A Triple-GEM Detector with Pixel Readout for High-Rate Beam Tracking

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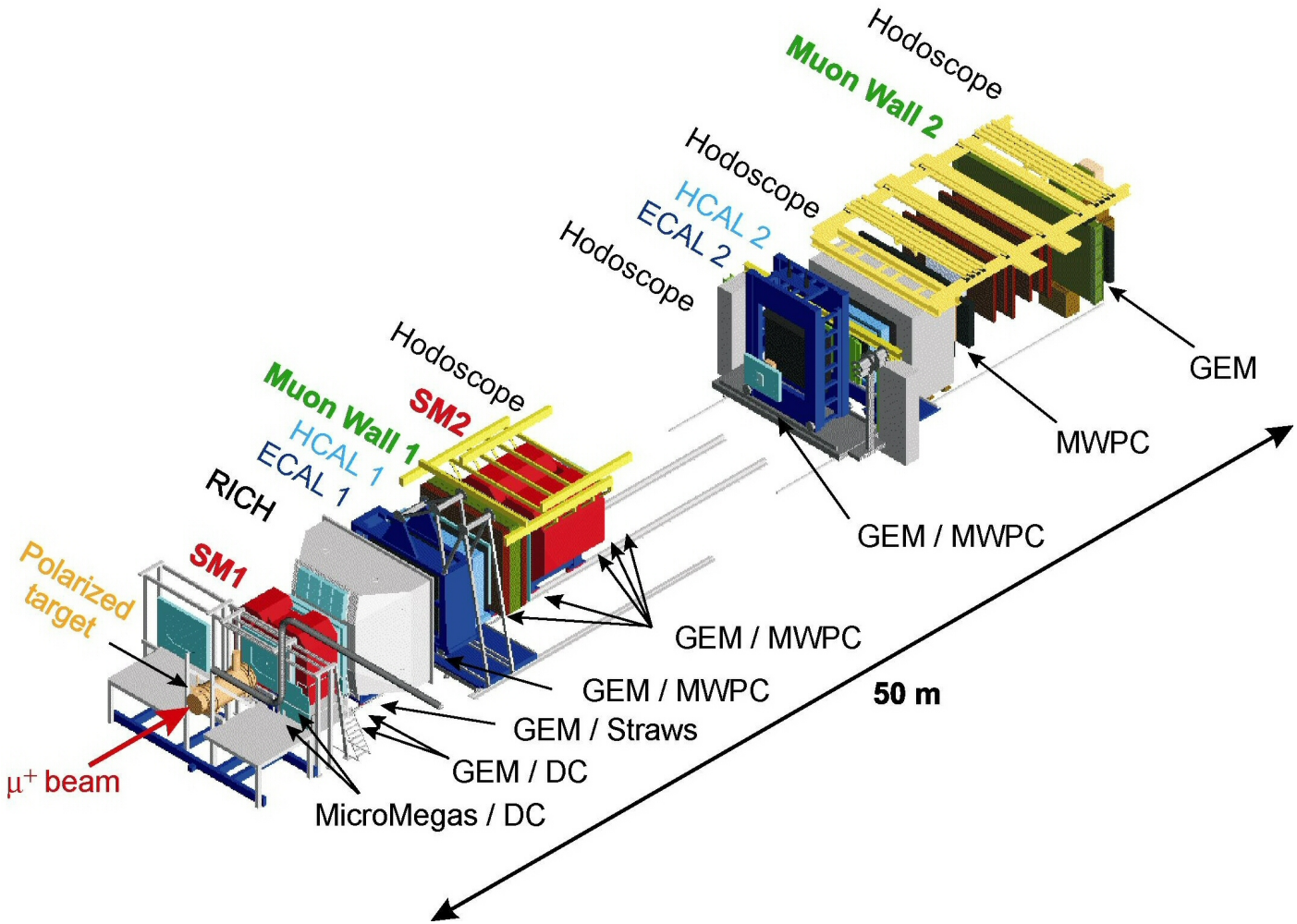
Overview

The COMPASS Experiment



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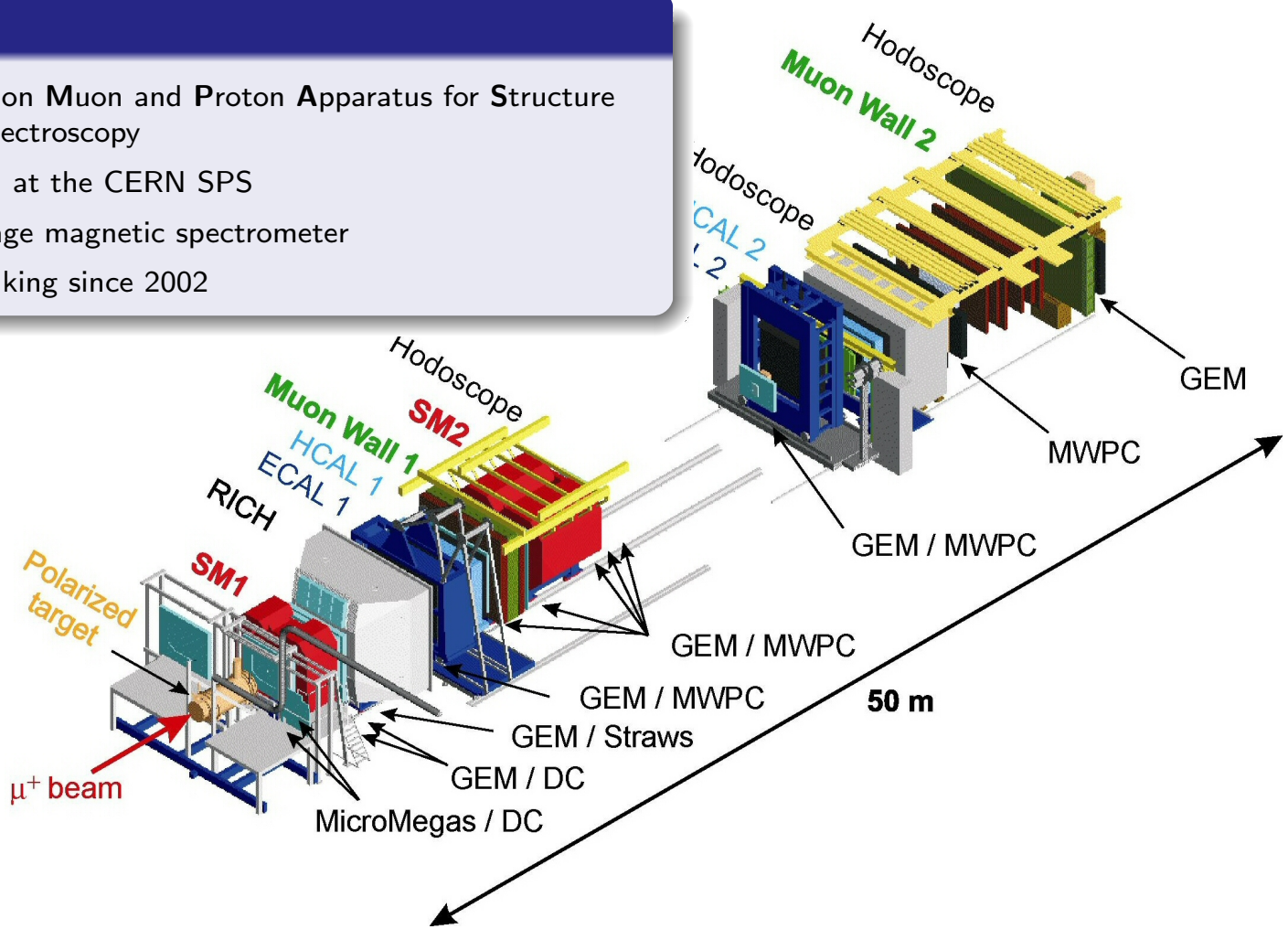
- located at the CERN SPS
- two stage magnetic spectrometer
- data taking since 2002



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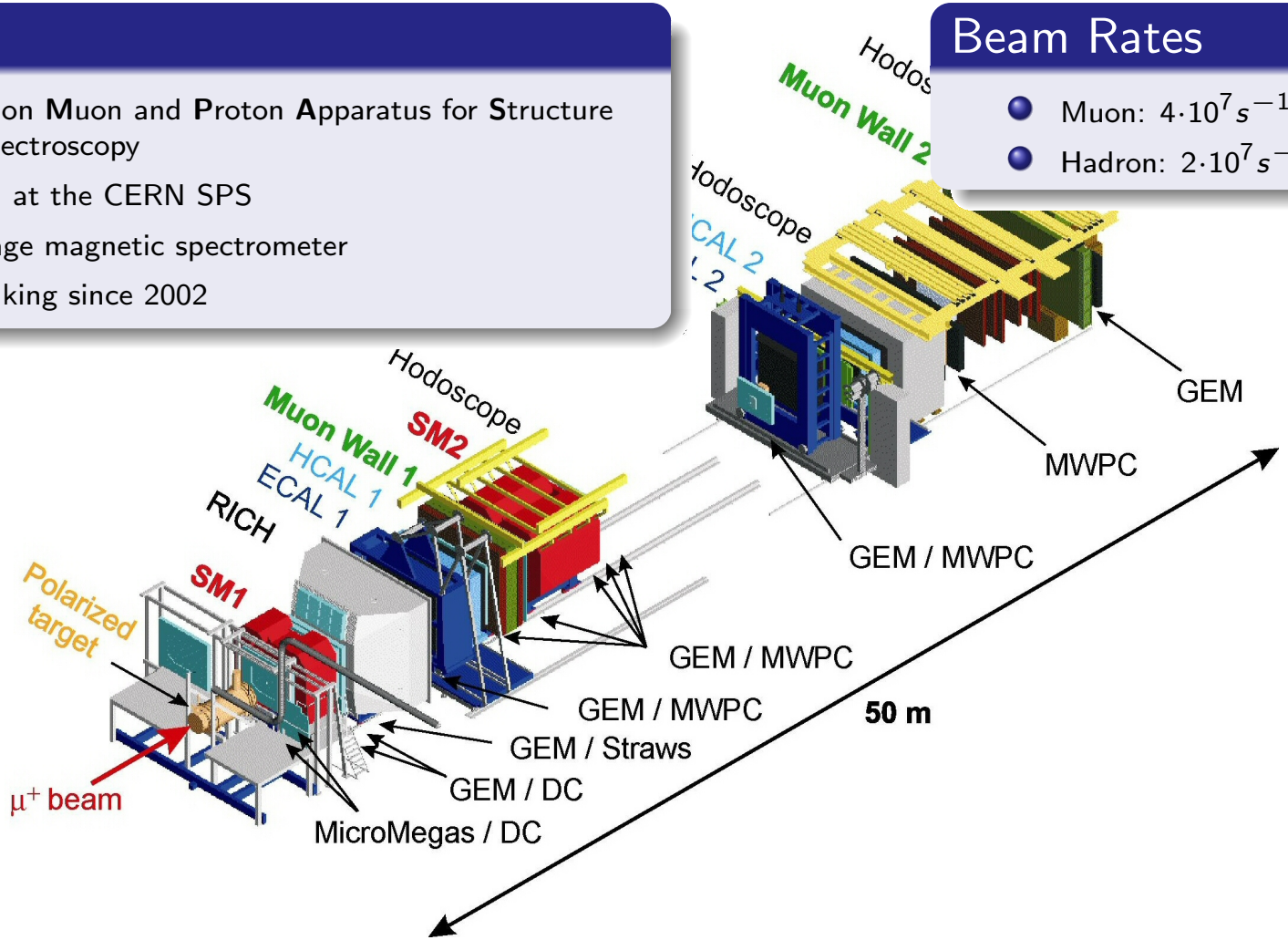

