Studies on GEM modules of a Large Prototype TPC for the ILC.

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on behalf of the FLC-TPC Group

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MPGD 2015 & RD51 collaboration meeting

Introduction

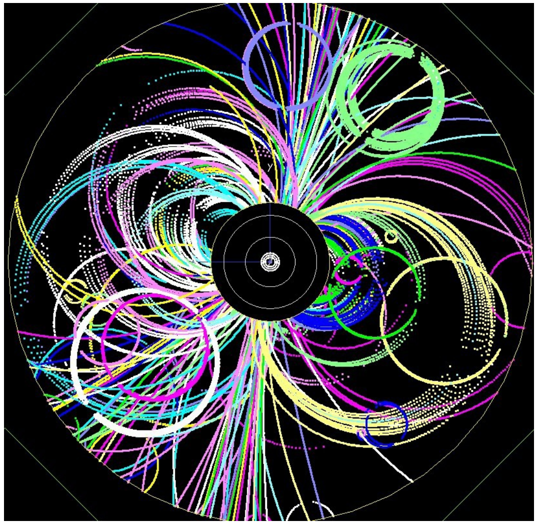
Testbeam measurements

GEM studies

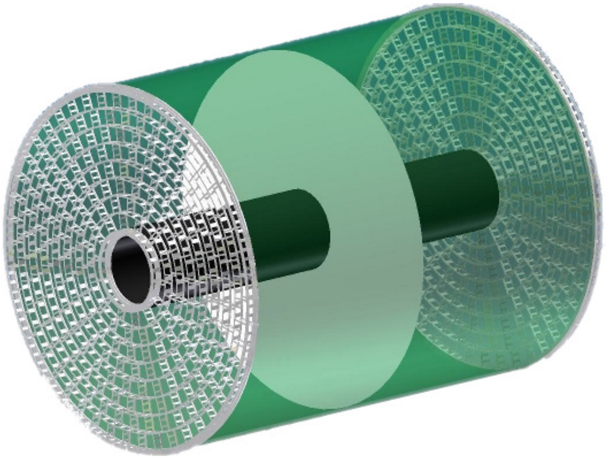
Outlook

Requirements ILD TPC.

International Large Detector (ILD) for the International Linear Collider



- **Momentum resolution**
  $\sigma(1/p_t) = 2 \times 10^{-5}$ /GeV
  (TPC alone 10^{-4} /GeV)
  single point resolution $\sigma_{r\phi} < 100\,\mu\text{m}$
- **Tracking efficiency**
  close to 100% down to
  low momenta for Particle Flow
  $\approx$ 200 points along track in TPC
- **Minimum material**
  in front of calorimeter
  TPC: less than $0.05X_0$ (barrel)
  / $0.25X_0$ (endcaps)



Cornell University (2010)

Large Prototype TPC.

Built to compare different readouts under identical conditions

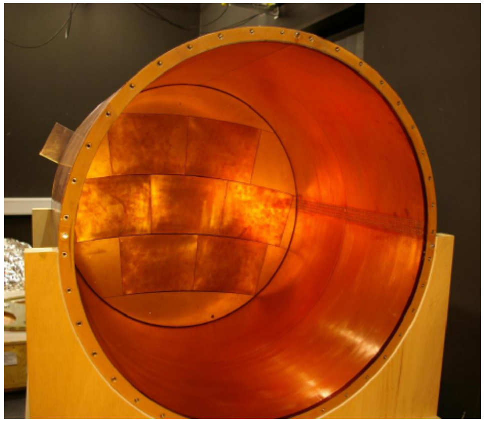
see talks by J. Kaminski (Tuesday) and P. Colas (today)

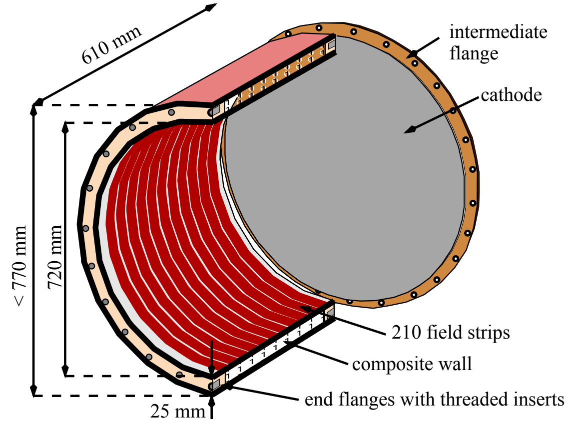
LP field cage parameters:

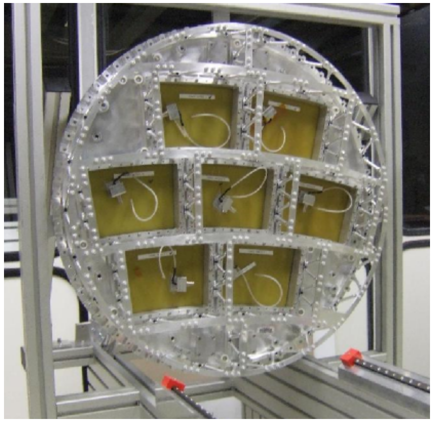
- length 61 cm, diameter 72 cm
- up to 25 kV ⇒ $E_{\mathrm{drift}} \approx 350$ V/cm
- made of composite materials ⇒ 1.24% X_0

