A pixel TPC for the Linear Collider: Towards a demonstrator module

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GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

LCTPC Collaboration Meeting
DESY 30.06.2014

Outline

- LCTPC-pixel collaboration
- Timepix Chip
- 2013 Testbeam and data analysis
- New demonstrator module
- Summary

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LCTPC-pixel collaboration

- 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 demonstator module for a pixel-TPC

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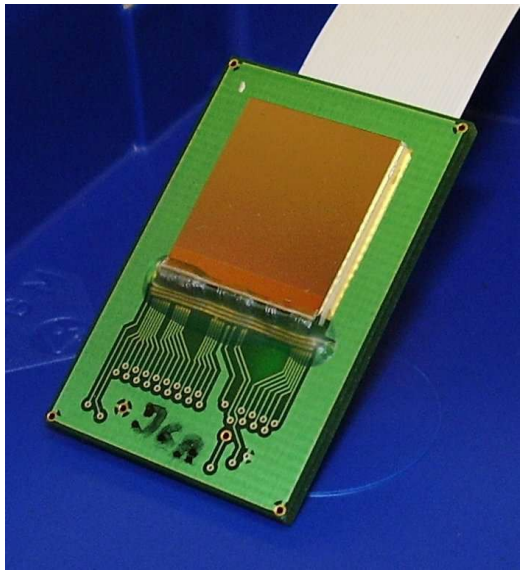
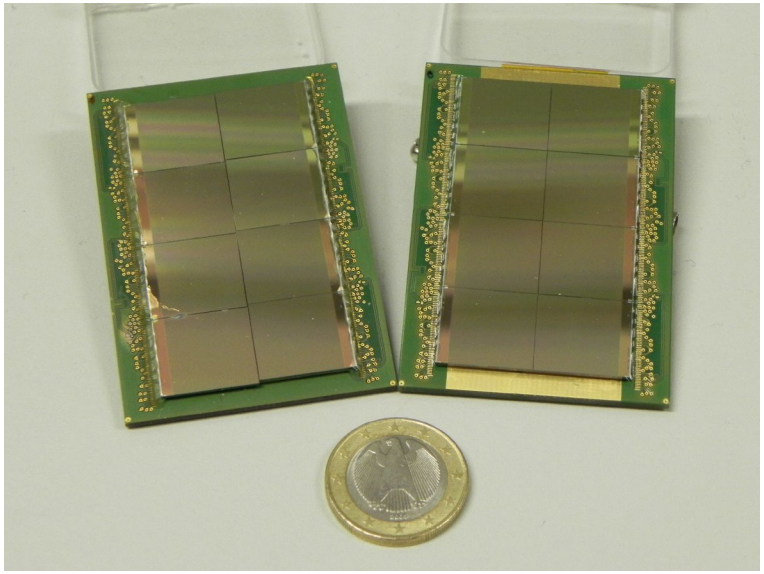
Timepix chip

- Universal readout chip
- Properties:
  - active surface: 1.4 x 1.4 cm²
  - pixel size 55 x 55 µm²
  - 256 x 256 pixel array
  - 14 bit counter in each pixel (ToA or ToT)
  - Noise threshold ~500e^- (ENC ≈ 90e^-)





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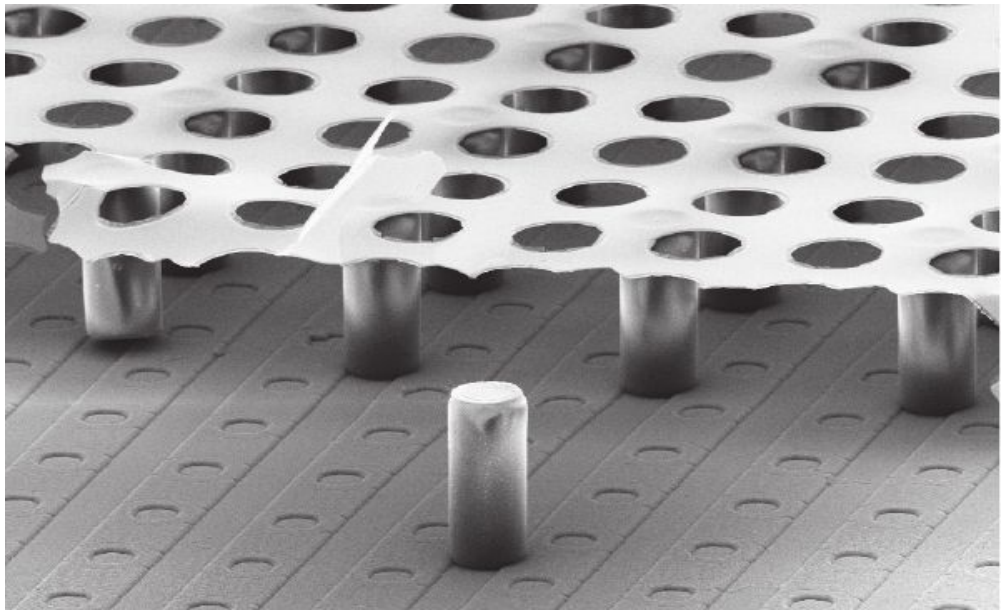
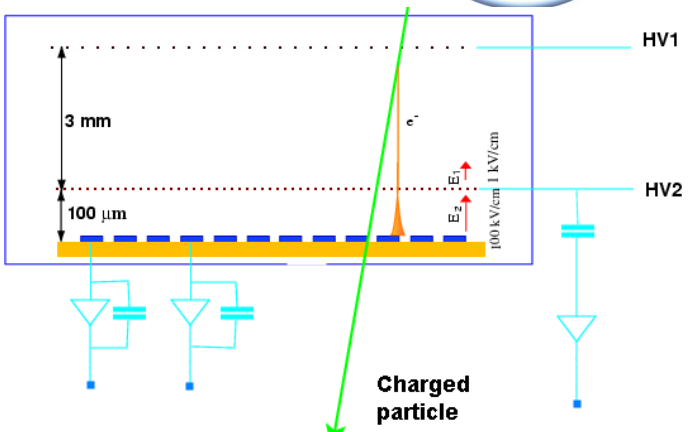
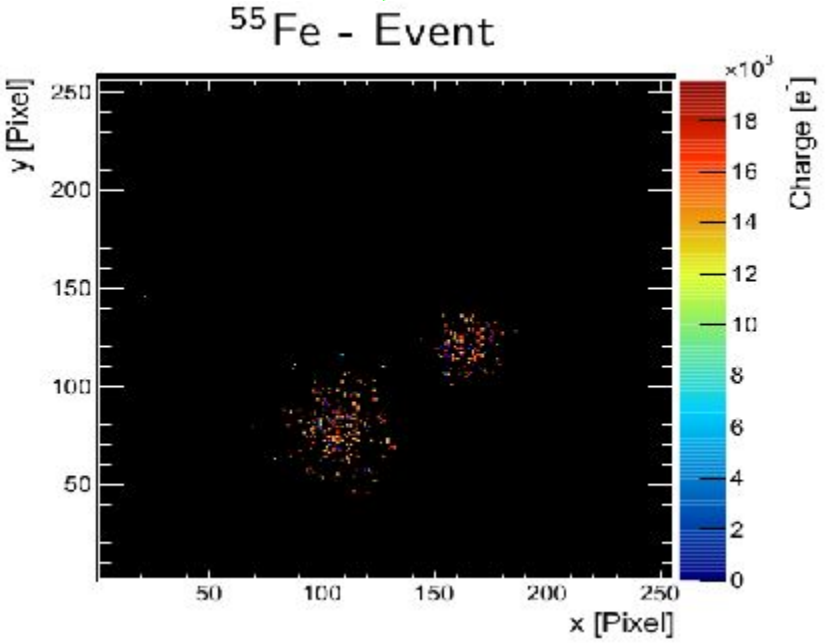
Timepix+Micromegas=InGrid

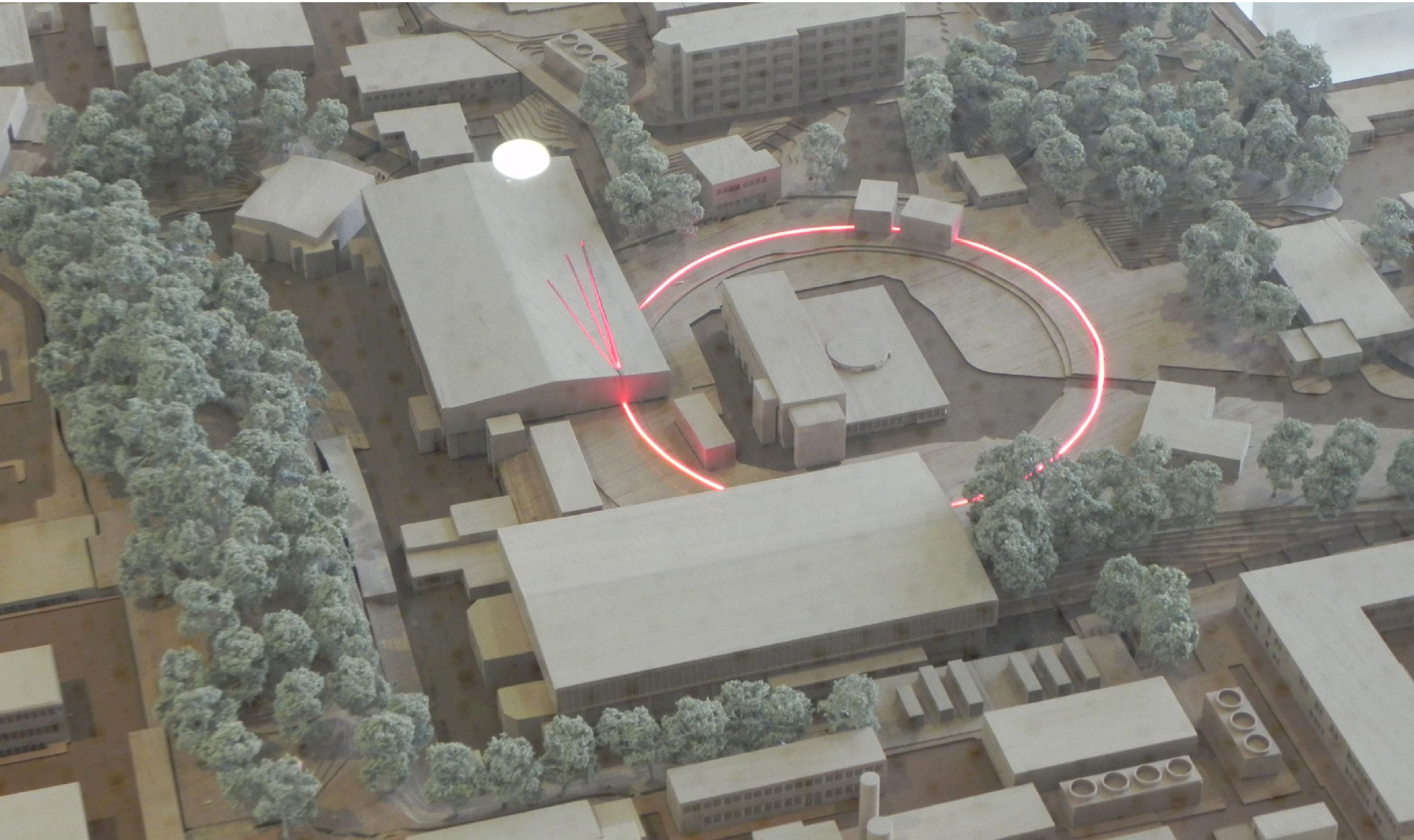
- Aluminium mesh on chip
- Use photolithographic process
  - Hole to pixel alignment
  - Pillar height uniformity





