Inverse Kinematics Study

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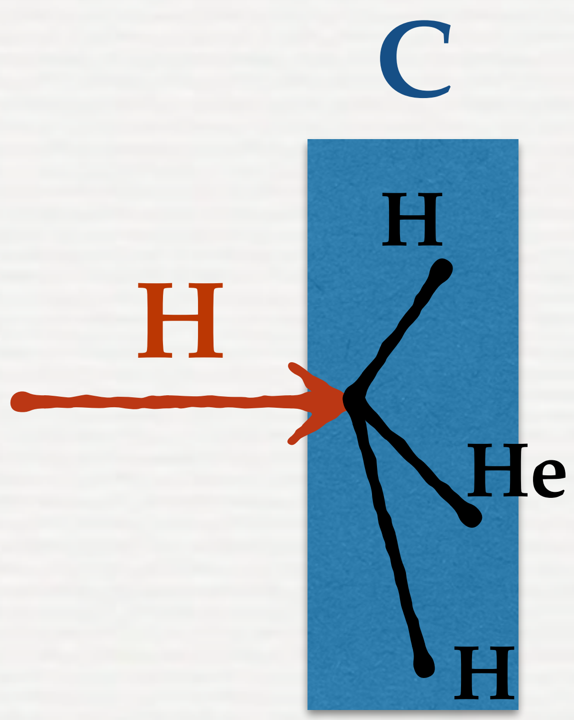
OUTLINE

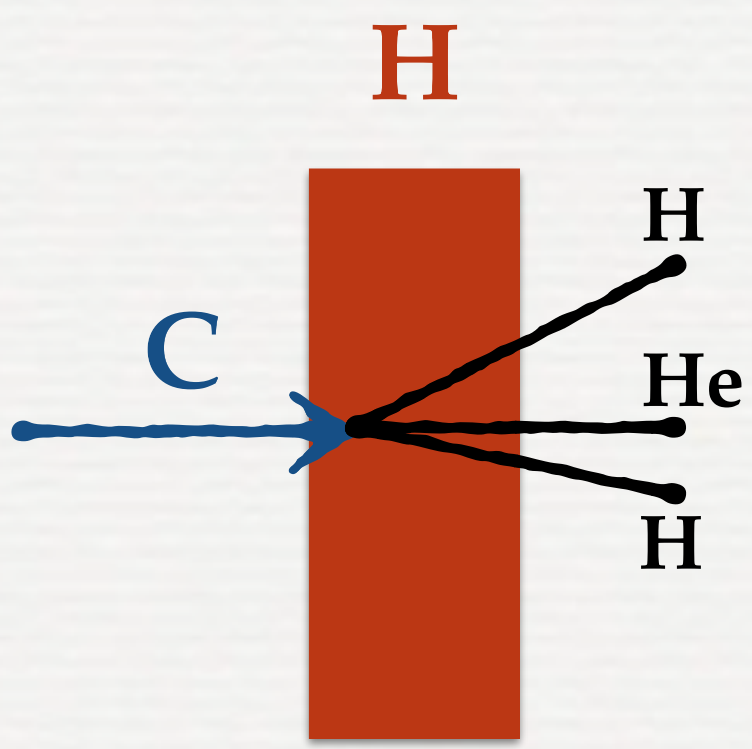
- **Aim**: estimation of H→C differential cross-section in inverse kinematics
- **Framework**: official FOOT simulation software on Tier3
- Estimation of fragments kinematical variables in direct and inverse kinematics
- Estimation of energy resolution in direct and inverse kinematics
- Estimation of differential cross sections in inverse kinematics for different fragments
- Estimation of H→C cross-section

