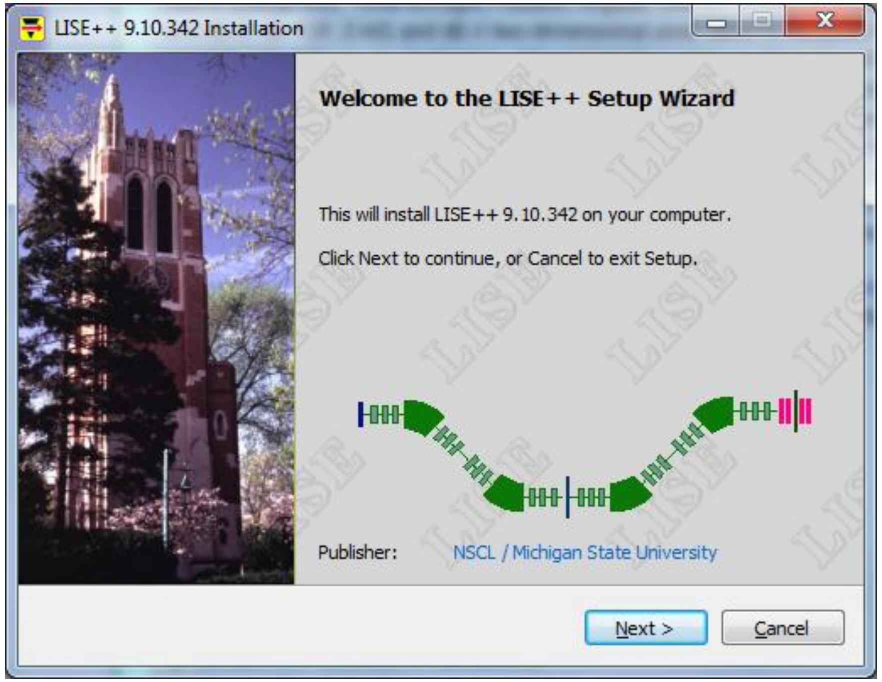
LISE^{++} : exotic beam production with separators

Oleg B. Tarasov (NSCL/MSU)*



- 30 years of development
- Introduction
- Development v.9.9
- Development v.9.10.345
- Extended configurations
- LISE^{++} Statistics
- Next steps
- Porting to Qt-framework
- Summary
- Acknowledgments

* On leave FLNR / JINR, Dubna, Moscow region, 141980, Russian Federation

30 Years

Already 30 years…

GRAND ACCELERATEUR NATIONAL D'IONS LOURDS

1986-1990
D.Bazin, GANIL
v.1.0-1.*

The program LISE is designed to predict intensities and purities for the planning of future experiments using radioactive beams with in-flight separators, as well as for tuning experiments where its results can be quickly compared to on-line data.
An application of transport integral [1] lies in the basis of fast calculations of the program for the estimation of temporary evolution of phase space distributions.

1) D.Bazin and B.Sherrill, Phys.Rev.E50 (1994) 4017.

1990-1993
D.Bazin, MSU
O.Sorlin, Orsay
v.2.1-2.3

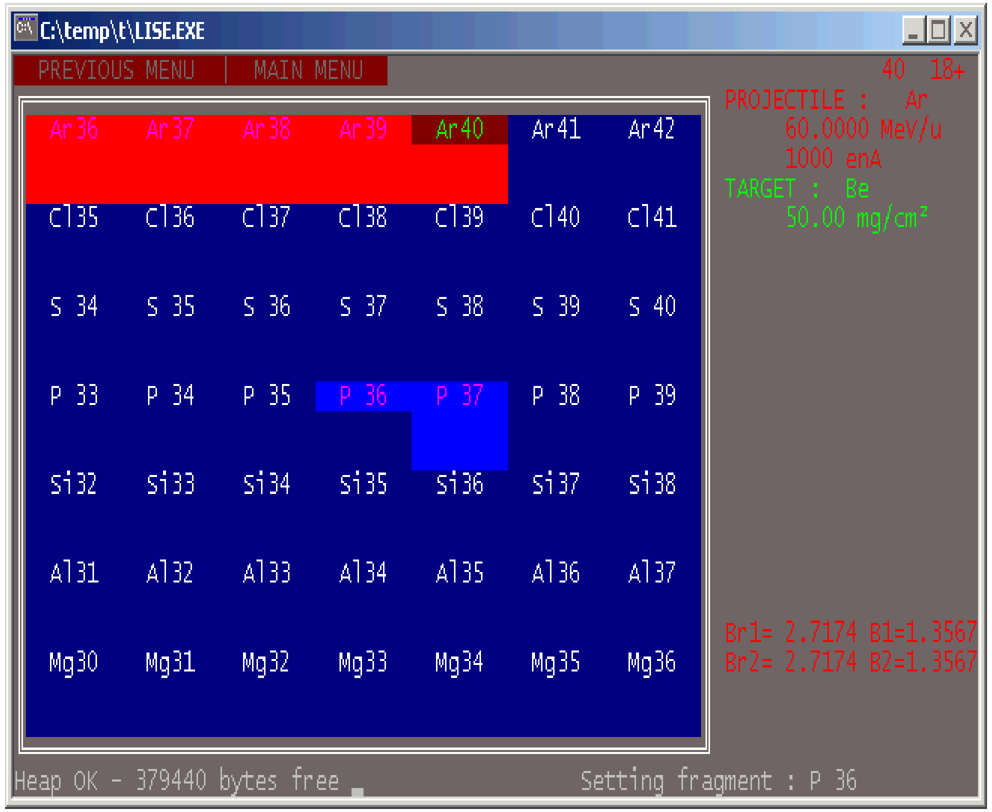
The deliberate choice of personal computers (PCs) to implement the program was made for two reasons:

* to make use of user-friendly features (menus, etc.);

* so that the program could be used in different laboratories worldwide without modification.

Evolution shows this was a good choice!

Already 30 years…



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[FILES]		<DIR>
[ISOTOP]		<DIR>
[RANGE]		<DIR>
[RESULTS]		<DIR>
EGAVGA	BGI	5,363
LISE	EXE	383,909
LISE	MAN	64,227
READ	ME	3,684

Almost 593 kBytes

GANIL
GRAND ACCELERATEUR NATIONAL D'IONS LOURDS

LISE REFERENCE MANUAL

Version 2.2 - June 8, 1992 ….

LISE is a DOS-based software running on any IBM compatible PC. It runs under DOS 3.1 and following versions, and only needs 640 kbytes of memory. The speed of the program depends greatly on the CPU type, speed and configuration. The use of a co-processor is greatly recommended: the program uses FFT (Fast Fourier Transform) algorithms which contain extensive floating-point operations.The last version has been developed on a 386-SX at 16 MHz with a *co-processor* which provides a *reasonable speed* (about 1 second per transmission calculation).

In 1998 the MS-DOS version with 14 C++ files and
less than *10 000* lines of code,

and grew on MS Windows today to
615 files, about *400 000* lines,
and size of ~69 MB after Installation.

Already 30 years…

1994-1997
O.T., GANIL/Dubna
v.2.3 – 2.9

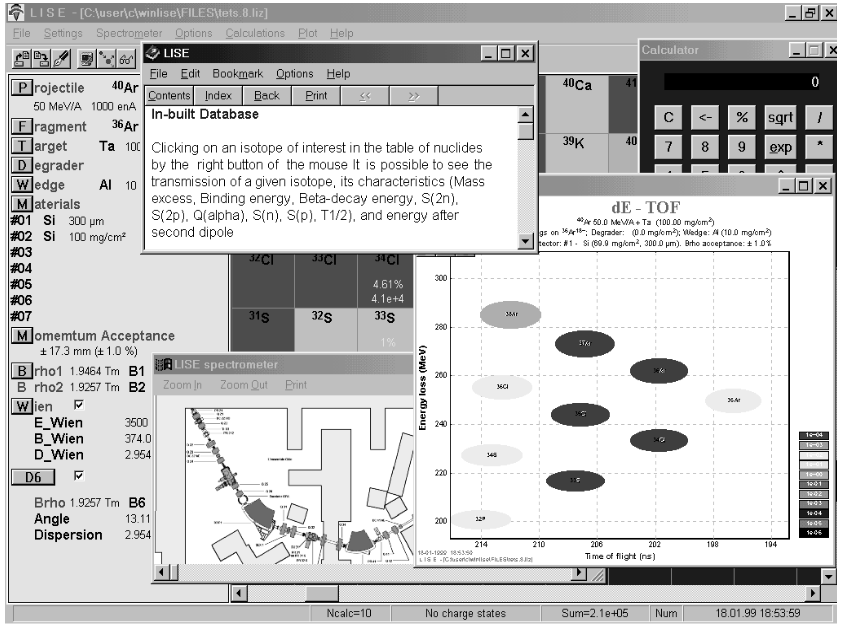
Corrections, Modifications, Development (compound target, compensating dipole)

1998
O.T., GANIL/Dubna
v.3.1

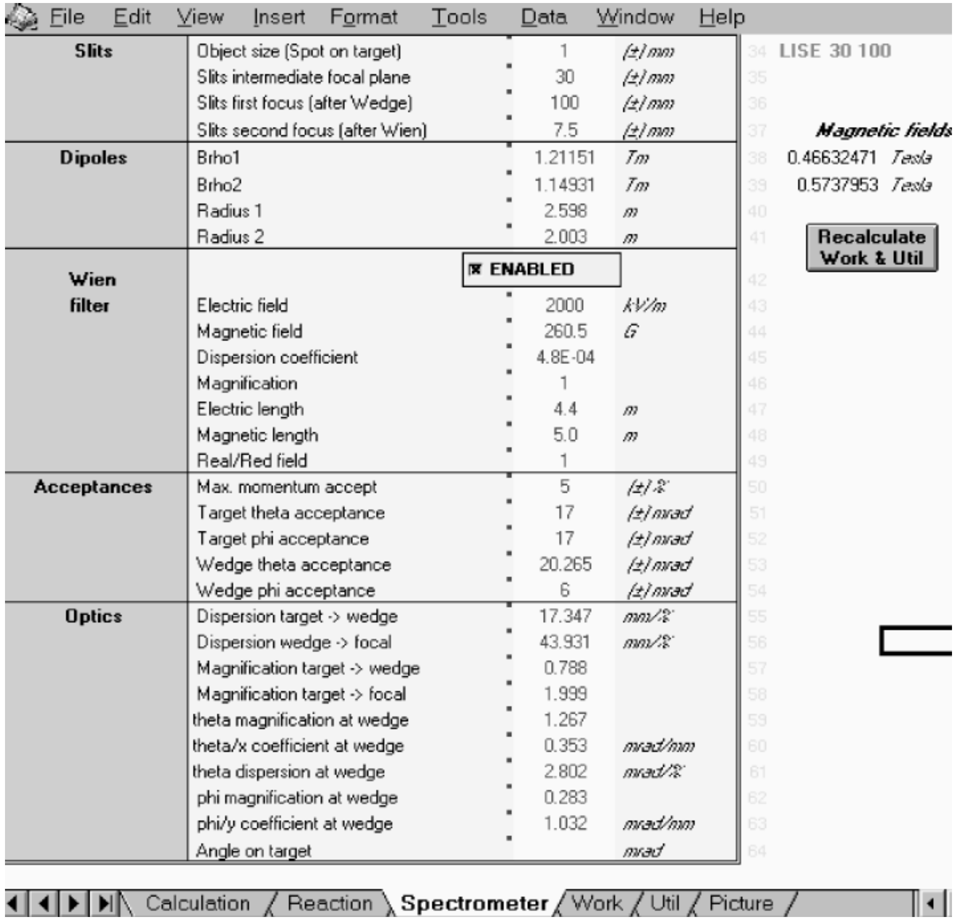
LISE operates under MS Windows

1999-2000
O.T., GANIL
v.3.2-4.9

Active development of the LISE code stimulated by M.Lewitowicz



LISE for Excel.
It includes even transmission calculations.



Already 30 years…

2001 NSCL / MSU v.4.10 –5.12	Active development of the LISE code stimulated by B.Sherrill. Abrasion-Ablation model construction, ATIMA implementation	1) D.Bazin, O.Tarasov, M.Lewitowicz, O.Sorlin, NIM A 482 (2002) 314.
2002 NSCL / MSU v.5.13 –5.15	First references [1,2] since 16 years! Fusion residues transmission [3]. PACE4 implementation.	2) O.Tarasov, D.Bazin, M.Lewitowicz, O.Sorlin, NP A 701 (2002) 661. 3) O.Tarasov and D.Bazin, NIM B 204 (2003) 174.
2003 NSCL / MSU v.6	LISE++ [4,5] is the new generation of the LISE code, which allows the creation of a spectrometer through the use of different "blocks".	4) O.T., Preprint NSCL MSU, MSUCL-1248, 45 pages 5) O.Tarasov and D.Bazin, Nuclear Physics A746 (2004) 411-414
2004 NSCL / MSU v.7.1	Convolution Model of Proj.Frag. momentum distributions [6] Implementation of codes Charge and Global Coulomb Fission [7,8]	6) O.T., Nuclear Physics A734 (2004) 536-540 7) O.T., Preprint NSCL MSU, MSUCL-1299, 2005, 64 pages 8) O.T., EPJ A25 (2005) 751
2005 NSCL / MSU v.7.5	RF separation system, Isomers Abrasion – Fission [9]	9) O.T. Preprint NSCL MSU, MSUCL-1300, 2005, 131 pages
2006 NSCL / MSU v.7.9	Fusion – Fission [10]	10) O.B.Tarasov, and A.C.C.Villari, NIM B 266 (2008) 4670-4673
2007 NSCL / MSU v.8.0	Monte Carlo calculation of fragment transmission, Fragment production in material [11]	11) O.B.Tarasov, and D.Bazin, NIM B 266 (2008) 4657-4664

Already 30 years…

2008 v.8.4	MC : Use of High order optics MOTER code development, new blocks "Solenoid", "Delay block", Bunch of new utilities
2010 v.9.1	Working on 64-bit Windows OS, MC : Extended configurations
2012 v.9.3	MC : Optics calculation up to second order inside LISE^{++}, Utilities to develop and modify extended configurations "DF4 distribution" class : Important updates of analytical transmission calculations
03.**2013** v.9.5	Physics (^{76}Ge,^{82}Se): EPAX3, Probability for compound nucleus formation, Abrasion-Ablation update, Momentum Distributions, Initial prefragment analysis; Optics: New block "RF-buncher"
11.**2013** v.9.7	Physics: User Differential Cross Sections for Two body reactions; MC: new fields, gates optimization, input & output rate files Optics: New blocks "Shift", "E-quad", "E-dipole";
01.**2015** v.9.9	Optics: S & E blocks, revision of "Compensating dipole" block, Quadrupole & Sextupole superposition, TRANSPORT code file Import, Active construction of new extended configurations («BigRIPS»,«SHELS»,«MSP144+Q2»,«PRISMA» ,«MARS» …)
2015	Brief report of LISE^{++} status [12)] *LISE^{++} porting process started!!* [13,14)] 12) O.Tarasov and D.Bazin, NIM B 376 (2016) 185. 13) M.P.Kuchera, O.B.Tarasov, D.Bazin, B.Sherril, K.V.Tarasova, Journal of Physics: 664 (2015) 072029 14) M.P.Kuchera, O.B.Tarasov, D.Bazin, B.Sherril, K.V.Tarasova, NIM B 376 (2016) 168
09.**2016** v.9.10.345	Physics: Update of Fusion reaction mechanism, Radiation Residue Calculator, ETACHA4, Ionization energy database Optics: Beam Optics Optimization (incl. 2nd order), Reverse configuration technique, active construction of new configurations

INTRODUCTION

Introduction

❑ The LISE^{++} program is designed

- to predict intensities and purities for the planning of future experiments with in-flight separators
- is also essential for radioactive beam tuning where its results can be quickly compared to on-line data.

User who is far from isotope production → LISE^{++} utilities

Some definitions will be used in the presentation


User


Advanced


Beam physicist

Sorry in advance for mix of languages…

Documentation

http://lise.nscl.msu.edu/lise.html

"Production of Fast Rare Ion Beams"
Lectures at the Euroschool on Exotic Beams
including examples of how to use the LISE^{++} code

Conference and Workshop presentations based on the LISE^{++} code development (2013-2016)

Conference and Workshop presentations based on the LISE^{++} code development (2013-2016)

Ref	Date	Title, Contents	Presentation place
PDF Adobe	30.08-01.09.2016	**LISE^{++} code: 30 years and counting**	Grand Rapids, MI, USA 6th Fragment-Separator Experts Meeting
PDF Adobe	17-19.08.2016	**Predictions of Isotope Production Yields with LISE^{++}**	East Lansing, MI, USA FRIB Workshop on Isotope Harvesting
PDF Adobe	10.08.2016	**Nuclear Data Needs for LISE^{++}**	University of Notre Dame, South Bend, IN, USA Workshop for Nuclear Data Needs and Capabilities for Basic Science, Low Energy Community Meeting
PDF Adobe	01-04.09.2015	**Production of neutron-rich isotopes** *LISE^{++} reaction mechanism discussions, examples prepared with the LISE^{++} code*	ECT*, Trento, Italy Interfacing Structure and Reaction Dynamics in the Synthesis of the Heaviest Nuclei
PDF Adobe	31.03-02.04.2015	**Recoil separator "SECAR" configurations in the LISE^{++} package**	MSU, East Lansing, USA SECAR collaboration meeting @ Low Energy Workshop
PDF Adobe	11.05-15.05.2015	**LISE^{++} : Exotic Beam Production with Fragment Separators and Their Design**	Grand Rapids, USA EMIS conference
		Plans for Performance and Model Improvements	

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LISE^{++} : Exotic beam production with fragment separators and their design O.B.Tarasov, D.Bazin	NIM B 376 (2016) 185
LISE^{++} Software Updates and Future Plans M.P.Kuchera, O.B.Tarasov, D.Bazin, B.Sherril, K.V.Tarasova	Journal of Physics: CS 664 (2015) 072029 NIM B 376 (2016) 168
LISE^{++} : Radioactive beam production with in-flight separators O.B.Tarasov, D.Bazin	NIM B 266 (2008) 4657-4664
Fusion–fission is a new reaction mechanism to produce exotic radioactive beams O.B.Tarasov, A.C.C.Villari	NIM B 266 (2008) 4670-4673
LISE^{++} : design your own spectrometer	Nuclear Physics A746 (2004) 411-414 Preprint NSCL MSU, MSUCL-1248

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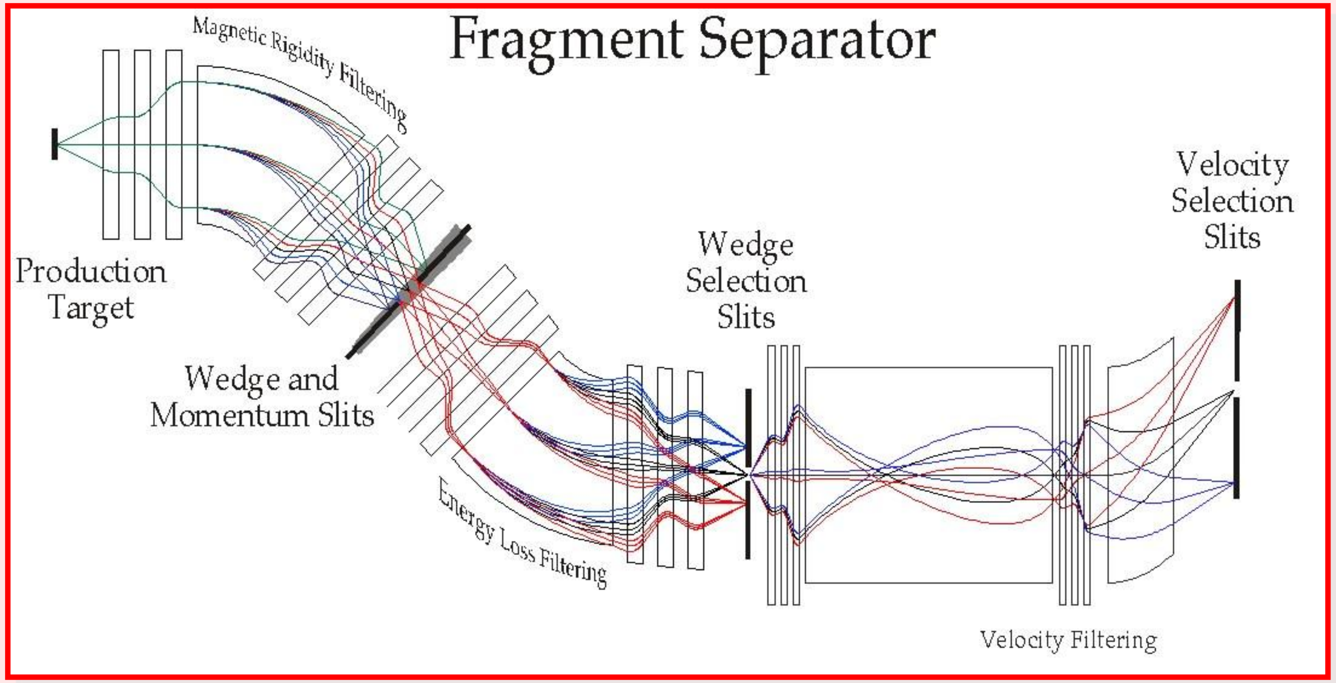
Last Changes

Version	Description
9.10.345 22-08-16	List of recent modifications
9.10.342 09-08-16	Decay Branching Ratio Dialog & Database for using with the Radiation Residue Calculator
9.10.332 01-08-16	Radiation Residue Calculator v.2

In-flight isotope production : 3 steps

In-Flight isotope production: Basic principle of operation

1. Production



3. Registration, Identification

2. Separation

2. Production

1. **Choice of place for the experiment**
   - ✓ Intensities
   - ✓ Primary beam lists
2. **Planning of Fast RIB Experiment**
   - ✓ Ion yields after target
3. **Settings**
   - ✓ Beam
   - ✓ Target
   - ✓ Fragment of interest
   - ✓ Charge state model
   - ✓ Energy loss model
   - ✓ Secondary reactions in target
   - ✓ Reaction mechanism
4. **Reaction mechanisms**
   - ✓ Evaporation cascade
     - Fission barrier
   - ✓ Projectile fragmentation
   - ✓ Fission fragment production model
   - ✓ Coulomb fission
   - ✓ Abrasion-Fission
   - ✓ Fusion-Fission
   - ✓ Fusion-Residual
   - ✓ Two body reactions
   - ✓ others
5. **Efficiency transmission at target**

3. Separation

1. **Beam optics**
   - ✓ Coordinate system
   - ✓ Transport matrix
   - ✓ Definitions
   - ✓ Focusing conditions
   - ✓ Separation and beam optics
   - ✓ Achromatic fragment separator
   - ✓ High order optics
2. **Separator features**
   - ✓ Ion transport codes
   - ✓ Fragment separator design
   - ✓ LISE++ block classification
   - ✓ Block properties
   - ✓ LISE++ configuration types
   - ✓ Angular acceptances
3. **Types of transmission calculations**
4. **Selections with EM devices**
   - ✓ Magnetic rigidity (Bρ) – selection
     - *Gas-filled separator*
   - ✓ Electrostatic rigidity (Eρ) – selection
     - *E & B bends combination : m & q dispersions*
   - ✓ Velocity selection
     - *Wien & B-bend combination : A/q dispersion*
   - ✓ Time selection
   - ✓ Selection with bunching
   - ✓ Selection with focusing
5. **"Wedge" selection**
   - ✓ Types of wedge
   - ✓ Fragment production in material
   - ✓ Two stage separation
6. **Transmission**
7. **Optimization utilities**
8. **New generation of fragment separators**
9. **Example of secondary beam production**

4. Identification

- What is PID?
- Detector setup
- Obtaining A, Z, q
- Momentum acceptance
- Particle identification assignments

What is Particle IDentification?

What do we want to know?

1. A
2. Z
3. Q
4. Energy (property of incoming ion in detectors)

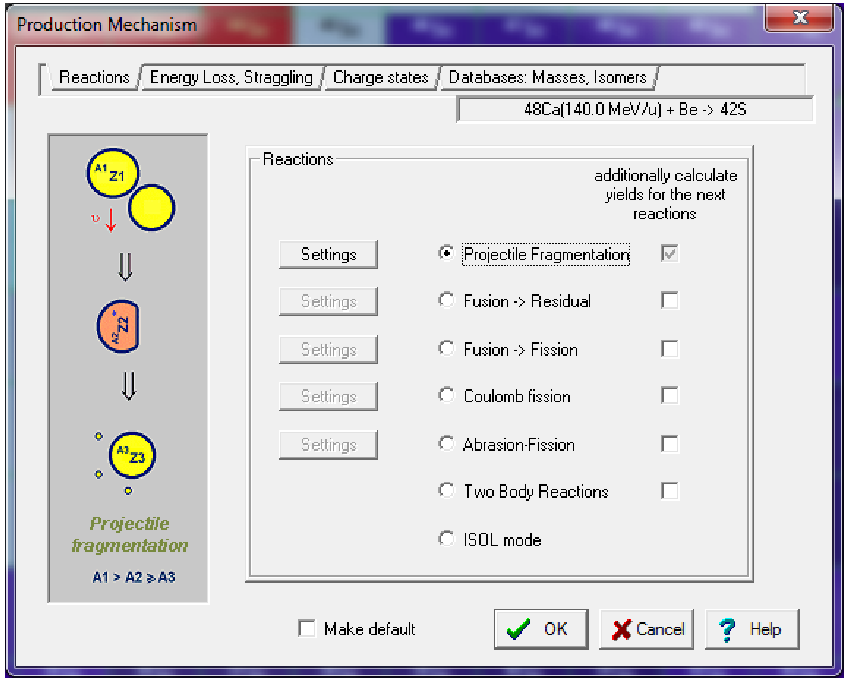
What do we measure?

1. Total kinetic energy
2. Magnetic (electric) rigidity
3. Energy loss in detector
4. velocity (time of flight)

Production : Reaction Mechanisms

Table
Reactions and production models implemented in LISE++

Reaction	Production cross-section model	Ref.
Projectile fragmentation	EPAX 2.15, 3.1	[17]
	LISE++ abrasion–ablation	[27]
Fusion-residues	LisFus model	[27]
	PACE4 (manually)	[28]
Fusion–fission	LISE++ package	[29]
Coulomb fission	LISE++ package	[30]
Abrasion–fission	LISE++ 3EER model	[31]
Two body kinematics	EPAX 2.15 (temporary)	



References:

[17] K. Summerer, B. Blank, Phys. Rev. C 61 (2000) 034607; K. Summerer, Phys. Rev. C 86 (2012) 014601

[27] O. Tarasov, D. Bazin, Nucl. Instr. and Meth. B 204 (2003) 74.

[28] A. Gavron, Phys. Rev. C 21 (1980) 230.

[29] O.B. Tarasov, A.C.C. Villari, , Nucl. Instr. and Meth. B 266 (2008) 4670-4673.

[30] O.B. Tarasov, Eur. Phys. J. A 25 (2005) 751; Tech. Rep. MSUCL1299, NSCL, Michigan State University, 2005.

[31] O.B. Tarasov, Tech. Rep. MSUCL1300, NSCL, Michigan State University, 2005.

Fragment Separator Construction

- with different sections called "blocks" (magnetic and electric multipoles, solenoid, velocity filter, RF deflector and buncher, material in beam, drift, rotation element, and others).
- a user-friendly interface that helps to seamlessly construct a fragment separator from the different blocks.

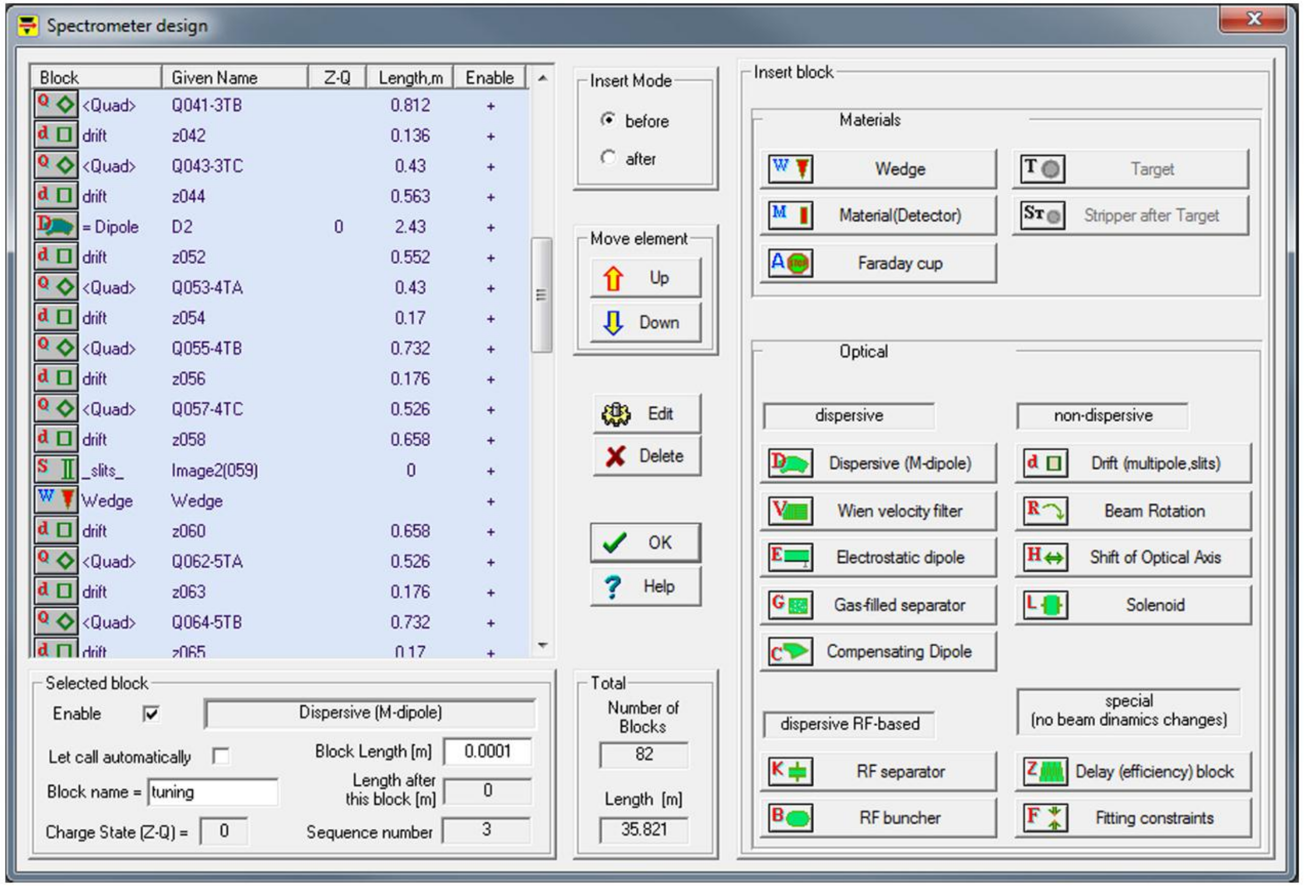
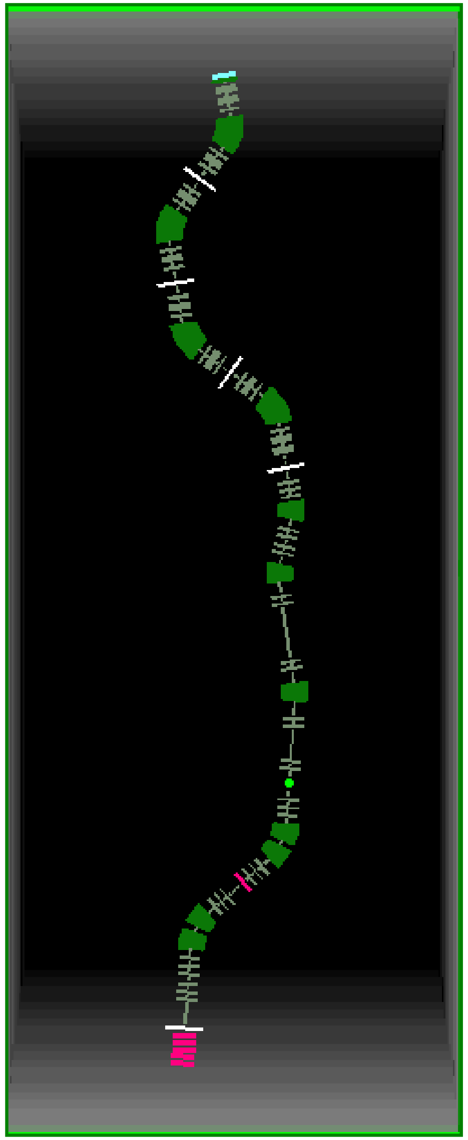
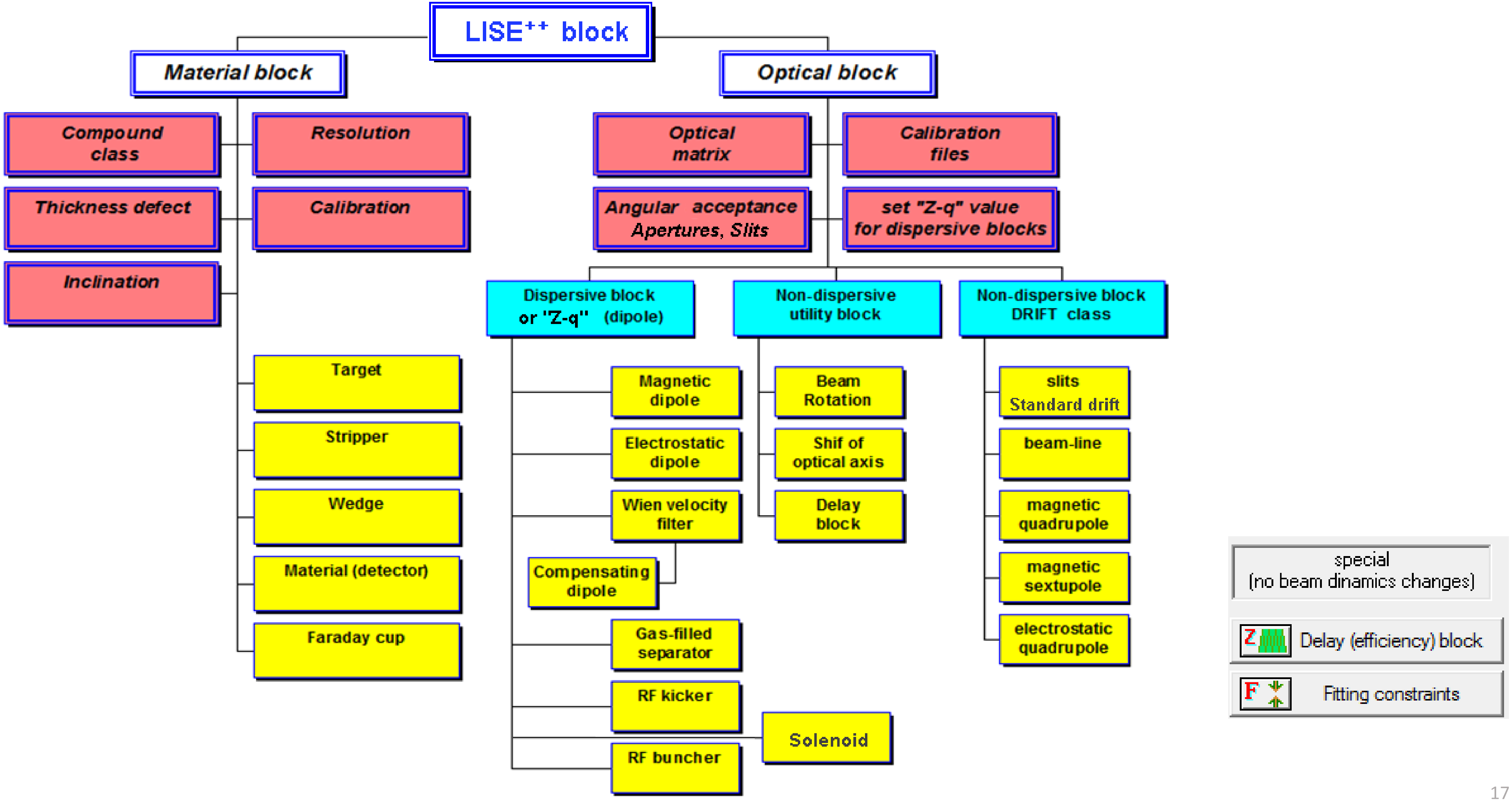


Fig. 1. Updated view of the "Spectrometer Design" dialog window.