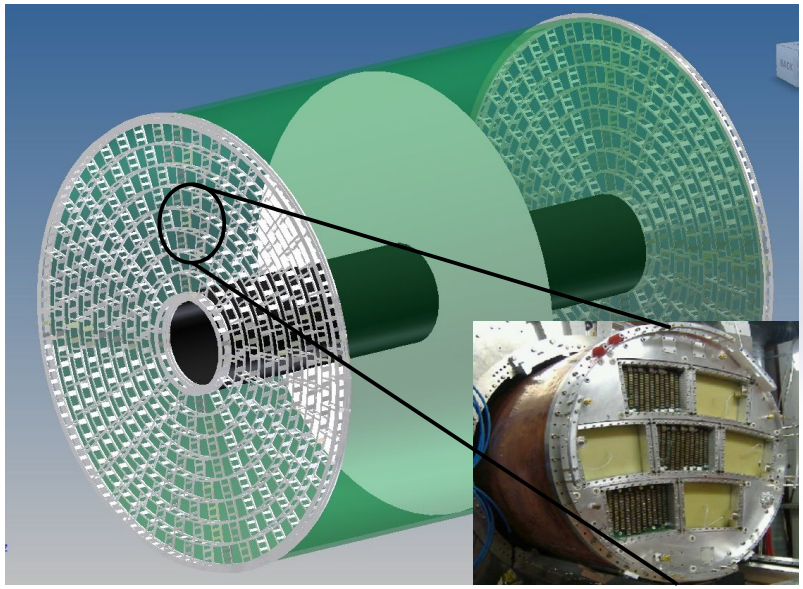


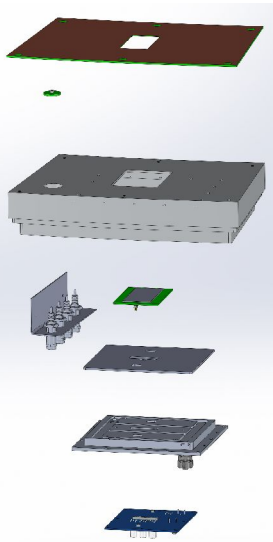
2013 test beam

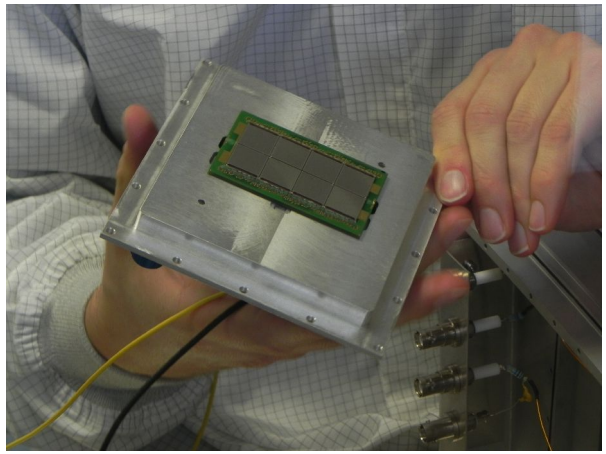


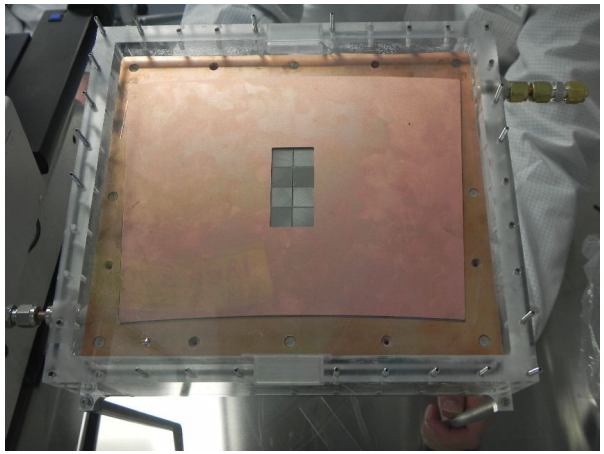
2013 test beam

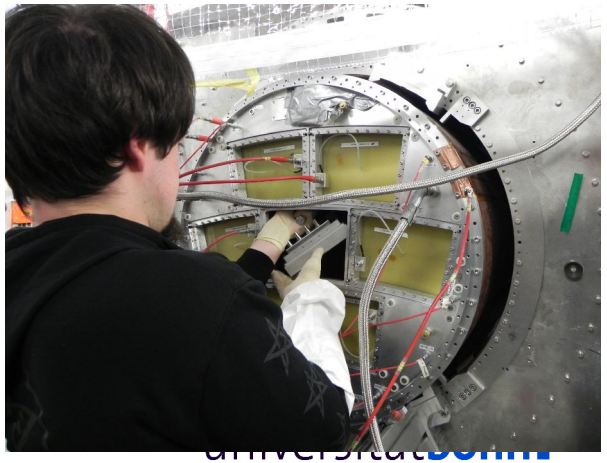
Setup at DESY



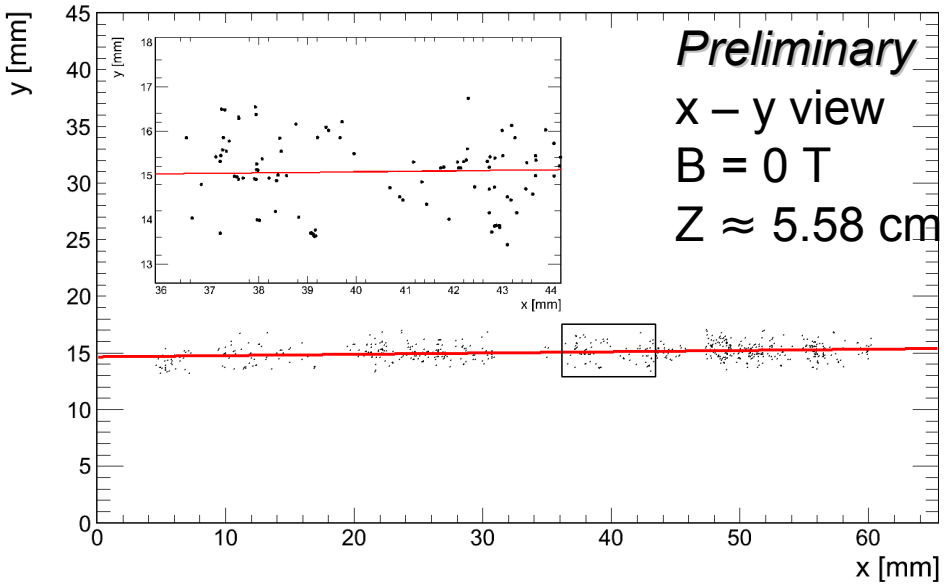


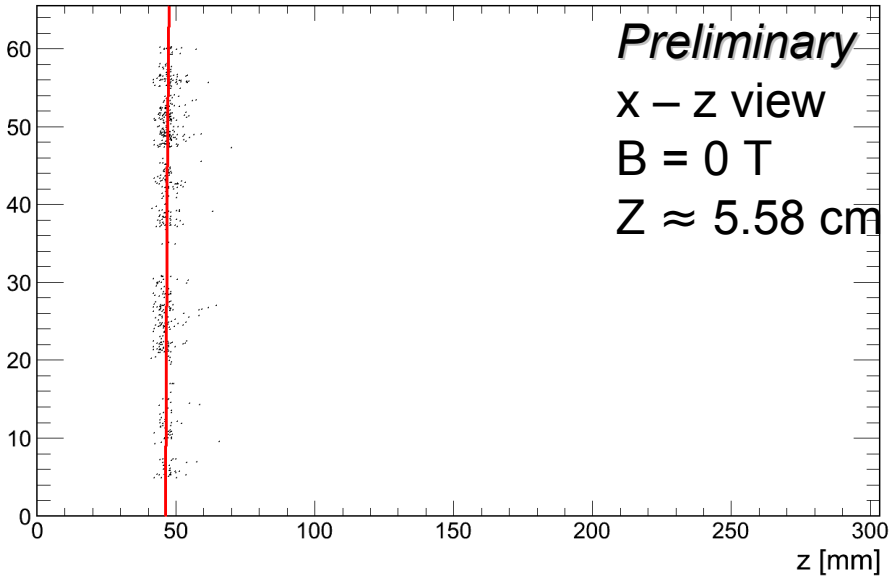


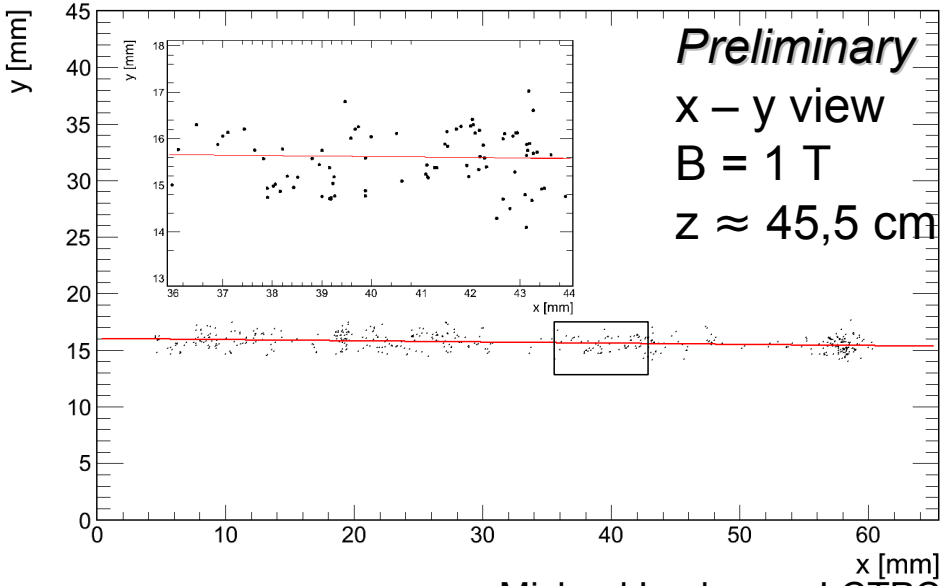




Reconstructed tracks







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LP module: next steps

~100 chip module (cover 50% of area, 6 mio. channels)

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

- Mechanical design (Bachelor student: Johann Tomtschak)
  - CAD drawings in SolidWorks
  - Construction of light LP frame in workshop
  - Construction of chip support structure in workshop
  - Use water cooling

