Update on Monte Carlo studies for ΔE-TOF detector

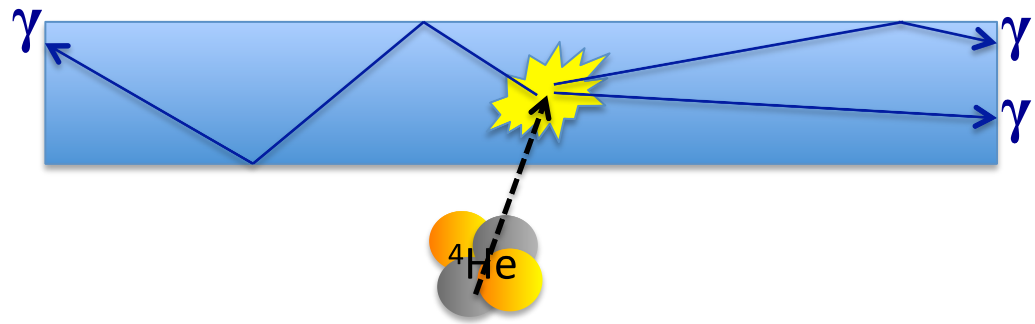
Outline

- Introduction
- M&M: Experimental setup and MC
- Results
- Conclusions

Introduction

Goal:

- Compare data june 2018 with MC
- Understand data and MC in detail (today: MC)



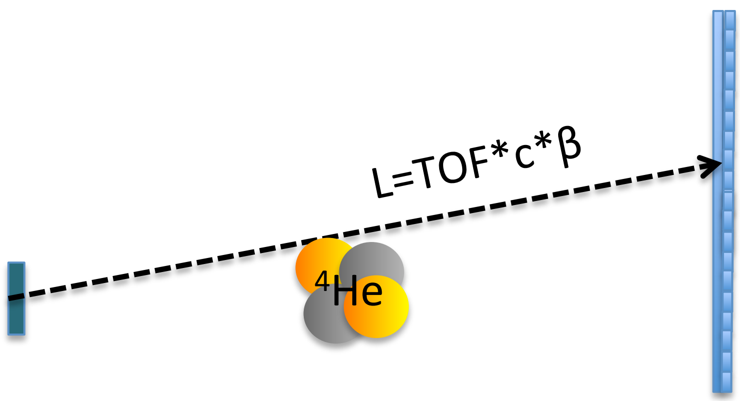
Reminder

- ΔE-TOF detector provides:
  - **Time-Of-Flight** of fragments
    - TOF→ velocity **β**
    - **Energy** deposited

Bethe-Bloch (relevant terms)

$$-\frac{\Delta E}{dx} = Kz^2 \frac{Z}{A} \frac{1}{\beta^2} [\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 W_{max}}{I^2} - \beta^2]$$

$$\rightarrow z = \beta \sqrt{\frac{E_{bar}}{d}} \frac{1}{K \frac{Z}{A} [\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 W_{max}}{I^2} - \beta^2]})$$

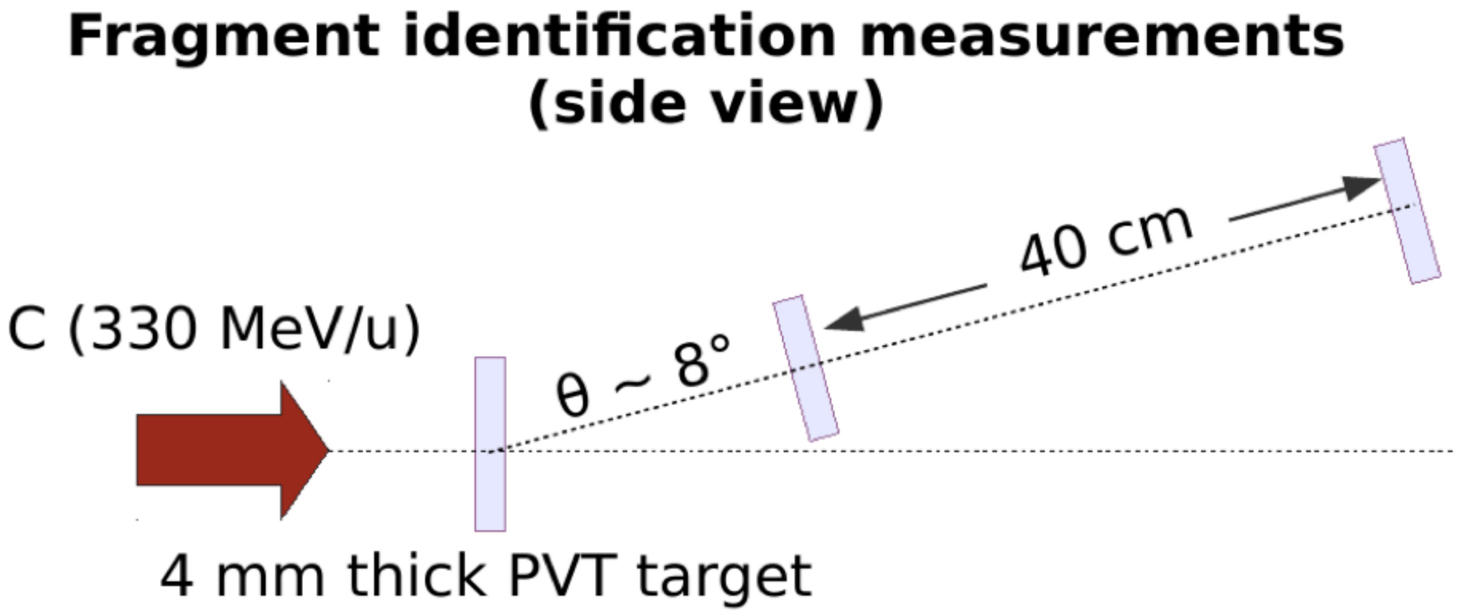


BB formula → Z of fragment

  - **Position** (2D by orthogonal arrangement)

Methods & Materials: data

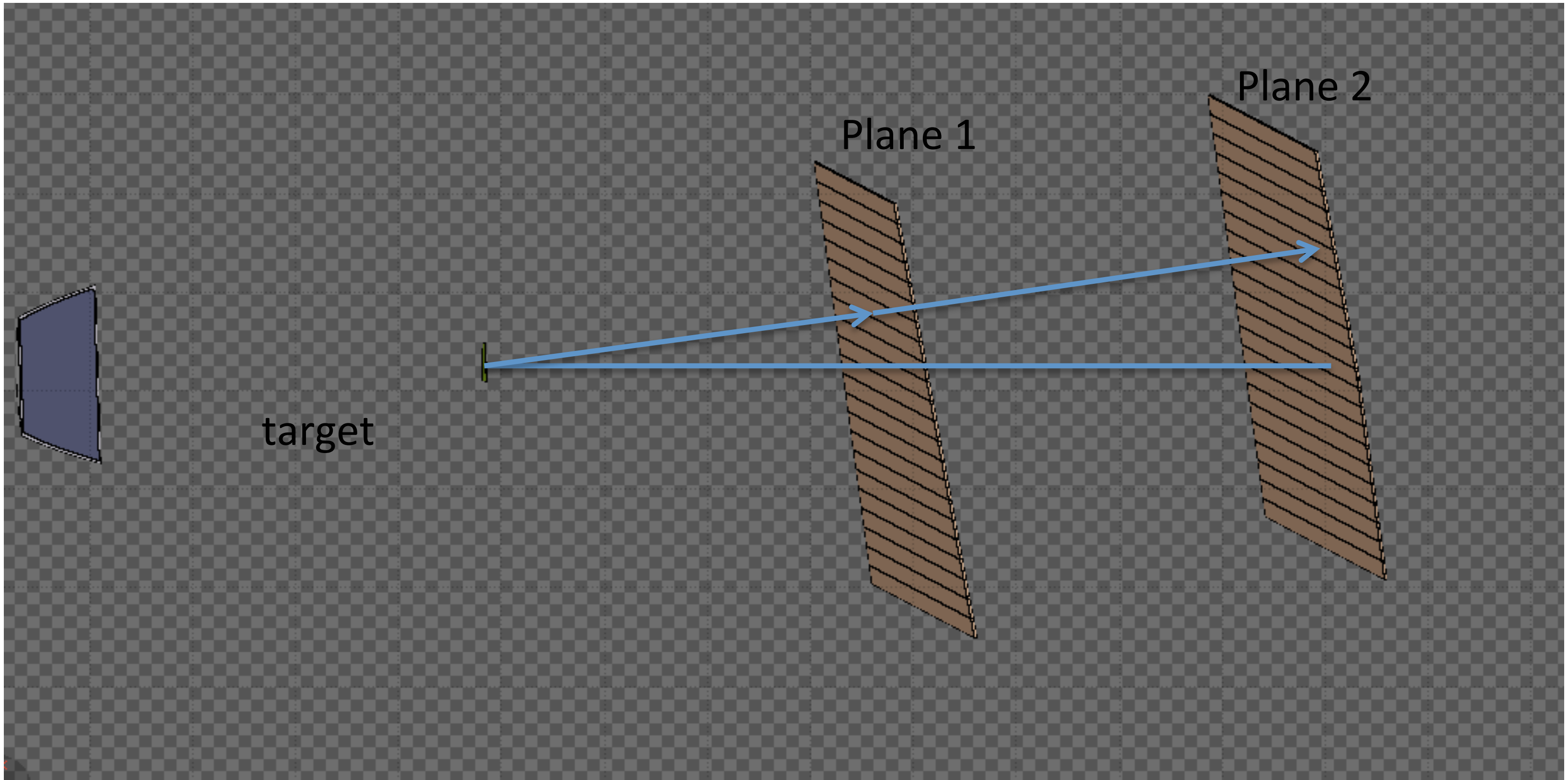
- Data were taken at CNAO in June 2018
- Goal: test particle ID
- 330 MeV/c carbon ions



