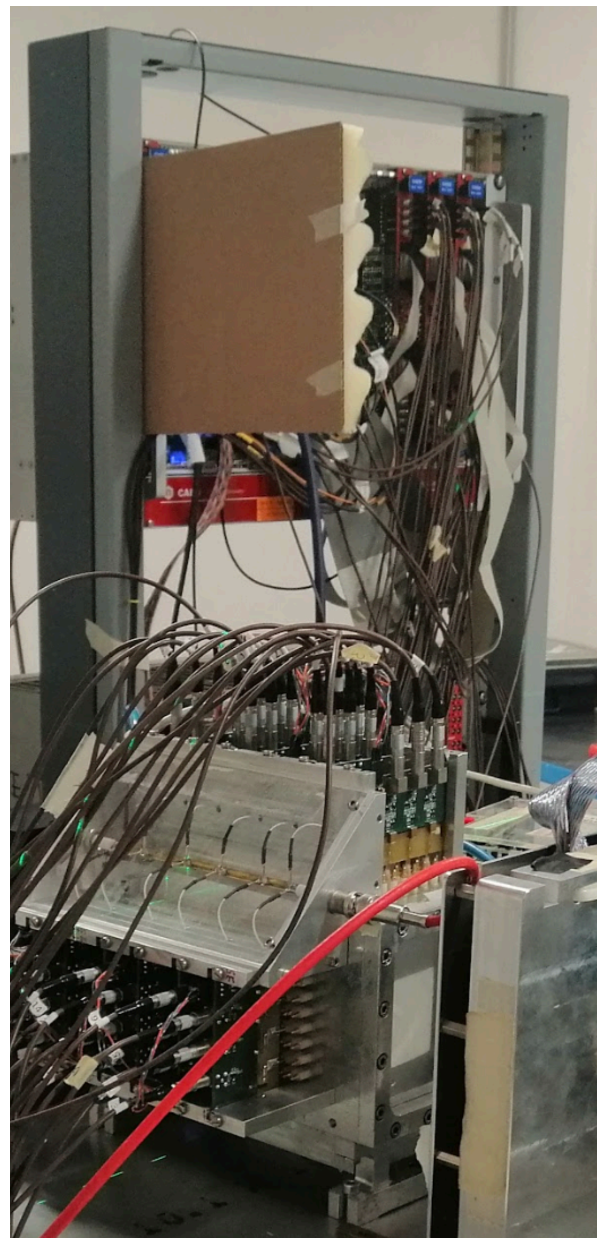
Beam Monitor @ CNAO2024

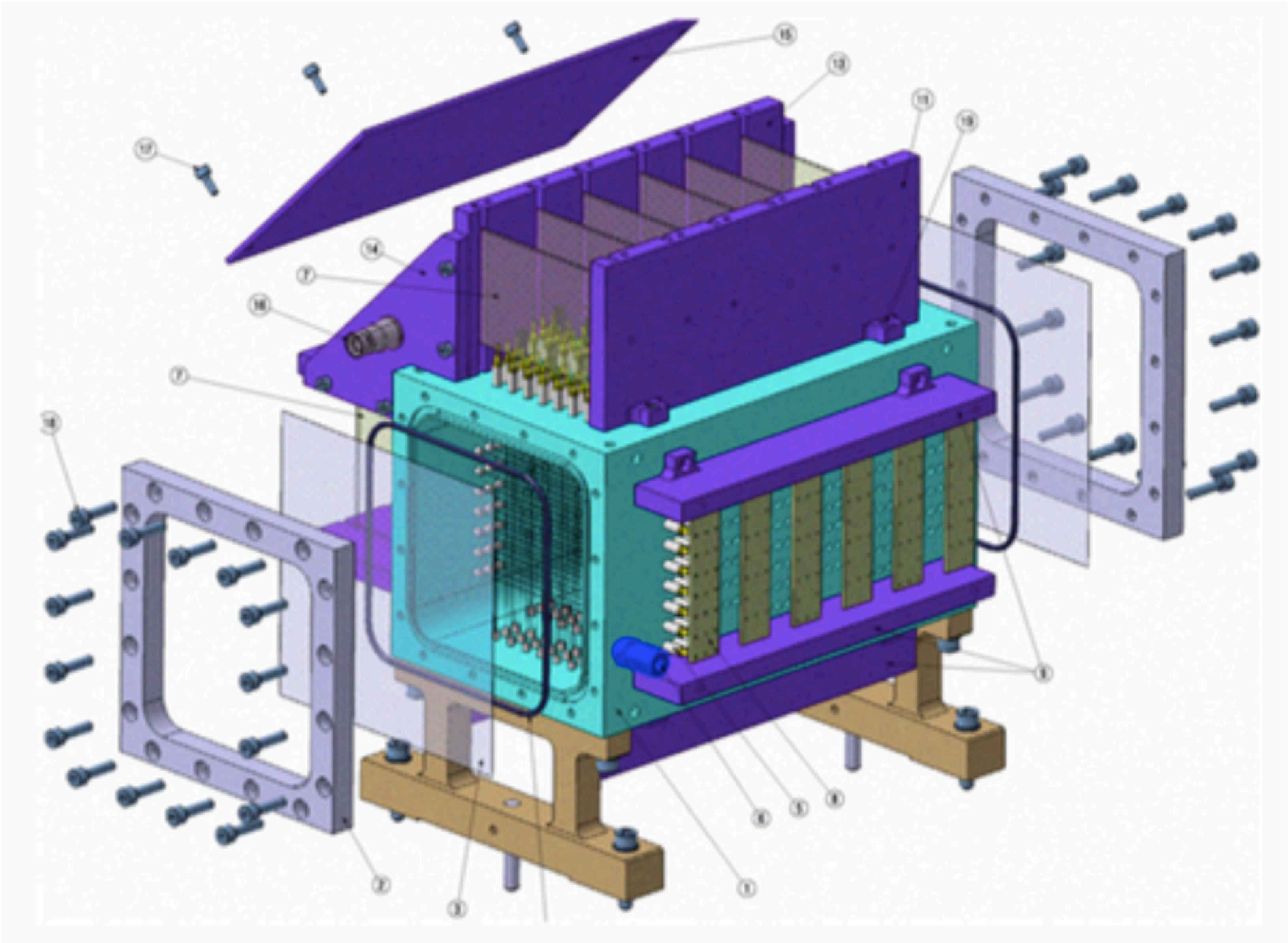
Yunsheng Dong

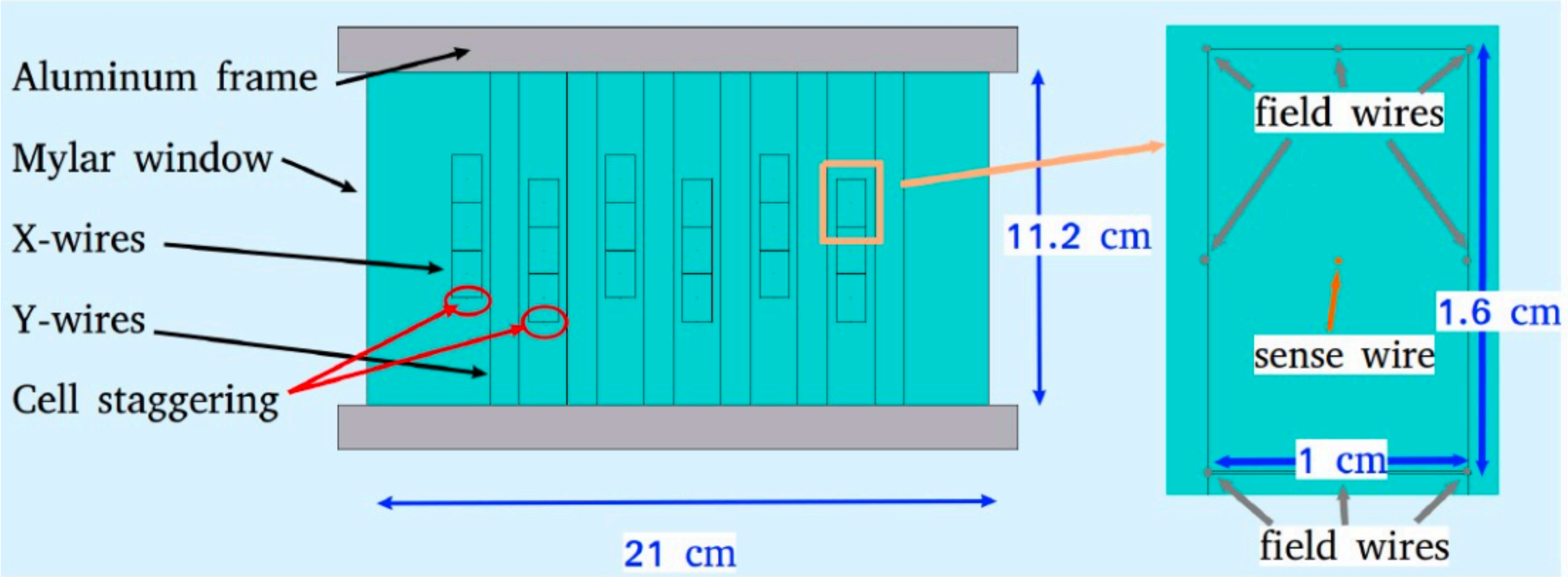
FOOT General Meeting

16/12/2024

The Beam Monitor (BM) detector







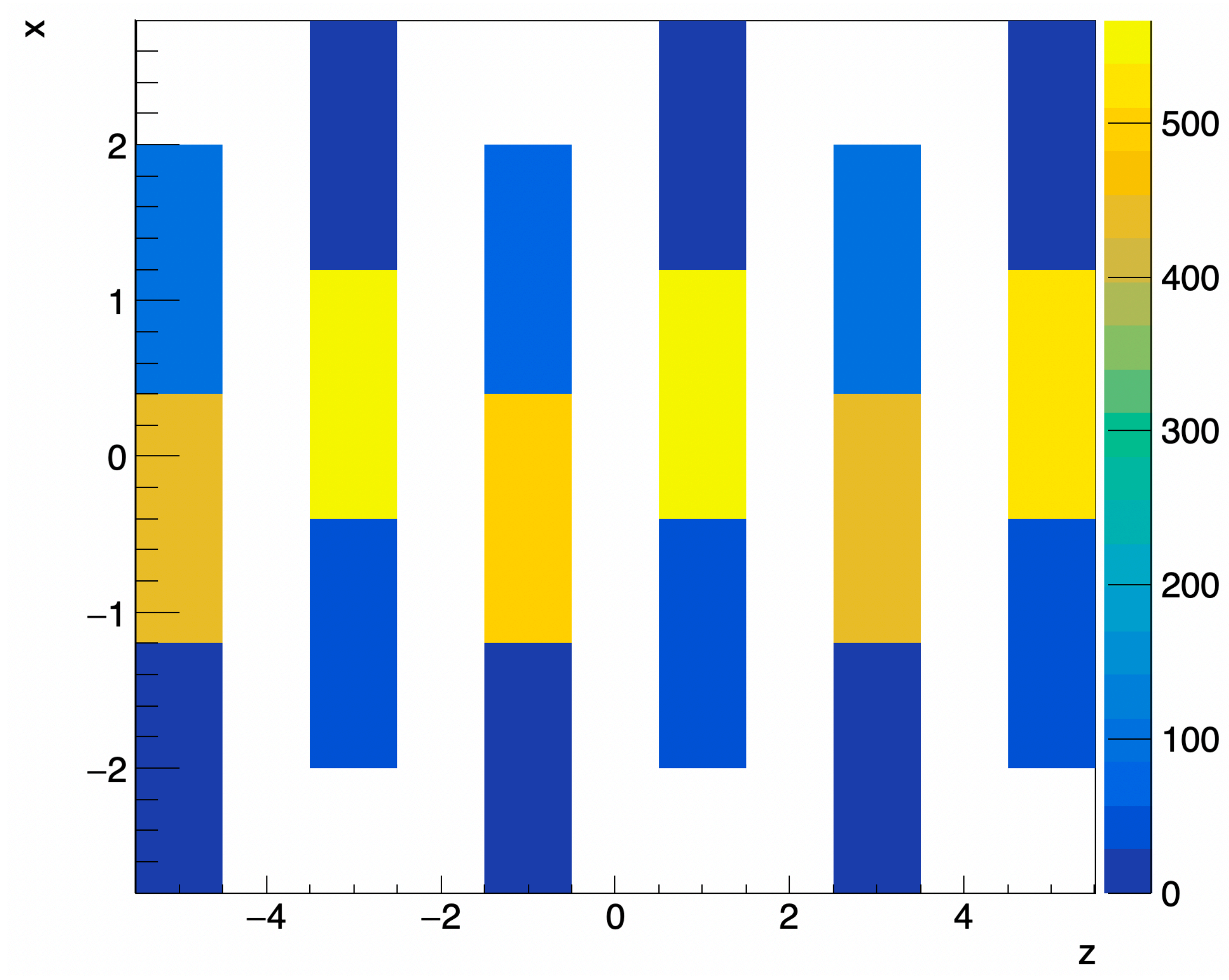
Goal

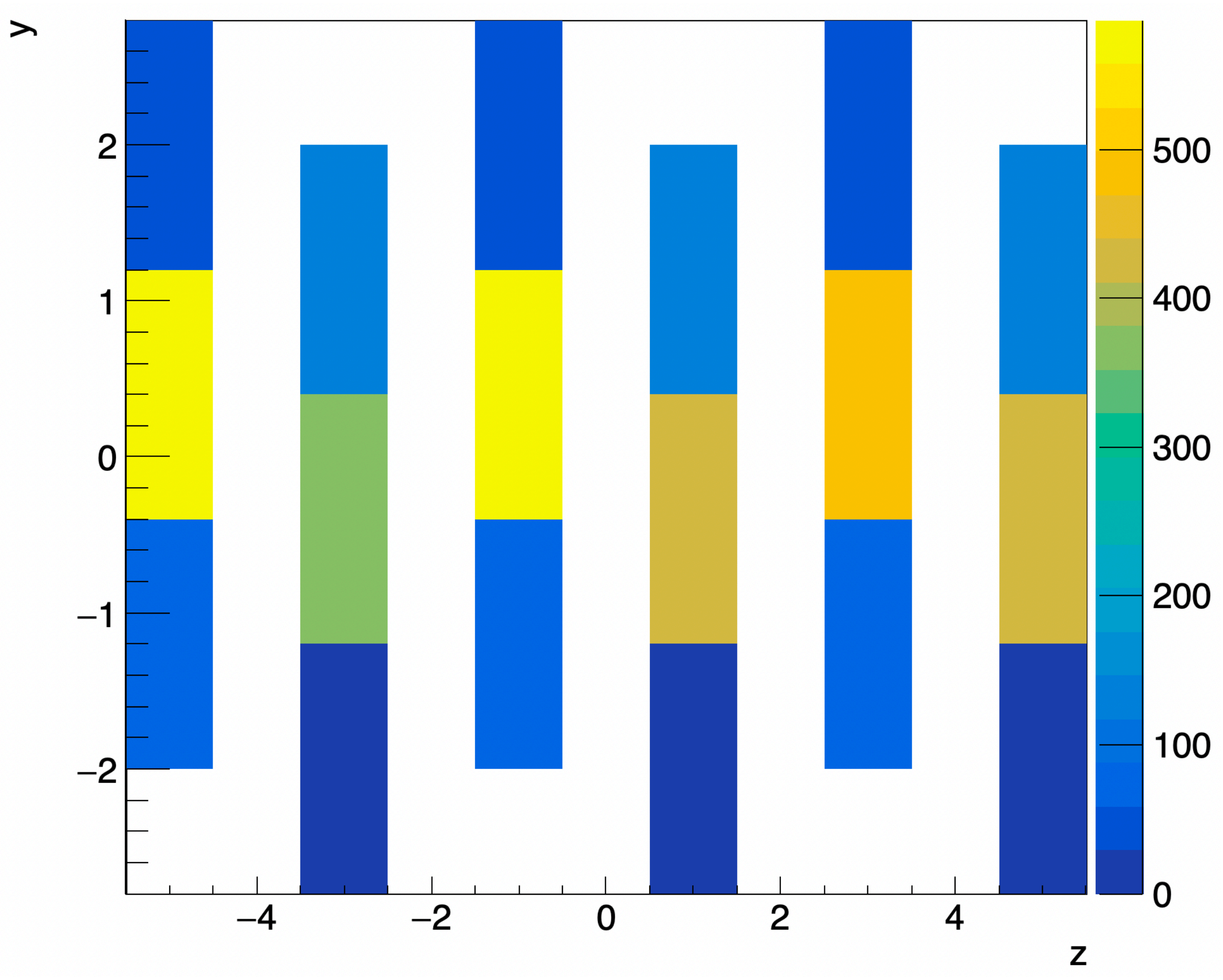
- Measure the beam direction and impinging position on the target
- Resolve VTX pile up