Inverse Kinematics

proton on patient

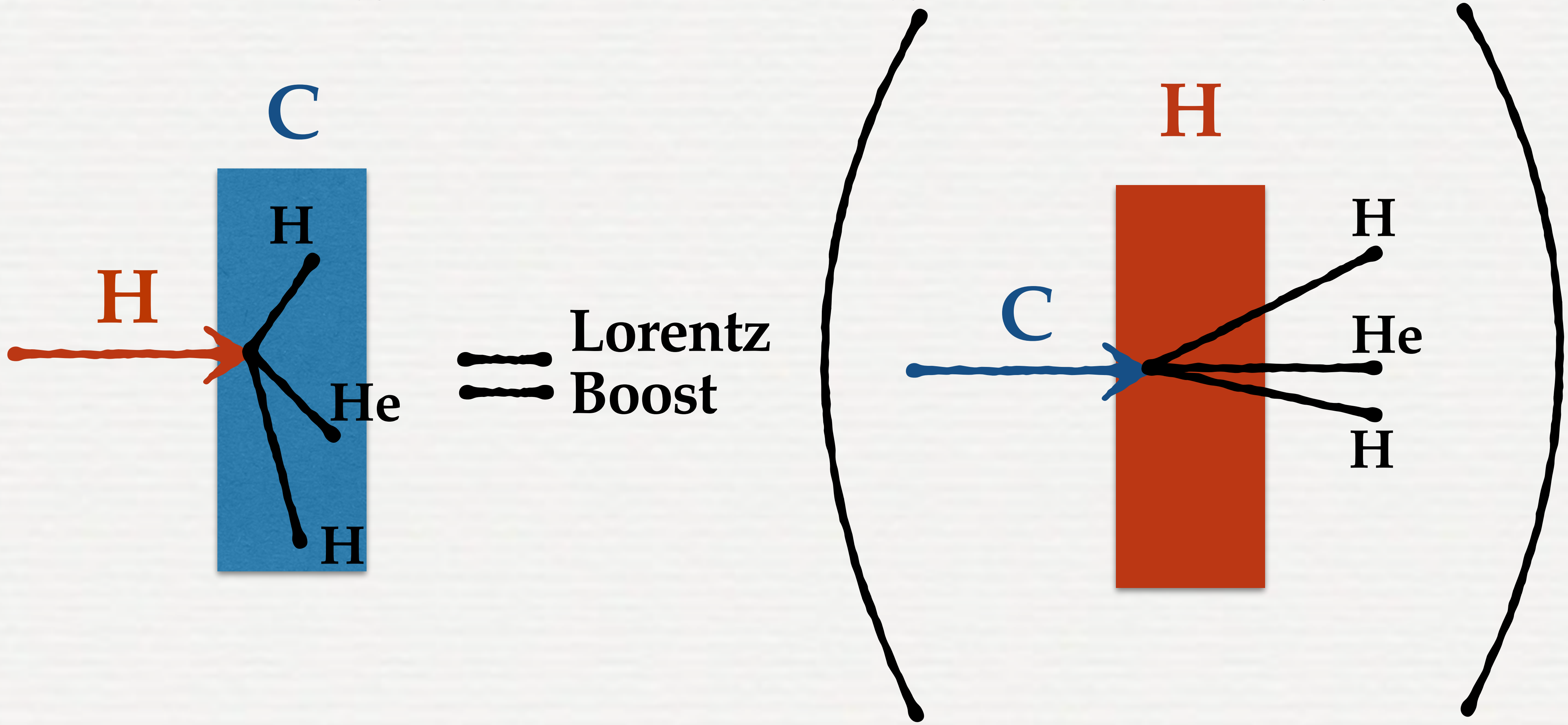


patient on proton



Inverse Kinematics

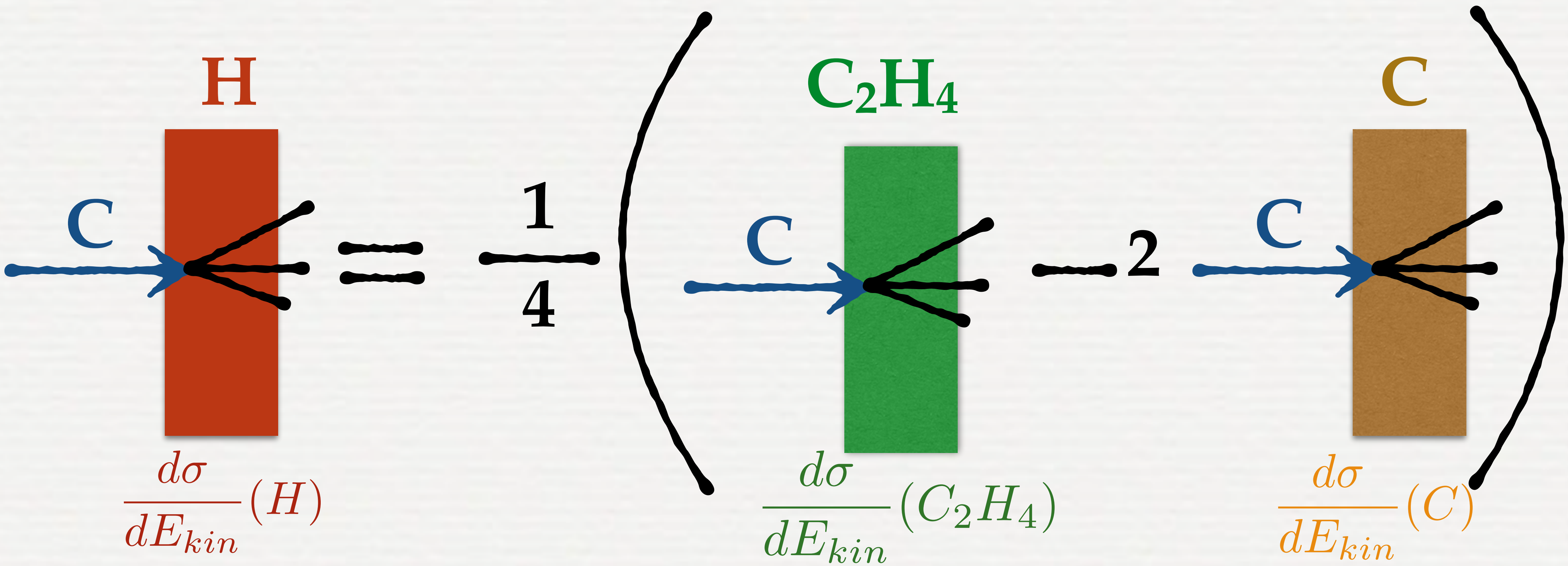
proton on patient — patient on proton



Cross-Section Combination

- Measurements performed with C_2H_4 and C targets
- C→H cross-section estimated as a combination of C→C_2H_4 and C→C cross-sections

$$\Delta\sigma(C_2H_4, C) = \frac{d\sigma}{dE_{kin}}(H) = \frac{1}{4}\left(\frac{d\sigma}{dE_{kin}}(C_2H_4) - 2\frac{d\sigma}{dE_{kin}}(C)\right)$$



Estimation of H→C Cross-Section

- **Procedure**

1) Evaluate C→ C_2H_4 cross section for different fragments
2) Evaluate C→C cross section for different fragments
3) Apply Lorentz boost to retrieve C_2H_4→C and C→C cross-sections (inverse kinematics)
4) Evaluate H→C cross section as the difference between C_2H_4→C and C→C cross-sections
5) Compare with C→H Monte Carlo production

- **Monte Carlo data files**

Beam: 12C, 200 MeV/n
Target: C_2H_4, C
Thickness: 1 mm
Tot statistics: 10^7

/gpfs_data/local/foot/Simulation/NewGeo/MagOff_HT/1mm_ok/*.root

Beam: 12C, 200 MeV/n
Target: C_2H_4, C
Thickness: 2 mm
Tot statistics: 10^7

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/gpfs_data/local/foot/Simulation/NewGeo/MagOff_HT/C_H/*.root
/gpfs_data/local/foot/Simulation/NewGeo/MagOff_HT/H_C/*.root

Beam: 12C, 200 MeV/n
Target: C_2H_4, C
Thickness: 4 mm
Tot statistics: 10^7

/gpfs_data/local/foot/Simulation/NewGeo/MagOff_HT/4mm_ok/*.root

GEOMETRICAL ACCEPTANCE

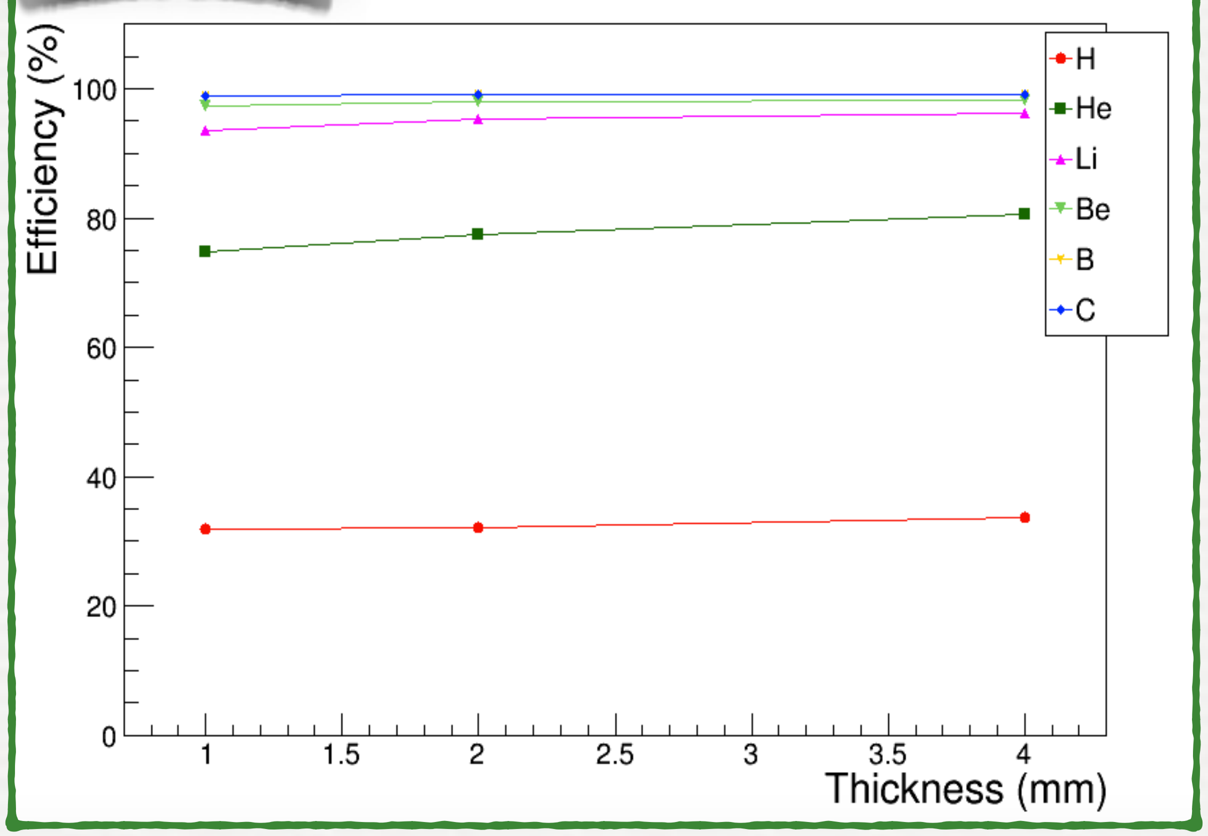
- Geometrical efficiency $\varepsilon_{geo} = N_{cal} / N_{target}$