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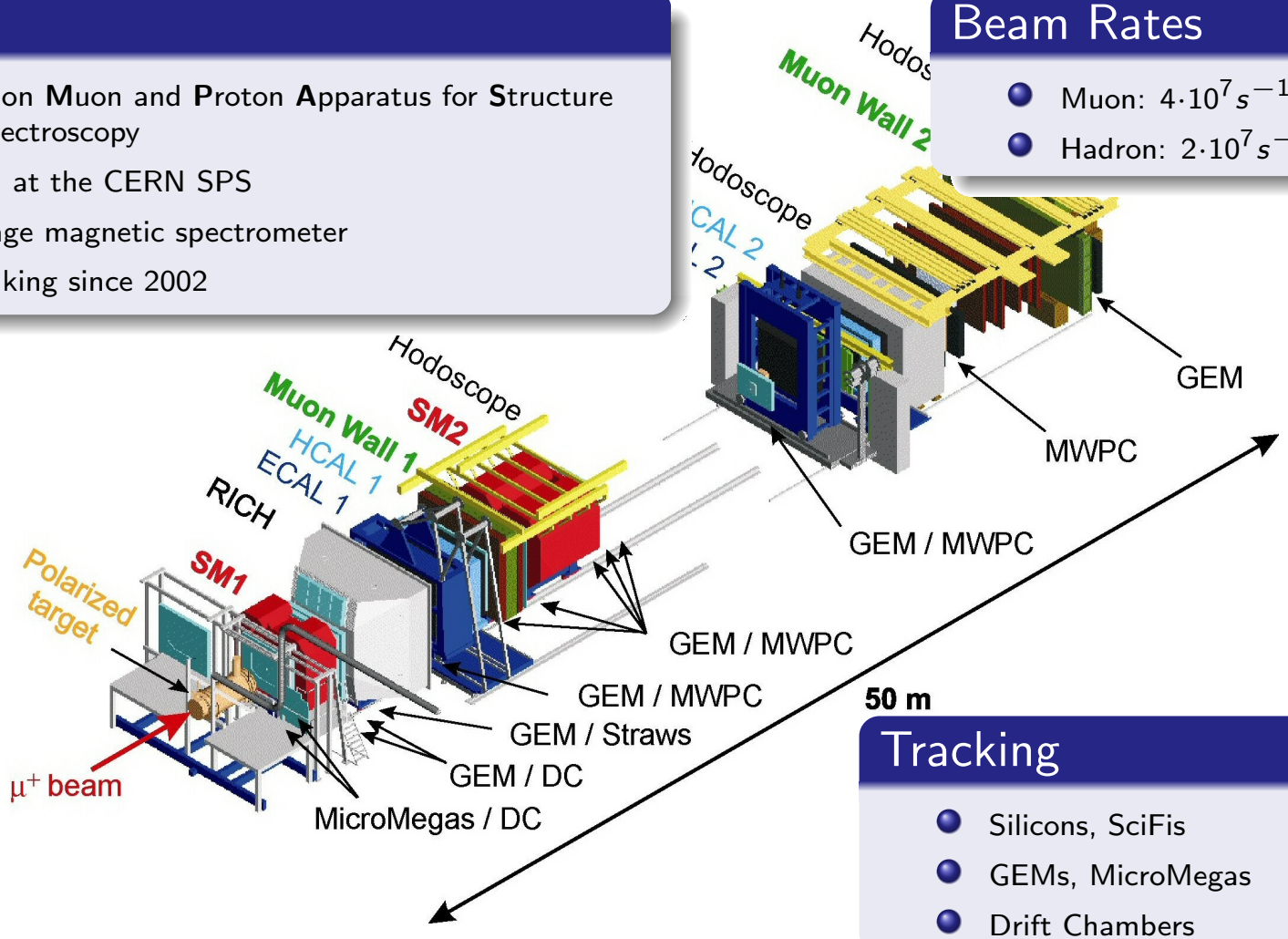
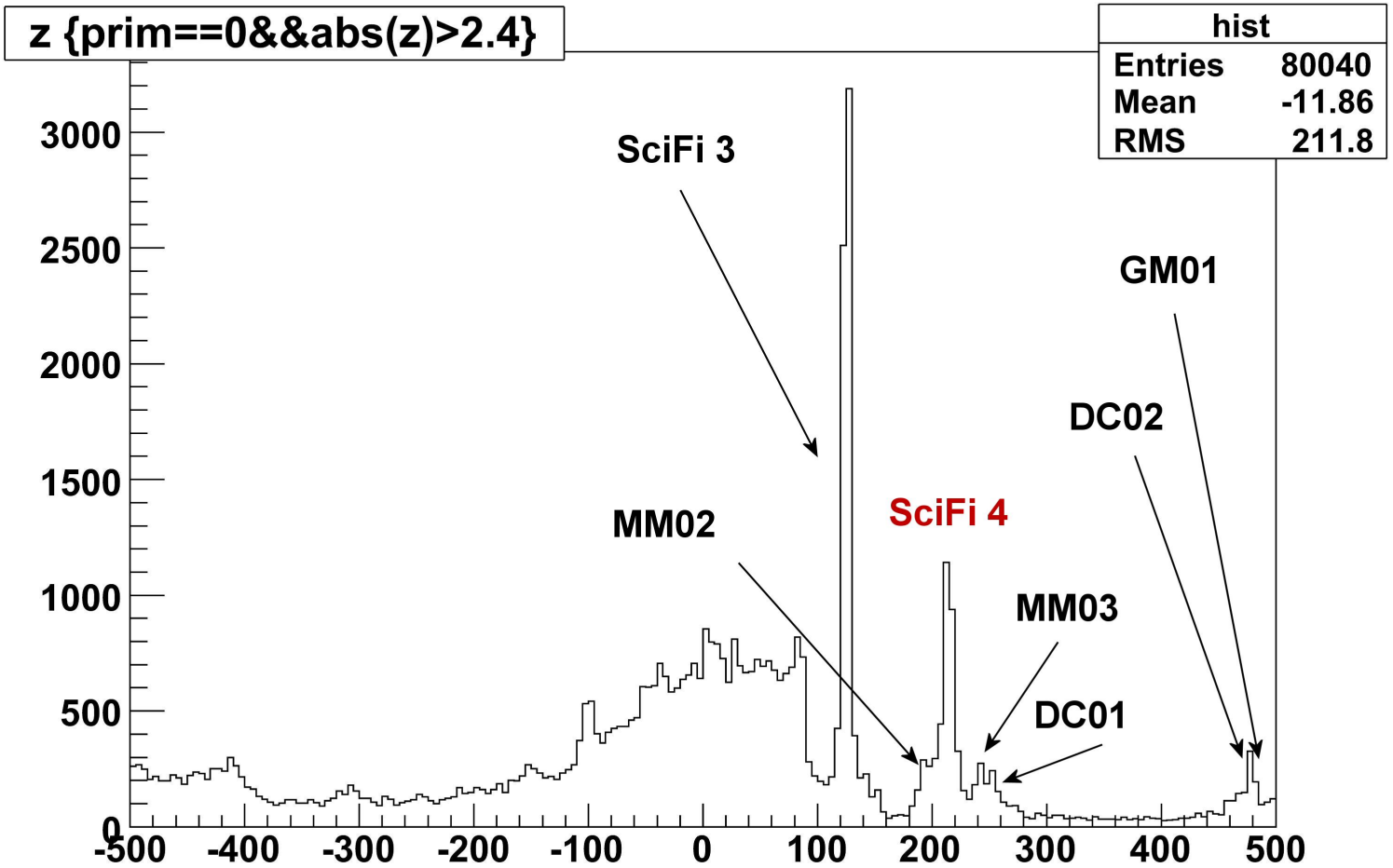


Tracking

- Silicons, SciFis
- GEMs, MicroMegas
- Drift Chambers

Motivation


z {prim==0&&abs(z)>2.4}
hist
Entries 80040
Mean -11.86
RMS 211.8
SciFi 3
GM01
DC02
SciFi 4
MM02
MM03
DC01
3000
2500
2000
1500
1000
500
0
-500
-400
-300
-200
-100
0
100
200
300
400
500

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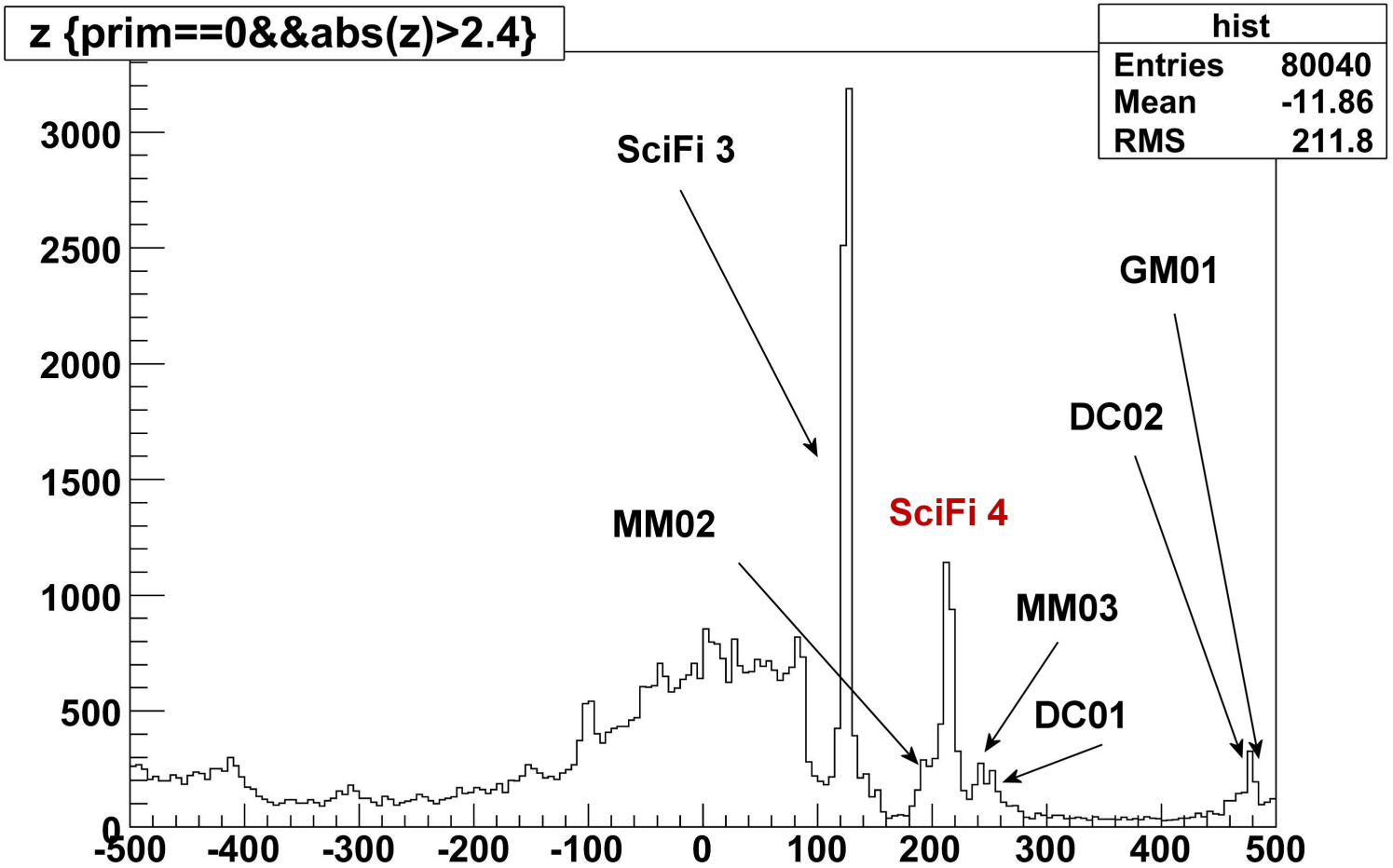

- SciFis act as secondary targets in hadron beam
- Thickness SciFi: x/X_0 =1.6-2.8 %

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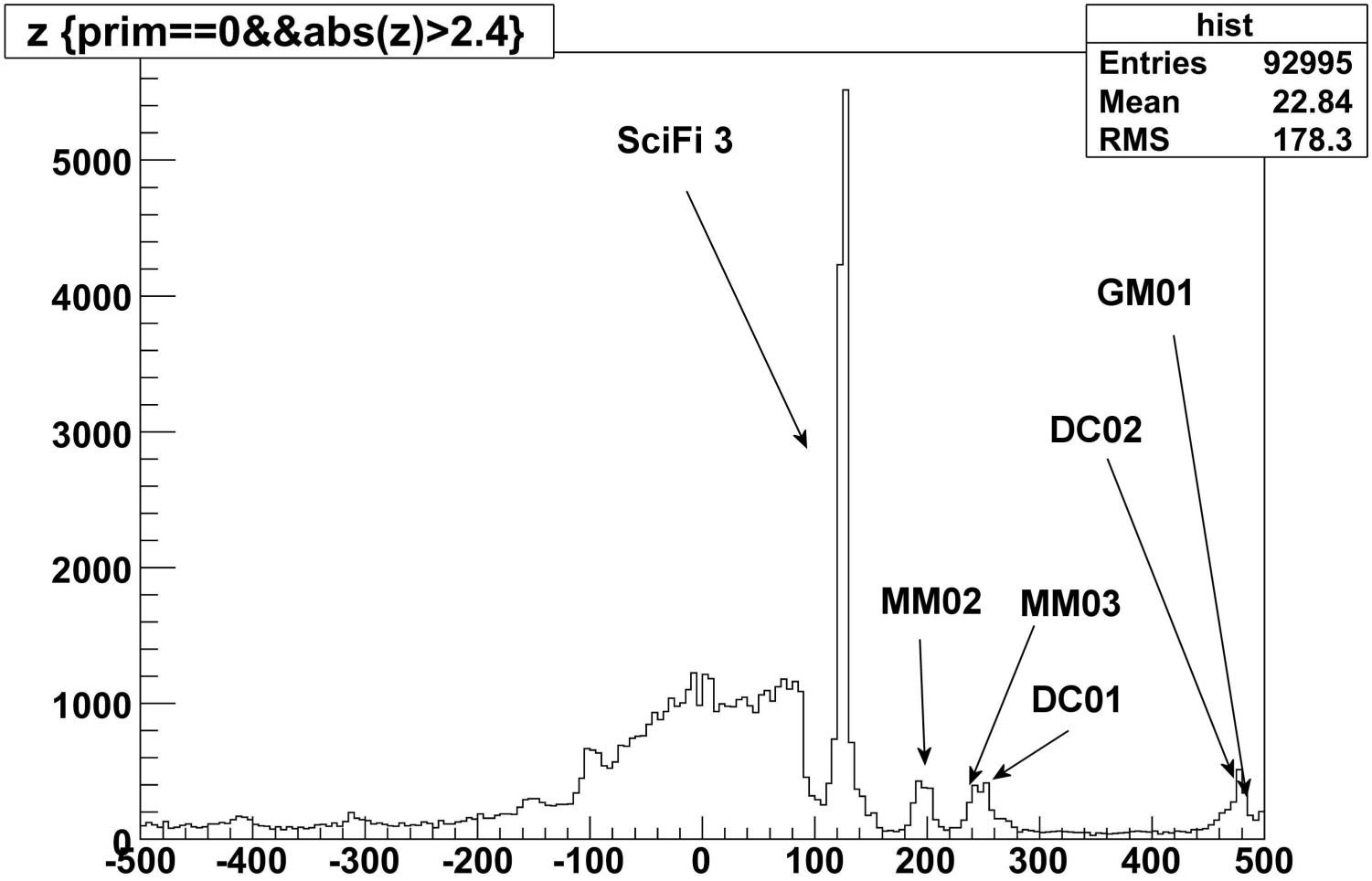
z {prim==0&&abs(z)>2.4}
hist
Entries 92995
Mean 22.84
RMS 178.3
SciFi 3
GM01
DC02
MM02
MM03
DC01
5000
4000
3000
2000
1000
0
-500
-400
-300
-200
-100
0
100
200
300
400
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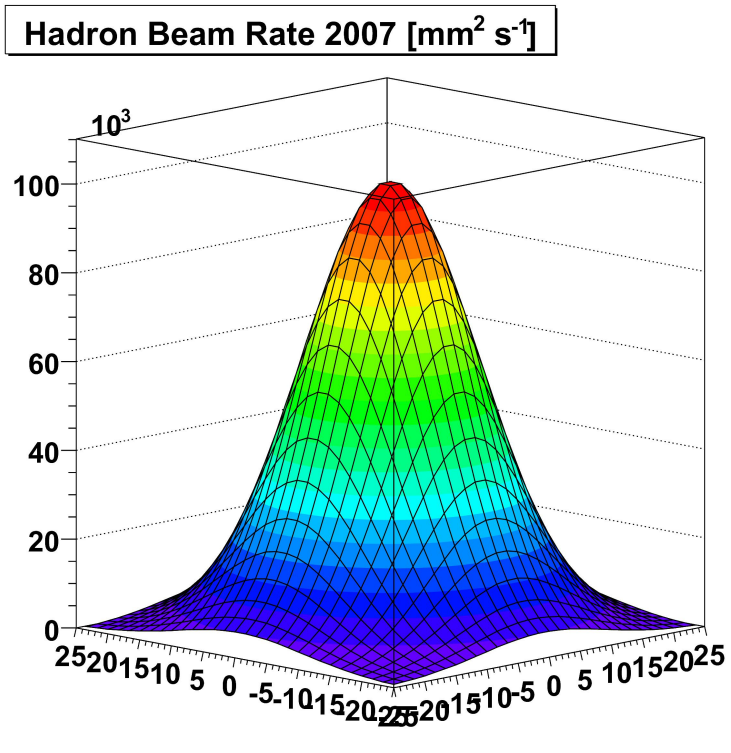
Motivation

Triple-GEM Detectors:

- high rate capability [1,2]
  COMPASS requirements:
  - beam rates: $\lesssim 10^5$ mm^{-2} s^{-1}



[1] [S. Bachmann, A. Bressan, B. Ketzer et al., Nucl. Instr. and Meth. A470(2001)548.]
[2] [S. Bachmann, S. Kappler, B. Ketzer et al., Nucl. Instr. and Meth. A478(2002)104.]

