LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

Elastic scattering of radioactive nuclei at relativistic energies

LIP Internship Program 2023

Supervisors: Professor Daniel Galaviz, Manuel Xarepe e Diogo Miguel

Catarina Santos

ELASTIC NUCLEAR SCATTERING

In an **elastic scattering** process, the system's **kinetic energy** and the total linear momentum ($|\boldsymbol{p}|$) are **conserved**.

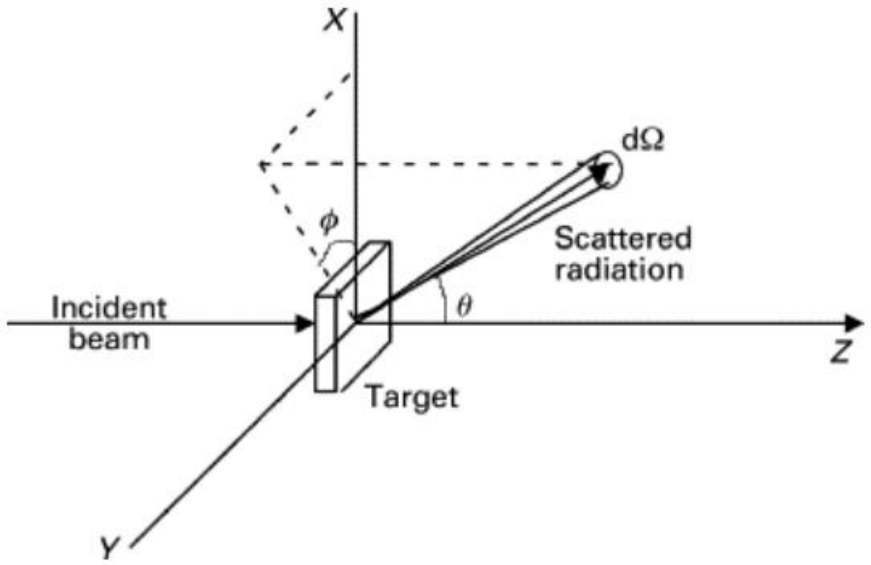


Fig.1 Scattering of an incident beam of particles. The incoming beam arrives in the z direction and is scattered to the solid angle dΩ. θ is the angle between the scattered beam and the z-axis; ϕ is the angle on the xOy plane.

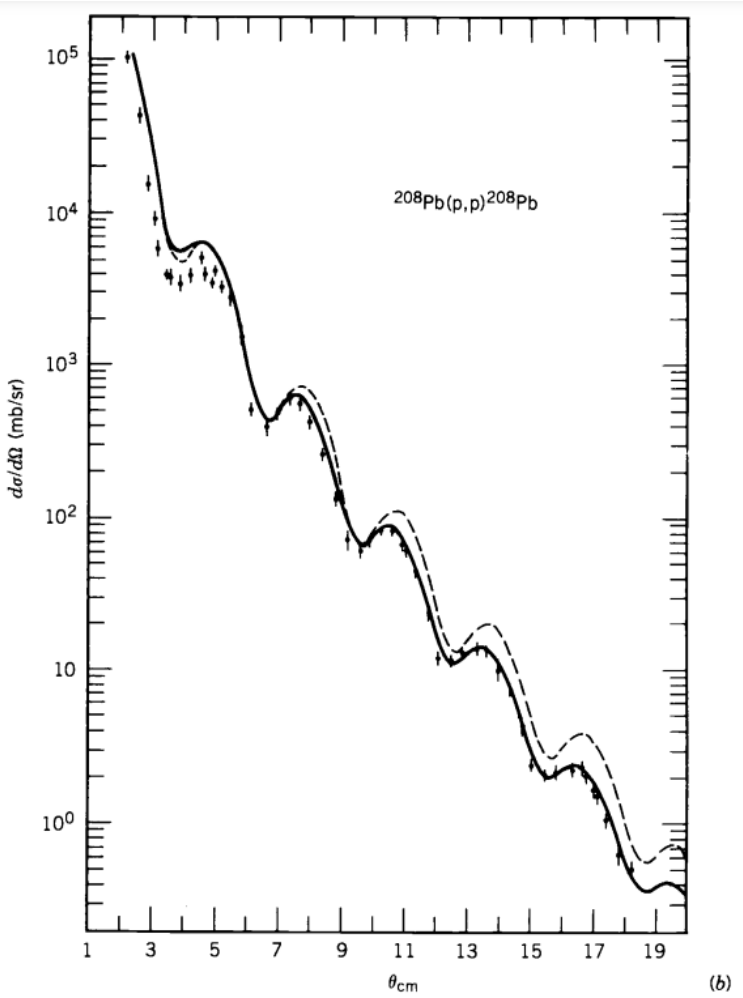


Fig.2 Differential angular cross section at small angles for protons from ^{208}Pb with 1050 MeV.

STUDYING RADIOACTIVE NUCLEI

Inverse kinematics enable the **study of radioactive isotopes. Using this** and of all the products of the reaction.

Radioactive beams are produced by **In-flight separation**. A primary stable beam hits a light target and the fragments of the reaction are released in the same direction, creating a **beam with a diversity of different isotopes.**

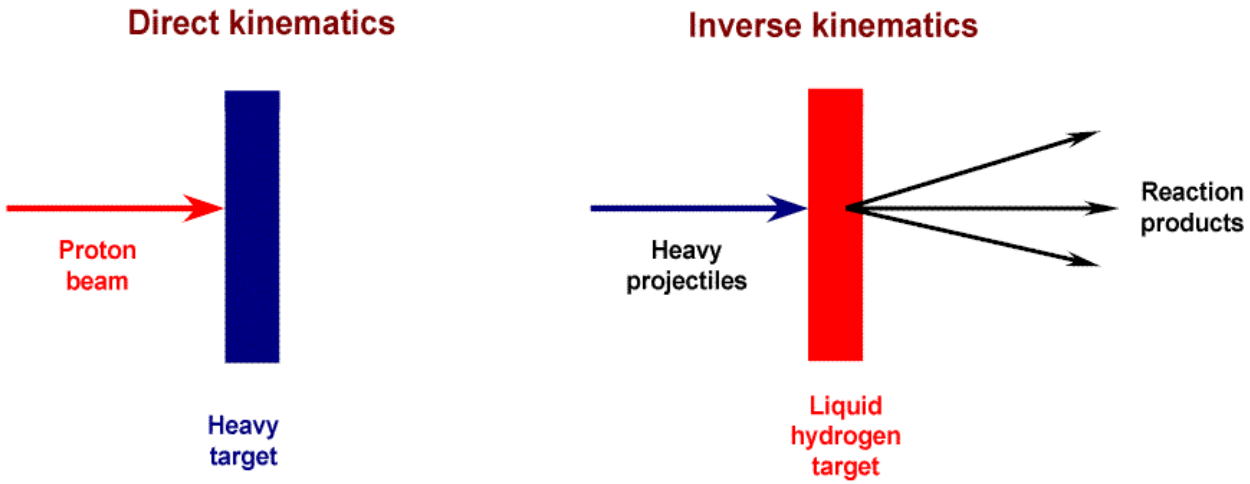


Fig.3 Comparison between direct kinematics and inverse kinematics.

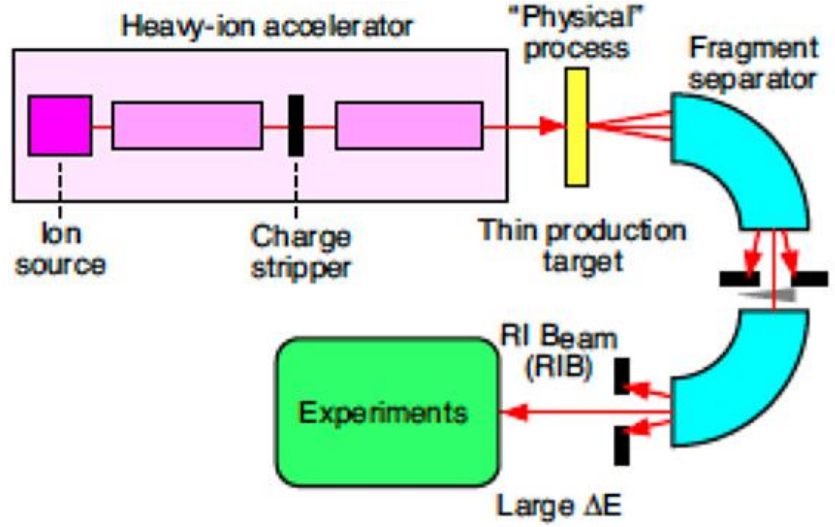


Fig.4 Scheme of the production of radioactive beams using the In-flight separation method.

EXPERIMENTAL SET UP R3B

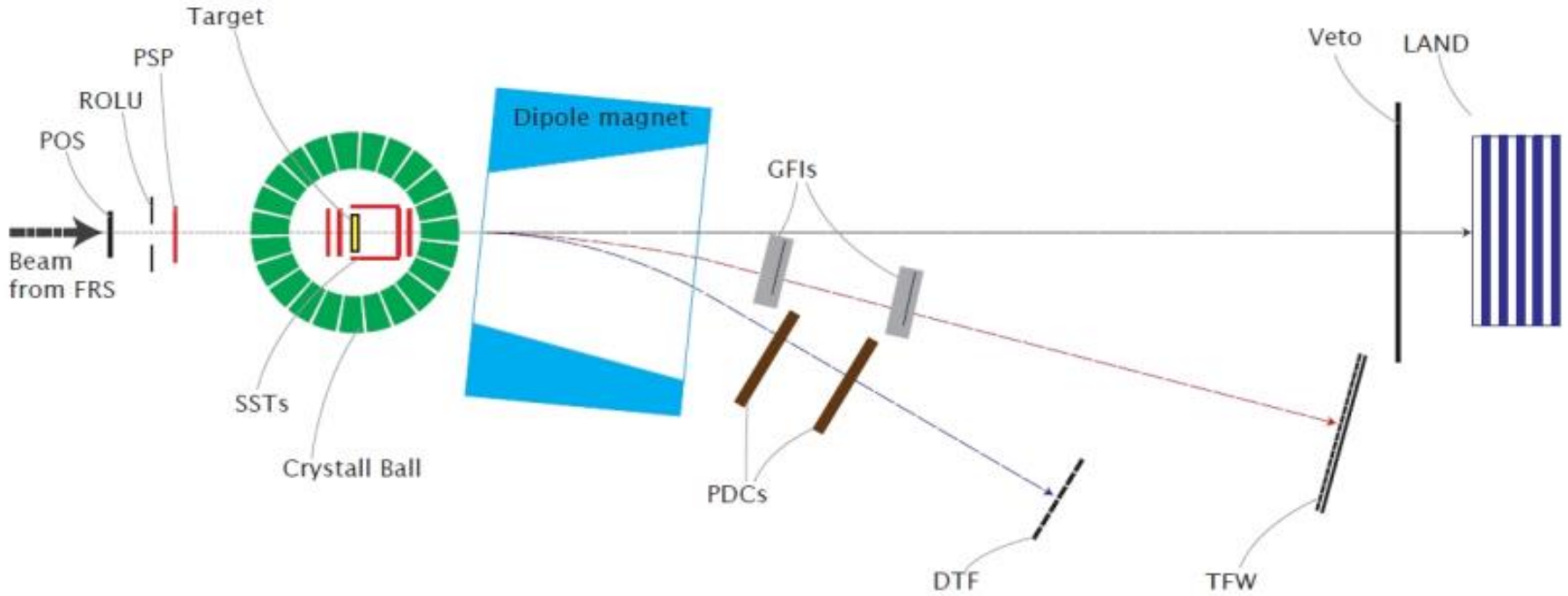
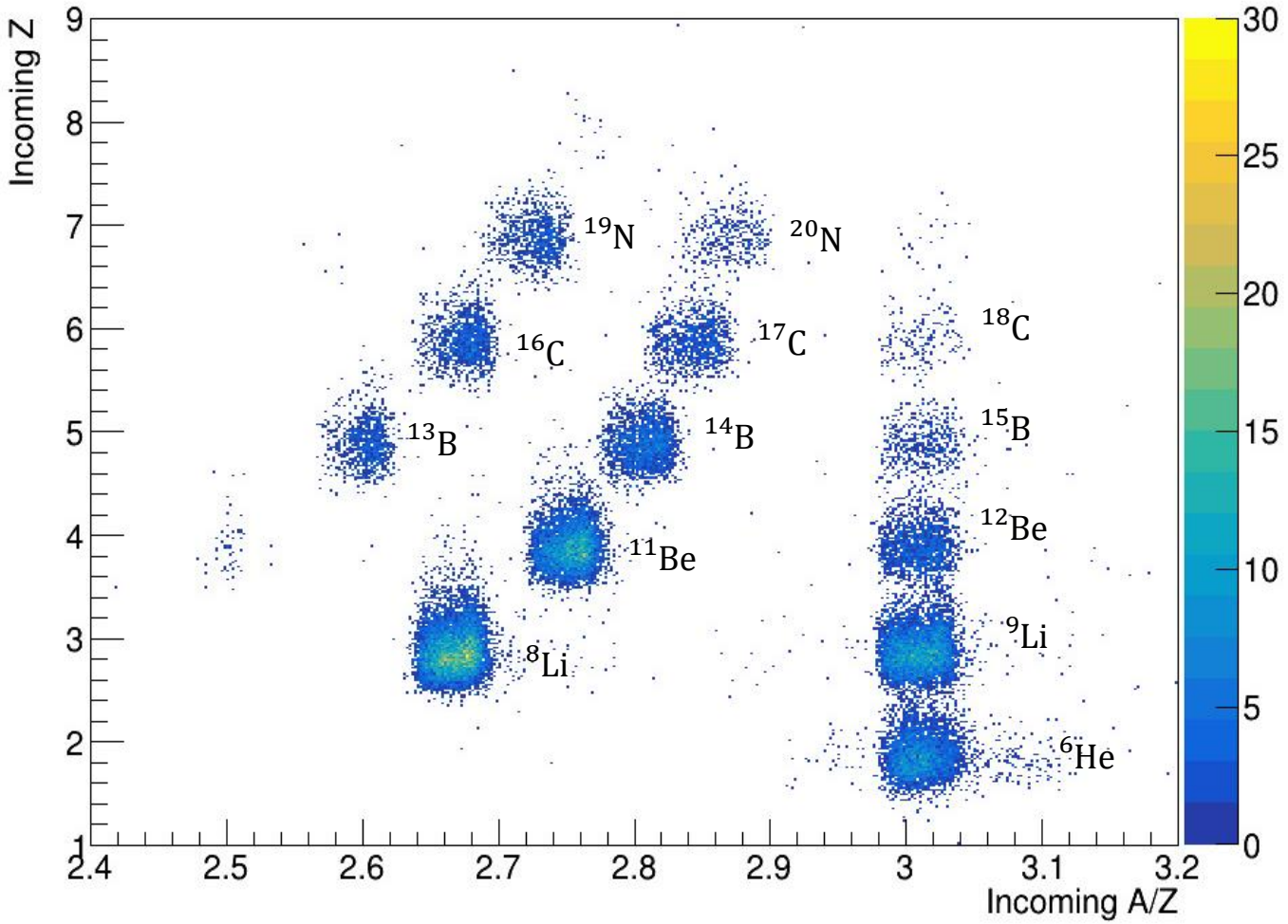


