Report from the pixel-TPC test beam in March/April

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GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

LCTPC Collaboration Meeting

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Outline

- Introduction:
  - Pixel-TPC working principle
  - 2013 test beam

- 2015 test beam impressions
  - Preparation
  - Installation
  - Some event display images

Introduction

- TPC endplate: measure x, y, z(drift time) of primary electron as precise as possible, need of charge amplification
- x, y precision: highly granular readout → pixel ASCI
- z precision: fast sampling frequency → ToA with fast clock
- Charge amplification: MPGDs → integrated Micromegas

- Pixel-TPC: combine Timepix chip with Micromegas

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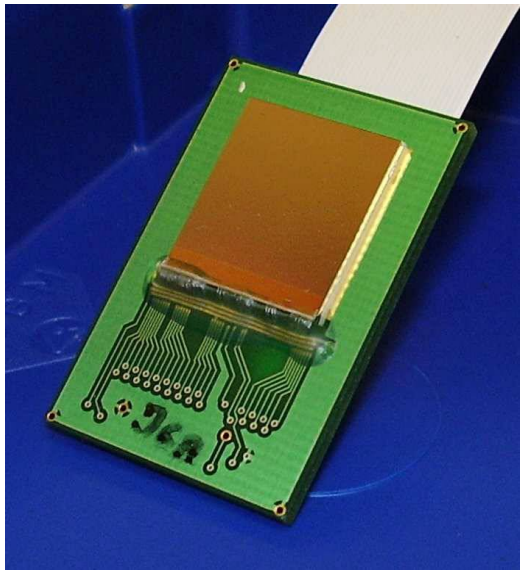
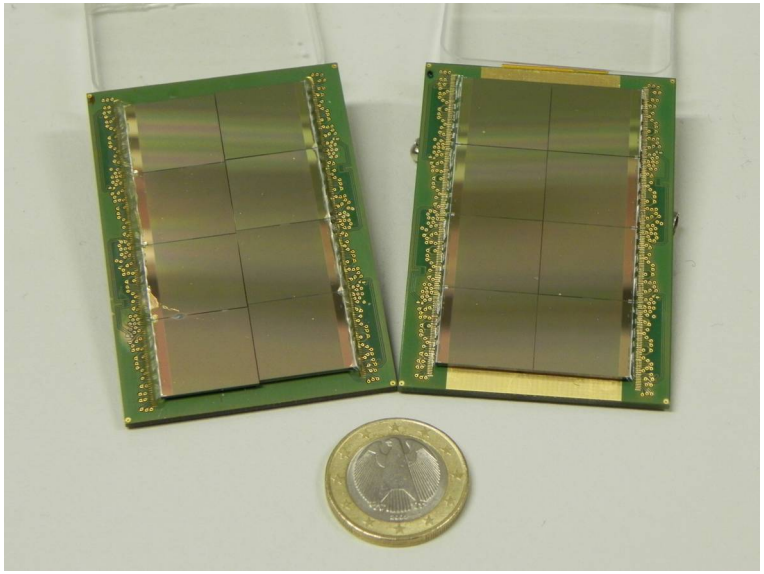
Timepix chip

- 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), 100 MHz clock
  - Noise threshold ~500e^- (ENC ≈ 90e^-)





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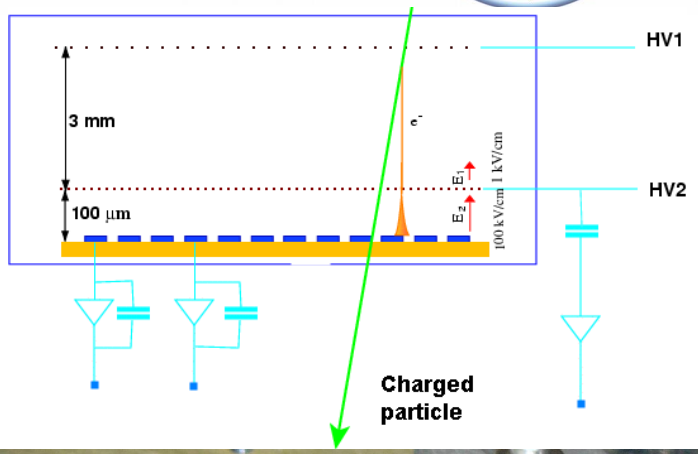
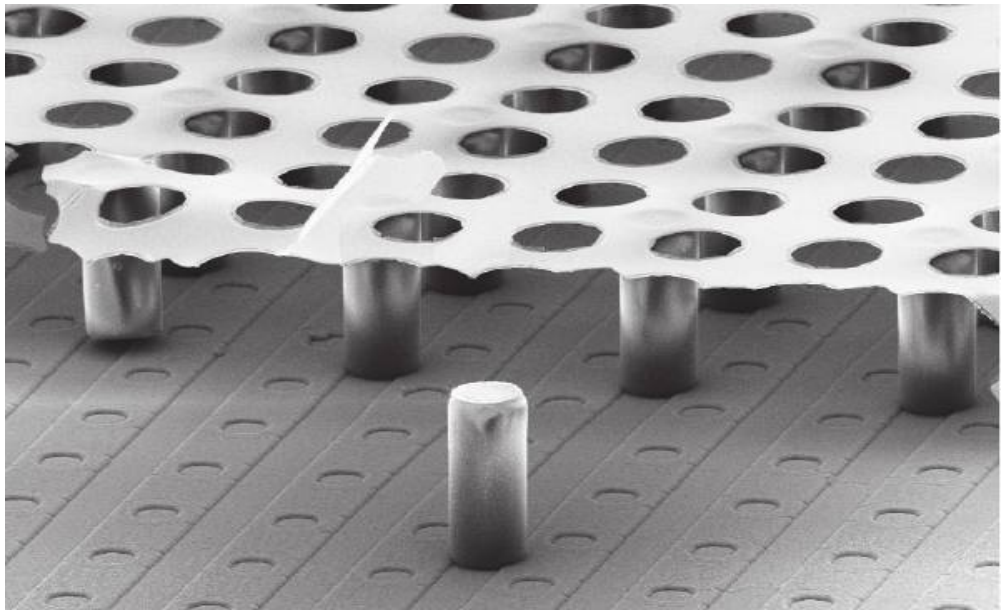
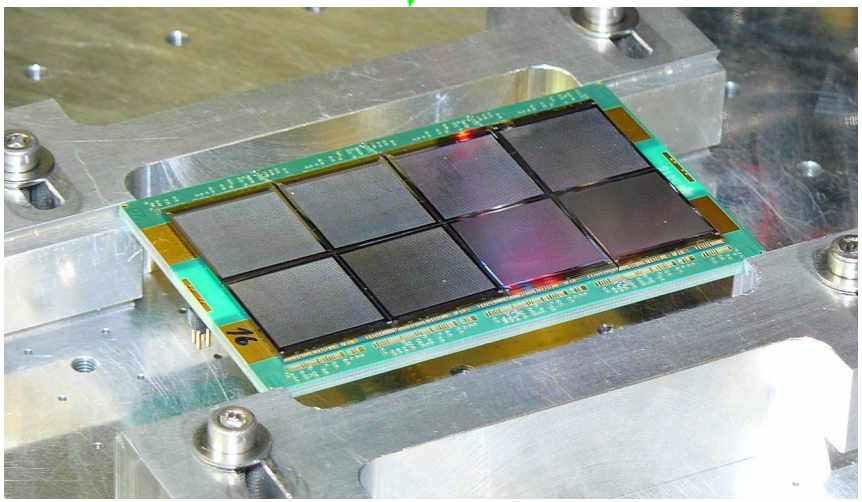
Timepix+Micromegas=InGrid

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







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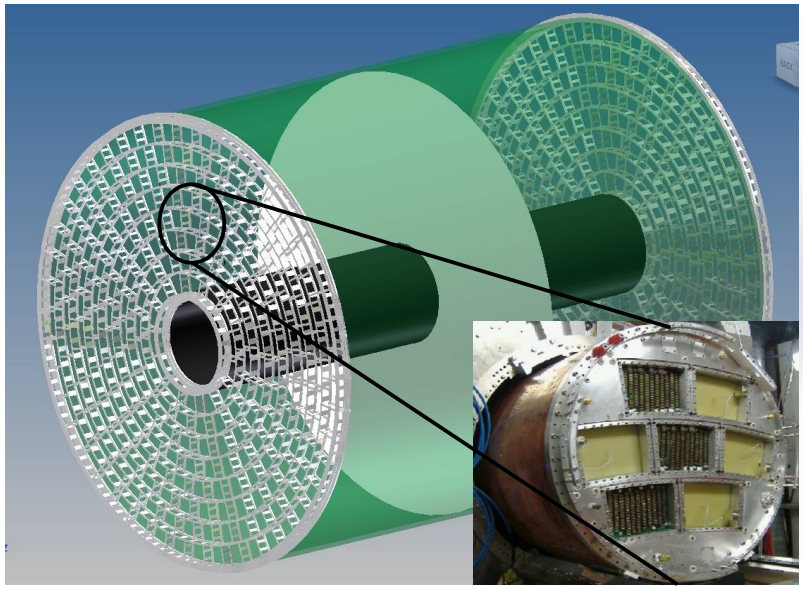
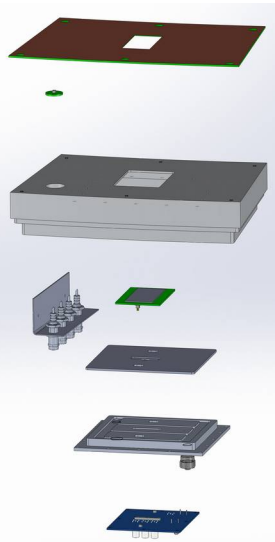
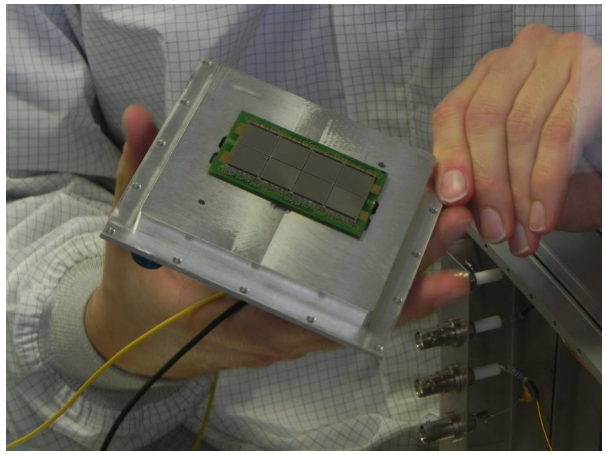
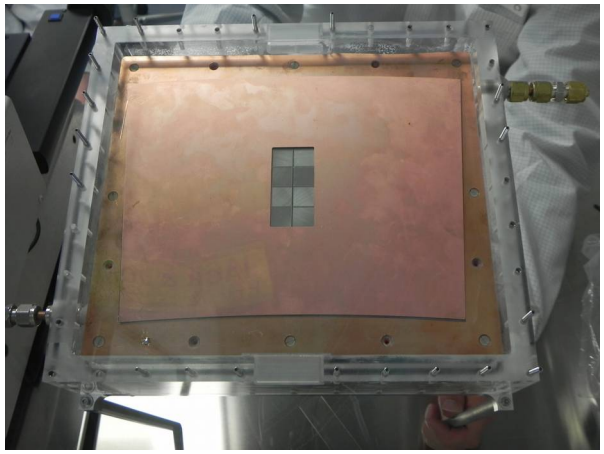
2013 test beam

