The Forschungs und Technologiezentrum Detektorphysik (FTD) at Bonn

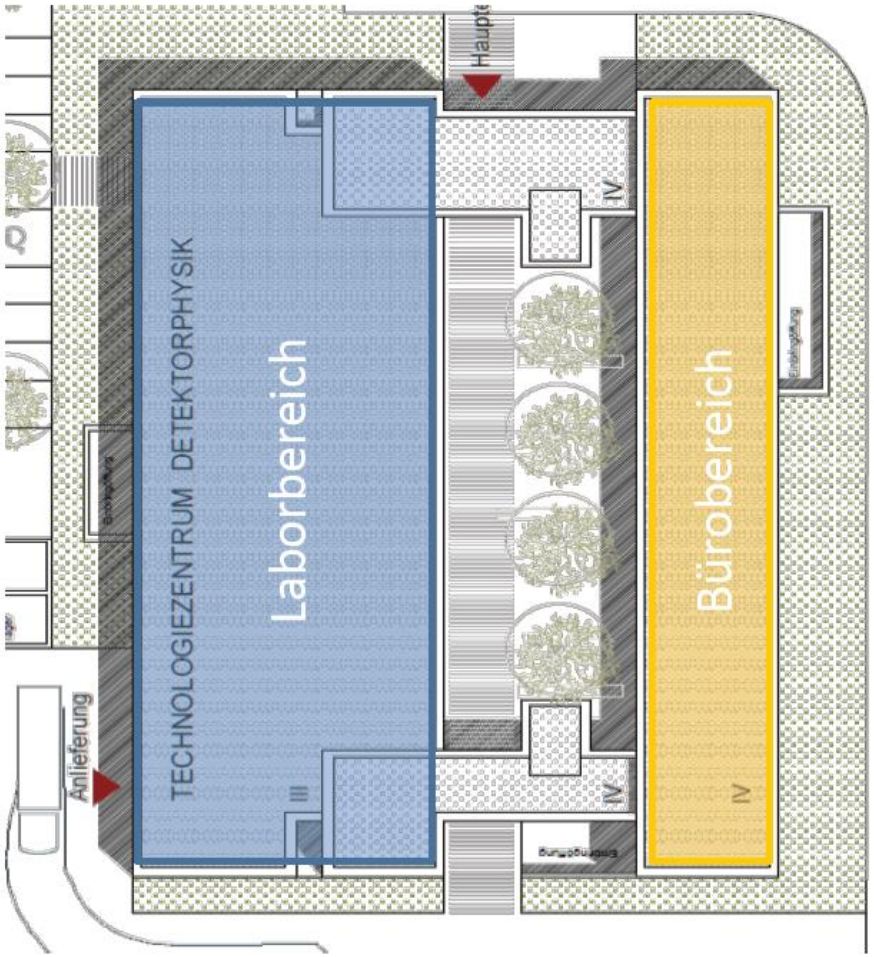
Markus Ball

Overview

- **From plan to reality the history of the FTD**
- The FTD as a part of a research infrastructure at Bonn
- Key technologies and tools of the FTD
- The experiments at FTD (selected view)
- Common infrastructure of the FTD

The FTD

FTD is short for Forschungs- und Technologiezentrum Detektorphysik (FTD) at the university of Bonn



WR
WISSENSCHAFTSRAT

Research buildings

With the German Federalism Reform, the joint task of university construction, including university medical schools, was abolished on 31 December 2006 and general university construction transferred to the sole responsibility of the states (Länder). At the same time, the Federal Government and the states created a jointly financed instrument for investments in the higher education sector with the funding of supra-regionally important research buildings, including large-scale equipment.

Since 2007, the German Science and Humanities Council (Wissenschaftsrat, WR) has been implementing the Research Buildings Programme on behalf of the Federal Government and the states (Länder). It provides funding for investment projects that are "distinguished by excellent scientific quality and national significance". The aim is to improve the conditions for German universities as successful players within the field of national and international competition in research.


Ministerium für Innovation, Wissenschaft und Forschung des Landes Nordrhein-Westfalen

universitätbonn

Forschungsbauten an Hochschulen - Antrag - Förderphase 2013

Forschungs- und Technologiezentrum Detektorphysik

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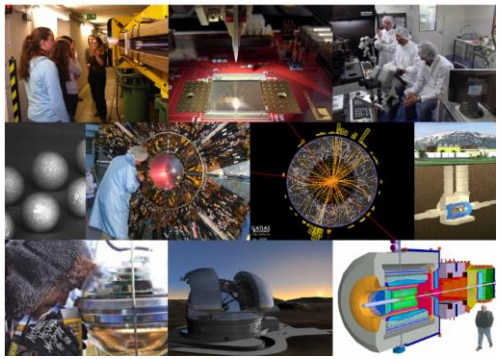
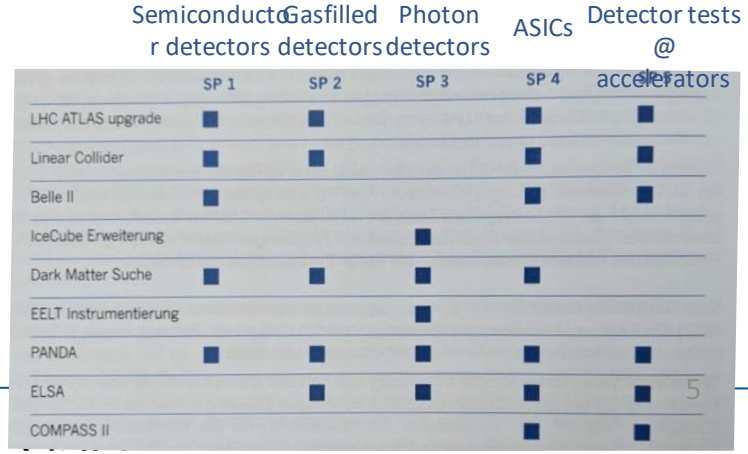
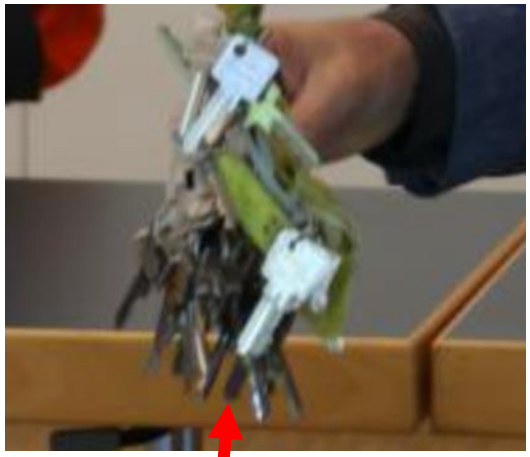




- 2-stage proposal (pre-proposal, full proposal)
  - Full proposal submitted: March 2012
  - **Final positive decision**: July 2012
- **Financing volume**: Proposed: 40 MEUR
- Granted: 33 MEUR
- Real Cost 55 MEUR
- **Planned start of operation: July 2016**
- **FTD spokespersons since 2015:**

J. Dingfelder, B. Ketzer

Hand Over



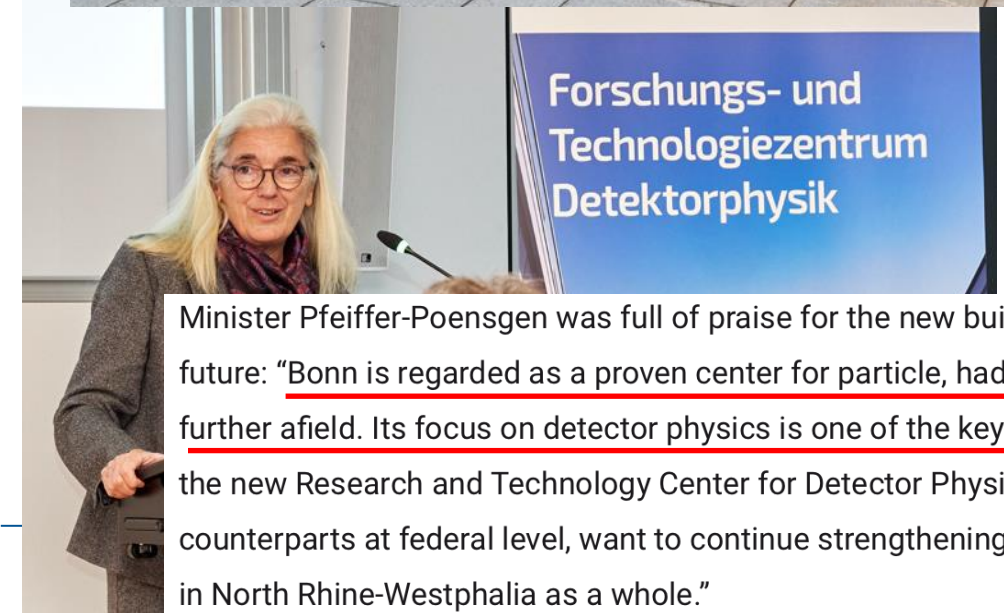
15.07.2021

Visit of Secretary of Science

08.11.2021

Over 32,000 More Square Feet for Top-Level Research

University of Bonn's Research and Technology Center for Detector Physics gets ceremonial opening



Minister Pfeiffer-Poensgen was full of praise for the new building, holding it up as an important investment in the future: "Bonn is regarded as a proven center for particle, hadron and astroparticle physics, both within Germany and further afield. Its focus on detector physics is one of the key things that makes the University of Bonn unique. With the new Research and Technology Center for Detector Physics, we in the state government, together with our counterparts at federal level, want to continue strengthening basic research in this field and thus top-level research in North Rhine-Westphalia as a whole."

Timeline

Proposal 15.03.2012

Excavation 04.11.2014

Foundation ceremony 02.10.2015

Envelope closure 04.04.2016

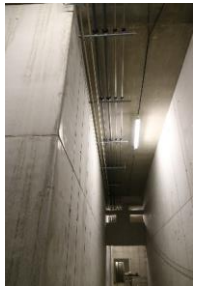
Hand over to the University 02.11.2016

14.03.2017 28.02.2018 05.07.2018 05.07.2021 08.11.2021

Demolition Alte Pharmazie

Shell construction

Interior work



Clean room installation

Inauguration

Overview

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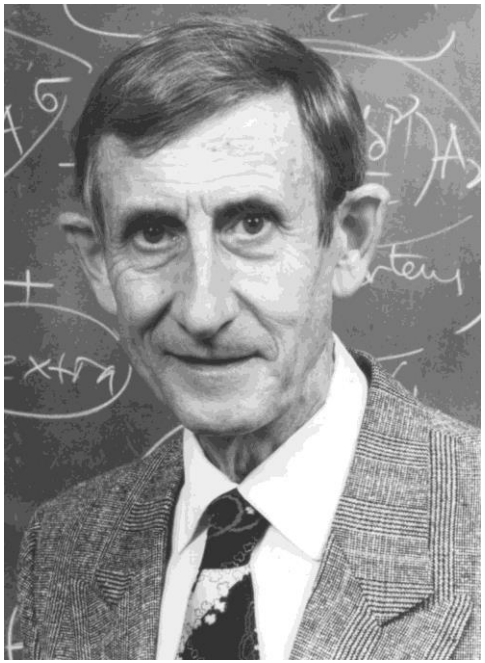
Technology and Basic Science



"New directions in science are launched by new tools much more often than by new concepts.

The effect of a concept-driven revolution is to explain old things in new ways.

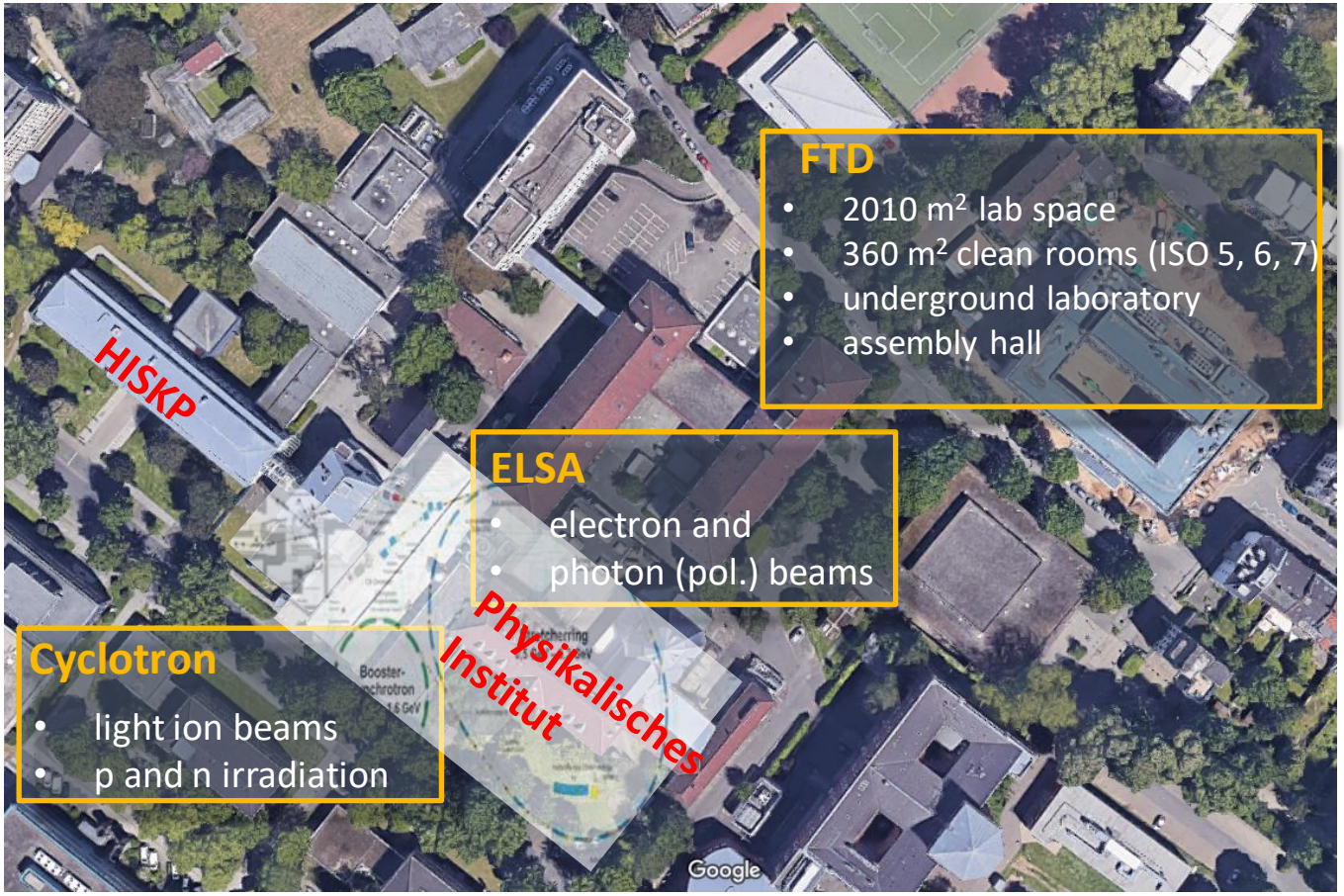
The effect of a tool-driven revolution is to discover new things that have to be explained."

