Developments in MPGD based photon detection for RICH application in view of the future EIC

Daniele D'Ago

University of Trieste and INFN Trieste
On behalf of Trieste EIC group

HADRON IDENTIFICATION AT EIC

Key requirement at EIC > efficient particle identification at high momentum

RICH technique in this environment is challenging:

Compact geometry > short radiator

High momentum > gaseous radiator

High space resolution is required

Reduce pad size

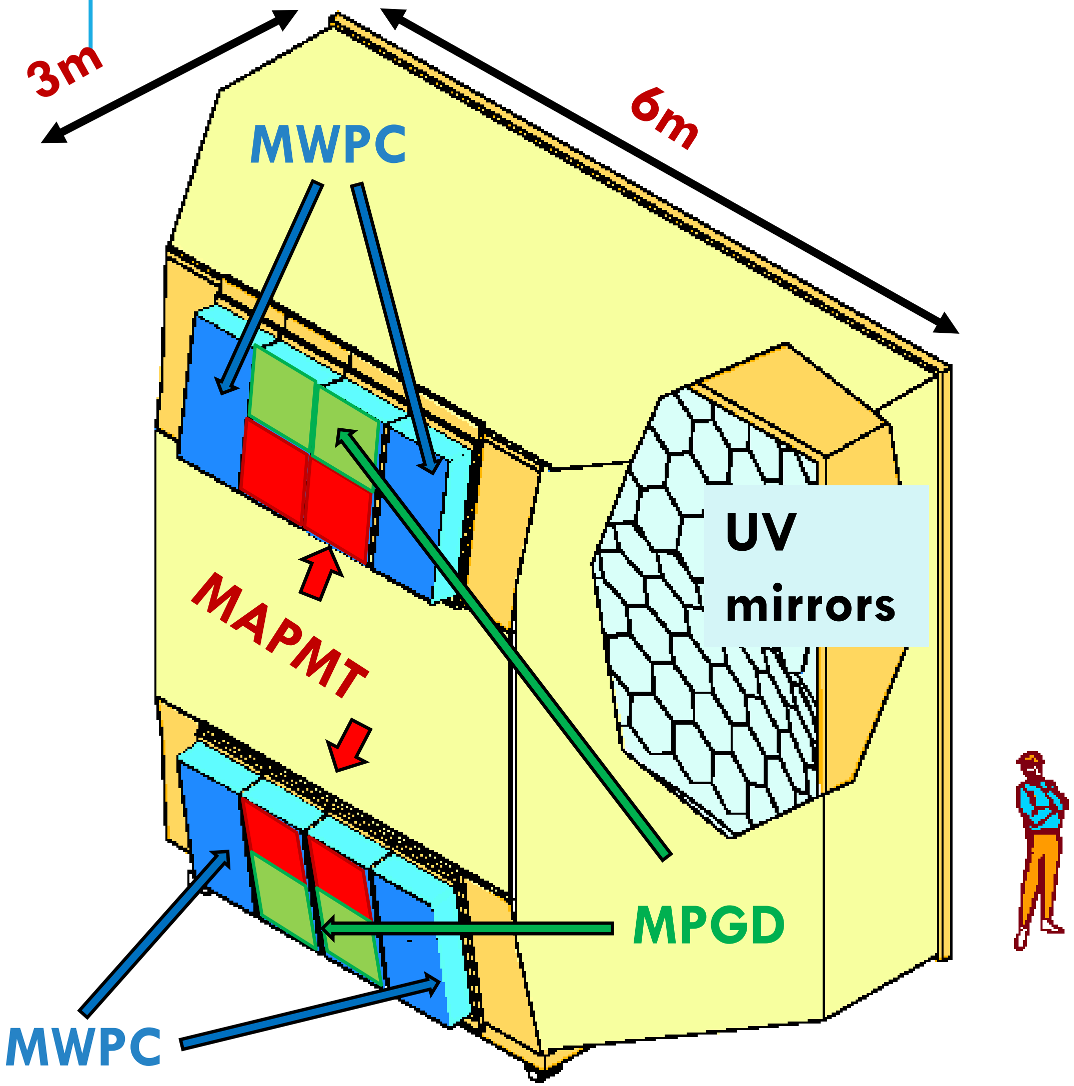
Low number of photons

Frank - Tamm > work in VUV

Since quartz is opaque to VUV > Windowless RICH (gaseous photon detector)

Quest for a suitable photocathode for replacing CsI

COMPASS EXPERIENCE



Large gaseous RICH:

> hadron PID from 3 to 60 GeV/c

> acceptance: H: 500 mrad V: 400 mrad

> trigger rates: up to ~50 kHz
beam rates up to ~10^8 Hz

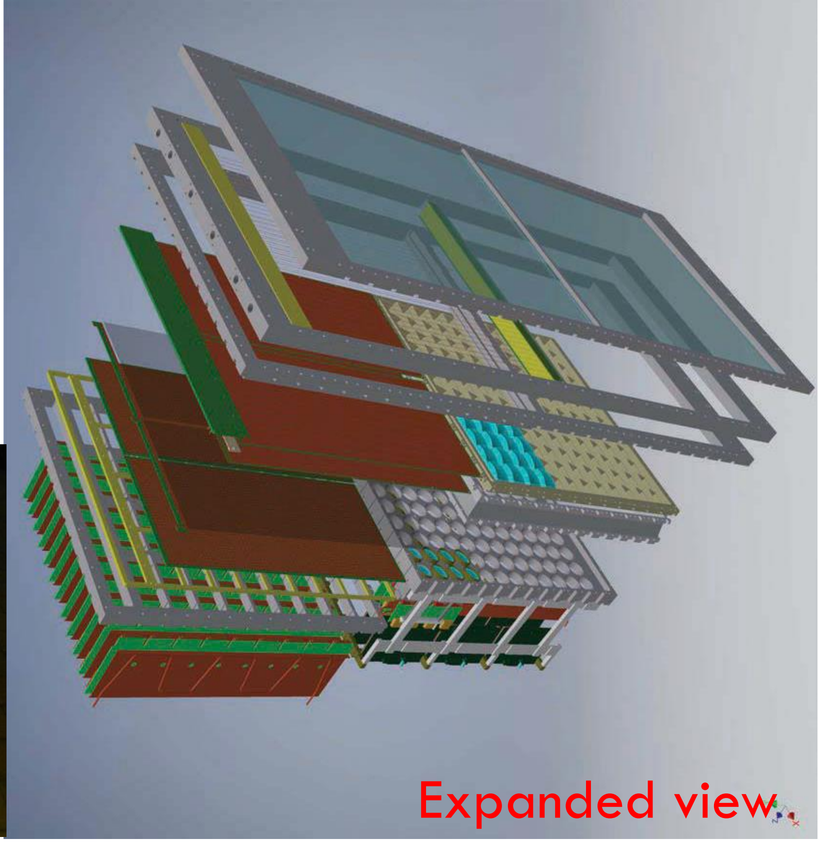
> material in the beam region: 1.2% Xo
material in the acceptance: 22% Xo

> detector designed in 1996, in operation since 2002 with MWPCs, upgraded in 2006 with MAPMTs, in 2016 with THGEMs + Micromegas

