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AIDA-2020 WP15 satellite meeting, 7th BTTB Workshop

# D15.7: IRRAD Facility Beam Profile Monitors and Sample Holders Upgrades

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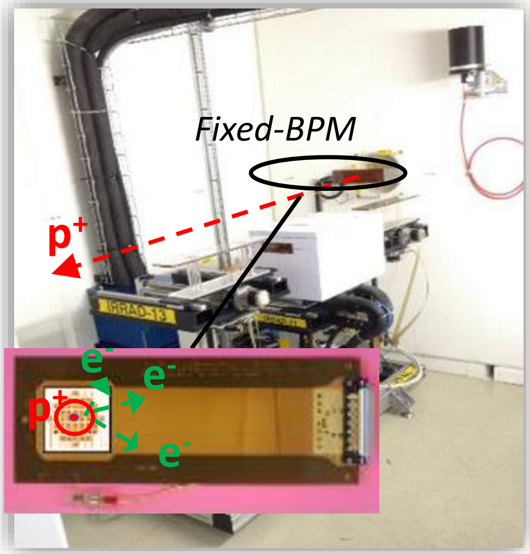
CERN, 14/01/19

IRRAD Proton Facility

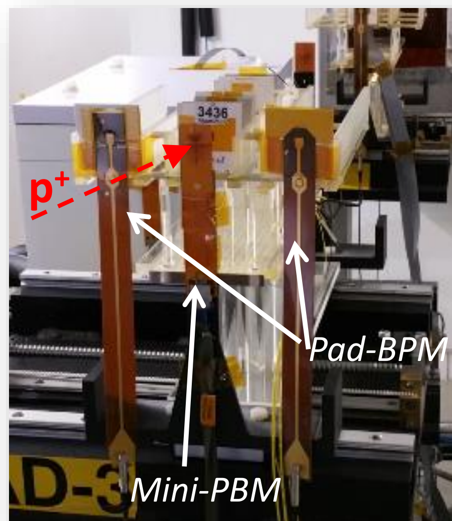
# I. BEAM PROFILE MONITORS UPGRADES

# Beam Profile Monitor (BPM) System

- Patterned copper foils placed perpendicular to the beam. Signal generation via secondary electron emission (SEE)
- 3 patterns
  - Fixed BPM: beam alignment (40 channels)
  - Mini-BPM: Table alignment (9 channels)
  - Pad BPM: In beam/Out of beam detector (1 channel)
- Dedicated BPM DAQ unit can read out 1 Fixed BPM or 4 x (1 Mini + 1 Pad)




