ASSET - Photocathode characterisation device

Overview of the setup and measurement capabilities

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RD51 MINI-WEEK

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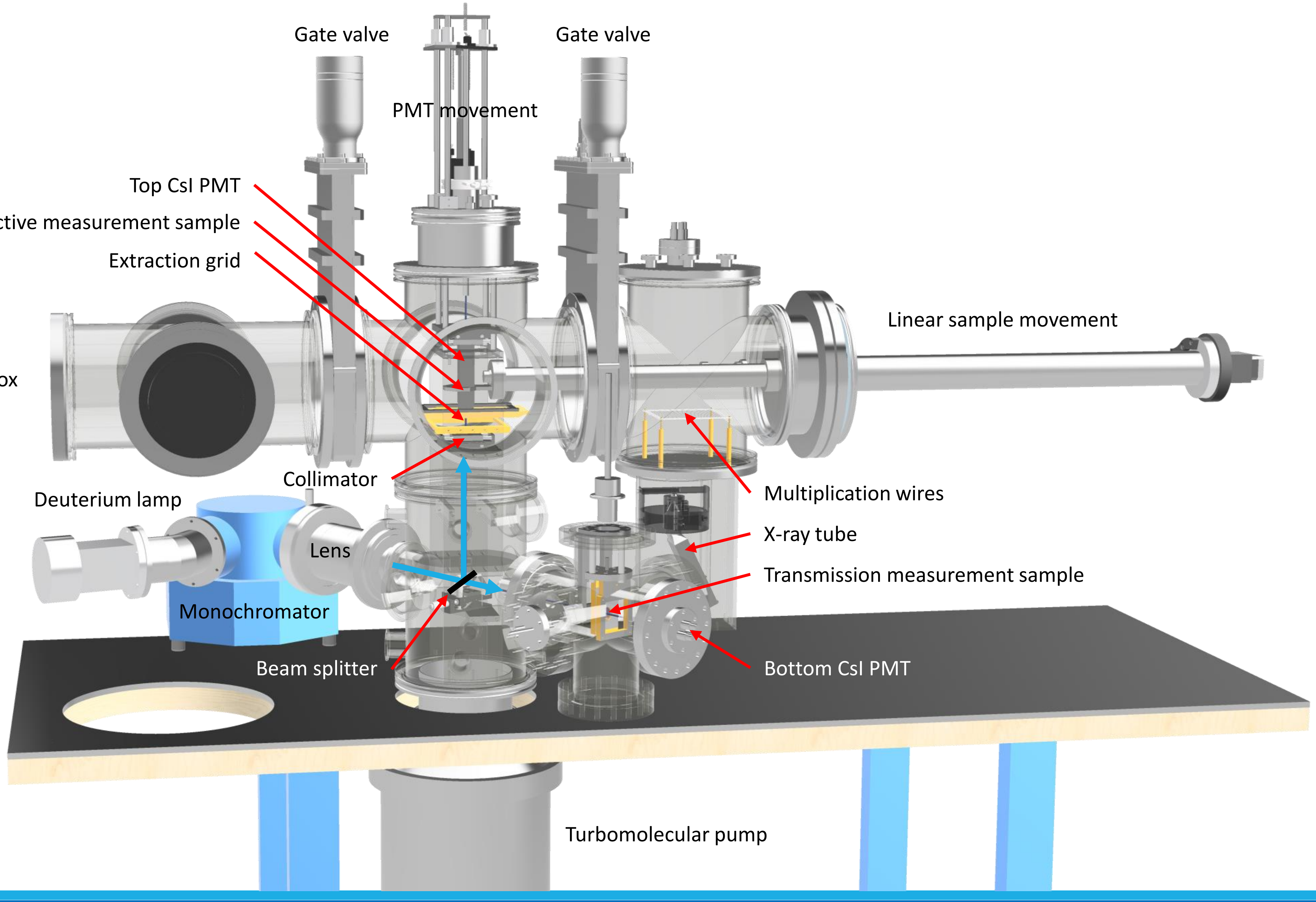
Introduction

- Motivation:
  - Robust photocathodes for use with precise timing Micromegas.
- The PicoSec project:
  - *Reference, L. Sohl: https://indico.cern.ch/event/872501/contributions/3726013/*
  - The detector uses semi-transparent CsI photocathodes (18 nm) on MgF_2 crystals.
  - Degradation of CsI QE is a concern in the development of this concept.
- Goals:
  - Quantify the degradation of photocathodes when exposed to ion back flow.
  - Examine possible alternative photocathode materials as well as protective layers.