Modular endplate:

- space for 7 modules, area $\approx 22 \times 17\,\mathrm{cm}^2$



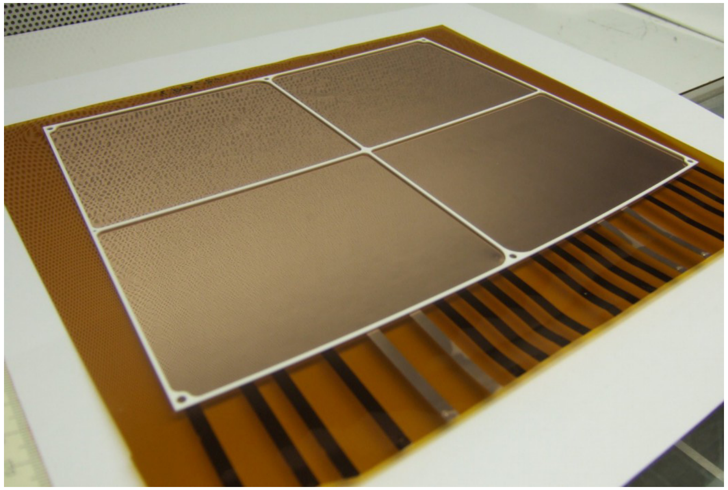




DESY GEM Module.

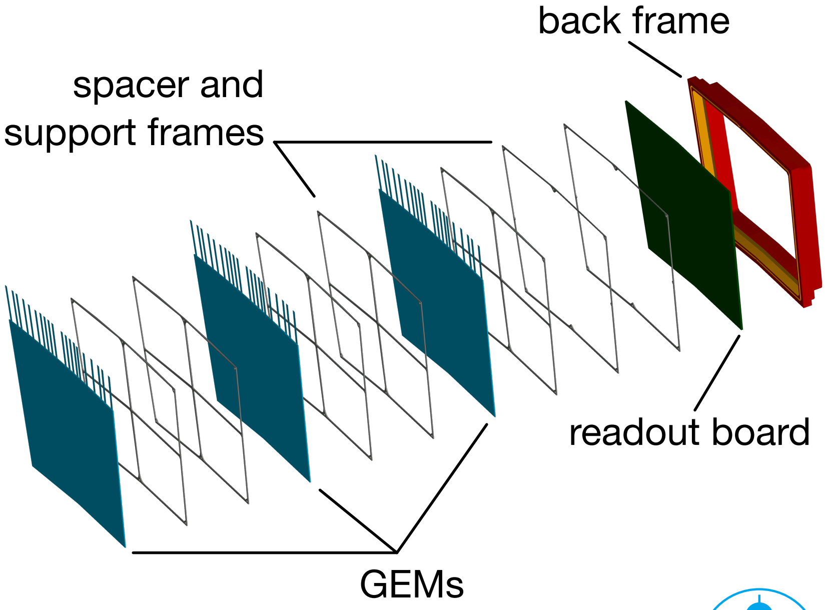
Goals:

- minimal dead space
- minimal material budget
- even surface of GEMs
- stable operation



Solution:

- triple GEM stack
- thin ceramic mounting grid
- anode divided into 4 sectors
- no division on cathode side
- 4829 pads ($1.26 \times 5.85\,\mathrm{mm}^2$)
- field shaping wire



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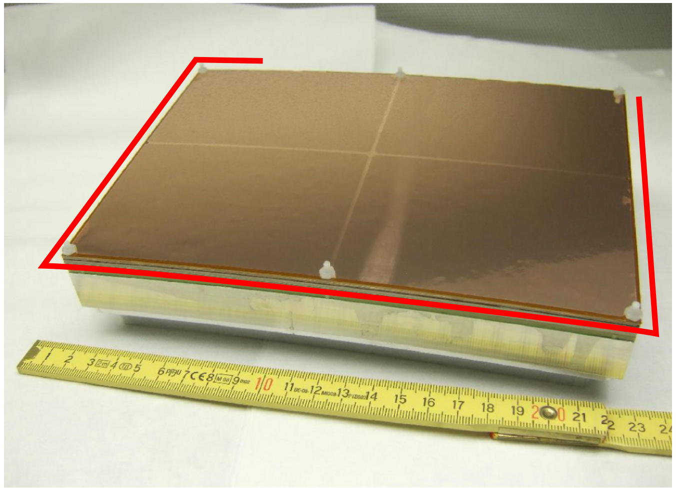

