LISE^{++}

Oleg Tarasov

Research Staff Physicist,
LISE^{++} Lead

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Overview and Goals

- The proposed research on rare isotope production will be incorporated into the LISE^{++} program

A
- The underlying physics of LISE^{++}, i.e., cross sections and momentum distribution of fragments, is central to accurate simulation of experiments; this is the subject of our grant proposal

B
- The broader impact of this work is significant. All rare isotope facilities, and many low-energy laboratories use LISE^{++} for spectrometer design, experiment planning, and data analysis

C
- The PIs are uniquely qualified to do this work

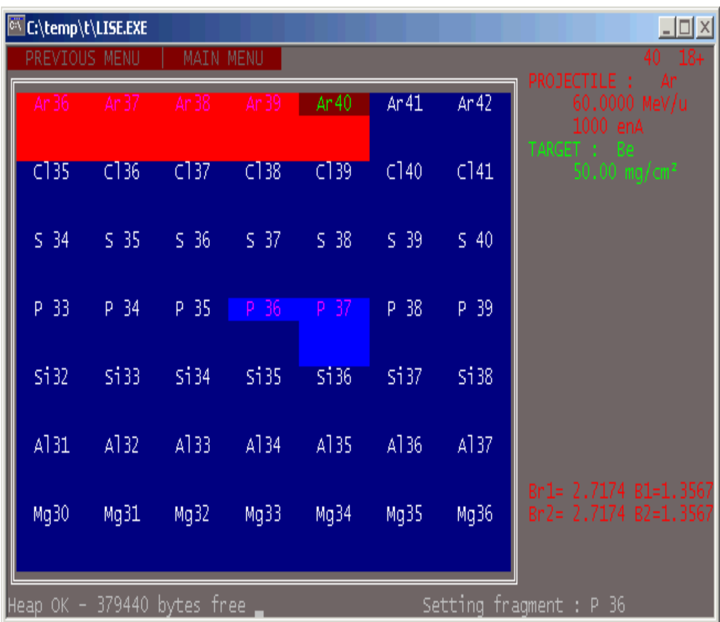
History: France

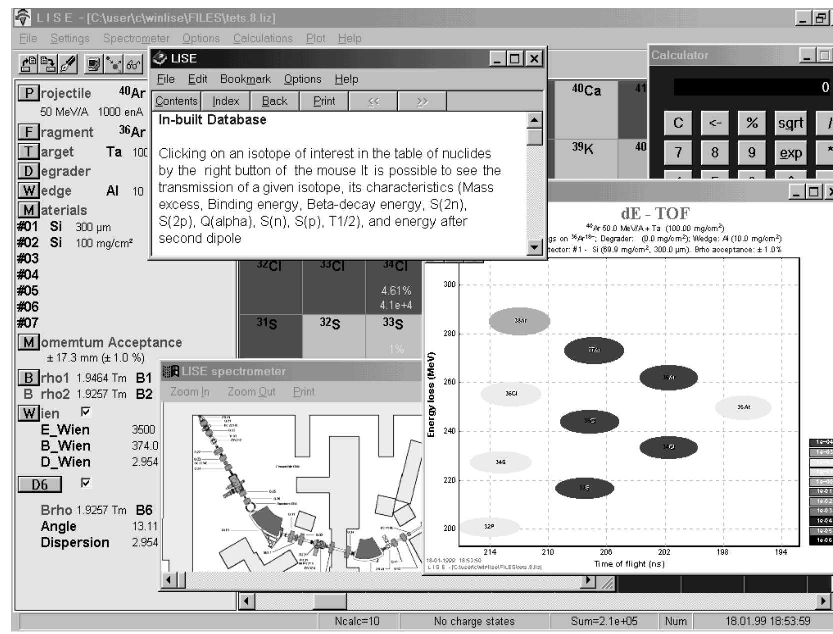
- GANIL - The program LISE was designed to predict intensities and purities for the planning of experiments at the LISE fragment-separator as well as for tuning experiments where its results can be quickly compared to on-line data.

1986-1993
D.Bazin, O.Sorlin
v.1.0-2.2

1994-2000
O.Tarasov
v.2.3 – 4.9

- 1998: LISE operates under MS Windows





History: USA

NSCL / MSU

- Active development of the LISE code stimulated by B. Sherrill at MSU by the hire of O. Tarasov
- LISE^{++} is the new generation of the LISE code, which allows the creation of any spectrometer through the use of different "blocks"
- Fusion – Residues, Coulomb Fission, Abrasion – Fission, Fusion – Fission
- Monte Carlo calculation of fragment transmission
- Optics calculation up to 2nd order (5th order use)
- Optics minimization
- v.12 was recently released

2001
NSCL / MSU
v.4.10 –5.12

2003
NSCL / MSU
v.6

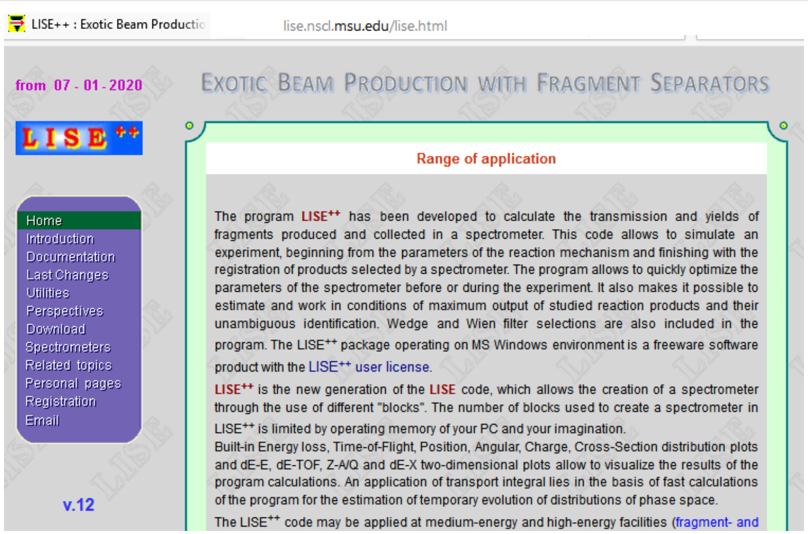
20…
NSCL / MSU
v.7-9.10

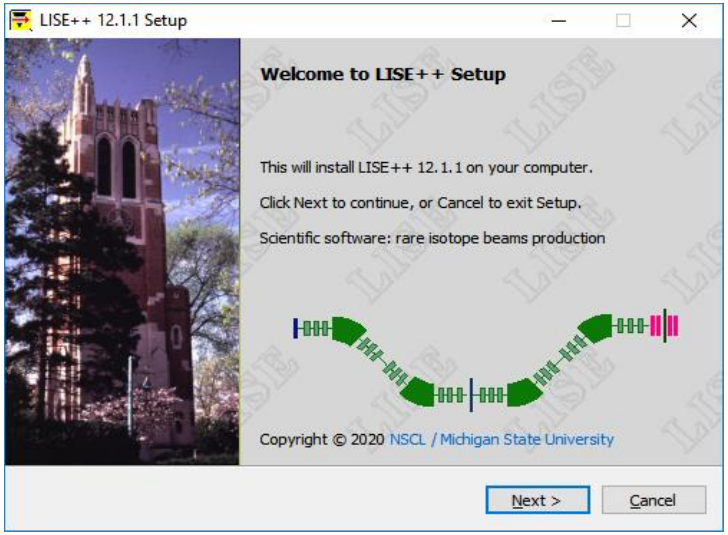
2020
NSCL / MSU
v.12

Authors	Name	Journal	citations
O.B.Tarasov, D.Bazin	LISE^{++} : Exotic beam production with fragment separators ..	NIM B 376 (2016) 185	16
M.P.Kuchera, O.B.Tarasov et al	LISE^{++} Software Updates and Future Plans	NIM B 376 (2016) 168	1
O.B.Tarasov, D.Bazin	LISE^{++} : Radioactive beam production with in-flight separators	NIM B 266 (2008) 4657-4664	231
O.B.Tarasov, D.Bazin	LISE^{++} : design your own spectrometer	Nuclear Physics A746 (2004) 411-414	49
O.B.Tarasov, D.Bazin et al.	The code LISE: The code LISE: a new version for 'Windows'	Nuclear Physics A701 (2002) 661-665	15
D.Bazin, O.B.Tarasov et al.	The program LISE: a simulation of fragment separators	NIM A482 (2002) 307-327	87

