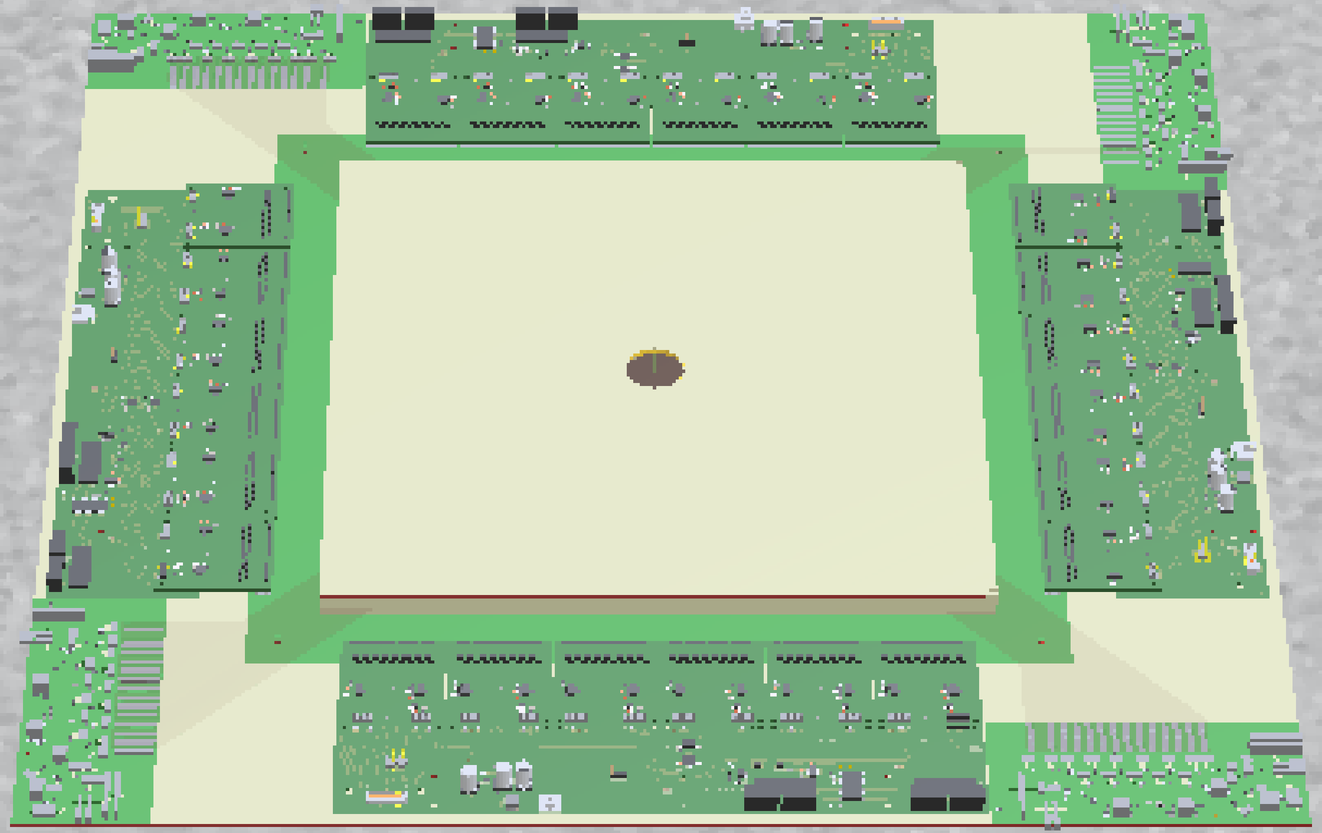
Bundesministerium
für Bildung
und Forschung

562. A new Triple-GEM Tracking Detector for COMPASS++/AMBER



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UNIVERSITÄT BONN

CERN

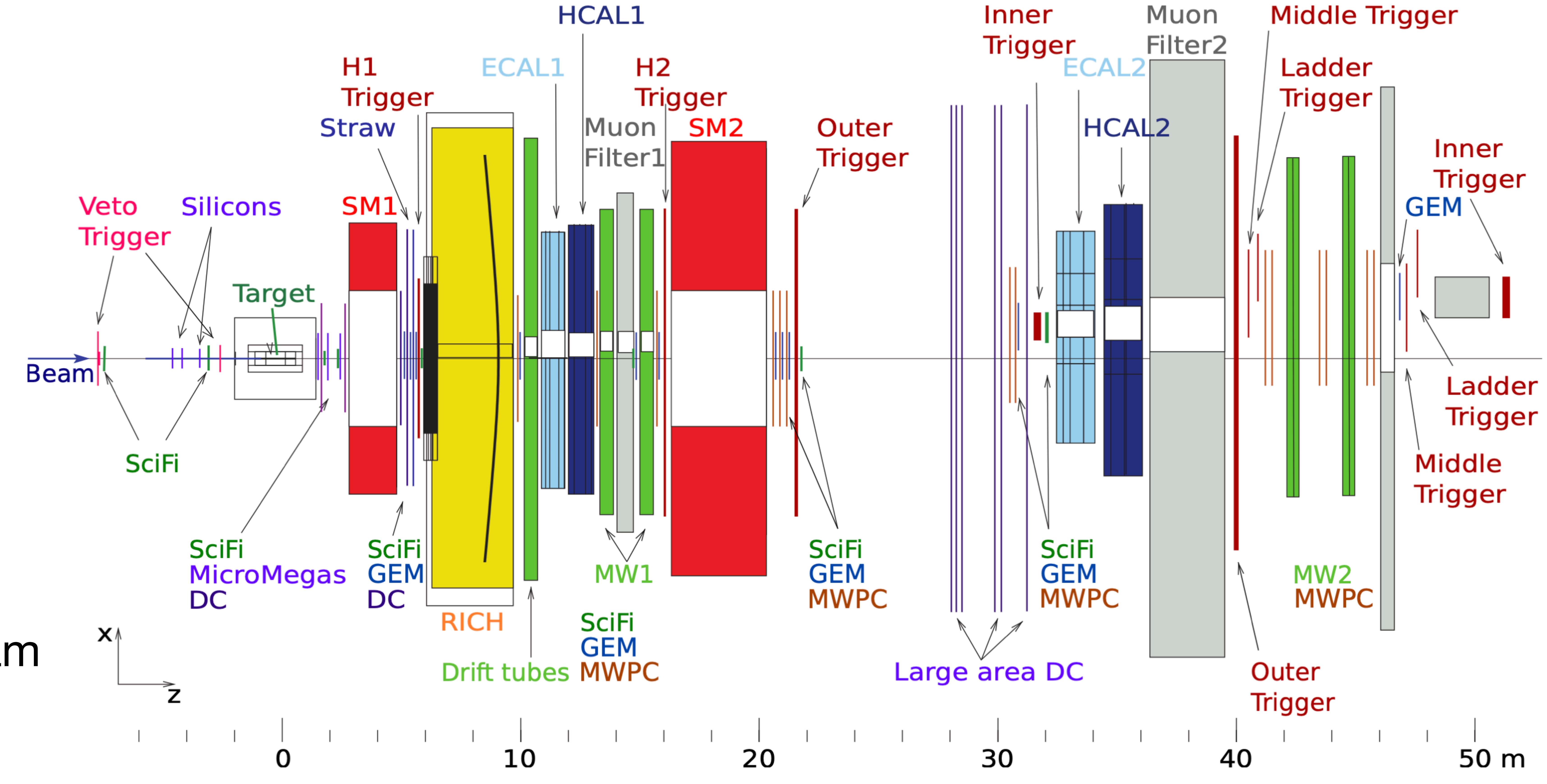
GDD

AG Ketzer

COMPASS

<u>CO</u>mmon <u>M</u>uon and <u>P</u>roton <u>A</u>pparatus for <u>S</u>tructure and <u>S</u>pectroscopy

- Located at CERN
- Two-stage spectrometer
- Will be used for AMBER
- μ - p elastic scattering
  - Active target
  - 2MHz with 100 GeV μ-beam



[1]

Motivation for new Detectors

- 22 first large-size GEM detectors in operation since 2001/2002 (Replacement and spares needed until 2021)
- General need to upgrade electronics (e.g. exchange outdated connectors)
- Self triggered readout planned in future (i.e. replace APV25 by e.g. VMM)

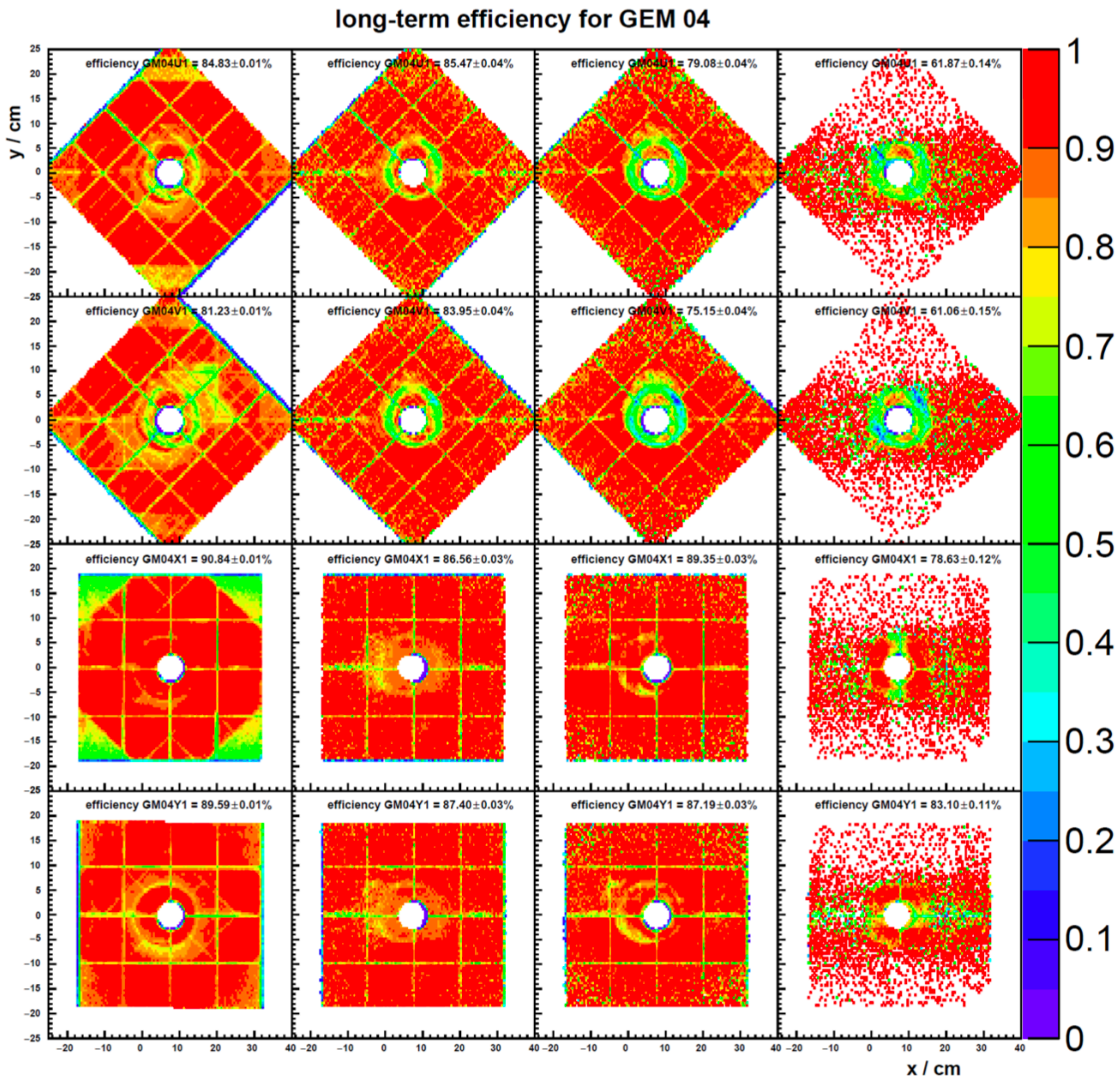
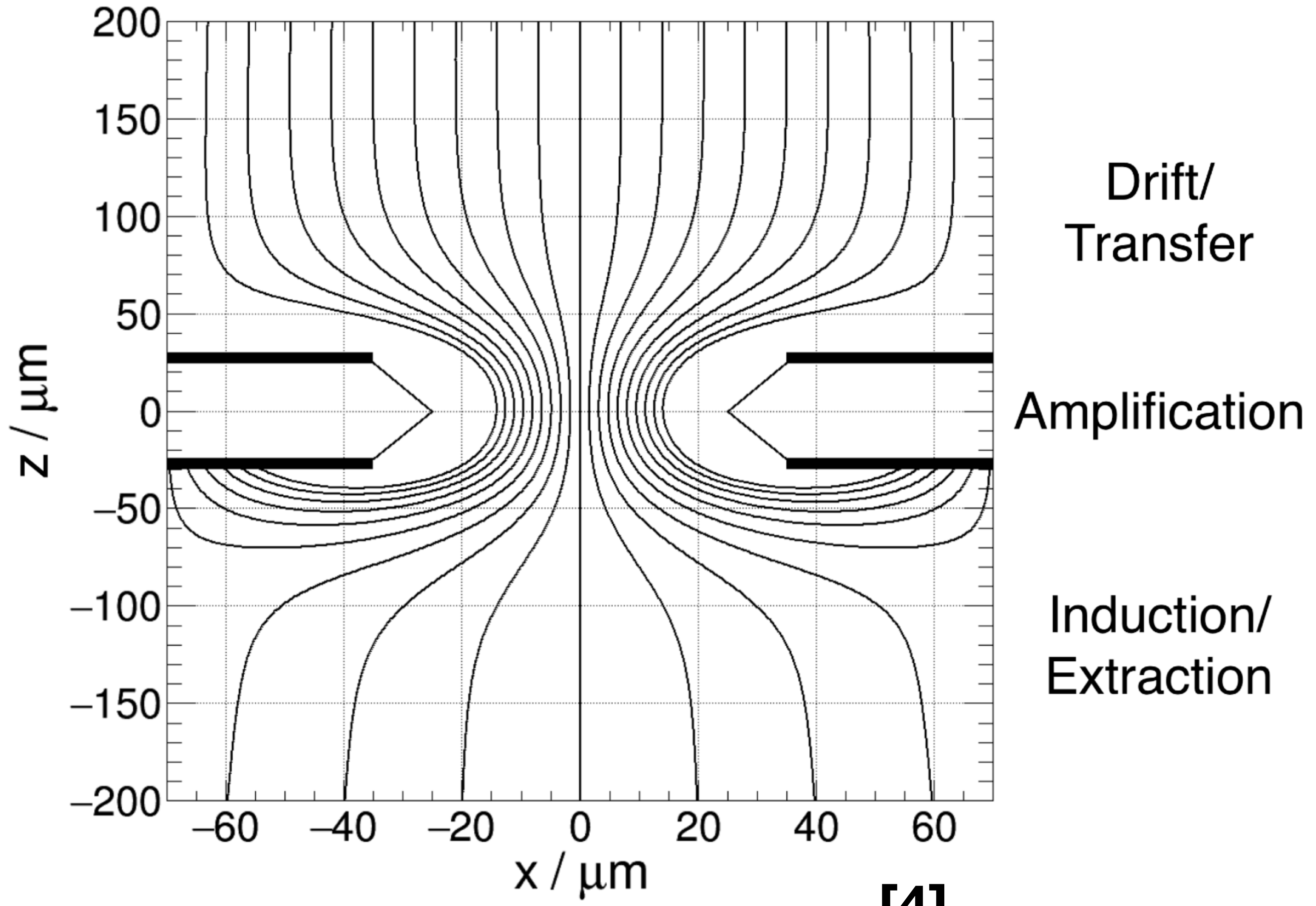


Figure B.4: 2D efficiency maps for each projection of GEM4 for years 2008, 2015, 2016 and 2017

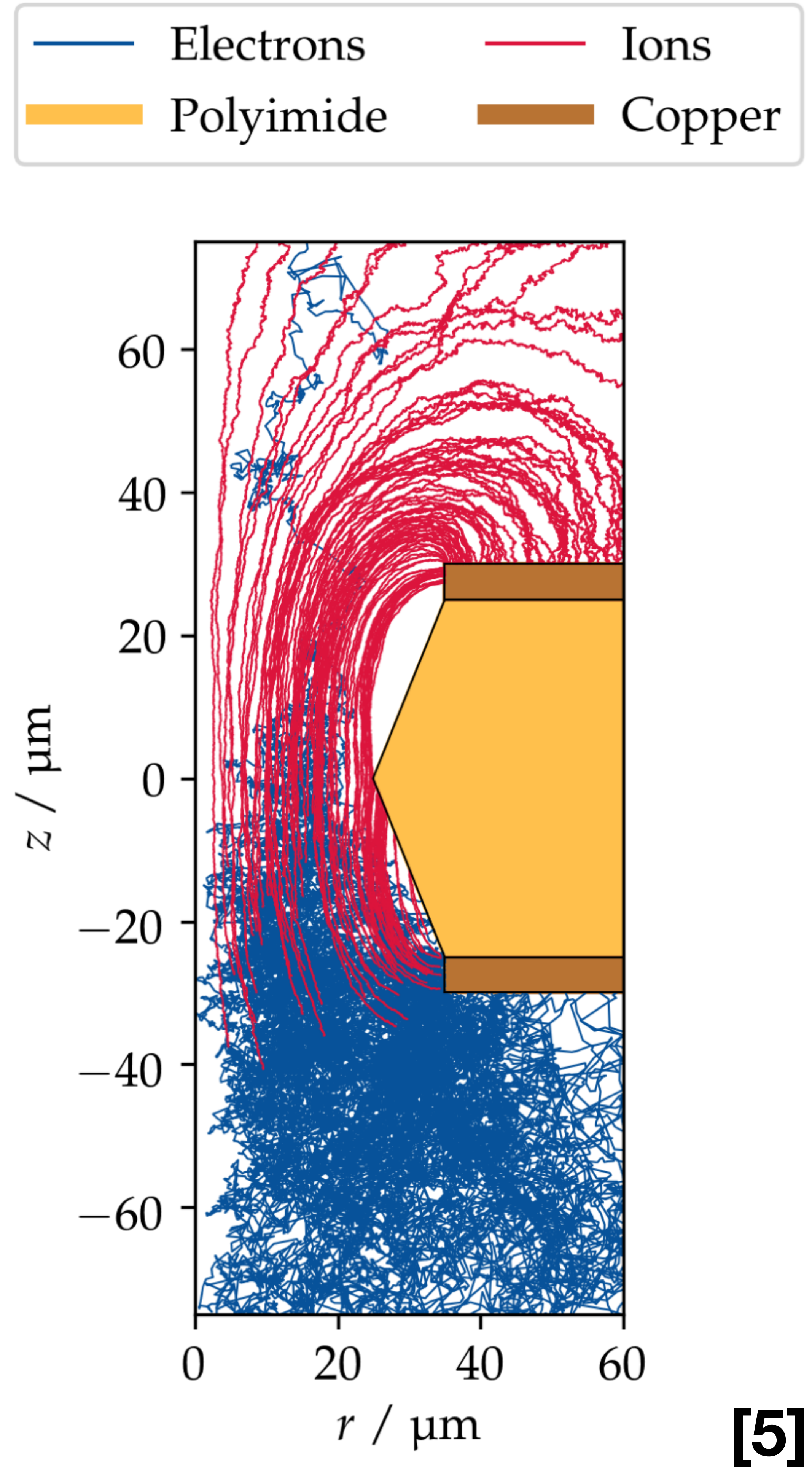
GEM

Gas Electron Multiplier

- Invented by F. Sauli 1997
  [Nucl. Instr. and Methods A386(1997)531]
- Belongs to MPGD
- Perforated metal-coated polyimide foil
- Standalone amplification stage
  - Separated readout



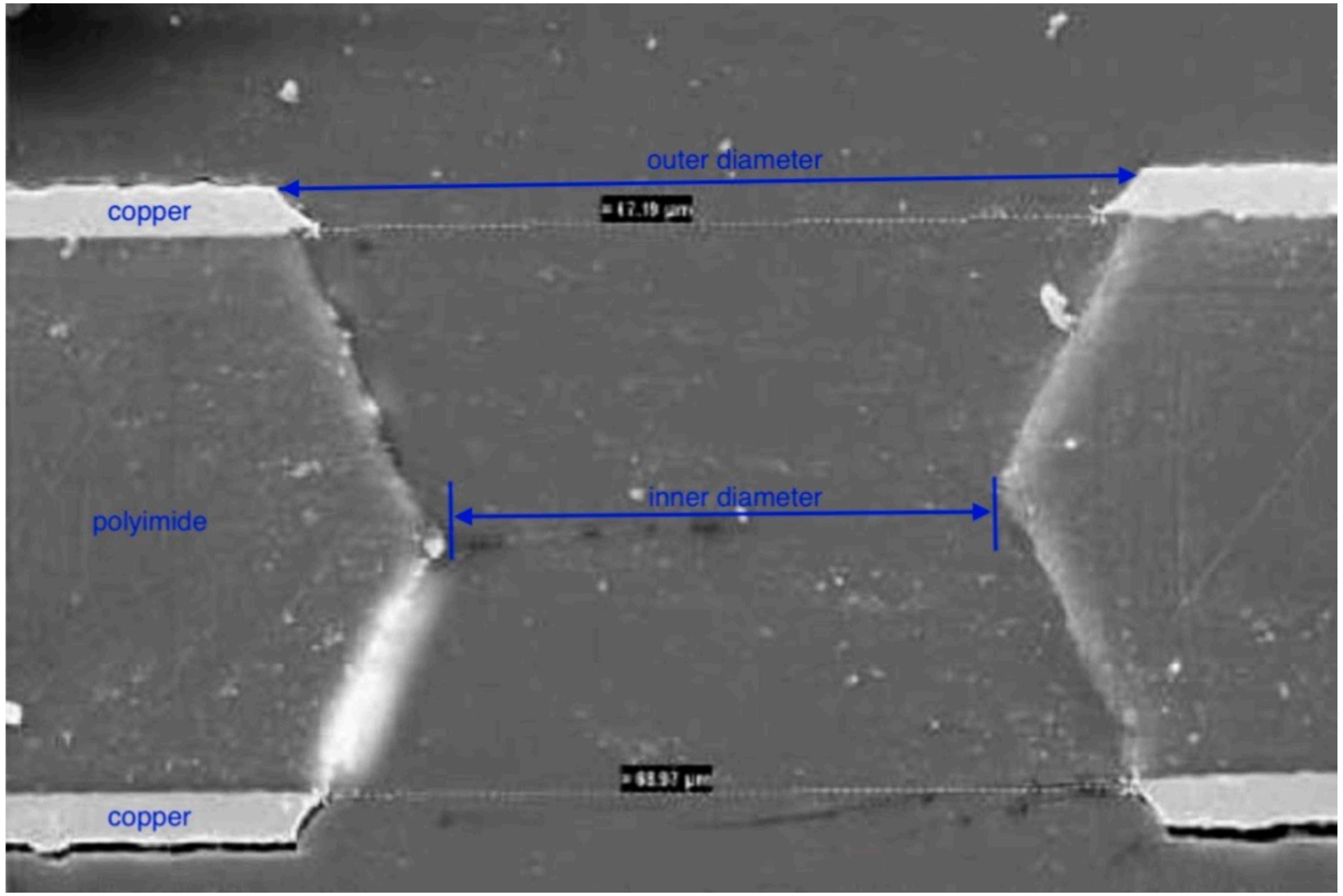
[4]



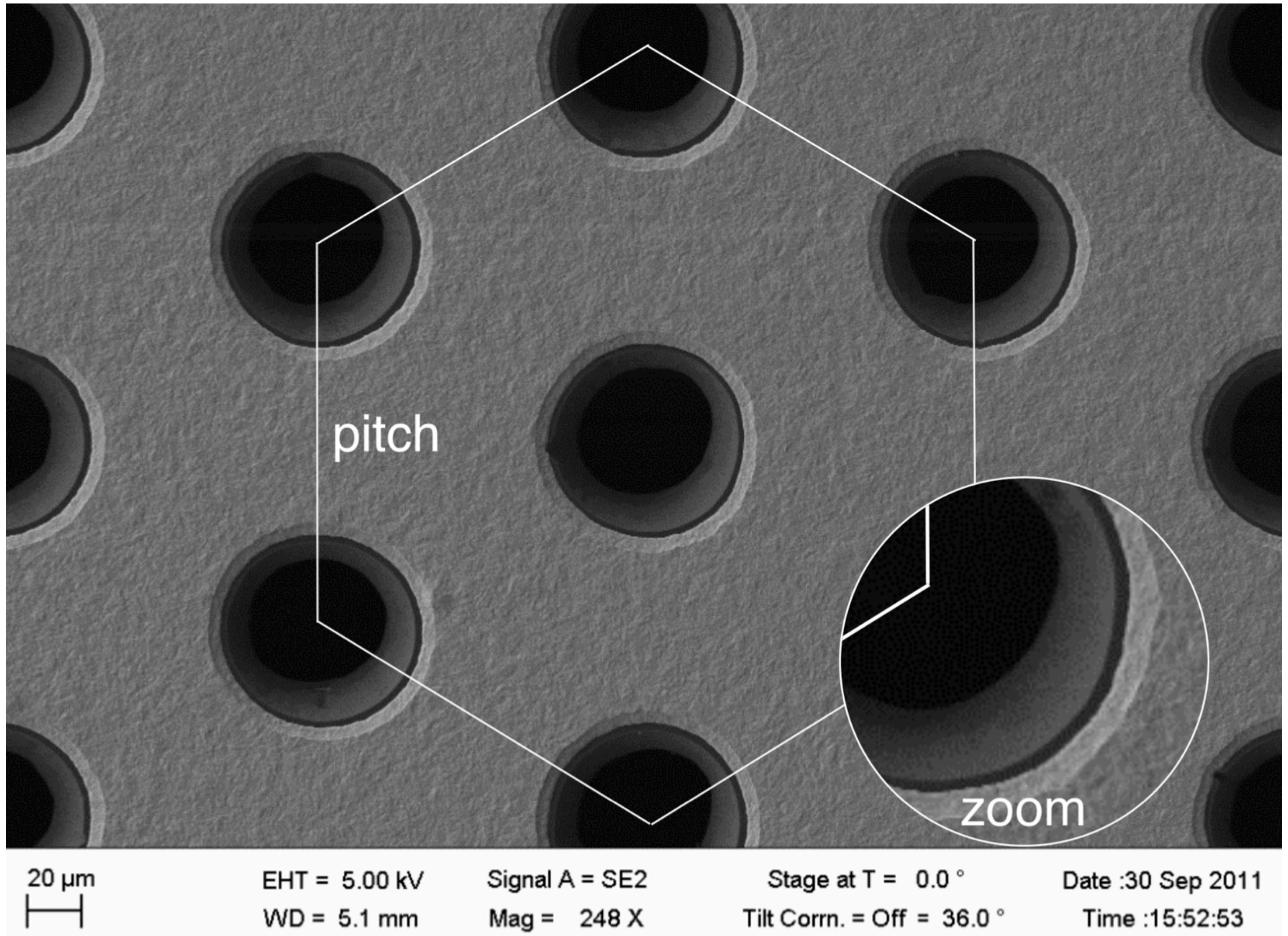
[5]

GEM

Gas Electron Multiplier



[6]



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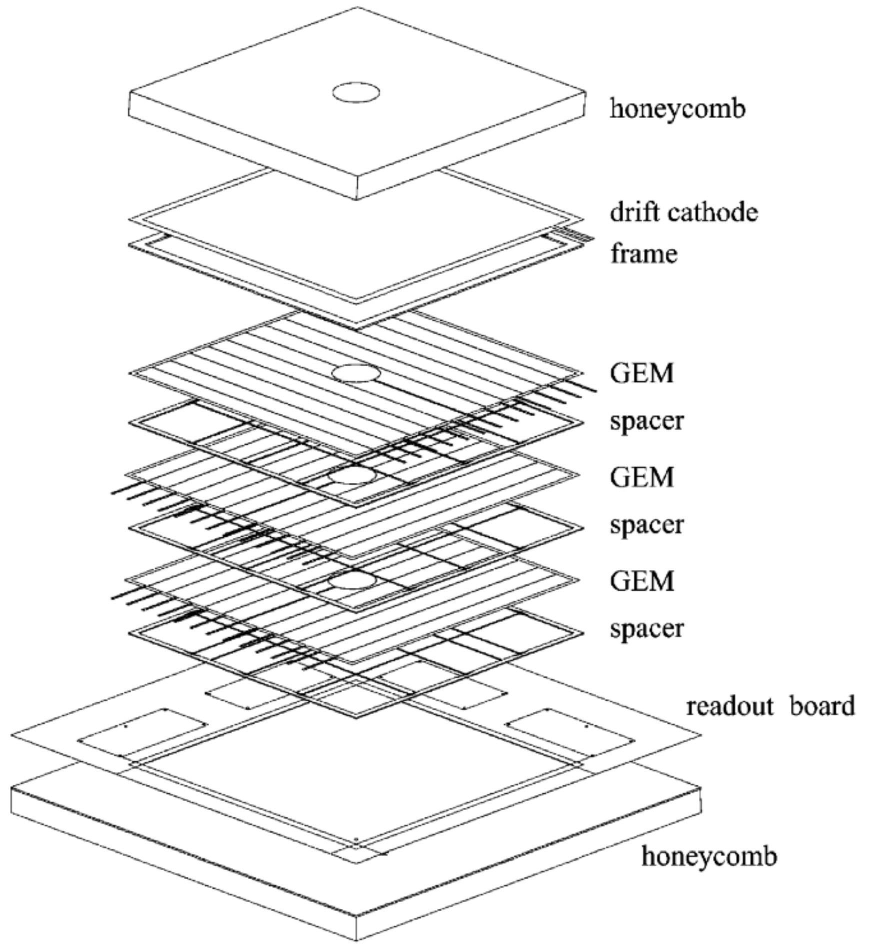
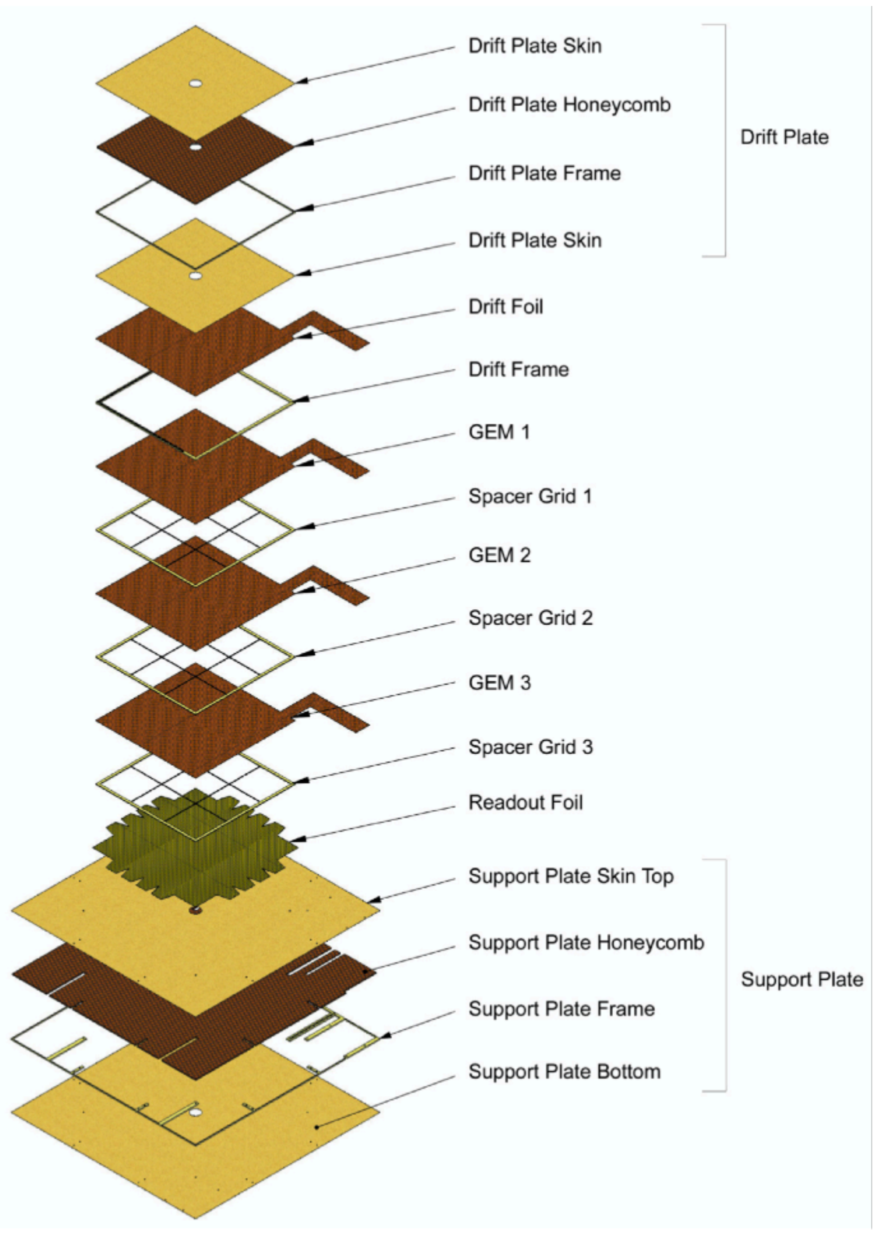
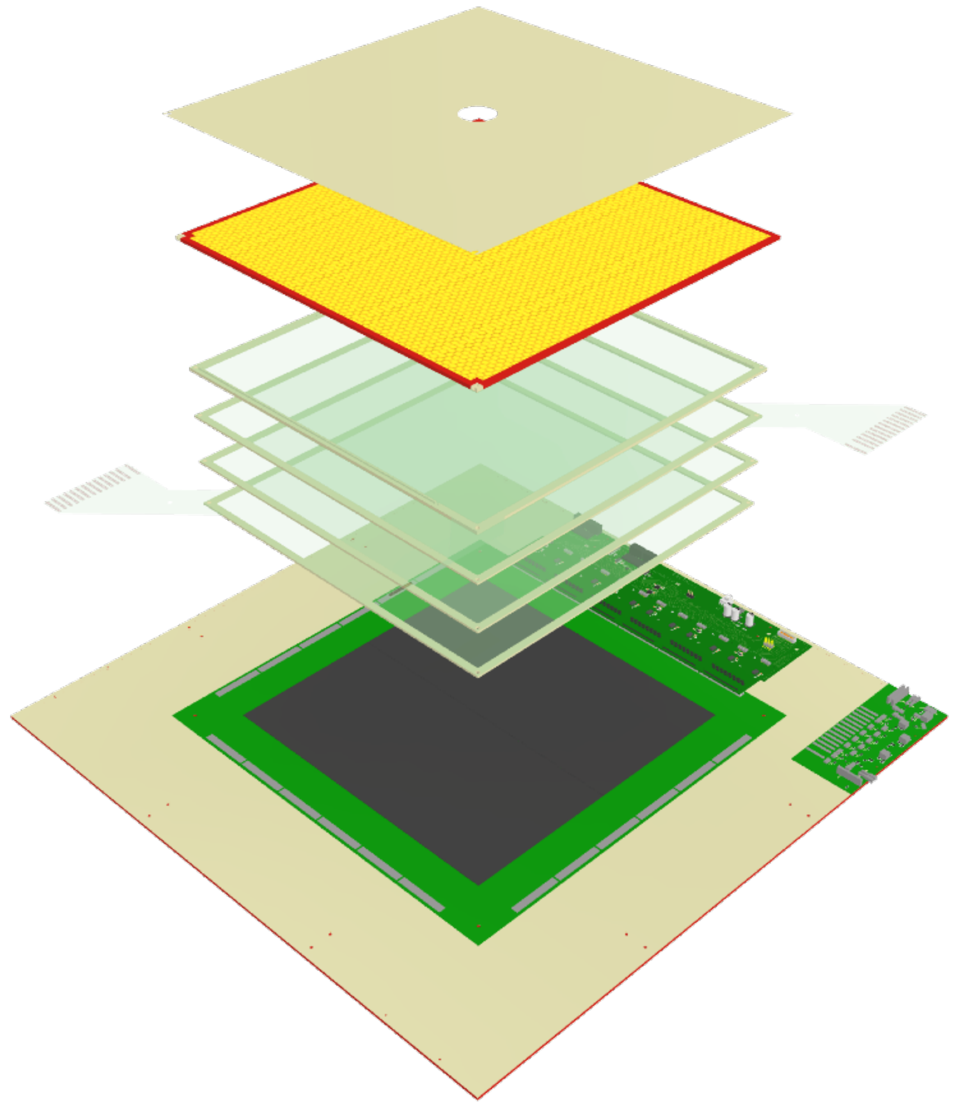