Details: see Esther's presentation

Methods & Materials: MC

- Used FOOT simulation framework rotated 8 degrees. Advantage:
  - Can use existing analysis framework
  - Can easily test other angles
- Bars nr 16 corresponded to the position of the bars in the experimental setup



Bethe-Bloch-formula

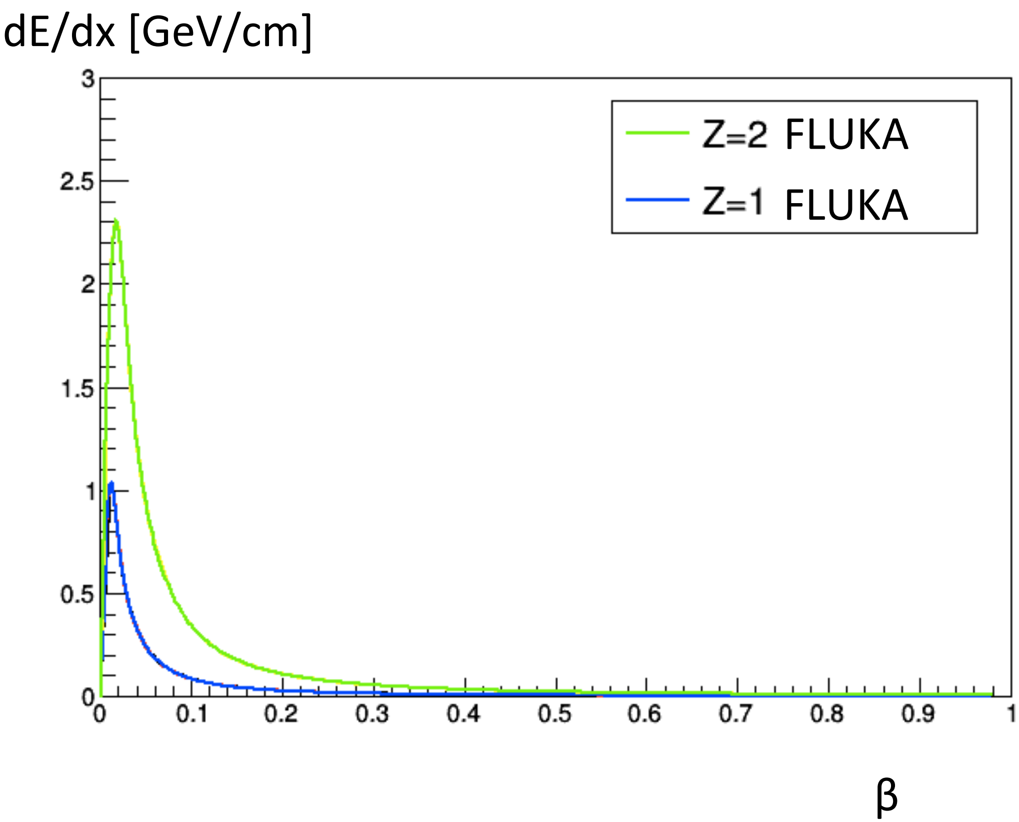
First check: be sure the BB formula used in the analysis code is ok!

For Z=1 and Z=2, plot shows

- MC dE/dx, tabulated from FLUKA output, including all relevant physics
- Theoretical dE/dx from Bethe-Bloch formula included in AnaFoot
- They are perfectly superimposed!

Conclusion:

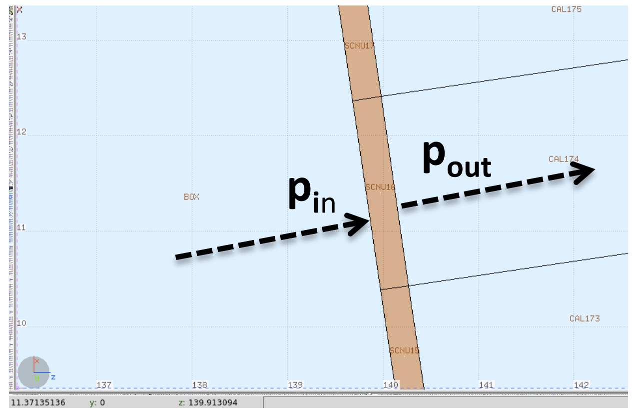
- BB formula we use in the analysis code later to extract Z later is fine!
- BB formula from slide 1 is perfectly valid up to β~0.02
- Checked also that nuclear stopping power is not an issue until very low velocity



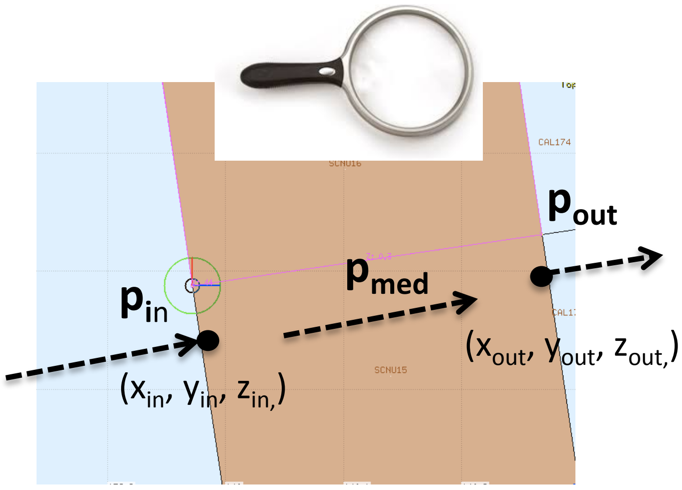
In the following, will try to go in steps towards what we see in the TOF

A perfect world (1)

- Perfect world = having access to the crossings in the detector:
  - Momenta in and out of scintillator
  - Positions in and out of scintillator → get Δx
  - Masses, charges, of particles, their origin, etc
  - **E_{loss} in SCN is E_{kin} (start of bar) – E_{kin} (end of bar)**



- Event selection
  - 1 hit in bar 1 && 1 hit in bar 2
  - 1 crossing in bar 1 and 1 crossing in bar 2
  - Particle crossing bar 1 is the same as the one in bar 2 (i.e., no fragmentation)
  - Enter from air, exit into air, no escape into other bars



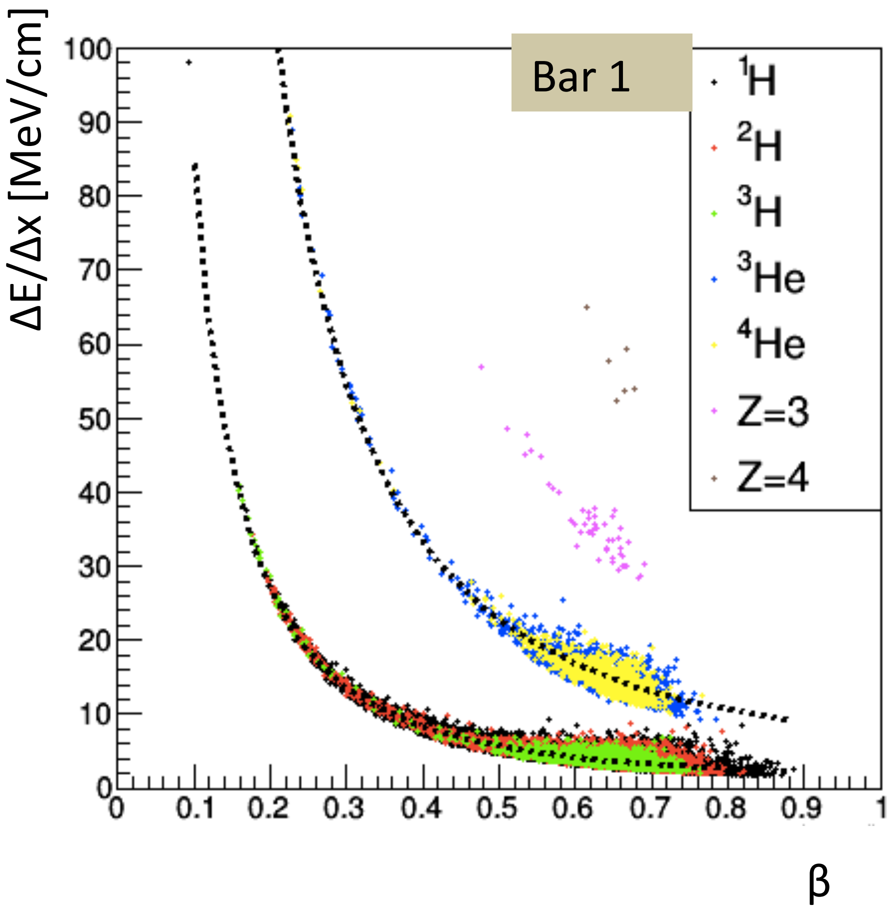
- Energy deposit is the true **kinetic energy** lost in the bar!

