# Gaseous Detectors for Hadron Physics Infrastructures

## Letter of Intent

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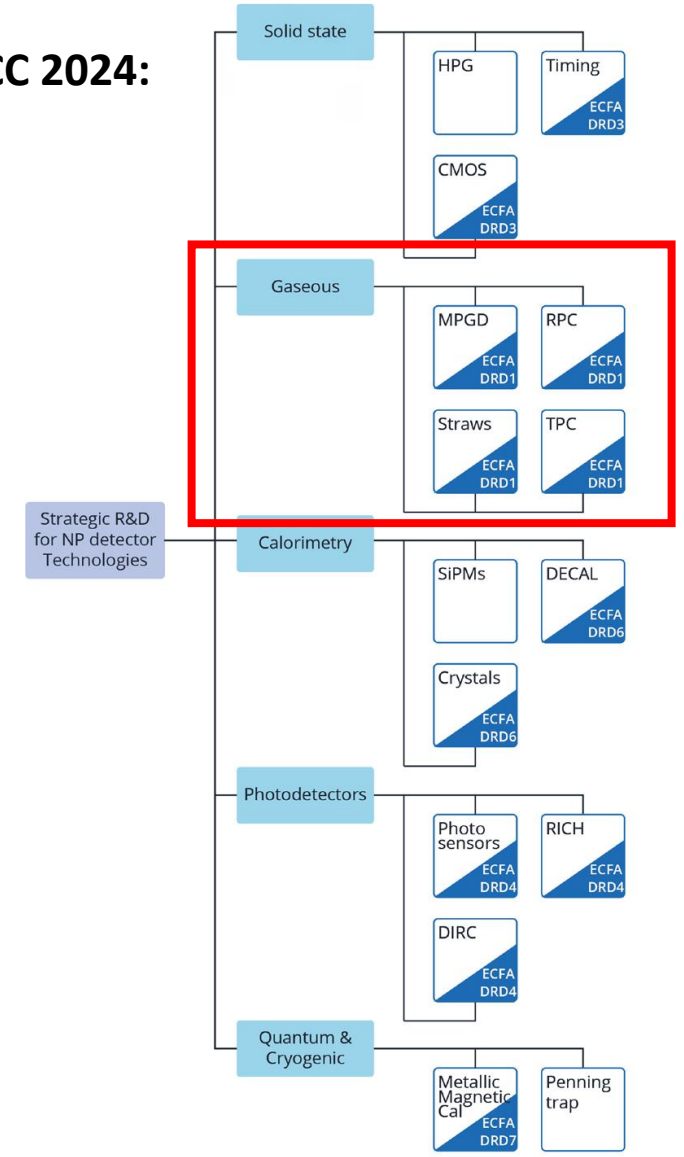
UNIVERSITÄT BONN FTD AG Ketzer

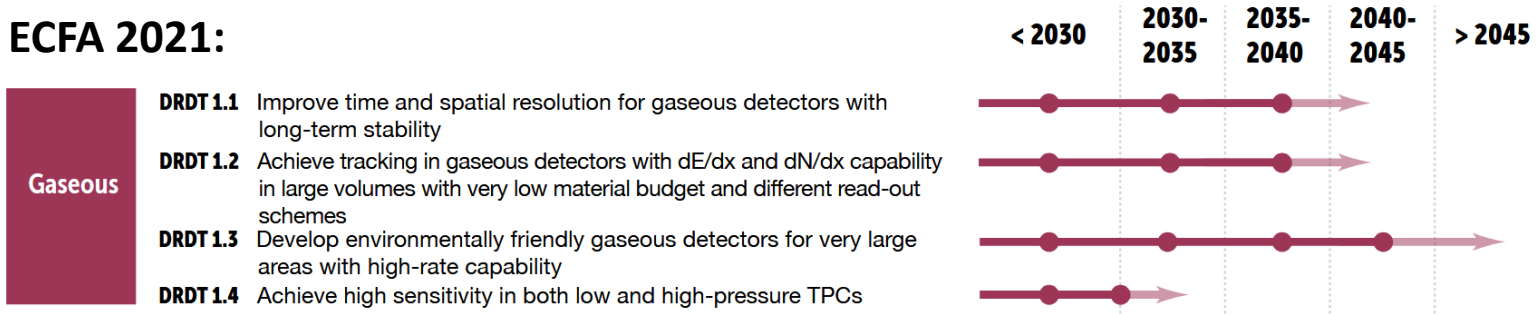
# Research Objective – Gaseous Detectors

- Recommendation by
  - European Committee for Future Accelerators 2021 (ECFA)
  - NuPECC Long Range Plan 2024
- Gaseous detectors: One key technology
  - Micropattern Gaseous Detectors (MPGDs)
  - Resistive Plate Chambers (RPCs)
  - Wire-based Detectors (Straws)
  - Time Projection Chambers (TPCs)
- Organization in Europe via CERN-based Collaboration (DRD1)

