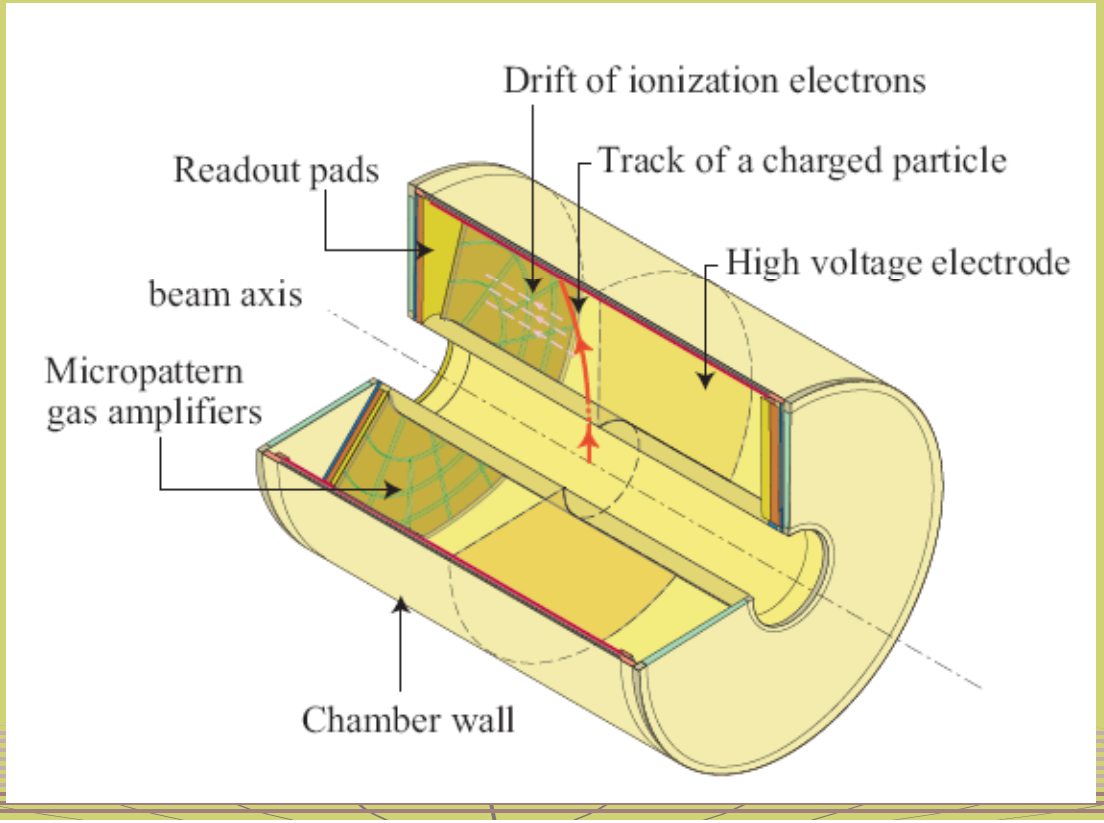
Tracking in a TPC

D. Karlen / U. Victoria & TRIUMF
for the LCTPC collaboration

TPC tracking

- Time Projection Chambers have performed well as the main tracker in a wide range of physics experiments & environments
  - eg. underground, LEP, heavy ion collisions



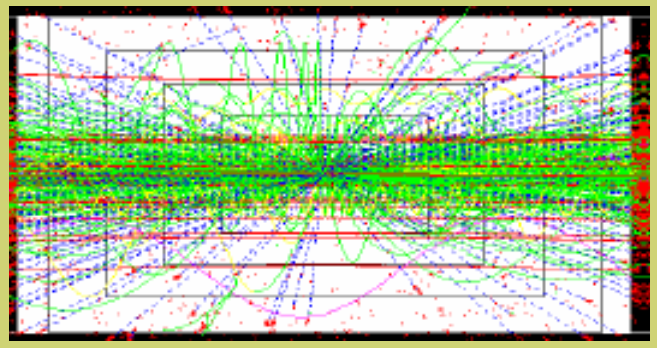
RDR IV-74

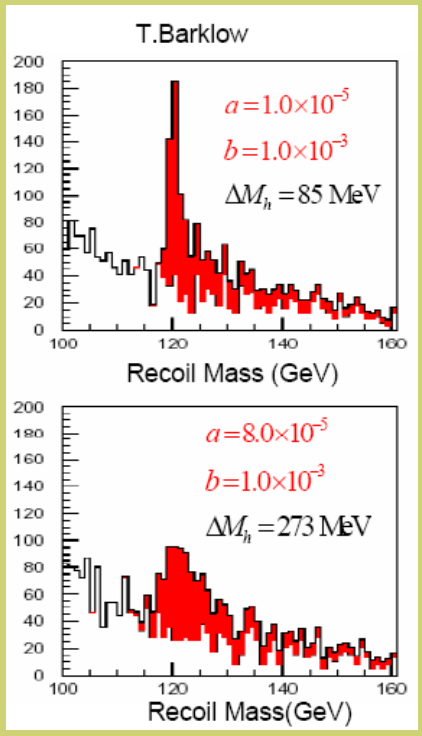
TPC tracking

- Is a TPC tracker suitable for the environment and physics at the ILC?
  - ie. will operate well and not compromise the physics potential of the ILC?
- A growing worldwide community has been active for many years to answer this question
  - we must have a definitive answer before the ILC lab is ready to approve detector construction

Key physics issues

- Momentum resolution
  - recoil mass (HZ^0)
  - $\mu\mu\gamma$ lumi spectrum
- Pattern recognition





- Low mass
  - preserve good jet energy resolution

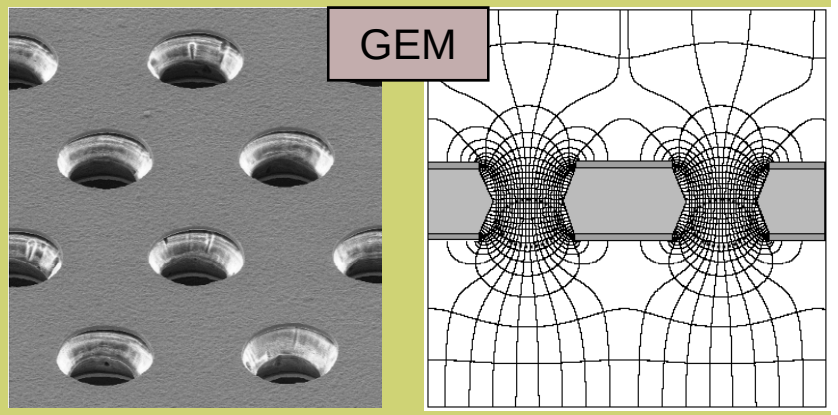
Key environmental issues

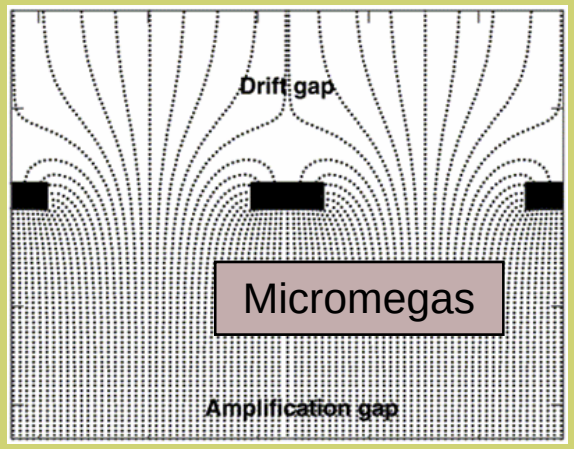
- Beam structure

  - TPC integration time: O(100) BX
  - low duty factor – pulsed electronics
- Machine backgrounds
  - will additional occupancy break pattern recognition?
  - will TPC suffer HV incidents?
- Magnetic field non-uniformities
  - can corrections recover momentum resolution?