*Fixed BPM*



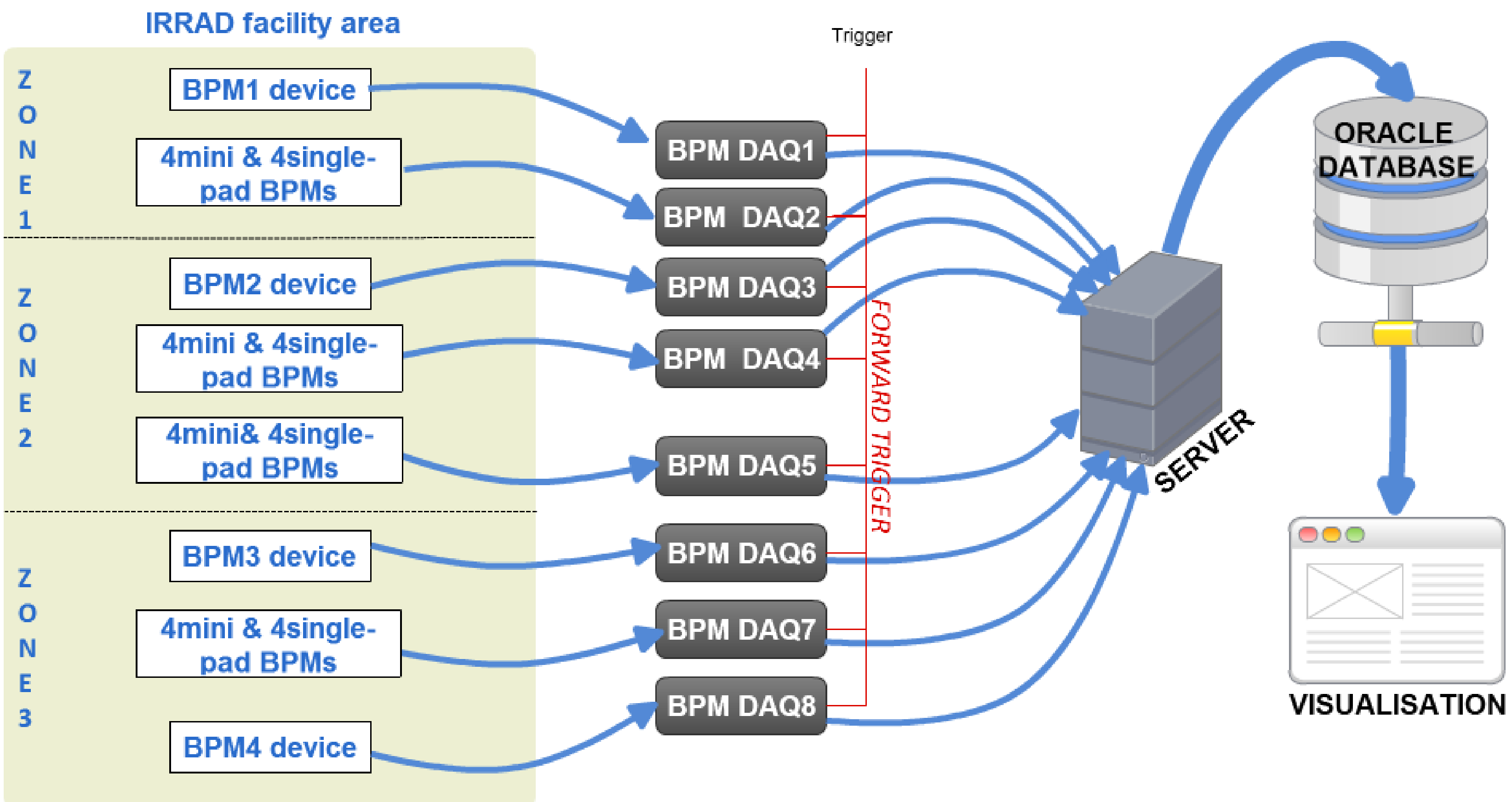

*Mini-BPM and Pad BPM*


*DAQ unit*

*See F. Ravotti, "The Beam Profile Monitoring System for the CERN IRRAD Proton Facility", International Beam Instrumentation Conference, Barcelona, 2016.doi:10.18429/JACoW-IBIC2016-WEPG75*

# Architecture

IRRAD BPM infrastructure since 2017 irradiation campaign:




See B. Gkotse, M. Glaser, E. Matli, F. Ravotti, "System architecture and data processing capabilities of the Beam Profile Monitor for the CERN IRRAD Facility", In Proc. IEEE Nuclear Science Symposium Conference (NSS/MIC 2016), Strasbourg, France, October 29 – November 06, pp. 1-4, doi: 10.1109/NSSMIC.2016.8069891, ISBN: 978-1-5090-1642-6, 2016

# BPM Information Display

The data from the different BPM is available to the IRRAD operators/users and beam operators at the CERN Control Center (CCC) via a set of web based visualization tools.

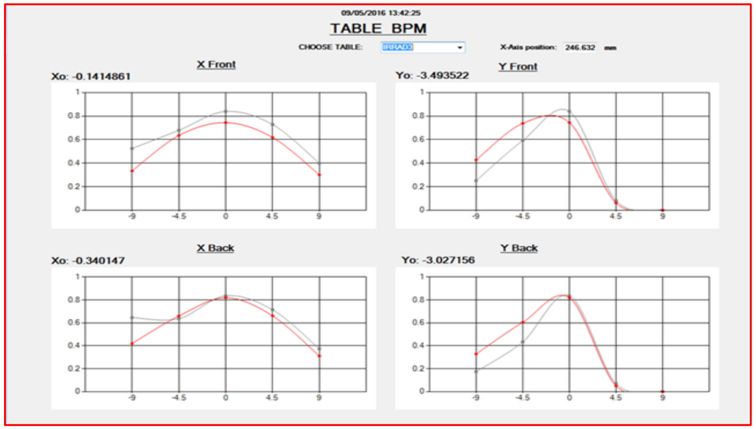



*Table alignment (Mini-BPMs)*

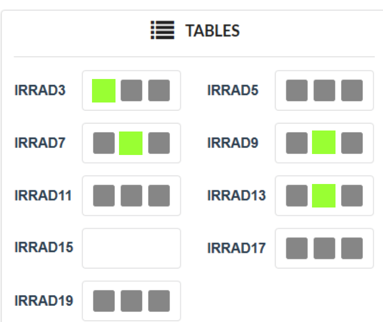
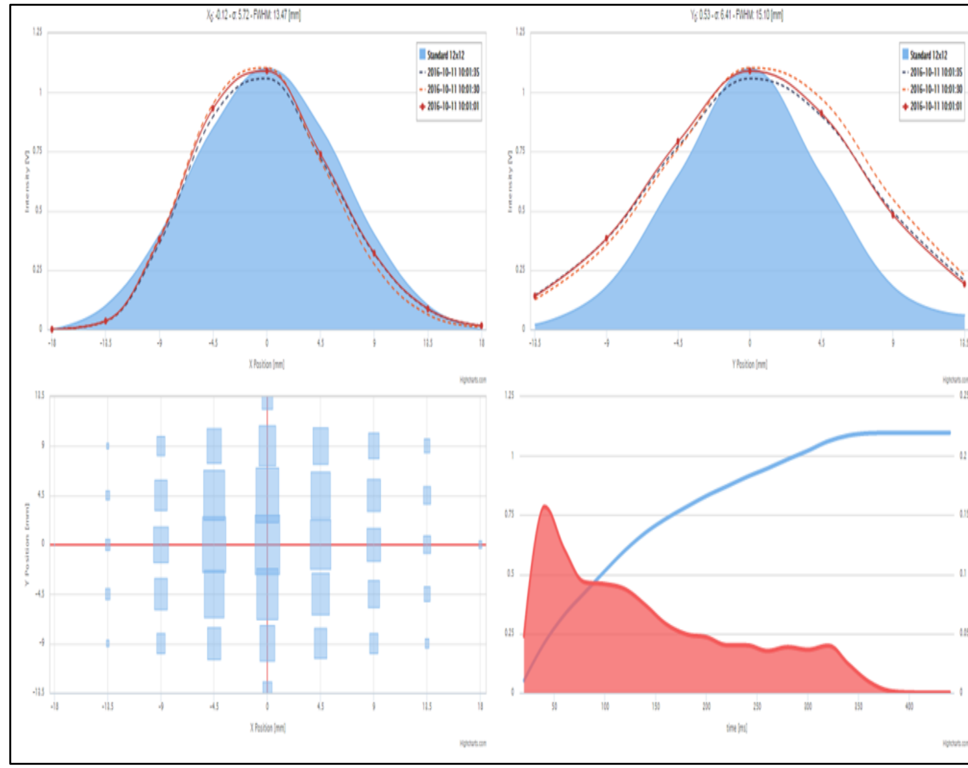


