The pixel TPC

Michael Lupberger

University of Bonn

Outline:

- Pixelated gaseous detectors: Motivation & History
- Timepix and InGrid
- LCTPC-pixel group activities
- Demonstrator module

AIDA

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

universitätbonn

Linear Collider Forum 2014, April 29, Bonn

Motivation

Semiconductor detectors: micro structuring led to breakthrough in charged particle tracking (Si strips, Si pixel)

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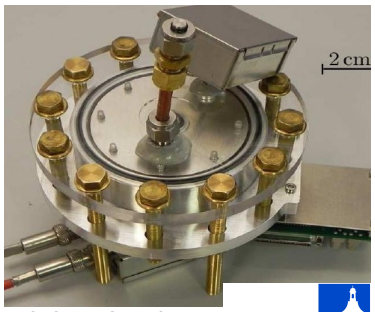
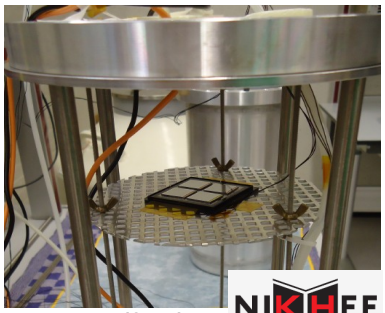
Possible applications:

- Rare event searches: CAST, DARWIN
- Tracking: GOSSIP, ILC



Christoph Krieger universitätbonn


Rolf Schön NIKHEF

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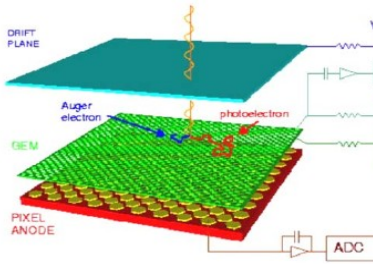

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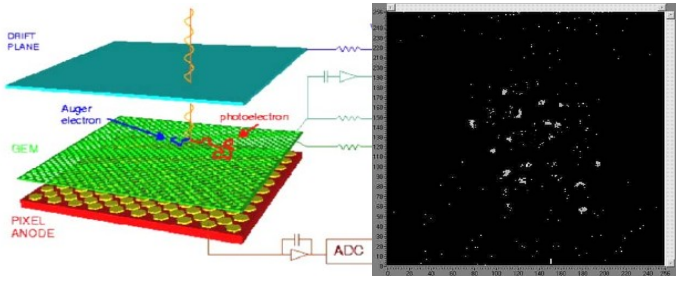

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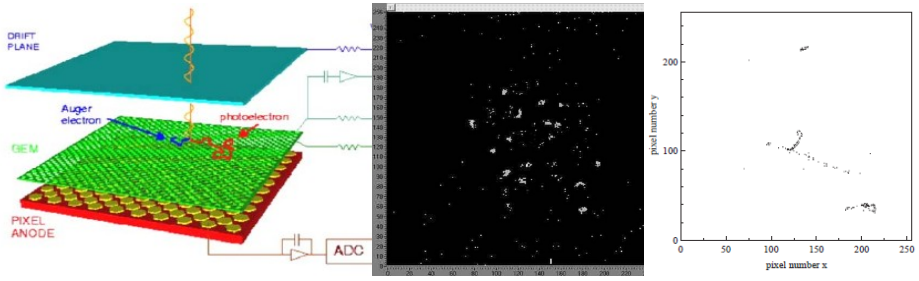

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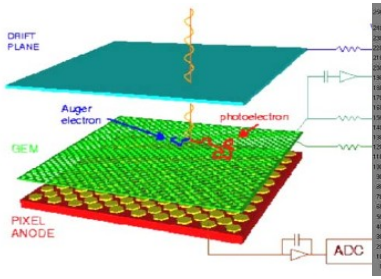

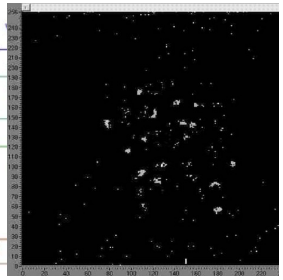
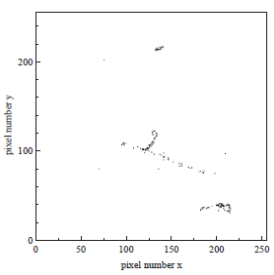

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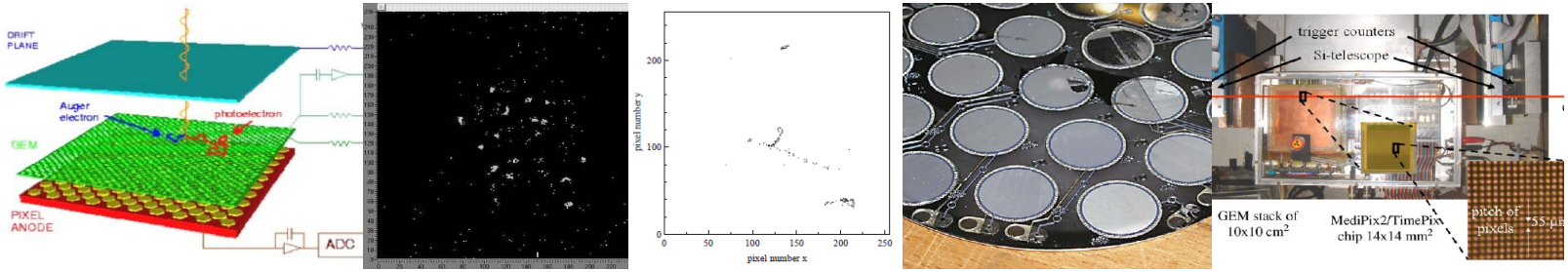

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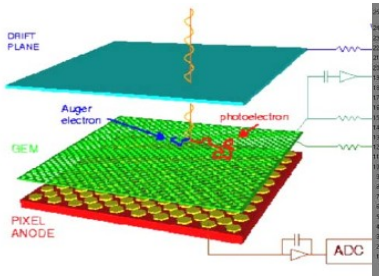
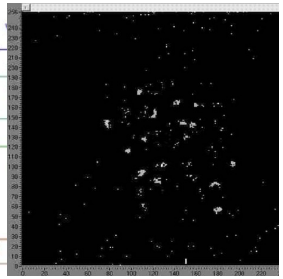
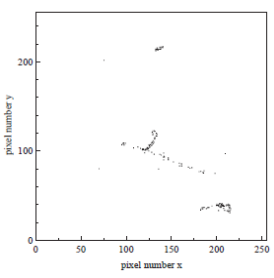
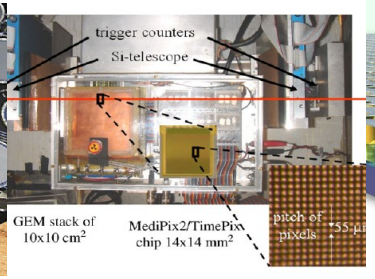
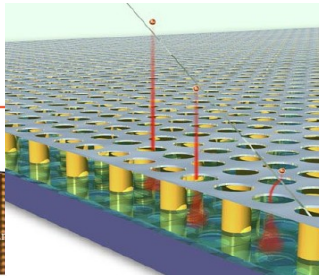
- 2009: Performance and prospects of GridPix and Gossip detectors
  H. van der Graaf, F. Hartjes, A. Romaniouk, ATLAS note ATL-P-MN-0016





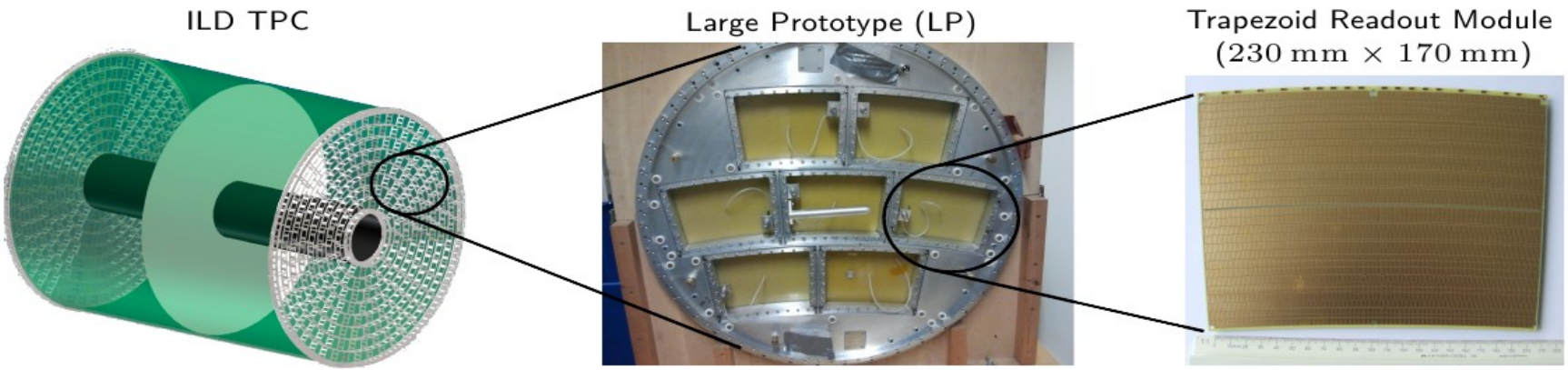
LCTPC-pixel collaboration

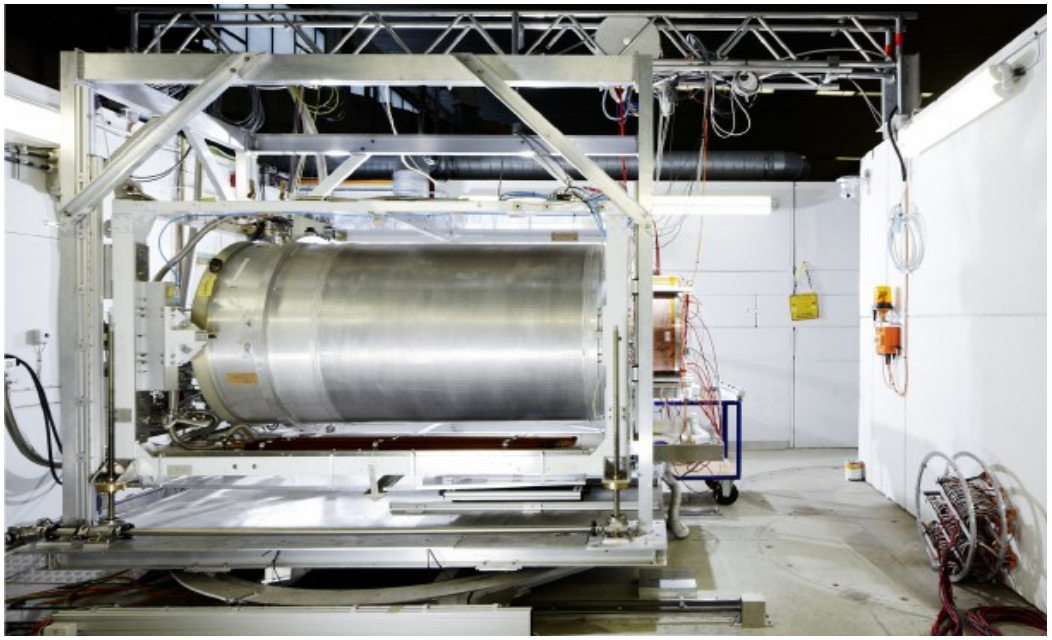
- LCTPC collaboration:
  - Develop a TPC for physics up to 1 TeV (at the ILC)
  - Groups from America, Europe and Asia
  - Several readout concepts using GEM/Micromegas

- LCTPC-pixel
  - R&D towards a pixel-TPC: MPGD + pixel readout
  - Groups:
    - NIKHEF: Module construction
    - University of Kiew: Simulation
    - LAL Orsay: Simulation
    - CEA Saclay / DESY: Data analysis
    - Uni Bonn: Module construction, readout system, data analysis
    - Uni Siegen: Data analysis
  - Goal: build a demonstrator module for a pixel-TPC