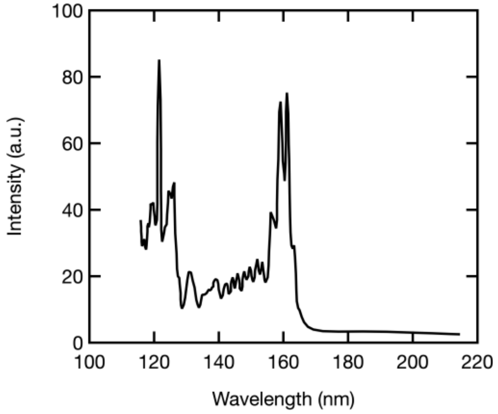
ASSET

Overview of the setup

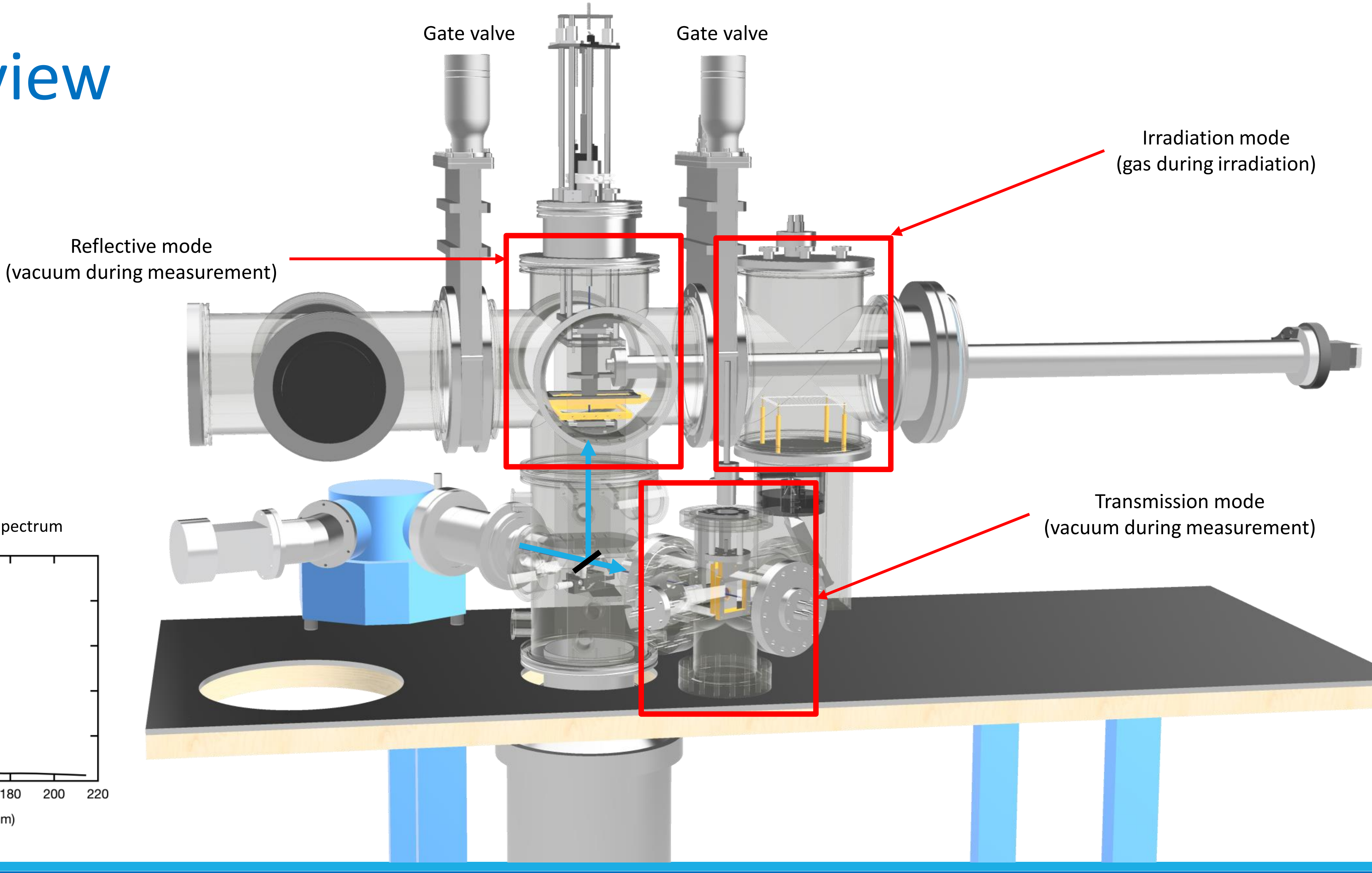
Overview



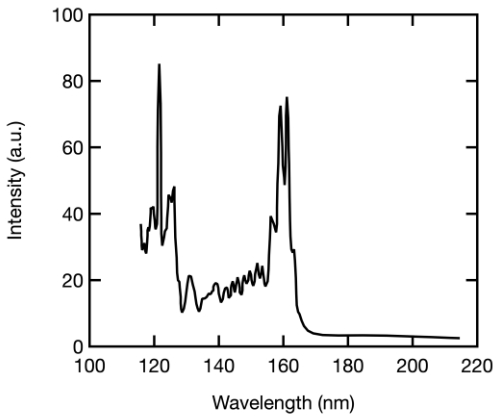
Deuterium lamp spectrum



Overview

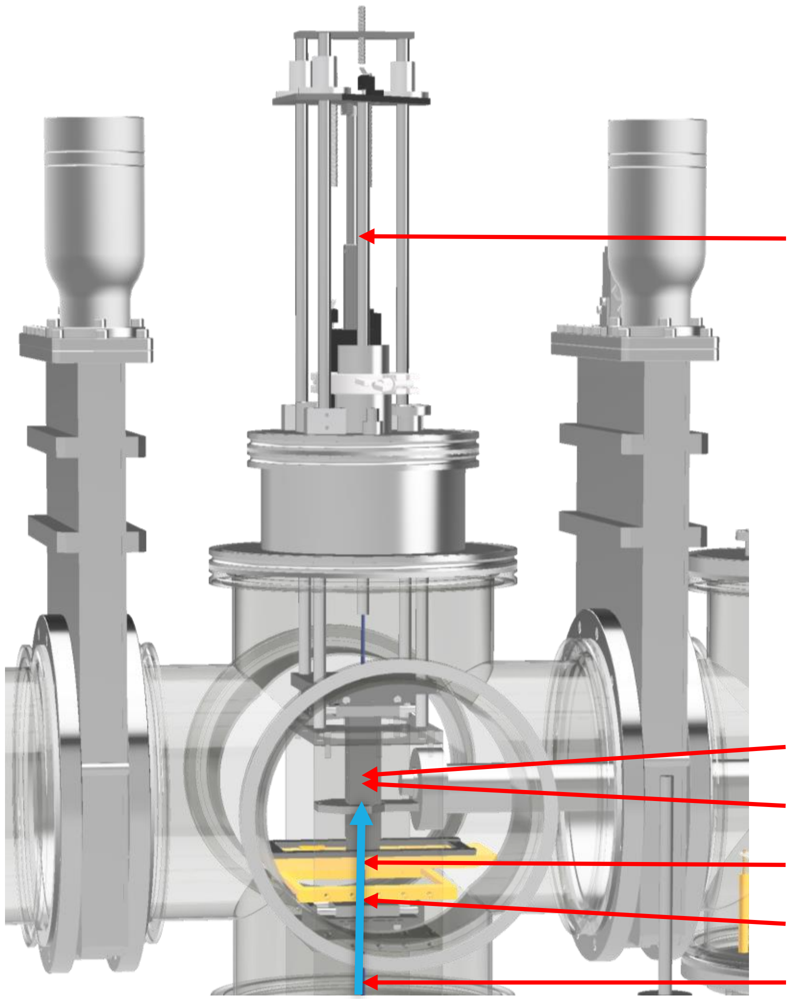


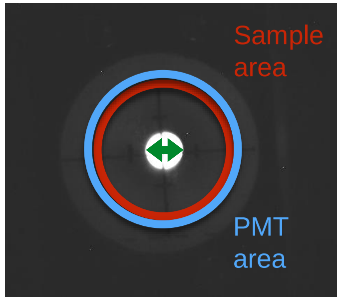
Deuterium lamp spectrum

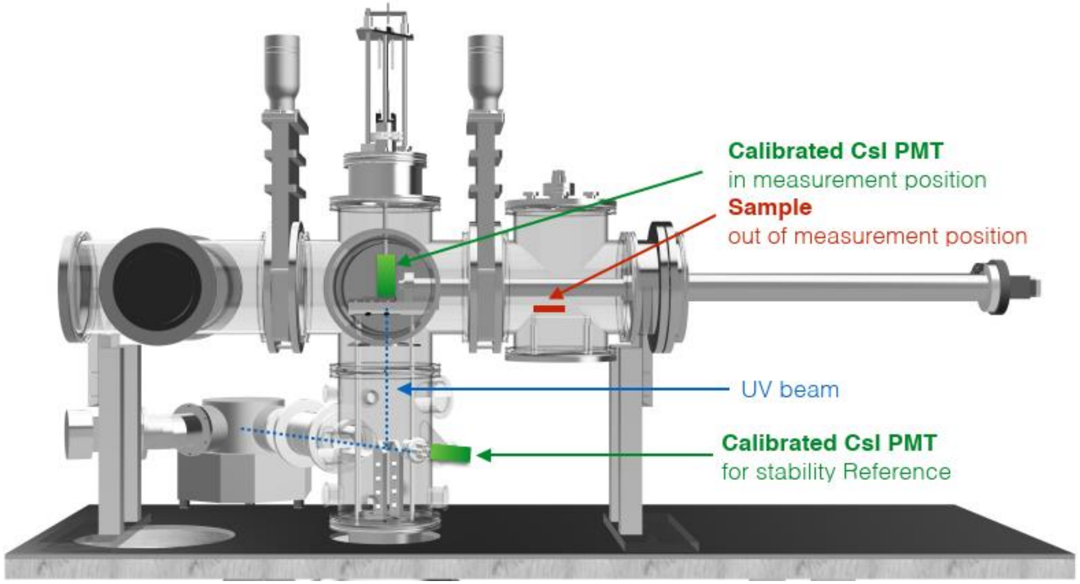


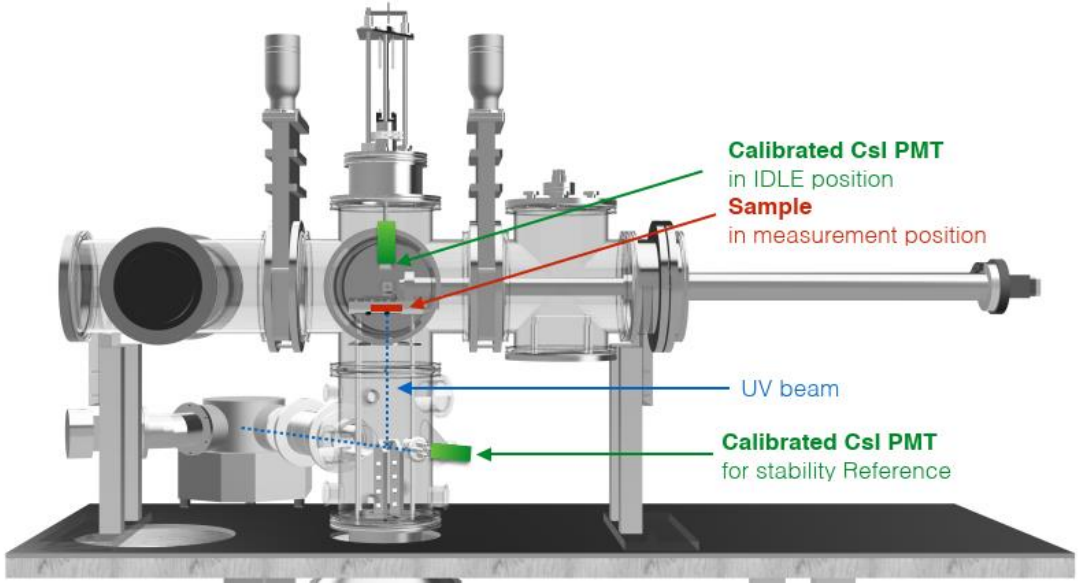
