Antiproton background and the vertical misalignment of the Mu2e beamline

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In partnership with:

Outline

- Mu2e signal and backgrounds
- Beam transport
- Antiproton background and vertical misalignment of the beamline
- Preliminary results and conclusions
- Plan for the future

Mu2e signal and backgrounds

- Mu2e will search for a neutrinoless conversion $\mu^- \rightarrow e^-$.

- Main backgrounds:

- RPC – Radiative capture of pions
- Antiprotons
- DIO – Decay in orbit of Muons
- Cosmic rays

- The estimated total background for Mu2e is $\sim 0.1/year$.

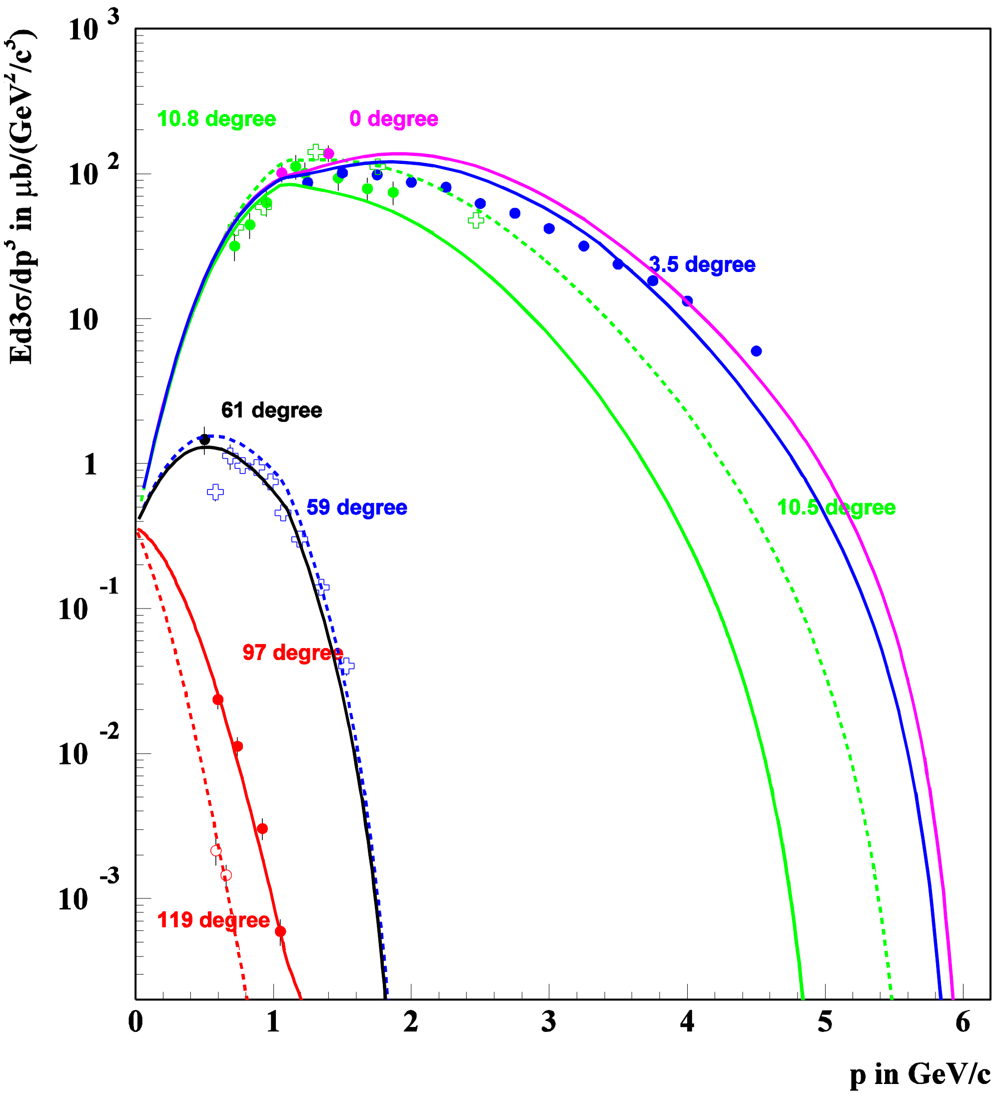
- Need to prove experimentally that the backgrounds are small.

Antiproton Background

➢ Antiproton annihilation in Al, with the probability $\sim 10^{-5}$, produces a $105\ MeV/c\ \ e^{-}$.

➢ Expected antiproton background is $\sim 0.01/year$.

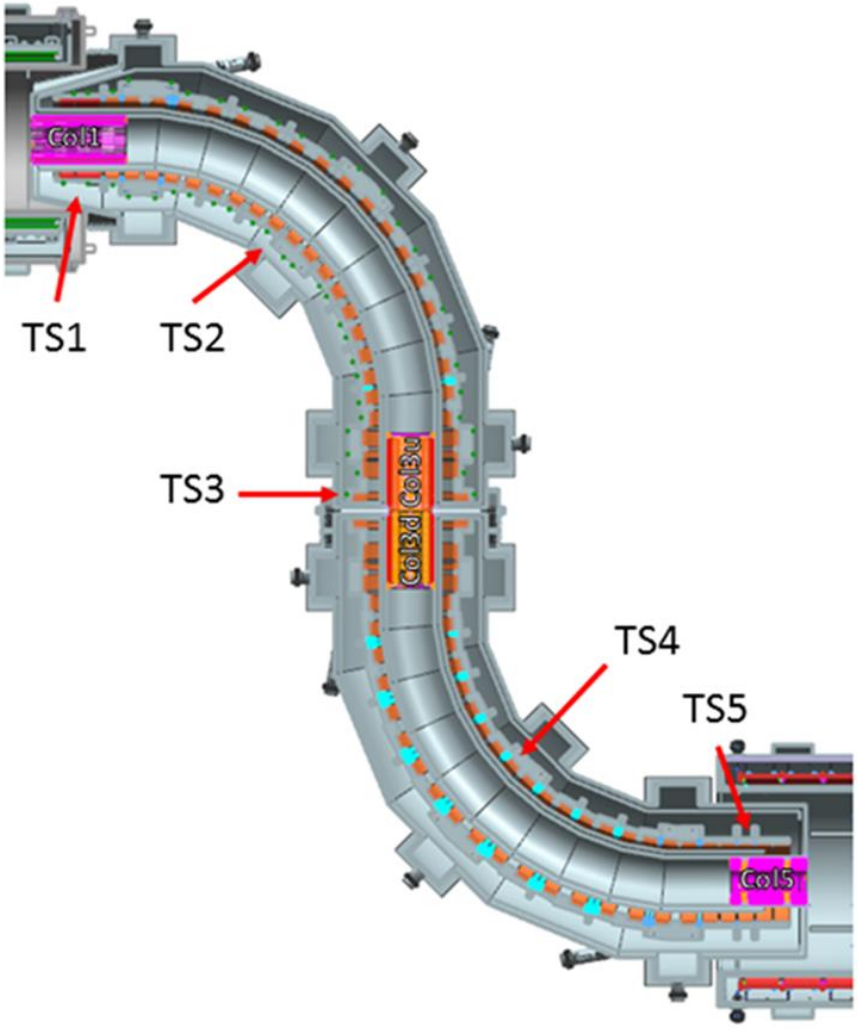
➢ The cross section angular dependence is not very well known.



