A first look at CNAO 2024 global tracking

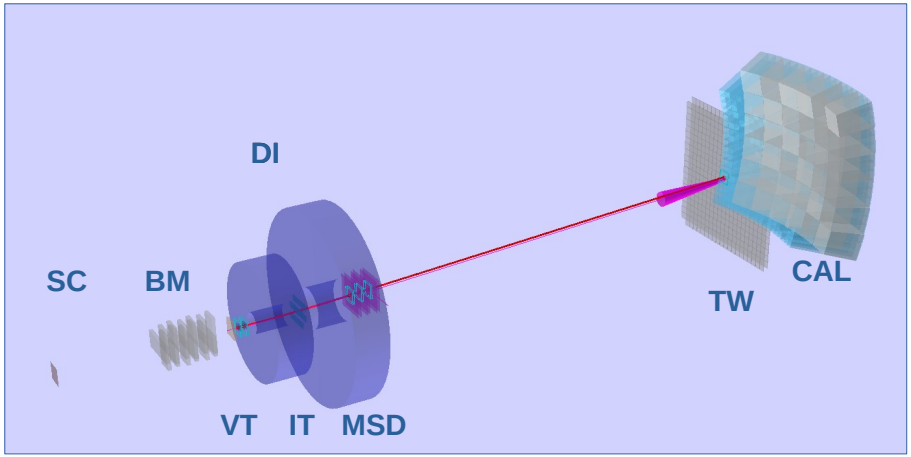
Giacomo U., Yun D., Roberto Z.

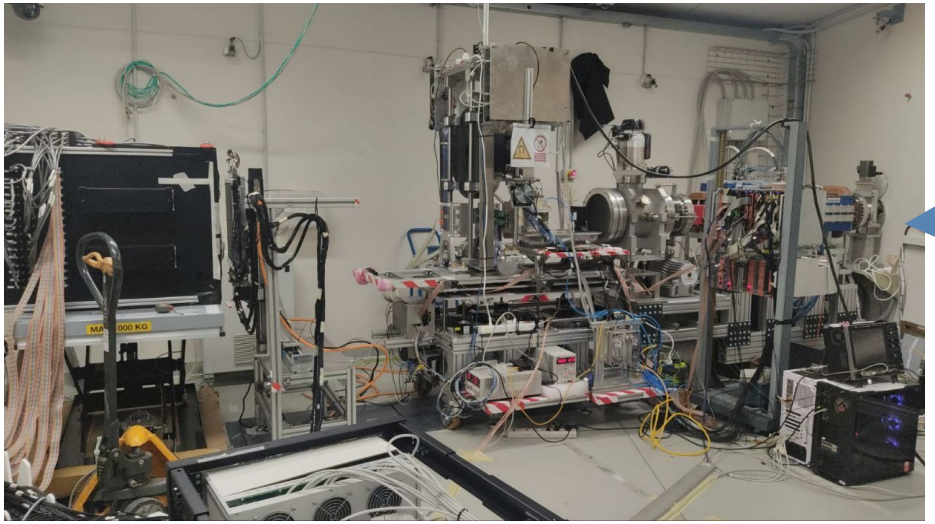
FOOT Physics Meeting

02/04/2025

CNAO2024

- Data-taking at CNAO in November 2024
- **^{12}C 200 MeV/u** on 5 mm **C target** with **B** field
- Total setup





- **VT, MSD, TW** considered
- **Global tracking** reconstruction

runs

Run	Beam energy	Target	Magnets	Total events	
6925	200 C	NO	NO	45k	used for aligment
6959	200 C	5mm C	YES	100k	physics
7074	200 C	5mm C	No	54k	alignment
7076	200 C	5mm C	YES	190k	physics

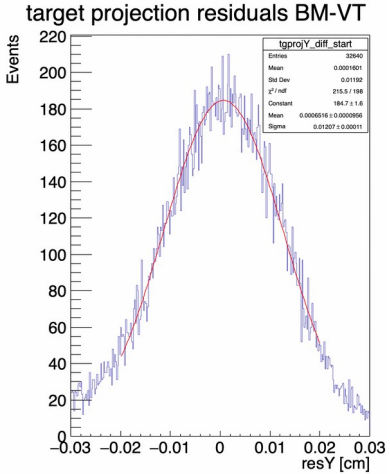
last night,
when **VT** and **IT** were tuned in the best way

Alignment

- thanks to Yun for all the efford in alignment
- all the details in *https://baltig.infn.it/asarti/shoe/-/wikis/Campaign_details/CNAO2024*
- TW has been placed in (-11,0) as measured in the geometrical survey.
- VTX XY position fixed such that the projection in TG is (0,0)
- VTX rotated to minimize residual wrt TW
- A **cut on the energy loss of the MSD** to get rid of noise
- MSD alignemnt and inter-alignment using VT tracks extrapolations
- **BM-VT**, **MSD-VT**, **TW-VT** position aligment verifications

Alignment

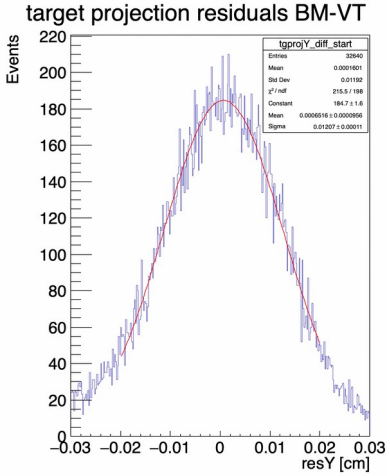
- thanks to Yun for all the efford in alignment
- all the details in *https://baltig.infn.it/asarti/shoe/-/wikis/Campaign_details/CNAO2024*
- TW has been placed in (-11,0) as measured in the geometrical survey.
- VTX XY position fixed such that the projection in TG is (0,0)
- VTX rotated to minimize residual wrt TW
- A **cut on the energy loss of the MSD** to get rid of noise
- MSD alignemnt and inter-alignment using VT tracks extrapolations
- **BM-VT**, **MSD-VT**, **TW-VT** position aligment verifications



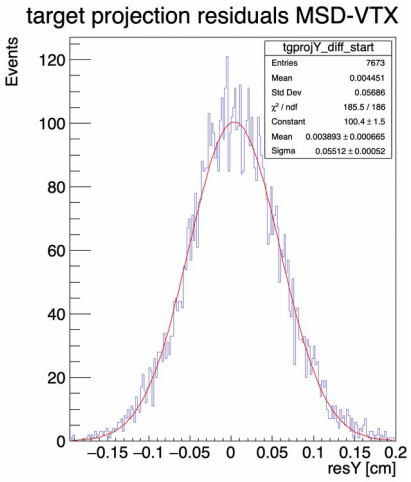
r = 0.01 ± 0.12 mm

Alignment

- thanks to Yun for all the efford in alignment
- all the details in *https://baltig.infn.it/asarti/shoe/-/wikis/Campaign_details/CNAO2024*
- TW has been placed in (-11,0) as measured in the geometrical survey.
- VTX XY position fixed such that the projection in TG is (0,0)
- VTX rotated to minimize residual wrt TW
- A **cut on the energy loss of the MSD** to get rid of noise
- MSD alignemnt and inter-alignment using VT tracks extrapolations
- **BM-VT**, **MSD-VT**, **TW-VT** position aligment verifications



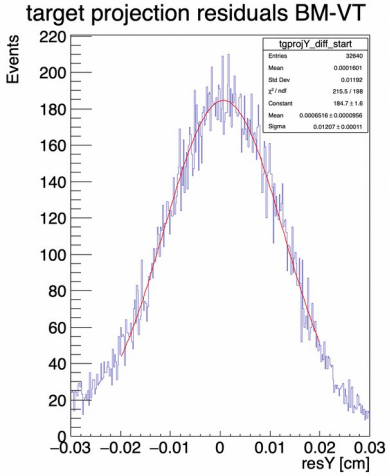
r = 0.01 ± 0.12 mm



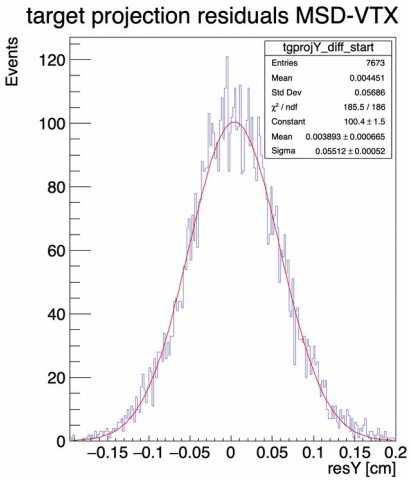
r = 0.040 ± 0.55 mm

Alignment

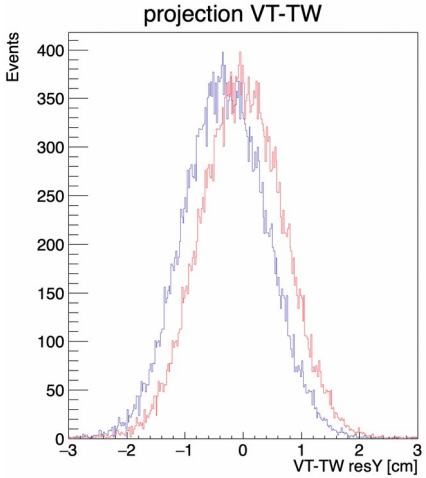
- thanks to Yun for all the efford in alignment
- all the details in *https://baltig.infn.it/asarti/shoe/-/wikis/Campaign_details/CNAO2024*
- TW has been placed in (-11,0) as measured in the geometrical survey.
- VTX XY position fixed such that the projection in TG is (0,0)
- VTX rotated to minimize residual wrt TW
- A **cut on the energy loss of the MSD** to get rid of noise
- MSD alignemnt and inter-alignment using VT tracks extrapolations
- **BM-VT**, **MSD-VT**, **TW-VT** position aligment verifications