Reflective mode

Vacuum during measurement



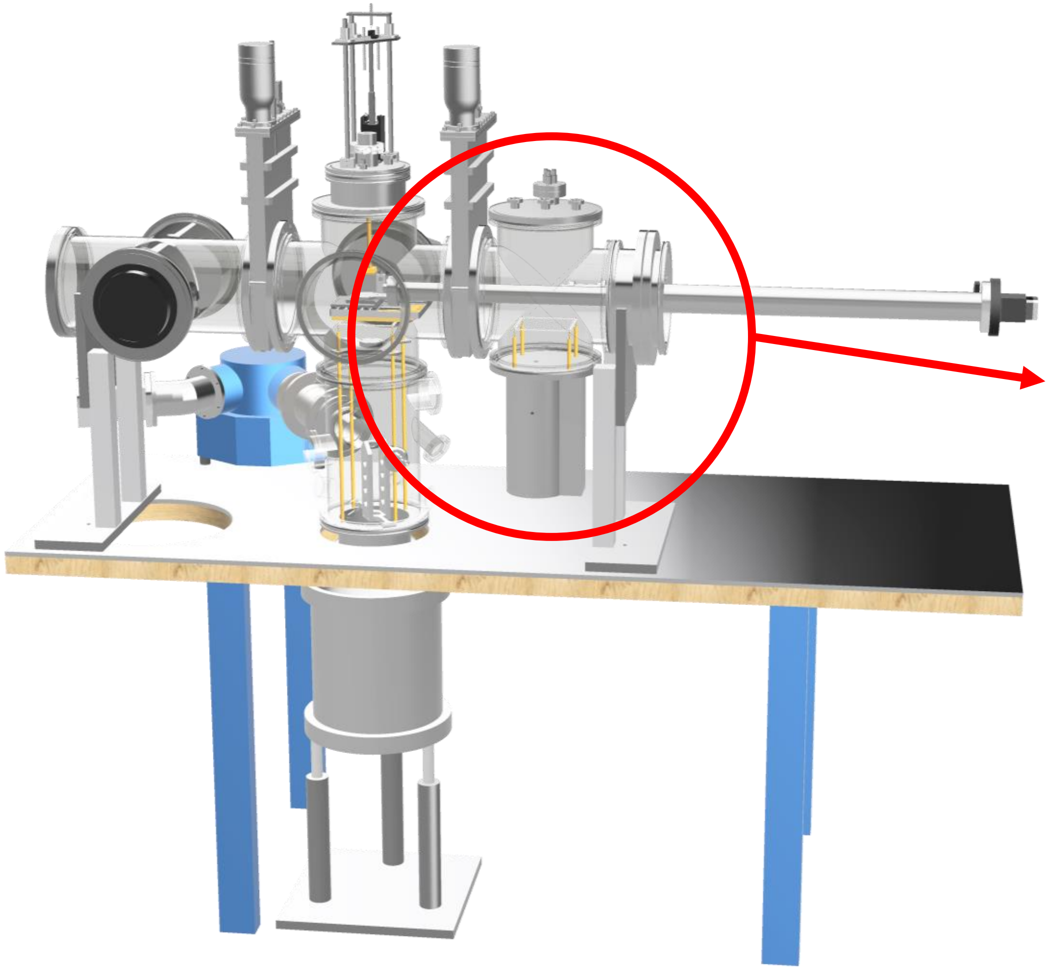


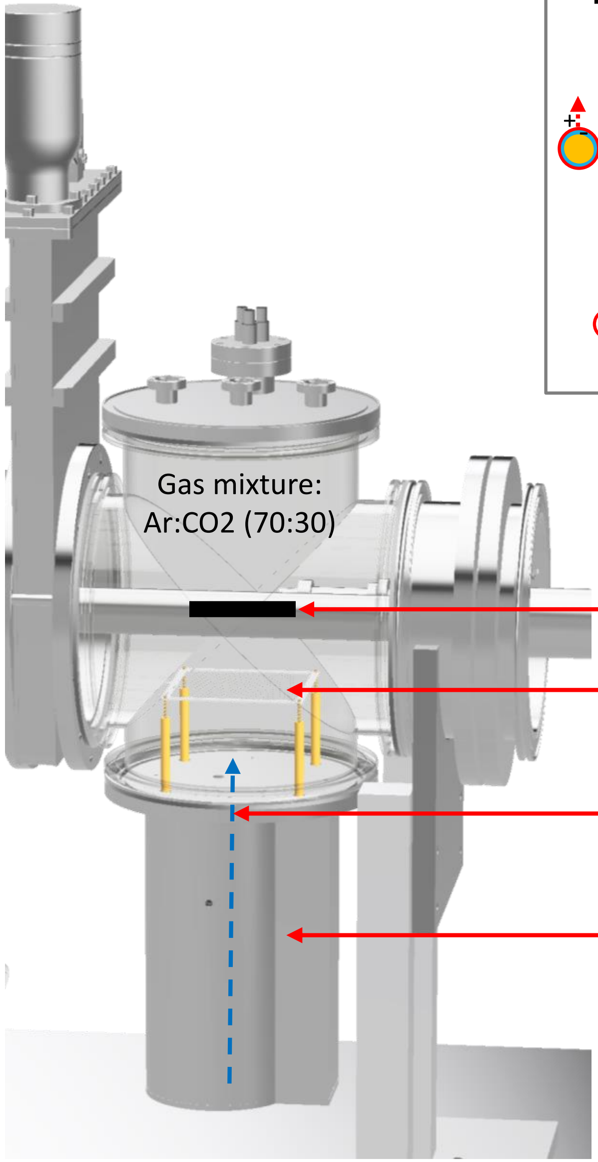


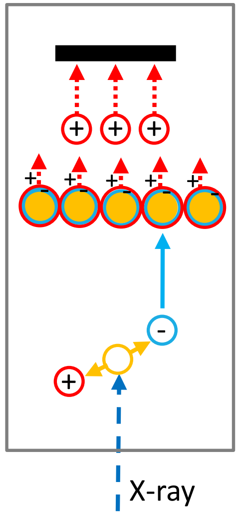


Irradiation mode

Gas during irradiation







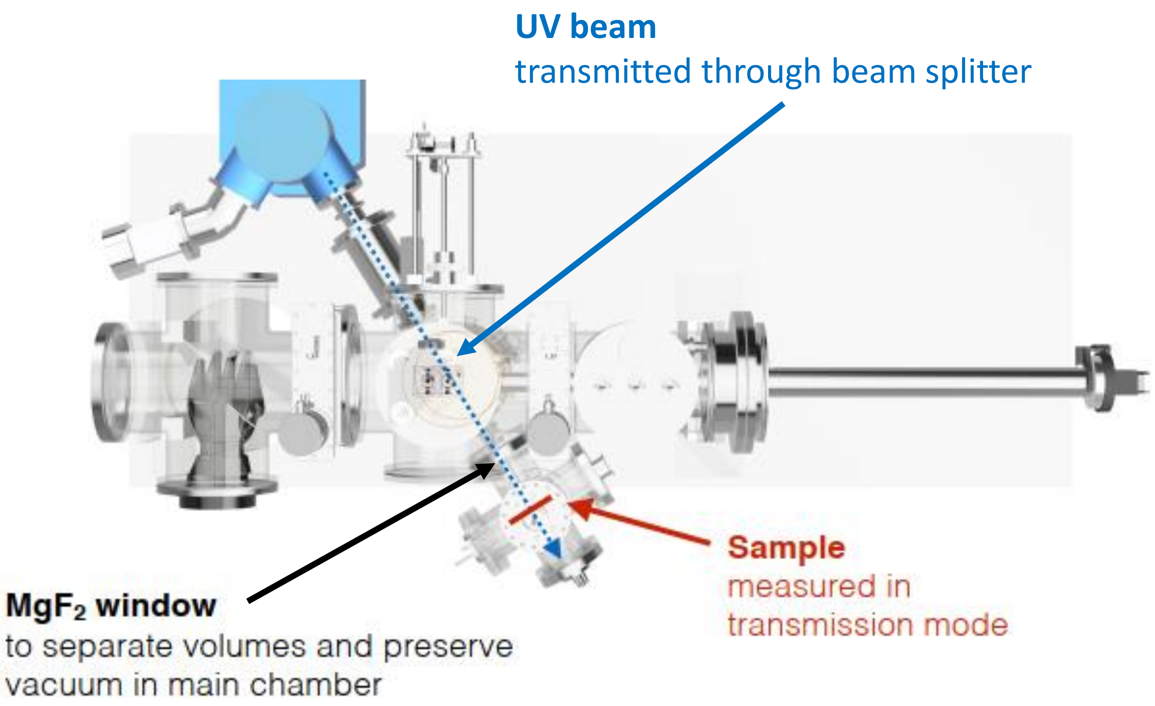
3. Irradiated sample (grounded):
Attraction of ions from avalanche
Accumulation of charge