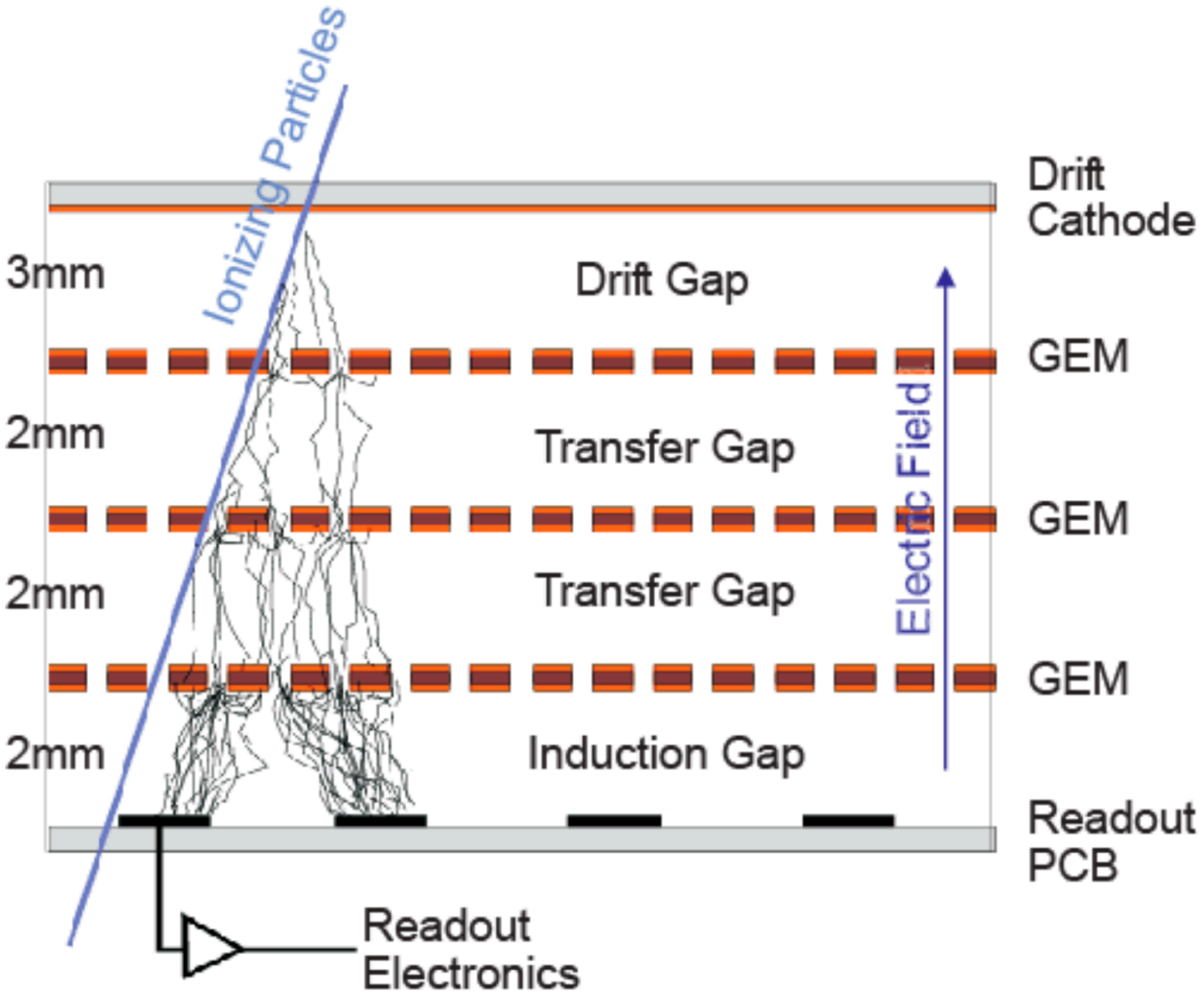
COMPASS GEM Detectors

Content:

- Multi-GEM Detector
- COMPASS GEM Generations

Multi-GEM Detector

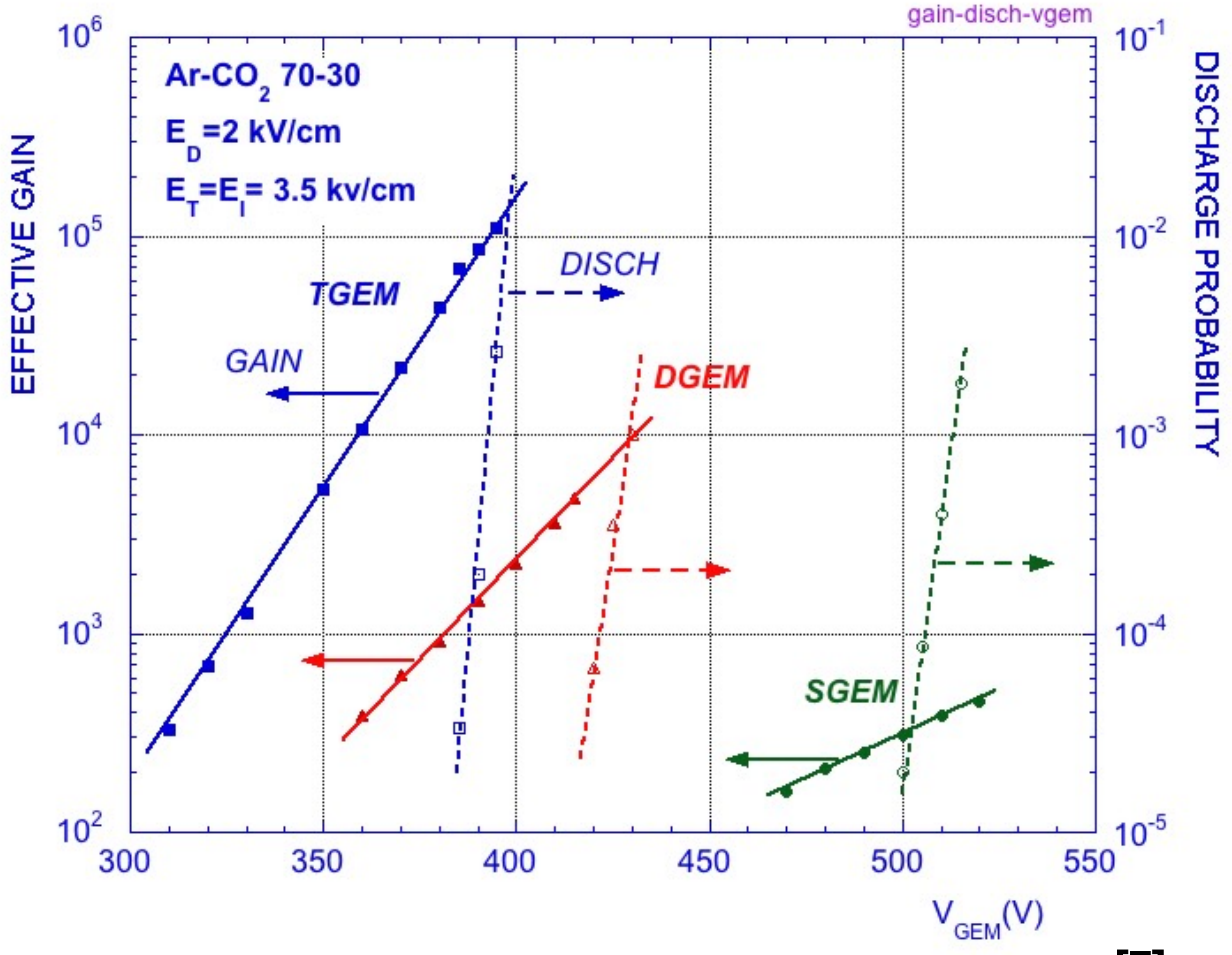
- COMPASS setup as example
- Cascade of several GEMs
- Higher gain possible
- Discharge prevention



[3]

Multi-GEM Detector

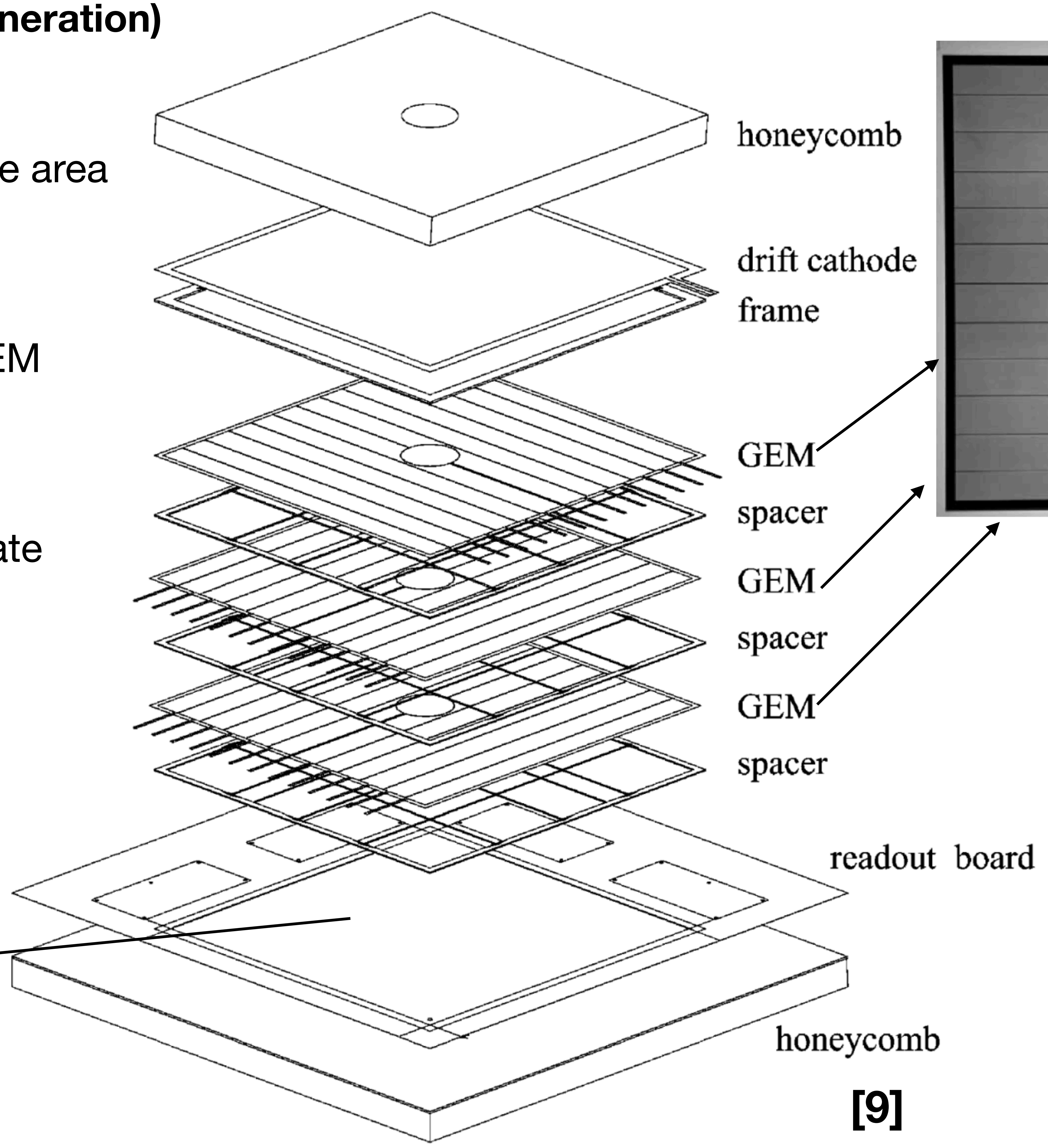
- COMPASS setup as example
- Cascade of several GEMs
- Higher gain possible
- Discharge prevention

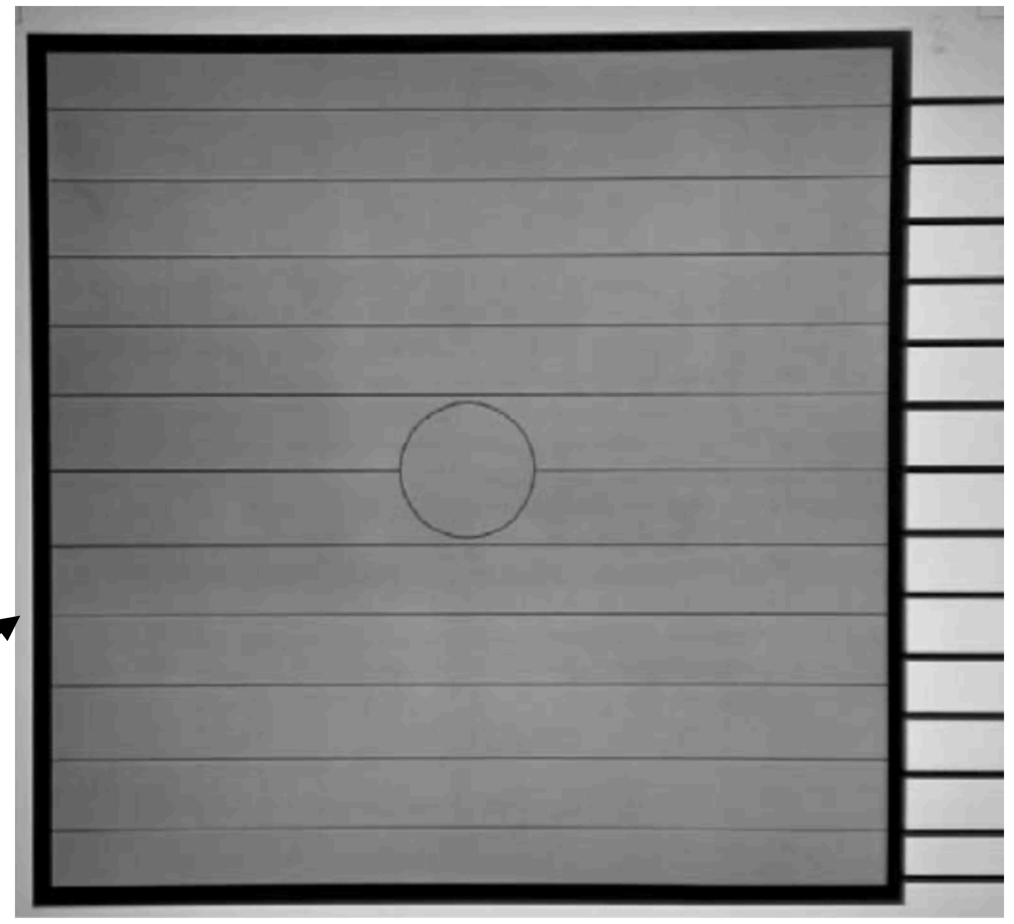


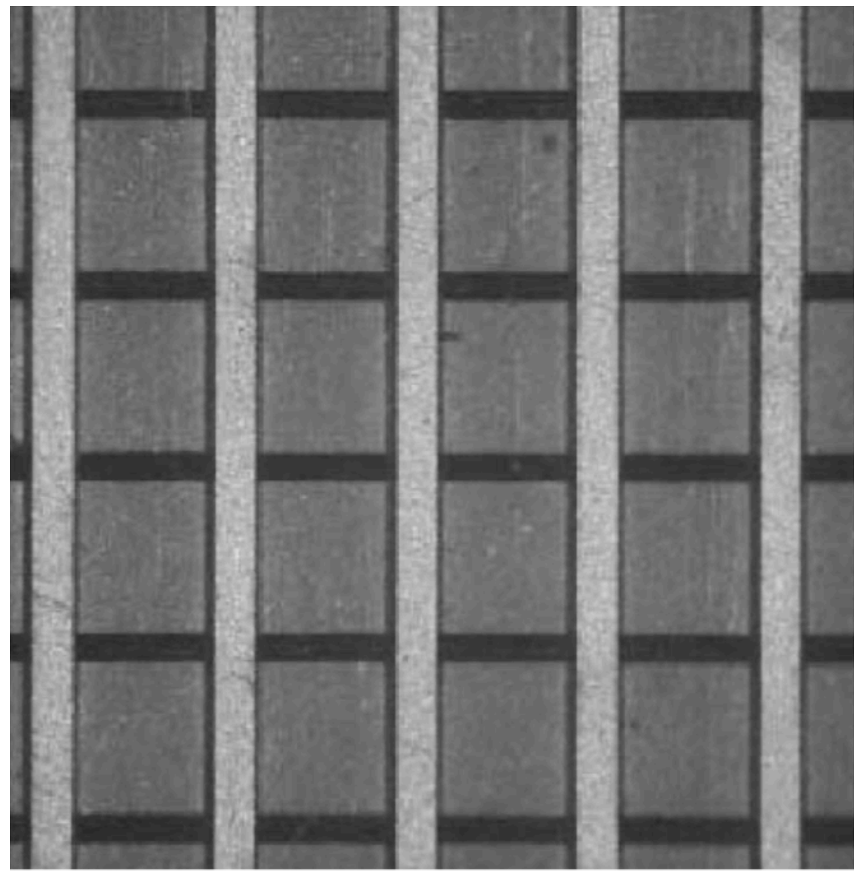
[7]

1st generation large-size GEM
(Compass GEM 1st Generation)

- 30.7 cm x 30.7 cm active area
  - Continuous strips
- 13-fold top-sectored GEM
- Spacer frame with grid
- Gas-inlet via support plate
- Honeycomb plates



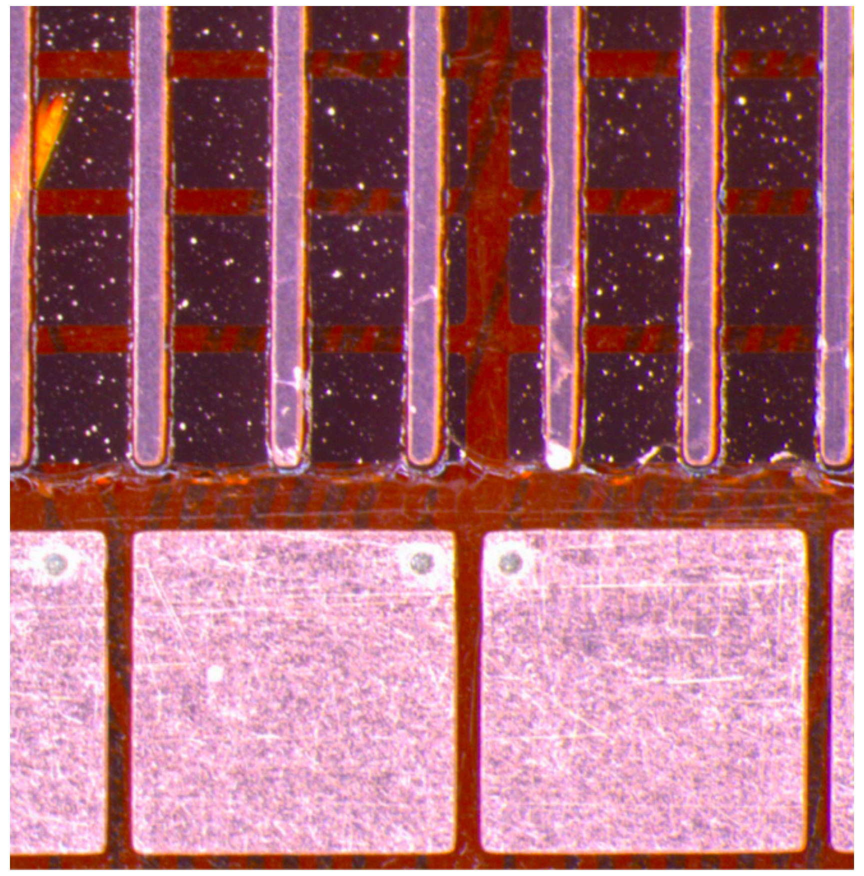


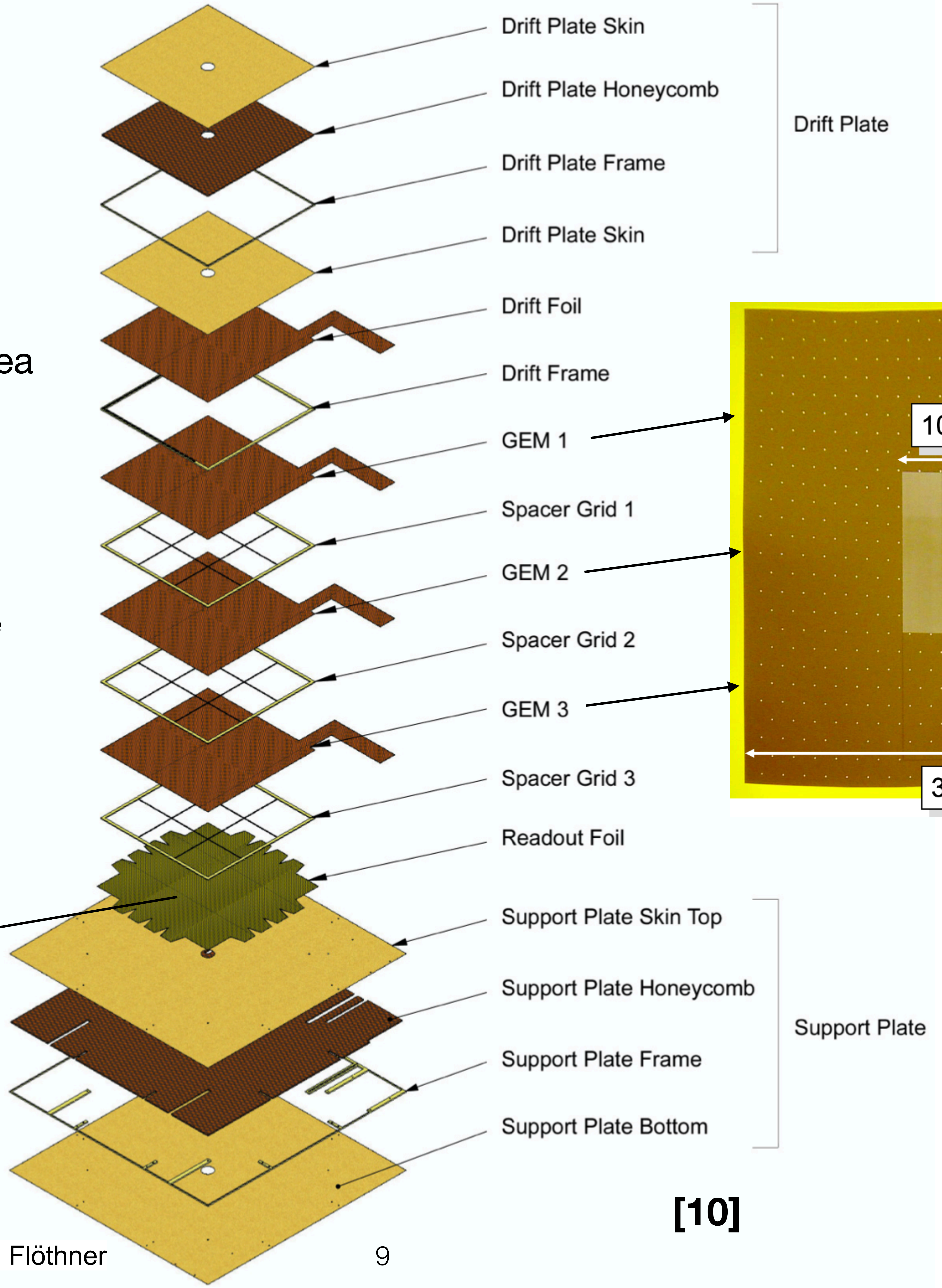


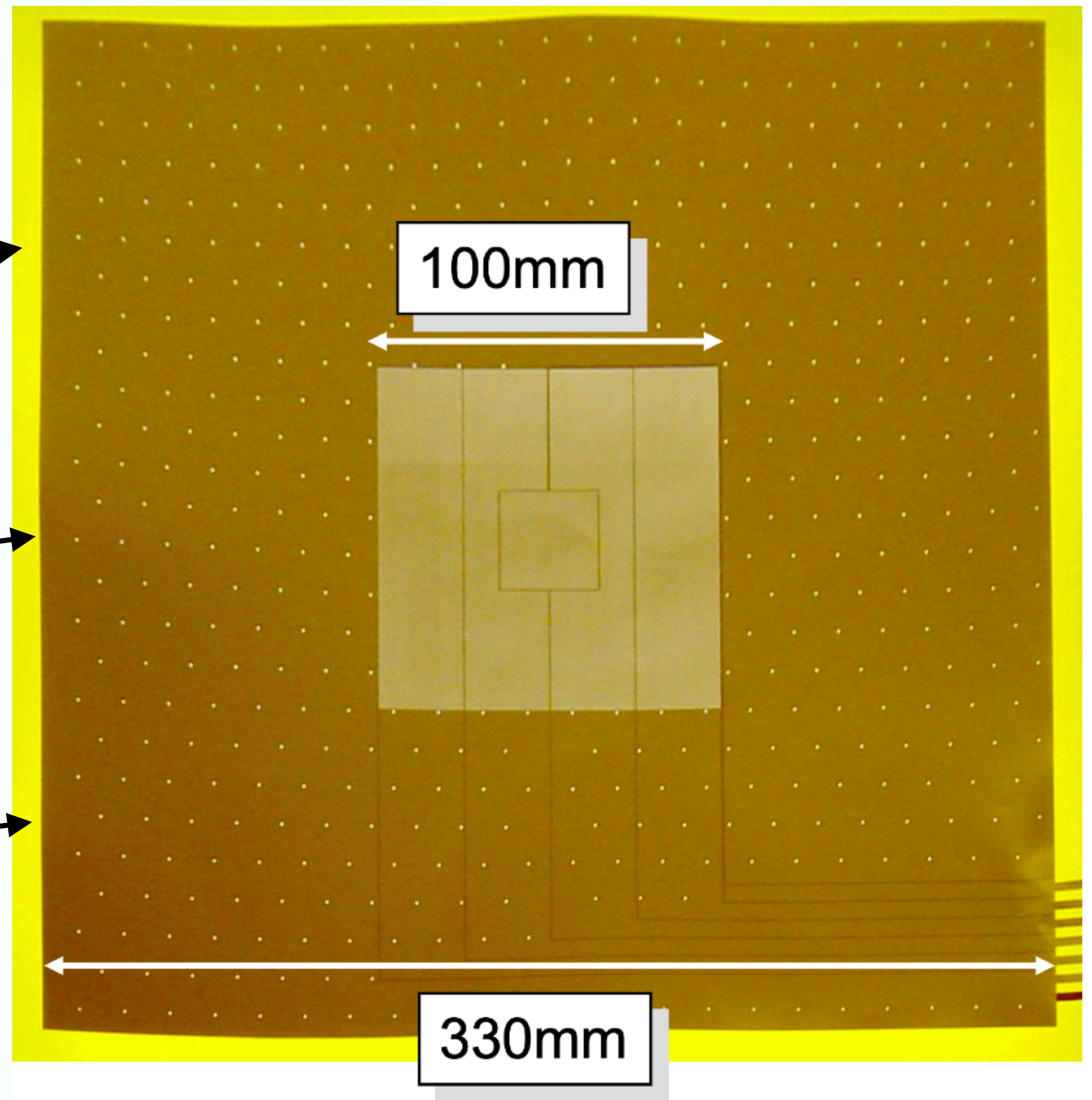
[9]

PixelGEM
(CG2G)

- 10 cm x 10 cm active area
  - 3.2 cm x 3.2 cm pixel area
- 5-fold top-sectored GEM
- Spacer with grids
- Gas-inlet via support plate
- Honeycomb plates



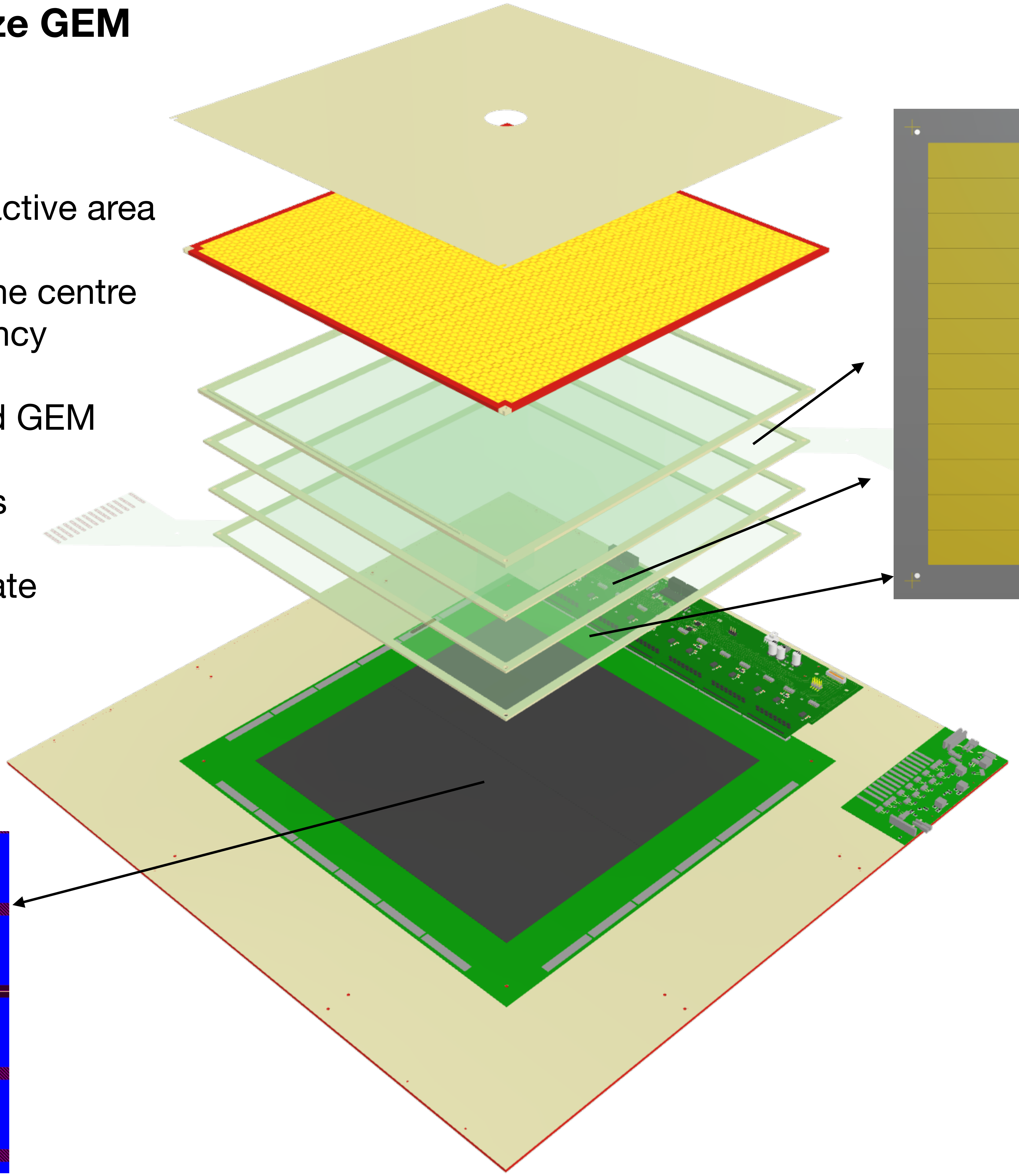


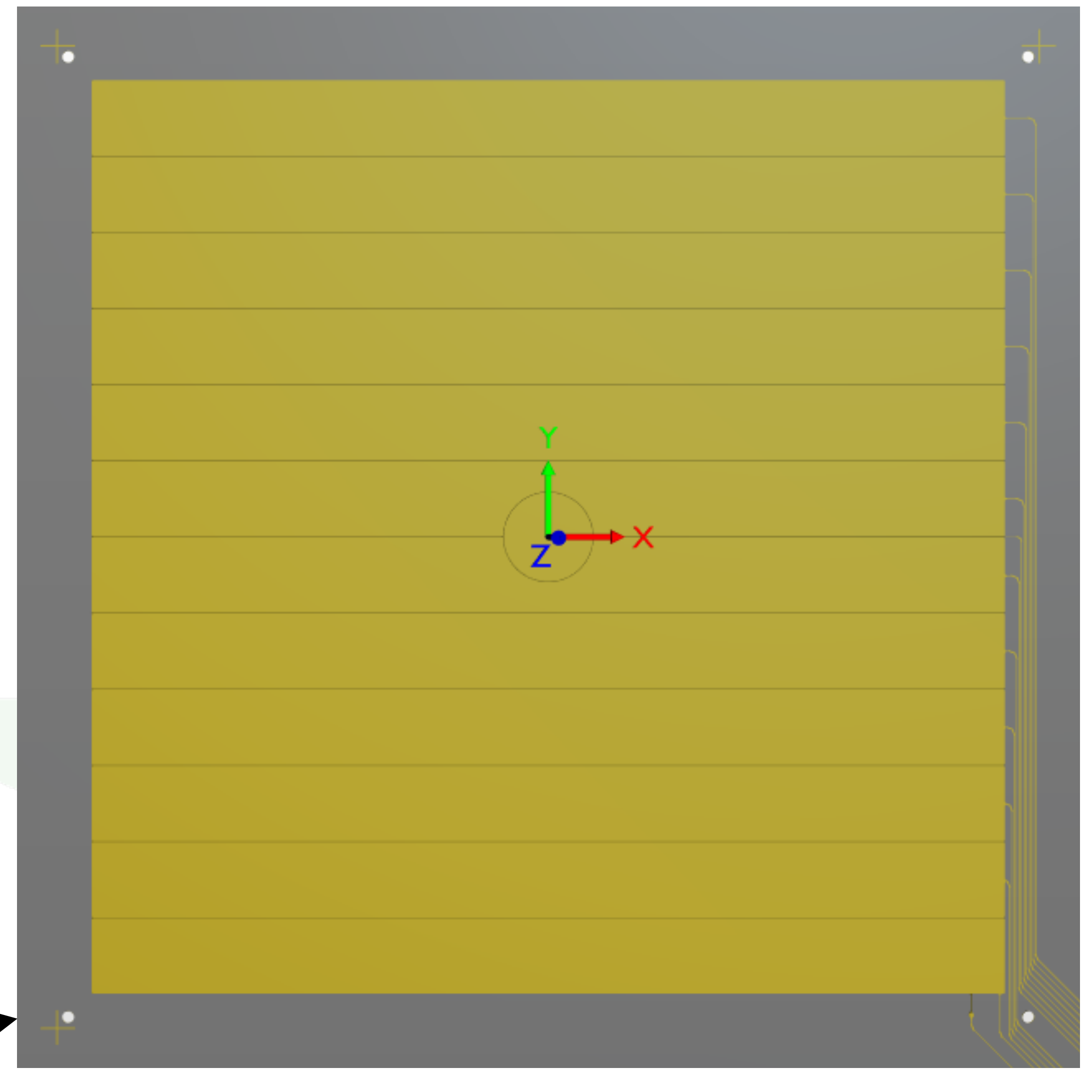


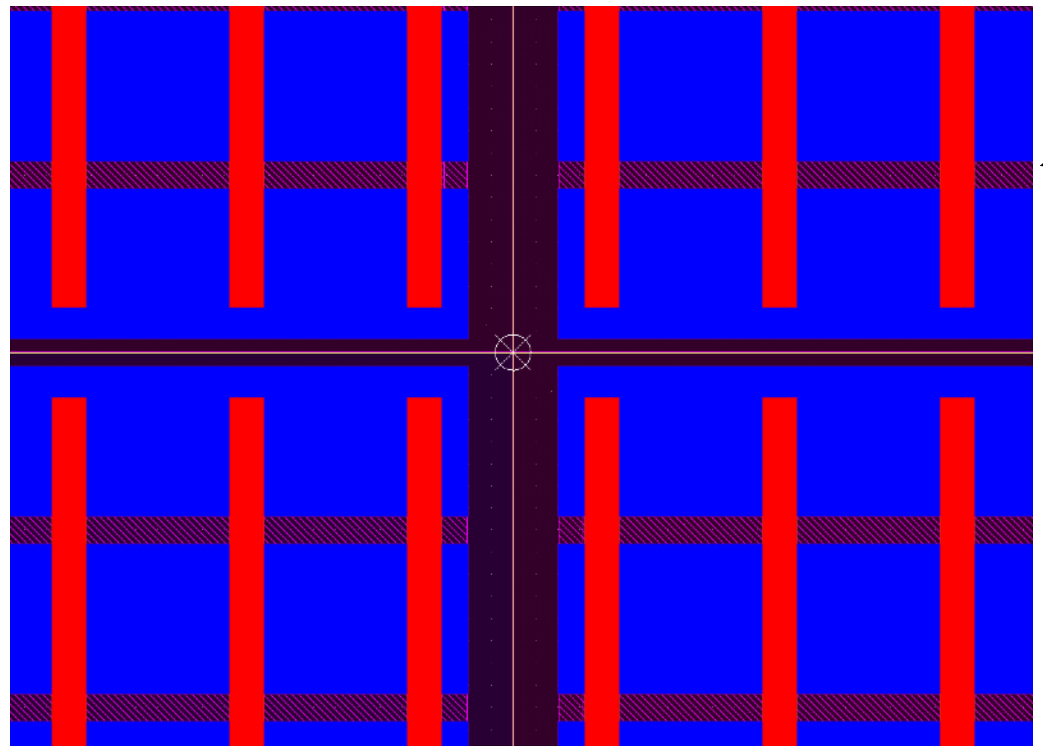
[10]