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- small material budget[3]
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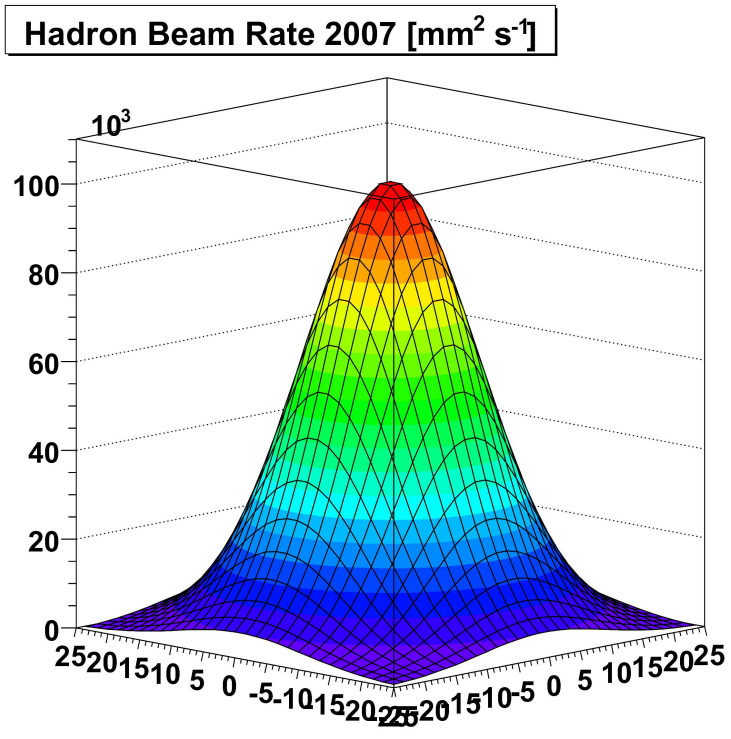

[3] [C. Altunbas et al., Nucl. Instr. and Meth. A490(2002)177]

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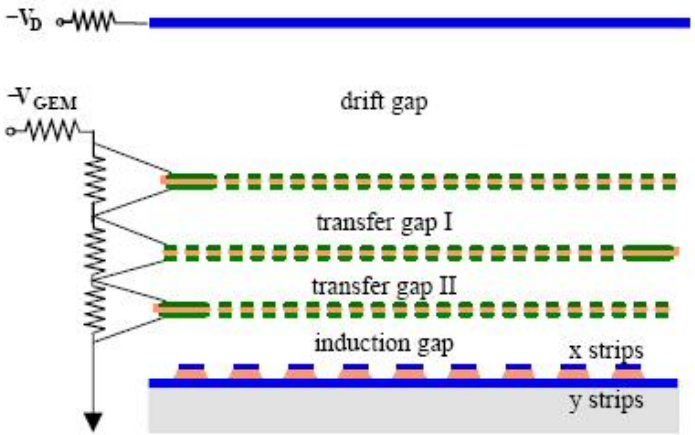
Strip Readout

- strip occupancy too high
- no sufficient beam tracking with strip readout



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GEM detector with combined pixel/strip readout

The combined Pixel-Strip-Readout

- 3-layer PCB
  (base material: Kapton)
- thickness: 100 μm

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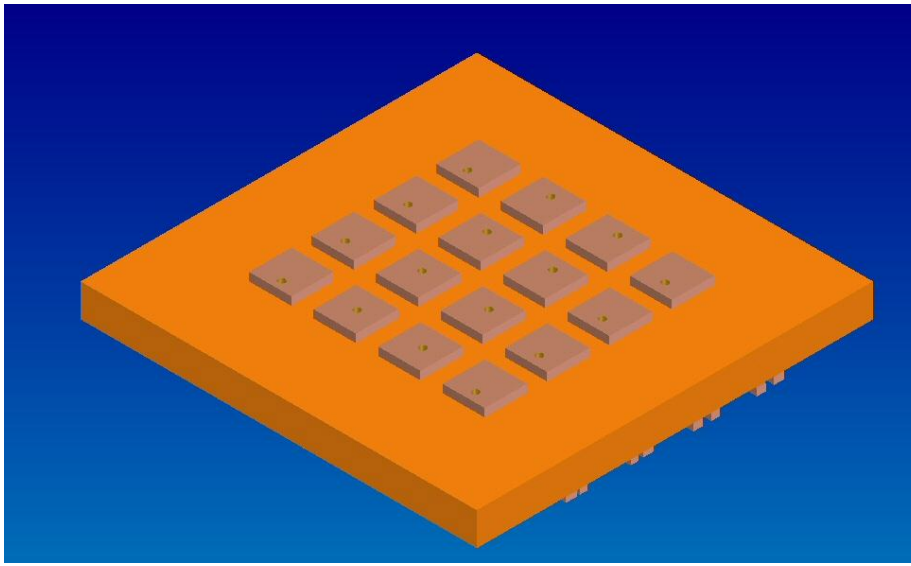
- pitch: 1 mm



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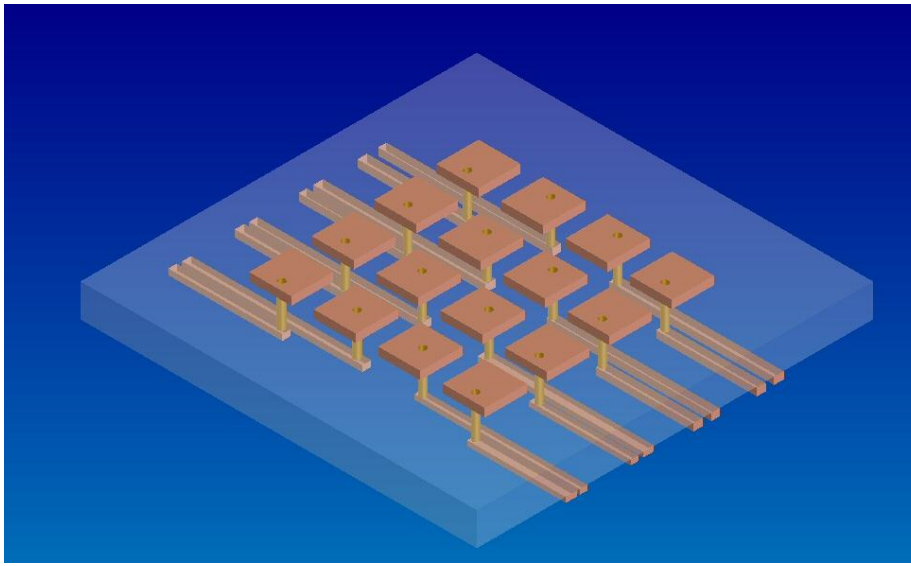
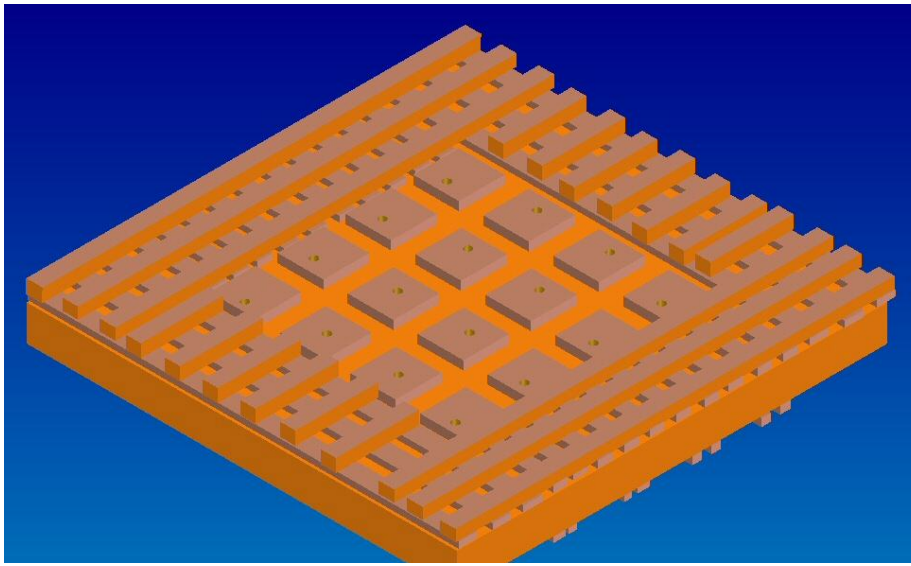


The combined Pixel-Strip-Readout

- 3-layer PCB
  (base material: Kapton)
- thickness: 100 μm
- 32 x 32 pixels
- pitch: 1 mm
- 1024 strip channels
  (512 x, 512 y)
- pitch: 400 μm
- equal charge sharing



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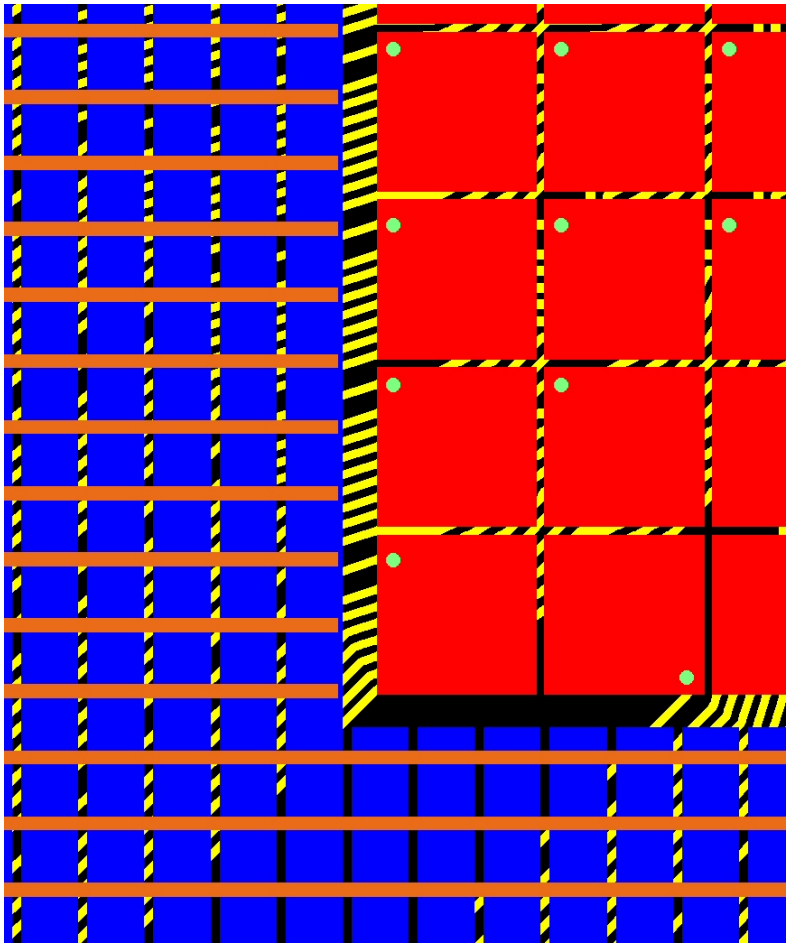
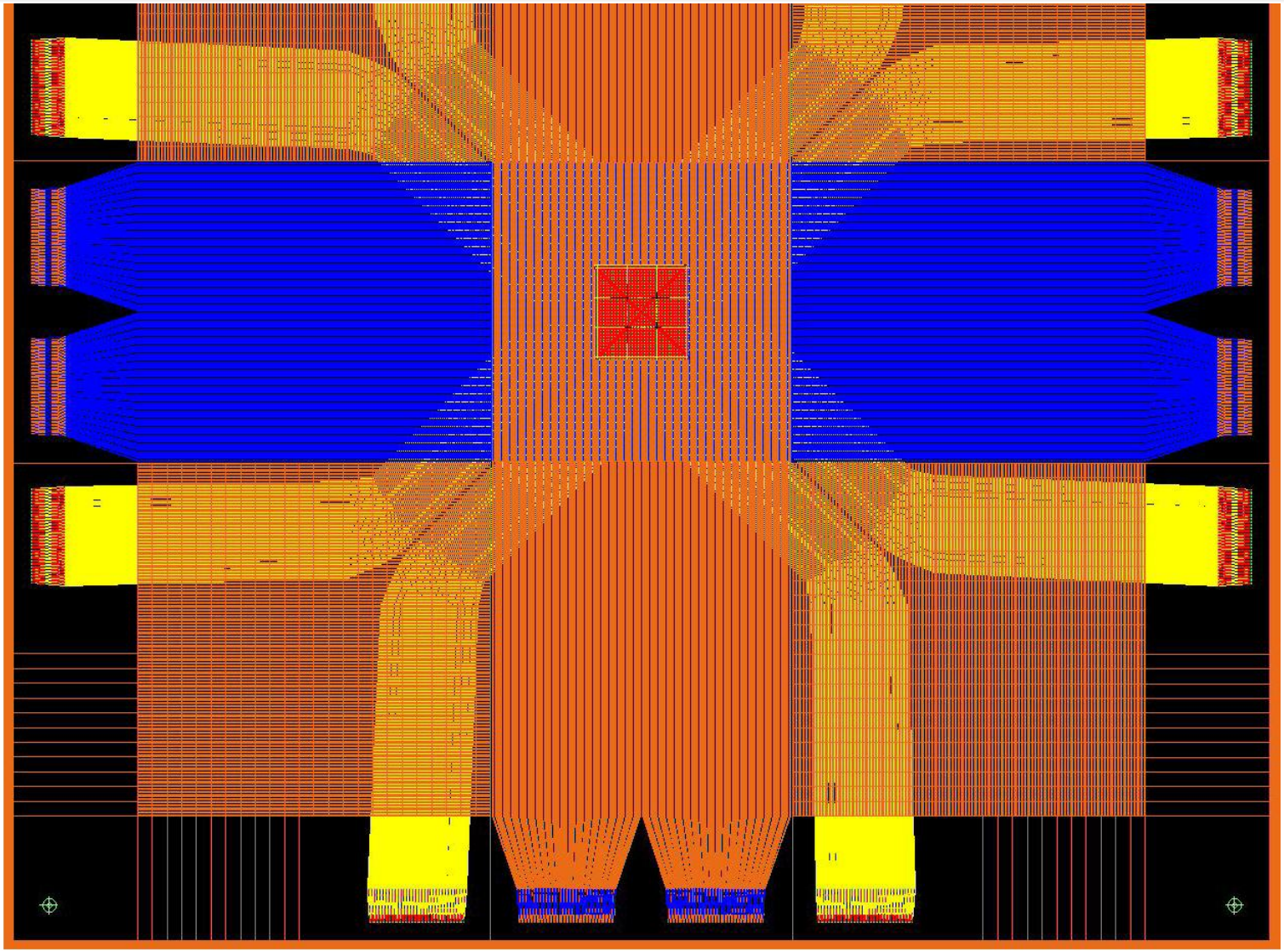


