Space Charge in the CLIC TPC

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Calculation E-Field and Drift Distortions

Based on Keisuke's *ioneffects* programme

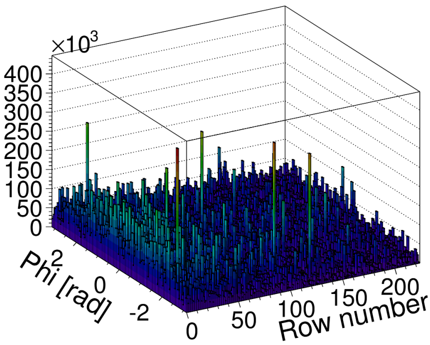
- Use parameterised, factorisable ion density $\rho = \rho_z \rho_r$
- No φ dependency
- Calculate E_r by solving Green's function (see Keisuke's talk from March)
- "Track" electrons along z for constant r
- Calculate $\Delta r\varphi$ for fix E_z, B and $\omega\tau$

Ion densities available for

- 1 BT ILC background (fit by D. Arai on A. Vogel's data) $\rho = p_0/(r - p_1)^2$, no z dependence
- 5 BT ILC background (1 second = max. ion drift time)
- 1 BT CLIC background
- 50 BT CLIC background (1 second = max. ion drift time)

Charge per r-φ Segment

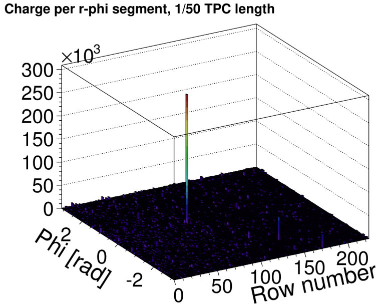
Integrated 1 CLIC BT over the full drift length



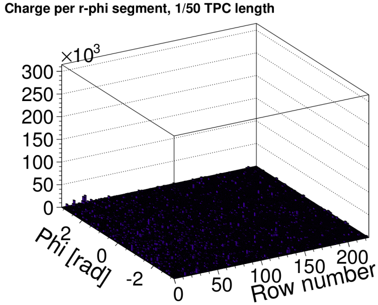
- Not flat in φ
- Distribution has spikes

Charge per r-φ Segment and z Slice

Slice 14



Slice 15



- Local depositions in 1 voxel only
- MC Truth list shows they originate from pions
- Is this plausible?

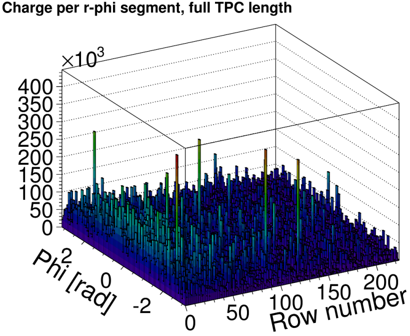
- Pion interaction length in Ar ≈900 m.
- 4500 pions in the $\gamma\gamma \rightarrow$hadrons background (1 BT)
- Low angle (≈2 m track length)

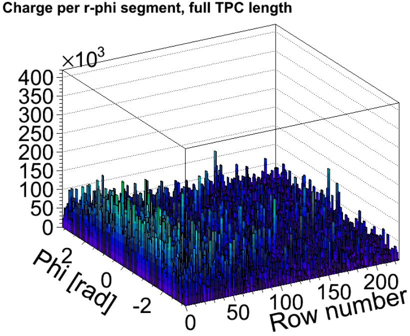
⇒ 9000 pion-TPC-meters = 10 interaction lengths

