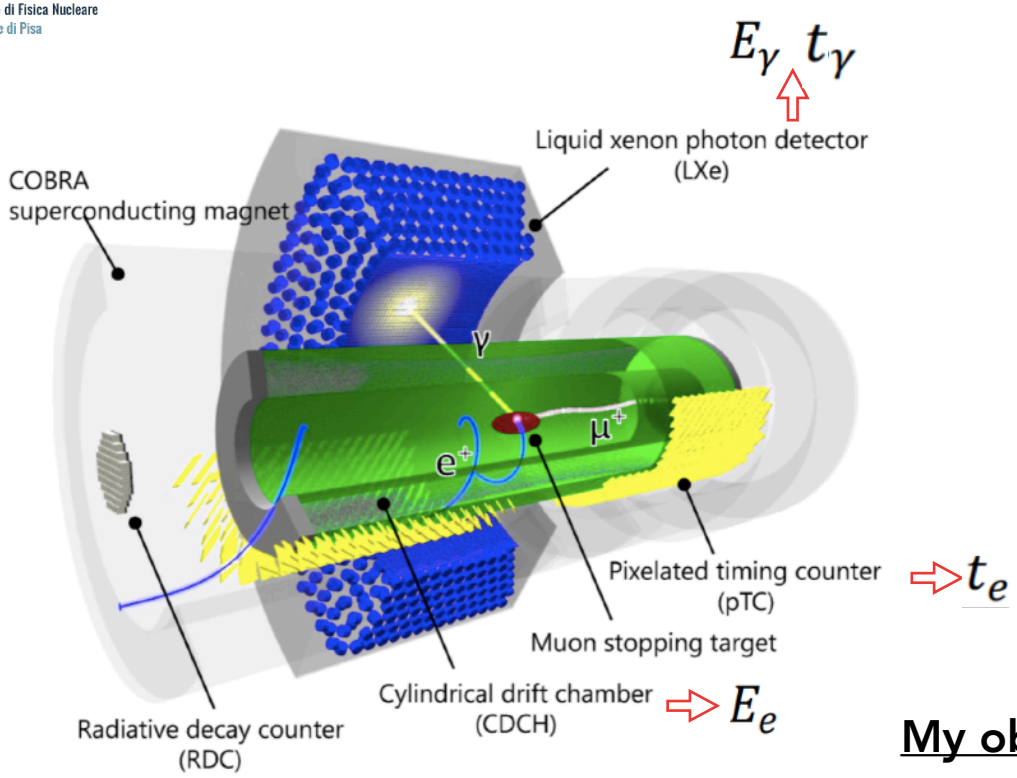
X17 search with the MEGII apparatus at PSI

Hicham Benmansour

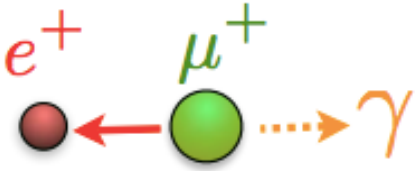
INTENSE: Particle Physics Experiments at the Intensity Frontier

Introduction

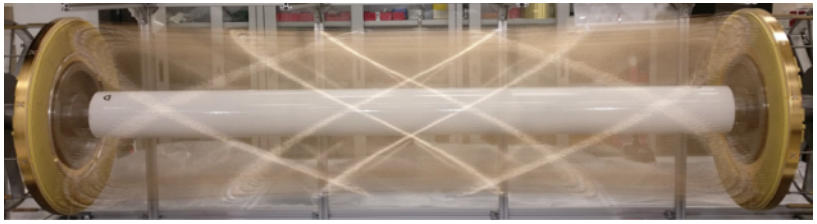
The MEG-II experiment



SIGNAL



$$E_\gamma = E_e = 52.8\ \text{MeV}$$
$$\theta_{e\gamma} = 180°$$
$$t_{e\gamma} = 0\ \text{s}$$



Low-mass single volume detector
—> 9 concentric layers of 192 drift cells defined by ~12k wires

My objectives

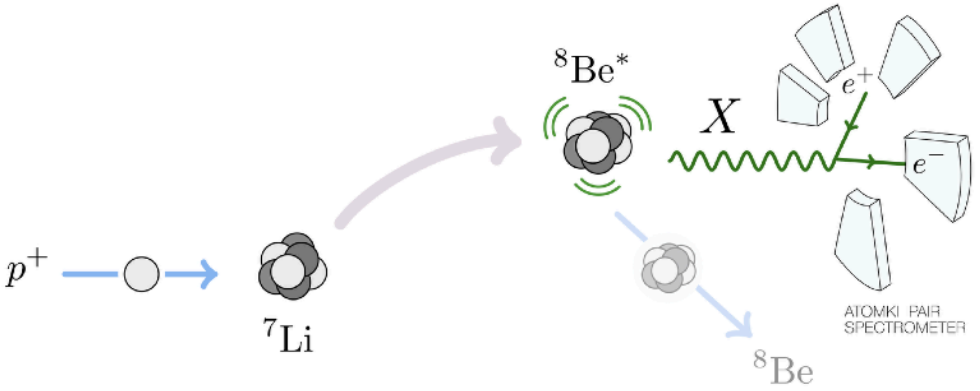
1. Perform the positron analysis for the $\mu^+ \to e^+\gamma$ search

2. Study other physics channels that can be exploited with MEGII focused on the positron analysis (X17 search, $\mu^+ \to e^+ X$)

3. Develop new calibration methods for the MEGII experiments

The X17 search with MEG-II

- Objective: measurement of excess in angular opening of:

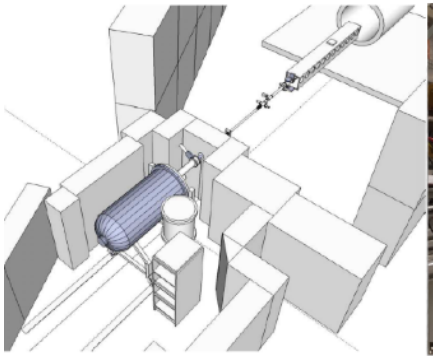


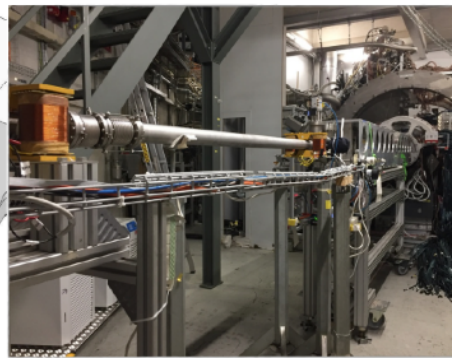
- Three key elements:

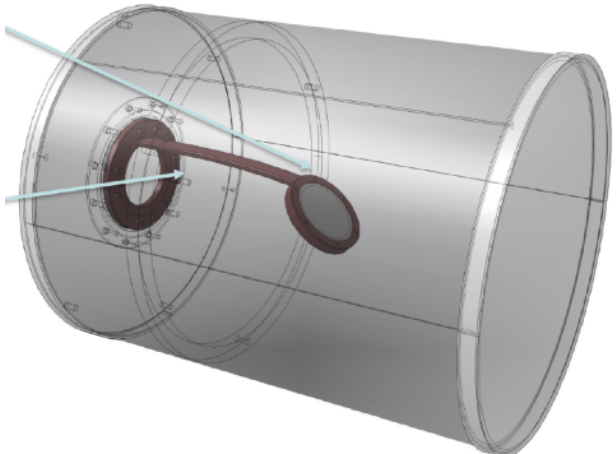
—> **Cockcroft-Walton accelerator** which produces 1.05MeV protons with 1uA current

—> **lithium target** optimized for the X17 search, 5um LiF on 25um copper substrate with copper arm (heat dissipation)

—> the **MEG-II drift chamber** with reduced magnetic field allows to detect the e+/e- pair (momentum ~ 9MeV)







Analysis procedure

How to search for electron/ positron pairs

The MEG-II tracking is designed **for the search of positrons only**, needs to be adapted for electron search as well. Following technique was developed:

1) For each set event, run the analyzer twice: first with magnetic field **+B (0.15 scaling)** to look for positrons, then with **-B (-0.15 scaling)** to look for electrons.

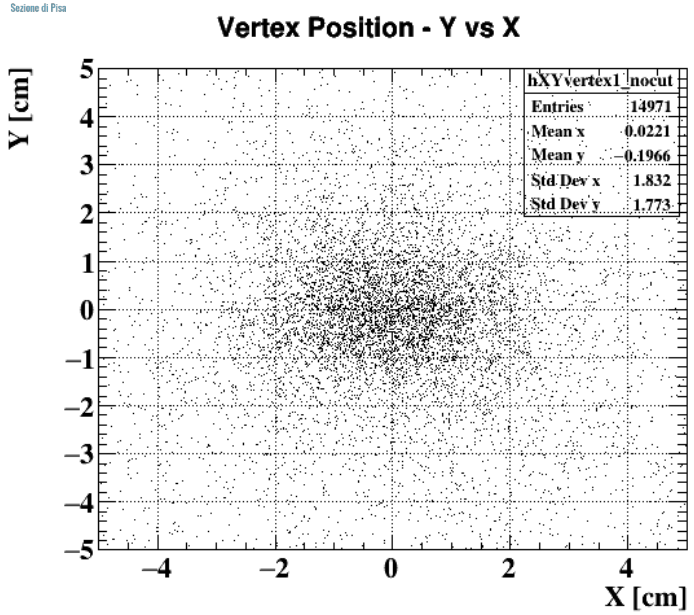
Problem: e+ going towards +z can be mistaken for e- going towards -z.

Solution: request propagation of tracks to the physical target.

