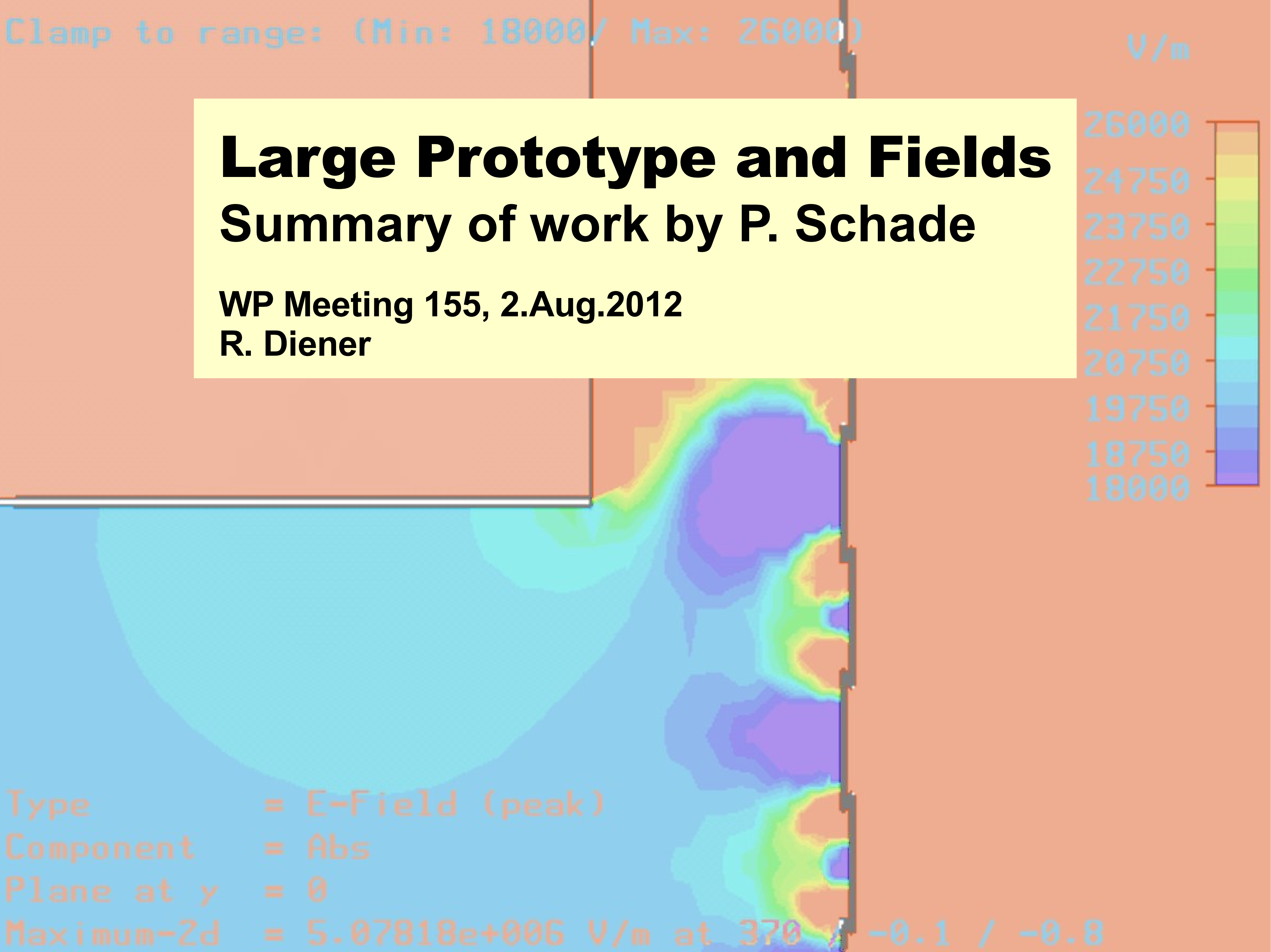
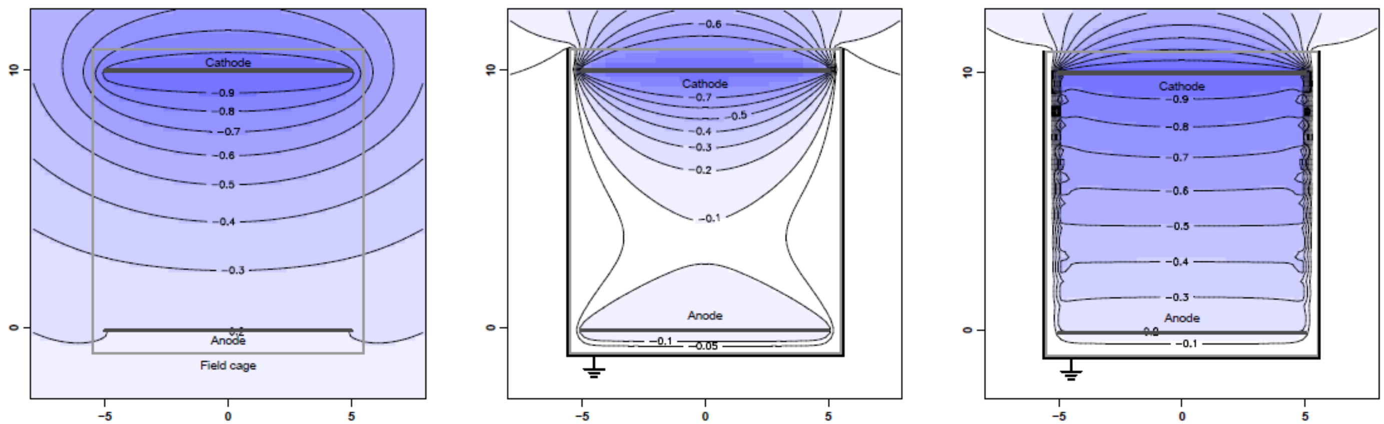
Large Prototype and Fields
Summary of work by P. Schade

WP Meeting 155, 2.Aug.2012
R. Diener



Introduction

- Need for homogeneous electric field
  → Field shaping on outer walls



(a) TPC consisting only of anode and cathode

(b) TPC with additional shielding layer

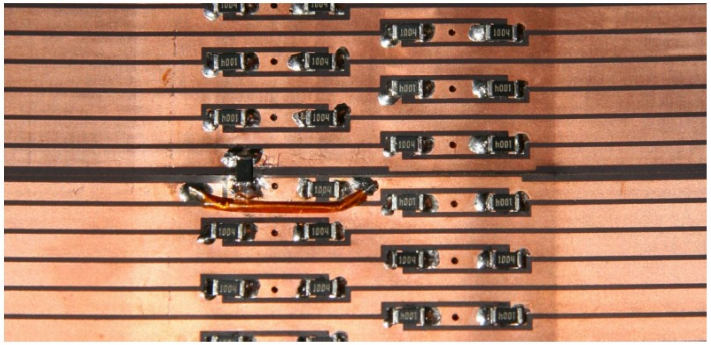
(c) TPC with shielding layer and field strips

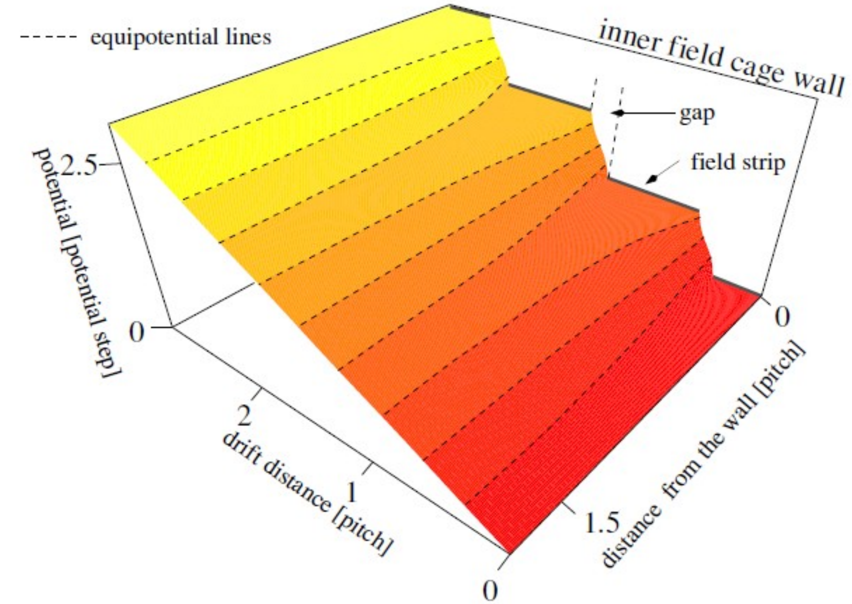
- Best shaping: highly resistive material (foil) between cathode and anode
  → linear decreasing potential
  - No foil with the right properties obtainable