Fig.5 Schematic view of the LAND/R3B setup for the S393 campaign. In blue the group of detectors before the target, in red the ones surrounding the target and in brown the detectors after the target.

DETECTORS: BEFORE THE TARGET



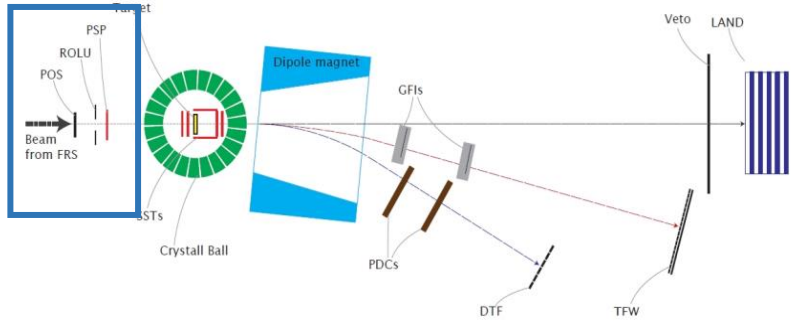
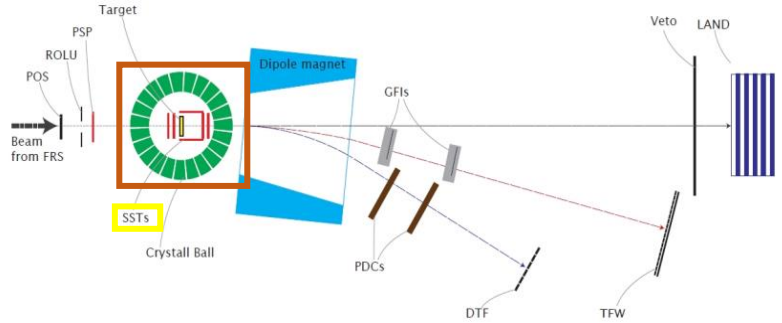


Fig.6 Correlation between incoming charge (Z) and mass-to-charge ratio (A/Z) values. Each reagion represents a different isotope.

DETECTORS: ARROUND THE TARGET



When **radiation** (energy) hits the Silicon Strip Tracker (SST) information about its **position and energy** can be acquired.

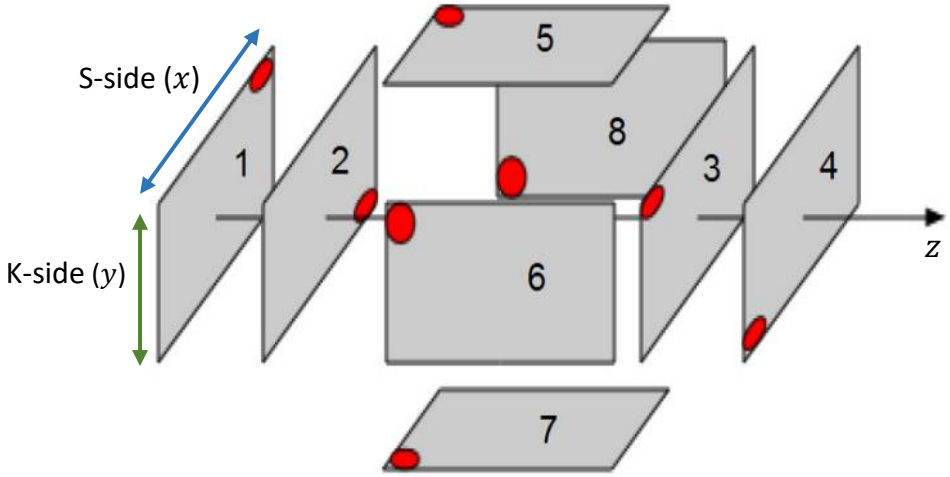


Fig.7 Scheme of the Silicon strip trackers (SST). SST 1 and 2 are before the target, SST 3 and 4 are after the target and SST 5,6,7,8 surrounding the target.

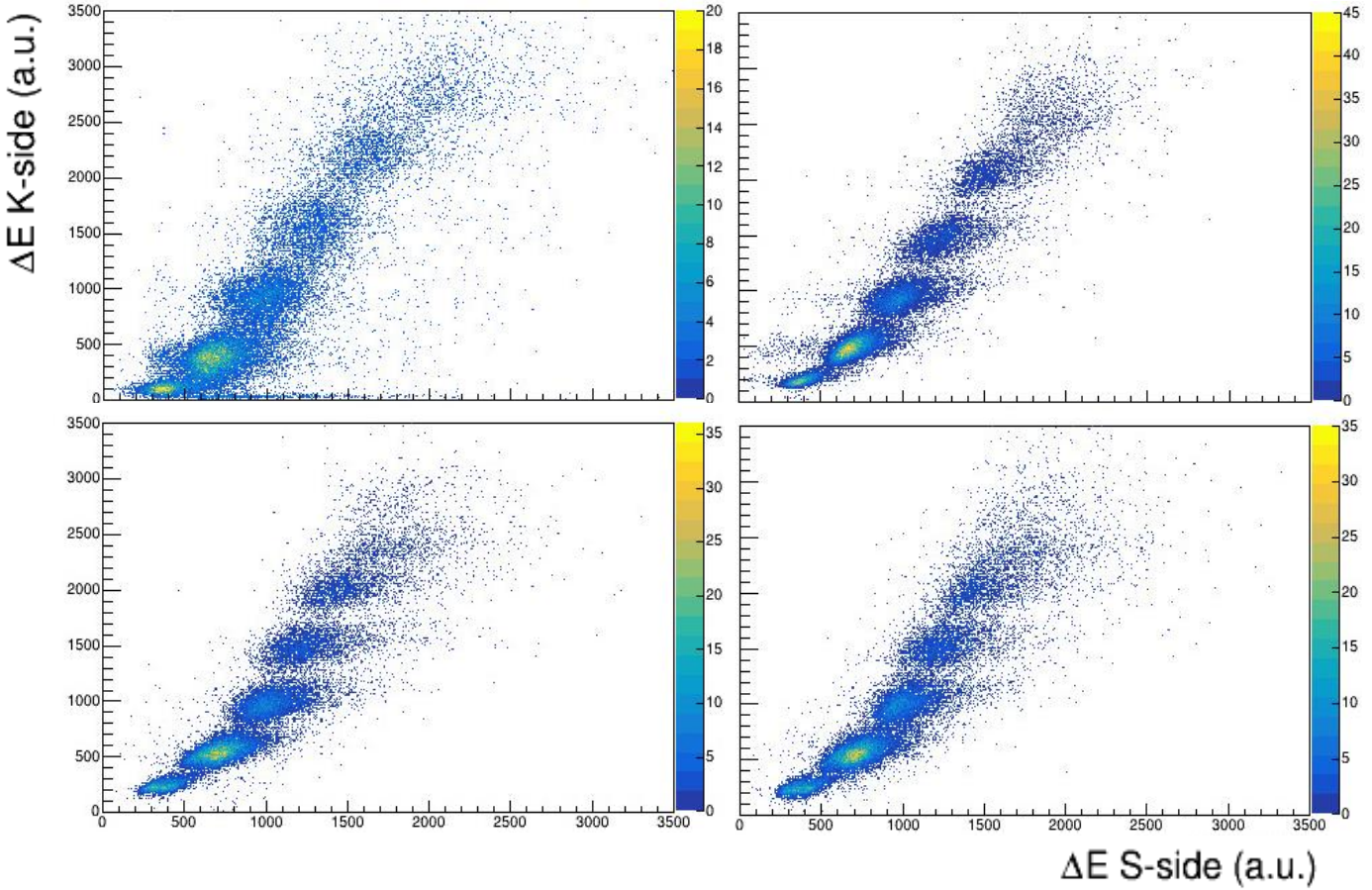
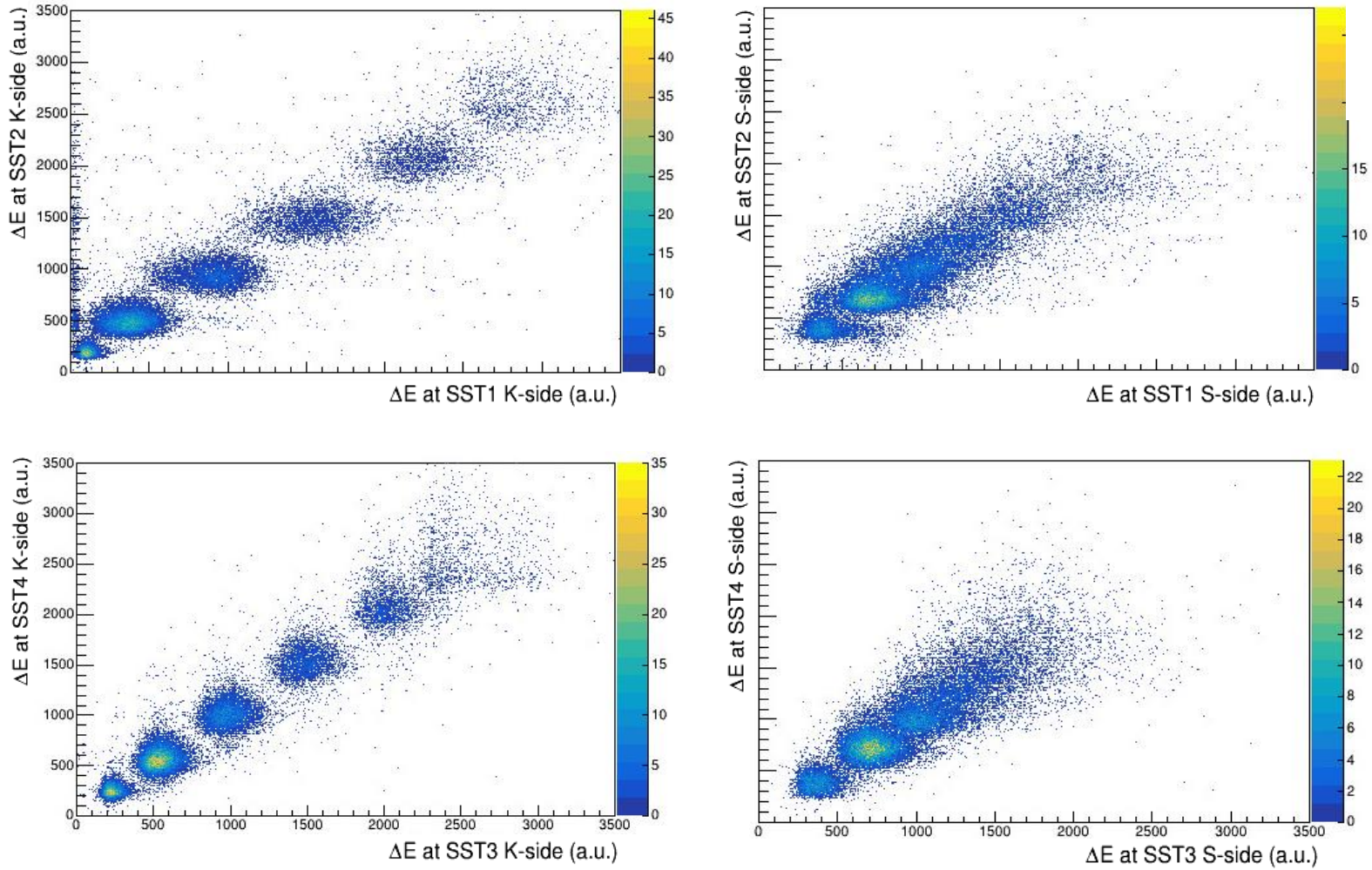


Fig.8 Energy loss measurements on each SST (1,2,3,4) for the incoming beam.