Freeman Dyson (1923 - 2020), Imagined Worlds

The Research Infrastructure at Bonn

Combined **Research Infrastructure**:

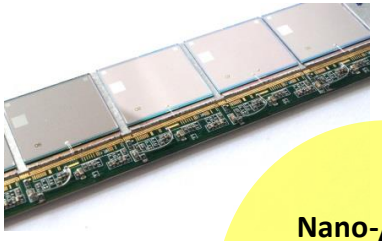
- FTD
- ELSA (Phys. Institut)
- Cyclotron (HISKP)



Development of **detector and accelerator technologies** for fundamental physics

- international collaborations
- local experiments
- open for external users through EU-funded transnational access (STRONG-2020)

Key Technologies and Applications



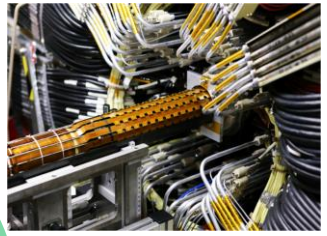
Semiconductor pixel detectors (hybrid, monolithic/CMOS)

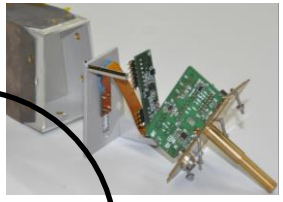
Nano-/Micro-structuring
wafer post processing (...)
photonic metamaterials
micropattern structures

Micro-bonding techniques & Wafer tests
flip-chip/3D-assemblies
wire bonding
chip tests

Fine-pitch structures
high-density interconnects
Kapton flex circuits

Detector modules
readout electronics
mechanics
QA

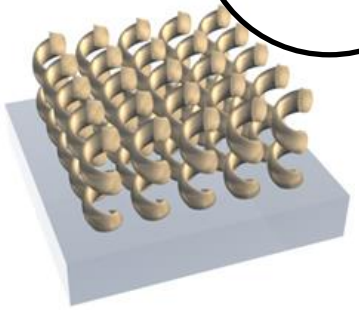


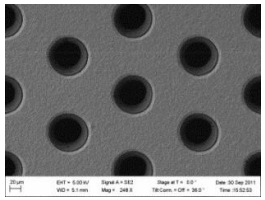


Photonics

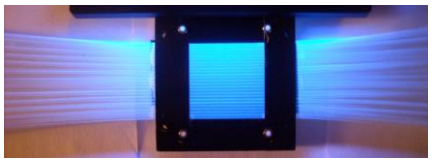
Micropattern gaseous detectors

Calorimeters
Scint. fibers





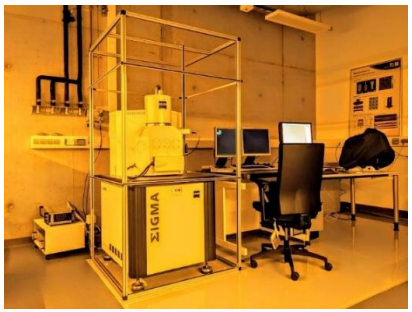
Structure size

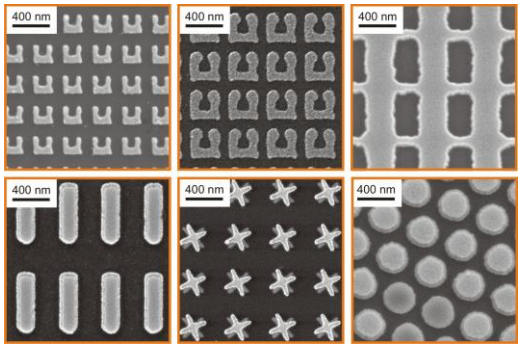


Goal: maximize synergies between development areas

Nano- and Micro-Fabrication

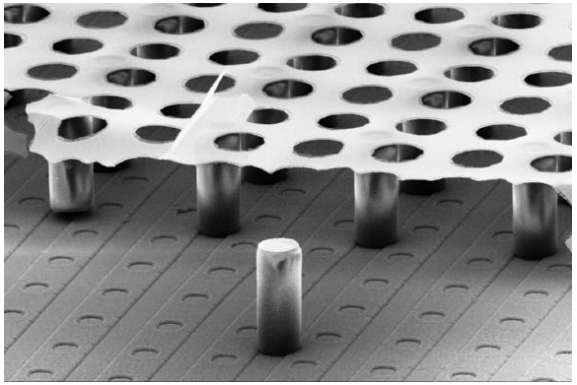
Electron beam + optical lithography





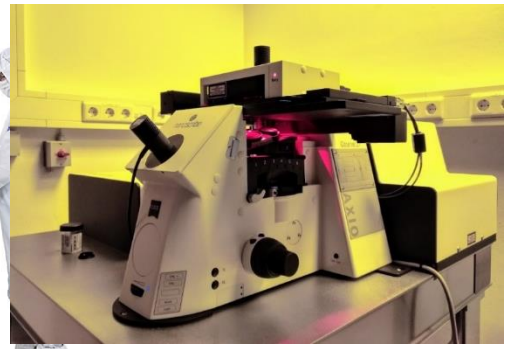
- Planar nanostructures with feature sizes down to 50 nm

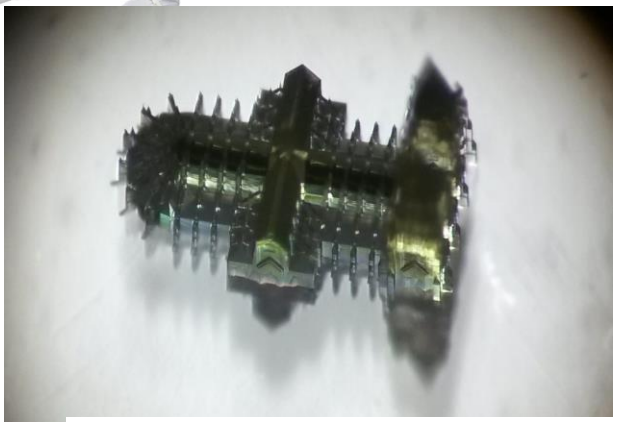
Postprocessing



- Etching (chemical, plasma)
- Deposition (metals, dielectrics)

3D Direct laser writing

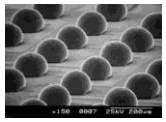


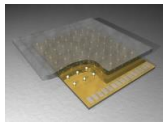


Mer han d'r Dom och en Bonn!
Translation provided by
https://mingsprooch.de/

Interconnect and Characterization

Solder Ball Placer





CR: Nikon

X-ray Inspection Device

X-ray Irradiation Device

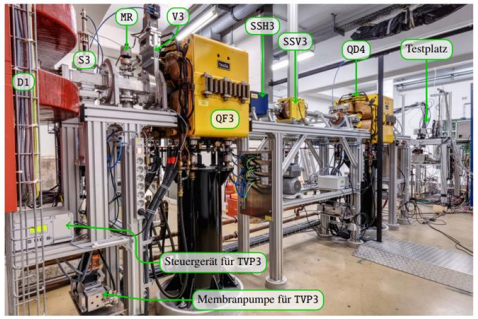
Scanning Electron Microscope

Flip Chip Bonder

Wire Bonder

Wafer Probe Station

3D Laser Tracker



Dissertation N. Heurich (2017)

In-beam testing and irradiation

- Cyclotron
- ELSA

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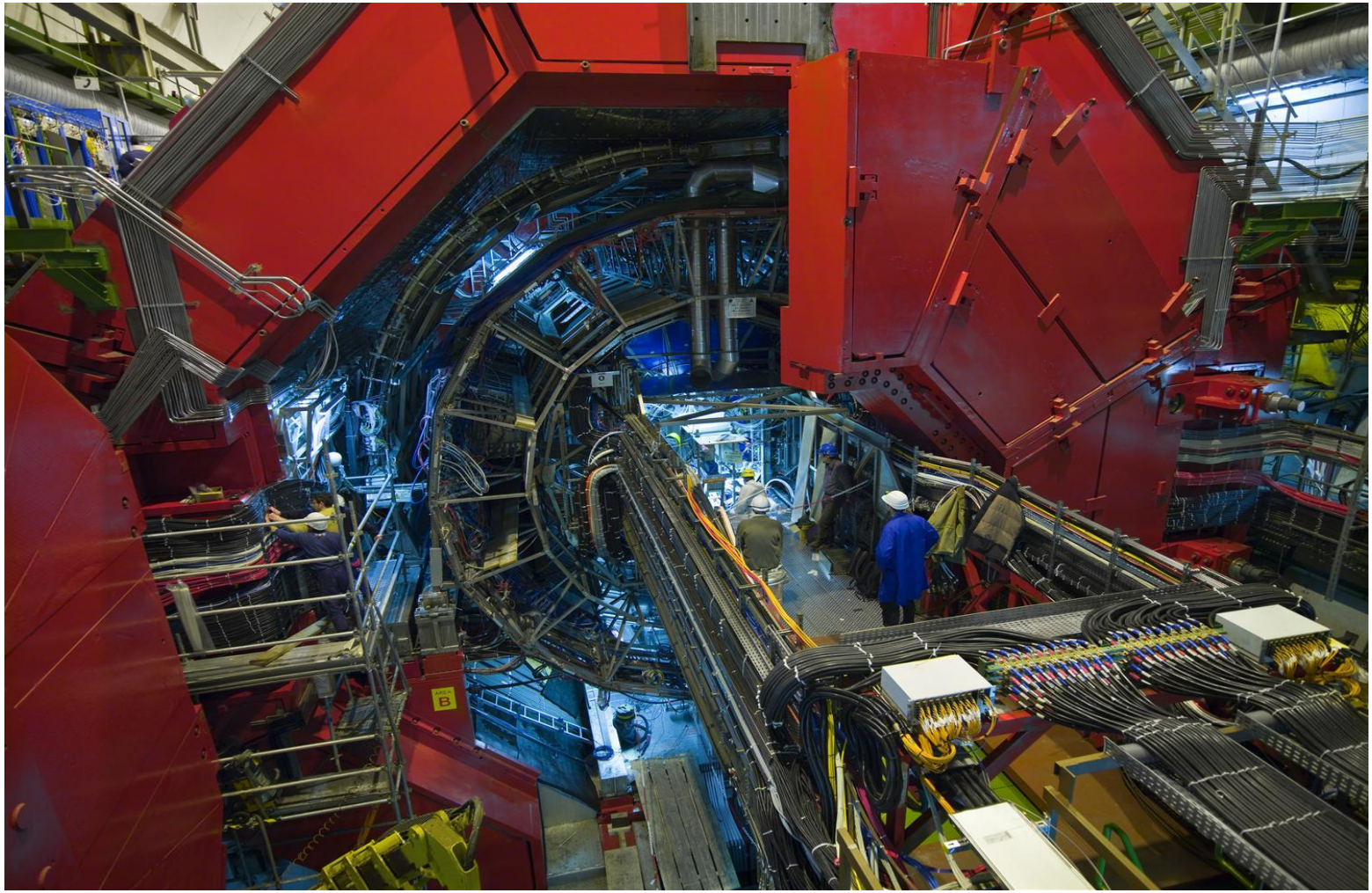
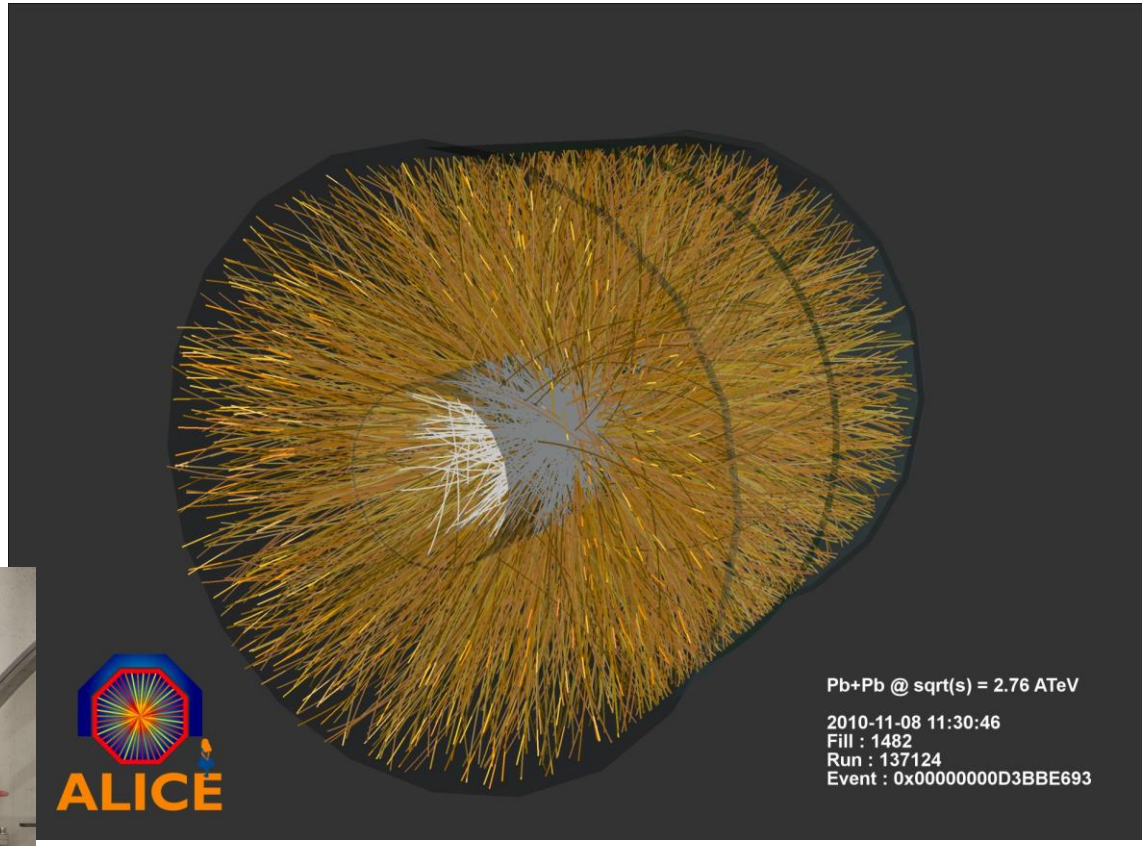
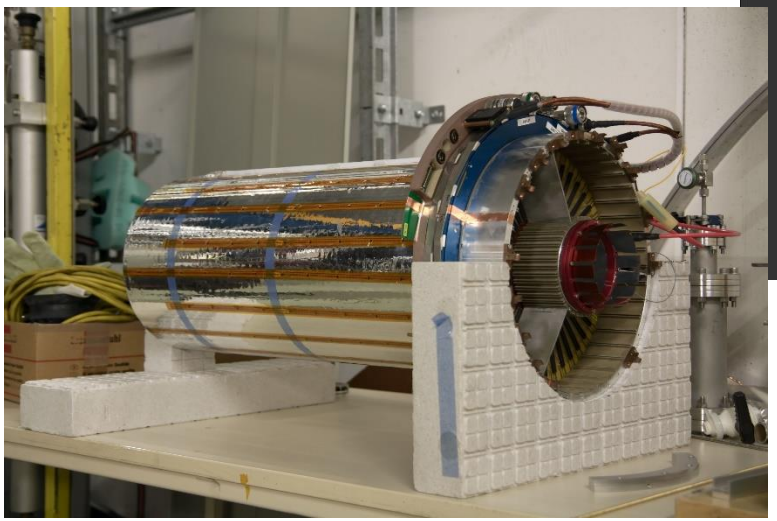
ALICE Detector



ALICE Tracking Detector

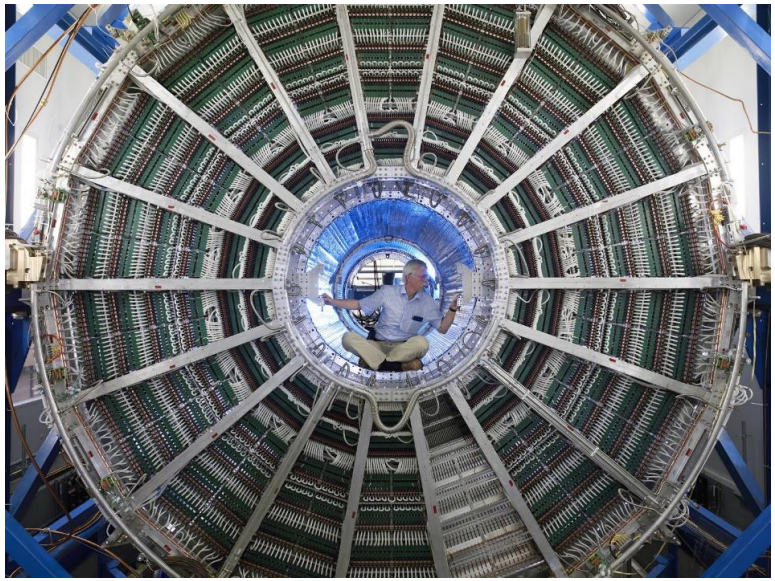
- Central tracking detector
- Upgrade with GEM amplification system
- From 3D-pictures to 3D-movies of particle collisions
- First TPC prototype developed at GSI for FOPI by AG Ketzer with strong participation of the group of L. Fabbietti

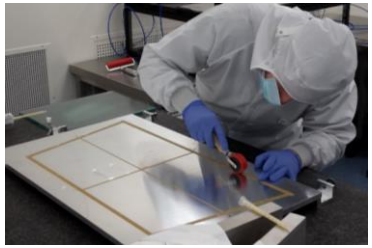


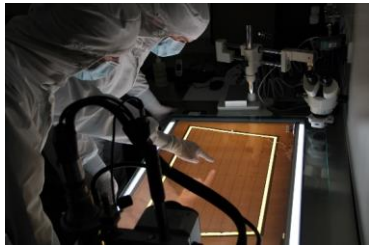


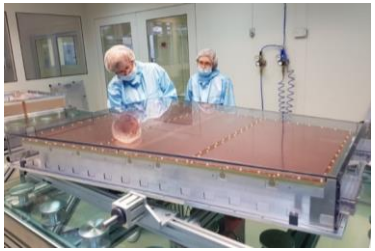
F.V. Böhmer et al., NIM A 737, 214 (2014)

Upgrade of Central Tracking Detector





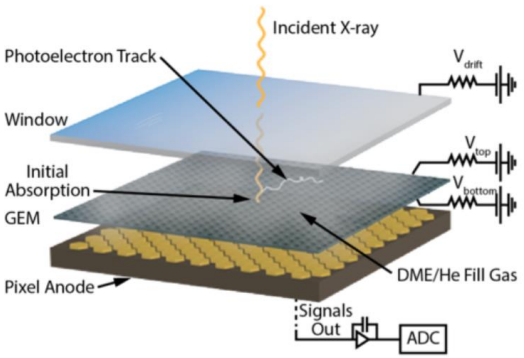


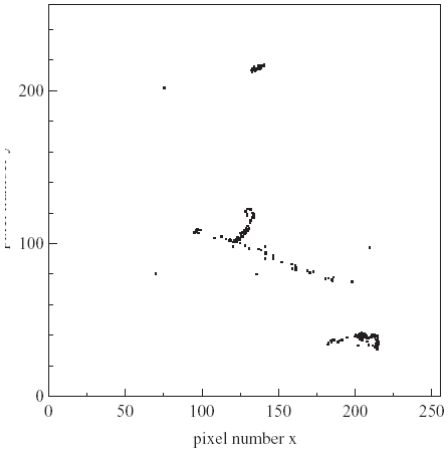


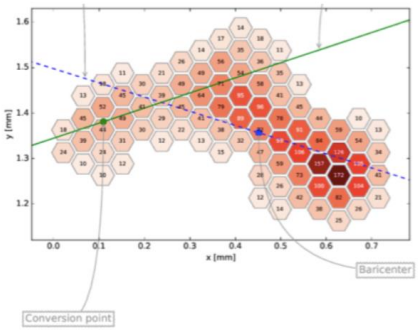
INGRID for IAXO

Integrated Micromegas and Pixel Sensor

(Si wafer post-processing & MEMS)







