STRONG-2020 ANNUAL MEETING (2022) – JRA14

Bernhard Ketzer – Univ. Bonn
Fulvio Tessarotto – INFN Trieste

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

PLAN OF PRESENTATION

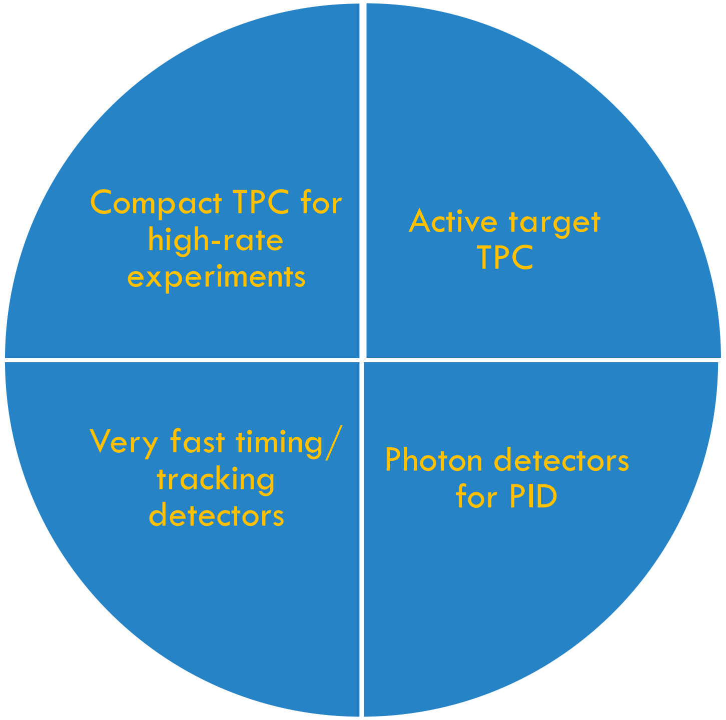
1) Scientific results obtained since the last year
2) Modifications of the scientific Work Plan (as compared to the initial plan in the Grant Agreement)
3) Possibilities/needs of another request for the extension of the project (beyond 30 November 2023)

(We kindly ask to focus on the scientific aspects of the work carried out without administrative issues or timeline questions for deliverables and milestones)

OVERVIEW OF JRA14 – MICROPATTERN GASEOUS DETECTORS

Coherent effort on MPGD by world experts:

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



Joao Veloso
Bernhard Ketzer
Hannes Zmeskal
Bernd Voss
Rachel Montgomery
Antonio Valentini
Fulvio Tessarotto
Laura Fabbietti
Damien Neyret

Objective: improve MPGD capabilities for tracking, photon detection, PID, timing

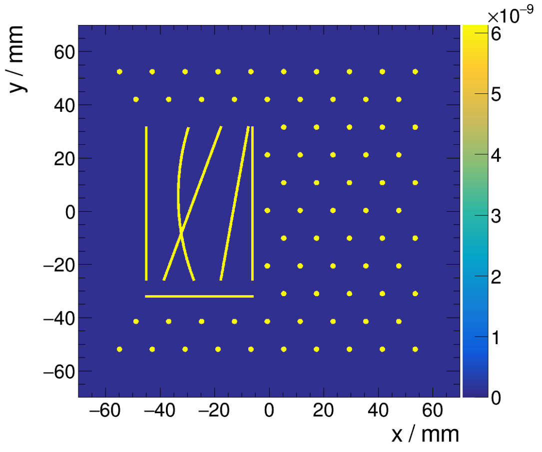
Status:

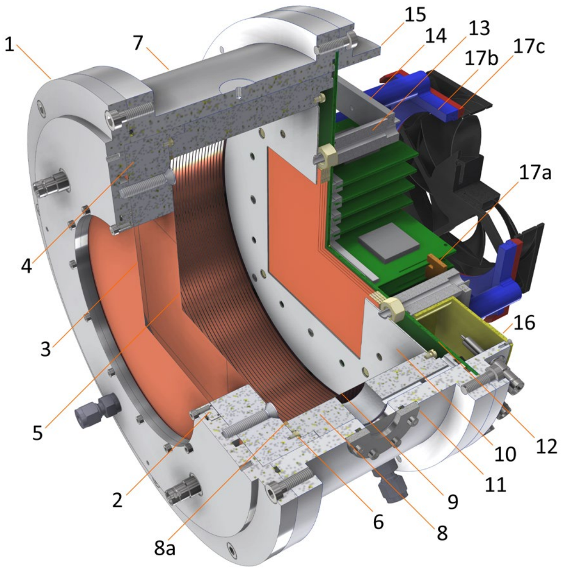
- all **3 Milestones achieved** in time
- **Deliverables:** first achieved in time, other 4 on track (1×month 42/3×month 48)

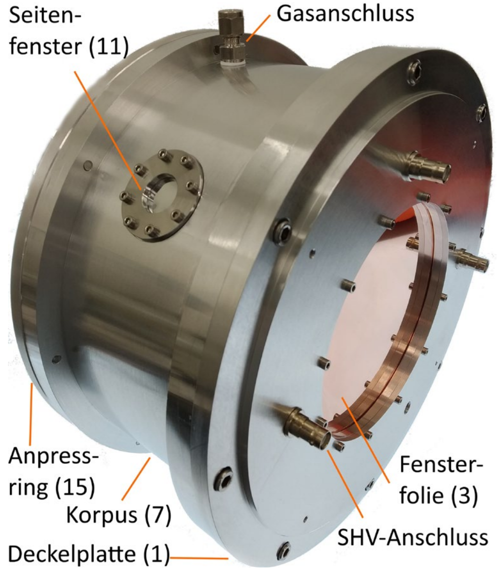
TASK 1 – COMPACT HIGH-RATE TPC

University of Bonn

- GEM-TPC with continuous readout established: FOPI, ALICE, sPHENIX, ….
- Advanced calibration methods are a prerequisite to achieve performance
  - static distortions: pad-by-pad gain map, electrostatic field distortions
  - dynamical distortions: charging-up, T/p, space-charge
- Compact TPC designed to study these distortions:
  - UV light injected from anode side
  - cathode with specially designed pattern
  - modular: 3- or 4-GEM stack, other MPGD
  - precision field cage
  - hexagonal pads
- Construction of chamber ongoing (D32.3)
- Laser system commissioned

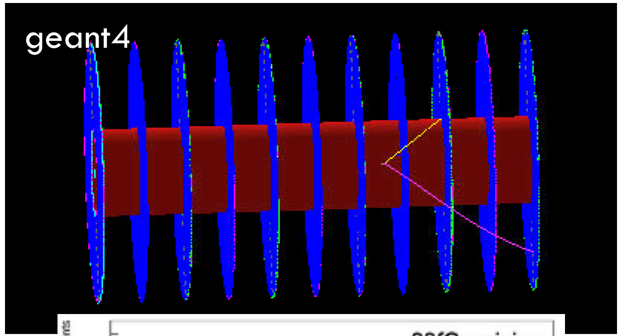


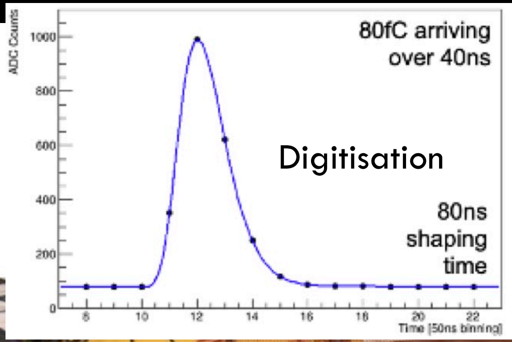


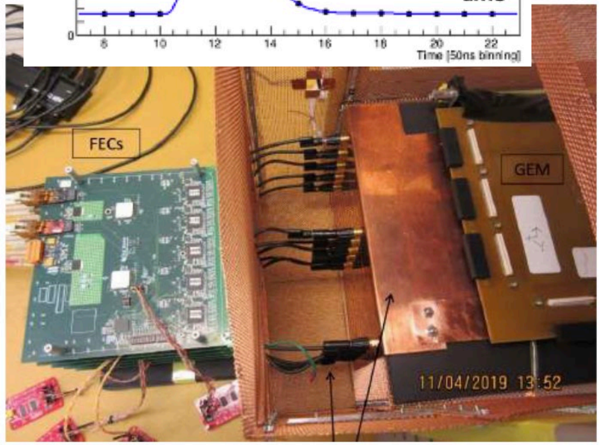


TASK 1 – HIGH RATE TPC FOR JLAB HALL A

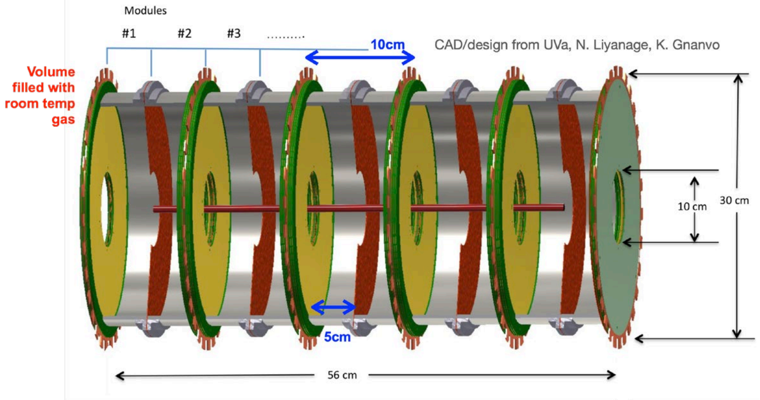
University of Glasgow

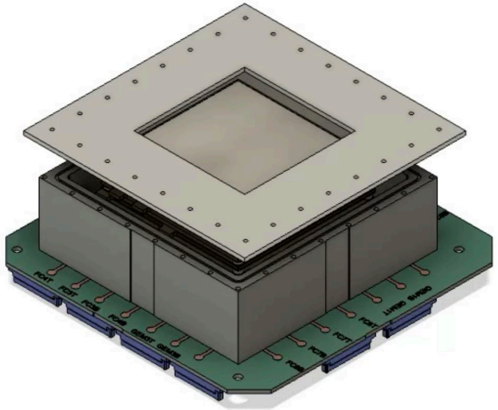






Jlab test stand (E. Jastrzembski, G. Heyes…)



