SOCIETÀ ITALIANA
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The FOOT experiment:
A first measurement of nuclear fragmentation cross-sections for hadrontherapy

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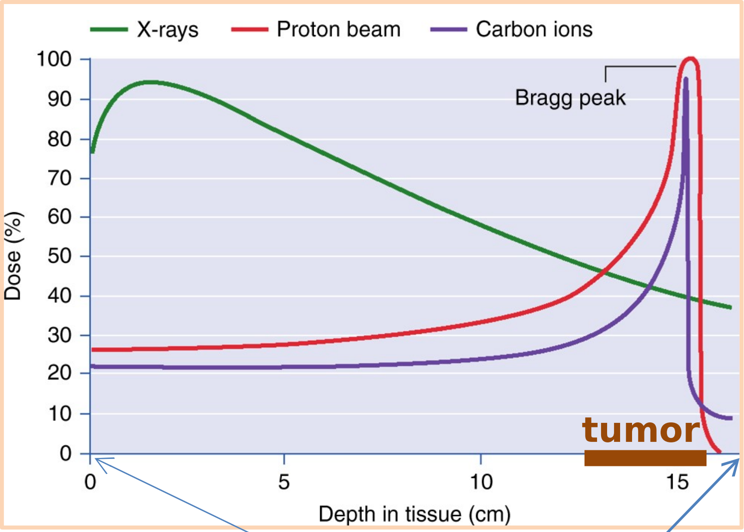
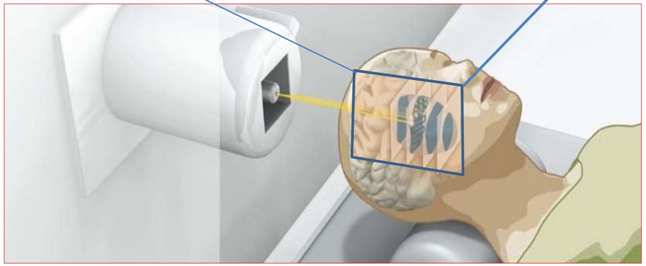
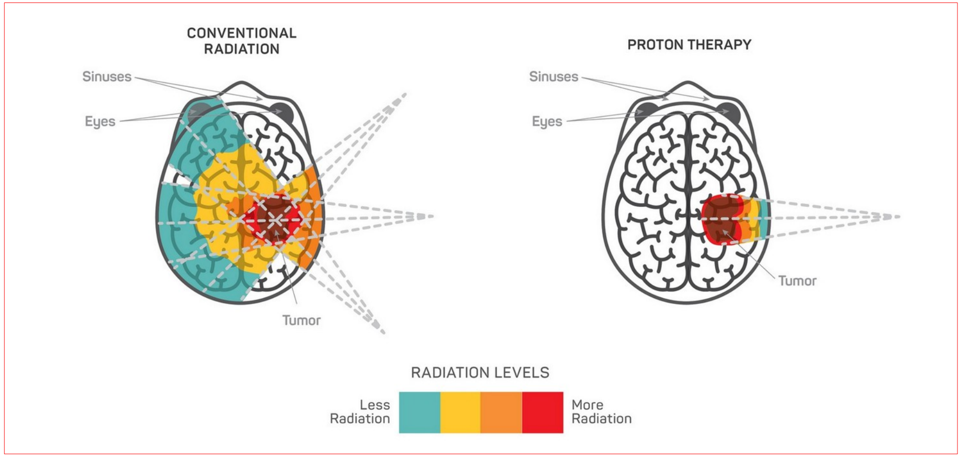
Hadrontherapy







Hadrontherapy vs radiotherapy:

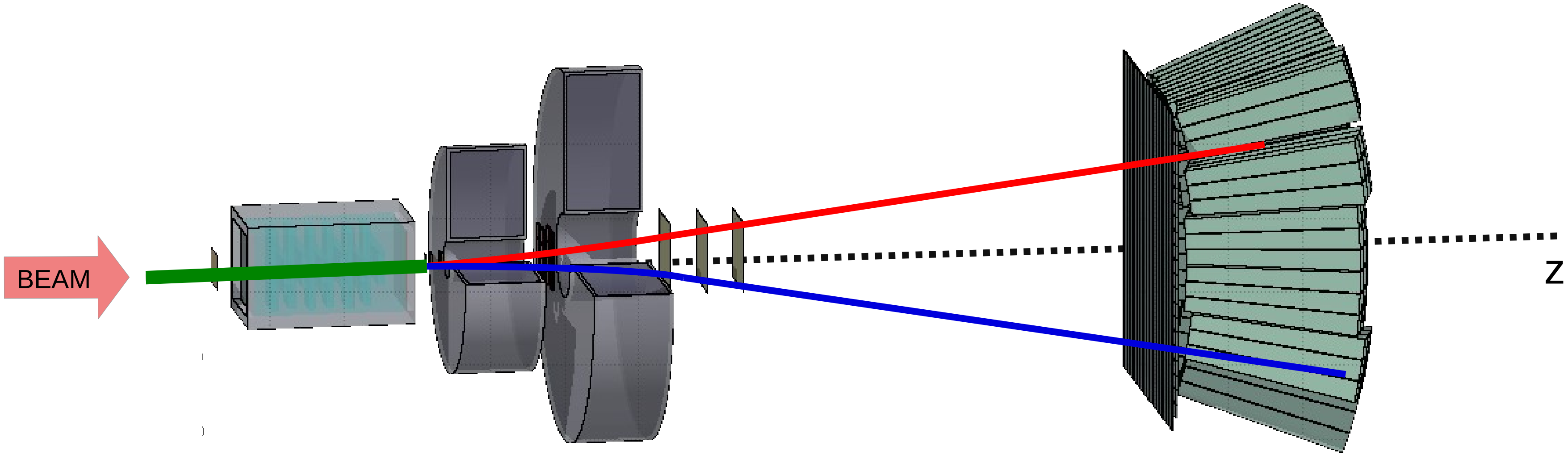
- ✔ **Finite range**
- ✔ **Localized dose profile**
- ✔ **Spare of healthy tissues**
- ✘ **Nuclear Fragmentation**

