$O+C_2H_4$, O+H and H+O cross sections at GSI2021

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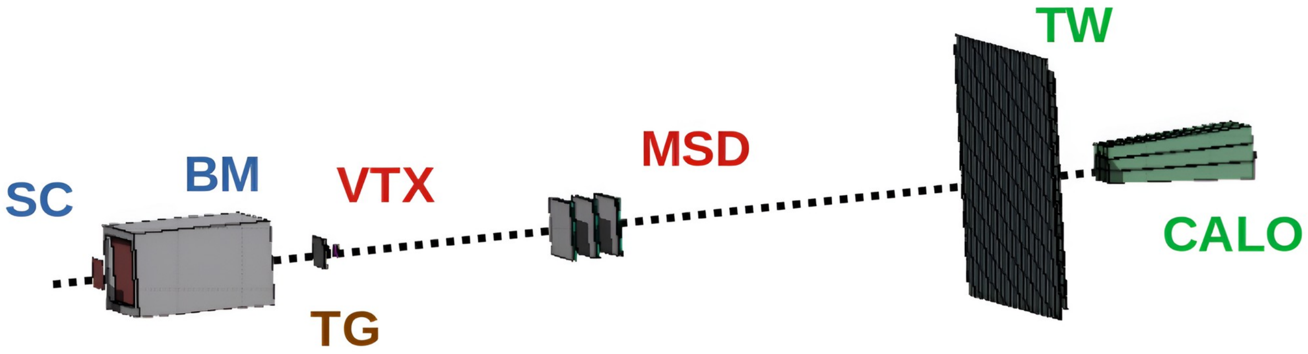
MAECI - MOFFIITS Meeting

GSI2021 setup



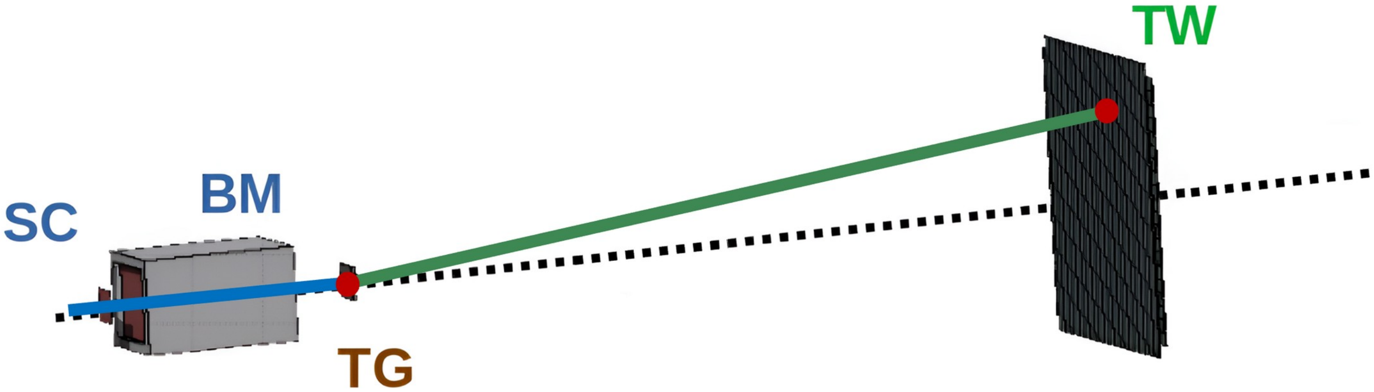
GSI2021 data

- **SC**, **BM** and **TW** information used in the analysis
- **400 MeV/u** beam on C target (5 mm) and C_2H_4 target (10 mm)

Cross section measurement

Angular differential cross section

$$\frac{d\sigma}{d\Omega}(Z)=\left(\frac{Y_{TG}(Z,\theta)}{N_{prim,TG}}-\frac{Y_{no\,TG}(Z,\theta)}{N_{prim,no\,TG}}\right)\frac{1}{N_{TG}\,\epsilon(Z,\theta)\,\Delta\Omega}$$



Cross section measurement

Angular differential cross section

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- **Number of primaries:** evaluated after selection cuts on SC and BM
- Rescaling factor for **fragmentation trigger** events
- Small background statistics (only ~57000 events)
- **Total cross section**: integrated from angular cross section (0° - 5.7°)

Analysis flow

- **Efficiencies** and **purities** calculated from the Monte Carlo simulations
- Purities applied **separately** for signal and background
- **Background subtraction** from a no target run
- **Unfolding** to solve **angle mixing**
- **Cross section** calculation (with **efficiencies**)

New binning

- Increase number of bins?

Z	$\theta[^\circ]$	$\sigma \pm \Delta_{stat} \pm \Delta_{sys}$ [b sr^{-1}]	Δ_{stat}/σ	Δ_{sys}/σ
	$0 - 0.6$	$110 \pm 13 \pm 5$	11.6%	4.3%
	$0.6 - 1.2$	$87 \pm 6 \pm 3$	7.2%	4%
	$1.2 - 1.8$	$65 \pm 3 \pm 2$	5.2%	3.1%
	$1.8 - 2.4$	$45 \pm 2 \pm 1$	4.7%	3.2%
2	$2.4 - 3$	$34 \pm 1 \pm 2$	3.6%	4.4%
	$3 - 3.6$	$20 \pm 1 \pm 1$	4.2%	4.5%
	$3.6 - 4.2$	$14 \pm 1 \pm 0.5$	4.2%	3.5%
	$4.2 - 4.8$	$9 \pm 0.4 \pm 0.3$	4.3%	3.5%
	$4.8 - 5.7$	$5 \pm 0.3 \pm 0.7$	5%	14%
	$0 - 0.6$	$9 \pm 4 \pm 0.3$	40%	3.7%
	$0.6 - 1.2$	$11 \pm 2 \pm 0.4$	15%	4.2%
3	$1.2 - 1.8$	$6 \pm 1 \pm 0.2$	17%	3.1%
	$1.8 - 2.4$	$5 \pm 0.5 \pm 0.2$	9%	3%
	$2.4 - 5.7$	$1 \pm 0.04 \pm 0.04$	5%	4.2%
	$0 - 0.6$	$13 \pm 3 \pm 0.7$	20%	5.3%
4	$0.6 - 1.2$	$7 \pm 1.5 \pm 0.2$	21%	3.2%
	$1.2 - 5.7$	$1 \pm 0.1 \pm 0.03$	9%	3.5%
	$0 - 0.6$	$30 \pm 6 \pm 1$	20%	3.1%
5	$0.6 - 1.2$	$19 \pm 2 \pm 1$	10%	4.7%
	$1.2 - 5.7$	$1 \pm 0.1 \pm 0.05$	7%	4.3%
	$0 - 0.6$	$86 \pm 13 \pm 3$	15%	3%
6	$0.6 - 1.2$	$52 \pm 3 \pm 2$	5.5%	4.3%
	$1.2 - 5.7$	$2 \pm 0.1 \pm 0.08$	5.6%	4.6%
	$0 - 0.6$	$160 \pm 15 \pm 6$	9%	3.9%
7	$0.6 - 1.2$	$42 \pm 3 \pm 3$	6.8%	7.5%
	$1.2 - 5.7$	$1 \pm 0.1 \pm 0.03$	13%	4.4%

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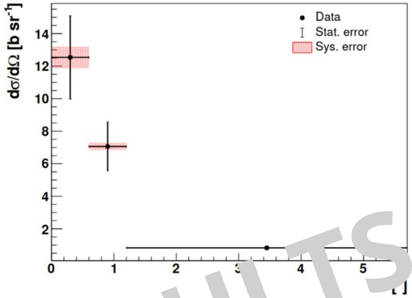
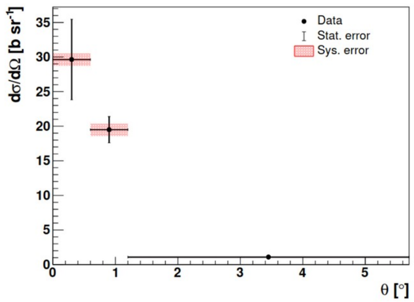
Z = 4



Z = 5



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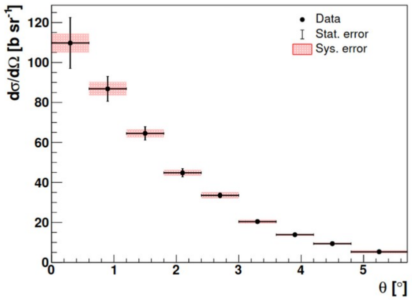

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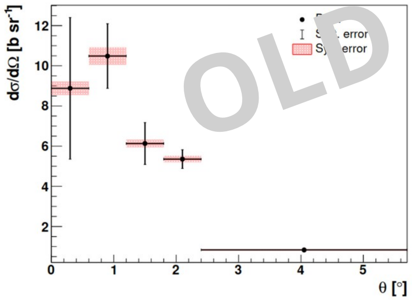

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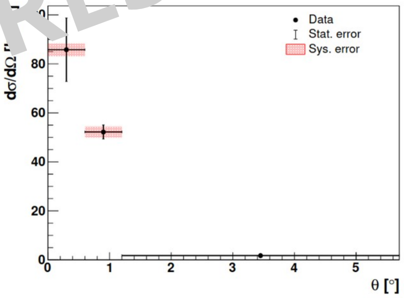

