LISE++ : Exotic Beam Production with Fragment Separators and Their Design

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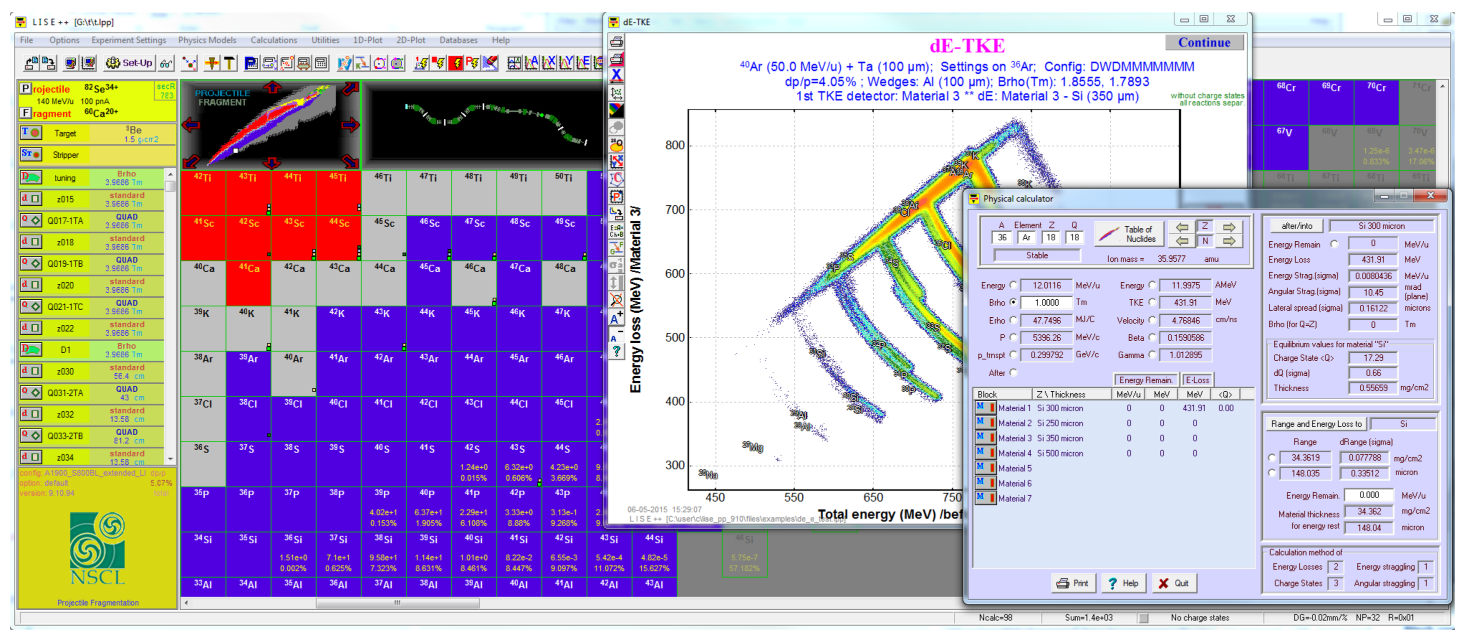
Introduction

The LISE++ program [1] is designed to predict intensities and purities for the planning of future experiments with in-flight separators, but is also essential for radioactive beam tuning where its results can be quickly compared to on-line data. The code is built around a user-friendly interface that helps to seamlessly construct any fragment separator from different types of blocks. The LISE++ package [2] includes configurations of existing separators at NSCL/MSU, RIKEN, GANIL, GSI, FLNR/JINR, TAMU and others. A large number of reaction mechanism models are used in the program to simulate experiments at beam energies above the Coulomb barrier. The main code development features since EMIS2007 are presented.

Current Status

Since the last LISE++ presentation at the EMIS conference (2007) significant updates have been implemented for beam optics: new block types development, embedded matrix calculations, beam optics optimization. In addition to its primary purpose – secondary beams intensities calculations – the code now allows to design and optimize separators, deduce angular and momentum acceptances, and analyze transmission in detail. The LISE++ software package will soon be converted to a modern graphics framework using new compilers to improve its performance and sustainability, as well as cross-platform compatibility [3].