- Fits with the number of peaks in the histogram

Charge per r-φ Segment

Integrated 1 CLIC BT over the full drift length





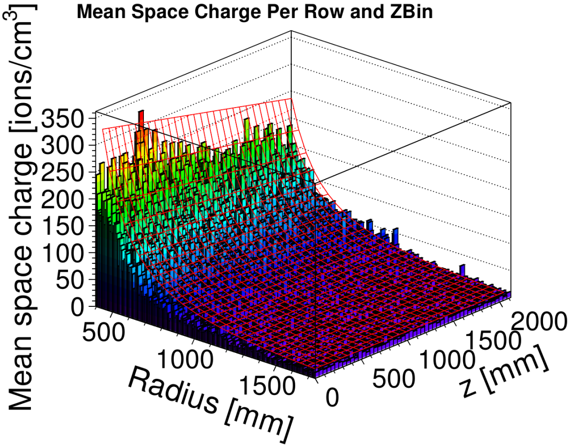
Without cut

- Not flat in φ
- Distribution has spikes

With cut on highest voxels charges

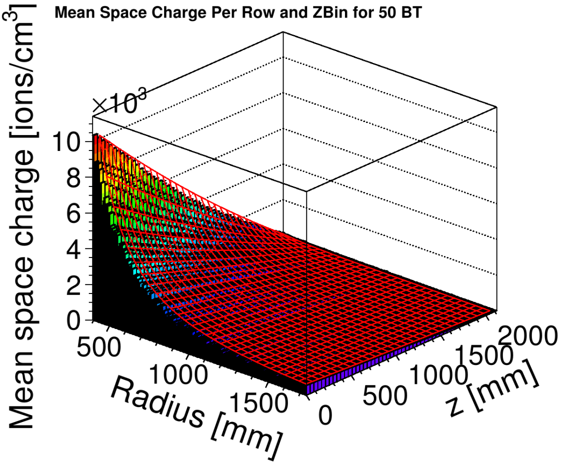
- Huge spikes are gone
- Still a bit bumpy
- Good enough to assume φ independence

Charge Fit in r-z (1 CLIC BT)



- Slight dependence on z
- Parametrisation $(p_0 + p_1 z)/(r - p_2)^2$
- Charge up to 350 ions/cm^3
- A bit more than 1 ILC BT

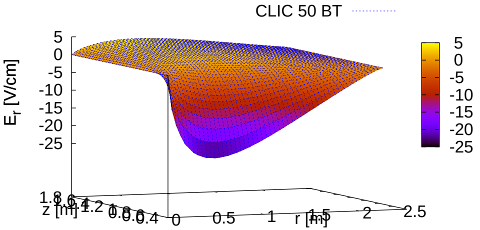
Charge Fit in r-z (50 CLIC BT)



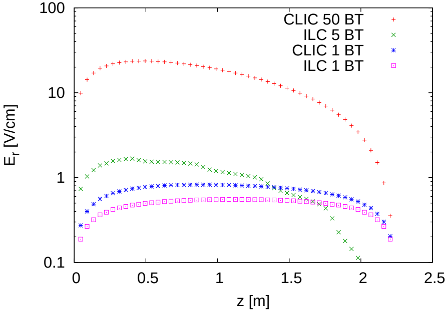
- Strong dependence on z
- Parametrisation $(p_0 + p_1 z + p_2 z^2)/(r - p_3)^2$
- Very high charge near the cathode
- Charge up to 10,000 ions/cm^3

I used 50 times the same bunch train.

E-Field



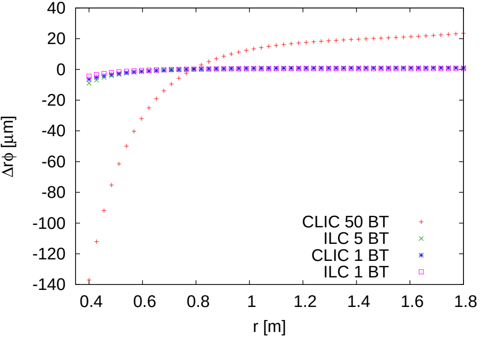
Electric field near the inner field cage

