FOOT

Study on vertex

FACULTY OF PHYSICS
CURRICULUM: Fundamental interactions: Theory and Experiment

SAPIENZA
UNIVERSITÀ DI ROMA

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Study on Vertex

- Vertex reconstruction algorithm
- Studies to assess the algorithm's performance:
  - **CNAO2023**
  - Comparison with MC
  - Comparison with previous campaign
    - CNAO2022
    - GSI2021

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Classification of Vertices:

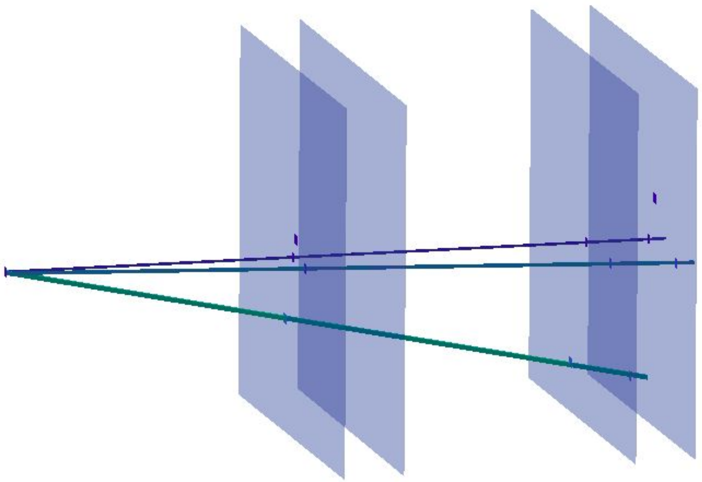
-1 **no BM** (check only for not valid vertex)

0 **Diffusion**

1 **Valid vertex:** is a fragmentation vertex

2 **Nuclear reaction**

(not valid vertex consist of only one track)



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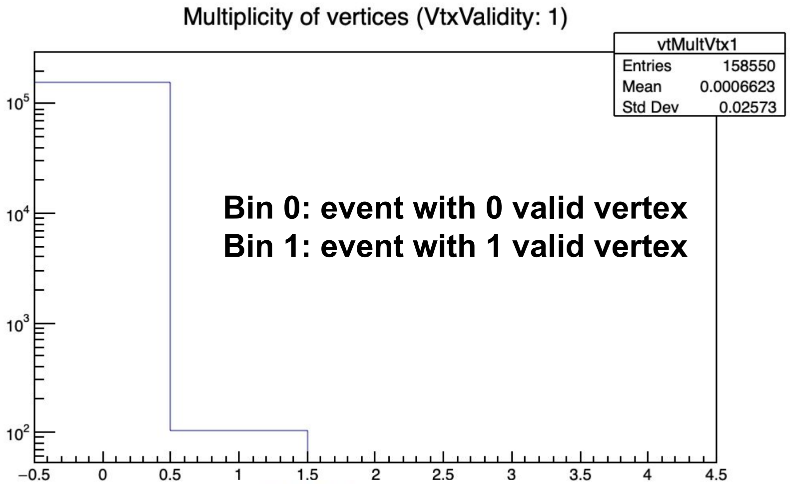
“Valid” and “not valid” vertex classifications

Old configuration

Entries: Events with a single track in the BM and at least one track in the vertex
Bin 0: event with 0 valid vertex
Bin 1: event with 1 valid vertex

❖ CNAO2023

Run: 6136

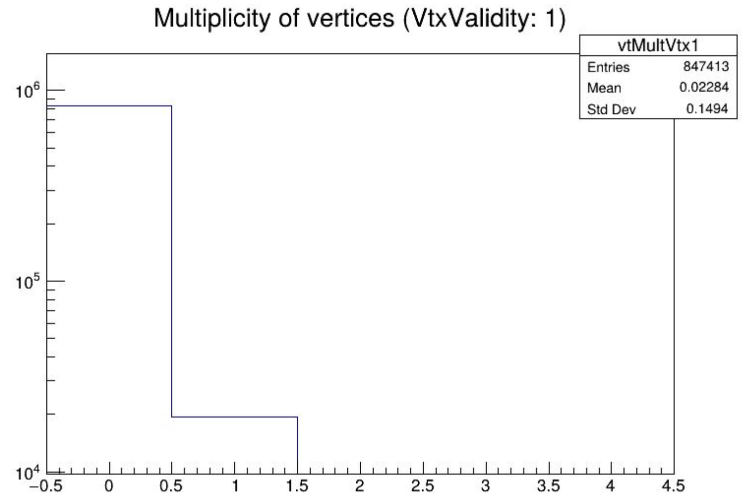


$$\frac{Bin1}{Entries} = 0.06\%$$

Run: 6124 $\frac{Bin1}{Entries} = 0.03\%$

❖ MC: CNAO23_PS

Layer 3= OFF



$$\frac{Bin1}{Entries} = 2.28\%$$

❖ GSI2021

$\frac{Bin1}{Entries} = 1.6\%$

Run: 4305

❖ CNAO2022

$\frac{Bin1}{Entries} = 0.8\%$

Run: 5468

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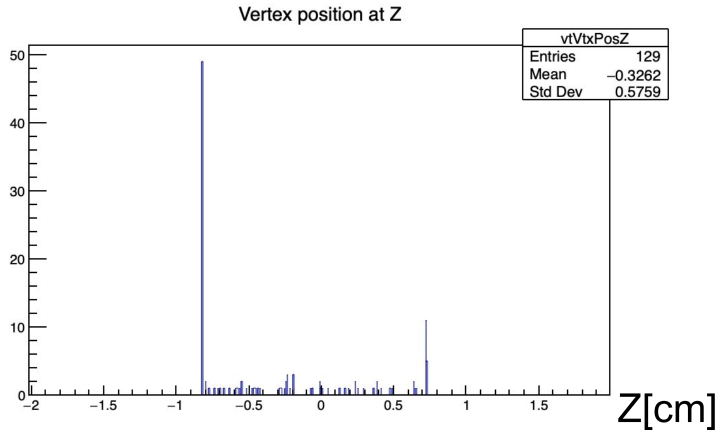
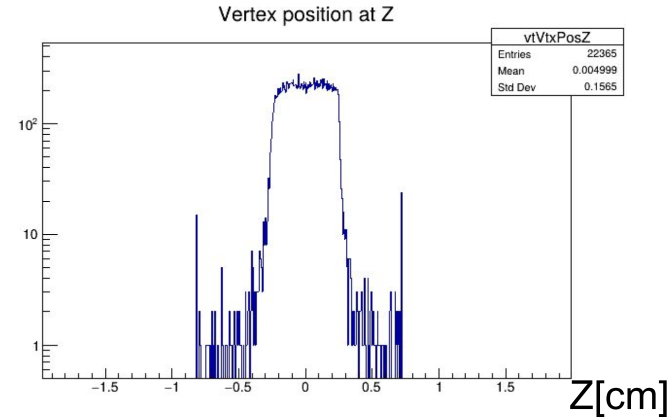
Z position of valid vertex