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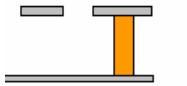
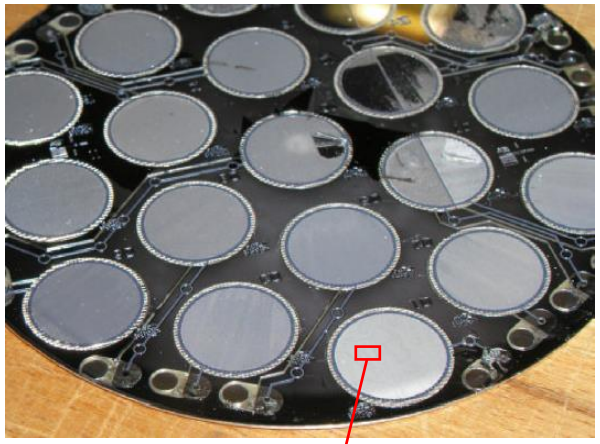
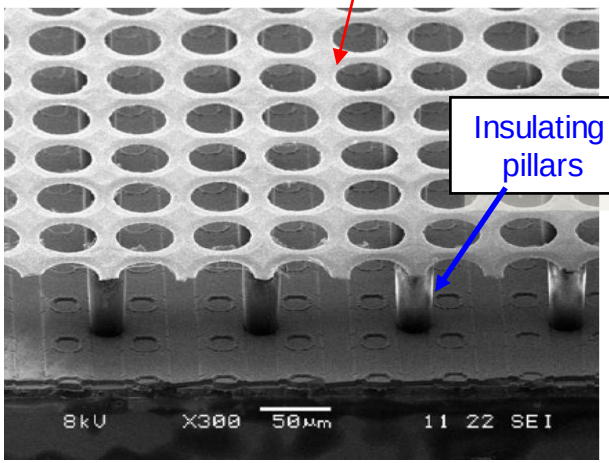


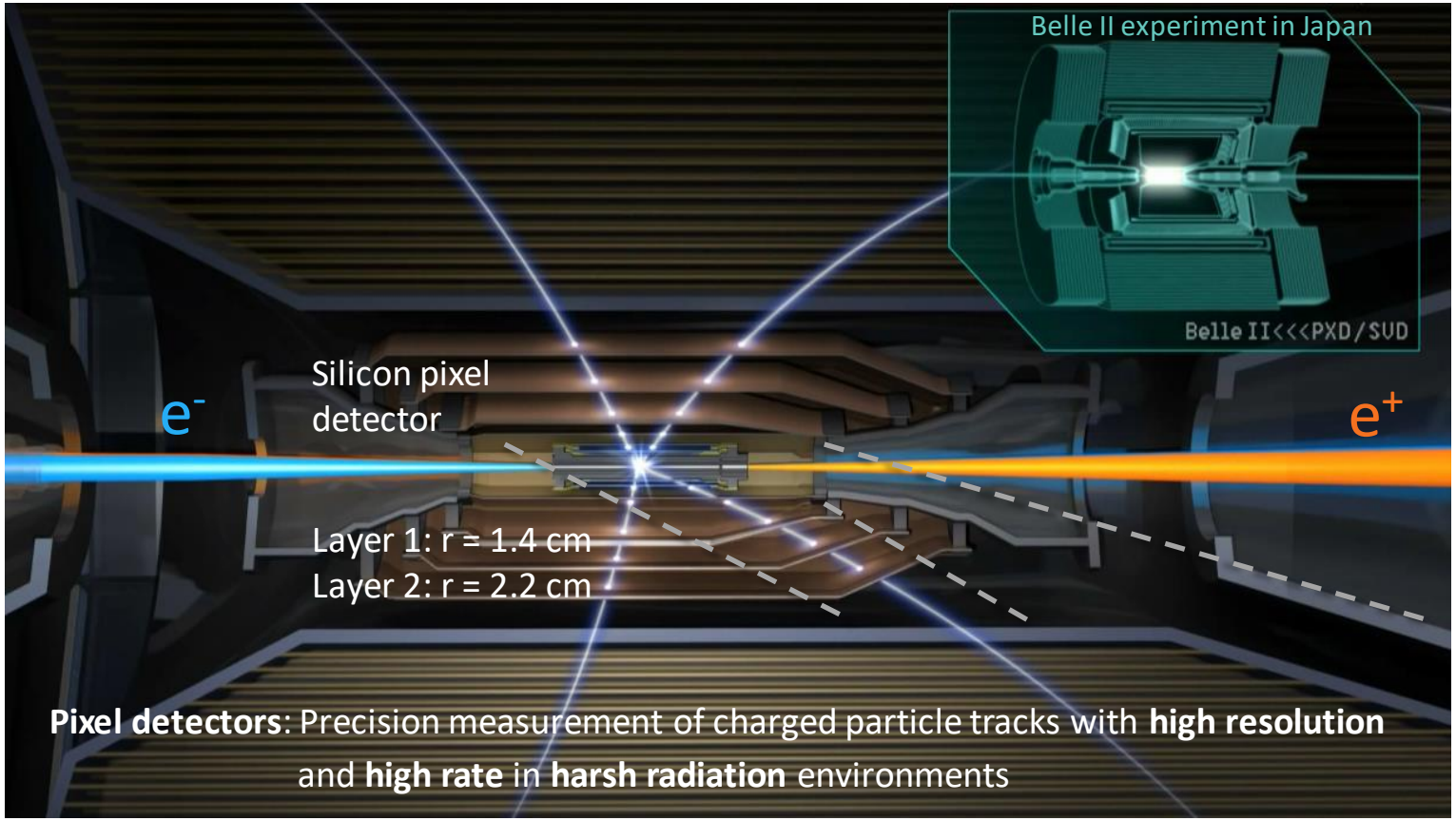
elop resist

[J. Timmermans, VCI 2007]



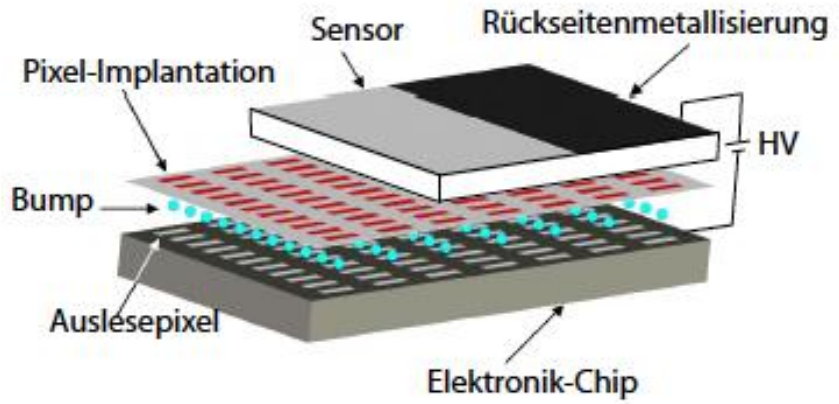


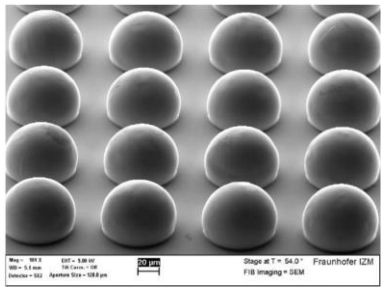
Silicon Detectors



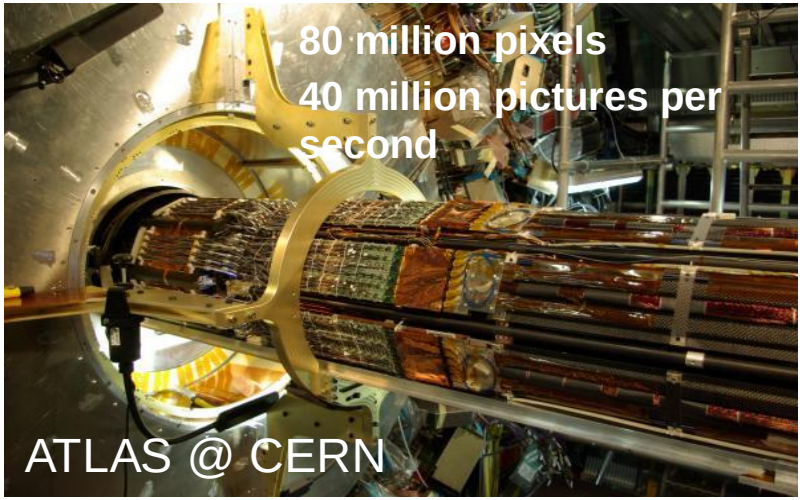
Silicon Detectors

Hybrid pixel detector





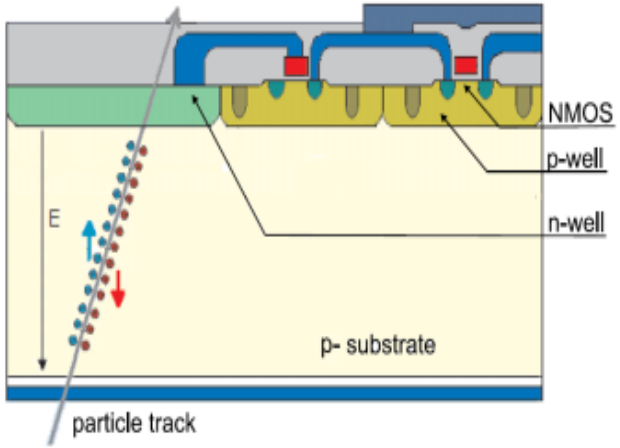
- Amplification of signal by dedicated R/O chip (1-to-1 cell correspondence)
- Micro-interconnection/bump bonding and post processing can be done at FTD (for prototyping)



Silicon Detectors

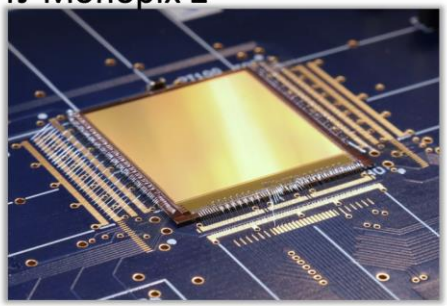
R&D for future particle and imaging detectors

Monolithic (CMOS) pixel detector



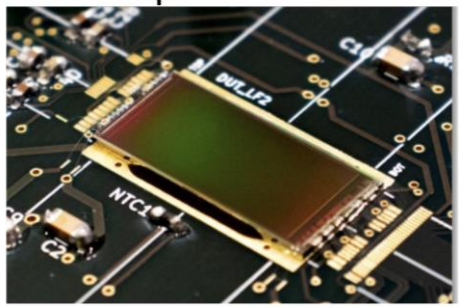
Prototypes with various CMOS vendors, e.g.

TJ-Monopix 2



- Pixel pitch: 33 × 33 μm^2
- 512 × 512 pixels

LF-Monopix 2

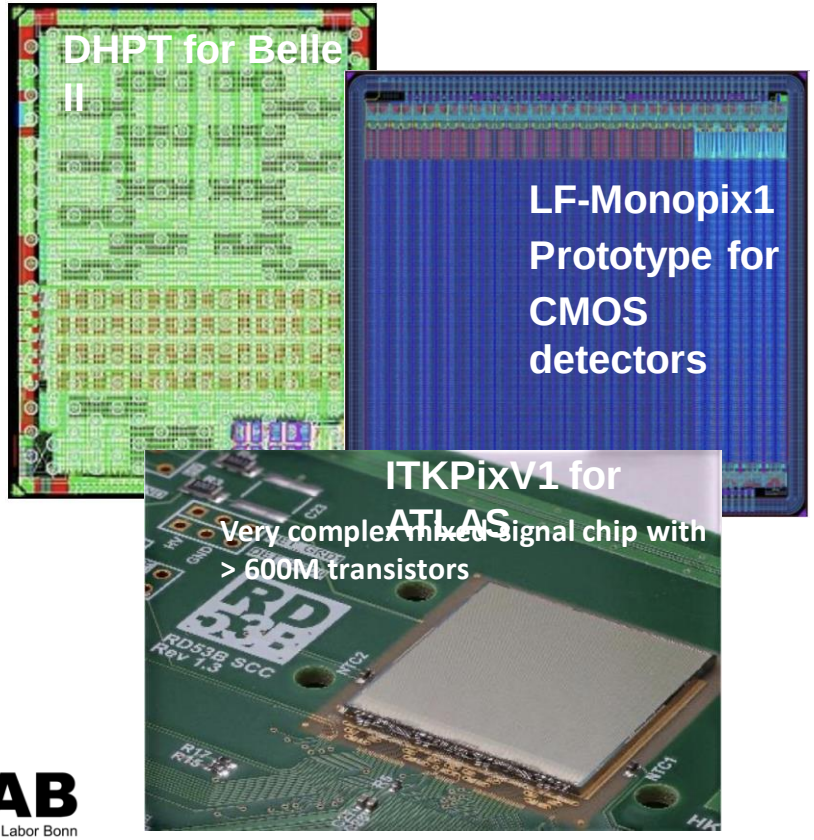


- Pixel pitch: 50 × 150 μm^2
- 340 × 56 pixels

- Sensor and readout electronics in same silicon substrate
- Cost-effective (no bump bonding needed)

Silicon Detectors

- **Development of custom readout chips**
  - Chip design in SILAB at FTD
  - Production at CMOS fabs
- Testing/characterization at FTD
- Development of lab data acquisition systems (hardware, firmware, software)
- SILAB has longstanding expertise in development of **radiation-hard** readout chips



… and many more
…

Silicon Detectors

Some examples …

Imaging applications in

- medical sciences
- biology
- material science

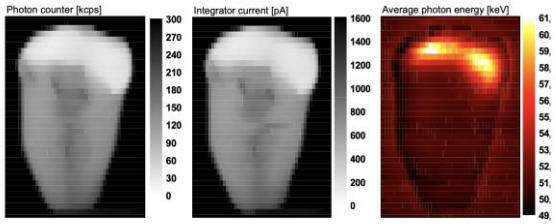
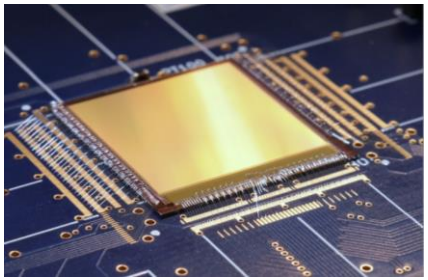


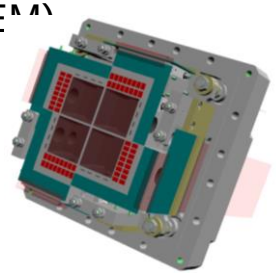
Fig. 14: Radiograph of a tooth (CdZnTe, 90 kVp, 300µm Al filter, 10 keV counter threshold). Scan step size: single pixel.



EDET

(collab. with HLL Munich)

Stroboscopic imaging in transmission electron microscopy (TEM)



AGIPD - Adaptive Gain Integrating Pixel Detector

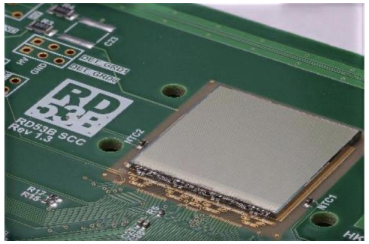
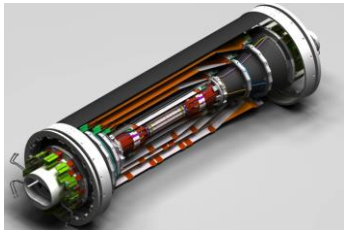
(collab. with DESY)

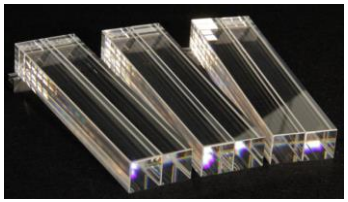
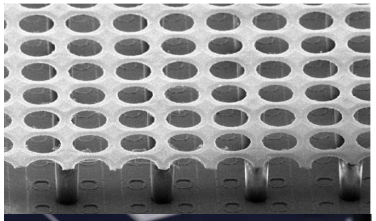
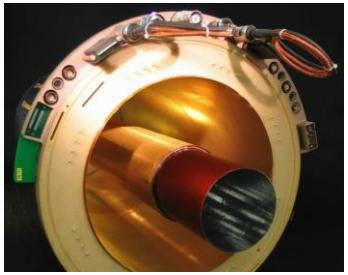
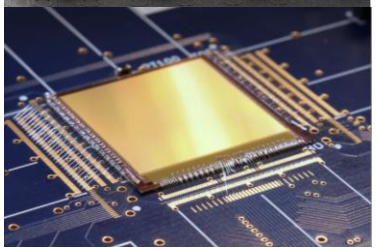
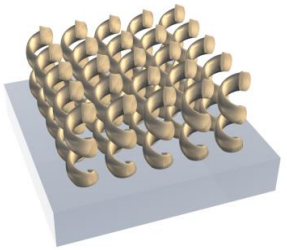
High-speed X-ray detector for European XFEL

SI LAB Silizium Labor Bonn

Projects of the FTD

- ATLAS (CERN): Inner Tracker Upgrade: 13m^2 Hybrid Pixel detector
- Belle II (KEK): DEPFET Pixel detector and upgrade with monolithic CMOS detectors
- ALICE (CERN): Upgrade of Time Projection Chamber with GEM detectors, 50m^2, new readout electronics
- AMBER (CERN): Planar GEM detectors with triggerless readout
- PANDA (FAIR): high-resolution electromagnetic calorimeter (20'000 crystals)
- IAXO (axion search at DESY/CERN): InGrid detectors
- ILC: TPC readout with pixelized gaseous detectors
- ELSA:
  - hadron physics: upgrade with charged-particle tracking and forward detectors
  - Lohengrin: dark photon search
  - Bethe-Heitler experiment: form factors
- Nanodetectors for photonics
- Chip design for readout and control of detectors
- Generic R&D on detectors: semiconductors, micropattern gaseous detectors
- Electronics for particle detectors
- Connection to Quantum Optics: Fibre Lab
- Cooperations with external partners

