Nanodiamond photocathodes for MPGD based single photon detectors at the future EIC

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On behalf of Trieste, Bari and CERN collaboration

OUTLINE

> motivation of the R&D

> Nano diamond (ND): a novel photocathode

> Setup in Bari: QE measurements

> Setup at CERN: QE measurements and ageing study

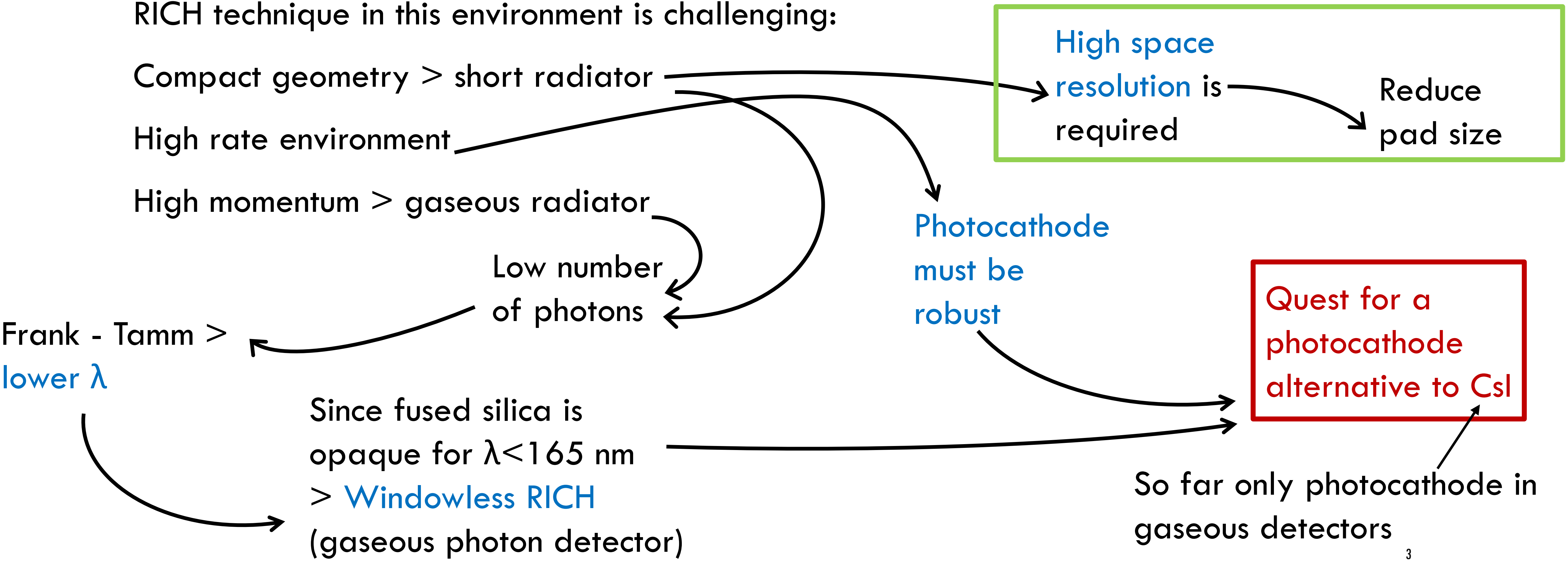
> THGEM characterization

> Conclusion

HADRON IDENTIFICATION AT EIC WITH RICH

Key requirement at EIC > efficient particle identification at high momentum

RICH technique in this environment is challenging:



CHANDRADOY'S PRESENTATION

Compact geometry > short radiator

High rate environment

High momentum > gaseous radiator

High space resolution is required

Reduce pad size

Low number of photons

Photocathode must be robust

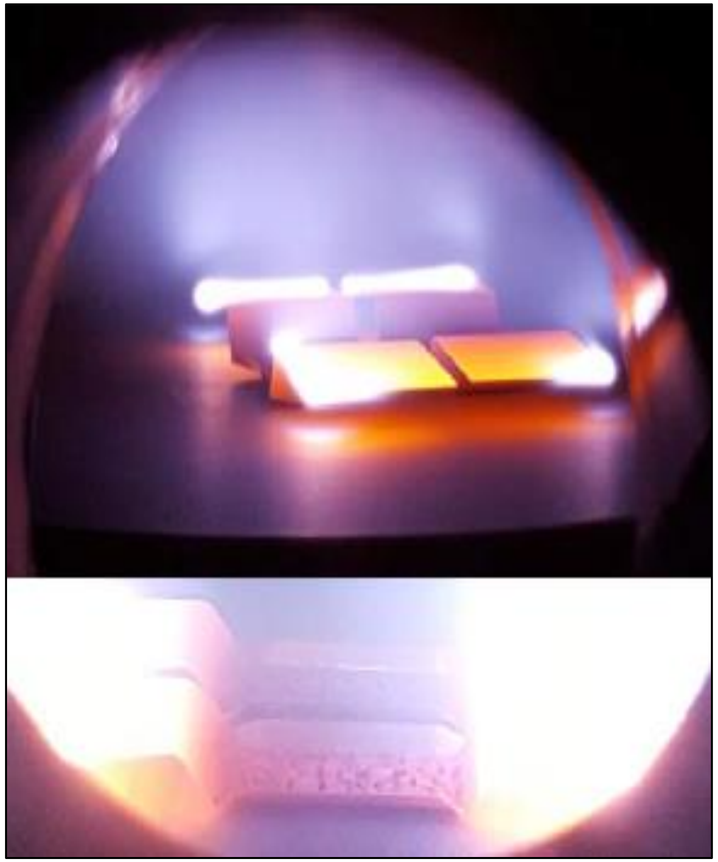
Frank - Tamm > lower λ

Since fused silica is opaque for λ<165 nm > Windowless RICH (gaseous photon detector)

Quest for a photocathode alternative to CsI

So far only photocathode in gaseous detectors

HYDROGENATION AND COATING OF ND



Hydrogenation:

> Hydrogenation lowers electron affinity (hydrogenation of ND powder)

> However, hydrogenation with MWPECVD requires high temperature ($> 800^{o}$C)

Coating:

1) Preparation a solution (1:1) of H-ND powder with distilled water

2) Spraying the solution on the substrate using a pulsed spray technique.

3) No of spray shots determine the coating thickness

VUV SENSITIVE PHOTOCATHODES

CsI

> Low electron affinity > 0.1 eV

> Wide band gap > 6.2 eV

> Typical Quantum Efficiency > 35 – 50% @ 140 nm

> CsI has hygroscopic nature

> Aging > Ion Accumulation > Degradation in QE of PC

Nanodiamond (ND)

> Low electron affinity > 0.35 – 0.5 eV

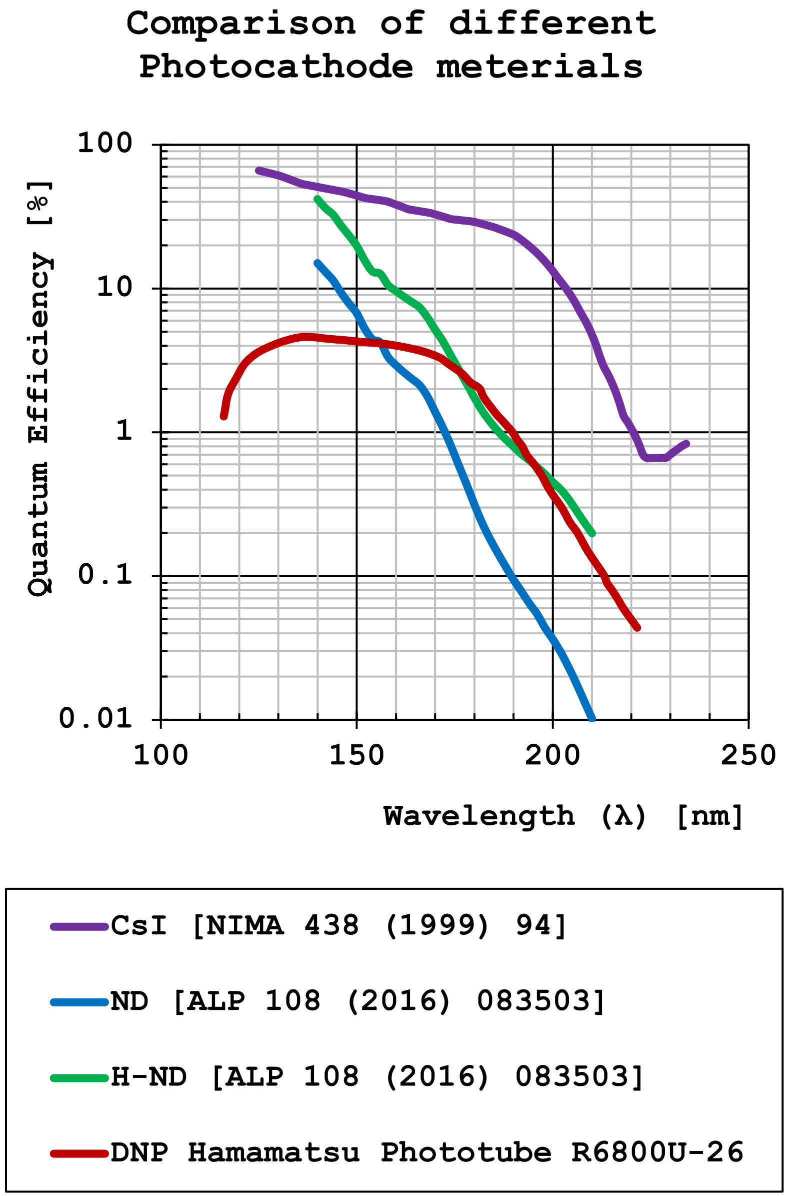
> Wide band gap > 5.5 eV

> Preliminary measured QE > 30 – 40% @ 140 nm for Hydrogenated ND. (We meas 7.7% after one year H-ND in H_2O).

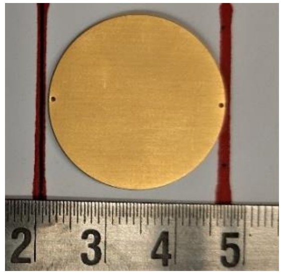
> Chemically inert

> Radiation hard

> Good thermal conductivity



ND R&D SCHEME



COIN

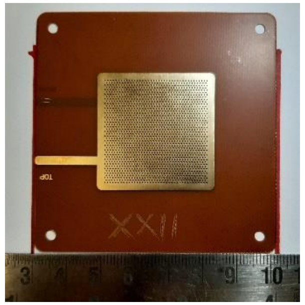
to explore the properties of photoconverters by different powders and different spray procedures

Identification of the best powder

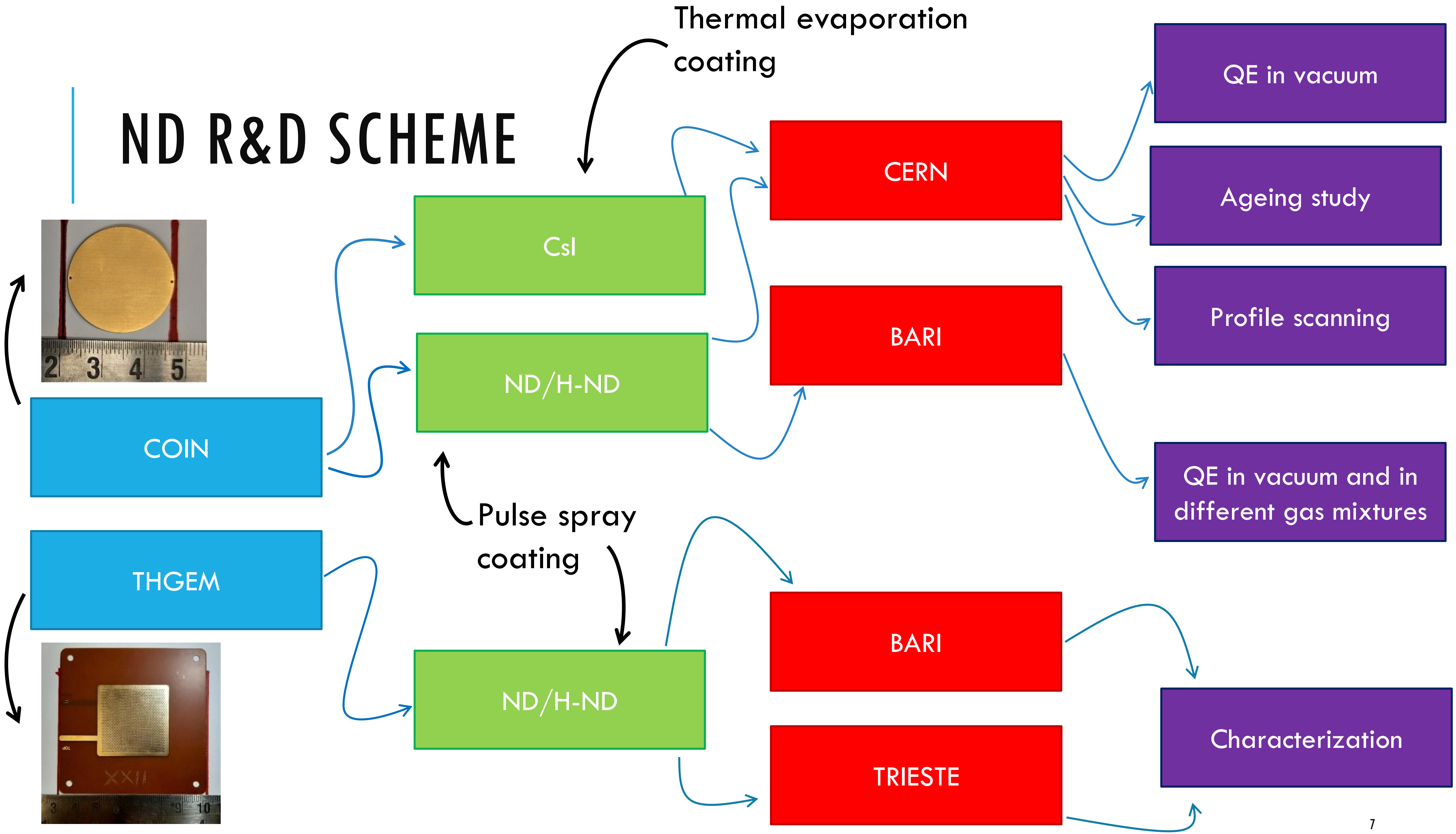
small samples to characterize the photoconverter and its properties