❖ CNAO2023

Run: 6136

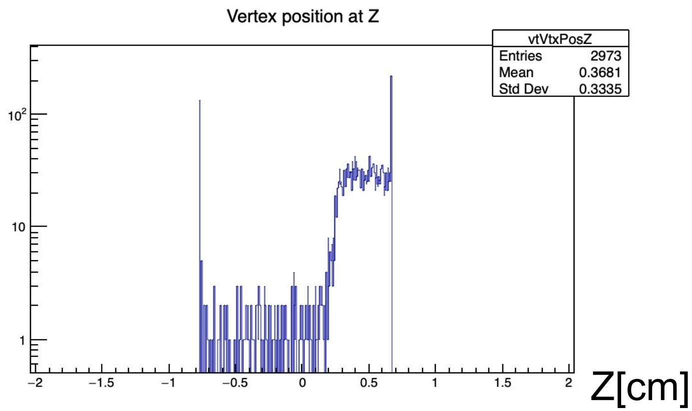


❖ MC CNAO23_PS



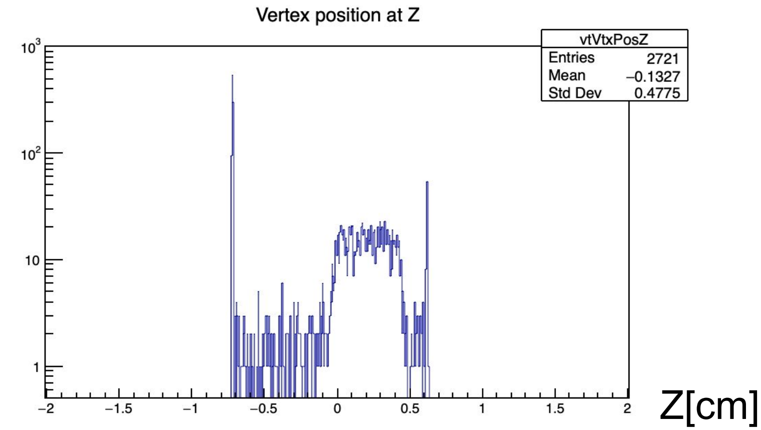
❖ CNAO2022

Run: 5468



❖ GSI2021

Run: 4305



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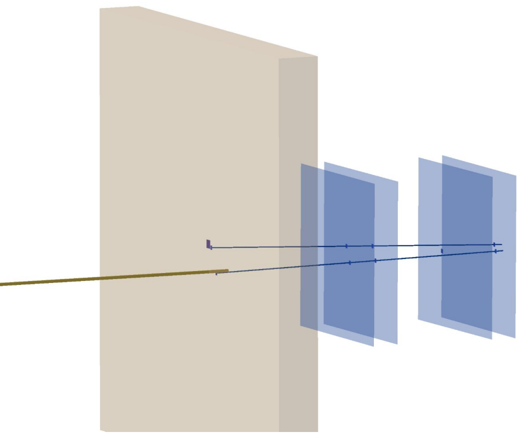
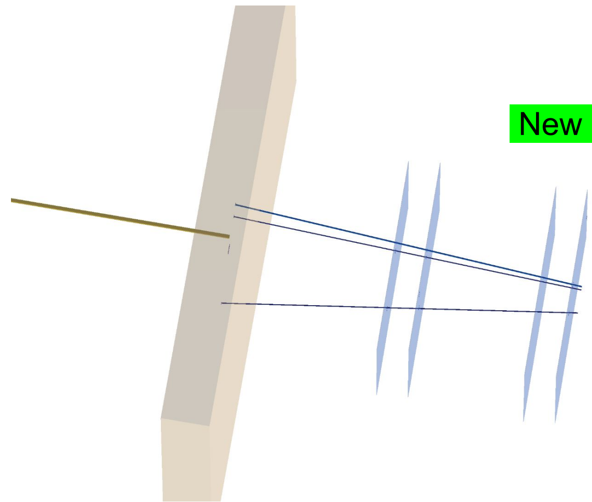
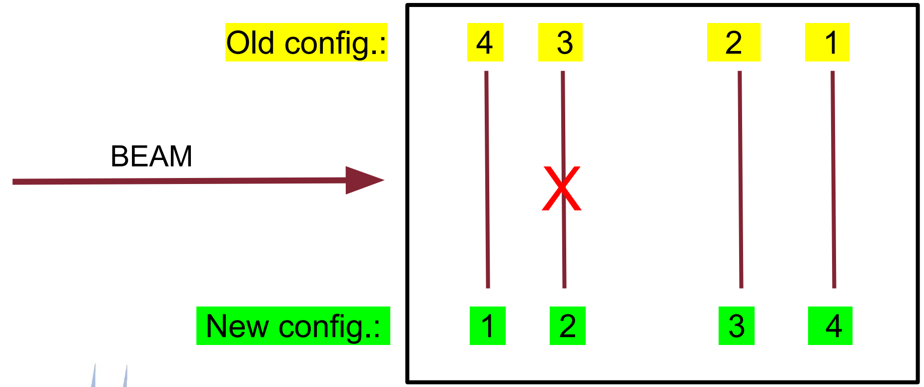
Event display



run: 6136 event:536



run: 6136 event:384



- By examining the event display, it was observed that for several events, **the vertices appeared to be present but were oriented in the opposite direction**.
- **Now in Shoe the vertex is in the right position**
- In the new configuration the “inefficient” layer is the number 2
- The alignment with the other detectors has been adjusted (Yun)
- Still needed some inter-alignment (Chris)

From now on, the new configuration will be used

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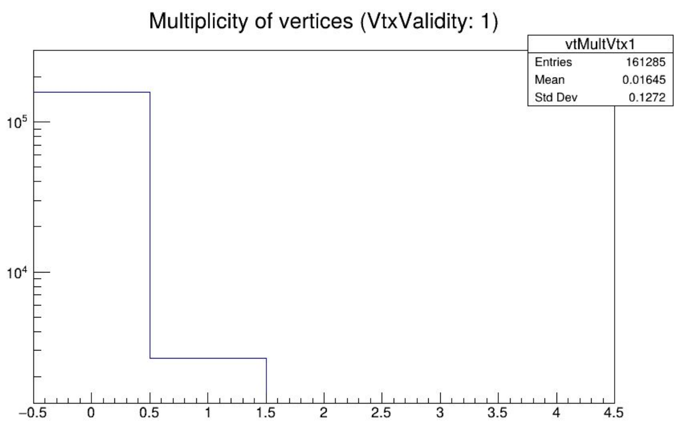
New configuration

Layer 2= OFF

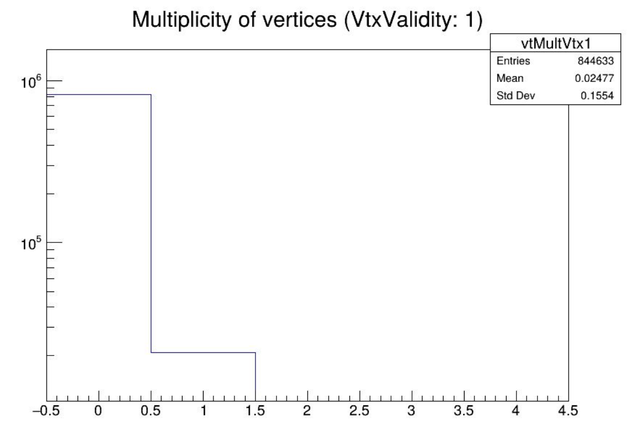
Valid Vertex

❖ CNAO2023 Run: 6136



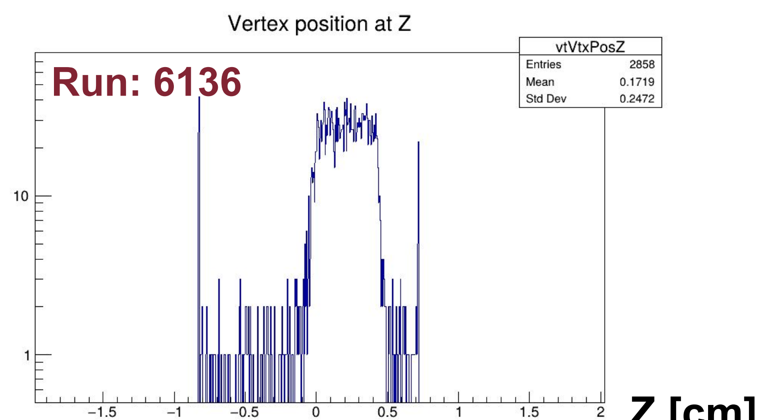
$$\frac{Bin1}{Entries} = 1.64\%$$

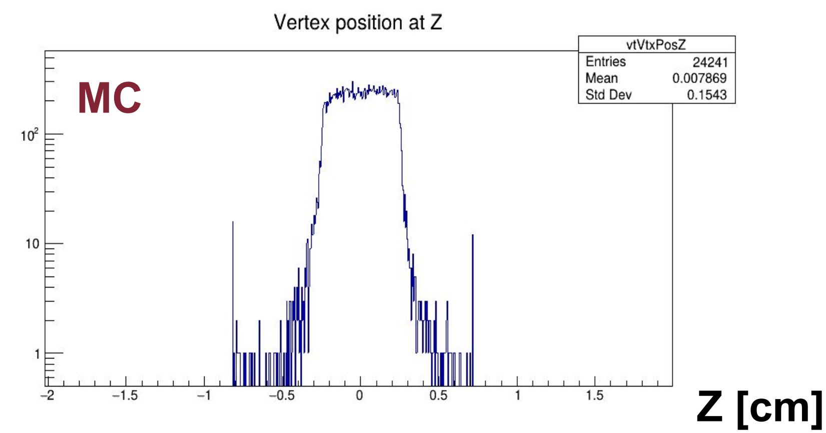
❖ MC: CNAO23_PS



$$\frac{Bin1}{Entries} = 2.47\%$$

Z position of valid vertex





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Why do the data deviate so much from the MC?

