‘The strong interaction at the frontier of knowledge: fundamental research and applications’

WP 32 – JRA14: Micropattern Gaseous Detectors for Hadron Physics

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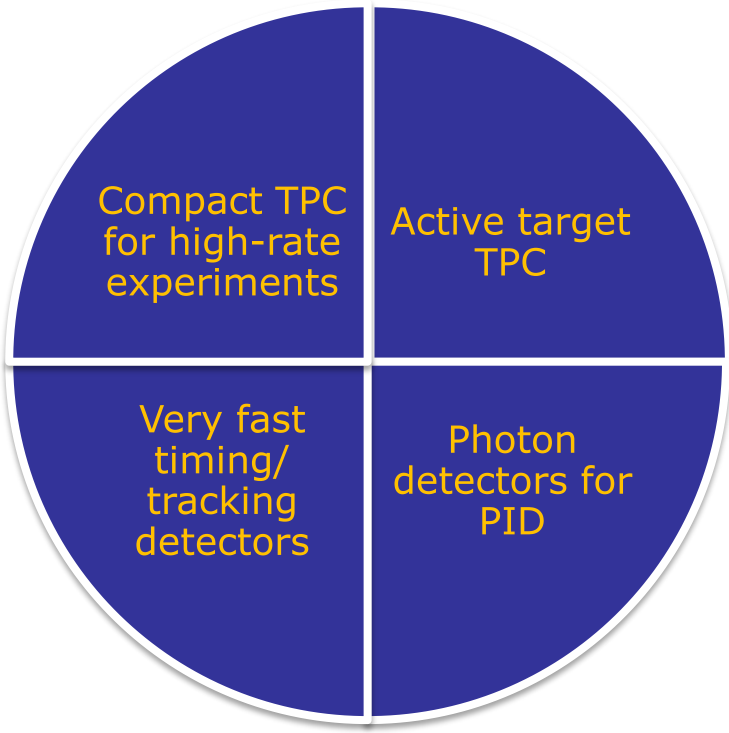
STRONG-2020 Kick-off meeting

October 23-25, 2019

Micropattern Gaseous Detectors for Hadron Physics

University of Aveiro
University of Bonn
Stefan-Meyer-Institut
GSI
University of Glasgow
INFN Bari
INFN Trieste
TU München
CEA Saclay



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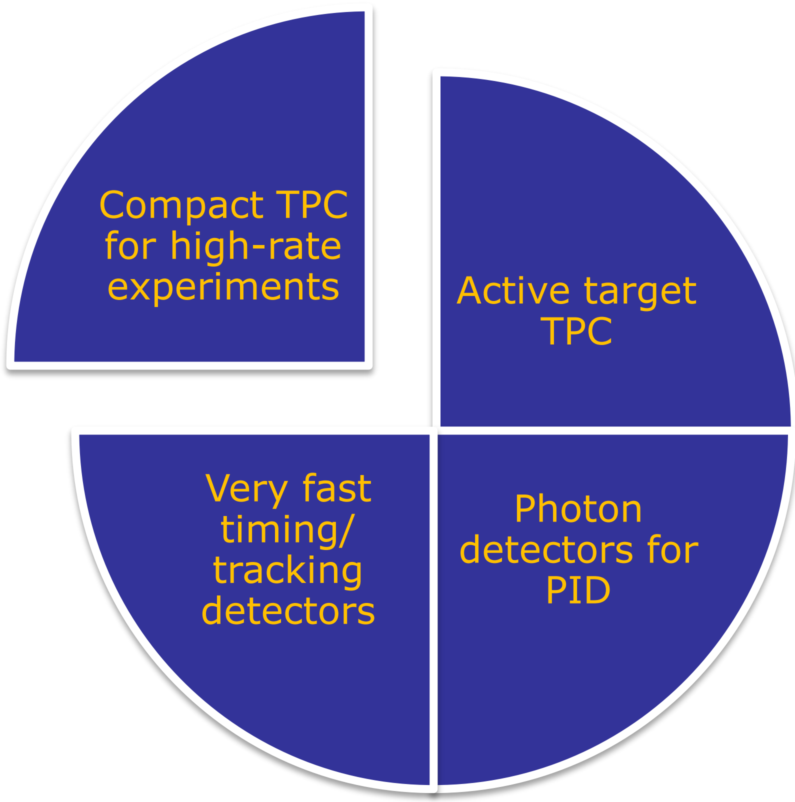
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 824093.

Micropattern Gaseous Detectors for Hadron Physics



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Task 1: Compact TPC for high-rate experiments

- Goal: Prepare foundations for 3D continuous tracking with minimal material budget in environments with extremely high intensities and track densities.
- Tasks:
  - investigate properties of MPGD components at very high rates or local charge densities in terms of charge transport, ion backflow, possible instabilities and aging ⇨ already started
  - develop numerical simulations for MPGDs with the power to make quantitative predictions ⇨ already started
  - construct detector vessels with very low material budget in combination with ultra-thin solenoid magnet structures to be developed in cooperation with the JRA CryPTA (H. Dutz et al.) ⇨ will start at a later stage
  - characterize prototype detectors in particle beams and intense sources in order to optimize their performance ⇨ will start in 2020
- Deliverables: small-scale prototype of the high-rate TPC. Delivery: month 48.
- Applications: JLAB (tagged DIS), RHIC (SPHENIX), CBELSA/TAPS, EIC

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Charge Transfer

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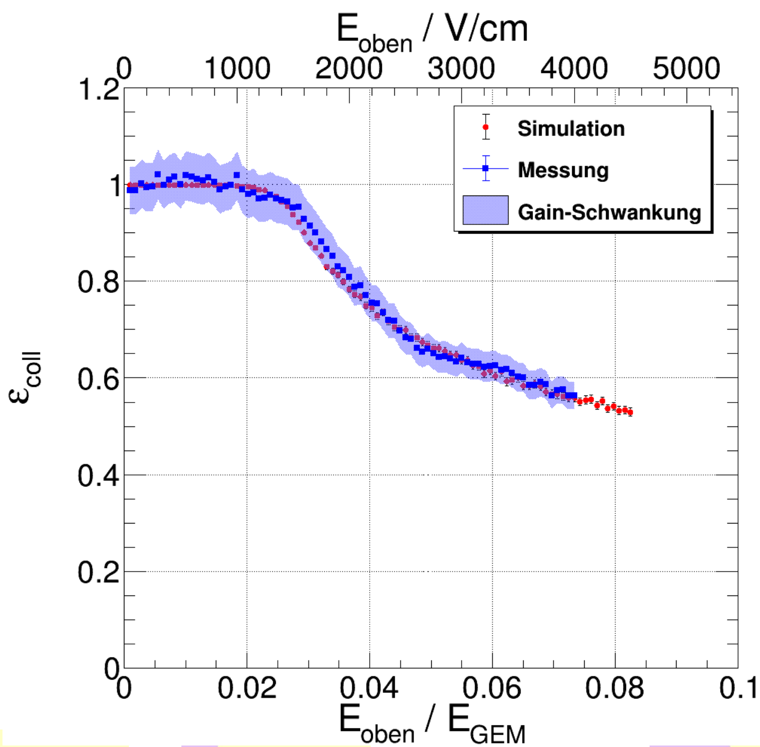
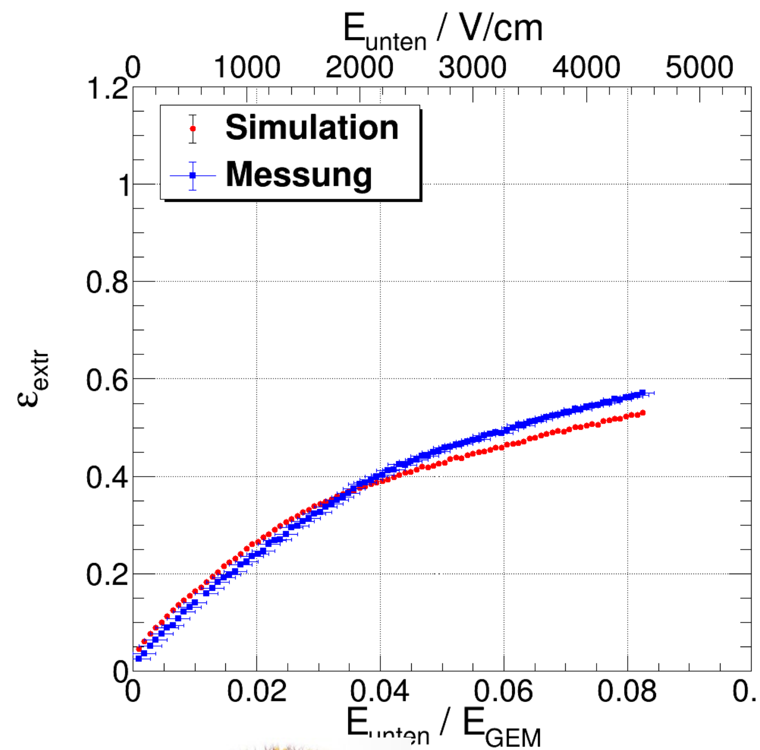
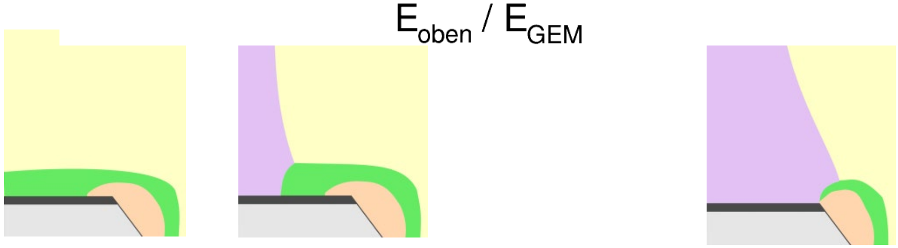
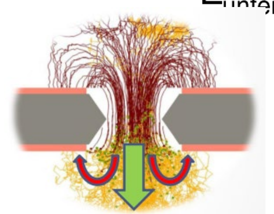
Need to understand charge transfer ⇨ simulations + measurements