The FOOT experiment

Goal:

double differential **nuclear cross section** measurements with uncertainty < 5%

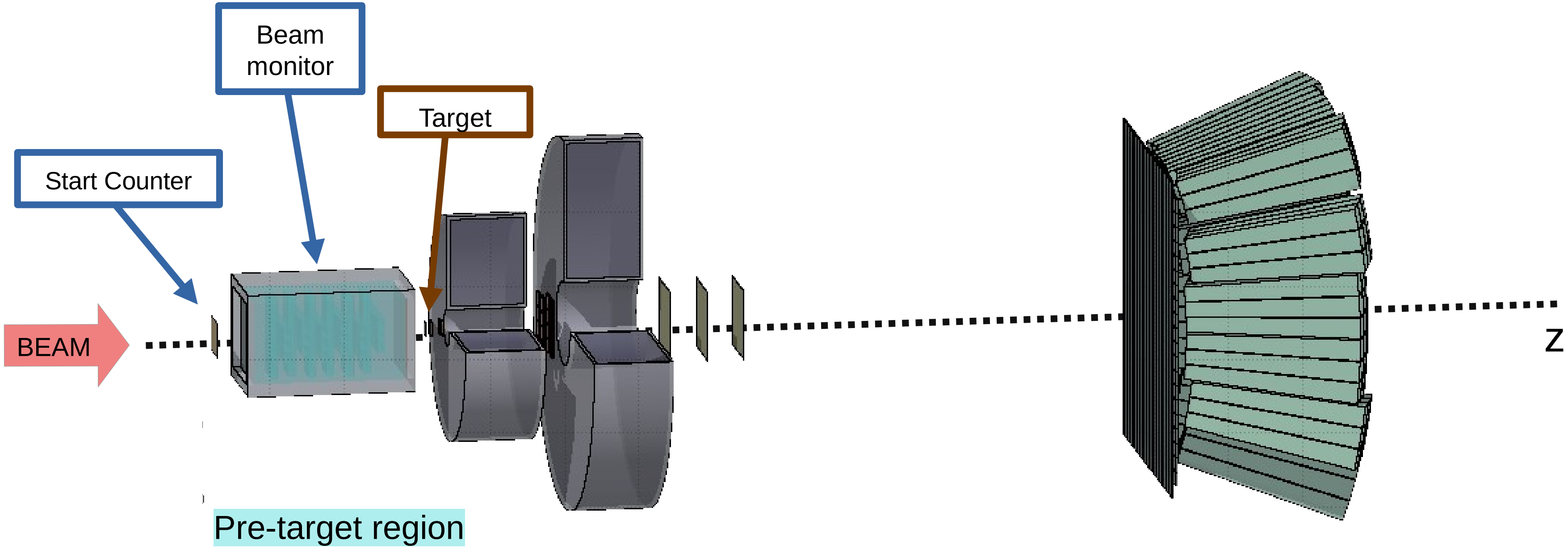
- Fixed target collisions
- Beam energies between 200 MeV/u and 700 MeV/u for **hadrontherapy** and **space radioprotection** topics
- **table top setup** to be moved according to beam facility availability



The FOOT experiment

Goal:
double differential **nuclear cross sections** mesurements with uncertainty < 5%

- Particle identification by measuring all kinematic quantities



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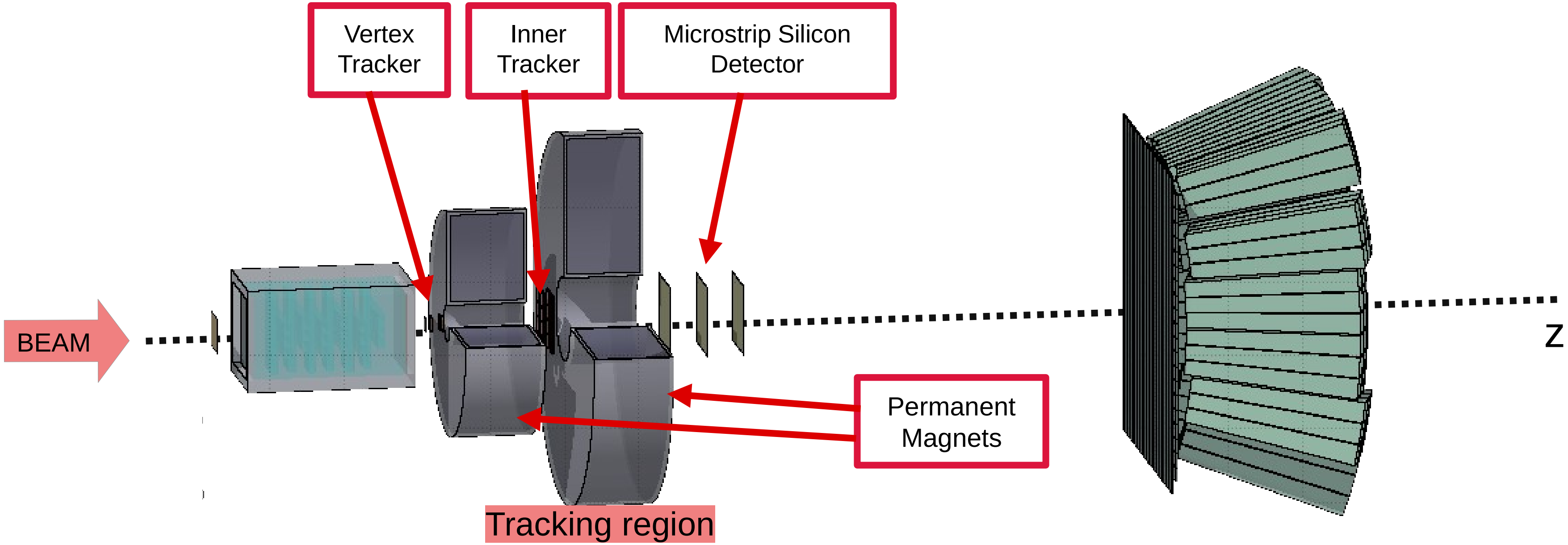

