Estimation of Magnetic Rigidities for Experiments Involving the S800 Spectrograph

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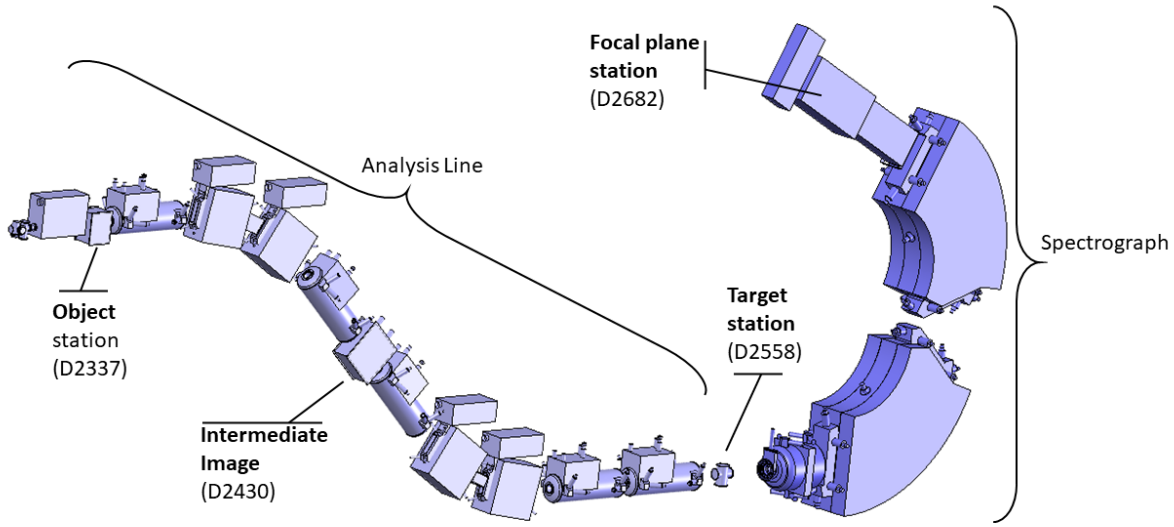
1. Introduction

The S800 Spectrograph has two parts: The analysis line (running from the Object position to the Target Station) and the spectrograph itself (See Fig. 1). The maximum magnetic rigidity (Bρ) of these two sections is defined by the maximum fields and bending radius of the dipole magnets, and by the maximum currents (fields) of that the different quadrupoles can withstand. In the case of the spectrograph, the typical maximum value is 4 Tm. As for the analysis line, the limit depends slightly on the optics mode used (focus or dispersion matched). Typical maximum values for these two modes are **~5 Tm** (dispersion matched), and **~4.2 Tm** (focus mode).



2. Evaluation of Magnetic Rigidities in S800 Experiments

During the preparation of a FRIB proposal, it is important to estimate the rigidities of the nuclear beams involved in order to make sure that they do not exceed the maximum rigidities of the S800. These rigidities depend on the mass-over-charge ratio and velocity of the nucleus:

$$B\rho\ (in\ Tm) = \frac{A}{Q} \cdot \beta\gamma \cdot \frac{uc}{e} = 3.1071 \cdot \frac{A}{Q} \cdot \beta\gamma$$

where *e* is the electron charge, *u* is the amu in MeV/u, *c* is the speed of light, and

$\gamma = \frac{1}{\sqrt{1-\beta^2}}$.