TPC R&D program

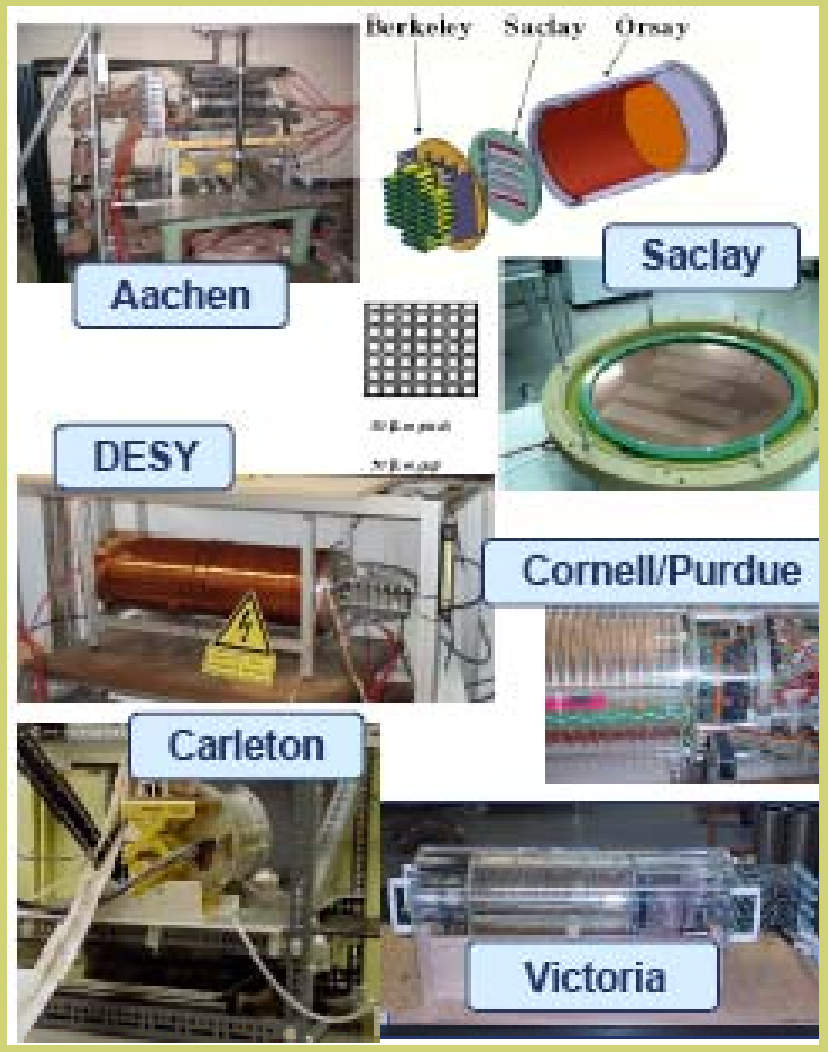
- The ILC TPC R&D program began by tackling the momentum resolution question early this decade
  - It was quickly realized that to achieve the resolution goals, the gas amplification system must be miniaturized
  - Natural application for micro pattern gas detectors





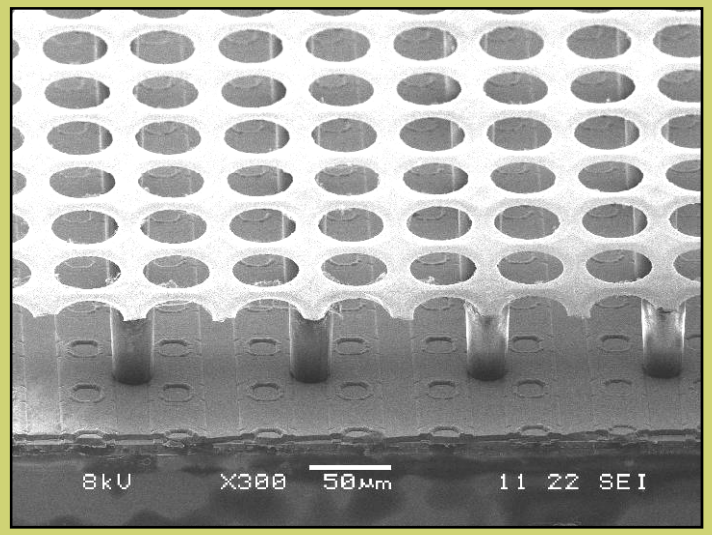
Momentum resolution

- Spatial resolution
  - several small prototypes constructed by groups around the world
    - 15-60 cm drift
    - 5-15 mm^2 pads
    - B=0-5 T
  - spatial resolution targets achieved for large B (100 μm or better per pad row)
  - reported at previous meetings



New developments

- Very fine segmentation is possible with silicon sensors readout (medipix / timepix)
  - 55 μm × 55 μm pixels detect signals from individual primary ionization electrons
  - possible improvement in dE/dx resolution
- Integrated amplification stage, with spark protection:
  - with 20 μm resistive layer, silicon survives breakdowns now

