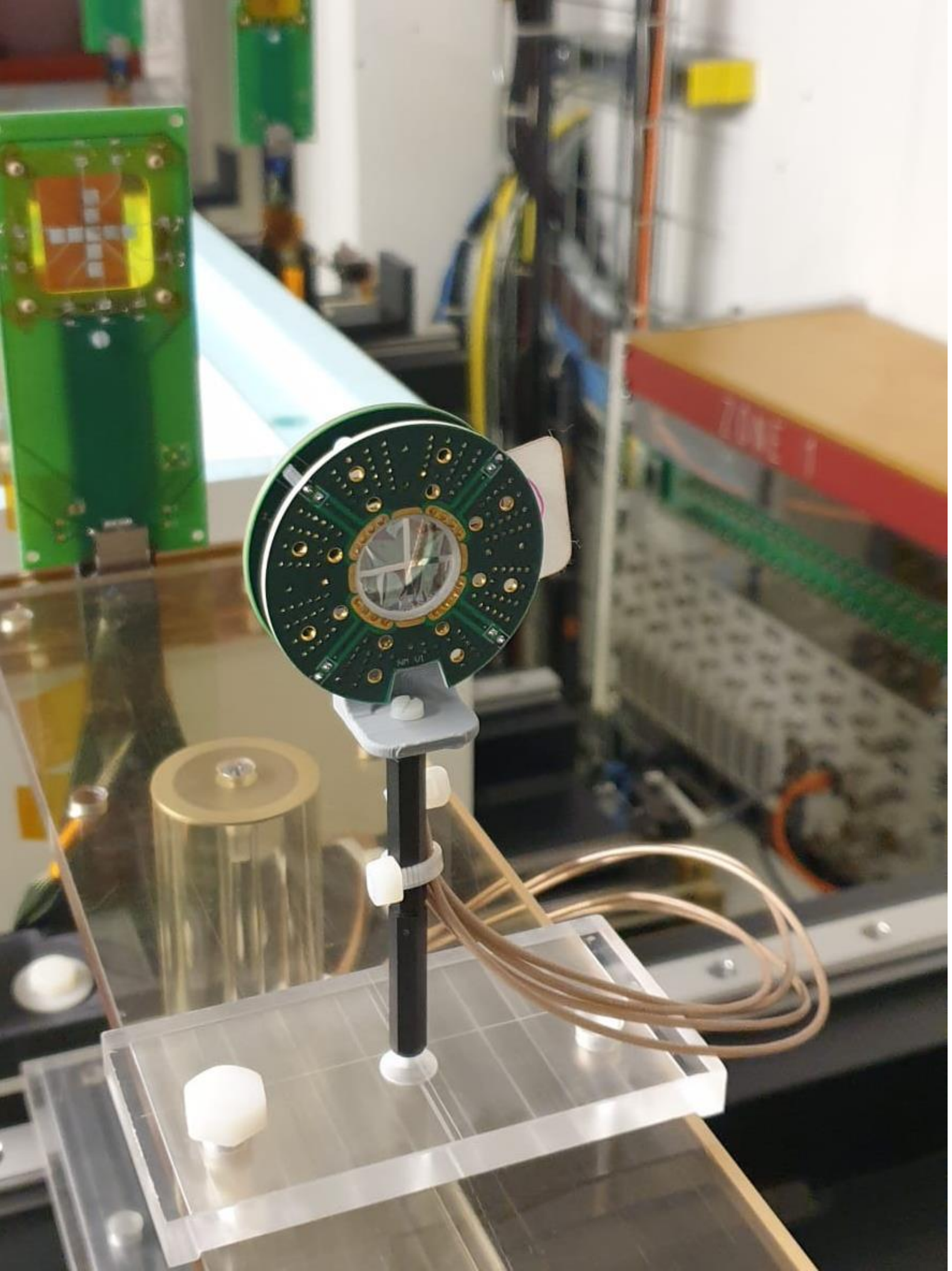

Ultra Thin Secondary Electron Emission Sensors for Beam Monitoring

Nicola Minafra (The University of Kansas (US))

Grant #1945038

Ruggero Caravita°
Michael Doser*
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Stefan Haider*
Robert Loos*
Giuseppe Pezzullo*
Federico Ravotti*

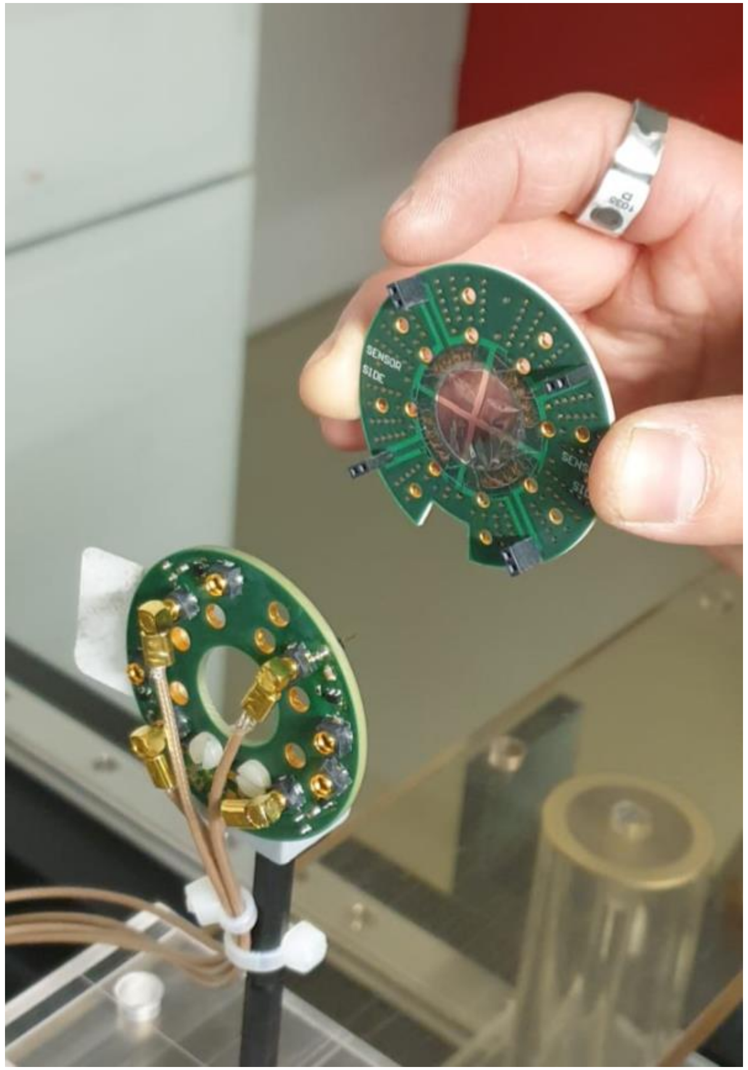
*: CERN

IRRAD Proton Facility

°: (Universita degli Studi di Trento and INFN (IT))

10th Beam Telescopes and Test Beams Workshop (Lecce, June 2022)
https://indico.cern.ch/event/1058977/

Outline

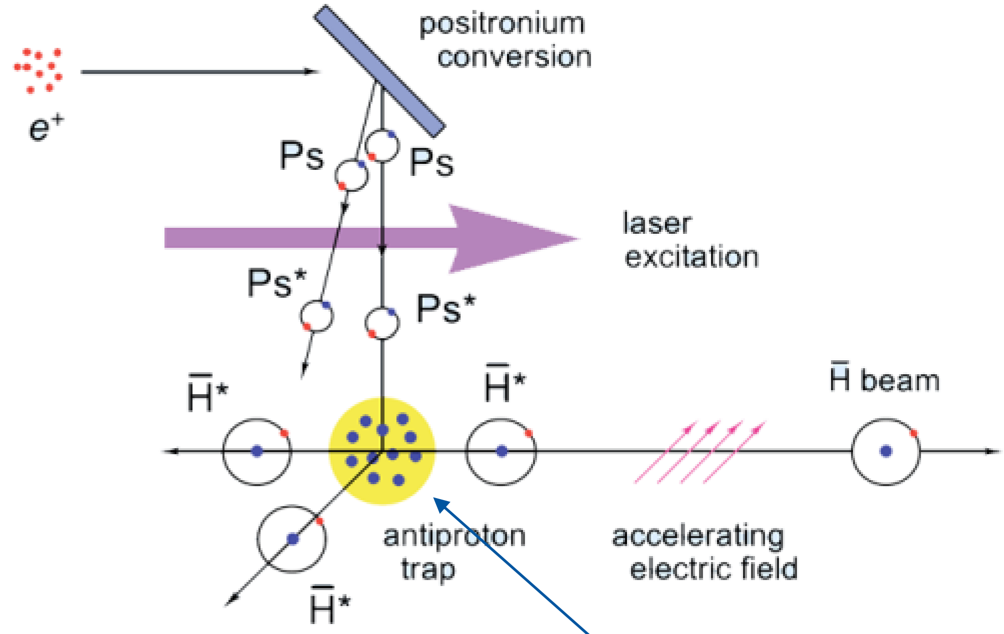


- The Aegis Experiment at the CERN Antimatter Factory
- Secondary Electron Emission: from theory to particle detectors:
- From Beam Position Monitor to Sensitive Degrader
- Test of the ultra thin BPM (nanoBPM)
- Development of a new BPM Front-End Electronics
- Test of the new BPM FE Electronics

The Aegis experiment at the CERN Antimatter Factory

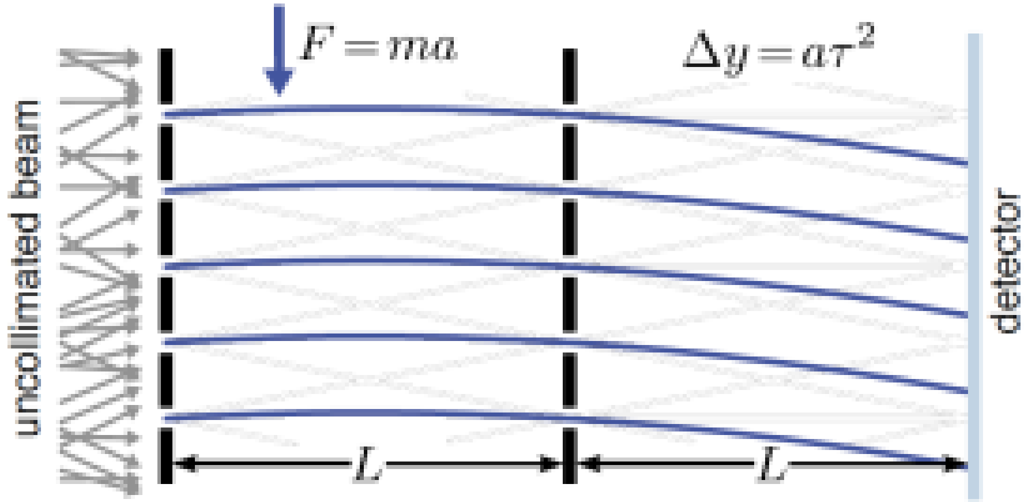
How to measure gravity with neutral antimatter?