Readout(1)



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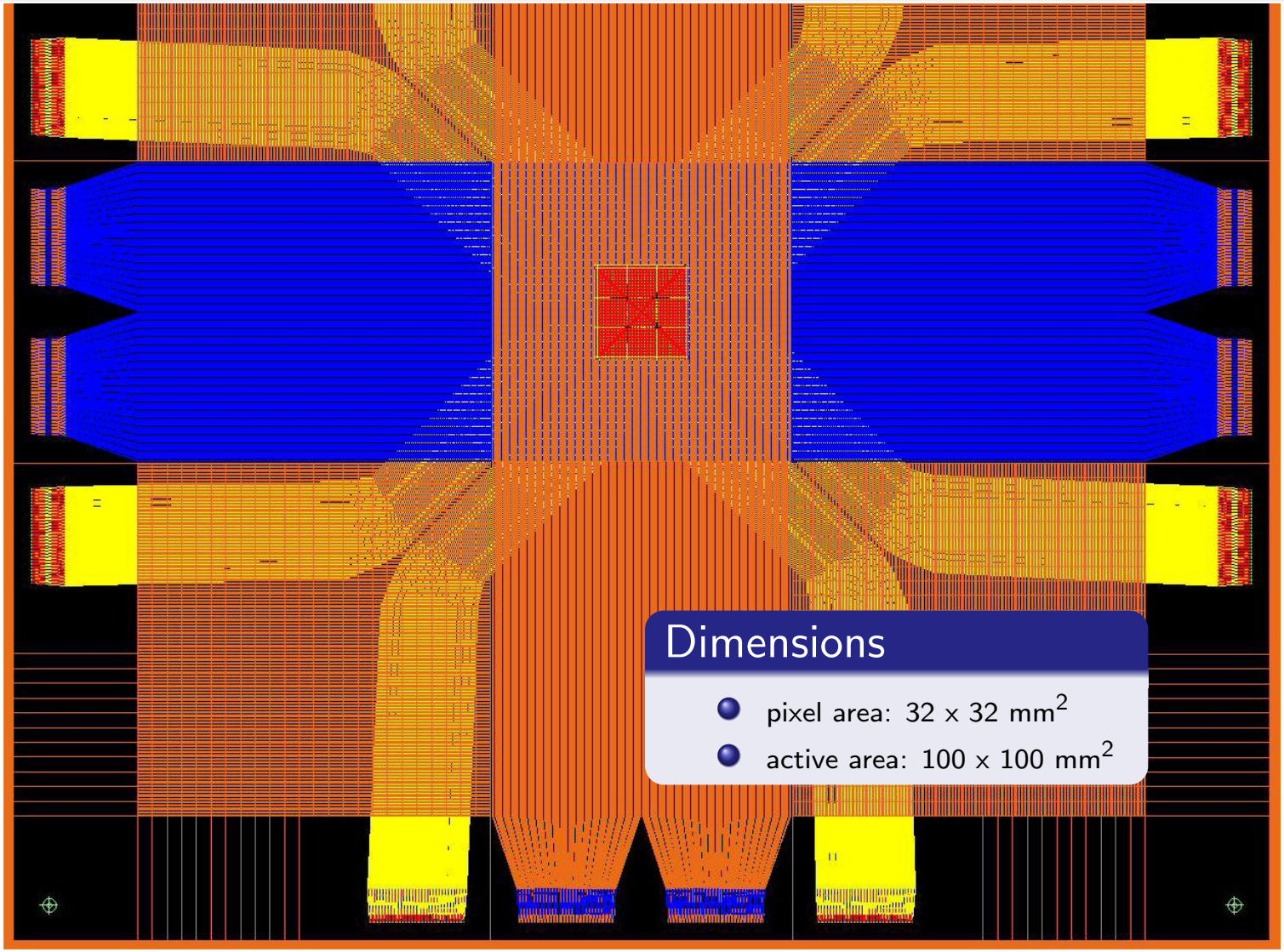
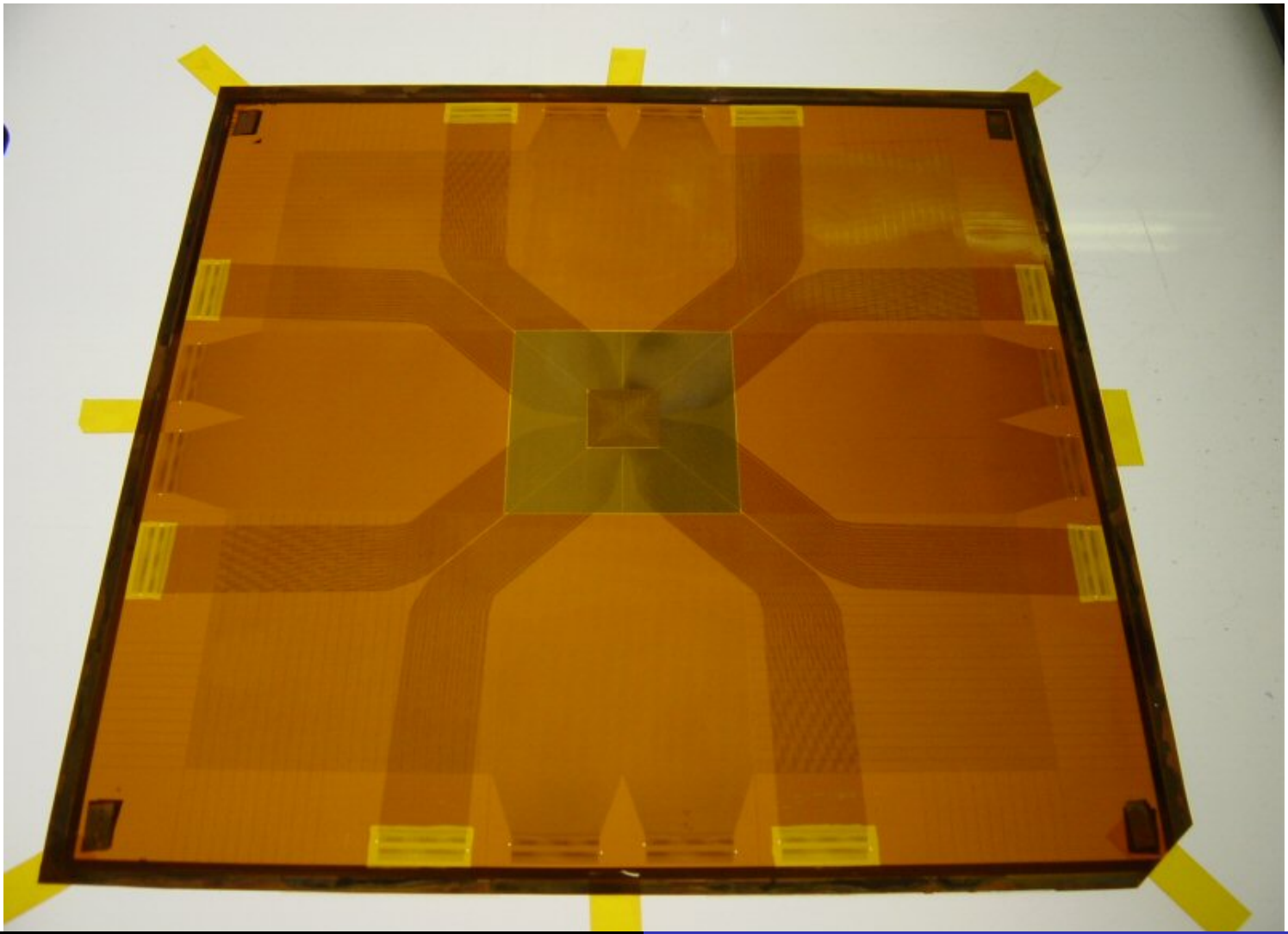


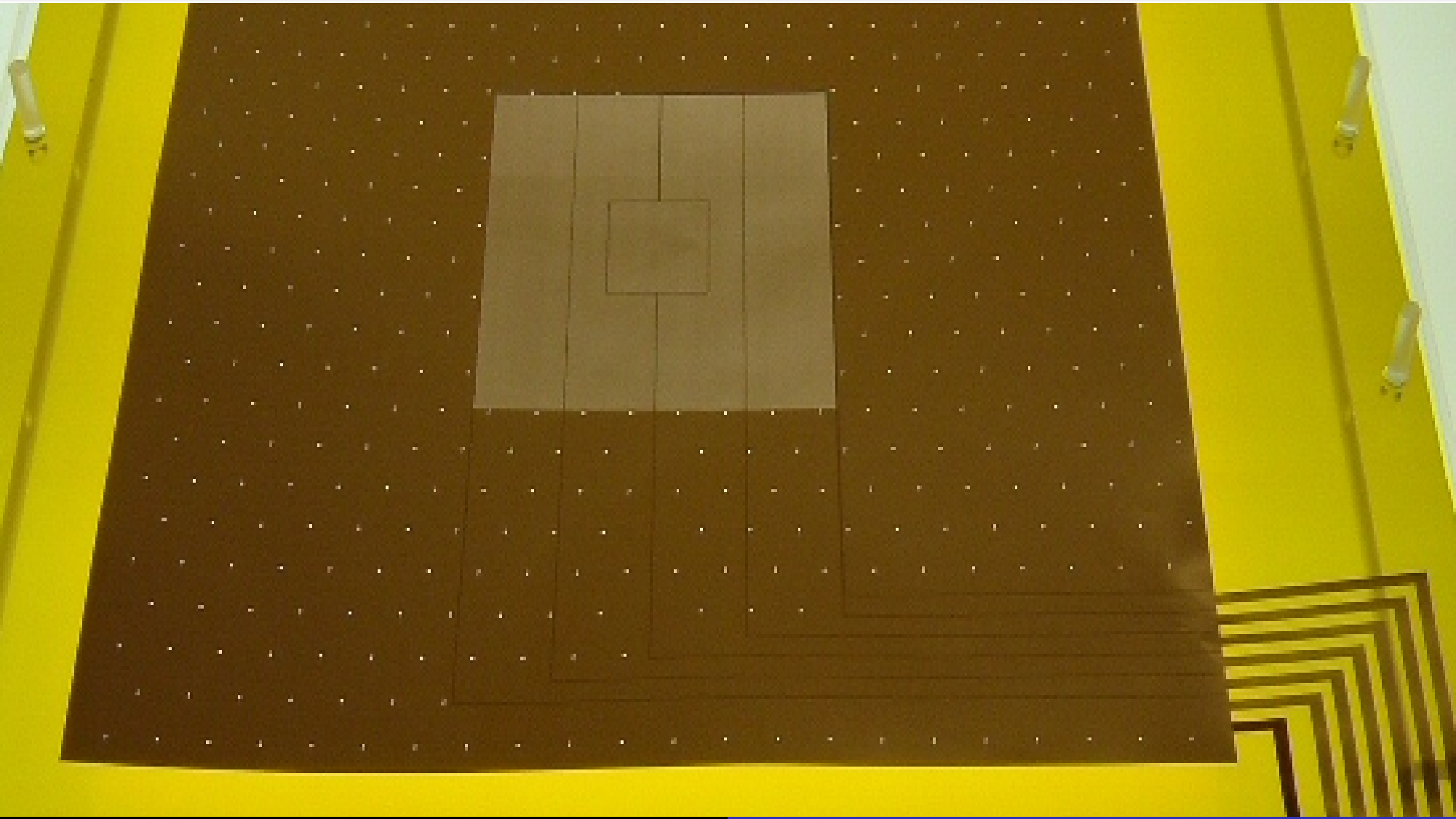
Dimensions

- pixel area: 32 x 32 mm^2
- active area: 100 x 100 mm^2

Readout(2)



GEM Geometries and Settings



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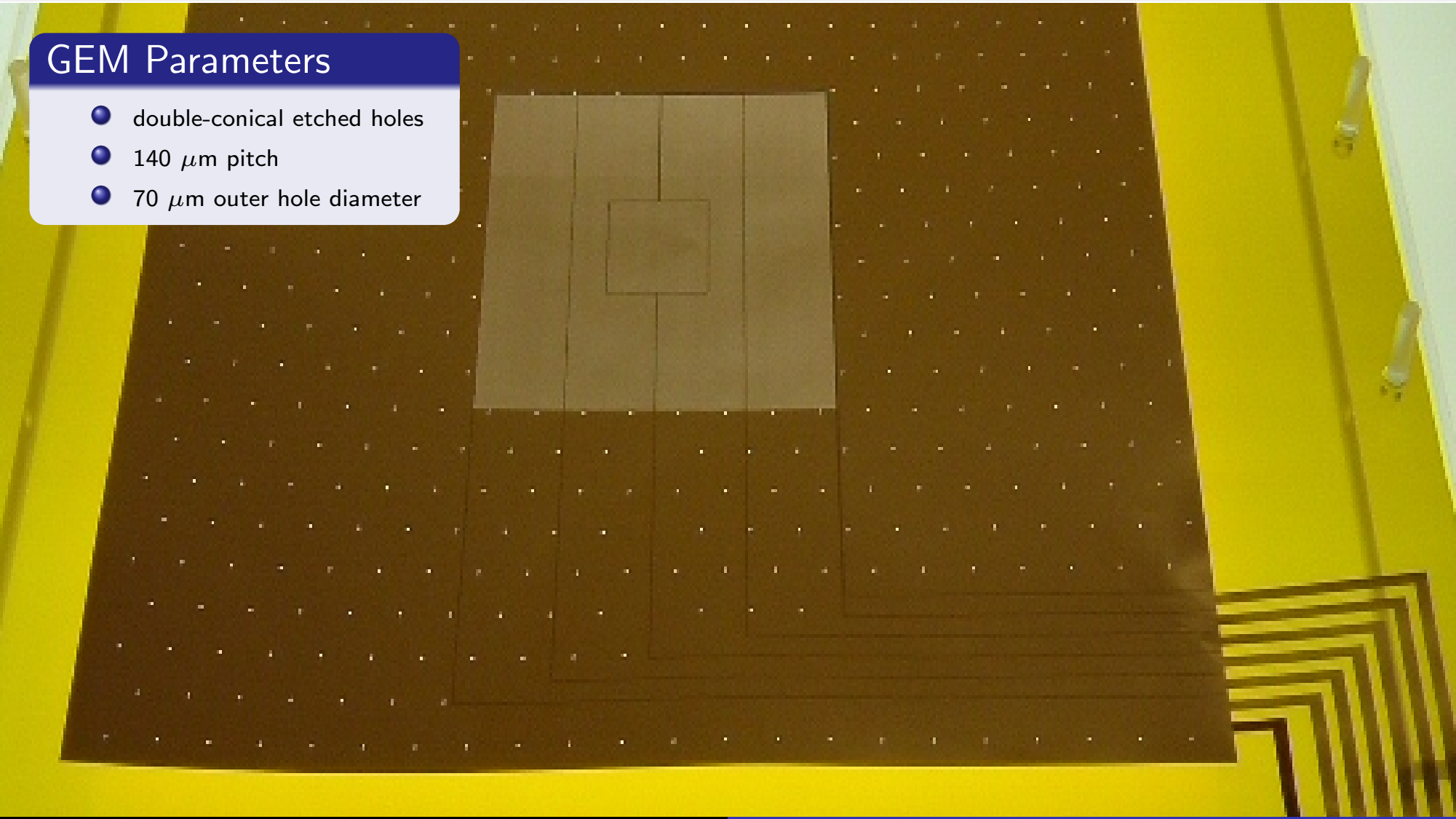
GEM Parameters