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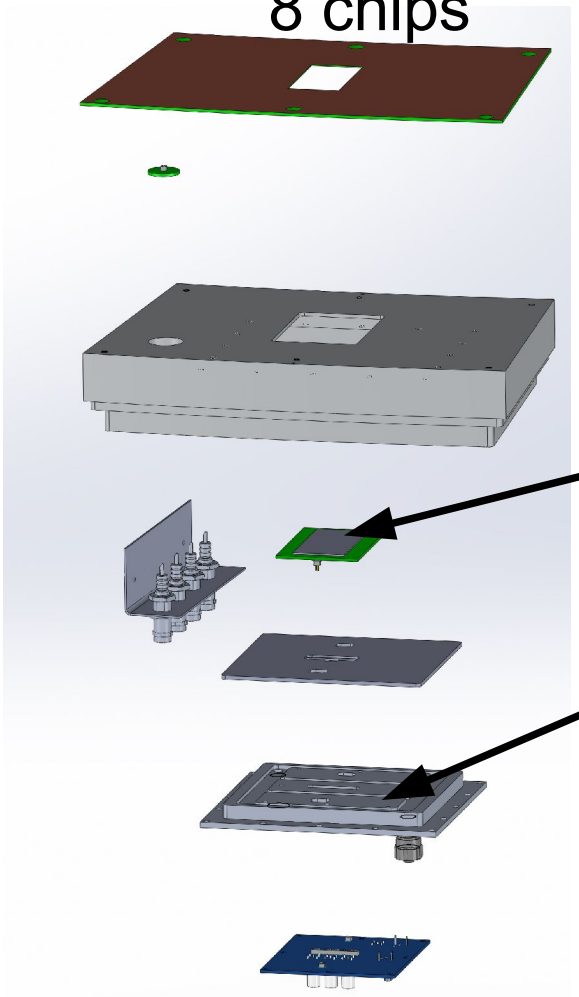
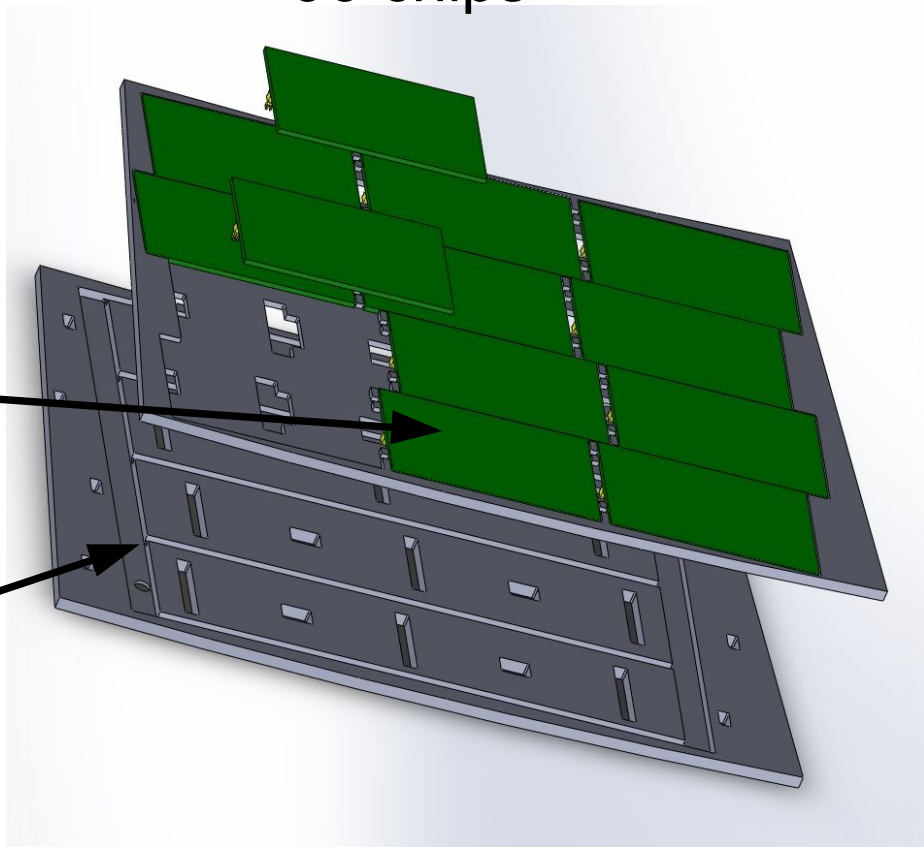
InGrid modules

2013
8 chips



2014
96 chips



InGrid octoboard

water channels for cooling

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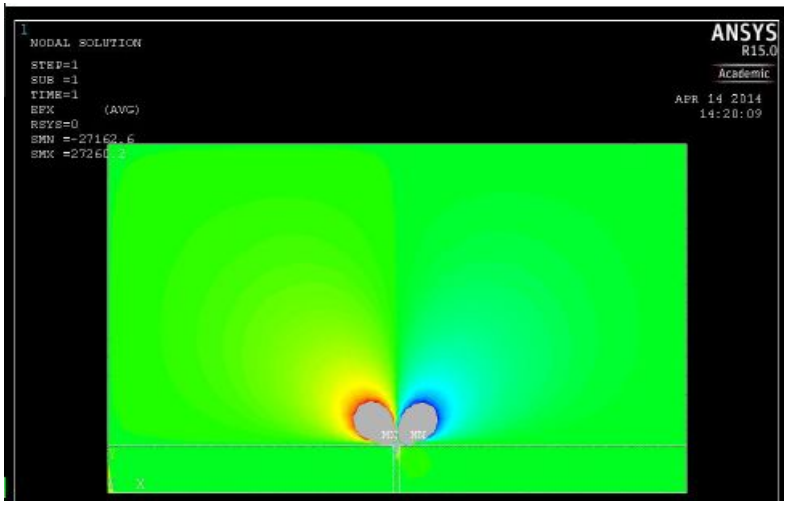
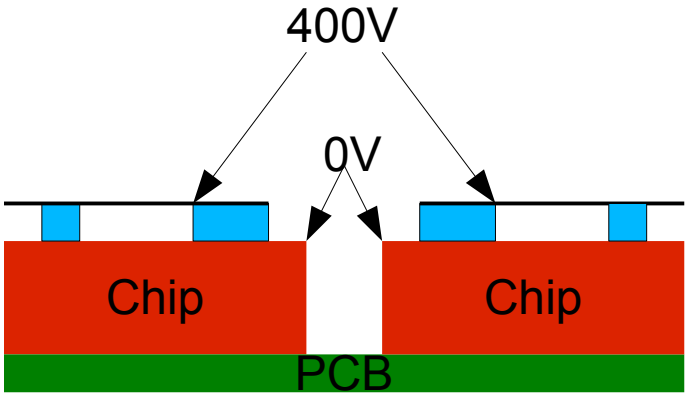
LP module: next steps

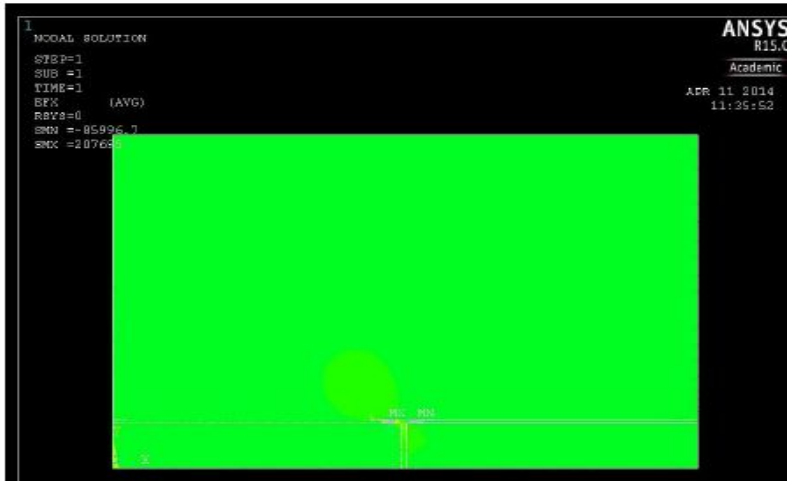
~100 chip module

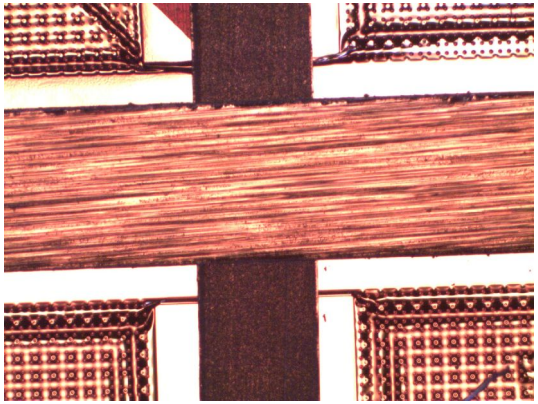
- Powering (Bachelor student: Katrin Kohl)
  - Was already critical for a single octoboard
  - Low voltage supply for 4/12 octoboards?
  - High voltage supply
- Field distortions between chips (Katrin Kohl)
  - Simulation, implementation and measurements with „road-like strips“
- PCB layout (Jochen Kaminski)
  - Depends on powering
  - Space is limited
  - Need many HDMI cables
- InGrid bonding, testing, quality control, calibration