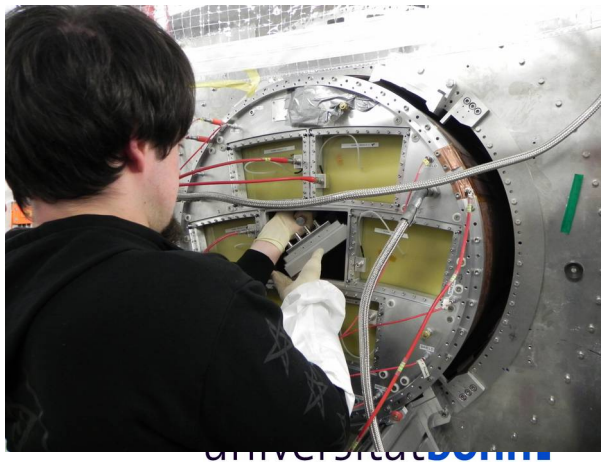
Setup at DESY



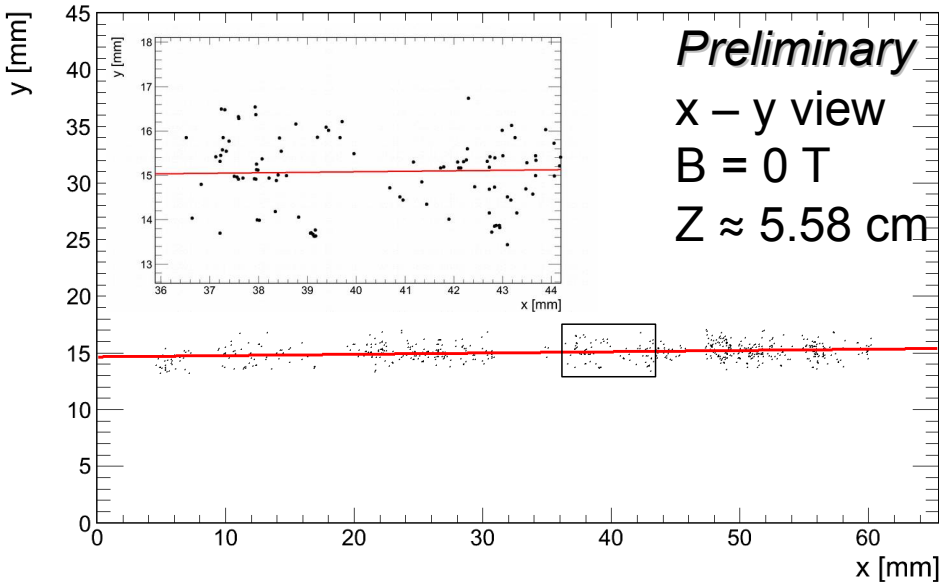


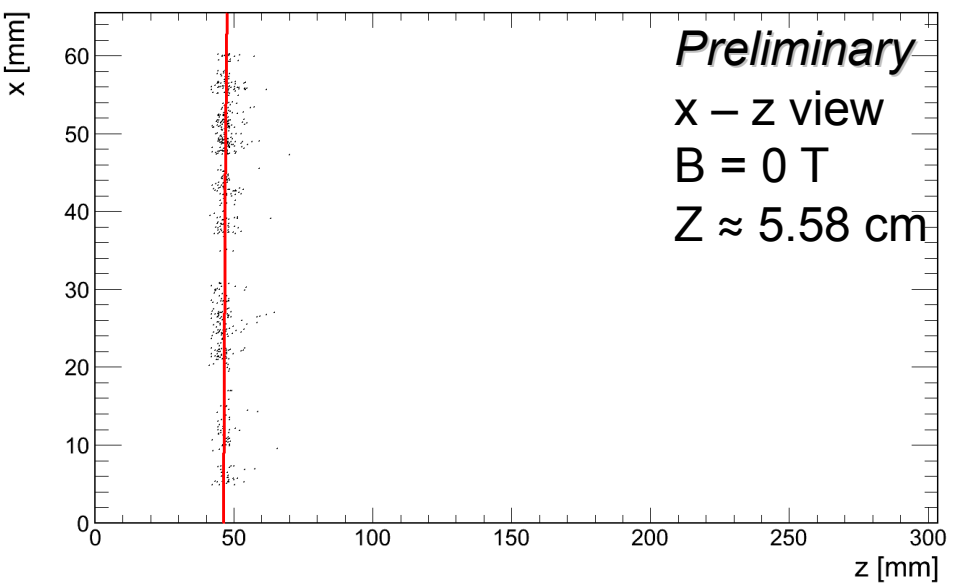


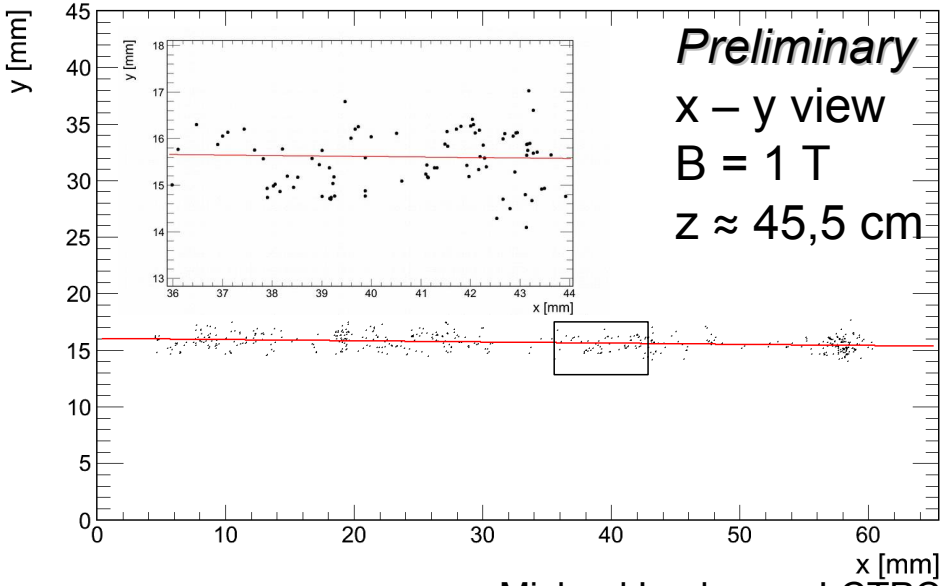




Reconstructed tracks







- Track length: 5.6 cm
- ≈ 100 hits/cm

- Field distortions at chip edges
- Small sensitive area
- Powering

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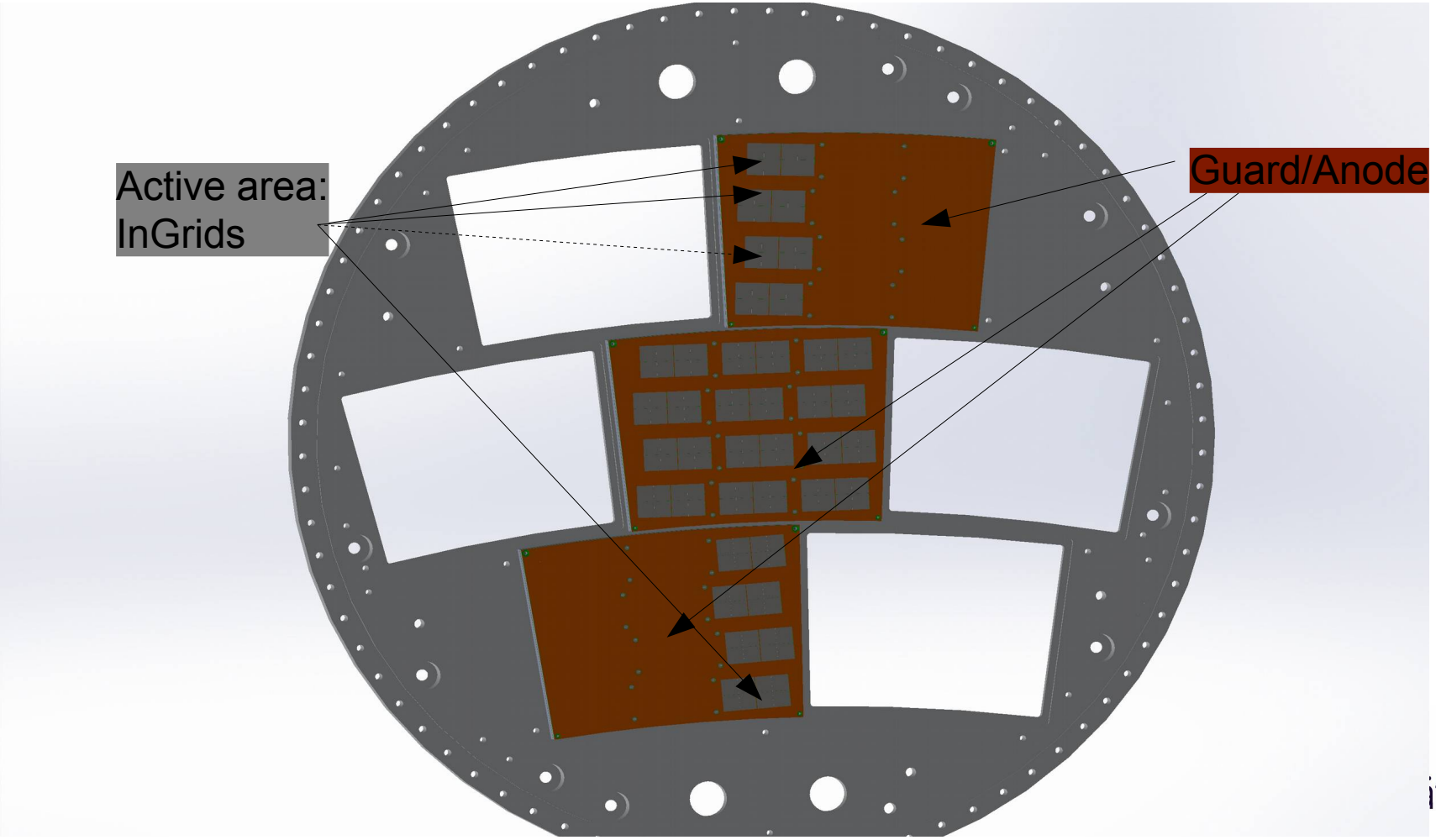
2015 test beam

Goal: ~100 InGrid module (cover 50% of area)

Achieved: 3 modules (1x96, 2x32 InGrids) ≈ 10.5 mio. channels



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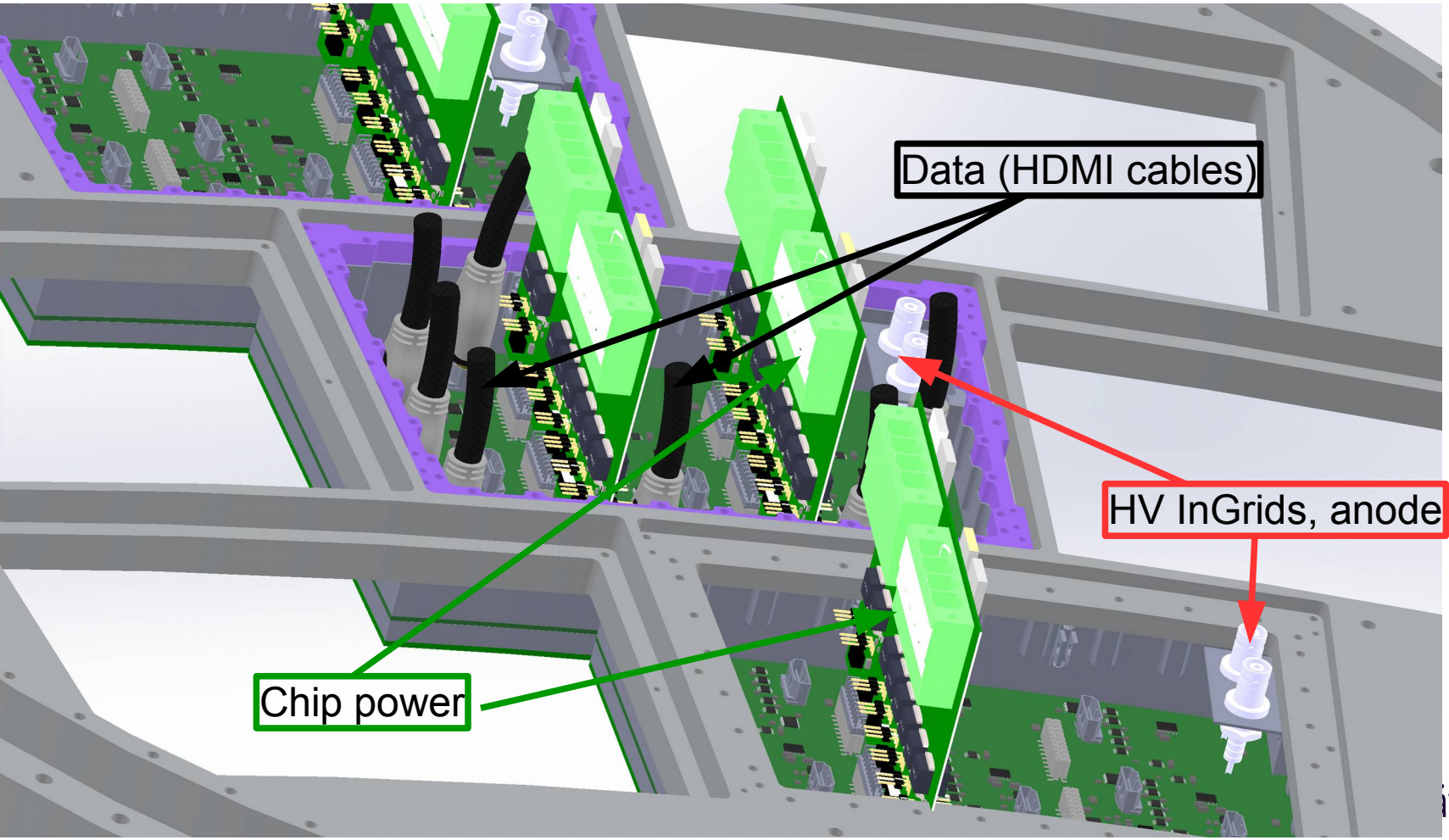

2015 test beam

Goal: ~100 InGrid module (cover 50% of area)

Achieved: 3 modules (1x96, 2x32 InGrids) ≈ 10.5 mio. channels

- Water cooling inside aluminium support structure
- Stable powering of Timepix chips (LDOs, capacitors)
- Integration of Timepix chip in Scalable Readout System (SRS) (RD51, CERN): 5 FECs, maximum readout rate
- Study of field distortions: can be avoided by design

  → only partly applied, due to lack of time
- Dedicated InGrid production for test beam
- Light weight frame + brackets

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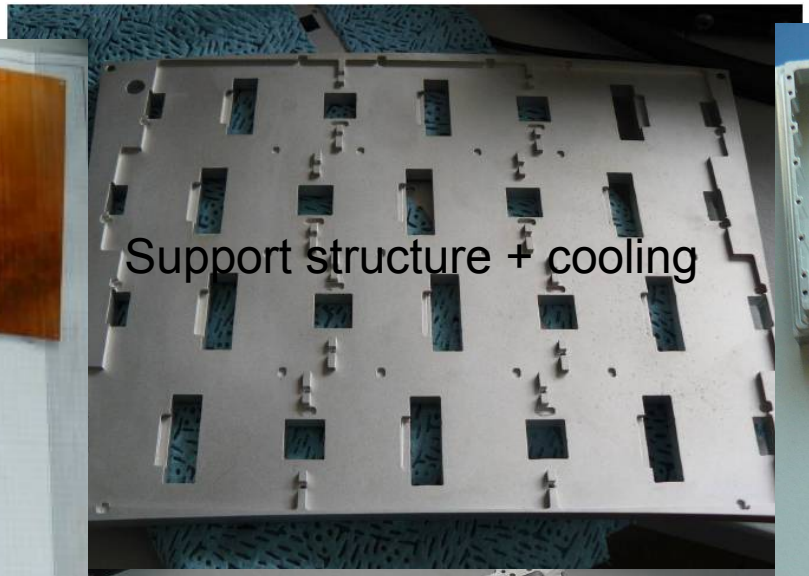
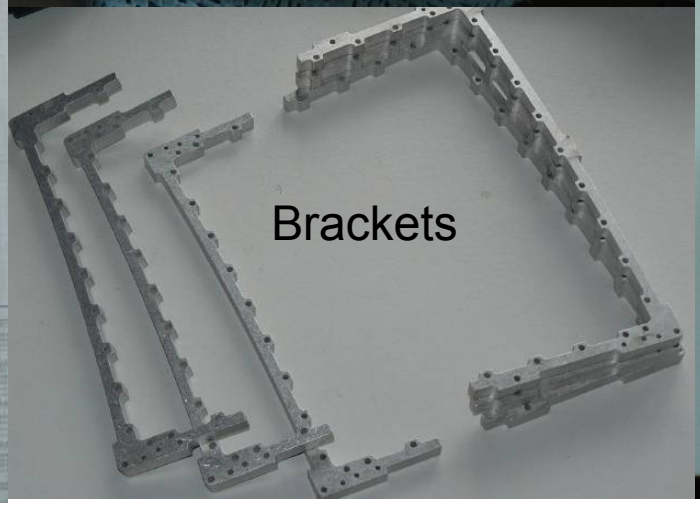
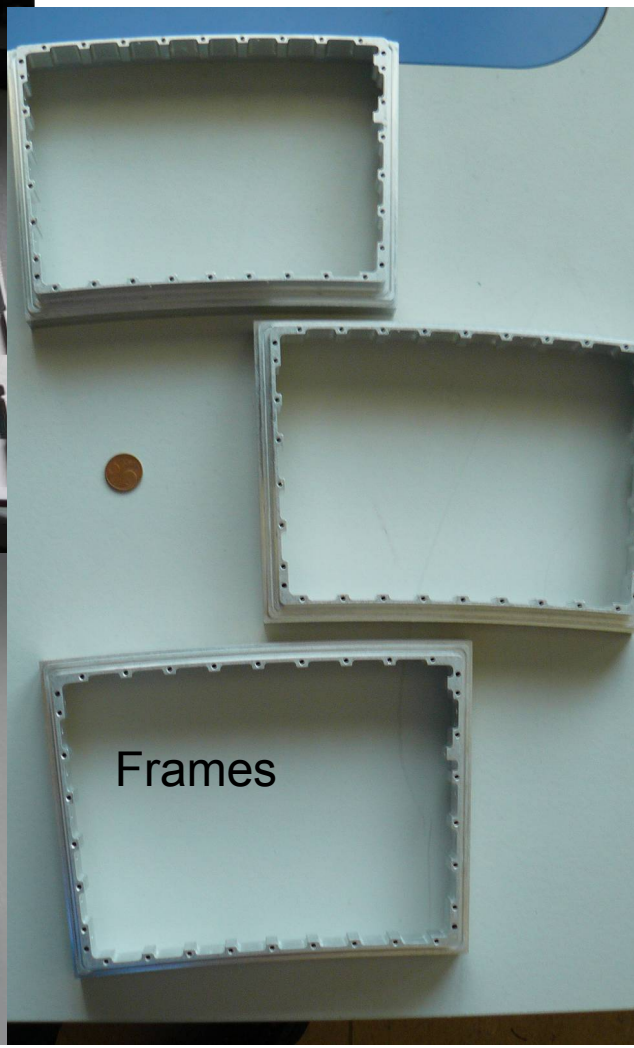
2015 test beam