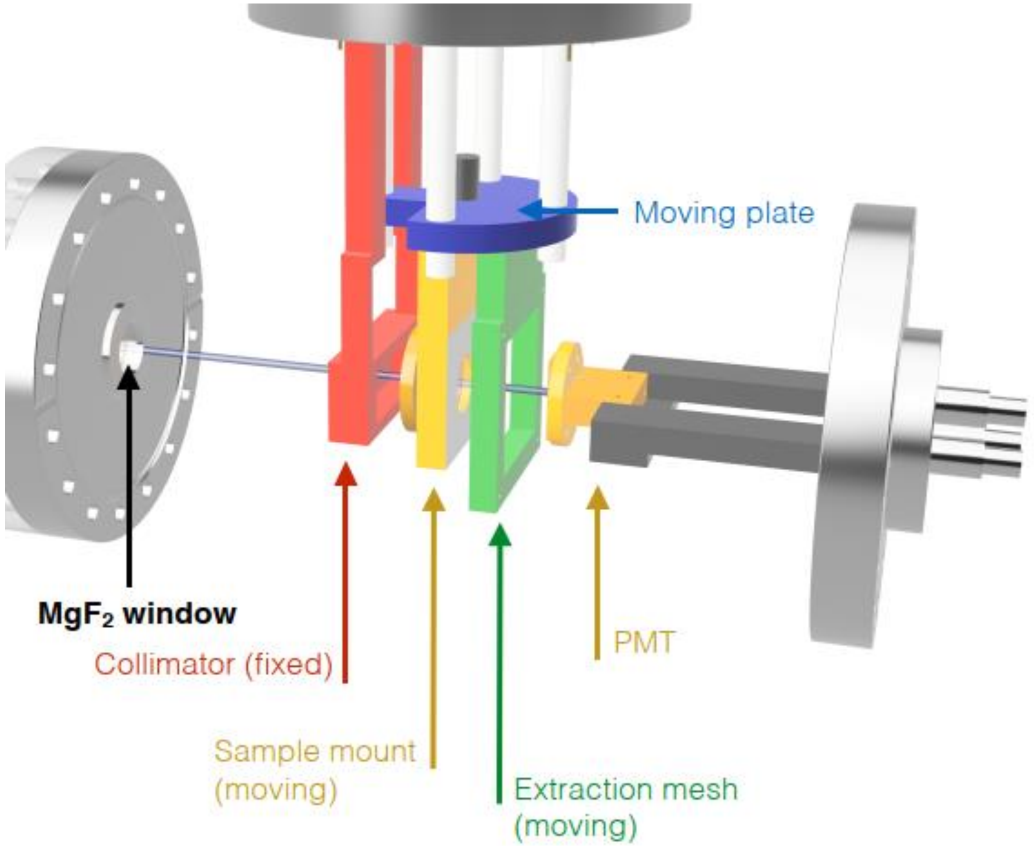
2. Multiplication wires (positive HV):
Attraction of primary electrons
Avalanche multiplication
Production of electrons and ions

1. X-ray beam in a gas chamber:
Ionization of particles
Creation of primary charge

Transmission mode

Vacuum during measurement





ASSET

Measurement capabilities

Photocurrent, QE, transparency measurements

Reflective/Transmission mode

- Measurement of photocurrent and calculation of QE (both modes) and transparency (only transmission mode).

- $$QE = \frac{Electrons_{sample}}{Photons_{PMT}} = \frac{\frac{I_{sample}}{e}}{\frac{Electrons_{PMT}}{CalFac_{PMT}}} = \frac{\frac{I_{sample}}{e}}{\frac{I_{PMT}}{e \cdot CalFac_{PMT}}} = \frac{I_{sample} \cdot CalFac_{PMT}}{I_{PMT}}$$

$Electrons_{sample}$ - electrons extracted from sample (measured on sample in meas. position)

$Photons_{PMT}$ - photons that arrived to sample (measured on PMT in meas. position)

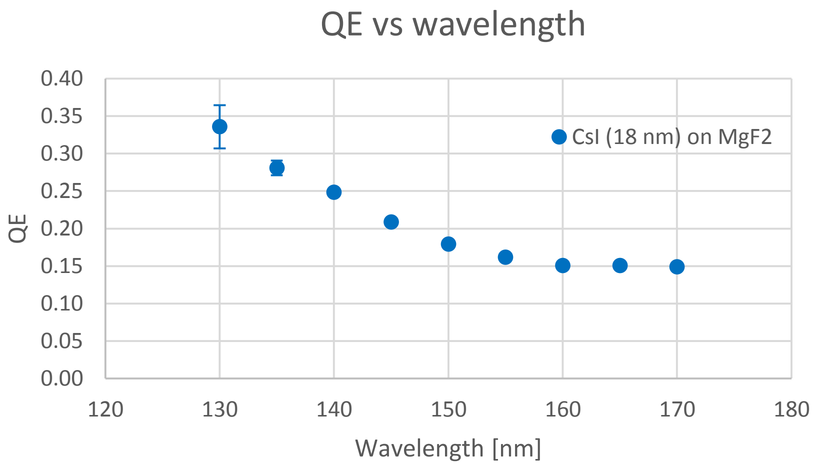
I_{sample} - current measured on sample (offset subtracted)

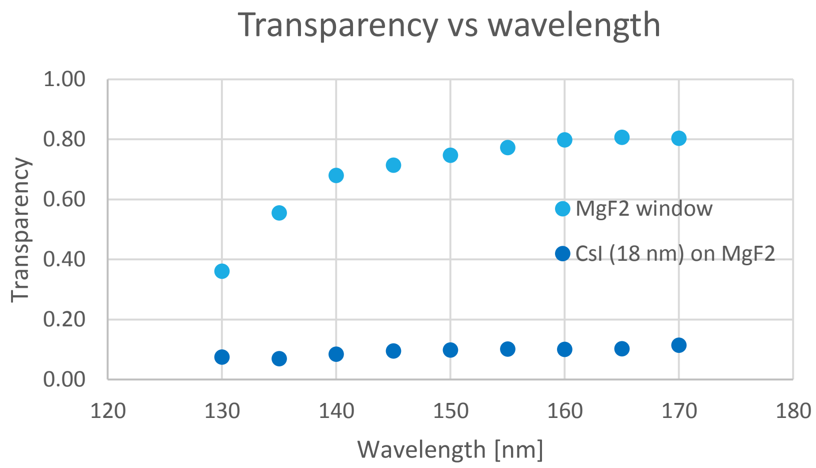
I_{PMT} - current measured on PMT (offset subtracted)

$CalFac_{PMT}$ - calibration factor from calibrated CsI PMT (depends on wavelength)

$e = 1.602 \cdot 10^{-19}\ [C]$ - elementary charge

- $$\text{Transparency} = \frac{\text{PMT current: sample in}}{\text{PMT current: sample out}}$$

