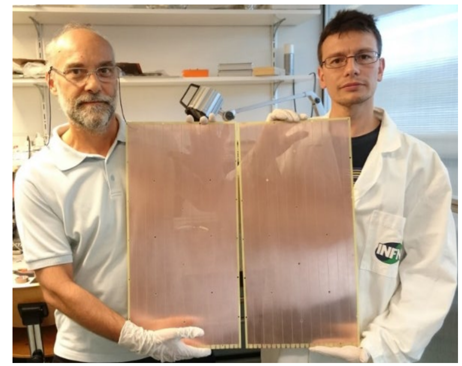
CPAD 2021

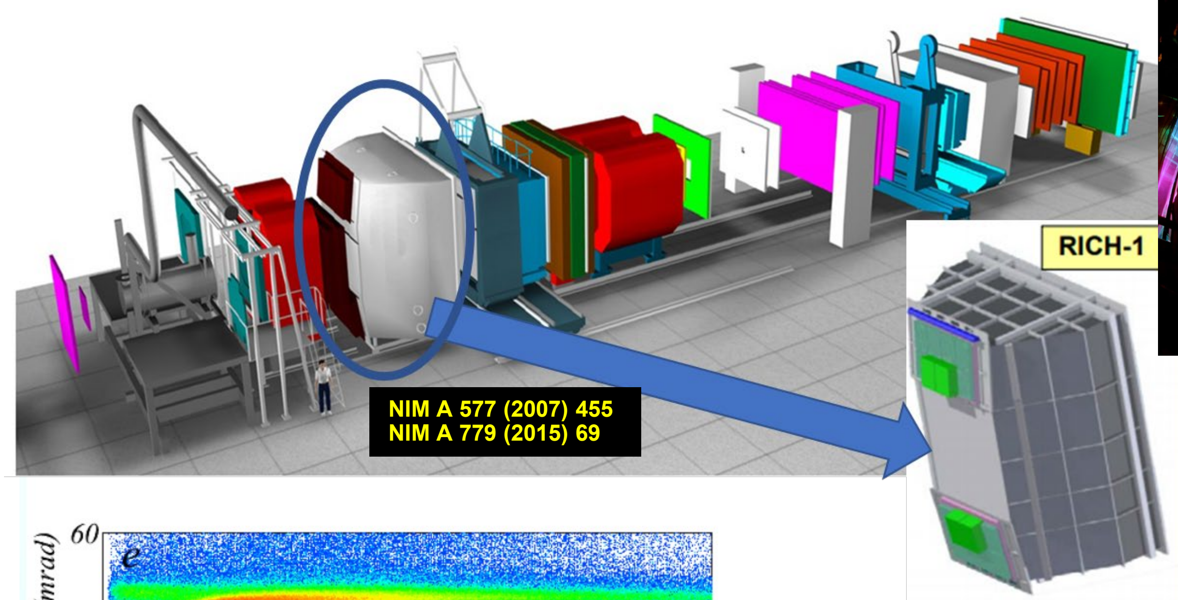
MPGD-based detectors of Cherenkov photons in COMPASS and for future applications

Fulvio Tessarotto (CERN and INFN - Trieste)

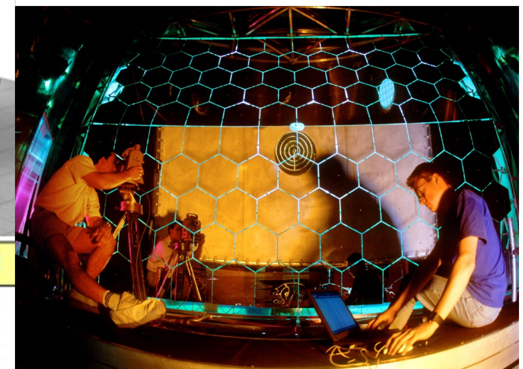
- Hadron PID in COMPASS
- Hybrid THGEM+MM PDs
- Hybrid PDs performance
- Minipad prototype
- Test beam results
- Hydrogenated nano-diamond powder
- Compatibility with THGEMs and robustness
- Perspectives



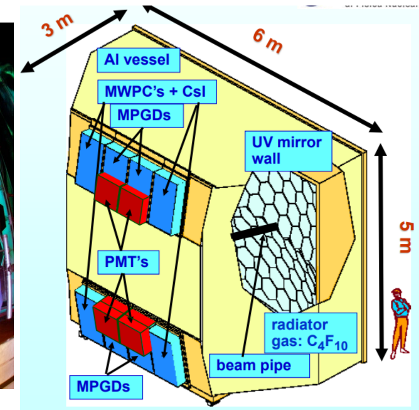
Hadron PID in COMPASS

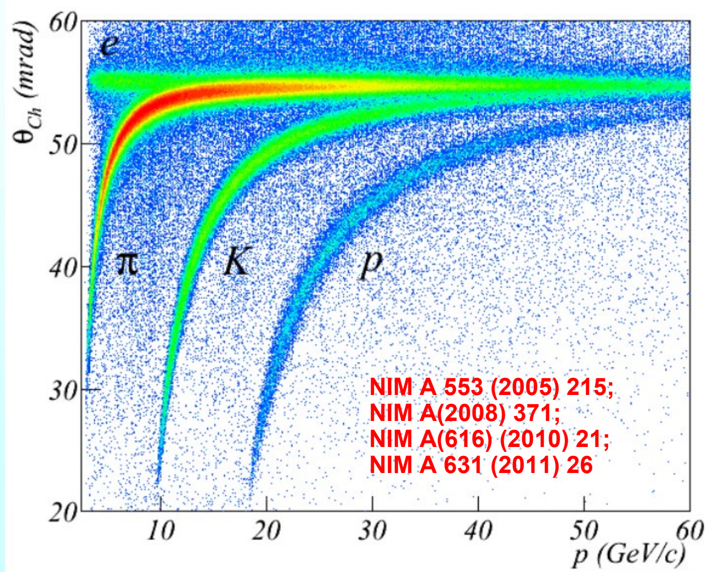


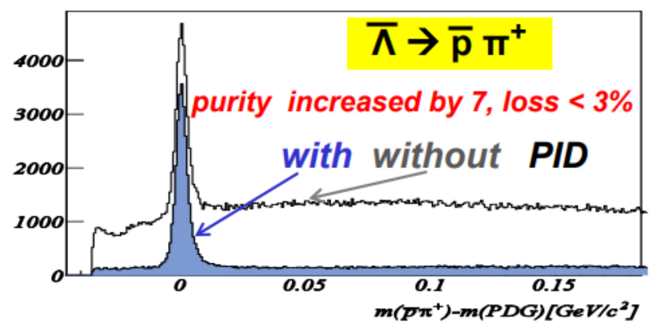
3 m long C_4F_{10} radiator



21 m^2 UV reflective mirror



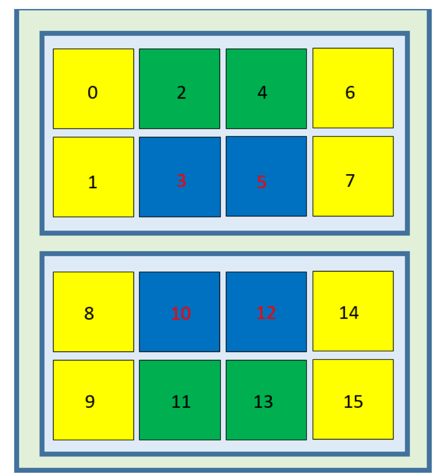




5.6 m^2 photon detection surface

three photon detection technologies:

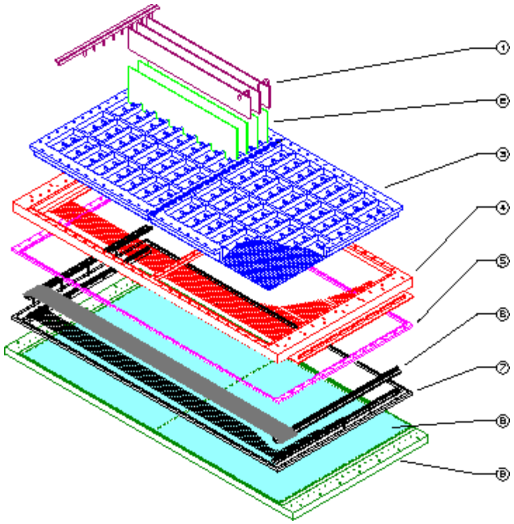
- MAPMTS
- Hybrid PD
- MWPC

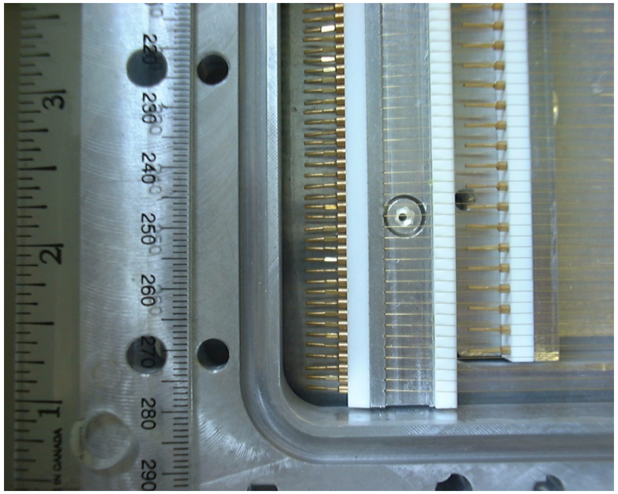


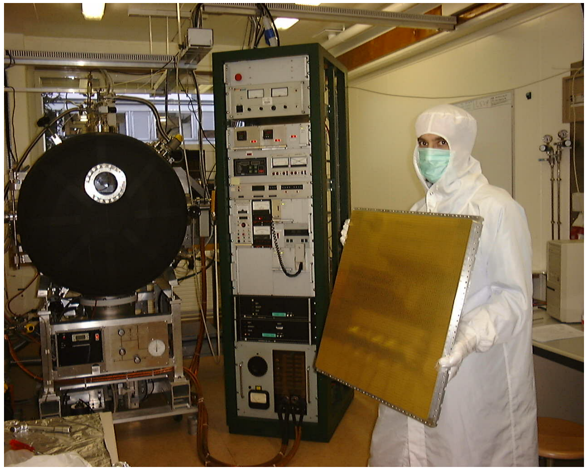
Vast number of COMPASS physics analysis require excellent PID.

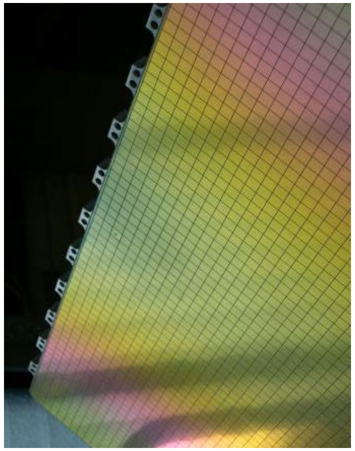
Approved SIDIS data taking in 2021 and 2022 → RICH is crucial.