- Algorithm in data could failing more than in MC due to:
  - Misposition of the vertexes with respect to the target
  - Misalignment effect (between vertices layers)
  - Noise effect
  - PileUp effect
  - Efficiency effect

- Are we losing particles (e.g., protons) and so some vertexes (C->B+p)?

- Can Flag 2 events be valid vertices that we can recover?

- Is it possible that some of the valid vertices we are observing have missing tracks, and if so, can we recover them?

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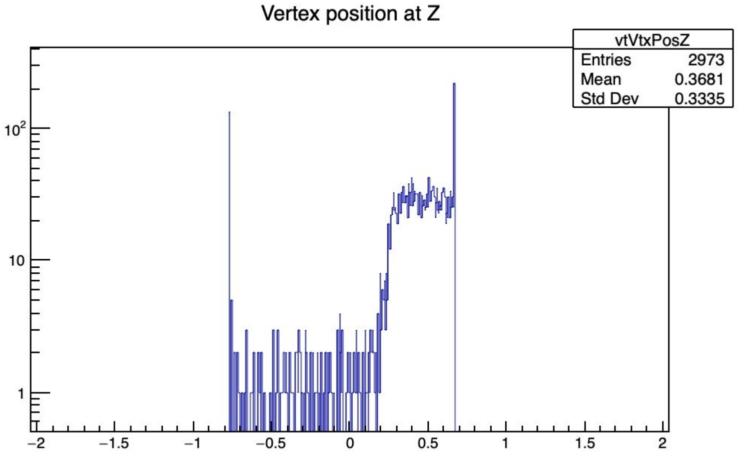
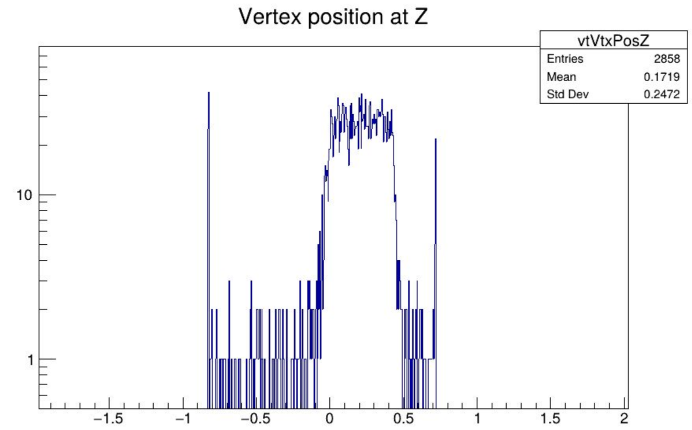
Misposition of the vertexes with respect to the target (in data and in MC)

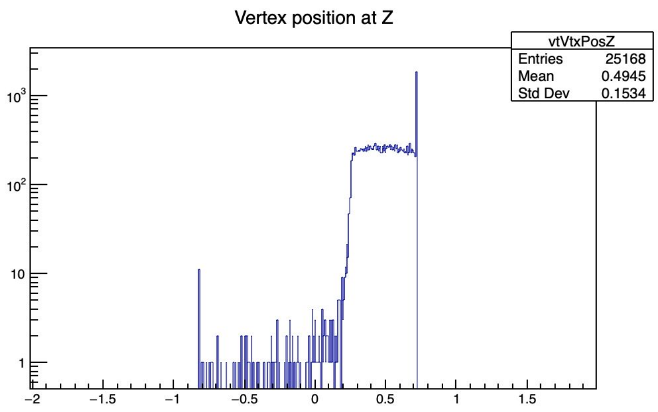
CNAO2022: run 5468



CNAO2023: run 6136



GSI2021_MC



Only in the MC campaigns: **CNAO23PS_MC, CNAO2022_MC, GSI21PS_MC** the position of the vertices is center in the target

- **Is there some reconstruction algorithm effect or is only geometry?**

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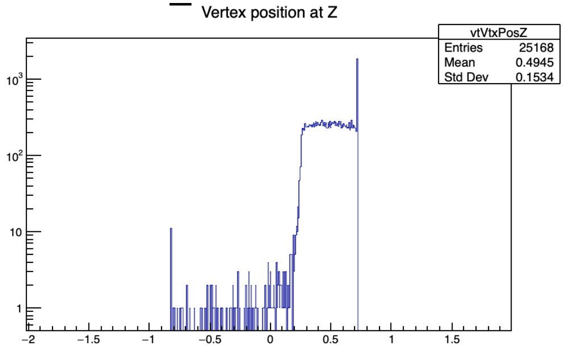
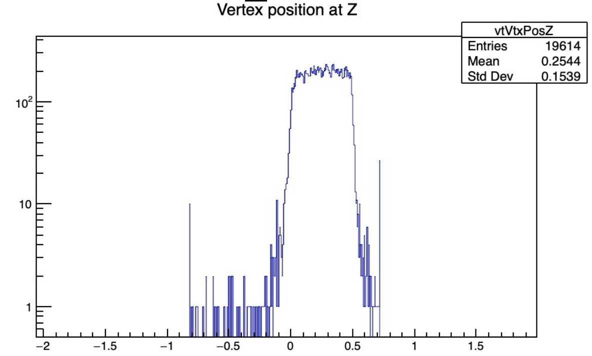
Center of the target: MC

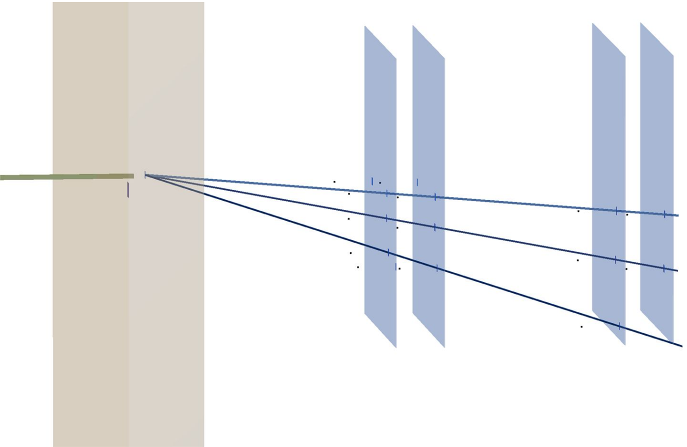
GSI2021_MC



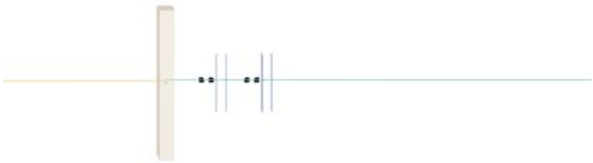
CNAO2023_MC



Event6_12C_CNAO2023_MC



Event0_16O_C_400_1_GSI2021_MC



The reconstructed MC deviates from the true MC (the dots).

Solution: It was only a matter of geo-files to be fixed (not committed yet)

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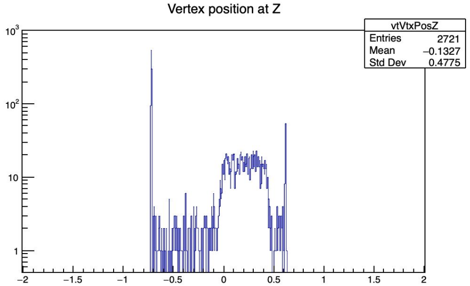
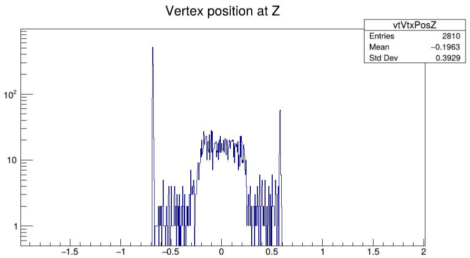
2. DATA