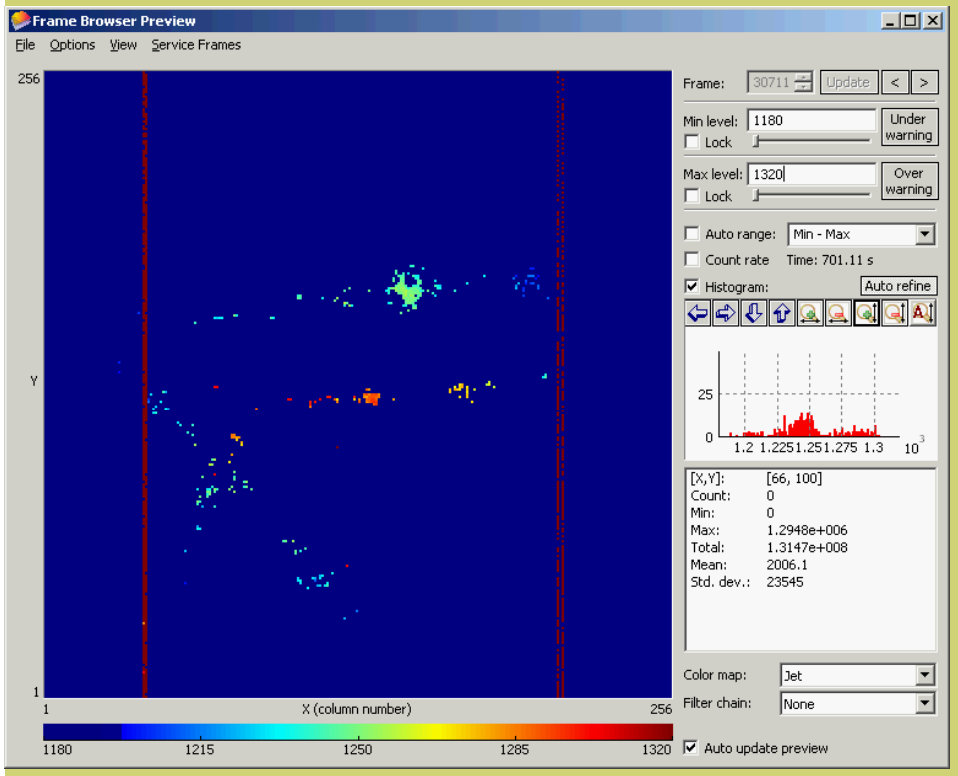


J. Timmermans, Nikkef

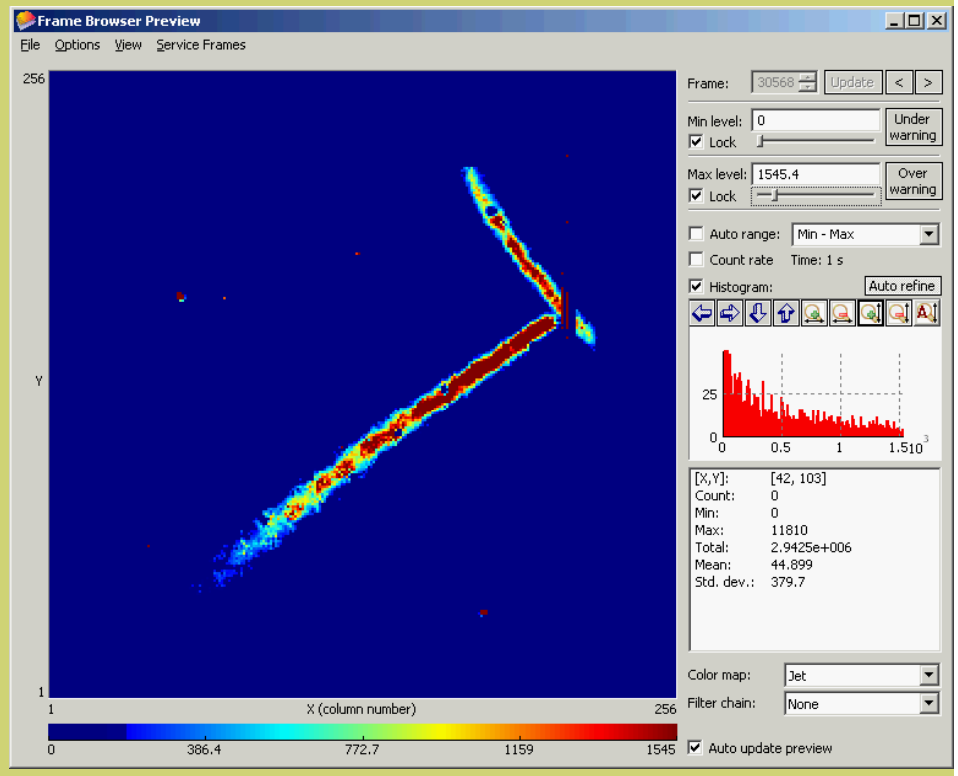
Timepix events

- Like a miniature bubble chamber

cosmics (time mode)



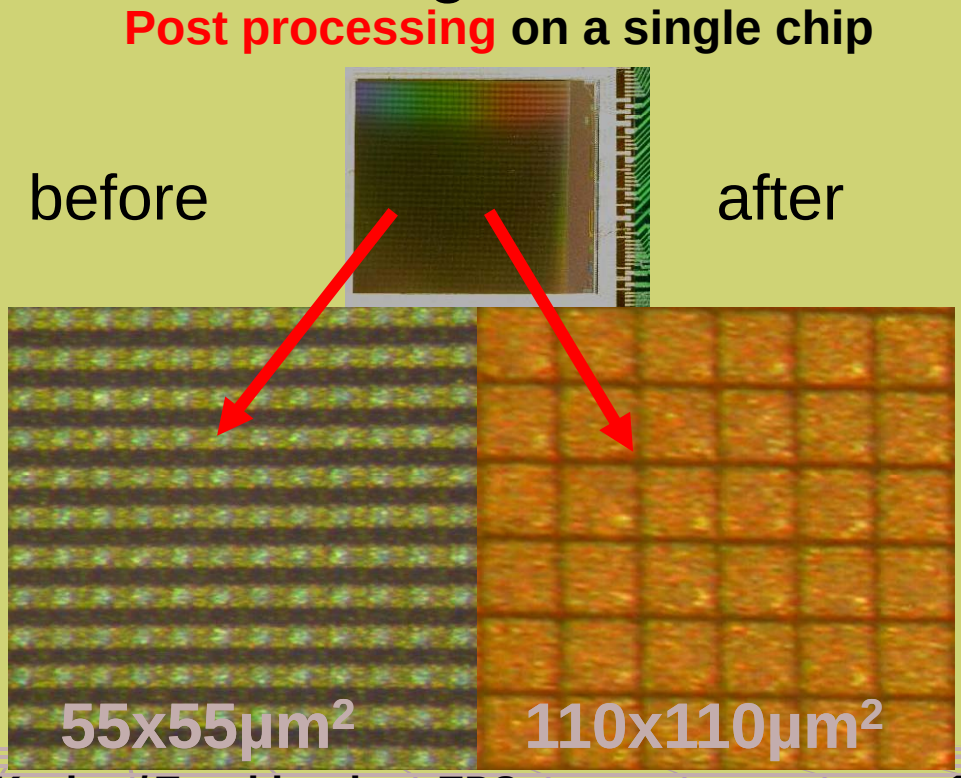
alphas (amplitude mode)



14 mm

Pixilized readout

- For the GEM+pixel option, the diffusion after gain spreads the charge over many pixels. Larger pixels would allow lower gain in the amplification stage
  - developments underway to increase pixel size – useful for GEM+pixel option



… beyond spatial resolution

- Most of the other issues need larger scale hardware & software efforts to address
  - LCTPC group developing into a formal collaboration

Memorandum of Agreement

on the Formation of the LCTPC Collaboration

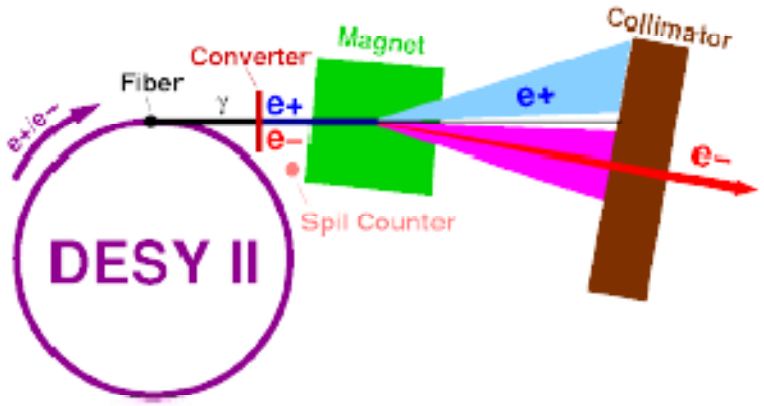
October 2007

LCTPC goals

- Build a large prototype TPC for test beams and cosmic ray operation in a magnet
  - tiled endplate
  - interchangeable modules using different amplification technologies
  - high density electronics developments
  - EUDET program provides much of the necessary infrastructure
- Build software suite suitable for simulation and reconstruction:
  - for use with prototype data (test beam and cosmics) and full size TPC with ILC events

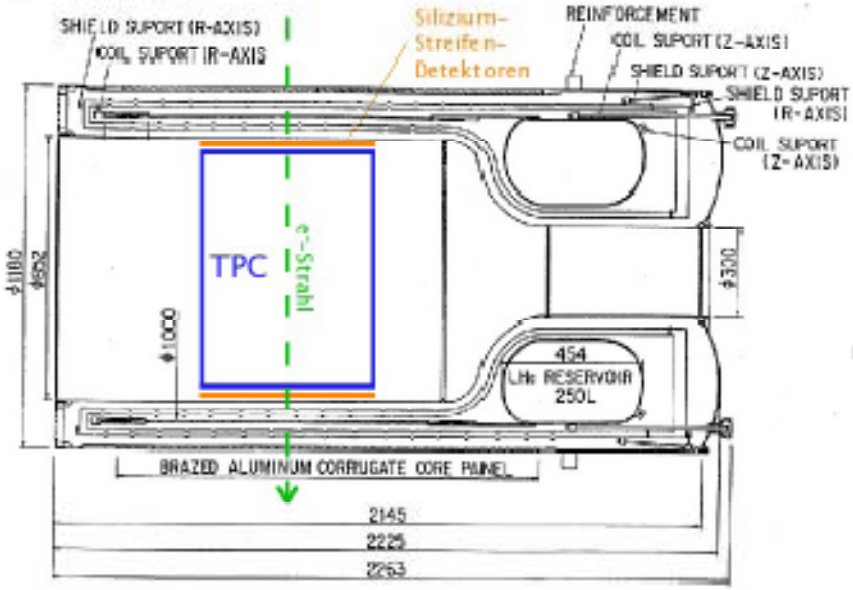
Infrastructure at DESY

- Testbeam: electrons (1-6 GeV)