COMPASS MWPC's with CsI

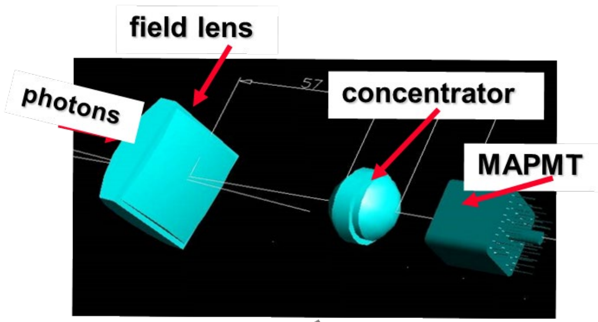


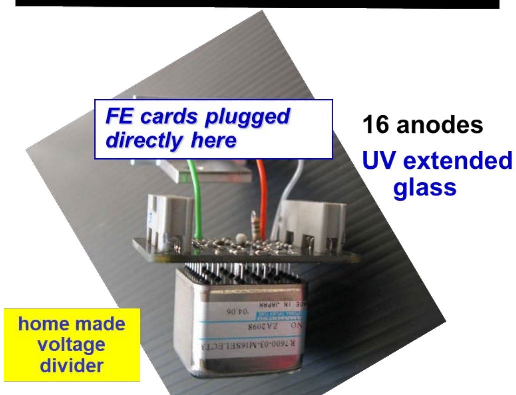


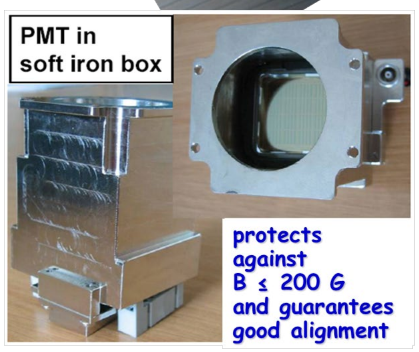


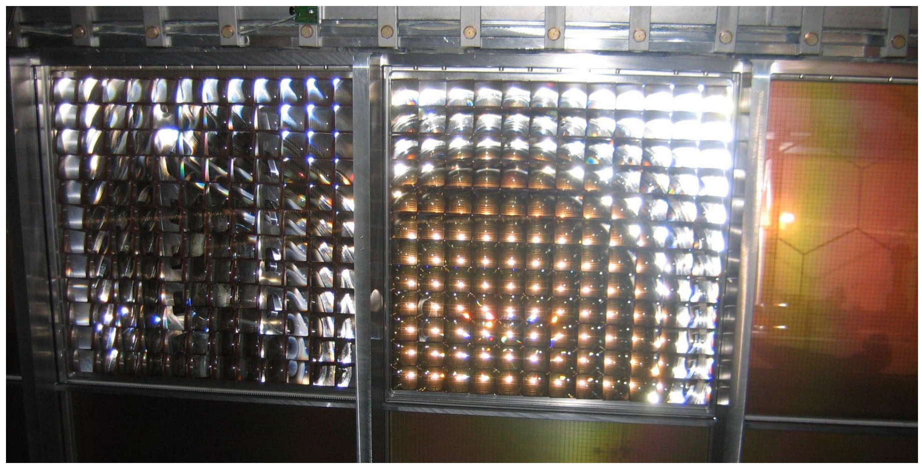


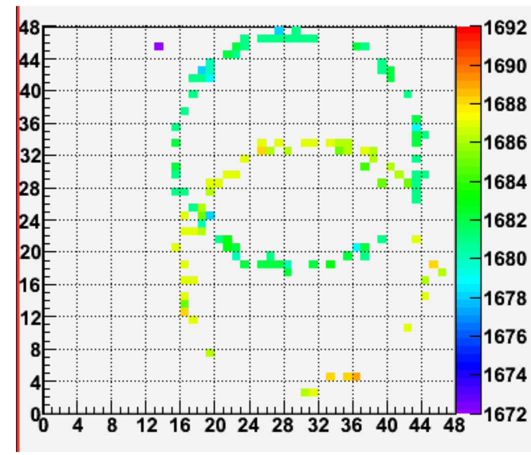
COMPASS MAPMTs with lenses

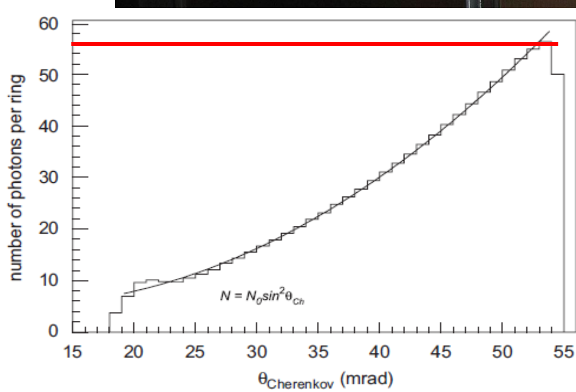


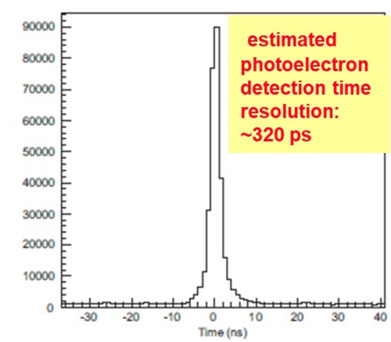


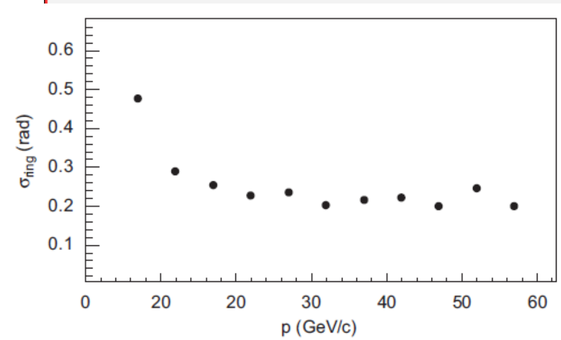






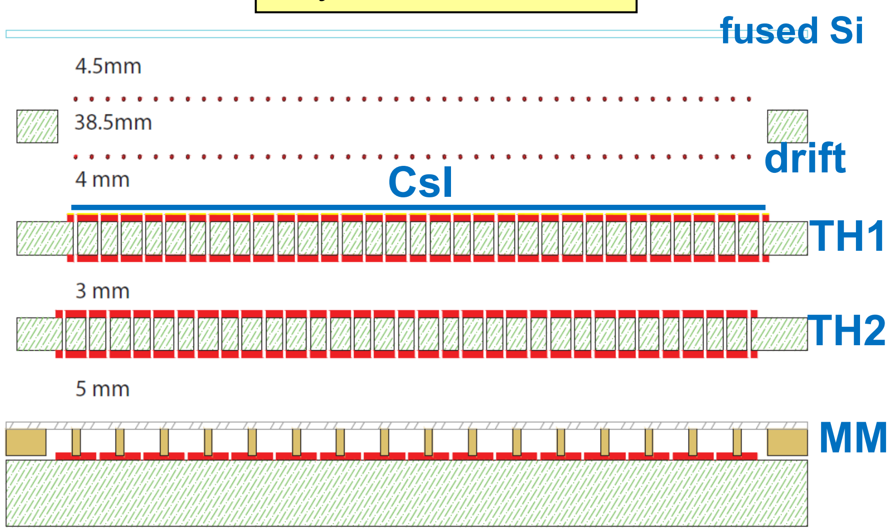




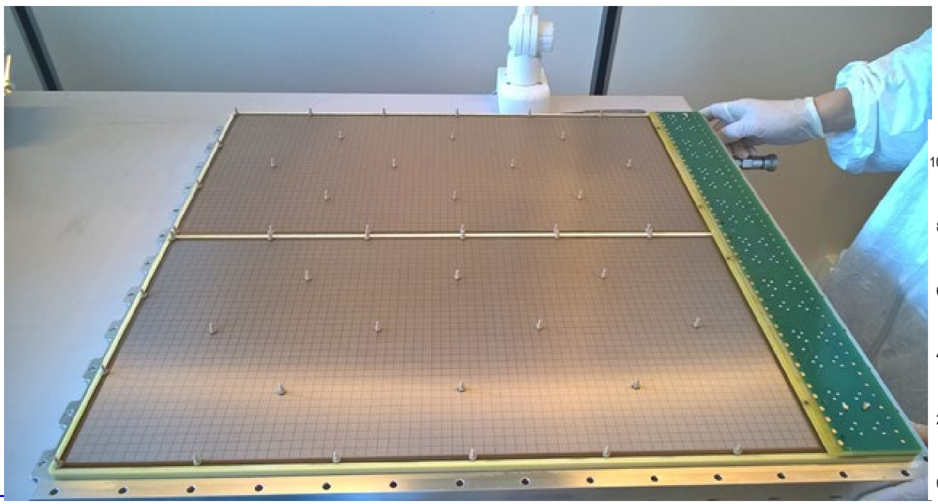


Hybrid MPGD-based PDs

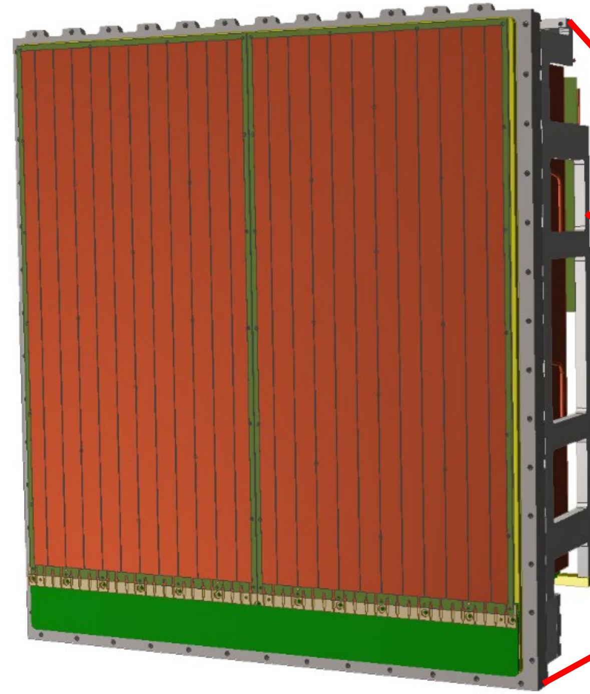
Hybrid PD scheme

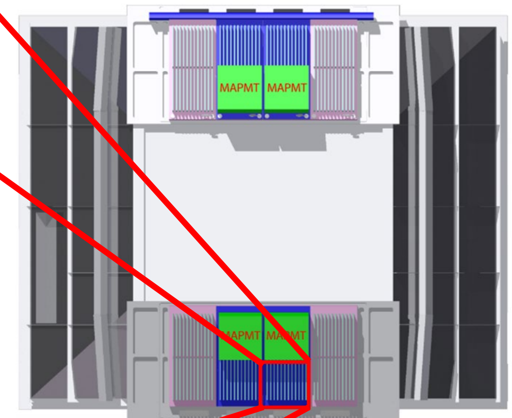


Standard Bulk Micromegas produced at CERN

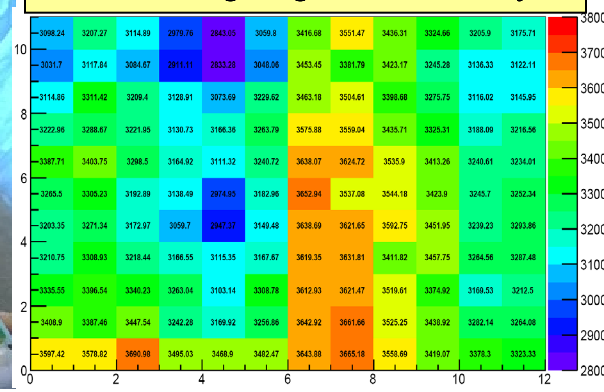


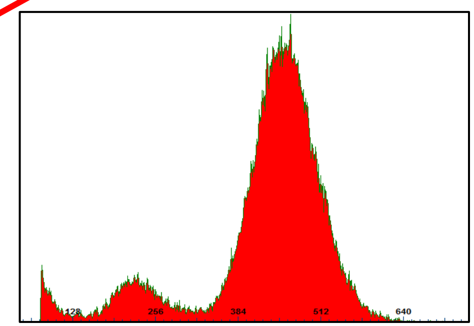
modular structure: one module = 600x300 mm^2





Micromegas gain uniformity

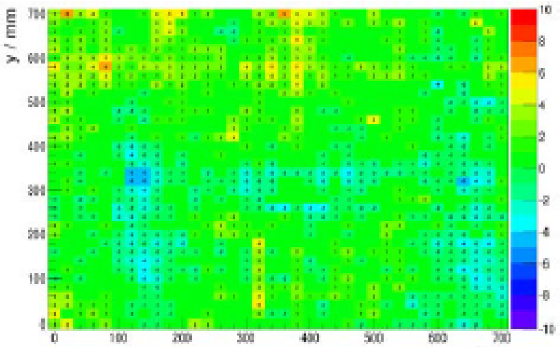




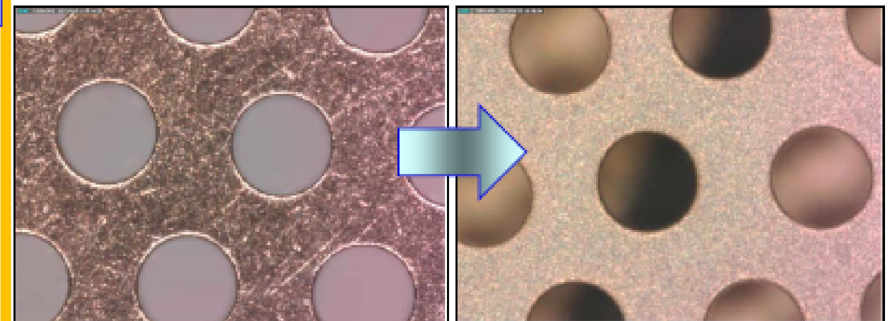
$$\delta_G = \frac{G_{max} - G_{min}}{G_{min}} < 5\ \%$$

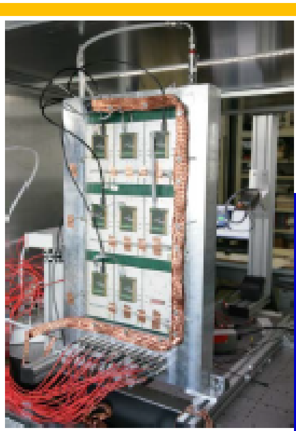
COMPASS THGEMs

Measurement of the raw material thickness before the THGEM Production, accepted:
± 15 μm ↔ gain uniformity σ < 7%