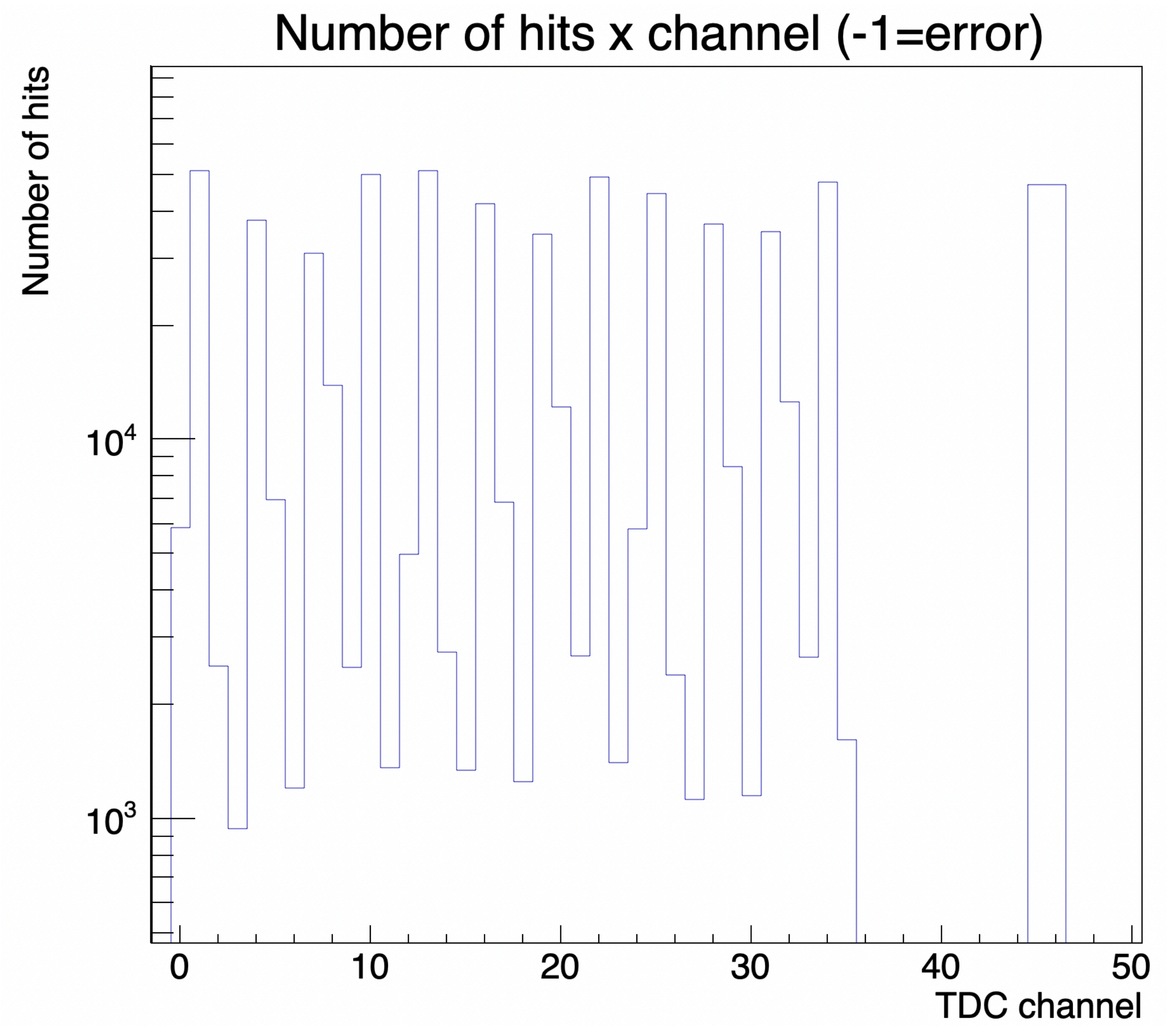
Drift chamber geometry

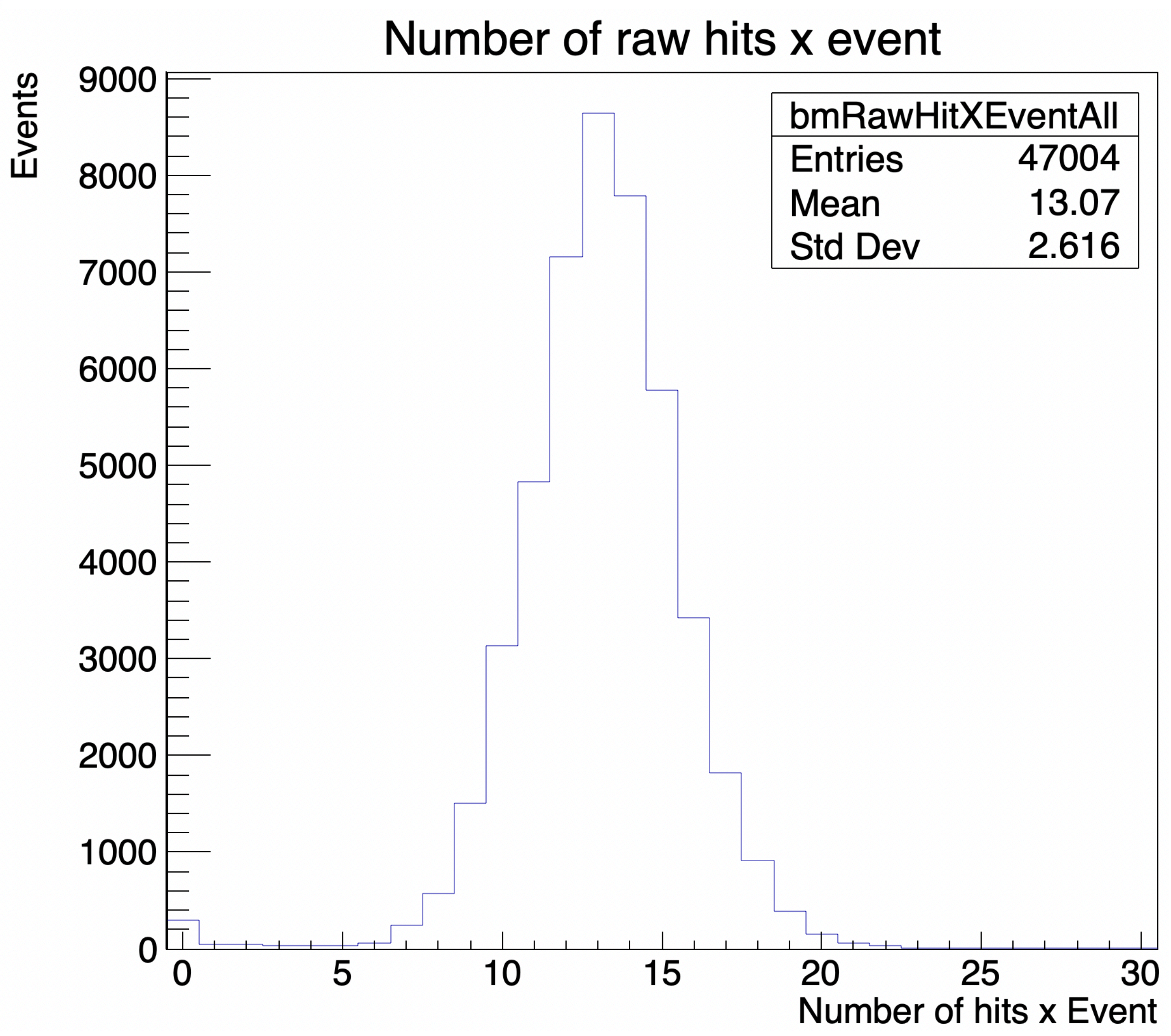
- 6 staggered layers of cells on X and Y view
- 3 cells (16 mm x 10 mm) x layer
- Contiguous BM layers of the same view are staggered by a half of a cell
- Field wires d ~ 90 μm, sense wires d ~ 25 μm

BM @ CNAO2024









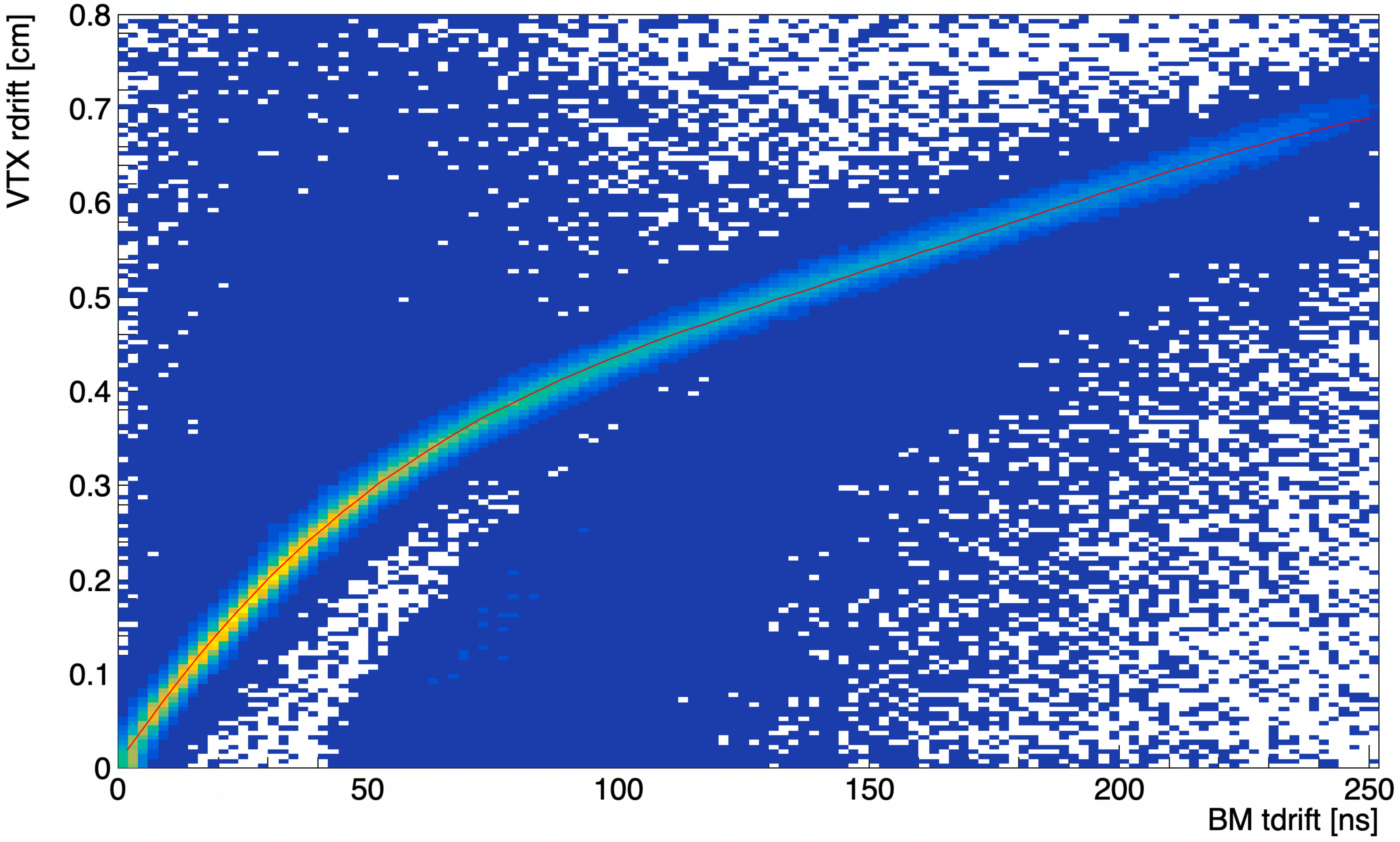
Detector status

- New lemo cables 3 m long
- NO issues for the gas flow (as in CNAO2023)
- Dead channel (discovered in CNAO2023) successfully repaired

Working point

- The HV has been modified for different beam particle/energy combination in order to obtain a number of hits per events distribution centred in 13-14 hits
- In principle: 12 hits from the primary + 1-2 hits from noise (delta rays etc.)

