

METHOD FOR NUCLEAR FRAGMENTS IDENTIFICATION IN FOOT EXPERIMENT

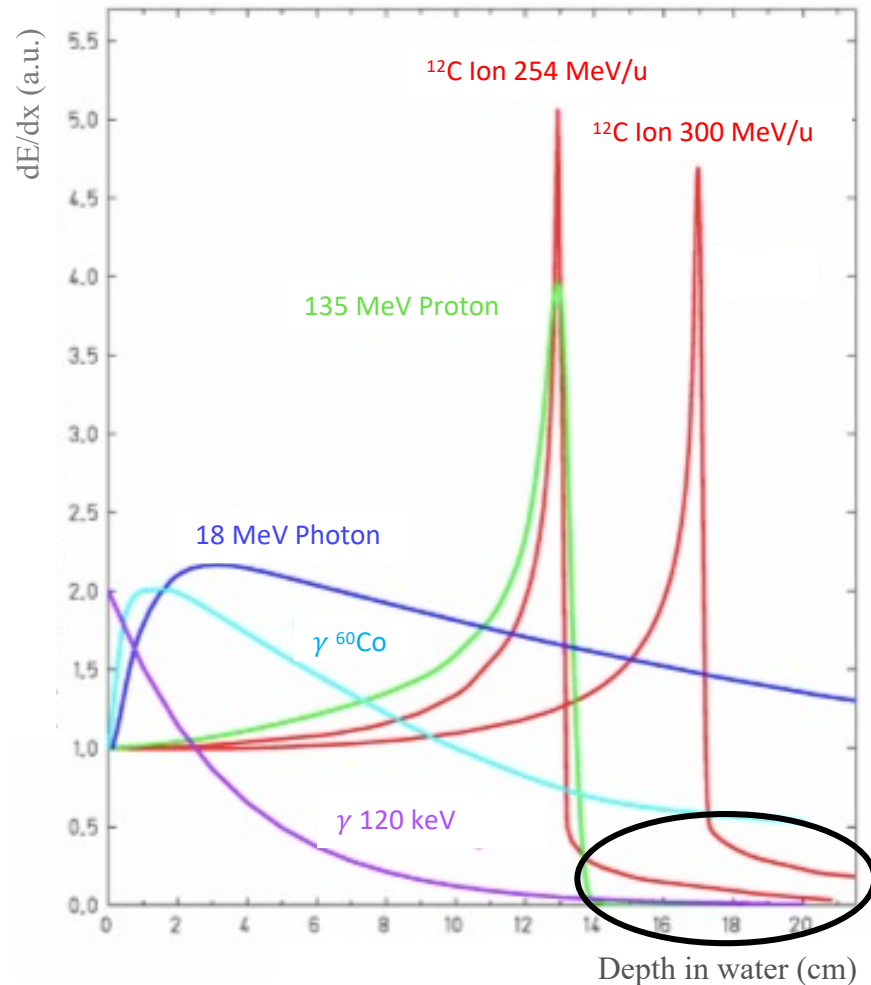
Presented by:

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BCD school – 29/03/2023

HADRONTHERAPY



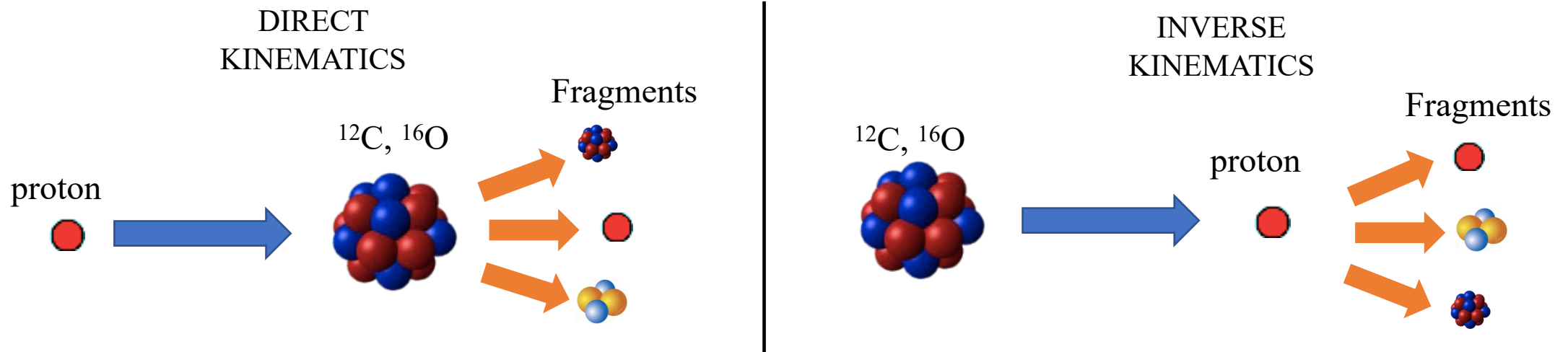
- ^{12}C ions or protons instead of electromagnetic radiation.
- More precise therapy \longrightarrow *Bragg Peak*.
- Not complete knowledge of nuclear fragmentation processes and need of a Standard Treatment Protocol.

FOOT EXPERIMENT

- Goal: differential cross section for fragments production.
- Use of *inverse kinematics*.