Rare Isotope Beam Production with Fragment Separators

- The program LISE^{++} is designed to predict the intensity and purity of rare isotope beams (RIB) produced by In-flight separators
- The program is constantly expanding and evolving from the feedback of its users around the world
- The LISE^{++} package includes configuration files for most of the existing fragment and recoil separators found in the world
- Many “satellite” tools have been incorporated into the LISE^{++} framework
- The code operates under MS Windows environment and provides a highly user-friendly interface
- It can be freely downloaded from the following internet addresses: http://lise.nscl.msu.edu

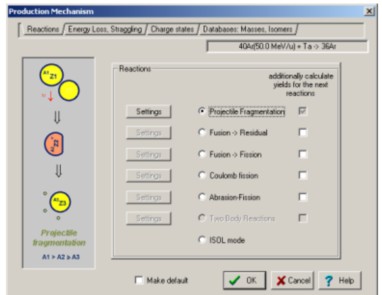




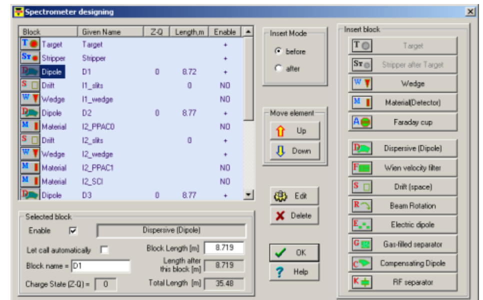
Main LISE++ Functions

- predict the fragment separator settings necessary to obtain a specific RIB
- predict the intensity and purity of the chosen RIB
- simulate identification plots for on-line comparison
- provide a highly user-friendly graphical environment
- allow configuration for different fragment separators

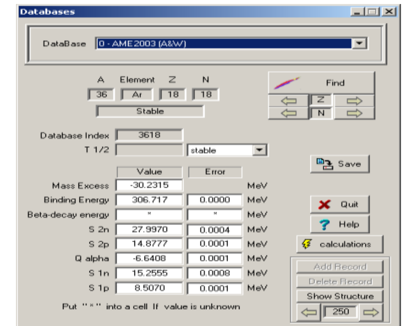
LISE++ physics: Production mechanisms, energy loss etc

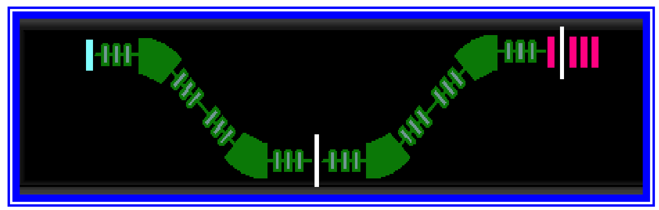


Shell to construct a spectrometer



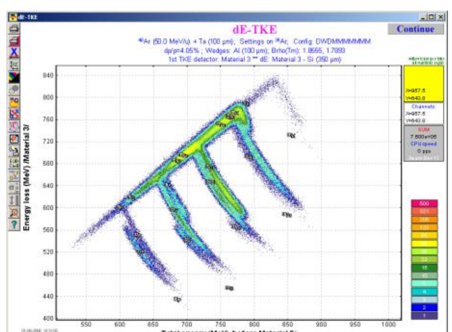
LISE++ databases





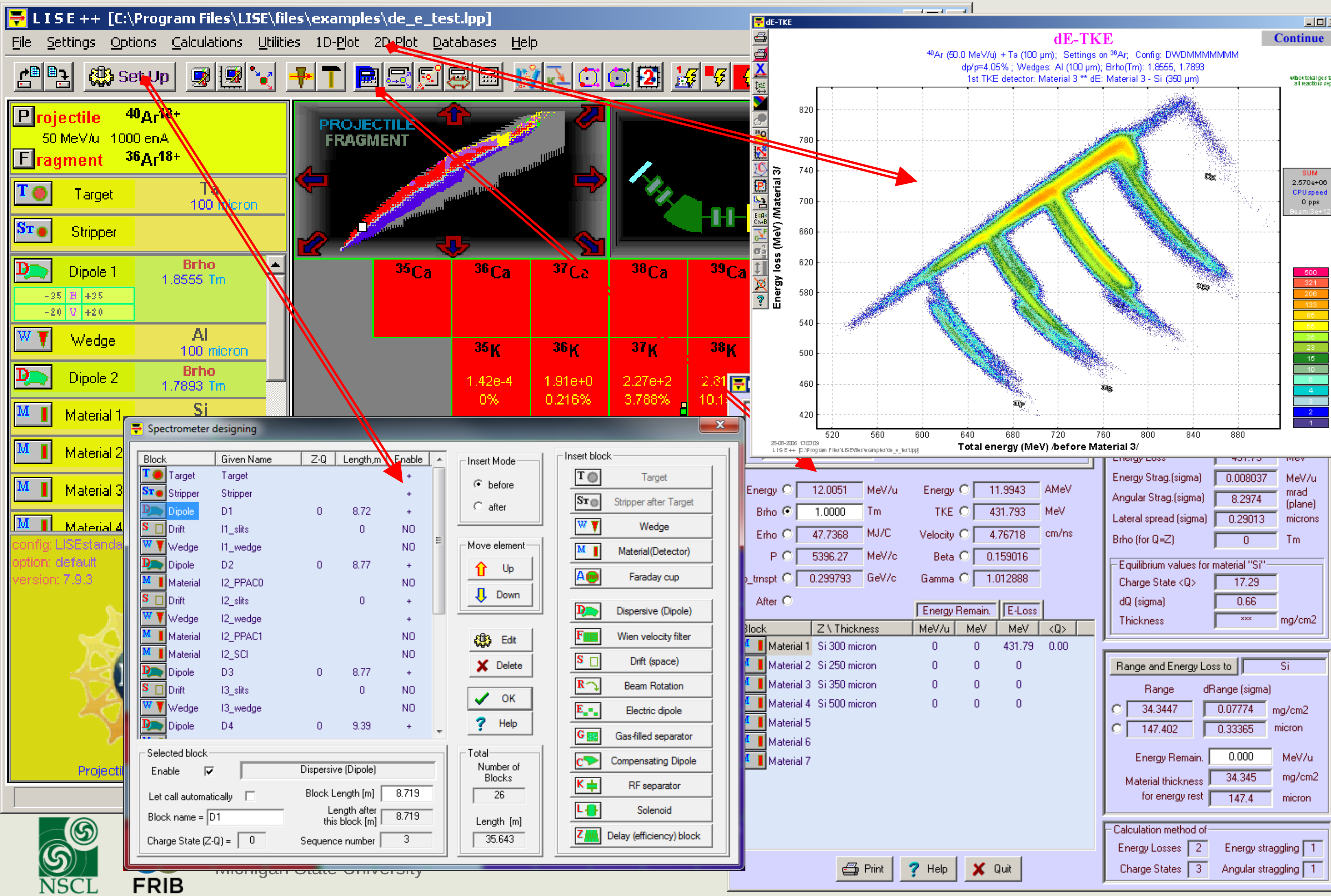
Beam Optics calculation and optimization

LISE++ graphics



LISE++ utilities and satellites

LISE^{++} in Action



NSCL FRIB Michigan State University

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.