Field distortions









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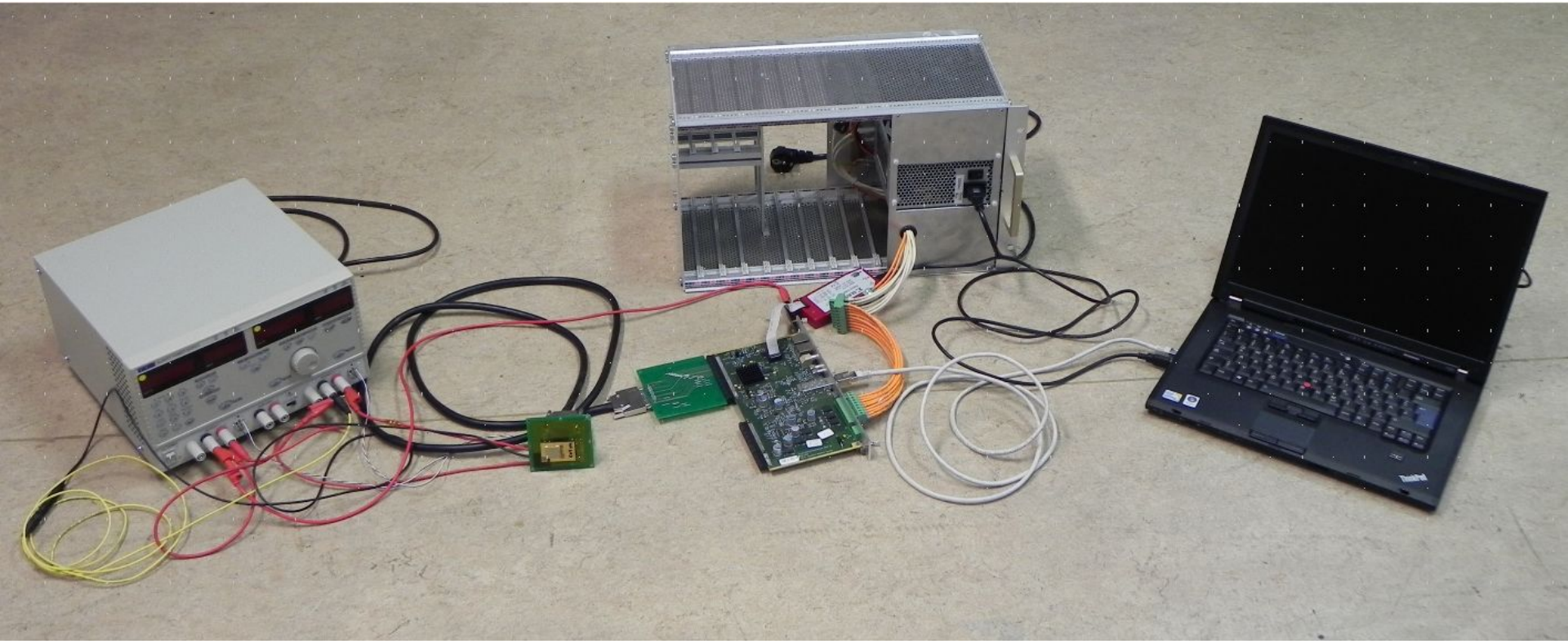
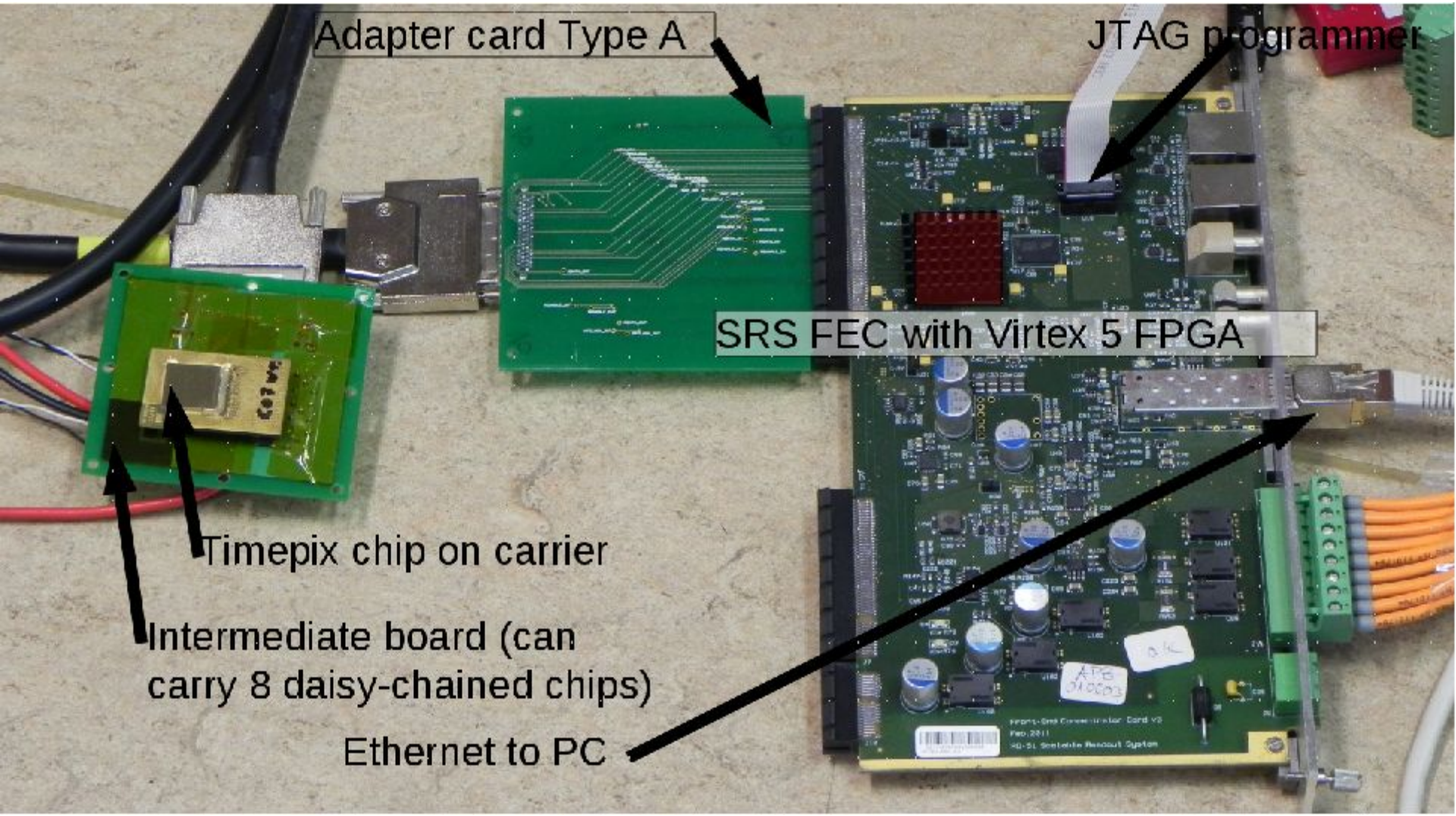
Readout system

Scalable Readout System (RD51, CERN)

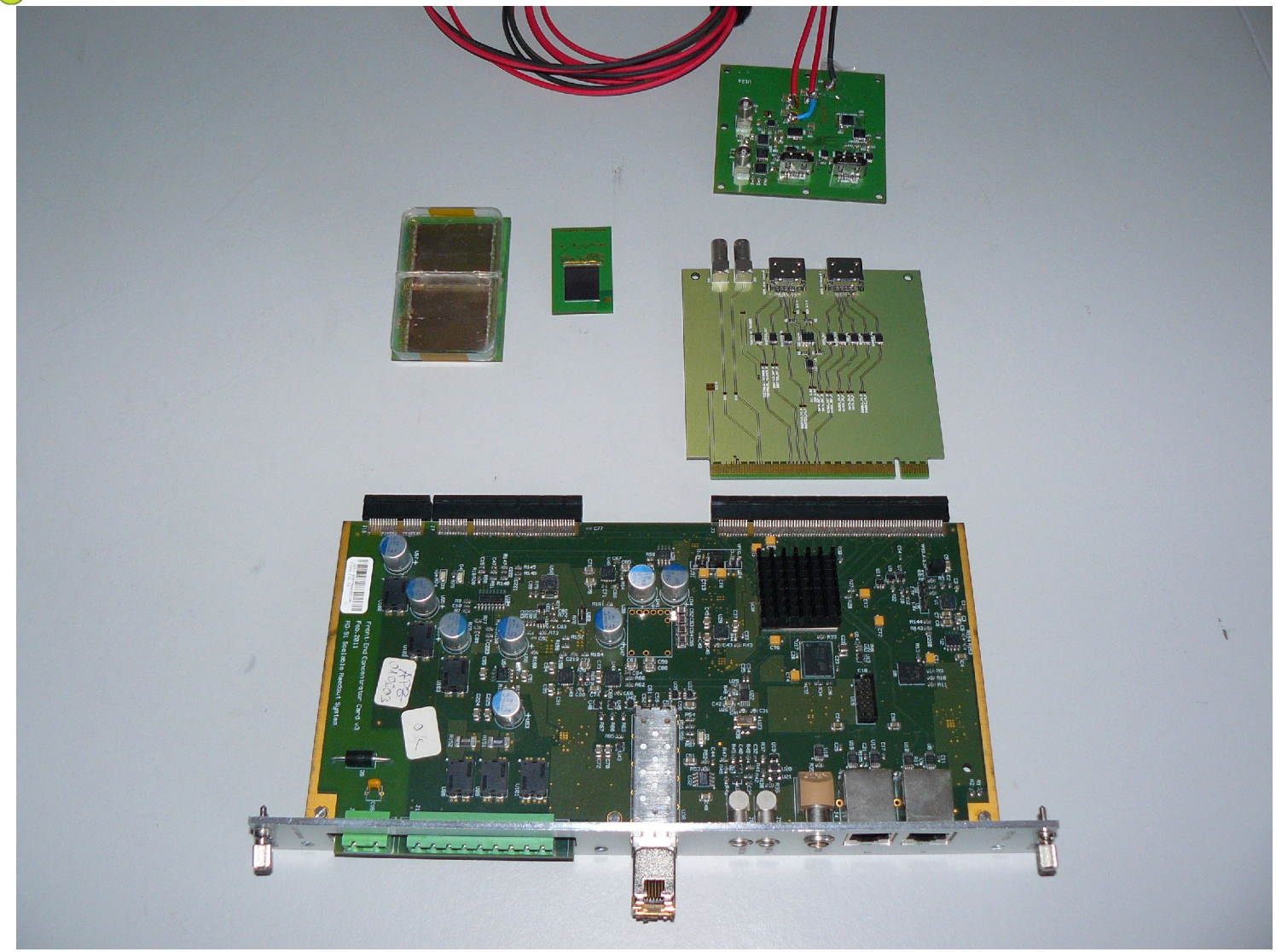


Chain: Chip – Adapter card+FEC – Computer

SRS VHDCI


Adapter card Type A
JTAG programmer
SRS FEC with Virtex 5 FPGA
Timepix chip on carrier
Intermediate board (can carry 8 daisy-chained chips)
Ethernet to PC

SRS HDMI



Readout system status

- FEC5 based readout worked very well at testbeam
  - Virtex5 FPGA, DDR2 RAM
  - Readout of one octoboard
  - Updates of firmware
  - New hardware e.g. HDMI cables, intermediate boards
- For 96 chip module:
  - 4 octoboards / FEC
  - 3 FECs
- FEC6
  - Virtex6 FPGA, large internal memory
  - 3 FEC6 arrived in Bonn in April
  - Code migration started
  - Design of LP module shaped intermediate board for 12 octoboards started

