(Some thoughts/reminders on) Calibration/alignment scenarios for ILD/ILC

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Initial requirements on tracking

- Lightweight, but stiff detectors
- Stable to electric and magnetic fields (in particular gas tracking)
- Robust against temperature and humidity gradients/variations
- Precise alignment of (sub)detectors

Particular conditions:

- Power pulsing
- Push-pull of the two detectors

Temperature “policy” ?

- Probably every sub-detector needs cooling
- Working temperatures likely different, with gradients
- Are sub-detectors thermally neutral?
  – Likely not
  – Should they be?
  – Would they need thermal shield?

- TPC might need a thermal shield if external temperature gradients

Initial and track-based alignment

- Si tracking sensors positioned inside module ≈5μm
- Modules positioned into higher order structures and surveyed/aligned at ≈100 μm
- Pad positions inside TPC pad plane at <20 μm
- Module positions inside TPC endplate (for current LP) ≈20 μm
- Track based alignment precision needed:
  - VTX: ≈2 μm
  - Si inner: ≈4 μm, Si outer: ≈6 μm
  - TPC: ≈20 μm

This ensures degradation of momentum resolution due to alignement errors w.r.t. nominal of less than 5%

Track samples

- Cosmics, but rate limited:
  - Underground
  - Duty cycle 0.5-1 % due to power pulsing
- Beam collision data: tracks with known momentum from Z, J/ψ, ϒ.

  Z-peak running @ L = 10^{32} $cm^{-2}s^{-1}$:
  - 30k hadronic and 1.5k μμ per 1 pb^{-1}

    (takes ≈ 3 hours of beam)
- LEP experience:
  - 10 pb^{-1} Z running for commissiioning (30 hours of beam)
  - 1 pb^{-1} per year (depending on “interventions”; 0.5 pb^{-1} per case

But could need more e.g. TPC has more (smaller) modules than at LEP. Need for alignment simulation study.

Vertex Detector

- Supported by beam pipe, which is supported by the inner support tube
- During assembly: micron precise pre-alignment via optical survey
- After installation: beam based alignment
  – Within a layer using overlap between ladders (of few 100 μm)
  – Global alignment of layers

Si tracker

- Internal hardware alignment of microstrip tracker uses infrared lasers passing through consecutive layers: relative resolution (between measurements) of 10 µm within 1 min

- Deformations/displacements and temperature/humidity monitoring through in-fiber Bragg grating (FBG) sensors, embedded in composite materials ("smart structures")

- Frequency Scanning Interferometry under investigation

- Track-based alignment:
  - Total number of degrees-of-freedom: ~10^5
  - For quick re-alignment: if sensor positions within modules known @ 5µm: ndof = ~10^4-5.10^4
  - If only sub-detectors need to be re-aligned: ndof = 26