  N_{cal} = Number of fragments reaching the calorimeter

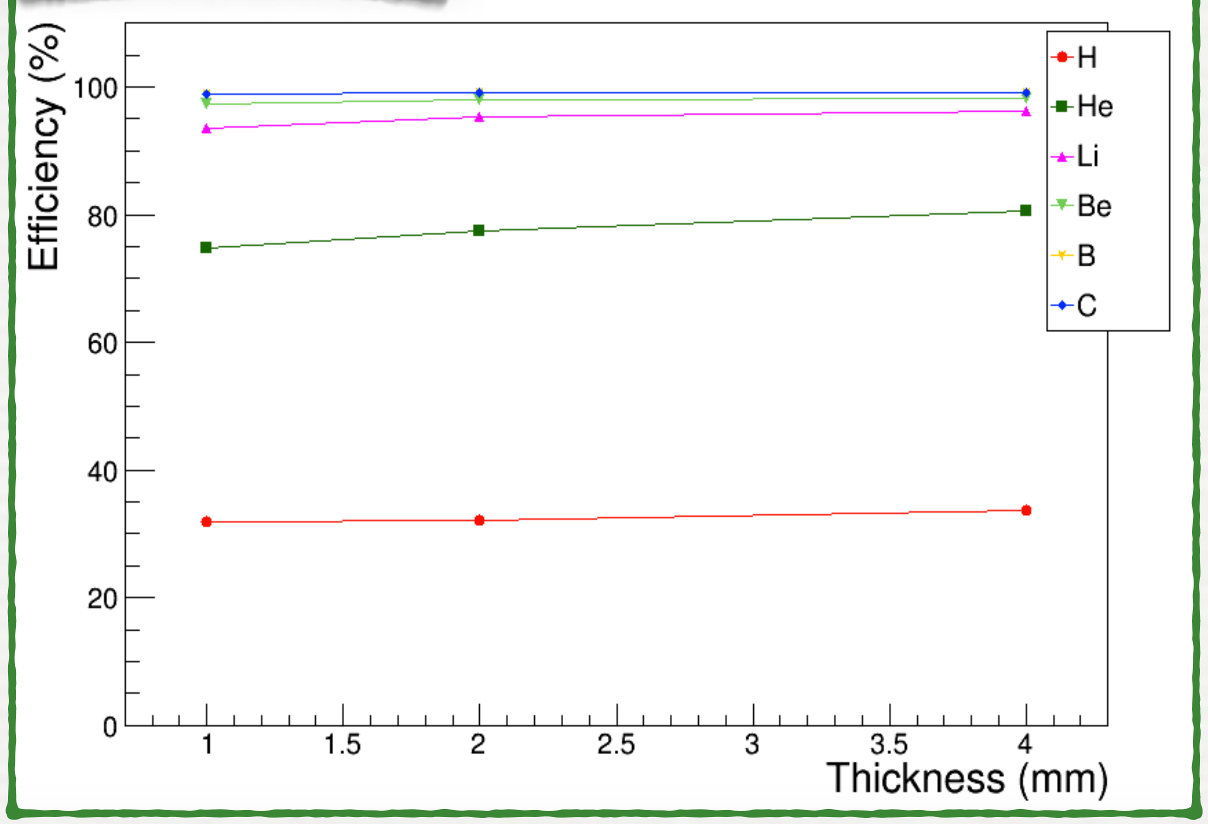
  N_{sec} = Number of fragments exiting the target

Selection criteria: fragments produced by C beam fragmentation

Target: C



Target: C_2H_4

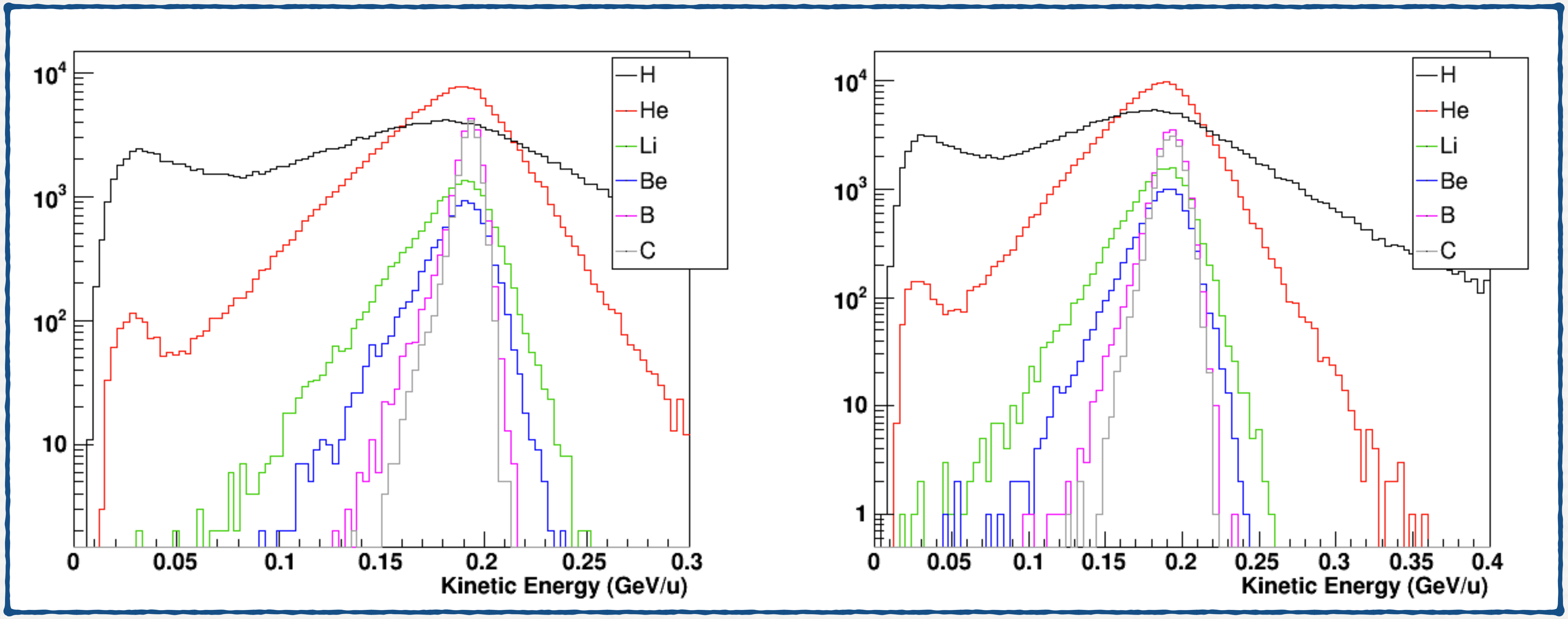


Energy Distribution - Direct Kin

- Kinetic energy/nucleon for fragments produced in C beam fragmentation in the target
- Selection criteria: fragments reaching the calorimeter
- Target material: C
- Target thickness: 2 mm

$\{\sigma_\theta^{beam} = 3 \text{ mrad}\}$
$\{\sigma_\theta^{frag} = 3 \text{ mrad}\}$
$\{\sigma_E/E = 3\%\}$
$\{\sigma_P/P = 4\%\}$

