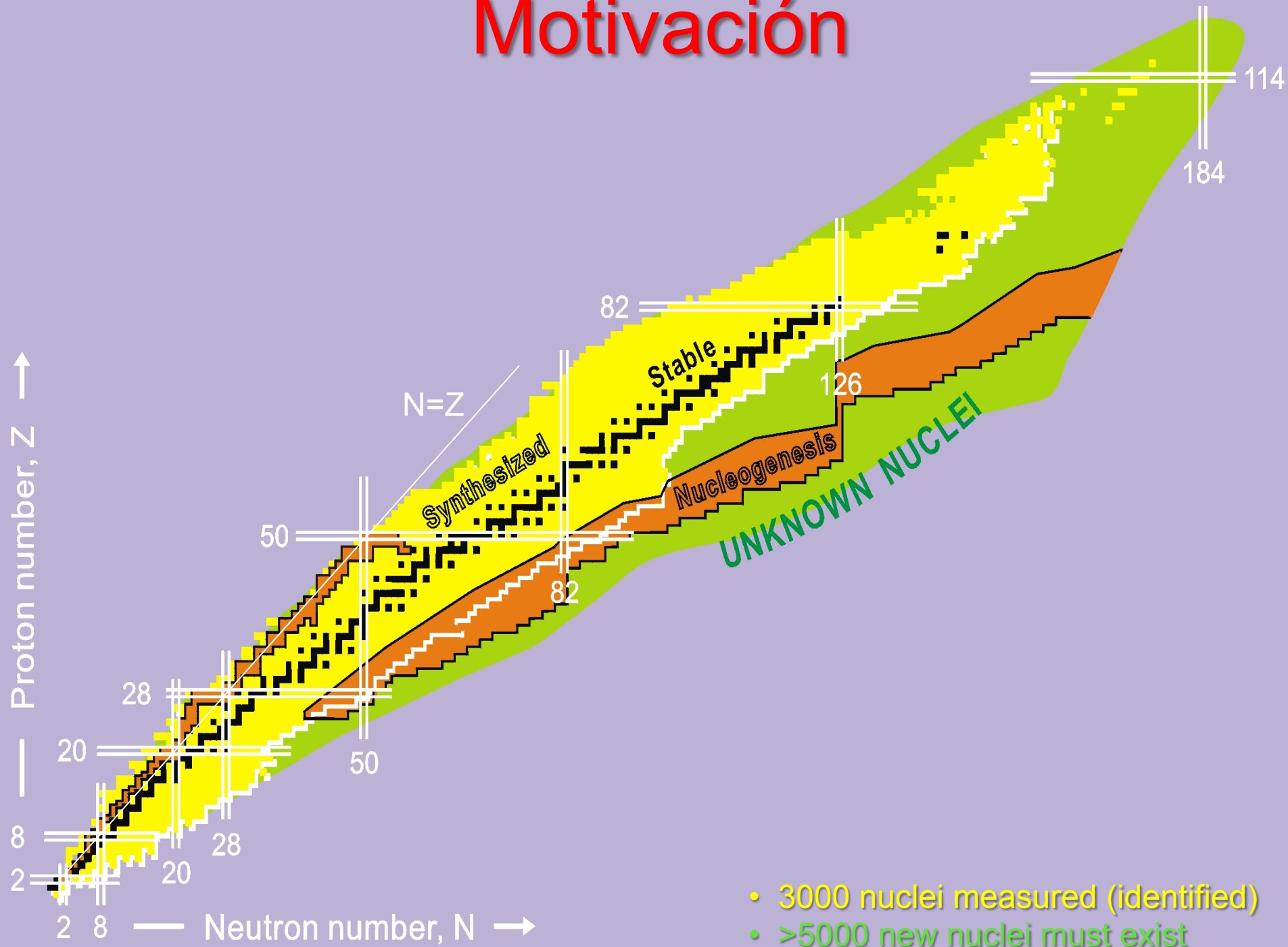


Introducción a LISE++

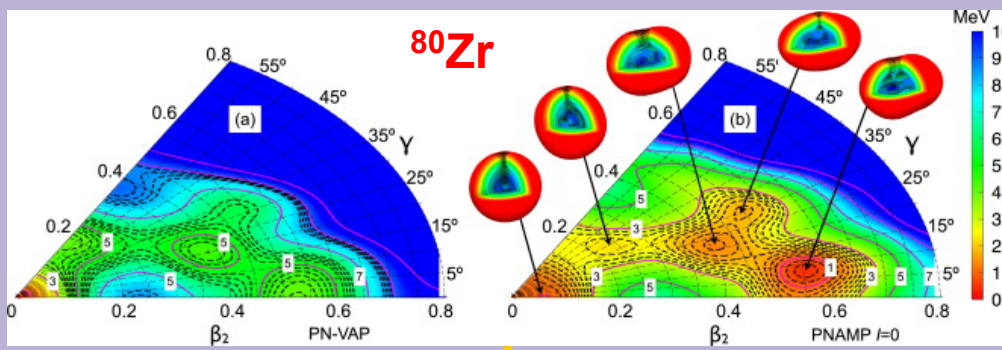
César Domingo Pardo

Instituto de Física Corpuscular
(CSIC-Universidad de Valencia)

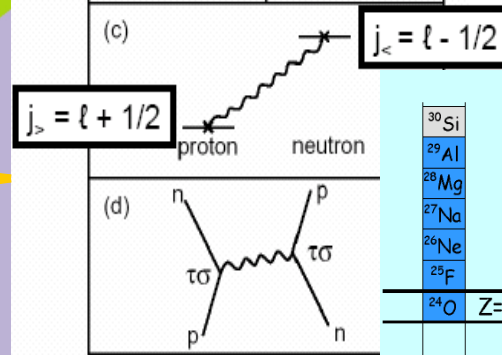
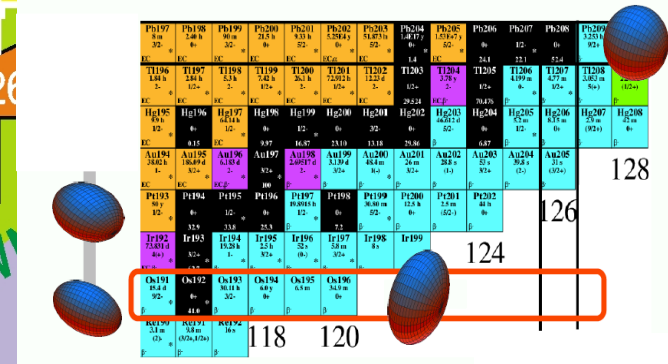
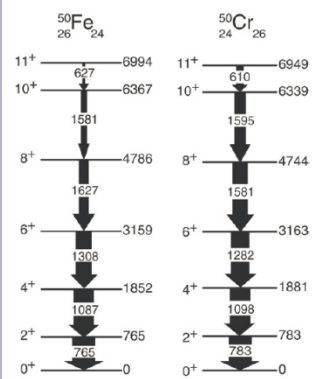
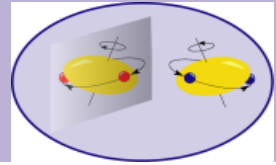
Motivación



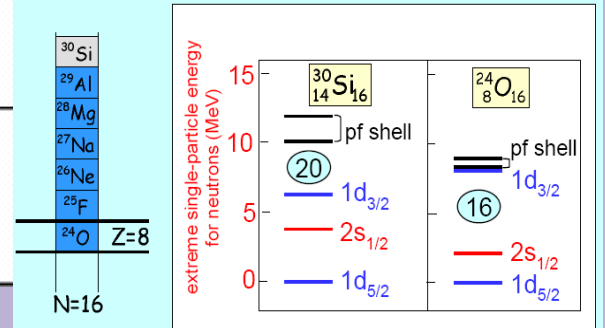
Motivación



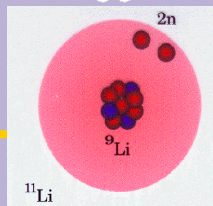
T.R.Rodriguez, PLB (2011)



New shell gaps



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

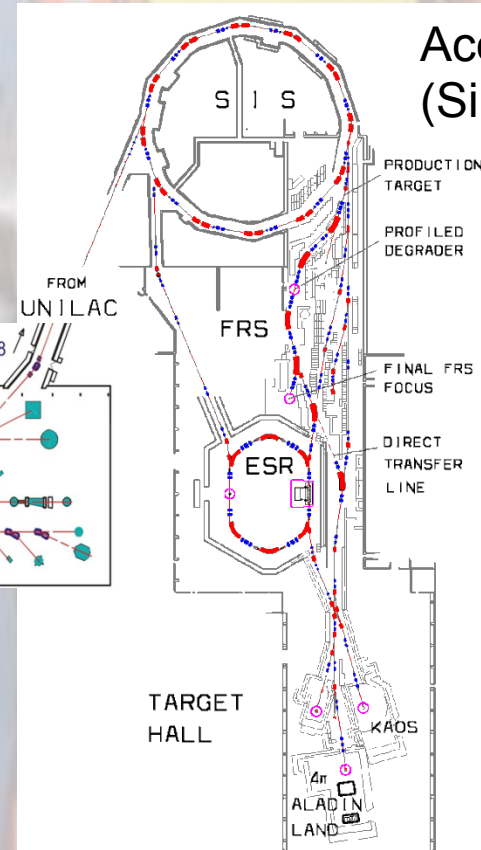
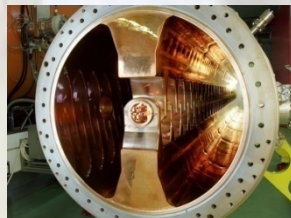
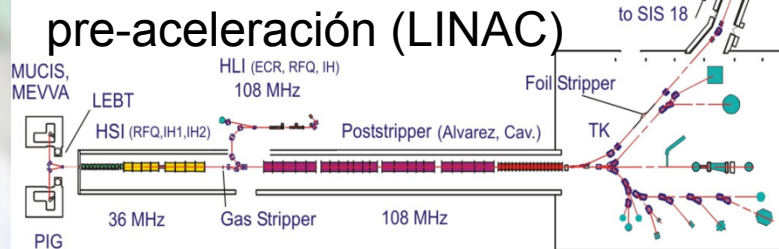


Neutron number, N →

Producción de haces de iones exóticos



Fuente
iones
estables



Aceleración
(Sincrotrón)

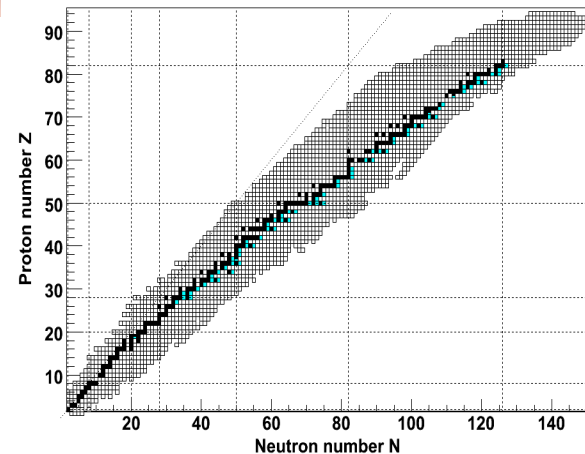
Producción de haces de iones exóticos



Es posible acelerar, cualquier isótopo estable, desde Hidrógeno hasta Uranio-238, para obtener un haz primario.