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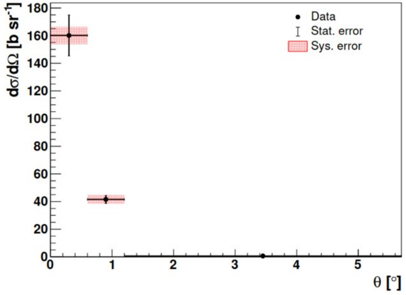
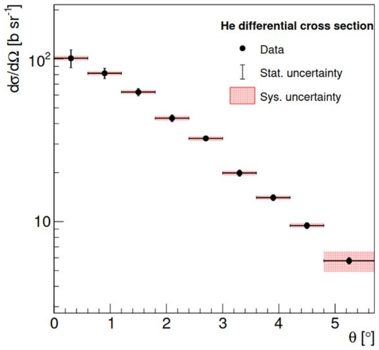
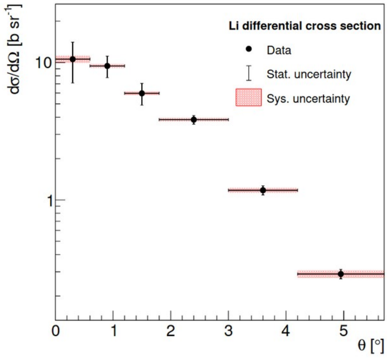