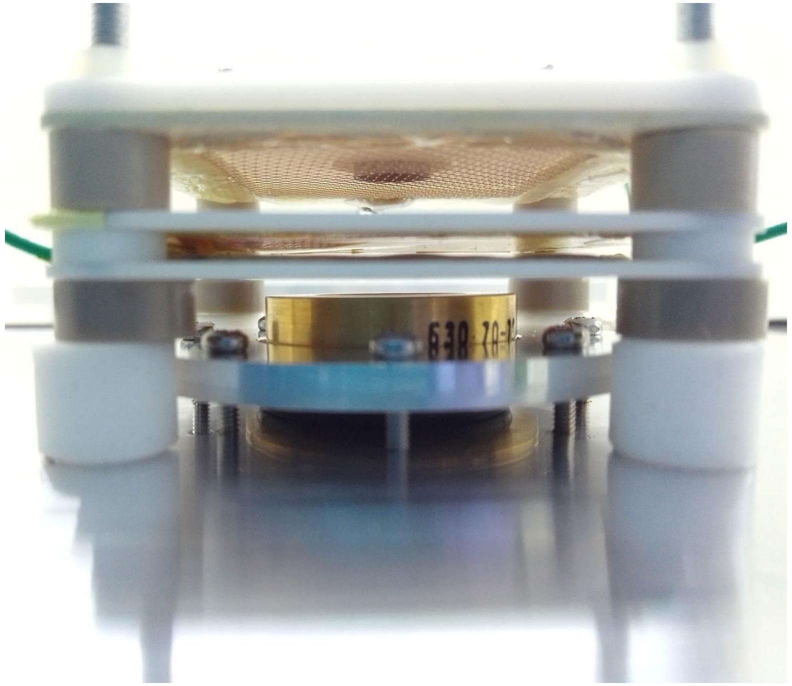


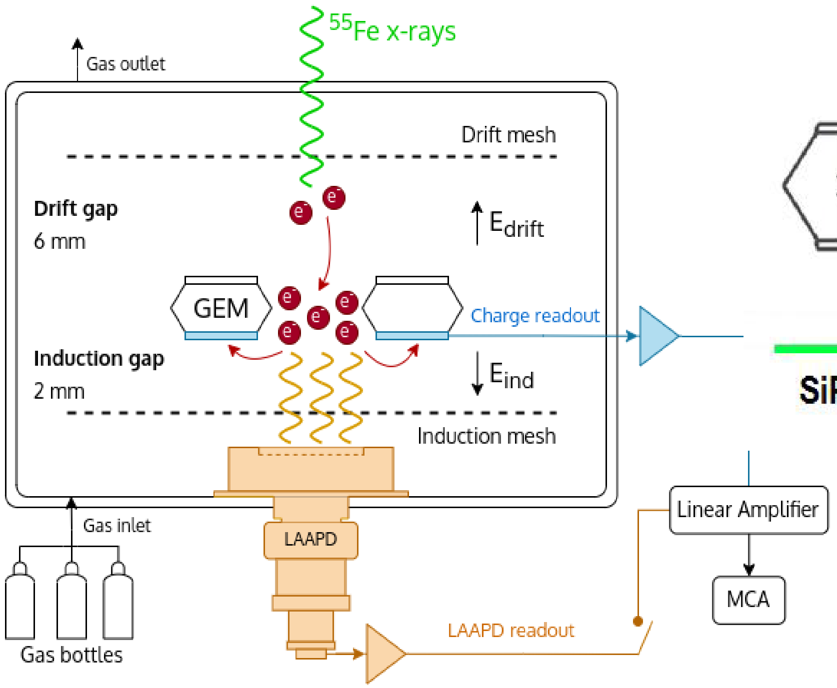
CAD of prototype (S. Ali, N. Liyanage Uva)

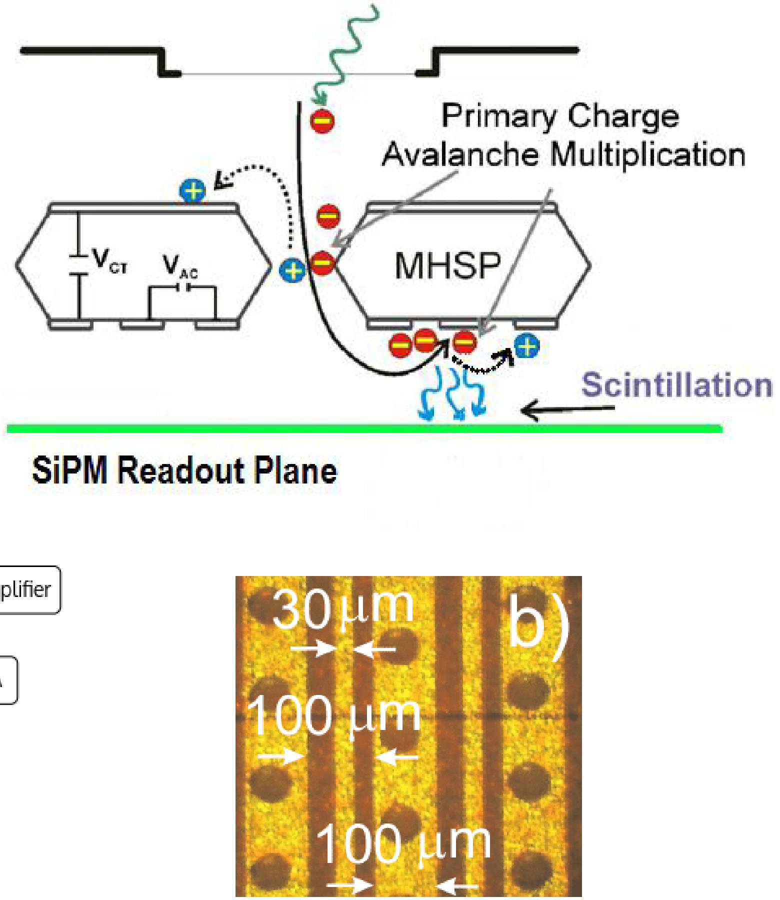
1. Development of multiple time projection chamber (mTPC) for upcoming meson structure studies in tagged deep inelastic scattering at Jefferson Lab (JLab) Hall A continues on track
2. Geant4, Garfield++ and MAGBOLTZ simulations to optimise mTPC design
    1. Most of work over last year has been focussed on digitisation in simulation and testing simulated data with initial tracking algorithms
3. Colleagues at JLab continue to testing readout ASIC front end card prototype with GEM detector
    1. SAMPA ASIC was successfully used to readout prototype continuously at JLab
    2. Prototype used as input for simulation digitisation
4. Colleagues at University of Virginia continue to work on building hardware for first prototype. Slightly delayed compared ot last years' estimate of Summer 2022, but it is almost ready
    1. Testing this prorotype and tuning of smulations based on the data will be major objective over next year

Task 1 - Studies on optical readout from charge avalanches produced in GEM and MHSP : The PISA concept - Photon Induced Scintillation Amplifier

University of Coimbra







Task 1 - Studies on optical readout from charge avalanches produced in GEM and MHSP : The PISA concept - Photon Induced Scintillation Amplifier