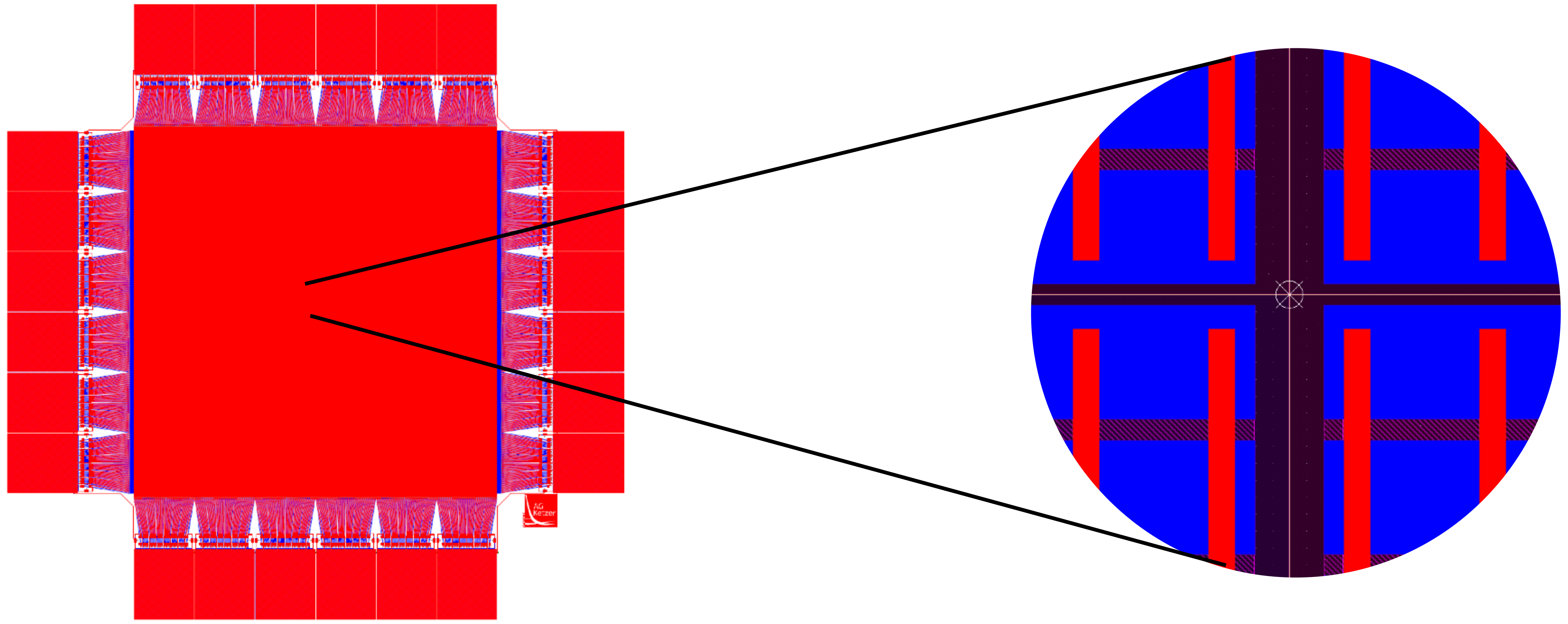
Ongoing large-size GEM
(CG3G)

- 30.7 cm x 30.7 cm active area
  - Strips divided in the centre to reduce occupancy
- 13-fold top-sectored GEM
- Spacer without grids
- Gas-inlet via drift plate
- Honeycomb plates

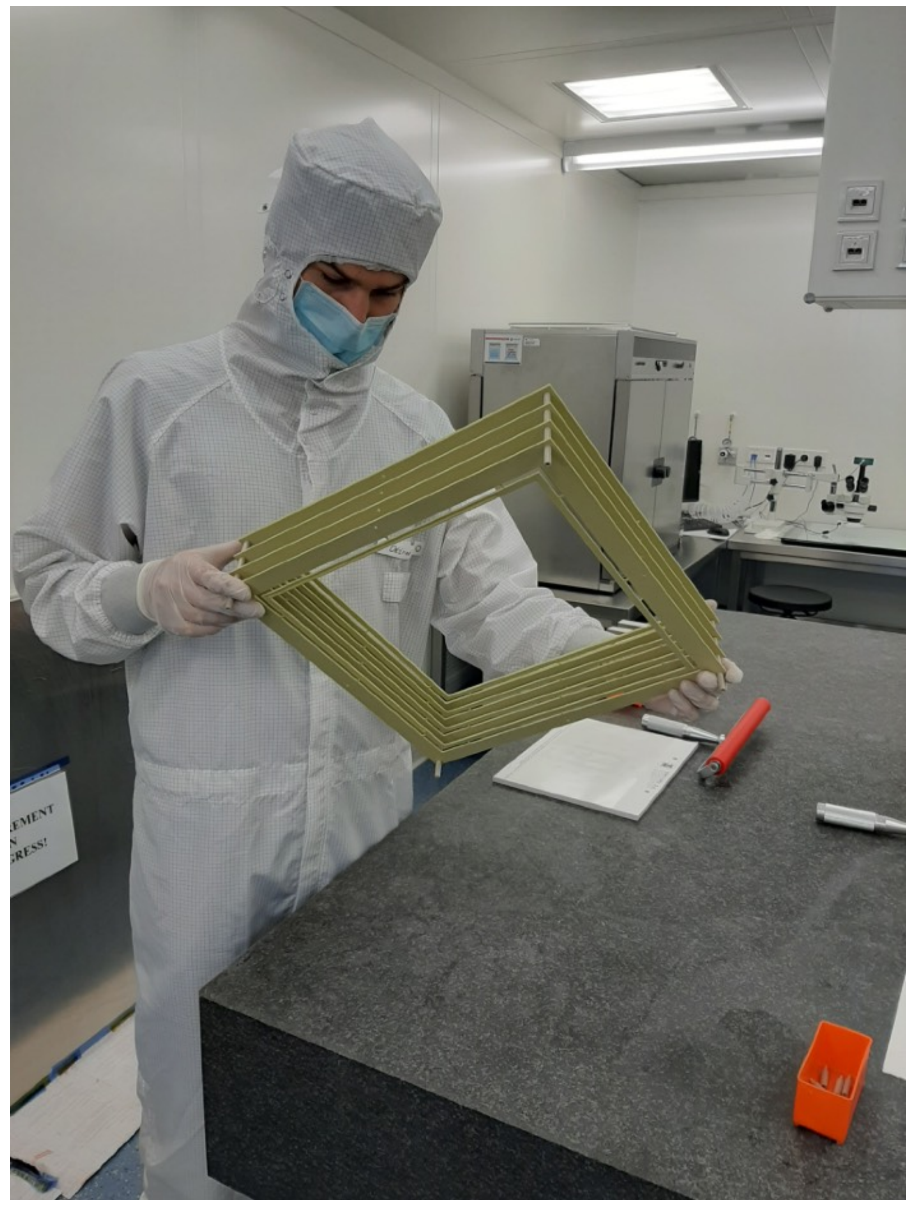






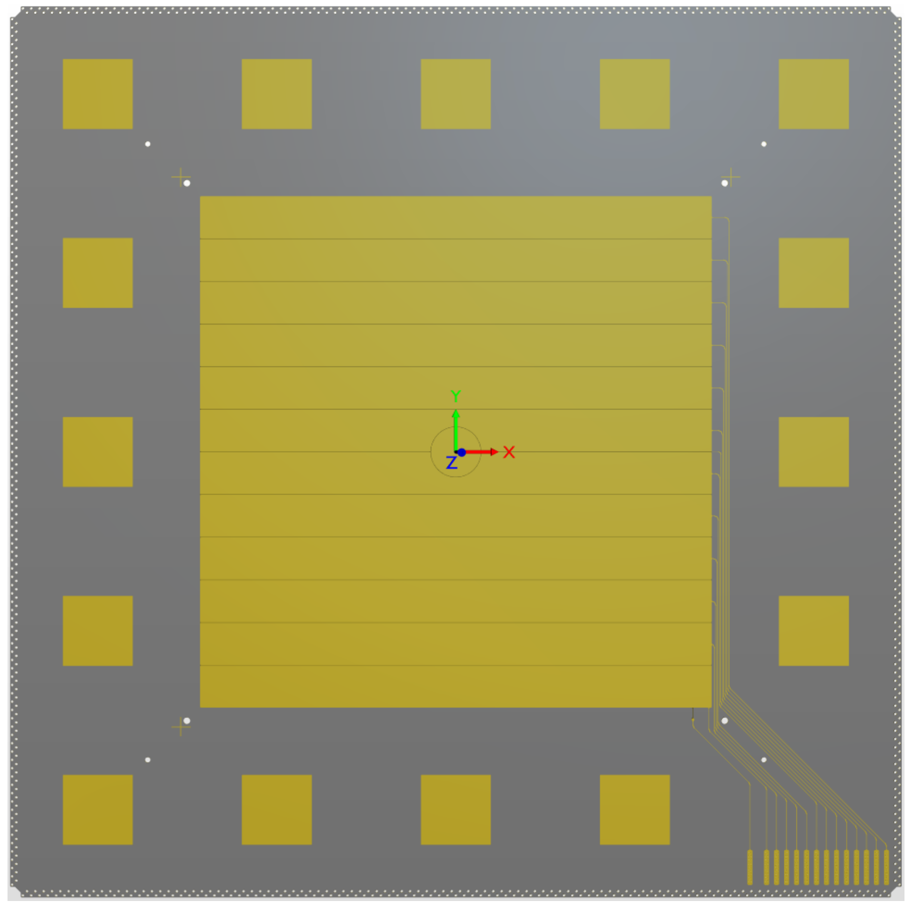


Insight into the design

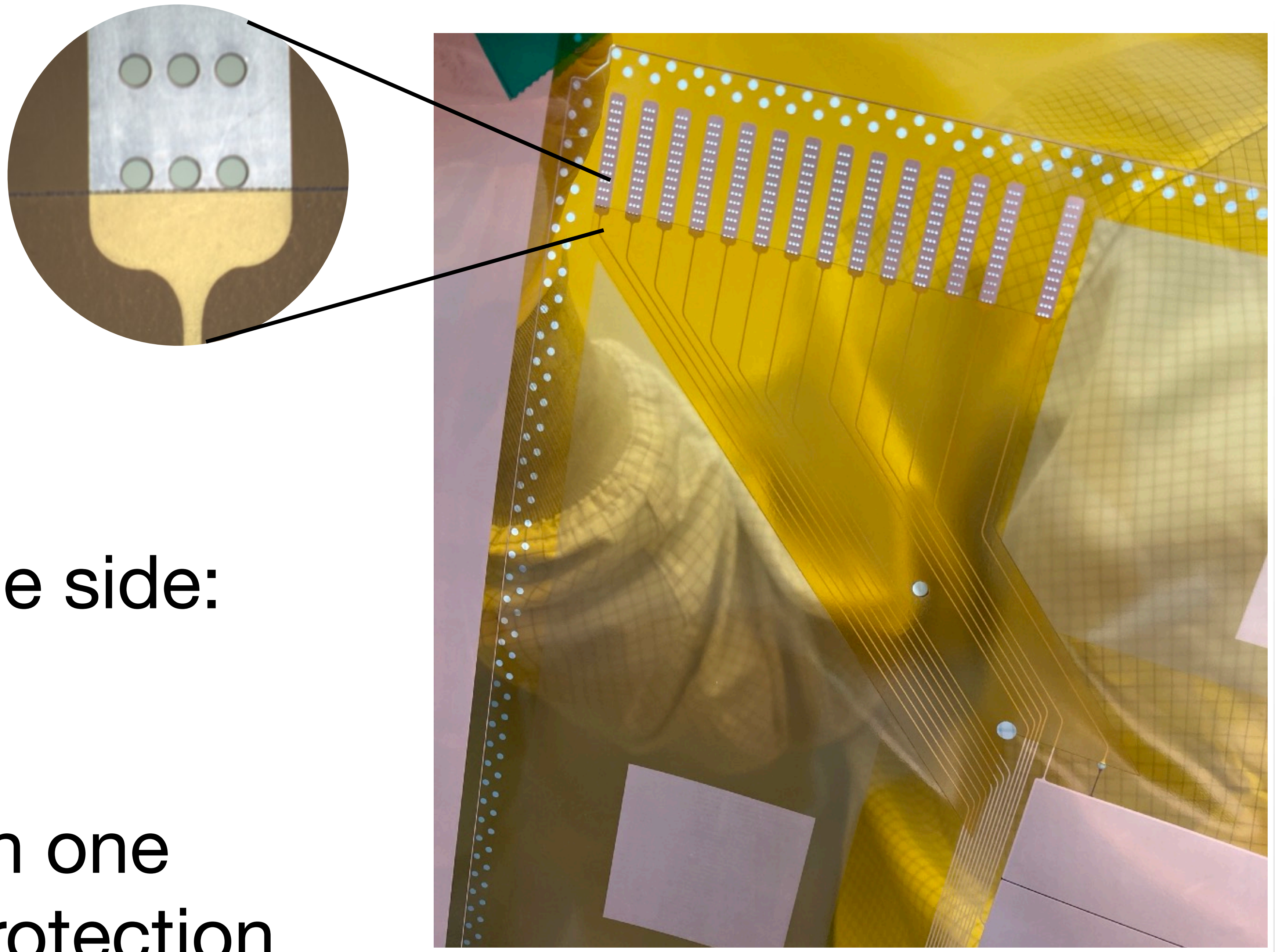


Content:

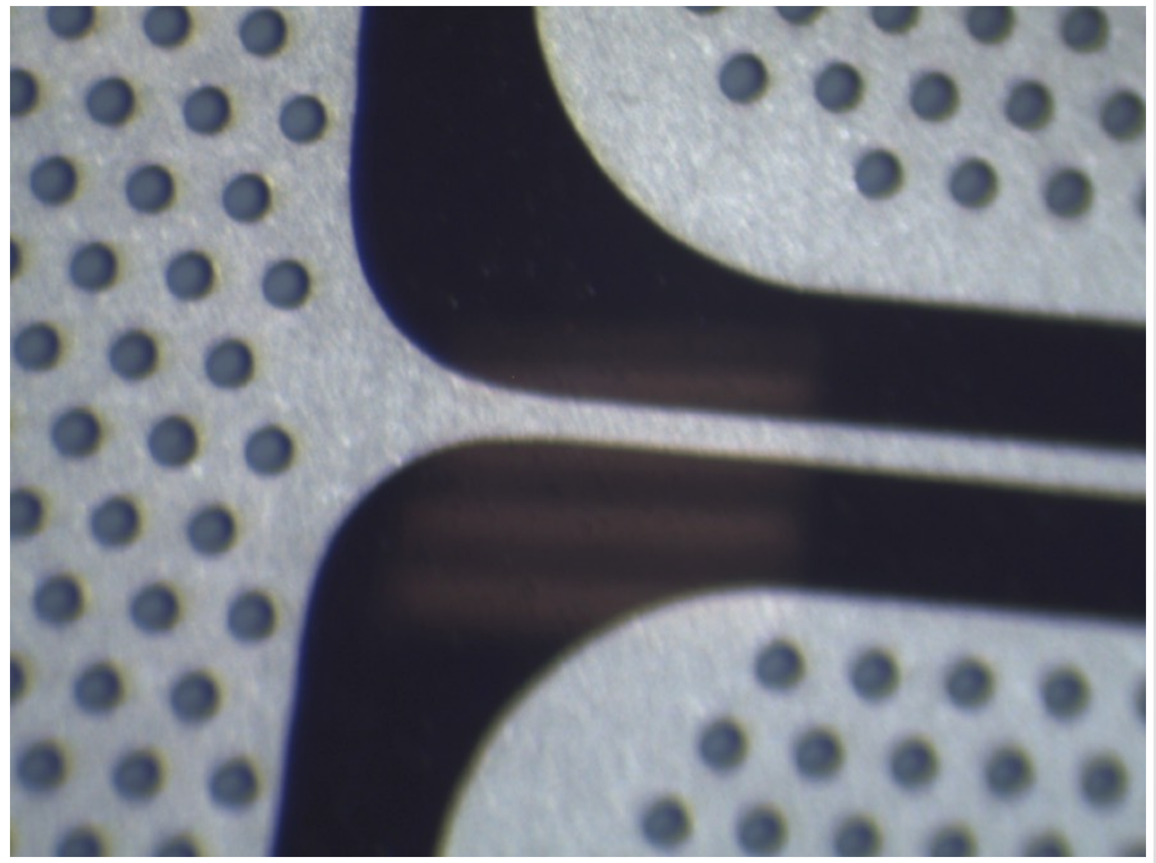
- GEM foils
- Readout foil
- Frames

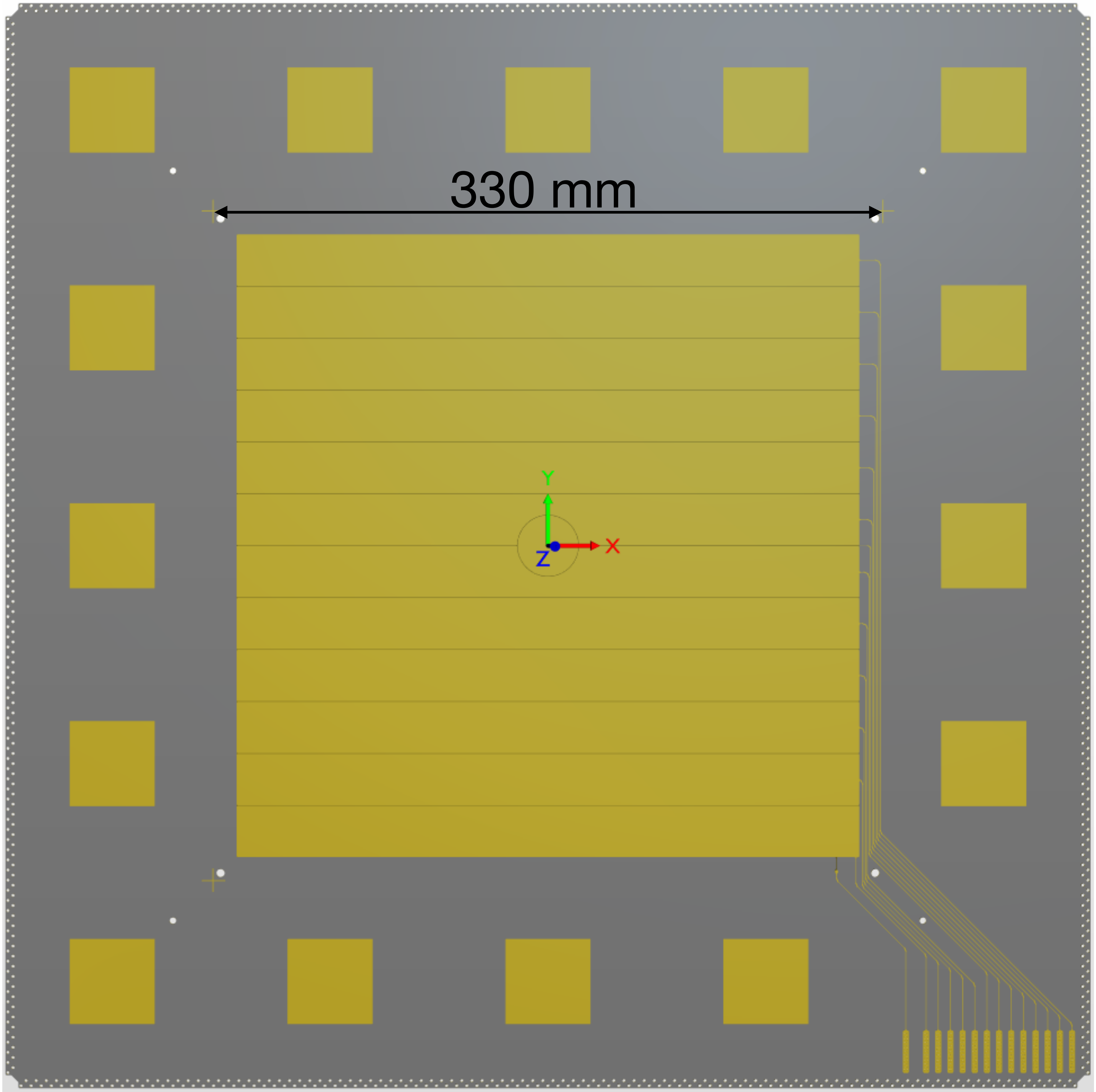


GEM Foil Design



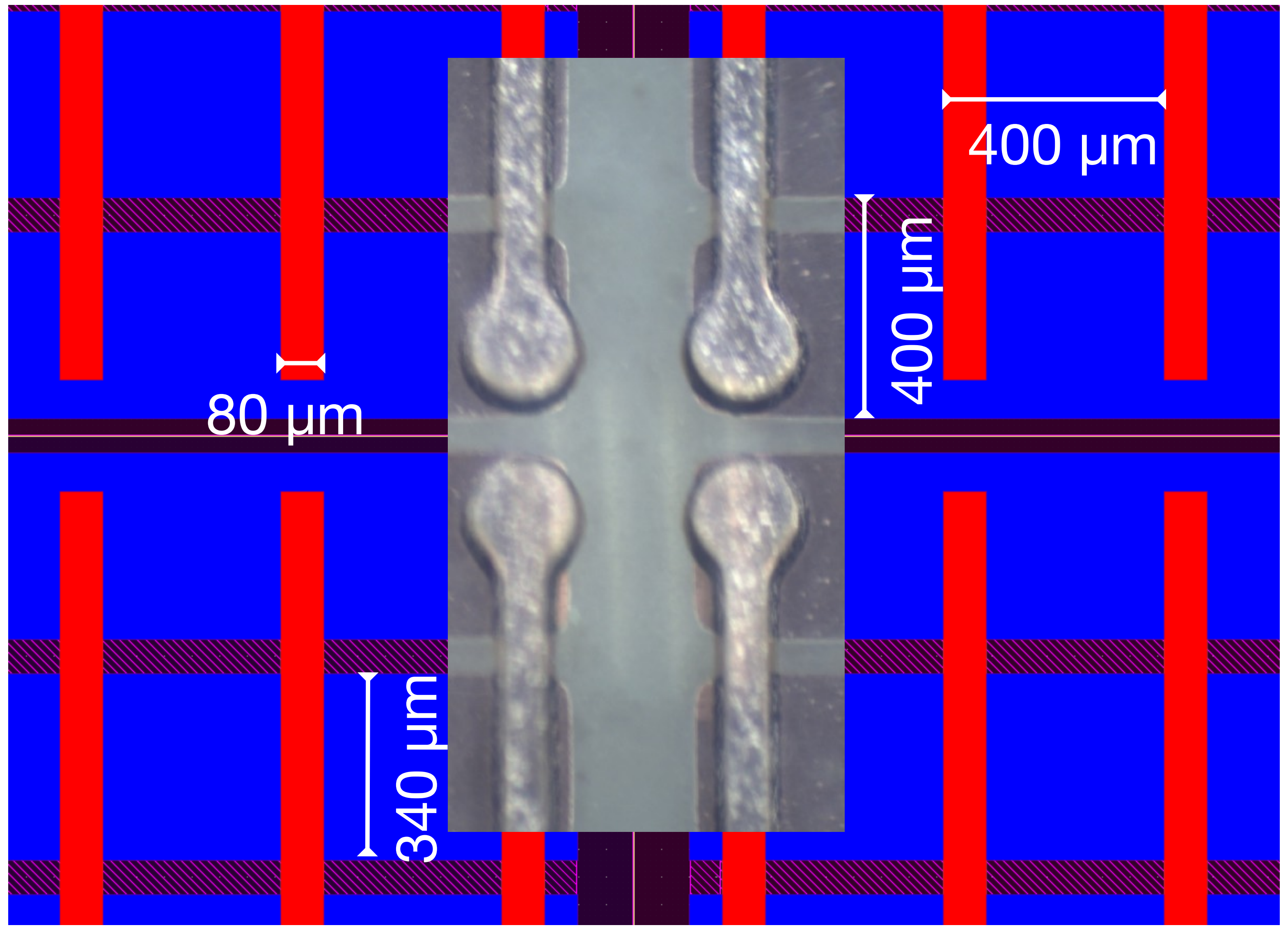
- Triple GEM stack
- Foils segmented on one side: 12 sectors + centre
- All lines guided through one corner with coverlay protection
- Cu thickness reduced

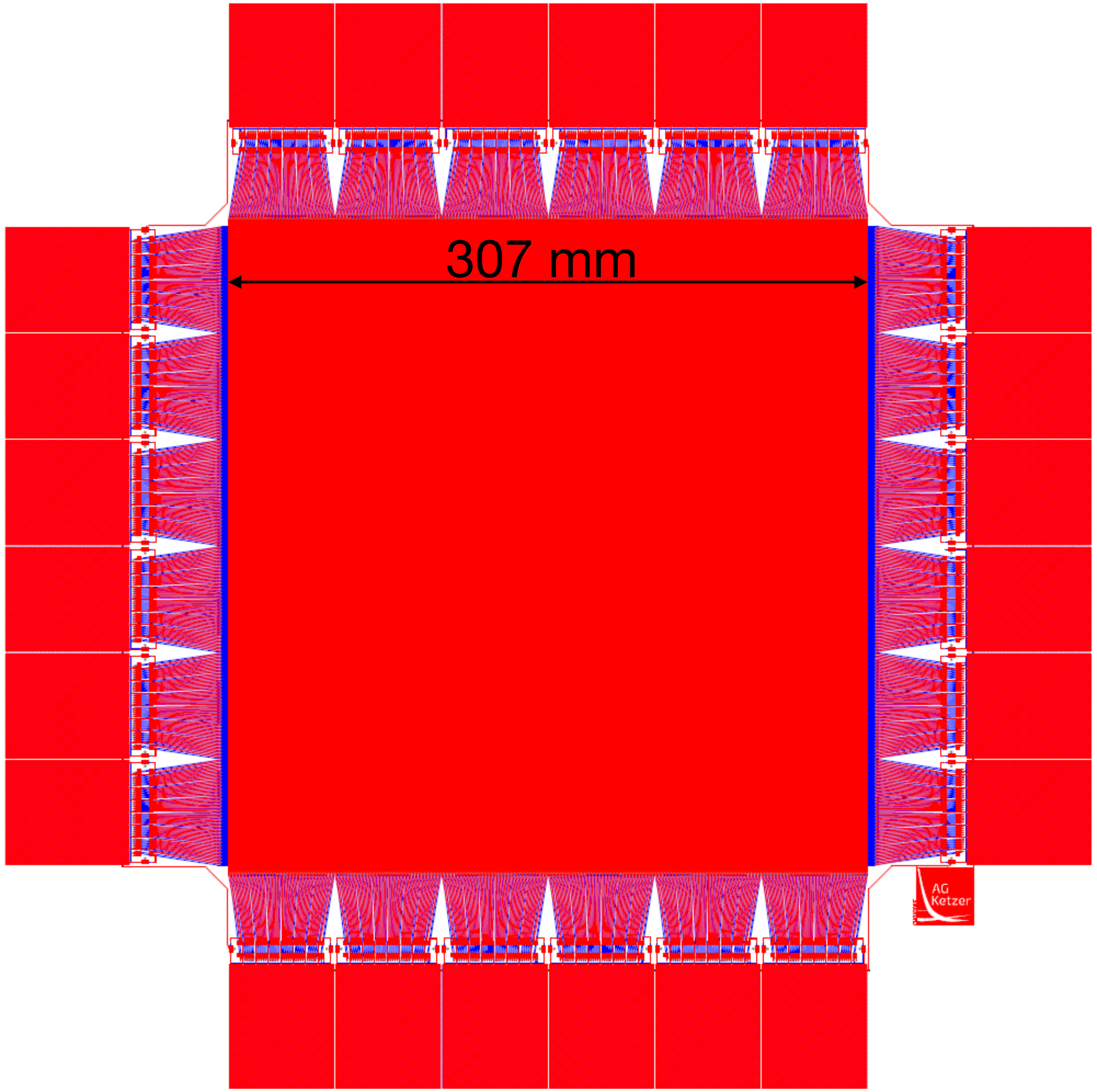




Readout Plane

- Readout from all sides
- 4x768 strips (cut in middle)
- Hirose FX10 replace older Panasonic P5 series