- double-conical etched holes
- 140 μm pitch
- 70 μm outer hole diameter



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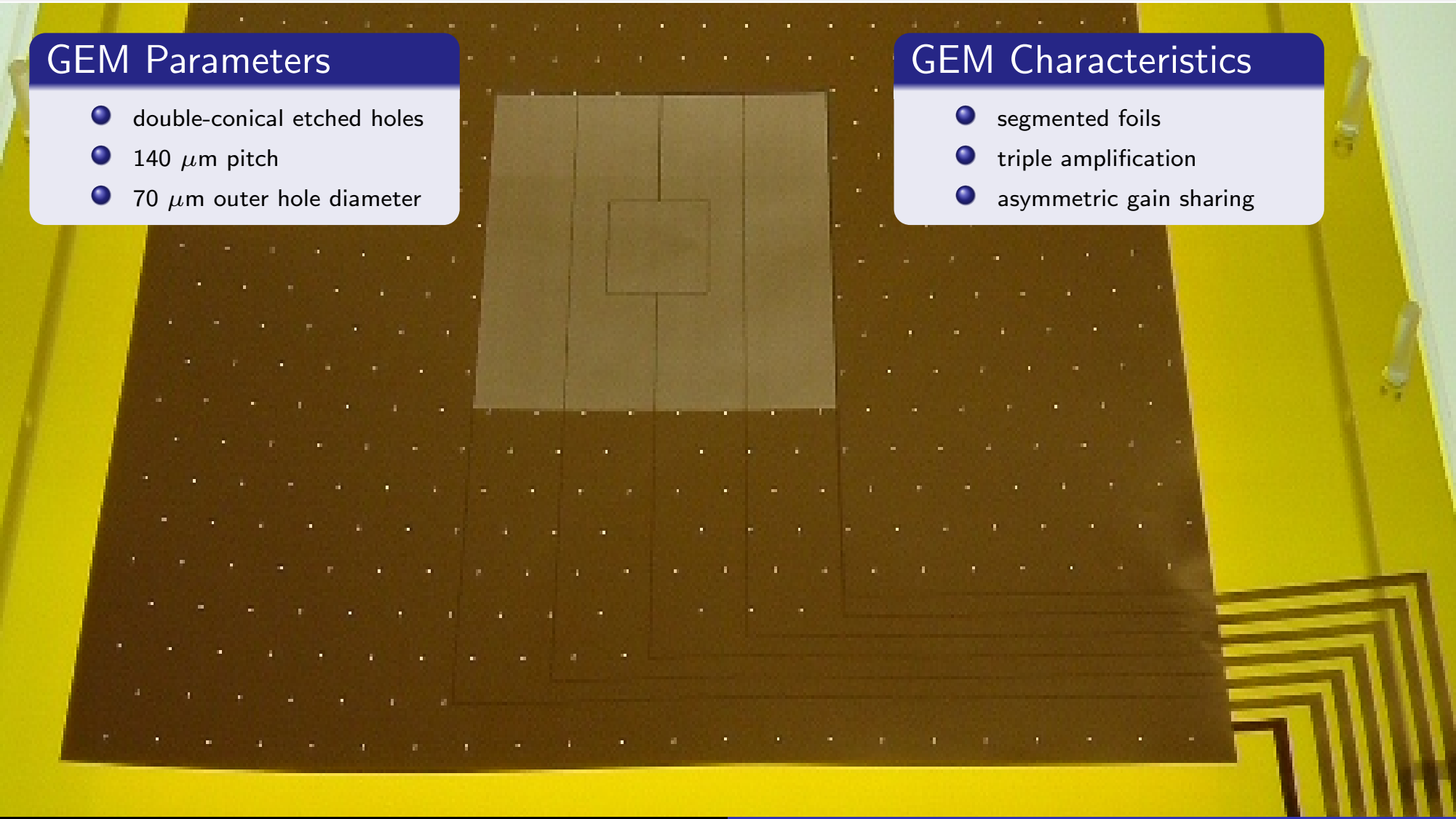

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- asymmetric gain sharing

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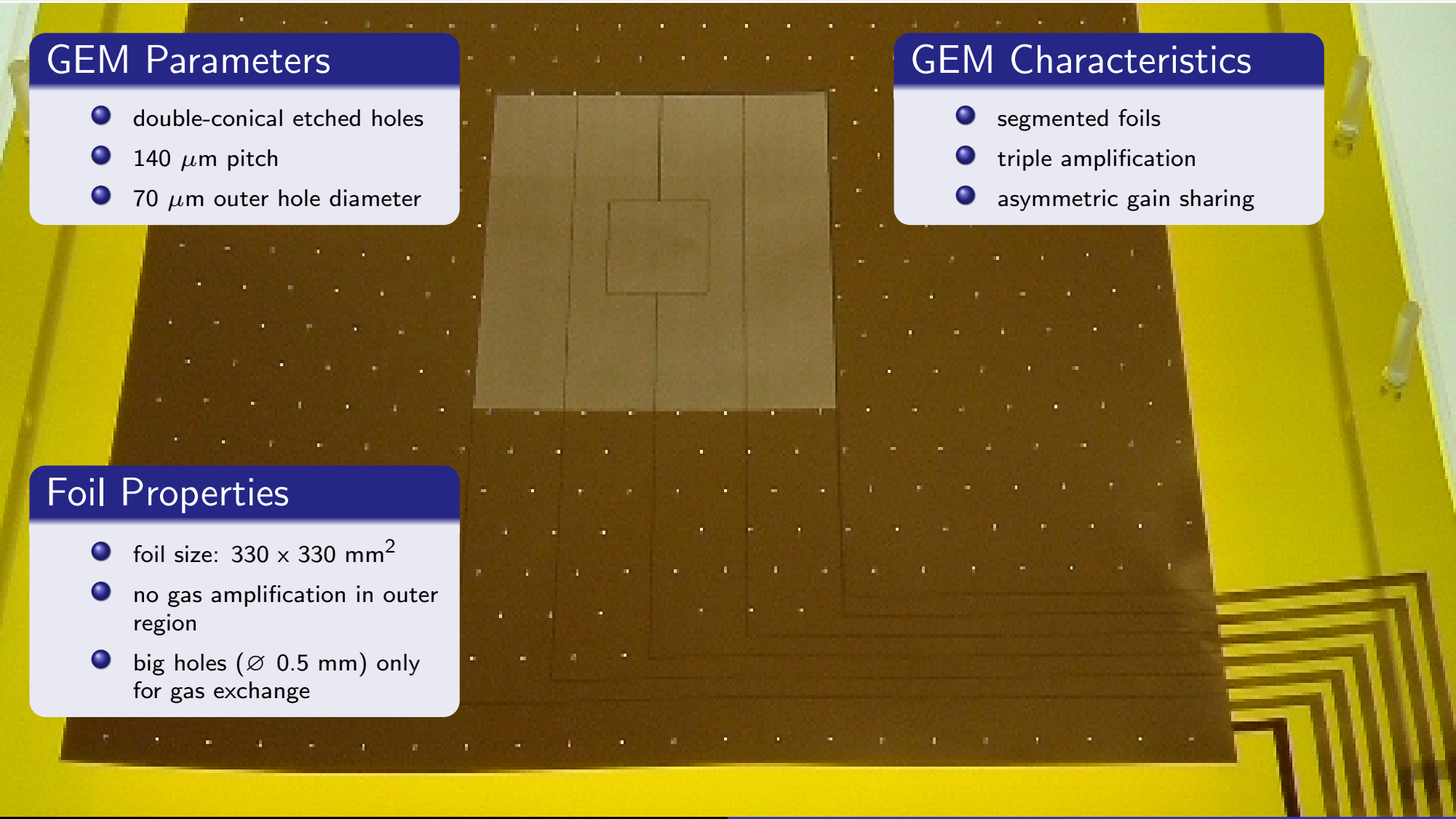

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- foil size: 330 x 330 mm^2
- no gas amplification in outer region
- big holes ($\varnothing$ 0.5 mm) only for gas exchange

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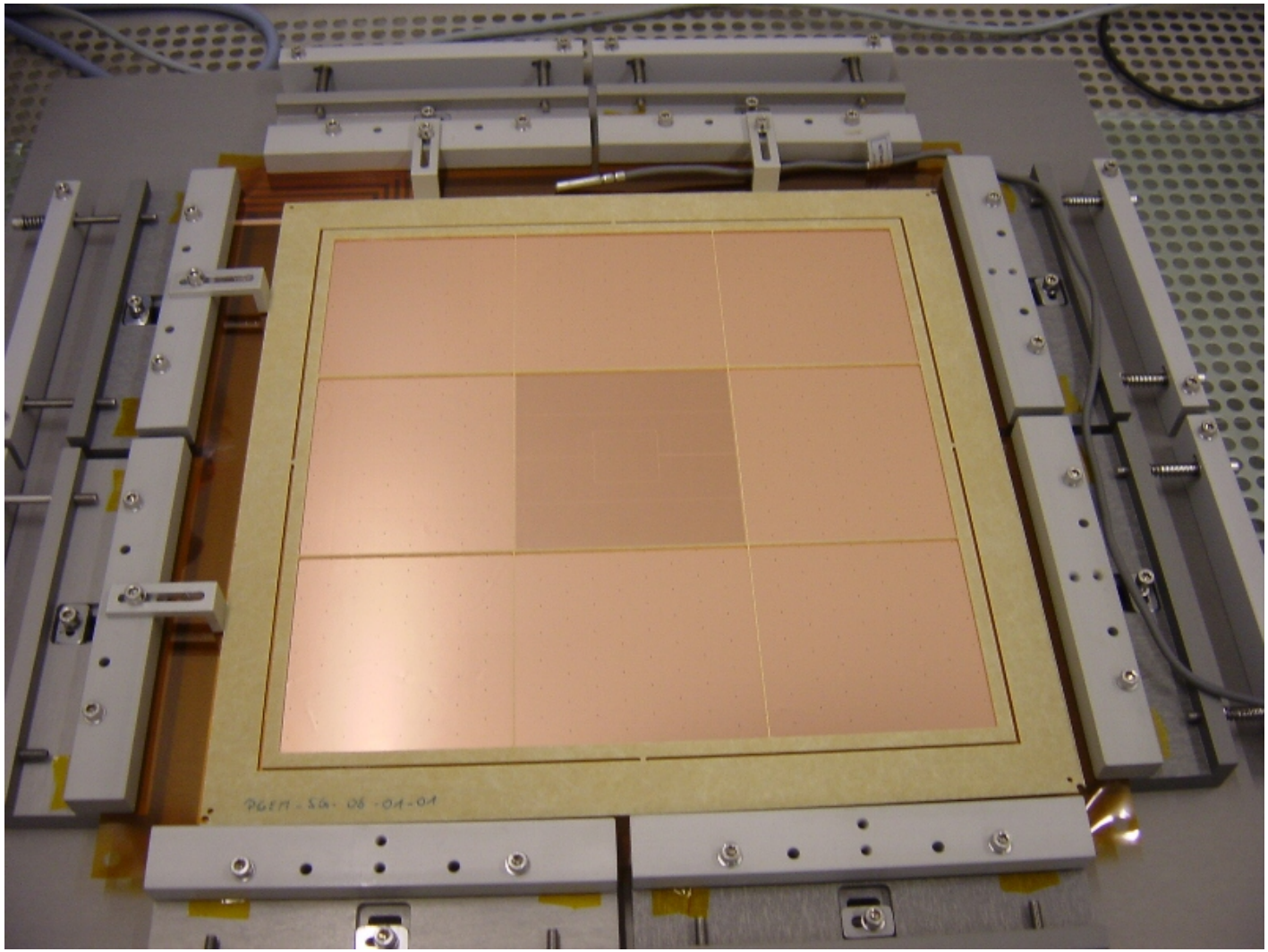
thin copper

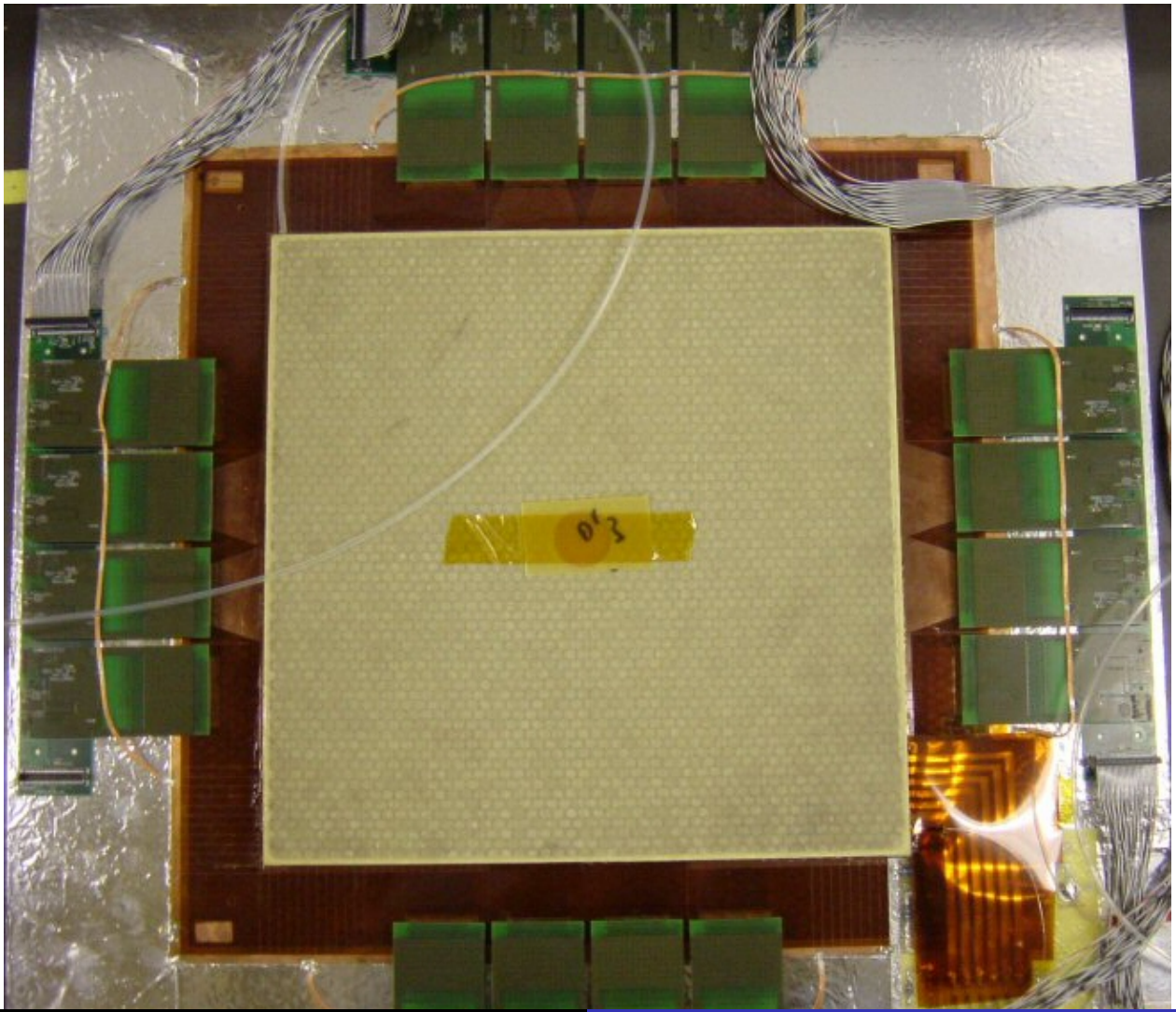
- foils with only 1 μm thick copper[1]