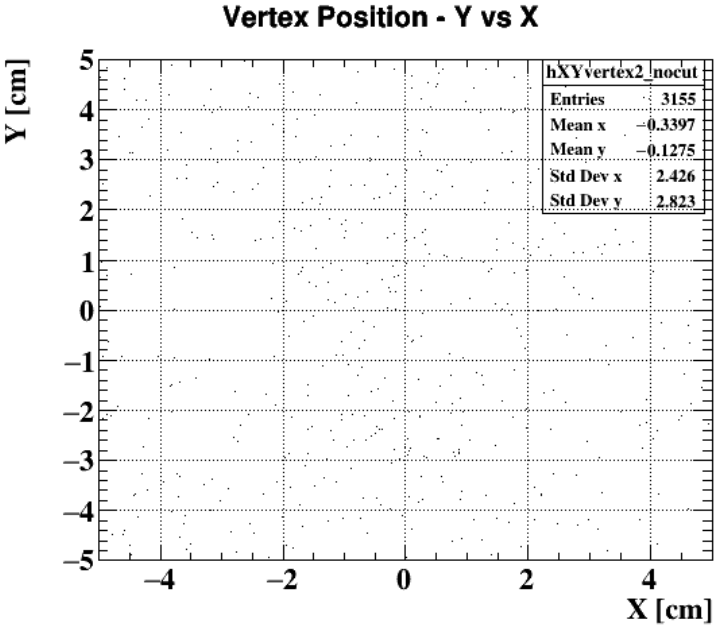
To check efficiency of this technique, e+ only and e- only were simulated with Monte Carlo.

Vertex on target

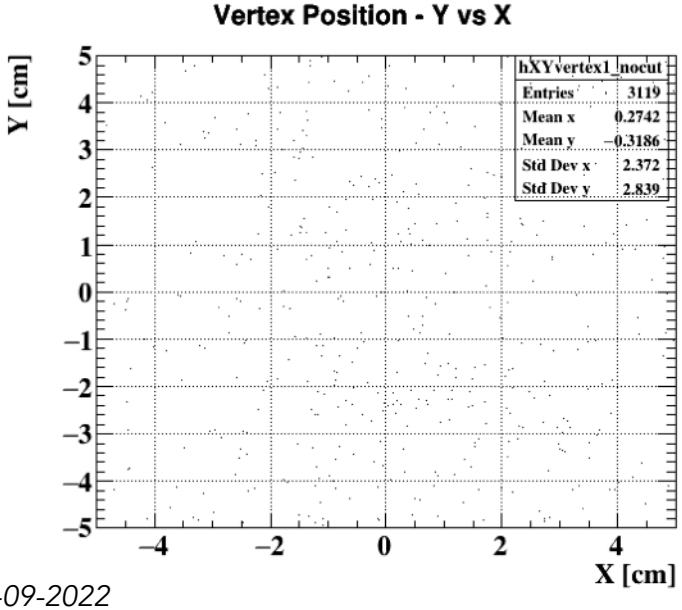
Positrons: +B search



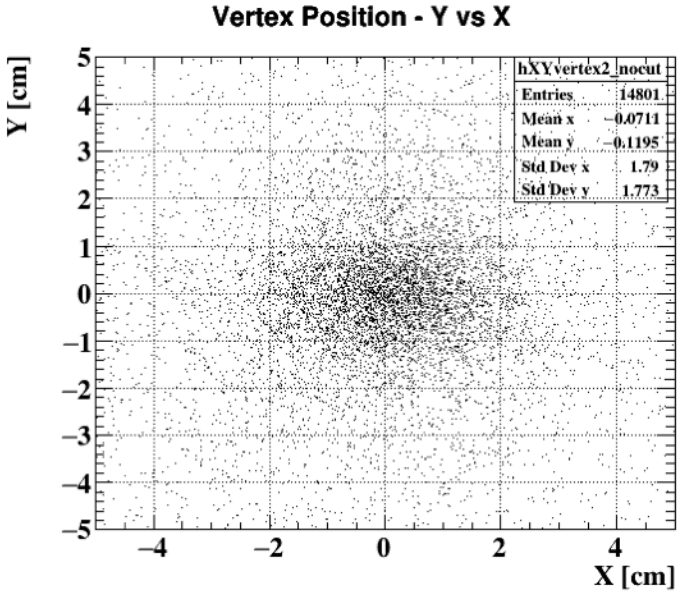
Electrons: +B search



Positrons: -B search



Electrons: -B search



How to search for electron/ positron pairs

Still, a fraction of particles are reconstructed with wrong sign.
Solution: if a track is reconstructed as both an e+ and an e-, not consider it.

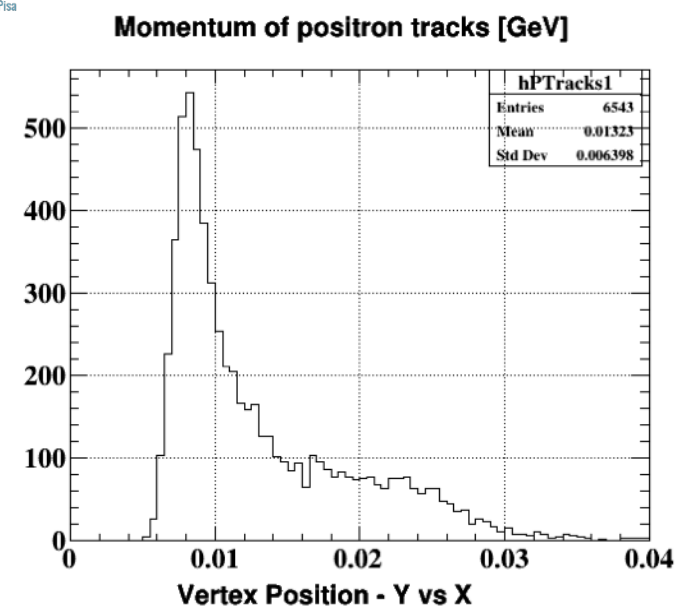
2) Compare all tracks in same event for both analysis: **degree of correlation** can be estimated by counting hits in common (hits on the same wire)

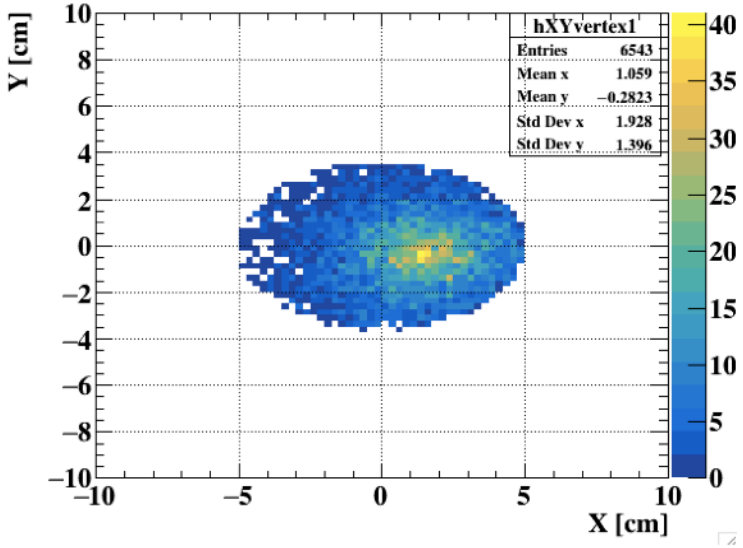
3) For tracks with a non-zero correlation, put to trash: **—> kill fake tracks**

4) Search events with pairs requiring MEG selection, **propagation length to target** (45 cm), **vertex position** (on physical target), **vertex distance** (target size) (possibility to cut as well on energy asymmetry)