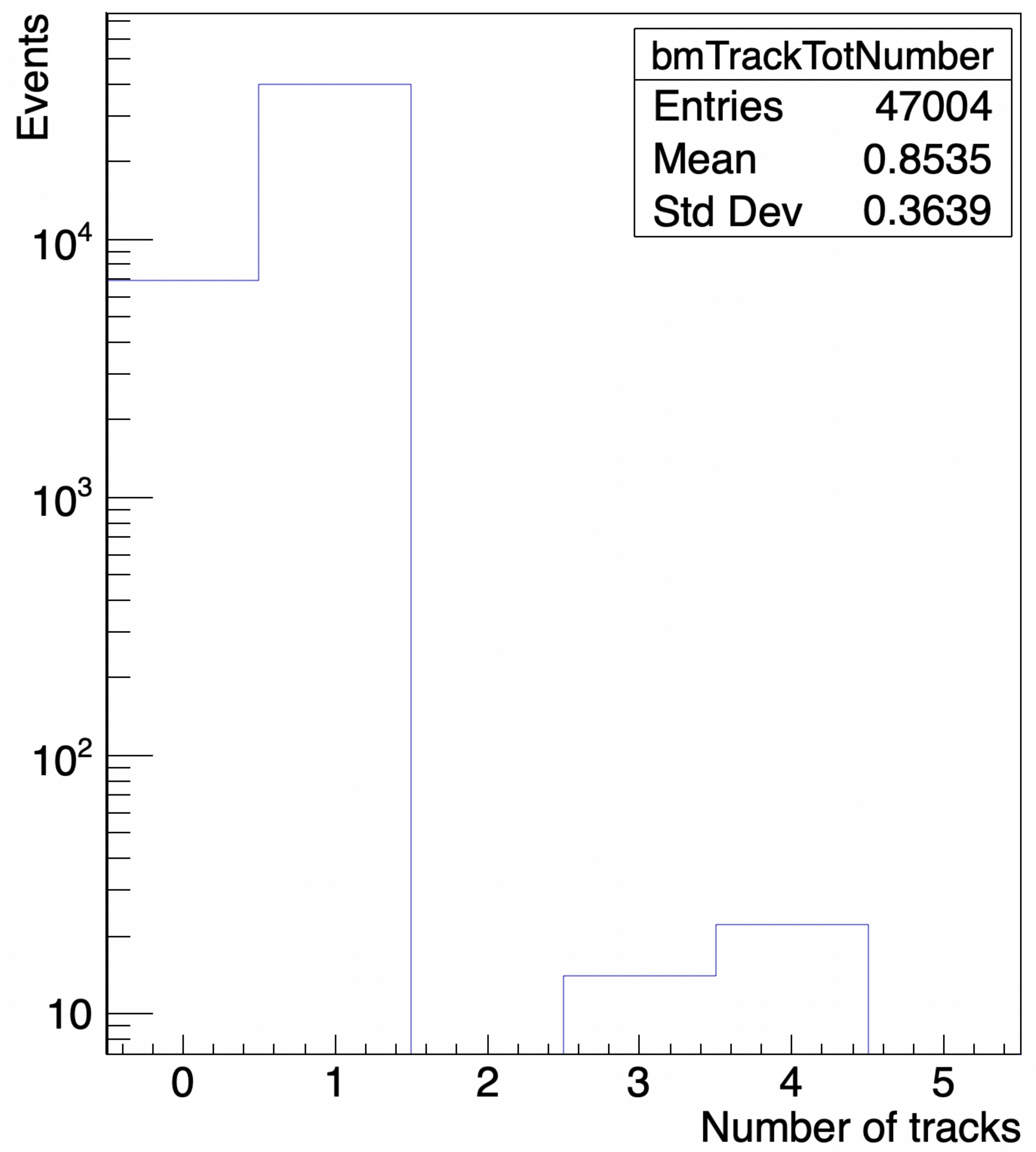
Space time relation

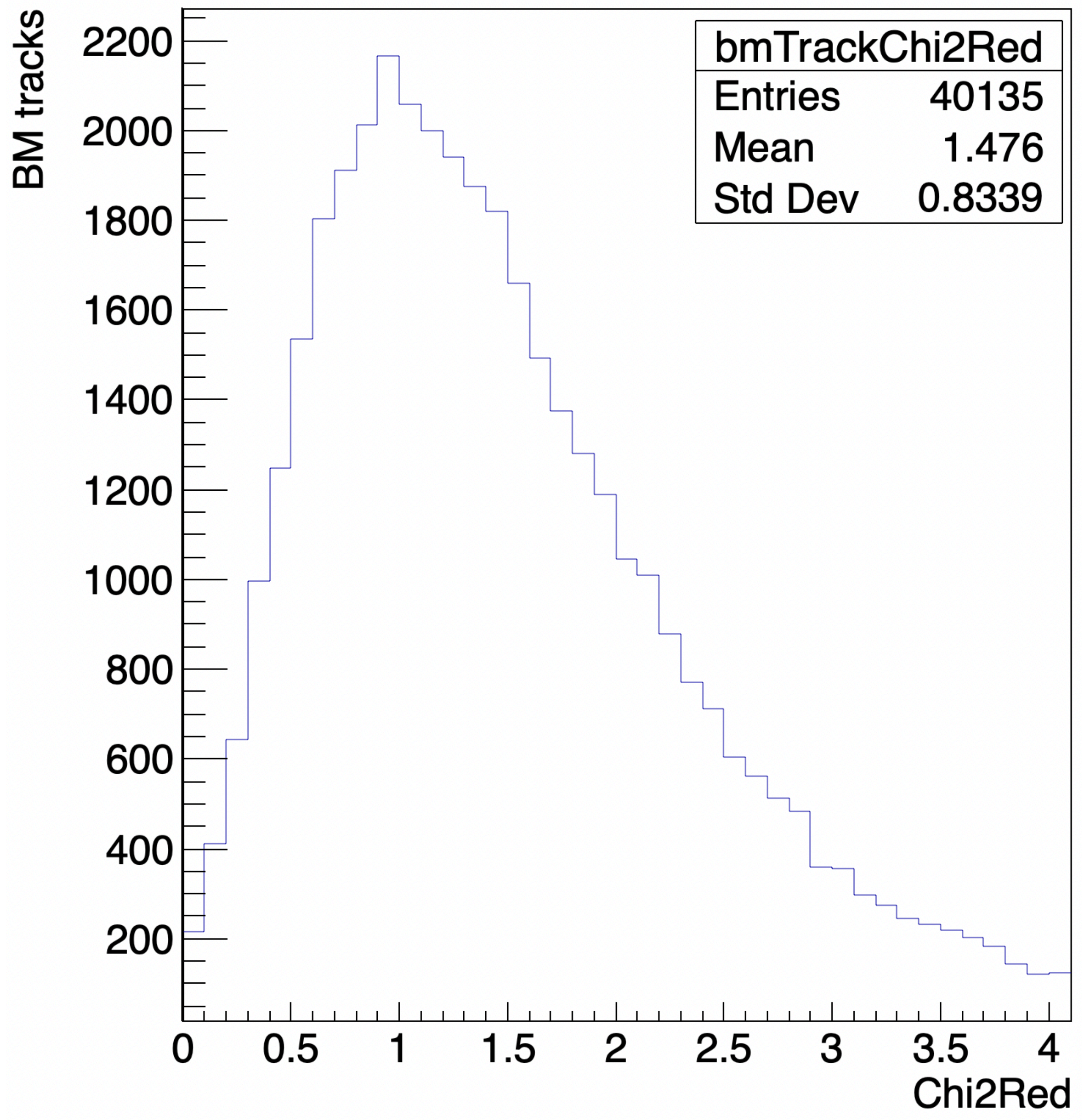


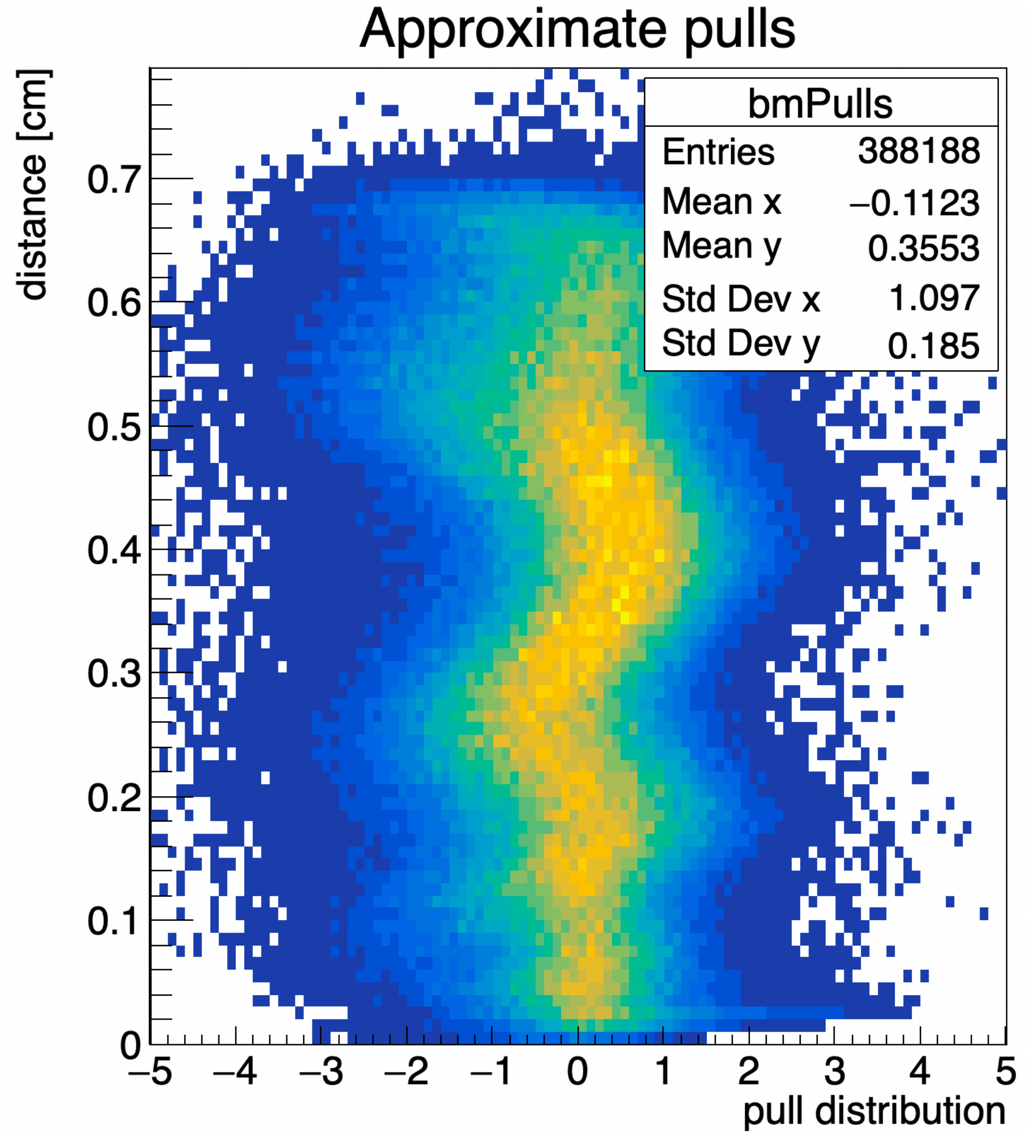
Space-time relation optimization

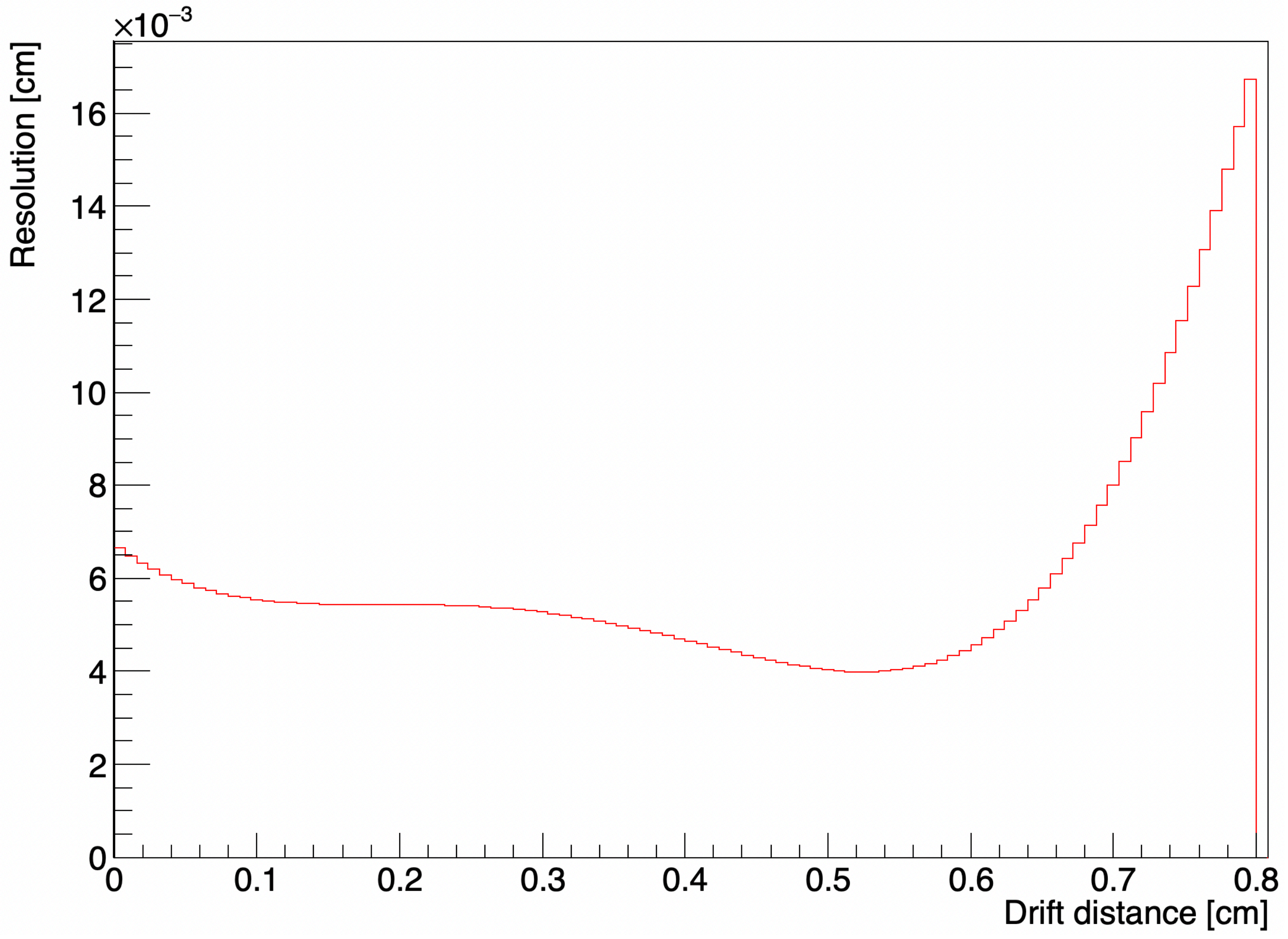
- Space time relations calculated combining BM time measurements and VTX tracks
- Need alignment, that is done by means of BM and VTX tracks —> iterative method
- Initial S-T relation guess from CNAO2023 campaign is suitable for CNAO2024 (one iteration seems to be sufficient)
- ST rel are different for different particles (also due to different HV levels)
- S-T rel. optimization conducted during the data taking in few minutes
- No relevant differences has been found for P @ different energies