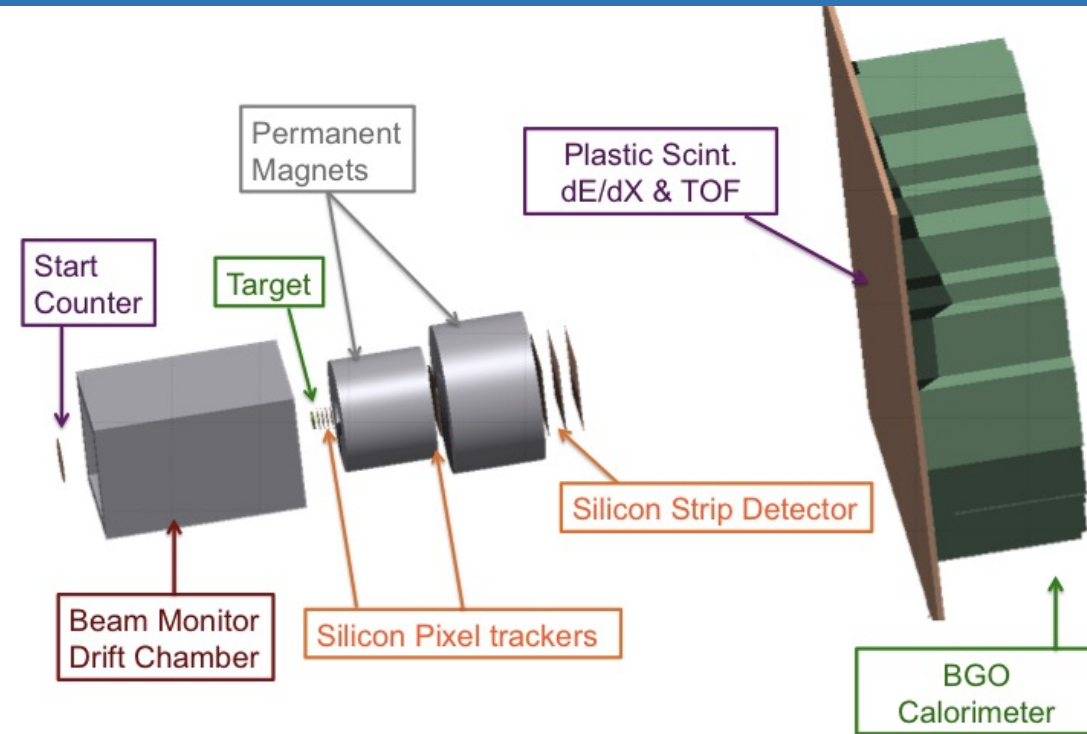


**FragmentatiOn
Of Target**



EXPERIMENTAL APPARATUS

- Heavy fragments setup.
- Pre-target region.
- Tracking zone.
- Final region.



DATA ANALYSIS

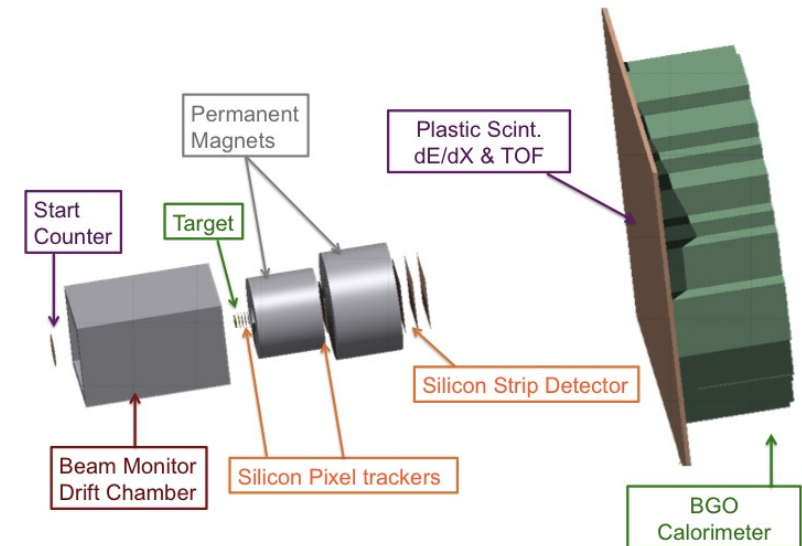
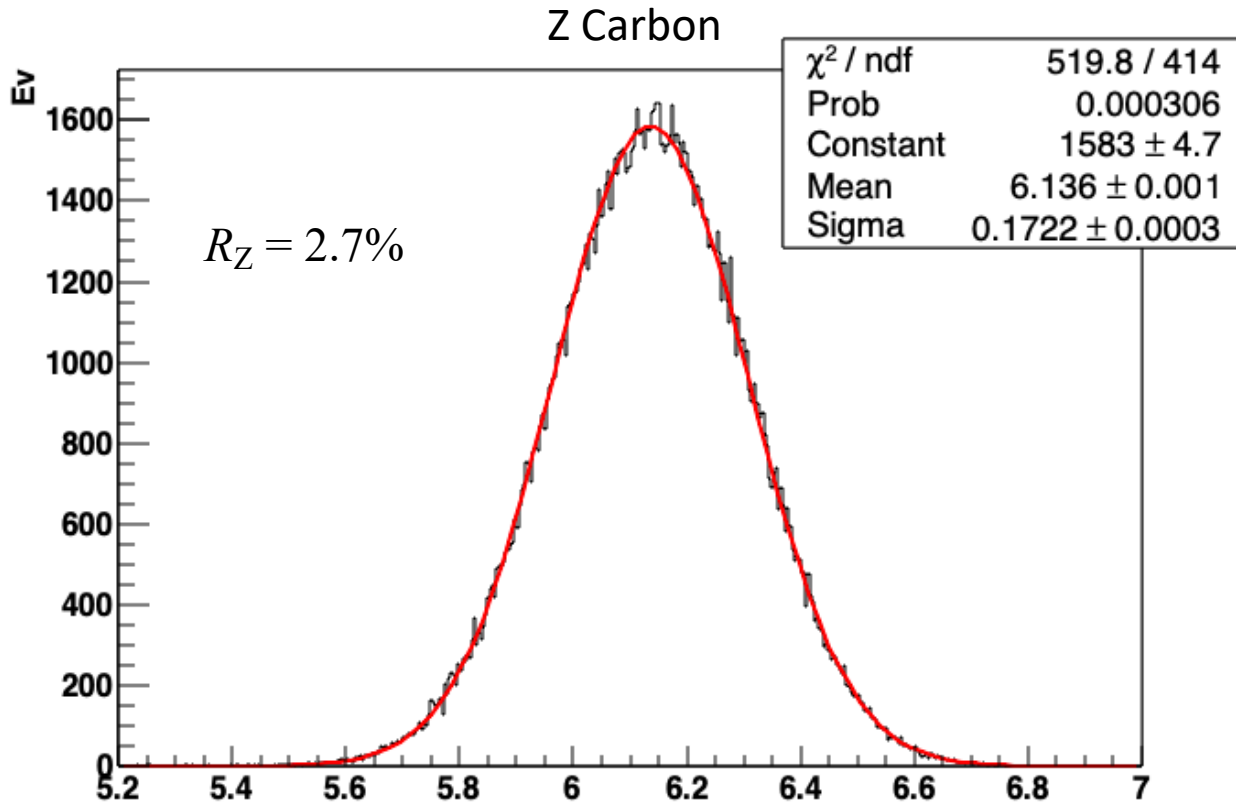
Analysis done on simulated data from ^{16}O @ 200 MeV/u vs C_2H_4 interaction, and the resolutions applied to the kinematical quantities of the evaluated fragments are the following:

- p momentum resolution: $R_p = 4\%$;
- E_{cal} deposited energy in calorimeter resolution: $R_{E_{\text{cal}}} = 1.5\%$;
- TOF time of flight: $R_{\text{tof}} = f(Z) = 70 \text{ ps}$ (^{12}C);
- ΔE_{scint} deposited energy in scintillator resolution: $R_{\Delta E_{\text{scint}}} = f(E)$.