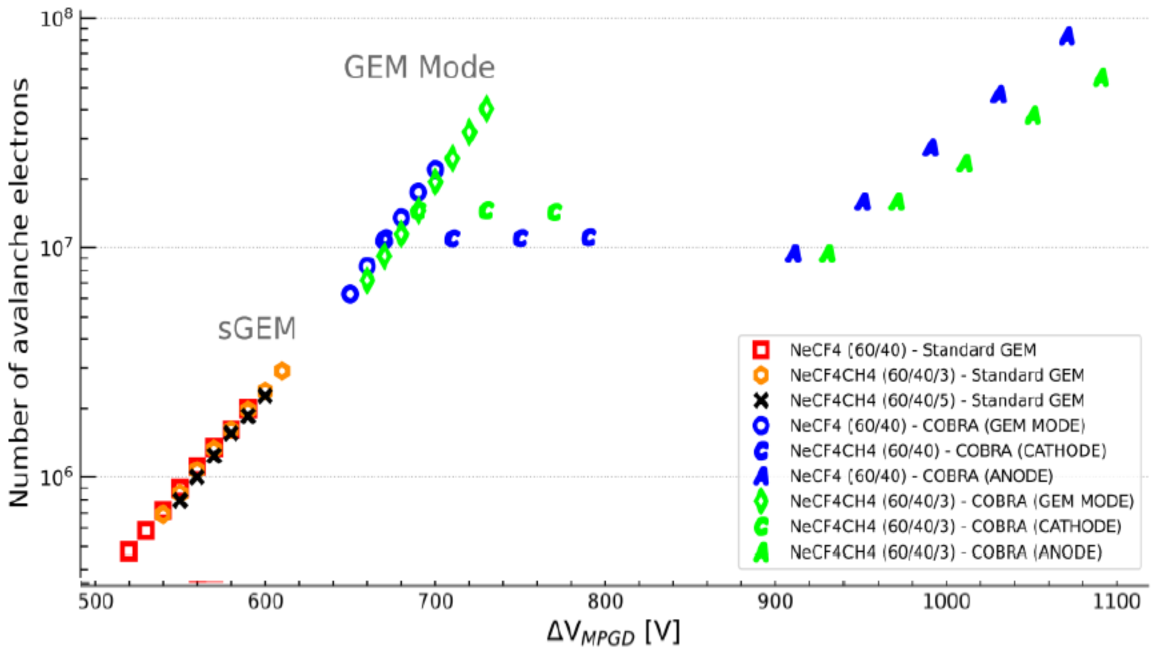
University of Coimbra

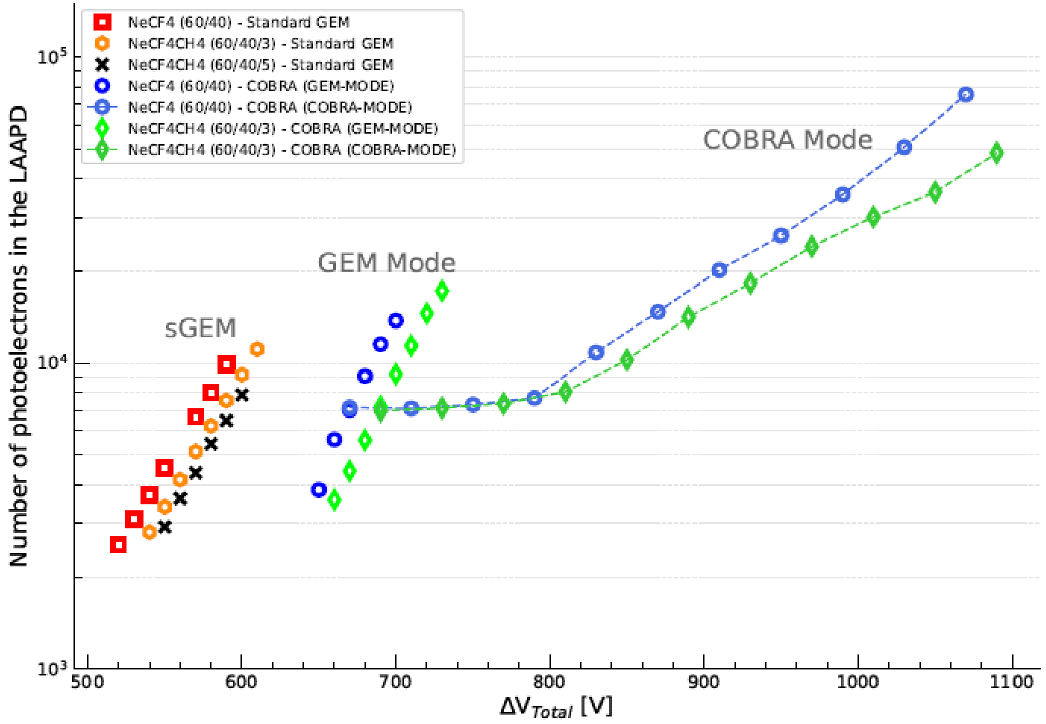
- Ionisation signal readout via reading out the scintillation produced in the electron avalanches instead of the charge. (Using SiPM for scintillation readout possibility to achieve large signal output with better SNR and placing the electronic readout away from the microstructure plane).
- Using MHSP/COBRA microstructure (GEM hole type micropattern foil having strips etched on the bottom surface of the foil for a second charge amplification stage achieving larger scintillation output and lower ion backflow).
- **Applications:** VUV Gas Photomultiplier (with a photocathode film coating the upper surface of the micropattern foil); ionization signal readout in TPCs (Optical TPCs);
- **1st step:** using LAAPD for obtaining absolute values of photon output in GEM and MHSP/COBRA;

1^{ST} Results: Ne-CF_4 mixtures

- Standard GEM – 50 μm thick
- MHSP – 125 μm thick
- Irradiation with 5.9-keV x-rays

University of Coimbra





Assuming a conservative W-value ~ 40 eV, for the mixtures of Ne-CF4 (60/40)

- **Charge readout** (left) – gain **~ 10^5** for a single MHSP_125
- **Scintillation readout** (right) – in the LAAPD **~500** photoelectrons per primary electron produced in the gas (to determine the number of electrons at the LAAPD output, one has to consider the additional photosensor gain)

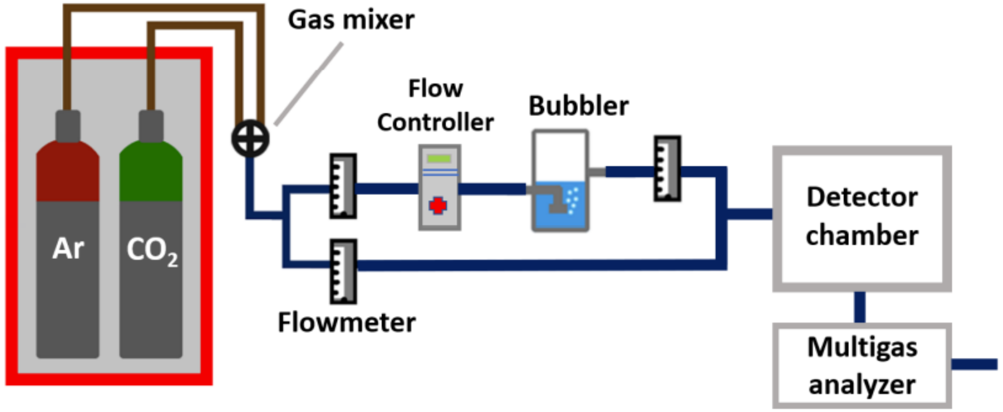
TASK 1 - INVESTIGATING IMPROVED WAYS OF OPERATING MPGDS

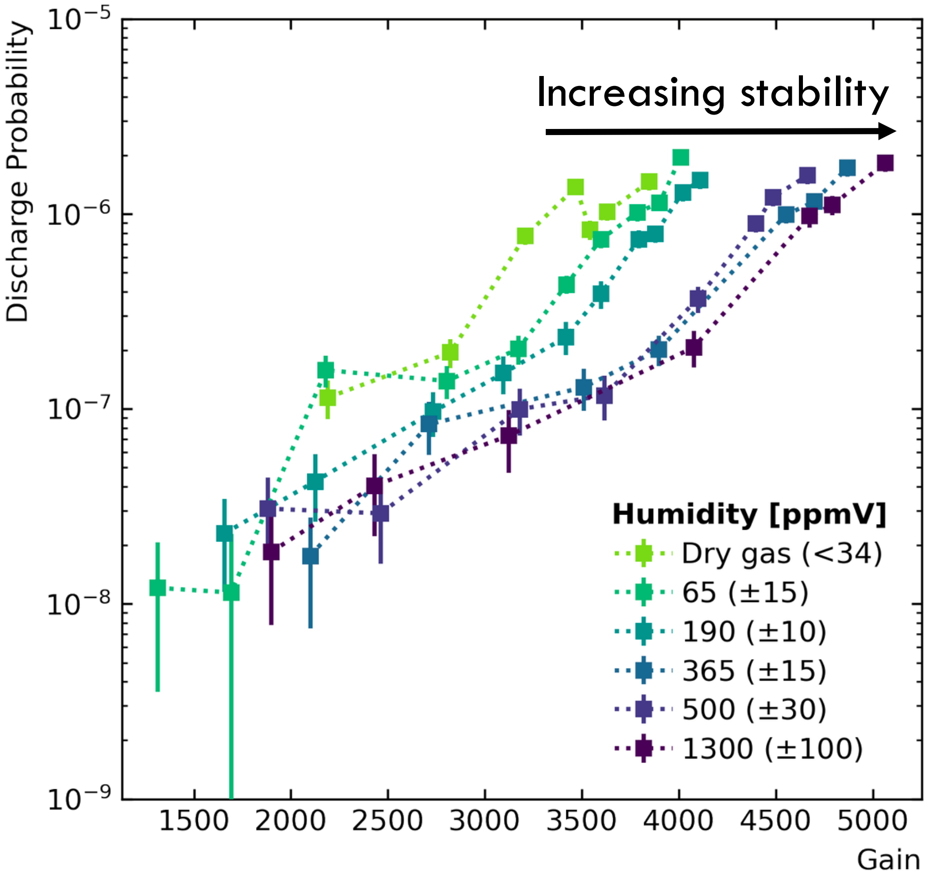
TU Munich

Humidity studies

First systematic studies on effects of humidity contamination on performance of MPGDs (Micromegas, GEM & THGEM)

No drawbacks of humidifying the used Ar-CO_2 (90-10) gas mixture & increased stability against spurious discharges observed





TASK 1 – NEW MATERIALS AND GEOMETRIES

TU Munich

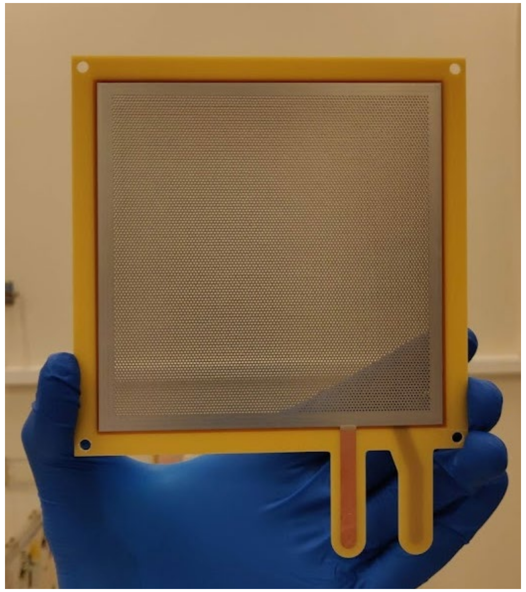
THGEMs with new materials

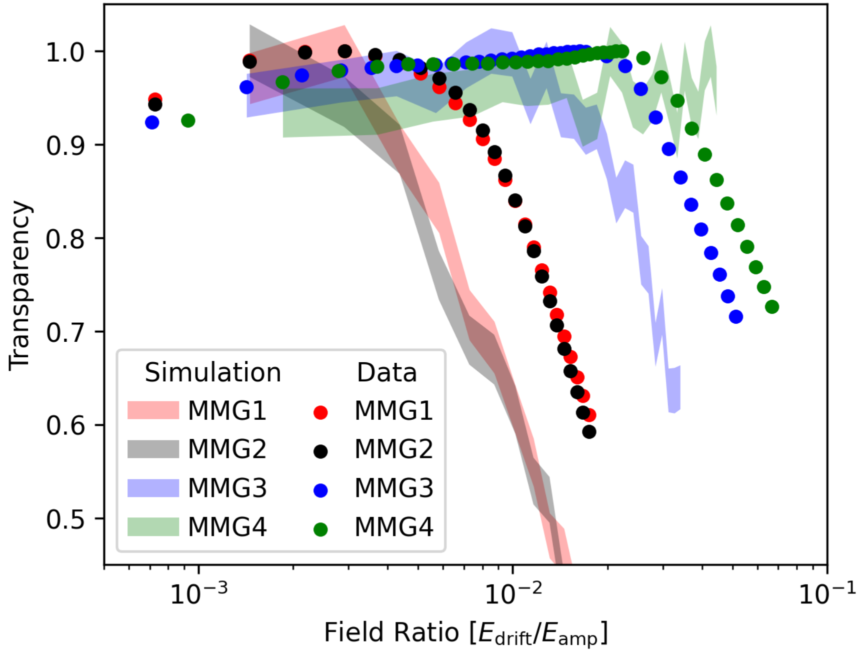
Investigating the first Molybdenum coated full scale THGEM