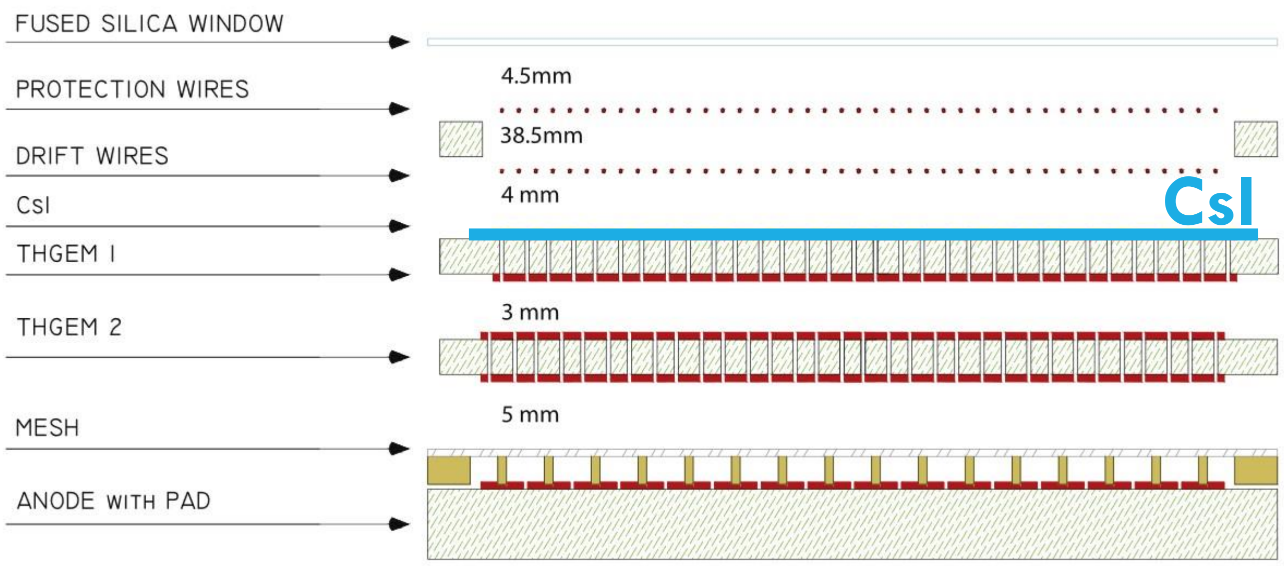
STARTING POINT:
COMPASS HYBRID MPGD BASED PDs

2 layers of staggered THGEMs
> Top of THGEM1 CsI coated
> Pre-amplification
> Tranversally enlarged avalanche
> 400 µm thickness, 400 µm hole diameter, 800 µm pitch, no rim

Pad size: 8x8 mm^2



Expanded view



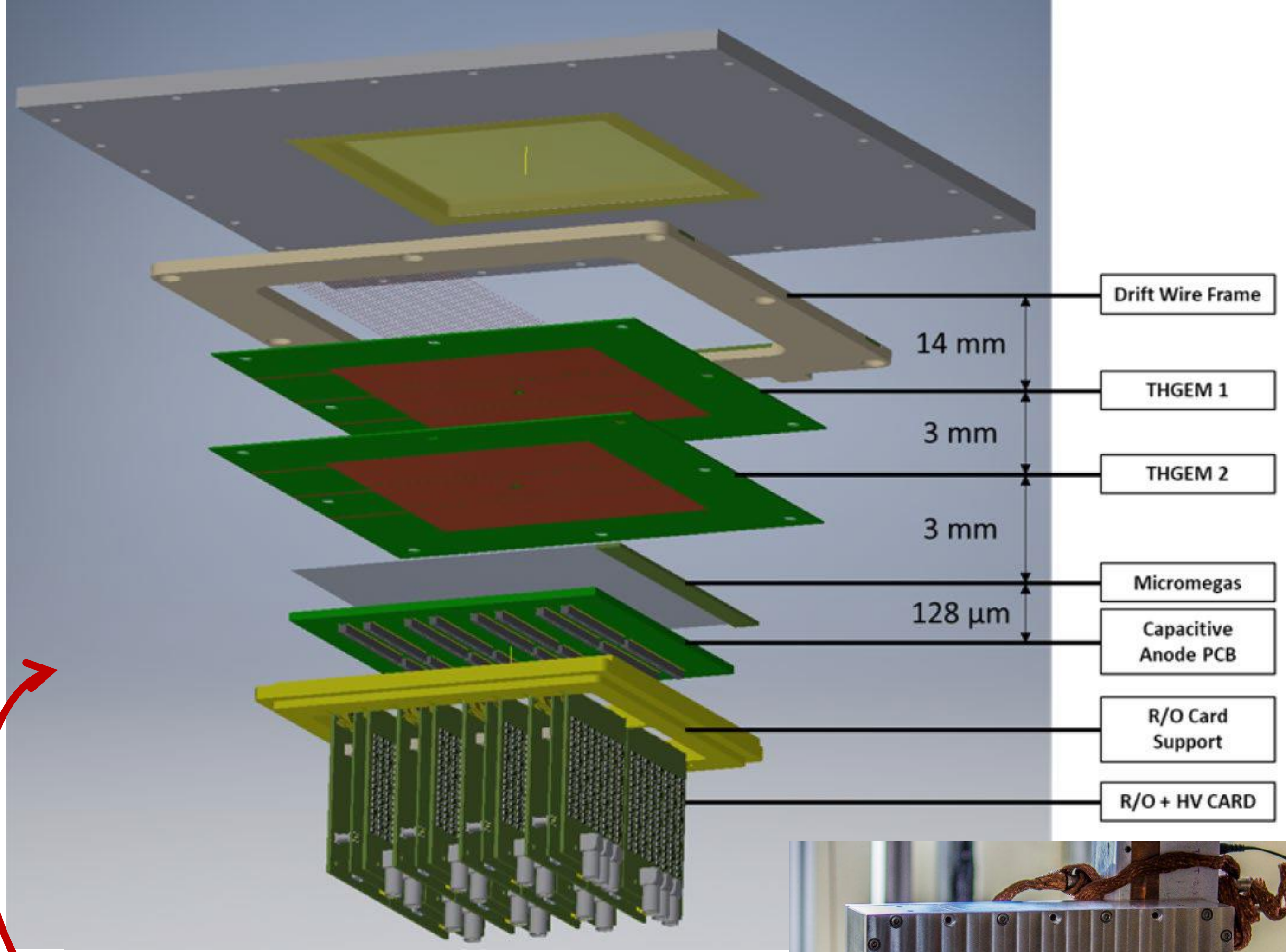
Resistive Micromegas (bulk technology)
> Trap ions
> ~100 ns signal formation
> woven stainless steel mesh,18 µm wires, 63 µm pitch
> One pillar per pad, 500 µm diameter.
> Gap = 128 µm.

MINI PAD PROTOTYPE

Modular structure: all components and services within active area

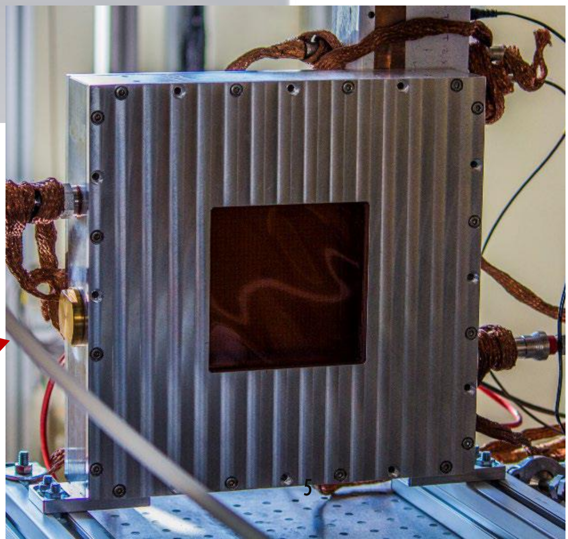
Pad size: $3x3\ \mathrm{mm}^2$ (0.5 mm inter-pad spacing)

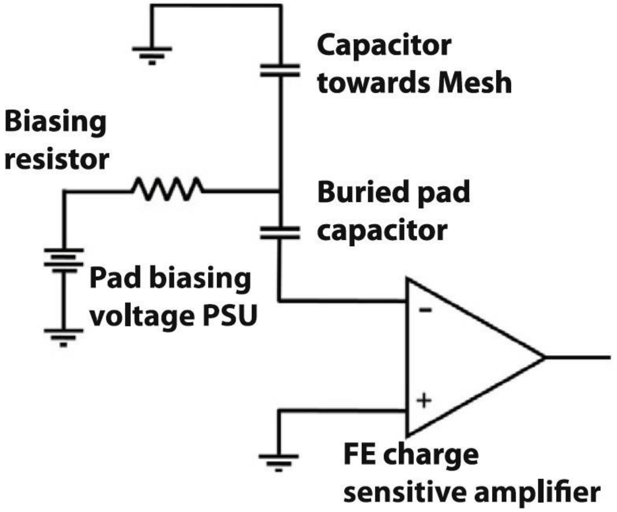
$10x10\ \mathrm{cm}^2$ active area - 1024 pads.