[1] [A. Bondar, et al., Nucl. Instr. and Meth. A 556 (2006) 495]

Assembly

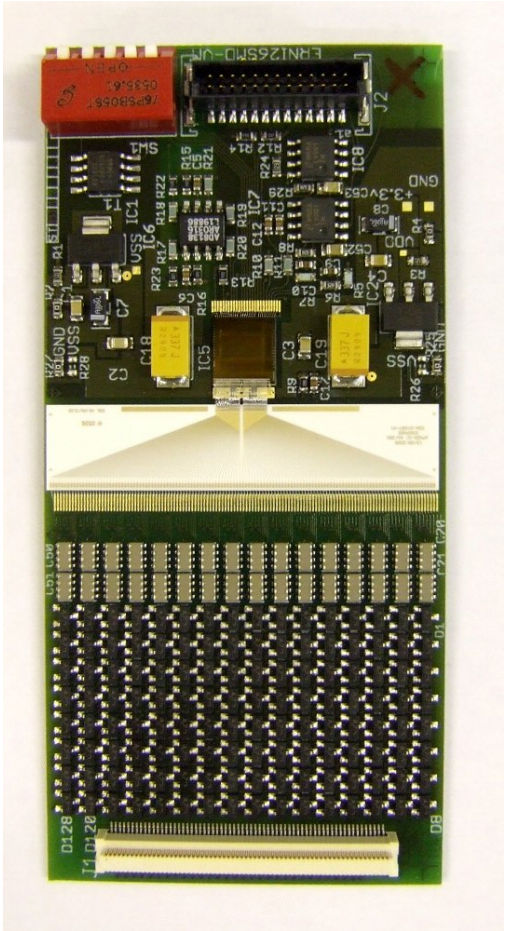


Complete Detector



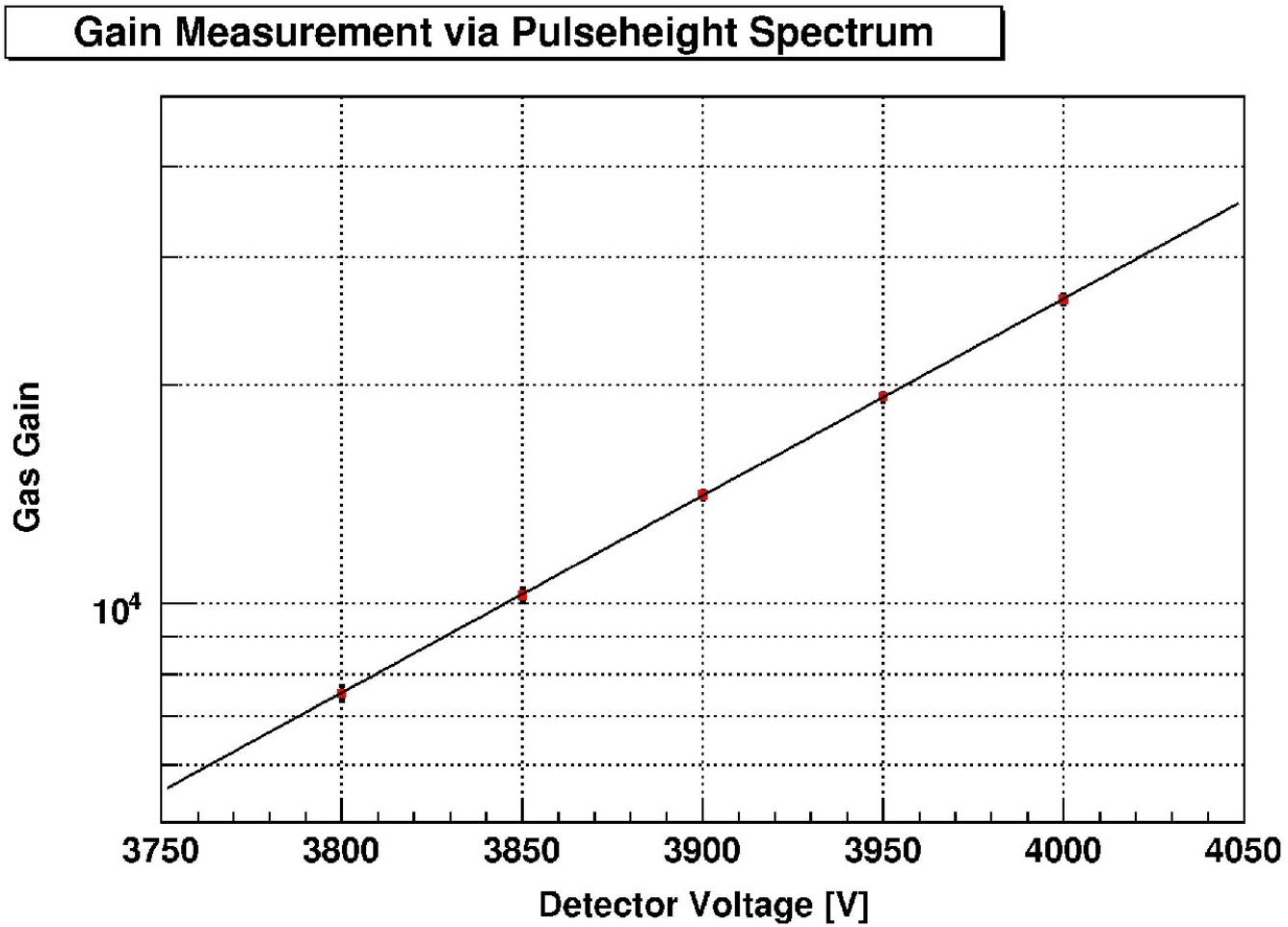
FrontEnd-Electronics

- APV25 S1 ASIC[1]
- 128 channels per APV
- average noise:
  $\sim$ 1300 - 1500 electrons
- used for Silicon, GEM and RICH at COMPASS

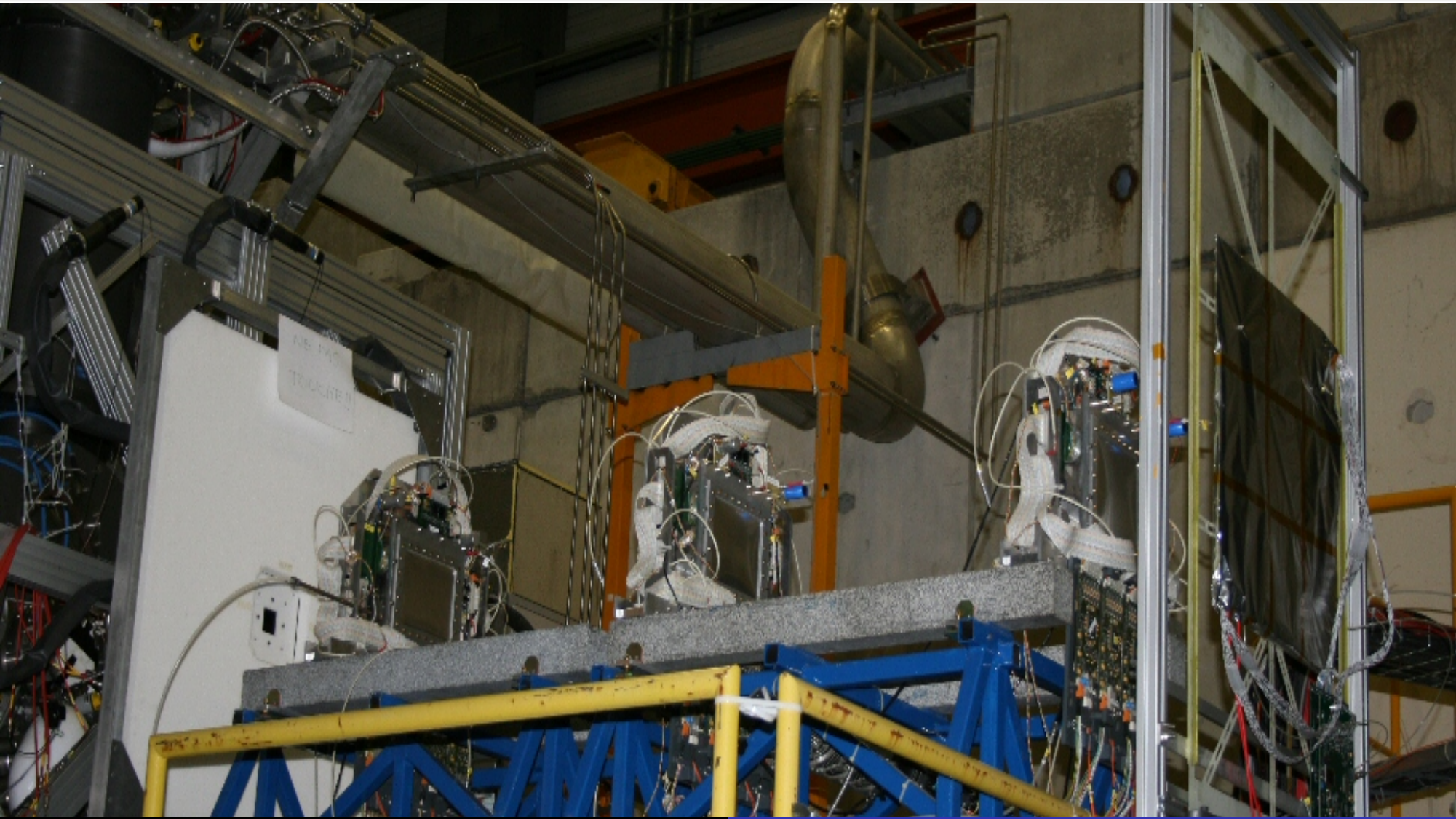


[1] M.J. French, et al. Nucl. Instr. and Meth. A 466 (2001) 359

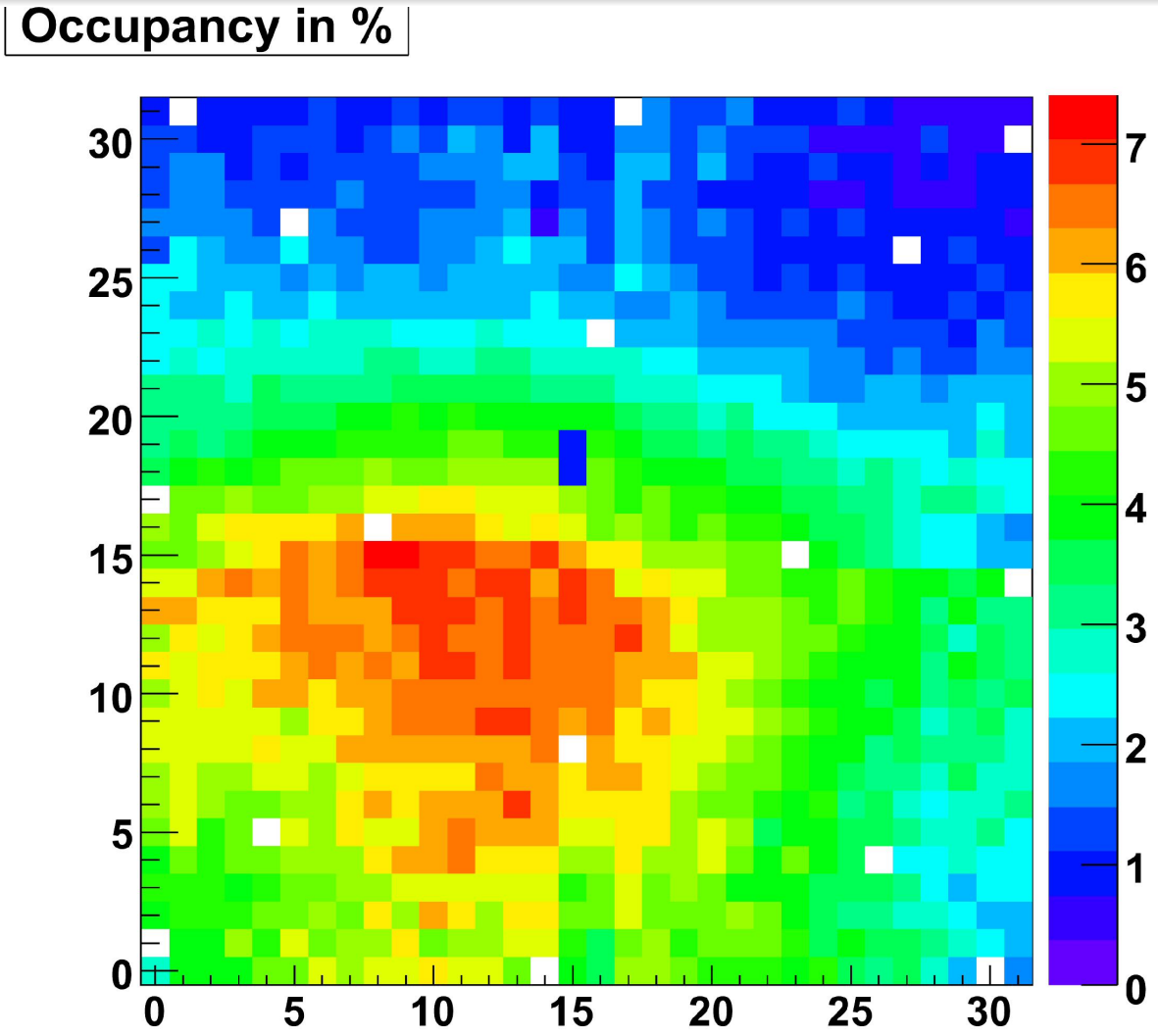
Gain


Gain Measurement via Pulseheight Spectrum
Gas Gain
10^4
3750
3800
3850
3900
3950
4000
4050
Detector Voltage [V]