LCTPC Prototype

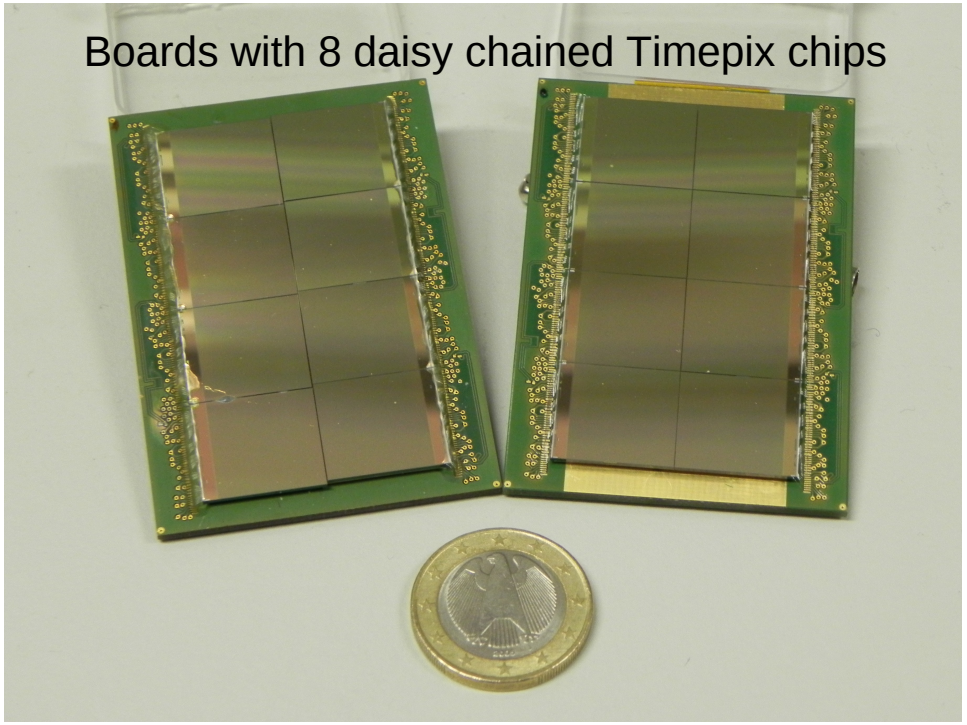
Setup at DESY





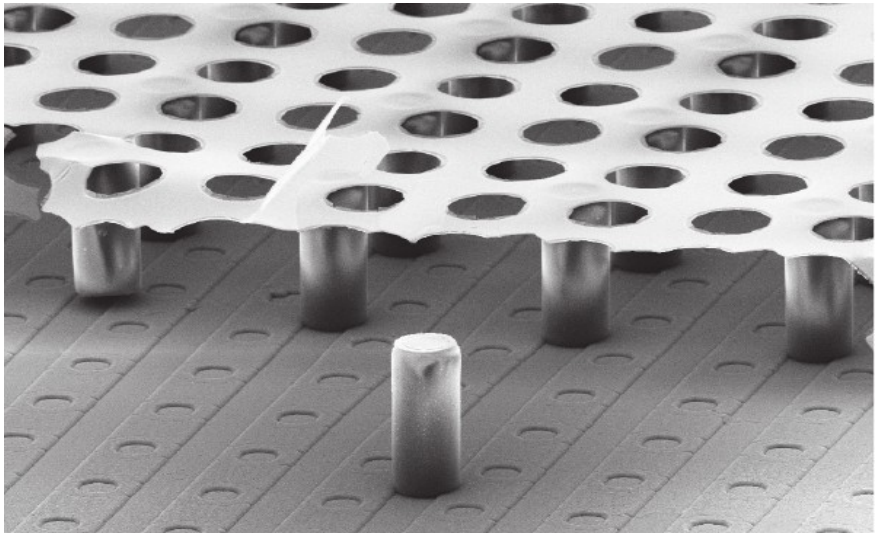
Timepix chip

- Readout chip used for many applications
- Characteristics:
  - Active surface: 1.4 x 1.4 cm², 256 x 256 pixel array
  - Pixel size 55 x 55 µm²
  - 14 bit counter in each pixel (measure arrival time or charge)
  - Analog part: single threshold typical at ~500e^- (ENC ≈ 90e^-)

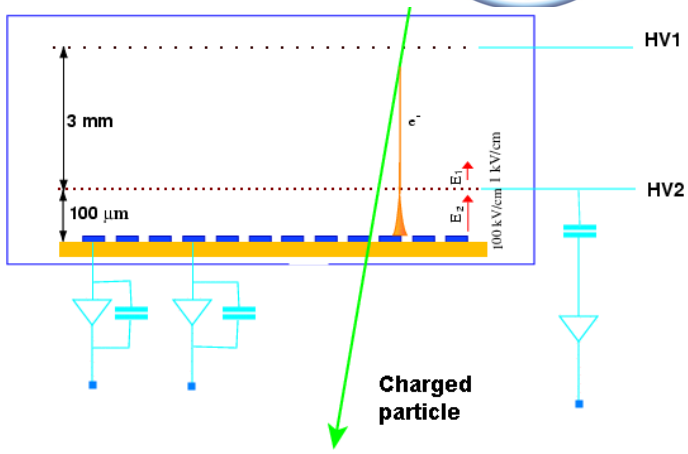


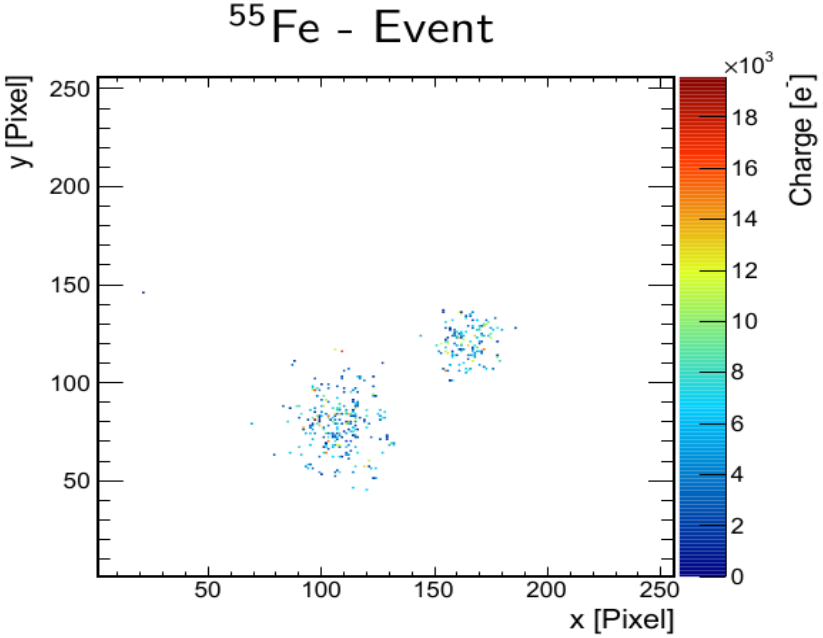
Timepix+Micromegas=InGrid

- Aluminium mesh on chip
  - Hole to pixel alignment
  - Pillar height uniformity



- Use photolithographic process
  - Pioneered and optimised by NIKHEF and University of Twente
  - Production on single chip basis





Production on wafer scale

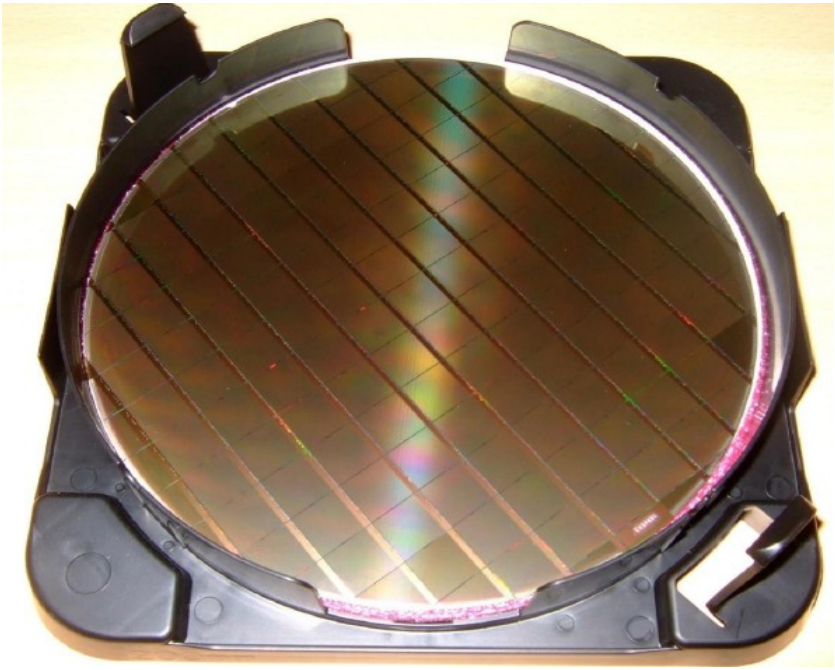
- High demand for InGrid chips:
  - R&D at Bonn, NIKHEF, Saclay
  - Equipment of larger surfaces

⇒ Production on wafer scale

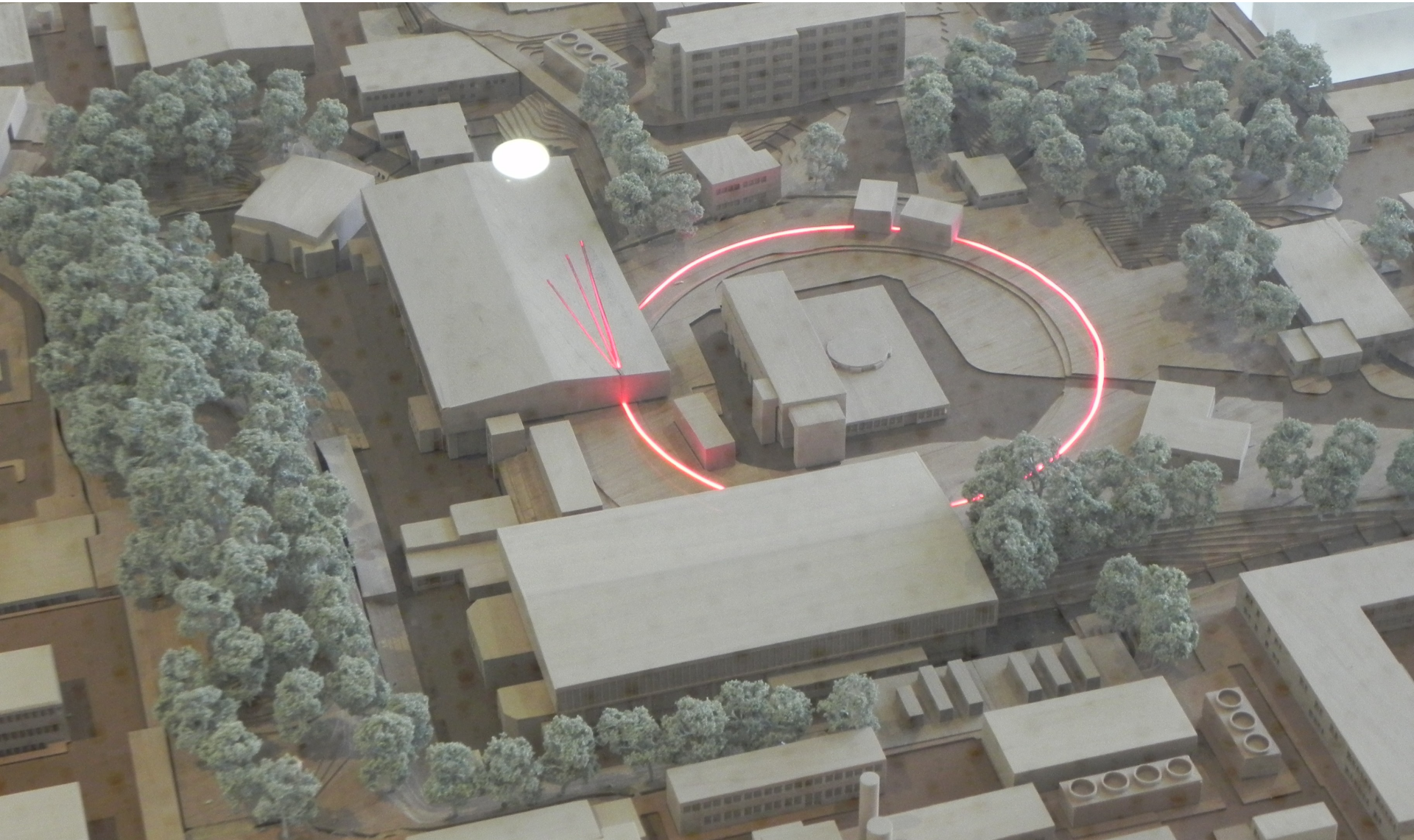
- 8 inch wafer = 107 chips

Fraunhofer IZM (Berlin)