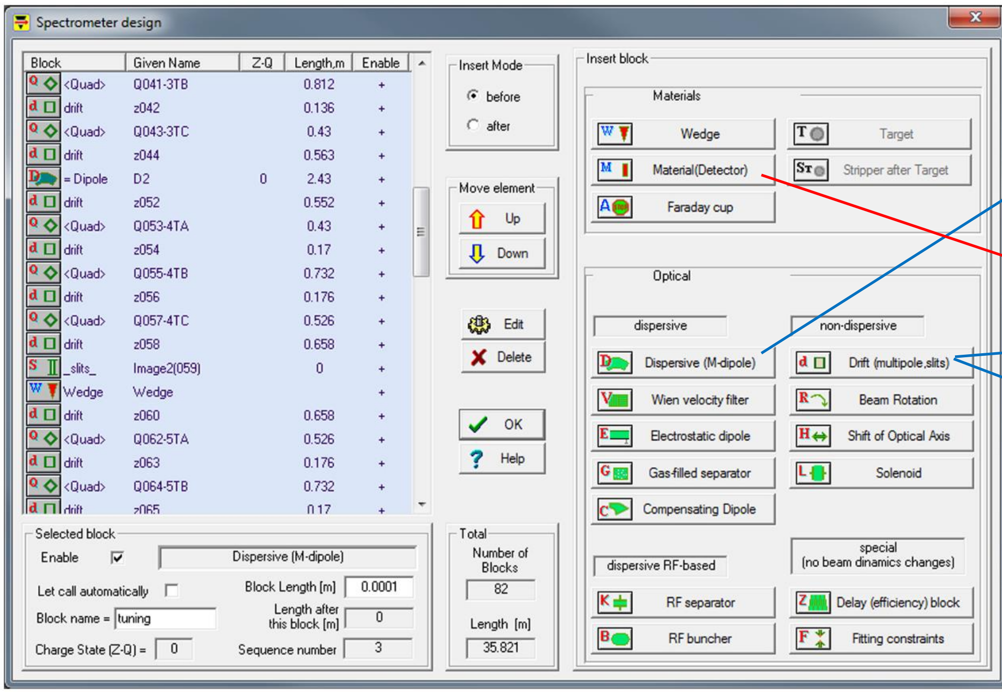
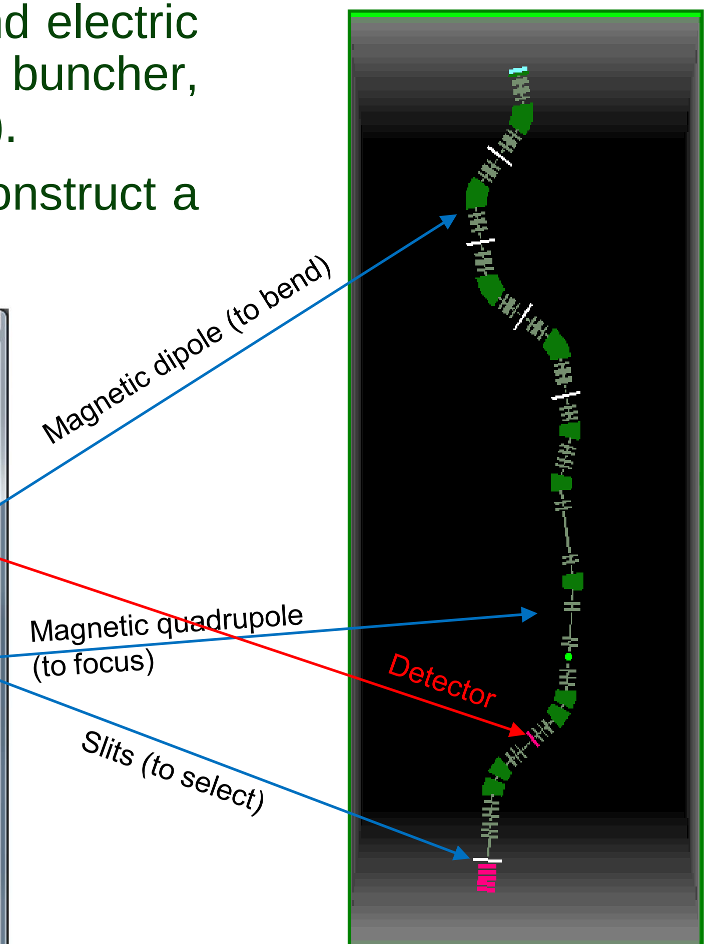
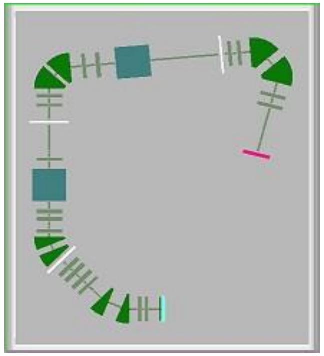


Fig. 1. Updated view of the "Spectrometer Design" dialog window.

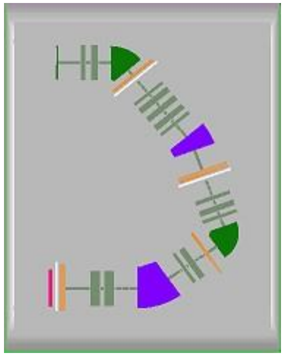


Configuration: A1900_S800BL (2nd order) 164 blocks

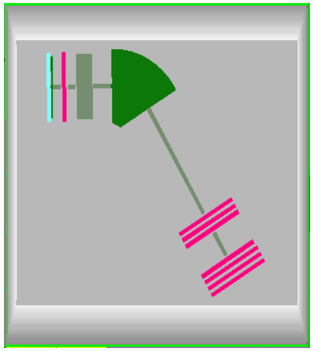
Examples of LISE^{++} Use



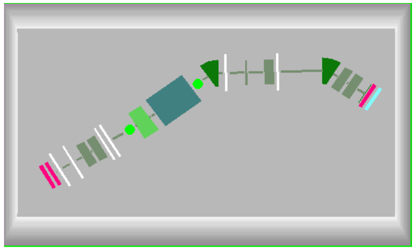
SECAR, ***MSU***



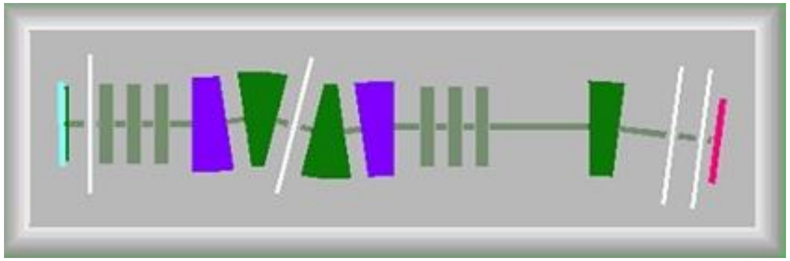
DRAGON, ***Canada***



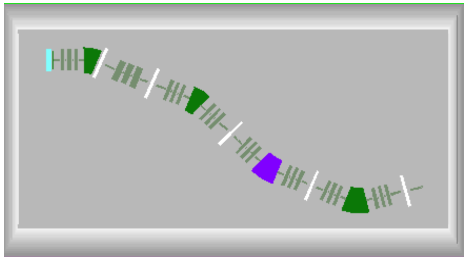
PRISMA, ***Italy***



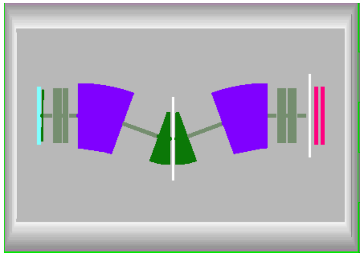
MARS,
Texas A&M U



SHELS, ***Russia***

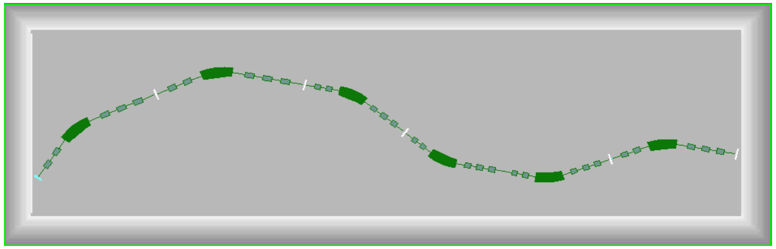


S^3, ***France***



FMA, ***ANL***

BigRIPS+ZeroDegree, ***Japan***



SuperFRS_HEB, ***Germany***

World Wide Use: PAC requirements

- Some laboratory PACs require to attach RIB estimations done with the LISE^{++} code