THGEM

to study the compatibility of these photoconverters with the MPGD operation



ND R&D SCHEME



Thermal evaporation coating

Pulse spray coating

COIN

THGEM

CsI

ND/H-ND

ND/H-ND

CERN

BARI

BARI

TRIESTE

QE in vacuum

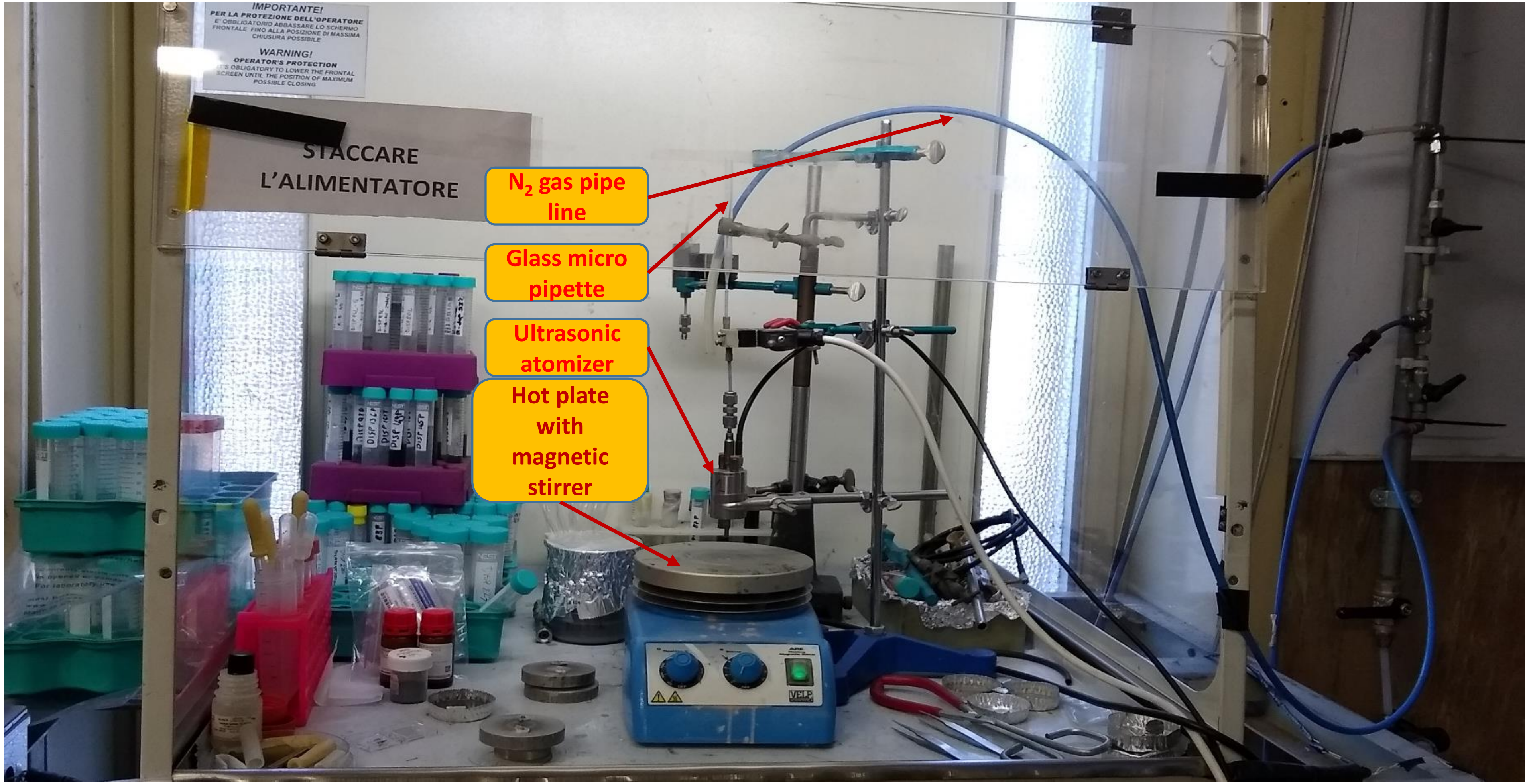
Ageing study

Profile scanning

QE in vacuum and in different gas mixtures

Characterization

Pulsed spray thin film coating setup:
No of Shots determine the coating thickness



N_2 gas pipe line

Glass micro pipette

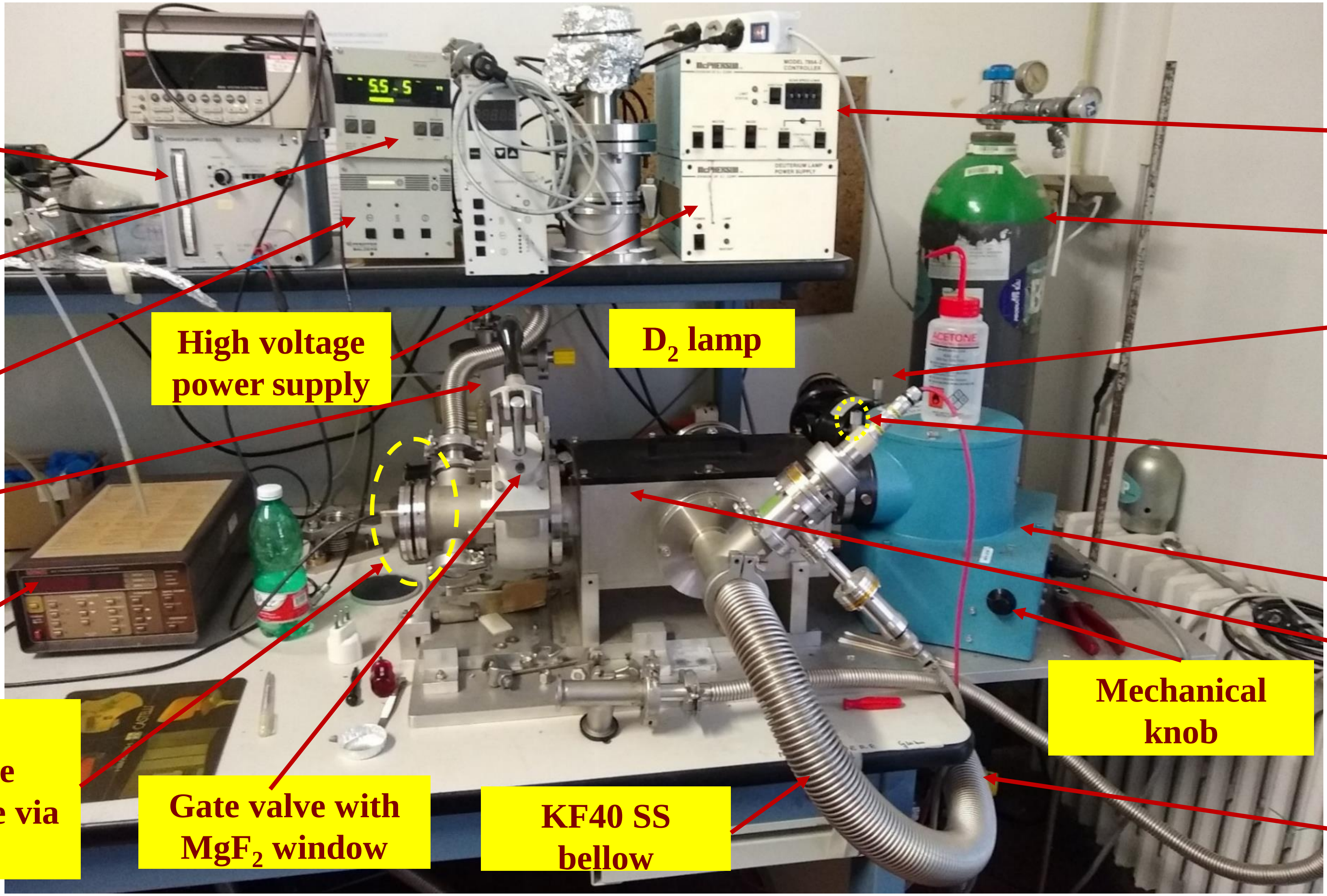
Ultrasonic atomizer

Hot plate with magnetic stirrer

Figure : The pulsed spray technique for thin film coating, equipped with an ultrasonic atomizer and with a heater at INFN Bari, Italy

Courtesy of Triloki (presented in RD51 Mini-week feb 2020)

Pictorial view of photoemission measurement setup:



High voltage power supply

Display unit of vacuum pump

Vacuum pump control unit

TMP vacuum pump

Kiethley Picoammeter

Sample photocathode interchangeable via NIST PMT

High voltage power supply

D_2 lamp

Gate valve with MgF_2 window

KF40 SS bellow

Monochromator controller

Ar gas cylinder

Entrance Slit (0.01 to 3mm)

Exit Slit (0.01 to 3mm)

VUV Monochromator

Mechanical knob

Reflective Collimator

Vacuum pump unit

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

Courtesy of Triloki (presented in RD51 Mini-week feb 2020)

