TPC specific issues

- A critical review of using GEMs in TPC detectors, oriented at the practical aspects
- Examples shown with the purpose of mentioning problems, not to report results
- I assume that all the preparation, handling precautions, step-by-step testing are like already explained in the previous talks.

Why should you choose MPGDs for TPC

	Aleph	ILC
Rϕ resolution at full drift	170μm	190μm
Z resolution	~2mm	1mm
2-track rϕ	~cm	~mm
Pad size (→electronics!!!)	6x30mm^2	1x6 mm^2
2-track z	~cm	~cm
dE/dx	4.4%	4.3%
dP/P	~10^{-3}	~10^{-4}

- What are the advantages. This is easy to say
  - Higher track density
  - Reduced ion feed-back
  - Larger gain
  - Geometrical freedom
  - Manufacturing cost / skills, outsourcing
- What are the DISadvantages. This will take longer
- Where one has to take special care

Single GEM-module TPCs

- This is the simplest possible case
- Typical situation of prototype testing
- Most of the effort goes in
  - Match GEMs with the pad plane
  - Study gasses
  - Prototype electronics
- The practical aspects are not very different from those of GEM planar chambers

... with one exception

Normalized PRW: $\hat{\sigma}^2 = \frac{\sigma^2_{prw}}{\Delta^2}$

Δ pad pitch

$\hat{\sigma}^2$ is a function of:

- the pad crossing angle β
  - spread in rϕ

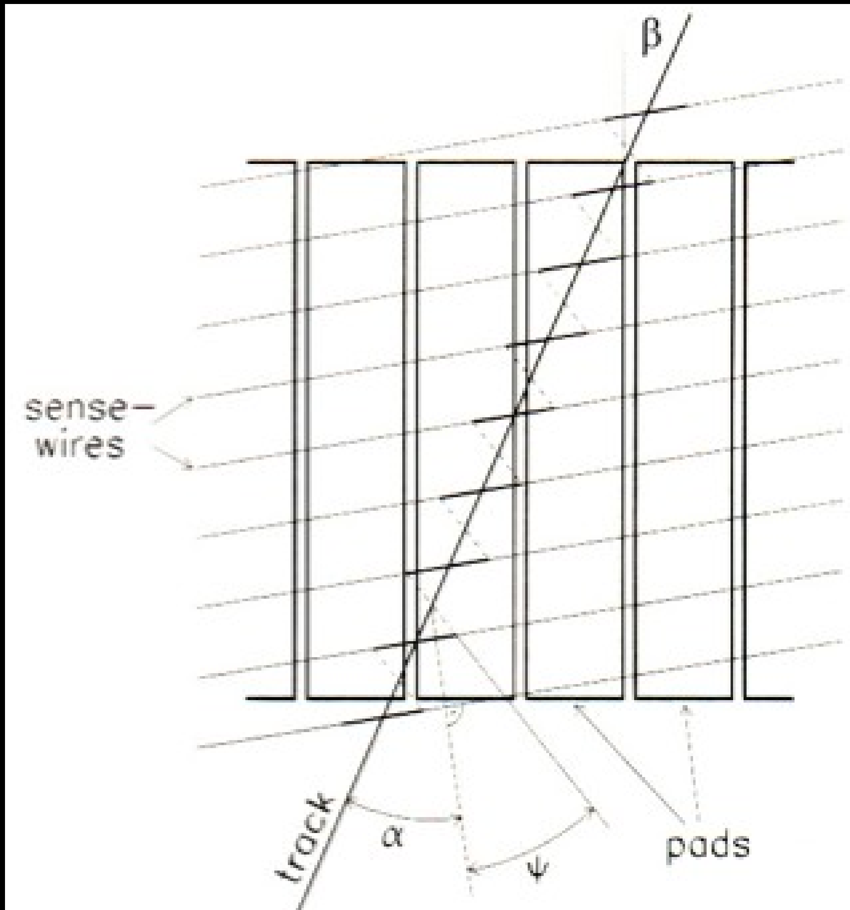
  $$\hat{\sigma}^2 \sim \tan^2\beta$$

- the wire crossing angle α
  - ExB effect, lorentz angle ψ

  $$\hat{\sigma}^2 \sim (\tan\alpha - \tan\psi)^2 \cos\alpha$$

- the drift distance
  - diffusion

  $$\hat{\sigma}^2 \sim \Delta z$$



Matching with pad plane

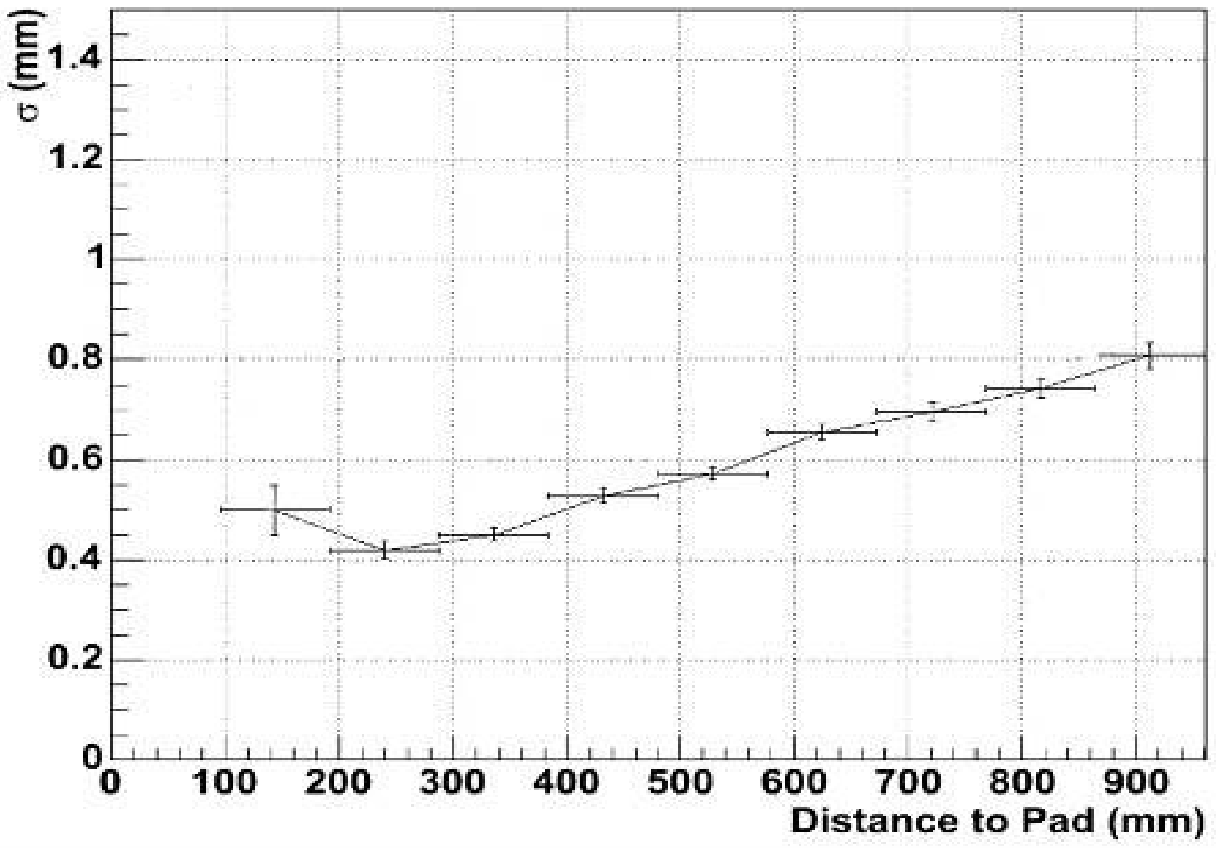
- Matching in the era of MPGDs
  - PRW is extremely small: ≈1mm for GEMs, even smaller for μM
  - Large **B** and/or small diffusion gas --> small pad size matches PRW
- More complicated to match larger pads
  - e.g. you do not need/want to pay for many channels (low track density)
  - Delicate balance between pads, gas, magnetic field