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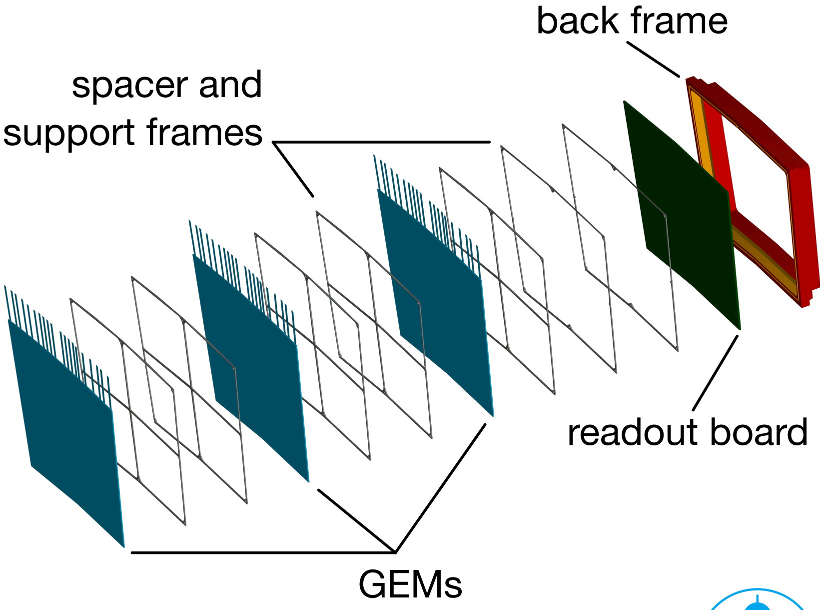

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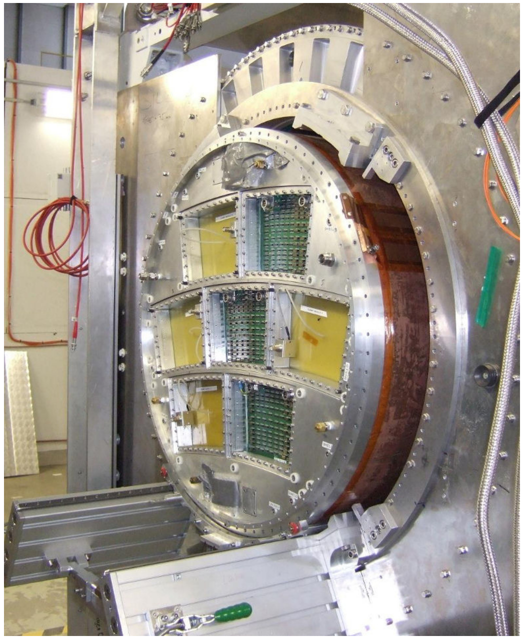
DESY II Testbeam Campaigns 2013.

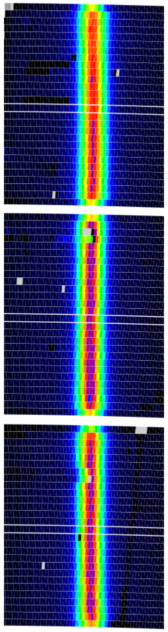
Goals:

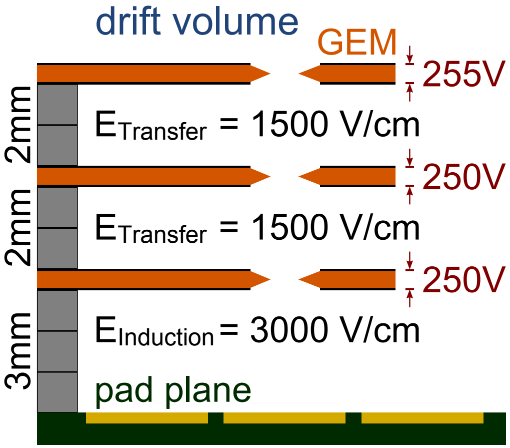
- validation of module design
- understand field distortions

Testbeam setup:

- e^- beam up to 6 GeV
- magnetic field of 0 or 1 T
- 3 modules, half equipped
  $\rightarrow$ 7212 ALTRO channels
- gas mixture:
  95% Ar, 3% CF_4, 2% iC_4H_{10}
- most runs at ~240 V/cm drift field
  (maximum drift velocity)