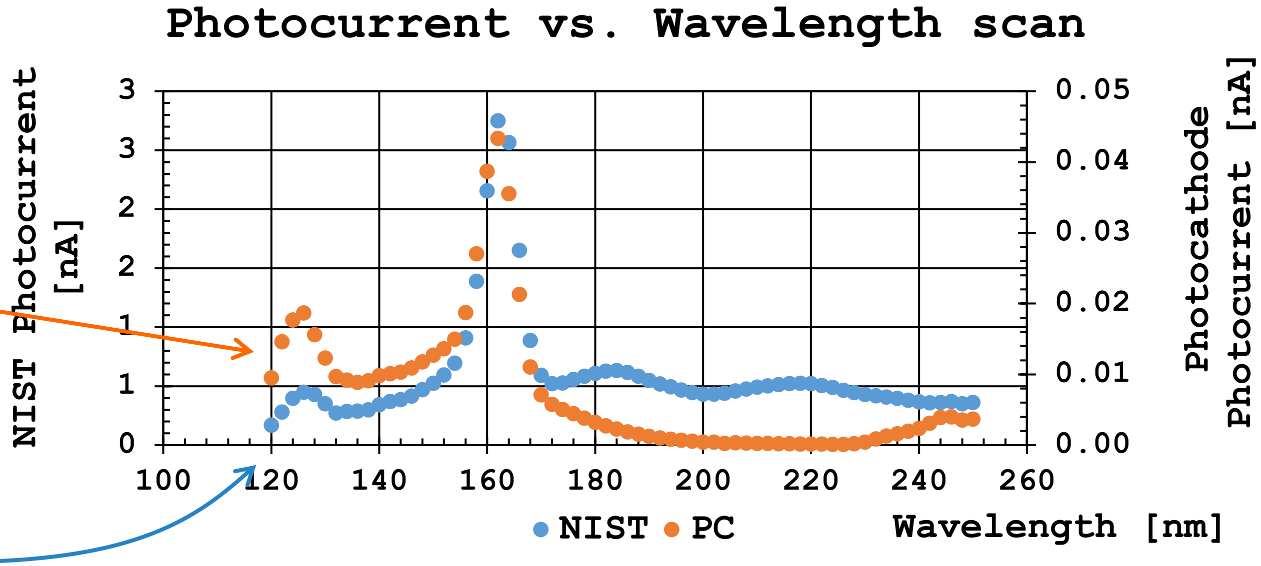
MEASURING QUANTUM EFFICIENCY IN BARI

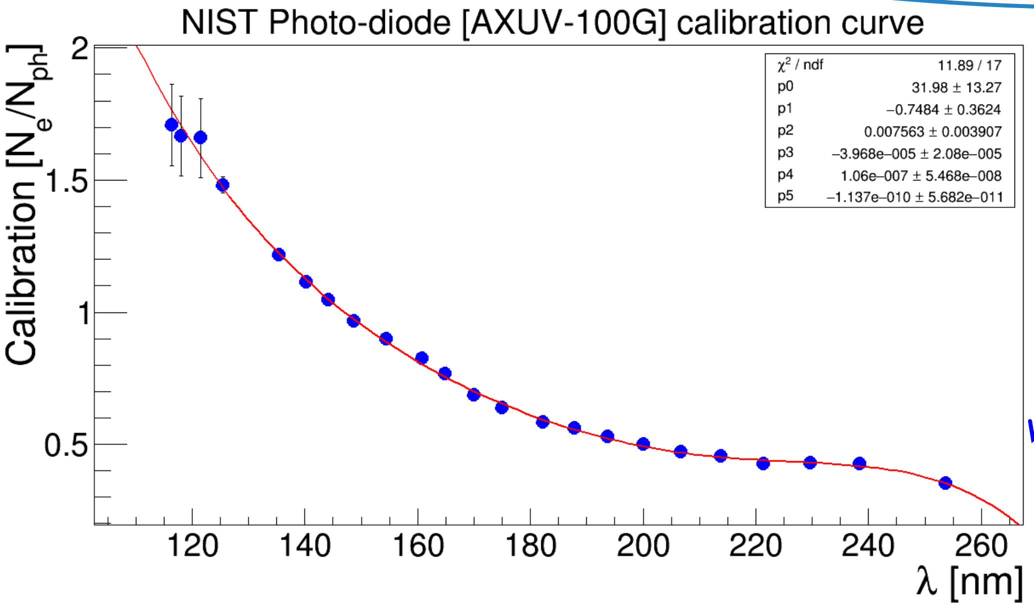
Repeated measurements > results are reproducible

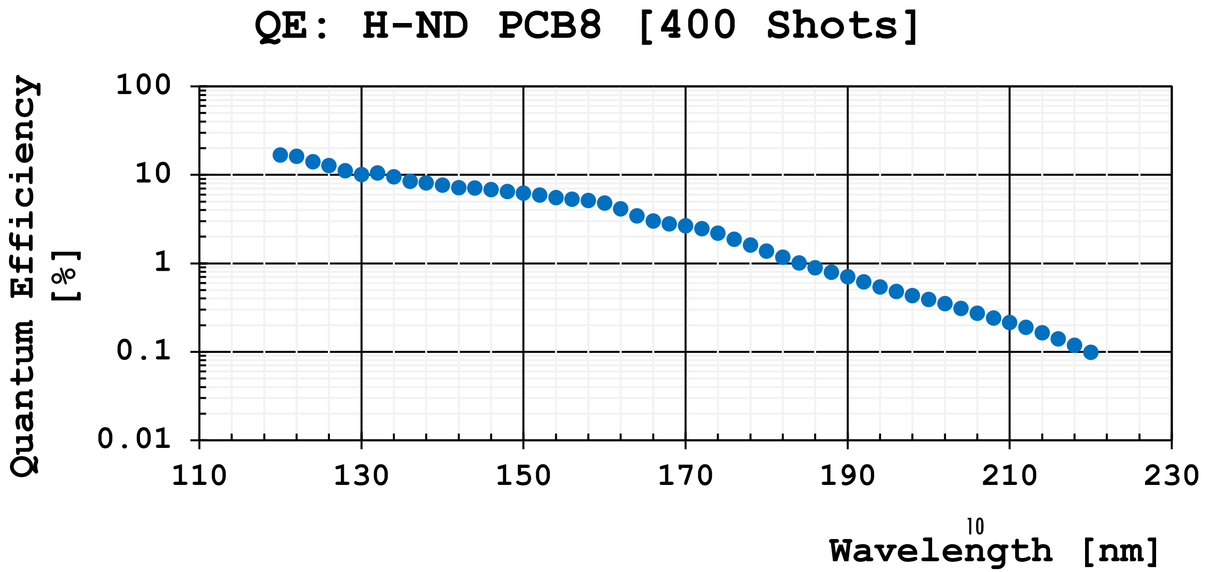
$$Q.E. = \frac{N_e}{N_\gamma};\ N_\gamma = \frac{I_{NIST}(\lambda) - I_{NIST}^{dark}}{e} \times \frac{1}{Calibration\ factor};$$

$$N_e = \frac{I_{PC}(\lambda) - I_{PC}^{dark}}{e};$$

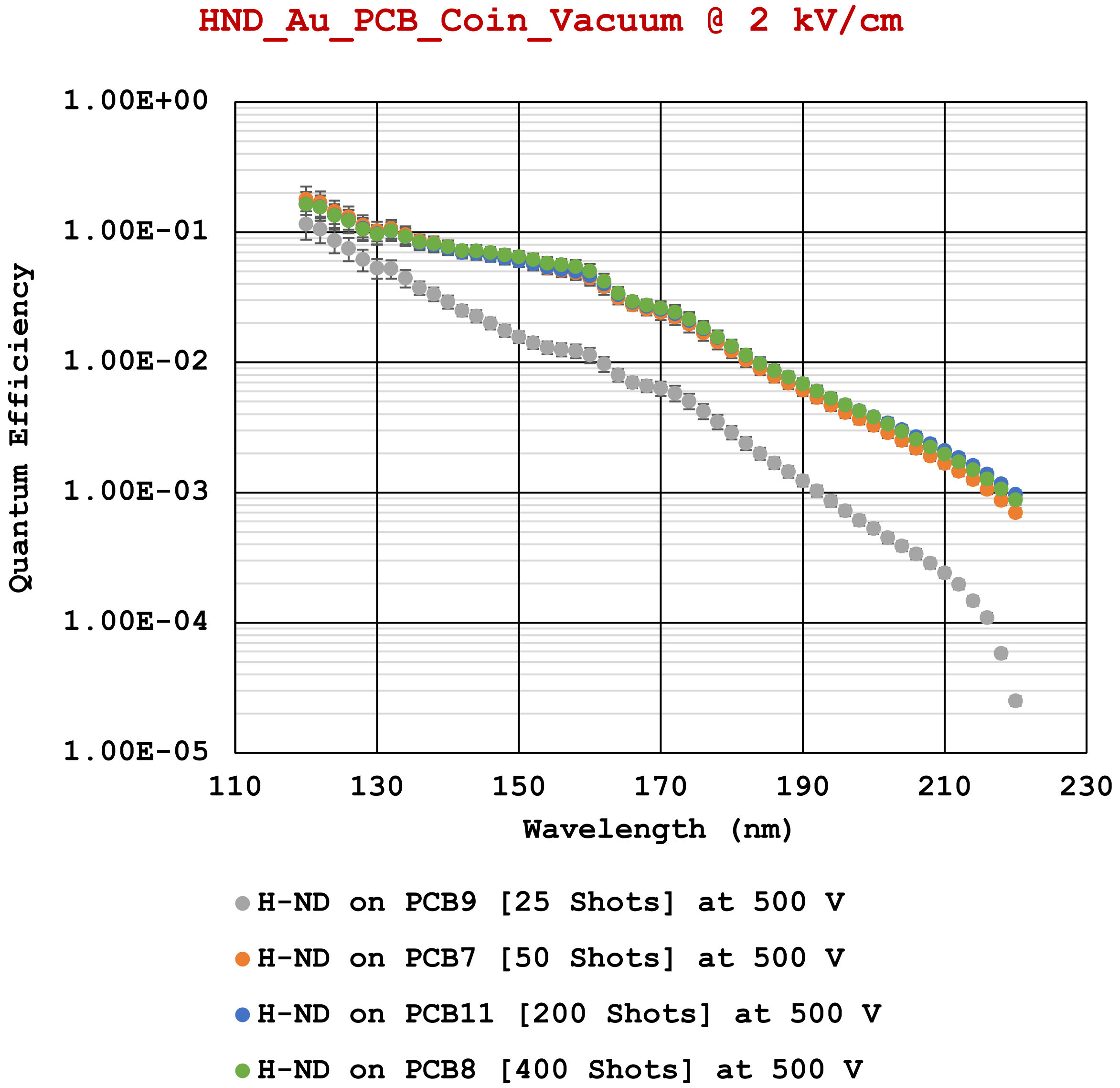
$$\boxed{Q.E.\ (\lambda) = \frac{I_{PC}(\lambda) - I_{PC}^{dark}}{I_{NIST}(\lambda) - I_{NIST}^{dark}} \times Calibration\ factor}$$