Configuration: A1900_S800BL (2nd order) 164 blocks

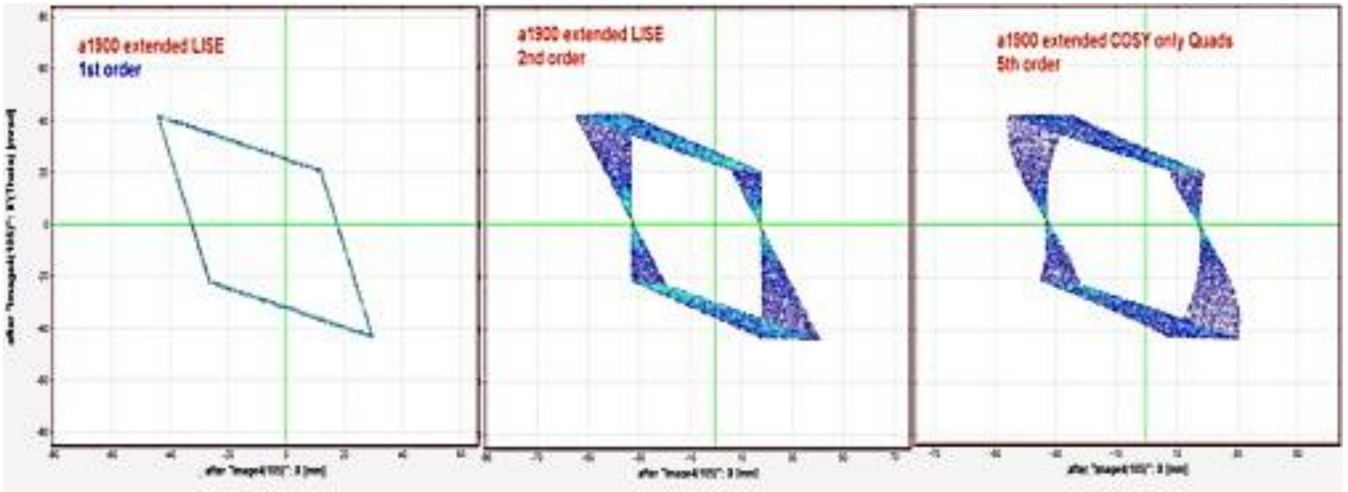
LISE^{++} block classification

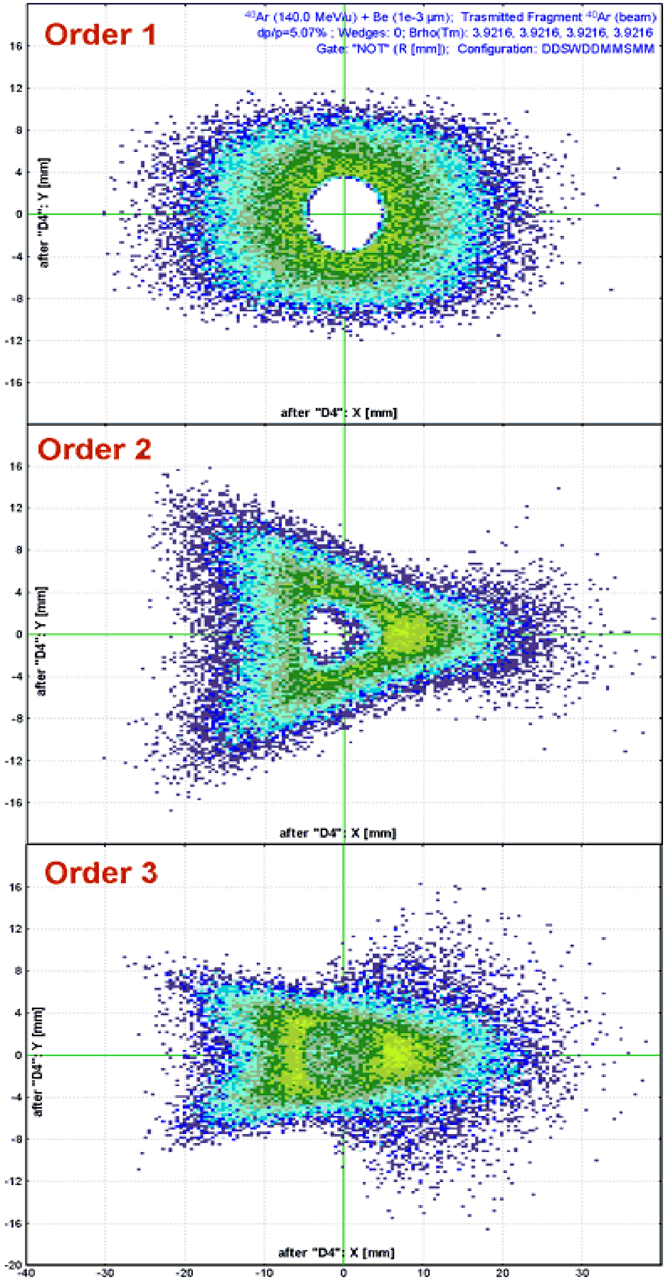


High order optics LISE^{++}

- LISE^{++} is able to operate with 5th order matrices
- High order optics can be used only in Monte Carlo mode

- LISE^{++} can calculate 1st and 2nd order matrices based on the Transport formalism
- Higher matrices can be loaded (or linked) from files prepared by the COSY code





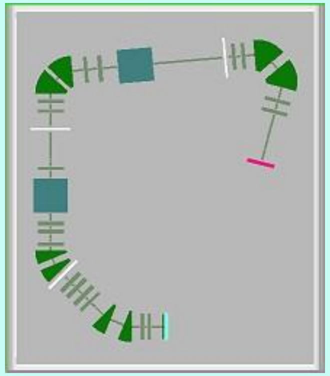
Selections @ LISE^{++}

Electromagnetic separation devices in LISE^{++}

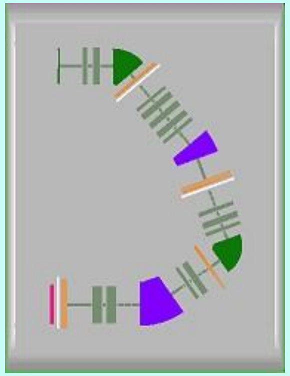
Separation device	Changeable field	Strength	Selection by
Magnetic dipole	Magnetic (B[T])	$\vec{F}_B = q\vec{v} \times \vec{B}$	Magnetic rigidity $B\rho = \frac{mv}{q}$ [T·m]
Gas-filled separator	Magnetic (B[T])	$\vec{F}_B$	Magnetic rigidity
Solenoid	Magnetic (B[T])	$\vec{F}_B$	Focusing (combination A,q,v)
Electrostatic dipole	Electric (E [kV/m])	$\vec{F}_E = q\vec{E}$	Electric rigidity $E\rho = \frac{mv^2}{q}$ [J/C]
RF kicker	Electric (E [kV/m])	$\vec{F}_E$	Time
RF buncher	Electric (E [kV/m])	$\vec{F}_E$	Bunching
Wien-filter *E-cross-B filter*	Magnetic (B[T]) Electric (E [kV/m])	$\vec{F} = \vec{F}_B + \vec{F}_E$	Velocity

- “Wedge” selection
- Decay time selection

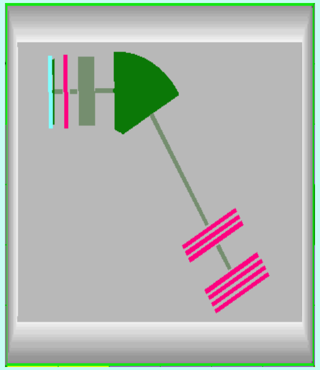
Application



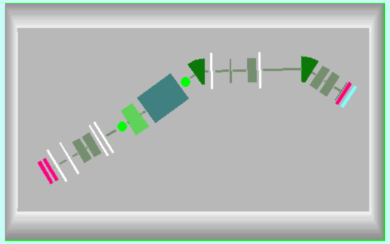
SECAR, *MSU*



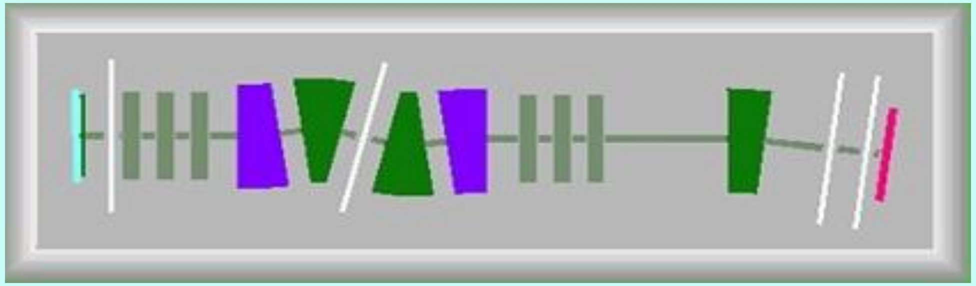
DRAGON, *Canada*



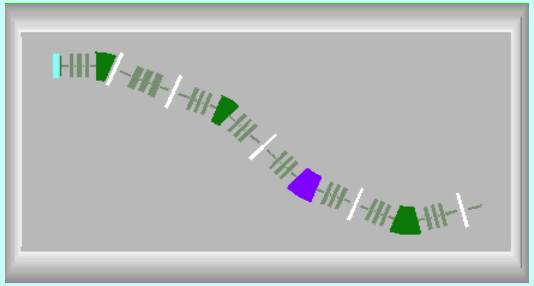
PRISMA, *Italy*



MARS, *TAMU*

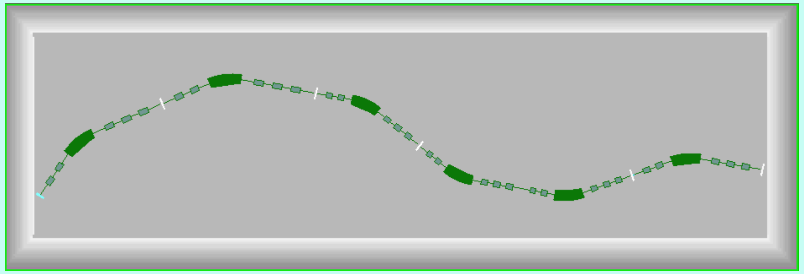


SHELS, *Russia*



S^3, *France*

BigRIPS+ZeroDegree, *Japan*



SuperFRS_HEB, *Germany*

Includes *extended* configurations of separators at NSCL/MSU, RIKEN, GANIL, GSI, FLNR/JINR, TAMU, TRIUMF, ANL and others.

LISE^{++} package

- The code is distributed free with the LISE^{++} user license
- Official site : lise.nscl.msu.edu
- Current version 9.10.343, 15-Aug-2016

- Version 10 will be released soon
- Current operating system : MS Windows
- Currently porting to new framework : cross platform & parallel computing

Built-in powerful tools:

- Monte Carlo simulation of fragment transmission,
- Monte Carlo simulation of fission fragment kinematics,
- Ion Optics calculation and Optimization *(new)*,
- LISE for Excel (MS Windows, Mac OS - download)

LISE^{++} calculators:

- «Physical Calculator»,
- «Relativistic Kinematics Calculator»,
- «Evaporation Calculator»,
- «Radiation Residue Calculator» *(new)*,
- «Ion Mass calculator" *(new)*,
- «Matrix calculator"

Implemented codes:

- «PACE4» (fusion-evaporation code),
- «MOTER» (raytracing-type program for magnetic optic system de
- «ETACHA4» (charge-state distribution code) *(new)*,
- «Global» (charge-state distribution code),
- «Charge» (charge-state distribution code),
- «Spectroscopic Calculator" (of J.Kantele»)

LISE^{++} Utilities:

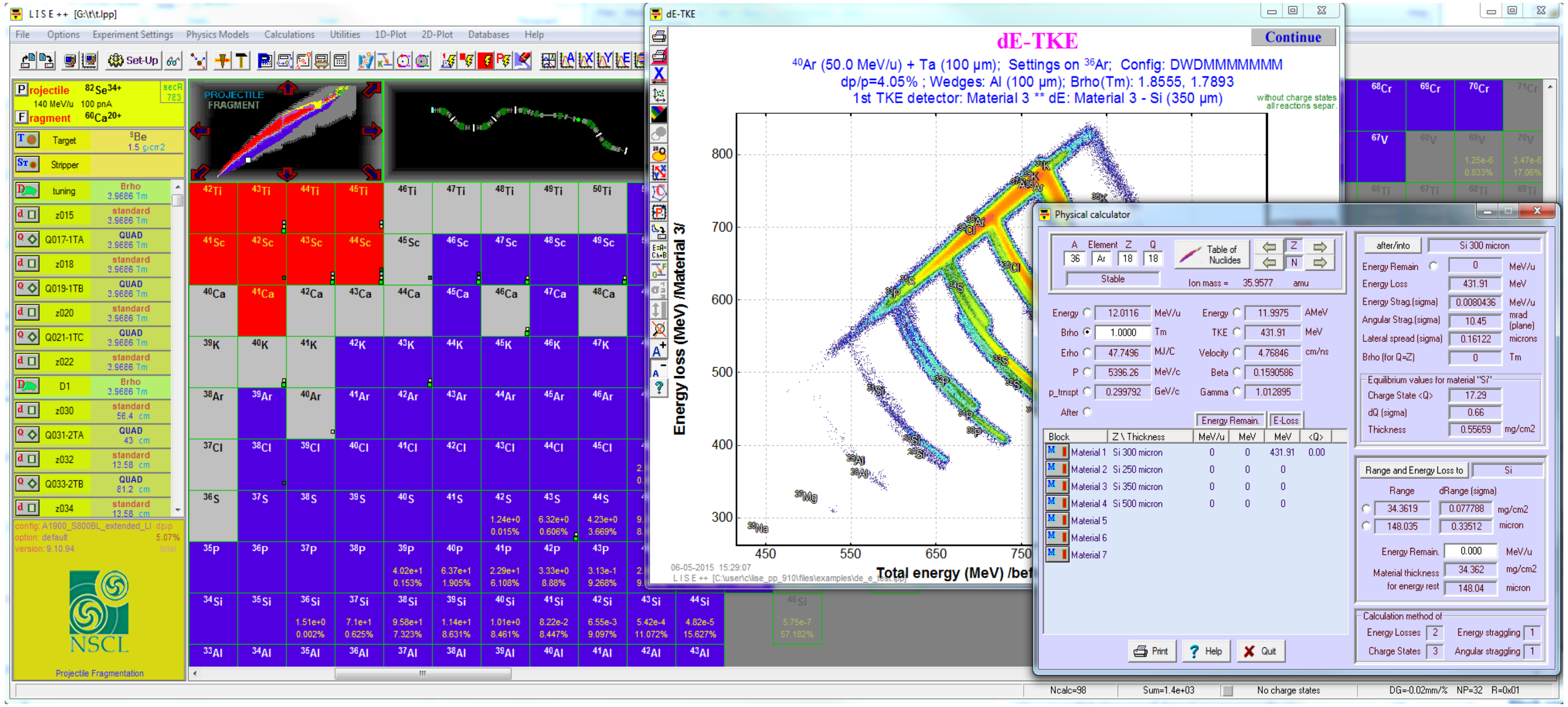
- Stripper Foil Lifetime Utility,
- Brho Analyzer,
- Twinsol (solenoid) utility,
- Units Converter,
- ISOL Catcher,
- Decay Analysis (includes Proton, Alpha, Cluster, Sp.Fission half-lives calculation),
- Reaction Utilities (Characteristics, Converters, Plots),
- «BI»- the automatized search of two-dimensional peaks in spectra

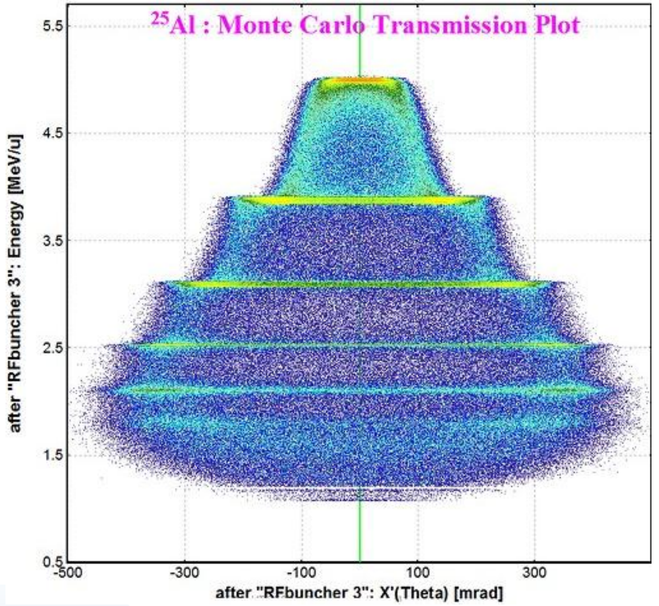
Databases:

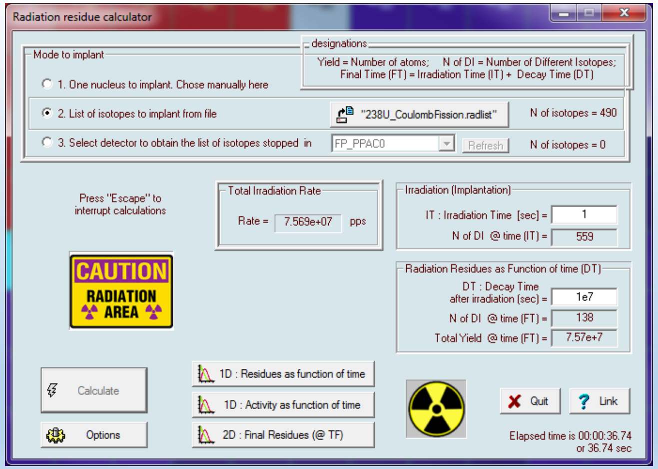
- Nuclide and Isomeric State databases with utilities,
- Large Set of Calculated Mass Tables (includes FRIB mass tables),
- Ionization Energy database (used with the Ion Mass calculator),
- Decay Branching Ratio database (used with the Radiation Residue calculator),

permit to work well below this energy limit, and this makes the program very attractive for all users dealing with physics of heavy ions from 10 keV up to some GeV per nucleon.

LISE^{++} framework







New utility from 08/01/16

"Radiation Residue Calculator"

is important tool regarding to isotope harvesting

http://lise.nscl.msu.edu/9_10/RadiationResidue.pdf

Current LISE++ development strategy

High priority

- Bug fix (if still exist ☺)
- Requests
  - FRIB fragment separator group
  - A1900 fragment separator group
- User support
- Tasks from the accepted high priority list
- Sufficient improvement of existent blocks

Low priority

- Requests
  - Outside
- Tasks from the accepted low priority list

Medium priority

- Documentation
- Requests
  - Local (MSU)
  - Collaborations
- Tasks from the accepted medium priority list
- Sufficient improvement of existent utilities

Strategy

- Engage users in the creation and use of the extended configurations
- Do not create utilities based on outside requests, which wont be widely used

User requests, the code support : high priority (2013)

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[2013_11_18..]	<DIR>	11/18/2013 13:58

RECENT DEVELOPMENT

LISE++ Recent Development : Summary

v.9.9

- ❑ Optics: S & E construction methods
- ❑ Extended configurations in LISE++
- ❑ Compensating dipole
- ❑ Multipole : Quadrupole & Sextupole superposition
- ❑ TRANSPORT code file import to LISE++
- ❑ Range Optimizer (Gas cell utility) update

- ❑ Extended Configurations

- ❑ Regular support routine:
  - user requests, calculation optimization, fix of bugs, interface improvement, Databases and other updates

v.9.10.345

- ❑ Update of Fusion reaction mechanism
- ❑ Optics minimization (up to 2nd order)
- ❑ Reverse configurations: ray trajectory reconstruction
- ❑ Radiation Residue Calculator
- ❑ ETACHA4 (GUI) (still under construction)

- ❑ Others notable
  - Decay Branching Database
  - Ionization energy database & Ion mass calculator
  - Utility "Angular Straggling & Rutherford scattering probabilities in compound“
  - Rutherford scattering of primary beam in target in MC mode
  - FRIB mass tables in the LISE++ package
  - Second order optics calculations of electric dipole

V. 9.9

(BRIEFLY)

LISE++ configuration types

- **Classical or original (segmented) configuration:**
  dispersive block contains quads, drifts, dipole and other optical components

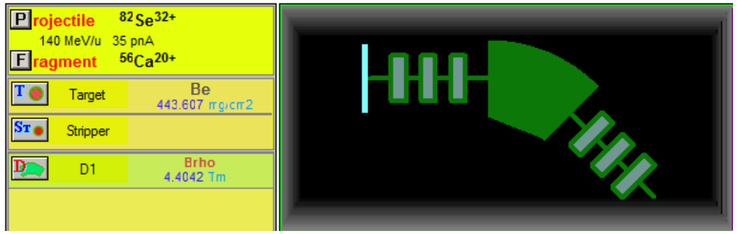
- **Extended (elemental) configuration:**
  like in the TRANSPORT or COSY codes all elements are separated, and their matrices can be calculated by the LISE++ code

---

So, let's take the first dispersive block of A1900 as an example

---

segmented — *Only 1 block after stripper*



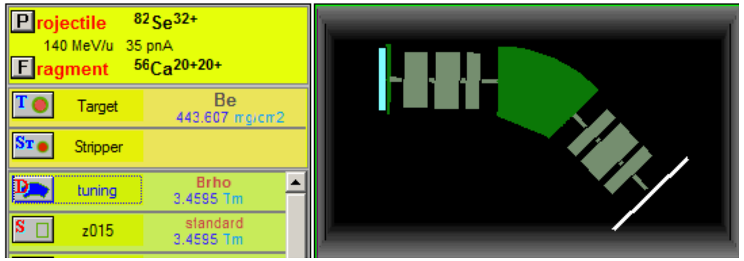
Taken from TRANSPORT

Block matrix

1. X	-2.28459	0.009	0	0	0	29.2533
2. T	1.06245	-0.44189	0	0	0	-0.00283
3. Y	0	0	0.73853	0.0022	0	0
4. F	0	0	3.74271	1.36526	0	0
5. L	3.10738	-1.2927	0	0	1	5.7769
6. D	0	0	0	0	0	1

---

extended — *16 blocks after stripper*



Calculated by LISE++ including 2nd order (see next page)

Global matrix

-2.30361	0.00906	0	0	0	28.88518	[mm]
1.07573	-0.43836	0	0	0	-0.00018	[mrad]
0	0	0.73839	0.00259	0	0	[mm]
0	0	3.731	1.36722	0	0	[mrad]
3.10724	-1.26623	0	0	1	-2.42226	[mm]
0	0	0	0	0	1	[%]
/[mm]	/[mrad]	/[mm]	/[mrad]	/[mm]	/[%]	

S (sector) & E (element) optical block property

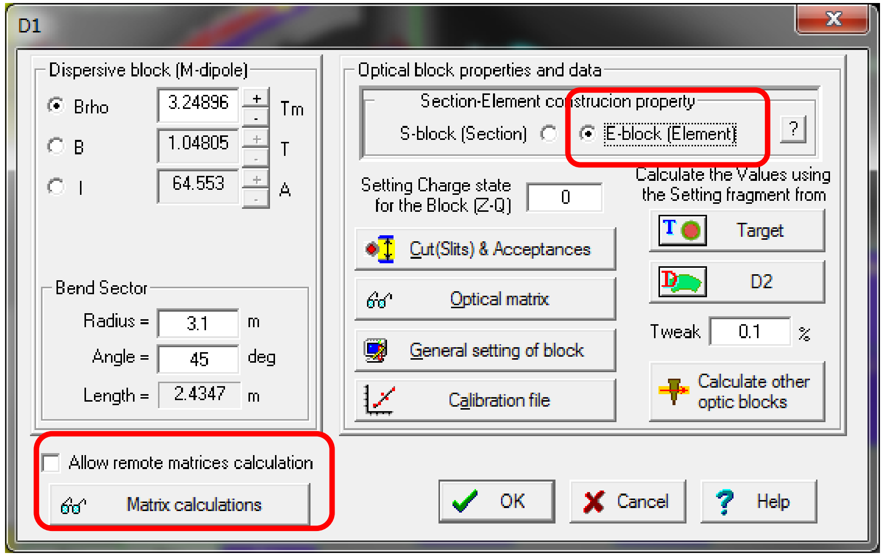
s-block

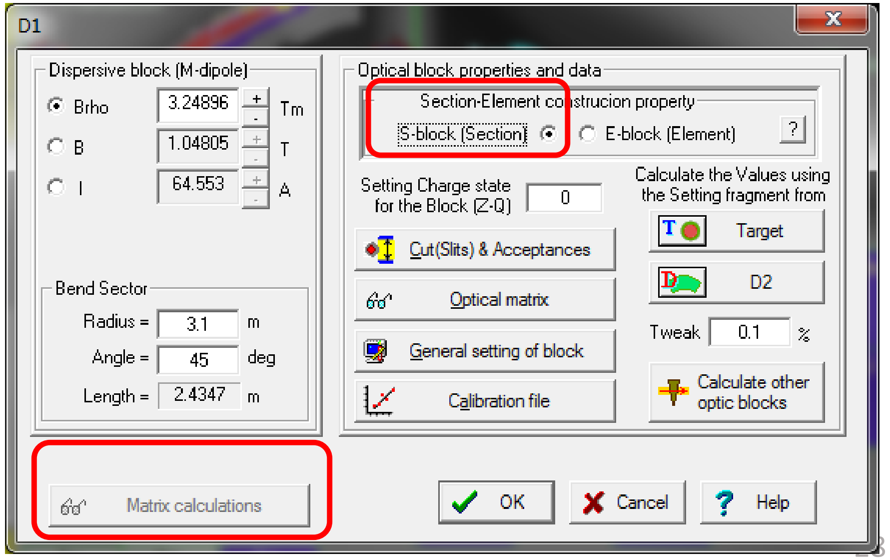
(**s**ection, **s**egment configuration)

Construction property

e-block

(**e**lement, **e**xtended configuration)





1. Main feature of E-block – possibility to calculate the optical matrix by means of LISE^{++} :
   so, this construction property tells to the code how and where this block can be used

2. **<u>This new construction property allows split properties and utilities of optical blocks.</u>**
   So, less confusion for the user, more simple and informative

3. **Use new commands only for blocks of specified construction properties**

4. All optical block classes are separated on three construction categories (on 11/14/2014):

   a. only e-blocks (6 classes); *b. only s-blocks (6 classes);* *c. property defined by user (M & E-dipoles, Wien-filter)*

Comparisons

Classical Segmented & Extended configurations

Classical (segmented) configuration:

- Fast transmission calculations
- Optical matrices can be input by user or linked to COSY maps
- Simple and compact description of optical system
- Effective with analytical calculations for experiment planning

Extended (elemental) configuration:

- Allows detailed analysis of transmission
- Optical matrices can be input by user, linked to COSY maps or calculated in the LISE^{++} code, and used in segmented configurations
- Tools to obtain angular acceptances, (which can be entered into classical segmented configurations)
- Tools for displaying ion-beam optics

Very useful with Monte Carlo calculations including fragment separator design

Types of transmission calculations

"Distribution" (analytical) method

- Fast calculations
- All internal optimization procedures in the code are based on this method
- Mostly used with segmented configurations for experiment planning
- Calculation of very small transmission values (for example charge states of primary beams)

LISE ver.1	"Distribution"	: 1986
LISE ver.4	"Distribution2"	: 2000
LISE++ ver.6	"Distribution4"	: 2002

Monte Carlo method: (since 2007)

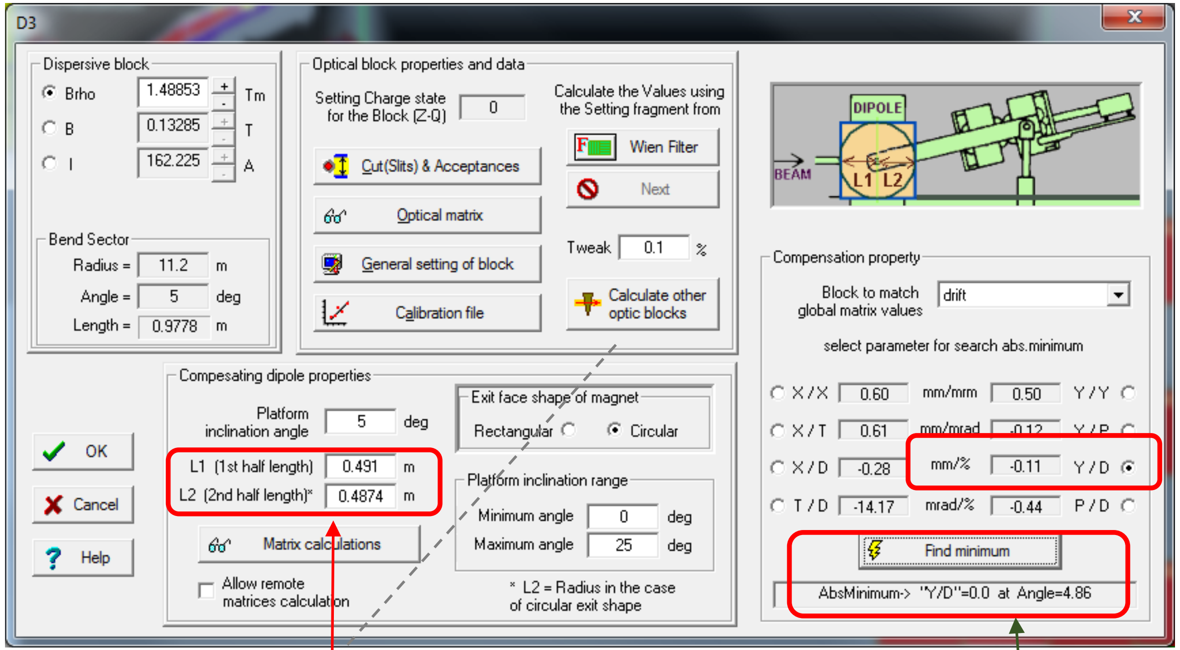
- Used to benchmark the fast "Distribution" method
- Allows detailed analysis of transmission with extended configurations
- Allows using High Order Optics (up to fifth order)
- Allows observation of correlations between parameters in different blocks
- Includes gating on all correlations in parameters (four gates)
- Tools for displaying ion-beam optics

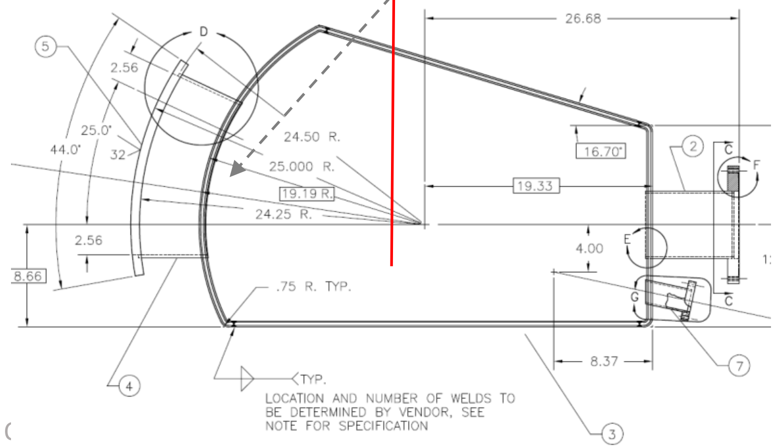
Useful for fragment separator design

Some optical blocks (Solenoid, RF buncher) are calculated exactly only in MC mode

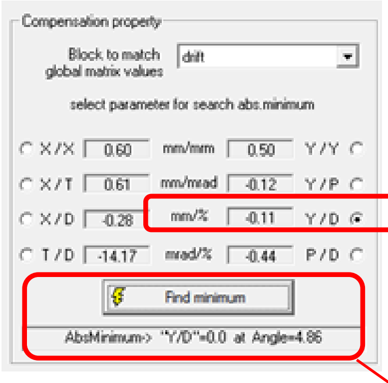
Compensating dipole (magnetic dipole after Wien filter : LISE3, MARS)

- The Compensating dipole can own only "E-block" property.
- **The matrices (up to second order) are calculated by the code** based on its geometry (L1,L2,Platform inclination angle, Y-gap)
- **Calculation of platform inclination angle** based on user's condition request

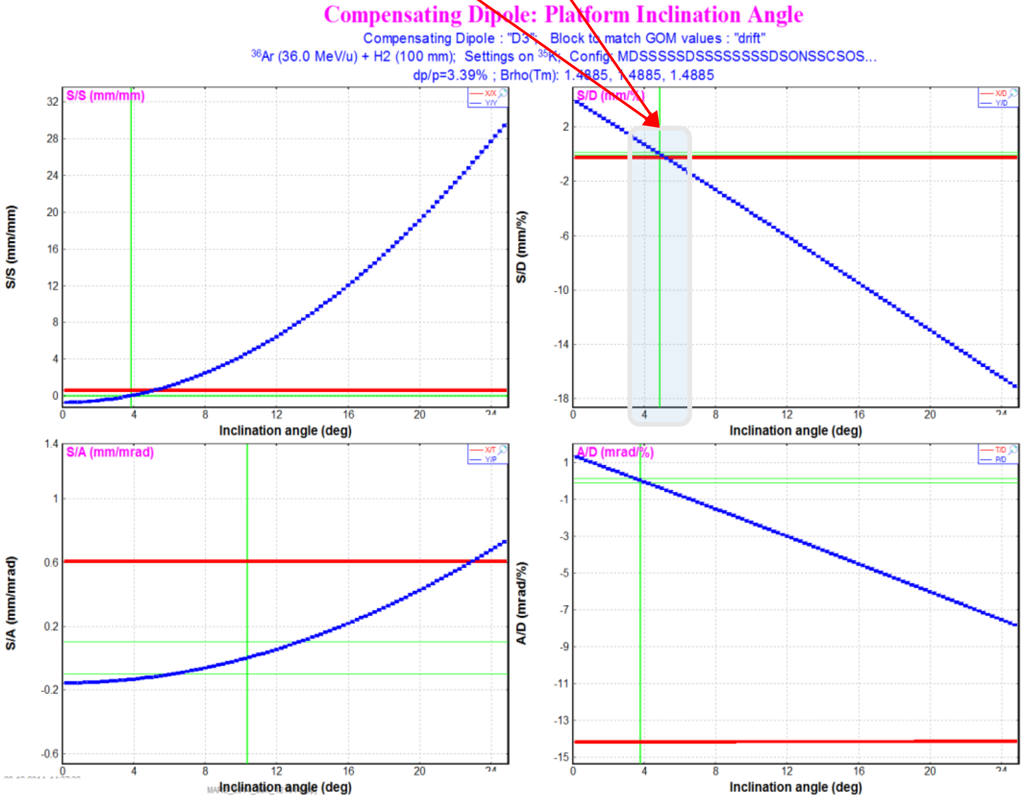




calculation of platform inclination angle



calculation of platform inclination angle



Multipole in LISE^{++} : Quadrupole & Sextupole superposition

Magnetic Multipole Settings

	QUADrupole	SEXTupole	
L_eff (effective length)	1		m
B (field at pole tip)	10	1.	kG
Radius (half-aperture)	10	10	cm

Multipole fixed Brho-value corresponding to the setting fragment: 1 Tm [Fix current value]

☑ calculate 2nd order matrix elements

- There is not Quadrupole & Sextupole superposition in the TRANSPORT code.
- Or only Quadrupole element (command 5.), or only Sextupole (command 18.)
- Now LISE^{++} allows Quadrupole & Sextupole superposition

LISE^{++}

Block: "Multi_LISE" Matrices: "LOCAL"

```
Block:  "Multi_LISE"     Matrices:  "LOCAL"
                                              transport format [cm-mrad]

                        * TRANSFORM 1 *

 1 [X]:     -9.9979e-01  -6.5000e-04   0            0            0            0
 2 [T]:     +6.5407e-01  -9.9979e-01   0            0            0            0
 3 [Y]:      0            0           +1.1833e+01  +3.7286e-01   0            0
 4 [F]:      0            0           +3.7290e+02  +1.1833e+01   0            0
 5 [L]:      0            0            0            0           +1.0000e+00   0
 6 [D]:      0            0            0            0            0           +1.0000e+0(
--------------------------------------------------------------------------------------

                        * TRANSFORM 2 *

 1   1:     -6.6674e-03
 1   2:     +8.7200e-06  -1.3330e-05
 1   3:      0            0           +2.9005e-01
 1   4:      0            0           +1.7652e-02  +2.7006e-04
 1   5:      0            0            0            0            0
 1   6:     -3.2704e-04  +4.9662e-04   0            0            0            0
--------------------------------------------------------------------------------------
 2   1:     -2.1793e-03
 2   2:     +1.3326e-02  +8.7200e-06
 2   3:      0            0           +1.7645e+01
 2   4:      0            0           +1.1202e+00  +1.7652e-02
 2   5:      0            0            0            0            0
 2   6:     -5.0316e-01  -3.2704e-04   0            0            0            0
--------------------------------------------------------------------------------------
 3   1:      0
 3   2:      0            0
 3   3:     +9.2706e-02  +7.4876e-03   0
 3   4:     -6.2238e-05  +1.9029e-04   0            0
 3   5:      0            0            0            0            0
 3   6:      0            0           -1.8643e-01  -4.0523e-03   0            0
--------------------------------------------------------------------------------------
 4   1:      0
 4   2:      0            0
 4   3:     -9.2559e-02  +2.8299e-01   0
 4   4:     -3.2753e-02  +7.4254e-03   0            0
 4   5:      0            0            0            0            0
 4   6:      0            0           -7.7810e+00  -1.8643e-01   0            0
--------------------------------------------------------------------------------------
 5   1:      0
 5   2:      0            0
 5   3:      0            0            0
 5   4:      0            0            0            0
 5   5:      0            0            0            0            0
 5   6:      0            0            0            0            0            0
--------------------------------------------------------------------------------------
 6   1:      0
```

COSY

Block: "Multi_COSY" Matrices: "LOCAL"

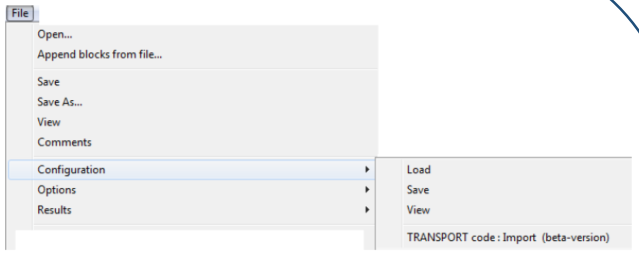
```
Block:  "Multi_COSY"     Matrices:  "LOCAL"
                                              transport format [cm-mrad]

                        * TRANSFORM 1 *

 1 [X]:     -9.9979e-01  -6.5000e-04   0            0            0            0
 2 [T]:     +6.5407e-01  -9.9979e-01   0            0            0            0
 3 [Y]:      0            0           +1.1833e+01  +3.7286e-01   0            0
 4 [F]:      0            0           +3.7290e+02  +1.1833e+01   0            0
 5 [L]:      0            0            0            0           +1.0000e+00   0
 6 [D]:      0            0            0            0            0           +1.0000e+0(
--------------------------------------------------------------------------------------

                        * TRANSFORM 2 *

 1   1:     -6.6674e-03
 1   2:     +8.7200e-06  -1.3330e-05
 1   3:      0            0           +2.9005e-01
 1   4:      0            0           +1.7652e-02  +2.7006e-04
 1   5:      0            0            0            0            0
 1   6:     -3.2704e-04  +4.9662e-04   0            0            0            0
--------------------------------------------------------------------------------------
 2   1:     -2.1793e-03
 2   2:     +1.3326e-02  +8.7200e-06
 2   3:      0            0           +1.7645e+01
 2   4:      0            0           +1.1202e+00  +1.7652e-02
 2   5:      0            0            0            0            0
 2   6:     -5.0316e-01  -3.2704e-04   0            0            0            0
--------------------------------------------------------------------------------------
 3   1:      0
 3   2:      0            0
 3   3:     +9.2706e-02  +7.4876e-03   0
 3   4:     -6.2238e-05  +1.9029e-04   0            0
 3   5:      0            0            0            0            0
 3   6:      0            0           -1.8643e-01  -4.0523e-03   0            0
--------------------------------------------------------------------------------------
 4   1:      0
 4   2:      0            0
 4   3:     -9.2559e-02  +2.8299e-01   0
 4   4:     -9.7583e-02  +7.4254e-03   0            0
 4   5:      0            0            0            0            0
 4   6:      0            0           -7.7810e+00  -1.8643e-01   0            0
--------------------------------------------------------------------------------------
 5   1:     -2.4837e-02
 5   2:     +2.1390e-07  -2.5163e-05
 5   3:      0            0           -1.0781e+00
 5   4:      0            0           -6.9514e-02  -1.1281e-03
 5   5:      0            0            0            0            0
 5   6:      0            0            0            0            0            0
--------------------------------------------------------------------------------------
 6   1:      0
 6   2:      0            0
 6   3:      0            0            0
```

COSY , Q (10) +S (1), R=10cm Br=1 Tm

Import of a TRANSPORT code file to LISE^{++}

How to create LISE++ setup from a TRANSPORT "deck"

Version 9.8.89, Menu "File → Configurations → Transport code : import"



Rules for interpreting the deck

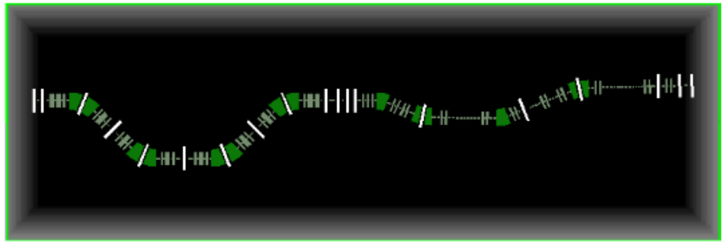
1. The first line always contains a title
2. Spaces are ignored at the beginning of line
3. LISE^{++} is looking for a line beginning with "0" to start interpretation
4. If "0" line is absent, then LISE^{++} terminates interpretation
5. Next line after "0"-line begins the "deck", LISE^{++} creates an empty configuration and starts to analyze the Transport file
6. A deck line is valid if it starts with a number ("-", text and so on lines are not analyze)
7. Labels (block names) are selected by characters ["], ['] or [/]
8. LISE^{++} uses semicolons to separate inputs on one line
9. LISE^{++} ends importation when a line starts with "SENT"

LISE^{++} settings for initial empty configuration

1. Target, stripper thicknesses are zero
2. Setting fragment is the same as the beam
3. Mechanism set to Projectile fragmentation
4. First block after stripper will be 0-length "tuning" dipole
5. After TRANSPORT file is imported, LISE^{++} runs automatically the "save as" file dialog

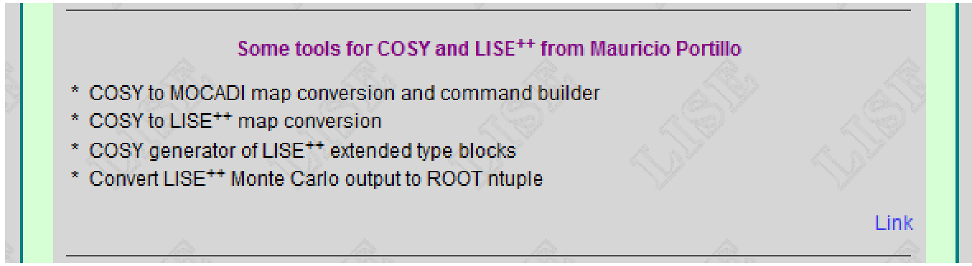
Transport cards can be imported as of 07/07/2014

1. Beam	2. Pole face rotation
3. Drift	4. Dipole
5. Quadrupole	16.1 Quadratic term of bending field
16.4 X Half-aperture	16.5 Y Half-aperture
16.7 Fringe coefficient K1	16.8 Fringe coefficient K2
16.12 Curvature of entrance face	16.13 Curvature of exit face
18. Sextupole	20. Beam rotation