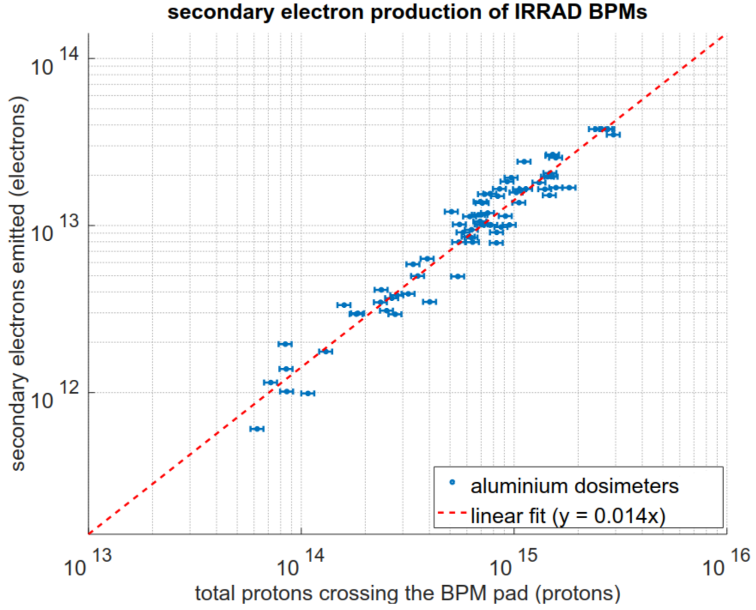

*Table position (Pad BPMs)*

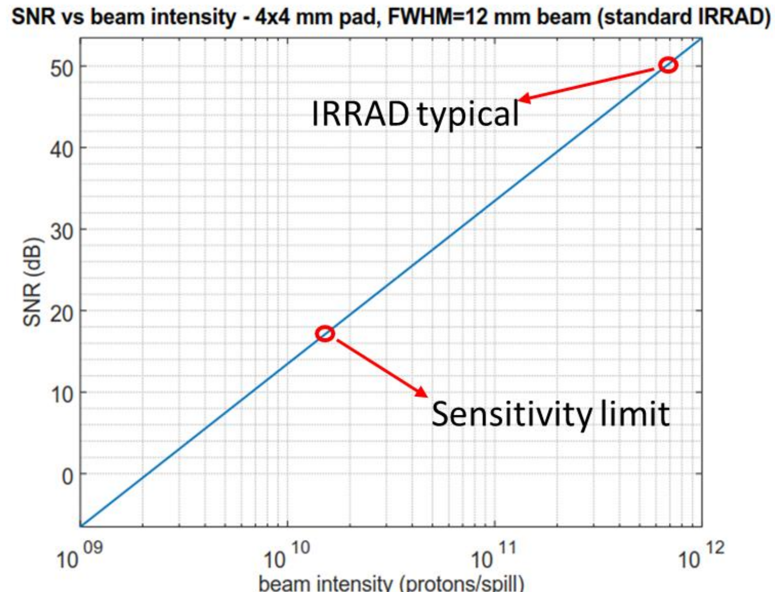


*Beam Profile (Fixed BPMs)*

# BPM Performance

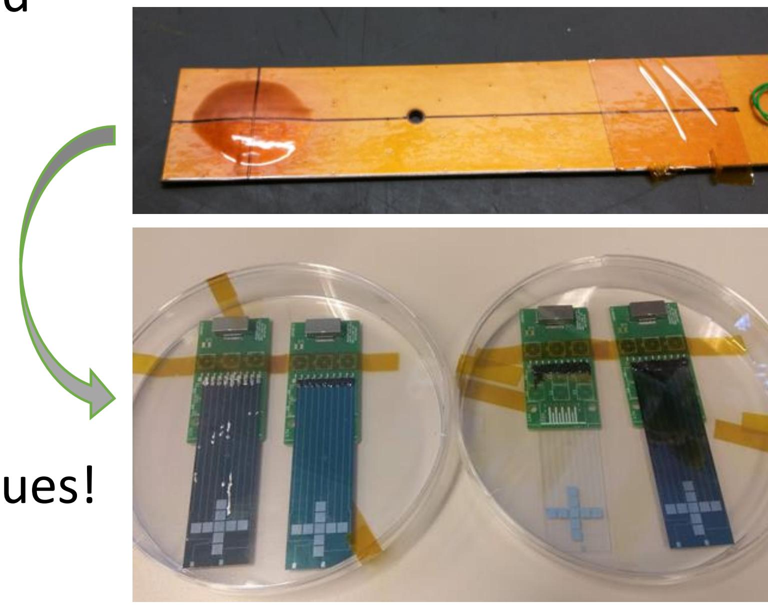
- Complete performance analysis of the BPM system can be found in the D15.7 document (being prepared). It includes:
  - Linearity of response for different beam intensities ➔ BPM response was found to be linear in all range of intensities used during the operation.
  - Calibration of the secondary electron yield (SEY) of the IRRAD BPMs based on the aluminium foils used for dosimetry ➔ **The SEY was measured at 1.4%** , in line with previous findings at CERN.
  - Sensitivity analysis ➔ Considering the original design requirement (SNR = 50 (17dB) on the central pad), the **minimum measureable beam intensity is of 1.5e10 protons/spill.**
  - Verification of correct functioning for special beam conditions **(fast extraction, heavy ion beam).**