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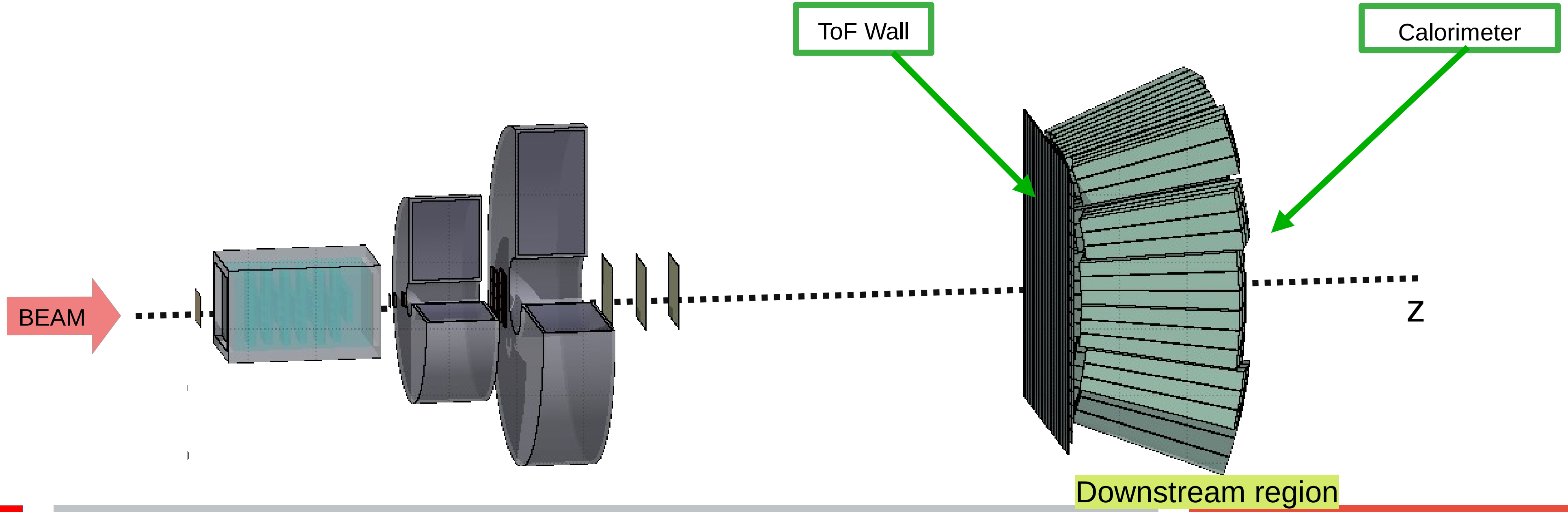
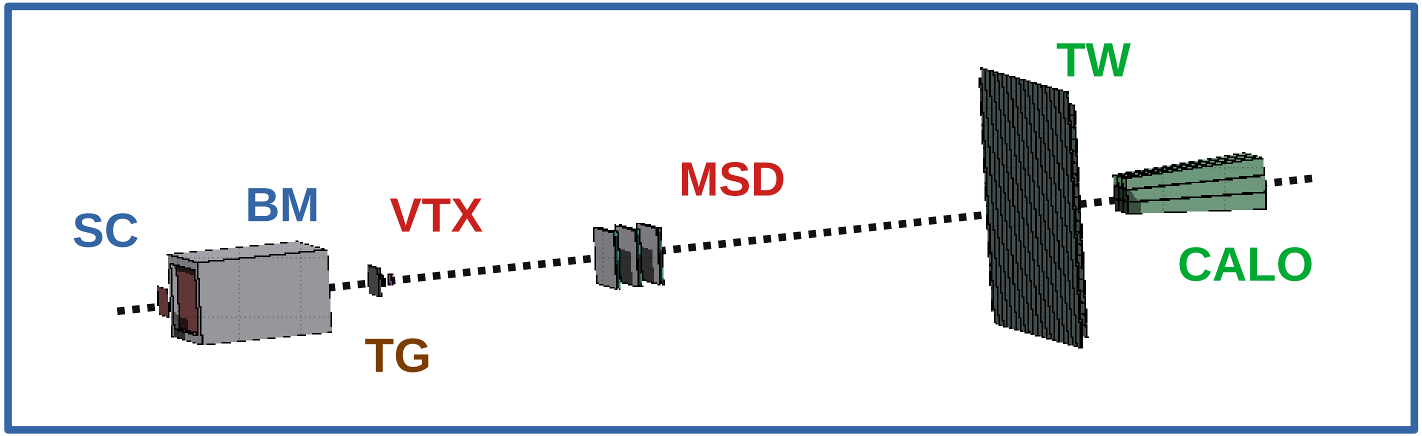
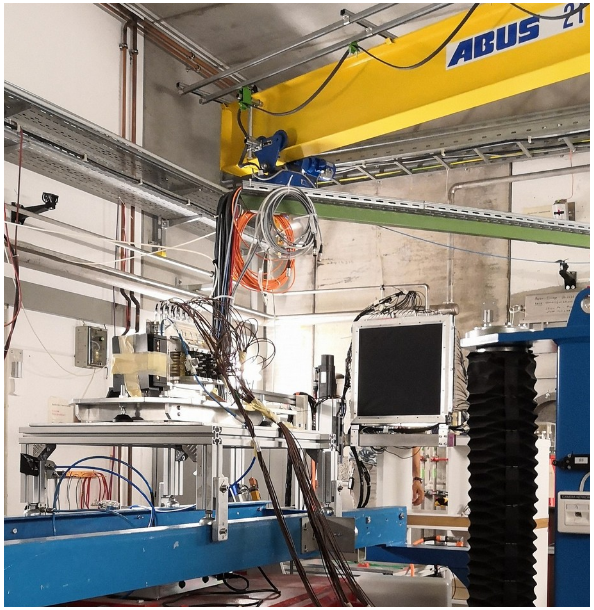