GSI2021: run 4305

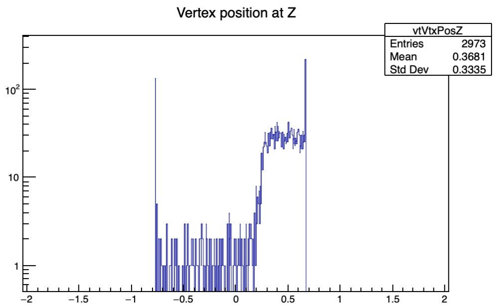
VtxPosZ: 2.10 cm → VtxPosZ: 1.90 cm

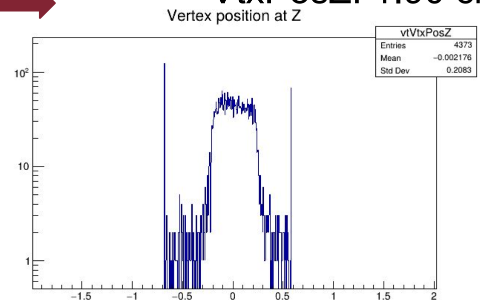




CNAO2022: run 5468

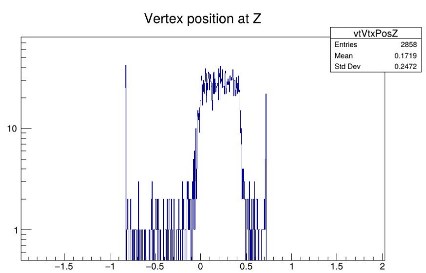
VtxPosZ: 2.35 cm → VtxPosZ: 1.90 cm

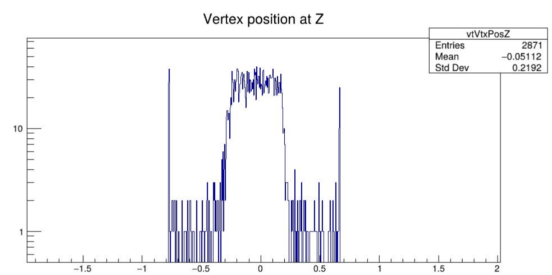




CNAO2023: run 6136

VtxPosZ: 2.60 cm → VtxPosZ: 2.35 cm





- The shift appears to be associated with a measurement error: the vertexes position measurements is more precise
- Although the difference is very small (on the order of 2 mm) it has a significant impact when we require the vertex to be within the target
- Modified the geo files: yet committed is Shoe

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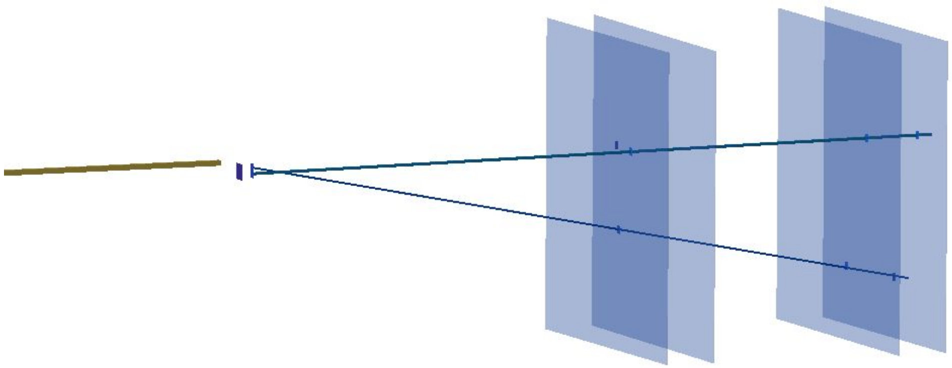
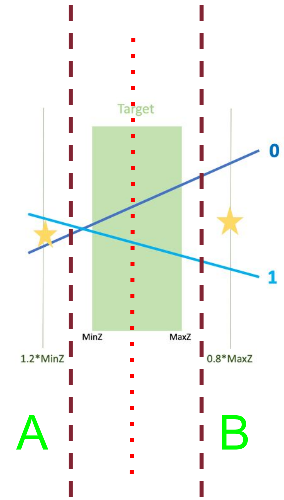
Some vertices lost due to algorithm



We fix a small bug in the vertex algorithm, that was preventing to reconstruct some valid vertex! 💪💪



- For each pair of tracks it create 2 vertices as the middle point of the intersection of the 2 tracks with the 2 plane
- Calculate the probability of each trace to belong to the found vertices

$$\begin{cases} P_A = P_0 * P_1 \\ P_B = P_0 * P_1 \end{cases}$$

- $$slope = \frac{P_B - P_A}{B - A} \qquad \begin{cases} if(slope > 0) \quad A = \frac{A+B}{2} \\ else \quad B = \frac{A+B}{2} \end{cases}$$

If slope ==0?

Sometimes (when the vtx is in the center of the target) the slope turns out to be 0, so the program enters the else and redefines B. It can happens that by doing so the vtx turns out to be outside the range in which it is searched for.

Solution: When the slope is 0 we tighten the range at the two extremes A=A+0.1 and B=B-0.1 (0.1 for All and 0.01 for C and Poly).

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Studies of efficiency in MC

- **Reconstructable vertexes**
  - Reconstructable vtx / all true vtx= 86.77%

- **Reconstructed vertexes**
  - Reconstructed vtx / all true vtx= 79.55%

- **Vertex reconstruction efficiency**
  - Reconstructed vtx / Reconstructable vtx=91.67%

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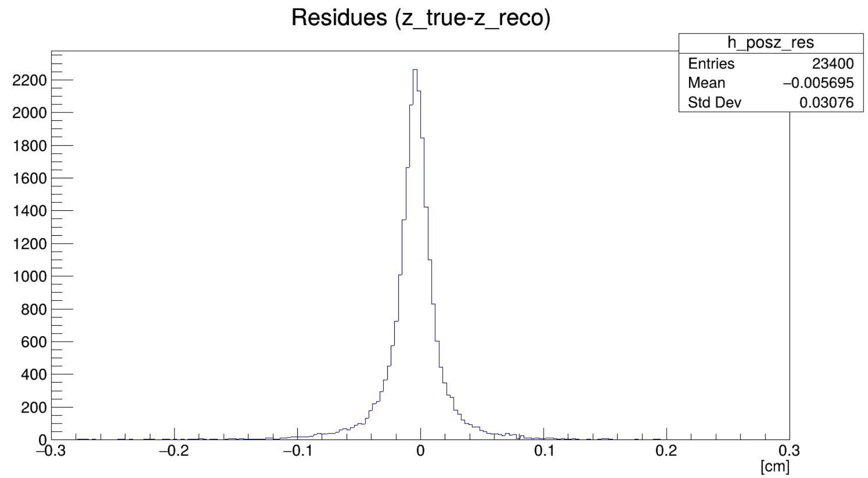
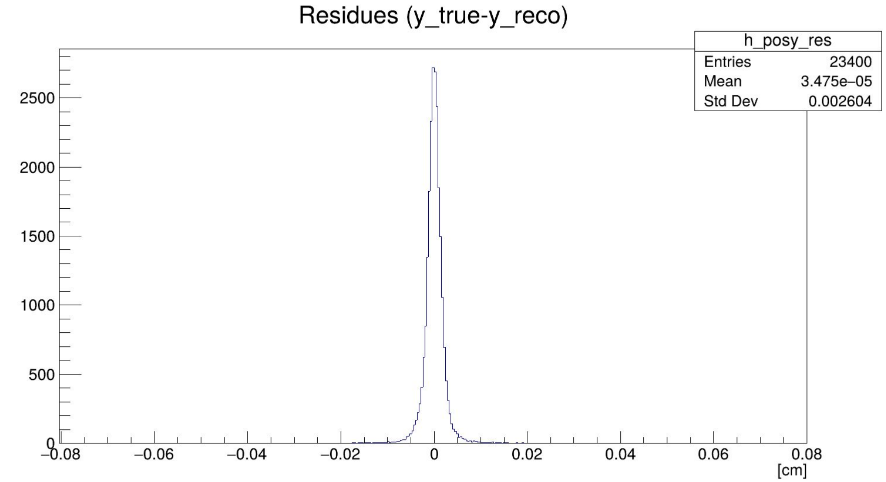
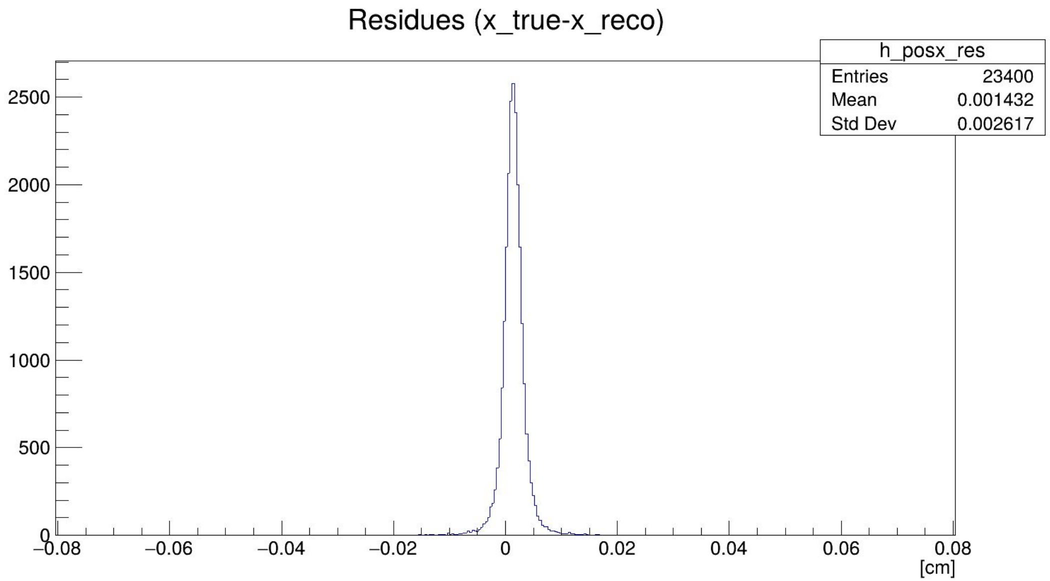
Coordinates true vs coordinates reco (MC)







We already knew that the resolution in z is worse, but in general we have a good true-reconstructed correlation.