**NuPECC 2024:**

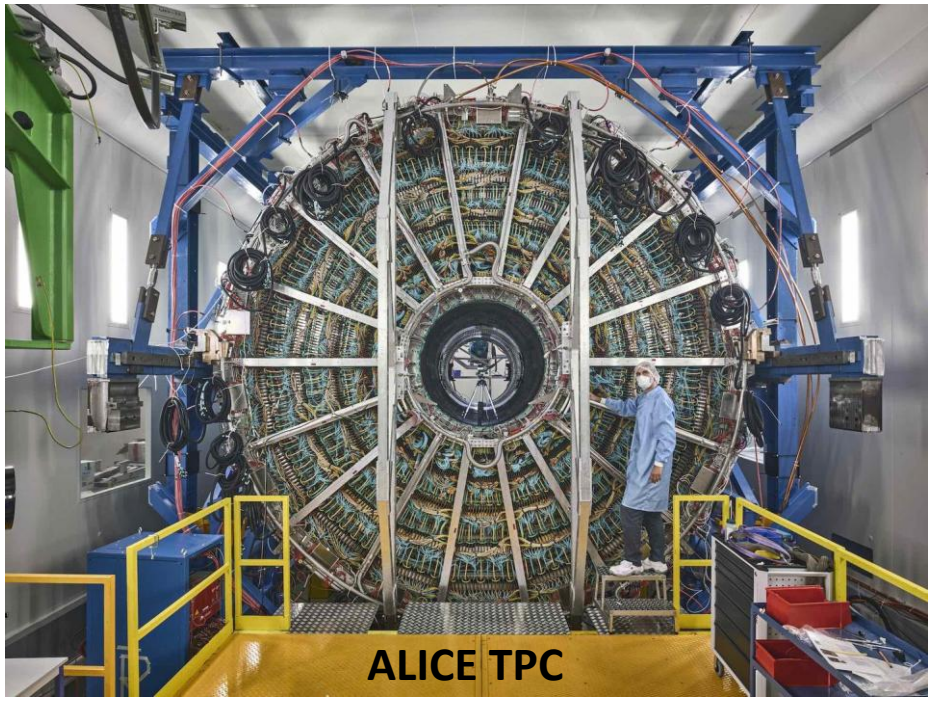


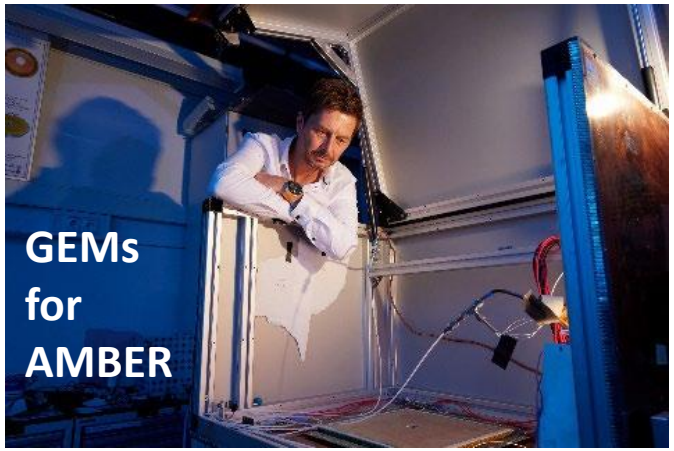

**ECFA 2021:**



# From Laboratory to Experiments

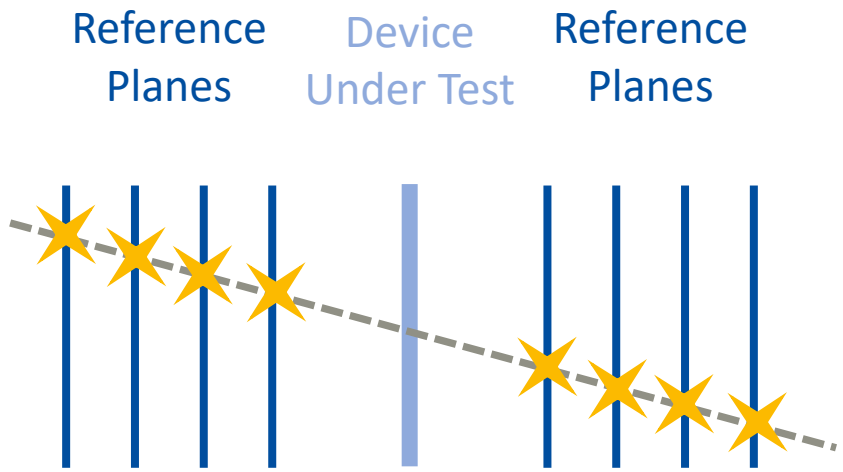
- All gaseous particle detectors started as a small prototype in a laboratory
- Before using them in a big experiment: Test in a beam required!
- Common DRD1 testbeams are typically heavily booked
- Need for more testbeam sites




# Motivation for a Beam Telescope

- We propose to set up a common beam telescope based on gaseous detectors
- 8 layers of MPGD-based tracking detectors (reference planes)
  - Each: Spatial resolution of 50 µm
  - Track resolution for DUT is then 20 µm
- Cover large area of 20 x 20 cm²
  - Comparison: Silicon-based telescopes have a size in the order of 2 x 2 cm²
- Readout possible via
  - VMM3a (ATLAS NSW)
  - CTR16 (GSI)
  - ToRa (Torino)
- RPCs or Szintillators for timing
  - Time resolution better than 1 ns
- Rate capability > 50 kHz/cm²
- Modular design
  - Can be used at various accelerator sites