GSI 2021 Analysis

- Data-taking at GSI (Darmstadt, Germany) in 2021
- ^{16}**O 400 MeV/u** on 5 mm **C target**
- Partial setup: no magnet, only one module of calorimeter





Specific goal:

- Elemental (charge differential) fragmentation cross section
- Angular differential cross section in charge

Analysis procedure

To compute elemental cross-section:

$$\sigma(Z) = \frac{Y(Z) - B(Z)}{N_{beam}\ N_{target}\ \epsilon(Z)}$$

- Starting from **MC dataset** to study Background and Efficiency from true values

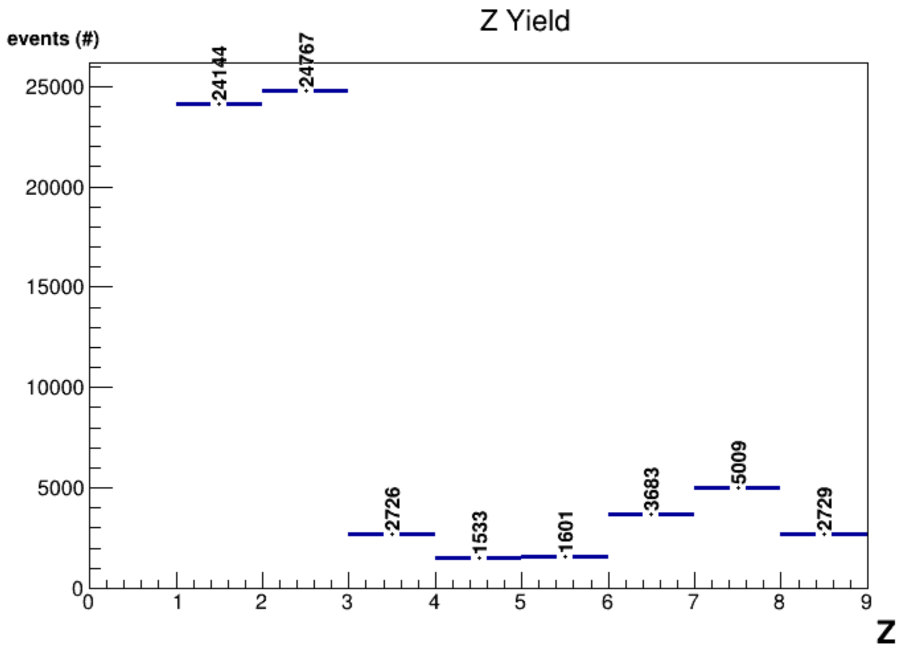
Analysis procedure

To compute elemental cross-section:

$$\sigma(Z) = \frac{Y(Z) - B(Z)}{N_{beam}\ N_{target}\ \epsilon(Z)}$$

Yield of Z obtained from reconstructed tracks

- Exploiting charge reconstruction algorithm
- Exploiting tracking reconstruction algorithm
- Simulating a “trigger” in order to consider only fragments