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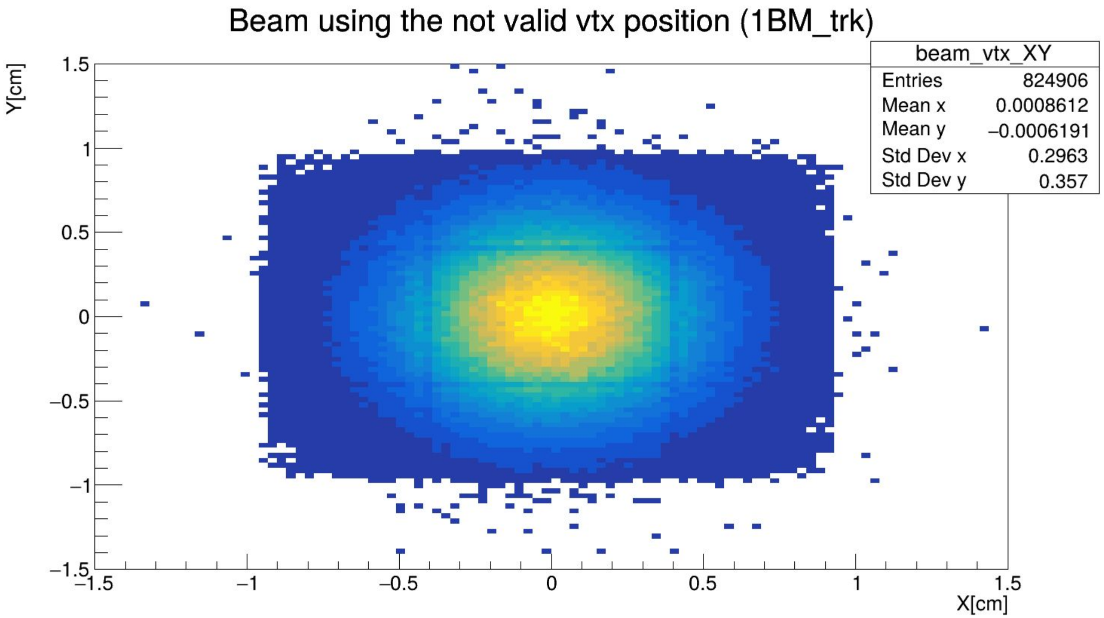
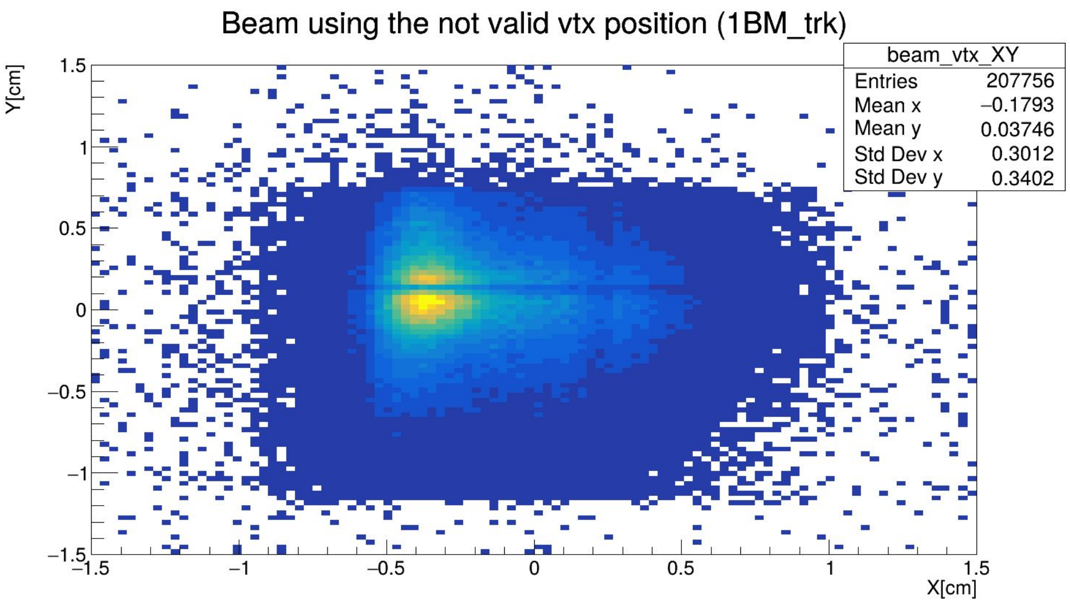
Beam projection on target



MC



Data
6136

Already triggered G. Battistoni to improve beam profile and position in CNAO2023_MC

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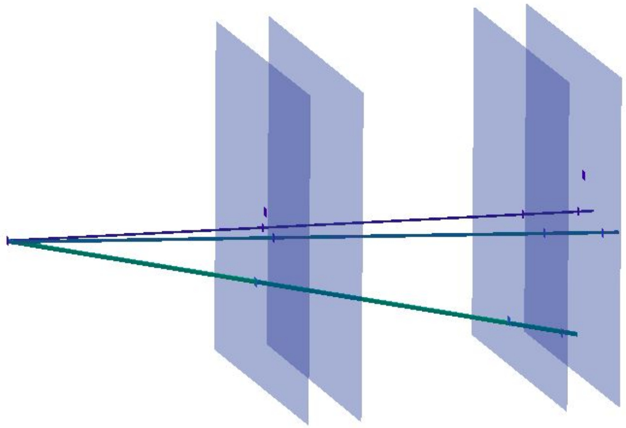
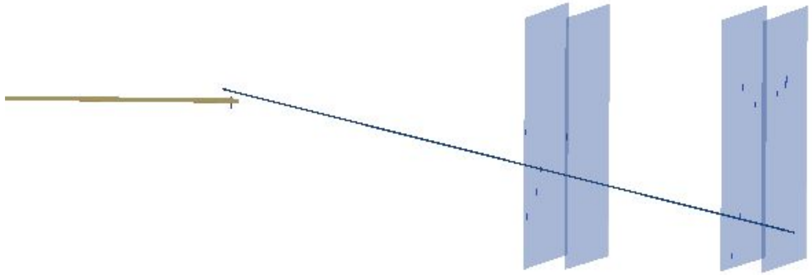
Are we losing tracks?

- Vertex algorithm needs 3 clusters over the 4 layers to reconstruct a track.
- Layer 2 is OFF
- Increased the possibility to lose tracks:
  - Lose 1 track in a valid vertex
  - Lose a valid vertex because 1 of the 2 tracks is lost





2 possibility:

- C->B+p
- 12C->11C+n

- Are we losing tracks in data?
- Is the threshold too high (for protons) ?

