The mystery of the shadow of the Beam Monitor Wires

A new movie by:

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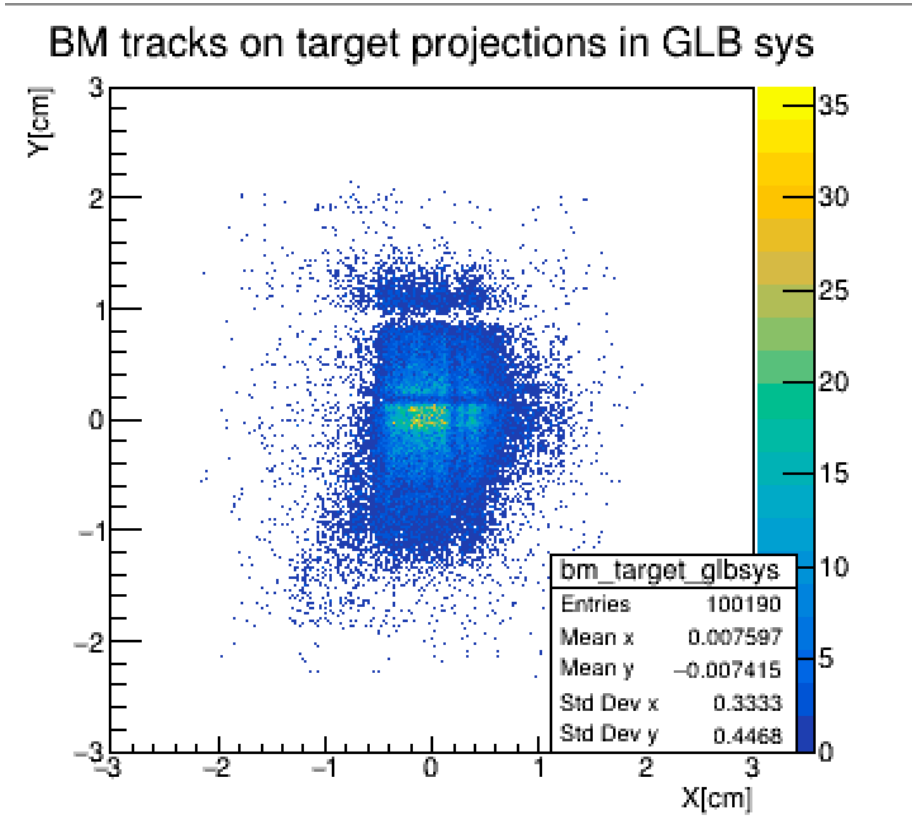
FOOT INFN Milano

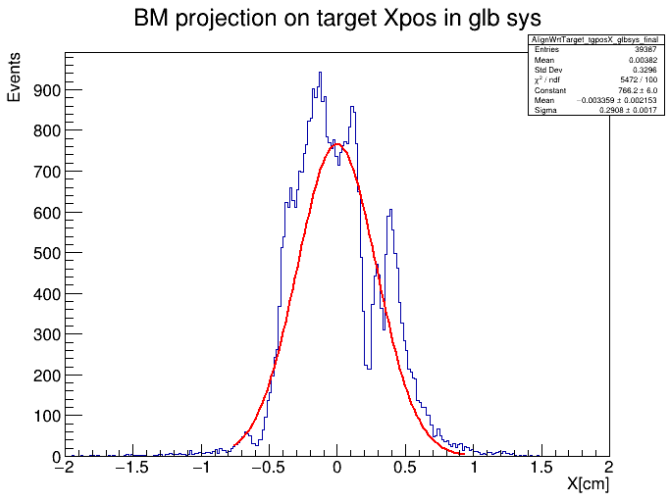
An old open question:

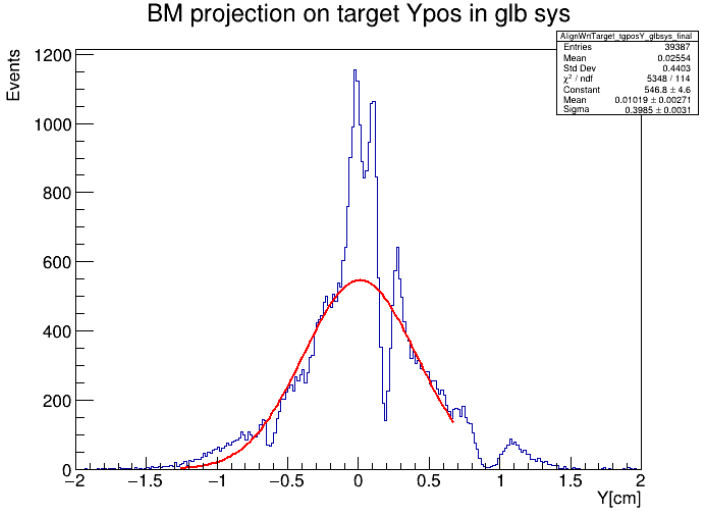


- Since we started to use the BM, we've always seen a grid corresponding to the BM wire positions on the beam profile measured by the BM and the other detector placed beyond the BM,
- The grid in the BM profile can be due to the BM detector itself: low efficiency at cell border, space time relation uncertainties, T0 evaluation

check the MC studies conducted in the past: https://agenda.infn.it/event/17473/contributions/37042/attachments/25830/29496/2018_12_bm_borgomale.pdf)

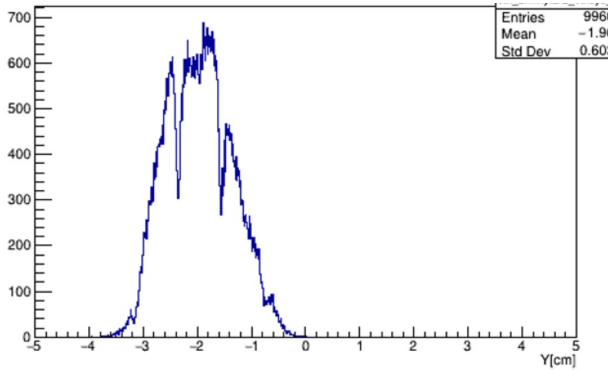
- That's not true for the other downstream detectors



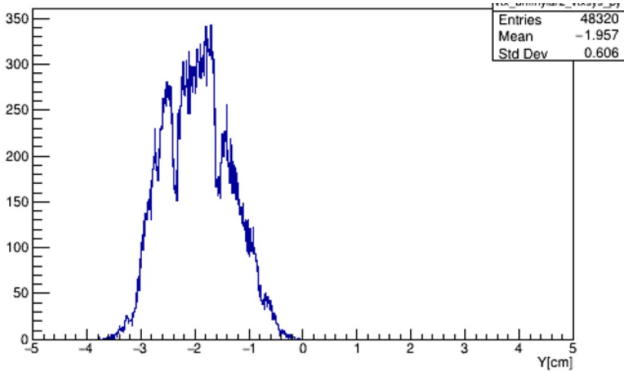


BM wire profile from other detectors

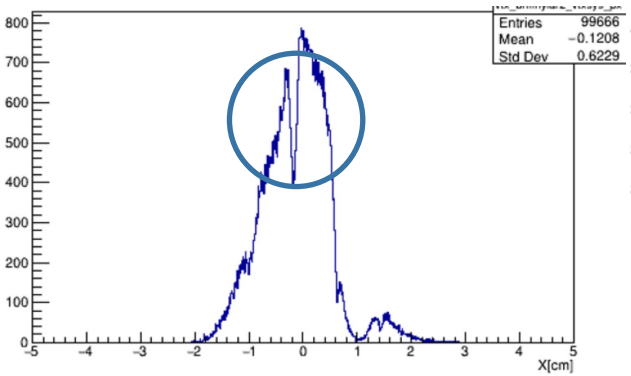
MSD beam profiles collected @ Trento with p @ 80 MeV