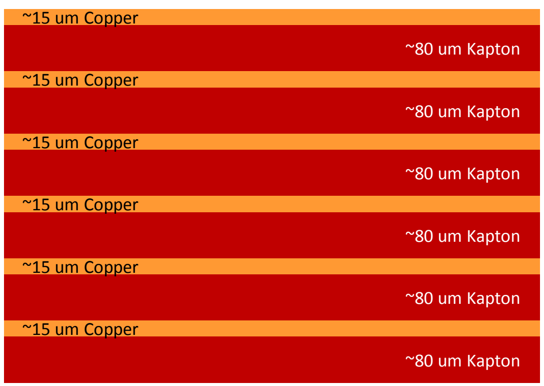



# Development of a new RadHard BPM (μ-BPM)

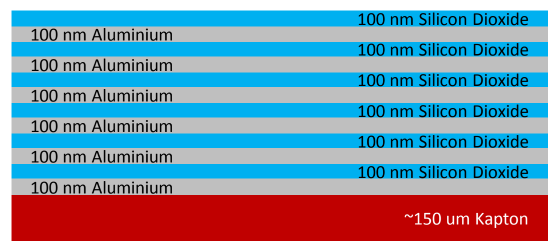
- Today`s mini-BPMs are produced with standard PCB manufacturing techniques, and show:
  - **(relatively) low "transparency"** to the beam
  - **big degradation** due to glue bubbling/burning
    - ➢ *Need to change* INSULATING MATERIAL
    - ➢ *Ideally, avoid glue*
  - **very radioactive** and long cool-down required
    - ➢ *Need to reduce* THICKNESS OF METAL
- This is possible using microfabrication techniques!



*Different stacks were produced and tested*




**2.5x** thinner
~**200x** less metal




CMi EPFL Center of MicroNanoTechnology

**Mini-BPM**: 6 layers 0.5 mm thick ~100 um of Cu

**Micro-BPM**: 6 layers 0.2 mm thick, 0.6 um of Al

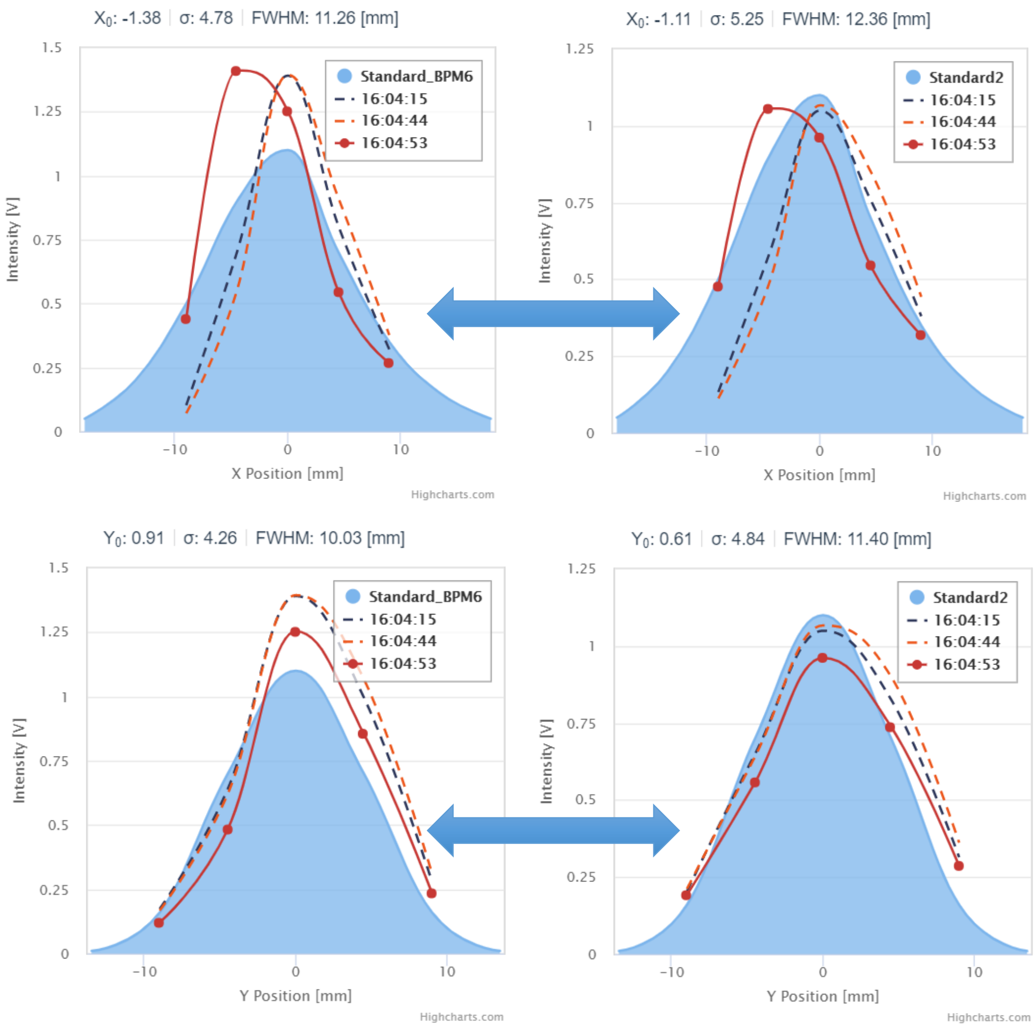
1. *Submission to the 7th International Conference on Radiation in Various Fields of Research (RAD2019: http://www.rad2019.rad-conference.org/);*
2. *Submission to NIMA (https://www.journals.elsevier.com/nuclear-instruments-and-methods-in-physics-research-section-a-accelerators-spectrometers-detectors-and-associated-equipment/).*