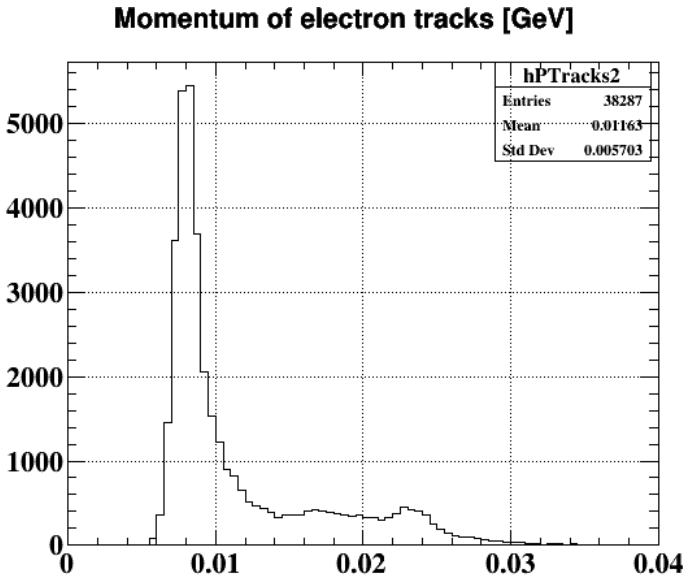
First analysis of data

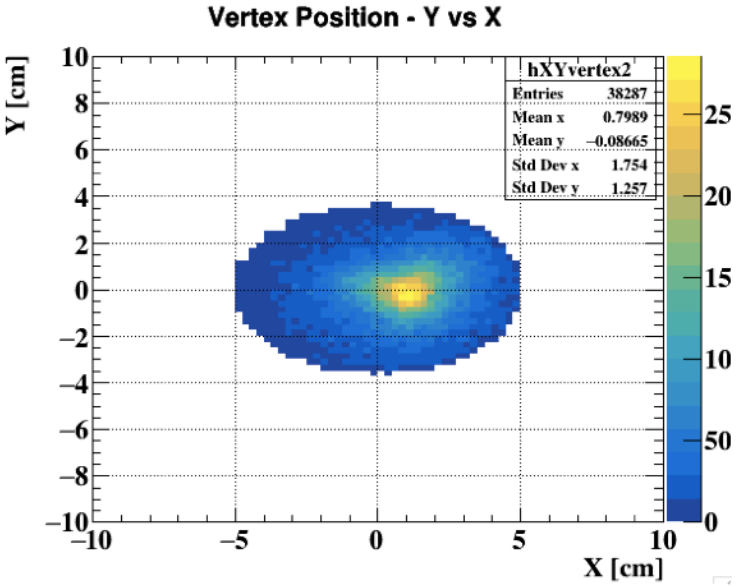
Positrons





Electrons

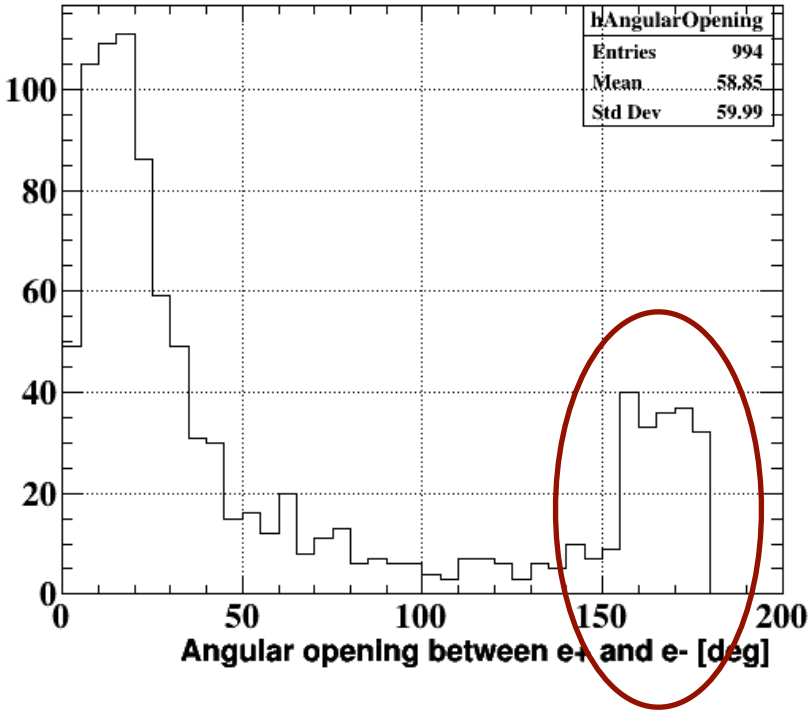




–> momentum around 9 MeV and beam spot well defined

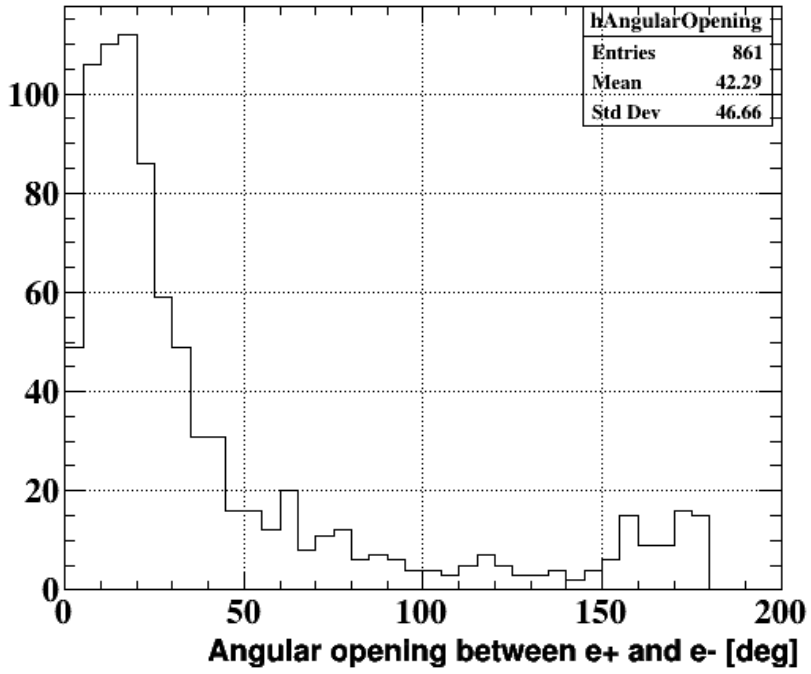
Application to Monte-Carlo IPC (main background)

IPC reconstruction:
no cut on correlated tracks



Wrong sign tracks leads to bad pairs reconstructed at ~180°

IPC reconstruction:
cut on correlated tracks



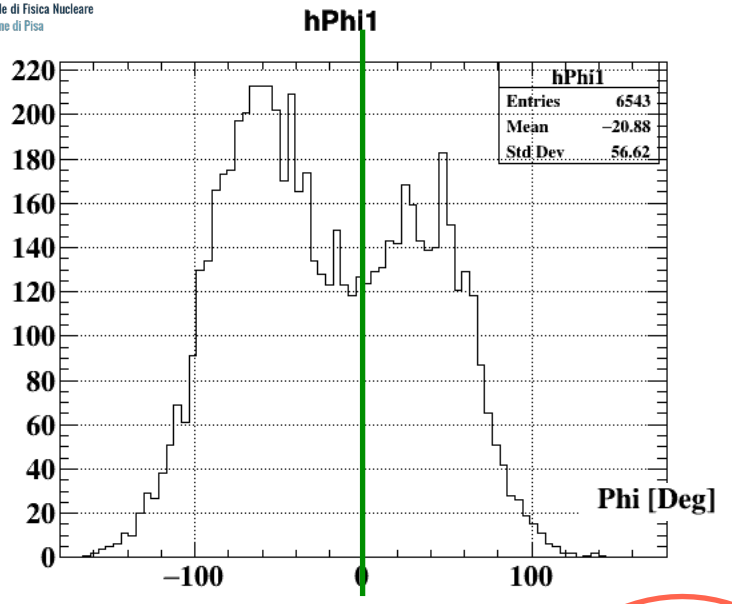
–> Mitigated by cutting on correlated tracks

