estimate of TPC ion density at teraZ using ILD full simulation

preliminary!

Daniel Jeans, IPNS/KEK November 2022

Keisuke just showed estimates based on a toy MC

I will use ILD full simulation to estimate ion densities,
and Keisuke's code to calculate the resulting distortions

qq (uds) events at 91 GeV
no bg, beamstrahlung, or beam en spread (JER calibration sample)
`E91-nobeam.Pqq.Gwhizard-1_95.e0.p0.I110025.${n}.stdhep`

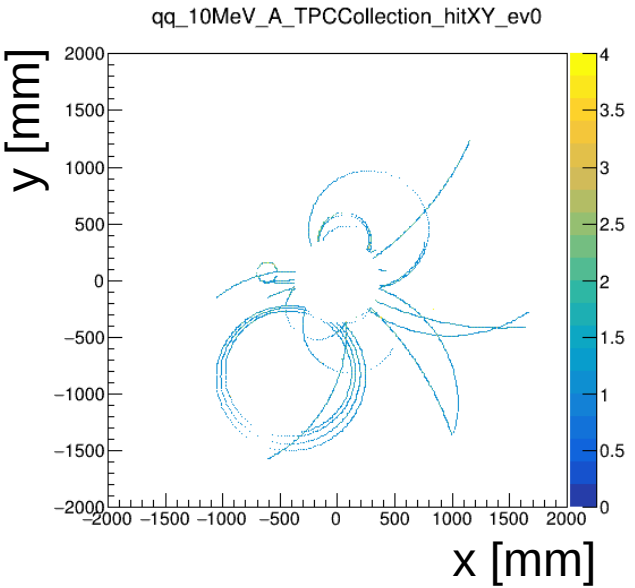
simulated in ILD model ILD_l5_v02 with reduced B-field: 3.5 → 2T

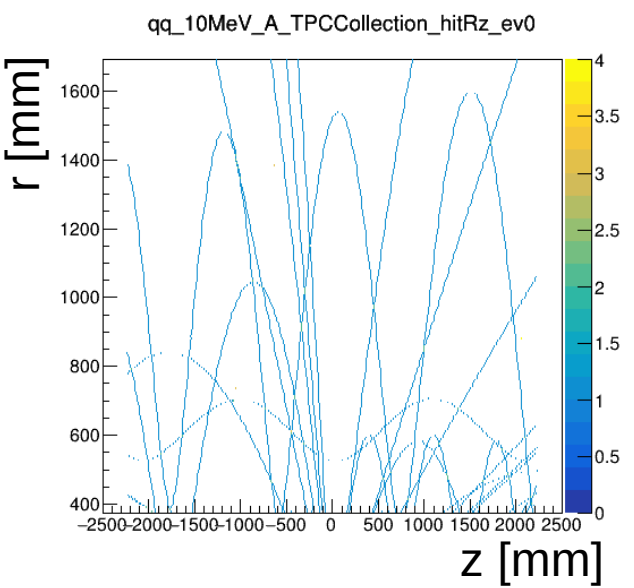
keep "LowPt" TPC hits (default is not to keep in output file)

(+ some small fixes of lcgeo/plugins/TPCSDAction.cc :
defines how to go from G4 steps → SimTrackerHits)

one event

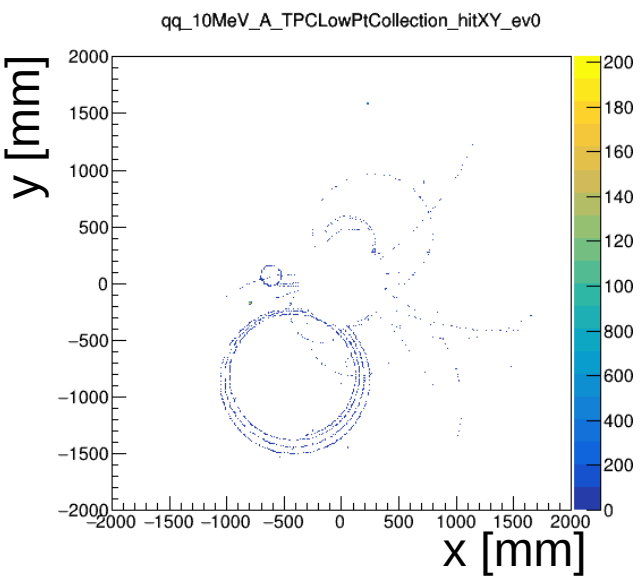
hits associated to track with
pT > 10 MeV
“high pT”

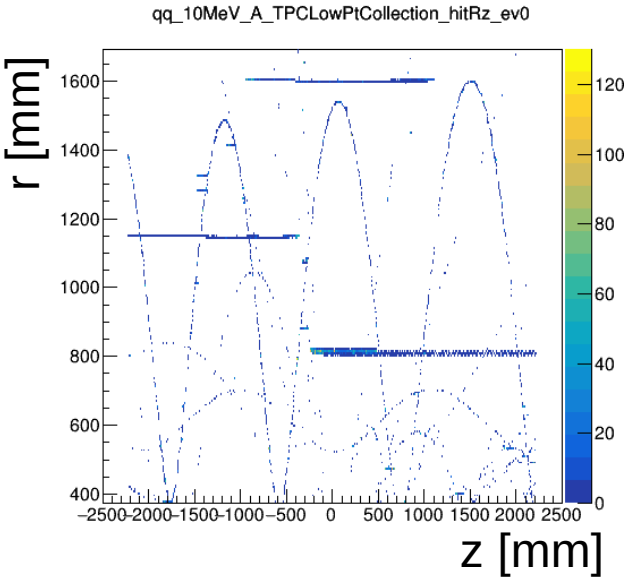




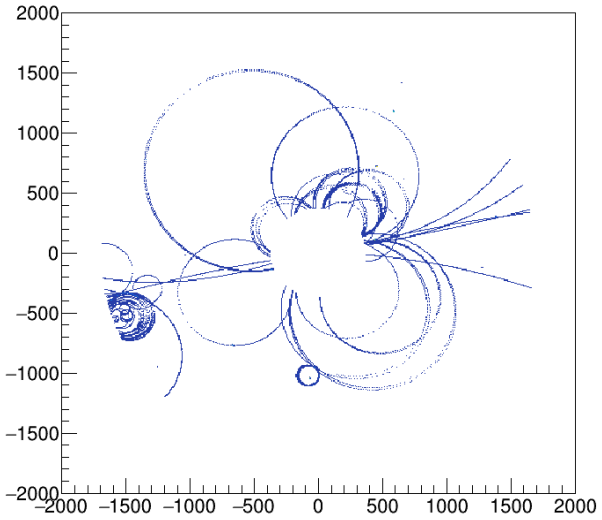
pT < 10 MeV
“low pT”