# Development of a new RadHard BPM (μ-BPM)

Mini-BPM | Micro-BPM

X profile

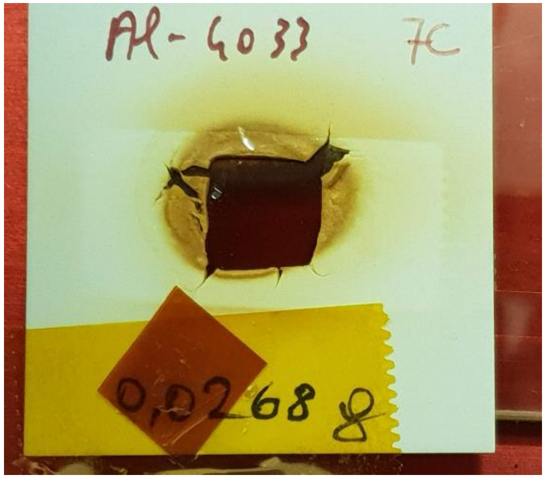
Y profile



# II. SAMPLE HOLDERS UPGRADES

# Motivation

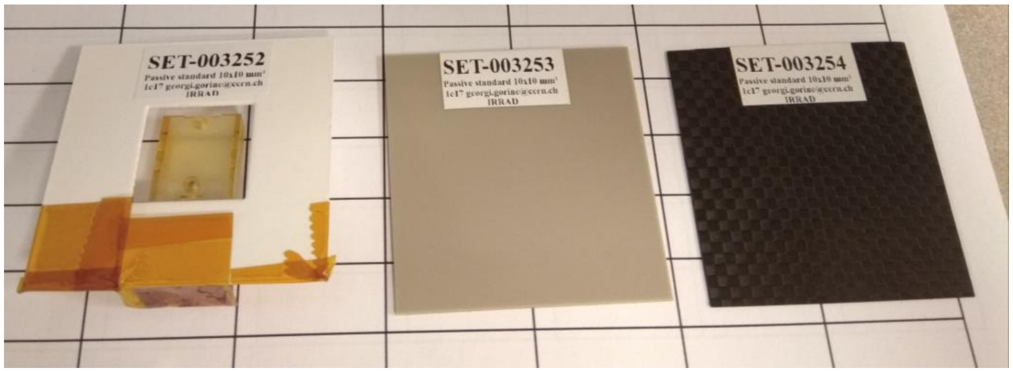
- ~2e18 protons on target in 5 years in IRRAD and ~30% of experiments in the range of 1e16-1e17 protons/cm2 in 2018.
- A new generation of sample holders is required in IRRAD to substitute currently used cardboards which:
  1. After a long irradiation (>$1x10^{16}$ p/$cm^2$), strongly deteriorate being incompatible with HL-LHC requirements.
  2. Cannot be reused, generating a lot of radioactive waste.
  3. Due to impurities in the cellulose can become very radioactive.
- New Sample Holders of more suitable materials where tested in JSI and IRRAD for:
  1. Low activation after a long irradiation.
  2. Fast decay to ease handling.
- Only tests performed in 2018 in IRRAD are reported here
- 2017 tests in JSI reported in *I.Mateu, "IRRAD Facility BPM and sample holders (D15.7) & GIF++ Gas System Upgrade (D15.10)", 2018 AIDA 2020 Satellite Meeting during BTTB6, Zurich.*



