

### **Vertex Track Perfomance Studies**

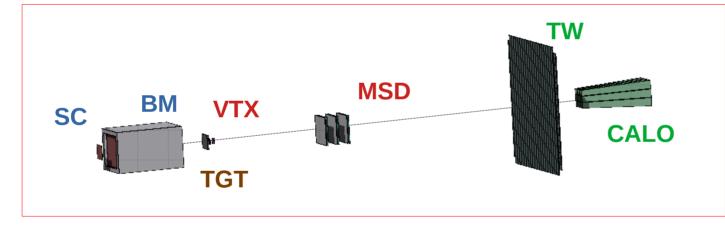
Giacomo Ubaldi

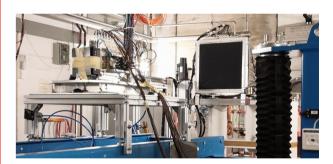
XIV FOOT Collaboration Meeting

Bergamo

06/06/2023

- Performance studies applied on MC GSI 2021 campain
- Data-taking at GSI (Darmstadt, Germany) in 2021
- 16O 400 MeV/u on 5 mm C target
- Partial setup: no magnet, only one module of calorimeter





# **Definitions for performance factors**

### • Reference set: N<sub>reference</sub> (truth side)

all the tracks that an algorithm performing ideally should find and reconstruct:

- all the tracks associated to a MC particle that crosses the FOOT apparatus at least until the last plane of the vertex (using MCRegion)
  - beam
  - primary fragment generated in the target
- Good reconstructed set: NGoodReco

all the tracks that are reconstructed by the tracking algorithm which are associated to MCparticles in the reference set .

• Bad reconstructed set: NBadReco

all the tracks that are reconstructed by the tracking algorithm but associated to MC particle that do not belong to the reference set.

## **Track reconstruction**

For the track reconstruction I considered: **case 1**: a track is reconstructed with 4 clusters (one for each VT plane) **case 2**: a track is reconstructed with at least 3 clusters **case 3**: a track is reconstructed with at least 3 clusters + random noise pixels are generated

### NB:

To associate a MC Particle to a reconstructed track:

- I consider the MC ID of all the clusters belonging to the track
- I take the most frequent one: this is the ID of the MC Particle matched

### • Reconstruction efficiency:

eff 0.98 0.96 0.94 0.92 0.9 0.88 0.86 0.84 0.82 8 Ζ

Efficiency of reconstructed tracks

 $\epsilon_{track}(Z) = rac{N_{GoodReco}(Z)}{N_{reference}(Z)}$ 

tracks with 4 clusters (case 1) tracks with >=3 clusters (case 2) tracks with >= 3 clus + noise (case 3)

### FIRST vertex efficiency:

Table 2

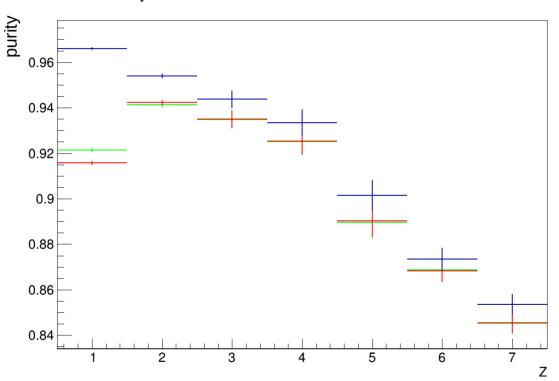
Tracking efficiencies and associated errors for different charge values of detected particles (simulated data).

Z	1	2	3	4	5	6
Efficiency (%)	93.6	88.9	97.5	97.7	98.8	99.9
Error (%)	0.3	0.6	0.7	0.8	0.4	0.1

Nuclear Instruments and Methods in Physics Research A 767 (2014) 34-40

• elemental efficiency higher than 0.9 for  $Z \ge 2$ , close to 1 for  $Z \ge 3$ 

• Purity:



Purity of reconstructed tracks out of the selected ones

$$p_{track}(Z) = rac{N_{GoodReco}(Z)}{N_{GoodReco}(Z) + N_{BadReco}(Z)}$$

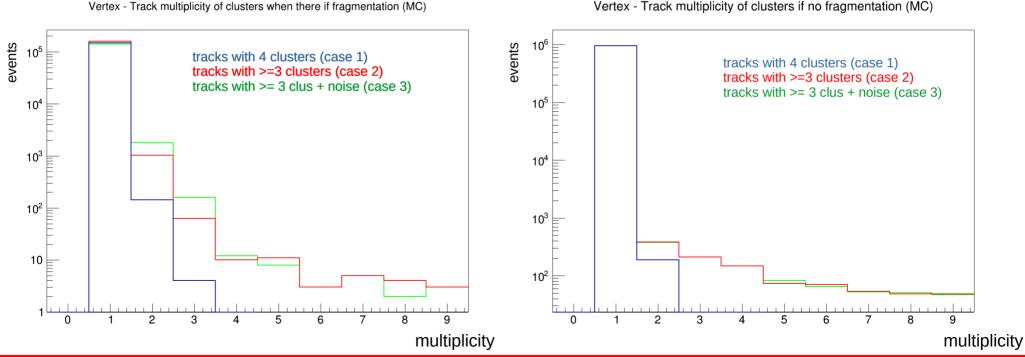
tracks with 4 clusters (case 1) tracks with >=3 clusters (case 2) tracks with >= 3 clus + noise (case 3)

• elemental purity higher than 0.8, it decreases with heavier Z

### **Multiplicity**: n° of different clusters MC ID associated to a given track •

- es: m=1 all clusters are of the same MC particle
- es: m=2 clusters belong to two different MC particle (1-3,2-2)

NB: multiplicity can be higher than 4 (despite the clusters are at max 4) because every one can be associated to different MC particles (with different MC ID)



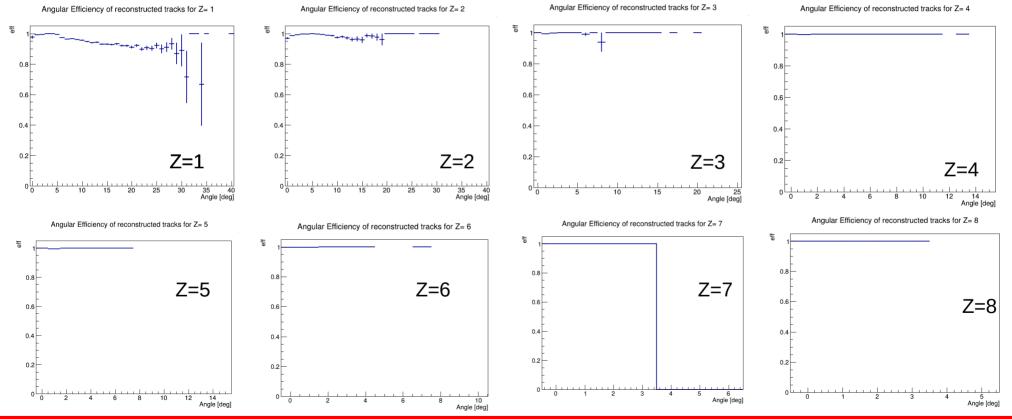
Vertex - Track multiplicity of clusters if no fragmentation (MC)

• Angular efficiency:

tracks with >= 3 clus + noise (case 3)

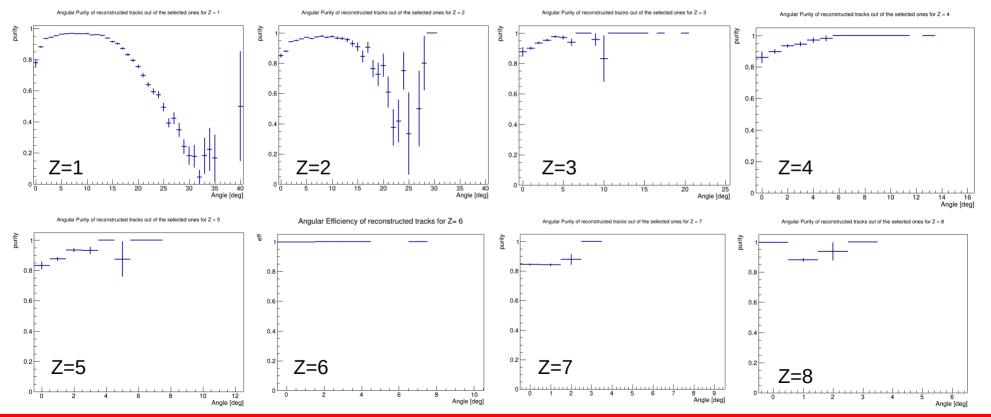
 $\epsilon_{track}(Z, heta) = rac{N_{GoodReco}(Z, heta)}{N_{reference}(Z, heta)}$ 