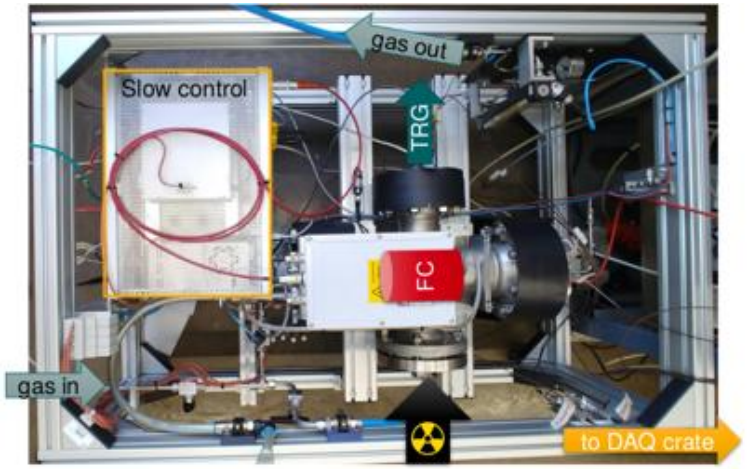


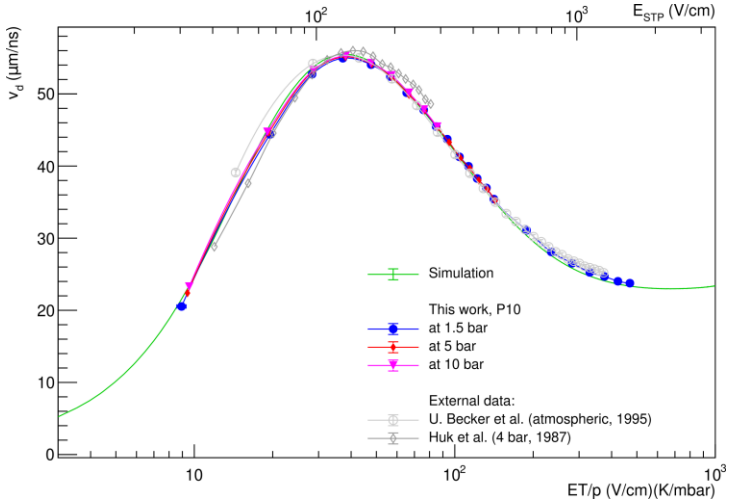
# Involved Institutes – Aachen

- R&D for high pressure TPC (HPTPC)
  - Parameters for suitable gas mixtures
  - Optical readout
- Profits from the common beam telescope:
  - Test of HPTPC prototypes, e.g. measurement of spatial resolution and d*E*/d*x* resolution
- Contribution:
  - Gas system for telescope
  - Reconstruction software