has machinery for post-processing

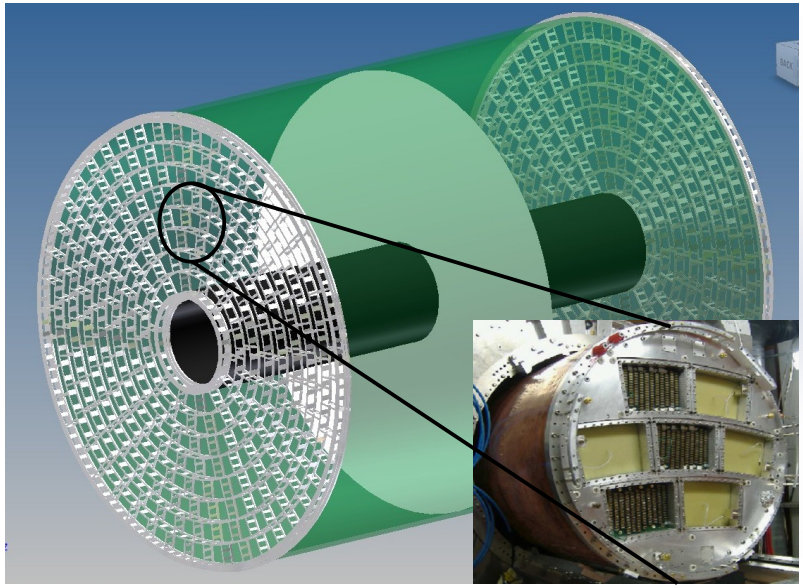


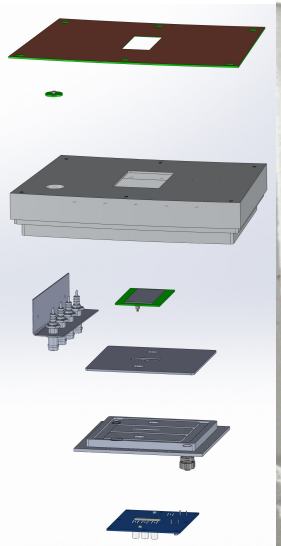
2013 test beam @ DESY

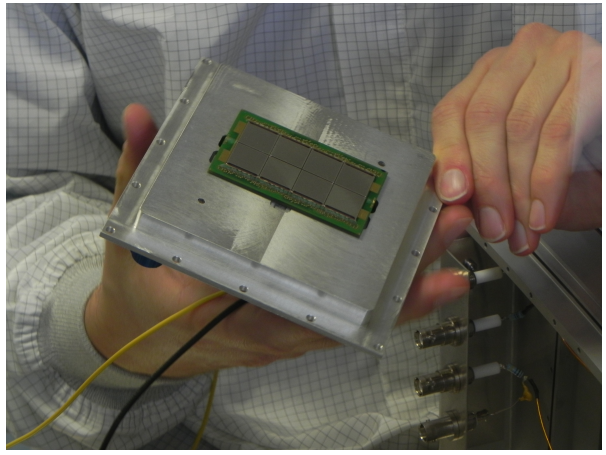


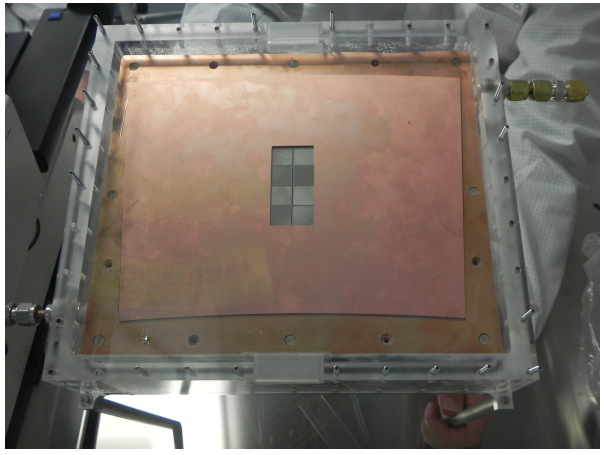
Prototype + pixel module

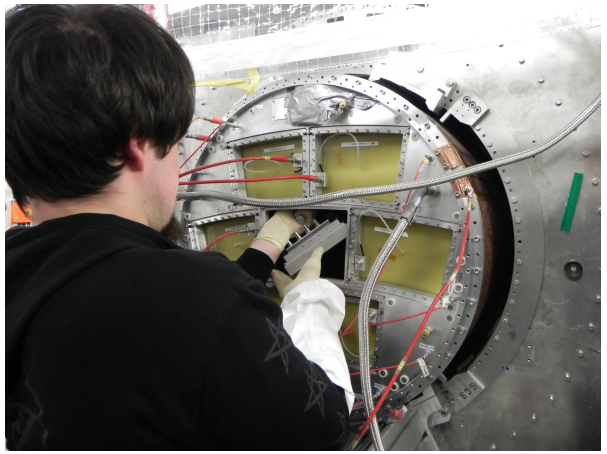
Setup at DESY











2013 test beam

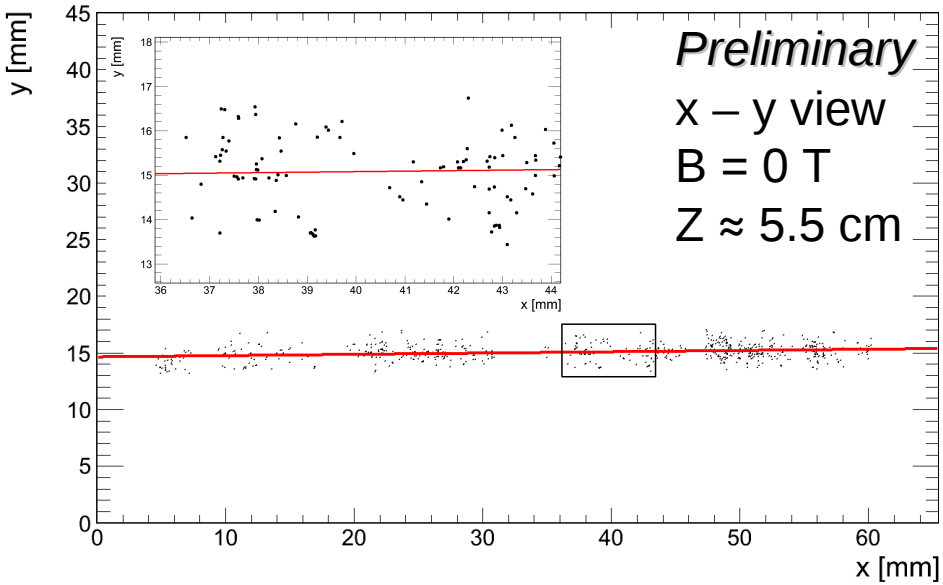
March/April 2013: 2 LCTPC octoboard modules

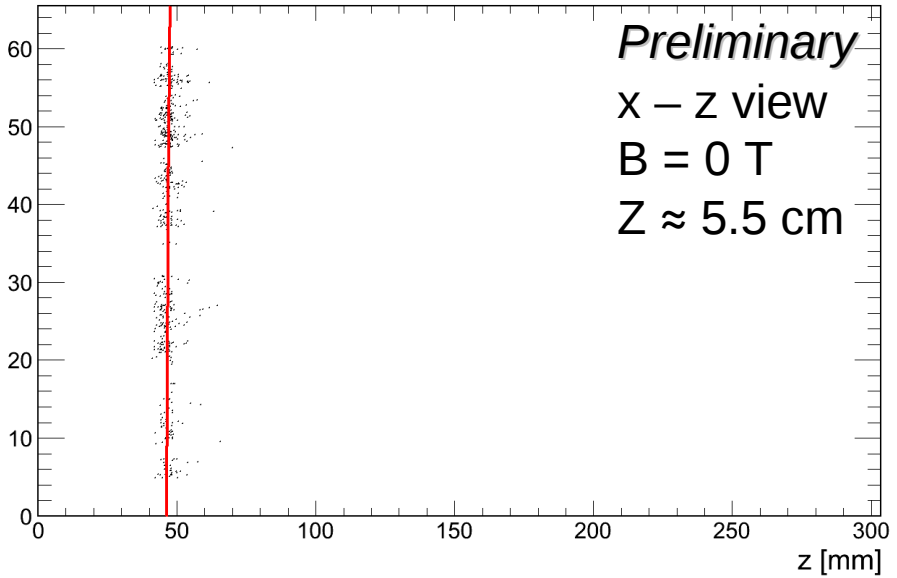
- Different amplification structures: GEM / InGrid
- Test of readout system

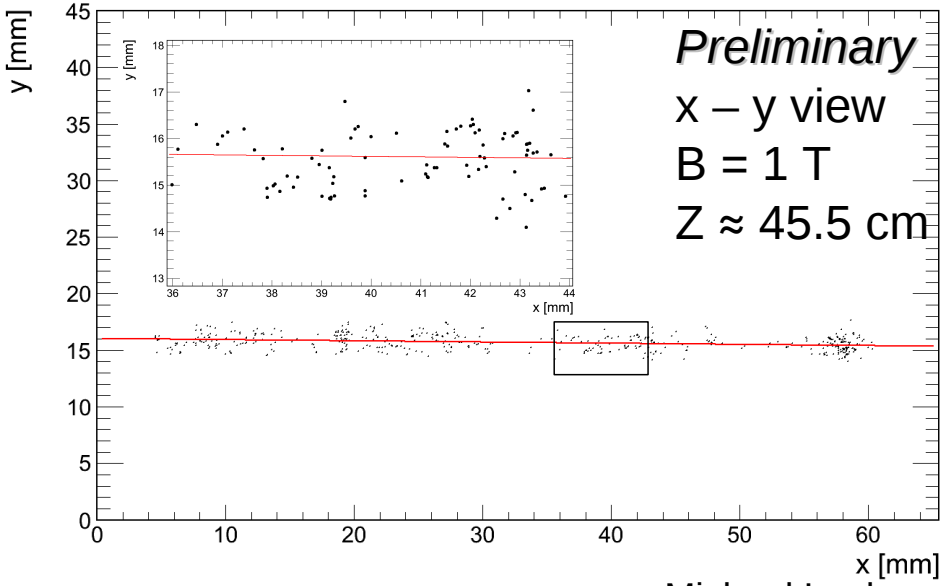
- Readout rate: 2.5 Hz; 40MHz clock
- Electron beam of up to 6 GeV
- Gas: Ar:CF4:iC4H10 (95:3:2) = T2K gas
- ~ 2 Mio. frames recorded, including B = 1 T
- Extensive testbeam program

