TPC Distortions at Tera-Z

Status report

Mingrui Zhao China Institute of Atomic Energy Niels Bohr Institute, Copenhagen University 2023/Mar/09 (Updated on Mar/13) LCTPC WP Meeting

General Information

- The Feasibility of TPC for Z pole was studied in 2017 in [2017 JINST 12 P07005]
- Conclusion of the paper:
 - At Lumi = 2×10^{34} cm⁻² s⁻², Backflow k=5
 - Very low voxel occupancy
 - Max Distortion = 10 μ m << intrinsic TPC spatial resolution of 100 μ m
- Now:
 - Lumi = 2×10^{36} cm⁻² s⁻² (Safety to scale the results by 100)
 - Many of the details are missing
 - To do a step by step (as possible) comparision with Serguei and Keisuke
 - Primary ion were not considered carefully in previous paper
 - The impact on track resolution should be investigated

General Picture (Primary ions)



- Primary charge is z dependent
- At Lumi = 10³⁴ cm⁻² s⁻¹, R = 300 Hz
- V_ion = 5m/s
- L_TPC (half length) = 2.35m
- At Lumi = L * 10^{34} cm⁻² s⁻¹
- N_disc = L * 141
- 30000 (for L = 200)

General Picture (Backflow ions)



- Backflow charge is z independent
 - At Lumi = 10³⁴ cm⁻² s⁻¹, R = 300 Hz
 - V_ion = 5m/s
 - L_TPC (half length) = 2.35m
 - At Lumi = L * 10³⁴ cm⁻² s⁻¹
 - N_disc = L * 141
 - 30000 (for L = 200)

Method

- Calculate the charge distribution
 - Simulation
- Calculate the electric field
 - Green function
- Calculate the distortion

$$\left(\frac{\omega\tau}{1+(\omega\tau)^2}\right)\frac{\boldsymbol{E}_{\perp i}\times\hat{\boldsymbol{B}}}{E_0}$$

Keisuke's slide in previous meeting: https://agenda.linearcollider.org/event/9871/contributions/51577/attachments/38550 /60647/20221124ioneffect_kf.pdf

Simulation

• TPC Geometry in simulation:



- Collect all the sim hits, and calculate the distance between each hit and next hit.
- Assign number of ions to each hit randomly from a Poisson distribution (lambda = length * 9.4)
- Require the distance between hits < 100 mm, and number of ions < 1000.

- SimTrackerHits, hits are put in only one container, they are not separated by particles.
- Collect all the sim hits, and calculate the distance between each hit and the next hit.

• The hit and the next hit do not necessarily belong to the same MCParticle. (To remove this situation, Require the distance between hits < 100 mm, and the number of ions < 1000.)



Some more explaination

- In the simulation, we loop through the long-lived charged particles, when the particle flies through a "layer" of the TPC, we get a SimTrackerHit. And this hit is put in an array, for example, called TPCHits.
- The Next hit just means: TPCHits[i] and TPCHits[i+1].
- Please also note that this process is not something that really happens in the TPC, but is just a simplified method for simulation.
- So, for each of the SimTrackerHit, we calculate the number of generated electrons/ions in the tracklet: TPCHits[i]->TPCHits[i+1]. This number is just N_ions = Length(TPCHits[i]->TPCHits[i+1])*9.4.
- And when we fill the charge distribution, we fill the position of these SimTrackerHit, and use N_ions as a weight.
- Usually, the TPCHits[i] and TPCHits[i+1] belong to the same particle, and they are the adjacent hits in position. But sometimes, TPCHits[i] can be the last hit of particle A and the first hit of particle B. Then we put a cut of Length(TPCHits[i]->TPCHits[i+1]) < 100 and N_ions < 1000 to reject this situation.

Charge distribution (backflow ions)

2000 2000 24000 22000 1500 1500 20000 1000 1000 18000 16000 500 500 14000 y [cm] y [cm] 0ŀ 12000 10000 -500 -500 8000 -1000-1000 6000 4000 -1500 Print . -1500 2000 -2000 -1500 -1000 -500 -20000 0 -2000 - 1500 - 1000 - 500 500 1000 1500 2000 0 x [cm] x [cm]

Not carefully normalized



1 event

22000 events

Charge distribution (Compare)

Not carefully normalized





22000 events

Parameterization of charge density (backflow ions)

$$\rho = \frac{9.135 \times 10^{-3}}{r/\text{mm} - 97.87} - 4.166 \times 10^{-6} \,[\,\text{fC}\,\text{mm}^{-2}]$$



New parameters:

9.8E-3 94.5 4.3E-6

Consistent with each other

Compare the parameterization with Serguei



- Consist in magnitude
- Method may cause the difference
- By Serguei: Estimation was done in 2014. There was no dedicated simulation at those time. There was just an estimation of the average charged track length in the TPC volume.



Serguei's parameterization has a stronger field Consist with Serguei's previous study



Summary

- Re-checking the distortion
- Well consistent results with previous publication aquired. (Up to charge distribution)
- Next: calculate the electric field / distortion (electric field calculation is CPU heavy and running now, using both parameterization from Mingrui and Serguei), expect to get full of them soon.

(electric field calculation done this morning)