New development and first measurements of the DESY readout module for a Large Prototype TPC

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LCTPC Collaboration - Desy

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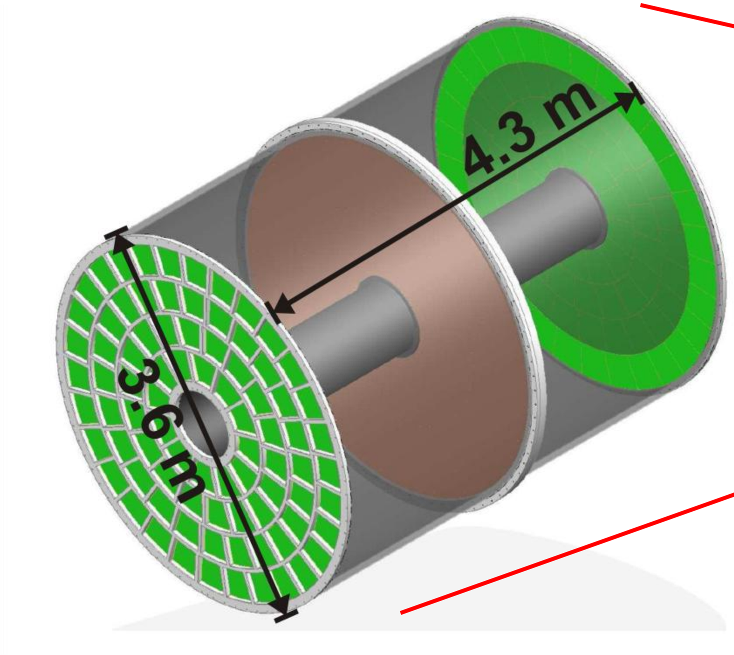
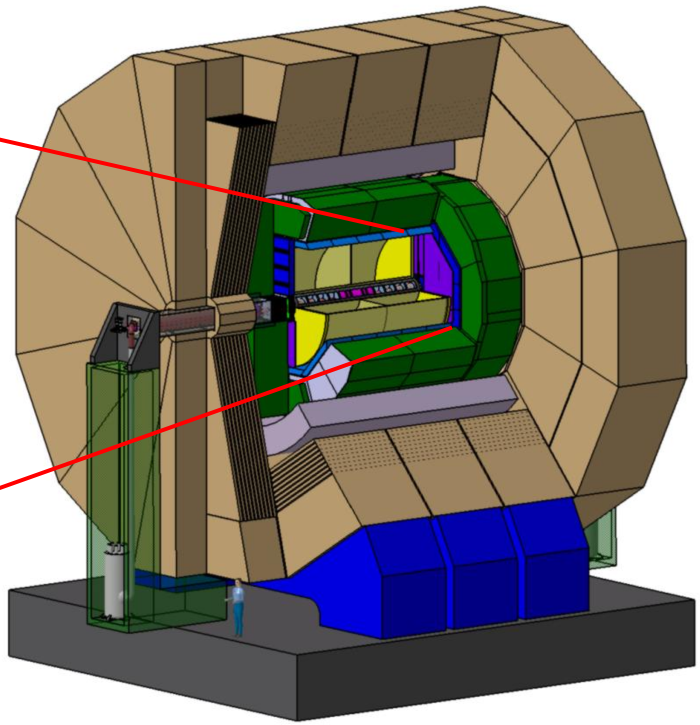
INTERNATIONAL LARGE DETECTOR

Omnipurpose detector for ILC experiments

TPC as main tracker

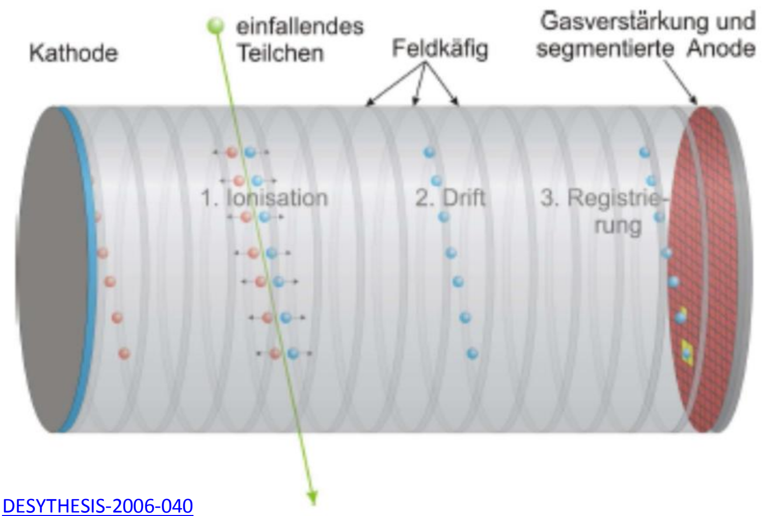




ILD LOI: arXiv:1006.3396

FLC-TPC develops the TPC tracker (in the LC-TPC collaboration)

TIME PROJECTION CHAMBER



DESYTHESIS-2006-040

Main components

- Ionization volume with a well chosen gas
- Well known electric field
- Well known magnetic fields collinear with E
- Amplification & readout system on the anode side of the gas volume

Goal

- 3-dimensional reconstruction of the particle trajectory

Physic processes in a TPC

Charged particles, curved in the B field, ionize the TPC gas

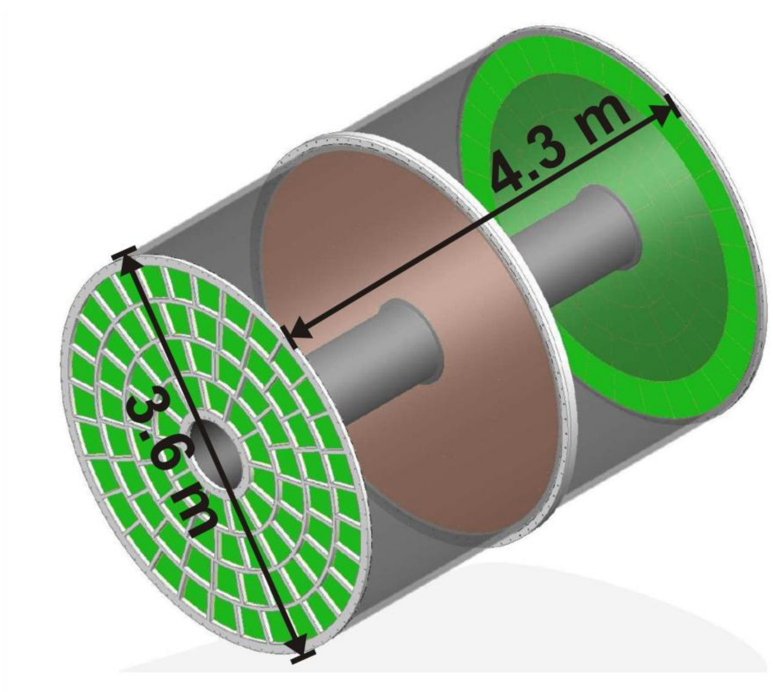
The ionization electrons drift along the E-field lines