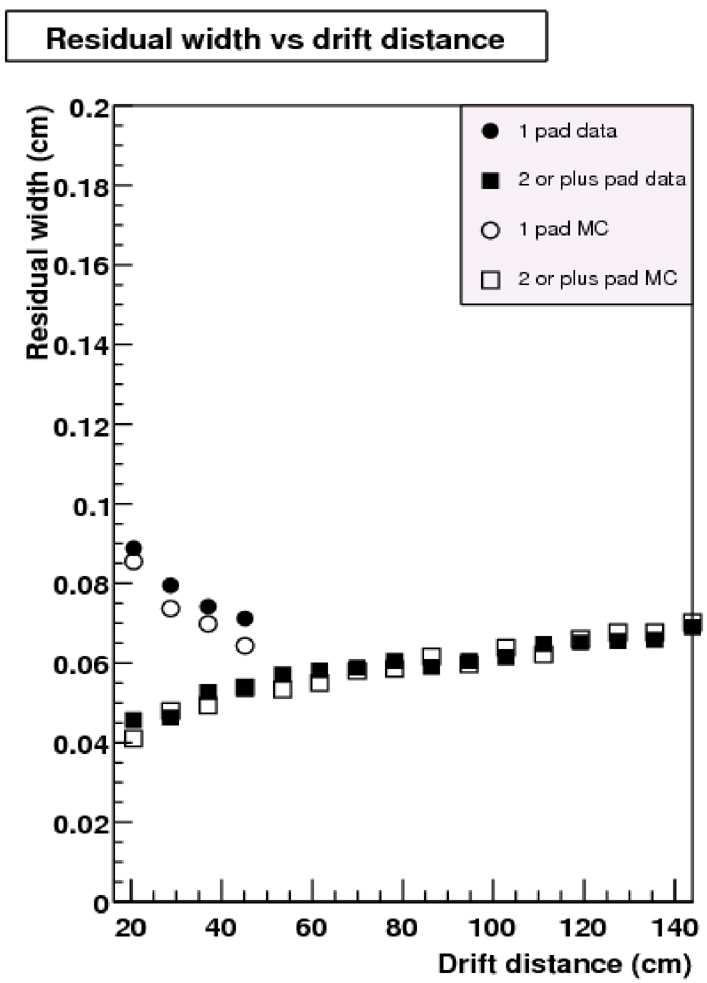
Re-thinking diffusion

- Might help, in certain situations

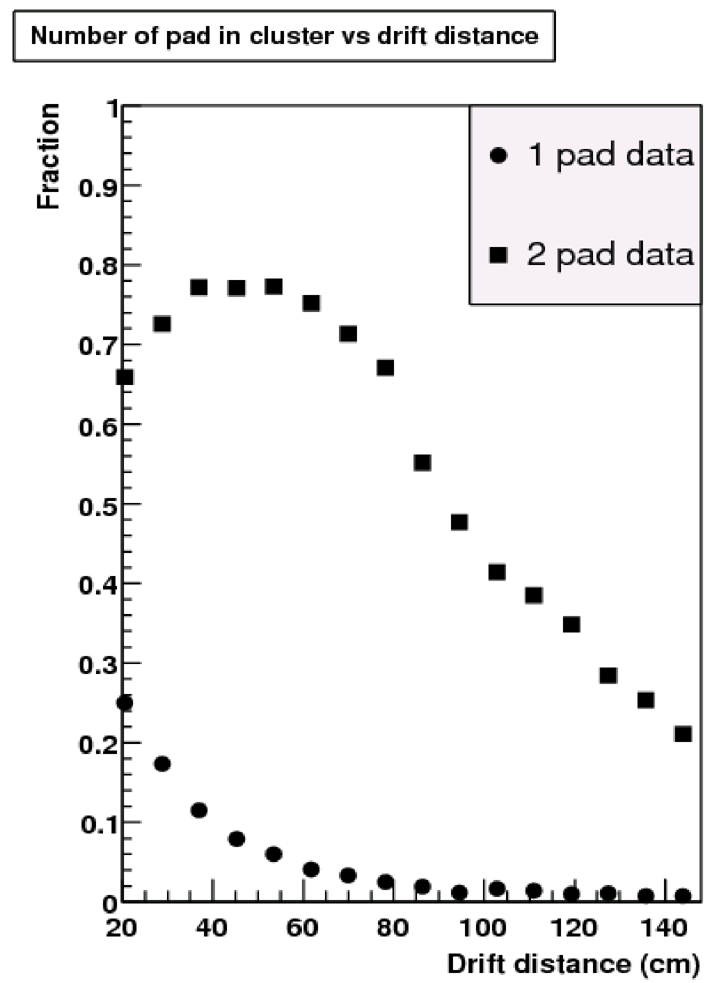
GEM readout
8x8mm^2

HARP field cage
Ar/CH4 95/5





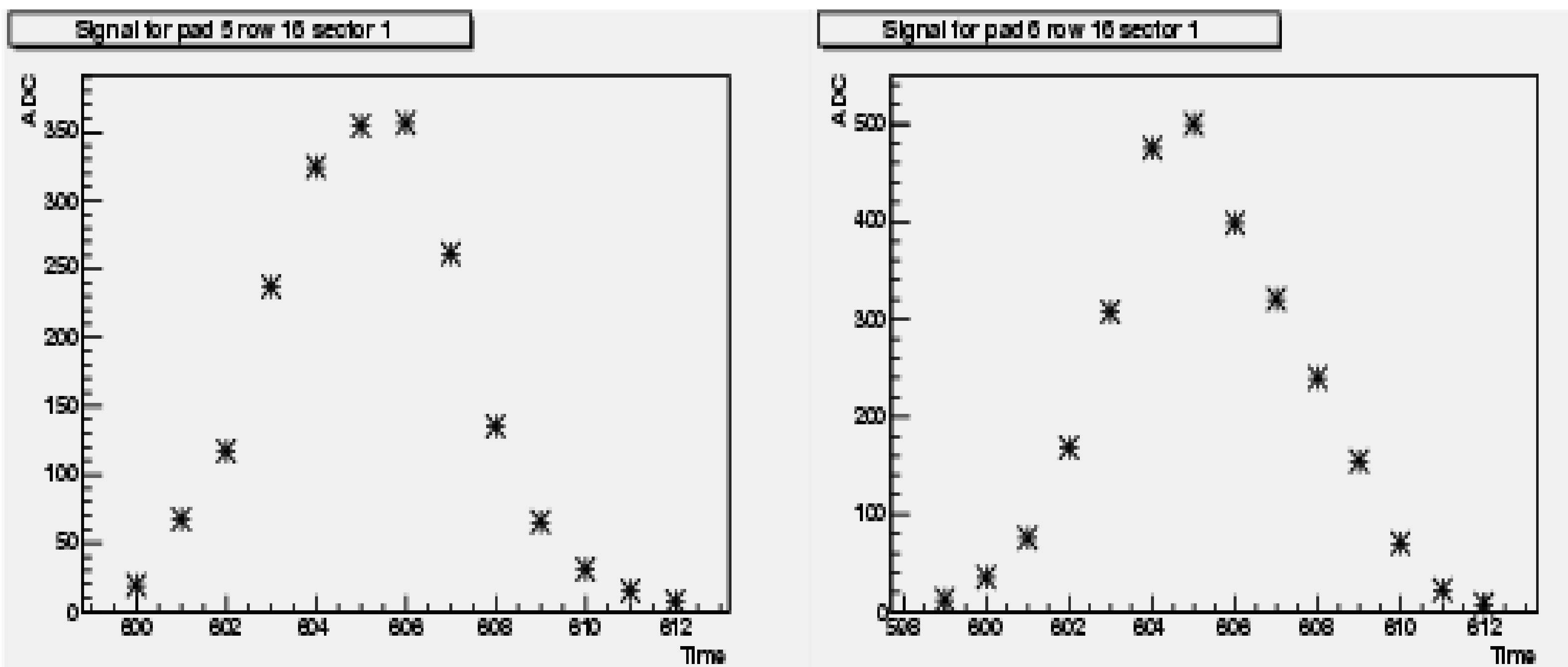
Residual width vs drift distance
Residual width (cm)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
20
40
60
80
100
120
140
Drift distance (cm)
1 pad data
2 or plus pad data
1 pad MC
2 or plus pad MC



Number of pad in cluster vs drift distance
Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
120
140
Drift distance (cm)
1 pad data
2 pad data

Re-think about certain gasses

– Low-amplification gasses might become interesting