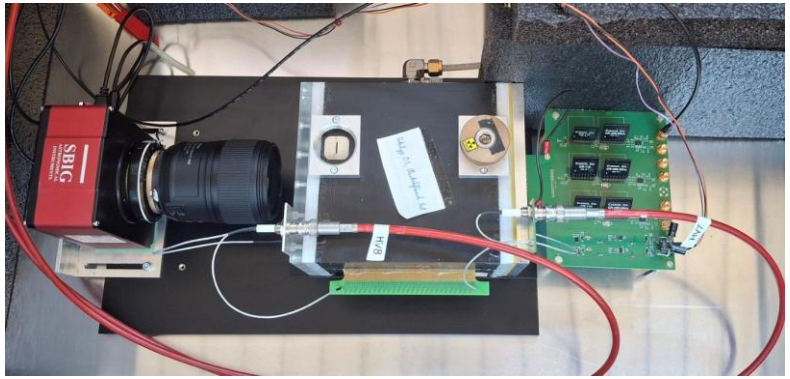
Stefan Roth
Jochen Steinmann

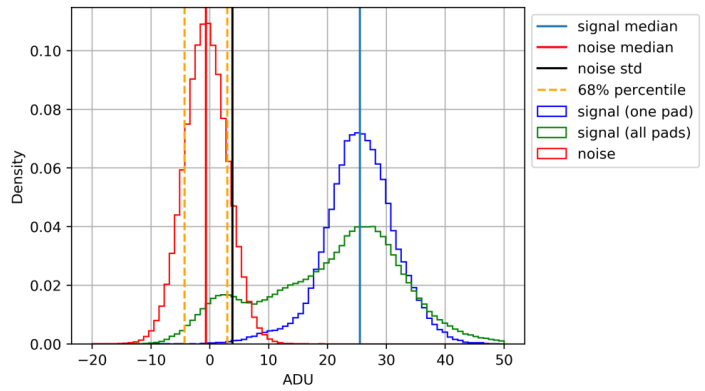
**Gas Parameters:**




**Optical Readout:**



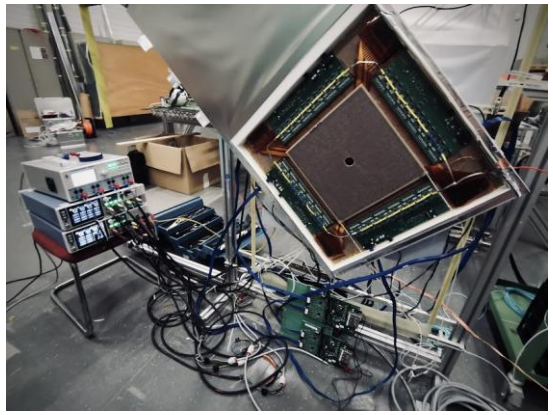


# Involved Institutes – Bonn

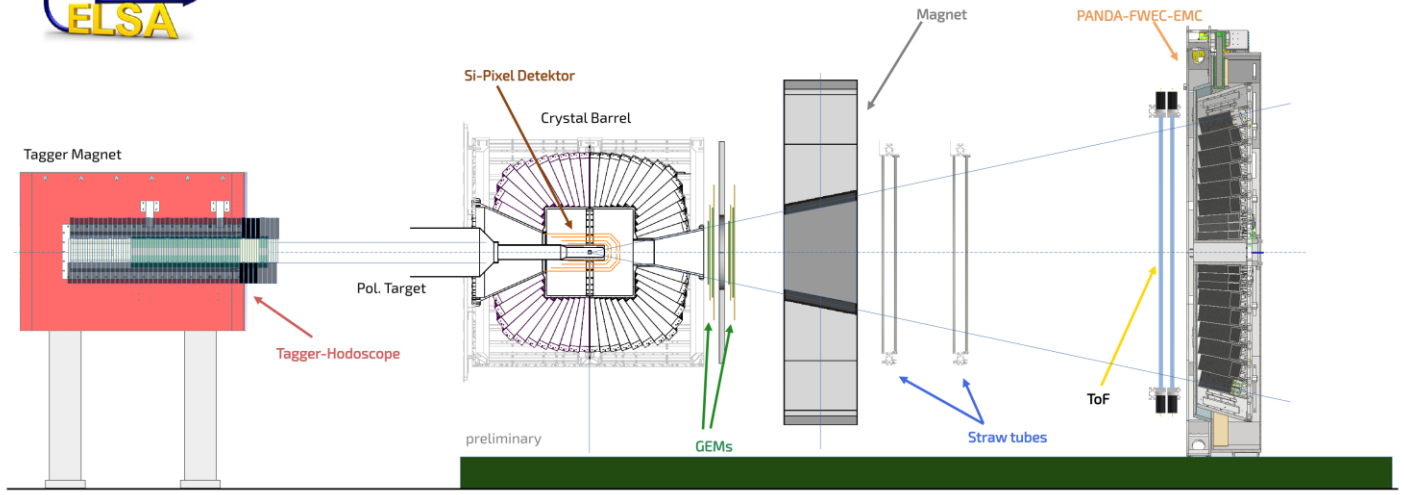
- Experience with GEM detectors
  - ALICE TPC
  - Trackers for COMPASS/AMBER
  - FOPI TPC
- Currently involved in the detector development for
  - AMBER
  - INSIGHT
- Common requirements:
  - Large area coverage (typ. 30 x 30 cm²), high rates, low material budget
- Need to test detectors in a beam before installation in experiment

Bernhard Ketzer
Michael Lupberger
PH

**AMBER GEMs:**



**ALICE GEMs:**



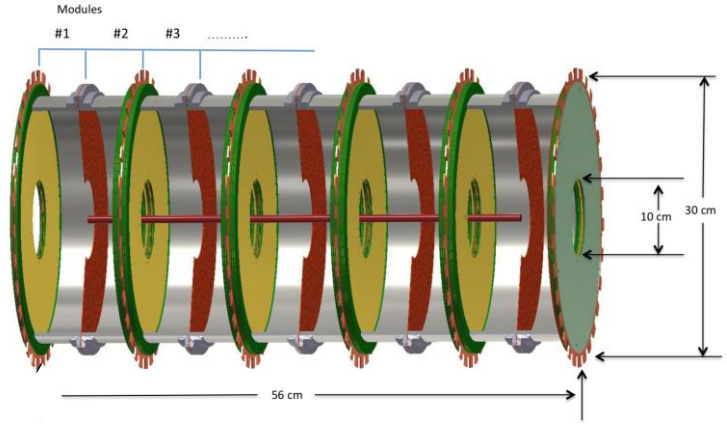

**Sketch of the future INSIGHT detector**

# Involved Institutes – Glasgow

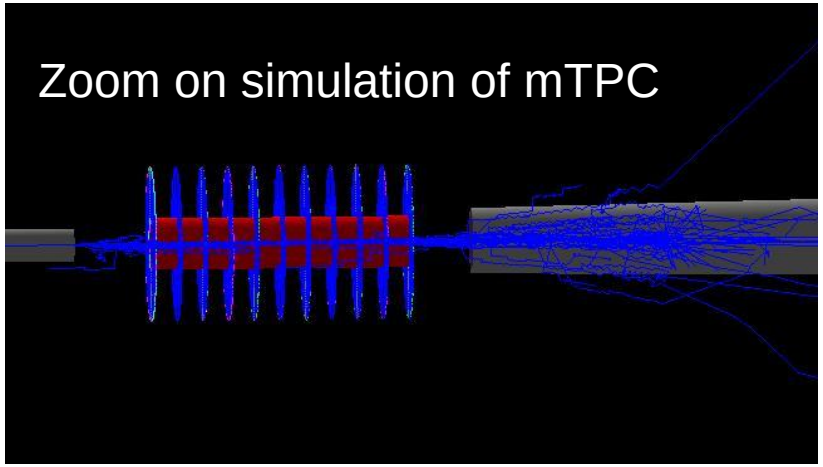
Rachel Montgomery

- Current focus on gaseous detectors for:
  - Tagged Deep Inelastic Scattering (TDIS) for Jefferson Lab
  - R&D of high-rate multiple time projection chamber (mTPC)
  - Tracking recoil hadrons of momenta 100-400 MeV/c
  - Low density gas detector needed for low momenta hadrons
  - High-rate capabilities needed due to high backgrounds from high-luminosity running
- Access to common beam telescope:
  - Provide data to test gaseous detector design elements
  - Tune TDIS simulations
  - Benchmark and test TDIS tracking algorithms
- TDIS prototypes could be tested as DUT within the beam telescope
  - TDIS has several test beams and prototype planned in future

High rate multiple time projection chamber (mTPC) to tag recoiling/spectator hadrons