r = 0.01 ± 0.12 mm



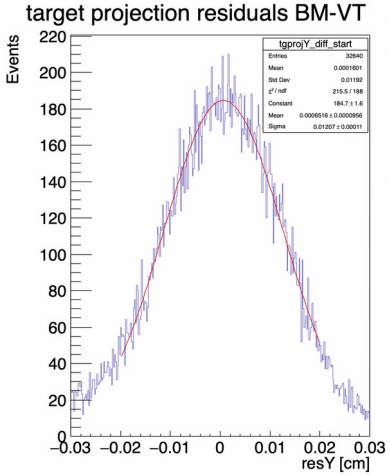
r = 0.040 ± 0.55 mm



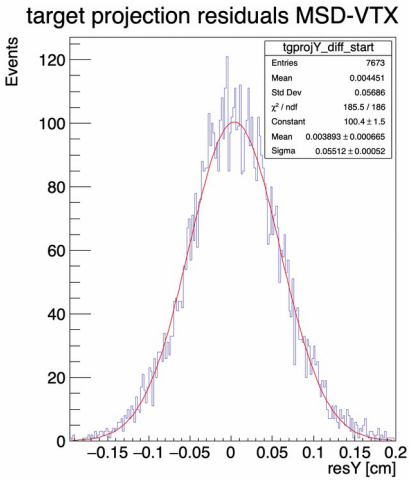
red: after a further TW shift of 5 mm

Alignment

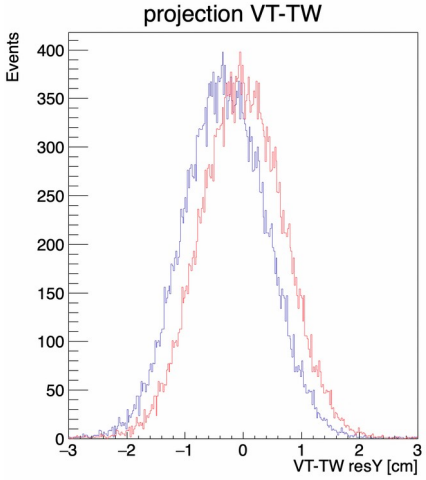
- thanks to Yun for all the efford in alignment
- all the details in *https://baltig.infn.it/asarti/shoe/-/wikis/Campaign_details/CNAO2024*
- TW has been placed in (-11,0) as measured in the geometrical survey.
- VTX XY position fixed such that the projection in TG is (0,0)
- VTX rotated to minimize residual wrt TW
- A **cut on the energy loss of the MSD** to get rid of noise
- MSD alignemnt and inter-alignment using VT tracks extrapolations
- **BM-VT**, **MSD-VT**, **TW-VT** position aligment verifications



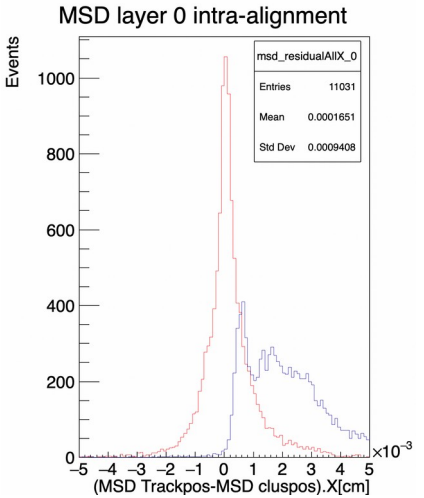
r = 0.01 ± 0.12 mm



r = 0.040 ± 0.55 mm



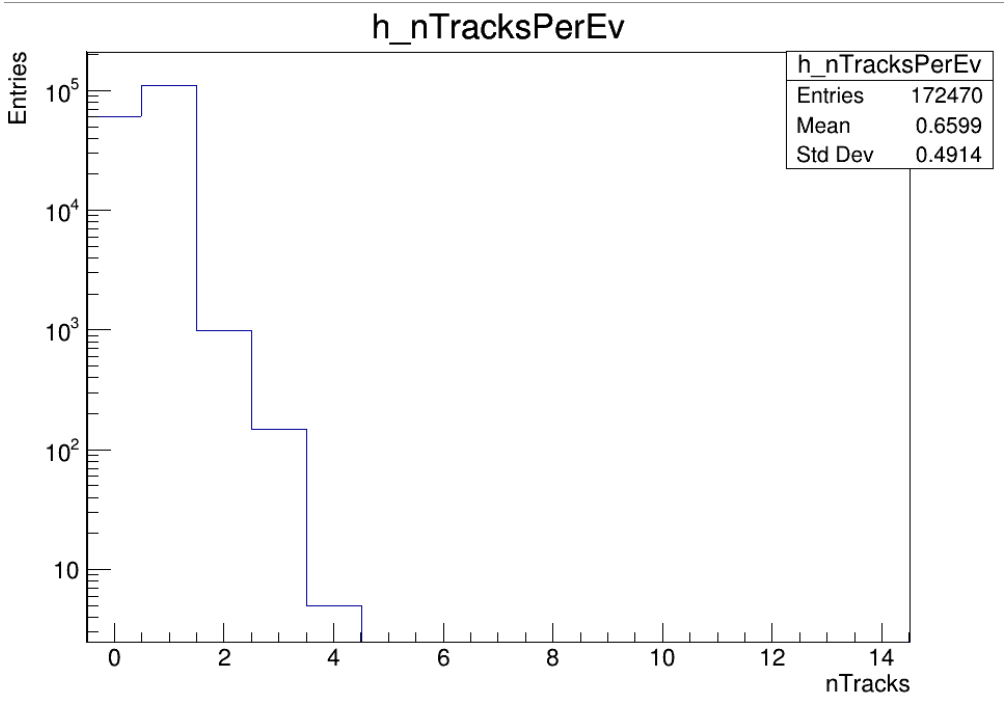
red: after a further TW shift of 5 mm



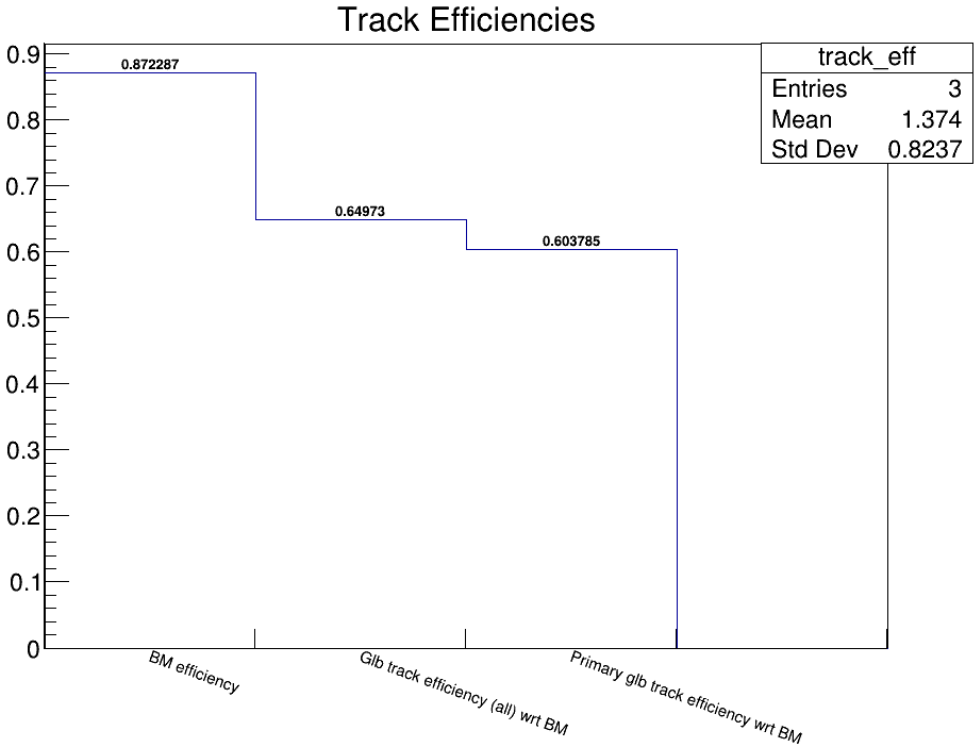
red: inter-aligment of MSD using VTX track