The B field reduces the transversal diffusion

The electrons are amplified and readout at the anode side

Data analysis to reconstruct the track of the incoming particle

THE ILD TPC



$$\frac{\delta p_\perp}{p_\perp^2} = \frac{\sigma_\perp}{0.3B^2L}\sqrt{\frac{720}{N+5}}$$

Size

- Diameter: 3.6 m
- Length: 4.3 m
- Solid angle coverage: Up to $|\cos\theta| = 0.98$

Momentum resolution: ~ 9×10^{-5} / GeV / c

- About 200 measurement point per track
- $r\varphi$ point resolution < 100 μm

Other performance requirements

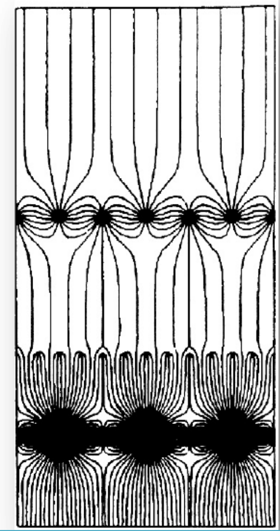
- rz point resolution < 0.5 mm
- dE / dx resolution ~5%

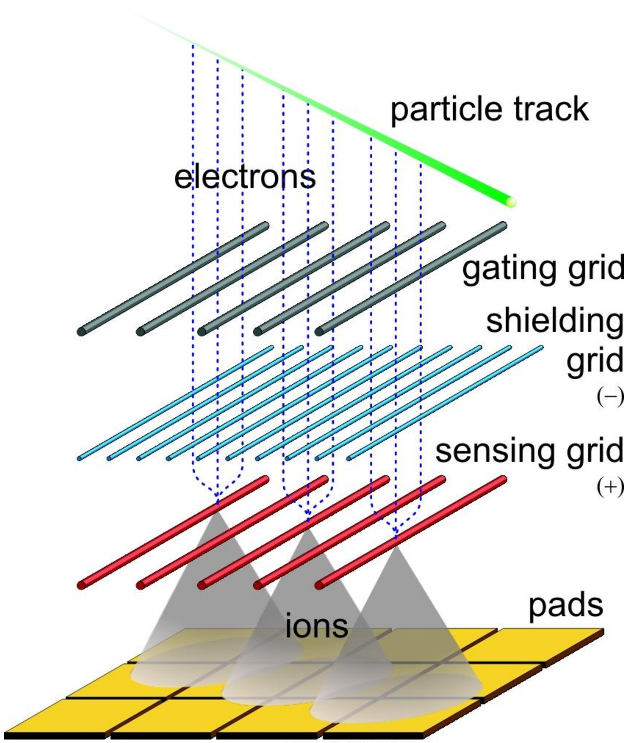
Material budget

- 0.04 X_0 in the barrel
- 0.15 X_0 in the endcaps

LIMITATIONS OF WIRE CHAMBERS

Array of charged wires. → Strong E-field near the wire → Electron avalanche multiplication → Readout of the position of the avalanche





Resolution limitations

- Minimum wire distance ~ 1 mm
- ExB effects on the same size scale

Ion backflow

- Ions produced at the wire distort the drift field
- A gating system can block the ions but blinds the detector for some time

Materials

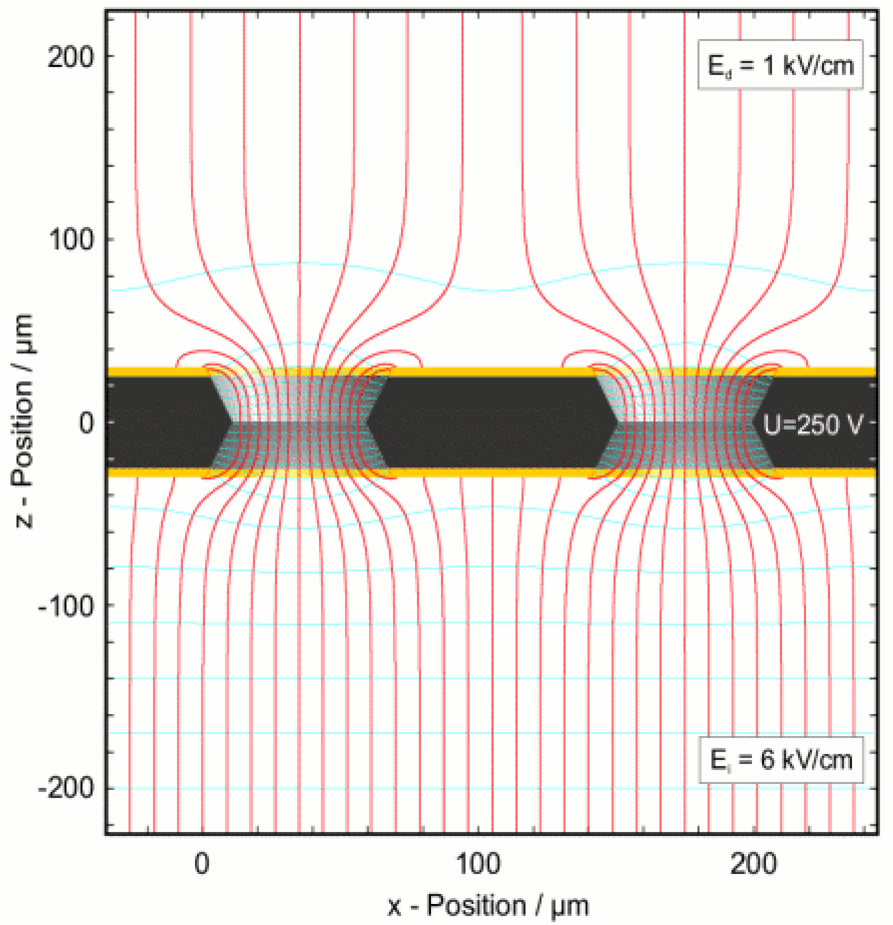
- Need robust framing to fix the stretched wires
- More dead space
- Higher material budget