Tracking performance



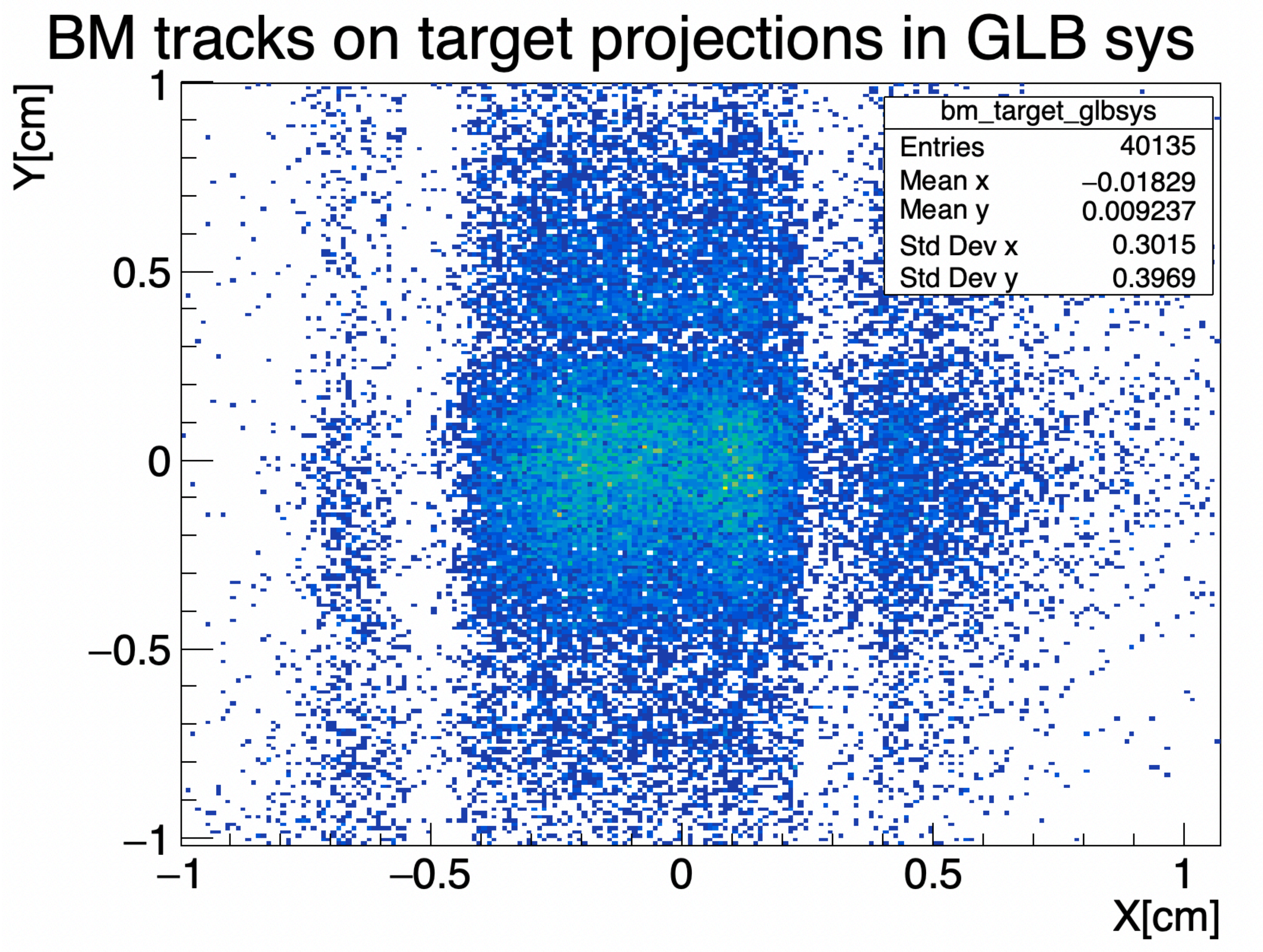


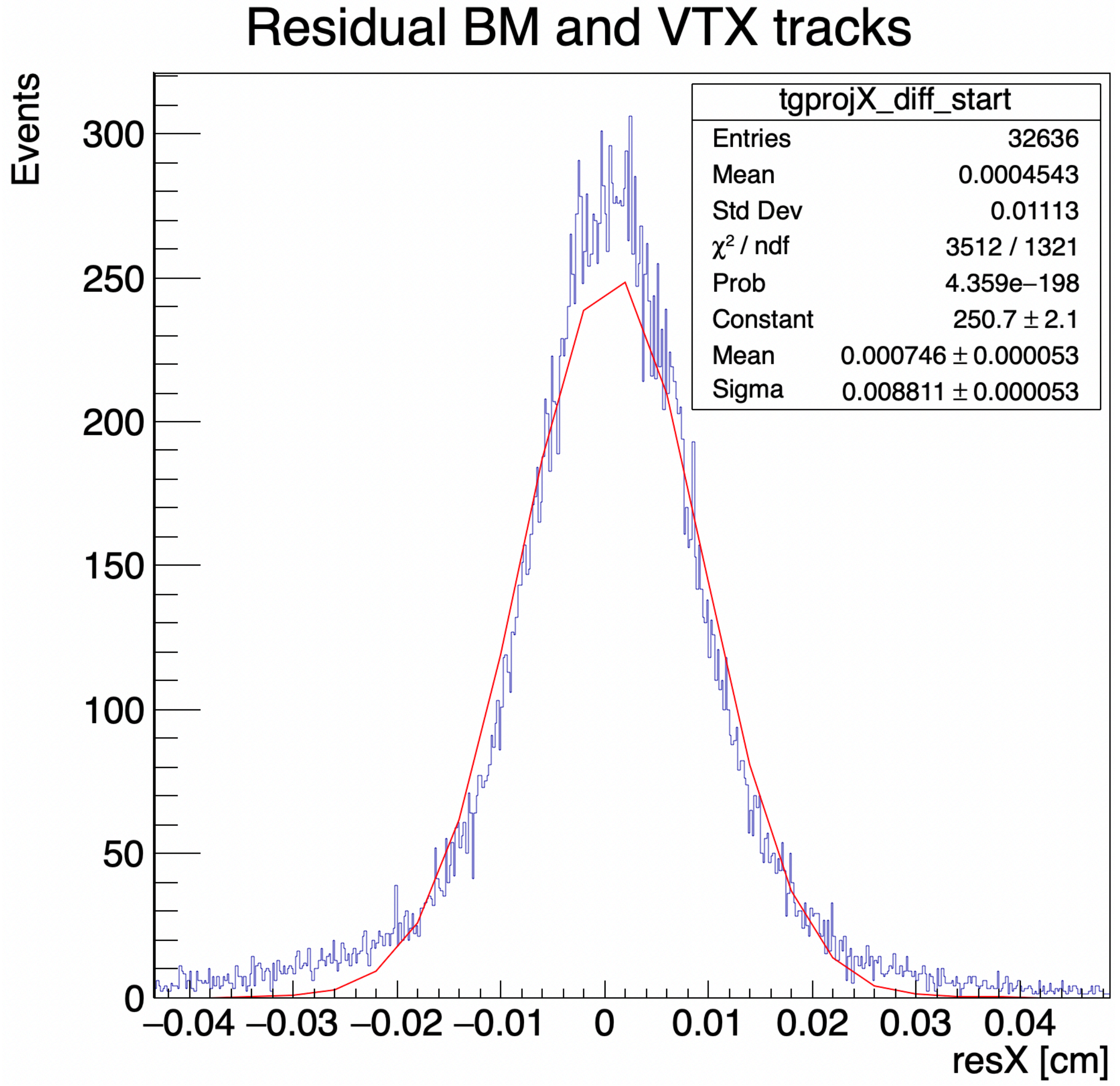


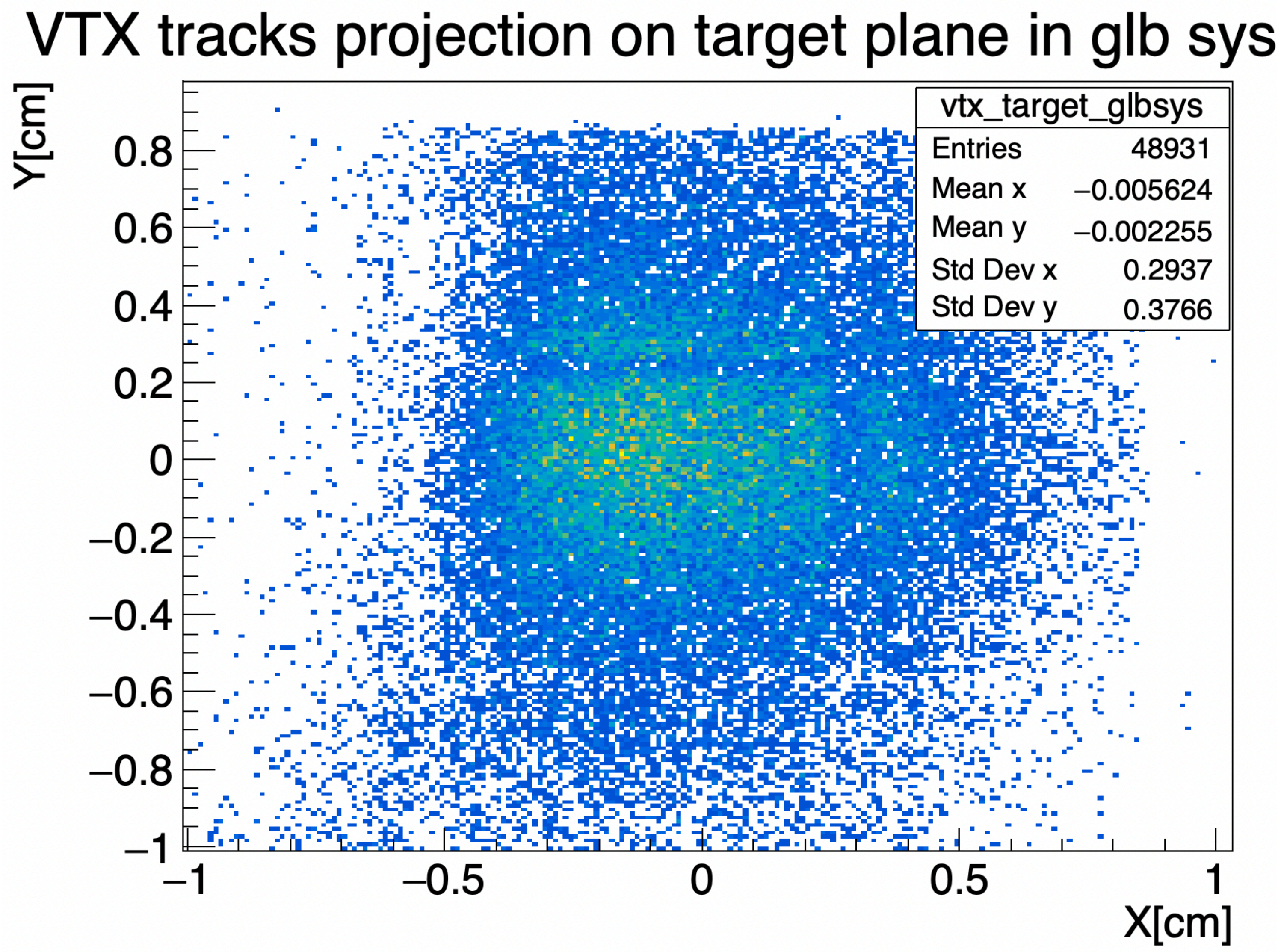


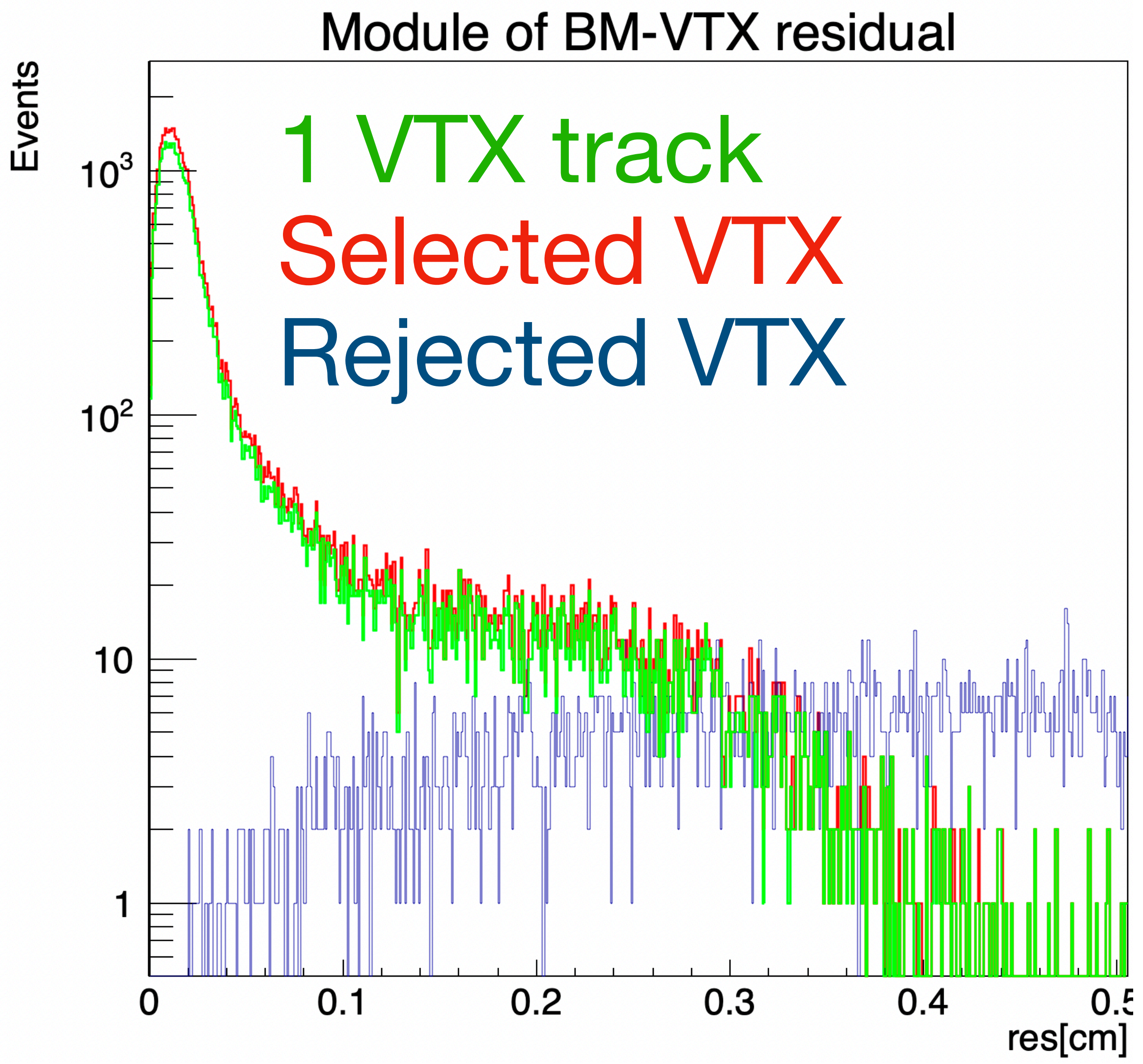
- **BM track efficiency for 12C @ 200 MeV/u ~ 85-90%**
- S-T rel already optimized
- Spatial resolution evaluated with the residuals between the BM measured and fitted positions
- **Spatial resolution of the order of 50 μm up to 0.6 cm, then it decreases rapidly with increasing drift distances**
- The pull distribution has a devstd close to 1 for almost all the drift distances
- Room for improvement optimizing the track reconstruction parameters:
  -track selection matrix binning, track parameters range etc.
  -Need time to optimise this parameters and we can expect only a slight improvement of the results

BM-VTX





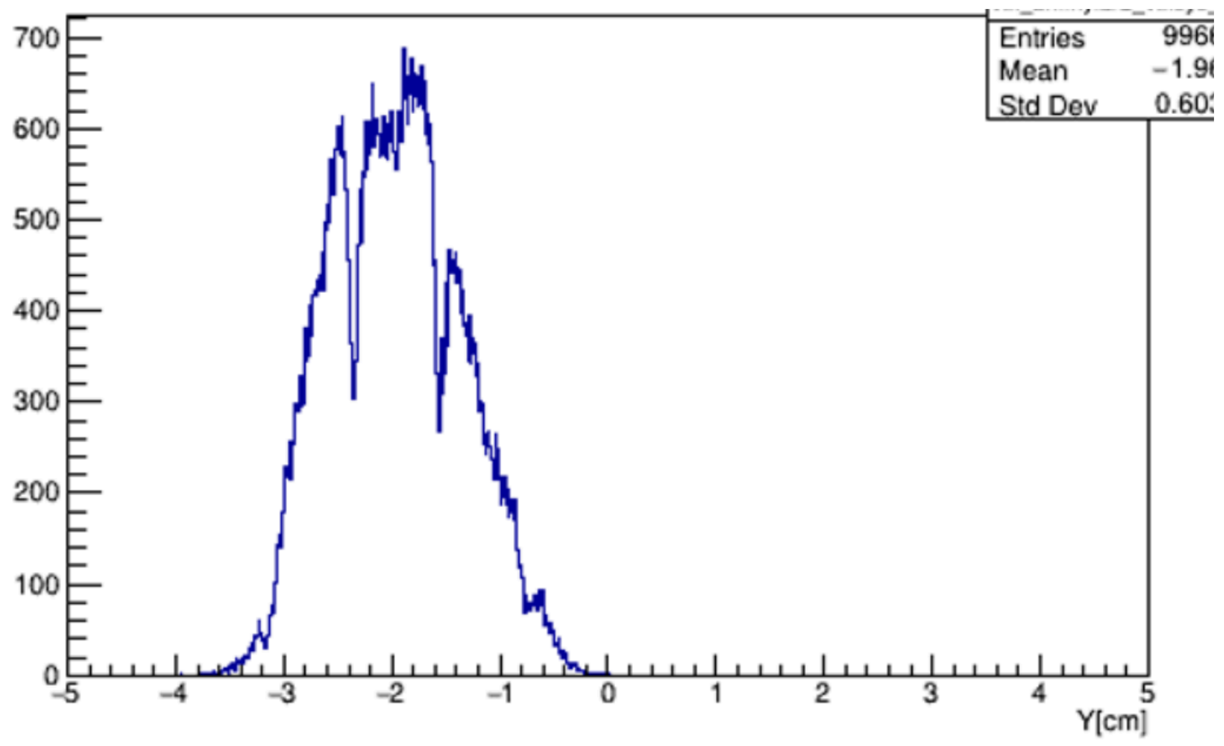




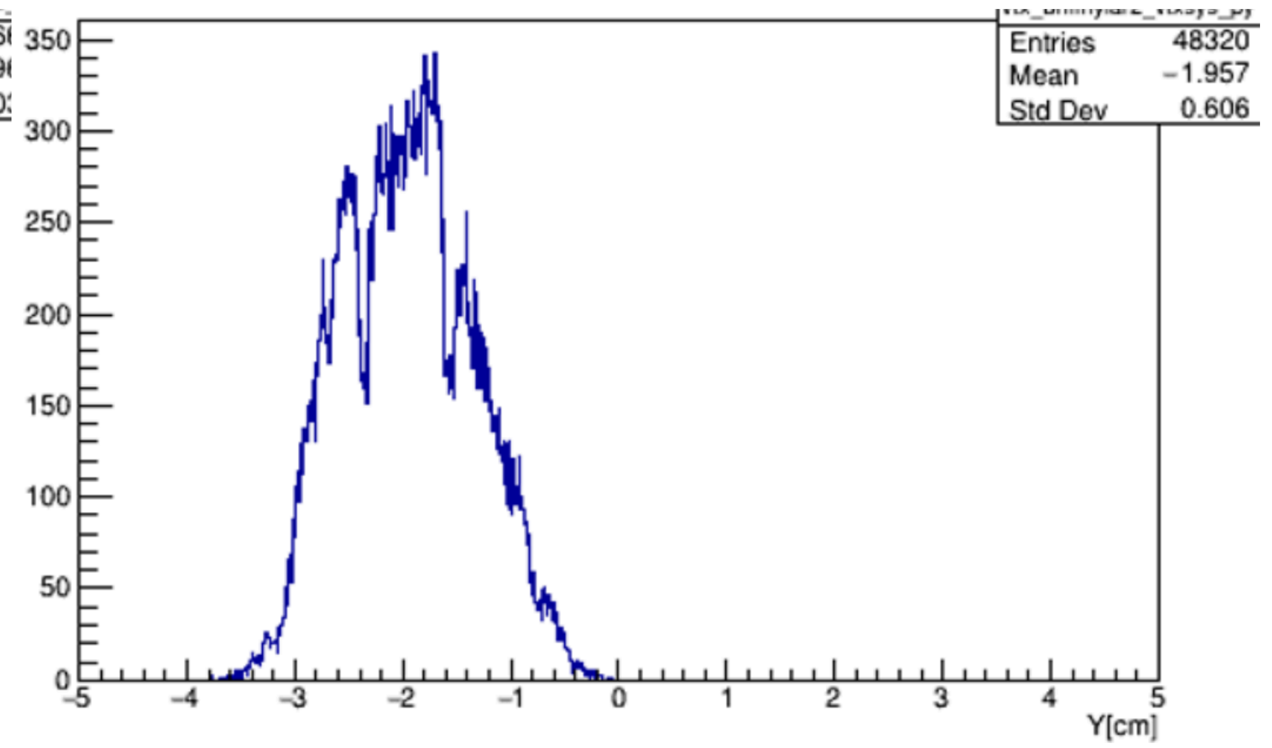
- Residuals between BM and VTX of the order of 100 μm
- Low VTX pile up
- Both detector show holes in the beam profile due to the BM wires

BM wire profile from other detectors

MSD beam profiles collected @ Trento with p @ 80 MeV



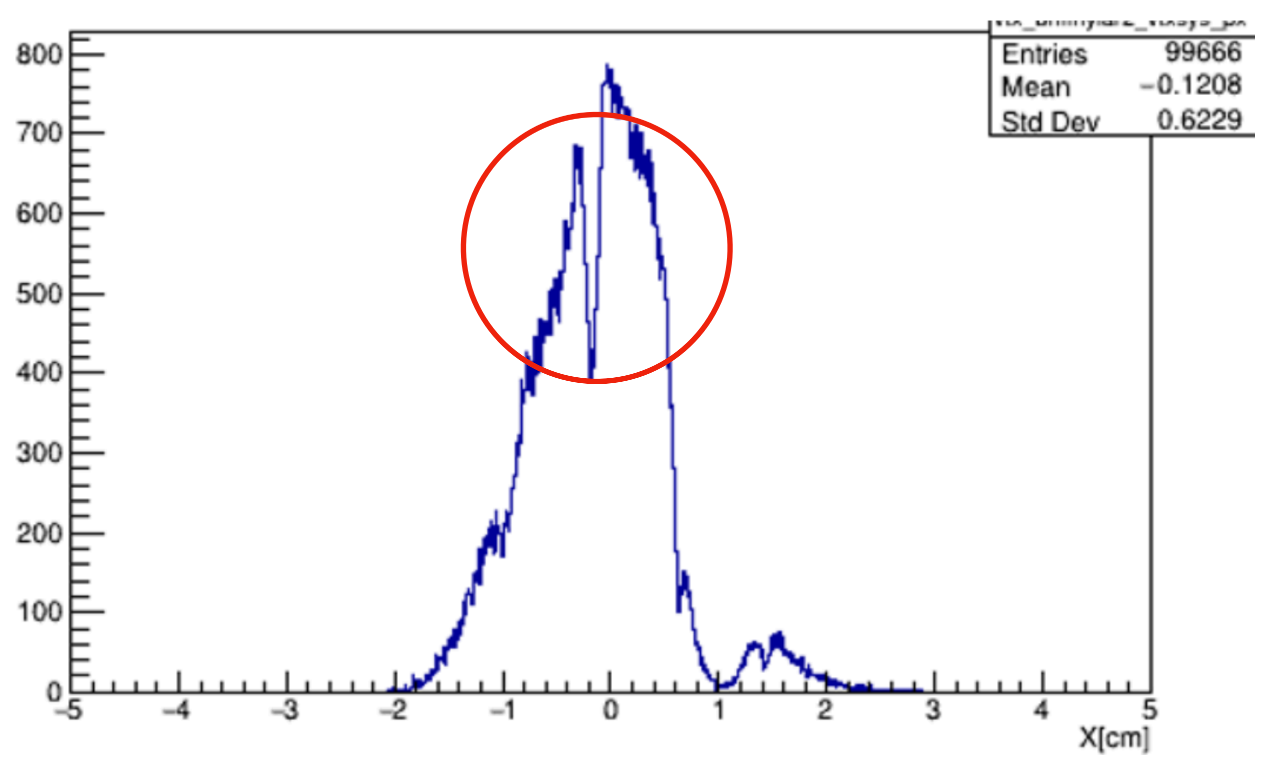
Y view, no BM tilt



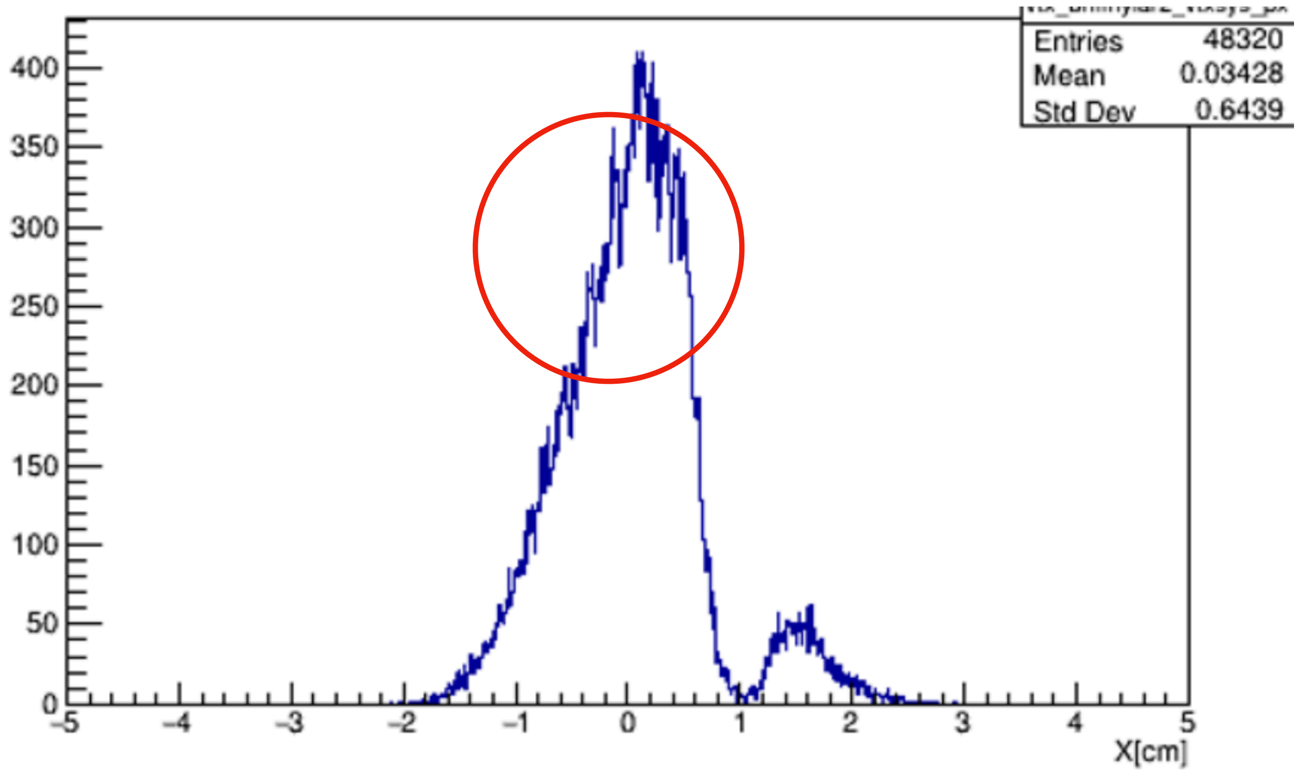
Y view, with BM tilt on Y

- During the BM characterisation data taking conducted @ Trento with protons and with a MSD like detector, we tilted the BM on one view and the grid detected by the MSD disappeared on one view