A1900 @ NSCL

http://www.nscl.msu.edu/exp/propexp/procedure

National Superconducting Cyclotron Laboratory
Call for Proposals—PAC 37

February 2, 2012

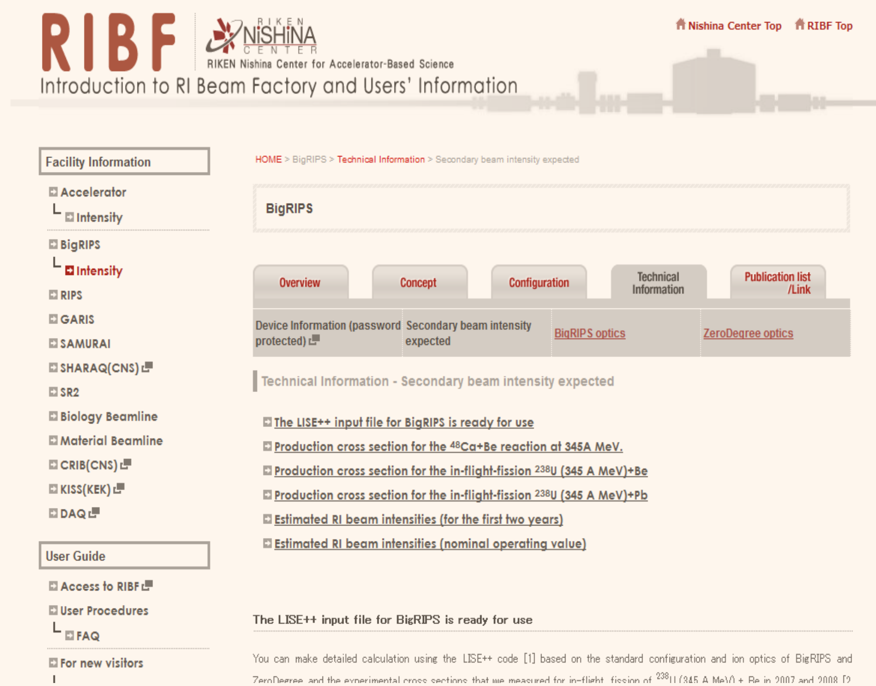
Dear NSCL User:

We invite proposals for beam time to be considered at the next meeting of the NSCL Program

(C) An electronic copy of the LISE++ files used to obtain rare isotope intensity estimates with the official version of LISE++ (referenced in item 3 of the "Notes for PAC37" below). The LISE files can be e-mailed to the A1900 Device Contact at the time of submission of the proposal.

BigRIPS @ RIBF

http://www.nishina.riken.jp/RIBF/BigRIPS/intensity.html


RIBF
RIKEN NISHINA CENTER
RIKEN Nishina Center for Accelerator-Based Science
Introduction to RI Beam Factory and Users' Information
Nishina Center Top   RIBF Top

Facility Information
Accelerator
Intensity
BigRIPS
Intensity
RIPS
GARIS
SAMURAI
SHARAQ(CNS)
SR2
Biology Beamline
Material Beamline
CRIB(CNS)
KISS(KEK)
DAQ
User Guide
Access to RIBF
User Procedures
FAQ
For new visitors

HOME > BigRIPS > Technical Information > Secondary beam intensity expected

BigRIPS

Overview | Concept | Configuration | Technical Information | Publication list /Link

Device Information (password protected) | Secondary beam intensity expected | BigRIPS optics | ZeroDegree optics

Technical Information - Secondary beam intensity expected

The LISE++ input file for BigRIPS is ready for use
Production cross section for the ^{48}Ca+Be reaction at 345A MeV.
Production cross section for the in-flight-fission ^{238}U (345 A MeV)+Be
Production cross section for the in-flight-fission ^{238}U (345 A MeV)+Pb
Estimated RI beam intensities (for the first two years)
Estimated RI beam intensities (nominal operating value)

The LISE++ input file for BigRIPS is ready for use

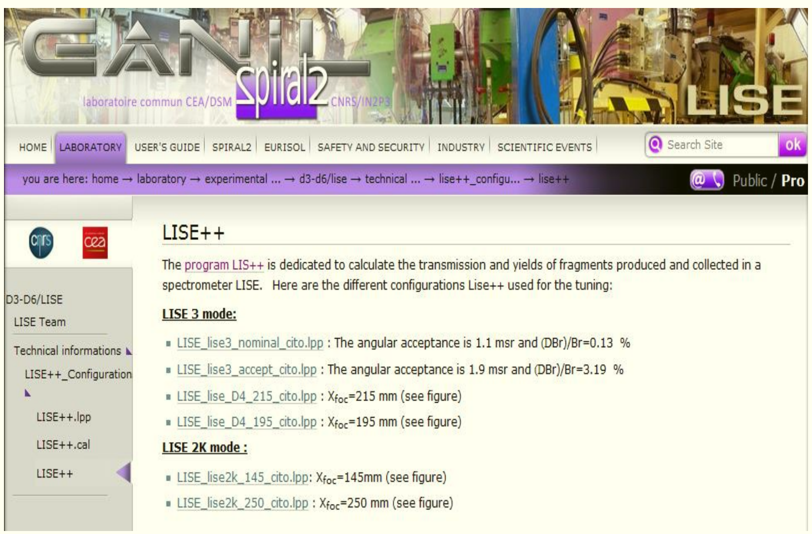
You can make detailed calculation using the LISE++ code [1] based on the standard configuration and ion optics of BigRIPS and

World Wide Use: configuration development inside laboratories

- The LISE^{++} code can be used at low-energy, medium-energy and high-energy facilities (fragment- and recoil-separators with electrostatic and/or magnetic selections)

LISE separator @ GANIL (France)

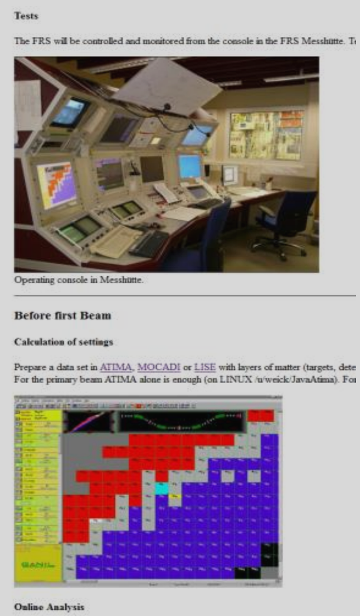
http://pro.ganil-spiral2.eu/laboratory/experimental-areas/lise/technical-informations/lise-_configuration/lise/

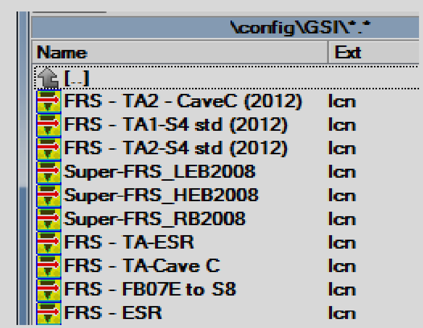


FRS @ GSI (Germany)

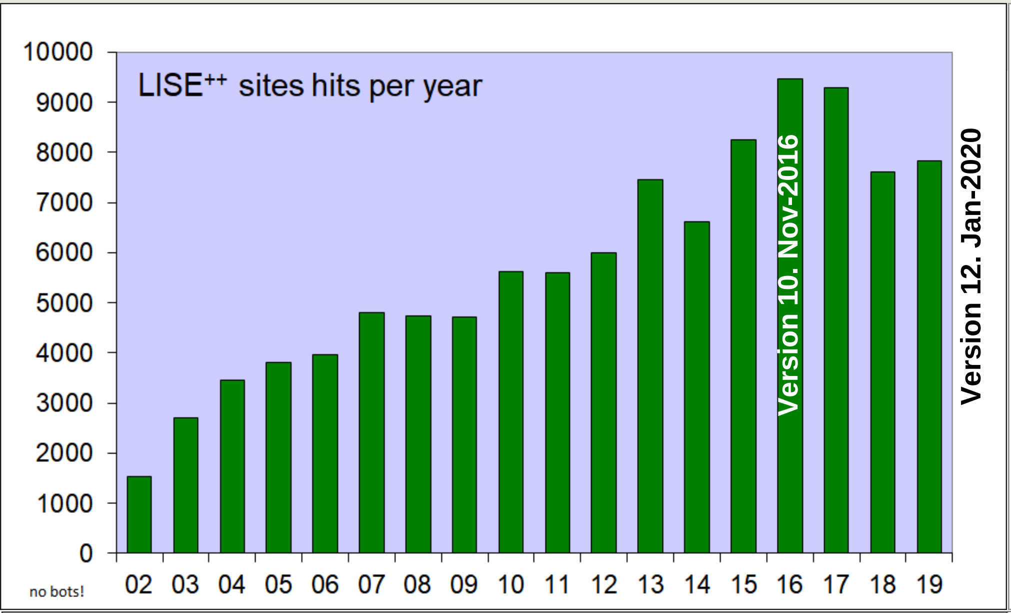
http://web-docs.gsi.de/~weick/frs/frs-steps.html