**Fuente
iones
estables**

^{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 ...)

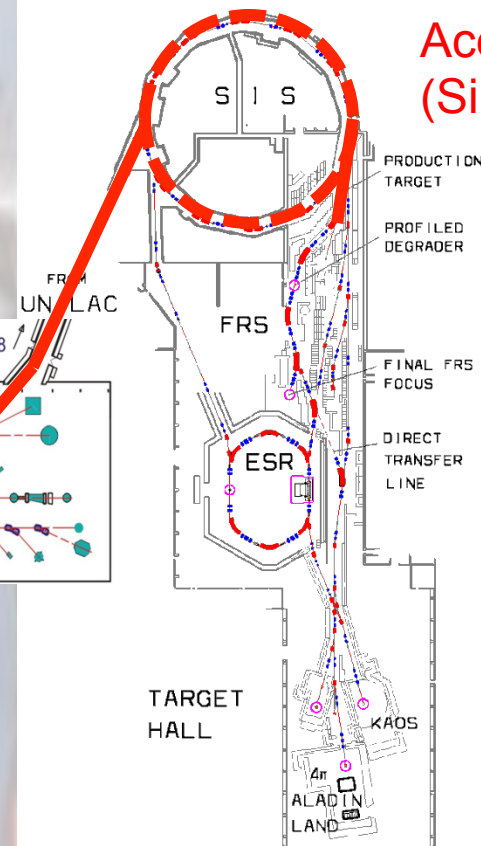
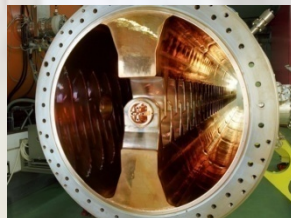
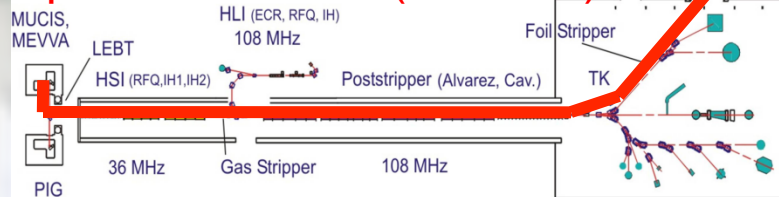


Producción de haces de iones exóticos



Fuente
iones
estables

pre-aceleración (ULINAC)

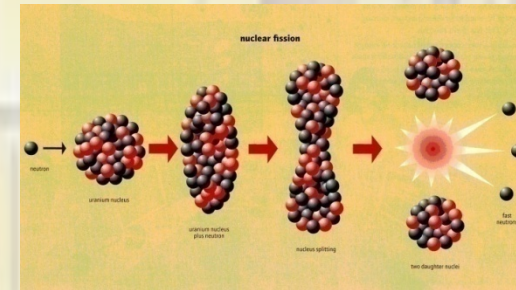
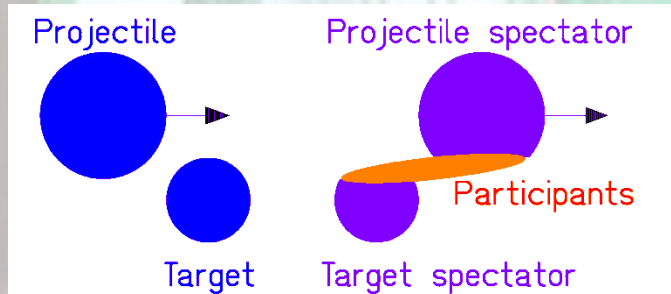


Aceleración
(Sincrotrón)