  - strong amplification possible, advantageous S/N
  - ... but watch out for pre-amp saturation if you need dE/dx



HARP test-bed
GEM amplif.
8x8mm^2 pads
Ar/CO2 90/10

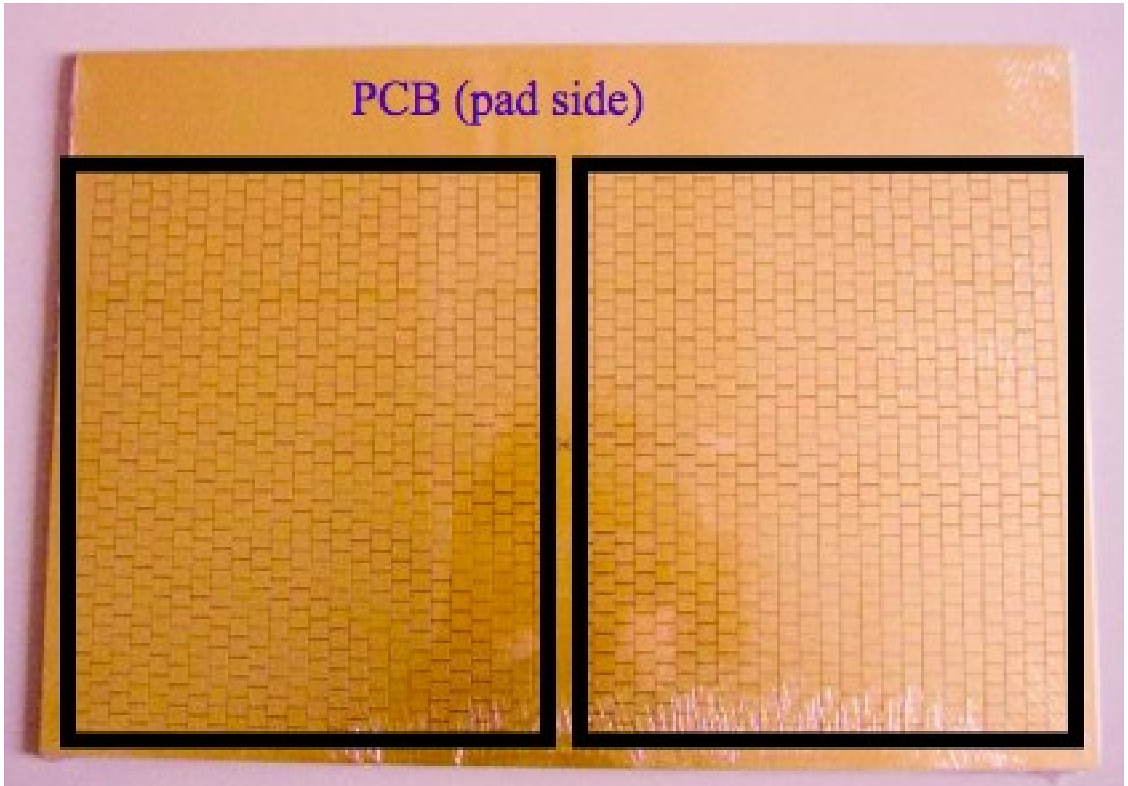
ALTRO FADCs

Stepping up to larger TPCs

- Minimize dead regions (TPC has only 1 readout plane)
  - The possibility to relax the requirements of preferential direction of tracks makes dealing with dead regions more important than ever
  - Minimal dead space conflicts with maintainability
  - Crowded HV distribution at the pad plane
- Maintenance / quality control
- Matching with the field-cage
- Electrostatic distortions