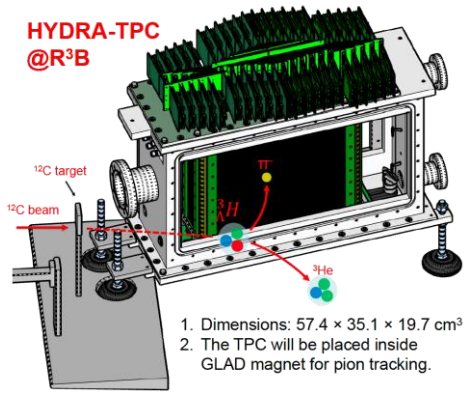

Tracking, dE/dx

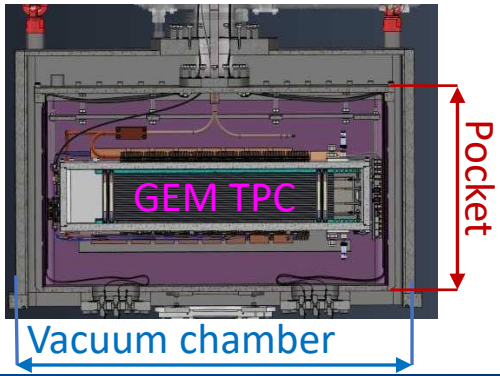


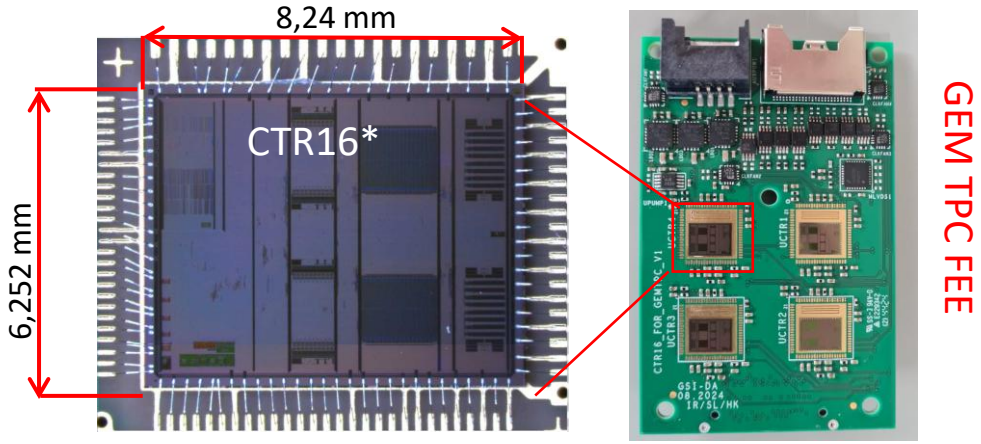
# Involved Institutes – GSI

Elena Rocco
Christian Schmidt
Piotr Gasik

- Current focus on gaseous detectors for:
  - Beam diagnostics, beam particle tracking
    accelerator chain, **FR**agment **S**eparator @ GSI and **S**uper-**FR**agment **S**eparator @ FAIR
  - Experiments
    CBM, Hades, R³B @ FAIR, ALICE TPC, ALICE TPC Upgrade, ALICE TRD
- Common requirements:
  - Low material budget, several kHz/mm² hit rate, trigger- and triggerless- mode operation
- Mixed signal readout ASIC development & design in house
- Tests in beam feasible (from proton to uranium) at FRS and Cave C (R³B)



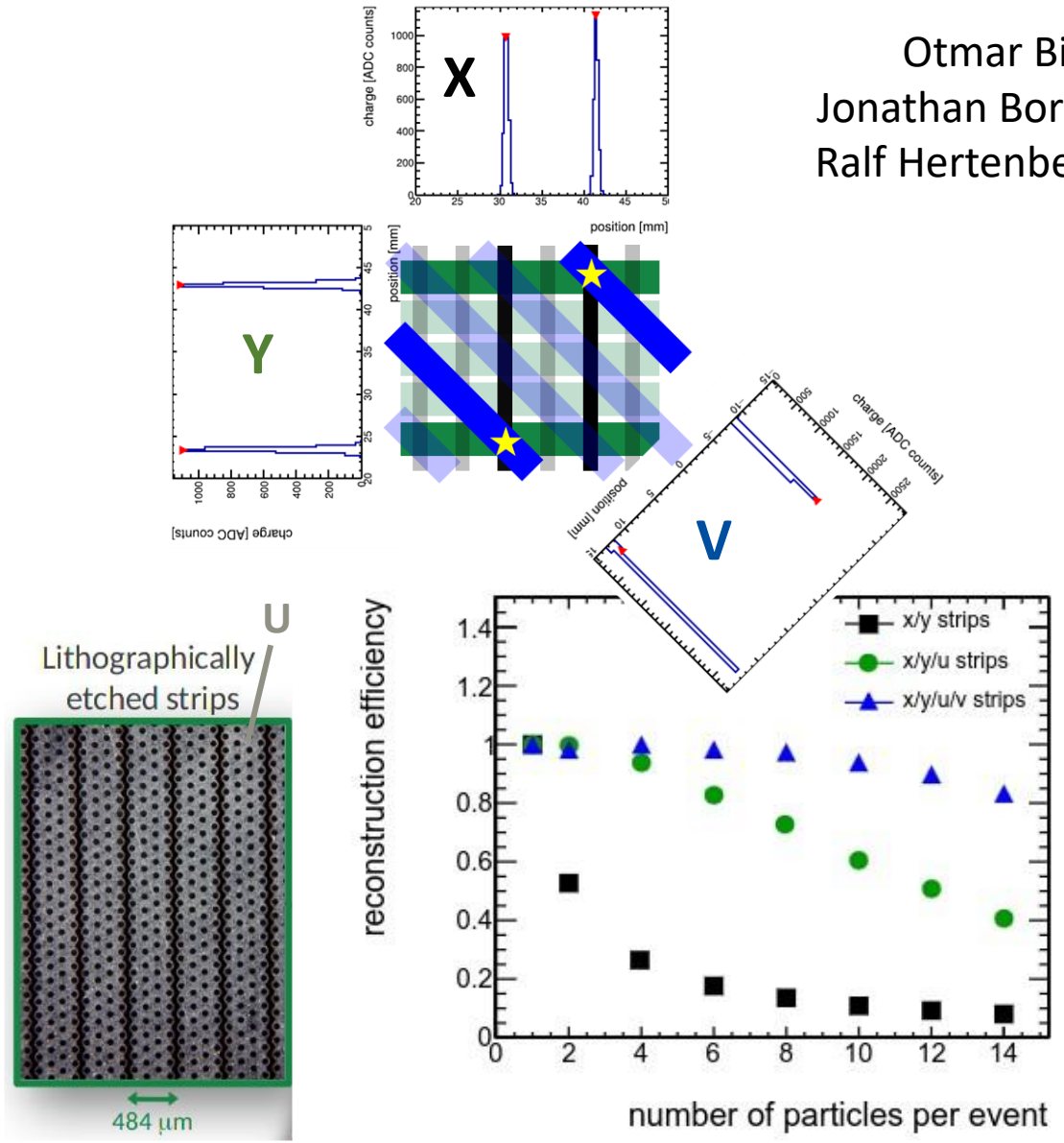
# Involved Institutes – Munich

- Current R&D activities with gaseous detectors:
  - Improve the rate capability of micro structured gaseous detectors
  - Micromegas and GEM detectors using X/Y and U/V strips for readout

