ECNS 2023 Garching

EUROPEAN CONFERENCE ON NEUTRON SCATTERING

Development of neutron detectors with solid converters and Timepix3 readout

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20-23 March 2023

UNIVERSITÄT BONN

Gas Det Bonn

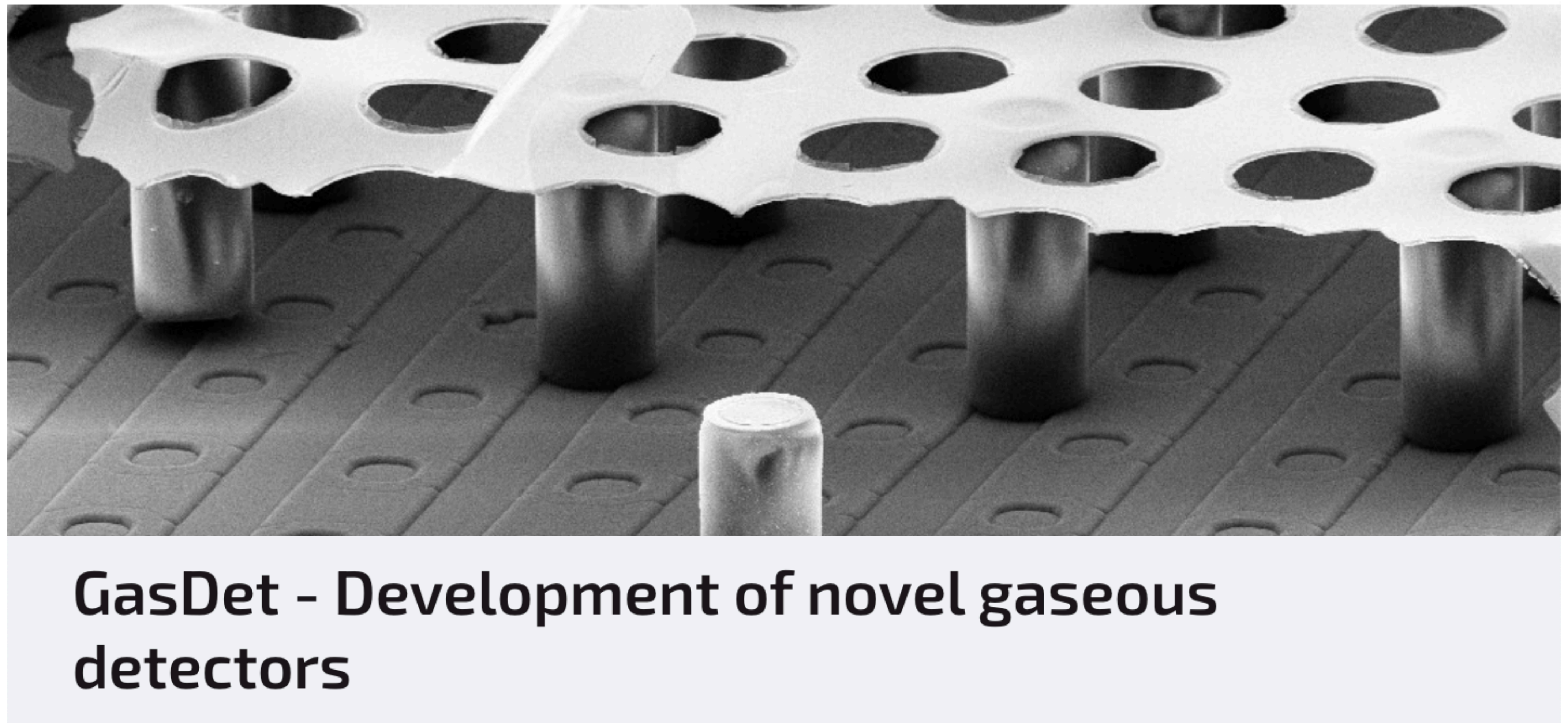
FTD

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

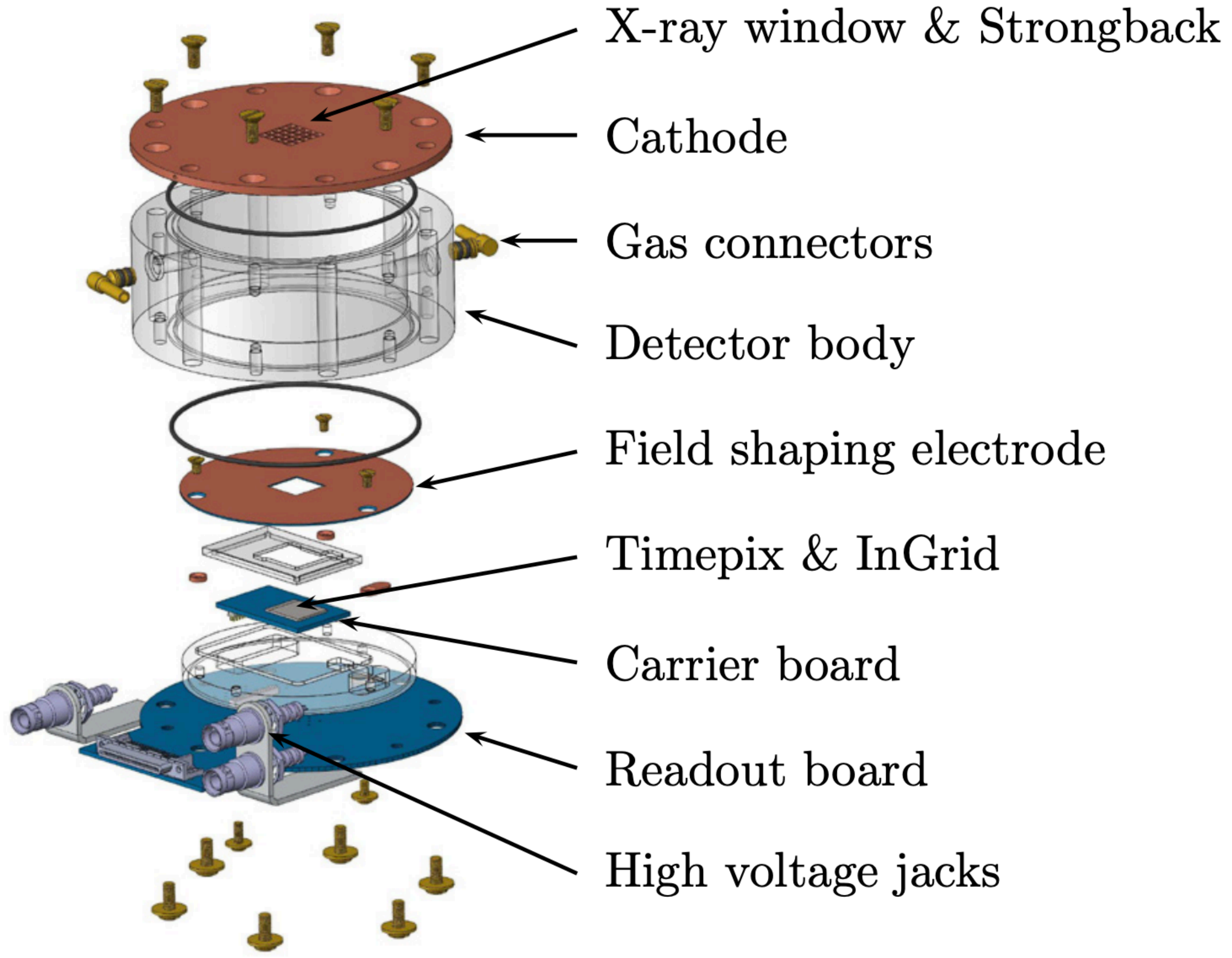
Gaseous detector group (@University of Bonn)

https://www.pi.uni-bonn.de/desch/en/research/gas-filled-detectors/

- Highly granular gaseous detectors
- Novel detectors with improved capabilities to improve the potential of future instruments
- Expertise on Timepix3 readout with Scalable Readout Systems
- Part of Research and Technology Center Detector Physics (FTD)

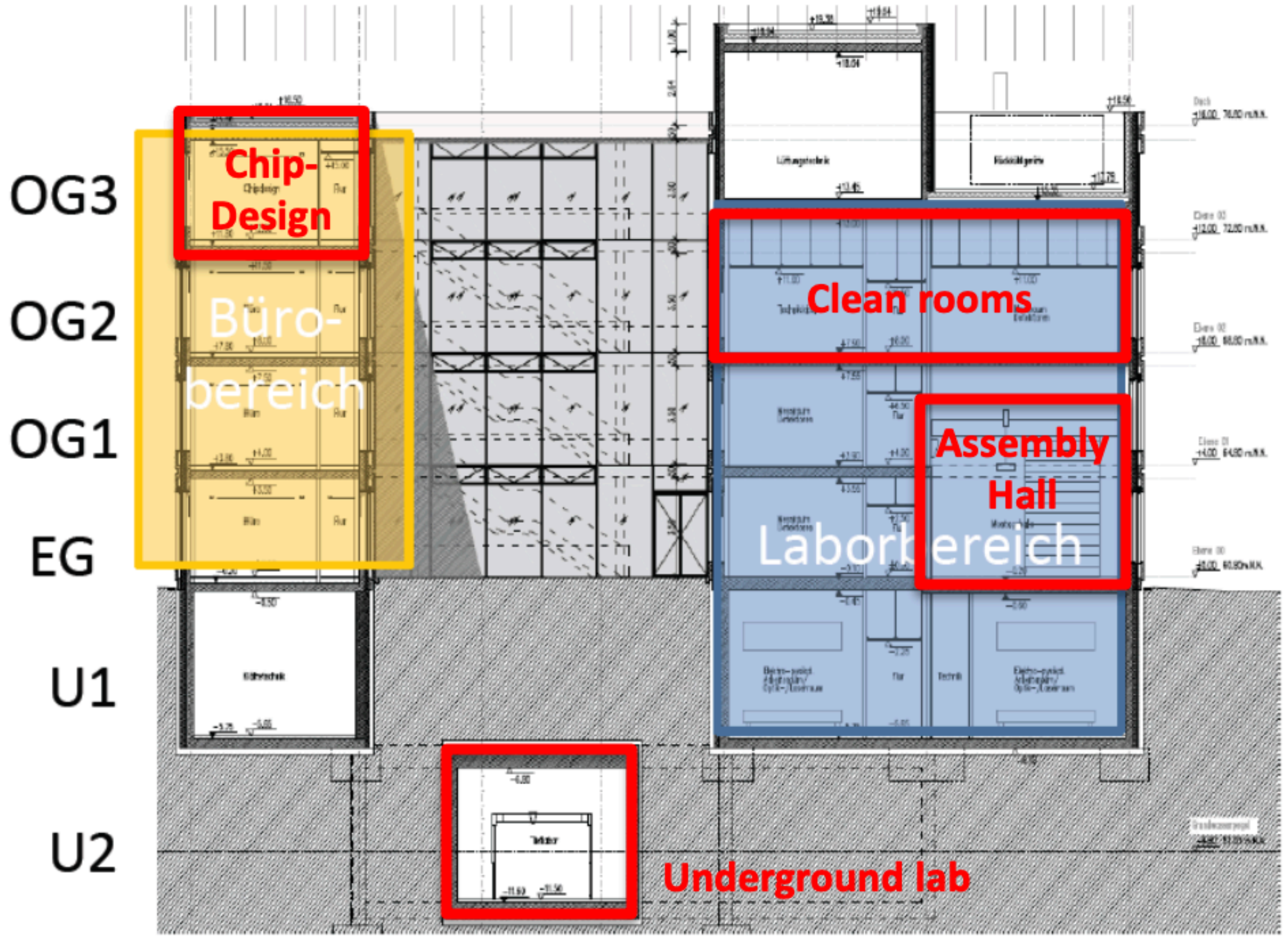


https://cds.cern.ch/record/2314331/



Research and Technology Center for Detector Physics

- Forschungs- und Technologie-Zentrum Detektorphysik (FTD)
- Studies on the latest detector technologies for the detection of radiation and particles
- Lab Space: 2010m^2
- Nano-micro fabrications, bonding machines, inspection devices, SEM etc.



https://www.ftd.uni-bonn.de/en/homepage?set_language=en

Team


Prof. Dr. Klaus Desch


Dr. Jochen Kaminski

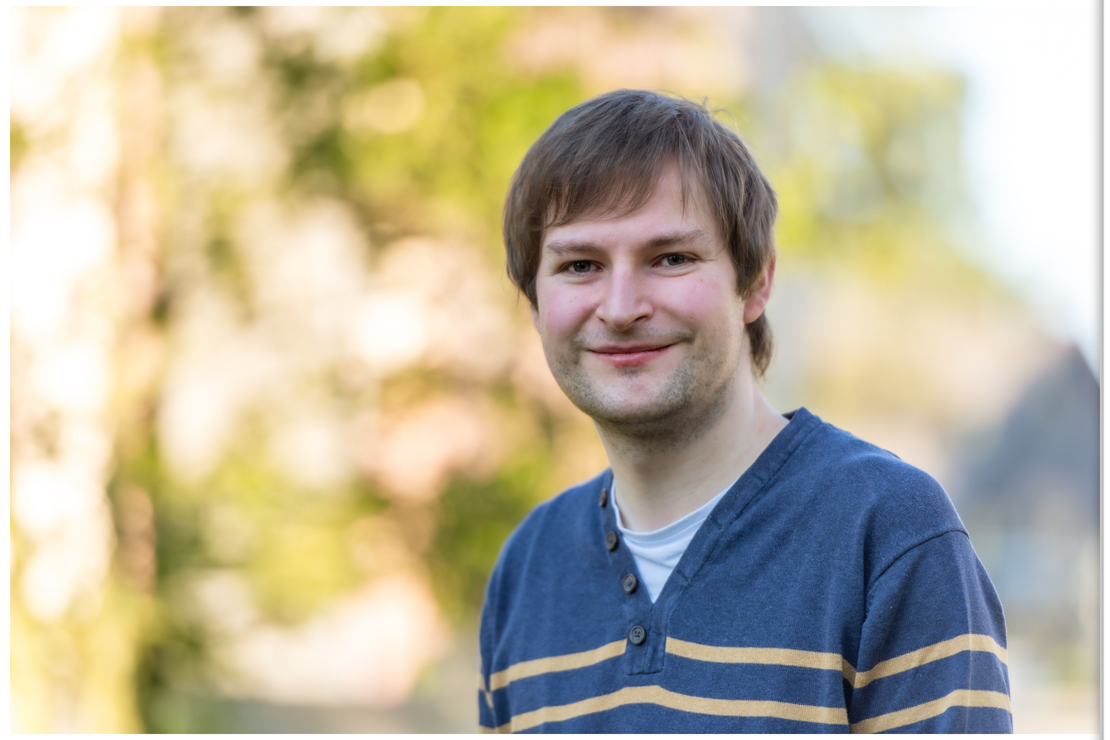

Dr. Michael Lupberger


Dr. Markus Köhli


Dr. Saime Gürbüz


Divya Pal


Thomas Block


Markus Gruber

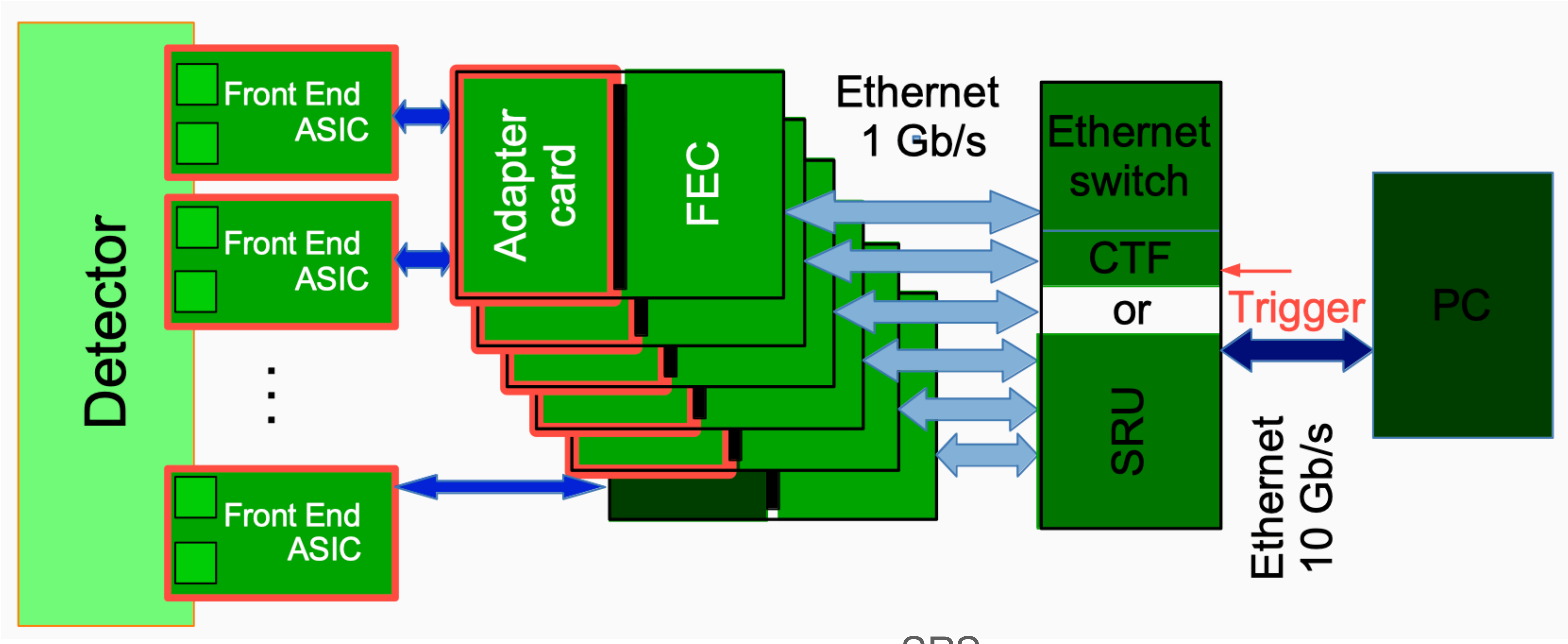
+ Former BSc. and MSc. students who graduated…

Novel neutron detectors

(@University of Bonn)

Element	Reaction
^{3}He	$^{3}\text{He} + \text{n} \rightarrow {}^{3}\text{H} + \text{p} + 764\,\text{keV}$
^{6}Li	$^{6}\text{Li} + \text{n} \rightarrow {}^{3}\text{H} + \alpha + 4.78\,\text{MeV}$
^{10}B	$^{10}\text{B} + \text{n} \rightarrow {}^{7}\text{Li} + \alpha + 2.79\,\text{MeV}\ (6\%)$
	$^{10}\text{B} + \text{n} \rightarrow {}^{7}\text{Li}^{*} + \alpha + 2.31\,\text{MeV}\ (94\%)$
^{113}Cd	$^{113}\text{Cd} + \text{n} \rightarrow {}^{114}\text{Cd} + \gamma + 9.04\,\text{MeV}$
^{155}Gd	$^{155}\text{Gd} + \text{n} \rightarrow {}^{156}\text{Gd}+\gamma+\text{e}^{-}+(30\text{–}180)\,\text{keV}$
^{157}Gd	$^{157}\text{Gd} + \text{n} \rightarrow {}^{158}\text{Gd}+\gamma+\text{e}^{-}+(30\text{–}180)\,\text{keV}$
^{235}U	$^{235}\text{U} + \text{n} \rightarrow \text{fission fragments} + 160\,\text{MeV}$

Solid converters

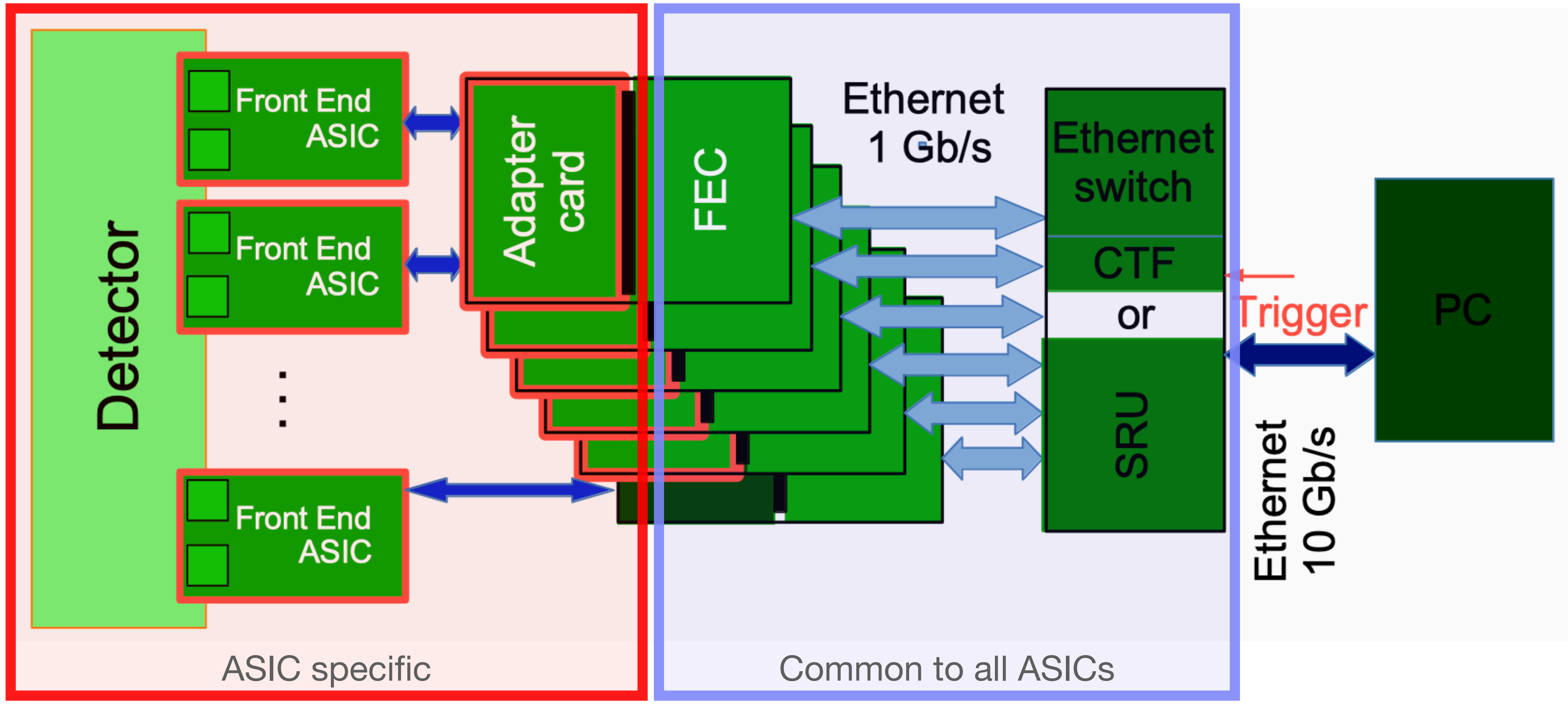


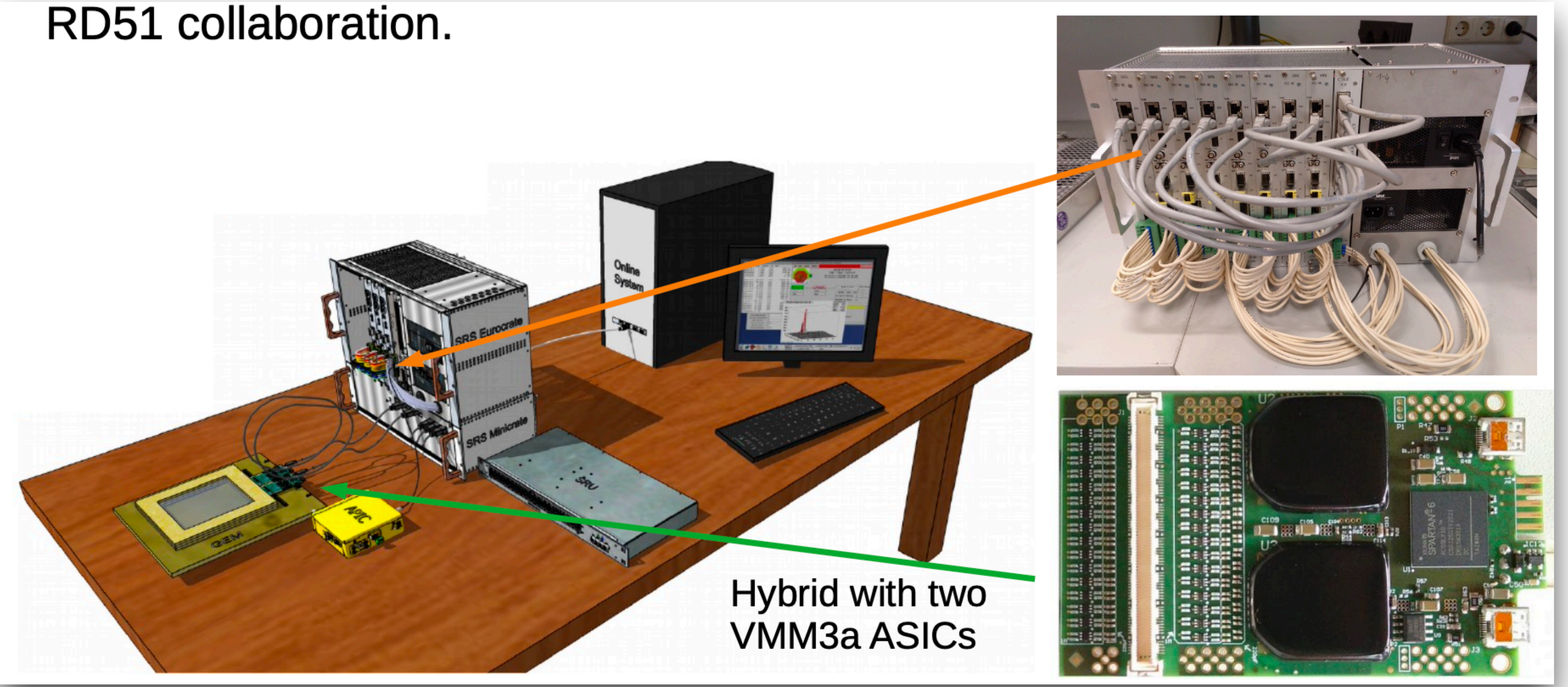
SRS

Scalable Readout System

Scalable Readout System (SRS)