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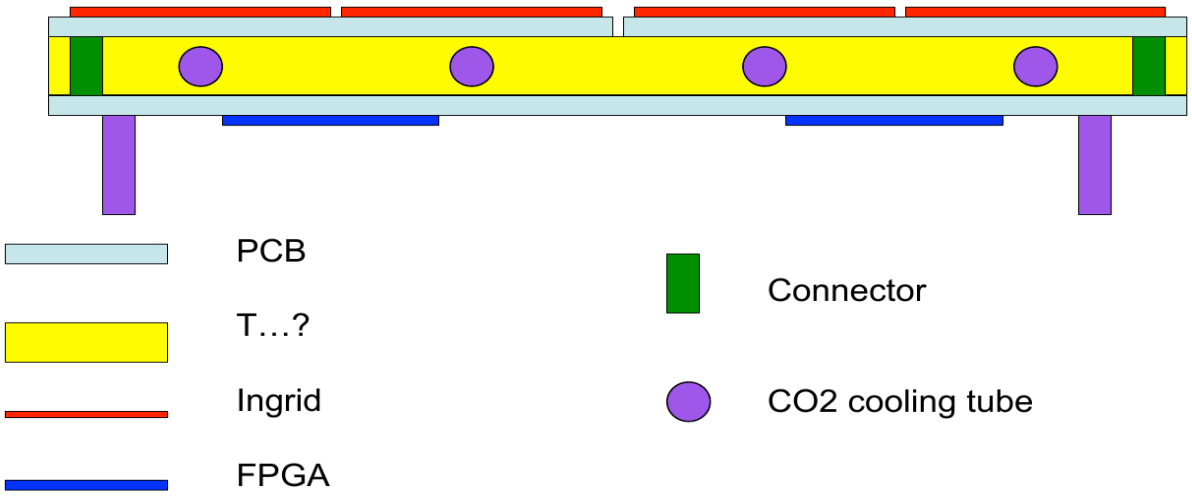
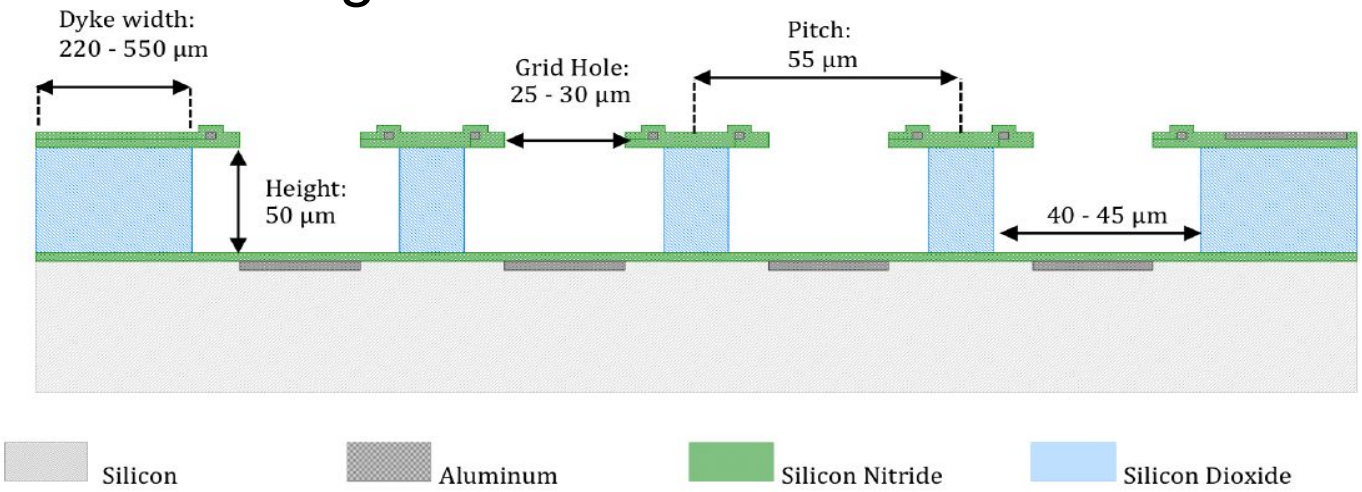
Outlook

- Fully integrated module (Jan Timmermans)



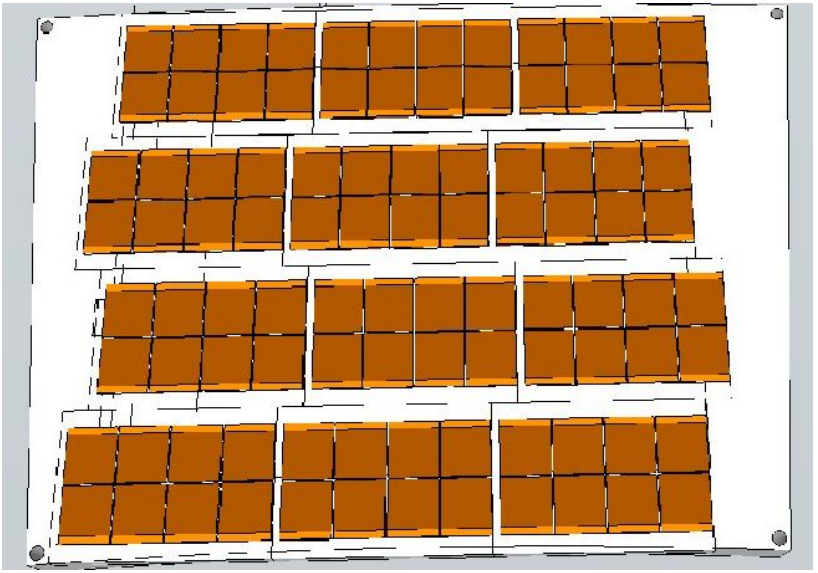
- Timepix3
- All ceramic grid



Summary

Pixel-TPC project advances very well

- Successful testbeam 2013
- Data analysis ongoing
- Development of readout system
- Design of a 32 / 96 chip module



=> Demonstrator for a pixel-TPC at the end of this year

Timepix 3, Ceramic grid

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Collaborators

LCTPC-pixel:

- CEA Saclay: Andrii Chaus, David Attié, Maxim Titov, Paul Colas
- DESY: Felix Müller, Ralf Diener, Ties Behnke
- NIKHEF: Fred Hartjes, Harry van der Graaf, Jan Timmermans, Rolf Schön, Wilko Koppert
- Uni Bonn: Alexander Deisting, Christoph Krieger, Jochen Kaminski, Johann Tomtschak, Kathrin Kohl, Klaus Desch, Michael Lupberger, Robert Menzen, Thorsten Krautscheid, Yevgen Bilevich,
- LAL Orsay/Uni Kiew: Sergey Barsuk, Oleg Bezshyyko, Oleksiy Fedorchuk
- Uni Siegen: Amir Shirazi, Ivor Fleck

Special thanks to: Fraunhofer IZM, LCTPC Collaboration, DESY testbeam support

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Readout system

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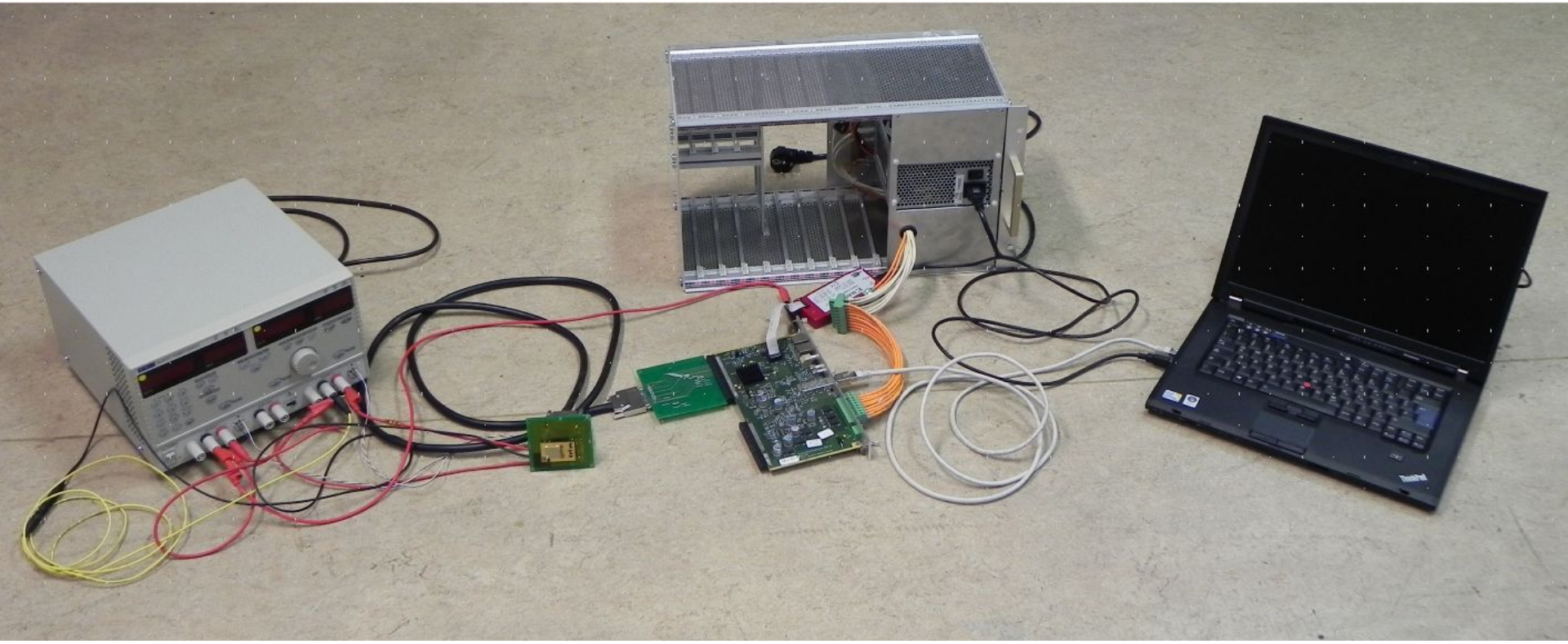
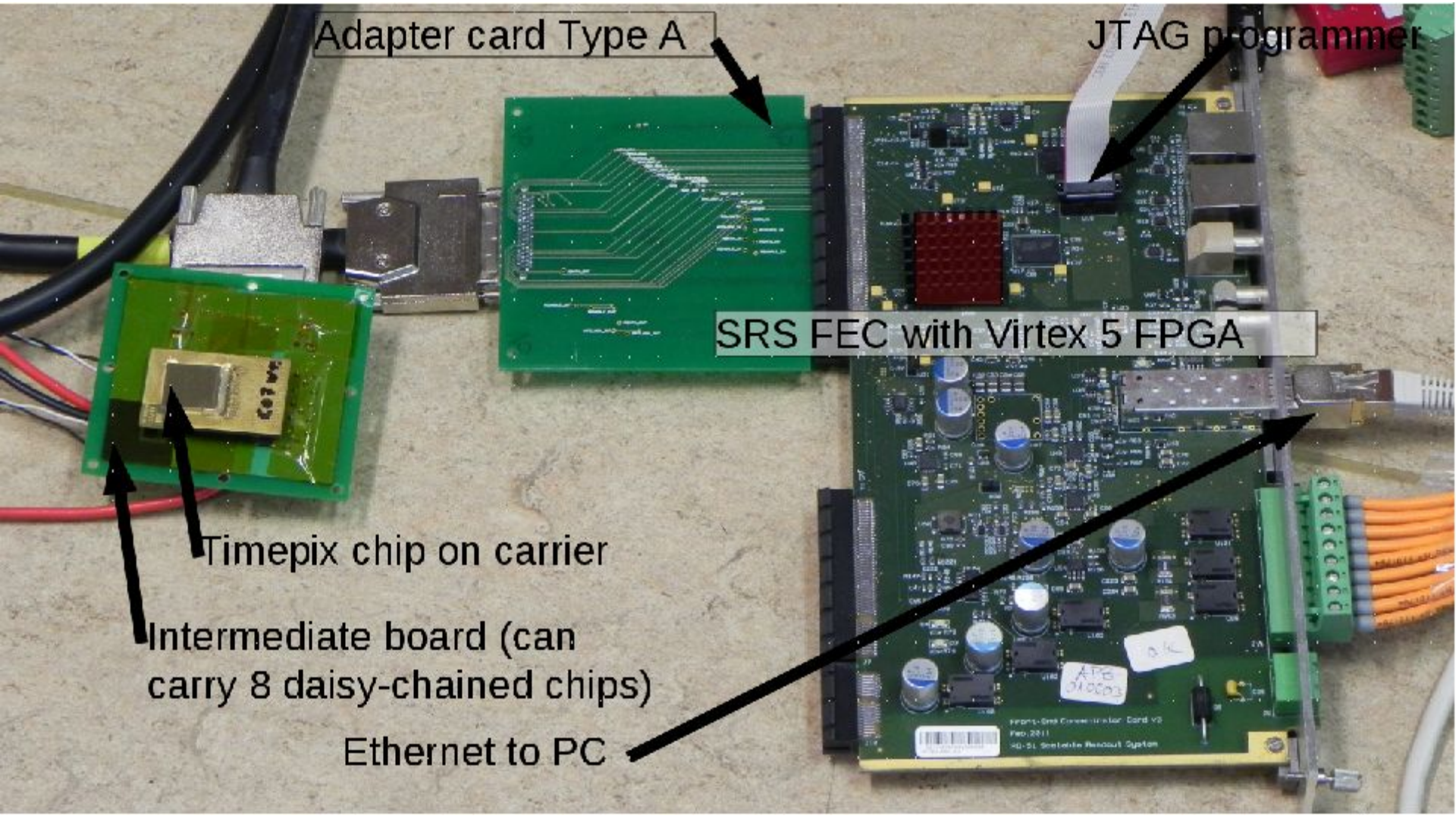
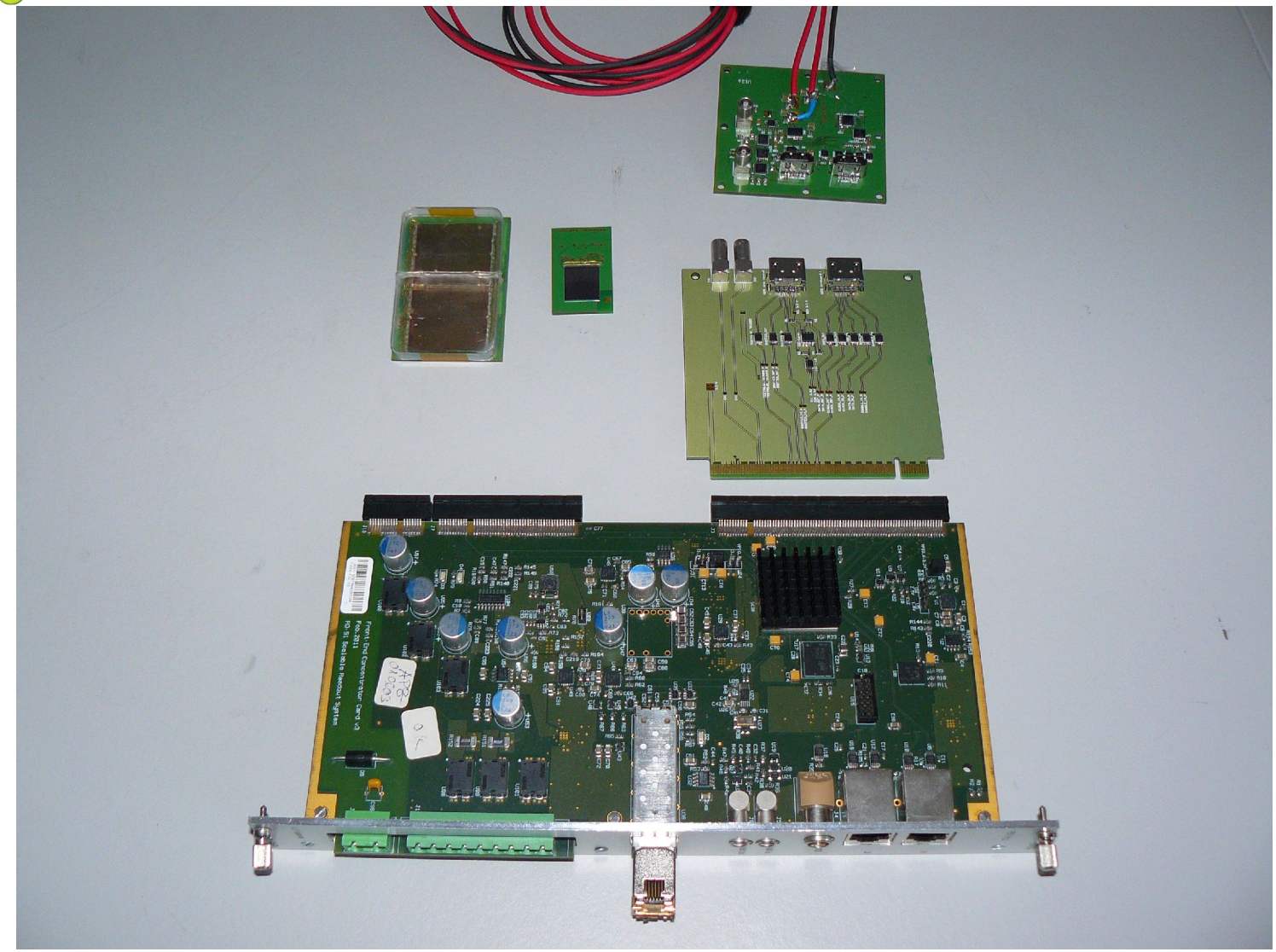