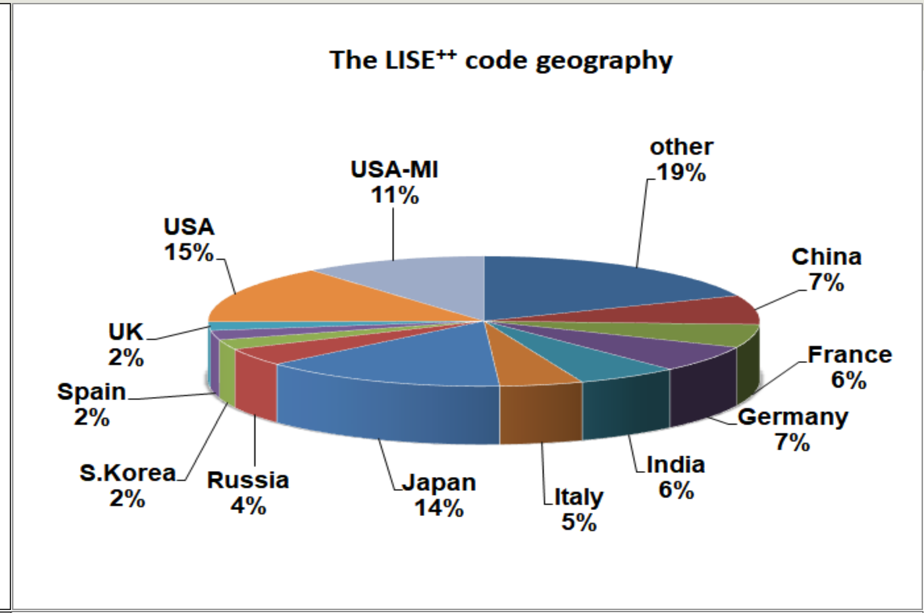
How to set up the FRS –
From SIS extraction of primary beam to isotope identification