- Preliminary data analysis in MarlinTPC Robert Menzen

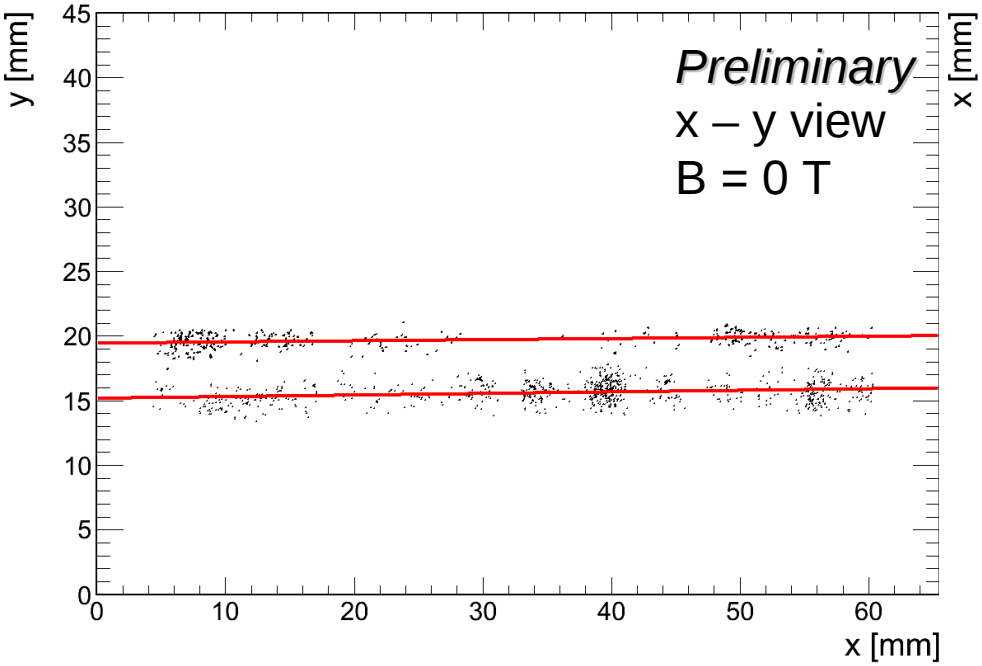
Reconstructed tracks

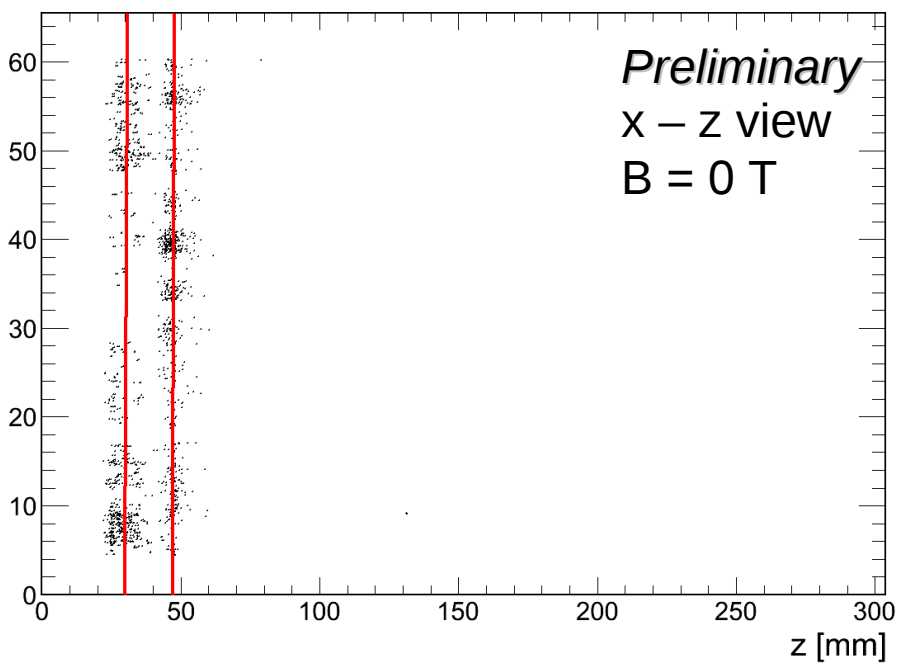






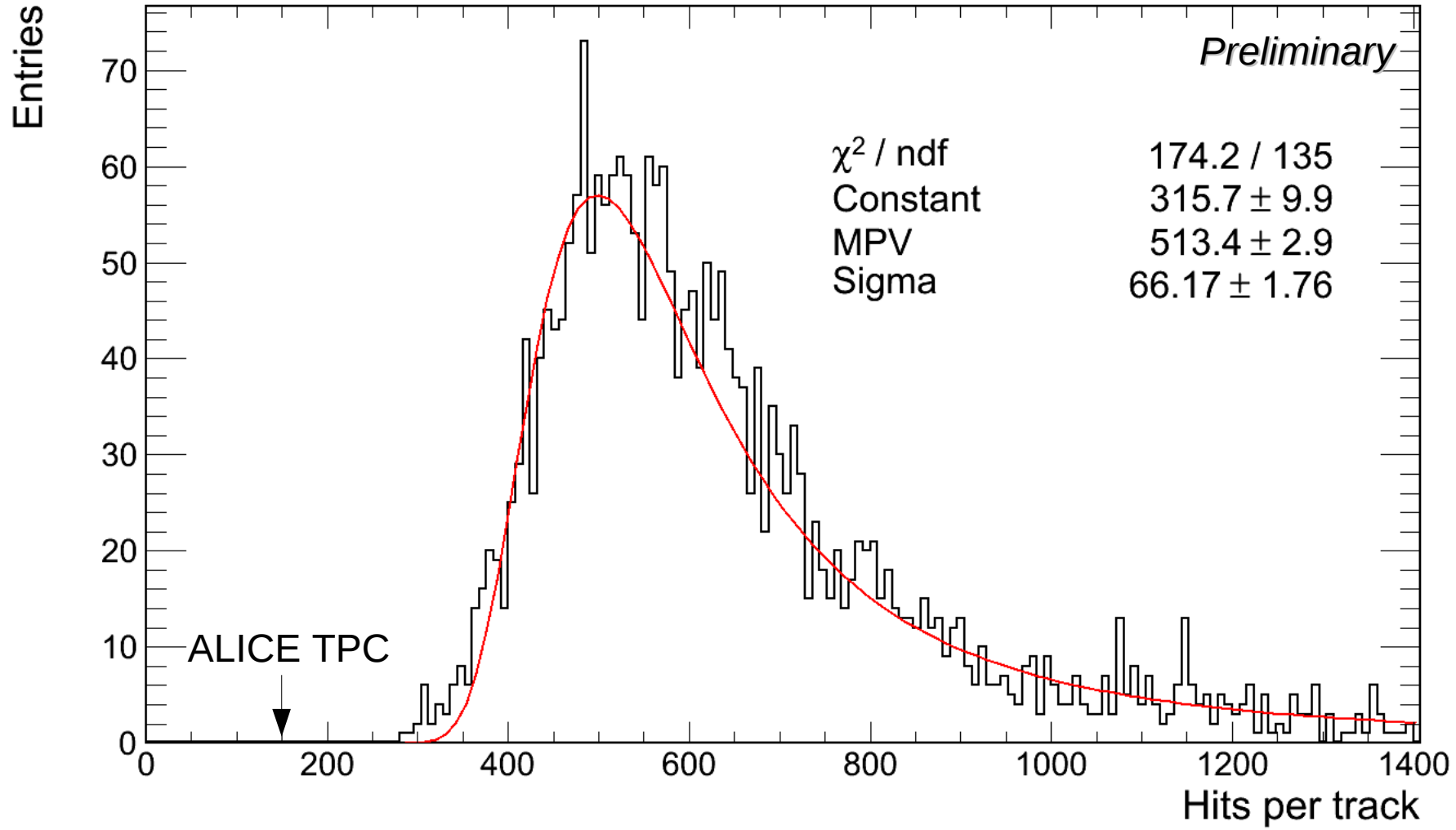
Reconstructed double tracks



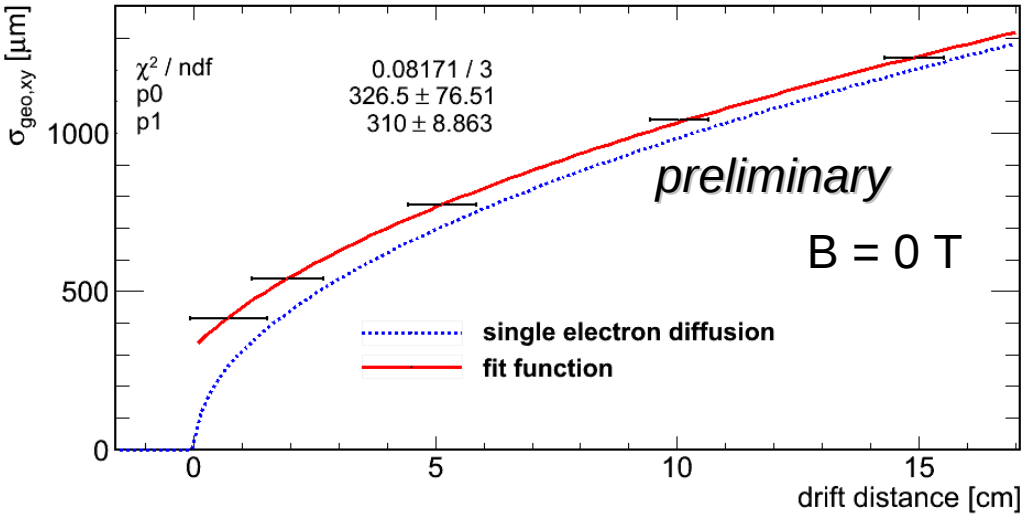


Hits per tracks

B = 0 T, z = 5.58 cm, track length ≈ 5.6 cm

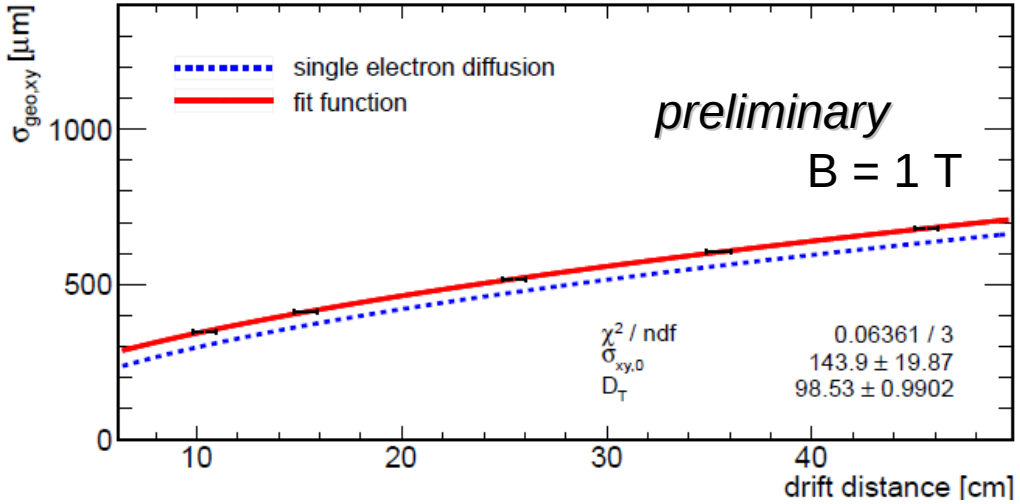


Preliminary z-scan results



Fit function $f(x) = \sqrt{P0^2 + P1^2 \cdot z}$

P0: intrinsic x-y resolution 327 µm
dominated by field distortions
P1 = 310 µm/√cm:
diffusion in T2K for E = 230 V

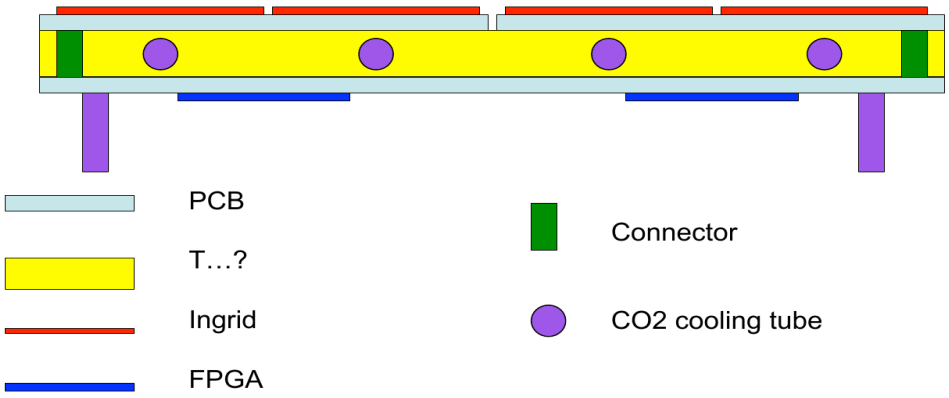


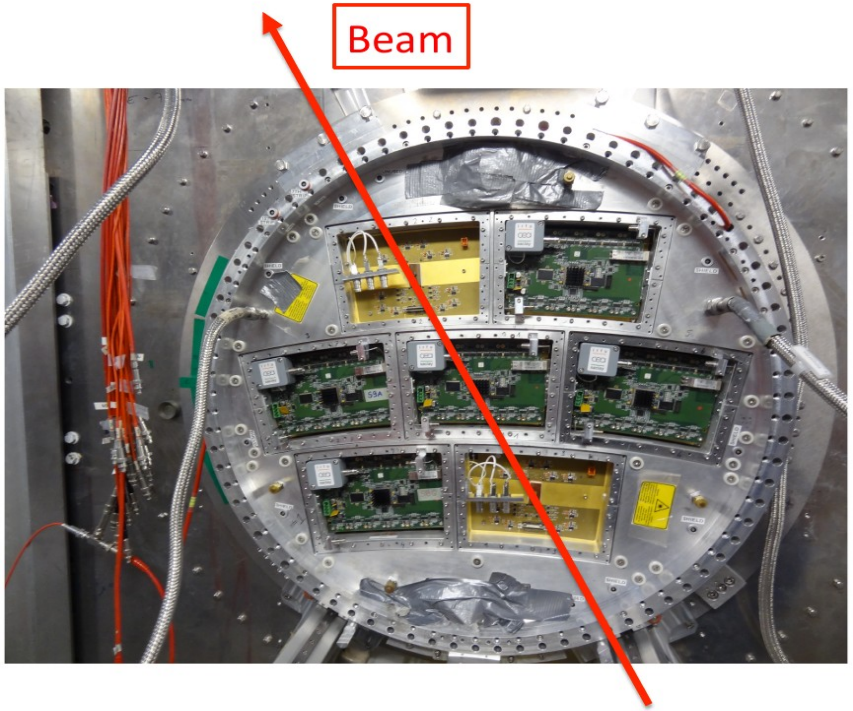
=> Field distortions under investigation

Detector construction

Jan Timmermans (NIKHEF) : 2 Octopuce testbeam

- Construction of InGrid octoboards
- Testbeam with 2 Octoboards @ LP in March 2014
  - B = 0T and B = 1T
  - Stable operation
  - Analysis not started
- Plan for module layout + readout





Data analysis

Andrii Chaus (DESY/CEA Saclay):

Processing Octoboard test beam data

- MAFalda analysis framework ok for fast analysis at testbeam
  - Track reco based on raw data, no GEAR info
  - Field distortions, drift velocity, residuals, diffusion
- MarlinTPC for real analysis (using GEAR information)
  - Processors for octoboard analysis
  - Analysis chain setup ongoing
  - GEAR geometry for 2 InGrid octoboards + 5 Micromegas

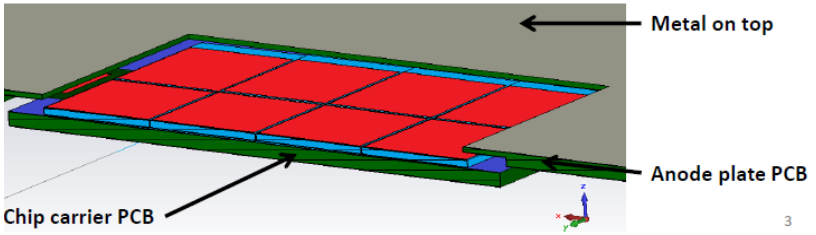
Amir Shirazi (Uni Siegen):