Tracks, run 7076

- Number of tracks per event

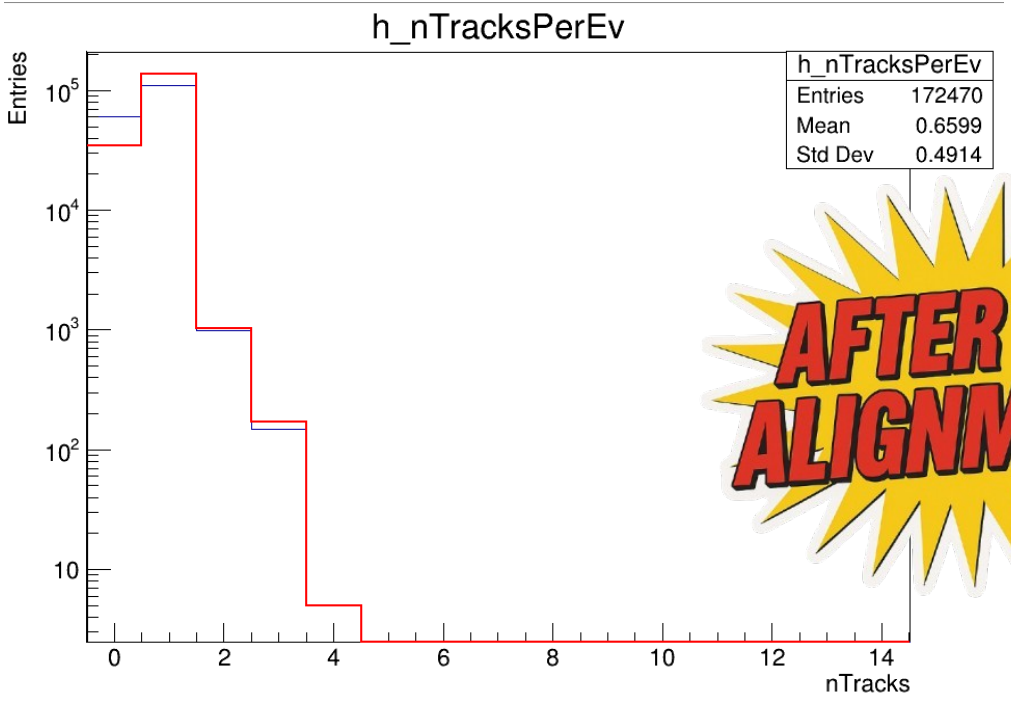


- Efficiency of reconstructed primary events when the BM has a track

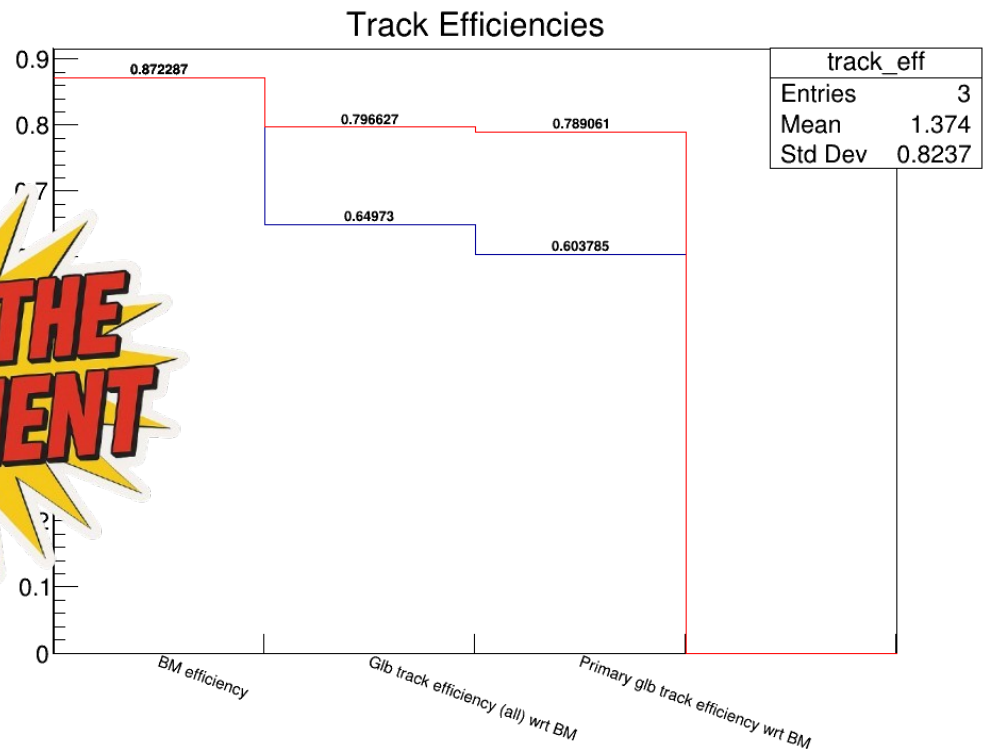


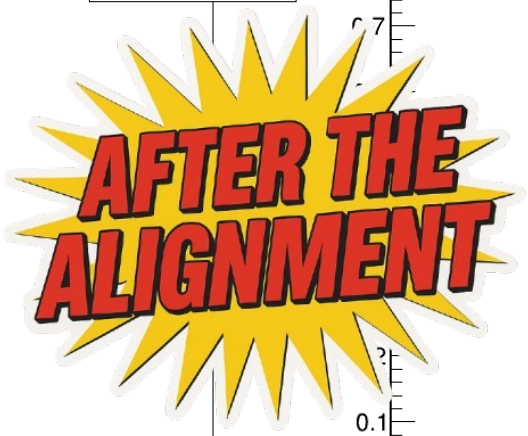
Tracks, run 7076

- Number of tracks per event



- Efficiency of reconstructed primary events when the BM has a track

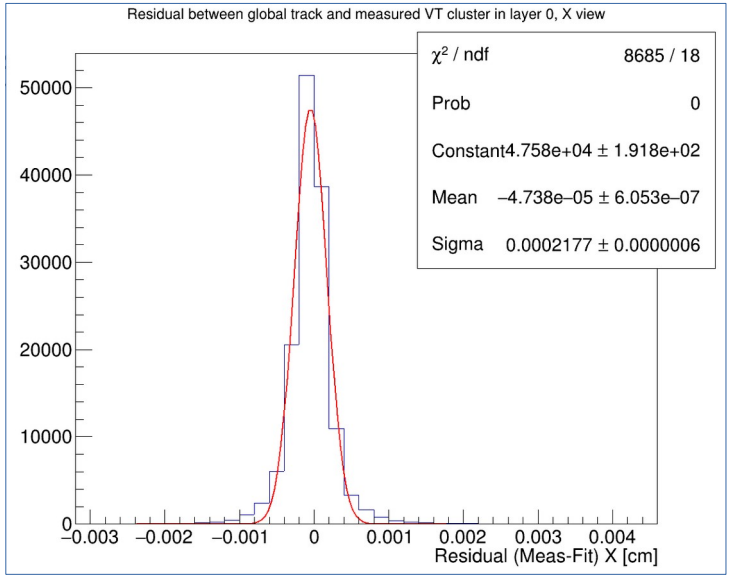


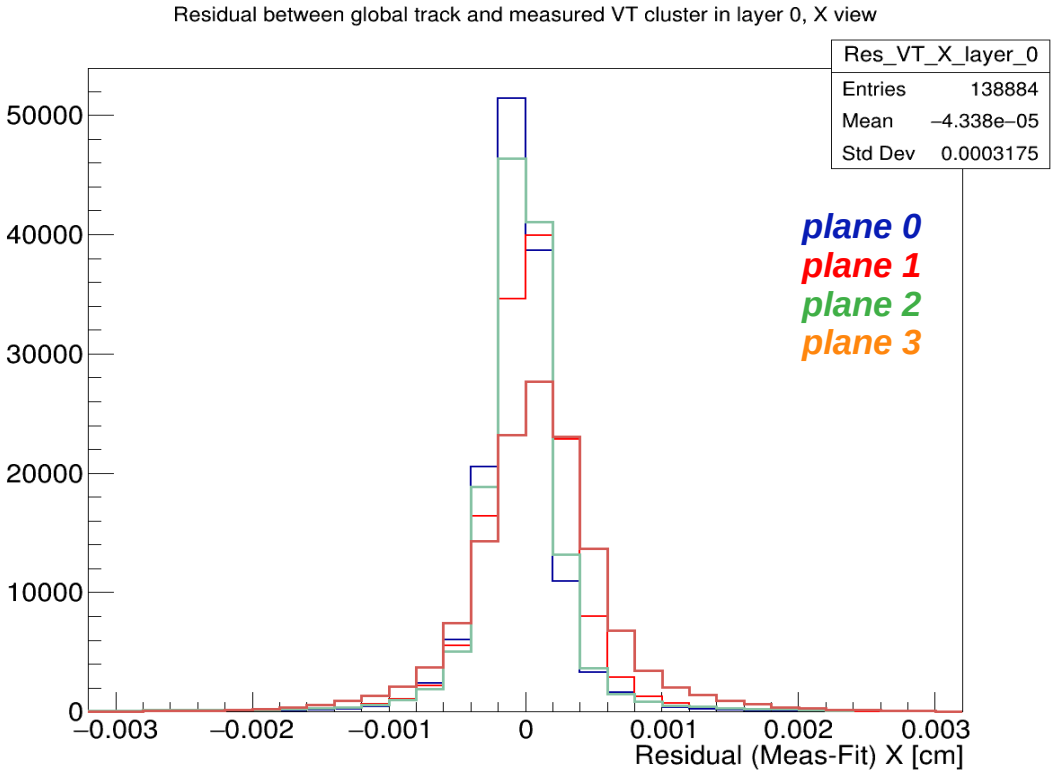


- more clusters in the “right” positions → more global tracks → **highest track efficiency**

residuals, run 7076

- VTX X axis residuals

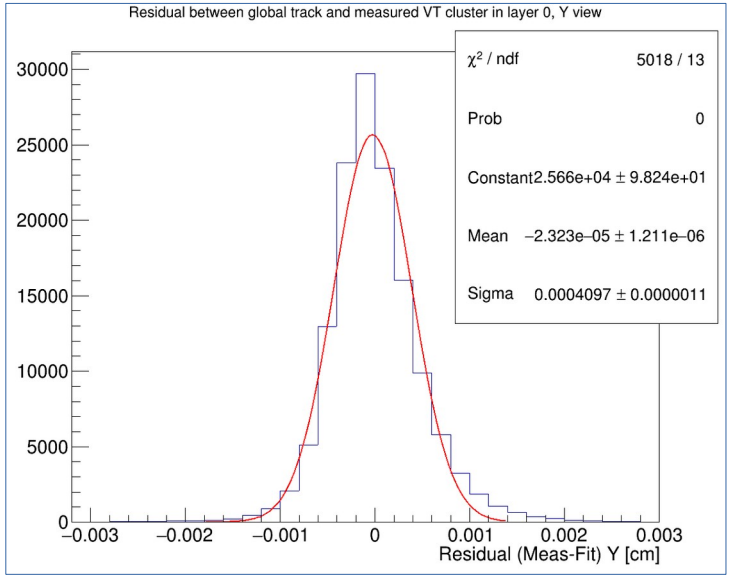


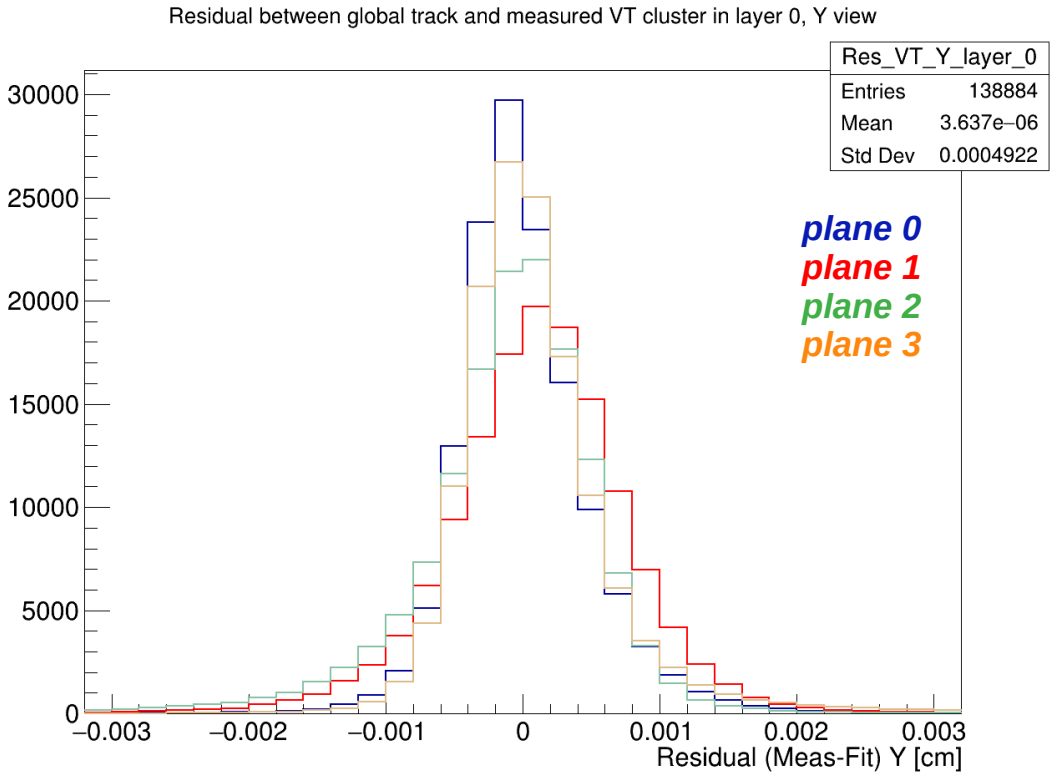


- NB: the residuals in the previous slides are wrt detector tracklets (w/out B field)
  from now let's see residuals wrt global tracking (in B field)
- misalignment lower than 2 μm, inside the spatial uncertainty of VTX