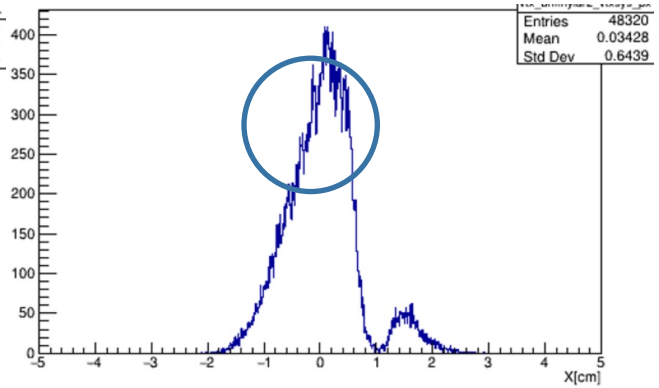
Y view, no BM tilt



Y view, with BM tilt on Y



X view, no BM tilt

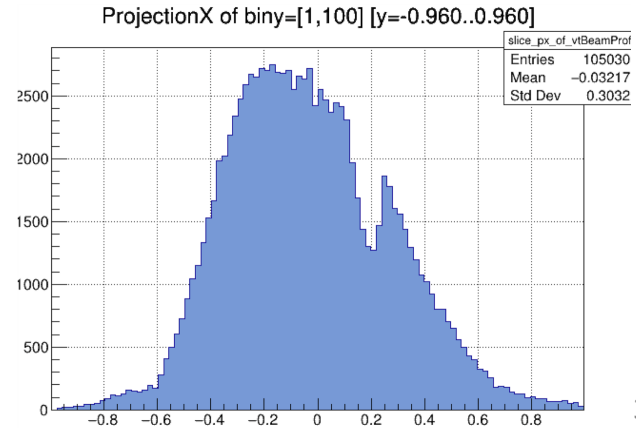


X view, with BM tilt on Y

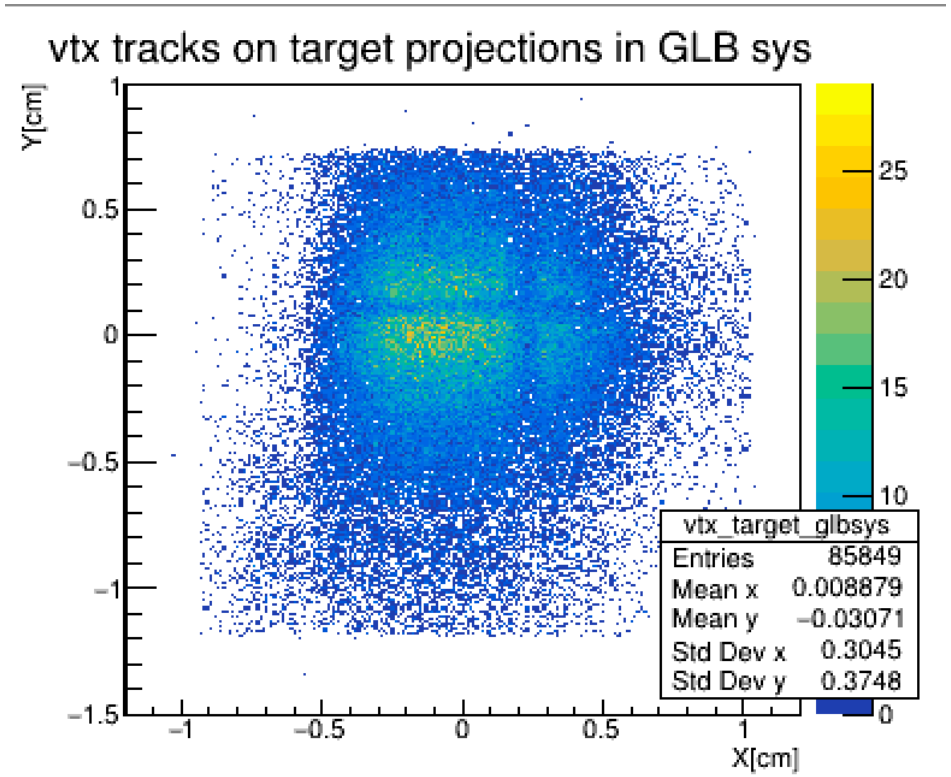
- **The grid is reconstructed also in the other tracking detector placed beyond the BM**

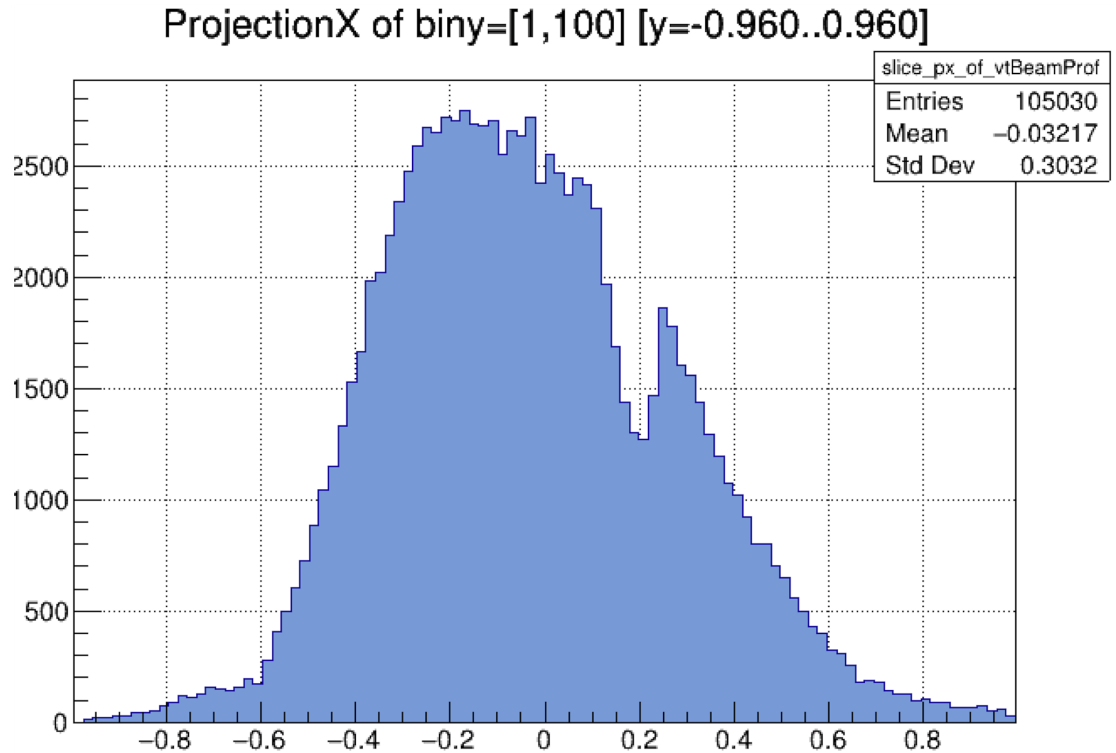
- During the BM characterisation data taking conducted @ Trento with protons and with a MSD disappeared on one viewlike detector, we tilted the BM on one view and the grid detected by the MSD
Check here:
https://agenda.infn.it/event/18616/contributions/95072/attachments/63979/77180/BM_FOOTCollaborationMeeting.pdf)

- **Conclusion: the grid is a physics effect due to the BM field wires, not something related to reconstruction**



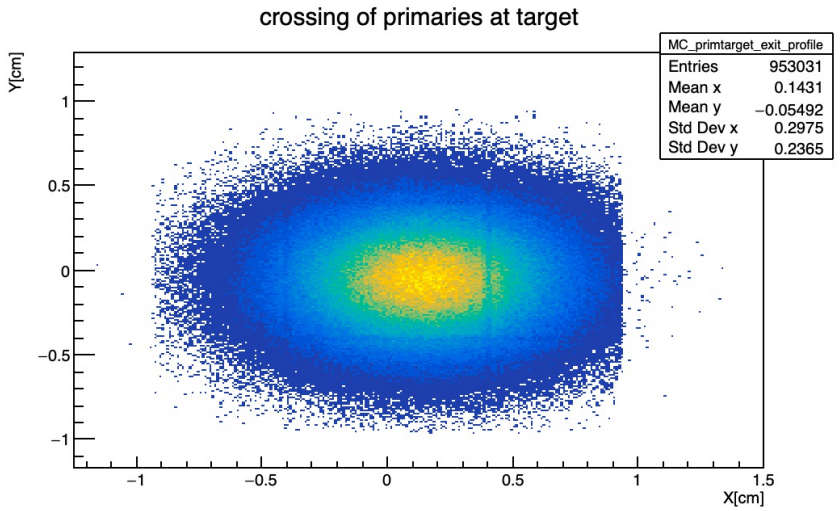
CNAO 2023 data. VTX profile

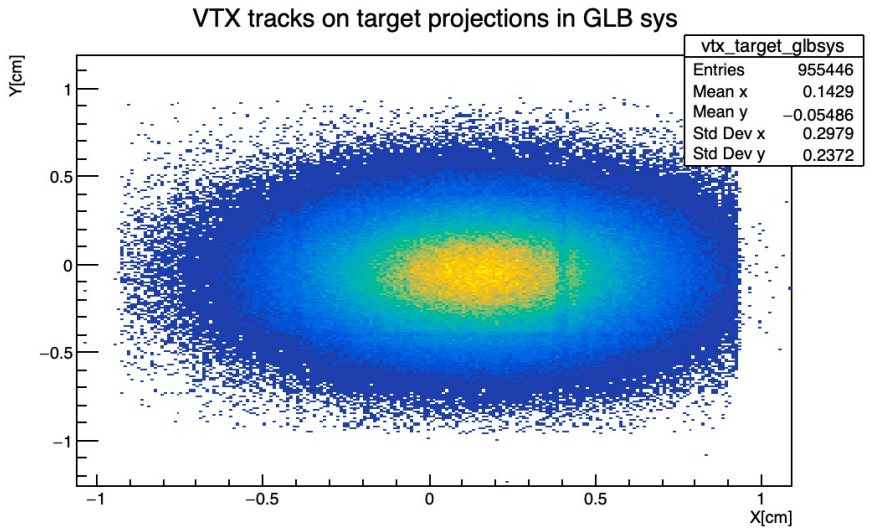




MC simulations

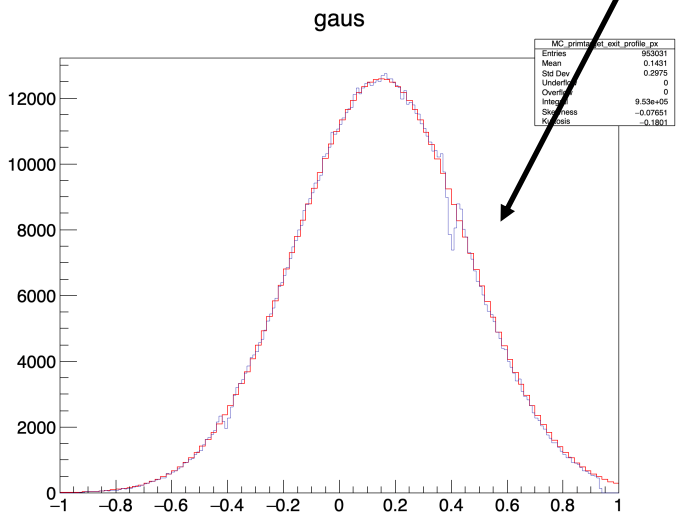
MC simulation of O @ 400 MeV/u (GSI2021)

