

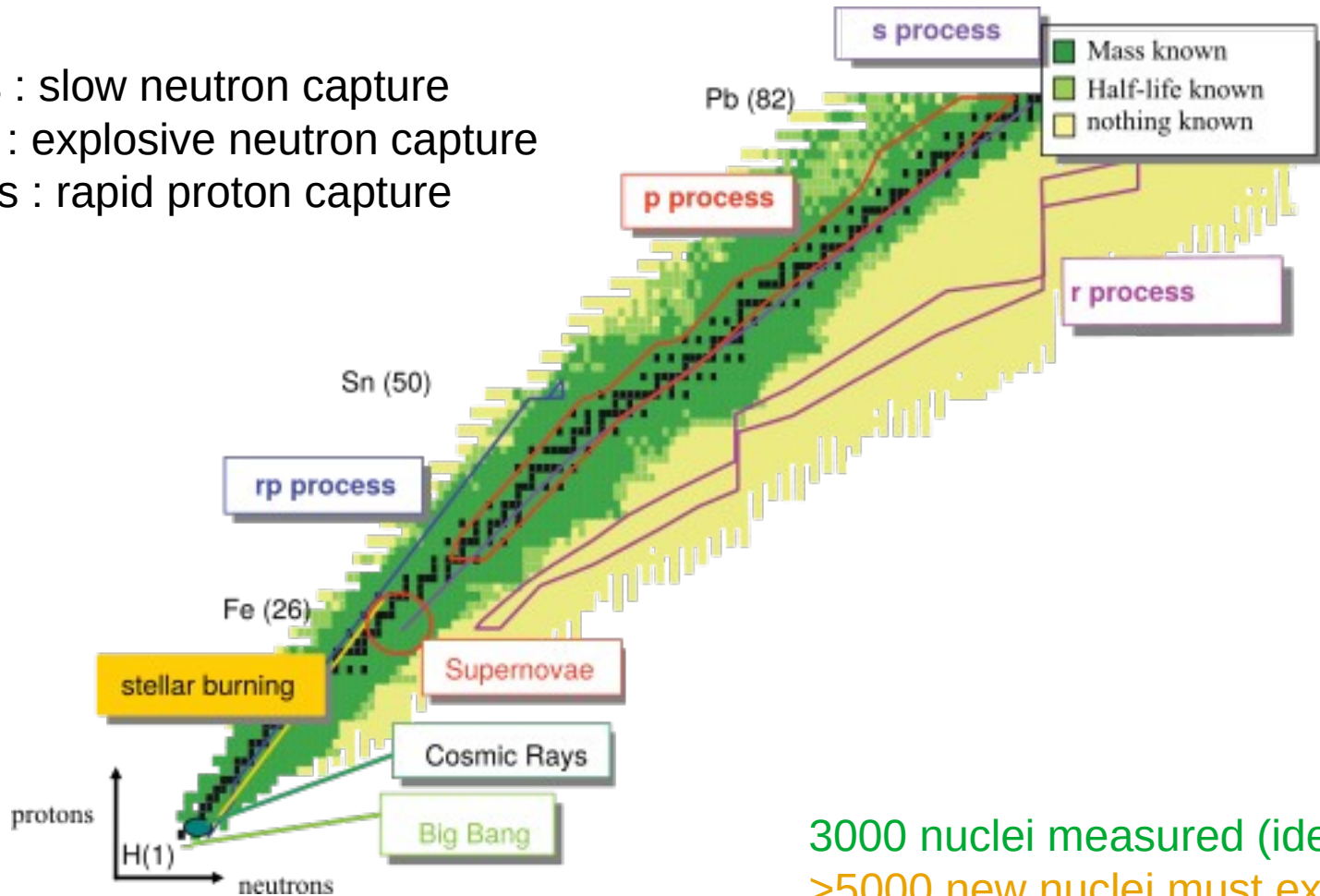
Introduction to LISE++

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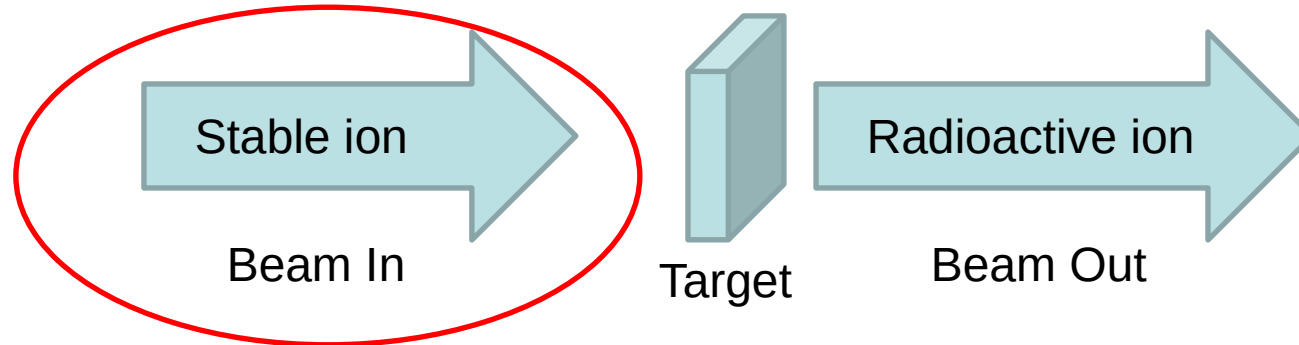
Motivation

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 : $2 \cdot 10^9$

^{208}Pb : $2 \cdot 10^9$

^{144}Sm : $2 \cdot 10^9$ (ns, used once)

^{136}Xe : 10^{10}

^{124}Xe : 10^{10} (requires enriched material)

^{112}Sn : $\sim 10^8$ (requires enriched material)

^{107}Ag : $4 \cdot 10^9$

^{86}Kr : $2 \cdot 10^{10}$

^{78}Kr : $2 \cdot 10^{10}$ (requires enriched material)

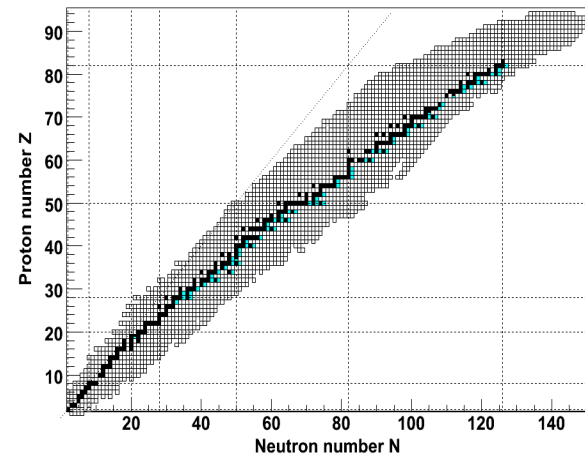
^{76}Ge : $3 \cdot 10^8$ (no standard beam, needs to be developed)

^{64}Ni : $5 \cdot 10^9$ (requires enriched material)