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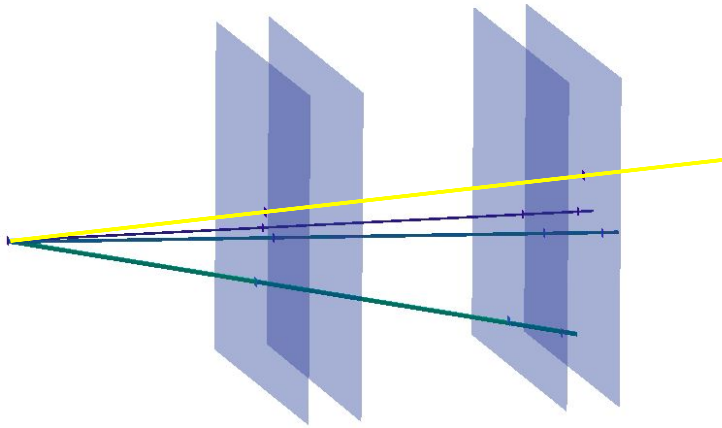
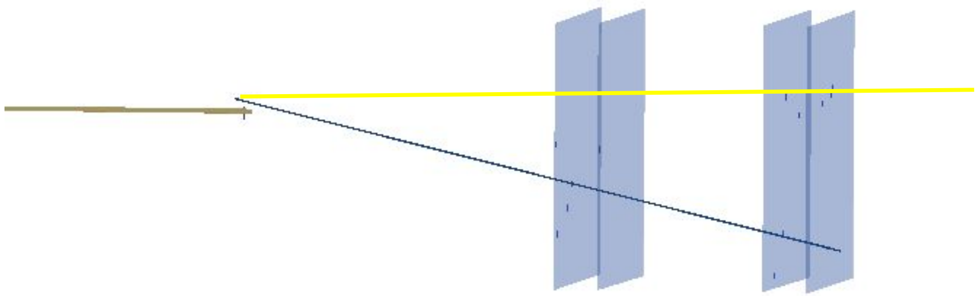
Are we losing tracks?

- Vertex algorithm needs 3 clusters over the 4 layers to reconstruct a track.
- Layer 2 is OFF
- Increased the possibility to lose tracks:
  - Lose 1 track in a valid vertex
  - Lose a valid vertex because 1 of the 2 tracks is lost (ex.: C->B+p)



↓

Post tracking



- Are we losing tracks in data?
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2 possibility:

- C->B+p
- 12C->11C+n

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Threshold M28

$thr = 250 \cdot \sigma_{NOISE}$ $\quad \sigma_{NOISE} = 4e^-$ → $thr = 1000e^-$

M28

$$\begin{cases} \rho_{Si} = 2.329 \frac{g}{cm^3} \\ d = 14\mu m \end{cases}$$

Energy for electron-hole pair production:

$$E_{e-h} = 3.62eV$$

- 100 MeV Protons

$$S^* = 5.838 \frac{Mev\ cm^2}{g} \rightarrow \Delta E = S \cdot \rho_{Si} \cdot d = 19.035\ kev$$

$$\frac{\Delta E}{E_{e-h}} \simeq 5258\ e^- > thr$$

- 200 MeV Protons

$$S^* = 3.628 \frac{Mev\ cm^2}{g} \rightarrow \Delta E = S \cdot \rho_{Si} \cdot d = 11.829keV$$

$$\frac{\Delta E}{E_{e-h}} \simeq 3267\ e^- > thr$$

- 1 GeV Protons (MIP)

$$S^* = 1.830 \frac{Mev\ cm^2}{g} \rightarrow \Delta E = S \cdot \rho_{Si} \cdot d = 5.967keV$$

$$\frac{\Delta E}{E_{e-h}} \simeq 1684\ e^- > thr$$

* NIST PSTAR program

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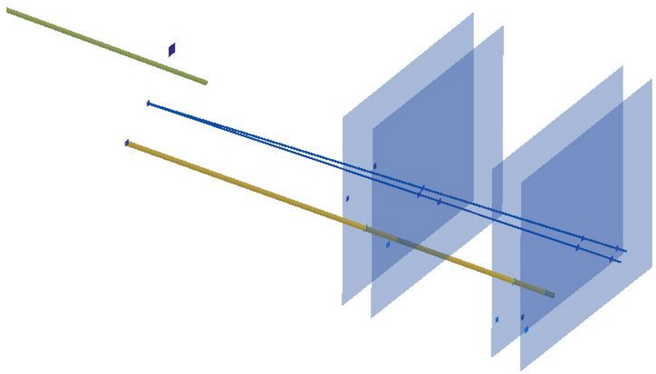
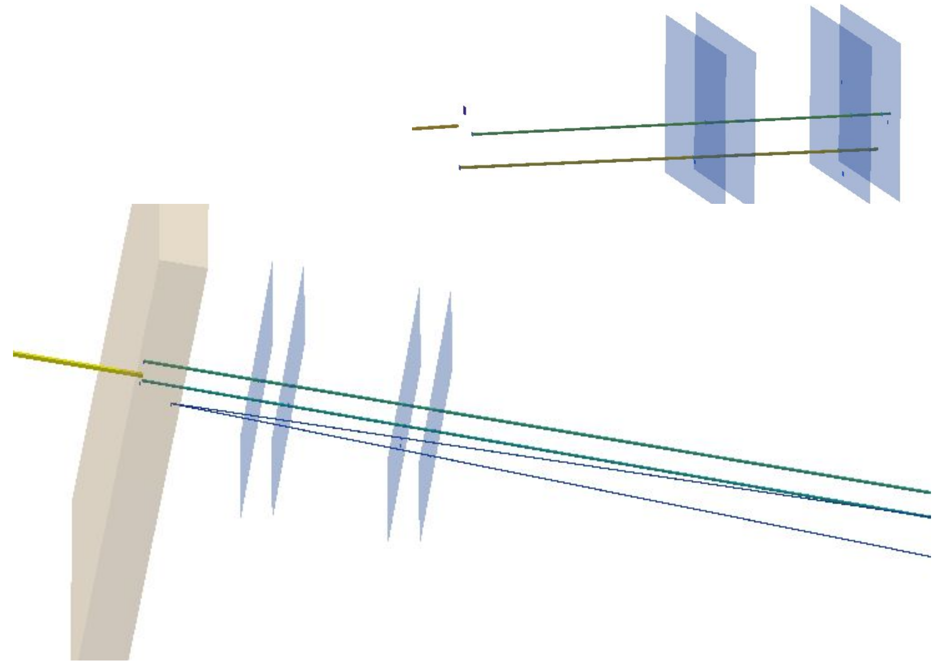
Pile-up

★ Is the pile-up a real problem for the vtx?





If the valid vertex was the one matched with the BM and the fragments detected by subsequent detectors, could we recover this type of event?

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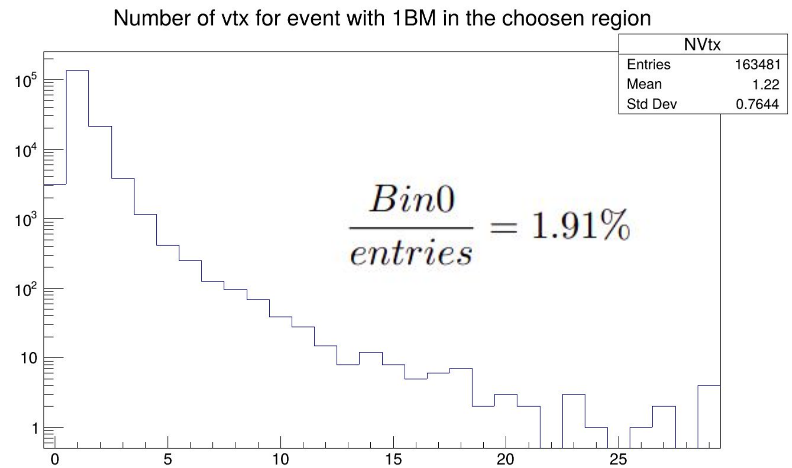
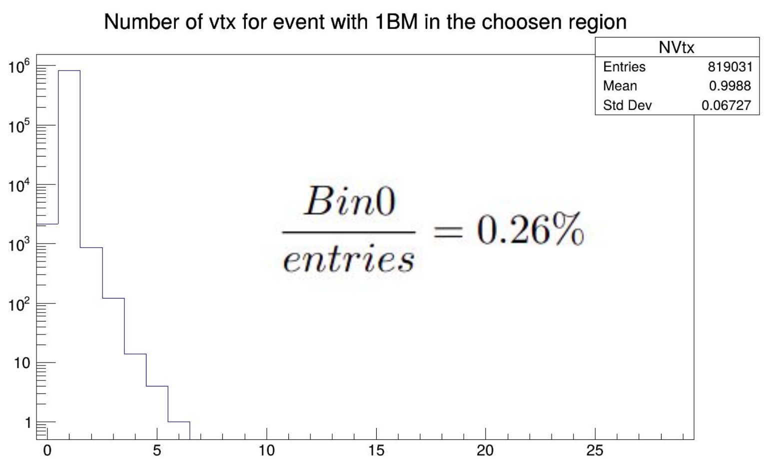
Number of vertexes for each event

6136



Inefficiency (bin0/entries) in data are of the order 1-2%

MC



What are events with 0 vertices?