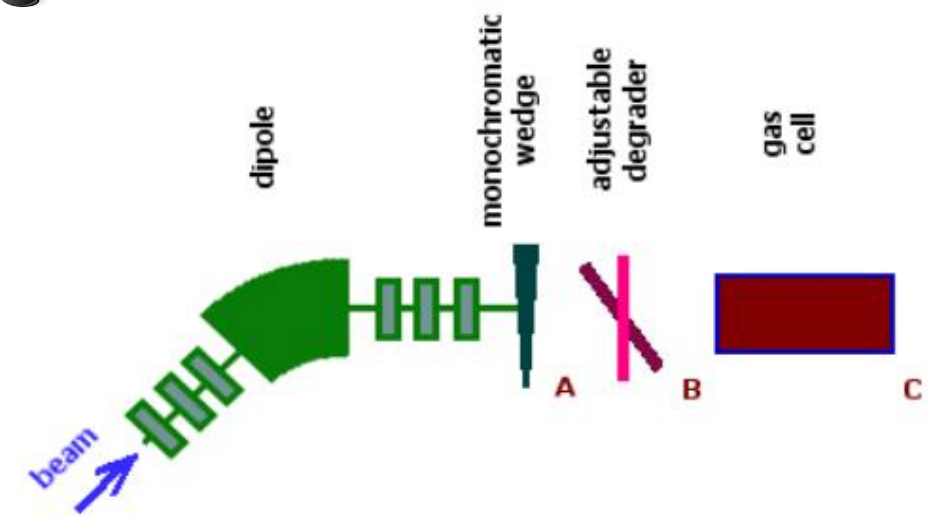


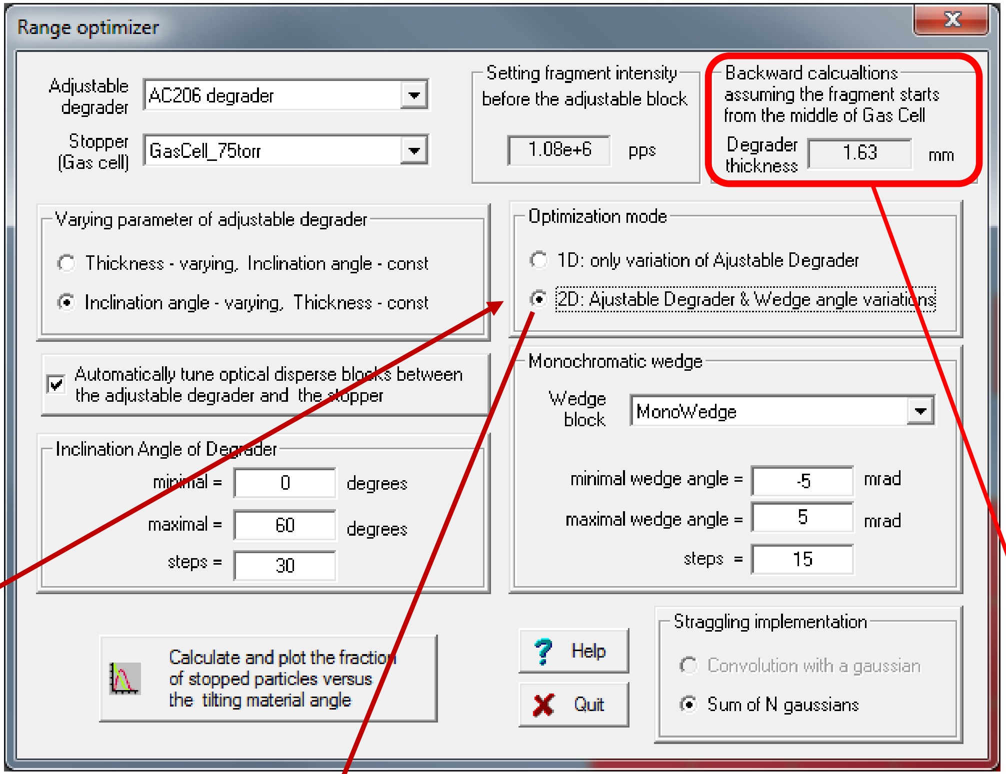
10. Fitting constraints @ v. 9.10

https://www.msu.edu/~portill2/cosy_tools/



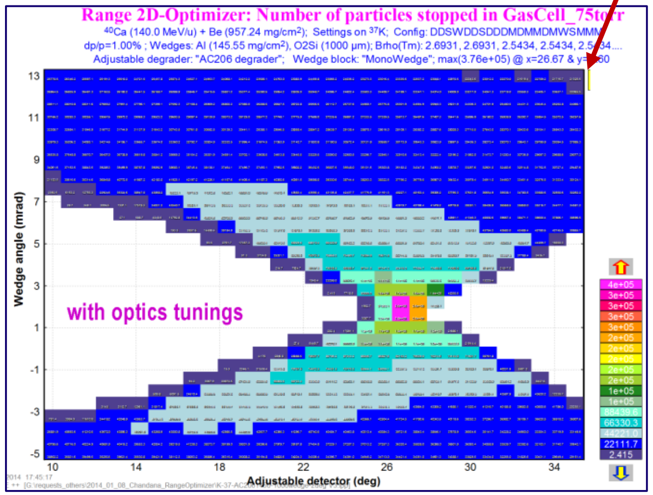
Range optimizer (Gas cell utility) update

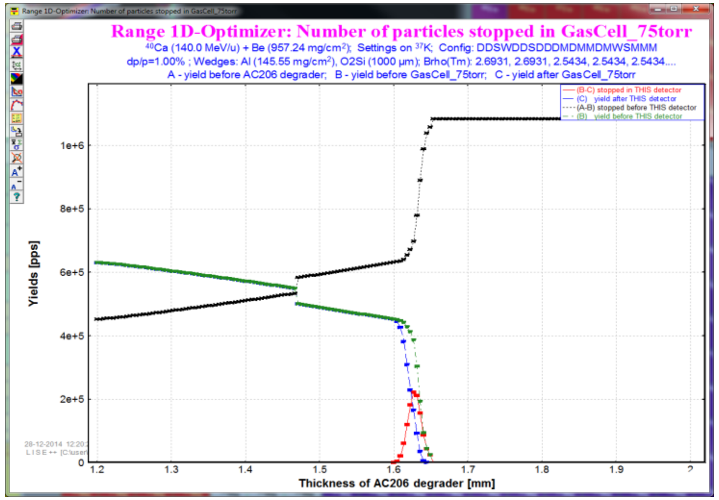




Backward calculations to estimate a thickness of degrader

- 2D optimization : wedge angle & adjustable degrader
- Update for Save and Restore Brho-values and Wedge properties
- New option : recalculate optics between materials during optimizations





V. 9.10.345

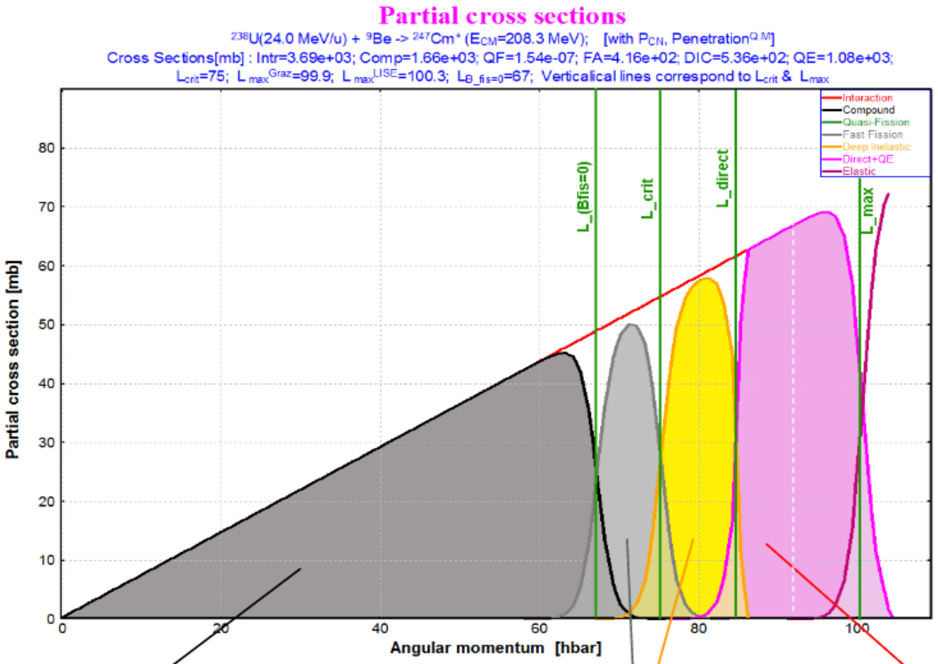
Low-Energy Reaction Mechanism Update

http://lise.nscl.msu.edu/9_10/9_10_Fusion.pdf

A recent update of low-energy reaction mechanism was performed to simulate the dependence of different reaction channels from angular momentum and qualitatively estimate production cross sections in the case of Fusion-Fission and Fusion- Residue.

The development was connected to the analysis of the e547 GANIL experiment

Fission channels for ^{238}U (20 MeV/u) + Be,C reactions



Compound fission ~100%
Fissile Z = 96
High Excitation Energy

Sequential fission after DIC
Fissile Z < 92
High Excitation Energy

Partially go to fission
Fissile Z~92
Low Excitation Energy

$$\sigma_{\mathrm{ER}}^{xn}(E) = \frac{\pi}{k^2}\sum_{l=0}^{\infty}(2l+1)P_{\mathrm{cont}}(E,l)P_{\mathrm{CN}}(E^*,l)\,P_{xn}(E^*,l)$$

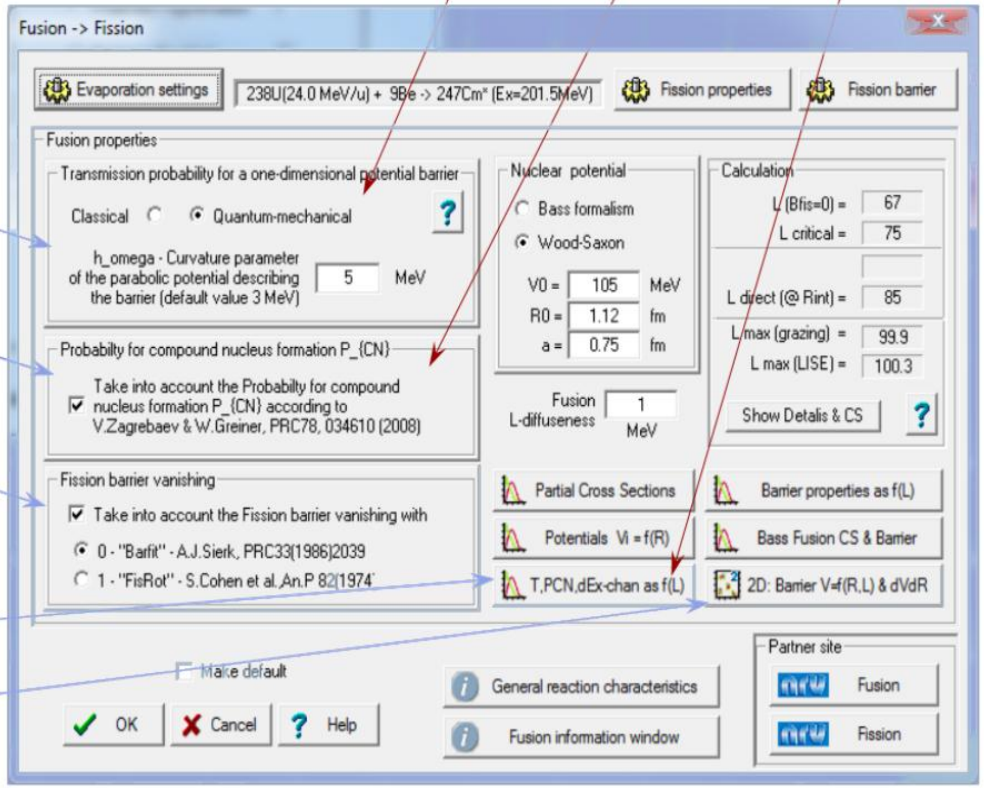
Fusion or Quasi-Elastic?

Compound or Quasi-Fission?

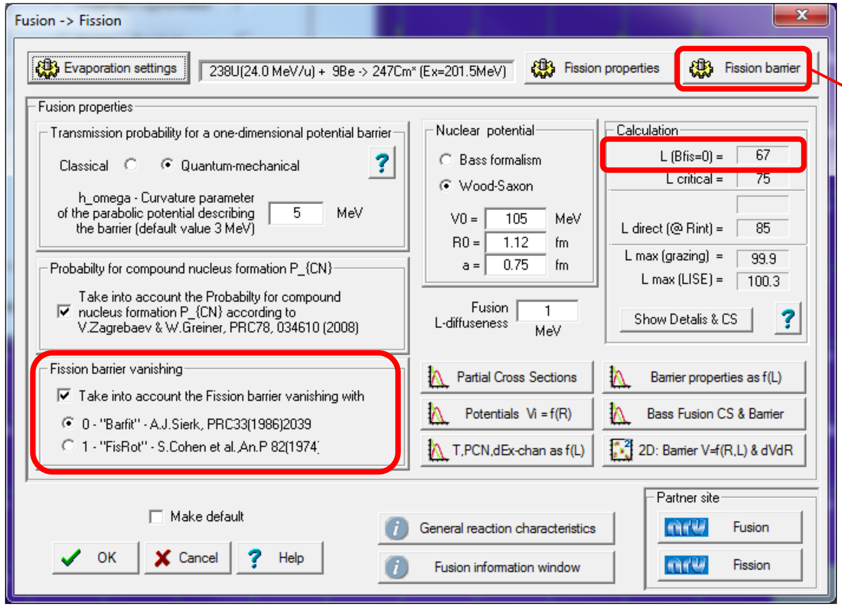
Fusion or Fast Fission?

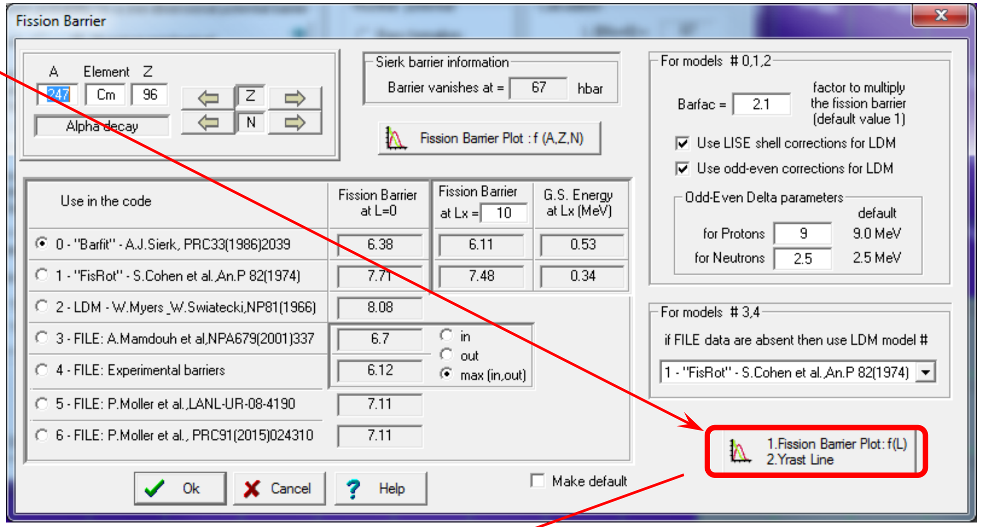
Fusion-Evaporation or Fusion-Fission?

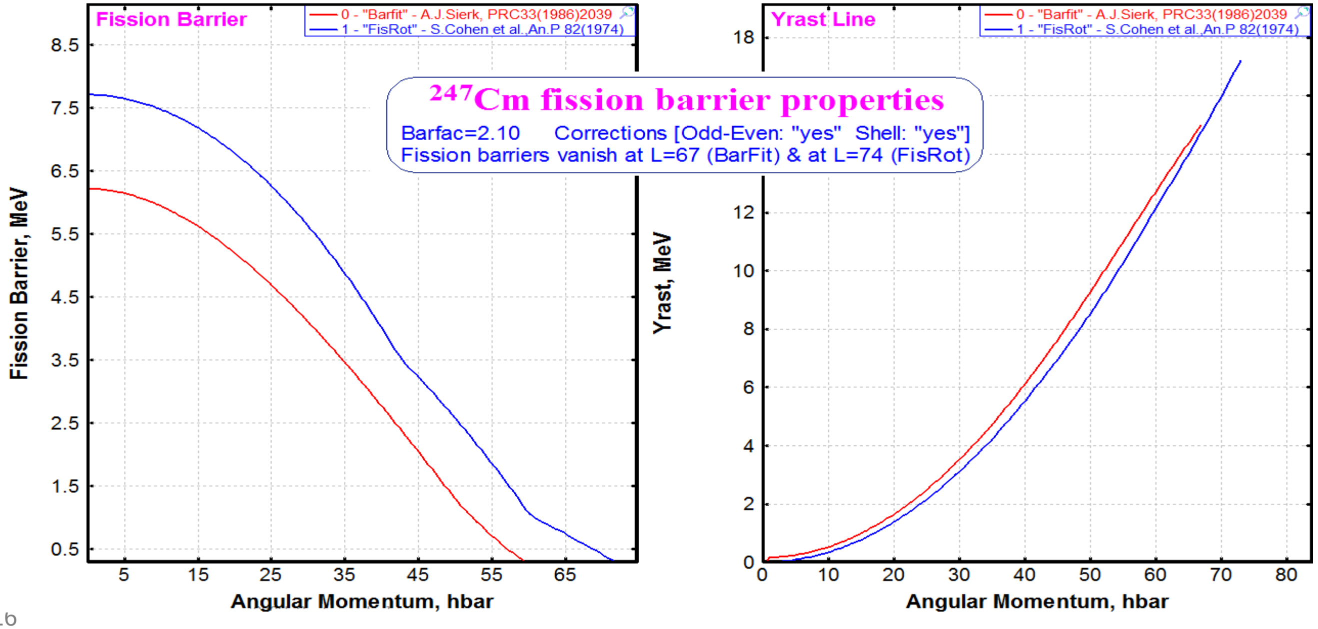
Fusion or Deep-Inelastic?



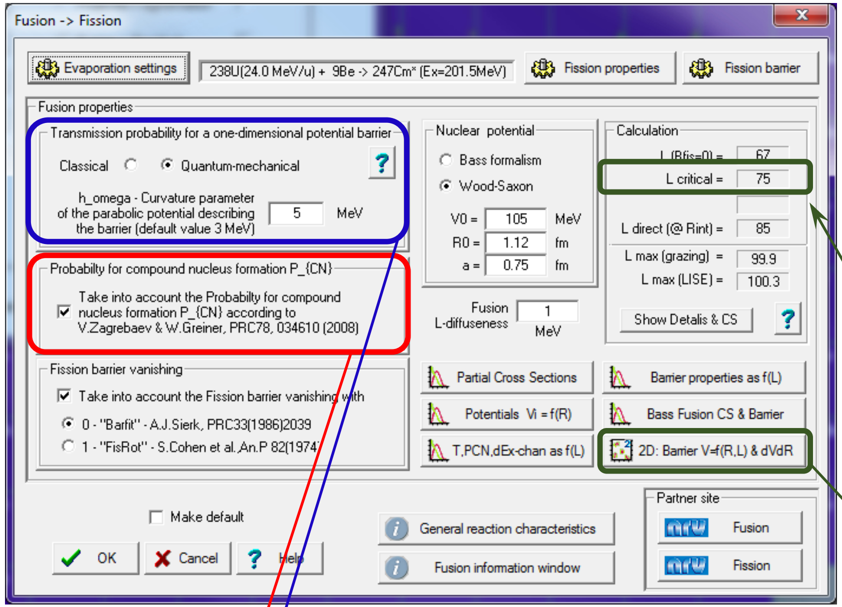
Fission Barrier Vanishing as f(L)





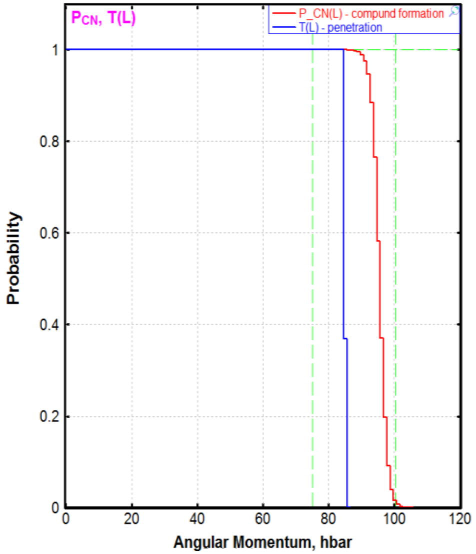


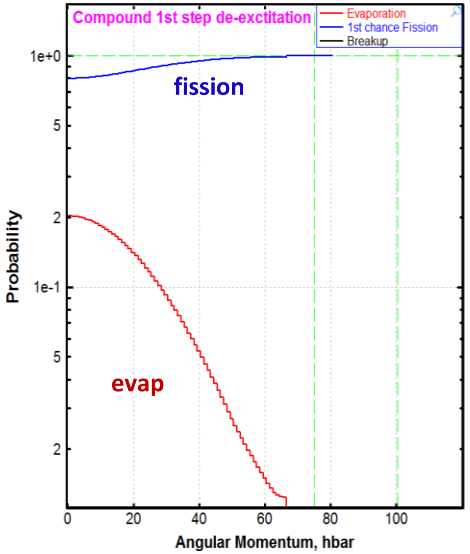
Transmission for a barrier & CN formation probabilities as f(L)



Probabilities as f (L)

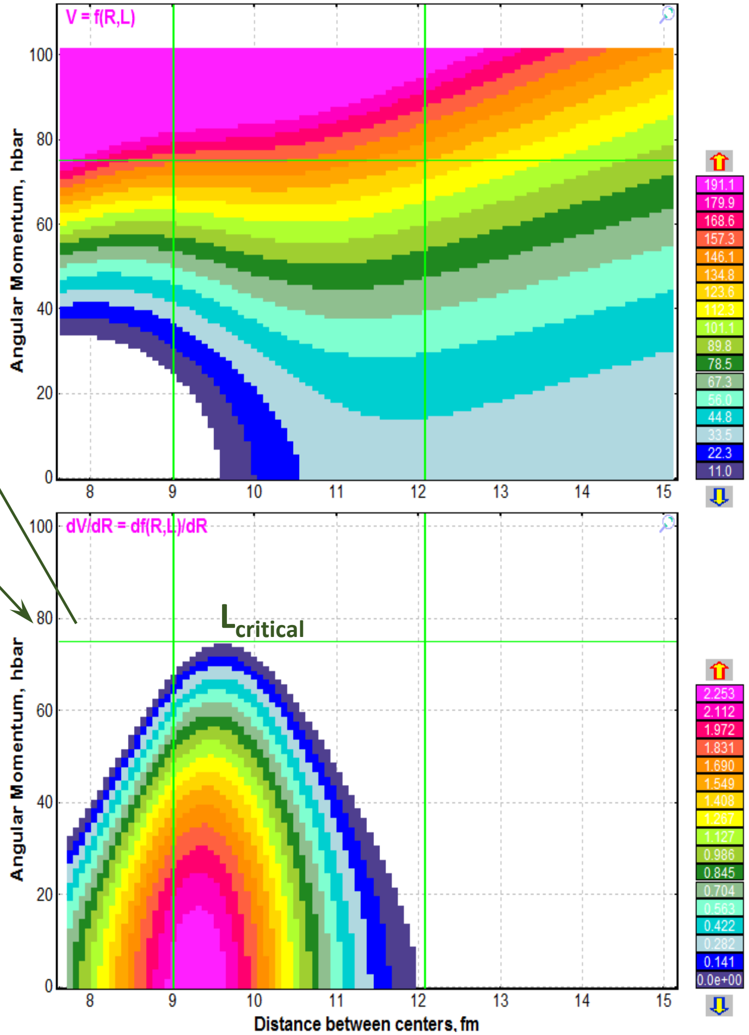
^{238}U(24.0 MeV/u) + ^{9}Be -> ^{247}Cm* (E_{CM}=208.3 MeV); h_omega=5.0
L_{crit}=75; L_{max}^{Graz}=99.9; L_{max}^{LISE}=100.3; Nuclear potential: WoodSaxon
Vertical lines correspond to $L_{critical}$ & $L_{maximum}$





2D Potential plots as f(R,L) & df(R,L)/dR

^{238}U(24.0 MeV/u) + ^{9}Be -> ^{247}Cm* (E_{CM}=208.3 MeV)
L_{crit}=75; L_{max}^{Graz}=99.9; L_{max}^{LISE}=100.3; Nuclear potential: WoodSaxon; WS params: 105.0,1.12,0.75
Vertical lines correspond to (C_p + C_t) and $R_{interaction}$, Horizontal line to $L_{critical}$



Optics minimization of existed separators

Links → Optics minimization (main part) Optics minimization (update) 2nd order Optics minimization

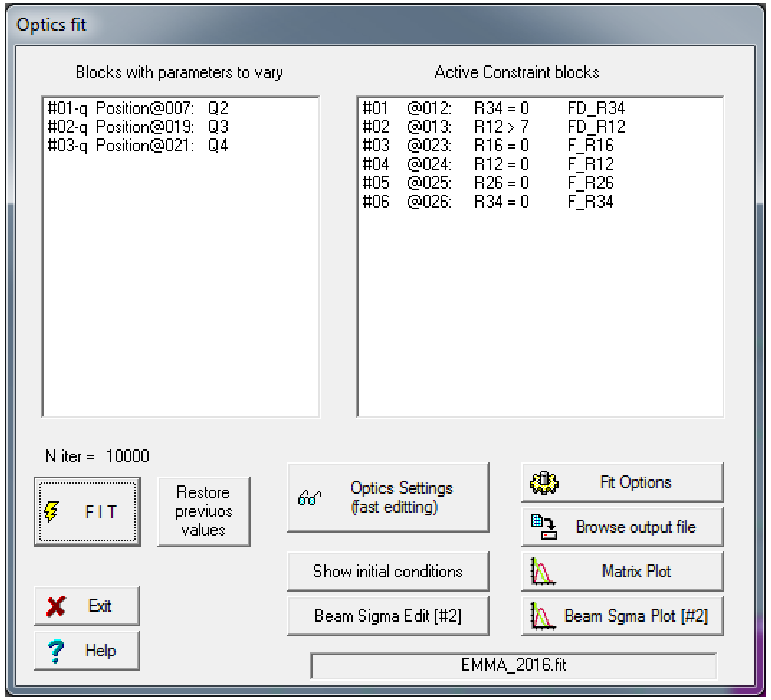
The optics minimization procedure was introduced, based on the "levmar" package by M.I.A. Lourakis using the Levenberg-Marquardt nonlinear least square algorithm [1]. At this stage only the quadrupole fields can be varied to minimize user constraints for matrix (1st and 2nd orders) and beam ellipse elements.

The continuous function has been created to be applied for boundary constraints .

Existed separators. Block size (length, radius) minimization : it is possible, but not necessary

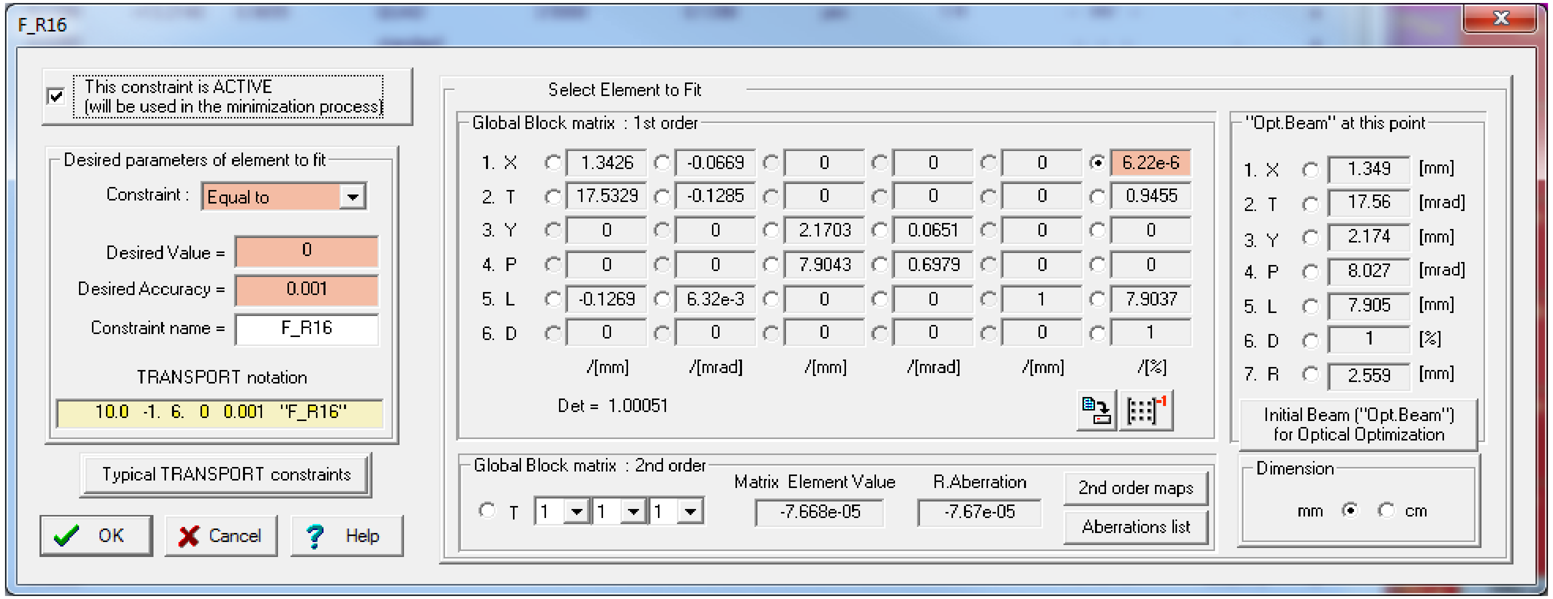
In the future this minimization procedure will be used to define curved profile shape, fragment spatial distributions in Monte Carlo mode, and optimize intensity/purity combination.

[1] levmar: Levenberg-Marquardt nonlinear least squares algorithms in C/C++. M.I.A. Lourakis July 2004. http://users.ics.forth.gr/~lourakis/levmar



The "Optics Fit" dialog. The left panel shows optical blocks with varying parameters, whereas blocks with fitting constraints.

This is HUGE-HUGE-HUGE new feature!!!!!



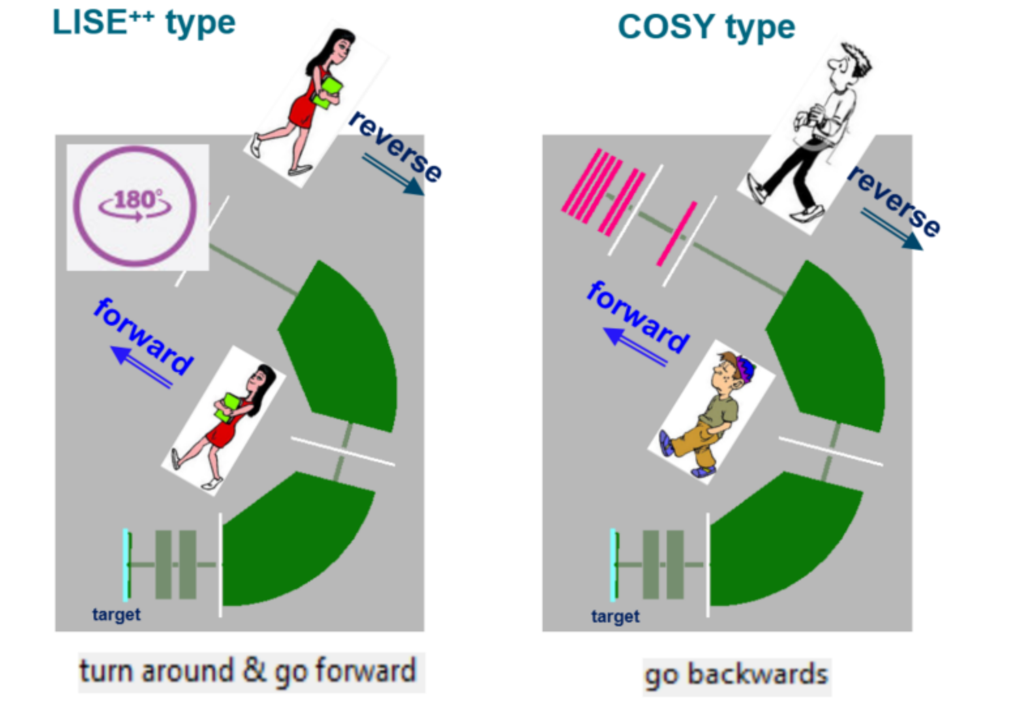
The "Fit constraint" dialog. For a constraint the user selects an element from an optical matrix or beam sigma vector, and set its desired value and precision (weight).

Reverse configurations: ray trajectory reconstruction

The LISE++ reverse technique approach is assumed to be applied for extended (elemental) configurations, that makes it more useful for beam dynamics and benchmarking.

Therefore, local maps are used in reverse configurations, which can be calculated by LISE++, or be entered by the user directly or linked to COSY maps (up to fifth order).

The development was connected to the analysis of the e12006 NSCL experiment.



- *The coordinate system is changed (x_n = -x, y'_n= $-y_n$, L_n= -L)*
- *Matrices are calculated by LISE++*

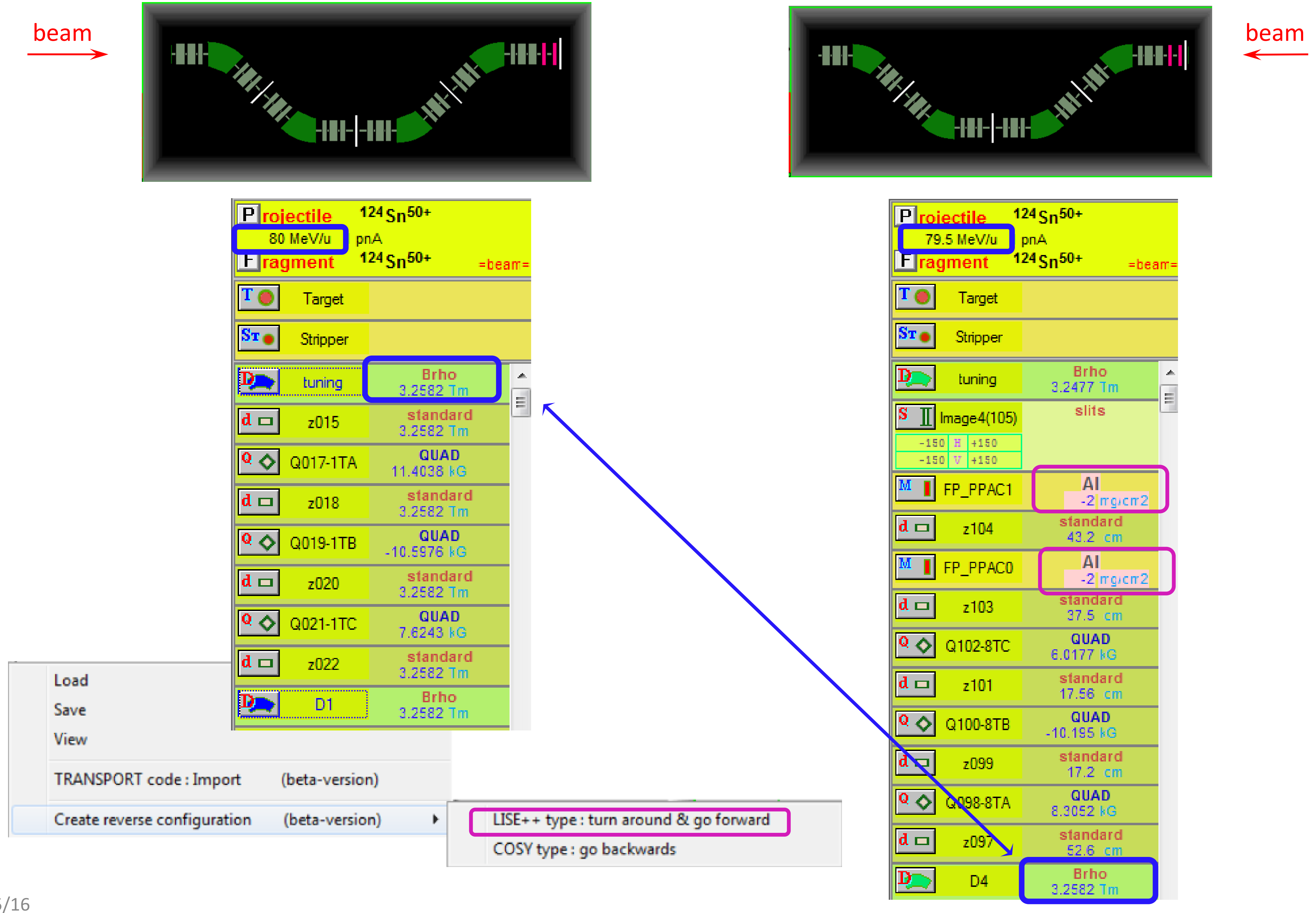
- *The coordinate system is not changed*
- *COSY matrices are imported (linked)*
- *These maps are inverted from the "direct" maps by the COSY procedure "MI"*
- *Ideal case : invert matrices inside LISE*

http://lise.nscl.msu.edu/9_10/ReverseConfiguration.pdf

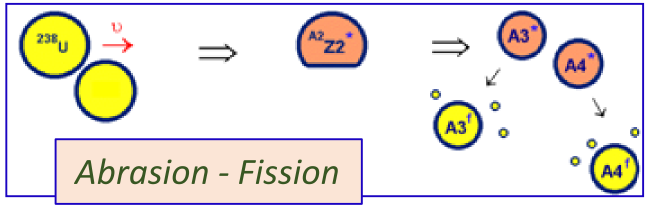
Application:

- **Momentum vector after reaction in target**
  (for example standard S800 technique)
  - Reaction mechanism study
  - Beam spot
  - Angular acceptance vs emittance
- **Beam emittance measurement (X,A,Y,B,E)**
  - Study of correlations between beam emittance components
- **Determination of location of background production**
  - BigRIPS case : production in the beam-dump
  - FRS case (H.W.)
- **Benchmarks based on LISE++ MC apparatus and spectrograph segmentation**
  - Beam dynamics visualization
  - Beam optics calculation verification
  - Experimental analysis and calibrations test
- **Experiment set-up feedback with LISE++ (in future)**
  - Obtaining experimental information by detecting devices in some (or one) locations
  - Retracing up-stream (or down-stream) from detection locations based
  - Analysis, minimization