Antiproton production in proton tantalum interaction near 10 GeV/c.

Transport solenoid (TS)

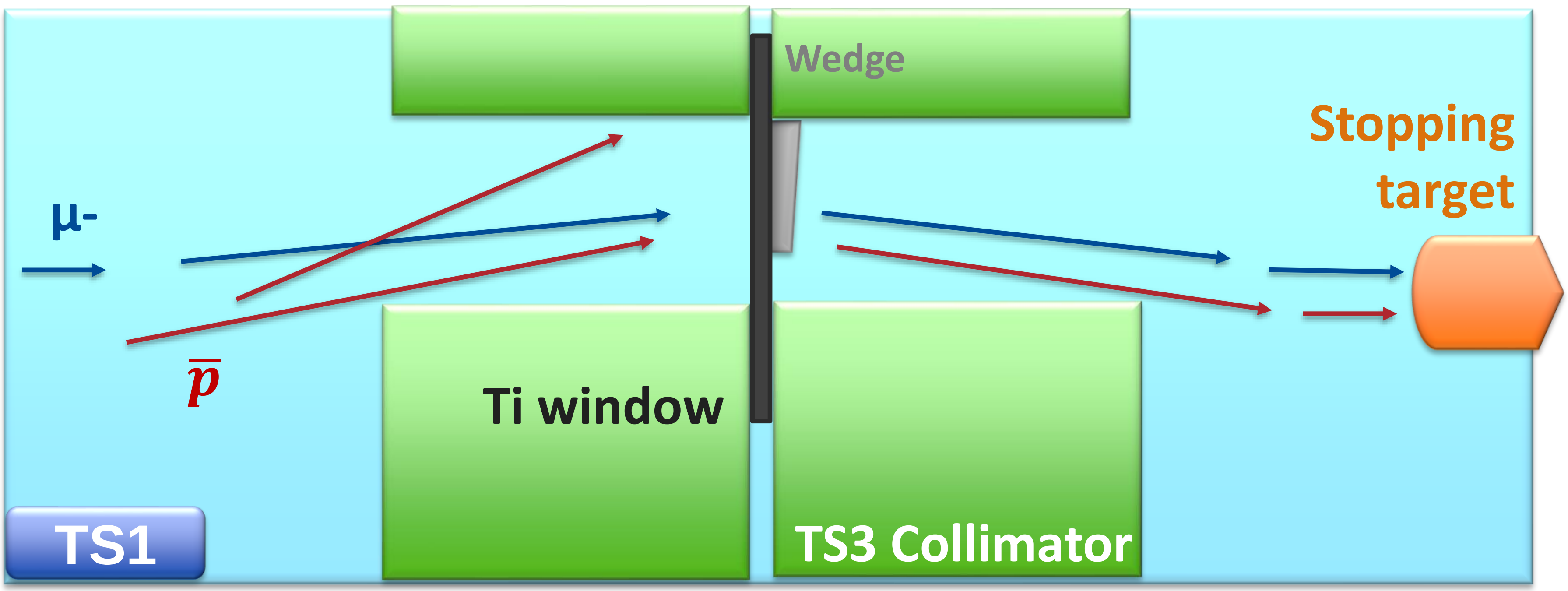
- Particles follow helical trajectories in the TS.
- Due to the shape of TS the magnetic field is curved.
- Localy the magnetic field inside the TS is directed toward the TS axis.
- A collimator placed in the middle of the TS blocks the +ve charged particles.
- Most of $\overline{p}$ hit the absorber, collimators and cryostat.



Trajectory of a negative particle

- Drift proportional to momentum and direction depend on the charge.

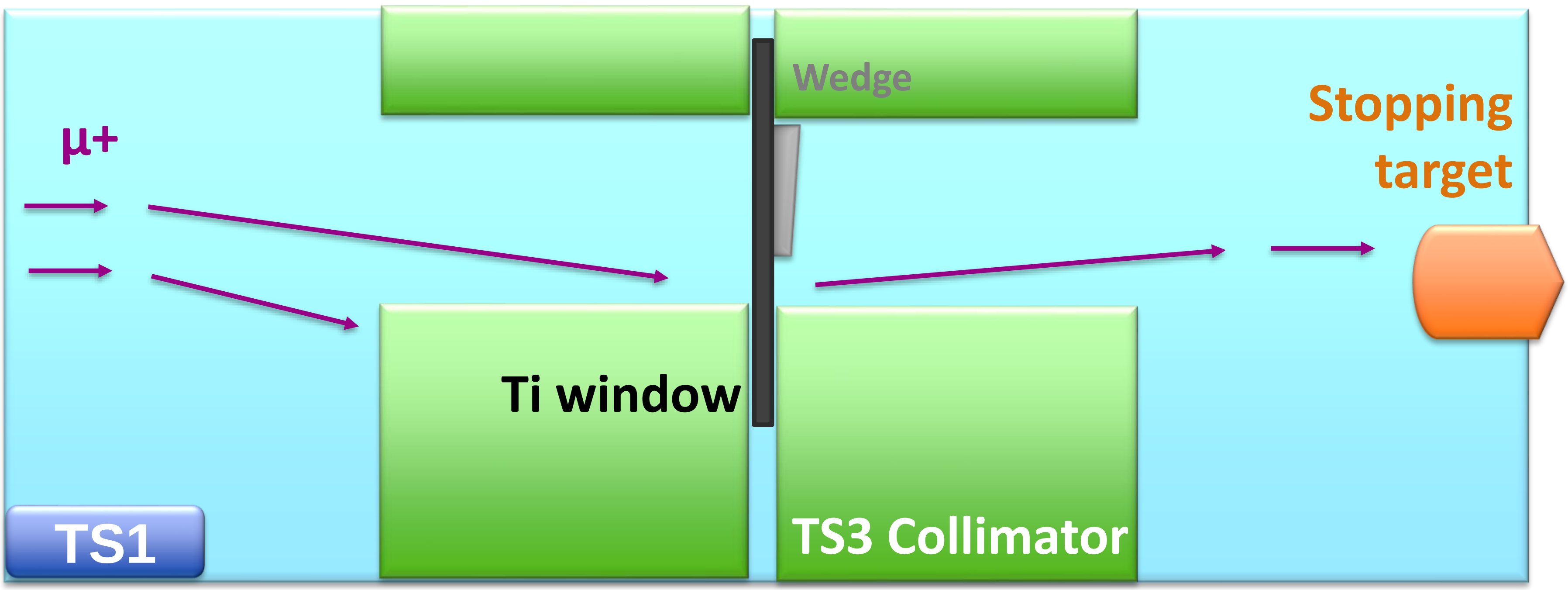
- Antiprotons with $P < 100\ MeV/c$ stopped by the titanium window.