Micrometric structures

- Amplifying structures of the same order of magnitude of the resolution
- Field distortions of the same order of magnitude

Intrinsic ion suppression

- Many field lines from the amplification area end on the negative electrode
- Up to 10^{-4} ion suppression

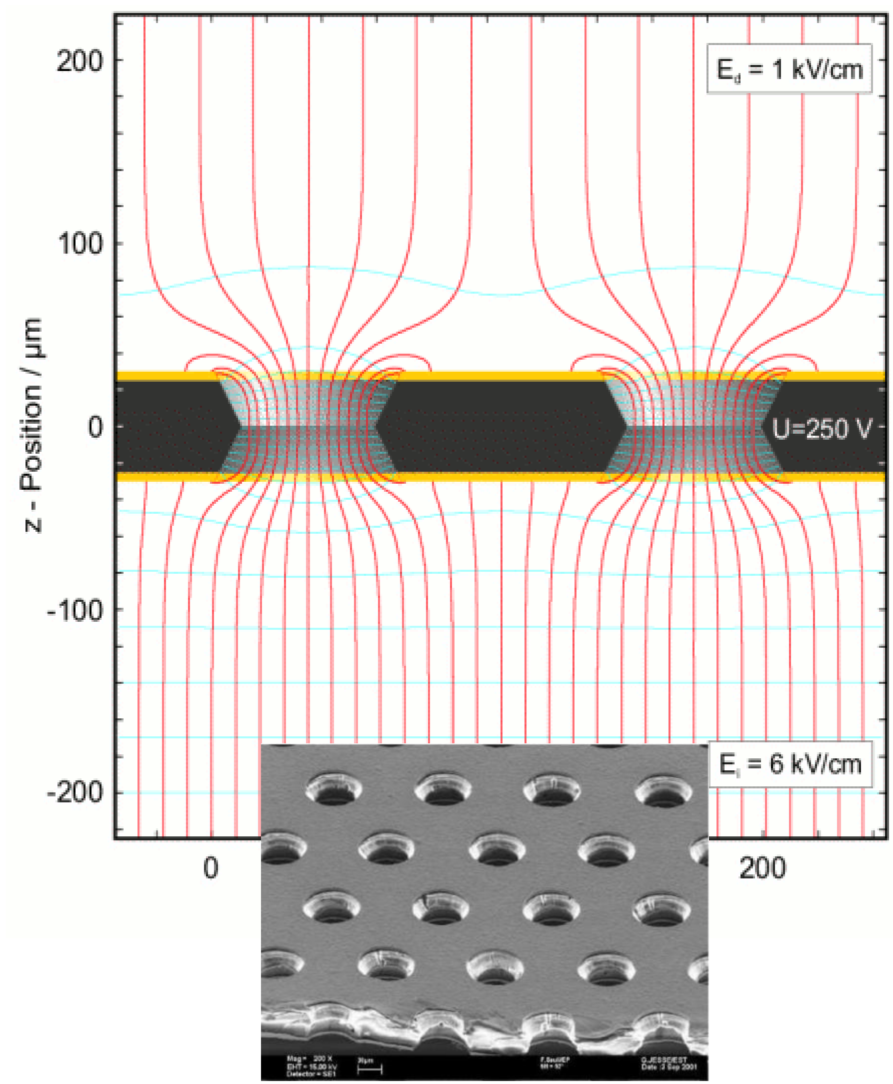


GAS ELECTRON MULTIPLIERS

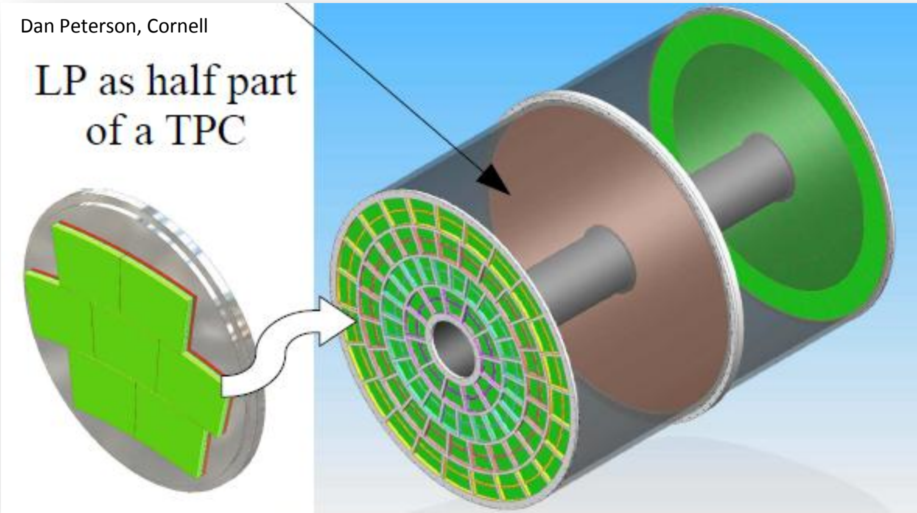
Sandwich structure
- Insulator between 2 electrodes
- Pierced by many holes
- High E-Field in the holes

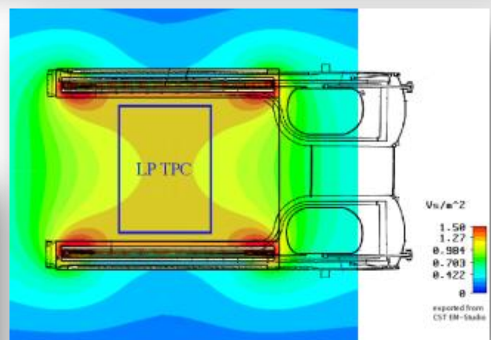
Gain
- Between 0 (gating mode)
- And a few thousands