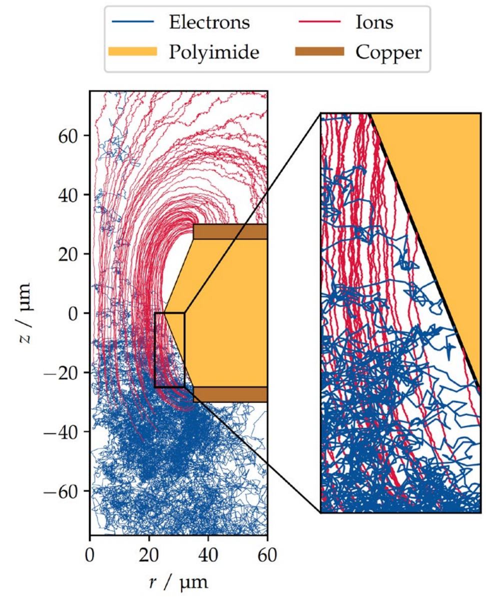
[J. Ottnad, V. Ratza, HISKP]

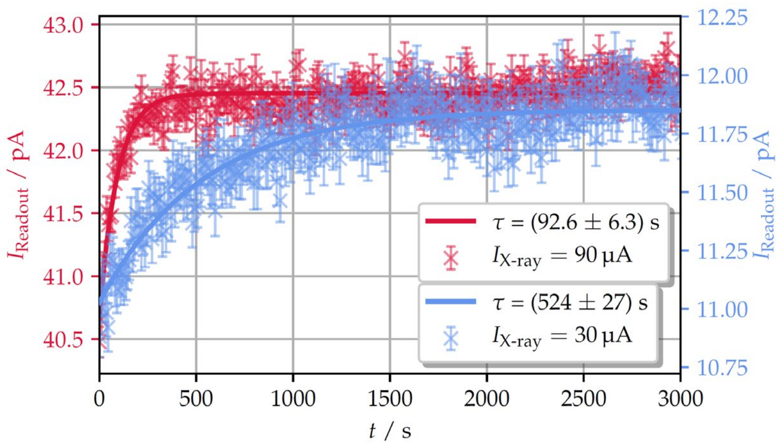
similarly for back-drifting ions…

Charging-Up Effect

U Bonn

- Observed experimentally: initial change of gain under irradiation
- Experiments:
  - rate-dependent effect
  - gain increase 5-10%
  - time constant ~10^6 av./hole
- Generally ignored in simulations!
- Simulations: ANSYS + GARFIELD++ (iter.)
  - rate-dependent effect
  - gain increase ~25%
  - time constant ~10^6 av./hole





[S. Urban, P. Hauer, HISKP]

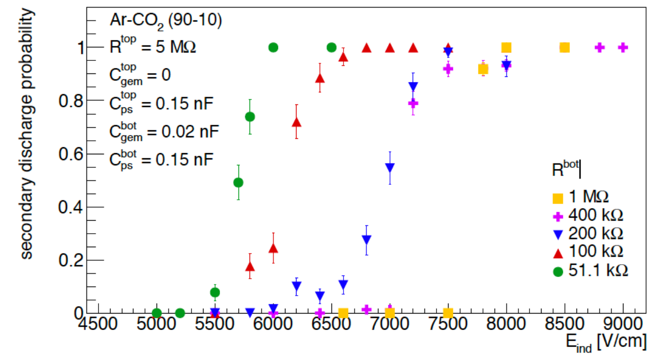
Stability limits of MPGD structures

TU München

- Optimization of the HV system for GEM-based detectors; mitigation of the secondary discharge development with passive *RC* components
  L. Lautner, L. Fabbietti, P. Gasik, T. Klemenz, JINST 14 (2019) P08024

- Discharge studies with the TH-GEM structures; comparison with GEMs by estimating critical charge limits within the framework of a geometrical model
  L. Lautner, P. Gasik, B. Ulukutlu , submitted to JPCS

- Development of the optical methods to study development and quenching of the secondary discharges in (TH)GEM detectors.
  B. Ulukutlu, P. Gasik, submitted to JPCS



Influence of the protection resistor on the secondary discharge development
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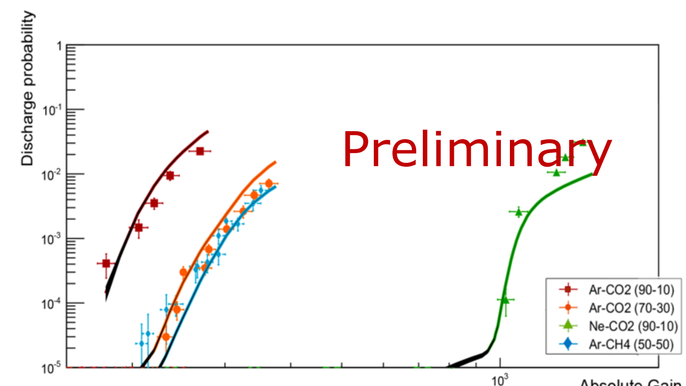
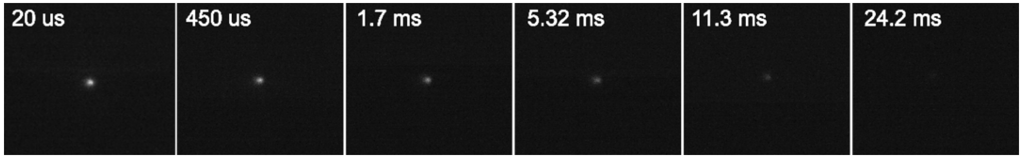


Discharge probability of a THGEM structure and comparison to the geometrical model
RD51 Collab. Meeting, (link)



Glow after primary discharge in a GEM hole
MPGD2019, Submitted to JPCS

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Application: High-rate TPC for tagged DIS