typically delta-rays along main tracks
some long micro-curlers

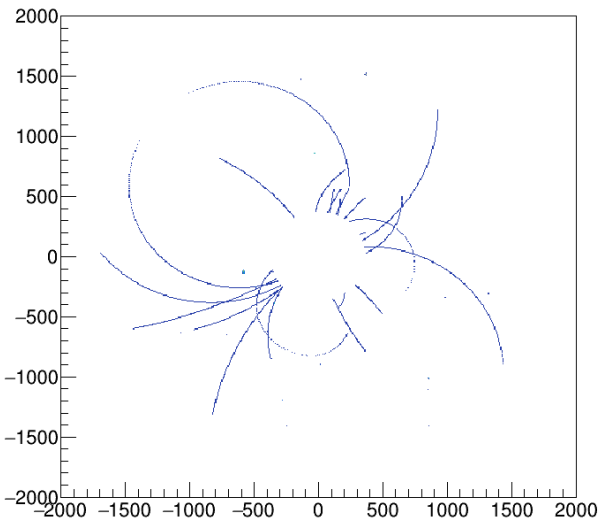




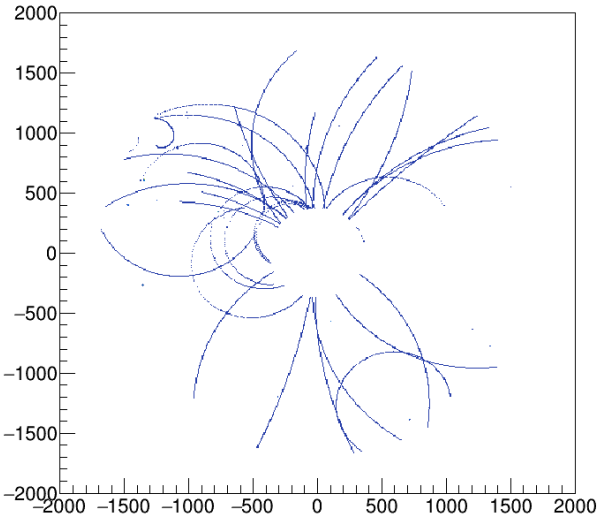
qq_10MeV_A_ALLTPC_hitXY_ev7



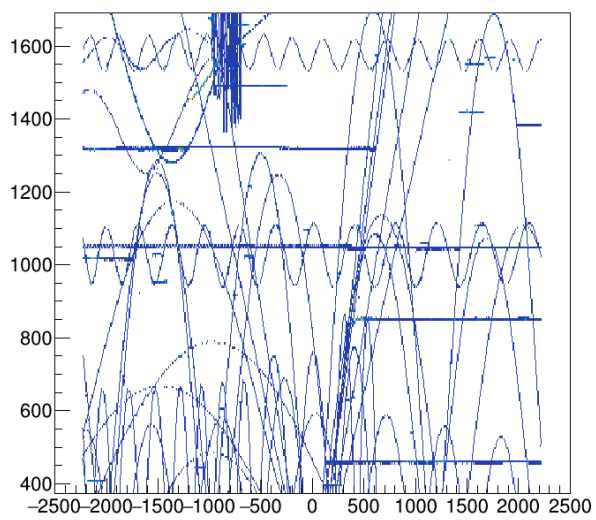
qq_10MeV_A_ALLTPC_hitXY_ev8



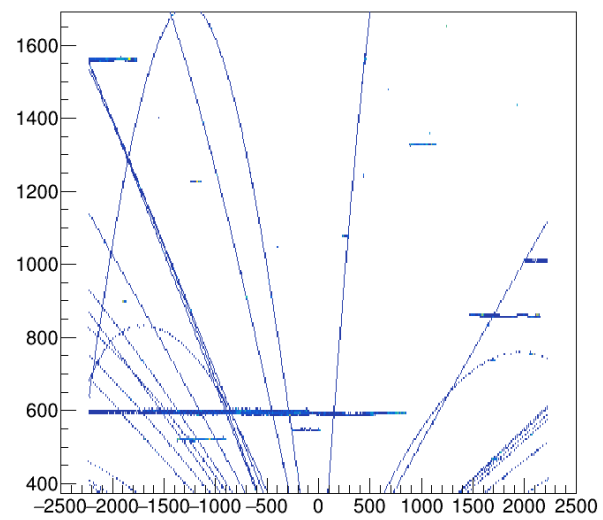