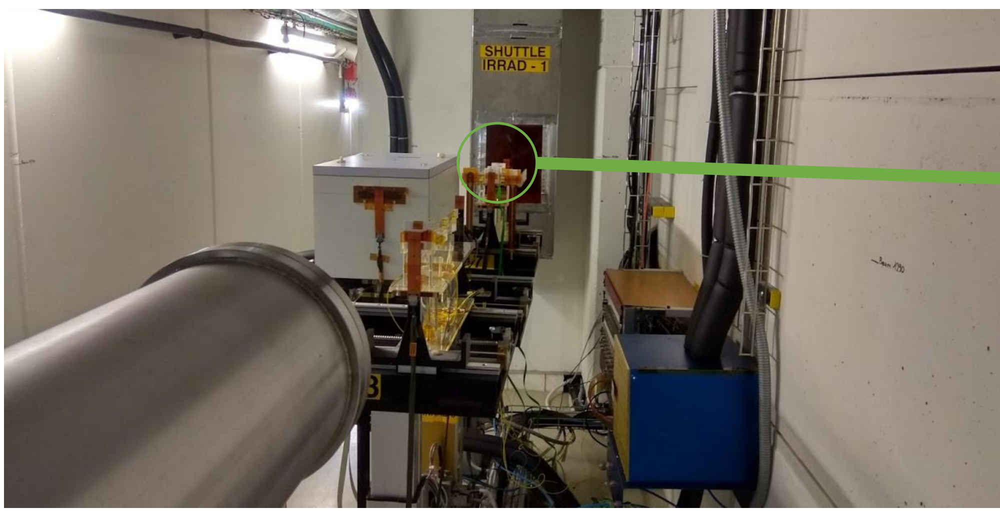

*Current Sample Holder after high fluence irradiation*

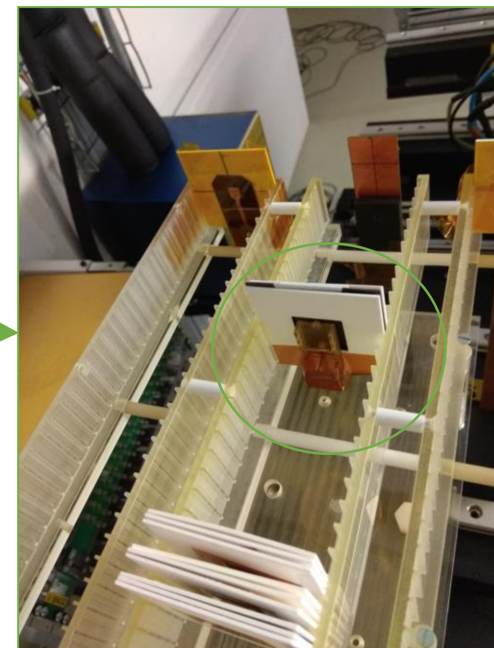
# Tested Sample-Holders

Three samples prepared and installed on IRRAD7



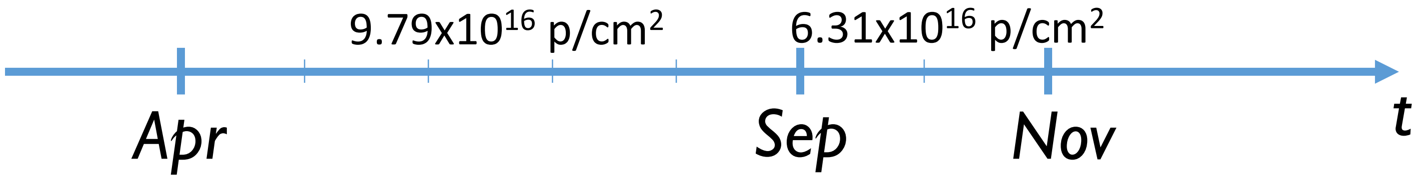

1. ULTEM1000 connector
2. PEEK
3. Carbon Fiber



# Irradiation Steps

- 1st step: from 18/04/2018 to 05/09/2018, $\phi$ = 9.79x10$^{16}$ p/cm
- 2nd step: from 12/09/2018 to 06/11/2018, $\phi$ = 6.31x10$^{16}$ p/cm$^2$
- Overall irradiation: $\phi$ = 1.6x10$^{17}$ p/cm$^2$

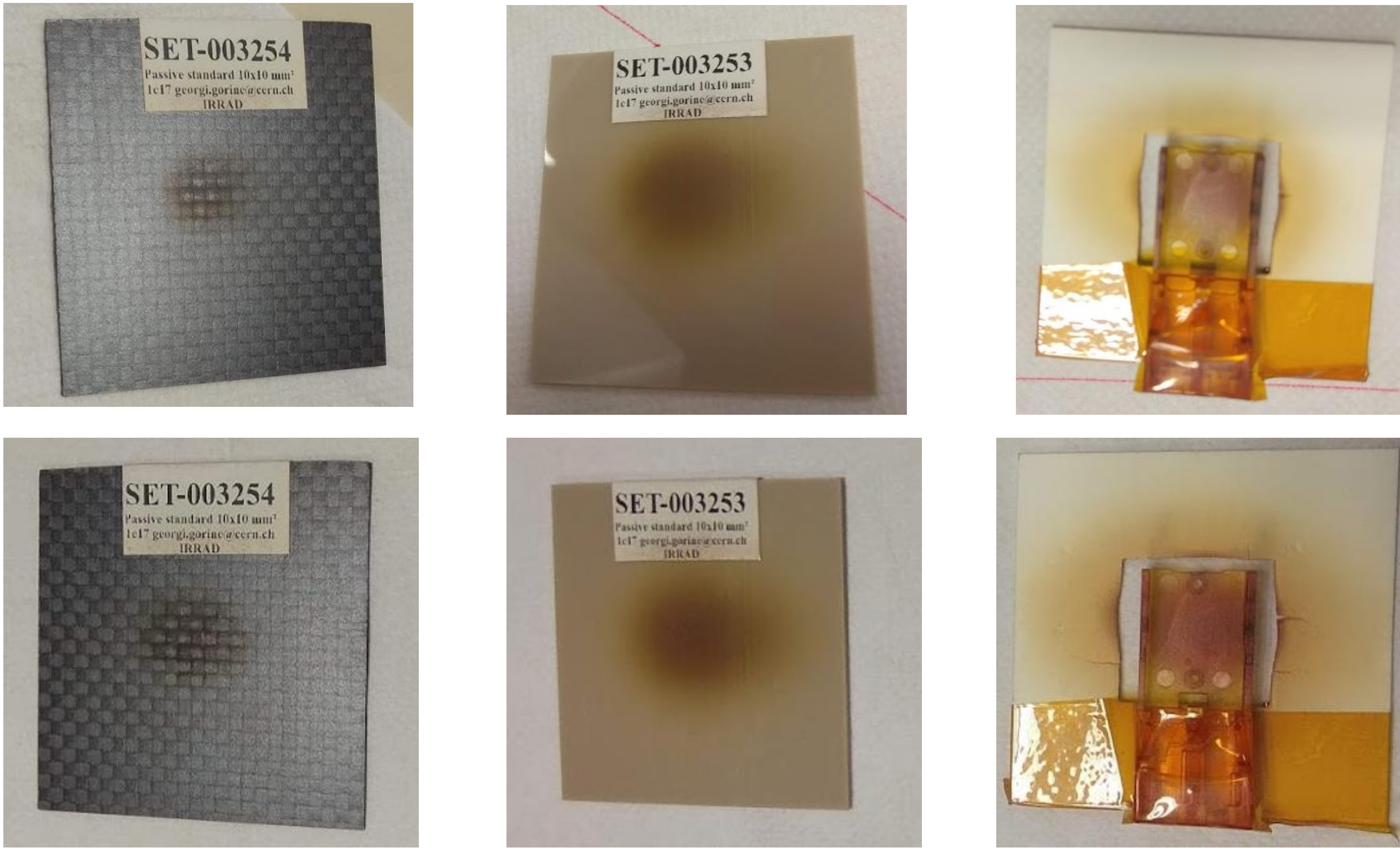


# After first irradiation

Carbon Fiber | PEEK | ULTEM

1st Step

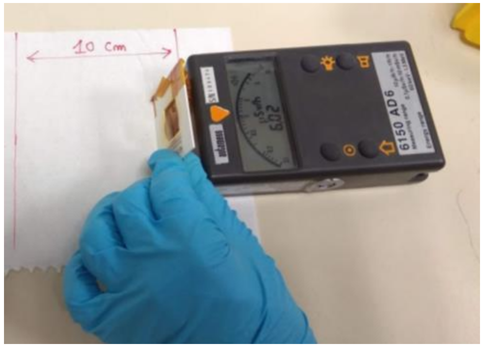
2nd Step



# Dose Rate Tests

- Measuring dose rate with an AD6 @contact and @10 cm distance, to assess the residual induced radioactivity.