Modularity / Dead space

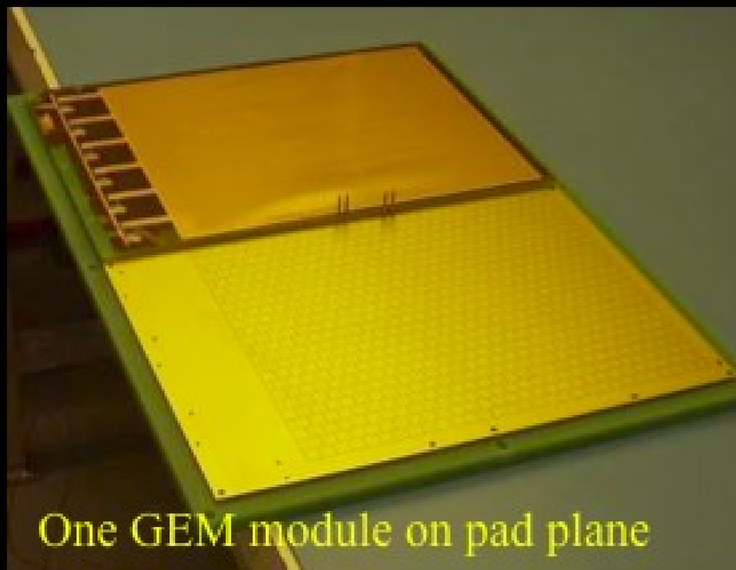
- Possible approaches
  - Larger GEMs
  - >= 2 GEM modules on one pad-plane PCB
- They are not opposed, it depends on the application and – ultimately – in large detectors a combined approach will likely be the way



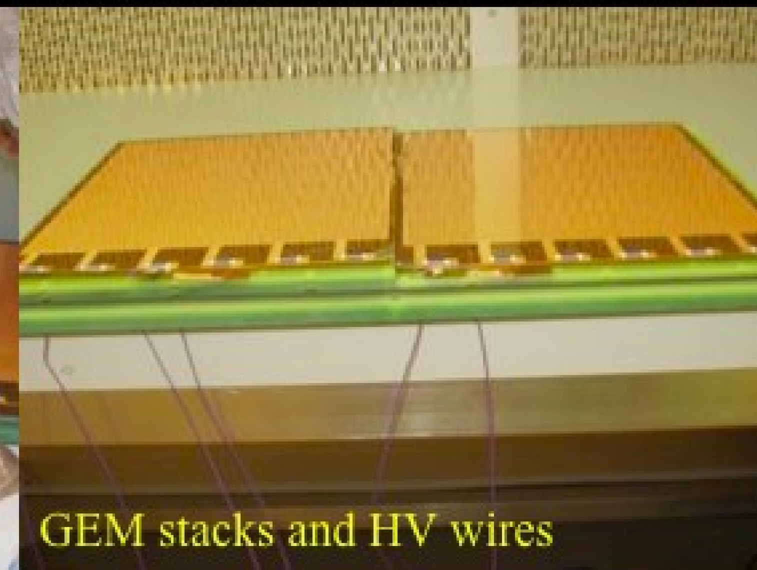
- GEM stretching "by hands"
- No spacers
- No frame is glued (GEM package can be re-made)
- Individual HV channels, no resistor network
- Protection resistors embedded in frames
- Field-shaping frame with dual role: define field, mechanical bind of GEM packs to pad plane

Final assembly

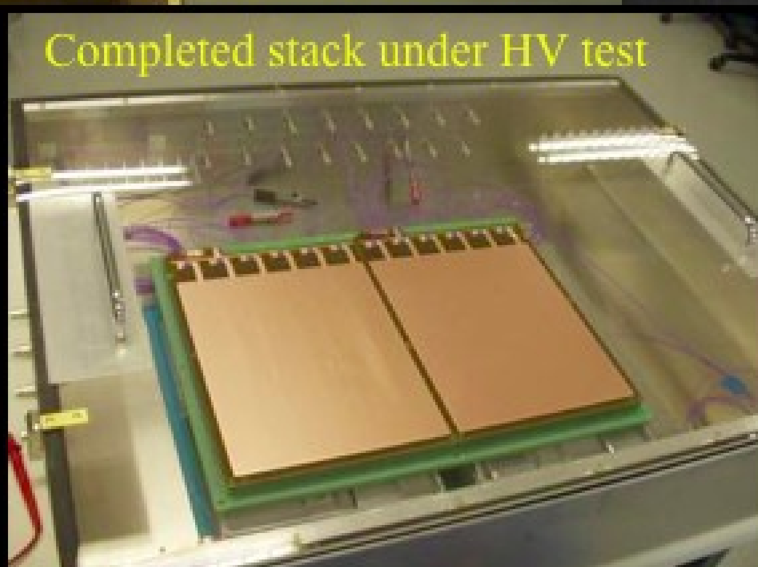
GEM-TPC pad plane (T2K prototype)



One GEM module on pad plane



GEM stacks and HV wires



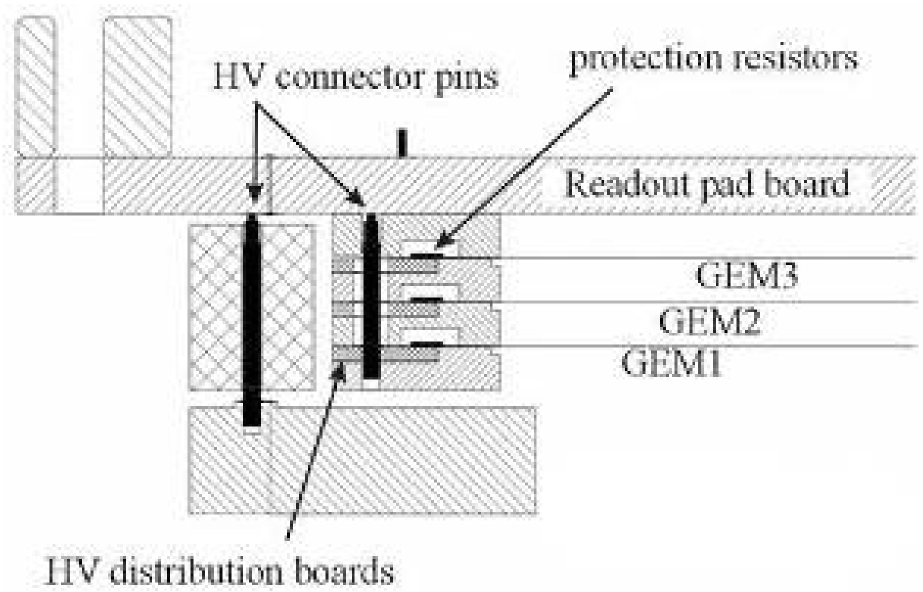
Completed stack under HV test

GEMs being fixed with the guard ring

- It also depends on the tolerances one want (needs) to keep
- Electrostatics must also be taken in to account
  - Big modules --> planarity more critical
  - Smaller modules --> repositioning issues