MC True Smearing



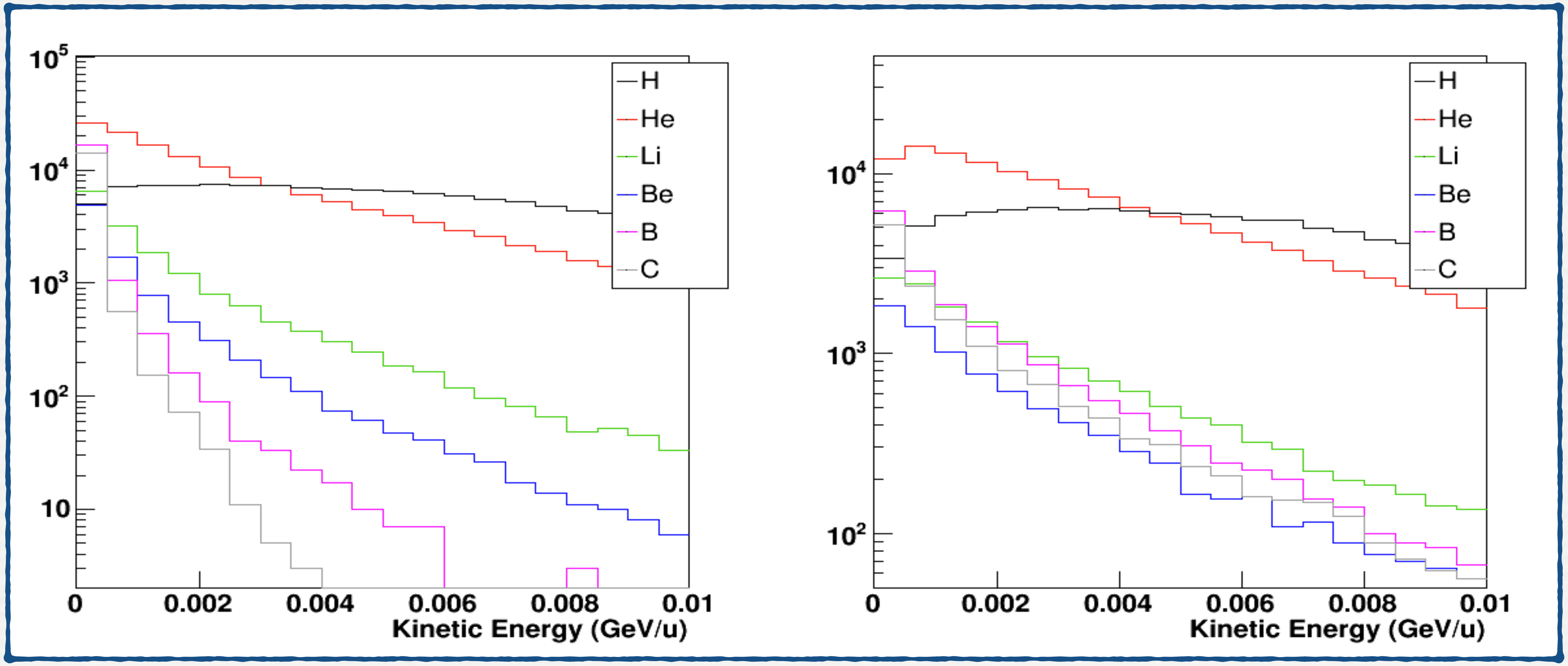
ENERGY DISTRIBUTION - INVERSE KIN

- Kinetic energy/nucleon for fragments produced in C beam fragmentation in the target
- Selection criteria: fragments reaching the calorimeter
- Target material: C
- Target thickness: 2 mm

$\{\sigma_\theta^{beam} = 3\text{ mrad}\}$
$\{\sigma_\theta^{frag} = 3\text{ mrad}\}$
$\{\sigma_E/E = 3\%\}$
$\{\sigma_P/P = 4\%\}$