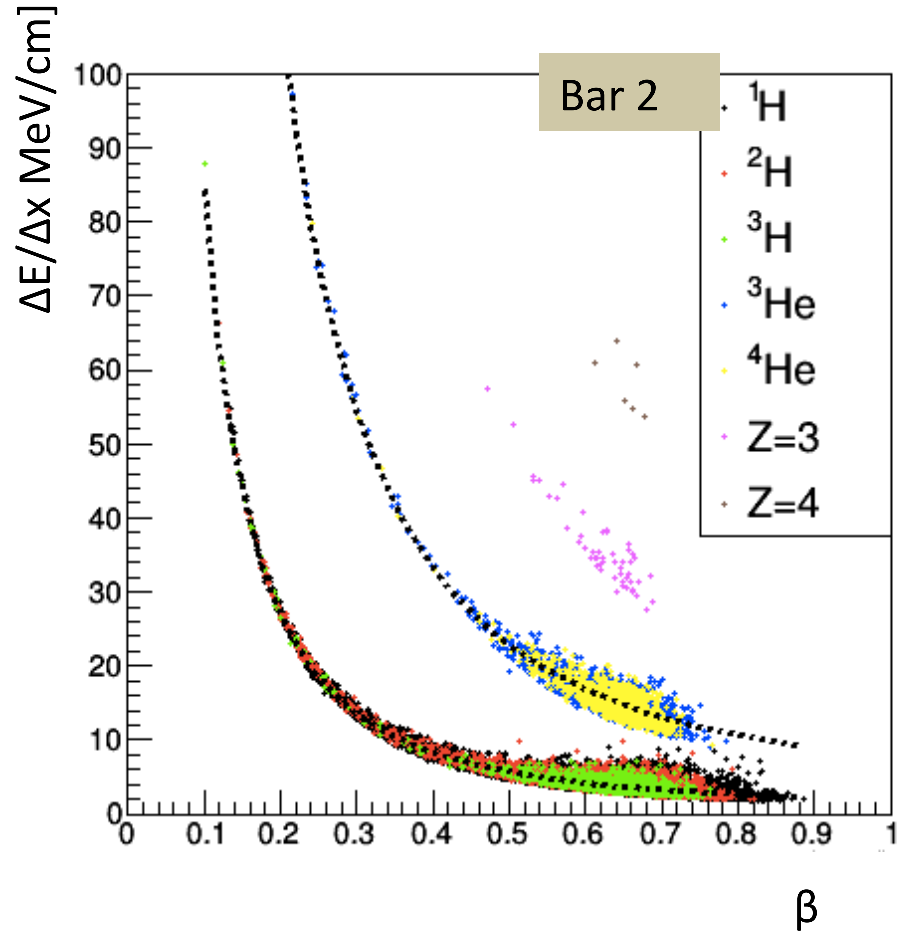
- β calculation
  - Since Bethe-Bloch B depends on β^2, define:

  $\mathbf{p_{med}}^2 = (\mathbf{p}^2_{out} + \mathbf{p}^2_{in})/2$

```
Δx=sqrt(pow((cross_xout-cross_xin),2)+
        pow((cross_yout-cross_yin),2)+
        pow((cross_zout-cross_zin),2));)
```

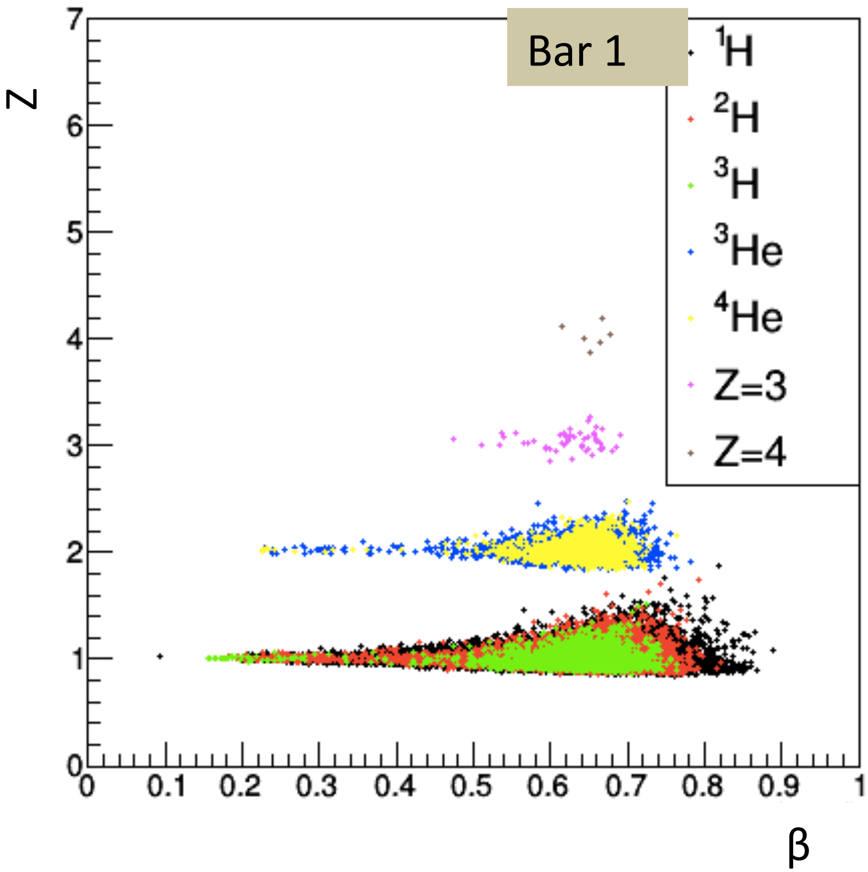
A perfect world (2)

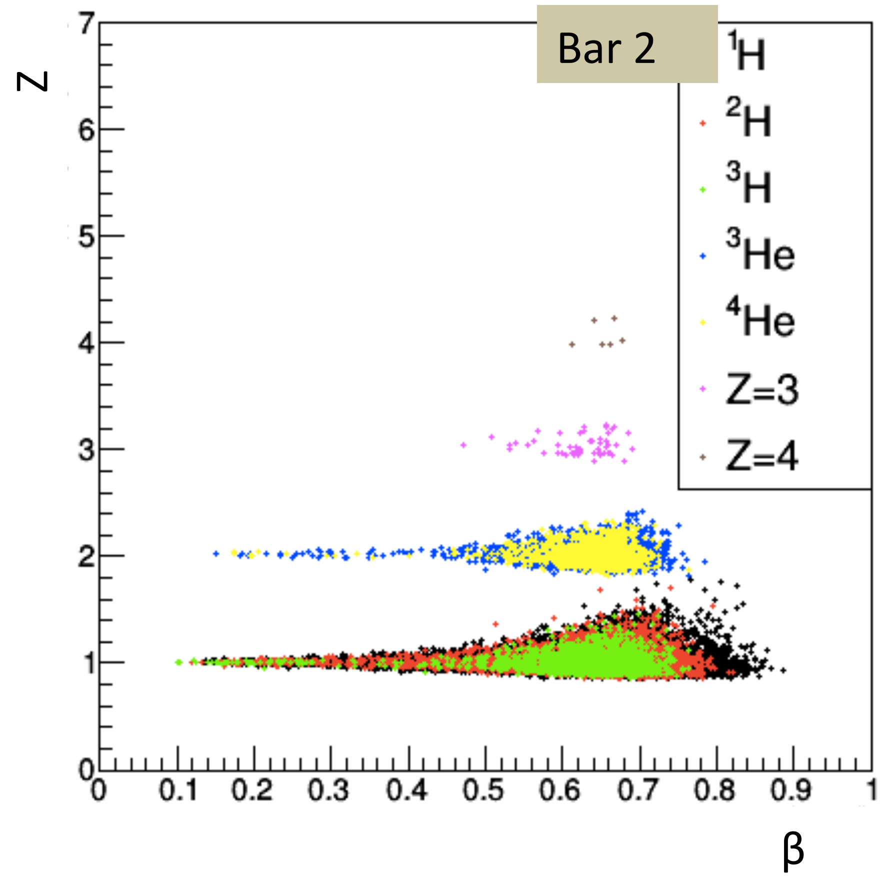




- Remember: only passing fragments, perfectly clean → only electromagnetic losses are important → perfectly following the BB formula
- Physics in bar 1 and bar 2 is the same