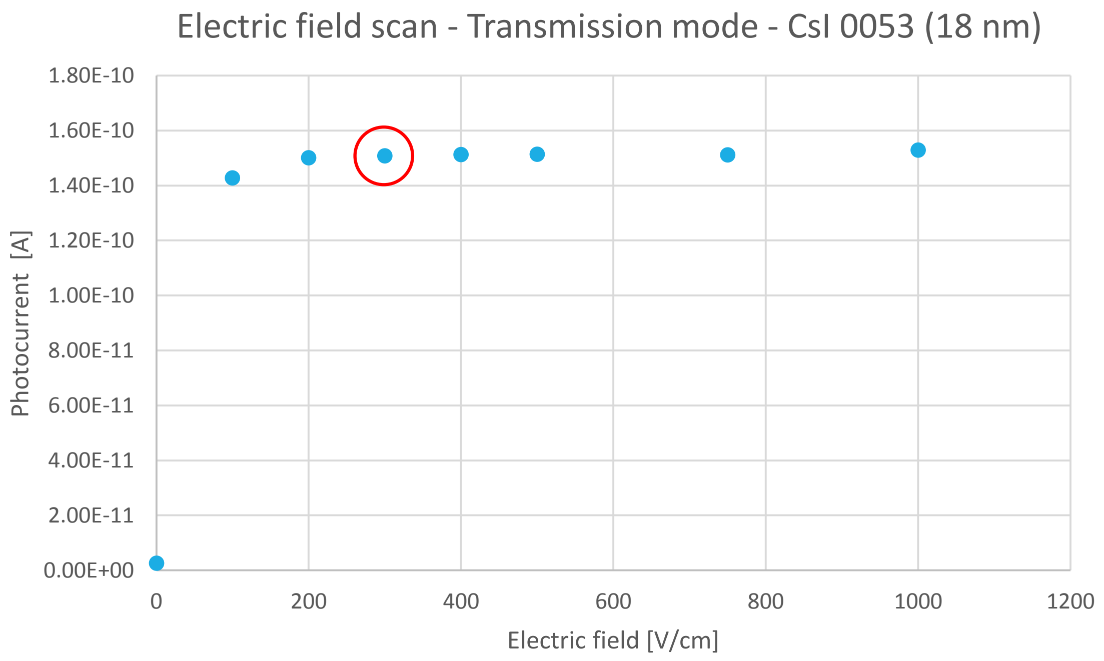


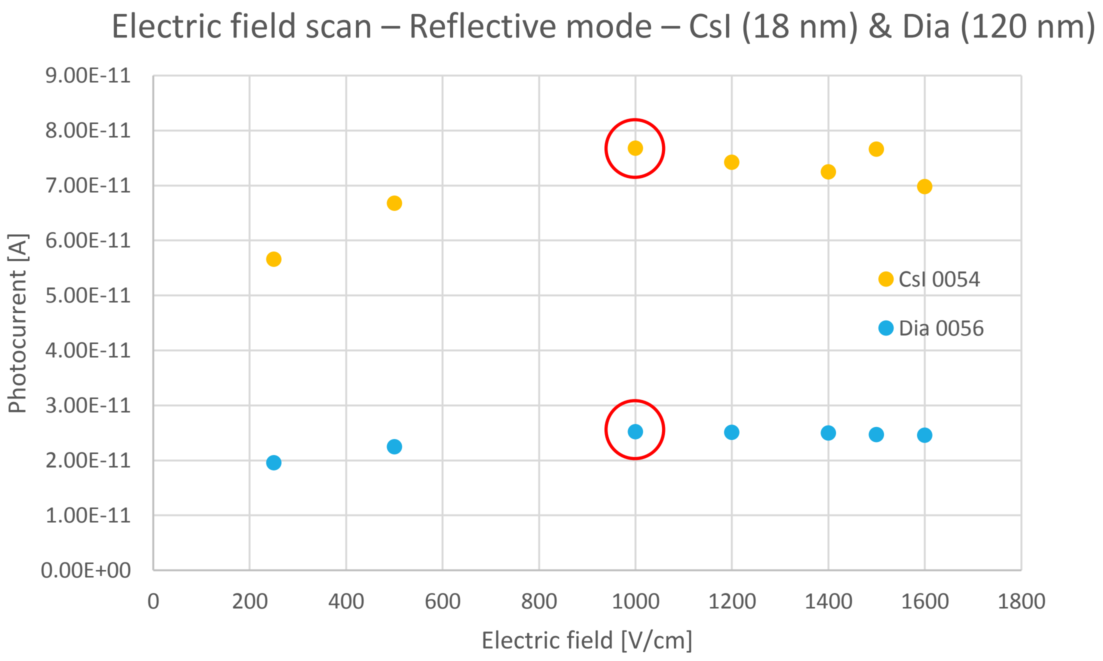


Electric field scanning

Reflective/Transmission mode

- To determine efficient extraction voltage for different samples.
- Photocurrent measured @ WL = 160 nm (+- 5 nm).
- Drift gap: transmission mode: 1 cm; reflective mode: 0.5 cm.
- Electric field set at plateau: transmission mode: 300 V/cm (U = 300 V); reflective mode: 1000 V/cm (U = 500 V).