1) Produce an anti-hydrogen beam



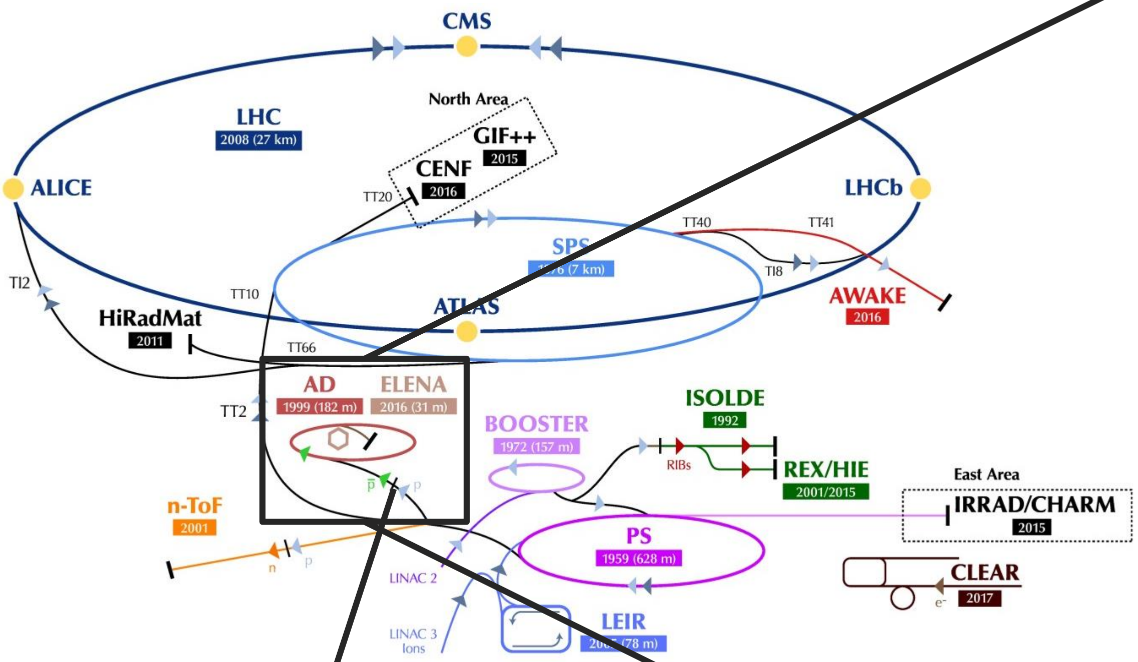
How to produce and trap antiprotons?