Progress in Ion Beam Optics

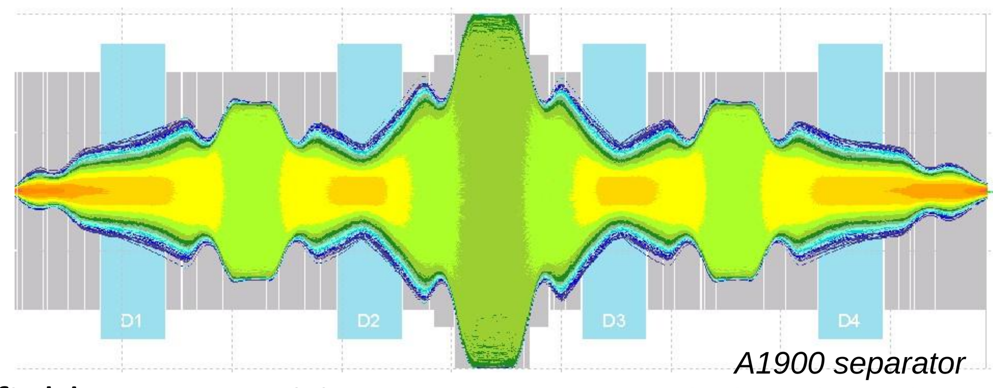
Large progress in ion-beam optics was implemented with the introduction of elemental blocks that enable a new type of configuration, labeled "extended (or elemental)" in addition to the classic "sector" configuration.

Optical matrices can now be calculated within LISE++ (up to second order), directly input by the user, or linked to COSY maps (up to fifth order).

This enables a detailed analysis of the transmission, useful for fragment separator design, provides a powerful tool to calculate angular acceptances, and allows to display ion-beam optics characteristics.

New Features are:

- Magnetic field vs. current calibration B(I)
- Effective multipole length calculation
- Quadrupole & sextupole fields superposition
- possibilities of Import/Export operations of/to TRANSPORT code files
- In-house second order optical matrix calculation for most of optical blocks
- Optics minimization (first step : optimization of quad fields)