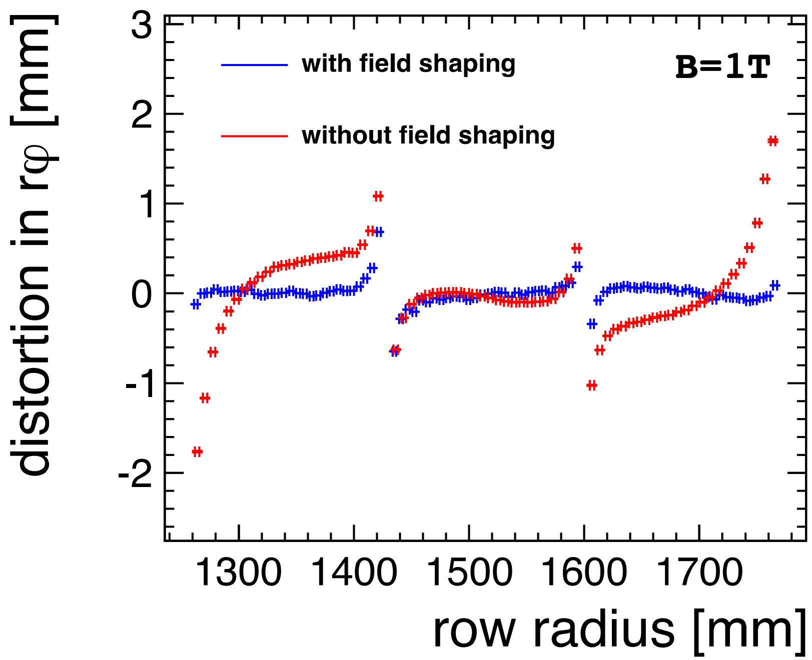
TPC calibration issues

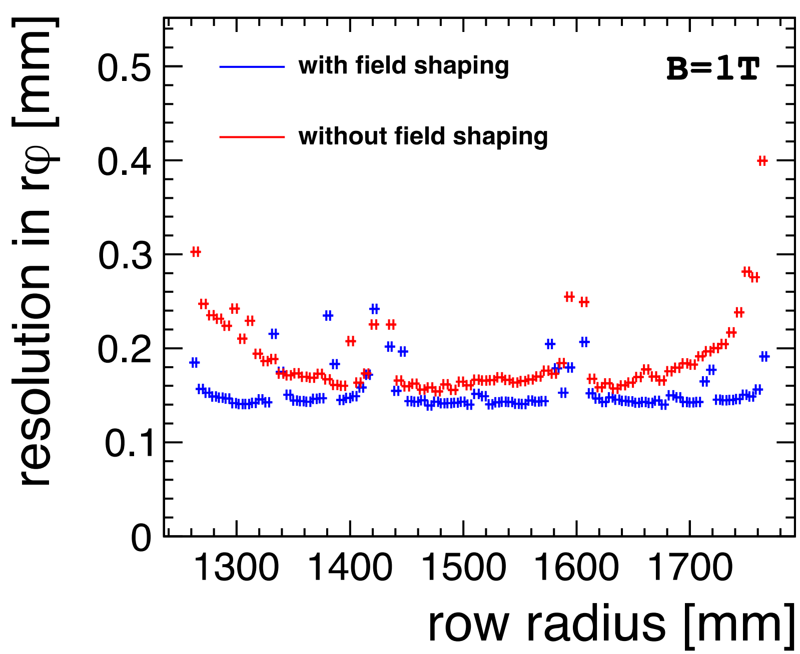
Need:

- Good B-field map, 1-2 G precision and sufficient number of points (> 10^4 locations)
- Hall probes mounted around TPC; NMR probes?
- UV lasers:
  - generating ionising tracks in drift volume
  - illuminate the calibration spots on the cathode, which then generate electrons drifting over full length
- Cosmics: duty cycle 0.5%, would give ≈10 Hz through hor. cut plane through TPC of 14 m^2 at surface; less rate underground
- Z-peak running: 10 pb^{-1} commissioning; 0.5-1 pb^{-1} for quick re-alignment check after “incidents” (e.g. Push-pull)

Example: distortions in LP TPC

- Tracks in 3 DESY GEM modules
- Distortions at module boundaries largely corrected; distortions should be less at final TPC, smaller gaps beteen modules
- Resolutions remain affected





Distortions seen by laser

- 7 Micromegas modules, 1 without HV
- Shift arrows scaled 5x
- Displacements are ~2.5 mm