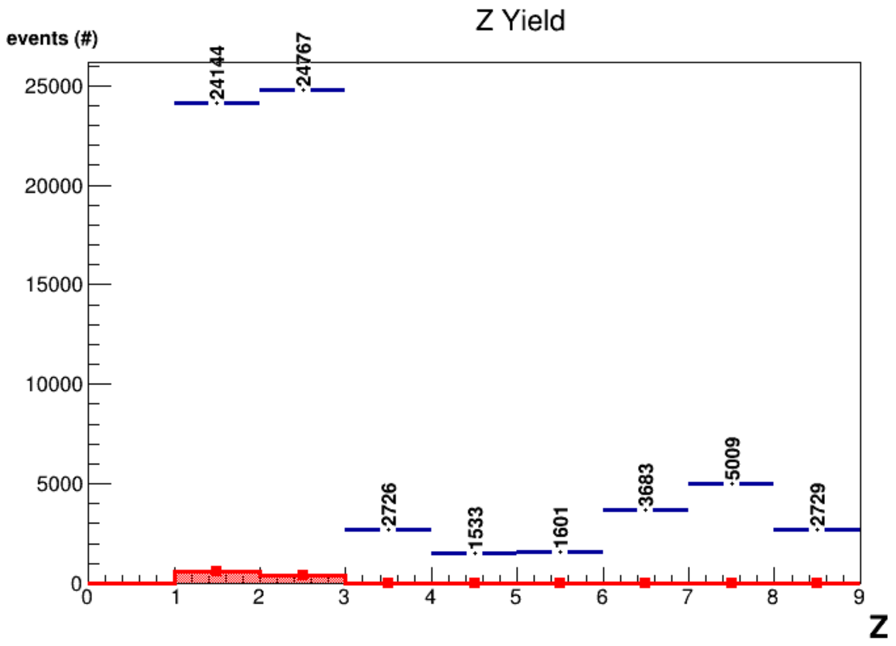
Analysis procedure

To compute elemental cross-section:

$$\sigma(Z) = \frac{Y(Z) - B(Z)}{N_{beam}\ N_{target}\ \epsilon(Z)}$$

Background obtained from MC cuts on:

- Charge algorithm mis-reconstruction
- Tracking algorithm mis-reconstruction
- Trigger mis-reconstruction



Analysis procedure

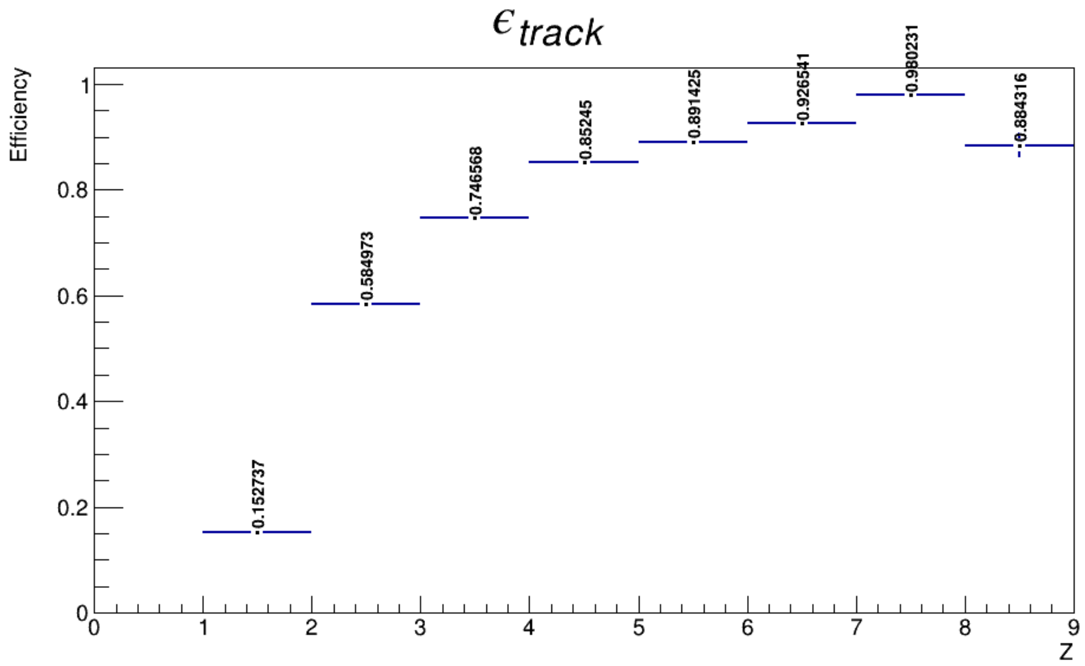
To compute elemental cross-section:

$$\sigma(Z) = \frac{Y(Z) - B(Z)}{N_{beam}\, N_{target}\, \epsilon(Z)}$$

Efficiency obtained as:

$$\epsilon_{track}(Z) = \frac{Y(Z)_{track}}{Y(Z)_{MC}}$$

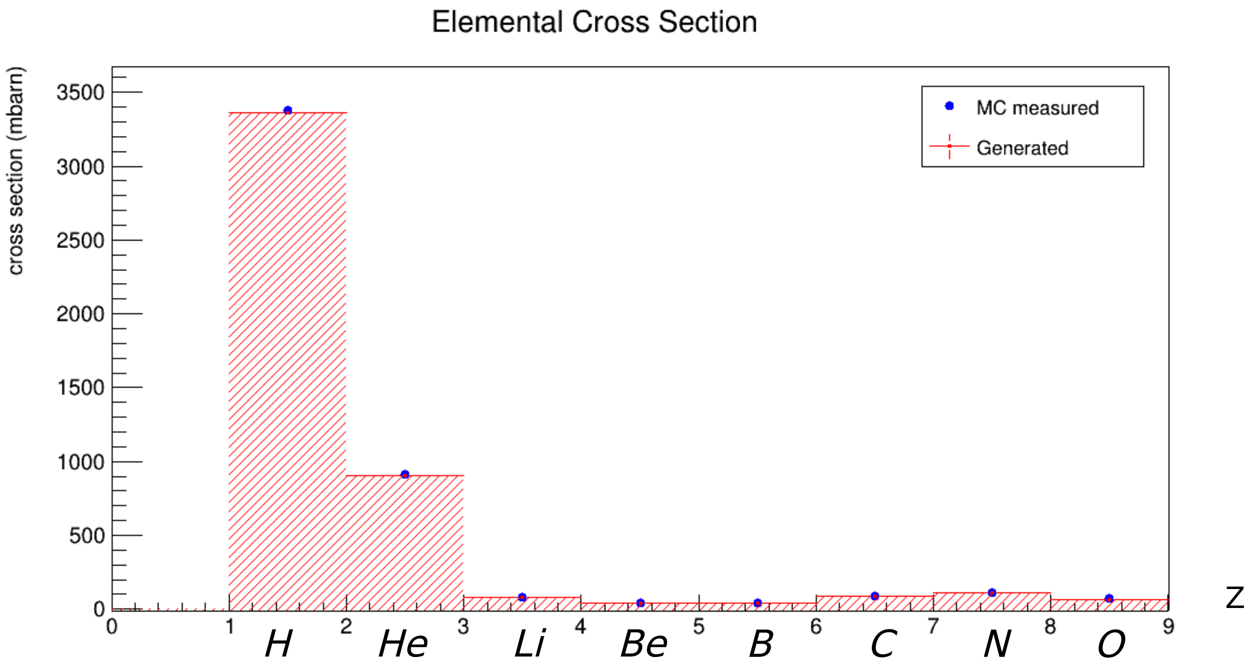
- where track is obtained by tracking algorithm
- MC particles are from the generated simulation