A perfect world (2)



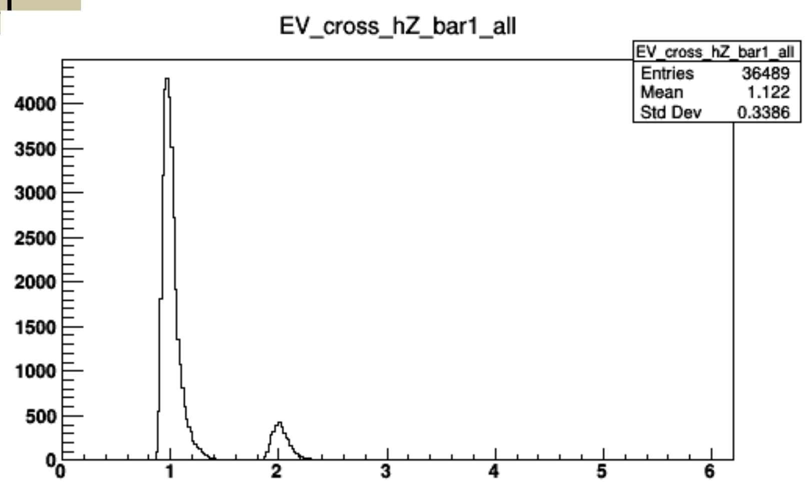


- Even in a perfect worlds, due to statistics, the Z determination would never be perfect

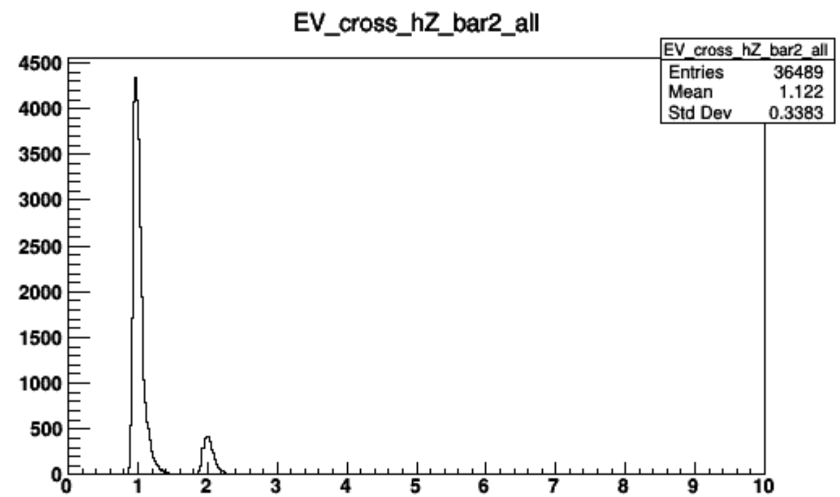
A perfect world (3)

Bar 2

Bar 1



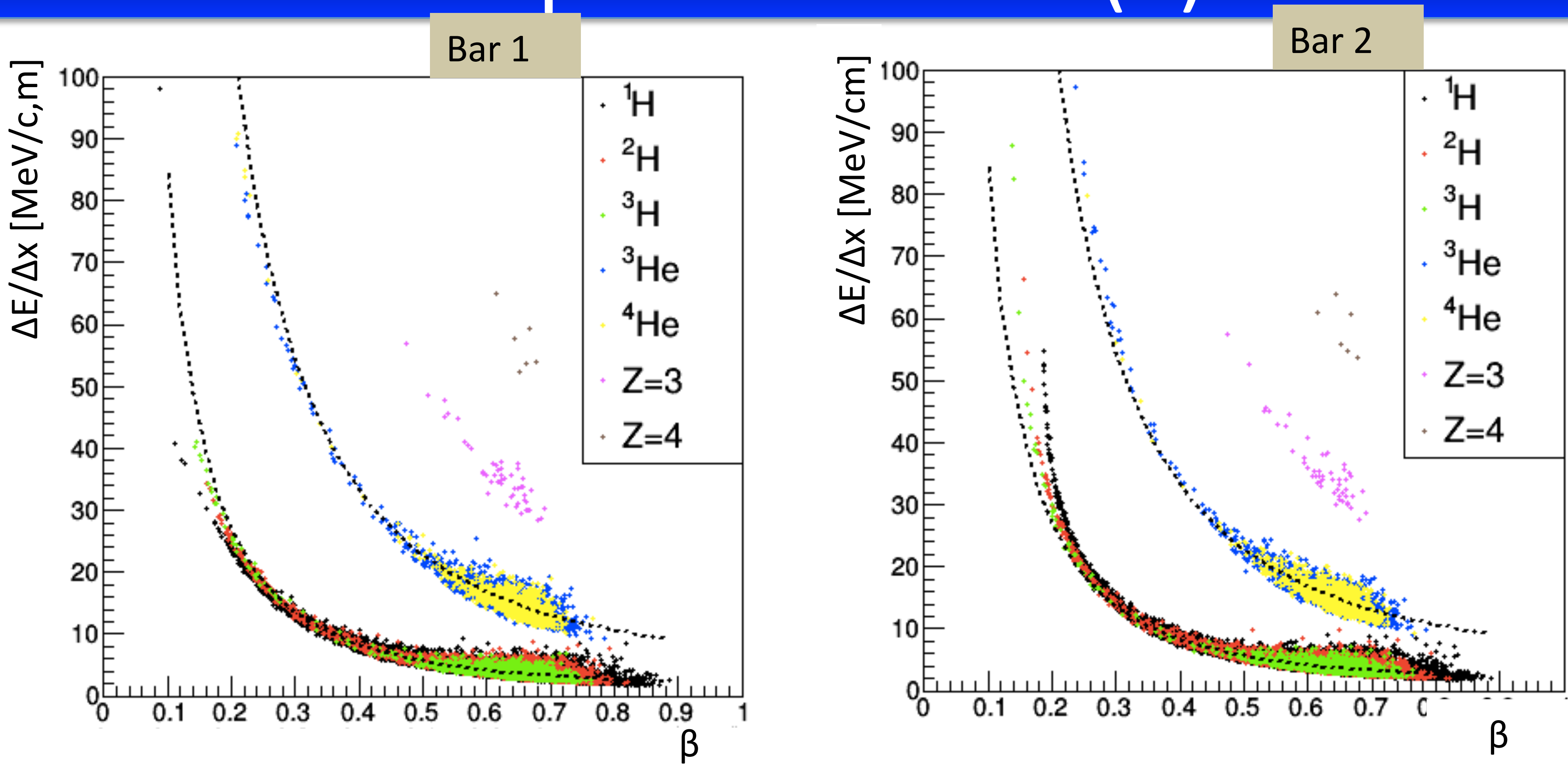
Z



Z

- Even in a perfect worlds, due to statistics, the Z determination would never be perfect

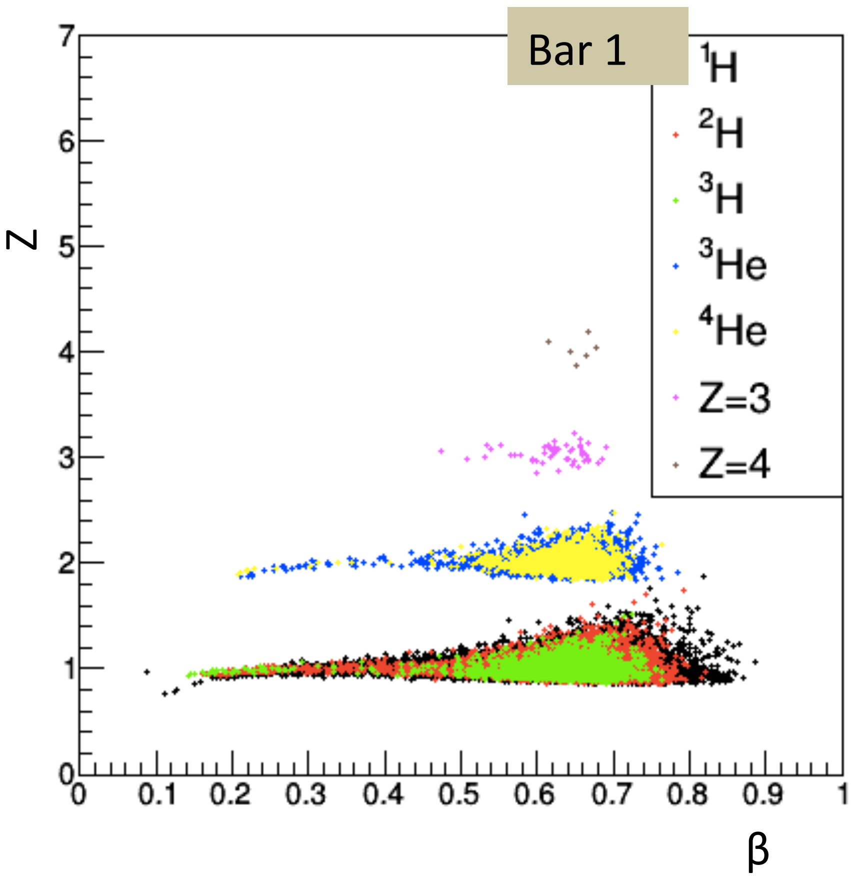
A less perfect world (4)