- Next best solution: field strips

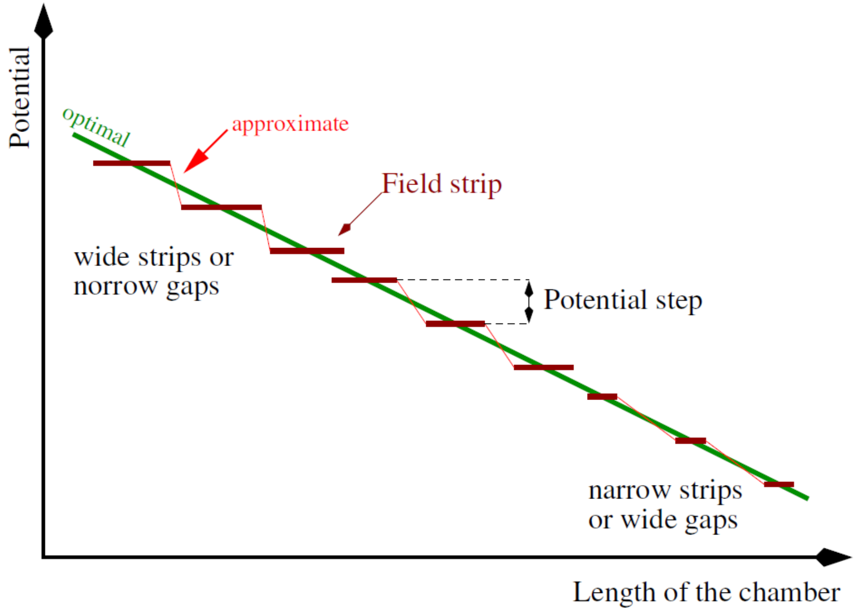
Field Strip Size and Pitch

- Large Prototype
  - pitch=2.8mm ← distance needed for SMD mounting





- Field strip / gap ratio (at given pitch):
  - Strip width:
    - Should be as small as possible for a smooth field
    - Should be as large as possible to minimize area where charge-up can happen
  - Gap must be large enough to avoid discharge (LP: 0.5mm)
  - In LP case: >80% covered by copper



Field Calculations

- Studies done with FEM program *CST*

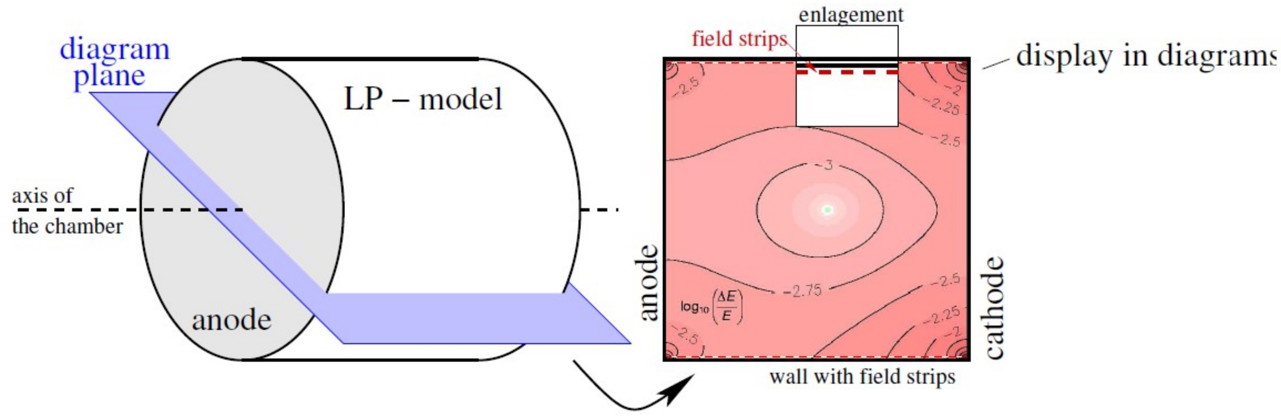


Figure 5.6: *Display of calculated field deviations in the following diagrams*

- Displayed:

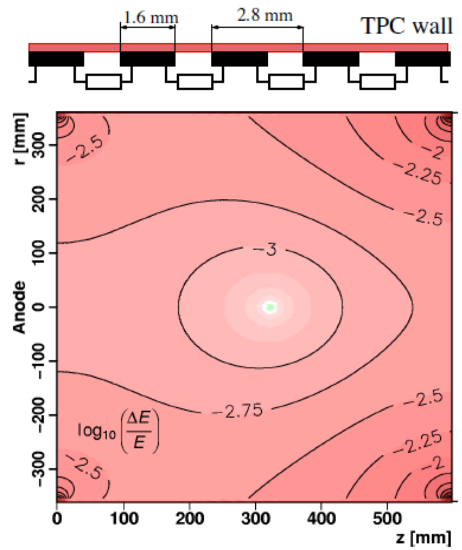
$$\frac{\Delta E}{E}(\vec{r}) = \frac{|\vec{E}_{\text{calculated}}(\vec{r}) - \vec{E}_{\text{nominal}}|}{|\vec{E}_{\text{nominal}}|}$$

- ΔE/E should be smaller than 10^{-4} to minimize impact on resolution
  - With this homogeneity: $\Delta R_\perp < 30\mu m$ (accuracy of transverse component of correction vector $\vec{R}_{cor}$)

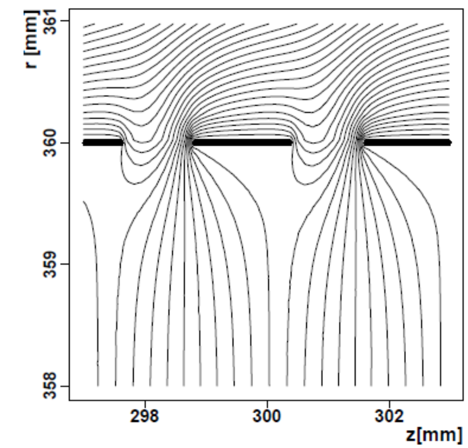
$$\sigma_\perp \rightarrow \sqrt{\sigma_\perp^2 + \Delta R_\perp^2} \leq 105\,\mu\text{m} \quad \text{for} \quad \sigma_\perp = 100\,\mu\text{m}.$$