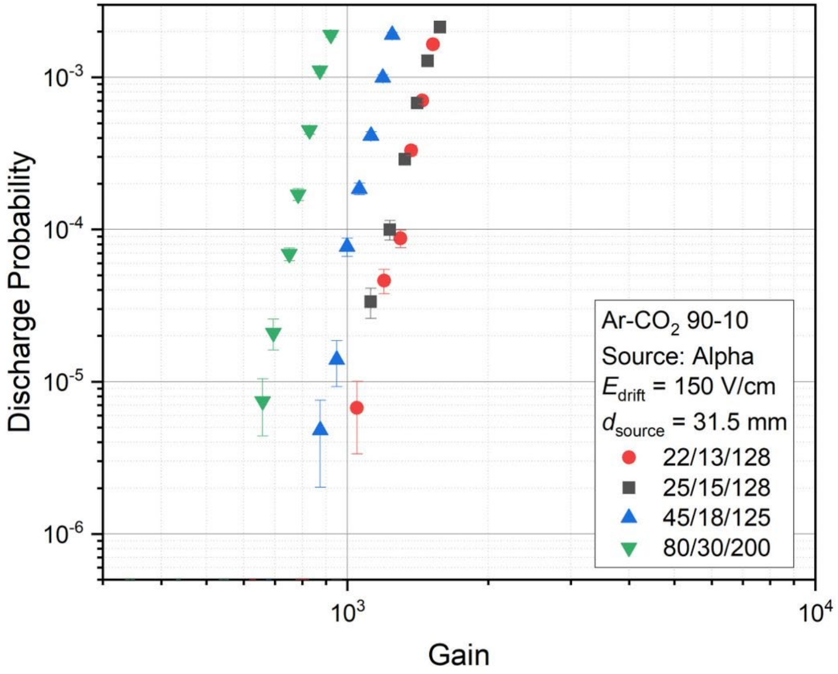
Significant mitigation of the dangerous, delayed secondary discharges

Mesh geometry of Micromegas

- Systematic studies of discharge formation in Micromegas
- Using Garfield++ simulations to model discharge formation



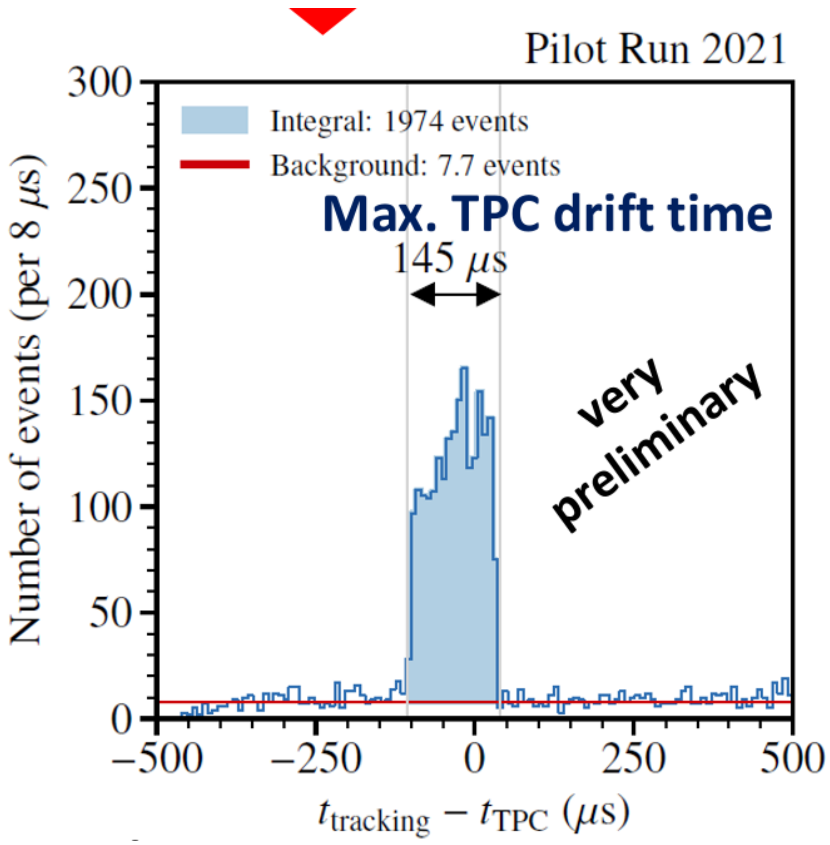


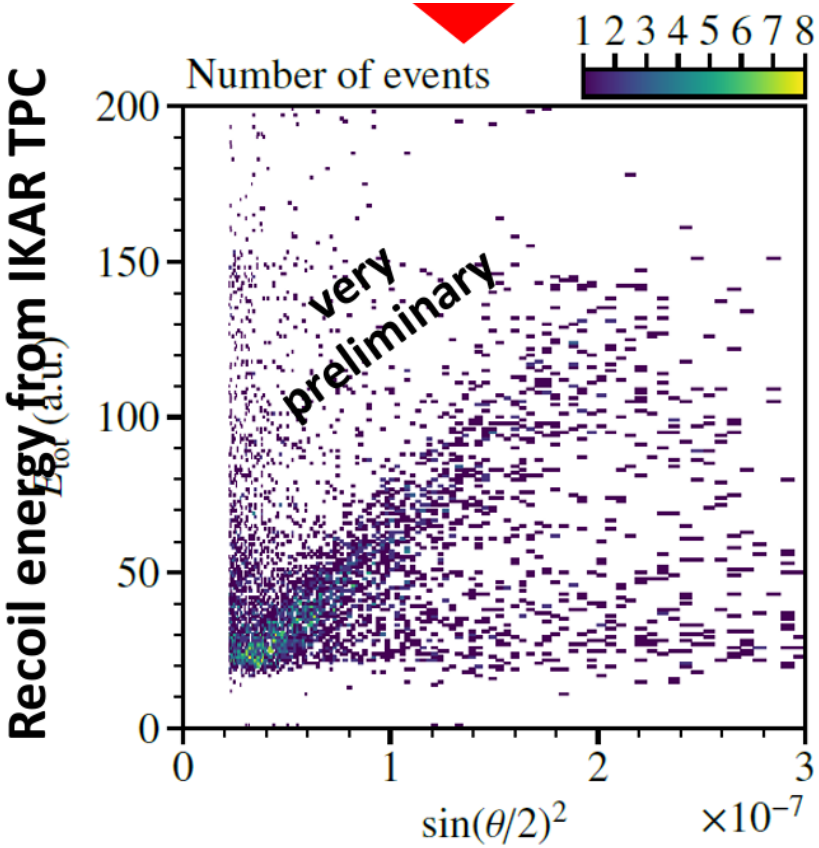


TASK 2 – ACTIVE TARGET TPC

- AMBER Pilot run for Proton Radius Measurement: successful data taking during October 2021
- 2-cell TPC filled with 8 bar hydrogen
- Optimized pad plane structure
- Magnetic spectrometer for muon reco.
- First reconstruction of combined events

  expect about 10k events (700 in 2018)
- Correlation of energy in TPC and μ scattering angle from trackers



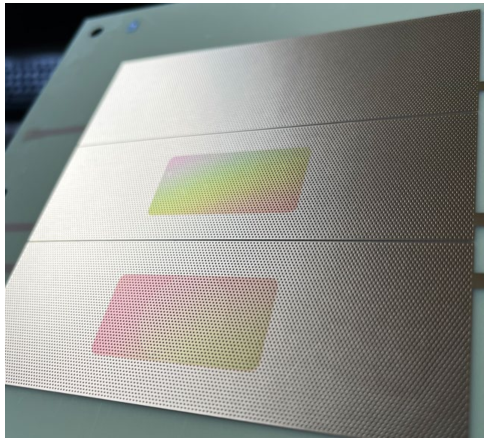


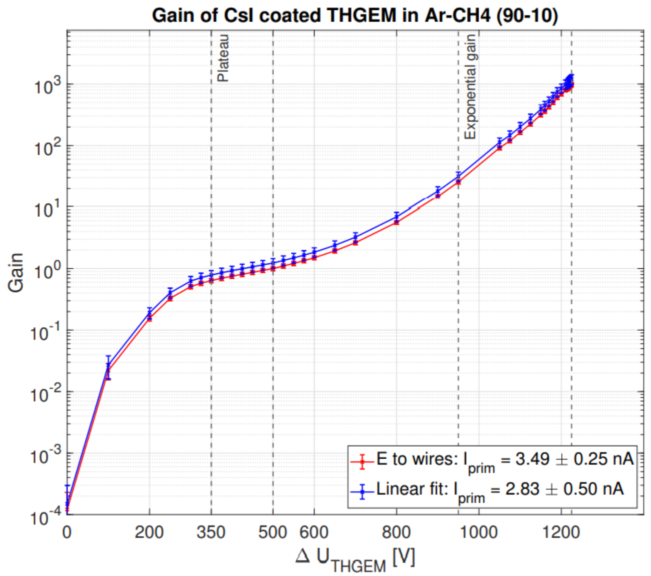
TASK 3 – PHOTON DETECTION WITH THGEMS

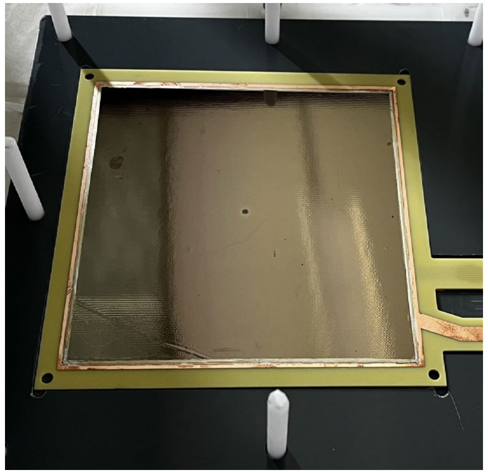
TU Munich

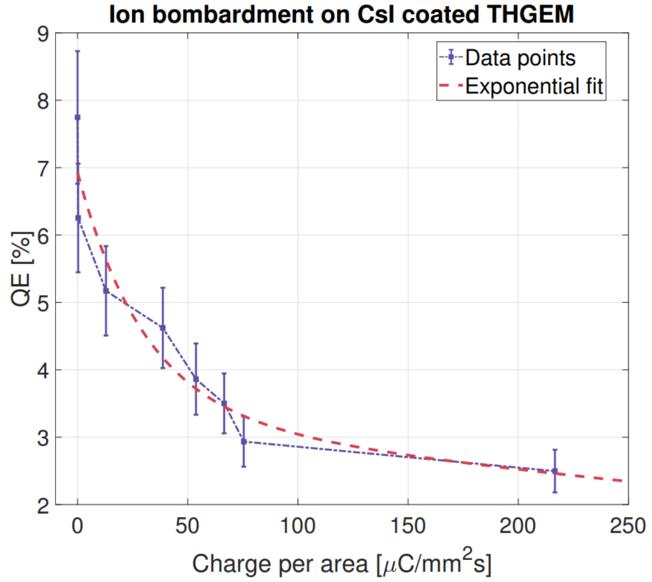
Combining a photosensitive material with a robust and low-cost device: THGEMs