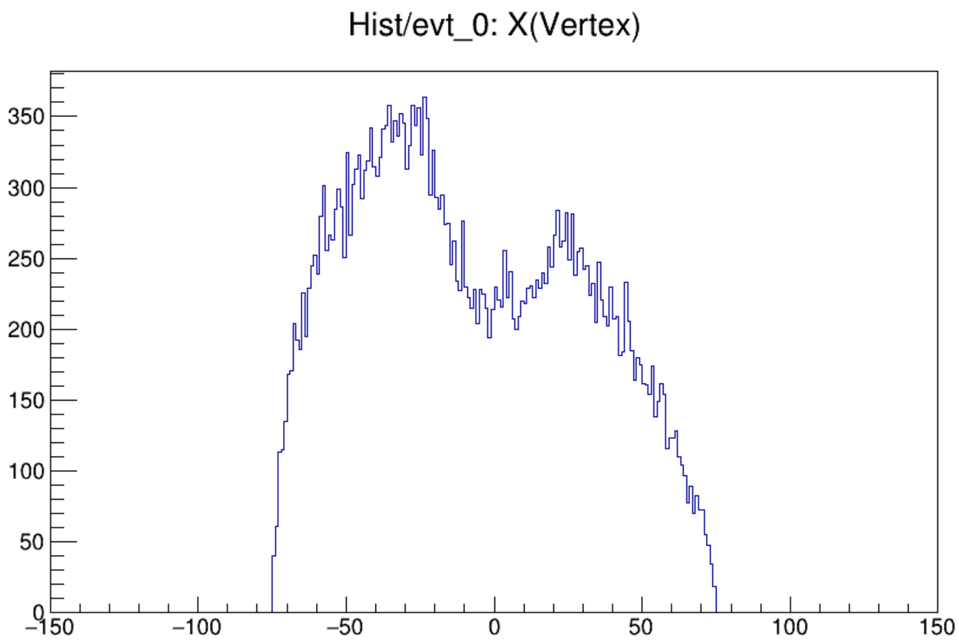
Trajectory of a positive particle

- μ^+ are blocked by the collimator.

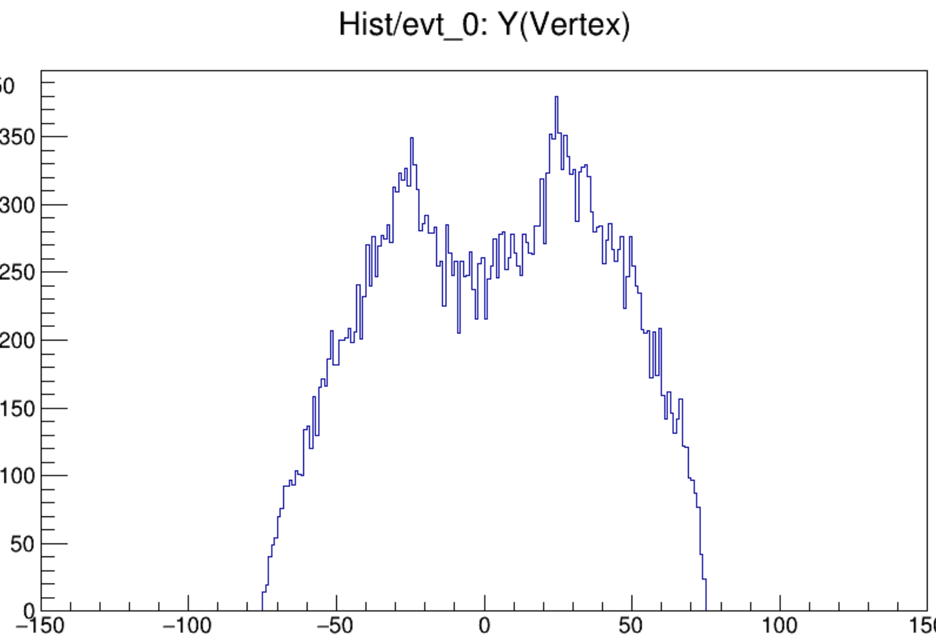
- A small fraction $\sim 10^{-3}$ of the μ^+ passes through the TS and reaches the ST.