LISE-type reverse file creation

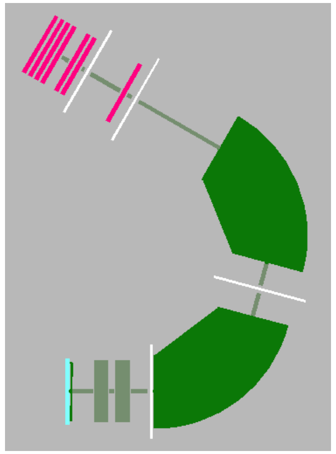


In-flight Fission kinematics and Abrasion excitation energy



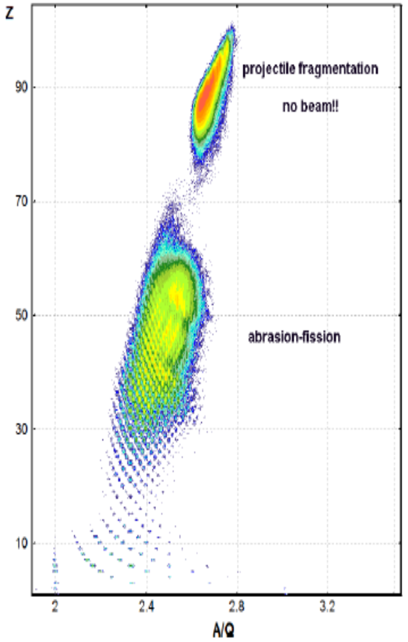
LISE++ Abrasion-Fission
Three Excitation-Energy regions model

e12006

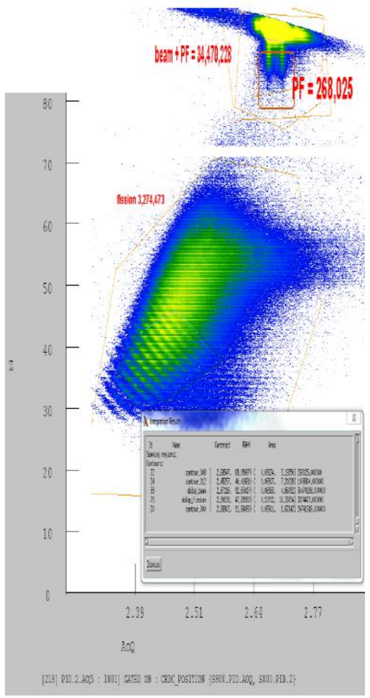


Diamond target:
ToF start

LISE++ simulation

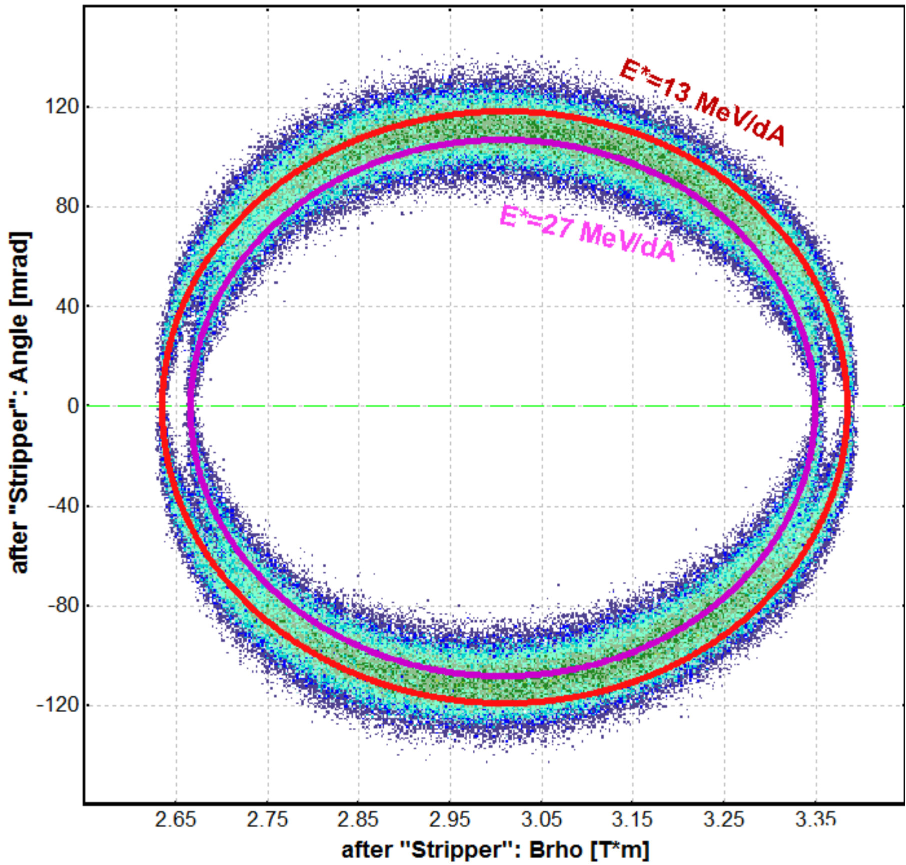


Experiment



^{238}U (79.56 MeV/u) + C
Transmitted Fragment ^{83}Kr (AFmid)

special case: d(E*)=0 & thin target



3D fission kinematics

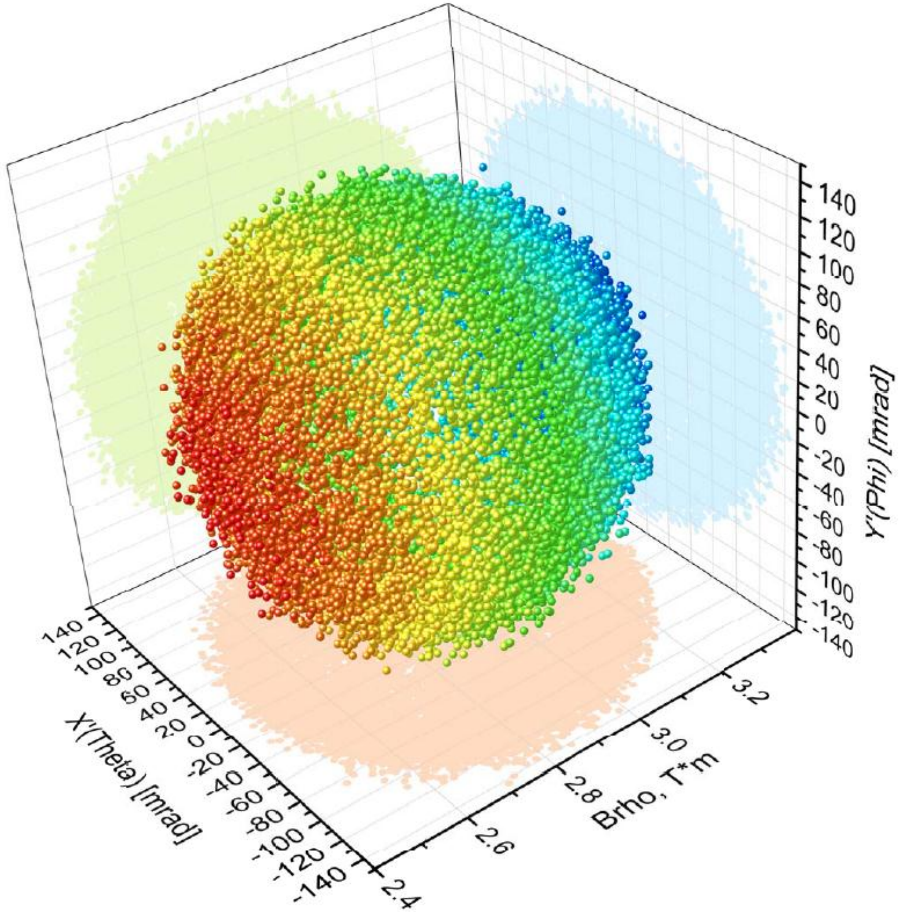
$^{238}U_{\ (80\ MeV/u)} + C \rightarrow {}^{83}Kr_{\ Mid\ EER}$

after target

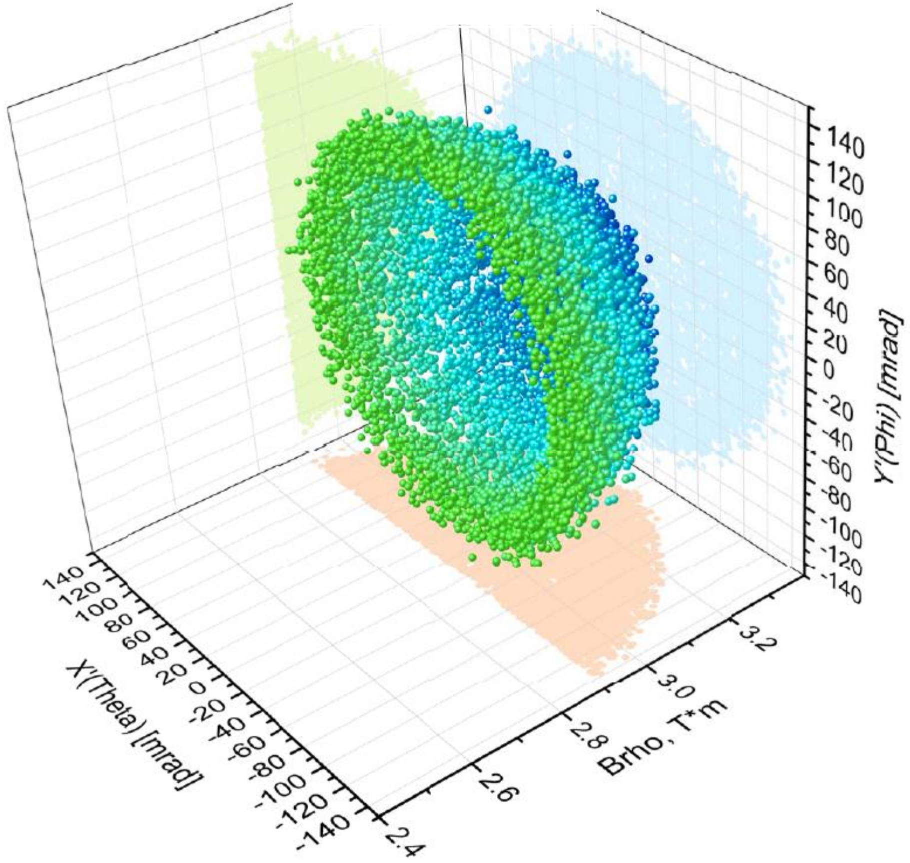
LISE^{++}

Bρ=3.1743 Tm,

Target C (33.5 mg/cm^2)



Fast Half



$^{238}U_{(80\ MeV/u)} + C \rightarrow {}^{83}Kr_{Mid\ EER}$

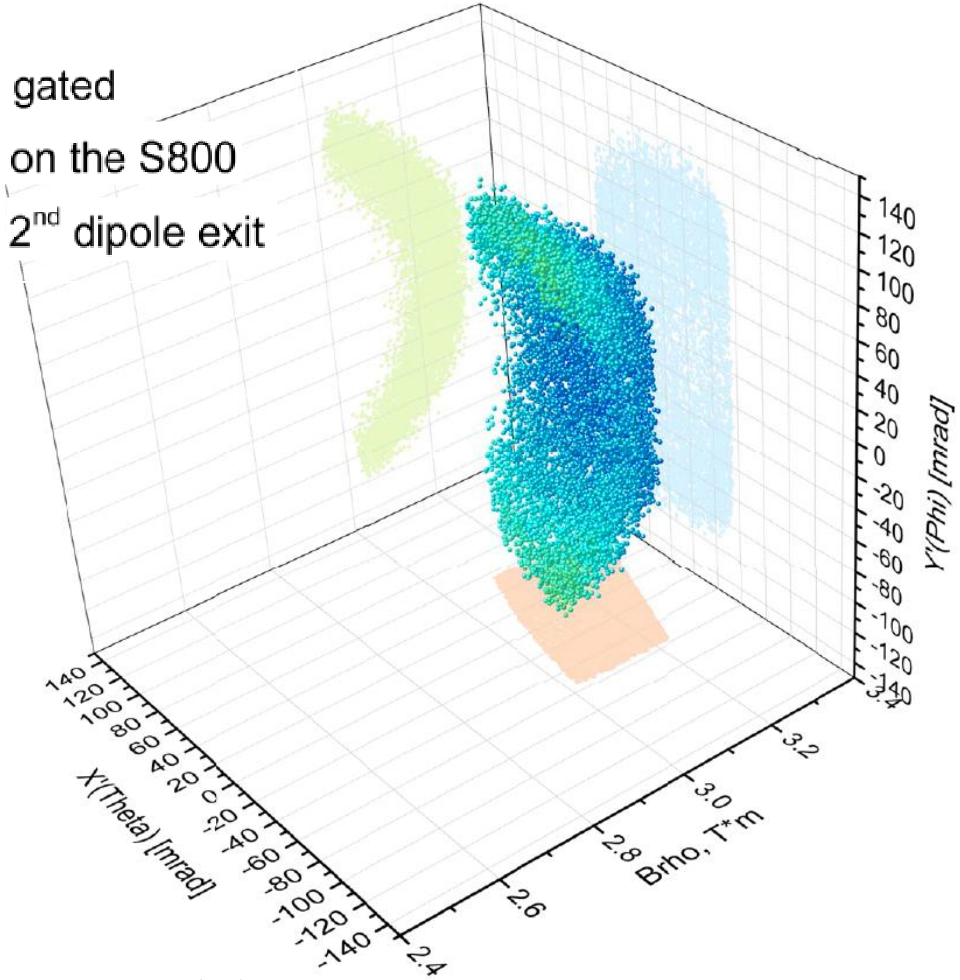
after target

LISE++

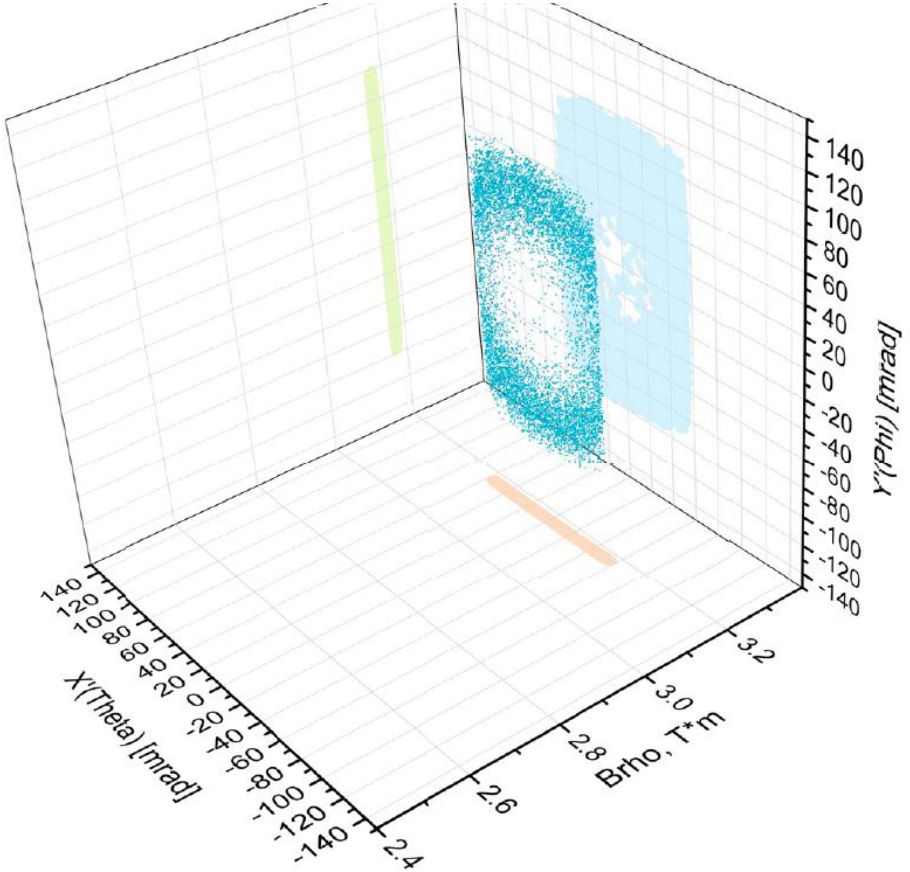
Bρ=3.1743 Tm,

Target C (33.5 mg/cm^2)

gated on the S800 2nd dipole exit

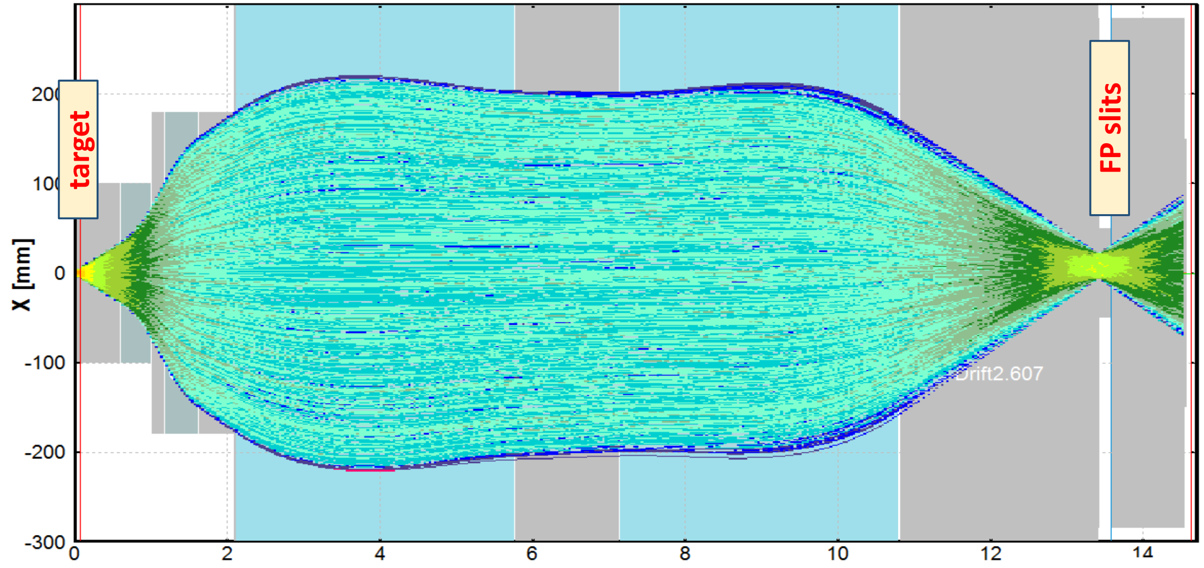


gated on the FP slits (±10mm)

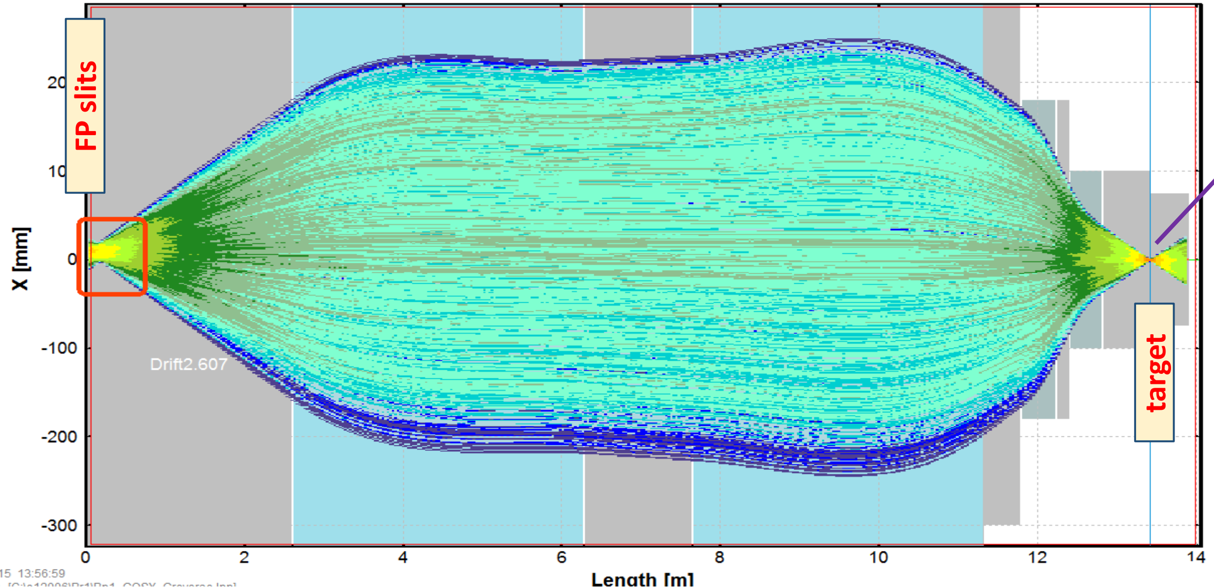


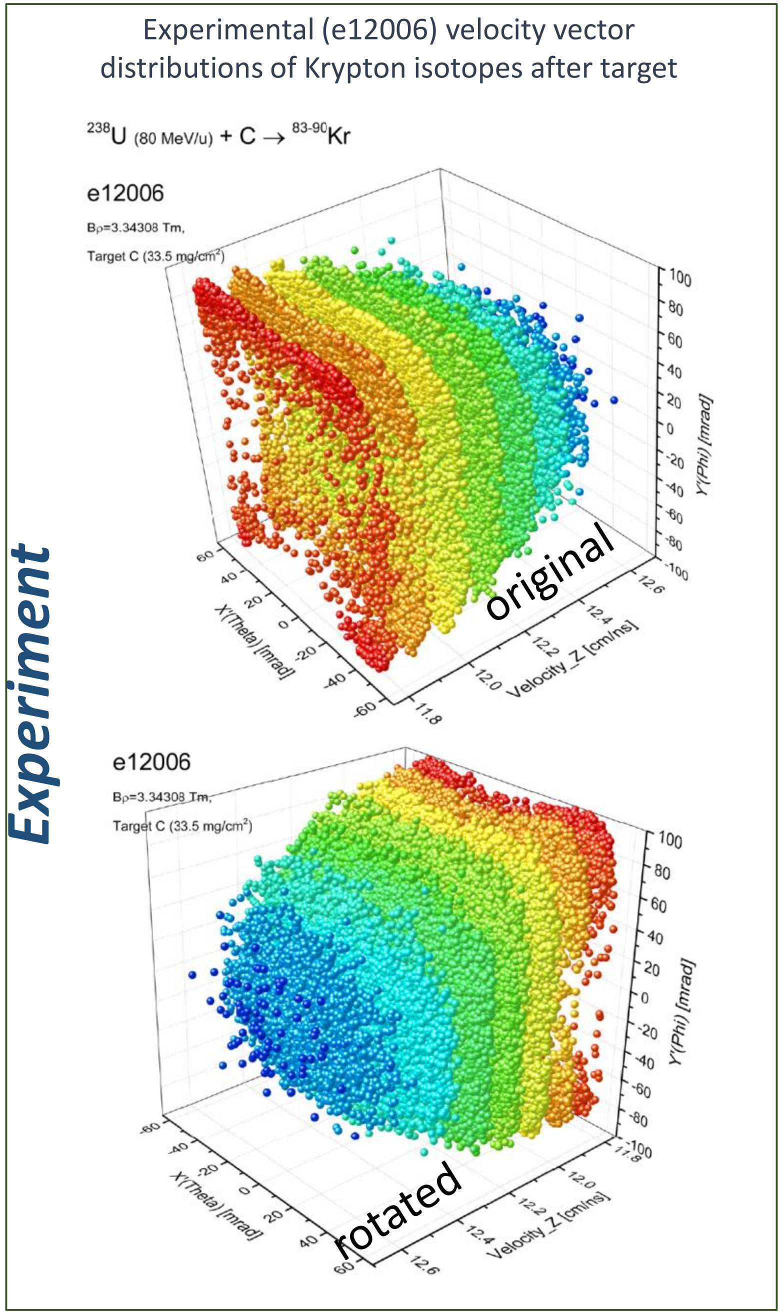
Reverse configurations: ray trajectory reconstruction for ^{238}U(80 MeV/u)+Be→**Kr

S800 Forward direction : LISE++ simulation

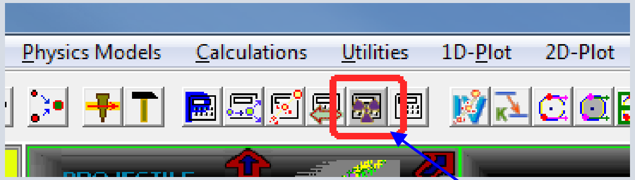


S800 Backward direction : e12006 experiment

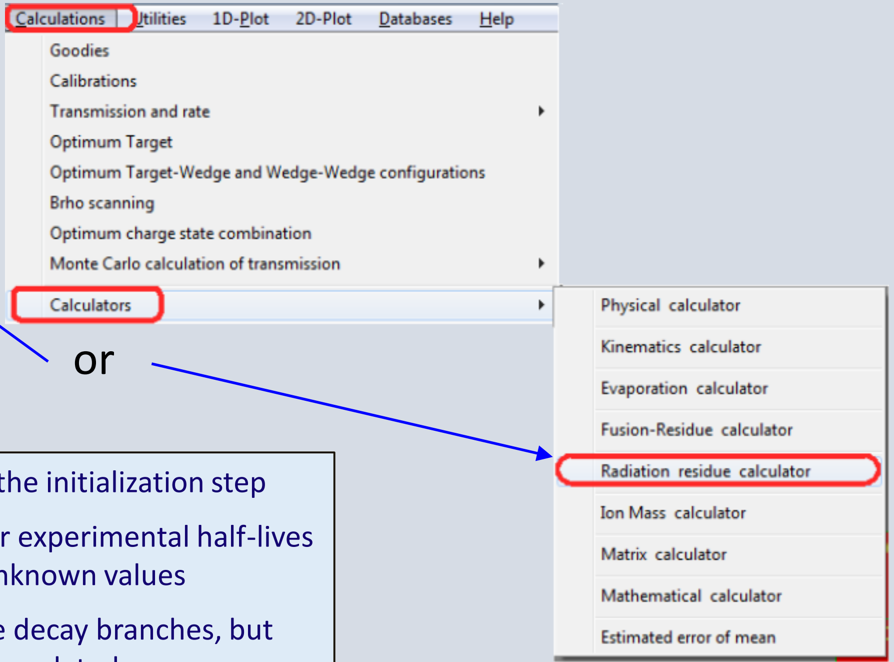




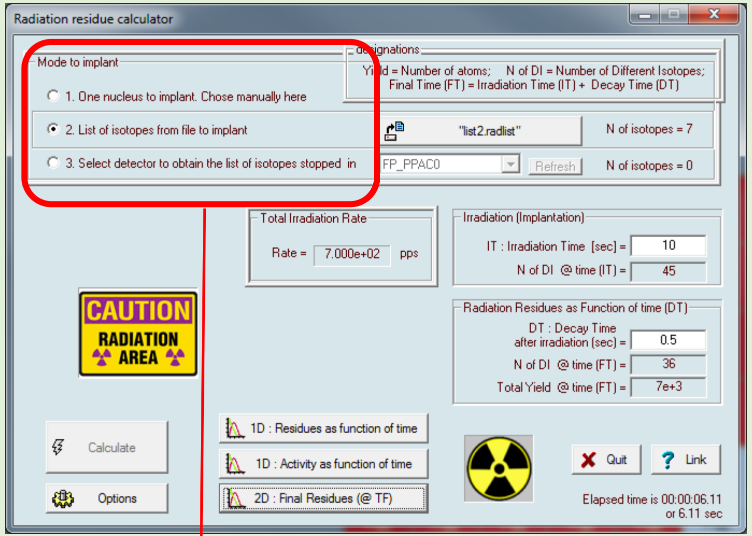
Radiation Residue Calculator



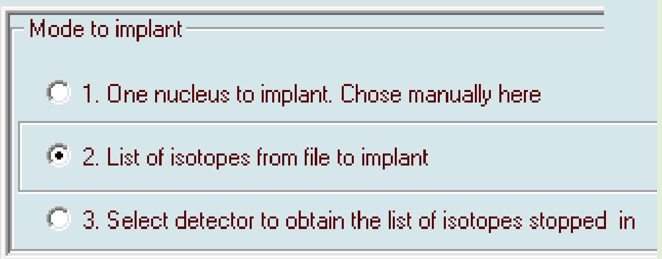
or



- About 7300 differential equations at the initialization step
- LISE++ uses the AME2012 database for experimental half-lives and internal calculation models for unknown values
- LISE++ takes into account two possible decay branches, but the Decay Branch database should be updated

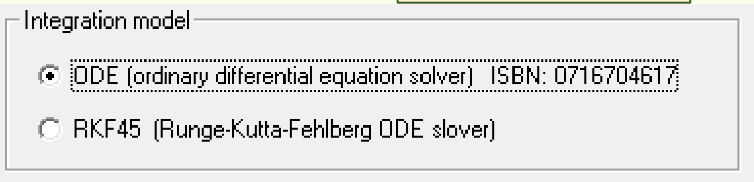


zoom



"integrators"

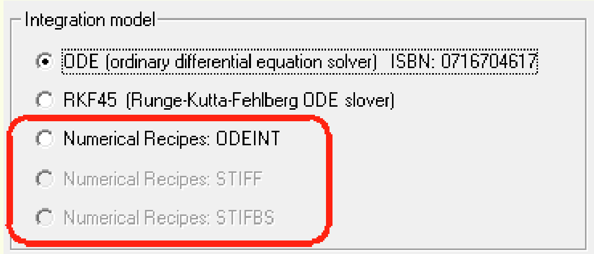
v.1



Lawrence Shampine, Marilyn Gordon,
Computer Solution of Ordinary Differential Equations:
The Initial Value Problem,
Freeman, 1975, ISBN: 0716704617, LC: QA372.S416.

C++ version by John Burkardt

v.2



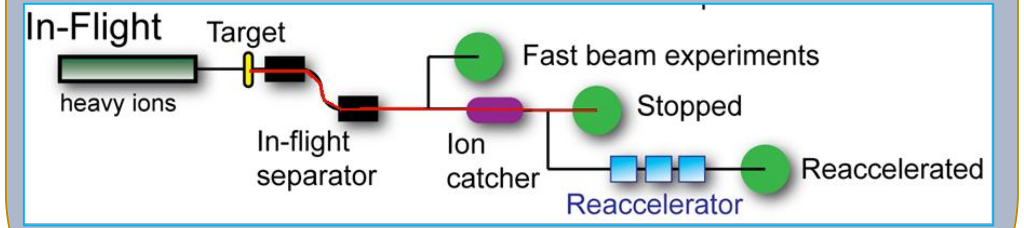
Numerical Recipes in ANSI C++ 2.11

NUMERICAL RECIPES SOFTWARE
P.O. Box 243, Cambridge, MA 02238 (USA)

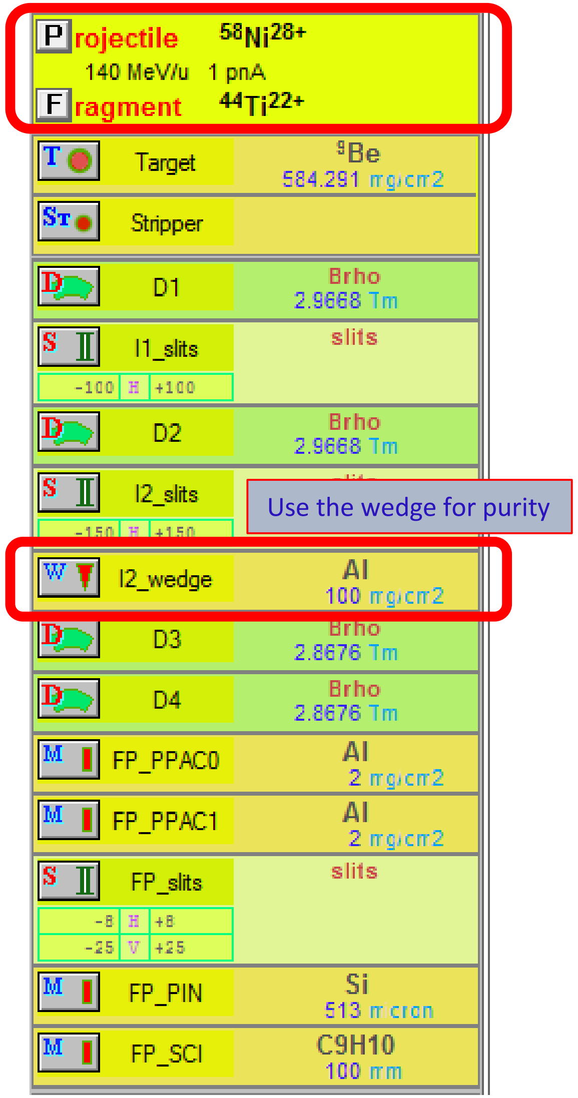
“Direct” production: ^{44}Ti example

Table 1. Priority isotopes for harvesting at FRIB. These isotopes were identified at t
Working Group meeting in Santa Fe, NM September 30 – October 1, 2010.

Isotope	Half-life	Application
^{32}Si	160 y	Tracer; geology and botany
^{44}Ti	60 y	Medicine, astrophysics, nuclear structure
^{48}V	16 d	Stockpile Stewardship
^{67}Cu	2.6 d	Medicine
^{85}Kr	10.0 d	Astrophysics, stockpile stewardship
Eu*		Stockpile Stewardship
^{211}Rn	14.6 h	Medicine
^{225}Ra	14.9d	Medicine, Electric Dipole Moment
^{225}Ac	10.0 d	Medicine

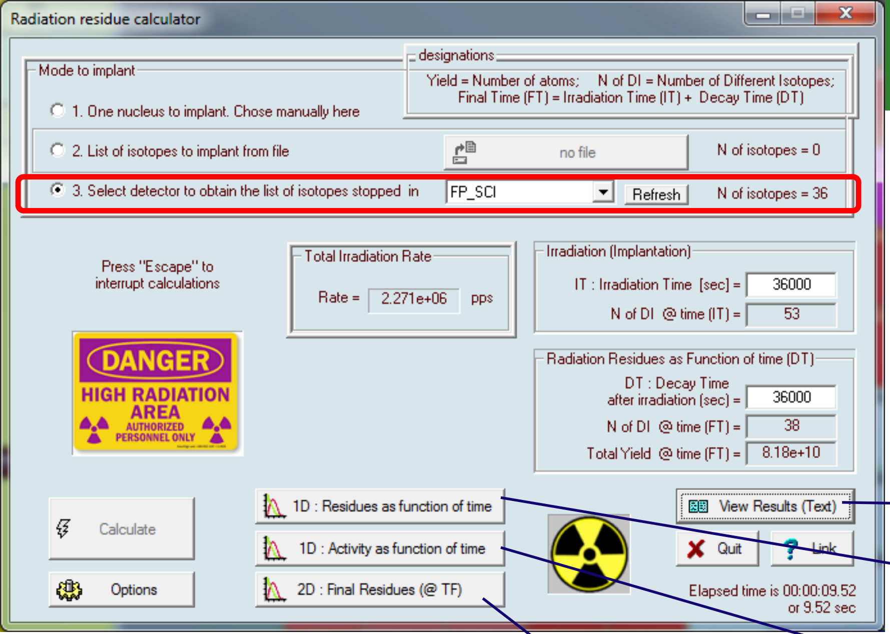


settings



http://lise.nscl.msu.edu/9_10/radiation/RadiationResidue_44Ti.pdf

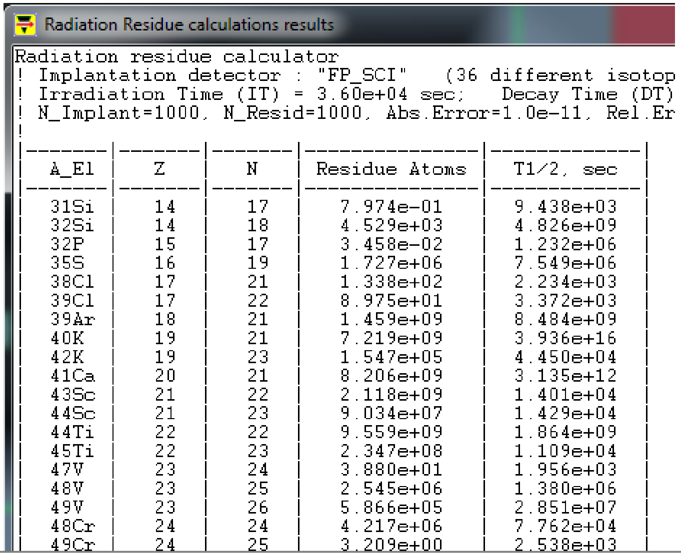
^{44}Ti case : Residues



Isotopes selected by the Fragment-Separator are implanted in FP_SCI detector

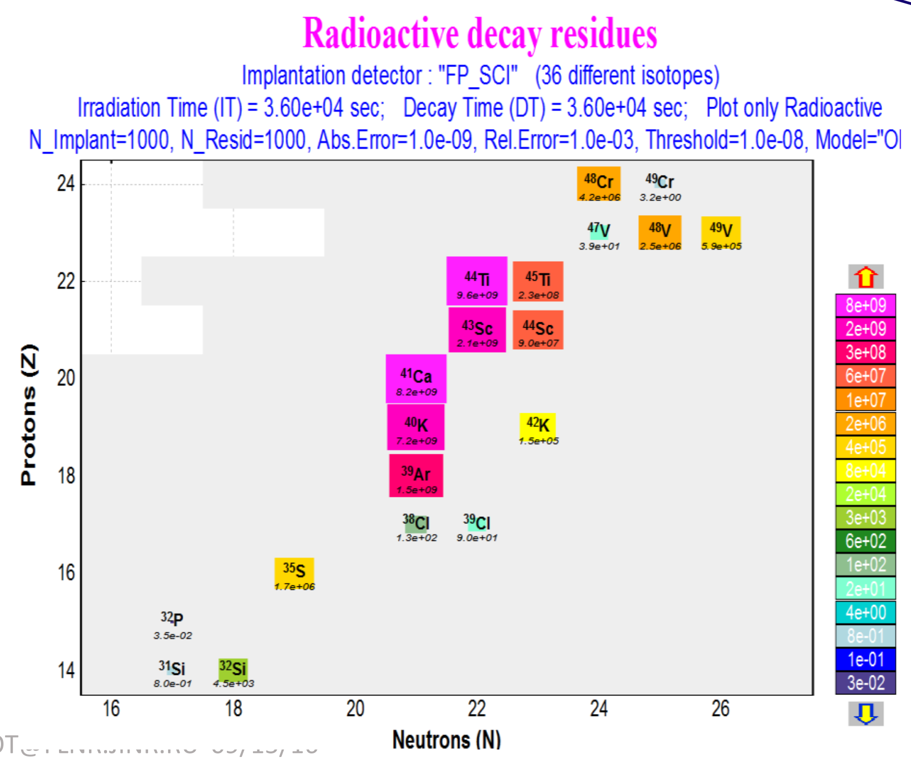
http://lise.nscl.msu.edu/9_10/radiation/44Ti%20from%2058Ni.lpp

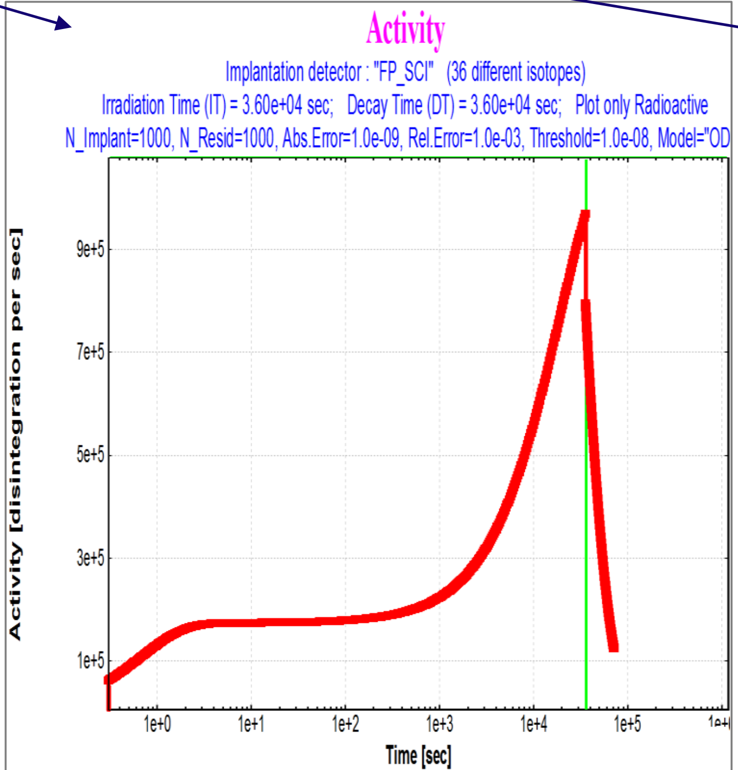
10 hours of irradiation, 10 hours of decay :
^{44}Ti's number of atoms is highest!

