Introduction to LISE++

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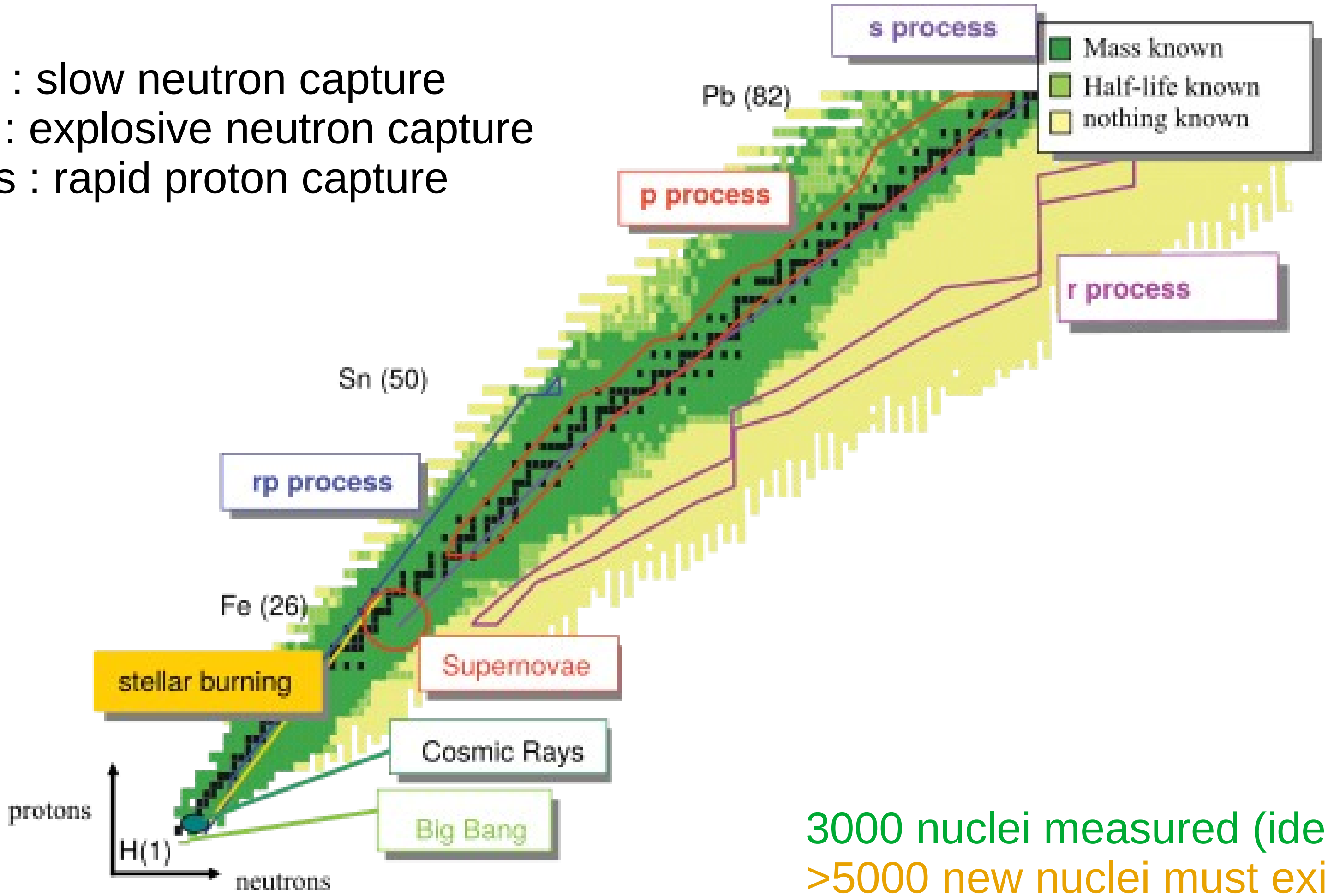
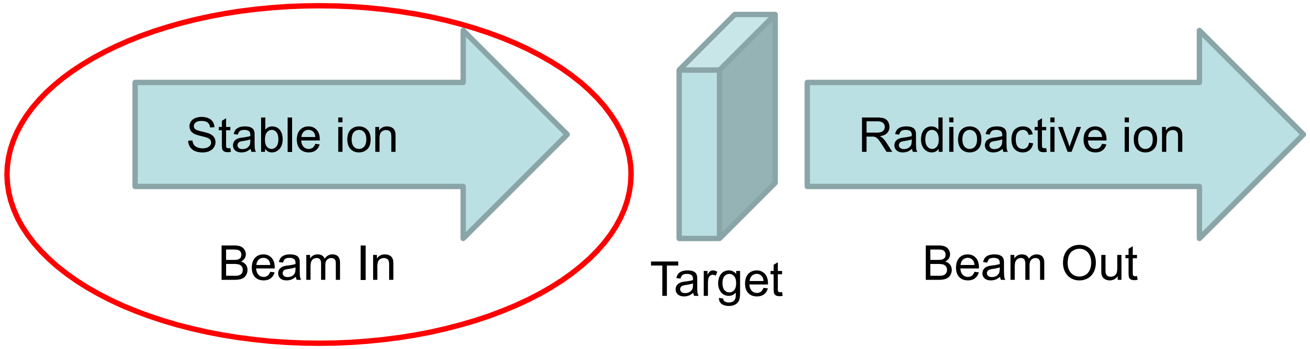
Motivation

s-process : slow neutron capture
r-process : explosive neutron capture
rp-process : rapid proton capture

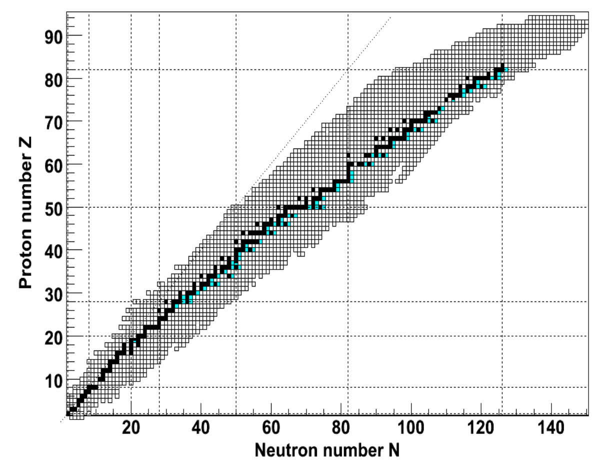


3000 nuclei measured (identified)
>5000 new nuclei must exist

Production of radioactive ion beams



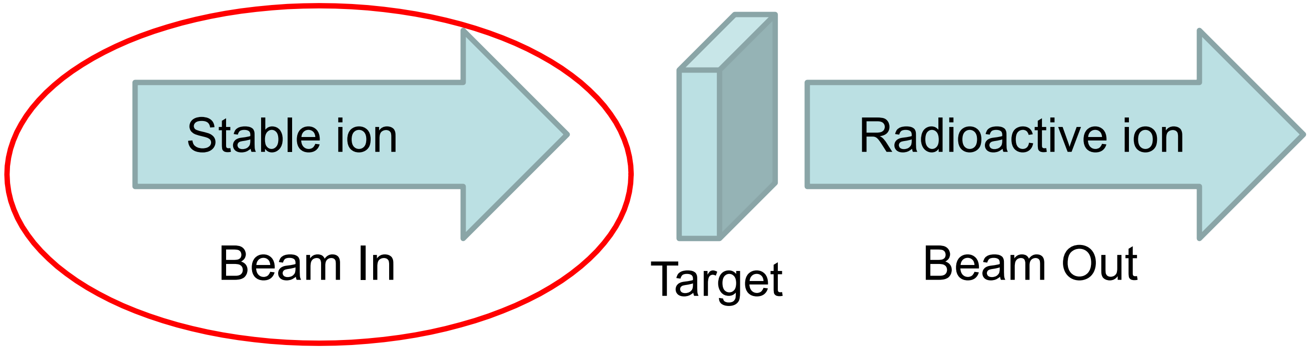
It is possible to accelerate every stable isotope, from hydrogen to uranium-238, in order to obtain the primary beam.