There is a higher percentage of events with 0 vertices in the data. Is the vertex inefficient?

- Use runs with ^{16}O, ^{12}C and p without the target to study vertex inefficiencies

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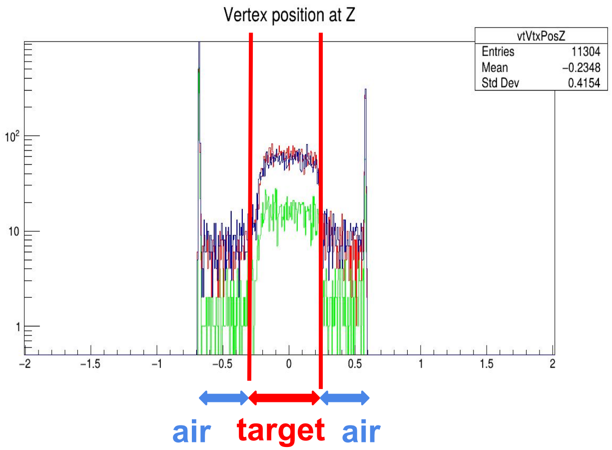
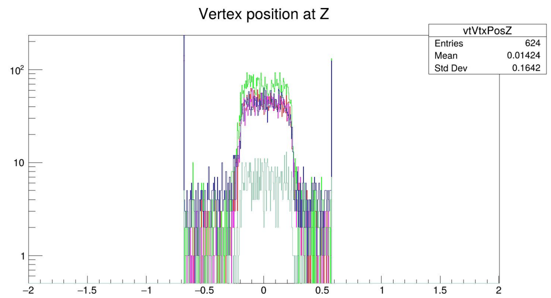
PileUp

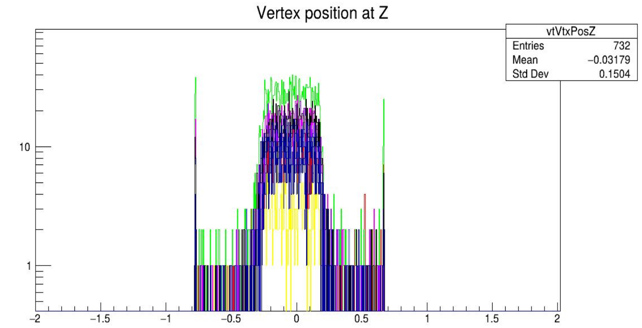
GSI2021



CNAO2022



CNAO2023



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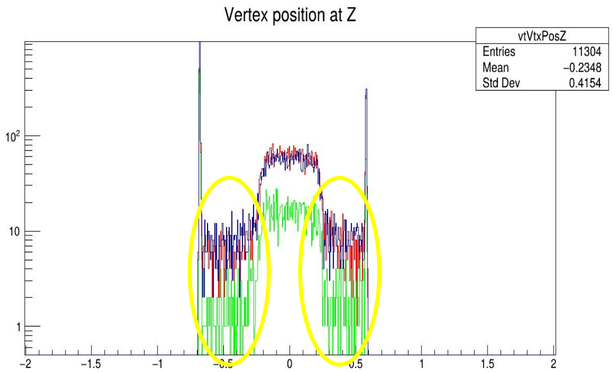
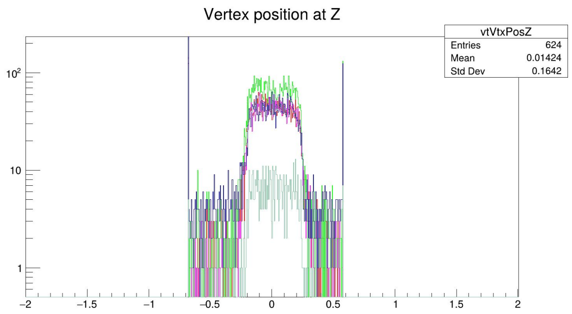
PileUp

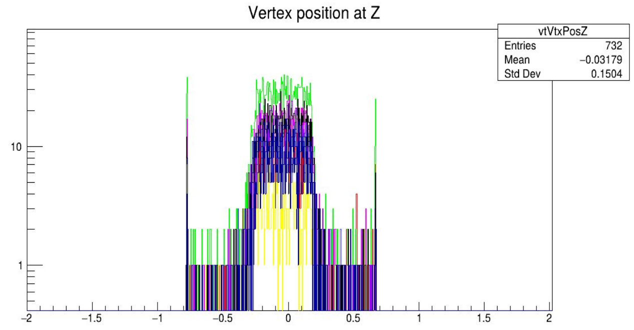
GSI2021



CNAO2022



CNAO2023



It appears that special in GSI2021, valid vertices outside the target are more than the expected one.

Could this abundance of valid vertices outside the target be an effect of PileUp?

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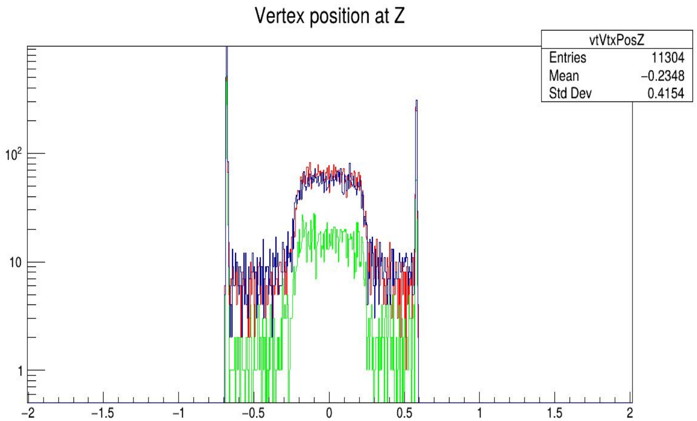
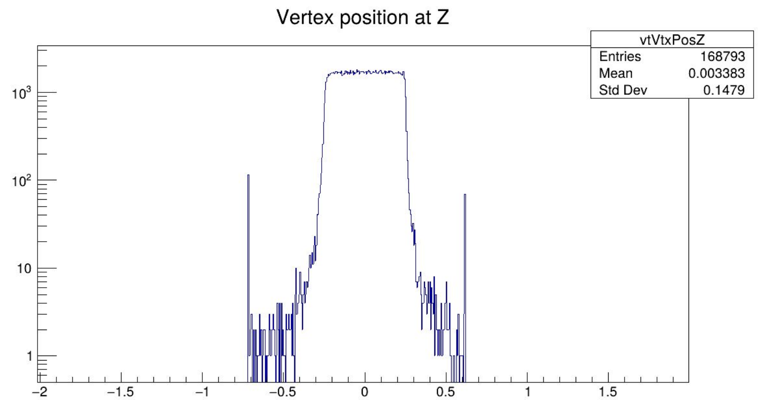
Pile_Up

GSI2021

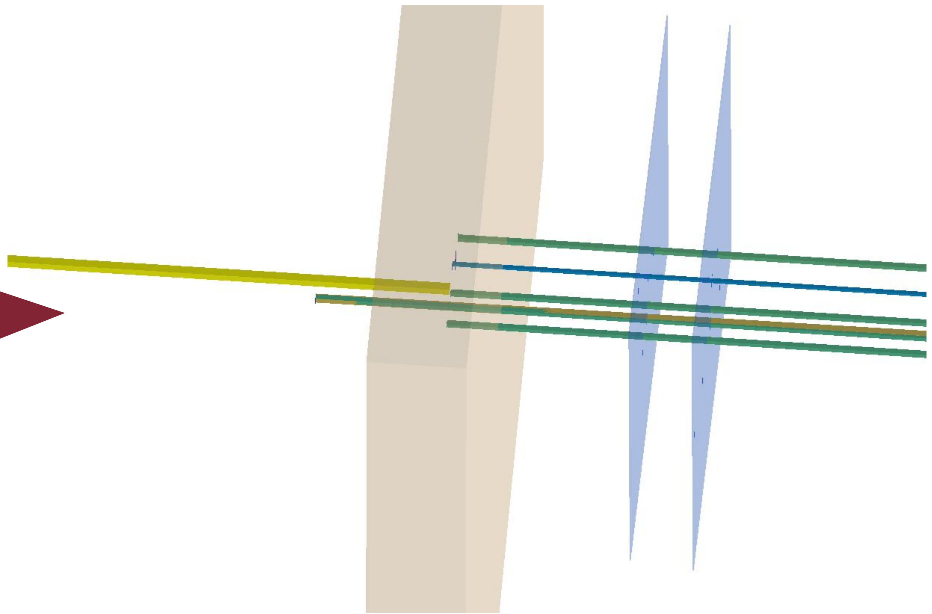


GSI21PS_MC



Event display

Example of a valid vtx out of tgt done by PileUp of primaries.