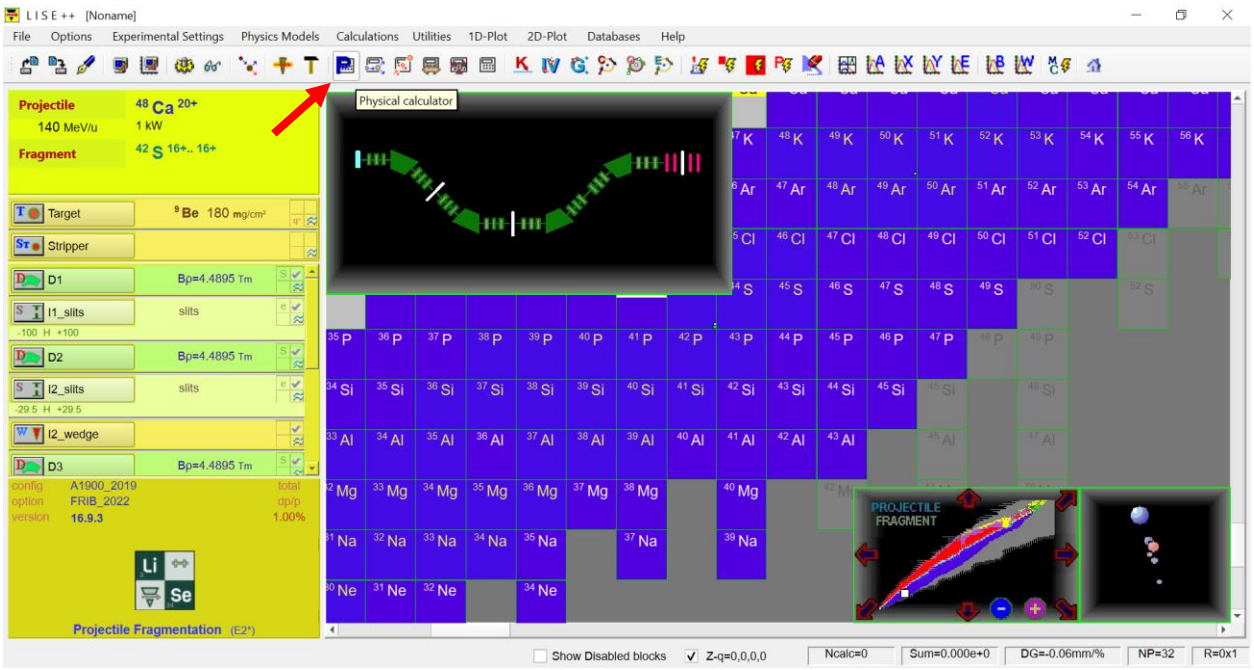
The following guideline describes how to evaluate the magnetic rigidity of a nuclear beam using the Physical Calculator of LISE++:

2.1. DETERMINATION OF MAGNETIC RIGIDITY FROM ENERGY

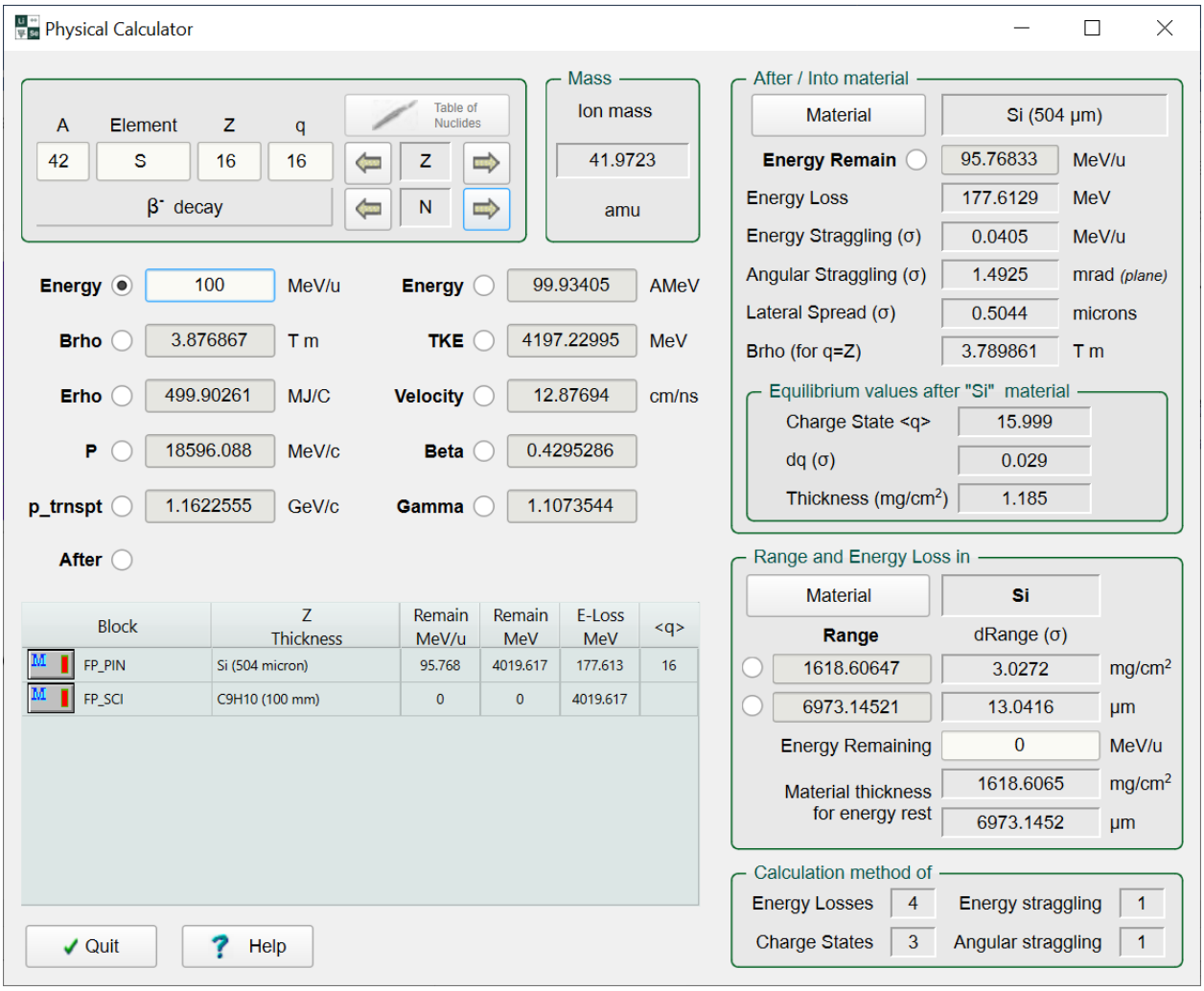
LISE++ Physics Calculator allows to straightforwardly calculate the magnetic rigidity of a nuclear beam.The information required is the energy of the beam provided by ARIS **(ARIS beam)** and the energy of the reaction product after the S800 target **(S800 recoil)** , as well as their mass and proton numbers (**A and Z**), and their charge state **Q**.

Step 1

Open LISE++ and click on the Physical Calculator icon shown in the figure below (see red arrow)



The Physical Calculator window will pop out (see Figure below).