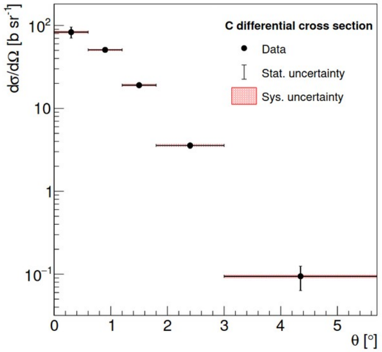
OLD RESULTS

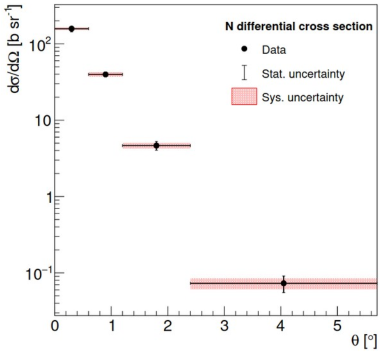
NEW results
O +C

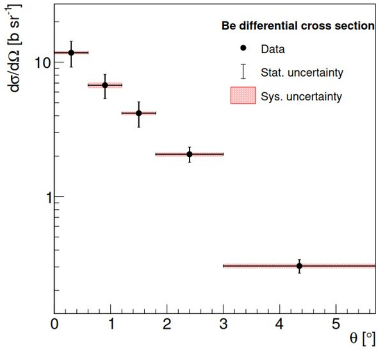
New binning

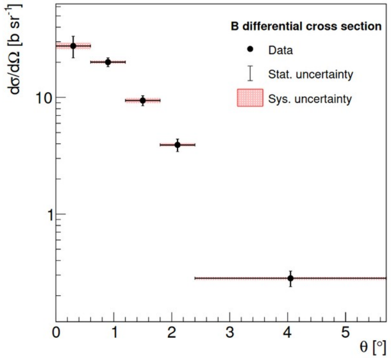


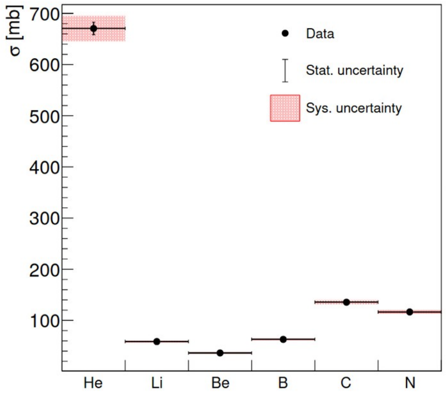






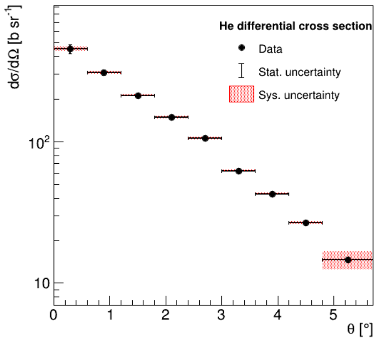


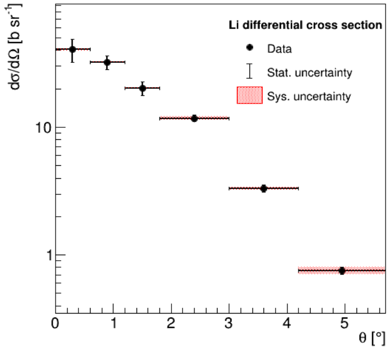


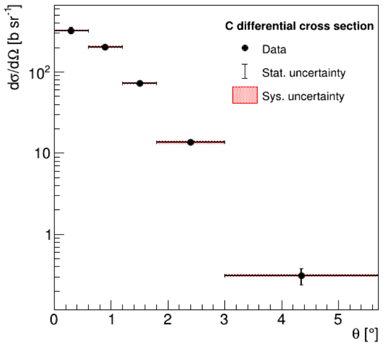


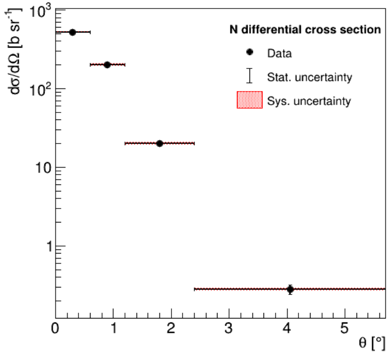
NEW results
O + C_2H_4

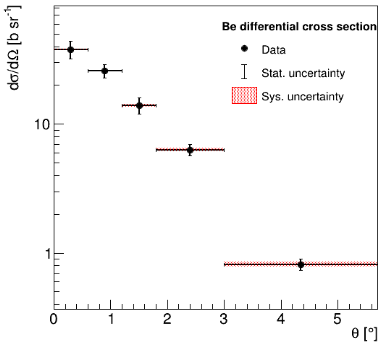
New binning

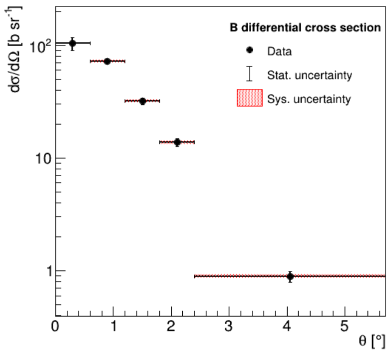


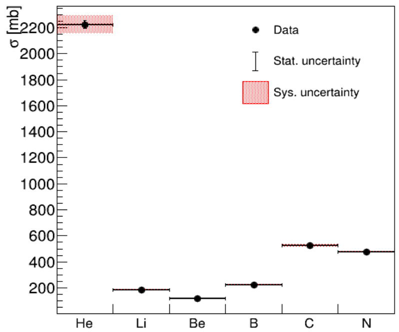




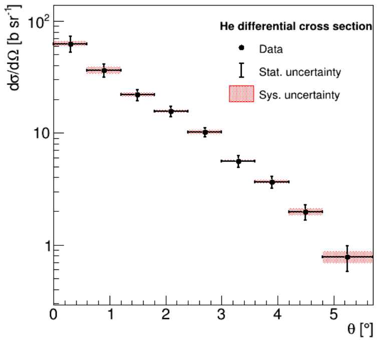


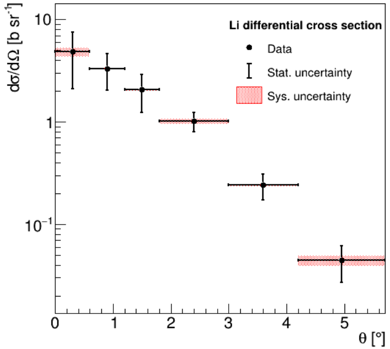


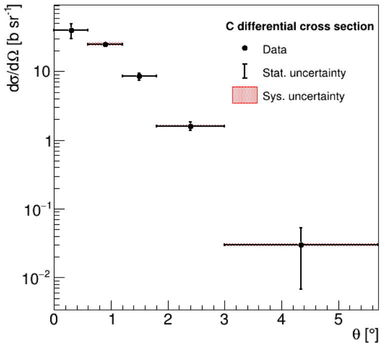


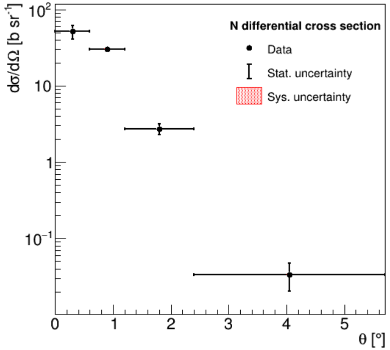


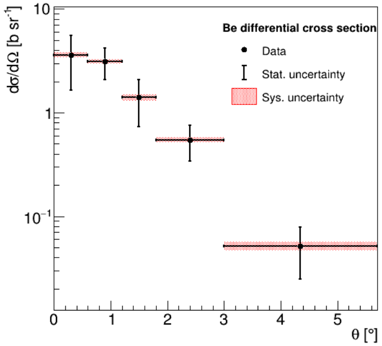
Cross section for O+H

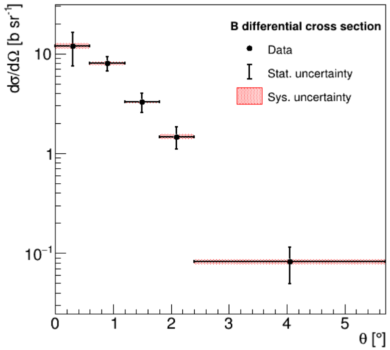






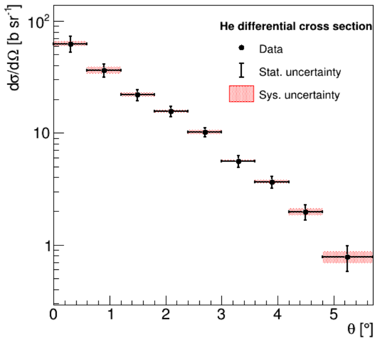


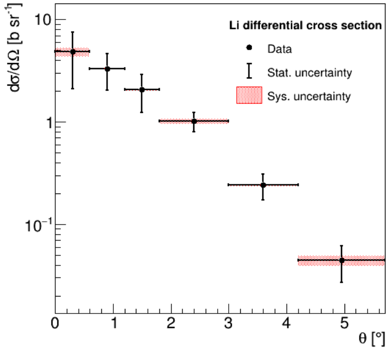


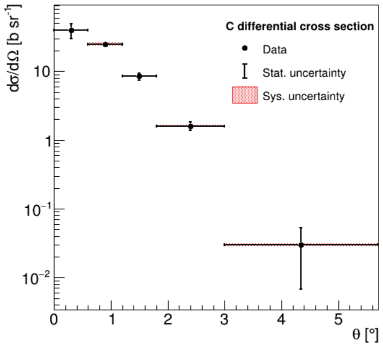


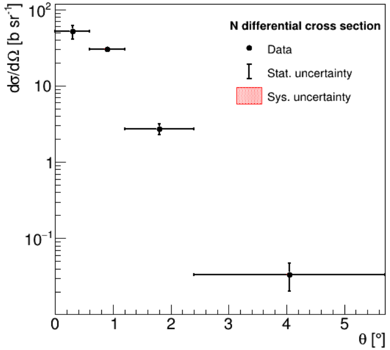
- Systematic uncertainty accounts for reconstruction strategy (reconstructed MC vs true MC result) and stoichiometric subtraction

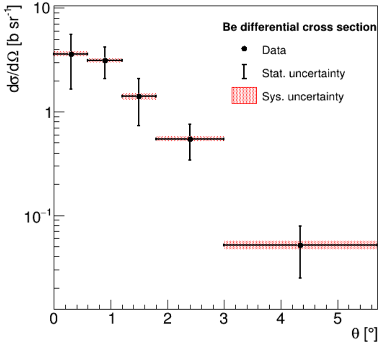
Cross section for O+H

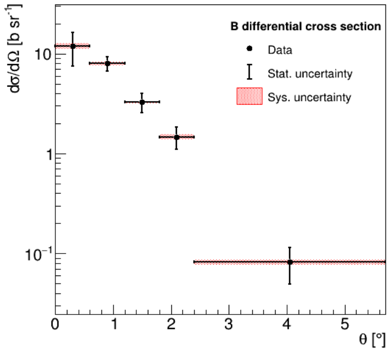


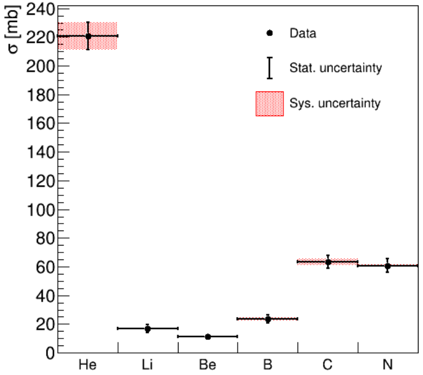










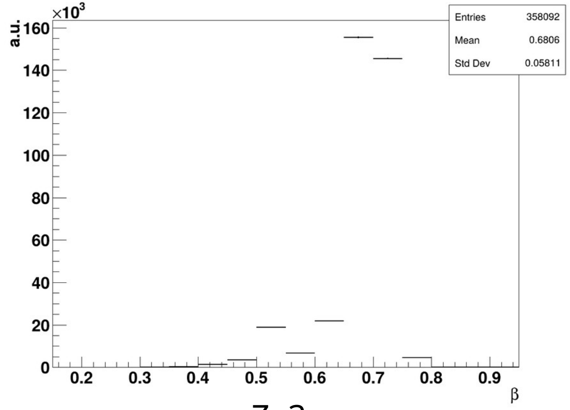


β distributions (MC)

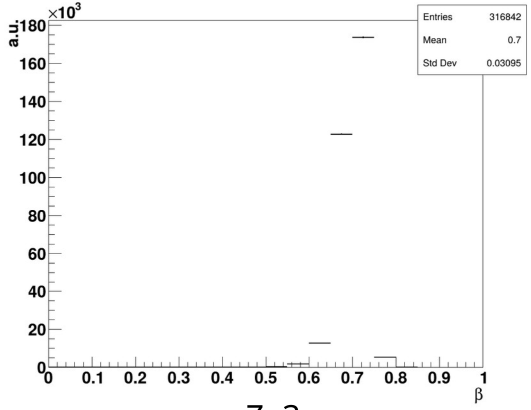
YIELDS WITHOUT CORRECTIONS

TRUE YIELDS

Z=2

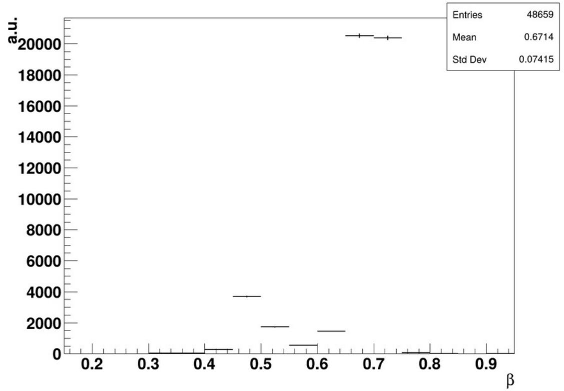


Z=2

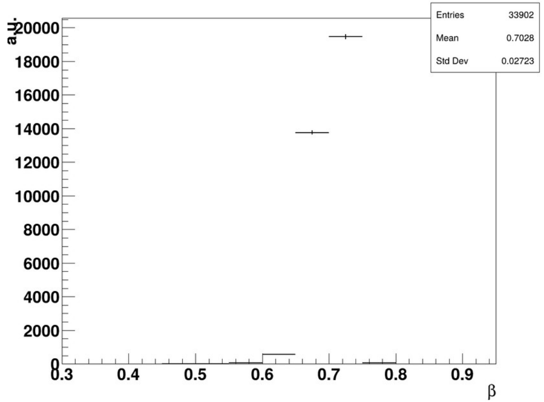


- β distributions according to TOF resolution

Z=3



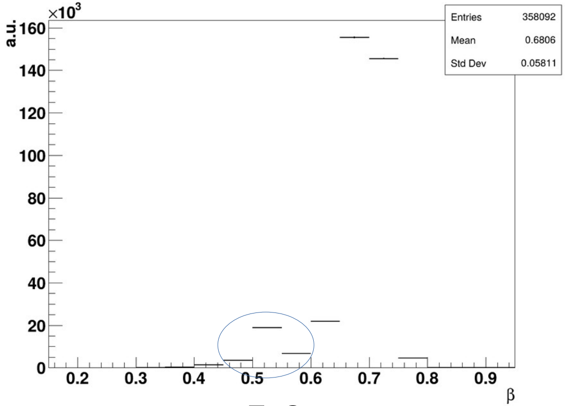
Z=3



β distributions (MC)

