Introduction

Application

Statistics

Monte Carlo calculation of fragment transmission

EBSS tutorial

The code operates under MS Windows environment and provides a highly user-friendly interface. It can be freely downloaded from the following internet address:

http://www.nscl.msu/edu/lise
The program LISE \(^1\) 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 \(^2\) lies in the basis of fast calculations of the program for the estimation of temporary evolution of phase space distributions.


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!**

IBM sold PCs in 1992 twice more than in 1991 after release the LISE version 2.2.
25 years of the LISE code

Corrections, Modifications (compound target, compensating dipole)

LISE operates under MS Windows

1994-1997
O.T., GANIL
v.2.3 – 2.9

1998
O.T., GANIL
v.3.1
Active development of the LISE code stimulated by M.Lewitowicz

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

LISE for Excel.
It includes even transmission calculations.

2001
NSCL / MSU
v.4.10 – 5.12

LISE group @ MSU
Active development of the LISE code stimulated by B.Sherrill.
Abrasion-Ablation model construction, ATIMA implementation

2002
NSCL / MSU
v.5.13 – 5.15

Fusion residues transmission ¹). PACE4 implementation.
First reference ²) since 16 years!

²) D.Bazin et al., NIM A 482 (2002) 314.
LISE++ ¹) is the new generation of the LISE code, which allows the creation of a spectrometer through the use of different “blocks”.


- Convolution Model of momentum distributions of projectile fragmentation products developed in the LISE framework ¹)
- Coulomb Fission ²)

2) EPJ A25 (2005) 751

Abrasion – Fission
Tech.report NSCL MSU, MSUCL-1300

Fusion – Fission
NIM B 266 (2008) 4670-4673

Monte Carlo calculation of fragment transmission
Fragment production in material
NIM B 266 (2008) 4657-4664

High order optics, extended configurations, calculation of magnet transport matrices within LISE++ and links with maps from other codes (such as COSY), optimization, adaptation for 64-bit OS Windows, new utilities and so on…
LISE++ is a Windows 32-bit application

- Installation for 64-bit OS Windows

Now runs on Intel Macintosh computers!

- Working emulators: Parallels, CrossOver
- Same speed as on PC computers

Under constant evolution

- New features and possibilities added upon experimenter’s requests
- "Official" version for proposing experiments at the NSCL: 9.1.23
- Last version as of today: 9.2.109
- Web site: http://groups.nscl.msu.edu/lise
Main Features

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).
A number of these facilities, like A1900 and S800 at NSCL, RIPS and BigRIPS at RIKEN, LISE3, SISSI/LISE3 and SPEG at GANIL, FRS and SuperFRS at GSI, ACCULINNA at Dubna, based on the separation of projectile-like and fission fragments are included or can be easily added to the existing configuration files.

Fast analytical calculations
(Monte Carlo calculations are available too)

Reaction mechanisms
Projectile Fragmentation
Fusion-Evaporation
Fusion-Fission
Coulomb Fission
Abrasion-Fission

Highly user-friendly environment
Built-in help support

Ion charge state distribution calculations
(4 methods)

Range and energy loss in material calculations
(4 methods)

Contribution of secondary reactions in the target

Fragment production in Material

Different selection methods

Optics
(2nd order map calculation,
5th order map use in MC mode)

Built-in powerful tools

- Physical Calculator
- LISE for Excel
- Nuclide and Isomeric states* Databases utilities
- Relativistic Reaction Kinematics Calculations
- Curved degrader calculation
- PACE4 – evaporation MC code for Windows
- The spectrometric handbook of J.Kantele & Units converter
- Codes “Global” & “Charge” (charge state distributions)
- Range optimization utility
- “Brho” analyzer, Solenoid (Twinsol)* & ISOL-catcher* utilities
- Automatical search of two-dimensional peaks in experimental spectra
- “Evaporation” calculator
- “MOTER” ray-tracing code with optimization capabilities operating under MS Windows
LISE++ in action
Utilities: Calculators

**Physical calculator**
- Convert energy, momentum, magnetic rigidity seamlessly
- Calculate energy loss, range, angular and energy straggling
- “Backwards” modes to find energy of particles based on their energy loss or range

**Kinematics calculator**
- Calculate two-body, elastic scattering or breakup kinematics
- Results in laboratory and center of mass systems
- Kinematics results can be exported to file

**Evaporation calculator**
Monte Carlo calculation of fragment transmission

Like in a regular experiment: the user chooses two coordinates in the MC transmission dialog to create a 2d-spectrum

38Cl: Monte Carlo Transmission Plot

40Ar (84.3 MeV/u) + Be (500 µm), C (500 µm); Trasmitted Fragment 38Cl (Fragment)
dp/p=1.00%; Wedges: A1 (200 mg/cm²); Brho(Tm): 2.7747, 2.7747, 2.5299, 2.5299
Configuration: DDSWDDMSMMM