MC TRUE

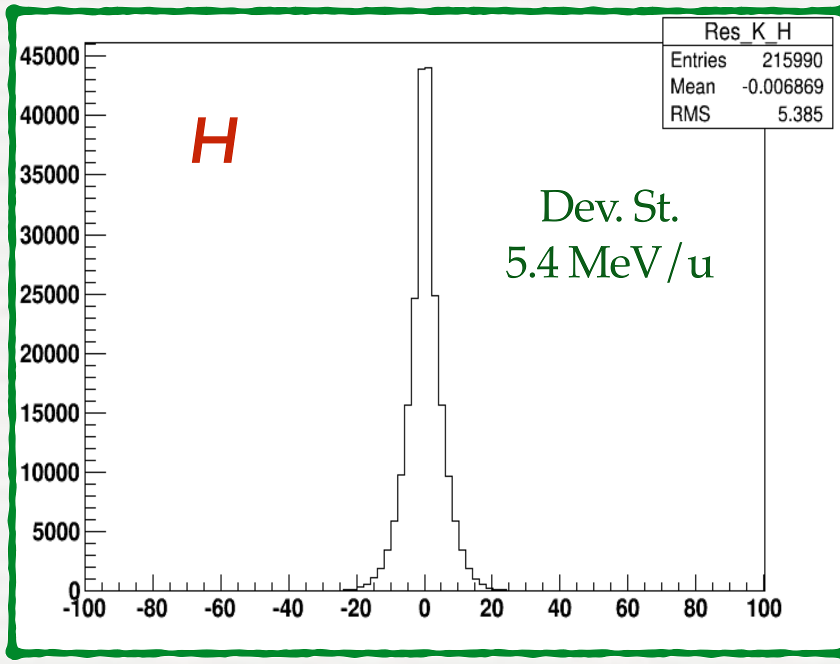
SMEARING

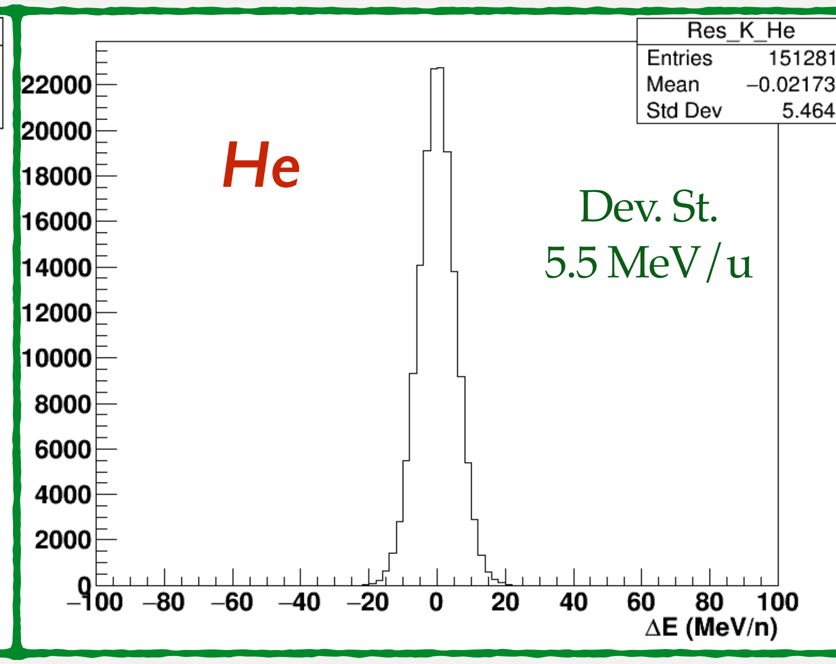


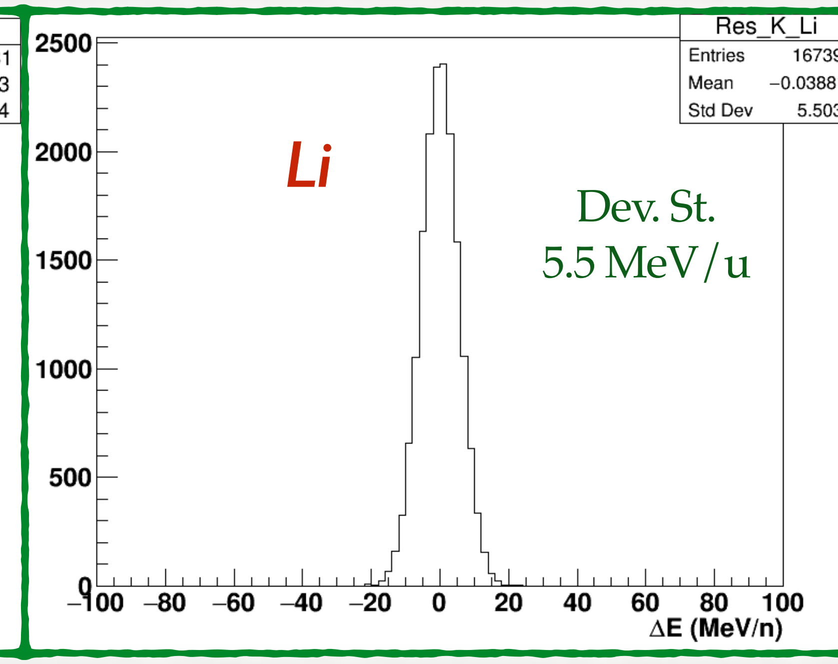
Energy Resolution - Direct Kinematics

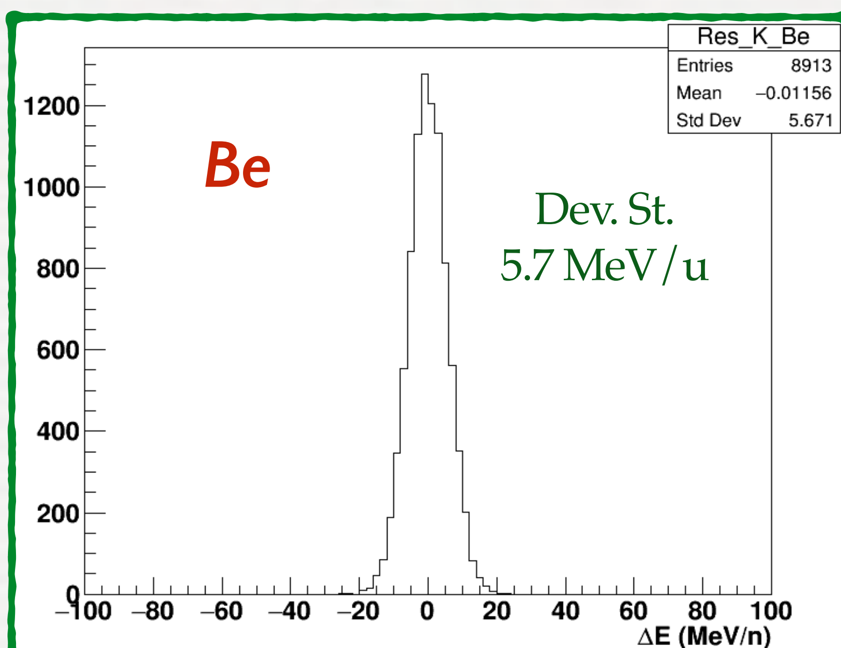
- Target material: C
- Target thickness: 2 mm

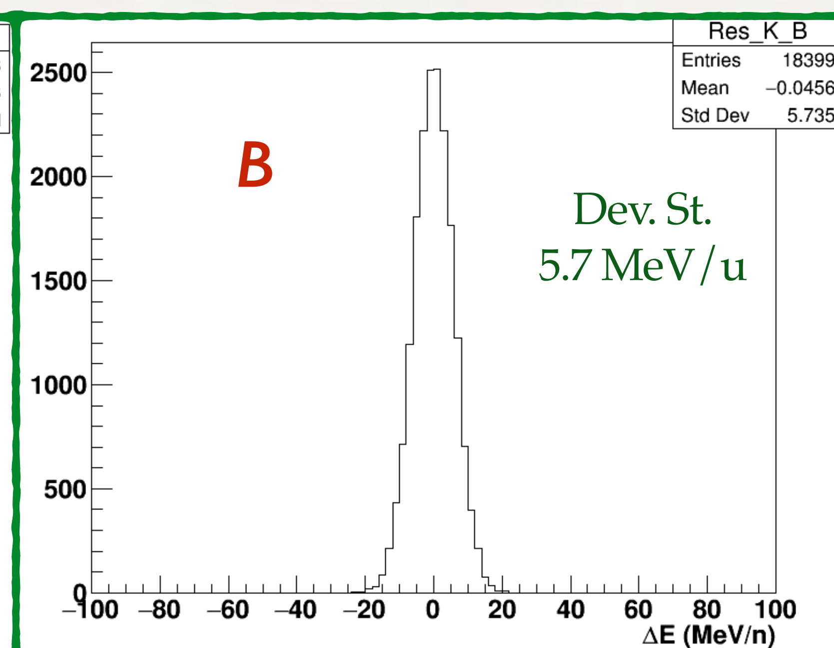
Residuals = $Ekin_{smear} - Ekin_{true}$