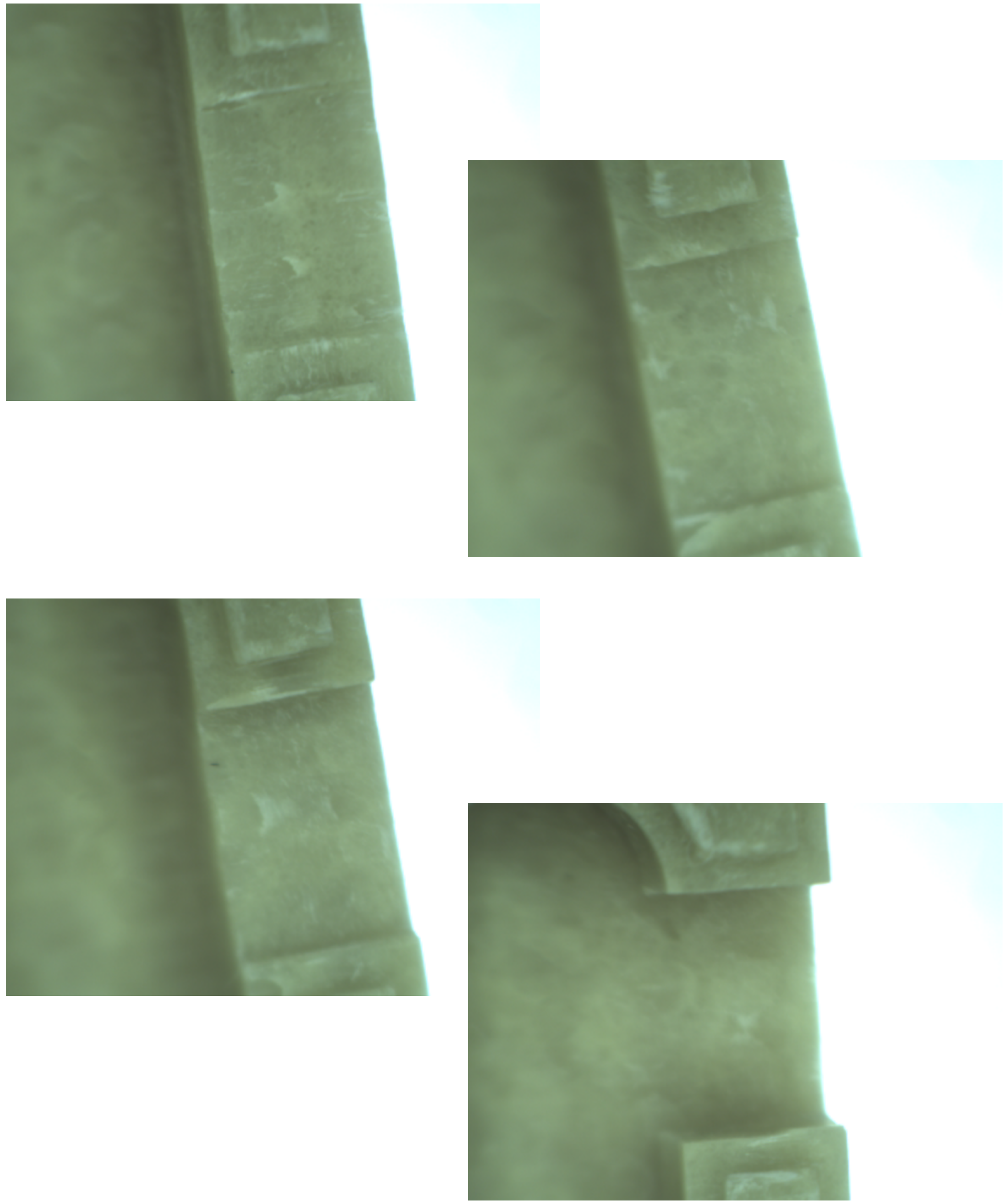
Frame-Stack for one Detector

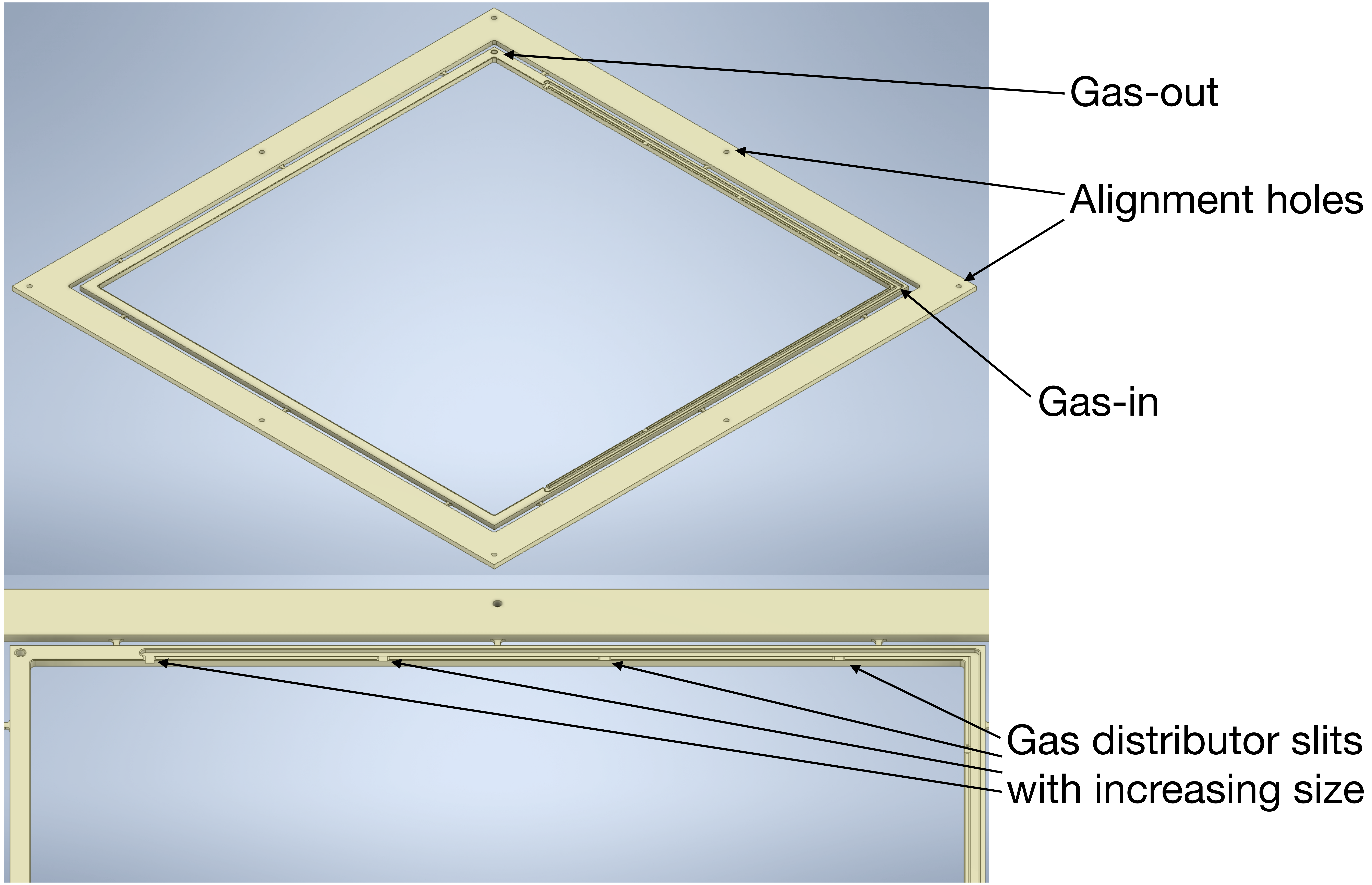
Drift-Frame
3 mm

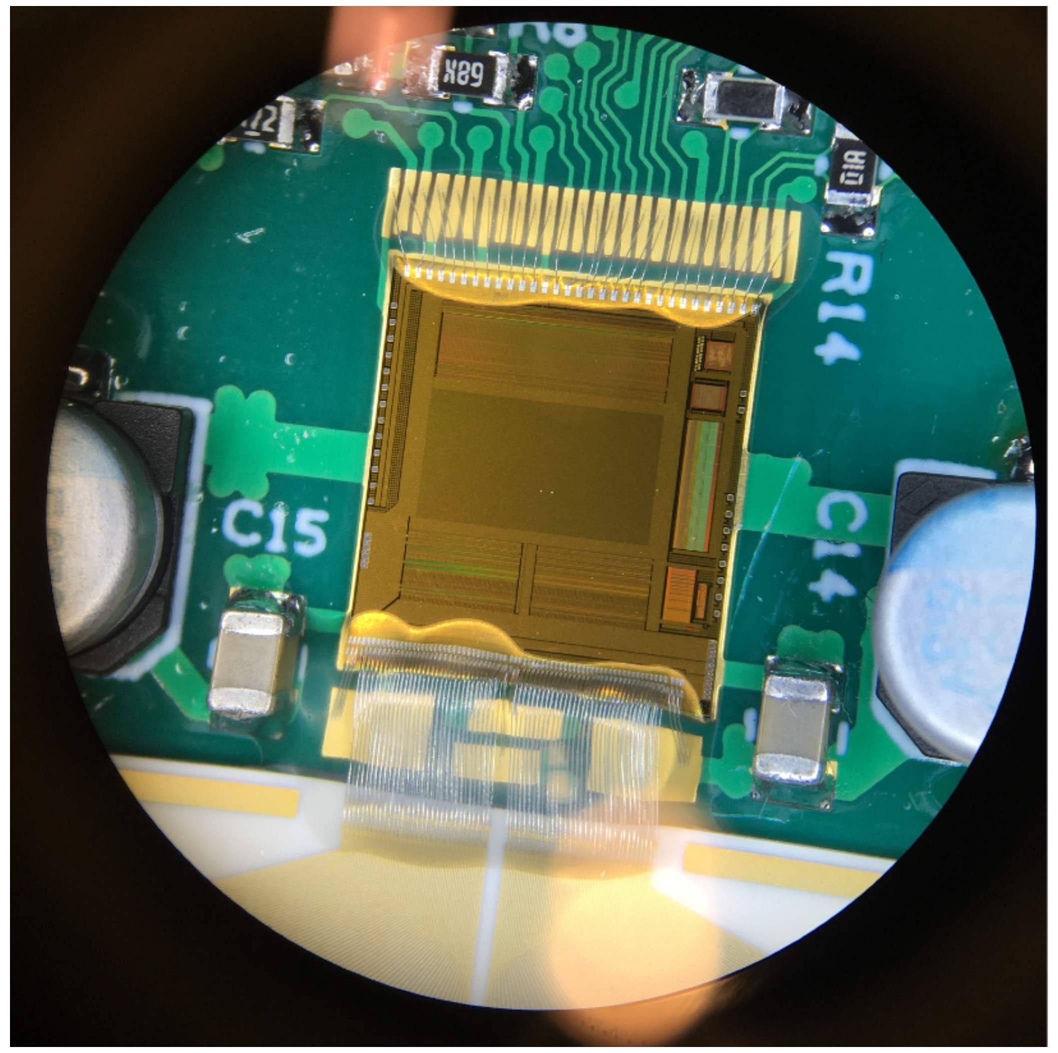
GEM-Frames
2 mm

R/O-Frame
2 mm

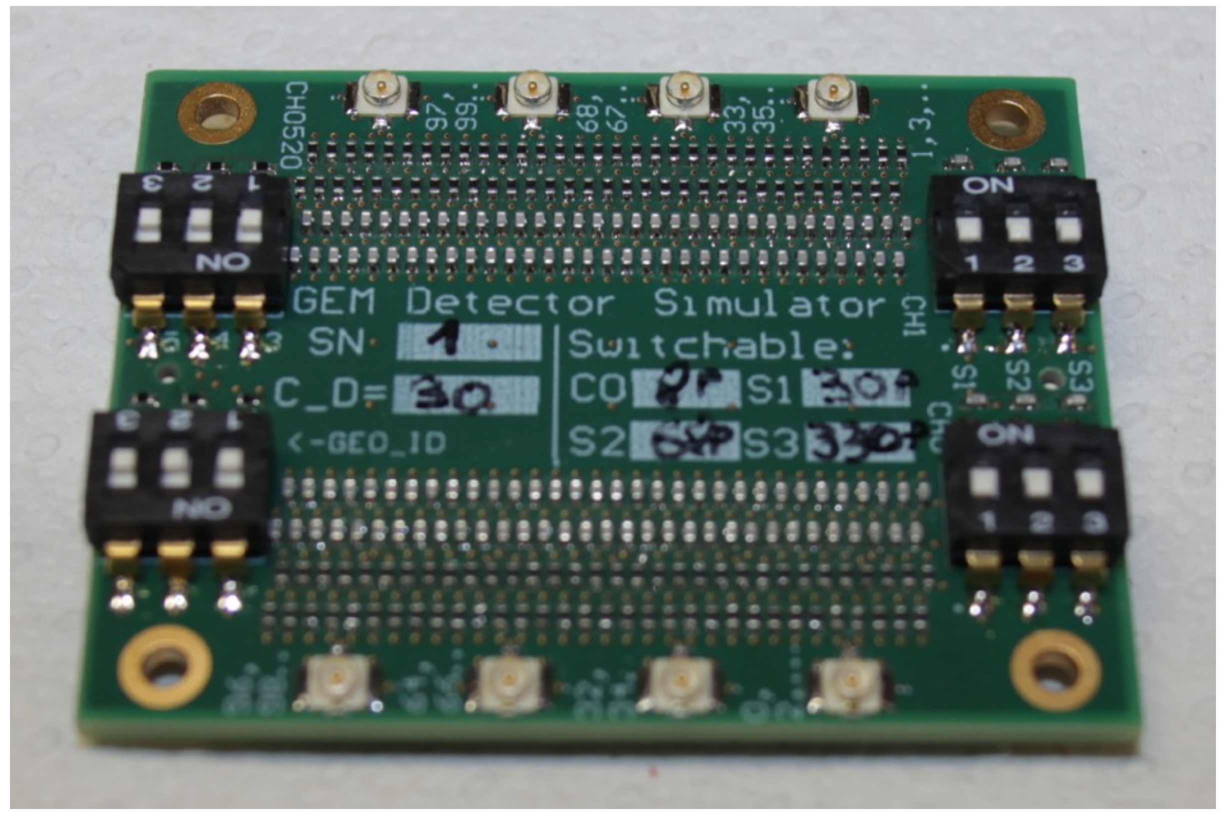
Drift Frame of 3 mm





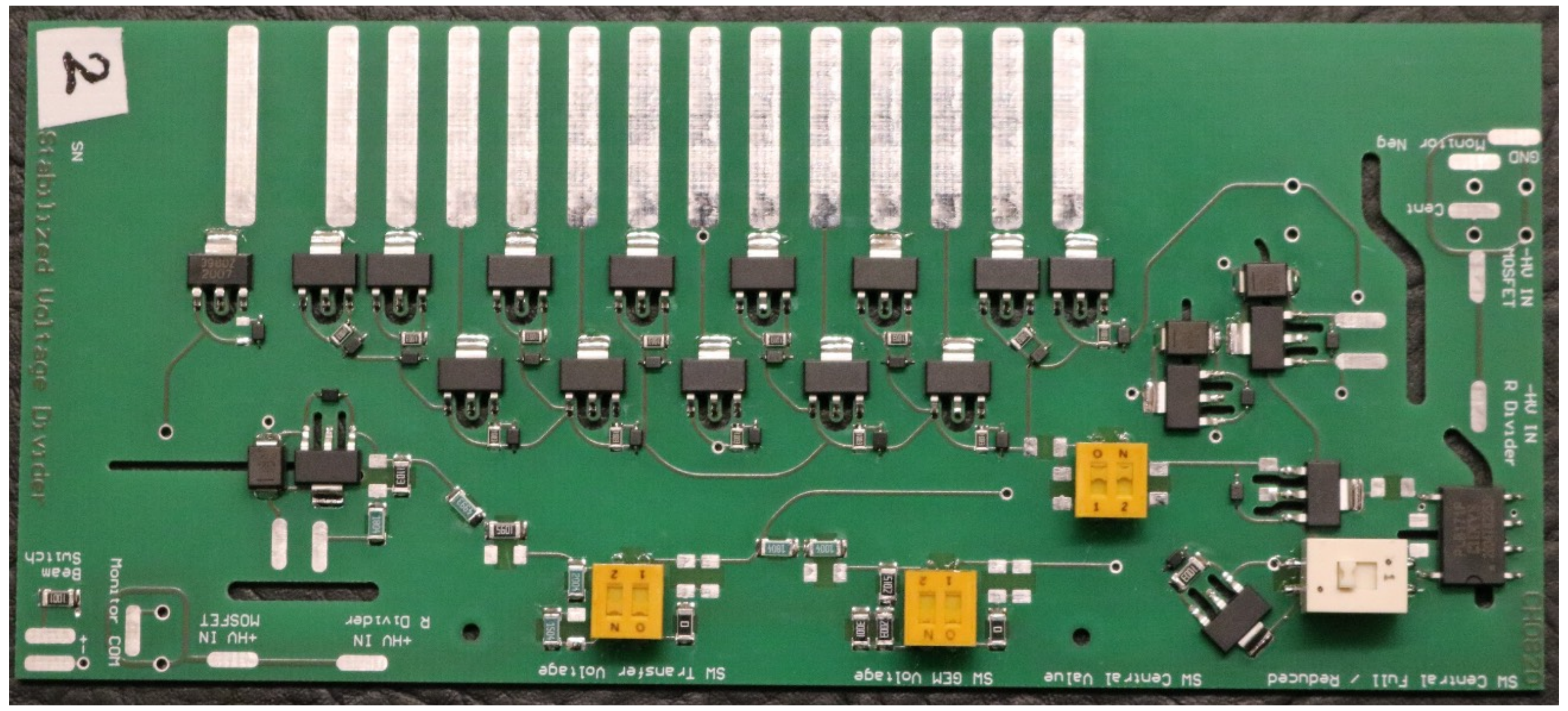


Electronics



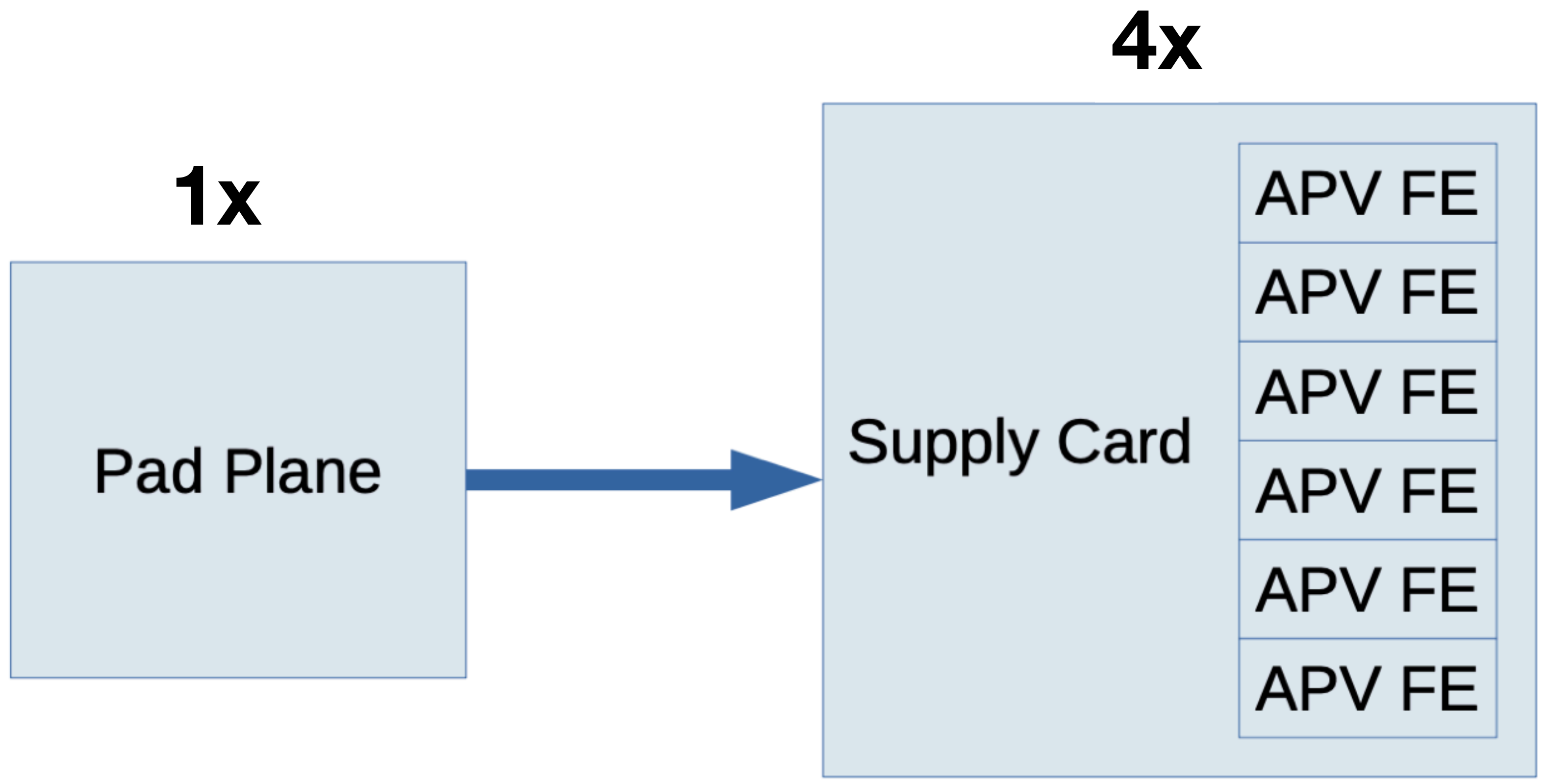
Content:

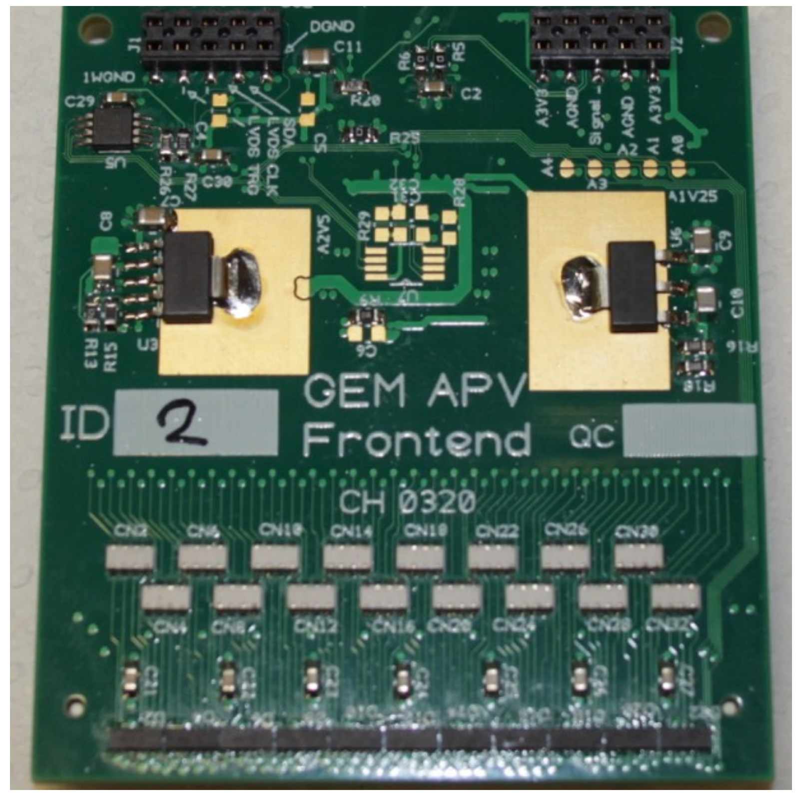
- APV Front-End
- Supply Card
- HV-Board(s)



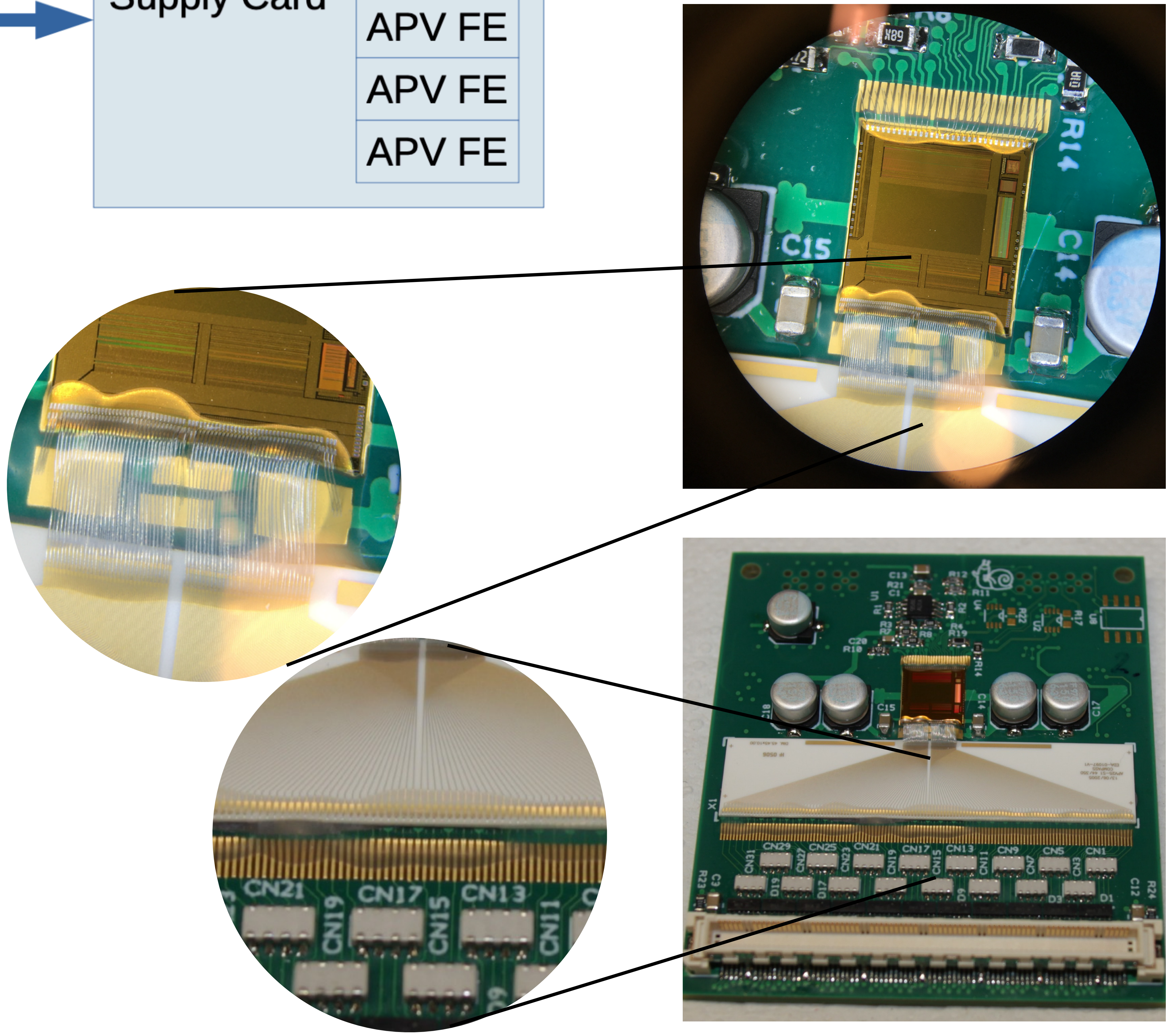
APV Frontend

Christian Honisch (honisch@hiskp.uni-bonn.de)





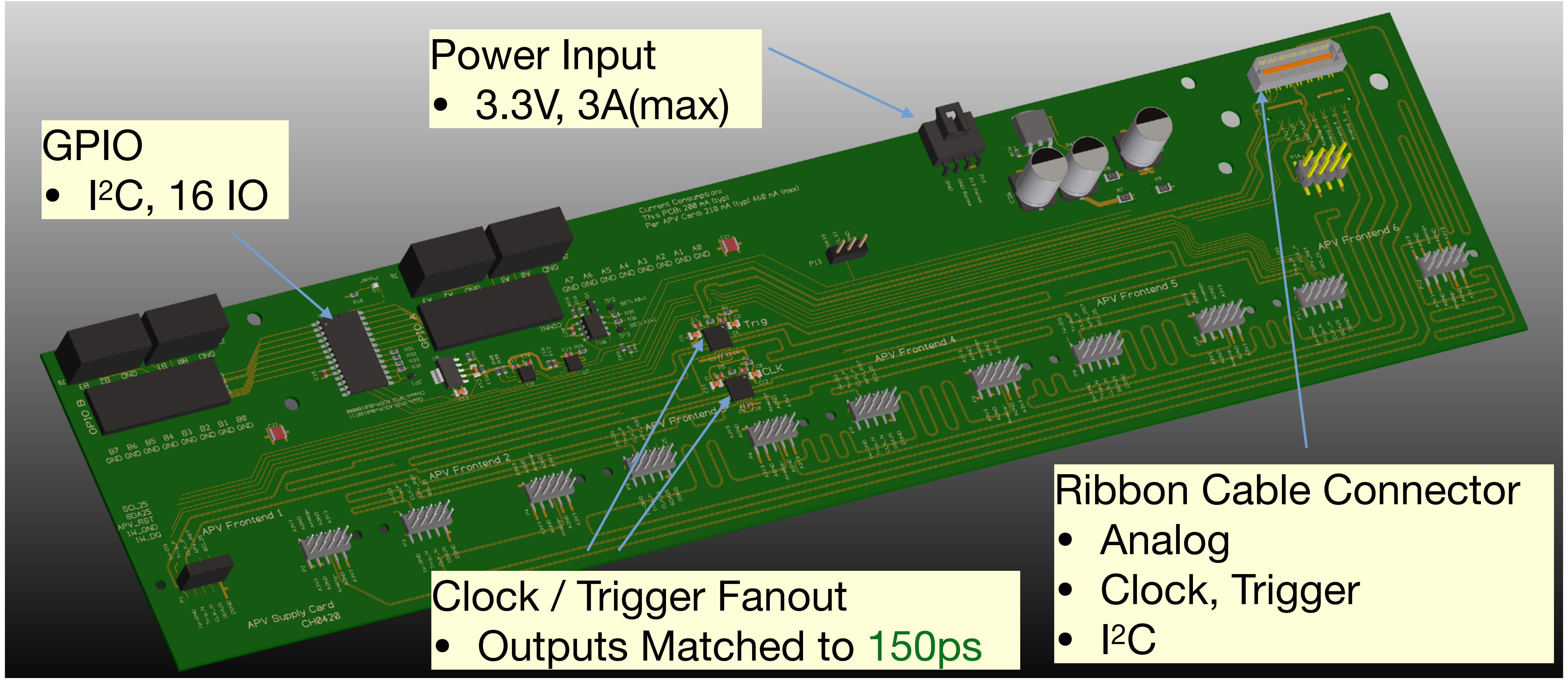
- One Detector:
  - 4x Supply card
    - ➡ Each 6x APV Front-End
- Improved input protection
- I²C temperature sensor
- I²C addresses: via detector connection



Supply Card

Christian Honisch (honisch@hiskp.uni-bonn.de)

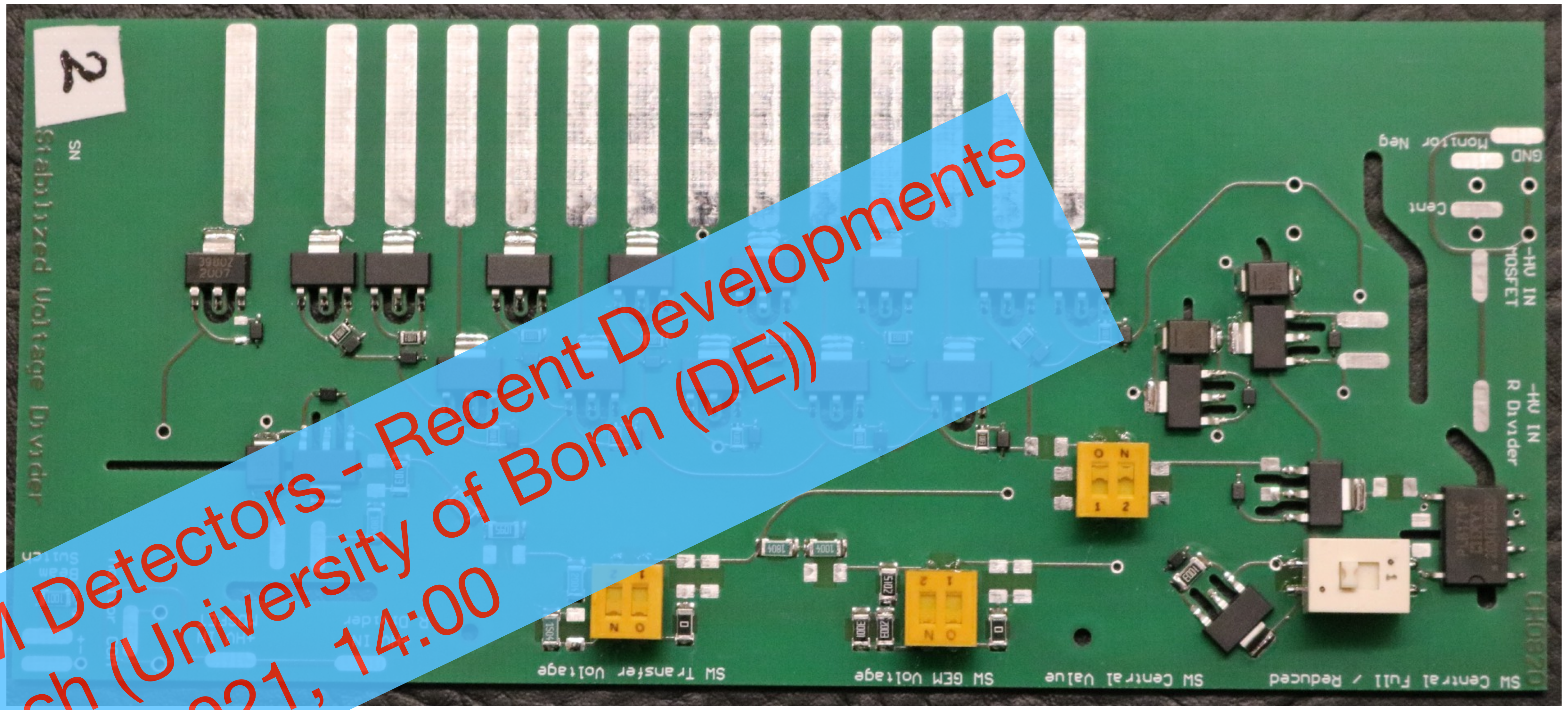
- Provides Power, Clock, Trigger to APV-FE
- Concentrates analog signals from APV-FE
- **Clock, Trigger, Analog: Matched Lengths**



HV Board(s) SVD

Christian Honisch (honisch@hiskp.uni-bonn.de)

- One Detector:
  - 3+1 HV-Boards
- Stabilized voltage
- Switchable configuration
- Low impact of shorted segments
  - Short circuit on segment A -> 15mV drop on segment B (previous: 25V)
- Switch for Central Pad Voltage
- Protection for Fault Cases (GEM<500V)
- Monitoring in preparation

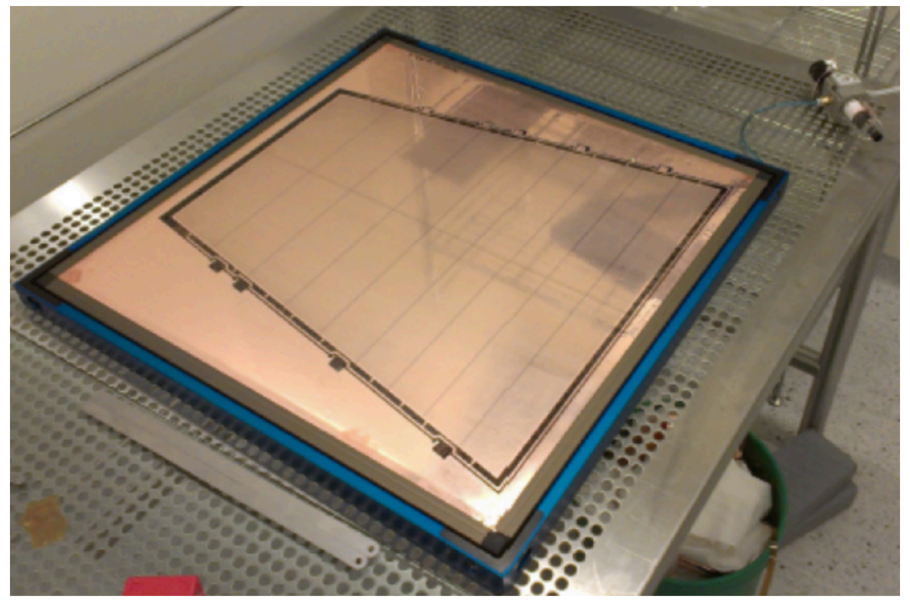


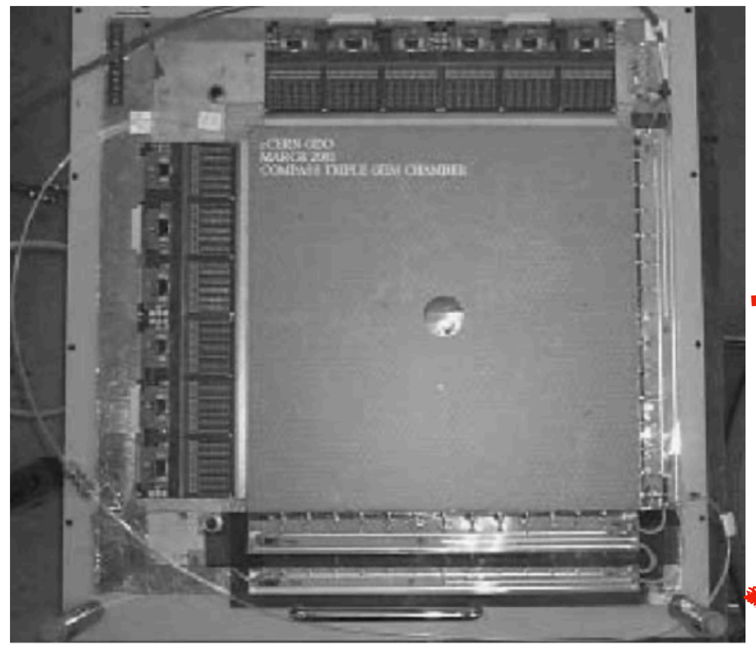
Electrode	COMPASS / V	BONN[3] / V
Drift	−4100	−3255
GEM1 TOP	−3353	−2508
GEM1 BOT	−2943	−2102
GEM2 TOP	−2196	−1751
GEM2 BOT	−1822	−1384
GEM3 TOP	−1075	−1068
GEM3 BOT	−747	−747
PCB	(GND) 0	(GND) 0

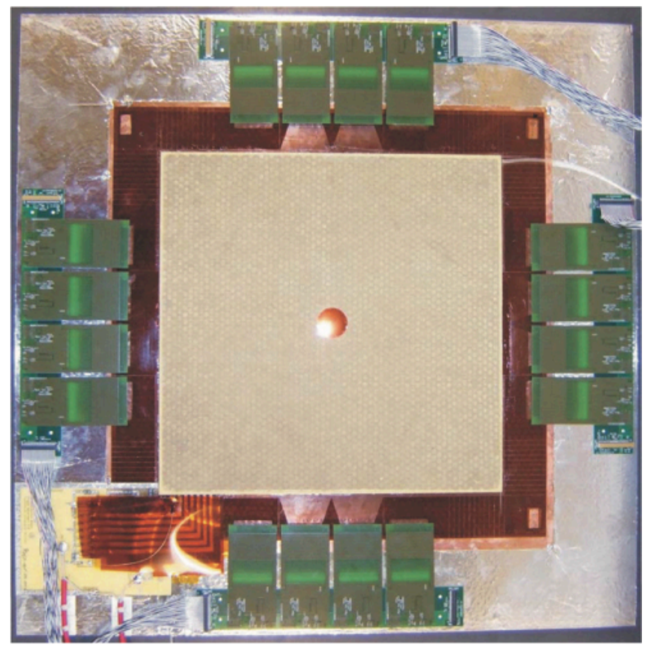
[4]

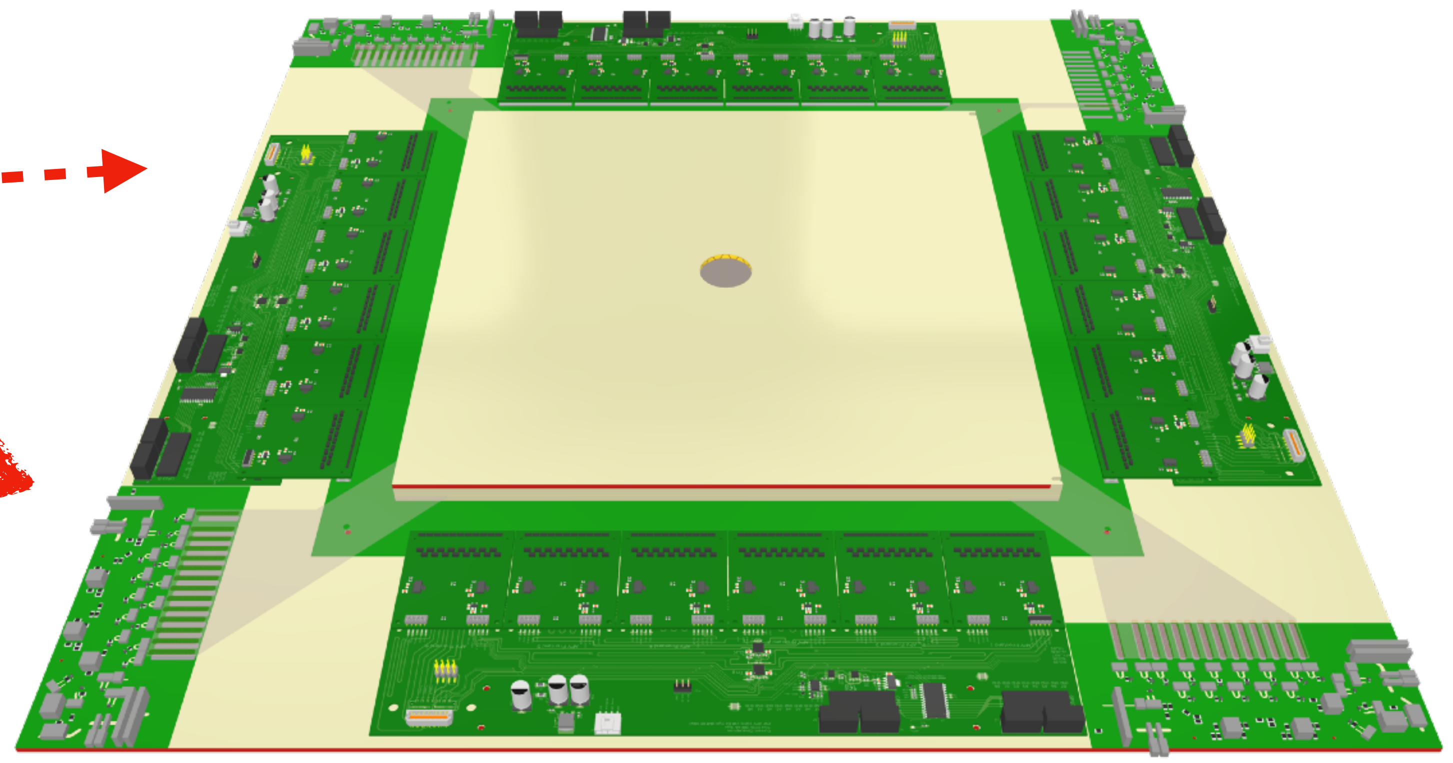
Next Steps

- Commissioning of the new CG3G prototype
- Tests measurements with the new SVD (BONN settings)
- Further production with slight optimizations
- Integration of CG3G detectors in the COMPASS spectrometer