LP TPC cathode

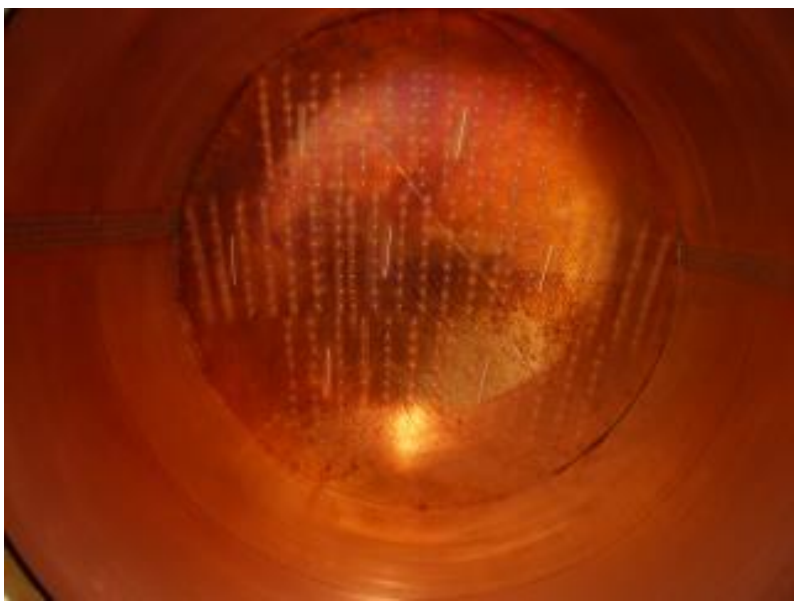
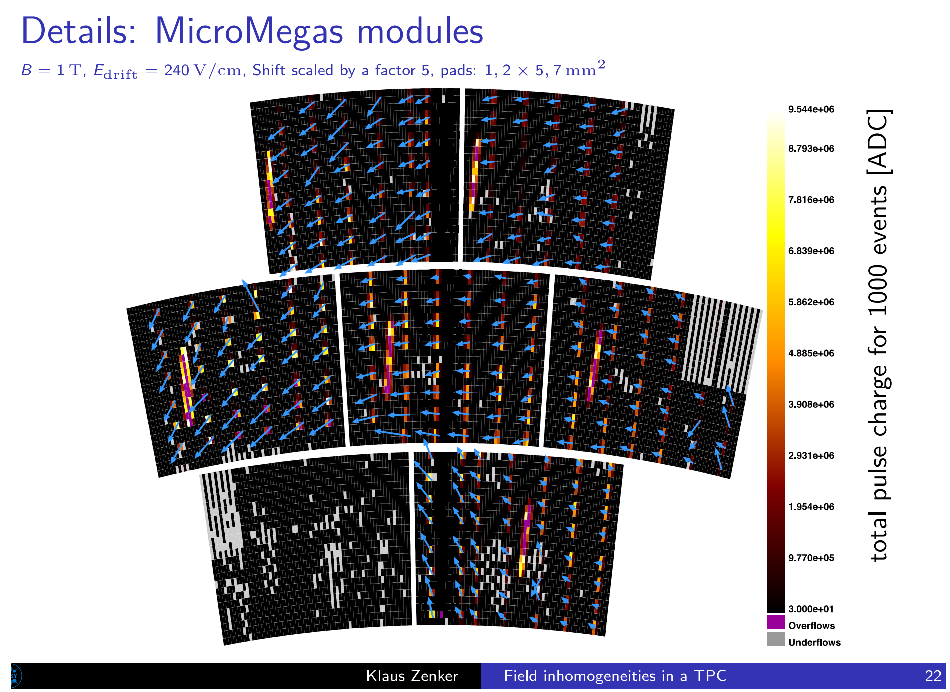
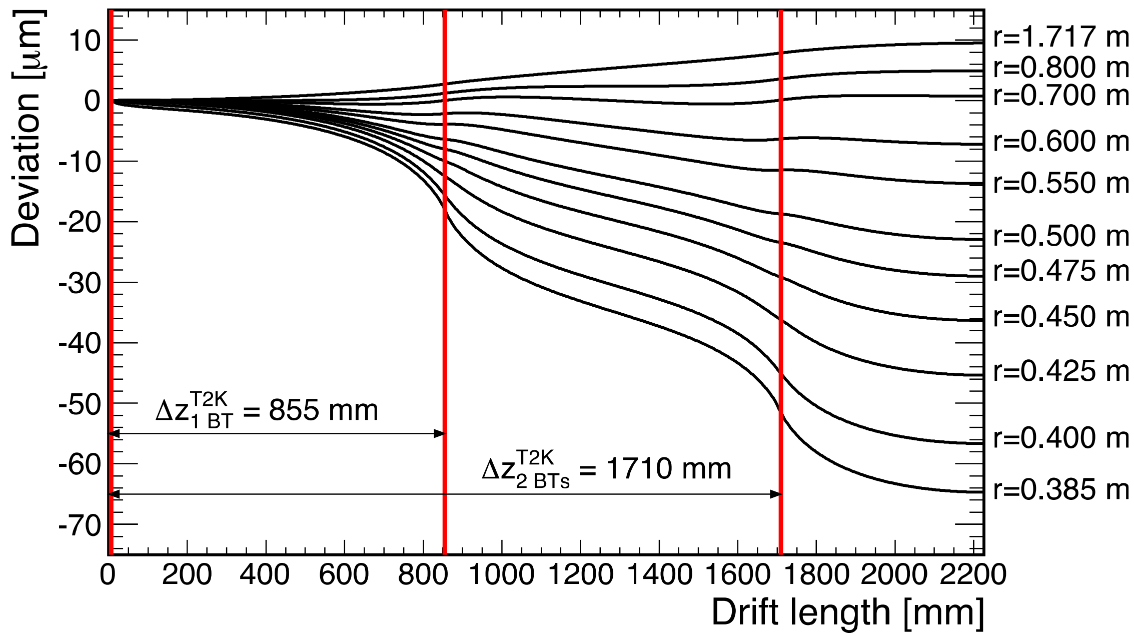


Fig.: Cathode mounted in the Large Prototype.



Space charge effects in TPC from ions

- Negligible effect on electron drift from primary ions
- Distortion on drifting electrons from backflow ion sheets is up to 60 μm
- Need ion gate to eliminate the backflow; under development



In-situ calibration calorimetry

- Absolute calibration ECAL can be checked/adjusted by comparison with tracker or using electrons and photons from Bhabha's or return-Z + kinematical constraints. No need for running at Z peak
- Cosmic rays may not be sufficient for MIP-scale monitoring, but MIP-like segments in hadronic showers can be used
- Z-peak running: 1 pb^{-1} sufficient to have >1000 tracks per layer module AHCAL up to layer 20; To reach out to layer 48 would need 20 $pb^{-1,}$, but can be reduced to 10 pb^{-1} by adding the mu-pair tracks.
- 500 GeV: 3% calibration out to layer 20 can be reach with ~2 fb^{-1}
- Beam halo muons: could be useful for endcap detectors; rate depends on shielding

Conclusions

- Z-peak running:
  - Are the canonical numbers based on LEP experience (10 pb^{-1} commissioning, 0.5-1 pb^{-1} quick re-alignment) sufficient for ILD detector modularity?
  - Simulation alignment excercise needed?
- Alternatives at nominal beam energy?
  - Z return
  - Momentum calibration from Z, J/ψ, Y (e.g. Graham Wilson at AWLC14)
- Cosmics, yes (LHC has shown importance), but:
  - 0.5% duty cycle due to power pulsing
  - reduced rate, because of underground location, but maybe not so deep
- B-field mapping
  - Can we measure it precisely enough?

    (study on use of detailed map in reconstruction ongoing)