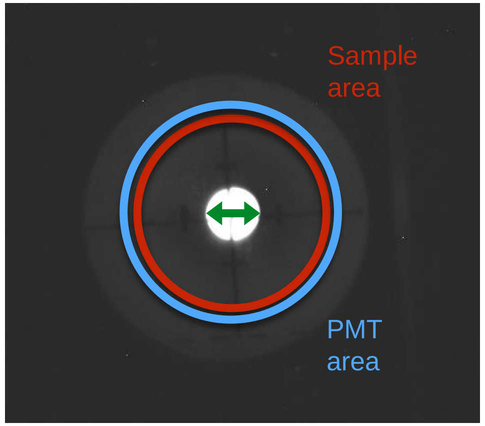


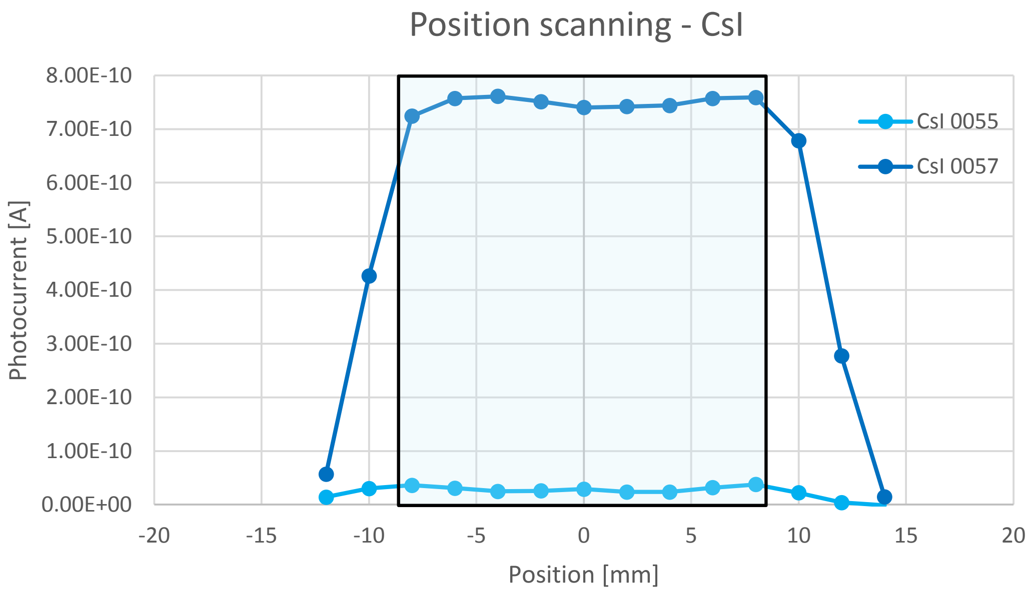


QE uniformity scanning

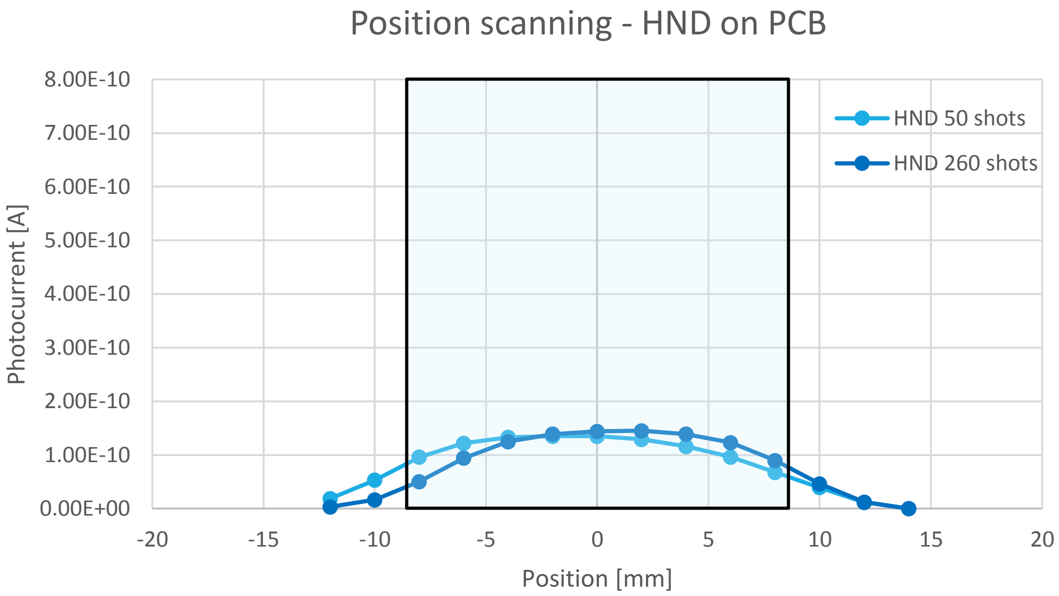
Reflective mode

- UV beam dia. 5 mm; scanning area dia. 17 mm.
- Photocurrent measured @ WL = 160 nm (+- 5 nm).
- Samples: CsI (18 nm) and hydrogenated nanodiamonts (HND):
  reference, T. Triloki: https://indico.cern.ch/event/872501/contributions/3728175/
- Extraction grid: V = 500 V for CsI, V = 1000 V for HND on PCB.





- CsI samples have profile with edges decreasing when spot is off sample.
- CsI 0055 has lower photocurrent than CsI 0057 due to degradation.

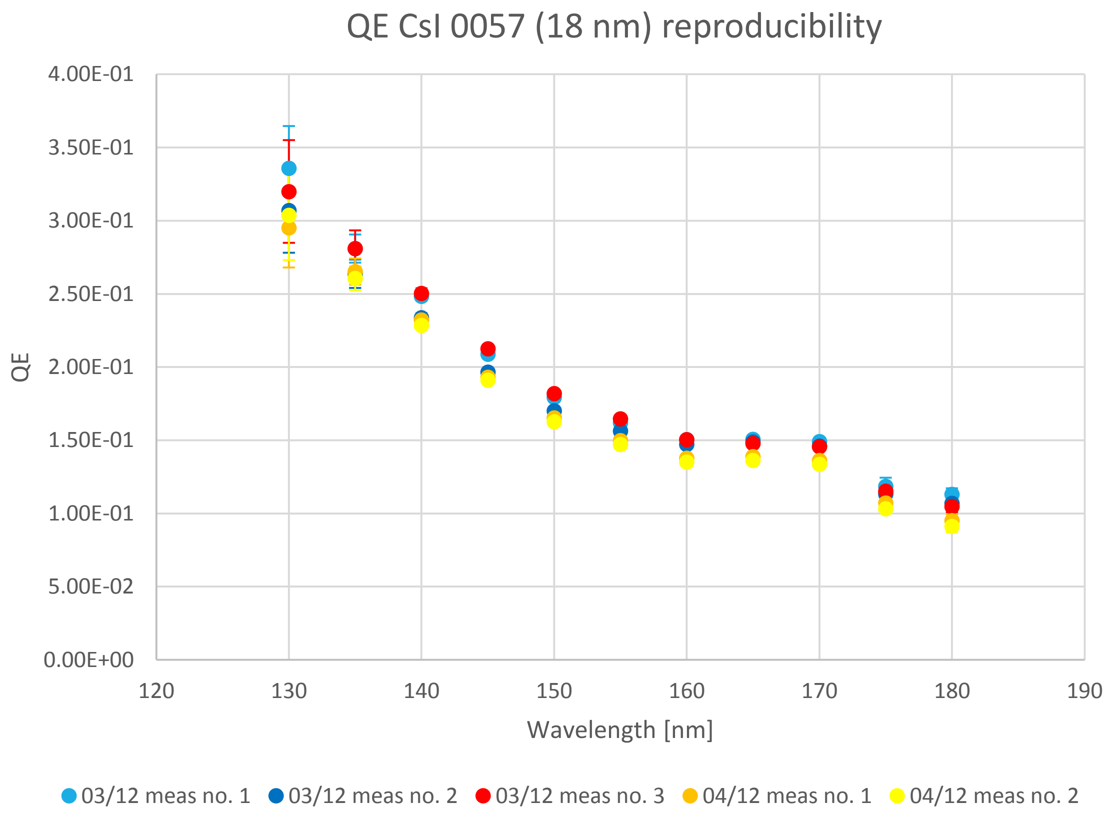


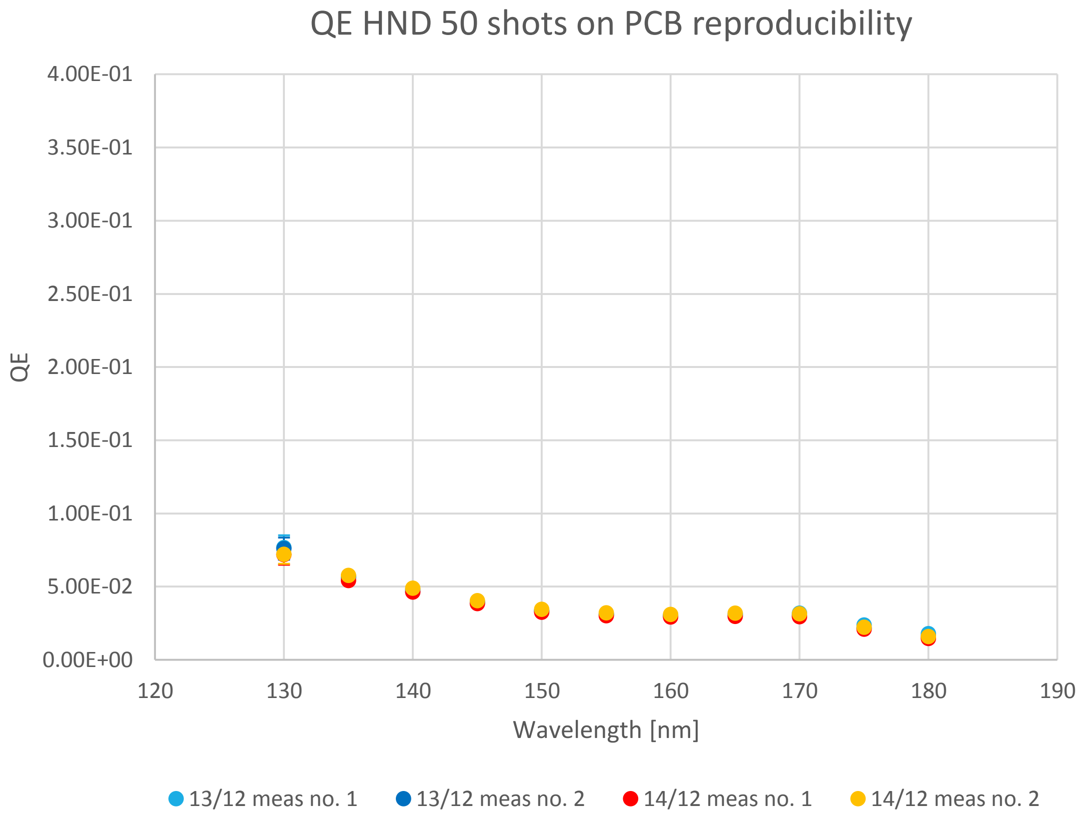
- HND on PCB samples have a gaussian shape profile.
- HND on PCB samples have lower photocurrent than CsI.

