CEPC Pixel Time Projection Chamber

- LCWS 2019 Sendai: for one of the CEPC experiments there is interest in a pixel TPC
- Discussed with Huirong Qi (see https://agenda.linearcollider.org/event/8217/contributions/44627/)
  - In his talk presented issues with a TPC running at the Z (next slides)
    - Higgs running no problem for TPC
    - For high Lumi Z run distortions due to Ion Back Flow
    - As ALICE one can run without gating (reducing the IBF of the GEMs)
    - Ion Back Flow measurements IBF with a MM show Gain*IBF = 5

Physics requirements

Huirong Qi

- TPC limitations for Z
  - Ions back flow in chamber
  - Calibration and alignment
  - Low power consumption FEE ASIC chip

	ALICE TPC	CEPC TPC
Maximum readout rate	>50kHz@pp	w.o BG?
Gating to reduce ions	No Gating	No Gating
Continuous readout	No trigger	Trigger?
IBF control	Build-in	Build-in
IBF*Gain	<10	<5
Calibration system	Laser	NEED

Compare with ALICE TPC and CEPC TPC

CEPC CDR

Lumi.	Higgs	W	Z	Z(2T)
$\times 10^{34}$	2.93	11.5	16.6	32.1

Luminosities exceeded those in the preCDR

- double ring baseline design (30MW/beam)
- switchable between H and Z/W w/o hardware change (magnet switch)
- use half SRF for Z and W
- can be optimized for Z with 2T detector

CEPC Pixel TPC

- What is the situation for a pixel TPC?
  - Large potential in terms of rate capabilities
  - Pattern recognition high granularity works in high Z rate
  - Question what is the IBF for our GridPix? O(0.1%) We will measure it.
- Can we apply gating in Z collisions?
  - High(est) luminosity CEPC L = 32-50 (17-32) 10^{34} $cm^{-2}s^{-1}$ at 2 T.
    - CEPC Ring length 50 km with 12 000 bunches and a hadronic Z rate of 10-15 (5-10) k Hz (cross section 32 nb). Beam structure rather continuous 14 ns spacing.
    - Note that this Luminosity gives about 60-120 (30-60) G Zs per running year
  - Time between Z interactions 120-60 (200-100) μs
  - TPC drift takes 30 μs
  - So events are separated in the TPC

CEPC Pixel TPC

- Possible gating scheme for physics events
- Make a GEM gating device a la ILD but now at 1-5 mm above the grid
- Gating in a triggered mode;
  - if a hadronic Z interaction in TPC start gating
- Gate length of 30-60 μs would stop the ions in Z triggered mode
  - the price is dead time, reduced efficiency;
  - One will start "leveling" if gate time = 20 μs -> efficiency 66-85%
- Needs thinking but might work and reduce IBF and (therefore) distortions

- High rate capabilities of the GidPix pixel chip TPX3
  - Bonn test beam was 5 kHz electrons for a quad
  - Link speed 80 Mbps per chip (256x256x 55 x 55 μm^2)
  - Testbeam 2018 1.3M hits/s per chip could be read out
  - In 2019 the link speed doubled to 2.6M hits/s per 1.42x1.42 cm^2.
- NB: ILC gating can exploit bunch structure: Gate opens 50 μs before the first bunch and closes 50 μs after last bunch. Close time between bunches 200 ms. Device 1 cm above grid.

CEPC Pixel TPC

- Important to estimate the charge in the TPC as it causes distortions.
  - Physics events like Zs
  - Beam-beam interactions that produce hits

- Distortions from primary ions due to Zs (back of the envelop)
  - Assume that the ions stay 0-300 ms before reaching the mid plane of the TPC. With a rate of 10-15 kHz one will accumulate 3000 - 4500 Zs; This gives 30 tracks producing 10^4 K primary electrons and ions. TPC volume: Inner radius 40 cm; outer 180 cm; 400 cm length; so volume $3.8\ 10^7$ cm^3. Charge density = 9-13 $10^8/3.8\ 10^7$ cm^3 = 23-34 e/cm^3. This is smaller than the ILC 3000 bunches from beam-beam. At ILC this bkg leads to distortions of max 4 microns (studies from Keisuke).
  - This calculation gives much smaller results than Huirong Qi his slide.
  - So assuming that the IBF for Zs can be gated (IBF < 1) with the proposed trigger scheme these distortions are rather small.