Stable ion sources

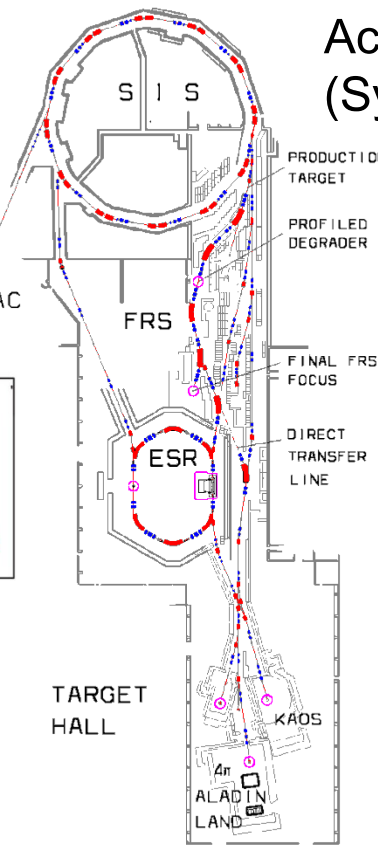
^{238}U: 2 10^{9}
^{208}Pb: 2 10^{9}
^{144}Sm:2 10^{9} (ns, used once)
^{136}Xe: 10^{10}
^{124}Xe: 10^{10} (requires enriched material)
^{112}Sn: ~10^{8} (requires enriched material)
^{107}Ag: 4 10^{9}
^{86}Kr: 2 10^{10}
^{78}Kr: 2 10^{10} (requires enriched material)
^{76}Ge: 3 10^{8} (no standard beam, needs to be developed)
^{64}Ni: 5 10^{9} (requires enriched material)
^{58}Ni: 5 10^{9}
^{48}Ca:3 10^{7} (low intensity from the ECR source when used for pulsed beams for SIS. Or very very expensive …)

Production of radioactive ion beams



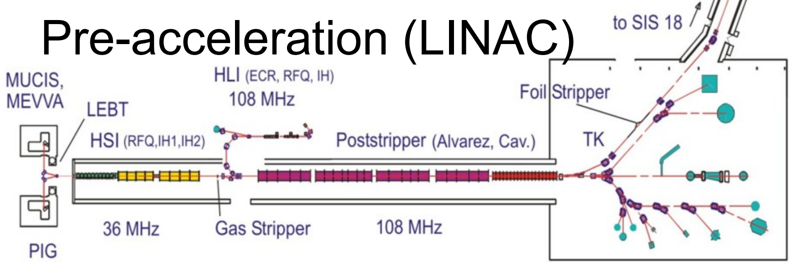
Acceleration (Synchrotron)

SIS18:
0.1-1 GeV/u

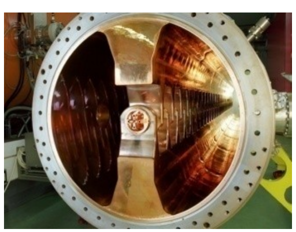


Stable ion sources

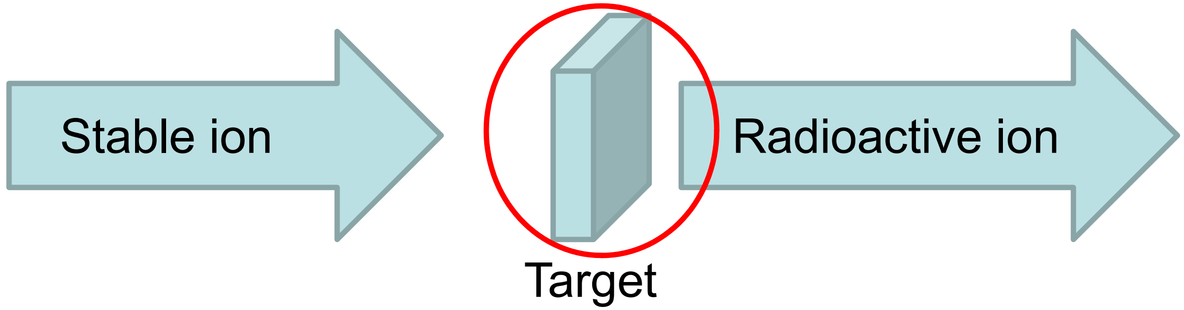
Pre-acceleration (LINAC)