Reproducibility

Reflective/Transmission mode

- The results mostly overlaps.
- Minor fluctuations between measurements may come from: different amount of light, different pressure, CsI degradation…

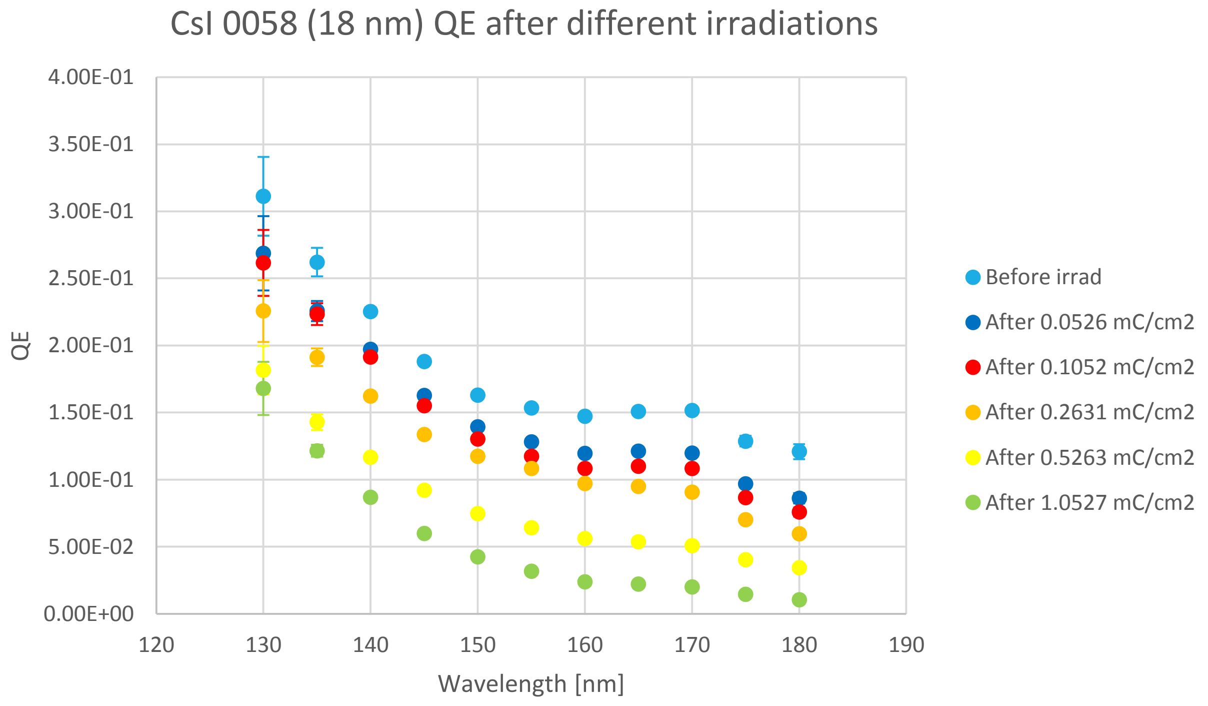


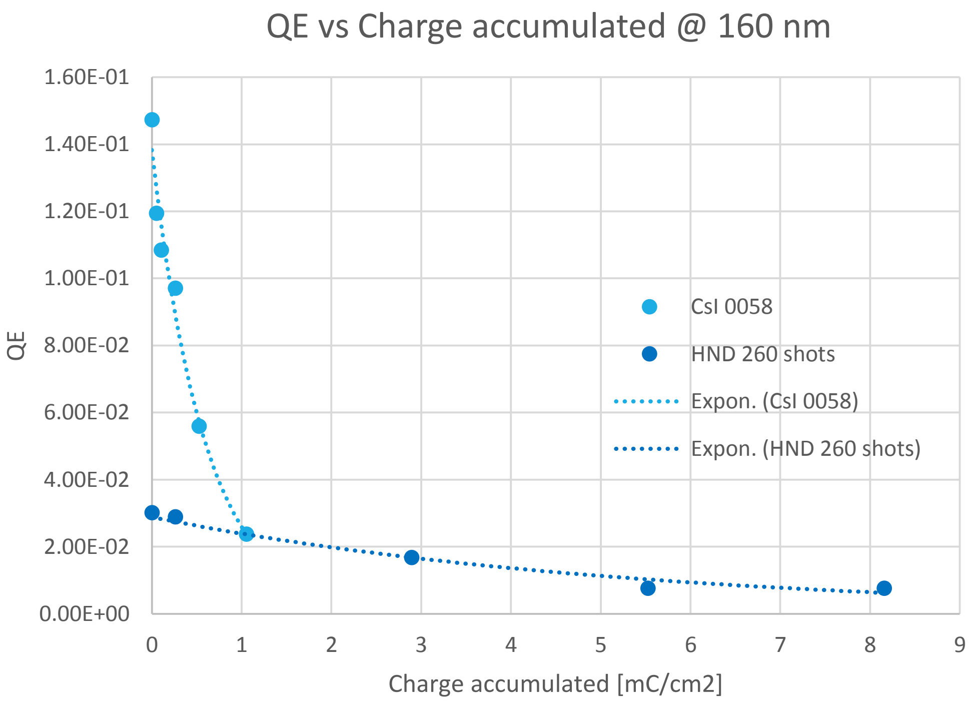


Ageing studies under ion bombardment

Reflective mode

- Studies of the CsI (18 nm) and HND (260 shots) degradation due to ion bombardment.
- Sample: dia. 1 inch circle; accumulated charge normalized to cm^2.



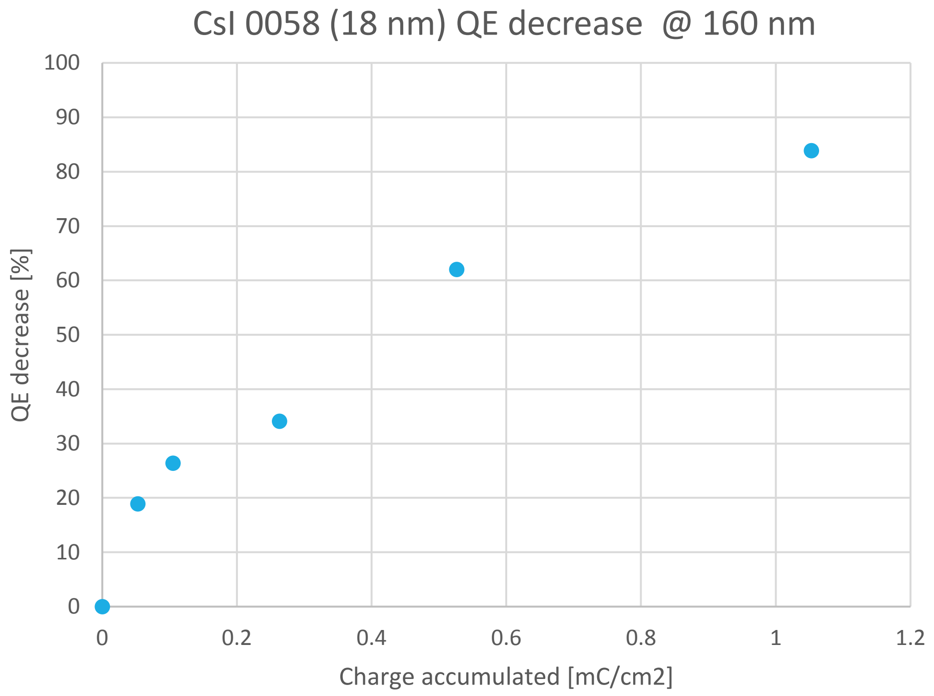


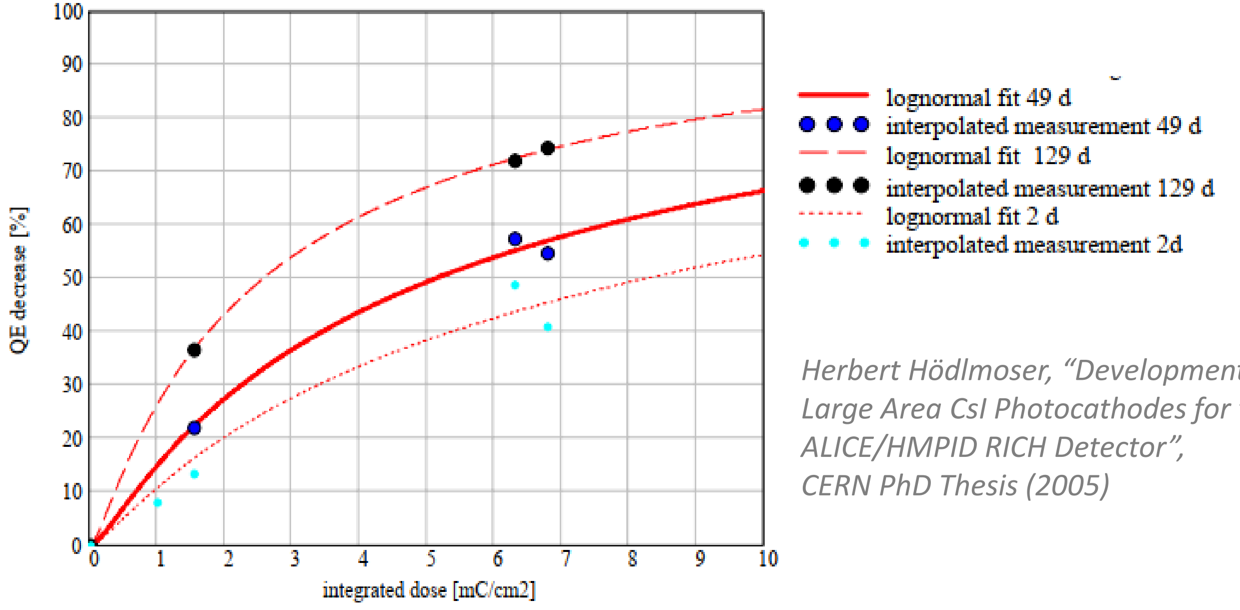
- Result: the dependence of QE vs charge accumulated has an exponential decay character.