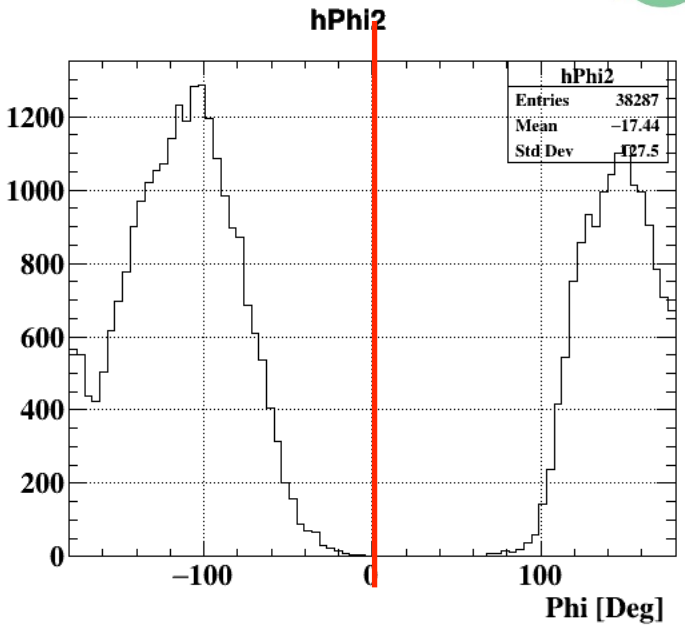
First analysis of data

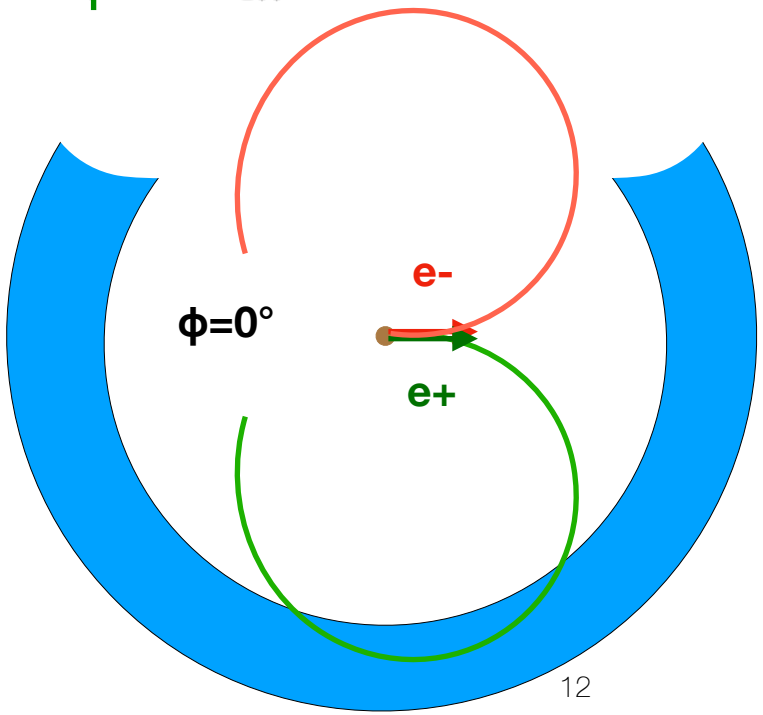
Momentum direction

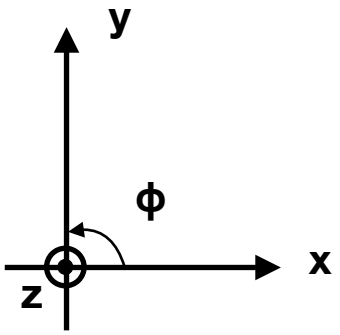
Positrons

Electrons



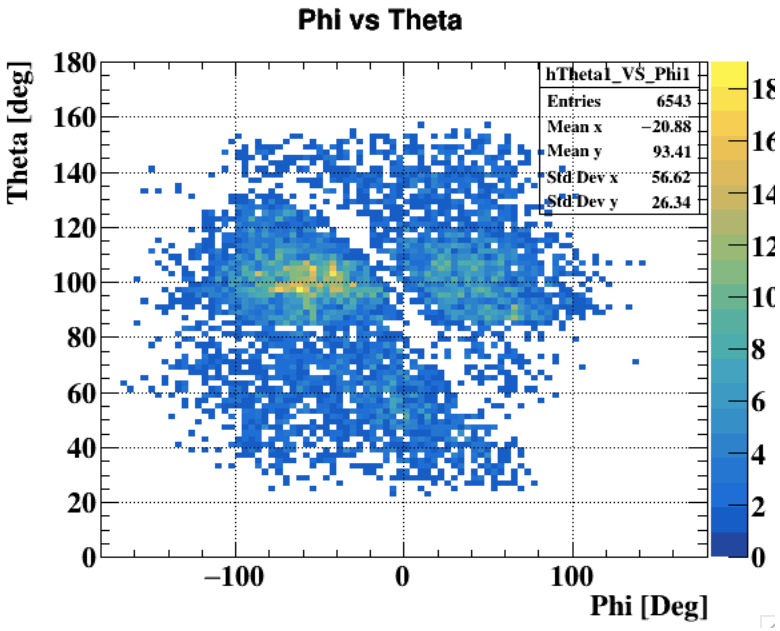




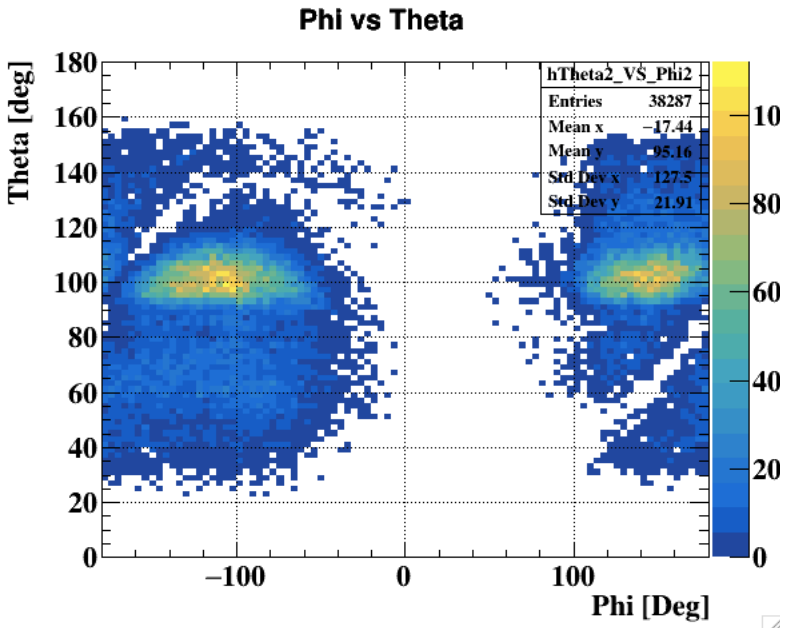


Momentum direction

Positrons

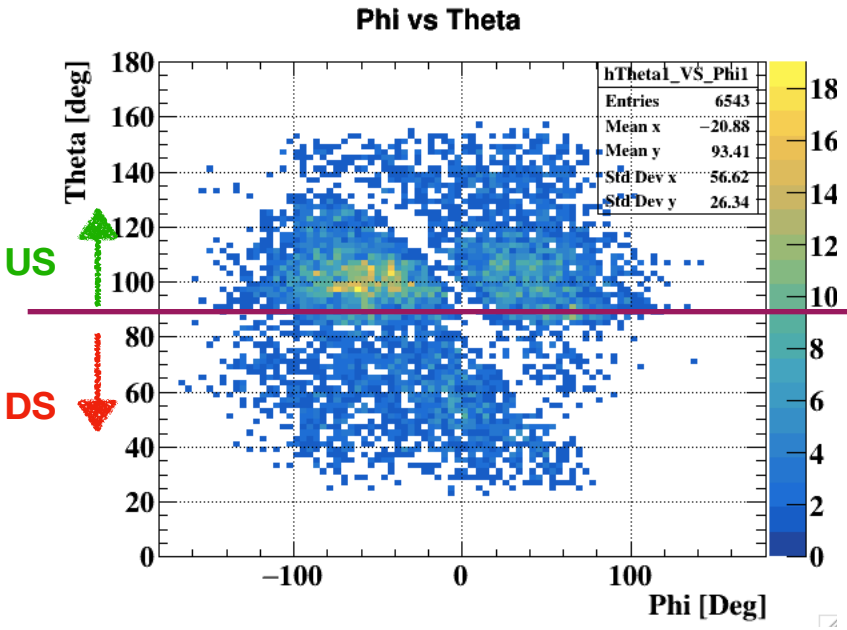


Electrons

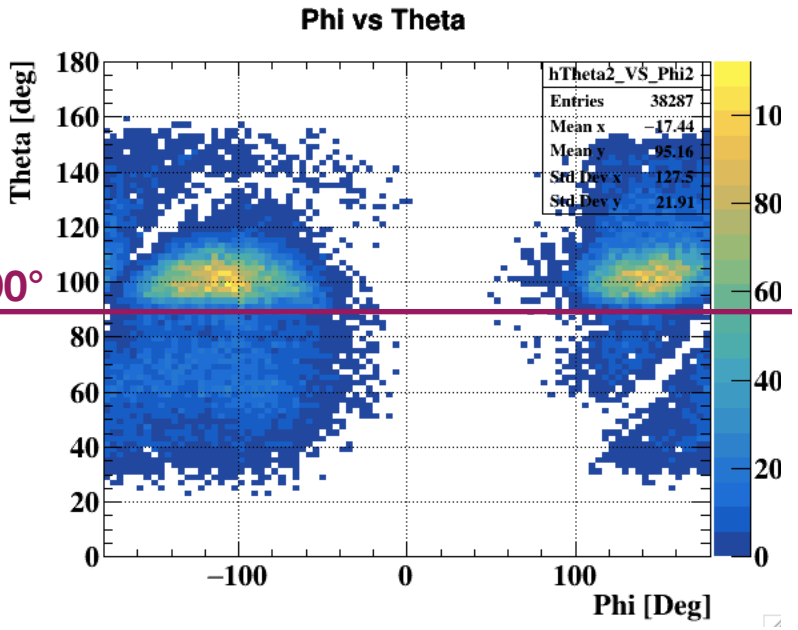


US/DS asymmetry

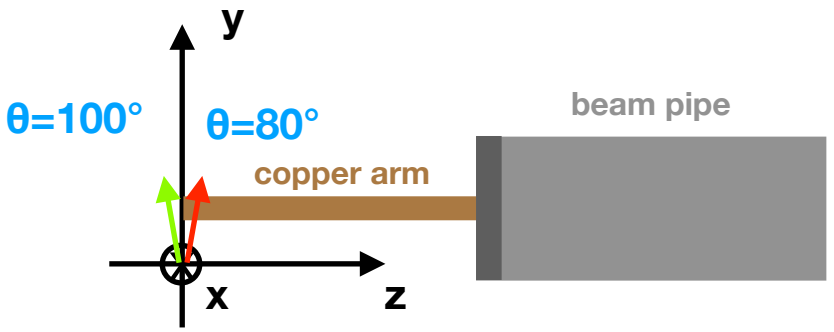
Positrons



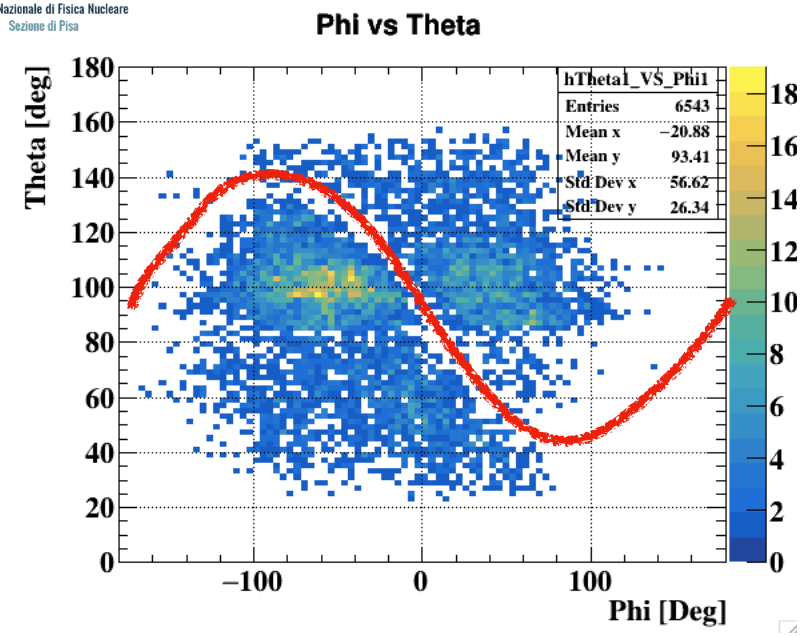
Electrons

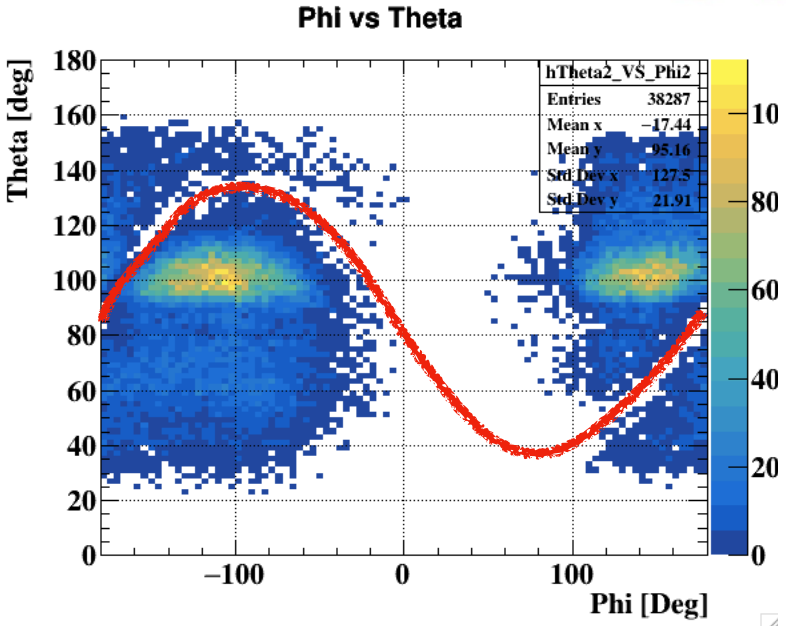


Clear asymmetry UpStream (US) vs DownStream (DS)
—> Copper arm and beam pipe prevent good tracks DS