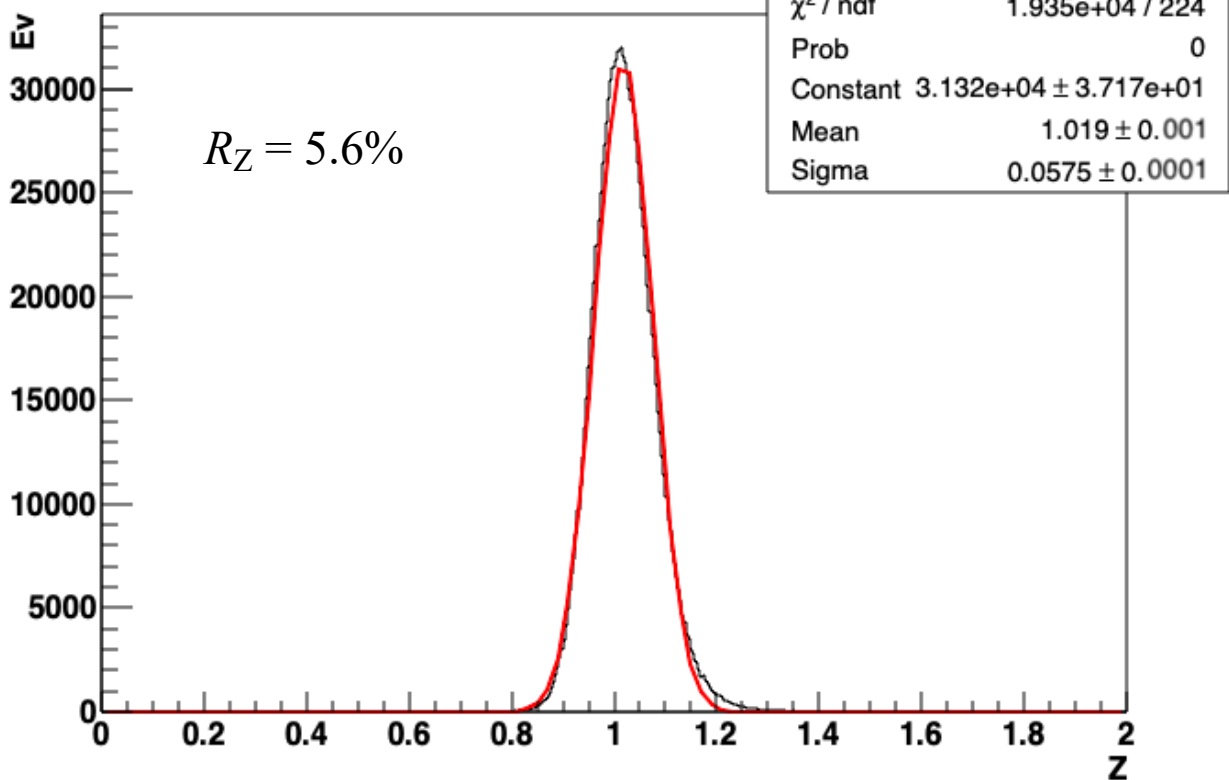
FRAGMENTS IDENTIFICATION

CHARGE Z

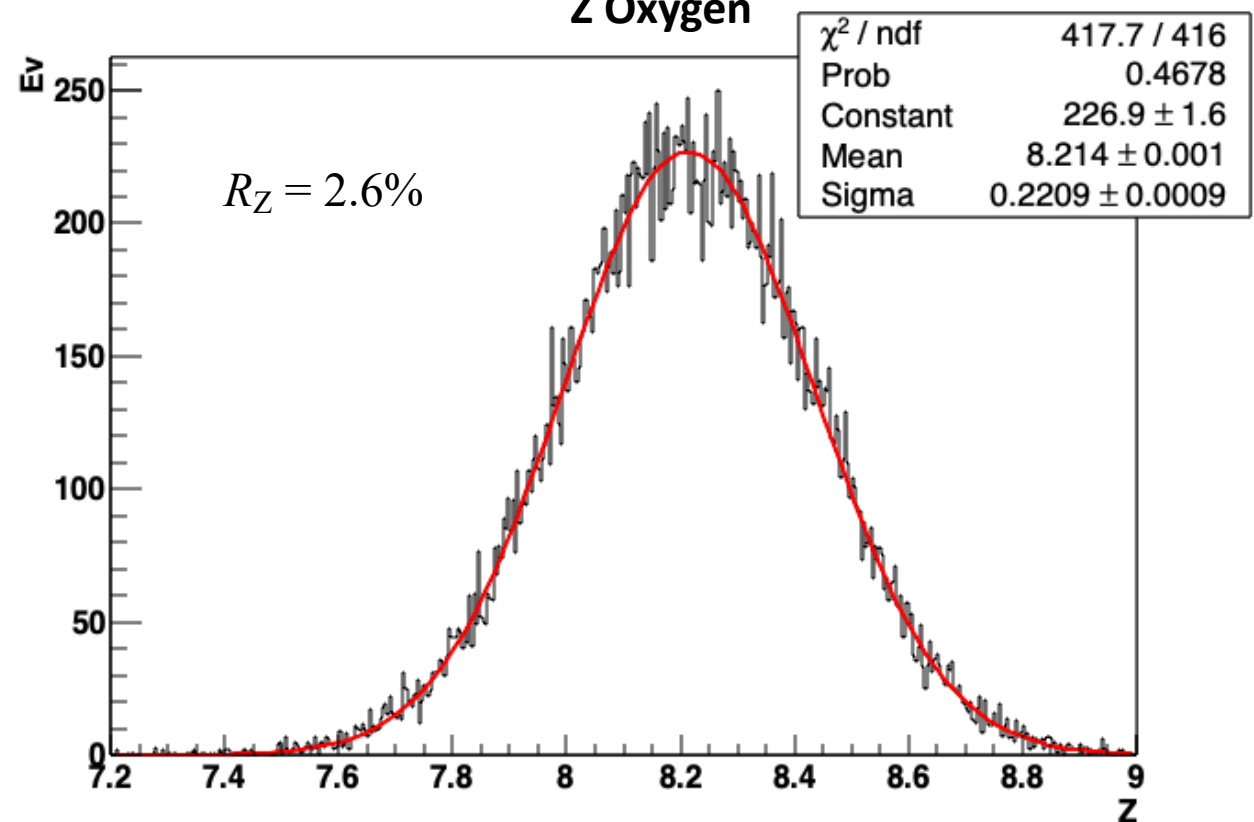
Obtained through the Bethe-Bloch formula: $-\frac{dE}{dx} = \frac{\rho Z_m}{A} \frac{4\pi N_A m_e c^2}{M_U} \left(\frac{e^2}{4\pi\epsilon_0 m_e c^2} \right)^2 \frac{Z^2}{\beta^2} \left[\ln \left(\frac{2m_e c^2 \beta^2}{I(1-\beta^2)} \right) - \beta^2 - \frac{\delta}{2} - \frac{C}{z_m} \right]$