drift volume

GEM

255V

2mm

$E_{Transfer}$ = 1500 V/cm

250V

2mm

$E_{Transfer}$ = 1500 V/cm

250V

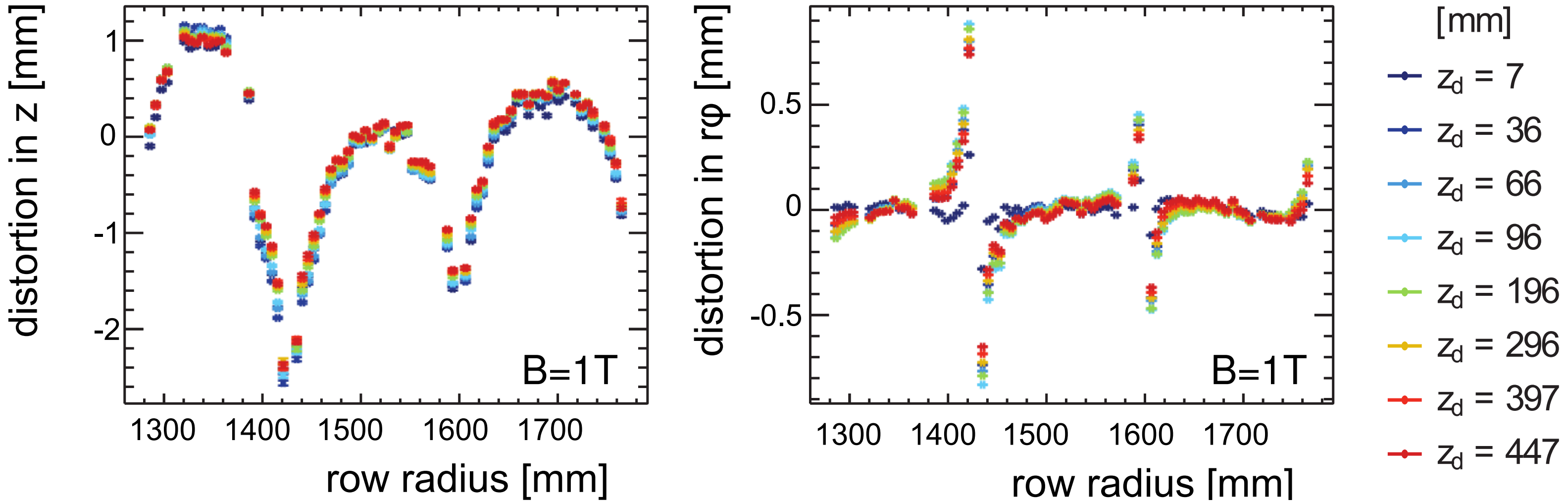
3mm

$E_{Induction}$ = 3000 V/cm

pad plane

Field distortions I.

Field distortions from inhomogeneities in magnetic and drift field, e.g. non-perfect E-field at gap between modules



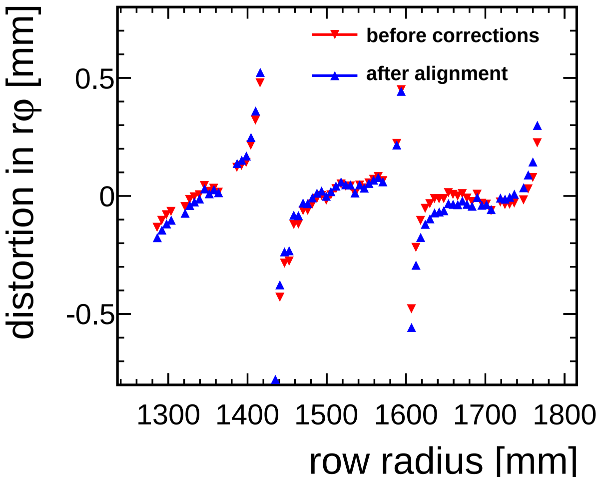
Field distortions II.

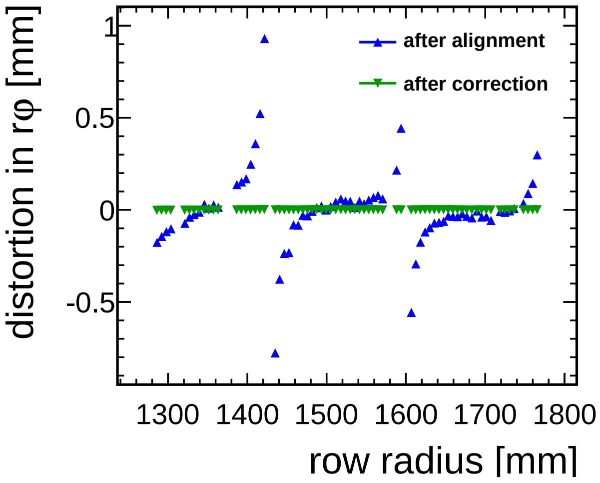
Module alignment using Millepede II

- simultaneous fit of the complete input, all alignment and track parameters
- rotations and translations of the modules
- $\vec{E} \times \vec{B}$ effects influence alignment
  $\rightarrow$ use only B=0 T data
  leads to corrections order of 0.1 mm
  and a few milliradians

Distortion corrections:

- derive from 10% of events, apply to all
  $\rightarrow$ systematic shifts of residuals close to 0