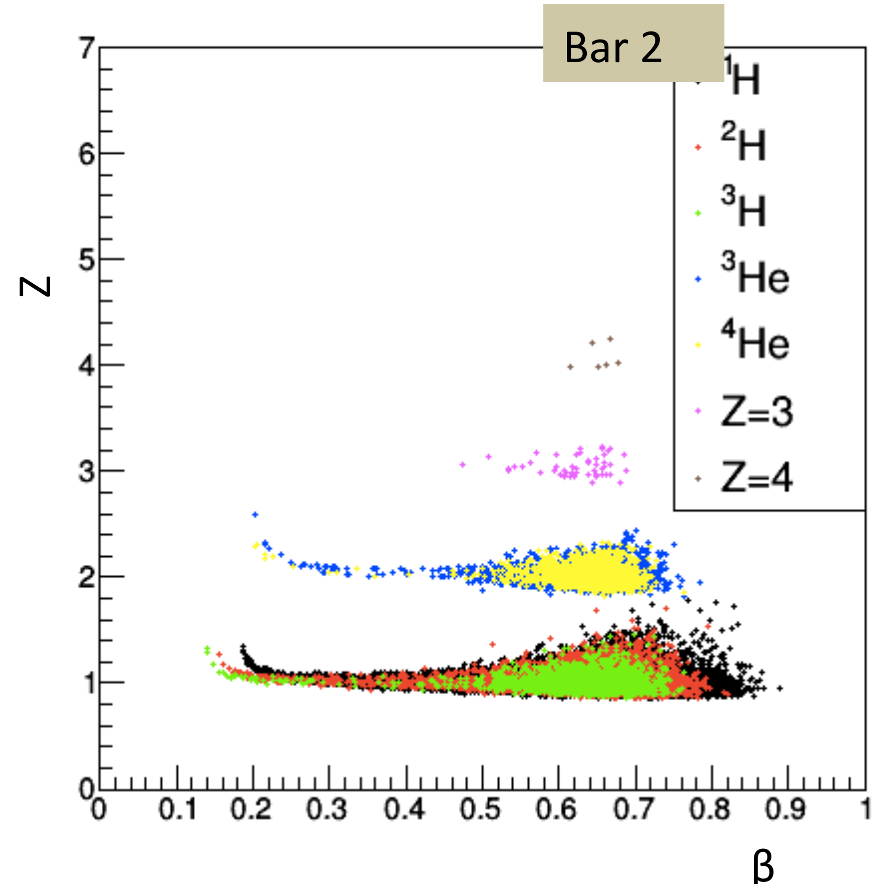


What happens if we do not have P_{med} , but only the info in between the bas?

- Take:
  - **Bar1: the P_{out}** of bar 1,
  - **Bar 2 the P_{in}** of bar 2
- Deviation from the Bethe-Bloch function: the beta **in between** the bars doesn't reflect the average beta **in** the bar

A less perfect world





What happens if we do not have P_{med} , but only the info in between the bas?

- Take:
  - **Bar1: the P_{out}** of bar 1,
  - **Bar 2 the P_{in}** of bar 2
- Z determination still fine as long as beta not too small

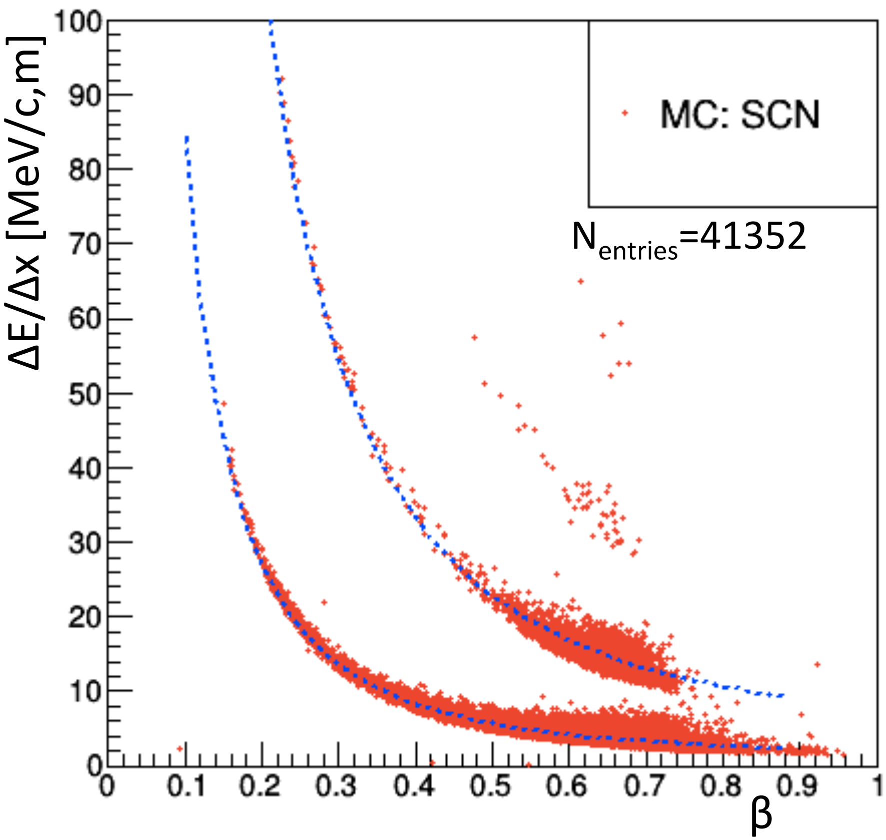
Closer to reality

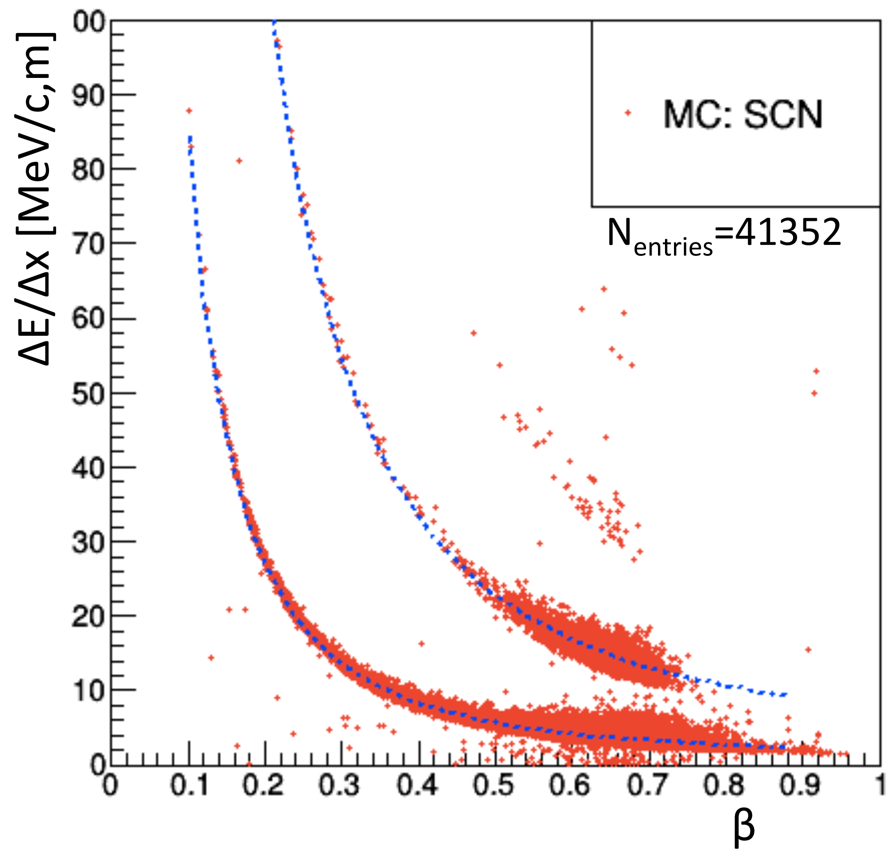
Closer to reality: analyze SCN block

- Energy deposits: now from evstr->SCNde[i]
- Beta in each bar: from the true crossings
- Selection: as previously