- FPGA Board developed by the RD51 Collaboration
- Scalable from a single front end board to a mid-size experiment.
  - Larger user community
  - Several front-end chips implemented
  - Comparably low cost per channel



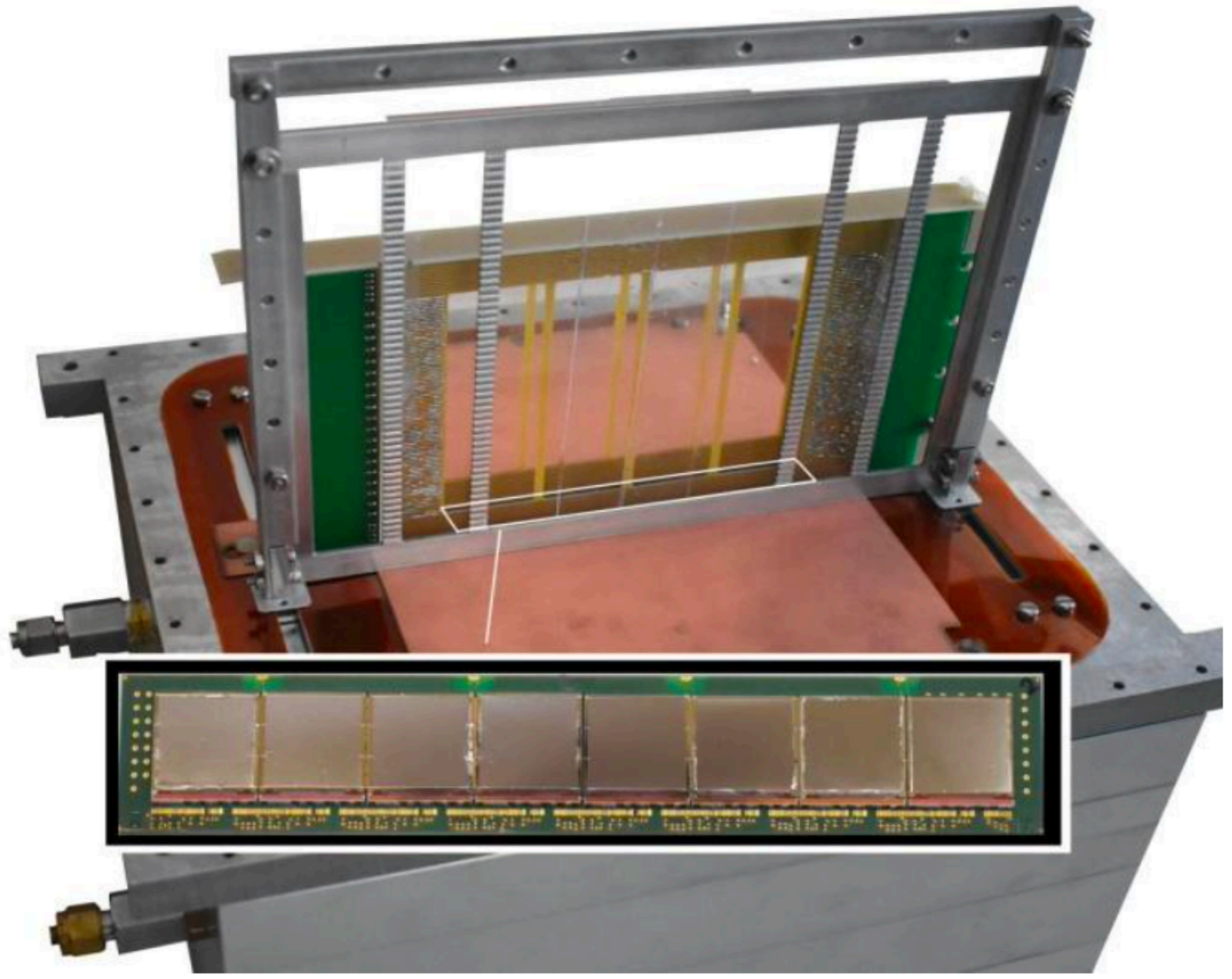


M. Gruber at al., “SRS-based Timepix3 readout system”, https://iopscience.iop.org/article/10.1088/1748-0221/17/04/C04015

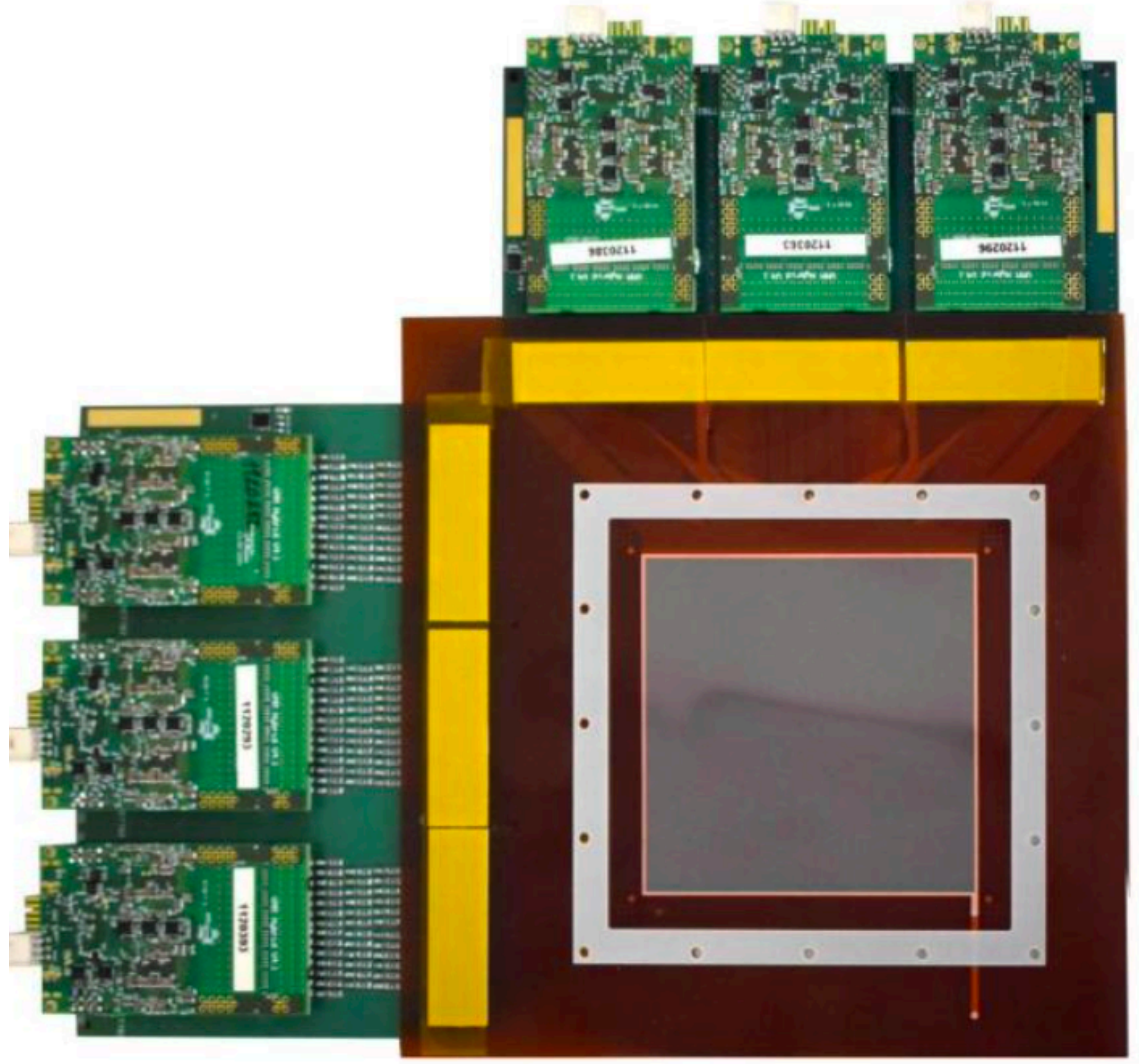
M. Lupberger et al. “Particle Physics Readout Electronics and Novel Detector Technologies for Neutron Science” NIMA 1046 (2023) 167753

Novel neutron detectors

Neutron Micro Channel Plate (nMCP)



Neutron Time Projection Chamber (nTPC)



Gaseous Electron Multiplier (GEM) based neutron detector (nGEM)

Novel neutron detectors

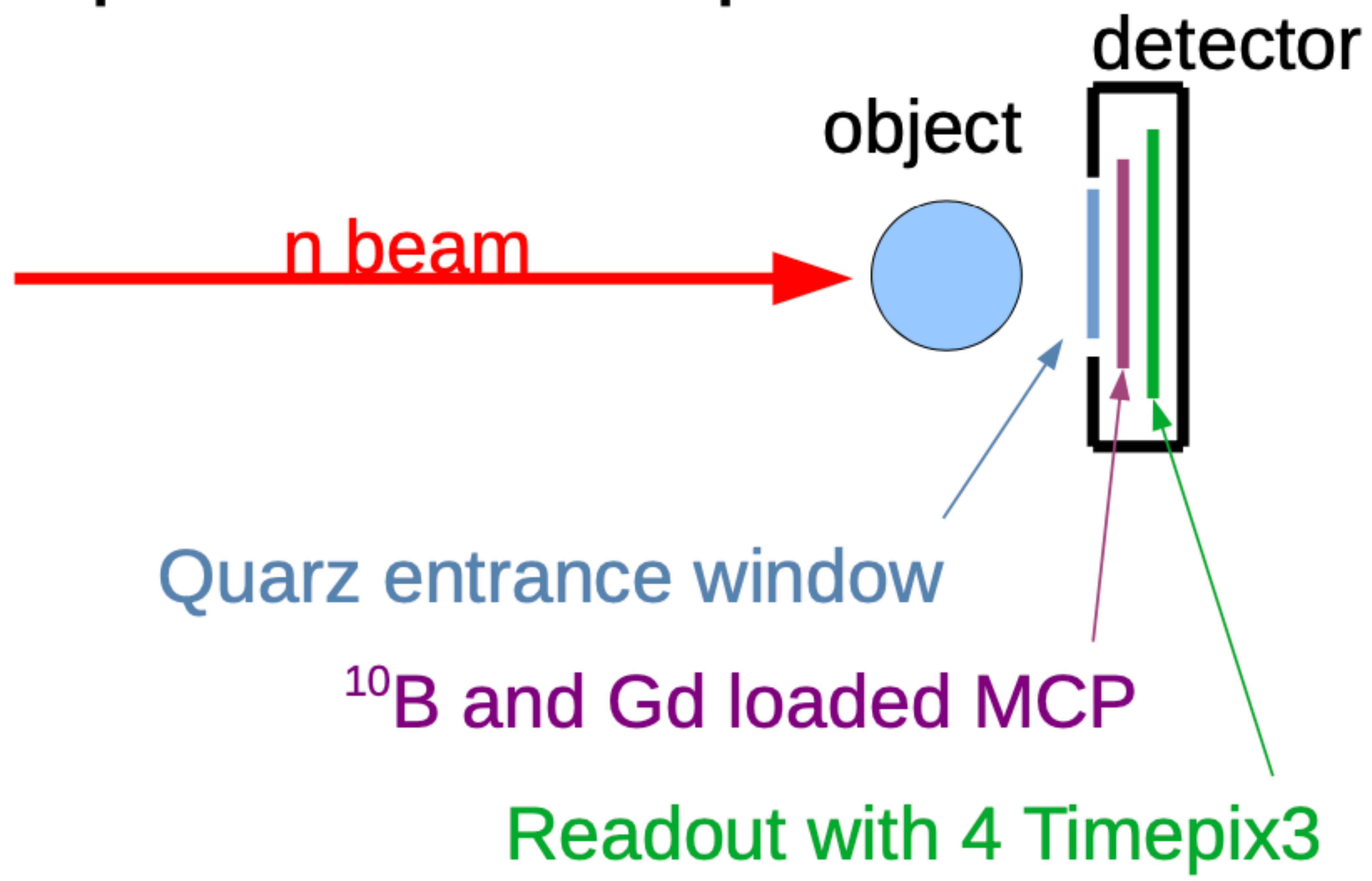
Neutron Micro Channel Plate (nMCP)

Neutron Time Projection Chamber (nTPC)

GEM based neutron detector

Neutron Micro Channel Plate (nMCP)

Experimental setup:



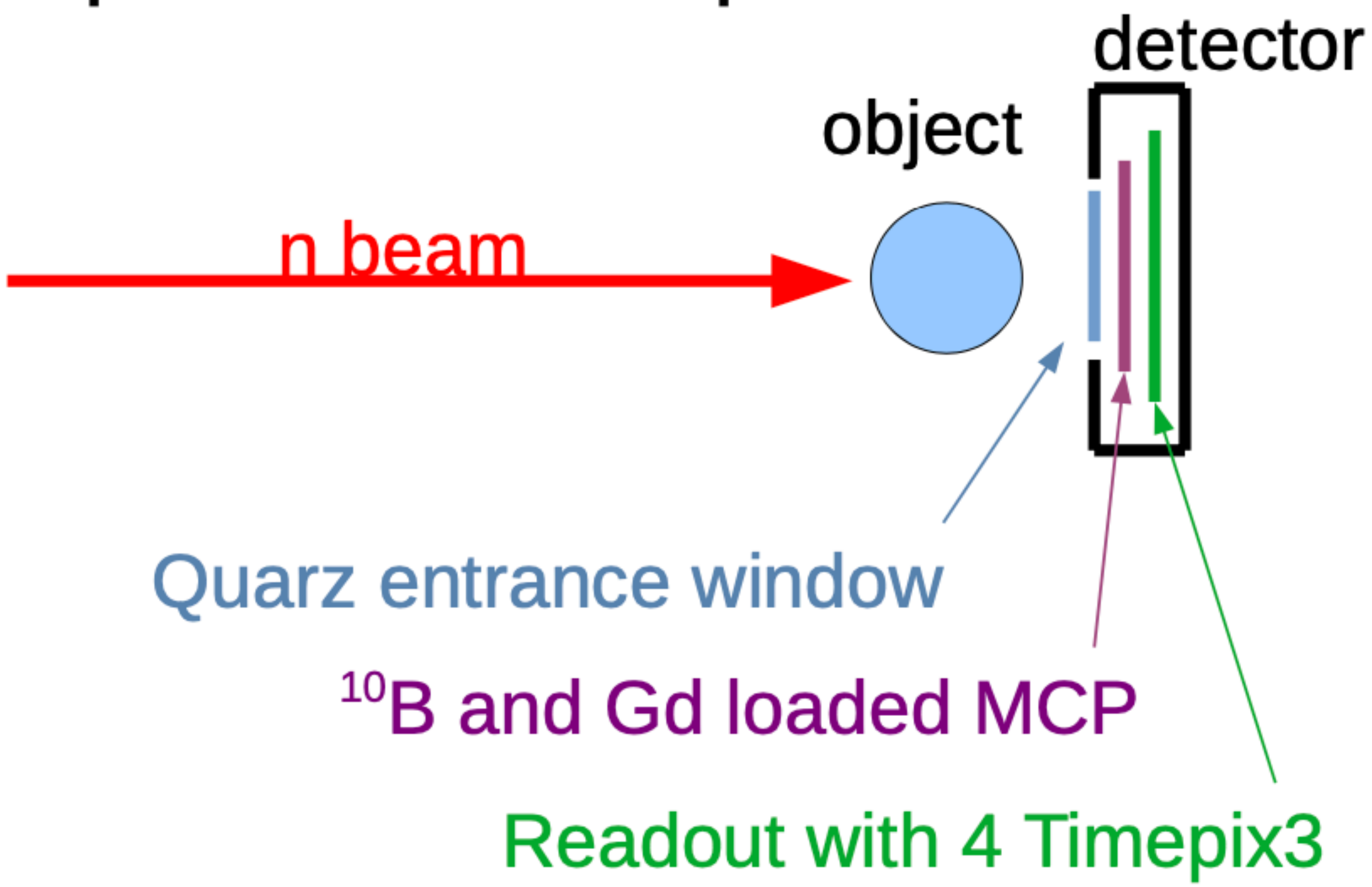
B and Gd enriched Micro Channel Plates (MCP):
Converts neutrons to electrons and produces the signal.

Quad-Timepix3 ASIC:
Electrons are captured and data readout.

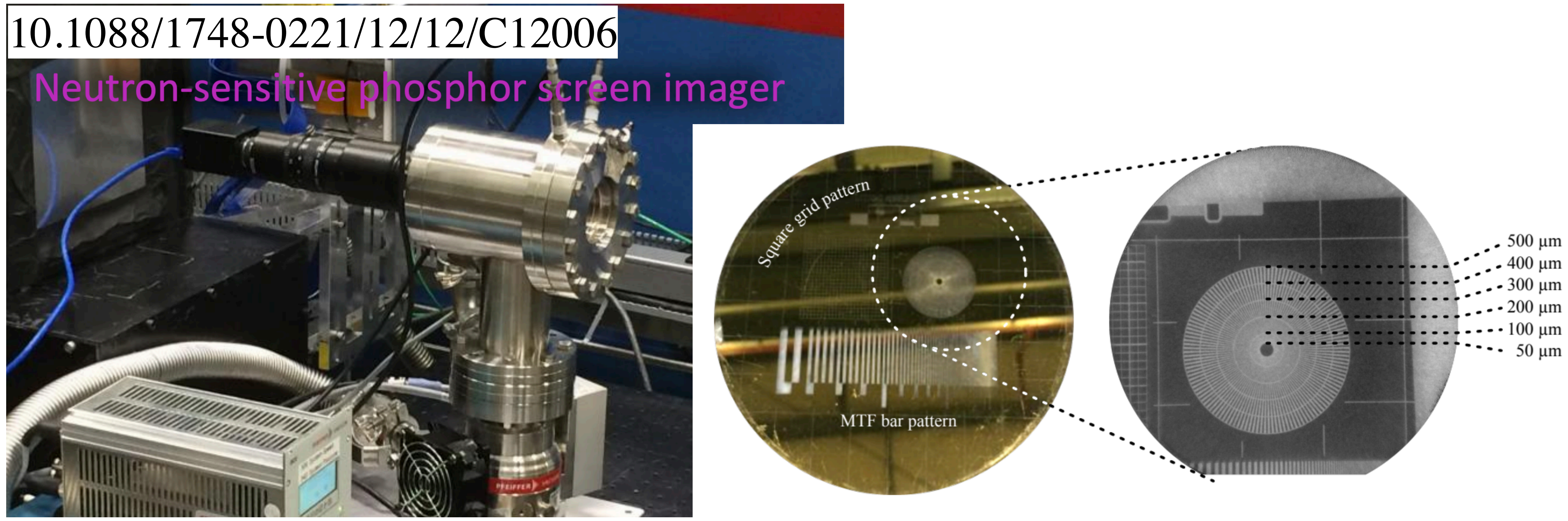
Aim:
Combining features of the Timepix3 with the efficiency and spatial resolution of neutron sensitive MCP

Neutron Micro Channel Plate (nMCP)

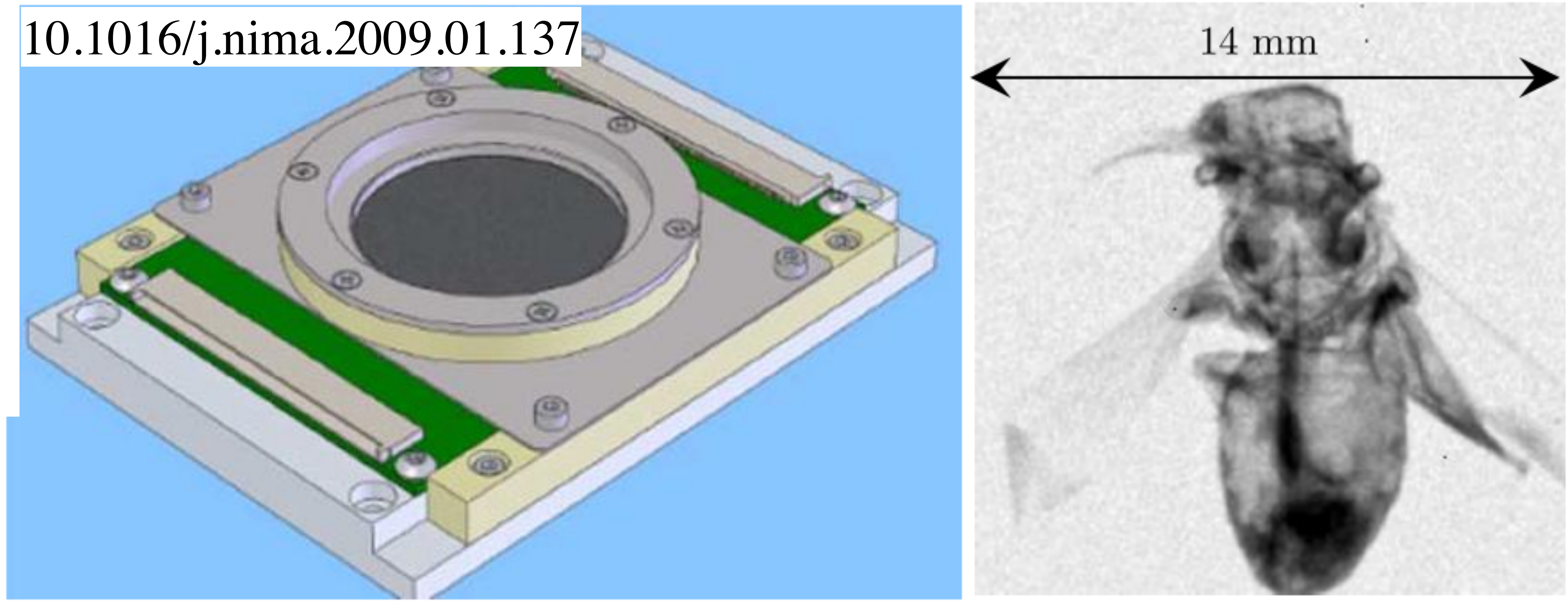
Experimental setup:



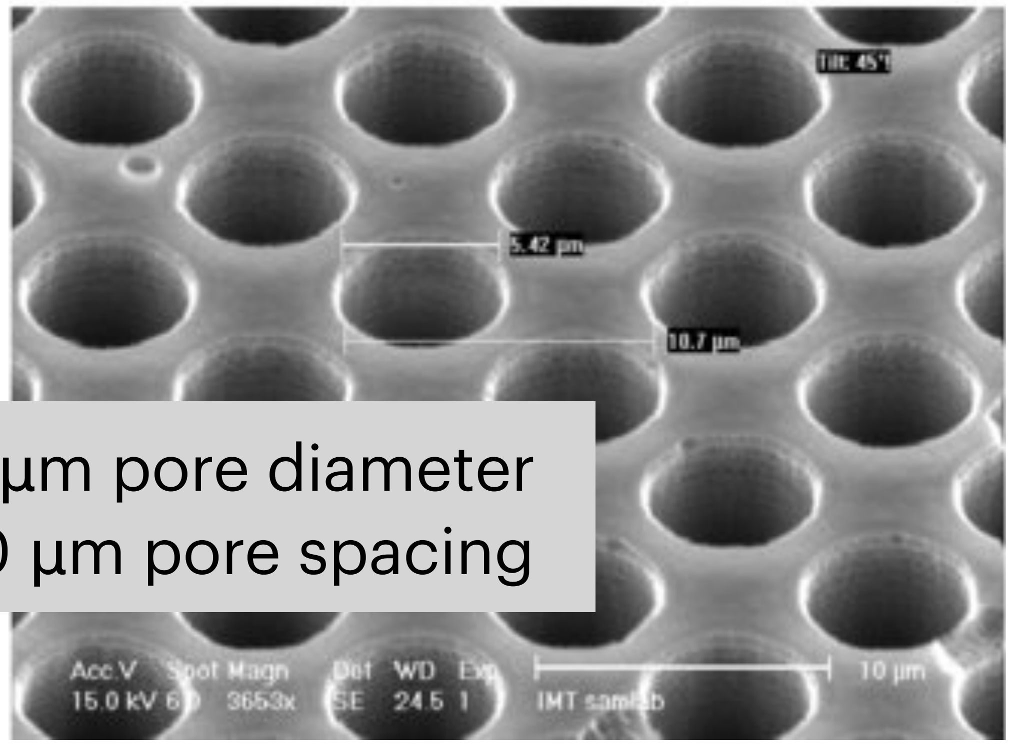
Neutron Sensitive MCP with optical readout by S.Pinto



Neutron Sensitive MCP with timepix readout by A. Tremsin



Neutron Micro Channel Plate (nMCP)



8 µm pore diameter
10 µm pore spacing

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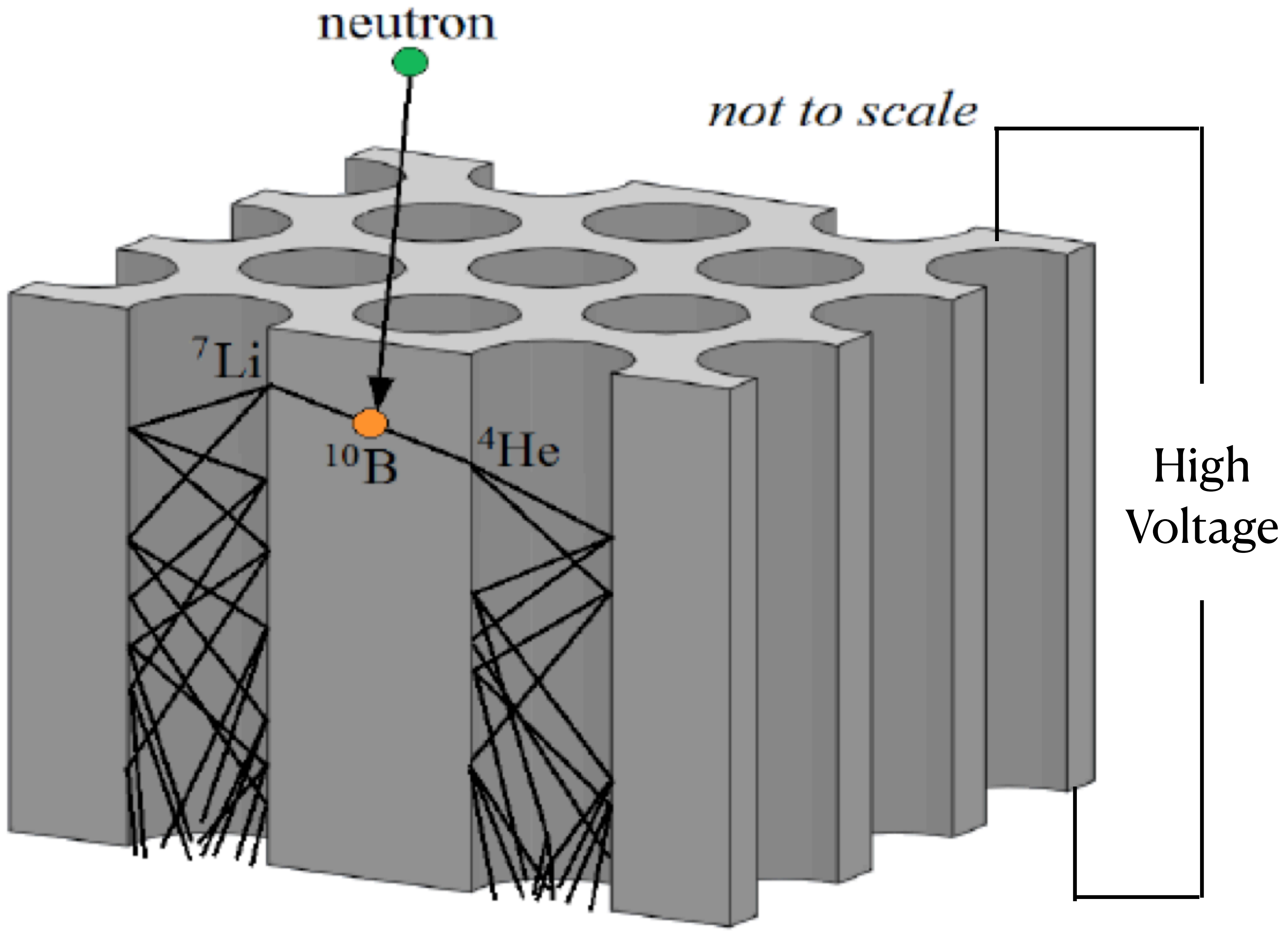
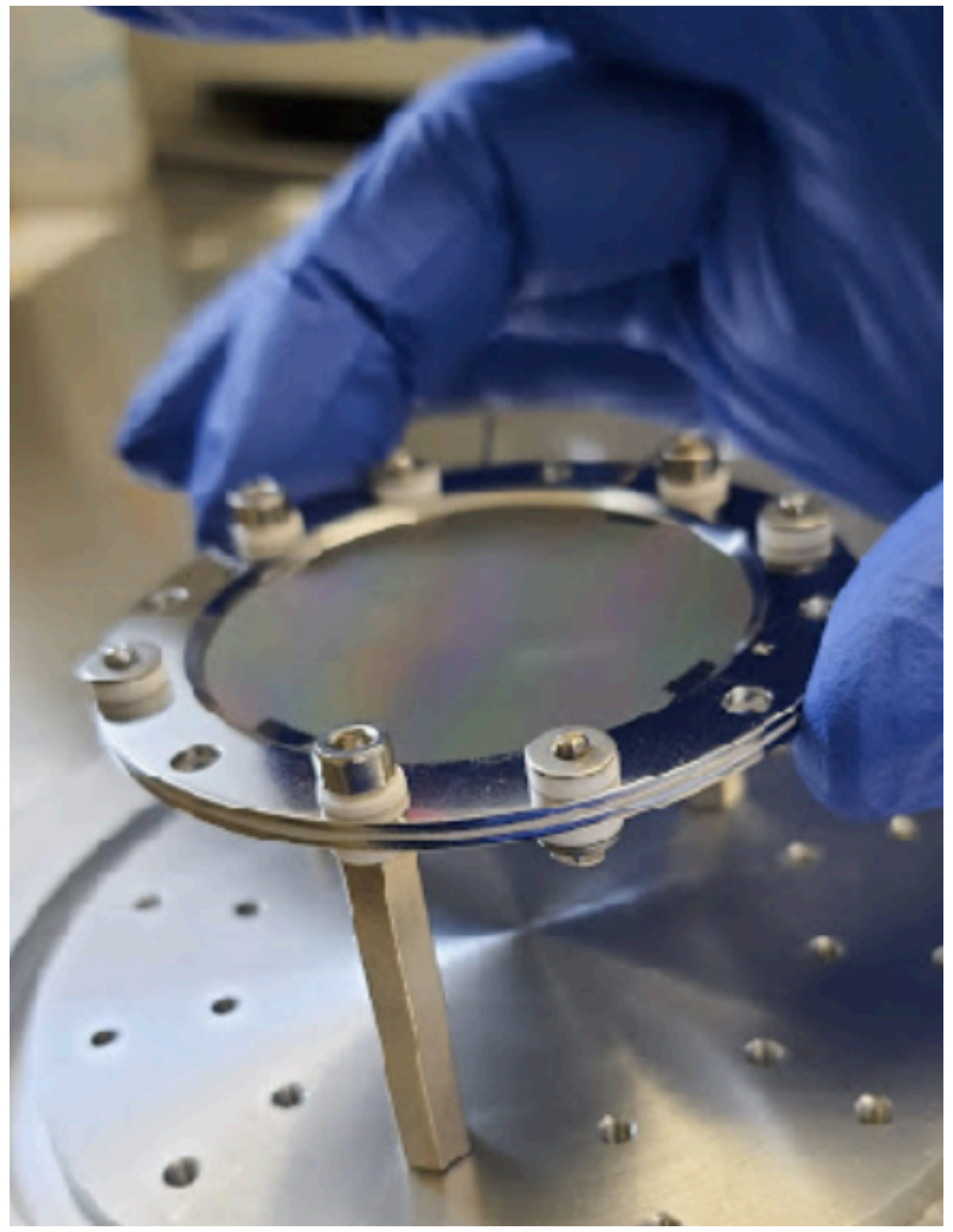
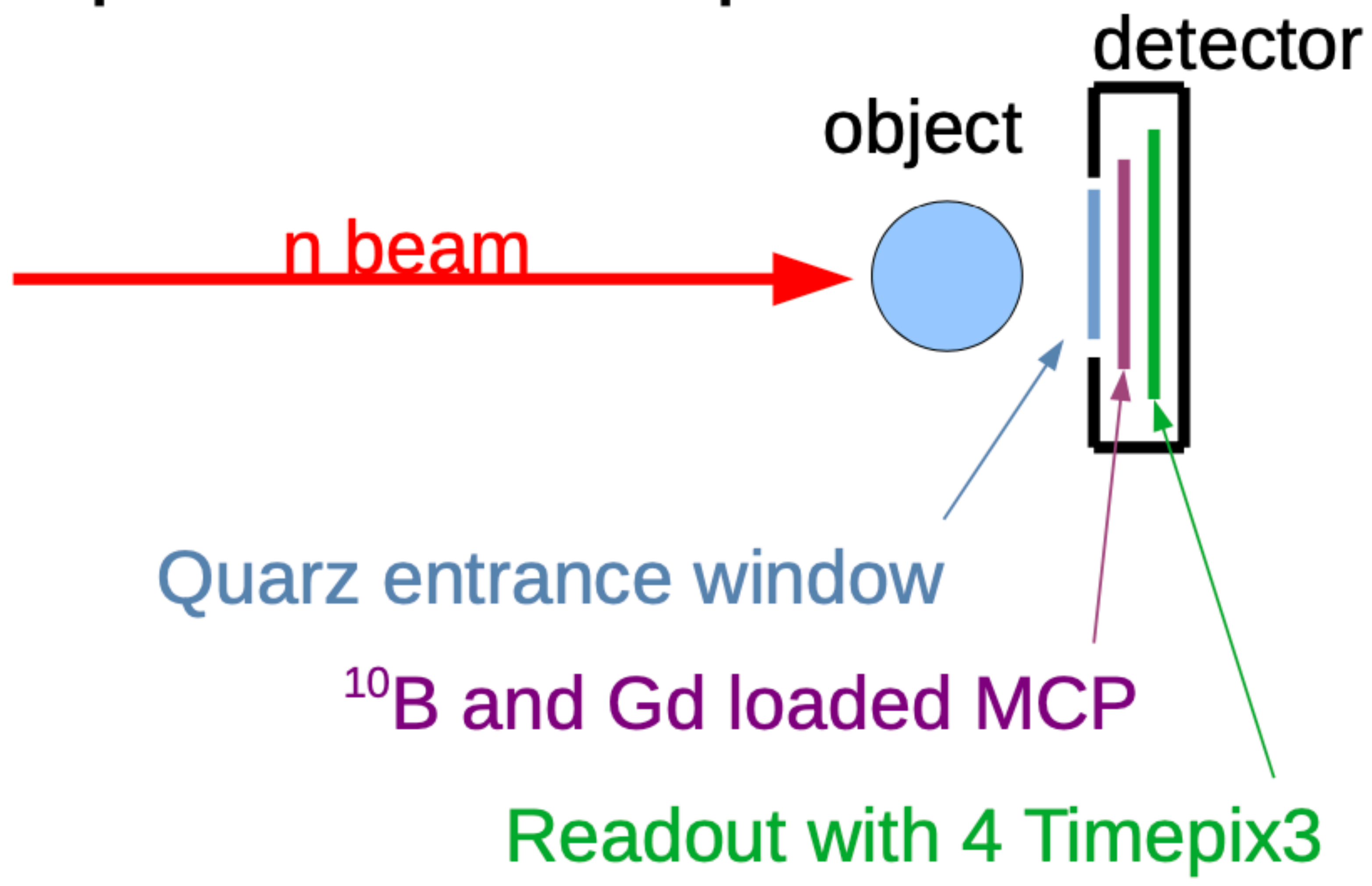


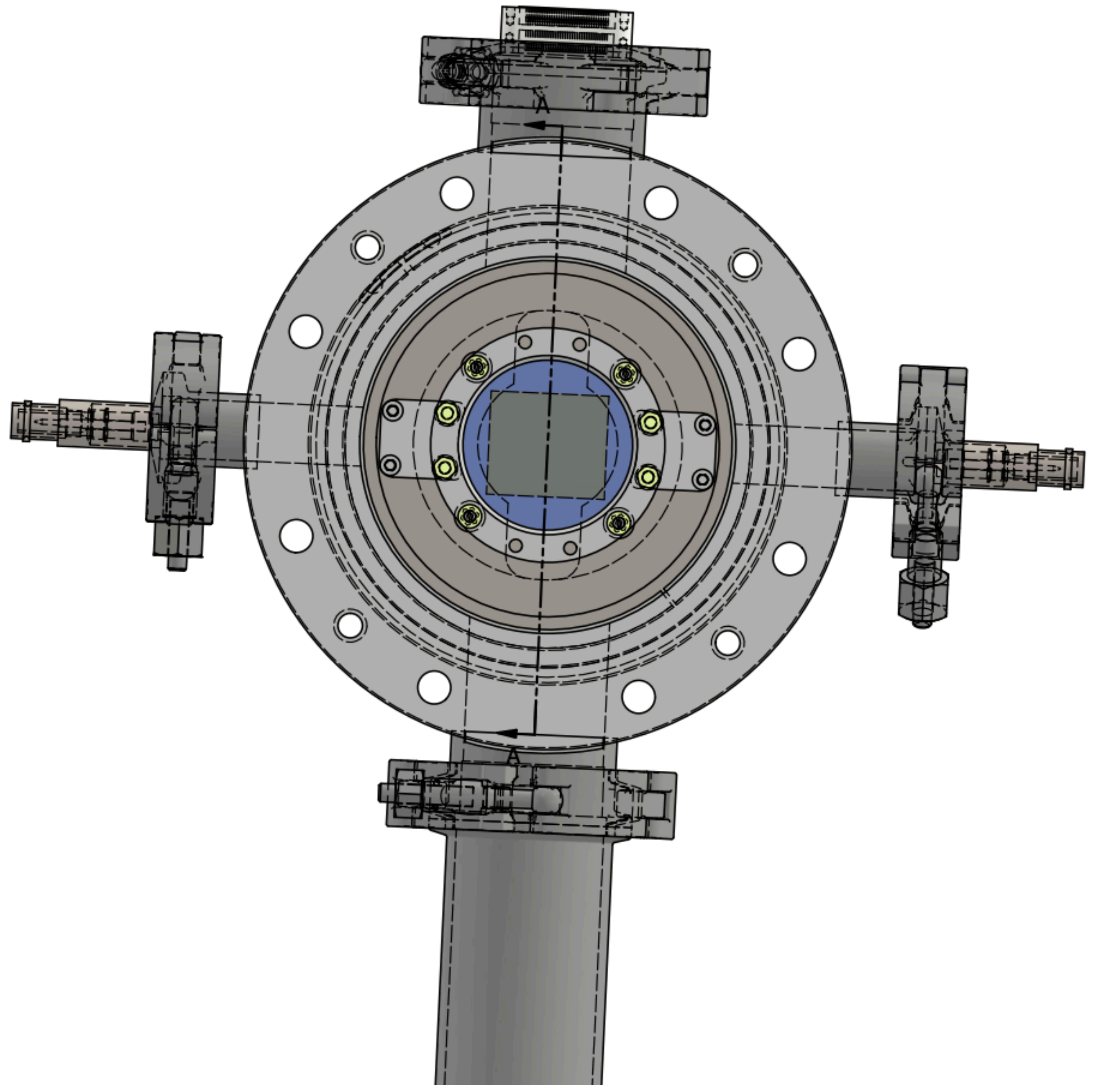
Abir, Muhammad. (2013). AFIP-7 Tomography – 2013 Status Report.
10.13140/RG.2.1.1732.4884.

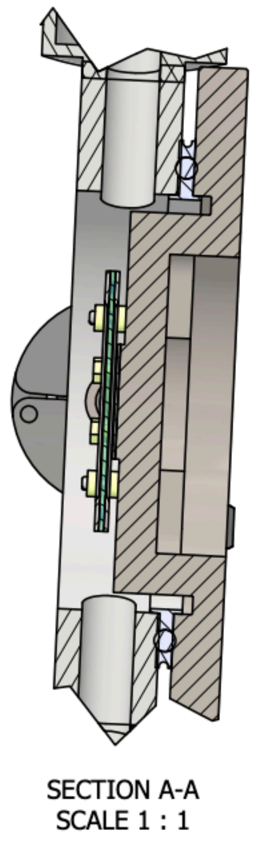


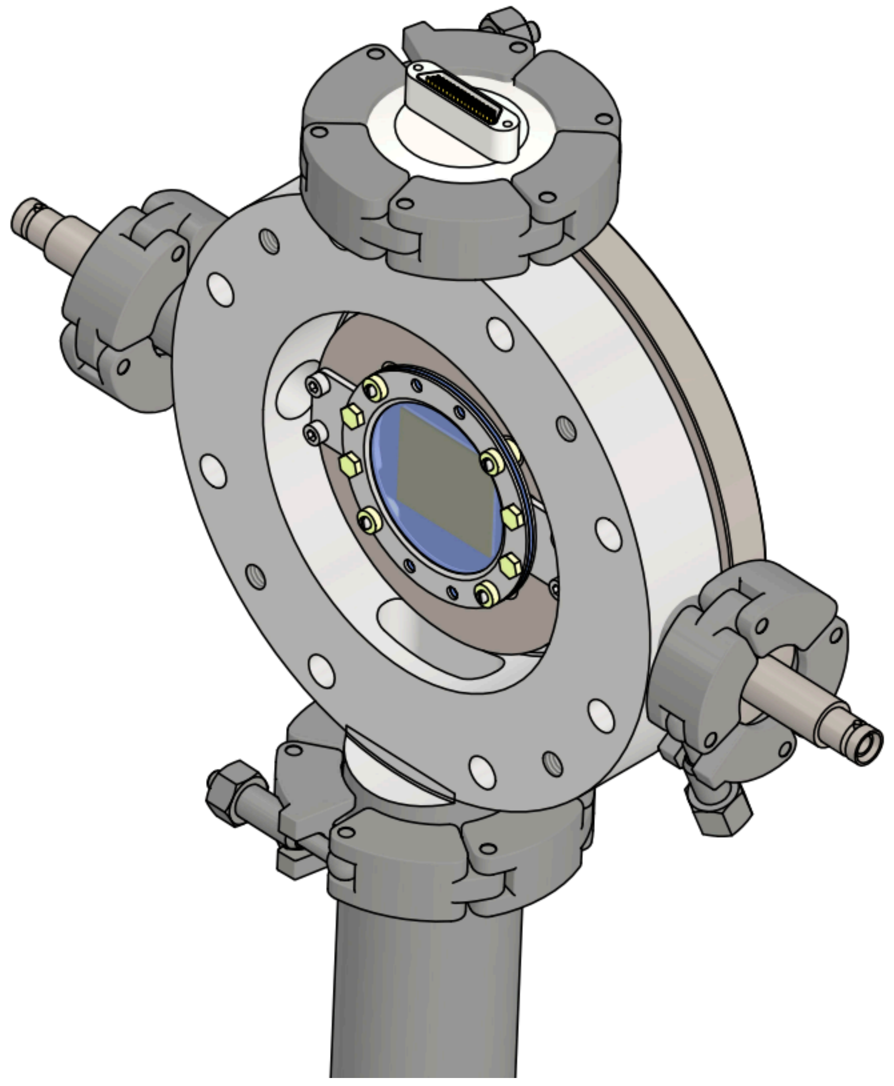
Design

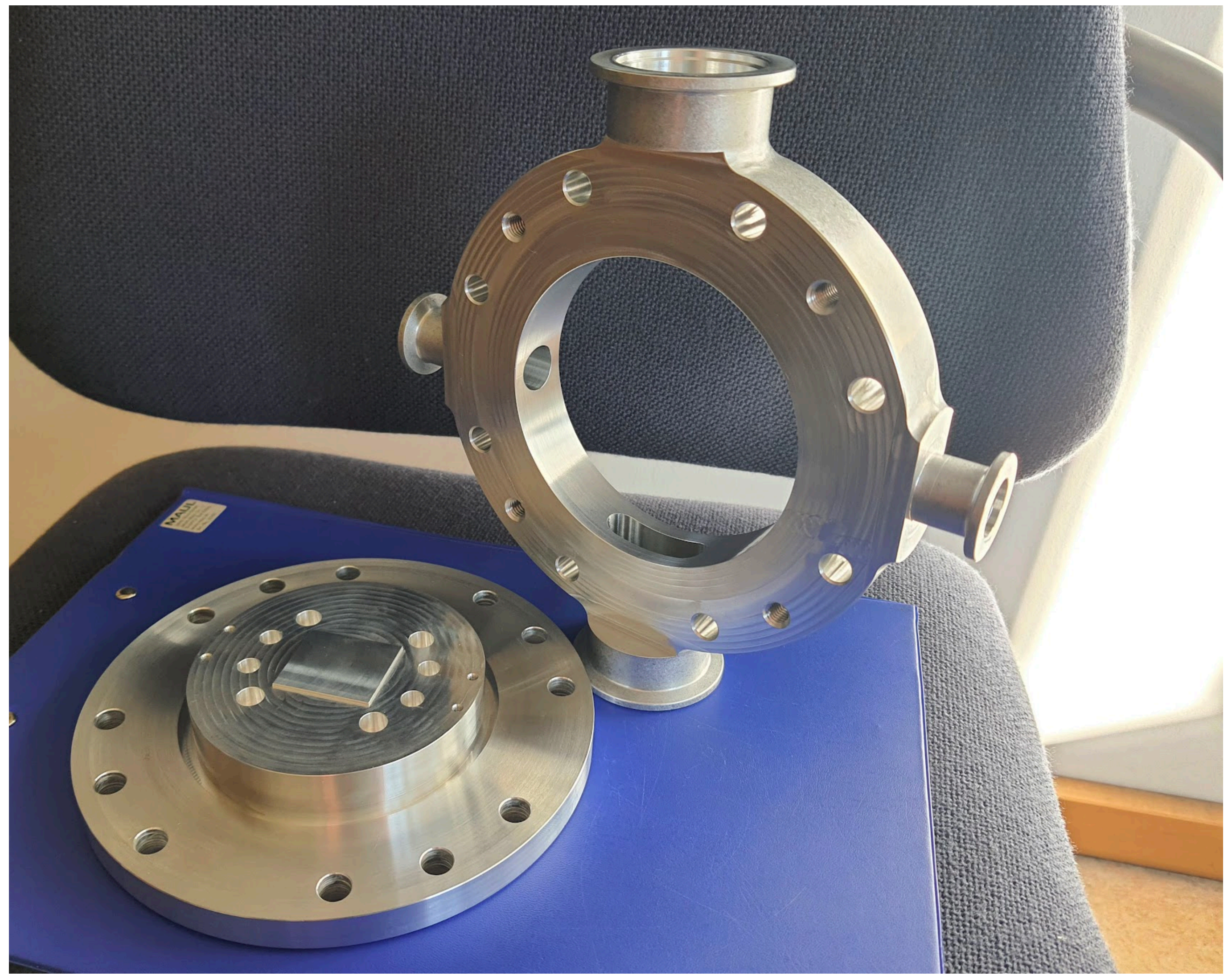
Experimental setup:

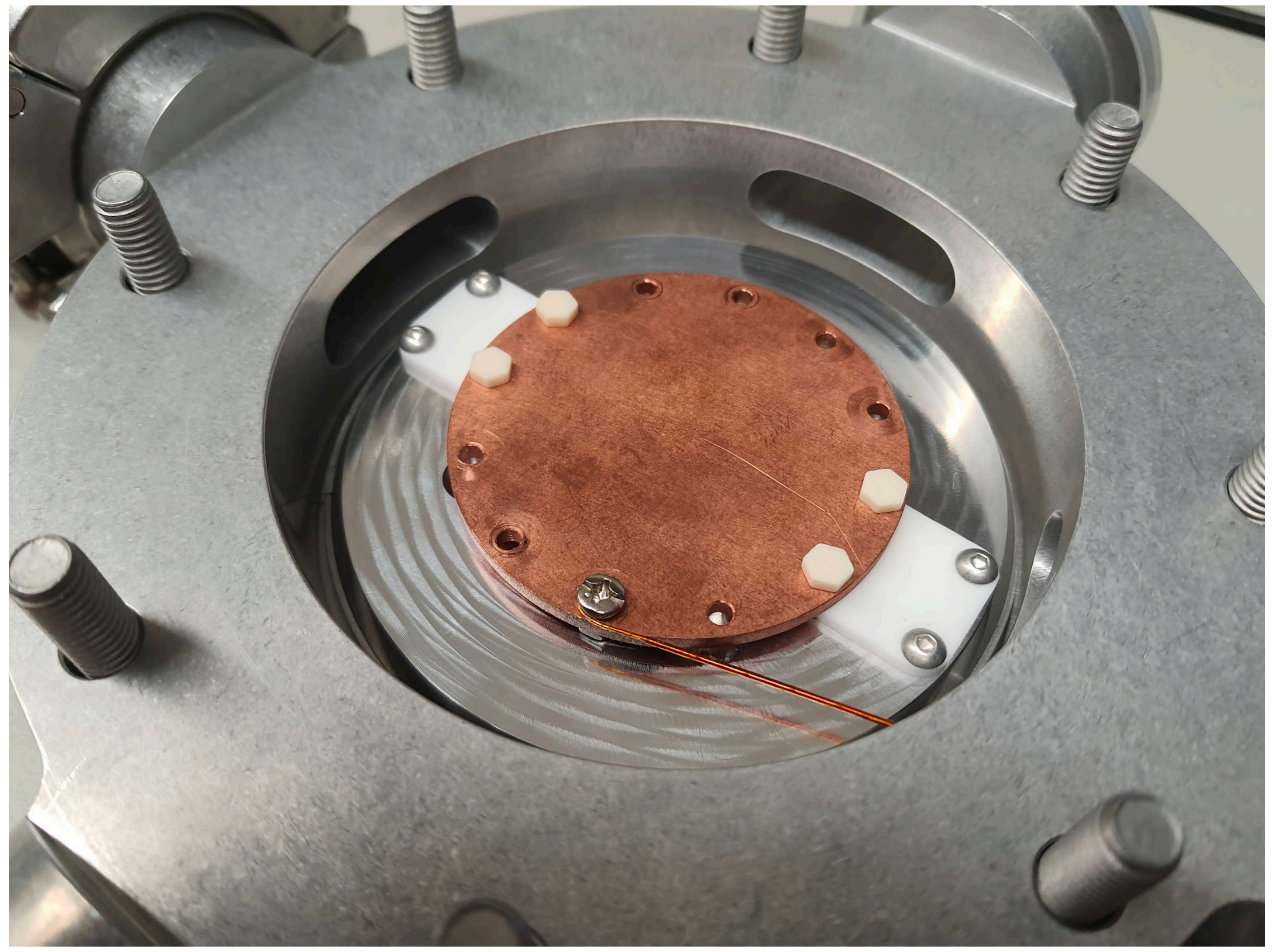








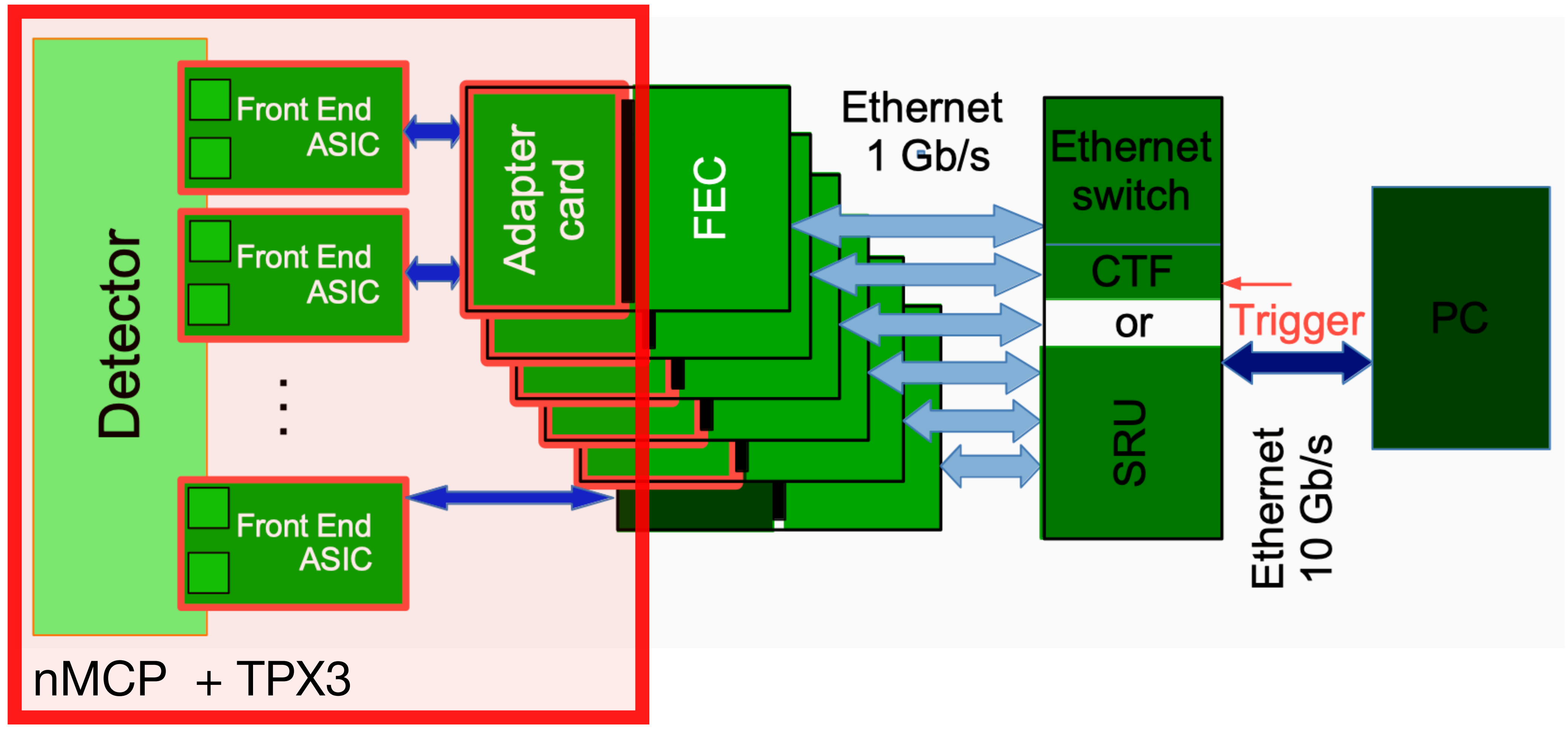


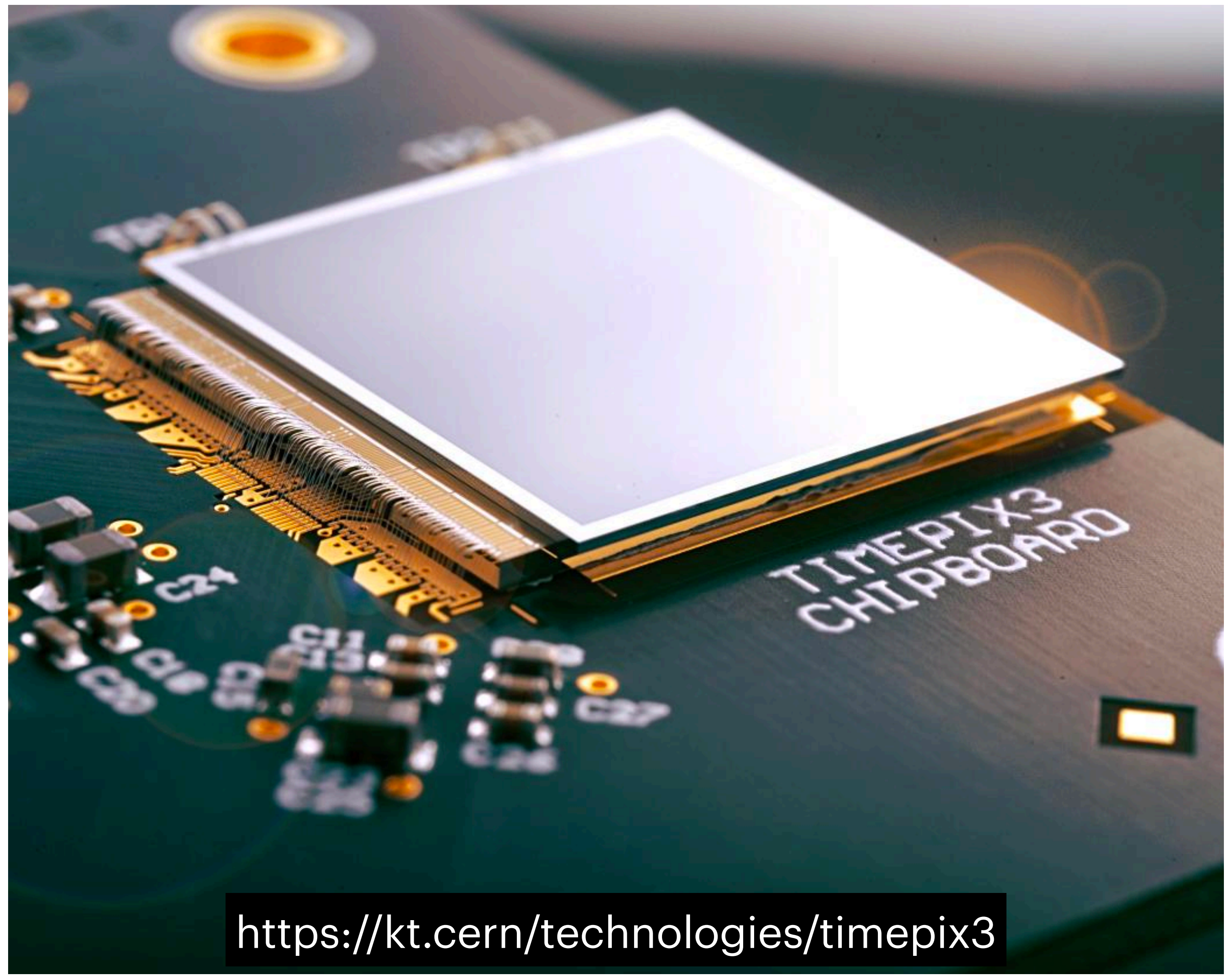


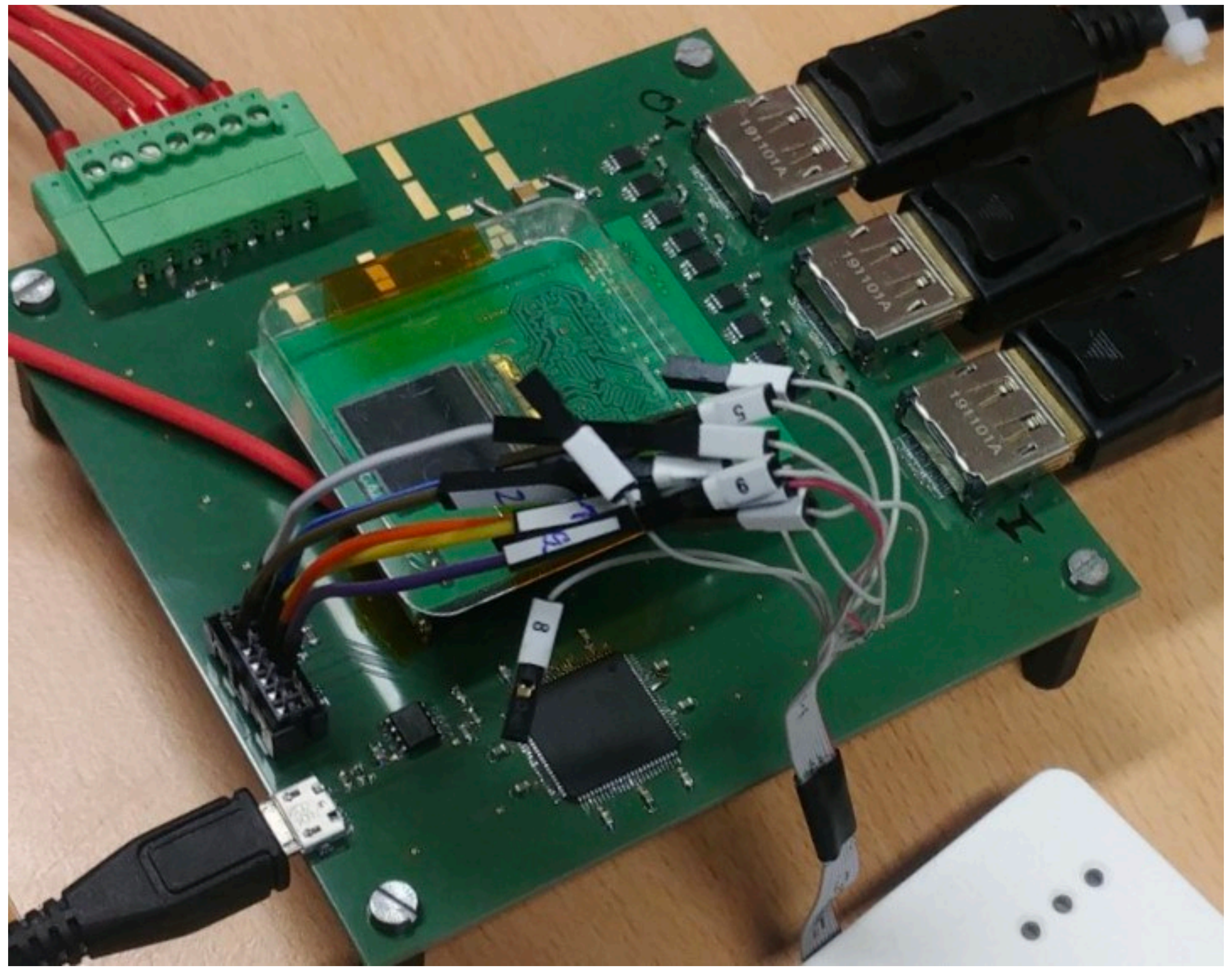
Flanges and insulators machined in our mechanical workshop

Timepix3 ASIC

- Charge sensitive pixel in 130 nm CMOS technology
- Quad Timepix3 with an active area of 7.9 cm^2
- Each ASIC: 256 × 256 pixels (55 µm pixel pitch)
- Advantages:
  - **Simultaneous charge and time measurement**
  - Time resolution: 1.56 ns
  - **Zero suppression on chip**
  - Self-triggered, **continuous data-driven readout**







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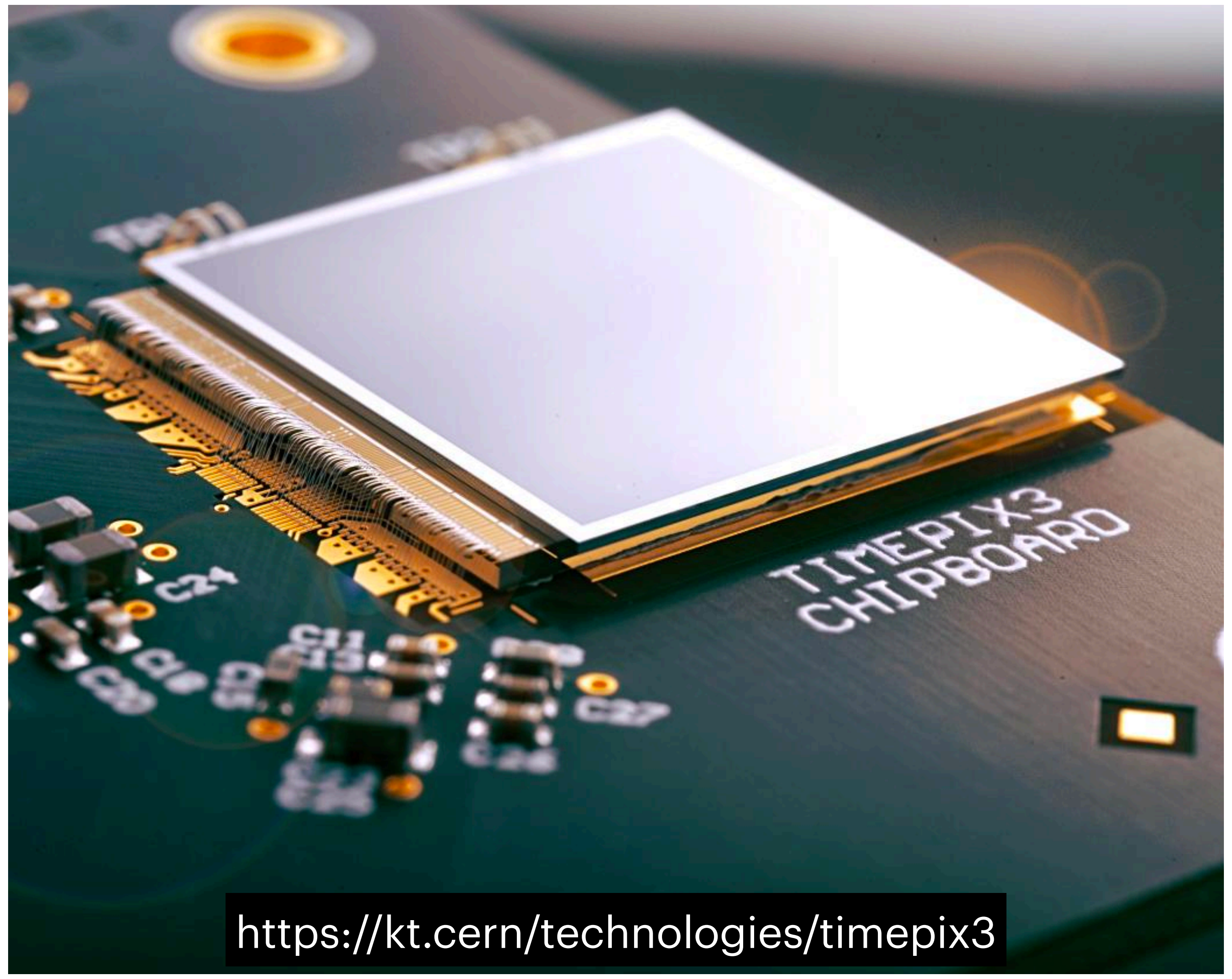
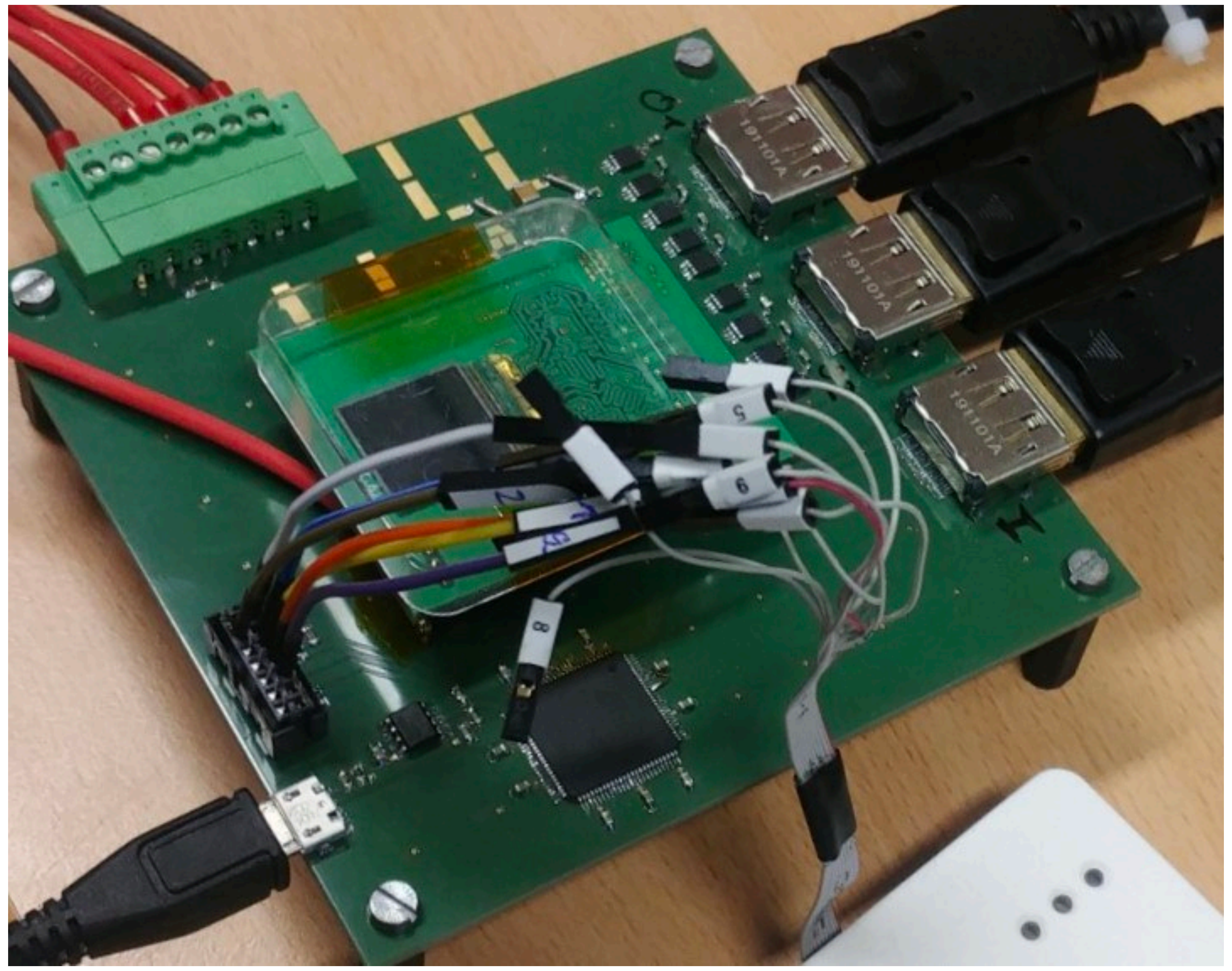
Better resolution in time & continuous readout
-> Time dependent imaging i.e. neutron radiography