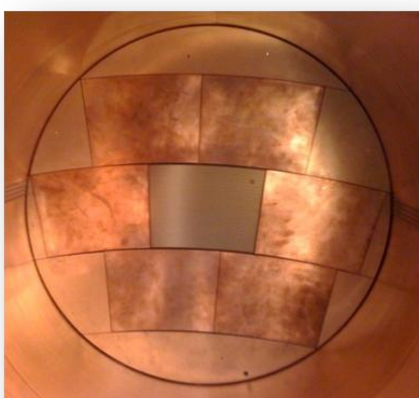
GEM stacking
- Gain increased reliably
- The field between the GEMs can be modulated to control properties



LARGE PROTOTYPE TPC







Goal

- To design and test the technologies for an ILD TPC
- First time MPGD used in a big TPC
- High channel density: ~30/cm^2 (pad readout)
- Mechanics
- …

Built and operated at DESY

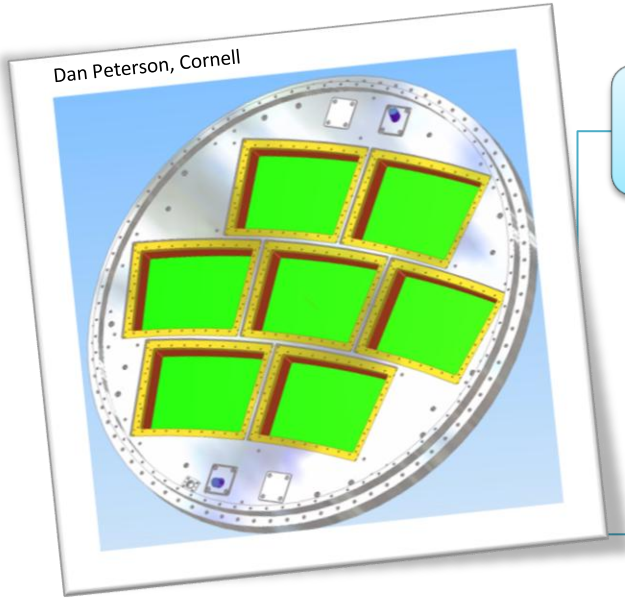
- 60 cm drift length, 72 cm inner diameter
- Field quality: $10^{-4} < \Delta E / E < 10^{-3}$
- Operational since the end of 2008

The Magnet - PCMAG

- 1.2 T magnet provided by KEK
- Operated at 1 T
  - Same L/B ratio of LPTPC and ILDTPC
  - Same transversal diffusion

Endplate

- 7 slots where to mount different modules
- Modules developed by various institutions to test different technologies
  - Saclay, KEK, Bonn, DESY



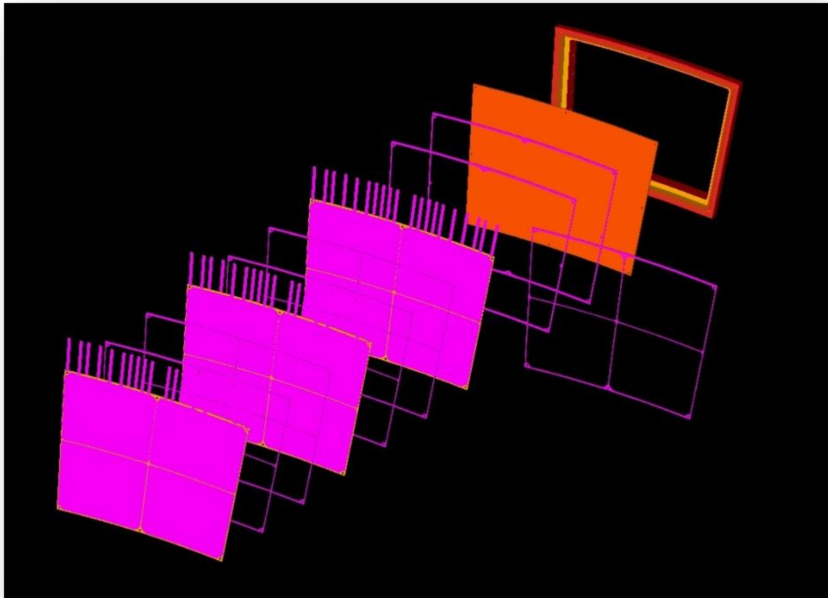
Common Features

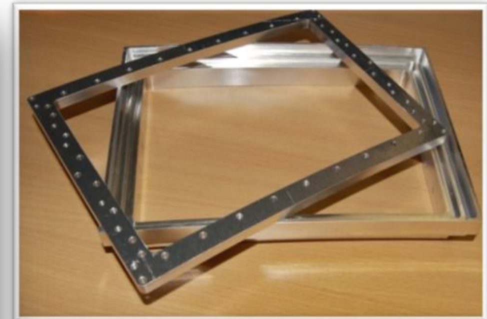
- Fixed allotted space
- Cornerstone shape
- 20-24 cm wide
- 17 cm high

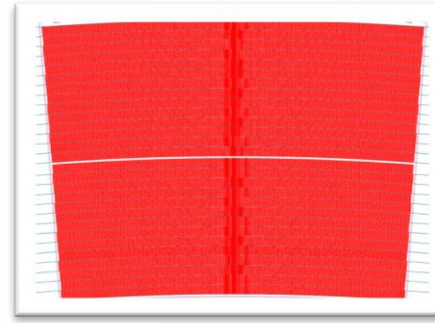
DESY Module Specific features

- 3 GEM stack
- Ceramic mounted structure developed at DESY
- Minimal amount of dead space
- Pad readout system
- Optional gating module

DESY LPTPC MODULE







Back frame

- Mounting structure
- Special aluminum to ensure flatness

Pad board

- 5000 channels
- 1.21 x 5.65 mm^2 pads
- ALTRO electronics (FADC)