MC Event selection

- 1 hit in bar 1 && 1 hit in bar 2
- 1 crossing in bar 1 && 1 crossing in bar 2
- Particle crossing bar 1 = the one in bar 2 (i.e., no fragmentation)
- Enter from air, exit into air, no escape into other bars





In these events, most energy is visible: E deposited in SCN ~E_{kin}(bar entrance)-E_{kin}(bar exit)

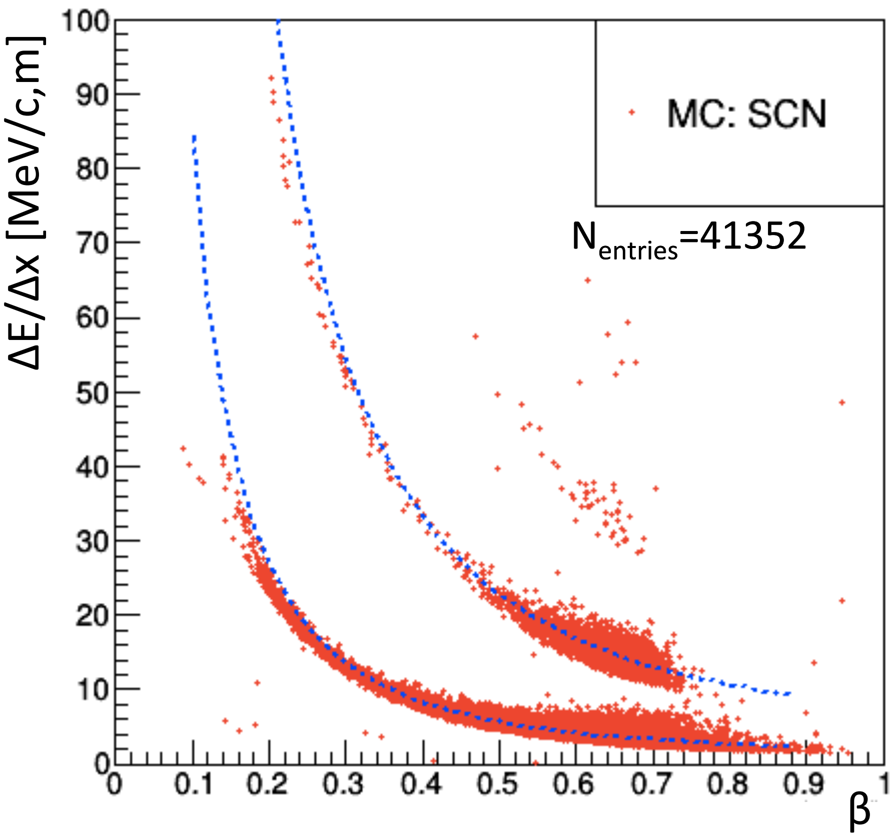
Closer to reality

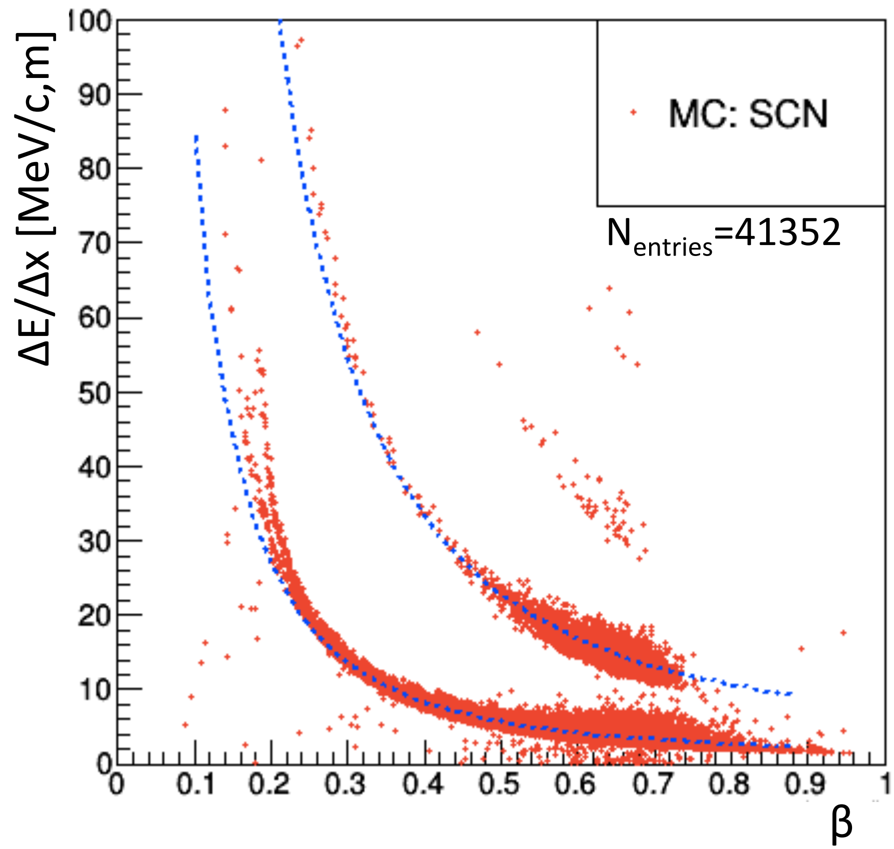
Closer to reality: analyze SCN block

- Energy deposits: from evstr->SCNde[i]
- Beta: from TOF
  - Time stamp: from hit in bar
- Selection: as previously

MC Event selection

- 1 hit in bar 1 && 1 hit in bar 2
- 1 crossing in bar 1 && 1 crossing in bar 2
- Particle crossing bar 1 = the one in bar 2 (i.e., no fragmentation)
- Enter from air, exit into air, no escape into other bars





Effect of 'wrong' beta becomes visible (compare with slide 11)