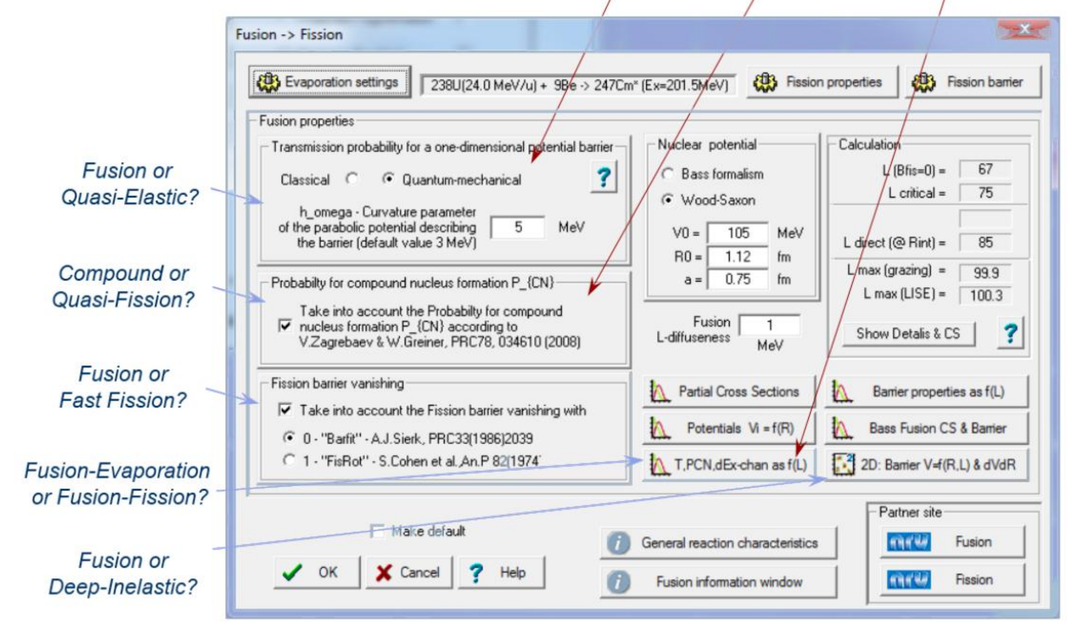


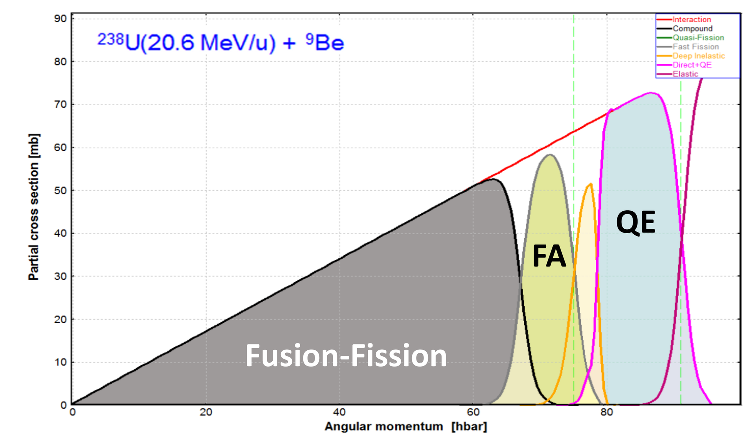
A1900 separator horizontal envelope

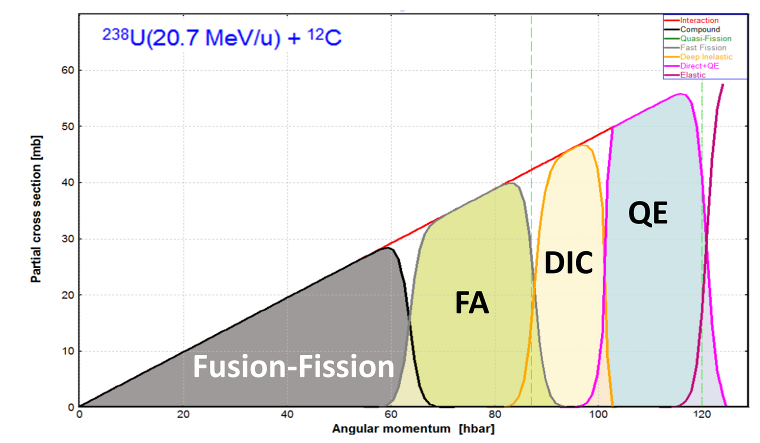
Low-Energy Reaction Mechanism Update

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 [4].

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



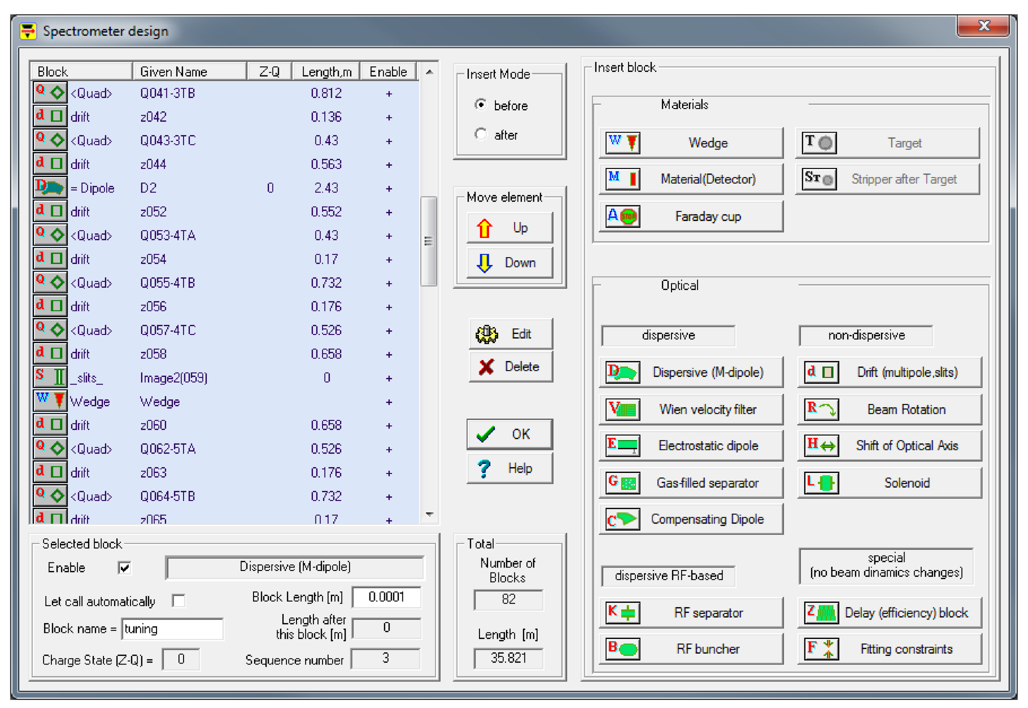




Block Types Development

The "Beam rotation", "Shift of Optical Axis", "Solenoid", "RF buncher", "Delay (efficiency)", and "Fitting constraints" blocks were created recently. Large developments took place for the "Drift", "Electrostatic Dipole" and "Compensating Dipole" blocks. The "Compensating Dipole" inclination angle and optic matrix calculations are now available depending on its geometry and compensation property defined by user. The "Drift" block has now the option to contain a magnetic quadrupole and sextupole, or electrostatic quadrupole.

The Gas-filled optical block will be developed soon in LISE++ to perform analysis of beam dynamics in low-energy recoil separators using the Monte Carlo calculation mode.