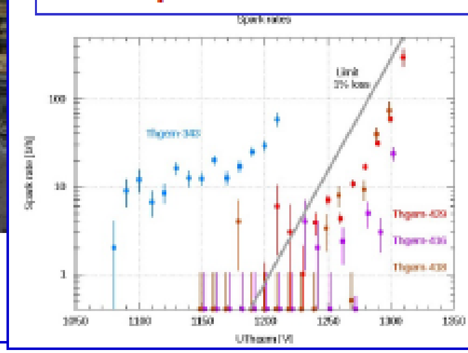


THGEM polishing with an "ad hoc" protocol setup by us:
>90% break-down limit obtained

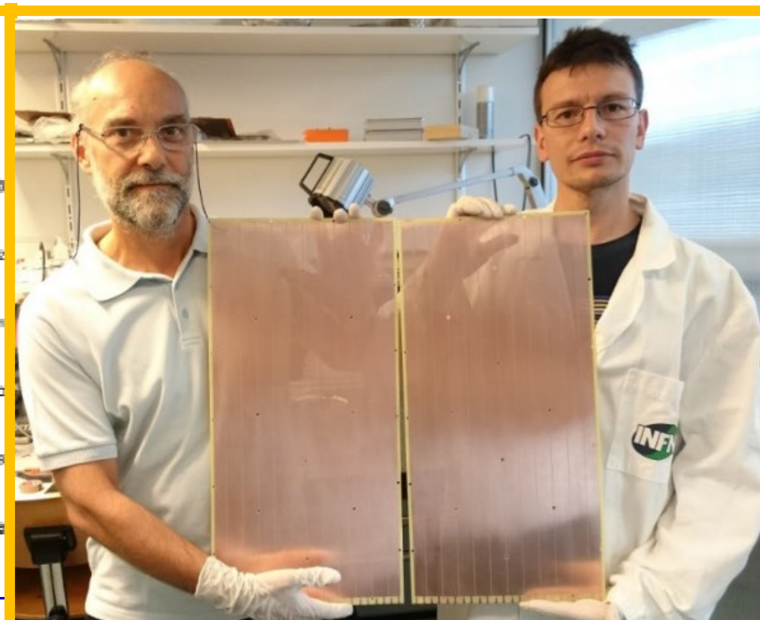




X-ray THGEM test to access gain uniformity (<7%) and spark behaviour

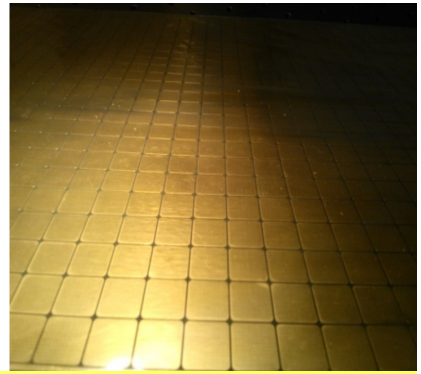


88	202	185	198	206	207
96	207	196	198	199	207
92		193	198	204	204
92		188	199	202	205
99	199	191	195	195	
99	196	199	205	195	199
92	190	194	197	195	194
98	190	195	209	195	199
98	199	195	208	197	201
98	199	195	199	200	199
90	186	185	199	190	199



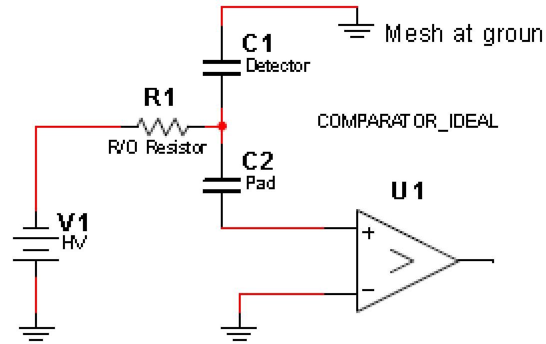
The anodic pcb

anodic pad PCB produced by TVR



8mm X 8mm pads at positive HV

Signal read out via capacitive coupling pad readout and APV25 F/E boards

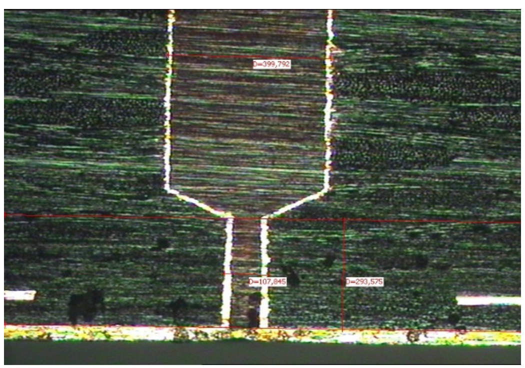


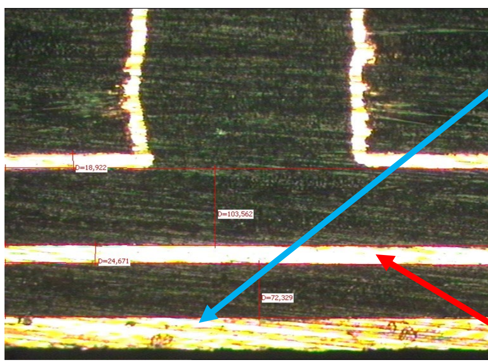
Strong technological effort for the PCB (multilayer 3.2 mm thick) to comply with specific requirements of planarity, surface quality, layer thickness uniformity, surface irregularities.

Tests on 2500 pads: electrical continuity and capacity meas. → 38-42 pF/pad

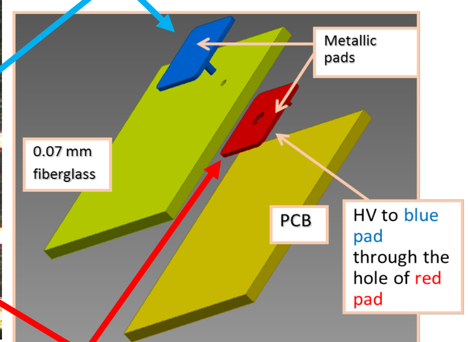
470 MΩ resistor for each anodic pad

"Z drilling controlled via" → planarity issue

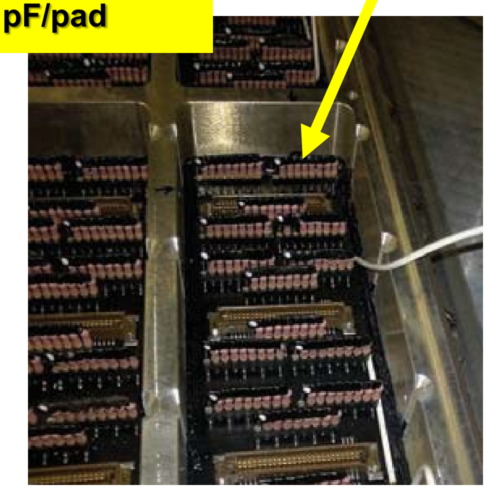




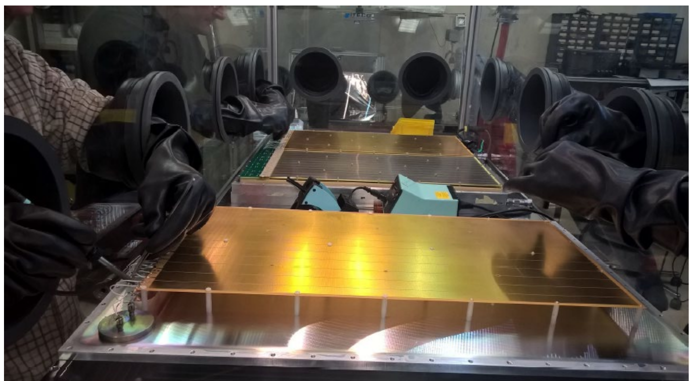
"surface anode" pad

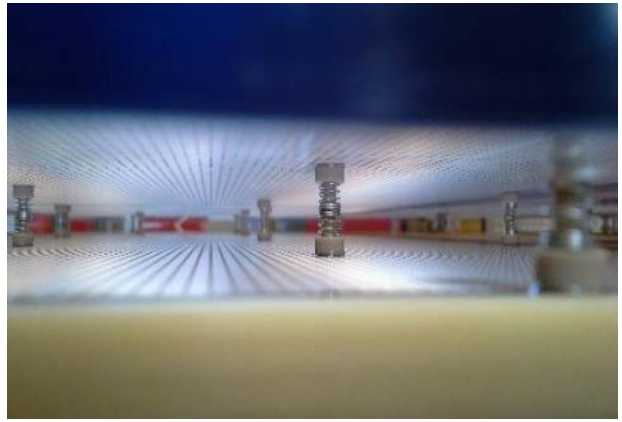
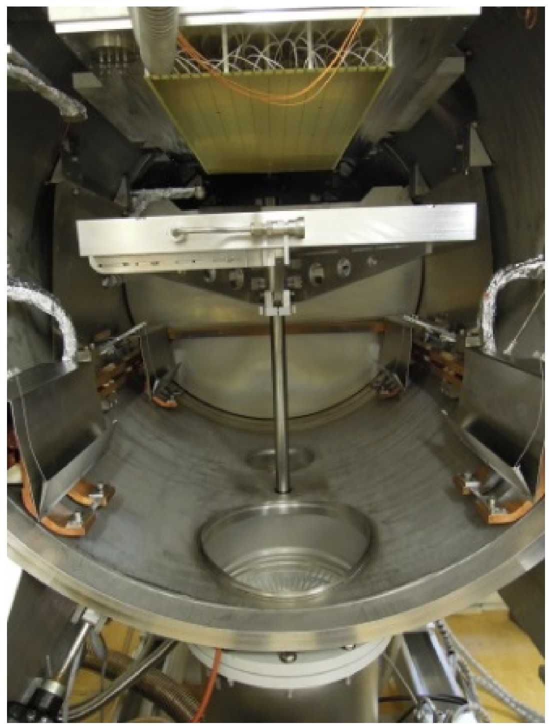
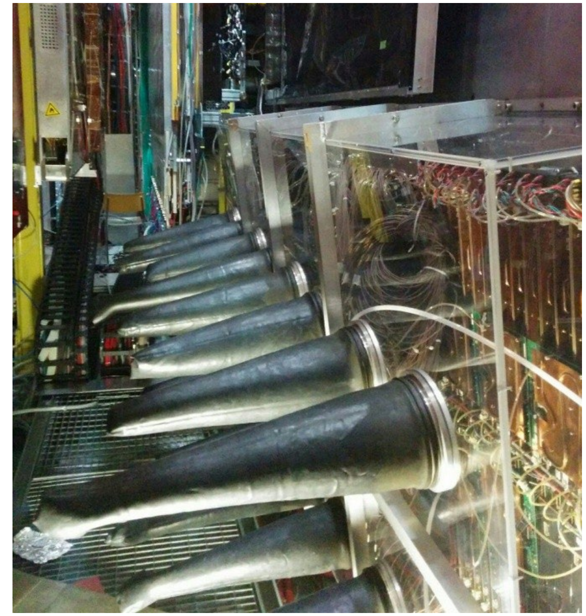
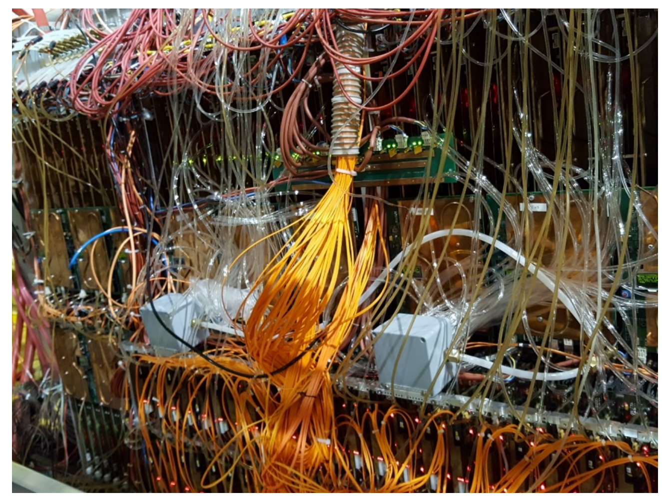


"buried pad"