HV distribution

- Every GEM module needs:
  - 3x 2 HV values (one per GEM side)
  - ≥1 value for HV guard planes (more on this later)
- For a pad plane with e.g. 10 modules, you need in excess of 70 HV connections + a network of protection resistors. And it must allow easy module replacement.
- Planning HV distribution without wasting space is a SERIOUS task when designing a large TPC



Maintenance / Quality Control

- Specific to TPCs: no redundancy! Everything MUST work, and work WELL.
- Calibration is a key issue in good operation of a TPC --> quality control must include initial calibration
- Quality control
  - Cannot stress individual GEM testing too much
  - Calibration of individual GEM modules should also be considered (gain uniformity --> less corrections to equalize response)

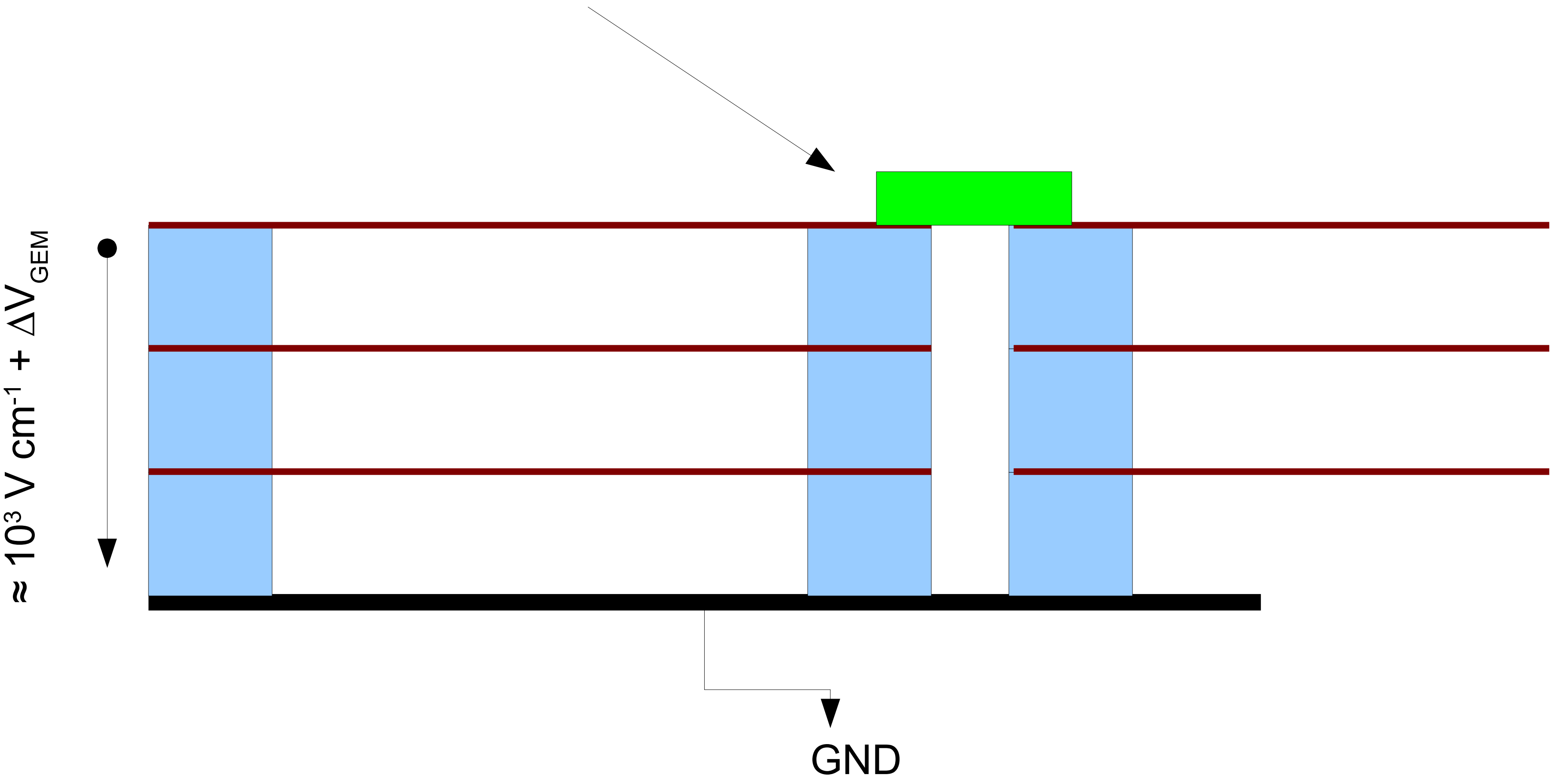
Testing and characterization PRIOR to assembly

- Shown here: µM T2K test-bench

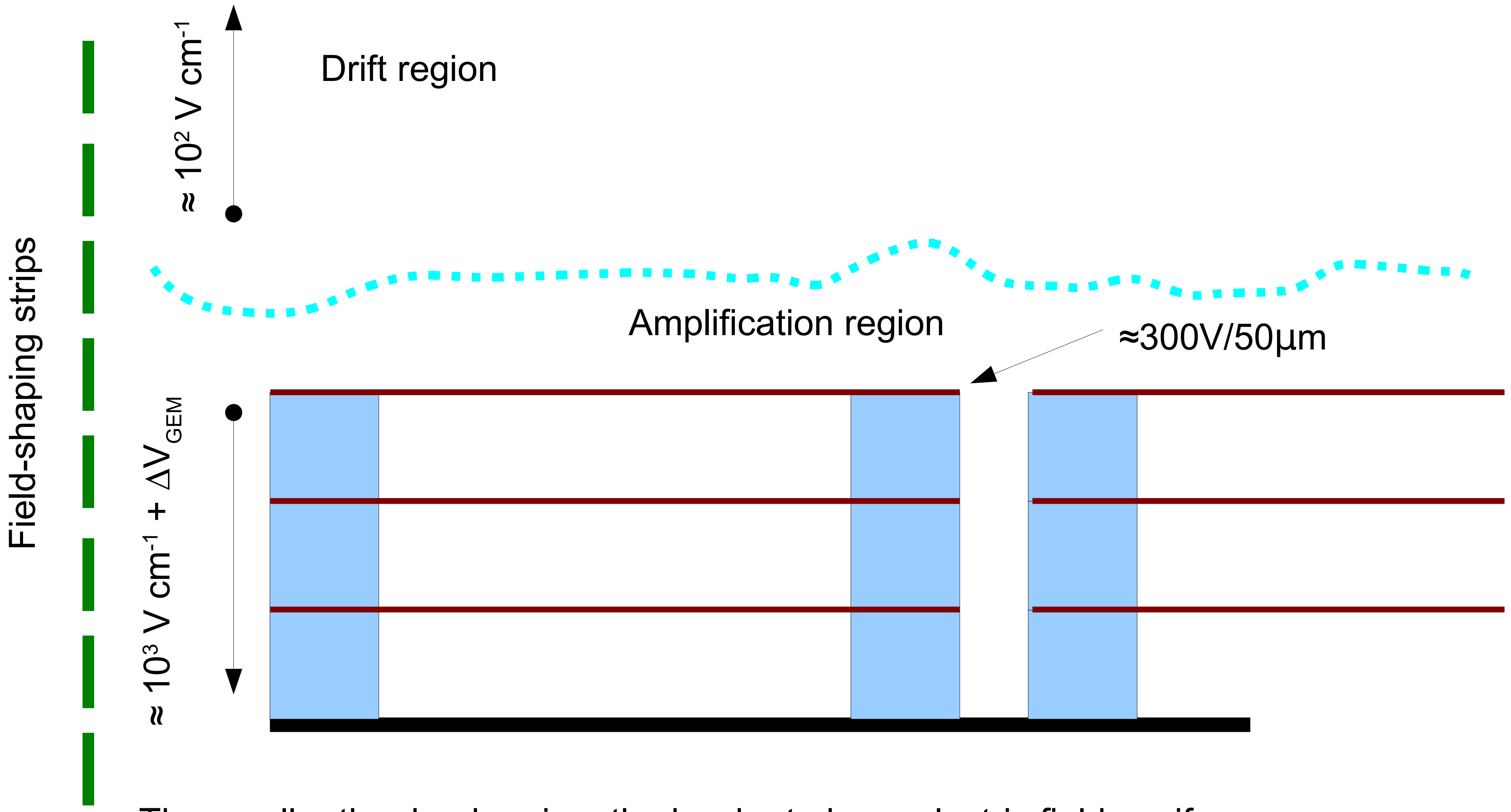
- Same must be done for (individual?) GEMs:
  - Individual testing of every module
  - Full surface scan
  - Measurement and mapping o amplification / gain
  - Identify defective areas
  - Store in calibration database