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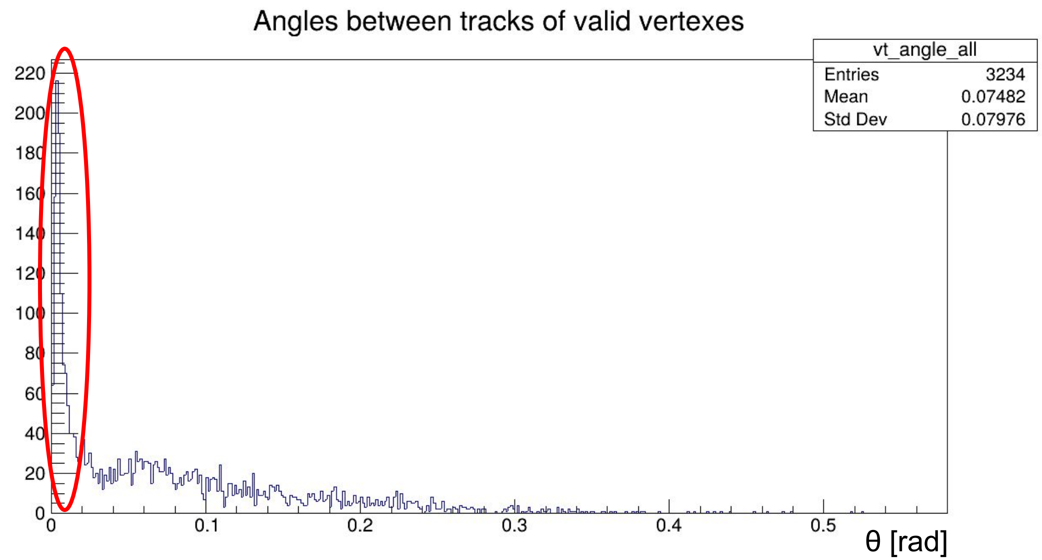
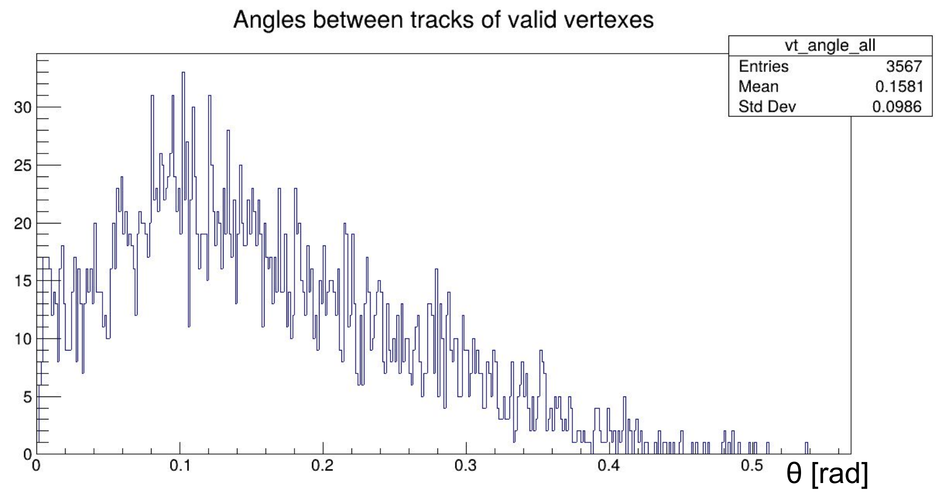
Angle Between Tracks of Valid Vertices

GSI2021



CNAO2023



- **Cut**: vertx with angles between the tracks < 0.02 rad

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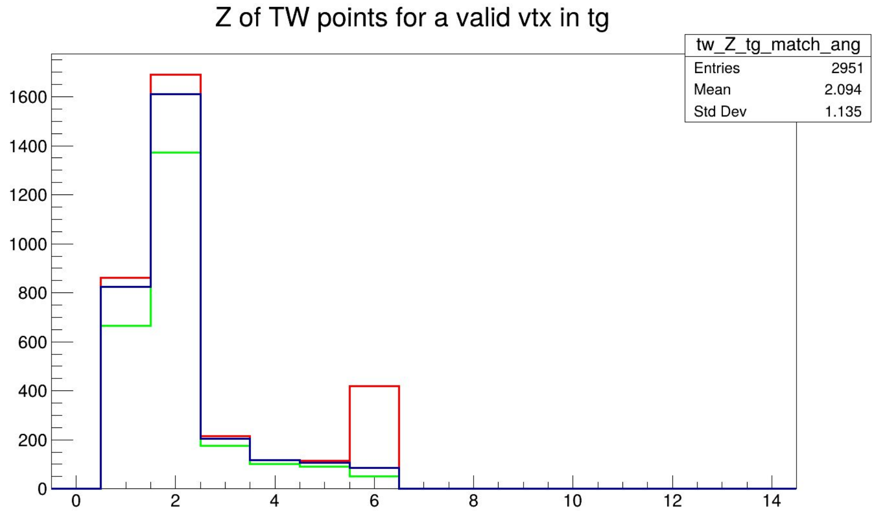
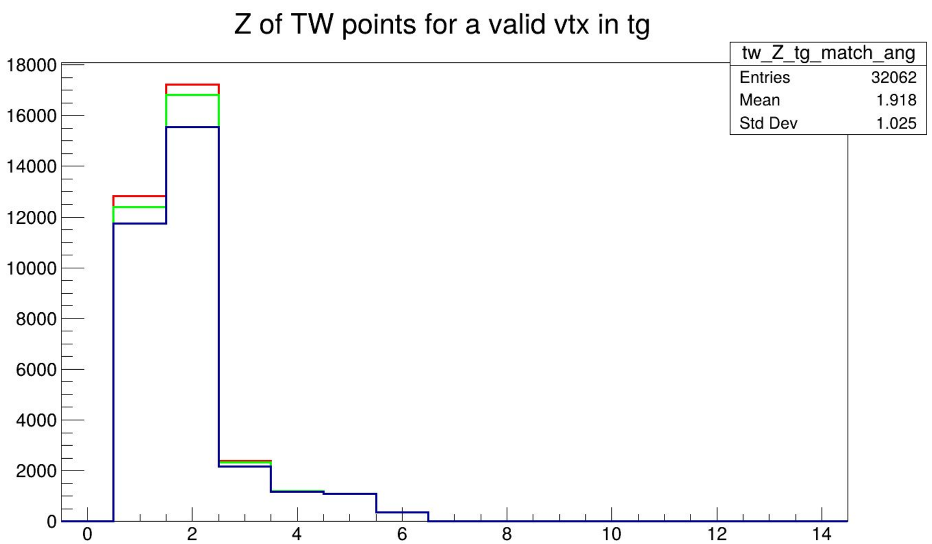
Charge in TW

6136



MC



- Valid vtx in tg
- Valid vtx in tg that is match and overcome the cut_angle
- Valid vtx when there is only 1 vtx

- ❑ Look event with z==6 at the event display
- ❑ Try to use the global tracking

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Valid vertexes in the different runs

- Valid vtx created in the target, matched with the BM and survived the cut_angle

run	valid_vertx/event_1BM
6124	(1.28±0.06)%
6135	(1.22±0.05)%
6136	(1.28±0.03)%
6138	(1.23±0.05)%
6139	(1.29±0.09)%
6173	(1.29±0.05)%
6175	(1.31±0.04)%
6176	(1.34±0.04)%
6177	(1.30±0.04)%
6178	(1.31±0.05)%
MC	(2.57±0.02)%

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Next steps

- Vertex alignment
- Tracking efficiency (p, O, C, e)
- Study of post-tracking
- PileUp studies:
  - Differences between the different campaigns
  - Using the global tracking
- MC
  - Center the beam according to the data
  - Study the angle for the cut of nuclear reaction
- After having recovered all possible vertexes and cleaned from the pileup, is possible to make a **cross section measurement**

Potential Measurements for CNAO2024

- Using a “new layer 2” to estimate efficiencies of the other 3 layers
- Tracking efficiency with respect different p and C beams energy

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Thank you for your attention!

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