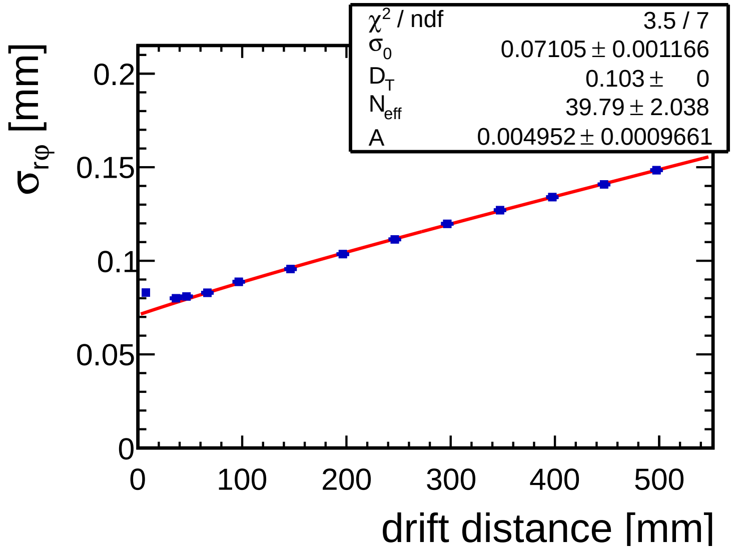


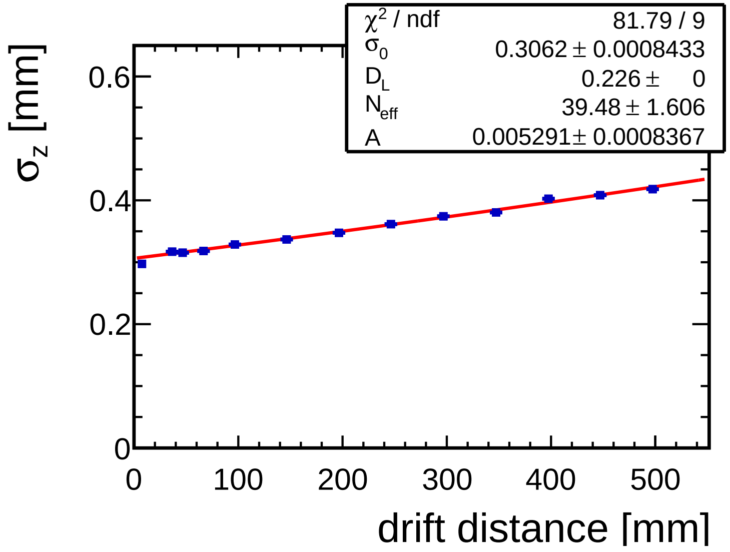
Resolution.

Single point resolution:

$$\sigma_{r\varphi/z}(z) = \sqrt{\sigma_0^2 + \frac{D_{t/l}^2}{N_{\mathrm{eff}} \cdot e^{-Az}} z}$$

determined using *geometric mean method*





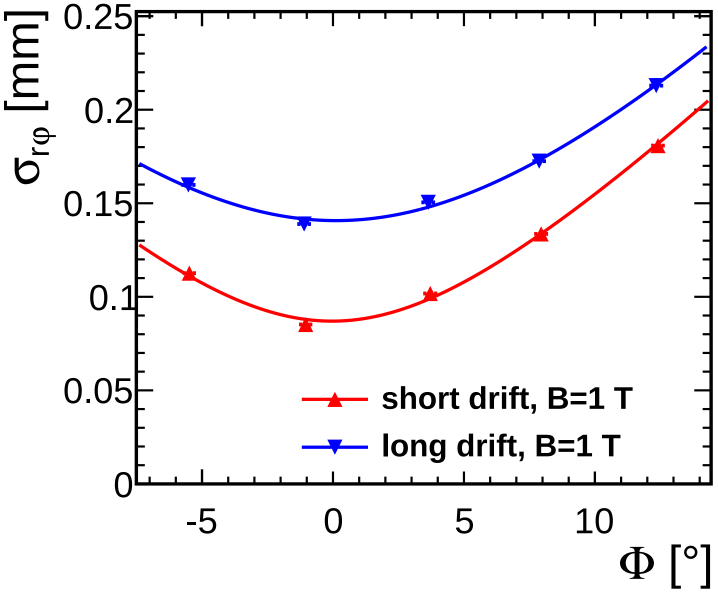
extrapolation of $\sigma_{r\phi}$ to 3.5 T and full ILD drift length close to 100 µm

Resolution - phi dependence.

Resolution dependence on azimuthal angle:

$$\sigma_{r\varphi}(\Phi) = \sqrt{\sigma_0^2(z) + \frac{L^2}{12\hat{N}_{\mathrm{eff}}} \tan^2(\Phi - \Phi_0)}$$

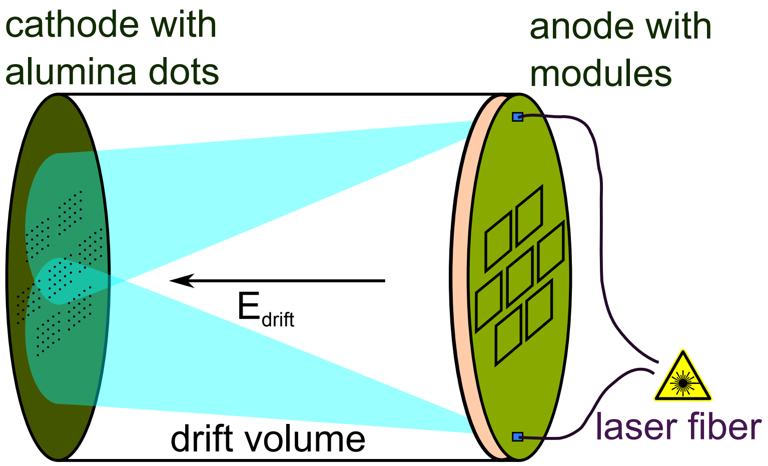
Analysis of tracks at short (10 cm) and long (40 cm) drift
→ data behaviour with $\tan|\Phi|$ as expected