- BM wire shadow detected by different detectors with different particles

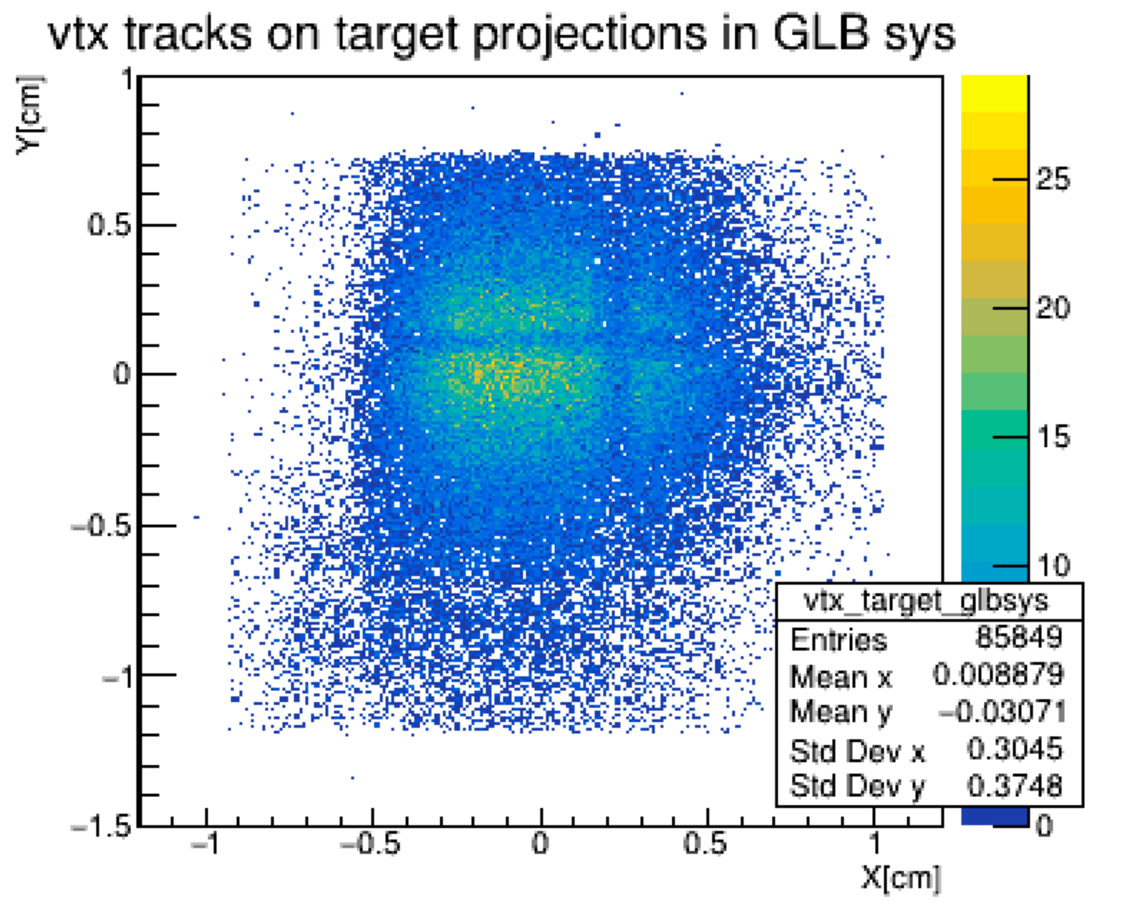


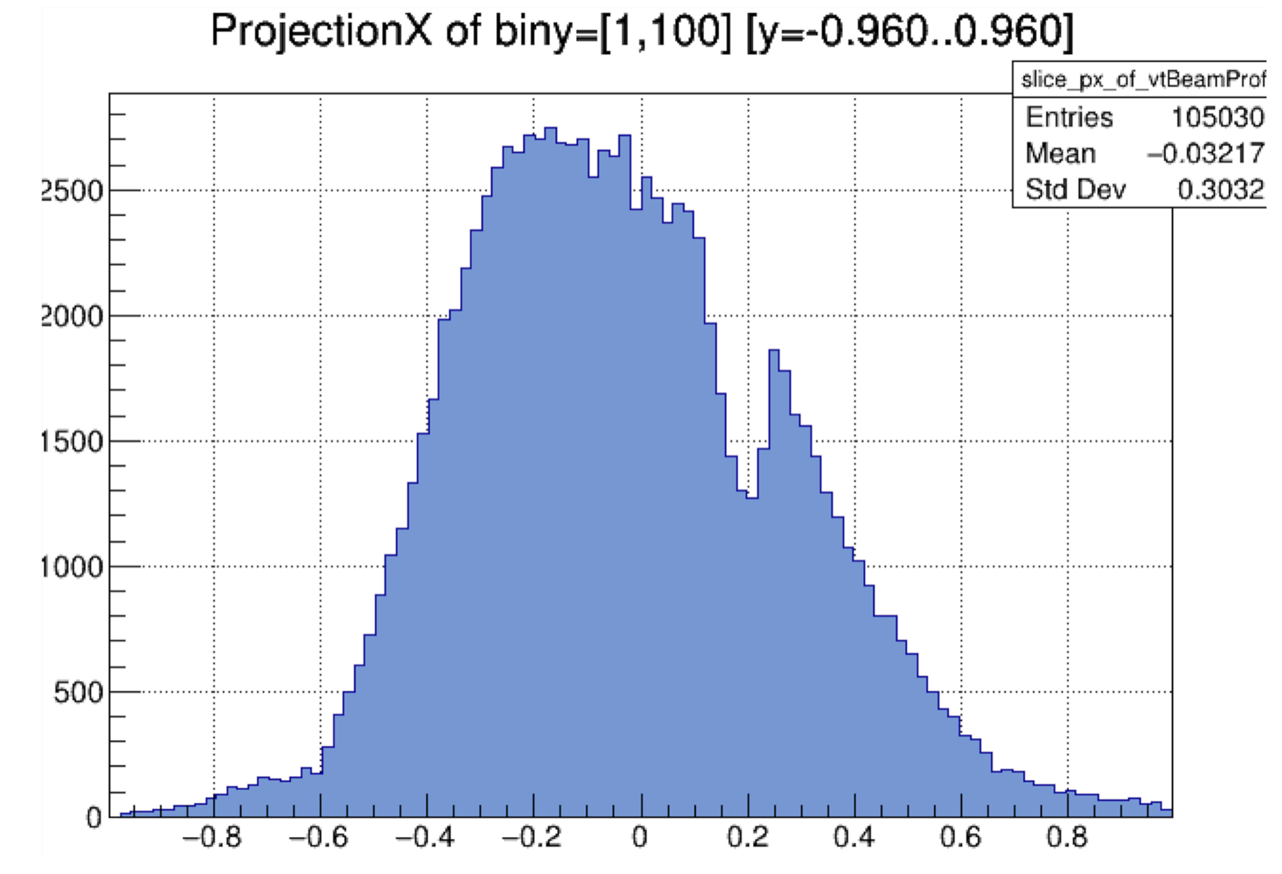
X view, no BM tilt



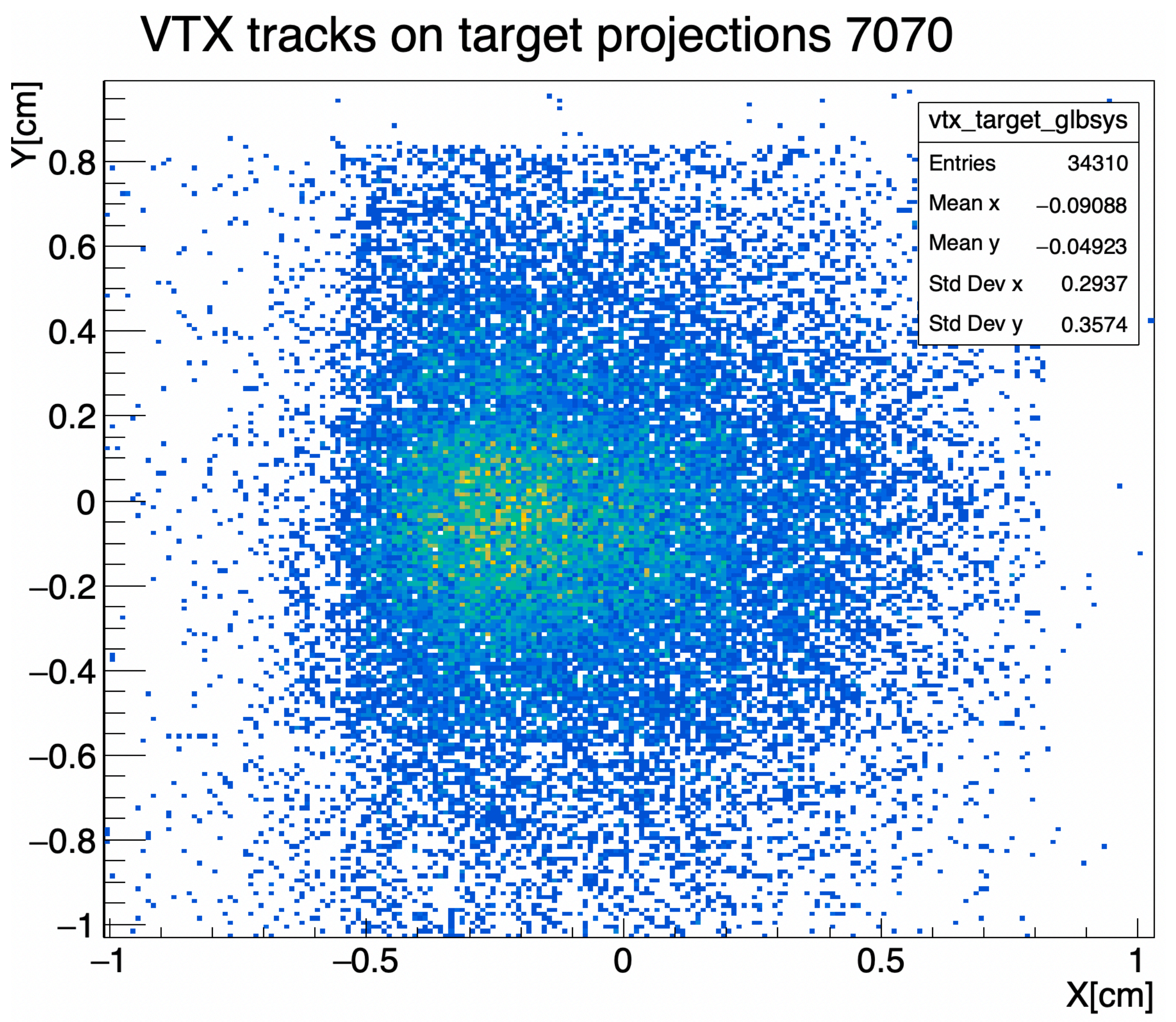
X view, with BM tilt on Y

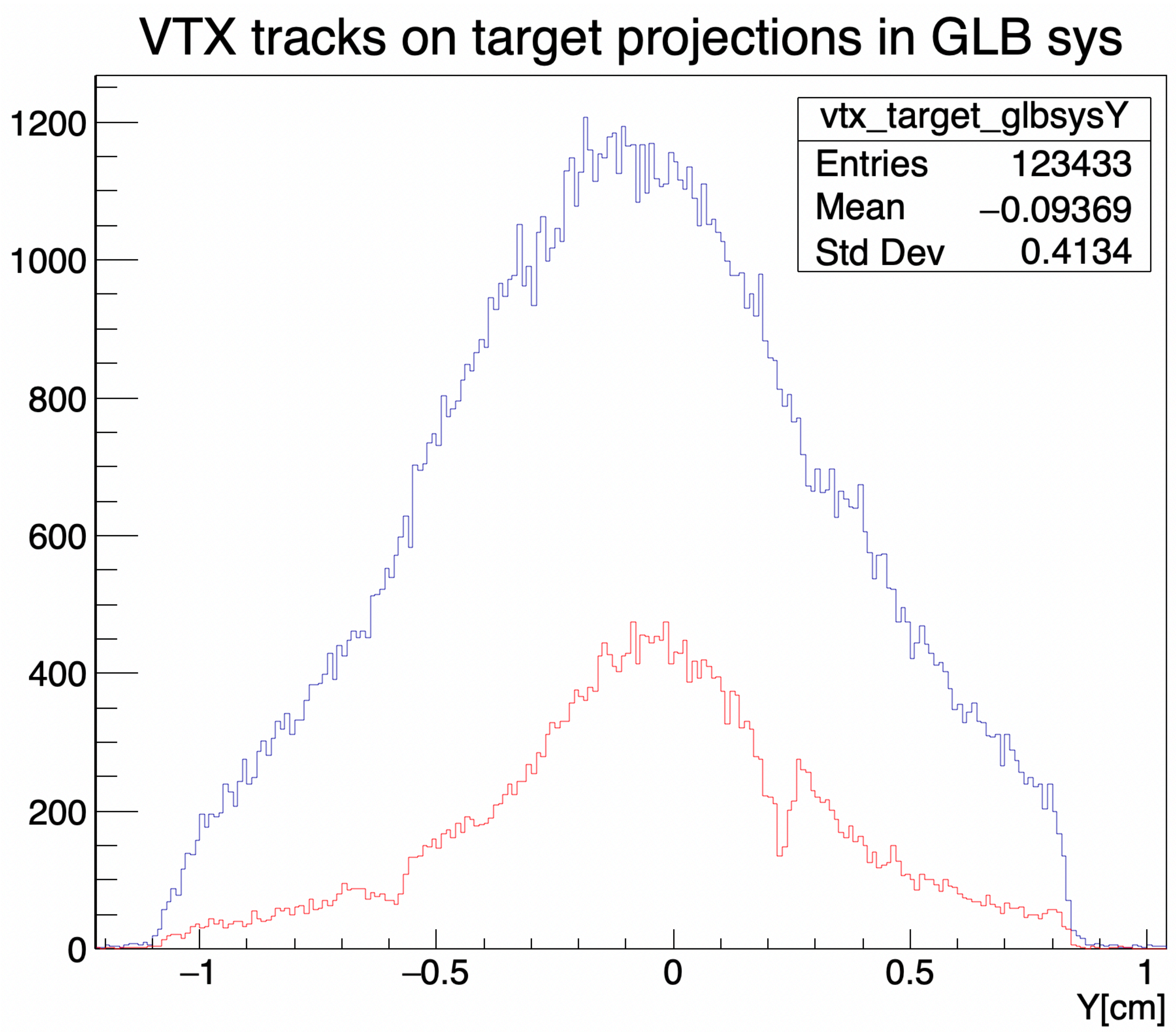
VTX beam profile @ CNAO23

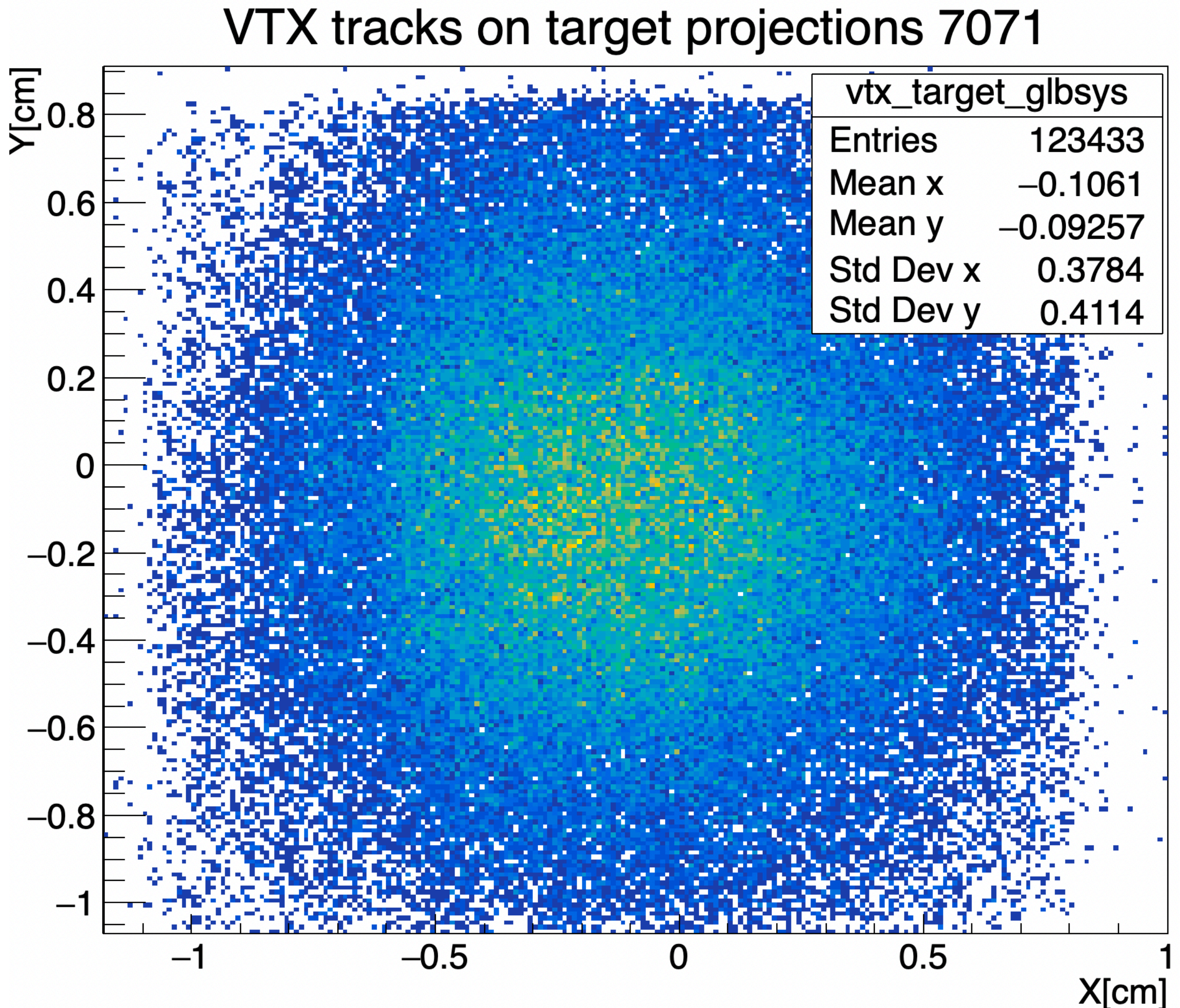




BM wire shadow



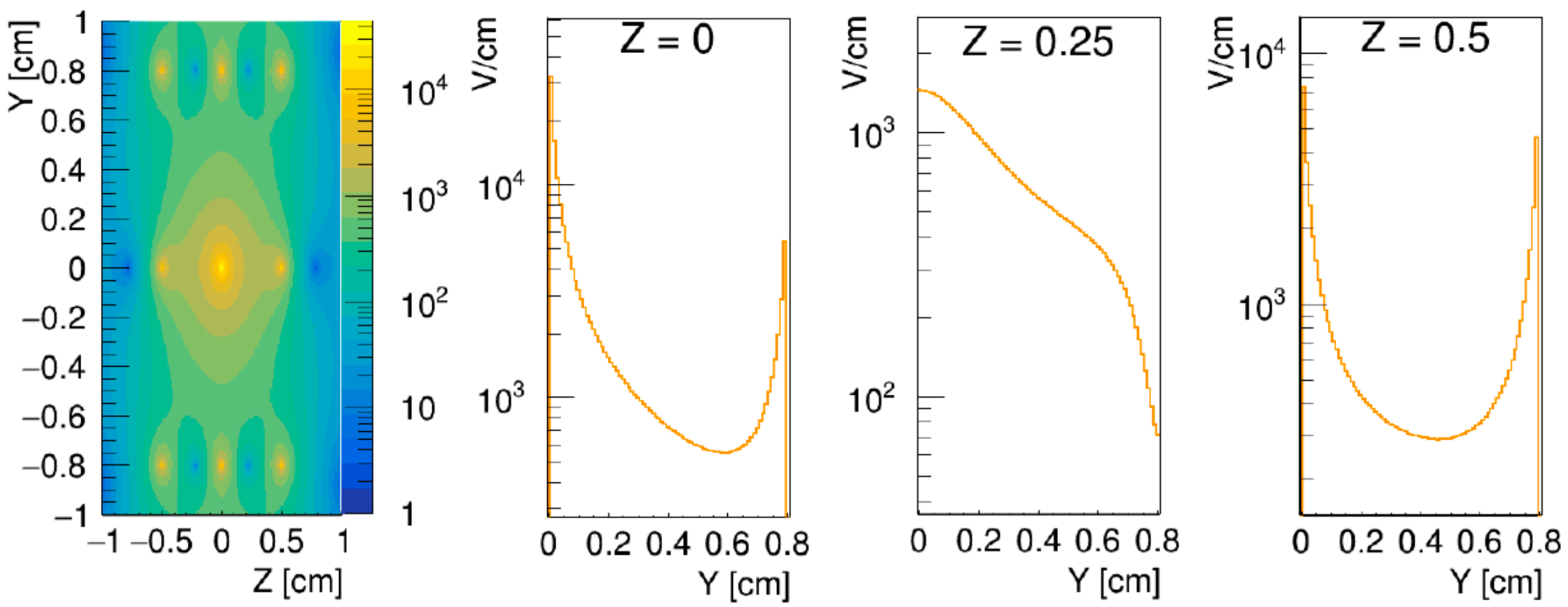




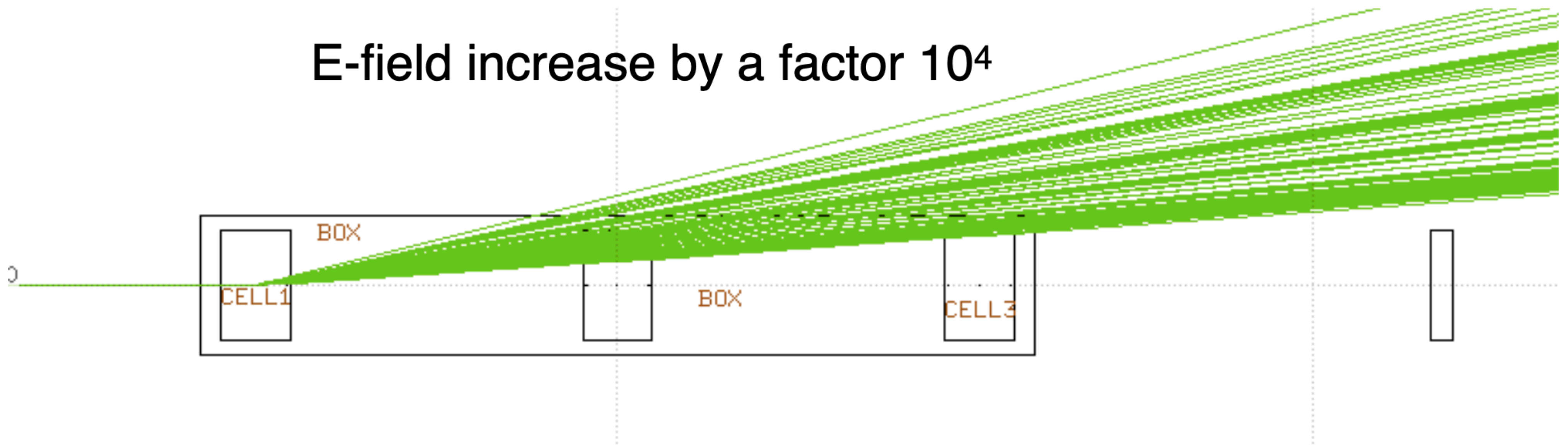
- Run 7070: 12C @ 200 MeV/u, beam checked and adjusted on the X axis of about 1 mm. No emulsion setup on the beam line, BM HV: 1740 V
- Run 7071: 12C @ 200 MeV/u We turned off the BM and added the emulsion between BM and SC
- The beam was well centred in the BM cell, however the BM wire shadow is present in the 7070 run (BM half cell size ~ 8 mm)
- **No BM wire shadow without the BM HV**
- Wire shadow due to the electric field effect? We need to re-check our previous calculations
- Maybe the BM inefficiency and low spatial resolution at the cell border is influenced by this effect

Electric field effect