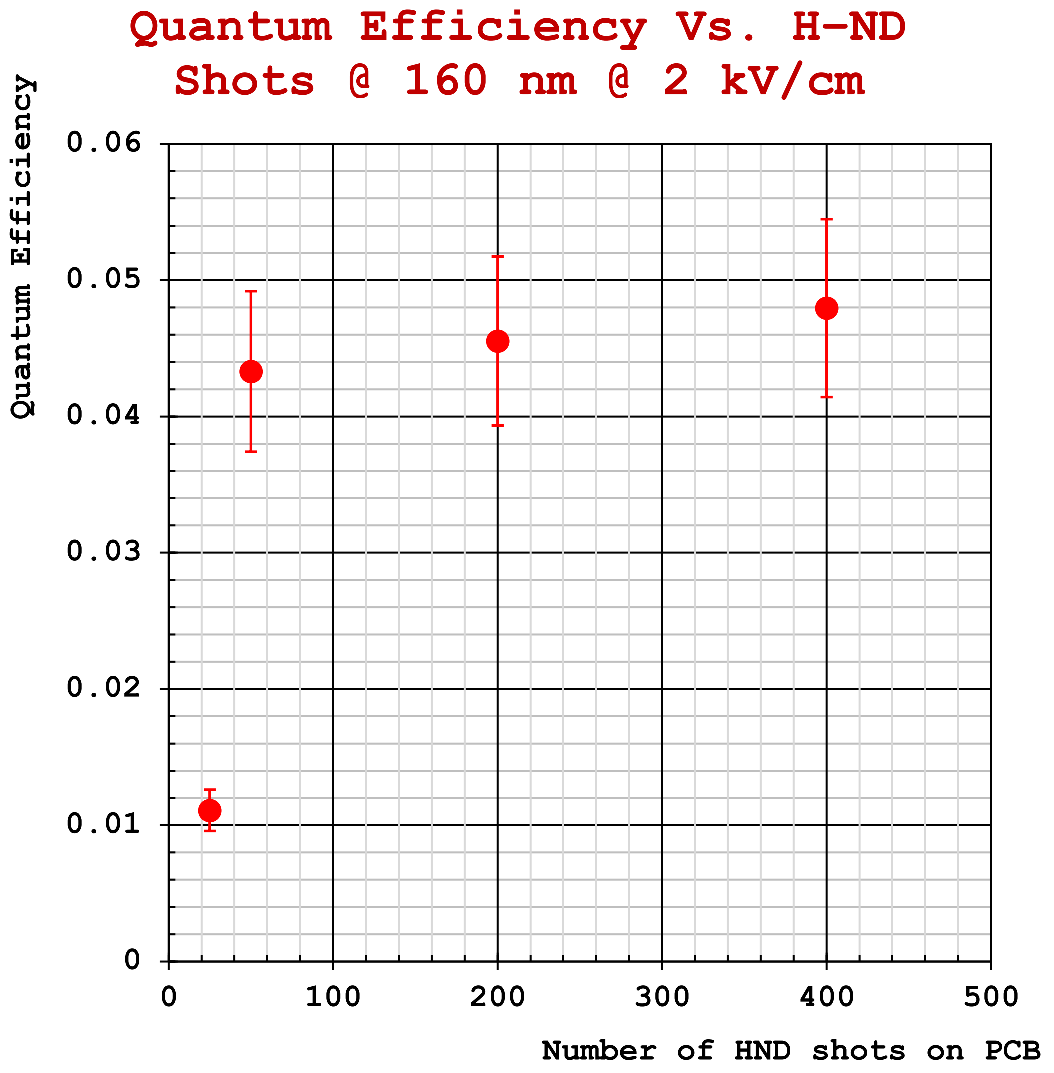

Photocurrent vs. Wavelength scan


NIST Photo-diode [AXUV-100G] calibration curve

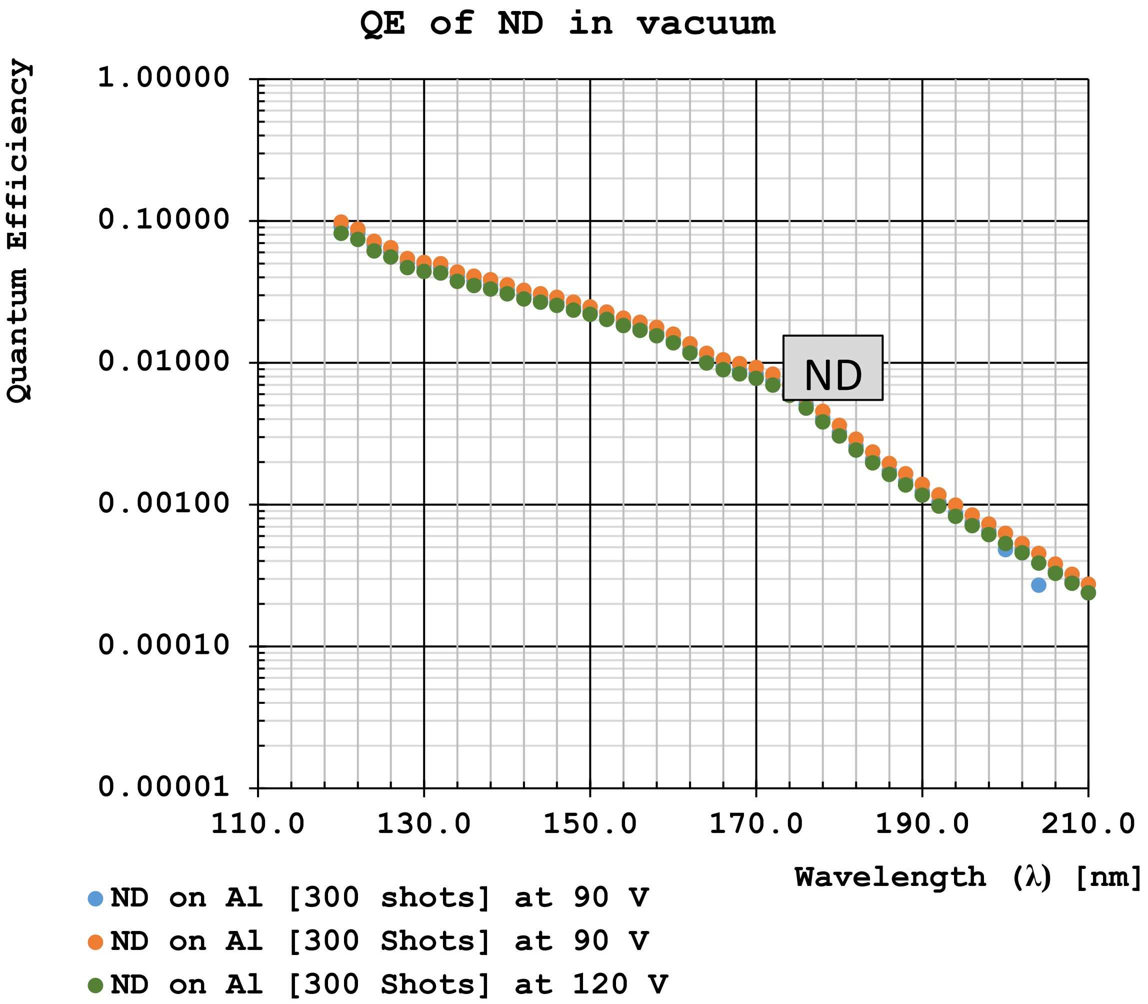

QE: H-ND PCB8 [400 Shots]

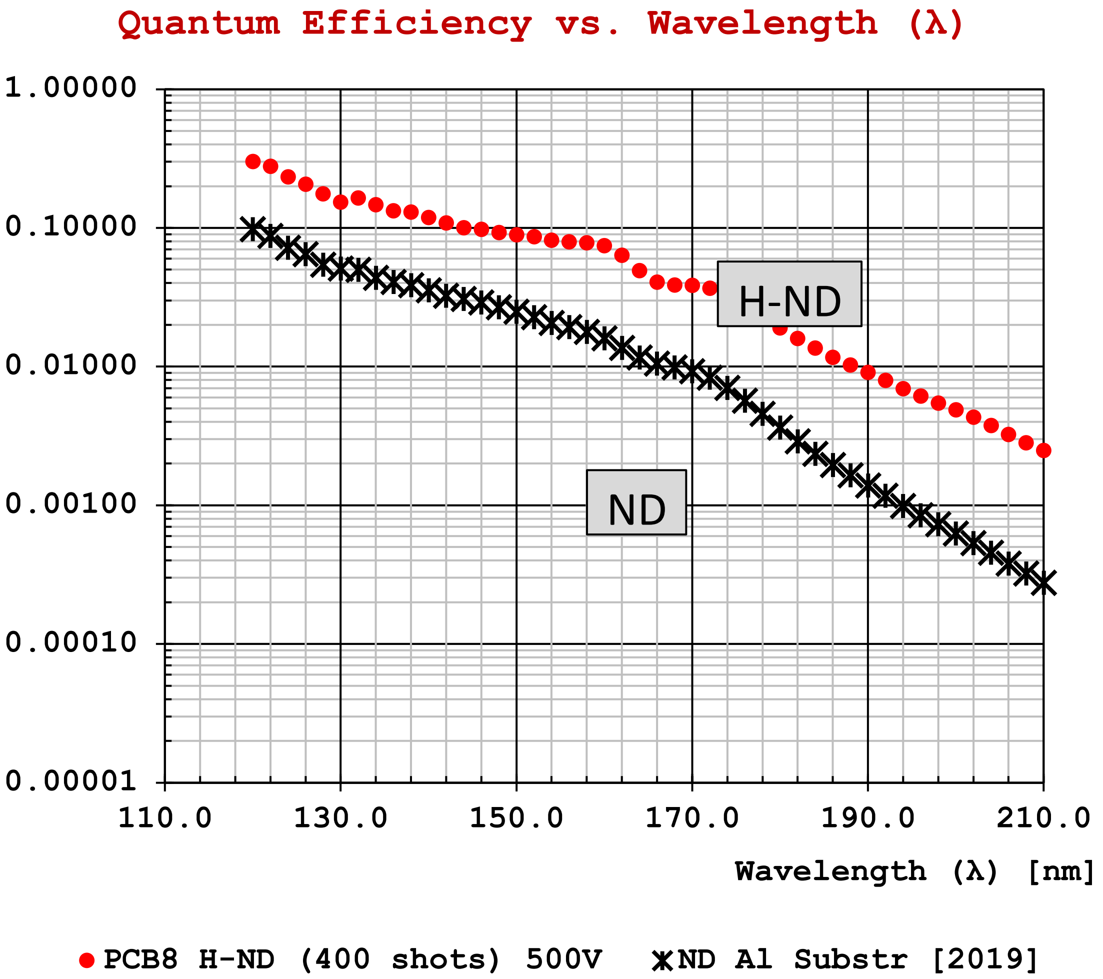
QE vs λ FOR VARIOUS H-ND SHOTS ON PCB COIN