- PCMAG:
  - Magnetic field up to ~1.25T
  - Installed at DESY and successfully operated
  - Additional safety modifications ongoing

- Sketch of TPC prototype in PCMAG

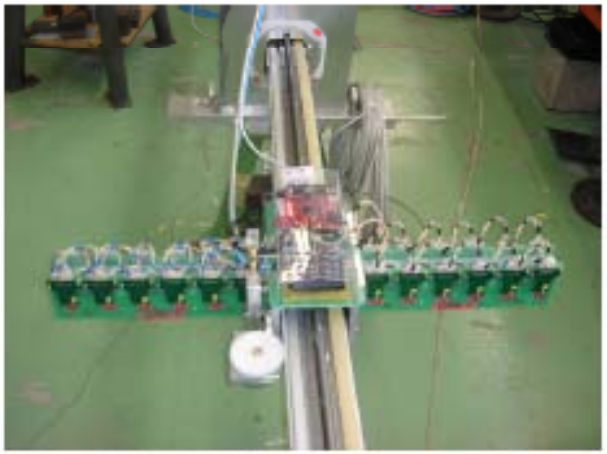


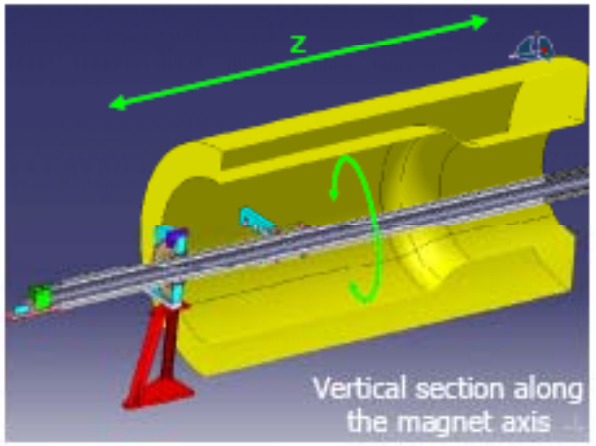
- Lifting table will be installed

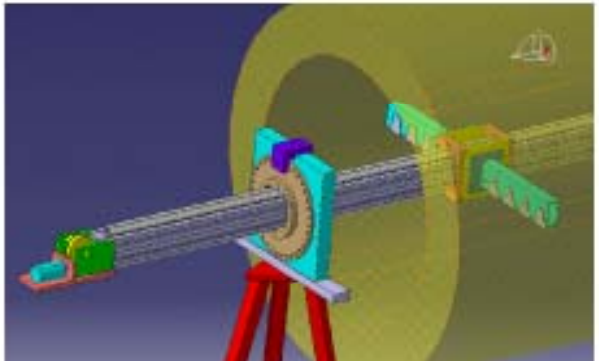
Ralf Diener,
Hamburg University

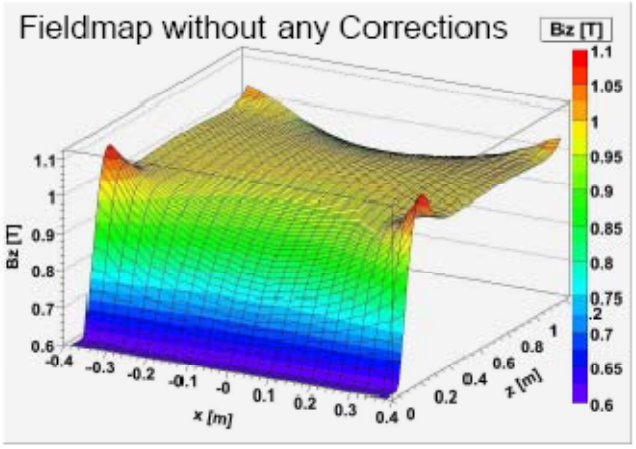
PCMAG Field Map

- Production of a magnet field map: Measurement finished (July 07)



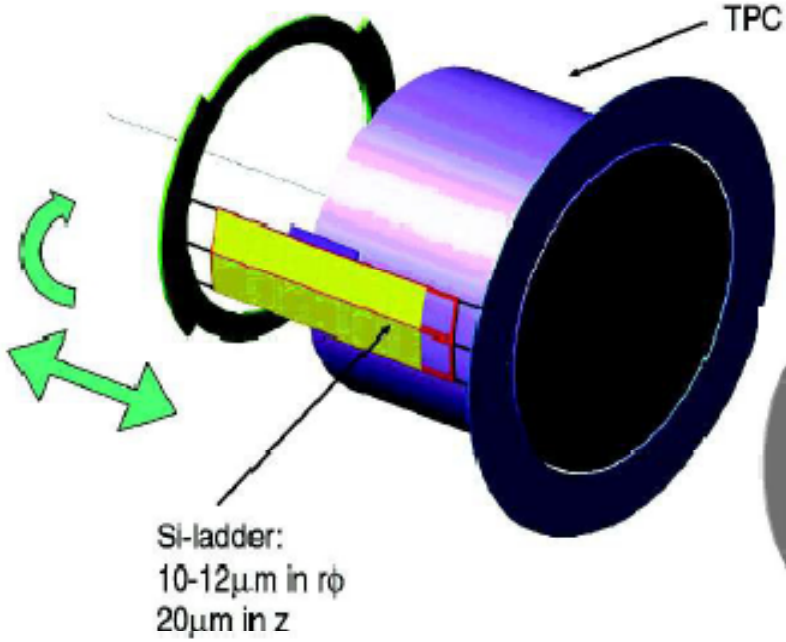




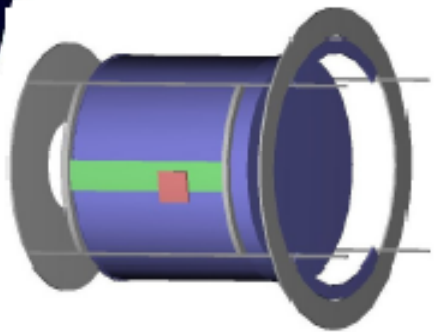


Ralf Diener,
Hamburg University

Surroundings: Hodoscope and Trigger

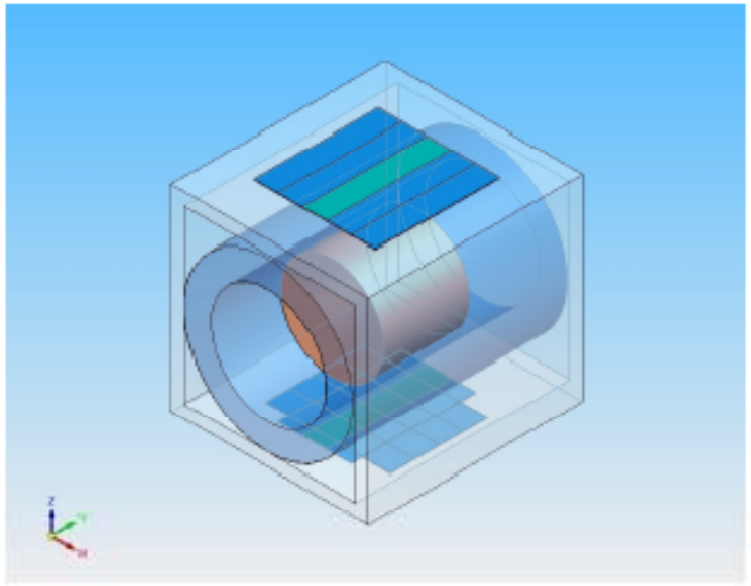


- Silicon hodoscope:
  - should be "rotatable"
  - design details of support structure still under discussion