Electrostatics of readout plane

- High-filed corners (≈300V/50µm) screened by guard structures
- At the price of additional HV feedthroughs

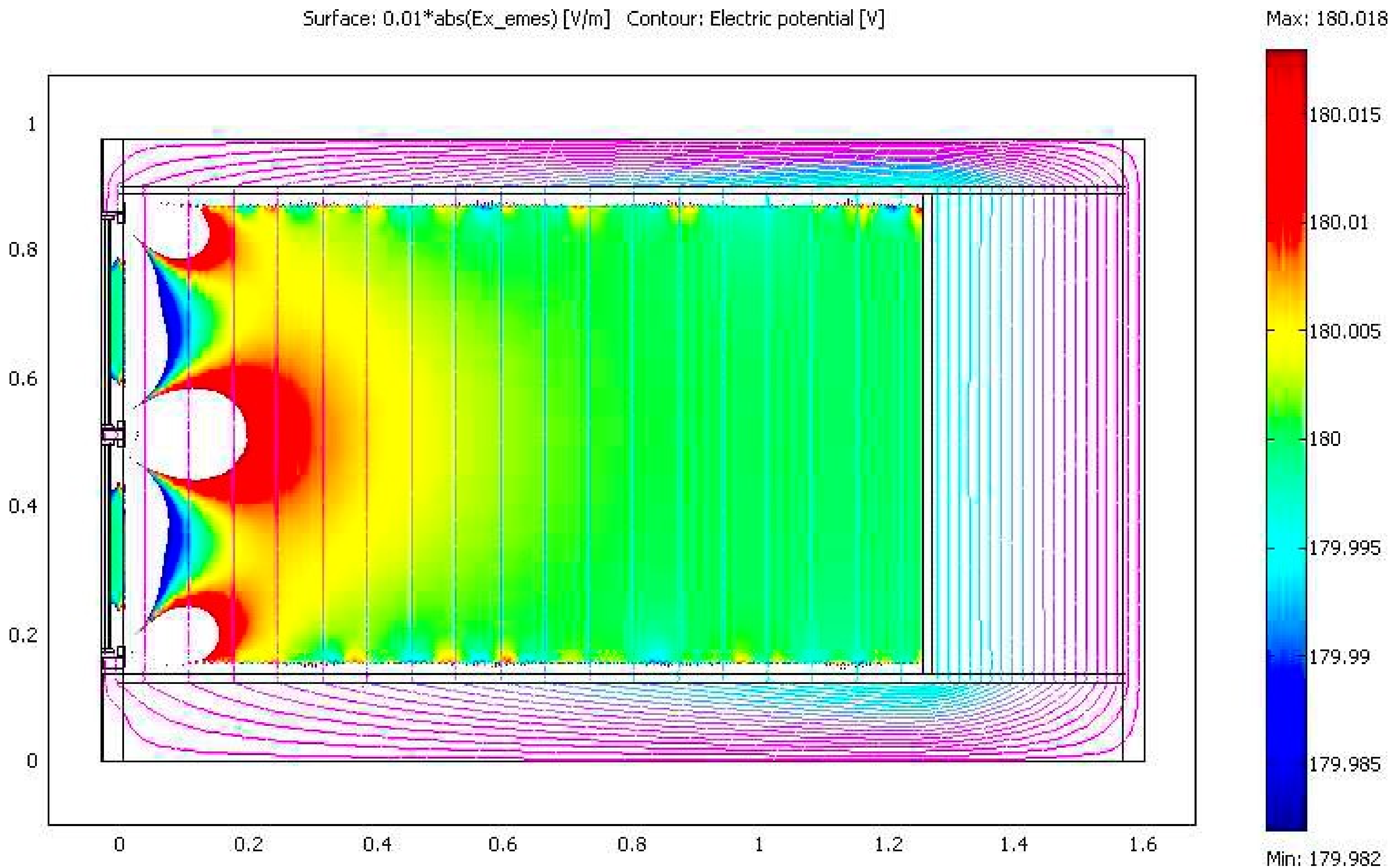


Matching with the field-cage

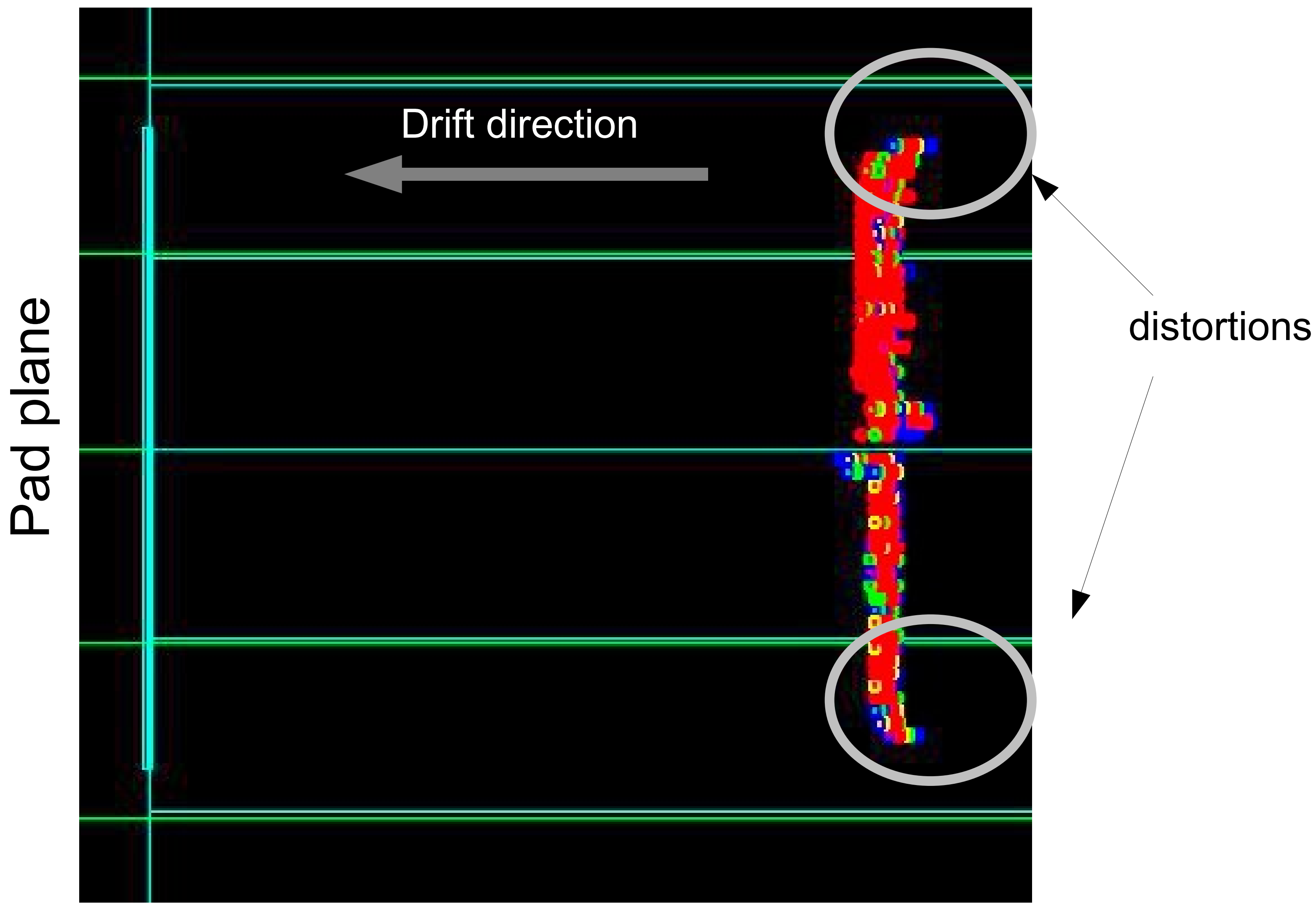


The smaller the dead region, the harder to keep electric fields uniform in the active area

T2K TPC, GEM option, simulations by Juergen Wendland (UBC)