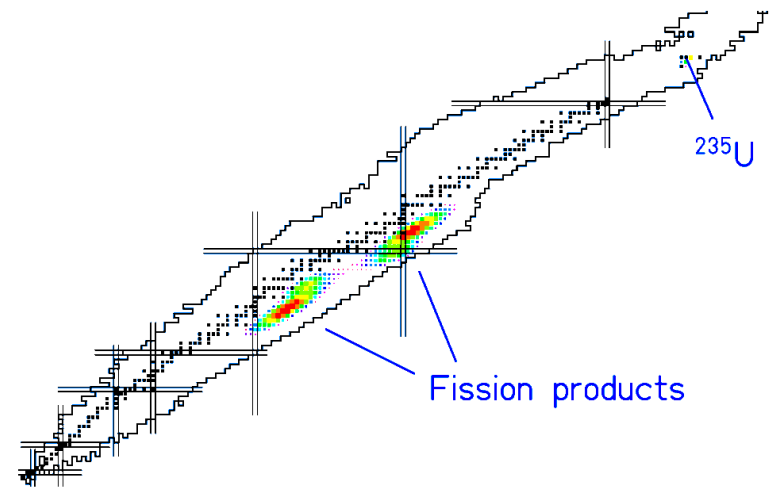
SIS18:
0.1-1 GeV/u

UNILAC:
11.4 MeV/u

Producción de haces de iones exóticos



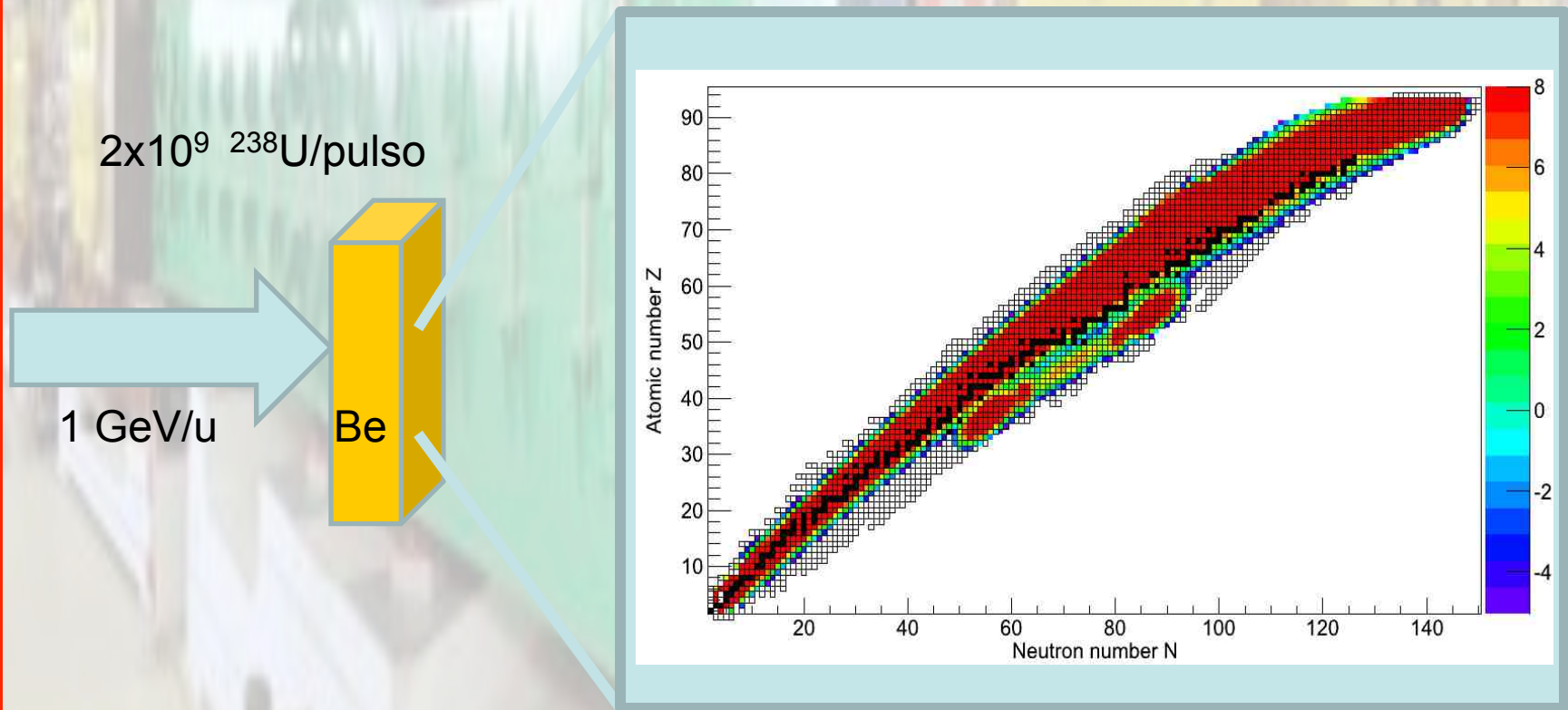
Fission induced by low-energy neutrons



Producción de haces de iones exóticos

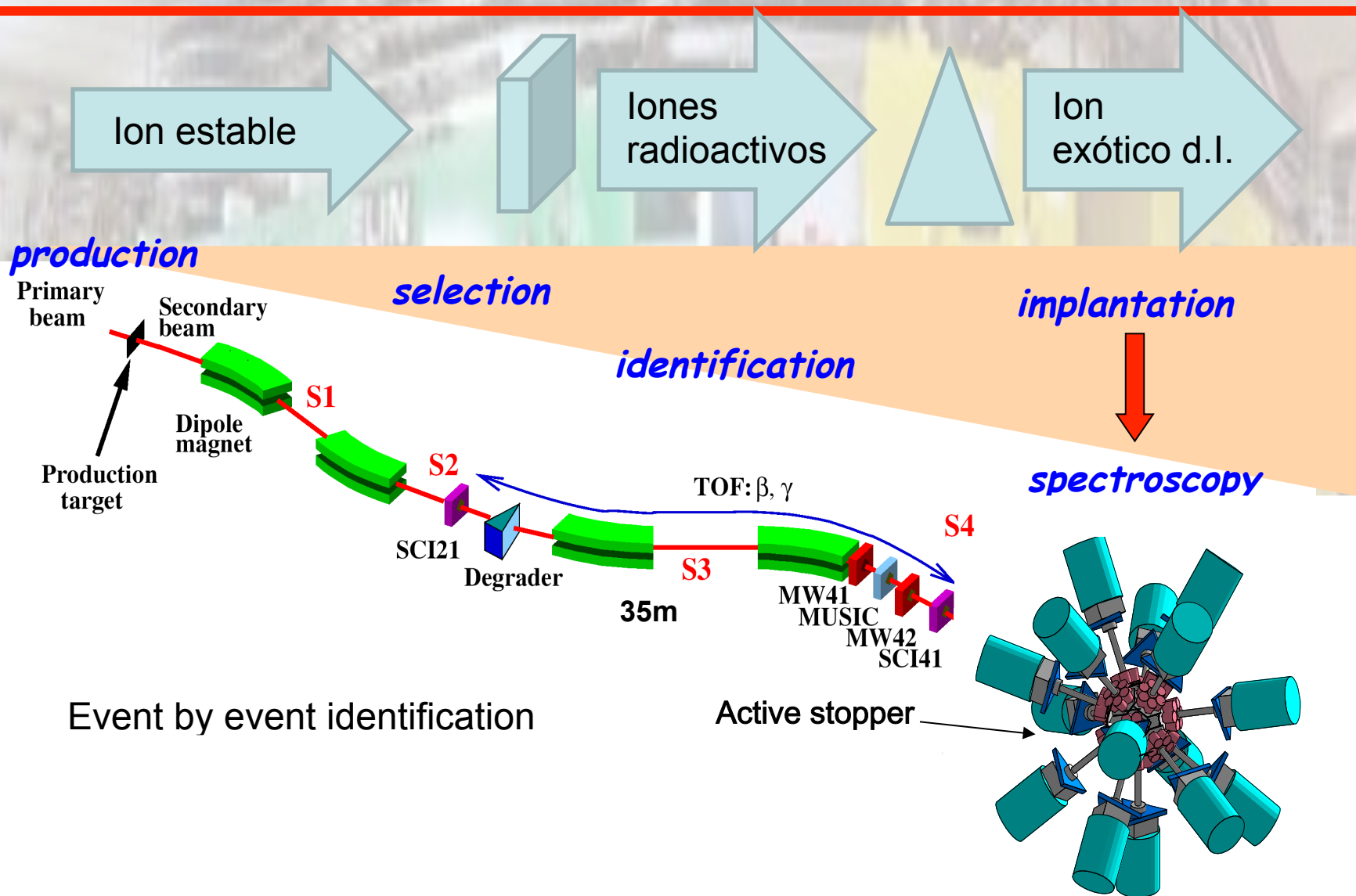


EJEMPLO:



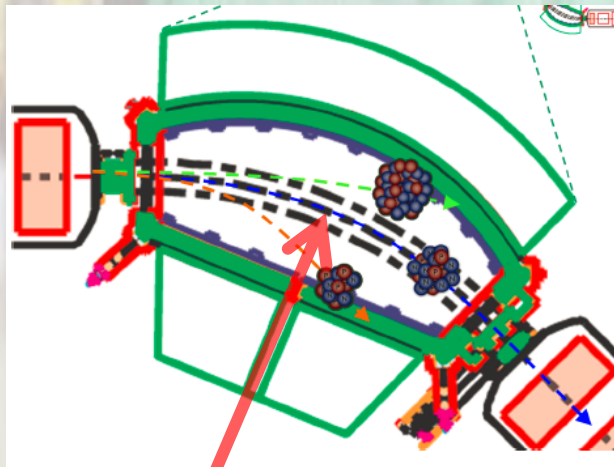
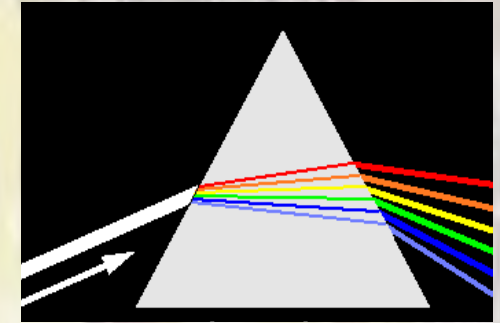
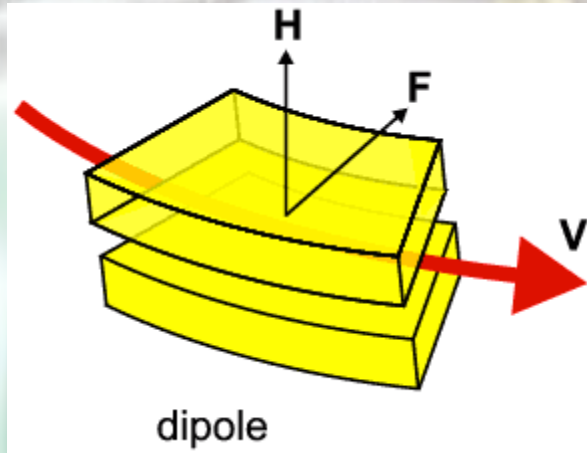
Tasas prohibitivamente altas para medirlos todos a la vez: hay que seleccionar una pequeña porción de todos ellos!

Selección/identificación del isótopo de interés



Selección del isótopo de interés

Dipolos magnéticos:

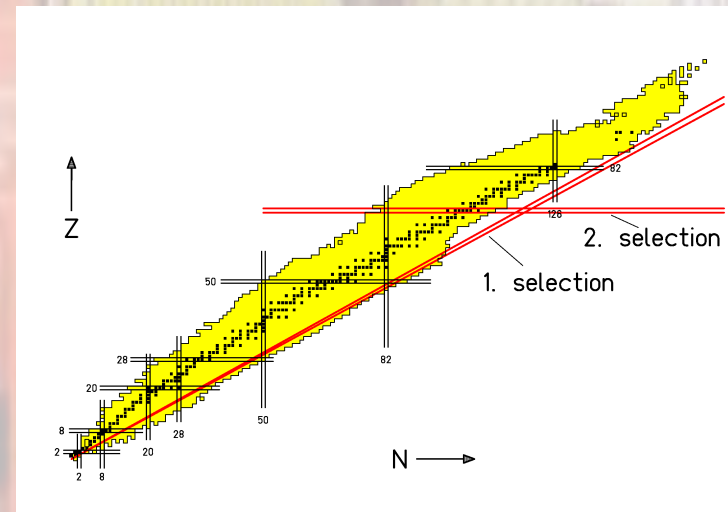


$$F_{\text{lorentz}} = F_{\text{centrípeta}}$$

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

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

$$B \cdot \rho = \beta \gamma c A / Z$$



$B\rho$ proportional to mass over charge

Dipoles: 1st Selection in A/Z

Selección/identificación del isótopo de interés

production

Primary beam

Secondary beam

Dipole magnet

Production target

selection

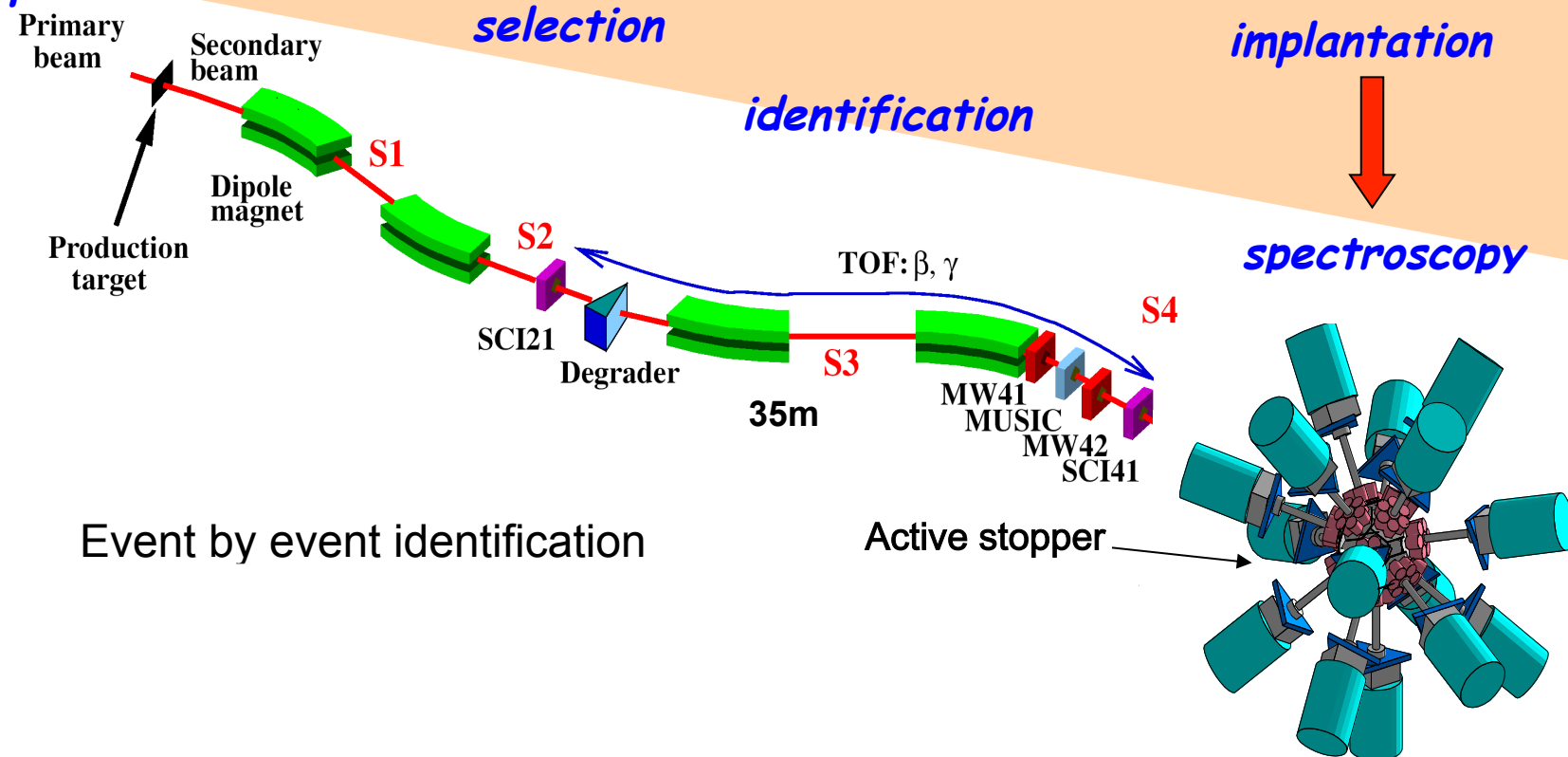
identification

implantation

spectroscopy

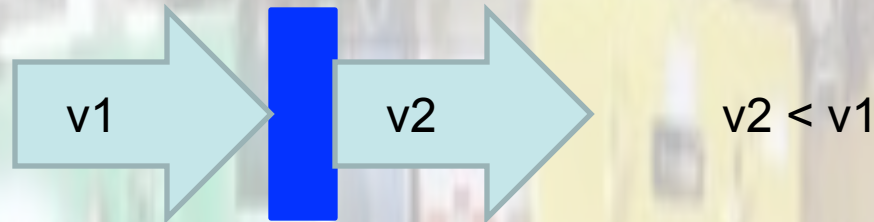
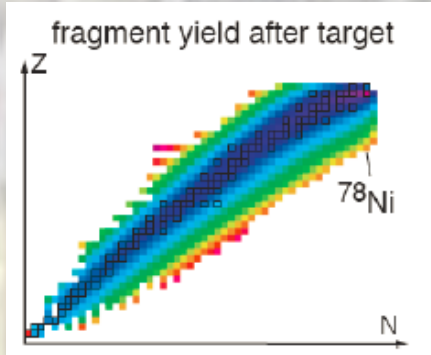
Event by event identification

Active stopper



Selección del isótopo de interés

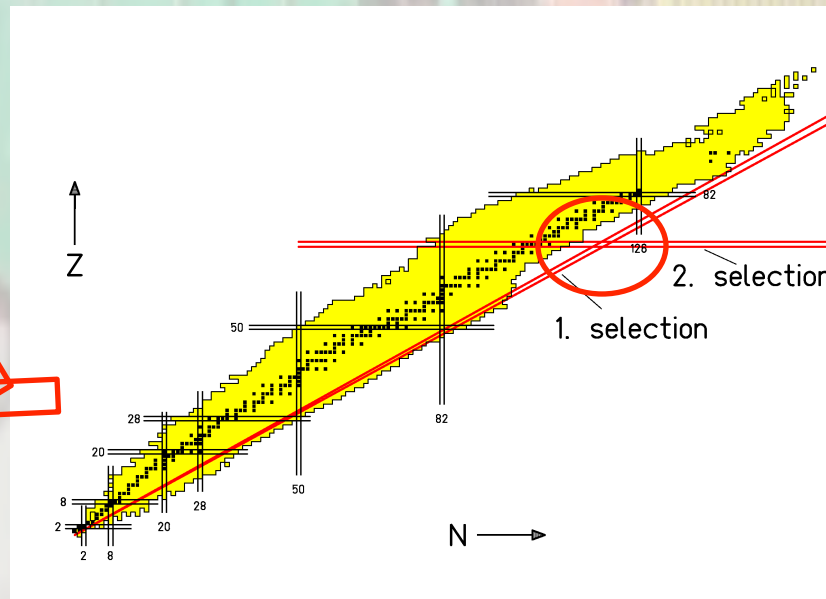
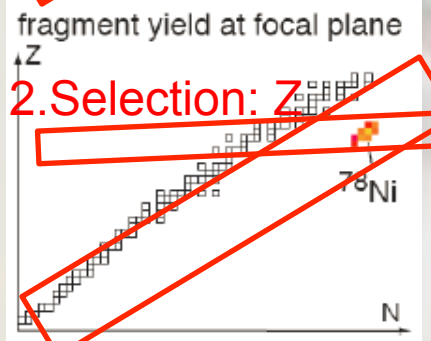
Degradadores:



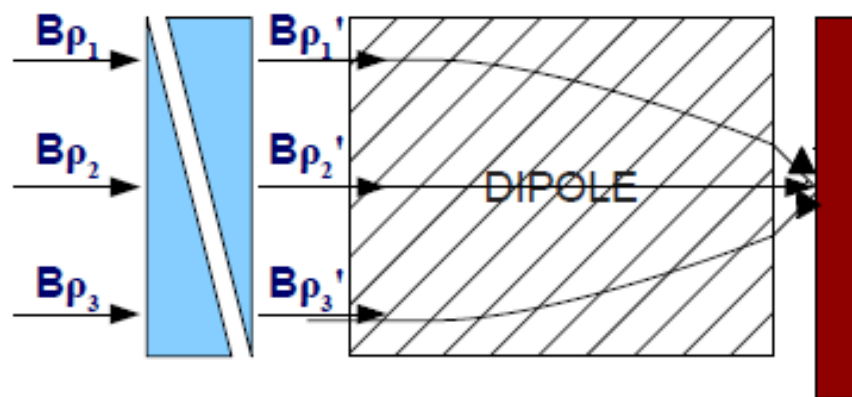
$$\frac{dE}{dx} = \frac{4\pi Z^2 e^4}{m_e v^2} N \left[\ln\left(\frac{2m_e \gamma^2 v^2}{I}\right) - \frac{v^2}{c_0^2} \right]$$

Eloss proportional to Z^2

Energy Degradar \rightarrow 2nd Selection: in Z

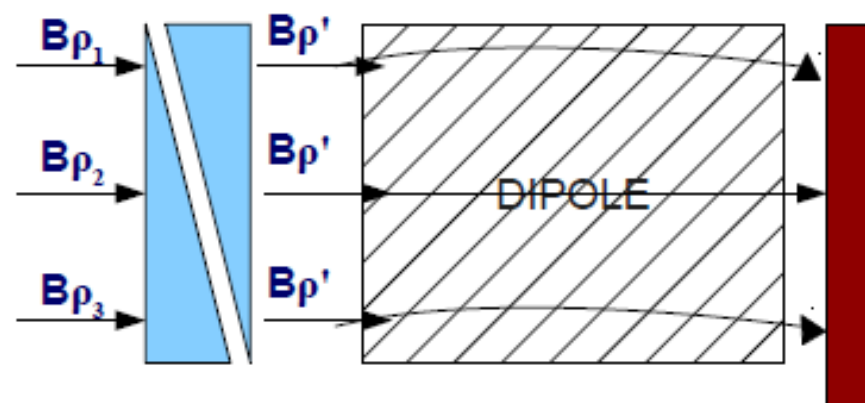


Selección del isótopo de interés



• ACHROMATIC MODE

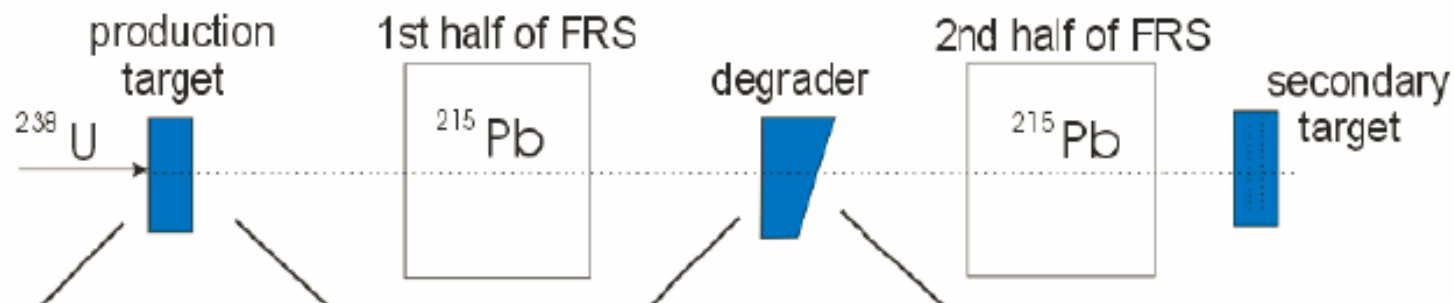
- Ions lose constant amount of energy in wedge
- All nuclei of same species arrive at same position on focal plane