Field Strip Optimization

- Simple, “easiest” field strip layout not sufficient

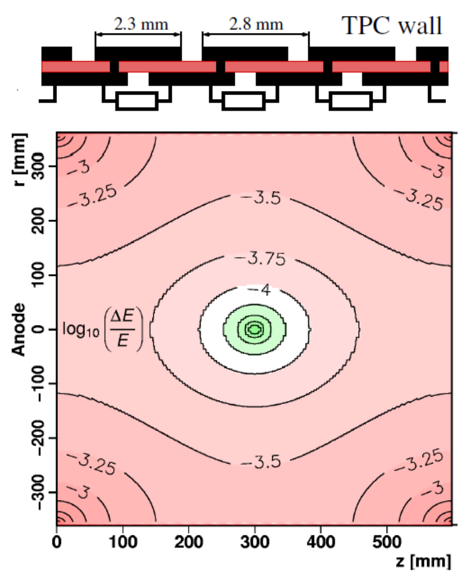


(a) strip layout and calculated field distortions

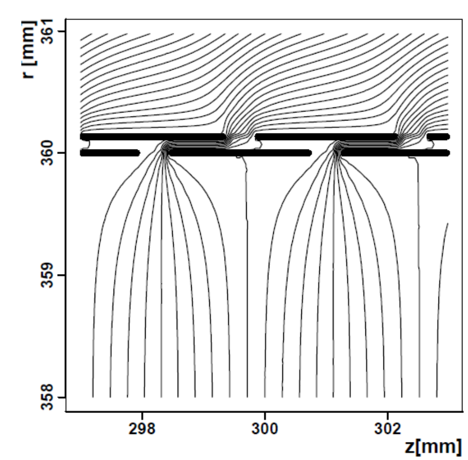


(b) punch-through the gaps between the strips

- Simple Layout with “directly connected” mirror strips



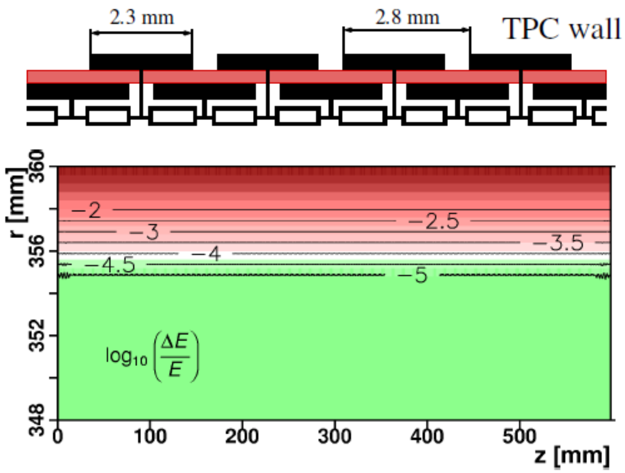
(a) layout of the strips and calculated field deviations



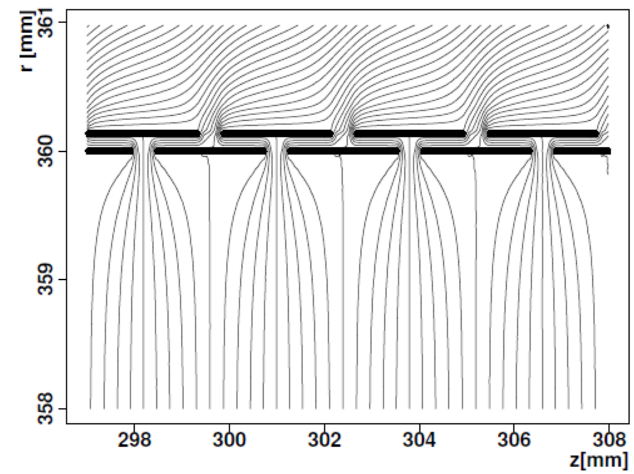
(b) equipotential lines in the vicinity of the wall

Field Strip Optimization

- Layout with mirror strips as implemented in the Large Prototype
  - ΔE/E > 10^{-5} only in ~ 5mm wide band at the wall

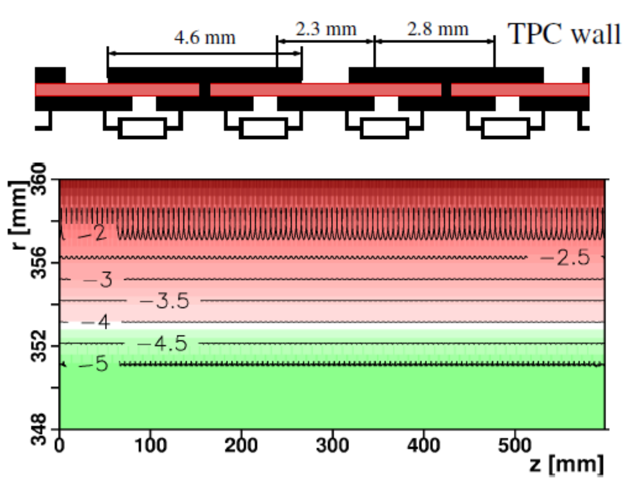


(a) field deviations for mirror strips on intermediate potential

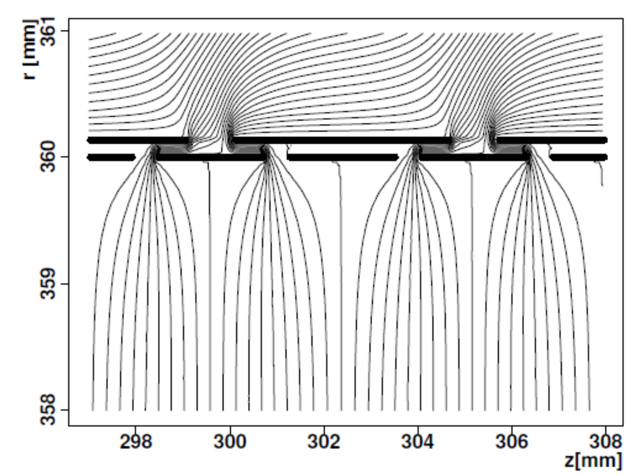


(b) equipotential lines for mirror strips on intermediate potential

- Alternative, simpler layout from Peter's thesis
  - ΔE/E > 10^{-5} only in ~ 9mm wide band at the wall



(c) field deviations for broadened parallel mirror strips



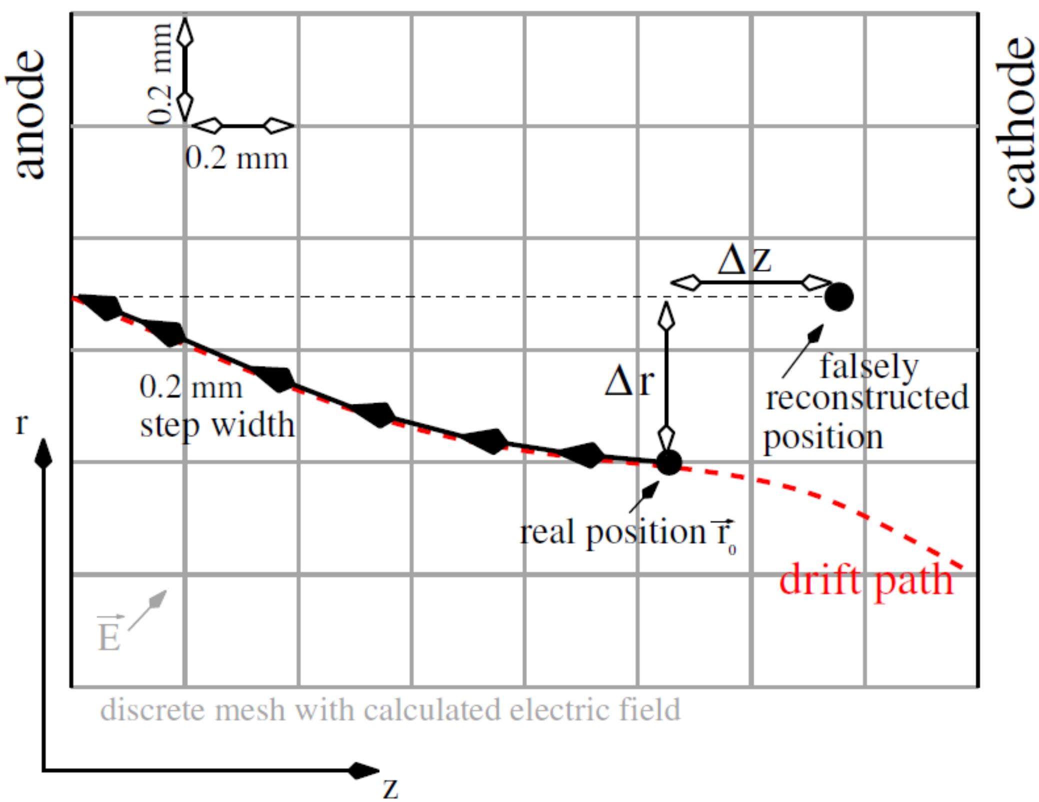
(d) equipotential lines for broadened parallel mirror strips