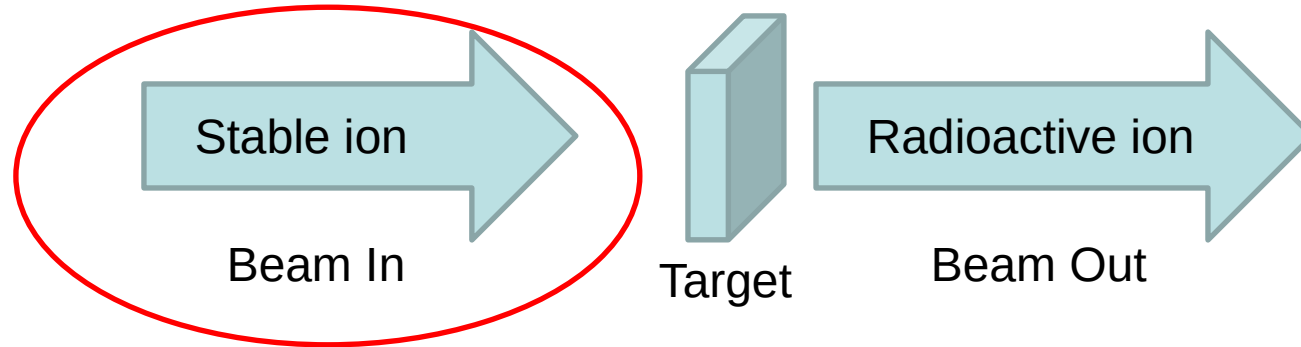
^{58}Ni : $5 \cdot 10^9$

^{48}Ca : $3 \cdot 10^7$ (low intensity from the ECR source when used for pulsed

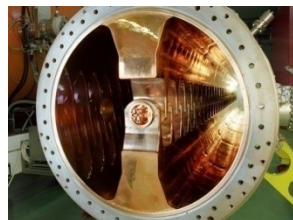
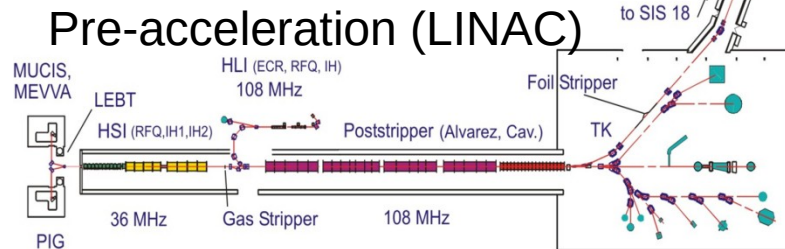
beams for SIS. Or very very expensive ...)



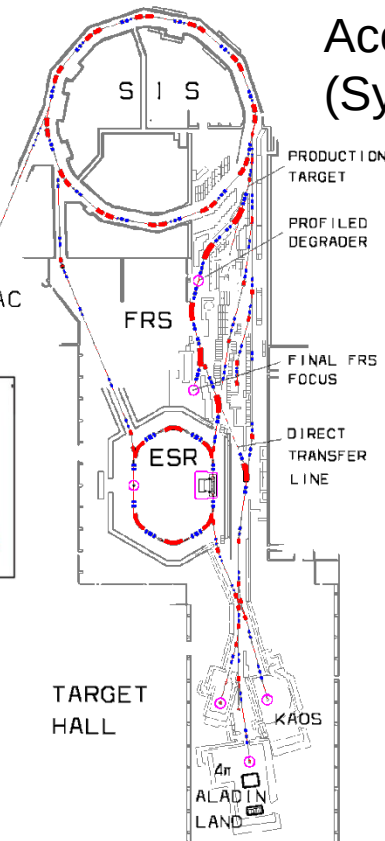
Production of radioactive ion beams



Stable ion sources



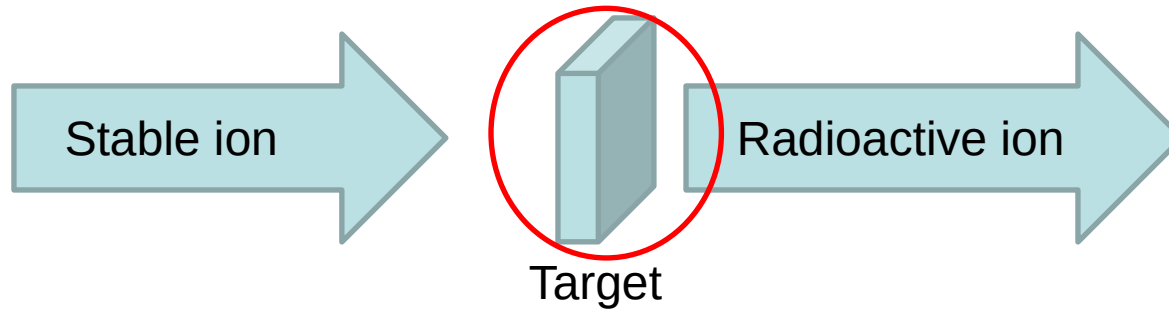
Acceleration
(Synchrotron)