Chain: Chip – Adapter card+FEC – Computer

SRS with Timepix chip



SRS HDMI



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

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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

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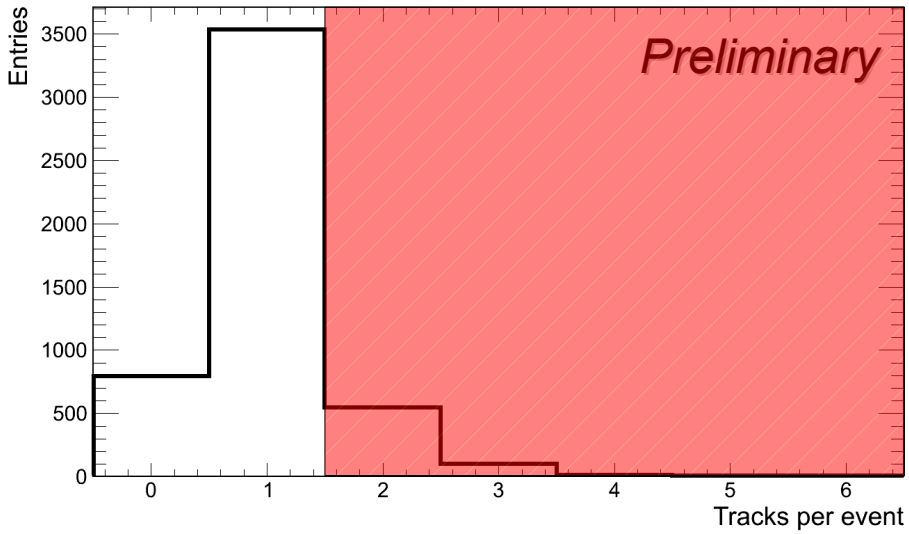

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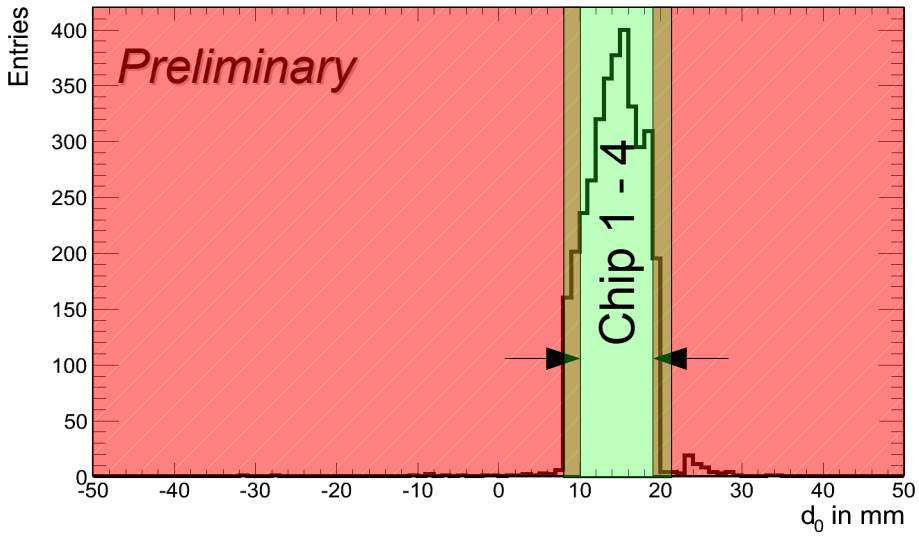

Cuts:

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

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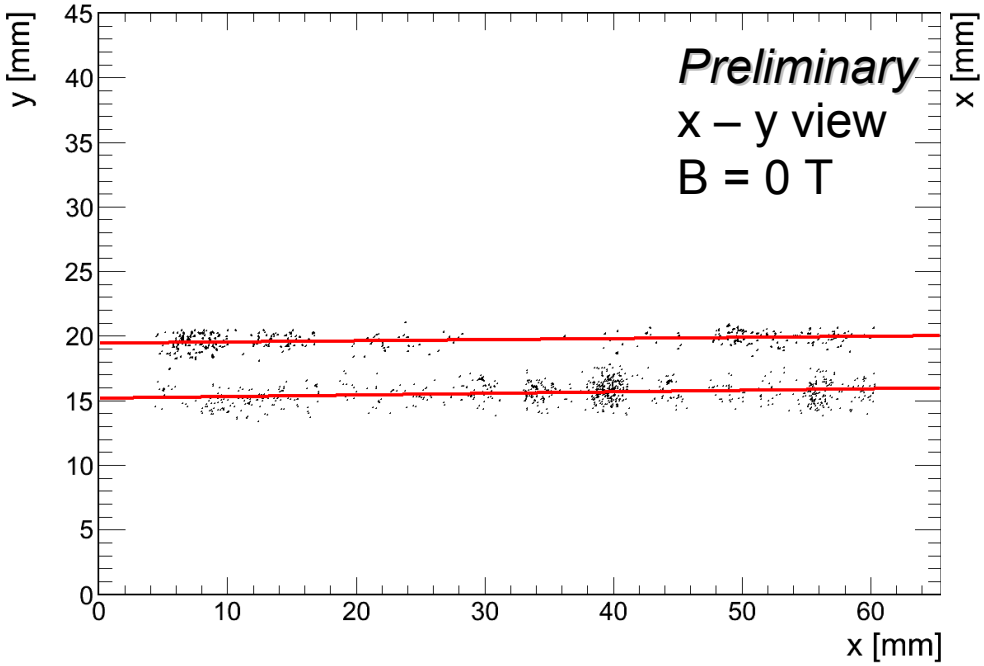
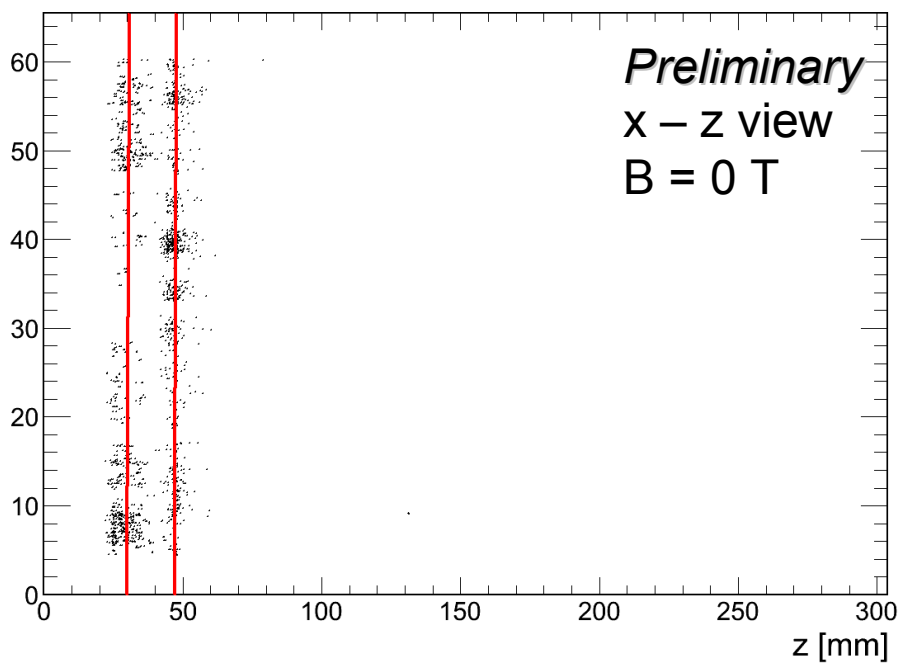
Reconstructed double tracks