- **X** / **Y** / **U** / **V** strips allow for resolving ≈ 12 particles @ >90% efficiency
  - Further improvement by using charge and time information

- Testbeam with common beam telescope at very high rates

Otmar Biebel
Jonathan Bortfeld
Ralf Hertenberger



# Involved Institutes – Torino

- Experience:
  - MWPC & MDT based detectors @ COMPASS
  - Large-size resistive bulk Micromegas for AMBER
  - ASIC & electronics design (ToRA)
- Currently involved in detector design for:
  - AMBER
  - ePIC (EIC)
- Common requirements:
  - Large areas (up to 50 x 50 cm²)
  - Low material budget
  - High rates
- Beam telescope required to qualify new detectors

Maxim Alexeev, Chiara Alice, Michela Chiosso, Gianni Mazza

## Torino Readout (for) AMBER ASIC (ToRA)

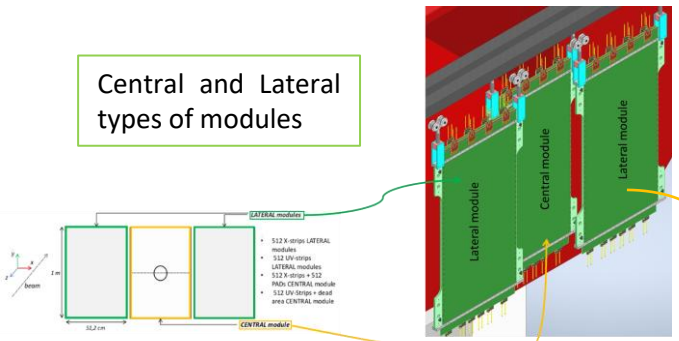
- MPGD and Wire detectors compatible
- Target specific application
- Limited complexity
- Reuse existing solutions (ToASt)
- 65nm
- Two step features design v1 (submitted 05.2025), v2

Will depend on the FE optimisation results

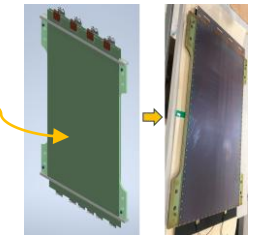
| Detector | MM | Straw | |
|---|---|---|---|
| Channels/ASIC | 64 | 64 | |
| Power/channel | ≤ 25 | ≤10 | mW |
| Input capacitance | ≤550 | 20-100 | pF |
| Input charge | 1-100 | 1-1000 | fC |
| Input impedance | ≤50 Ω | *tbd* | Ω |
| Max rate | ≤ 0.5 | ≤0.18 | MHz |
| Peaking time | 150-500 | 25-150 | ns |
| Time resolution | 1-2 | ≤1 | ns |
| Charge resolution | 8 | 10 | bits |
| Gain | 10-20 | 2 | mV/fC |
| ENC @10 pF | 500-1000 | | $e^-$ |
| ENC ? @550 ? pF | 1000-3000 | | $e^-$ |
| ENC @60 pF | | 3000 | $e^-$ |
| Threshold range | *tbd* | 0-15 | fC |
| Clock frequency | 200 | 200 | MHz |