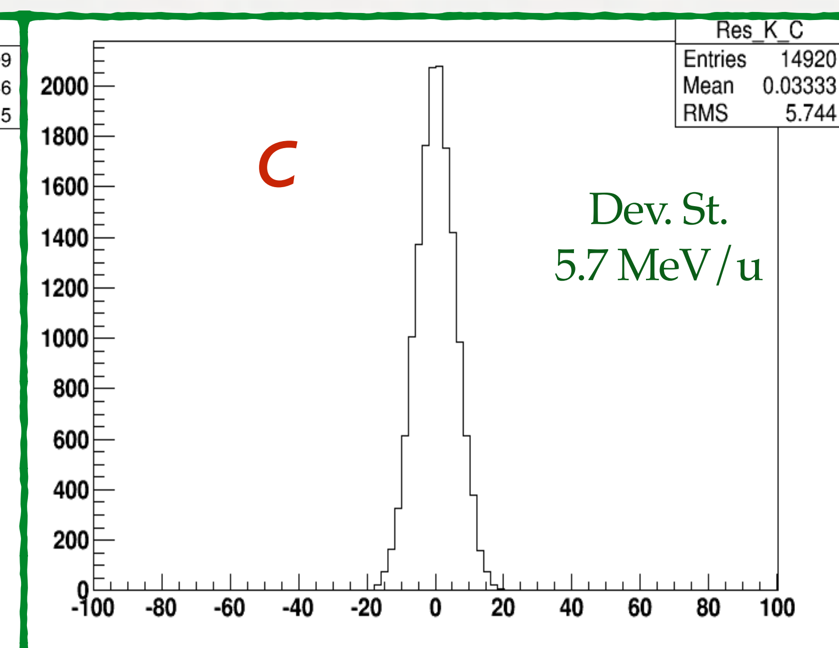








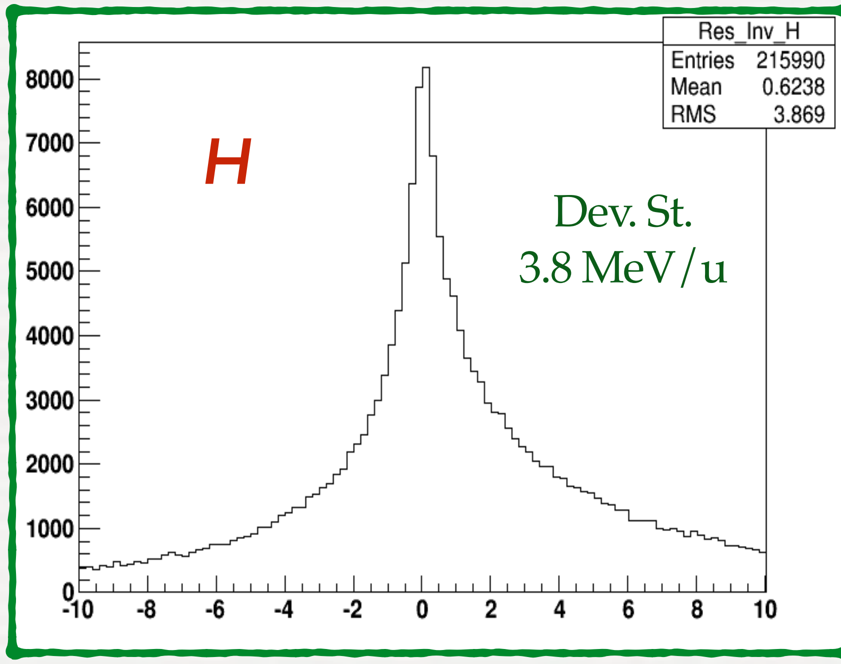


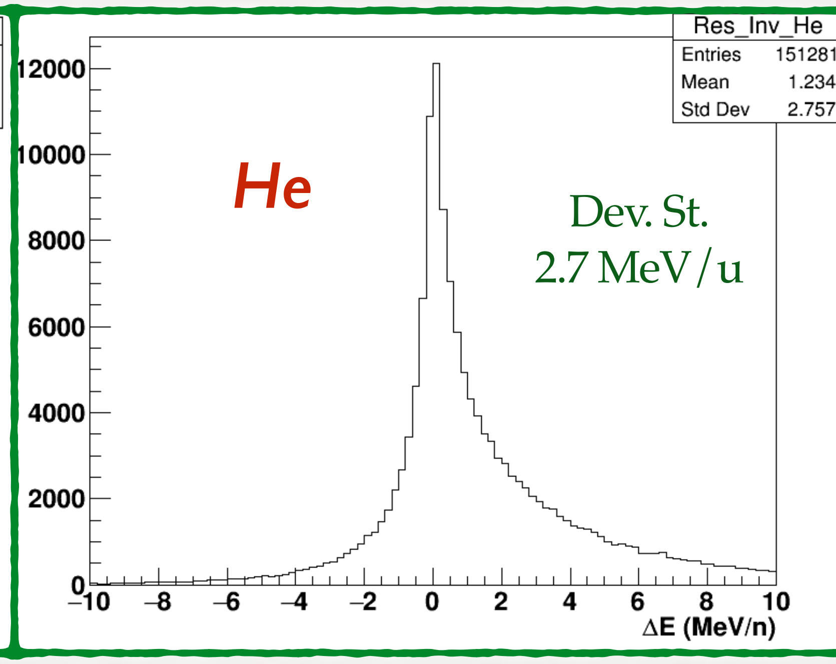


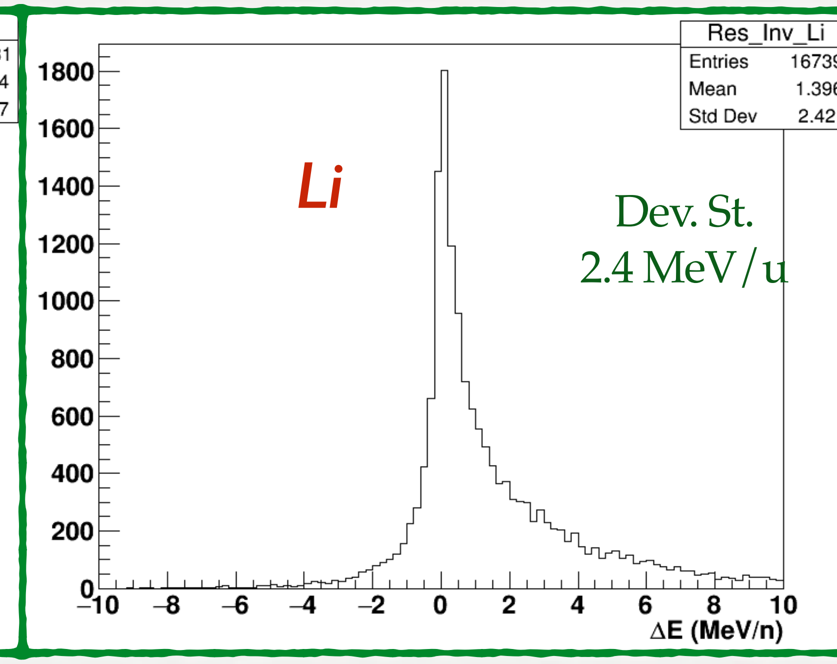
Energy Resolution - Inverse Kinematics

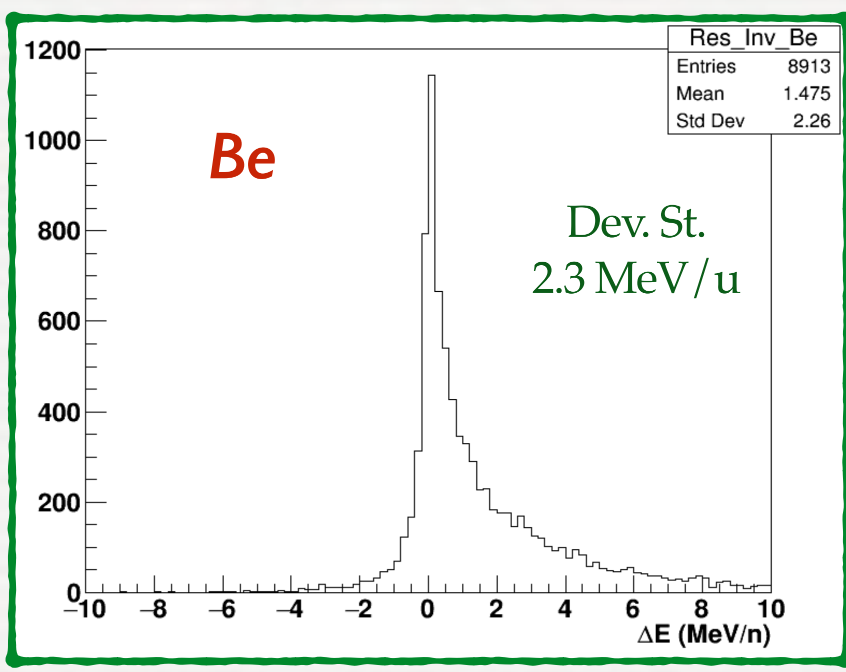
Residuals = $Ekin_{smear} - Ekin_{true}$

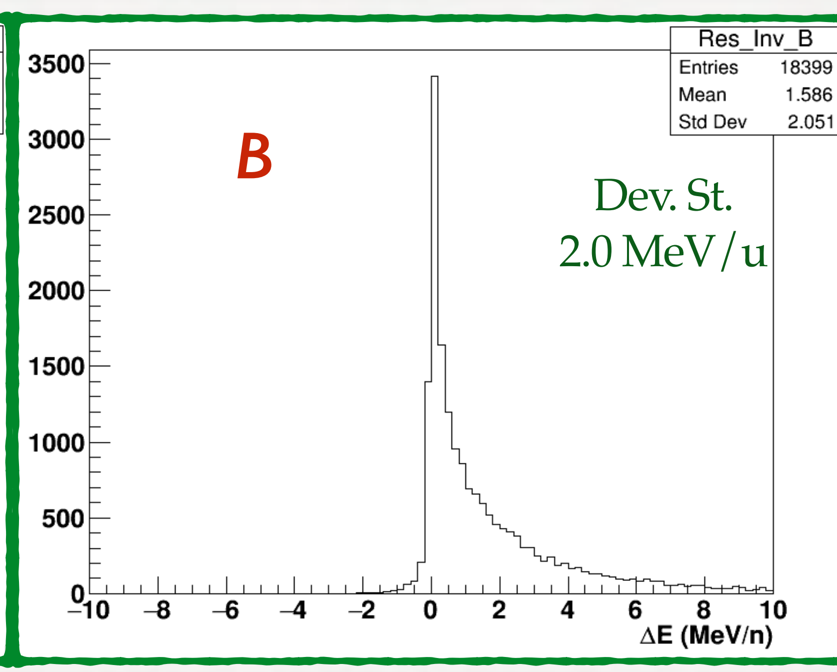
- Target material: C
- Target thickness: 2 mm