Elemental fragmentation cross-section

- Smeared MC dataset used as Yield
- Statistical uncertainties only

$$\sigma(Z) = \frac{Y(Z) - B(Z)}{N_{beam}\, N_{target}\, \epsilon(Z)}$$

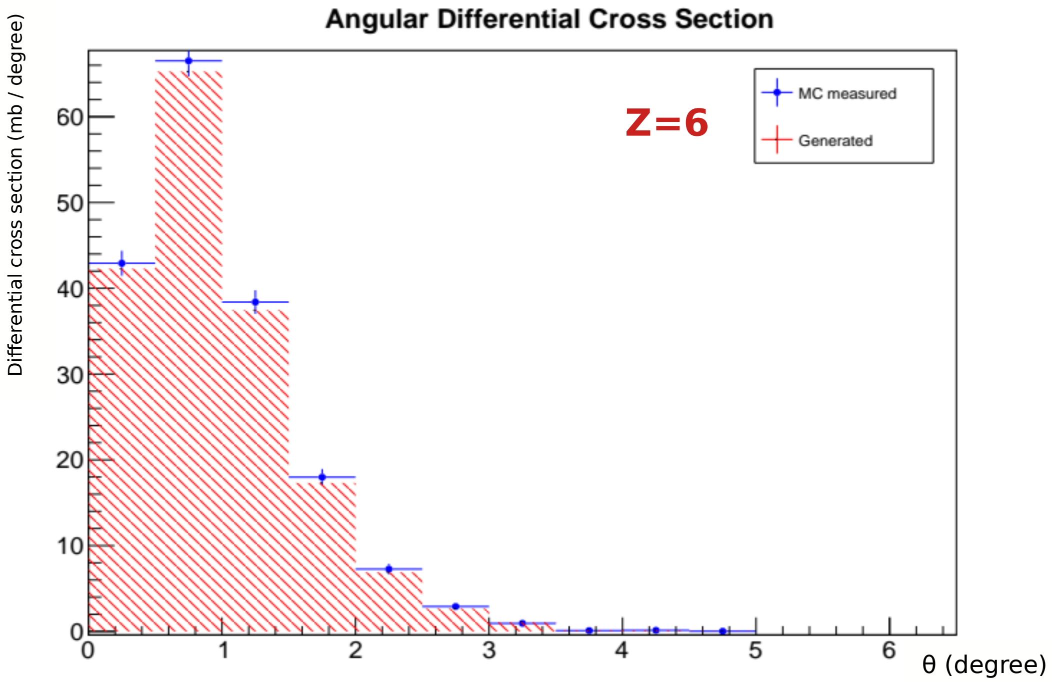


Fragment (Z)	σ_{meas} (mbarn)	σ_{MC} (mbarn)
1	3376 ± 30	3361 ± 8
2	911 ± 7	907 ± 5
3	80 ± 2	79 ± 1
4	40 ± 1	39 ± 1
5	40 ± 1	39 ± 1
6	87 ± 1	87 ± 1
7	112 ± 1	111 ± 2
8	68 ± 3	67 ± 1

Angular differential cross-section

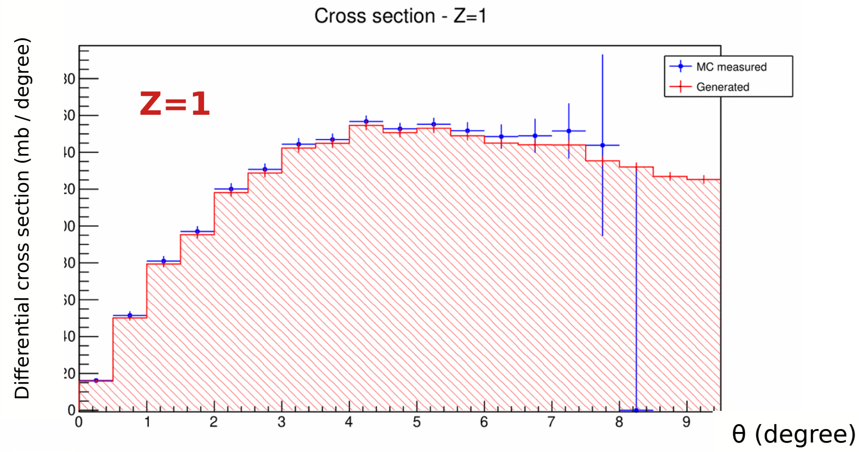
An analogous procedure has been followed to obtain angular differential cross section:

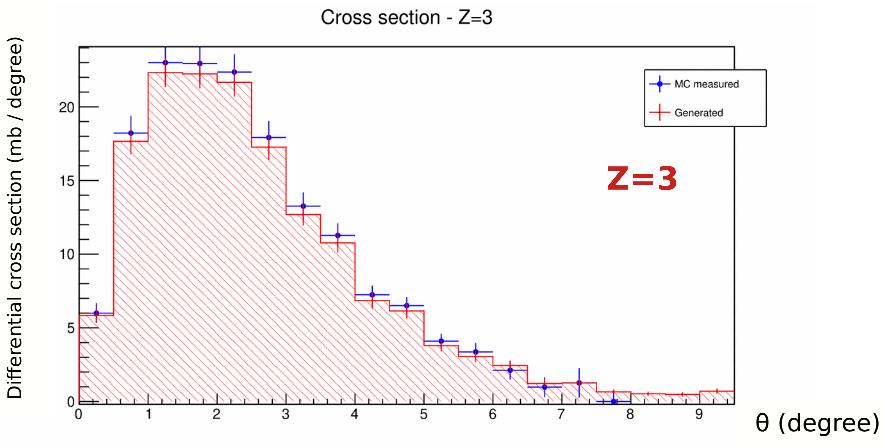
$$\frac{d\sigma(Z)}{d\theta} = \frac{Y(Z,\theta)}{N_{beam}\ N_{target}\ \Delta\theta\ \epsilon(Z,\theta)}$$

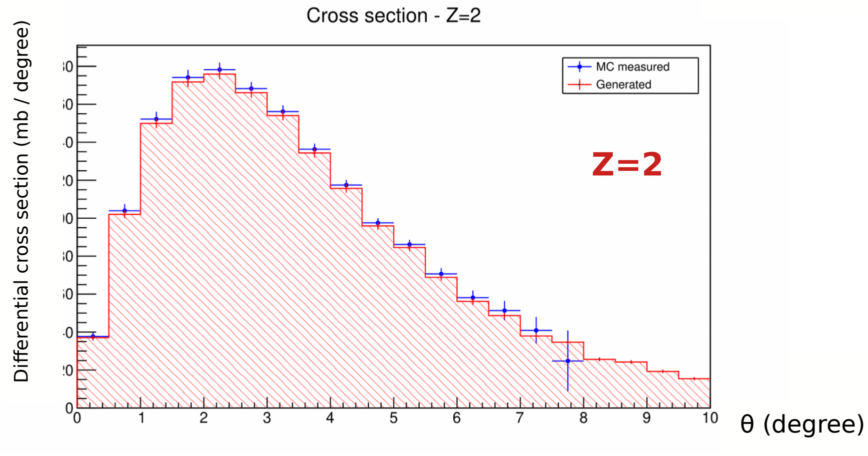


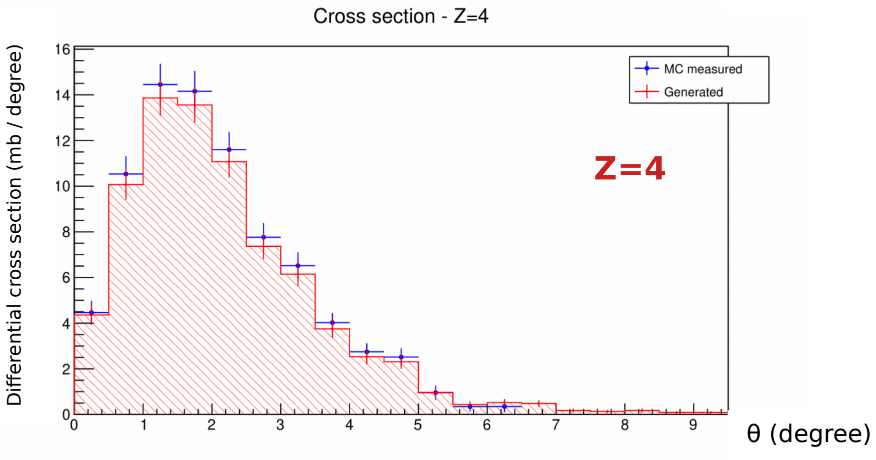
Angle $(degree)$	σ_{meas} (mb)	σ_{MC} (mb)
$0.0 \leq \theta < 0.5$	42.9 ± 1.5	42.3 ± 1.4
$0.5 \leq \theta < 1.0$	66.5 ± 1.8	65.3 ± 1.7
$1.0 \leq \theta < 1.5$	38.4 ± 1.4	37.4 ± 1.3
$1.5 \leq \theta < 2.0$	18.0 ± 1.0	17.3 ± 0.9
$2.0 \leq \theta < 2.5$	7.3 ± 0.6	6.9 ± 0.5
$2.5 \leq \theta < 3.0$	2.9 ± 0.4	2.7 ± 0.3
$3.0 \leq \theta < 3.5$	0.9 ± 0.2	1.1 ± 0.2
$3.5 \leq \theta < 4.0$	0.1 ± 0.1	0.1 ± 0.1
$4.0 \leq \theta < 4.5$	0.1 ± 0.1	0.1 ± 0.1