Z Hydrogen



Z Oxygen



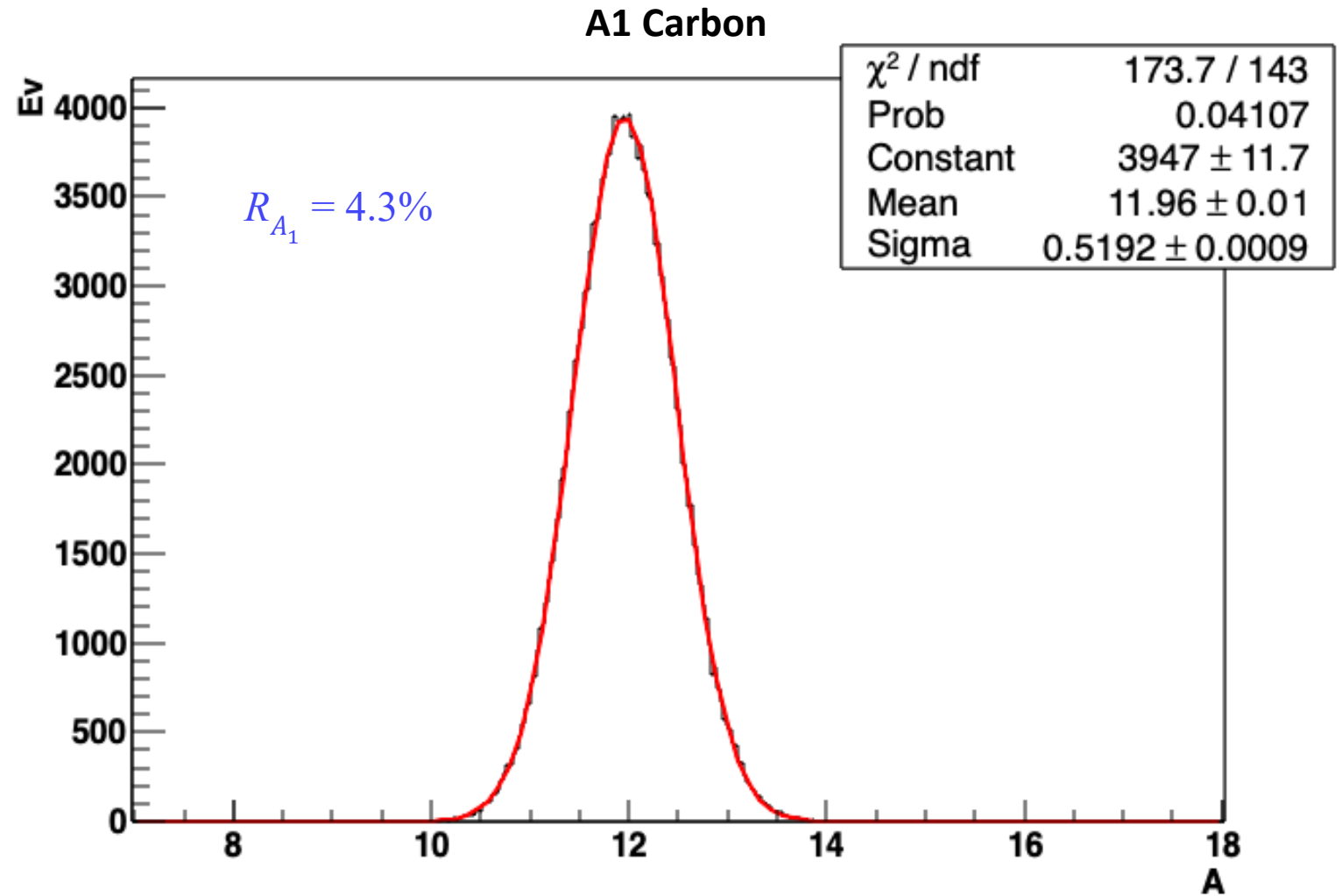
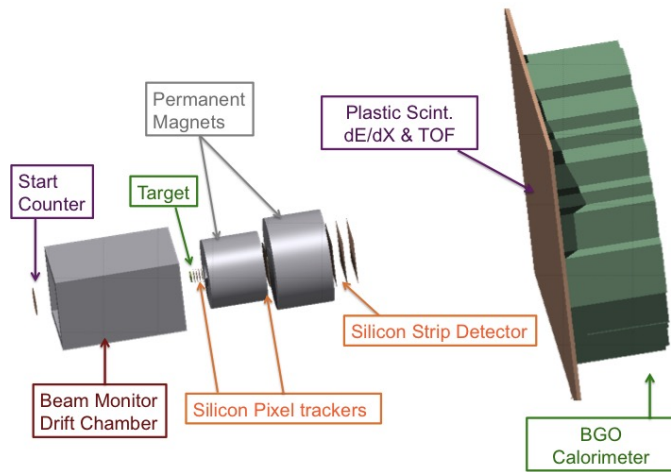
Fragment	1H	4He	7Li	9Be	${}^{11}B$	${}^{12}C$	${}^{14}N$	${}^{16}O$
Z expected	1	2	3	4	5	6	7	8
Z reco	(1.02 ± 0.06)	(2.03 ± 0.07)	(3.05 ± 0.10)	(4.07 ± 0.12)	(5.10 ± 0.14)	(6.14 ± 0.17)	(7.2 ± 0.2)	(8.2 ± 0.2)