angular efficiency decreases with angle > 10°



- Angular Purity: tracks with >= 3 clus + noise (case 3)
- $p_{track}(Z, heta) = rac{N_{GoodReco}(Z, heta)}{N_{GoodReco}(Z, heta) + N_{BadReco}(Z, heta)}$

angular efficiency decreases with angle  $> 10^{\circ}$ ٠



### **Resolution Measurements**

### **Track Polar Resolution**

### $res_{ heta} = heta_{track} - heta_{MCparticle}$ Polar angle resolution of the reconstructed track vs the mc particle: Vertex - theta track resolution for Z= 3 Vertex - theta track resolution for Z= 2 Vertex - theta track resolution for Z= 1 vtTrackThetaRes3 vtTrackThetaRes2 vtTrackThetaRes1 450 Entries Entries 2695 70505 Entries 30683 4500 8000 F 0.002207 Mean Mean Mean 0.001012 0.001822 400 4000 Std Dev 0.05652 7000 Std Dev 0.03359 Std Dev 0 02547 350 $\chi^2$ / ndf 4933 / 81 3500 F $\gamma^2$ / ndf 618.5 / 131 $\chi^2$ / ndf 31.29/24 Prob 6000 n 300 3000 4629 ± 34.7 Constant 7504 ± 42.6 Constant 0.1455 Prob 5000 0.001974 ± 0.000135 Mean Mean $0.001784 \pm 0.000149$ 250 $455.1 \pm 11.3$ 2500 F Constant Sigma $0.03451 \pm 0.00014$ 4000 Sigma $0.02589 \pm 0.00012$ 200 Mean $0.001121 \pm 0.000453$ 2000 F 3000 Sigma $0.02333 \pm 0.00036$ 150 1500 2000 100 1000F 7=2 7=3 7=1 1000 50 500 F 0.3 -04 -0.3-0.2-0.1 0 0 1 0.2 -0.2 0.1 0.2 0.3 0.4 -0.1 0.1 -0.3-0.10 04 -0.3-0.20 0.2 0.3 0.4 res [°] res [°] res [°] Vertex - theta track resolution for Z= 8 Vertex - theta track resolution for Z= 6 Vertex - theta track resolution for Z= 7 ×10<sup>3</sup> vtTrackThetaBes8 vtTrackThetaRes6 vtTrackThetaRes7 700 F 715305 Entries 500 Mean 0.003844 Entries 2934 Entries 3741 120 Std Dev 0.02407 600 0.0009032 0.001311 Mean Mean 0.02524 0.02397 400 Std Dev Std Dev 100 500 $\chi^2$ / ndf $\chi^2$ / ndf 28.42/22 37.13/24 80 Prob 0.1621 400 Prob 0.04251 300 Constant $503.6 \pm 12.0$ Constant 650.1±13.6 300 60 Mean 0.0008206 ± 0.0004287 Mear 0.001293 ± 0.000374 200 Sigma $0.02303 \pm 0.00035$ Sigma 0.02273 ± 0.00029 200 **σ~0.02°** 40 100

7=7

0.3

0.4

res [°]

20

-0.3

-0.2

-0.1

0

res [°]

0.4

7=6

0.3

-0.3

-0.2

-0.1

0

0.1

0.2

100

-0.3

-0.2

-0.1

0

0.1

0.2

res [°] 11

Z=8

0.3

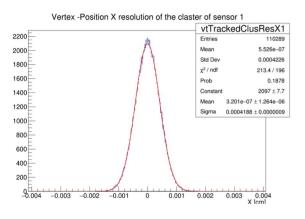
0.4

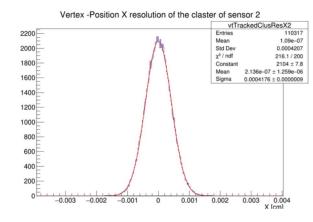
0.2

0.1

### Track – Cluster position Resolution

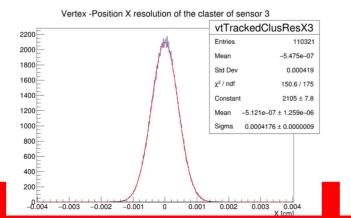
# Position resolution of the reconstructed cluster of a track vs the MC Hit (from which the cluster is generated) for every sensor of the vertex in X and Y