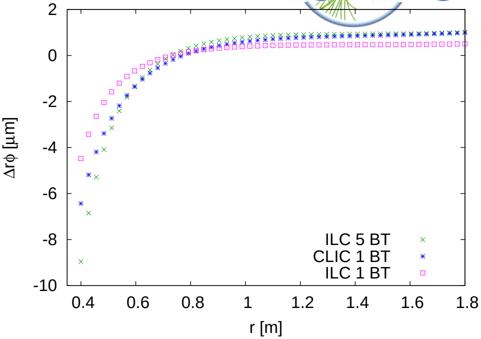


- E_r is largest near the inner field cage
- E_r changes sign towards outer field cage

- E_r for 50 BT at CLIC is up to 25 V/cm
- E_z component will not be negligible
- Effects on drift velocity and diffusion
- Simulations have to be adapted to include these effects!

Drift Distortions Near the Inner Field Cage





- Distortions for ILC are small
  - 5 μm for 1 BT
  - 9 μm for 5 BT
- Distortions for 1 BT CLIC are OK (7 μm)
- Distortions for 50 BT CLIC not negligible: 137 μm need to be corrected for
- Local distortions from large charge depositions not included yet

Summary

50 BT of CLIC background

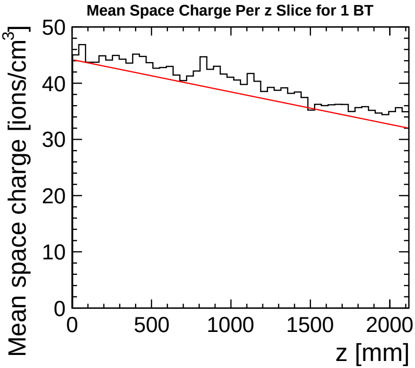
- Large local charge depositions from $\gamma\gamma \rightarrow$hadrons
- Distribution without spikes parameterisable
- Huge electric field distortions $\mathcal{O}(10\ \%\ E_z)$
  - Change in drift velocity and diffusion
- Distortions in $r\varphi$ $\mathcal{O}(140\ \mu\text{m})$ not deadly, but have to be corrected for

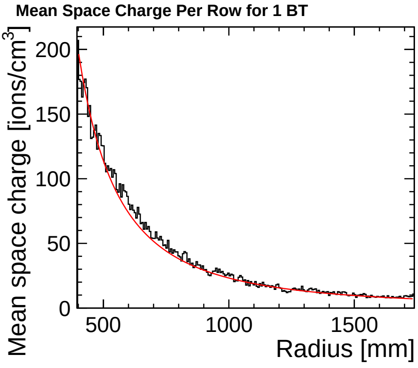
Next steps

- Local charges need full 3D calculations (Thorsten Krautscheid)
- Calculate also changes in E_z and E_φ
- Implement variation in v_{drift} and diffusion

Backup

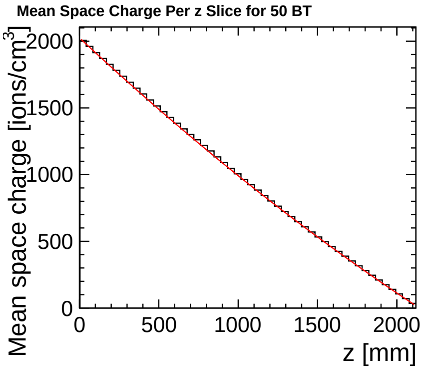
Mean Space Charge for 1 CLIC BT

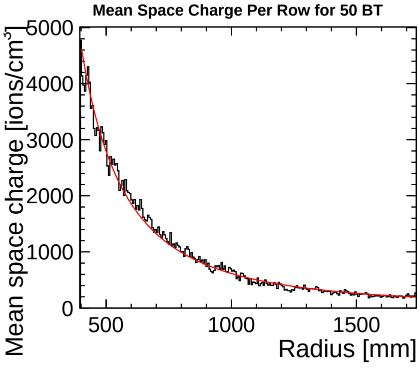




The fit is not a fit to the 1D histogram.
It is the analytical integral of the 2D parametrisation,
while the histogram is the projection of the 2D histogram.

Mean Space Charge for 50 CLIC BT





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