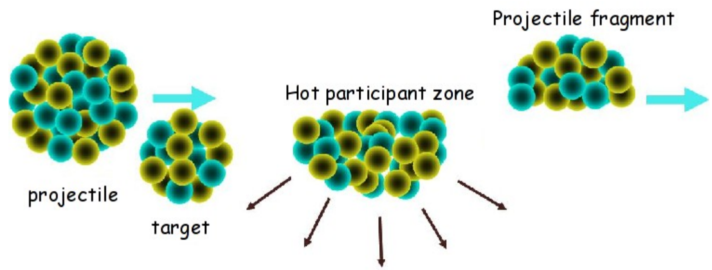
UNILAC:
11.4 MeV/u

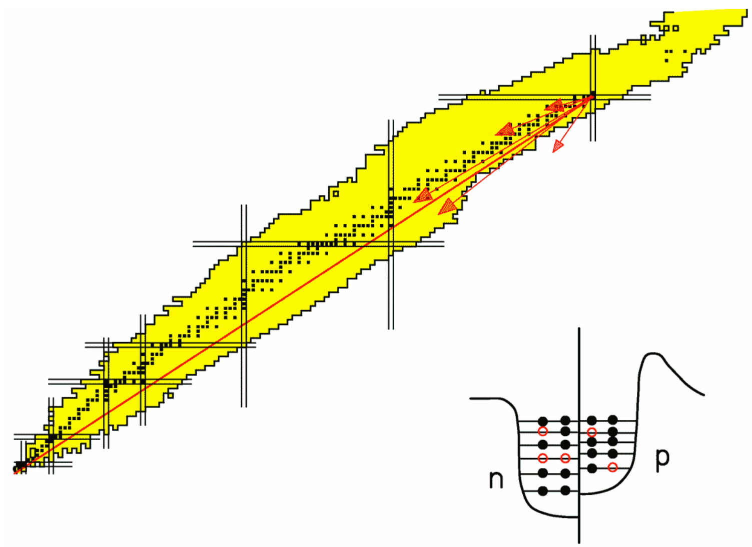


Production of radioactive ion beams

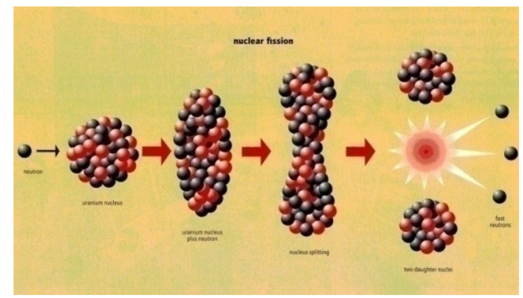


FRAGMENTATION

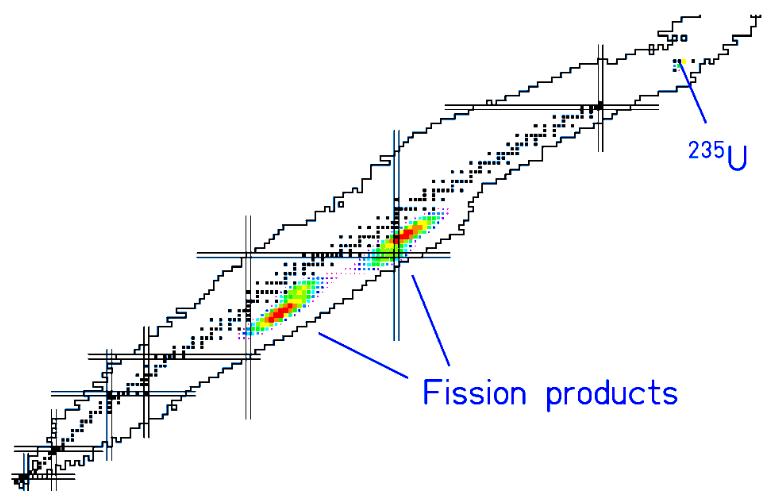




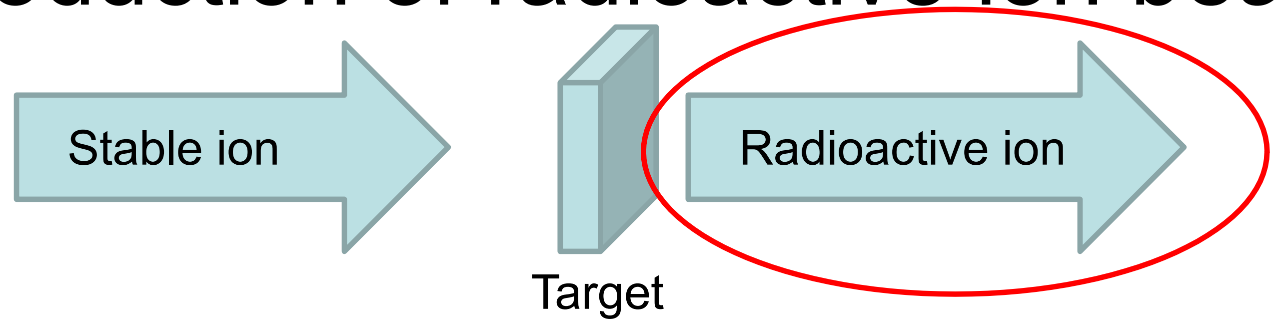
FUSION - FISSION



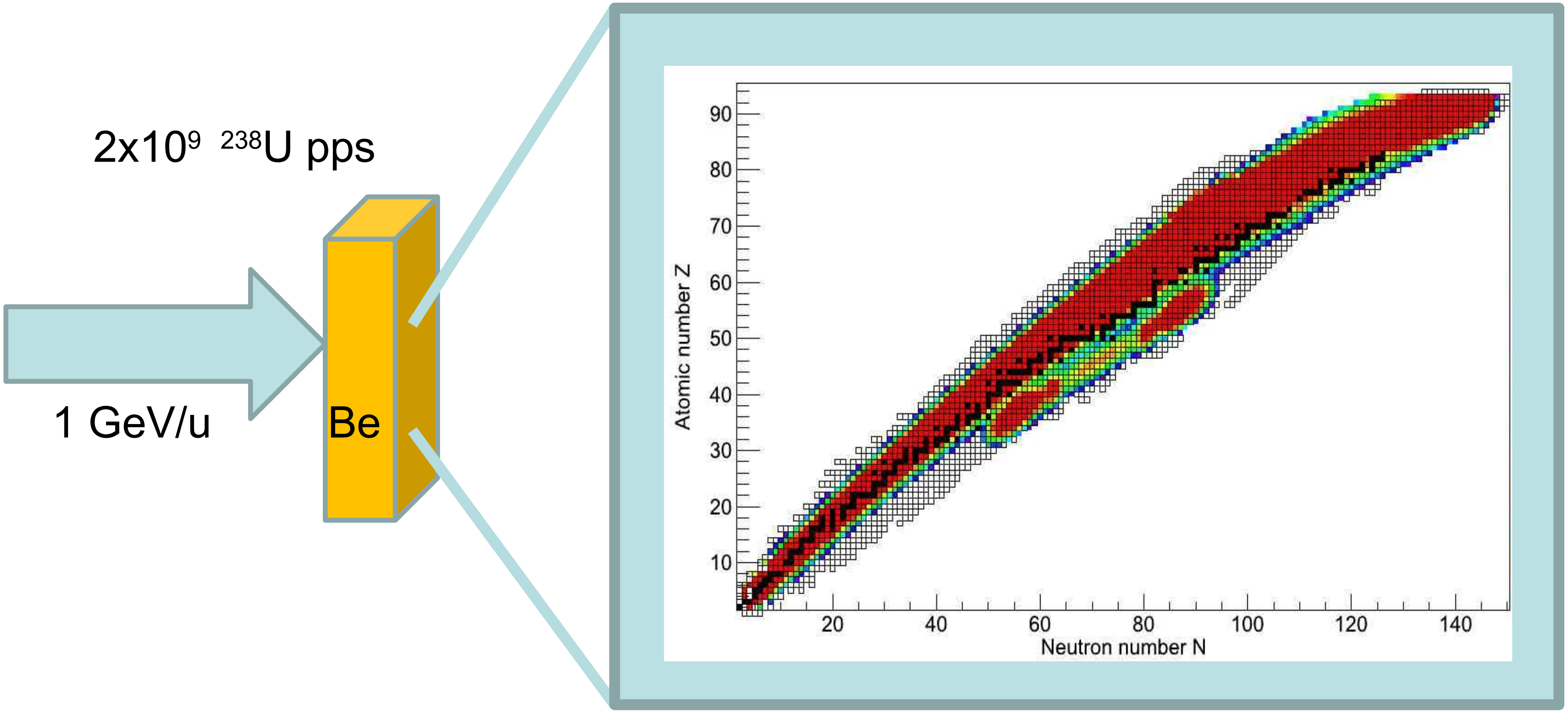
Fission induced by low-energy neutrons



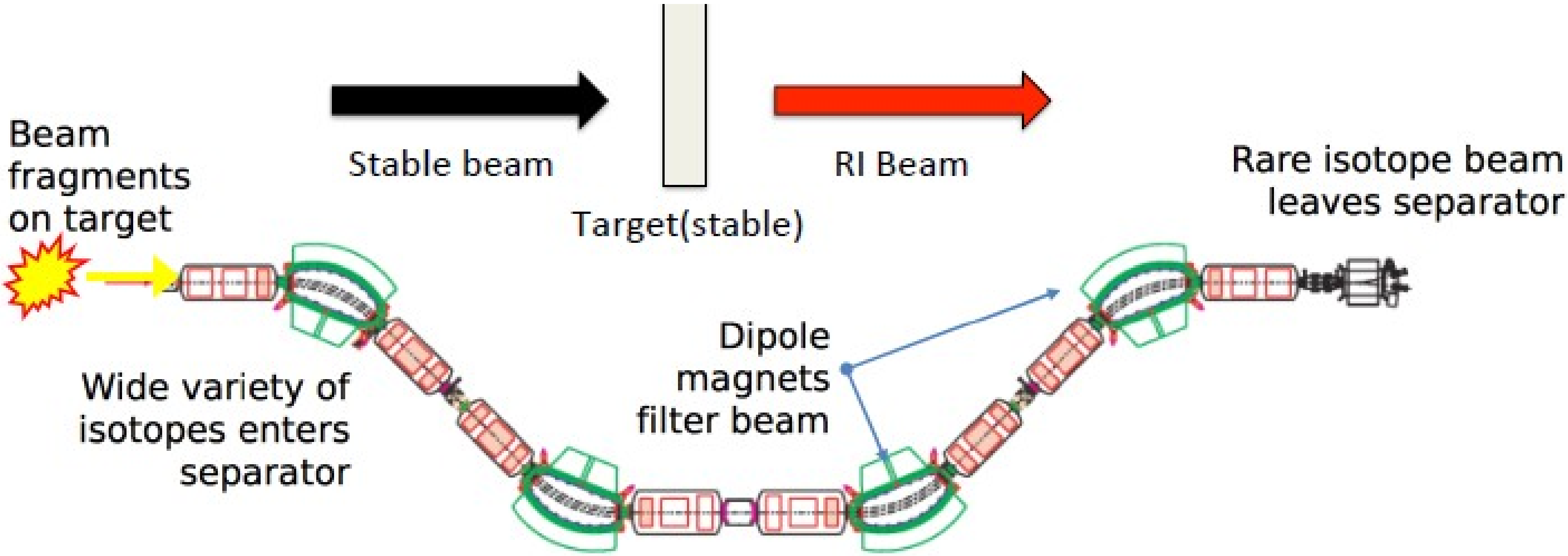
Production of radioactive ion beams

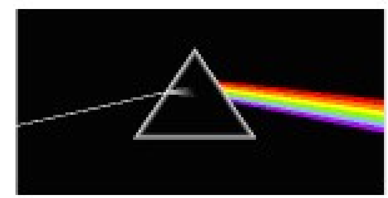


EXAMPLE:



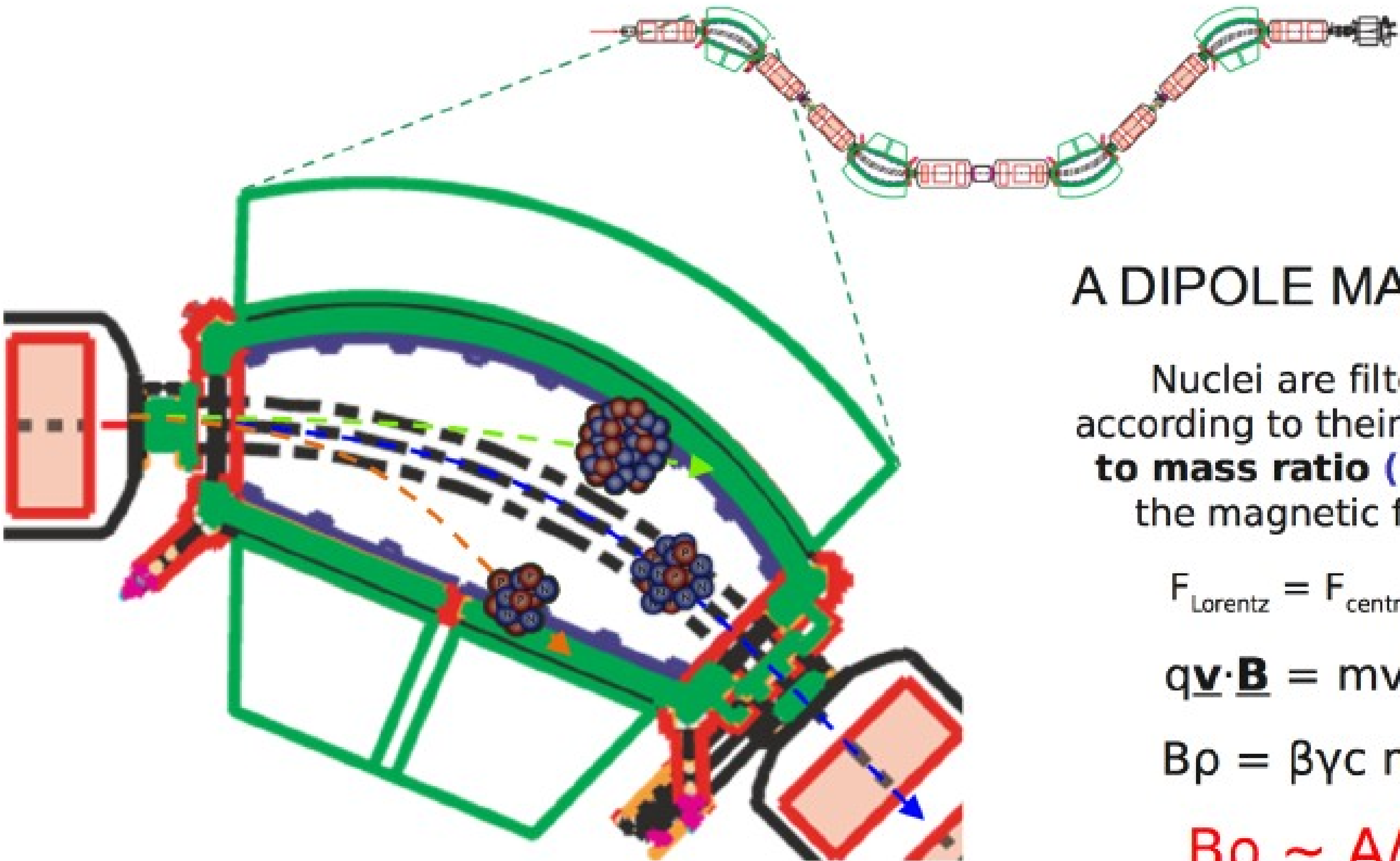
In-flight separation





The *dipole magnets* affect different isotopes “like prisms affect light”, separating the unwanted nuclei (of any isotope not currently being studied) out of the beam

In-flight separation



A DIPOLE MAGNET

Nuclei are filtered according to their **charge to mass ratio (Q/A)** in the magnetic field.