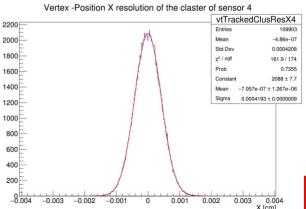




$$res_X = X_{cluster} - X_{MChit}$$

**σ** ~ 4 μm

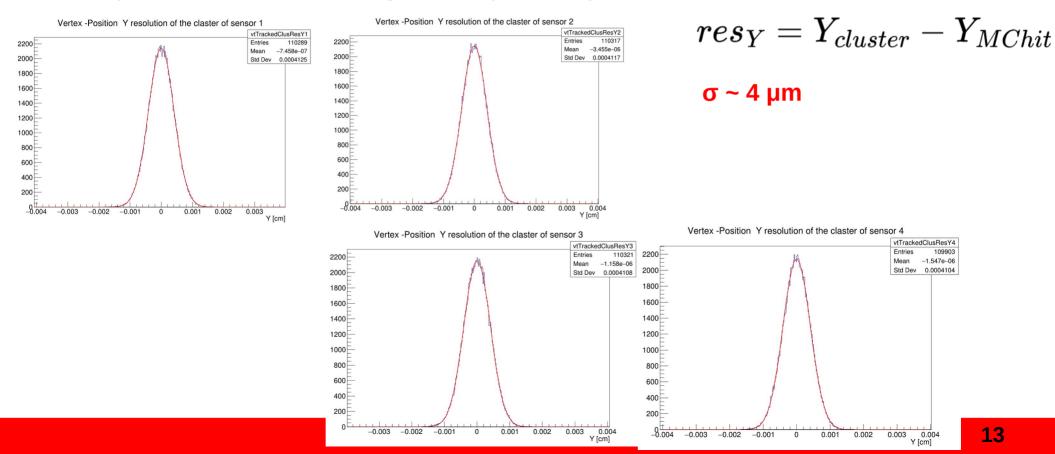




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### Track – Cluster position Resolution

# Position resolution of the reconstructed cluster of a track vs the MC Hit (from which the cluster is generated) for every sensor of the vertex in X and Y



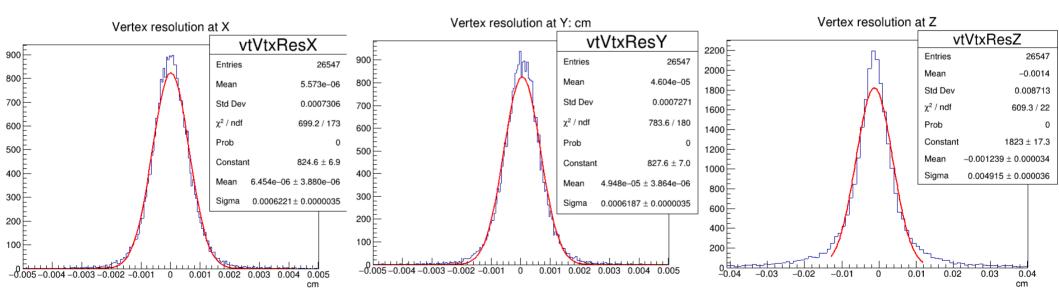
### Vertex position Resolution

Position resolution of the reconstructed vertex of tracks vs the MC fragmentation position

 $res_X = X_{vtx} - X_{MC}$   $\sigma \sim 6 \, \mu m$ 

$$res_Y = Y_{vtx} - Y_{MC}$$
o ~ 6 µm

$$res_Z = Z_{vtx} - Z_{MC}$$
o ~ 50 µm



### Conclusions

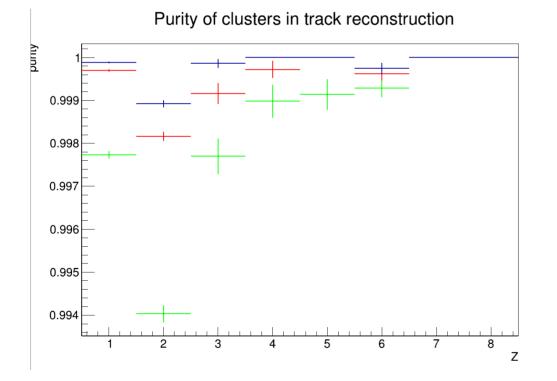
- Good efficiencies over ~90% and purities over ~80%
- Spatial resolution at the order of  $\sim \mu m$
- good vertex identification, fundamental for out of target fragmentation removal
- performances in agreement with already published results.
- Performance studies to be run on every campaign

Thanks to Marco and Chris for the assistance and help!