Components



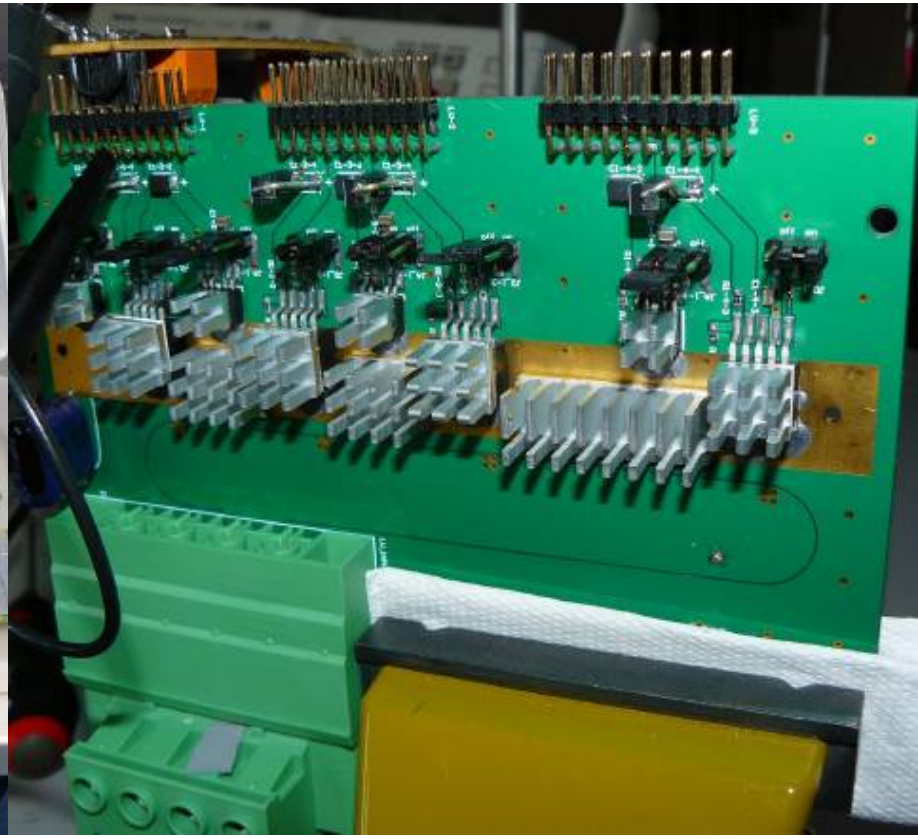




2015 test beam

Components

InGrid Octoboards



Low voltage power board
to supply Timepix chips

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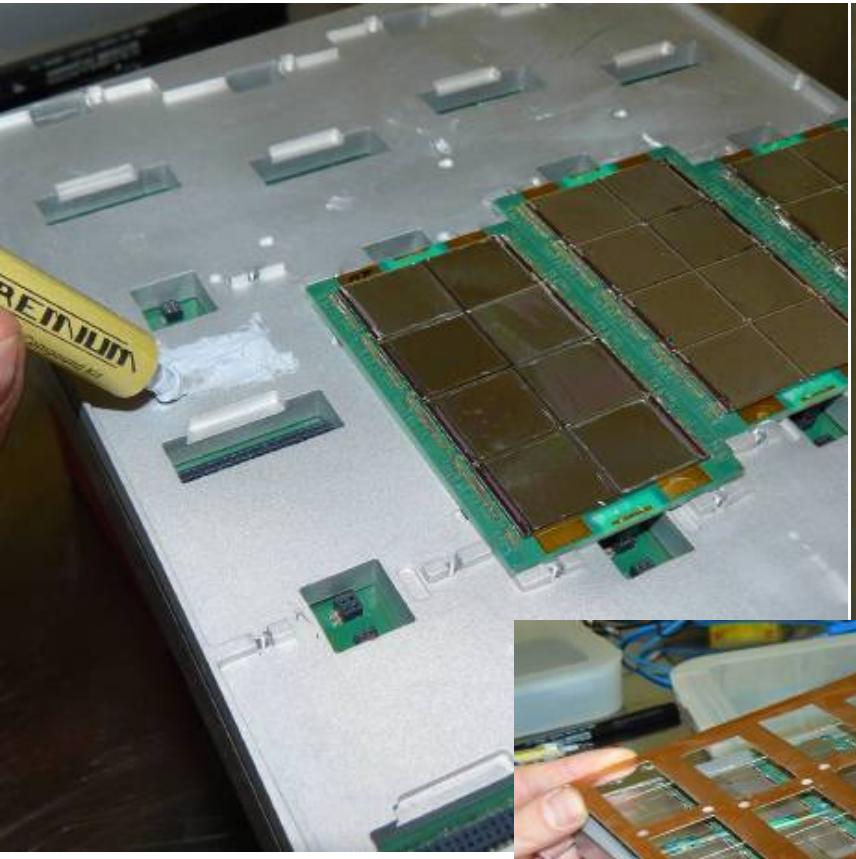
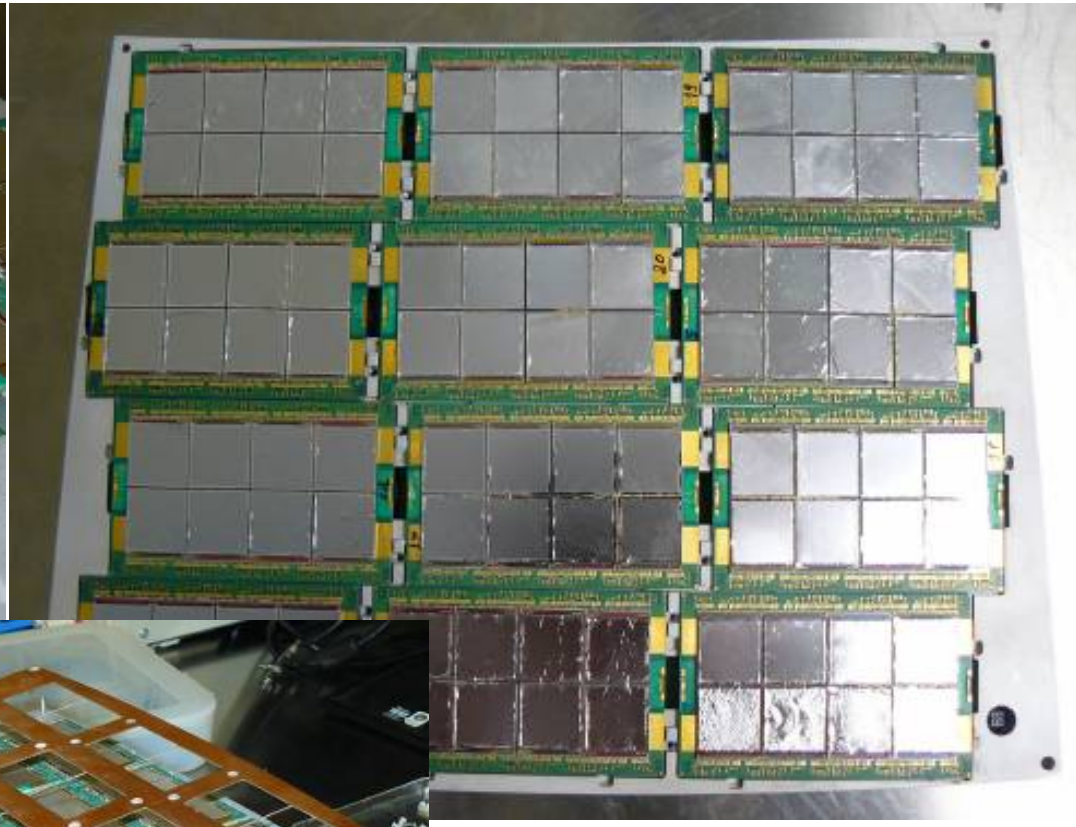
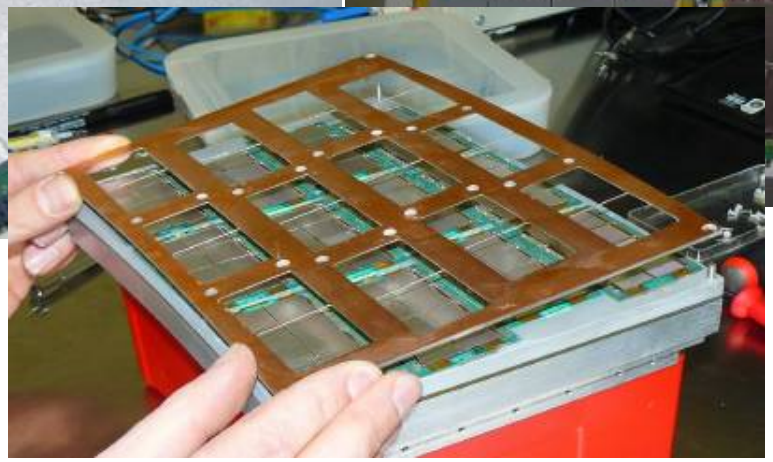
2015 test beam

Assembly in clean room







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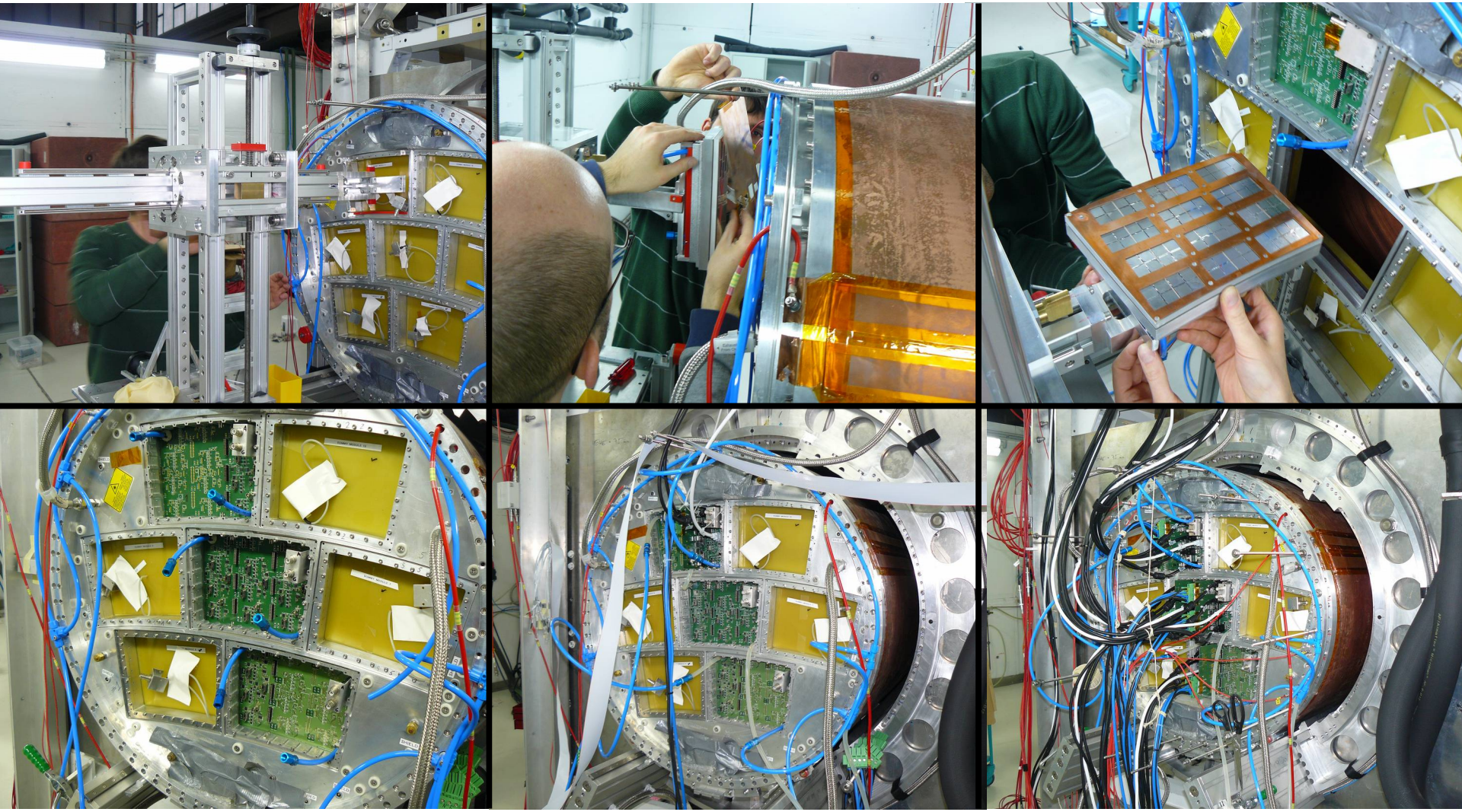
2015 test beam

Mounting at DESY



2015 test beam

Numbers:

- > 8.5 mio. channels permanently in operation
- > 1.5 mio. events recorded in one week (≈ 1 TB of a data)
- Up to 5.5 Hz readout rate (theo. maximum for octoboard)
- T2K gas
- ≈ 150 runs with different parameters
  - B = 0 / 1 T
  - E_{Drift} = 130 / 230 V/cm
  - TPC geometry (z: 0 → 460 mm, Θ:15 → -40°, Φ:9 → -90°)
  - Timepix ToA mode: 40 MHz, 80 MHz (=700µm@130V/cm)
  - Timepix ToT mode (gain measurement): V_{Grid} 280 → 350 V
  - Long term run with cosmics

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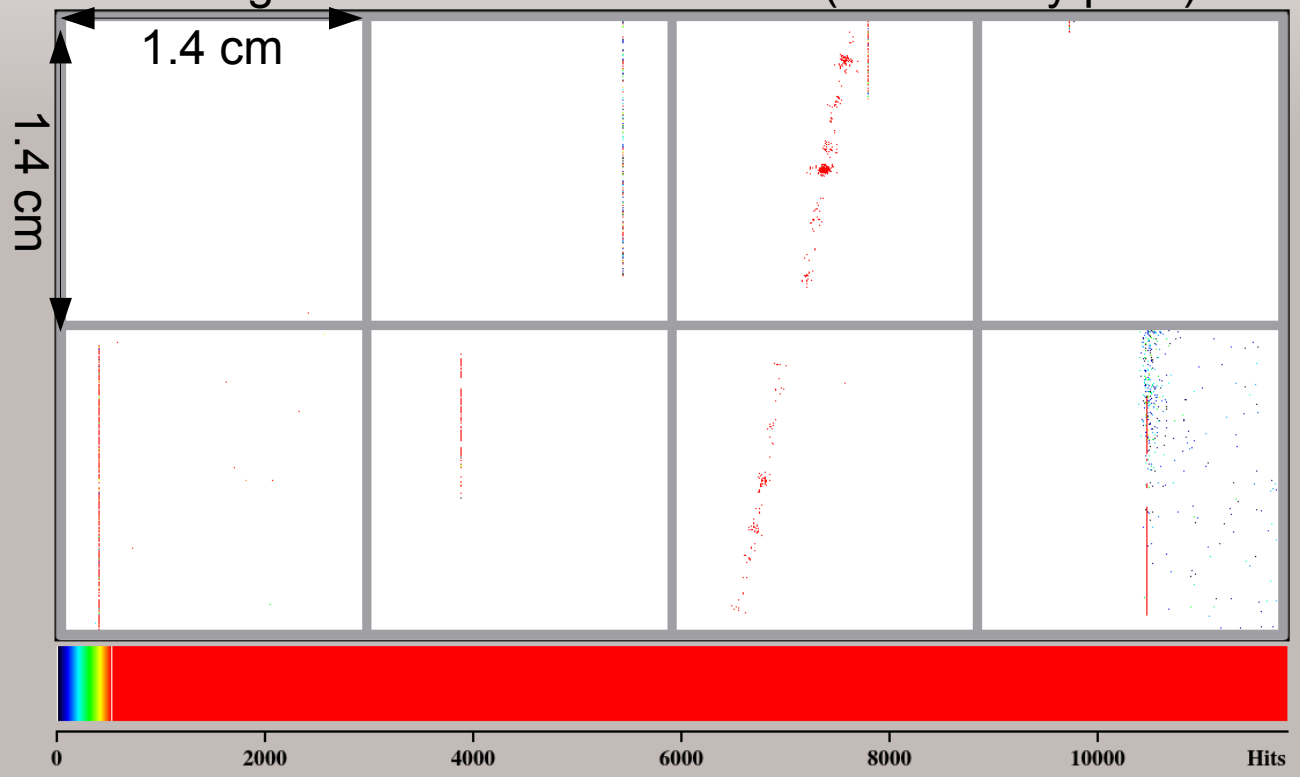
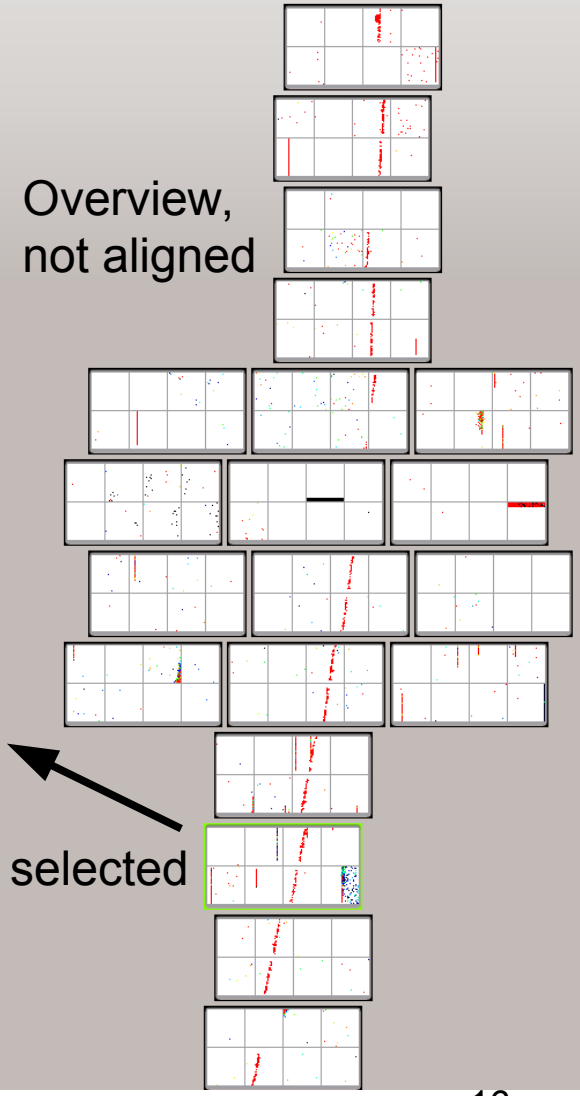
2015 test beam