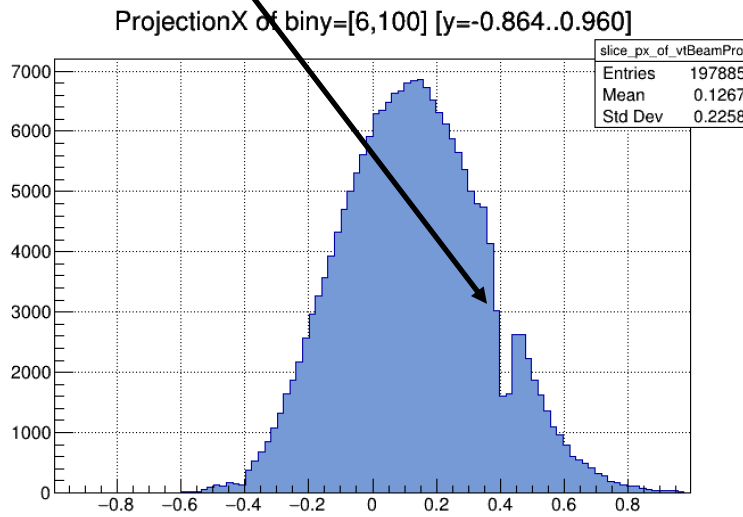




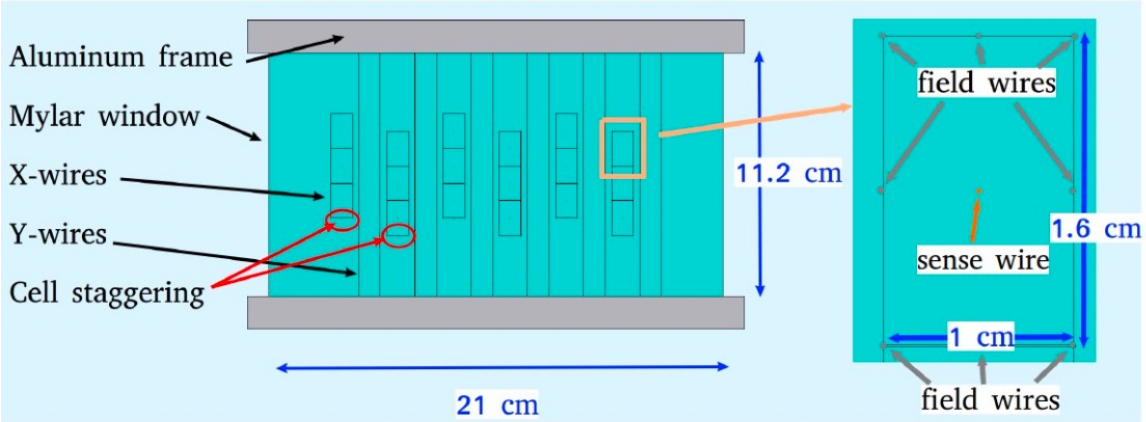
Where is the mistery?

- MC simulations never succeed to reproduce the grid correctly: **we can see the effect, but it is not so evident as in exp. data**
- No relevant effects due to the VTX reconstruction
- MC simulation missing evts in hole ~ 20%
- VTX data missing evts in hole ~ 50%
- From MC: Grid effect mainly due to MCS





A quick reminder on the BM detector



- BM reference paper from FIRST:

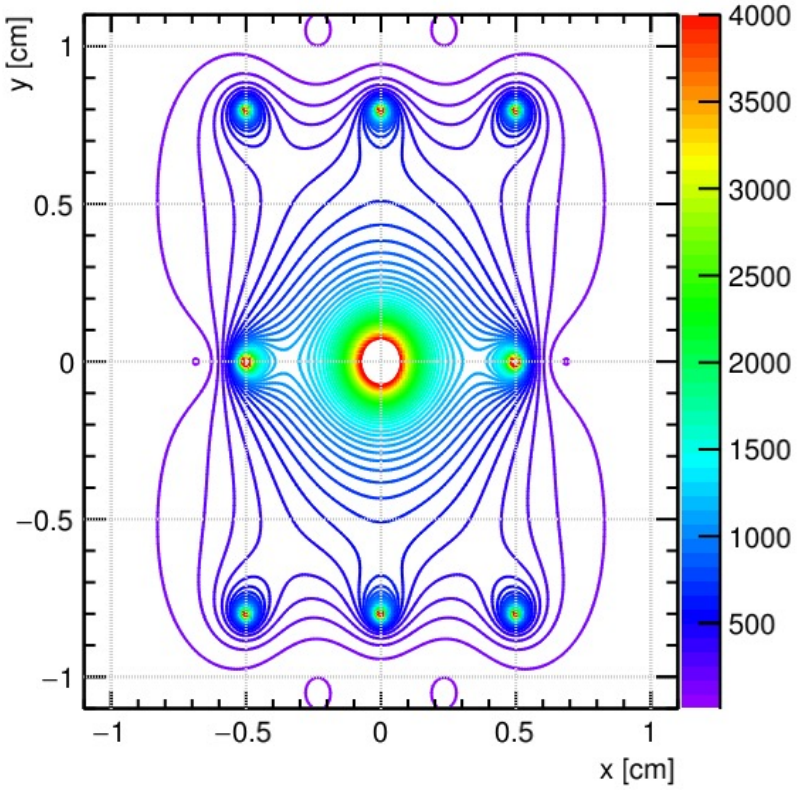
1) *Abou-Haidar et al. Performance of upstream interaction region detectors for the FIRST experiment at GSI. Journal of Instrumentation, 7(02):P02006–P02006, feb 2012*

2) A. Paoloni, M. Anelli, E. Iarocci, V. Patera, L. Piersanti, A. Sarti, and A. Sciubba. The upstream detectors of the first experiment at gsi. Physics Procedia, 37:1466 1472, 2012. Proceedings of the 2nd International Conference on Technology and Instrumentation in Particle Physics (TIPP 2011)

- 6 staggered layers of cells on X and Y view
- Each layer composed of 3 rectangular cells (16 mm x 10 mm)
- Contiguous BM layers of the same view are staggered by a half of a cell
- Field wire with a diameter of 90 μm
- Sense wire with a diameter of 25 μm
- A particle passing close to a cell border/center can “see” 15 field wires and 3 sense wires

Can it be an Electric Field Effect?

We have also investigated the possibility that the high electric field close to the sense wire could contribute to the deflection of a charged particle (the field close to the field wires is less intense)



It’s not possible to arrive easily to an analytical solution for the particle trajectory.

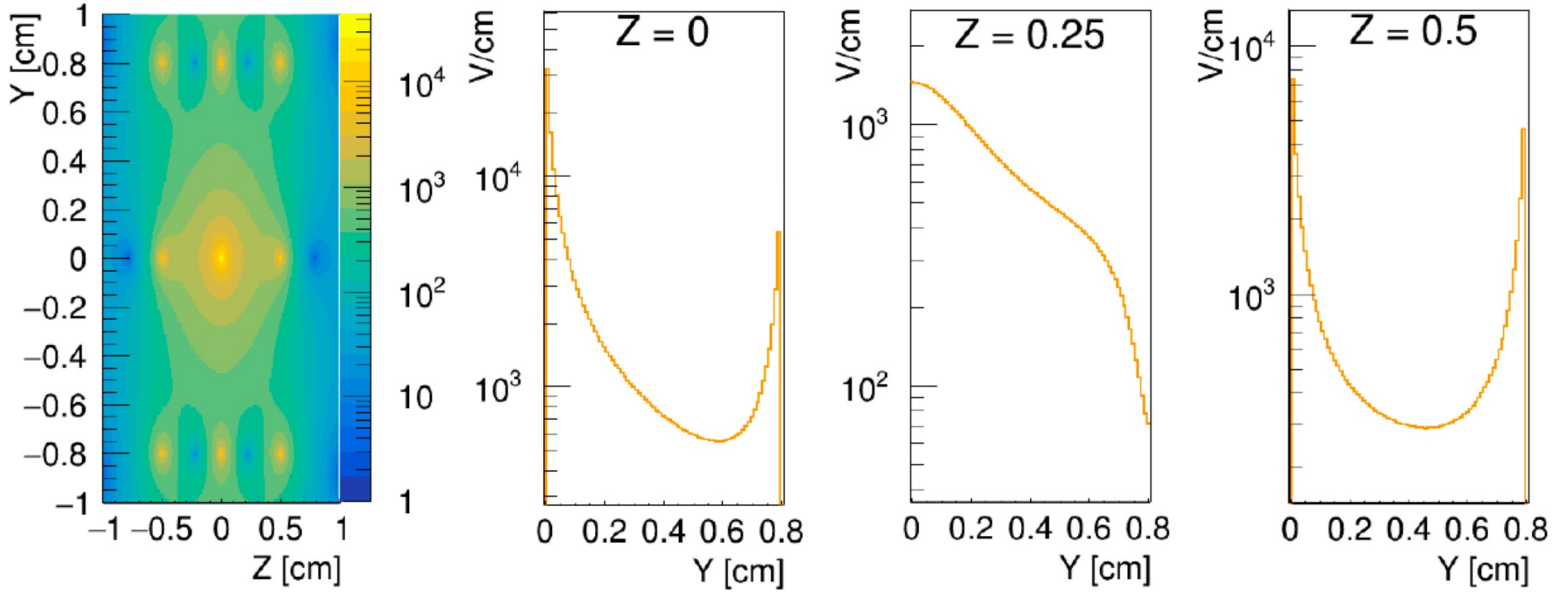
However, in the space region close to the sense wire E(r) is very similar to that of a wire of radius a inside a cylindrical cathode of radius b:

$E(r) = V/(\log[b/a]\, r)$

b = 0.5 cm, 2a = 25 µm, V = 2200 → **E(a) ~ 294 kV/cm**

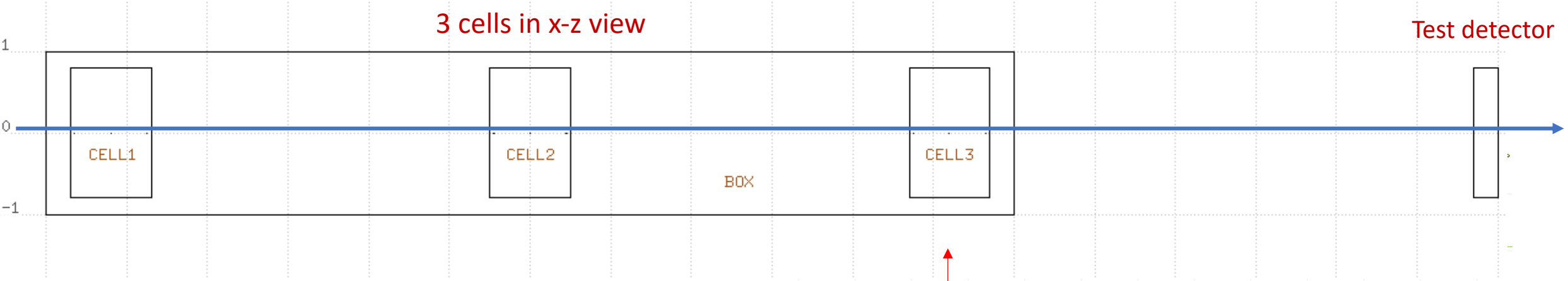
(confirmed by a Garfield calculation)

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

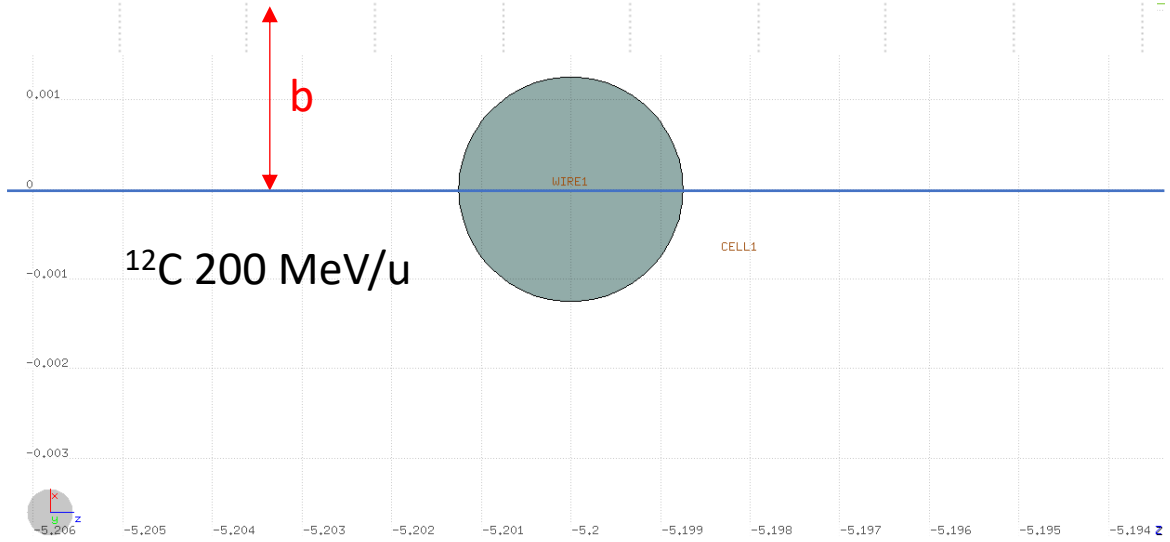


Can it be an Electric Field Effect?

Under the simple single wire approximation we performed a MC FLUKA simulation (possible only in vacuum). Charged particle trajectory calculated numerically solving differential equation with Runge-Kutta methods



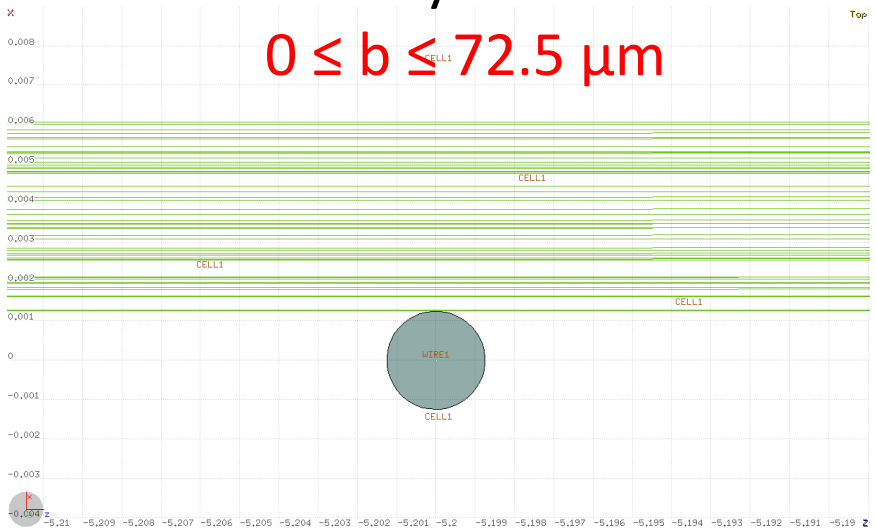
1. Inject straight tracks at a given impact parameter b from the wires
2. measure deflection and position at detector as a function of b measured at the starting point

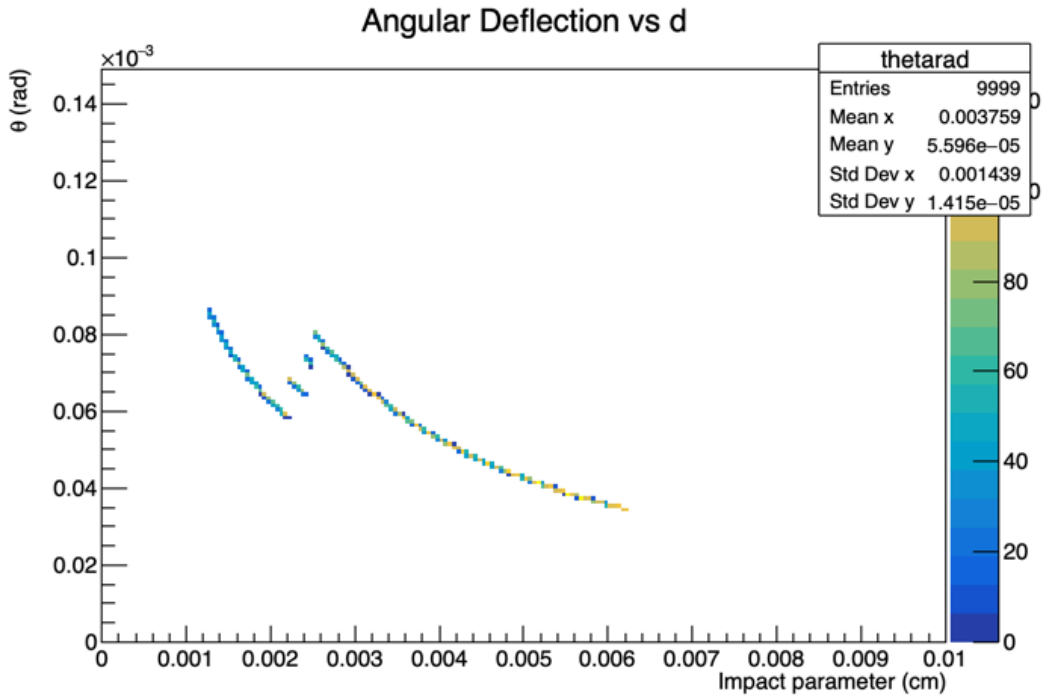


Results for ^{12}C @ 200 MeV

Tracks uniformly distributed with

$0 \leq b \leq 72.5\ \mu m$





Extremely small angular deflection

Event for tracks passing very close to the wire

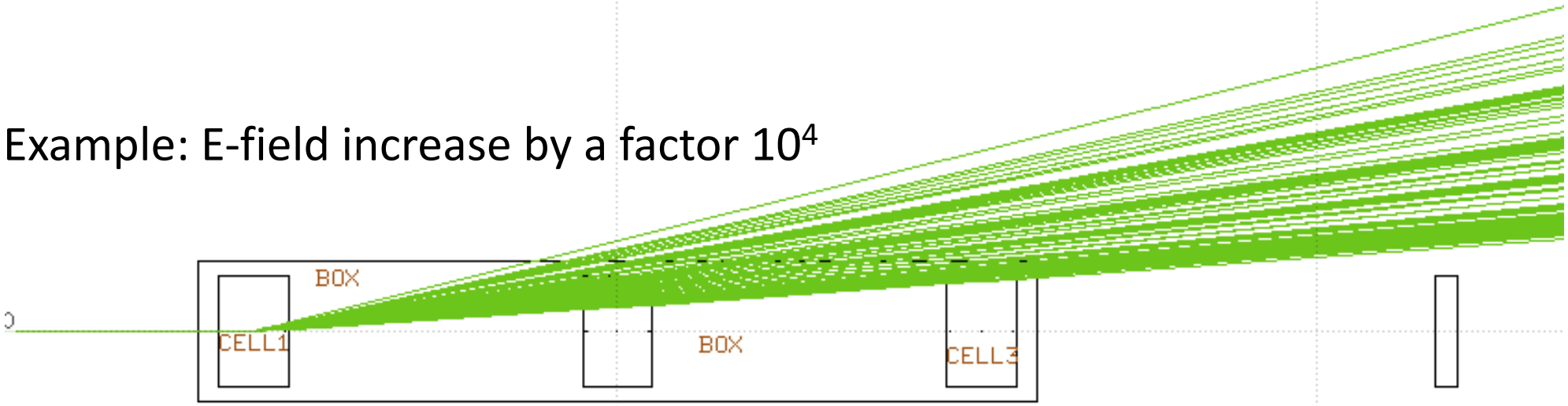
Result: for a ^{12}C at 200 MeV/u, the maximum deflection would be of the order **~8 10^{-5} rad**

Significative deflection could be observed only with E greater at least by a factor of thousand!!