- Studies ongoing with CsI and DLC coatings as photocathode layers on the THGEM surface
- Verification of the experimental setup successful
- First results from aging studies of used materials under operation





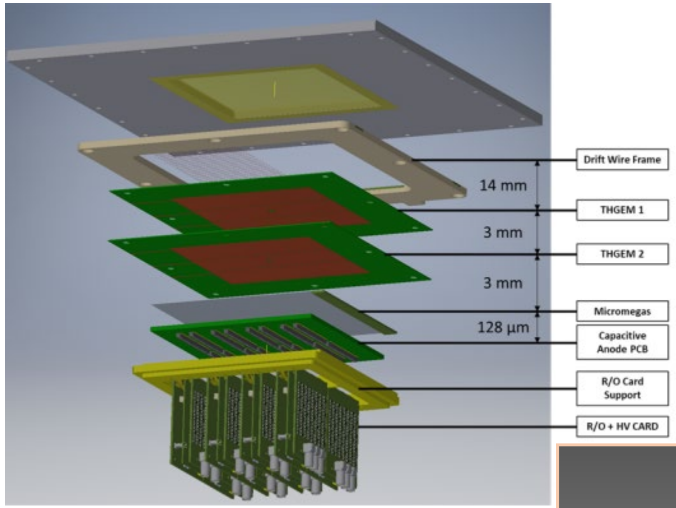




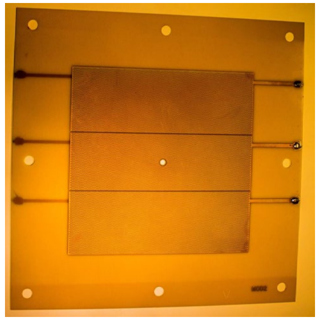
TASK 3 - R&D ON MPGD-BASED DETECTORS OF SINGLE PHOTONS

INFN Trieste

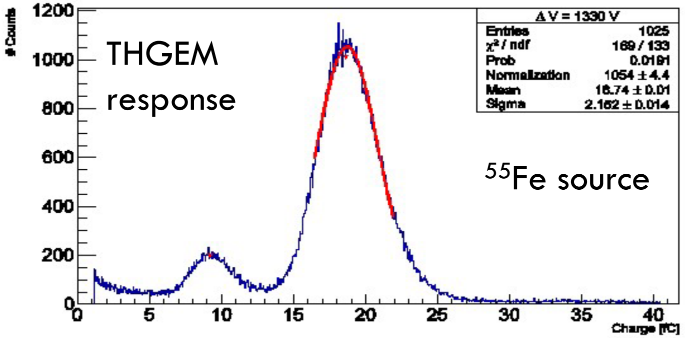
The fully modular hybrid prototype with small square pads has been built and tested: **this approach is valid** D32.1 achieved!

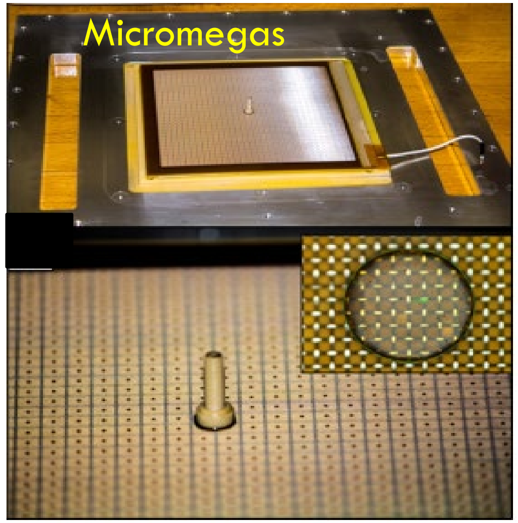


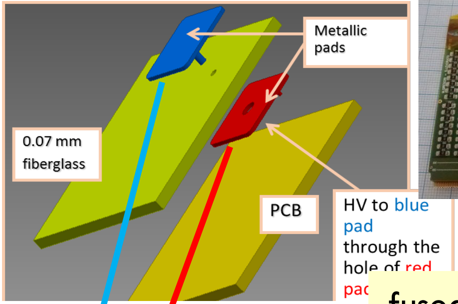
Anode pads of 3x3 mm^2 with 0.5 mm inter-pad space.
Modular structure: all components and services within the active area.
Prototype with 110x110 mm^2 active area: 1024 pads in groups of 128 (16X8)
APV-25 or VMM based readout

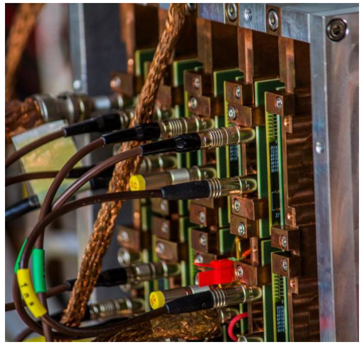


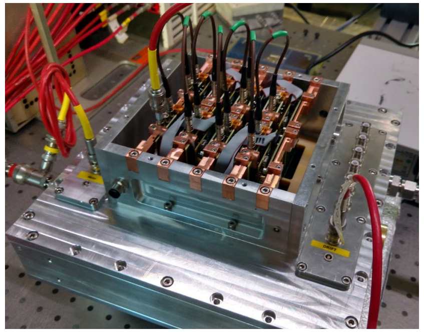
THGEM

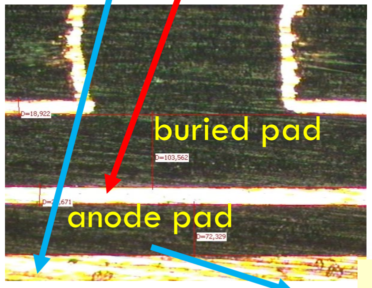


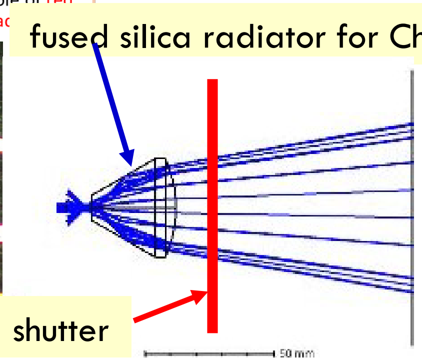


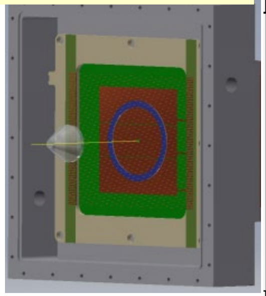




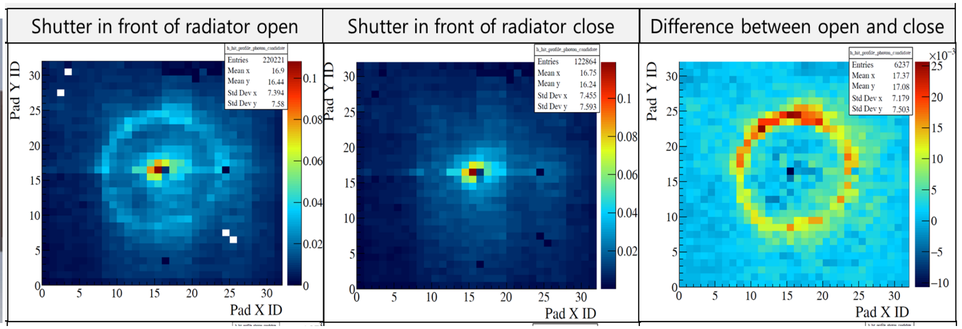








Encouraging results from the test-beam

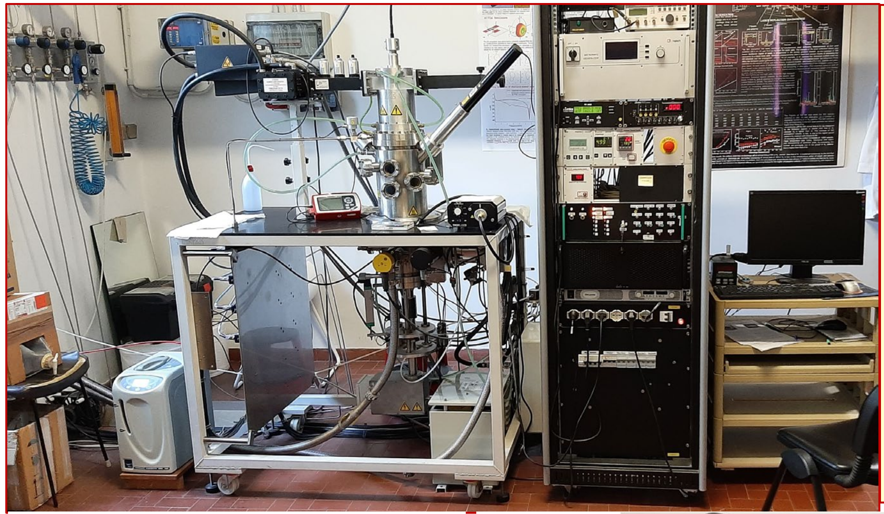


TASK 3 - R&D ON MPGD-BASED DETECTORS OF SINGLE PHOTONS

INFN Trieste

STRONG 2020

Hydrogenated diamond nanocrystals proven to be a **robust alternative to CsI for VUV photon conversion**