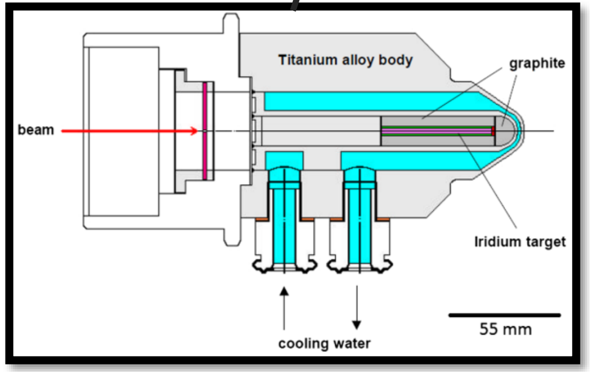
2) Let the anti-hydrogen fall

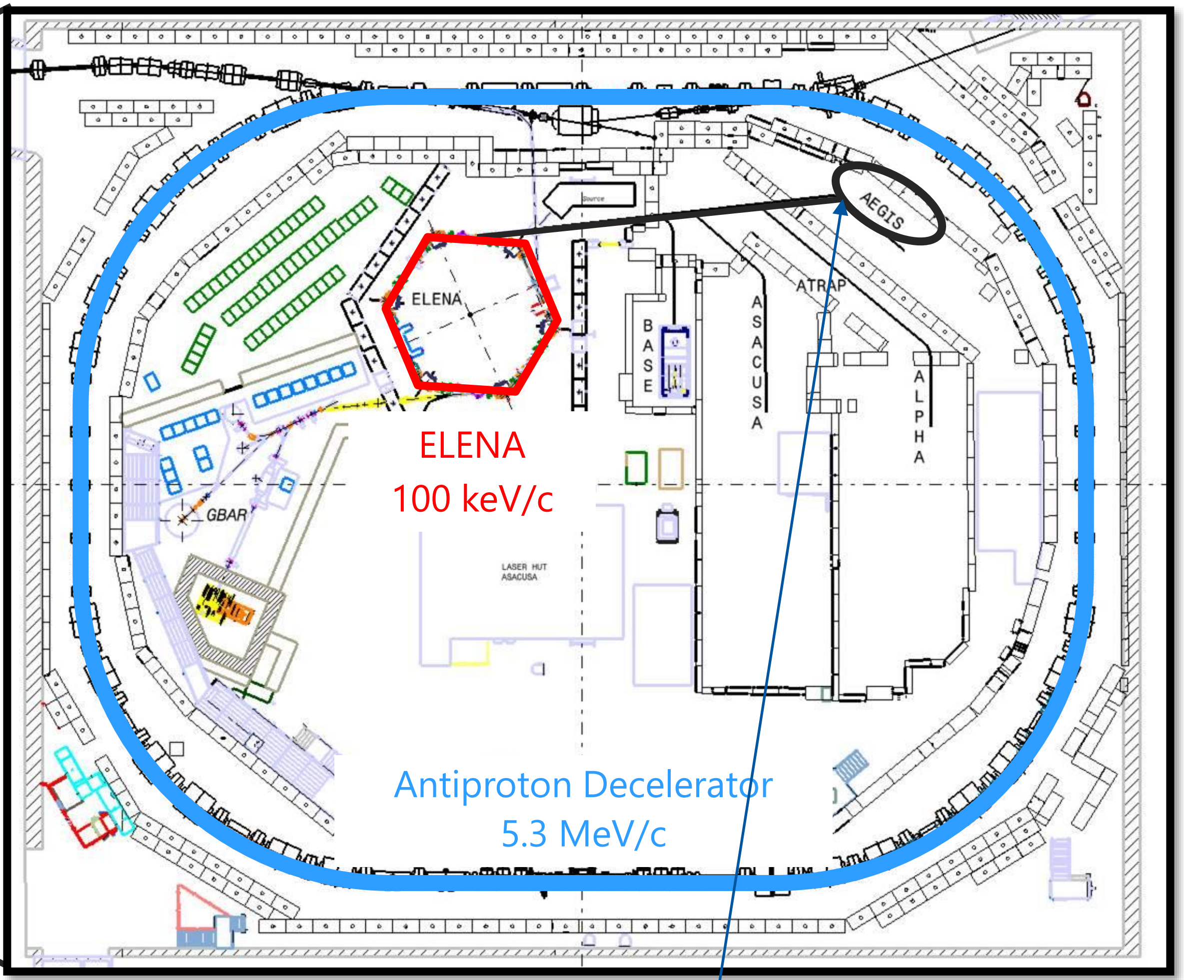


Aegis experiment at the CERN Antimatter Factory

Production of slow antiprotons at CERN





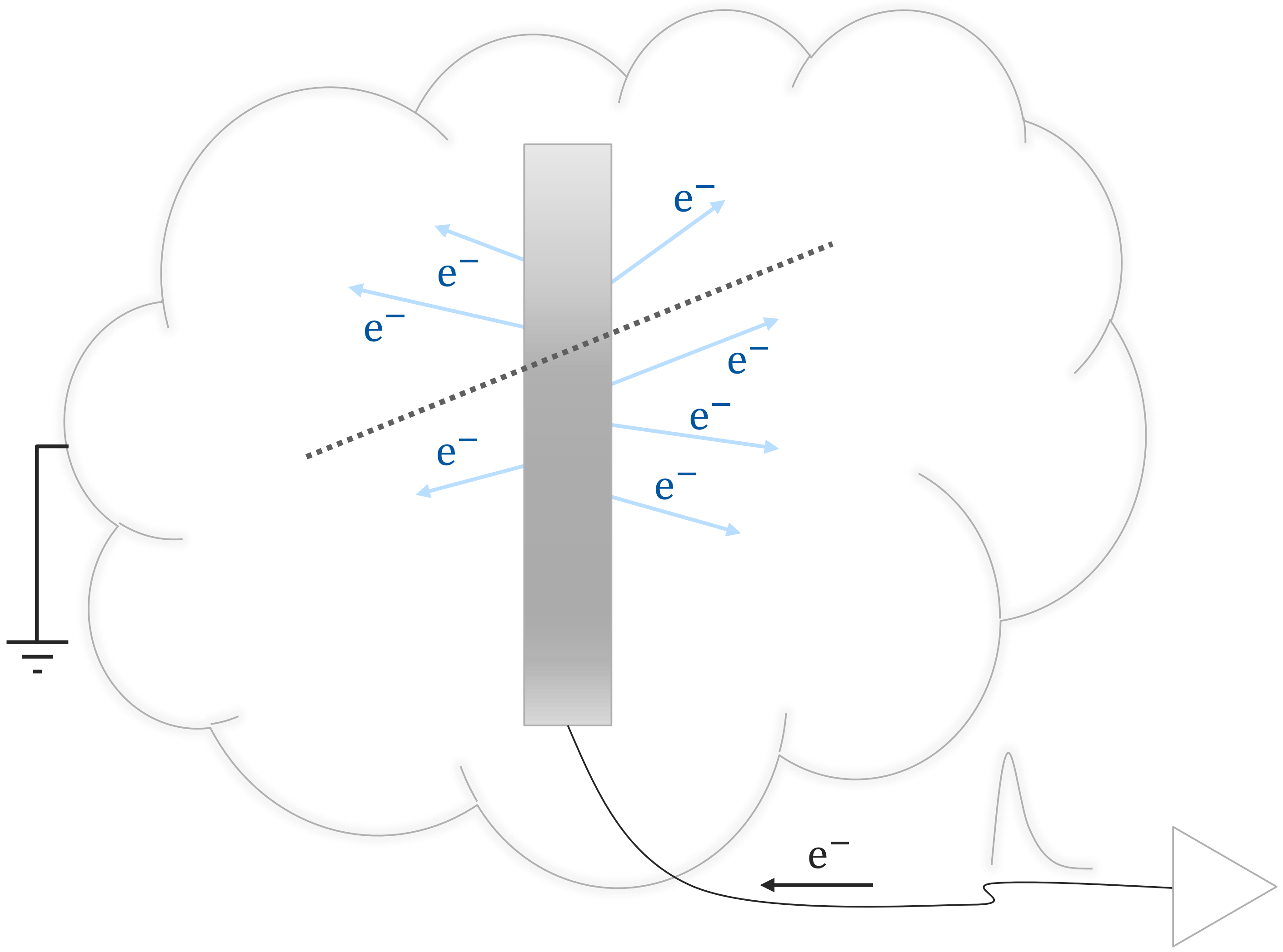


A **degrader** is needed to further slow down the antiptotons

http://dx.doi.org/10.1103/PhysRevAccelBeams.19.073402

Is it possible to design a sensitive degrader?

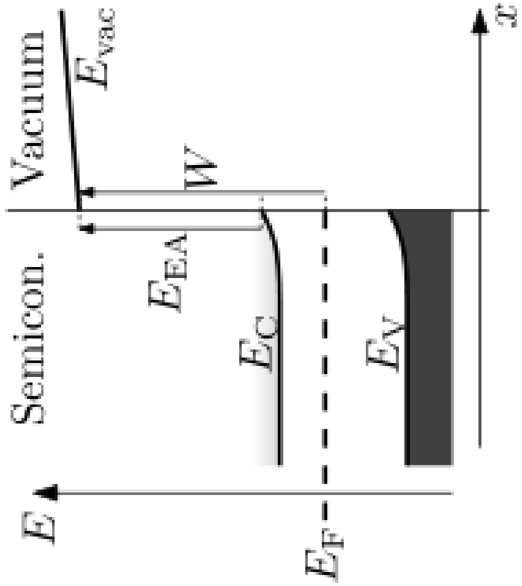
It is possible to produce extremely thin particle detector using **Secondary Electron Emission**

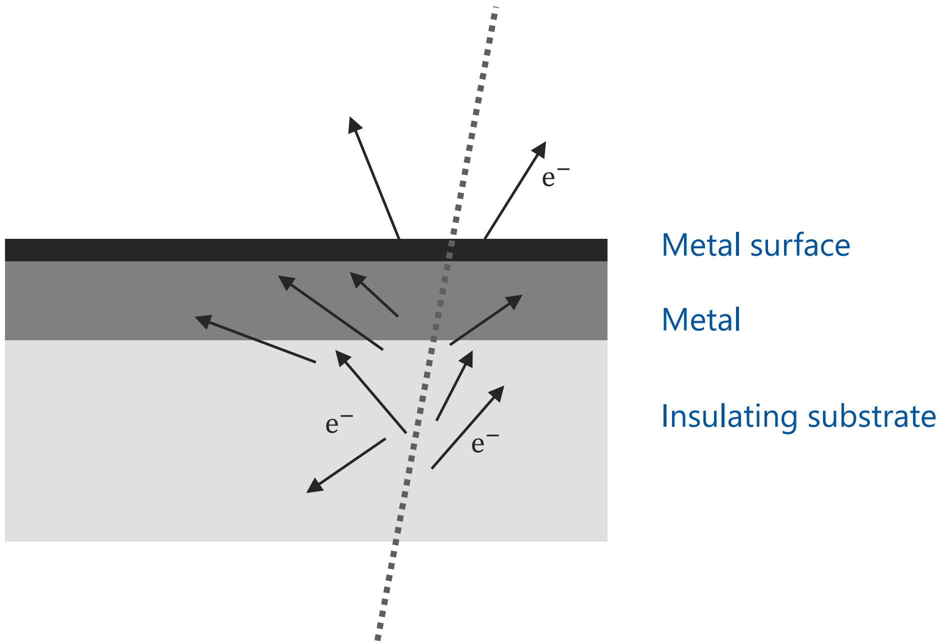


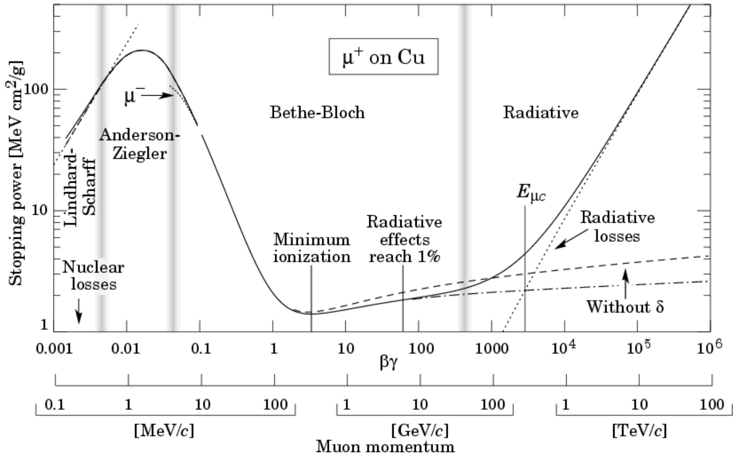
At the passage of a particle some electrons are emitted

If this is happening in a metal connected to ground, the emitted electrons will be replenished: the current generated by the metal will be proportional to the energy lost by the passing particle

Secondary Electron Emission







- The crossing particle loses energy
- Part of this energy can excite electrons
- Some of those electrons have enough energy to reach the surface
- Some of those electrons have enough energy to overcome the work function and they are emitted by the metal

Very inefficient process… ~1%

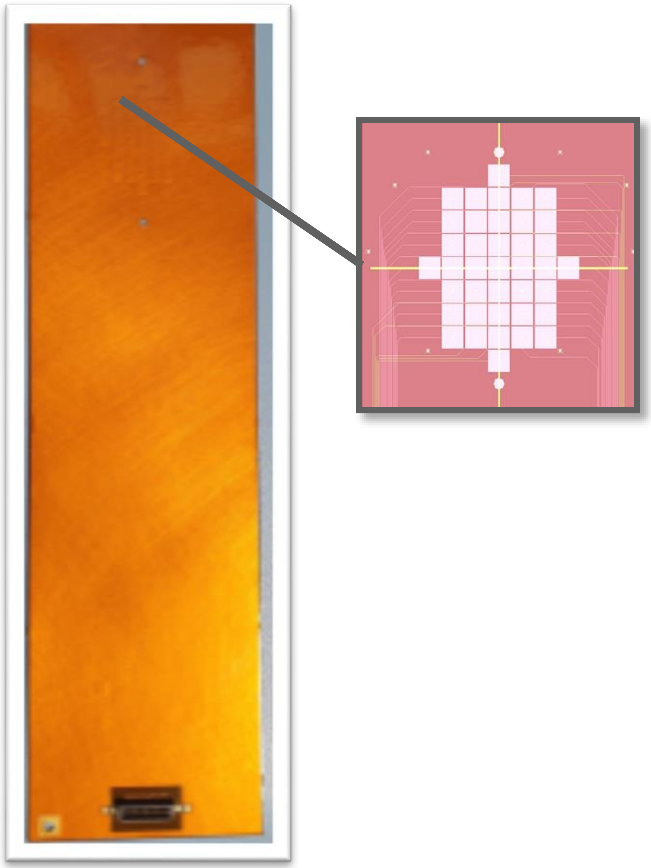
The Beam Profile Monitoring System for the IRRAD Proton Facility at the CERN PS East Area
https://cds.cern.ch/record/2235836