residuals, run 7076

- VTX Y axis residuals



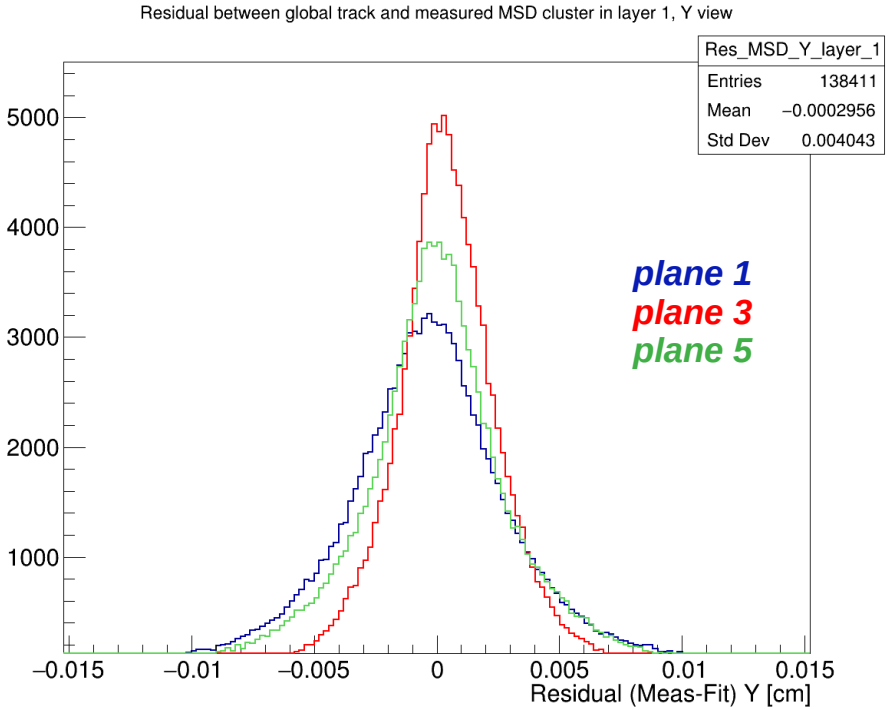


- misalignment lower than 2 μm, inside the spatial uncertainty of VTX

residuals, run 7076

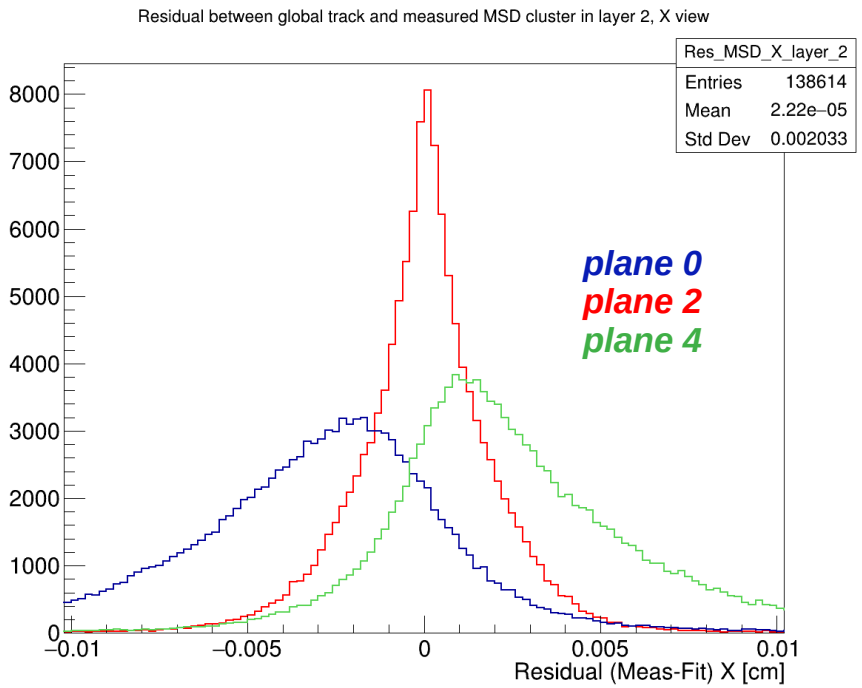
- MSD X axis residuals

- MSD Y axis residuals



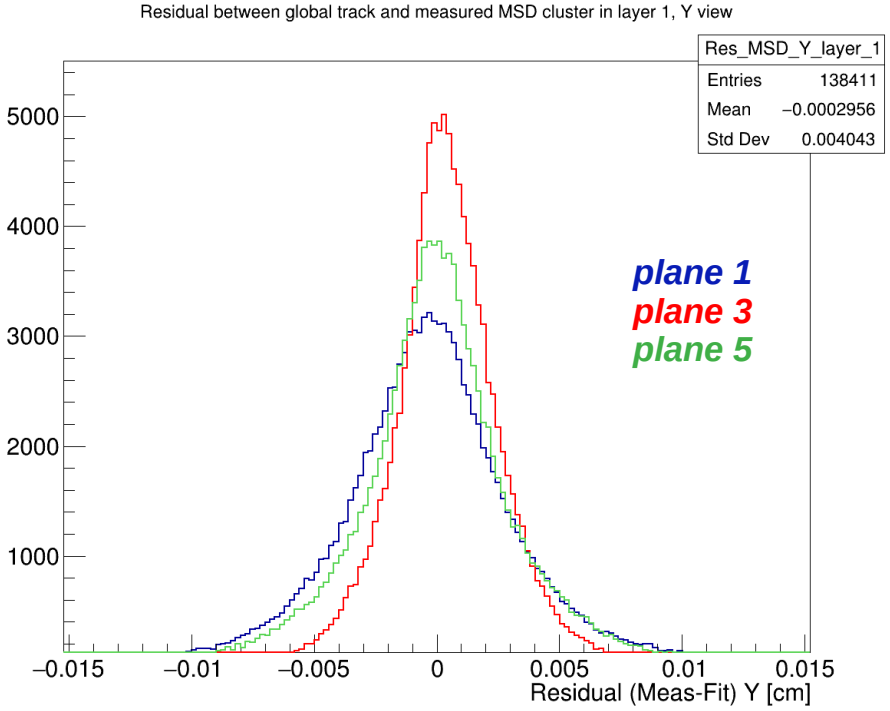
residuals, run 7076

- MSD X axis residuals



mis-inter-aligment of 25 μm on the X axis

- MSD Y axis residuals

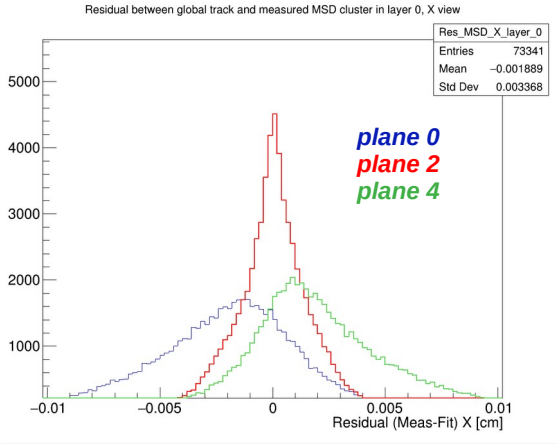


residuals MSD X axis

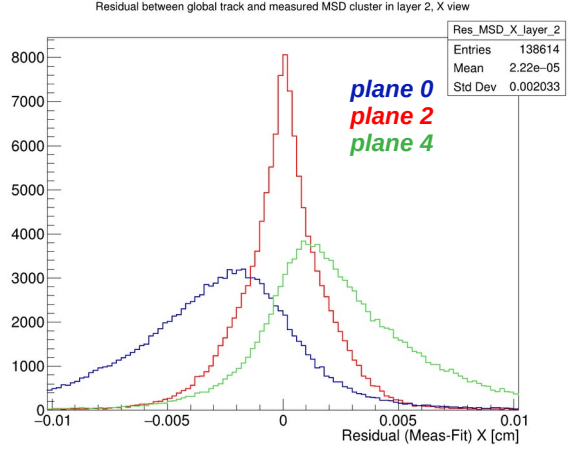
- run 6925 (no magnets)

- run 7074 (no magnets)

- run 6959 (w/ **magnets**)

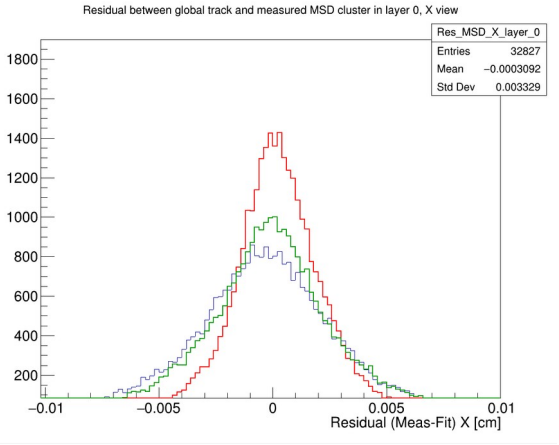


- run 7076 (w/ **magnets**)

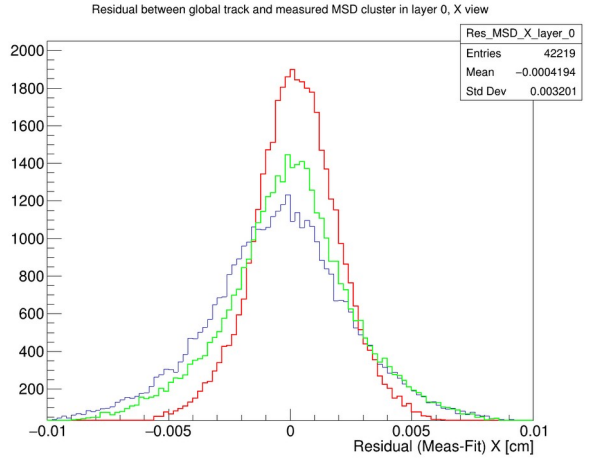


residuals MSD X axis

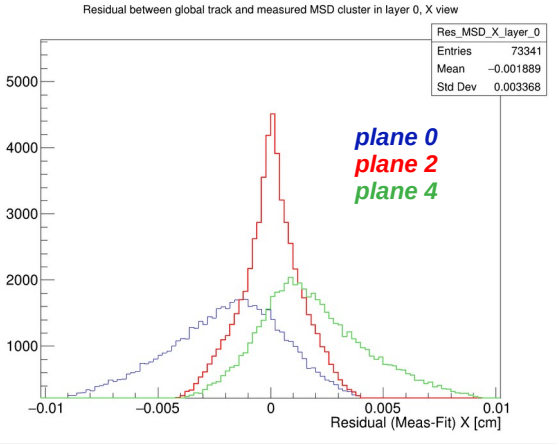
- run 6925 (no magnets)