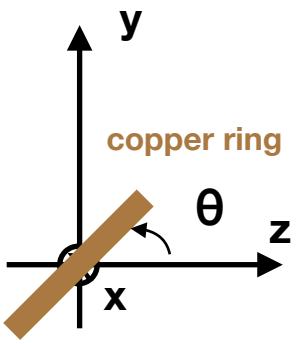


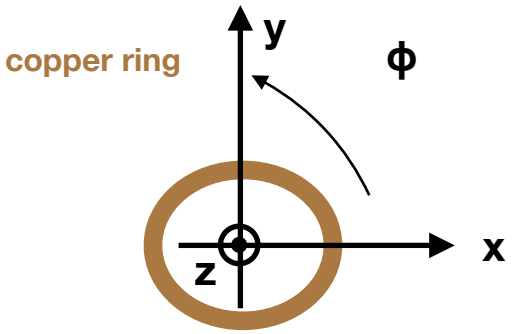
Copper ring?



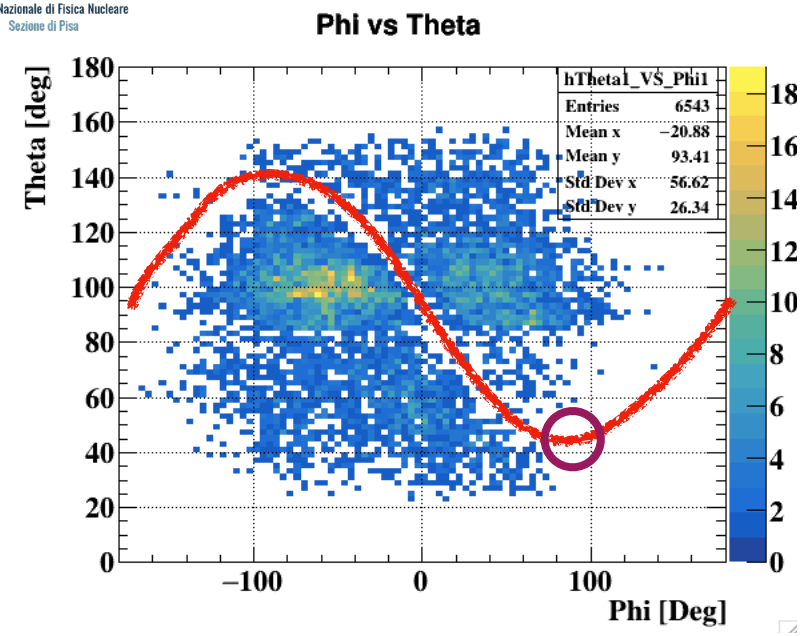


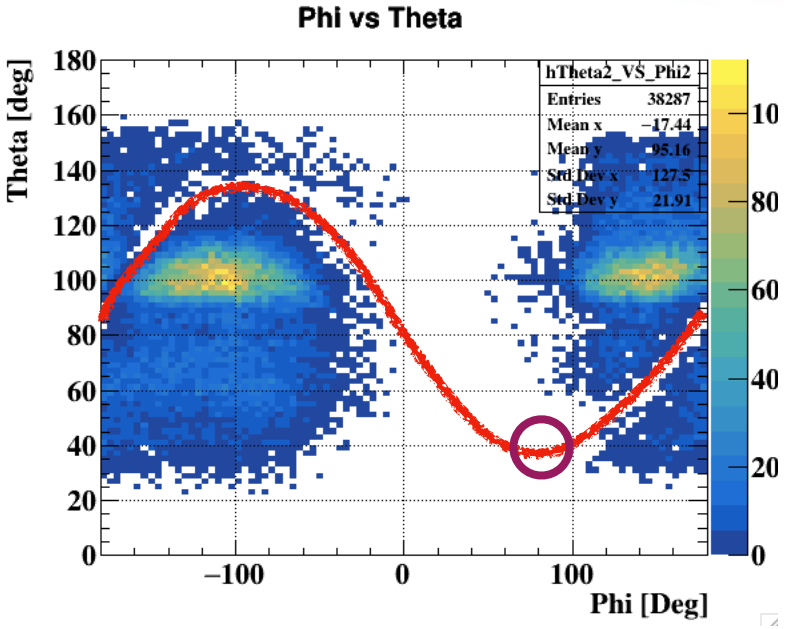
Copper ring is used to hold the target:

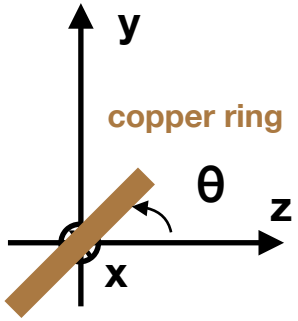


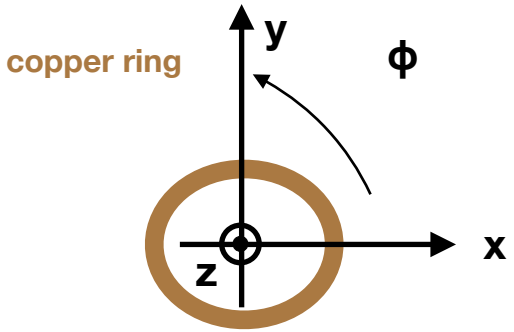


Copper ring?





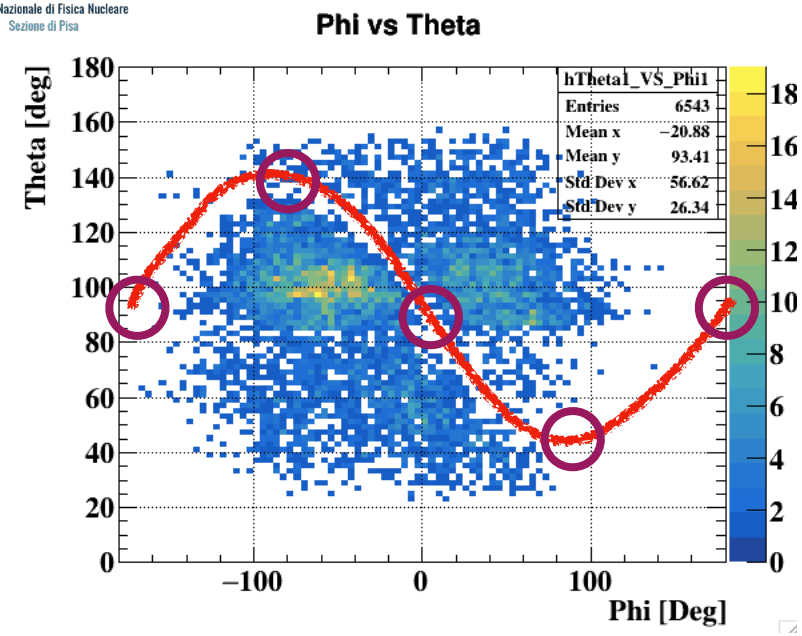


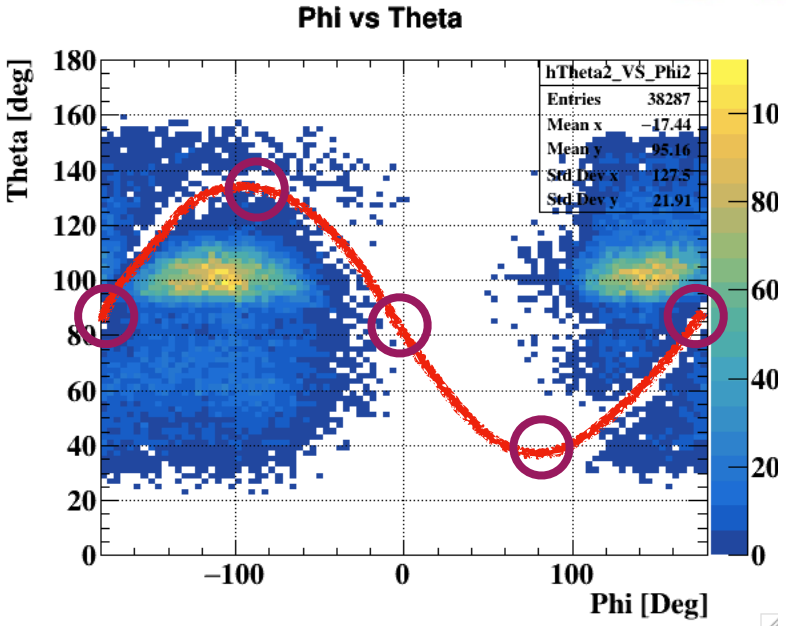


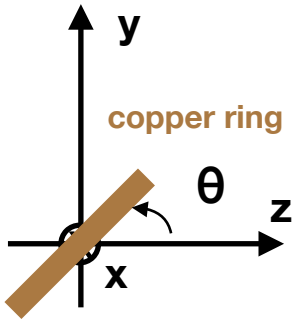
Ring coordinates:

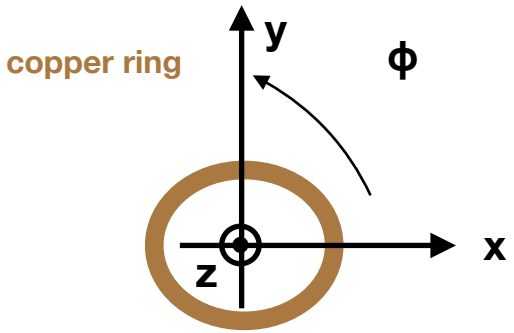
θ~45° —> ϕ~90°

Copper ring









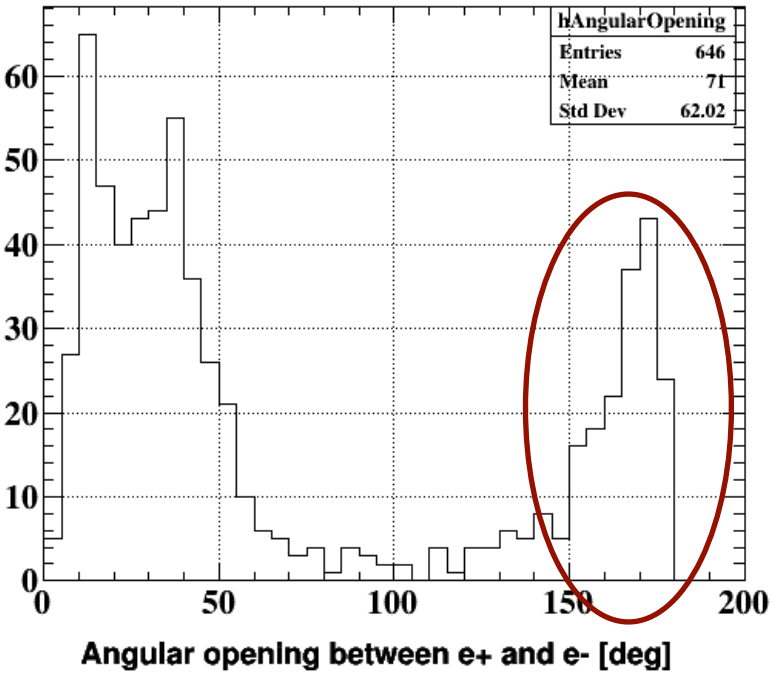
Ring coordinates:

θ~45° —> ϕ~**90°**

θ~135° —> ϕ~**-90°**

θ~90° —> ϕ~**0°** or ϕ~**180°=-180°**

LiPON data - 600k events



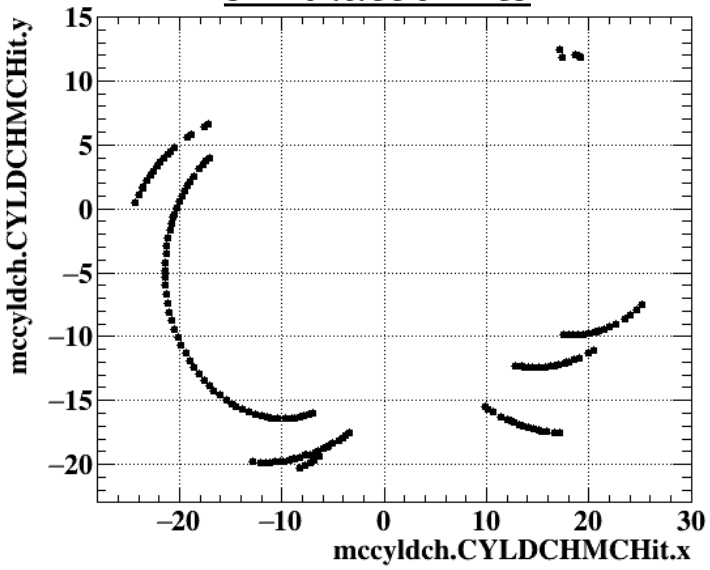
Peak at 180° from fake pairs reconstruction

–> Need to understand them better

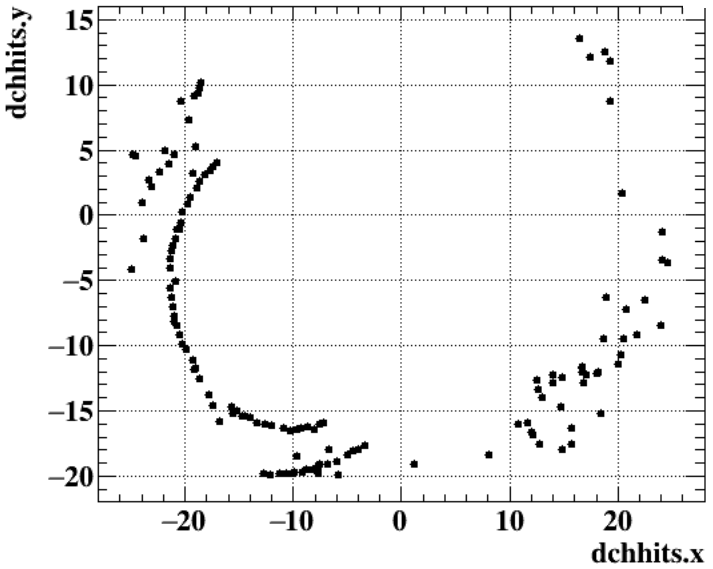
Bad pairs rejection

Bad pair event (reconstructed with 180° opening)