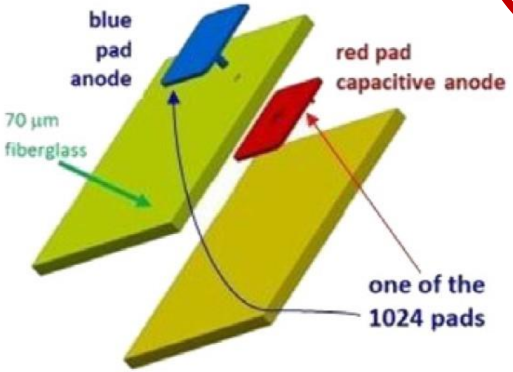


Expanded view

Mounted prototype



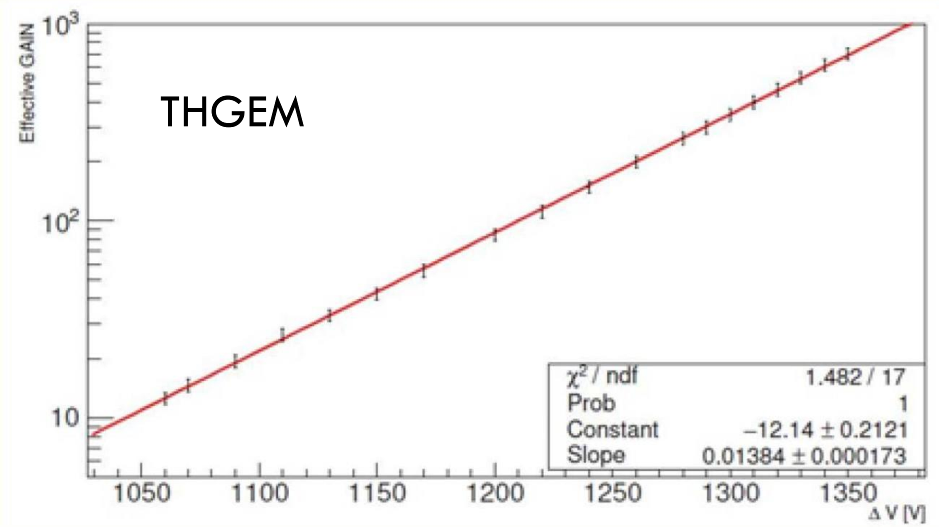


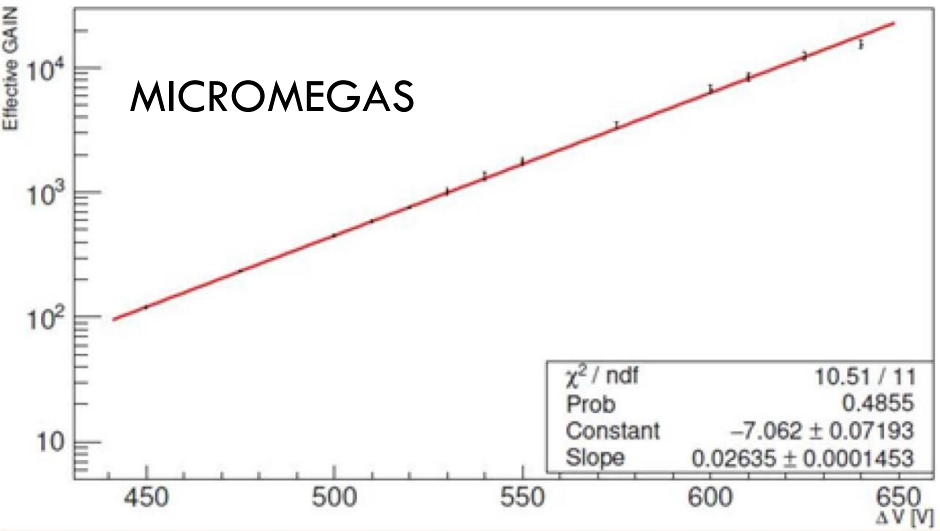


Schematic and view of capacitive coupling of each pad

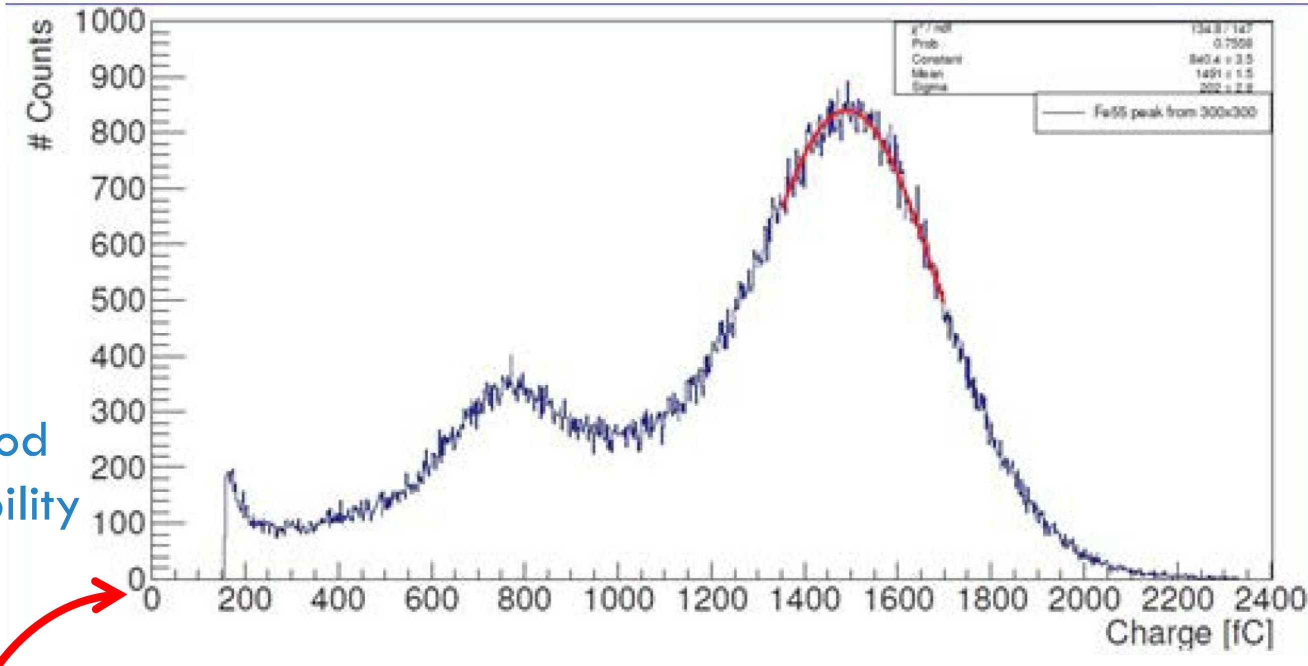
TESTS

Single elements have been tested with ^{55}Fe source, Amptek mini-X and PicoquantPLD 4000B