qq_10MeV_A_ALLTPC_hitXY_ev9



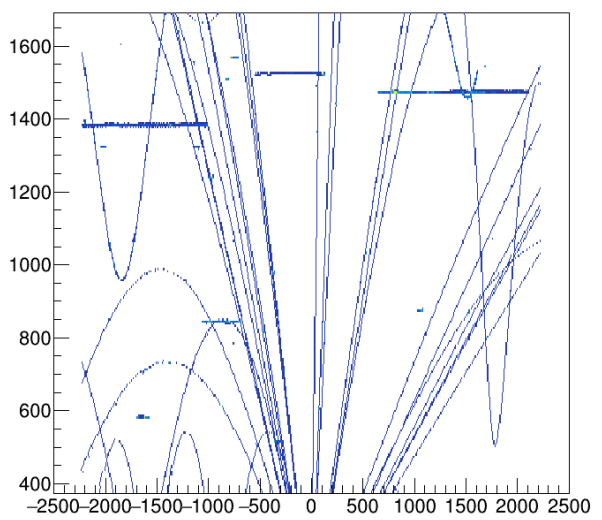
qq_10MeV_A_ALLTPC_hitRz_ev7



qq_10MeV_A_ALLTPC_hitRz_ev8



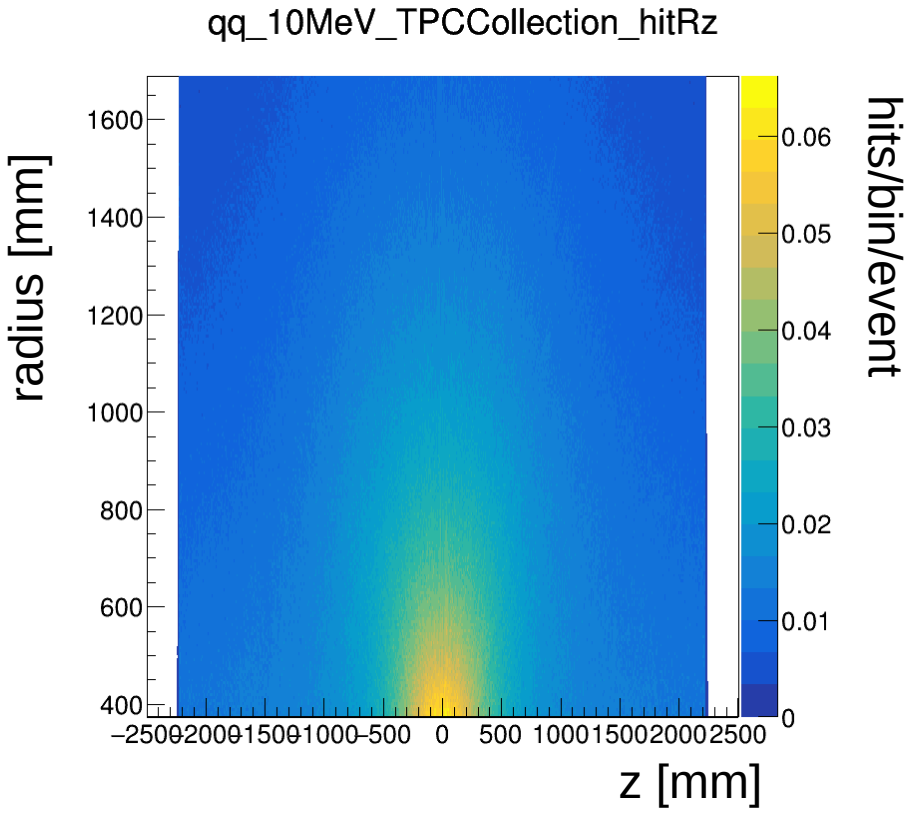
qq_10MeV_A_ALLTPC_hitRz_ev9



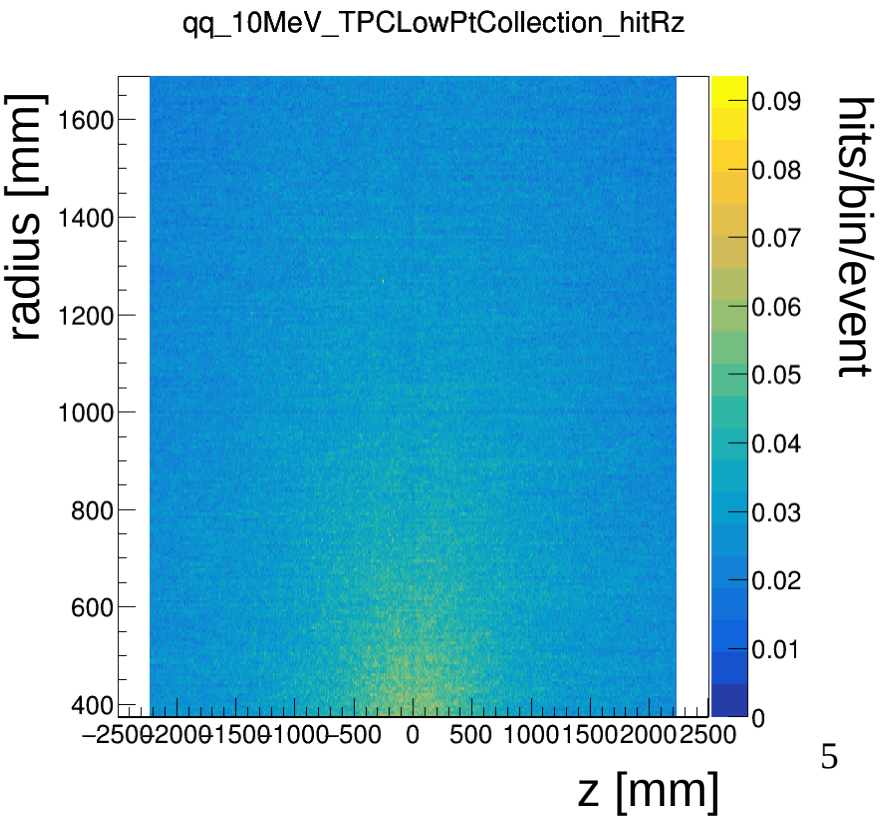
hit distributions in r-z (averaged over 25k events)