Events: Typical track

Enlarged view of one octoboard (sees every pixel)



Overview, not aligned

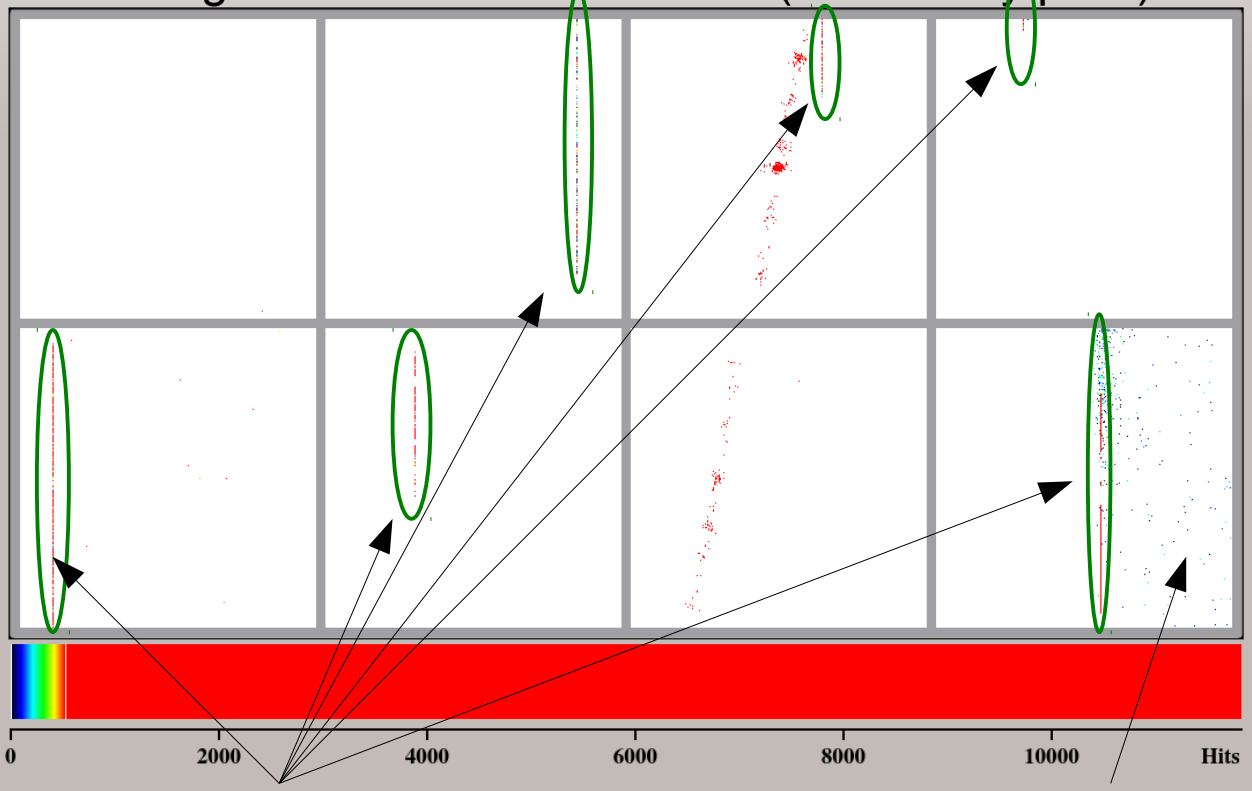


selected

2015 test beam

Events: Typical track (dead columns, noise)

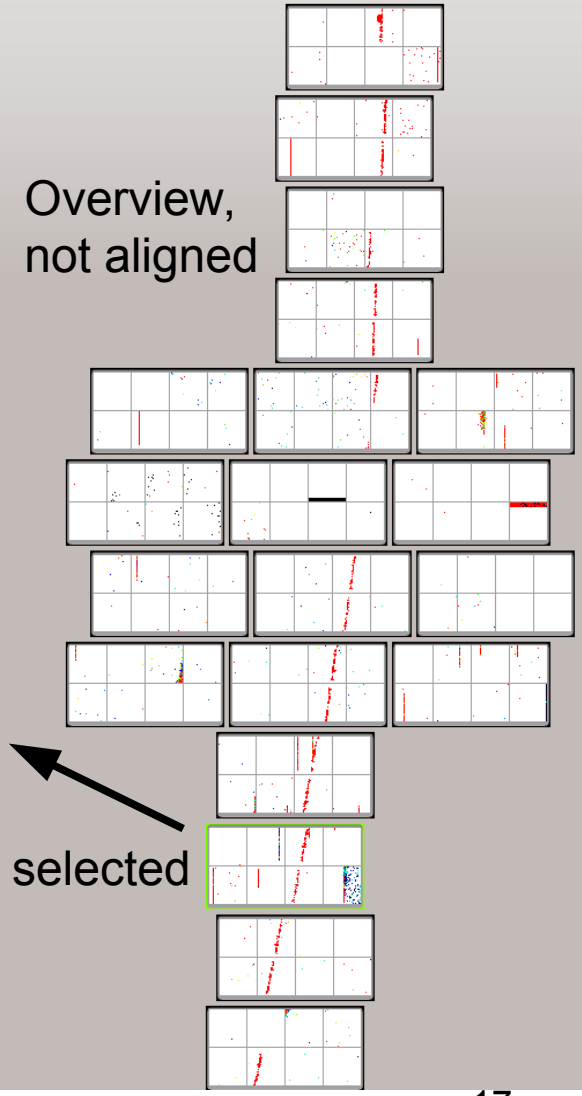
Enlarged view of one octoboard (sees every pixel)



Dead columns

Noise

Overview, not aligned

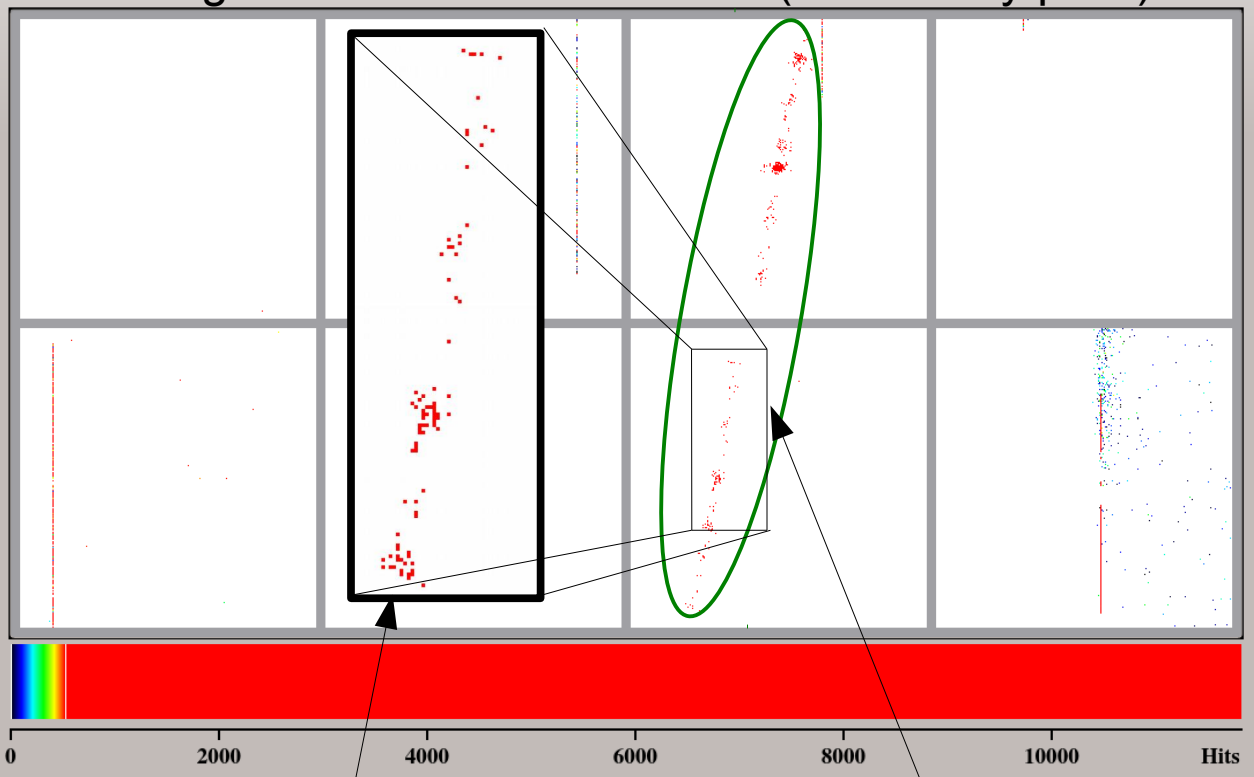


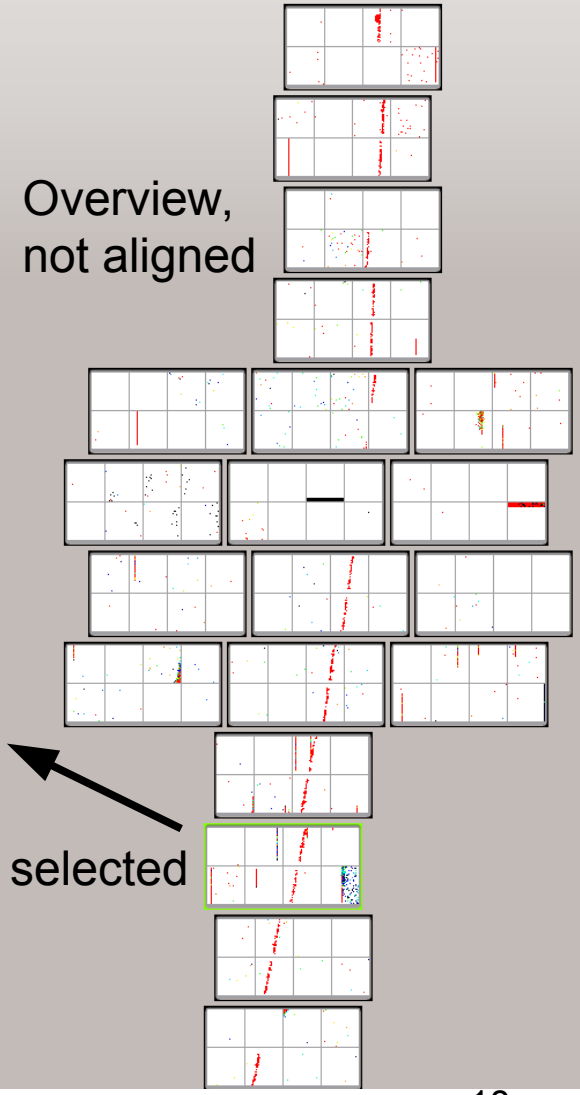
selected

2015 test beam

Events: Typical track

Enlarged view of one octoboard (sees every pixel)

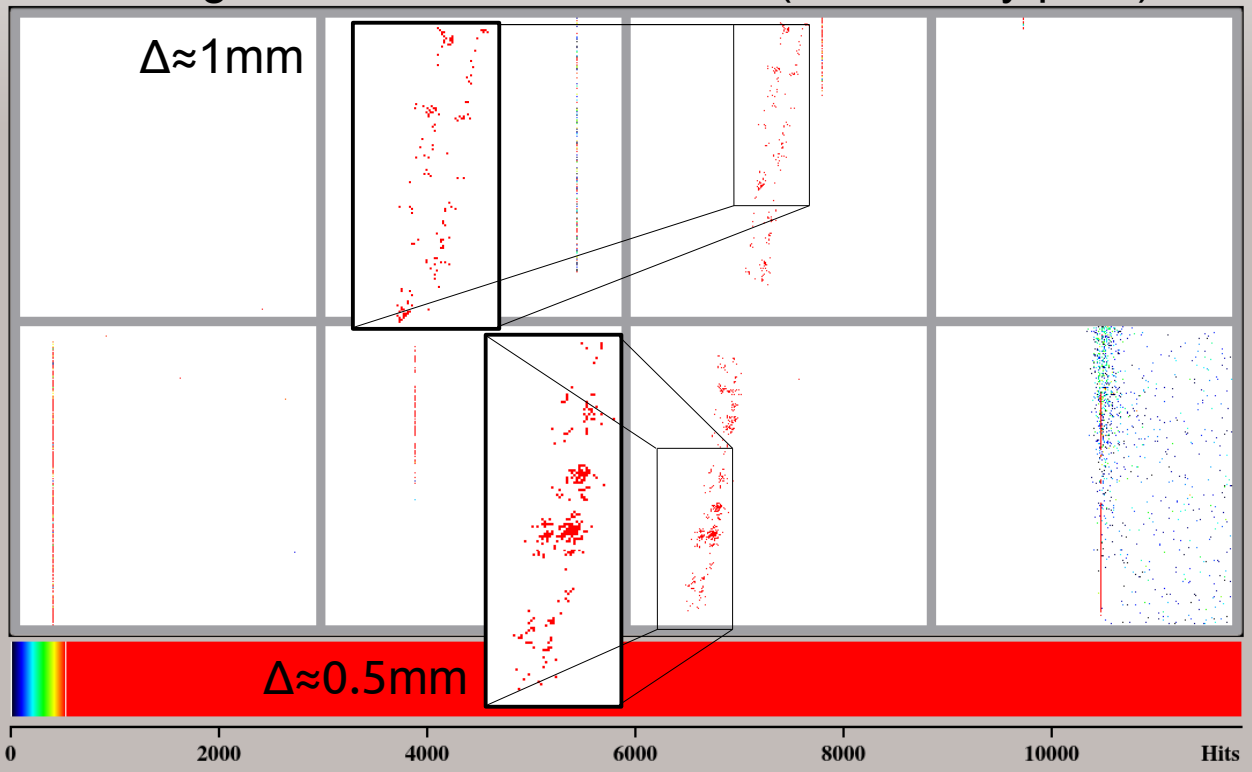




2015 test beam

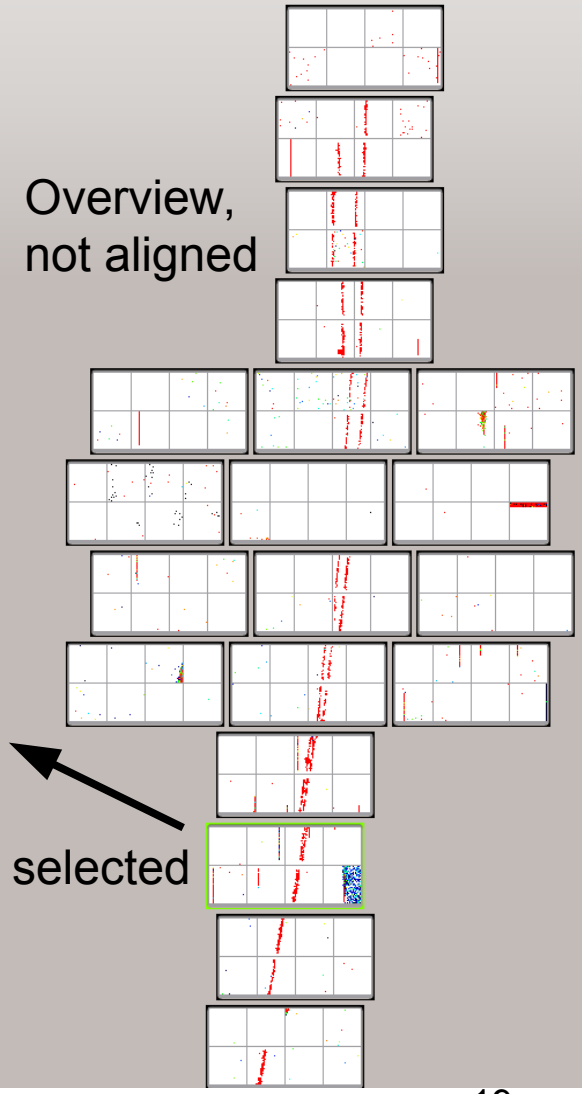
Events: Double track event

Enlarged view of one octoboard (sees every pixel)