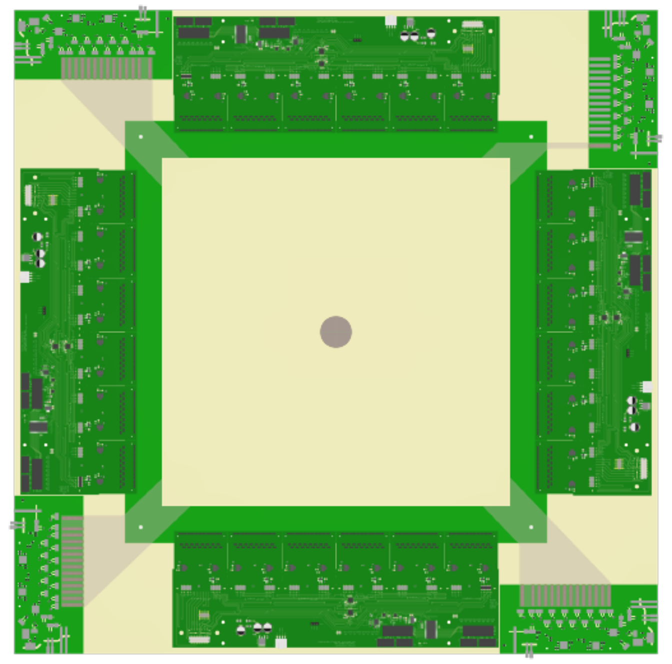




Outlook

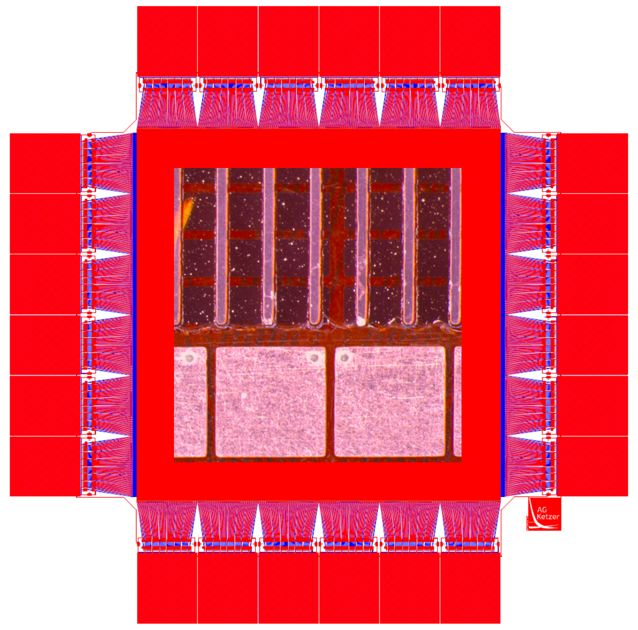
- CG3G production
- Further investigations in hybrid readout system
- Prototyping and testing CG4G
- Design for CG5G
- Prototyping and testing CG5G

CG3G

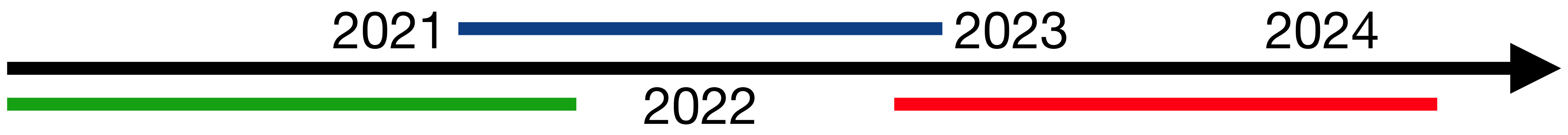


Updated Large-size

CG5G



Large-size with Pixel



CG4G

Self triggered readout
e.g. with VMM

463. Application and further improvement of the RD51 general Scalable Readout System with the VMM chip
Michael Lupberger (University of Bonn (DE))
27/05/2021, 14:00

Thanks
-
stay healthy

References

https://uni-bonn.zoom.us/j/96558841432?pwd=RE5pTUlLbStuWDlLNVZuVW9VSE0rQT09

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The collaboration has not yet constituted itself, thus instead of a Spokesperson currently the nominated Contact Person is acting in place.: CERN, 2019,
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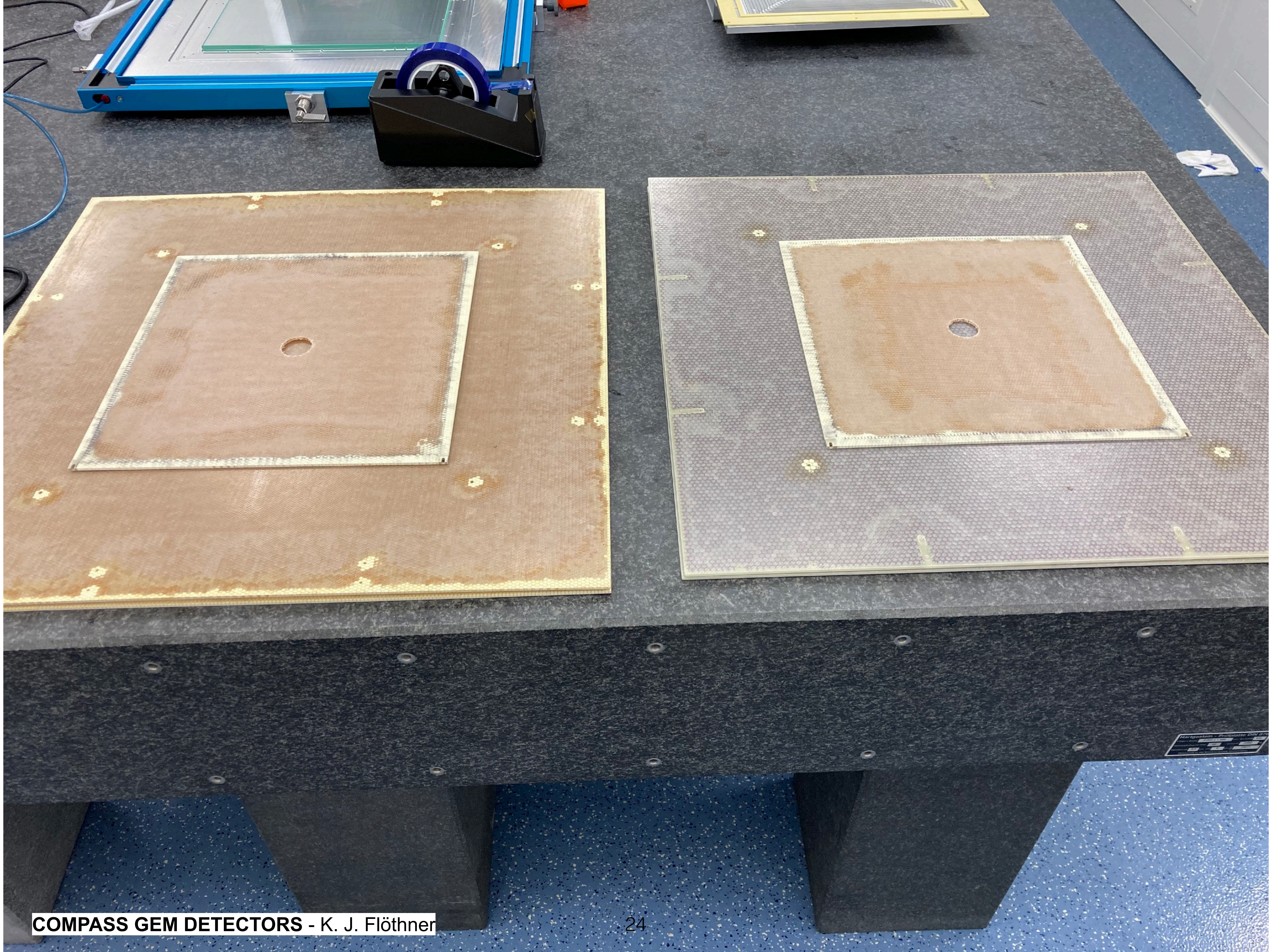
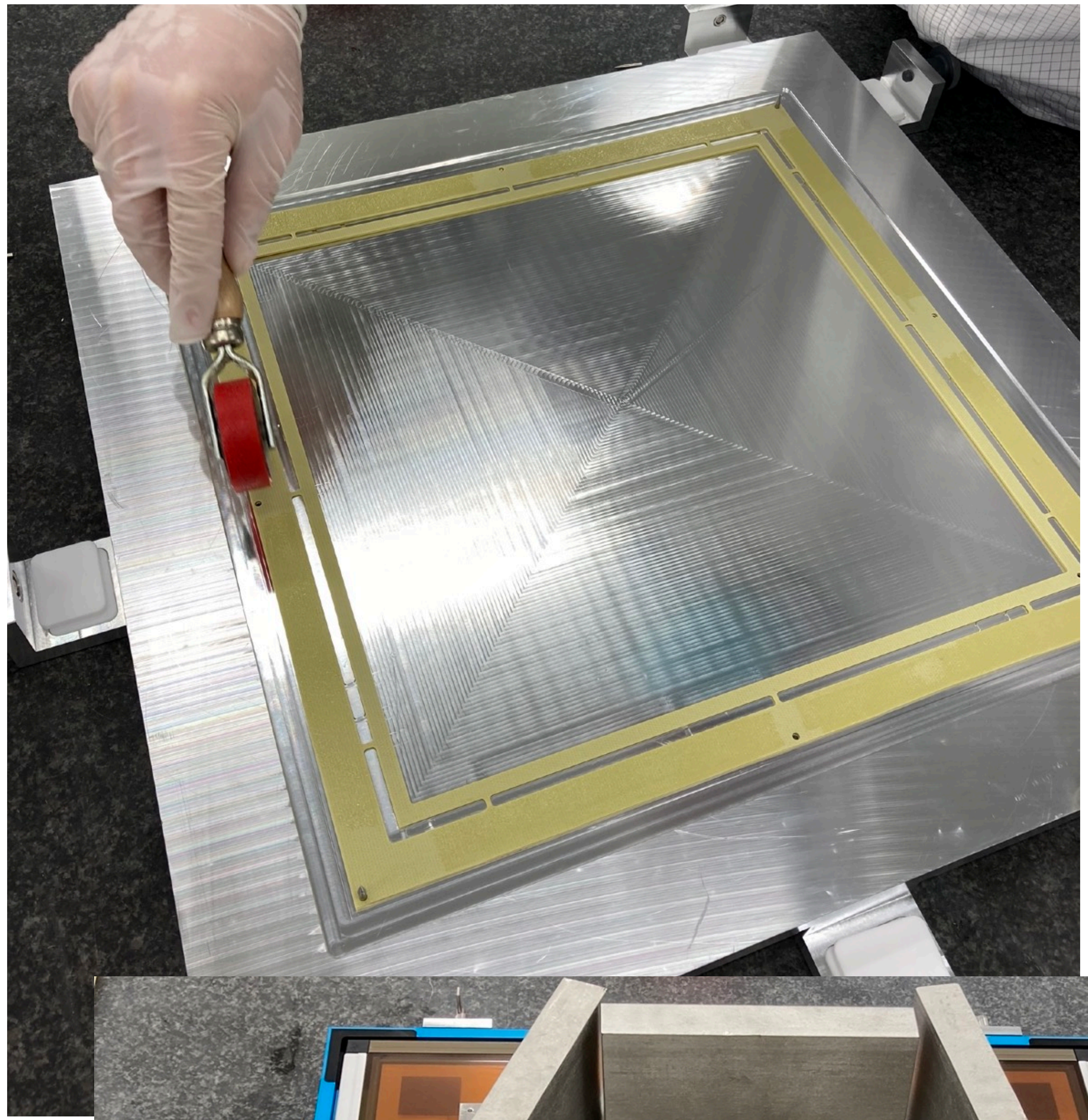
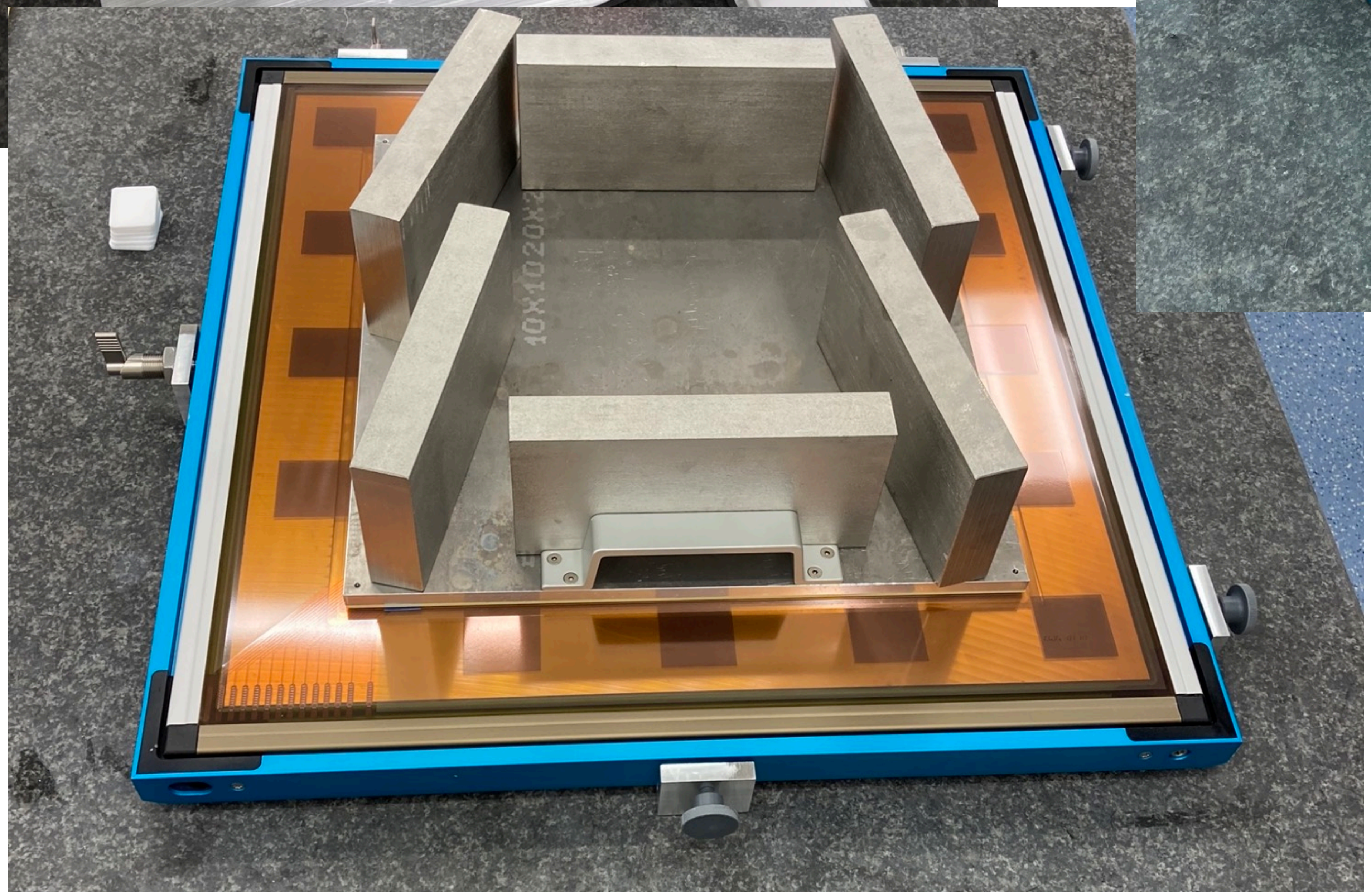
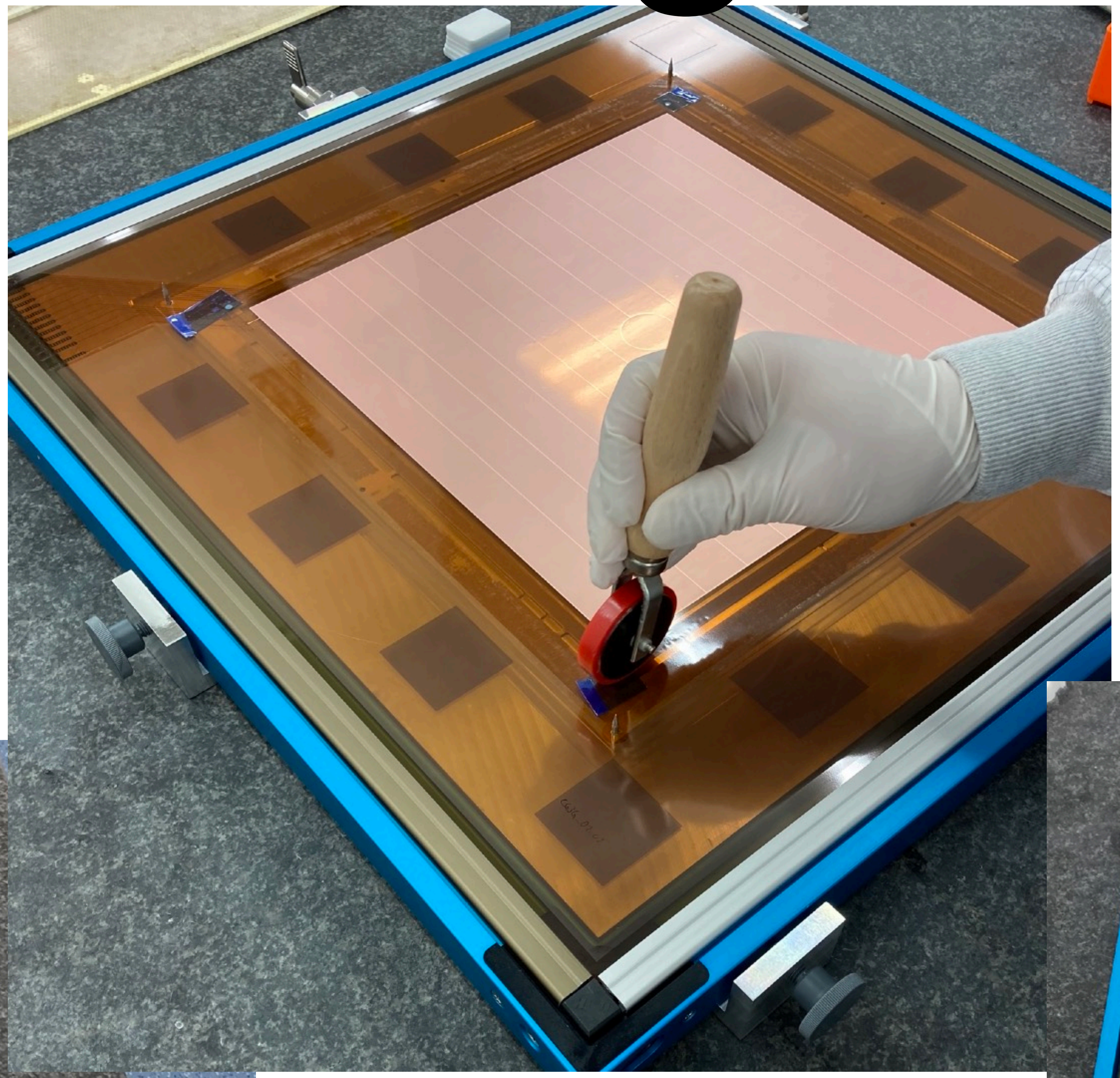
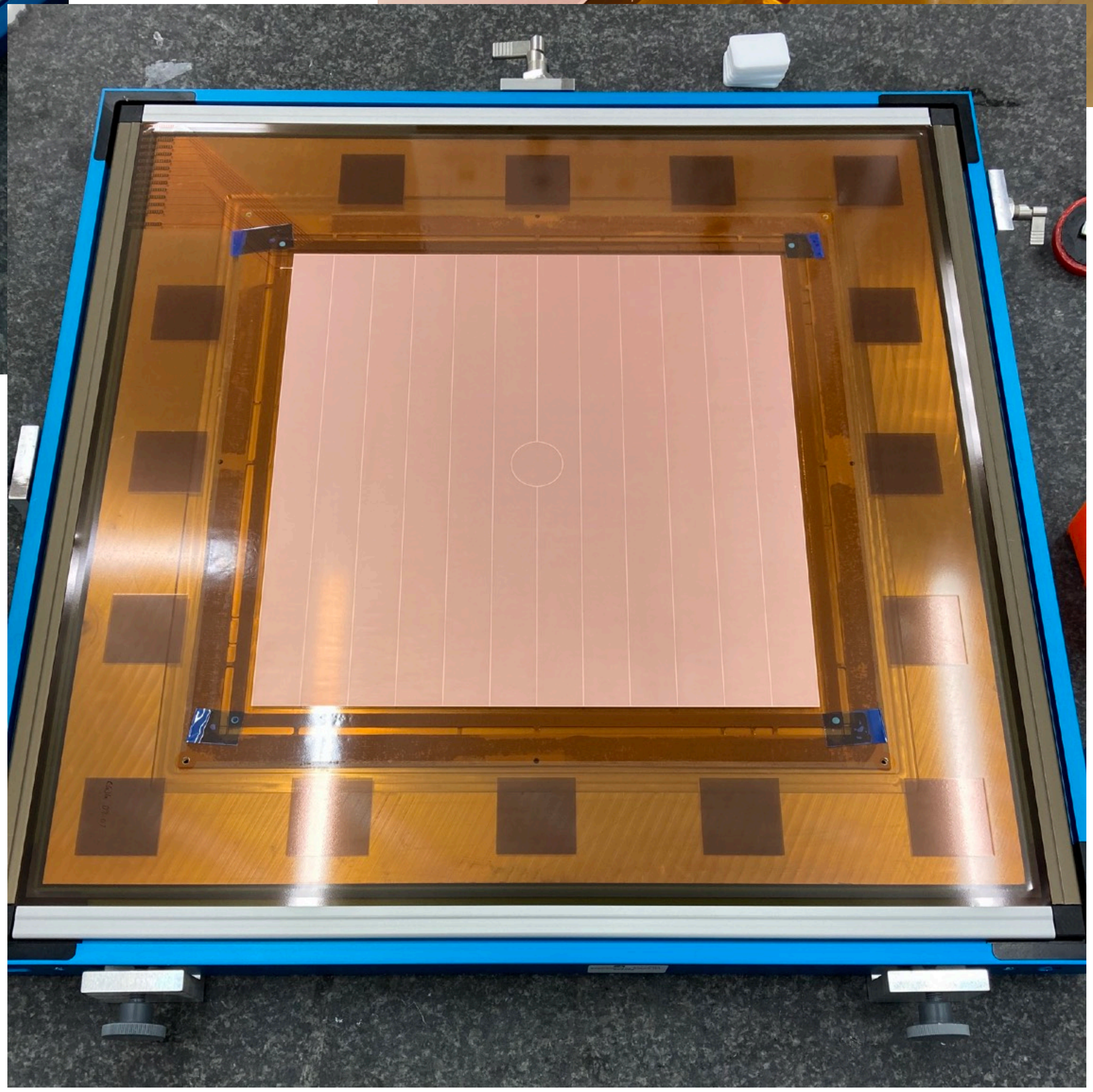


Framing: GEM



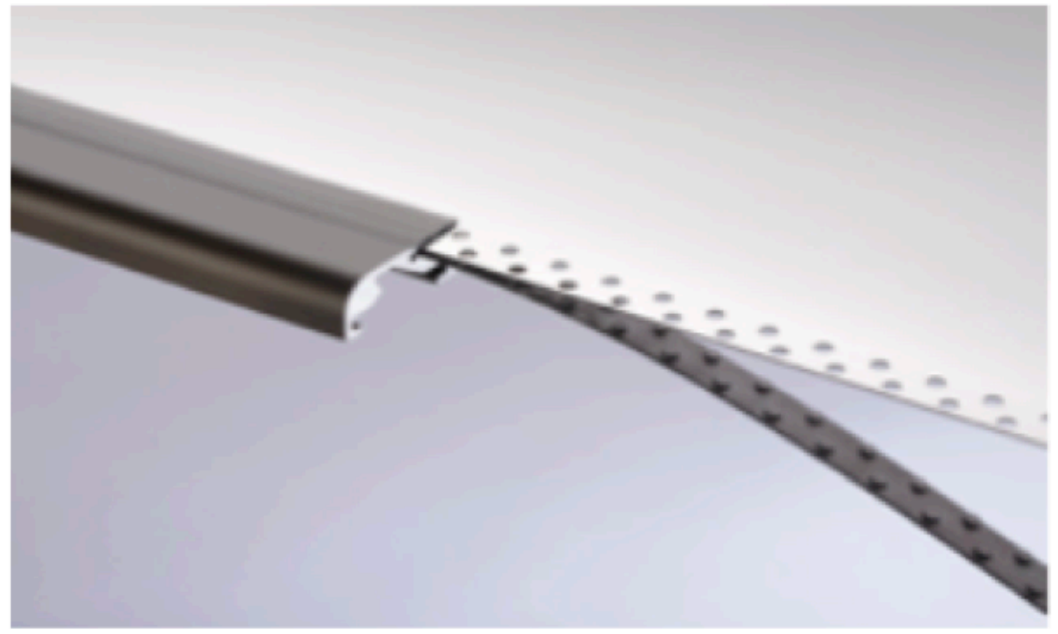




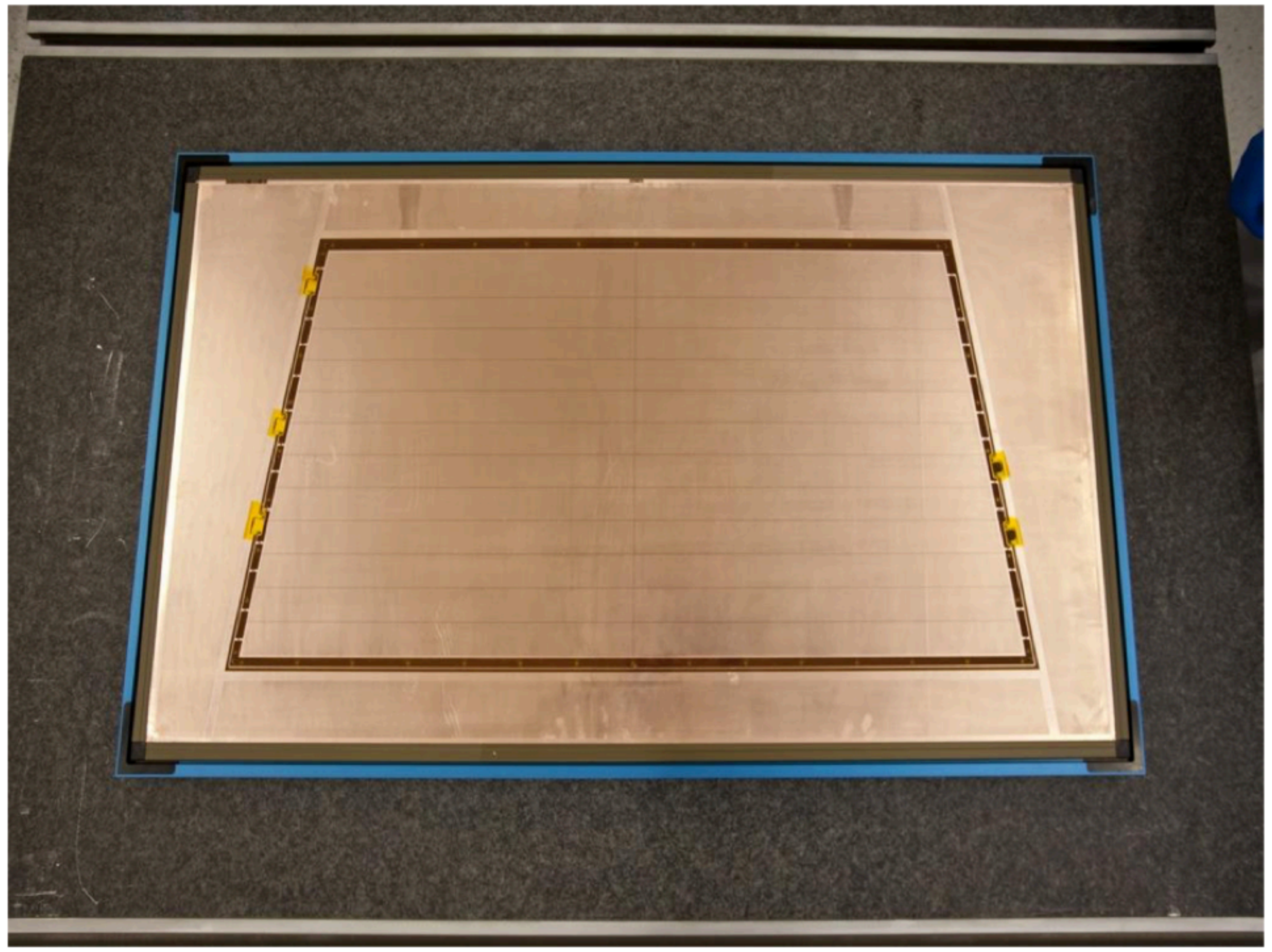


STRETCHING TOOLS

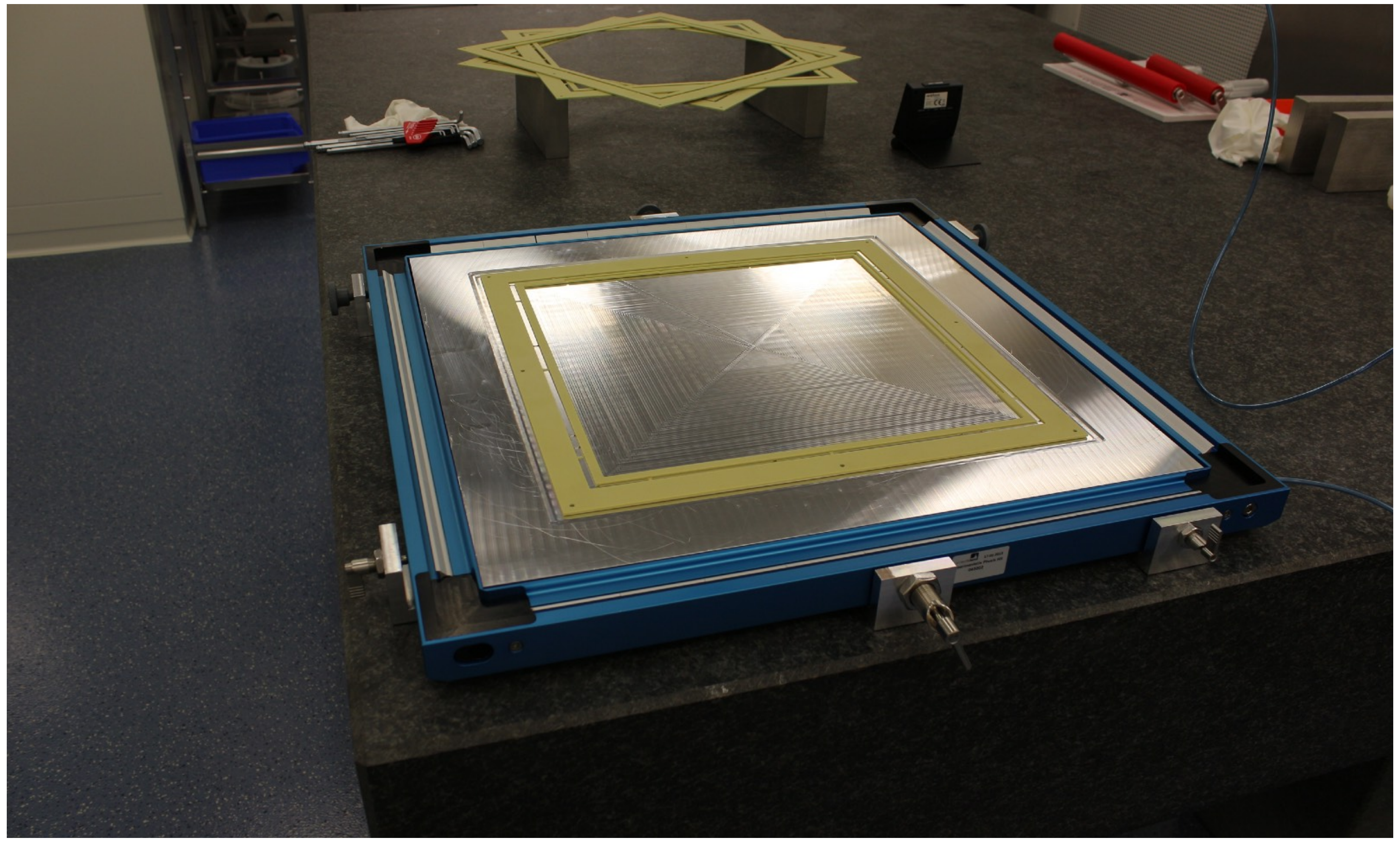
- Foil stretching by pneumatic DEK (Vectorguard®) frame produced by ASM Assembly.
- Foils equipped in aluminium profiles (Optiguard®) – see “*QA of GEM foils*”
- Foil in a profile is installed in the DEK frame
- By applying 0.5 MPa pressure DEK claws open allowing foil to be installed
- Releasing pressure closes DEK claws which stretch GEM
- DEK frame stretching force: **10 N/cm**



Optiguard® profile



Blue DEK frame with a stretched GEM



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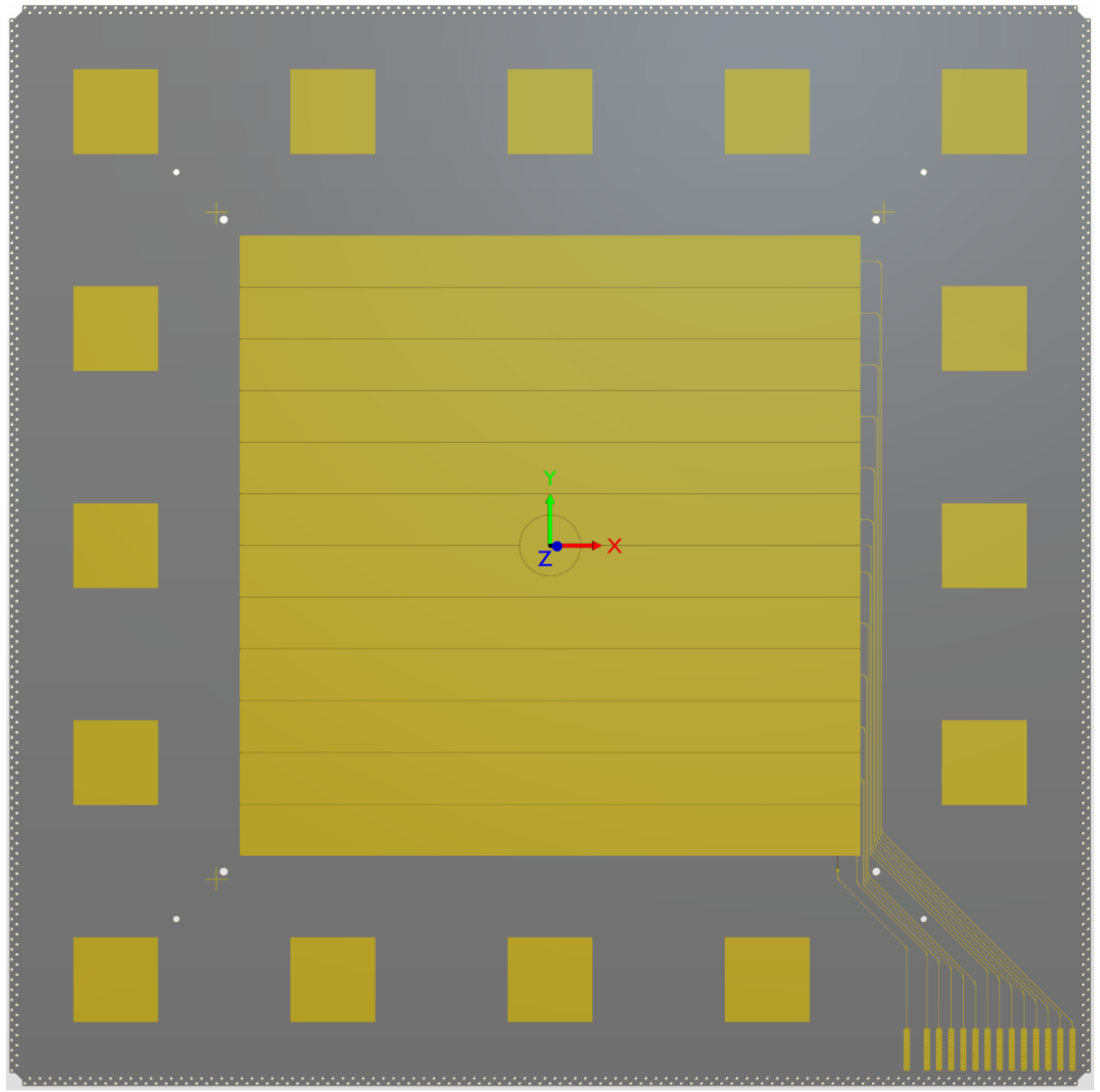