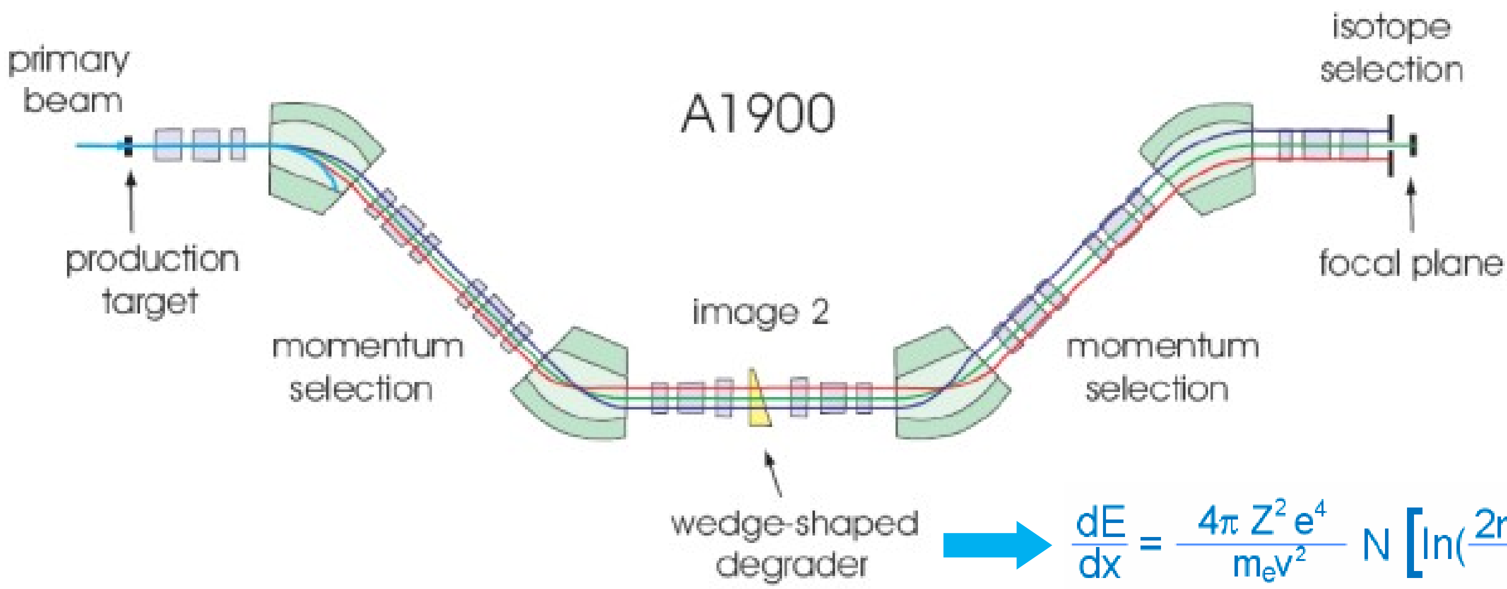
$$F_{Lorentz} = F_{centripetal}$$

$$q\underline{\mathbf{v}} \cdot \underline{\mathbf{B}} = mv^2/\rho$$

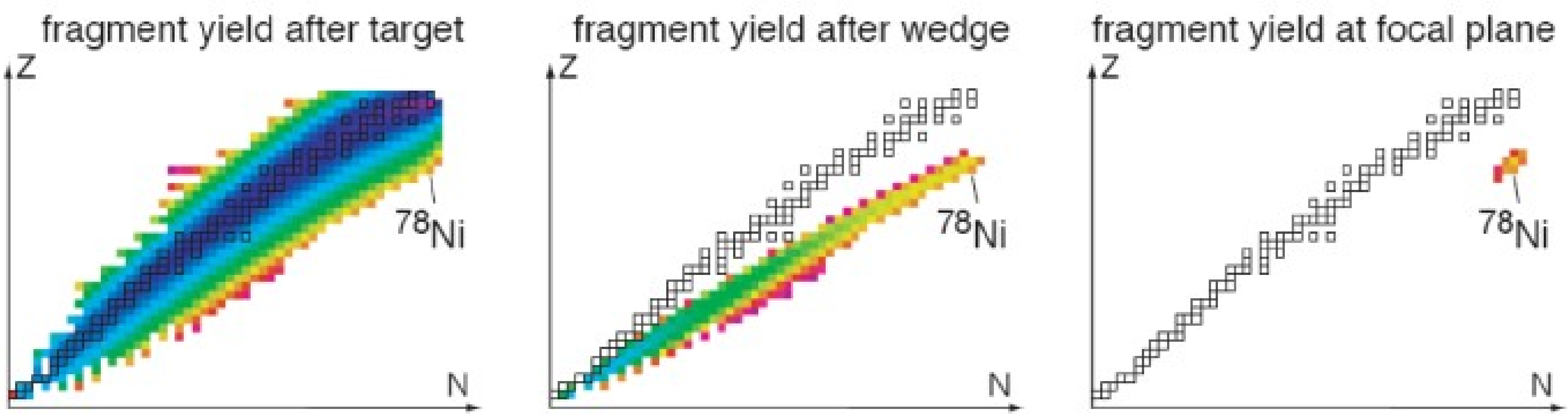
$$B\rho = \beta\gamma c \; m/q$$

$$B\rho \sim A/Z$$

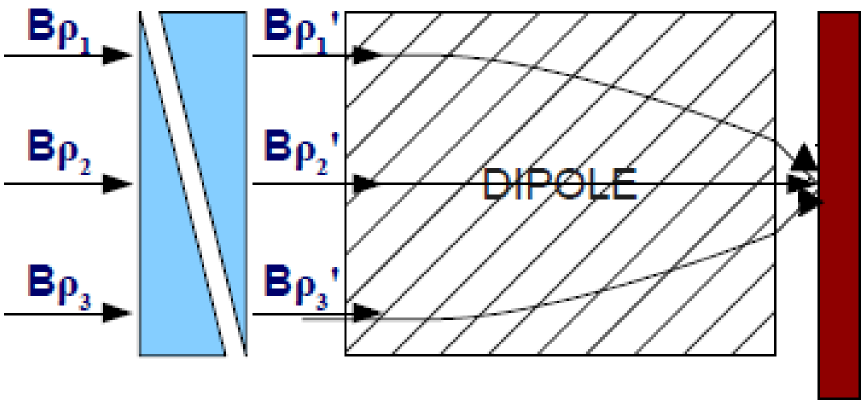
In-flight separation

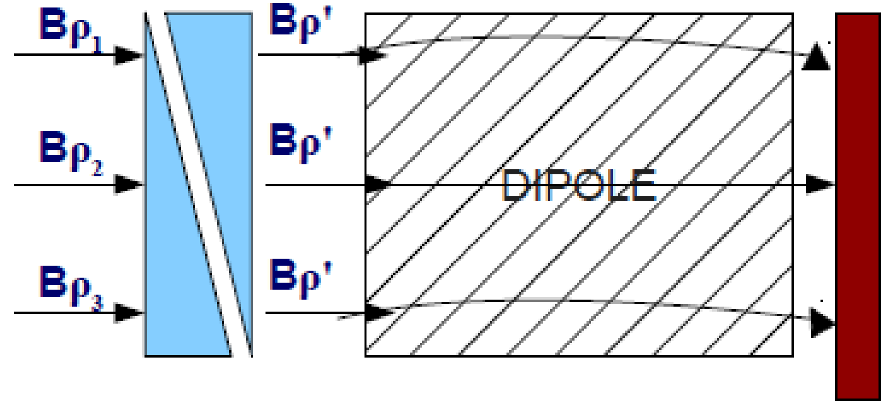


$$\frac{dE}{dx} = \frac{4\pi Z^2 e^4}{m_e v^2} N \left[\ln\left(\frac{2 m_e \gamma^2 v^2}{I}\right) - \frac{v^2}{c_0^2} \right]$$



In-flight separation





- **ACHROMATIC MODE**
  - Ions lose constant amount of energy in wedge
  - All nuclei of same species arrive at same position on focal plane

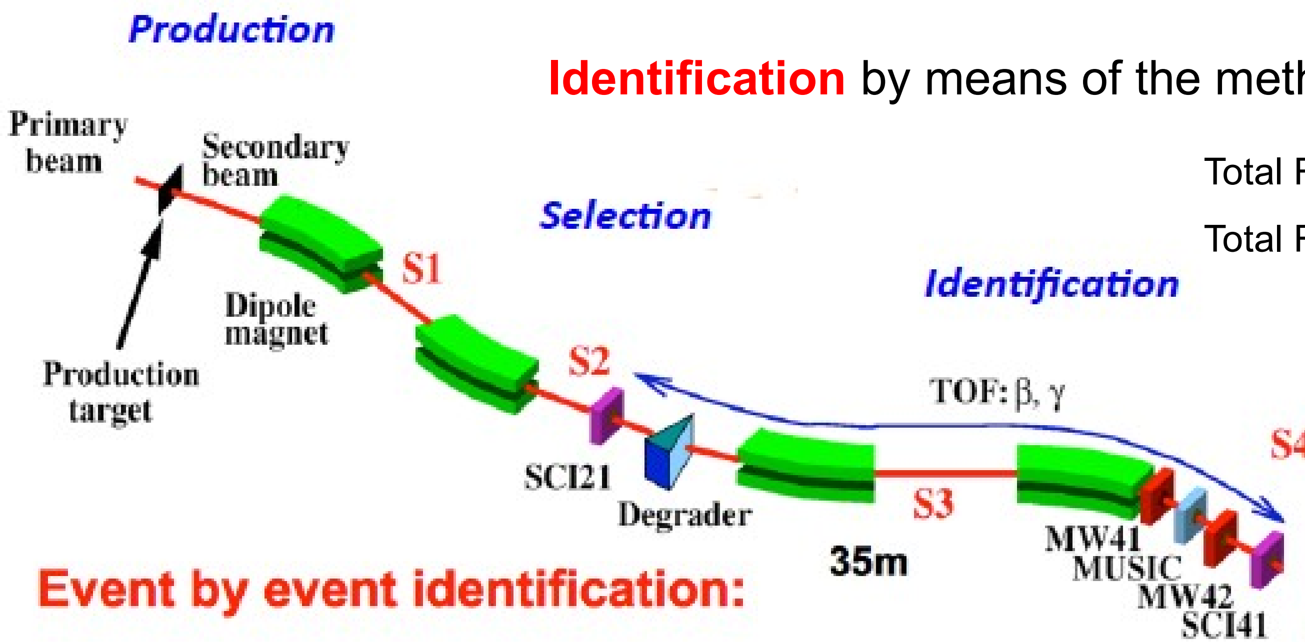
- **MONOENERGETIC MODE**
  - Momentum spread compensated by different path lenths in degrader
  - All fragments of same species have same energy
  - Fragments preserve their spacial distribution

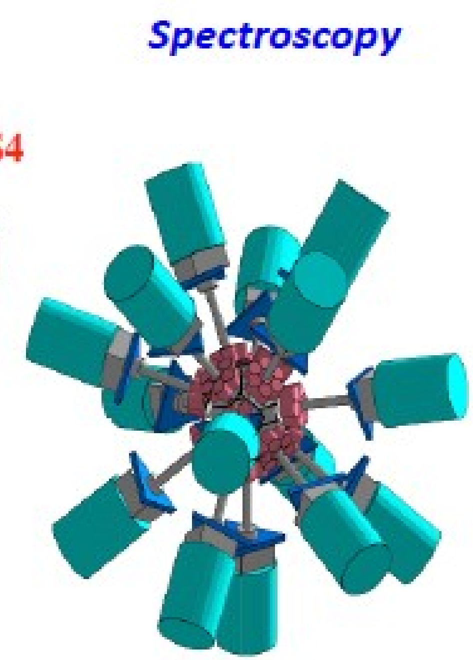
In-flight identification

Identification by means of the method: **Bρ – ΔE - ToF**

Total Rate Limit @ S2 = 1E6 pps

Total Rate Limit @ S4 = 1E4 pps





Event by event identification:

Ionization Chambers → ΔE → Z^2 → **Z**

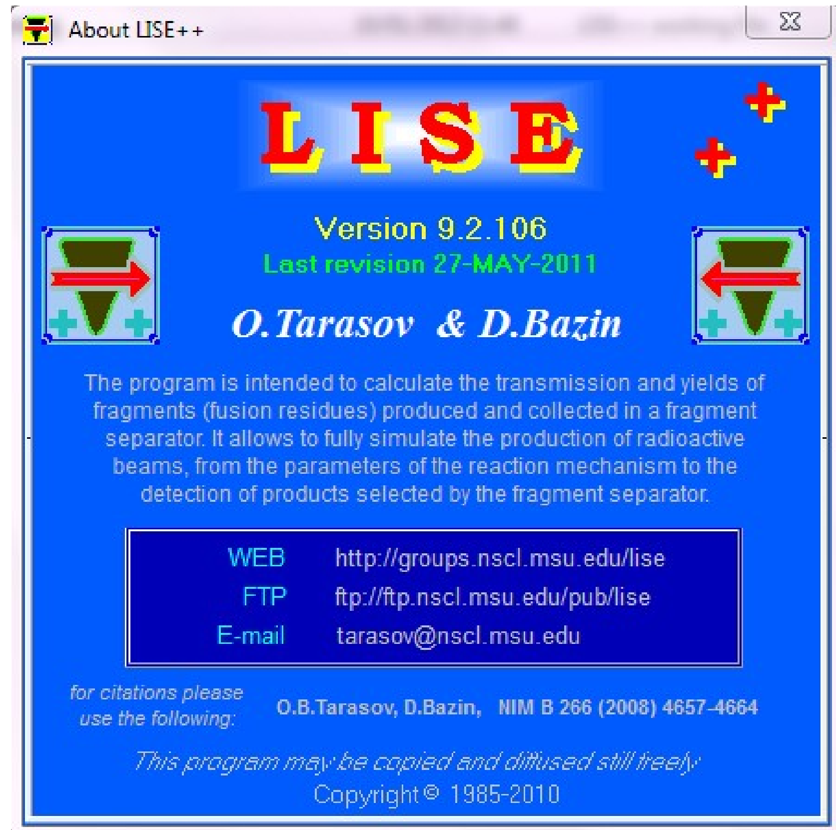
Scintillators S2, S4 → ToF → velocity = $L/\Delta t$

A/Z = $m/q = B\rho / (\gamma v)$

Practical aspects about the program:

0

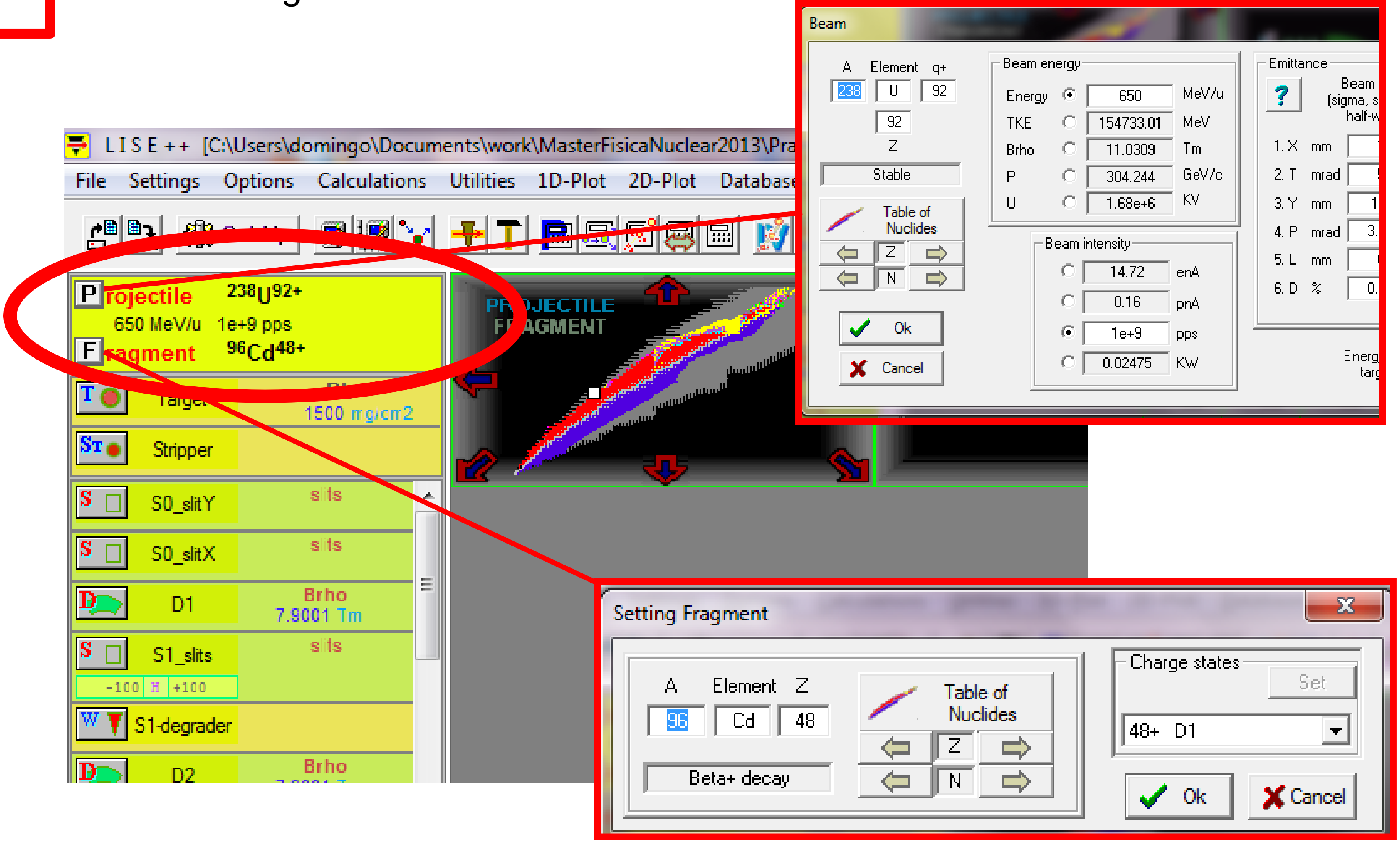
- LISE++ is a free software, it can be downloaded online.
- Created by O.Tarasov y D.Bazin of MSU-NSCL (USA).
- Useful for calculating the production and transmission of exotic fragments for nuclear physics experiments.
- Several utilities, as range calculation and energy loss in materials, and a long etc.
- The best way to learn about LISE++ is playing/practising with it



Practical aspects about the program:

1

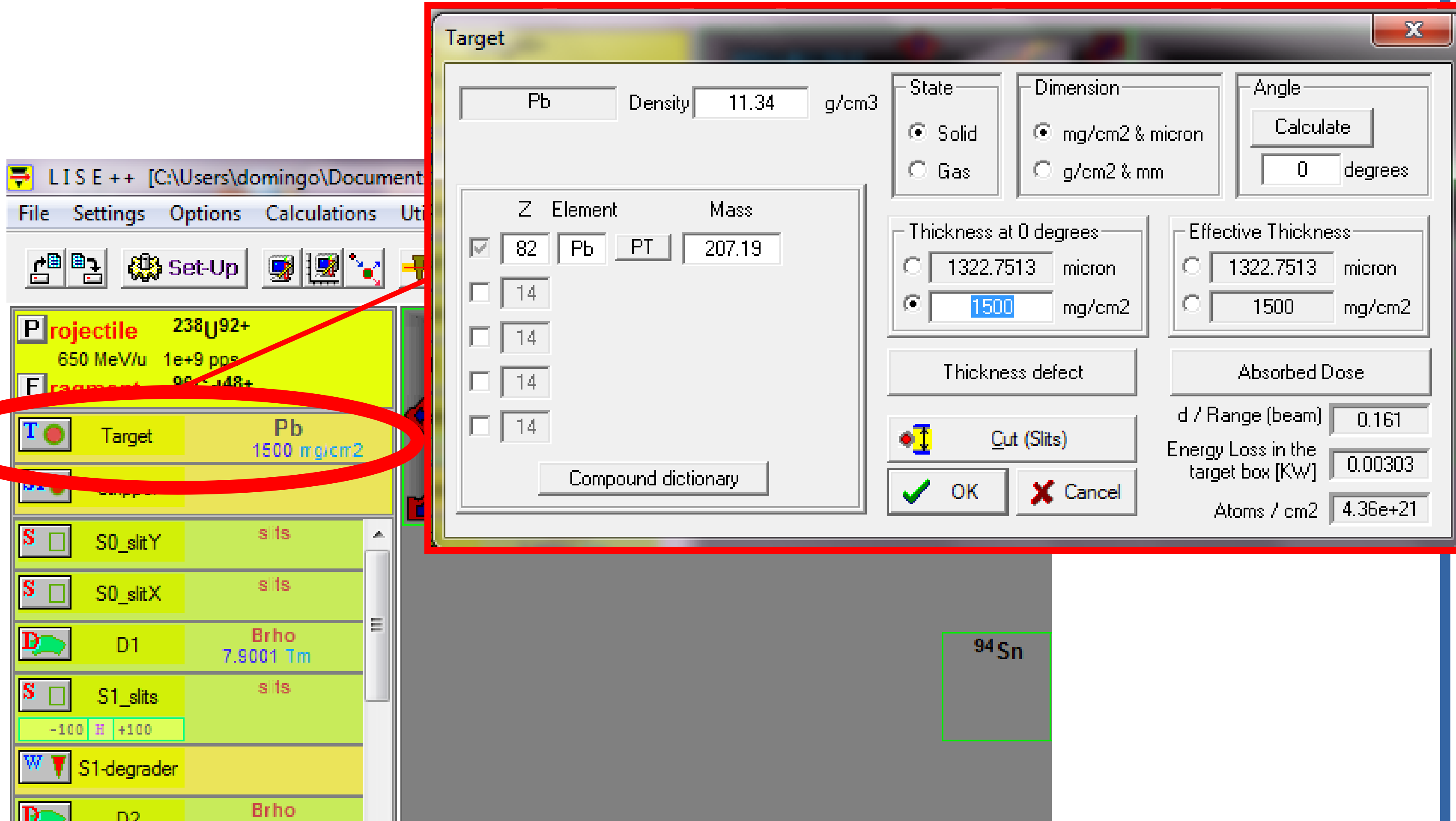
- Set the primary beam characteristics (isotope, energy and intensity)
- Set the fragment of interest