hits associated to tracks with

pT > 10 MeV
ave 6.8k hits / event



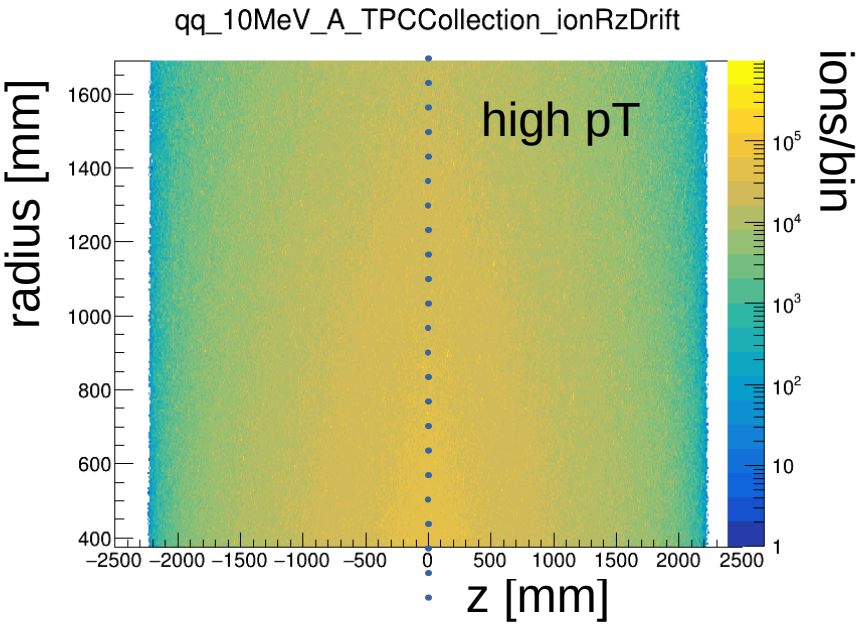
pT < 10 MeV
ave 14k hits / event



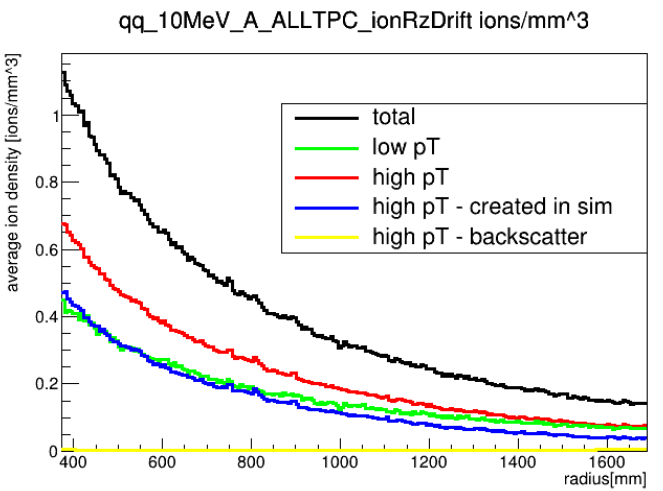
assume 26 eV energy deposit in TPC gas → one primary ion
→ average primary ions/event = 0.68 M (high pT) + 0.49 M (low pT)

also assume
ion drift vel = 5 m/s
max drift length = 2.2 m
→ max ion drift time = 0.44 s
hadronic Z event rate: 50 kHz → 22k events over 0.44 s

high pT primary ion distr
integrate over ~22k events
ion drift & absorption at
cathode (@ z=0)



average radial distribution of ion density



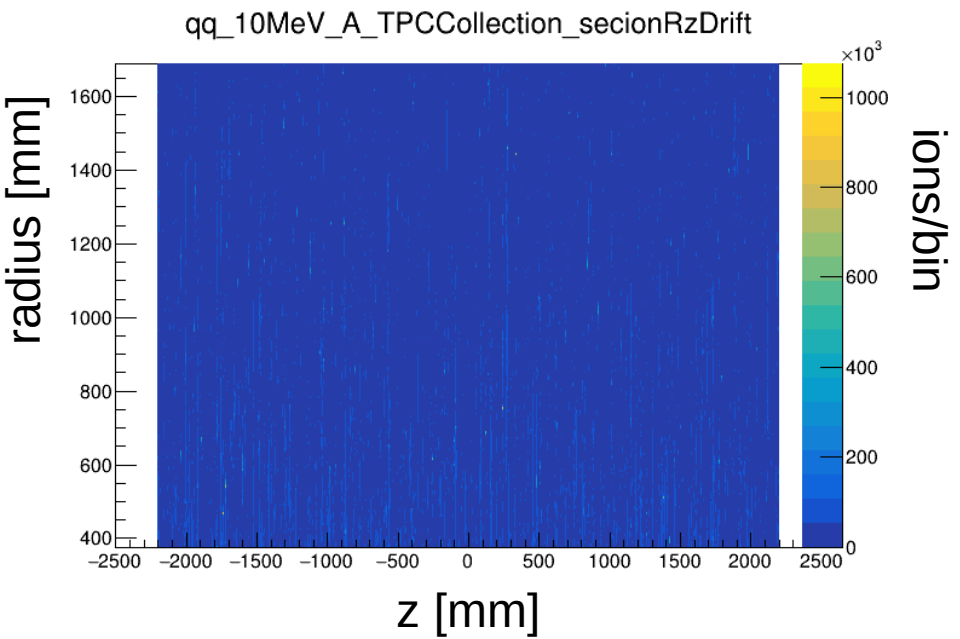
also consider Ion Back Flow (IBF) “secondary ions”

assume electrons from one event arrive at anode ~instantaneously, produce thin disk of ions