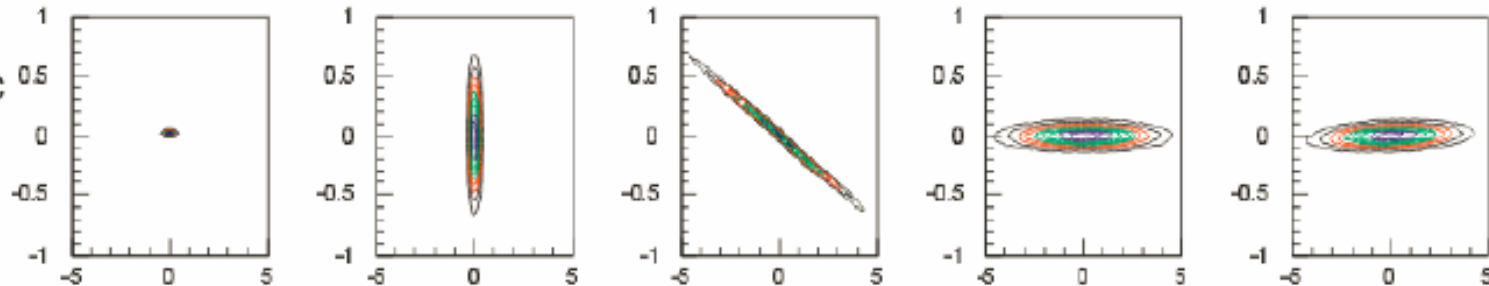
• MONOENERGETIC MODE

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

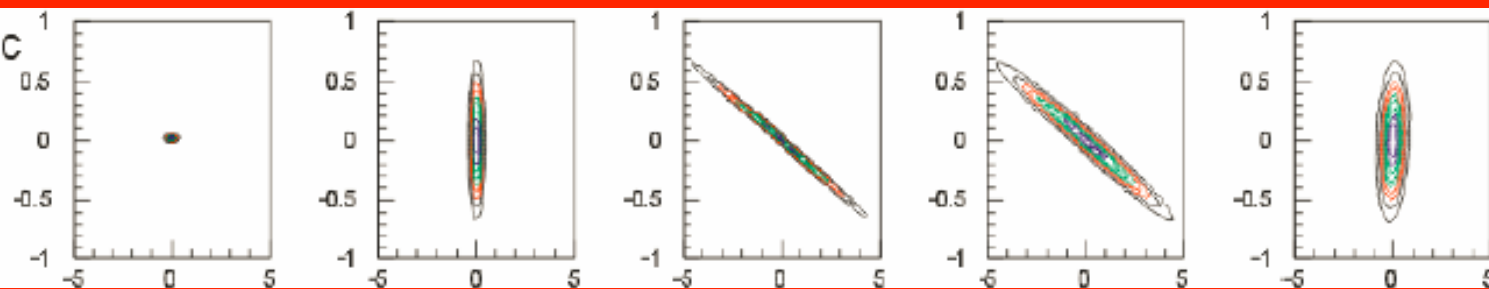
Selección del isótopo de interés



mono-energetic
 $\Delta p / p$
(%)



achromatic
 $\Delta p / p$
(%)



X (cm)

MONO

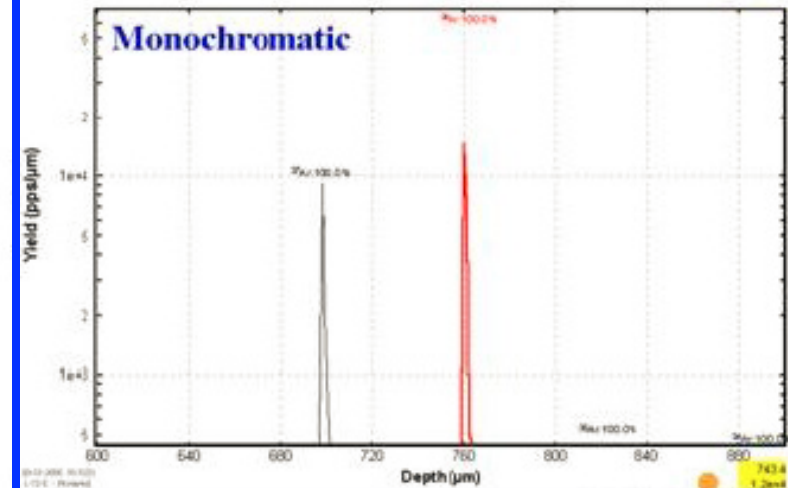
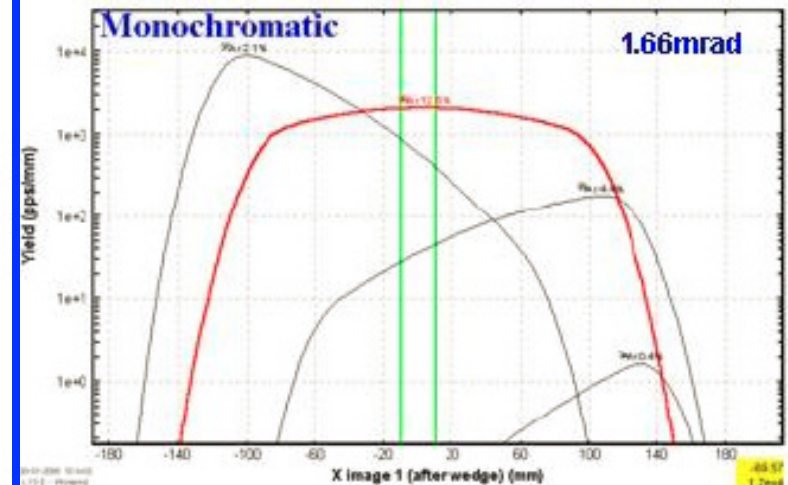
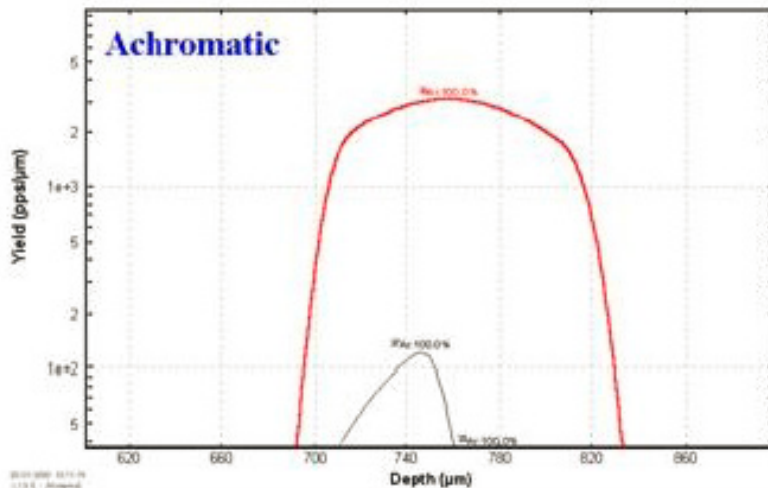
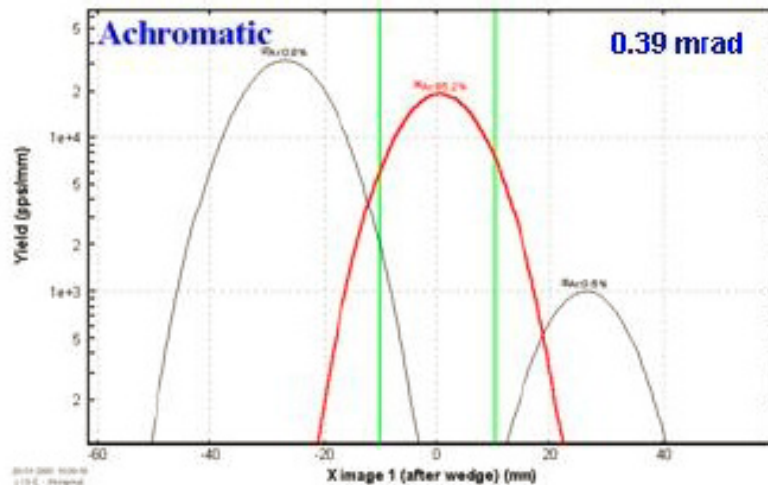
ACRO

Separación acromática y monoenergética

40Ar@50MeV/u + Ta 100 um – Degradador 200 um Al

ACRO

MONO



Selección del isótopo de interés

Selección final por medio de la técnica $B\rho - \Delta E - B\rho$

production

Primary beam
Production target

Secondary beam
Dipole magnet

S1

S2

SCI21

Degradar

35m

S3

MW41
MUSIC

MW42
SCI41

S4

TOF: β, γ

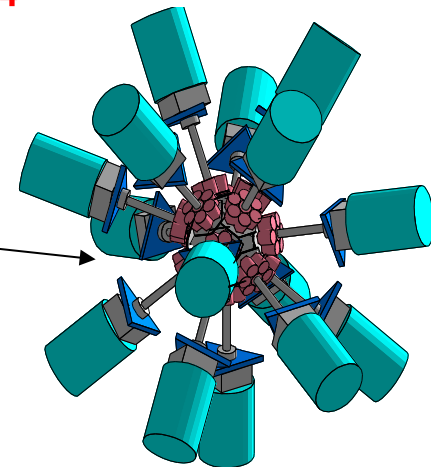
identification

implantation



spectroscopy

Active stopper



Identificación del isótopo de interés

Identificación por medio de detectores de tracking

production

Primary beam

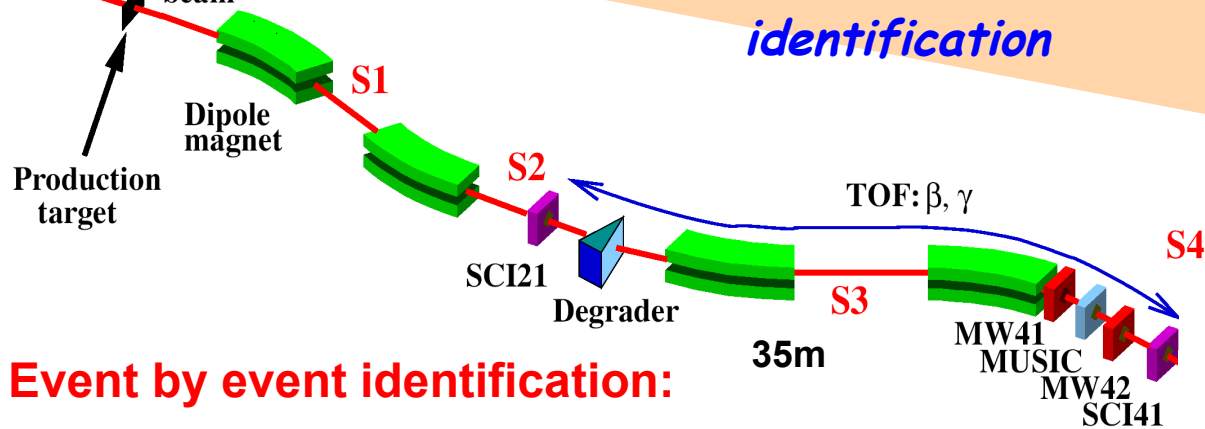
Secondary beam

selection

identification

implantation

spectroscopy



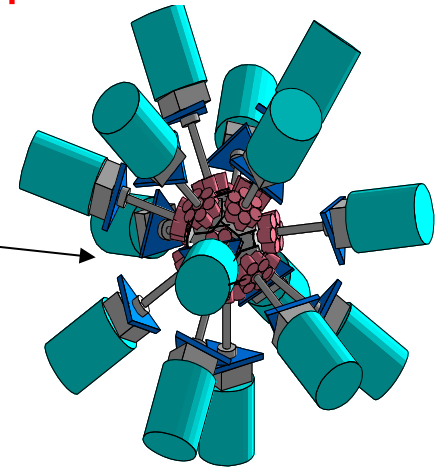
Event by event identification:

Ionization Chambers $\rightarrow \Delta E \rightarrow Z^2 \rightarrow \mathbf{Z}$

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

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

Active stopper



Identificación del isótopo de interés

Identificación por medio de detectores de tracking

production

Primary beam
Production target

Secondary beam
Dipole magnet

selection

S1

S2

SCI21

Degradar

identification

TOF: β , γ

35m

S3

MW41
MUSIC

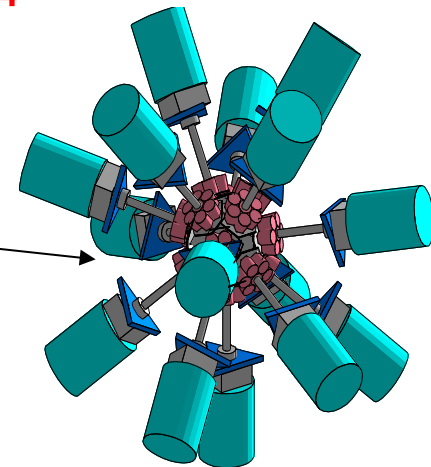
MW42
SCI41

S4

implantation



spectroscopy



Tracking Detectors → Total Rate Limits:

Total Rate Limit @ S2 = 3E6 Hz

Total Rate Limit @ S4 = 1E4 Hz

Active stopper

Aspectos prácticos del código:

0



- LISE++ es un código de libre uso, se puede descargar de internet y no necesita instalación.
- Creado por O.Tarasov y D.Bazin de MSU-NSCL (USA).
- Útil para calcular la producción y transmisión de fragmentos exóticos de interés en los experimentos de física nuclear.
- Muchas funcionalidades añadidas, como cálculo del rango y la pérdida de energía en materiales, y un largo etc.
- La mejor forma de aprender el código, es jugar/practicar con él.

Aspectos prácticos del código:

1

- Definir las características del haz primario (proyector isótopo, energía e intensidad)
- Definir el haz secundario (setting fragment)

The screenshot displays the Lise++ software interface. The main window shows a list of components on the left and a 2D plot of the beam trajectory on the right. A red circle highlights the 'Projectile' and 'Fragment' settings in the component list. Two dialog boxes are overlaid on the main window:

Beam Dialog:

- 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:** 14.72 enA, 0.16 pnA, 1e+9 pps (selected), 0.02475 KW.
- Emittance:** 1. X mm, 2. T mrad, 3. Y mm, 4. P mrad, 5. L mm, 6. D %.

Setting Fragment Dialog:

- Fragment settings:** A (96), Element (Cd), Z (48).
- Charge states:** 48+ D1.

The main window also shows a list of components: Projectile (238U92+, 650 MeV/u, 1e+9 pps), Fragment (96Cd48+), Target (1500 mg/cm2), Stripper, S0_slitY, S0_slitX, D1 (Brho 7.9001 Tm), S1_slits (-100 to +100), S1-degrader, and D2 (Brho 7.9001 Tm).

Aspectos prácticos del código:

2

- Definir las características del blanco de producción (Target)

The screenshot displays the LISE++ software interface. The main window shows a list of components in a simulation stack, including a projectile, target, and various slits and degraders. The 'Target' component is highlighted with a red circle. A red arrow points from this circle to a 'Target' dialog box that is open in the foreground.

The 'Target' dialog box contains the following settings:

- Target:** Pb
- Density:** 11.34 g/cm3
- State:** ☒ Solid, ☐ Gas
- Dimension:** ☒ mg/cm2 & micron, ☐ g/cm2 & mm
- Angle:** 0 degrees, with a 'Calculate' button
- Thickness at 0 degrees:** ☐ 1322.7513 micron, ☒ 1500 mg/cm2
- Effective Thickness:** ☐ 1322.7513 micron, ☐ 1500 mg/cm2
- Thickness defect:** (empty field)
- Absorbed Dose:** (empty field)
- d / Range (beam):** 0.161
- Energy Loss in the target box [KW]:** 0.00303
- Atoms / cm2:** 4.36e+21
- Buttons:** OK, Cancel, Cut (Slits), Compound dictionary

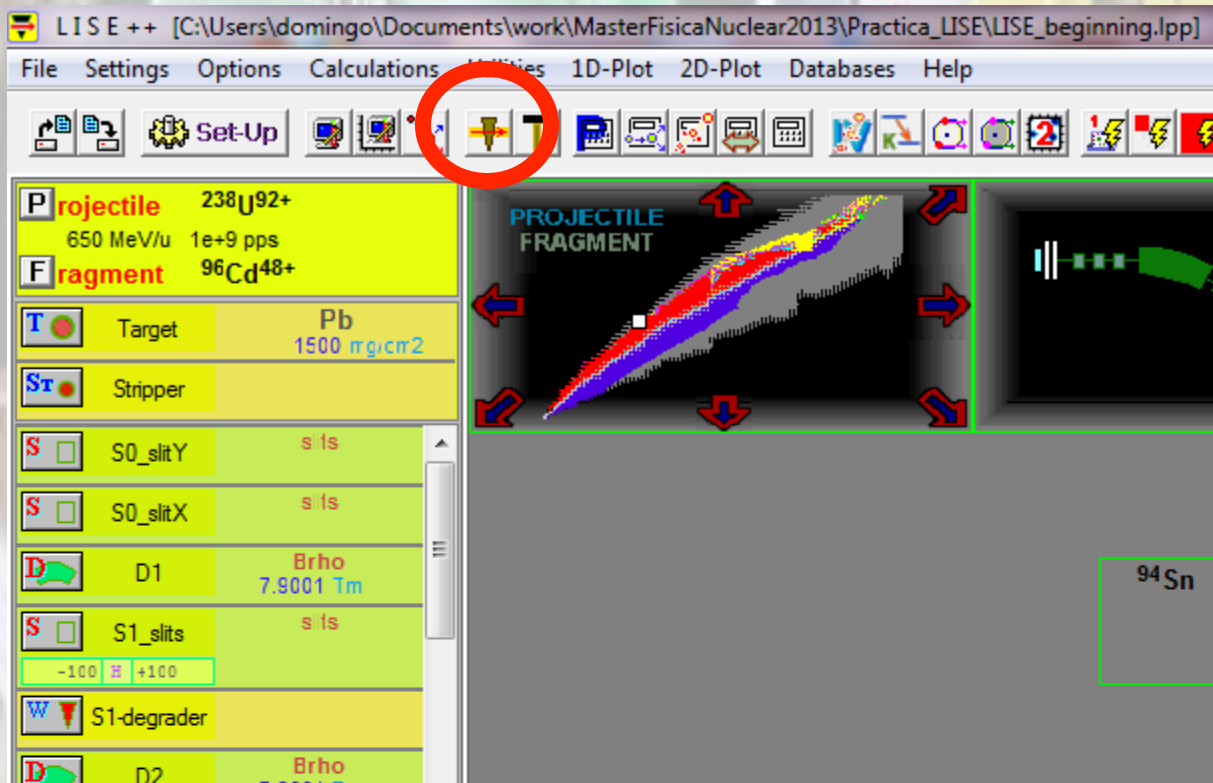
The main window also shows a list of components with their properties:

Component	Properties
Projectile	238U92+, 650 MeV/u, 1e+9 pps
Target	Pb, 1500 mg/cm2
S0_slitY	s is
S0_slitX	s is
D1	Brho, 7.9001 Tm
S1_slits	s is
S1-degrader	
D2	Brho

Aspectos prácticos del código:

3

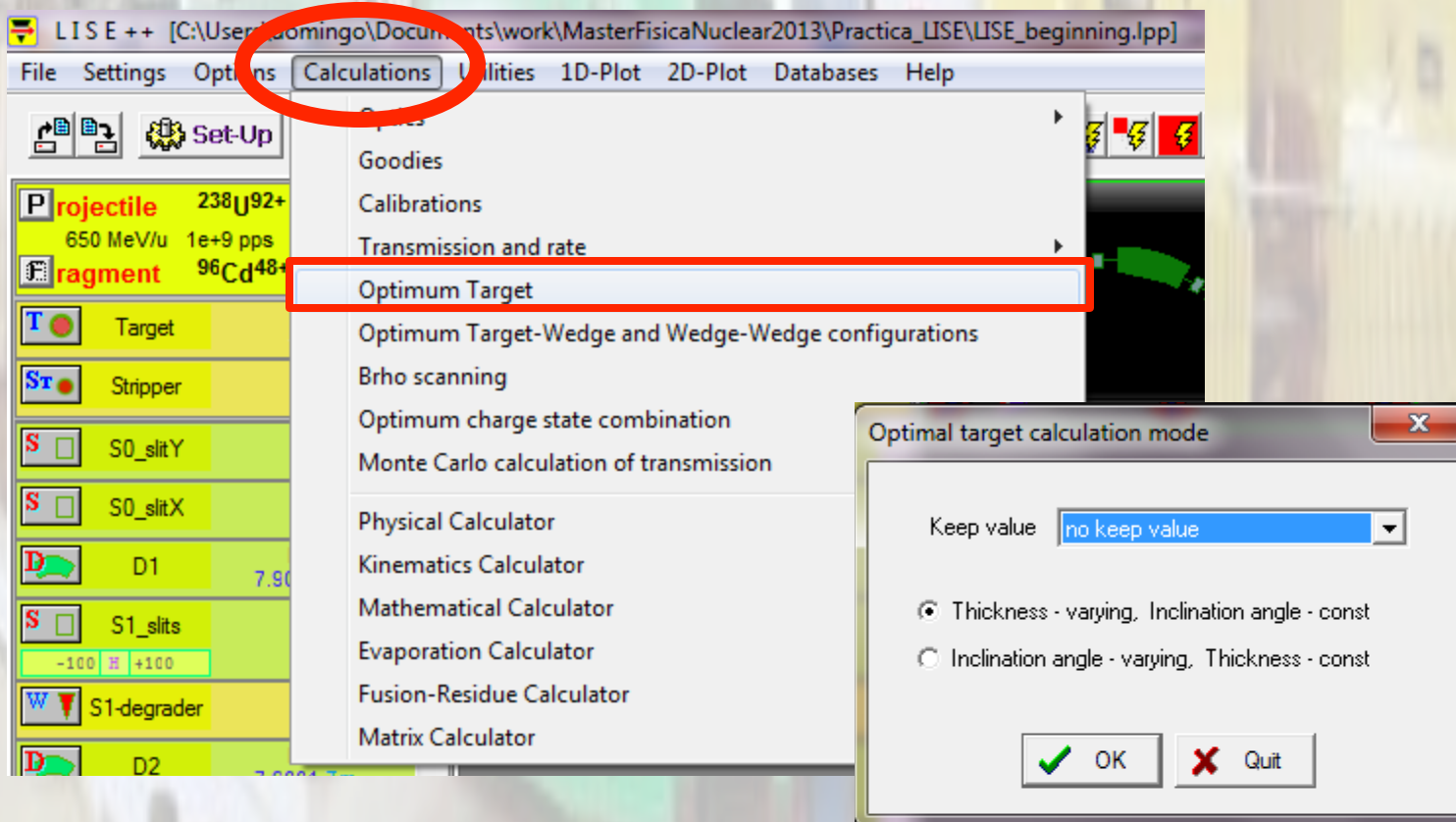
- Ajustar los campos magnéticos (Br) para el fragmento de interés (setting fragment)