Ageing studies under ion bombardment

Reflective mode

- Studies of the CsI (18 nm) degradation due to ion bombardment.
- Comparison of the QE decrease results with the literature.





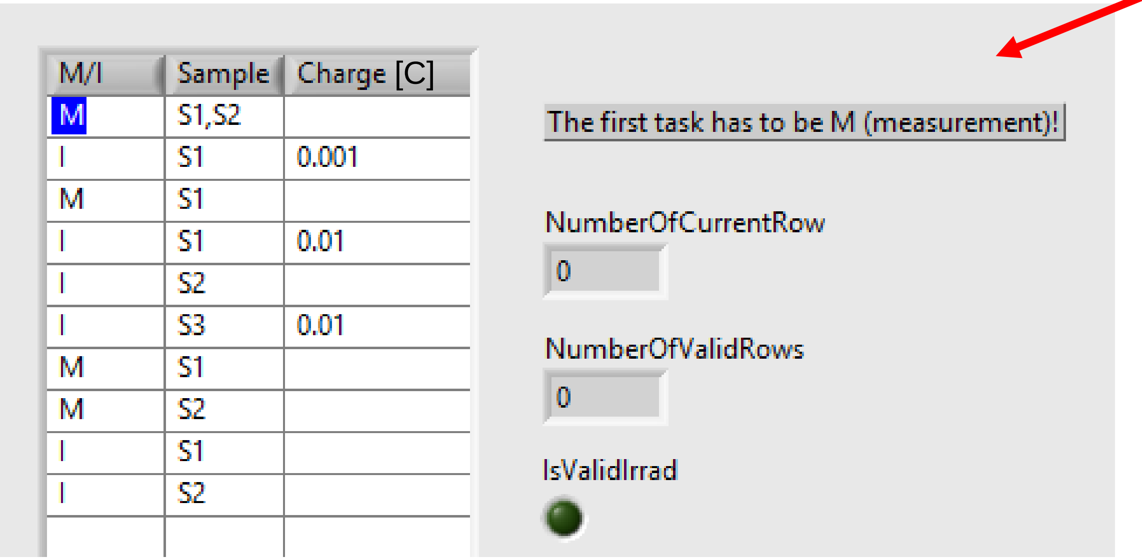
Herbert Hödlmoser, "Development of Large Area CsI Photocathodes for the ALICE/HMPID RICH Detector", CERN PhD Thesis (2005)

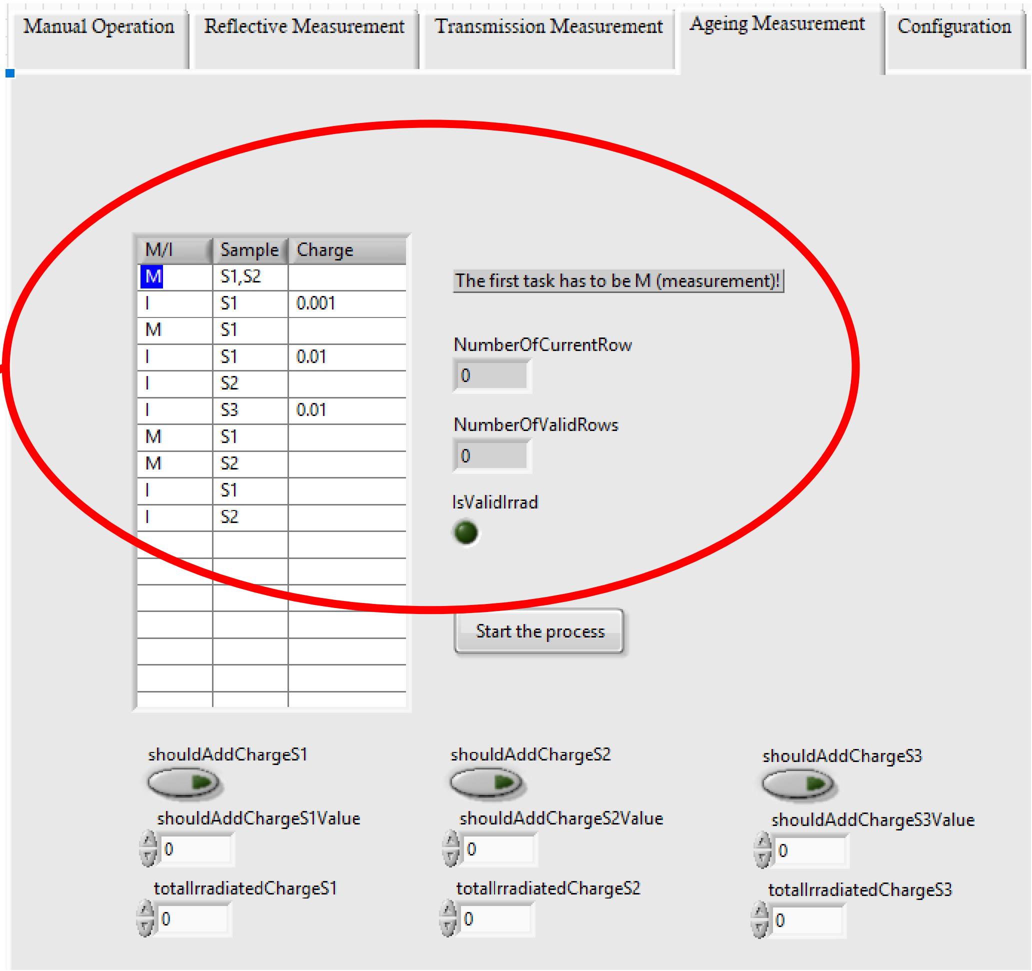
- Future plans: new CsI samples with protection layers: LiF and MgF_2 (2 nm); another possibility: graphene layer.

Automated M/I routine

Reflective mode

- Fully automated LabVIEW procedure of measurements and irradiations of the samples in reflective mode.
- The interface allows to select:
  - task: M (measurement) or I (irradiation);
  - sample (S1, S2, S3);
  - charge to be accumulated (in case of irradiation).





Summary

- ASSET is a photocathode characterisation device used to:
  - Quantify the degradation of photocathodes when exposed to ion back flow.
  - Examine possible alternative photocathode materials as well as protective layers.
- The setup permits reflective and transmission mode measurements as well as irradiation studies.
- Performed measurement campaigns with:
  - DLC photocathodes (USTC),
  - B4C photocathodes (CEA Saclay),
  - CVD Diamond samples (RAS),
  - Nanodiamond photocathodes (INFN Trieste/Bari),
  - CsI photocathodes (CERN).
- Limitation and plans:
  - Increase sensitivity and wavelength range.
  - Possibly move to closer focus.
  - QE in gas measurements.

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Thank you for your attention ☺

ASSET

Backup

Collimating optics

To extend sensitivity and wavelength range

- Currently limited due to low amount of UV light focused onto sample.

- Simple collimating lens has strong wavelength-dependence of focal length.
- Most of the light lost due to defocusing:
  - limited sensitivity;
  - limited accessible wavelength range.

- Collimating/focusing chamber can significantly increase amount of light focused onto sample and thus extend sensitivity and accessible wavelength range:
  - no wavelength-dependence;
  - maintains focus.