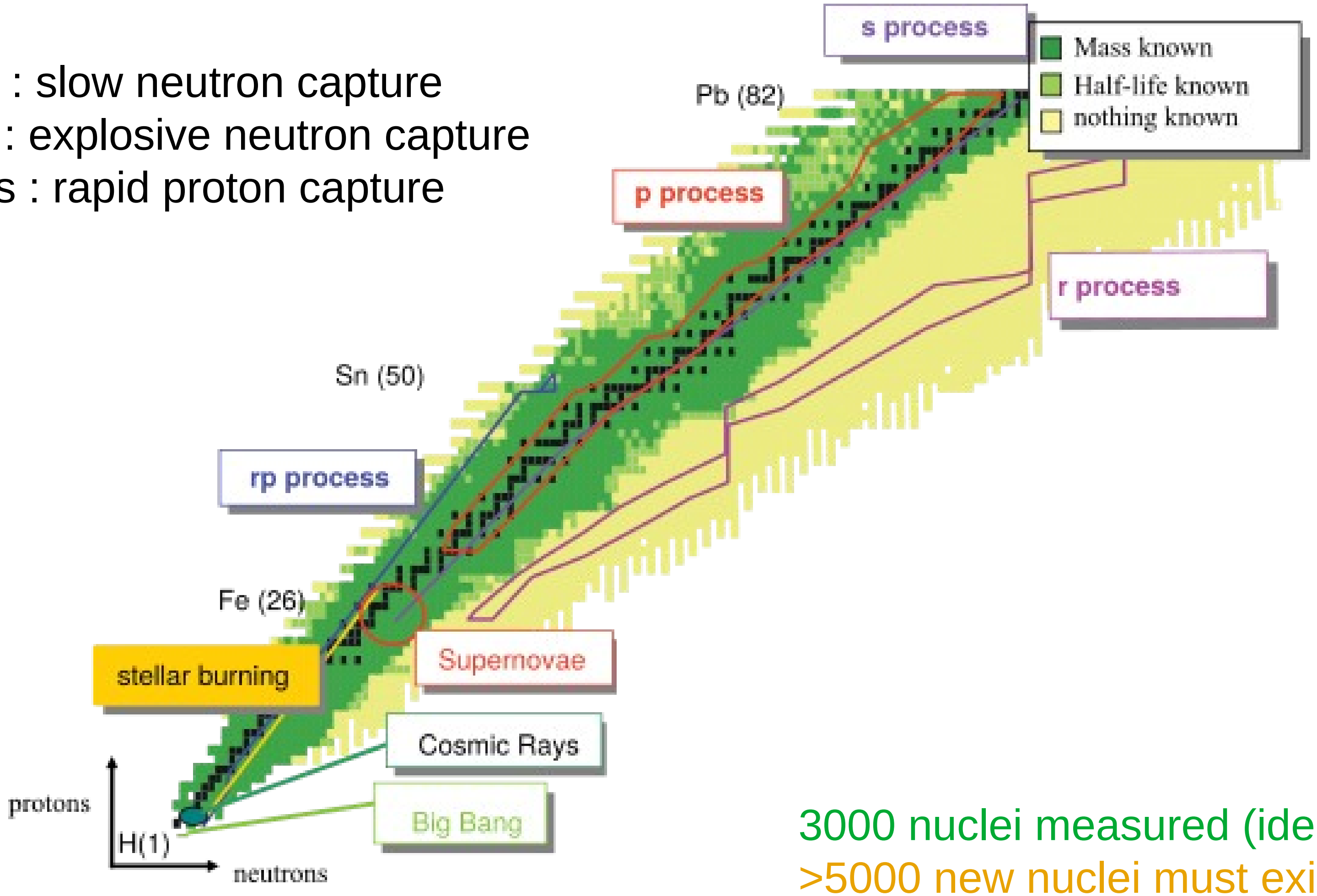
Introduction to LISE++

Christophe Rappold
Samuel Escrig
Teresa Kurtukian Nieto

Instituto de Estructura de la Materia
(CSIC)

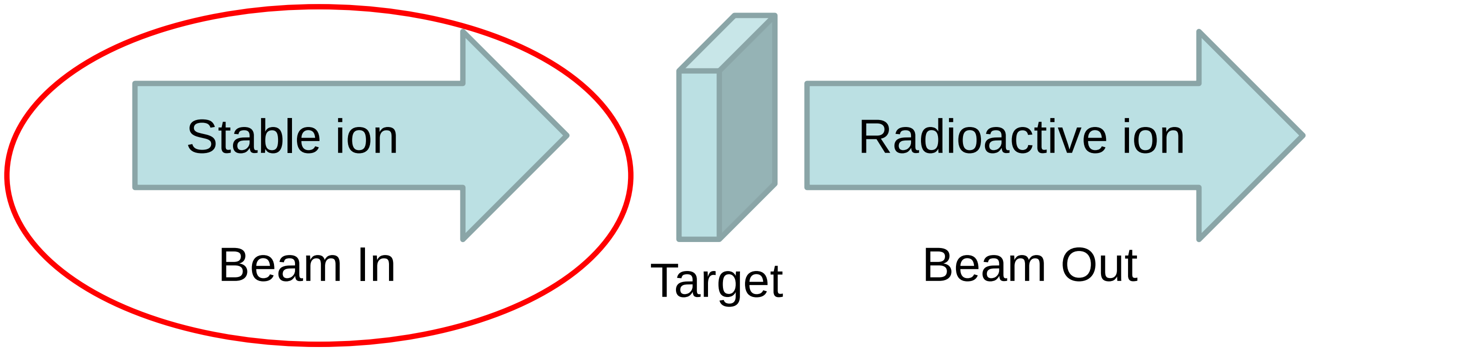
Motivation

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

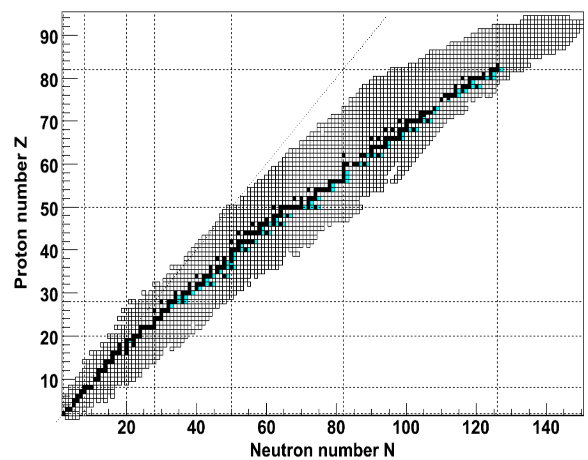


3000 nuclei measured (identified)
>5000 new nuclei must exist

Production of radioactive ion beams



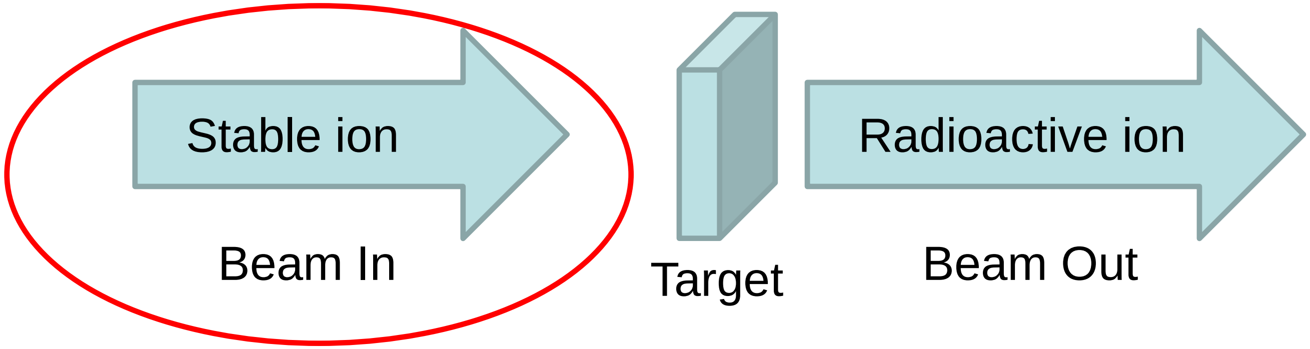
It is possible to accelerate every stable isotope, from hydrogen to uranium-238, in order to obtain the primary beam.