U Glasgow

- Developing design of a high-rate TPC
- TPC primarily intended to be used for measuring low momentum charged hadrons (e.g. protons/pions with 60-400MeV/c) for novel tagged deep inelastic scattering experiments studying meson/nucleon structure
- High luminosity experiments ($10^{37} cm^{-2} s^{-1}$) → very high background rates (several MHz in region of interest)
- TPC segmented along beamline direction to reduce rates in individual chambers
- TPC designed to have GEM-based readout detectors and continuously readout by triggerless electronics
- Currently on-going at University of Glasgow: developments of simulation software tools to model TPC and optimise design for high-rate environments

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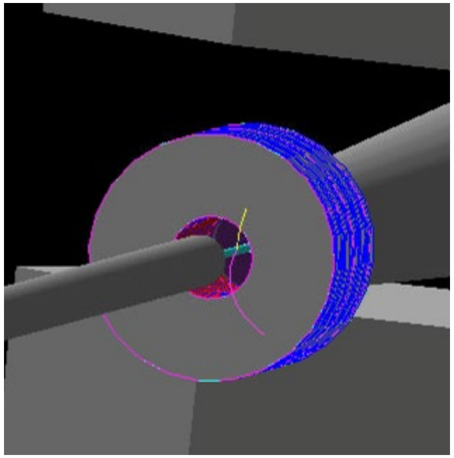
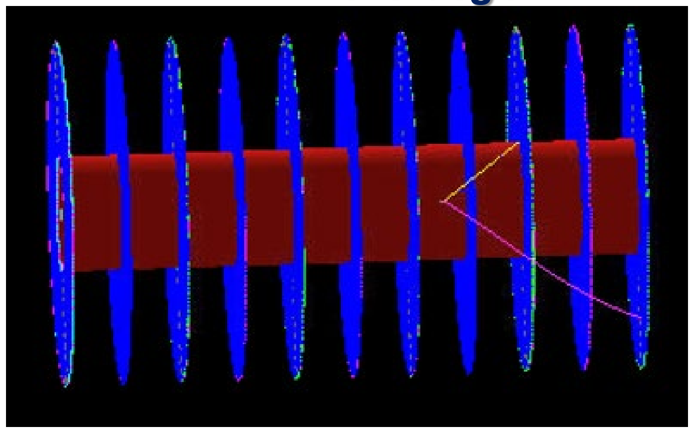
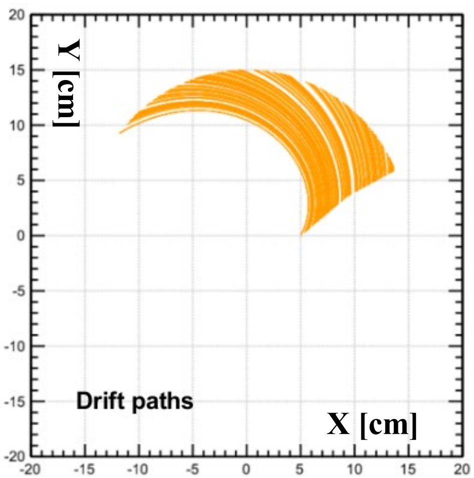
Application: high-rate TPC for tagged DIS

U Glasgow

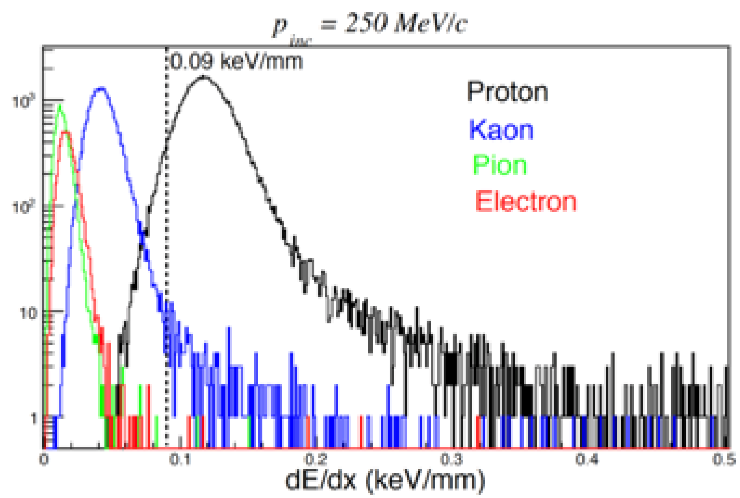




Geant4 Monte Carlo simulations: Geometry under optimization for high-rate TPC performance



Garfield++ Monte Carlo software under development to model electron drifts in TPCs



PID capability of TPC under study in Geant4

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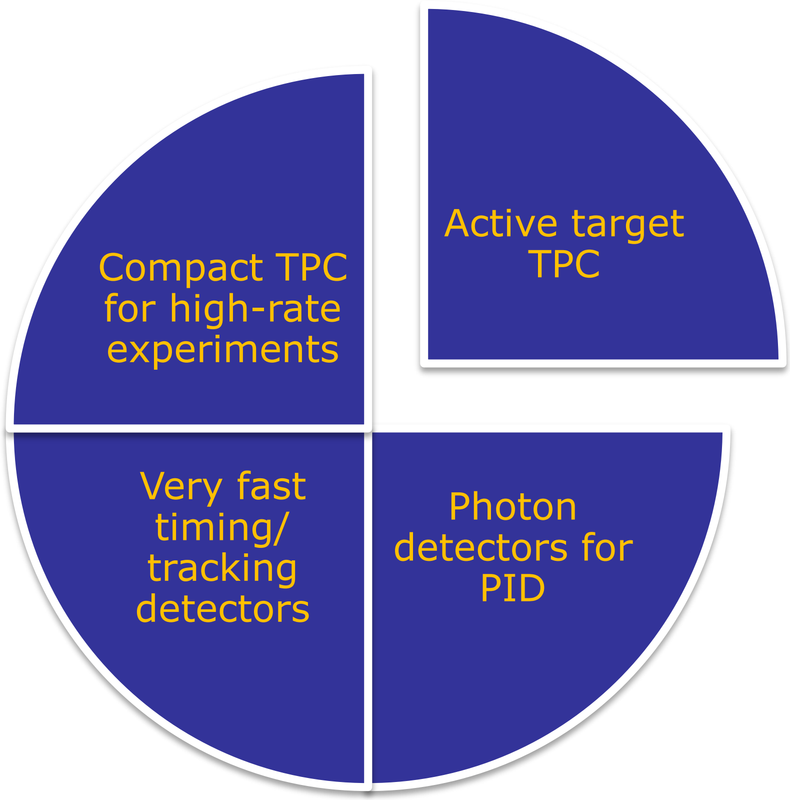
Micropattern Gaseous Detectors for Hadron Physics



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Task 2: Active target TPC

- Goal: Develop TPC which acts as an active target and at the same time performs tracking of low-energy recoil particles from interactions in the active volume.
- Tasks:
  - perform detailed simulations of the setup including beam-induced noise, space-charge effects, etc. at different gas pressures from 1 to 20 bar in order to define the granularity of the readout structure ⇨ already started
  - optimize energy resolution by studying detectors with and without gas amplifications and the associated low-noise readout electronics ⇨ will start in 2020
  - A collaboration with the Proton Radius European Network (PREN) on the impact of this technology for the solution of the proton charge radius puzzle
- Deliverables: Simulation results on energy ranges and resolutions in active target TPC. Delivery: month 48
- Applications: COMPASS++/AMBER, MAMI, DAFNE (AMADEUS)