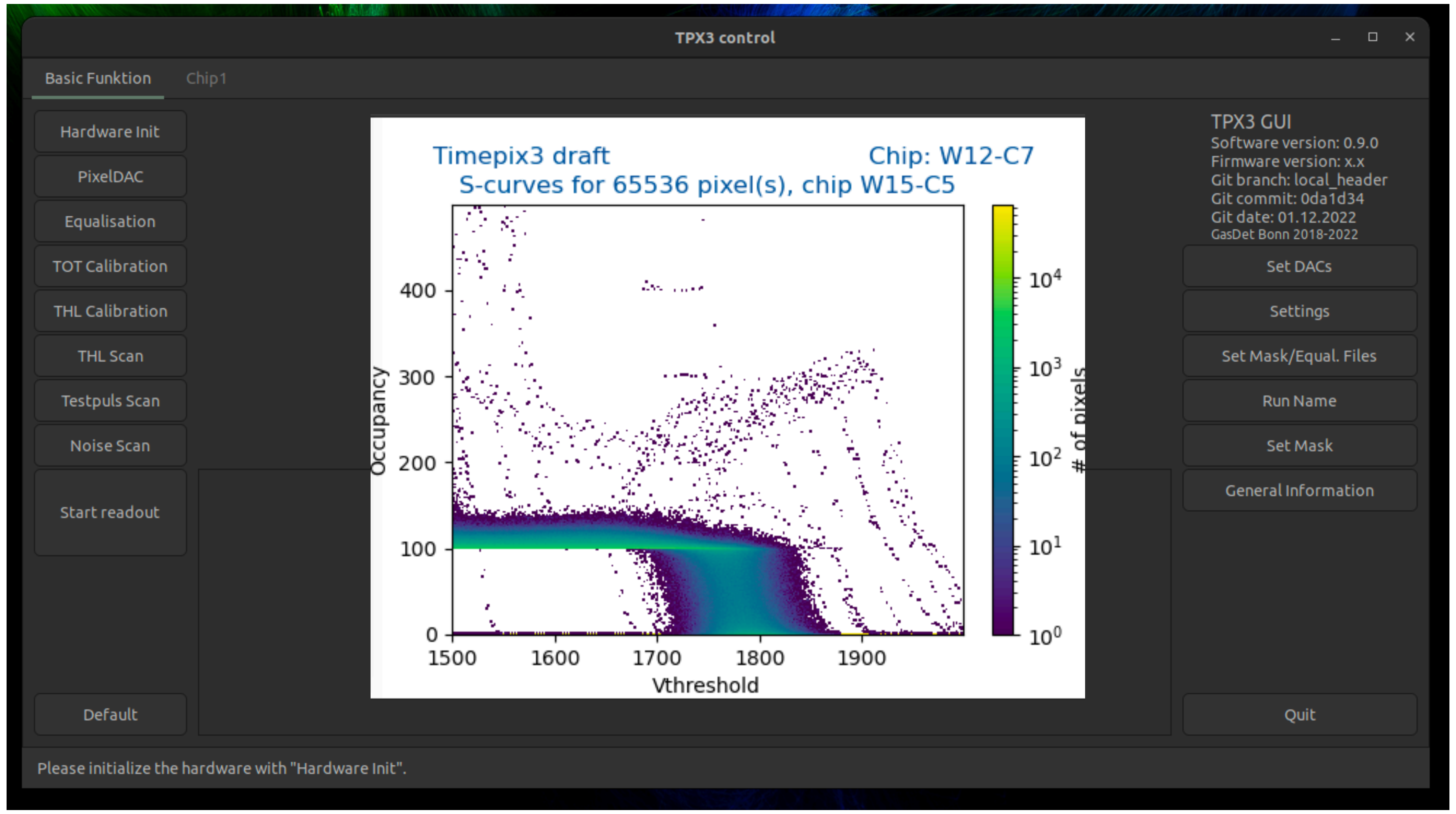


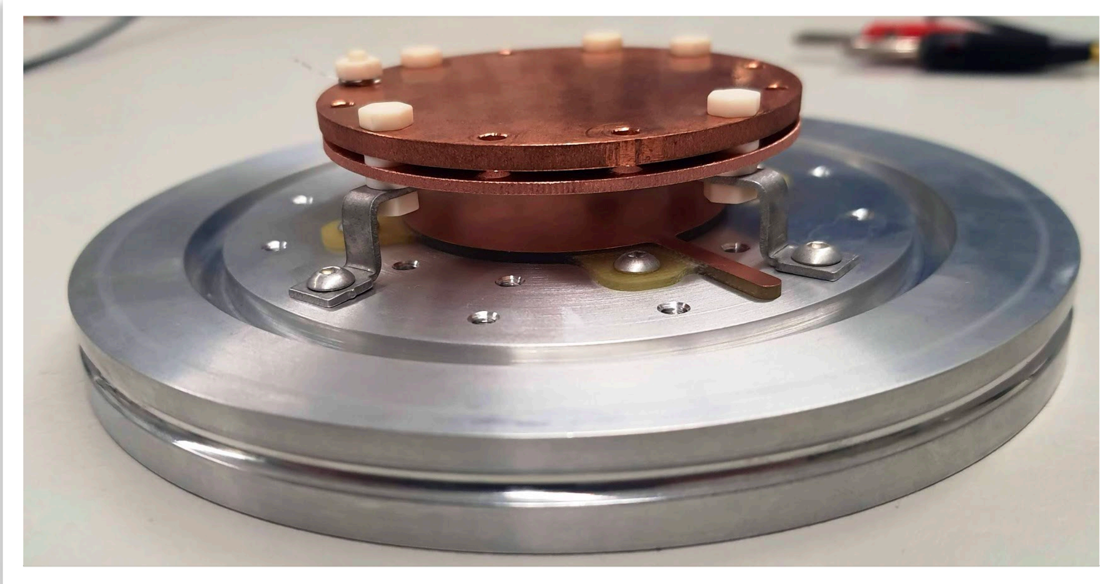
https://kt.cern/technologies/timepix3

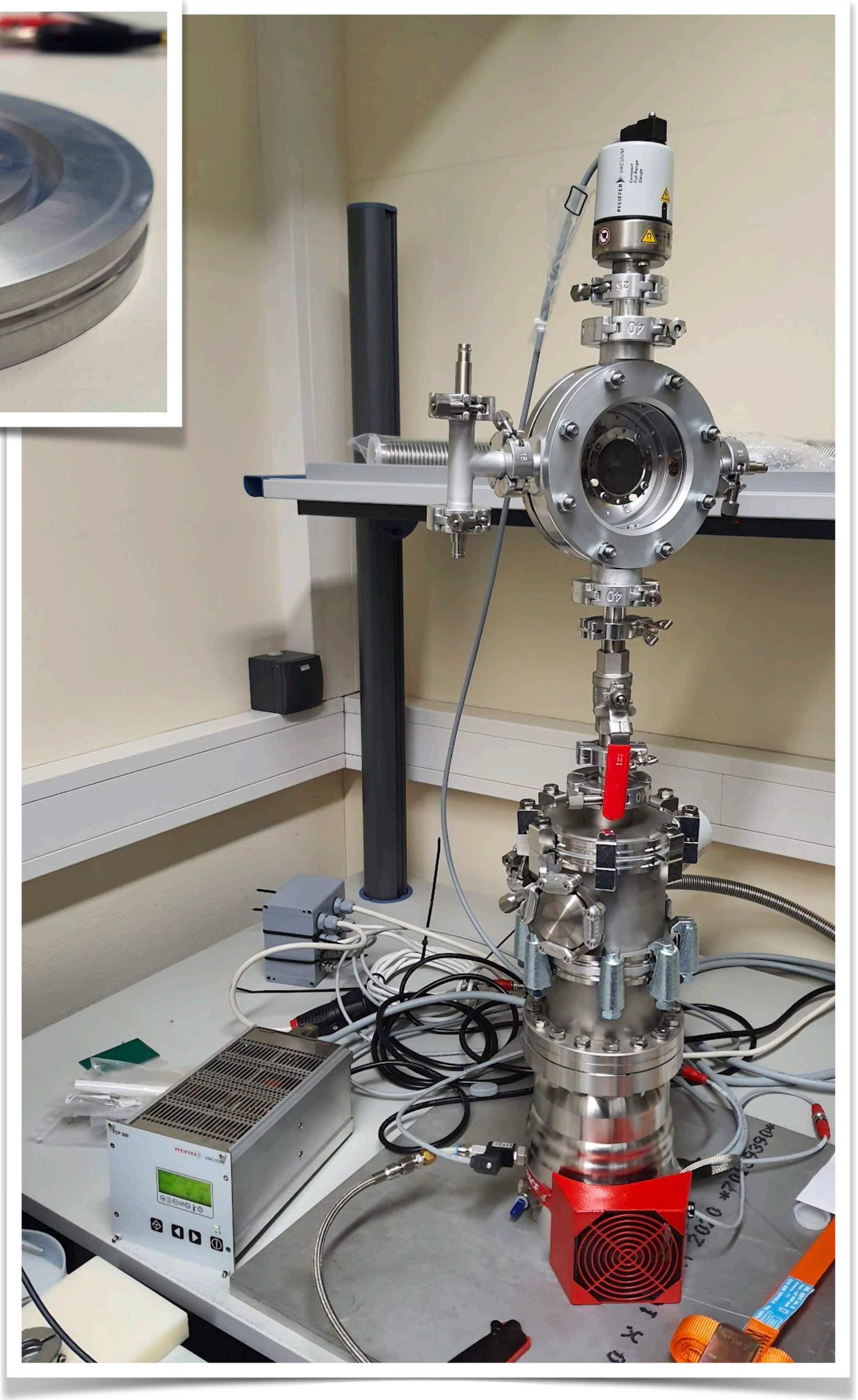


nMCP current status and plans

- All the mechanical components are ready and tested.
- Vacuum level of 10^{-7} mbar is achieved.
- High voltage tests are finished.
- Readout electronic designs are ongoing.
- Readout software mostly ready with multi-chip support developments ongoing

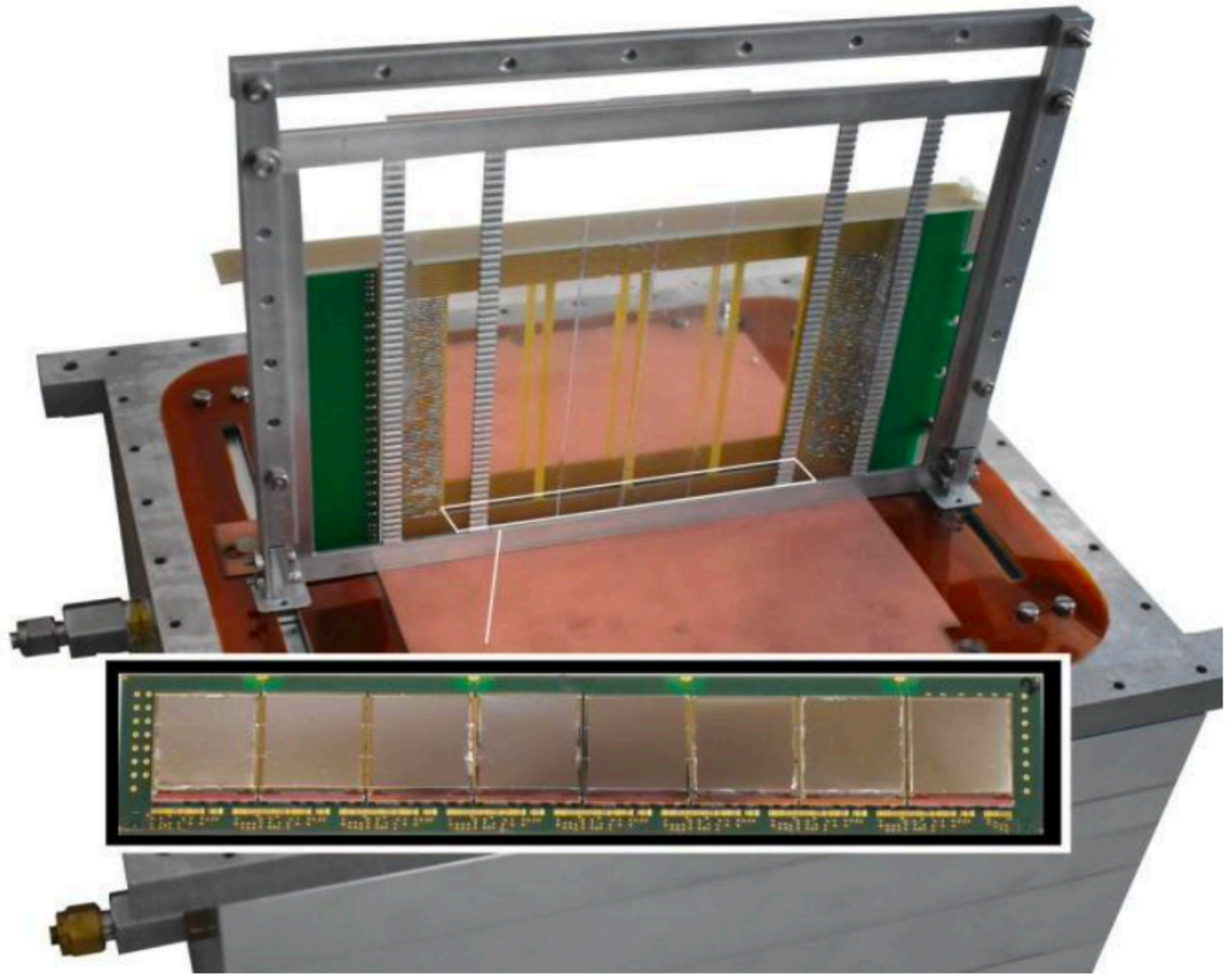






Novel neutron detectors

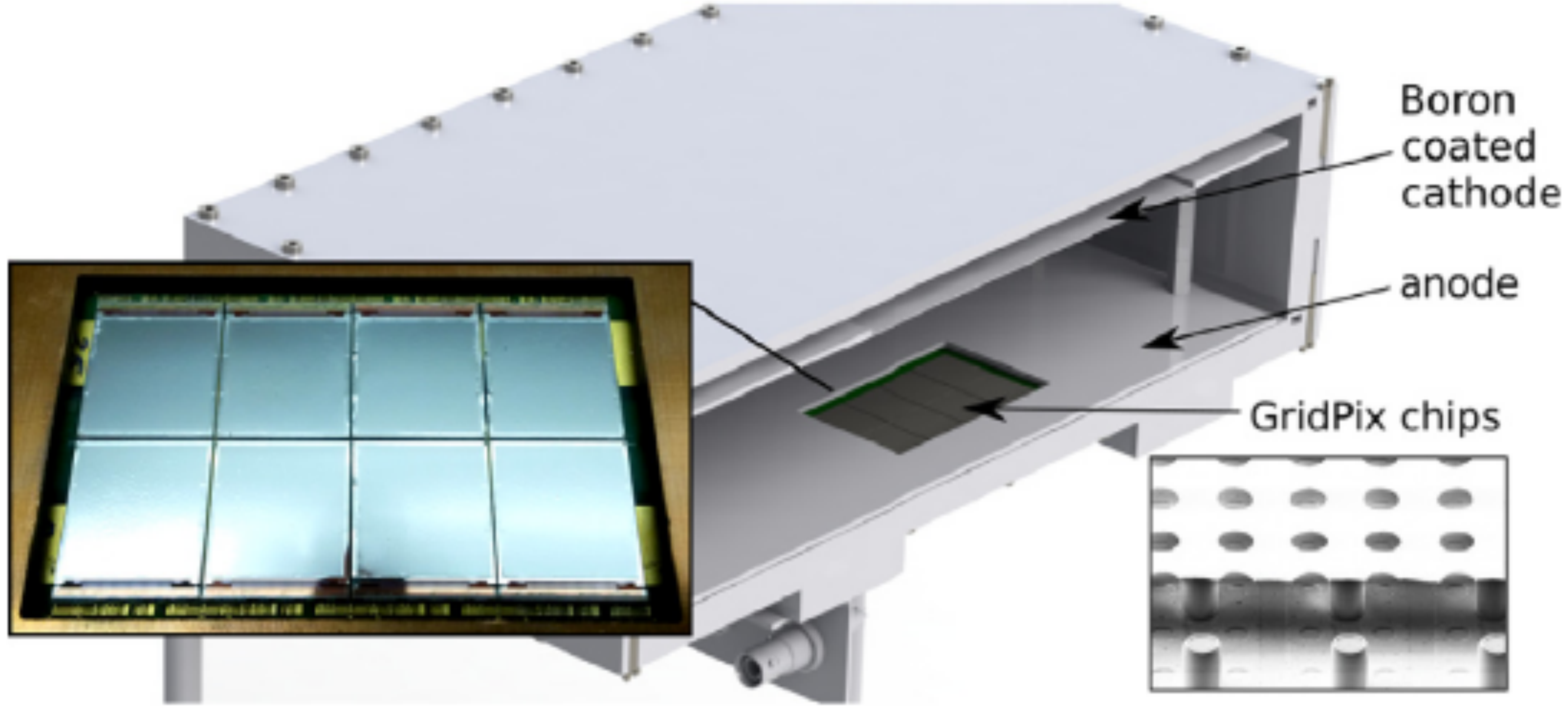
Neutron Micro Channel Plate (nMCP)



Neutron Time Projection Chamber (nTPC)

GEM based neutron detector

Preliminary study



- 8 GridPixes based on Timepix
- GridPixes at a distance of 3.8 cm
- Spatial resolution < 100 μm