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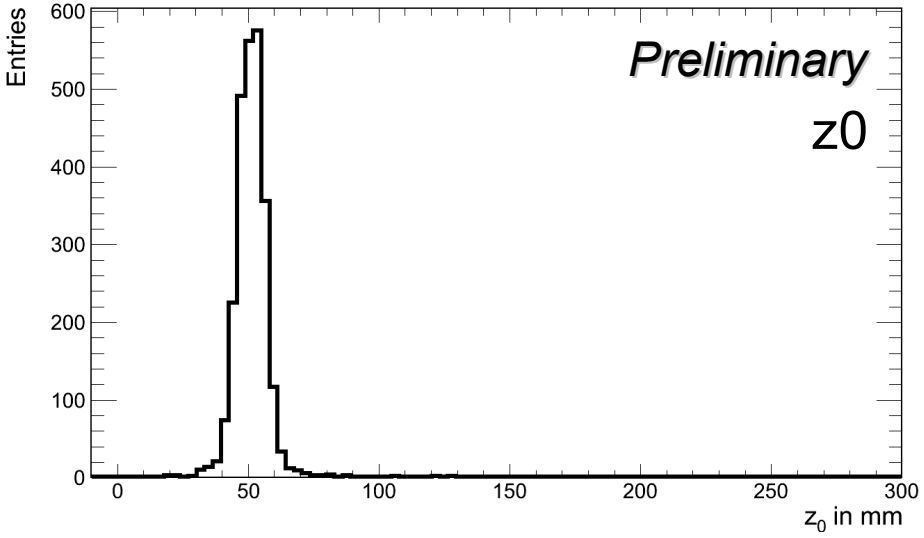
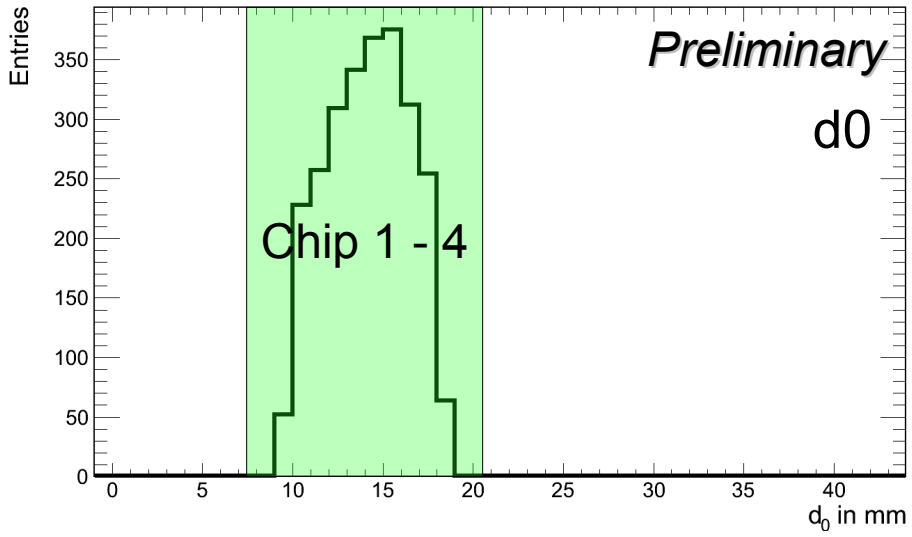
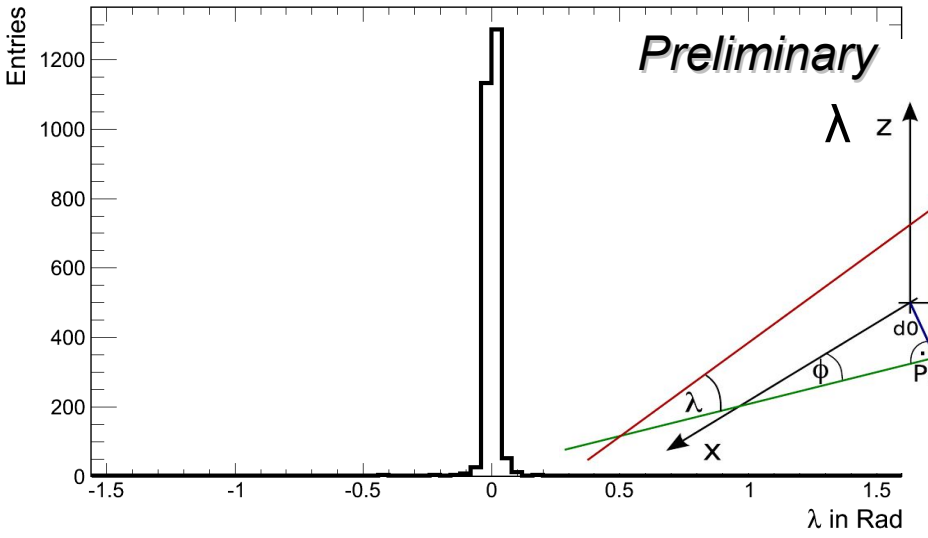
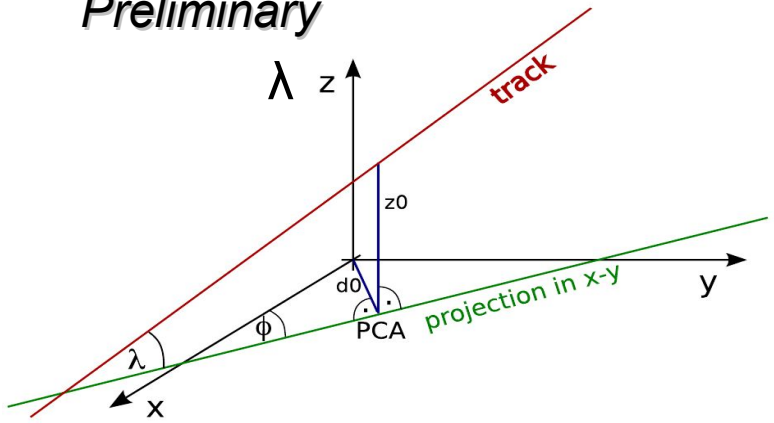
Track parameters