Wedge Angle = -0.43 mrad
Wedge Angle = -1.6276 mrad

(On this dialog for example the last block is "I2_wedge" block)
Application: World Wide Used

NSCL (3529)

- RIKEN (Japan)
- MSU (USA)
- GSI (GANIL, France)
- JINR (Dubna, Russia)
- Texas A&M (USA)
- Leuven (Belgium)
- INFN-Milan (Italy)
- CEA (France)
- Argonne (USA)
- INFN-Genova (Italy)
- Indian Institute of Science
- Tohoku University of Science
- University of Surrey
- Jyväskylä (Finland)
- China Institute of At. Energy
- LBNL (USA)
- University of Tsukuba (Japan)
- Chung-Ang University (South Korea)
- Tsukuba University
- TRIUMF (Canada)
- Nippon University (Japan)
- TU Darmstadt (Germany)

EBSS: 07/25-30/11, East Lansing
LISE++ tutorial from D. Bazin: Goals

- **Planning of radioactive beam experiment**
  - Choices of best primary beam and production target
  - Forecasting of yields and purity
  - Test of experiment feasibility
  - Configurable to simulate any fragment separator

- **Online help during experiment**
  - Calculation of fragment separator settings
  - Simulation of online identification spectra
  - Fast calculations
  - General purpose tools

- **Design of fragment separators**
  - Block structure for easy configuration
  - Manipulation of optics and acceptances
  - Numerous options for reaction mechanism and related calculations
Select forward focused fragments produced from projectile fragmentation reactions

Use various selection criteria: magnetic rigidity ($B\rho$), energy loss (wedge), velocity (Wien filter, RF Separator)
\[ Y = I \times N \times F \times A \]

- **Y**: Yield of fragment
- **I**: Primary beam intensity
- **N**: Probability of producing the fragment in the target
- **F**: Fraction of charge state Q
- **A**: Acceptances of the fragment separator
N: Probability of producing a fragment in the target

**Depends on:**

- **Target thickness**
  - Light targets have more nuclei per electron, hence larger nuclear interaction probability at fixed electronic slowing down than heavy target
  - This favors light targets at equal cross section (NSCL uses Be)

- **Cross sections**
  - EPAX parameterization based on target fragmentation data
  - Abrasion-Ablation model(s)

- **Multi-step fragmentation in very thick targets**

- **Other nuclear reaction process at lower energy**
  - Fusion-evaporation
  - Deep-inelastic
  - Coulomb induced fission
  - Abrasion-Fission
  - Fusion-Fission
Depends on:

- Primary beam atomic number
- Primary beam energy
- Target atomic number
- Complicates particle identification of radioactive beam
  - Isotopes of different masses and charges become mixed up during Bρ selection

\[ B_\rho = 3.107 \beta \frac{A}{Q} \]
A: Acceptances of the fragment separator

**Depends on:**

- Fragment separator characteristics
- Optics mode
- Production mechanism of fragments
  - Fragment velocity
  - Momentum width
- Energy loss straggling in materials
Select correct configuration file

Choose primary beam

Choose desired fragment

Optimize target thickness
- Compromise between target yield and energy loss
- Use optimum target calculator!

Choose wedge thickness
- Compromise between intensity and purity
- Also depends on the type of experiment
- Can use target-wedge optimizer, but slow…
There are many options in LISE++!

- **Setup of fragment separator**
  - “Blocks” are individual elements with their own characteristics
  - Optics blocks describe beam line components with optical matrix, acceptances, length and slits
  - Material blocks describe things in the way of the beam such as targets, wedges, detectors

- **Production of radioactive nuclei**
  - Reaction models
  - Cross section models
  - Energy loss and straggling models
  - Charge state models
Options (continue)

- **Reaction models**
  - Projectile fragmentation
  - Fusion-Evaporation (low energy)
  - Fusion-Fission
  - Coulomb induced Fission (high energy)
  - Abrasion-Fission

- **Cross sections for projectile fragmentation**
  - EPAX parametrization based on fragmentation data
    - Most used option because fastest
    - Error grows exponentially towards drip-lines (data unknown)
  - Abrasion-Ablation model
    - More accurate than EPAX, but slower
  - Possibility to input cross sections manually via file
Radioactive beam physicist task
- Produce an $^{22}$Al beam to be used in a $\beta$-delayed proton decay experiment
- Minimum required intensity: 1000 pps
- Minimum required purity: 50%
- Maximum implantation range in silicon: 100µm

Tutorial
- Walk through steps involved in making right choices to fulfill the radioactive beam requirements
- Use LISE++ to understand the various possibilities (and impossibilities!) in making these choices