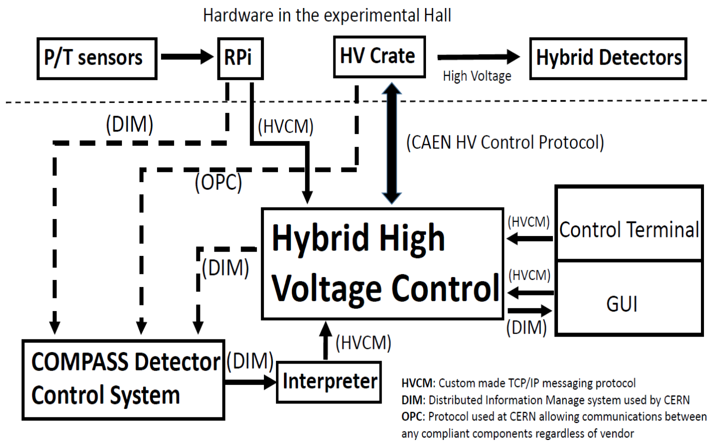


Assembling and installation

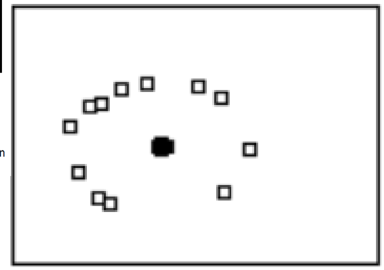





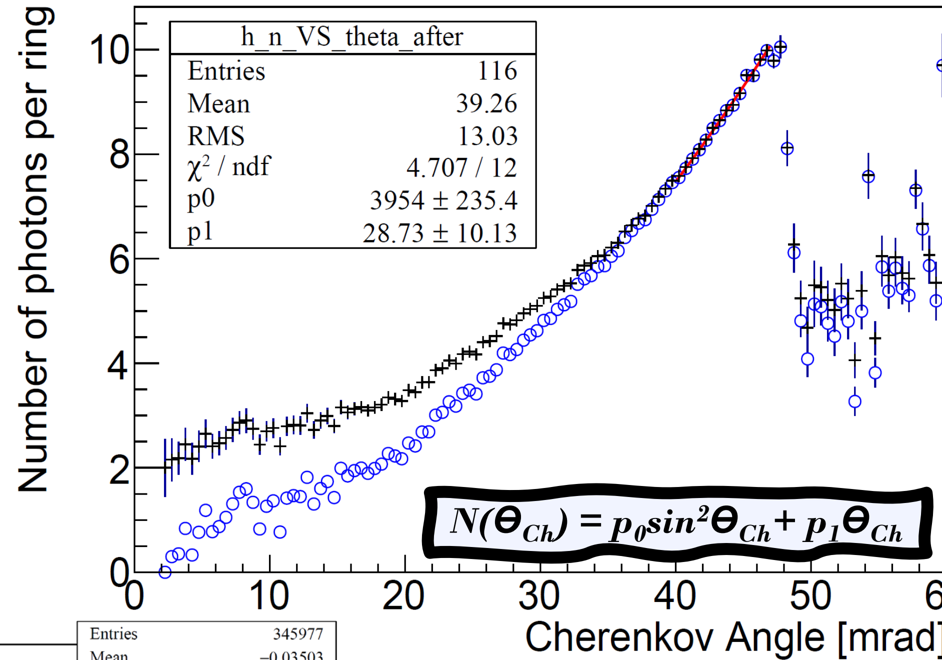
COMPASS Hybrid PDs performance

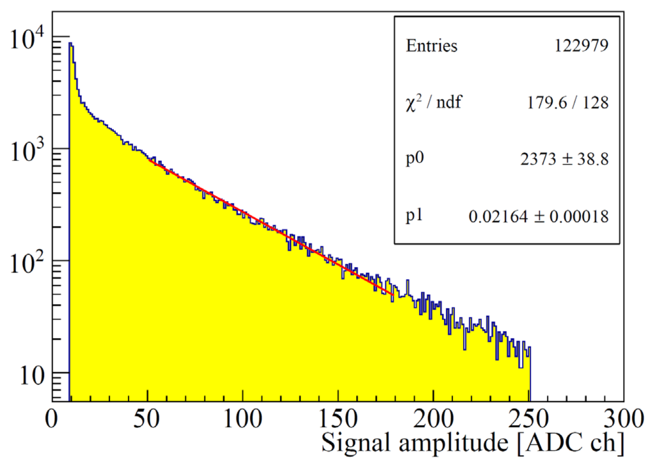


Effecting gain stability: 5%

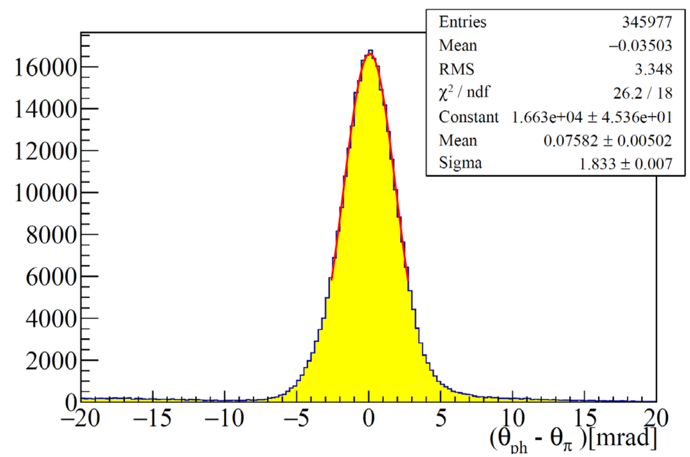
6.36 GeV pion







Effective gain : ~14000 +- 140



Single photon resolution: 1.83 +- 0.01 mrad

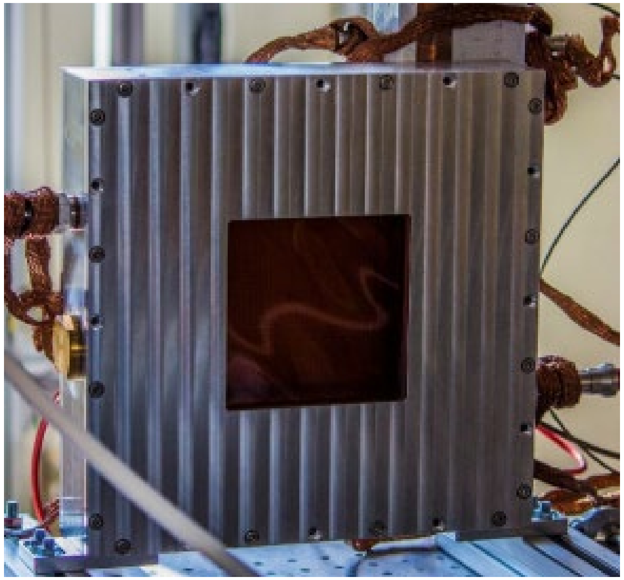
At saturation, N_{ph} = 12.9
Signal = 11.5 +/- 0.4
Background = 1.4 +/- 0.3

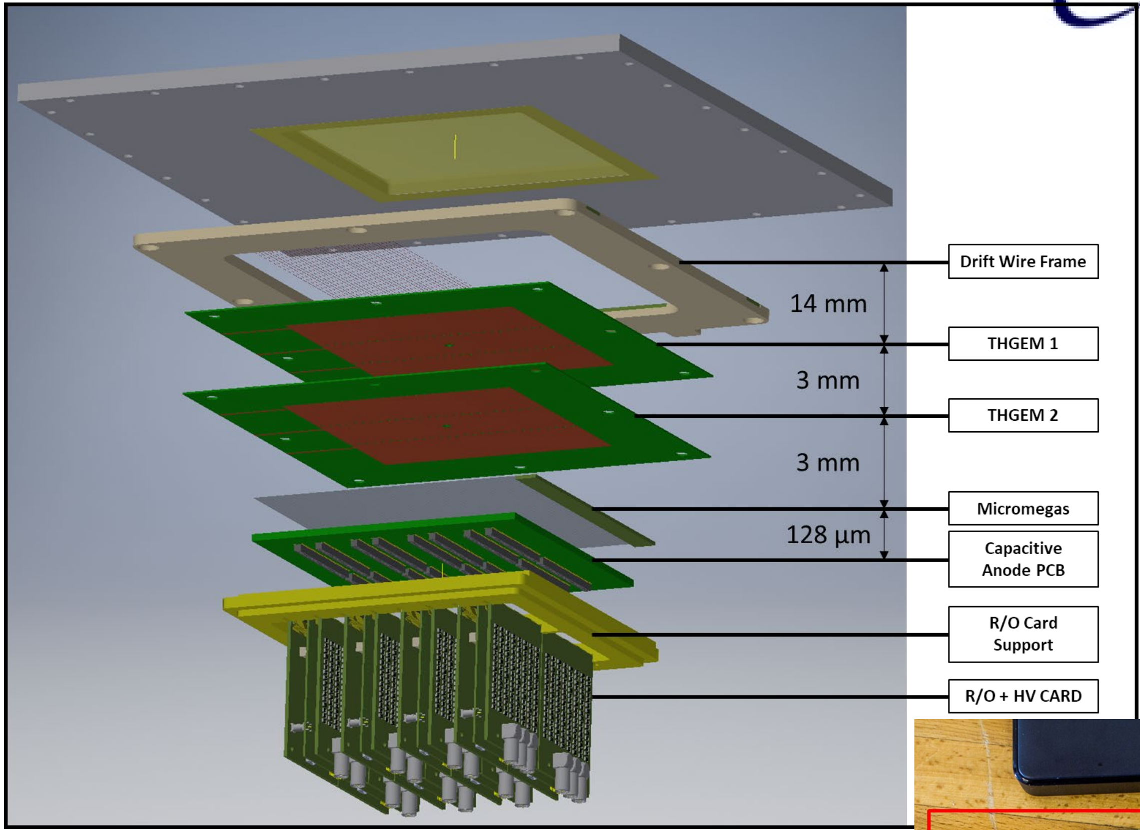
The modular minipad protoype

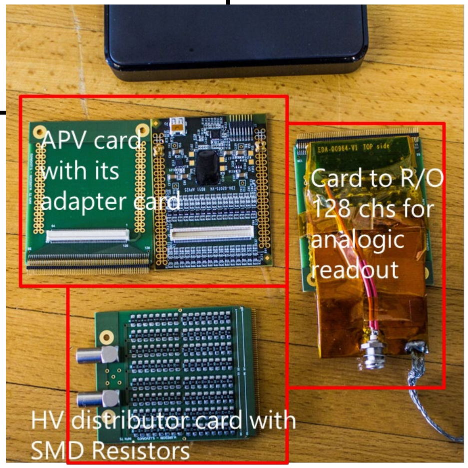
Modular structure: all components and services within the active area.

Prototype with 10x10 cm^2 active area.

1024 square pads of 3x3 mm^2 with 0.5 mm inter-pad space

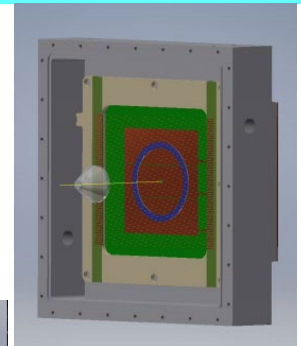
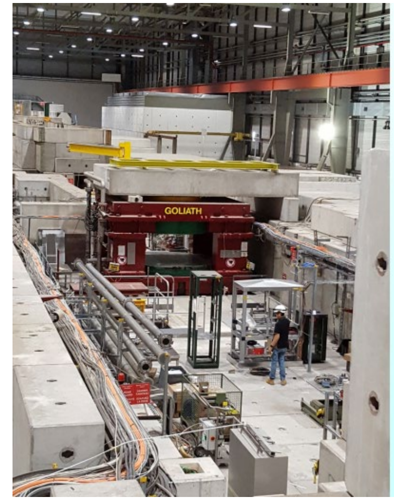


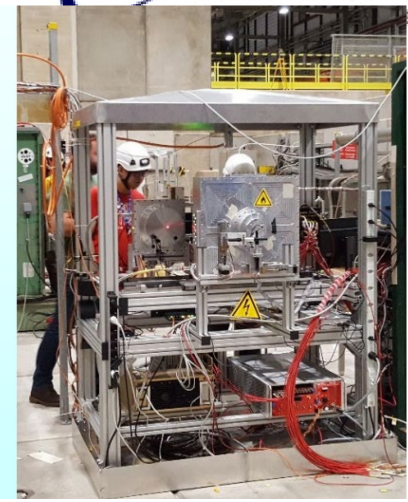
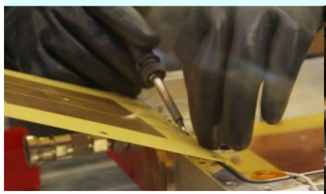
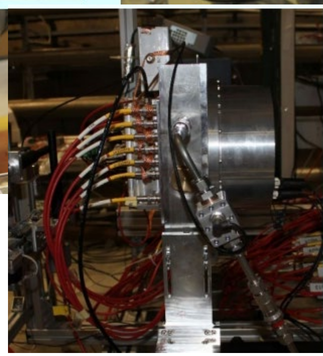
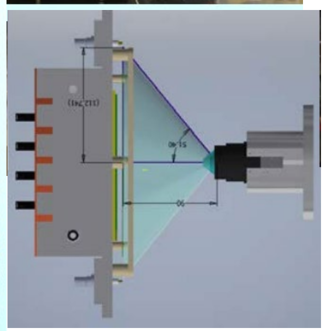