### • Cluster purity

counts of all the clusters matched well with the track MC\_ID (in reference set) among all clusters of all  $N_{\mbox{GoodReco}}$  tracks

$$\rho = \frac{\sum_{m=0}^{M} N_{correct}^{(m)}}{\sum_{m=0}^{M} N_{total}^{(m)}}$$

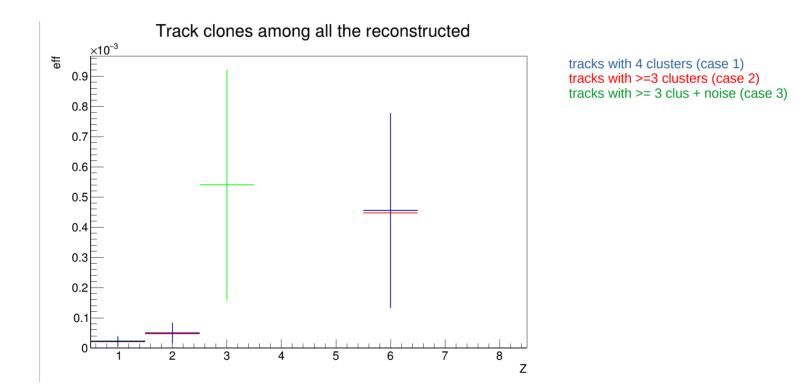


tracks with 4 clusters (case 1) tracks with >=3 clusters (case 2) tracks with >= 3 clus + noise (case 3)

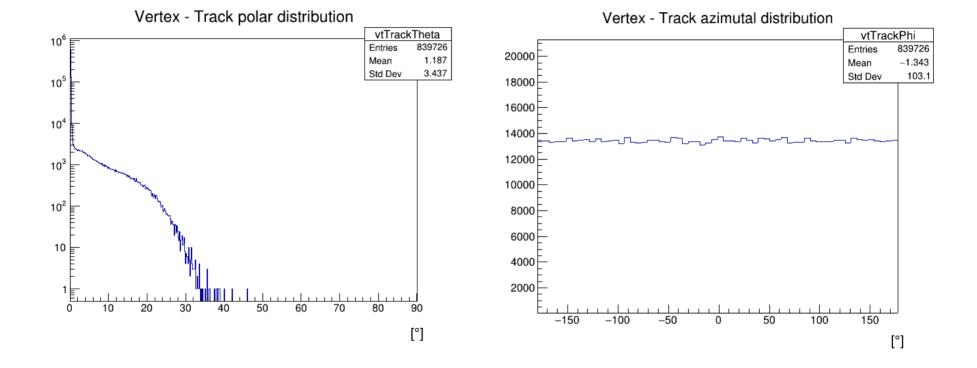
# **Definitions for performance factors**

### Clone multiplicity

quantification of the number of multiple cloned trajectories produced for the same MC particle matched to the track



### Vertex track angular distribution



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# efficiency resolution

• I consider the selection of an event of a given Z and theta as distributed with a binomial distribution

$$P(N_{sel}|N_{tot},\epsilon) = B(n; N_{tot},\epsilon)$$

- A good estimator of the efficiency is  $\hat{\epsilon} = \frac{N_{sel}}{N_{tot}}$
- The associated error is

$$\sigma_{\hat{\epsilon}}^2 = V[\hat{\epsilon}] = V[\frac{N_{sel}}{N_{tot}}] = \frac{V[N_{sel}]}{N_{tot}^2} = \frac{N_{tot}\epsilon(1-\epsilon)}{N_{tot}^2}$$
$$\sigma_{\hat{\epsilon}} = \sqrt{\frac{\epsilon(1-\epsilon)}{N_{tot}}}$$

then

# **N** reference

- Reference set: N<sub>reference</sub> (truth side) all the tracks that an algorithm performing ideally should find and reconstruct:
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