- From plan to reality the history of the FTD
- The FTD as a part of a research infrastructure at Bonn
- Key technologies and tools of the FTD
- The experiments at FTD (selected view)
- **Common infrastructure of the FTD**
- Clean room

Common Infrastructure

- In the FTD we want to add capabilities and infrastructure that normally is only available in laboratories (clean-room, electronics workshop, assembly hall, underground lab, chip- design)
- Working Groups will have there own laboratory space to work on their specific projects & research
- Common infrastructure is supported by the FTD staff, but also should be operated with the help of the groups at FTD
- Space in the Common Infrastructure is not assigned to a specific group, but will be used according to the need of running projects
- Staff is there to provide and maintain knowledge and expertise, but resources for projects have to come from the working groups

Common Infrastructure

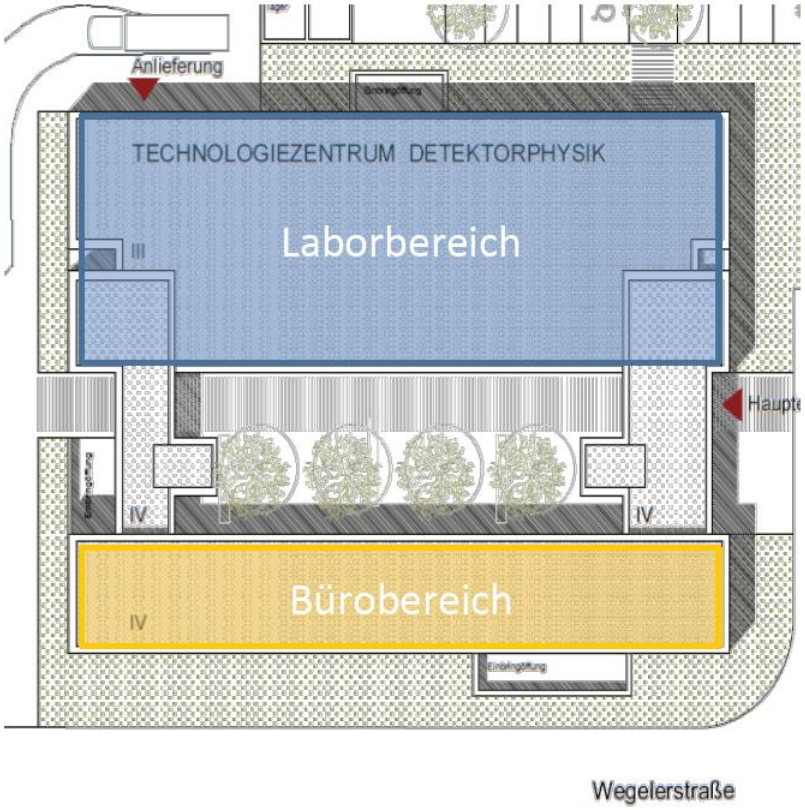
The FTD

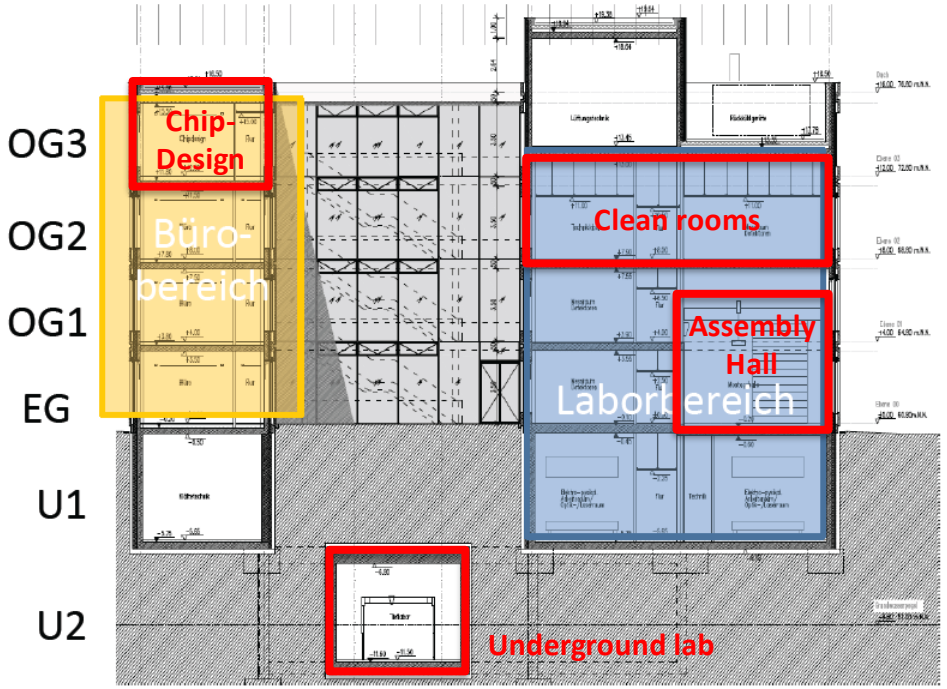
Office space:

- 880 m^2
- 4 Floors

Lab space

- 2010 m^2
- 4 Levels + Underground Laboratory
- 360 m^2 clean rooms (ISO 5, 6, 7)





The FTD


OG3
OG2
OG1
EG
U1
U2
Chip-Design
Büro-bereich
Clean rooms
Construction Hall
Underground lab

The Staff of FTD

Technical Coordinator
Dr. Markus Ball
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Secretary
Workshops, Guests, Web, Kommunikation, Outreach
Sarah Conee

IT
N.N.

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Head of Elektronic-development
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Detectordesign & -integration
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Janitor
Richard Lagemann

Technician
Gases, Chemicals
N.N.

Cleanroom-Technician
Jerome Laubner

Construction, CAD
N.N.

Common Electronic-Laboratory
Walter Honerbach
Alexander Ochs
Katharina Rosenthal
Candas Tezel
Michael Henseler

Radiation Protection Service
Dr. Christoph Wendel
Dr. Fabian Hügging
Dr. Marcus Grüner
Dr. Markus Ball

Laser Protection Service
Dr. Andrea Bergschneider

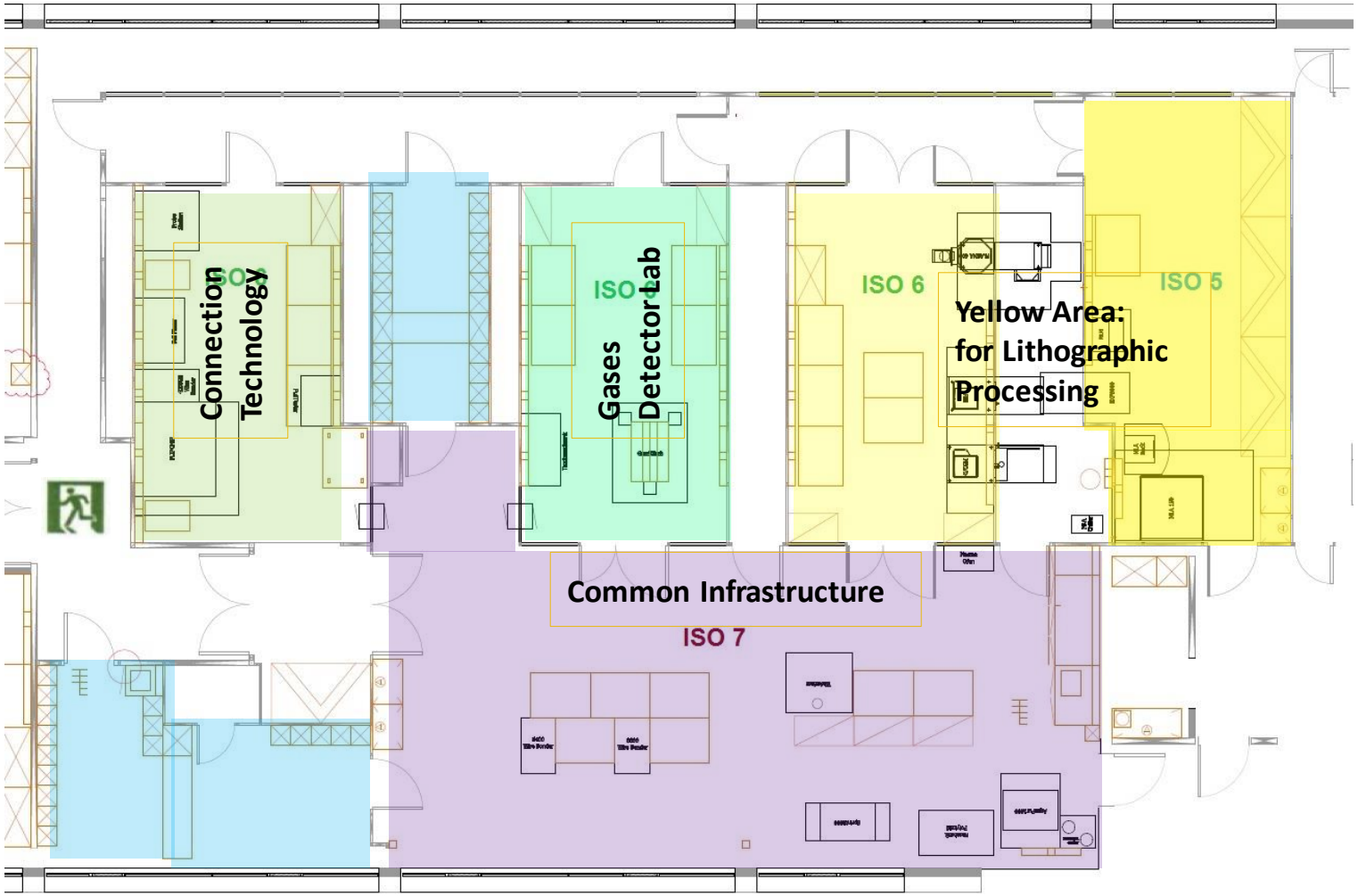
Enginers + Technicans
of the working groups

The clean room

The clean room

Cleanroom area – about 360 m2 for Nano- and Microstructuring

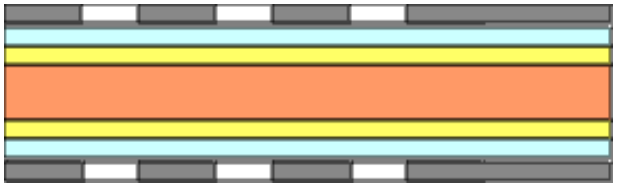
5 Labs – ISO-7, 3 ISO-6, ISO-5



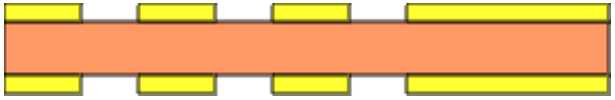
Two Processes for MPGD - GEM

50 µm Kapton
5 µm Cu both sides

Photoresist coating, masking and exposure to UV light

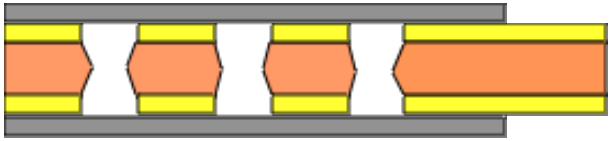


Metal chemical etching



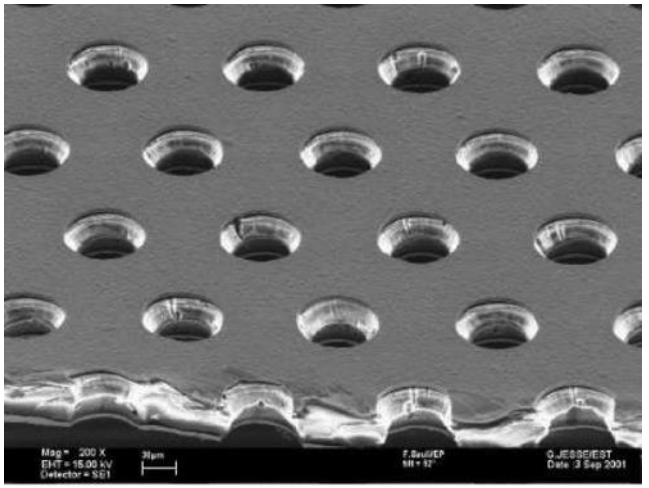
Kapton chemical etching

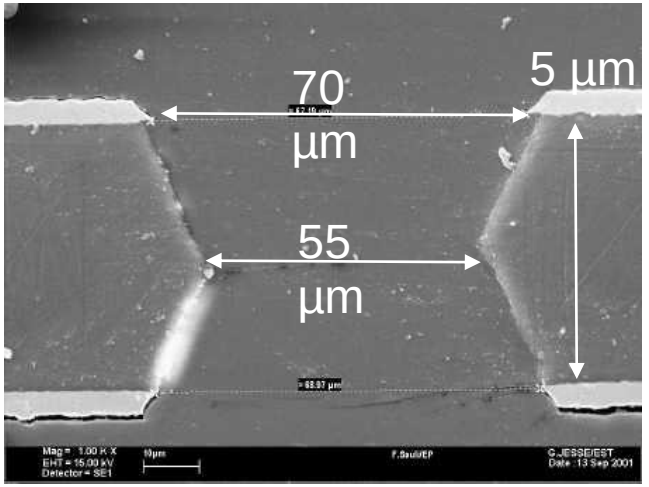
Second masking



Metal etching, cleaning, passivation

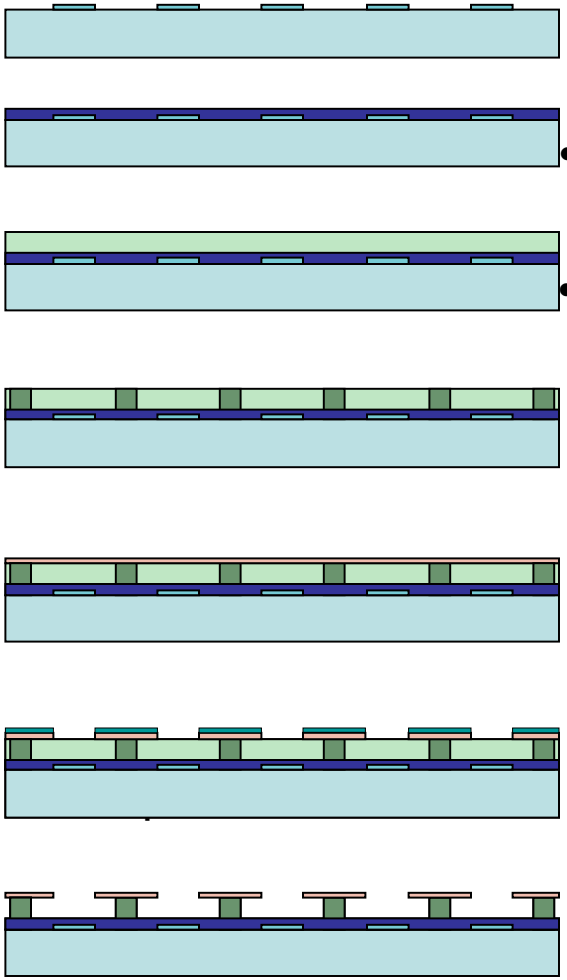
Standard GEM:70 µm Ø at 140 µm pitch





Two Processes for MPGD - InGrid

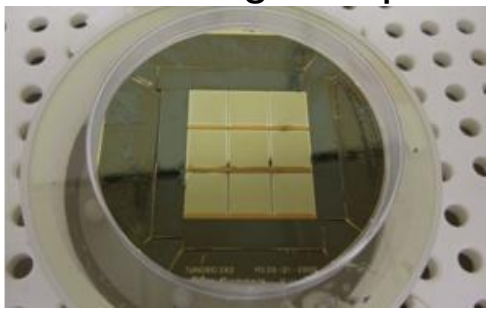
Courtesy of Y. Bilevych



- 1. Surface preparation
- 2. Protection layer (SixNy)
- 3. Spacer layer (SU-8)
- 4. Patterning of SU-8
- 5. Deposition of Al
- 6. Grid formation
- 7. Detector releasing