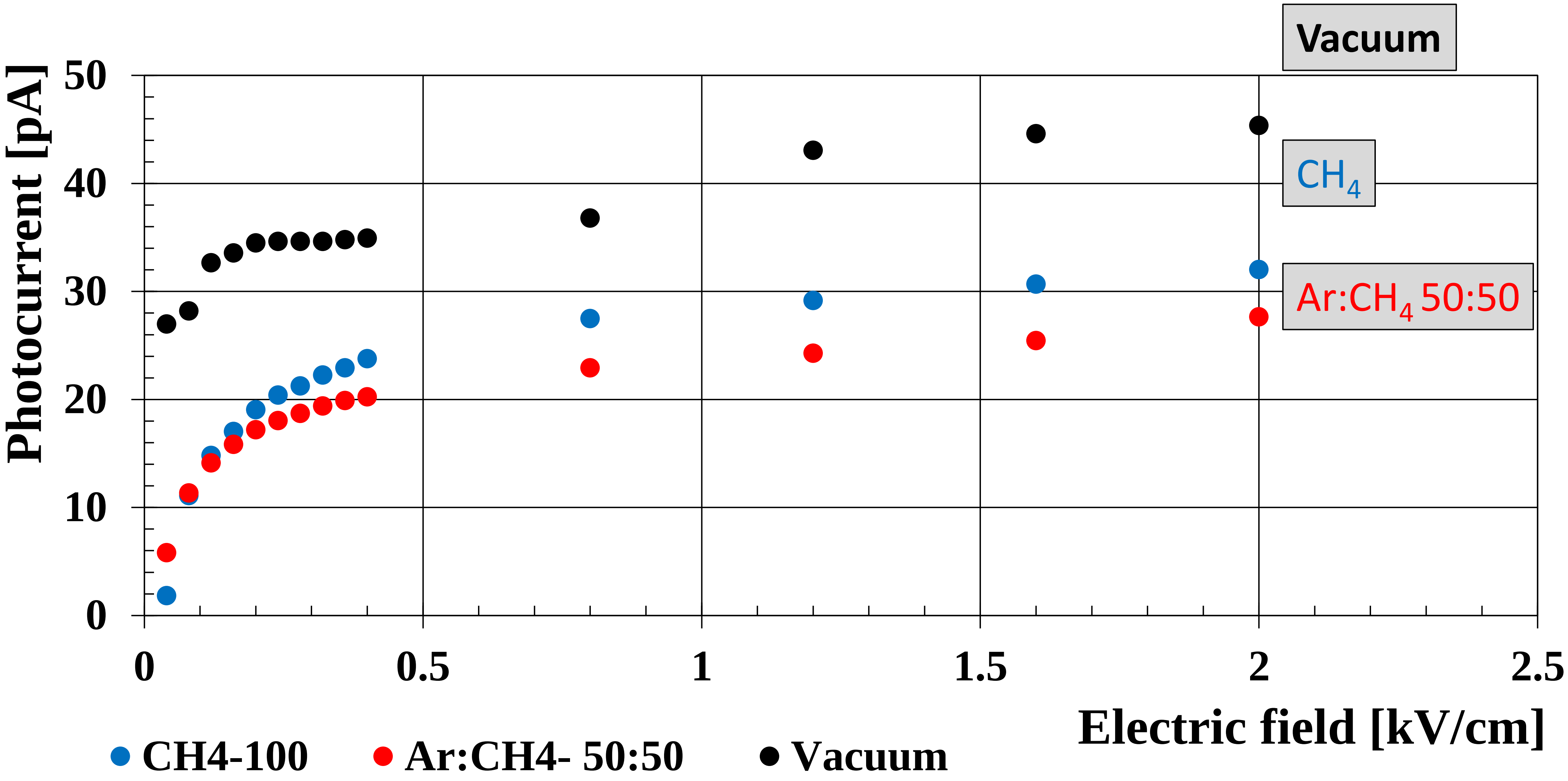


QE OF ND AND H-ND

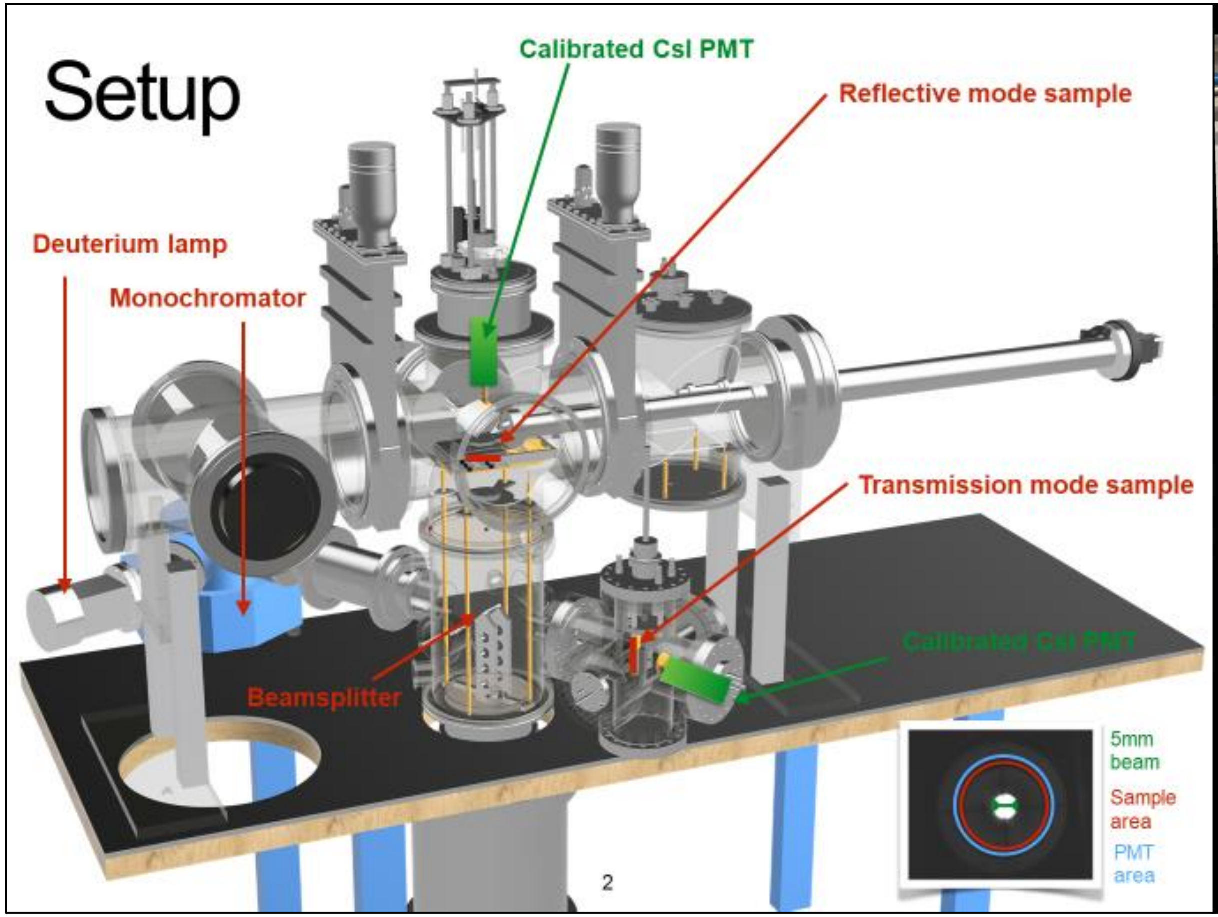


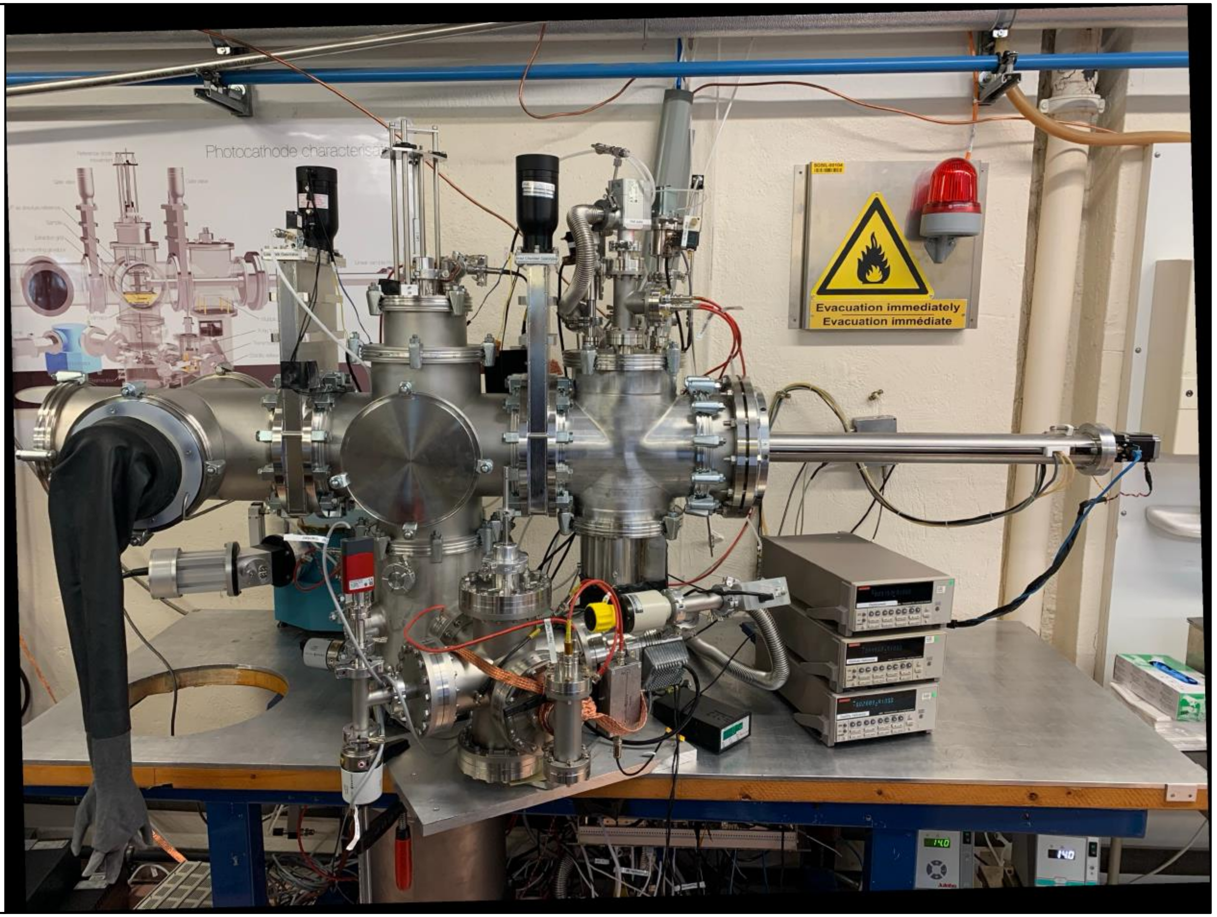


PHOTOCURRENT vs ELECTRIC FIELD in VACUUM & GAS @ 160 nm



Schematic & Pictorial view of photoemission measurement setup: ASSET





Courtesy of Triloki (presented in RD51 Mini-week feb 2020)

MEASURING QUANTUM EFFICIENCY AT CERN

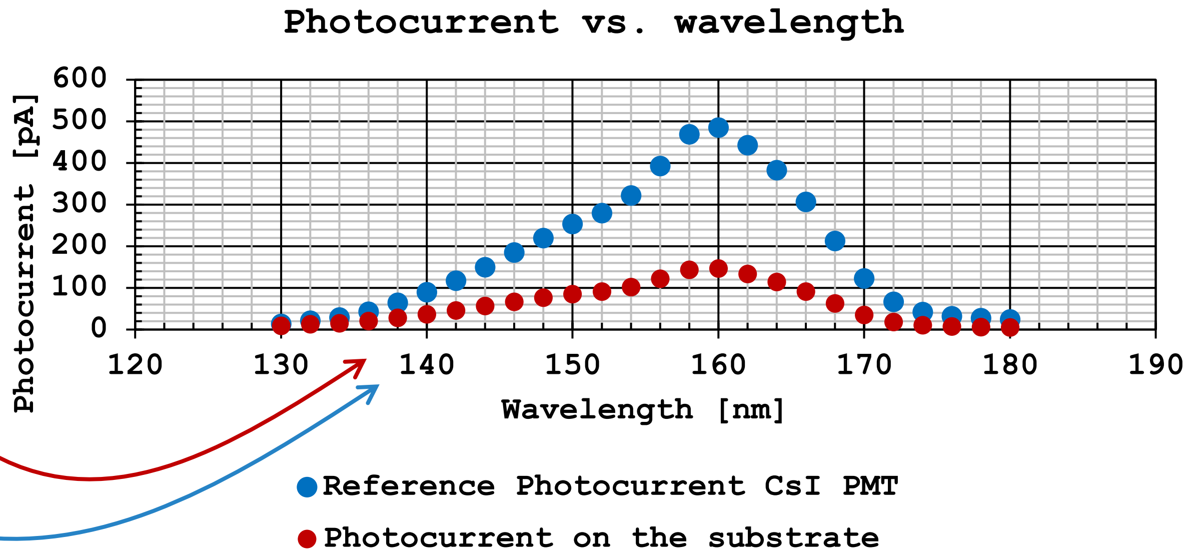
Repeated measurements > results are reproducible

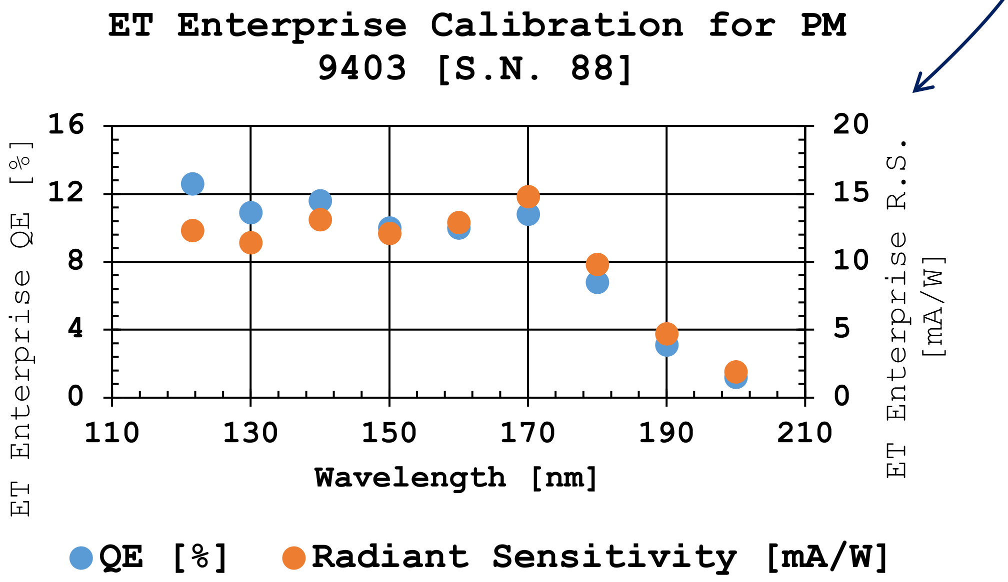
$$QE_{PC}(\lambda) = \frac{N_e}{N_\gamma} = \frac{(I_{PC}/e)}{(factor(\lambda) \times I_{ref(abs)})};$$

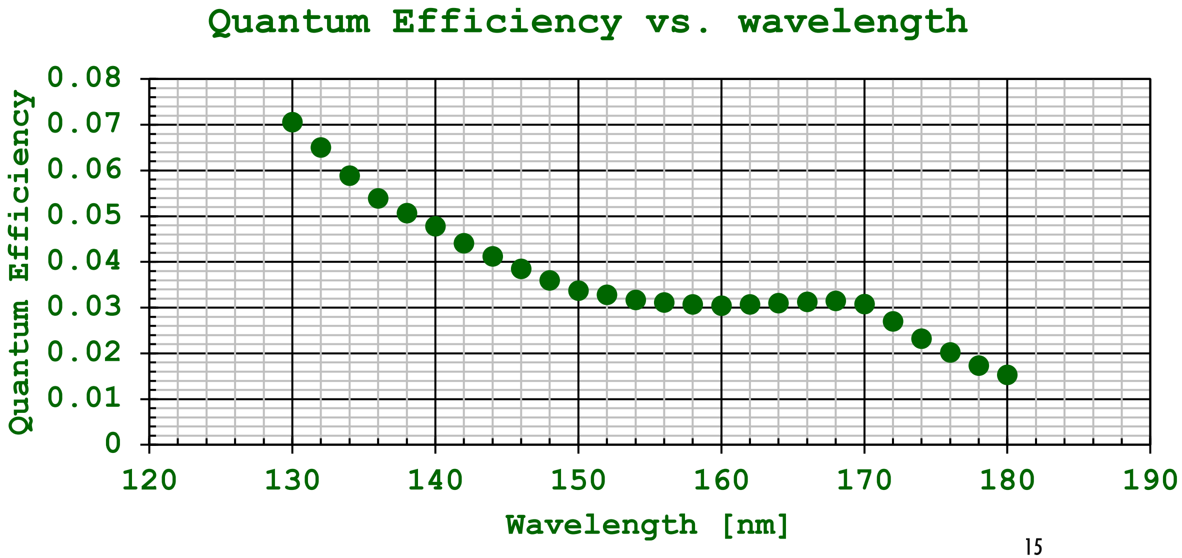
$$I_{ref(abs)} = I_{ref} \times \frac{I_{PMT(Top)}}{I_{PMT(Bottom)}};$$