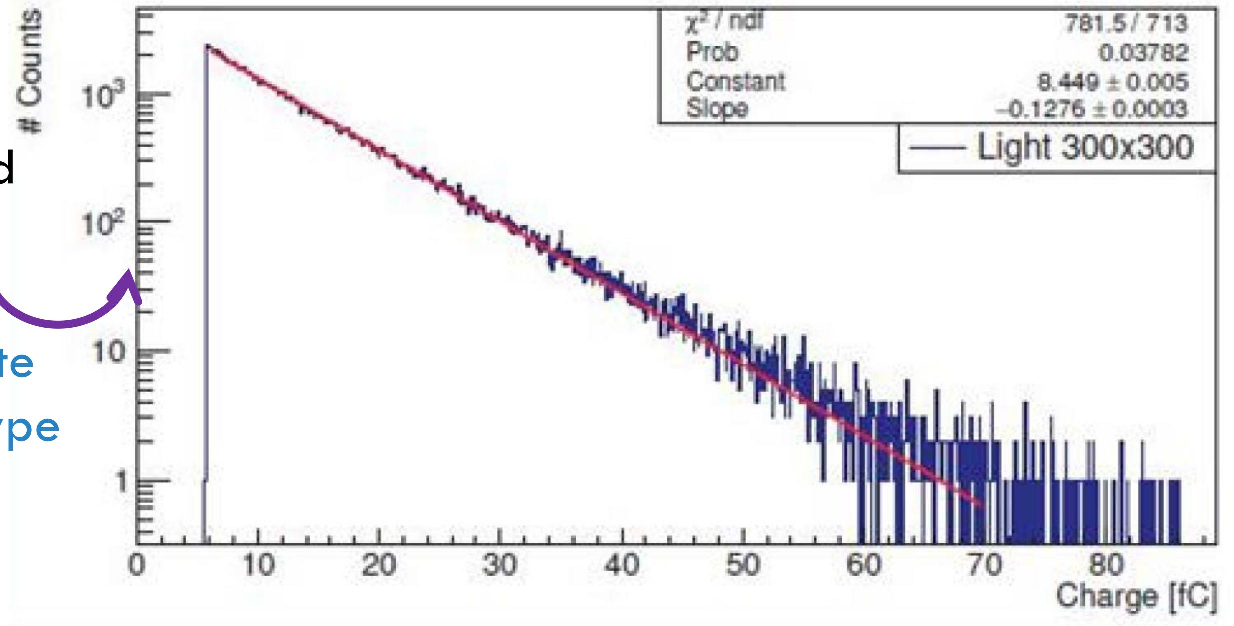


They show good electrical stability and gain performance

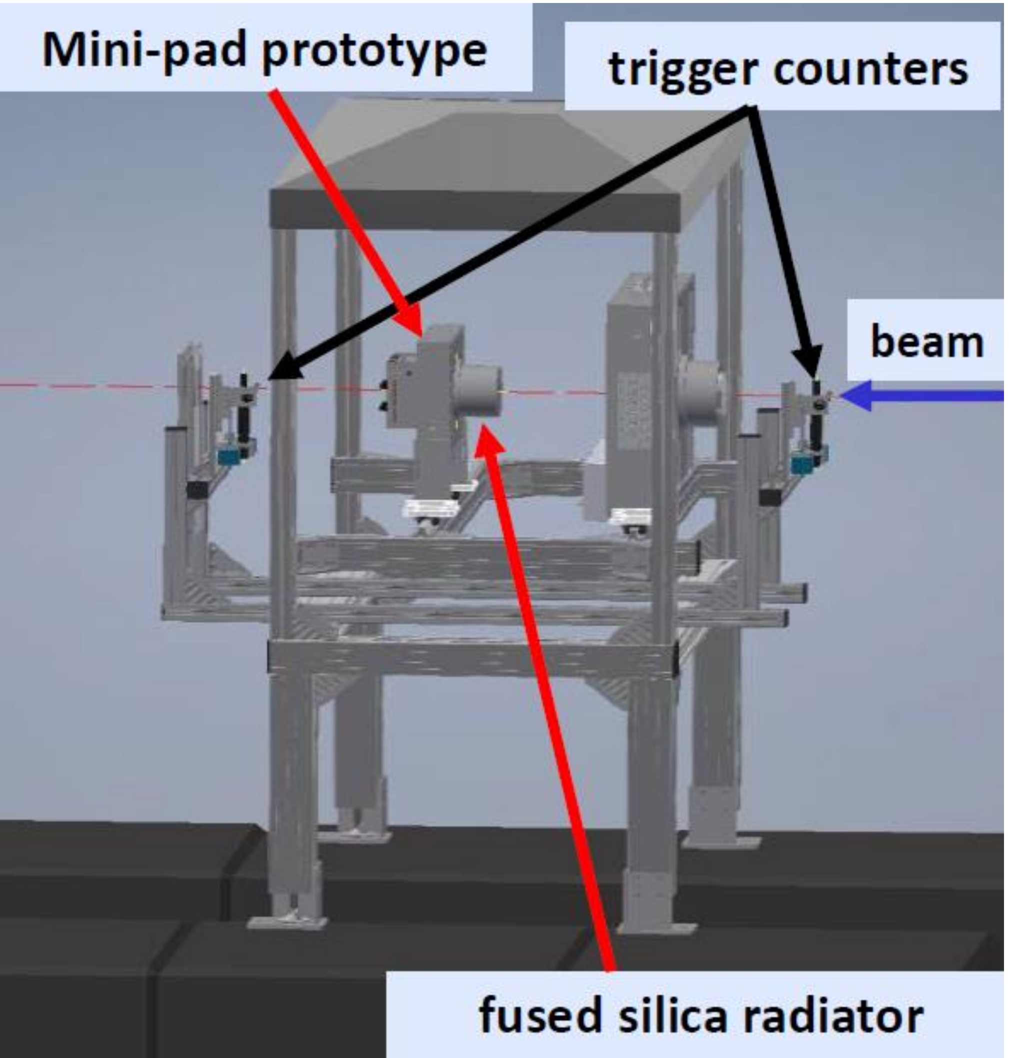


c

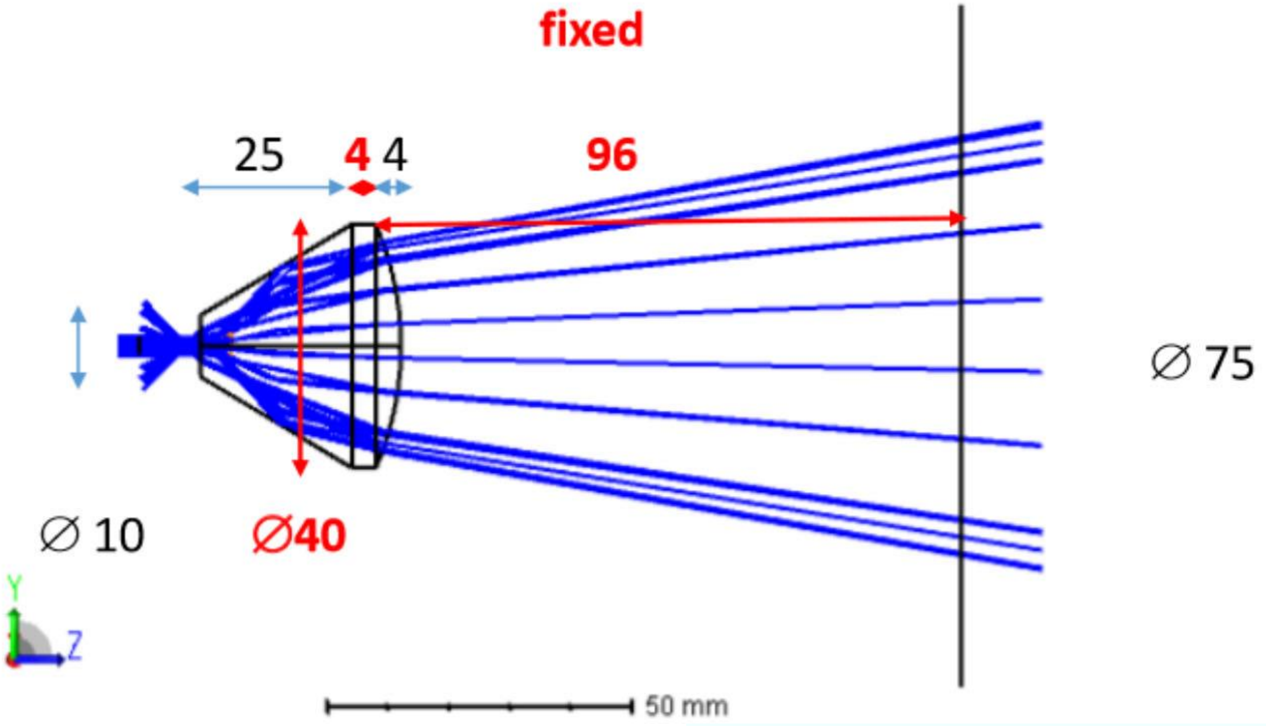
^{55}Fe source and PicoquantPLD 4000B spectra with the complete minipad prototype