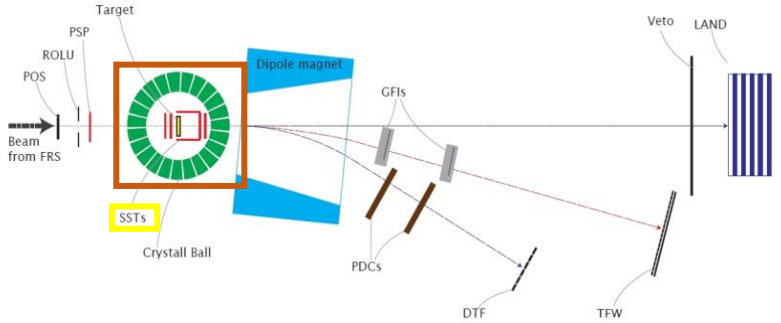
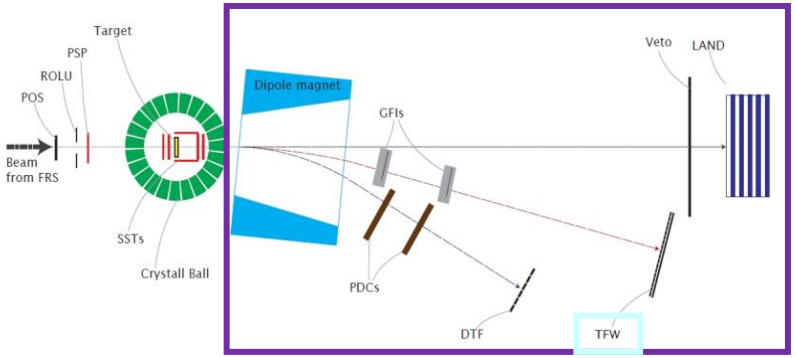


Fig.9 Energy loss measurements in consecutive SST in each direction for the incoming beam. SST2 vs. SST1 for K-side (top left) and S-side (top right) and for SST4 vs. SST3 for K-side (bottom left) and S-side (bottom right).

DETECTORS: AFTER THE TARGET



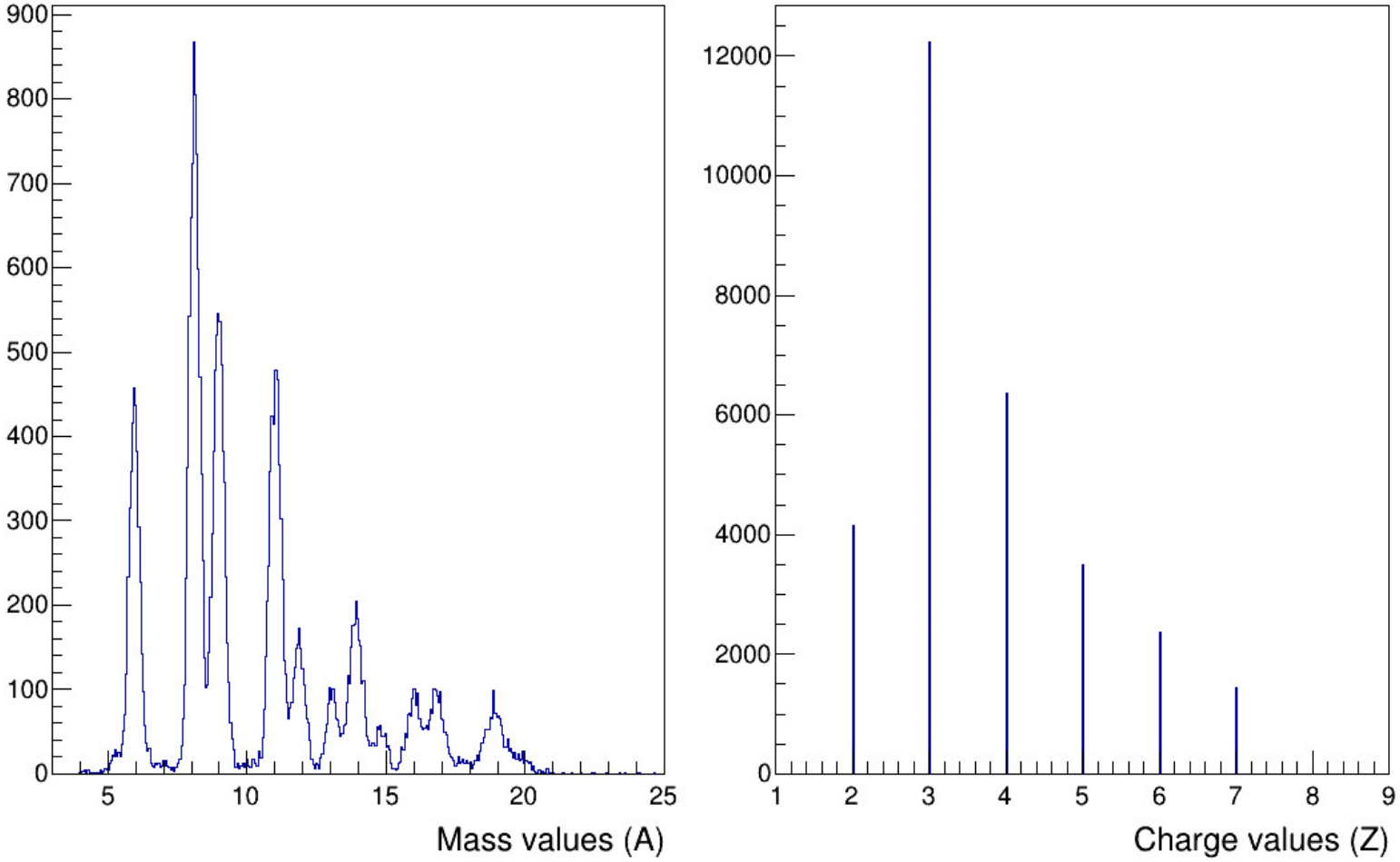


Fig.10 Mass (A) (left) and charge (Z) (right) measured at TFW for the incoming beam.

STAR OF THE ANALYSIS

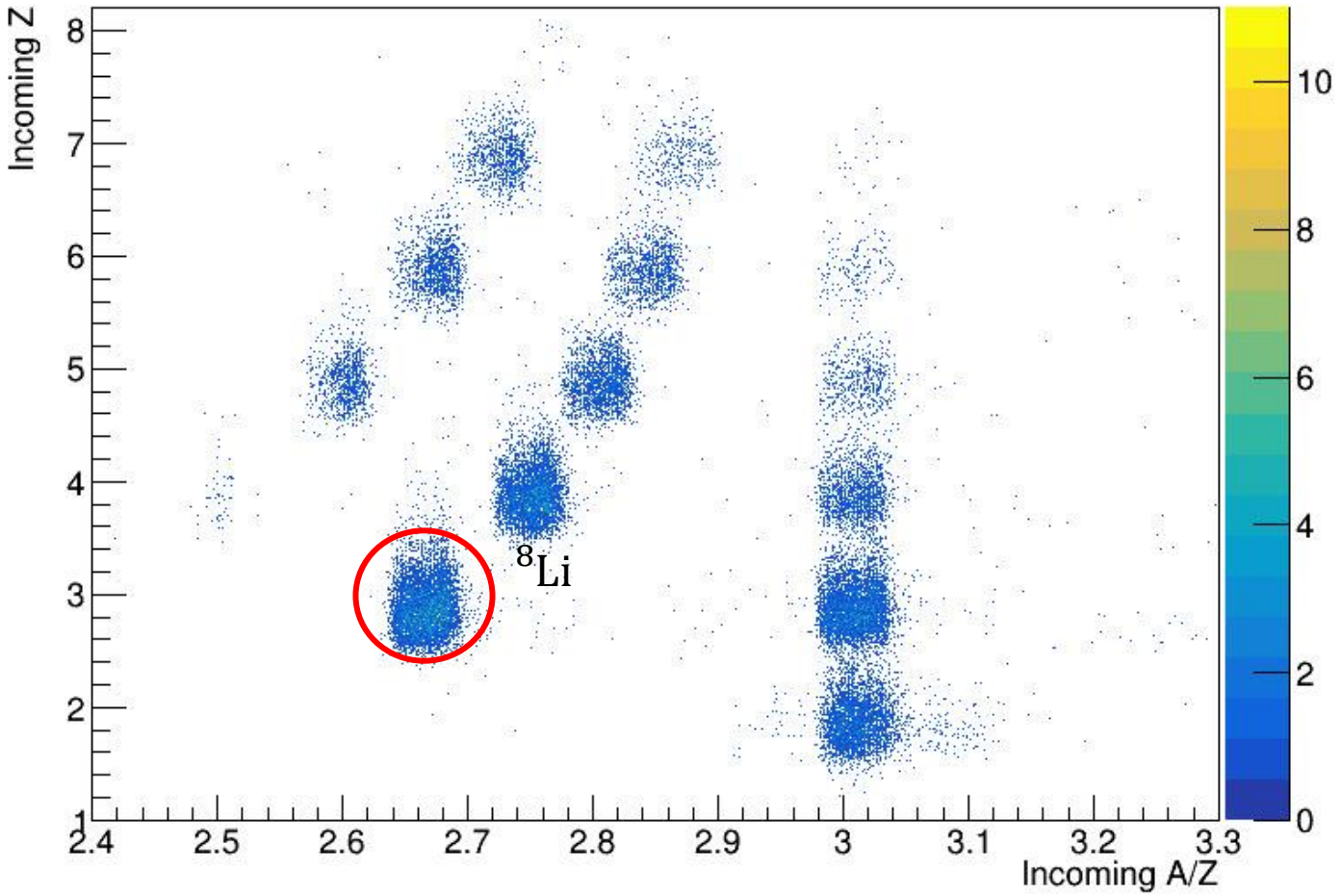
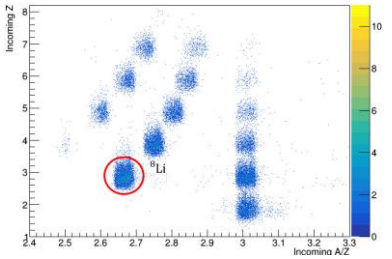


Fig.11 Correlation between incoming charge (Z) and mass-to-charge ratio (A/Z).

ENERGY ANALYSIS



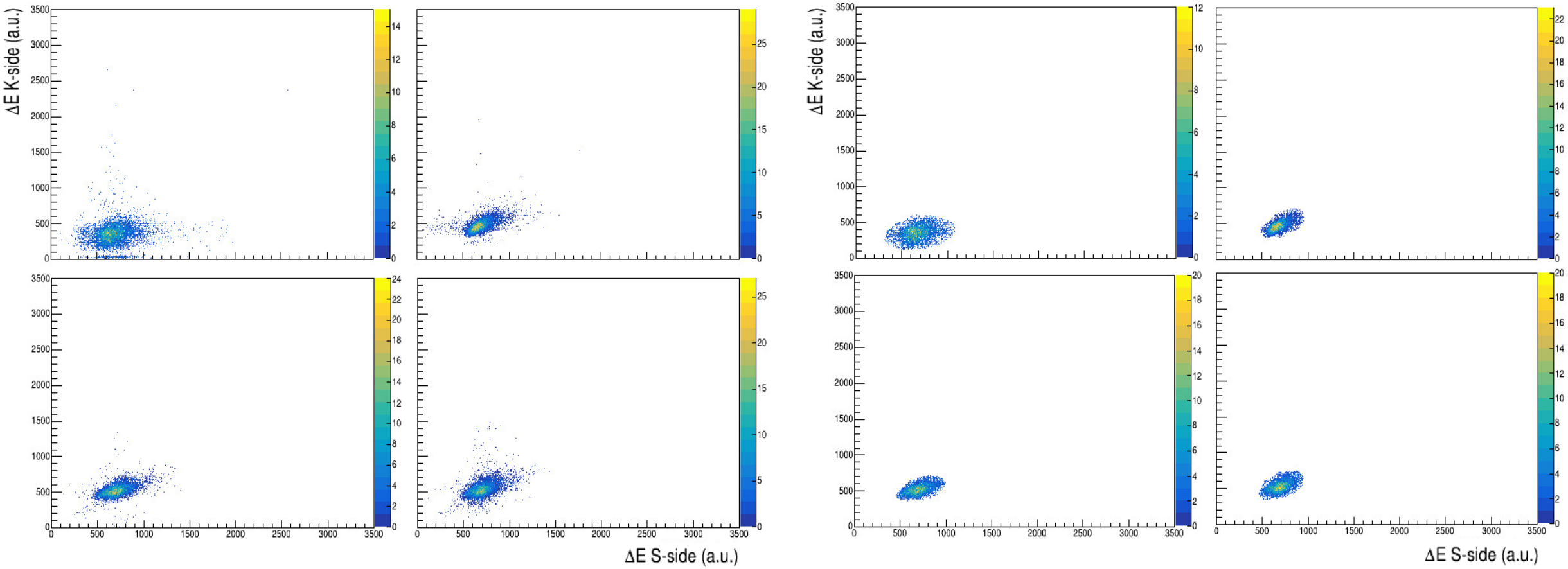
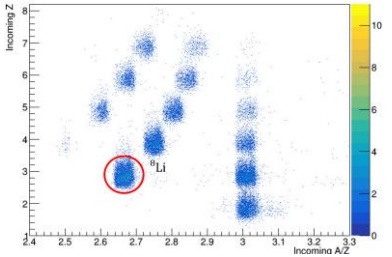


Fig.12 Energy loss measurements on each SST (1,2,3,4) for ^{8}Li (Z = 3) before and after energy conditions.