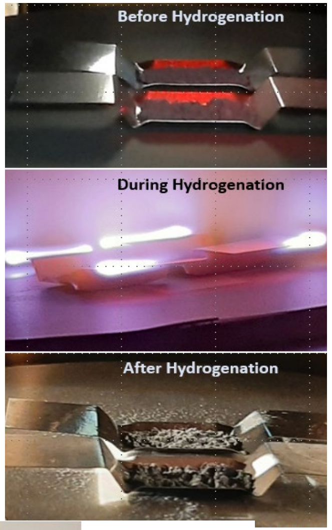
Hydrogenation details:

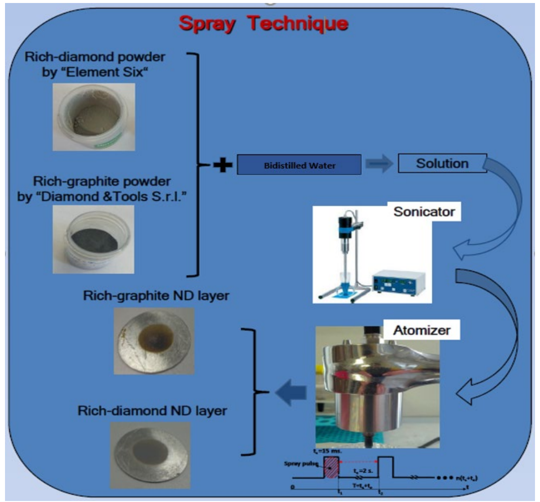
Vacuum: **~6.5x10^{-6}** mbar.

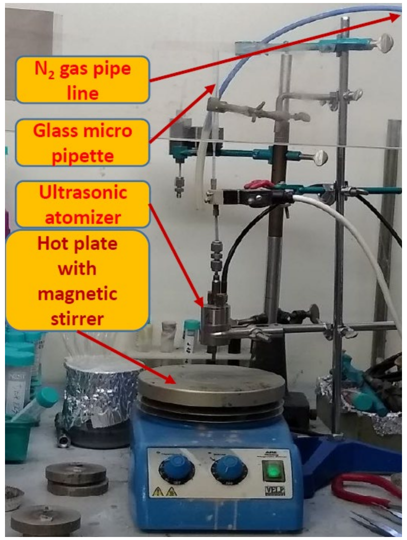
70 mm between H_2 source and ND powder.

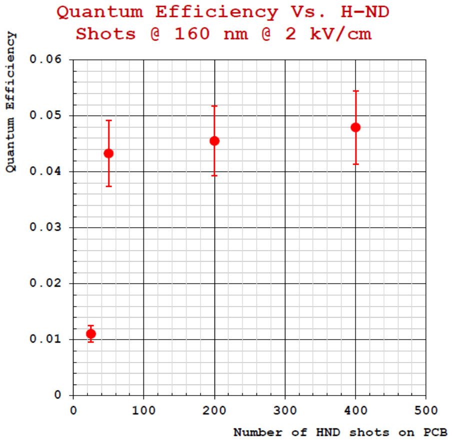
H_2 gas generated by electrolysis from distilled water. H_2 gas flow rate controlled to **200 sccm**.

Hydrogenation of ND powder: **1 hour at 43 mbar.**

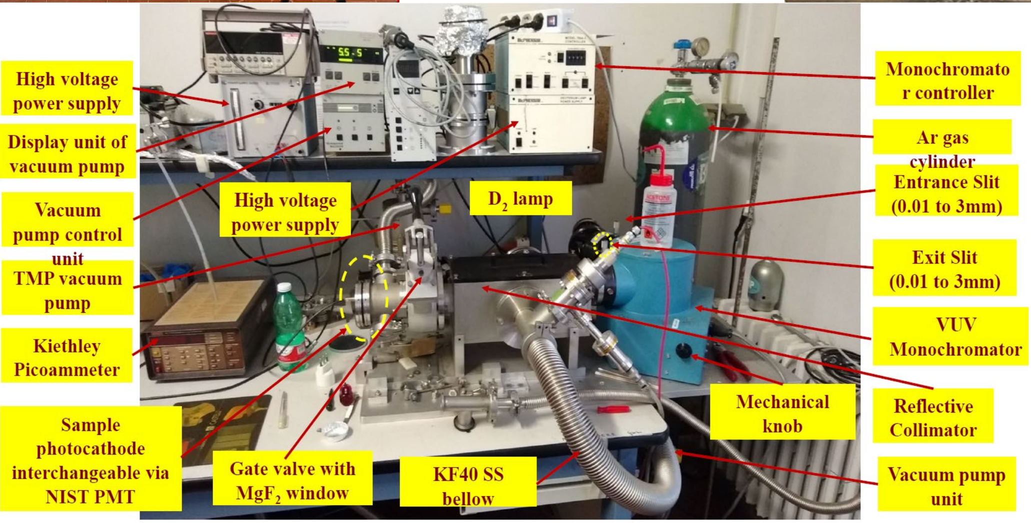




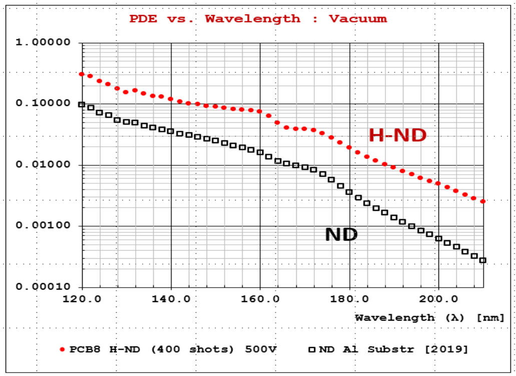




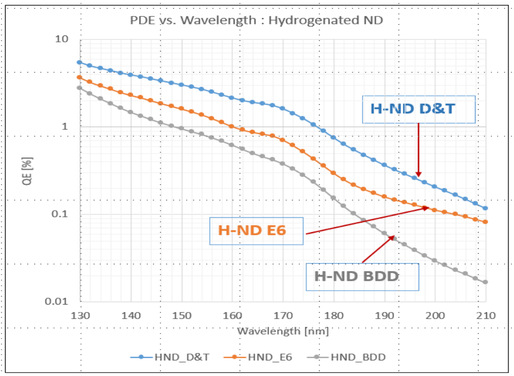
sufficient coverage: **100 shots**



OLD ND, H-ND [D&T]- 2019



New H-ND [D&T, E6, and BDD]- 2021



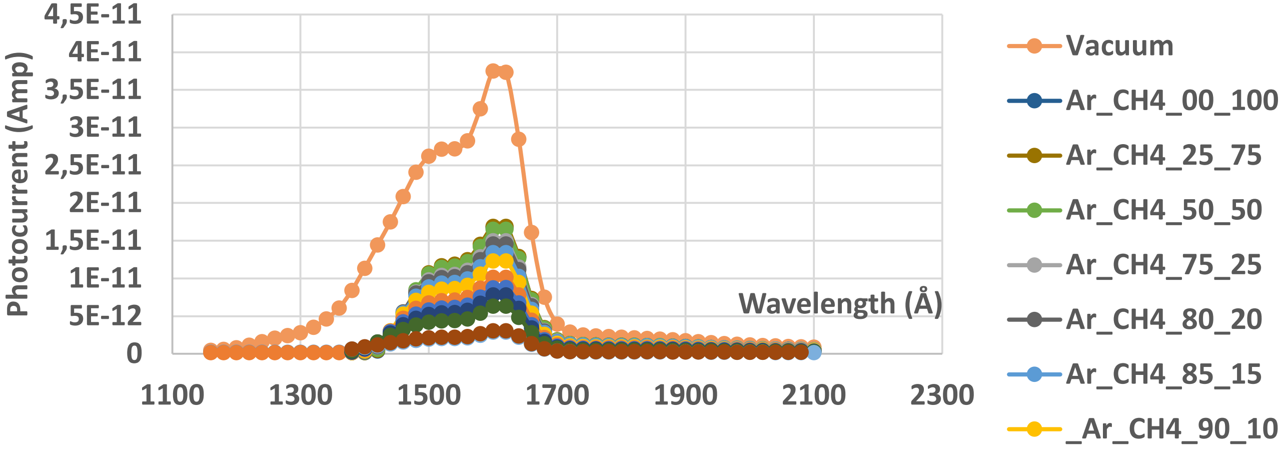
***Photocurrent values : H-ND Old/H-ND new factor ~3 for Vacuum @160 nm**

Promising Q.E. values; not reproducible. (each lot is different).
Powders from various producers compared: D&T 250 nm so far is best

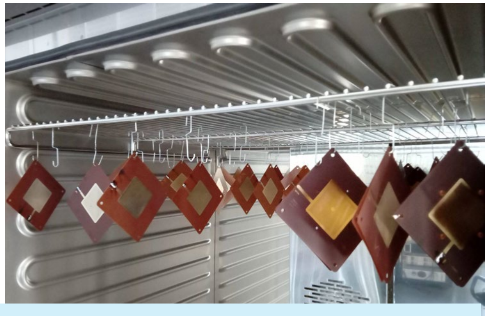
TASK 3 – R&D ON MPGD-BASED DETECTORS OF SINGLE PHOTONS

INFN Trieste

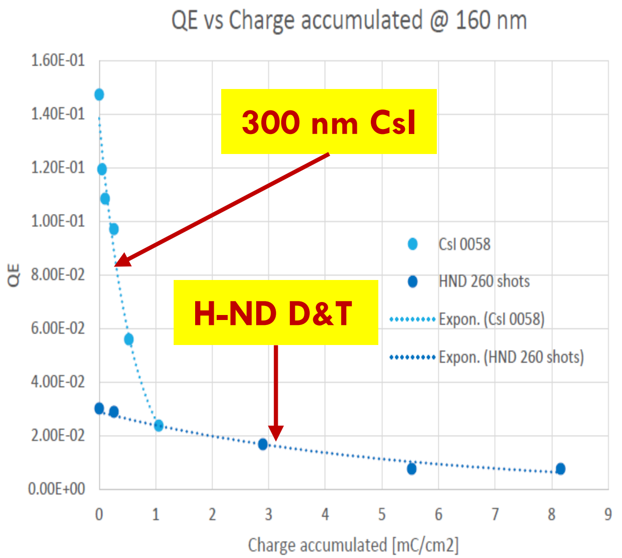
Hydrogenated diamond nanocrystals proven to be a **robust alternative to CsI for VUV photon conversion**