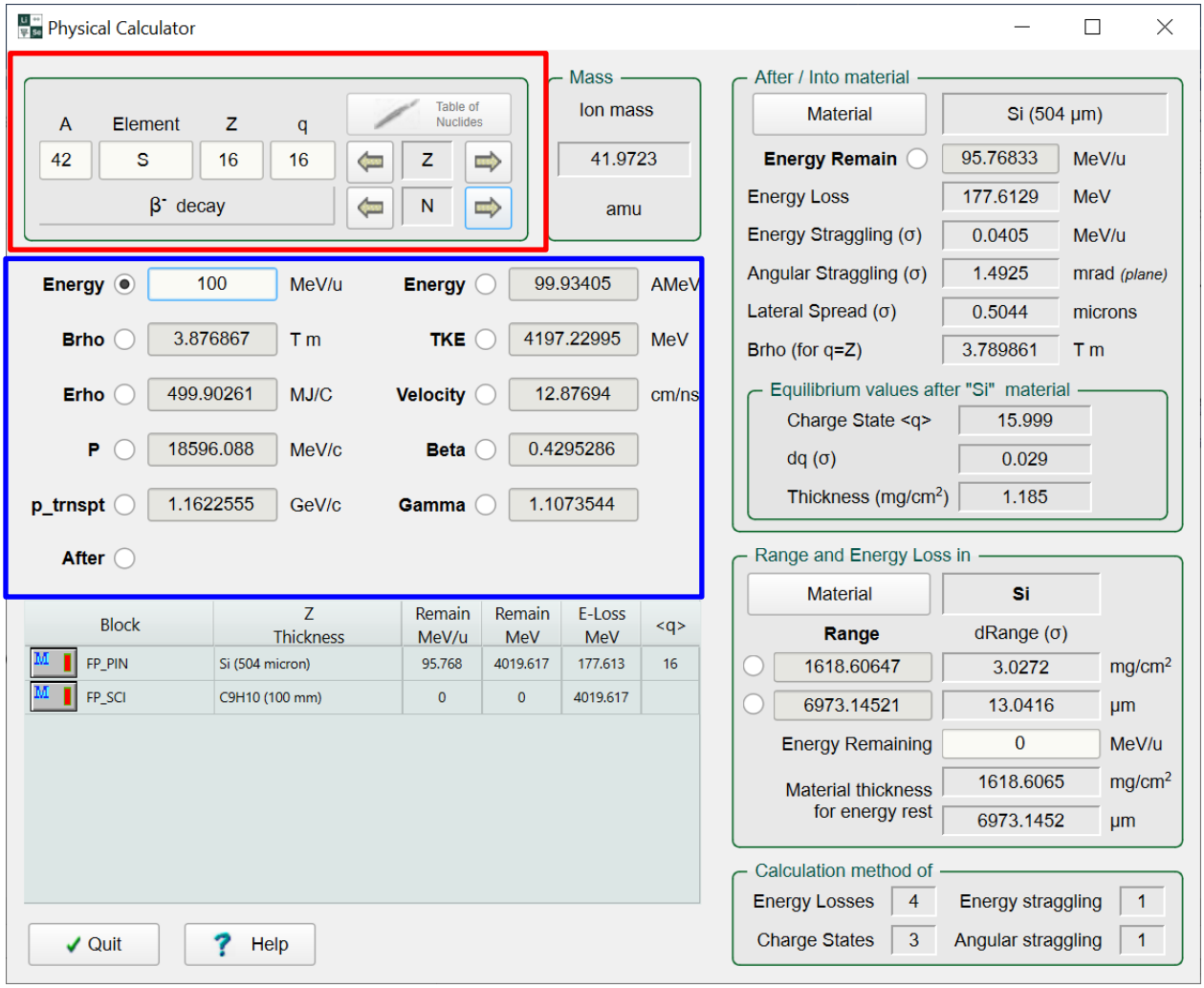


Step 2

Use the left top region of the window (indicated in the figure below by a red box) and enter the A and Z numbers, and charge state Q (In the example, the nuclear beam is ^{42}S fully stripped (Q=Z=16)).

Use the left middle region of the window (indicated in the figure below by a red box) and select **Energy** by clicking on the checking circle on the (see red arrow). Enter the energy value in MeV/u (in this example 100 MeV/u).

The Physics Calculator will automatically calculate the Magnetic Rigidity “Brho” (see blue arrow) (in this example 3.8769 Tm)



2.2. DETERMINATION OF MAGNETIC RIGIDITY AFTER MATERIAL

In some cases, beams are degraded by materials located in the beam line (e.g. degraders, detectors, etc.). LISE++ Physics Calculator allows to easily determine the magnetic rigidity (and energy) of beams after passing through these materials.

(**Note** that the calculation of rigidities after a reaction target must be properly determined based on the kinematics of the specific experiment.)