GEMs

- 70 μm hole size
- 140 μm hole pitch
- Stack of 3 GEMs

Ceramic grid

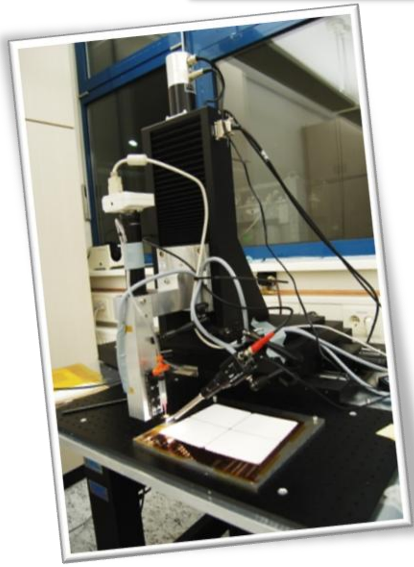
- Spacer, support and alignment
- No stretching necessary
- ~6% dead space

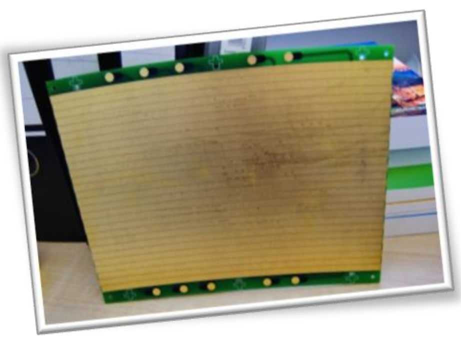
2010-11 DEVELOPMENTS

Design complete

Production and test

Detector assembly





GEM gluing

- Automatic system developed
- Glues of different viscosities under test to find an optimum

GEMs

- Tested up to 300 V in Argon
- Some of them are unstable
- Causes under investigation

Pad board

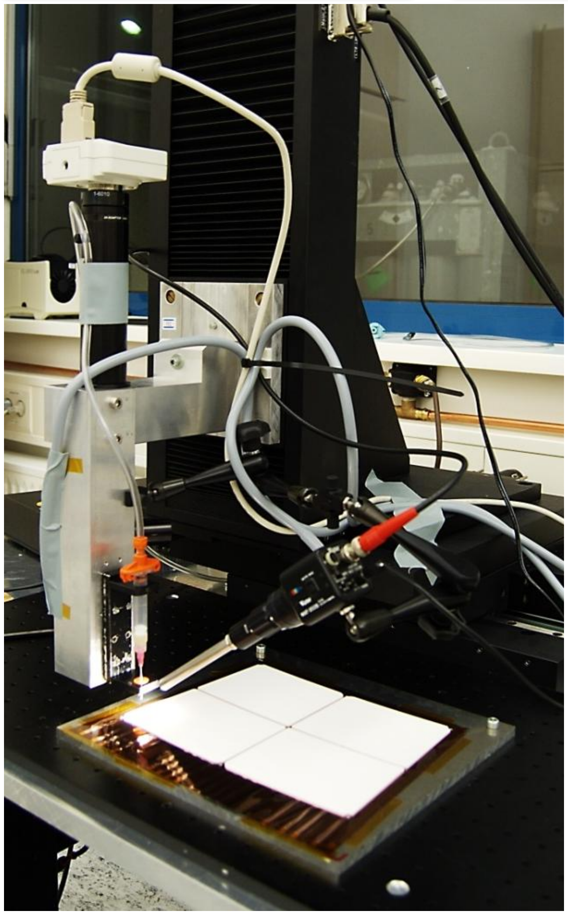
- Production delayed due to delays in design
- We obtained a similar board from colleagues at KEK

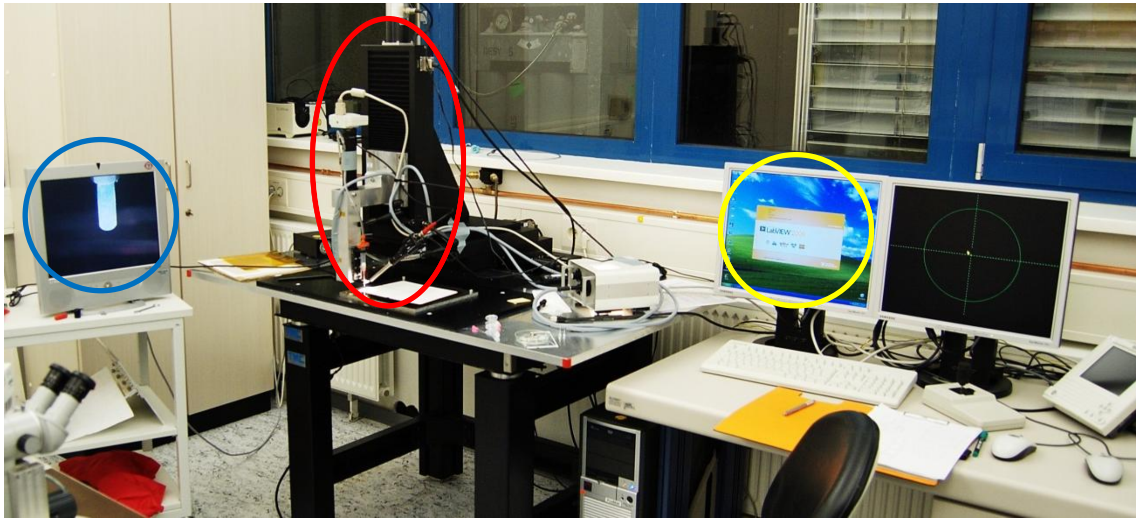
Testbeam

- December 2010
- Problems with the HV distribution
- Limited amount of data obtained