Stable ion sources

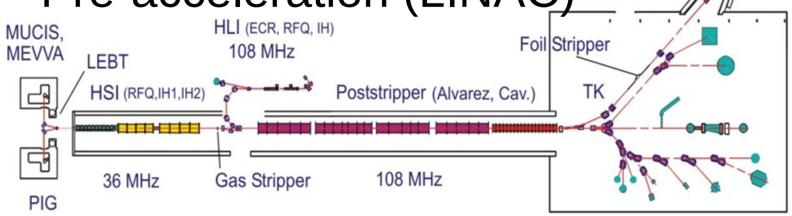
^{238}U: $2\ 10^{9}$
^{208}Pb: $2\ 10^{9}$
^{144}Sm: $2\ 10^{9}$ (ns, used once)
^{136}Xe: 10^{10}
^{124}Xe: 10^{10} (requires enriched material)
^{112}Sn: $\sim 10^{8}$ (requires enriched material)
^{107}Ag: $4\ 10^{9}$
^{86}Kr: $2\ 10^{10}$
^{78}Kr: $2\ 10^{10}$ (requires enriched material)
^{76}Ge: $3\ 10^{8}$ (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 …)

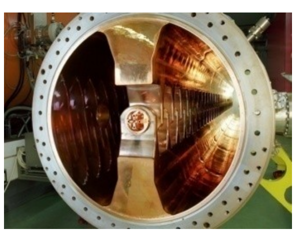
Production of radioactive ion beams



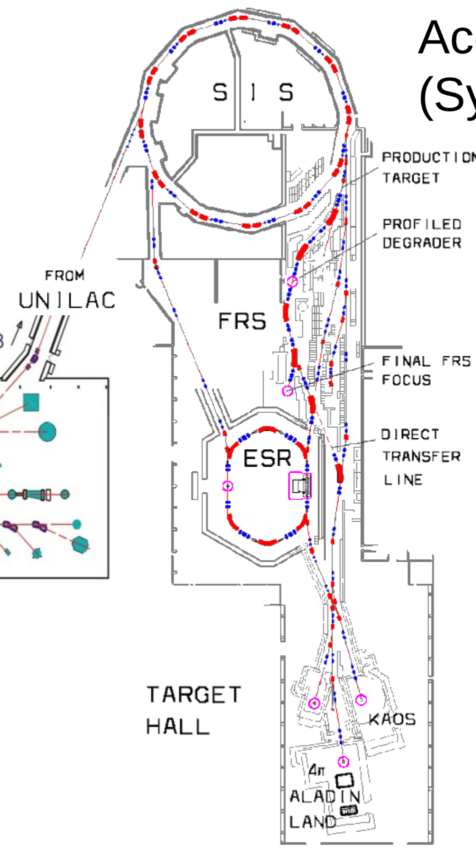
Stable ion sources

Pre-acceleration (LINAC)





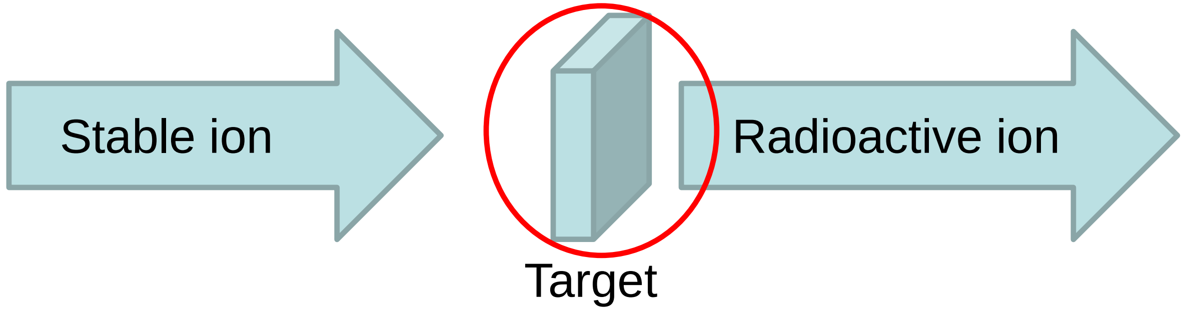
Acceleration (Synchrotron)