Overview, not aligned

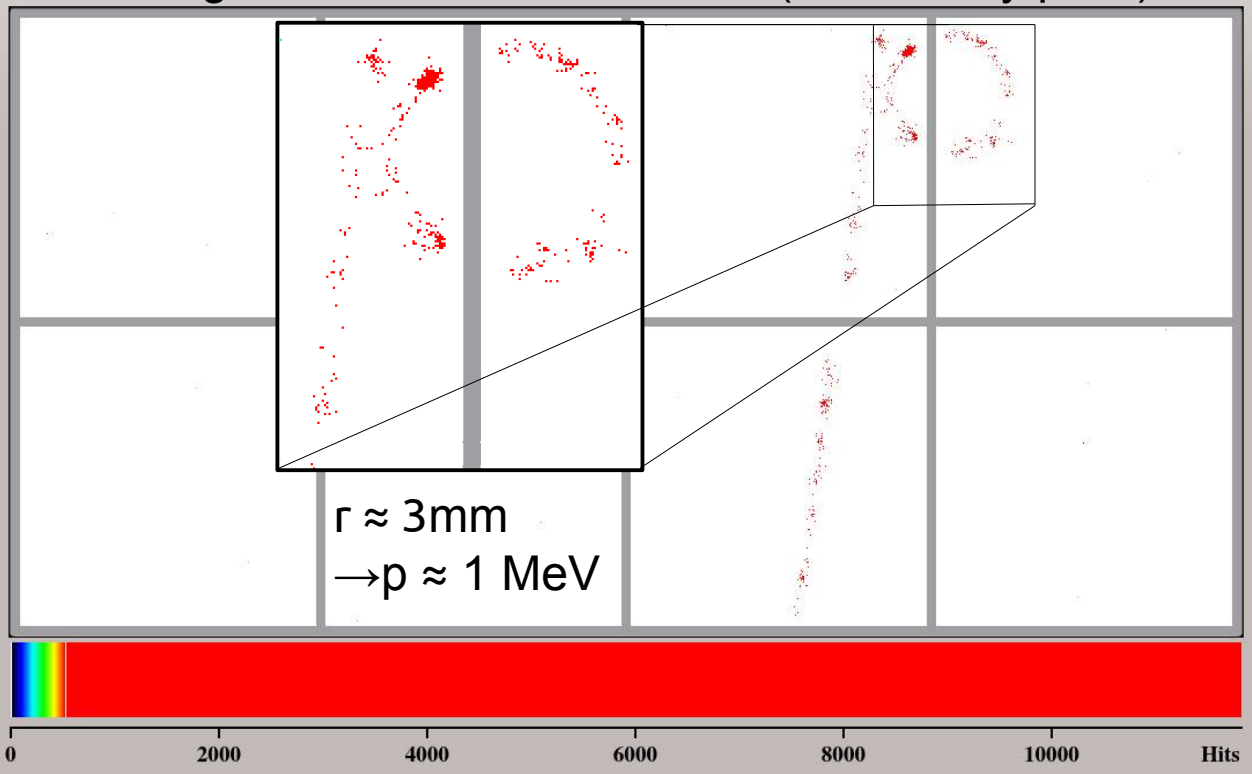
selected



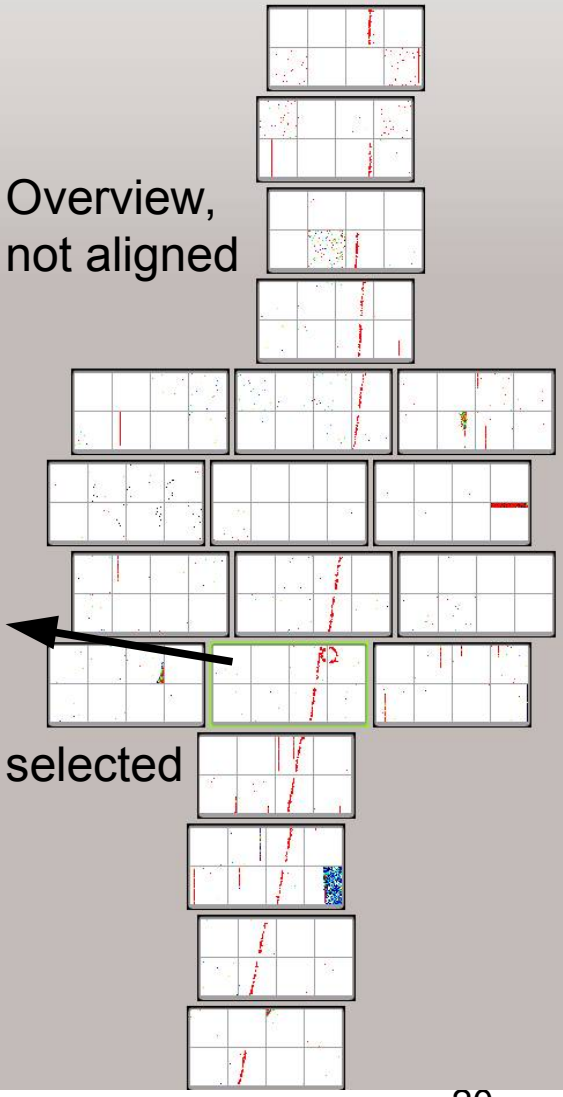
2015 test beam

Events: Delta electron on track

Enlarged view of one octoboard (sees every pixel)



Overview, not aligned

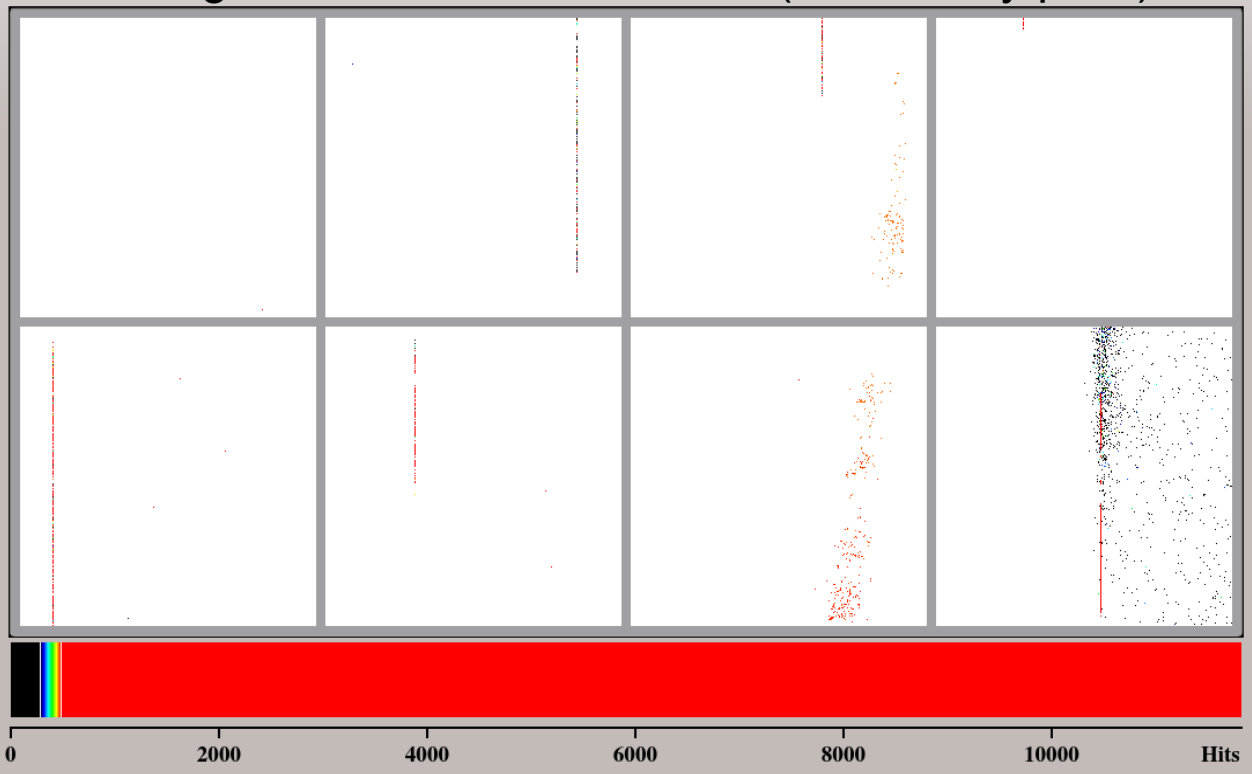


selected

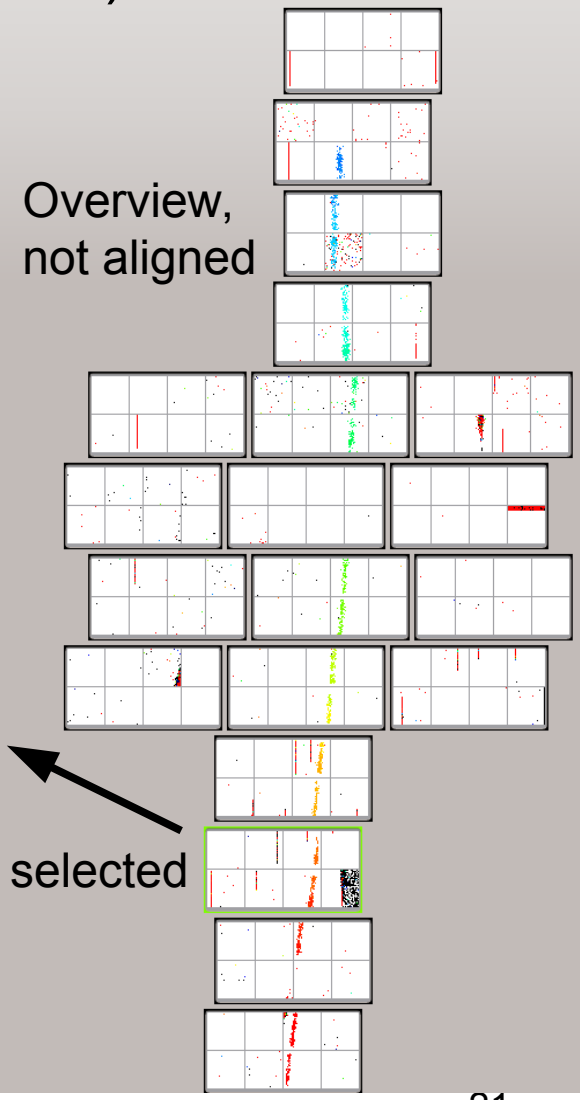
2015 test beam

Events: Track angle 35° to endplate (different run)
Hit colour indicates z position

Enlarged view of one octoboard (sees every pixel)



Overview,
not aligned

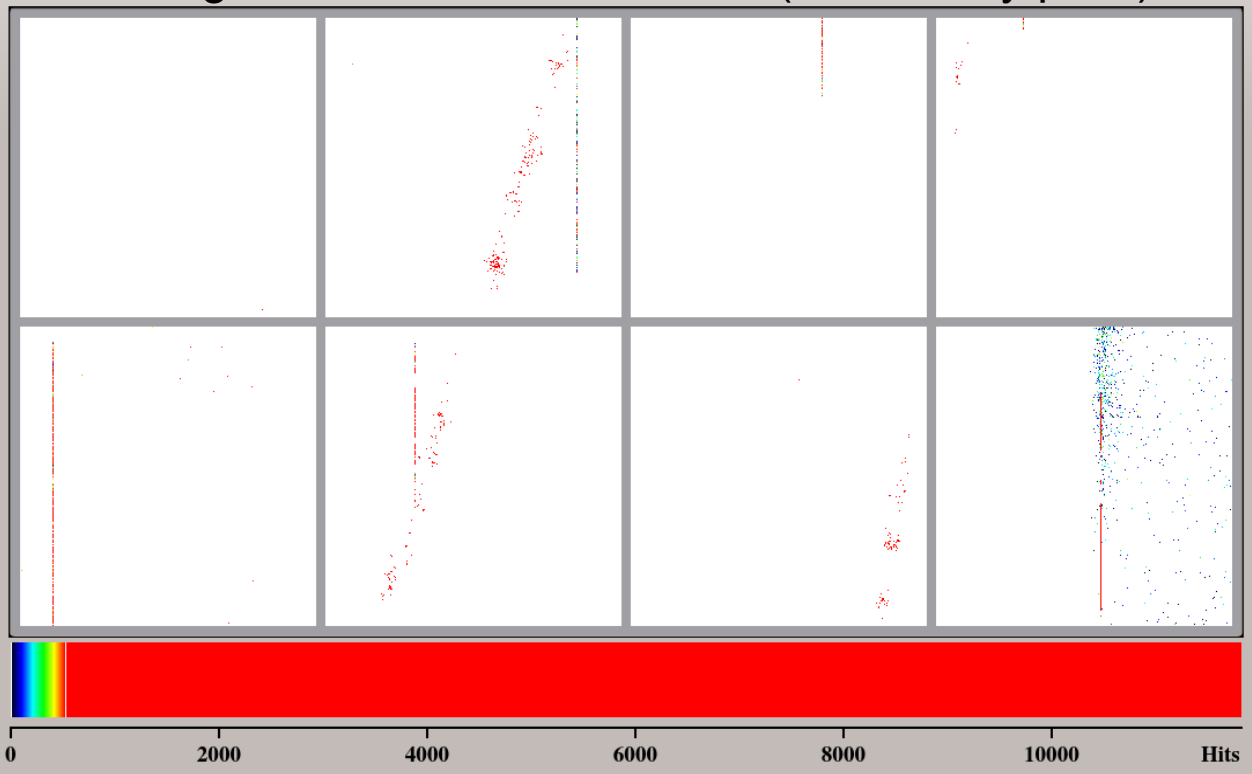


selected

2015 test beam

Events: Several tracks

Enlarged view of one octoboard (sees every pixel)