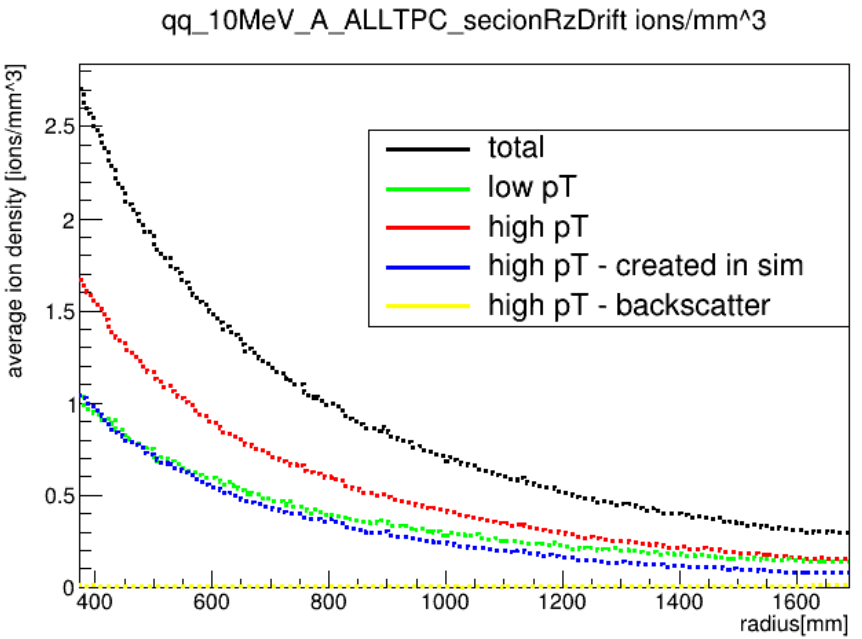
calculate for IBF=1 (one electron in → one ion out)

populate drift volume with ~22k such disks.

ions per bin

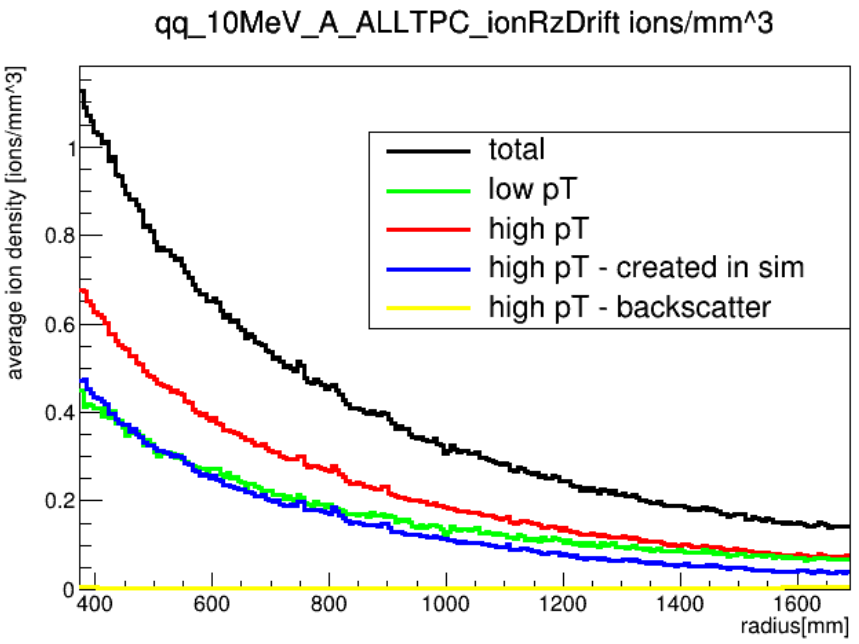


ion density

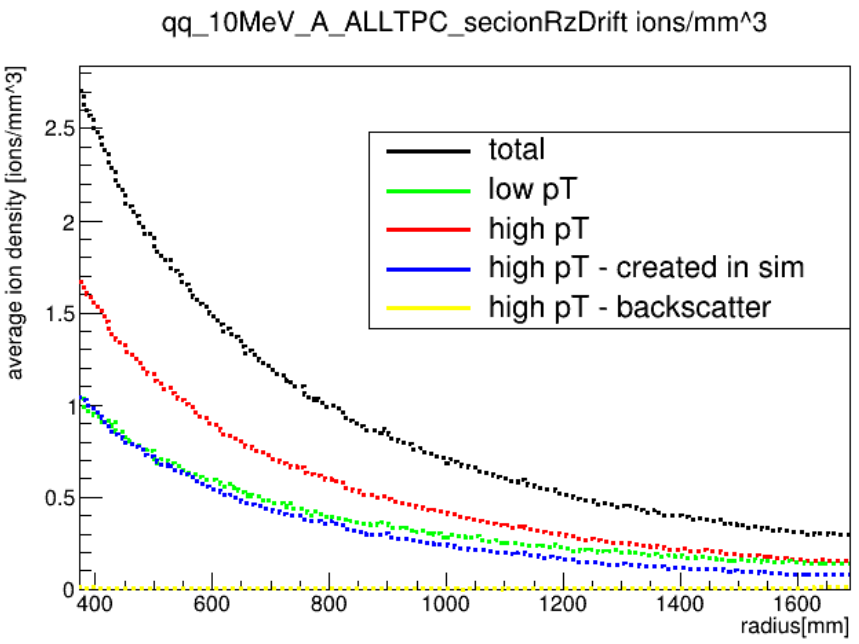


ion densities (wrt radius, averaged over z)

primary ions



secondary ions (IBF=1)



more important contribution

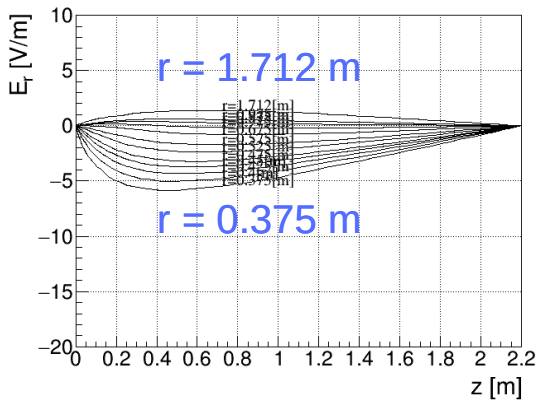
use Keisuke's code to calculate radial electric field induced by ion distributions