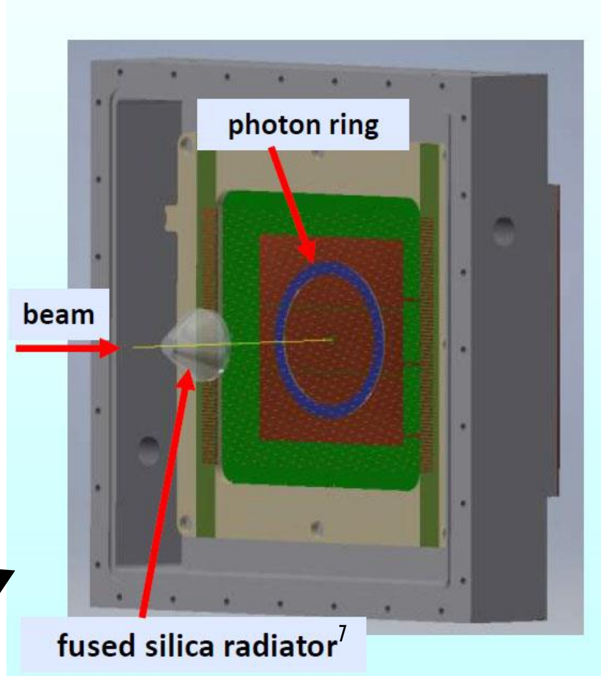
TEST BEAM - THE SETUP



The setup

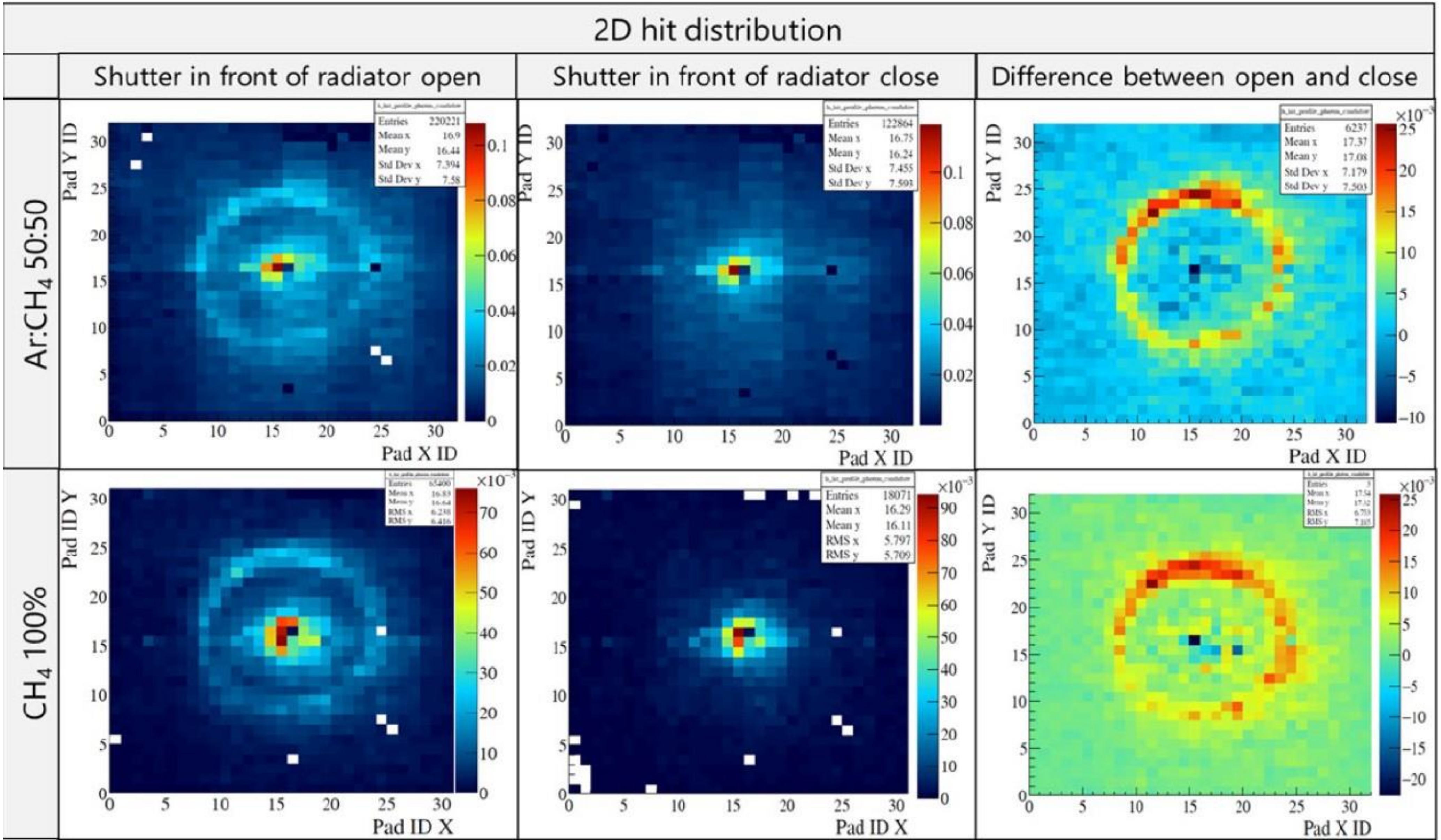


Cross section of the fused silica radiator. Blu lines are examples of Cherenkov photons trajectories



Expected photon ring

TEST BEAM - RINGS IN $Ar:CH_4$ 50: 50 AND PURE CH_4



HYDROGENATED NANODIAMOND

Gaseous Photon Detectors require a photocathode.
Up to date, only CsI has been successfully used. BUT:

> hygroscopic - water vapours dissociate the molecule

> not robust to ion bombardment

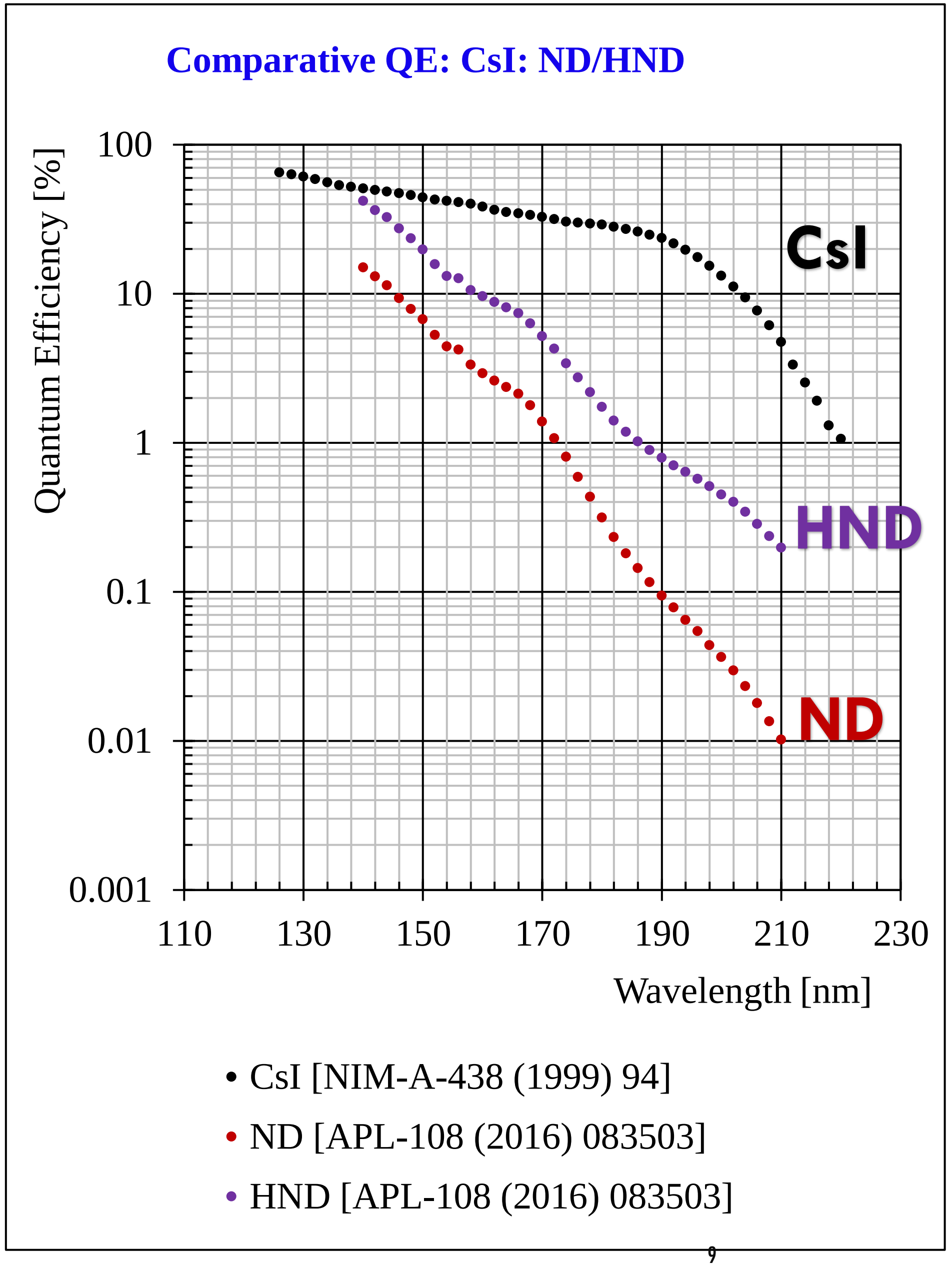
→ Degradation of Quantum efficiency

EXTREMELY DELICATE HANDLING IS REQUIRED

Recently, HND proposed as valid alternative in UV domain

@ λ=140 nm Q.E. is comparable with CsI

HND is chemically inert and radiation hard



HYDROGENATED NANODIAMOND

Gaseous Photon Detectors require a photocathode
Up to date, only CsI has been successfully use

> hygroscopic - water vapours dissociate the molecule

> not robust to ion bo

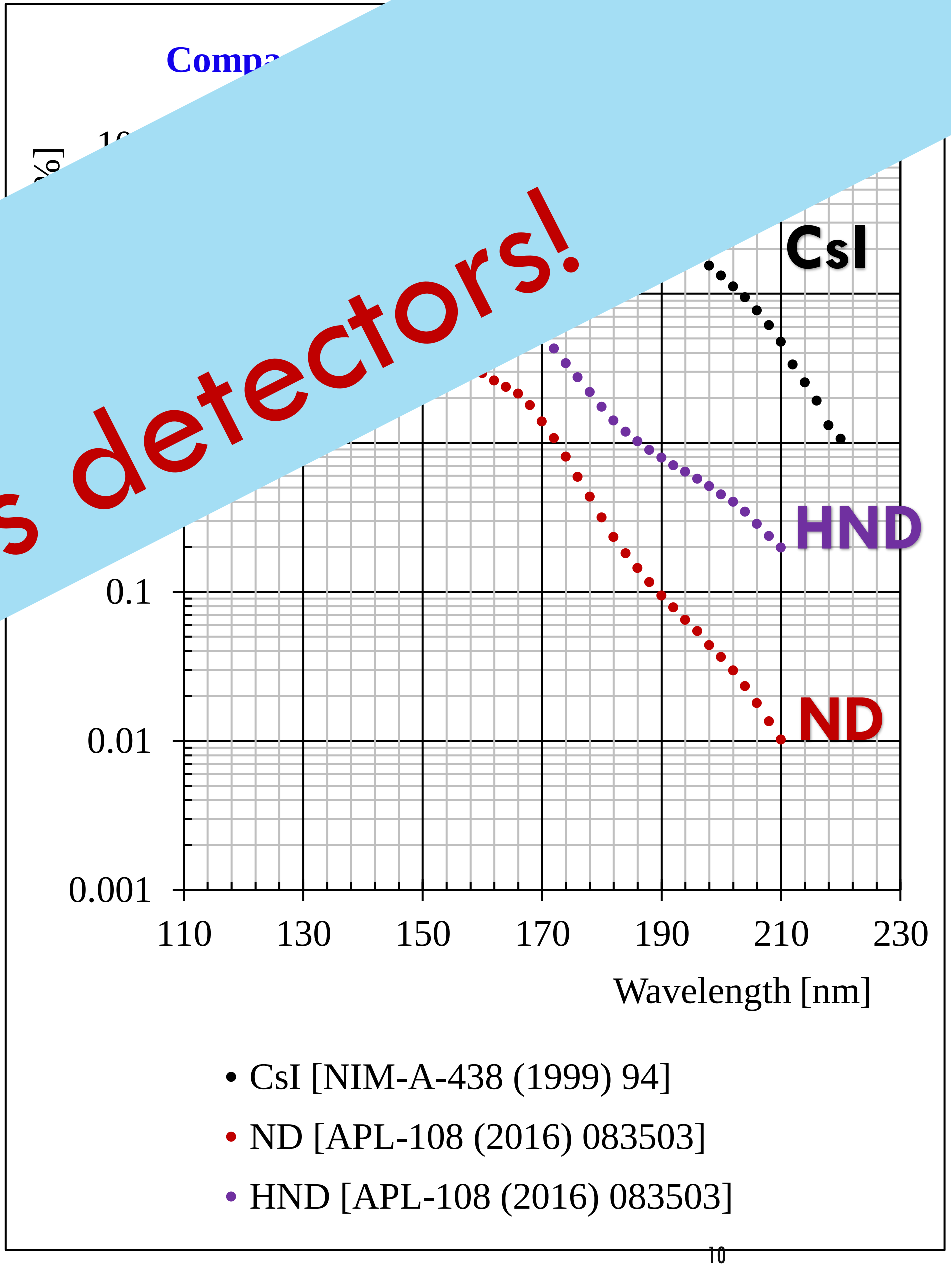
EXTREMEL ED

P ernative in UV

omparable with CsI

ically inert and radiation hard

CHALLENGE:
coupling with gaseous detectors!



R&D MILESTONES AND STATUS

> Hydrogenation of ND by plasma treatment (MWPHCVD) @ T > 800 ^{o}C

> Coating by pulsed spray technique

- On PCB > Q.E. measurement (vacuum, gas mixtures)
- On THGEM > gain and stability (gas mixture)

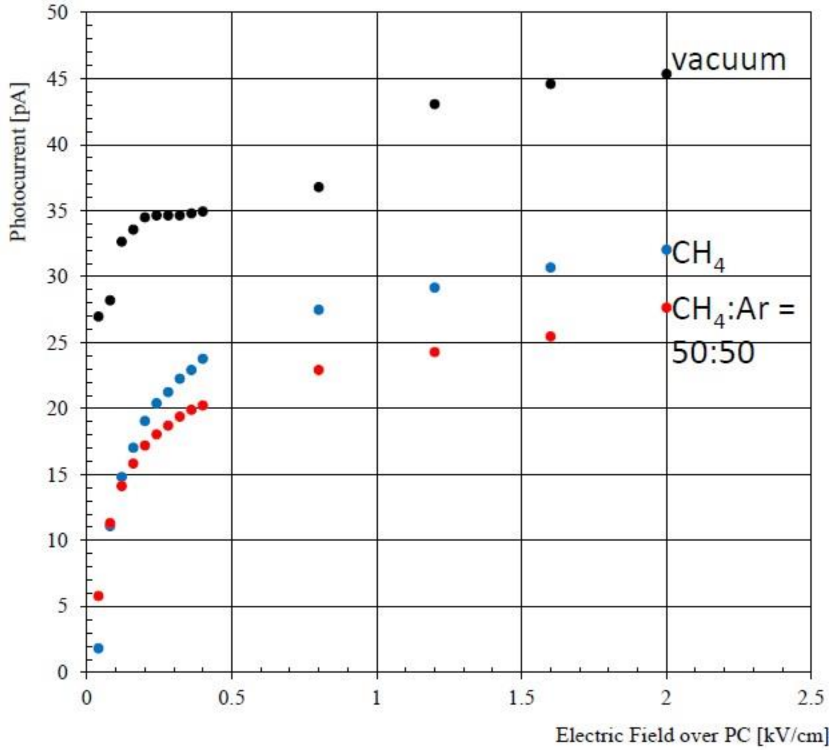
REMARKABLE:

Hydrogenating the powder before coating makes it compatible with gaseous detector components

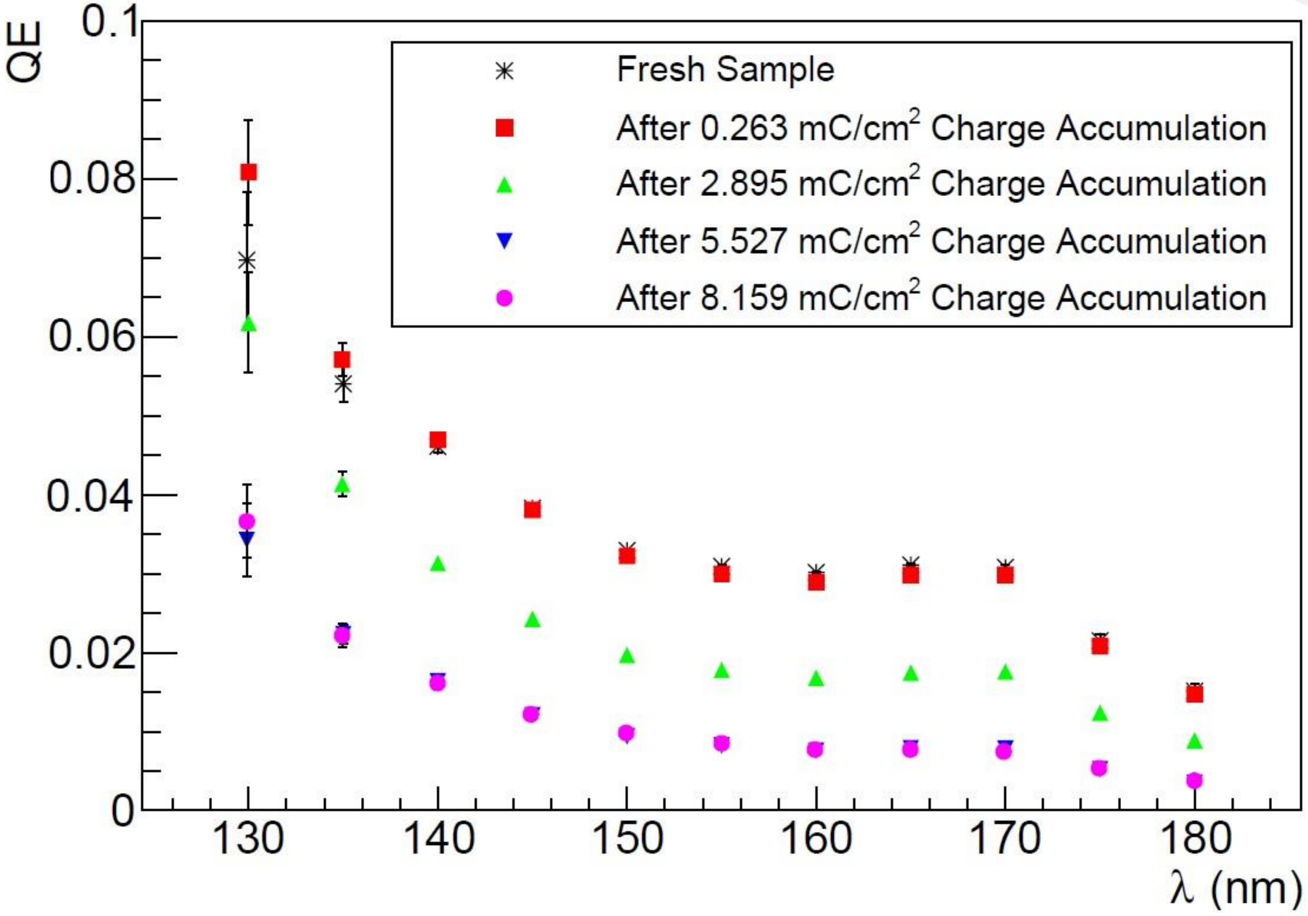
QUANTUM EFFICIENCY

Ageing due to ion bombardment
NEVER MEASURED BEFORE

PRELIMINARY

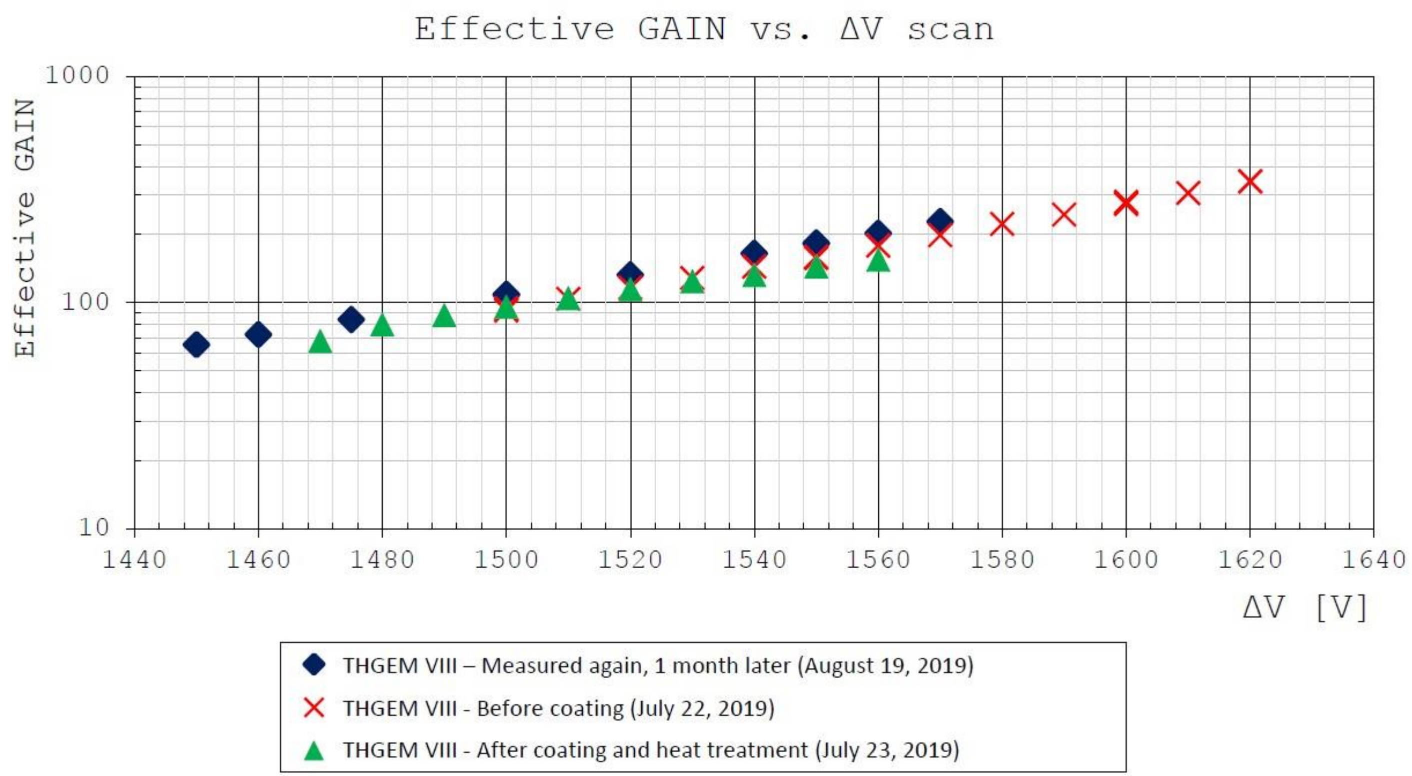


Photocurrent at photocathode @ λ = 162 nm. Normalized using a calibrated photodiode.