Secondary Electron Emission BPM @ IRRAD

The IRRAD team at CERN uses several BPM based on SEE

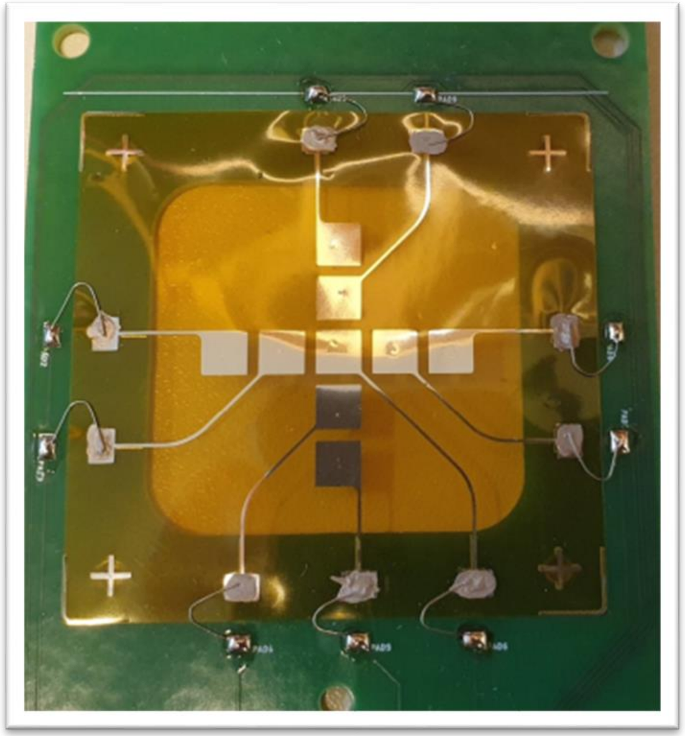
Extensive R&D for new generation sensors:

- Simpler production
- Higher radiation resistance
- Higher Secondary Emission Yield (SEY)
- Lower material activation
- Back compatibility with FE and mapping



BPM (2010):
600 um Kapton + 140 um Cu

mBPM: 600 um Kapton + 140 um Cu



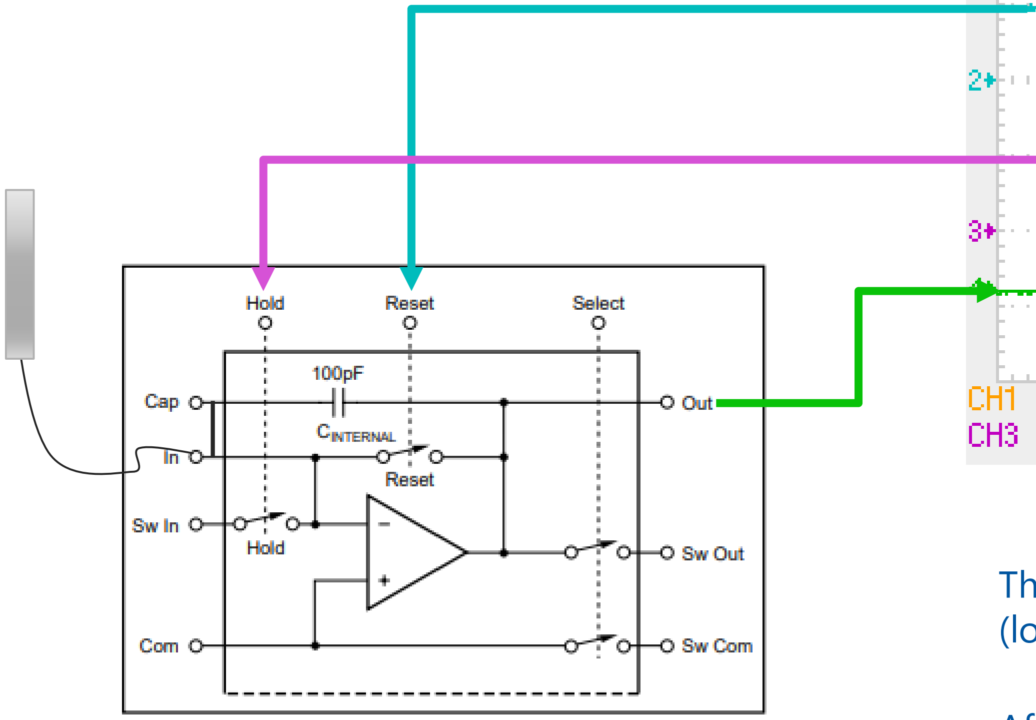
uBPM: 25 um + 300 nm Al

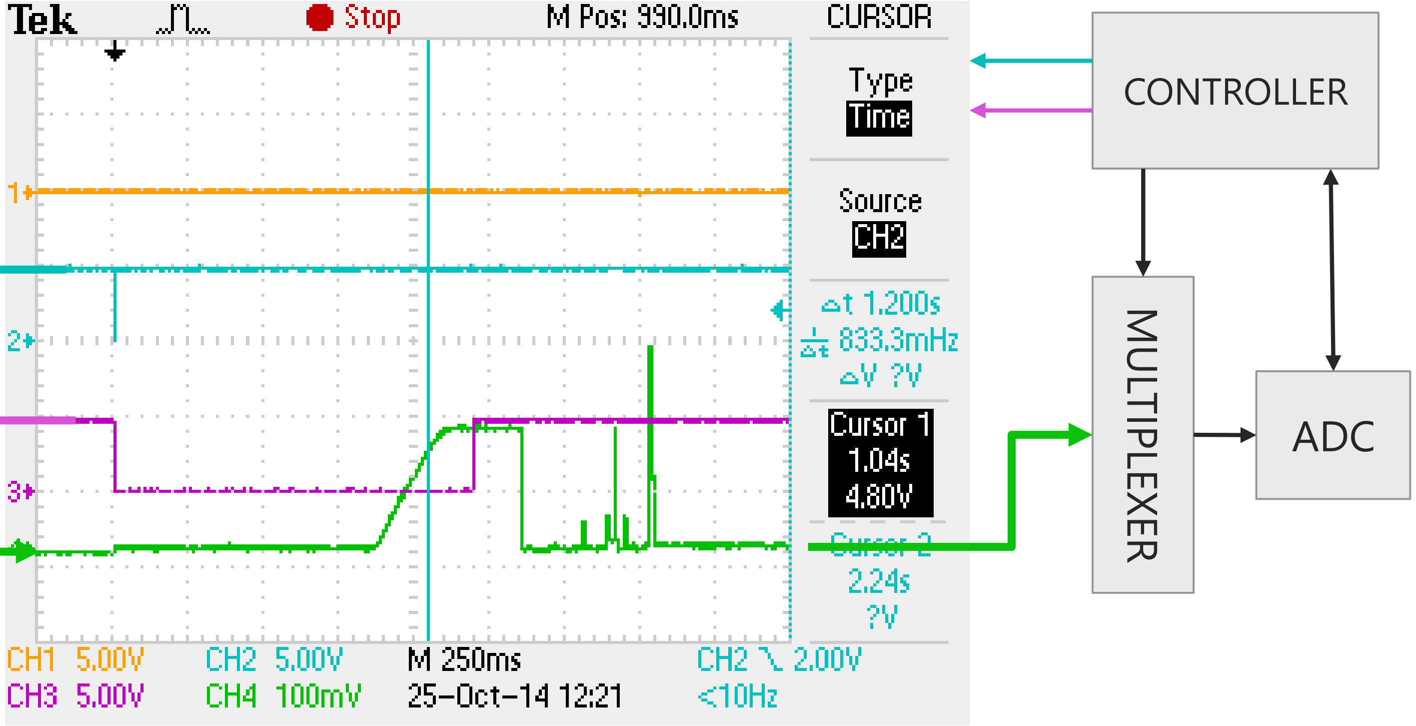
https://cds.cern.ch/record/2772583

Front-end electronics of the BPM @ IRRAD

The electrons emitted by the sensor can be measured using a charge amplifier (integrator)

When working with pulsed beams a gated integrator is used to improve the Signal to Noise Ratio (SNR)



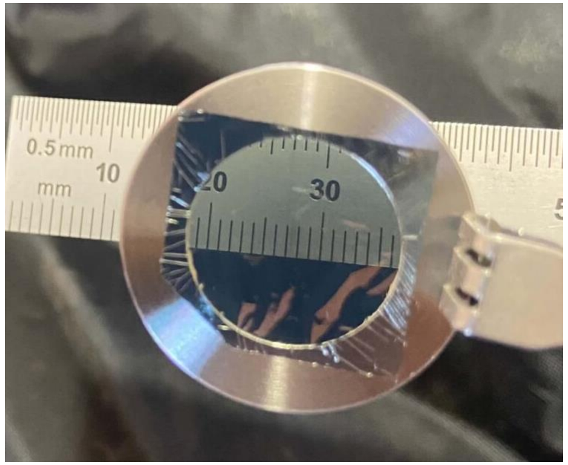


The feedback capacitance ($C_{INTERNAL}$) is discharged by the reset signal (low), then it is collecting charge while the hold signal is low.

After the integration, the integrated signal is digitized and stored

Is it possible to design a sensitive degrader?