Electric field map evaluated by means of Garfield++ MC simulation tool with the BM HV at 2200 V



E-field increase by a factor 10^4



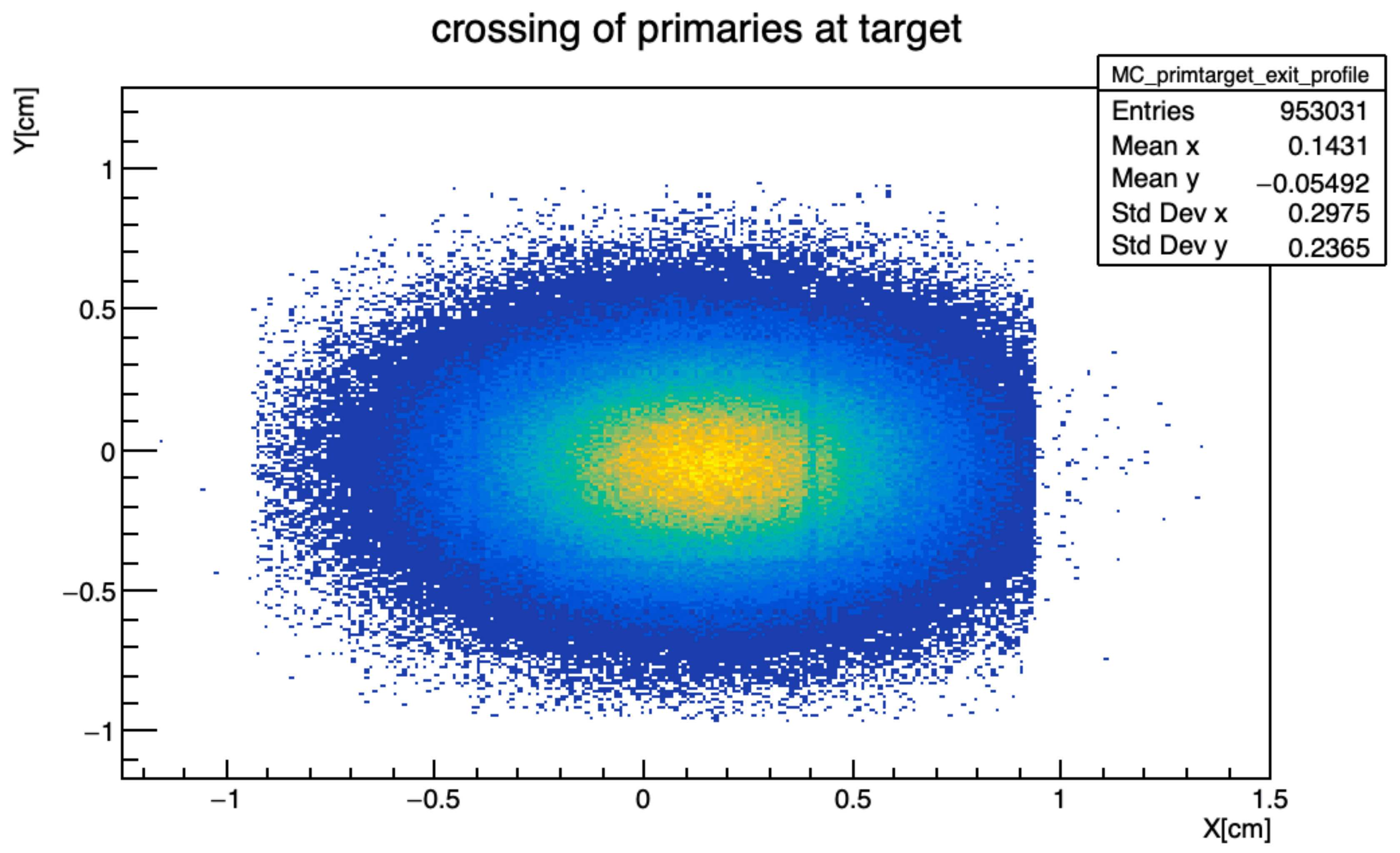
Deflection is a function of "impact parameter" of the incoming particle with respect to the sense wire

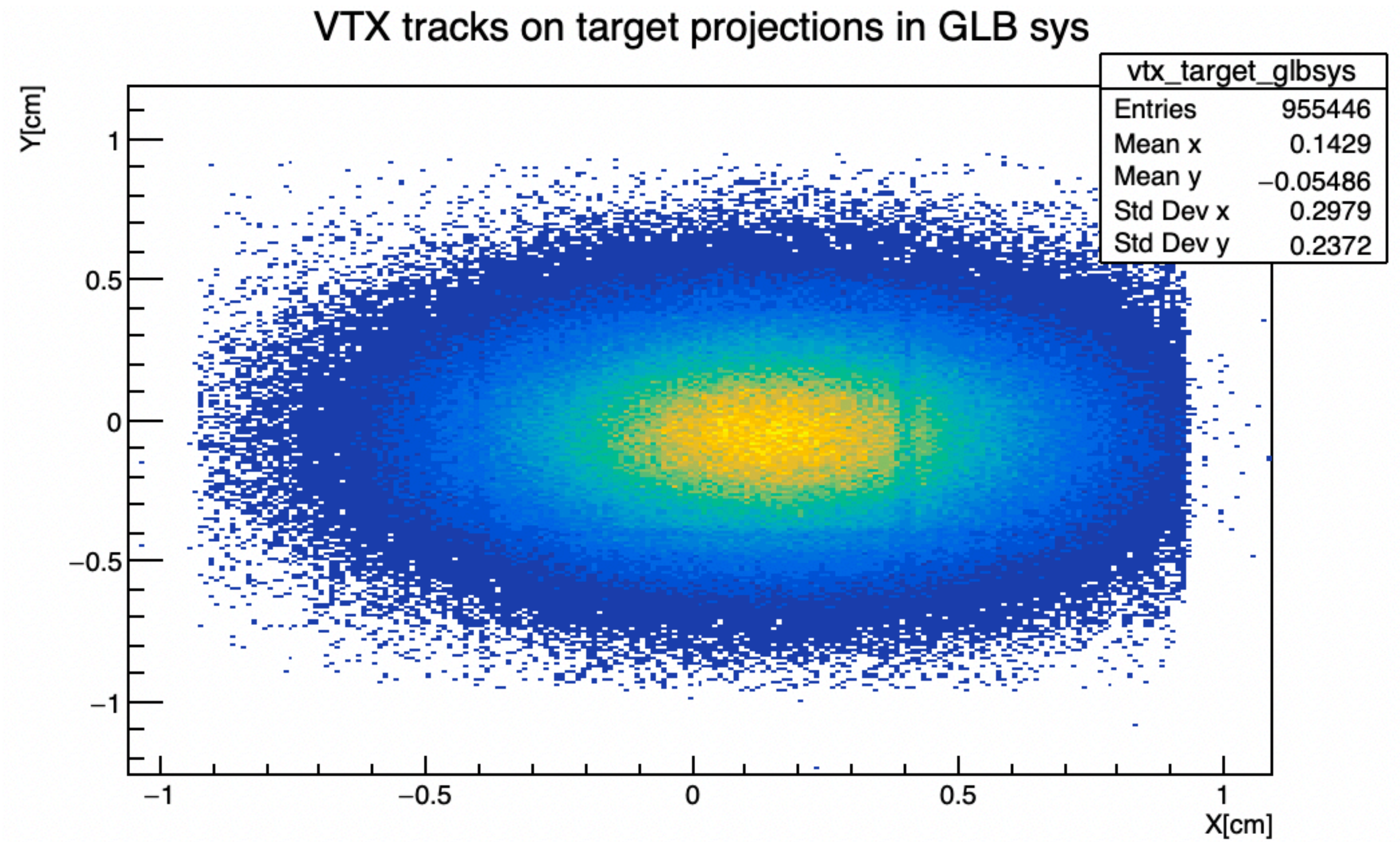
- The high electric field close to the sense wire could contribute to the deflection of a charged particle?
- In the space region close to the sense wire E(r) is very similar to that of a wire of radius a inside a cylindrical cathode of radius b:
  $E(r) = V/(\log[b/a]\, r)$ —> $E(a) \sim 294$ kV/cm ($b = 0.5$ cm, $2a = 25$ µm, $V = 2200$)
- This allowed to perform a MC FLUKA simulation in vacuum (trajectory calculated numerically solving differential equation with Runge-Kutta methods).
- Result: for a ^{12}C at 200 MeV/u, the maximum deflection would be of the order ~8 10^{-5} rad
- **Significative deflection could be observed only with E greater at least by a factor of thousand, but we do not believe that the electric field is so higher with respect to our calculation/simulation**