ENERGY ANALYSIS



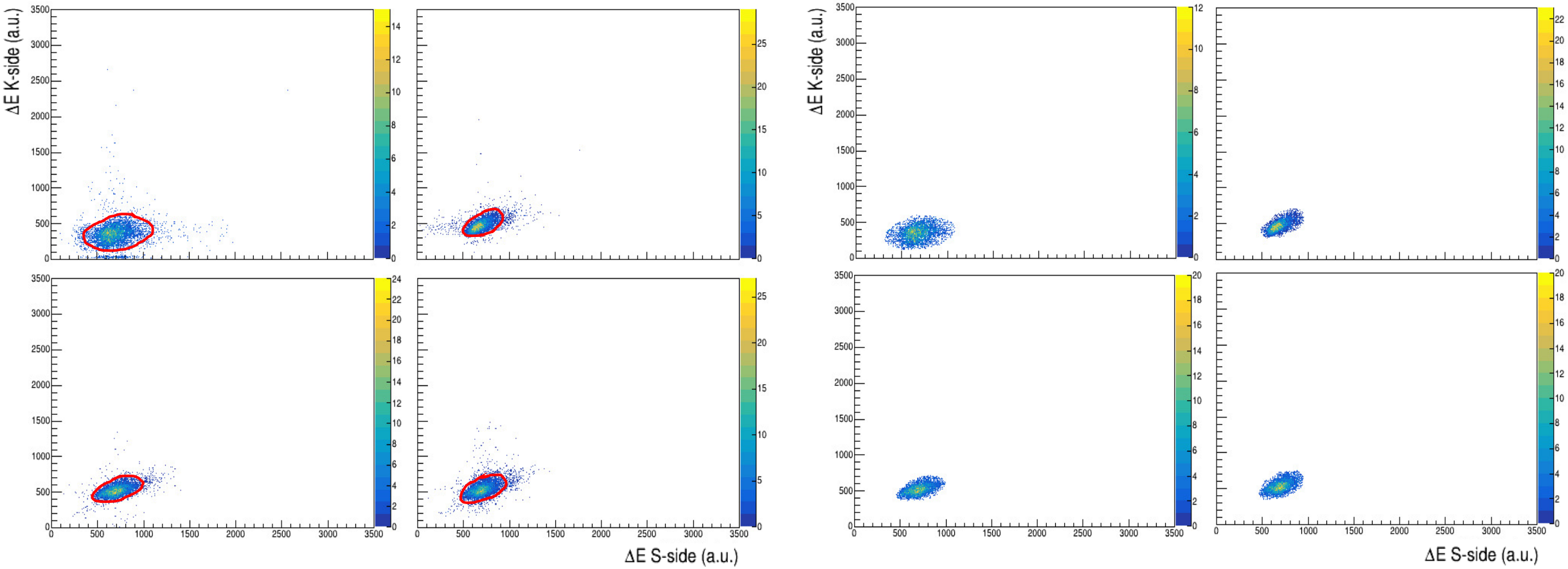
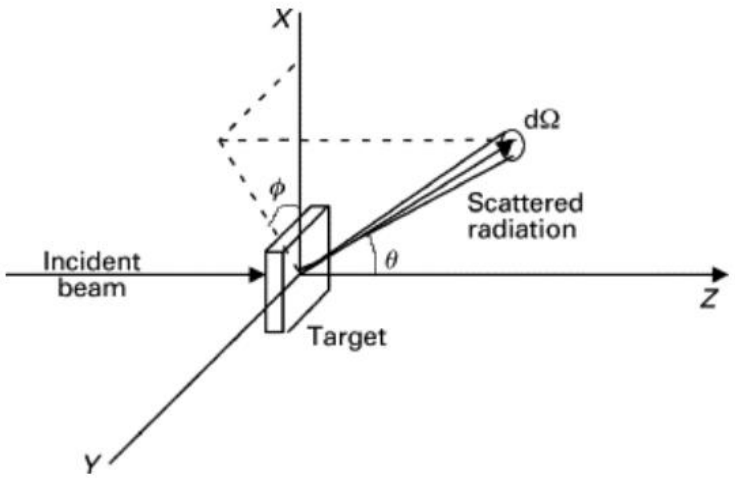


Fig.12 Energy loss measurements on each SST (1,2,3,4) for ^{8}Li (Z = 3) before and after energy conditions.

SCATTERING ANALYSIS



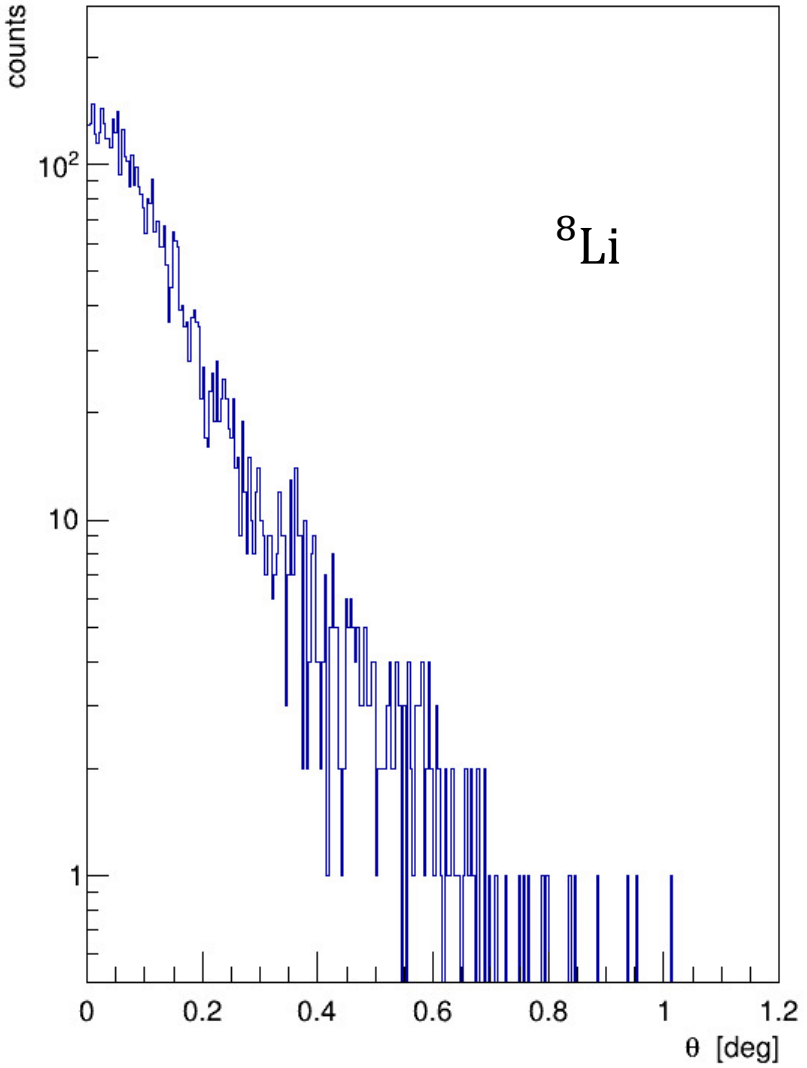
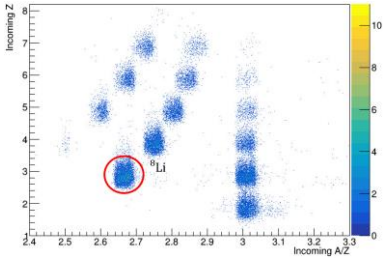


Fig.13 Scattered θ values for ^{8}Li at 490 MeV/u.



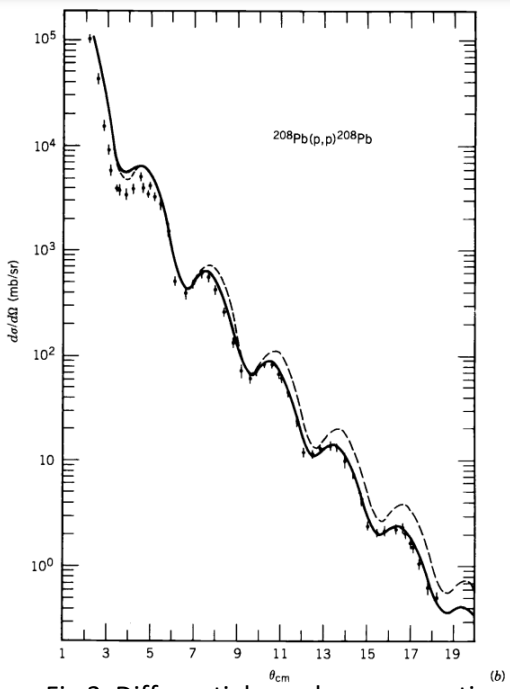
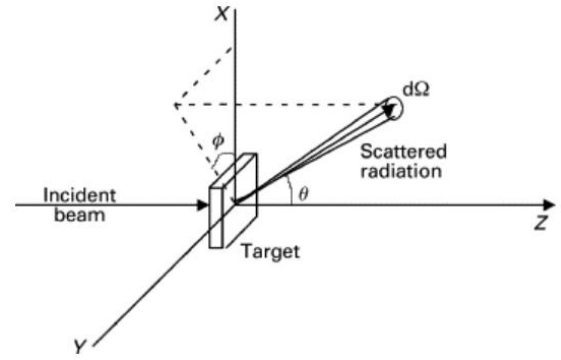
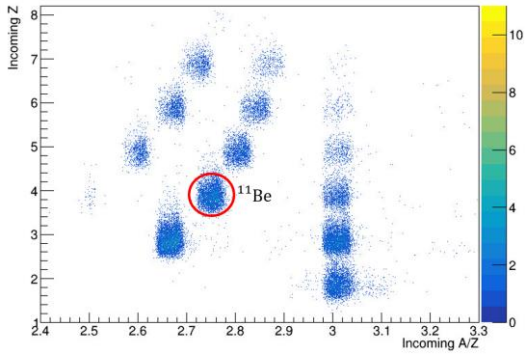
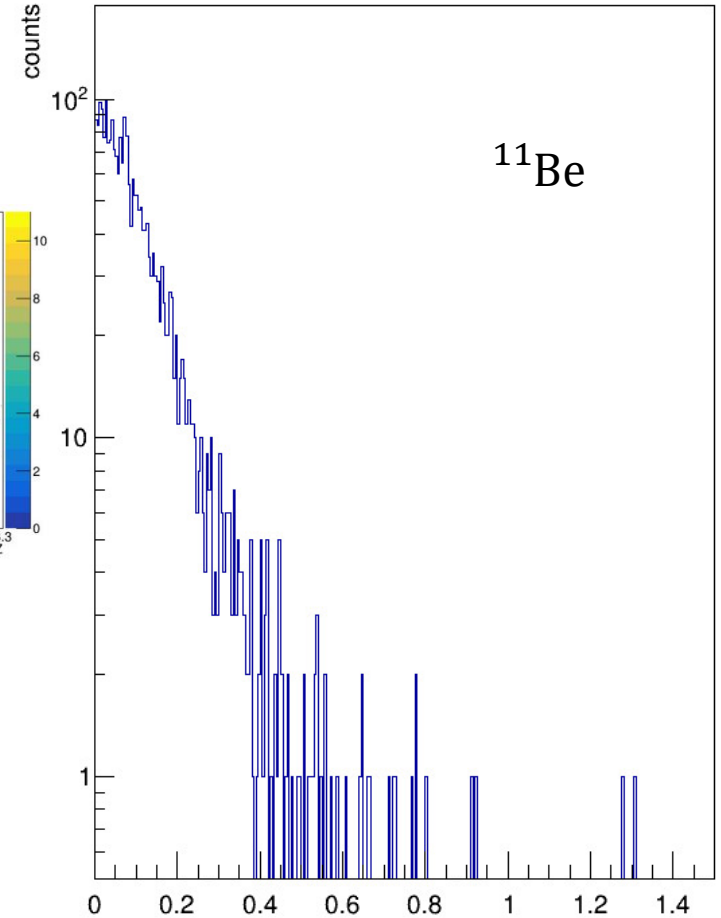