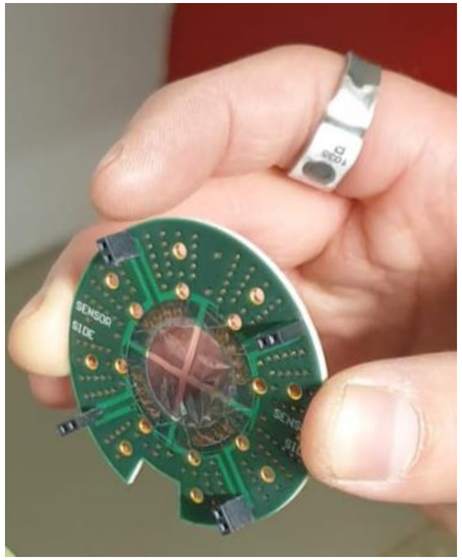
It is possible to produce extremely thin particle detector using **Secondary Electron Emission**

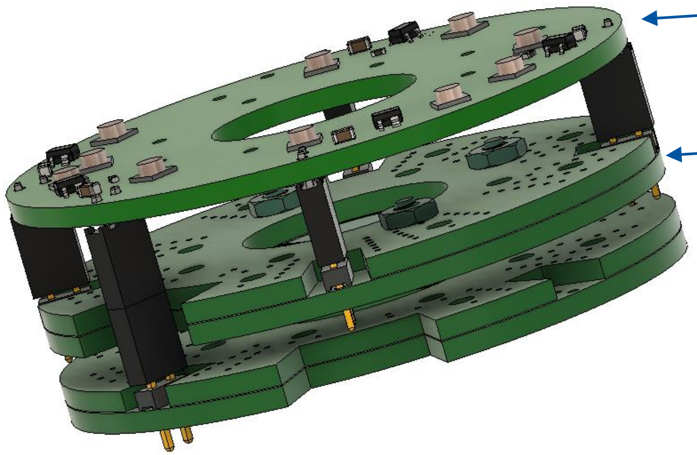


Parylene foil: thickness down to 100 nm

Why not add 10 nm of Al and read-out the SEE?

It is possible to deposit Al on the foil with a defined pattern





2 types of foils produced:

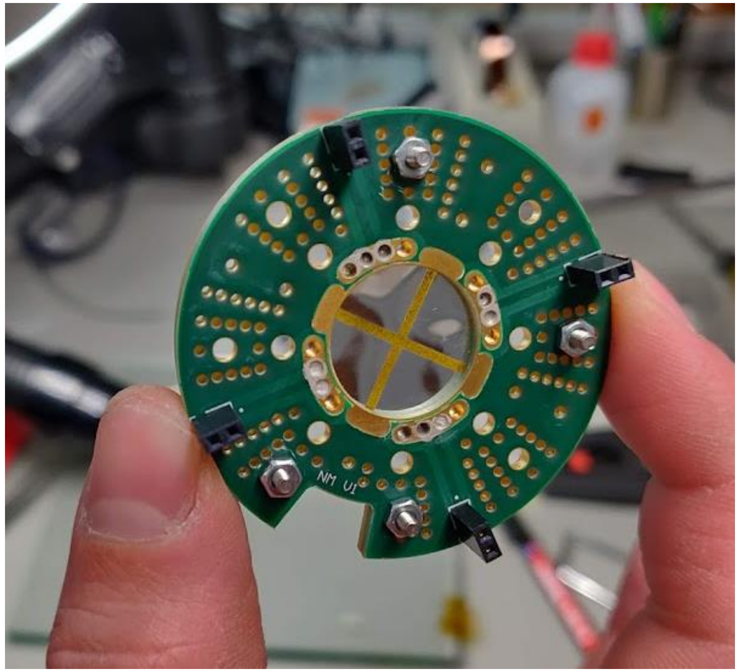
- 1 pad: 100 nm of parylene + 10 nm of Al
- 4 pad: 1500 nm of parylene + 10 nm of Al

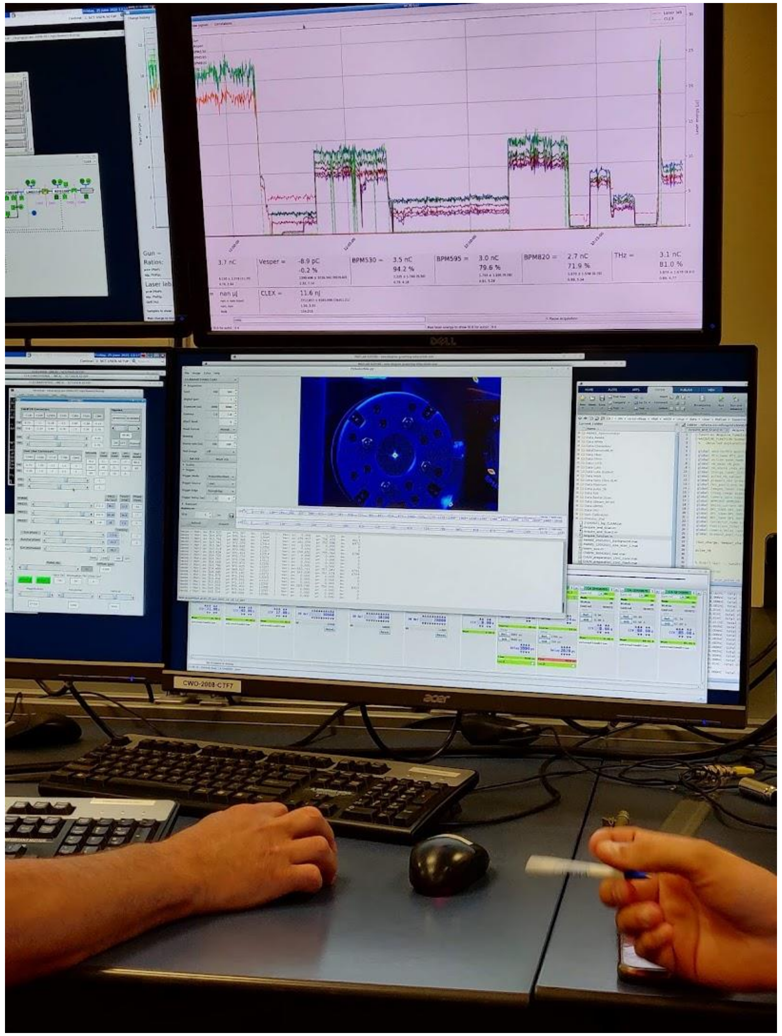
2 additional sets of Mylar foils produced:

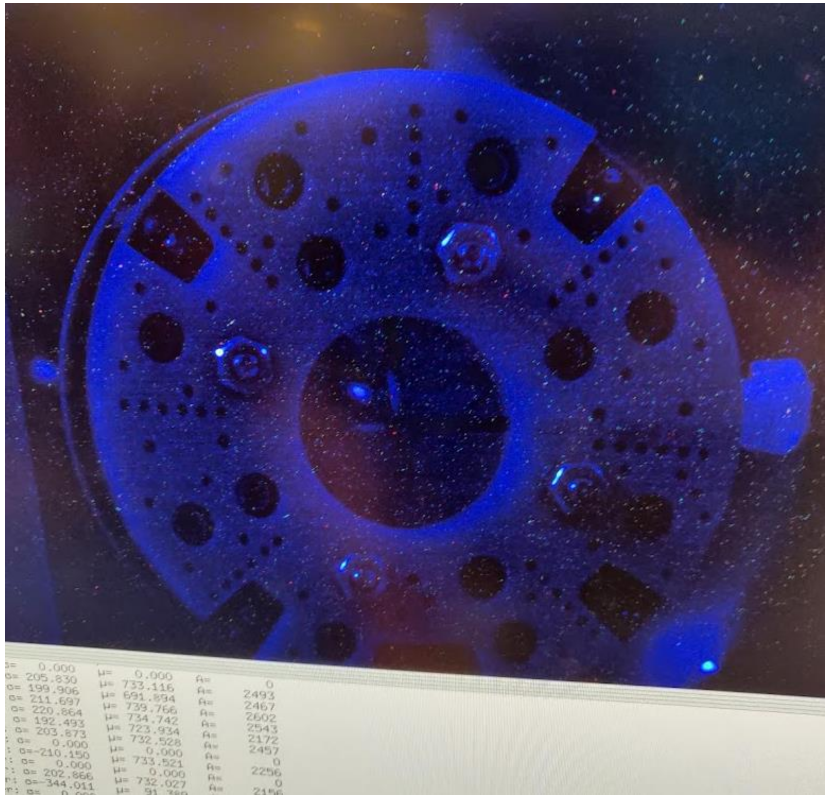
- 1 pad: 500 nm of Mylar + 10 nm of Al
- 4 pad: 900 nm of Mylar + 10 nm of Al

First prototype: 25 um *thick* nanoBPM

The *proof-of-concept* has been produced using aluminized Kapton and tested with 200 MeV electrons (~4 nC) @ CLEAR