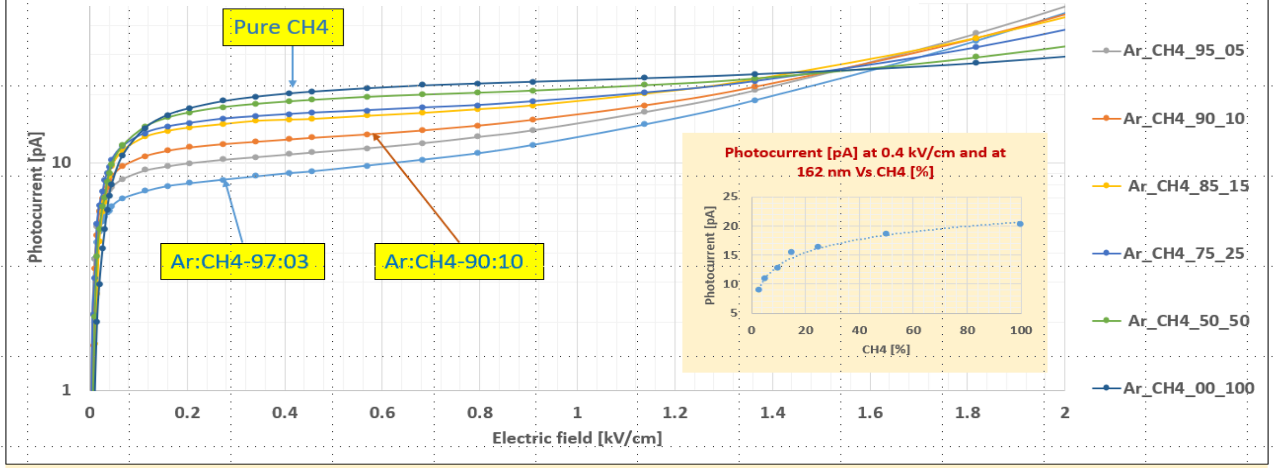
H-ND is at least ten times more robust than CsI against irradiation and ion bambardment



Systematic study performed

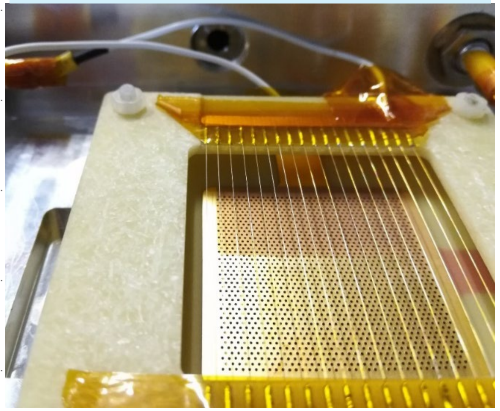


I(pA) vs E (kV/cm) for various Ar/CH_4 gas mixtures:

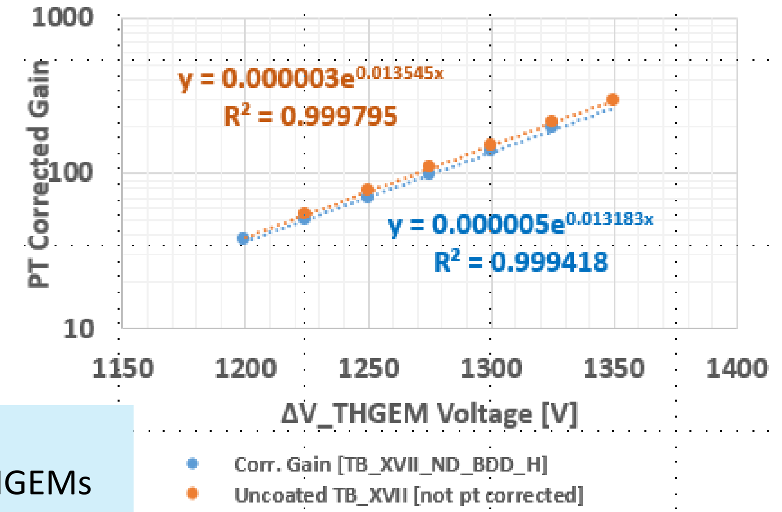


- Ar:CH4_50:50 ~9% lower PDE compared to Pure CH4
- Ar:CH4_75:25 ~24% lower PDE compared to Pure CH4
- Ar:CH4-97:03 ~55% lower PDE compared to Pure CH4

$\lambda = 162$ nm

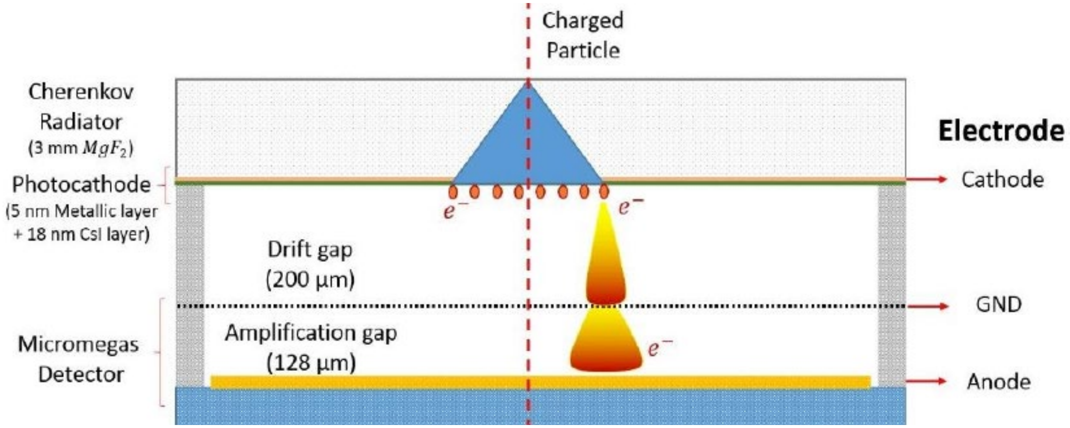


H-ND is compatible with THGEMs
Same response from coated/uncoated THGEMs



TASK 4 – THE PICOSEC DETECTORS

Picosec principle



Detection of Cerenkov light through photocathode emitter
Time resolution of a few 10ps from electron peak
Require flatness < 10 µm to equalize drift lengths and thus signal times

Goals : to develop modular scalable pixelated detectors

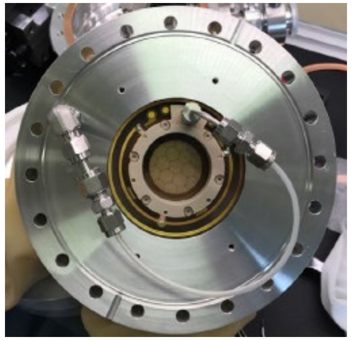
- 10x10cm active area
- Could be tiled
- Ensure uniform gaps over the active area
- Robust enough to be used on large surface

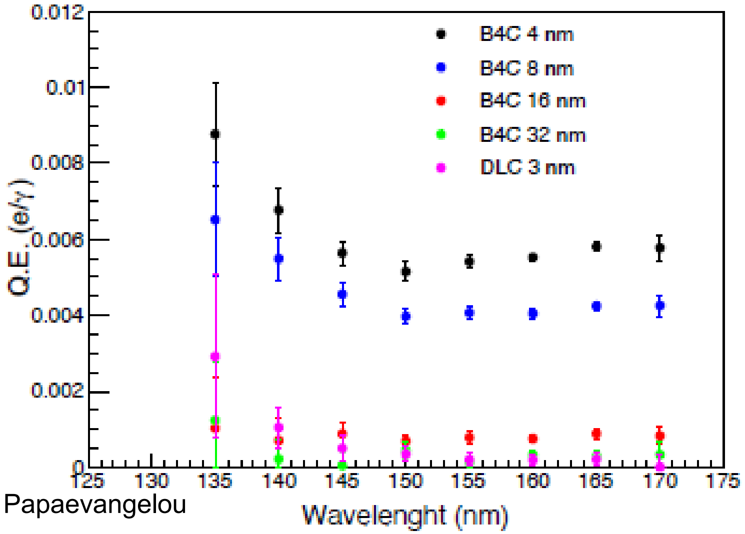
Several prototypes tested

- single 1cm pad
- 5cm large hexagonal multipads board
- 10x10cm 1cm-large pads board

Different photocathode materials tested on small prototypes

- CsI: largest e^- yield but fragile
- DLC: more robust but lower yield
- B_4C: better yield, promising material





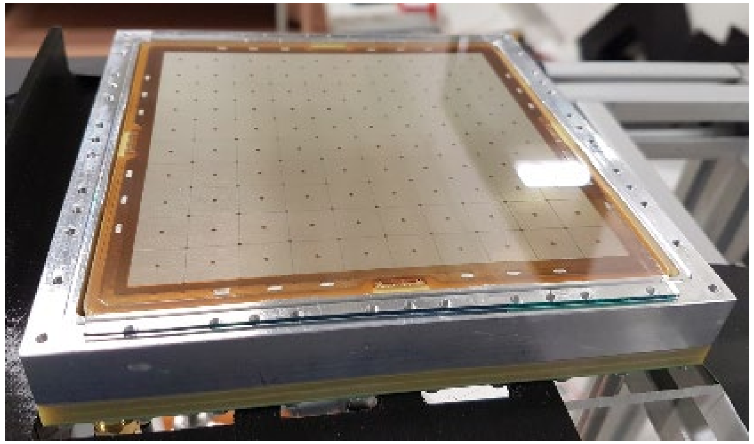
T. Papaevangelou

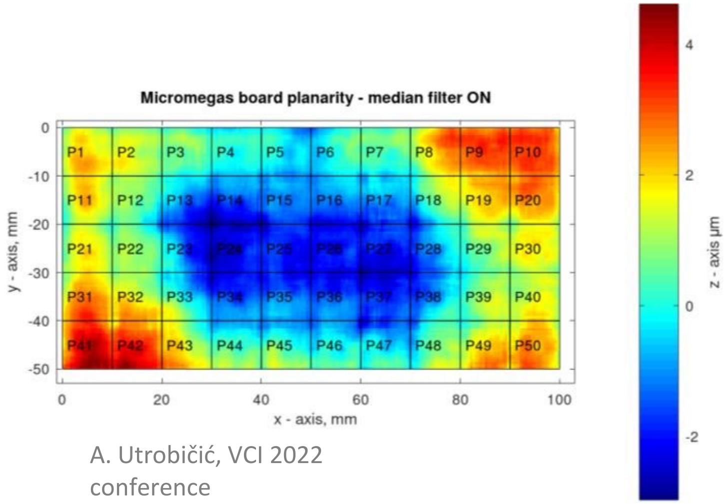
97% efficiency and 35 ps resolution with 2.5nm DLC