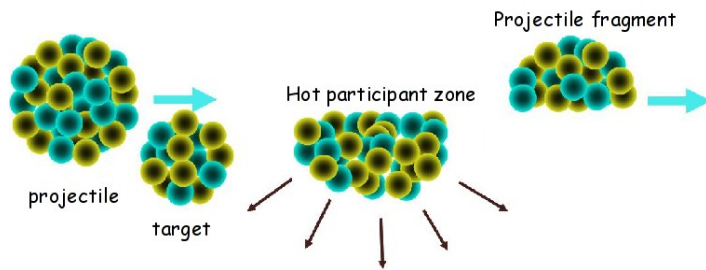
SIS18:
0.1-1 GeV/u

UNILAC:
11.4 MeV/u

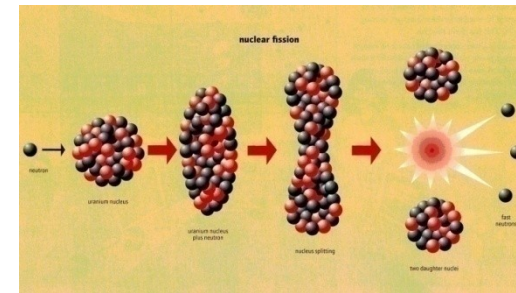
Production of radioactive ion beams



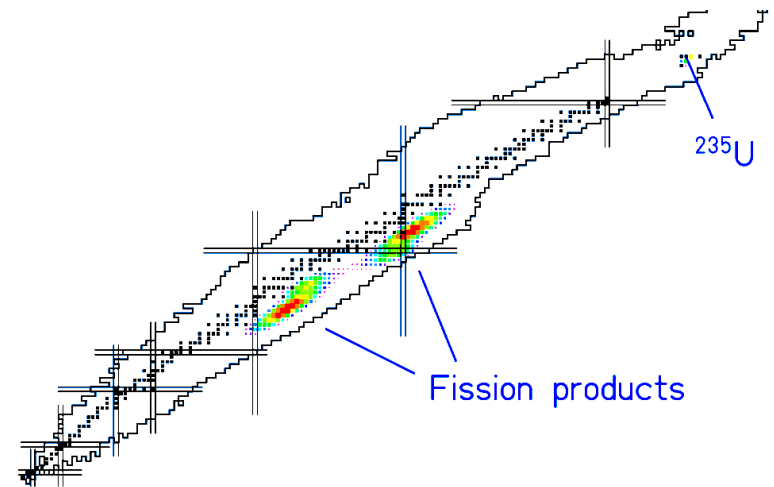
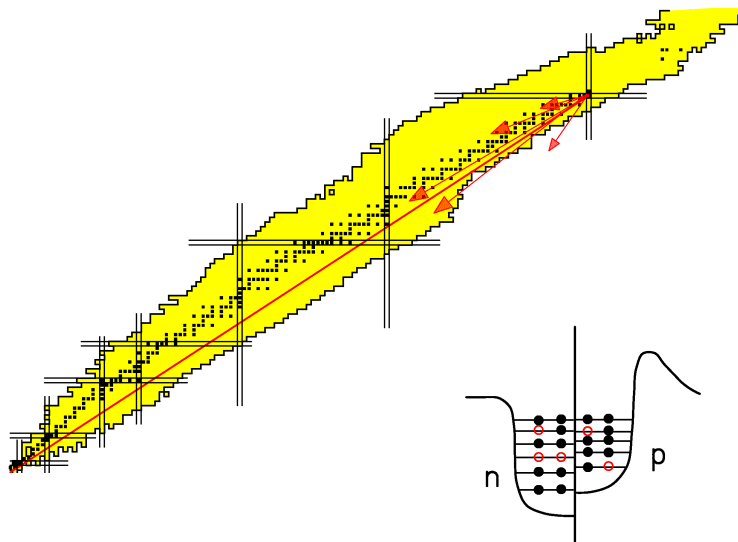
FRAGMENTATION