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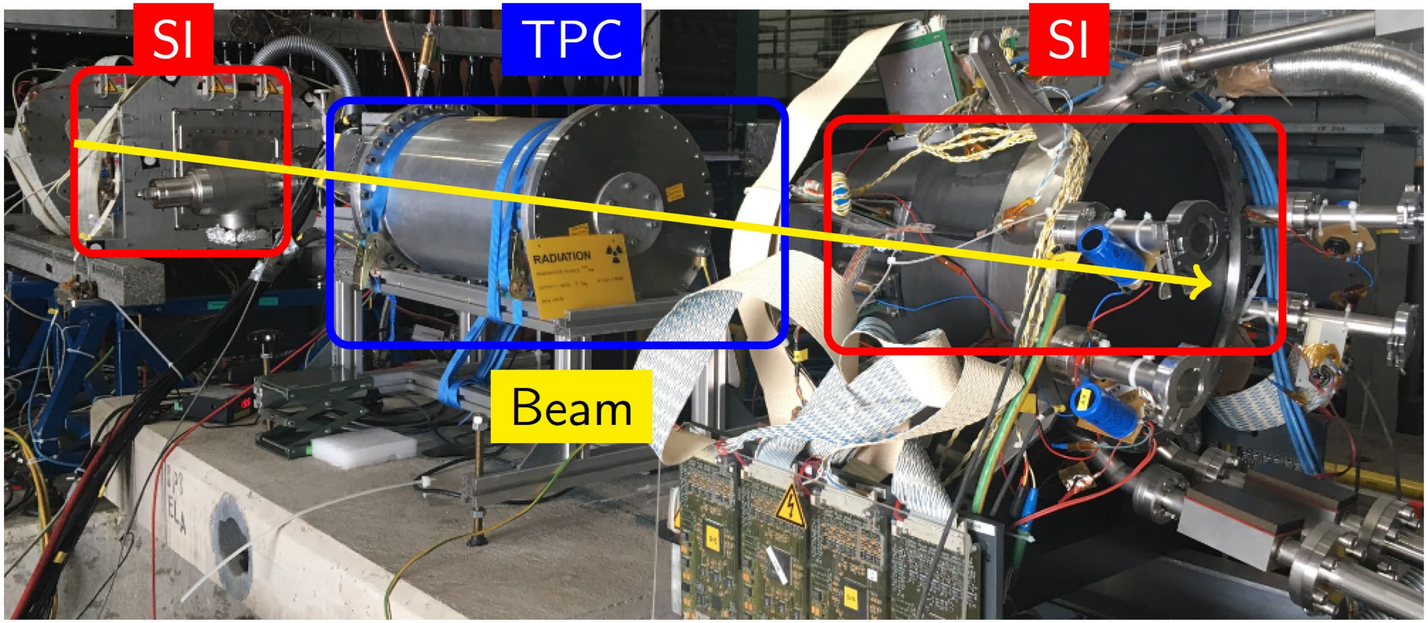
Test of μ-p elastic scattering at M2 CERN/SPS

U Bonn

UNIVERSITÄT BONN

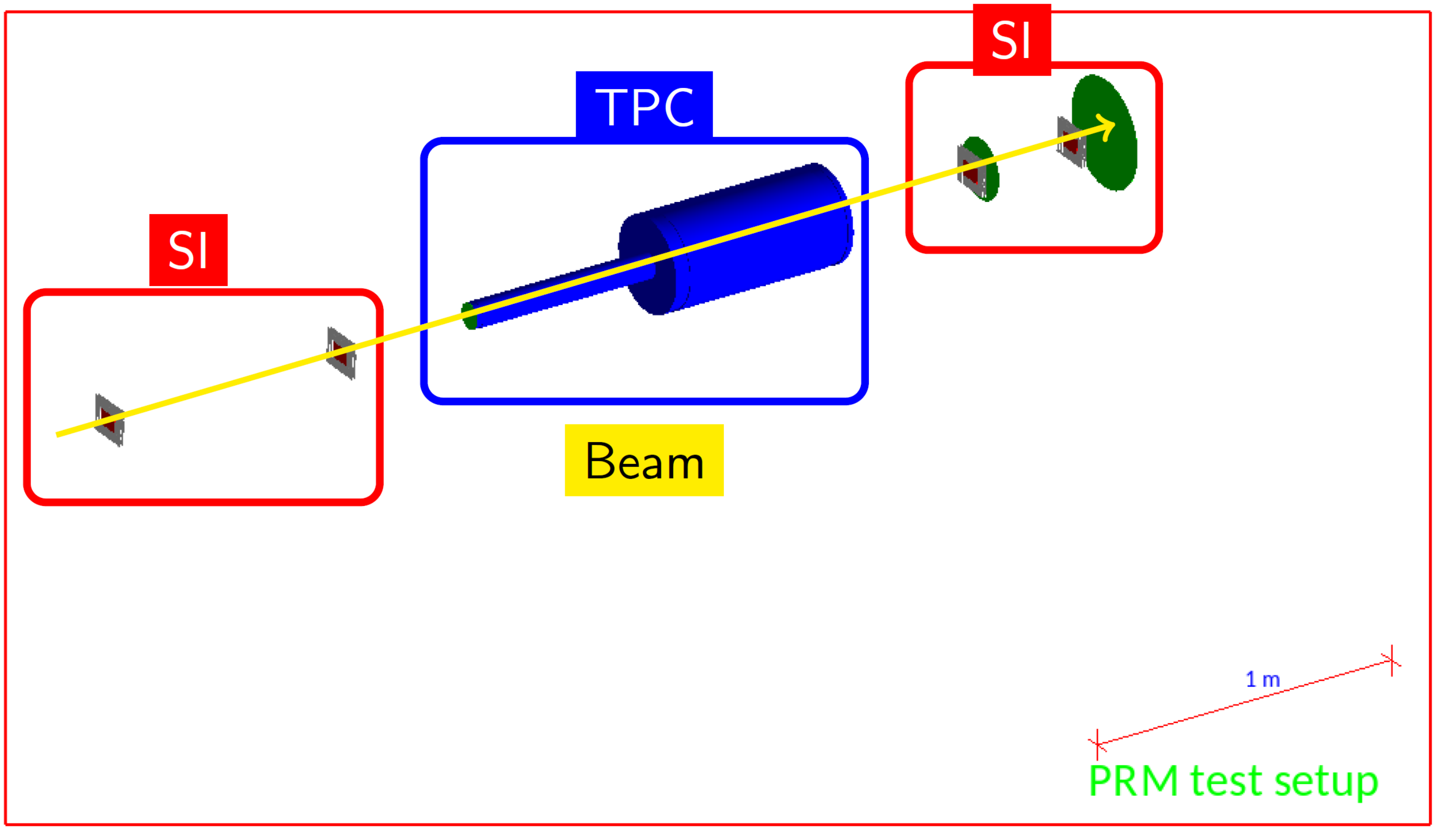


- Silicon tracking stations are triggered by coincident scintillator signals.
- TPC is self-triggered.
- Different DAQ for silicon tracking stations and TPC.

This projec t No 824093.

Monte Carlo simulations of active target TPC

U Bonn



Test setup is implemented in Geant4.

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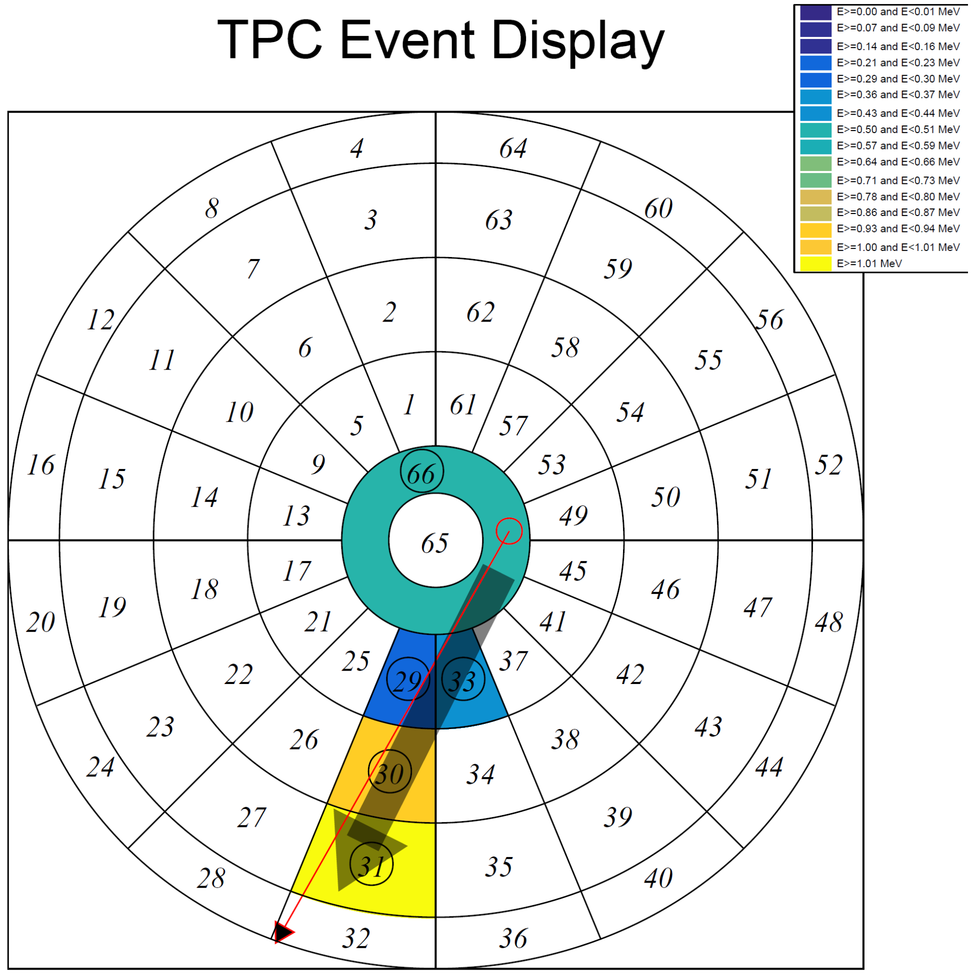
Monte Carlo simulations of active target TPC