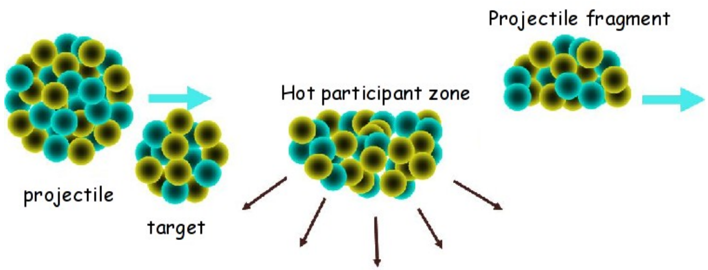
SIS18: 0.1-1 GeV/u

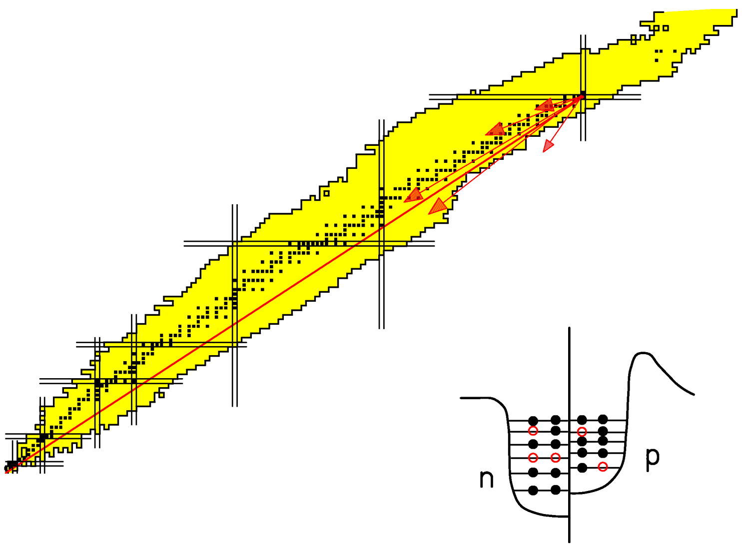
UNILAC: 11.4 MeV/u

Production of radioactive ion beams

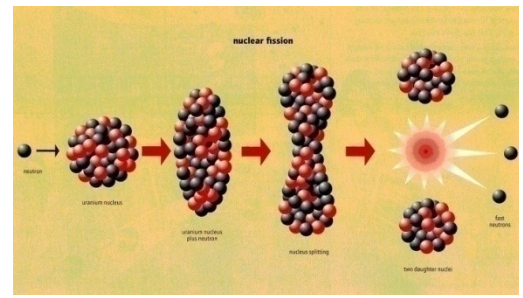


FRAGMENTATION

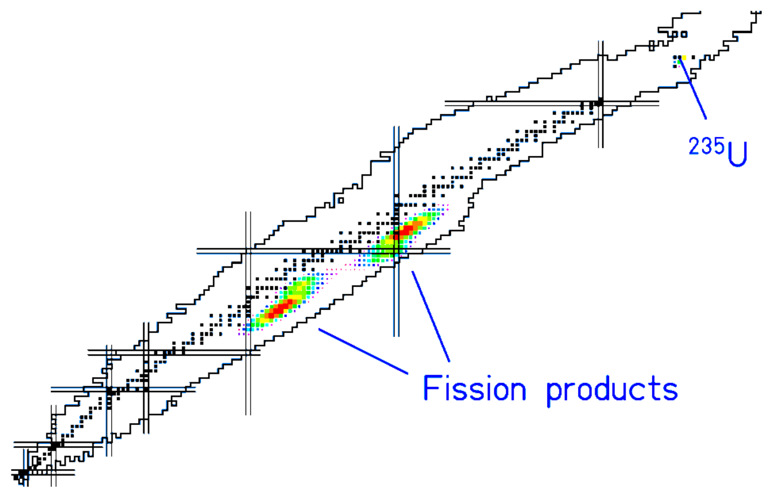




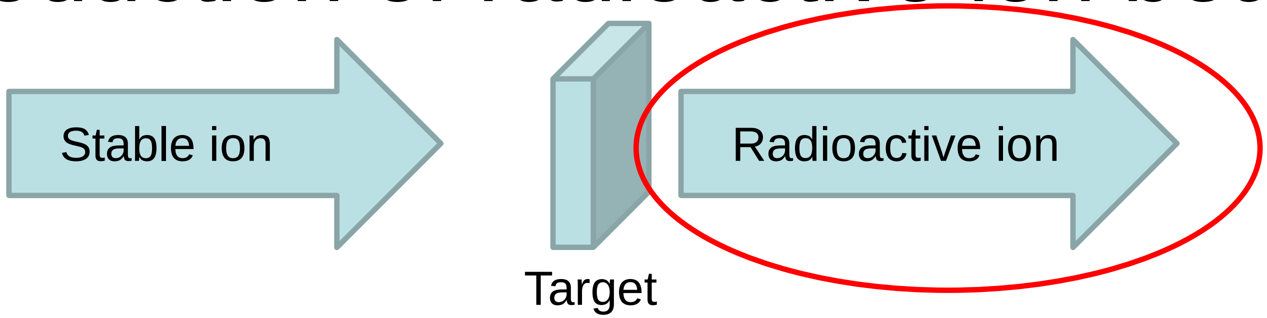
FUSION - FISSION



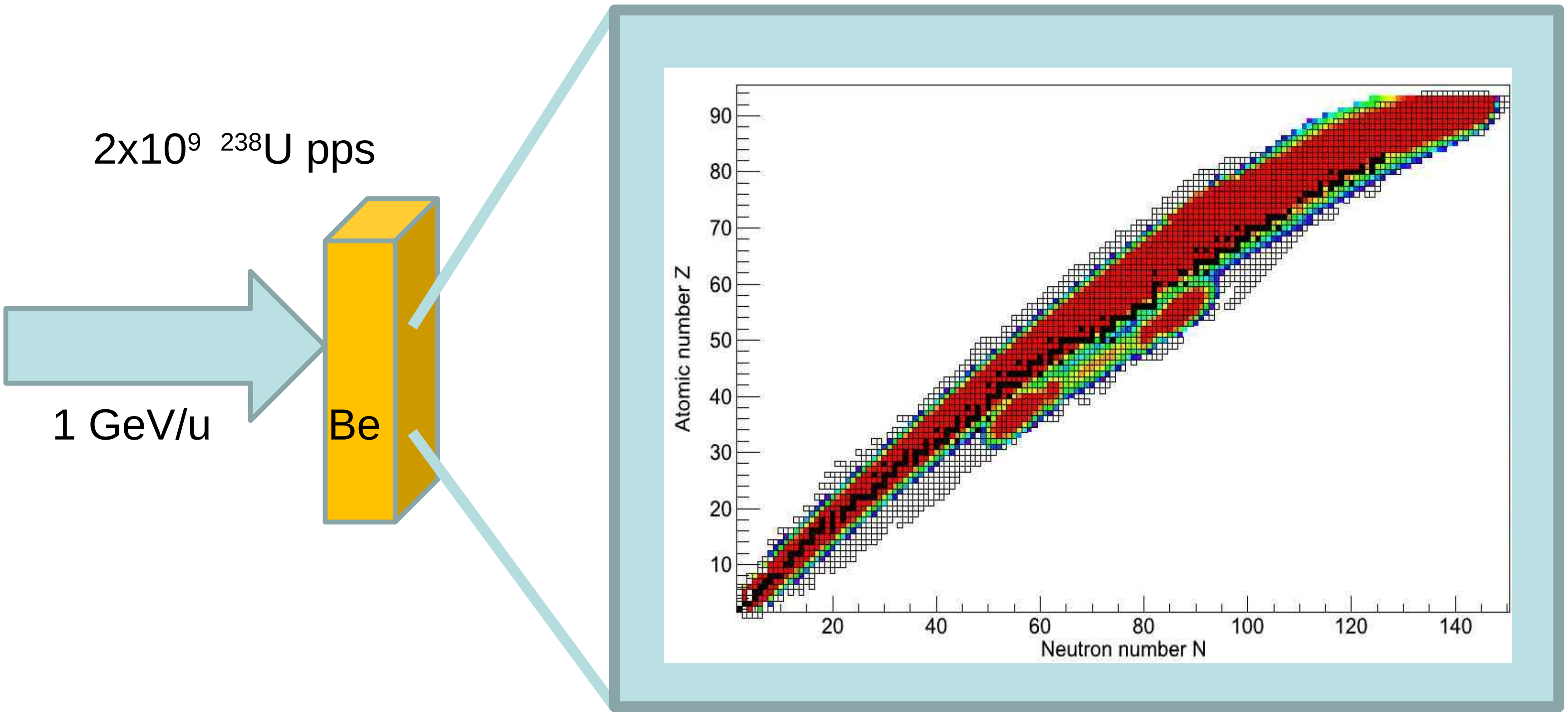
Fission induced by low-energy neutrons



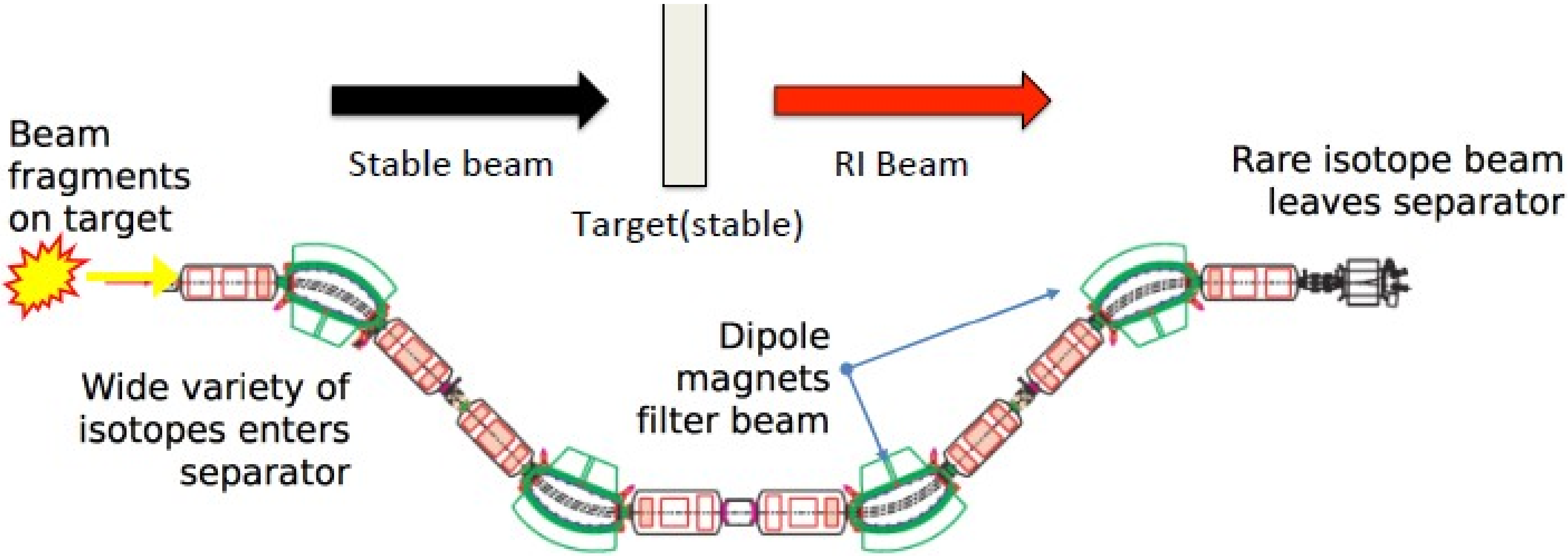
Production of radioactive ion beams



EXAMPLE:

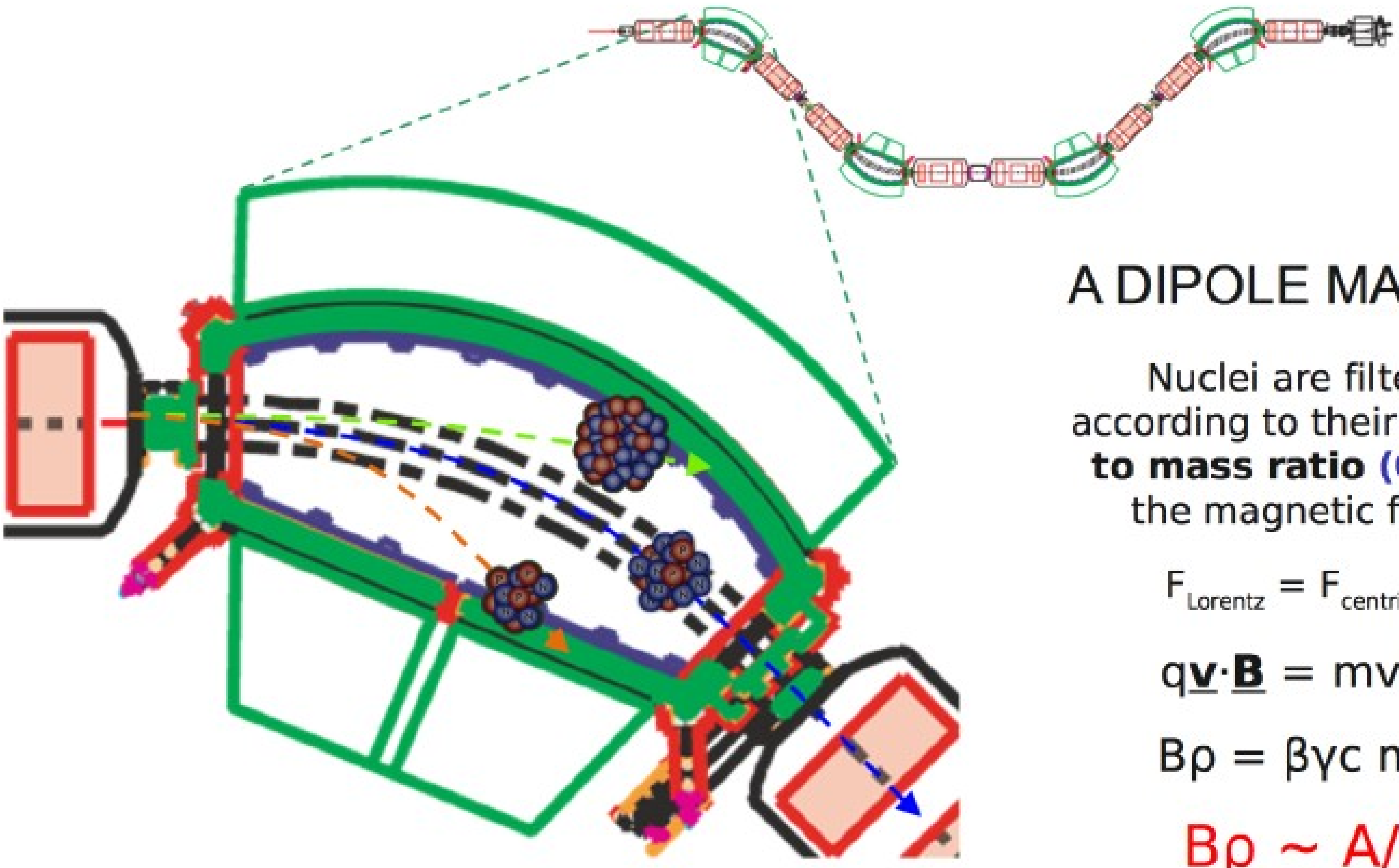


In-flight separation



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.