Simulation of deviation with IBF (k=Gain×IBF) @CEPC

here L = 17 10^{34} $cm^{-2}s^{-1}$

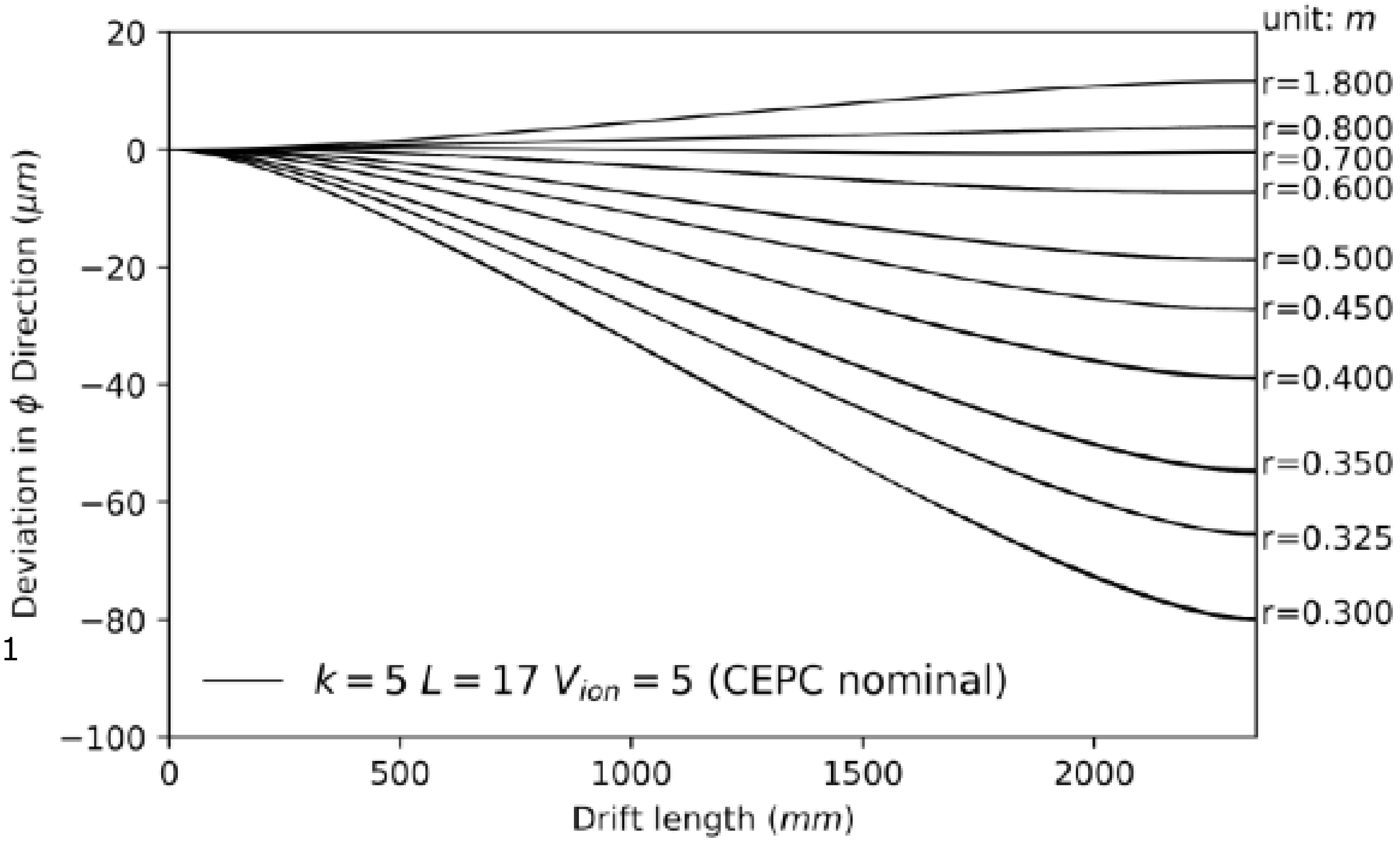
Huirong Qi

This is based on physics events

No beam-beam

Deviations due to primary ions should be factor 5 smaller

In my calculations
L = 32-50 10^{34} $cm^{-2}s^{-1}$
at 2 T.



CEPC Pixel TPC

- The remaining - and very relevant - question is in my opinion:
  - What is the charge of the beam-beam effects in the TPC?
  - Note that at ILC these beam-beam effects from primary ions are larger and dominant over the physics interactions. So they could be huge …
  - As Adrian Vogel (DESY-thesis-08-036) in his thesis showed the detector-machine design is important to reduce the number of back scattered photons.
  - On the other hand one can think of a detector and machine design where the back scattered photons are shielded off in a better way thus that the charge is of the same order as the Z interaction rate. This needs carefull investigation.