Vertex coordinate distributions of μ^-

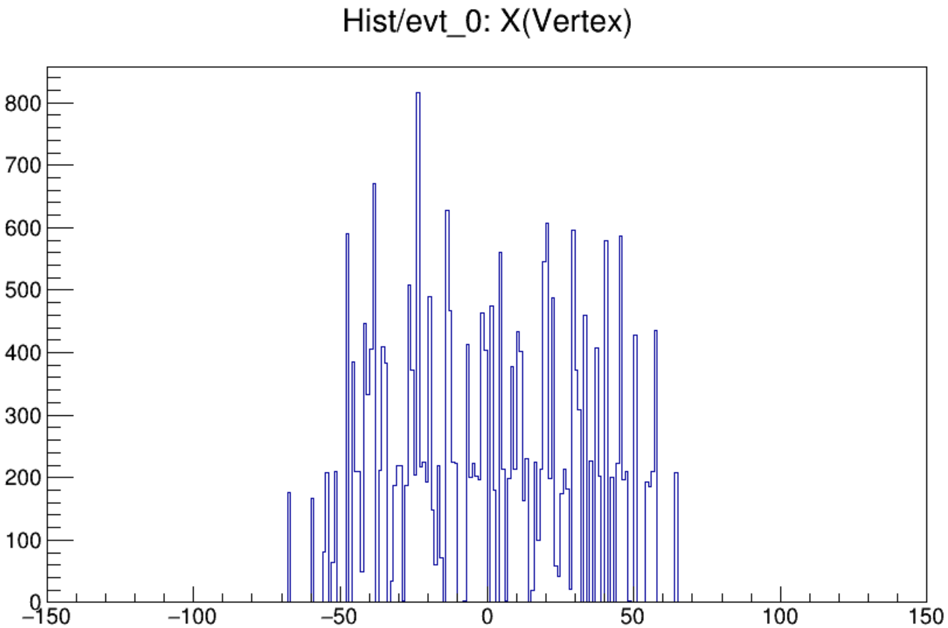


- **Unexpected asymmetry in X.**

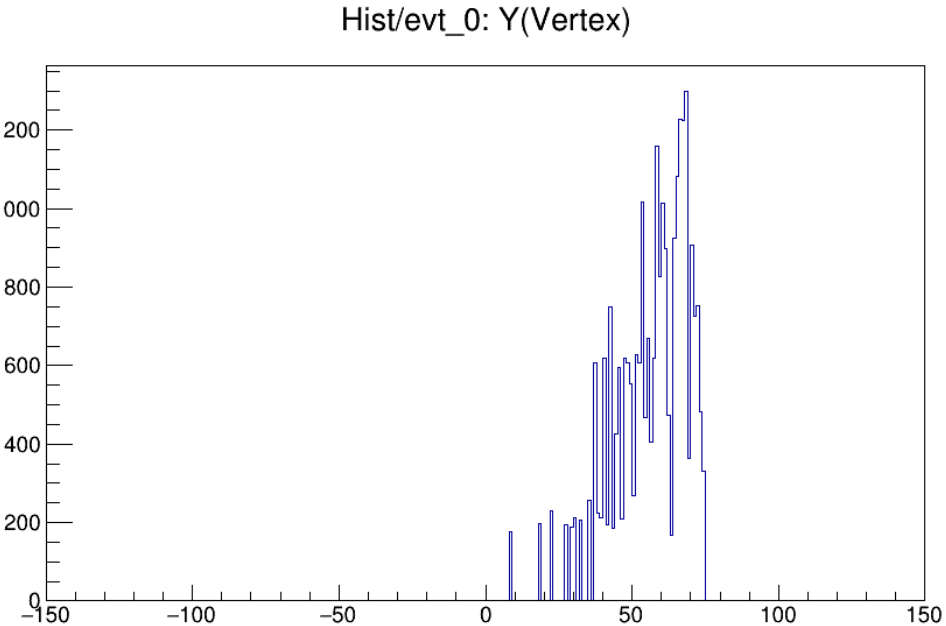


- **Y distribution more symmetric.**

Vertex coordinate distributions of μ^+

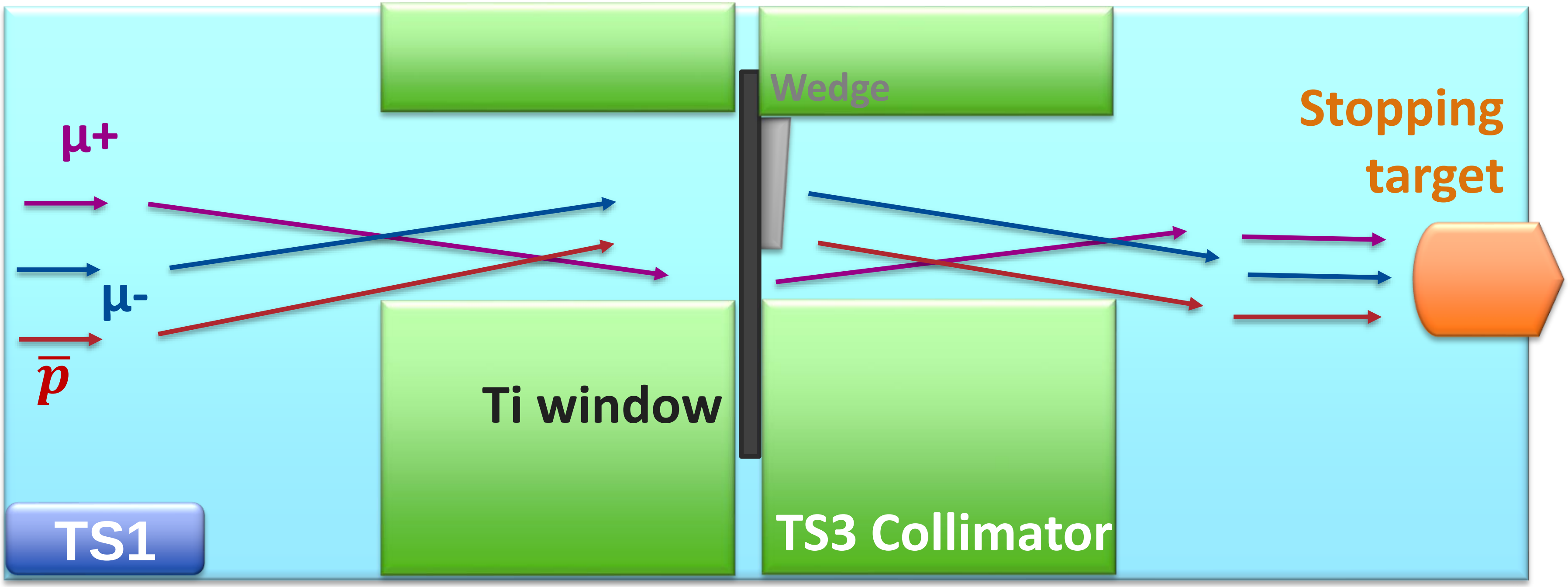


- **X distribution looks asymmetric.**
- **Need to increase the statistics.**



- **μ^+ are concentrated in the upper part of the stopping target.**

Vertical misalignment



- Antiproton background may be sensitive to the relative vertical alignment.