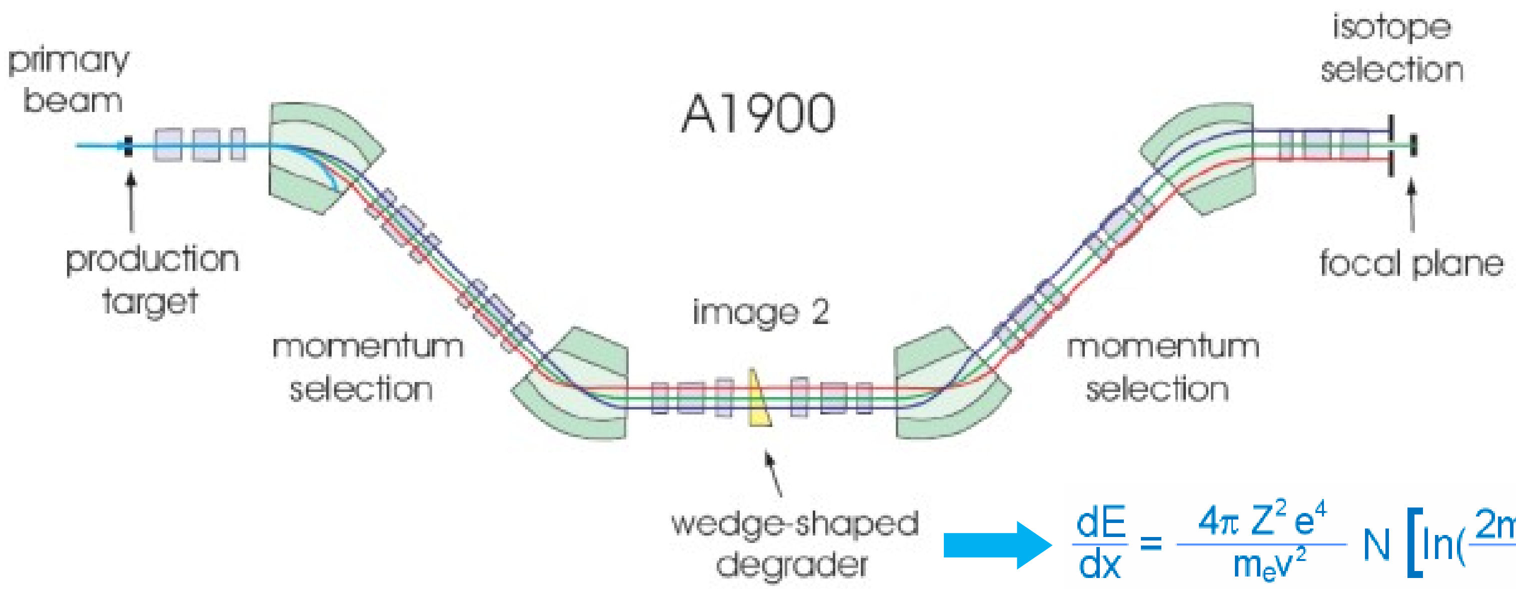
$$F_{Lorentz} = F_{centripetal}$$

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

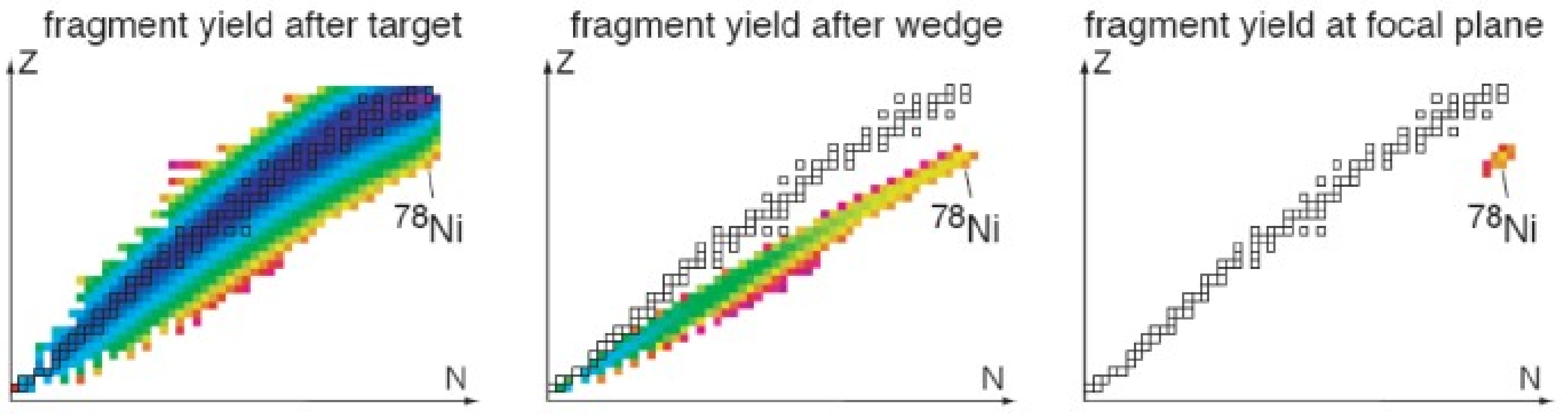
$$B\rho = \beta\gamma c\ m/q$$

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

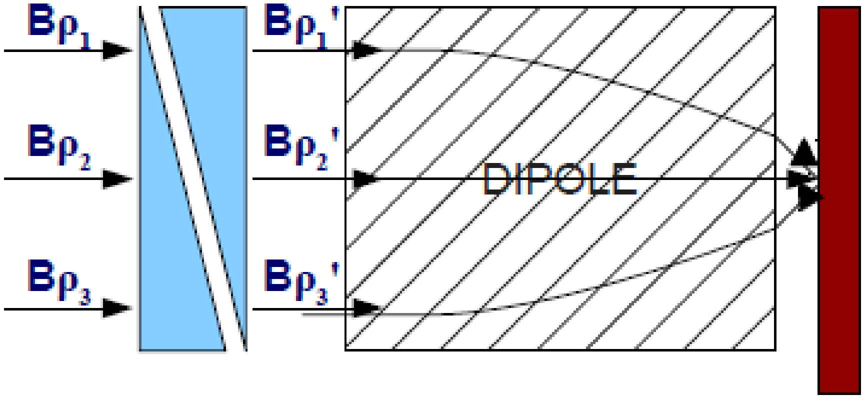
In-flight separation



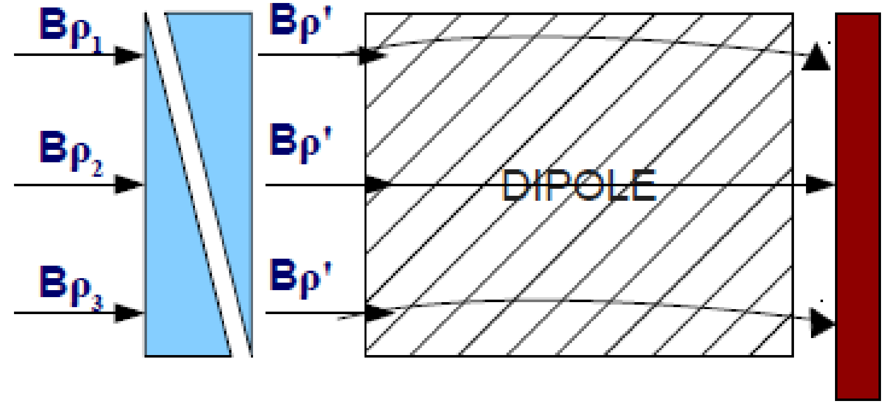
$$\frac{dE}{dx} = \frac{4\pi Z^2 e^4}{m_e v^2} N \left[\ln\left(\frac{2m_e\gamma^2 v^2}{I}\right) - \frac{v^2}{c_0^2} \right]$$



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



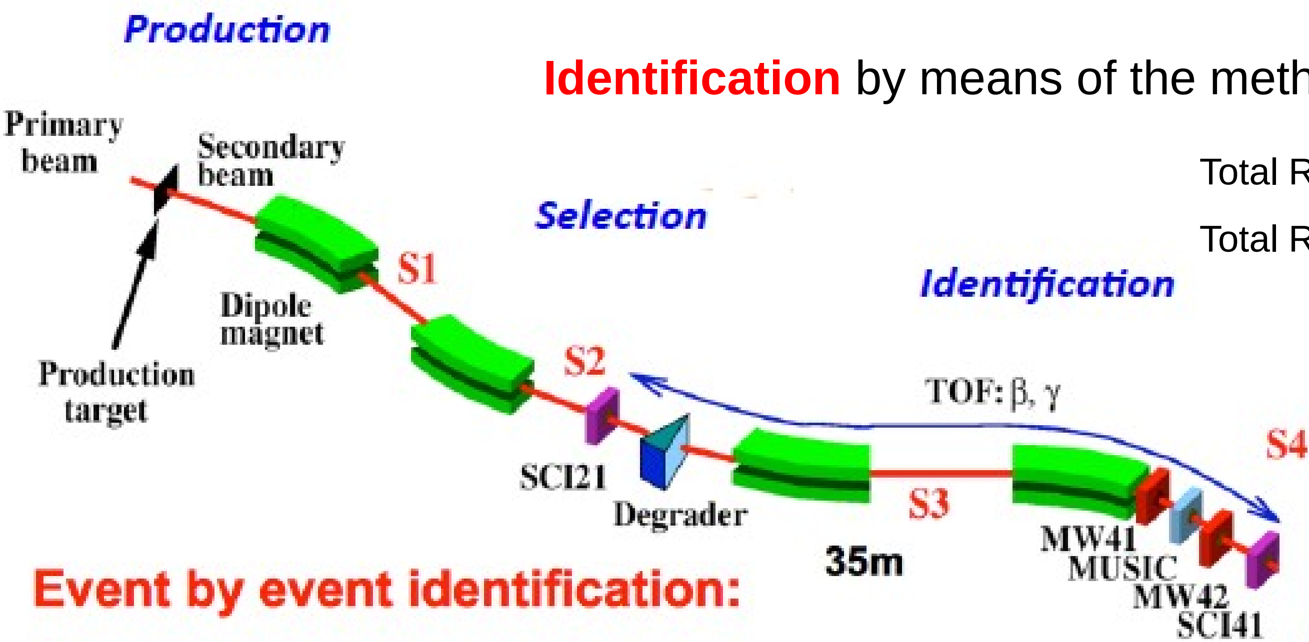
- **MONOENERGETIC MODE**
  - Momentum spread compensated by different path lenths in degrader
  - All fragments of same species have same energy
  - Fragments preserve their spacial distribution