## Large area Micromegas (LMM)

Central and Lateral types of modules



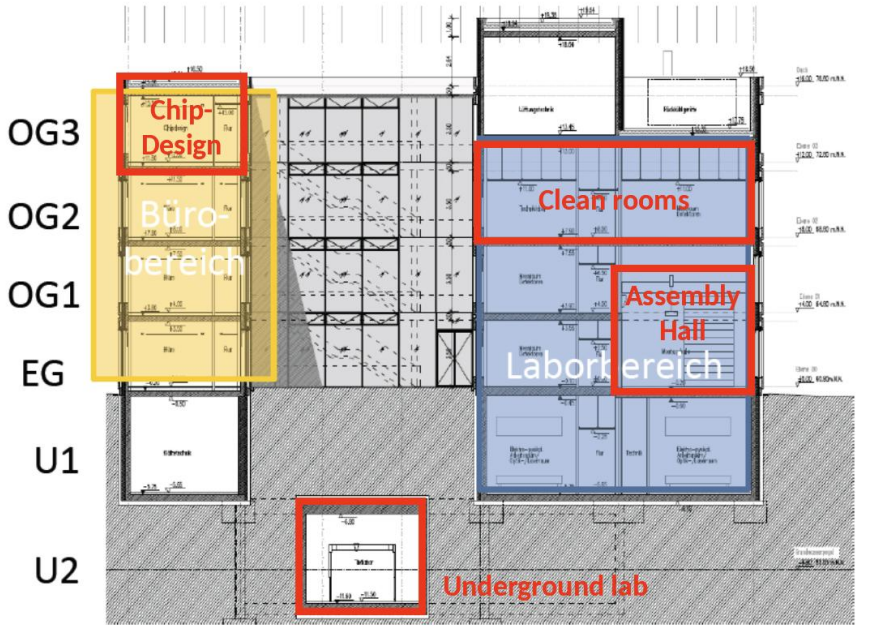

First full-size Lateral module produced & under test



- ❖ Concept design @ To
- ❖ Layout & Production @ CERN MPT

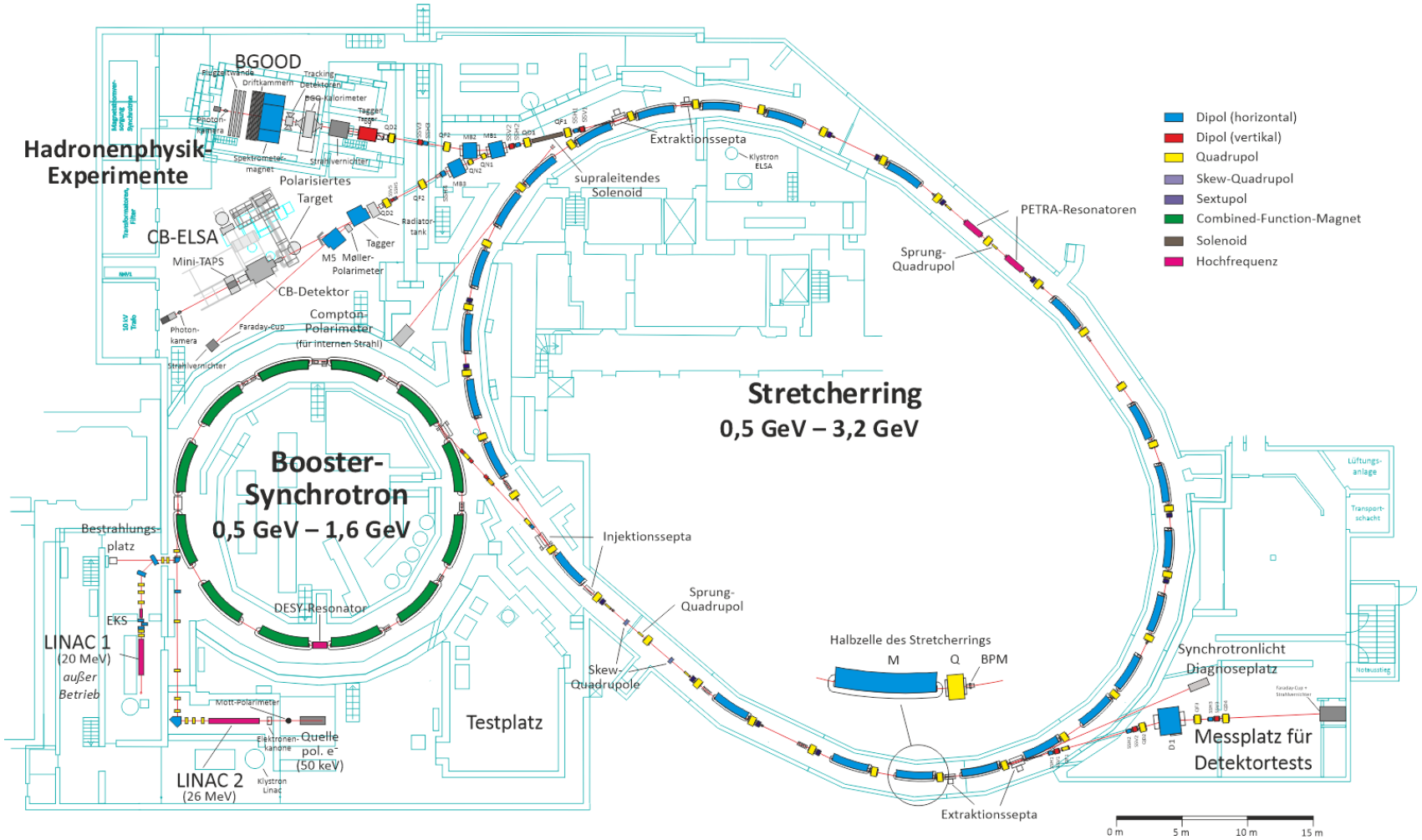
# FTD in Bonn

- Forschungs- und Technologie-Zentrum Detektorphysik
  - Research and Technology Center for Detector Physics
- Dedicated research infrastructure for particle detectors
  - 2010 $m^2$ in total
  - 360 $m^2$ clean room area (ISO5, ISO6 and ISO7)
  - 880 $m^2$ office space (also for external users)
- Provides all necessary tools to set up and maintain the telescope
  - Detector assembly in clean room
  - Lab tests in dedicated gaseous detector labs
- Directly next to local accelerator ELSA
  - Planned for commissioning of the telescope



# ELSA in Bonn

- Electron accelerator
- Used mainly for hadron spectroscopy
- Max. energy 3.2 GeV
- Dedicated site for detector tests
  - Primary beam
  - Particle rates from 100 Hz to 625 MHz
- Parasitic extraction possible