YIELDS WITHOUT CORRECTIONS

Z=2



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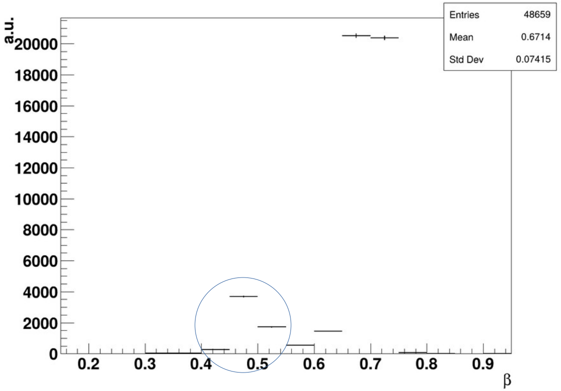
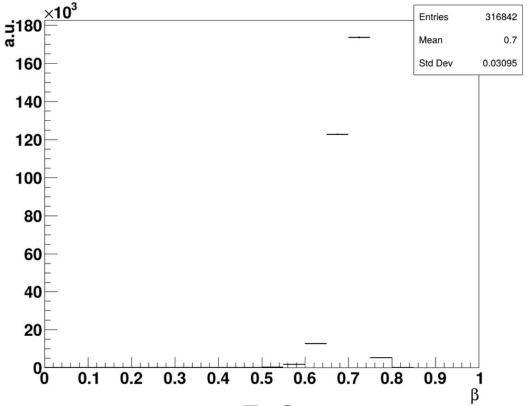
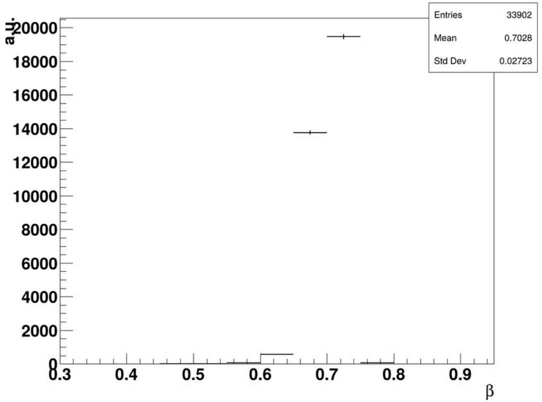


TRUE YIELDS

Z=2



Z=3

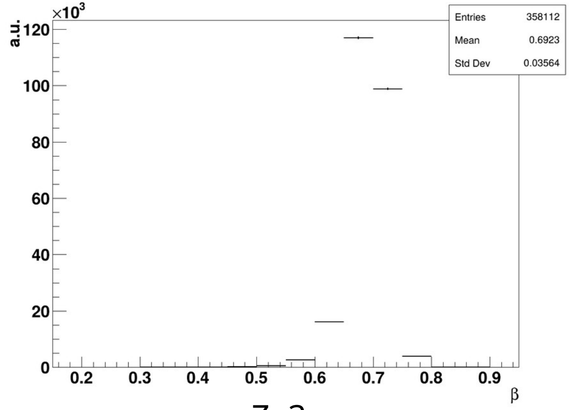


- β distributions according to TOF resolution
- Raw yields → need to be corrected for purity and background subtraction

Yields corrected for purity and bkg subtraction

β distributions: O+C (MC)

Z=2



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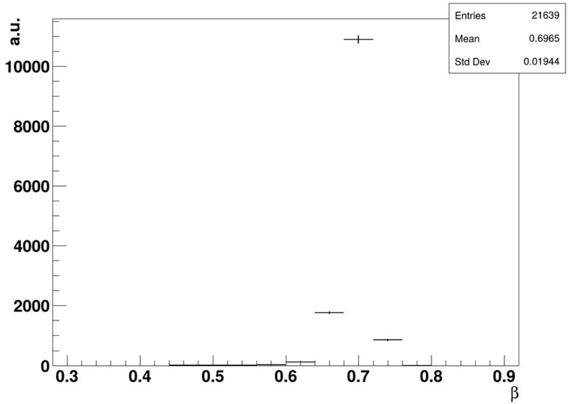

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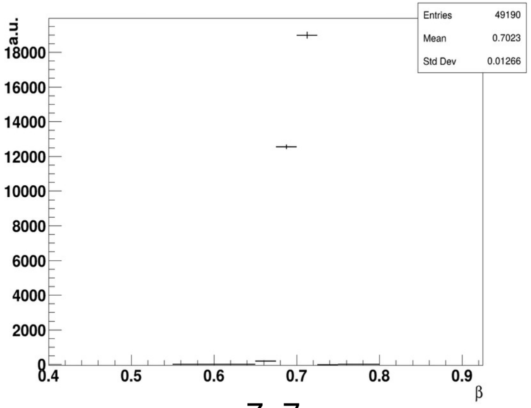

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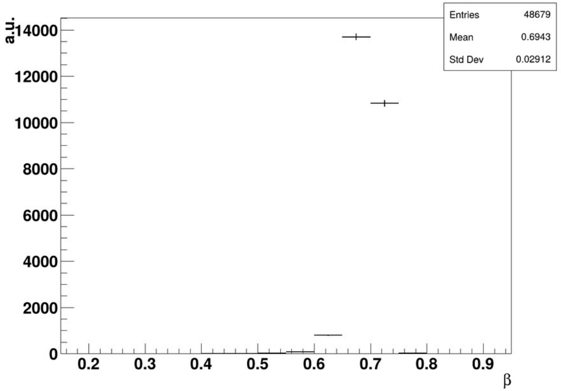

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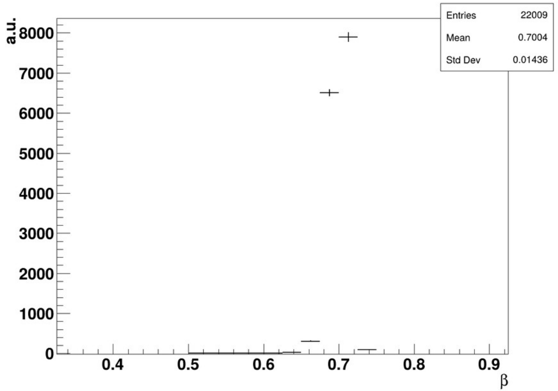

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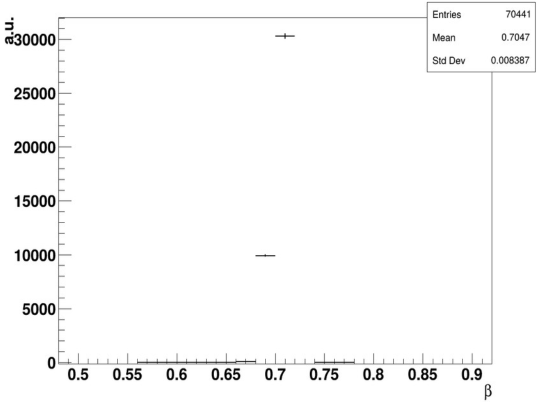
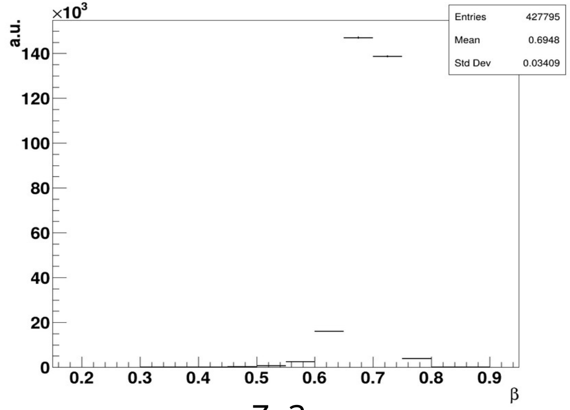


Yields corrected for purity and
bkg subtraction

β distributions: O+C_2H_4 (MC)

Z=2



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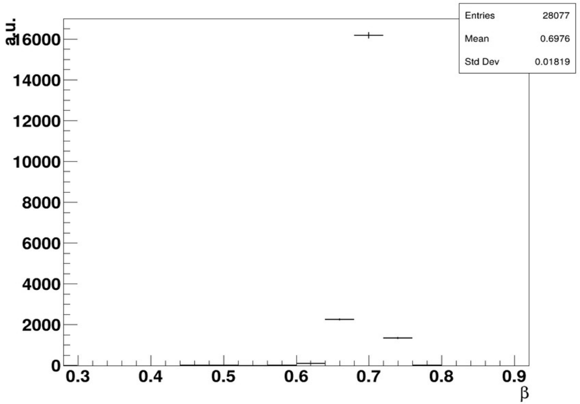

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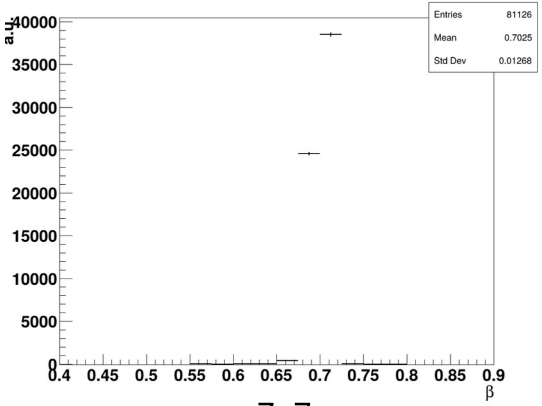

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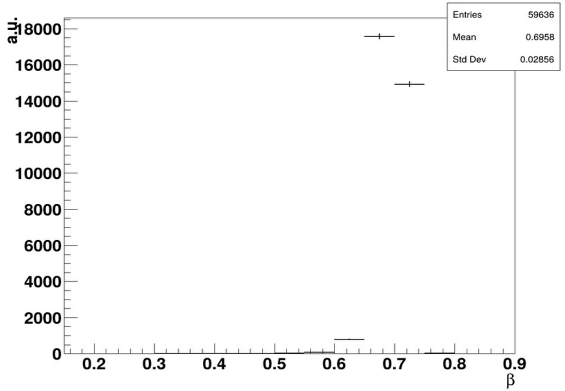