AUTOMATED GLUING

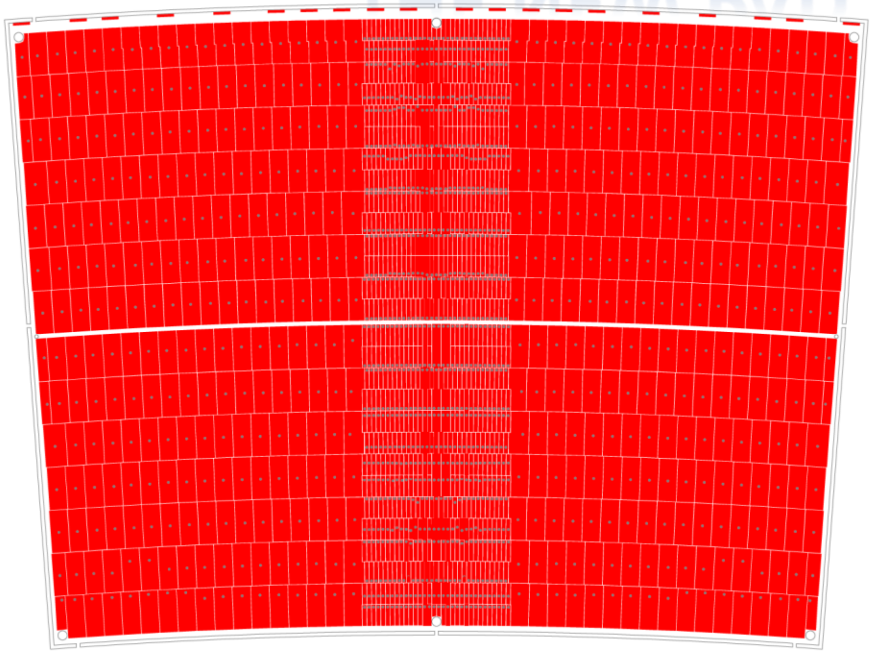
Small width of the elements to glue (1.4 mm)	Active area close to the grid elements	Total gluing length (> 1 m)	Complex gluing path

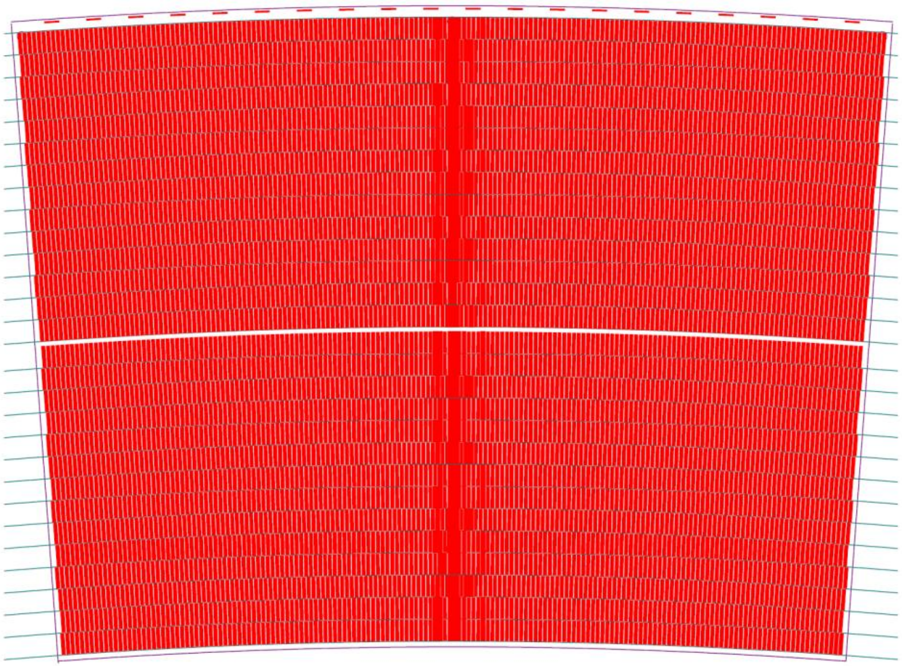




Labview Program	Robotized table with glue dispenser	Microscope monitoring

THE NEW PAD BOARD





Iteration 1

- 1000 channels
- Central track at full resolution
- Bigger pads in the rest of the board
- In production

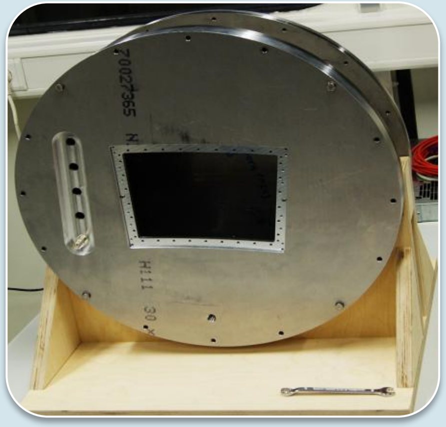
Iteration 2

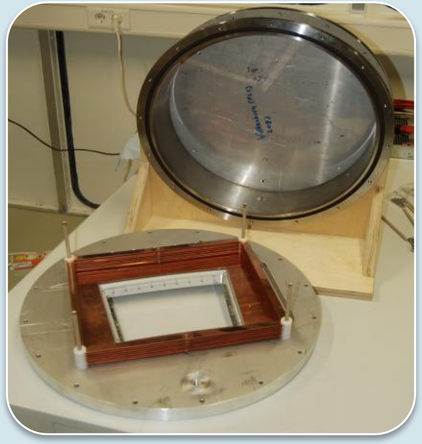
- 5000 channels
- Full board coverage at full resolution
- Final design phase

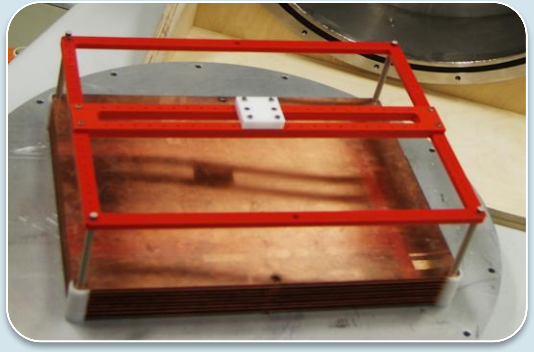
Designed at Bonn by Jochen Kaminsky

COMMISSIONING TEST BOX

To commission the module before going to the test beam







Gas tight container

- Hosts one LP Module
- Support structure for the other elements

Field rings stack

- Variable drift distance up to about 10 cm
- Variable ring number and gap
- Independent and versatile voltage divider

Radioactive source support

- Piled up over the cathode
- Can host more than one radioactive source at the same time