FRAGMENTS IDENTIFICATION

MASS NUMBER A_1

Obtained through:

$$A_1 = \frac{p}{Uc\beta\gamma}$$



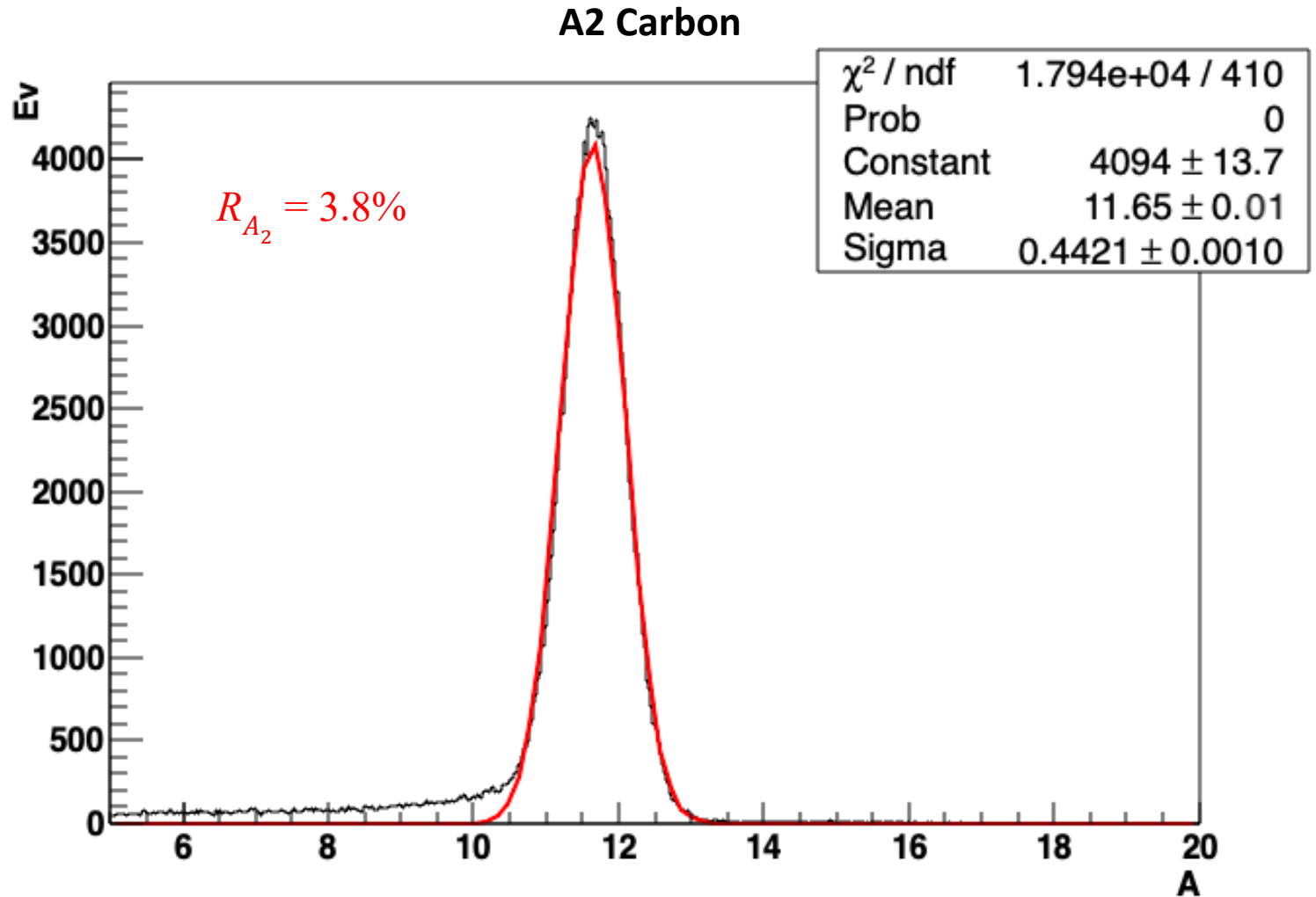
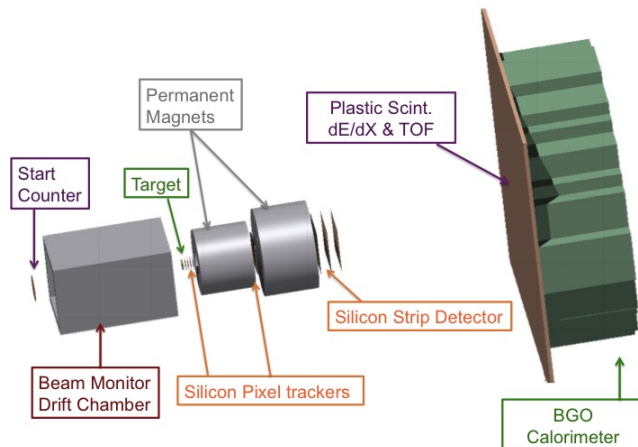
FRAGMENTS IDENTIFICATION

MASS NUMBER A_2

- Obtained through:

$$A_2 = \frac{E_k}{Uc^2(\gamma - 1)}$$

- Pre Bragg Peak-tail due to an underestimation of E_k .