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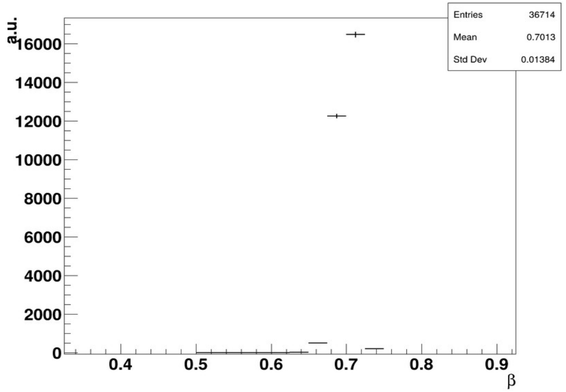

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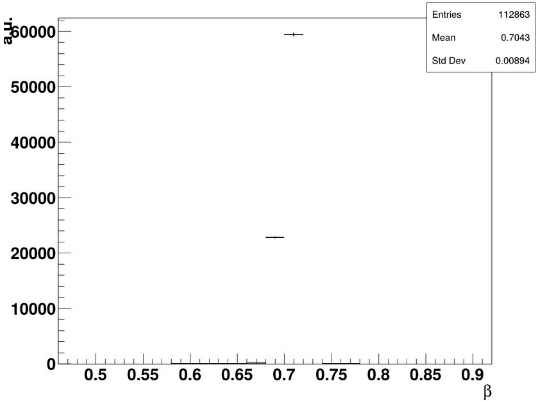


E_{kin} distributions

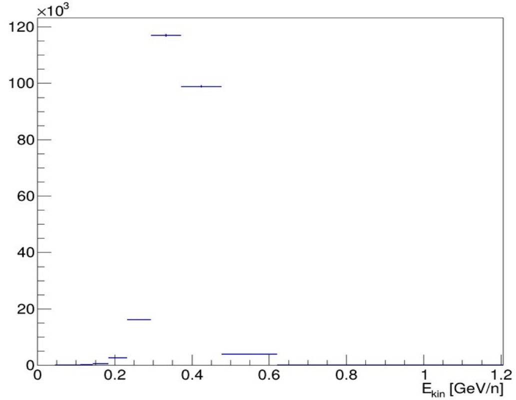
- E_{kin} distribution using mass of a single isotope: valid approximation for some isotopes (^{4}He, ^{12}C, ^{14}N)

- Necessary for inverse kinematics

Yields corrected for purity and bkg subtraction

E_{kin} distributions: O+C (MC)

Z=2



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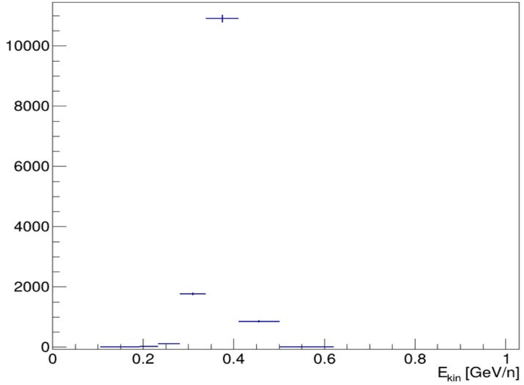

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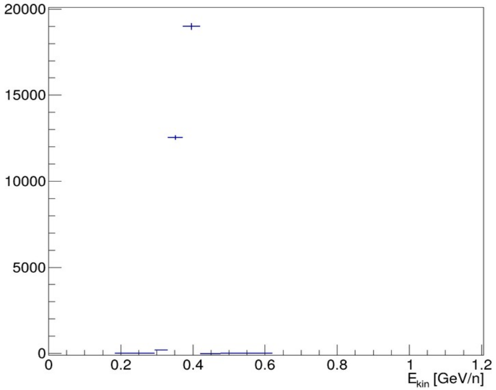

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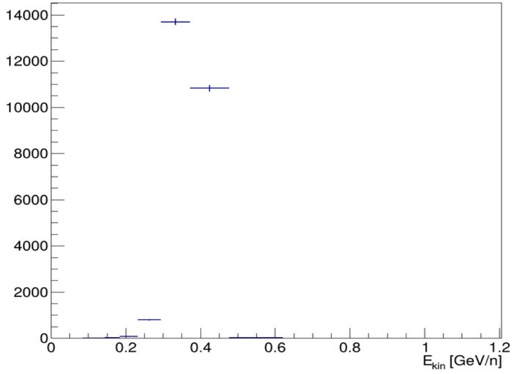

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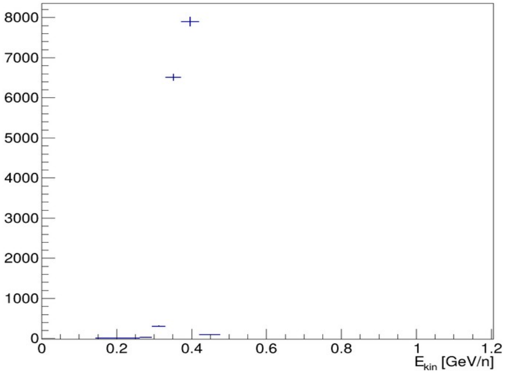

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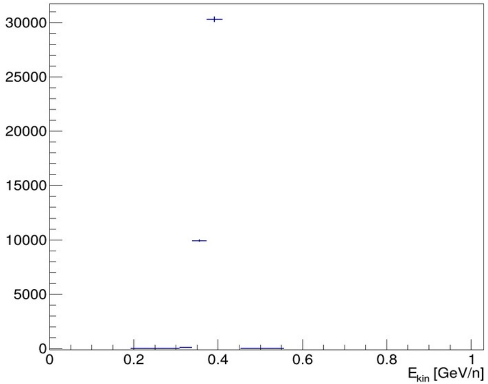
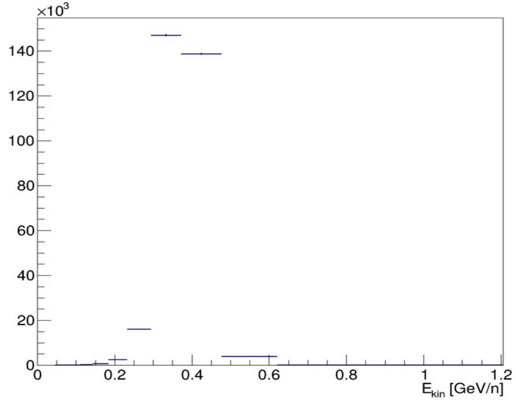


Yields corrected for purity and bkg subtraction

E_{kin} distributions: $O+C_2H_4$ (MC)

Z=2



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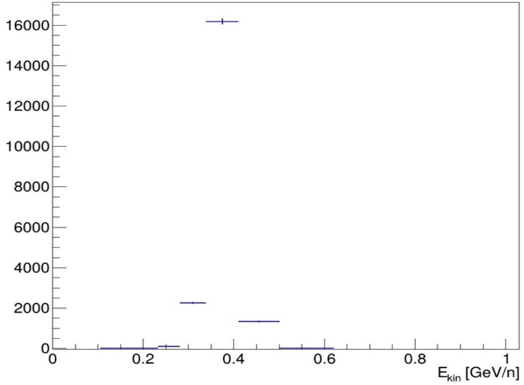

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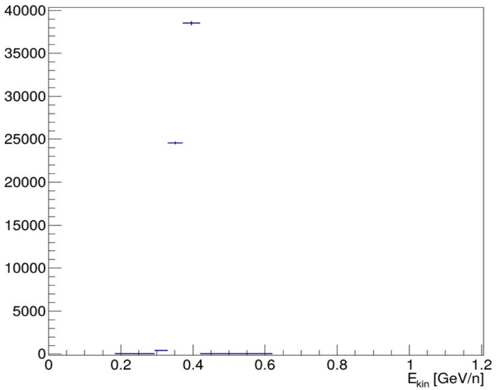

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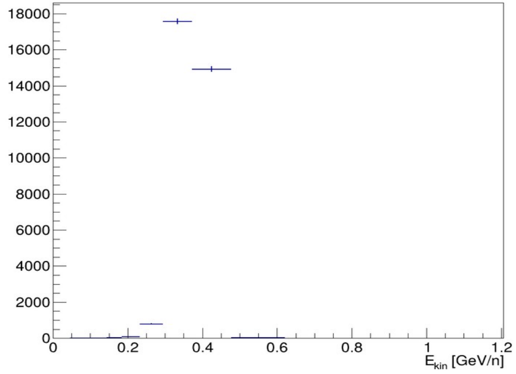

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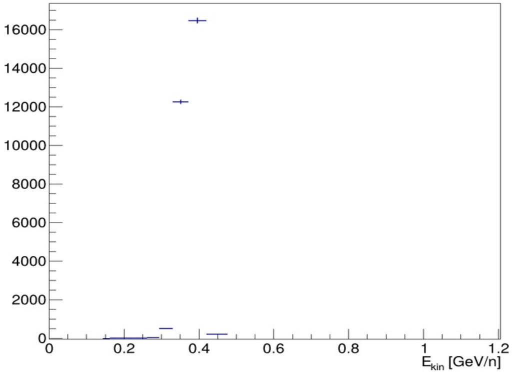