Board adaptation

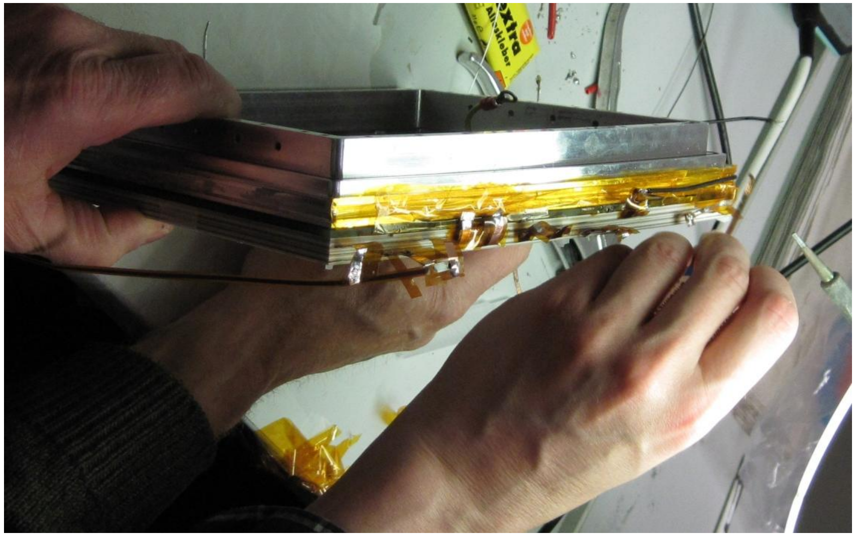
- The board was designed to use 2 GEMs
- The HV connectors it was designed for were not available
- Most of the adaptations on the HV distribution
- Thanks also to the Lund LC-TPC group

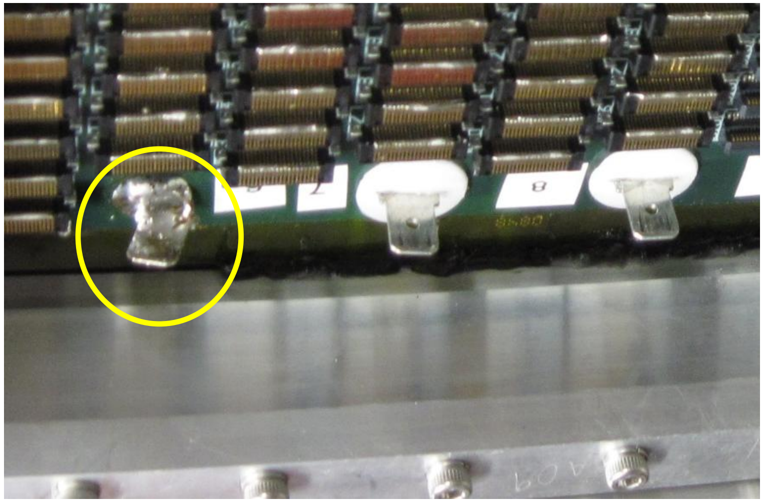
Problems on the HV distribution

- One connector broke
- One connector was unstable

Results

- 2 runs, 40k events collected
- Analysis on going





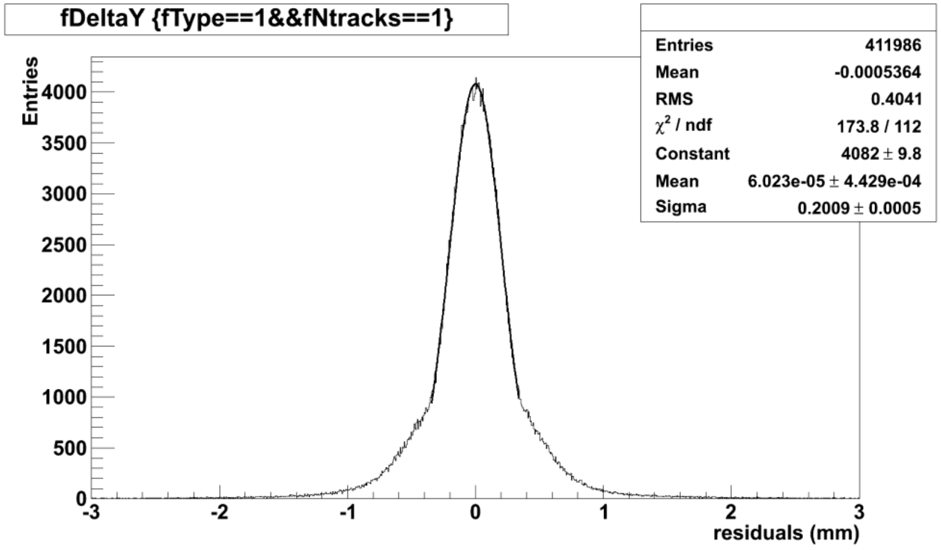
PRELIMINARY TESTBEAM RESULTS

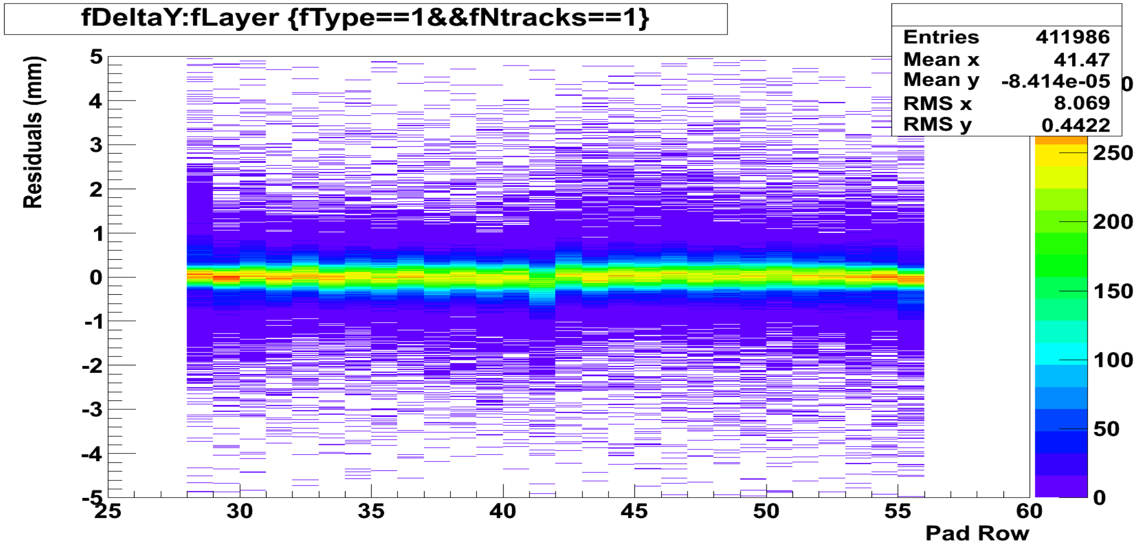
Data set

- 2 runs, 40k events collected
- GEM voltage: 250-260-260(265)