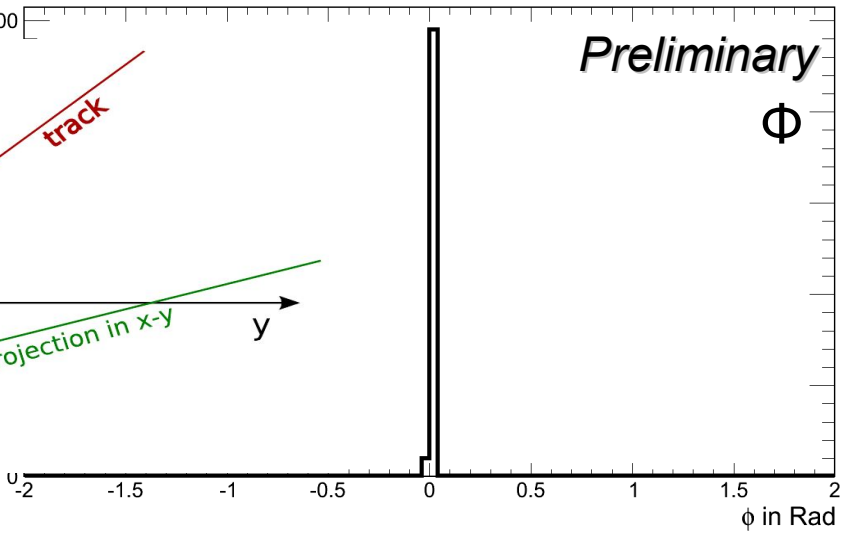
Run: z = 5,58 cm, B = 0 T



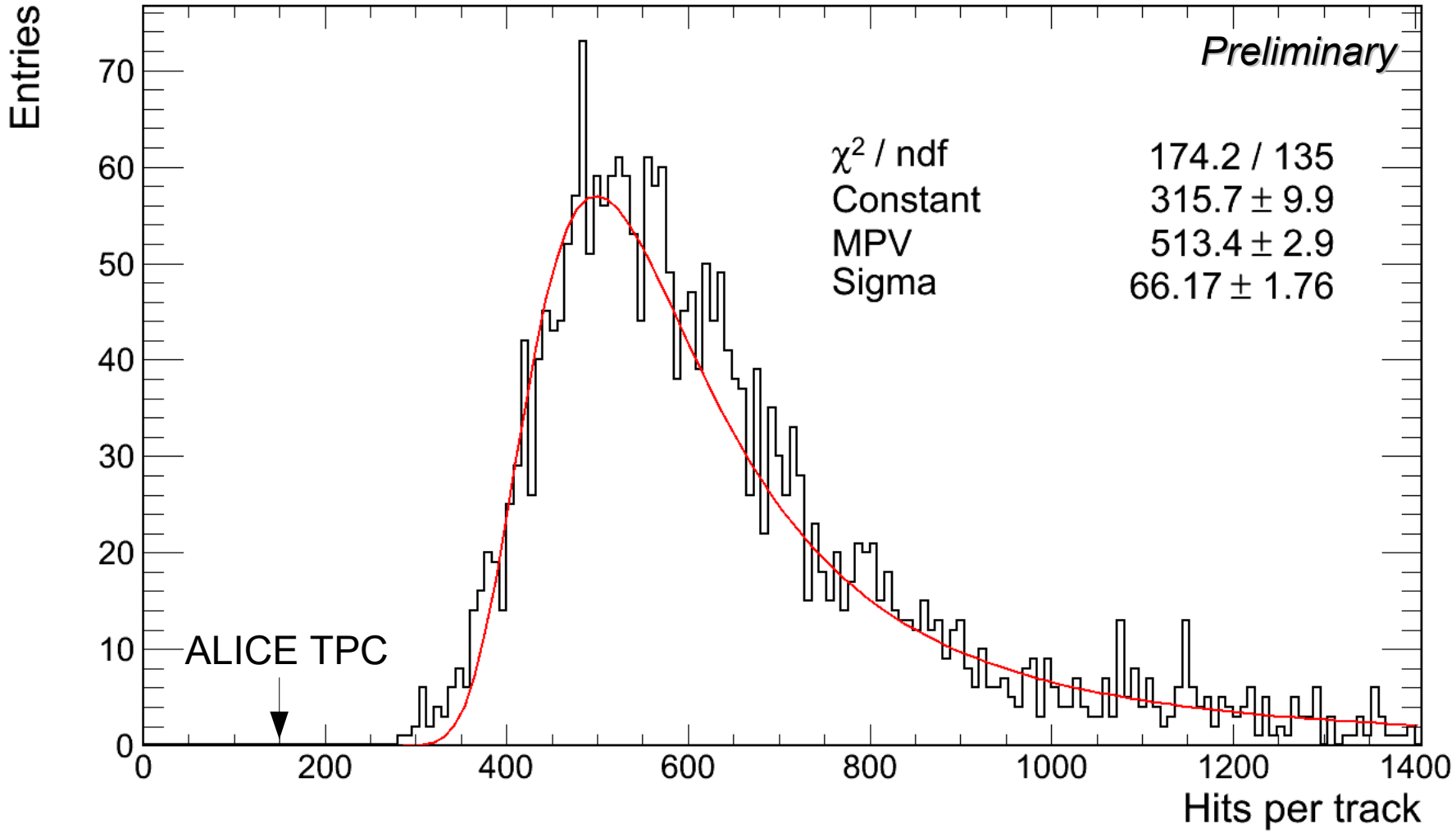




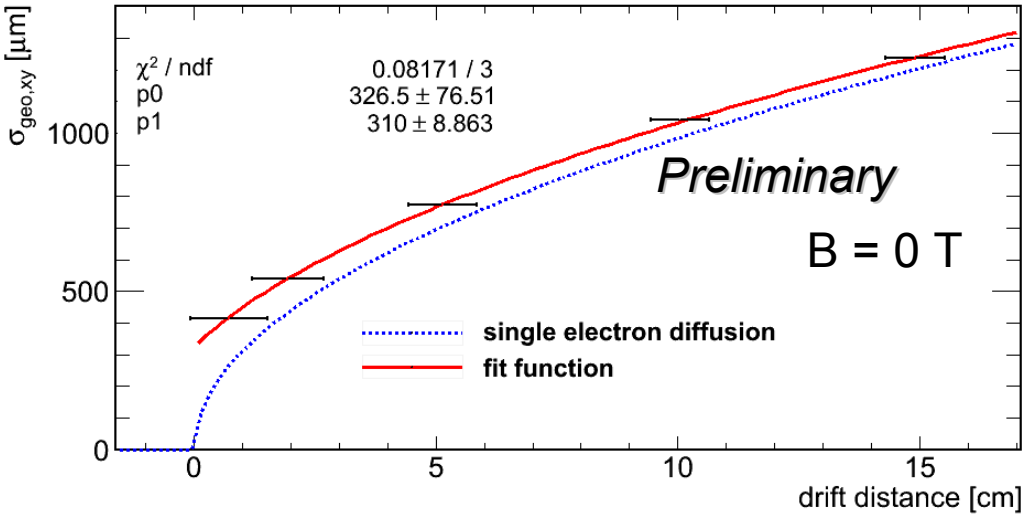




Hits per tracks

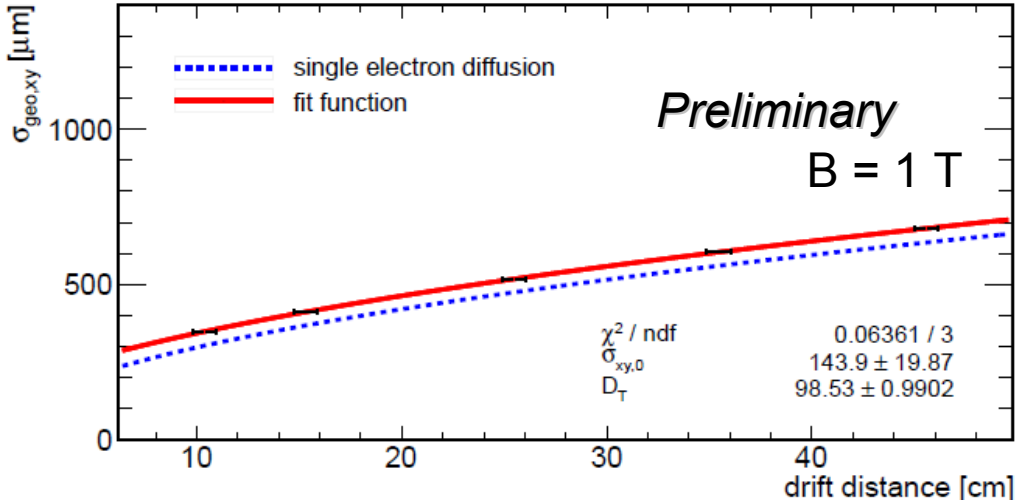


Transverse spatial resolution



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



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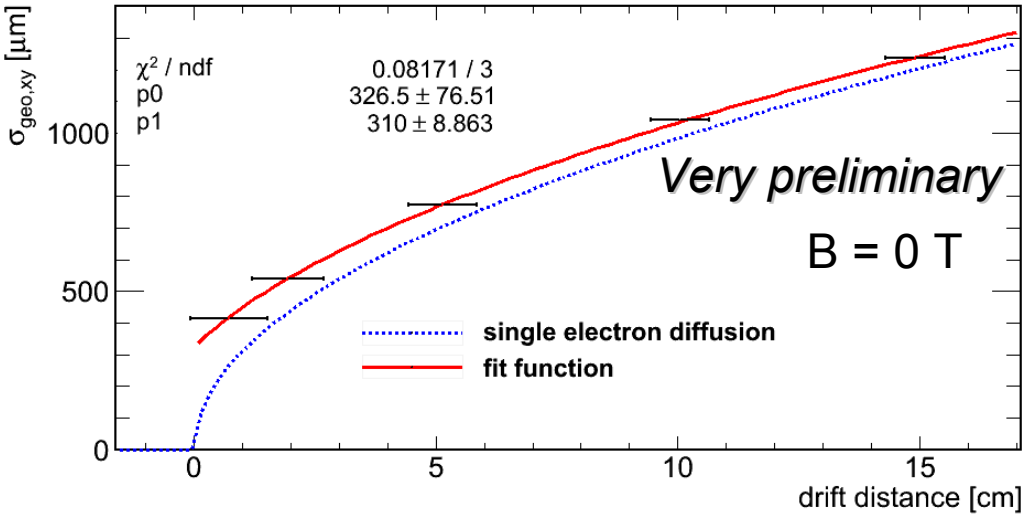
Preliminary z-scan results



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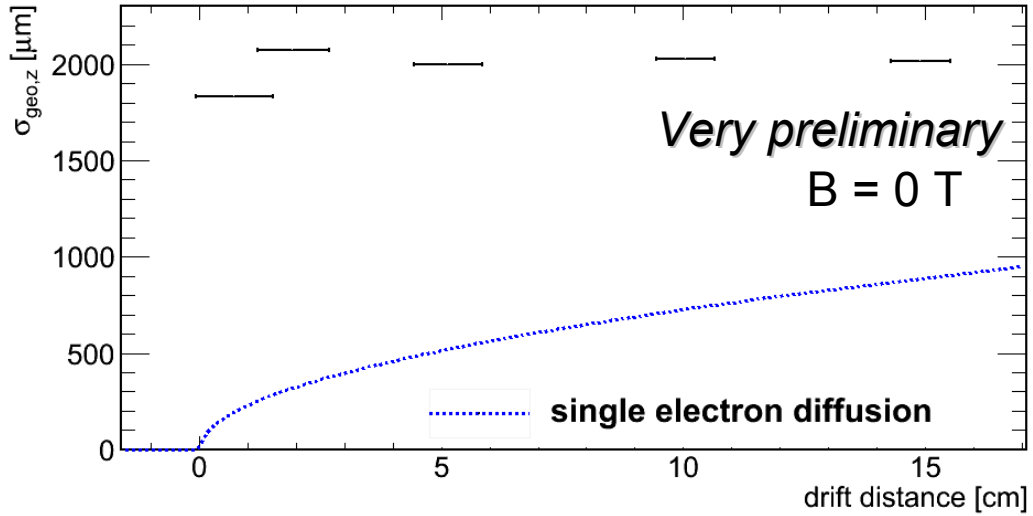

z resolution dominated by
- Clock frequency (25 ns time bins)
- Fast T2K gas (v_{Drift} ≈ 73 mm / µs)
- Timewalk effect

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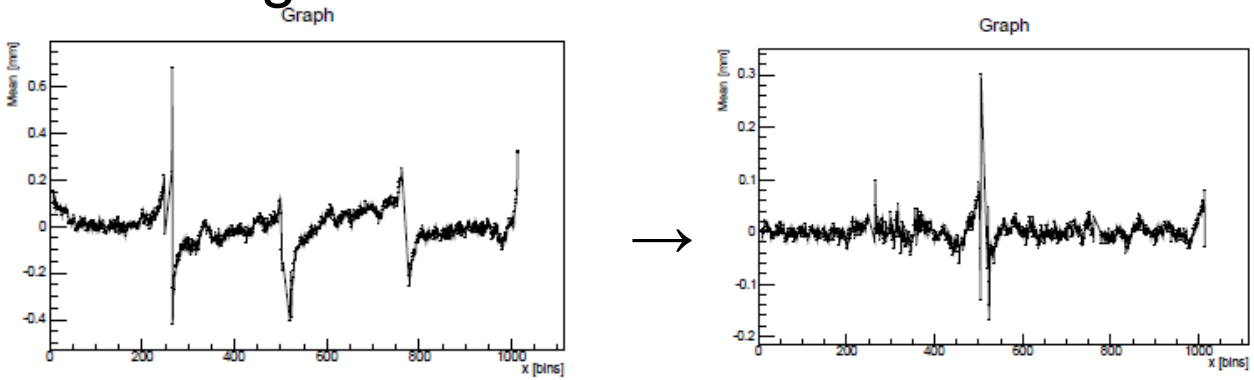
Data analysis

Martin Rogowski: A new tracking algorithm

- Reinvestigate field distortions of Roberts analysis



- Algorithm from Forward Tracking Detector for ILD

2013 testbeam

Analysis

Physics:

- Reconstruct tracks, identify characteristics
- Study detector properties
- Study point/track resolution
- Compare to traditional pad readout