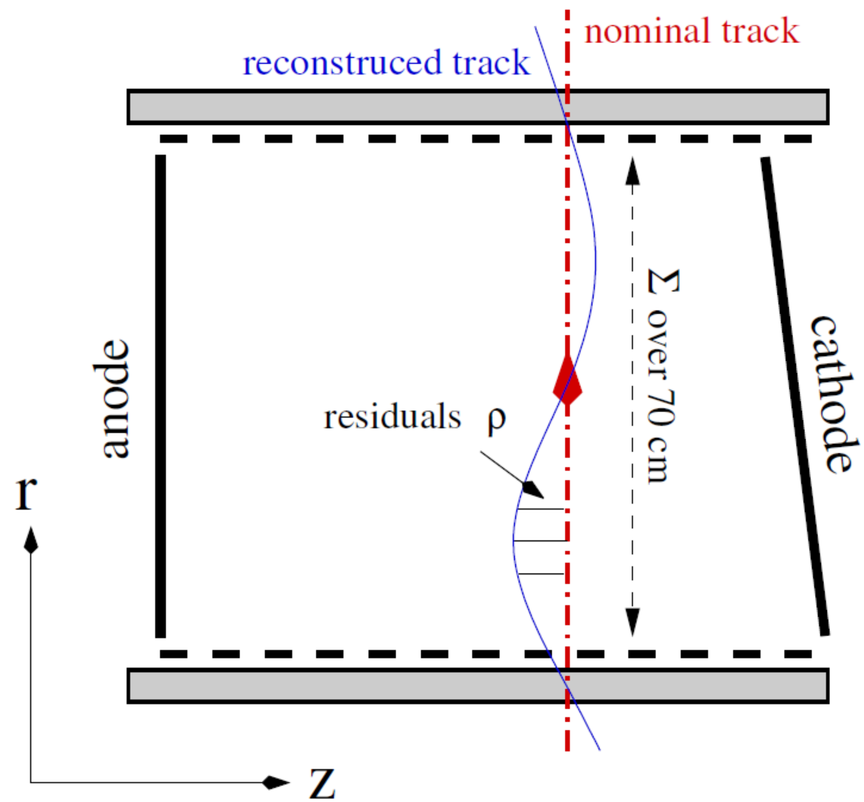
Impact of Mechanical Misalignments

- To judge impact, calculation of electron drift path step-wise:

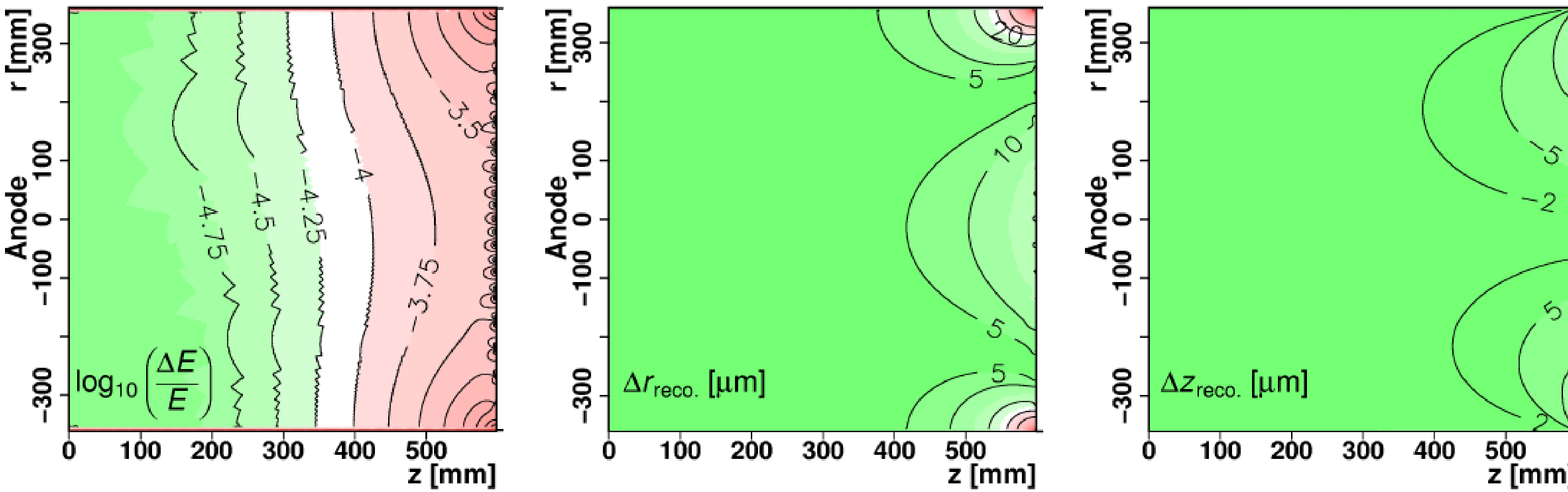
$$\vec{r}_{\text{drift}}(\vec{B},\vec{E}) = \vec{r}_0 + \sum_{\vec{r}_0}^{\text{anode}} \frac{\vec{v}_{\text{Drift}}}{|\vec{v}_{\text{Drift}}|}(\vec{B},\vec{E}) \cdot \delta l$$

- Step size is 200µm (value from comparison of step-wise calculation with analytical calculated drift for analytically constructed electric fields), B=1T