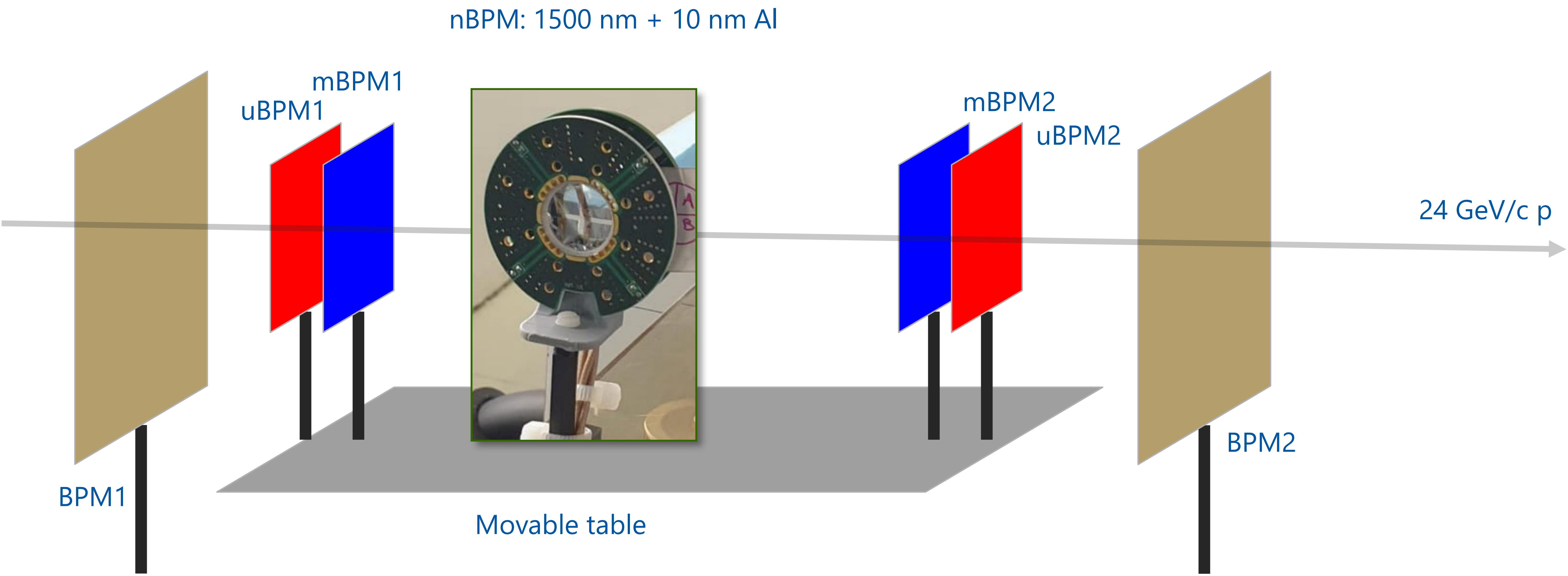






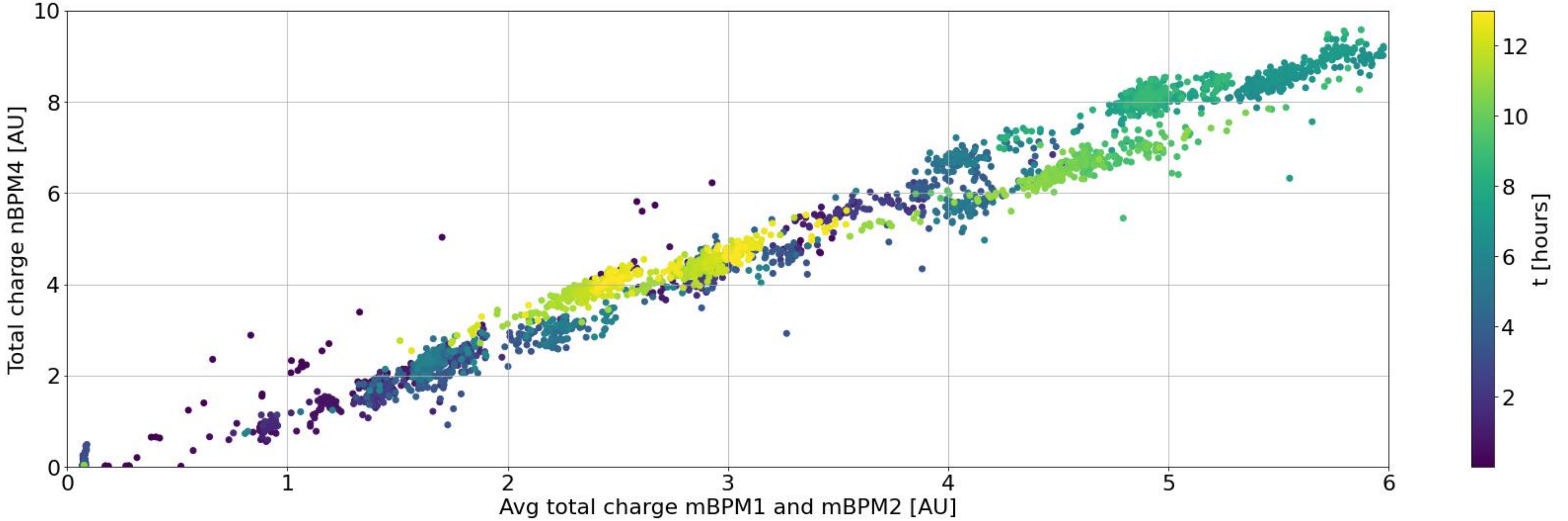
BPM @ IRRAD in 2021

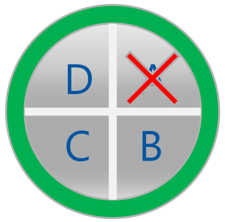
The nanoBPM was tested up to 6 x 10^{11} p/spill (400 ms) at the CERN IRRAD facility and compared with other BPM



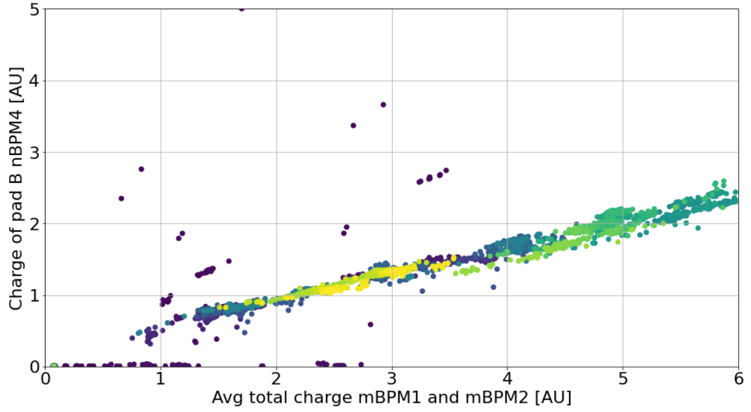
Tests @ IRRAD

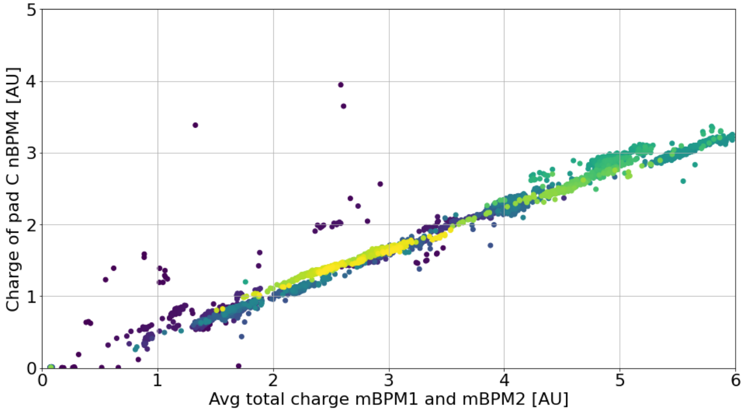
The nanoBPM was tested up to 6 x 10^{11} p/spill (400 ms) at the CERN IRRAD facility and compared with other BPM