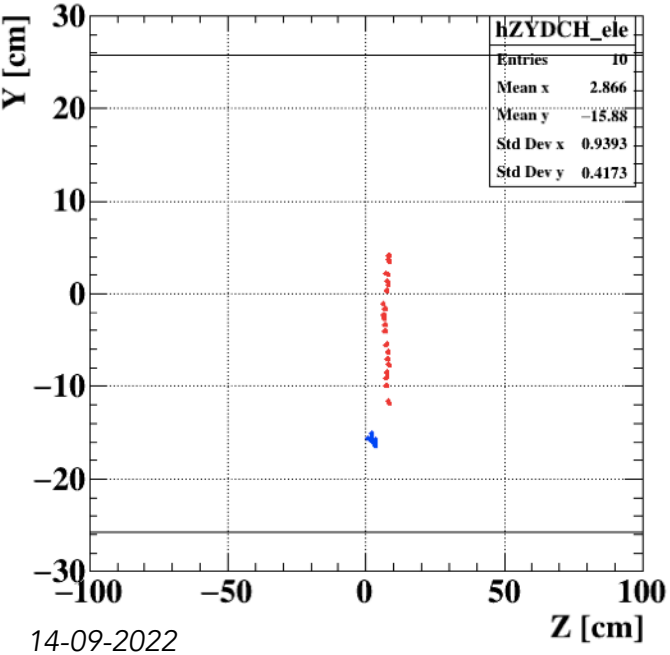
Simulated hits

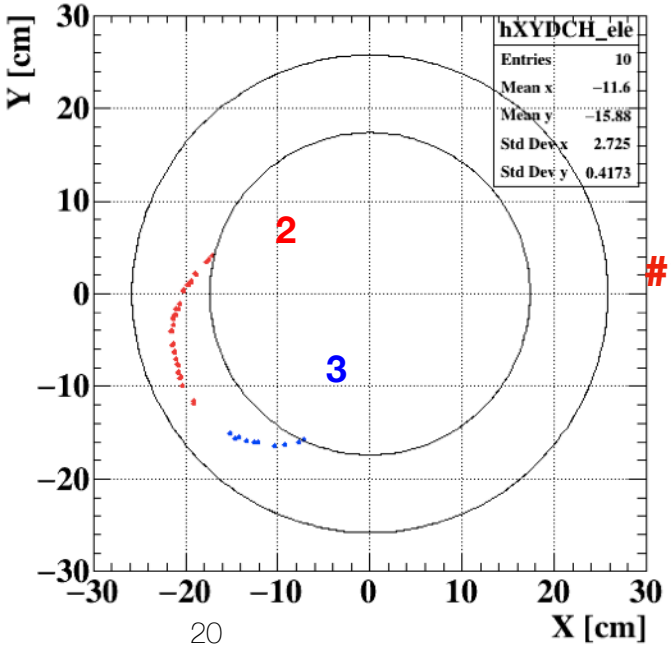


Reconstructed hits



Reconstruction tracks

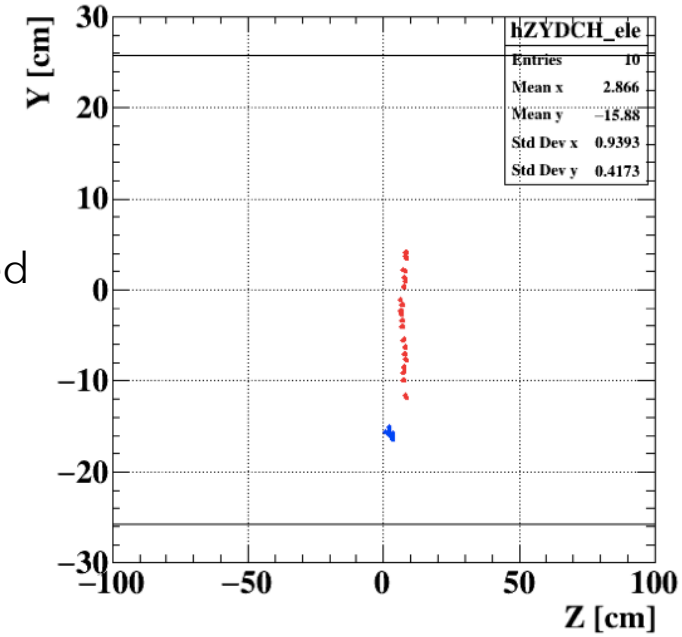


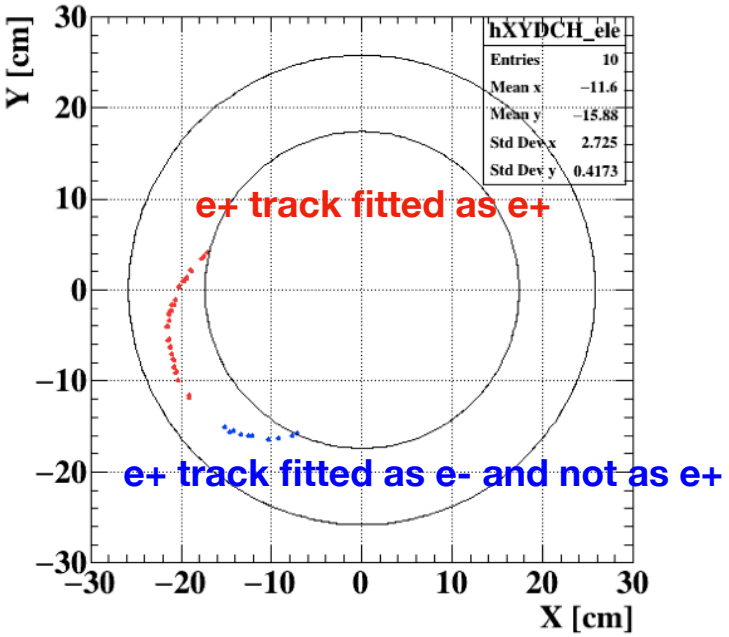


#2 and **#3** are propagated to target successfully

Physical target propagation

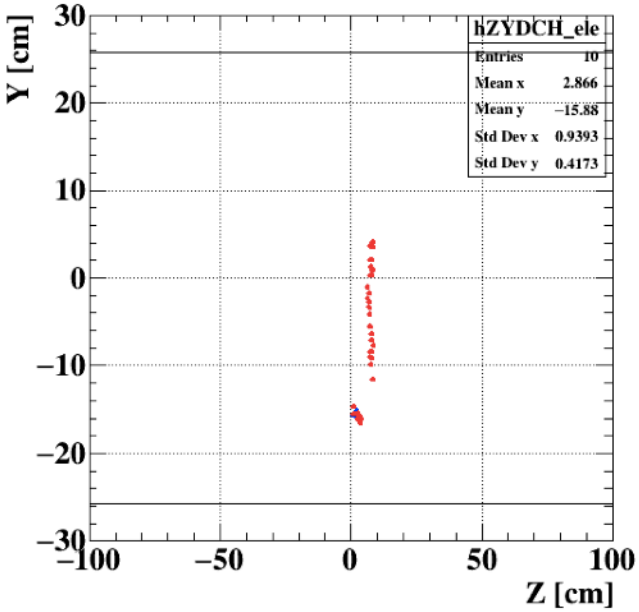
Tracks propagated to target

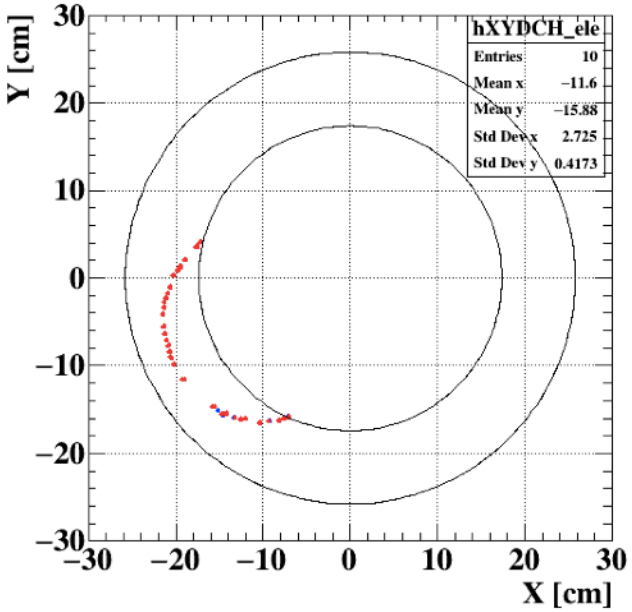




Enlarging the target to a 100 cm square plane

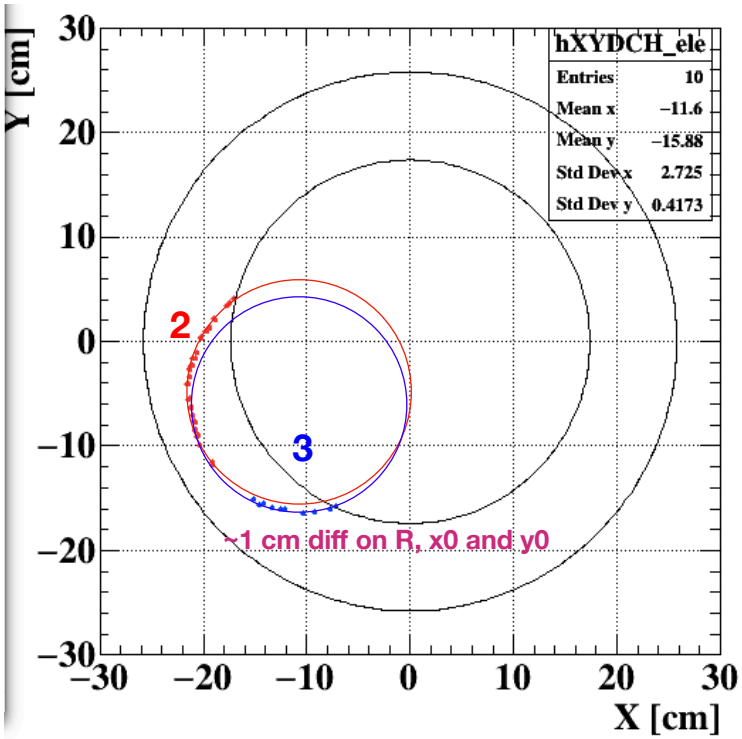
Tracks propagated to LARGE target





e+ track fitted as e- AND as e+ —> can be rejected

Procedure



–> do analysis with the physical target

–> look for e+/e- tracks correlation

–> fit both tracks with a circle

If |x1-x2|< 4cm
& |y1-y2|< 4cm
& |R1-R2|<4cm

–> do analysis requesting propagation to a squared 100 cm target

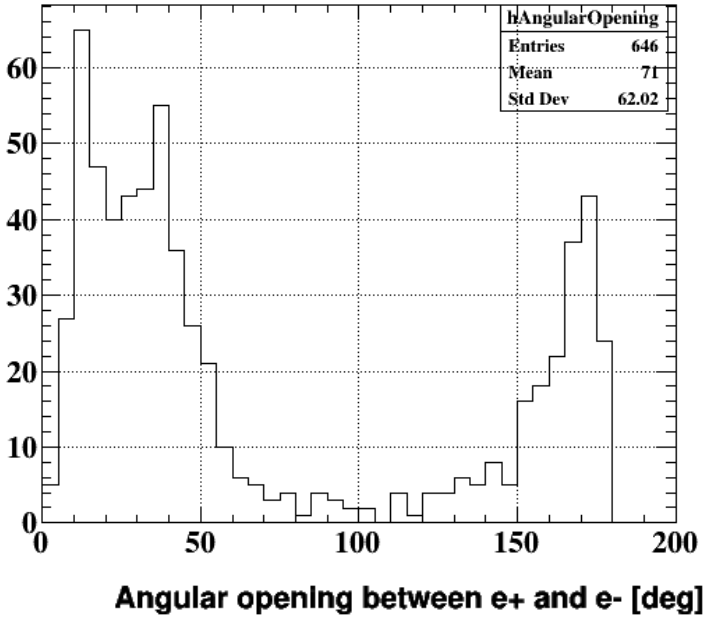
–> increases probability that pieces of real tracks are reconstructed

–> correlation between tracks should be recovered

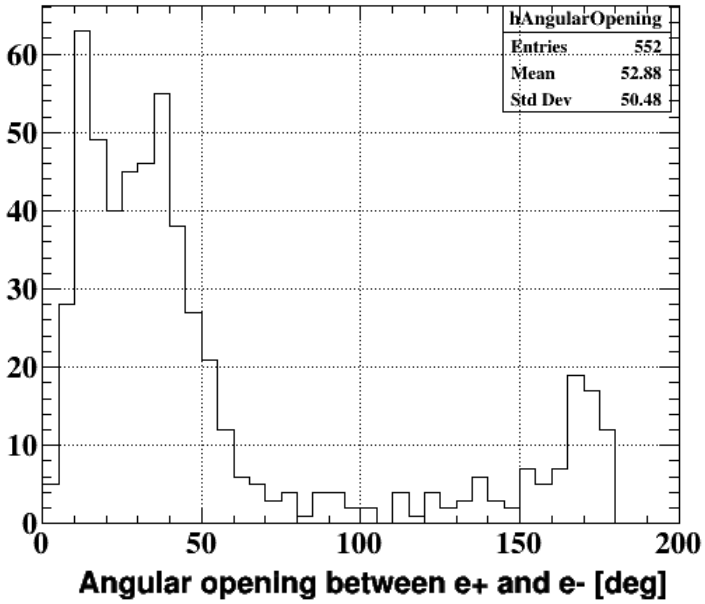
–> fake pair rejected

Application to data analysis

Without large target comparison



With large target comparison



–> most fake pairs rejected

Conclusion

- Procedure and algorithm were developed for e+/e- pair tracking

—> tracking of positrons adapted to electrons

—> Monte-Carlo simulations used for rejection of bad pairs

—> first understanding of data

- Next:

—> fake pairs still present: better characterization and find new techniques to reject them

—> estimate efficiencies of the search

—> final results

Courses and lectures

- **Particle Physics** - exam: July 4th
- **Instrumentation for Fundamental Interaction Physics** - exam: July 4th
- **Italian, A2 level** - exam: June 14th