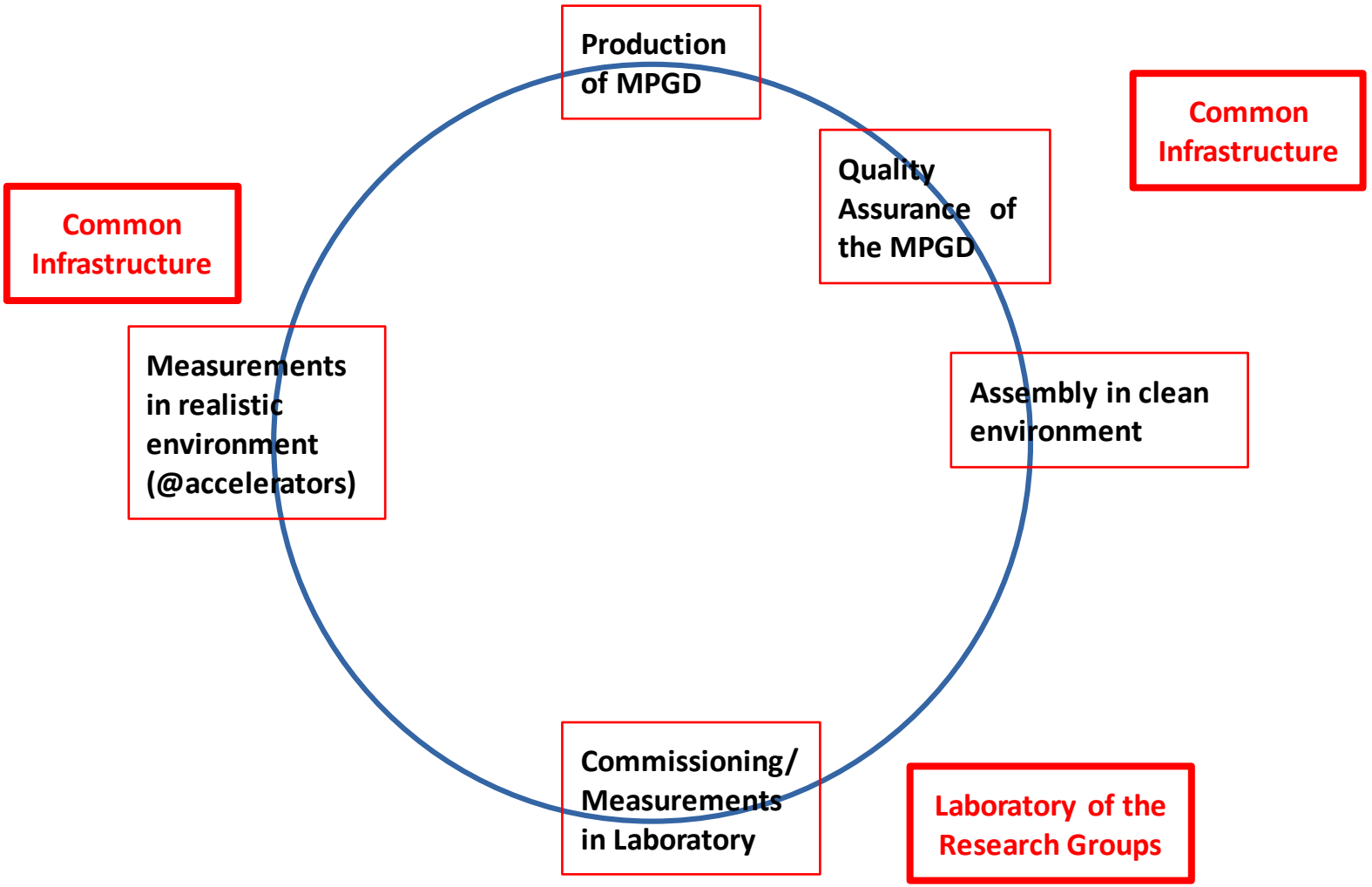
- Prototypes

- Single chip

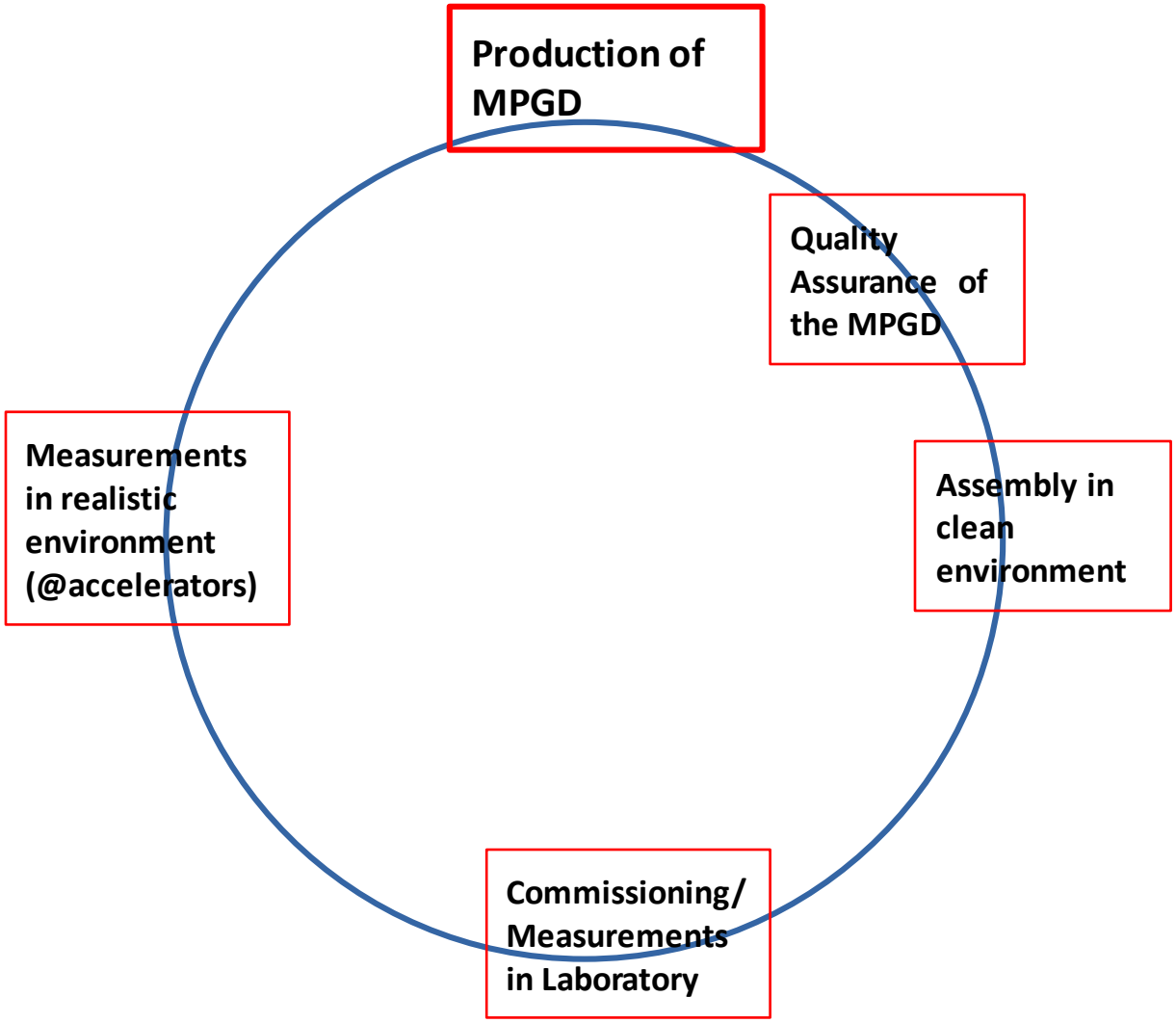


- 3x3 square

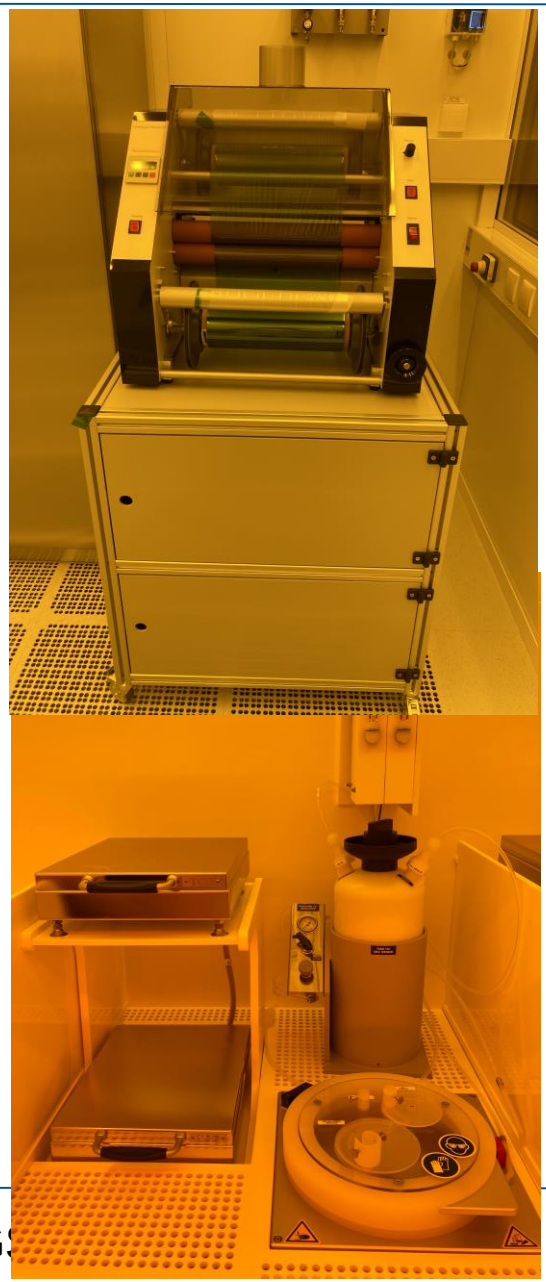
A cycle of R&D through the Research Infrastructure (MPGDs)

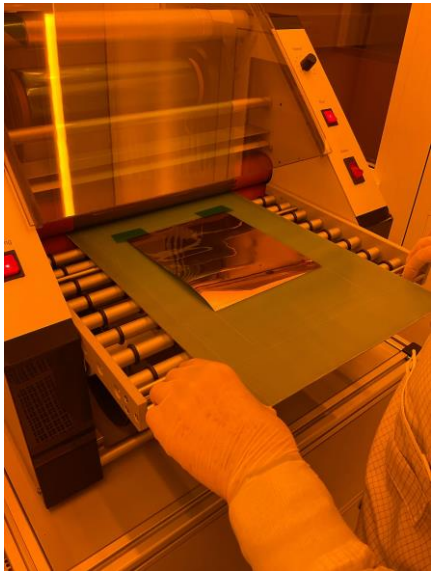


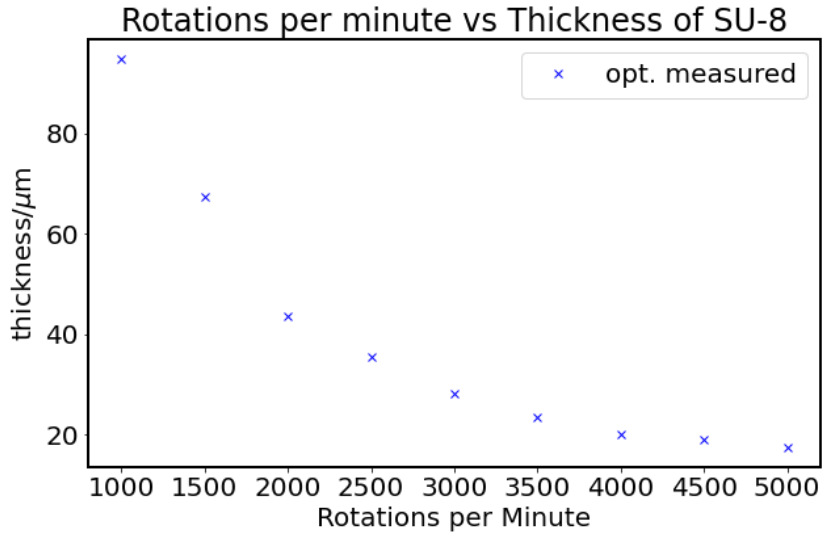
Cycle of R&D (exemplary for MPGDs)



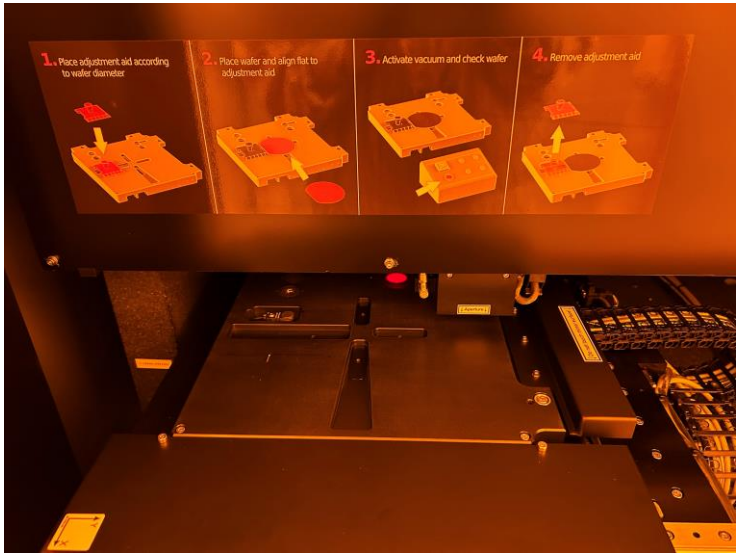
Photosensitive Layer Deposition

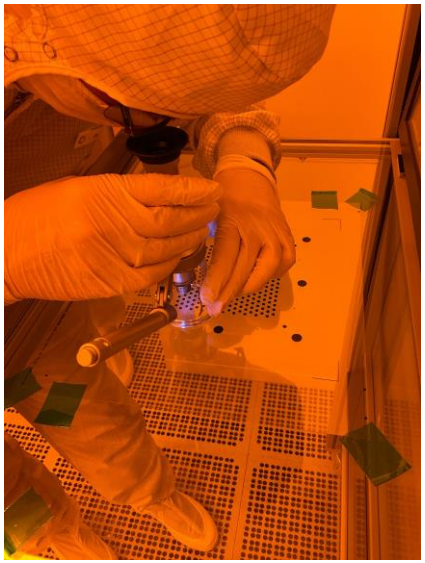


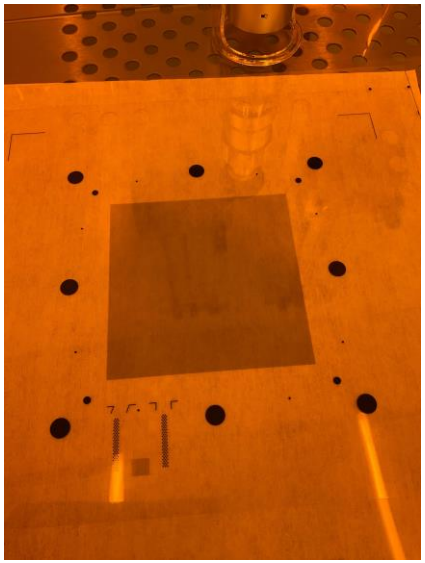




Machines for UV Exposure





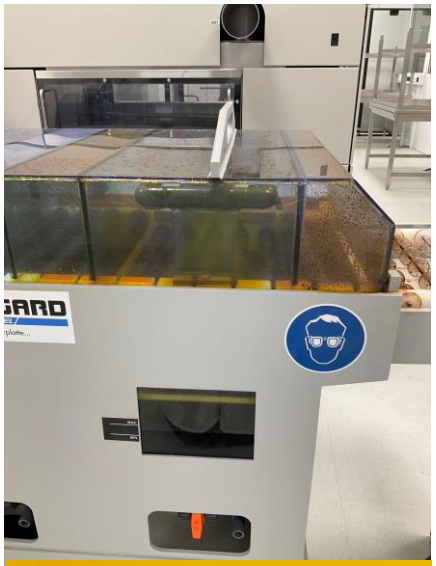


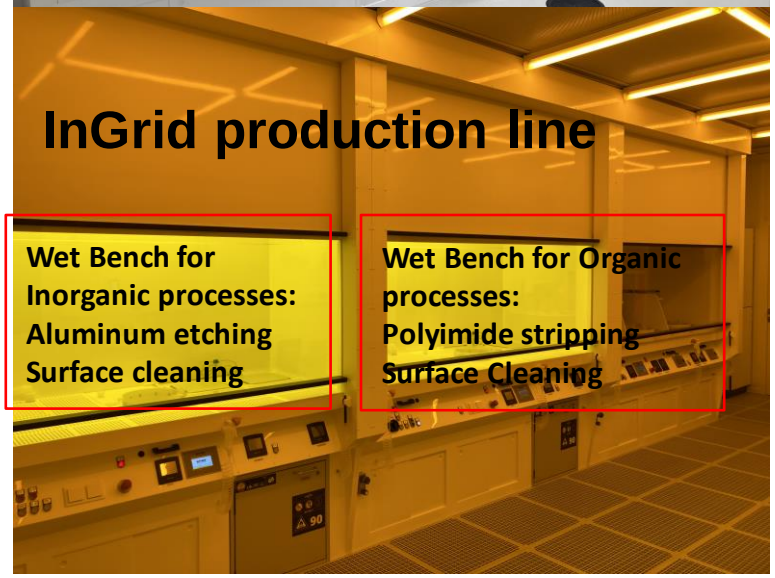
Metal & Polyimide Etching

UNIVERSITÄT BONN

FTD

GEM (flexible circuit boards) production line





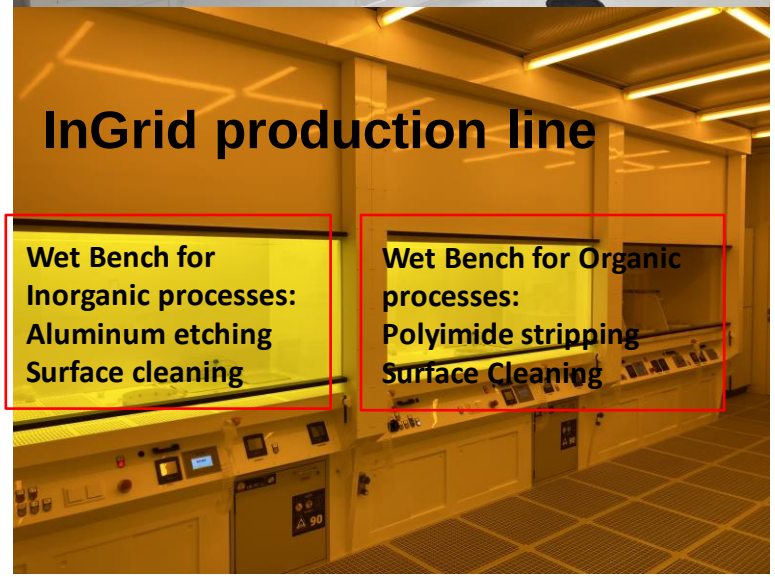
InGrid production line

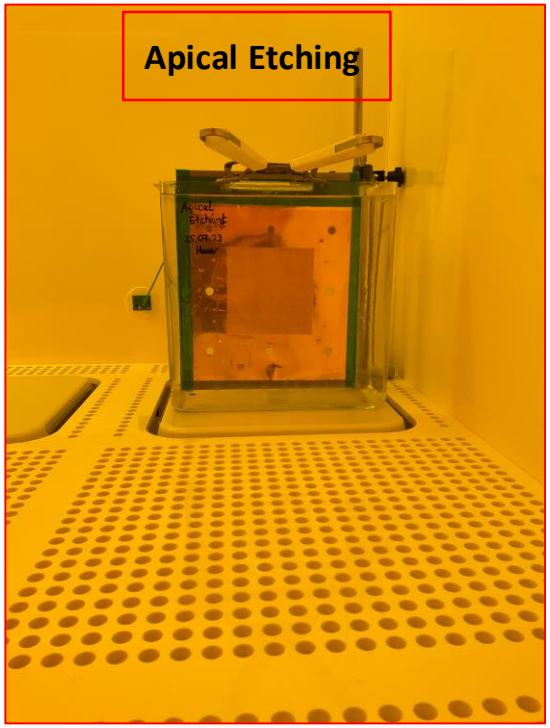
Wet Bench for Inorganic processes:
Aluminum etching
Surface cleaning