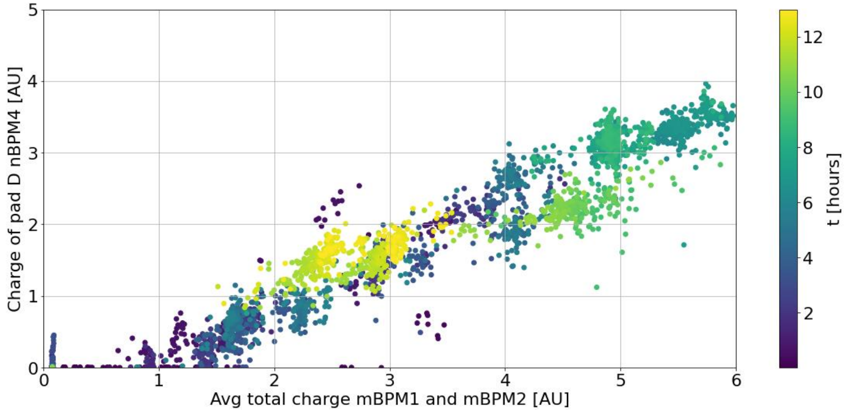




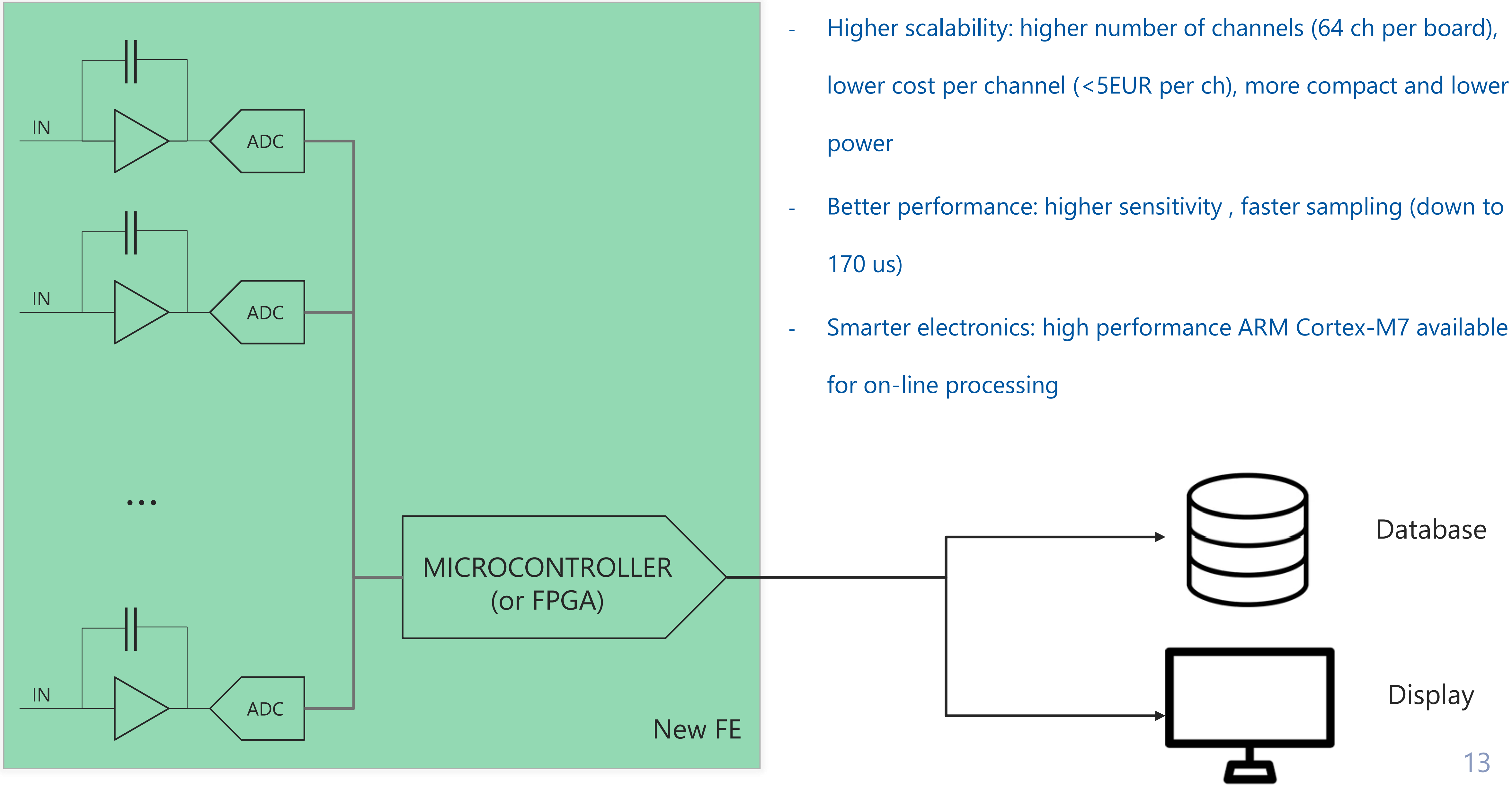
Connection problem on pad A





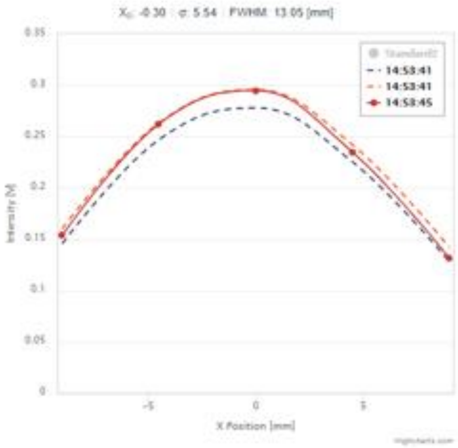


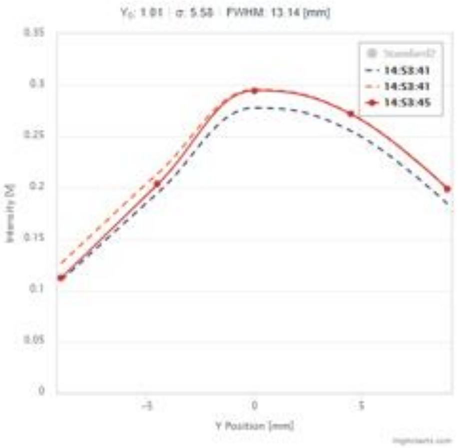
New Front-End Electronics



- Higher scalability: higher number of channels (64 ch per board), lower cost per channel (<5EUR per ch), more compact and lower power
- Better performance: higher sensitivity , faster sampling (down to 170 us)
- Smarter electronics: high performance ARM Cortex-M7 available for on-line processing

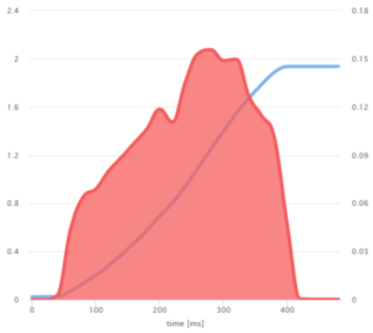
New Front-End Electronics: 8ch prototype



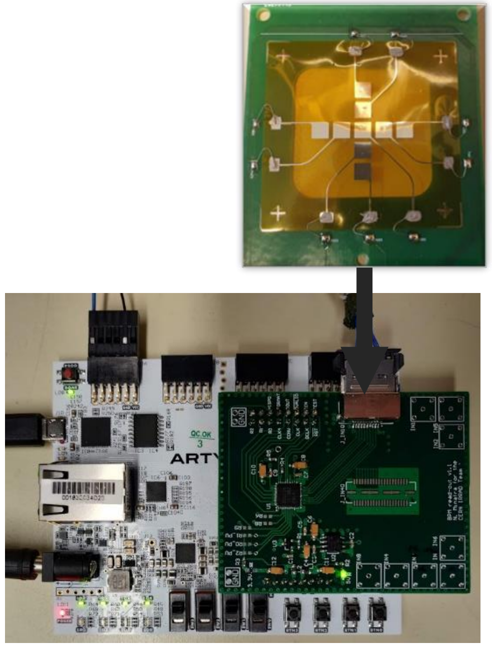


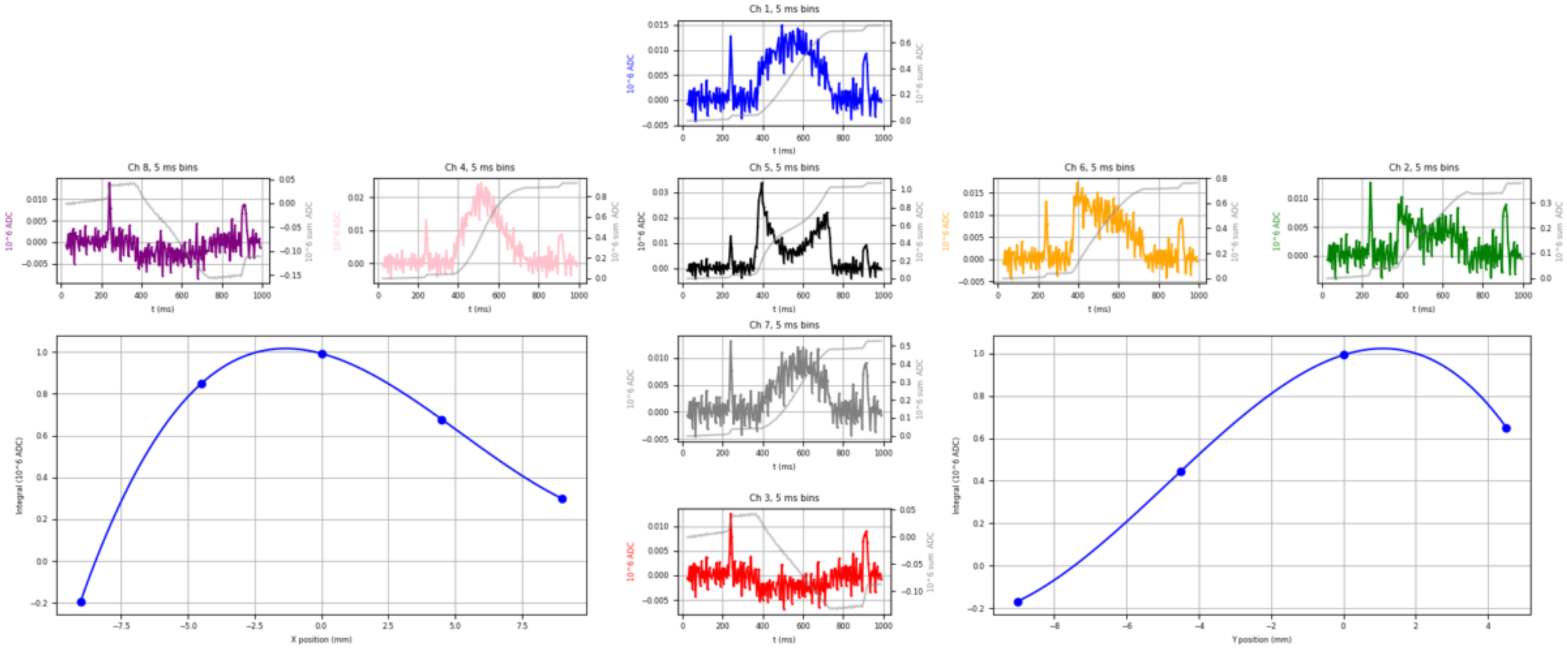
Present FE: 40 ch per board, measuring total charge per spill

Profile (20 ms sampling) available for a single channel



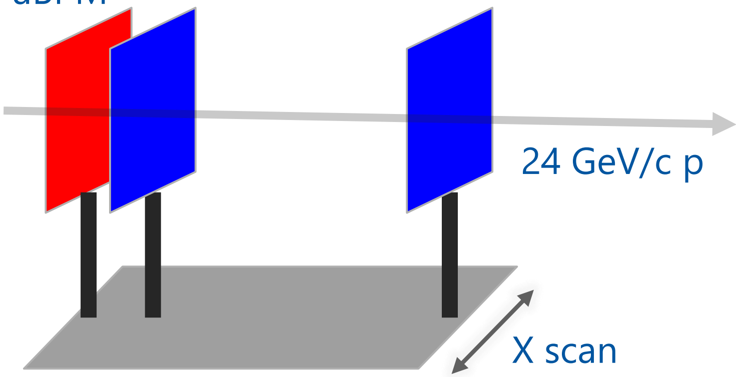
New FE: profile available for all channels with sampling down to 170 us (5ms in the picture)