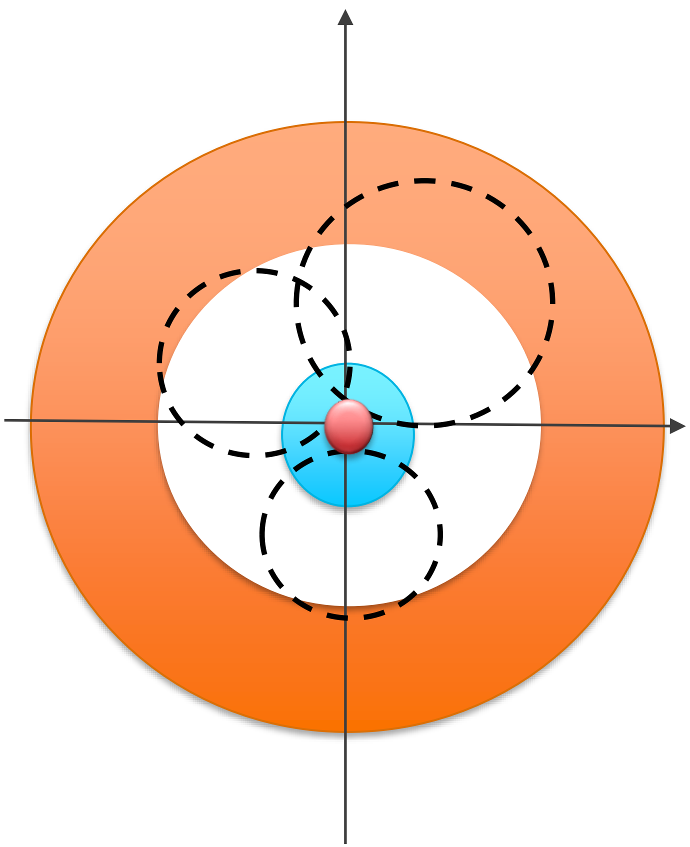
- Number of antiprotons could increase/decrease depending on the direction of misalignment.

Vertical misalignment

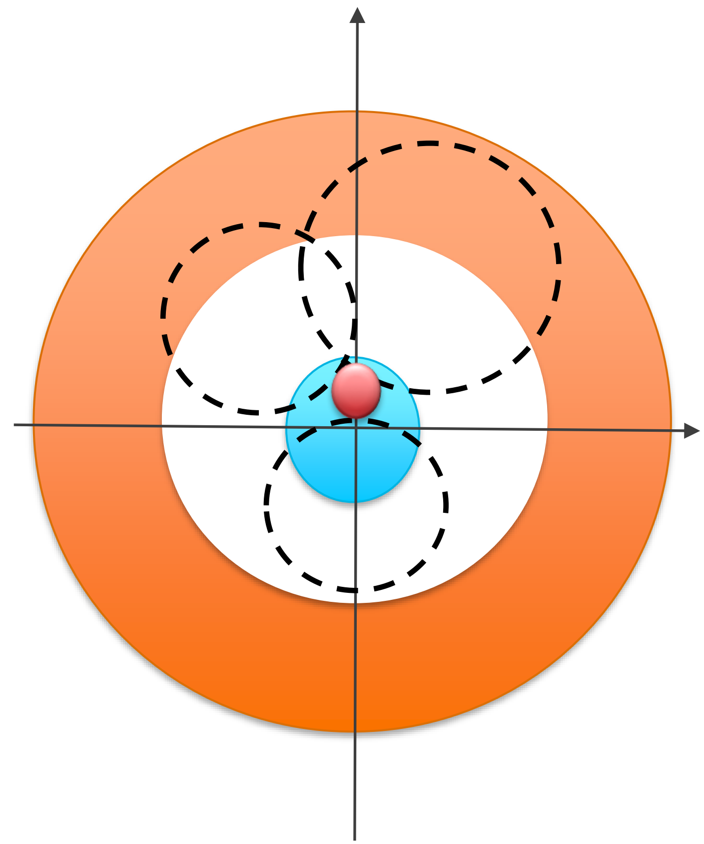
- The beam spot in the ST and the system axis will misalign.
- Number of blocked particles by the collimator changes.
- Expect a change in the ratio of μ^+/μ^- stopping rates.