U Bonn

TPC Event Display



- Silicon track (red):
- Interaction vertex
- Recoil proton direction
- Recoil proton energy

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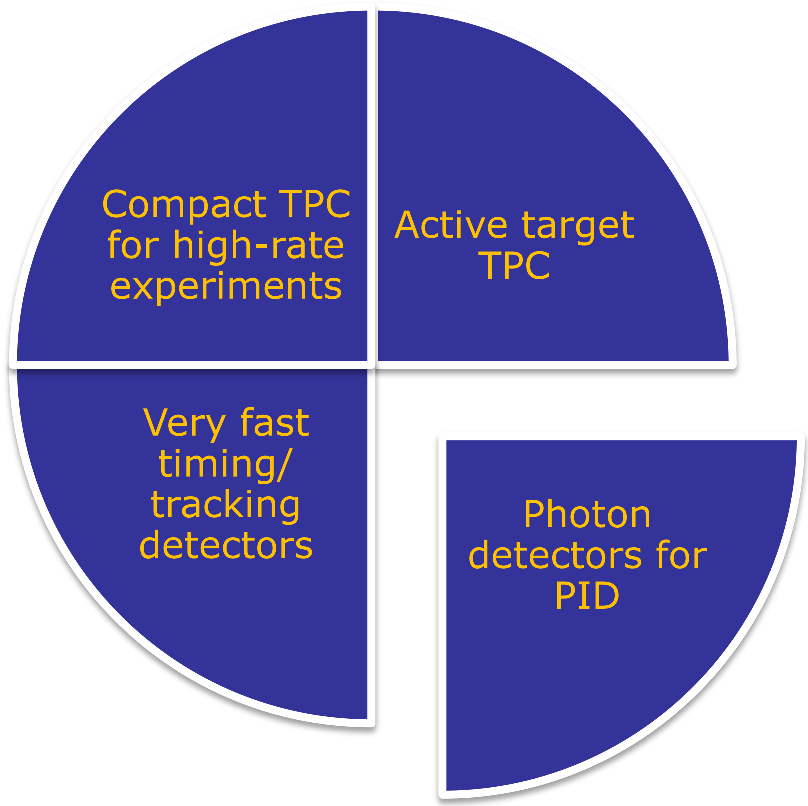
Micropattern Gaseous Detectors for Hadron Physics



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Task 3: Photon detectors for PID

- Goal: Develop a modular hybrid MPGD (Micromegas + THGEM or GEMs) with high-granularity readout elements for the detection of single photons in harsh environment
- Tasks:
  - develop a modular hybrid MPGD with miniaturized readout elements, high photosensitivity, minimal dead area and an architecture suppressing the ion back-flow ⇨ already started with a preliminary prototype
  - characterize photon response in various conditions, in particular operation in windowless mode and pure CF_4 ⇨ will start in 2020
  - explore the possibility to use graphite-rich nano-crystalline diamond grains as photoconverters in gaseous detectors for single photons ⇨ to be done, very first trials are ongoing
- Deliverables:
  - fully characterized prototype of the Minipad Modular PD. Delivery: month 36.
  - publication of the diamond-based photoconverter performance in gaseous PDs. Delivery: month 48.
- Applications: EIC, fixed target

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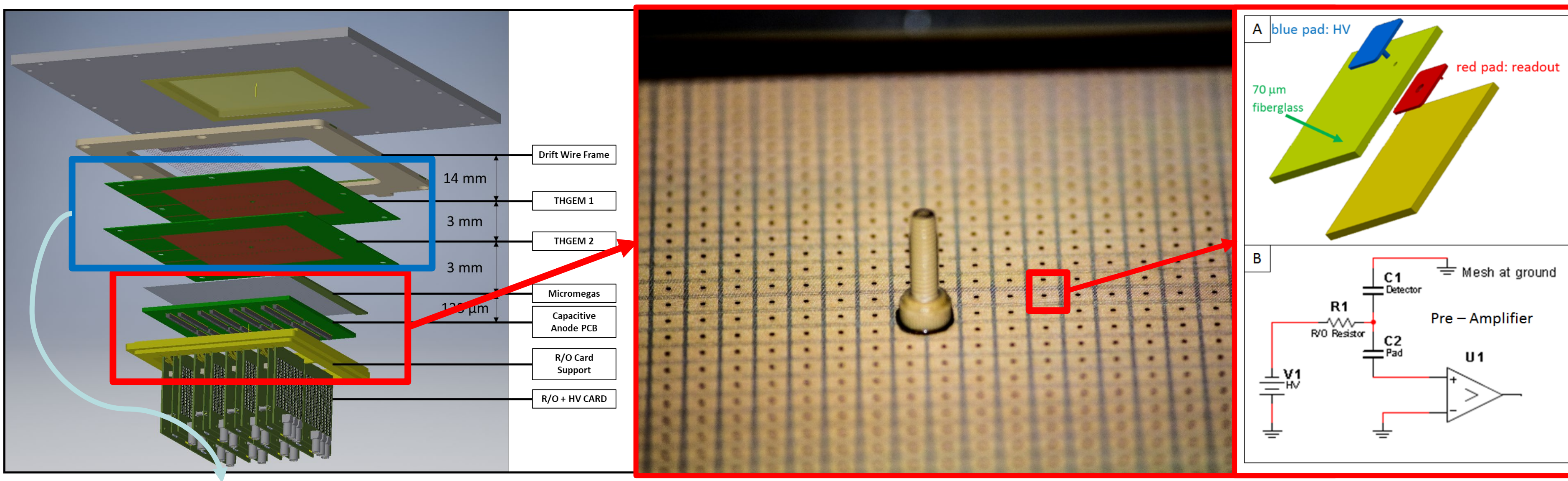
Modular minipad detector of single photons

INFN Trieste

EIC requirement: large area (several m^2) detectors of single photons with small pads (3 × 3 mm^2).
Mosaic architecture: all components and services installed within the active area of each tile.
A first, small active area (100 × 100 mm^2) prototype with hybrid THGEMs and Micromegas architecture has been built and tested.
Each component of the hybrid module was characterized in the lab before assembling the prototype.
An APV25-based readout and the Scalable Readout System (SRS) were used.
The prototype response has been studied in the laboratory and at a test beam.