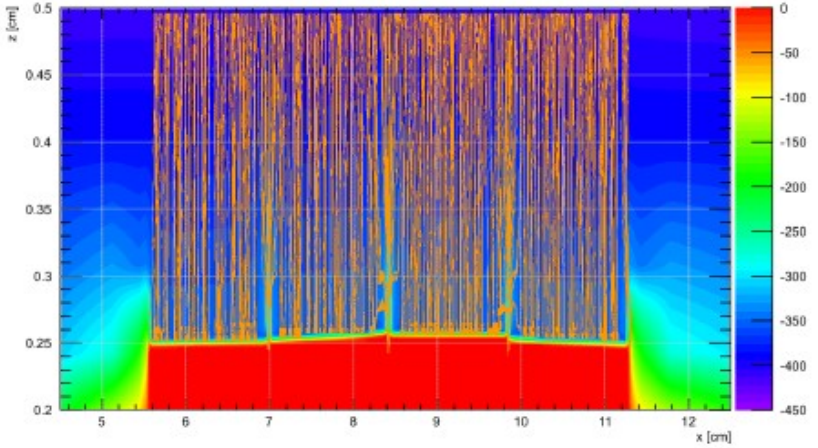
Just started to set up and learn MarlinTPC

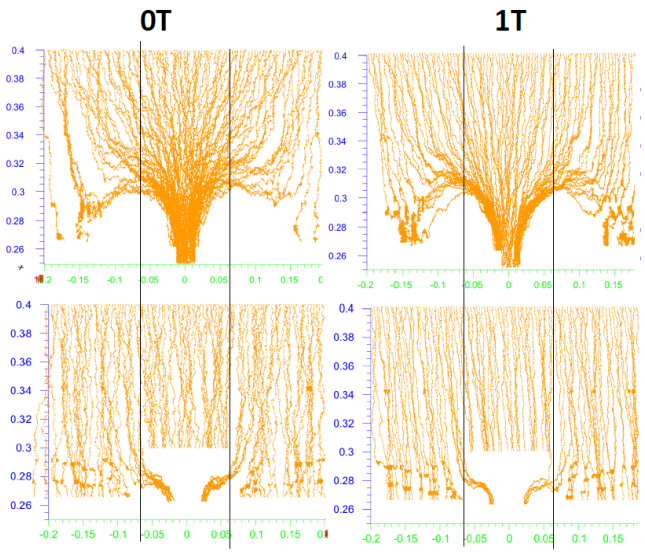
Simulation

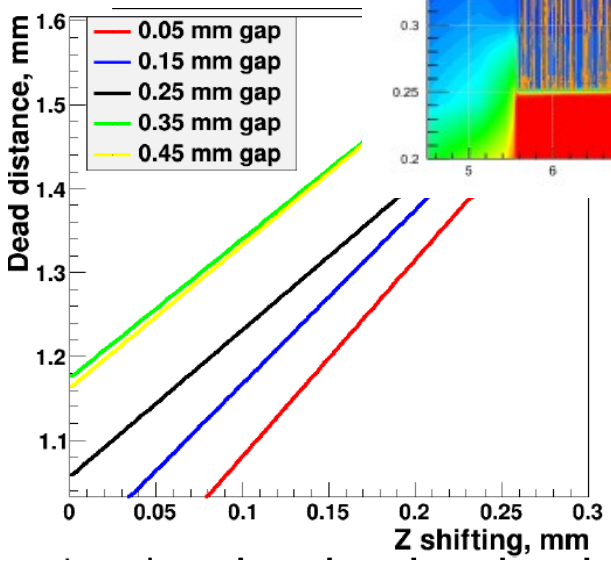
Oleksiy Fedorchuk (Uni Kiew) : Octoboard simulation

- Single octoboard simulation
  - Successfully modelled
  - Field distortions
  - Simulated occupancy similar to data
  - Impact of shifted chips
- Next step:
  - 100 chip module







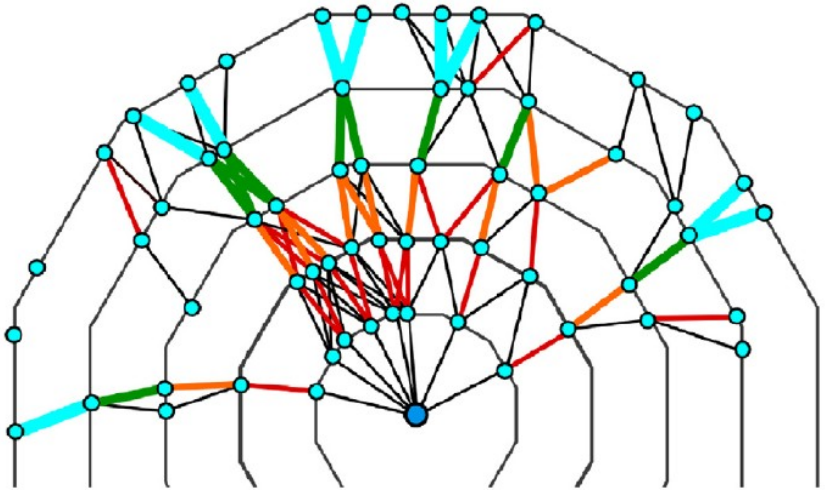


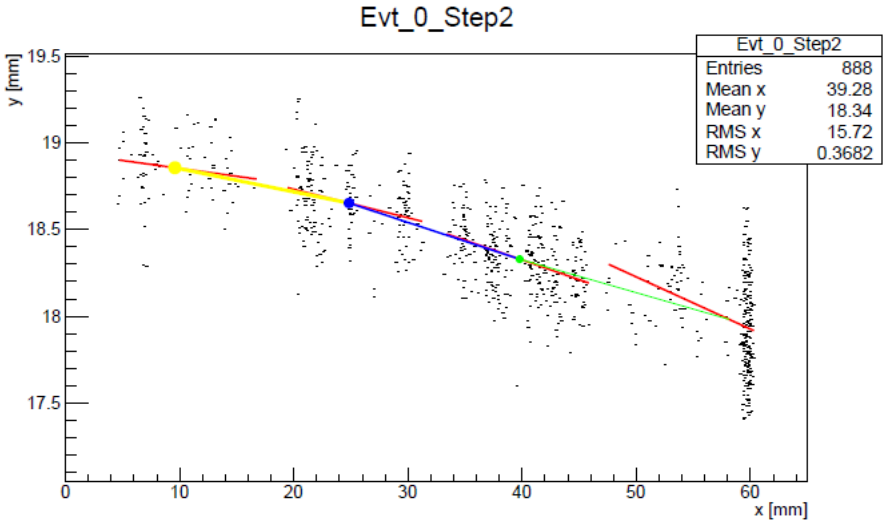
Bonn group activities

Data analysis

Martin Rogowski: A new tracking algorithm

- Algorithm from Forward Tracking Detector for ILD

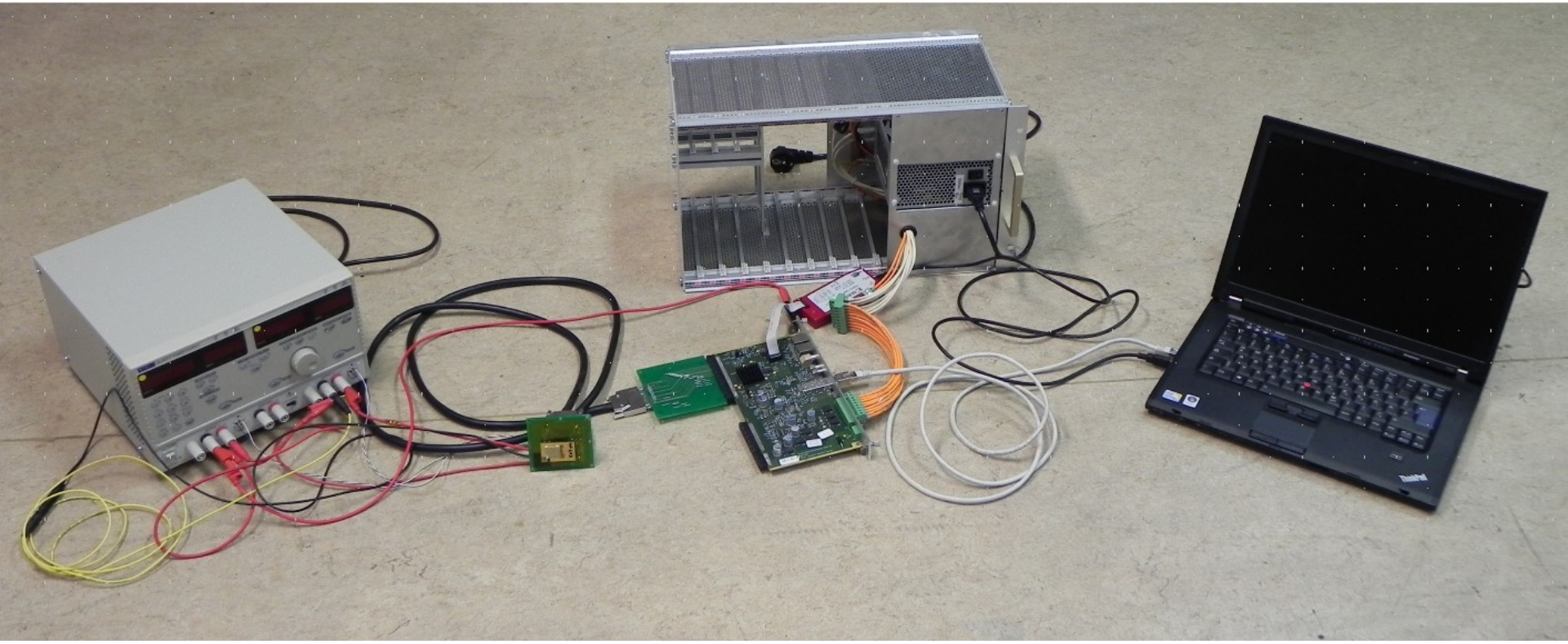




- Comparison of different algorithms
  - Standard Hough Transformation from MarlinTPC
  - Fast Hough Transformation (DESY)
  - Randomized Hough Transformation (Lappeenranta)

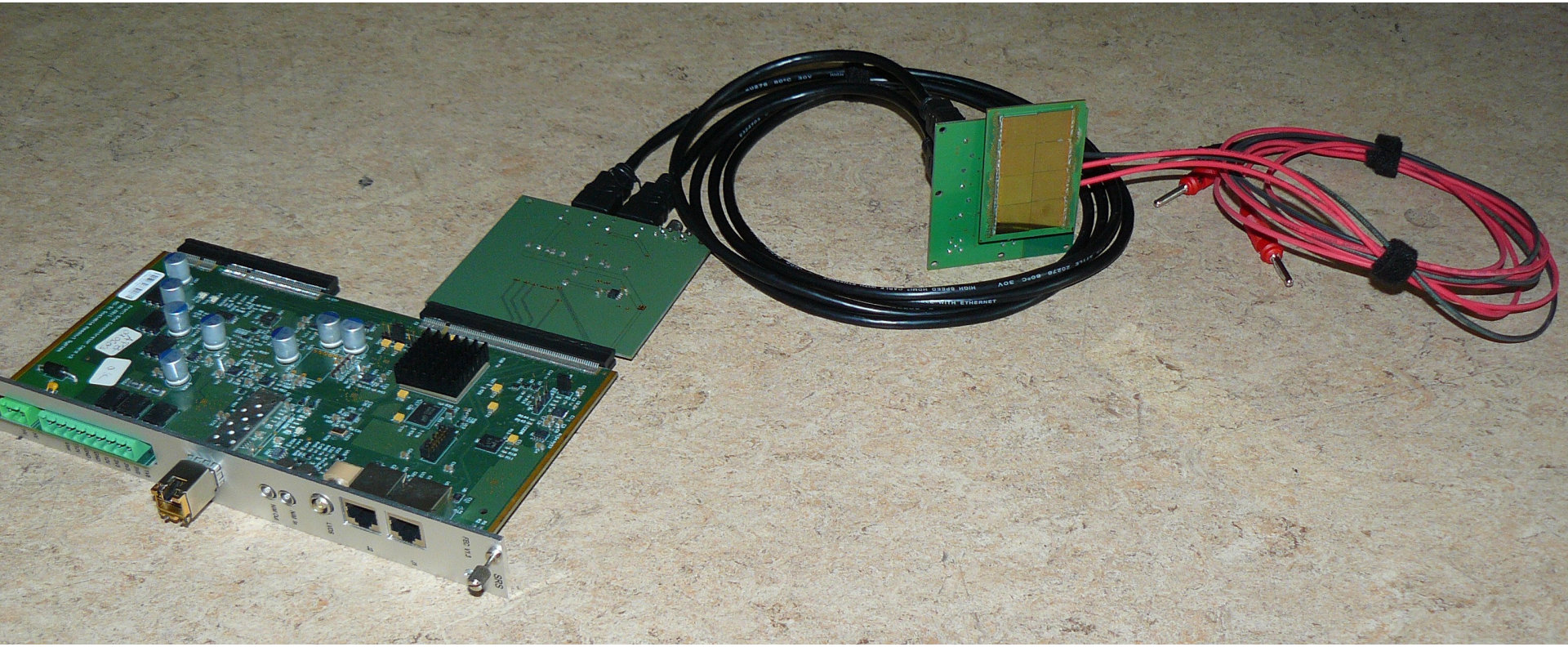
Readout system

Scalable Readout System (RD51, CERN)