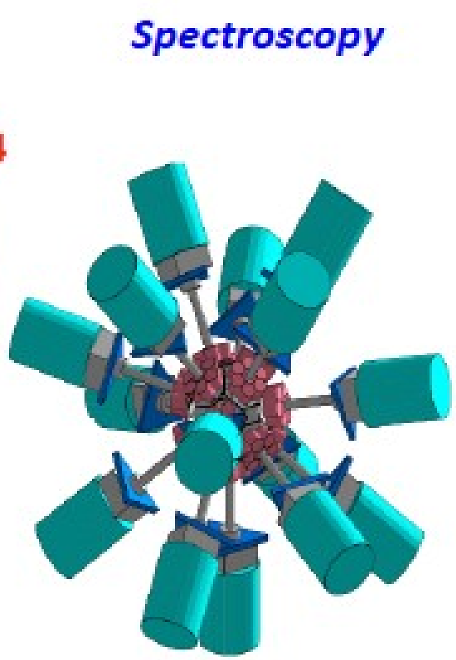
In-flight identification

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/Δt

A/Z = m/q = B ρ / (γ v)

Practical aspects about the program:

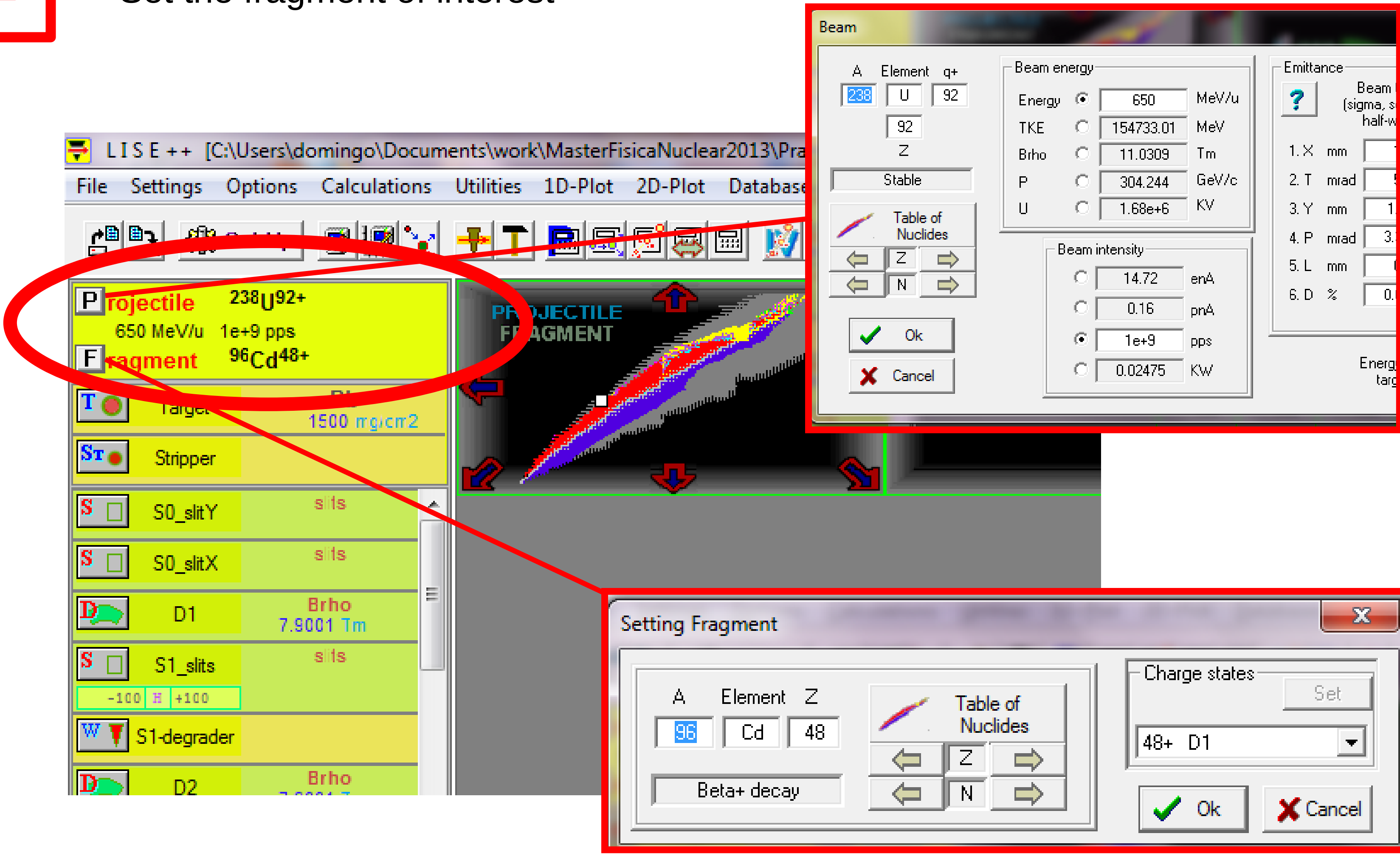
0

- 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

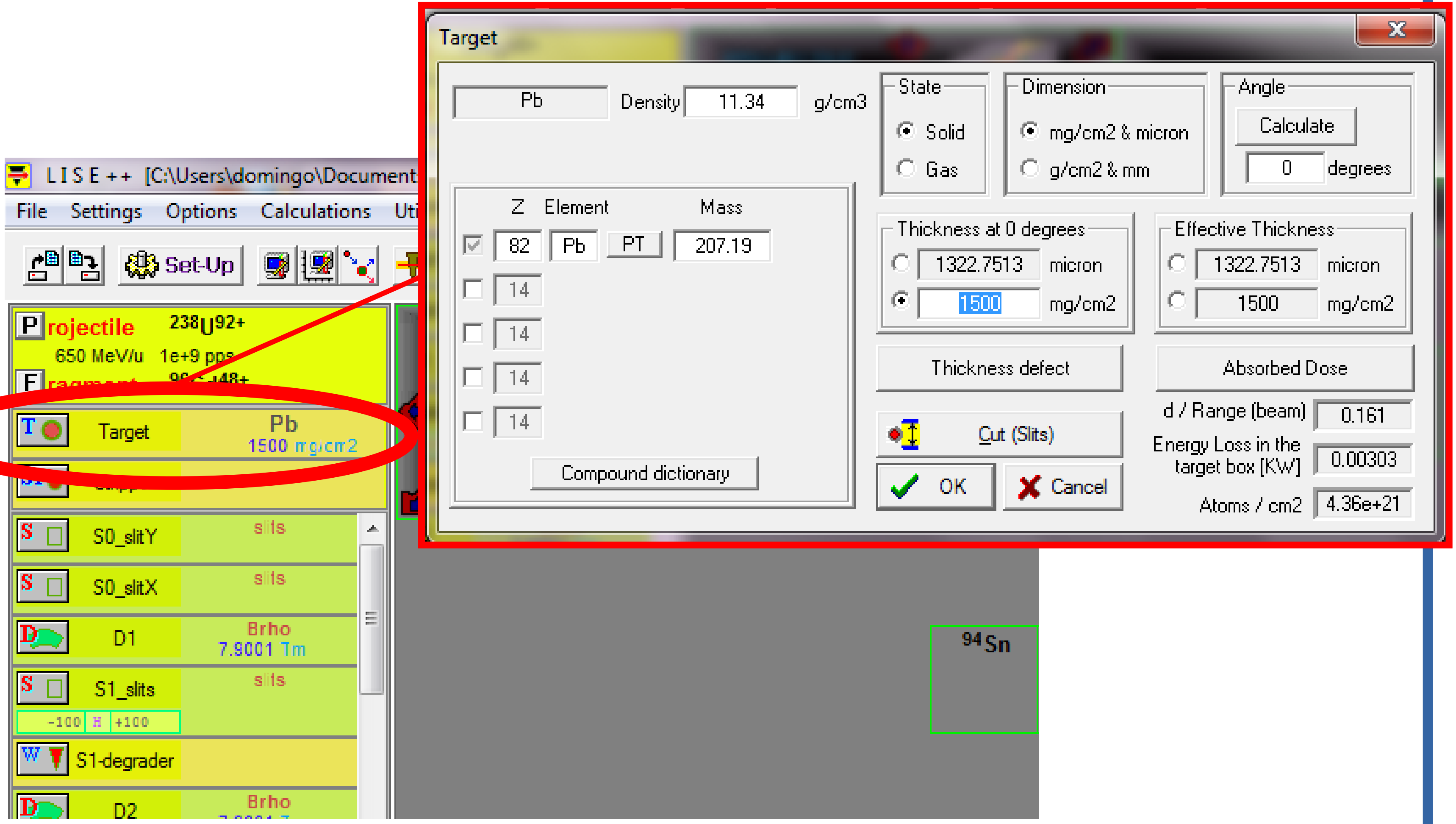
- Set the primary beam characteristics (isotope, energy and intensity)
- Set the fragment of interest