➔ **a possible E-field effect seems totally ruled out**

Significative deflection could be observed only with E greater at least by a factor of thousand

Example: E-field increase by a factor 10^4

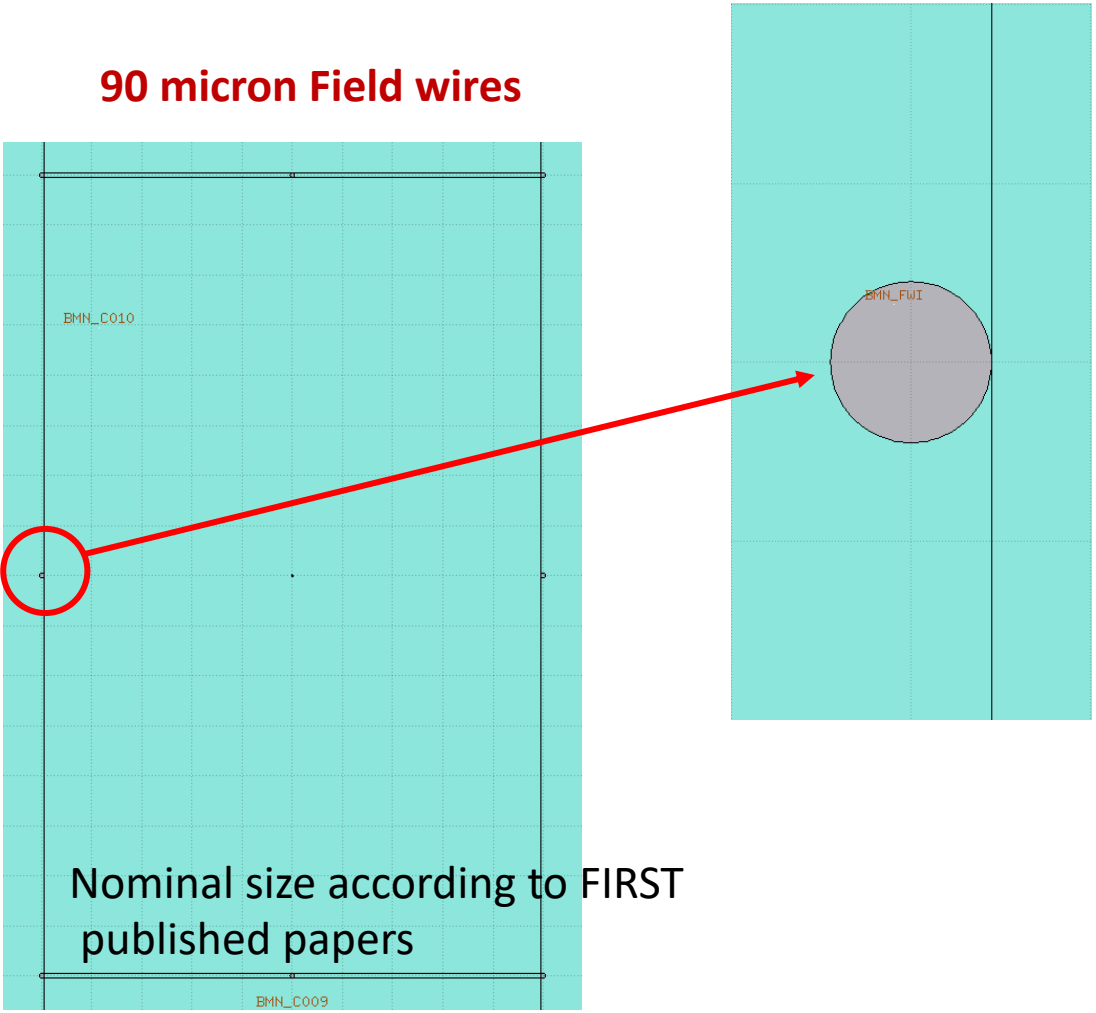


Deflection is a function of “impact parameter” of the incoming particle with respect to the sense wire

A diameter that actually is a radius?

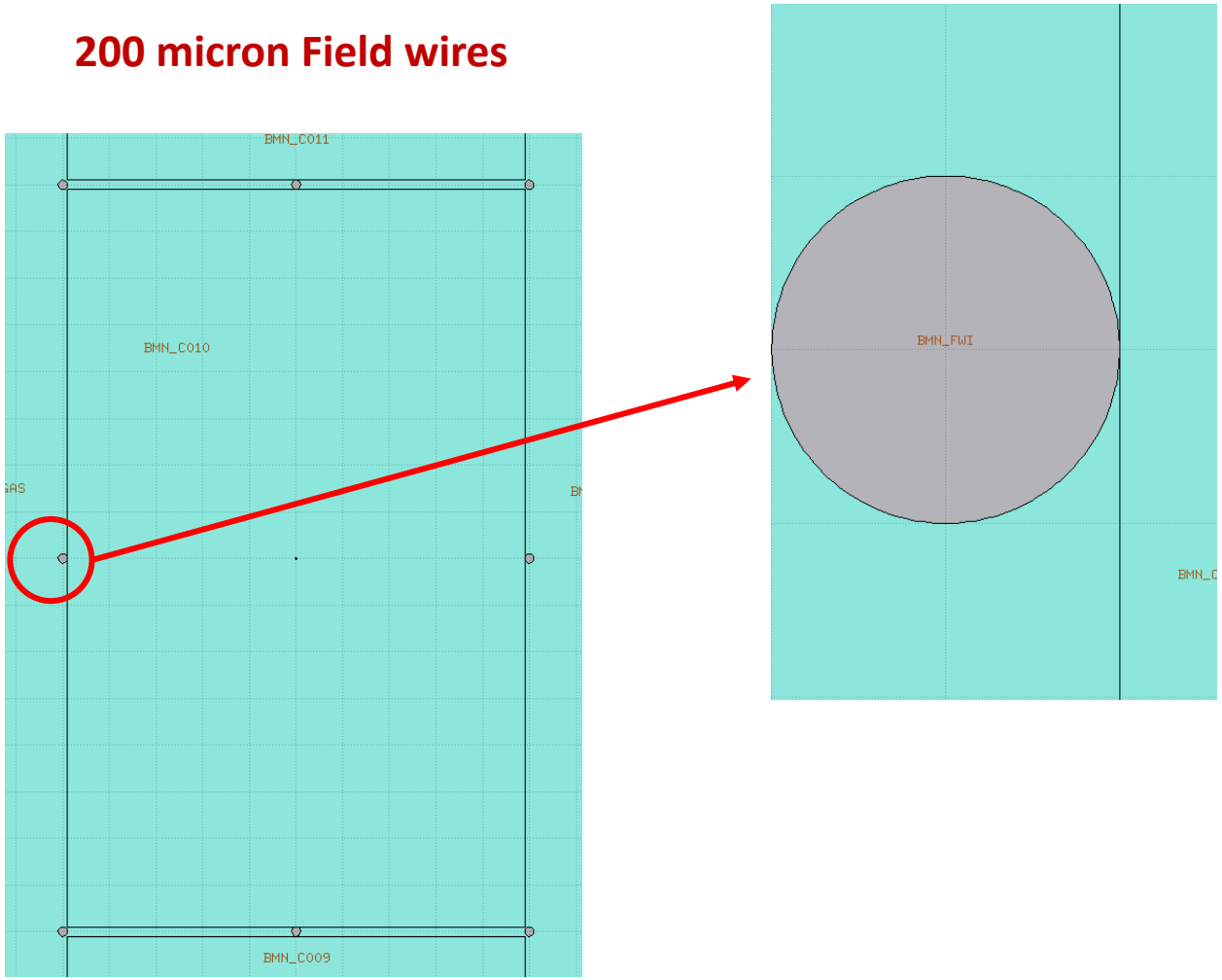
We increased the field wire size in the MC simulations and the beam profile seems to be more similar to data

90 micron Field wires



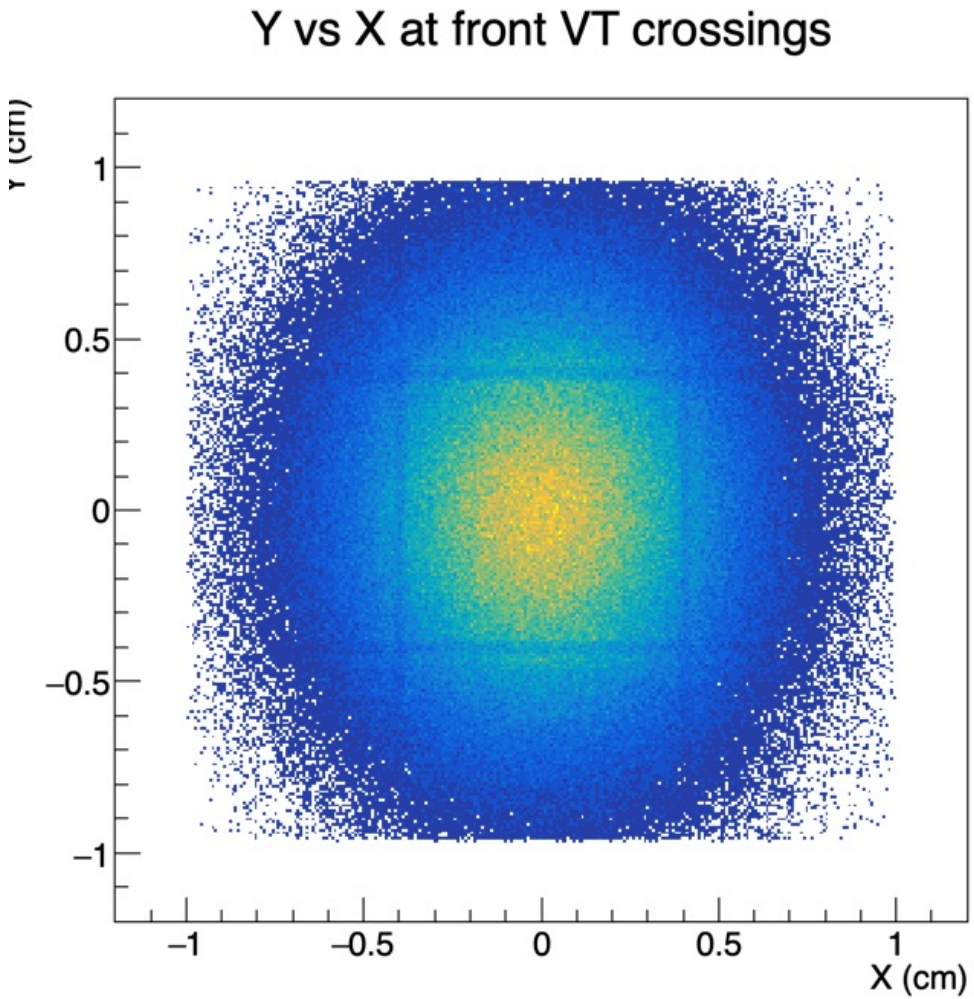
Nominal size according to FIRST published papers