Chain: Chip – Adapter card+FEC – Computer

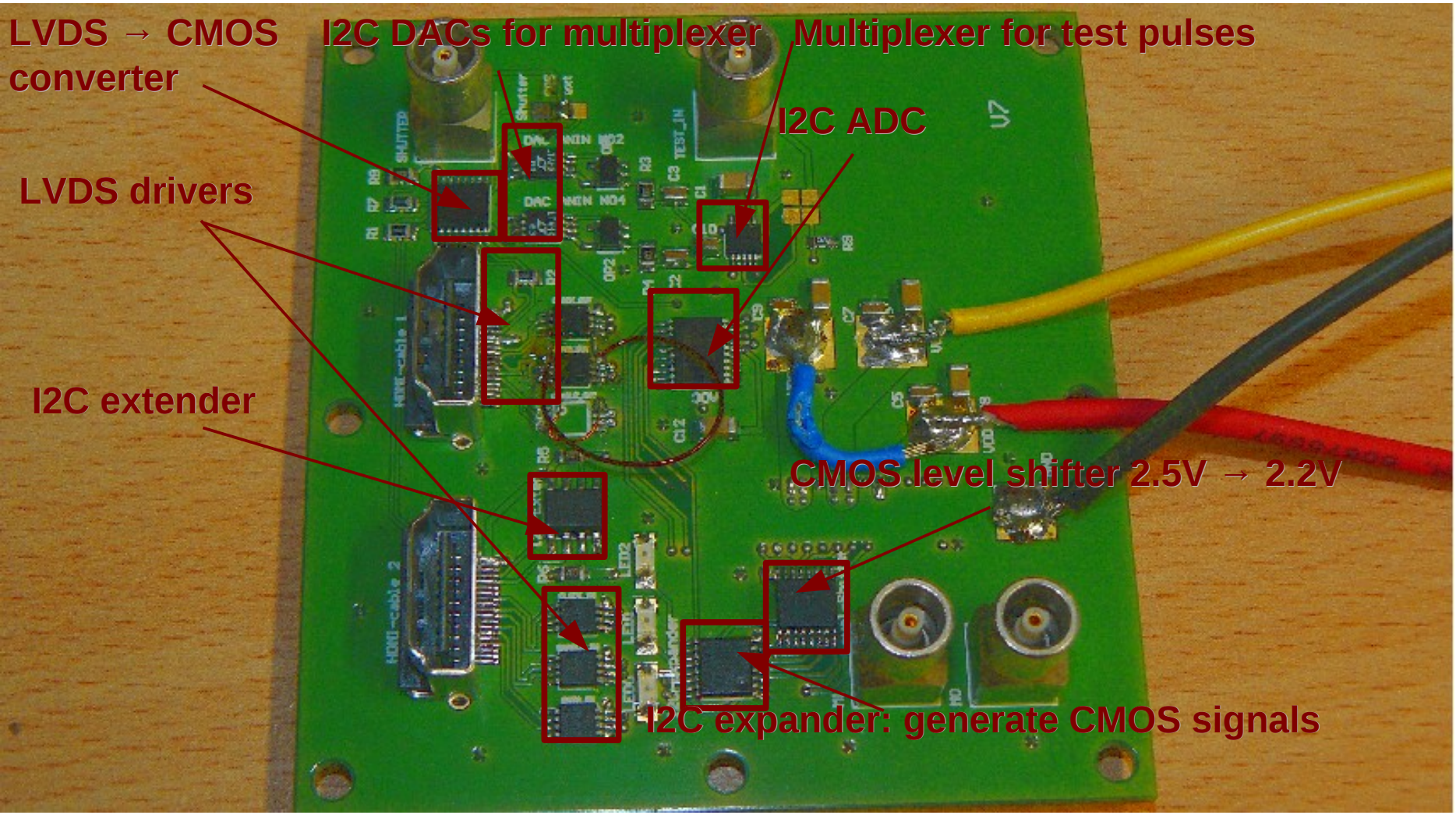
SRS with Timepix chip



SRS FEC – Adapter board – HDMI cables – intermediate board – octoboard

New intermediate board

I2C: standard for small network. Signals: scl (clock), sda (data)
Originally between PCBs next to each other. Several meters distance using extenders.



Status Timepix+SRS Readout

Since 2013 testbeam:

- Upgrade of hardware
  - HDMI cables
  - LVDS drivers
  - No analog/CMOS signals through cables
  - I2C for slow control
- Upgrade of FPGA firmware
  - DDR2 Ram
  - Support ADC and DAC
- Upgrade of DAQ software
  - ADC readout for DAC scan
  - automatic calibration with test pulses from multiplexer
- Redesign of intermediate board and A Card for scale-up
  - Error in layout found and fixed

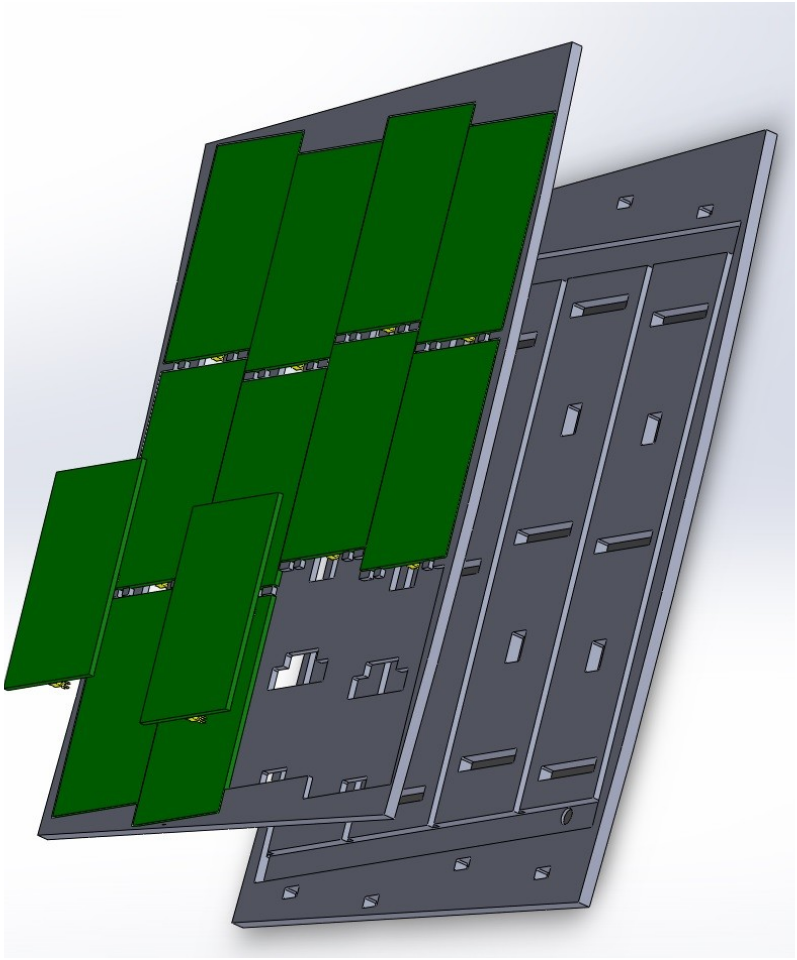
LP module: next steps

~100 chip module

- Project: test a 32 InGrid board in September/October
  - Similar design as 8 InGrid module
  - Expandable to 96 InGrids

- Mechanical design (Johann Tomtschak)
  - CAD drawings in SolidWorks
  - Use water cooling

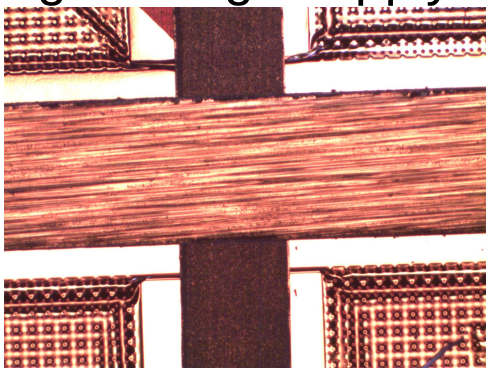
- Construction in workshop:
  - light LP frame
  - chip support structure

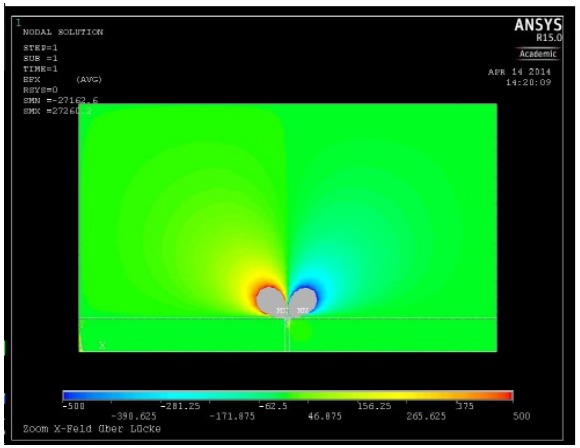


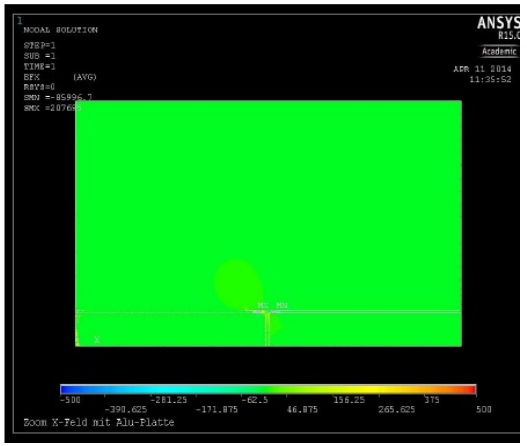
LP module: next steps

~100 chip module

- Field distortions & powering (Kathrin Kohl)
  - Was already critical for a single octoboard
  - Low voltage supply for 4/12 octoboards?
  - High voltage supply





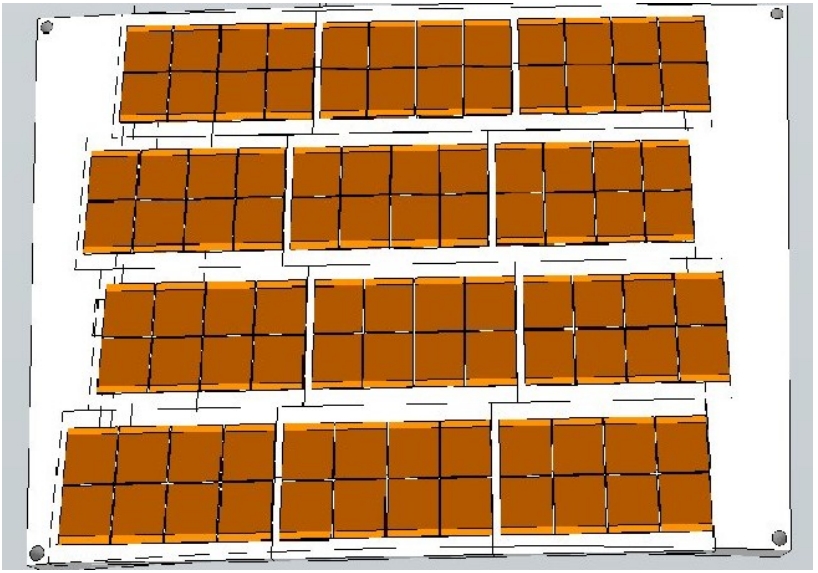


- PCB layout (Jochen Kaminski)
  - Depends on powering
  - Space is limited
  - Need many HDMI cables
- InGrid bonding, testing, quality control, calibration

Summary and Outlook

LCTPC-pixel collaboration is very active:

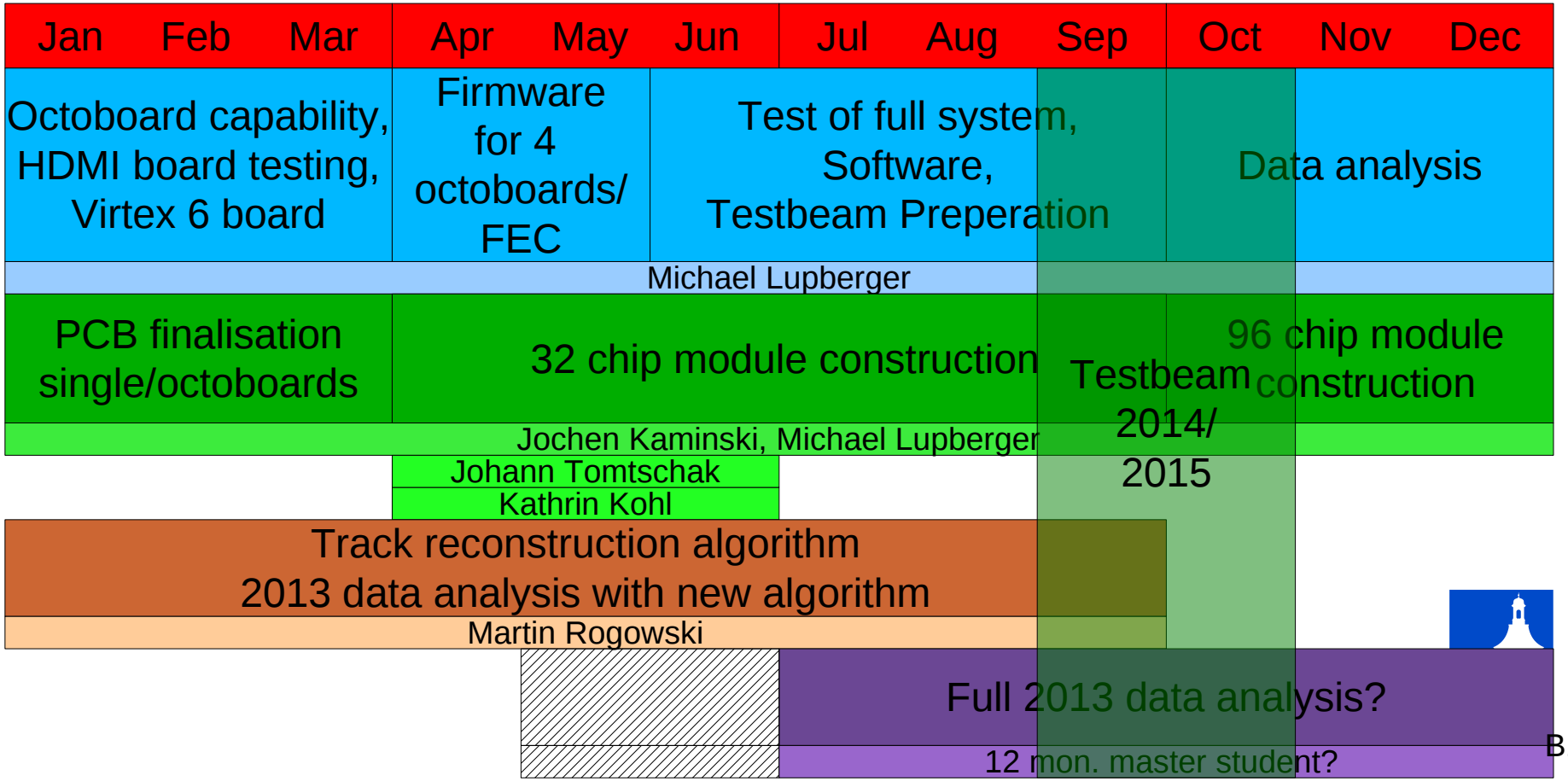
- Analysis of 2013 testbeam data
- Simulation of field distortions
- Development of readout system
- Design of a 32 / 96 chip module



=> Demonstrator for a pixel TPC (for ILD @ ILC)

Schedule for 2014

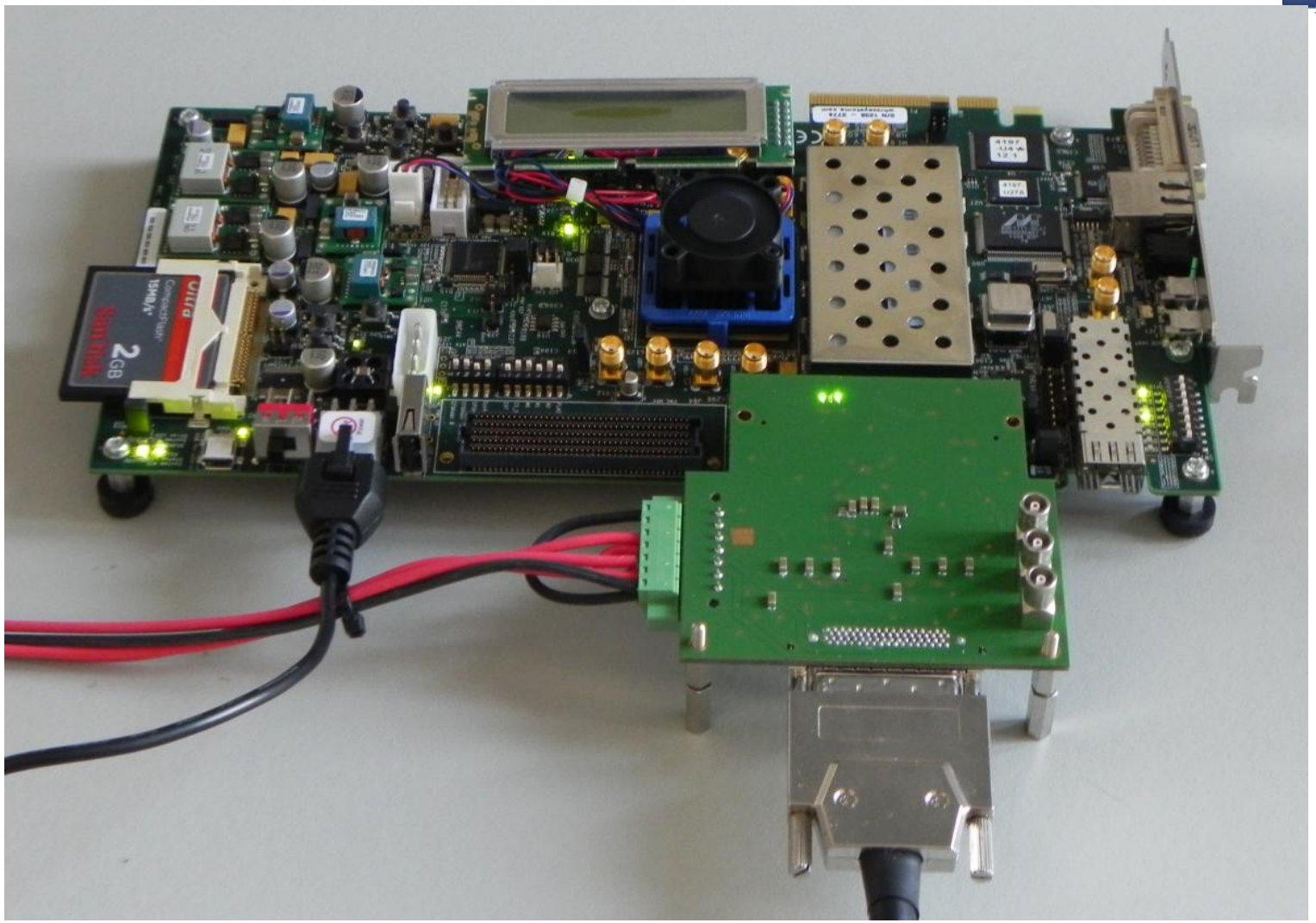
- Additionally:
  - Need/would like to have a master student for full analysis
  - Data analysis of new testbeam data
  - 96 chip module test in 2015 ?



We can provide soon:

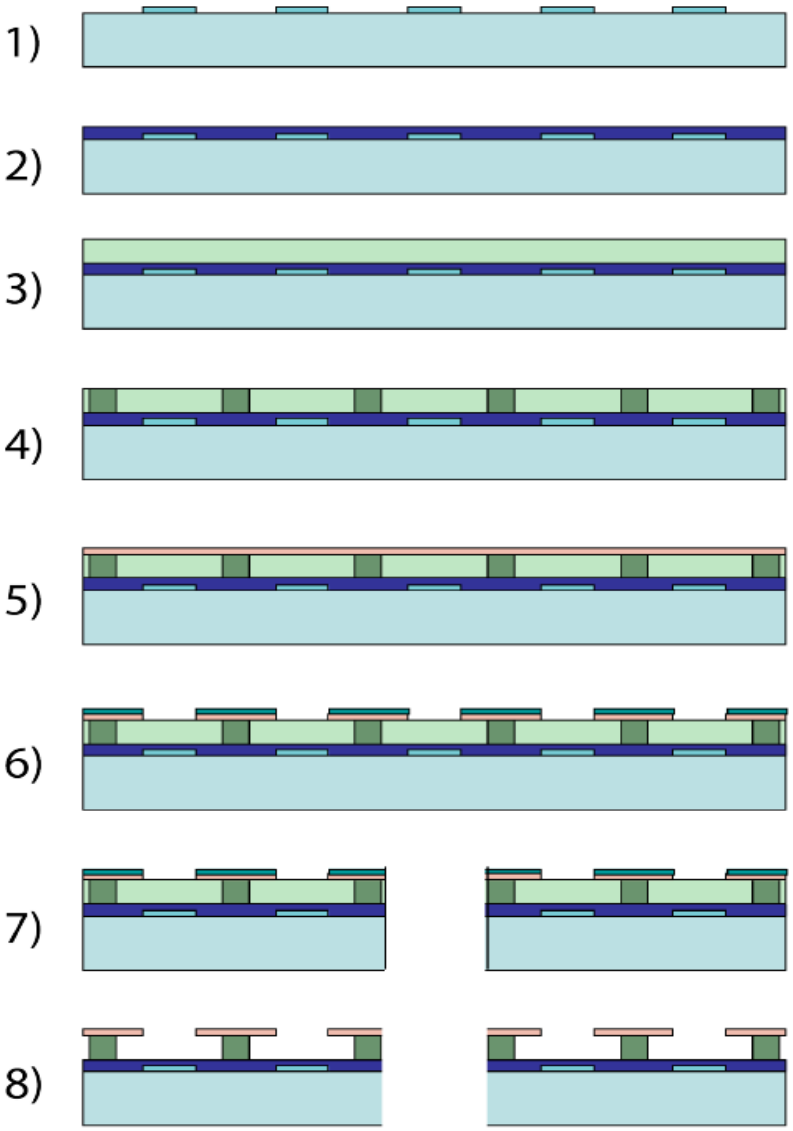
- SRS (A card) with full functionality (for MUROS compatible intermediate board)
  - Users with SRS can plug and play Timepix
  - Users can use MUROS or SRS for same detector
  - Comparability study, documentation
- V6 evaluation board (VHDCI cables MUROS compatible):
  - Updated adapter board, I2c network tested
  - ADC, DAC control and readout with i2c (firmware, software)
  - Users with V6 board can plug and play Timepix
    - Users can use MUROS or SRS for same detector
    - Comparability study, documentation:
  - Use in CAST

Xilinx Evaluation board



Virtex 6 FPGA

Production on wafer scale



1) Probing and cleaning of the wafer

2) Adding Si_x N_y protection layer

3) Application of the SU-8

4) UV-Exposure of the SU-8

5) Application of the grid

6) Patterning of the grid

7) Dicing of the wafer

8) Development of the SU-8

Preliminary Analysis: Cuts

Dataset for first analysis:

z-scan, B=0 T, E_{Drift} = 230 V/cm (D_T = 311 µm/√cm)

⇒ tracks parallel to x-axis

Cuts:

- Only hits within shutter window
- More than 200 hits per track

Preliminary Analysis: Cuts

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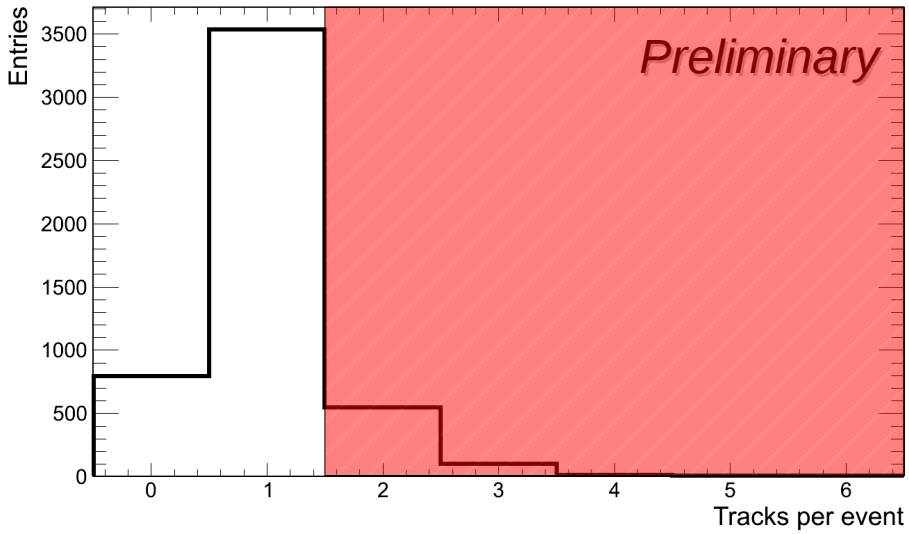

Cuts:

- Only hits within shutter window
- More than 200 hits per track

- Only single track events

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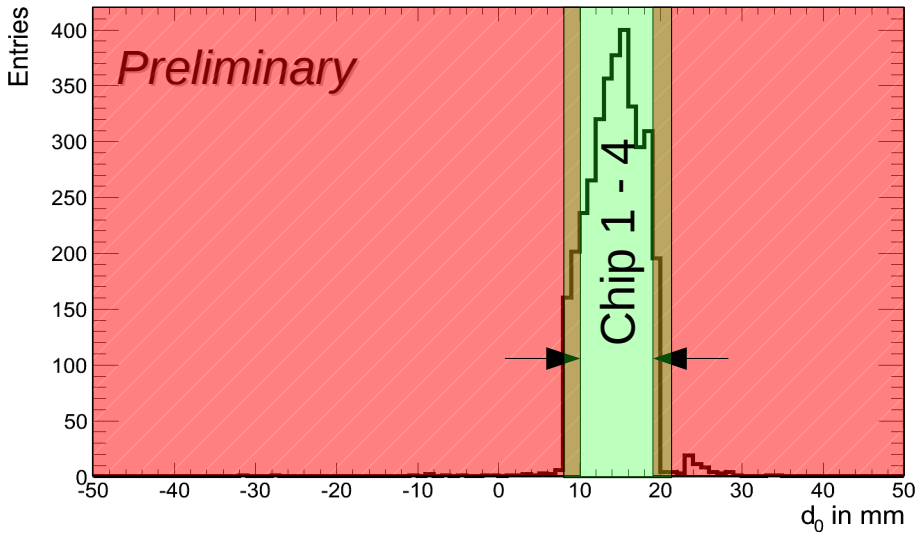
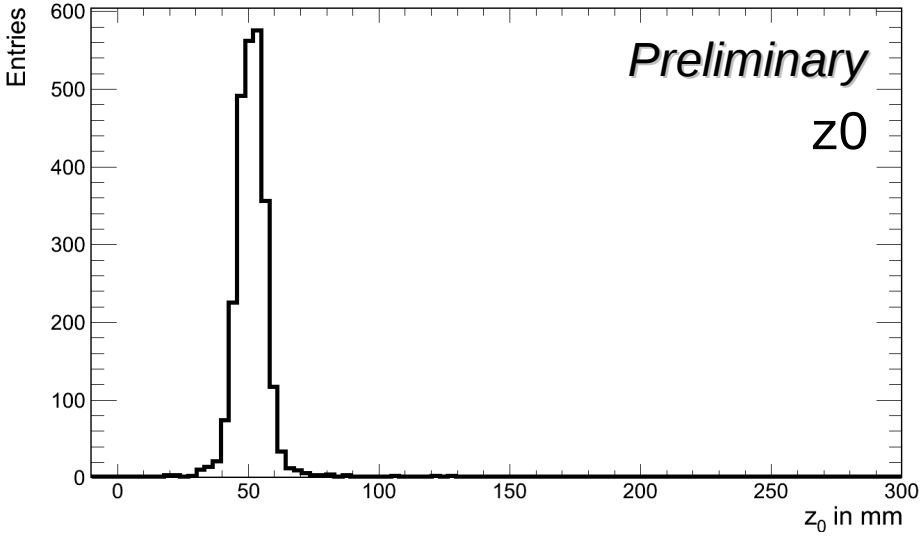


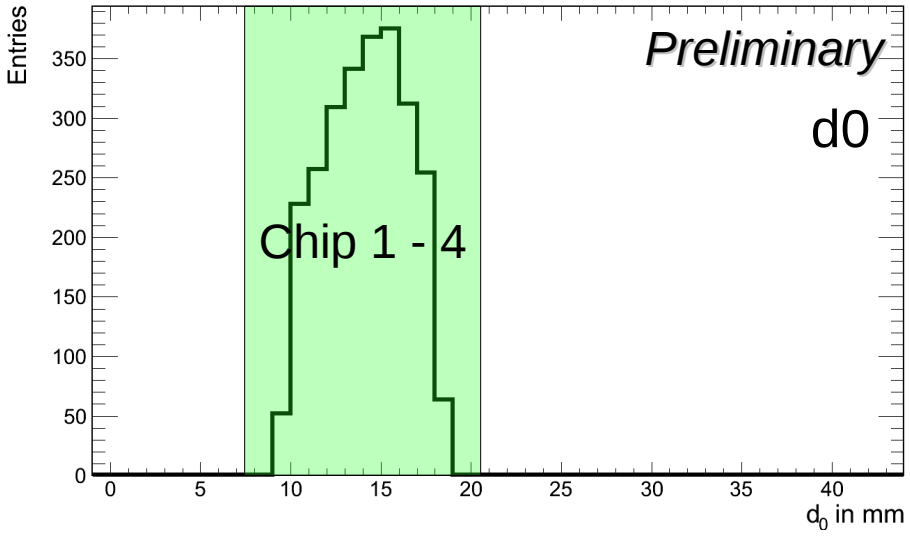
Cuts:

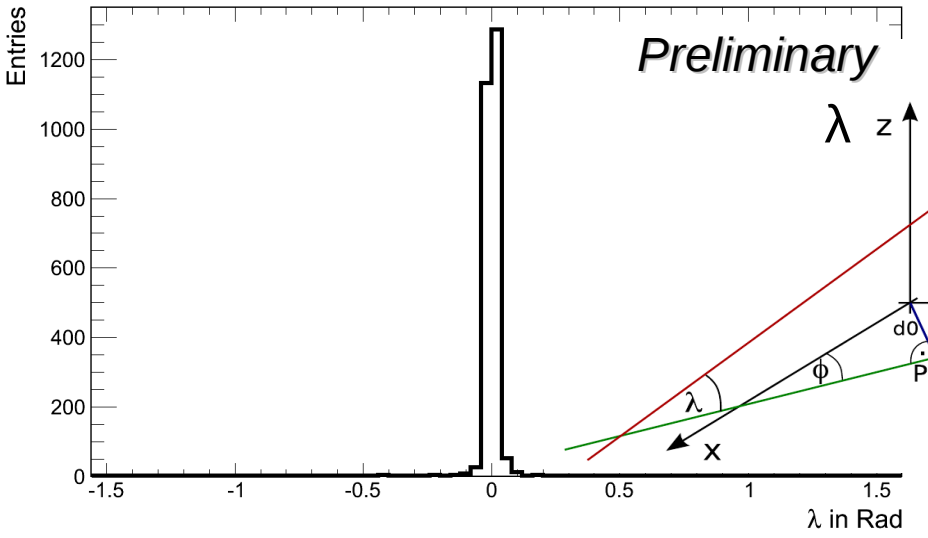
- Only hits within shutter window
- More than 200 hits per track
- Only single track events
- Tracks centred on lower chip row (z dependent)

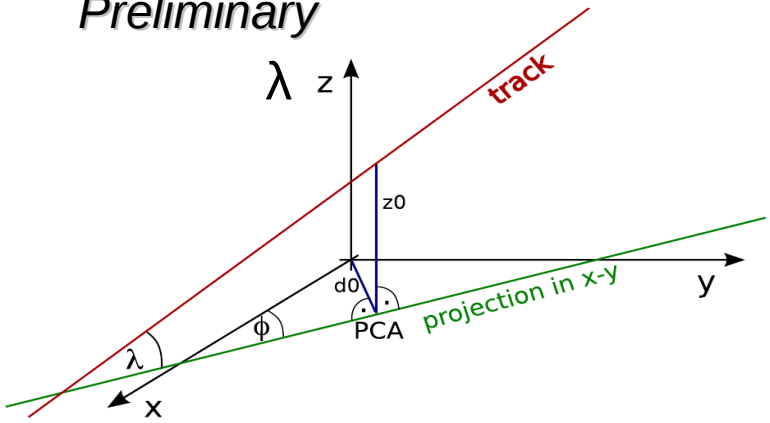
Track parameters

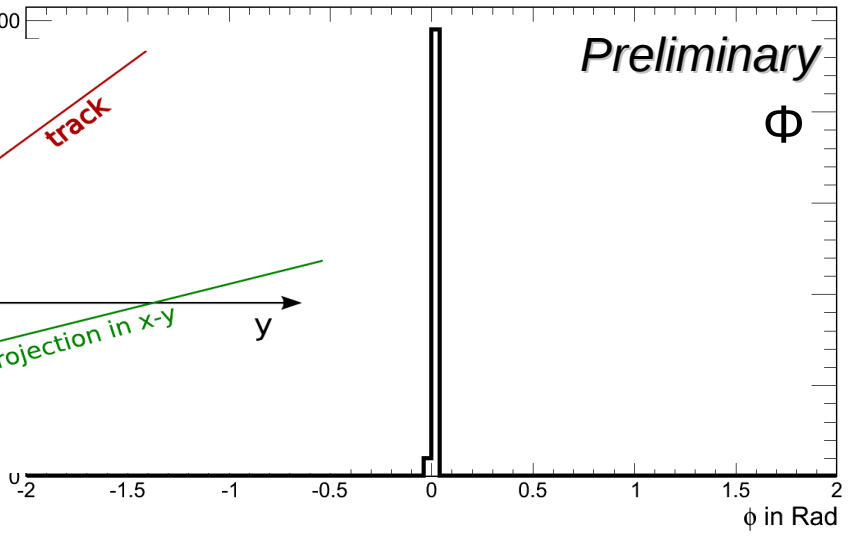
Run: z = 5.58 cm, B = 0 T



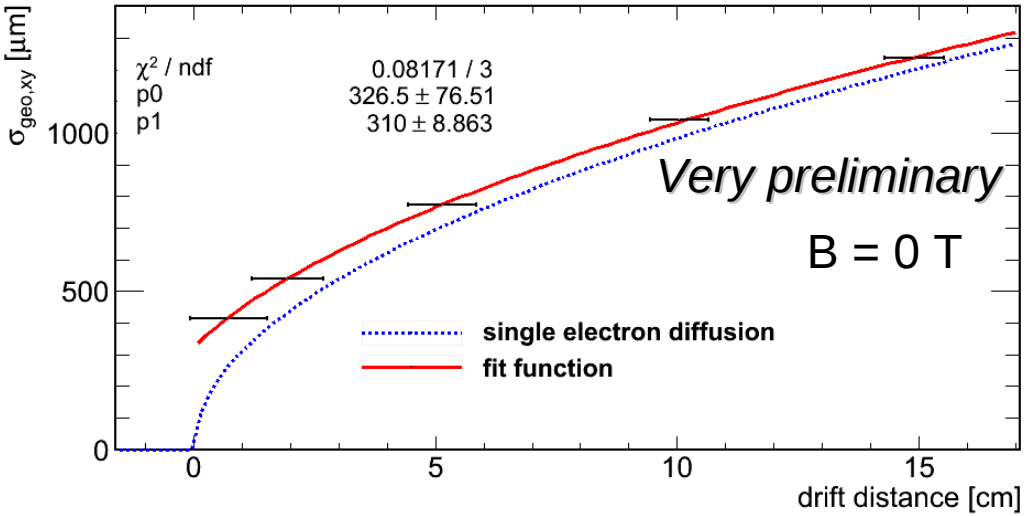






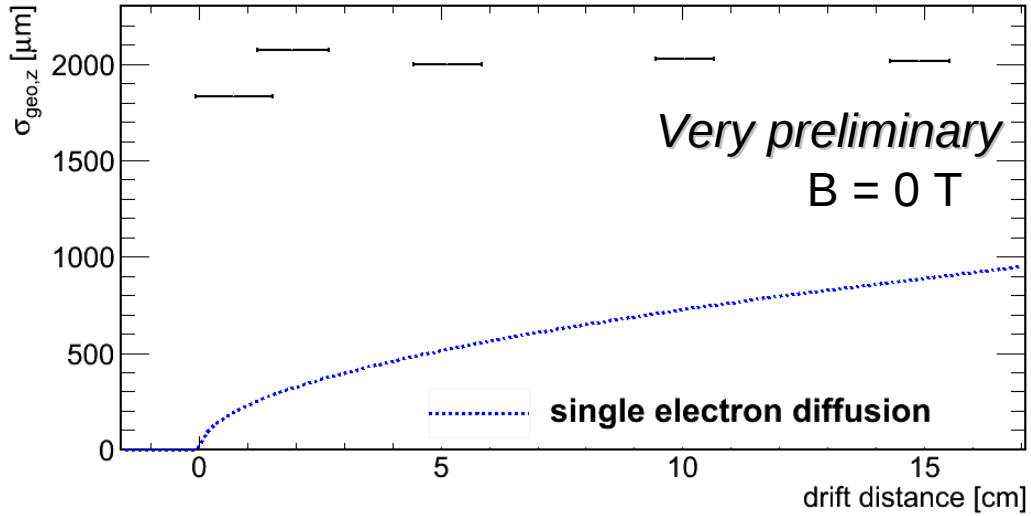


Preliminary z-scan results



Fit function $f(x) = \sqrt{P0^2 + P1^2 \cdot z}$

P0: intrinsic x-y resolution 327 µm
dominated by field distortions
P1 = 310 µm/√cm:
diffusion in T2K for E = 230 V



z resolution dominated by
- Clock frequency (25 ns time bins)
- Fast T2K gas (v_{Drift} ≈ 73 mm / µs)
- Timewalk effect