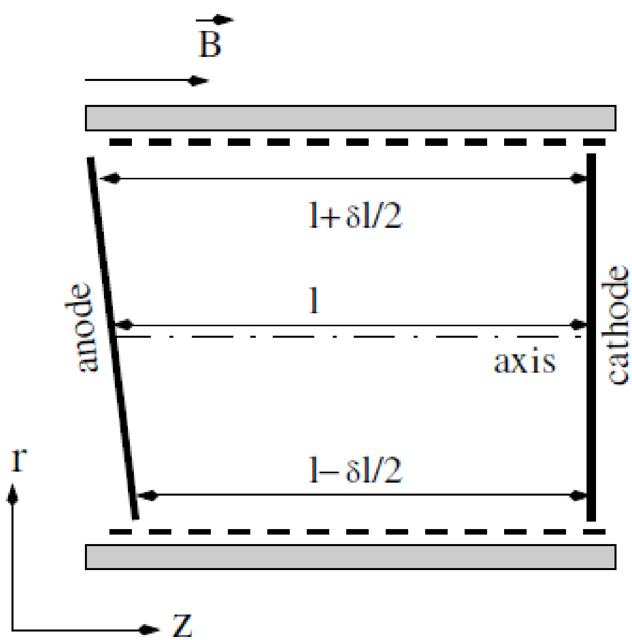


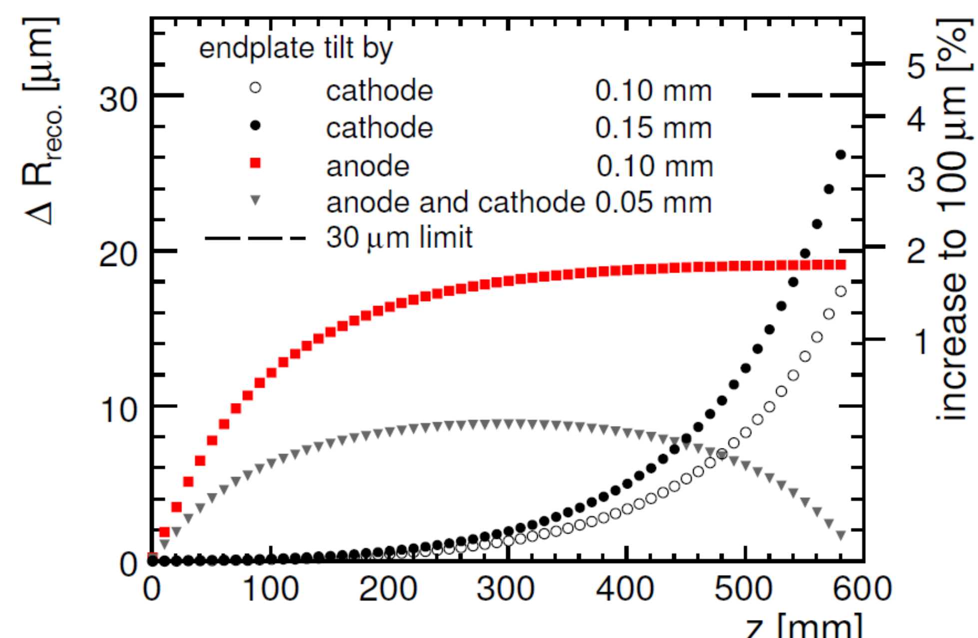


Tilted Cathode/Anode

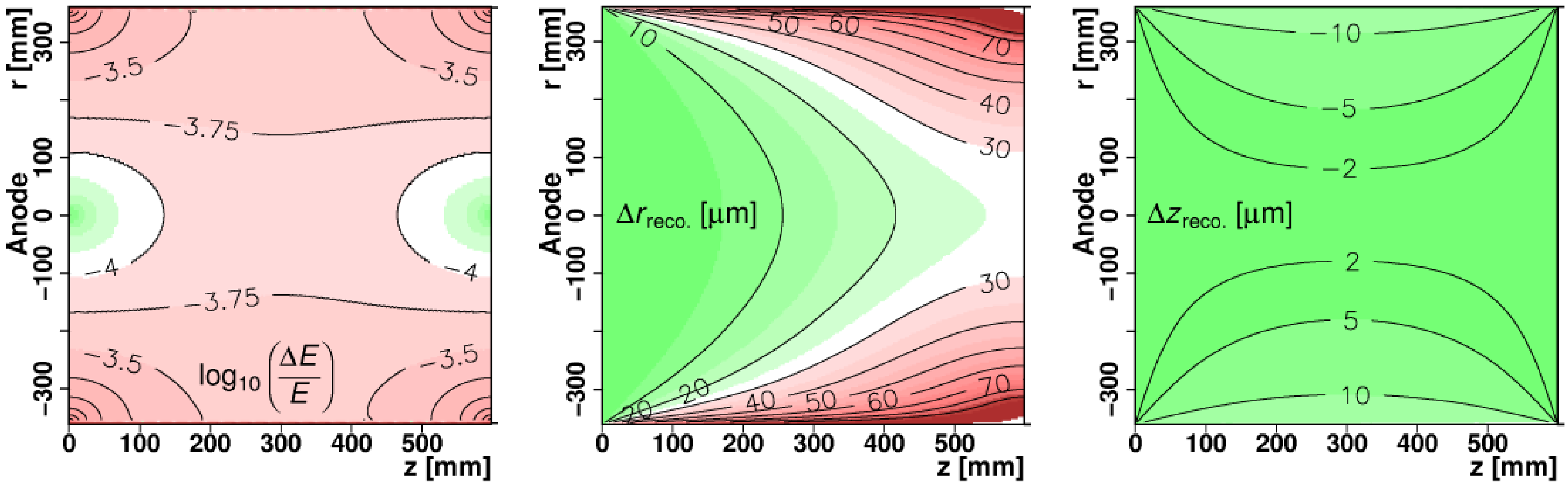


(a) field distortions (b) radial displacement (c) long. displacement

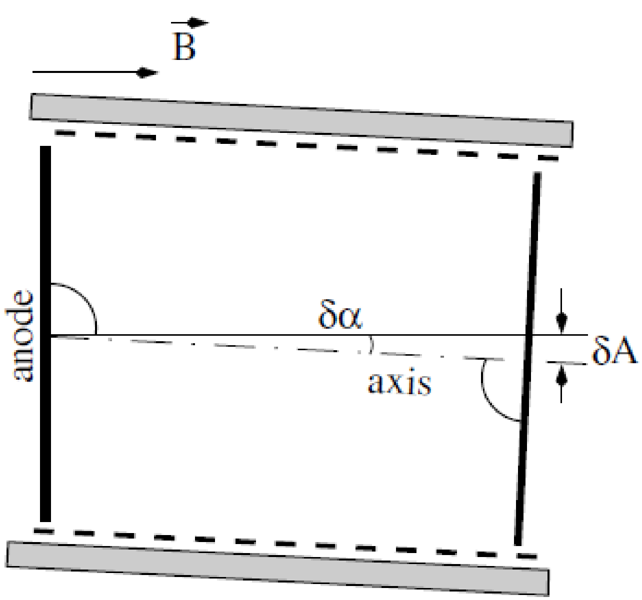


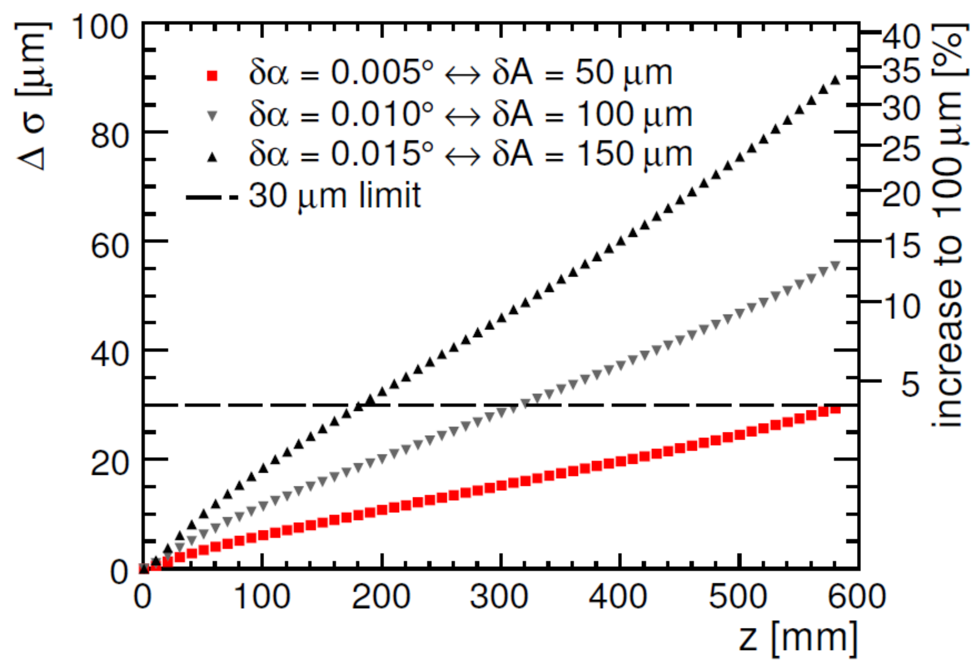


Tilted Axis



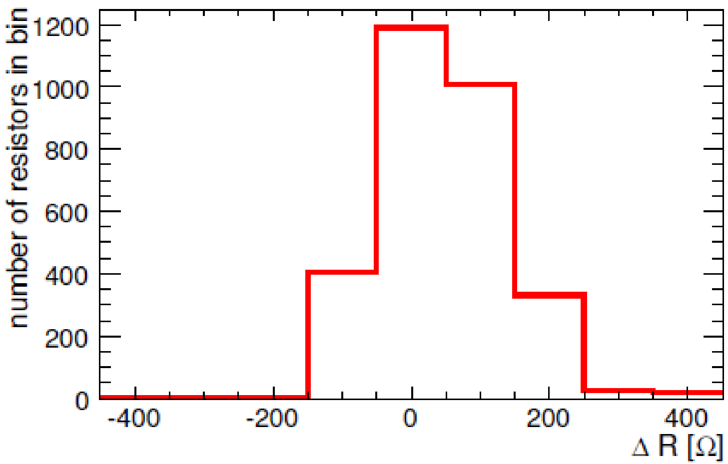
(a) field distortions (b) radial displacement (c) long. displacement