Practical aspects about the program:

2

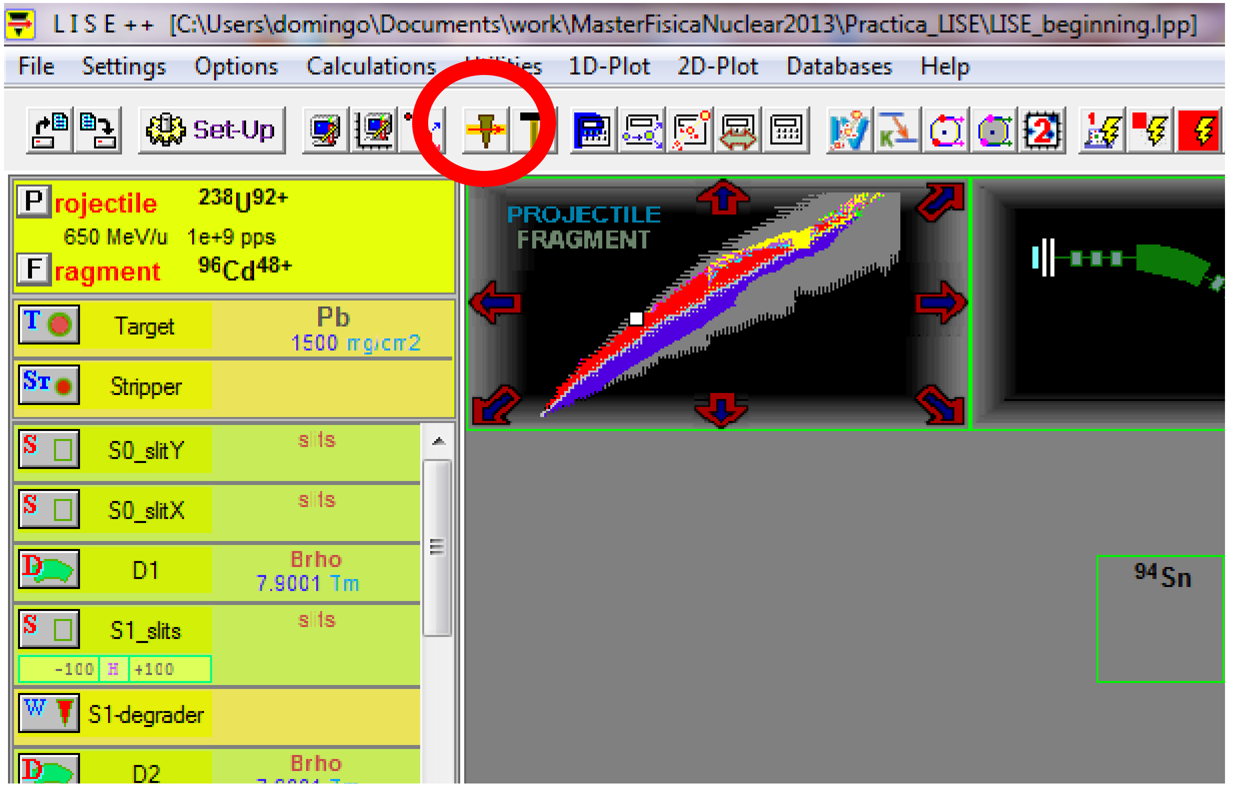
- Set the production target characteristics (element and thickness)



Practical aspects about the program:

3

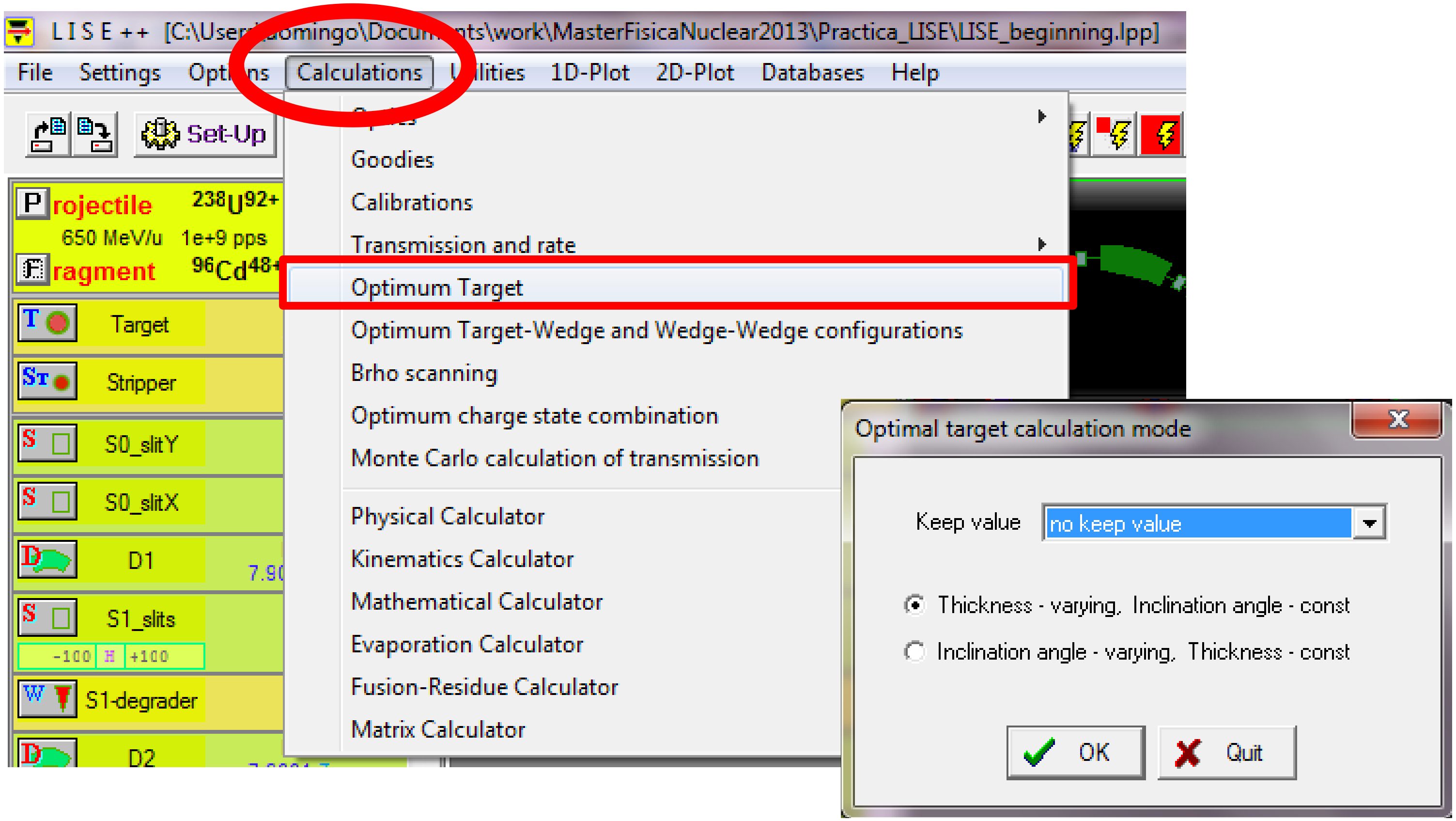
- Tune the magnetic fields (B) for the fragment of interest, depending on the spectrometer design