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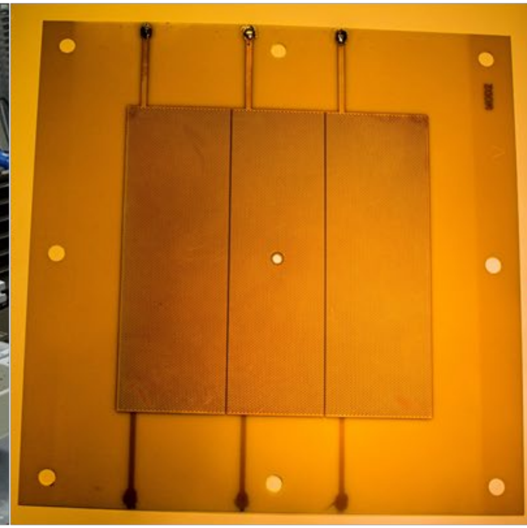
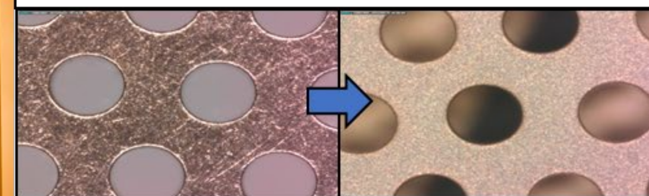
Components and assembly

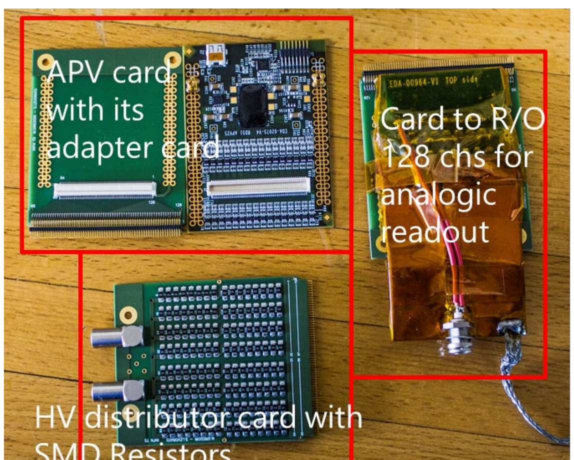
INFN Trieste

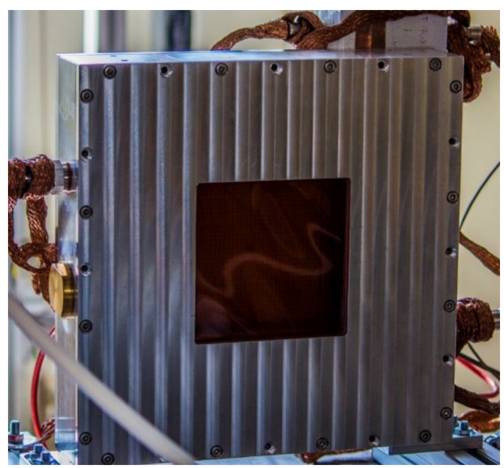


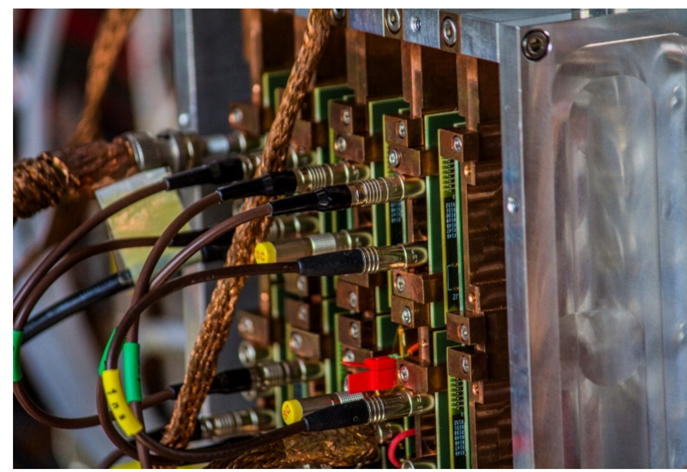
- To drill 15K holes, it takes ~ 3 hrs
- The cost is 1 Euro for 1000 holes...
- We (at ELTOS spa, Italy) produced ~ 8 Pcs.
- Polishing with pumice powder + cleaning in high pressure water and ultrasonic bath with high pH (~11) liquid + drying in oven at 160 ^{0}C also to fully polymerize the glue for 24h



Before treatment → After treatment







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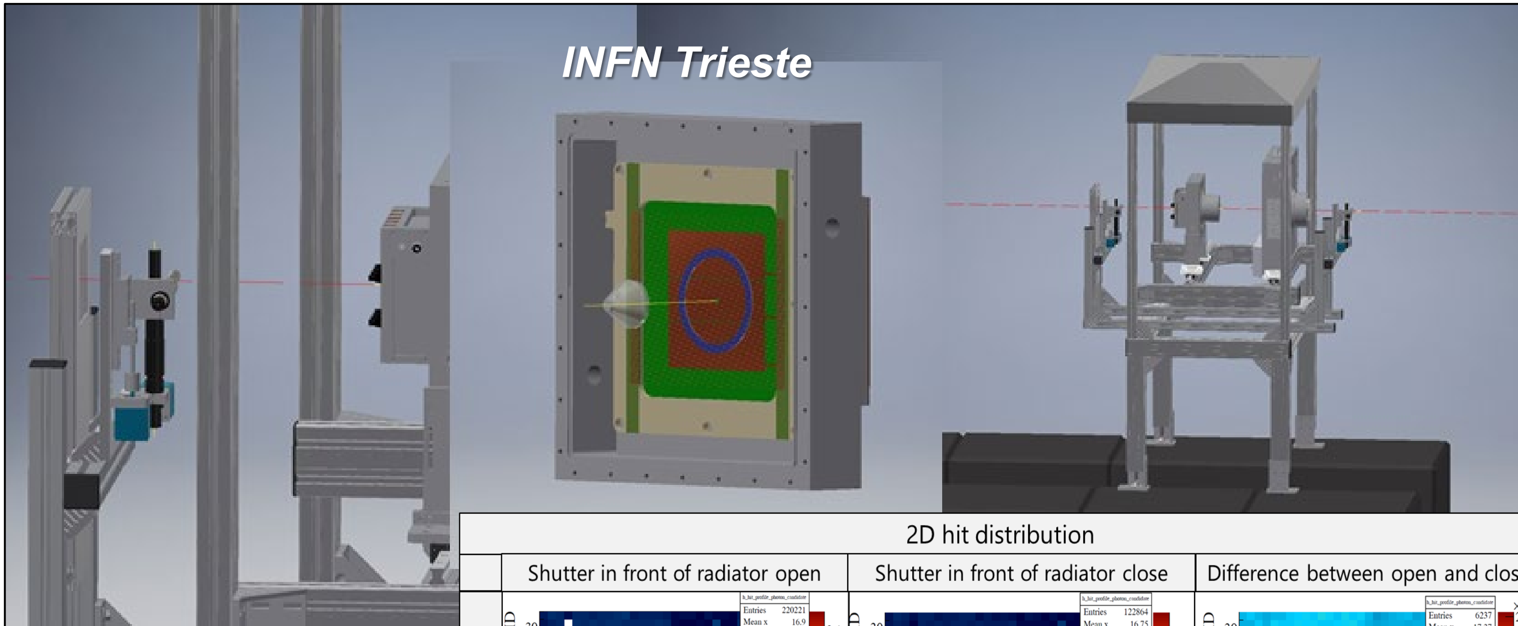
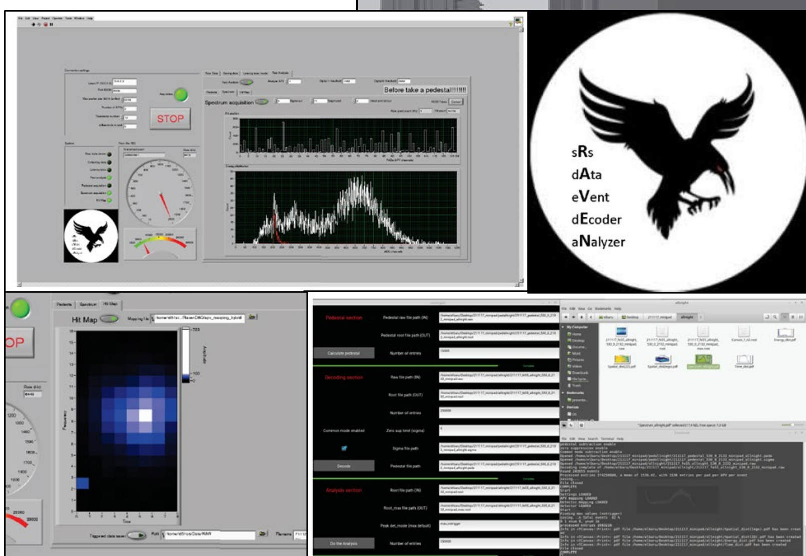
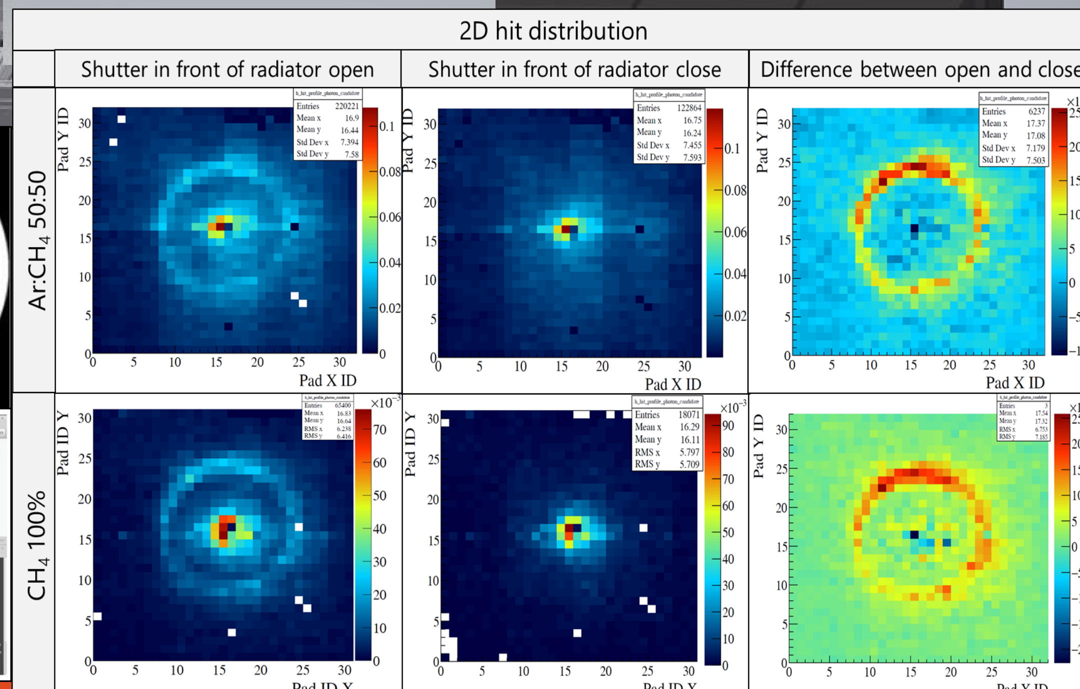
Test beam setup and first results