200 micron Field wires



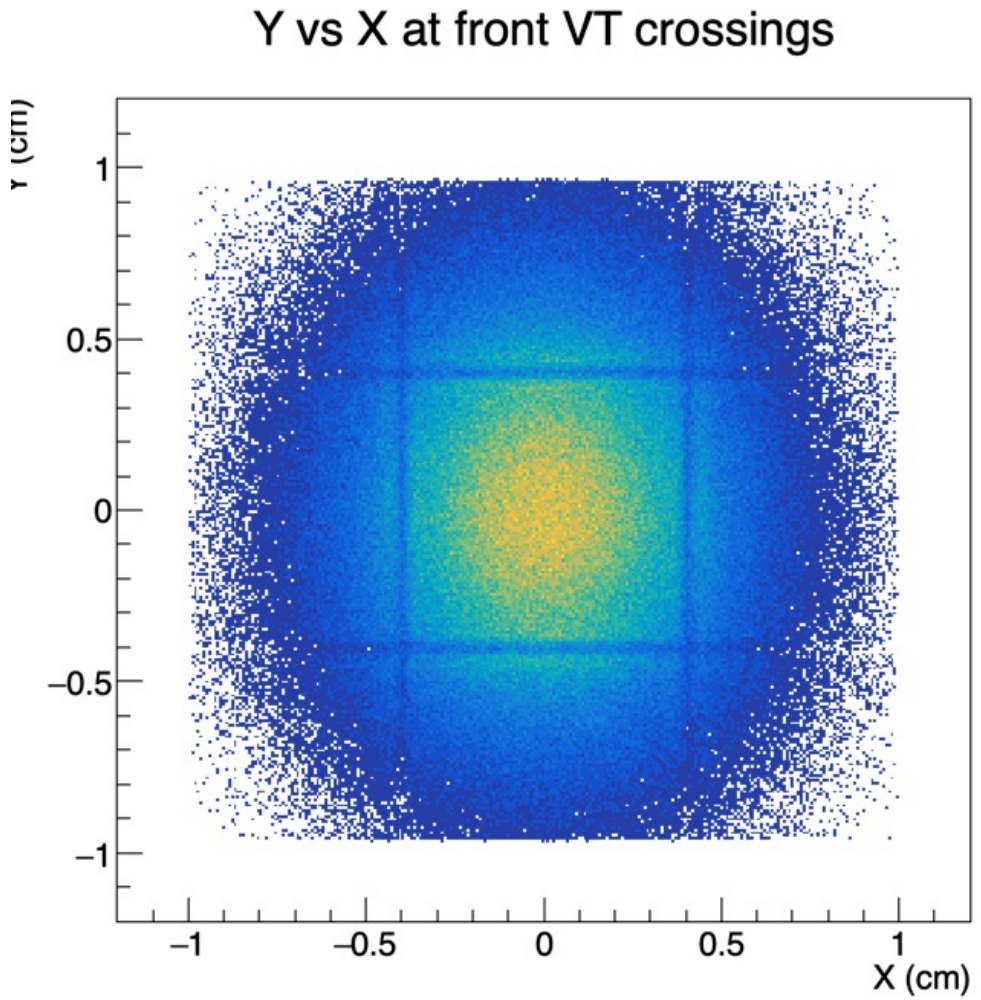
Impact point on 1st layer of VT

90 micron Field wires



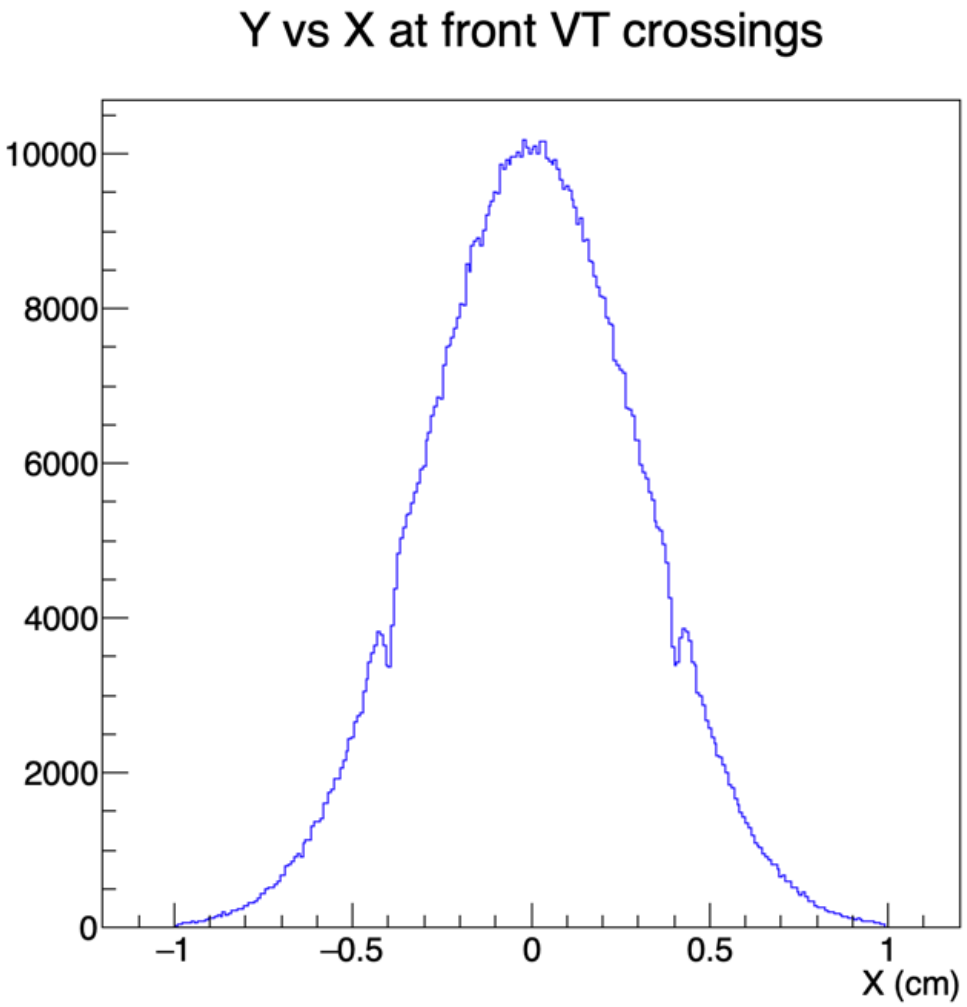
Simulation with 12CFull_MC campaign

200 micron Field wires

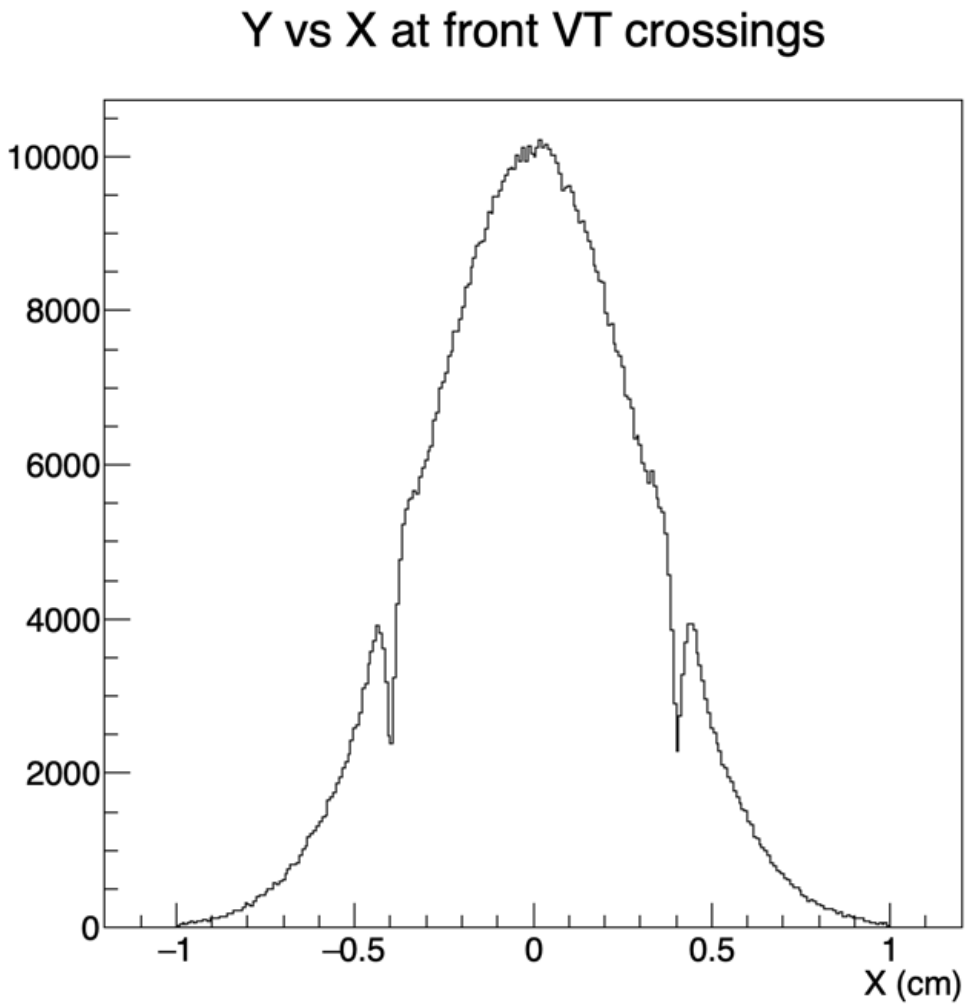


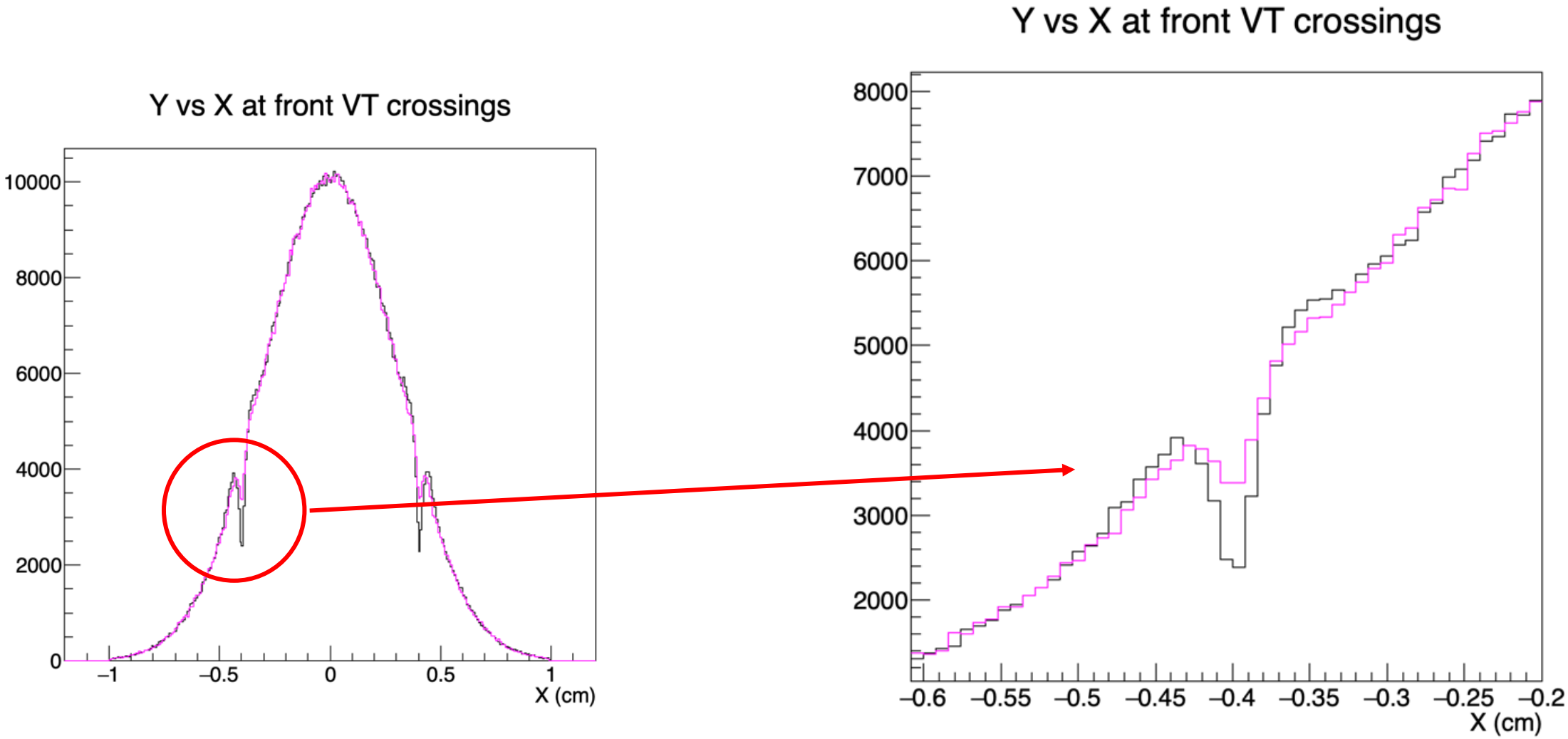