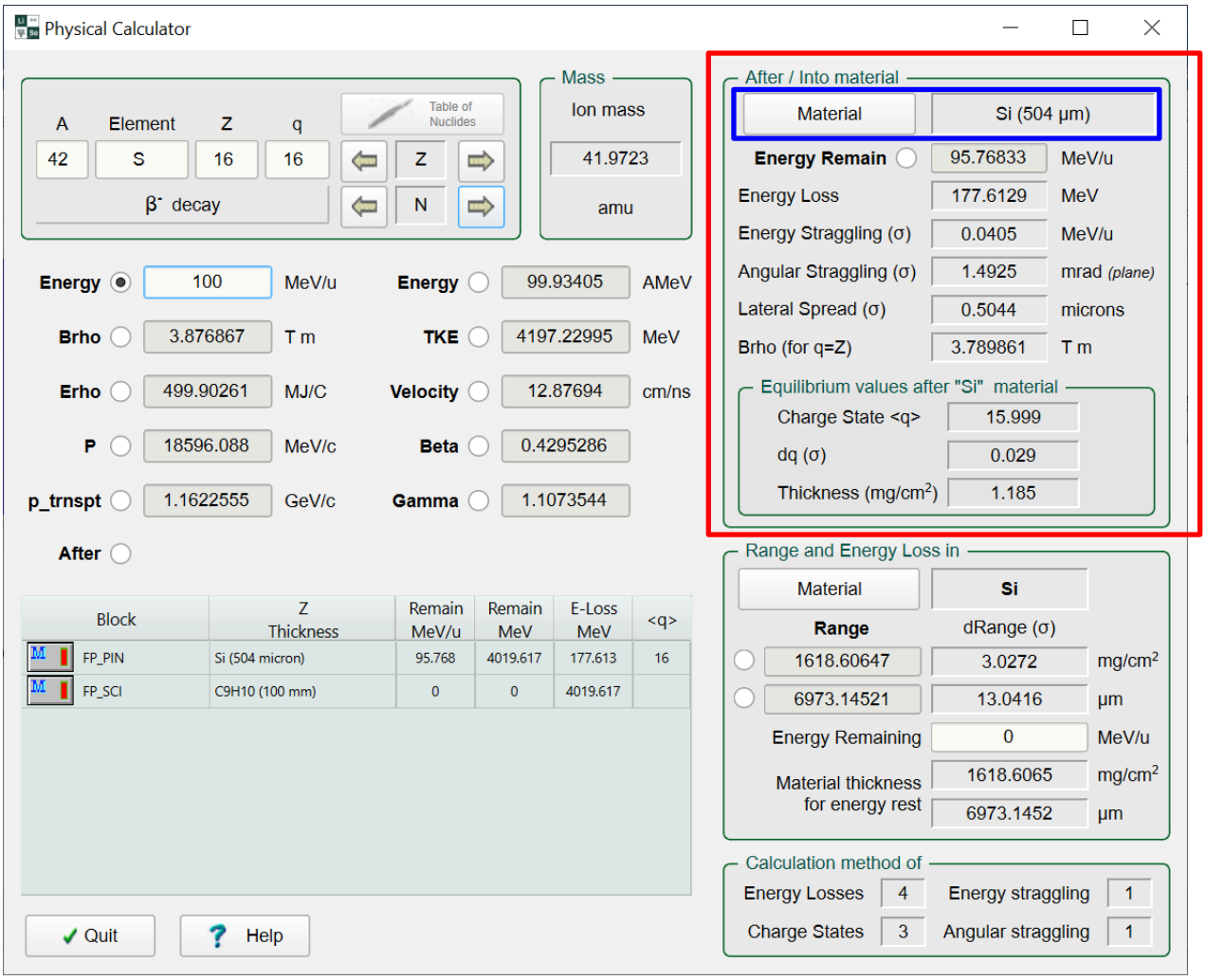
Step 1

Open the LISE++ Physical Calculator, and enter the beam information (Z, A, Q, energy) listed in the previous section. And select the box checked-circle “Energy” or “Brho” (this is necessary to ensure that LISE “fixes” that energy (or rigidity) before calculating the degraded beam).

Identify the region “After/Info material” (see red box in figure below) in the Physics Calculator window. This menu is used to calculate beam parameters after passing through the selected material. In the example provided in the figure, the material is a Si detector with a thickness of 504 um (see blue box)

The information provided includes:

- Energy remain (after material)
- Energy loss (in material)
- Energy and angular straggling (in material)
- Lateral spread
- Magnetic rigidity (for fully-stripped nuclei: Q=Z)