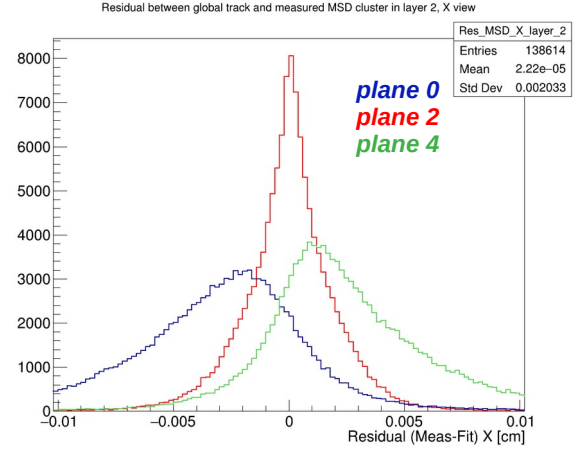
- run 7074 (no magnets)



- run 6959 (w/ **magnets**)



- run 7076 (w/ **magnets**)

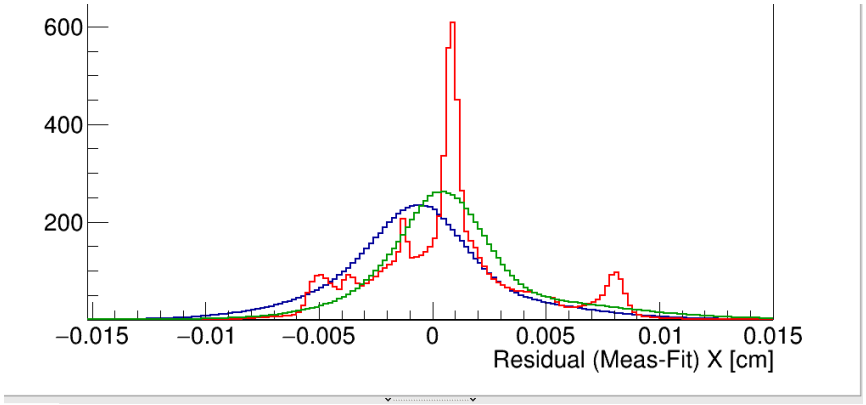


mis-inter-aligment on X axes
only with B field

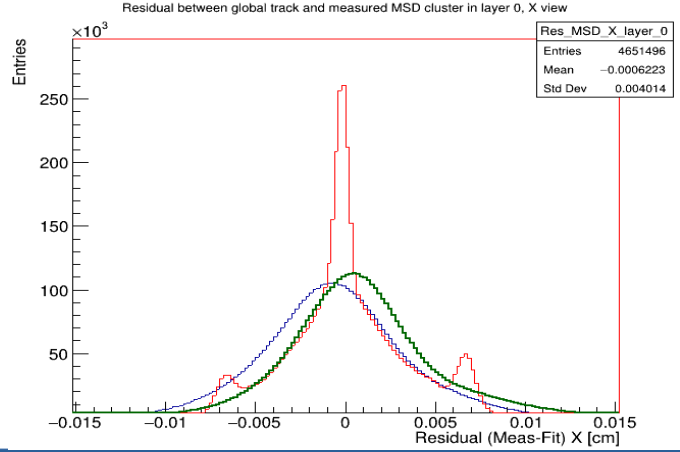
- little mis-alignment of MSD is enhanced when B field is on?
- the B field is mis-aligned wrt the inserted map?

residuals MSD X axis

- CNAO23PS_MC (w/ **magnets**)



- GSI21PS_MC (no magnets)



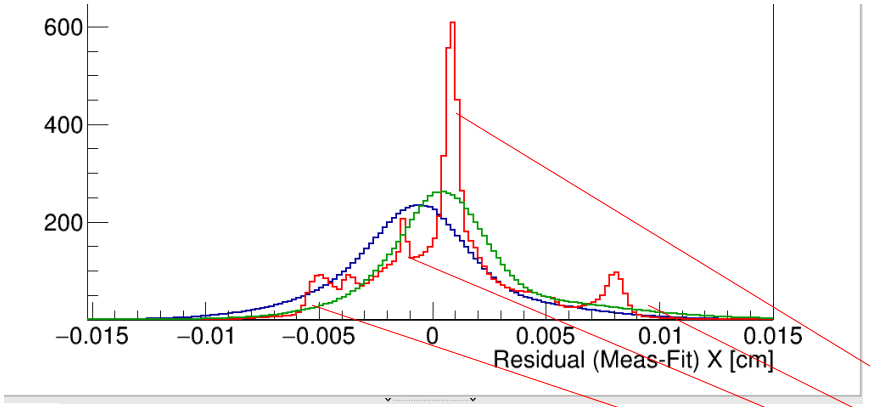
Actually this structure is still present in MC…

- MSD clustering?
- Global tracking?
- B field map?

- In MC, spikes are due to the fact that digitization is discrete, with a distance of ~ d/2 ~ 75 μm among cluster positions

residuals MSD X axis

- CNAO23PS_MC (w/ **magnets**)

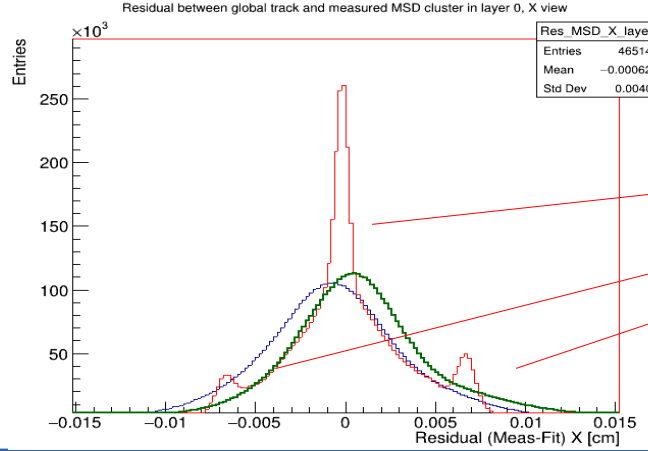


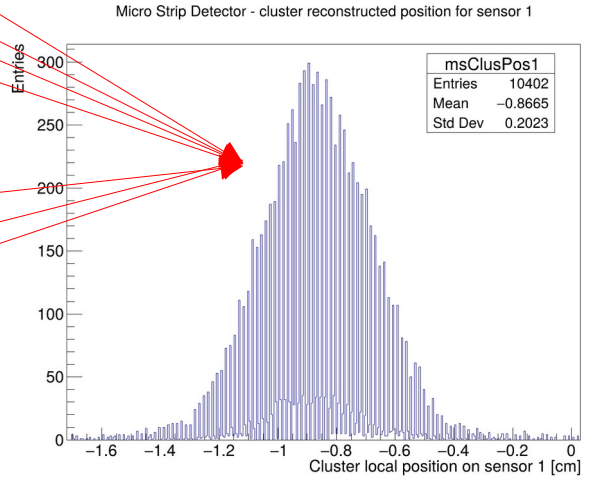
Actually this structure is still present in MC…

- MSD clustering?
- Global tracking?
- B field map?

- In MC, spikes are due to the fact that digitization is discrete, with a distance of ~ d/2 ~ 75 μm among cluster positions

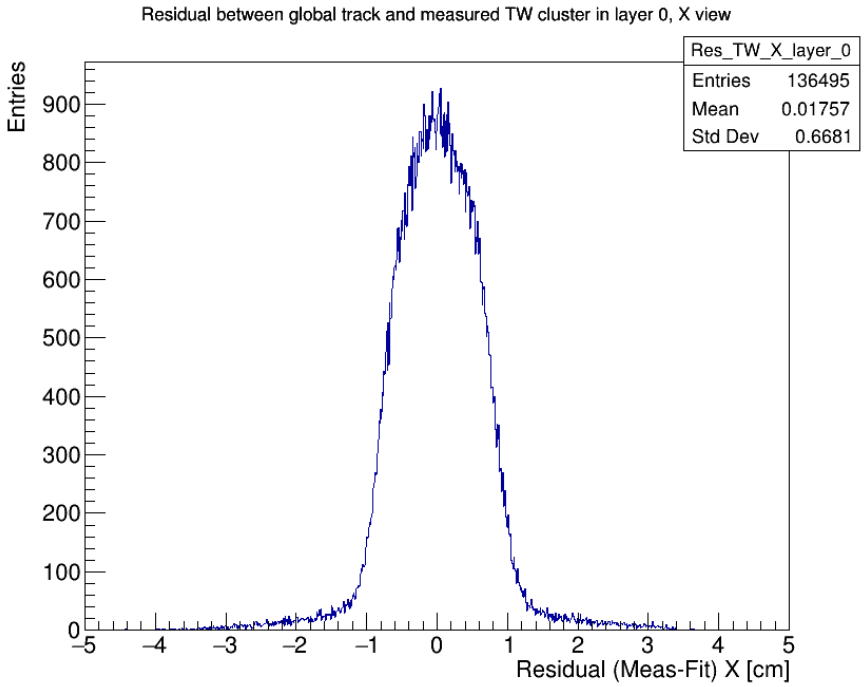
- GSI21PS_MC (no magnets)