Angular asymmetry

$\mu^- \rightarrow e^- \nu_e \nu_\mu$



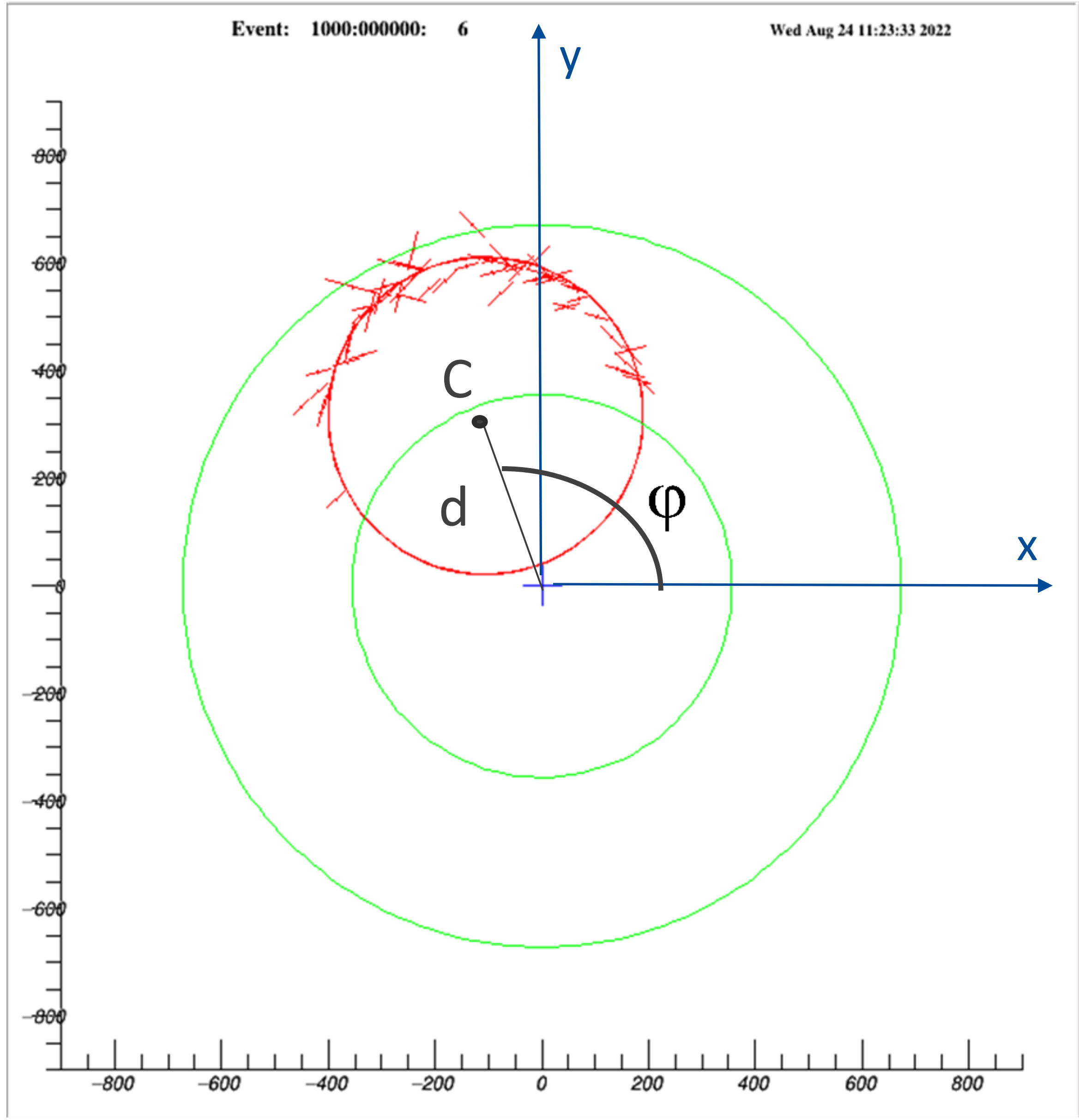
$\mu^+ \rightarrow e^+ \nu_e \nu_\mu$



- **Any asymmetry in the stopped μ should cause an asymmetry in the reconstructed observables of *e*.**

ϕ distribution

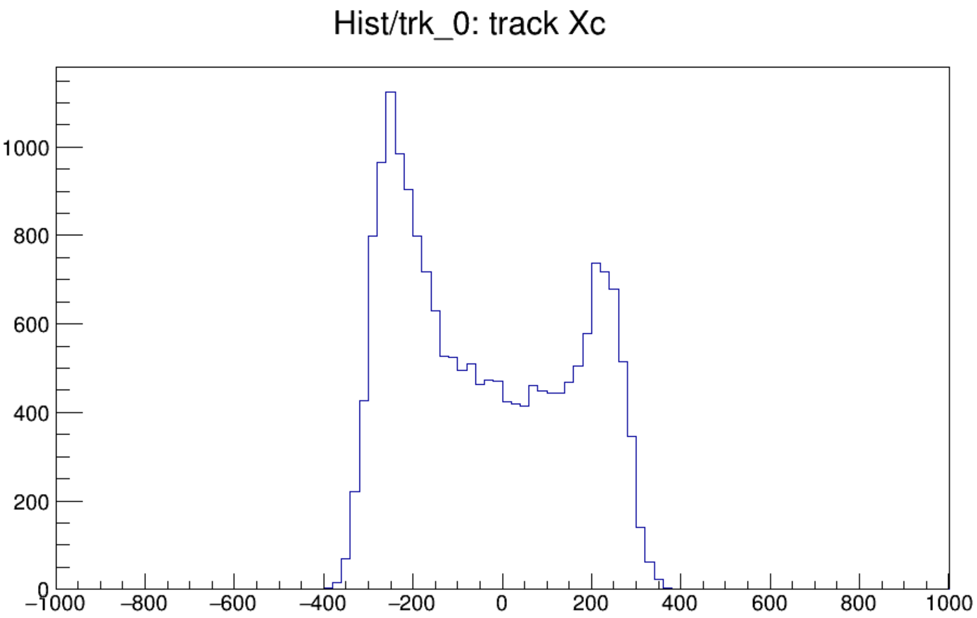
- ϕ **is the angle between x-axis and d.**

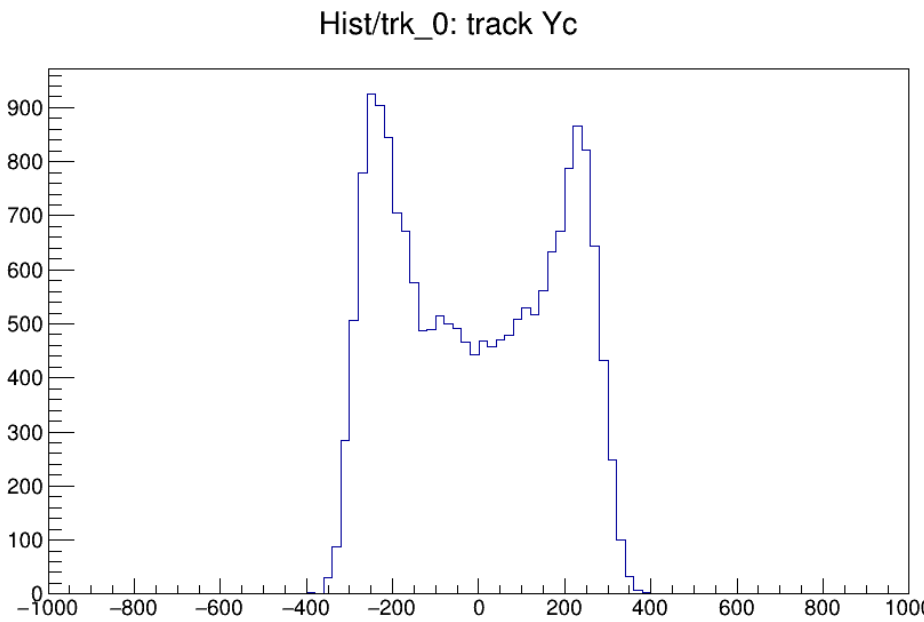


Beam transport simulation

- **Expected ratio** $^{\mu+}/_{\mu-} = 3 \cdot 10^{-3}$ **in** $B = 1\,T$ **.**
- 10^{8} **proton interaction in the production target.**
- $2 \cdot 10^{5}$ **mu+ and mu- decays.**
- **Rate** $^{\mu+}/_{\mu-} = 2 \cdot 10^{-3}$ **in** $B = 0.5\,T$ **.**