Aspectos prácticos del código:

4

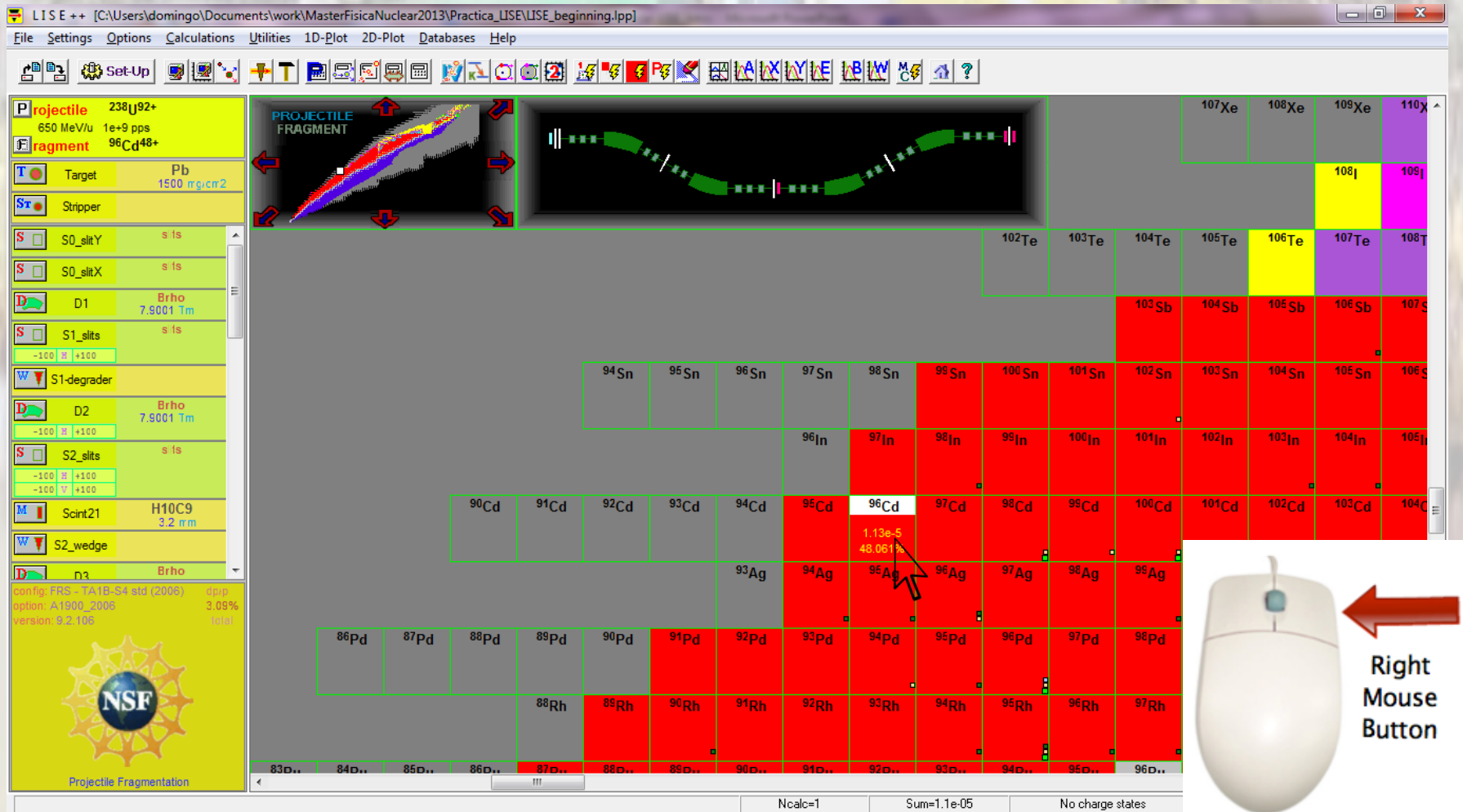
- Optimizar el target de producción (**cada vez que se modifiquen los parámetros del haz primario o del haz secundario**)



Aspectos prácticos del código:

5

- Calcular la producción del fragmento de interés (en primera aproximación):

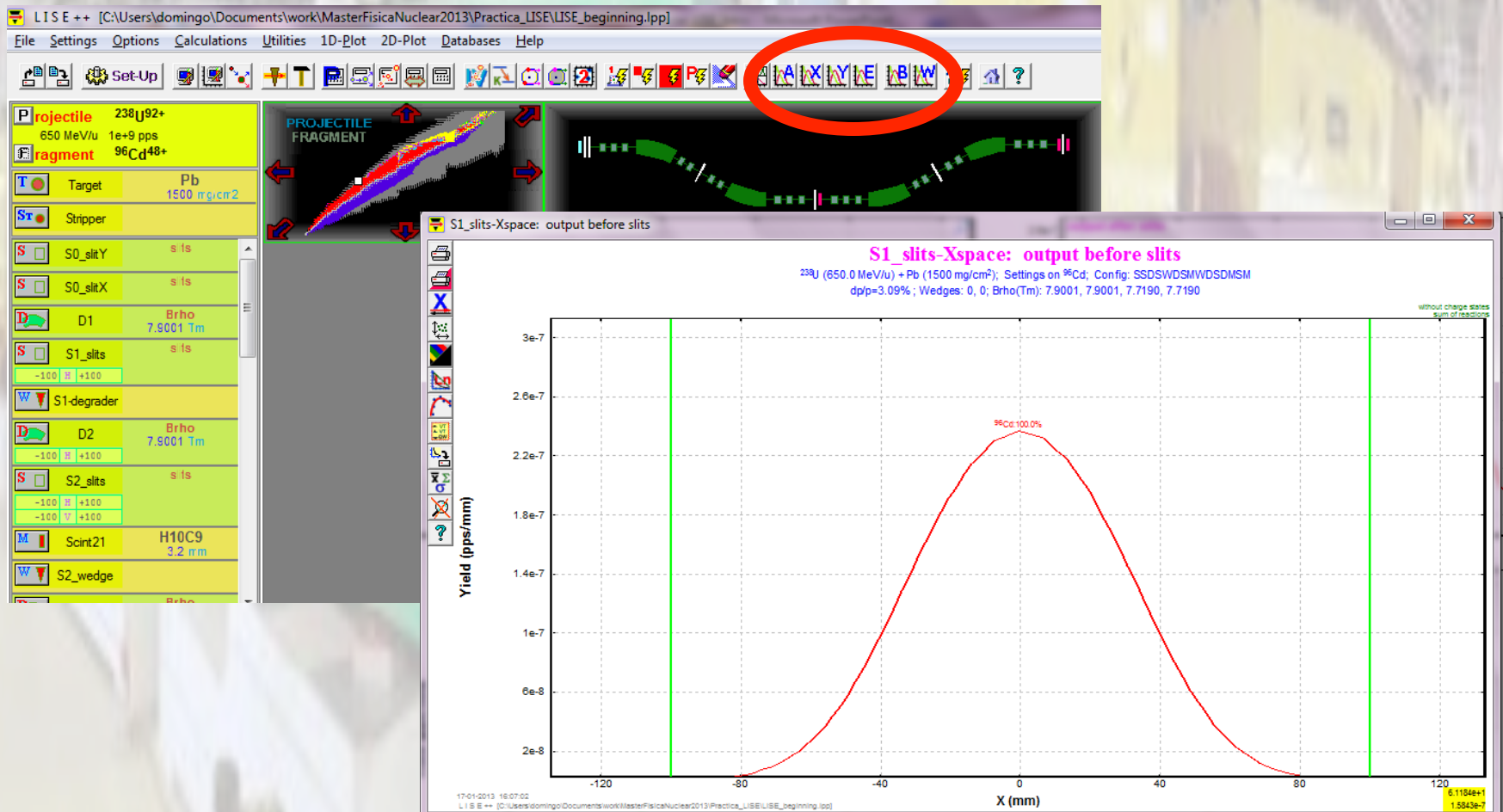


Aspectos prácticos del código:

6

- Menús de uso frecuente:

Distribución del RIB en posiciones (X) y en energía (E)