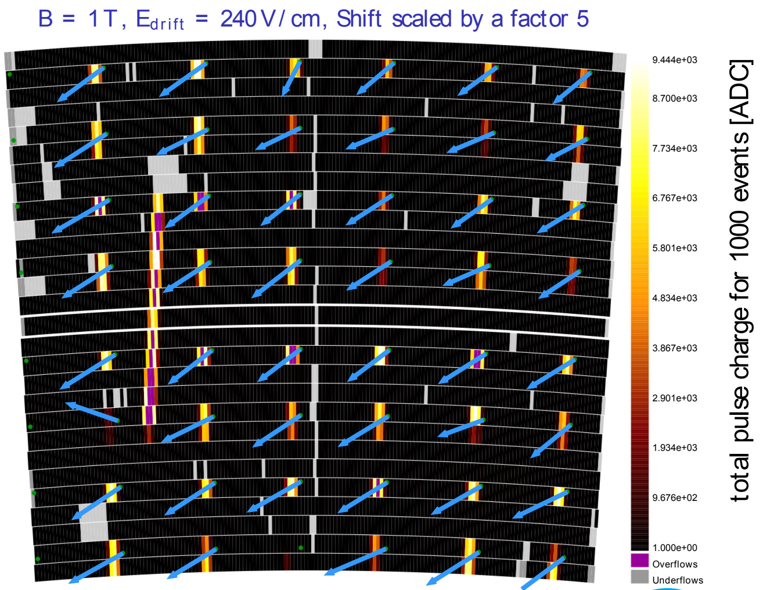


Laser measurements.

Global field distortion measurement

- laser to illuminate alumina dot pattern on cathode
- photoeffect liberates electrons from these “photodots“
- reconstruct position measured on the modules
- determine displacements
  φ displacements along row $-2\,\mathrm{mm}$ to $4\,\mathrm{mm}$,
  radial displacements $-1\,\mathrm{mm}$ to $3\,\mathrm{mm}$
- software framework available to map global distortions





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GEM module status.

Results of the testbeam

- modules worked very reliably
- field shaping wire: promising results
- improved understanding of alignment & distortions
- at the very end: one GEM destroyed

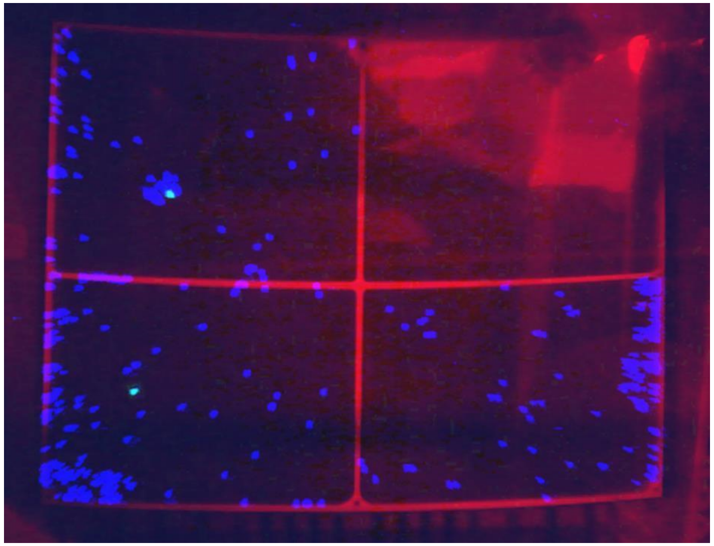
Main goals of current R&D:

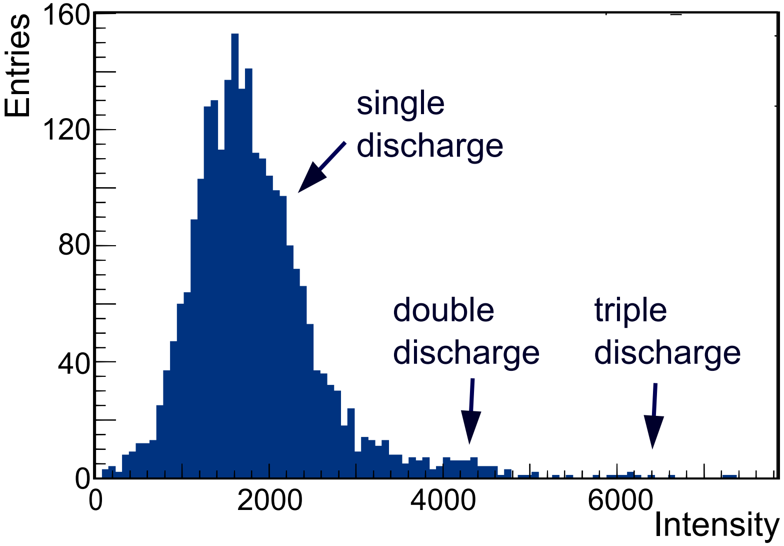
- long-term HV-stability
- improve maintainability (one broken sector disables whole module)
- reproducibility and optimisation of module production
- inclusion of ion gate in module design
- reconsider readout electronics (S-ALTRO readout, pad readout with chip?)

GEM stability I.

Goal: investigate / improve long-term stability

- understand discharges and why some are destructive
- observe sparking optically and electrically
- single GEM and module-like setup
- accompanied by simulations of the system





GEM stability II.