Wet Bench for Organic processes:
Polyimide stripping
Surface Cleaning

Metal & Polyimide Etching

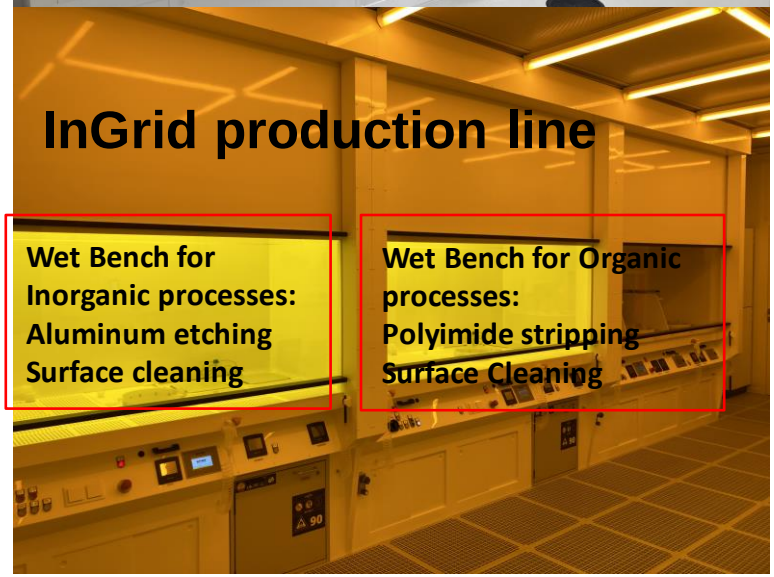
GEM (flexible circuit boards) production line

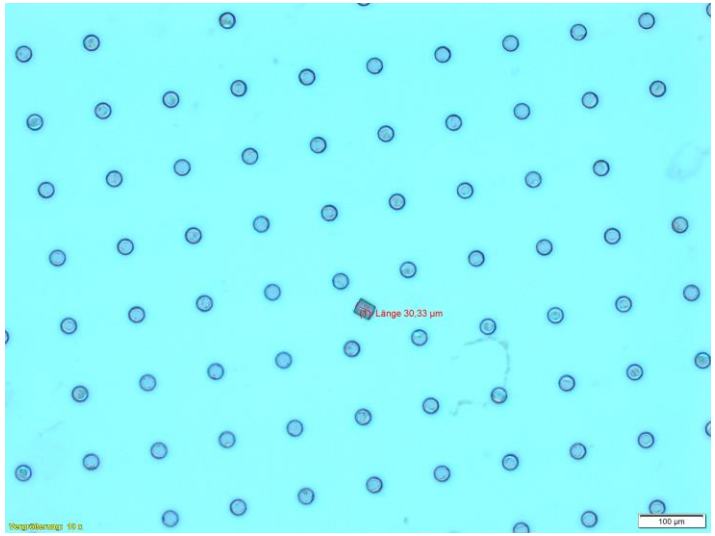


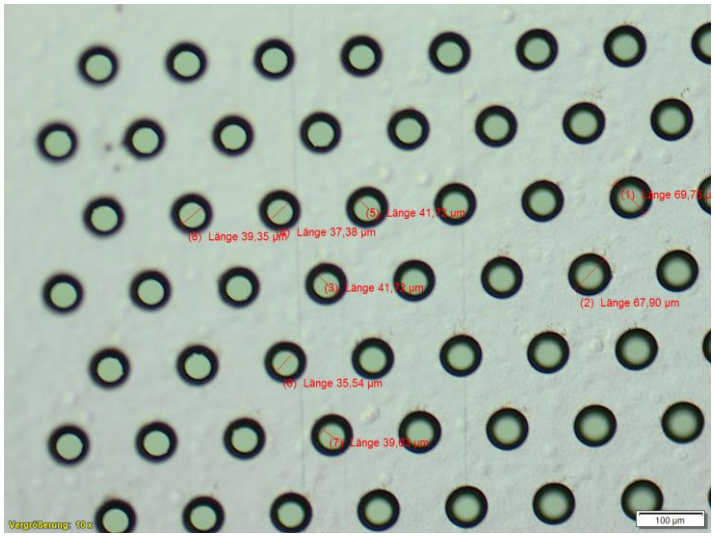


Metal & Polyimide Etching

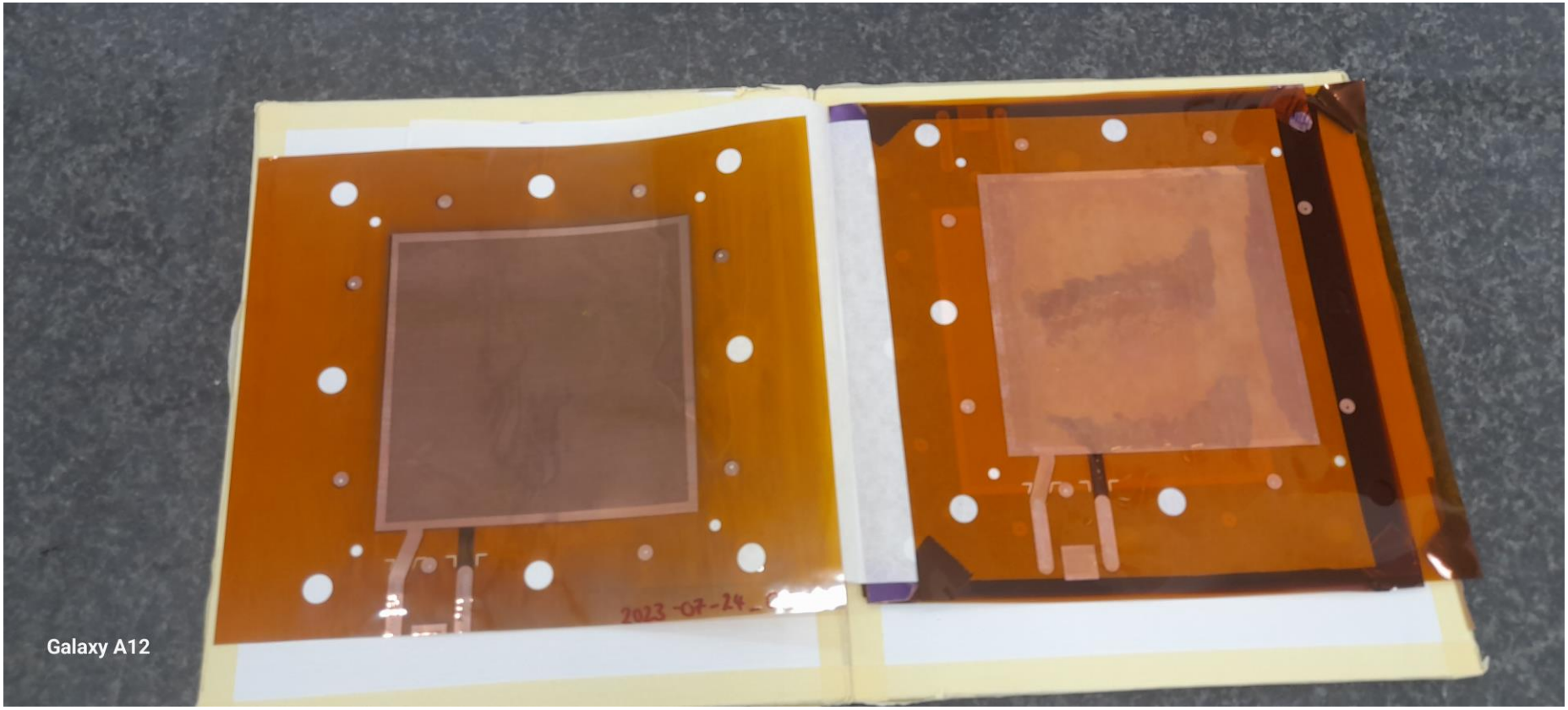
GEM (flexible circuit boards) production line



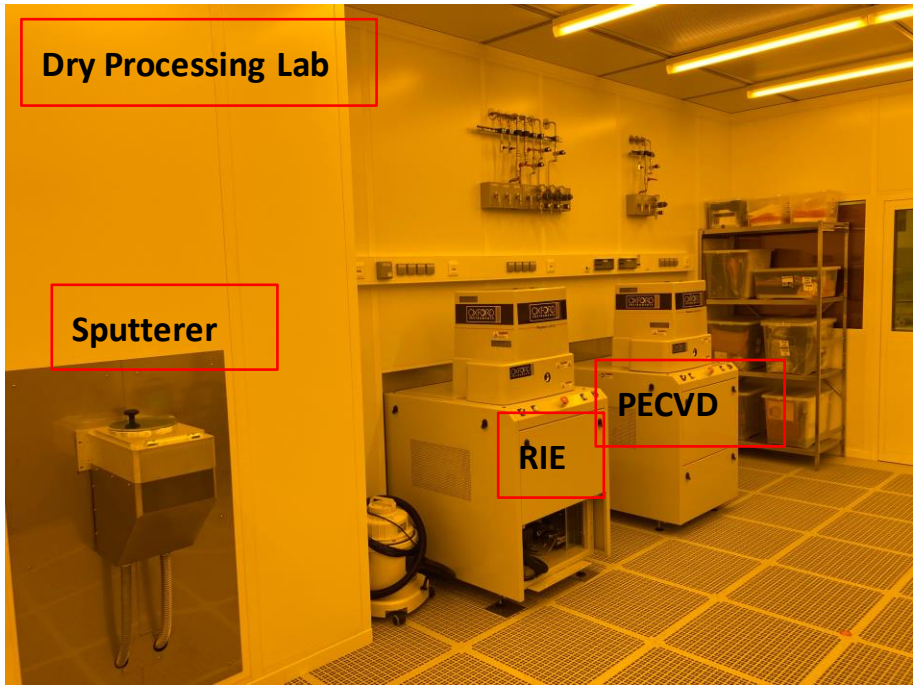


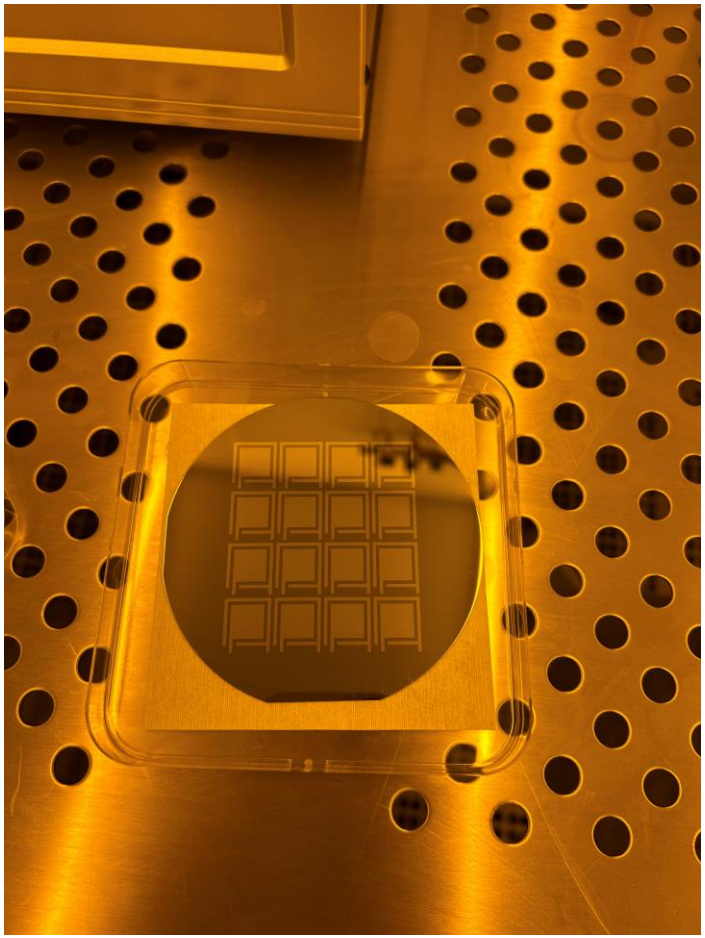


GEM from CERN and FTD

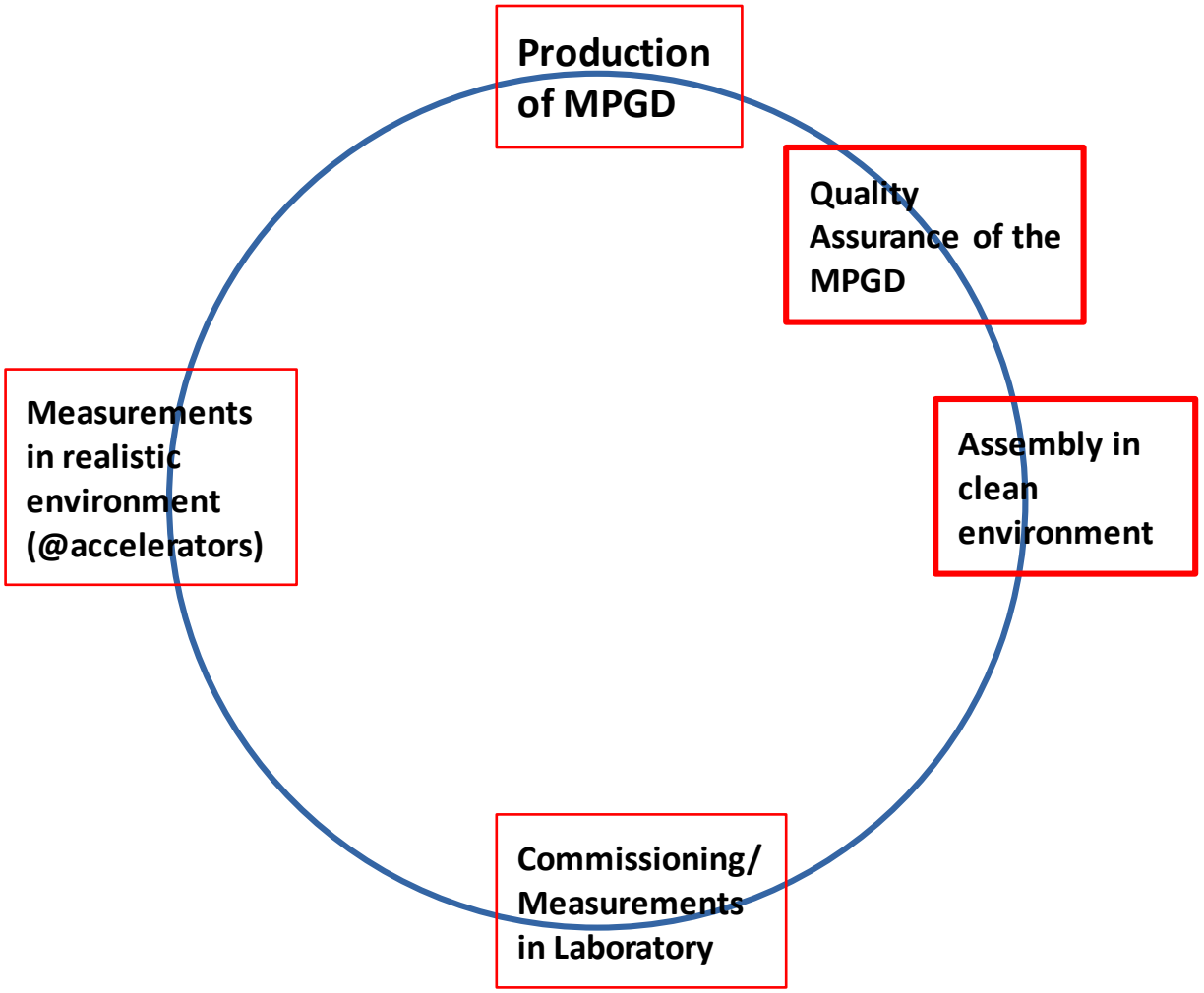


ISO6 Yellow area



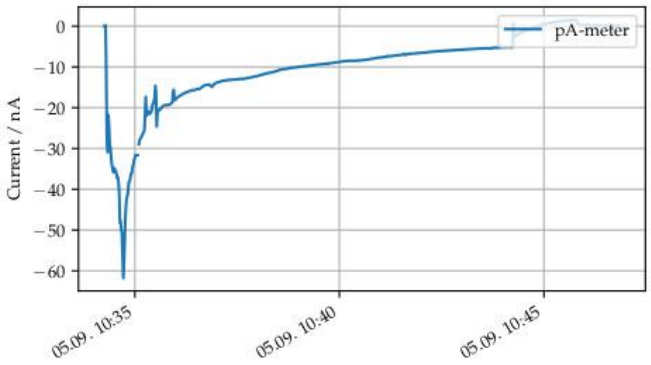


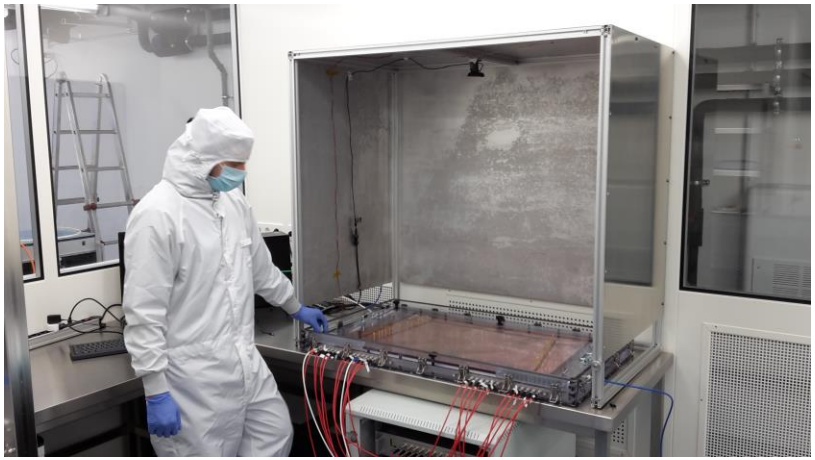
Cycle of R&D (exemplary for MPGDs)