Impact point on 1st layer of VT: 1-D projection

90 micron Field wires

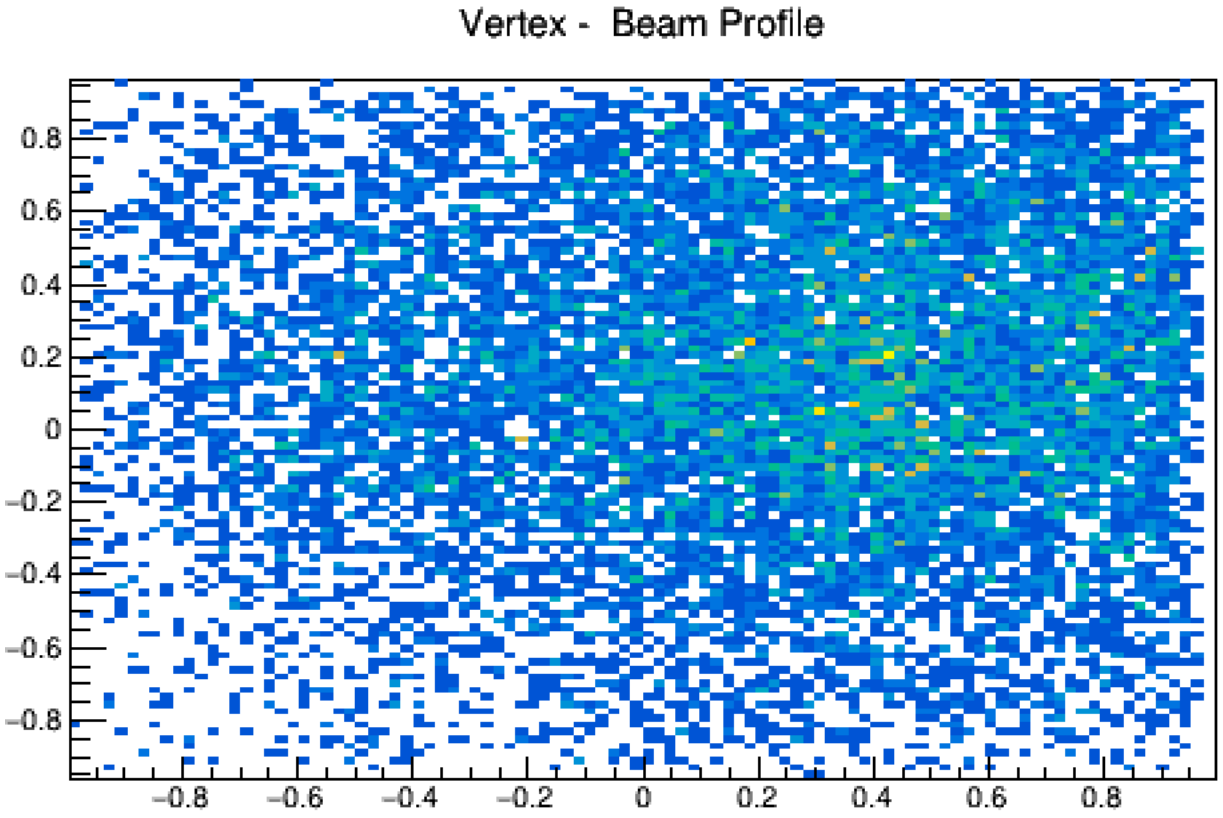


200 micron Field wires




Y vs X at front VT crossings
10000
8000
6000
4000
2000
0
−1
−0.5
0
0.5
1
X (cm)
Y vs X at front VT crossings
8000
7000
6000
5000
4000
3000
2000
−0.6
−0.55
−0.5
−0.45
−0.4
−0.35
−0.3
−0.25
−0.2
X (cm)