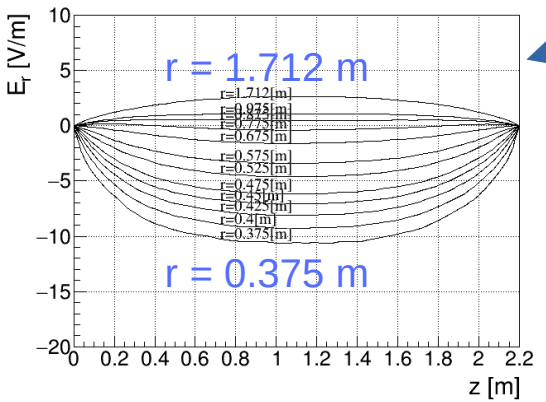
primary

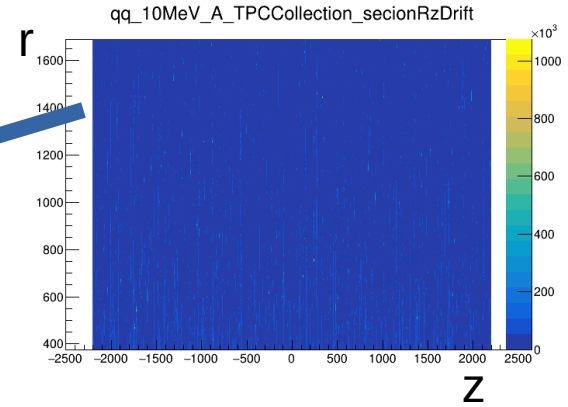
secondary IBF=1

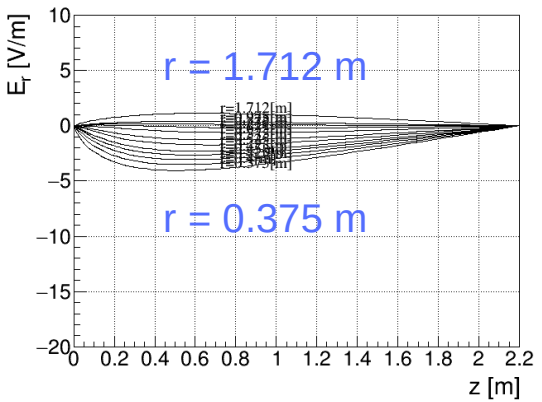
high pT

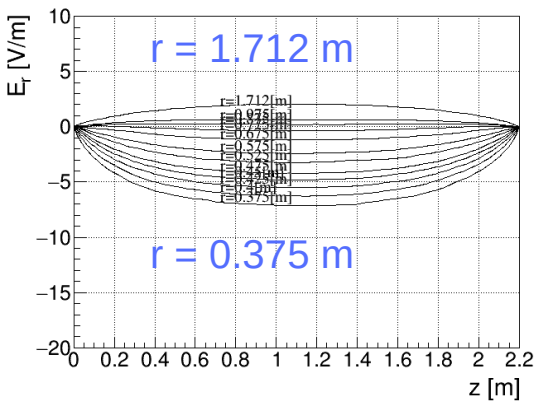
low pT









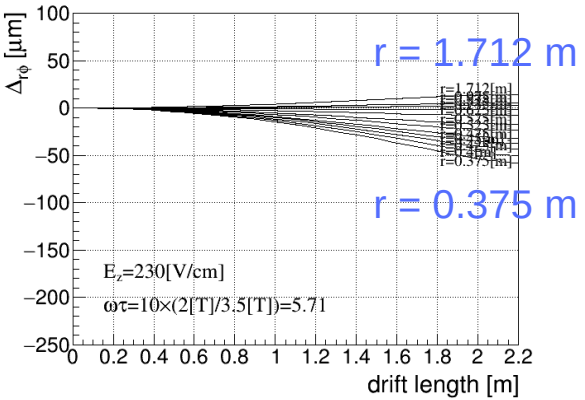


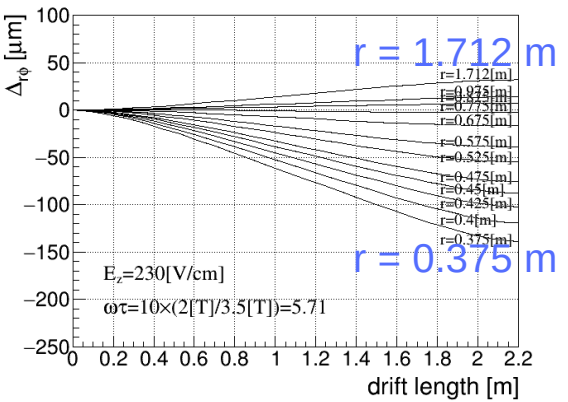
...and the resulting distortions in r-phi