Angular differential cross-section

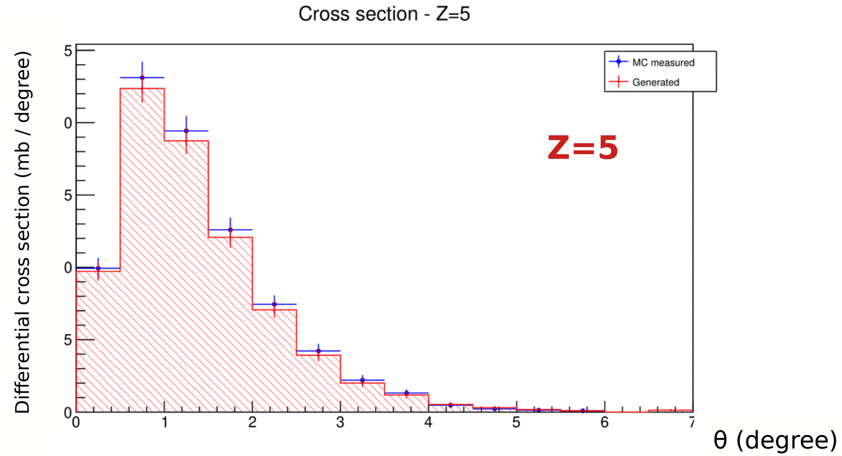


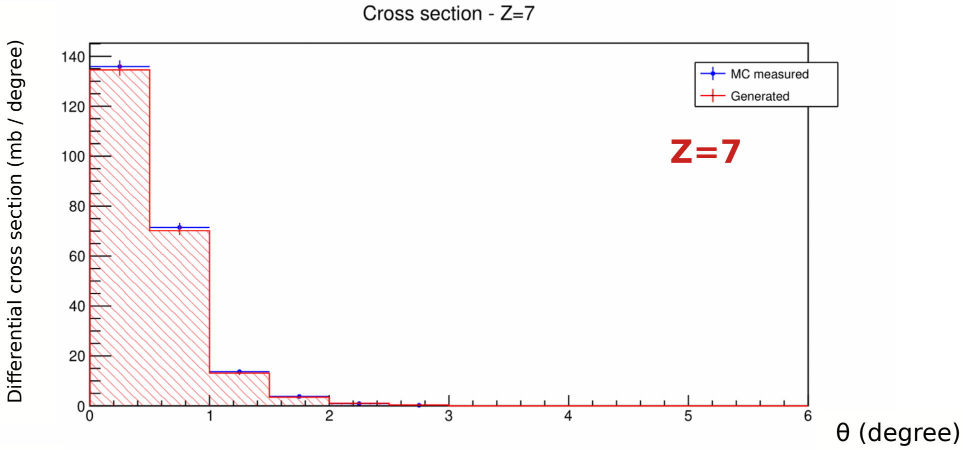


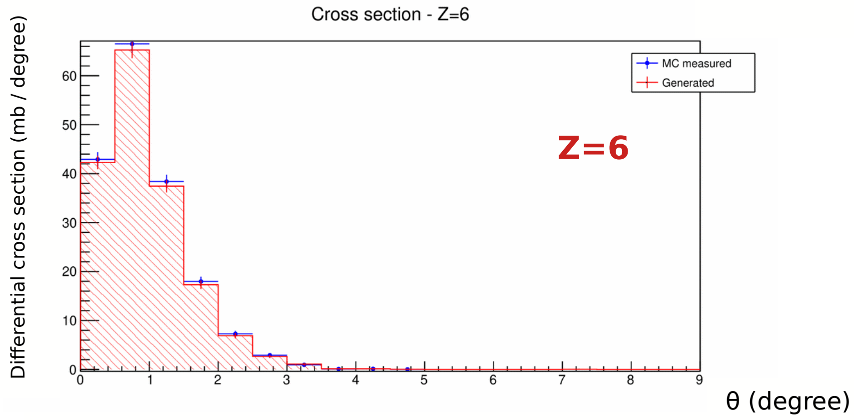


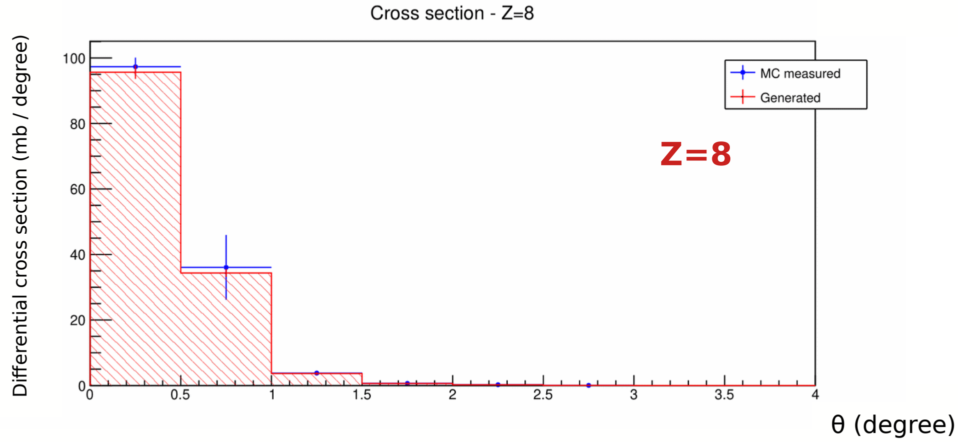


Angular differential cross-section









Conclusions

- First preliminary results of cross sections based on MC events with a **solid closure test**
- Study of background sources, corrections and efficiencies on MC level
- Low impact of statistic fluctuations

To do:

- Preliminary systematics uncertainties
- Including unfolding to correct for migrations
- Process real data
- Evaluating cross section differential also in kinematic energy and in mass
- Repeat the same steps for ^{16}O 200 MeV/u

Thank you for the attention!