Data with a thick target

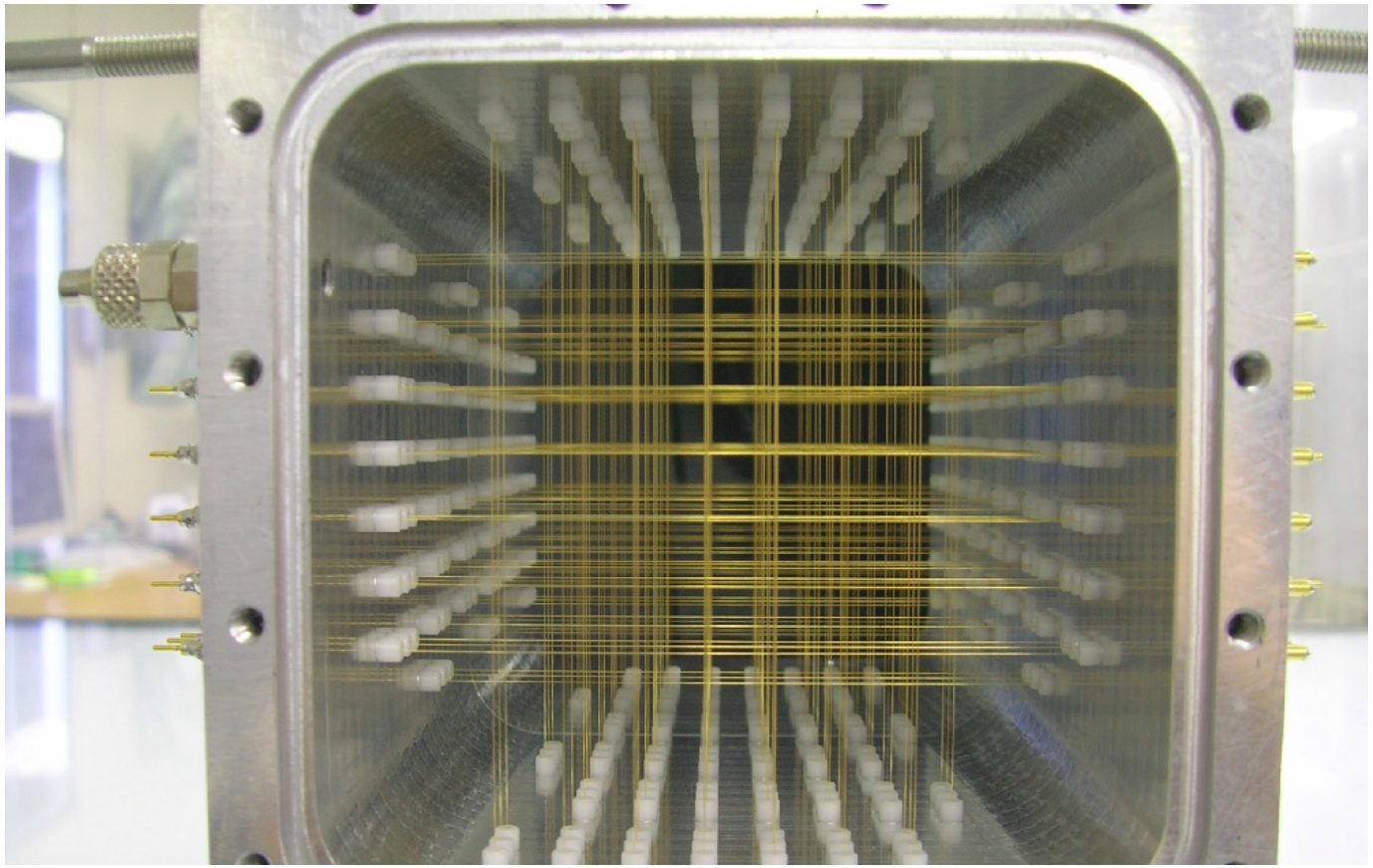


This is the VTX reconstruction of run 6705 at CNAO2023:
Protons at 125 MeV on a 2 cm thick Al target

There are few events, but the wire shadow seems to remain unvisible.
That was not true in other protons test with no target or with thin target.

This is in agreement with simulation: the increased MCS dilutes away the shadow

Still an open question



- **At the moment we do not have a definitive answer to the beam profile grid question**

- A possibility is that the BM field wire have a radius (not diameter!) of 90 µm:-Maybe in the original BM paper a diameter was a radius?
-Or maybe the BM wires had been substituted?

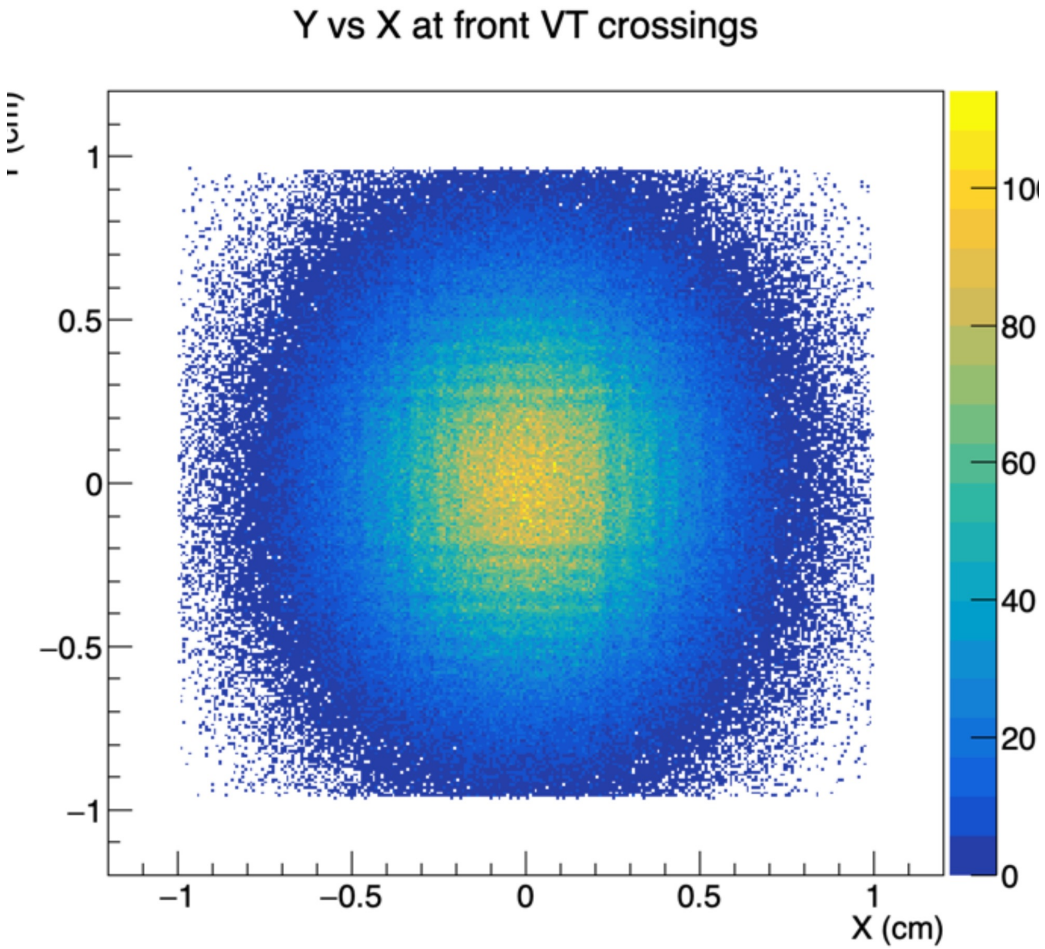
- Surely, the BM wires are gold plated and this is not included in the MC simulation, but the coating is of the order of 10-20 µm and it is negligible

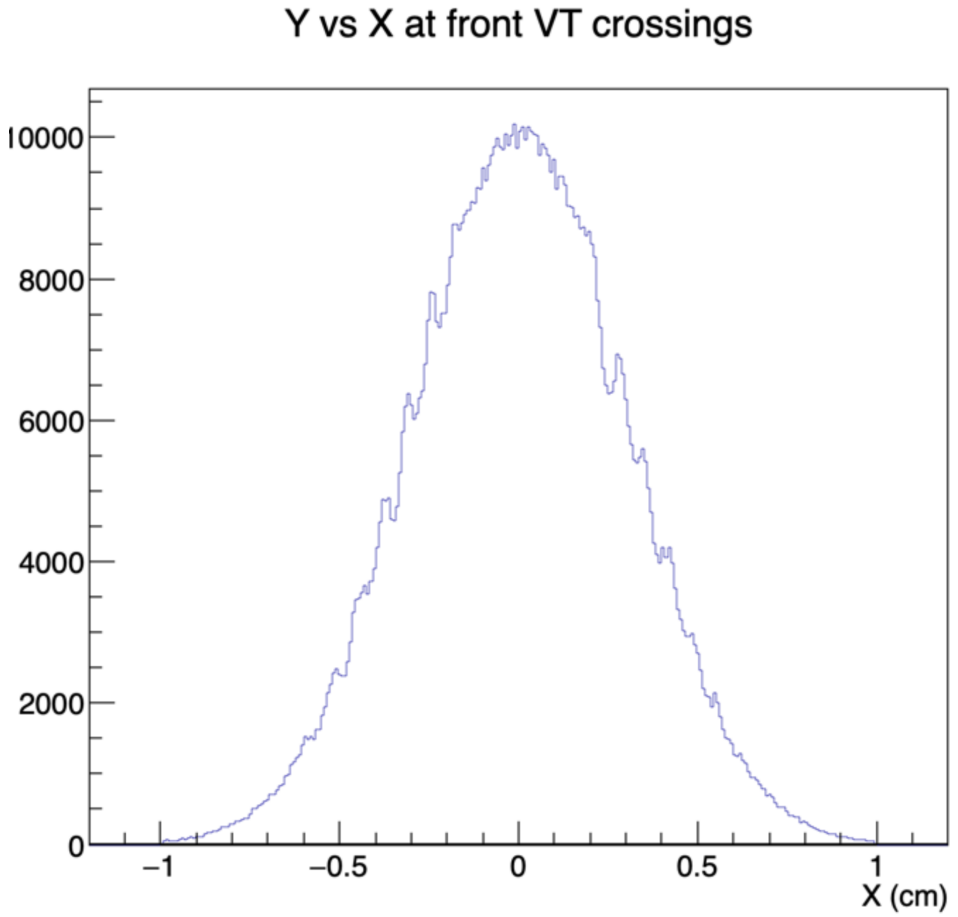
- **We cannot (we do not want to) disassemble the detector to measure the wire size (too risky)**

Towards CNAO2024: proposal of a test

- During a possible test of tracking devices, we would like to operate the BM as well
- As a first test, we would like to definitively exclude any electric field effect experimentally: take a short run without the BM HV
- The second test is to operate BM tilted by few degrees, with respect to X and/or Y axis, to reduce the alignment effect of several wires

Towards CNAO2024: example of X+Y tilt effect





Here the shadow should be further smoothed by the presence of noise in VTX