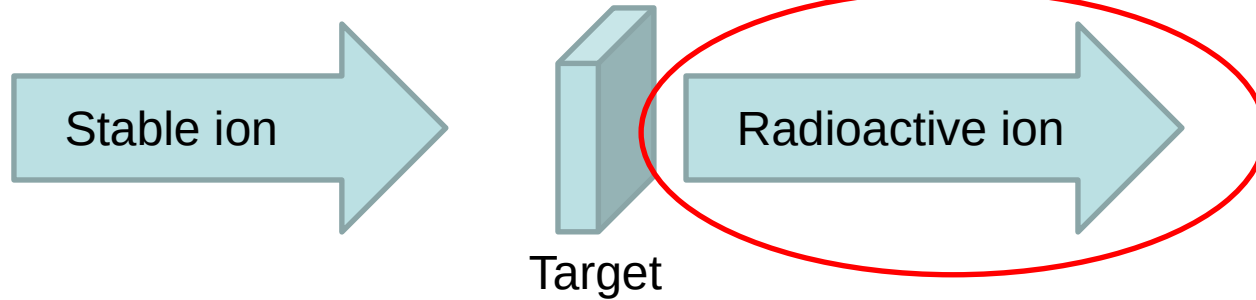
FUSION - FISSION



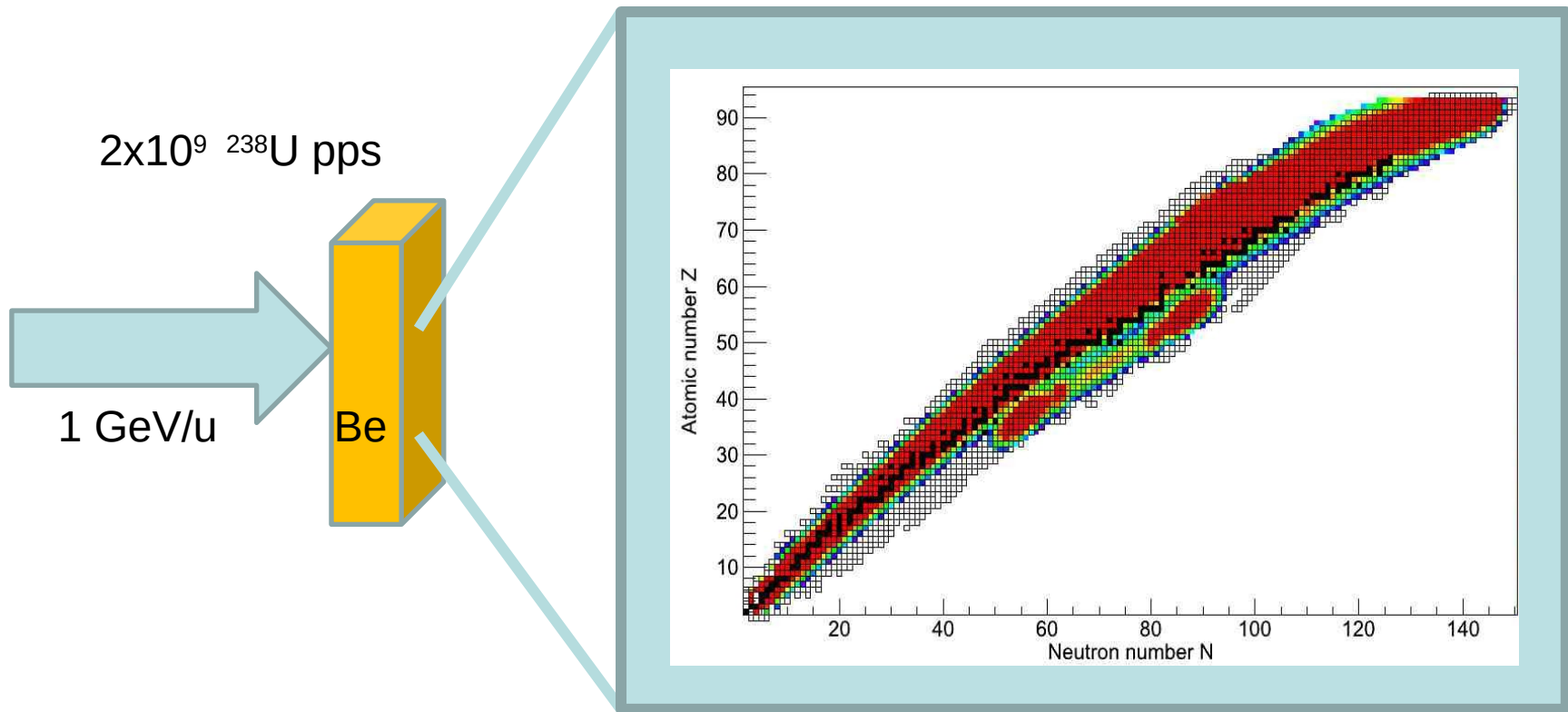
Fission induced by low-energy neutrons



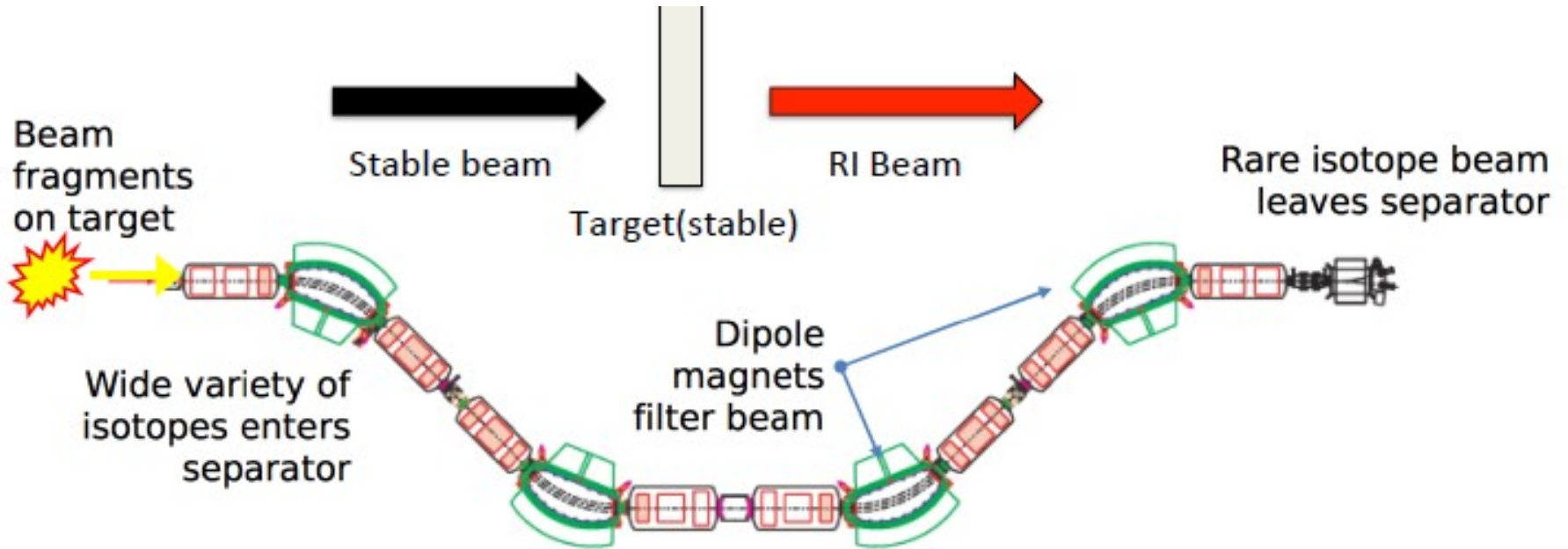
Production of radioactive ion beams



EXAMPLE:

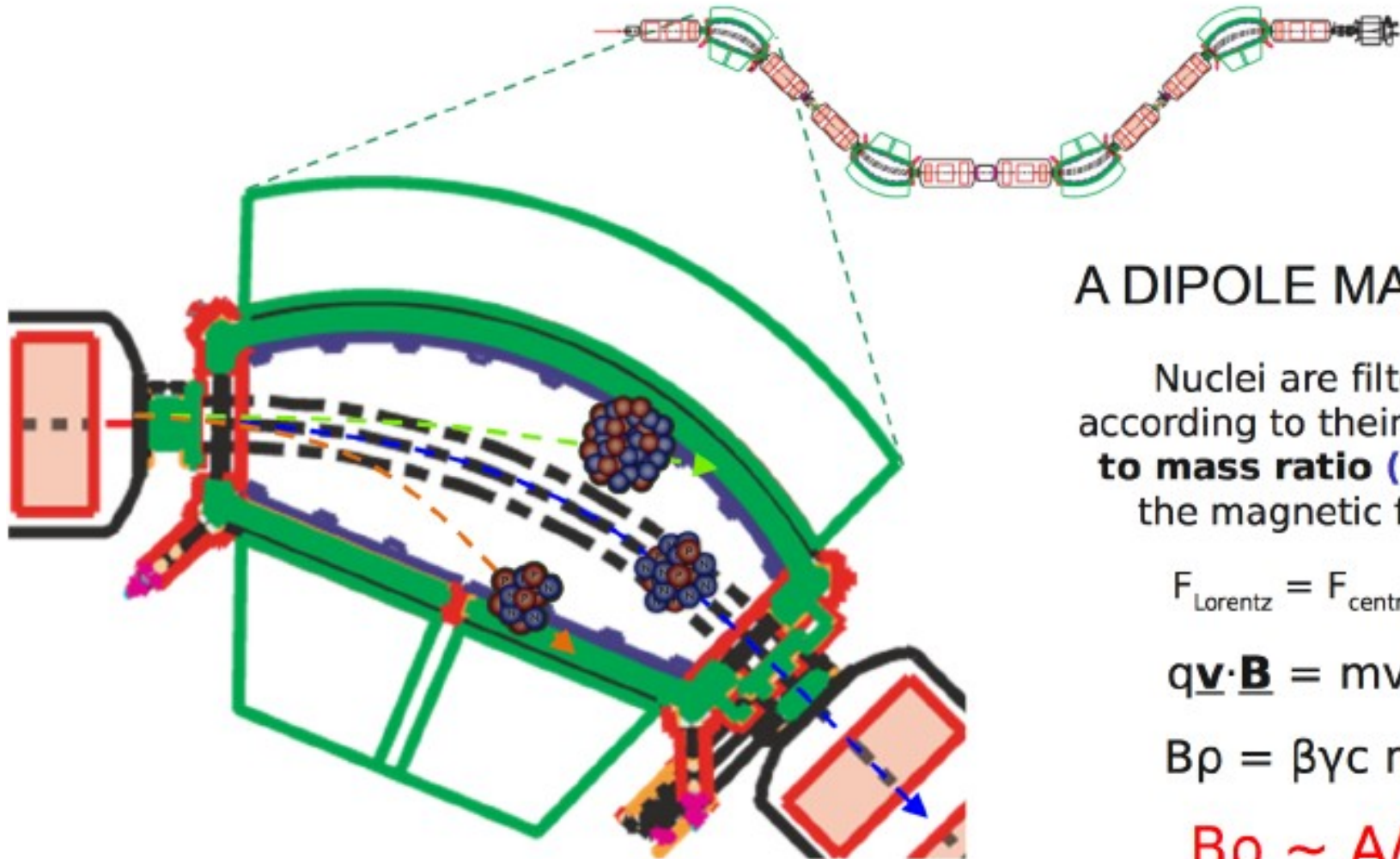


In-flight separation



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.