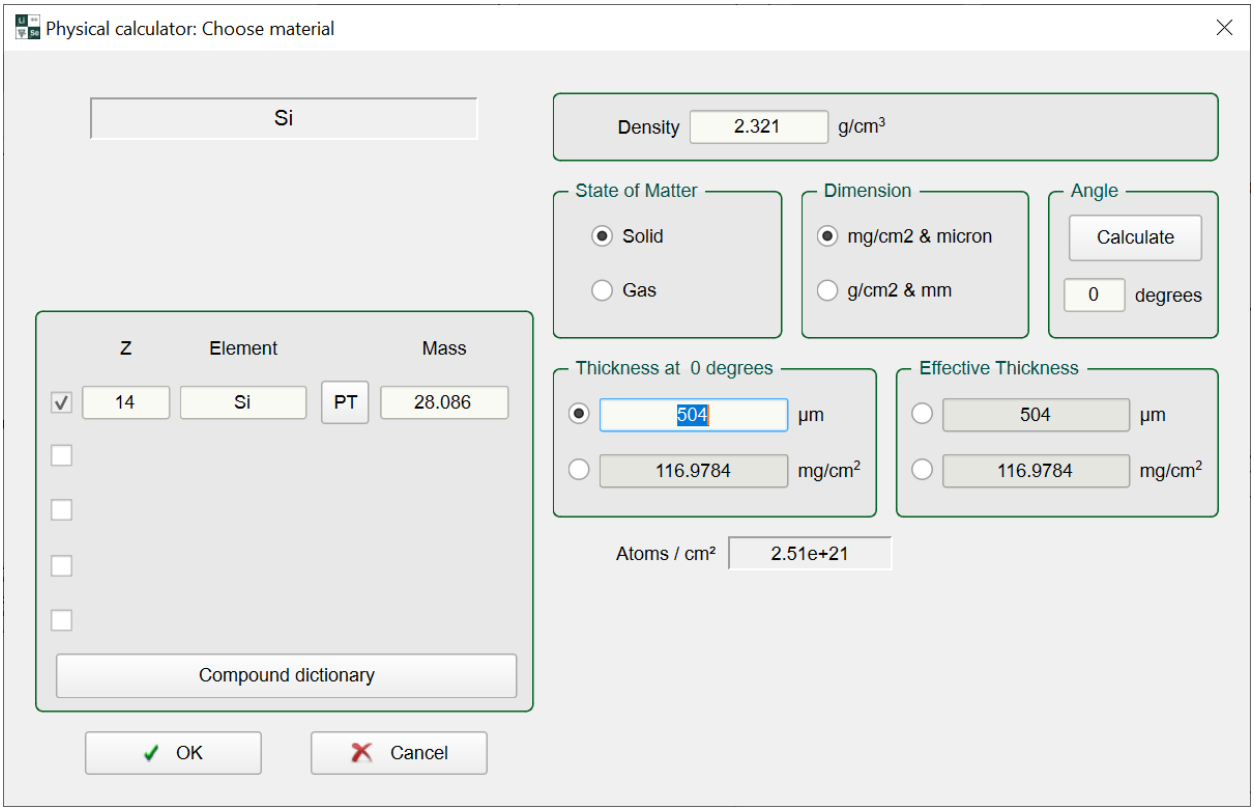
Step 2

To select a different material than the one provided in step 1, click on box “Material”. A window will pop out (see figure below)

This menu offers the possibility to select materials (gas or solid/liquids) by entering their composition (elements, mass, stoichiometry (for gases), and density). The material thickness can be entered in length units (mm or um) or mg/cm2 (g/cm2).

Alternatively, there is an extensive database of pre-defined materials that can be accessed by clicking button “Compound Dictionary”

Once the material and thickness are selected, close the window and get the rigidity from the “After/Info Material” section of the Physics Calculator window.


Physical calculator: Choose material
Si
Density 2.321 g/cm³
State of Matter
Solid
Gas
Dimension
mg/cm2 & micron
g/cm2 & mm
Angle
Calculate
0 degrees
Z Element Mass
14 Si PT 28.086
Compound dictionary
Thickness at 0 degrees
504 µm
116.9784 mg/cm²
Effective Thickness
504 µm
116.9784 mg/cm²
Atoms / cm² 2.51e+21
OK
Cancel