Tested at CERN T4 Beam line



Home made DAQ and Decoder based on LABView and C++

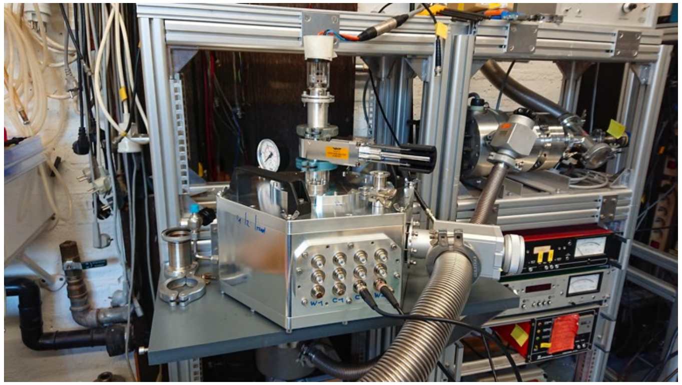




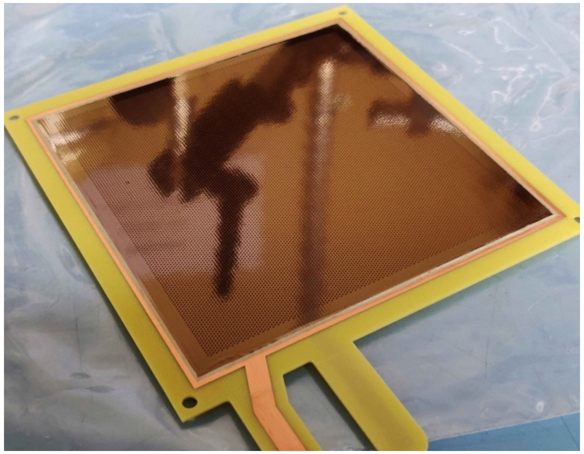
Development of MPGD for photons

TU München

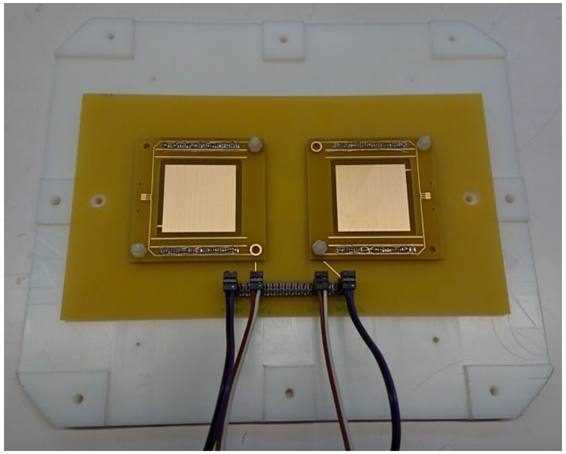
- Dedicated setup constructed at TU Müchen
- Organization of the photodetector laboratory
- In-house GEM coating with CsI – successfully commissioned
- Preliminary studies of QE ongoing
- Measuring campaign with CsI, DLC, … GEMs.



Gaseous photodetector at TUM



A DLC THGEM



CsI coated gold plates for calibration measurements

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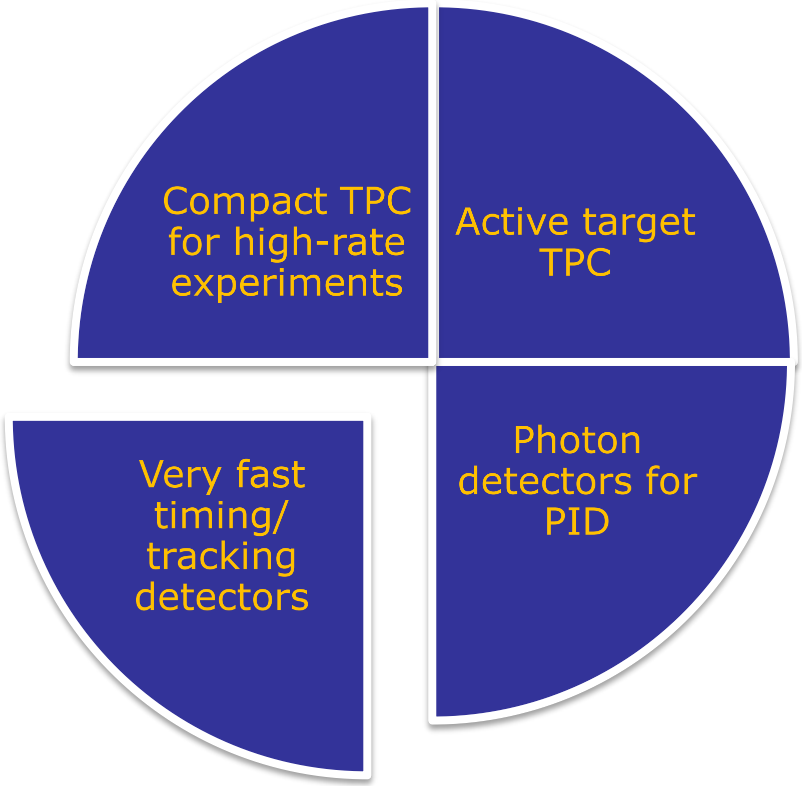
Micropattern Gaseous Detectors for Hadron Physics