primary

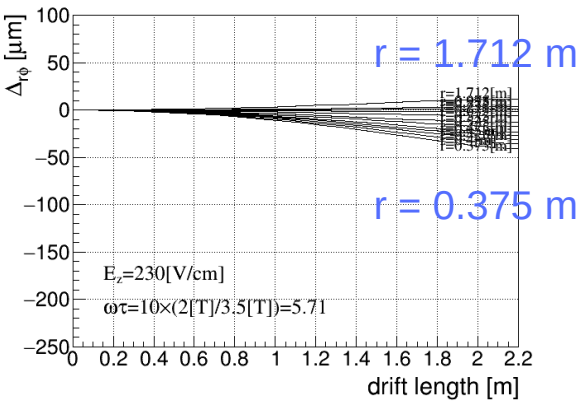
secondary IBF=1

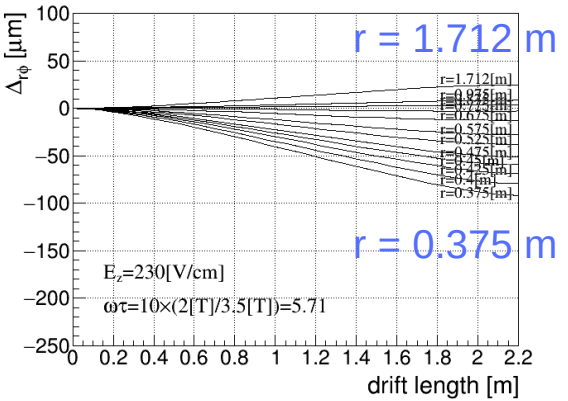
high pT



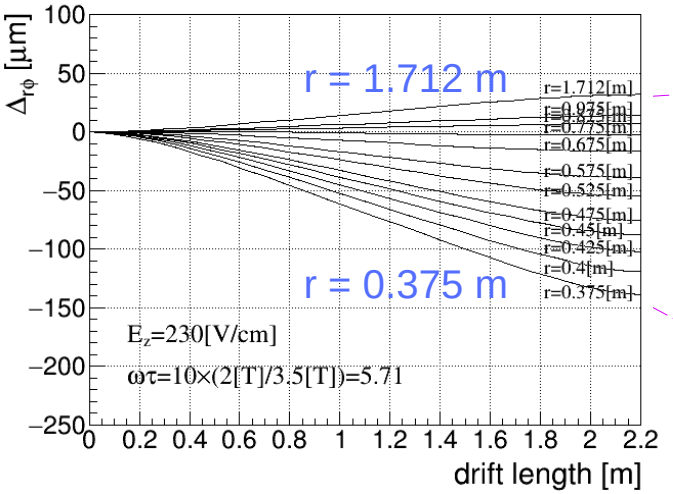


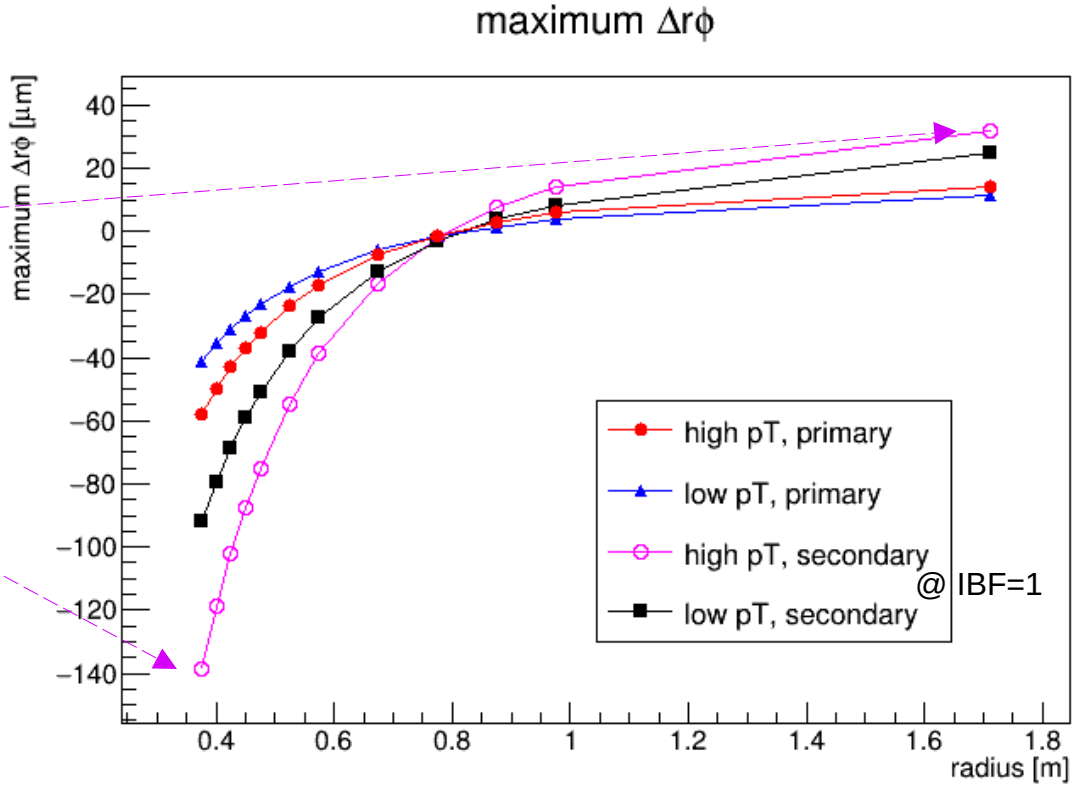
low pT





maximum distortions (i.e. at z=2.2 m)

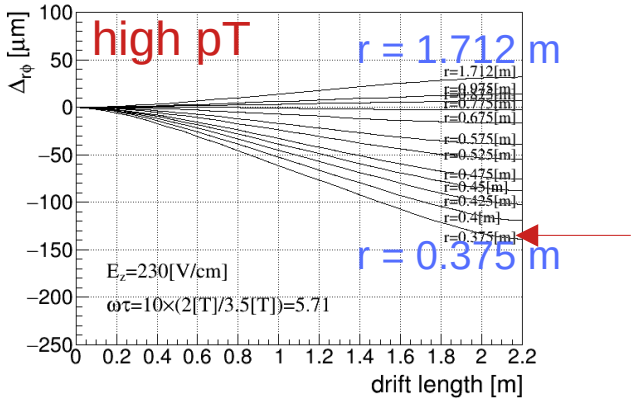


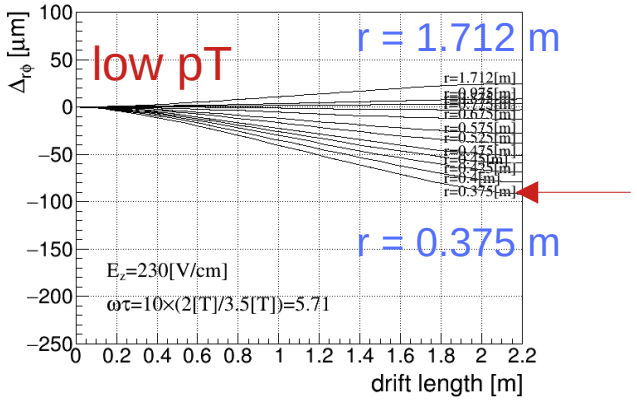


these distortions can be linearly summed to get total :

primaries	~100 micron	@ 0.375m
secondaries	~230 micron	@ 0.375 m & IBF=1
total	~330 micron	@ 0.375 m & IBF=1

my estimate (from secondaries)