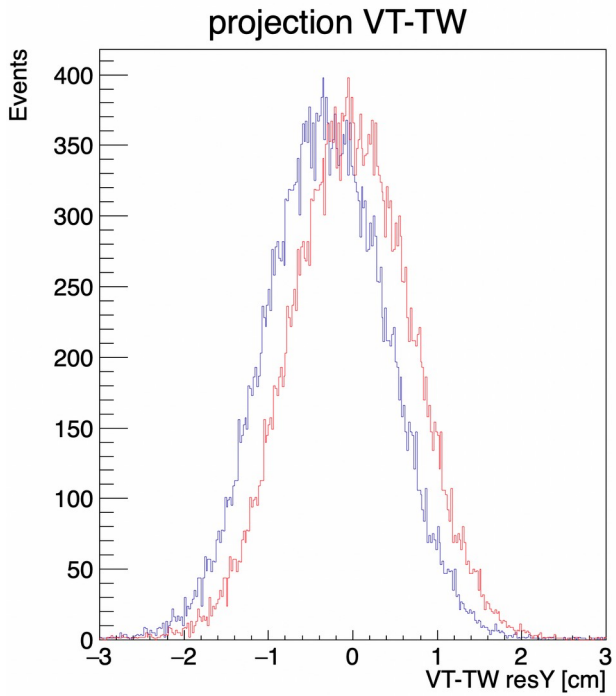


residuals, run 6959

- TW X axis residuals



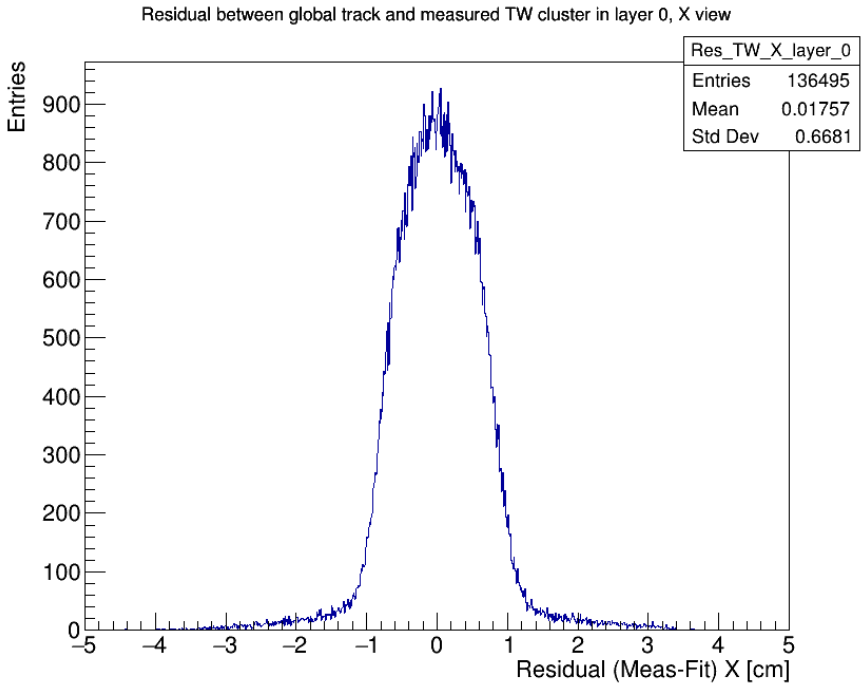
- TW Y axis residuals



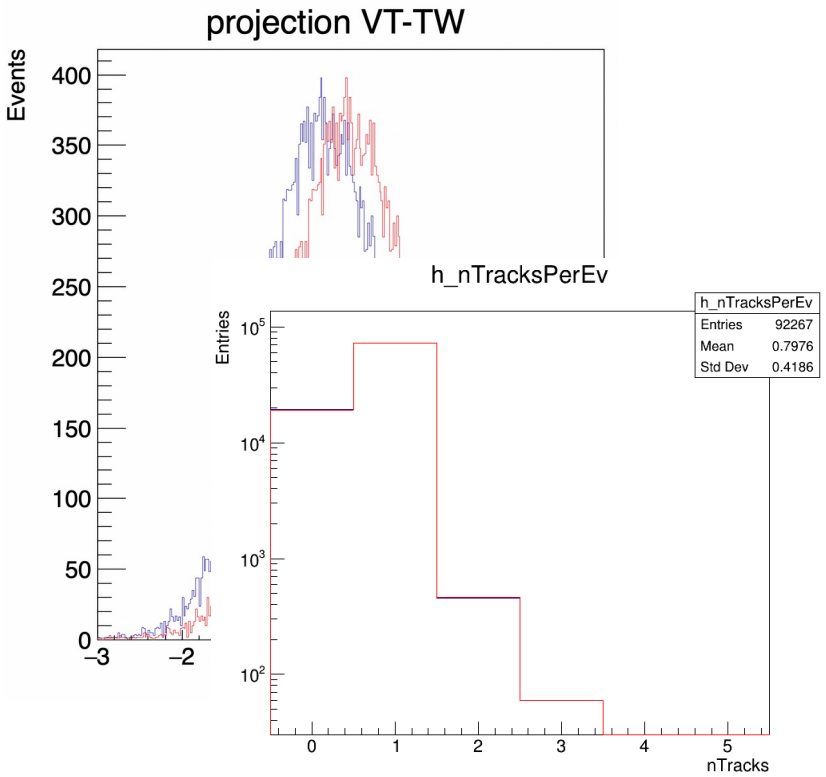
- there is a shift of ~ 3 mm on the TW Y residuals, a little Y component of the B field?

residuals, run 6959

- TW X axis residuals



- TW Y axis residuals

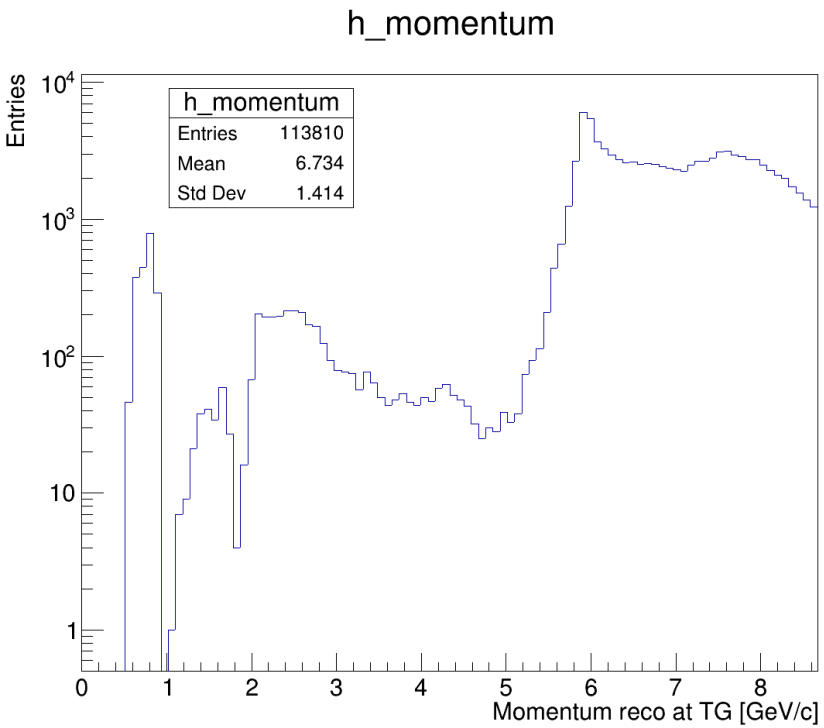


- there is a shift of ~ 3 mm on the TW Y residuals, a little Y component of the B field?
- no notable difference in tracks reconstruction before and after 3mm shift

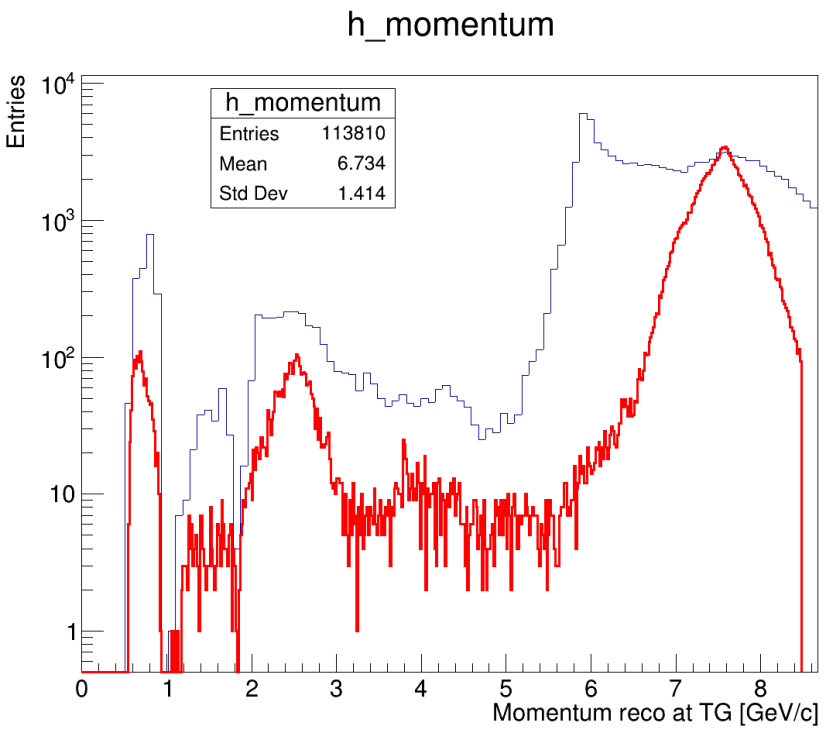
runs

Run	Beam energy	Target	Magnets	Total events		MSD residual shift	TW residual shift
6925	200 C	NO	NO	45k	used for aligment	no	no
6959	200 C	5mm C	YES	100k	physics	**yes**	**yes**
7074	200 C	5mm C	No	54k	alignment	no	no
7076	200 C	5mm C	YES	190k	physics	**yes**	no

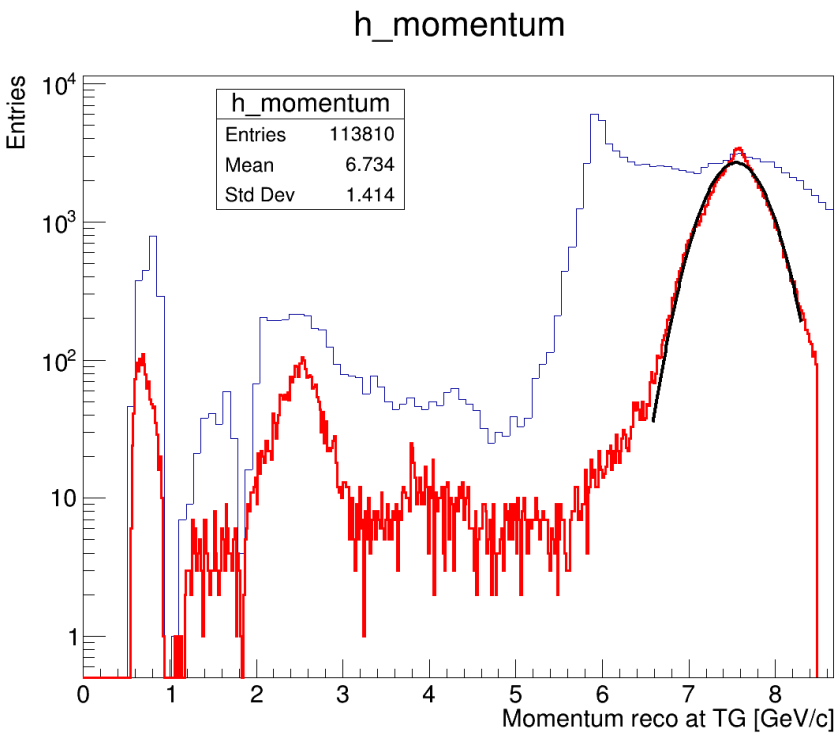
momentum, run 7076



momentum, run 7076



momentum, run 7076




```
Constant                =      2679.66   +/-   9.98394
Mean                    =      7.54666   +/-   0.000950669
Sigma                   =     0.326413   +/-   0.000869344     (limited)
```

- momentum peaked around primary momentum, with a resolution of **4.2%** (3% from CNAO23PS_MC)
- secondary particles peaks also visible (H, He...)