Physica B: Condensed Matter 551 (2018) 517–522

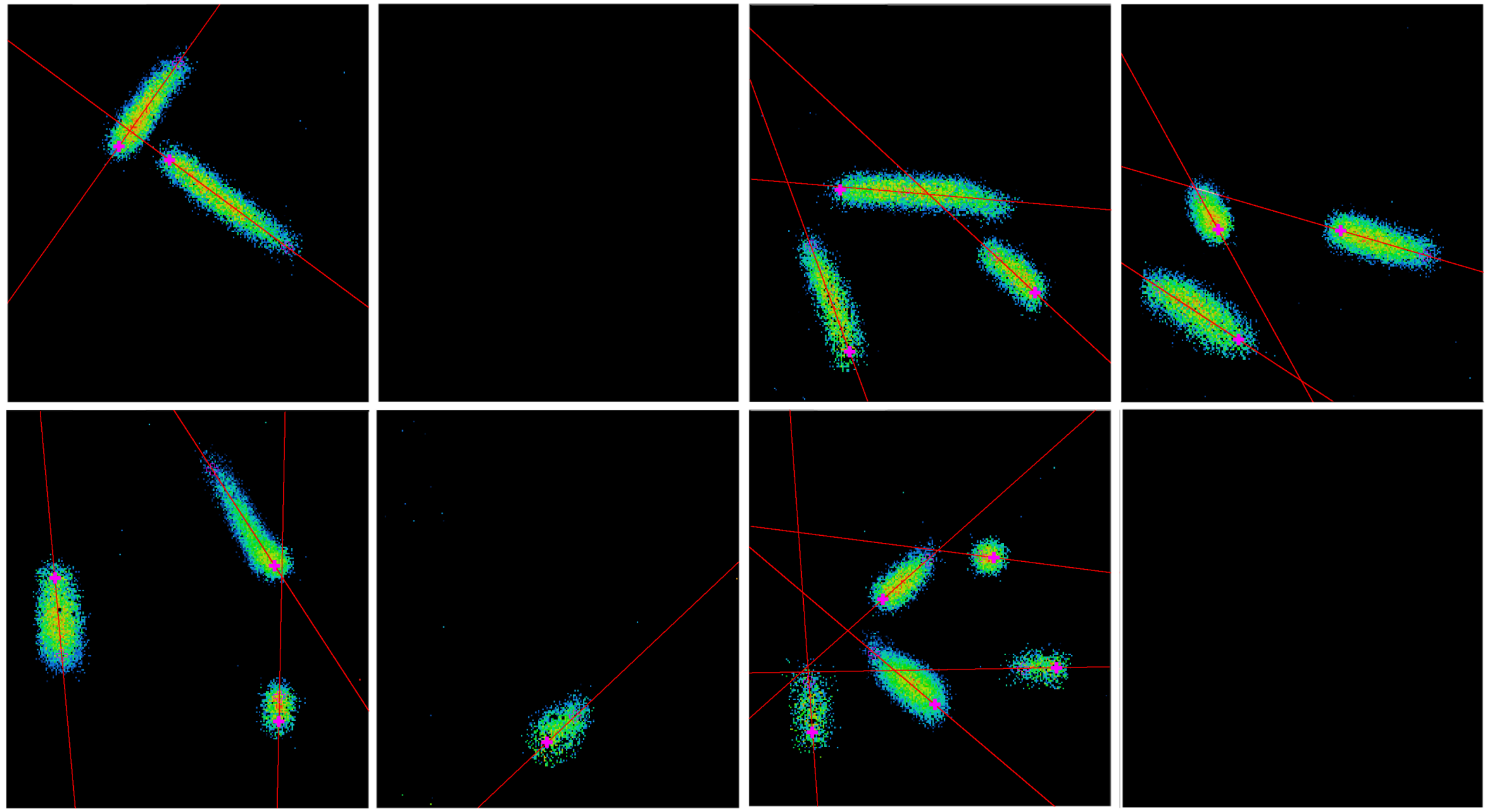
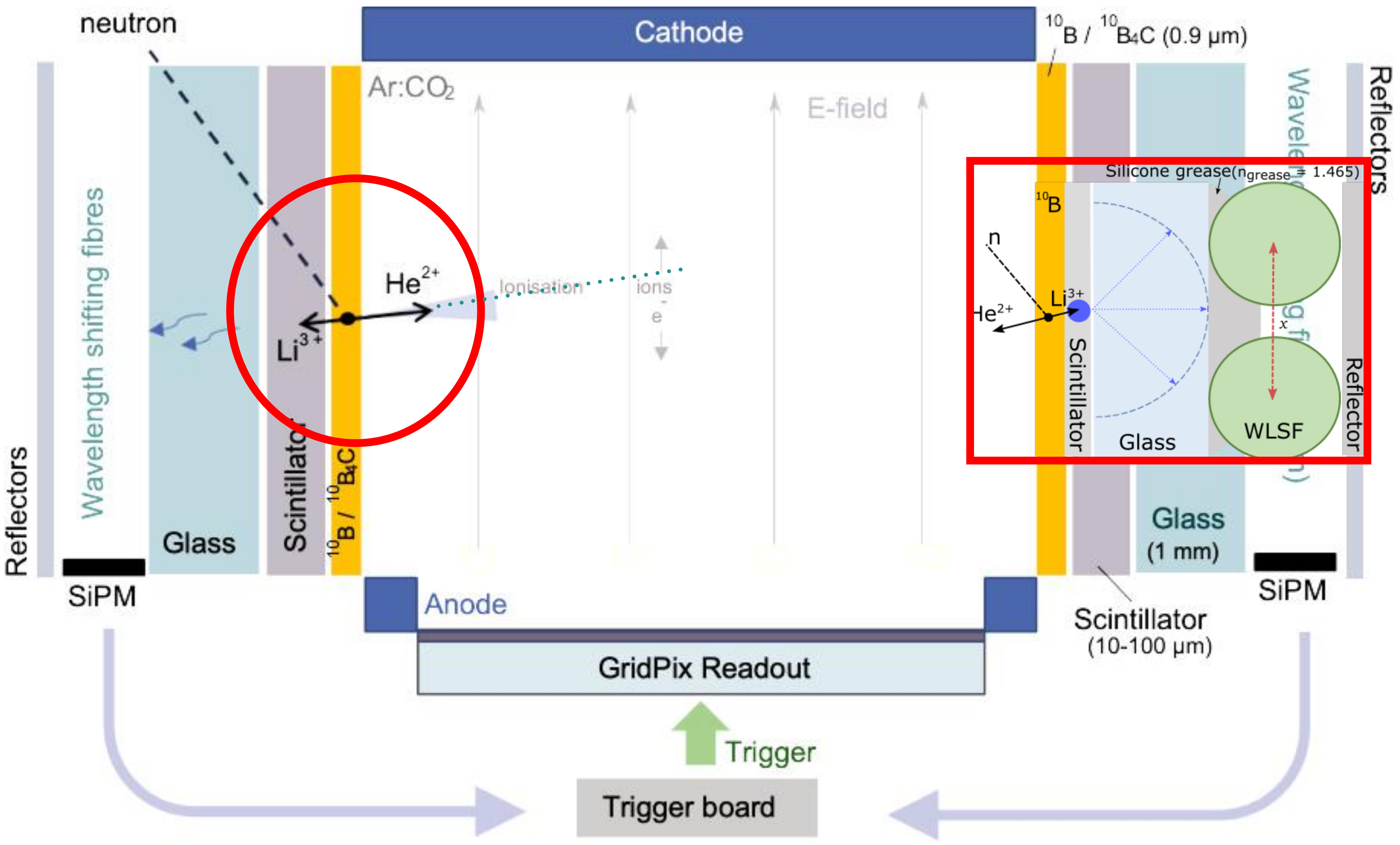


Figure 5: The event display showing exemplarily a collection of neutron conversions on the full Octoboard with Ar:CO_2 80:20 at 350 V grid voltage. Two of the chips are disabled.

nTPC detector concept

Side wall:

- ~1 µm ^{10}B layer
- 20 µm scintillator
- Quarz light guide
- Wavelength shifting fibers
- SiPMs for reading out WFSLs
- Reflector



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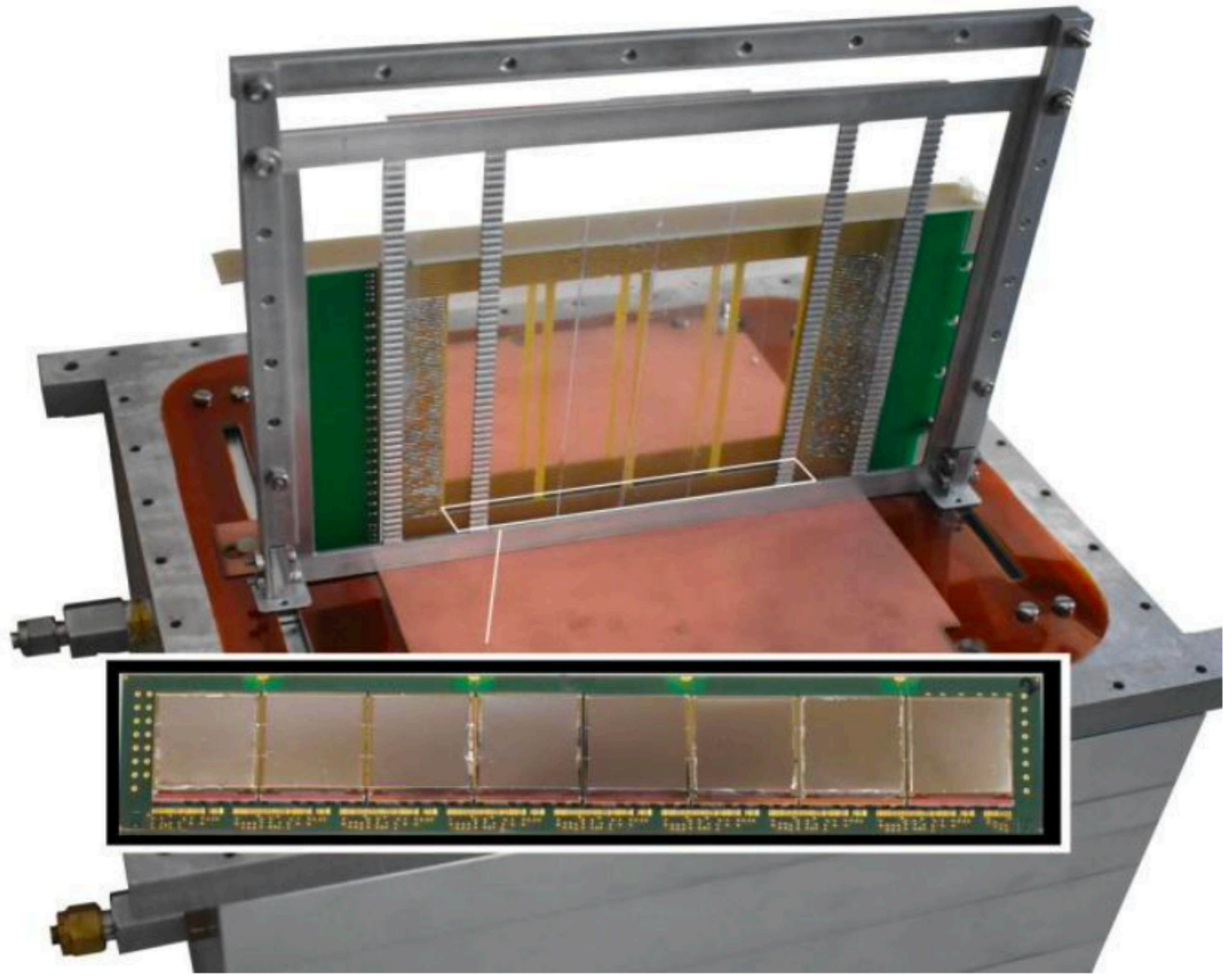
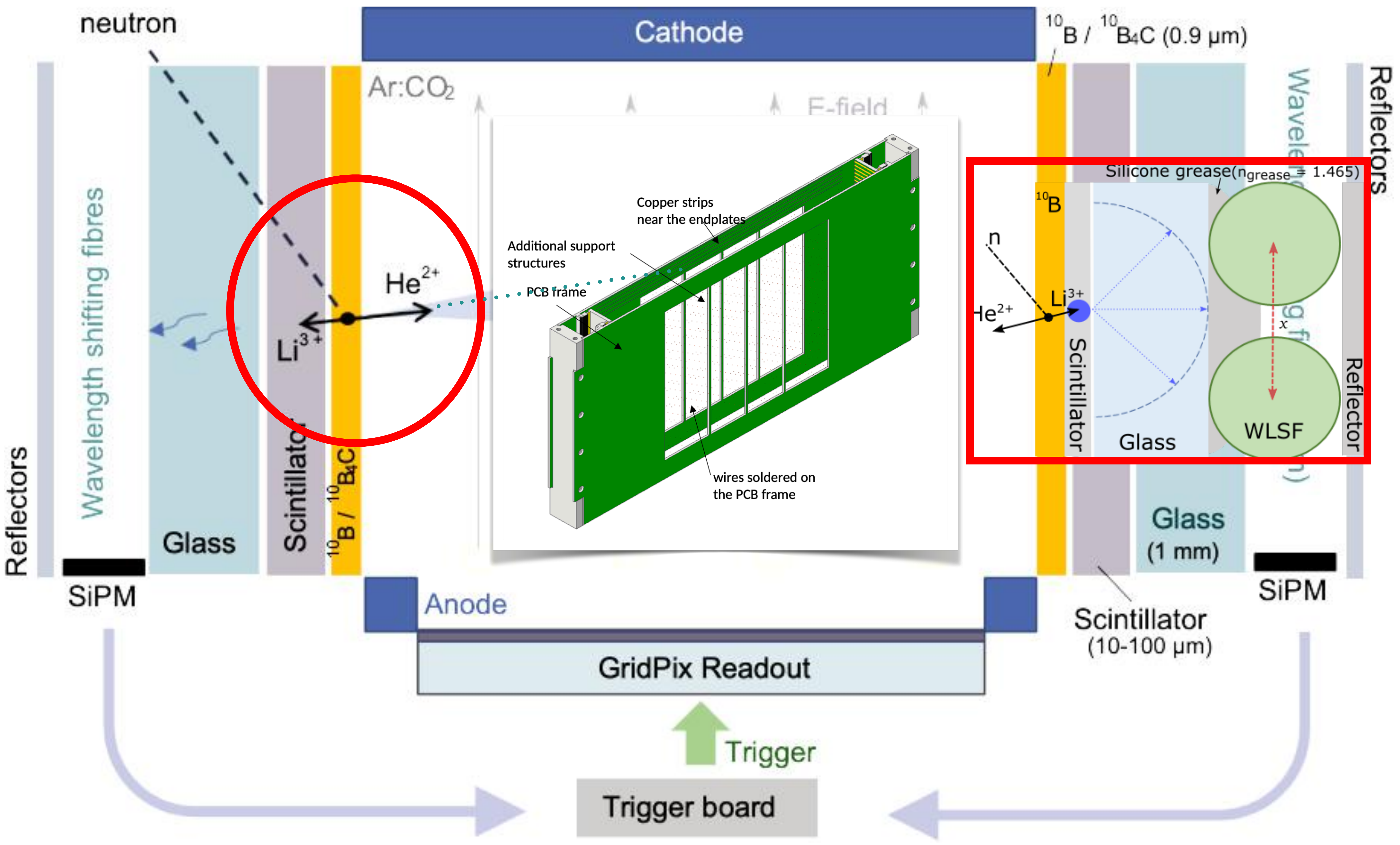
	$^{10}\mathrm{B} + \mathrm{n} \rightarrow {}^{7}\mathrm{Li}^{*} + \alpha + 2.31\,\mathrm{MeV}\ (94\%)$