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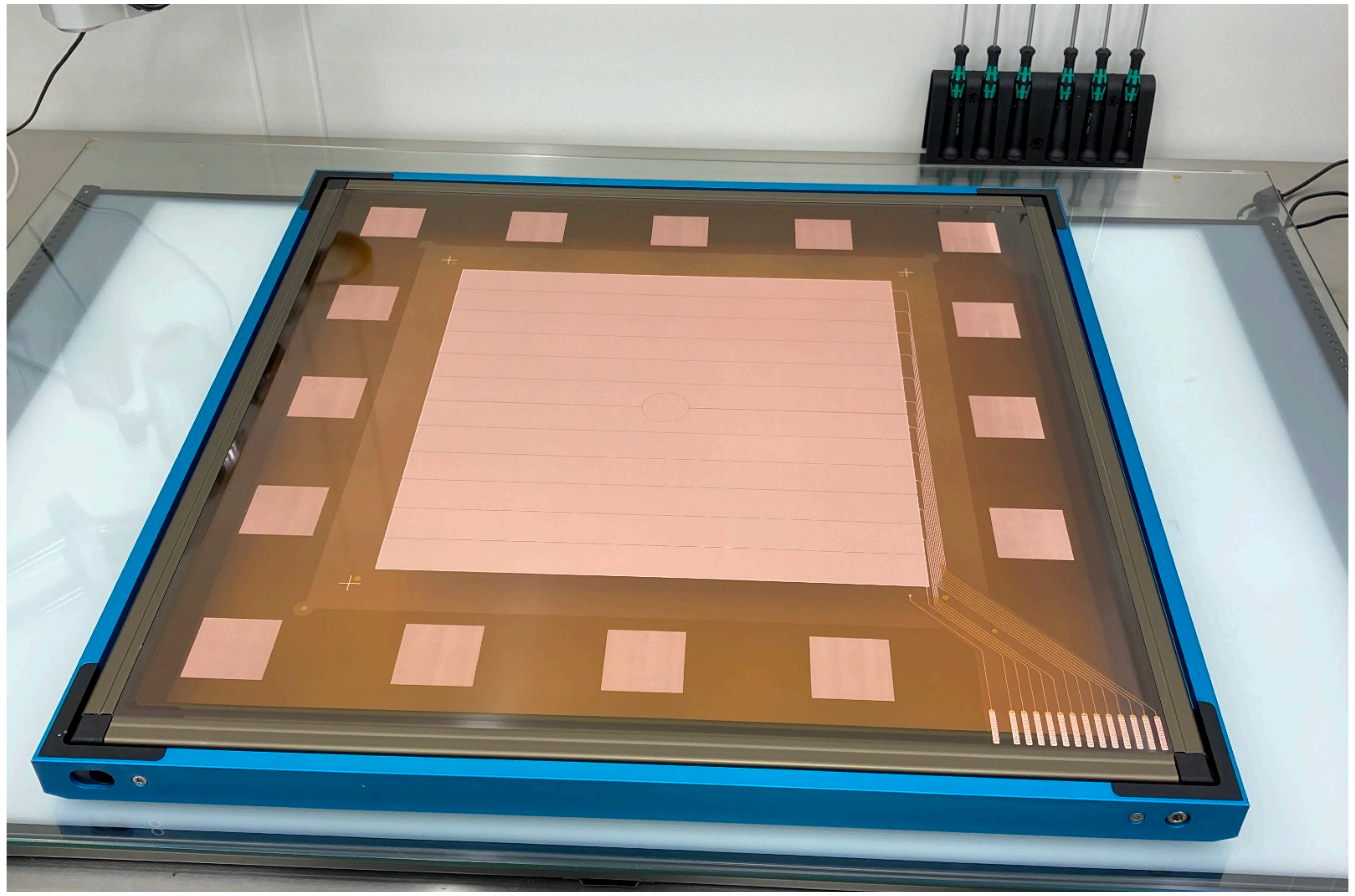
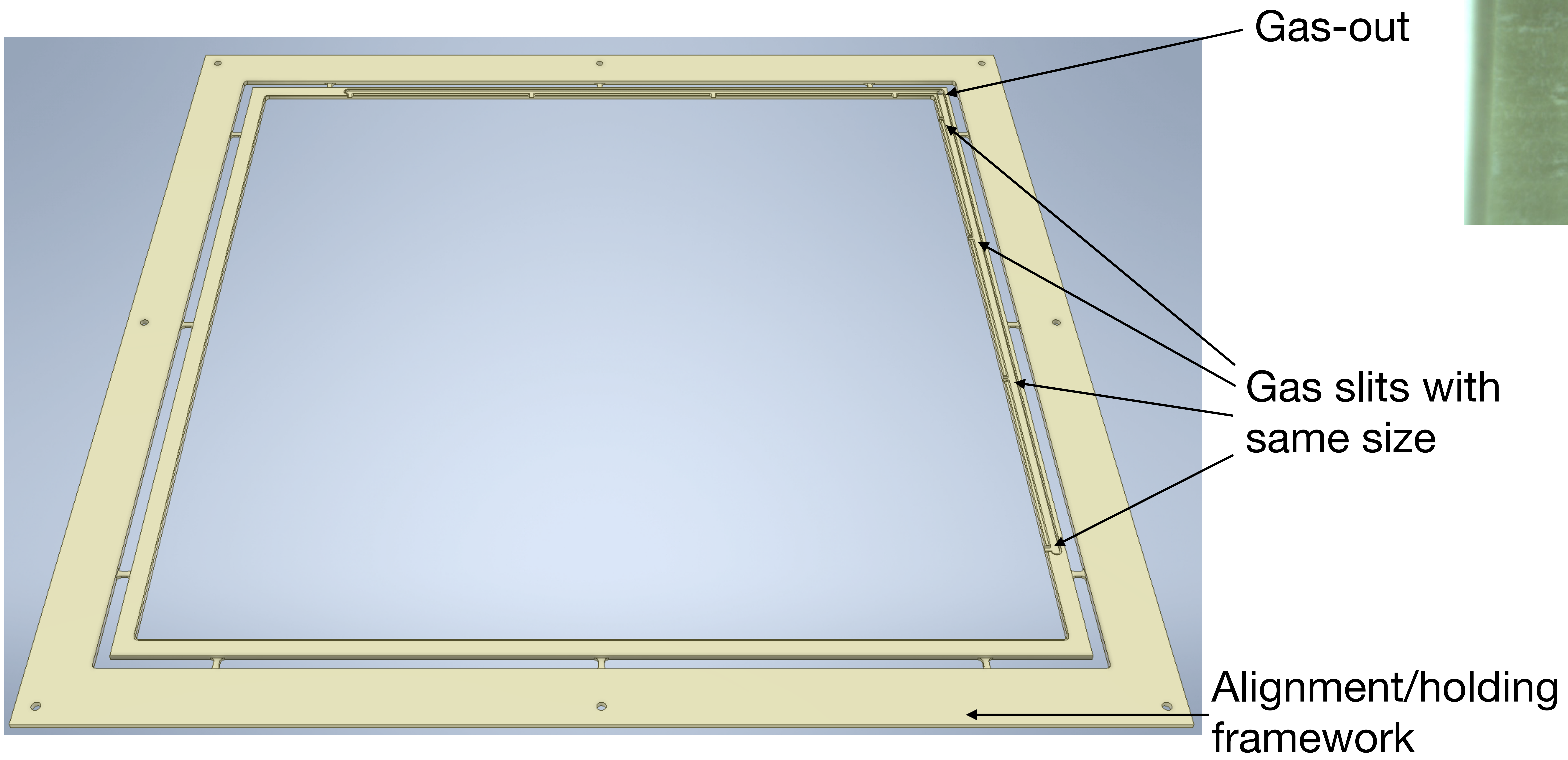
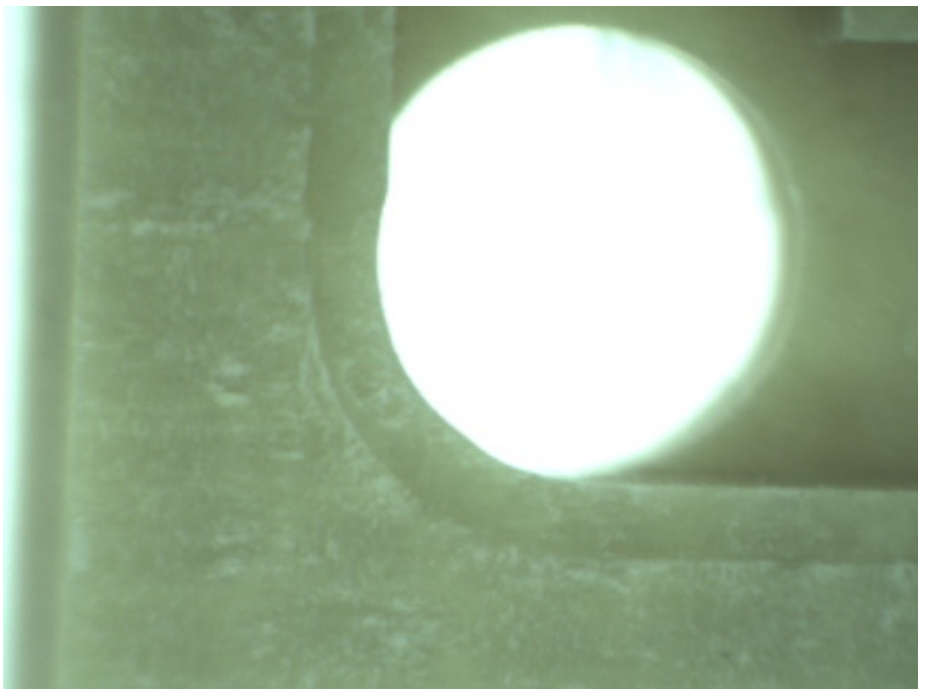
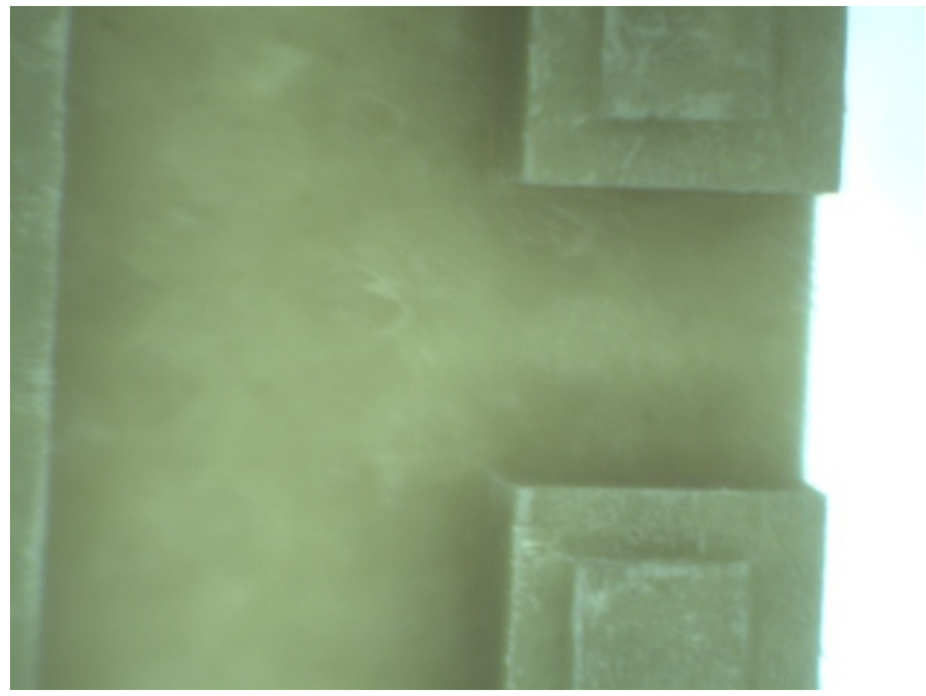
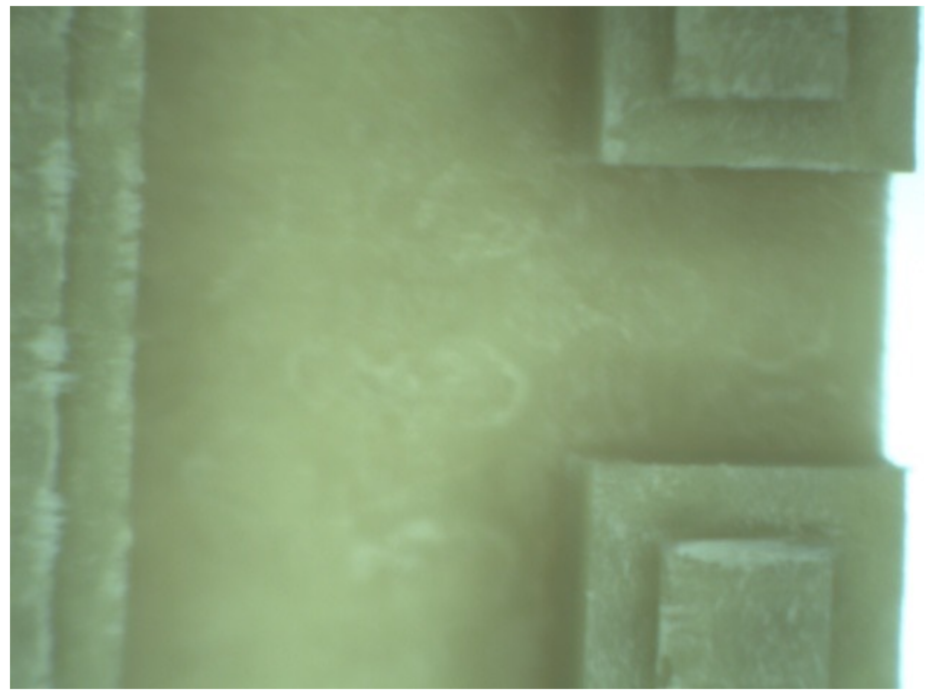


Readout Frame of 2 mm

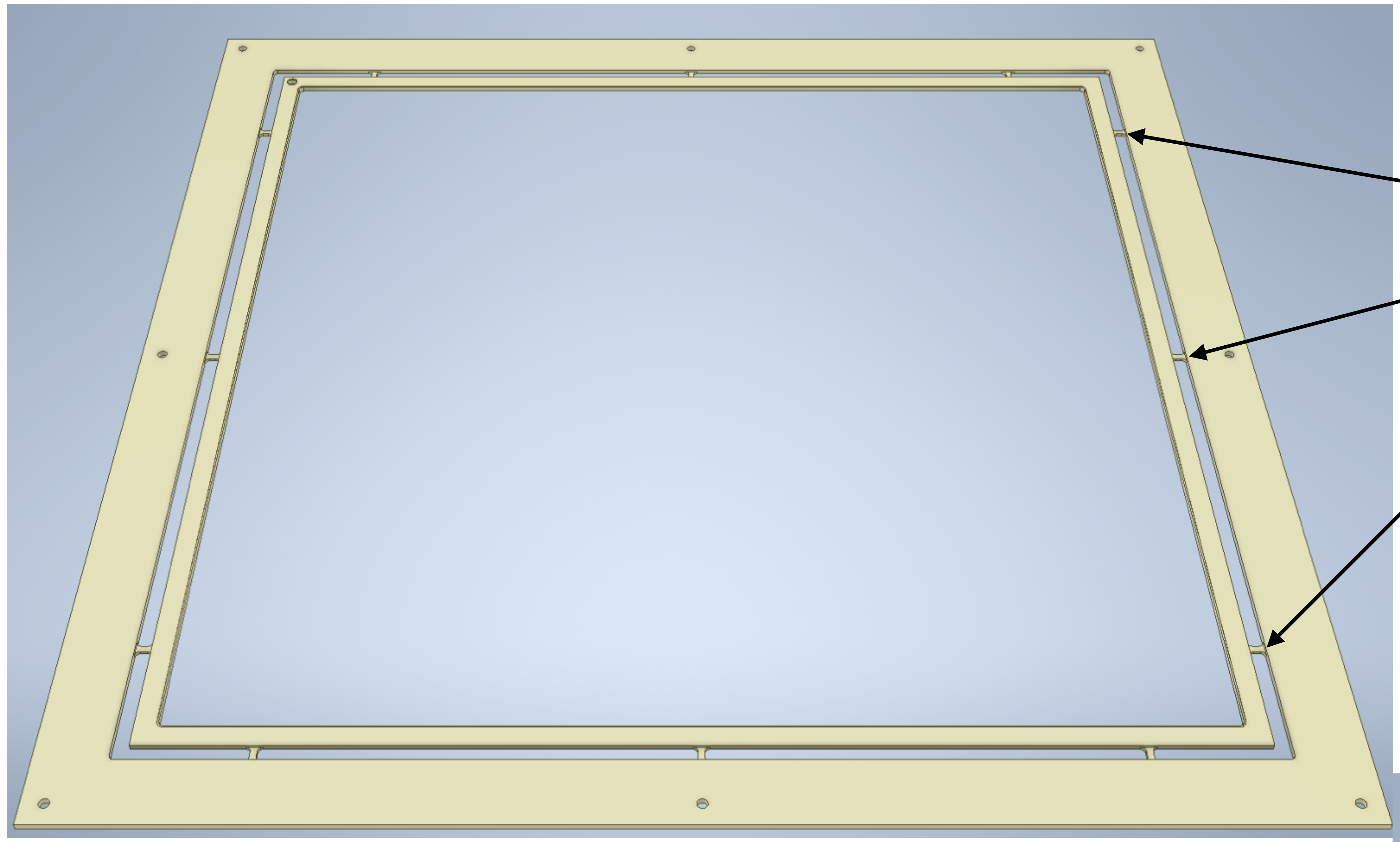


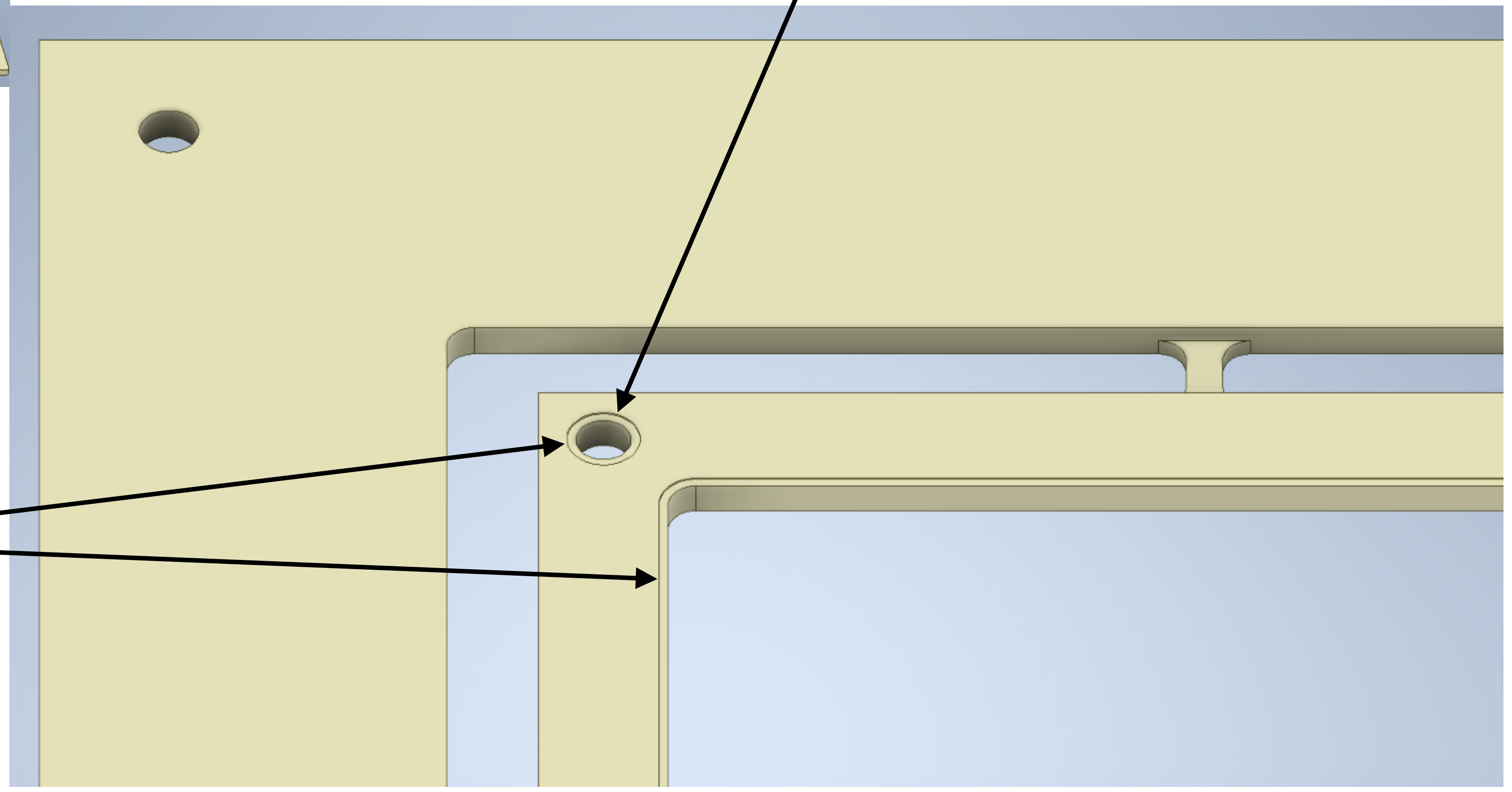






GEM Frame of 2 mm

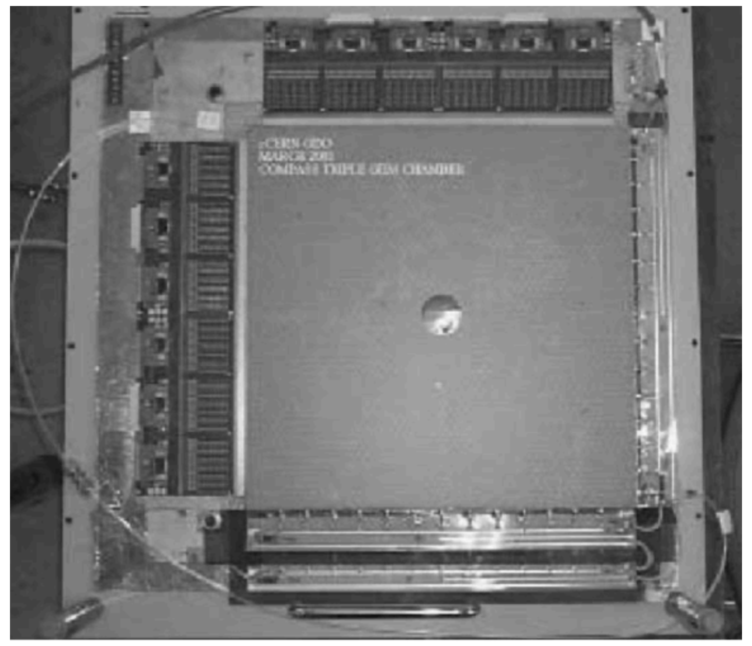




Progression

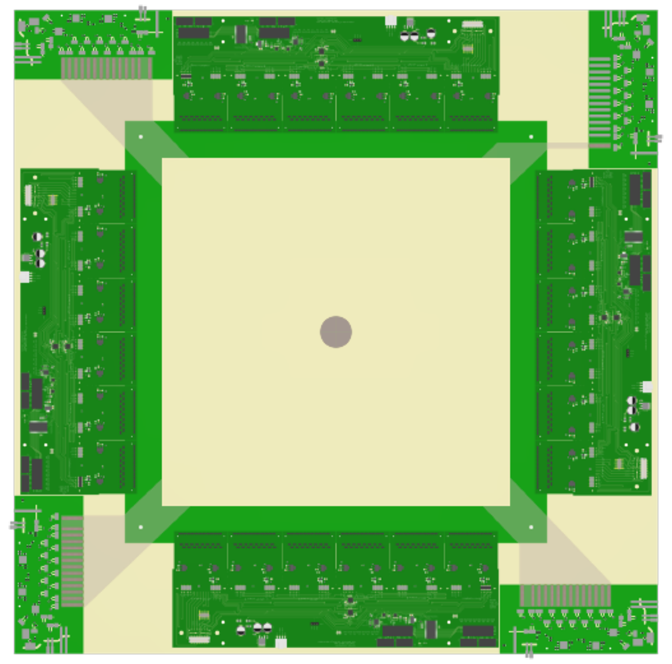
Of CompassGemGenerations

CG1G



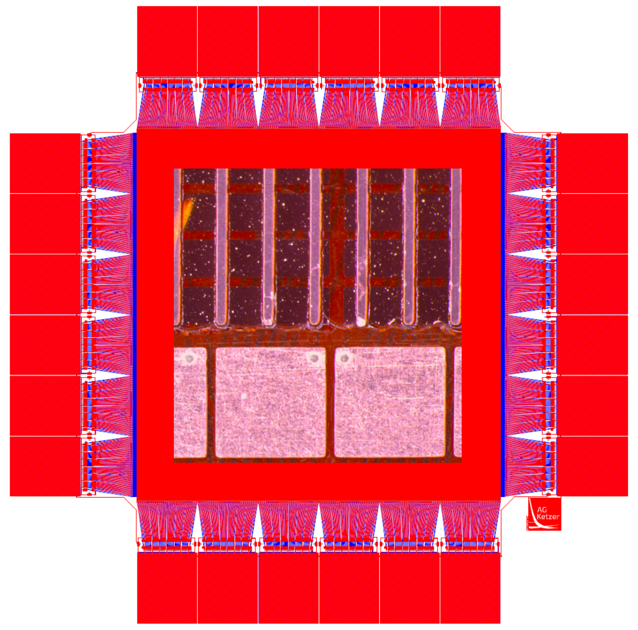
Large-size GEM

CG3G



Updated Large-size

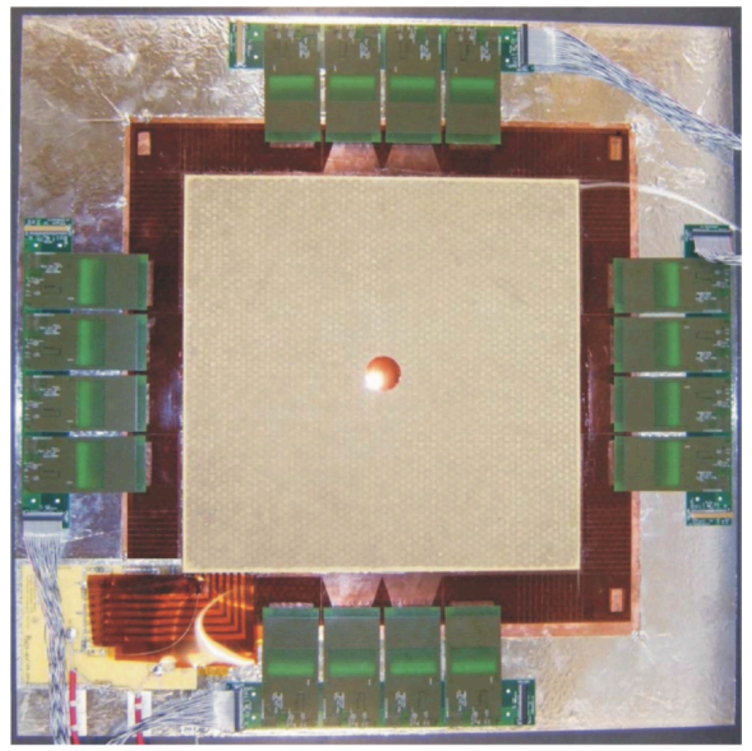
CG5G



Large-size with Pixel

2001 — 2008 — 2021 — 2022 — 2023 - 2024? (not to scale)

CG2G



Pixel GEM

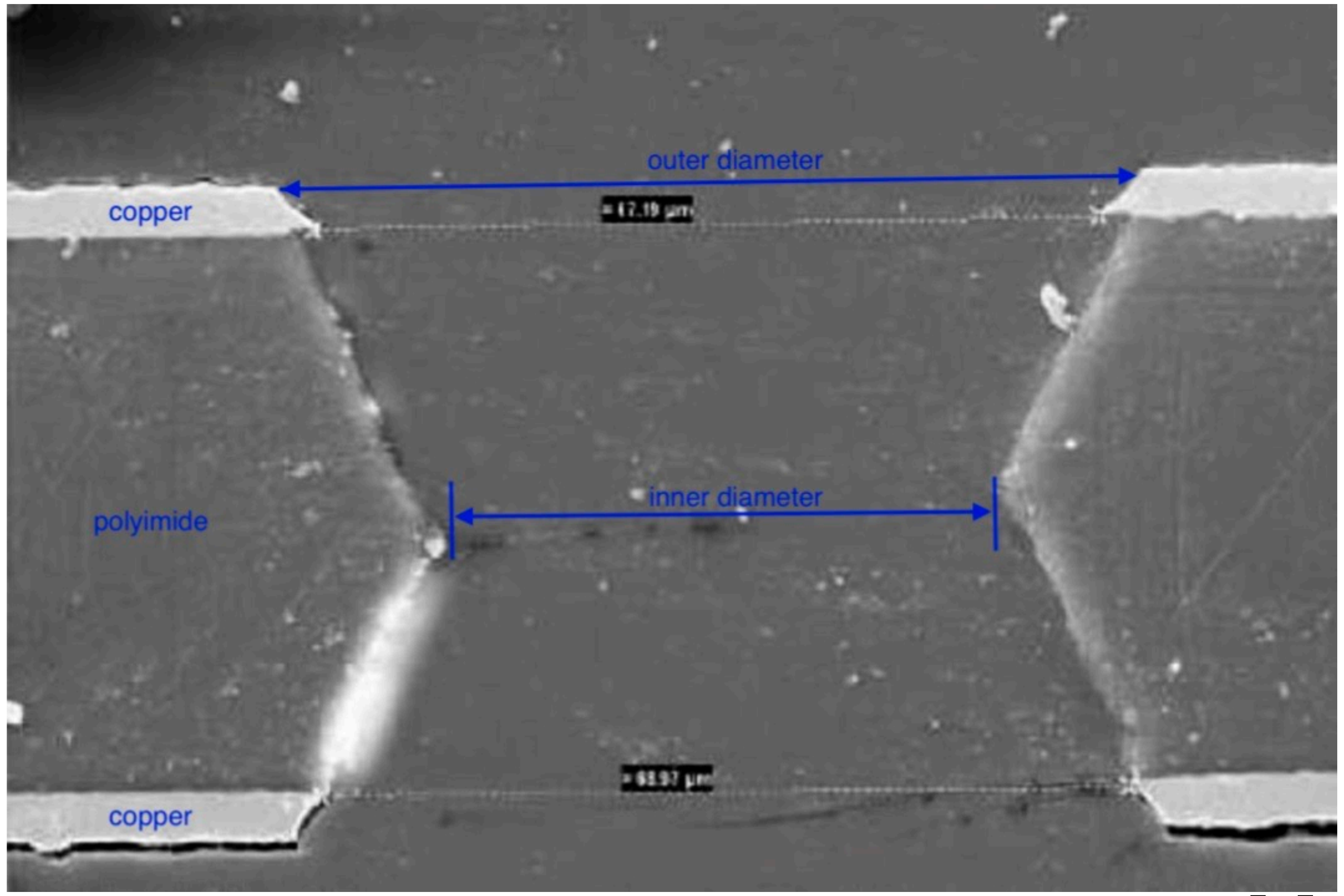
CG4G

Self triggered readout e.g. with VMM

GEM

Gas Electron Multiplier

- Standard parameters
  - Outer diameter: 70 µm
  - Inner diameter: 50 µm
  - 50 µm polyimide
  - 5 µm copper
  - 140 µm pitch

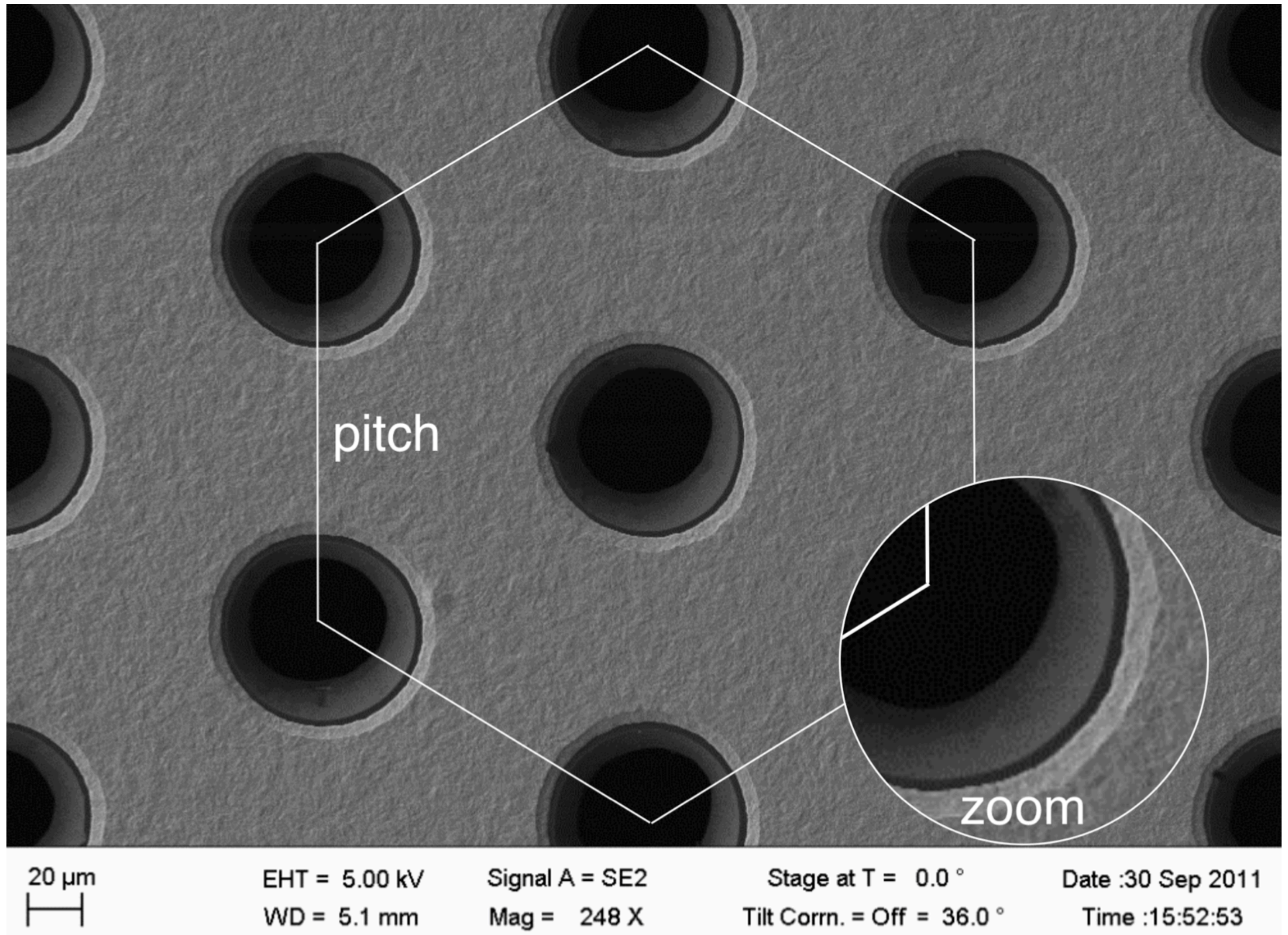


[6]