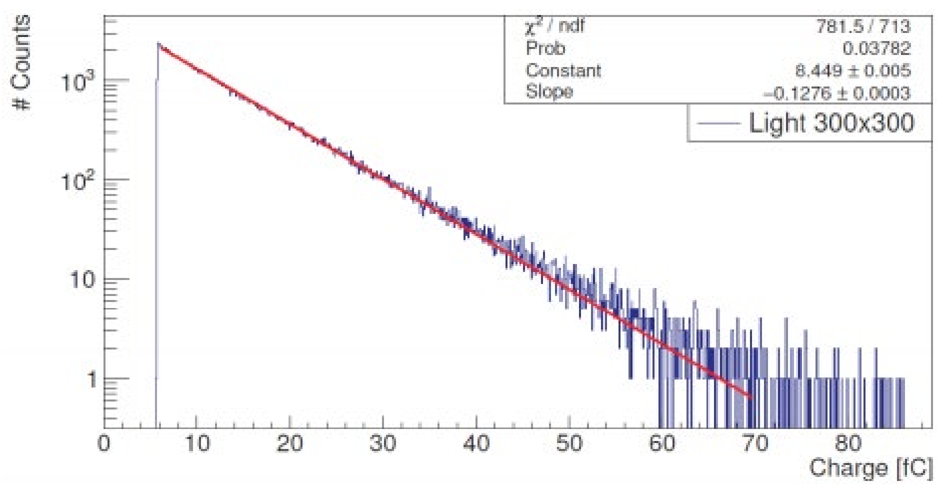
The minipad prototype tests

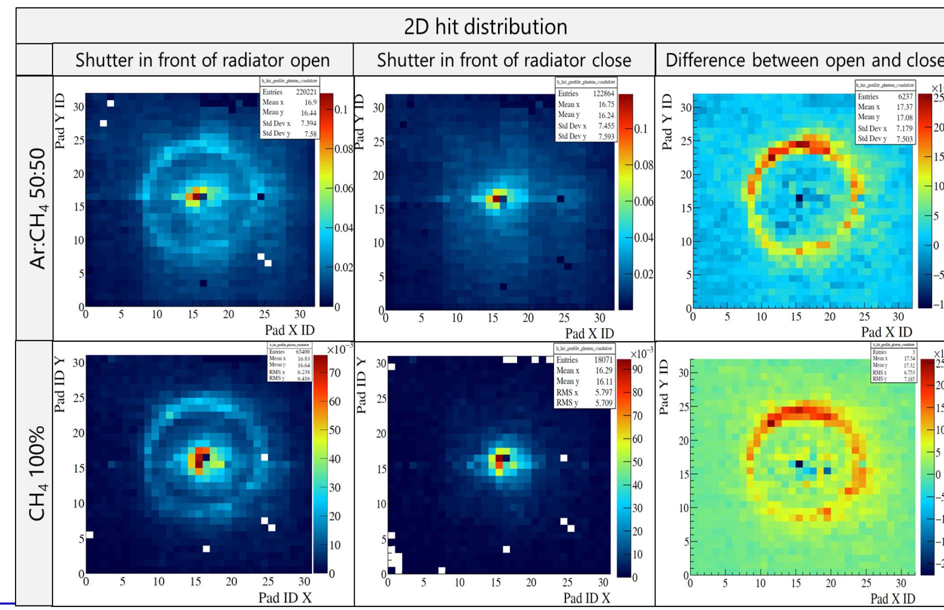


Ar:CH_4 50:50 Picoquant PLD 4000B pulsed UV laser source





A NEW PHOTOCONVERTER: Rich-graphite Nano-Diamond film

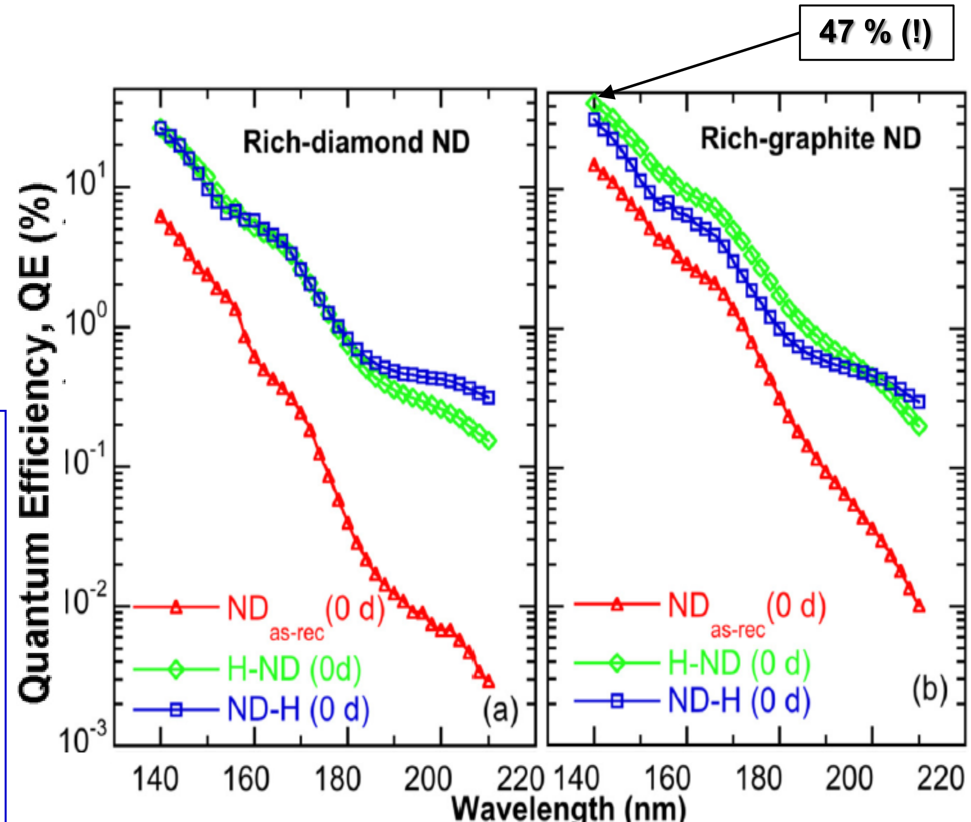
CsI bandgap: 6.2 eV; electron affinity: 0.1 eV; hygroscopic; ages by ion bombardment (~mC/cm^2)

Diamond bandgap: 5.5 eV; chemically inert and robust; if hydrogenated: electron affinity -1.27 eV

Hydrogenated chemical vapor deposited diamond films (4-6 µm) known to have QE ~15% @ 140 nm.

Heterogranular-structured diamond-gold nanohybrids proposed as stable field emission cathode material

Nano-Diamond grains (size: ~250 nm), with variable sp^2 (graphite phase) and sp^3 (diamond phase) hybridized carbon contents treated in H2 microwave plasma show large QE: ~50% @ 140 nm



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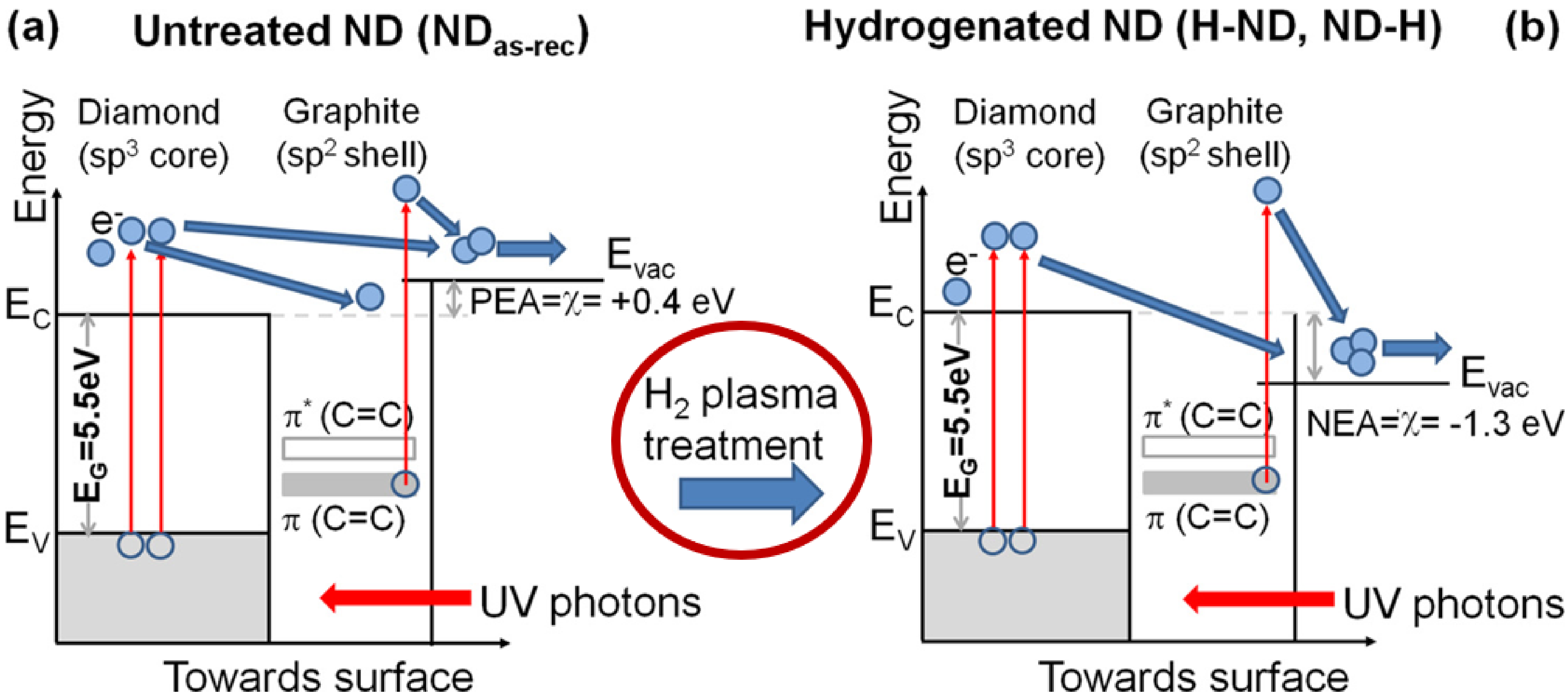
NEW !!!

Photocatodes: diamond film obtained with Spray Technique

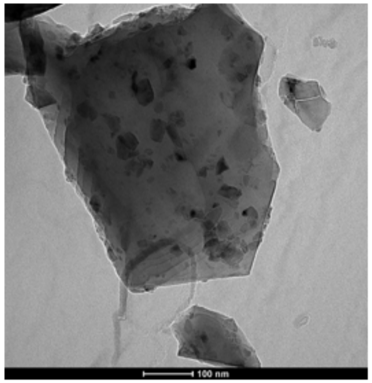
Spray technique: T ~ 120° (instead of ~800° as in standard techniques)

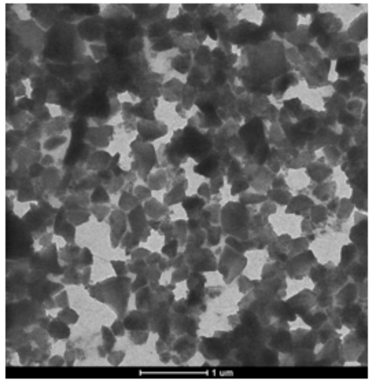
PHOTOEMISSION MODEL

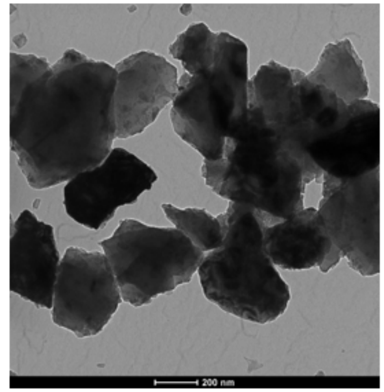


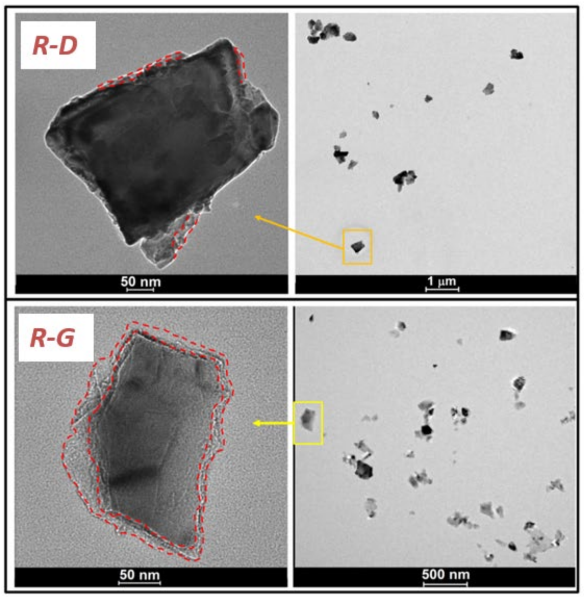
Schematic representation of the process of photoemission components **sp^3** e **sp^2** for **PEA** (a) and for **NEA** (b)