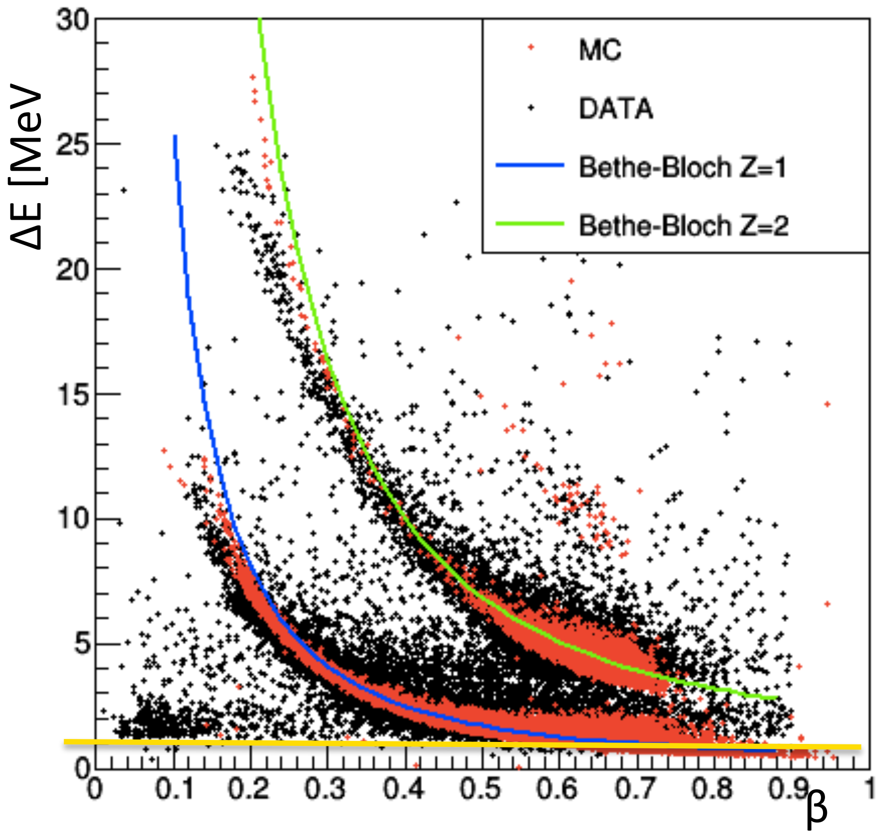
Comparison data-MC

Closer to reality: analyze SCN block

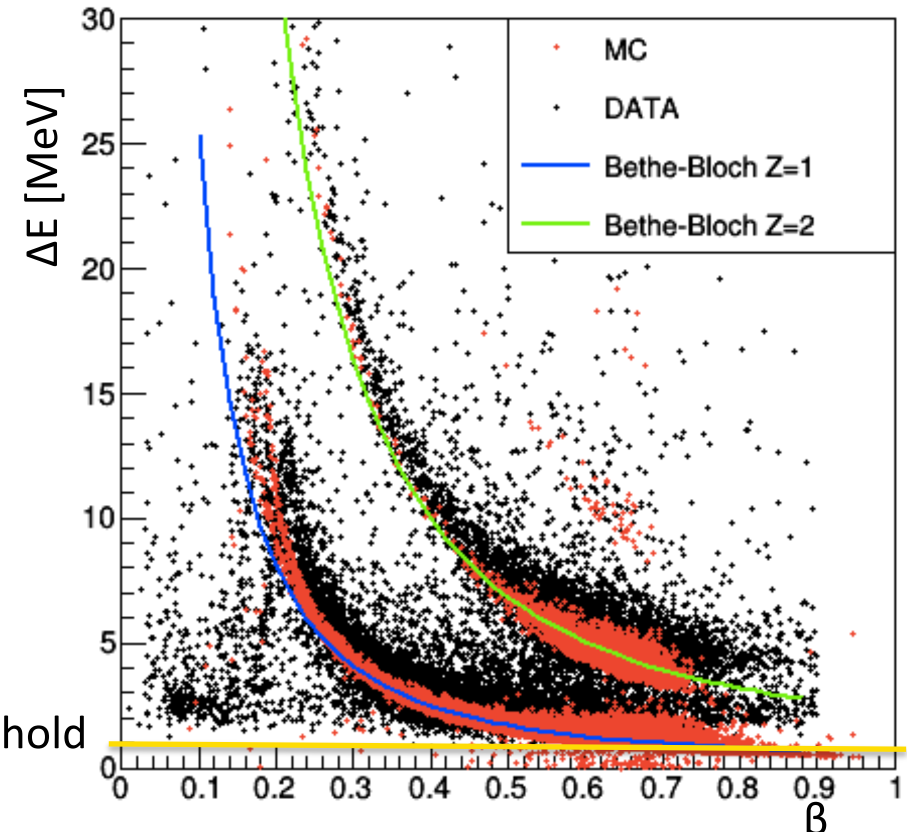
- Energy deposits: from evstr->SCNde[i]
- Beta: from TOF
  - Time stamp: from hit in bar
- Selection: as previously

MC Event selection

- 1 hit in bar 1 && 1 hit in bar 2
- 1 crossing in bar 1 && 1 crossing in bar 2
- Particle crossing bar 1 = the one in bar 2 (i.e., no fragmentation)
- Enter from air, exit into air, no escape into other bars



threshold



Bar 1: comparison ok. Bar 2: Energy too high→ Z too high

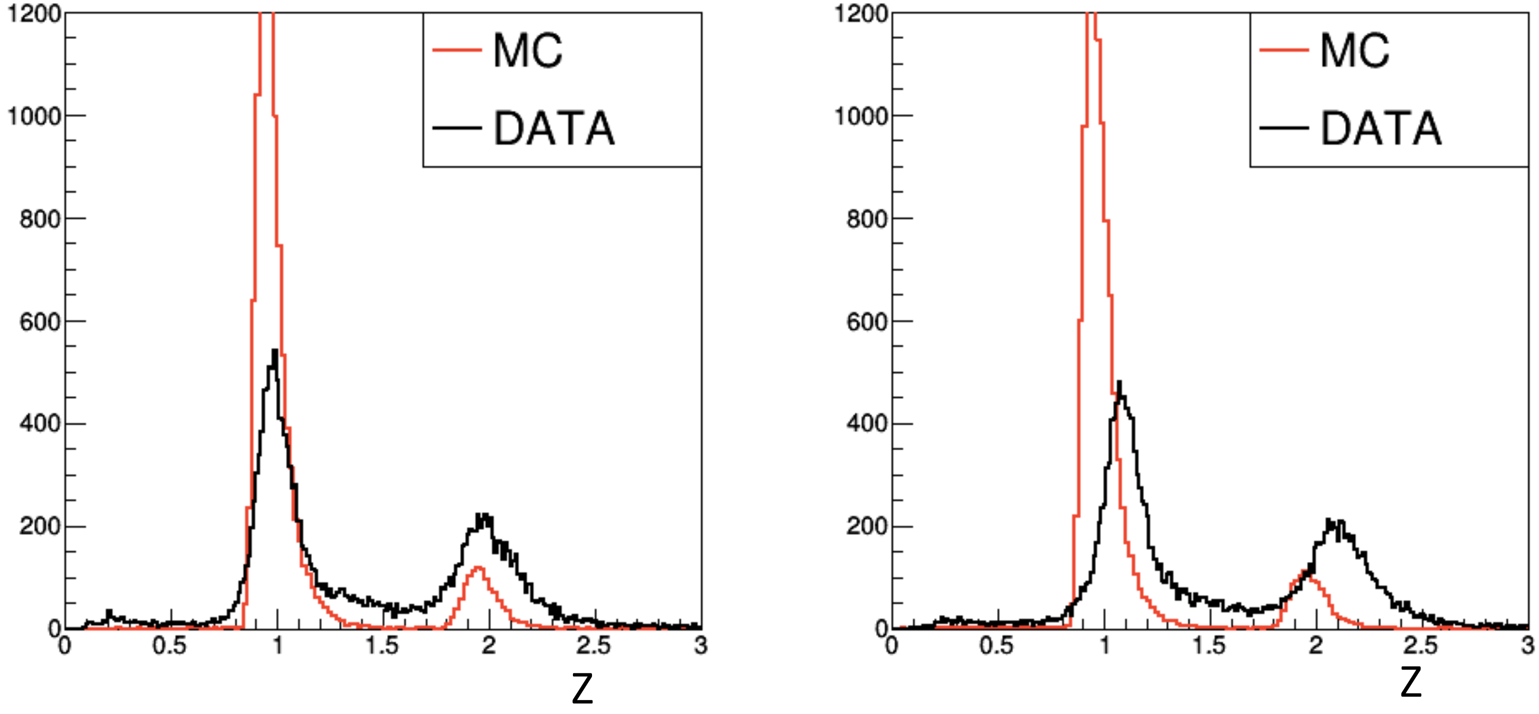
Comparison data-MC

Closer to reality: analyze SCN block

- Energy deposits: from evstr->SCNde[i]
- Beta: from TOF
  - Time stamp: from hit in bar
- Selection: as previously

MC Event selection

- 1 hit in bar 1 && 1 hit in bar 2
- 1 crossing in bar 1 && 1 crossing in bar 2
- Particle crossing bar 1 = the one in bar 2 (i.e., no fragmentation)
- Enter from air, exit into air, no escape into other bars