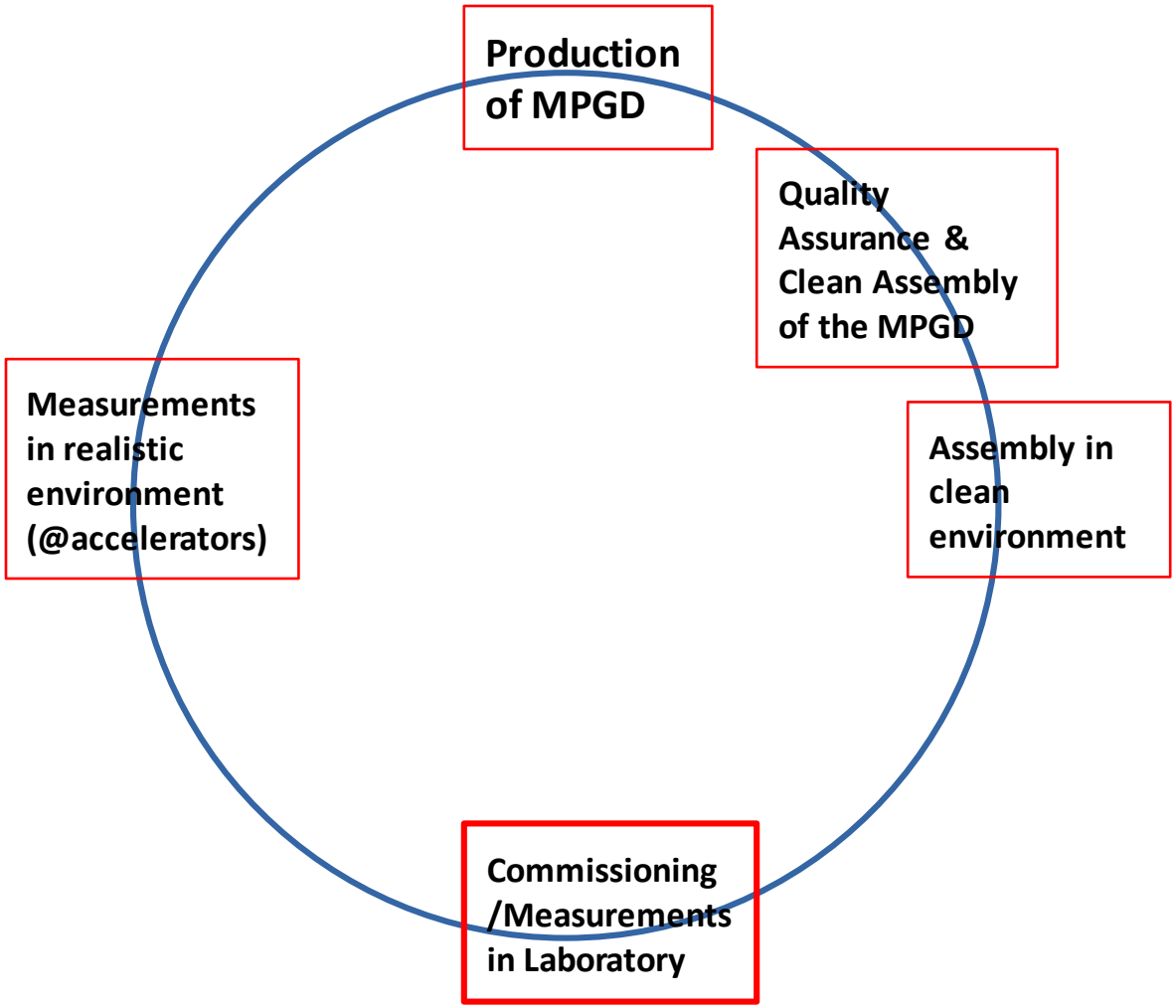
ISO6 Stonehenge

HV QA (SDS and leakage current easurement)



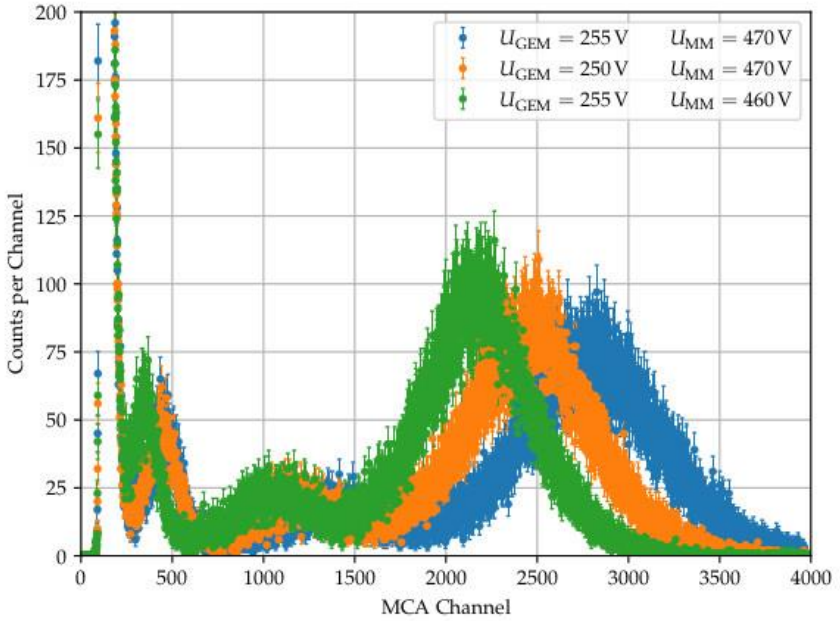


CON

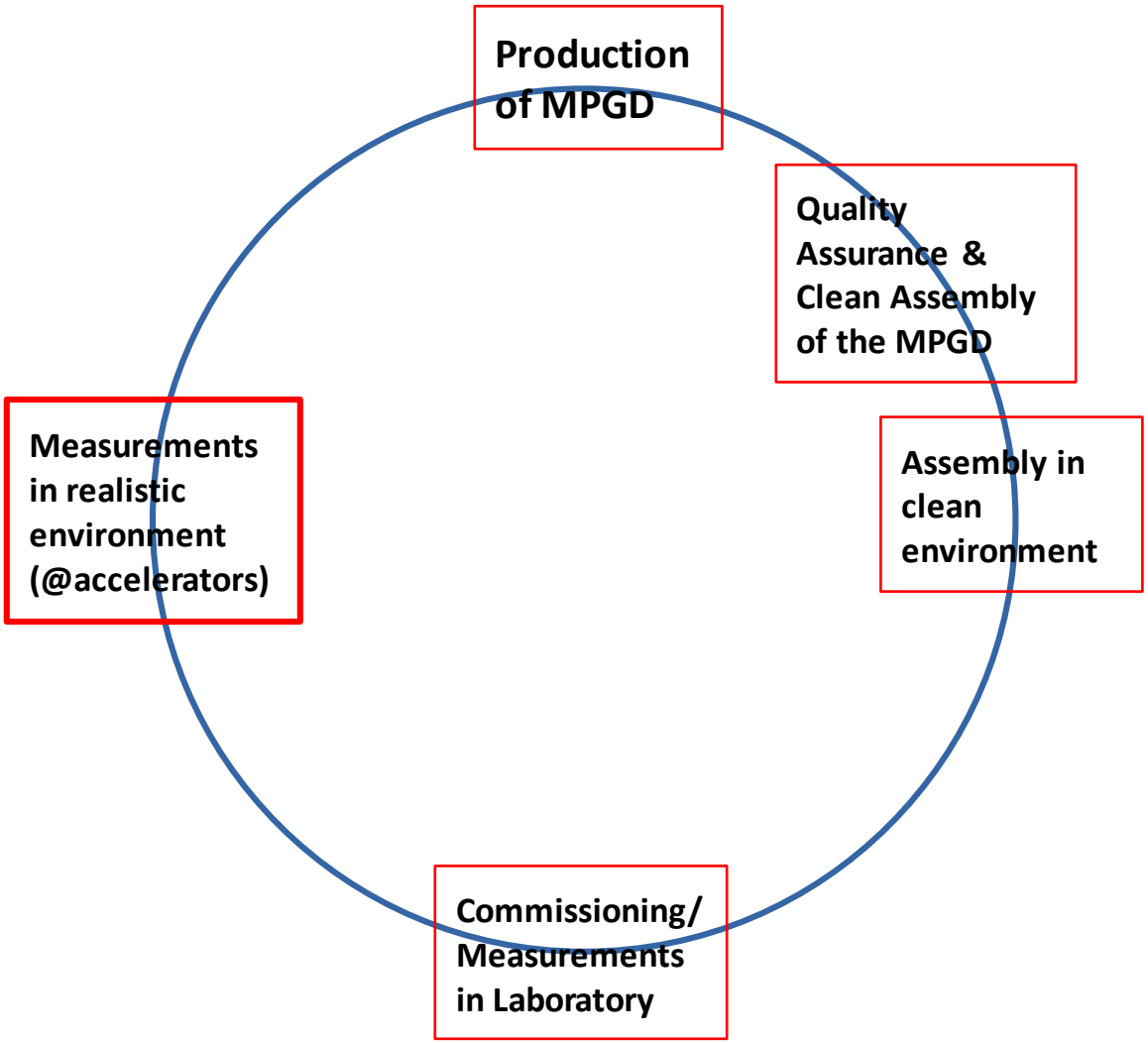

Production of MPGD
Quality Assurance & Clean Assembly of the MPGD
Assembly in clean environment
Commissioning /Measurements in Laboratory
Measurements in realistic environment (@accelerators)