Where $I_{ref} = I_{PMT(Bottom_{withPC})}$

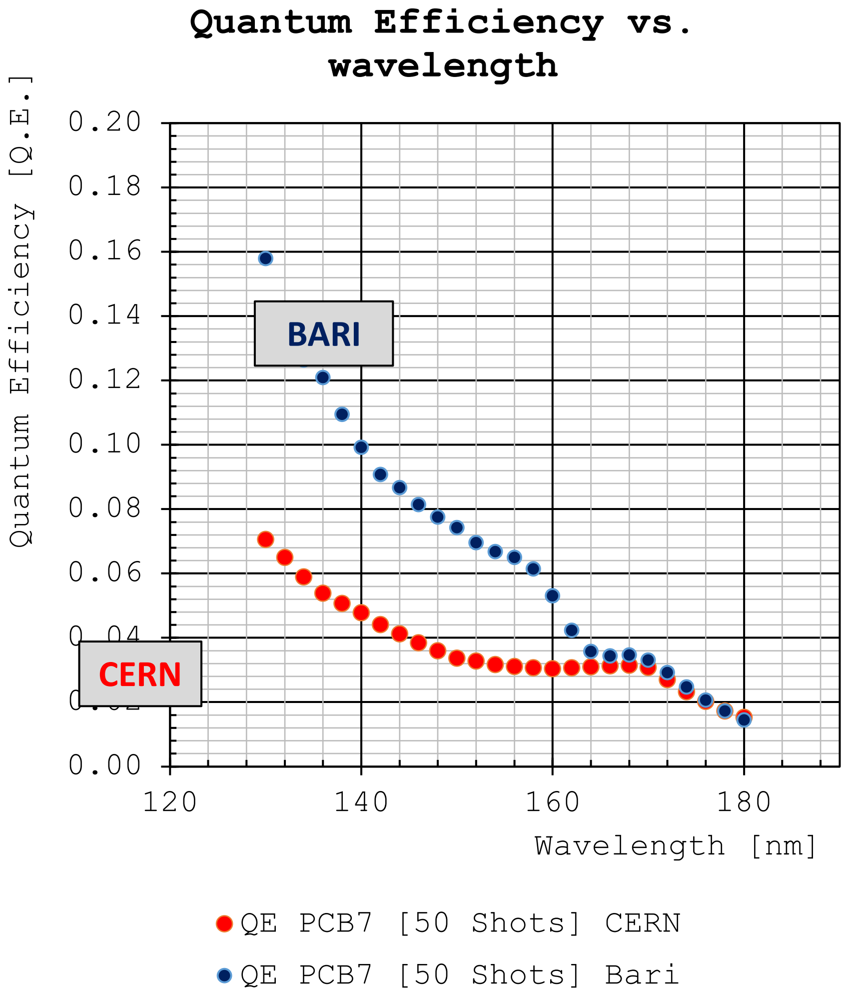
$$factor(\lambda) = \frac{\lambda}{h \times c \times radiant\ sensitivity}$$