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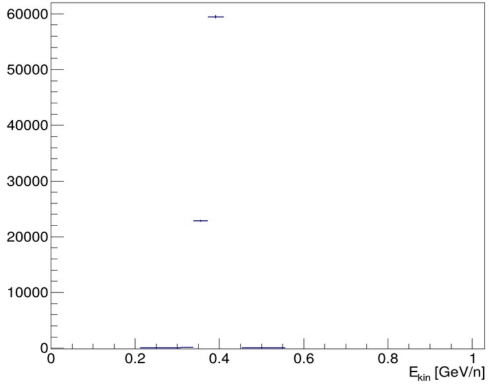


Inverse kinematics

Steps:

- E_{kin} distribution using mass of a single isotope (for elements with a particularly abudant isotope, like ^{12}C and ^{14}N)

- Calculate C+O and C_2H_4+O and subtract

Inverse kinematics

Steps:

- E_{kin} distribution using mass of a single isotope (for elements with a particularly abudant isotope, like ^{12}C and ^{14}N)

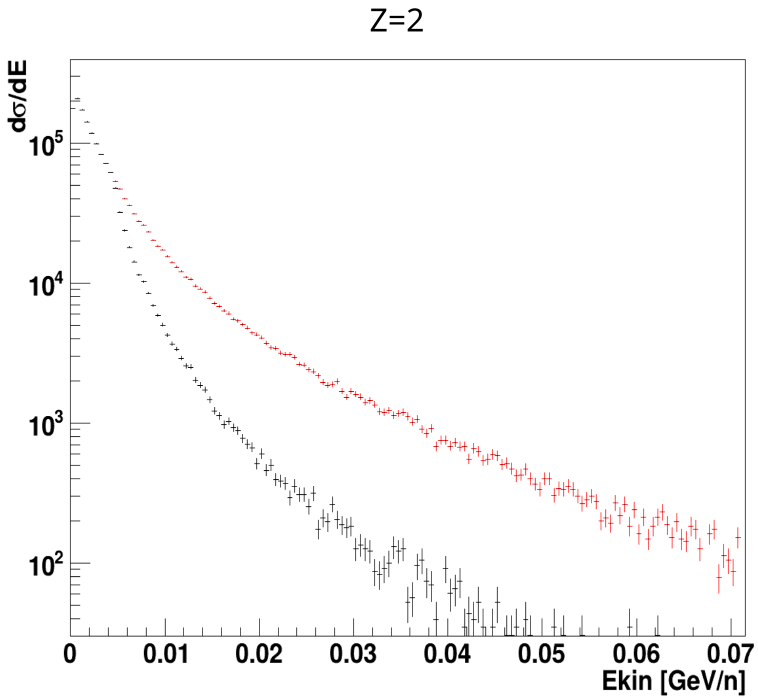
- Calculate C+O and C_2H_4+O and subtract

- Some considerations in the next slides

Angle limitations for He

- TW acceptance within 5.7° → in inverse kinematics some fragments are lost at higher energy
- Relevant for He

Inverse kinematics energy cross section calculated with MC truth C+O

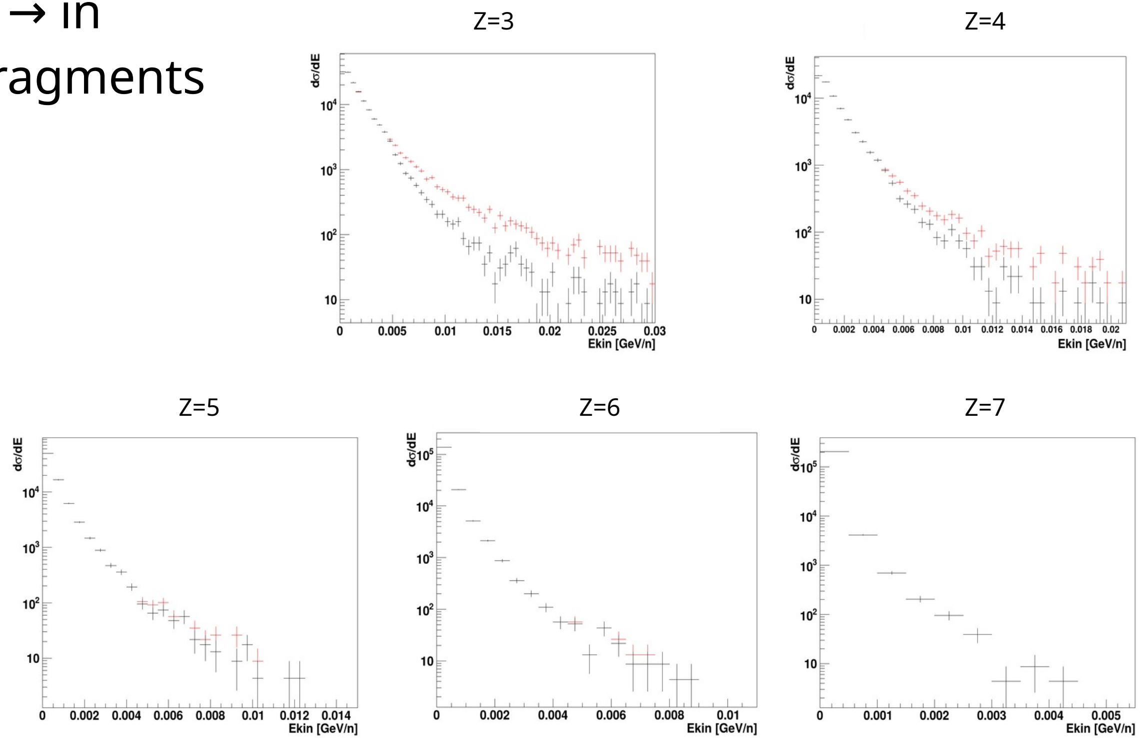


With cut in angle
Without cut in angle

Angle limitations for He

Inverse kinematics energy cross section calculated with MC truth C+O

- TW acceptance within 5.7° → in inverse kinematics some fragments are lost at higher energy
- Relevant for He
- Not so relevant for other Z



—— With cut in angle
—— Without cut in angle

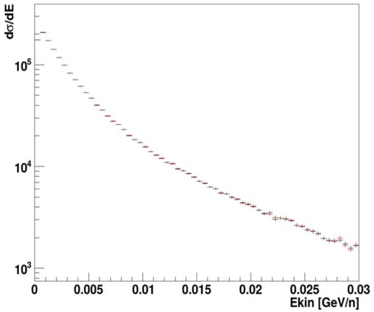
Mass fixed vs true mass

Inverse kinematics energy cross section calculated with MC truth C+O

- No mass reconstruction possible → use the mass of the most abundant isotope

- Used mass of ^{4}He, ^{12}C and ^{14}N

Z=2



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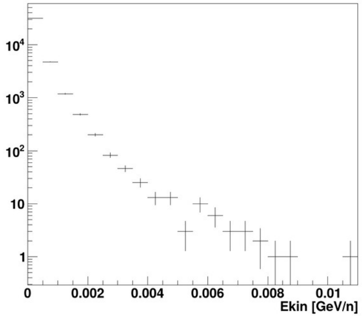

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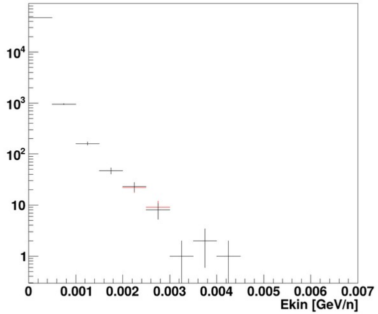
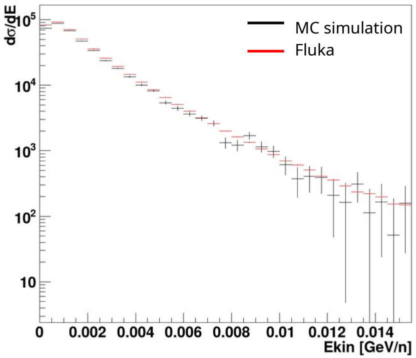


With mass of single isotope

With true mass

MC inverse kinematics (MC truth) vs fluka H + O

Z=2



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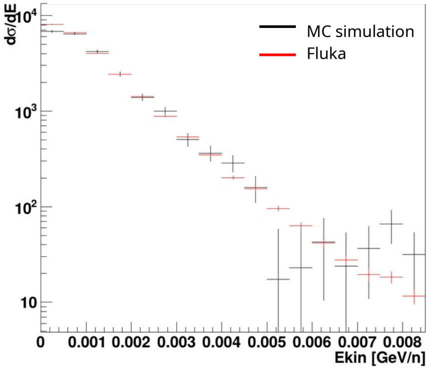