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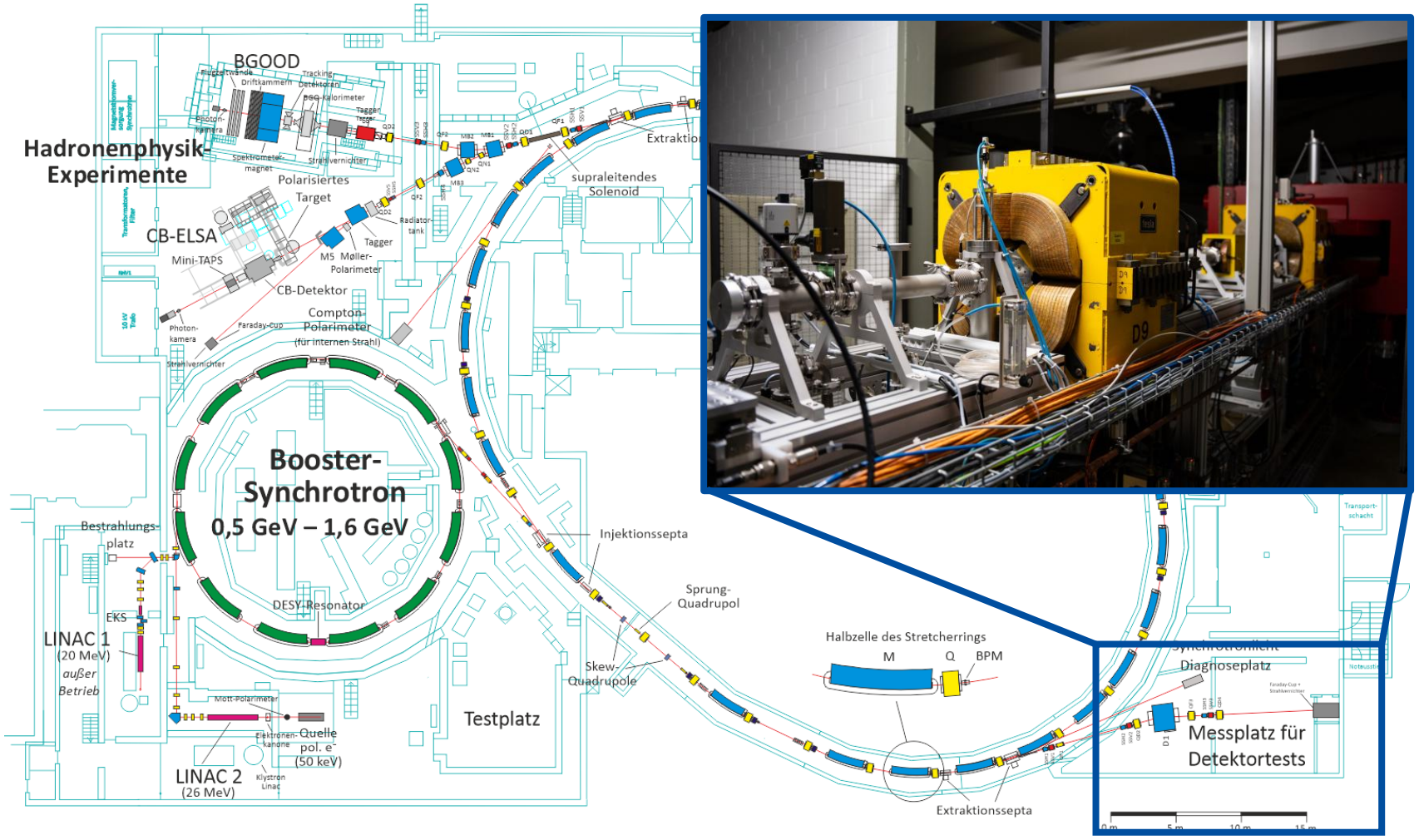
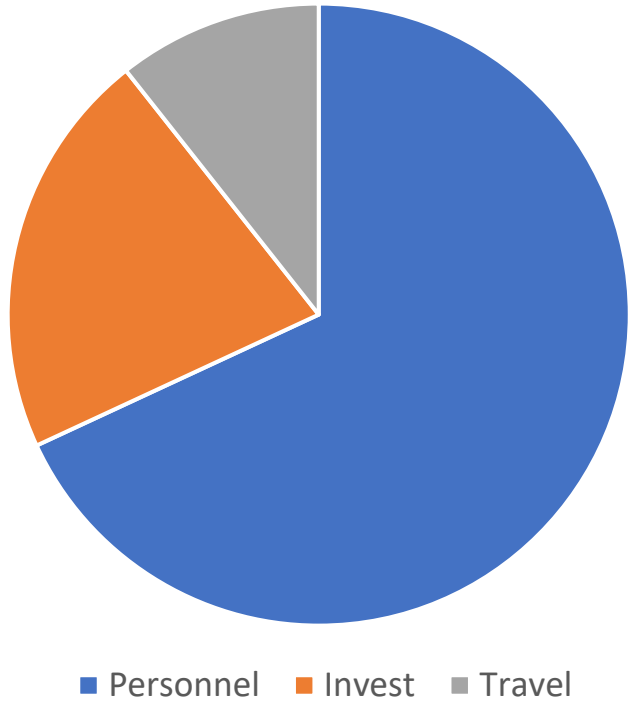


# Estimated Budget

| Category | Type | Task | Amount |
|---|---|---|---|
| **Personnel** | PhD (40 k€/year) | GEMs | 160 k€ |
| | PhD (40 k€/year) | Micromegas | 160 k€ |
| | PhD (40 k€/year) | Electronics | 160 k€ |
| | PhD (40 k€/year) | DAQ & Tracking | 160 k€ |
| **Invest** | Detector hardware | Detector components, Support | 100 k€ |
| | Electronics | Frontend & DAQ | 100 k€ |
| **Travel** | Common beam times | | 60 k€ |
| | Workshop, Conferences | | 40 k€ |
| **Total** | | | **940 k€** |




- Over 2/3 of the budget: Training of young scientists
- Travel money: Beam times at ELSA and/or at GSI
- Invest money only for telescope, surrounding infrastructure already exists

# Summary

- Proposal: **Beam Telescope based on modern gaseous detectors**
- Set up and commissioning in Bonn at the FTD and at ELSA
- Contributions from other institutes
- Further testbeams at other accelerator sites e.g. GSI
- Necessary tool for development of future gaseous detectors

- Total budget: 940 k€
  - 640 k€ for PhD students
  - 200 k€ invest (telescope only, infrastucture exists)
  - 100 k€ travel

- Beam time exploitation & efficient using of facilities ☑
- Method and tools development ☑
- Short-term R&D ☑
- Training of young students ☑

# Thanks For Your Attention!

Thanks for your attention!

Dr. Philip Hauer
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