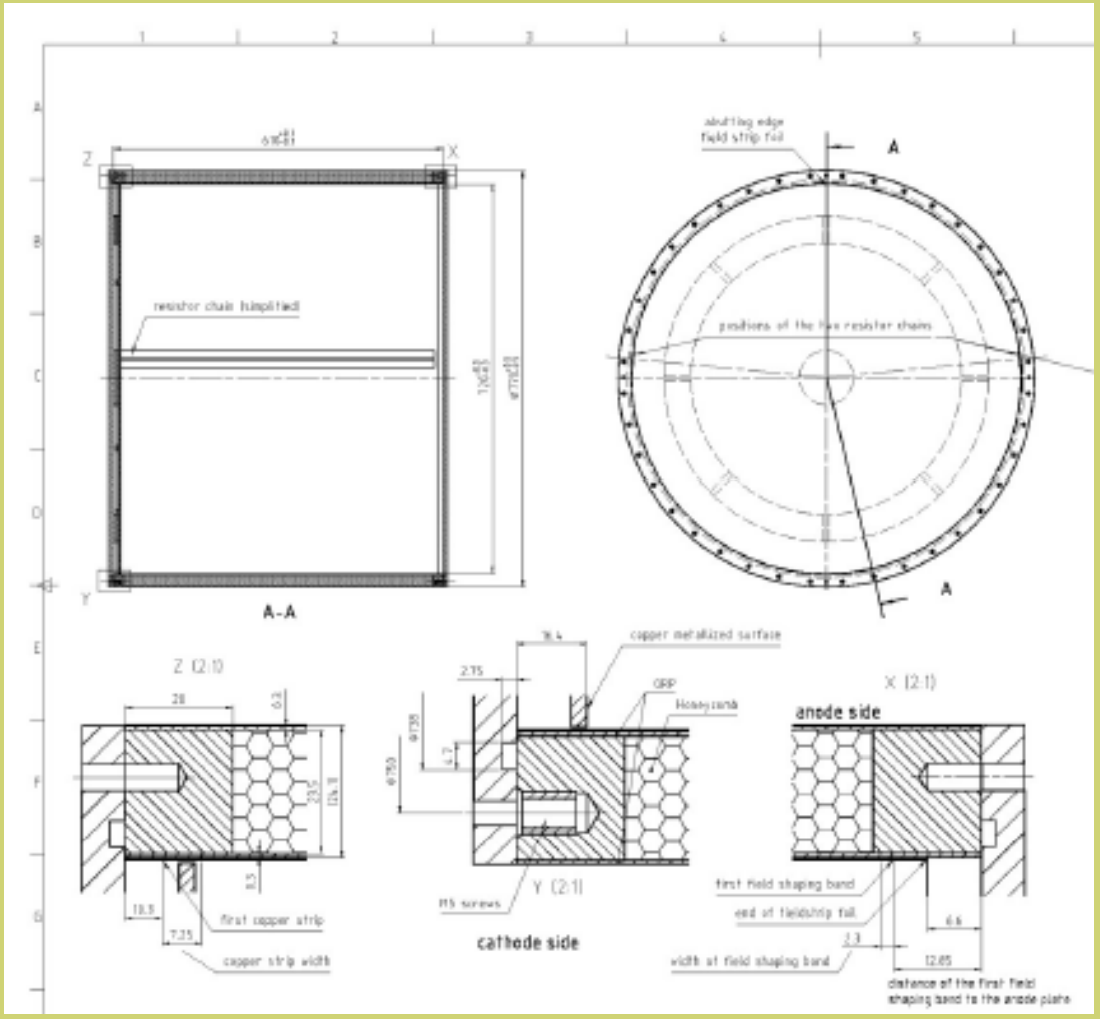
Limited readout area: 38.4 cm²

- Trigger (scintillators)
  - hardware ordered
  - simple holding structure
  - two perpendicular layers of slabs below the prototype