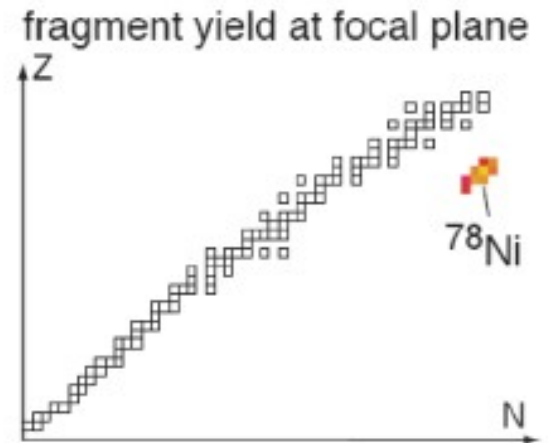
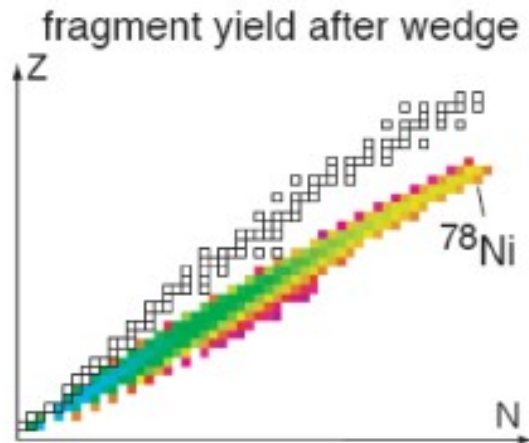
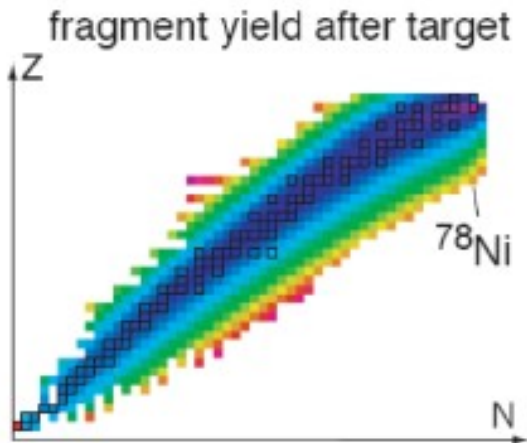
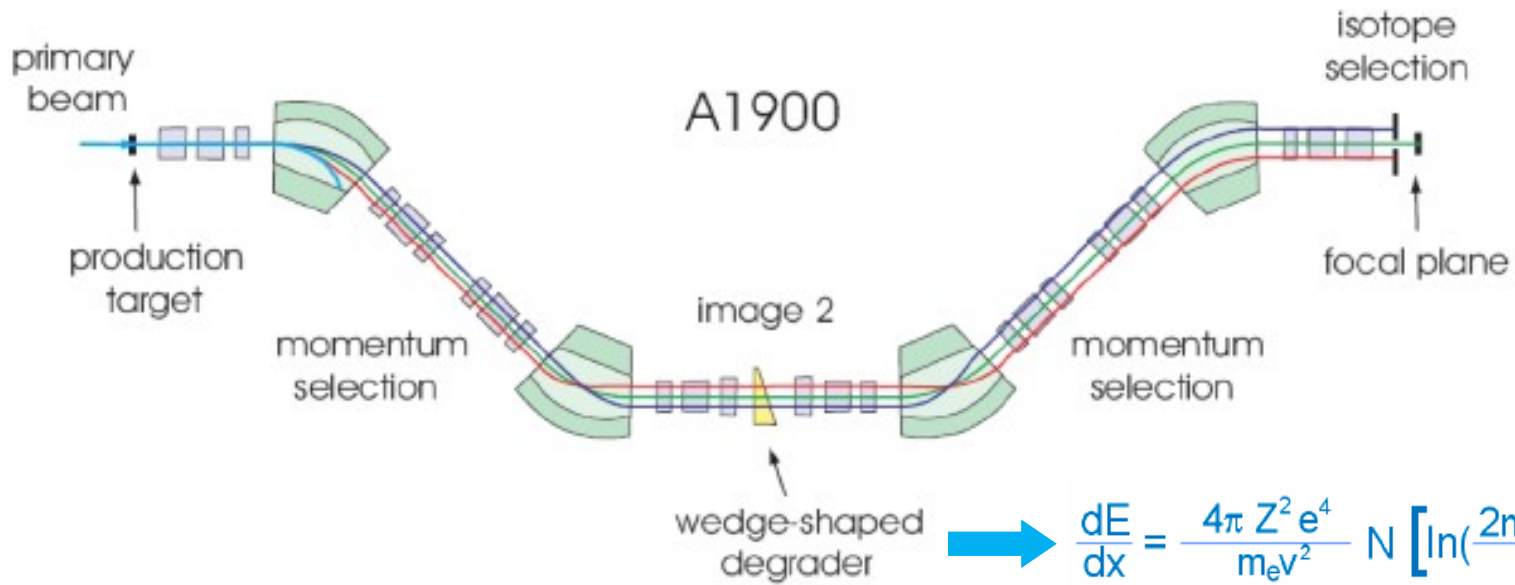
$$F_{\text{Lorentz}} = F_{\text{centripetal}}$$

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

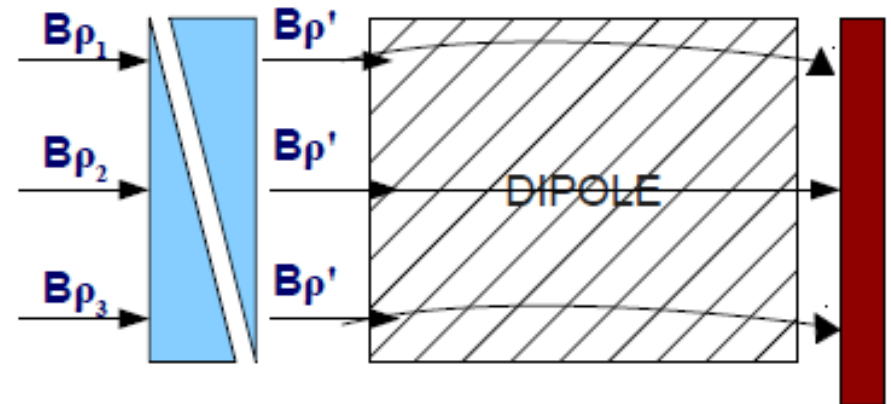
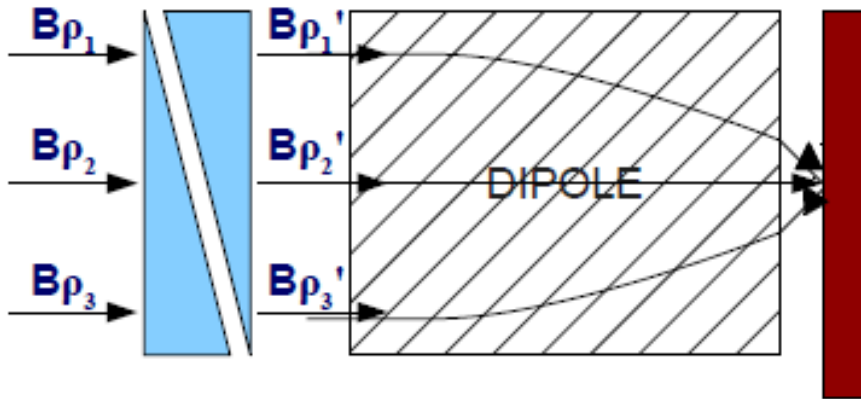
$$B\rho = \beta\gamma c m/q$$