TEM IMAGES









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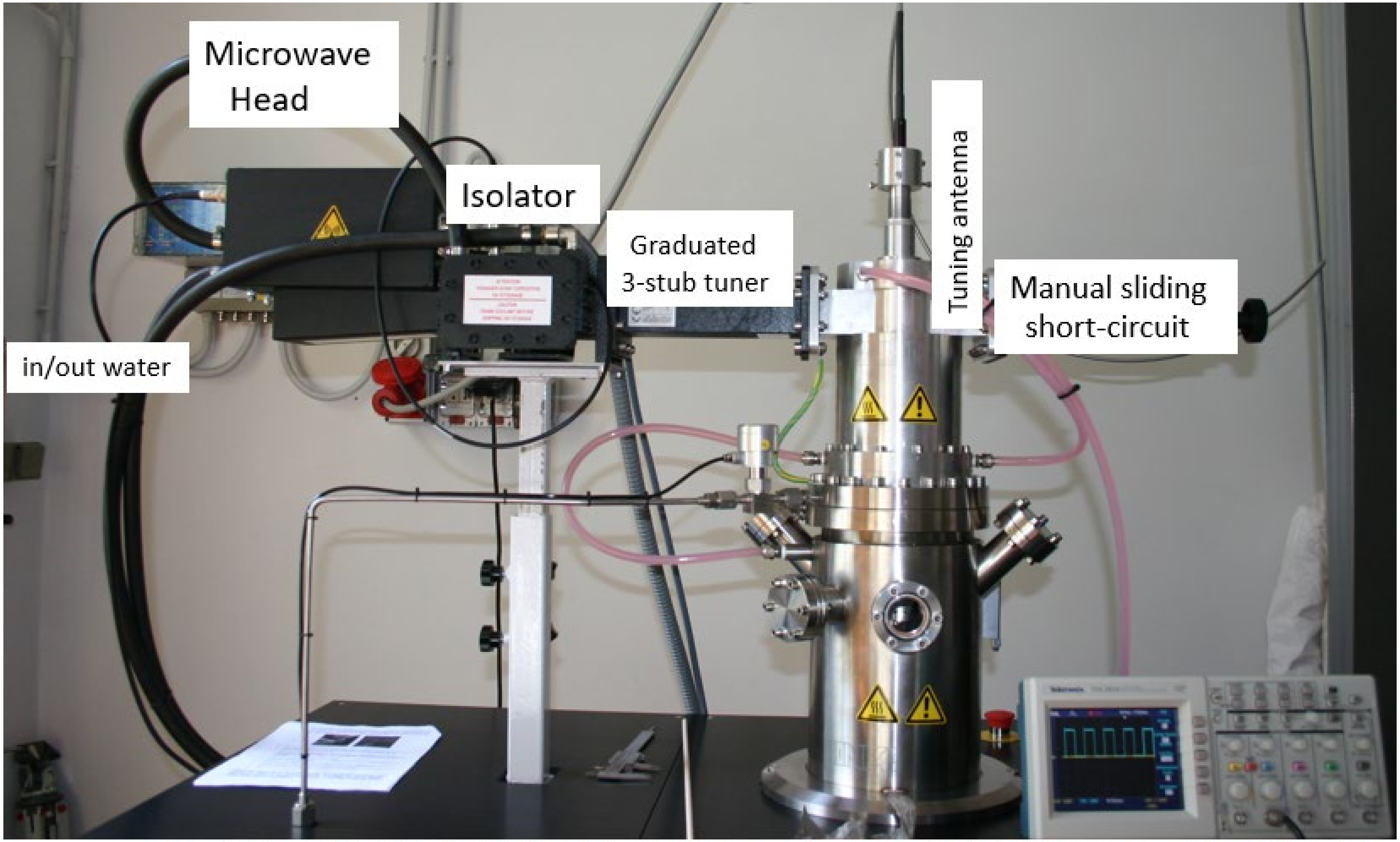
In **hatred** highlighted the ***sp²*** component present at ***the Grain Boundaries***

Properties	**Diamond**	**CsI**
Density (g/cm³)	3.51	4.51
E_G (eV)	**5.5**	6.2
Electron Affinity χ (eV)	**<1 eV (or negative)**	0.1
Resistivity (Ω cm)	**10^8-10^{12} !?**	10^{10}-10^{11}
Optical transparency	From UV to far IR	From UV to far IR

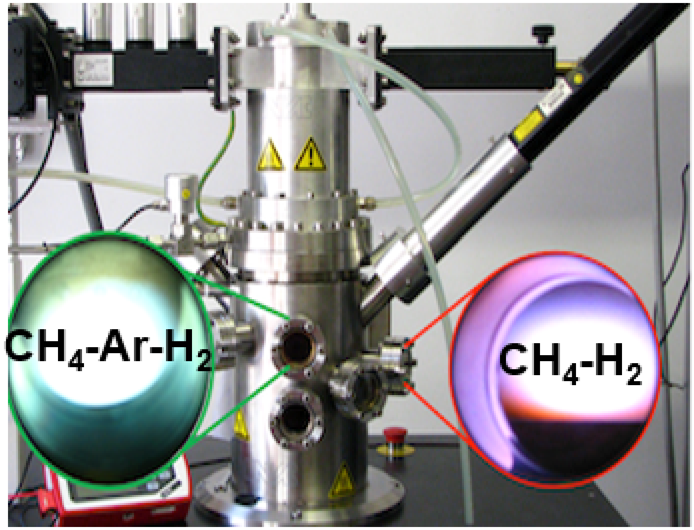
Hydrogenation setup



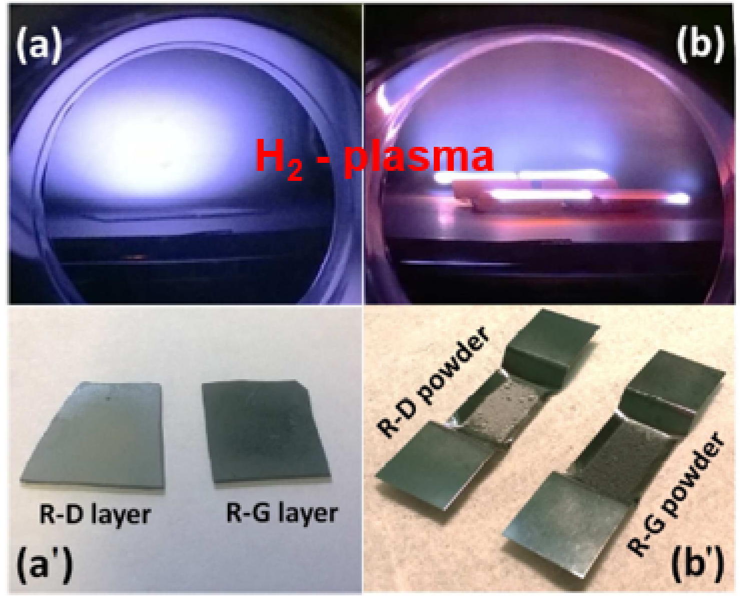
MWPECVD APPARATUS at lab of (CNR-ISTP BARI)

Hydrogenation setup

CH_4-H_2 and CH_4-Ar-H_2 plasmas for deposition of PCD and NCD films, and H_2 plasma for treatment of sprayed ND layer and ND particles



CNR-ISTP *Sezione di Bari*

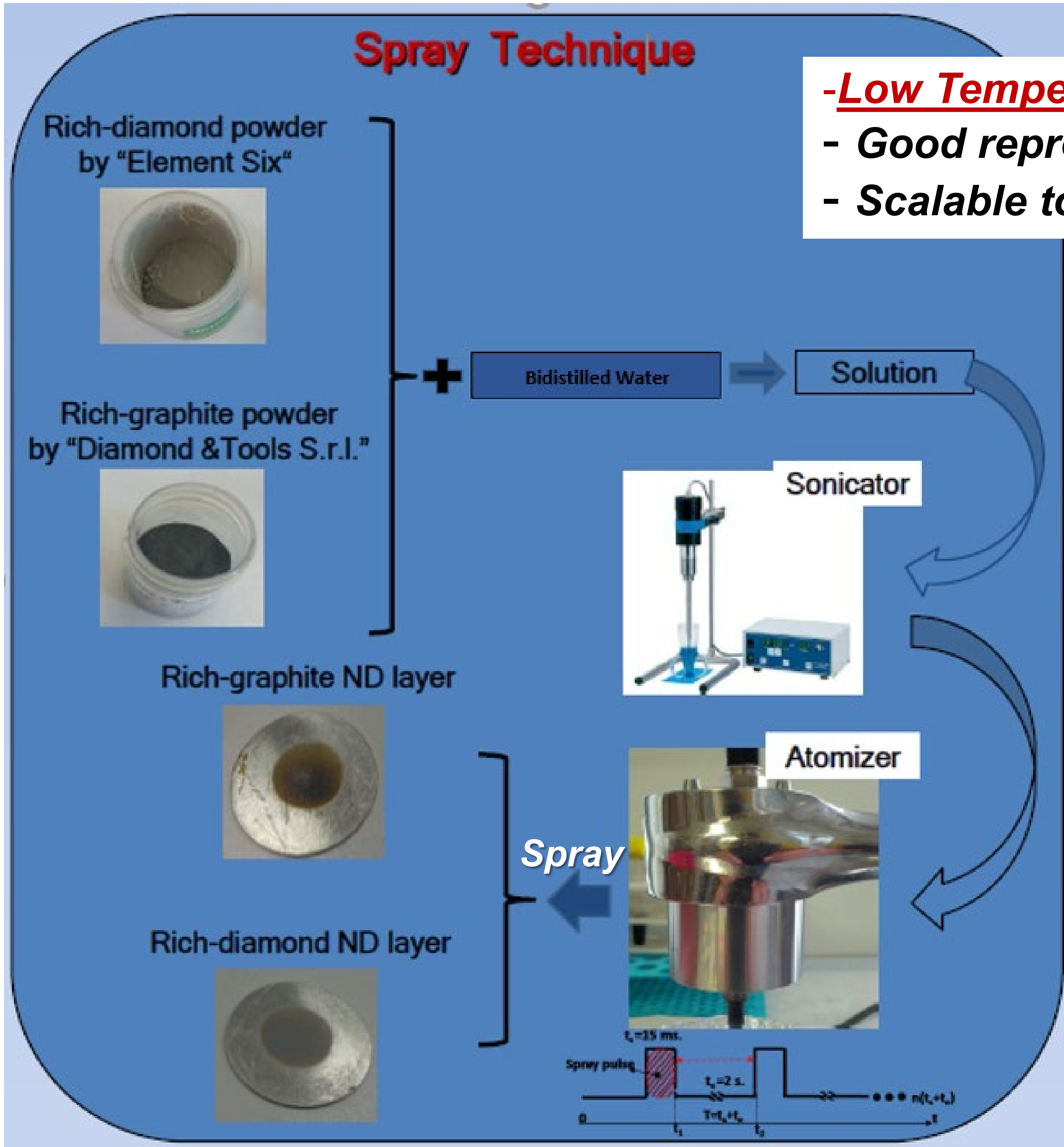


Sprayed ND Layer on Si

ND particles

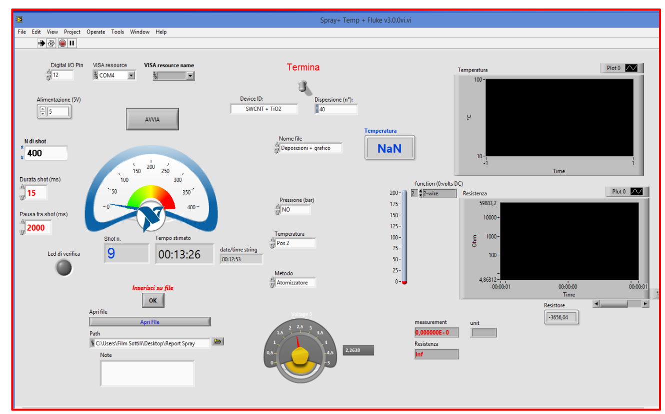
L. Velardi, A. Valentini, G. Cicala Diamond & Related Materials 76 (2017) 1–8