Overview, not aligned

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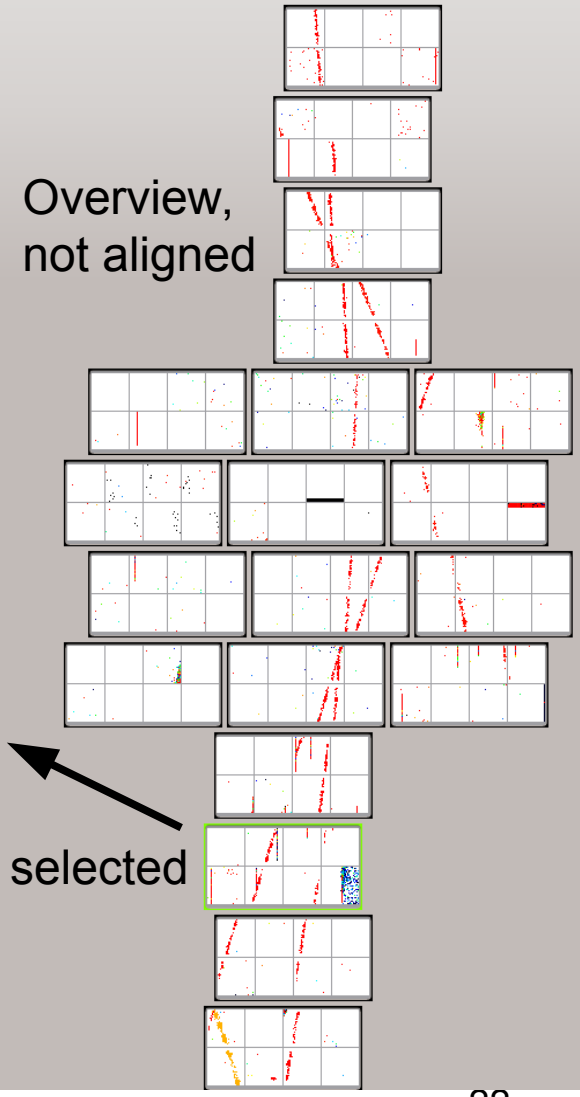
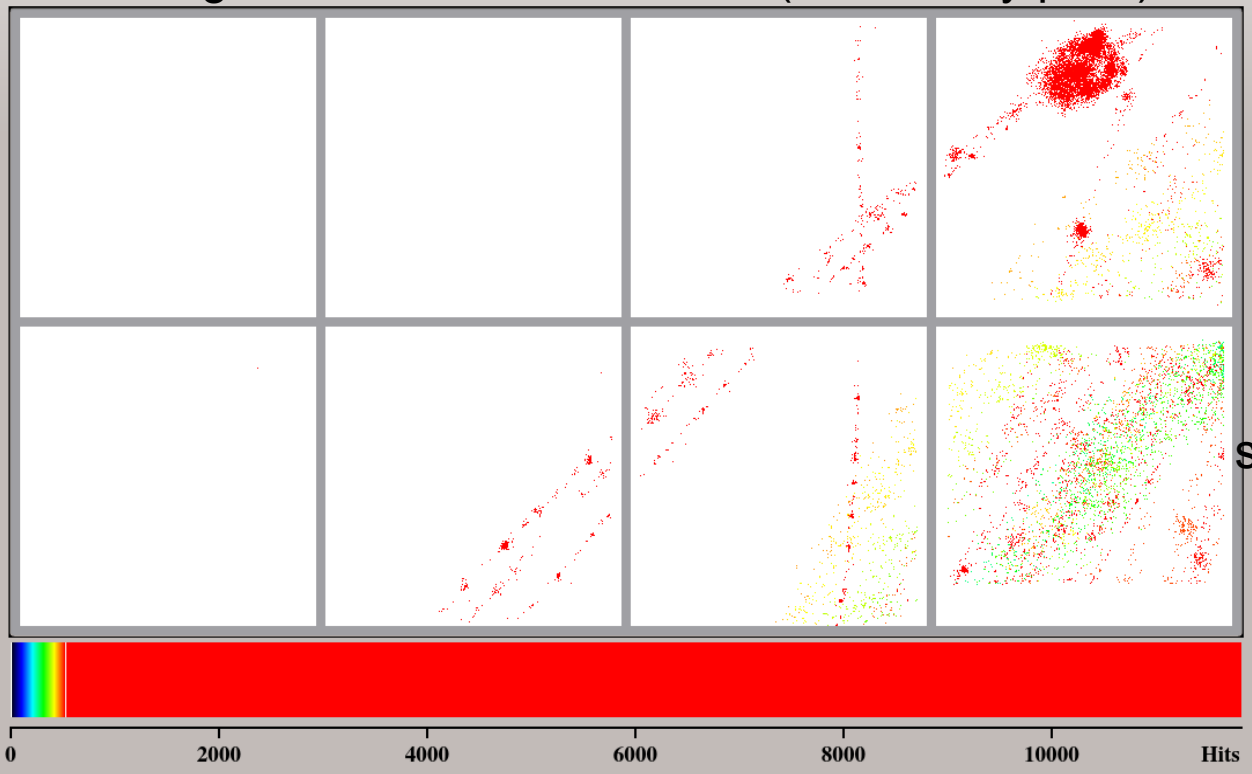


2015 test beam

Events: Curlers

Enlarged view of one octoboard (sees every pixel)



Overview, not aligned

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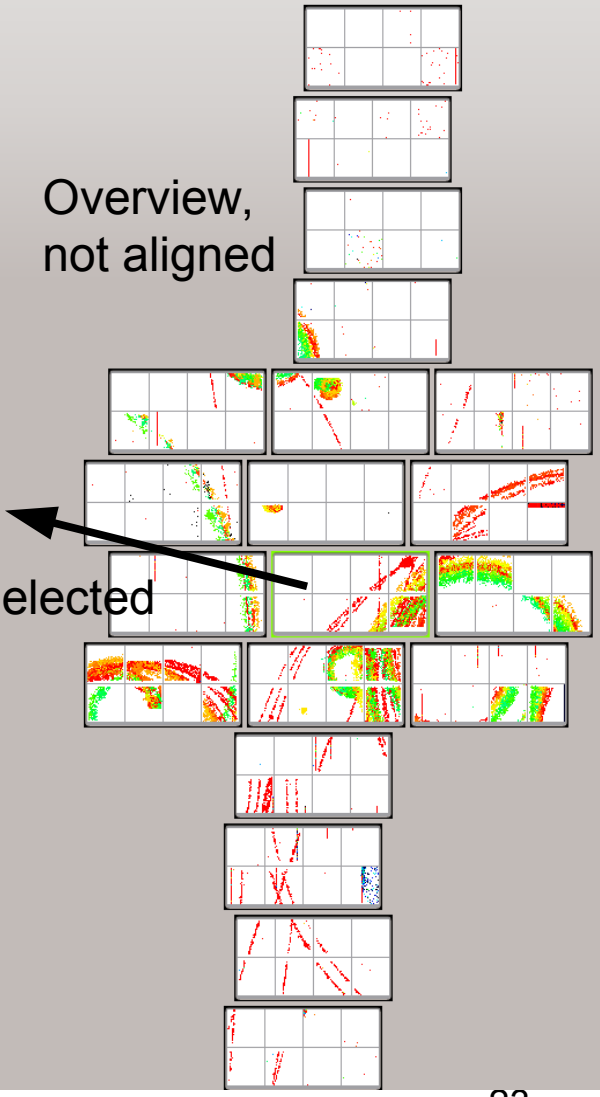

Summary and Outlook

- Built pixel-TPC+readout+DAQ with
  10,5 mio channels from 160 InGrid chips on 3 LCTPC modules
- Successful test beam at DESY in March/April
- Event displays already show features a pixel-TPC can resolve

- Find out why some chips died
- Detailed analysis to come:
  - Prepare GEAR file
  - Get MarlinTPC ready for analysis
  - Study resolution, double track resolution, dE/dx, resolution for different track angles, delta identification,...

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Thanks

to everyone who participated in this project

and to you for listening!

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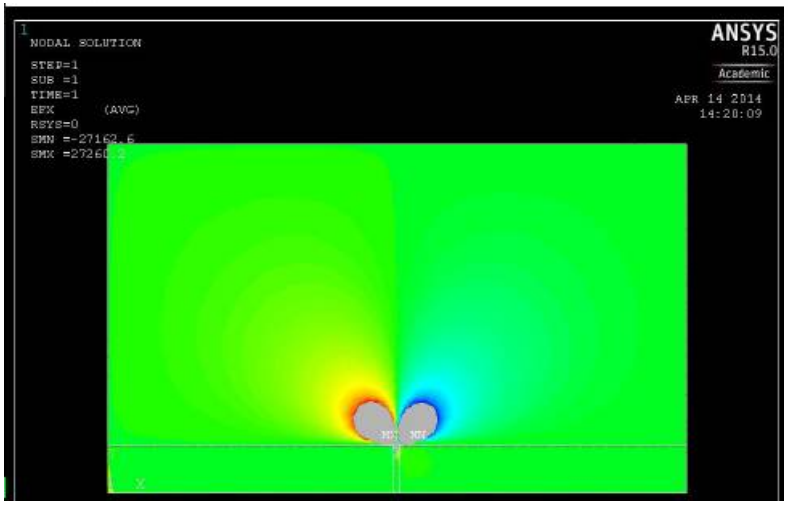
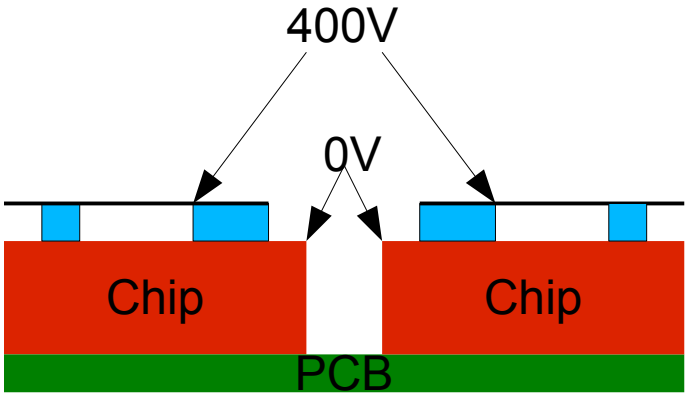
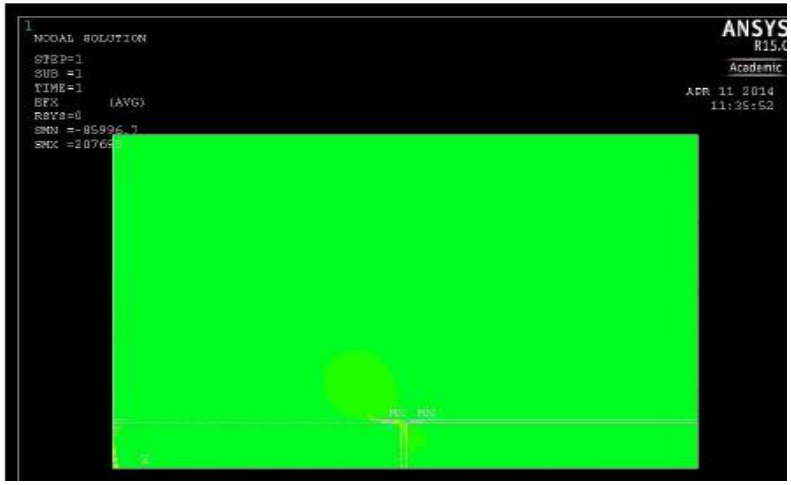
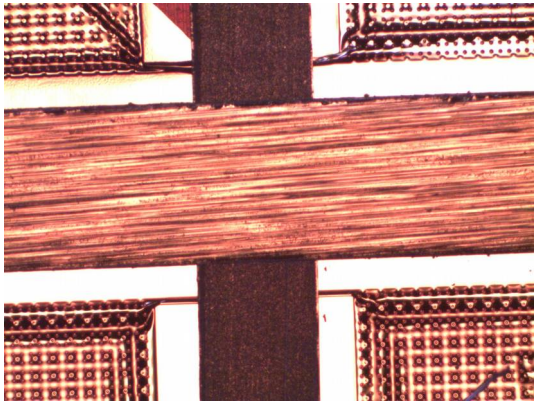
Backup

Field distortions









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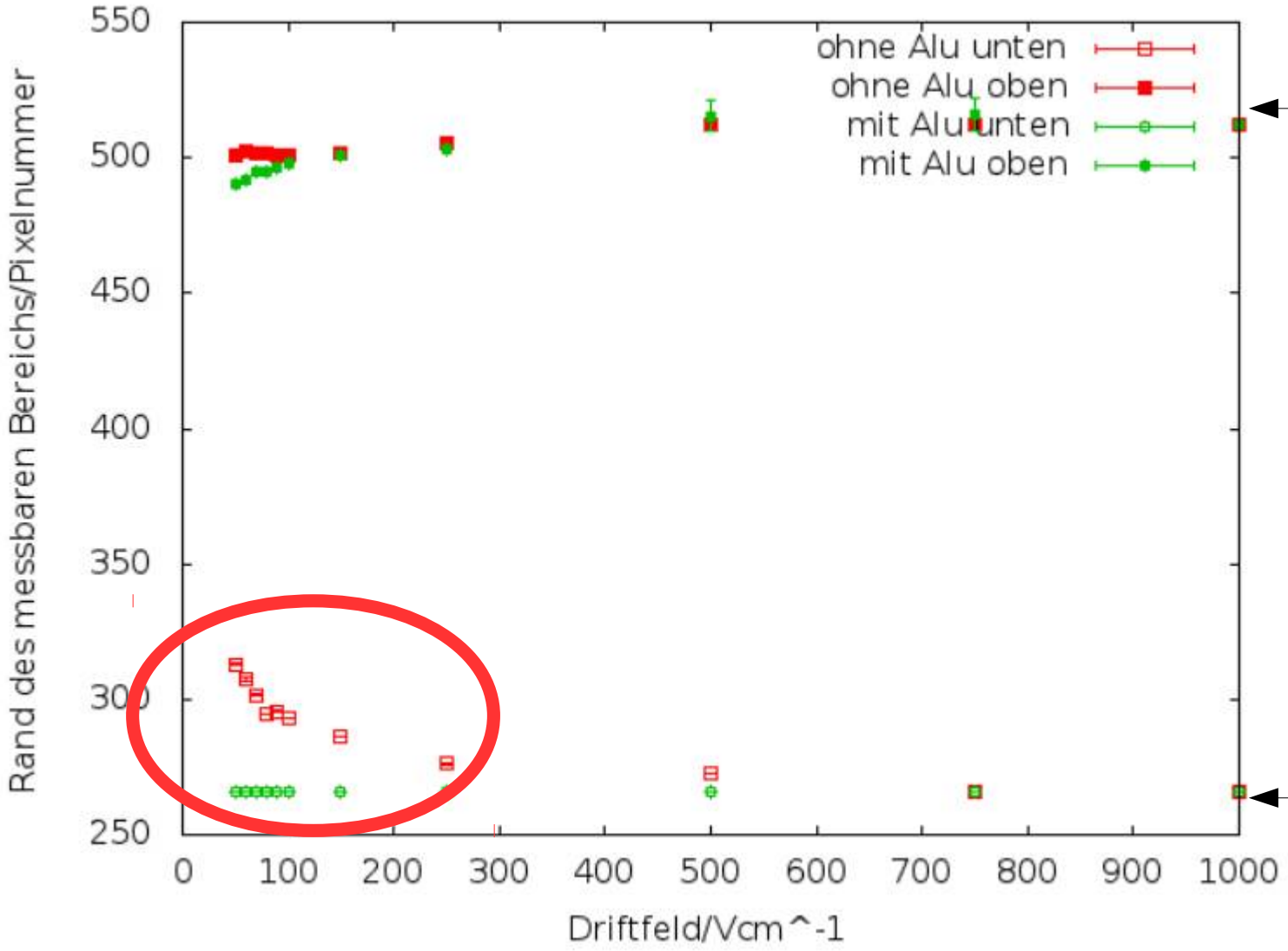
Field distortions



Chip edge

Chip edge

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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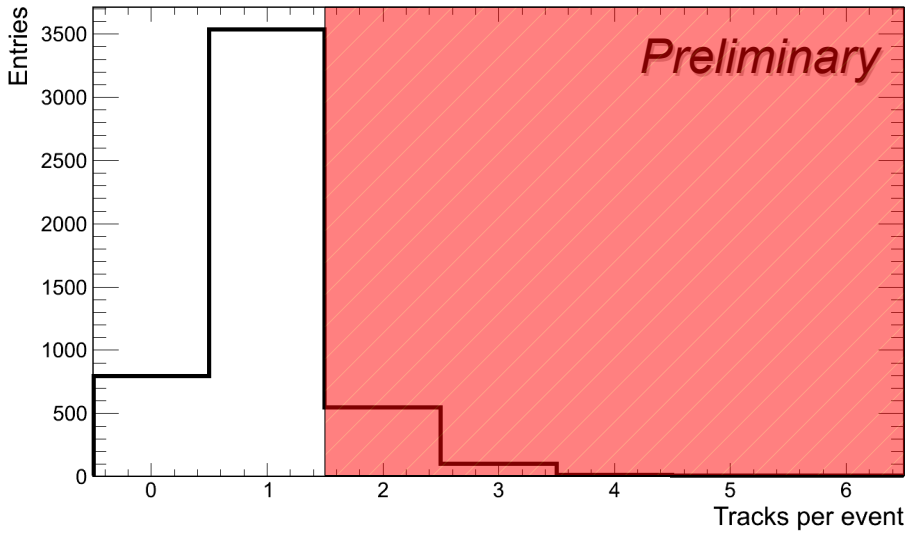