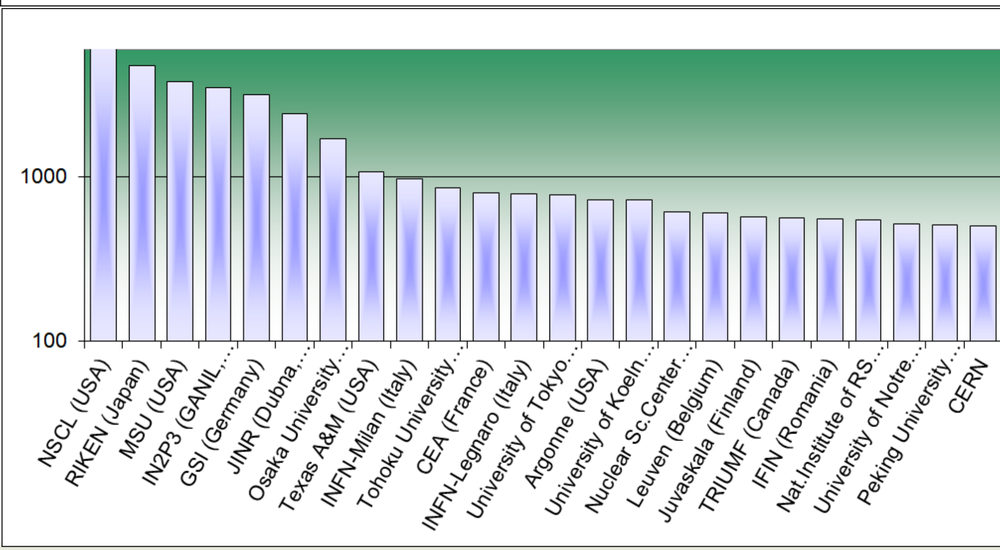


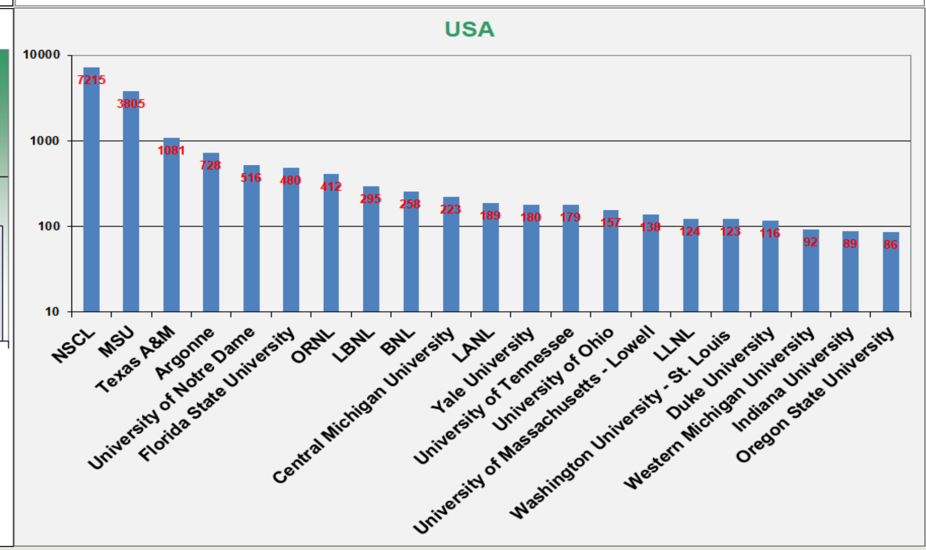


Statistics – LISE++ is Widely Used



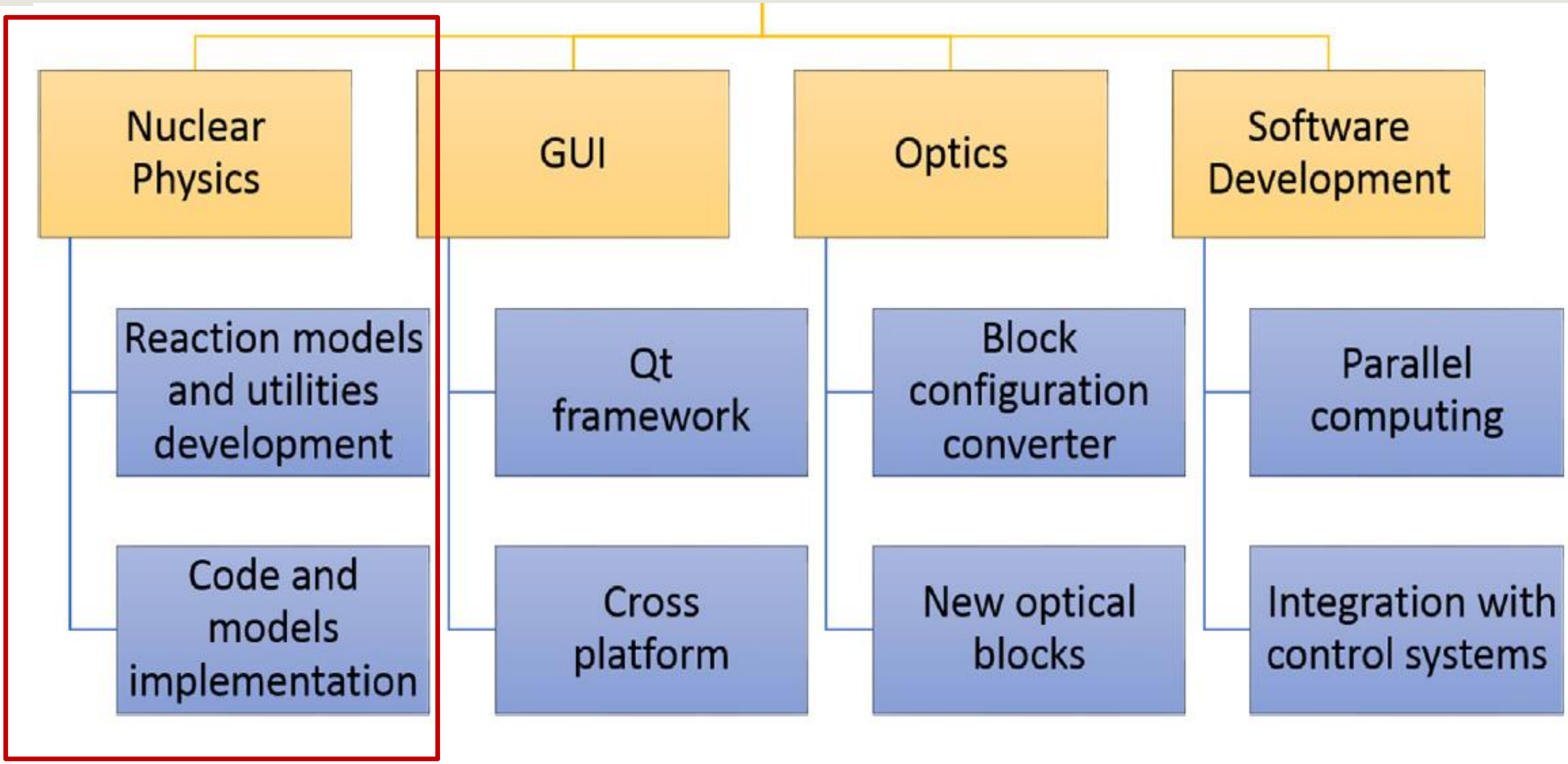






National Science Foundation
Michigan State University

LISE^{++} development



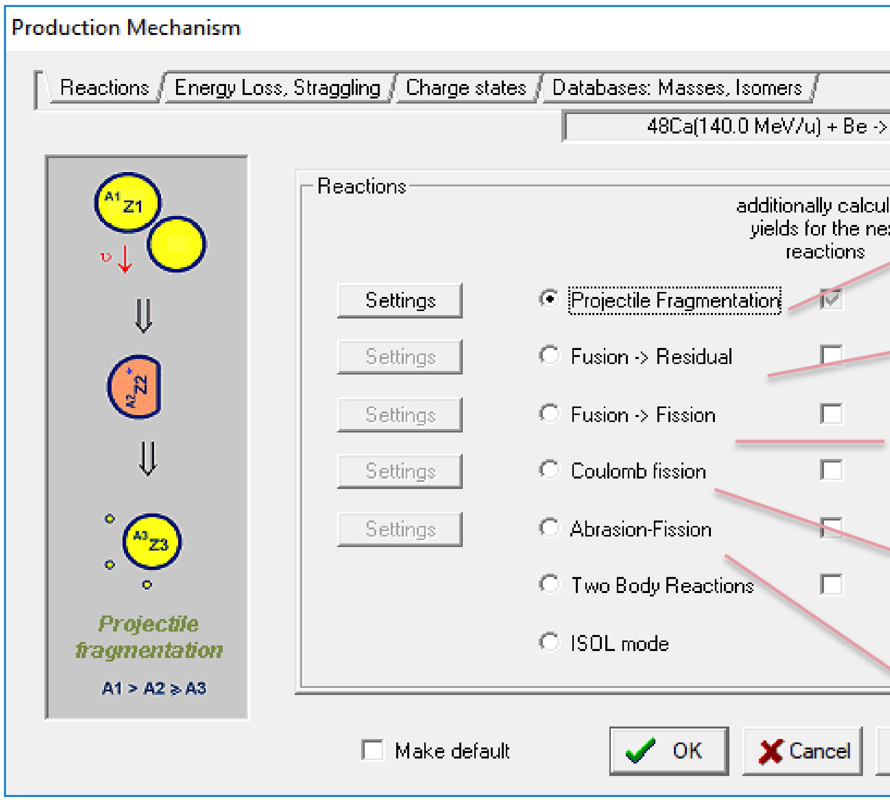
This Proposal

Fig. A schematic diagram of the LISE^{++} development plans.

M.P. Kuchera et al. / Nuclear Instruments and Methods in Physics Research B 376 (2016) 168–170

Reaction Mechanisms

- Not only using classical reaction mechanism models, but actively developing fast and accurate in-house models
- Includes fragment production in materials (wedges, detectors)



			cit-ns
O.B.Tarasov	Analysis of momentum distributions of projectile fragmentation products	NPA 734 (2004) 536-540	35
O.B.Tarasov, D.Bazin	Development of the program LISE: application to fusion–evaporation	NIM B204 (2003) 174-178	92
O.B.Tarasov, A.C.C.Villari	Fusion–fission is a new reaction mechanism to produce exotic radioactive beams	NIM B 266 (2008) 4670-4673	5
O.B.Tarasov	LISE++ development: application to low-energy fission of projectiles at realtivistic energies	ENAM2004: EPJ A25 (2005) 751	3
O.B.Tarasov	LISE++ development: Abrasion-Fission	Preprint NSCL MSU, MSUCL-1300, 09.2005	

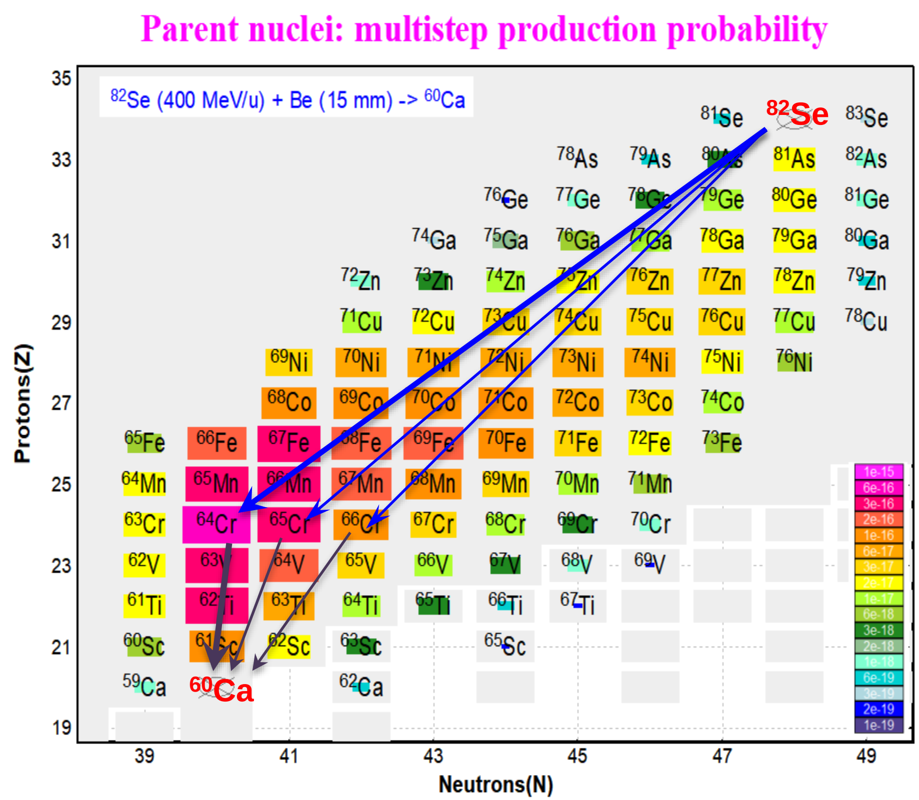
Reaction Models Development

- Development and improvement of fast model for multi-step reactions
- Investigate charge-exchange and pick-up reactions in RIB production
- Creation of Fast and accurate Abrasion-Fission model based on the Initial Fissile Nuclei Analyzer tables
- Intermediate Dissipation step in the Abrasion-Ablation model
- Implementation in LISE^{++} code for transmission and cross section calculations
  - ETACHA4: Low-energy non-equilibrium charge state evolution
  - PACE4: Projection Angular-momentum coupled evaporation
  - INC: intranuclear cascade model to use at higher energies with light targets
- Theoretical study of prefragment excitation energy
- Systematization of experimental production cross-sections
- Creation of Monte Carlo de-excitation cascade utility to benchmark the analytical LISE^{++} cascade subroutine and to create condition (gating) options

Multi-Step Reactions

- Multi-step reactions in thick targets is process then the projectile undergoes a series of successive reactions until the fragment of interest is produced

- For the second and next reactions we assume always a projectile fragmentation mechanism and uses the EPAX parameterization to speed up calculations



LISE^{++} → ^{64}Cr is more probable second-step projectile to produce ^{60}Ca with a ^{82}Se beam (400 MeV/u) on Be (15 mm).
Total Multi-step reaction factor is equal to 10.1