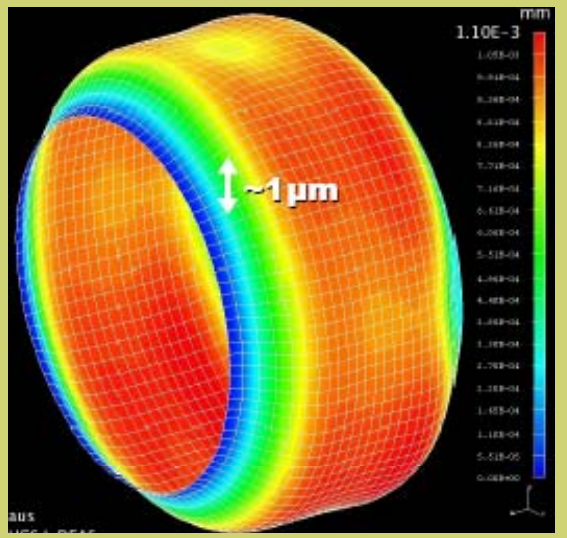


Ralf Diener,
Hamburg University

Field cage design

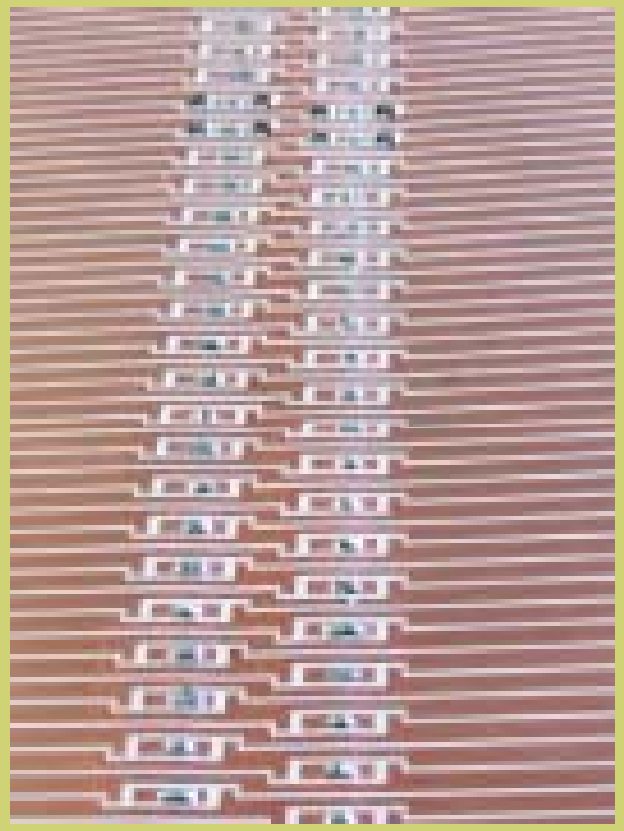


R. Diener



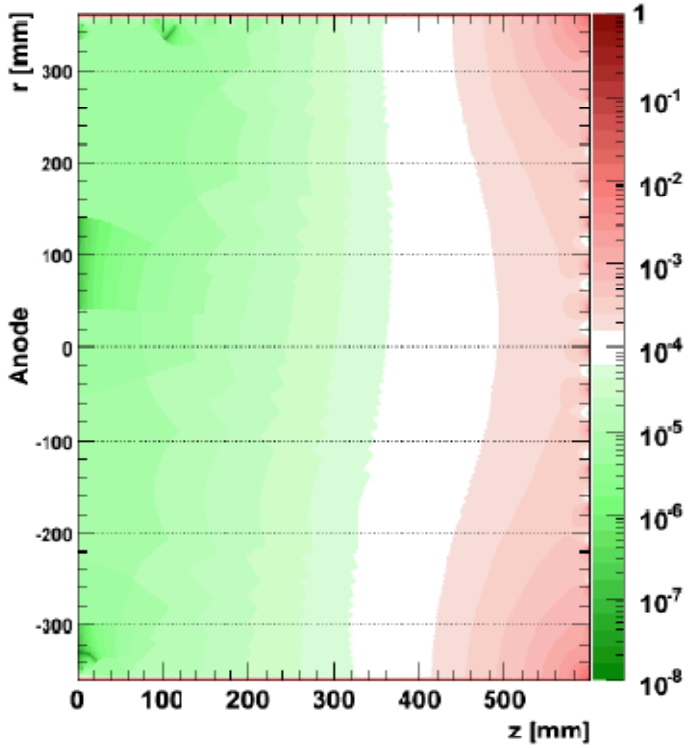
Field cage

- Tight tolerances



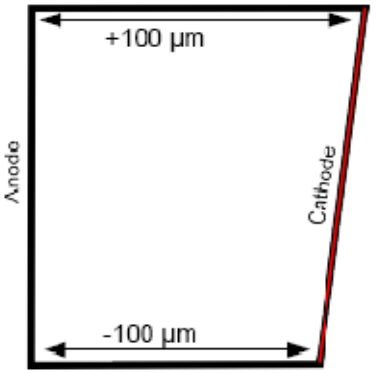
Field Calculations

- With non-perfect resistors and tilted cathode (manufacturing accuracy)