Setup in COMPASS



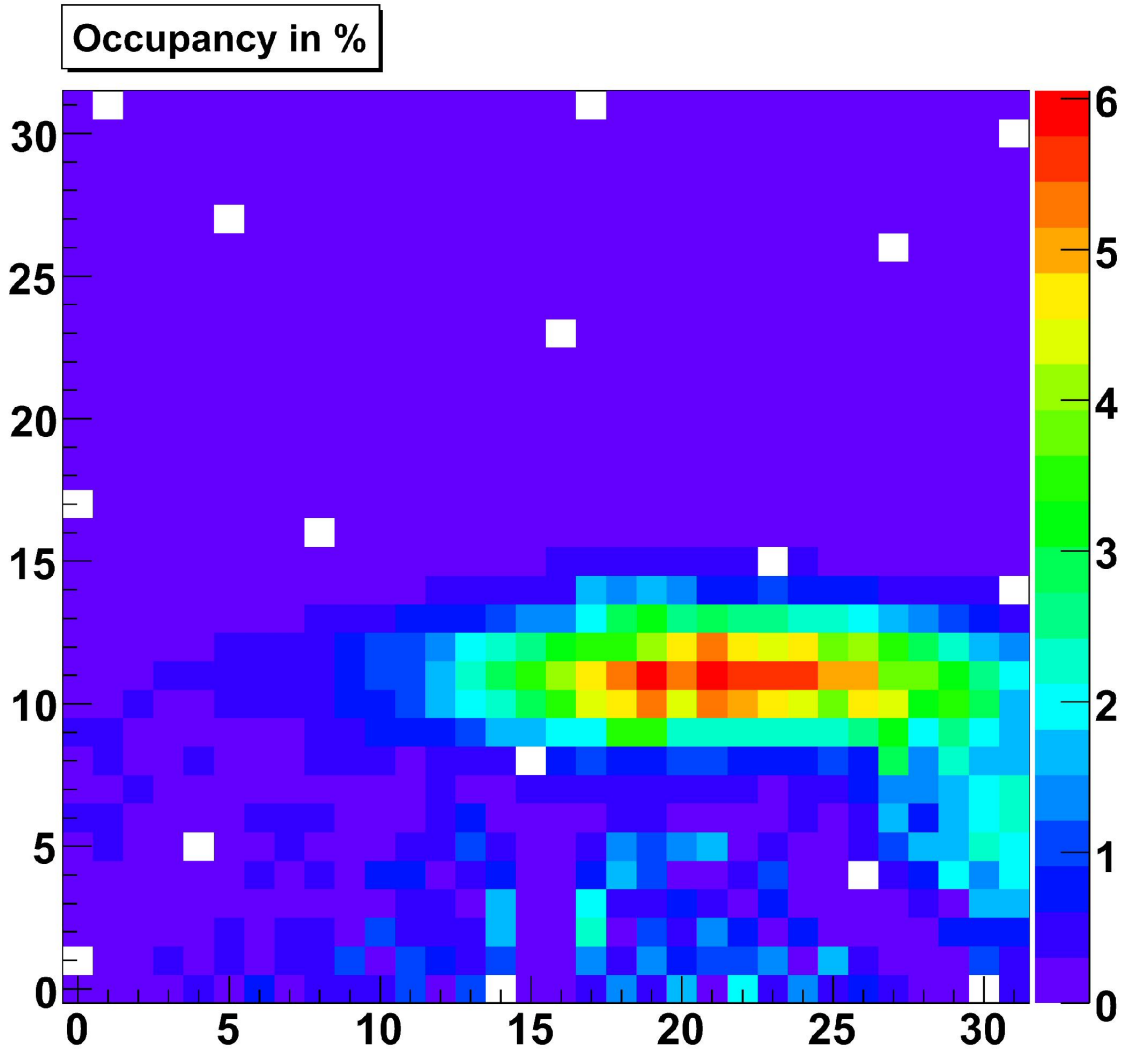
Beam Profile - Muon



beam parameters

- μ beam : $4.2 \cdot 10^7$ s^{-1}
- max rate: $5 \cdot 10^4$ mm^{-2}s^{-1}

Beam Profile - Hadron



beam parameters

- π^- beam : 10^6 s^{-1}
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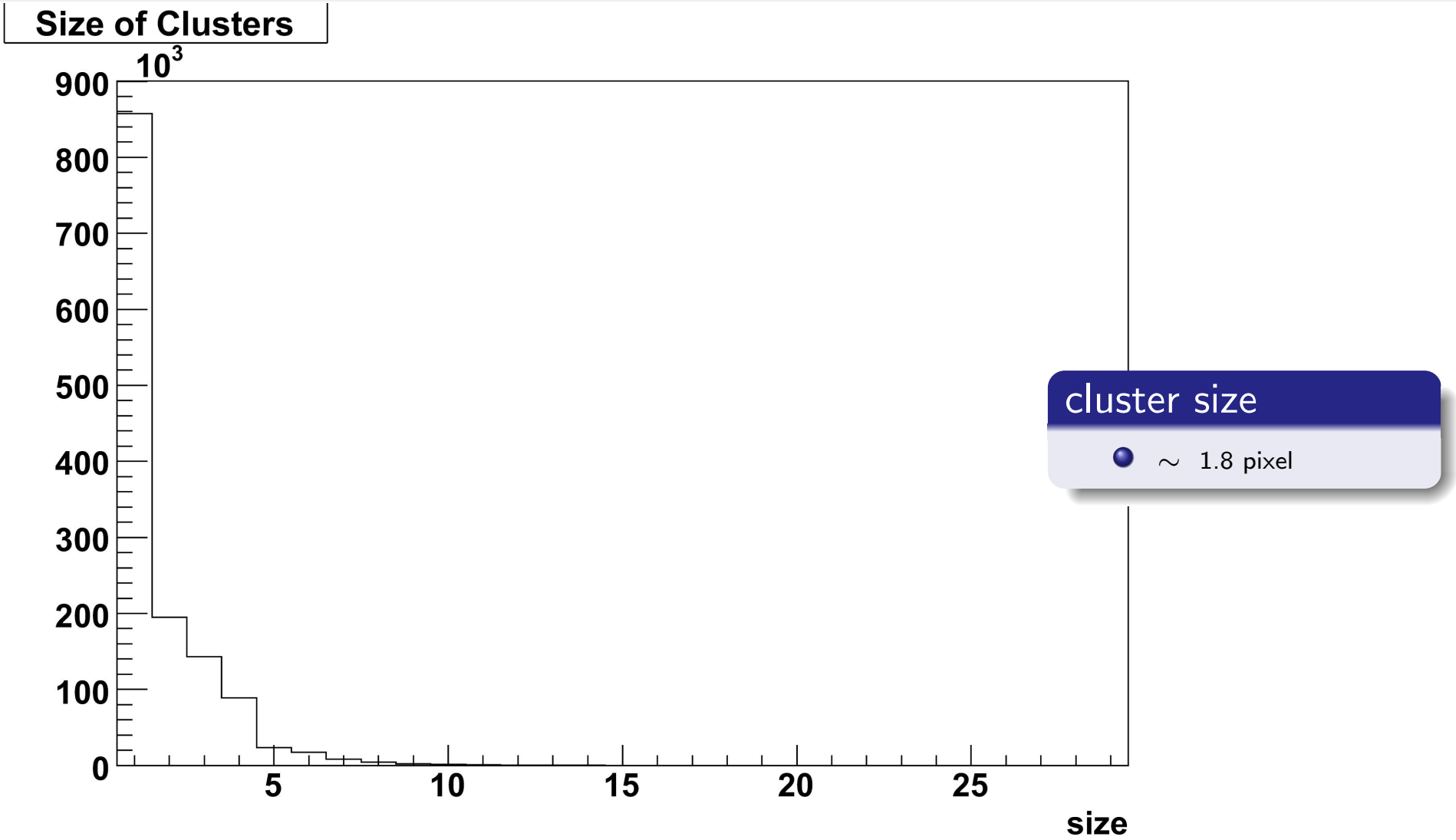
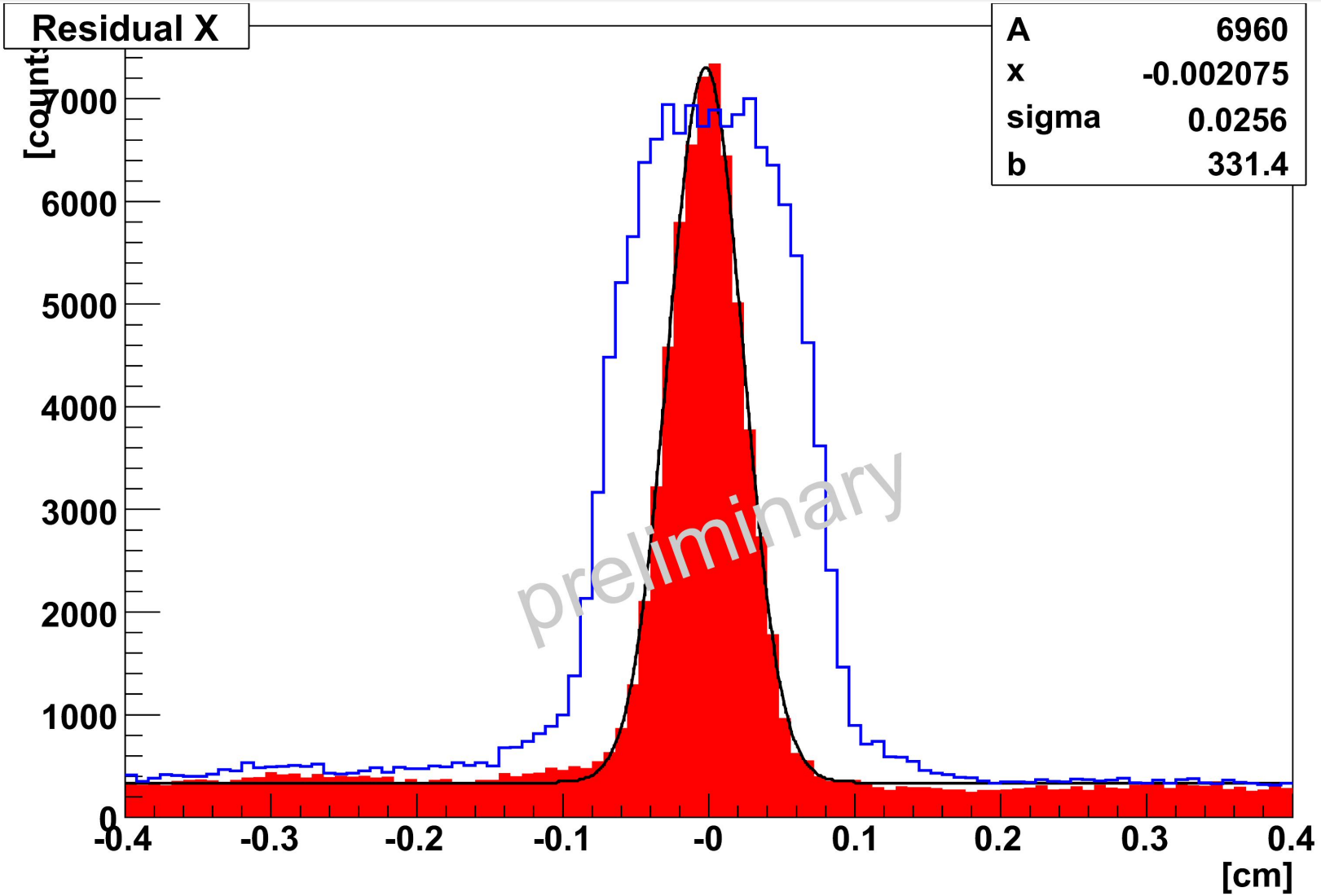
Cluster Size Distribution - Preliminary



Residuals - Preliminary



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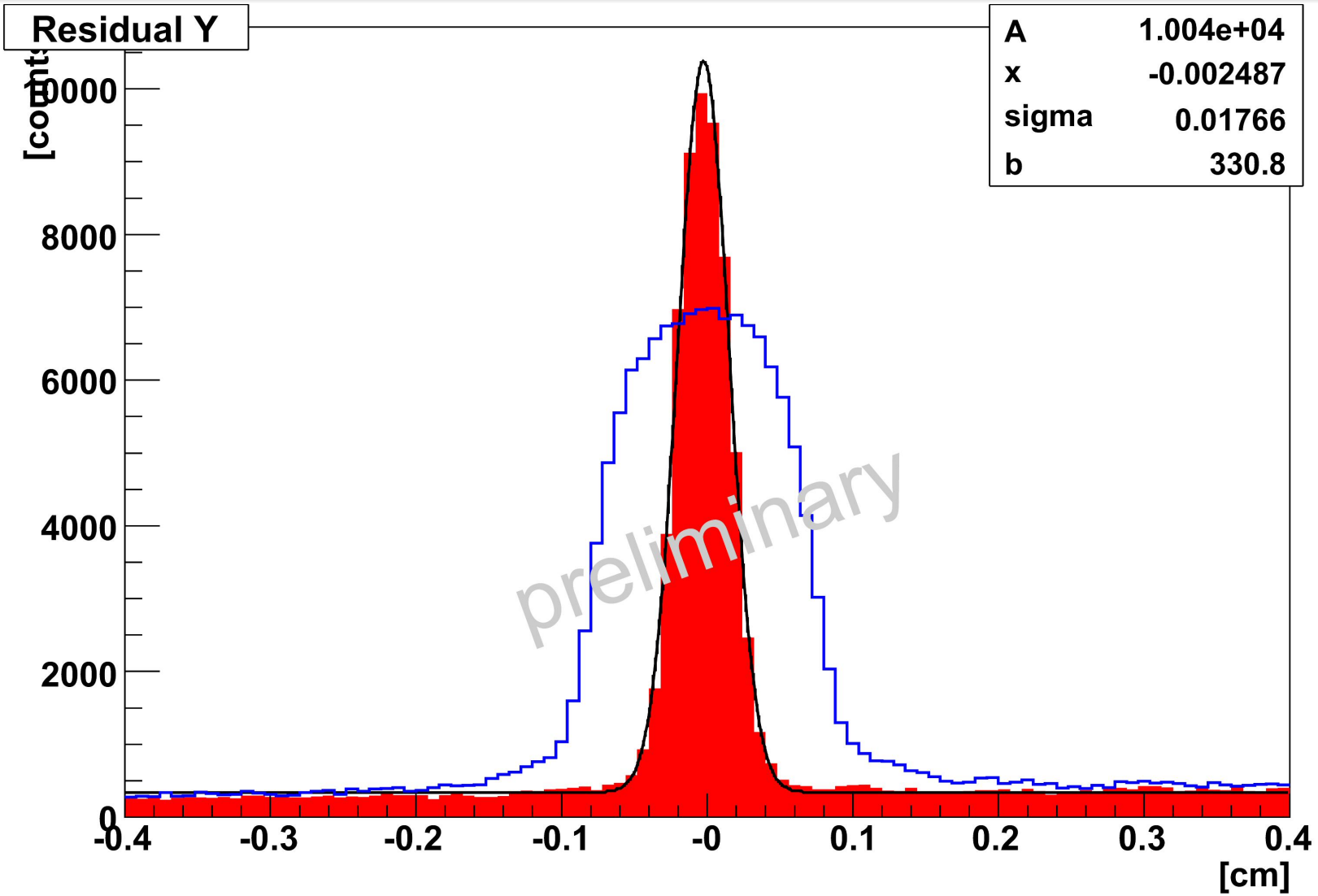