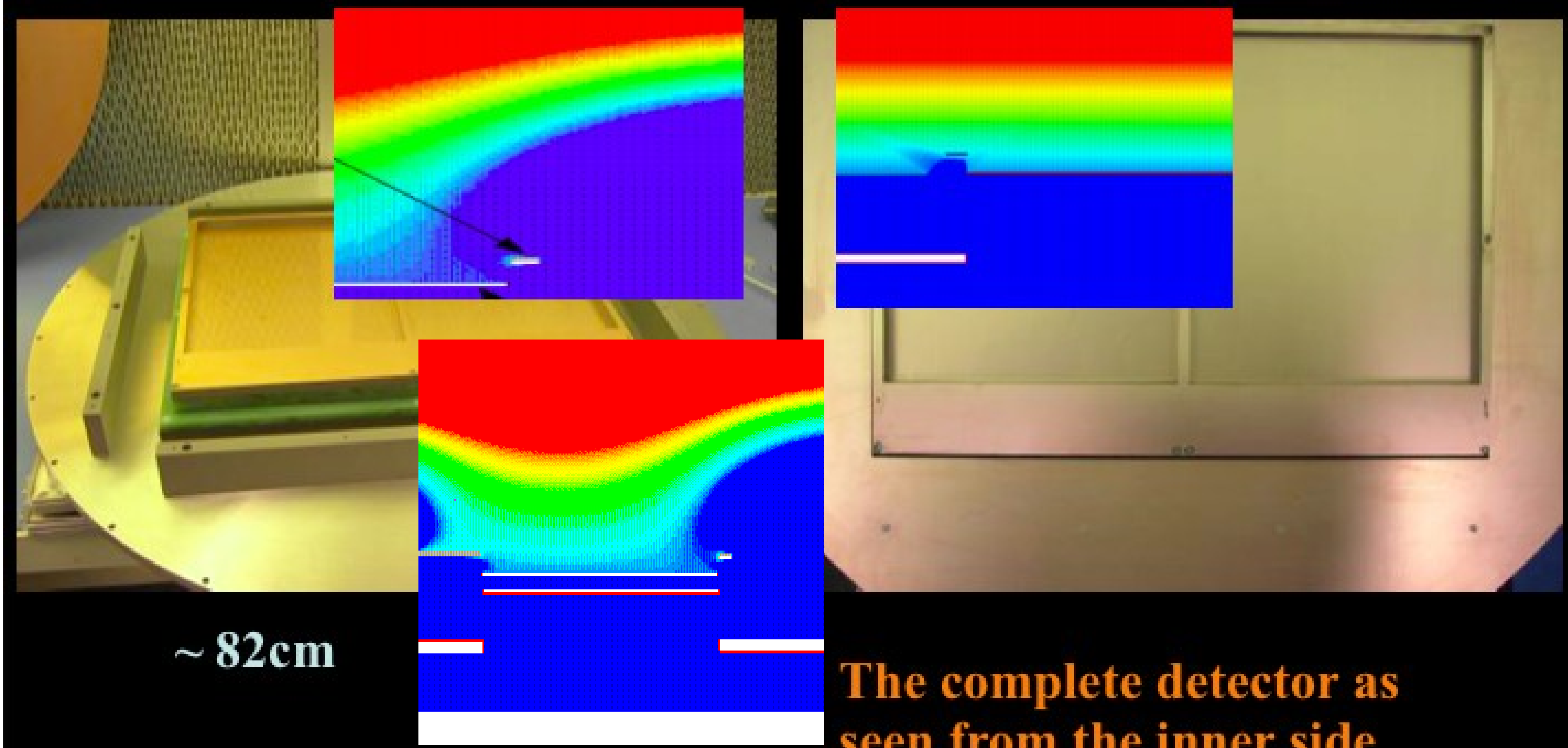
T2K TPC prototype, HARP test-bed



Final assembly

Detector mounted on supporting flange

PVC supports ready for large E shield

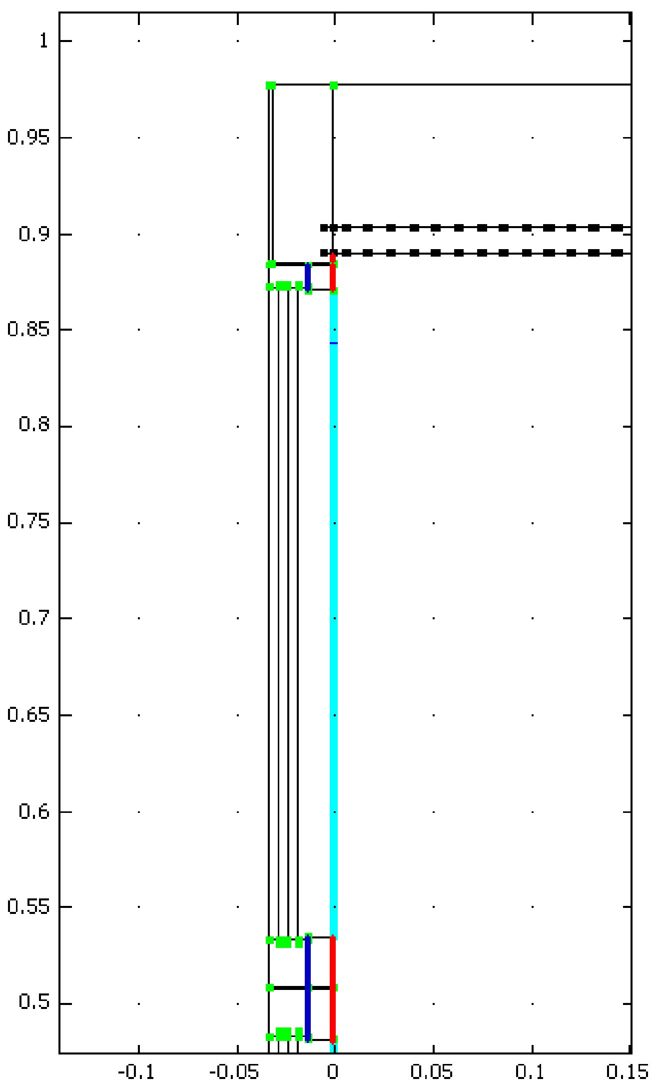


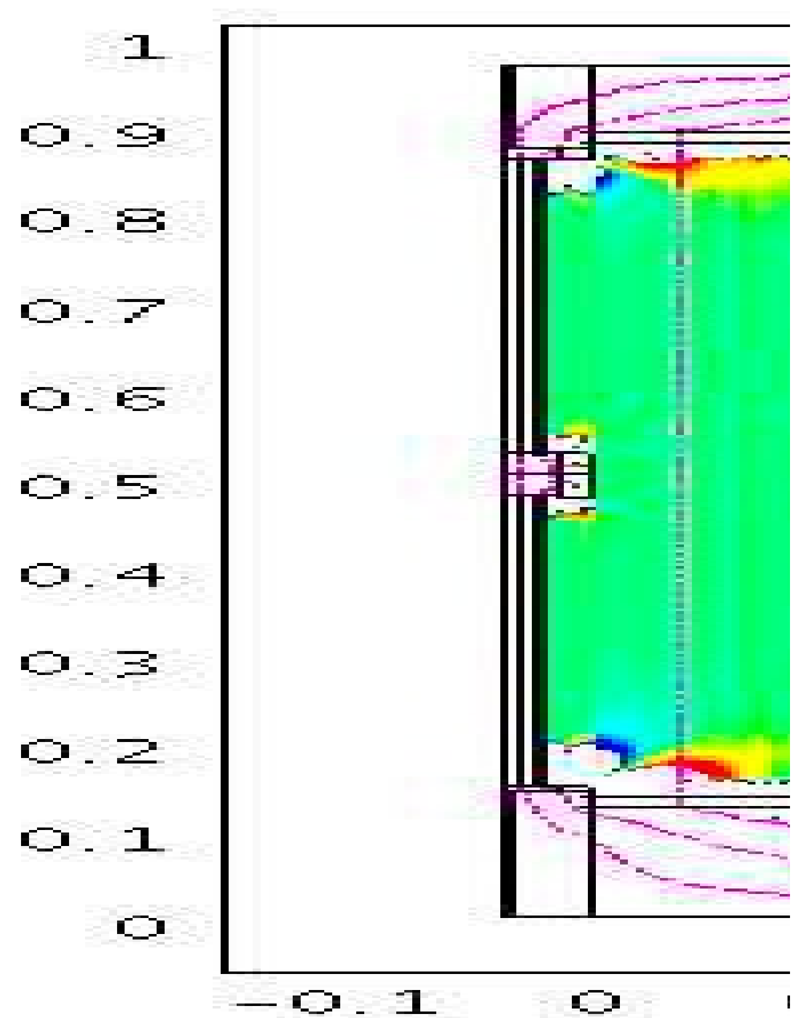
~ 82cm

The complete detector as seen from the inner side

T2K TPC, GEM option, simulations by Juergen Wendland (UBC)

- Planning enough additional potential-defining surfaces is the key
- ... but take into account in your mechanical design that this will further increase the number of HV connections and make more and more difficult the maintenance and replacement of modules





Distortions - 1

- Planarity is a key issue to reduce distortions
- It is easy to mis-configure the electrostatic matching of pad-plane and field-cage
  - Considerable (easily few 100 µm) track distortion may occur
  - Can later be corrected, but any correction generates systematic errors in your measurement
- Conflicting requirements
  - Smallest dead region between field-cage and pad-plane requires more correction surfaces

Distortions - 2

- We do not have time here to develop more the subject, but keep into account that
  - A broken module make intolerable perturbations if not dealt with properly
  - Any time a module is inserted, slight misalignments modify the electrostatics
  - Imperfect alignments will generate non-foreseen distortions
    - Importance of good mechanical precision
    - Importance of precise calibration every time the detector is touched
- Very demanding for HV distribution system:
  - Many channels, strict tolerance

Conclusion

- Using GEMs (and MPGDs in general) in TPCs offers unique opportunities but also new challenges
- Quality control and calibration
  - Good uniformity increases chance of success
- Mechanical design is of utmost importance
  - For maintenance
  - To keep electrostatics under control
- Design of electrostatics is more important than it used to be