Modern view of the "Spectrometer Design" dialog window

Segmented and Extended Configurations

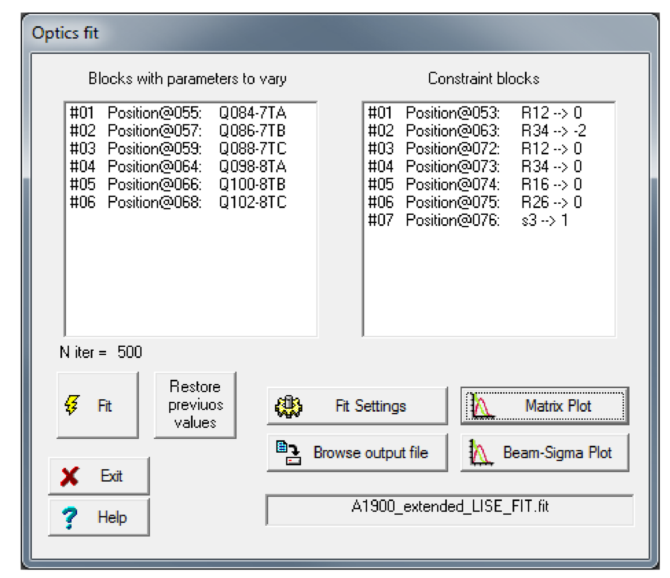
- Classical (segmented) configuration: dispersive block contains quads, drifts, dipole and other optical components.
  - *Fast transmission calculations*
  - *Optical matrices can be input by user or linked to COSY maps*
  - *Simple and compact description of optical system*
  - *Effective with analytical calculations for experiment planning*
- Extended (elemental) : all elements are separated, and matrices can be calculated
  - *Allows transmission detailed analysis*
  - *Matrices can be input by user, linked to COSY maps or calculated by LISE++*
  - *Tools to obtain angular acceptances,*
  - *Tools for displaying ion-beam optics*
  - *Very useful with Monte Carlo*

Comparison of "S" and "E" blocks properties

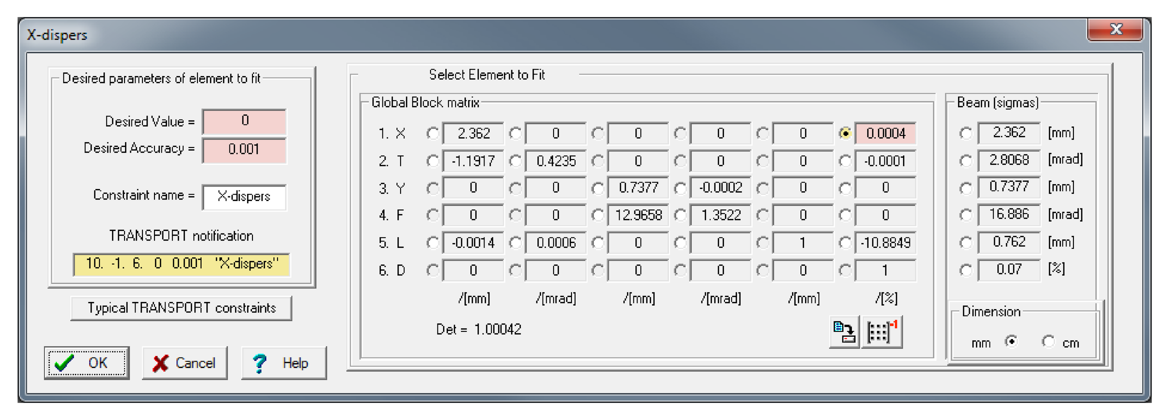
Property	S-block (sector)	E-block (element)
Optical matrix can be calculated inside of the code	no	yes
Length of block	manually	calculated
Optional drawing quadrupoles in scheme	allowed	no
Aperture property	no	yes
Slits after block property	yes	yes but not recommended
Angular acceptance block property	yes	yes but not recommended
Aperture property	no	yes
Block use in the segmentation process (G-block in future)	no	yes
Block use in the minimization process	no	yes
Export/Import separator configuration (LISE++ ? other beam transport codes)	no	yes
User level	Regular	Expert
Efficiency to calculation model, designation	**Effective with analytical calculations for experiment planning**	**Very useful with Monte Carlo calculations including fragment separator design**

Optics minimization

One week ago the first stage of optics minimization procedure was introduced, based on the "levmar" package by M.I.A. Lourakis using the Levenberg-Marquardt nonlinear least square algorithm [5]. At this stage only the quadrupole fields can be varied to minimize user constraints for matrix and beam ellipse elements. 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.



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



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).

References and Links

[1] "LISE++ : Radioactive beam production with in-flight separators", O.B.Tarasov, D.Bazin, NIM B 266 (2008) 4657-4664

[2] LISE++ website : http://lise.nscl.msu.edu

[3] See M. Kuchera's poster

[4] Update of Fusion reaction mechanism in LISE++ http://lise.nscl.msu.edu/9_10/9_10_Fusion.pdf

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

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