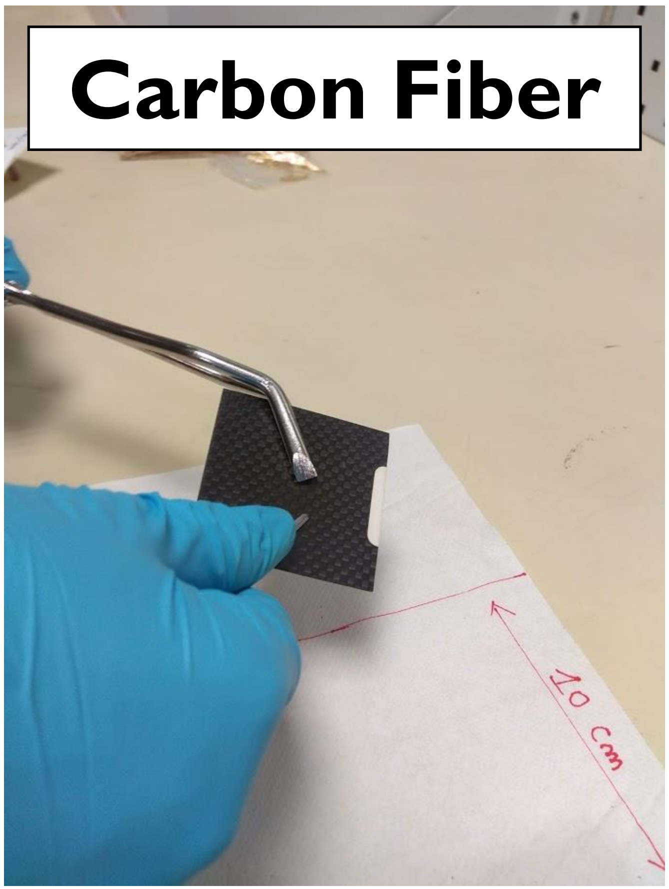
| | 10 CM [uSV/h] | | CONTACT [uSV/h] | | |
|---|---|---|---|---|---|
| Meas Date | **12-09-18** | **20-11-18** | **12-09-18** | **20-11-18** | **09-01-19** |
| Tot p/cm2 | $9.79 \times 10^{16}$ | $1.6 \times 10^{17}$ | $9.79 \times 10^{16}$ | $1.6 \times 10^{17}$ | |
| Cooldown | 7 days | 15 days | 7 days | 15 days | 65 days |
| **ULTEM** | 0.6 | 0.5 | 6 | 13.6 | 10 |
| **PEEK** | 0.5 | 1.1 | 7.5 | 21.4 | 12.5 |
| **CARBON** | 0.7 | 0.5 | 17 | 8.9 | 6 |

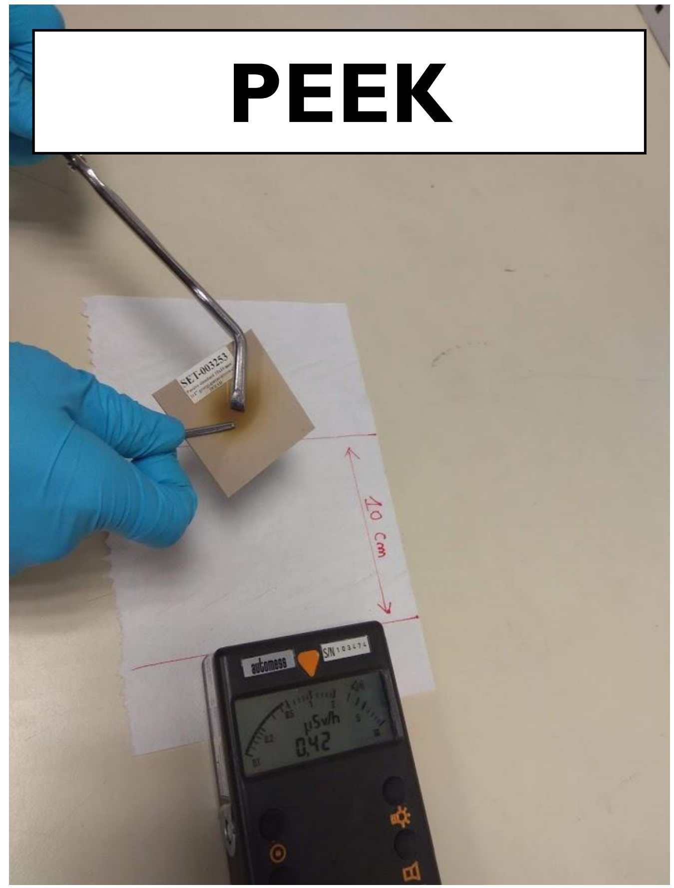




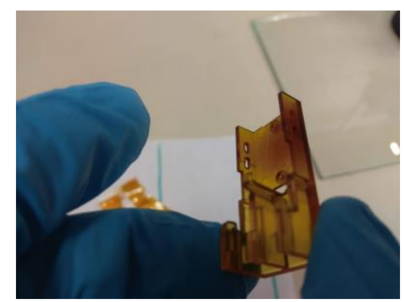
# Stress Test

- Stress test in "operative conditions" by bending the support in order to detach the detector
- No damage neither in the carbon fibre nor the peek laminate.