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- Analysis is ongoing
- Optimisation of design to minimize crosstalk
- thin GEM detetcor: $x/X_0 = 0.2$ %
- 6 PixelGEM detectors for COMPASS

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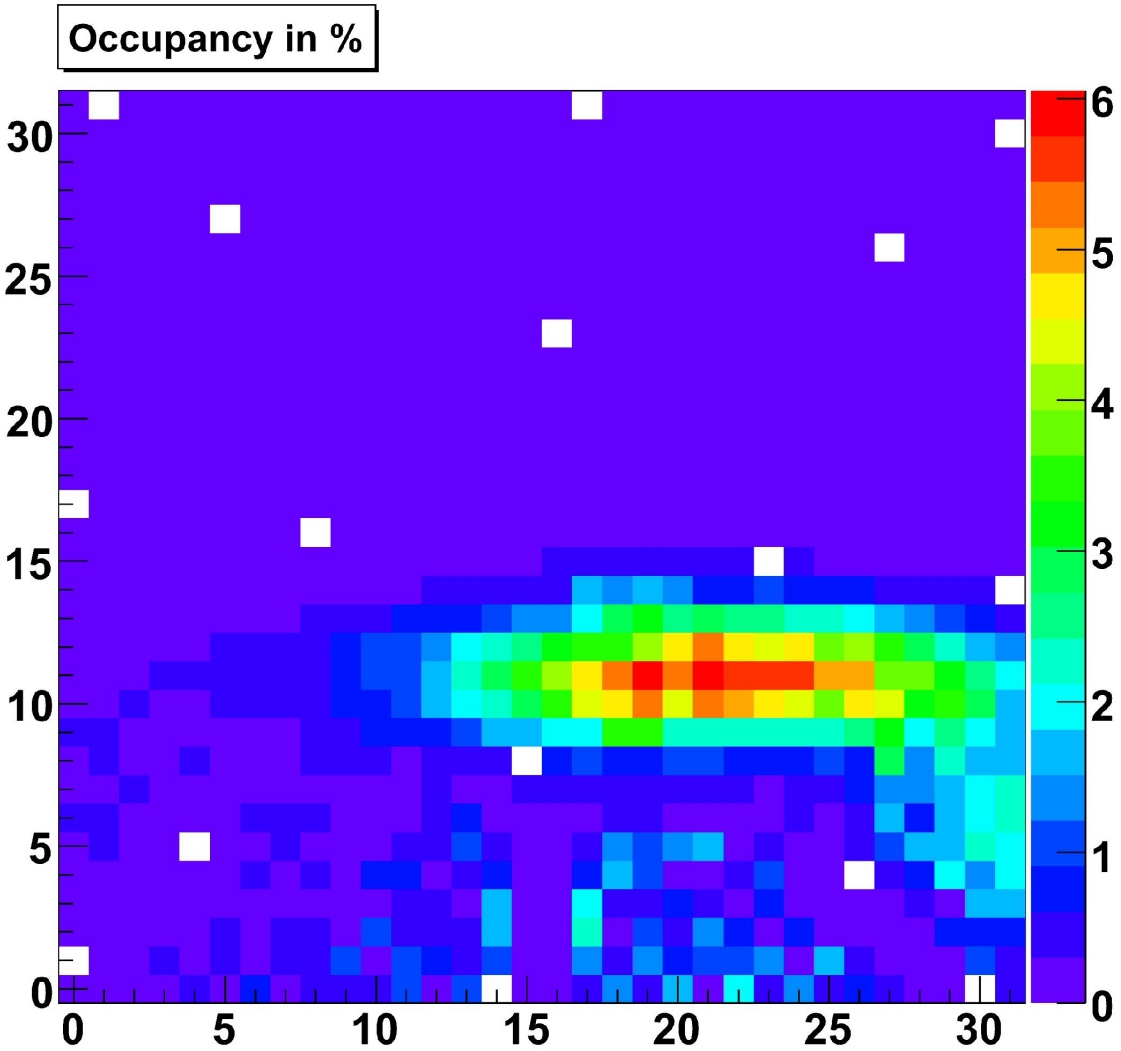
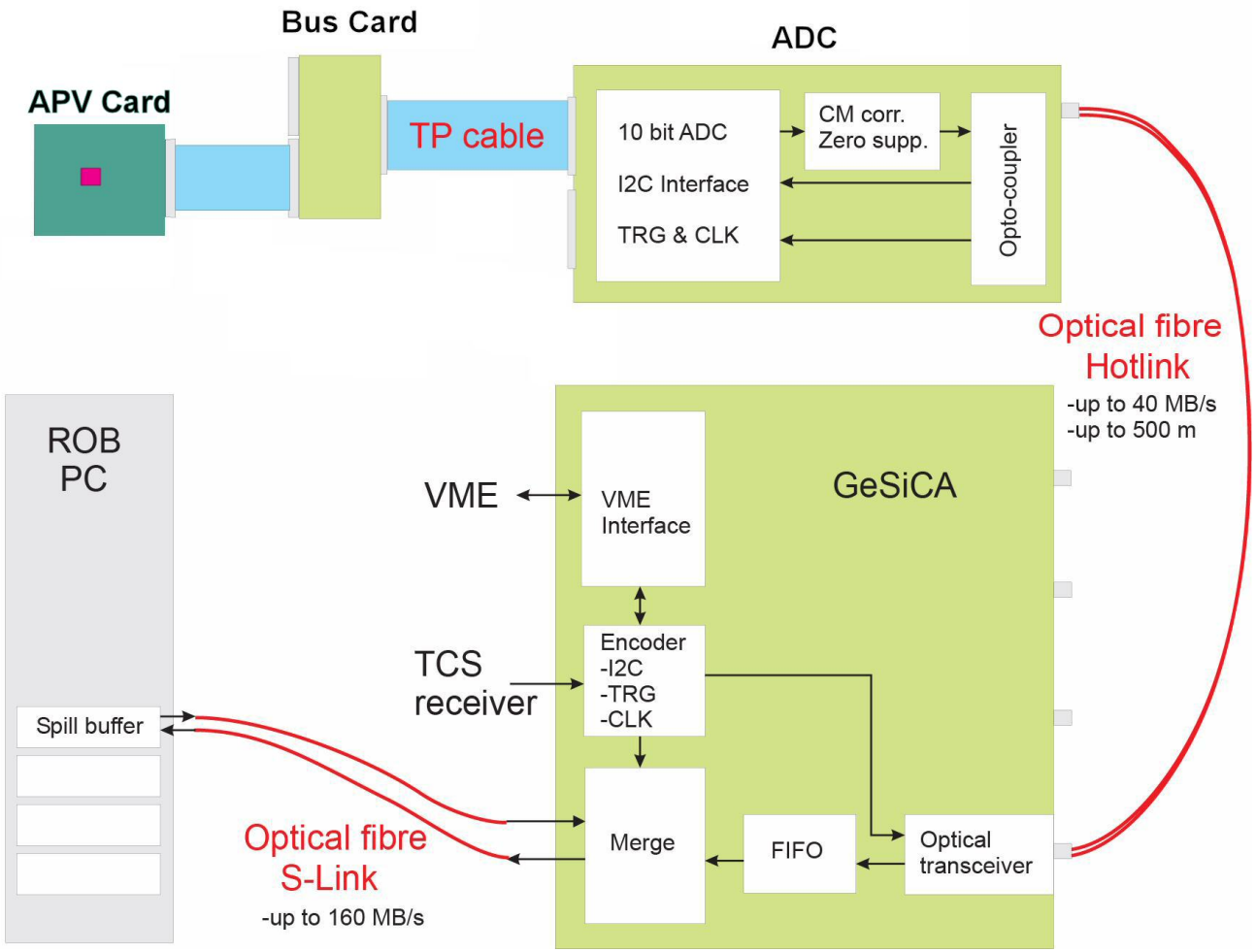
Acknowledgements

- Rui de Oliveira (CERN TS-DEM-PMT)
- Christian Joram, Eric David, Miranda van Stenis (CERN PH-DT2)
- Ian McGill (CERN PH-DT2)
- workshops at CERN and TU München

Occupancy Pixel Region



Readout Chain



Spatial/Time Resolution

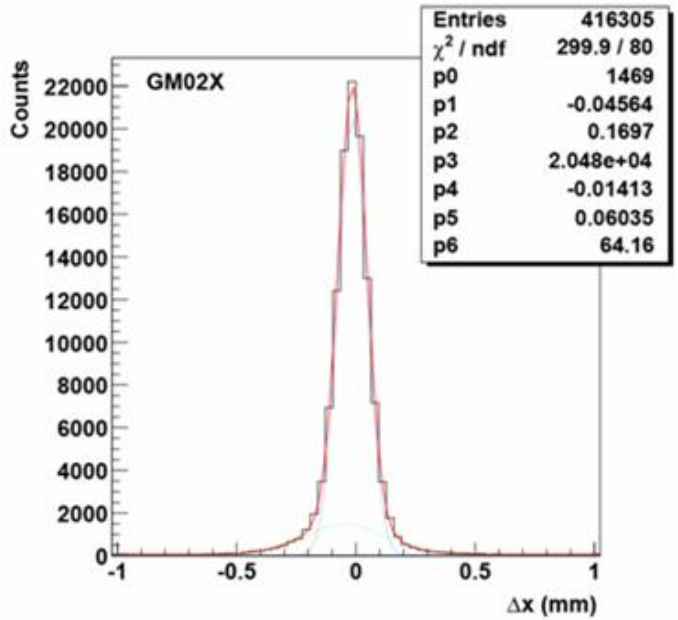
Spatial resolution

- Test beam/low intensity:

$$\langle \sigma_x \rangle \approx 50 \mu m$$

- Standard physics run: $4 \cdot 10^7$ μ^+/s:

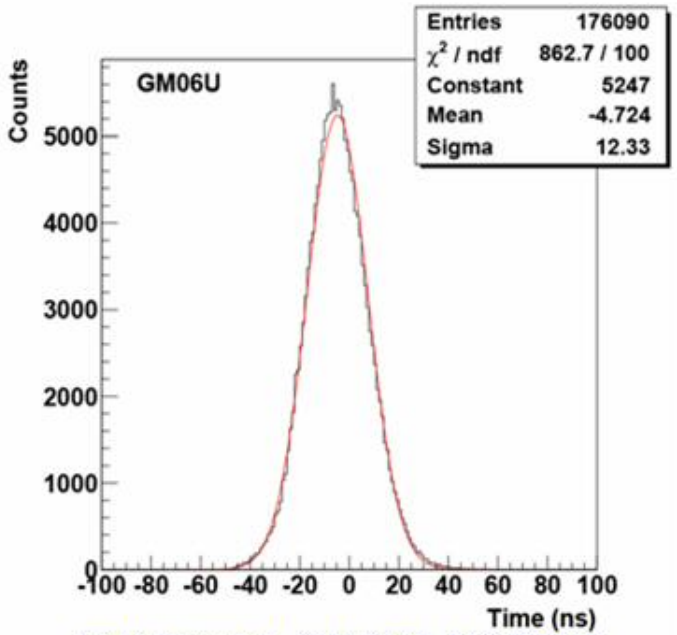
$$\langle \sigma_x \rangle \approx 70 \mu m$$



Time resolution

- 3 analog samples per trigger
- Rising edge of signal
- Reconstruct t_0 from known pulse shape

$$\langle \sigma_t \rangle \approx 12 ns$$



[B. Ketzer et al., NIM A535, 314 (2004)]

Efficencies

Low intensity beam: $5 \cdot 10^6$ μ^+/s

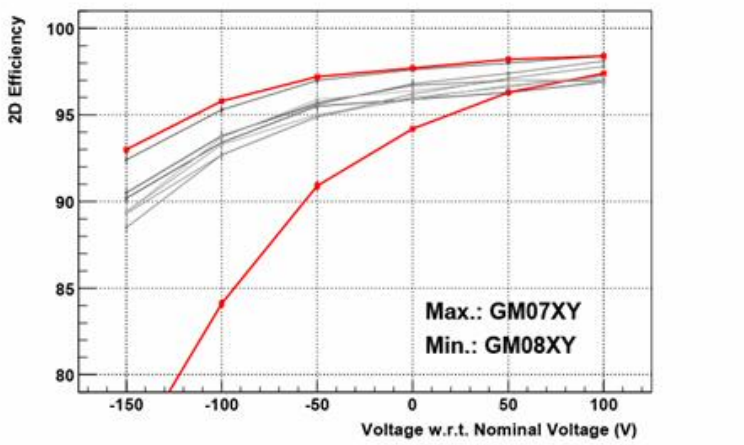
- All detectors reach plateau (ε>98%)
- Gain ~8000
- SNR ~18
- Losses due to spacer grid: 1.2-1.5%

Standard physics beam: $4 \cdot 10^7$ μ^+/s

- Background correction

$$\varepsilon_{app} = \varepsilon + (1-\varepsilon) \cdot b$$

- Single plane: $\langle \varepsilon_{1D} \rangle = 97.2\%$
- 2D (space point): $\langle \varepsilon_{2D} \rangle = 95.6\%$



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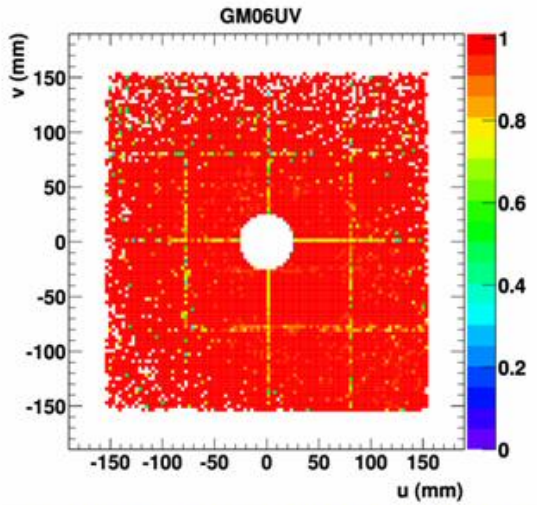

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