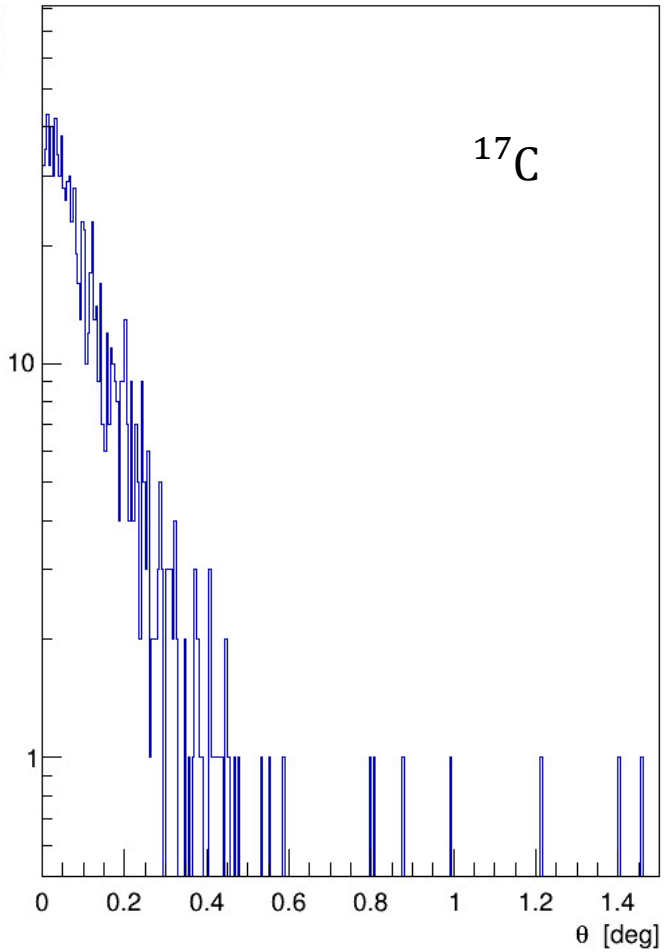
Fig.2 Differential angular cross section at small angles for protons from ^{208}Pb with 1050 MeV.

SCATTERING ANALYSIS FOR ^{11}Be AND ^{17}C









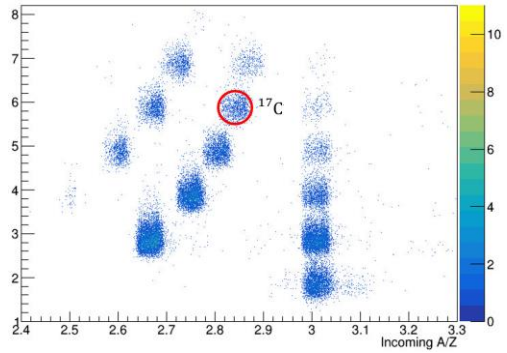
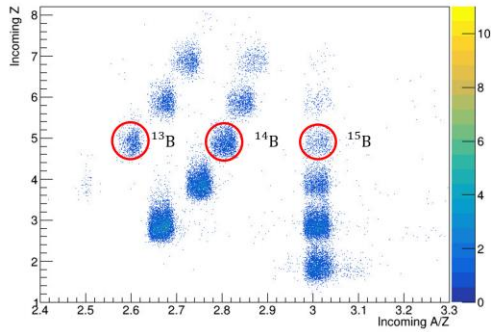


Fig.14 Scattered θ values for ^{11}Be (left) and ^{17}C (right) at 490 MeV/u.

SCATTERING ANALYSIS FOR ^{13}B ^{14}B AND ^{15}B



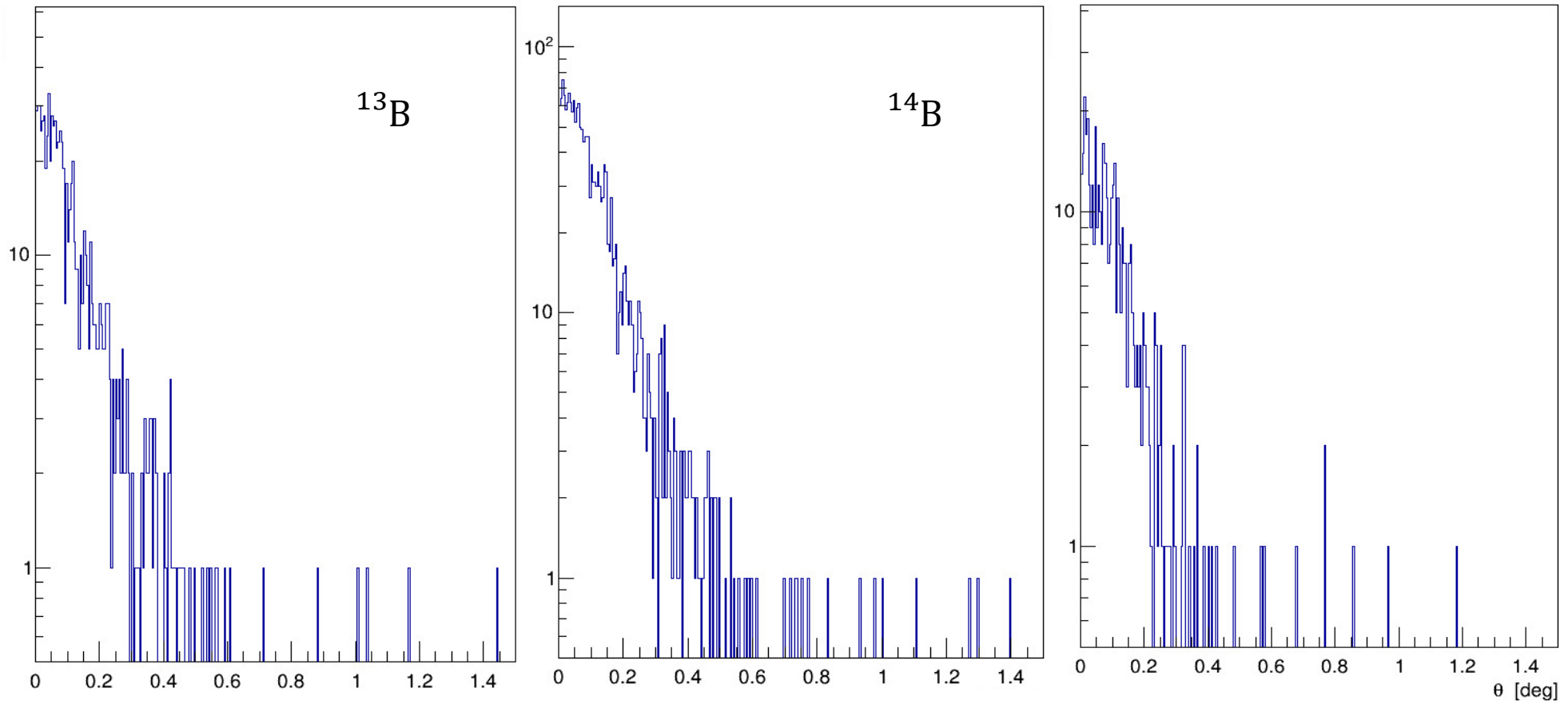
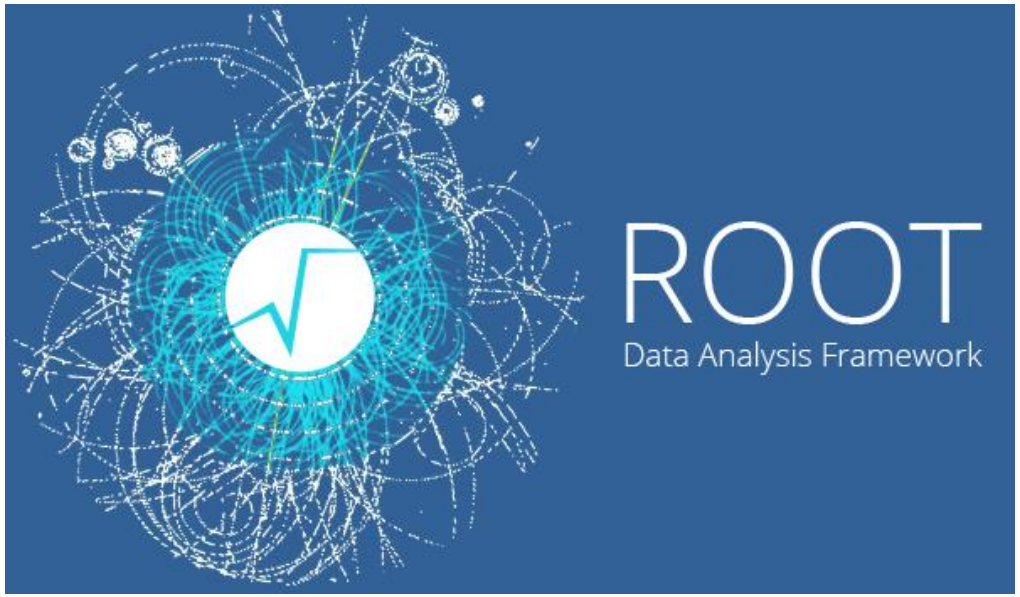
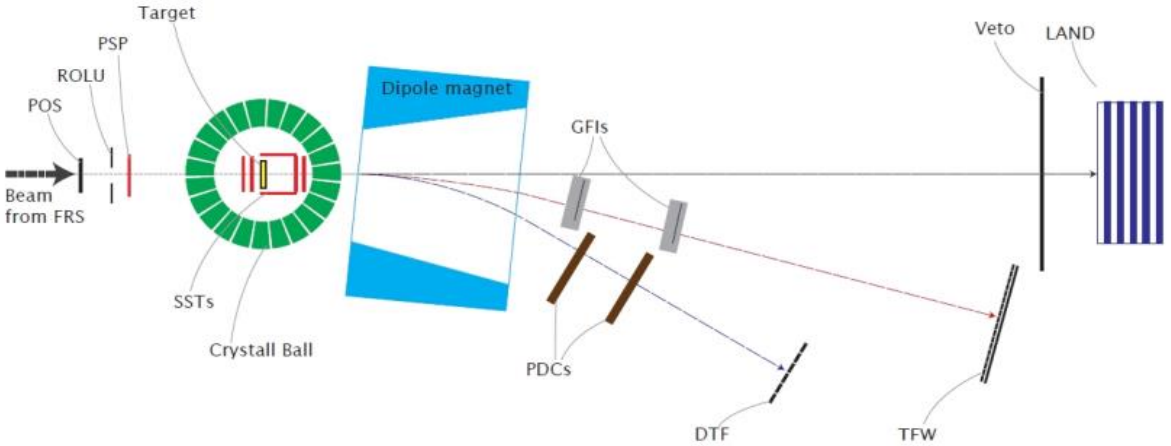
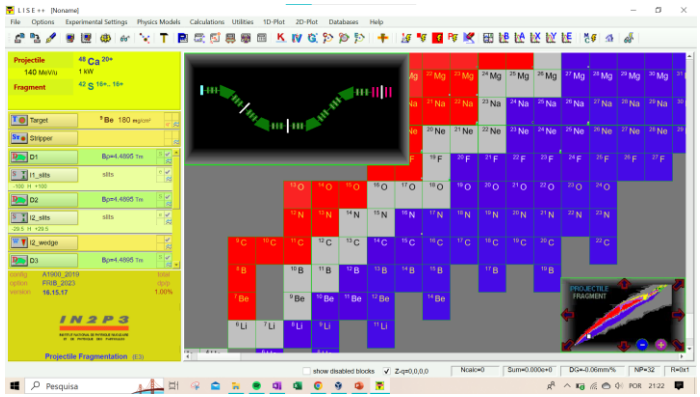


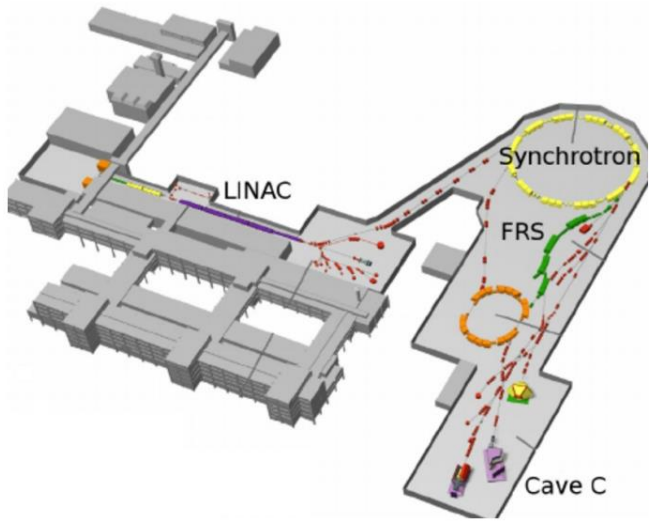
Fig.15 Scattered θ values for ^{13}B ^{14}B and ^{15}B (left to right) at 490 MeV/u.