Practical aspects about the program:

2

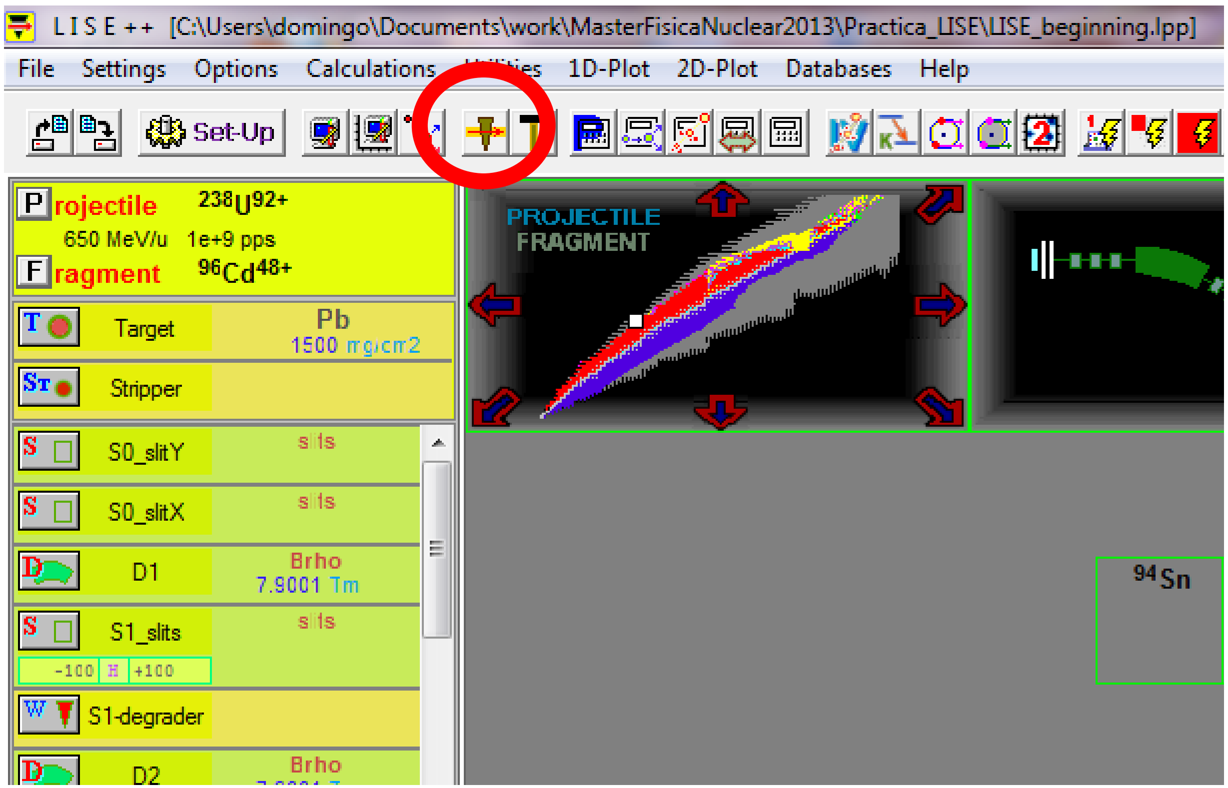
- Set the production target characteristics (element and thickness)



Practical aspects about the program:

3

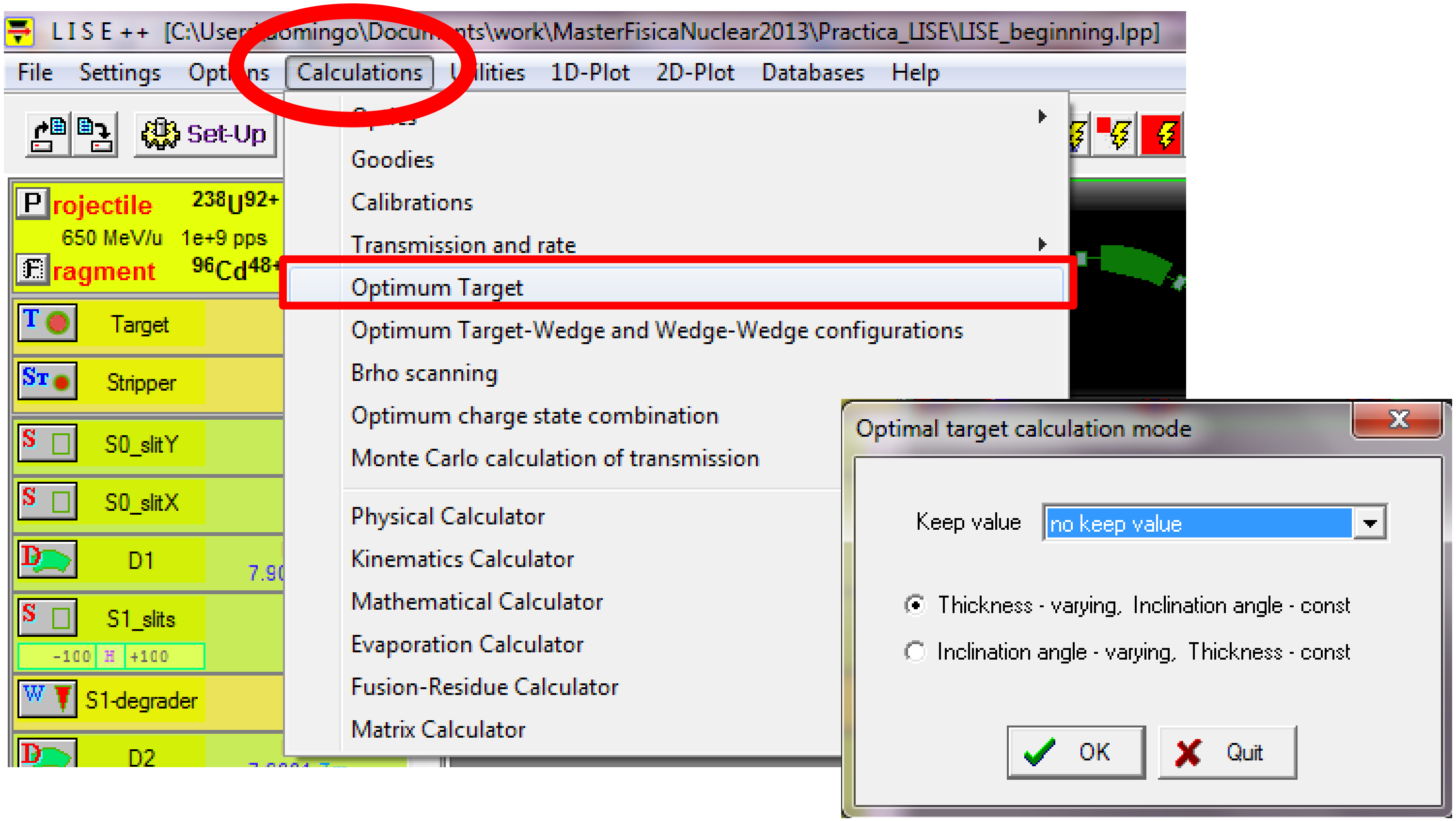
- Tune the magnetic fields (B) for the fragment of interest, depending on the spectrometer design