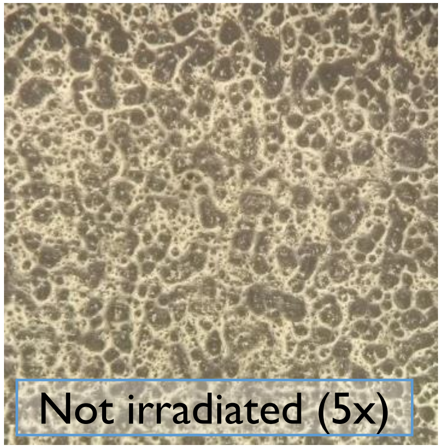



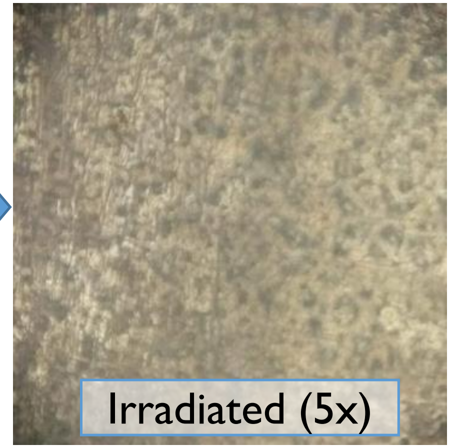

**ULTEM**

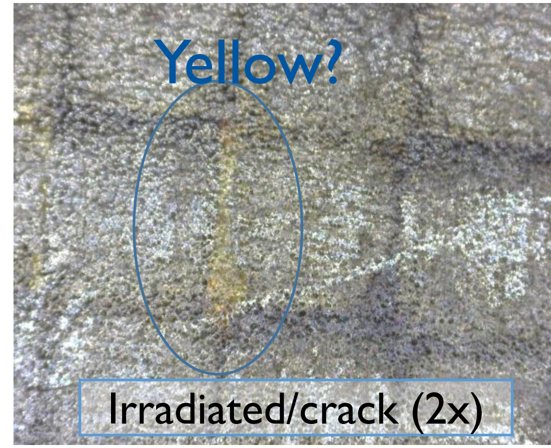


# Microscopic Pictures

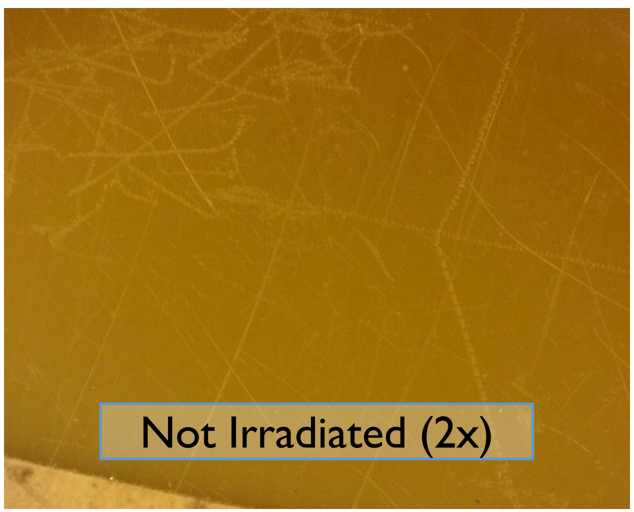
**Carbon Fiber**

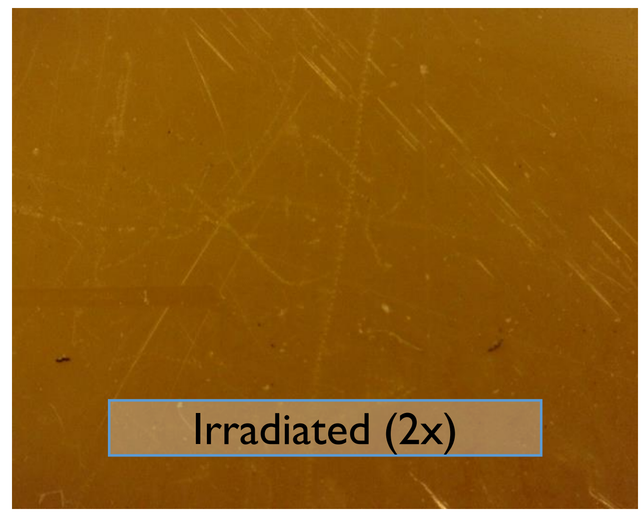



**PEEK**



# Performance Overview

- The final choice of the new Sample Holder material will take into account the results of the irradiation tests, but also other practical aspects such as price, safety regulations, expected lifetime…

| | Activation | Mechanical Strength ($\phi = 10^{17}\ n_{eq}/cm^2$) | Machining At CERN | Price | Recommendation from IS41* | Lifetime ( >1 IRRAD run) |
|---|---|---|---|---|---|---|
| Carbon Fibre | **** | ***** | *** | *** | **** | ***** |
| PEEK | *** | ***** | ***** | ** | ***** | ** |
| ULTEM | *** | ***** | ***** | ***** | ***** | ** |

**IS41 CERN Safety Instruction*

| | |
|---|---|
| ***** | Best |
| **** | Better |
| *** | Good |
| ** | Not so good |

# Conclusions

- Beam Profile Monitor (BPM) System:
  - BPM system plays a major role in the operation of the IRRAD facility.
  - Data analysis showed:
    - 1.4% Secondary Electron Yield.
    - Linear response in all range of beam intensities in IRRAD.
    - Current system could measure 15 times less intense beam.
    - Correct functioning verified for special beam conditions (i.e. fast extraction, heavy ion beam)
  - However, the current BPM detectors suffer from Radiation Damage and replacements are needed frequently.
  - Novel concept for a Radiation Hard BPM, using microfabrication techniques, has been produced and tested with success.
- Sample Holders Upgrades.
  - Different candidate materials irradiated in JSI and IRRAD in 2017 and 2018.
  - Carbon Fibre, PEEK and ULTEM showed low activation and no mechanical degradation after irradiation above $10^{17}$ $n_{eq}/cm^2$.
  - Final choice of material has to take into account other considerations (availability, cost, difficulty to machine…).