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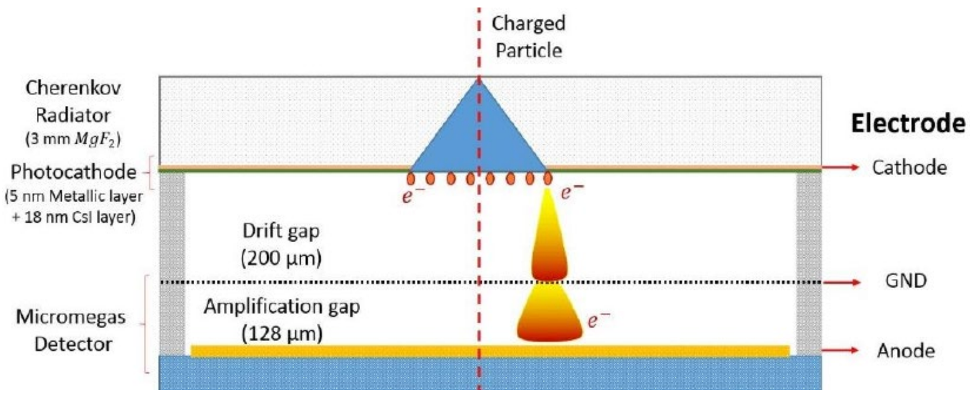
Context

CEA Saclay

Present MPGD trackers with very good spatial resolution and capability to stand high-rate environments, but with time resolution at the level of a few ns

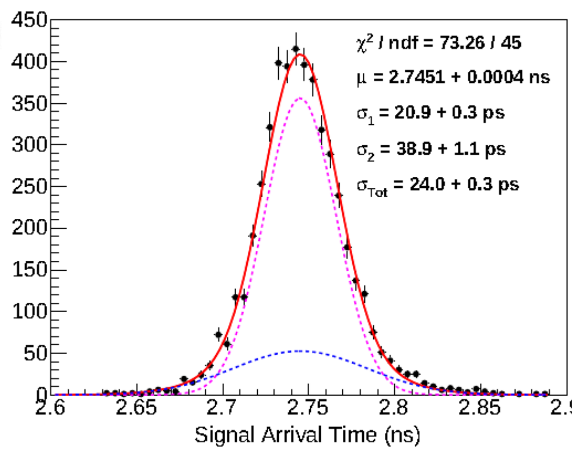
R&D in progress: *PICOSEC-Micromegas collaboration*

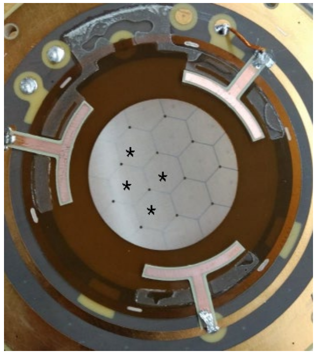
Micromegas based on Cerenkov light + CsI photocathode → 25-30ps time resolution for MIPs, but large spatial distribution of primary e^- → ~mm spatial resolution



J. Va'vra & I. Manthos talks, MPGD2019

J. Bortfeldt et al., NIM A 903 (2018) 317-325





Task 4: Very fast timing/tracking by Micromegas-based Cherenkov detectors

- Goal: Micromegas-based tracking technology combining good spatial resolution (~100µm), very good time resolution (~100ps) and high rate capability
- Tasks:
  - Improved photocathode material to stand large particle flux: DLC, metal (in common with Picosec), also diamond grains (task 3) ⇨ already started
  - Alternative methods of primary electron production in order to reduce spatial distribution of emission: metal plate, secondary emission, thinner Cerenkov radiator ⇨ will start in 2020
  - Development of prototypes with larger active area size (~10cm) and anode strips at small pitch (~500µm), read-out by multi-channel electronics ⇨ already started
  - Evaluation of existing multi-channel readout electronics for time resolution vs rate vs compactness vs cost optimization
- Deliverables: prototype of the Fast Cherenkov Micromegas Detector. Delivery: month 42.
- Applications expected for trackers at low angles in high rate environments (electron-ion collider, fixed target experiments)

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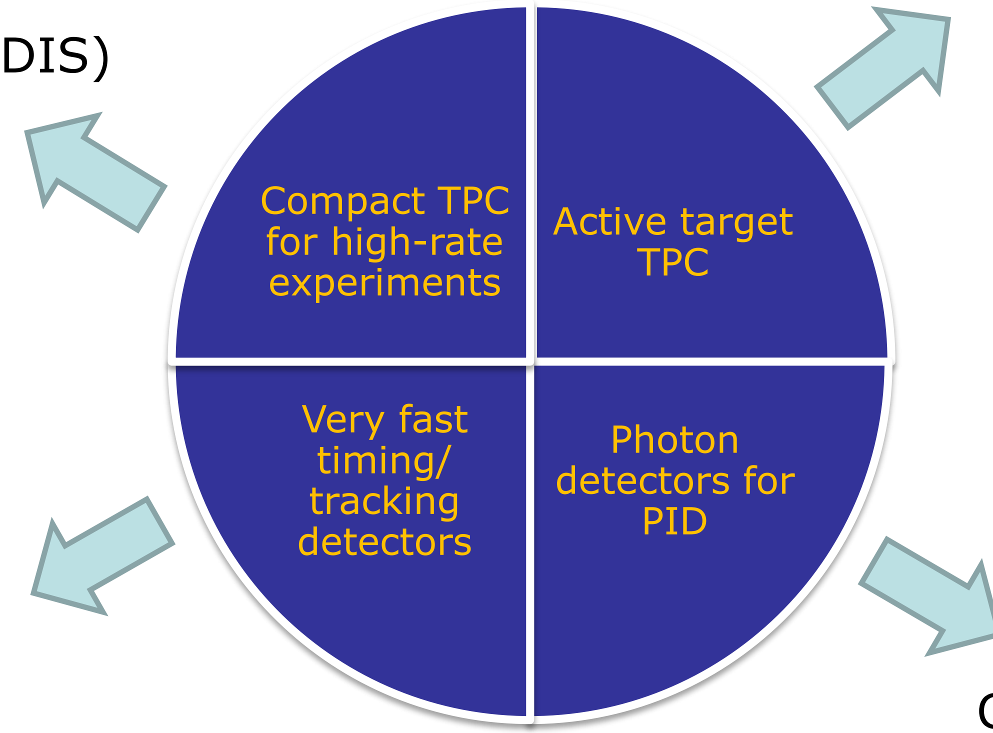
Micropattern Gaseous Detectors for Hadron Physics

RHIC
CBELSA/TAPS
JLAB (tagged DIS)
EIC

COMPASS++/AMBER
MAMI
DAFNE (AMADEUS)



EIC
Fixed target

EIC
COMPASS++/AMBER

A coherent effort towards these goals by world experts in MPGDs

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JRA... : Deliverables and milestones

- There are no deliverables nor milestones due for Reporting Period 1 (18 months, June 2019-November 2020)
- The first deliverable is due M36 (May 2022)
- The first milestone has to be achieved M24 (May 2021)

Deliverable Number[14]	**Deliverable Title**	**Lead beneficiary**	**Type**[15]	**Dissemination level**[16]	**Due Date (in months)**[17]
D32.1	Minipad Modular PD	30 - INFN	Demonstrator	Public	36
D32.2	Fast Cherenkov Micromegas Detector	24 - CEA	Demonstrator	Public	42
D32.3	A small-scale prototype of the high-rate TPC	13 - TUM	Demonstrator	Public	48
D32.4	Simulation results on energy ranges and resolutions in active target TPC	10 - UBO	Report	Public	48
D32.5	Publication of the diamond-based photoconverter performance in gaseous PDs	30 - INFN	Report	Public	48

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