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

In-flight separation



In-flight separation



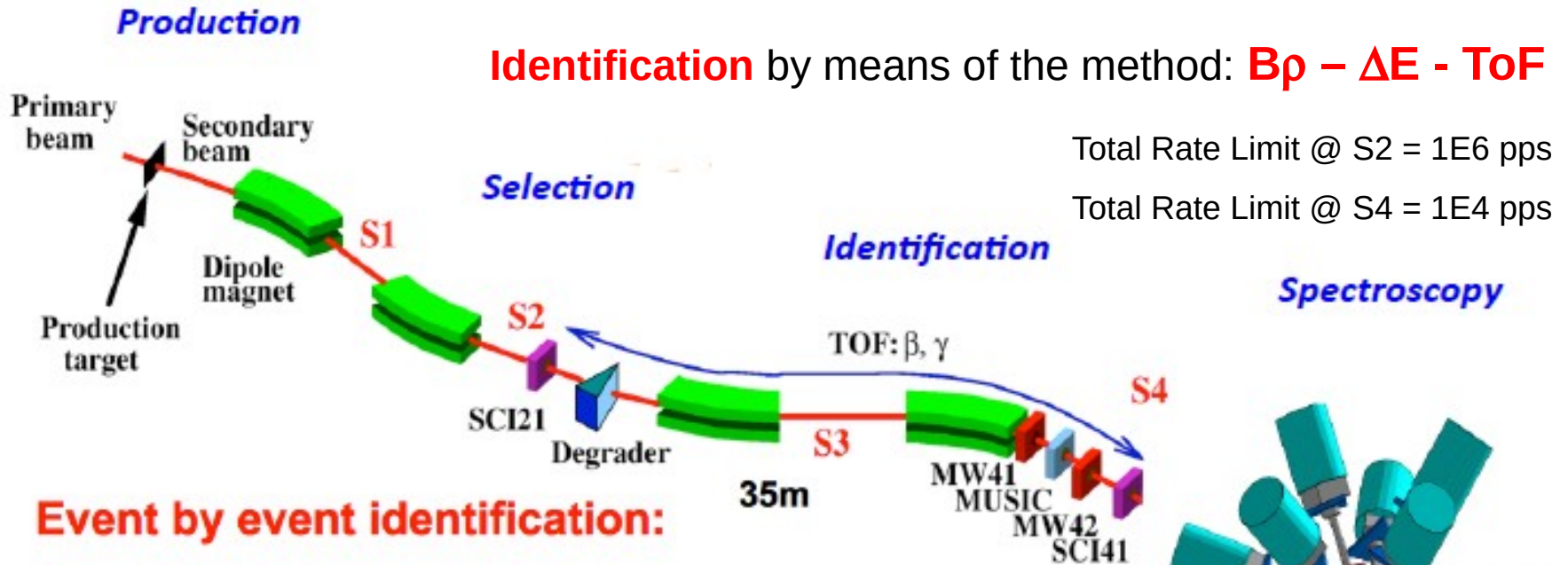
• ACHROMATIC MODE

- 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 lengths in degrader
- All fragments of same species have same energy
- Fragments preserve their spacial distribution

In-flight identification

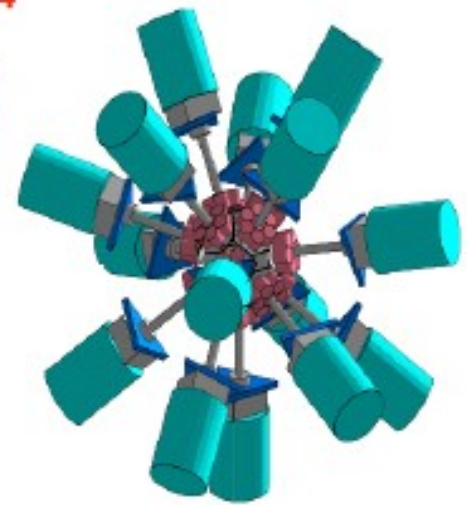


Event by event identification:

Ionization Chambers $\rightarrow \Delta E \rightarrow Z^2 \rightarrow Z$

Scintillators S2, S4 $\rightarrow \text{ToF} \rightarrow \text{velocity} = L/\Delta t$

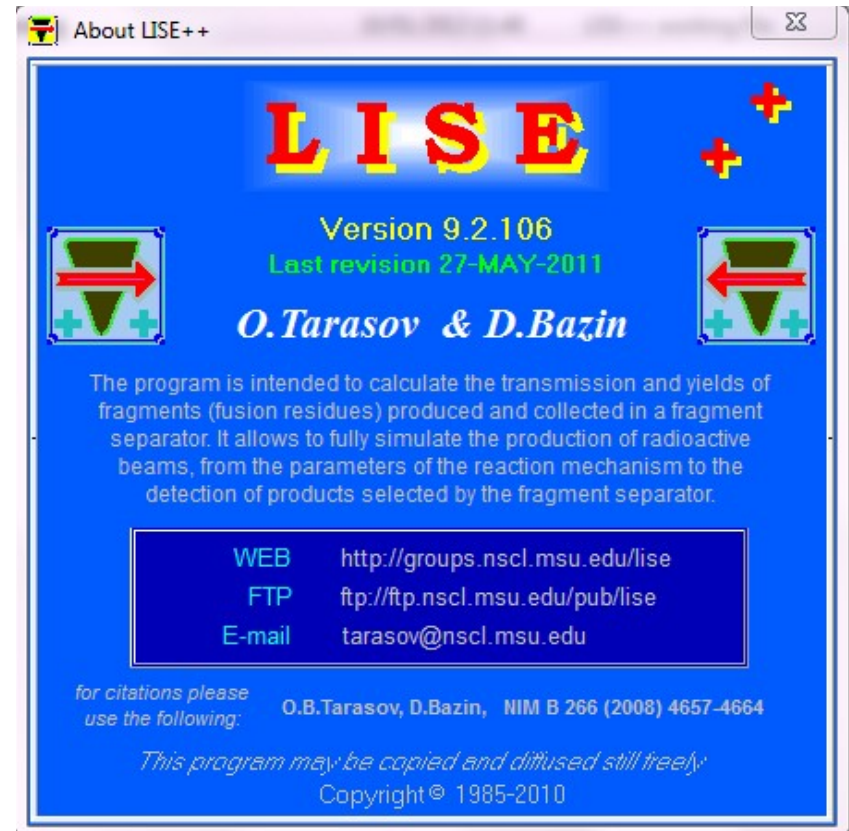
$$A/Z = m/q = B \rho / (\gamma v)$$



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

The screenshot displays the LIS E ++ software interface. The main window shows a list of components on the left and a central plot area. A red oval highlights the 'Projectile' and 'Fragment' settings in the component list. Two dialog boxes are overlaid on the interface:

Beam Dialog:

A	Element	q+
238	U	92

Beam energy:

Energy	650	MeV/u
TKE	154733.01	MeV
Brho	11.0309	Tm
P	304.244	GeV/c
U	1.68e+6	KV

Beam intensity:

<input type="radio"/>	14.72	enA
<input type="radio"/>	0.16	pnA
<input checked="" type="radio"/>	1e+9	pps
<input type="radio"/>	0.02475	KW

Emittance:

1. X	mm	
2. T	mrاد	
3. Y	mm	
4. P	mrاد	
5. L	mm	
6. D	%	

Setting Fragment Dialog:

A	Element	Z
96	Cd	48

Charge states: 48+ D1

Practical aspects about the program:

2

- Set the production target characteristics (element and thickness)

The screenshot displays the LISE++ software interface. The main window shows a list of components: Projectile (238U92+, 650 MeV/u, 1e+9 pps), Fragment (96Zr48+), Target (Pb, 1500 mg/cm2), S0_slitY, S0_slitX, D1 (Brho, 7.9001 Tm), S1_slits, S1-degrader, and D2 (Brho). The 'Target' button is circled in red. A 'Target' dialog box is open, showing the following settings:

- Element: Pb, Density: 11.34 g/cm³
- State: Solid, Gas
- Dimension: mg/cm² & micron, g/cm² & mm
- Angle: 0 degrees
- Thickness at 0 degrees: 1322.7513 micron, 1500 mg/cm²
- Effective Thickness: 1322.7513 micron, 1500 mg/cm²
- Thickness defect: []
- Absorbed Dose: d / Range (beam) 0.161, Energy Loss in the target box [KW] 0.00303, Atoms / cm² 4.36e+21
- Buttons: OK, Cancel

The dialog box also includes a table for element selection:

Z	Element	Mass
<input checked="" type="checkbox"/>	82 Pb	PT 207.19
<input type="checkbox"/>	14	
<input type="checkbox"/>	14	
<input type="checkbox"/>	14	
<input type="checkbox"/>	14	

Practical aspects about the program:

3

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

The screenshot displays the LIS E ++ software interface. The title bar shows the file path: [C:\Users\domingo\Documents\work\MasterFisicaNuclear2013\Practica_LISE\LISE_beginning.lpp]. The menu bar includes File, Settings, Options, Calculations, Utilities, 1D-Plot, 2D-Plot, Databases, and Help. The toolbar contains various icons, with the 'Utilities' icon (a wrench and screwdriver) circled in red. The main window is divided into a left sidebar and a central plot area.