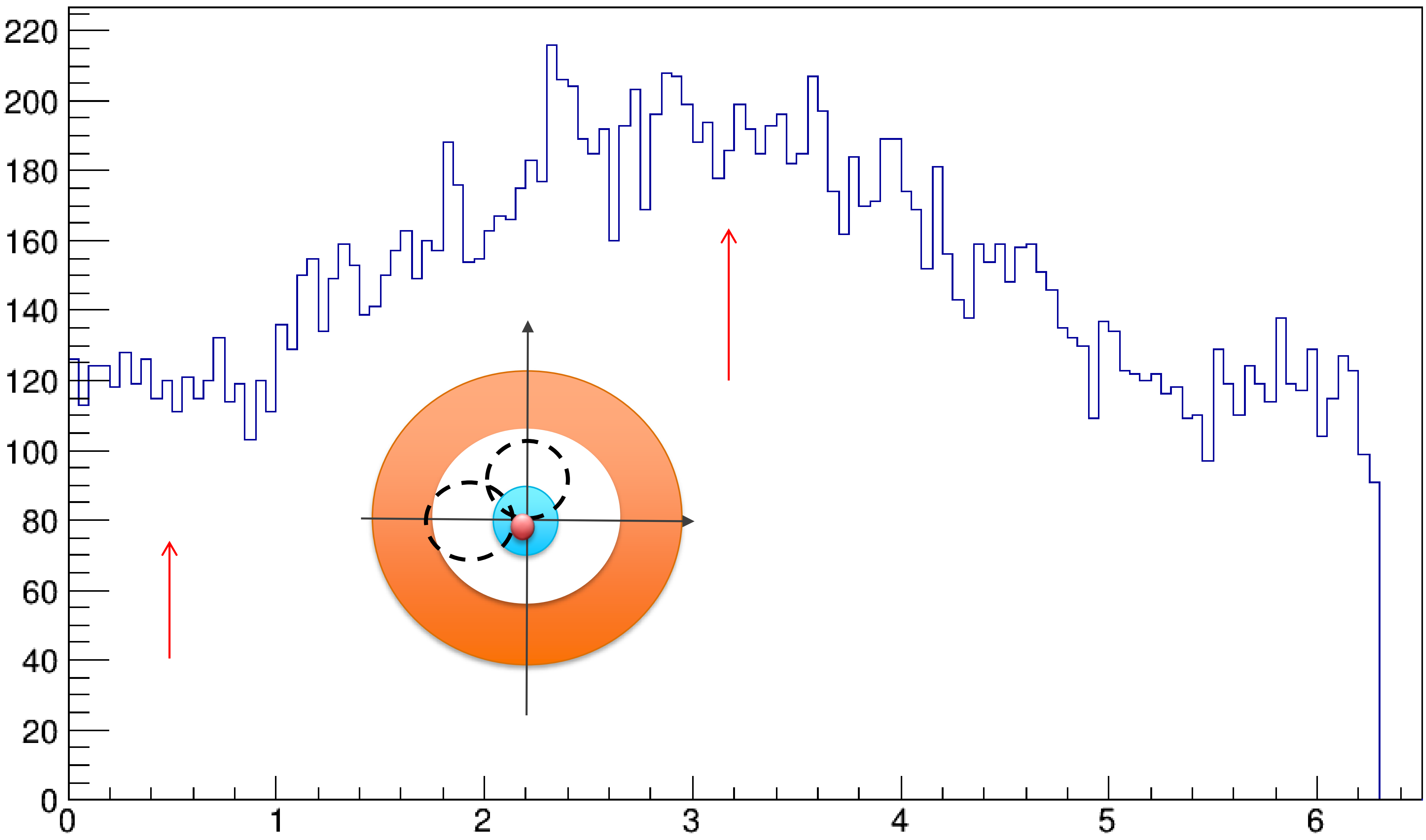
Track center coordinate distributions for e^-