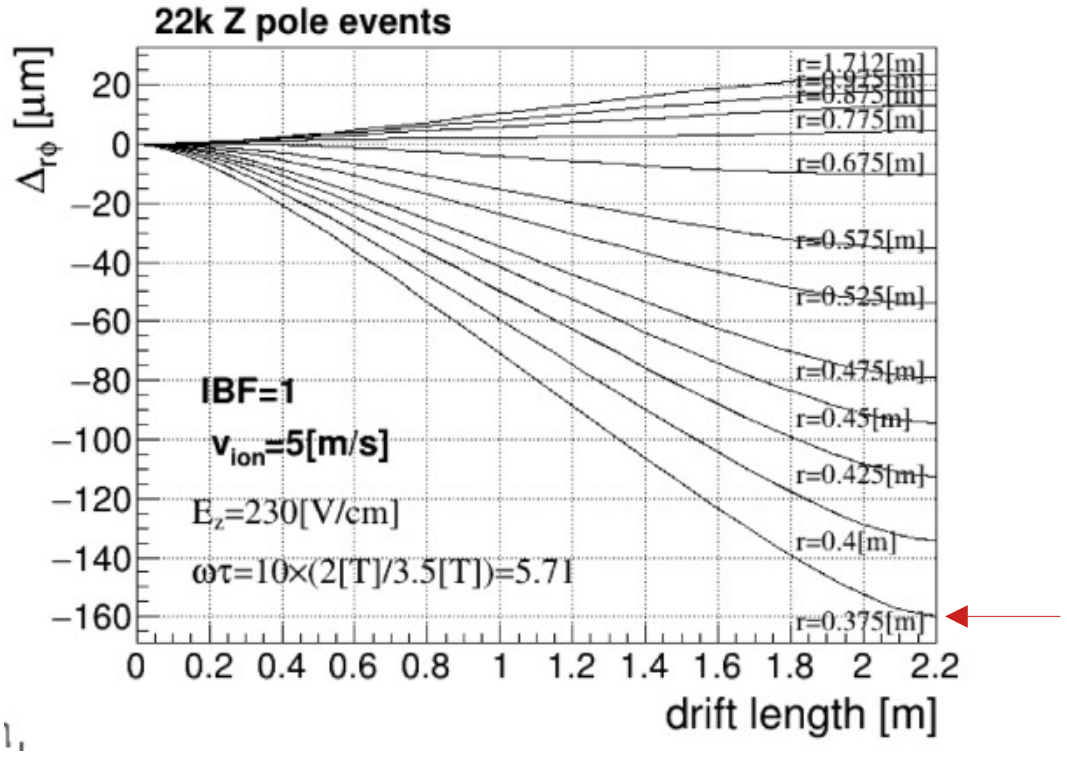




max total distortion (z=2.2m, r=0.375m)

~ 91+139 = 240 micron

Keisuke's estimate (from secondary ions)



max total distortion (z=2.2m, r=0.375m)

~ 160 micron

effect of additional particles created in simulation?

preliminary

conclusion

estimated ion densities from physics events at teraZ, using full ILD simulation

maximum distortion ~ (100 + 230*IBF) micron

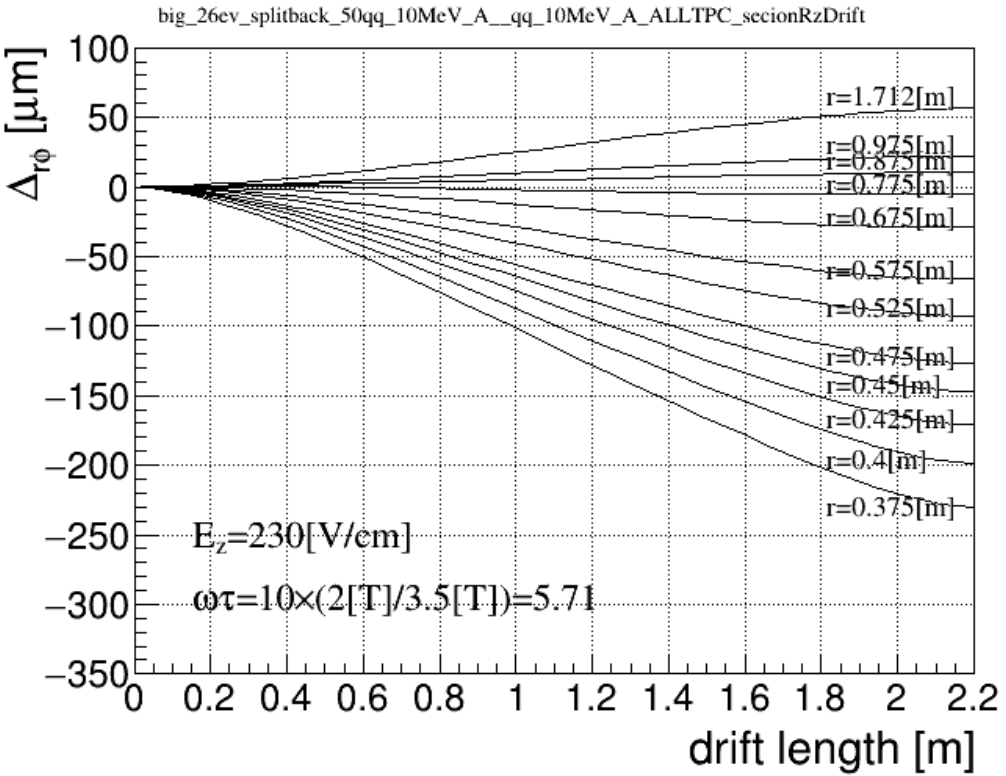
some differences with Keisuke’s toy MC results, but agree within factor <2

will ions in TPC be dominated by physics or machine backgrounds?

backup

r-phi distortions from secondaries

50 kHz



60 kHz