TASK 4 – RECENT RESULTS ON PICOSEC DETECTORS

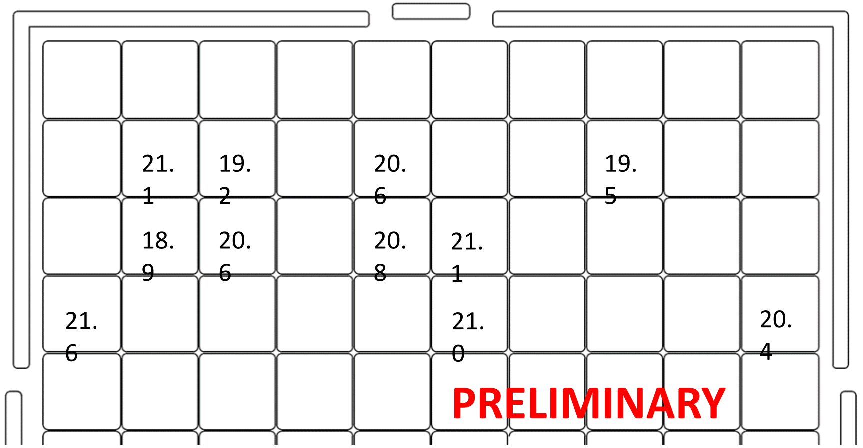
Tests on 10x10cm large prototypes
- Ceramic board
- 100 pads
- Integrated amplifier electronics
- Ne+10%CF4+10%C2H6 gas mixture
- Excellent planarity (<10µm)

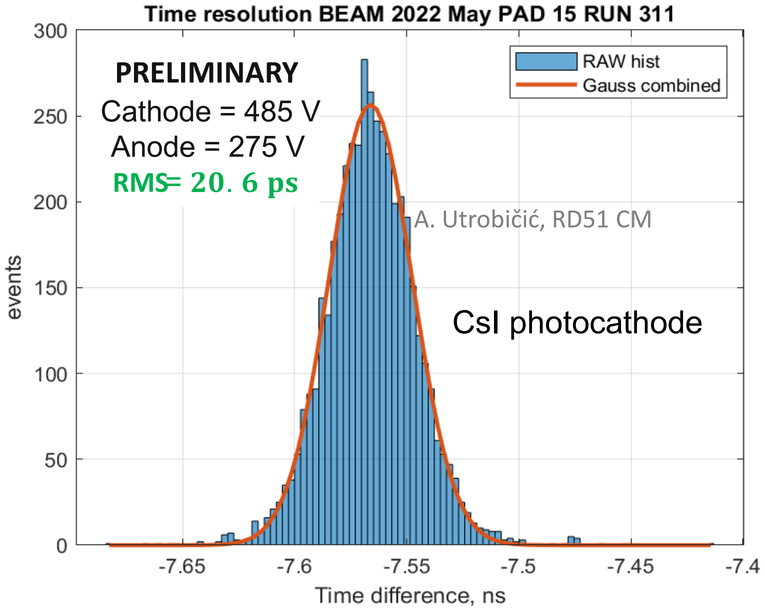
Tested on SPS beam in 2021-22
- Time resolution < 22ps in pad centers
- ~30ps for signals shared on 4 pads
- Homogeneous resolution over surface



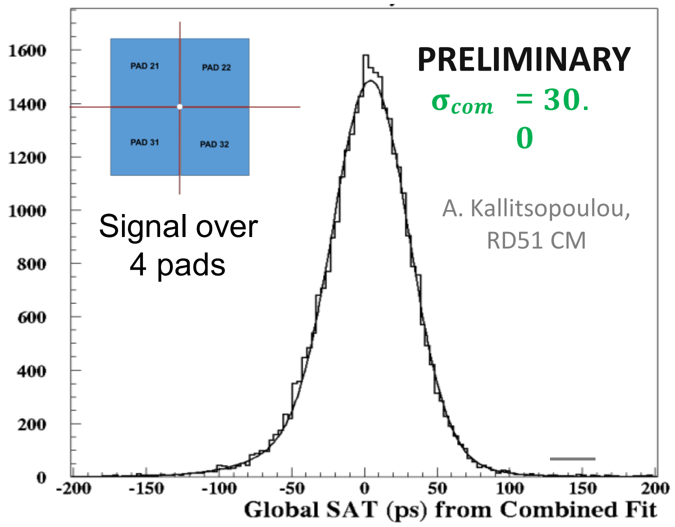


A. Utrobičić, VCI 2022 conference





A. Utrobičić, RD51 CM



A. Kallitsopoulou, RD51 CM

TASK 4 – NEXT STEPS OF THE PROJECT

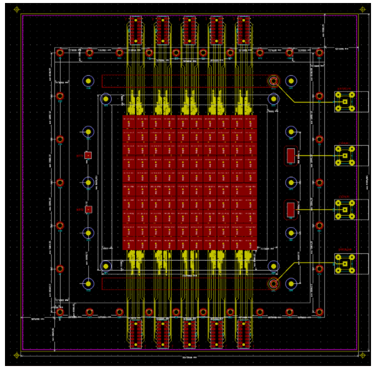
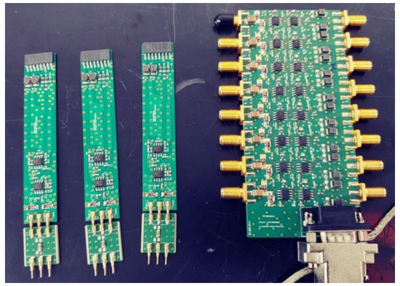
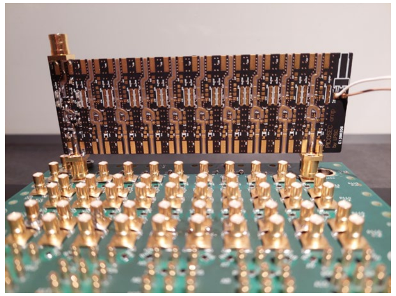
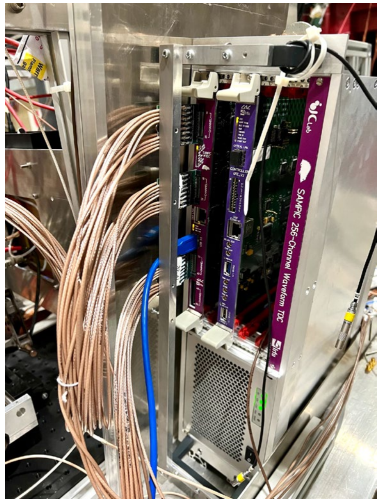
Front-end electronics

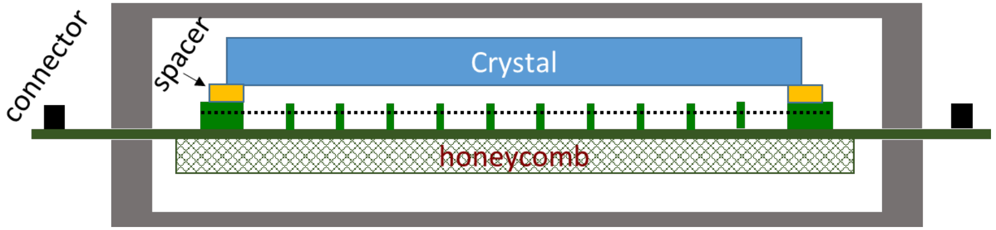
- Discrete 1-channel fast preamplifier
- 8-channels fast preamplifier cards
- Also optimized 1 and 10-channel RF pulse amplifiers
- Under production (Strong2020 budget): fast amplifiers with larger density to equip 100-channels detectors

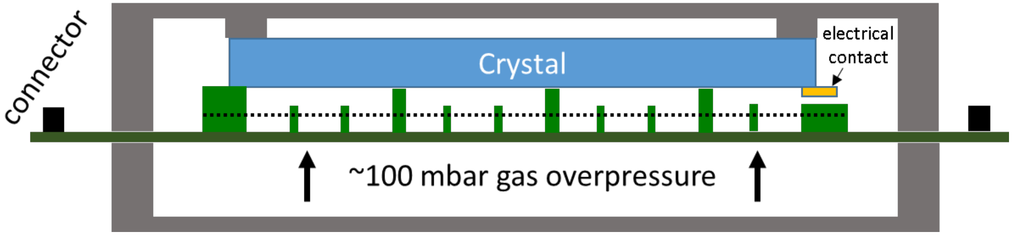
Digitization with new 64-channels fast SAMPIC TDC modules

New simplified and robust 10x10cm^2 detectors

- FR4 board instead of ceramic → lower material budget
- Resistive layer (tests planed with beam on small prototypes in October 2022)
- Planarity insured with honeycomb board or with gas pressure (both kinds will be produced)
- To be tested with CsI, DLC and B_4C photocathodes
- Design ongoing, to be produced beginning 2023
- Radiator crystals already ordered (Strong2020 budget)
- Beam tests planned in October 2023





CONCLUSIONS

- JRA14 activities are on track
- All Milestones + first Deliverable have been met
- Diverse contributions for the next generation of MPGD for hadron physics experiments
  - design of prototype high-rate TPC ready
  - several other TPC-related projects: mTPC for Jlab, optical TPC
  - active-target TPC: optimized pad plane used for IKAR TPC during AMBER Pilot Run in 2021
  - photon detectors: several new photocathode materials combined with THGEM investigated
  - fast timing and tracking: Picosec project advancing
- Possible extension of STRONG-2020 project beyond 11/2023:
  - some tasks/work packages may benefit from some time in 2024 to complete detector tests due to some delays in the production of electronic components
  - ideas for further development exist, but are probably outside the scope/budget of the JRA