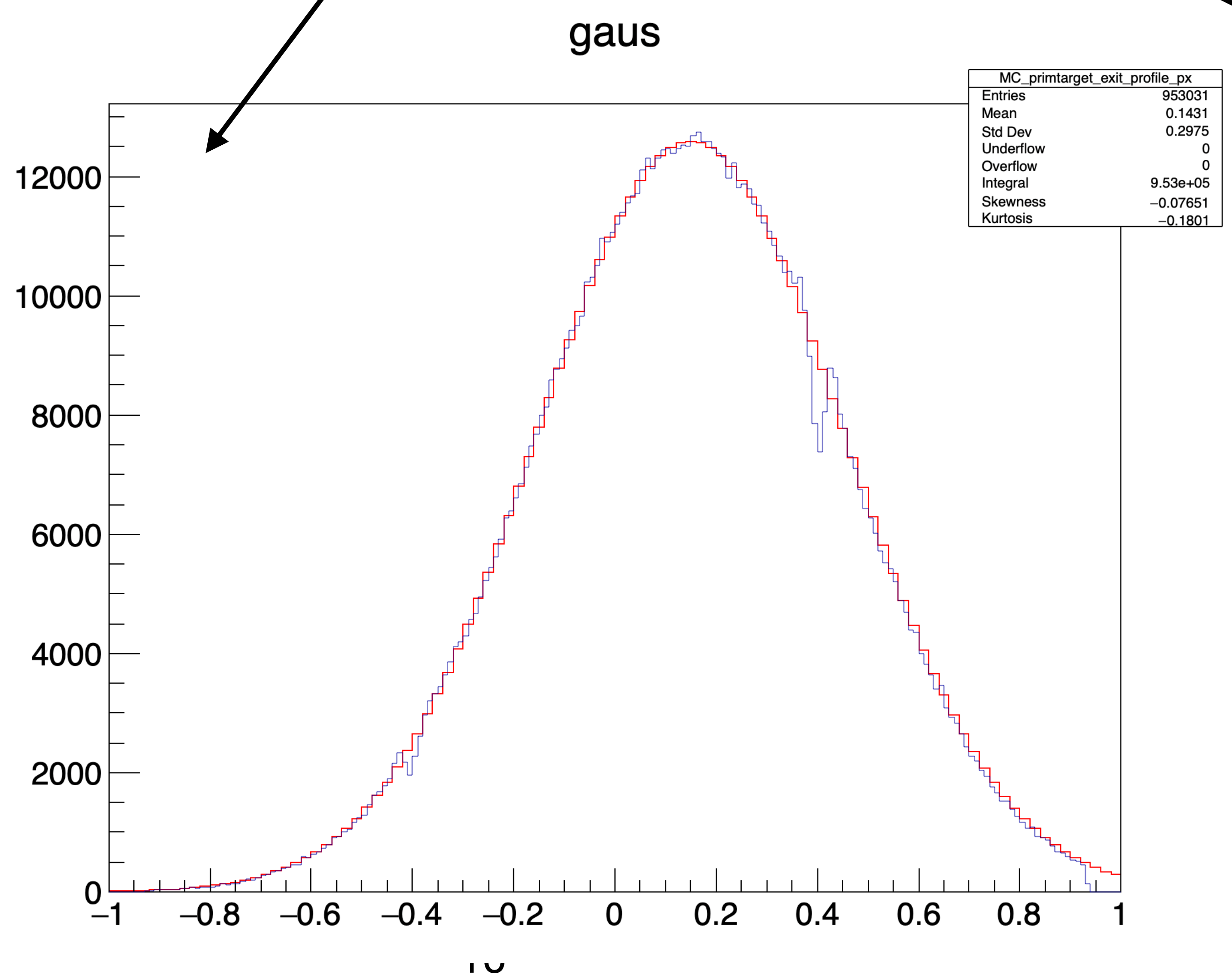
MC simulations to evaluate MCS

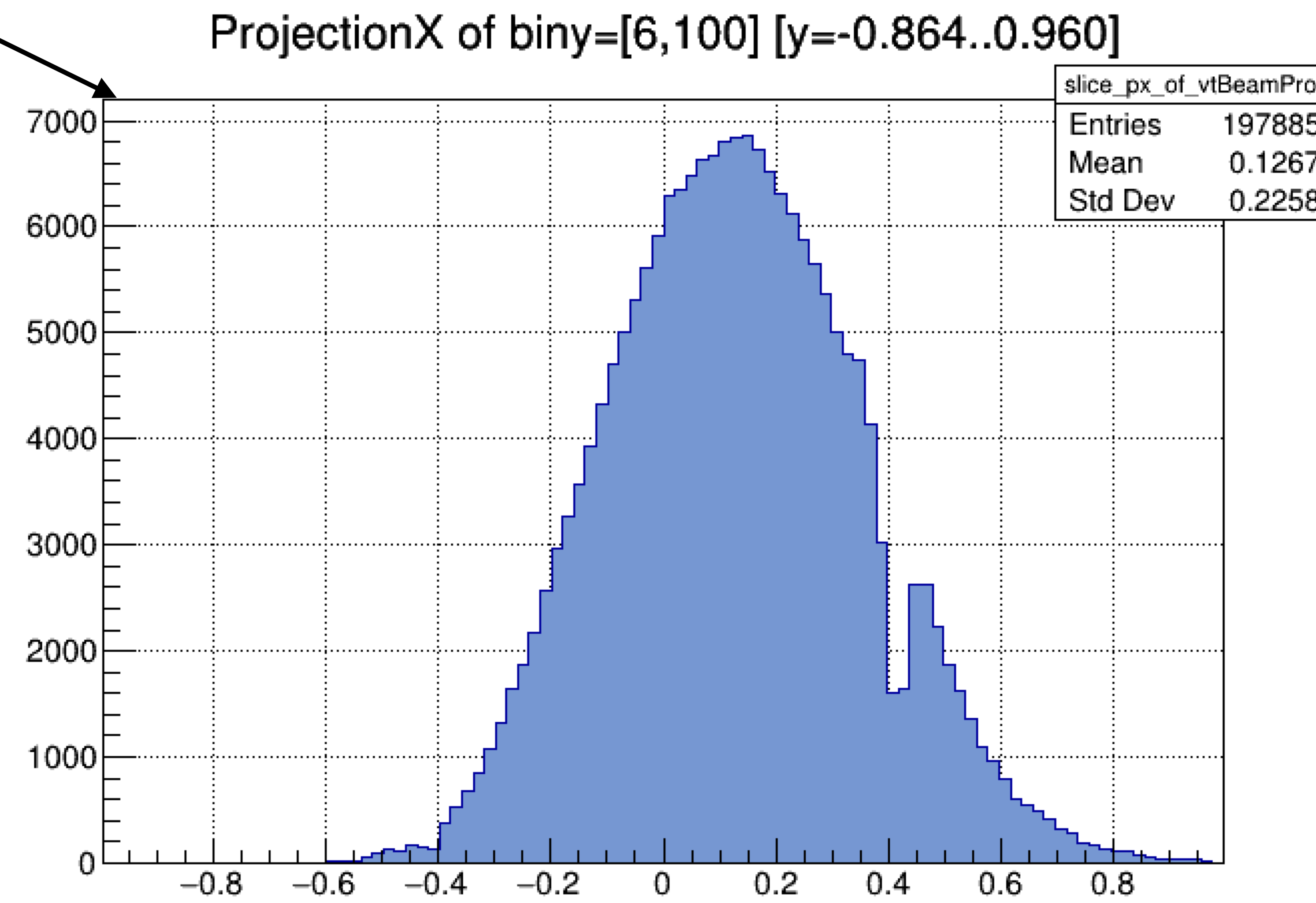
MC simulation of O @ 400 MeV/u (GSI2021)

- the MC simulations never succeed to reproduce the grid correctly: **we can see the effect, but it is not enhanced as in data**
- Grid effect mainly due to MCS
- MC simulation missing evts in hole ~ 20%
- VTX data missing evts in hole ~ 50%