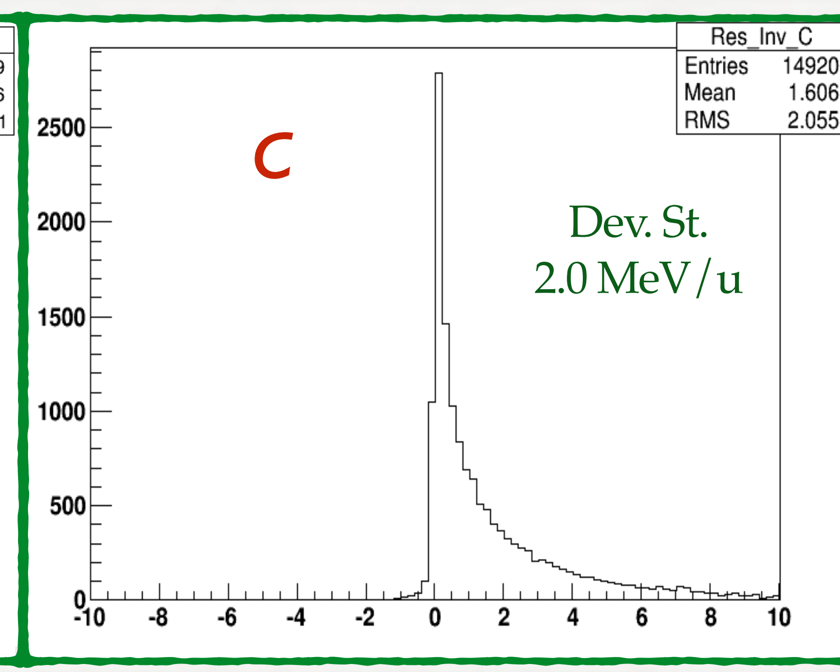










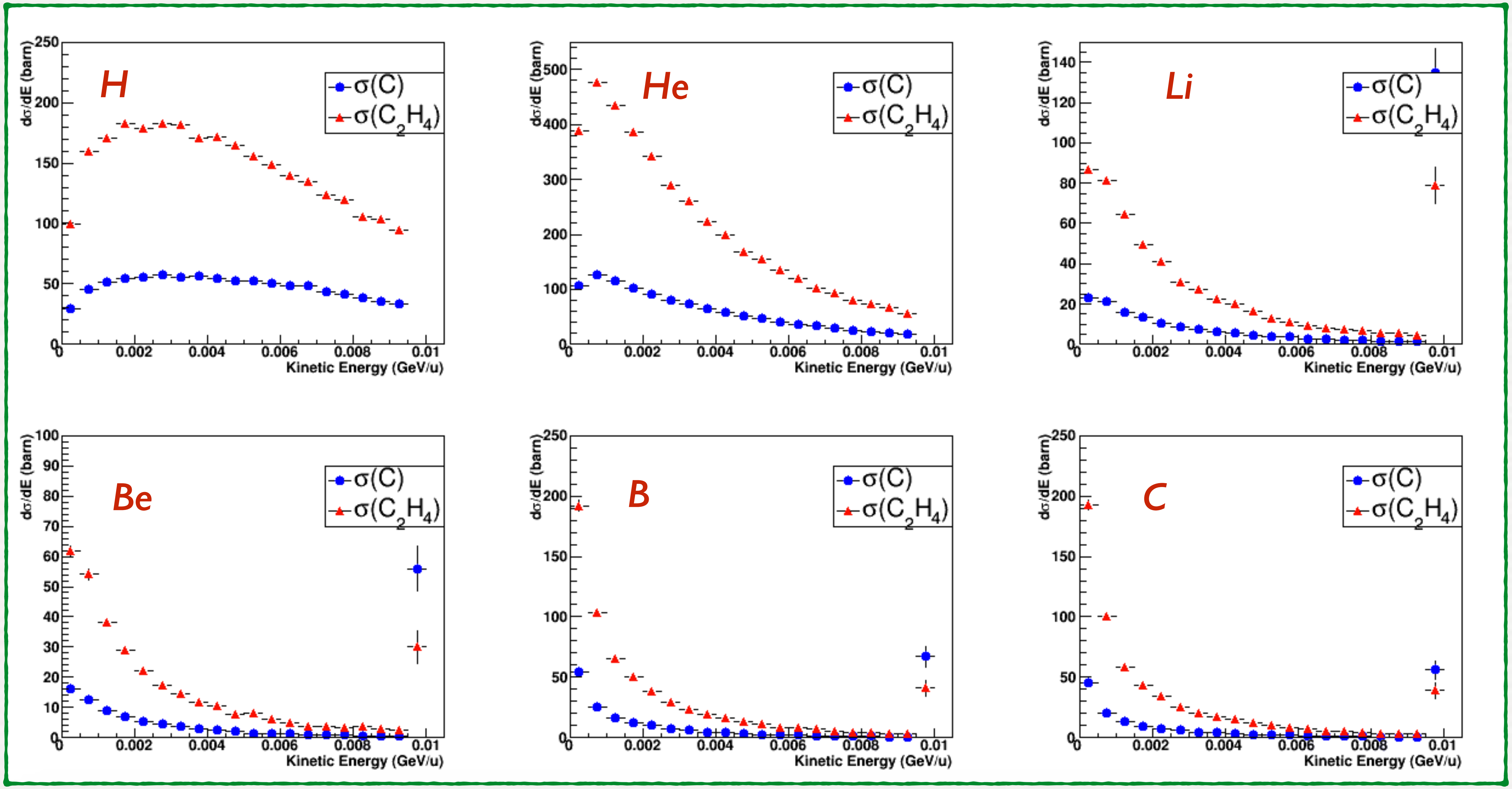


DIFFERENTIAL CROSS SECTION

Inverse kinematics

2 mm

$$\sigma(C_2H_4) = \frac{d\sigma}{dE_{kin}}(C_2H_4) \qquad \sigma(C) = \frac{d\sigma}{dE_{kin}}(C)$$