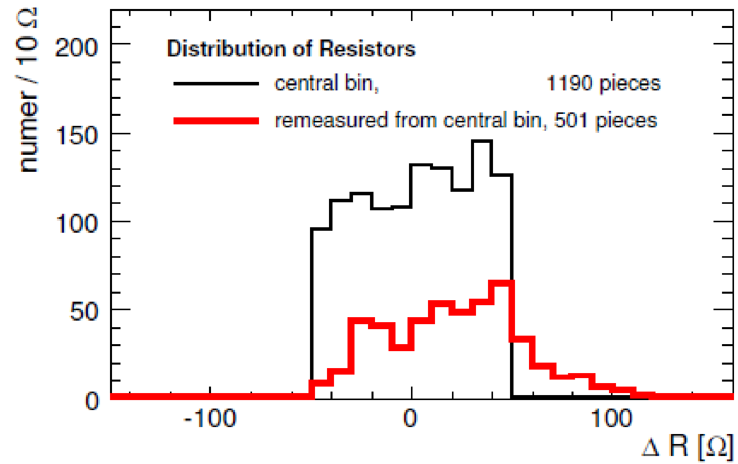


Getting Real: Resitors and Wall

- Real resistors not perfectly 1 MΩ: distortions order of 10^{-5}

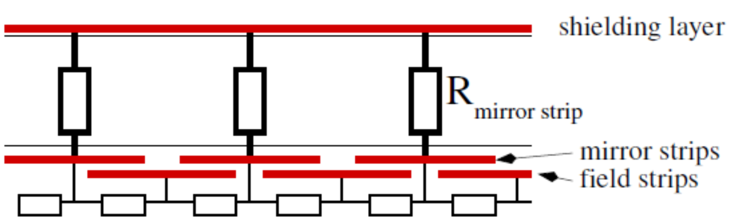


(a) 3000 one mega ohm resistors sorted into 50 Ω bins

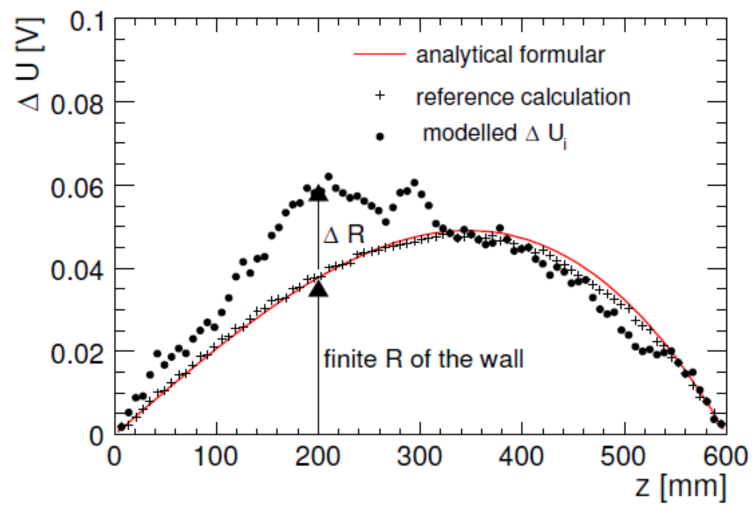


(b) distribution of the central bin with the result of a re-measurement

- Walls not perfect isolators
  R_{wall} estimated to ~ $5 \cdot 10^{12} \Omega$



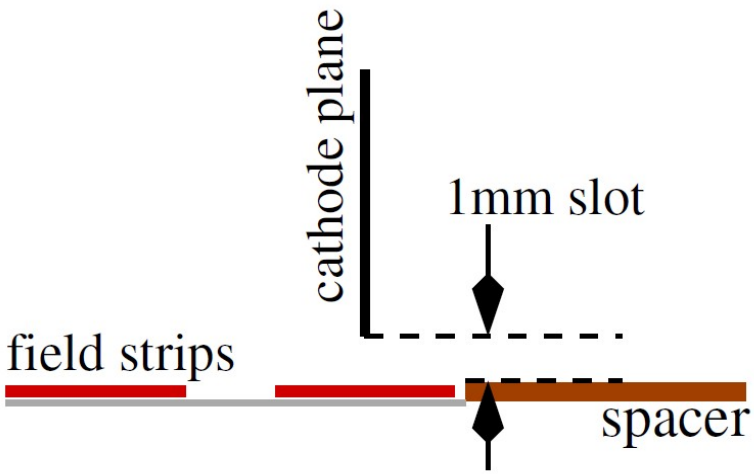
(a) finite resistivity of the wall



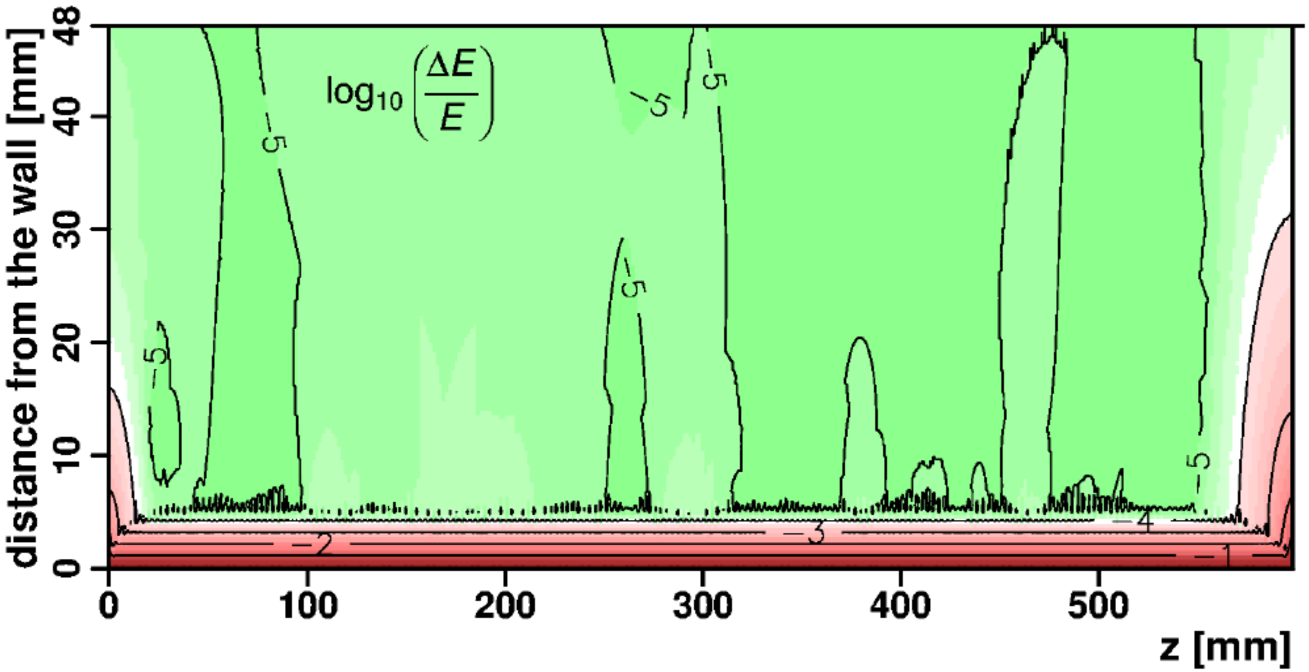
(b) additional potentials on the field strips

Getting Real: Gaps + Integral Effect

- Gaps at anode/cathode end plates:
  - Field distortions up to a distance of about 1cm at anode and about 3cm at cathode