DESY-thesis-08-036

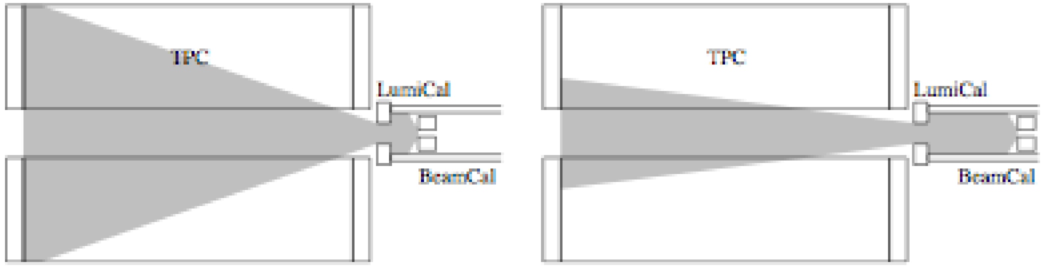
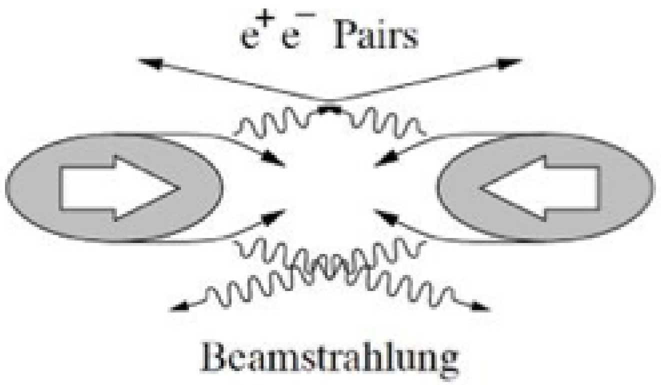


Figure 7.32: A larger distance between LumiCal and BeamCal reduces the backscattering of photons into the TPC.

Beamstrahlung & Pair Production

CEPC Oxford
https://indico.cern.ch/event/783429/contributions/3379893/attachments/1830789/2998159/CEPC_Backgrounds_Oxford_Zhu.pdf

- Estimated as the most important background at Linear Colliders, *not an issue for lower energy/luminosity machines*
- Charged particles attracted by the opposite beam emit photons (beamstrahlung), followed by electron-positron pair production (*dominate contributions from the incoherent pair production*)



Simulated with GUINEAPIG with external field implemented

Most electrons/positrons are produced with low energies and in the very forward region, and can be confined within the beam pipe with a strong detector solenoid;

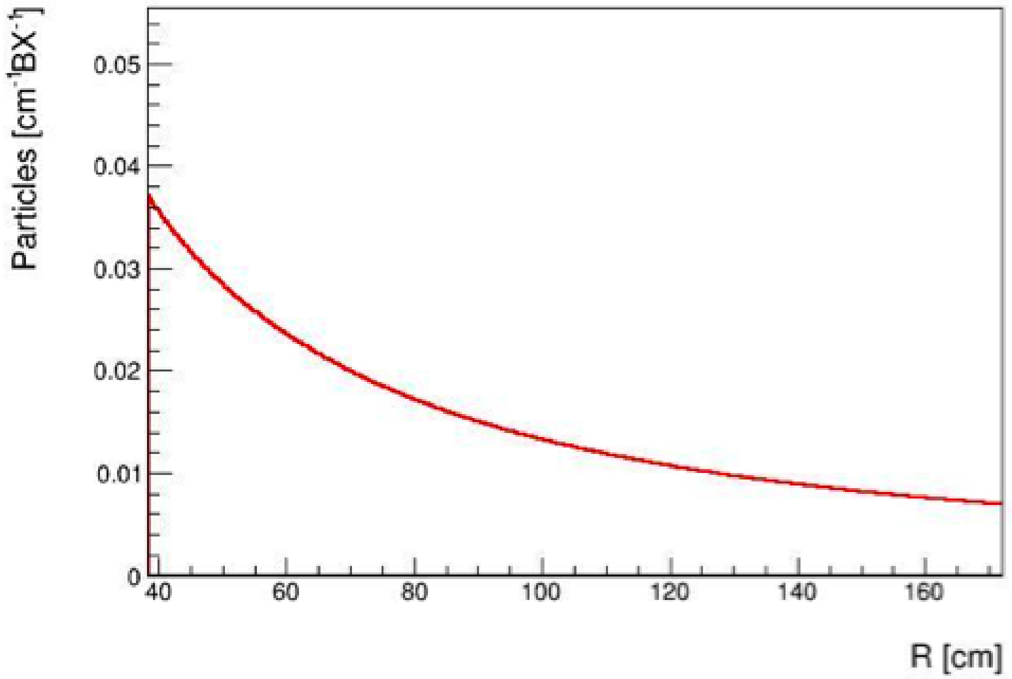
However, a non-negligible amount of electrons/positrons can hit the detector → radiation backgrounds

Hadronic backgrounds much less critical

CEPC Pixel TPC CEPC Oxford

EXTENDING TO OTHER SUBDETECTORS

Hit density in TPC



SIT/SET, LumiCal → larger background samples to see detailed distributions

What is the energy (Z pole) ?

What is a hit in the TPC?

Maybe we can calculate the charge (Radius) from this distribution.