Practical aspects about the program:

4

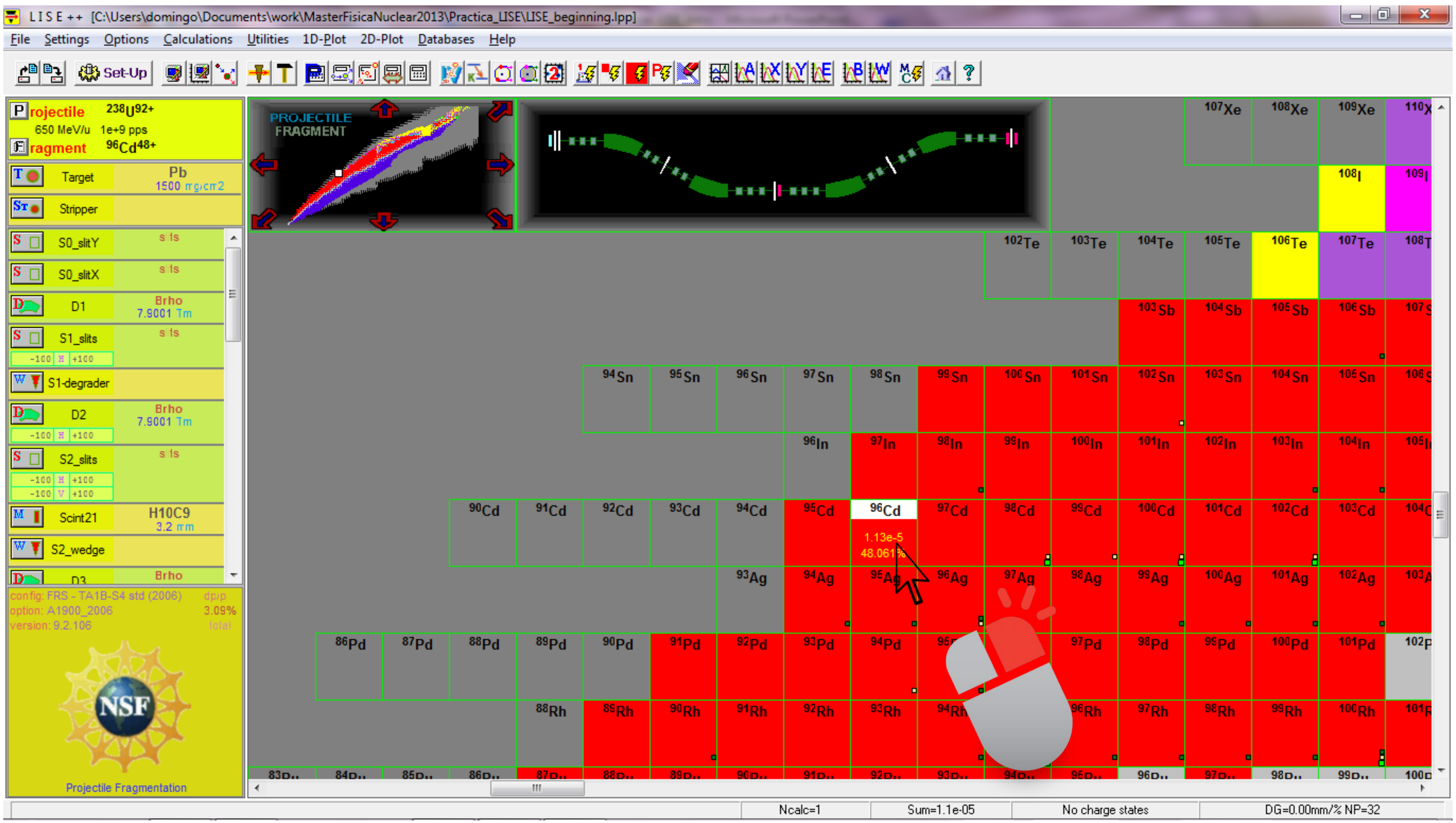
- Optimize the production target thickness (**each single time that primary or secondary beam parameters are modified**)



Practical aspects about the program:

5

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



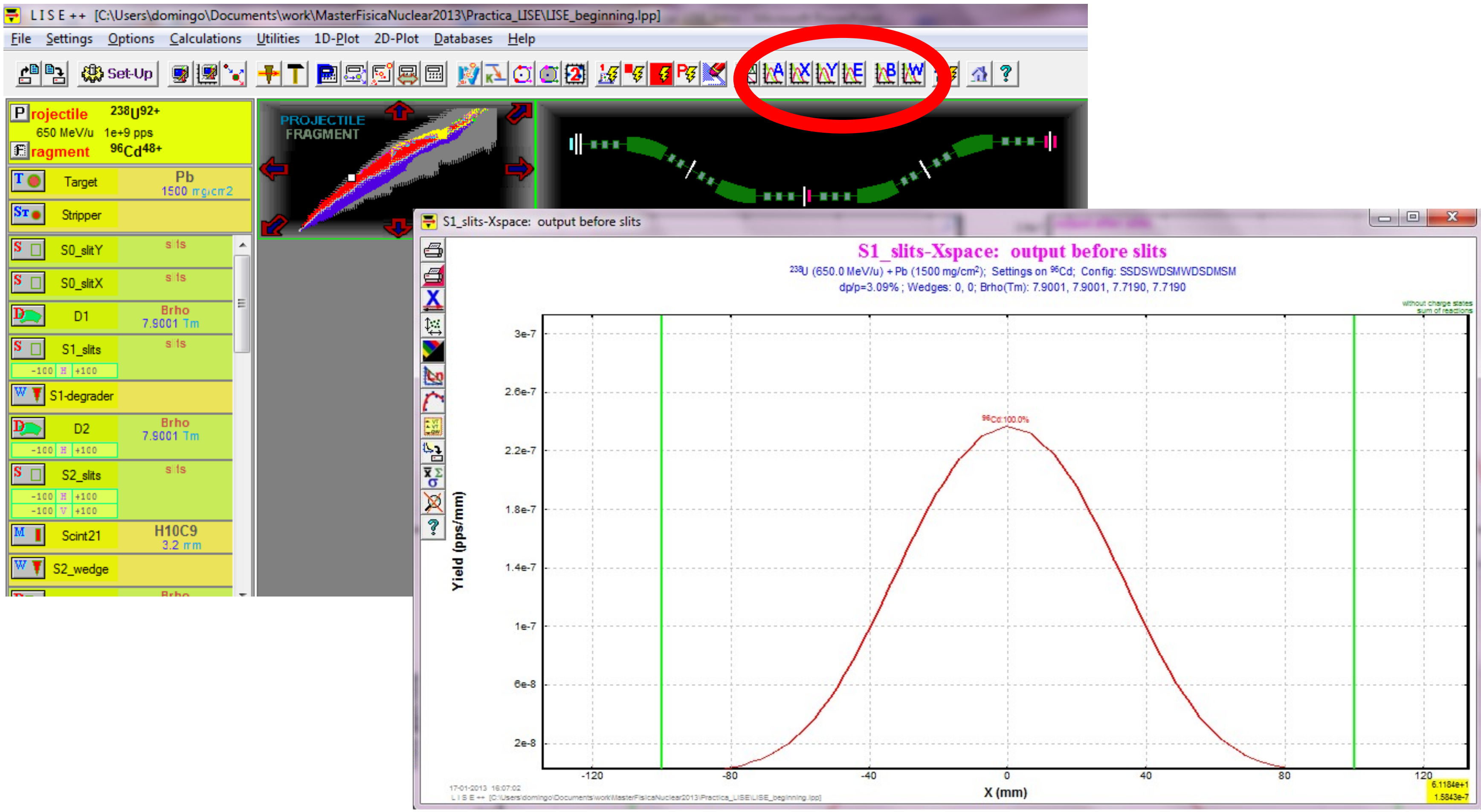
Right click

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