Lab Infrastructure

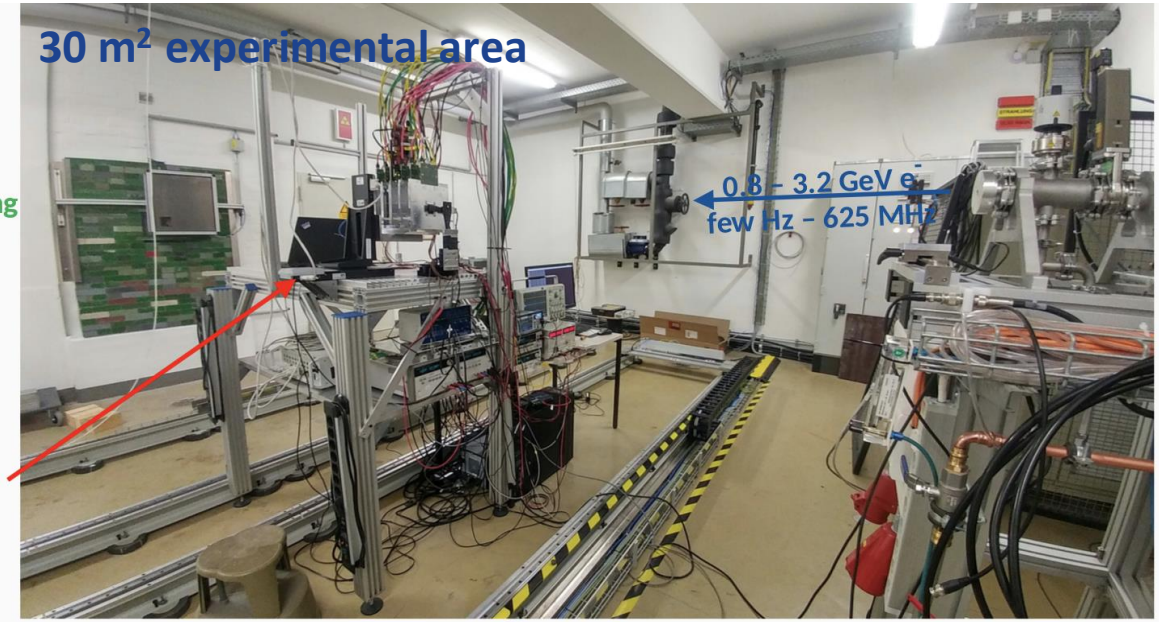
First Fe spectrum with a FTD GEM

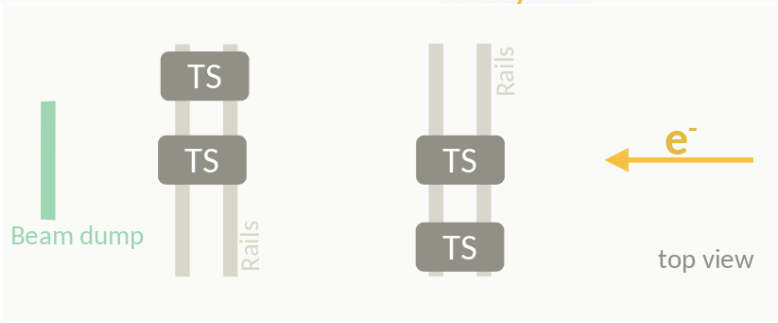


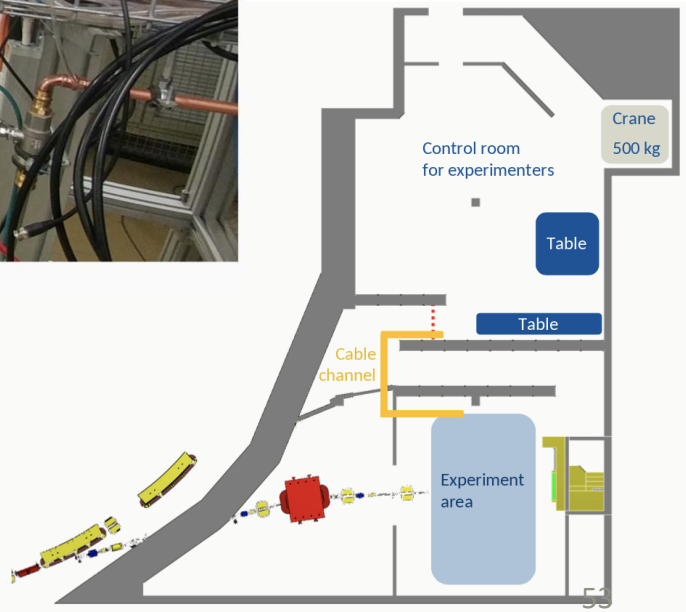
Irradiation Facility at Cyclotron



ELSA Test Stand



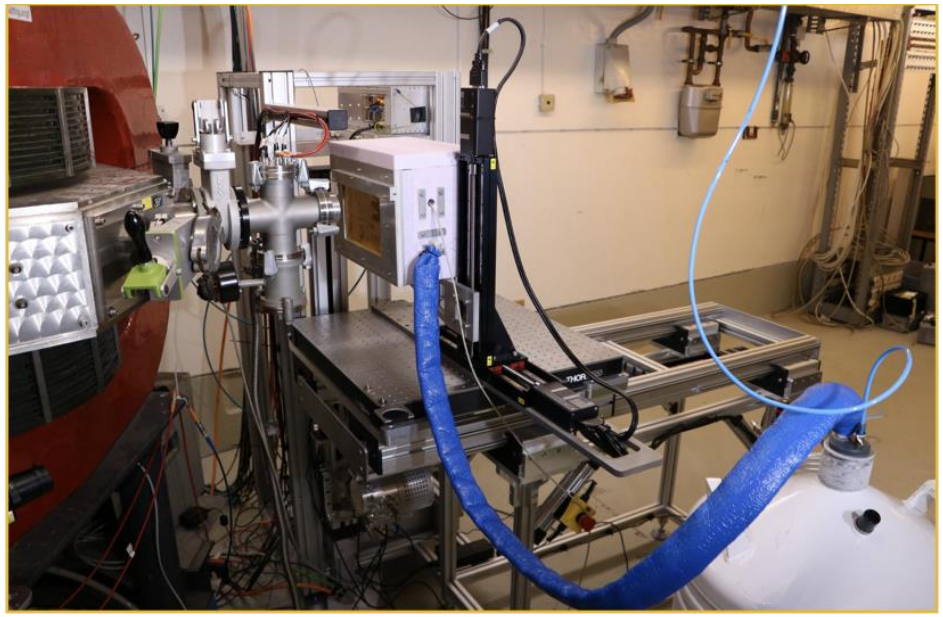


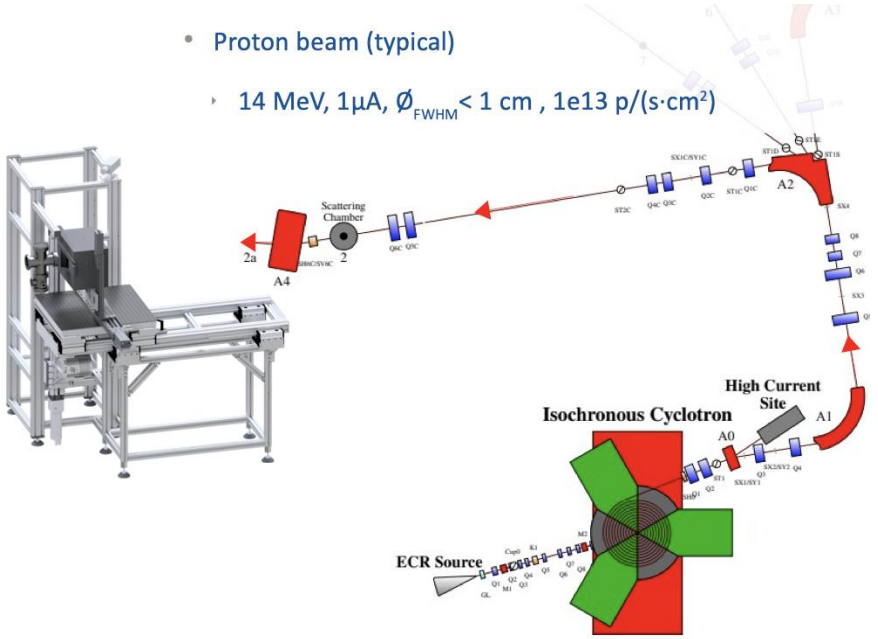


FTD

Irradiation Facility at Cyclotron

Irradiation setup

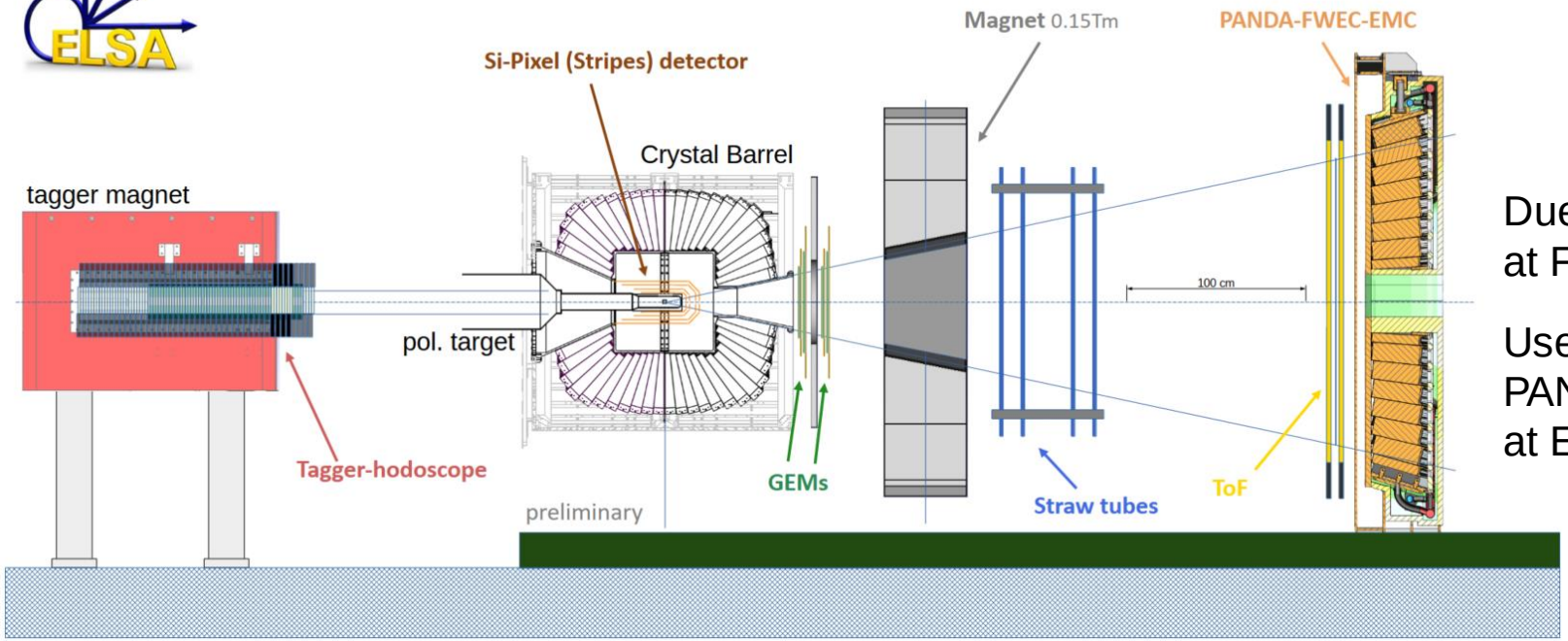




- Proton beam (typical)
  - 14 MeV, 1 µA, $ø_{FWHM}$<1 cm, 10^{13} p/s/cm^2
  - corresponds to 10^{16} n_{eq}/cm^2 in about 2 h
- Neutron irradiation region being prepared
- Future ideas: material investigation using proton and ion micro-beams (e.g. SNAKE)

- From plan to reality the history of the FTD
- The FTD as a part of a research infrastructure at Bonn
- Key technologies and tools of the FTD
- The experiments at FTD (selected view)
- **Common infrastructure of the FTD**
- Construction hall

Common Infrastructure – New Experiment at ELSA



Due to delays at FAIR:

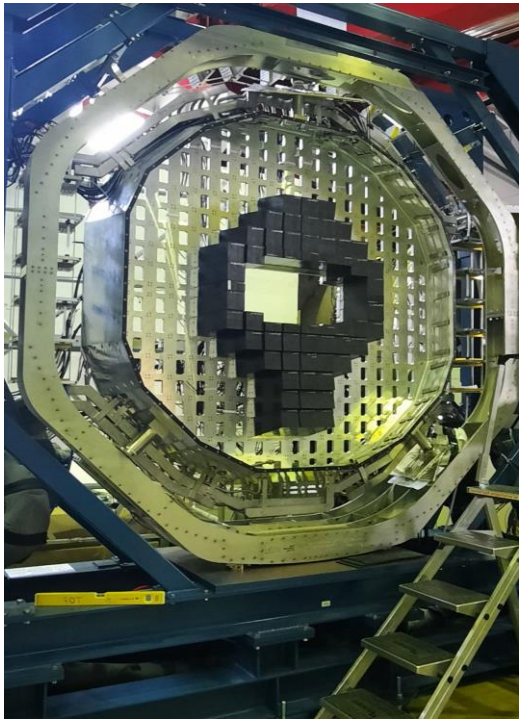
Use of the PANDA-FWEC at ELSA

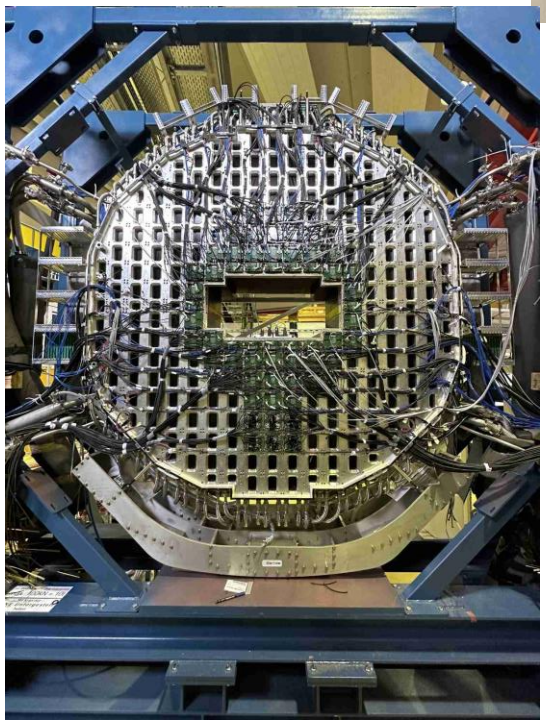
FWEC – EMC:

- 3856 $PbWO_4$-crystals in 268 modules
- for ELSA: filling of the inner hole

Common Infrastructure – FWEC PANDA

- 20% of the FWEC assembled
- First very successfull test at COSY at -25°C





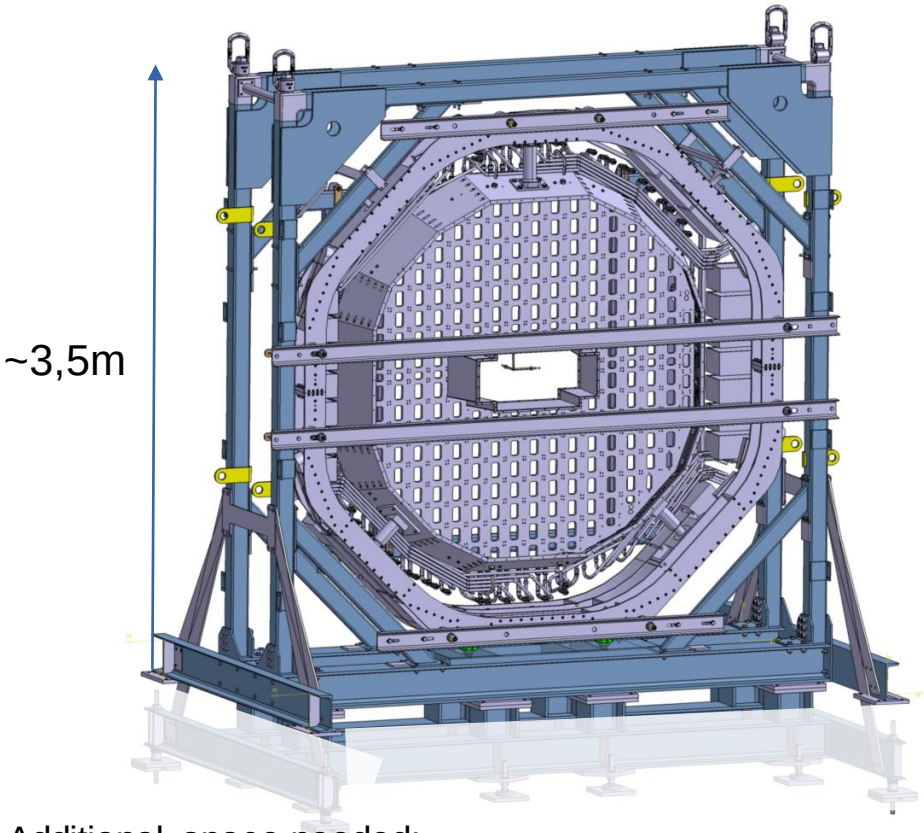
All modules tested and pre-calibrated in Bonn at -25°C

Before glueing precise geometry measurements with the FTD-laster tracker

Transport of the FWEC to Bonn + finalize its assembly at the FTD => use at ELSA

Common Infrastructure – FWEC PANDA

~6.2t plus support structures (~2.2t) = ~**8.4t** (FTD-crane: 7.5t)



Alveoles mounted with a specific device
=> space needed

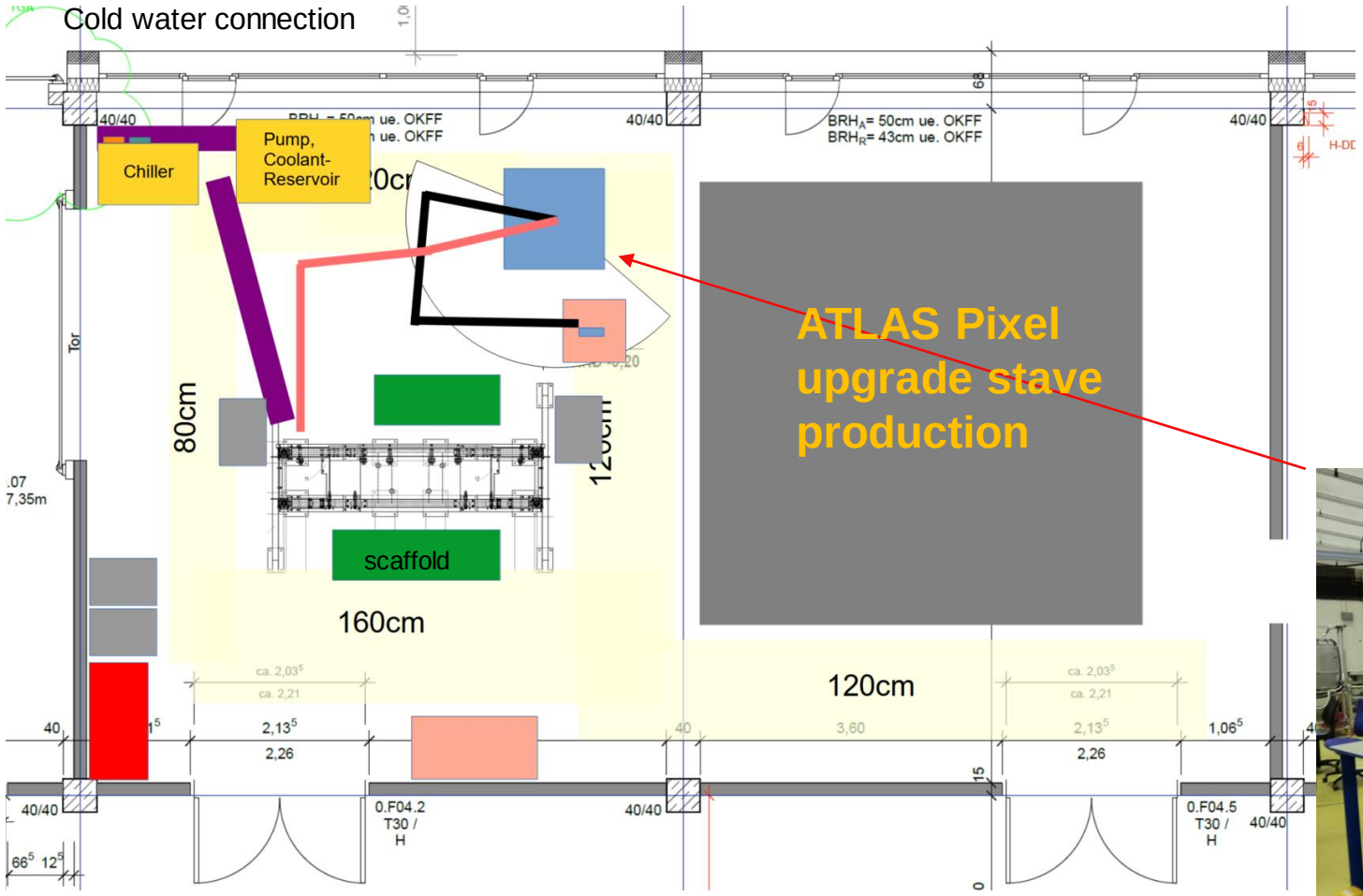
@COSY

Additional space needed:

- Frontend electronics integrated in detector system
- Racks for power supplies (HV,LV)
- Cooling (+ dry air) (+ nitrogen) for running at -25°C

Common Infrastructure – FWEC PANDA

Common Infrastructure – FWEC PANDA



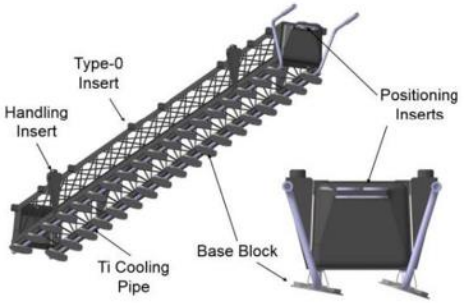
Alveole mounting device

⇔ **Left half of the assembly hall needed!**

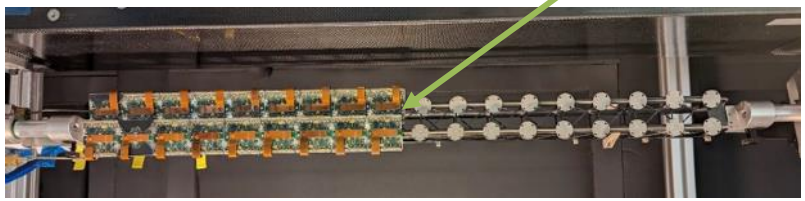
Common Infrastructure – ATLAS Pixel

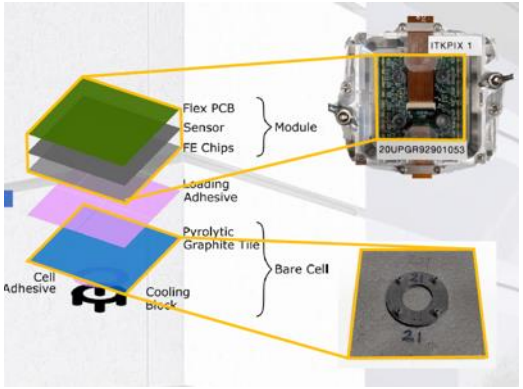
Common Infrastructure – ATLAS Pixel upgrade

- FTD contributes to ATLAS pixel detector production (2024 - 2026)
  - Assembly and testing of 1000 ATLAS pixel detector modules
  - Assembly and testing of 160 local supports (including cell integration)

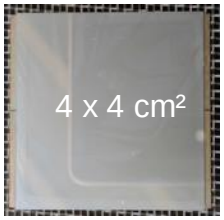


Loaded local support („stave“) with up to 36 modules





Silicon R/O chip and sensor



Flexible PCB

Glueing and wire bonding

ATLAS ITk Pixel detector module

Conclusion

- The FTD is a new facility that hosts detector groups from University of Bonn, but external groups are welcome for research activities
- The FTD is/will be a unique infrastructure with very modern facilities, tools and technologies.
- The FTD offers a unique chance to do research in one hand
- The common infrastructure should support experiments at every phase of their realization (R&D, Prototyping, Production, Commissioning)
- One Possibility of participation is through EU-funded transnational access (STRONG-2020), but we also explore different possibilities

Thanks for your attention