Diamond Layer Deposition

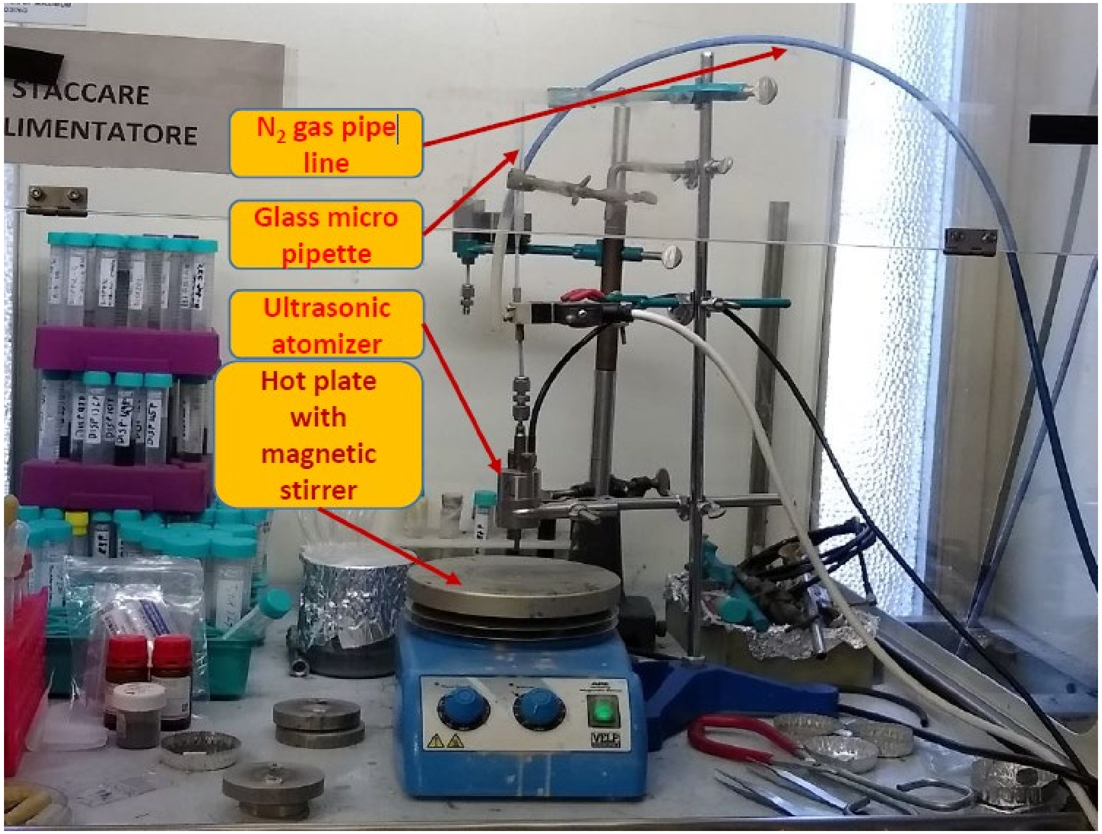


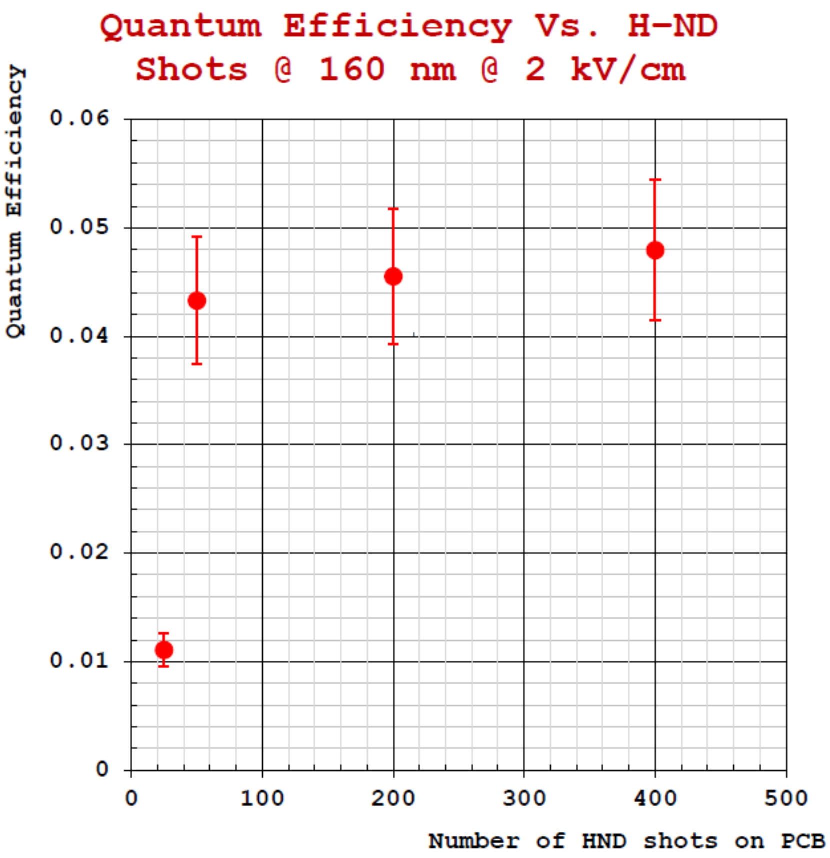
- ***Low Temperature Deposition (≤ 120 °C)***
- ***Good reproducibility technique***
- ***Scalable to cover large areas***

Spray Control Interface



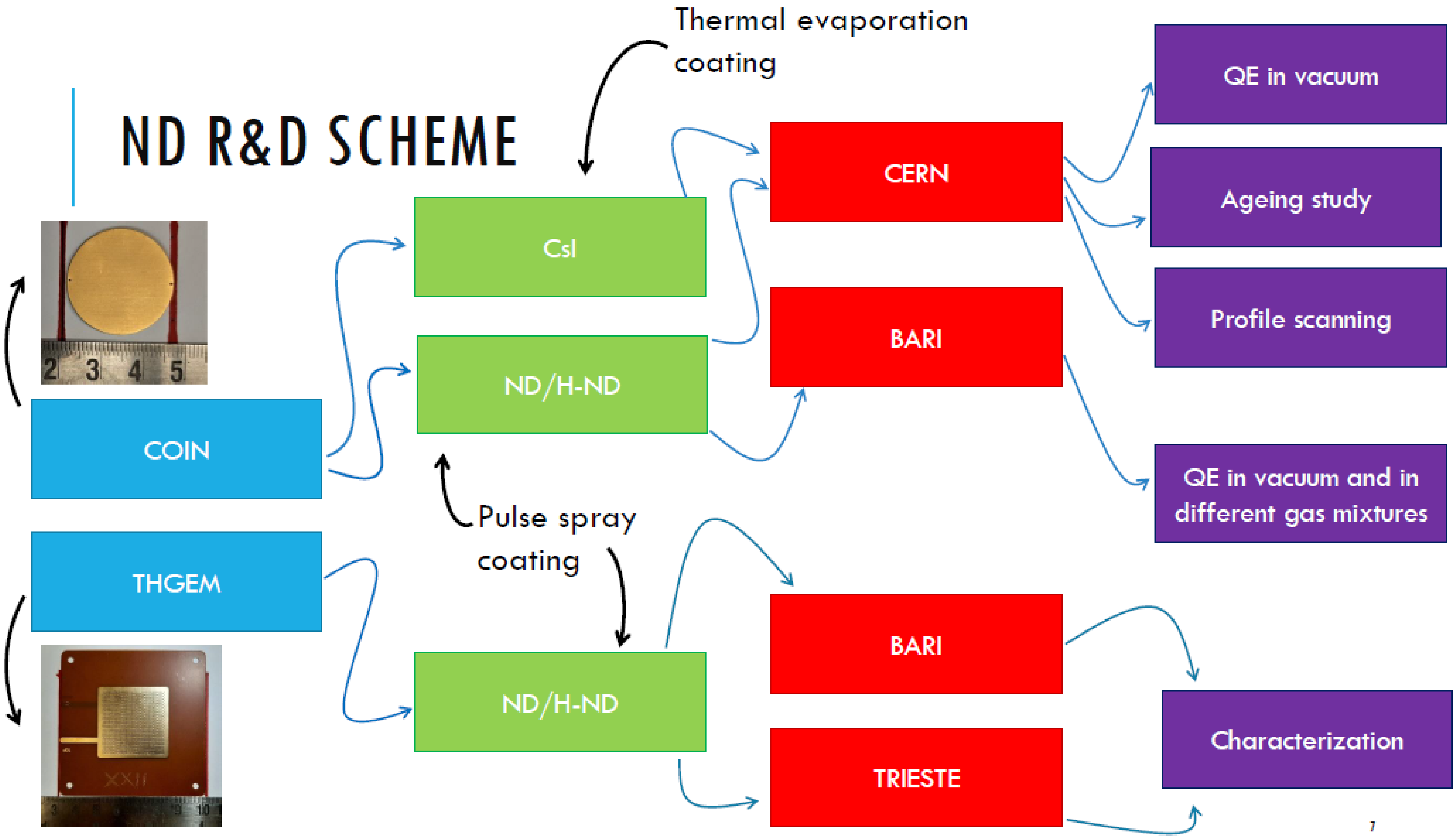
PULSED SPRAY TECHNIQUE





Sufficient surface coverage with "100 shots" thickness

H-ND on PCB and THGEMs



H-ND Q.E. measurement

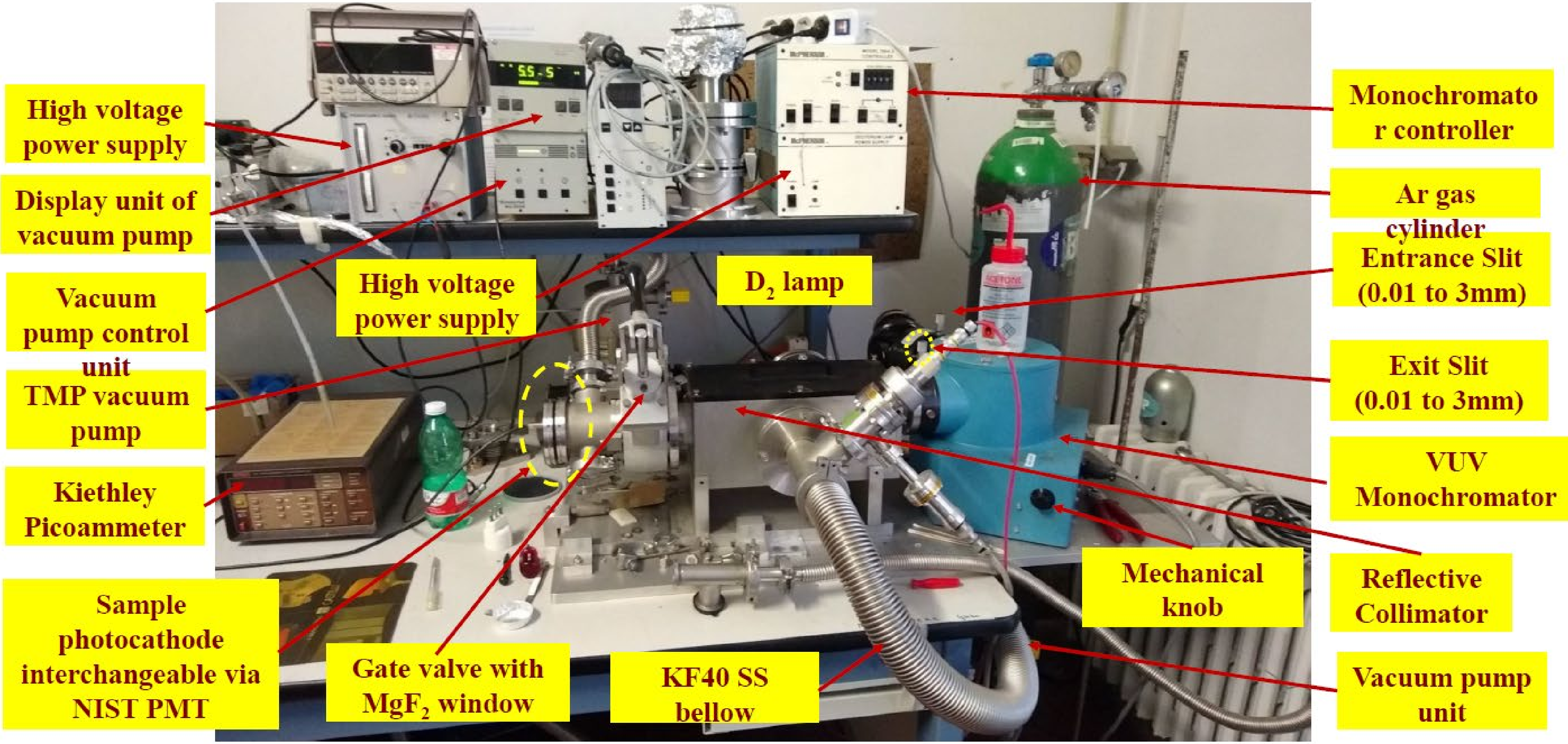
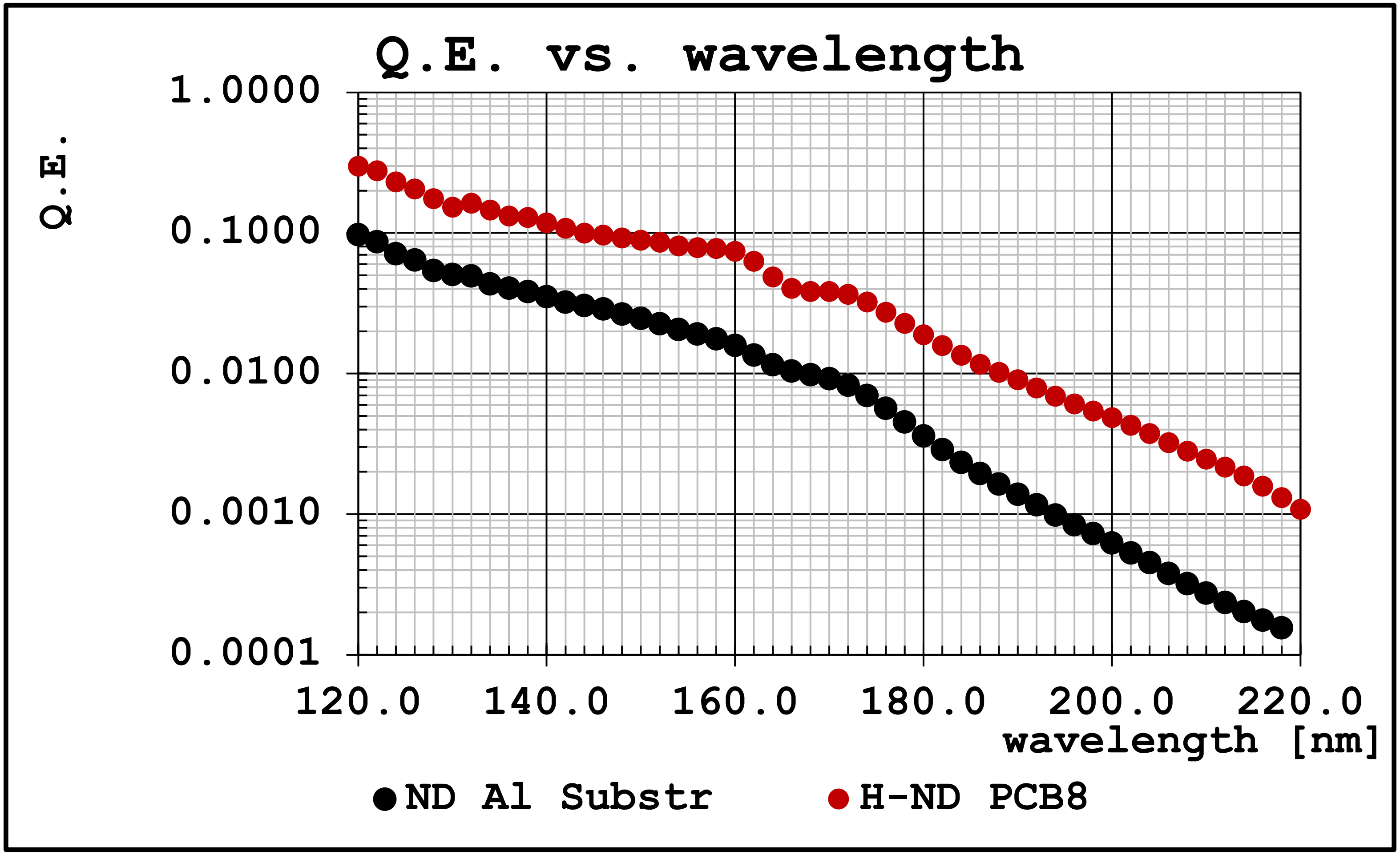