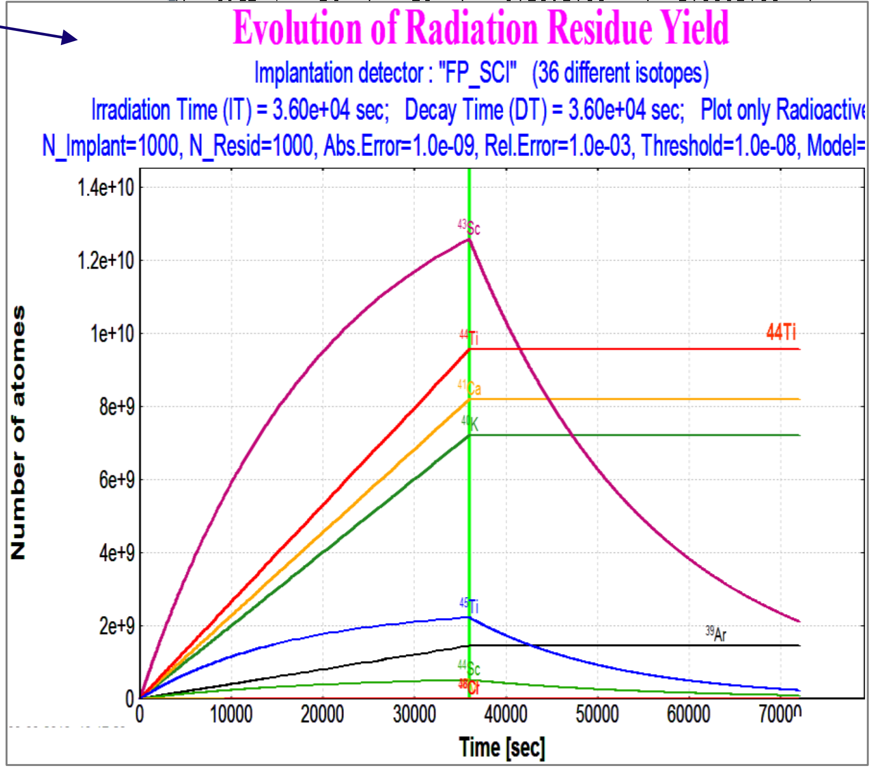

Radiation Residue calculations results

```
Radiation residue calculator
! Implantation detector : "FP_SCI"   (36 different isotop
! Irradiation Time (IT) = 3.60e+04 sec;   Decay Time (DT)
! N_Implant=1000, N_Resid=1000, Abs.Error=1.0e-11, Rel.Er
```

A_El	Z	N	Residue Atoms	T1/2, sec
31Si	14	17	7.974e-01	9.438e+03
32Si	14	18	4.529e+03	4.826e+09
32P	15	17	3.458e-02	1.232e+06
35S	16	19	1.727e+06	7.549e+06
38Cl	17	21	1.338e+02	2.234e+03
39Cl	17	22	8.975e+01	3.372e+03
39Ar	18	21	1.459e+09	8.484e+09
40K	19	21	7.219e+09	3.936e+16
42K	19	23	1.547e+05	4.450e+04
41Ca	20	21	8.206e+09	3.135e+12
43Sc	21	22	2.118e+09	1.401e+04
44Sc	21	23	9.034e+07	1.429e+04
44Ti	22	22	9.559e+09	1.864e+09
45Ti	22	23	2.347e+08	1.109e+04
47V	23	24	3.880e+01	1.956e+03
48V	23	25	2.545e+06	1.380e+06
49V	23	26	5.866e+05	2.851e+07
48Cr	24	24	4.217e+06	7.762e+04
49Cr	24	25	3.209e+00	2.538e+03

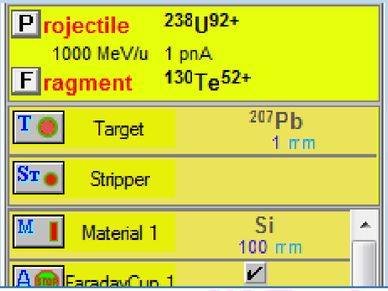




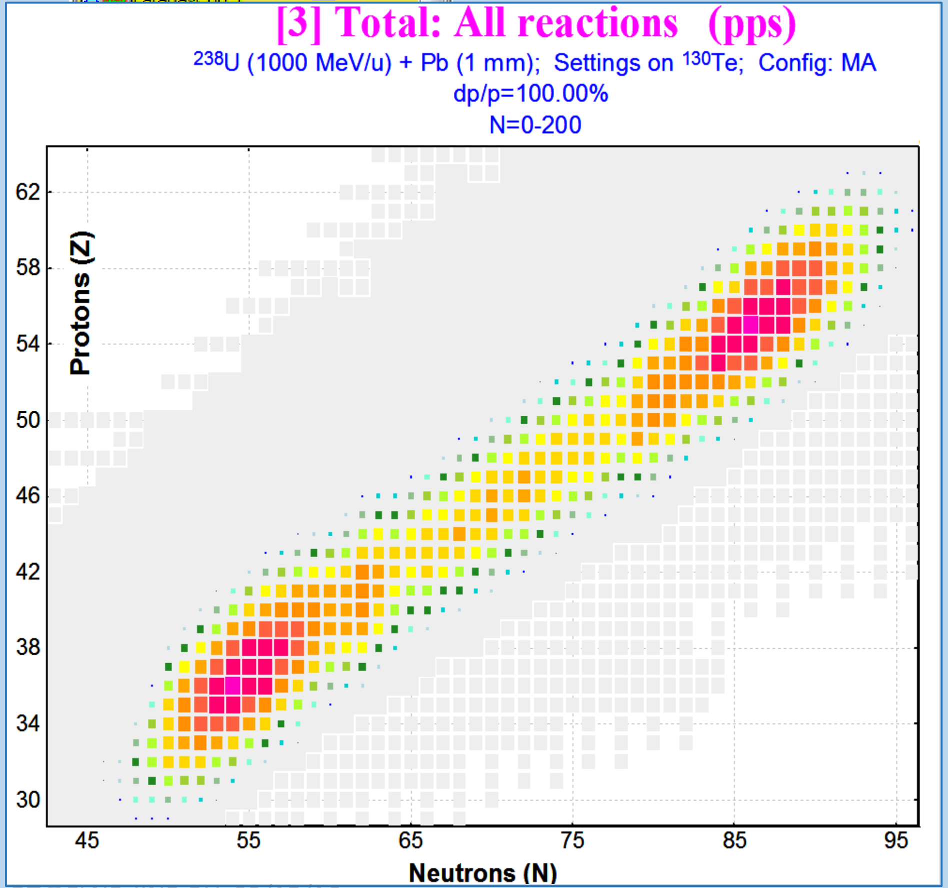


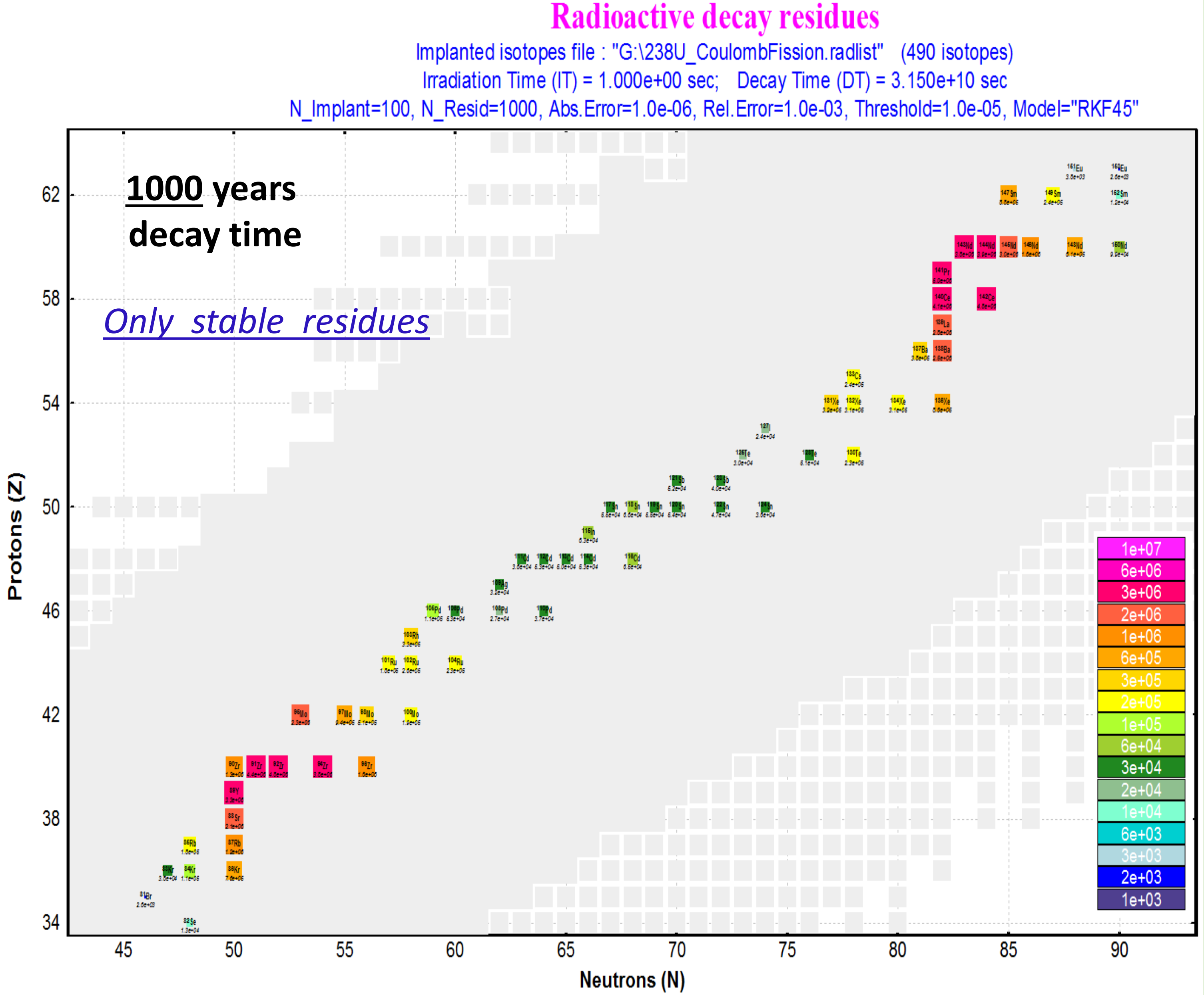
Radiation Residue Calculator : ^{238}U low excitation fission

This file has been produced by LISE++ with next settings and Coulomb Fission mechanism

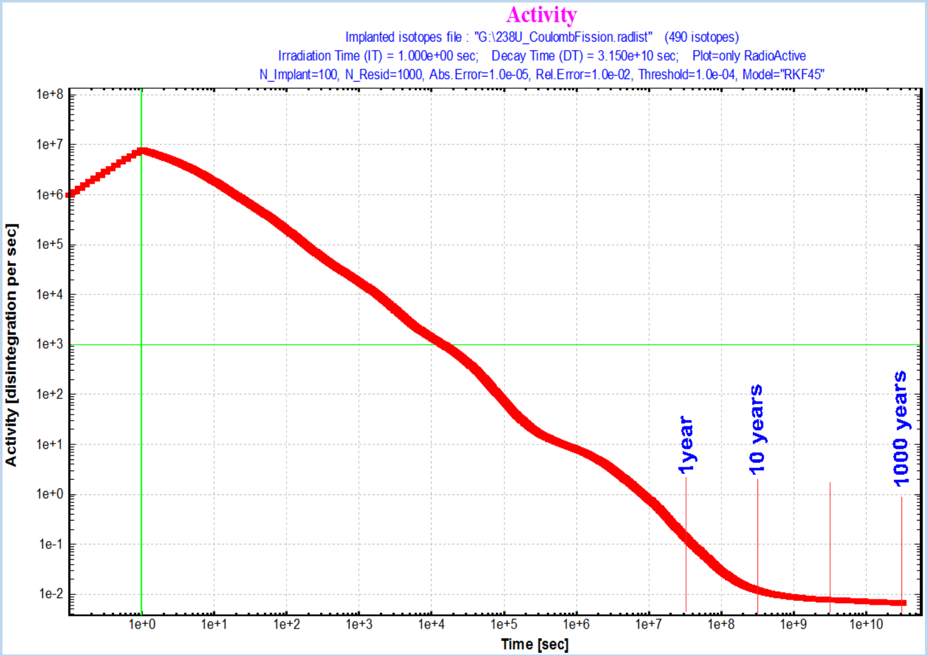


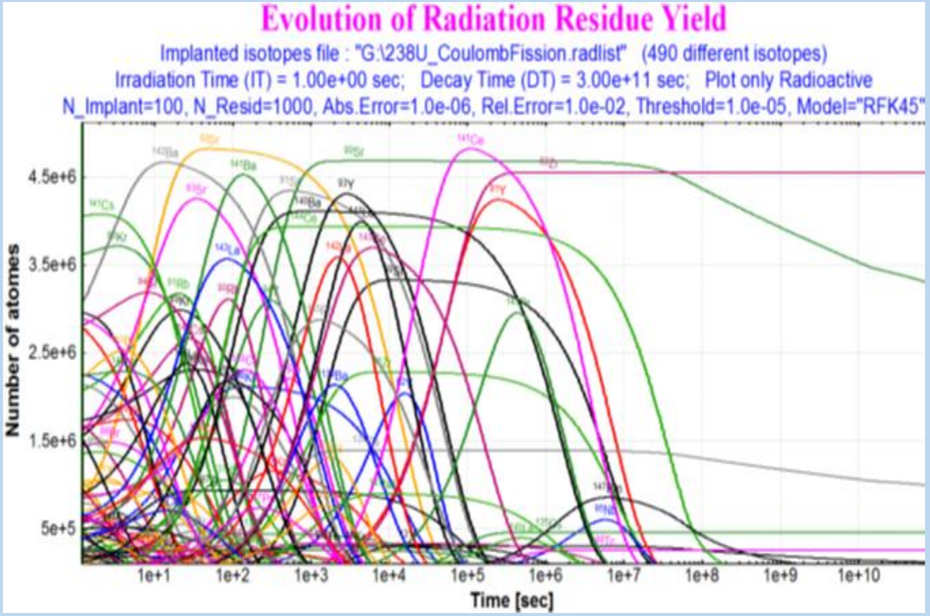
Implanted isotopes (number of different isotopes is 490)





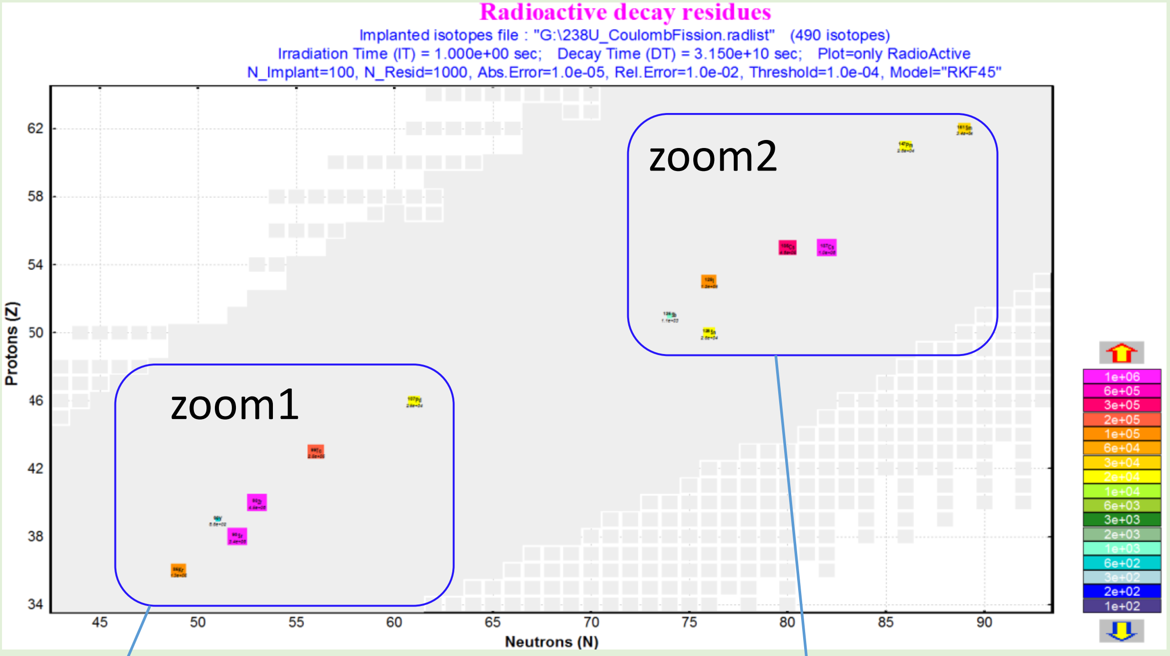
Radiation Residue Calculator : ^{238}U low excitation fission

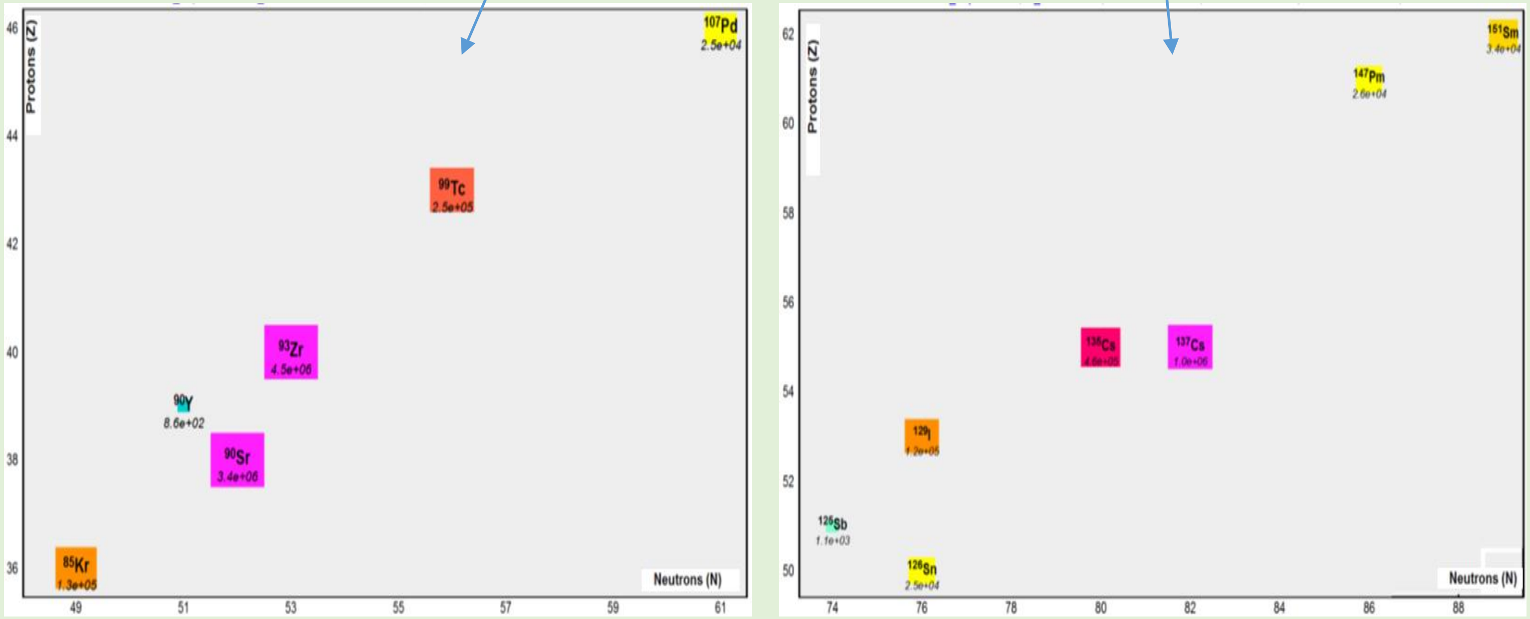




1000 years decay time

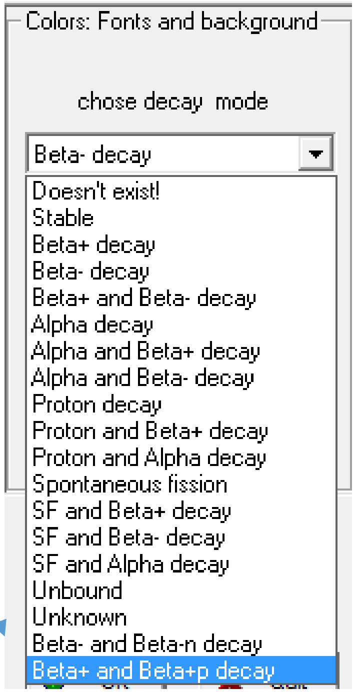
Only Radioactive residues

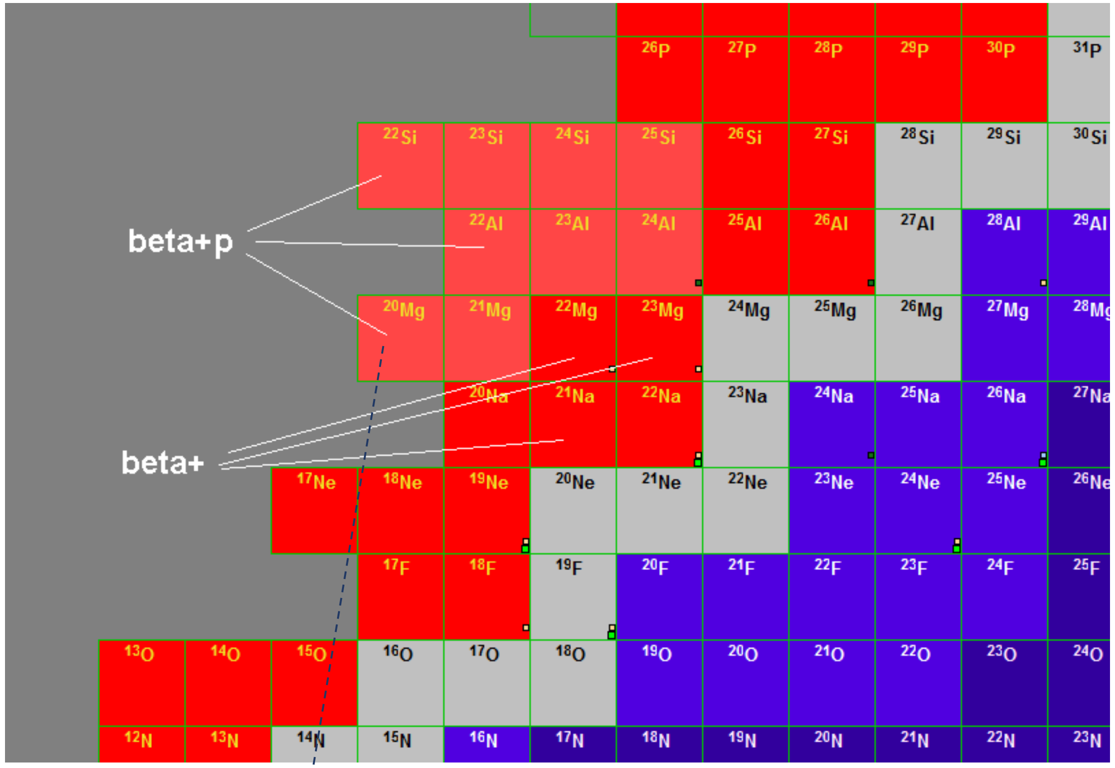


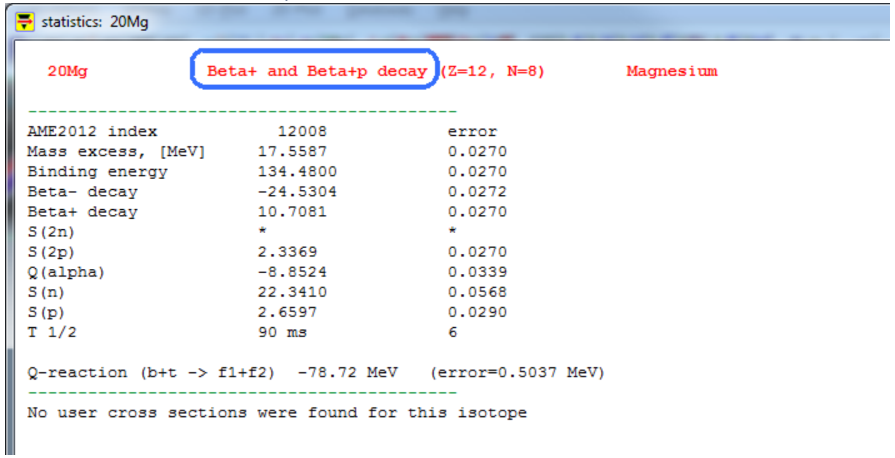


Decay Branching Ratio Database

1. Beta-Delayed Neutron Emission is new decay mode in LISE++
2. Beta-Delayed Proton Emission is new decay mode in LISE++
3. Decay branching ratio database
4. Editor of Decay branching ratio database
5. Using the Decay branching ratio database in Radiation Residue calculations







statistics: 20Mg

20Mg Beta+ and Beta+p decay (Z=12, N=8) Magnesium

AME2012 index	12008	error
Mass excess, [MeV]	17.5587	0.0270
Binding energy	134.4800	0.0270
Beta- decay	-24.5304	0.0272
Beta+ decay	10.7081	0.0270
S(2n)	*	*
S(2p)	2.3369	0.0270
Q(alpha)	-8.8524	0.0339
S(n)	22.3410	0.0568
S(p)	2.6597	0.0290
T 1/2	90 ms	6

Q-reaction (b+t -> f1+f2) -78.72 MeV (error=0.5037 MeV)

No user cross sections were found for this isotope

Decay Branching Ratio Database

\lise\bin*.*

Name	Ext	Size
[..]		<DIR>
branching_ratio	lbase	3,411

File Edit Options Help

```
2006 8.400000e-01
3006 4.950000e-01
3008 1.340000e-01
4008 9.950000e-01
4010 1.340000e-01
5008 9.973400e-01
5009 9.396000e-01
5010 3.200000e-03
5012 3.700000e-01
5014 2.820000e-01
```

2D-Plot Databases Help

- AME & properties: View, Edit
- AME & properties: Plots
- Isomer database
- Ionization energy database
- Decay Branching Ratio database

Isotopes

Chlorine

A: 36 Element: Cl Z: 17

Table of Nuclides

Z N

Beta+ and Beta- decay — Change

Branching

- Beta +: 1.9 %
- Beta -: 98.1 %

Save

Generate Z-wallet — Quit

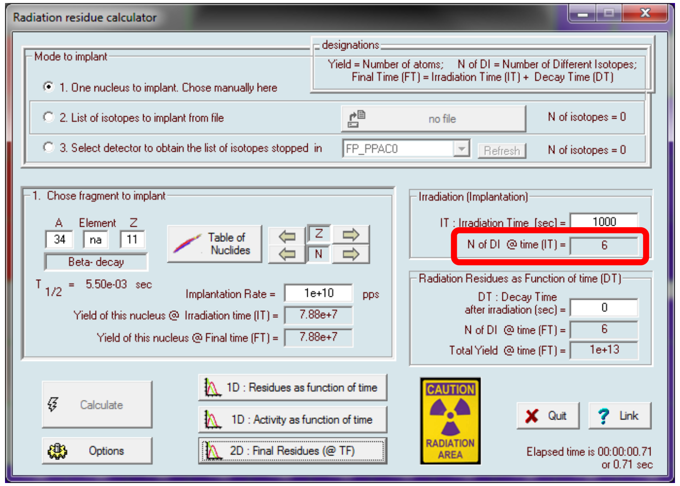
Decay Branching Ratio

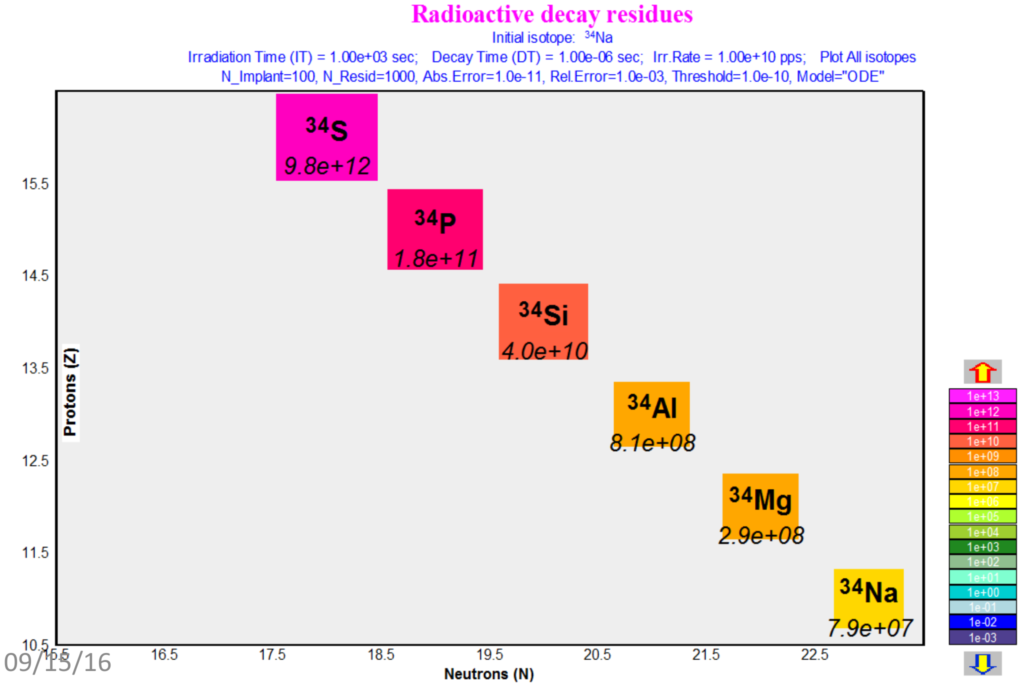
Z=17 (Chlorine)

A	decay1	branch,%	decay2	branch,%	T 1/2, s	Abundance,%
30	Unknown	100			8.430e-13	
31	Beta +	100			1.500e-01	
32	Beta +	100			2.980e-01	
33	Beta +	100			2.511e+00	
34	Beta +	100			1.527e+00	
35	Stable	100				75.760
36	Beta +	1.90	Beta -	98.10	9.503e+12	
37	Stable	100				24.240
38	Beta -	100			2.234e+03	
39	Beta -	100			3.372e+03	
40	Beta -	100			8.100e+01	
41	Beta -	100			3.840e+01	
42	Beta -	100			6.800e+00	
43	Beta -	100			3.130e+00	
44	Beta -	100			5.600e-01	
45	Beta -	76.00	Beta - n	24.00	4.130e-01	
46	Beta -	40.00	Beta - n	60.00	2.320e-01	
47	Beta -	100			1.010e-01	
48	Beta -	100			2.480e-02	
49	Beta -	100			1.890e-02	
50	Beta -	100			4.400e-03	
51	Beta -	100			6.180e-03	
53	Unknown	100			2.700e-03	
55	Unknown	100			8.600e-04	

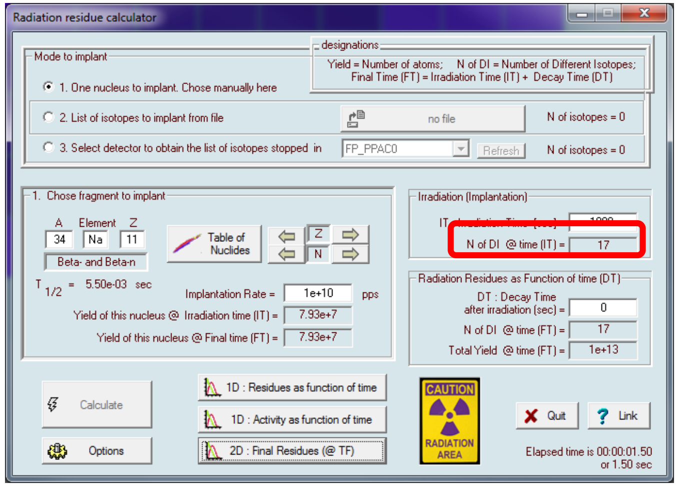
T 1/2 : compilation of experimental and calculated values.
See the AME dialog for details

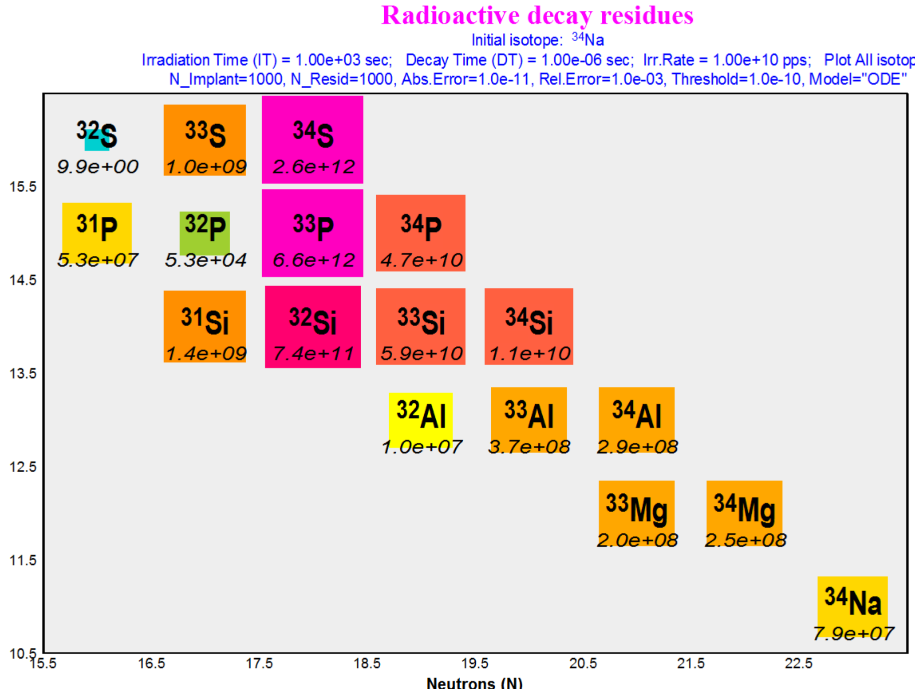
v.9.10.331. No Decay Branch Database





v.9.10.341. With Decay Branch Database





ETACHA4 (GUI) still under construction

1. Authors sent the e-mail with the source to implement in LISE^{++}
2. We discussed with the authors all moments recently for porting to C++ , the GUI shell creation, using in LISE^{++} , citations and so on. They proposed to create a link on the LISE^{++} site for ETACHA users

PHYSICAL REVIEW A **92**, 042703 (2015)

Extension of charge-state-distribution calculations for ion-solid collisions towards low velocities and many-electron ions

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[2]*Sorbonne Universités, UPMC Université Paris 06, INSP, UMR 7588, F-75005 Paris, France*
[3]*Centro Atómico Bariloche, Comisión Nacional de Energía Atómica and Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), 8400 San Carlos de Bariloche, Río Negro, Argentina*
[4]*Laboratorio de Colisiones Atómicas, Instituto de Física Rosario (CONICET-UNR) and Facultad de Ciencias Exactas, Ingeniería y Agrimensura, Universidad Nacional de Rosario, Avenida Pellegrini 250, 2000 Rosario, Argentina*

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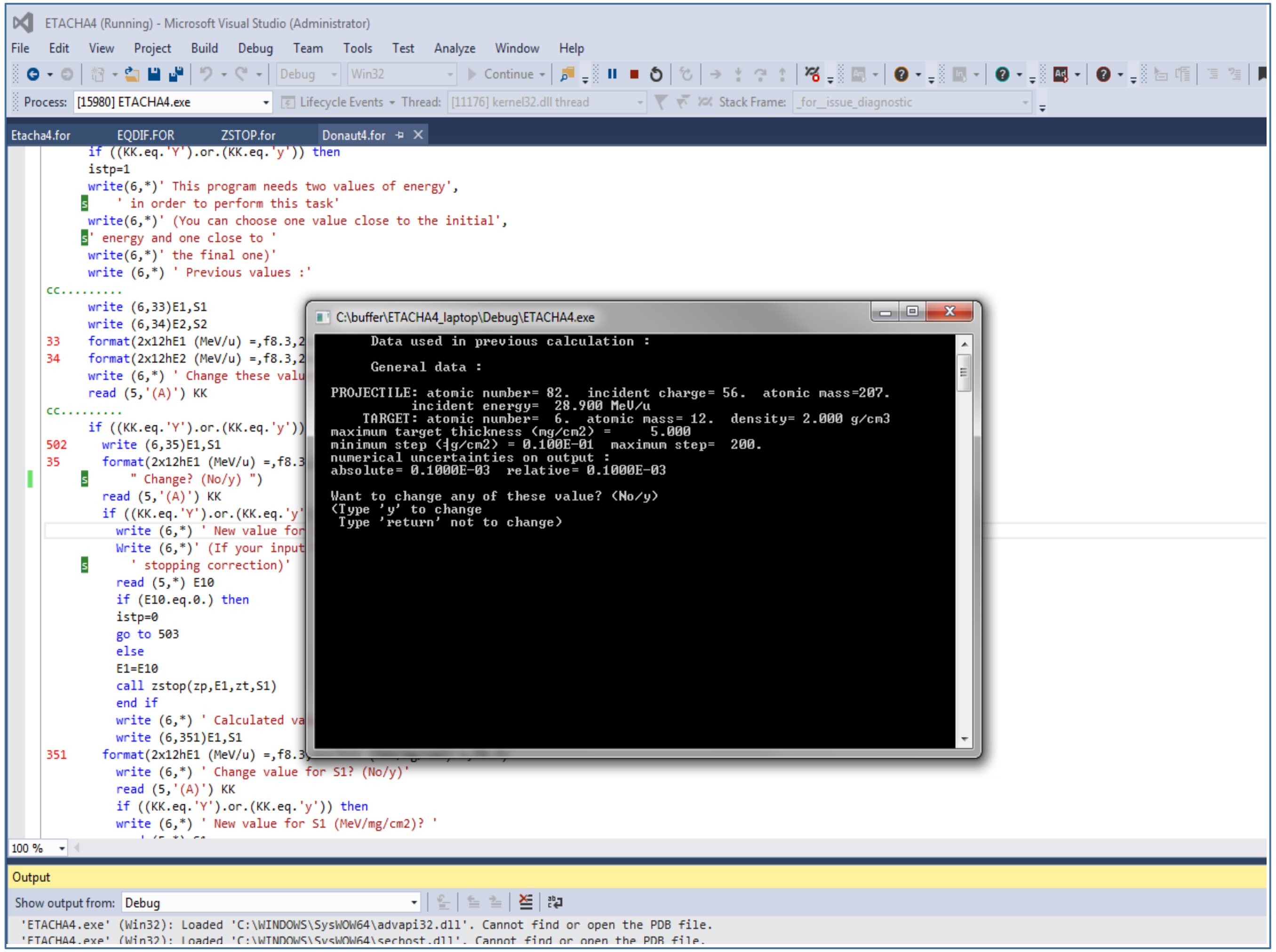
Knowledge of the detailed evolution of the whole charge-state distribution of projectile ions colliding with targets is required in several fields of research such as material science and atomic and nuclear physics but also in accelerator physics, and in particular in regard to the several foreseen large-scale facilities. However, there is a lack of data for collisions in the nonperturbative energy domain and that involve many-electron projectiles. Starting from the ETACHA model we developed [Rozet *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. B **107**, 67 (1996)], we present an extension of its validity domain towards lower velocities and larger distortions. Moreover, the system of rate equations is able to take into account ions with up to 60 orbital states of electrons. The computed data from the different new versions of the ETACHA code are compared to some test

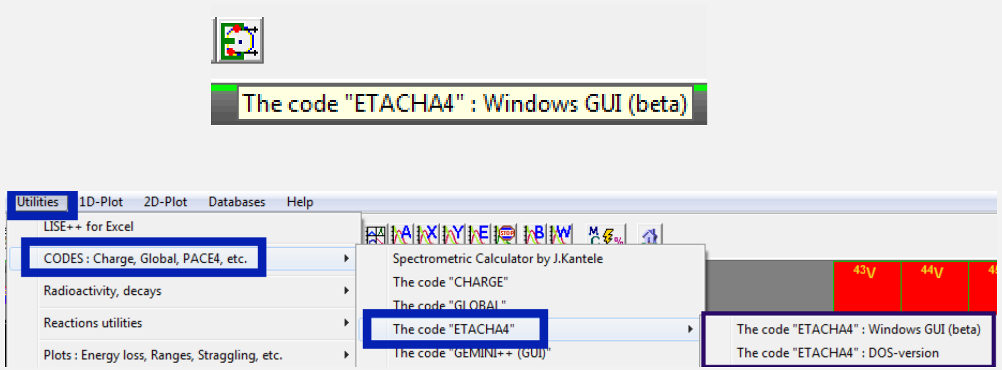
1. Implementation of the ETACHA4 code to the LISE^{++} package :
   - i. **Porting from FORTRAN to C++**
   - ii. **Creation the ETACHA GUI shell for Windows OS**
   - iii. Modify LISE^{++} to use ETACHA.dll in LISE^{++} transmission calculations
   - iv. *Update LISE.xls to provide ETACHA calculations in MS Excel (???)*
2. *Compare "LISE^{++} ETACHA4" or ("ETACHA4 GUI") results with the NSCL charge state measurement database (???)*