GEM

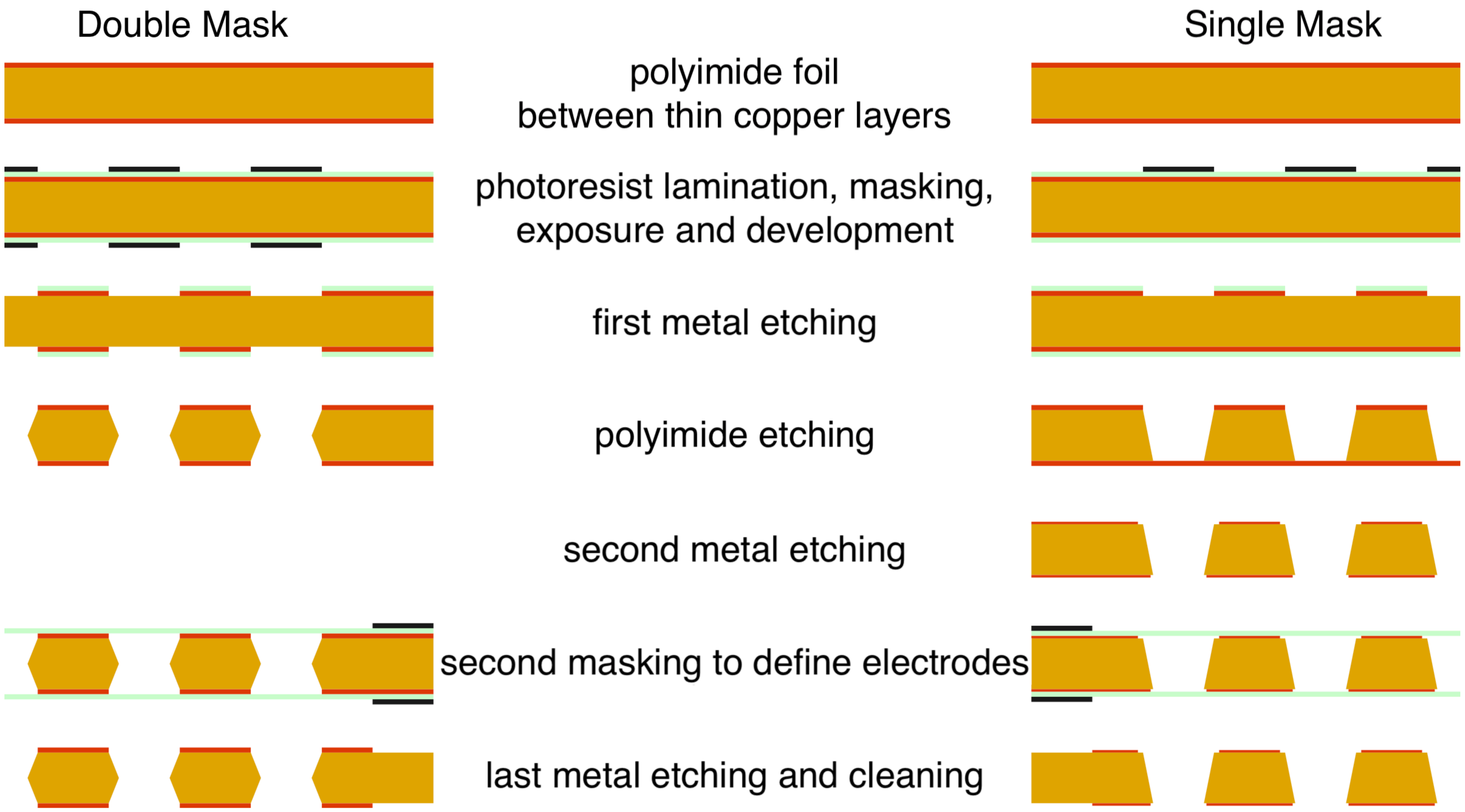
Gas Electron Multiplier

- Standard parameters
  - Outer diameter: 70 µm
  - Inner diameter: 50 µm
  - 50 µm polyimide
  - 5 µm copper
  - 140 µm pitch



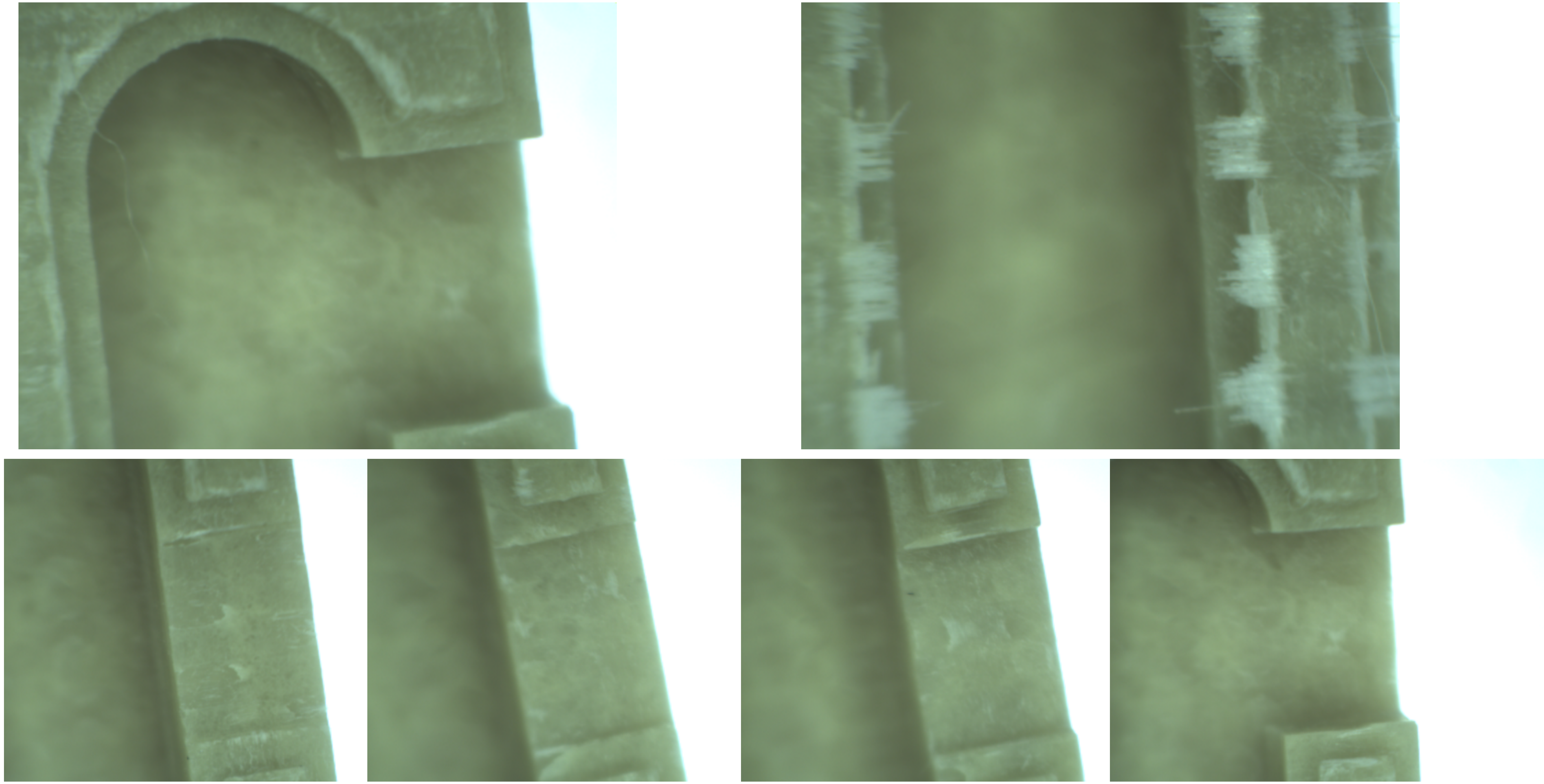
[3]

GEM Manufacturing



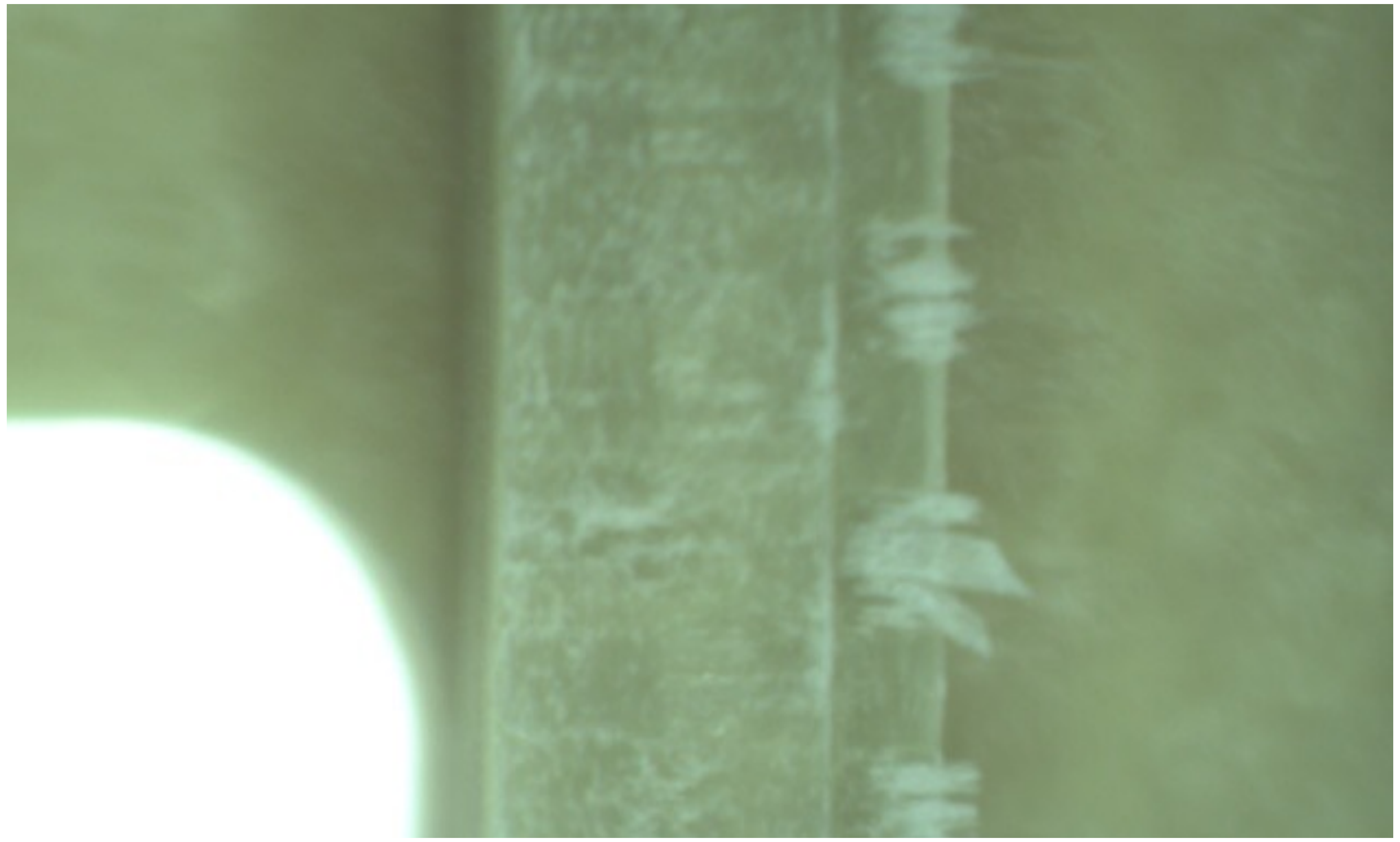
First Evaluation of Frames

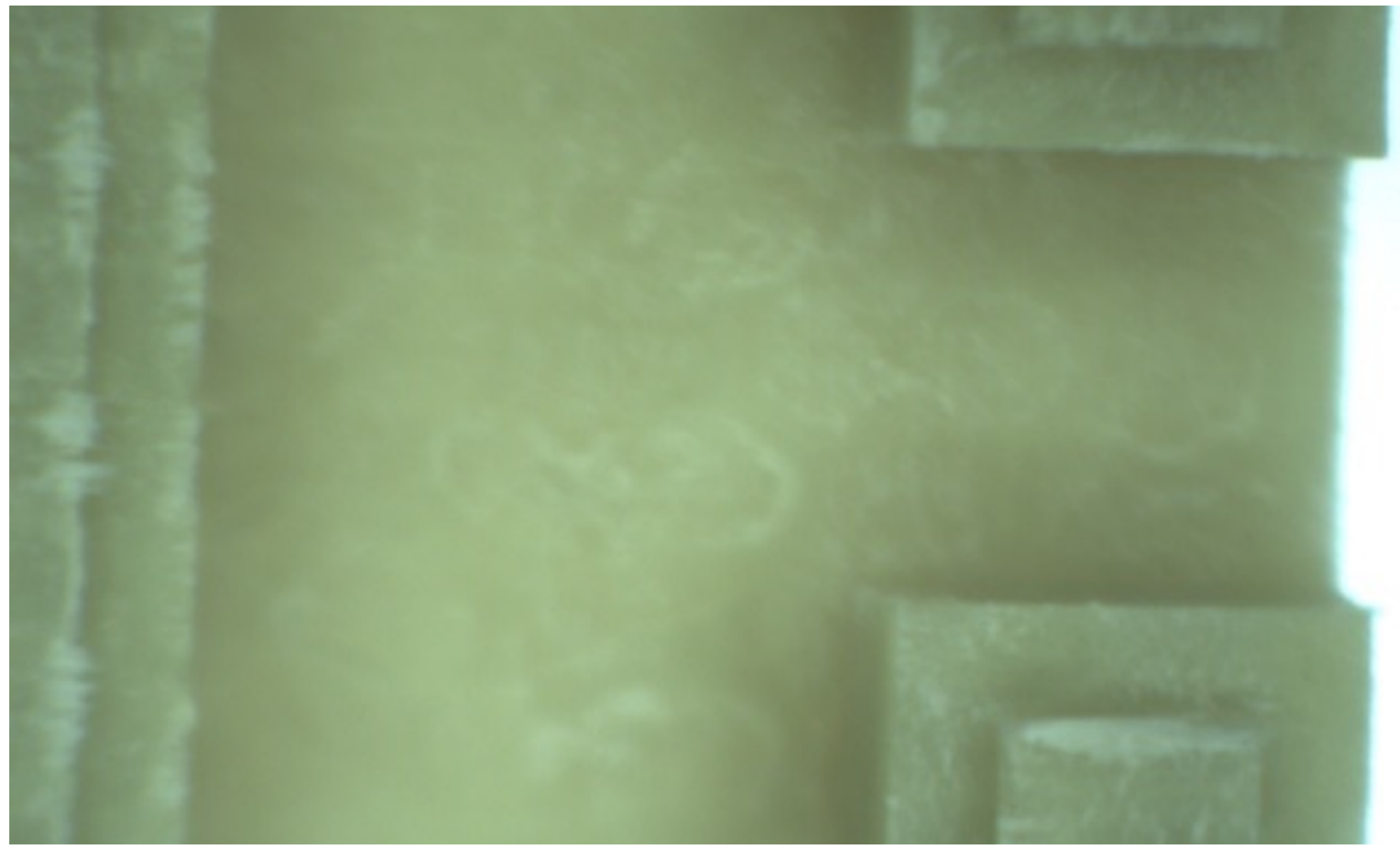
Drift Frame 01

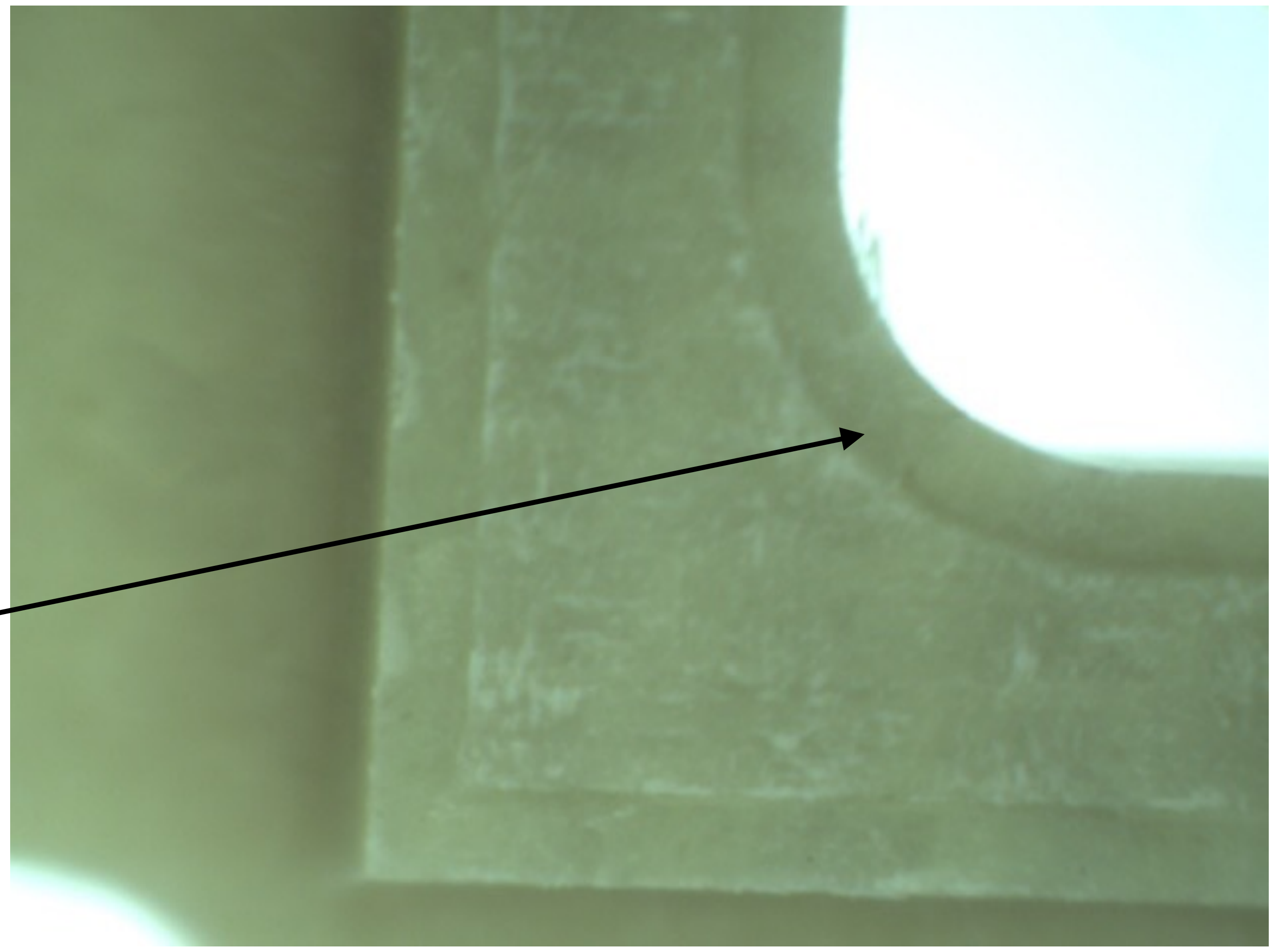


First Evaluation of Frames

Readout Frame 01

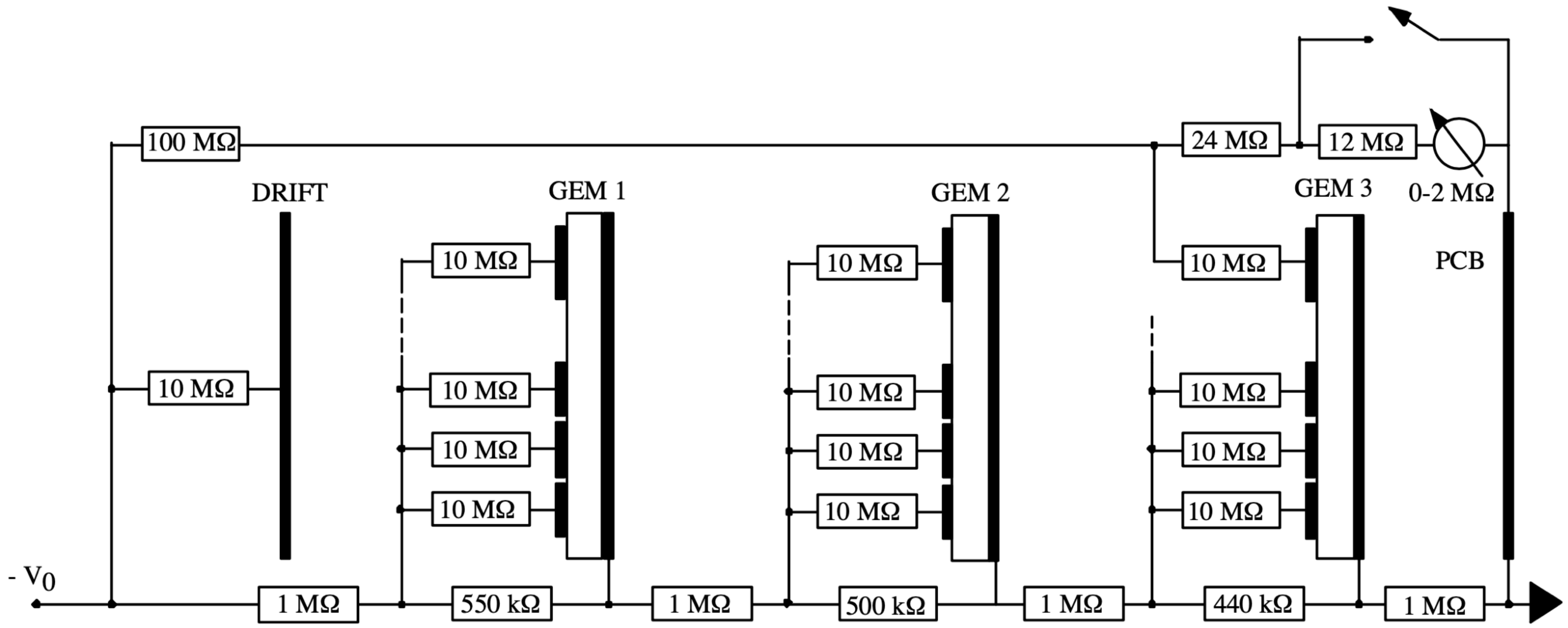






HV Board(s)

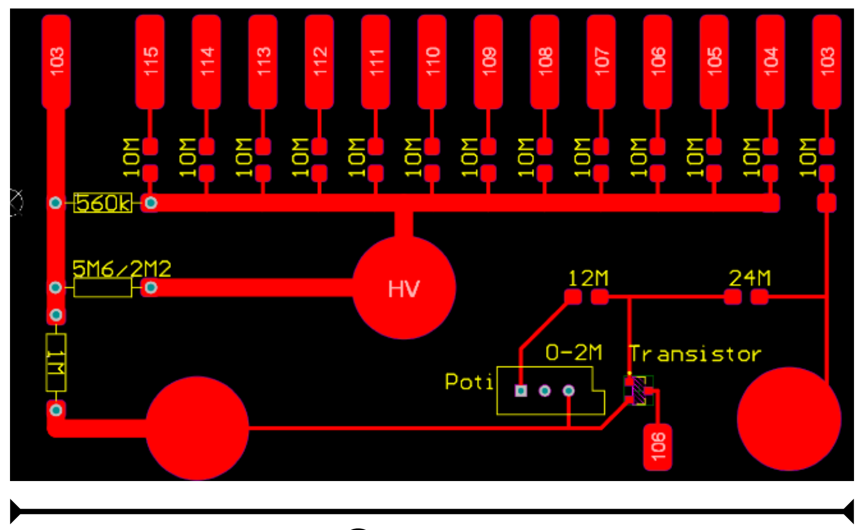
- Resistor chain for high voltage distribution
  - Remote-controlled switch to activate/de-activate central area (For CG1G with a separate relay near the detector)

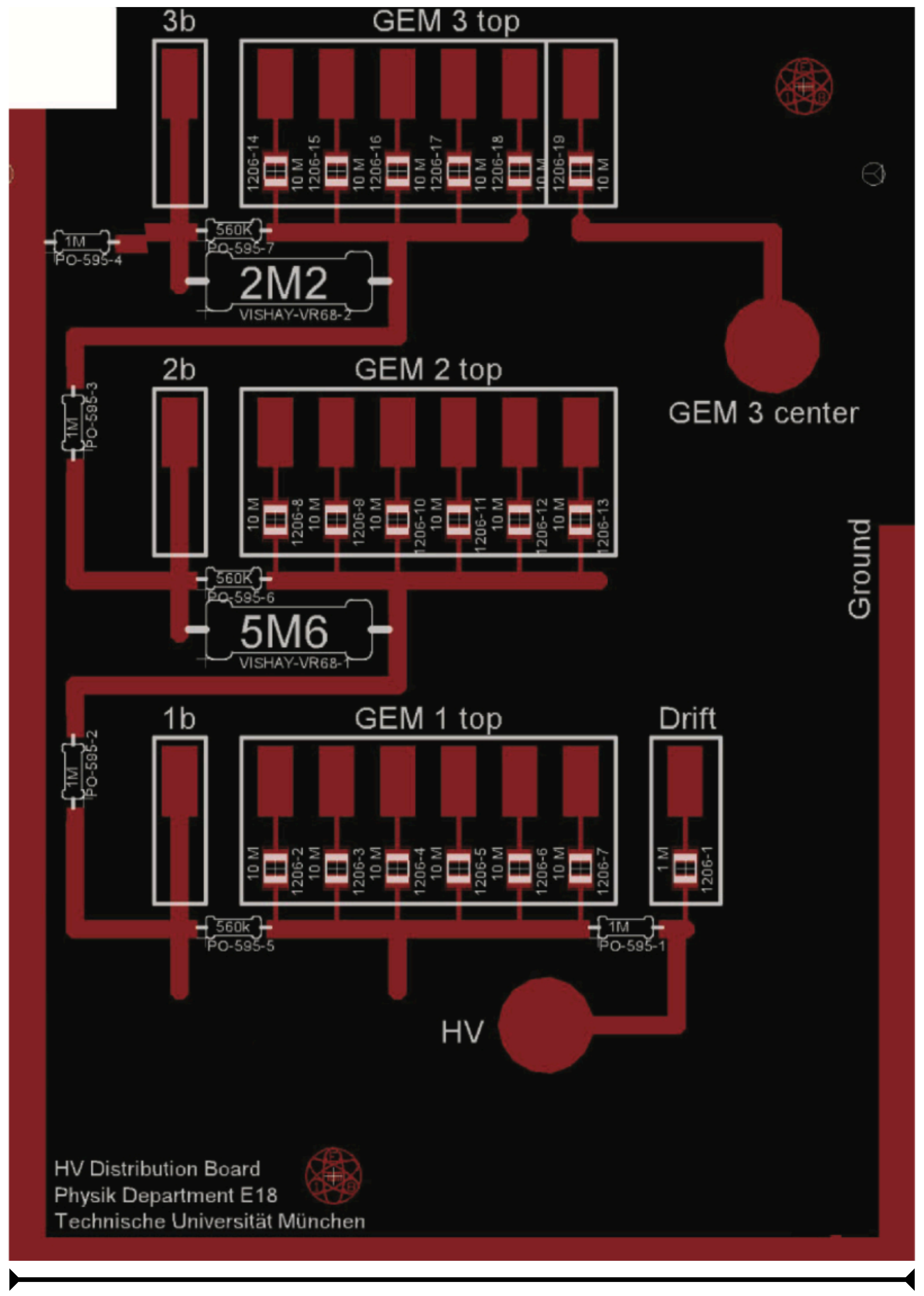


C. Altunbas et al., NIM A490, 188 (2002)

HV Board(s)

- One PCB for each foil (logic distributed over four identical boards)
- Stabilized Voltage Divider as second Step Project (idea by H. Müller, RD51)
- Switching of center voltage via I²C





B. Ketzer et al., IEEE NSS 2007, N12-5 (2007)

Further Potential

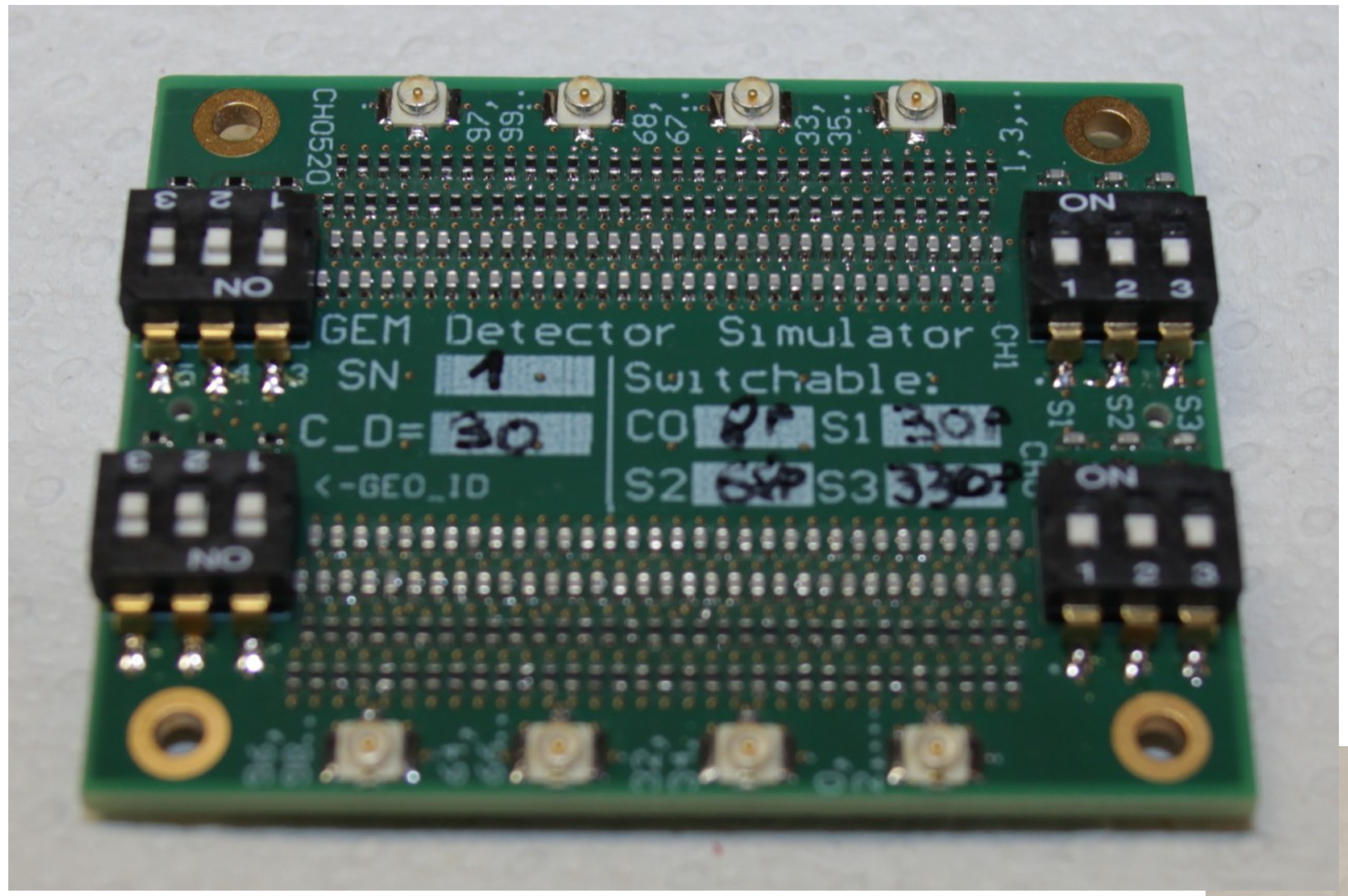
- Large areas covered
  (~ m2, in order to replace MWPC)
- Beam tracking for high-rate > 100MHz / cm2
- Hybrid readout optimized for fixed target geometry
- Radiation hard (small to no aging observed)
- Miniscule material budget in full active area with $< 1\%\ X_0$

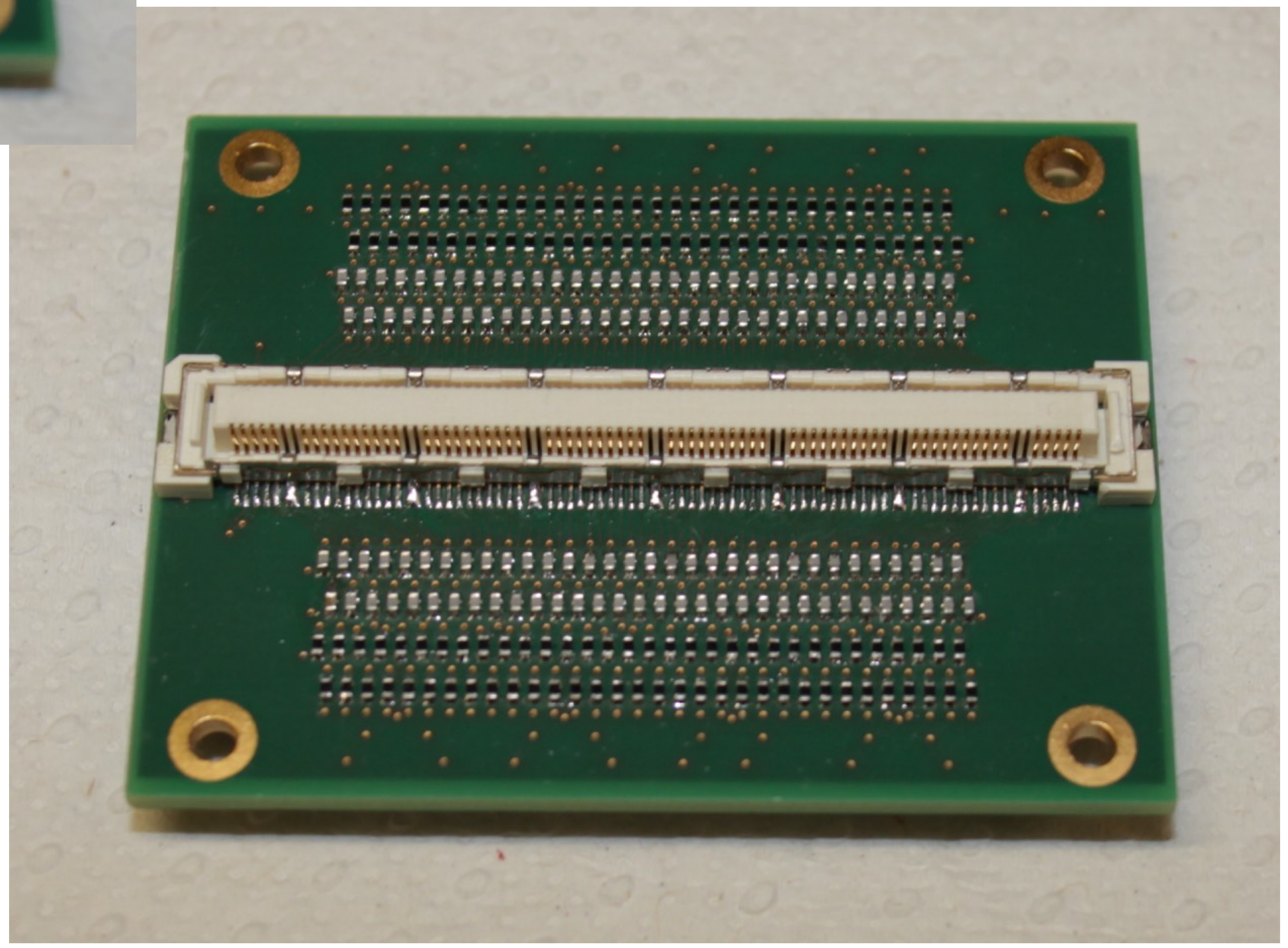
„Flying GEM“

Detector Simulator

Christian Honisch (honisch@hiskp.uni-bonn.de)