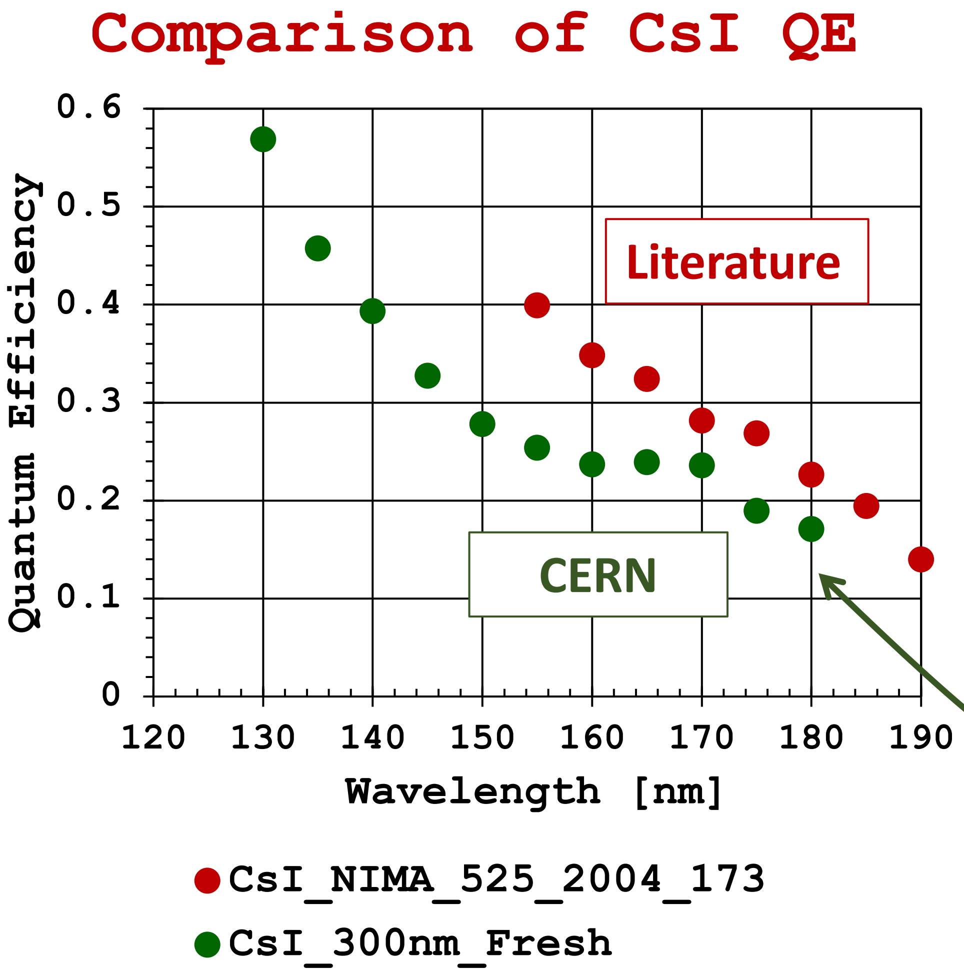






COMPARISON OF CERN RESULTS WITH BARI AND LITERATURE

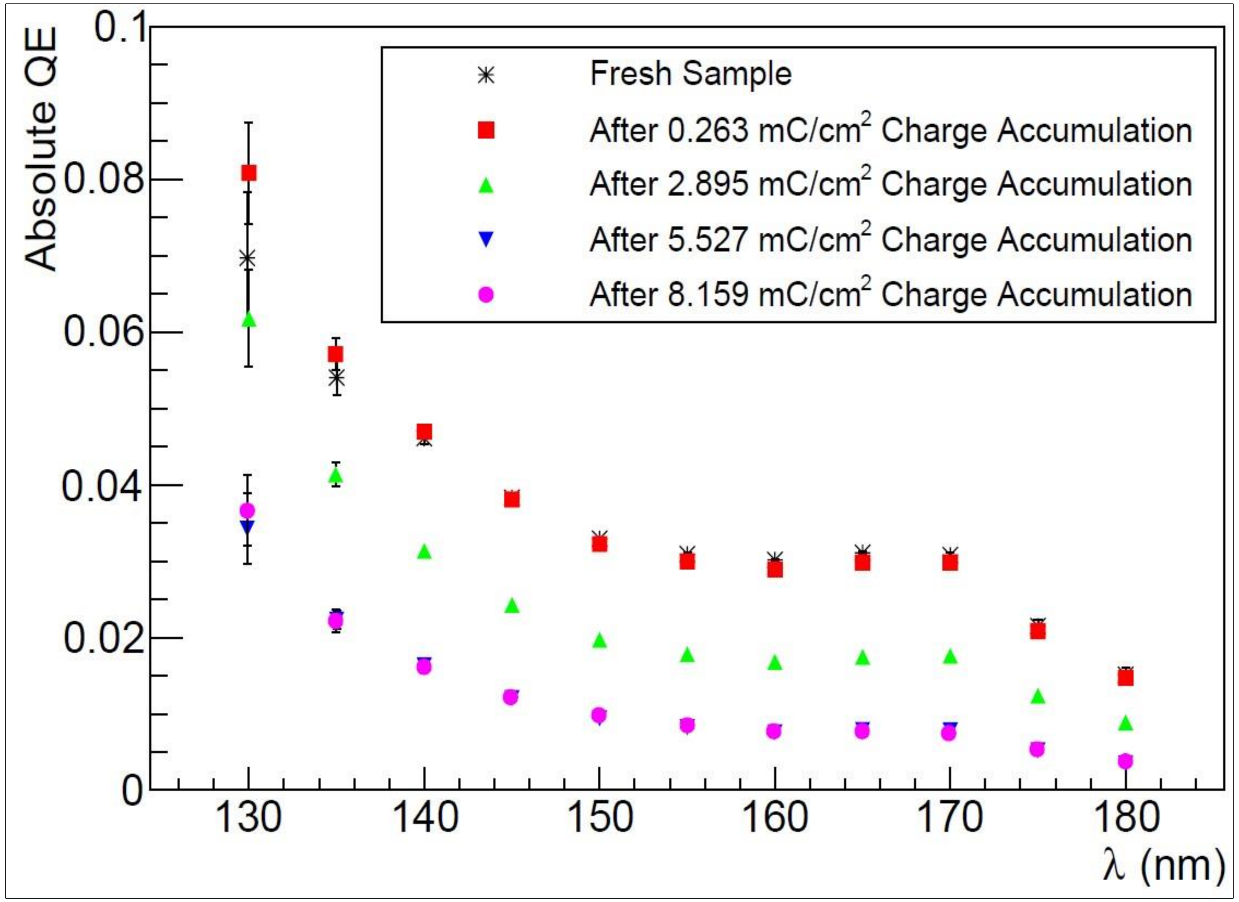


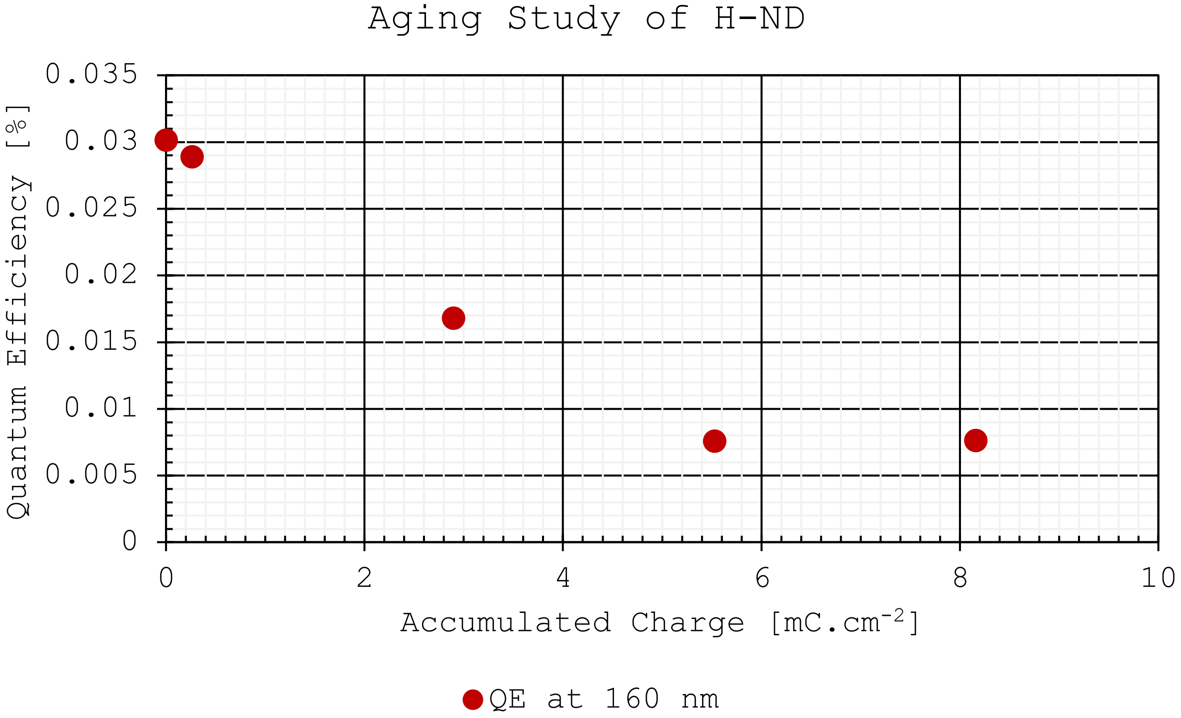


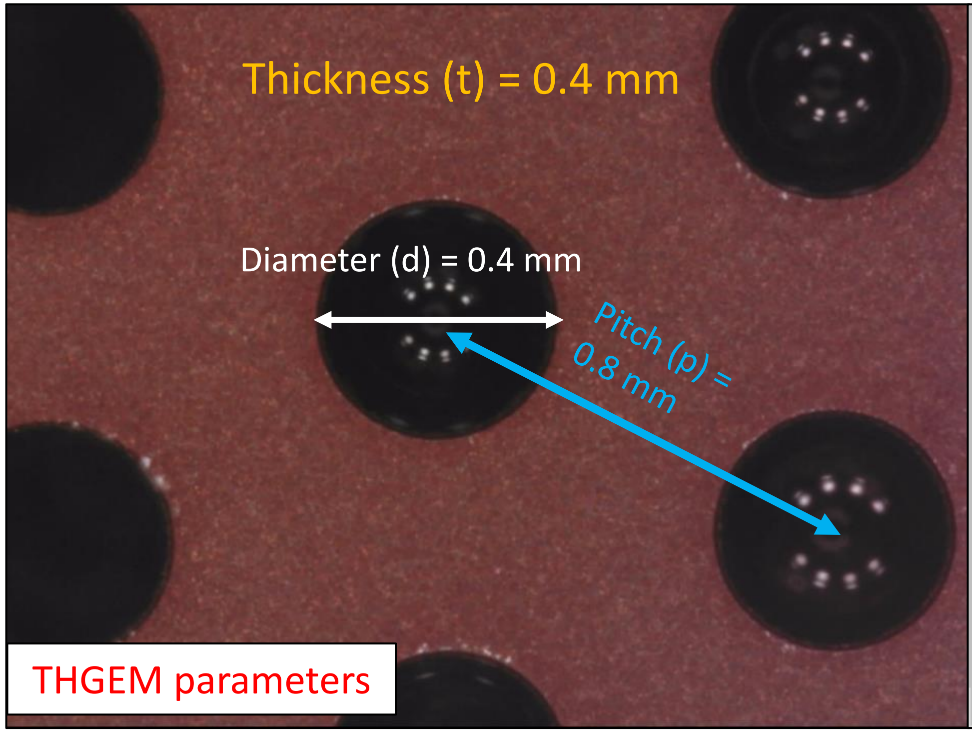
CsI coated at CERN and measured with ASSET setup

ASSET is in building up state, comparative analyses are useful

AGEING STUDY WITH X-RAY IRRADIATION OF H-ND

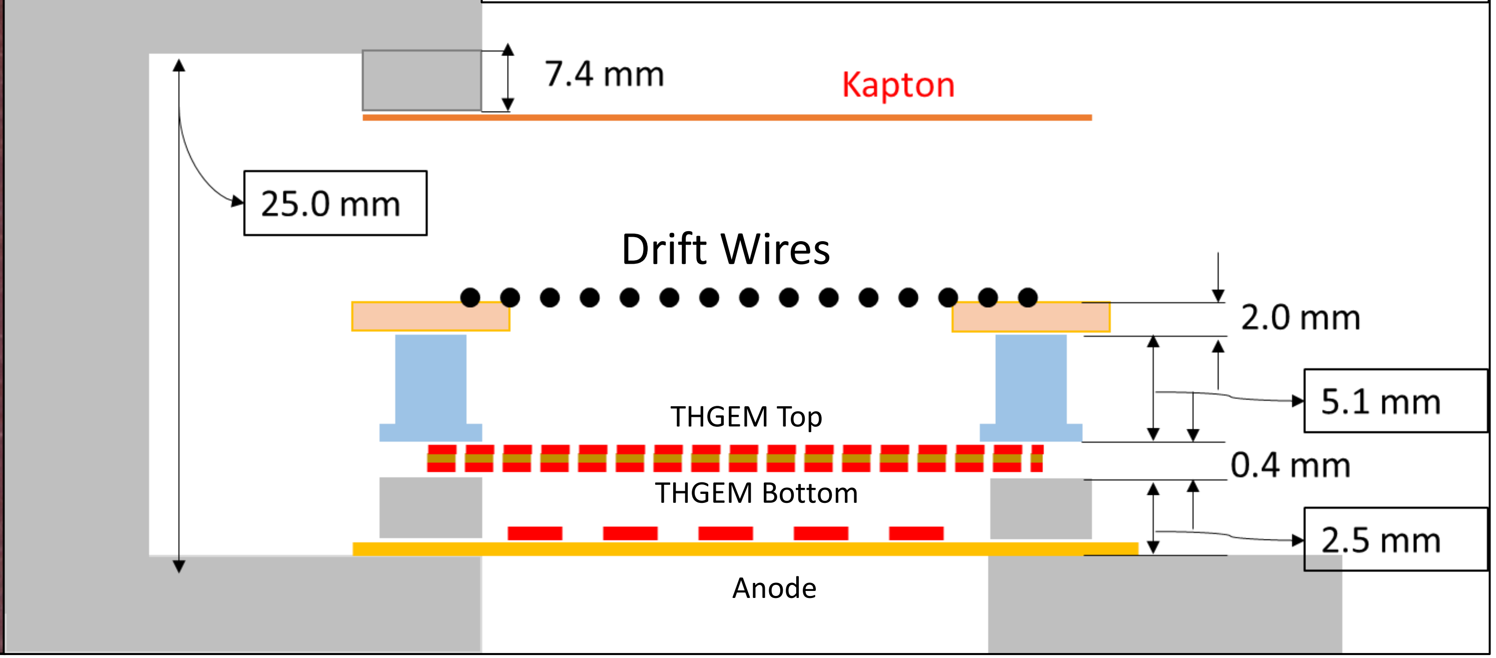






THGEM parameters

Prototype used for measurements (Schematic)



- THGEMs are standard Printed Circuit Boards (PCBs) with holes produced by mechanical drilling.
- Like in GEMs, in the presence of a correct electrical bias and in a proper gas mixture, each hole acts as an electron multiplier.
- The signal generated by the gas multiplication is collected at the anode.
- The geometrical parameters of our THGEMs are: hole diameter (d) = 0.4 mm; hole pitch (p) = 0.8 mm; thickness of the fiberglass (t) = 0.4 mm; and rim around holes < 5 um.

- For measurements the gas mixture used is: **Ar:CH_4 50:50**
- **CAEN N1471H** HV PS has been used.
- CREMAT **CR-110** Preamplifier with CREMAT **CR-150** r5 evaluation board has been used to read the signal from the detector.
- **Ortec 672** Spectroscopy amplifier with **AMPTEK MCA 8000A** has been used for processing the signal and for saving the data.

Courtesy of Triloki (presented in RD51 Mini-week feb 2020)

WHAT WE DID SO FAR

> We coated few old 30 X 30 mm^2 prototypes and as some of them showing pathologies we produced 25 new prototypes with COMPASS standard [$\emptyset$=0.4 mm; t=0.4 mm; p=0.8 mm; rim <5 μm].

> After postproduction they are characterized in Trieste LAB.

> To be sure we bring a small setup in Bari and characterized them before and after coating.

> First results are already presented in RICH 2018 and MPGD 2019 as a poster. RICH-2018 Proceeding is Published in NIMA_952_2020_161967.

> A very brief overview in next slide

THGEM CHARACTERIZATION IN BARI

> THGEM used: THGEM IX [d = 0.4 mm; t = 0.4 mm; p = 0.8 mm; RIM < 5 µm];

> Gas Mixture: Ar:CH_4 50:50.

> CAEN N1471H HV PS

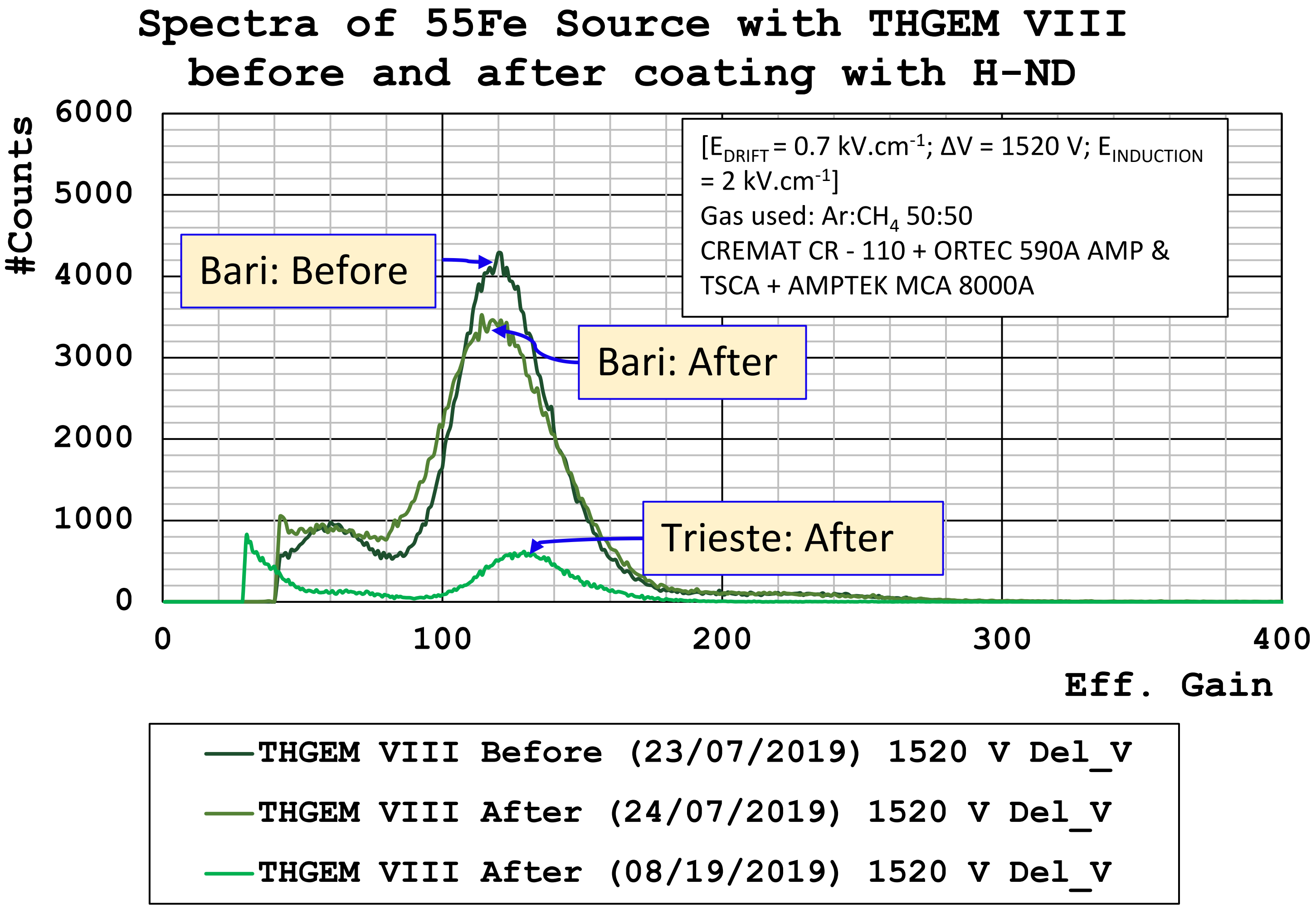
> Voltage Configuration: Drift = 2520 V; Top = 2020 V; Bottom = 500 V;

> 55Fe X-Ray source.

> Cremat CR-110 Preamp + ORTEC 590A Amplifier + AMPTEK MCA 8000A.