Current LISE++ Development : ETACHA4

1. The current ETACHA version is “DOS-window” (“terminal” window) application
2. To compile the current version you need MS Visual Studio (project) and Intel Parallel Studio XE2016 (FORTRAN)
3. Long-long manual data entry
4. The user should manually entry final energy at the exit of material

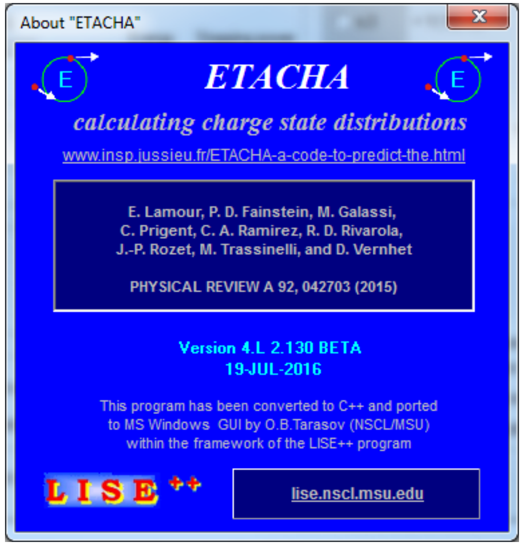


ETACHA GUI in LISE++ package

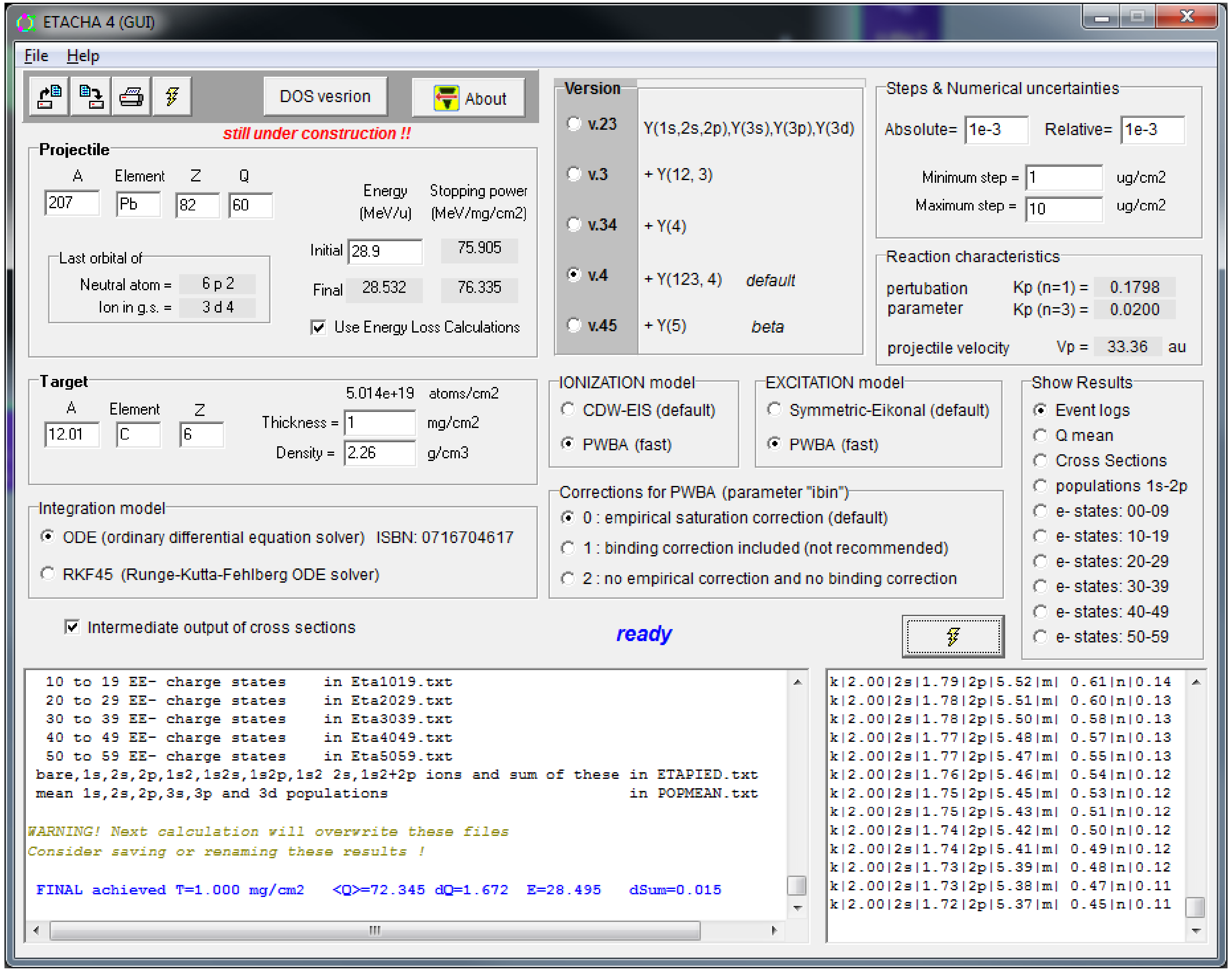


Current LISE^{++} Development : ETACHA4

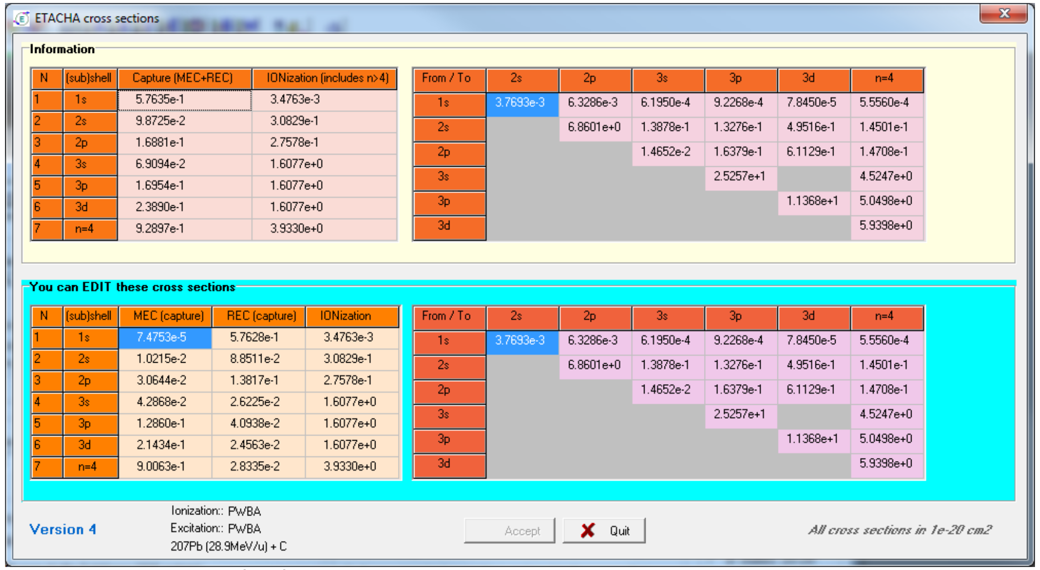
"About" window



Main window

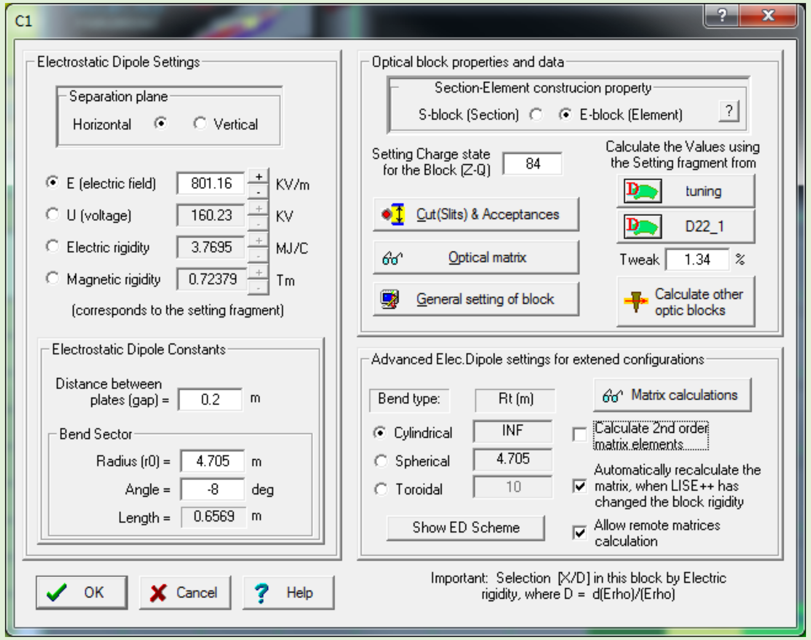


Intermediate output window of cross sections



2nd order Electric Dipole

The 2nd order approximation equations in C-format were provided by Robert Hipple (Department of Physics and Astronomy, Michigan State University) based on H.Wollnik's work NIM 34 (1965) 213-221



2nd order E.D. settings for already existed configuration

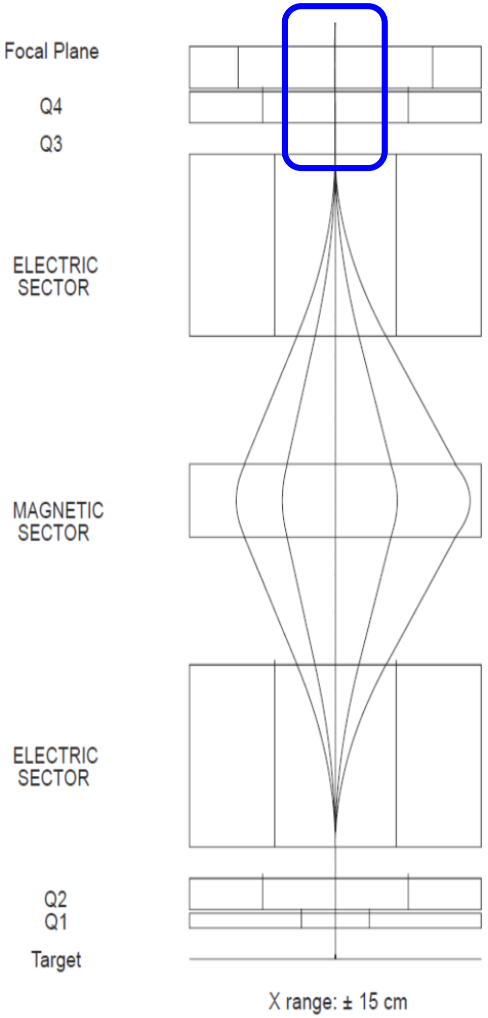
1st step: set "checked" the 2nd order box

2nd step: click "Matrix calculations" button

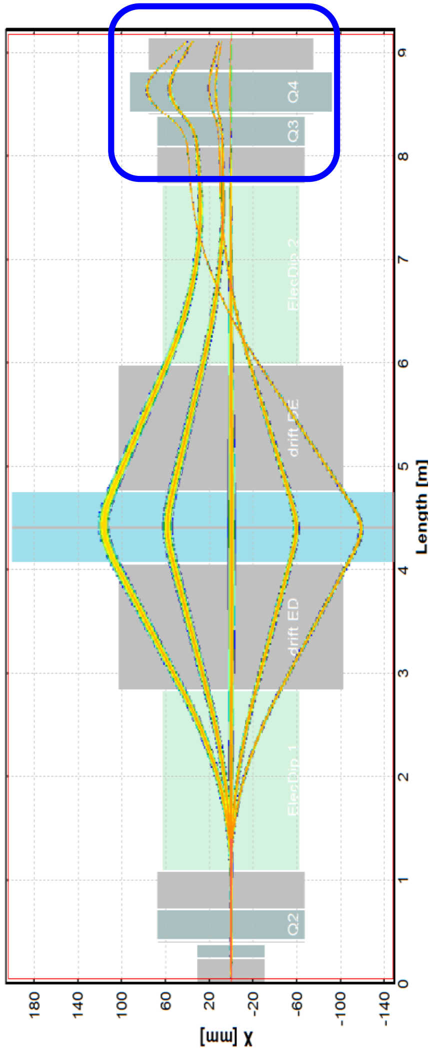
3rd step: Accept calculations

Using 2nd order electrostatic dipoles in EMMA @ TRIUMF

NIM A544 (2005) 565

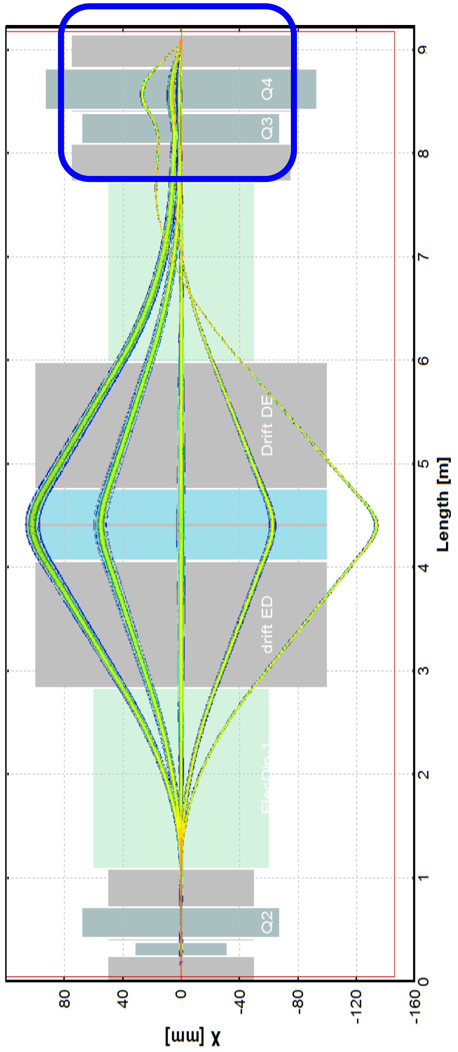


LISE++ v.9.10.207



2nd order

LISE++ v.9.10.296



2nd order

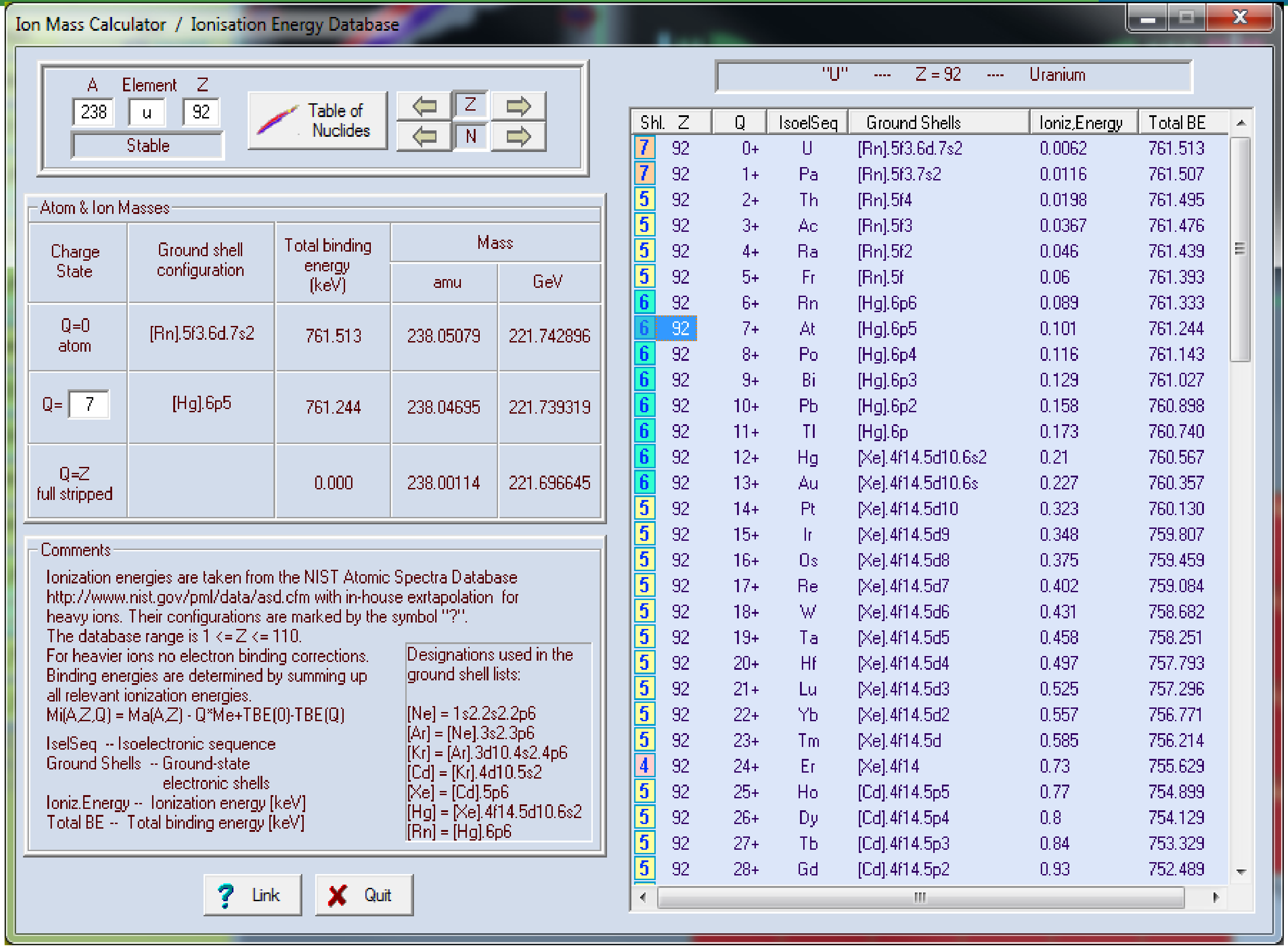
Ionization energy database & Ion mass calculator

9.10.131 07/10/15

- Ionization Energy Database
- Ion mass Calculator
- Ion mass corrections on electron binding energy (set default to use in LISE^{++})

$^{238}U^{92+}$ ion mass

- v.9.8.114 atomic mass was used 238.0508 amu
- v.9.8.117 correction for e- masses 238.0003 amu
- v.9.10.131 correction for e- binding energies 238.0011 amu

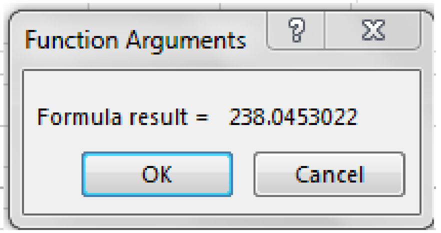


Charge State	Ground shell configuration	Total binding energy (keV)	Mass amu	Mass GeV
Q=0 atom	[Rn].5f3.6d.7s2	761.513	238.05079	221.742896
Q= 7	[Hg].6p5	761.244	238.04695	221.739319
Q=Z full stripped		0.000	238.00114	221.696645

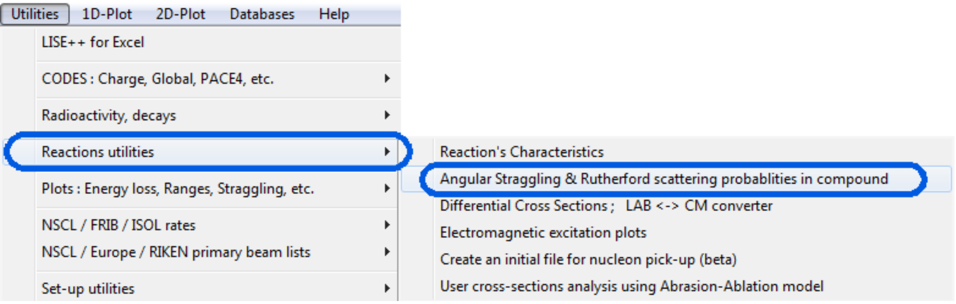
Shl.	Z	Q	IselSeq	Ground Shells	Ioniz.Energy	Total BE
7	92	0+	U	[Rn].5f3.6d.7s2	0.0062	761.513
7	92	1+	Pa	[Rn].5f3.7s2	0.0116	761.507
5	92	2+	Th	[Rn].5f4	0.0198	761.495
5	92	3+	Ac	[Rn].5f3	0.0367	761.476
5	92	4+	Ra	[Rn].5f2	0.046	761.439
5	92	5+	Fr	[Rn].5f	0.06	761.393
6	92	6+	Rn	[Hg].6p6	0.089	761.333
6	92	7+	At	[Hg].6p5	0.101	761.244
6	92	8+	Po	[Hg].6p4	0.116	761.143
6	92	9+	Bi	[Hg].6p3	0.129	761.027
6	92	10+	Pb	[Hg].6p2	0.158	760.898
6	92	11+	Tl	[Hg].6p	0.173	760.740
6	92	12+	Hg	[Xe].4f14.5d10.6s2	0.21	760.567
6	92	13+	Au	[Xe].4f14.5d10.6s	0.227	760.357
5	92	14+	Pt	[Xe].4f14.5d10	0.323	760.130
5	92	15+	Ir	[Xe].4f14.5d9	0.348	759.807
5	92	16+	Os	[Xe].4f14.5d8	0.375	759.459
5	92	17+	Re	[Xe].4f14.5d7	0.402	759.084
5	92	18+	W	[Xe].4f14.5d6	0.431	758.682
5	92	19+	Ta	[Xe].4f14.5d5	0.458	758.251
5	92	20+	Hf	[Xe].4f14.5d4	0.497	757.793
5	92	21+	Lu	[Xe].4f14.5d3	0.525	757.296
5	92	22+	Yb	[Xe].4f14.5d2	0.557	756.771
5	92	23+	Tm	[Xe].4f14.5d	0.585	756.214
4	92	24+	Er	[Xe].4f14	0.73	755.629
5	92	25+	Ho	[Cd].4f14.5p5	0.77	754.899
5	92	26+	Dy	[Cd].4f14.5p4	0.8	754.129
5	92	27+	Tb	[Cd].4f14.5p3	0.84	753.329
5	92	28+	Gd	[Cd].4f14.5p2	0.93	752.489

LISE for Excel new function

=lise.xlsm!MassIon(92,238,10)



New utility: Rutherford scattering and Angular straggling in compound



These P=f(angle) and E=f(angle) functions will be used in the Monte Carlo mode for the primary beam transmission calculations

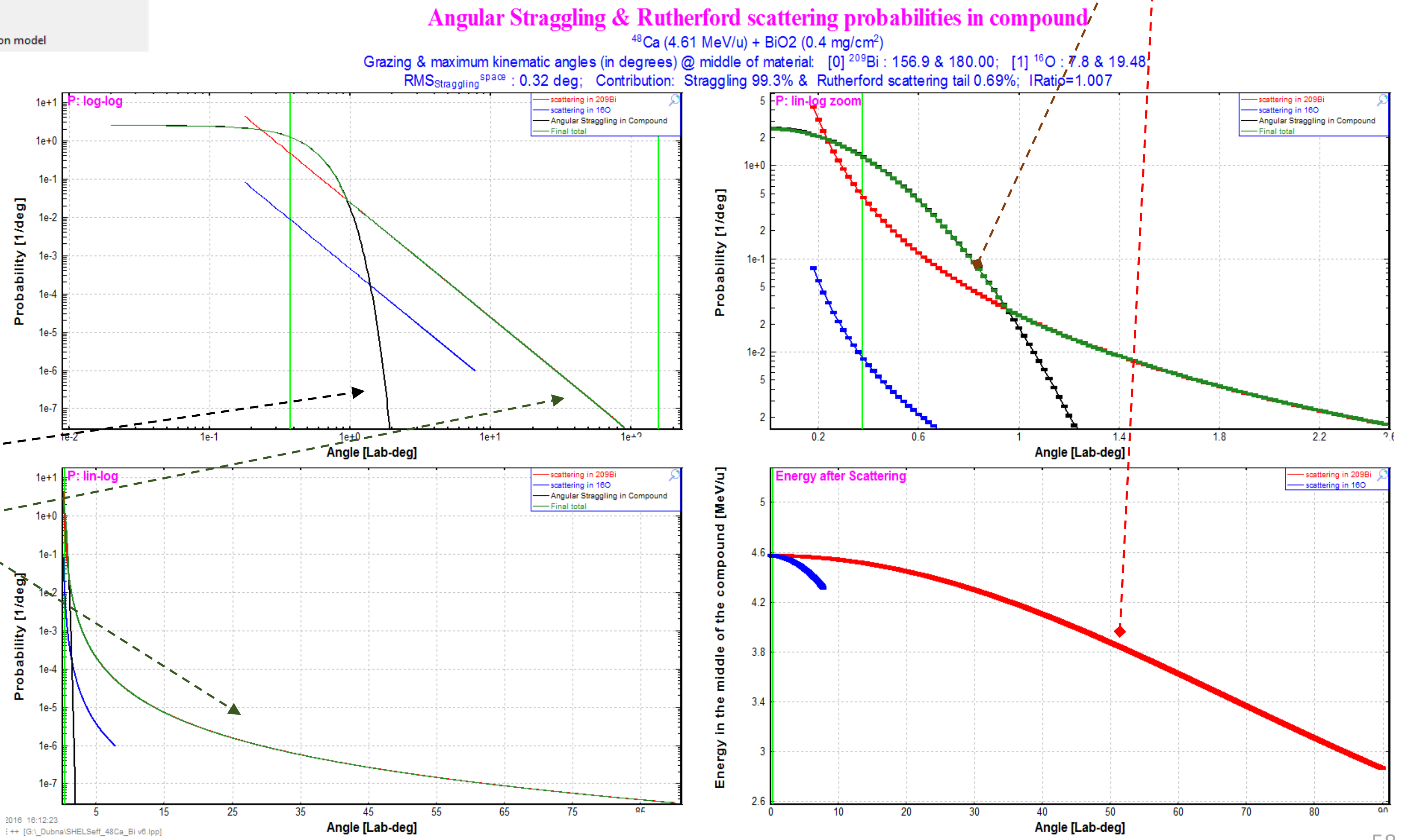
Angular straggling ≡ multiple scattering through small angles

How distinguish in Monte Carlo simulations ?

- Angular straggling (small angles)
- Rutherford scattering (large angles)

The nature is one for both processes.
It is necessary to have only one probability distribution for scattering process <u>through a material segment.</u>

Good benchmarks for angular straggling models!!
(Should be double crossing)



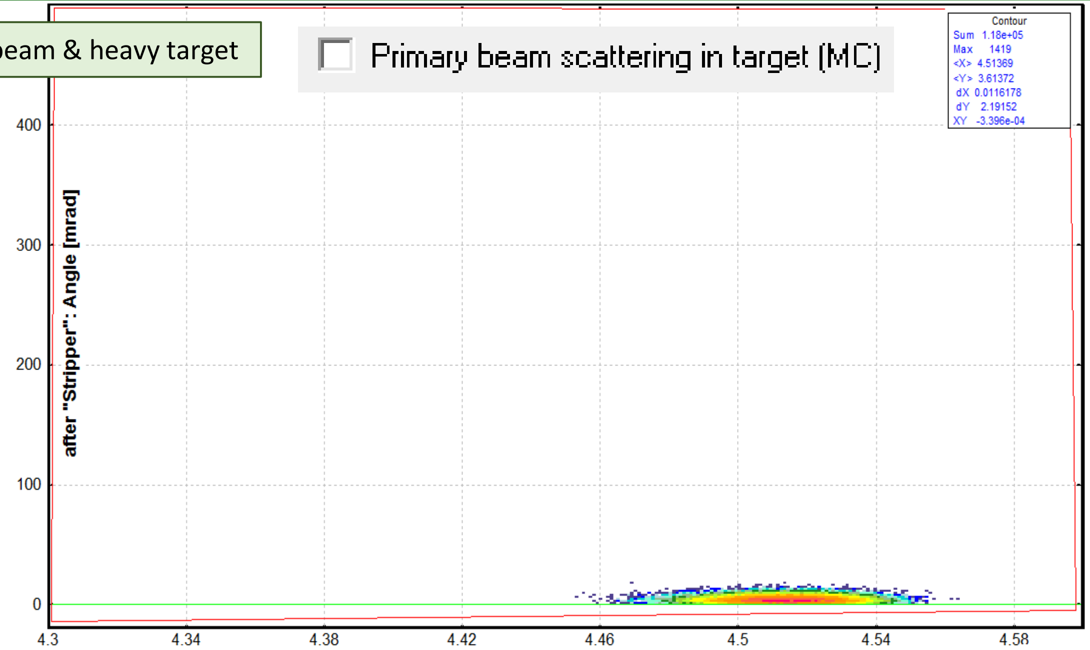
Rutherford scattering and Angular straggling

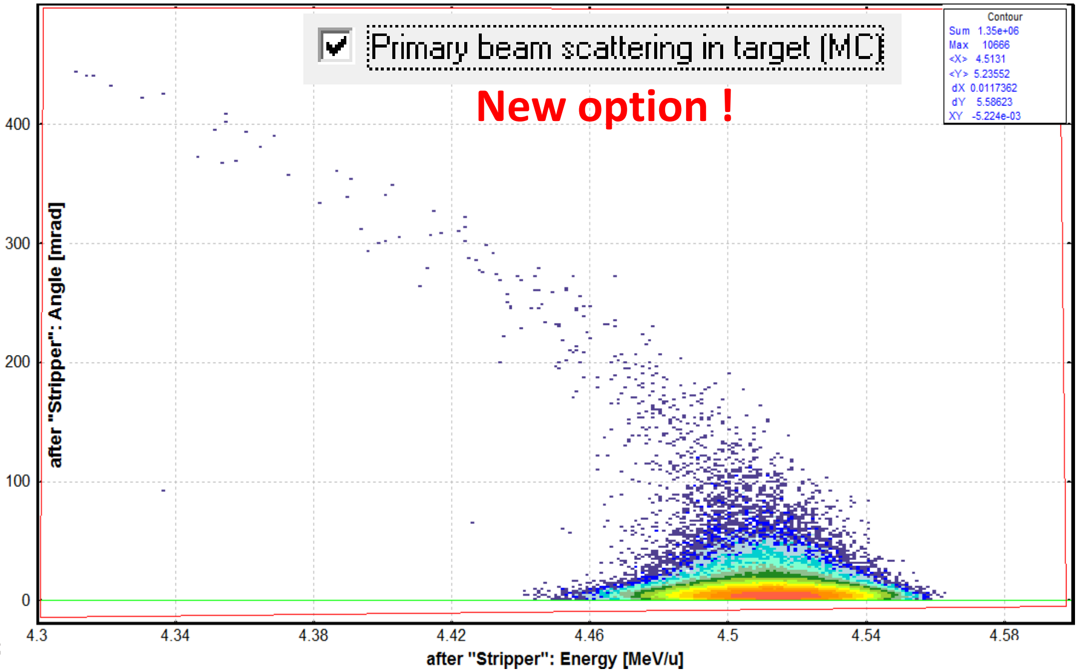
^{48}Ca (4.61 MeV/u) + Bi_2O_3 (0.39 mg/cm^2)

MICHIGAN STATE UNIVERSITY LISE++

Light beam & heavy target

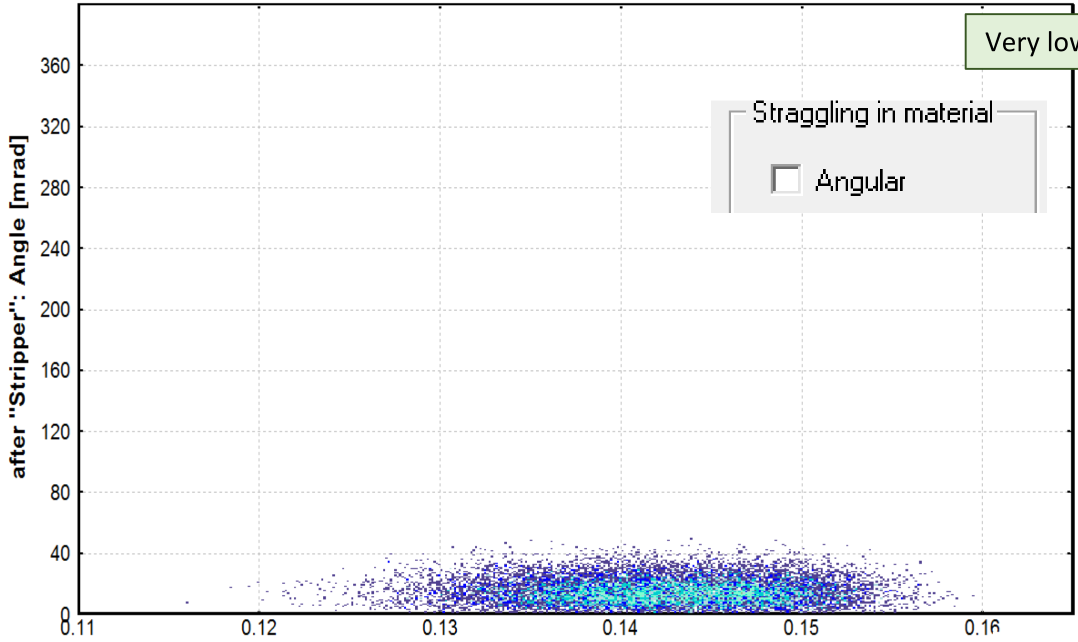
Primary beam (^{48}Ca)

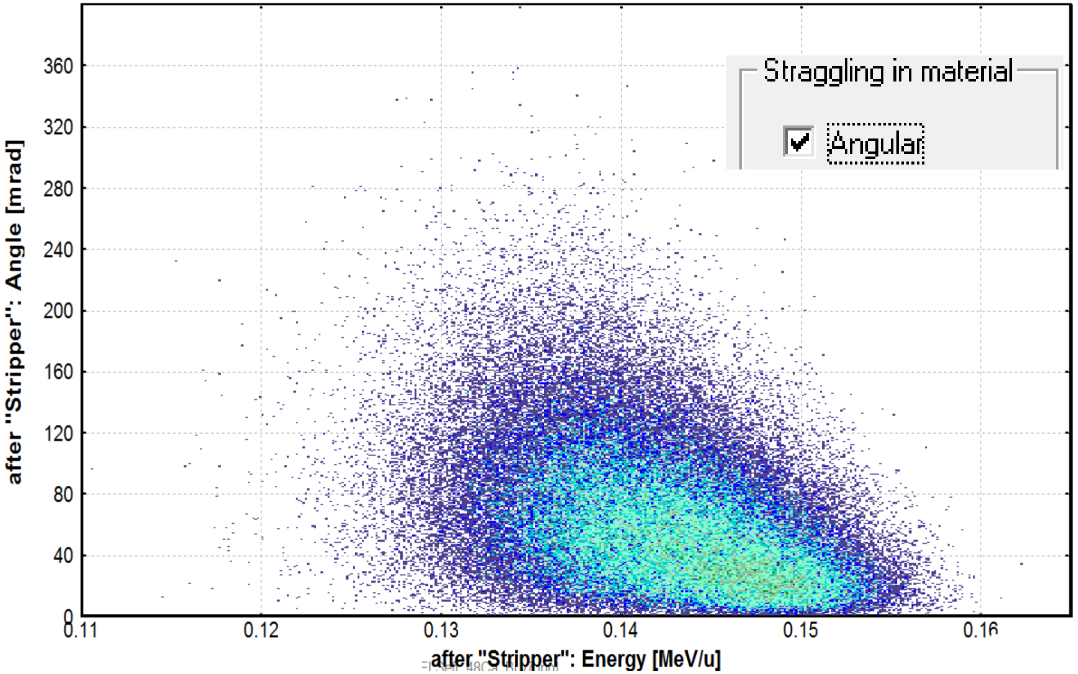




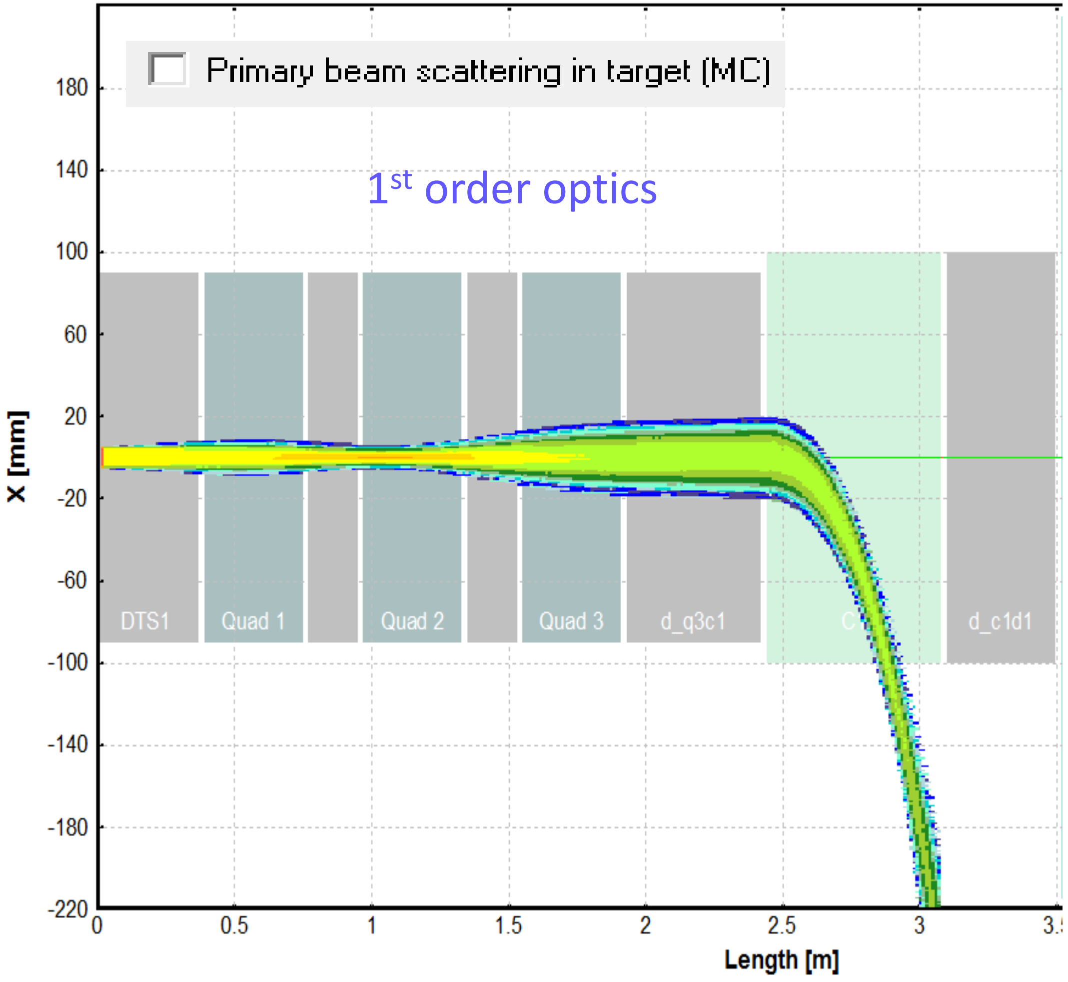
Very low energy

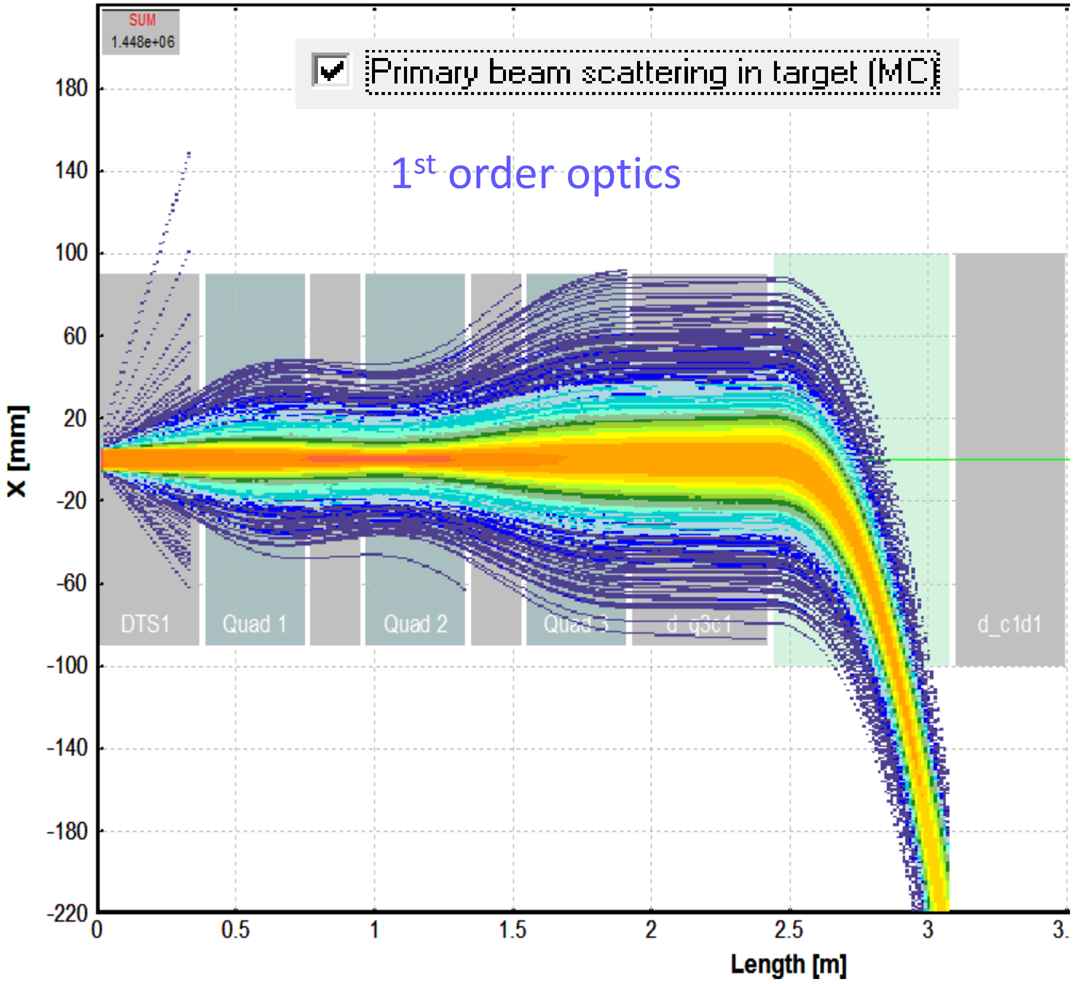
Setting ions ($^{255}Lr^{**+}$)





Primary beam scattering in recoil separators





CONSTRUCTION OF EXTENDED CONFIGURATIONS

Extended configurations construction

❑ Extended Configurations v.9.9

- Fragment Separator “**BigRIPS**" @ RIKEN
- Spectrometer “**MSP144**+Q2" @ FLNR/JINR
- Recoil separator “**SHELS**“ @ FLNR/JINR
- Spectrometer “**PRISMA** ” @ LNL/INFN
- Fragment separator “**MARS**“ @ TAMU (global revision)

❑ Extended Configurations v.9.10

- Recoil separator "**EMMA**" @ TRIUMF
- Recoil separator "**FMA**" @ Argonne NL
- Recoil separator “**S^3** ” @ GANIL
- Recoil separator "**SECAR**“ @ MSU
- Recoil separator "**DRAGON**“ @ TRIUMF
- Recoil separator “**SHELS**“ @ FLNR/JINR (global revision)
- Fragment separator “**ACCULINNA2**“ @ FLNR/JINR (global revision)
- **HRS** : A High Rigidity Spectrometer for FRIB

Mostly low-energy devices

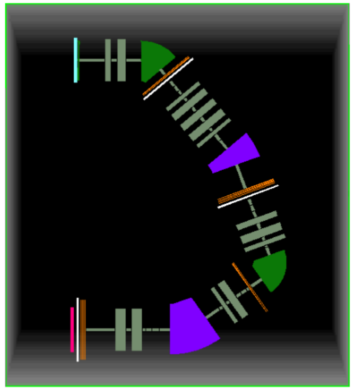
Recoil separator “DRAGON” @ TRIUMF

High Order extended configuration

Version 9.10.142
from 07/22/2015

Link: Spectrometer “DRAGON” (TRIUMF)

- ❑ DRAGON2000 extended configuration
  - DRAGON documentation
  - DRAGON files location
  - Optimization with LISE^{++}
  - Alternative configuration
  - 2015 settings vs. documentation 2000
- ❑ Angular Acceptance
- ❑ Momentum Acceptance
- ❑ Charge states selection
- ❑ Experiment $^{15}O(\alpha,\gamma)^{19}Ne$
  - Fusion
  - De-excitation by gamma at low energies vs. kinematics
- ❑ Segmented configuration
- ❑ Open questions



MASHA?
COMBAS?