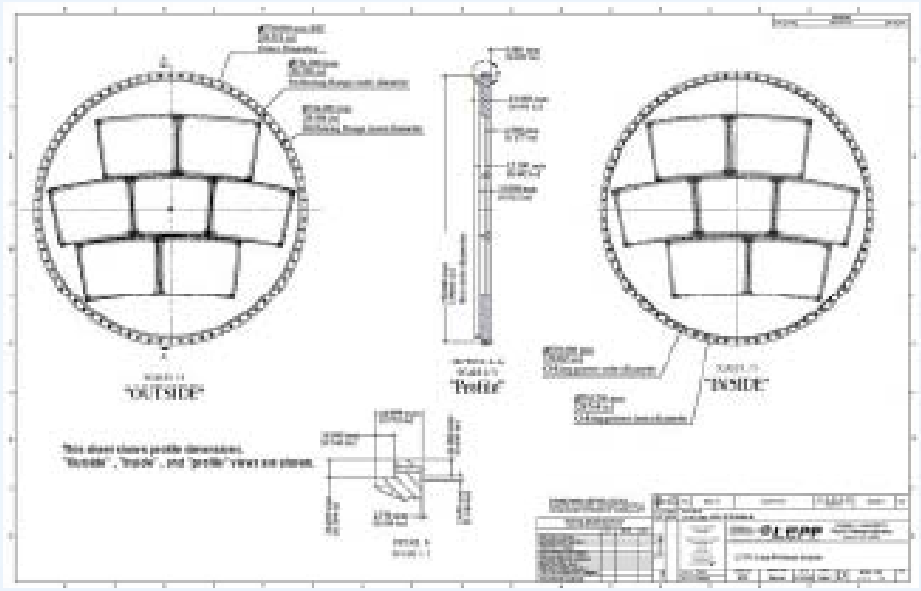
Shown: $\Delta E / E_{nominal}$

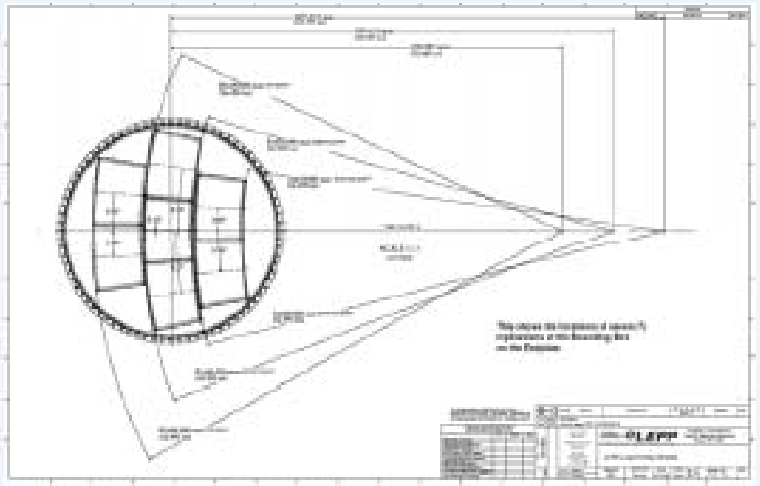
Goal: Deviations below 10^{-4}

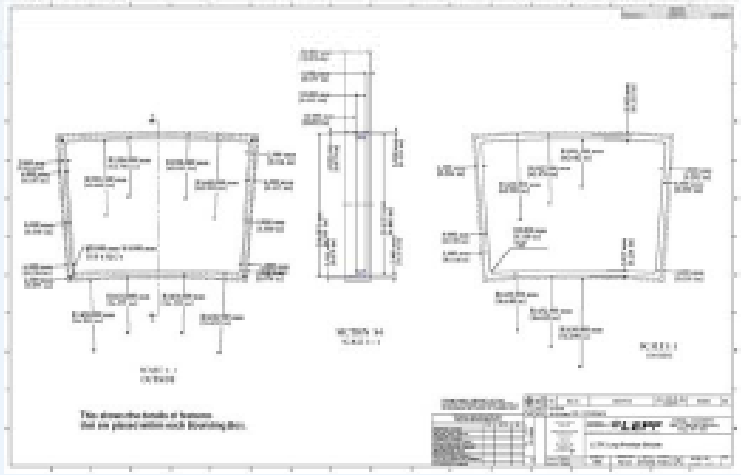


= Value below Accuracy Limit

LC-TPC Large Prototype



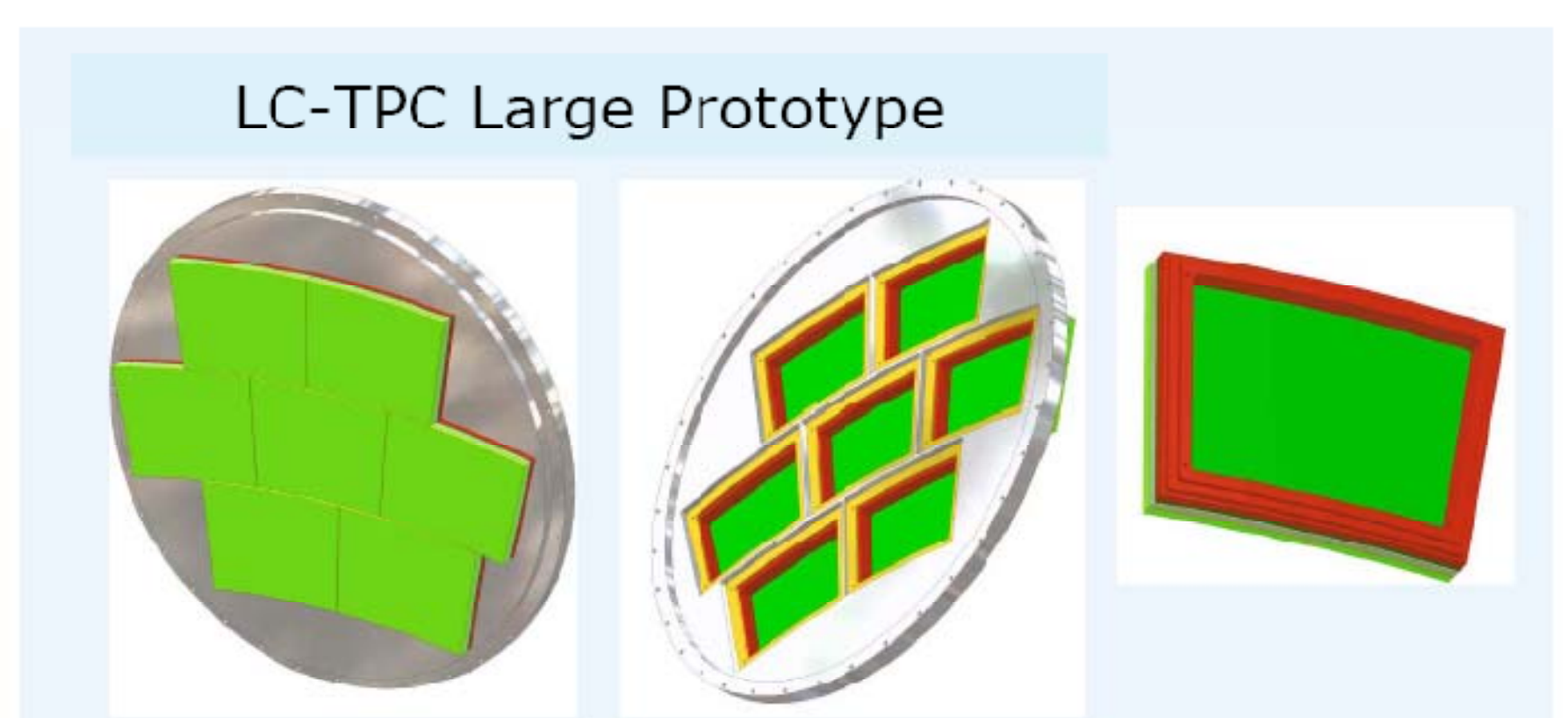




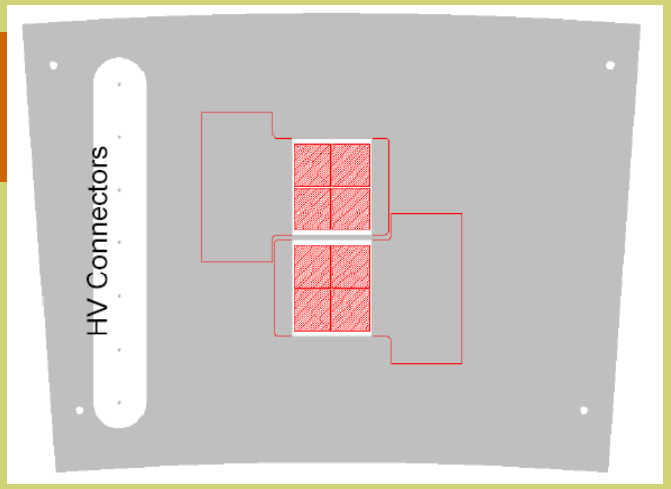
Drawing have been prepared and sent to vendors for bidding (October 19).

The endplate provides (7) identical locations for module installation.
The details for the installation hole are defined once.
Then the locations are defined.