Multi-Step Reactions Study

- The study (experimental and theoretical) of the multi-step reactions:
  - the development of a fast model for multistep reactions
  - the measurement of experimental secondary cross sections

- Important to approach the nucleon drip-lines
  - So, more probable path for ^{70}Ca production at FRIB is a three-step process:

1. Abrasion of ^{238}U to low-excited ^{237}U (E*~32 MeV) with sequential fission to ^{81}Ga (2e-2 mb)
2. First projectile fragmentation step : ^{81}Ga $\rightarrow$ ^{76}Fe (-5p, ~1e-5 mb)
3. Second projectile fragmentation step : ^{76}Fe $\rightarrow$ ^{70}Ca (-6p, ~1e-6 mb)

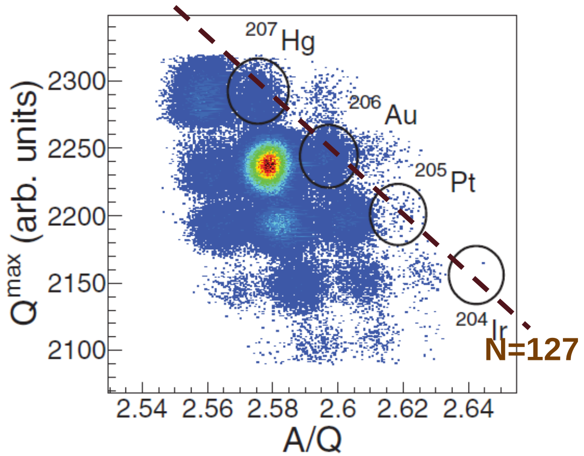
- MSU-RIKEN collaboration recent experiments with multi-step reactions analysis in process:
  - Production of neutron-rich isotopes around ^{60}Ca by projectile fragmentation of a beam of ^{70}Zn at 345 MeV/u *(O.Tarasov et al., PRL 121 (2018) 022501)*
  - Production of very neutron-rich Pd isotopes around *N* = 82 by projectile fragmentation of a RI beam of ^{132}Sn at 280 MeV/u *(H.Suzuki et al.)*

Charge-Exchange Reactions (1)

- The study (experimental and theoretical) of the charge-exchange mechanism as a **step for rare isotope production**

- (p,n)

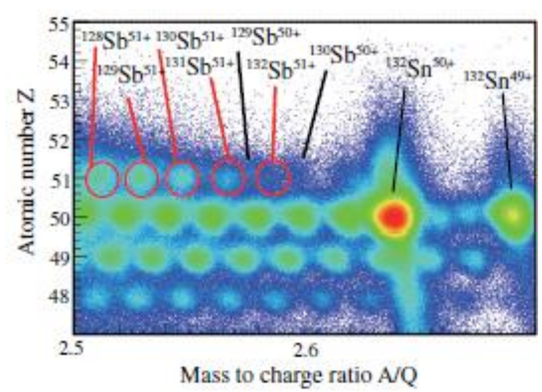
  - A. I. Morales, J. Benlliure et al., PRC84, 011601(R) (2011)
    $^{208}Pb_{126}$ (1 AGeV) + Be



- (n,p)

  - J. Yasuda, M. Sasano, et al., PRL 121, 132501 (2018)
    ^{132}Sn (200 MeV/u) + H → $^{**}Sb$

  - D.Kostyleva, I.Mukha et al., PRL 123, 092502 (2019)
    ^{31}Ar (620 MeV/u) + Be → ^{31}K



Charge-Exchange Reactions (2)

- Recent “^{60}Ca” experiment at RIKEN

O.Tarasov et al., PRL 121 (2018) 022501

- Production of ^{62}Sc is -9p,+1n
- Pickup is suppressed at these energies
- Two-step reactions through a charge-exchange channel?

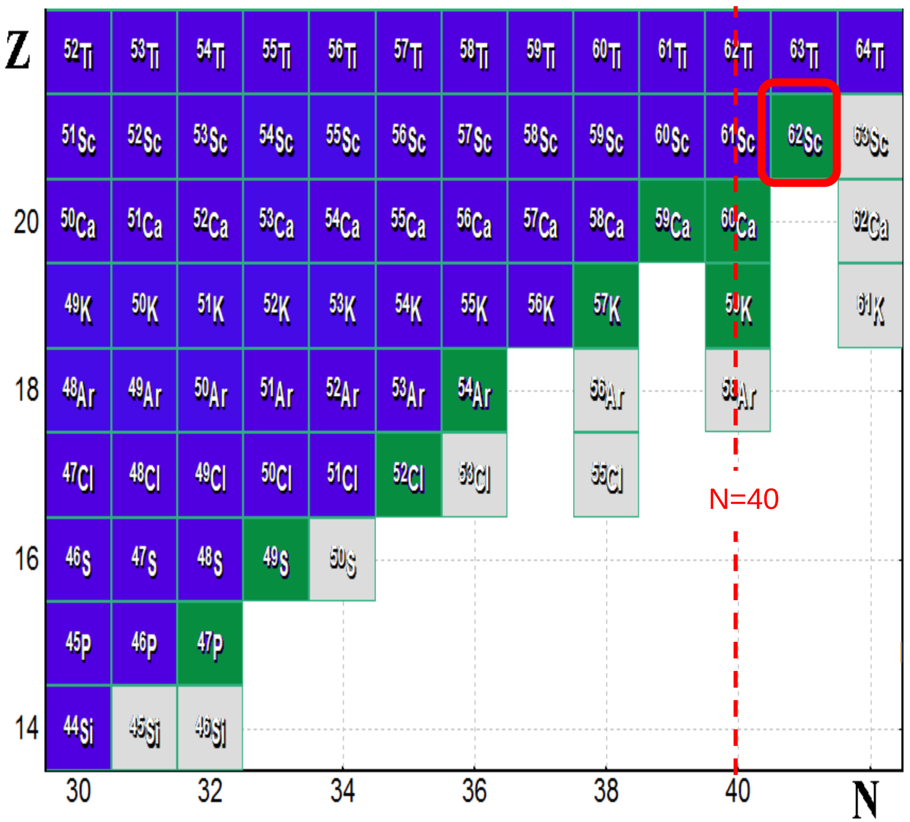
$^{70}Zn(p,n)^{70}Cu \rightarrow {}^{70}Cu(-8p)^{62}Sc$

or

$^{70}Zn(-8p)^{62}Ti \rightarrow {}^{62}Ti\,(p,n)^{62}Sc$

- Cross sections are under analysis
- Charge-exchange reactions become an important mechanism for the Rare Isotopes production

$^{70}Zn_{40}$ (345 MeV/u) + Be → $^{62}Sc_{41}$

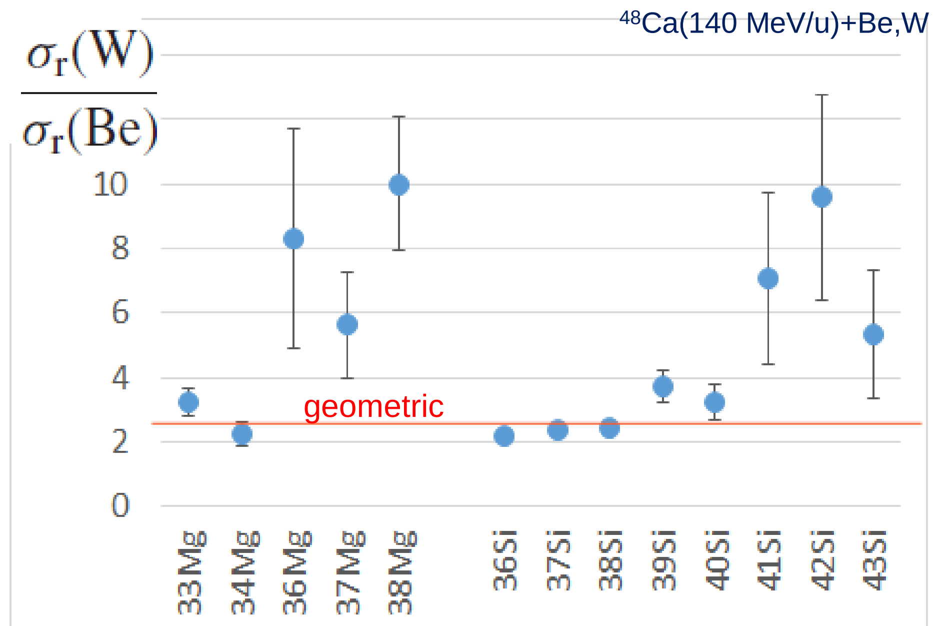


Target factor

- The study of the target factor in rare isotope yields for energies 50–150 MeV/u