QE as a function of λ for fresh and various charge accumulations due to ion bombardment on H-ND coated Au_PCB substrate.

H-ND COATED THGEMS



Systematic characterization of H-ND coated and uncoated THGEMs is ongoing

H-ND Coated THGEMs do not sustain HV

Possible explanation > water trapped due to spraying procedure

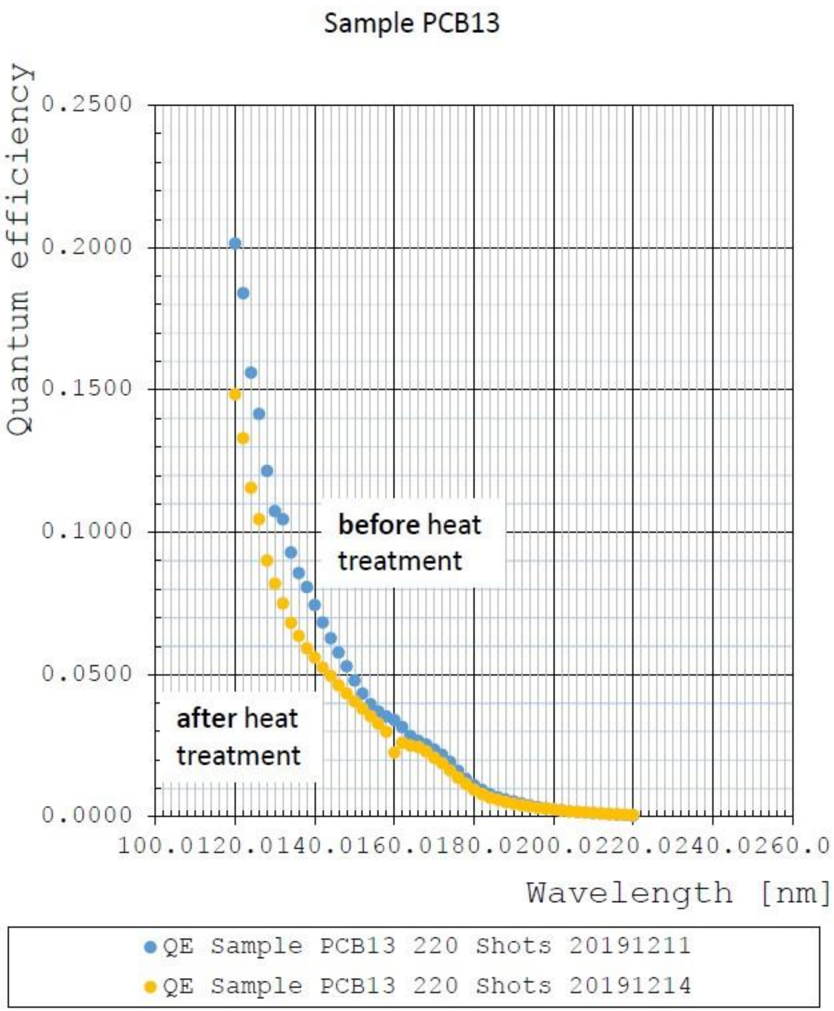
Cure > heat treatment (T > 100 ^{o}C)

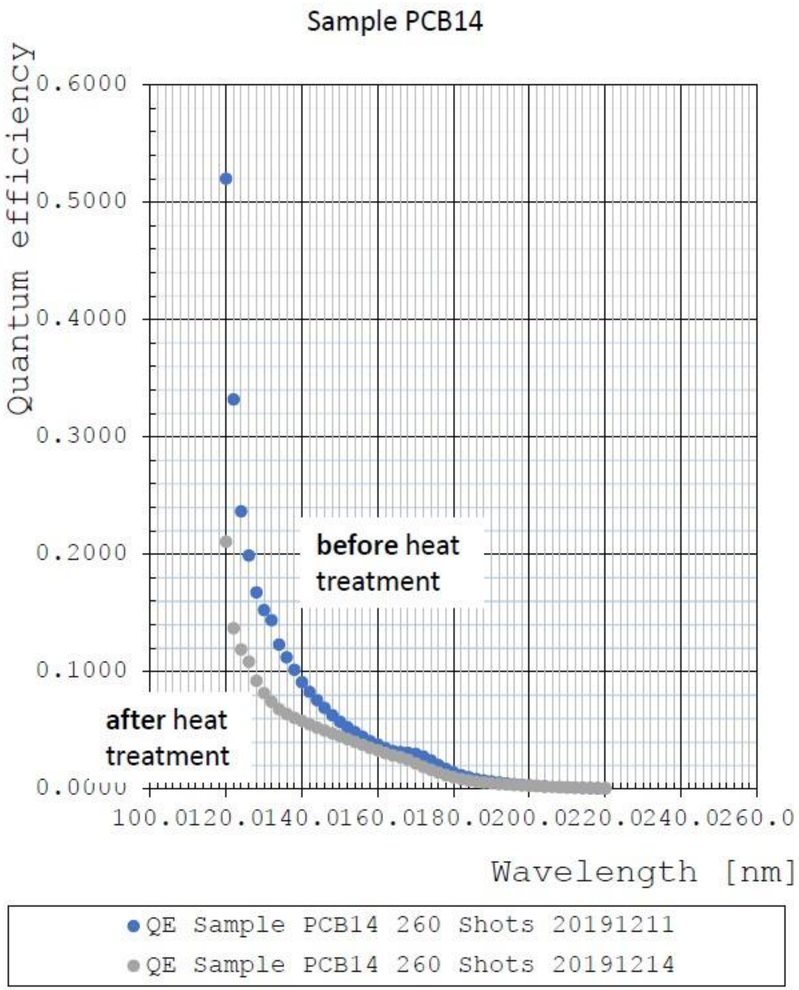
After heat treatment THGEMs performance recovered

SUMMARY of coated samples

substrate type	sample label	coating material	number of spray shots
THGEM	TB IX	ND	300
THGEM	TB VIII	HND	140
THGEM	TB III	HND	43
THGEM	TB VII	HND	55
THGEM	TB XIX	HND	59
THGEM	TB XI	HND	250
disc	PBC1	ND	100
disc	PBC2	ND	100
disc	PBC3	ND	200
disc	PBC4	ND	200
disc	PBC5	ND	50
disc	PBC6	HND	50
disc	PBC9	HND	25
disc	PBC7	HND	50
disc	PBC10	HND	100
disc	PBC11	HND	200
disc	PBC8	HND	400

QUANTUM EFFICIENCY AND HEAT TREATMENT





How does heat treatment affect quantum efficiency?

A little decrease in QE is observed (not dramatic though)

Possible explanation > THGEMs are treated in air, possible oxidation

CONCLUSION

Intense R&D is ongoing

MiniPAD prototype has been successfully tested in a test beam. Further work is required

- optimizing the design
- Study of a suitable front end electronics (current is no longer produced)

H-ND coated THGEMs are giving promising results. Next steps

- Complete ongoing comparative study (H-ND coated VS uncoated)
- Prototype with additional MM stage for single photon detection

BIBLIOGRAPHY

J. Agarwala, et al., *The MPGD-based photon detectors for the upgrade of COMPASS RICH-1 and beyond*, Nuclear Inst. and Methods in Physics Research, A (2018), https://doi.org/10.1016/j.nima.2018.10.092

J. Agarwala, et al., *Optimized MPGD-based Photon Detectors for high momentum particle identification at the Electron-Ion Collider*, Nuclear Inst. and Methods in Physics Research, A (2018), https://doi.org/10.1016/j.nima.2018.10.185

S. Levorato, *Performance of the discrete element Bulk MicroMegas of the COMPASS RICH-1 and the R&D for the EIC project*, EICUG2017

F. Tessarotto, *Development of a modular mini-pad gaseous photon detector for RICH applications at the EIC*, EICUG2019

F. M. Brunbauer, et el., *Nanodiamond photocathodes for MPGD-based single photon detectors at future EIC, (in press)*