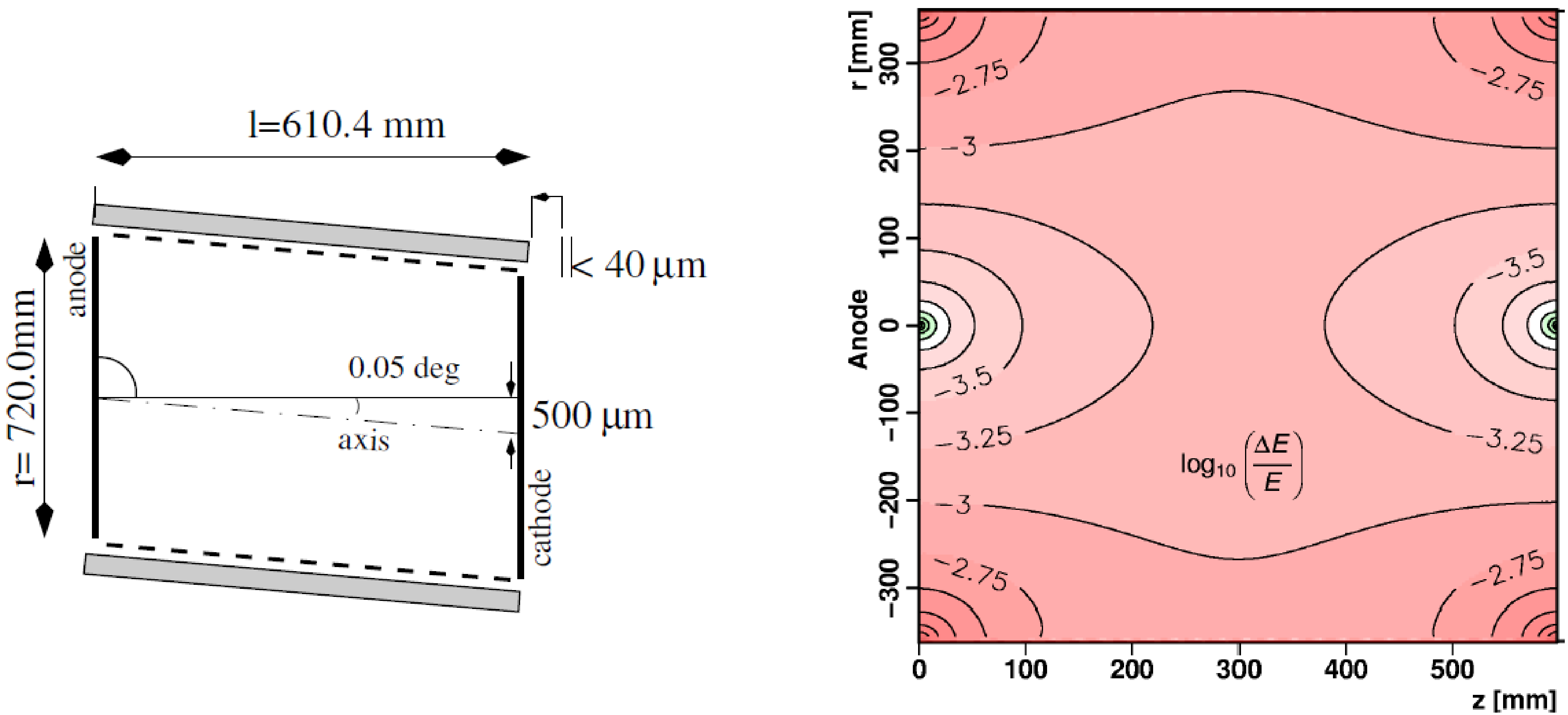


- Resulting field taking into account: resistor deviations, wall conductivity, gaps



Getting Real: Using LP Geometry

- Large prototype axis tilt from quality check, parallel cathode/anode assumed



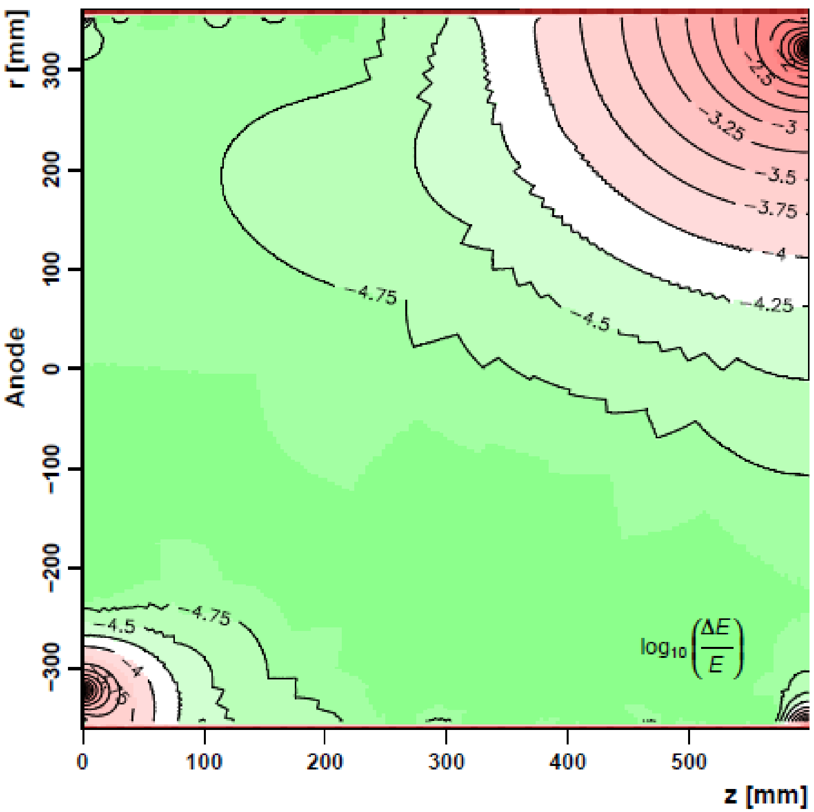
(a) measured dimensions of the field cage (b) calculated drift field deviations

Figure 6.14: *Dimension of the field cage and electric field quality*

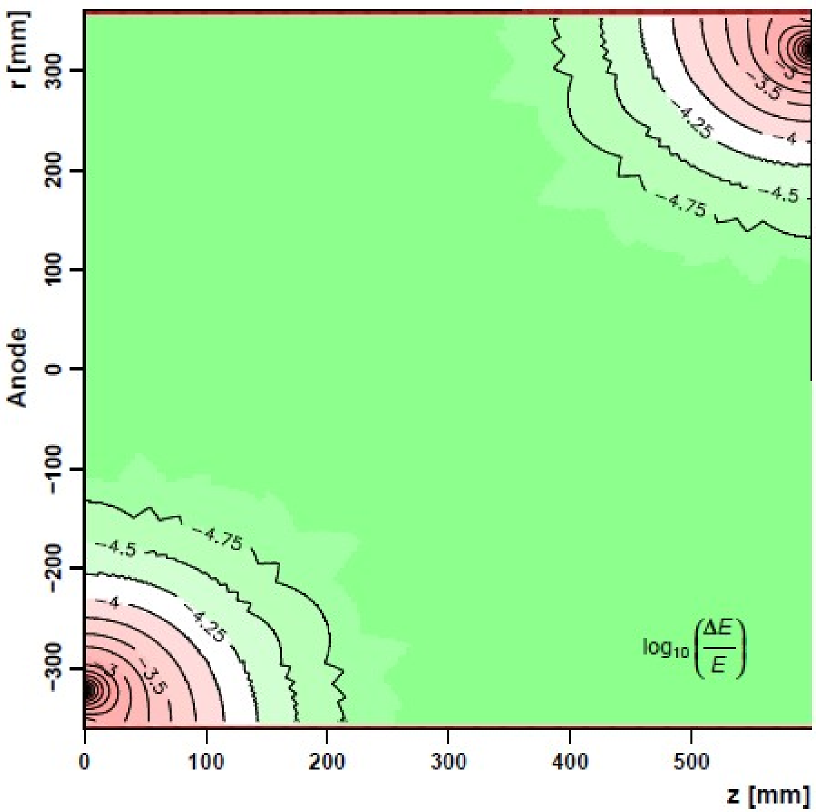
Holes in Anode/Cathode

- Calculated field deviation from holes:

Just the holes



"Pipe" on same potential behind holes



- Cathode side: pipe helps, Anode side: better without a pipe
- Possible improvement:
  mesh above the holes with 200 lines per cm → about 20% light loss

Influence of Amplification Flatness

- Example: GEM with maximal bending of 200µm (achievable with grid mounting)