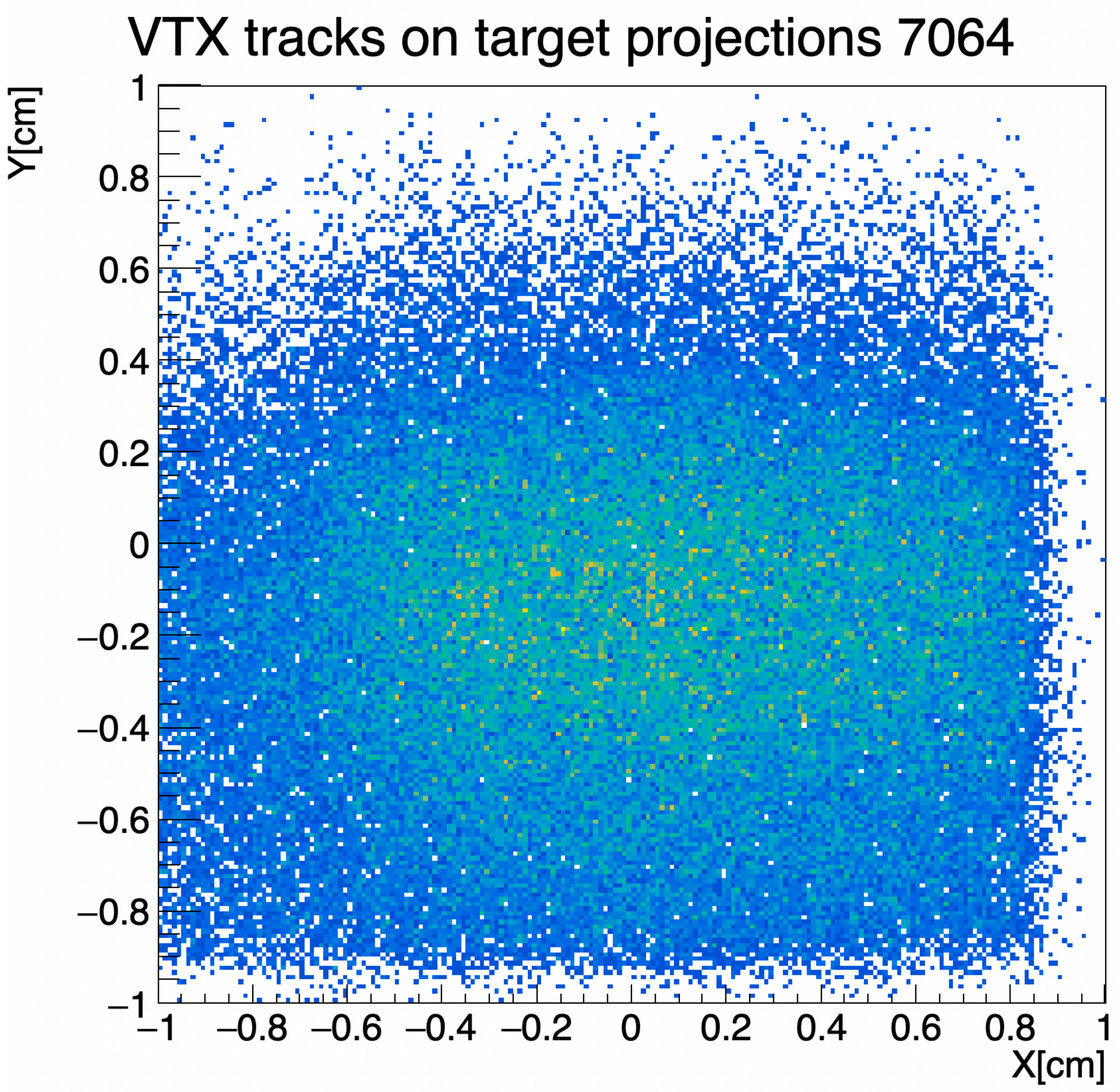


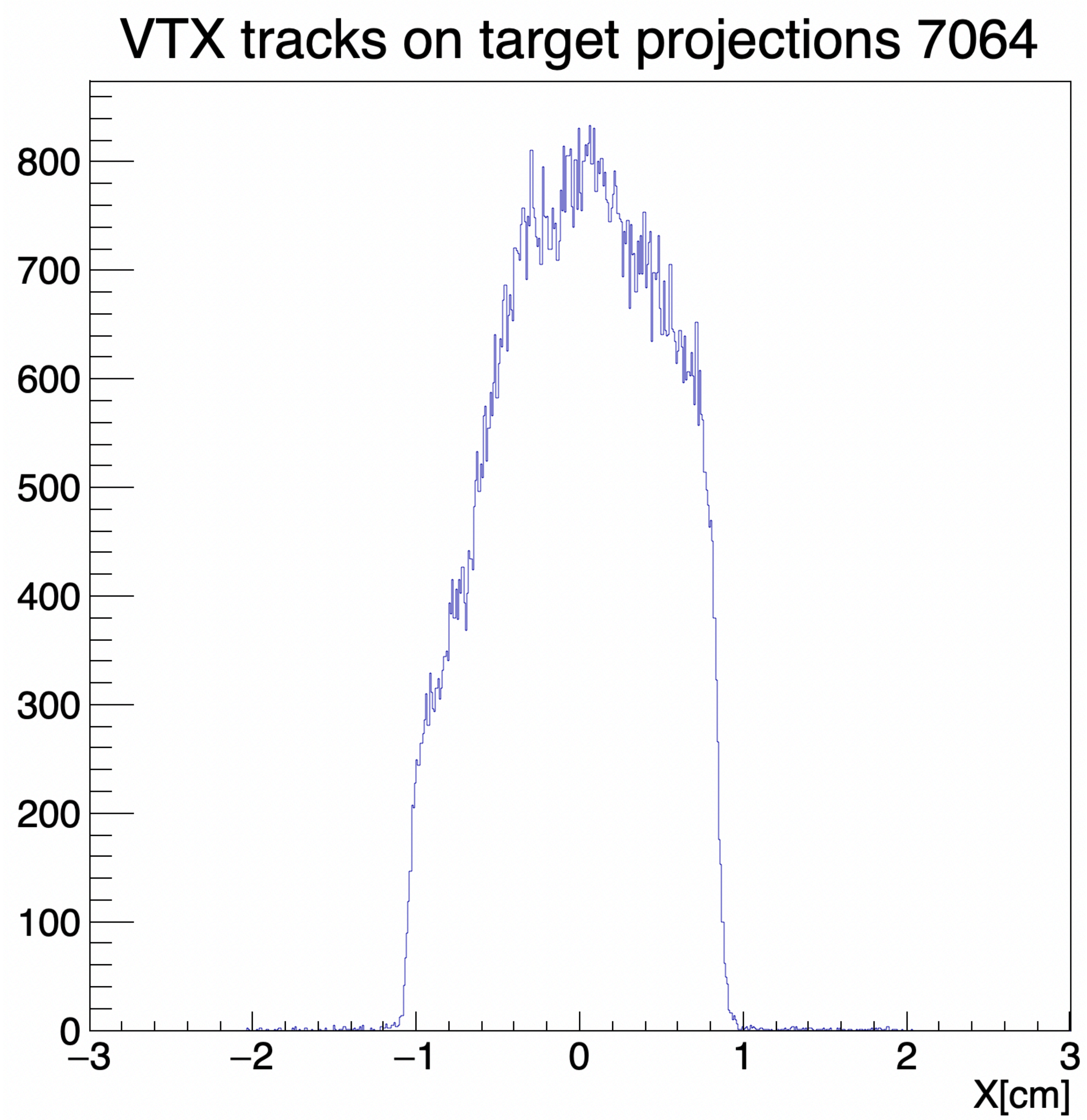


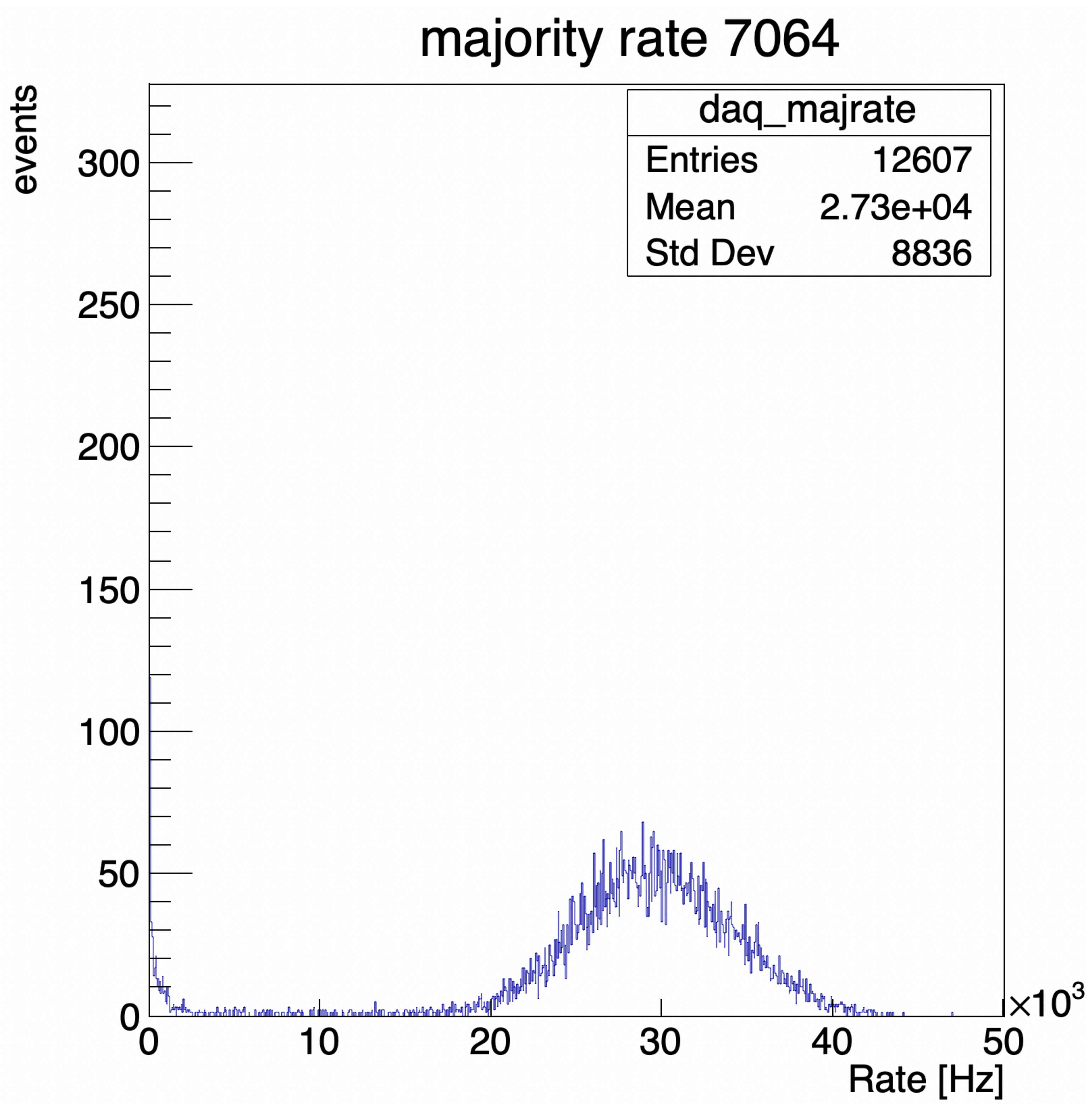




Other cases without wire shadow: 7064



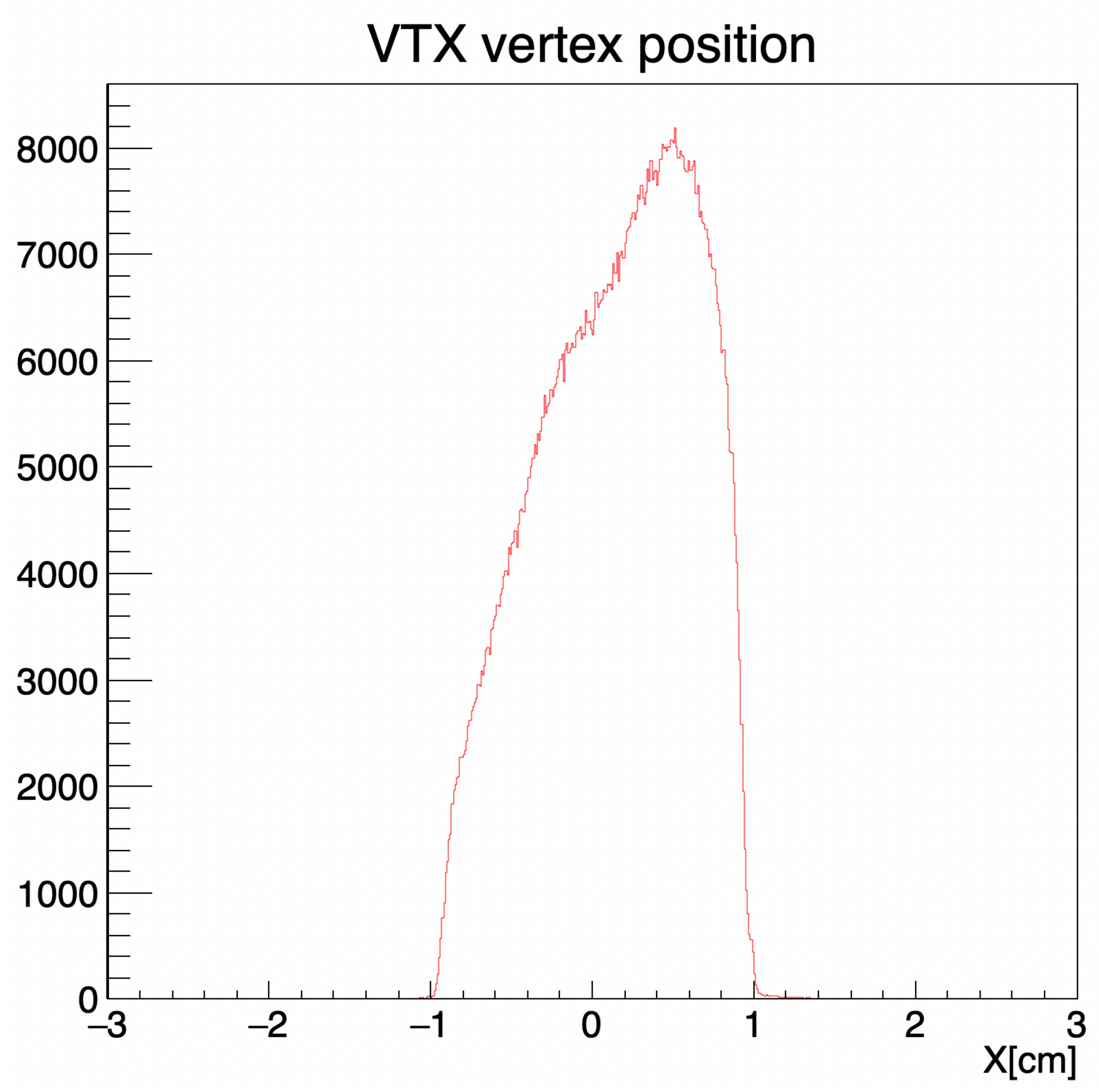


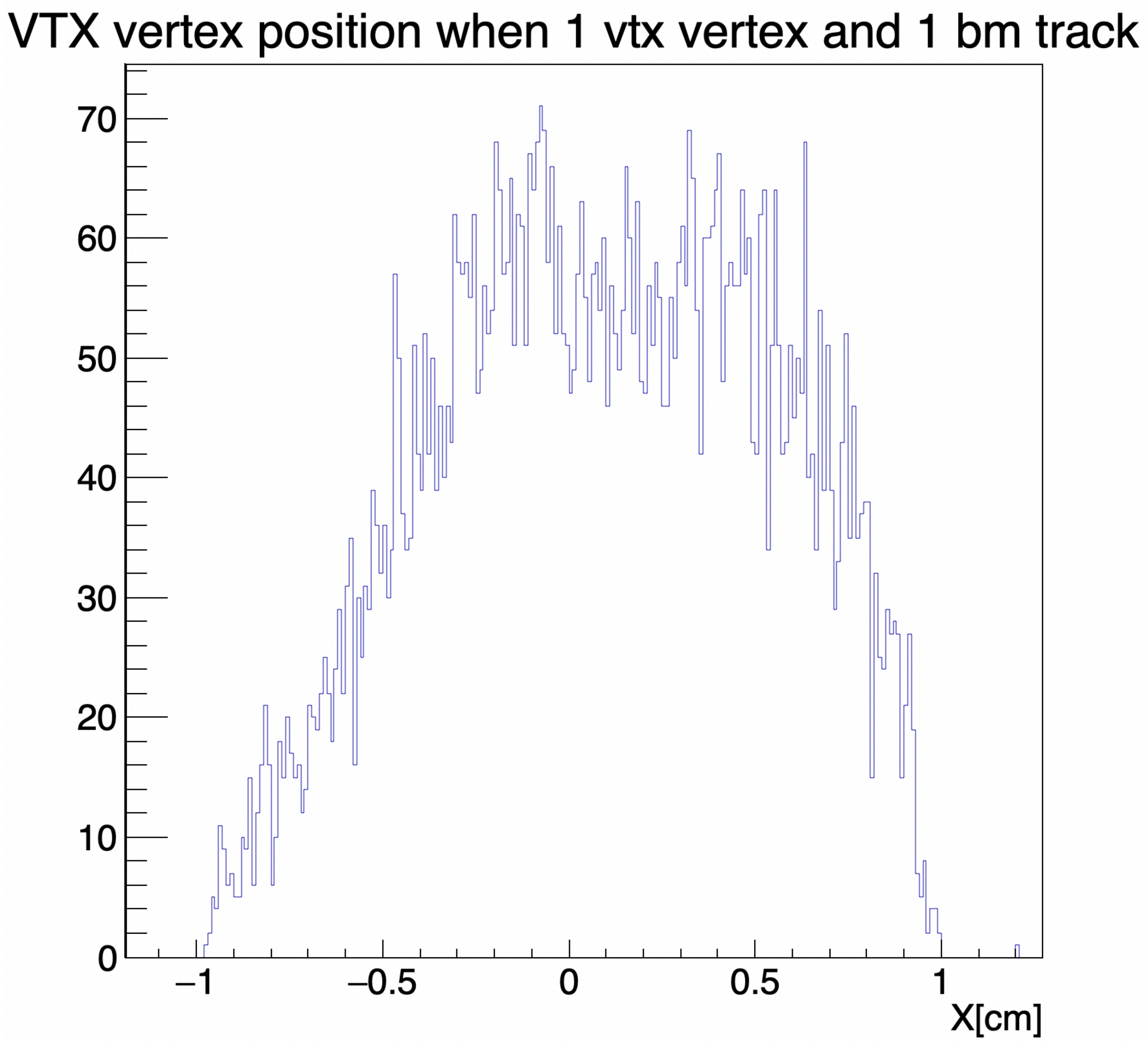


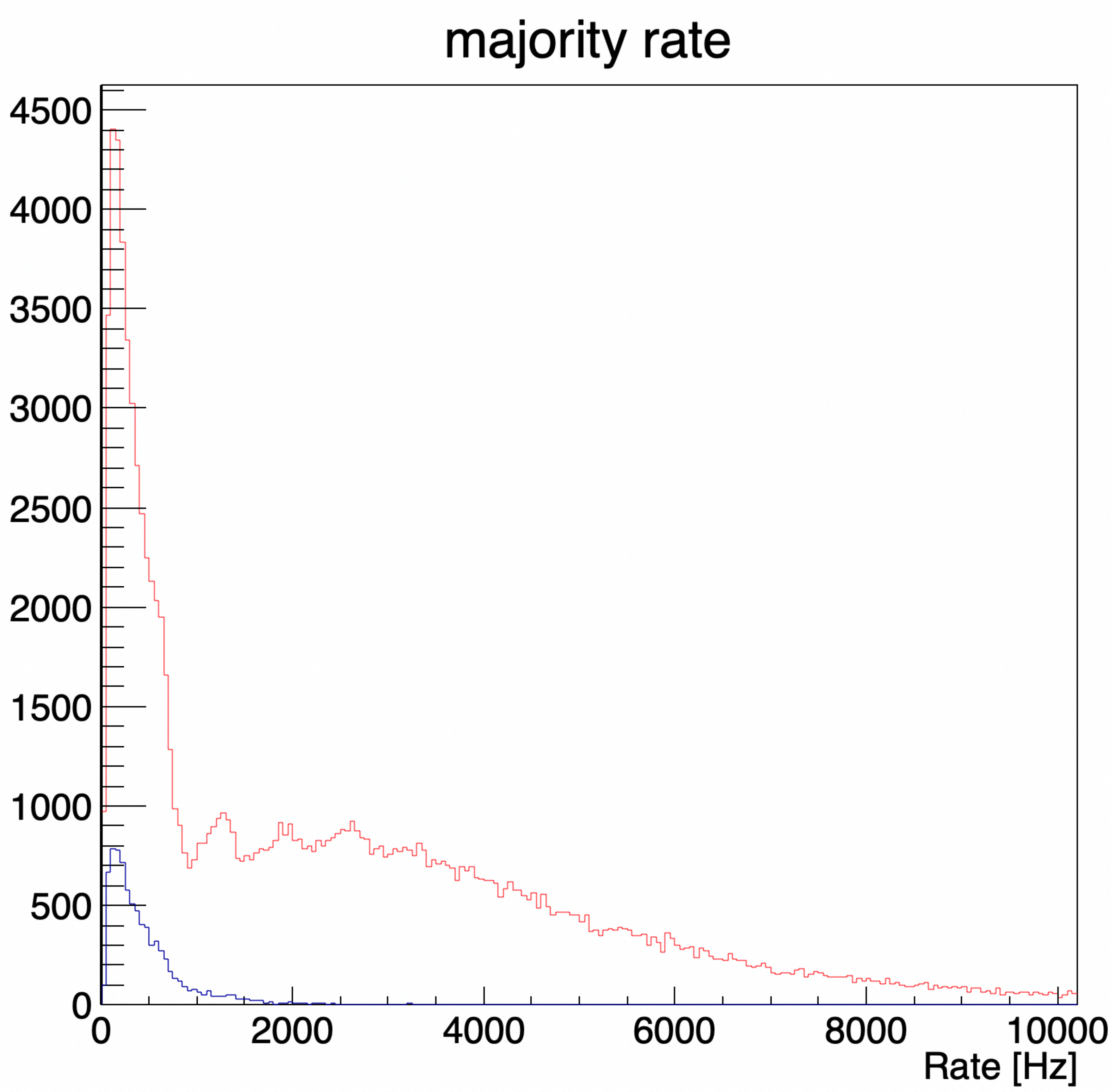
- The beam profile reconstructed by the VTX does **not show the wire shadow in the emulsion runs with protons @ 200 MeV with high beam rate (run 7064, BM HV @ 2070)**.
  Unfortunately, the number of events with a low majority rate is negligible

- BM wire grid seems to be present in VTX cluster map with protons @ 200 MeV at low beam rate (and without emulsions)

Other cases without wire shadow: CNAO2023

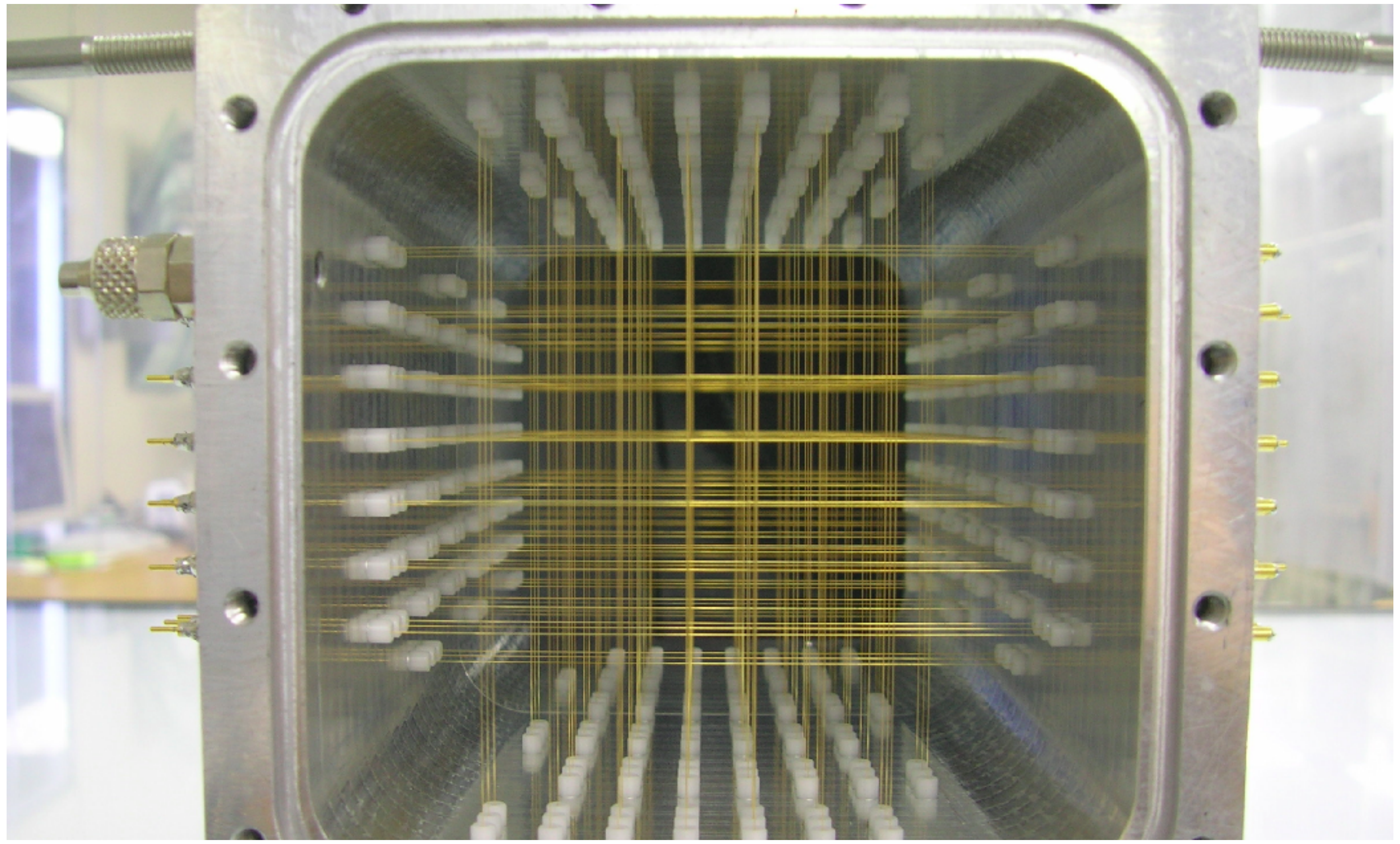






- Also in CNAO2023, during the emulsion irradiation with **protons at 70 MeV, the bm wire grid doesn’t seems to be present in the VTX beam profile (the BM HV was at 1975V)**
- The effect seems to be not present, **regardless of the instantaneous beam rate (majority rate)**

Still an open question



- **Apparently the effect seems to be linked to the HV and the beam rate**
- The BM shadow disappeared when HV is off with 12C @ 200 MeV/u, at low beam rate.
  However, the test has been conducted as a last minute test varying different parameters.
  We should repeat the test changing only the BM HV
- Also in some proton runs, the BM shadow seems to disappear when the overall beam rate is very high
- MCS ruled out
- Electric field calculation and simulations indicates that this is insufficient to justify the wire shadow
- **At the moment we do not have an answer to the beam profile grid question**

To do list

- Optimization of the BM track reconstruction parameters
- Check the wire shadow effect in the old data takings, particularly in the runs with a high beam rate
- Check possible effects due to other beam/detector properties
- Check space-charge effect