INTERNSHIP EXPERIENCE

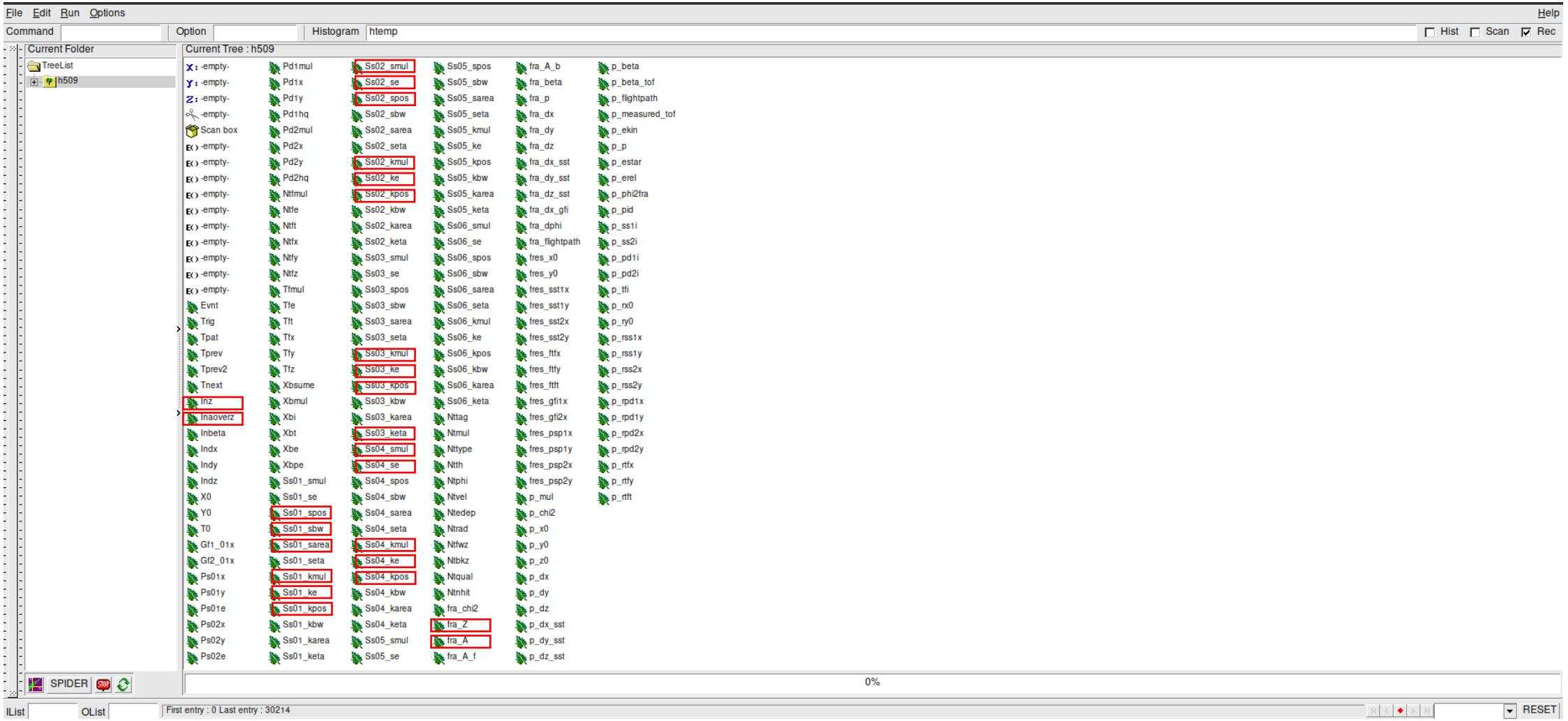




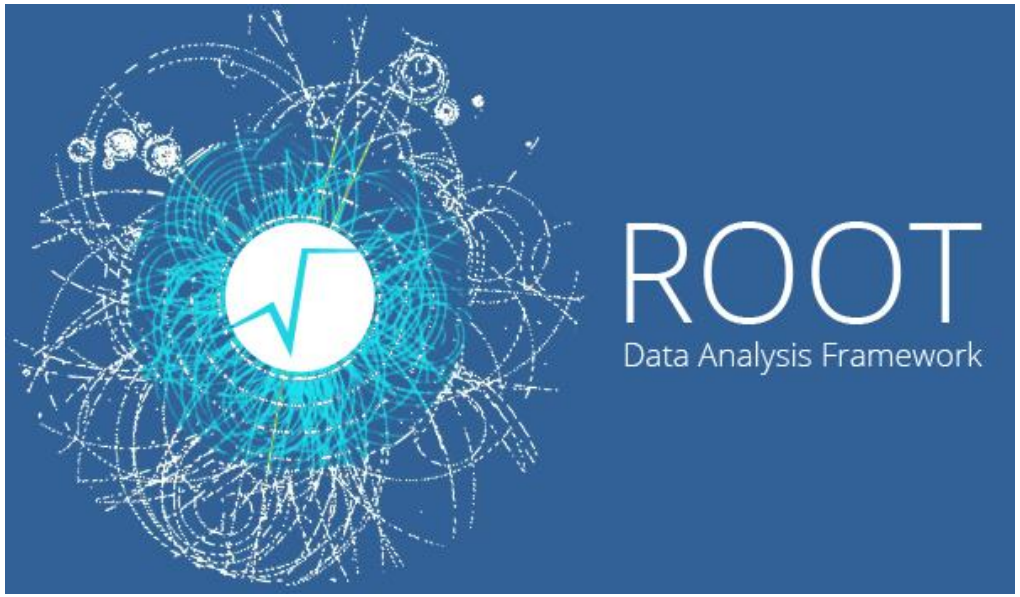


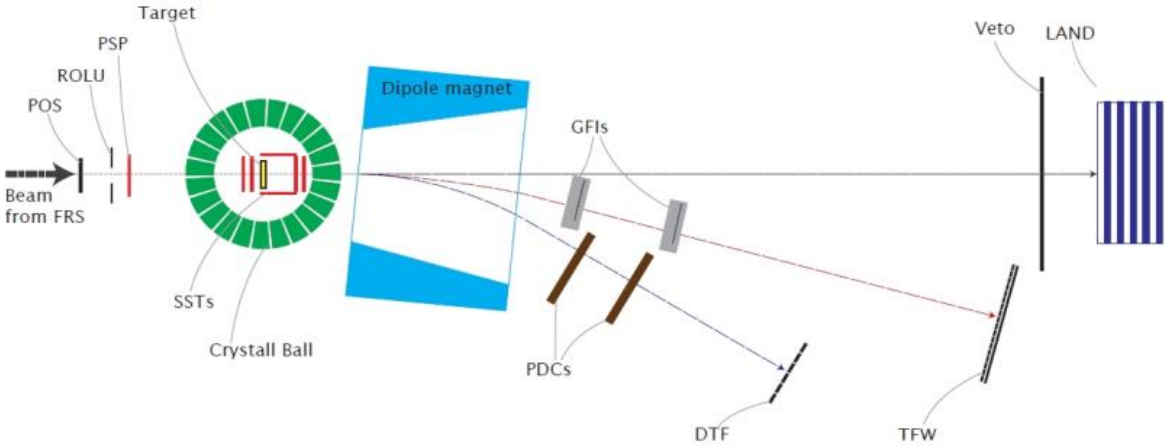


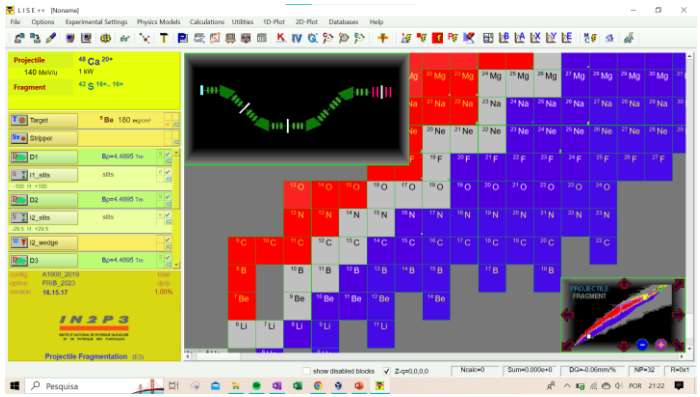
INTERNSHIP EXPERIENCE

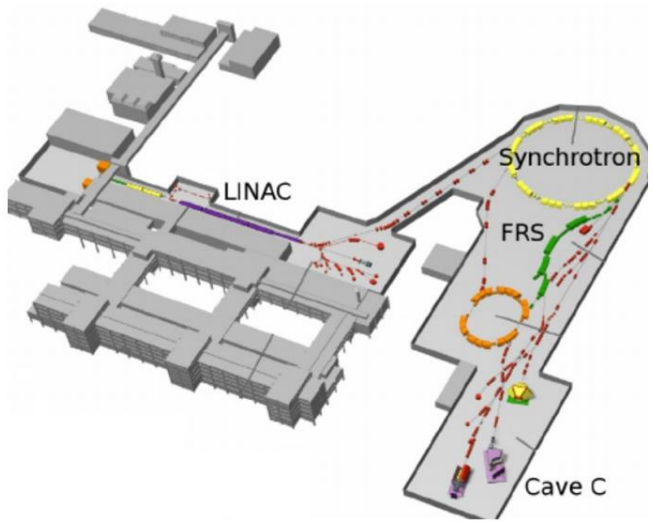


INTERNSHIP EXPERIENCE

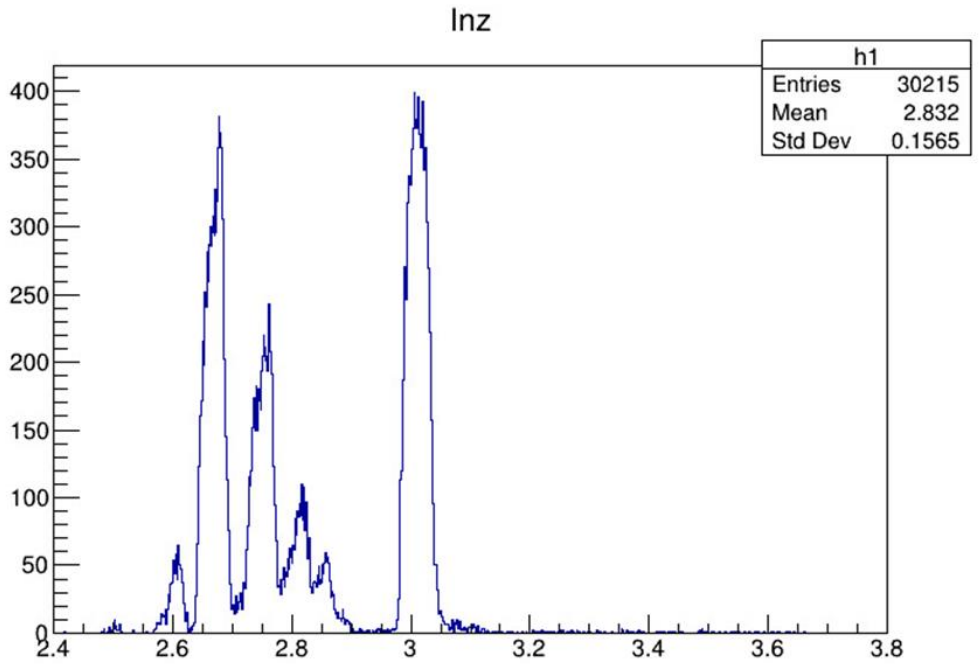


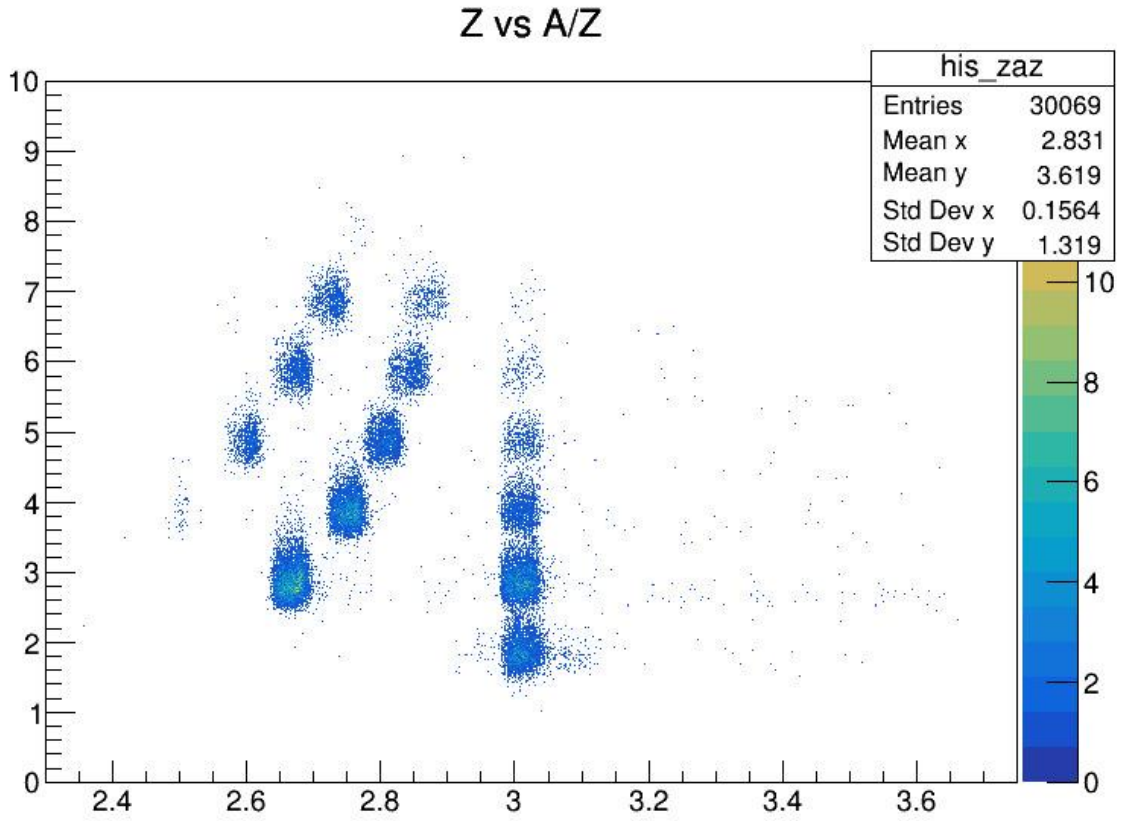


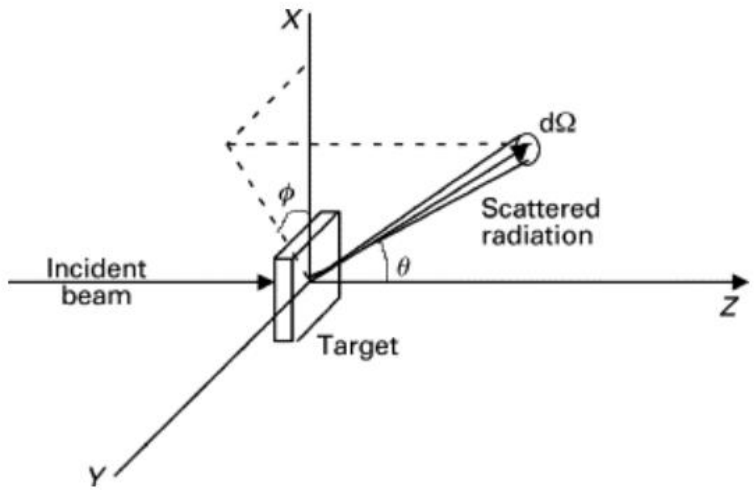


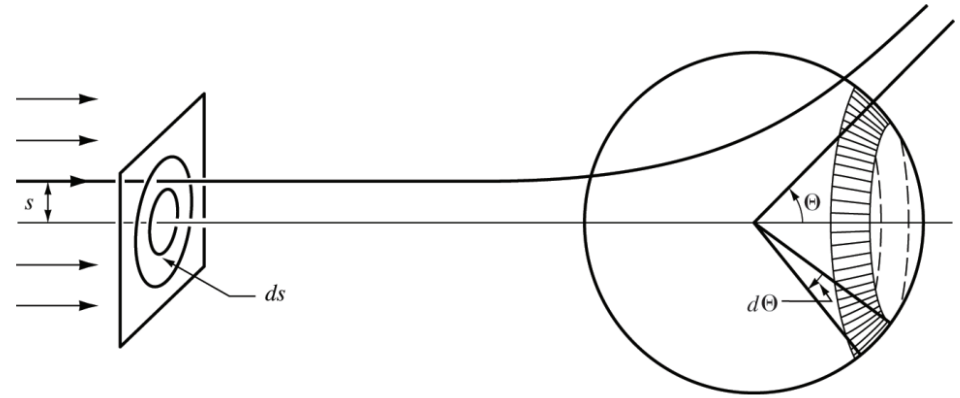


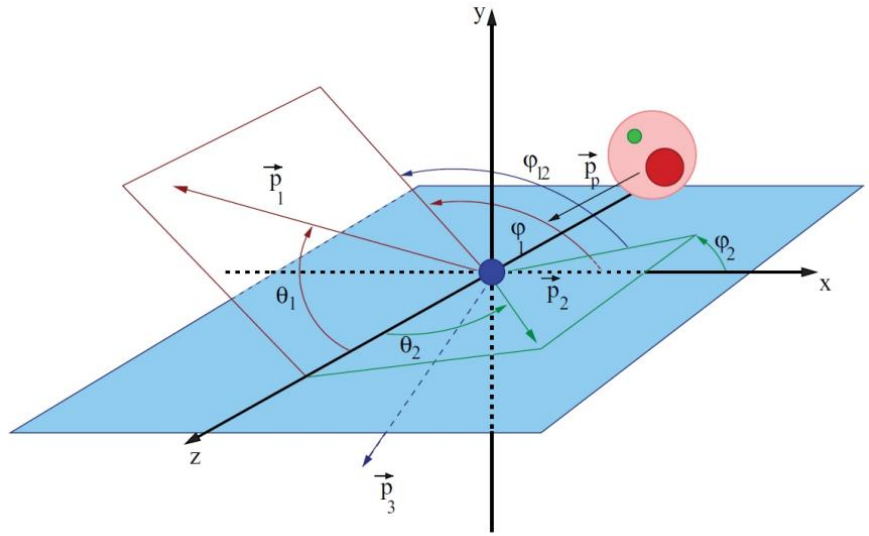
INTERNSHIP EXPERIENCE






X
dΩ
ϕ
Scattered
radiation
Incident
beam
θ
Z
Target
Y


s
ds
Θ
dΘ


y
x
z
$\vec{p}_1$
φ_{l2}
$\vec{p}_p$
φ_1
φ_2
θ_1
$\vec{p}_2$
θ_2
$\vec{p}_3$

ELASTIC NUCLEAR SCATTERING