Creation of Extended Configurations

- Recoil separator "EMMA" @ TRIUMF
- Recoil separator "FMA" @ Argonne NL
- S3 separator @ GANIL
- Recoil separator "SECAR" @ MSU
- Recoil separator "DRAGON" @ TRIUMF
- Recoil separator "SHELS" @ FLNR/JINR
- Fragment separator "ACCULINNA2" @ FLNR/JINR

Creation of Extended Configuration is not only LEGO-construction with LISE^{++} blocks!!!

- EMMA extended configuration
  - Documentation
  - EMMA files location
  - Optics
  - Optimization
- Angular Acceptance
- Momentum Acceptance
- Benchmarks
- Charge state selection
- LISE^{++} analytical and MC envelopes
- Reaction d(^{132}Sn,p)^{133}Sn

- DRAGON2000 extended configuration
  - DRAGON documentation
  - DRAGON files location
  - Optimization with LISE^{++}
  - Alternative configuration
  - 2015 settings vs. documentation 2000
- Angular Acceptance
- Momentum Acceptance
- Charge states selection
- Experiment ^{15}O(α,γ)^{19}Ne
  - Fusion
  - De-excitation by gamma at low energies vs. kinematics
- Segmented configuration
- Open questions

- SECAR extended configurations
  - SECAR documentation
  - SECAR phase1
  - LISE^{++} modifications for SECAR
  - SECAR files location
  - SECAR phase 1 with COSY maps
  - Optimization with LISE^{++}
- SECAR phase1: Angular Acceptance
- SECAR phase1: Momentum Acceptance
- SECAR phase1: Charge states selection
- Experiment ^{15}O(α,γ)^{19}Ne
  - Fusion
  - De-excitation by gamma at low energies vs. kinematics
- Segmented configurat
- Open questions

- FMA extended configuration
  - Documentation
  - FMA files location
  - Optics
  - Optimization
- Angular Acceptance
- Momentum Acceptance
- Experiment ^{32}S (115 MeV) + ^{58}Ni
- Open questions

S^3

1. Introduction
2. Segmented configurations
3. Extended: Geometry, Corrections
4. Optimization
5. S^3 acceptances
6. Outlook

"SHELS"

- Introduction
- Effective lengths
  - ✓ Quadrupoles
  - ✓ Dispersive elements
- Dispersive elements settings
  - ✓ Electrostatic dipoles C1 and C2
  - ✓ Magnetic dipoles D22_1 and D22_2
  - ✓ Magnetic dipole D8
- Apertures & Slits
- Calibrations
- Reaction choice
  - ✓ Charge state model
  - ✓ Fusion residual (SHE region)
- Configurations
  - ✓ Experimental (logbook) settings
  - ✓ Brho values by LISE++
  - ✓ Q5 field value modification
  - ✓ Obtaining angular acceptance
  - ✓ Final version for the LISE++ package
- Angular acceptance
- Beam suppression

Nearest future LISE^{++} Development

1. Revision (and Creation) of extended configurations in the package (NSCL configurations - 1st priority)*

2. Preparation of documentation for the new official version 10

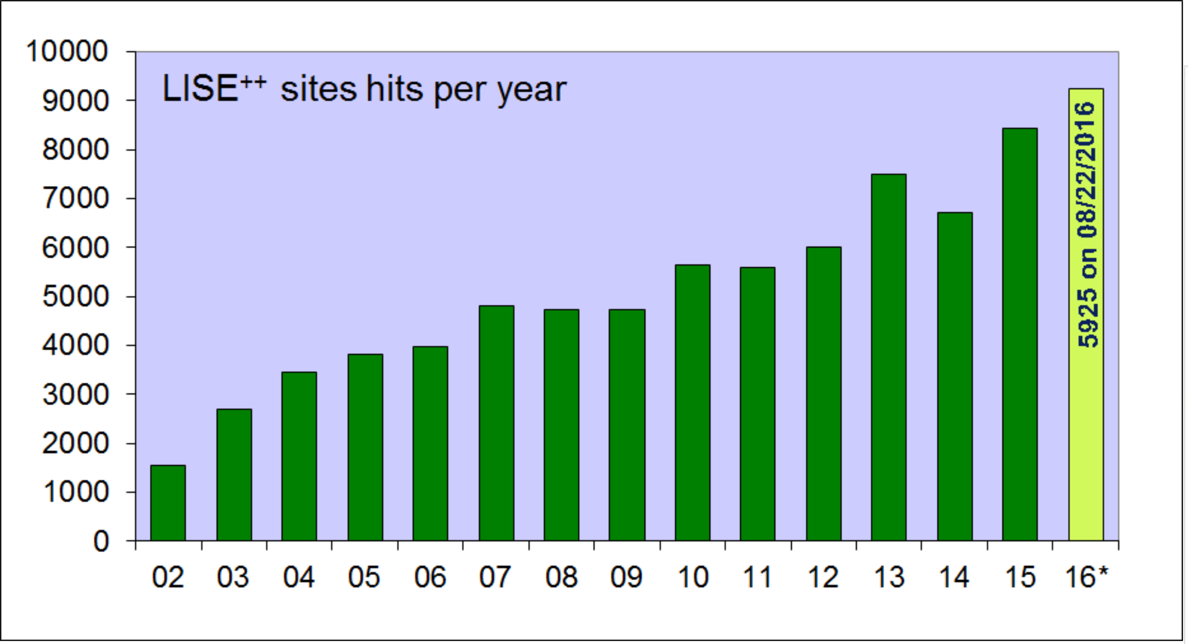
3. *Digital signing certificate*

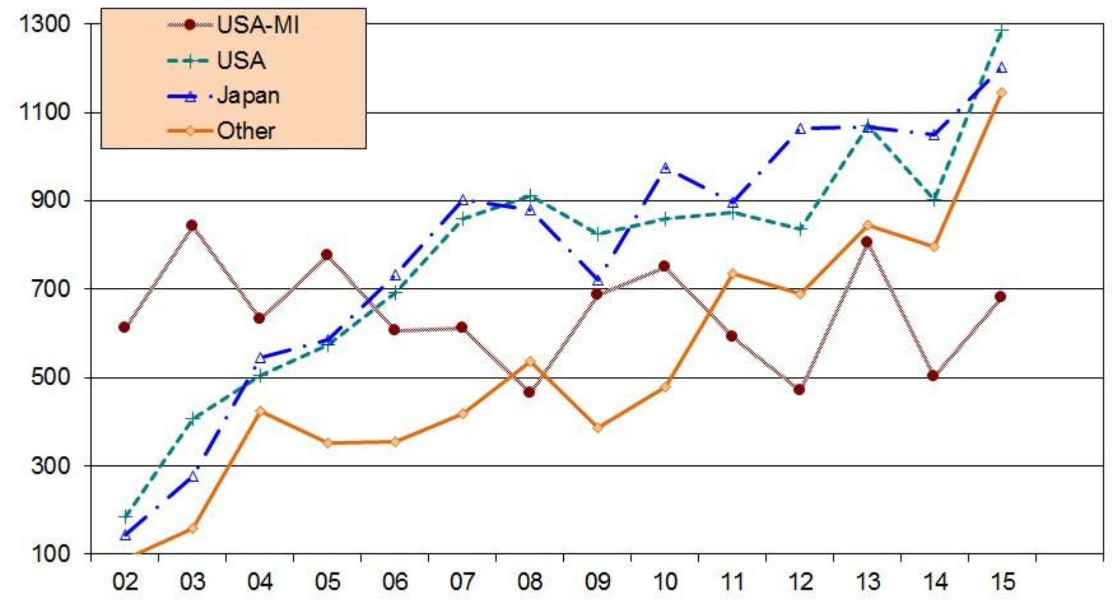
4. Release of version 10 after benchmarking by the A1900 FS group <u>(this fall)</u>

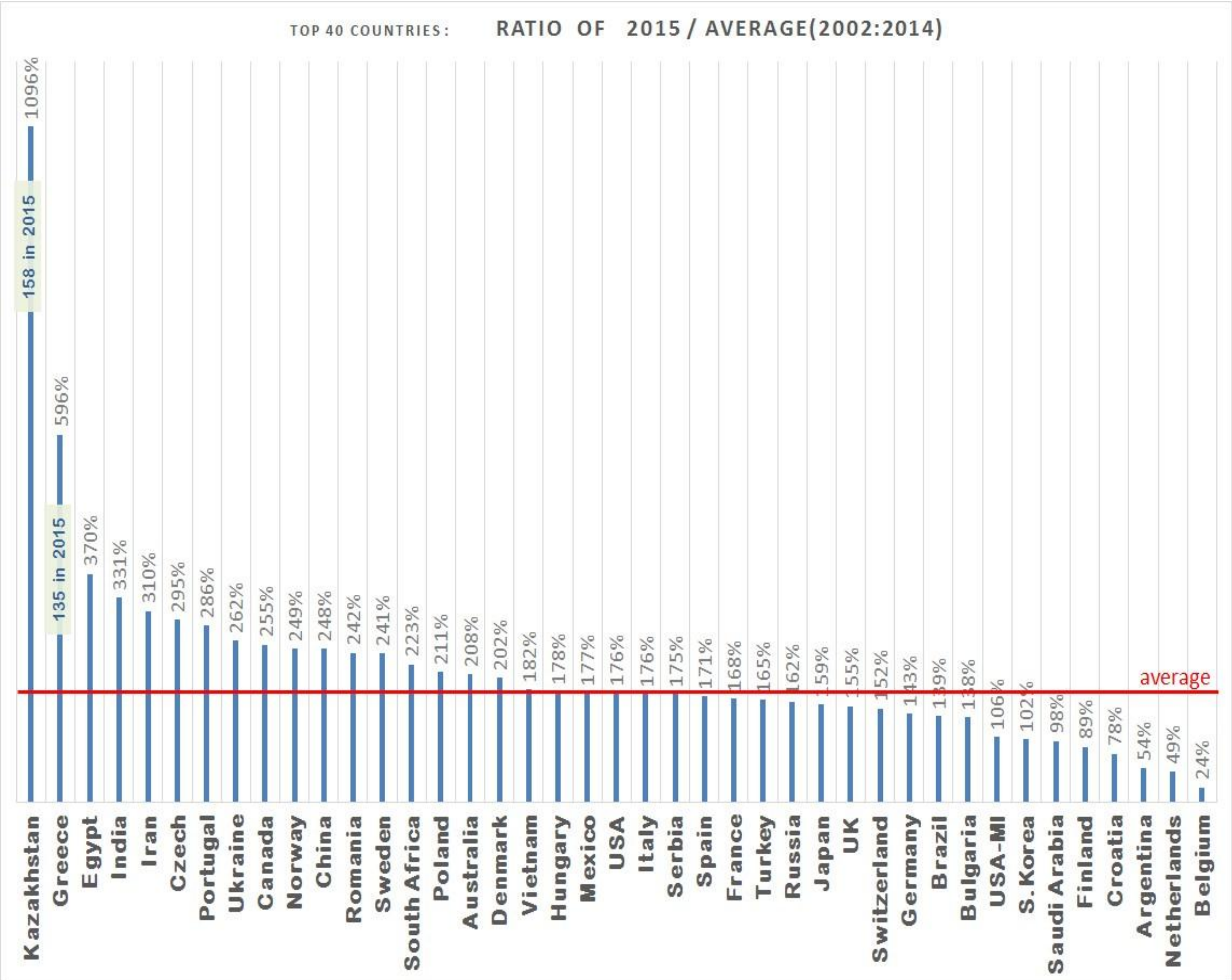
5. LISE^{++} development will be frozen with the Borland compiler.
   Only urgent modifications to fix important issues.

* - GSI, FAIR?

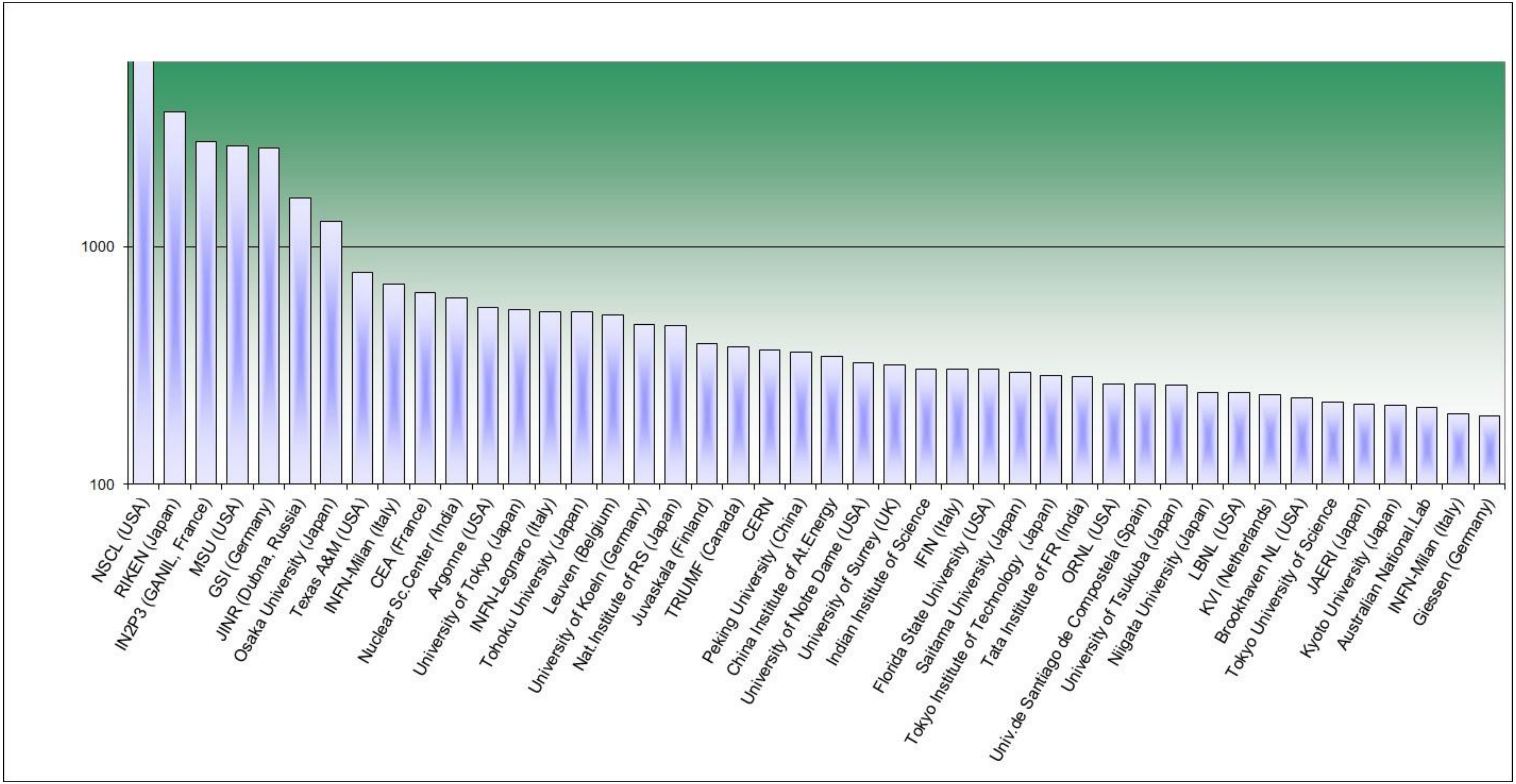
LISE++ statistics







LISE++ statistics



LISE^{++} package porting to Qt-framework

MICHIGAN STATE UNIVERSITY LISE^{++}

Plans for Performance and Model Improvements in the LISE^{++} Software

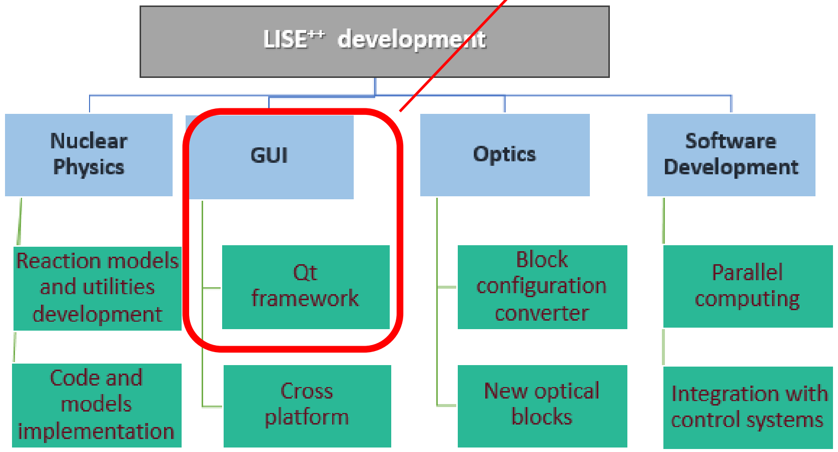
EMIS

O.B. Tarasov, M.P. Kuchera, D. Bazin, B.M. Sherrill, K.V. Tarasova
National Superconducting Cyclotron Laboratory, Michigan State University

LISE^{++} Development Plans

The LISE^{++} software package will be transported to a modern graphics framework with new compilers to aid in the performance and sustainability of the code. To accommodate user diversity, LISE++ will be adapted for cross-platform compatibility. The computational demands associated with more complicated devices at new large scale facilities should be addressed. In order to perform the necessary calculations in an acceptable time, code optimization and parallel methods will be applied. New features such as optimization, for example, of ion optics, improvements in reaction models, and new event generator choices are planned. Finally creation of a LISE^{++} interface with control systems is envisioned.

Development scheme for the LISE^{++} update. The plan is to first do a graphics framework transportation, verify the new code, then implement improvements and new features.

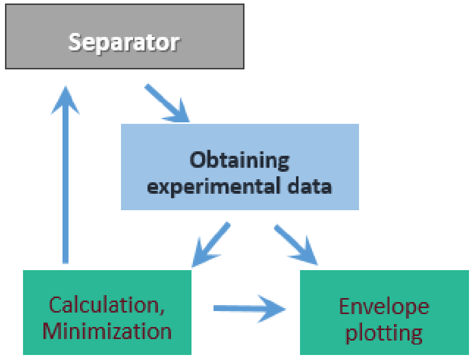


Software Development

Qt framework : The LISE^{++} program will be transported to a modern graphics framework for compatibility with future operating systems. Benefits include provisions for 64-bit operation, cross-platform compatibility, and the ability to take advantage of computational advances. Qt was chosen as the graphics framework based on its cross-platform capabilities, large feature set, and widespread use in cross-platform C++ applications.

Parallel computing : To take advantage of modern computing architecture, parallel computing methods are essential in achieving faster computation. Once transportation of LISE^{++} to the Qt graphics framework is complete, we will be able to implement parallel computing on personal computers using OpenMP. In the future, large-scale calculations using supercomputers or many-core machines using MPI is also planned.

Integration with control systems : In order to directly assist the tuning of a separator, the LISE^{++} program will be integrated with control systems. This will be tested at labs such as NSCL and GSI.



LISE++ porting to Qt-framework

LISE++ Overview Utilities Download Team

The LISE++ Transportation Team

Members working on the transportation of the LISE++ Software Suite to Qt.

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National Superconducting Cyclotron Laboratory
Michigan State University

Website »

Ksenia Tarasova

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National Superconducting Cyclotron Laboratory
Michigan State University

Webmaster Michelle Kuchera

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number: DE-NA0000979 through the Nuclear Science and Security Consortium. Disclaimer.

Last modified: Thu Jul 2 16:50:08 EDT 2015

Post-doc,
who already left us…

Partial time

?
Should be physicist
with beam optics
and programming
skills

LISE^{++} porting to Qt-framework : recent past

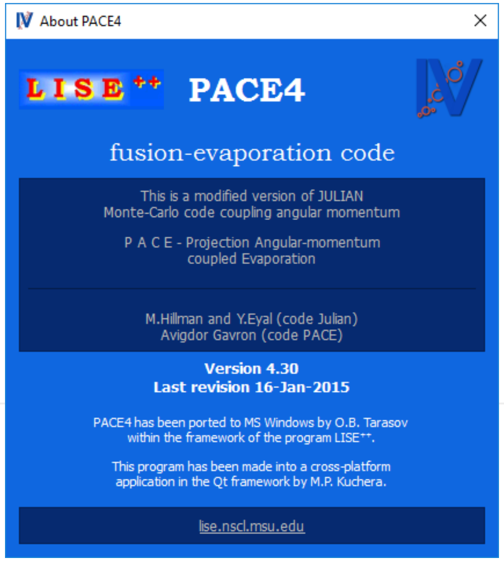
1. Platform selection, development of a transition strategy
2. Establishment of GIT for the software development of many programmers
3. LISE^{++} porting site
4. Porting LISE^{++} utilities to Qt
5. Cross-platforms (Windows, MAC, Linux):
   * build of executable codes
   * installation package creation
6. Creation of the executable shell for LISE^{++} Qt utilities
7. LISE^{++} code porting (in process)

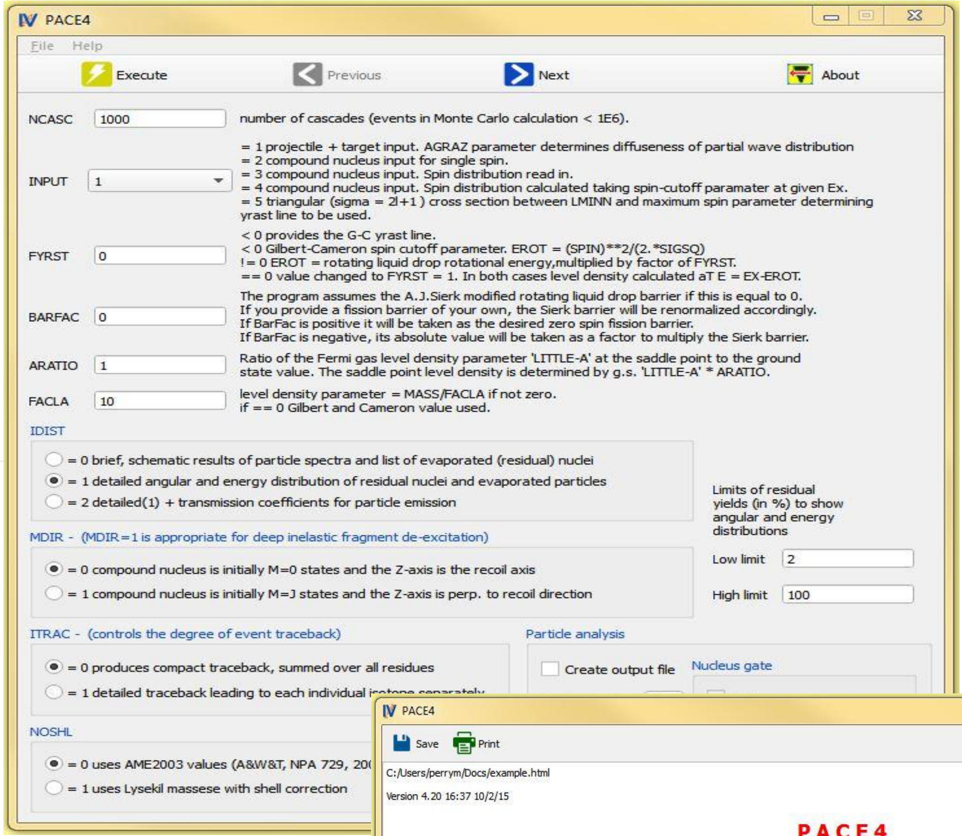
MICHIGAN STATE UNIVERSITY LISE++

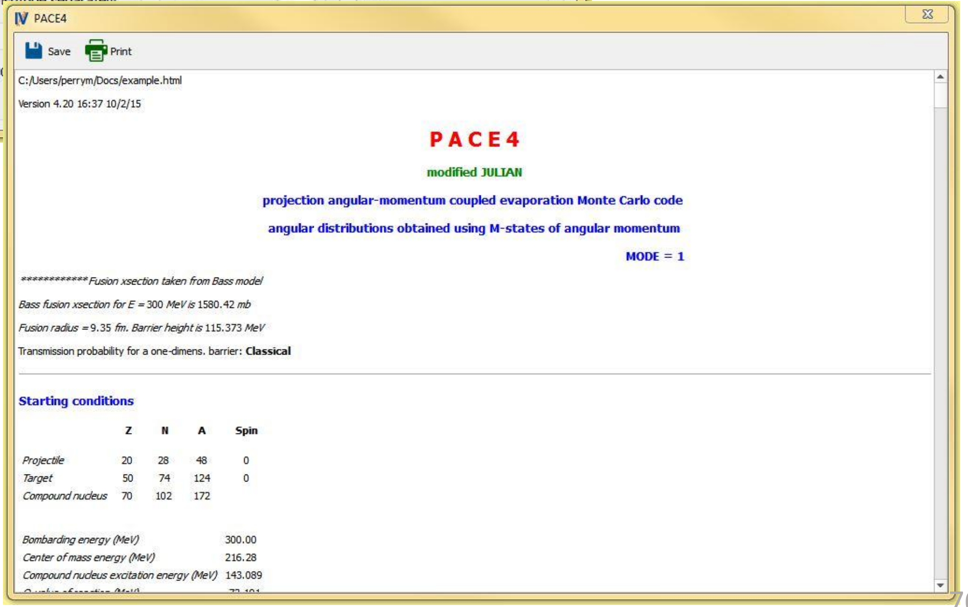
PACE4

Documentation

- Introduction
- PACE4 In Action
- Tutorials
  - Beginner
  - Intermediate Topics
- References







Introduction

PACE4 has been ported from Borland to Qt within the LISE++ framework [1]. The code PACE [2] is a modified version of JULIAN-the Hillman-Eyal evaporation code using a Monte-Carlo code coupling angular momentum.

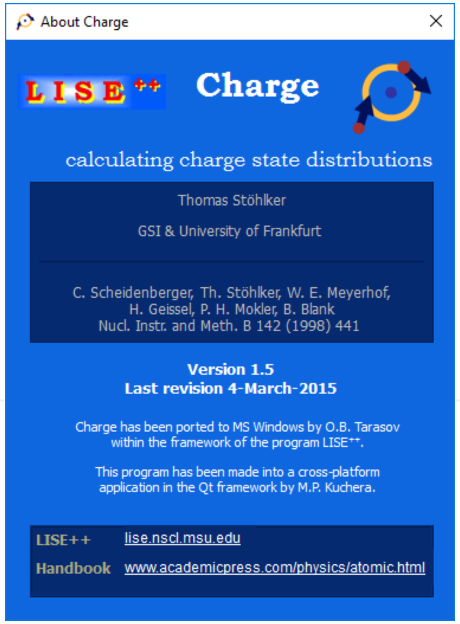
The version of PACE4 now distributed in the Utilities Package uses an updated mass table from 2013. Previous versions of PACE4 used a mass table from 2003.

[1] http://lise.nscl.msu.edu/5_13/lise_5_13.html
[2] A.Gavron, Phys.Rev. C21 (1980) 230-236;

Charge

Documentation

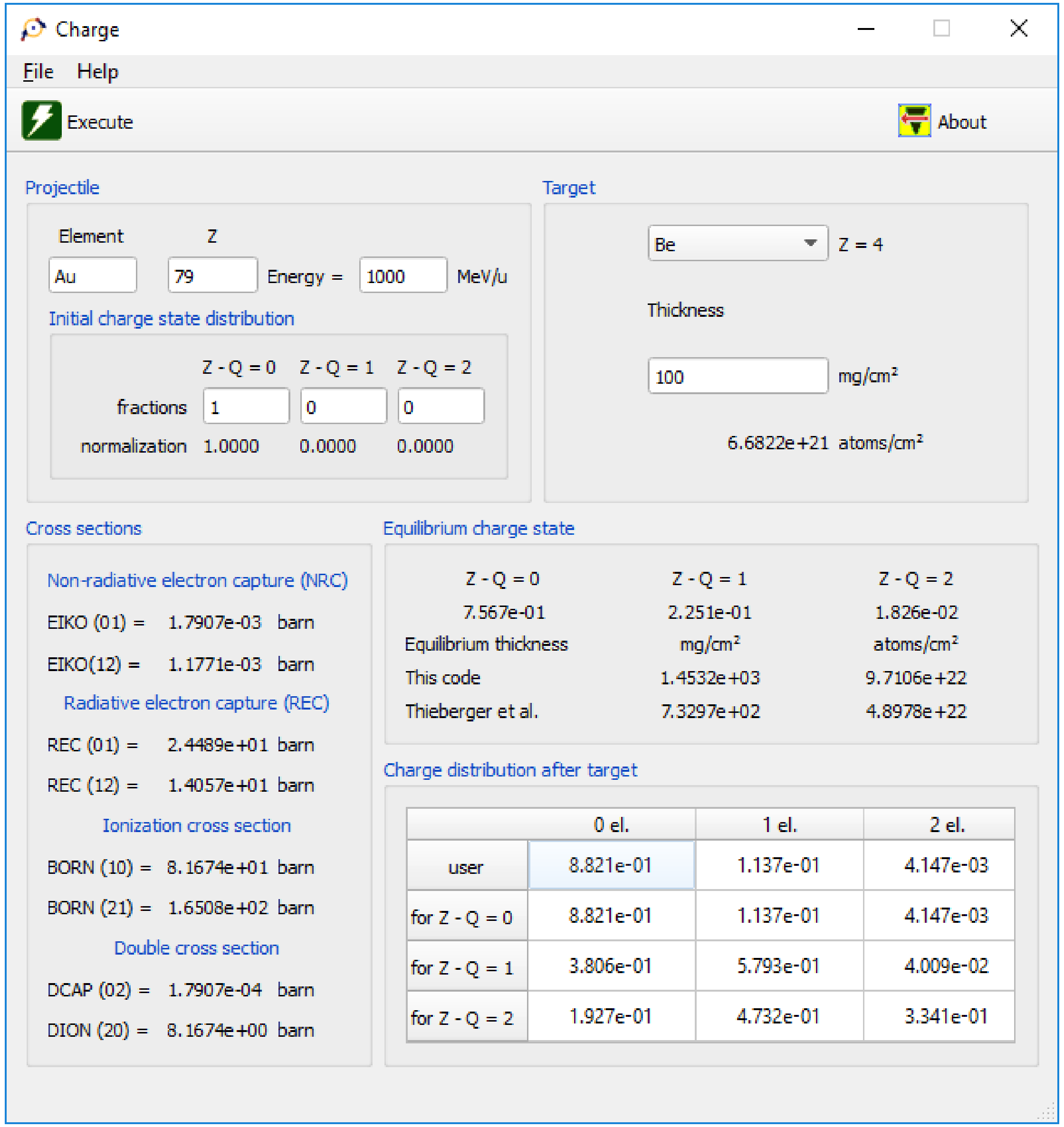
- Introduction
- Charge In Action
- Tutorials
- References



Introduction

The program Charge was transported to Qt from the Windows version within the LISE++ framework [1]. Charge calculates charge state distributions of relatavistic heavy ions [2].

[1] http://lise.nscl.msu.edu/lise.html
[2] C. Scheidenberger, Th. Stöhlker et al, Nucl. Instr. and Meth. B 142 (1998) 441



Global

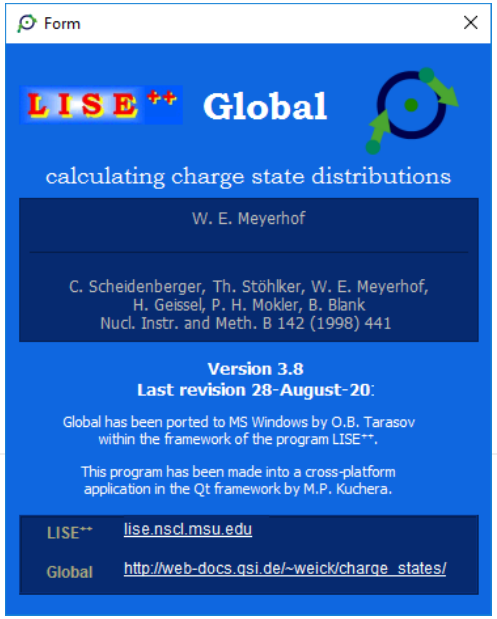
Documentation

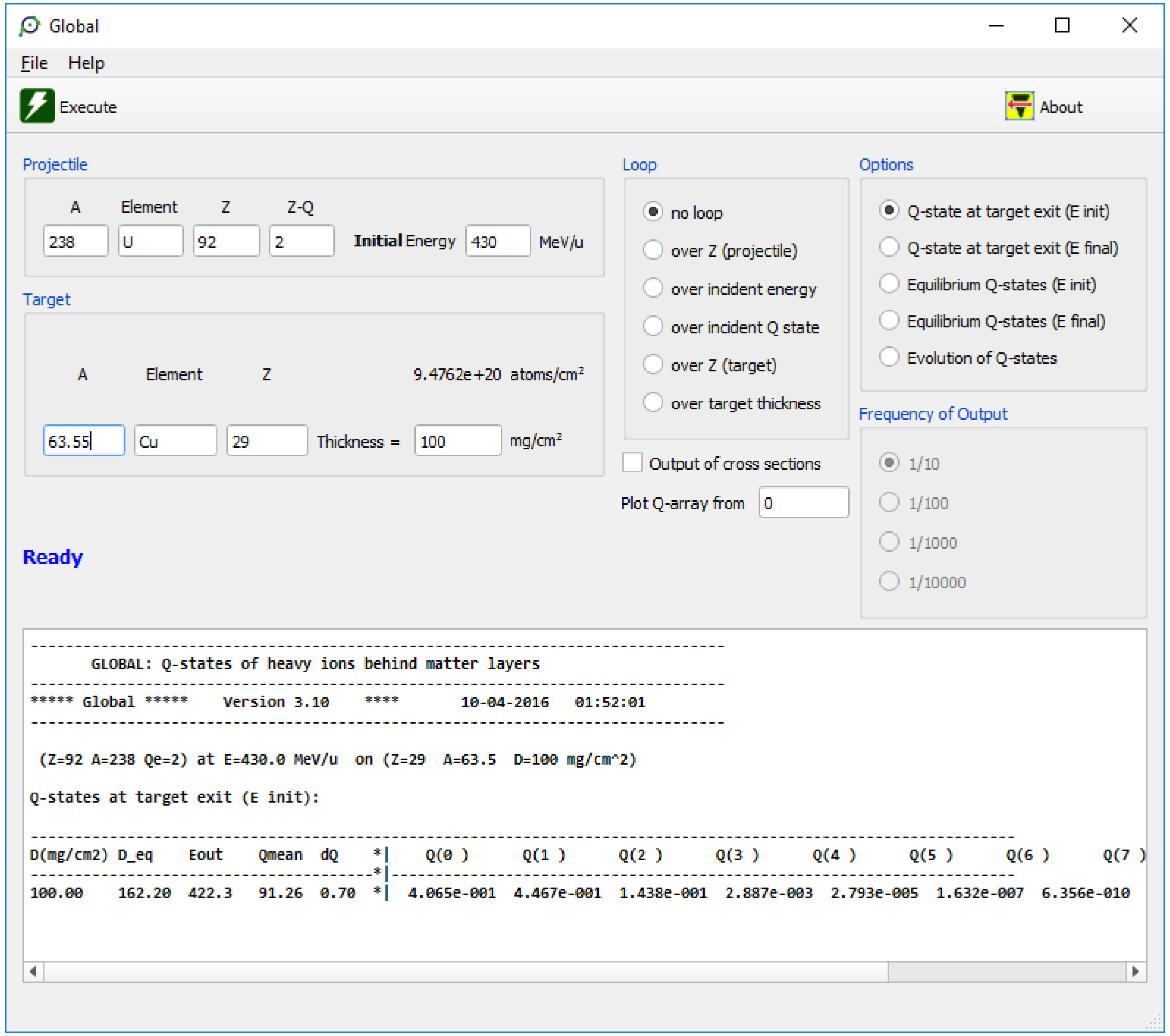
- Introduction
- Global In Action
- Tutorials
- References

Introduction

The program Global was transported to Windows within the LISE++ framework [1]. Global calculates charge state distributions of relatavistic heavy ions [2].