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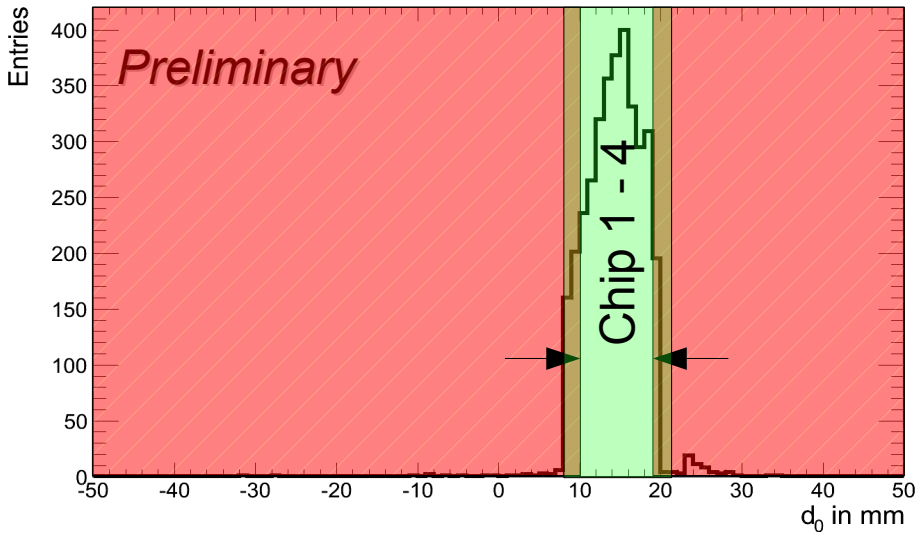
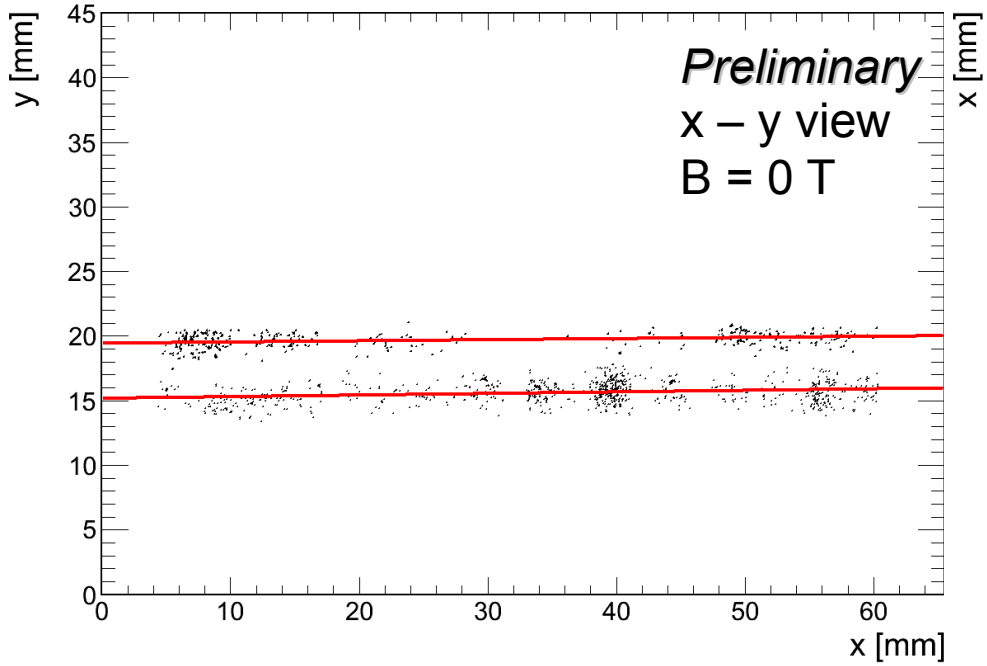
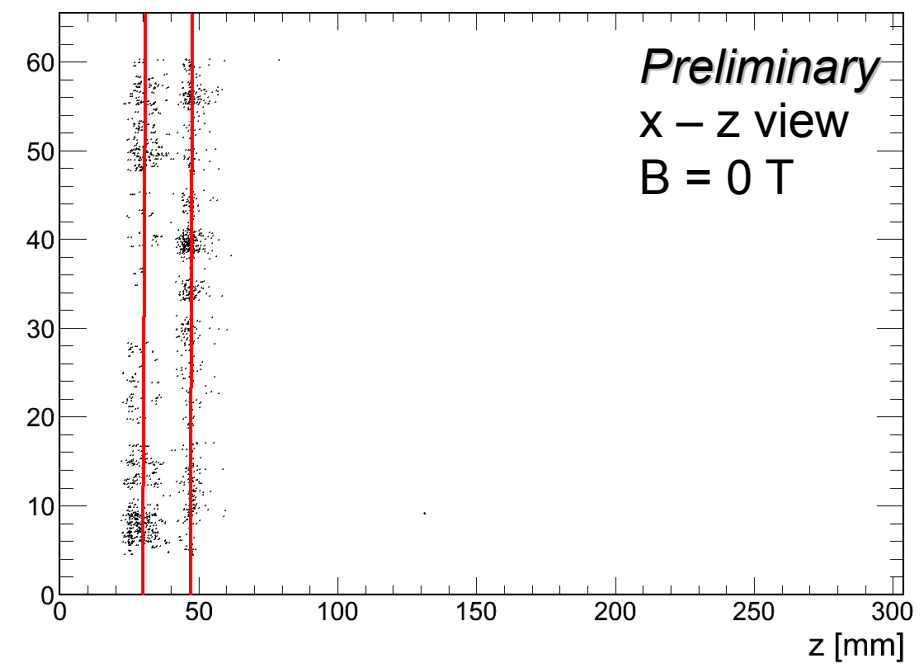


Cuts:

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

Reconstructed double tracks





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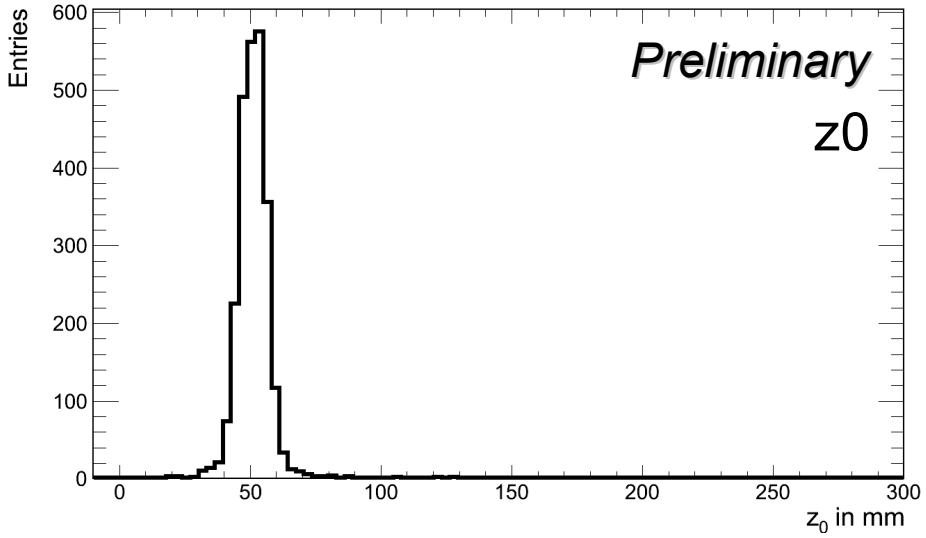
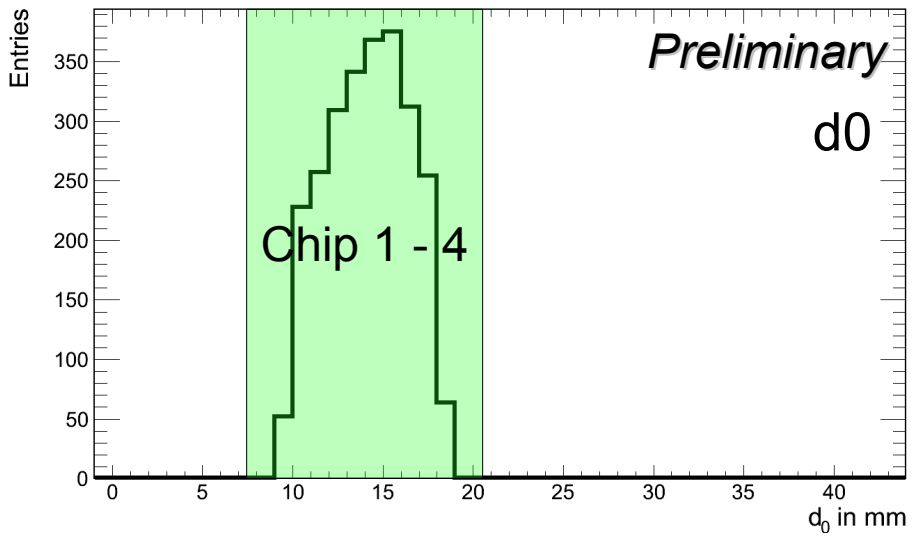
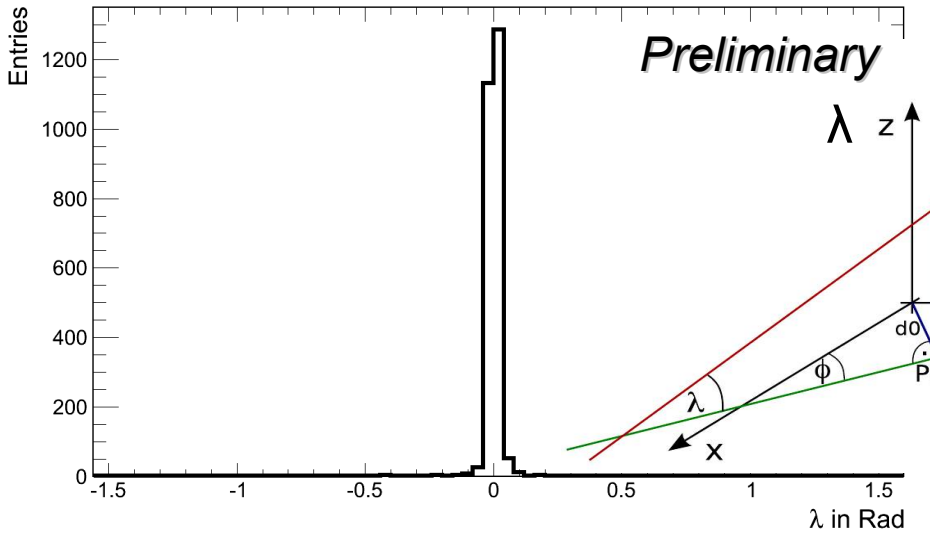
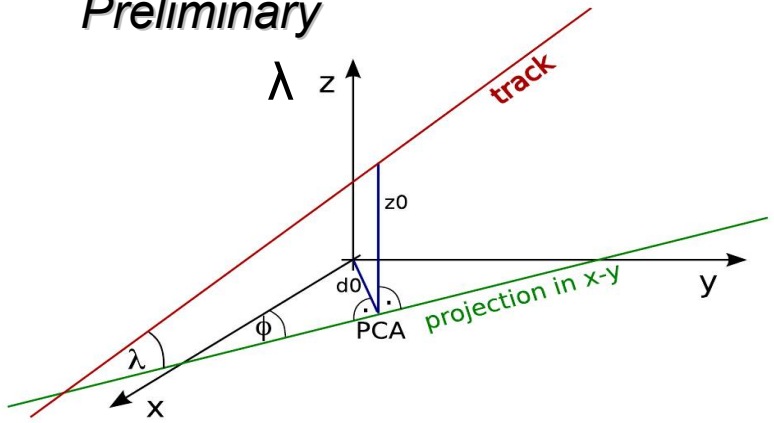
Track parameters