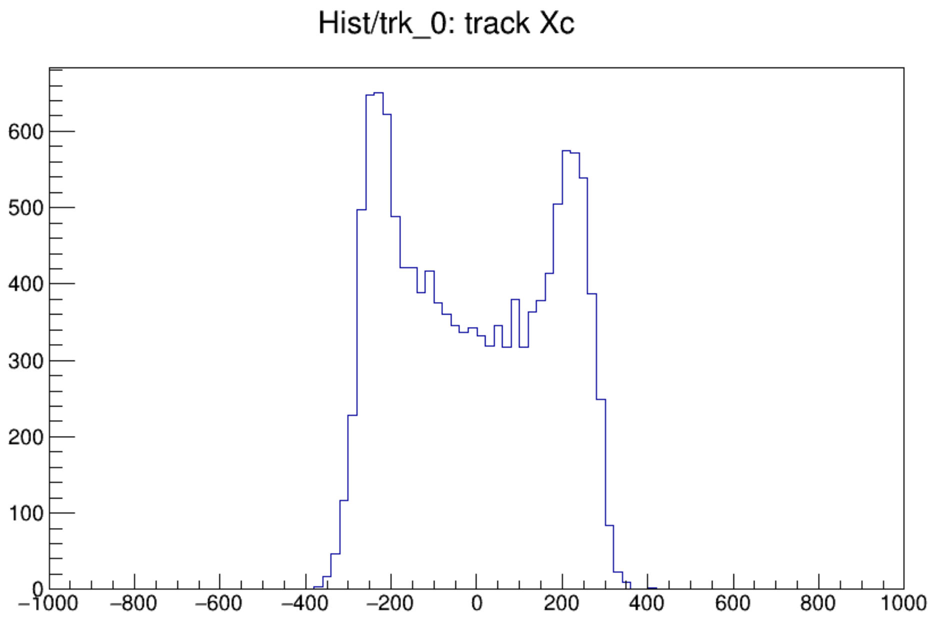


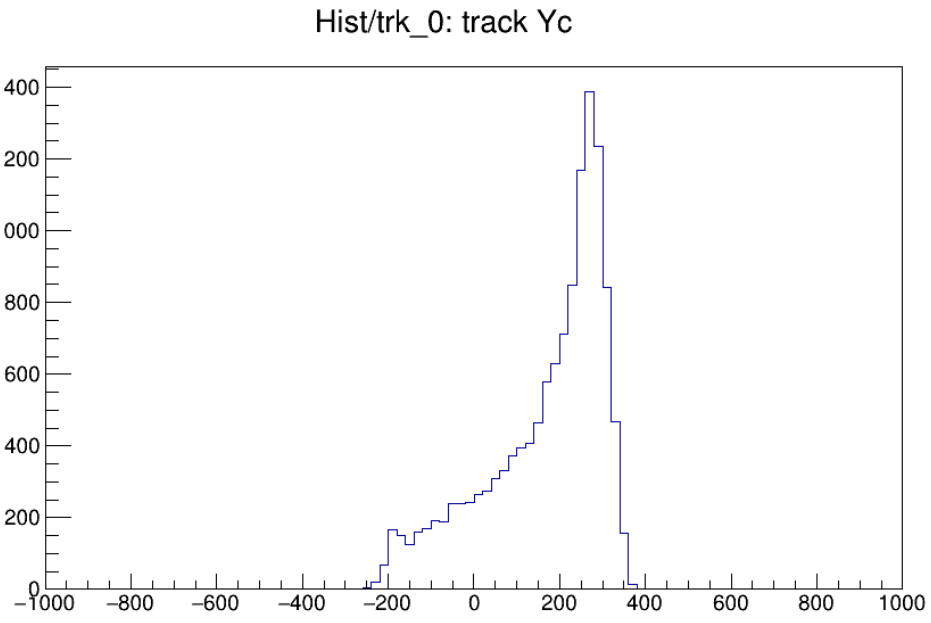
- **Asymmetry in X vertex distribution cause an asymmetry in Xc distribution.**
- **Not clear how the B field could explain it.**
- **Yc distribution more symmetric than Xc distribution.**

ϕ distribution for e^-



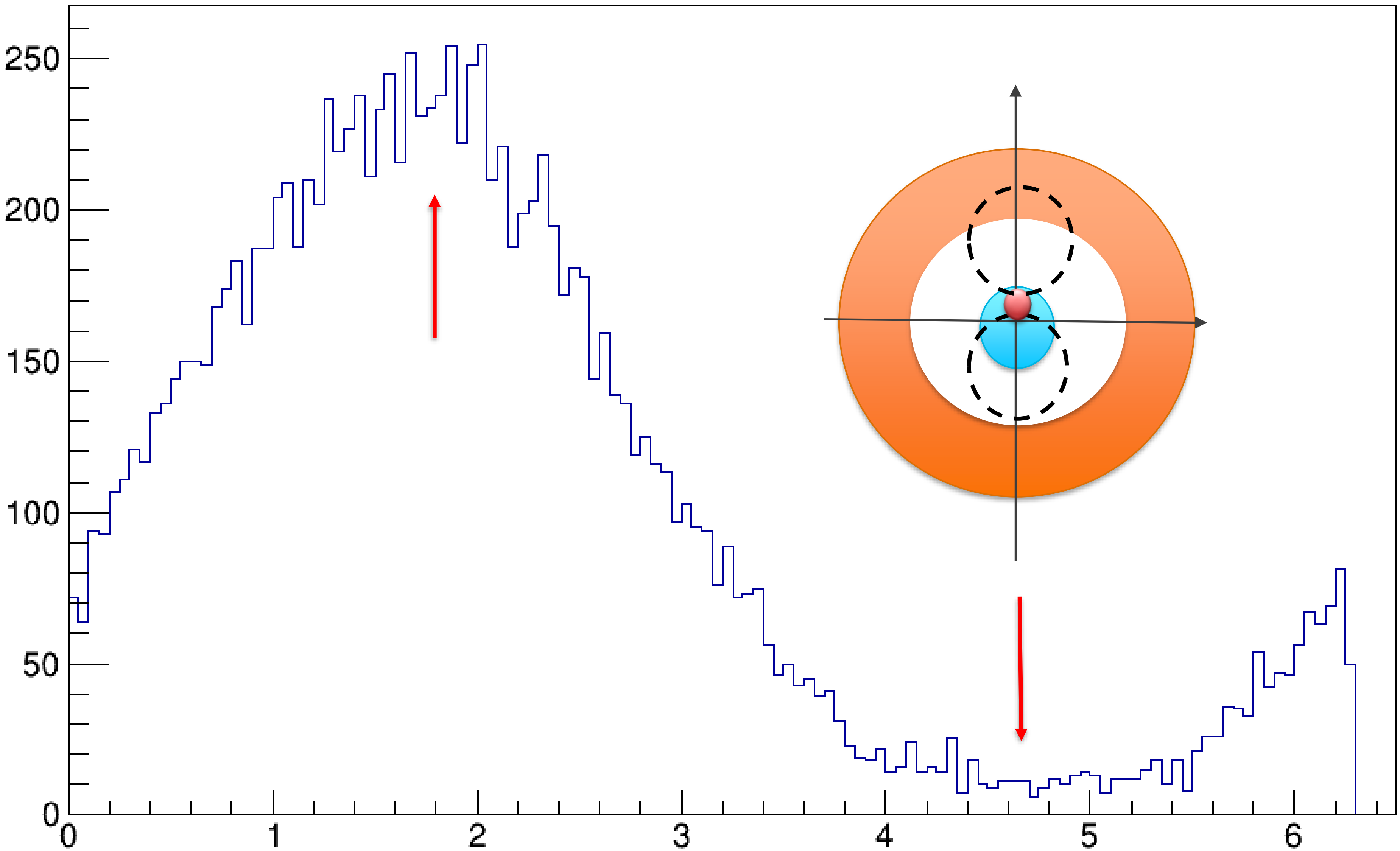
Track center coordinate distributions for e^+





- **Xc distribution is more symmetric compared to e- distribution.**
- **Expected asymmetry in the Yc distribution.**

ϕ distribution for e^+



Conclusions

- Observed the expected asymmetry in the phi distribution for e+.
- There could be more asymmetries in the beam that can cause asymmetries in the reconstructed track.
- The beam displacement in X could be on of those.
- Ready to proceed with the misalignment study.

Next steps

- **Study the sensitivity of e+ and e- asymmetries to vertical misalignment of the beamline.**

- **Study effect of the vertical misalignment on the antiproton background.**


THANK YOU FOR YOUR ATTENTION!