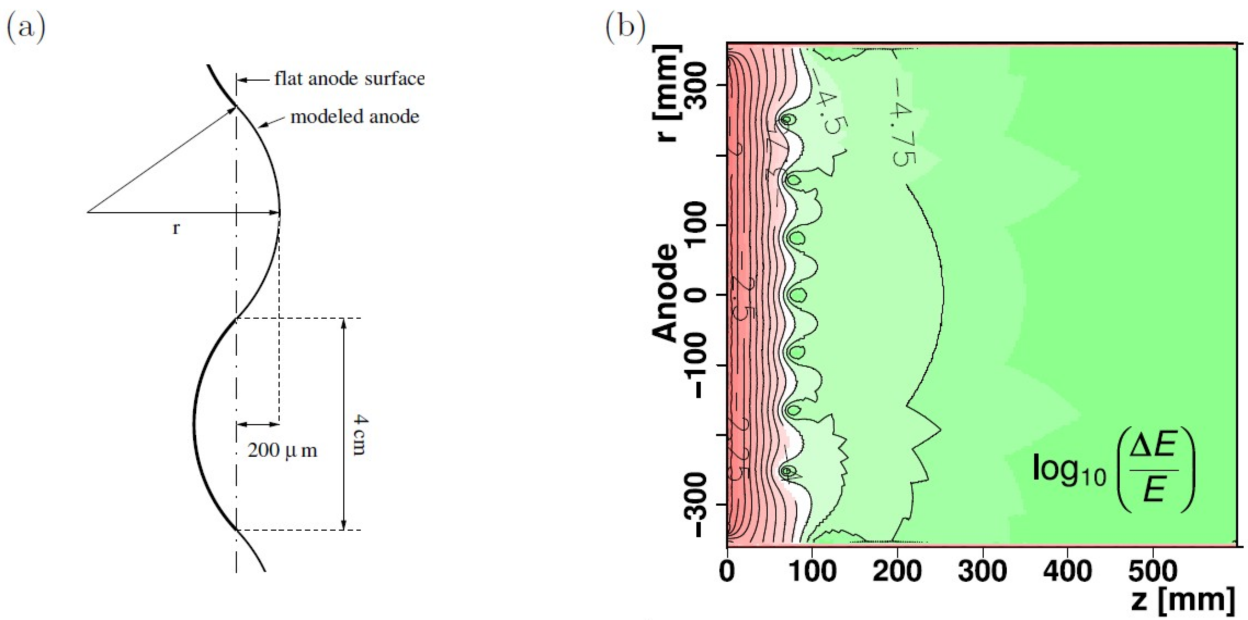


Figure 9.15: (a) Sketch of anode deflections for simulation. (b) Field quality with deflected anode. The contour lines have a distance of 0.25 and the green areas mark regions in the chamber, where the required field quality is reached [Sch10b].

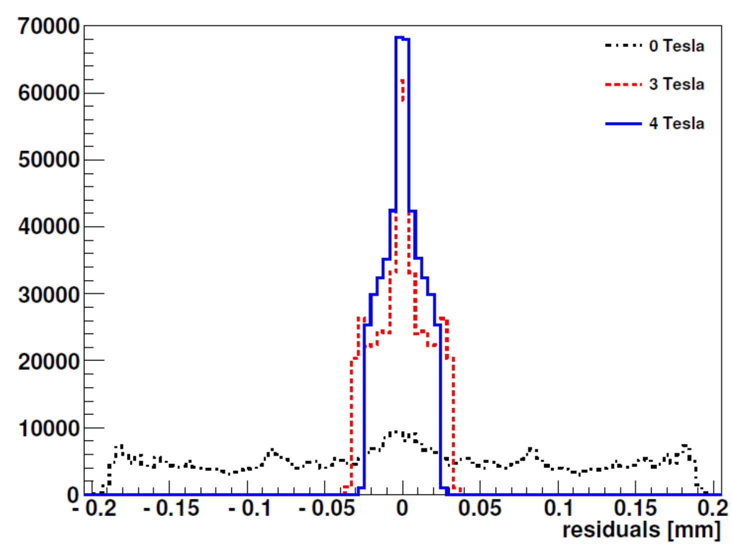
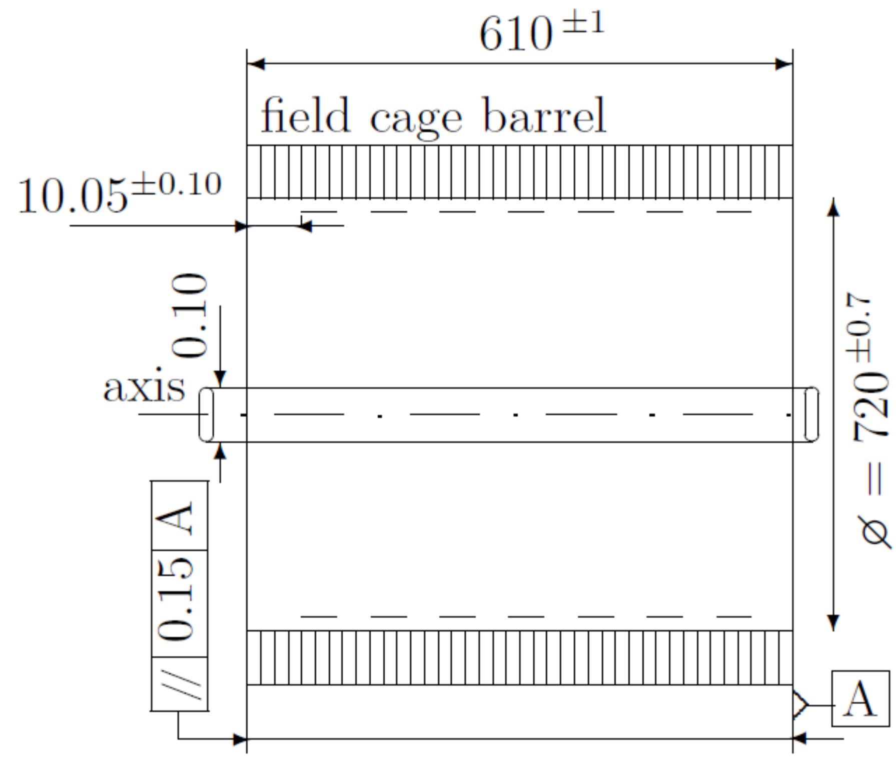


Figure 9.16: Residuals of reconstructed, simulated tracks going through an electric field distorted by deflected GEMs.

Conclusion & Summary

- Requirements on LP Field cage
  - Axis tilt < 100µm (better: 50µm)
  - Parallelity cathode/anode <150µm
  - Translate for ILD TPC:
    - Axis tilt < 300µm
    - Parallelity cathode/anode: < 450µm
  - Not met! Axis tilt about 500µm for LP
    - Build second field cage, same design as 1st
    - Mandrel been worked over
    - Planned for end this year/beginning next
  - No calculaton for uneven cathode
    - Measurements showed a bend of up to 600µm
    - Plan to build new cathode; maybe with composite materials?
  - No calculation for charge up effects in area between field strips



References

- WP Meeting #49, 13.2.2008, P. Schade:
  "Impact of holes in anode and cathode on the field quality in the drift volume of the LP"
  http://ilcagenda.linearcollider.org/getFile.py/access?contribId=2&resId=3&materialId=slides&confId=2533
- Talk at LCTPC collaboration meeting 22.Sep.2009:
  http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=17&sessionId=2&confId=3742
- PhD Thesis P. Schade, Nov.2009
  "Development and Construction of a Large TPC Prototype for the ILC and Study of τ Polarisation in τ Decays with the ILD Detector"
  http://www-library.desy.de/cgi-bin/showprep.pl?desy-thesis-09-040
- JINST Paper, 2010:
  http://iopscience.iop.org/1748-0221/5/10/P10011
- LCNote LC-DET-2010-001, P. Schade, Aug.2010:
  "Correction Methods for TPC Operation in Inhomogeneous Magnetic Fields"
  http://www-flc.desy.de/lcnotes/notes/LC-DET-2010-001.pdf
- Various Talks by Peter:
  http://www-flc.desy.de/tpc/documents/talks.php?author=schade
- PhD Thesis L. Hallermann, Apr..2010
  "Analysis of GEM Properties and Development of a GEM Support Structure for the ILD Time Projection Chamber"
  http://www-library.desy.de/cgi-bin/showprep.pl?desy-thesis-10-015