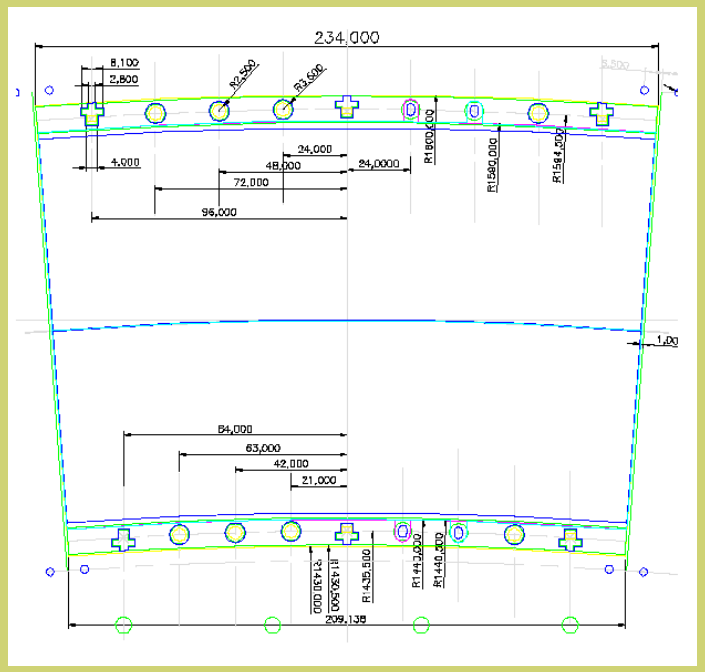
Populated endplate



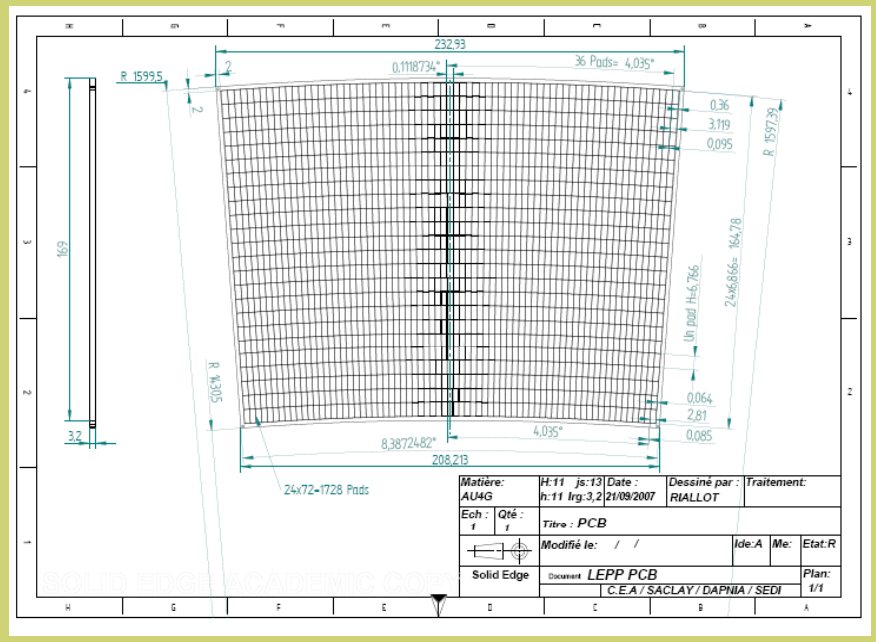
Readout designs



Pixel
readout
M. Killenberg



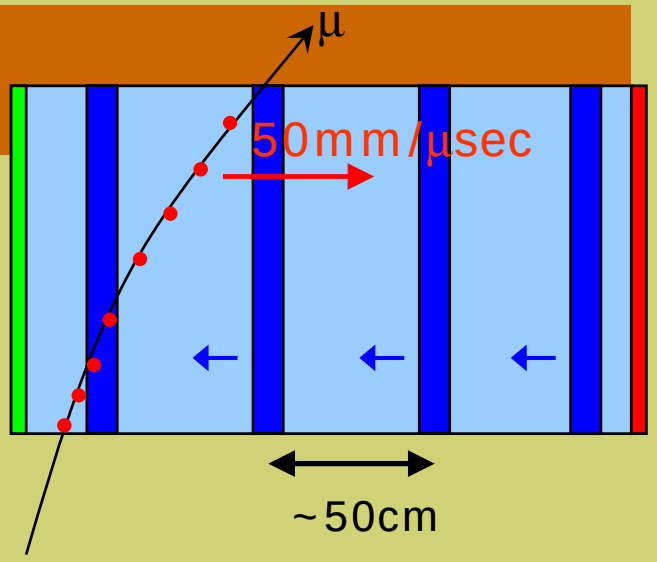
GEM module (no side frames)
A. Ishikawa

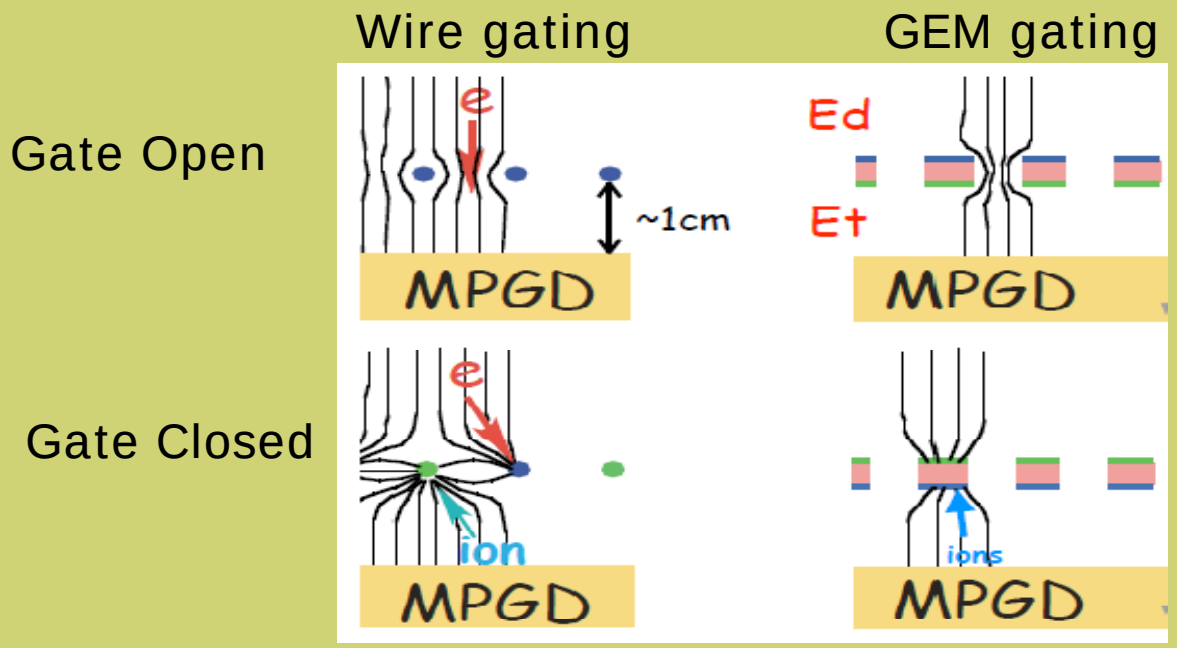


Bulk micromegas
P. Colas

Gating

- Gating can reduce the number ions produced in the amplification stage.





- gating can be done with wires or a GEM operated at unit gain

A. Ishikawa

Power pulsing

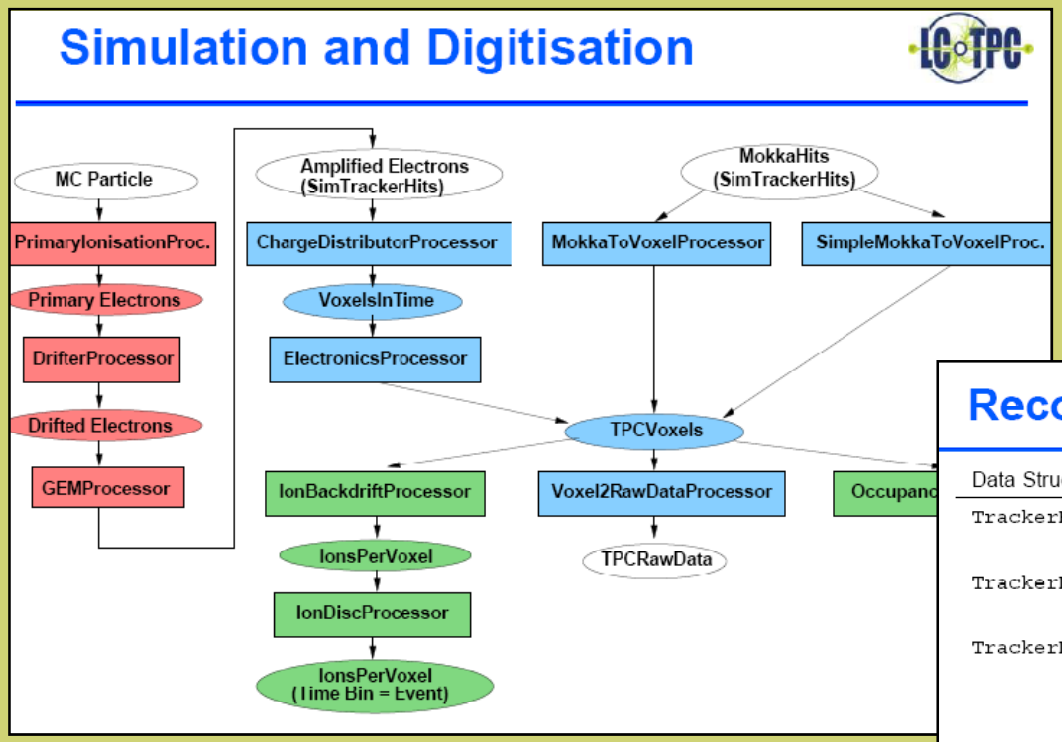
- Power supplies designed for average power rather than peak power
- Distributed charge storage capacitors close to the switchable loads supply the peak current. Allow ~ 1 volt drop during power on cycle
- Local « Low dropout » voltage regulators keep voltage stable on the electronics

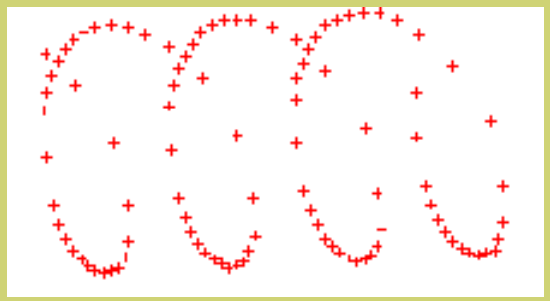
- Properly controlled constant current sources recharge the capacitors between cycles

J.P. Martin (U. Montreal)

Software development

Simulation and Digitisation





Reconstruction Data Flow

Data Structure	Processor Name	Collection Name
TrackerRawData		TPCRawData
	TrackerRawDataToDataConverter	
TrackerData		TPCConvertedRawData
	PedestalSubtractor	
TrackerData		TPCData
	PulseFinder	
	ChannelMapper	
	CountsToPrimaryElectronsProcessor	
TrackerPulse		TPCPulses
	HitTrackFinderTopoProcessor	
		TPCHits
		TPCTrackCandidates
	TrackSeeder	
		TPCSeedTracks
	TrackFitterLikelihood	
		TPCTracks

Developers: Jason Abernathy[1], Klaus Dehmelt[2], Ralf Diener[2], Jim Hunt[3], Matthias Enno Janssen[2], Martin Killenberg[4] Thorsten Krautscheid[4], Astrid Münnich[5], Martin Ummenhofer[4], Adrian Vogel[2], Peter Wienemann[4] and Simone Zimmermann[4]

1: University of Victoria — 2: DESY Hamburg — 3: Cornell University
4: University of Bonn — 5: RWTH Aachen

M. Killenberg U. Bonn

Scorecard

- Spatial resolution – established
- Pattern recognition – to start again
  - full pad readout simulation / reconstruction
- Low mass – underway
  - field cage designs / electronics considerations
- Beam structure – not demonstrated
  - tests at FNAL foreseen
- Beam backgrounds – not demonstrated
- Magnetic field non-uniformities – starting
  - software development, large prototype tests

Summary

- A worldwide team of people are working together towards the common goal of developing a TPC design that will satisfy the needs of the ILC physics program
- The more challenging issues requiring large hardware and software investments are just getting underway
- Plenty of room for new collaborators and new ideas!