nTPC detector concept

Mechanical Construction

- Detector is designed and built
- Field cage is ready
- Active area 10cm x 10cm

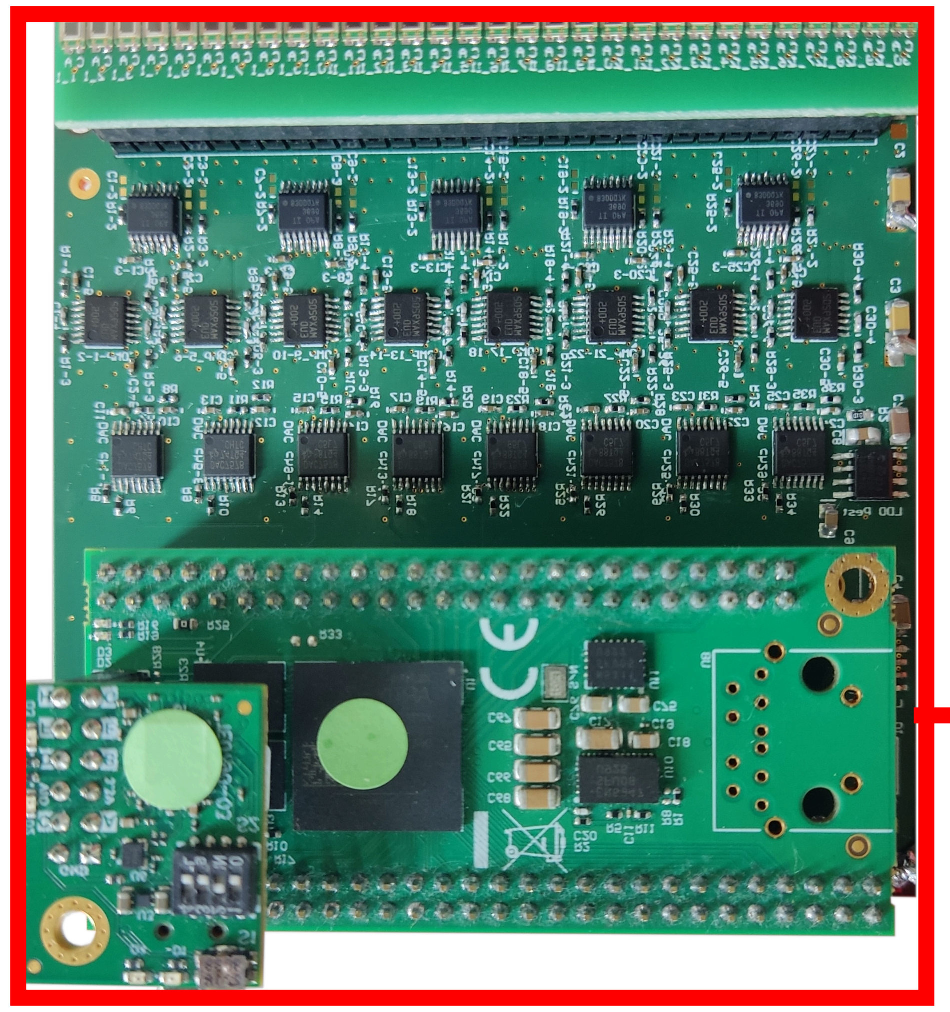


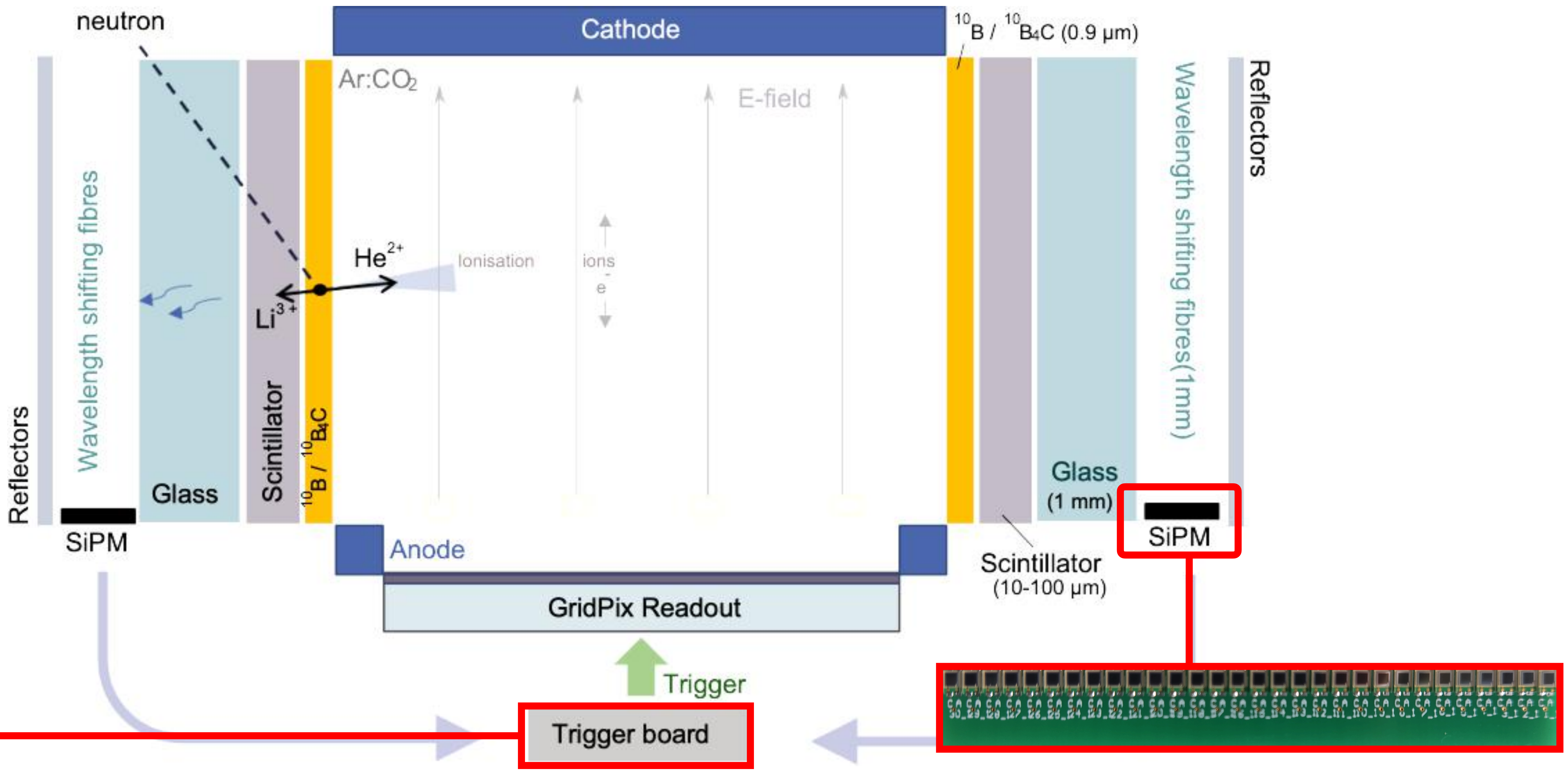


nTPC detector concept

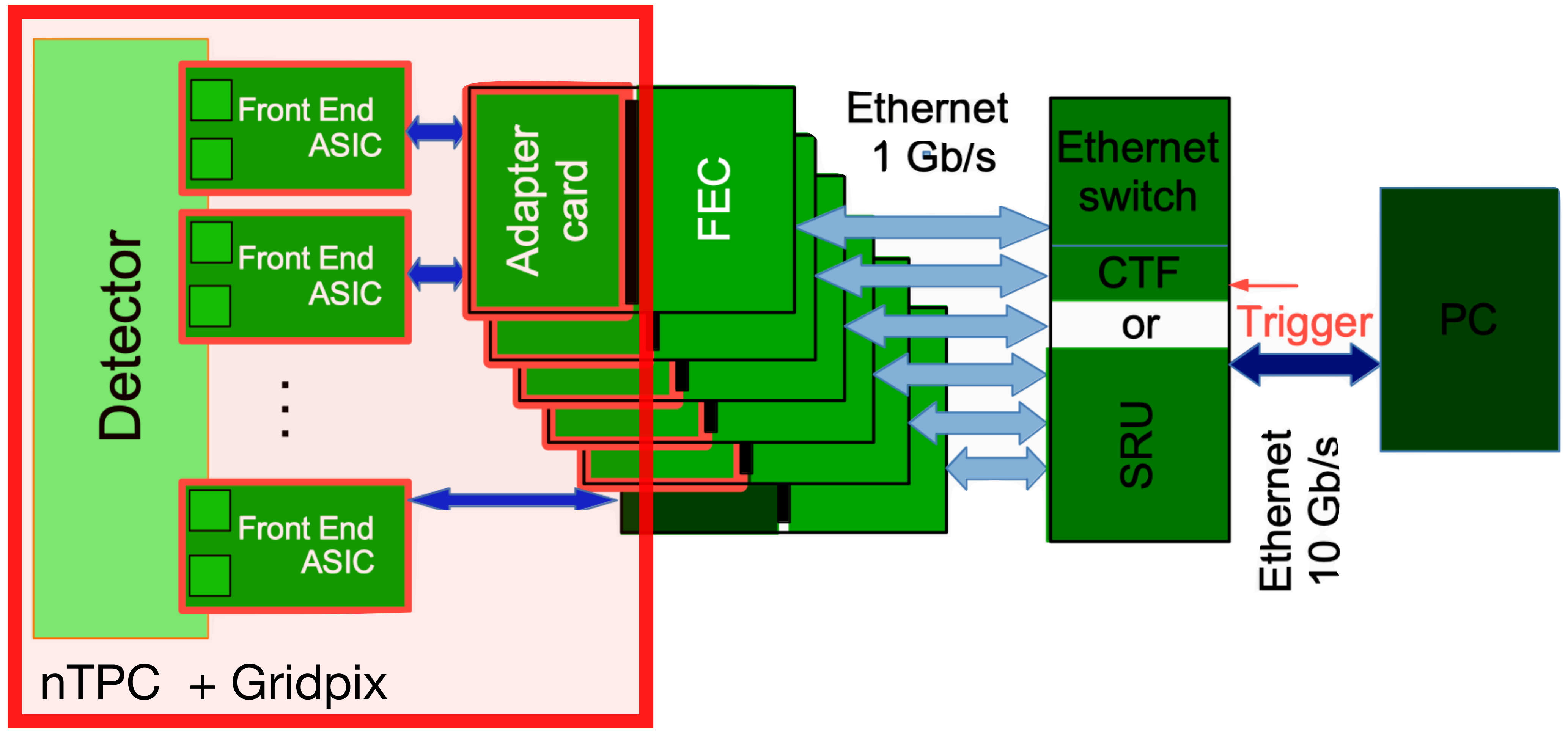
Trigger

- SiPM feeding the Trigger Board
- GridPix readout

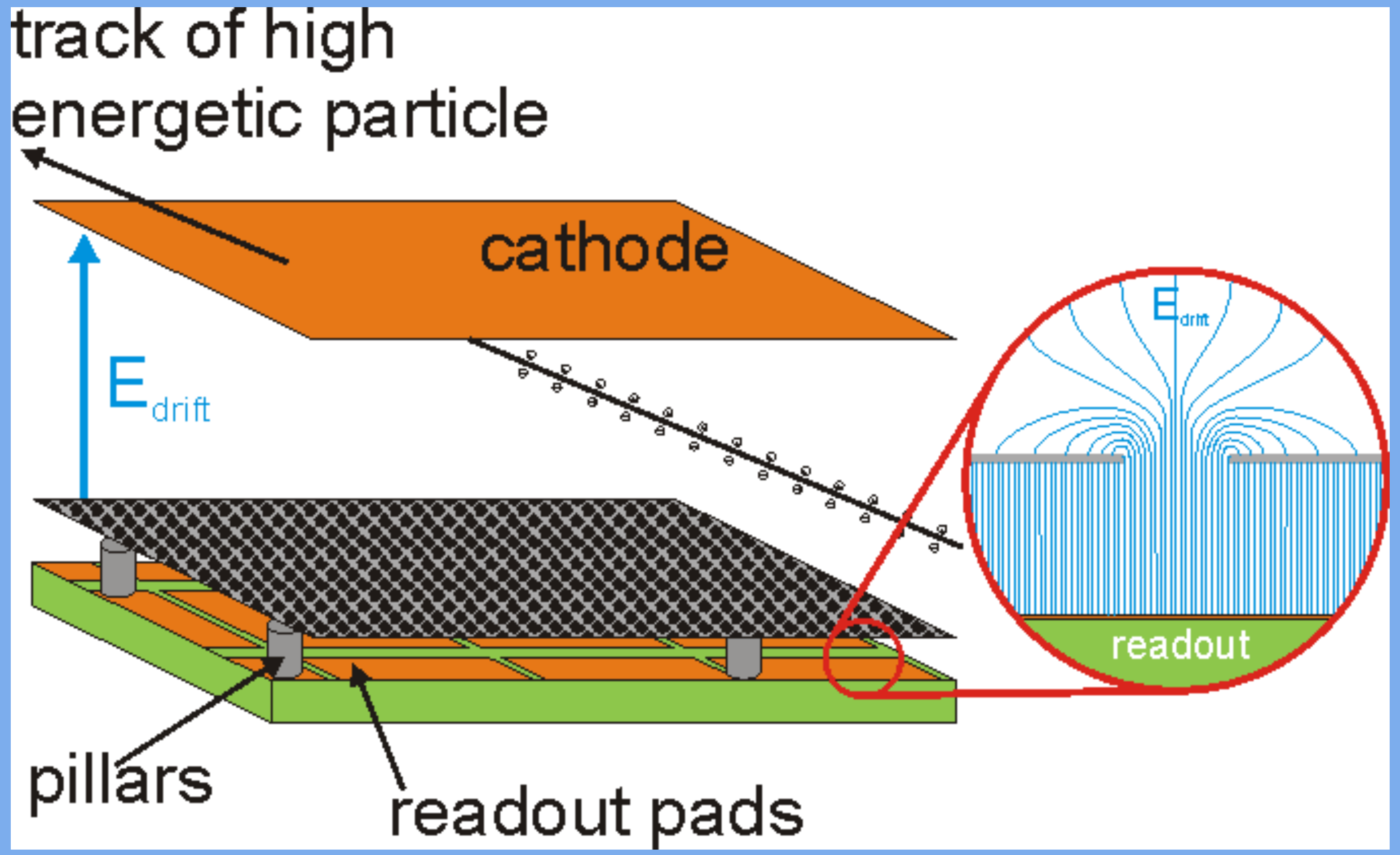


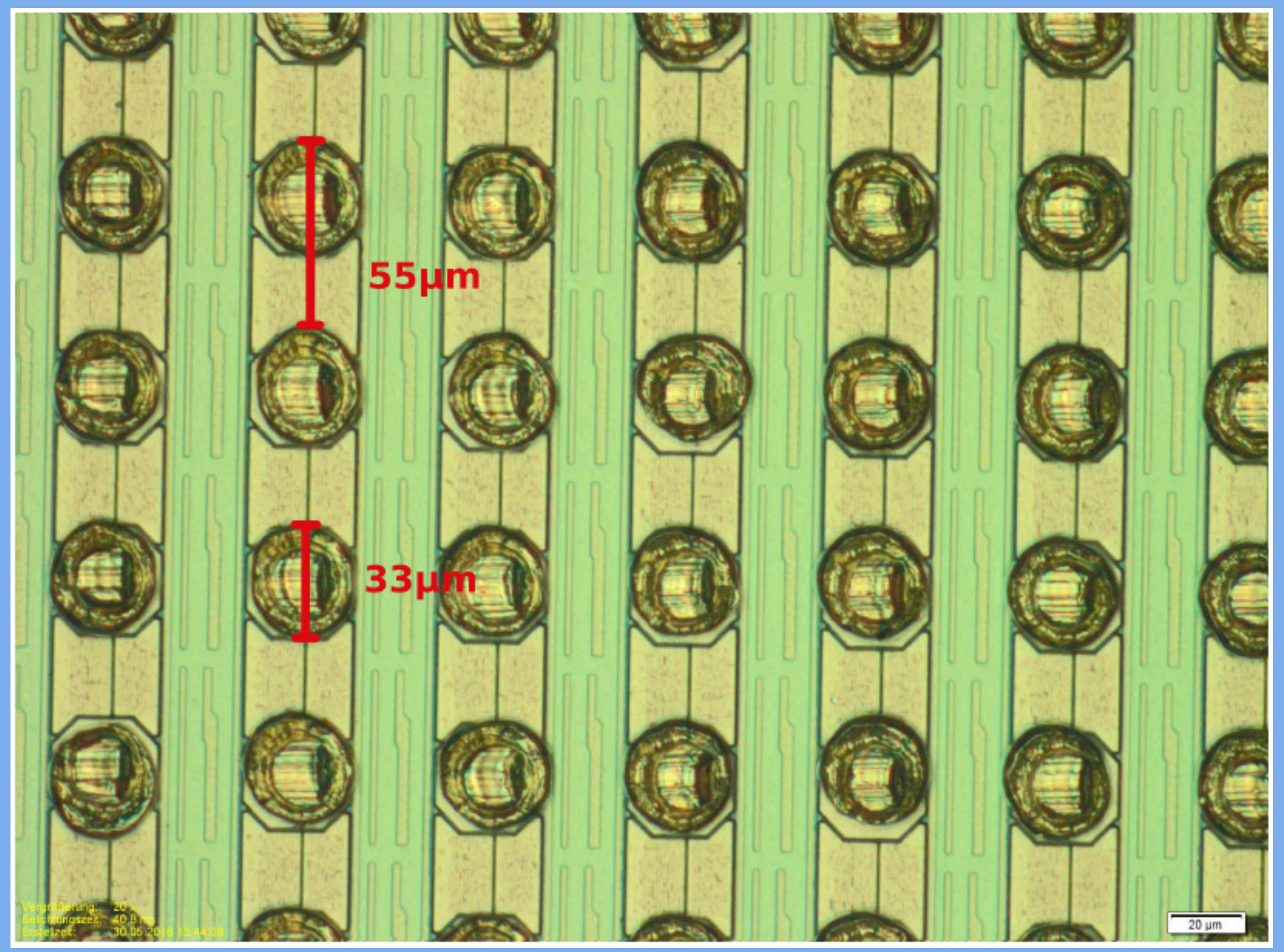


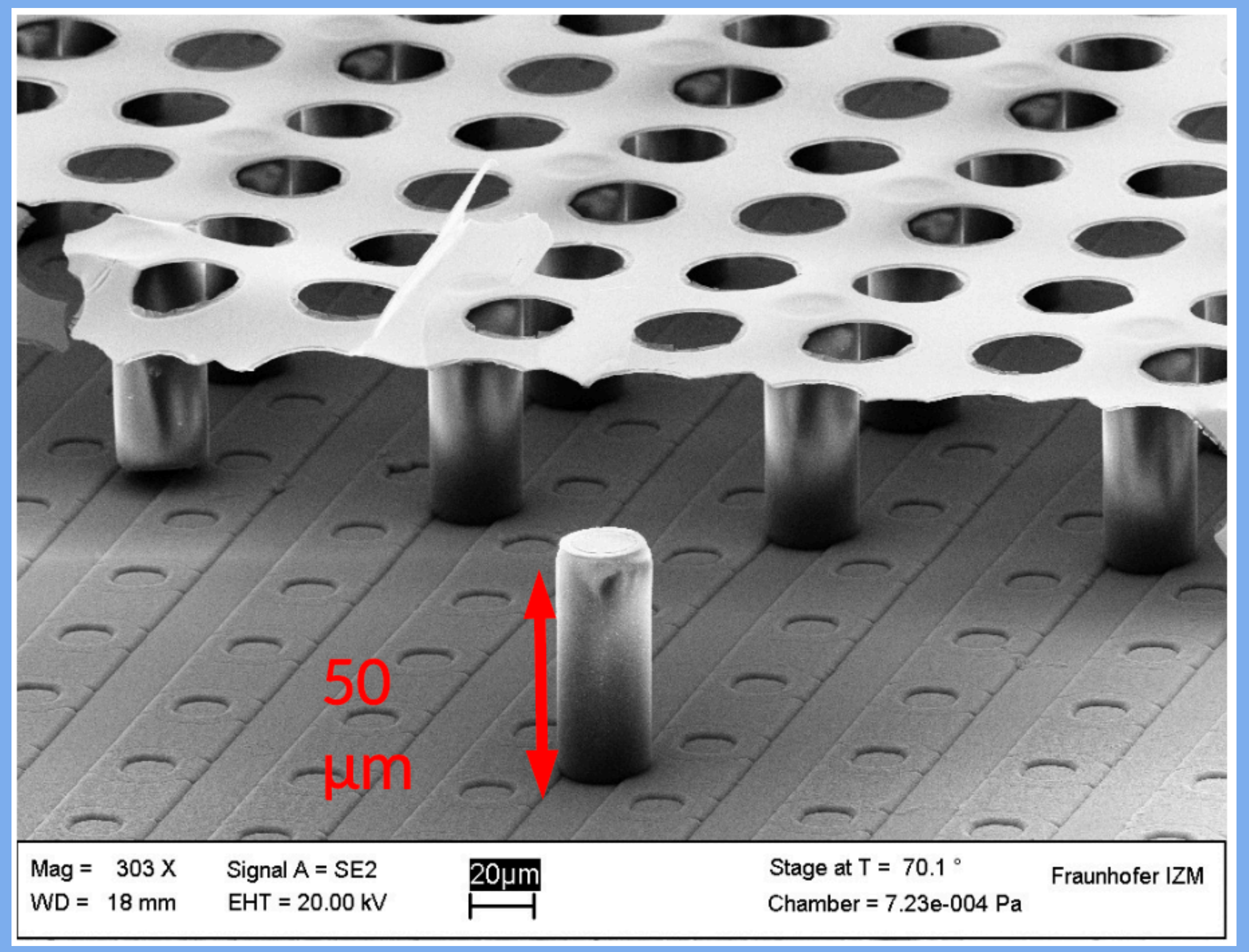
GridPix



- Invented and developed by Nikhef and University of Twente
- Used in CAST (up to seven Timepix), proposed for ILD TPC (ILC), EIC TPC and IAXO with Timepix3.





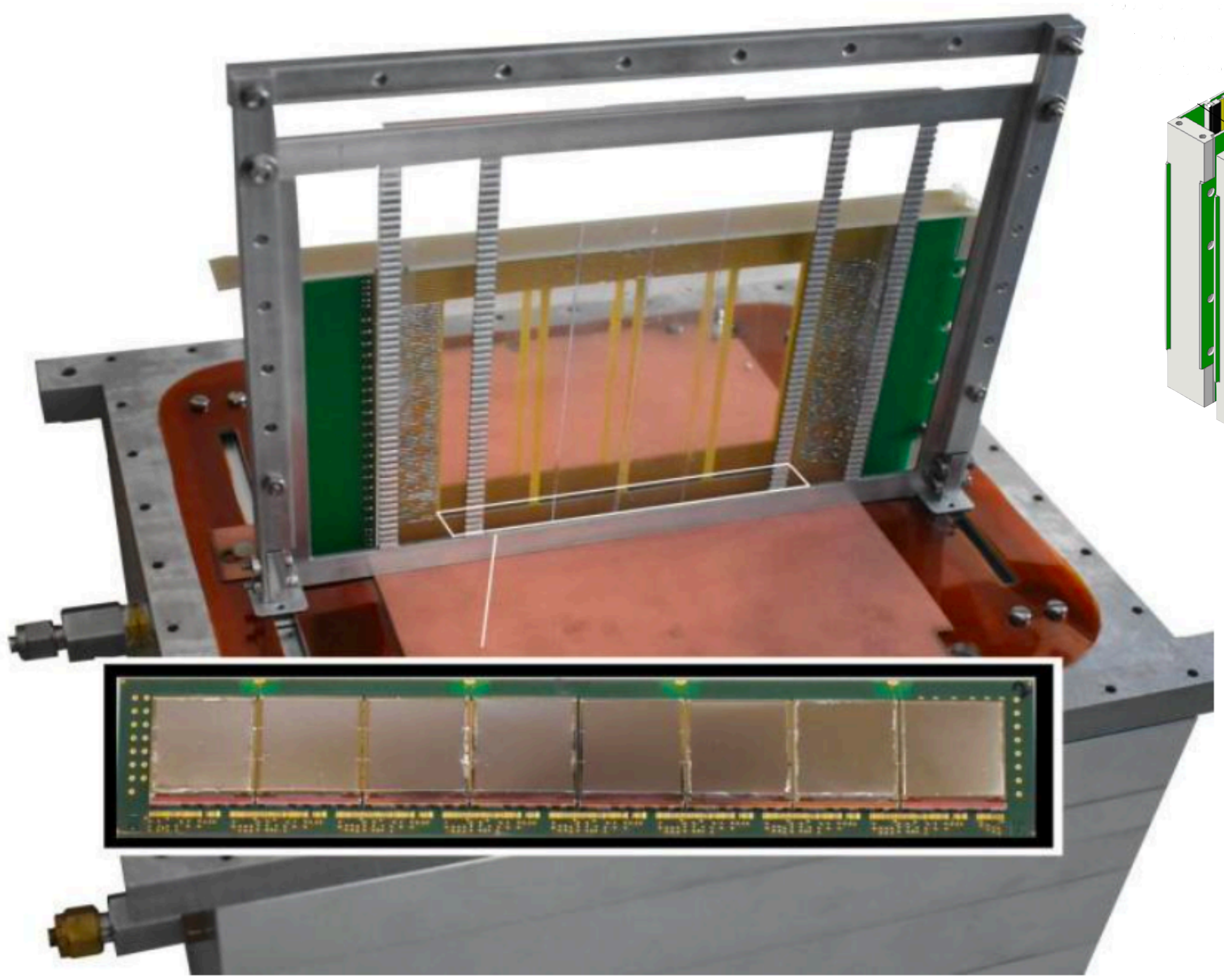


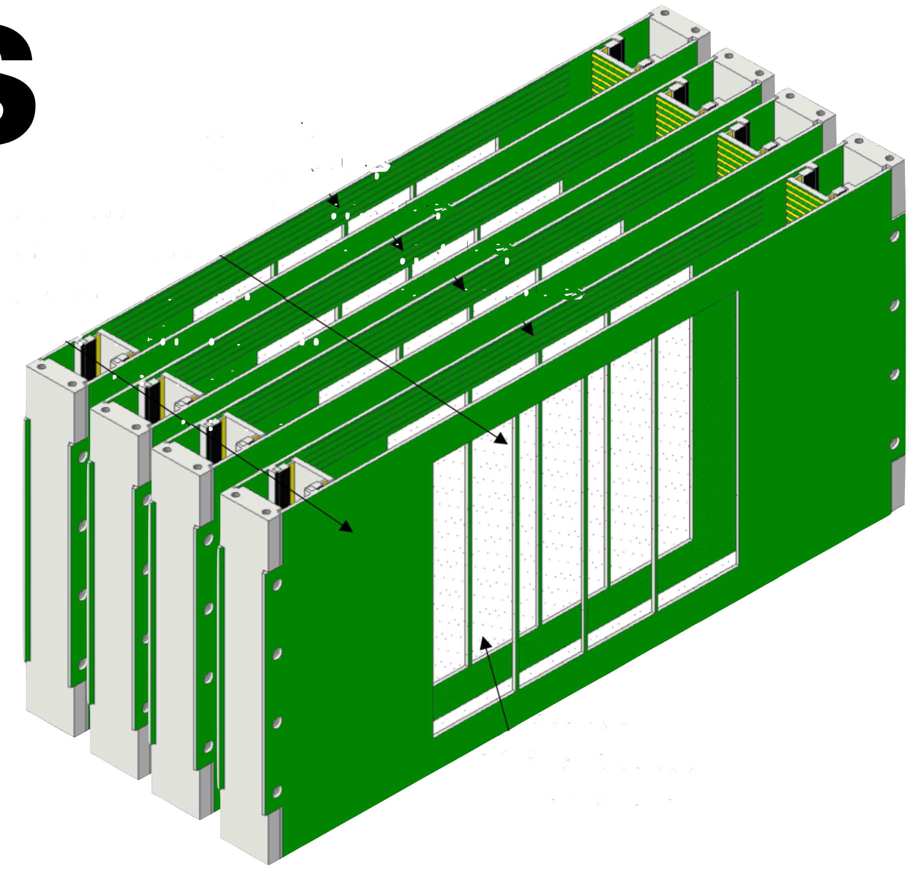
NIM A535 (2004) 506-510
NIM A845 (2017) 233-235

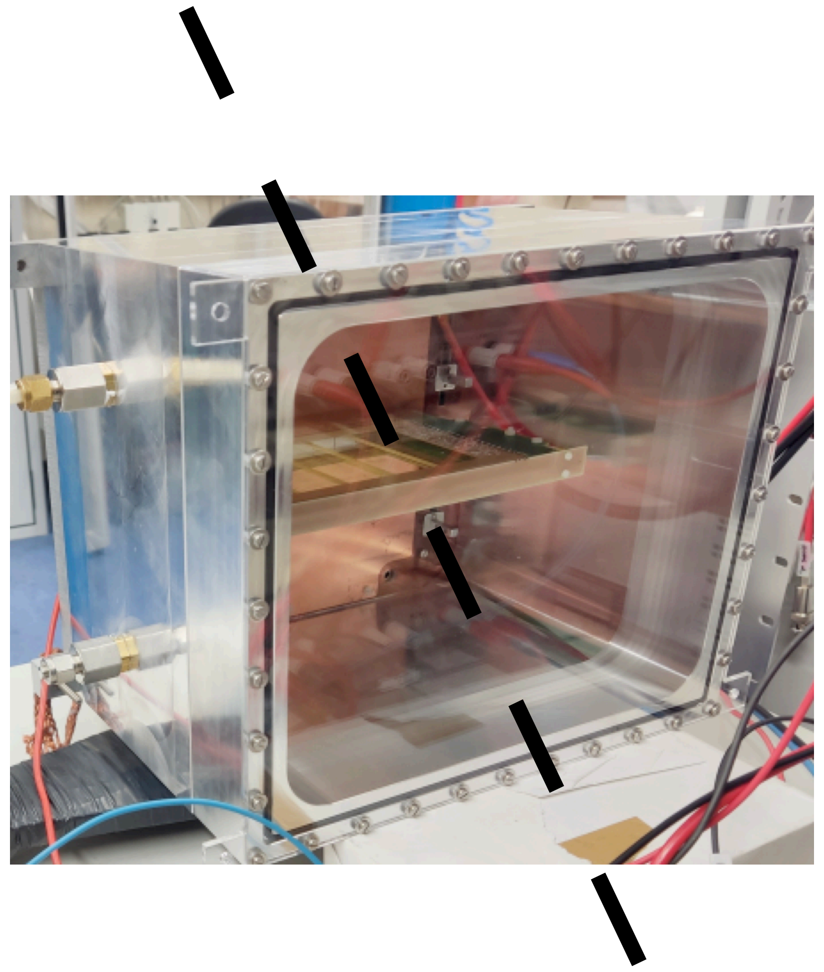
Micromegas + Bare Pixel ASIC = GridPix

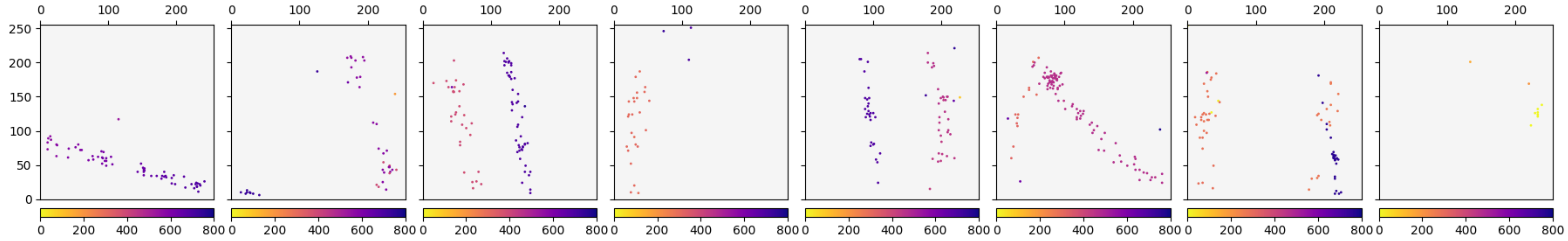
nTPC current status and plans

- Spatial resolution < 100 µm is aimed for.
- Cosmic muon tests proves very low track distortion close to the field cage
- Currently: Implementing boron layers.
- Plan to increase the number of the layers for better neutron detection efficiency.