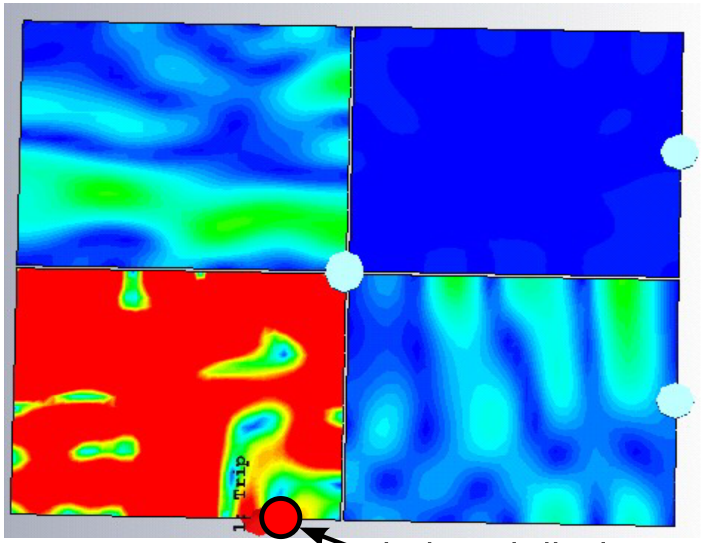
CST^{TM} simulations: discharge causes surface current oscillations

First tests with protection circuit (R-C) to damp oscillations and reduce “double“ discharges:

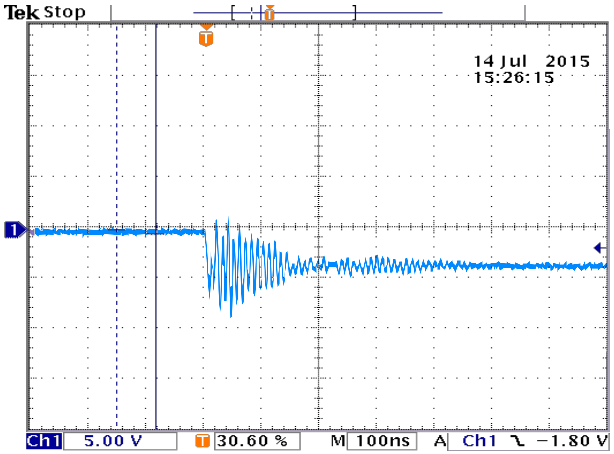
	without RC	with RC
registered discharges	166	76
incl. double discharges	14	0

Detailed measurements ongoing

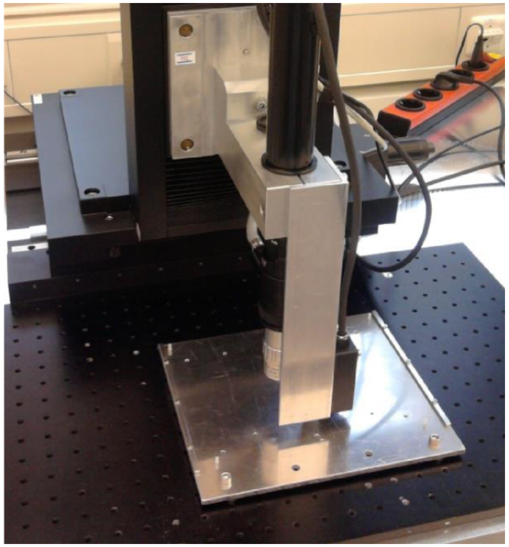
simulation: surface current after ~10 ns



induced discharge



GEM flatness I.

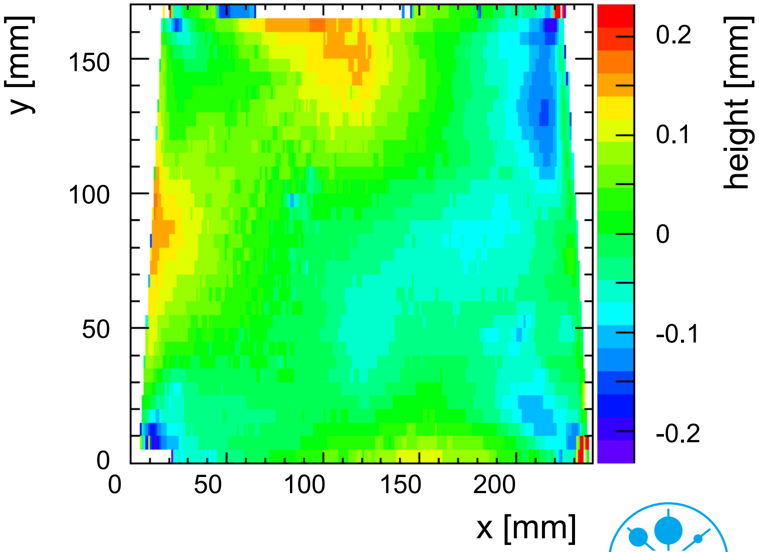


Flatness of GEMs in the stack
→ gain distribution and dE/dx measurements

Flatness measurements:

- XYZ table with
  laser measurement head
- resolution around 10 µm
- precision mounting plate
  for GEMs (horizontal and vertical)