- ^{48}Ca(140 MeV/u) + Be,W
  - ^{40}Mg, $^{42,43}Al$:
    T. Baumann, et al.,
    Nature 449 (2007) 1022
  - ^{44}Si:
    O.B.Tarasov, et al.,
    PRC75 (2007) 064613

- ^{198}Pt (85 MeV/u) + Be, NI
  NCSL/MSU, 2019
  O.Tarasov et al, under analysis



The cross sections for reaction with the tungsten target are larger than those with beryllium by factors that range from approximately 2.5 at A = 36 (Z=14) to about 10 at A = 42, values that become significantly larger than the ratio of the geo-metric reaction cross sections equal to 2.66

LISE^{++} porting

- The LISE^{++} code is developing at Borland C++ 5.02 IDE (integrating development environment), which is not compatible with the next Borland (Builder, Embarcadero C++) generations
- The LISE^{++} software suite is undergoing a major transportation to a new graphics framework (Qt) in order to
  - Aid in sustainability of the code
  - Support modern compilers and computing methods:
    - ✓ 64-bit operation
    - ✓ cross-platform compatibility (Windows, Mac, and Linux versions)
    - ✓ the ability to take advantage of computational advances (for example parallel computing methods)
    - ✓ Integration with control systems

Summary

A B C

- The program LISE^{++} is designed to predict the intensity and purity of rare isotope beams (RIB) is widely used at heavy ion collision facilities
- A B The program is constantly expanding and evolving from the feedback of its users around the world
- A C Fast and accurate models of rare isotope production mechanism are being developed in the LISE^{++} framework
- B Work is underway to update the LISE^{++} software suite by transferring to a new graphics framework, Qt, to use with modern compilers
- B New code capabilities such as parallel computing, cross-platform functionality, and integration with control systems are planned
- B Computational speedup is requested from users at many facilities, and becomes more crucial with the new large-scale nuclear physics facilities under construction, such as FRIB and FAIR, that have keen interest in integrating the LISE^{++} software with their control systems

Site visit charge - symbols

A Intellectual Merit

B Broader Impacts

C Synergy Between PIs

D Budget Analysis

B Broader Impacts out of this proposal

Reaction Mechanisms

- In recent years, the LISE^{++} group has been the leader in the development of rare isotope production mechanism models

Version	Changes	Mechanism
12.1.1 07-01-20	- Universal parameterization ('Convolution' method) revision - AA model minimization to describe user cross sections	Projectile fragmentation
	- Initial Fissile Nuclei Analyzer (IFN) - AF 3EER: High Z isotopes production	Abrasion-Fission
	- Plotting and passing both two fission fragments - Two Fission Fragments registration efficiency BATCH	In-flight Fission products registration
10.0 18-11-16	- Update of Fusion reaction mechanism	Fusion-Fission Fusion-Residual
	- FRIB Theory Alliance mass predictions	Applied for excited prefragment reactions

LISE^{++} Powerful Tools

Besides analytical calculation of the transmission and yields of fragments

- Monte Carlo simulation of fragment transmission,
- Monte Carlo simulation of fission fragment kinematics,
- Ion Optics calculation and Optimization ,
- 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"
- "Initial Fissile Nuclei analyzer" *(new)*

Implemented codes:

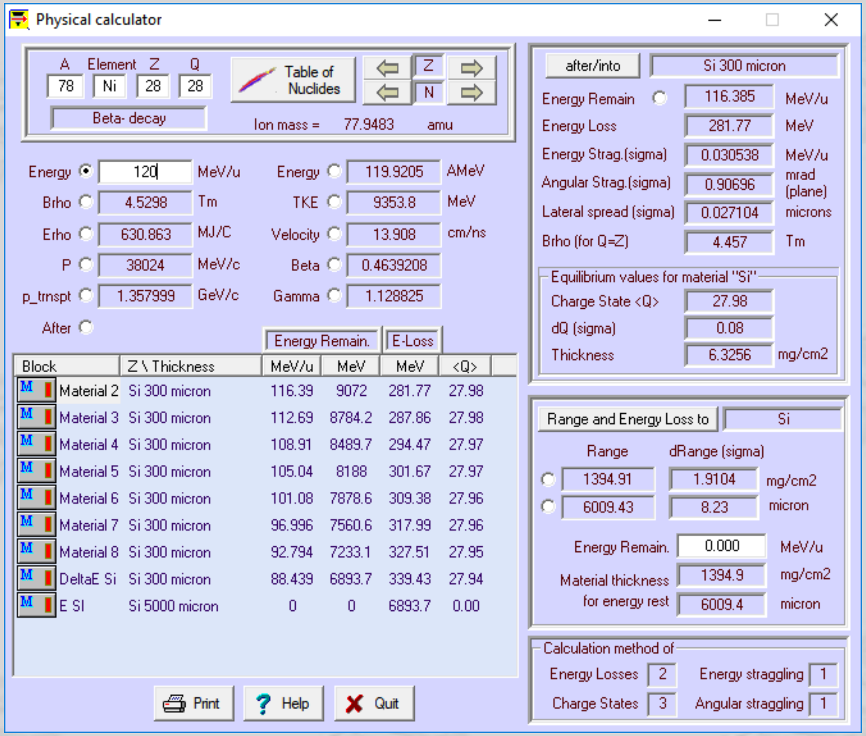
- «PACE4» (fusion-evaporation code),
- «MOTER» (raytracing-type program for magnetic optic system design)
- «ETACHA4» (charge-state distribution code) *(new)*,
- «Global» (charge-state distribution code),
- «Charge» (charge-state distribution code),
- «Spectroscopic Calculator" (of J.Kantele»)

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:

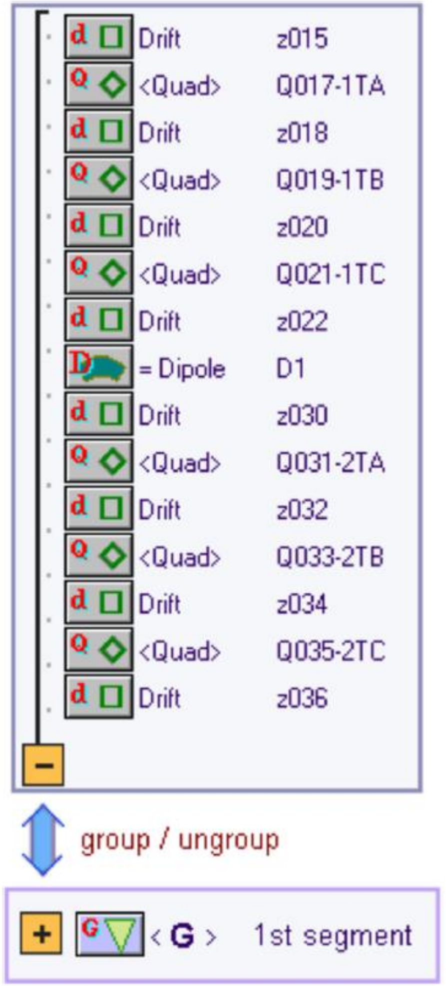
- Nuclide and Isomeric State databases with utilities,
- Large Set of Calculated Mass Tables (includes FRIB mass tables),
- Ionization Energy database (used with the Ion Mass calculator),
- Decay Branching Ratio database (used with the Radiation Residue calculator)



Ion Optics: Block Configuration Converter

- Configurations
  - **S**egmented: comprised of Sector (S) blocks, which are dispersive blocks that can contain quadrupole and dipole magnets, drift elements, along with other optical components *– fast analytical calculations for planning experiments*
  - **E**xtended: all elements are separated into their own blocks and their matrices can be calculated and used in minimization by the LISE^{++} code *– Monte Carlo high-order optics transmission calculations*

- Converter: This new tool will be built around a new type of block, labeled G (Group), which allows the grouping E blocks to S block, and reverse ungrouping.



The new LISE^{++} feature for converting a series of extended blocks to a single segmented block.