Novel neutron detectors

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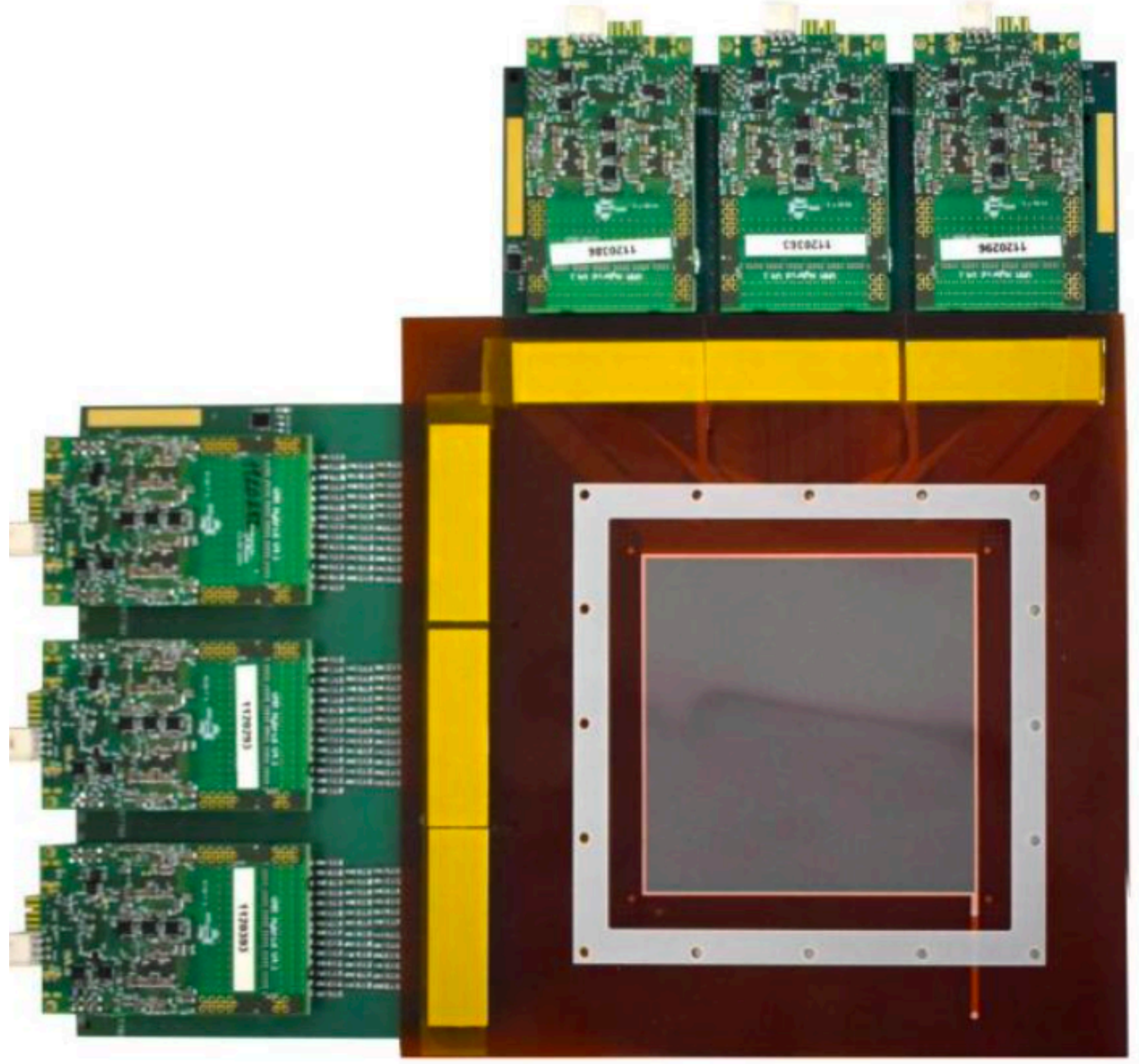
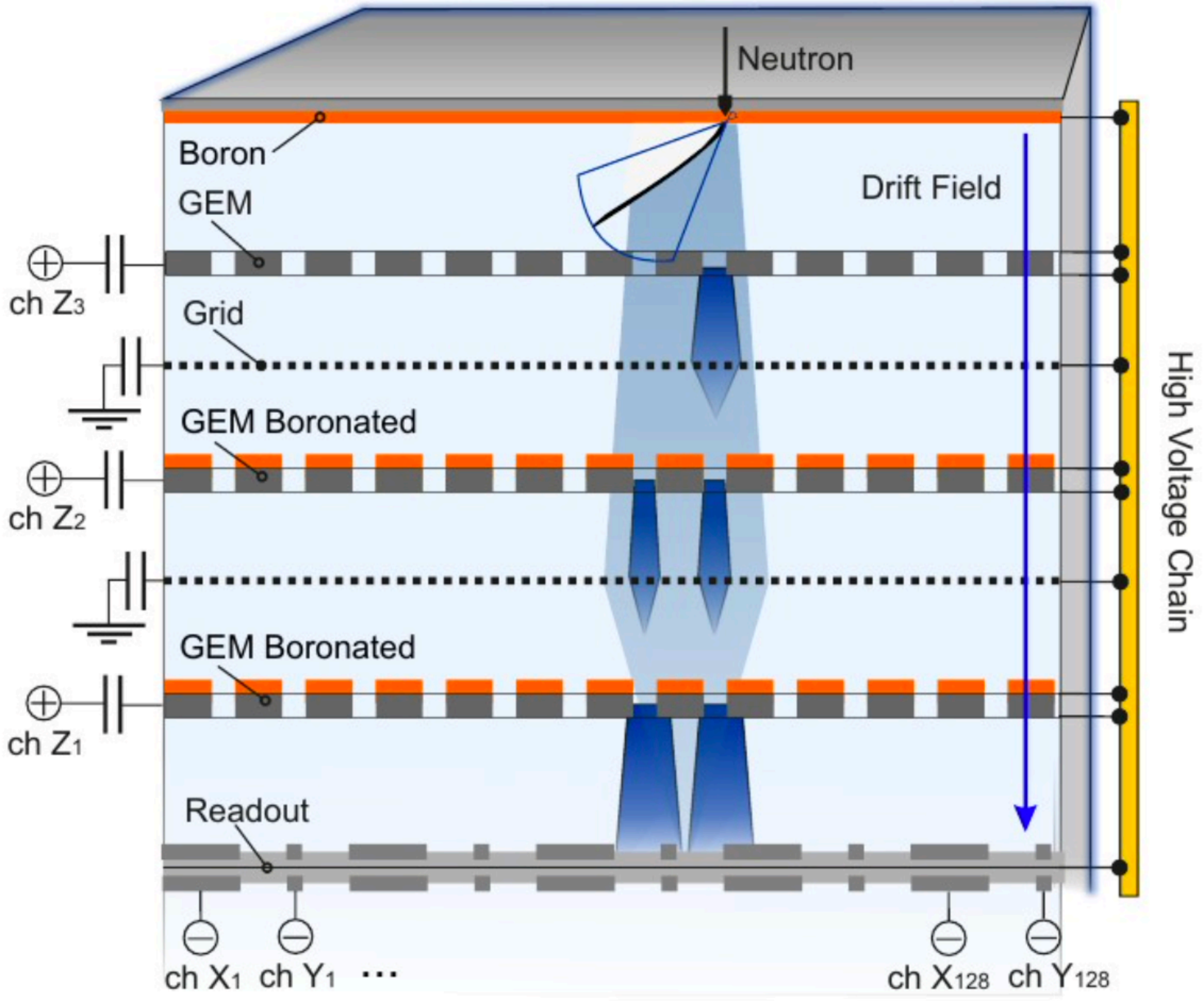
Neutron Time Projection Chamber (nTPC)



GEM based neutron detector

GEM based neutron detector concept

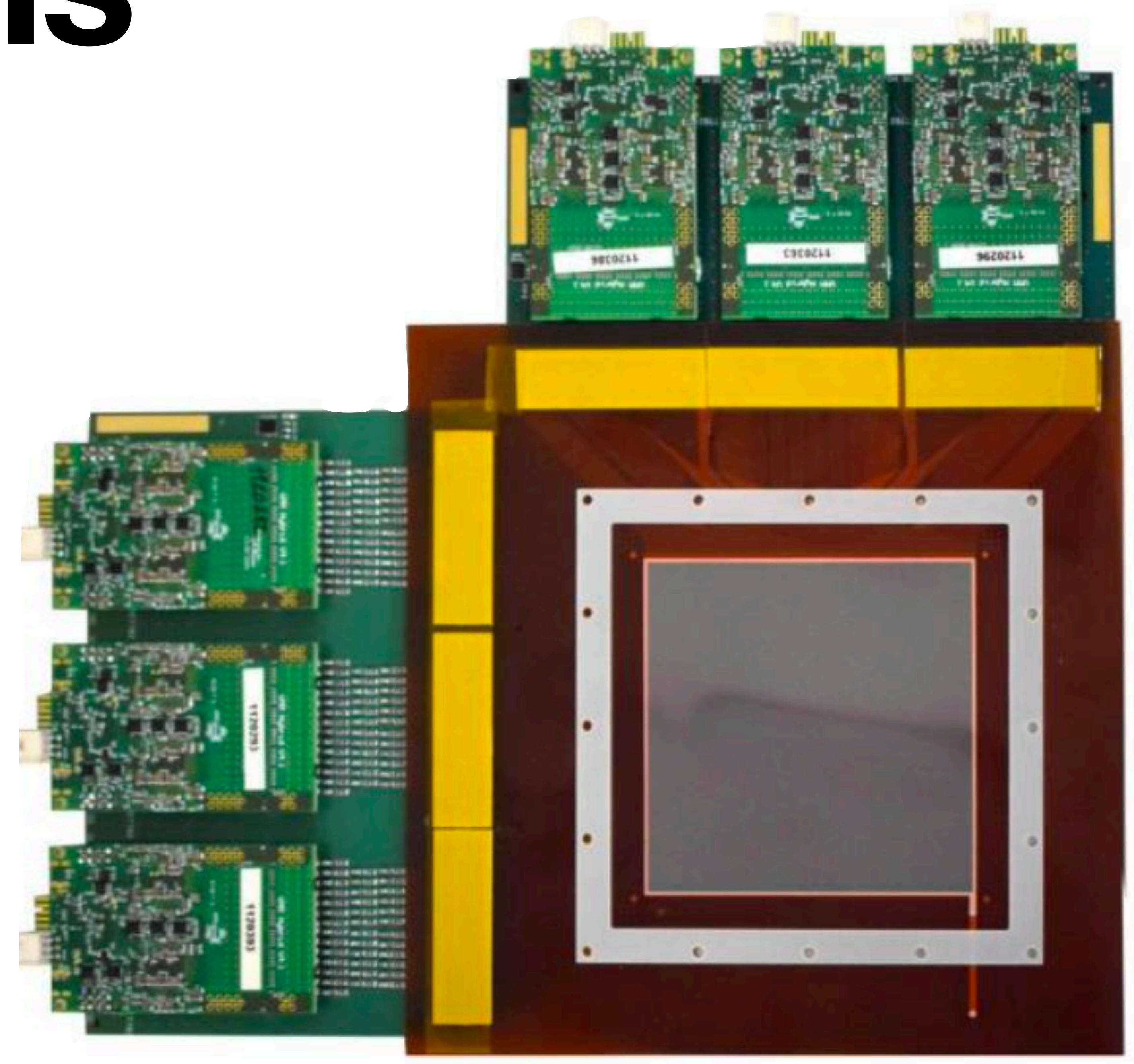


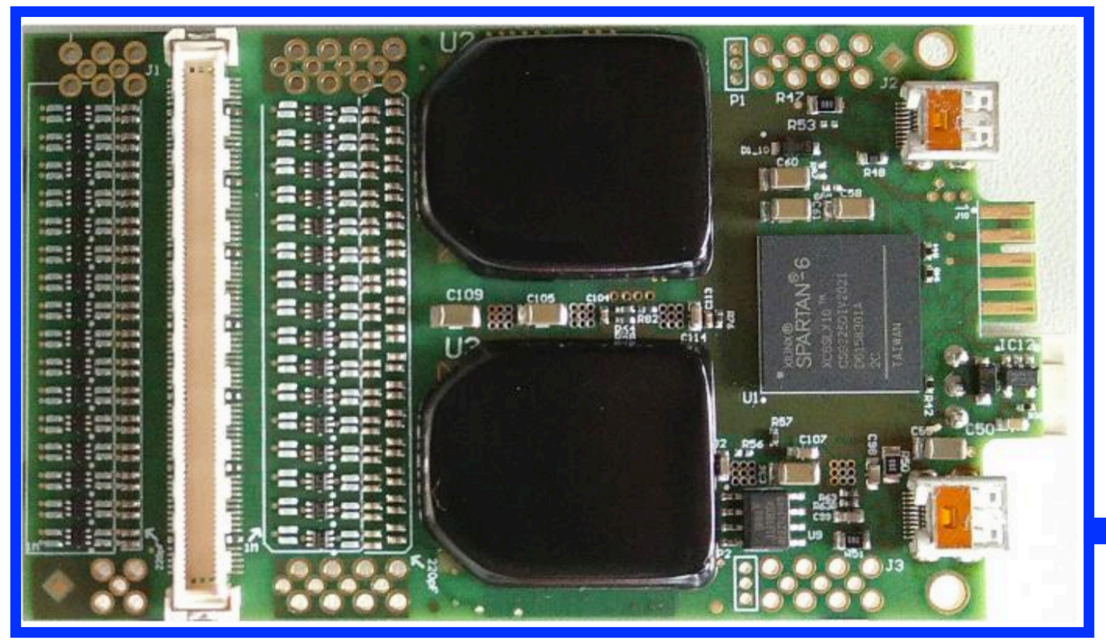
CASCADE detector: PhD thesis M. Köhli

- Similar to the CASCADE detector used at RESEDA/MIRA instrument (MIEZE) at the FRM II
- Our detector:
  - Independent layers, each with own cathode, coating and readout
  - Thin BC_4 coating $\Longrightarrow$ Many layers needed
  - Increase the number of independent layers

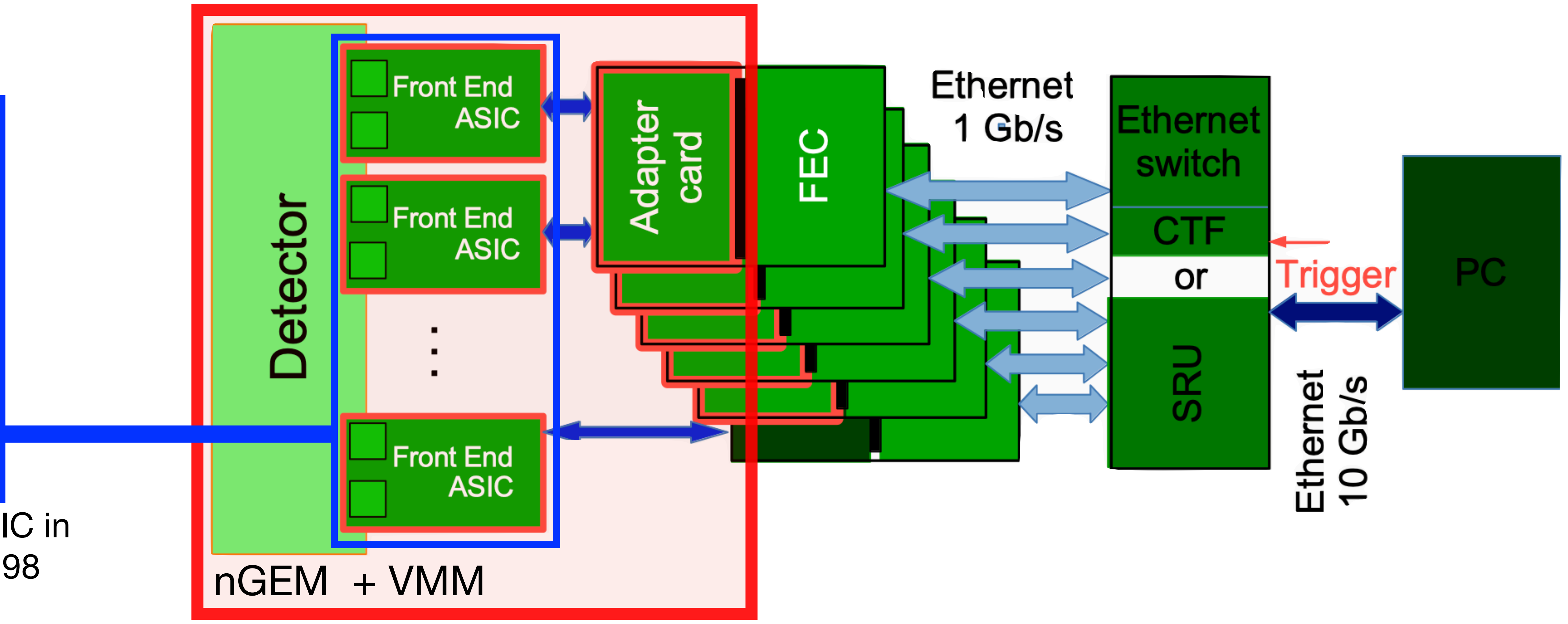
nGEM current status and plans

- A first test layer is being assembled and can be equipped with readout electronics
- Active area: 10×10 cm² and plan to upgrade to 30×30 cm² in future
- Main challenge: significantly large number of electronic channels
- VMM3a-based version of the Scalable Readout System (SRS) of the RD51 collaboration
- PhD position available

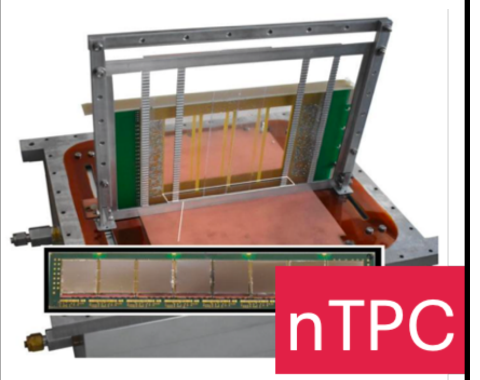




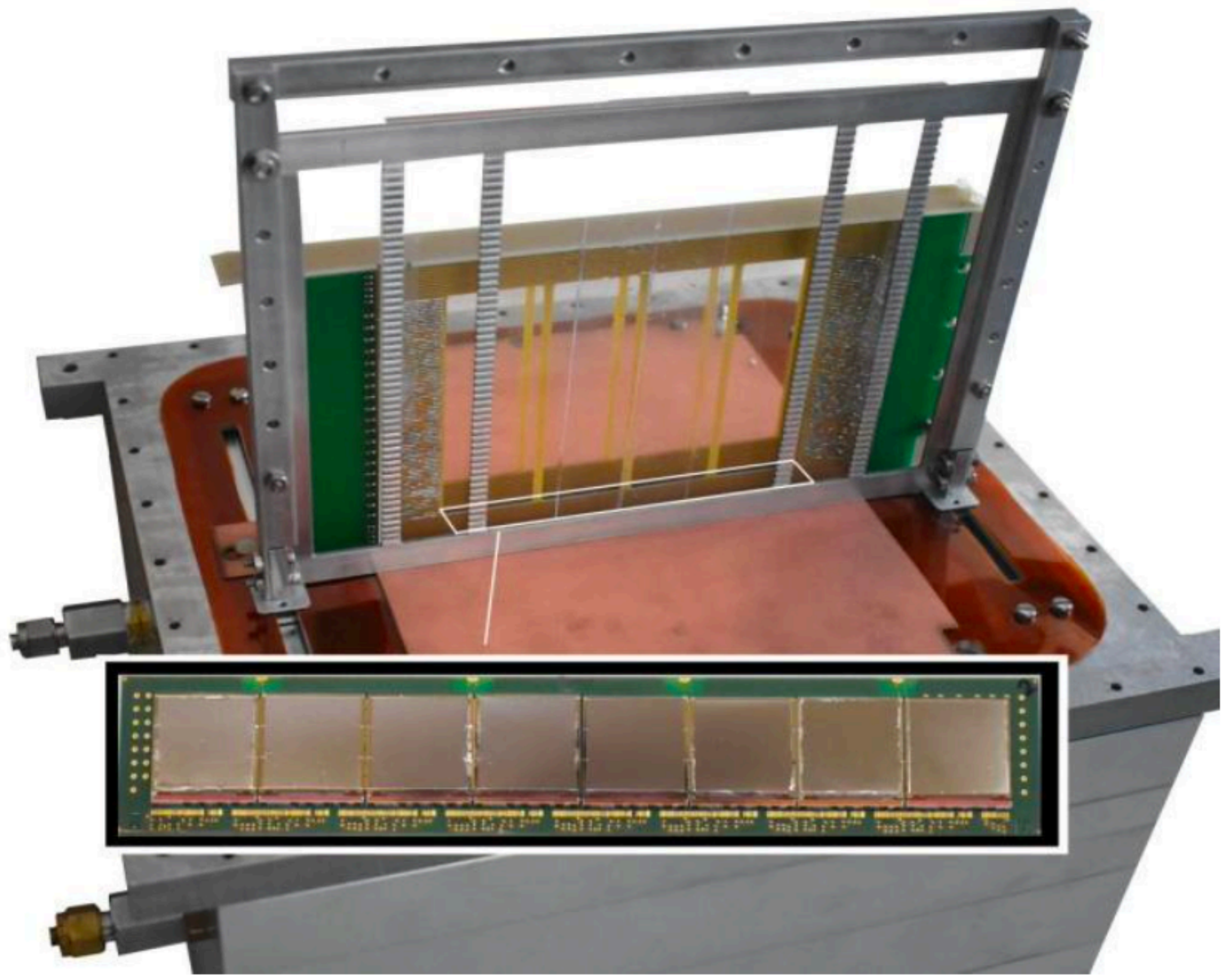
M. Lupberger et al. "Implementation of the VMM ASIC in the Scalable Readout System" NIMA 903 (2018) 91-98

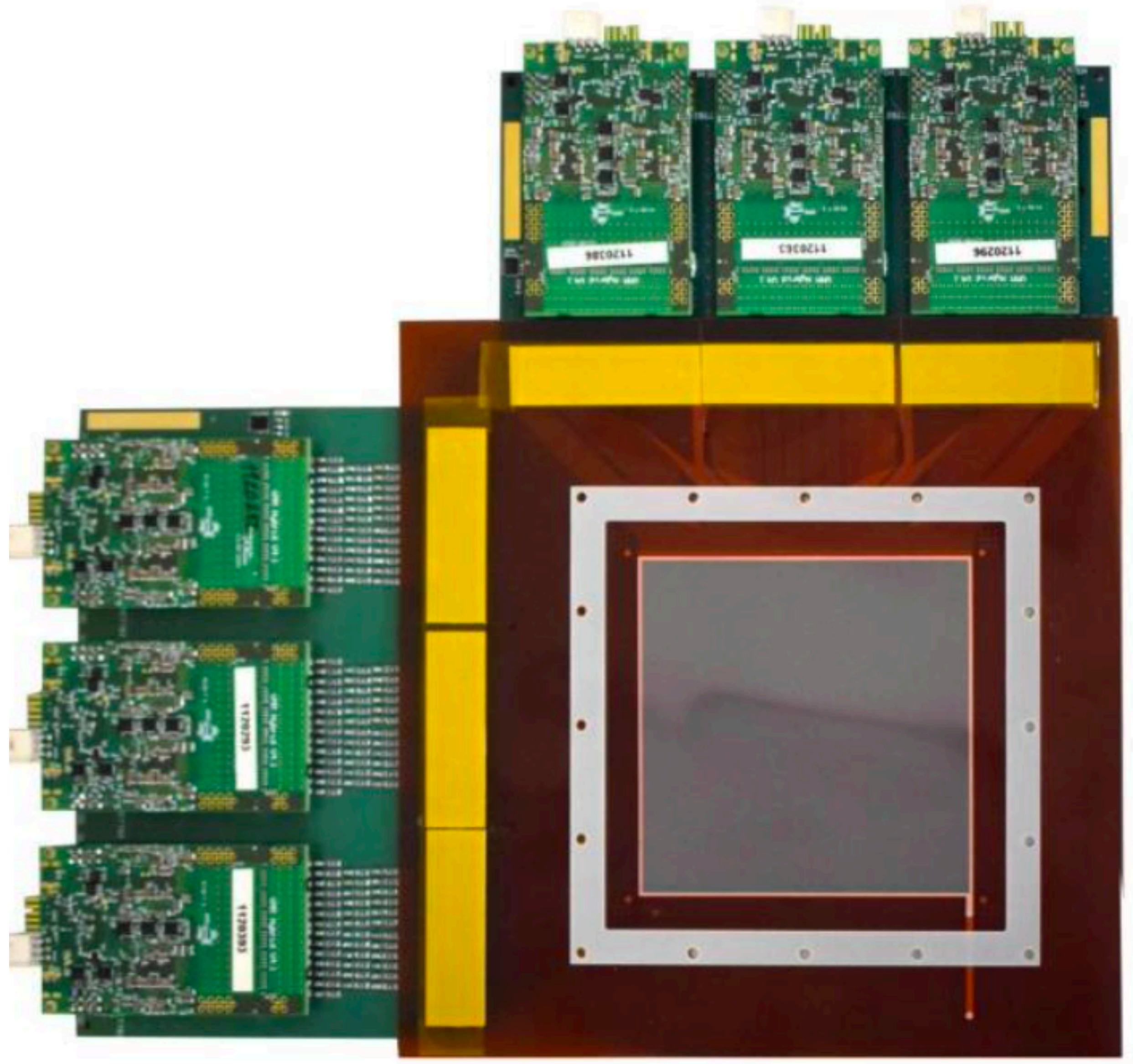


Summary

Detectors	Readout Electronics	Active Area	Expected resolution	Benefits	Challenges	Possible Fields of Applications
	Timepix3 + SRS	2.8cm x 2.8cm	O(10 μm)	High position and time resolution	Vacuum requirements	Neutron imaging and radiography
	GridPix + SRS	10cm x 10cm	O(10-100 μm)	Good position and time resolution	Trigger setup	Neutron scattering experiments
	VMM3a + SRS	10cm x 10cm (30cm x 30cm)	O(100 μm)	High Rate (Large Area)	Large number of electronic channels	Neutron scattering experiments

Looking forward for future collaborations!





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