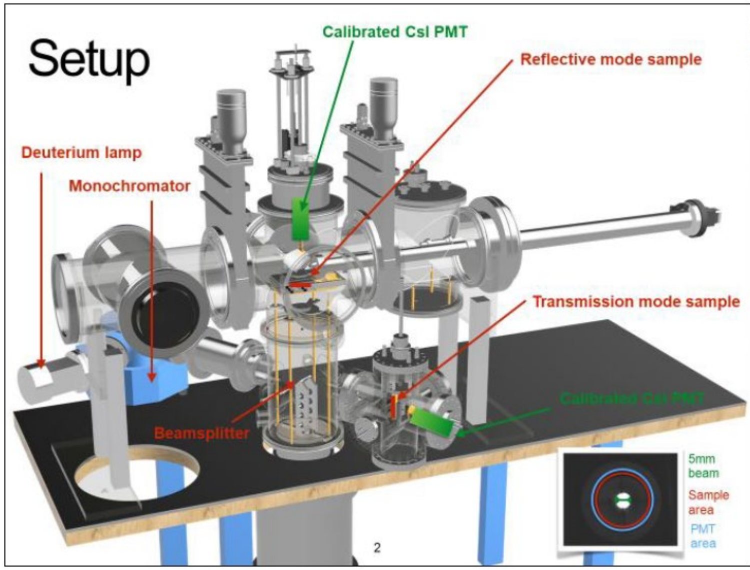
Figure : McPherson VUV monochromator for the photocurrent measurement at INFN Bari, Italy

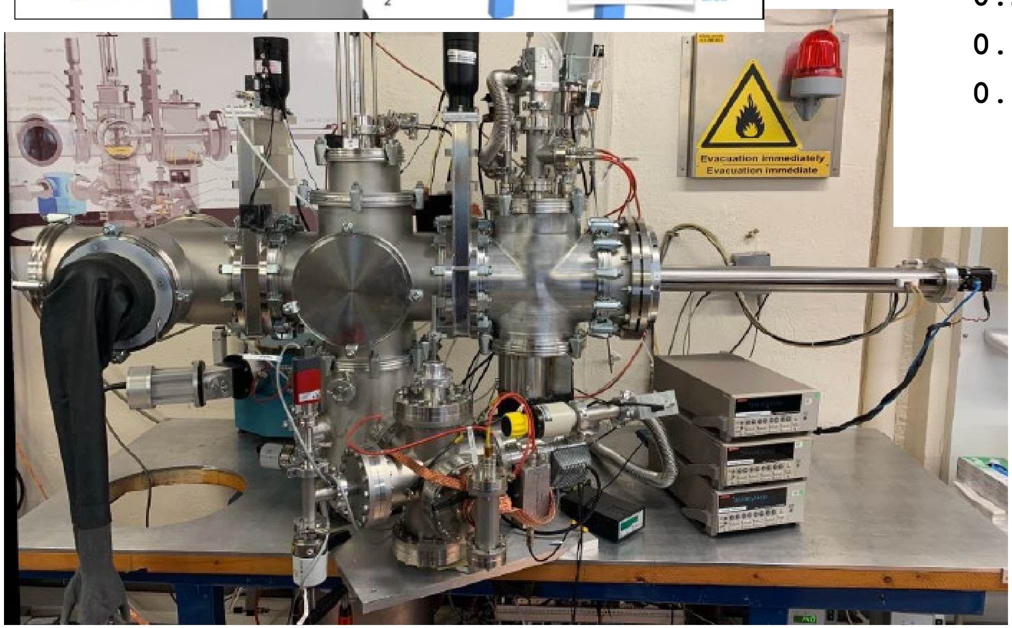
ND and H-ND Quantum Efficiency

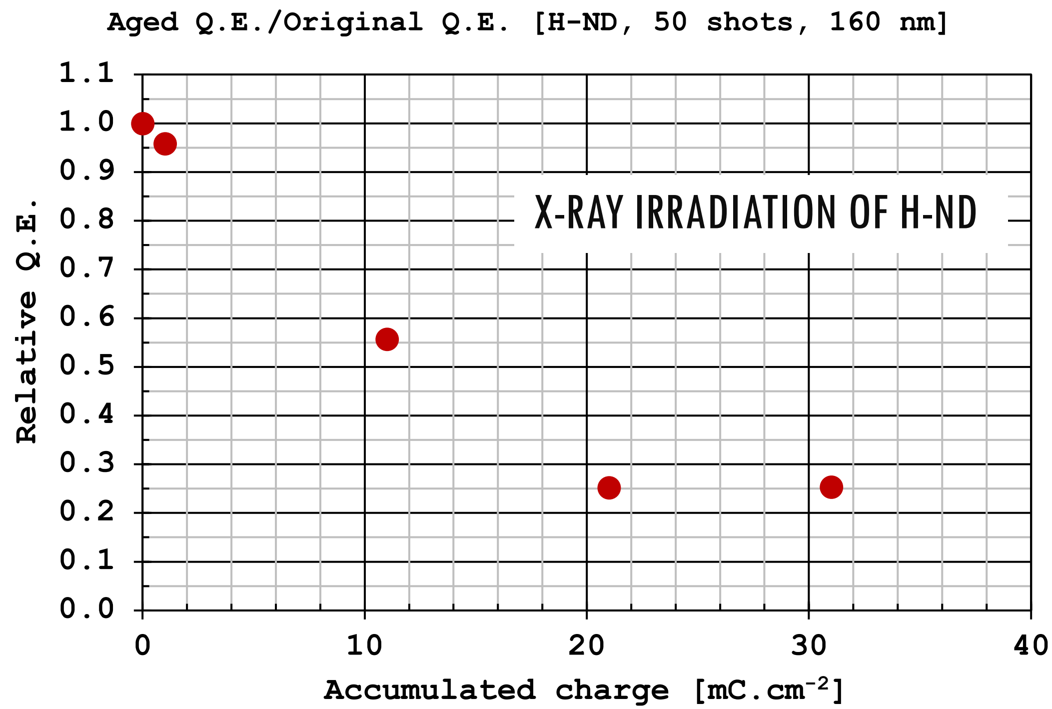


H-ND sprayed on Au-coated PCB (THGEM like) shows promising Q.E. values

Exploratory H-ND aging study



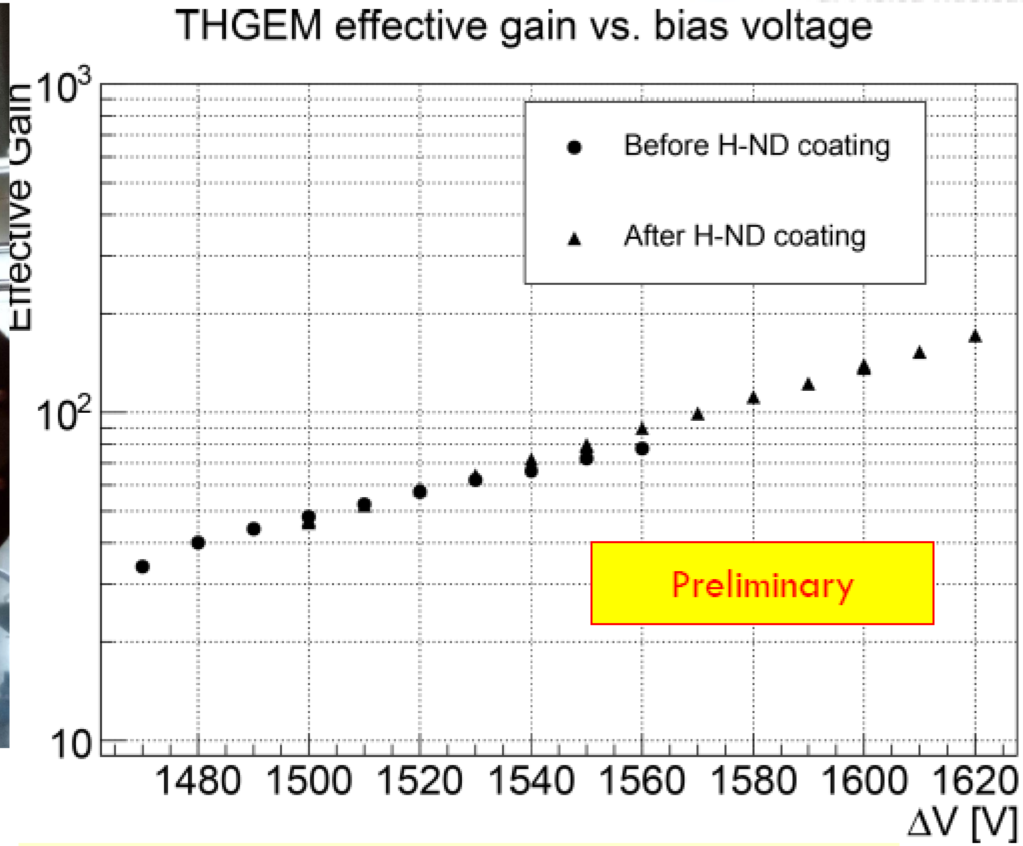




preliminary indication: H-ND at least ten times more robust than CsI

H-ND compatibility with THGEMs

A SET OF SMALL THGEMS PREPARED AND CHARACTERIZED FOR SYSTEMATIC H-ND STUDIES



H-ND coated THGEMS operate nicely as electron multipliers

next step: build and test a full prototype of hybrid THGEM + MM PD with H-ND

CONCLUSIONS

- COMPASS MPGD-BASED PHOTON DETECTORS
  - COMPASS RICH-1 provides outstanding hadron PID
  - MPGD-based hybrid THGEM+MM PDs nicely operating since 2016
- QUEST FOR HIGHER SPACE RESOLUTION
  - Minipad modular prototype with COMPASS hybrid architecture
  - Promising results from lab and test-beam exercises
- Hydrogenated Diamond Nanogranes are a potential alternative to CsI:
  - Competitive QE in the very low wavelength range
  - Coupling to THGEM-based PDs seems feasible
  - A more robust photocathode for future applications