Conclusions

- Alignment procedure for 12C at 200 MeV/n runs of CNAO24 (w/ and w/out magnets)

- First look at residuals: peaked around 0 with sigma in agreement with detector resolutions

- MSD shift under investigation, clustering? B field map?
- **threshold tuning** could also improve MSD performance and then Glb tracking preformance
- how to **rotate the B field** in a smart way? Dipoles position in solidarity with VTX?

- guess of a **B field component in Y axis**: see TW residuals
- **correct TW calibration** needed for a better Z identification

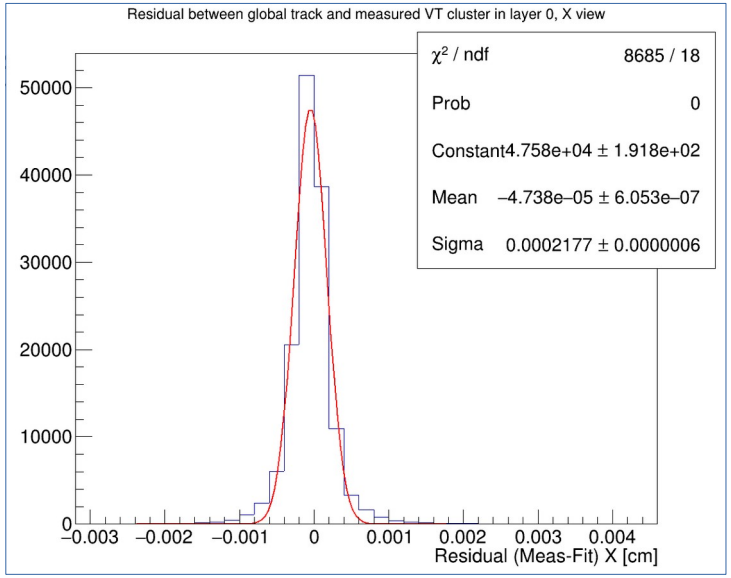
- Looking at all the events (so ~ primaries), the results are promising
  even in retrieving physical quantities

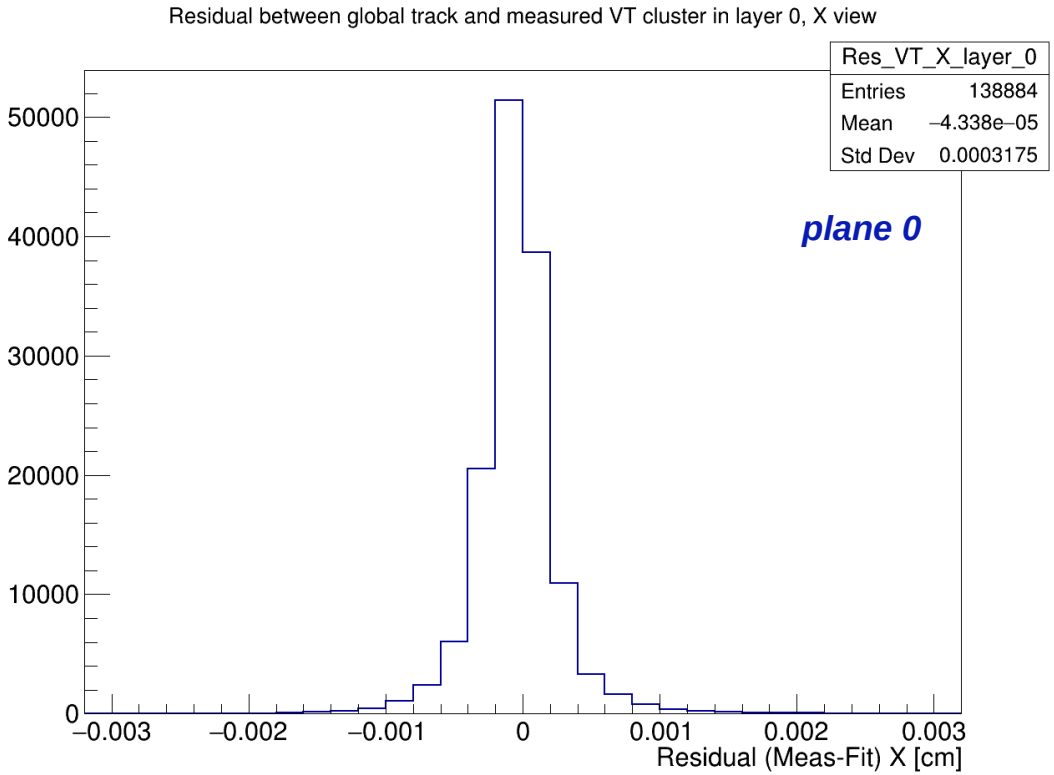
Thank you for the attention!

Back up slides

residuals, run 7076

- VTX X axis residuals

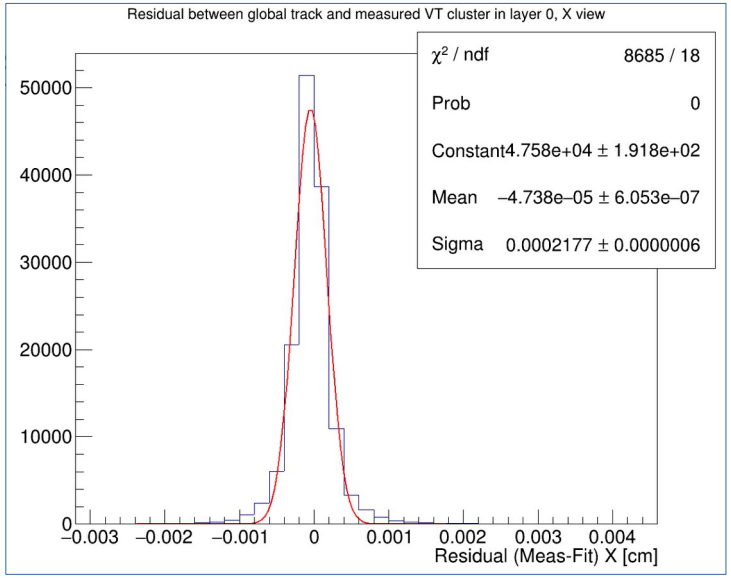


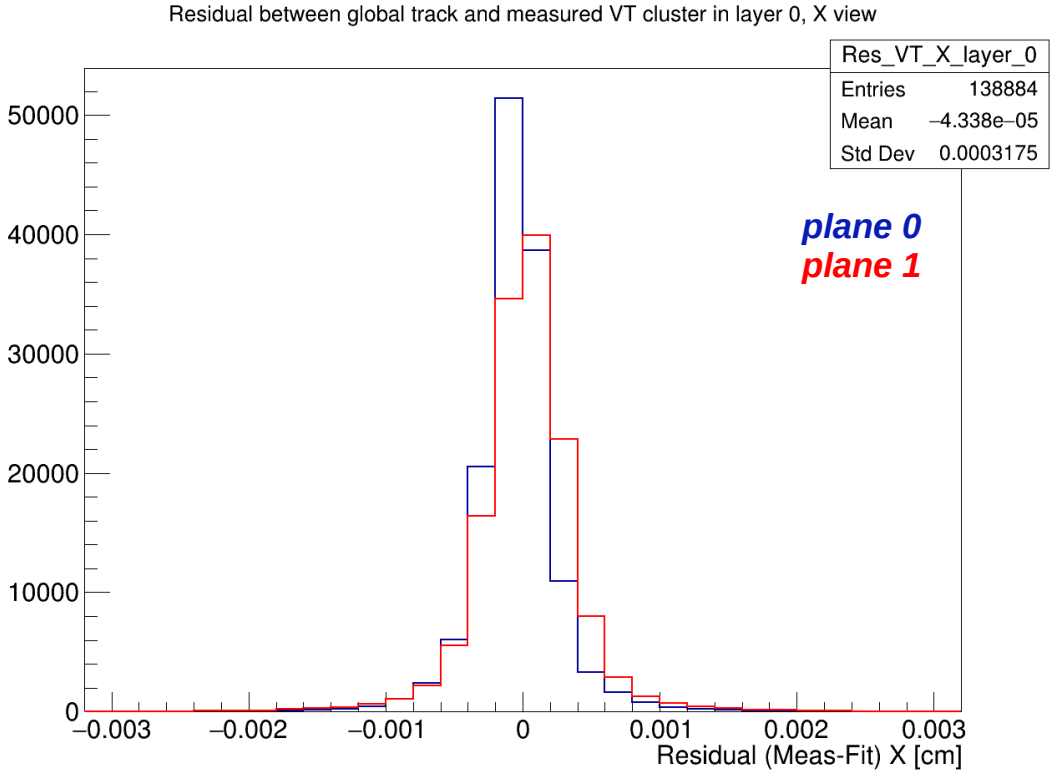


NB: the residuals in the previous slides are wrt detector tracklets (w/out B field)
from now let's see residuals wrt global tracking (in B field)