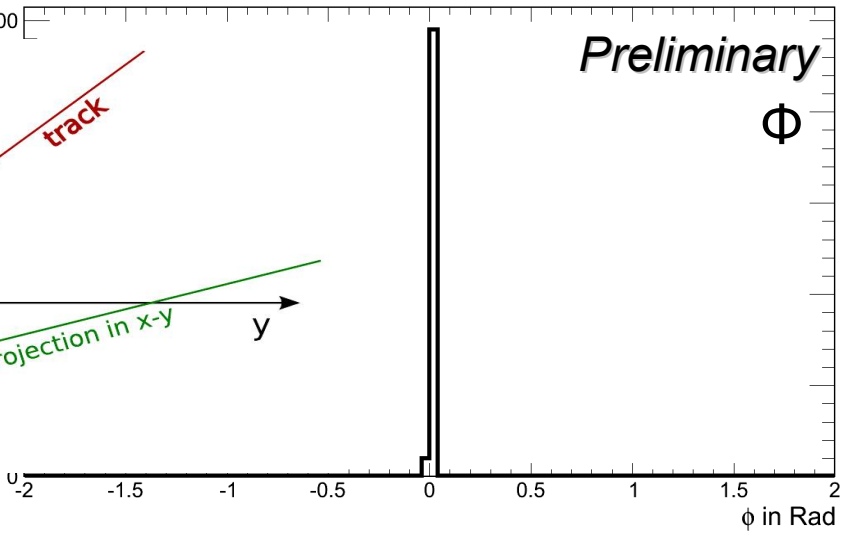
Run: z = 5,58 cm, B = 0 T



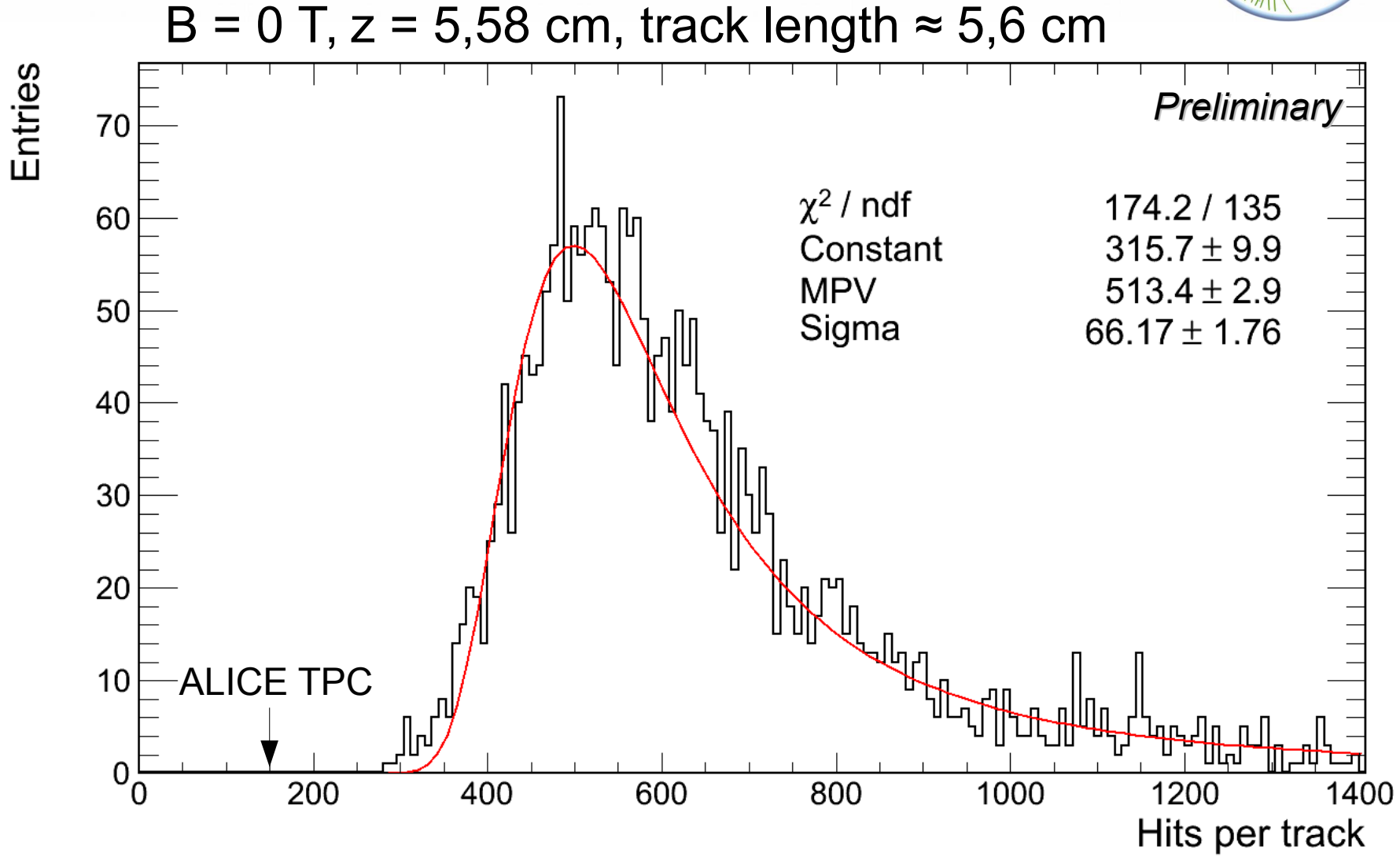




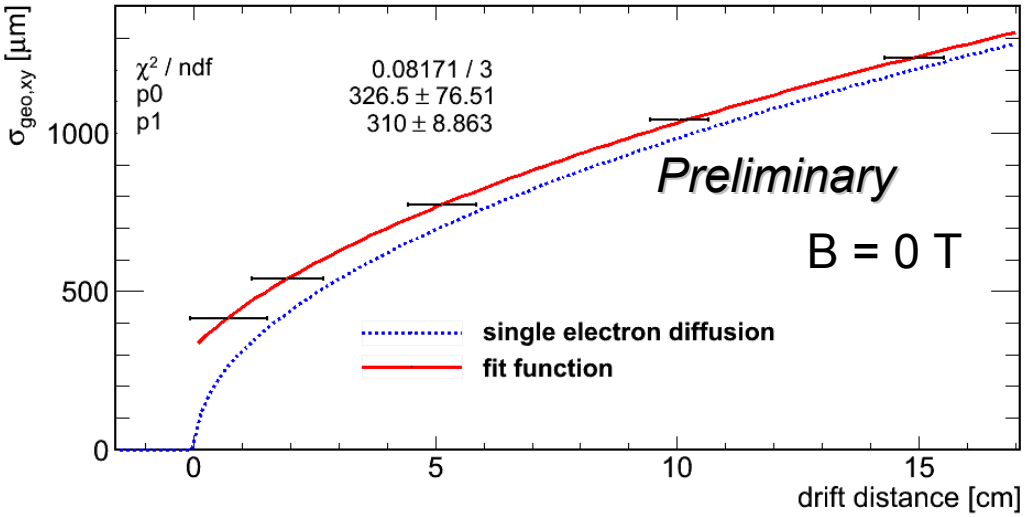




Hits per tracks

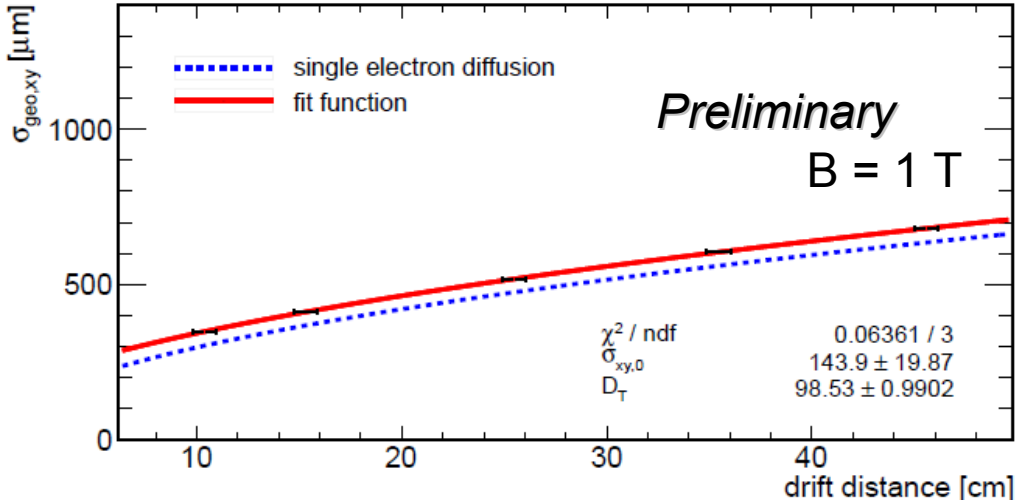


Transverse spatial resolution

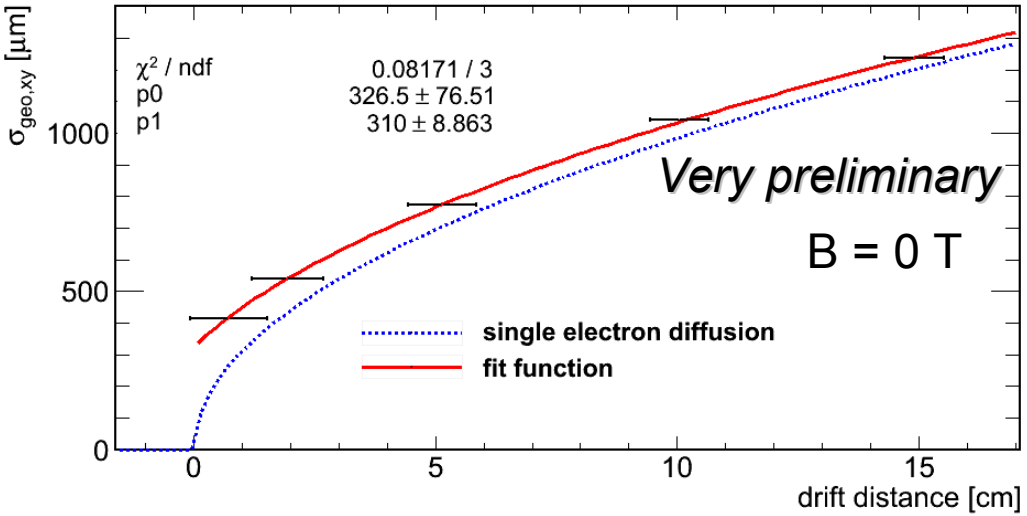


Fit function $f(x) = \sqrt{P0^2 + P1^2 \cdot z}$

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



Preliminary z-scan results



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

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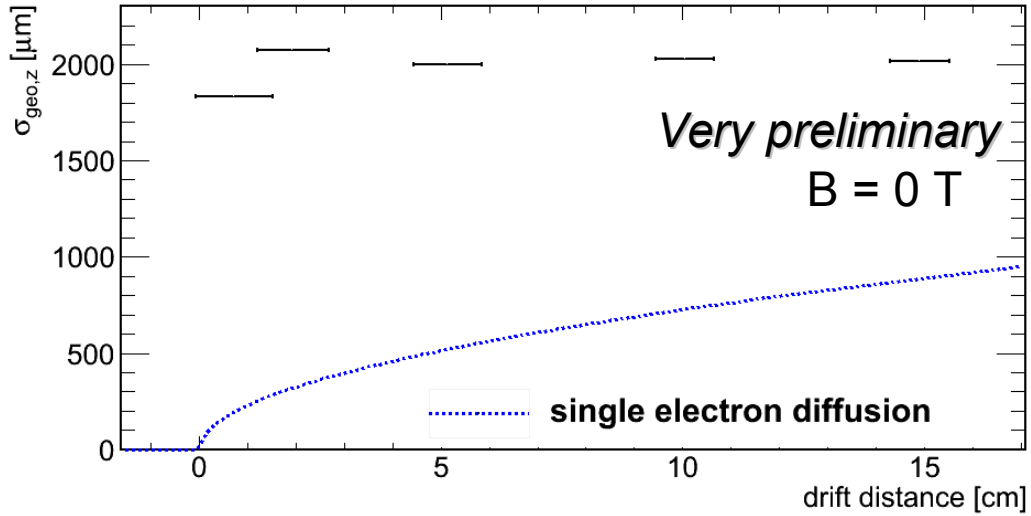
dominated by field distortions
P1 = 310 µm/√cm:
diffusion in T2K for E = 230 V



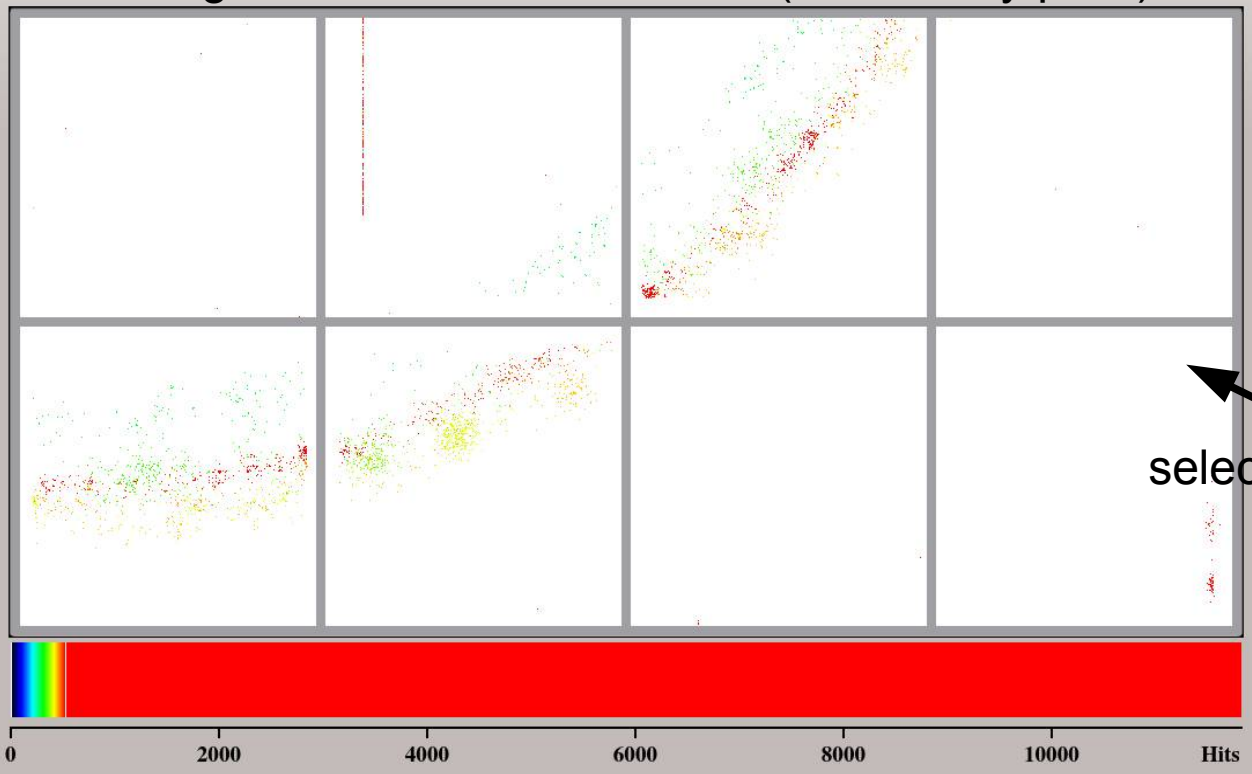
z resolution dominated by
- Clock frequency (25 ns time bins)
- Fast T2K gas (v_{Drift} ≈ 73 mm / µs)
- Timewalk effect

universitätbonn

2015 test beam

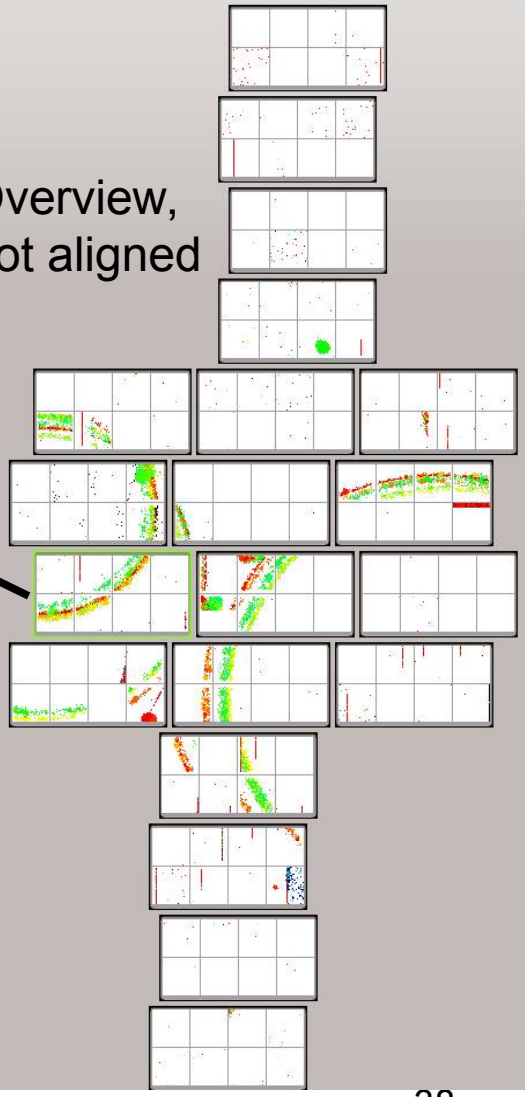
Events: Curlers

Enlarged view of one octoboard (sees every pixel)



Overview, not aligned

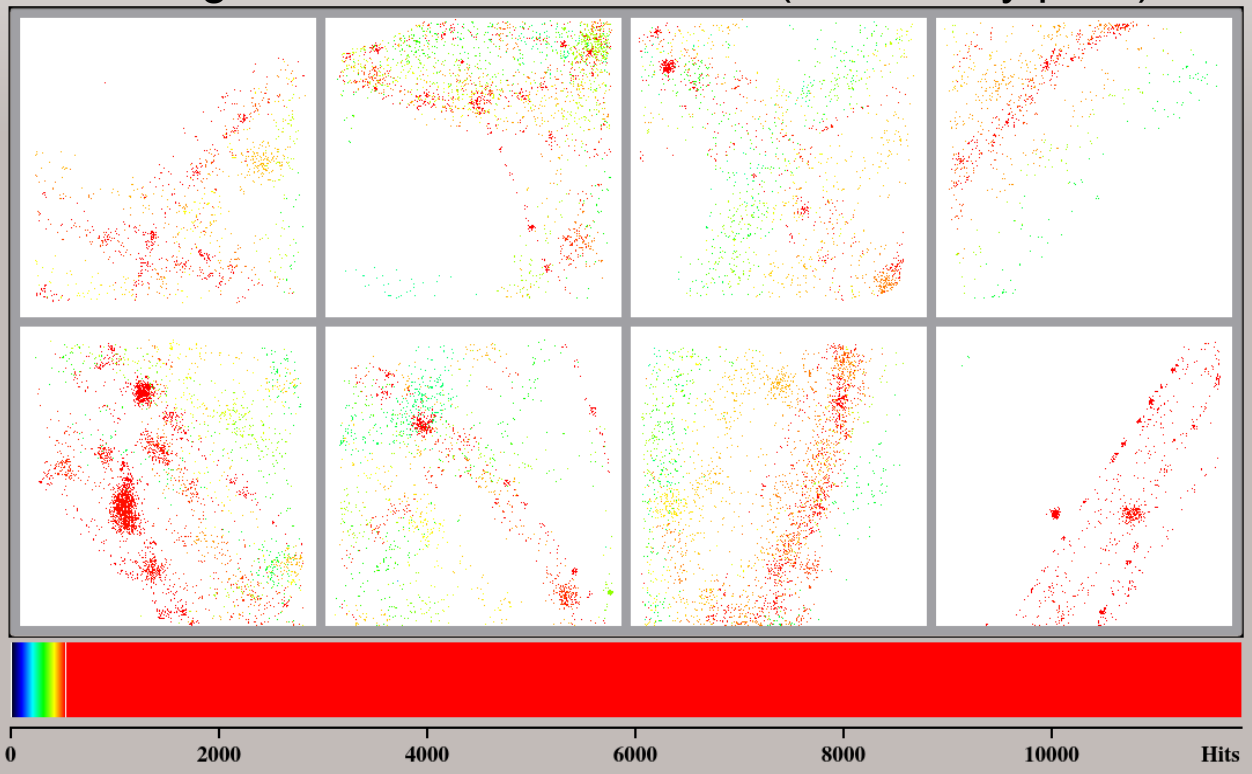
selected



2015 test beam

Events: Curlers

Enlarged view of one octoboard (sees every pixel)



Overview, not aligned

selected