Left Sidebar:

- P**rojectile: 238U92+, 650 MeV/u, 1e+9 pps
- F**ragment: 96Cd48+
- T**arget: Pb, 1500 mg/cm2
- St**ripper
- S**0_slitY: s is
- S**0_slitX: s is
- D**1: Brho, 7.9001 Tm
- S**1_slits: s is, -100 | +100
- W** S1-degrader
- D**2: Brho

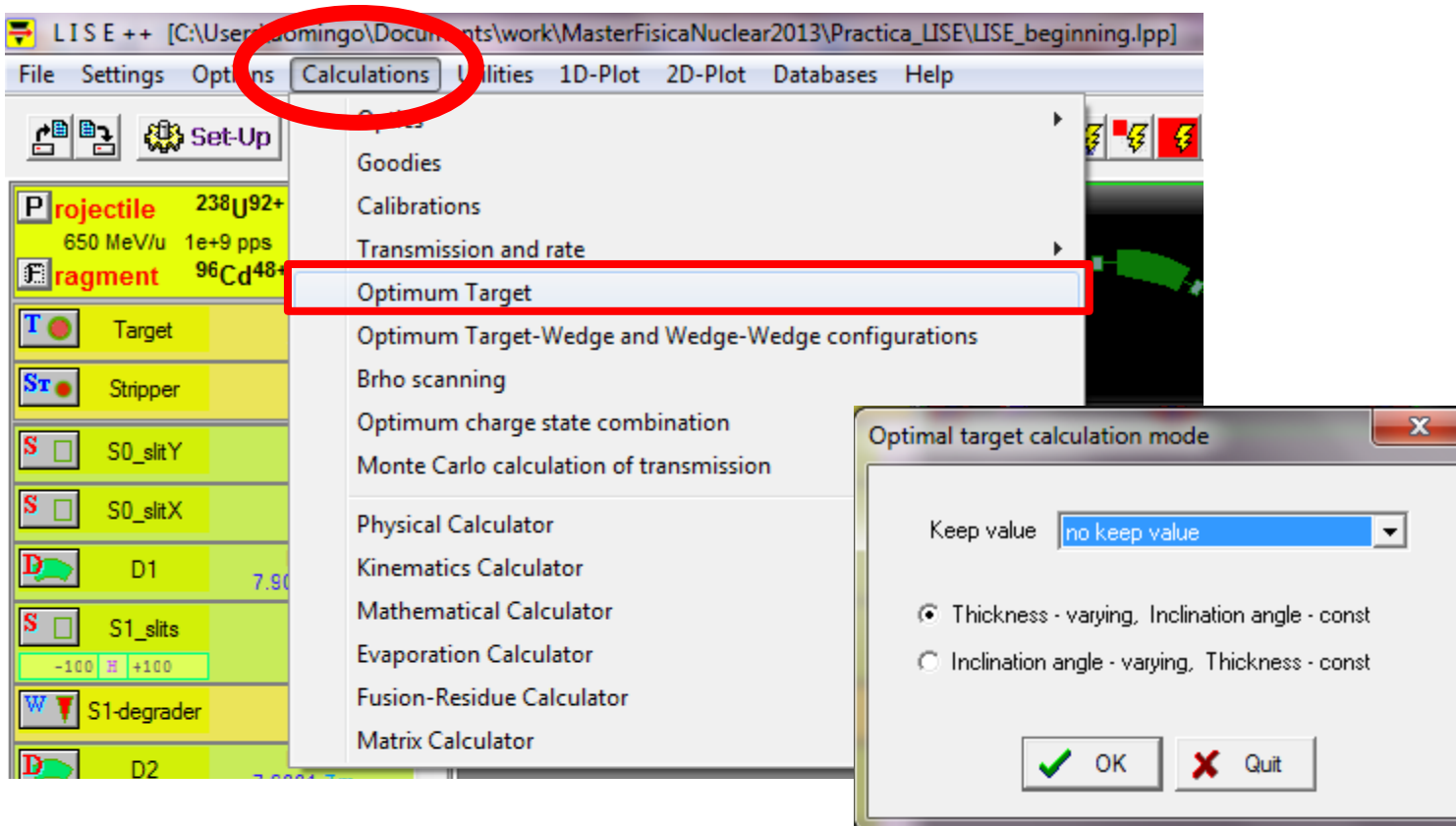
Central Plot Area:

- 3D plot titled "PROJECTILE FRAGMENT" showing a distribution of particles in a 3D space, with red arrows indicating movement directions.
- A schematic diagram on the right shows a particle trajectory through a series of slits and a detector labeled ^{94}Sn .

Practical aspects about the program:

4

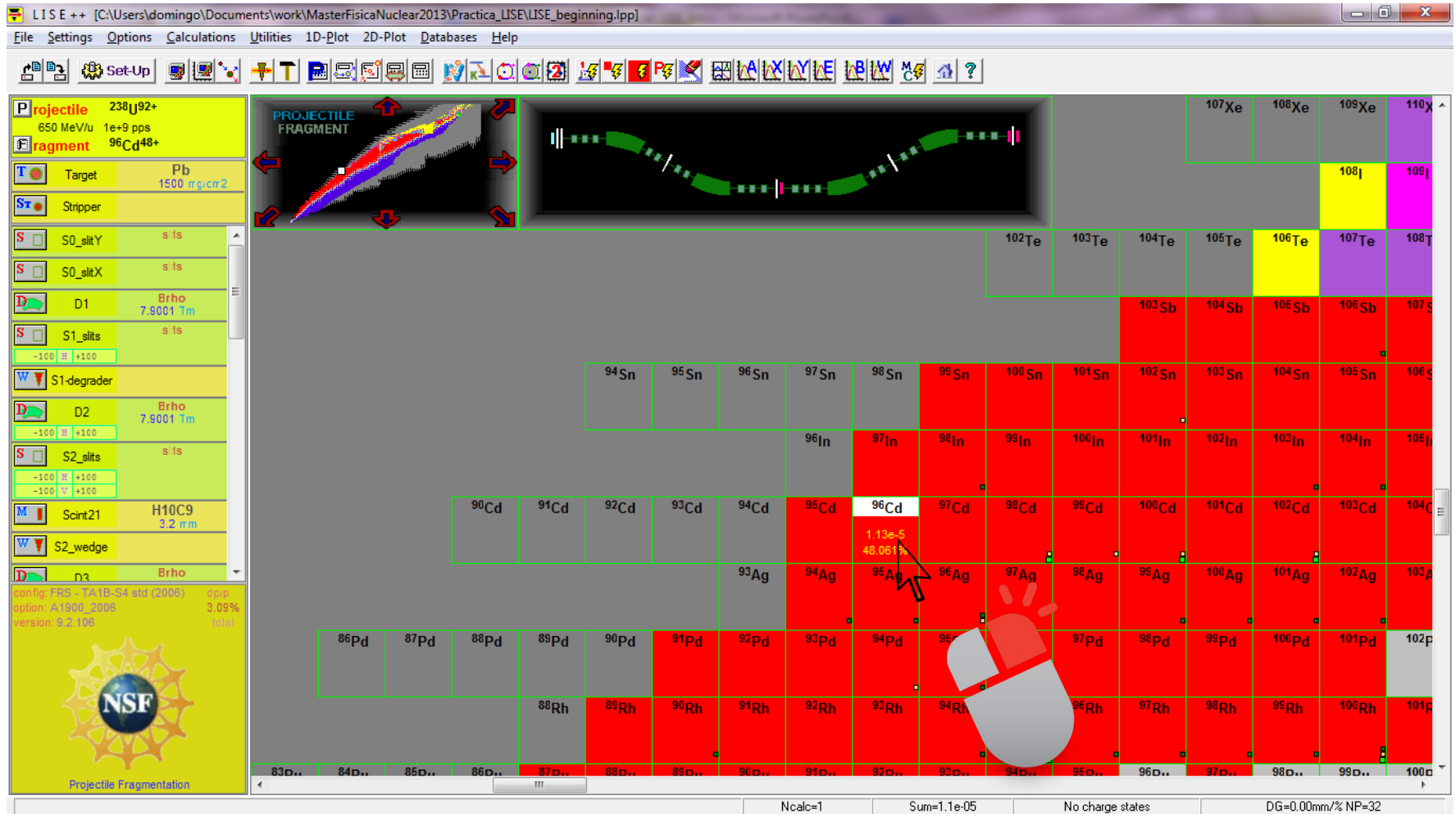
- Optimize the production target thickness (**each single time that primary or secondary beam parameters are modified**)



Practical aspects about the program:

5

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



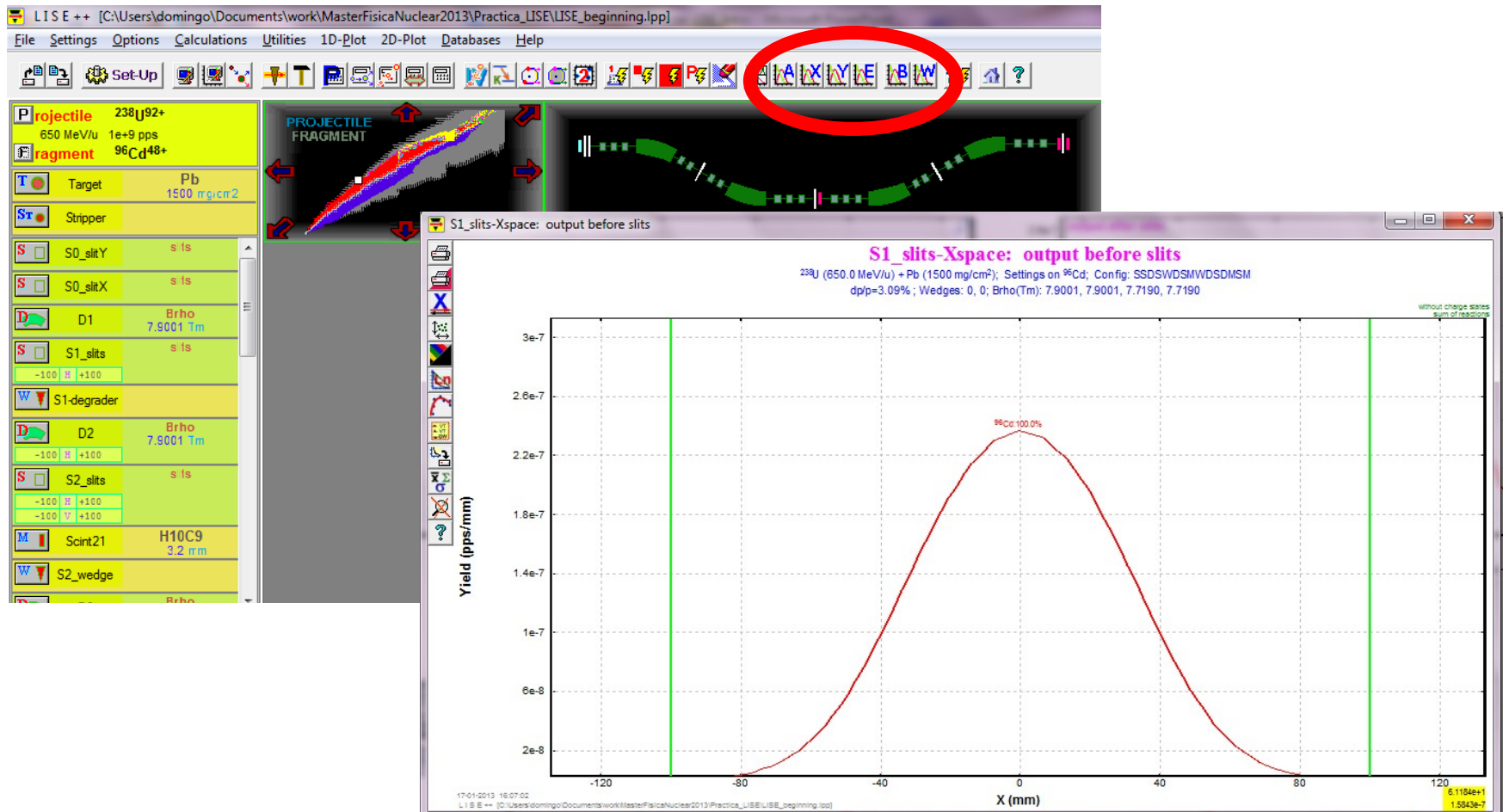
Right
click

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

The screenshot displays the 'Spectrometer designing' window in LIS E++. The 'Set-Up' button in the top-left toolbar is highlighted with a red circle. The main interface features a table of blocks and a 'Selected block' dialog.

Block	Given Name	Z-Q	Length, m	Enable
T	Target			+
Str	Stripper			+
S	Drift		0	+
S	Drift		0	+
D	Dipole	0	17.46	+
S	Drift		0	+
W	Wedge			+
M	Material			NO
M	Material			NO
M	Material			NO
M	Material			NO
D	Dipole	0	18.11	+
M	Material			NO
S	Drift		0	+
M	Material			+

Selected block: S1_slits

Enable: **Drift (space)**

Let call automatically: Block Length [m]: 0

Block name = S1_slits Length after this block [m]: 17.458

Sequence number: 6

Total

Number of Blocks: 86

Length [m]: 73.148

Insert block panel:

- Target
- Stripper after Target
- Wedge
- Material(Detector)
- Faraday cup
- Dispersive (Dipole)
- Wien velocity filter
- Drift (space)
- Beam Rotation
- Electric dipole
- Gas-filled separator
- Compensating Dipole
- RF separator
- Solenoid
- Delay (efficiency) block