residuals, run 7076

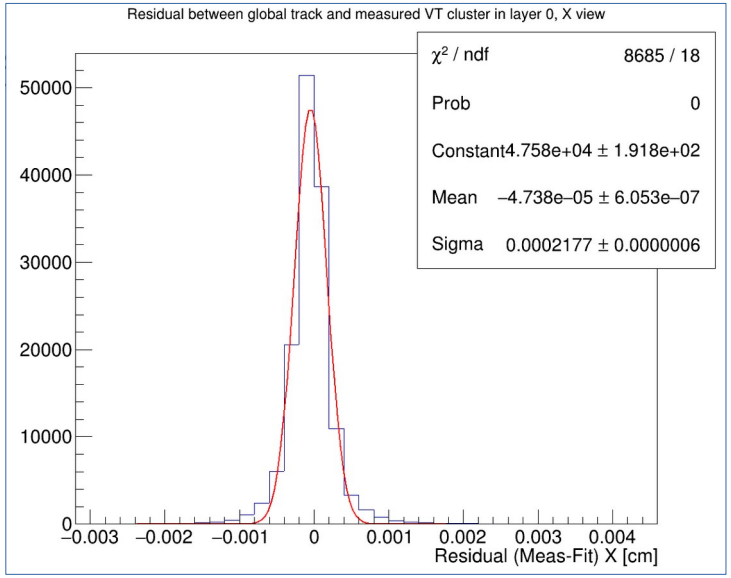
- VTX X axis residuals

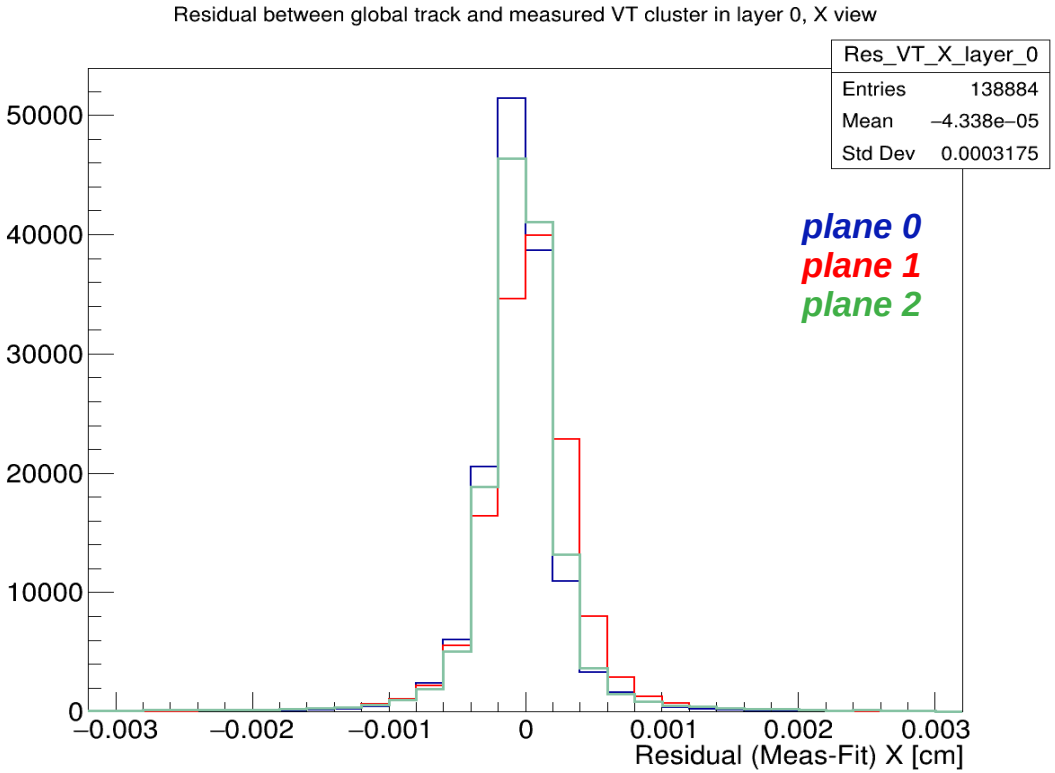




residuals, run 7076

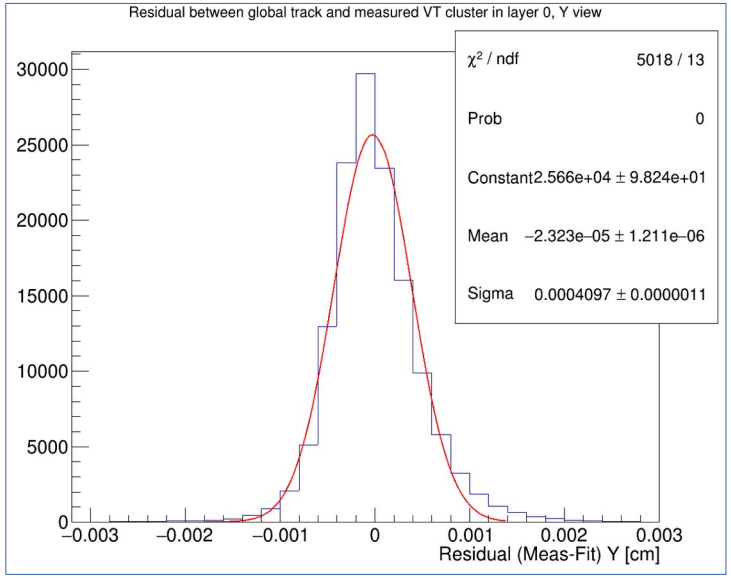
- VTX X axis residuals

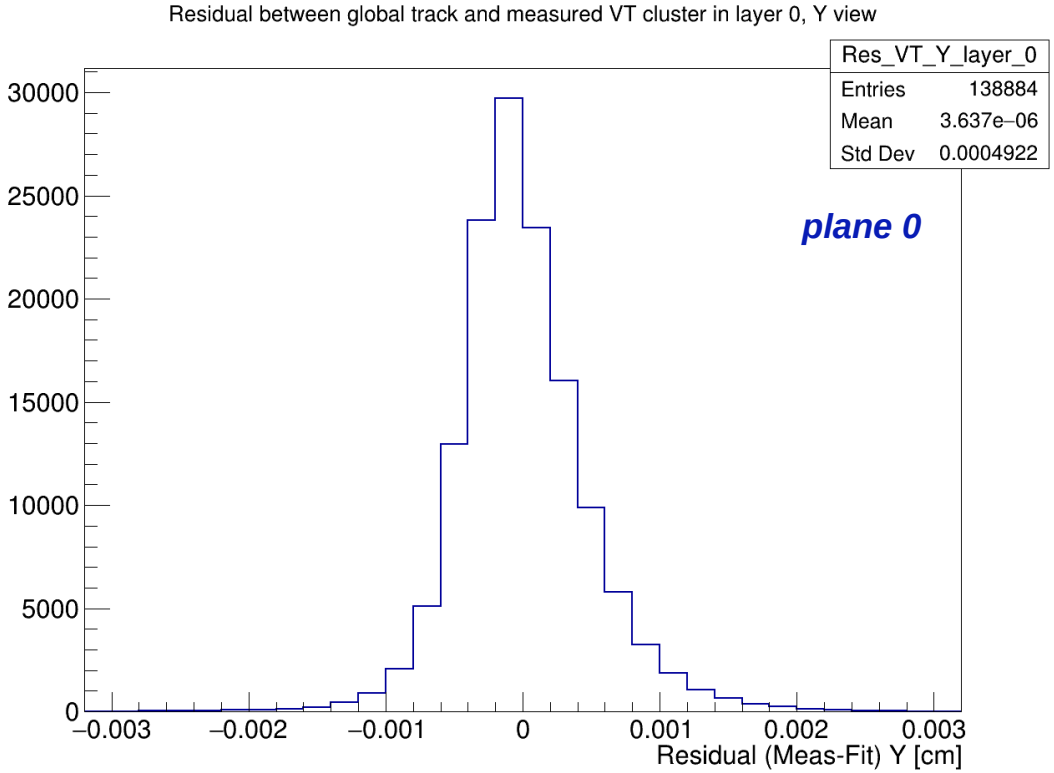




residuals, run 7076

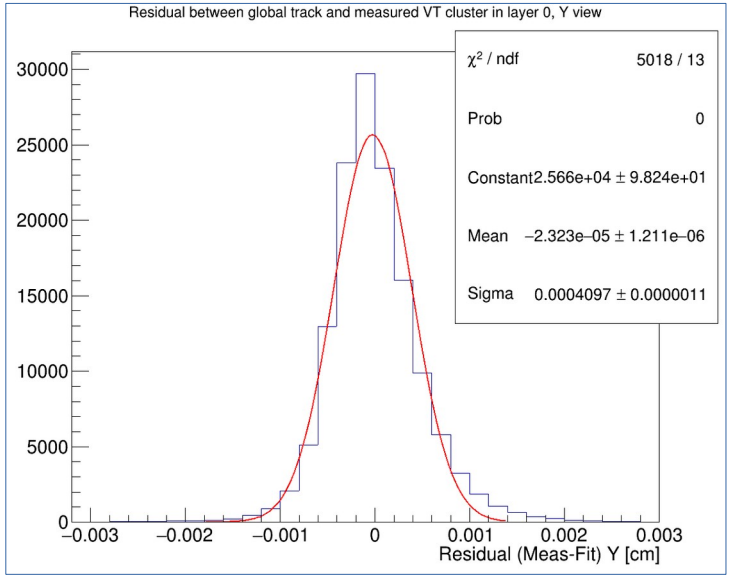
- VTX Y axis residuals

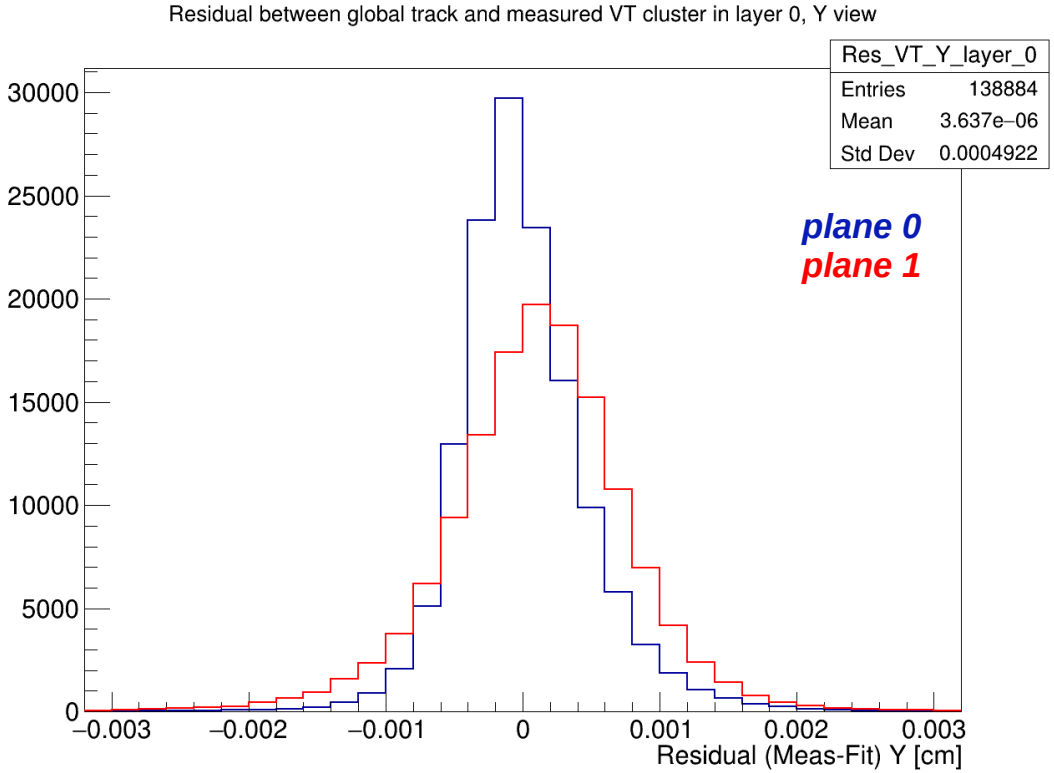




residuals, run 7076

- VTX Y axis residuals





residuals, run 7076

- VTX Y axis residuals