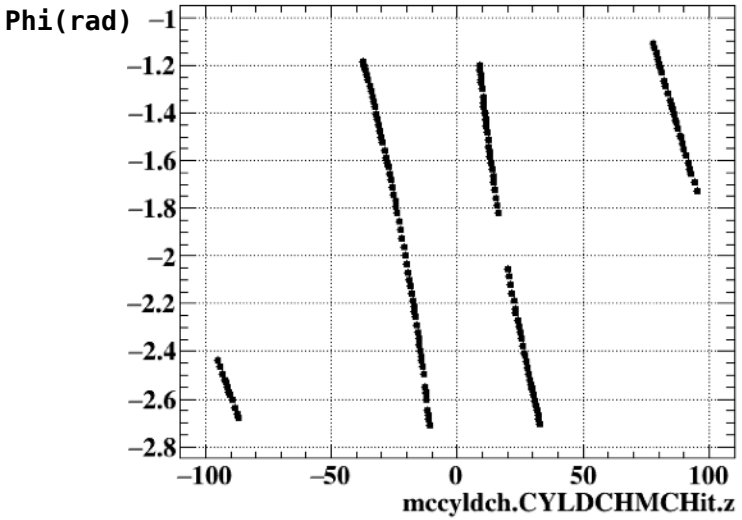
Conferences and trainings

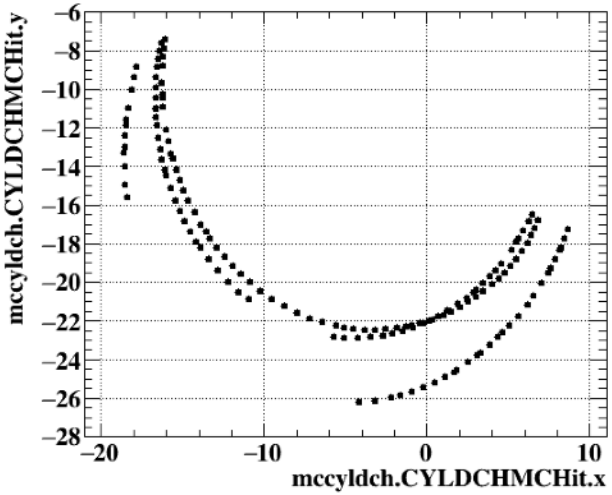
- International Workshop on Cosmic-Ray Muography, Ghent - November 2021
- 15th Pisa meeting on Advanced Detectors, Elba - May 2022
- International Conference on High Energy Physics XLI, Bologna - July 2022
- PSI Particle Physics Summer School - Vision and Precision, Zuoz - August 2022

Backup

Good pair

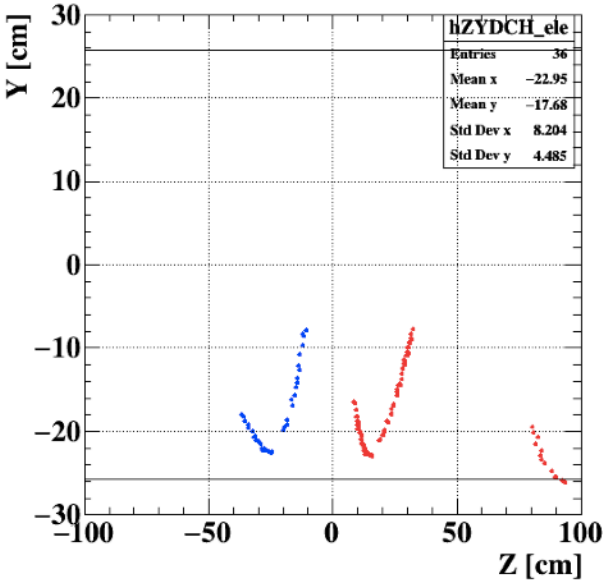
Simulated hits

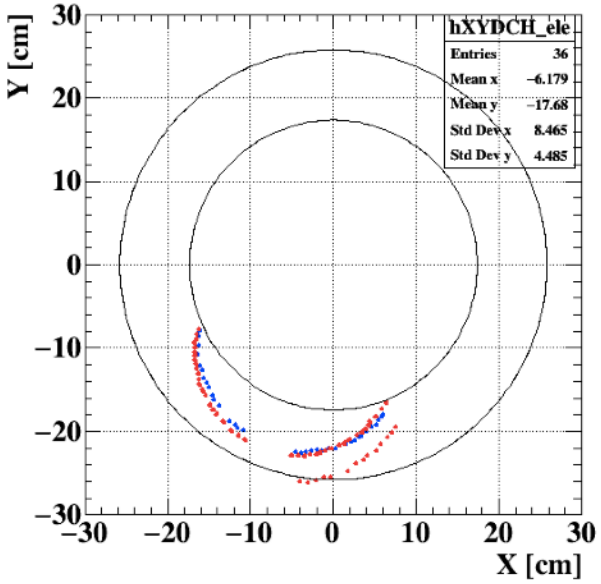





```
Event #1330
Angle = 173.714
Mom_e+ = 0.00899402
Mom_e- = 0.0208557
```

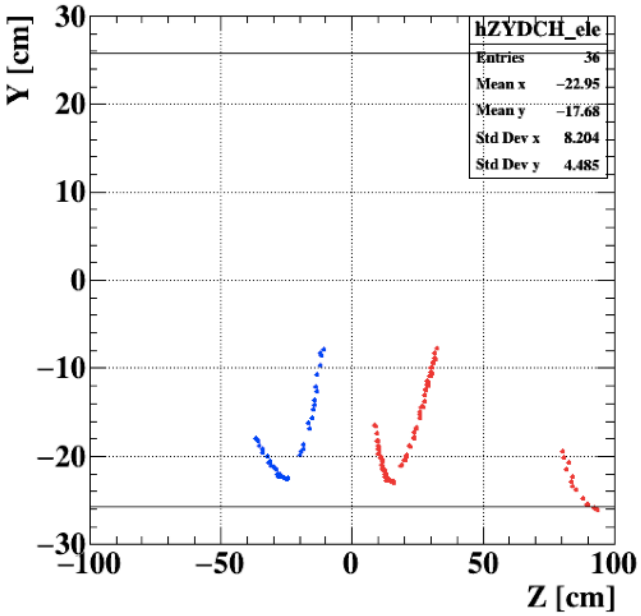
Reconstructed tracks

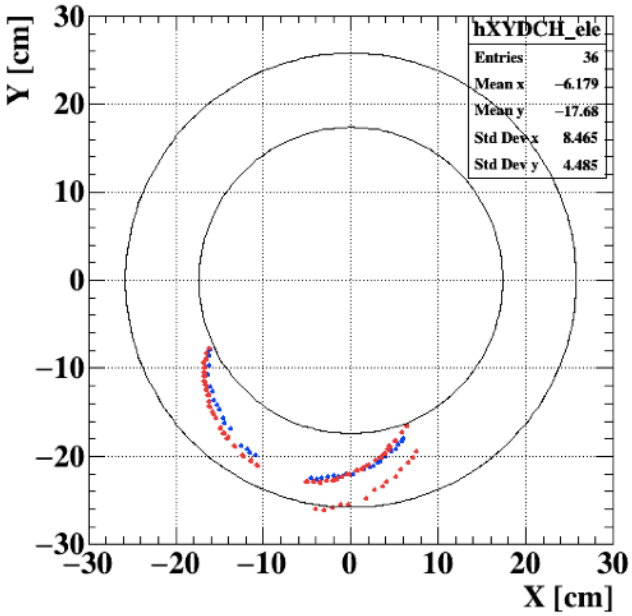




Physical target propagation

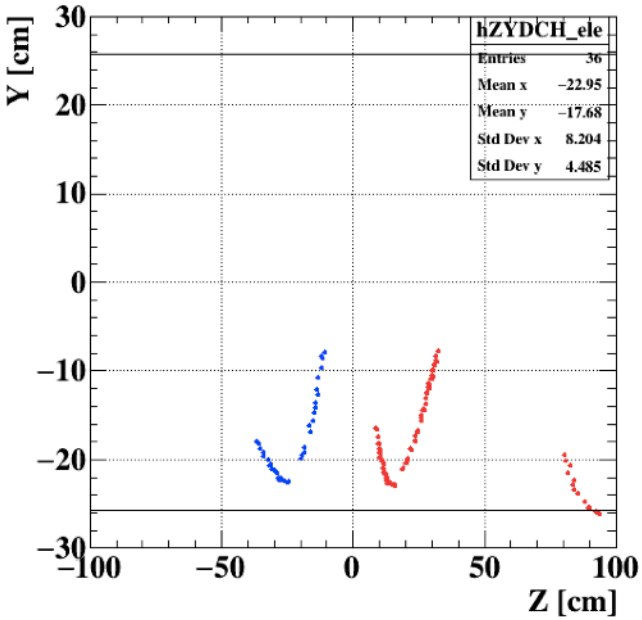
Tracks propagated to target

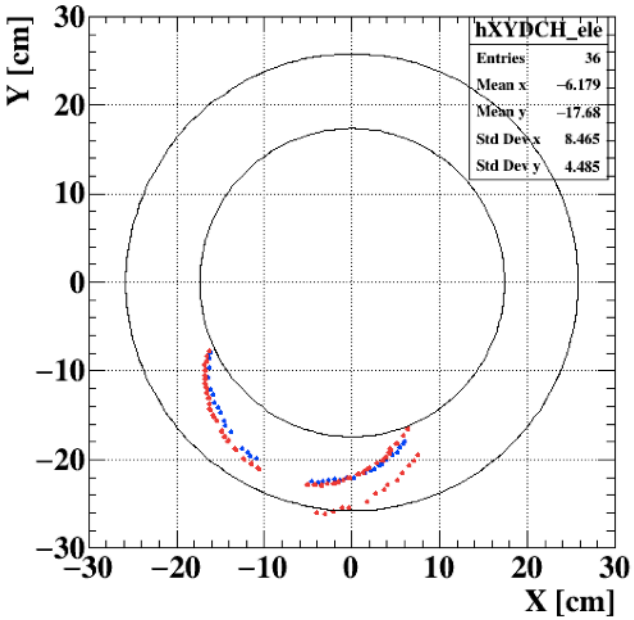




Enlarging the target to a 100 cm square plane

Tracks propagated to LARGE target





—> No correlation appears: event kept