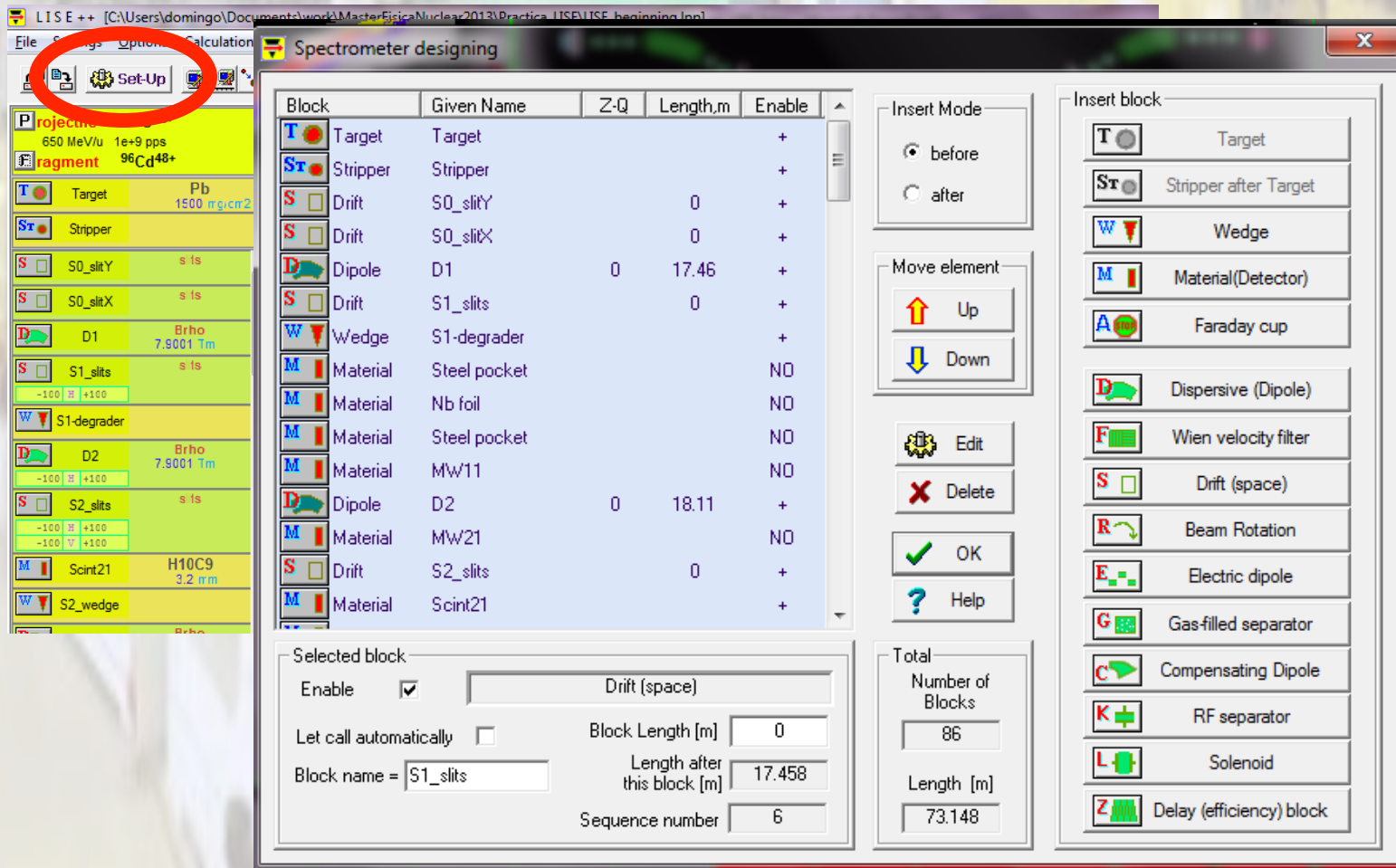


Aspectos prácticos del código:

6

- Menús de uso frecuente:

Diseño del espectrómetro: desactivar elementos, ajustar S2-wedge, añadir una Faraday Cup, etc



The screenshot shows the LITSE++ Spectrometer designing window. The 'Set-Up' menu is circled in red. The window displays a list of blocks, a table of block parameters, and a list of available blocks to insert.

Block	Given Name	Z-Q	Length,m	Enable
Target	Target			+
Stripper	Stripper			+
Drift	S0_slitY		0	+
Drift	S0_slitX		0	+
Dipole	D1	0	17.46	+
Drift	S1_slits		0	+
Wedge	S1-degrader			+
Material	Steel pocket			NO
Material	Nb foil			NO
Material	Steel pocket			NO
Material	MW11			NO
Dipole	D2	0	18.11	+
Material	MW21			NO
Drift	S2_slits		0	+
Material	Scint21			+

Selected block: Drift (space)

Enable: ☒ Block Length [m]: 0

Let call automatically: ☐ Length after this block [m]: 17.458

Block name = S1_slits Sequence number: 6

Total Number of Blocks: 86 Length [m]: 73.148

Insert Mode: ☐ before ☐ after

Move element:

Insert block:

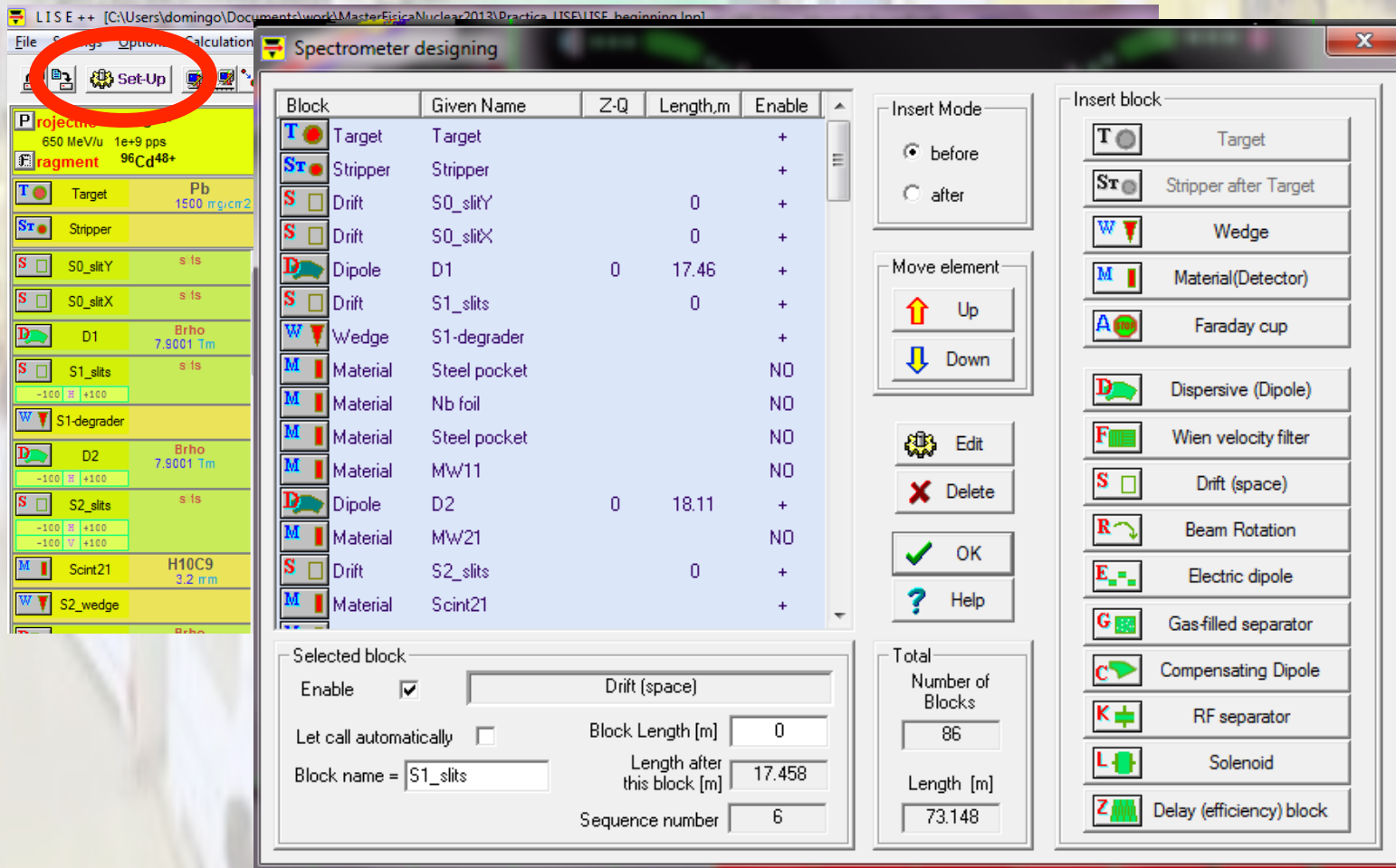
- Target
- Stripper after Target
- Wedge
- Material(Detector)
- Faraday cup
- Dispersive (Dipole)
- Wien velocity filter
- Drift (space)
- Beam Rotation
- Electric dipole
- Gas-filled separator
- Compensating Dipole
- RF separator
- Solenoid
- Delay (efficiency) block

Aspectos prácticos del código:

6

- Menús de uso frecuente:

Diseño del espectrómetro: desactivar elementos, ajustar S2-wedge, añadir una Faraday Cup, etc



The screenshot shows the LITSE++ Spectrometer designing window. The 'Set-Up' menu is circled in red. The window displays a list of blocks, a table of block parameters, and a list of available blocks to insert.

Block	Given Name	Z-Q	Length,m	Enable
Target	Target			+
Stripper	Stripper			+
Drift	S0_slitY		0	+
Drift	S0_slitX		0	+
Dipole	D1	0	17.46	+
Drift	S1_slits		0	+
Wedge	S1-degrader			+
Material	Steel pocket			NO
Material	Nb foil			NO
Material	Steel pocket			NO
Material	MW11			NO
Dipole	D2	0	18.11	+
Material	MW21			NO
Drift	S2_slits		0	+
Material	Scint21			+

Selected block: Drift (space)

Enable: ☒ Block Length [m]: 0

Let call automatically: ☐ Length after this block [m]: 17.458

Block name = S1_slits Sequence number: 6

Total Number of Blocks: 86 Length [m]: 73.148

Insert Mode: ☐ before ☐ after

Move element:

Insert block:

- 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