Bar 1: comparison ok. Bar 2: Energy too high→ Z too high

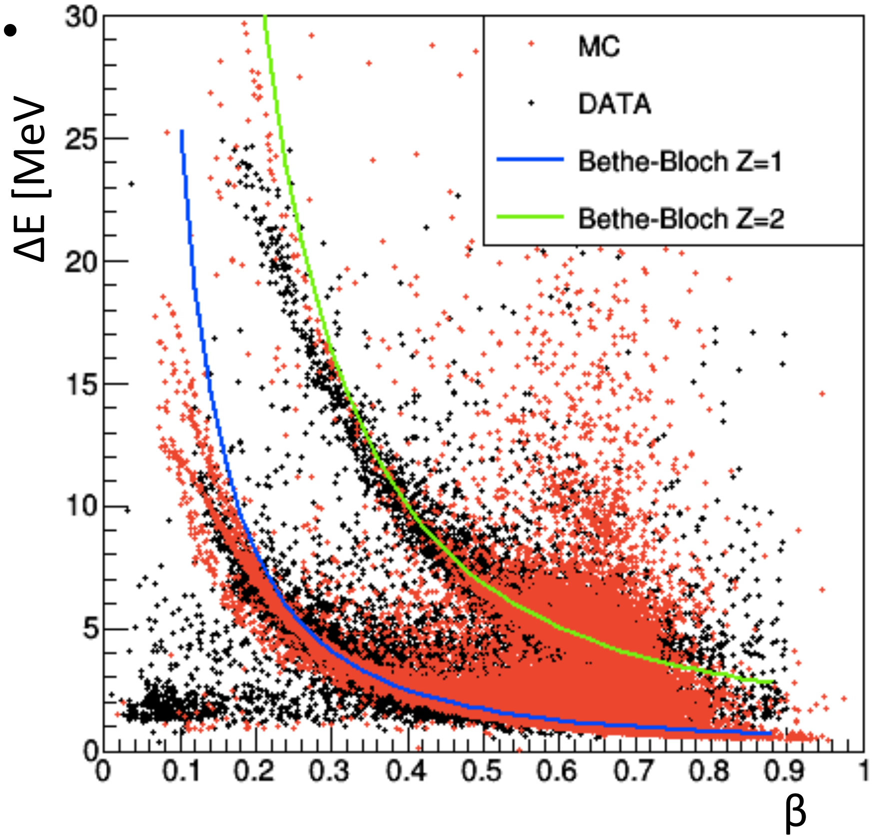
Comparison data-MC

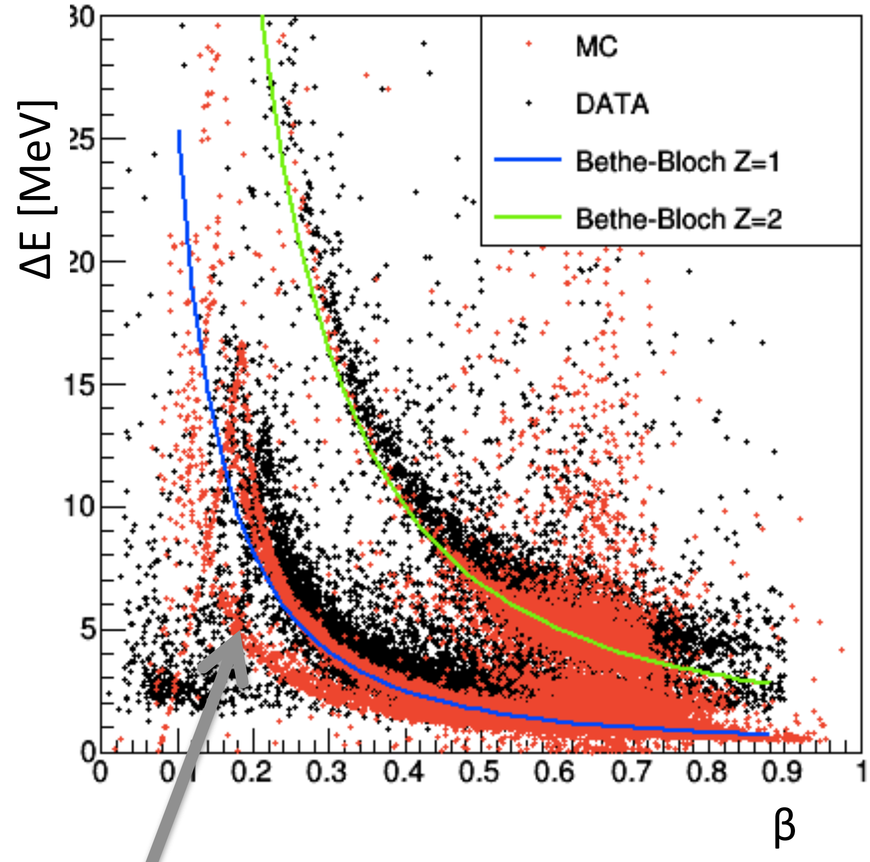
Closer to reality: analyze SCN block

- Energy deposits: from evstr->SCNde[i]
    - Summed energies
- Beta: from TOF
    - Time stamp: from **first** hit in bar

MC Event selection

- >=1 hit in bar 1 && >=1 hit in bar 2
- >=1 crossing in bar 1 && >=1 crossing in bar 2





????

Still under investigation

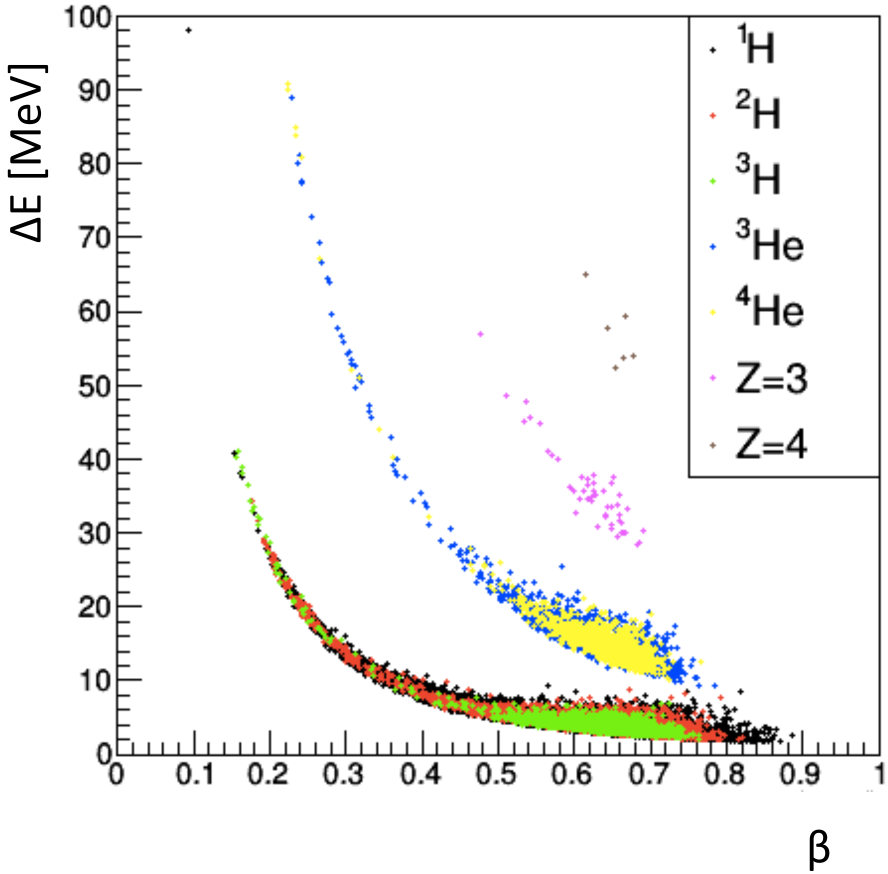
Software status

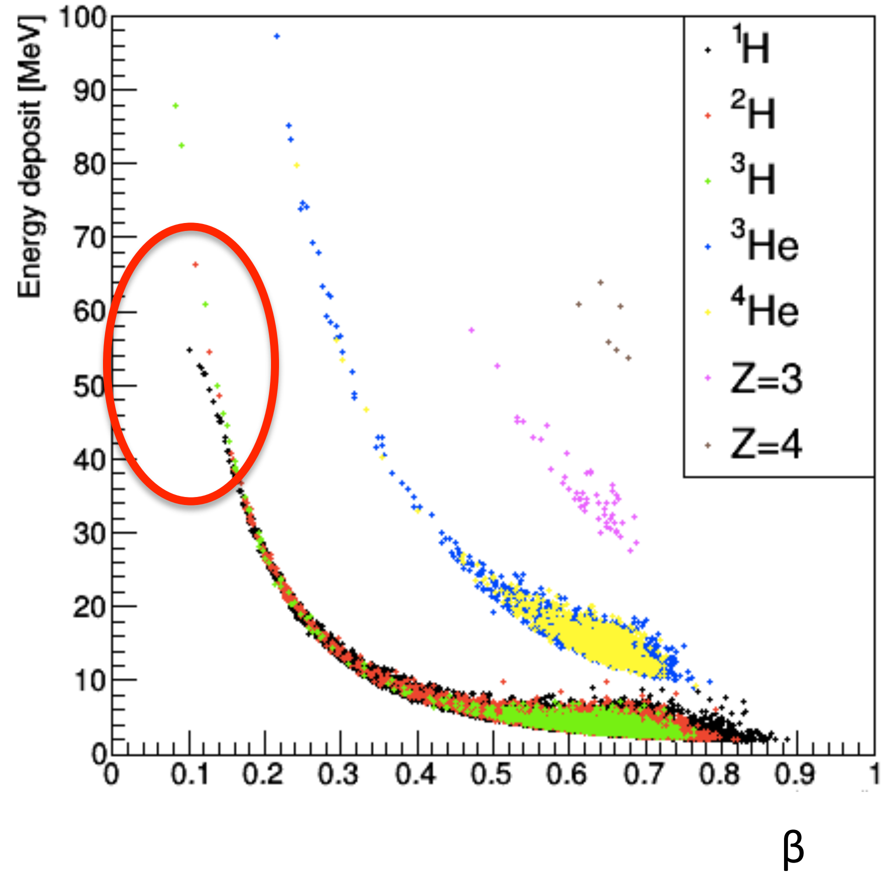
- First quick tries to install SHOE failed
- Account on TIER3 to facilitate collaboration with Bologna
- Good news! Niccolò Camarlinghi will help with implementation of TOF information in SHOE
- We plan to work with Matteo Franchini to implement relevant information

Conclusions

- Some final issues left to understand in MC (maybe with Giuseppe)
- A few small problems found
  - momenta in and out of SCN are not equal to crossing momenta
  - Old region in crossings not available
- Extend to smaller angles (more Z values)
- Prepare data taking next week CNAO (10-11 December)
- Focus more on SHOE

A perfect world (4)





What happens if I calculate β starting from

$\mathbf{P_{med}}$=($P_{x,}$ $P_{y,}$ $P_{z,)}$ with $p_{x,in}=(p_{x,\ in}+p_{x,\ out})/2$, $p_{y,in}=(p_{y,\ in}+p_{y,\ out})/2$ and $p_{z,in}=(p_{z,\ in}+p_{z,\ out})/2$

Conclusion: stick with $\mathbf{p_{med}}^2=(\mathbf{p}^2_{out}+\mathbf{p}^2_{in})/2$