Majority of area ±0.1 mm,
some deviations

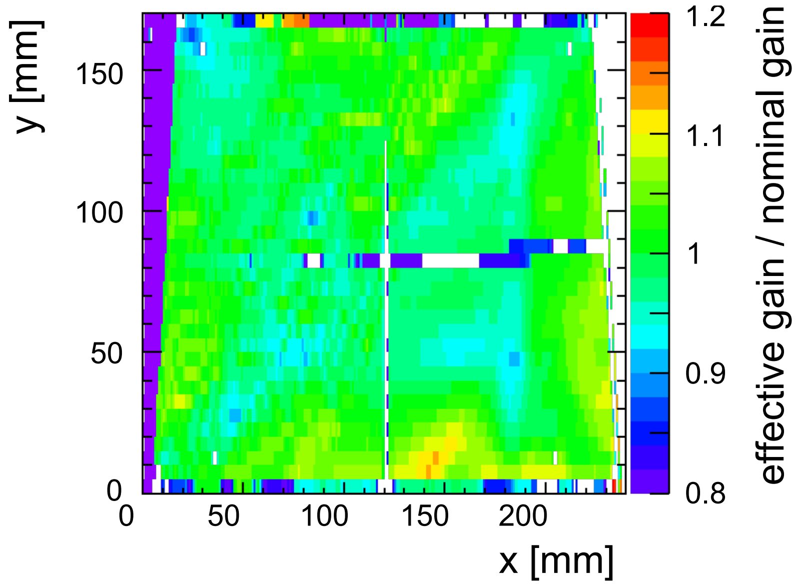


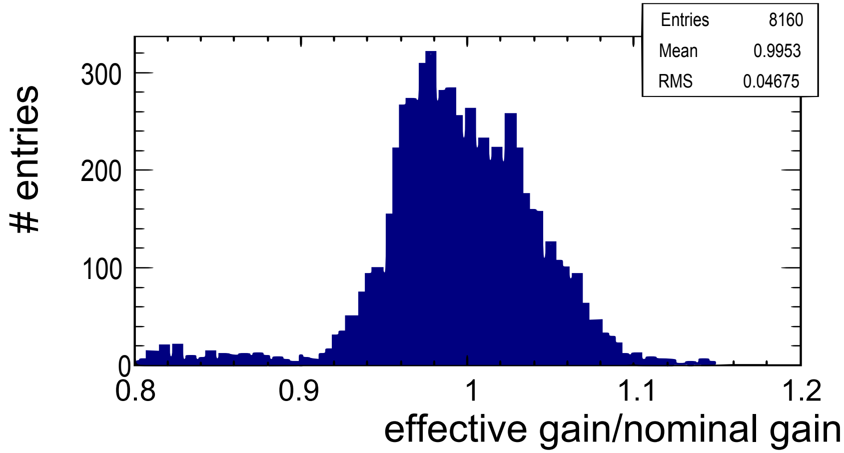
GEM flatness II.

Gain simulation:

- 3 GEM profile measurements to simulate stack
  (GEM Voltage: 250 V, drift field: 240 V/cm, transfer field: 1500 V/cm, induction field: 3000 V/cm)
- example shown: RMS $< 5\%$
- all possible combinations of 3 GEMs, with mirroring: RMS $\sim 5.6\%$

$\rightarrow$ reconsider mounting process, ceramic frame design

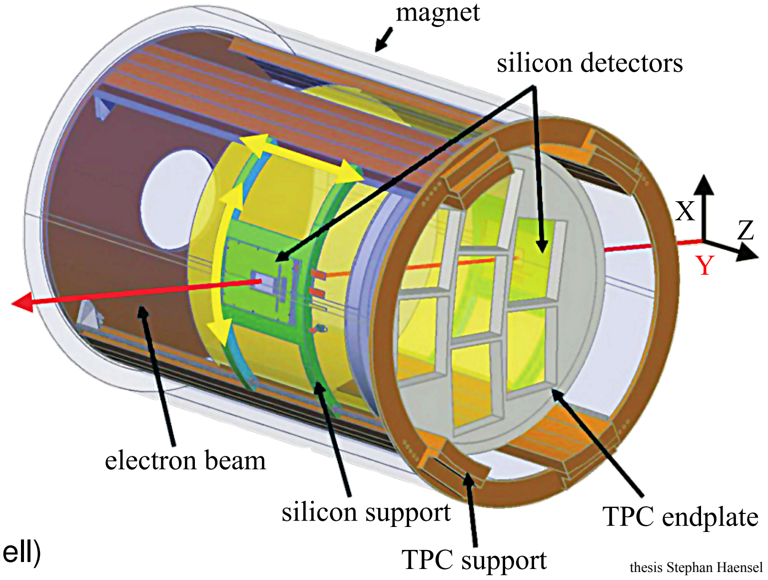




Improvements of testbeam setup.

2$^{\text{nd}}$ large prototype in preparation

- material choices for field cage under evaluation
- gain construction experience
- aiming for better precision (→ electric field homogeniety)
- use new light-weight endplate (U. Cornell)



thesis Stephan Haensel

External reference tracker:

- for momentum measurements
- four silicon detector layers
- inside the magnet, in front and behind TPC
- sensor and readout technology choice in progress

Conclusion.

- GEM modules have been shown to perform well
- promising towards meeting the requirements for ILD TPC
- research is ongoing on HV stability and GEM flatness
- large prototype infrastructure improvements in progress
- further goals: measurement of momentum resolution
  and dE/dx performance

Plan: operate the next generation of modules
at the DESY testbeam in spring 2016.