In an **elastic scattering** process, the system's **kinetic energy** and the total linear momentum ($|\boldsymbol{p}|$) are **conserved**.

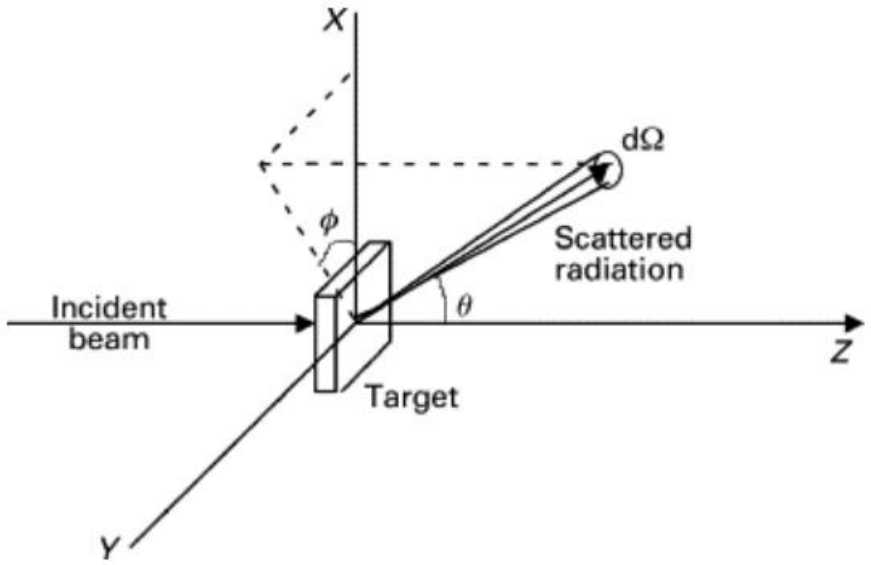


Fig.2 Scattering of an incident beam of particles. The incoming beam arrives in the z direction and is scattered to the solid angle dΩ. θ is the angle between the scattered beam and the z-axis; ϕ is the angle on the xOy plane.

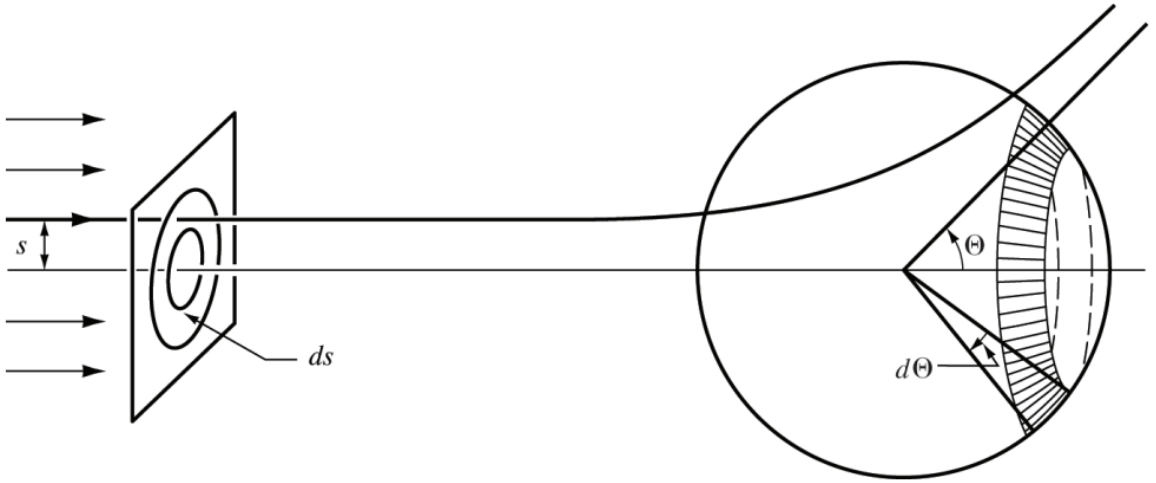
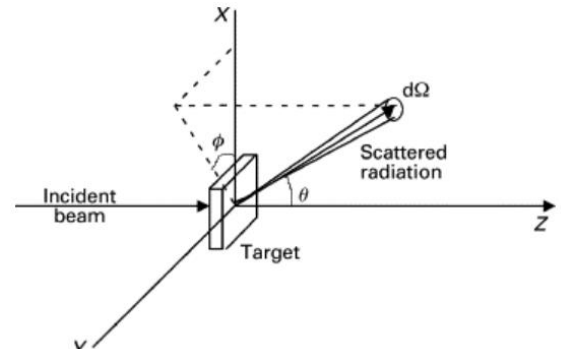
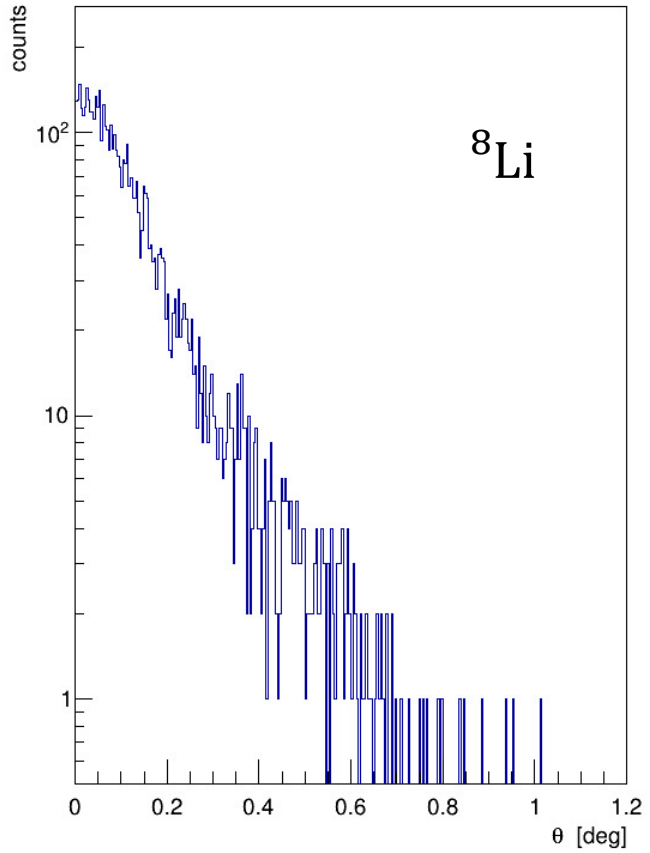
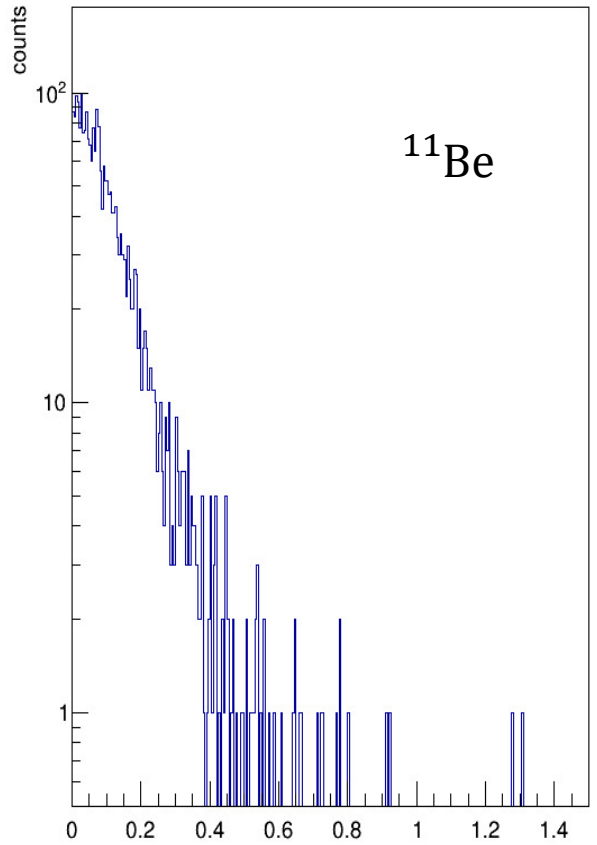


Fig.1 Scattering of an incident beam of particles, where s is the impact parameter and θ is the angle between the scattered and incident directions.