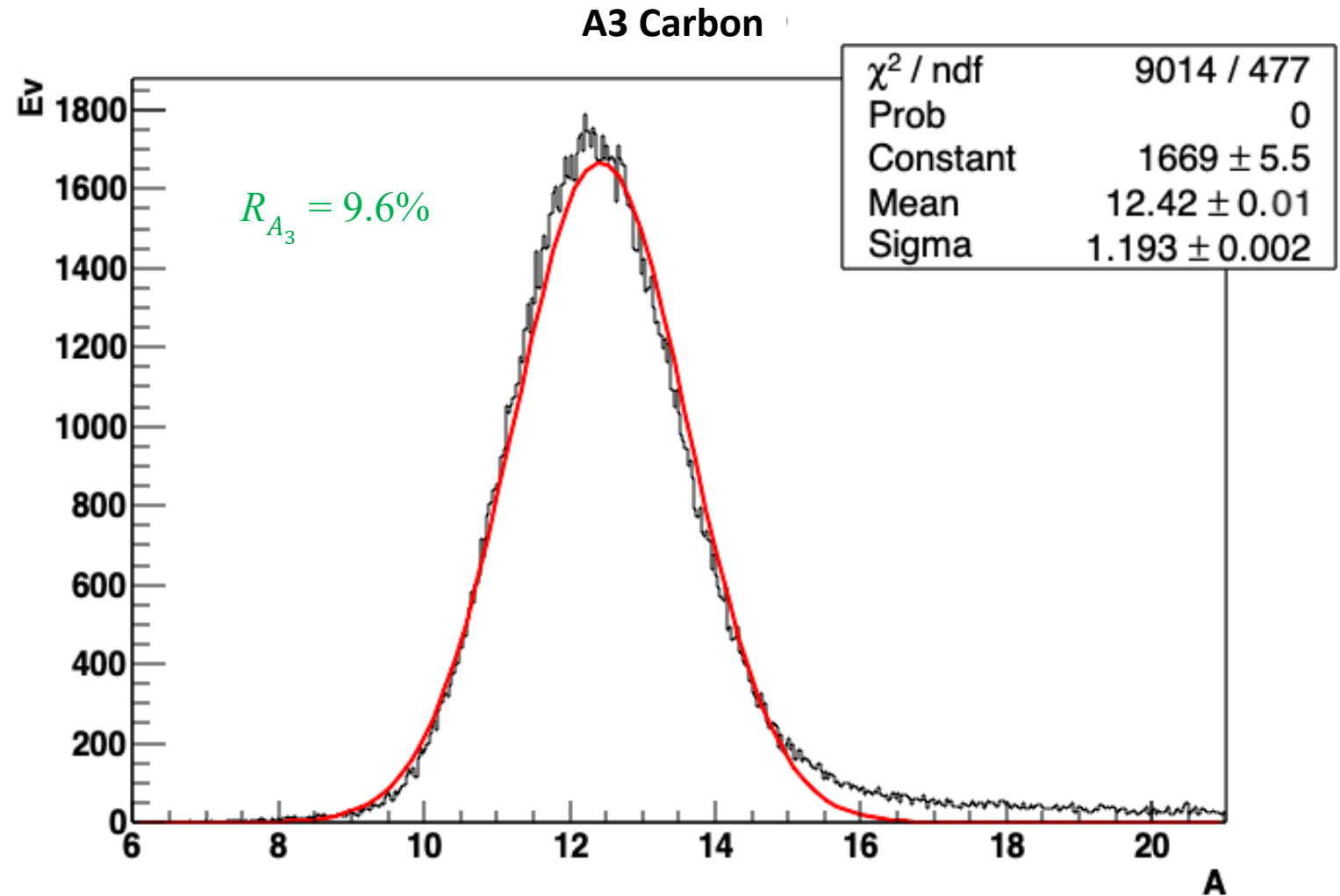
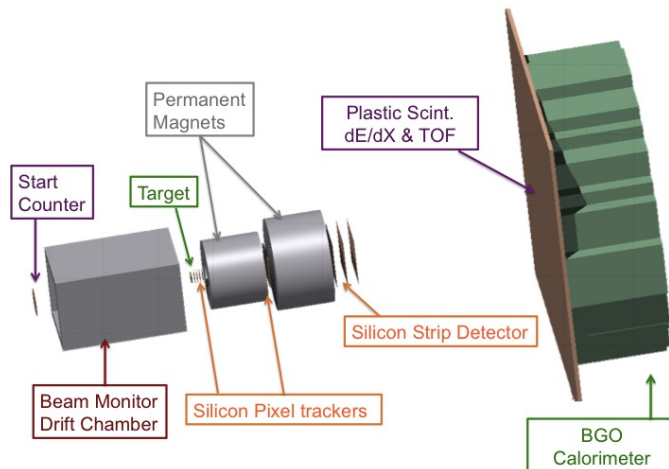
FRAGMENTS IDENTIFICATION

MASS NUMBER A_3

- Obtained through:

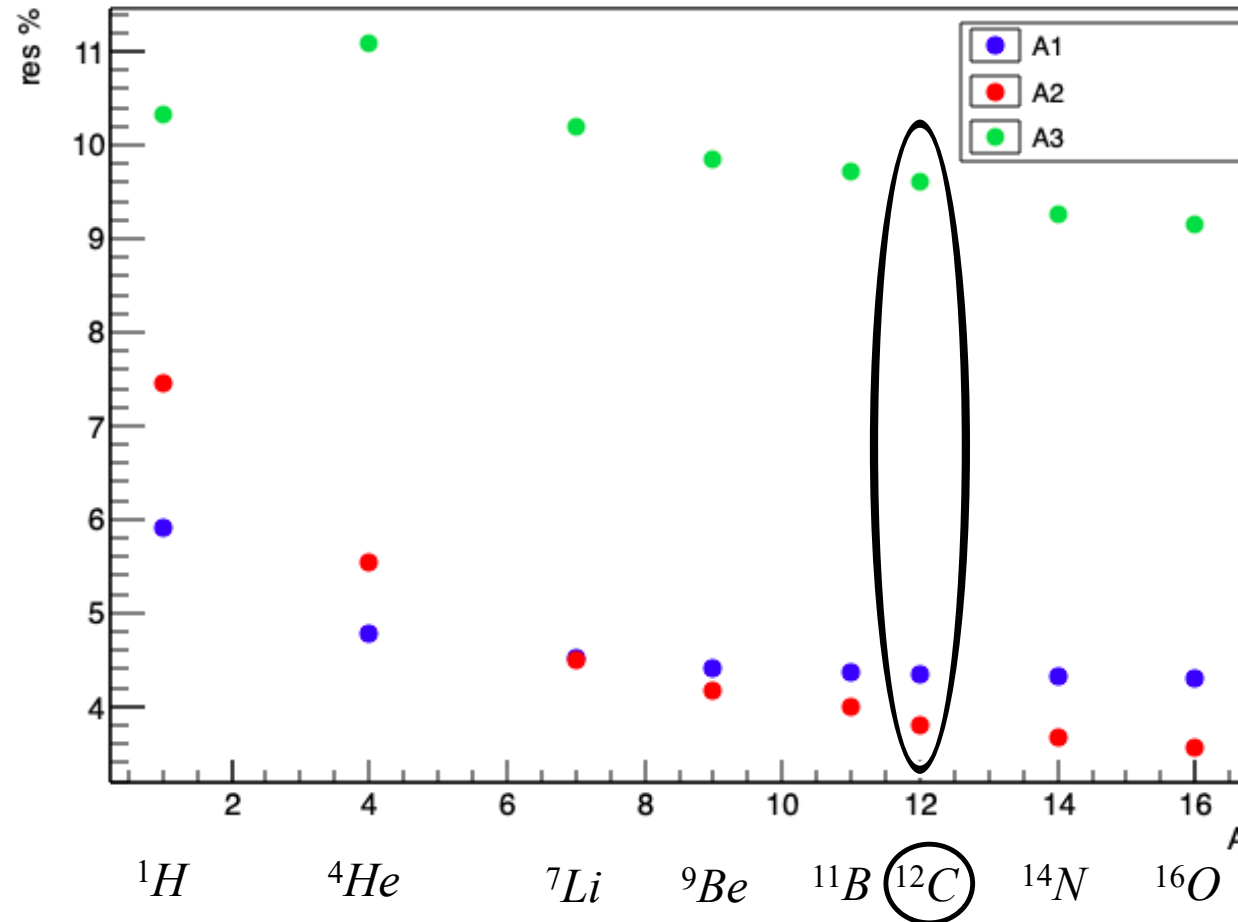
$$A_3 = \frac{p^2 c^2 - E_k^2}{2Uc^2 E_k}$$

- Post Bragg Peak tail due to an underestimation of E_k .



A PERCENTAGE RESOLUTION

A Percentage resolution



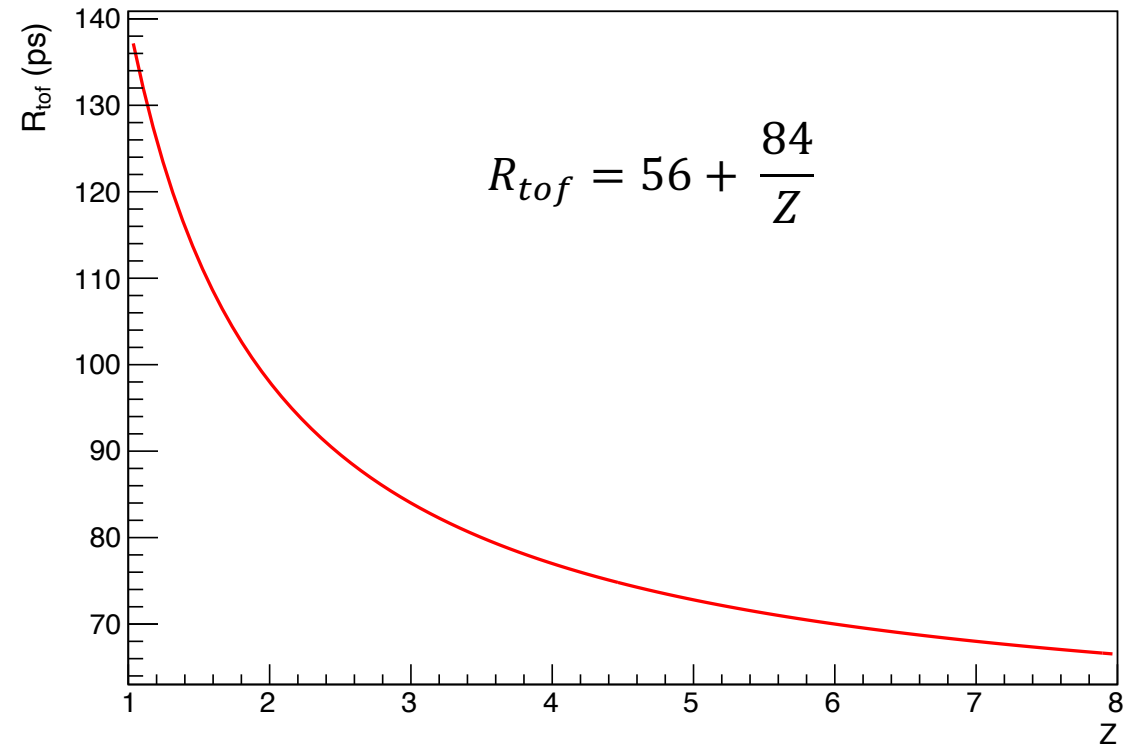
- A_1 resolution (p, TOF): about 5%.
- A_2 resolution (E_k, TOF): between 4-5%.
- A_3 resolution (p, E_k): about 10%.
- It gets better for heavier fragments.

TOF SYSTEMATIC STUDY

- TOF resolution parametrized as:

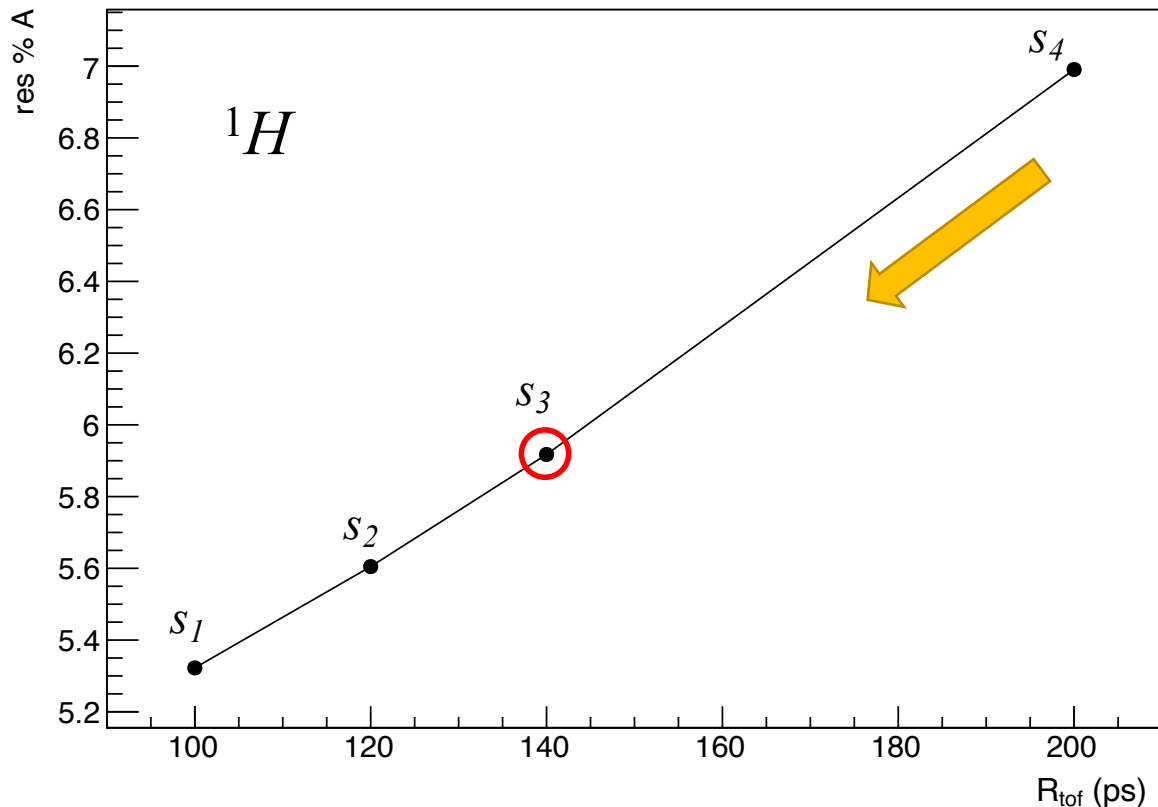
$$R_{tof} = A + \frac{B}{Z}$$

- Analysis repeated with different R_{tof} , changing A e B:
 - s_1 : A = 40, B = 60, $R_{tof} = 50$ ps (^{12}C);
 - s_2 : A = 48, B = 72, $R_{tof} = 60$ ps (^{12}C);
 - s_3 : A = 56, B = 84, $R_{tof} = 70$ ps (^{12}C);
 - s_4 : A = 80, B = 120, $R_{tof} = 100$ ps (^{12}C).



TOF SYSTEMATIC STUDY

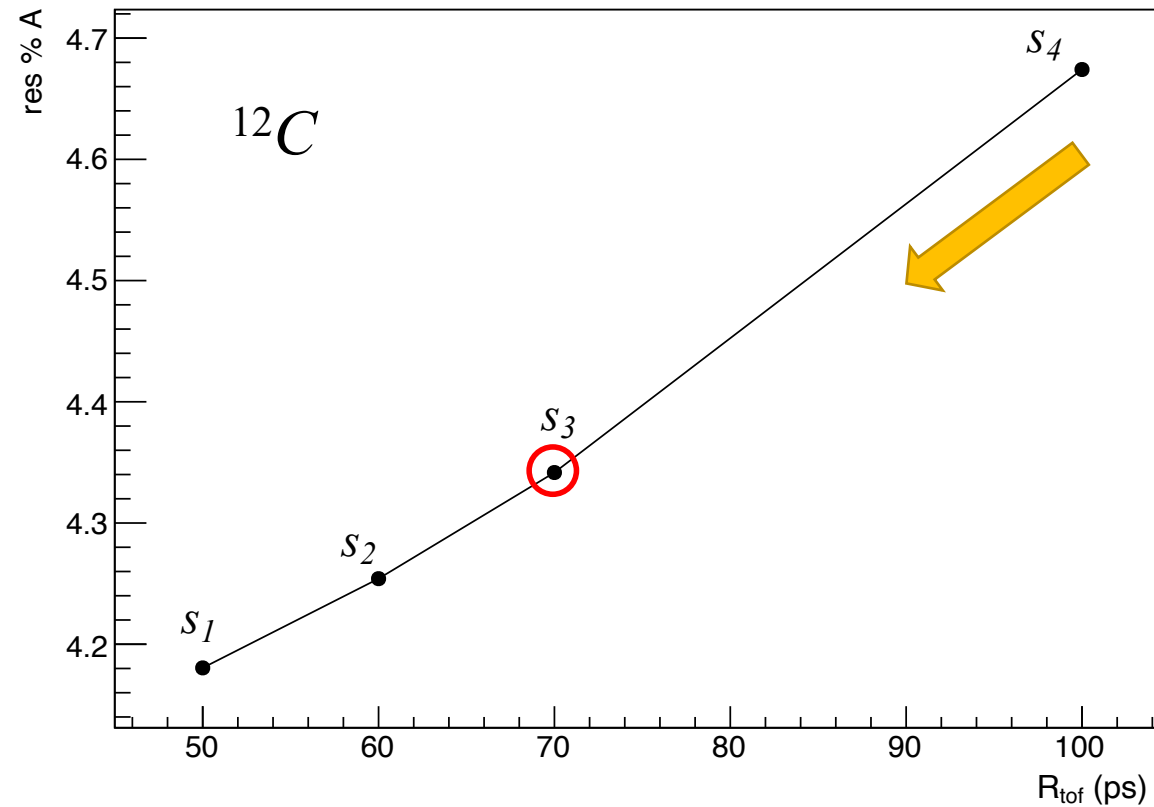
A1 resolution for H



Increasing by a factor 2 the *TOF* precision:

there is a 20% improvement in *A* reconstruction for 1H .

A1 resolution for C



there is a 10% improvement in *A* reconstruction for ^{12}C .

CONCLUSIONS

- I've studied a method for nuclear fragments identification produced in nuclear interactions.
- I've performed an analysis of simulated data. The algorithms used can be applied to real data acquired in July 2021 at GSI.
- In July 2021 42 million events were acquired at GSI, the analysis is still running and the results will be compared with the ones of this work.

THANKS FOR YOUR
ATTENTION.