Practical aspects about the program:

4

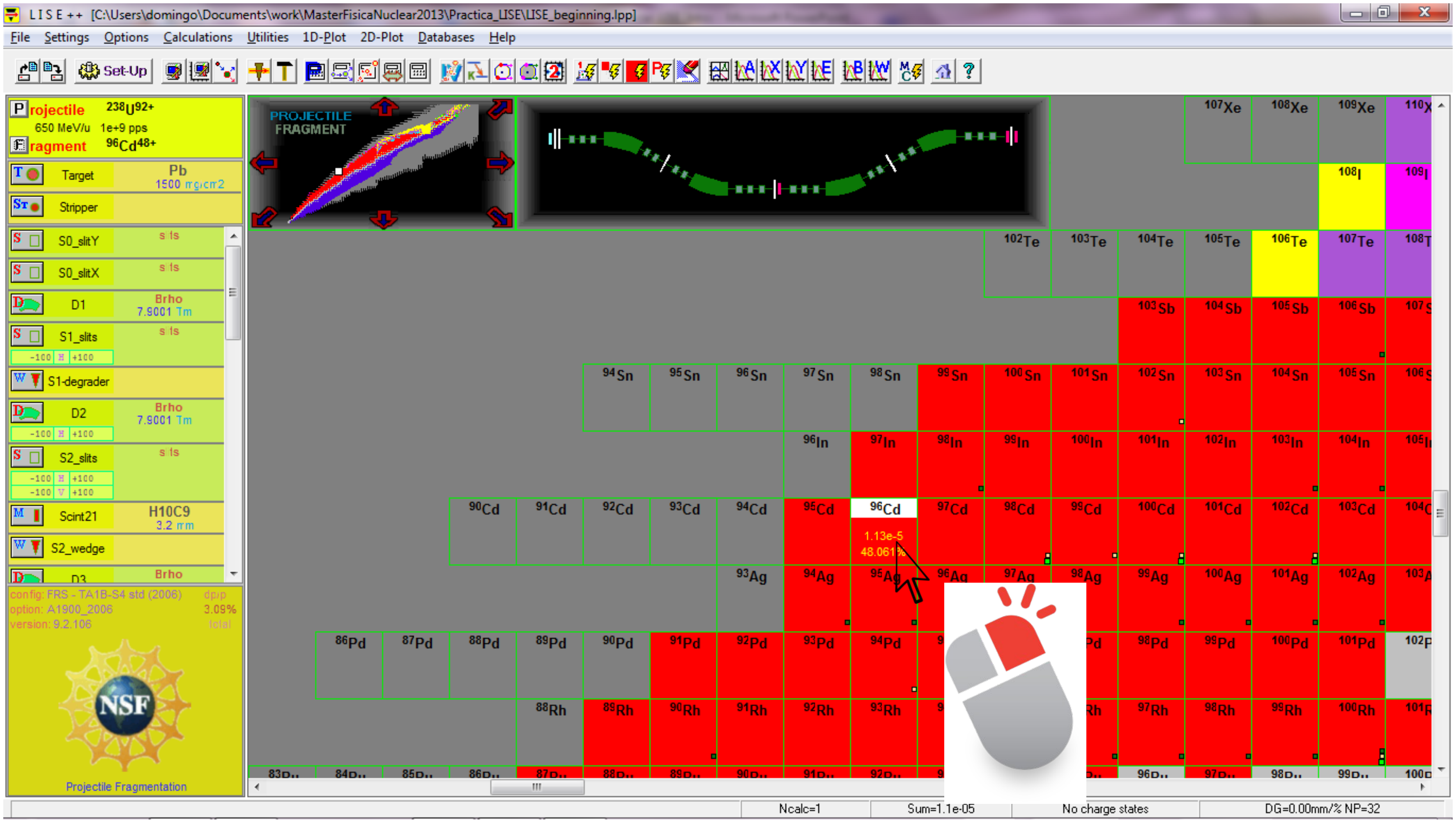
- Optimize the production target thickness (**each single time that primary or secondary beam parameters are modified**)



Practical aspects about the program:

5

- Obtain more details about the production and transmission of a specific fragment



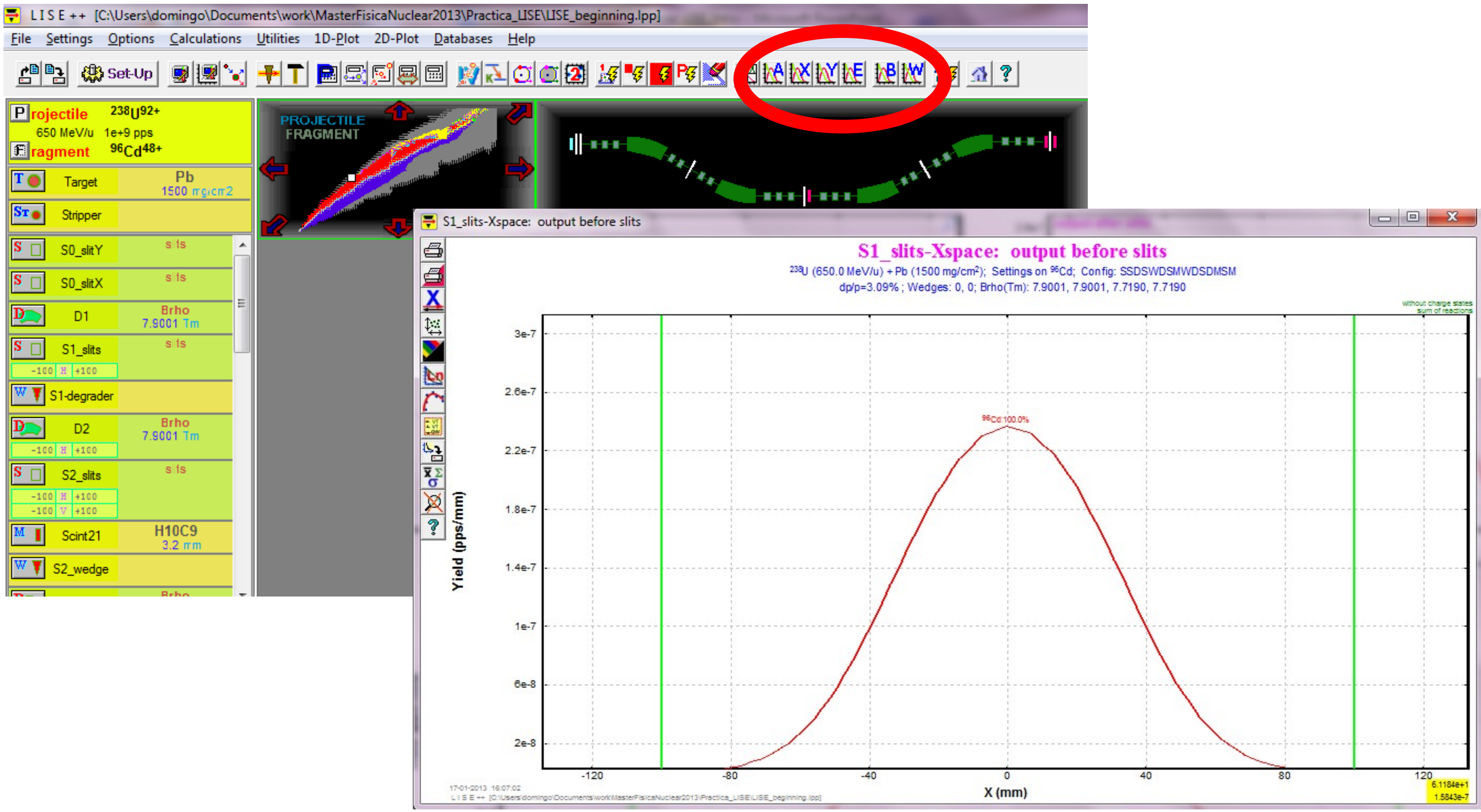
Right click

Practical aspects about the program:

6

- Useful options:

RIB distributions in position (X) and in energy (E)



Practical aspects about the program:

6

- Useful options:

Spectrometer design: turn off elements, modify S2-wedge, insert a Faraday Cup, etc