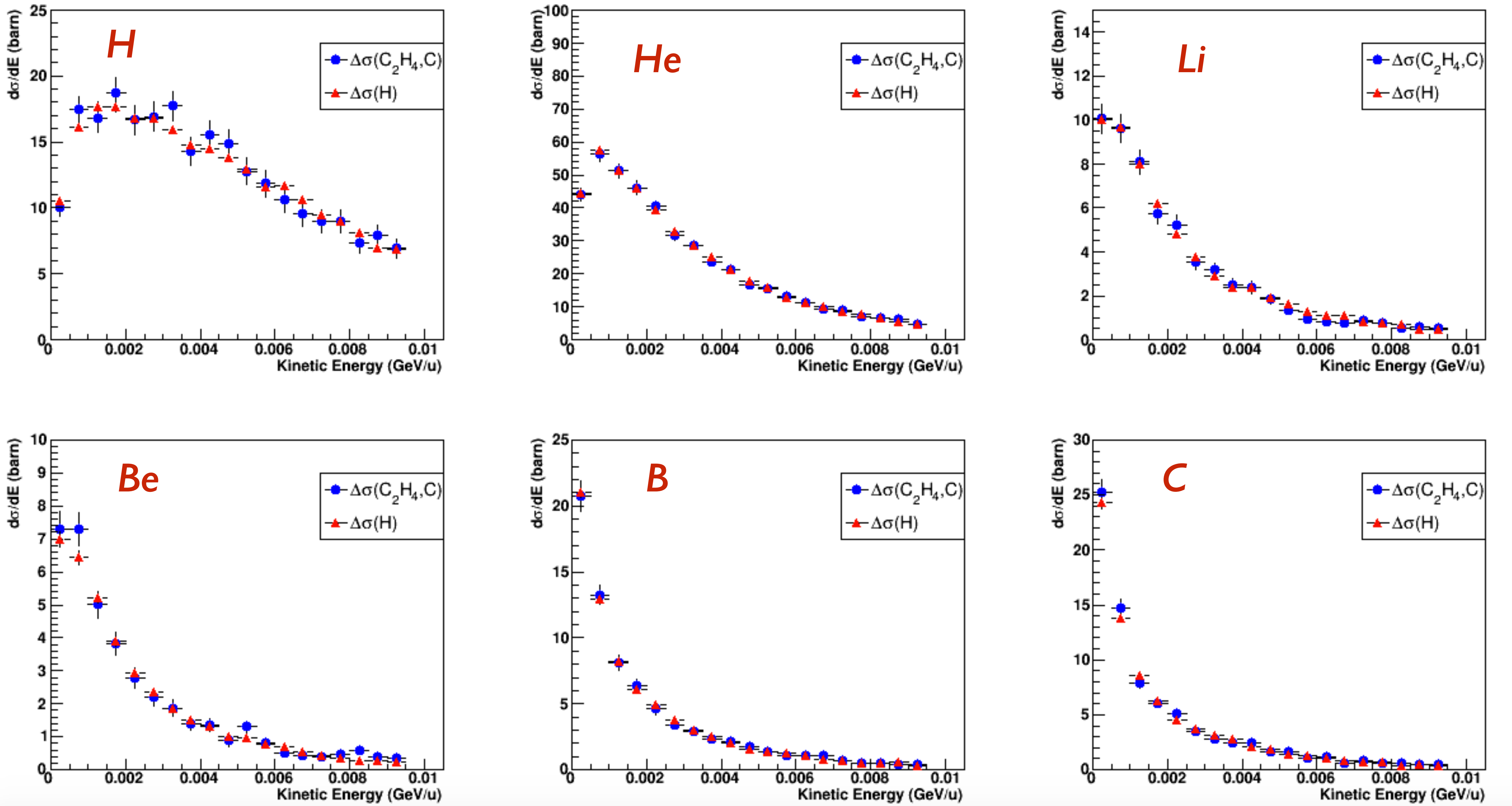


H→C DIFFERENTIAL CROSS SECTION

Inverse kinematics

2 mm

$$\Delta\sigma(C_2H_4, C) = \frac{1}{4}\left(\frac{d\sigma}{dE_{kin}}(C_2H_4) - 2\frac{d\sigma}{dE_{kin}}(C)\right) \qquad \sigma(H) = \frac{d\sigma}{dE_{kin}}(H)$$

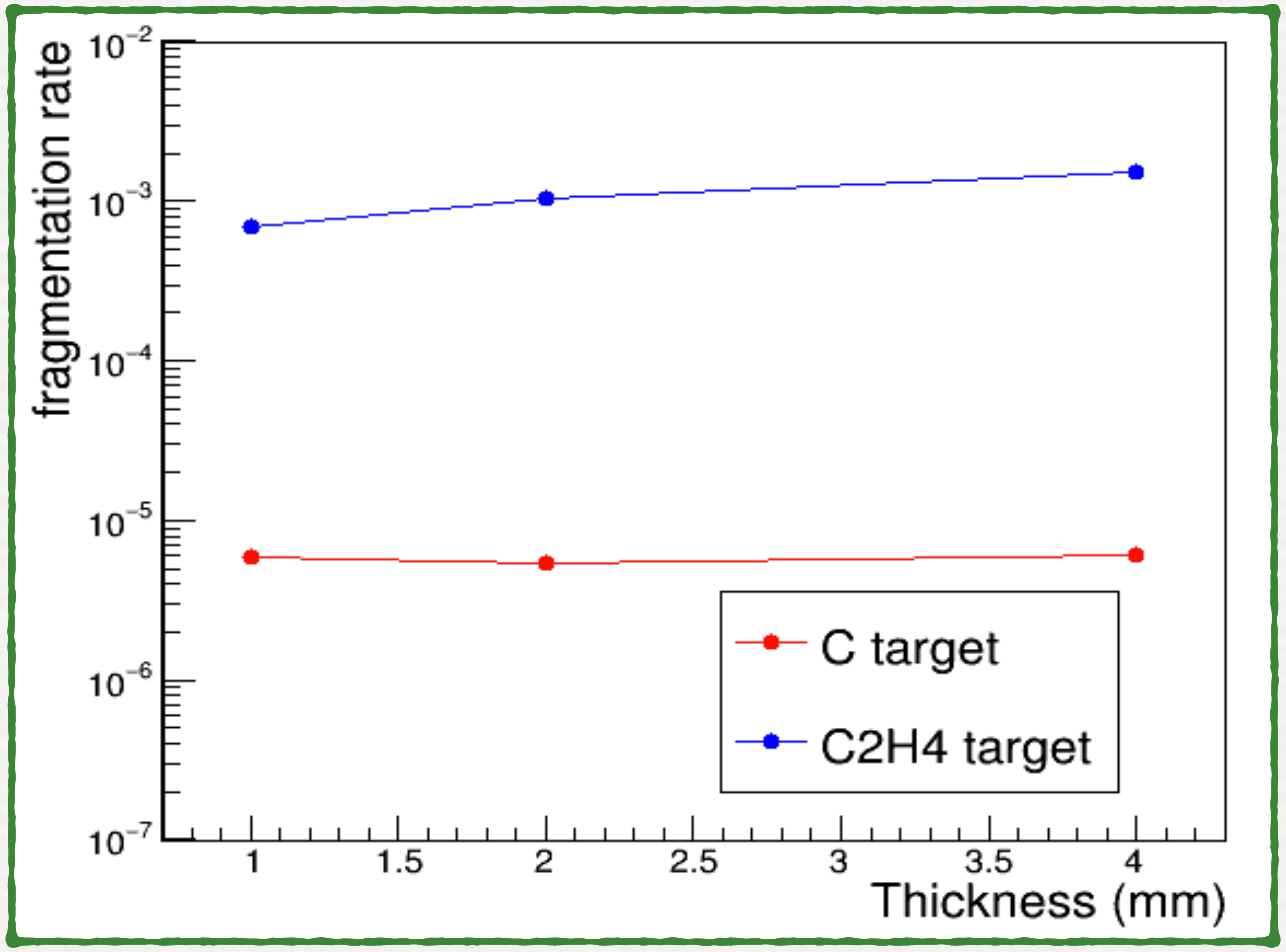


Re-Fragmentation In The Target

- Re-fragmentation rate $R = N_{sec} / (N_{sec} + N_{pri})$

$N_{pri} =$ Number of fragments produced by C beam fragmentation
$N_{sec} =$ Number of fragments produced by re-fragmentation

Selection criteria: fragments exiting the target



CONCLUSIONS

- Good agreement in H->C cross section evaluated as difference between C_2H_4 and C targets
- No significant loss in efficiency when different target thickness is used

NEXT STEPS (After CDR)

- Use detector response instead of smeared MC true information
- Use different incident beam particles (^{16}O) and energies

Backup Slides

RE-FRAGMENTATION IN THE TARGET

Selection criteria: fragments exiting the target

target: C	N_{pri}	N_{sec}	$N_{sec}/(N_{pri}+N_{sec})$
1mm	507070	3	0,0000059
2mm	928951	5	0,0000054
4mm	1675389	10	0,0000060

target: C_2H_4	N_{pri}	N_{sec}	$N_{sec}/(N_{pri}+N_{sec})$
1mm	255321	174	0,00068
2mm	484506	510	0,00105
4mm	921482	1387	0,00150

	C	C_2H_4
N_{pri}2mm/ N_{pri}1mm/	1,83	1,90
N_{pri}4mm/ N_{pri}2mm/	1,80	1,90
N_{pri}4mm/ N_{pri}1mm/	3,30	3,61

	C	C_2H_4
N_{sec}2mm/ N_{sec}1mm/	1,7	2,9
N_{sec}4mm/ N_{sec}2mm/	2,0	2,7
N_{sec}4mm/ N_{sec}1mm/	3,3	8,0

Re-Fragmentation In The Target

Selection criteria: reaching the calorimeter

target: C	N_{pri}	N_{sec}	$N_{sec}/(N_{pri}+N_{sec})$
1mm	227339	0	0,0000000
2mm	426242	0	0,0000000
4mm	809483	0	0,0000000

target: C_2H_4	N_{pri}	N_{sec}	$N_{sec}/(N_{pri}+N_{sec})$
1mm	128242	17	0,00013
2mm	246858	68	0,00028
4mm	487588	171	0,00035

	C	C_2H_4
N_{pri}2mm/ N_{pri}1mm/	1,87	1,92
N_{pri}4mm/ N_{pri}2mm/	1,90	1,98
N_{pri}4mm/ N_{pri}1mm/	3,56	3,80

	C	C_2H_4
N_{sec}2mm/ N_{sec}1mm/	-	4,0
N_{sec}4mm/ N_{sec}2mm/	-	2,5
N_{sec}4mm/ N_{sec}1mm/	-	10,1