SCATTERING ANALYSIS FOR ^{11}Be AND ^{17}C







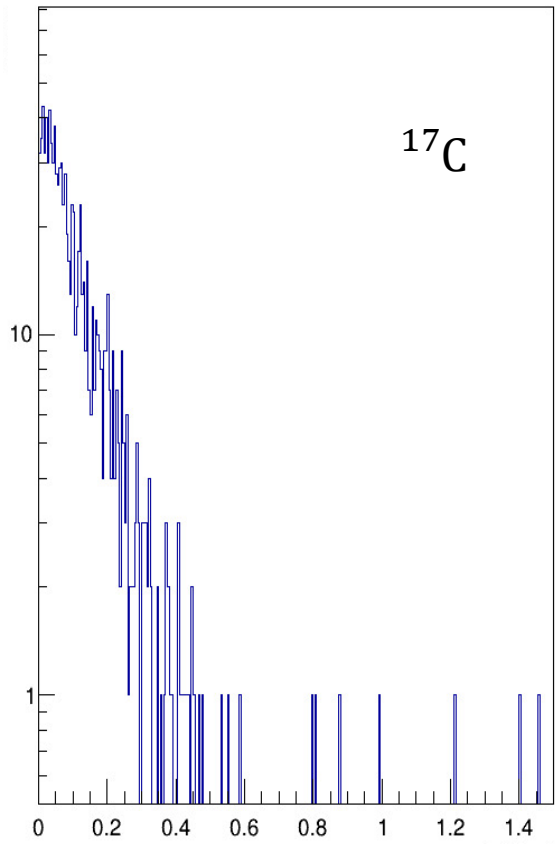
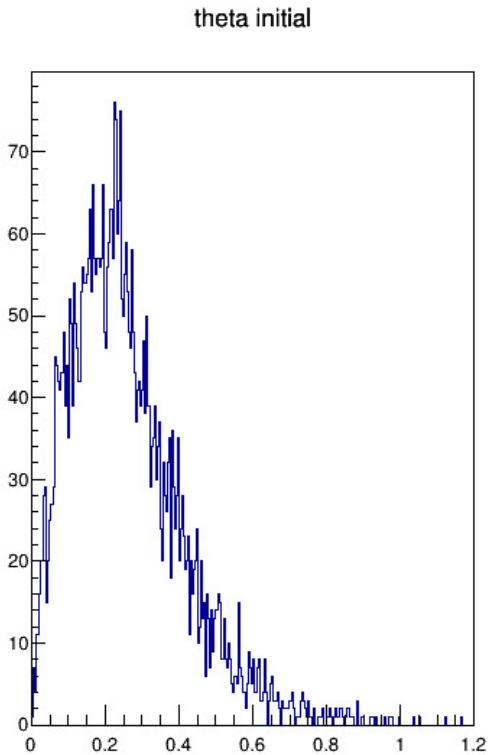
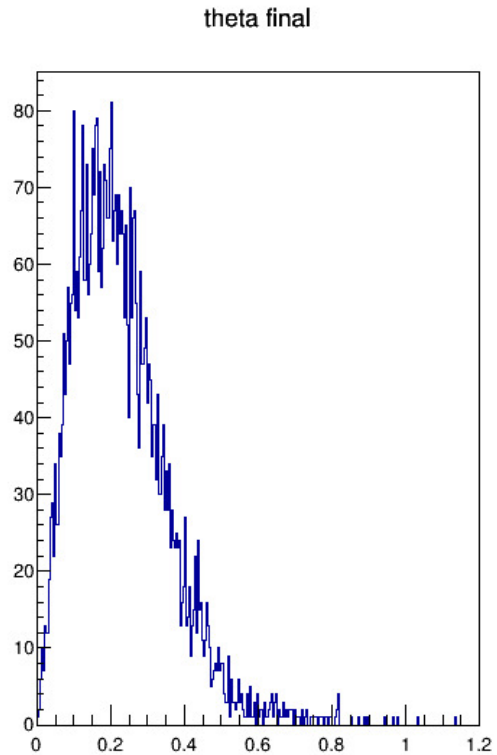
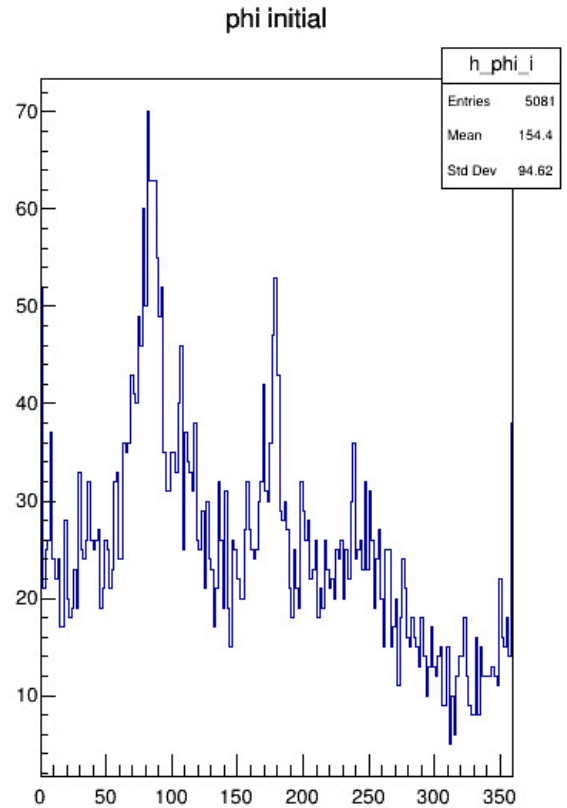
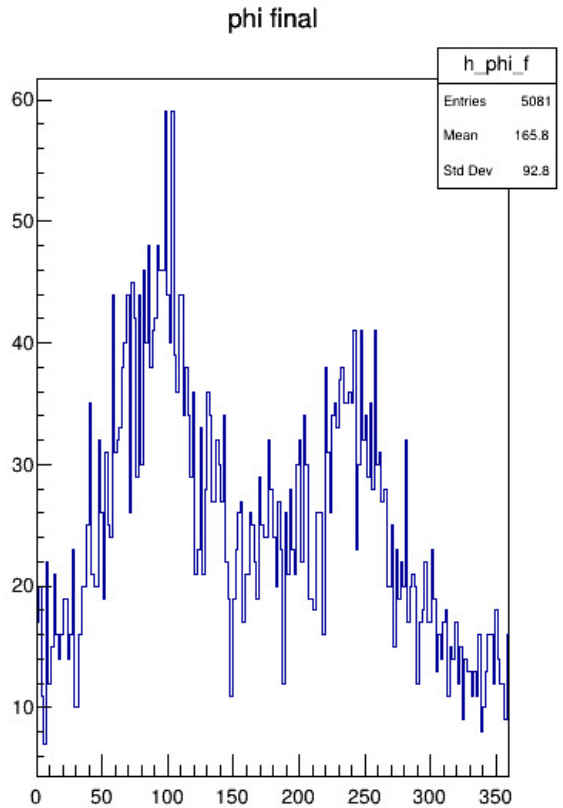


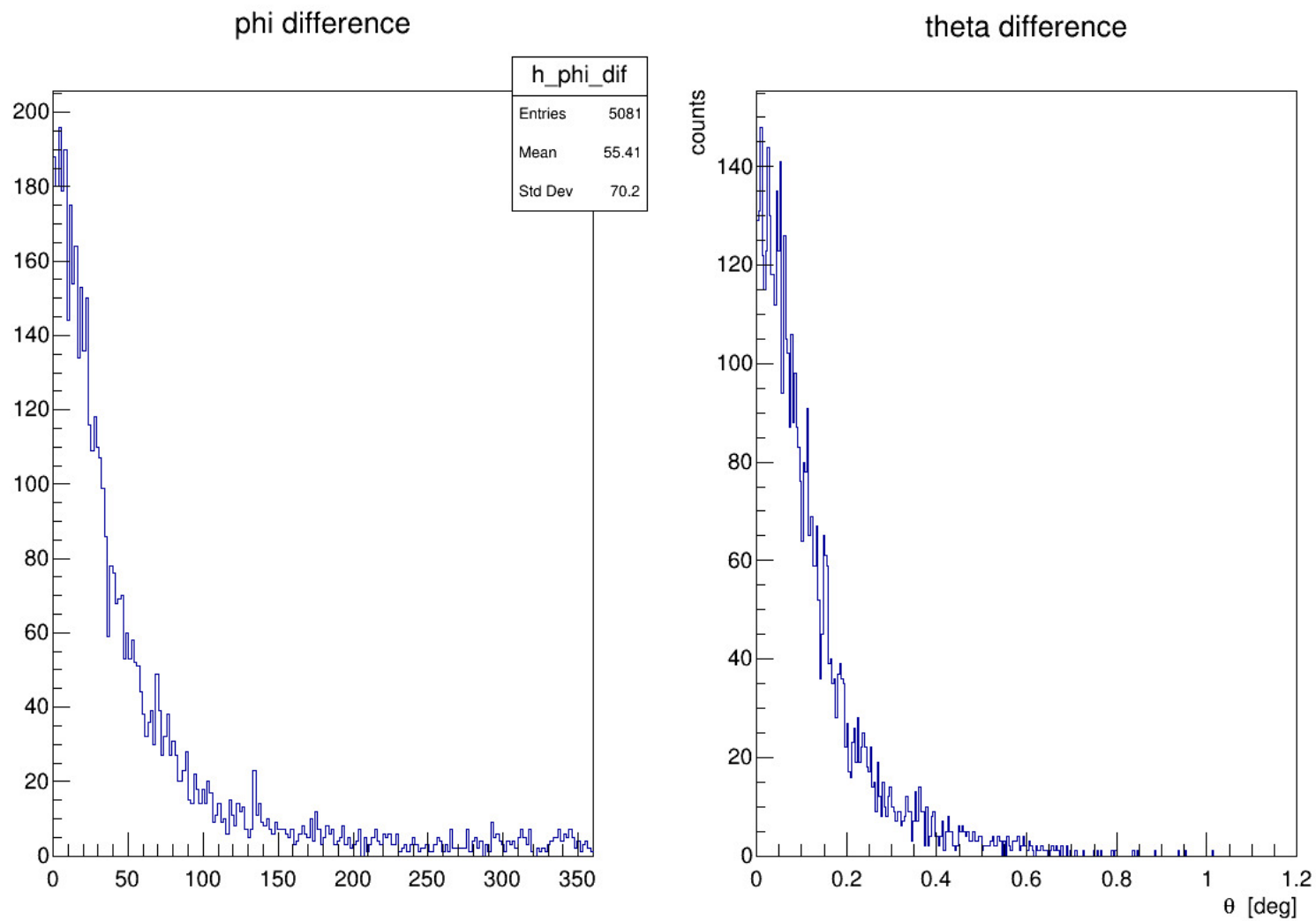
Fig.14 Scattered θ values for ^{11}Be (left) and ^{17}C (right) at 490 MeV/u.


theta initial
0
10
20
30
40
50
60
70
0
0.2
0.4
0.6
0.8
1
1.2


theta final
0
10
20
30
40
50
60
70
80
0
0.2
0.4
0.6
0.8
1
1.2


phi initial
h_phi_i
Entries 5081
Mean 154.4
Std Dev 94.62
10
20
30
40
50
60
70
0
50
100
150
200
250
300
350


phi final
h_phi_f
Entries 5081
Mean 165.8
Std Dev 92.8
10
20
30
40
50
60
0
50
100
150
200
250
300
350


phi difference
h_phi_dif
Entries 5081
Mean 55.41
Std Dev 70.2
0 20 40 60 80 100 120 140 160 180 200
0 50 100 150 200 250 300 350
theta difference
counts
0 20 40 60 80 100 120 140
0 0.2 0.4 0.6 0.8 1 1.2
θ [deg]