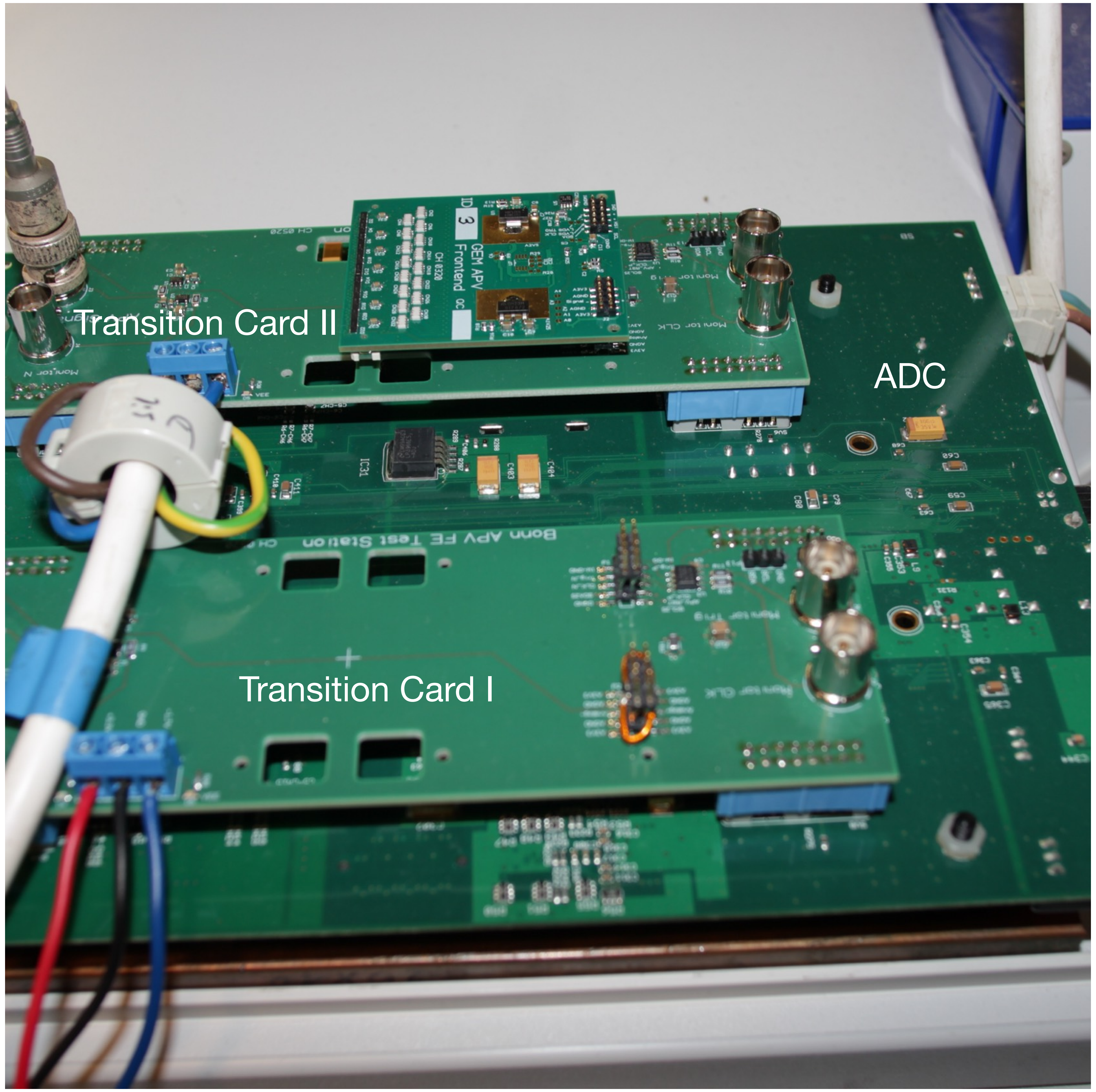
- Simulates detector capacity
- I^2C addresses switchable
- Capacity changeable for first two channels
- Can be used to inject test pulses



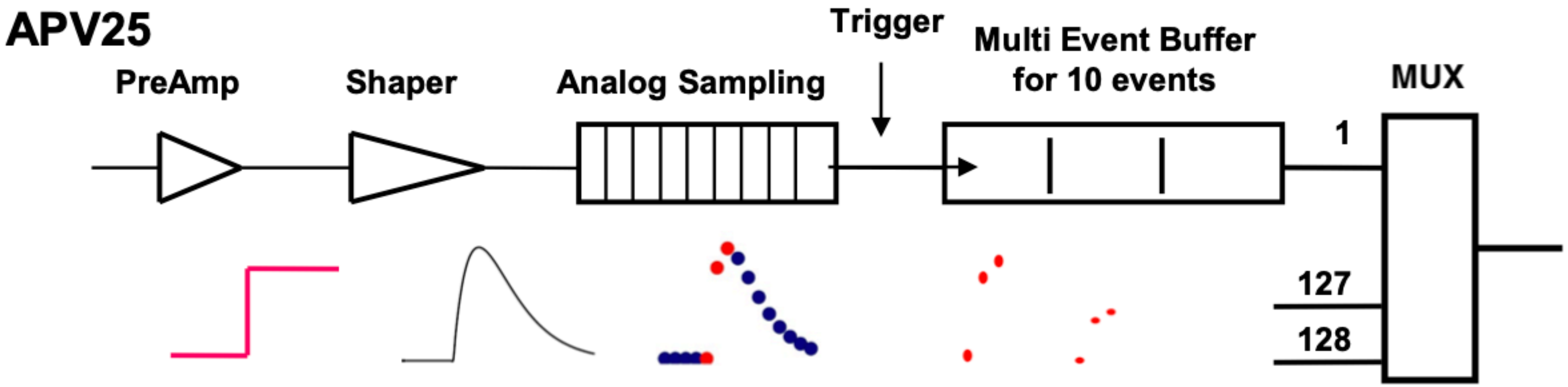


APV Test Station

- Space for two FE
- Four monitoring ports
  - Analogue positive/negative
  - Trigger
  - Clock



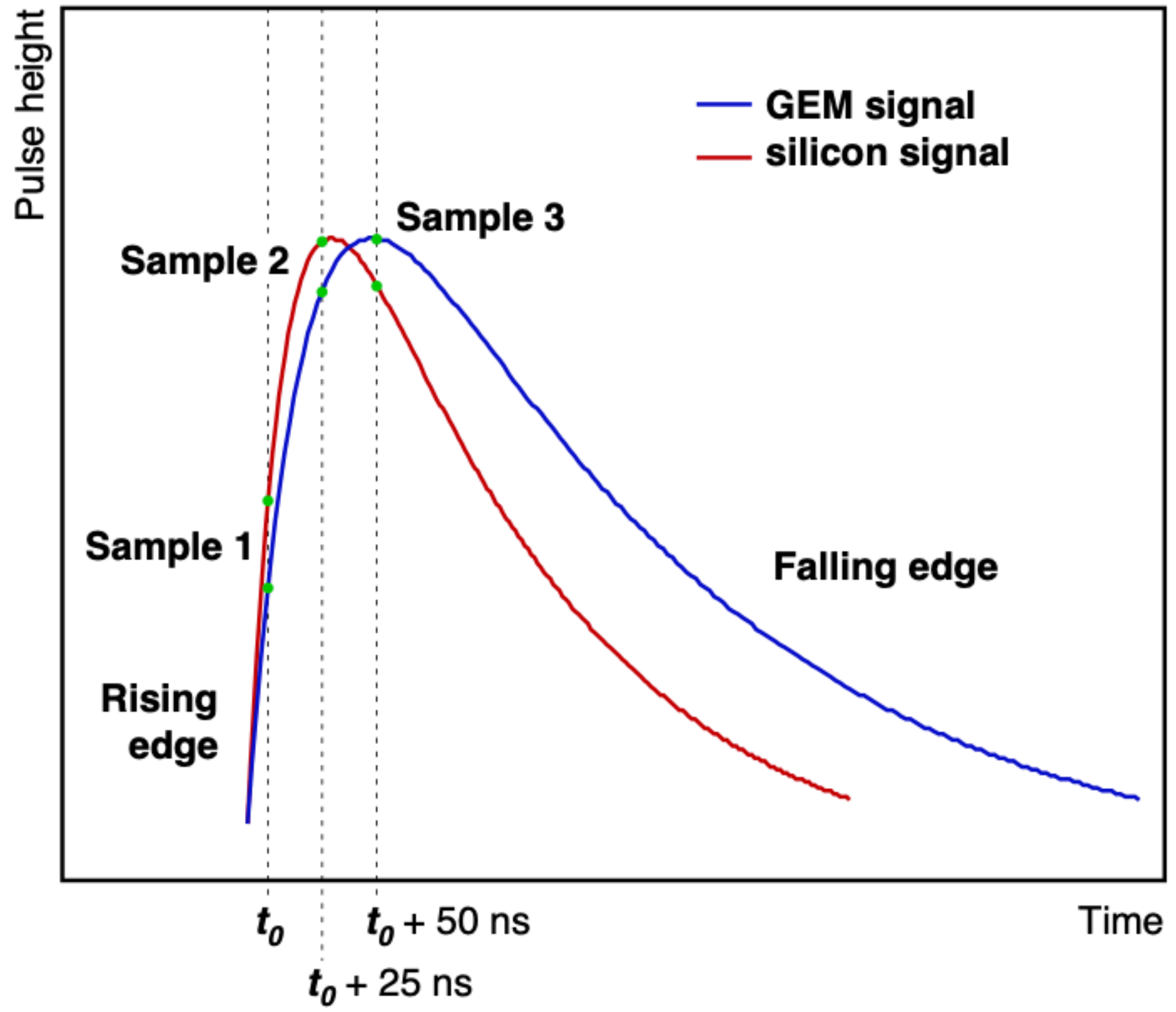
APV Signal Processing



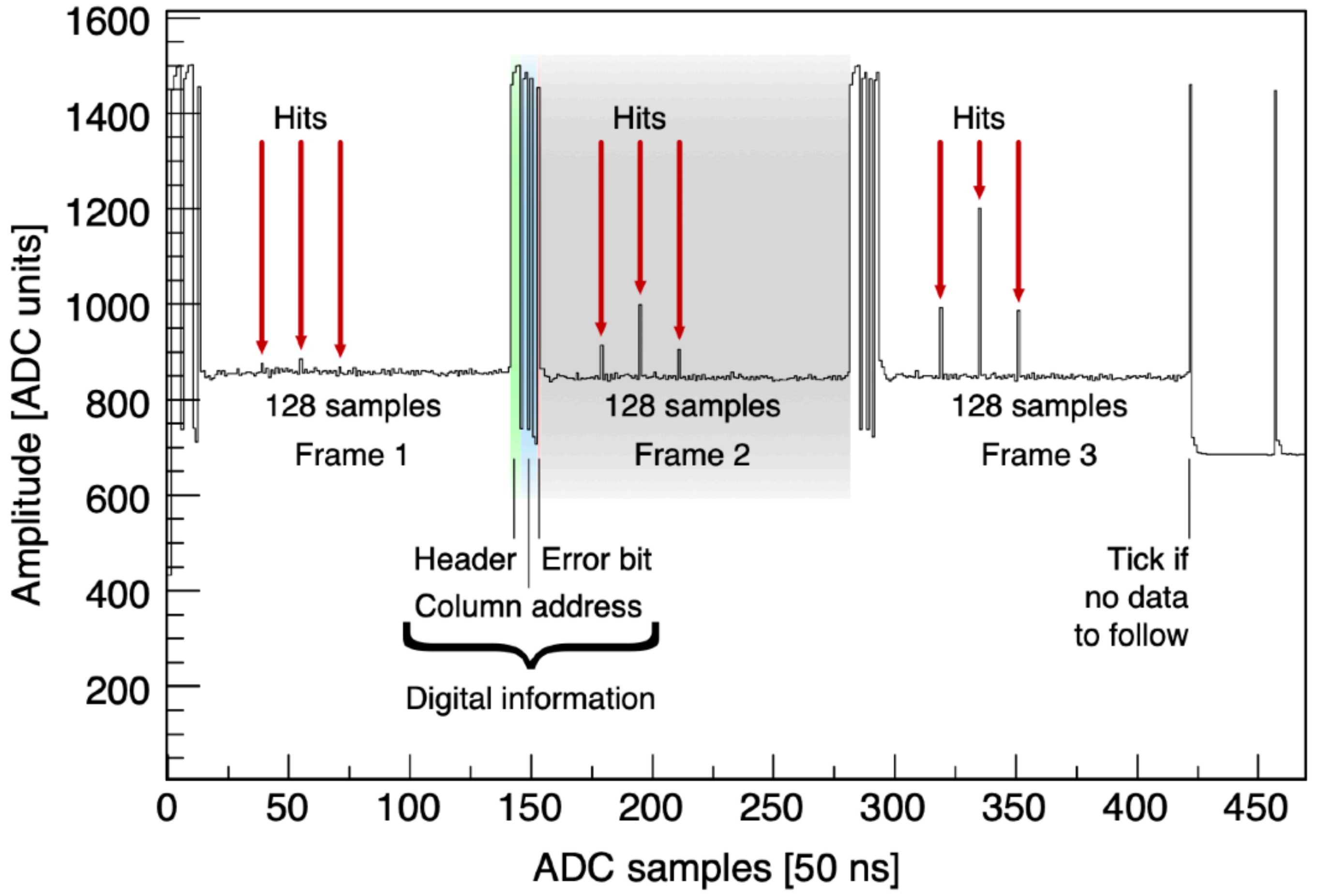
[3]

Pulse Shape Reconstruction

- Prove the functionality of new FE
- Three sample mode used
  - Each with 25 ns delay
- Latency scan performed
  - Systematic shift of t_0
- Latency defines at which point the pipeline should be analysed

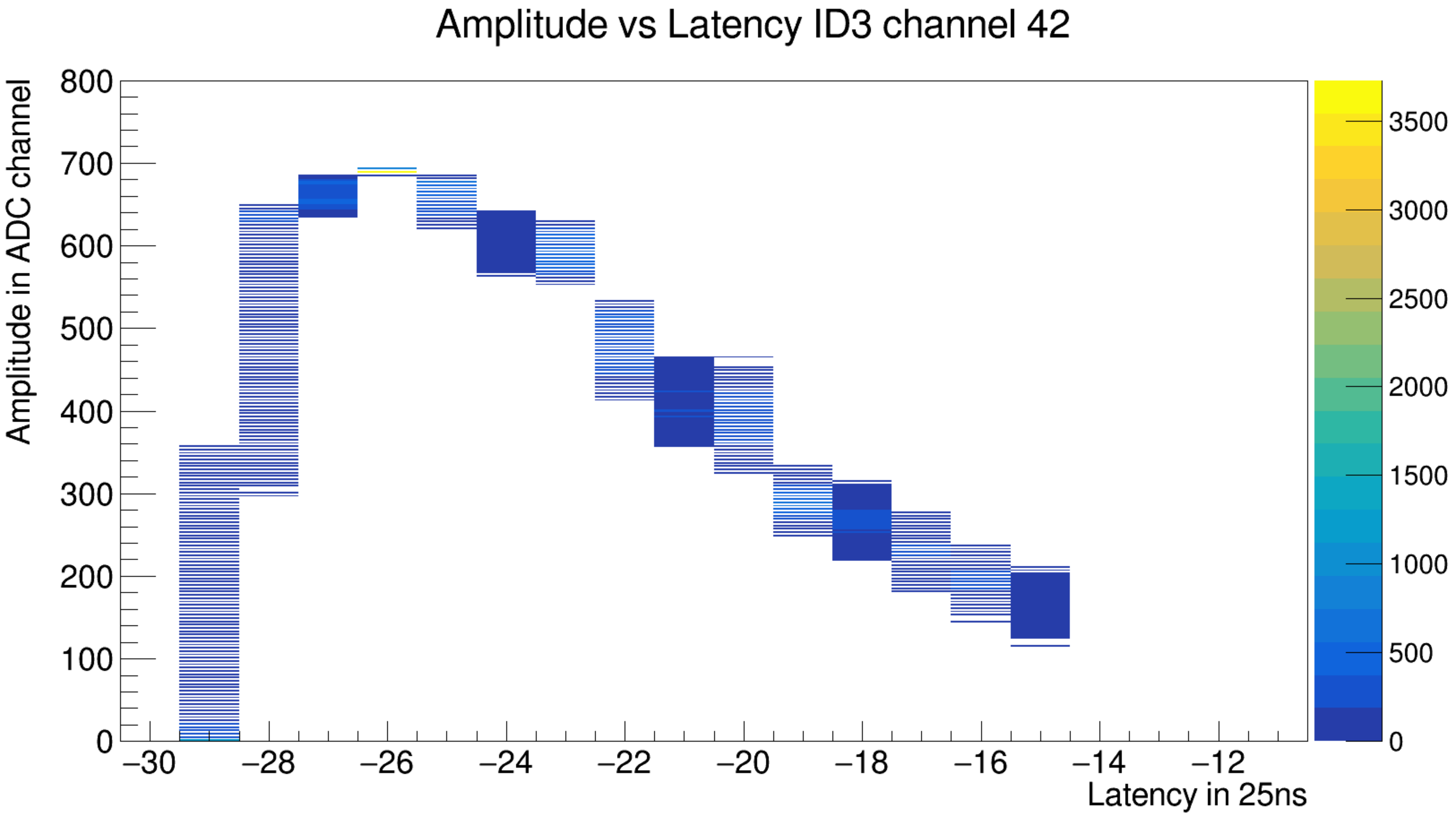


[11]



[11]

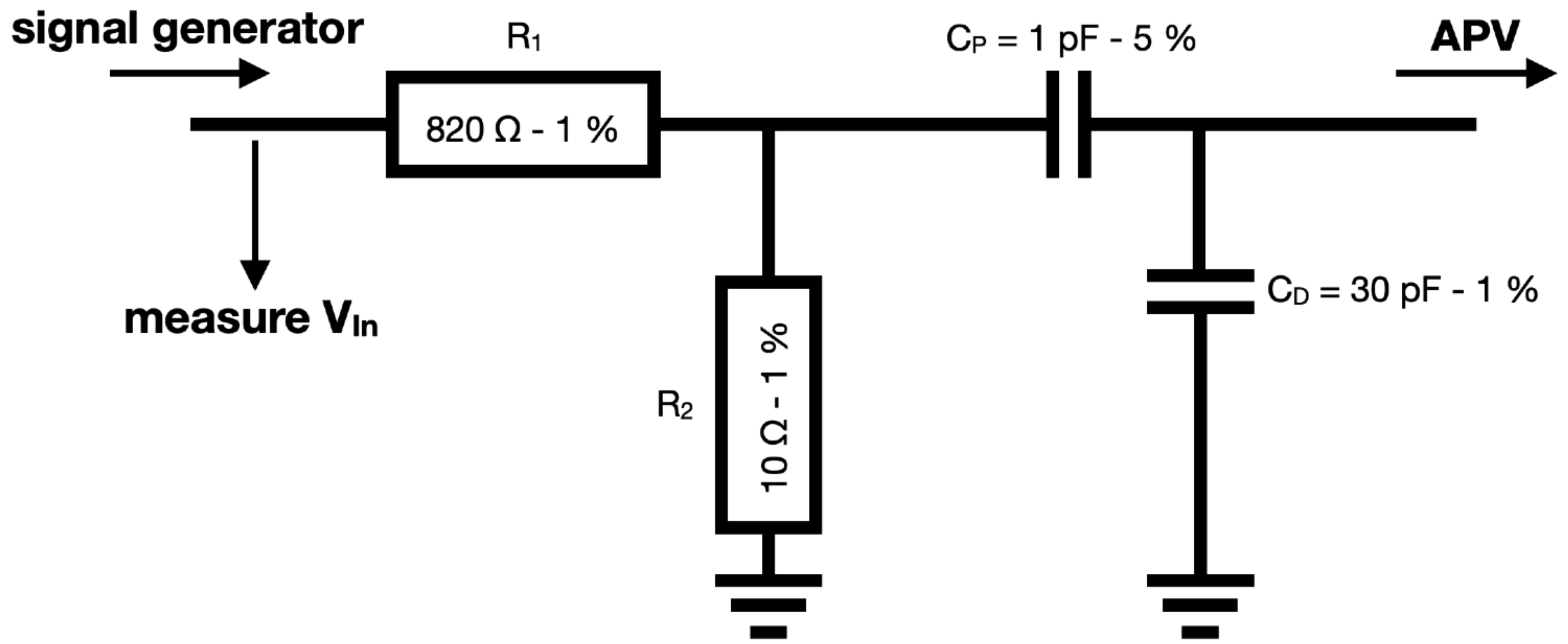
Pulse Shape Reconstruction



ENC Observation

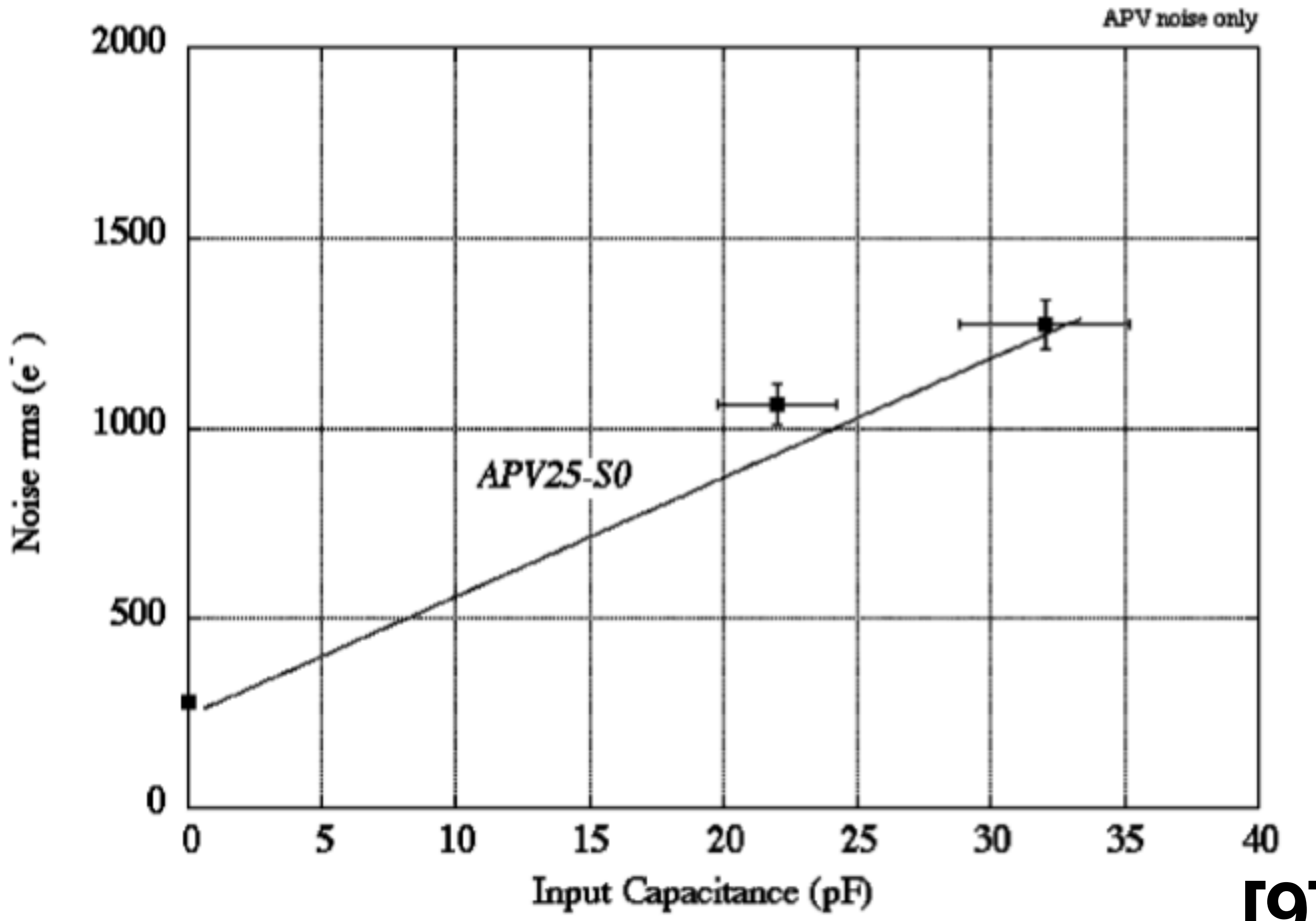
$$ENC = Q_{\text{Signal}} \frac{Noise}{Signal}$$

- Should give an estimate if the line driver improves the performance
- Realistic test pulse used
  - Corresponds to a MIP
  - 240.000 signal electrons
    - V_{In} set to 3.2 V

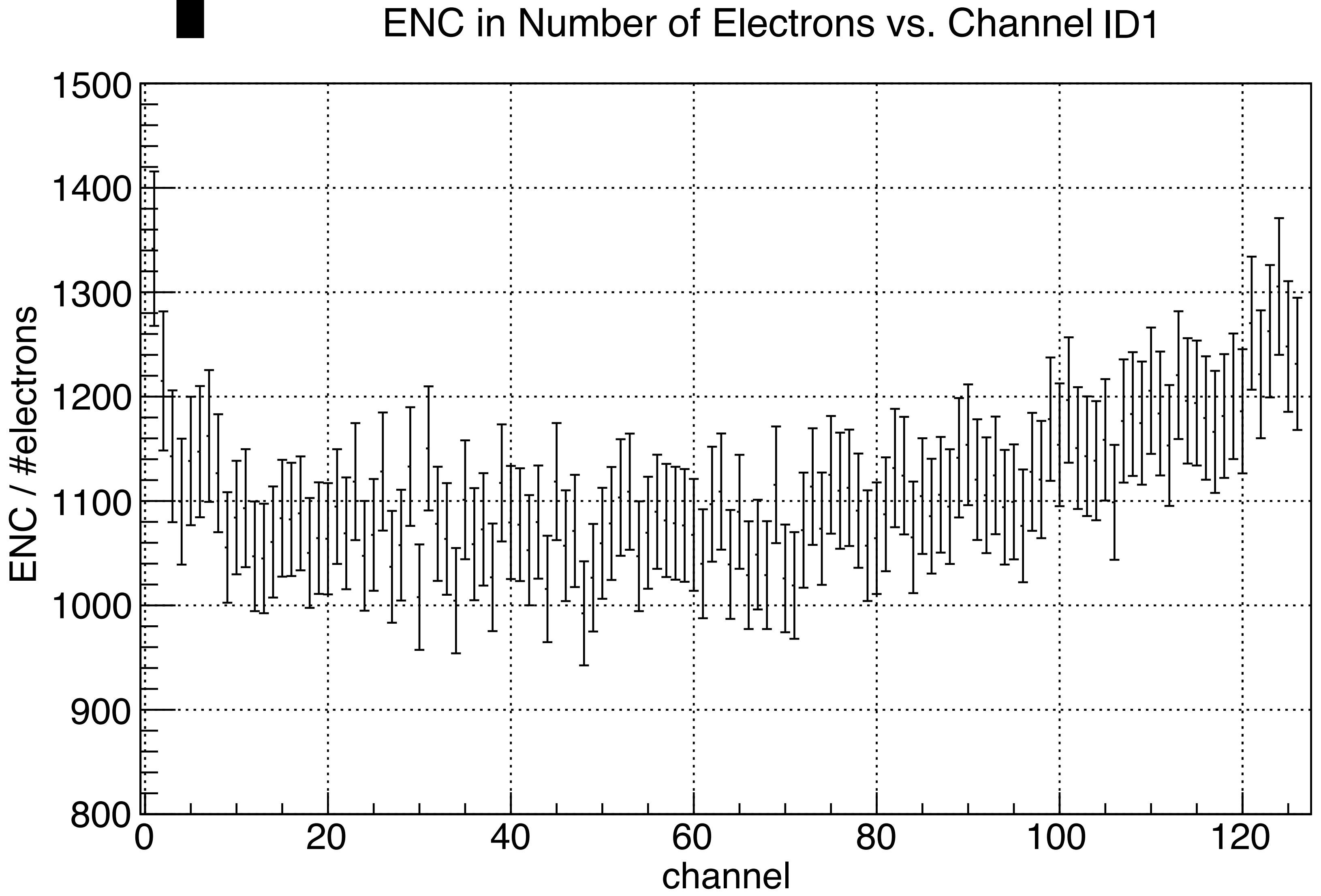


$$Q_{\text{Signal}} = V_{\text{In}} \frac{R_2}{R_1 + R_2} C_{\text{P}} = V_{\text{In}} \frac{10\,\Omega}{820\,\Omega + 10\,\Omega} 1\,\text{pF}$$

ENC Comparison



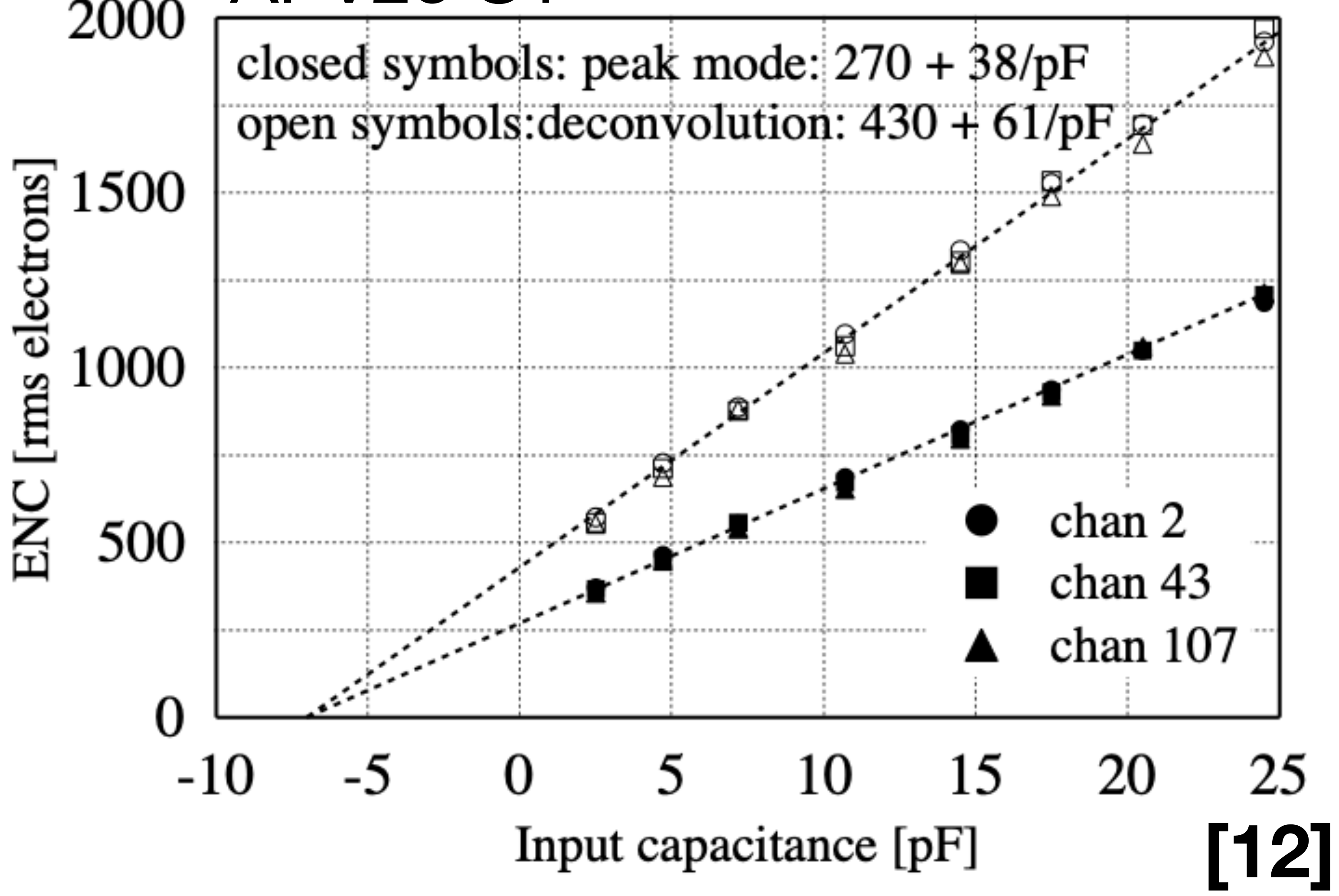
[9]



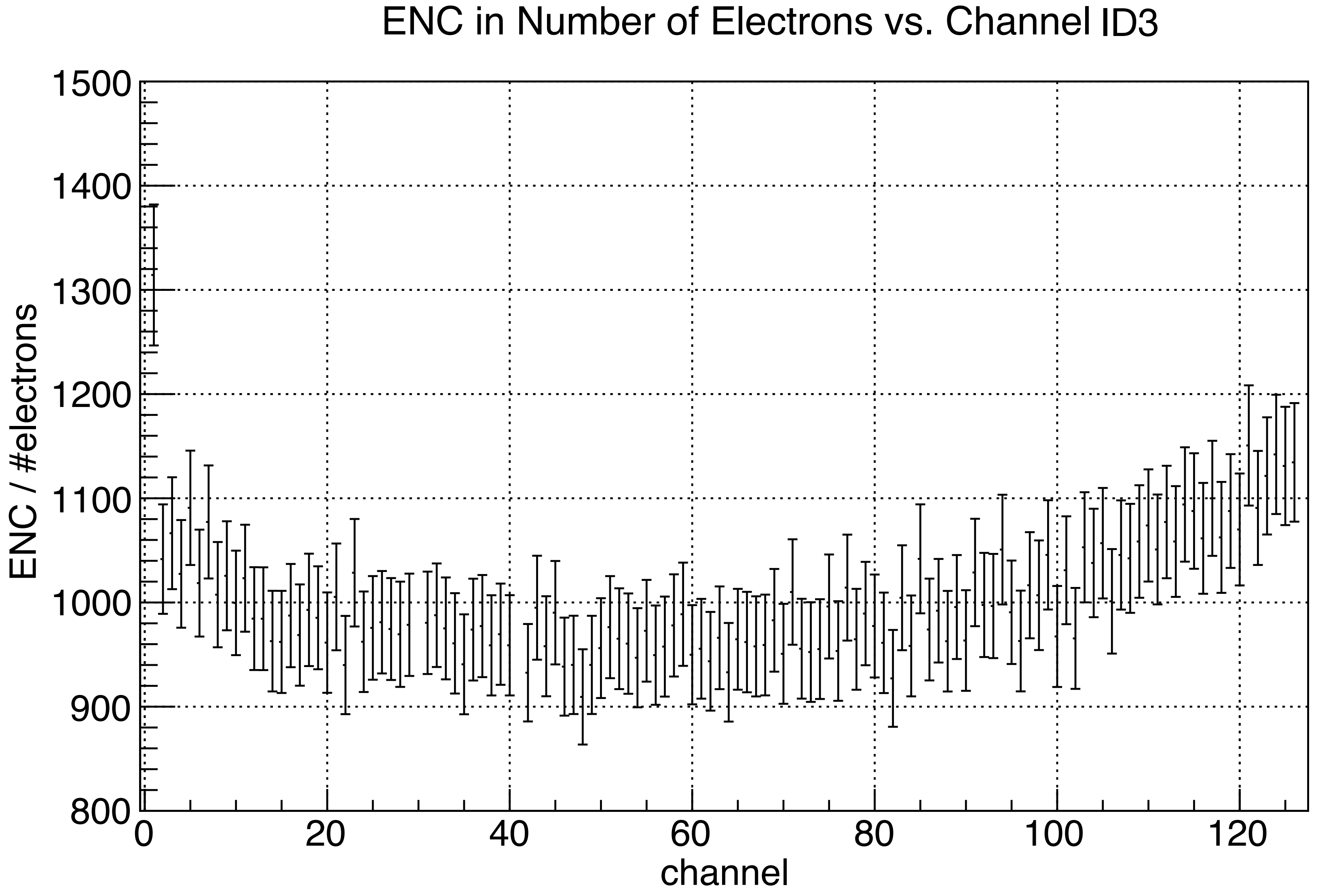
With line driver

APV25 S1

APV25 S1



[12]



Without line driver

Requirements

- High spatial and time resolution for optimized tracking
- High rate capability for stable operation
- Small material budget to reduce interactions with dead material
- Build for long-term operation

Spatial resolution	$< 100\,\mu\text{m}$
Time resolution	$\sim 10\,\text{ns}$
Rate capability	$> 10^4\,\text{part. mm}^{-2}\,\text{s}^{-1}$
Small material budget	$0.4\,\%X_0$
Large active area	31 cm x 31 cm
Low aging	up to $7\,\text{mC}\,\text{mm}^{-2}$
Discharge prevention	prohibit channel loss

[8]

Scope of Cooperation

- Simulations & GEM production optimization
  (J. Ottnads HV-settings & ALICE experience)

- Self triggered readout:
  - VMM
    (M. Lupberger - Bonn, L. Scharenberg - CERN)
  - TIGER (Torino)

- Front-end design (C. Honisch - Bonn)

- Production:
  FTD (Bonn) and/or CERN

- ADCs and DAQ (I. Konorov - TUM)

- (VonRoll for mass production of frames)

- (Piekenbrink Composite GmbH for Honeycomb Plates)