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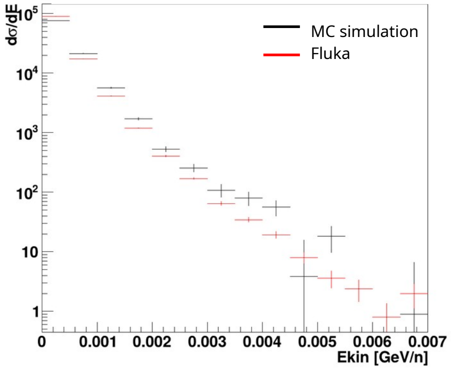

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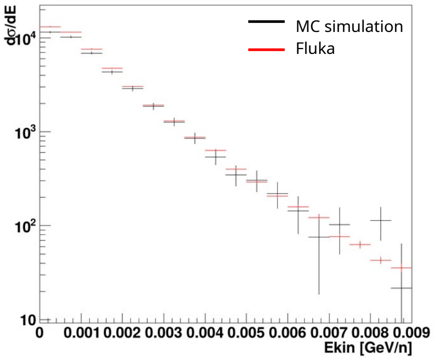

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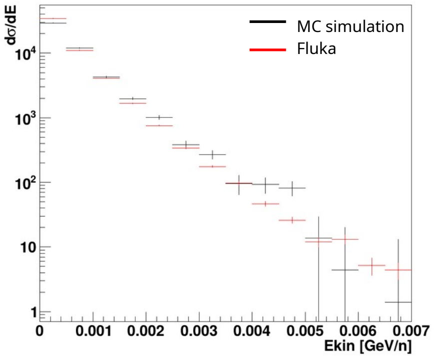

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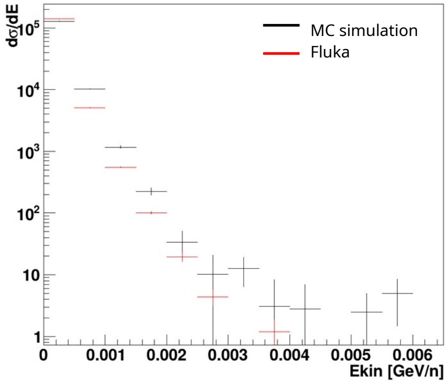


Conclusions and next steps

- Correctly calculate reconstructed cross section in kinetic energy in inverse kinematics for the MC sample for C+O and C_2H_4+O with also background subtraction for the chosen isotopes

- Subtract the two cross sections to obtain H+O

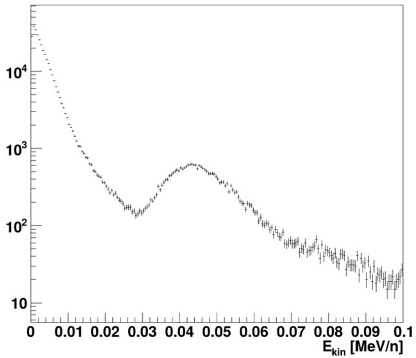
- Apply same steps to data

Thank you for your attention !

Back-up slides

First reconstruction attempt (MC reco) C+O

Z=2



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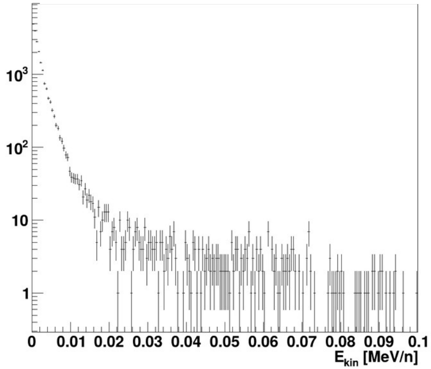

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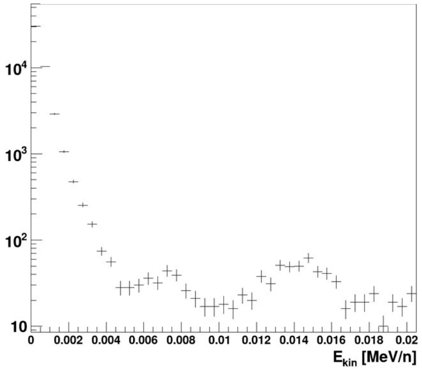

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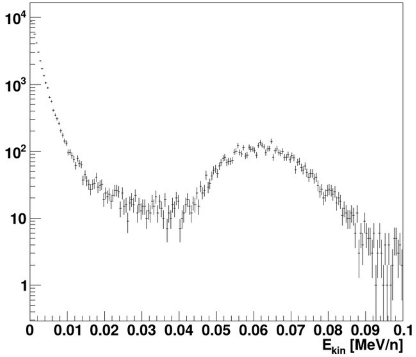

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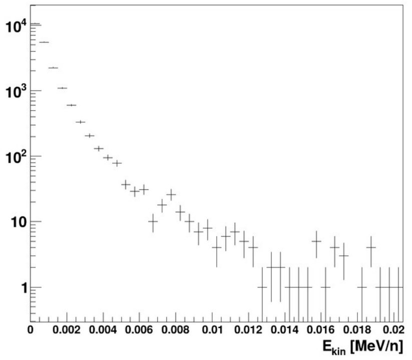

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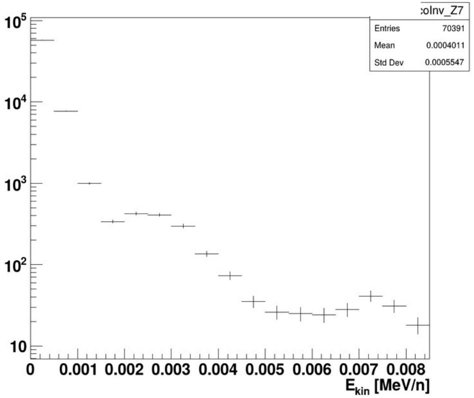
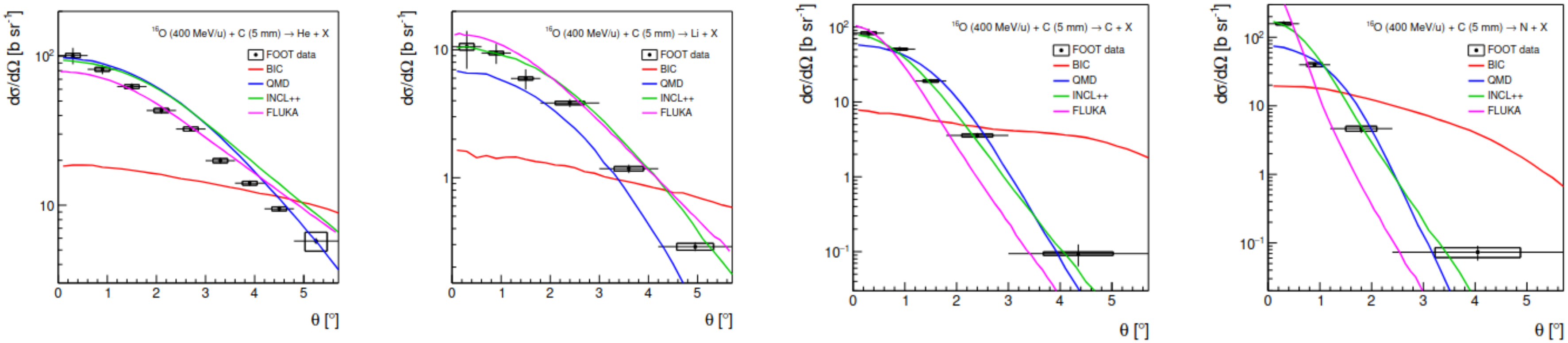
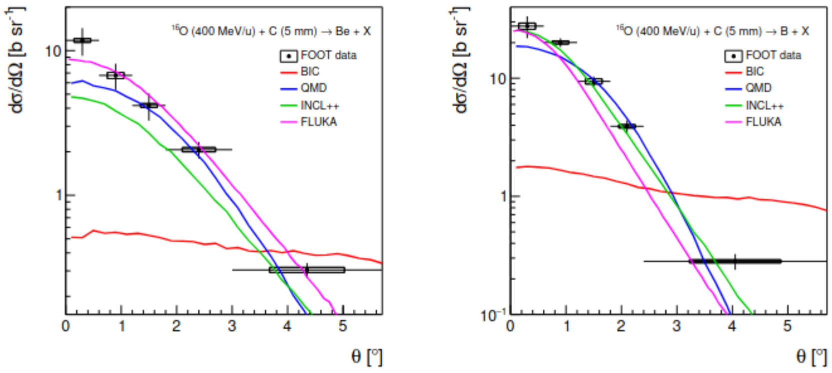