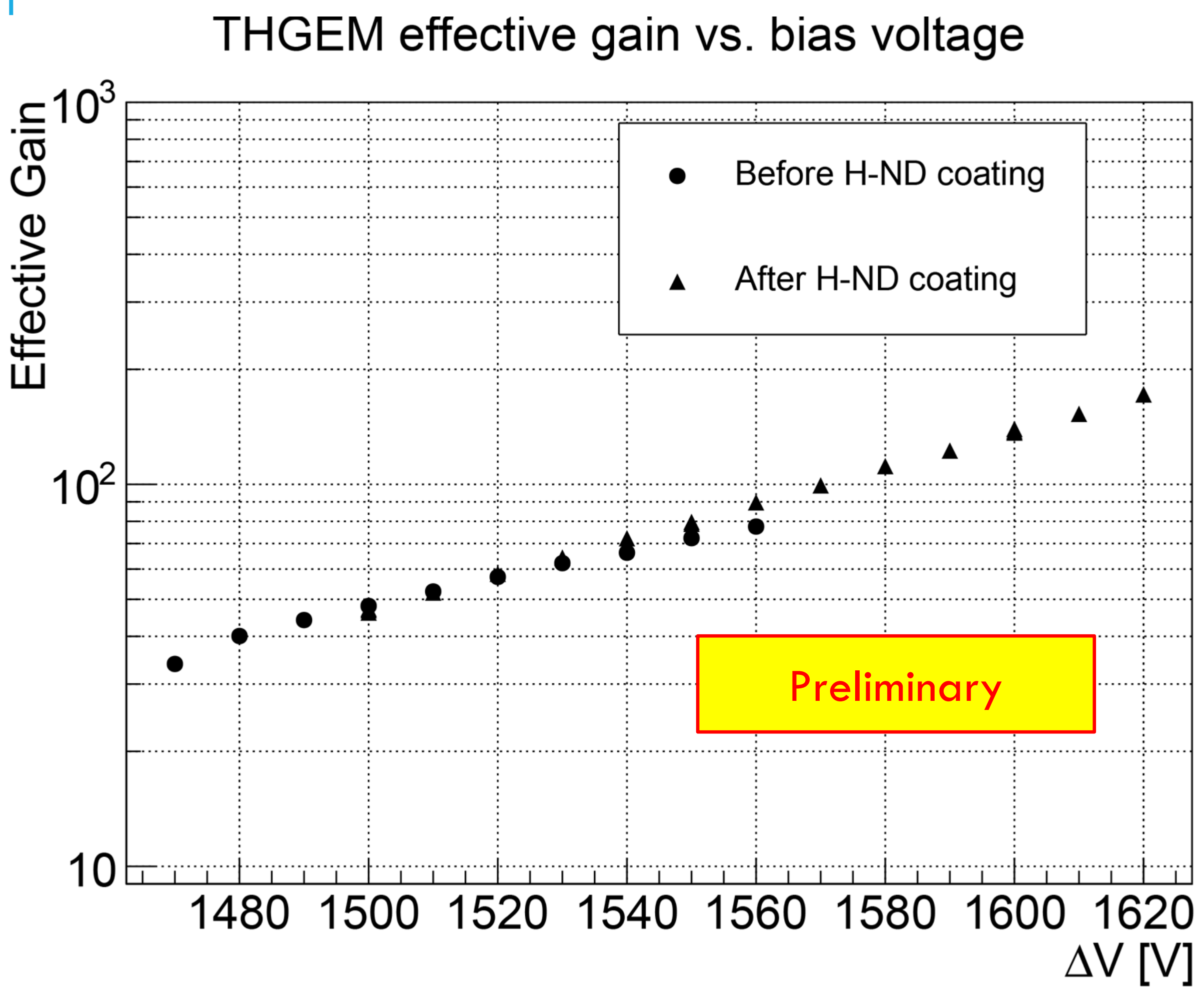
> Calc. Eff. Gain ~ 122

> Heat treatment after coating introduced (24 h at 120º C): W/O treatment THGEM does not stand HV


Spectra of 55Fe Source with THGEM VIII before and after coating with H-ND

[E_{DRIFT} = 0.7 kV.cm^{-1}; ΔV = 1520 V; $E_{INDUCTION}$ = 2 kV.cm^{-1}]
Gas used: Ar:CH_4 50:50
CREMAT CR - 110 + ORTEC 590A AMP & TSCA + AMPTEK MCA 8000A

THGEMS WITH H-ND



> Gas Mixture: Ar:CH_4 50:50

> 55Fe X-Ray source.

> Cremat CR-110 Preamp + ORTEC 590A Amplifier + AMPTEK MCA 8000A.

> After coating and after heat treatment THGEMs sustain higher bias voltage

FUTURE STEPS

> QE measurement with fresh H-ND

> Exploration of different powders

> Systematic characterization of THGEMs

> H-ND coated “hybrid prototype” (THGEMs + MM)

CONCLUSIONS

Preliminary results are encouraging:

> H-ND shows high QE (not as high as expected, though)

> H-ND shows robustness to ion bombardment

> Coated THGEM perform nicely thanks to heat treatment

Both BARI and CERN setup useful:

- BARI: (H-)ND photocathodes can be produced, mature setup for absolute QE measurement
- CERN: flexible setup where measurements like radiation damage profile scanning are possible

BIBLIOGRAPHY

> L. Velardi et el., Appl. Phys. Lett. 108, 083503 (2016);

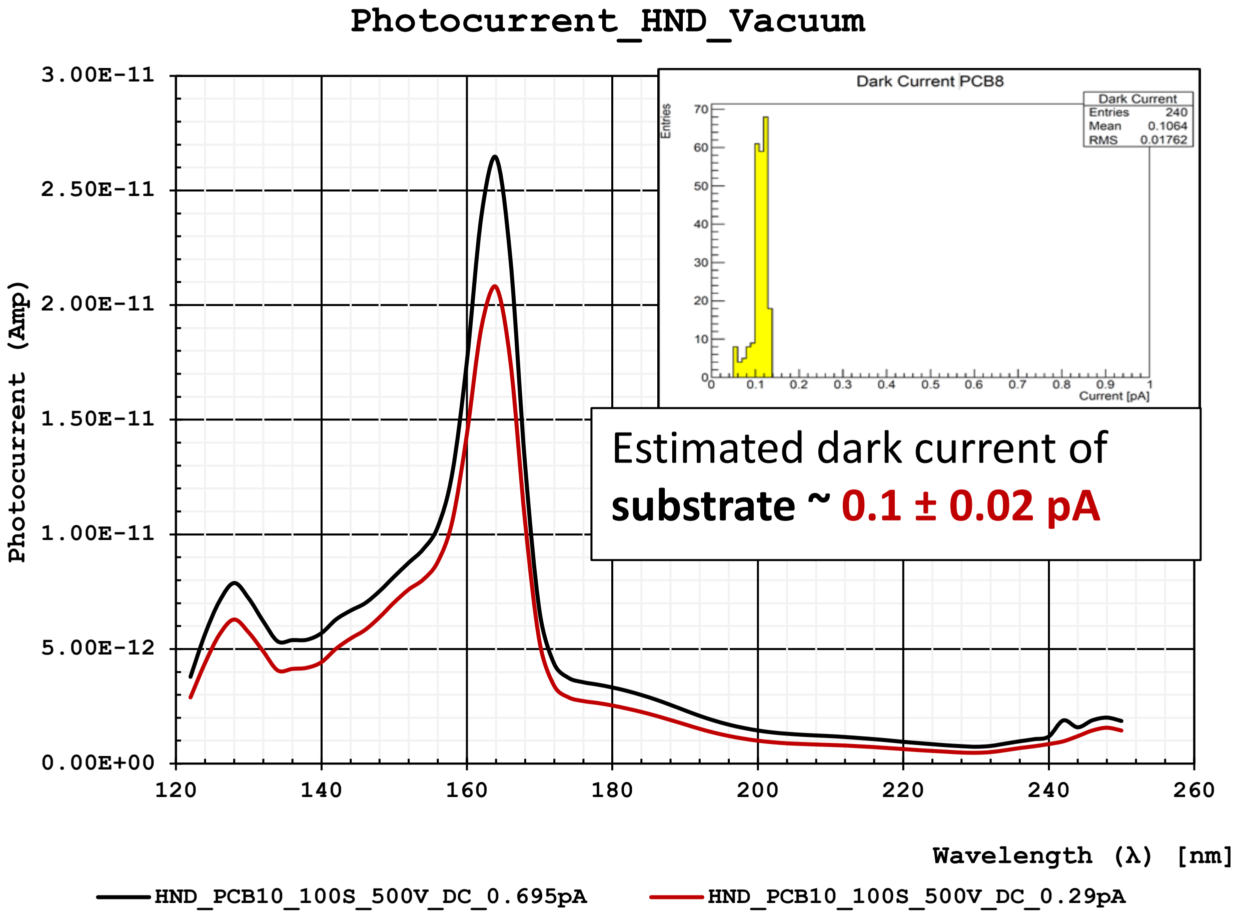
> Brunbauer F.M. et al., JINST, 15 (2020) C09052;

> Chatterjee C. et al., Nucl. Instrum. Methods Phys. Res. A, 952(2020) 161967;

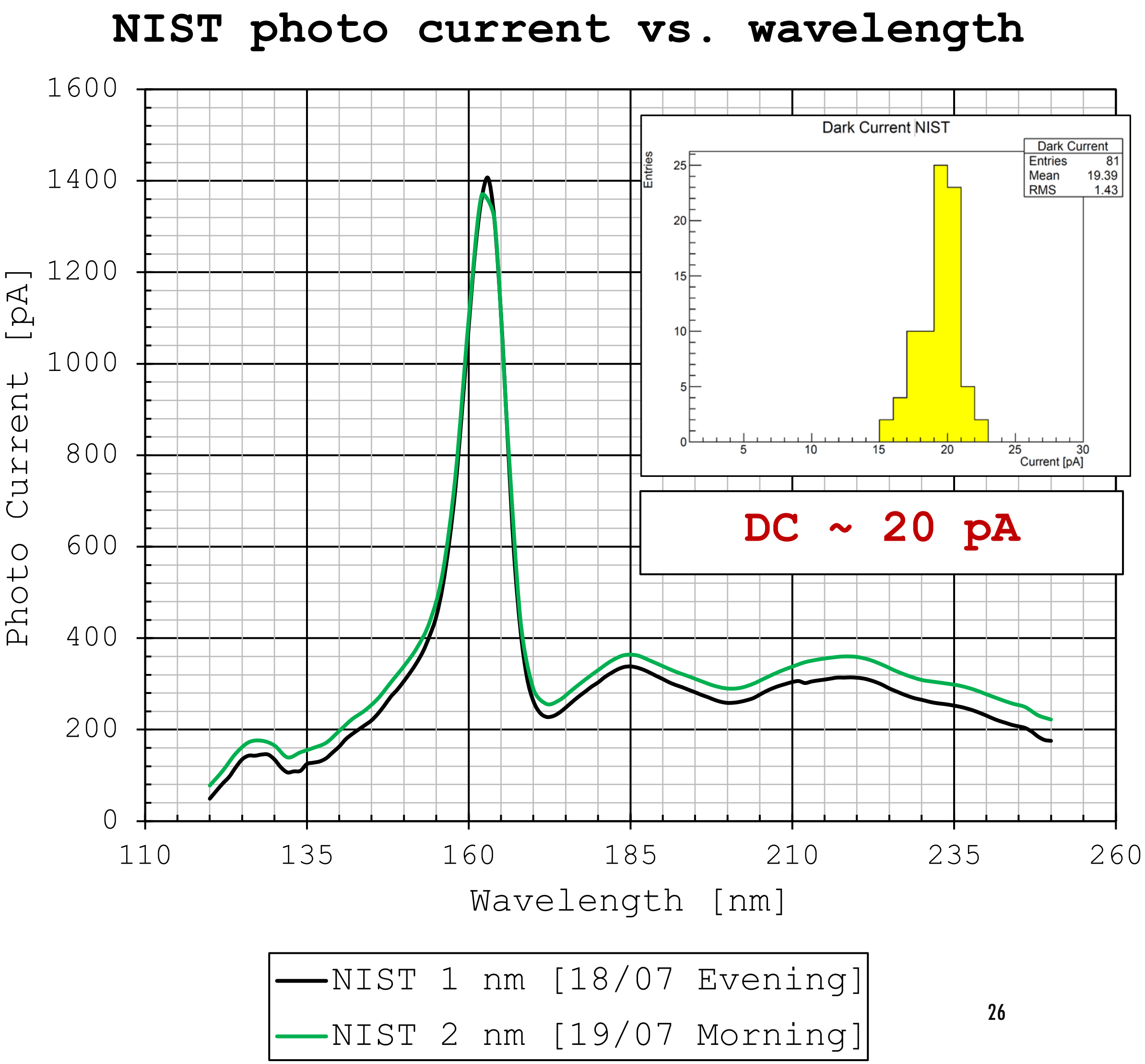
> Triloki, “Preliminary results of ND Photocathode coupled to THGEMs”, presentation at RD51 Mini-week, 10-13 February 2020, https://indico.cern.ch/event/872501;

BACKUP SLIDES

NOISE AND REPRODUCIBILITY (BARI SETUP)



Estimated dark current of **substrate ~ 0.1 ± 0.02 pA**



DC ~ 20 pA

REPRODUCIBILITY (CERN SETUP)