First look at the data

- Preliminary analysis performed at Lund
- No evident distortions
- ~200 μm point resolution (B=0) as expected





2011 SCHEDULE

Design upgrade

- Revised HV distribution system on our own pad board
- Upgraded gluing procedures.
- Other smaller improvements

Dedicated pad board

- Iteration 1: 1000 channels, 4 cm track
- Iteration 2: 5000 channels, full module coverage

Commissioning and operation of the test box

- Commissioning in completion
- We will test our modules there in between of the test beams

New test beams

- One test beam scheduled in May
- Follow up in June

Backup slides

DESY TESTBEAM SETUP

THE ILD DETECTOR

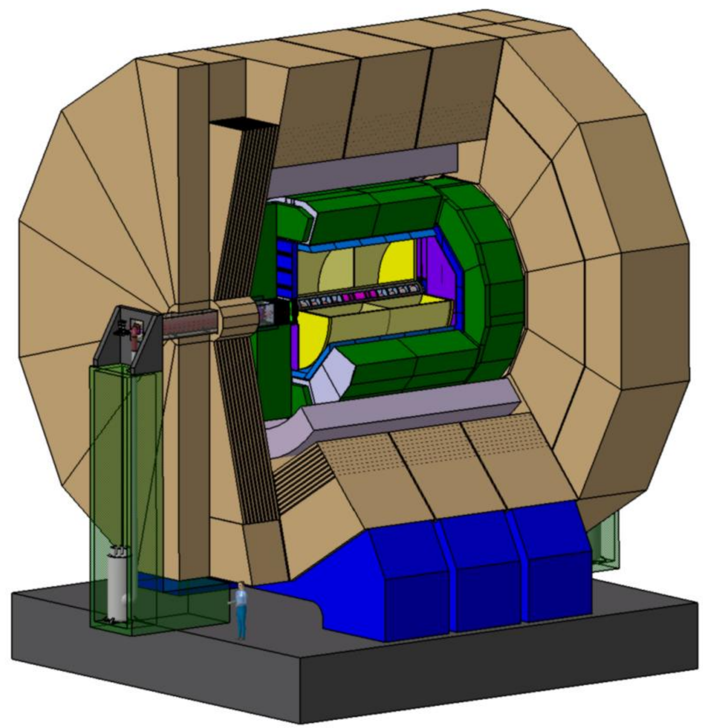
Omnipurpose detector for ILC experiments

Multiple tasks

- Vertex finding
- Momentum measurement
- Energy measurement
- Particle Identification

Multiple sub-detectors

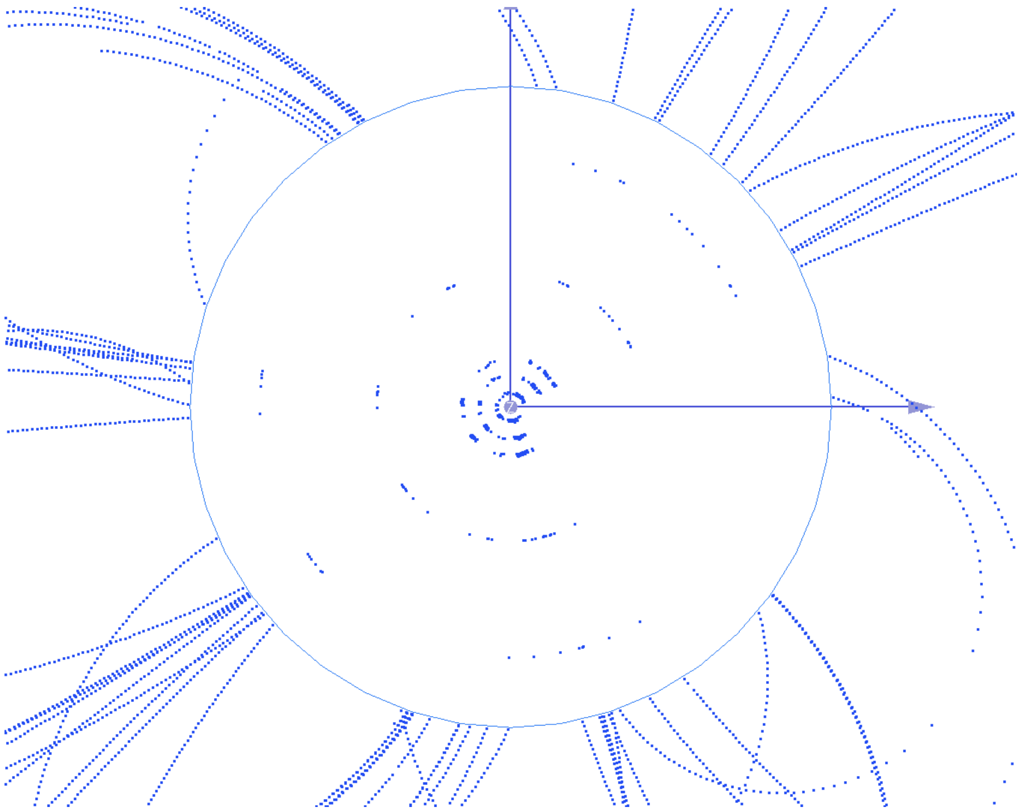
- Vertex finder
- Silicon tracker
- TPC
- ECAL
- HCAL
- Muon detector



ILD LOI

FLC-TPC develops the TPC tracker (in collaboration)

$$\frac{\delta p_\perp}{p_\perp^2} = \frac{\sigma_\perp}{0.3 B^2 L}\sqrt{\frac{720}{N+5}}$$



Larger σ compensated by large N

- 224 for the ILD TPC, about 10 for a Silicon detector

Other advantages of high N

- Make the pattern recognition easier
- Good dE/dx measurement

Minimum material budget

- TPC alone should be only 0.04 X_0 in the barrel