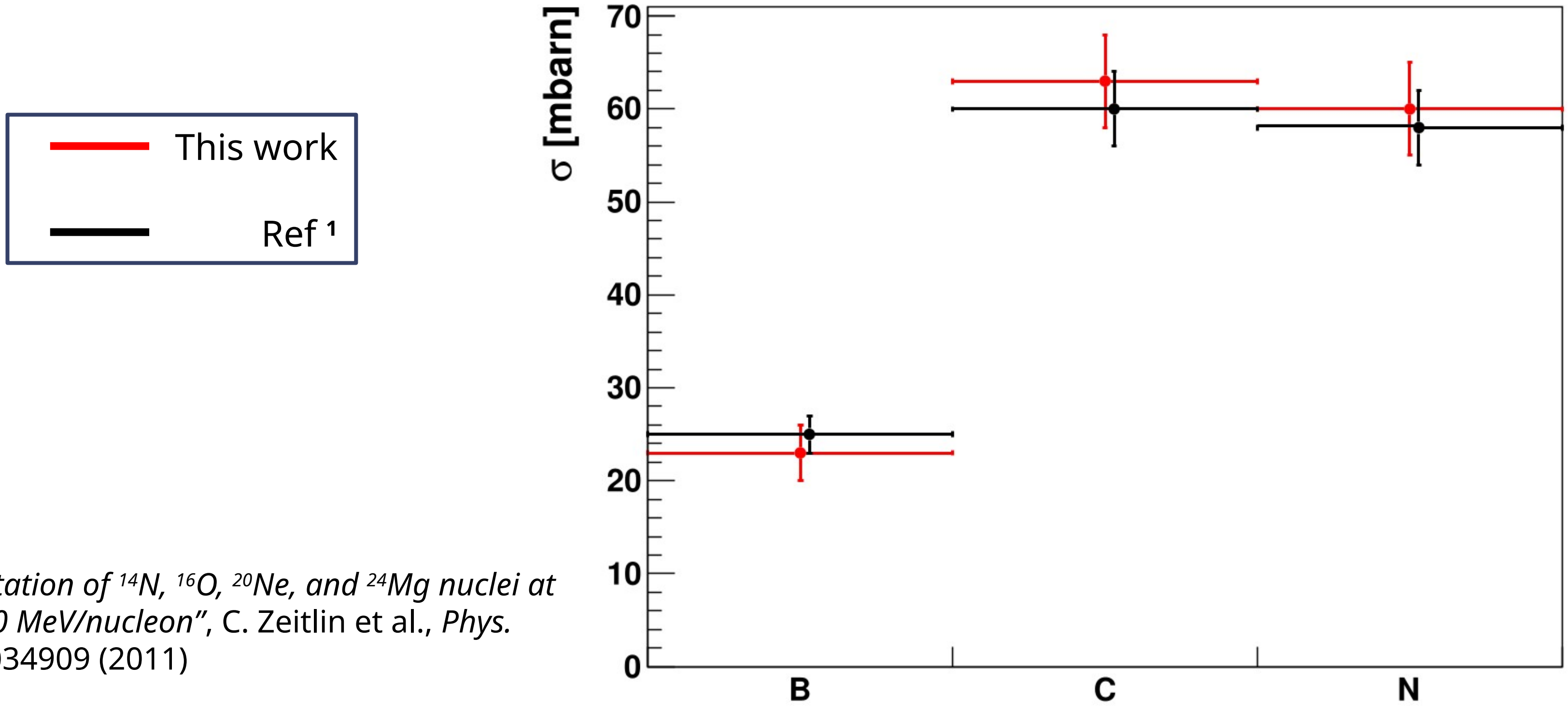
Comparison with nuclear models





- FLUKA
- Geant4 hadronic models:
  - Binary Ion Cascade (BIC)
  - Quantum Molecular Dynamics (QMD)
  - Liège Intranuclear Cascade (INCL++)

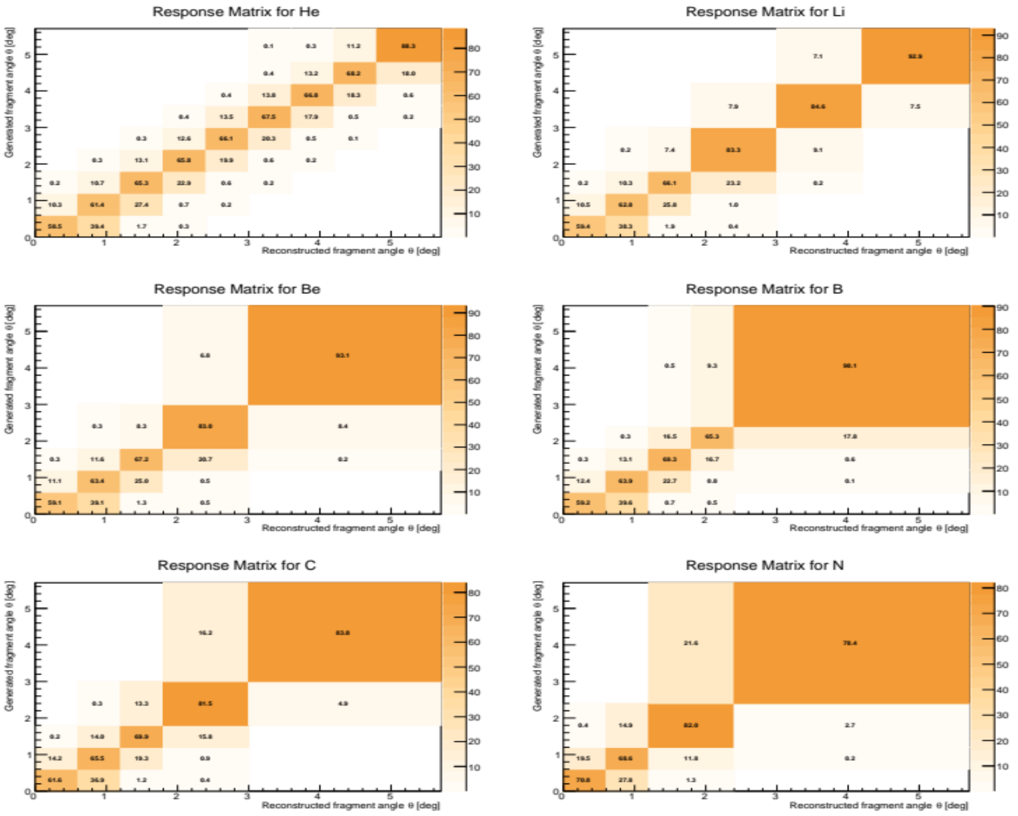
Literature comparison



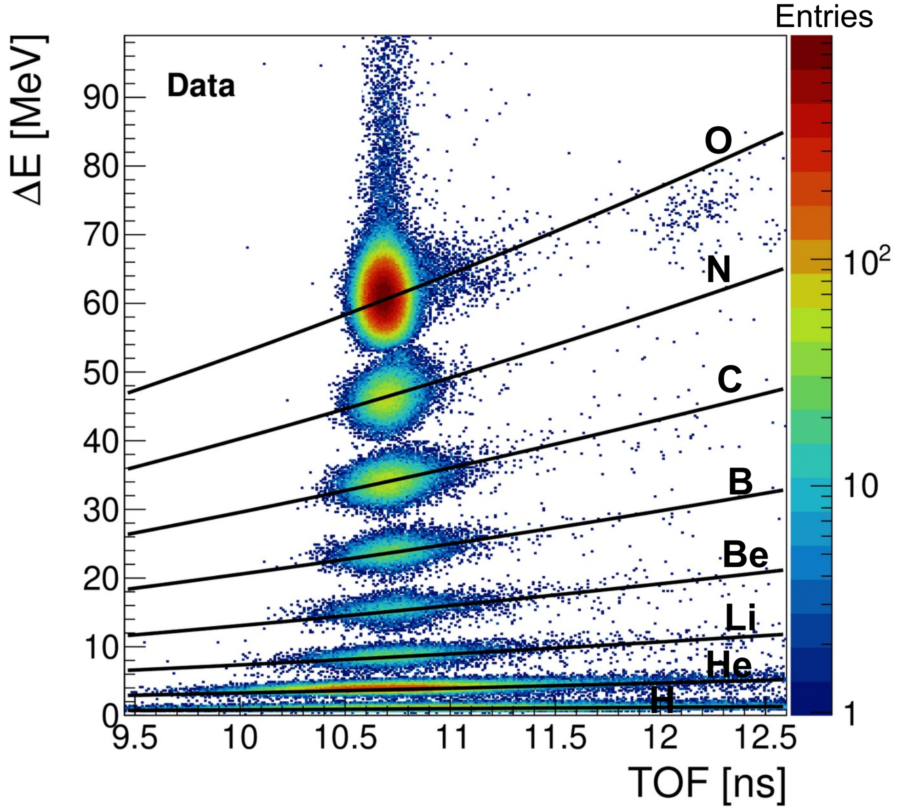
[1] "*Fragmentation of ^{14}N, ^{16}O, ^{20}Ne, and ^{24}Mg nuclei at 290 to 1000 MeV/nucleon*", C. Zeitlin et al., *Phys. Rev. C* **83**, 034909 (2011)

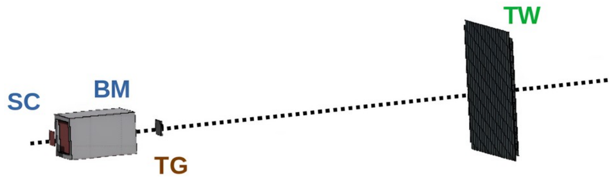
MC simulation: unfolding

- **Monte Carlo** simulations used to extract **purities** and **efficiencies**
- **Unfolding** to solve **angle mixing**



Cross section measurement





Charge identification

- Data for **400 MeV/u** beam on a 1 cm thick target