[1] http://lise.nscl.msu.edu/lise.html
[2] C. Scheidenberger, Th. Stöhlker et al, Nucl. Instr. and Meth. B 142 (1998) 441
http://web-docs.gsi.de/~weick/charge_states/





LISE++ Qt utilities : Kantele's Spectrometric Calculator

Kantele Calculator

Documentation

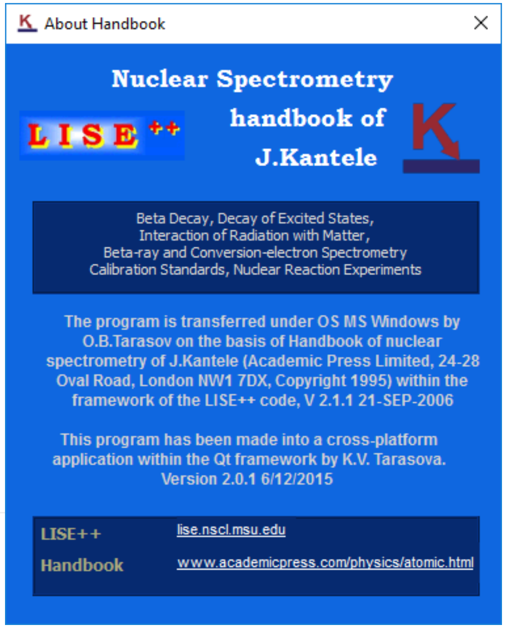
- Introduction
- Kantele Calculator In Action
- Tutorials
- References

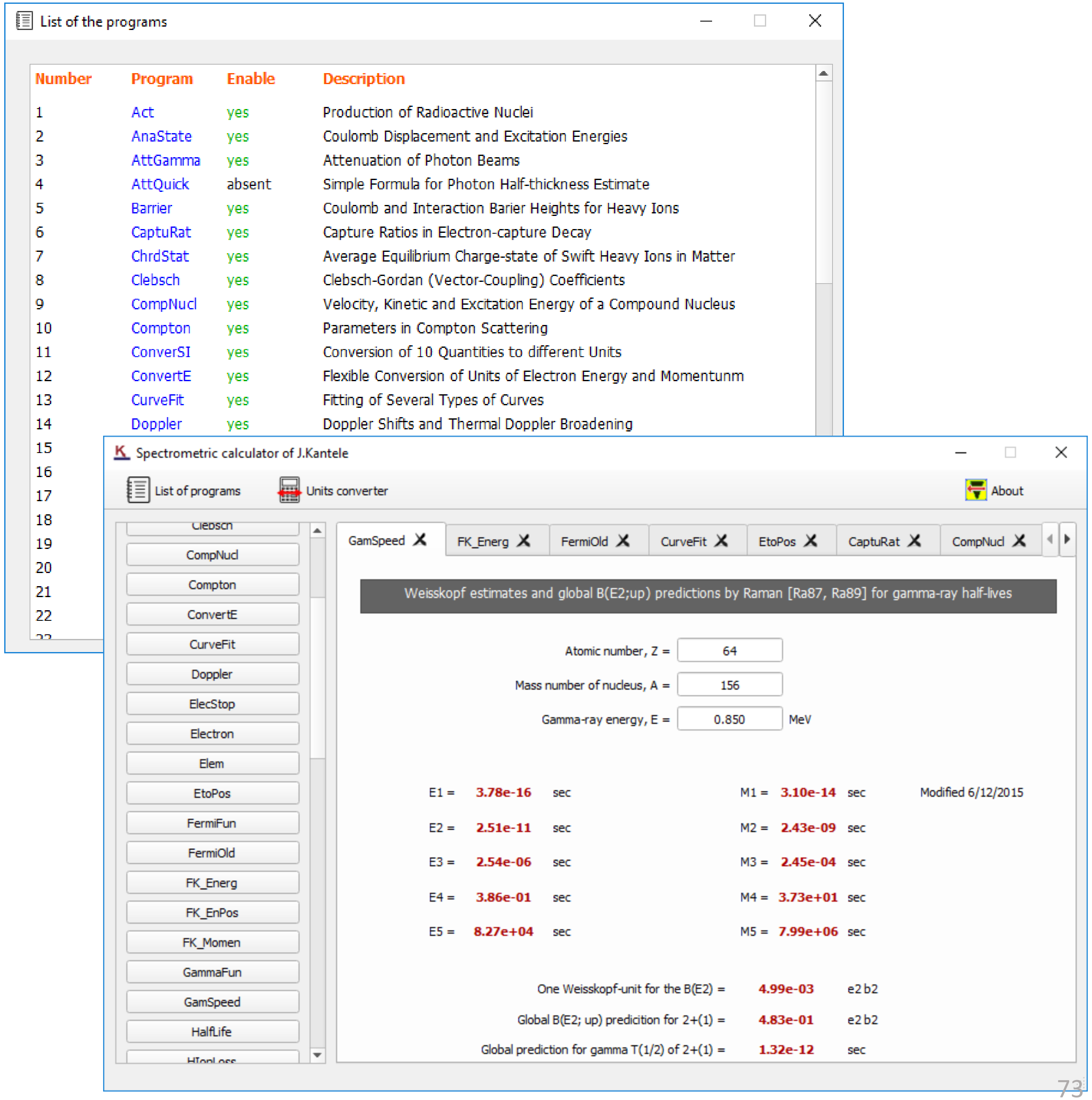
Introduction

The Kantele Calculator was transferred to Windows within the LISE++ framework [1]. The program is an implementation of the calculations in J. Kantele's *Nuclear Spectrometry Handbook* [2].

The Qt version of Kantele's Spectrometric Calculator operates the same way as the previous version packaged with LISE++. The interface has been redesigned to be more user friendly. The available calculations are on the left hand side of the window. A new tab populates the main frame with the chosen calculation. Only one tab per calculation type can be open at once.

[1] http://lise.nscl.msu.edu/lise.html
[2] J. Kantele, Academic Press Limited, 24-28 Oval Road, London NW1 7DX, Copyright 1995





Units Converter

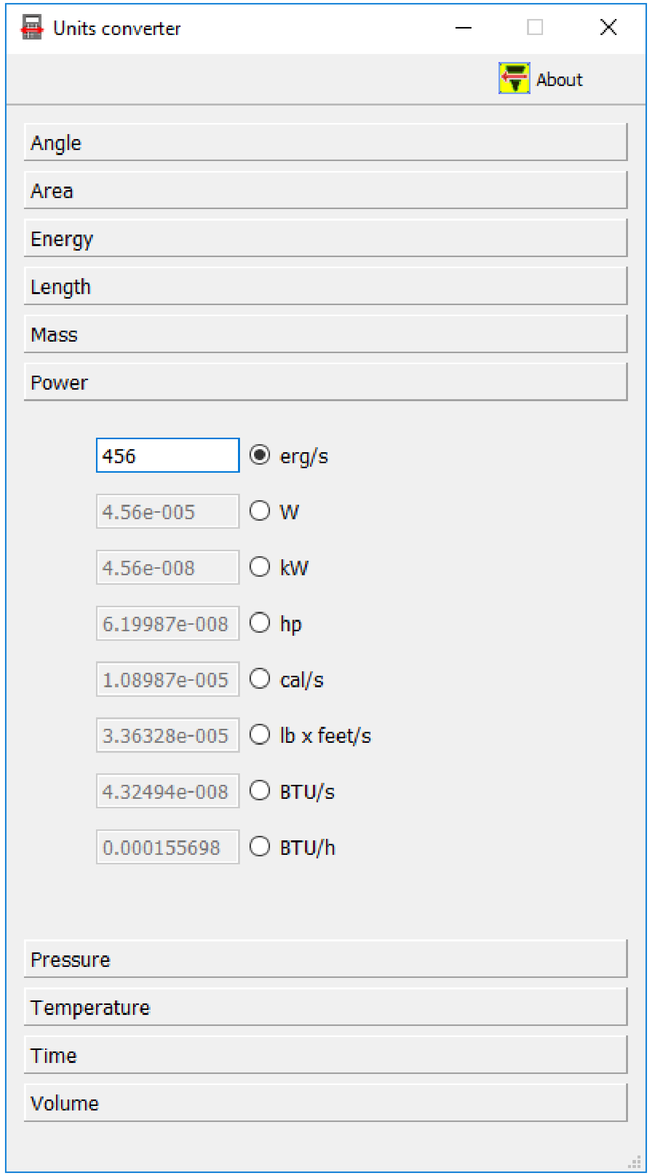
Documentation

- Introduction
- Units Converter In Action
- Tutorials
- References

Introduction

The Units Converter program was developed by O.B. Tarasov on the basis of the Handbook of nuclear spectrometry of J.Kantele within the LISE++ framework [1][2]. The program simply converts between various units.

[1] http://lise.nscl.msu.edu/lise.html
[2] Handbook of nuclear spectrometry, J.Kantele, Academic Press Limited, 24-28 Oval Road, London NW1 7DX, Copyright 1995



LISE^{++} Qt utilities : Shell

LISE++

LISE^{++} Utilites Package

Version 1.0.5

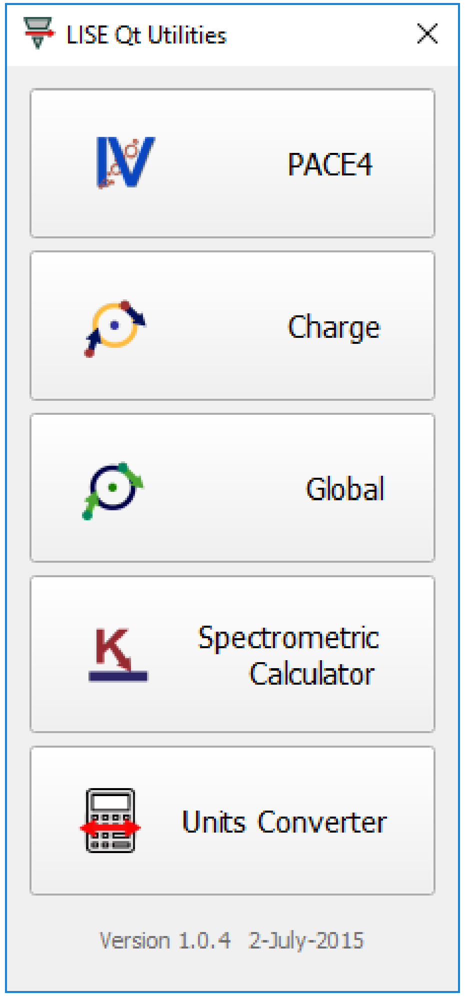
The LISE^{++} Utilities Package contains five satellite programs implemented in the LISE^{++} framework. These programs have been ported from Borland to the Qt graphics framework. This is the first release in the LISE group's process of porting the entire LISE^{++} software suite to Qt.

Transportation from Borland to Qt is being done first and foremost to ensure longevity of the LISE^{++} program for future operating systems. Additional benefits include providing a 64-bit application, cross-platform compatibility, and the ability to take advantage of computational advances.

These programs were found under the "Utilities" tab in LISE^{++} and the new versions are now being distributed as a standalone package for the first stage of the transportation. For more information on each of these programs, explore the links below.

Programs in the Package

- PACE4
- Charge
- Global
- Kantele Calculator
- Units Converter



LISE^{++} Qt utilities : Package installers

LISE^{++} Overview Utilities Download Team

Note: Please send any issues, comments, or suggestions to kucheram at nscl.

Download the LISE^{++} Utilites Package

Version 1.0.5

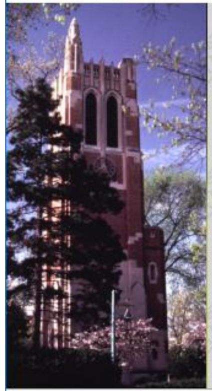
Please click on your operating system to choose installation:

Windows
Last updated: 3-September-2015

Mac
Last updated: 16-April-2015

Linux
Last updated: 12-June-2015

LISE Qt Utilities 1.0.5 Installation

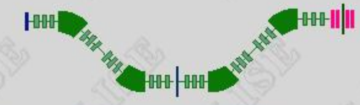


Welcome to the LISE Qt Utilities Setup Wizard

This will install LISE Qt Utilities 1.0.5 on your computer.

It is recommended that you close all other applications before continuing.

Click Next to continue, or Cancel to exit Setup.



Publisher: NSCL / Michigan State University

Next > Cancel

Download Windows Version

64-bit LISE^{++} Utilities Package

32-bit LISE^{++} Utilities Package 64-bit compatible.

Installation Instructions

Double click .exe file, follow instructions on screen to Install.

Close

Download Linux Version

Debian LISE^{++} Utilities Package

Ubuntu LISE^{++} Utilities Package 64-bit application

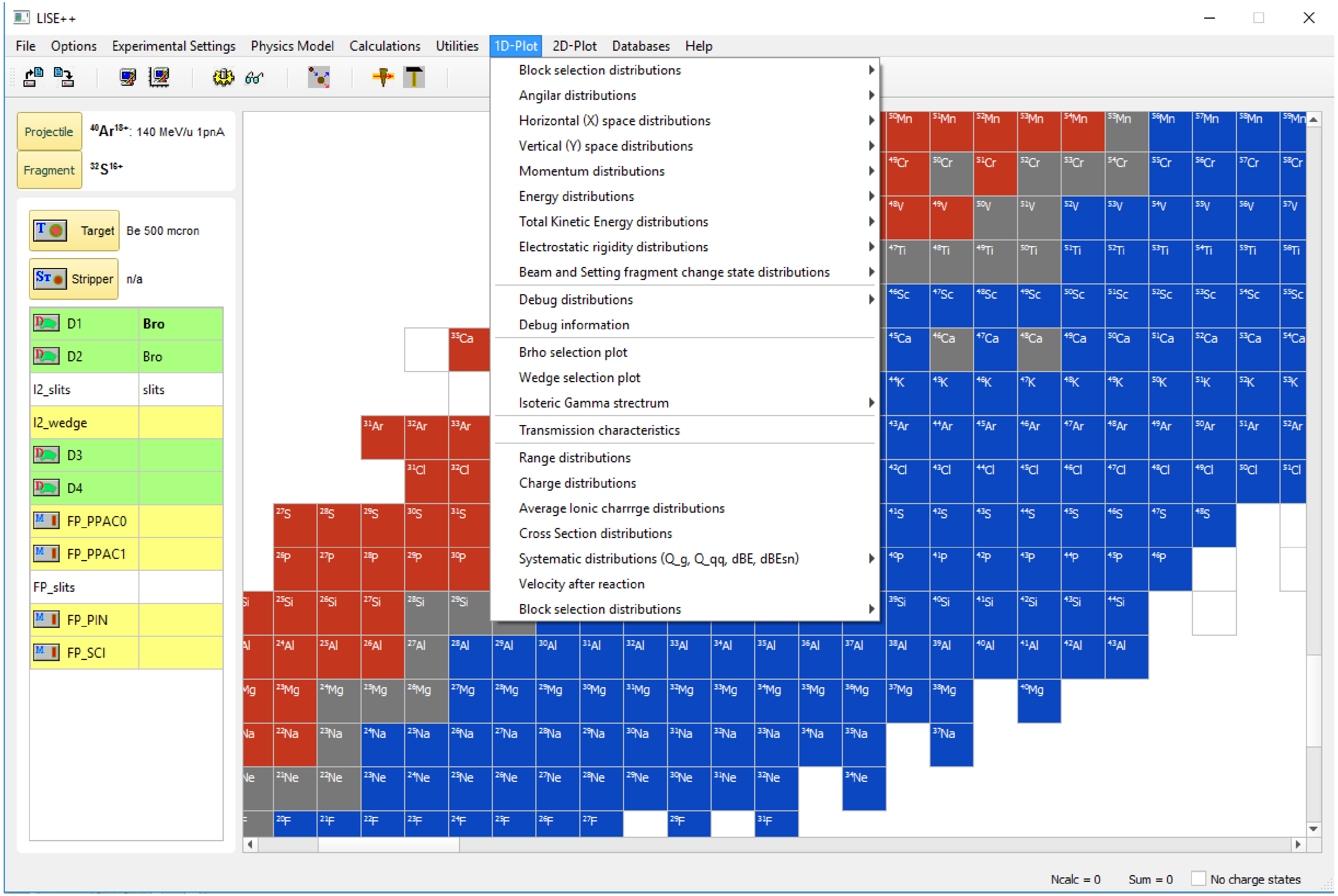
Ubuntu LISE^{++} Utilities Package 32-bit application

Red Hat LISE^{++} Utilities Package Coming Soon!

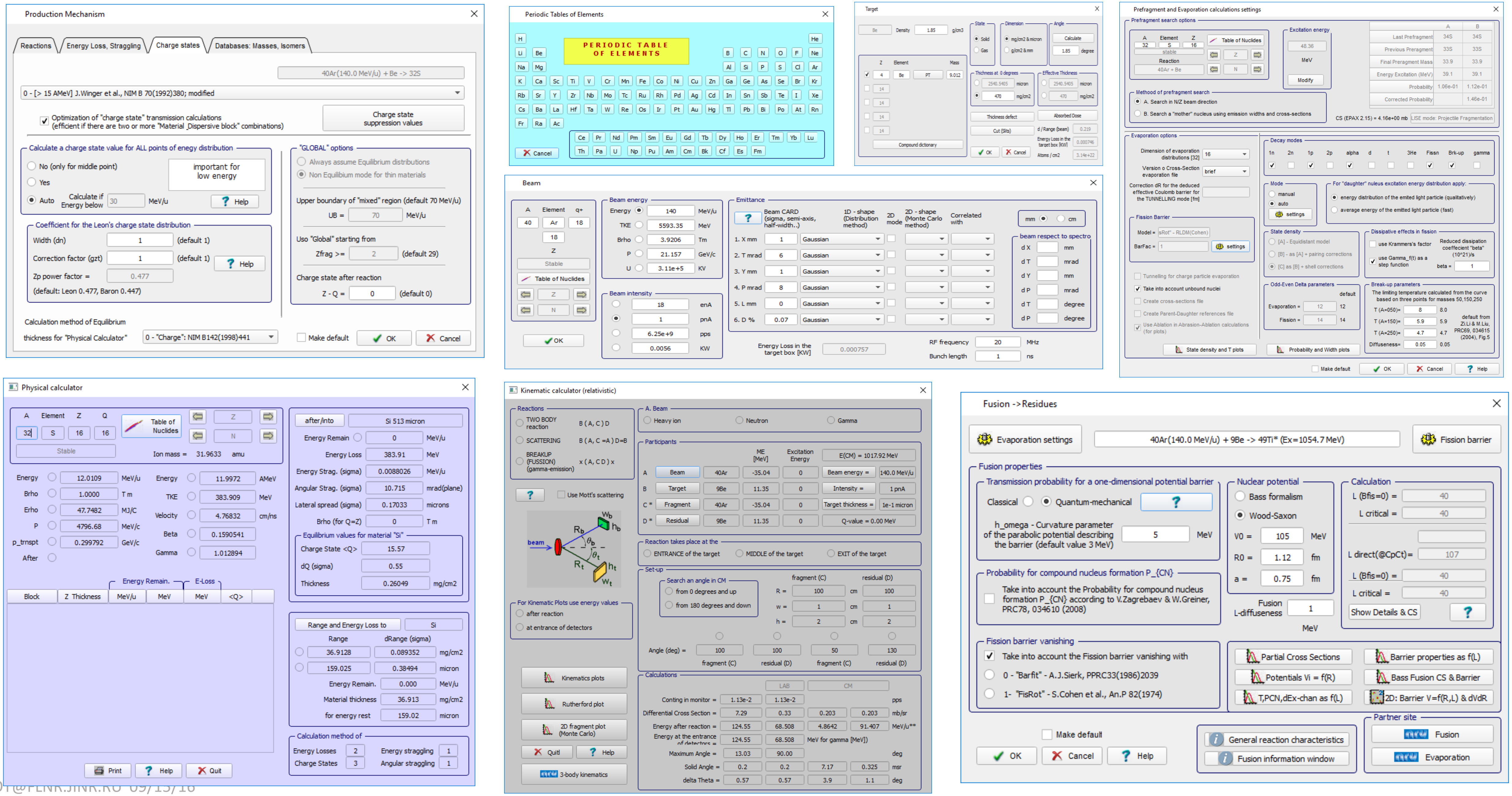
Installation Instructions

`tar xfv LISE_Utilities_Linux.tar.gz` to extract the package.
`cd LISE_Utilities_Linux/` to enter folder.
`./run.sh` to run the software.

LISE^{++} porting to Qt



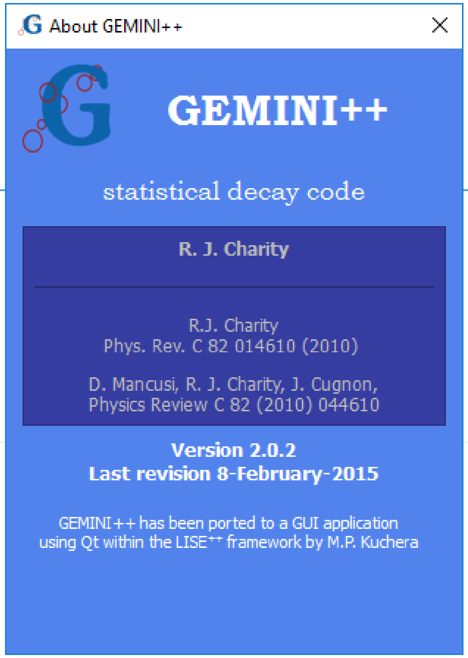
LISE++ porting to Qt : 1 to 1



GEMINI++ implementation to the LISE^{++} package

95% done

http://lise.nscl.msu.edu/porting/gemini.html



Gemini

Documentation

- Purpose
- Implementation
- In Action
- Download

Introduction

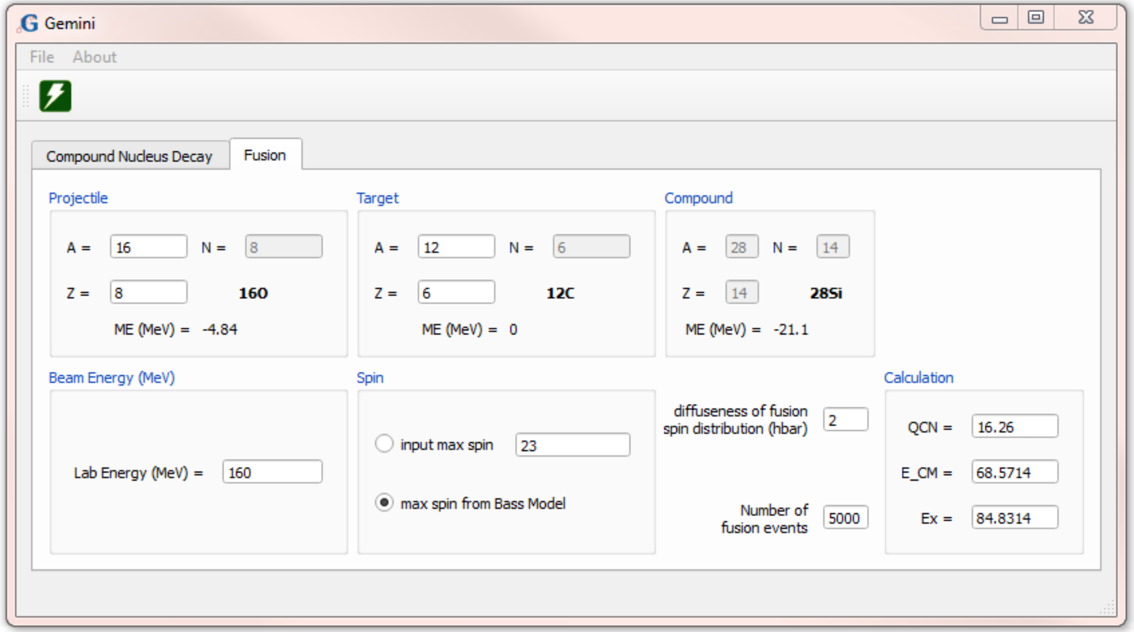
A Gemini++ Graphical User Interface (GUI) utility was created to complement with the other utilities in the LISE^{++} Utilities Package. The LISE^{++} Utilities Package is currently a package of 5 satellite utilities that are either used in the LISE^{++} projectile fragmentation software, or of use to the users of LISE^{++}. The Gemini++ libraries provide useful calculations for LISE^{++} users. Specifically, users can quickly compare yields and other interesting results with other codes provided in the Utilities, such as PACE4. This is great for those users who are not familiar with command-line programs, using libraries or just want to quickly check calculations.

[1] R.J. Charity, Phys.Rev.C 82, 014610 (2010)
[2] D. Mancusi, R.J. Charity, J. Cugnon, Phys.Rev.C 82, 044610 (2010)
[3] R.Charity: GEMINI: A Code to Simulate the Decay of a Compound Nucleus by a Series of Binary Decays. pdf.

Implementation

The Gemini++ code was implemented in the Qt graphics framework. Qt is a C++ graphics framework for cross-platform development. This can be compiled into Windows, Mac, and Linux GUI executables. The executables would be distributed for installation with our LISE++ Utilities Package. The mass tables were updated to use the AME2012 database where appropriate. Specifically, where the original code checked for an experimental value, the AME2012 database is checked instead. The AME database is implemented as a SQLite database for this project. In order to facilitate a cross-platform implementation, the *.tbl and *.tl files are stored as Qt "resources". This requires some syntax changes in the code. For this reason, the code was verified against the command-line version of the code. The random-number generator was fixed to constant values for both programs and results were compared.

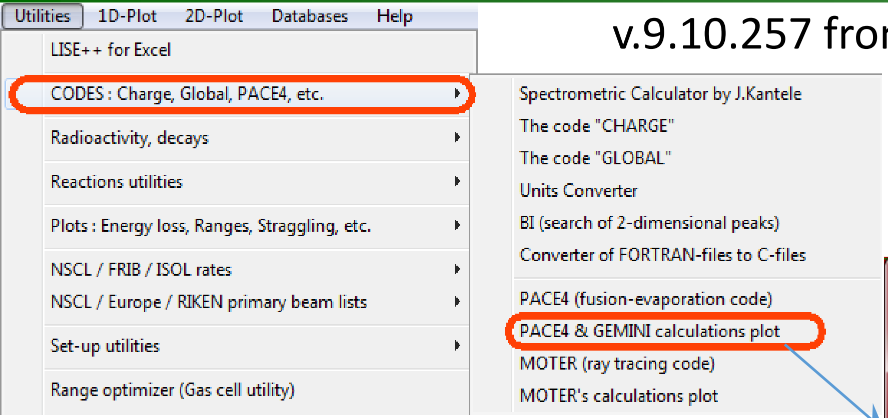
The simple example codes of testFusion and testDecay were used as reference for the Gemini Utility. Results from these are easily compared to PACE, another utility program, by looking at residual yields of nuclei. See below for a look at the GUI input and results forms.

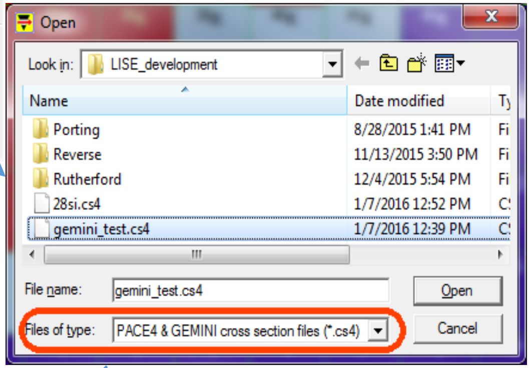


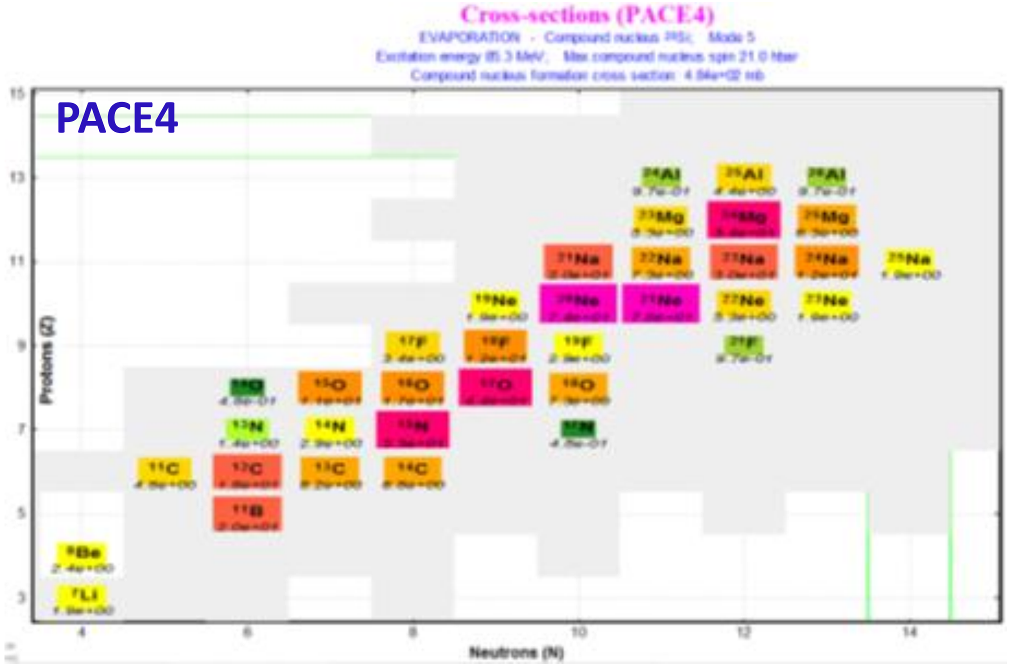
GEMINI++ implementation to the LISE++ package

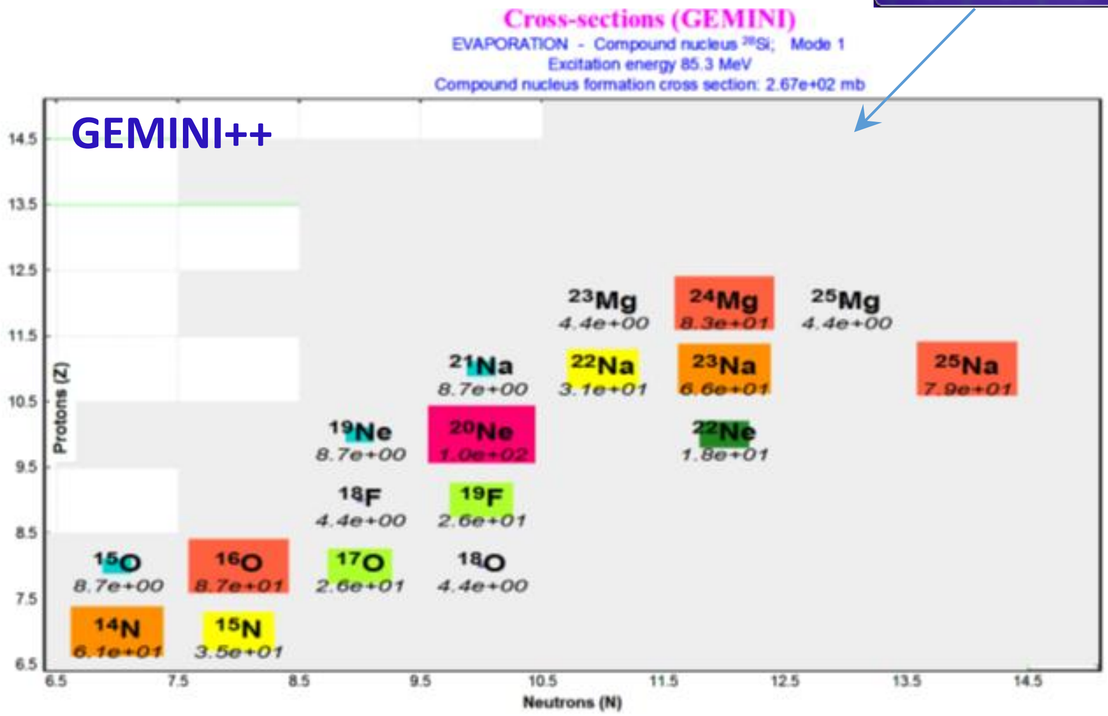
MICHIGAN STATE UNIVERSITY

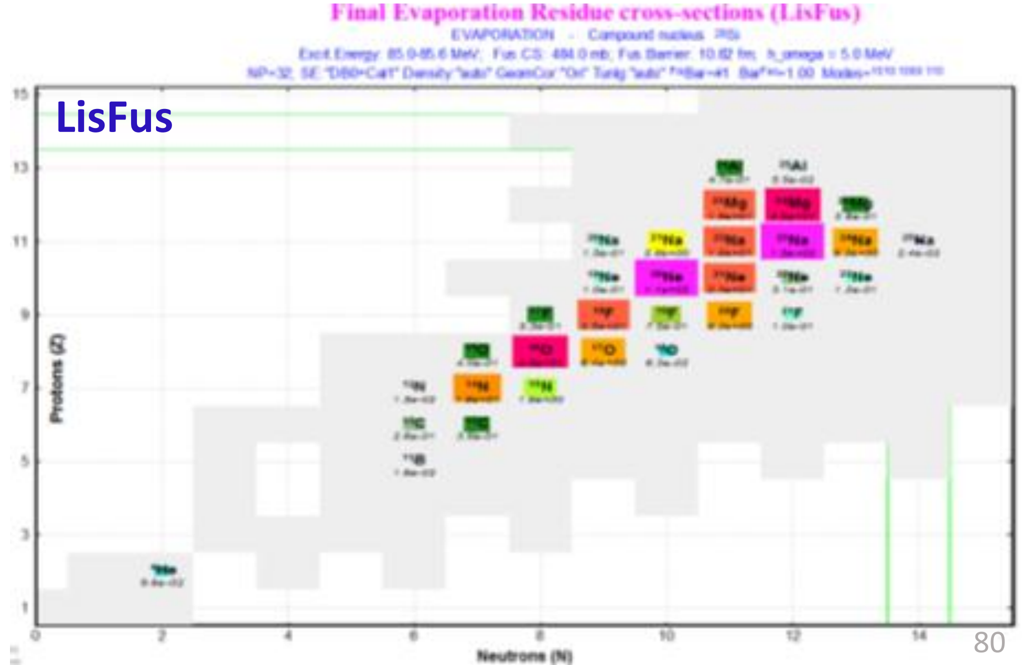
v.9.10.257 from 01/07/16



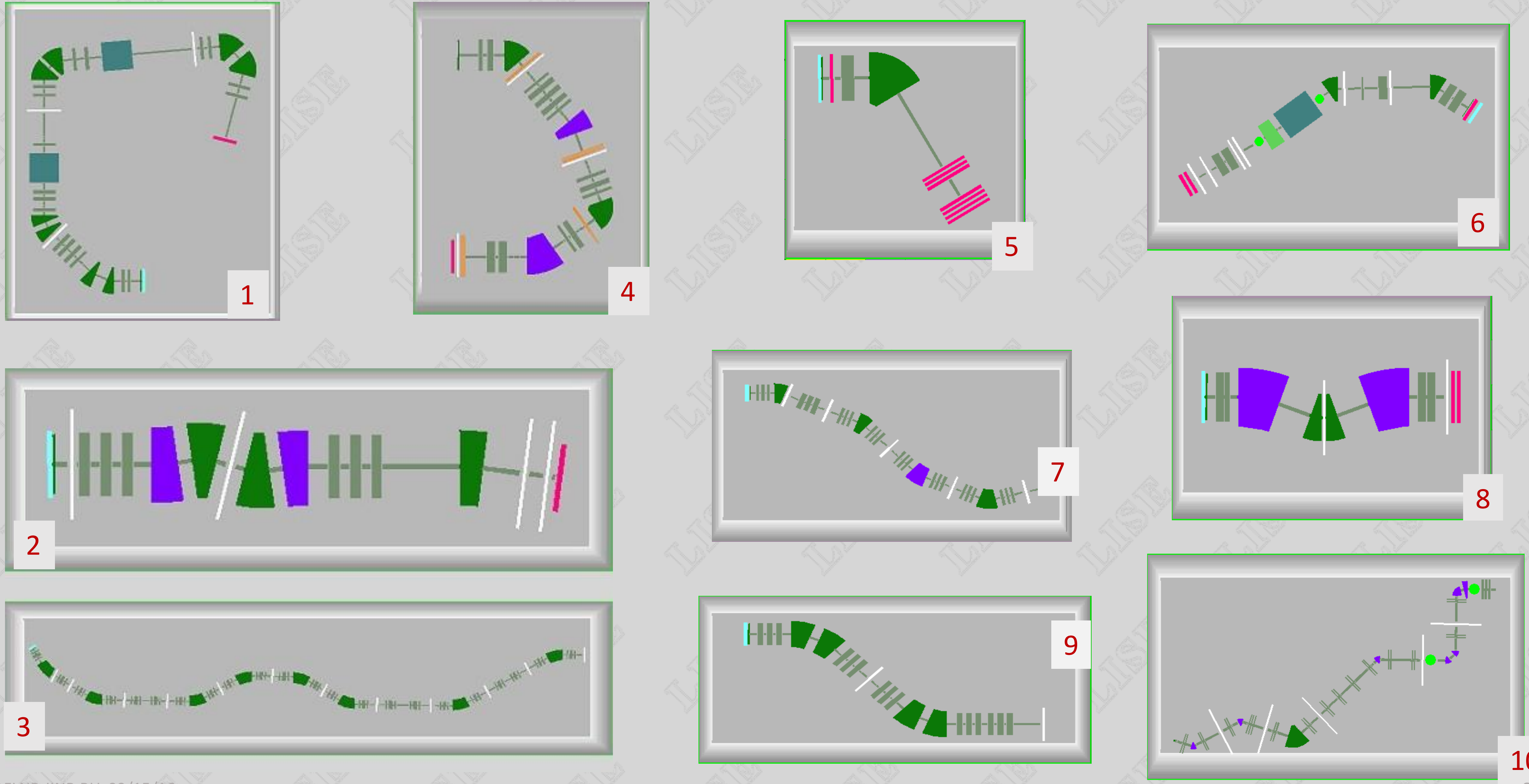








Example of set-ups in LISE^{++}



Summary

Next for 2016:

- Version 10 release
- ETACHA4 (GUI)
- GEMINI++ (GUI)
- Porting, porting, and again porting….

D. Bazin
M.P. Kuchera
B.M. Sherrill
O.B. Tarasov
K.V. Tarasova

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Discussions & Requests:	*D.J.Morrissey, M.Hausmann, M.Portilio, H.Weick*
Fusion update:	*D.J.Morrissey, M.Thoennessenn, Z.Kohley, G.Knyazheva*
Reverse configurations:	*M.Bowry, A.Gade, M.Portilio, M.Hausmann*
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Scattering:	*D.J.Morrissey, A.Popeko*
Radiation Residue Calculator:	*D.J.Morrissey*
Range optimizer (Gas cell utility) update:	*D.J.Morrissey, Ch.Sumithrarachchi*
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ETACHA4:	*Dominique Vernhet*
Second order optics calculations of electric dipole:	*Robert Hipple*
S3:	*Bertrand Jacqout, Omar Kamalou*
LISE3:	*Omar Kamalou*
SHELS :	*Andrey Popeko*
SECAR :	*H.Schatz, G.Berg, M.Couder*
FMA:	*Darek Seweryniak*
DRAGON:	*Chris Ruiz, D.A.Hutcheon, Ulrike*
EMMA:	*Matt Williams*
HRS:	*Th.Baumann*

And Next Acknowledgment to ….

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