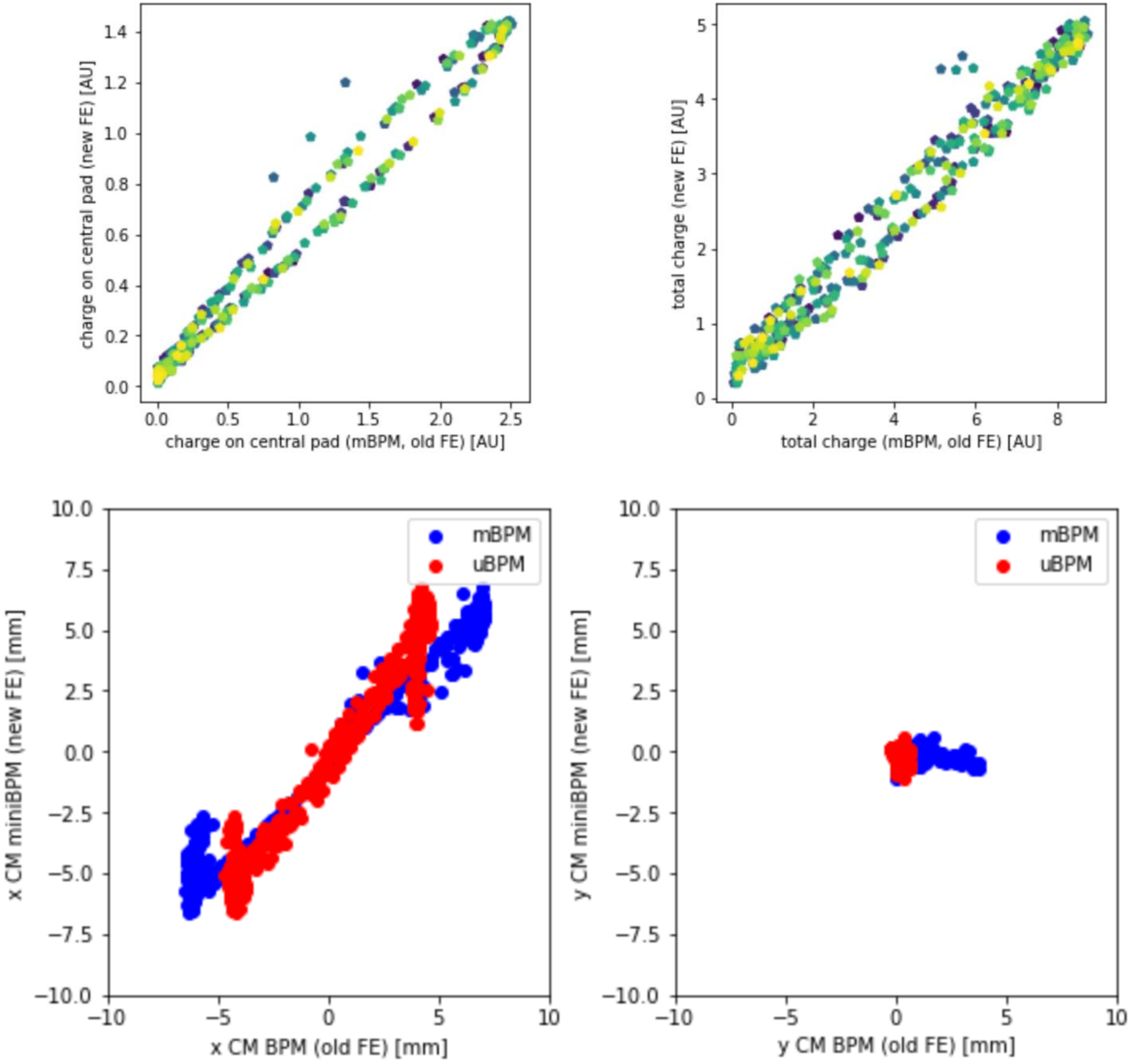




New FE Electronics: Correlations with old FE

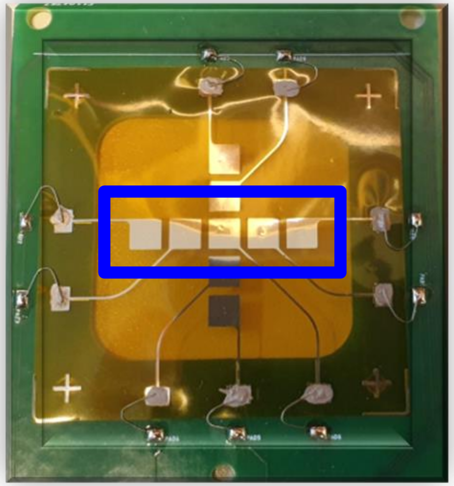
Good correlation observed between the new and the present FE electronics

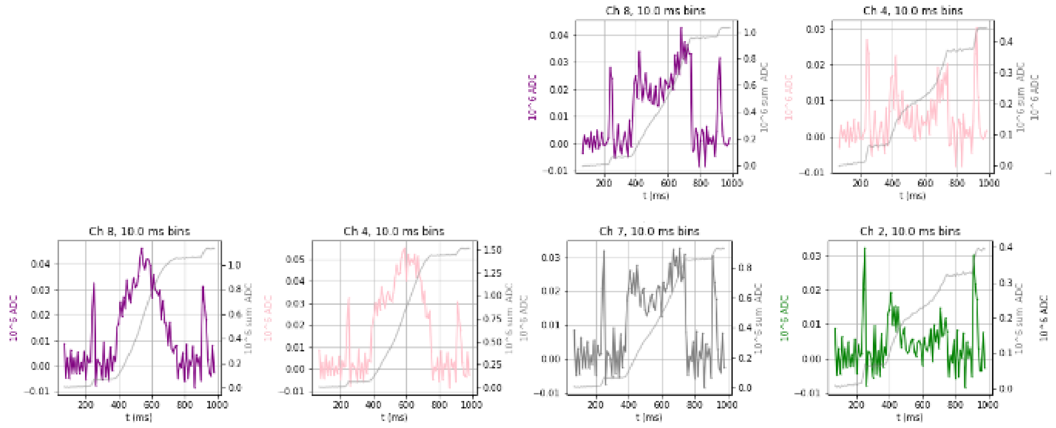


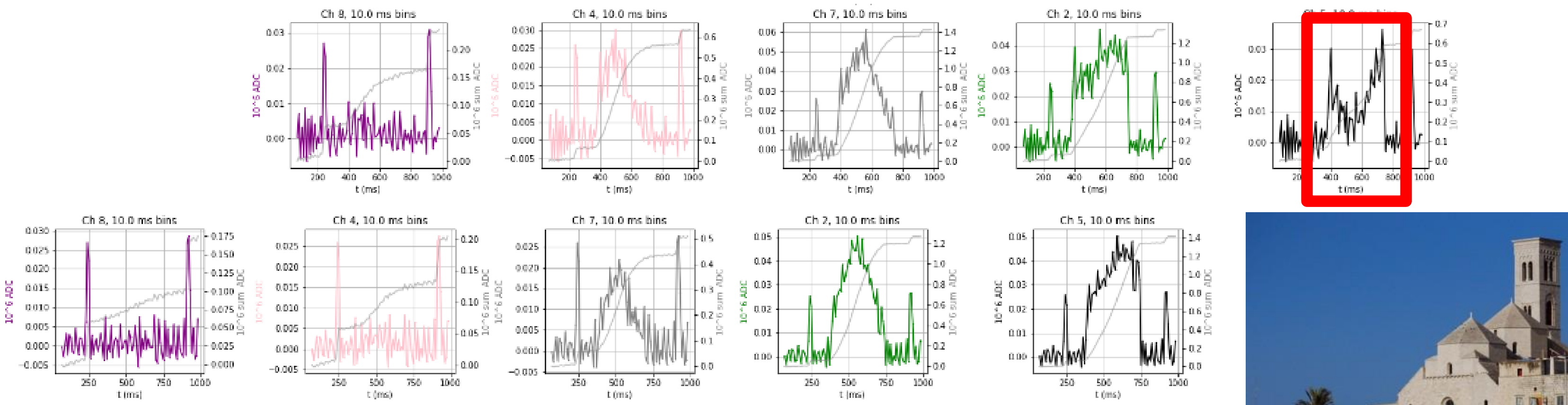


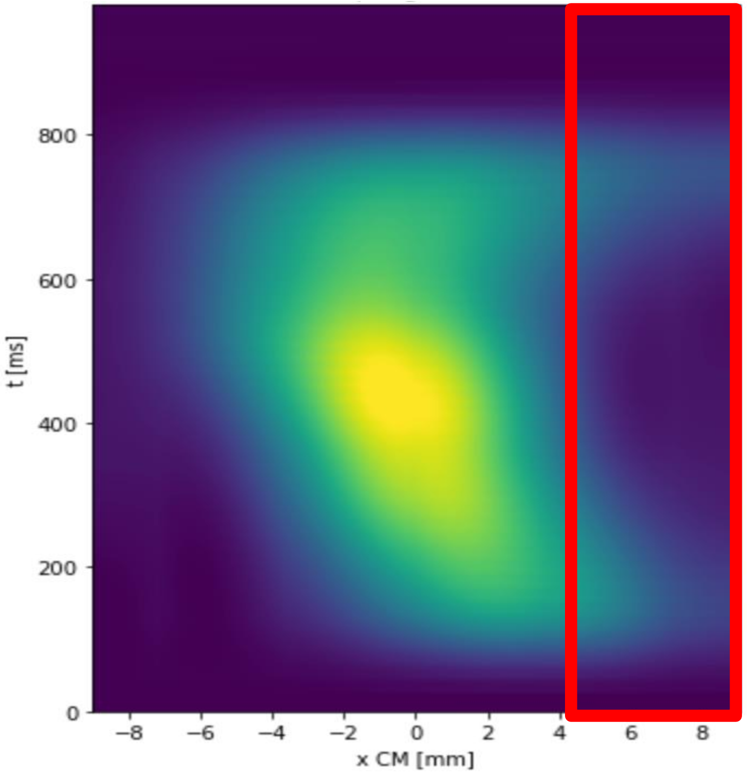
New FE Electronics: new observations possible

Thanks to the higher time resolution it is possible to observe new details of the beam structure







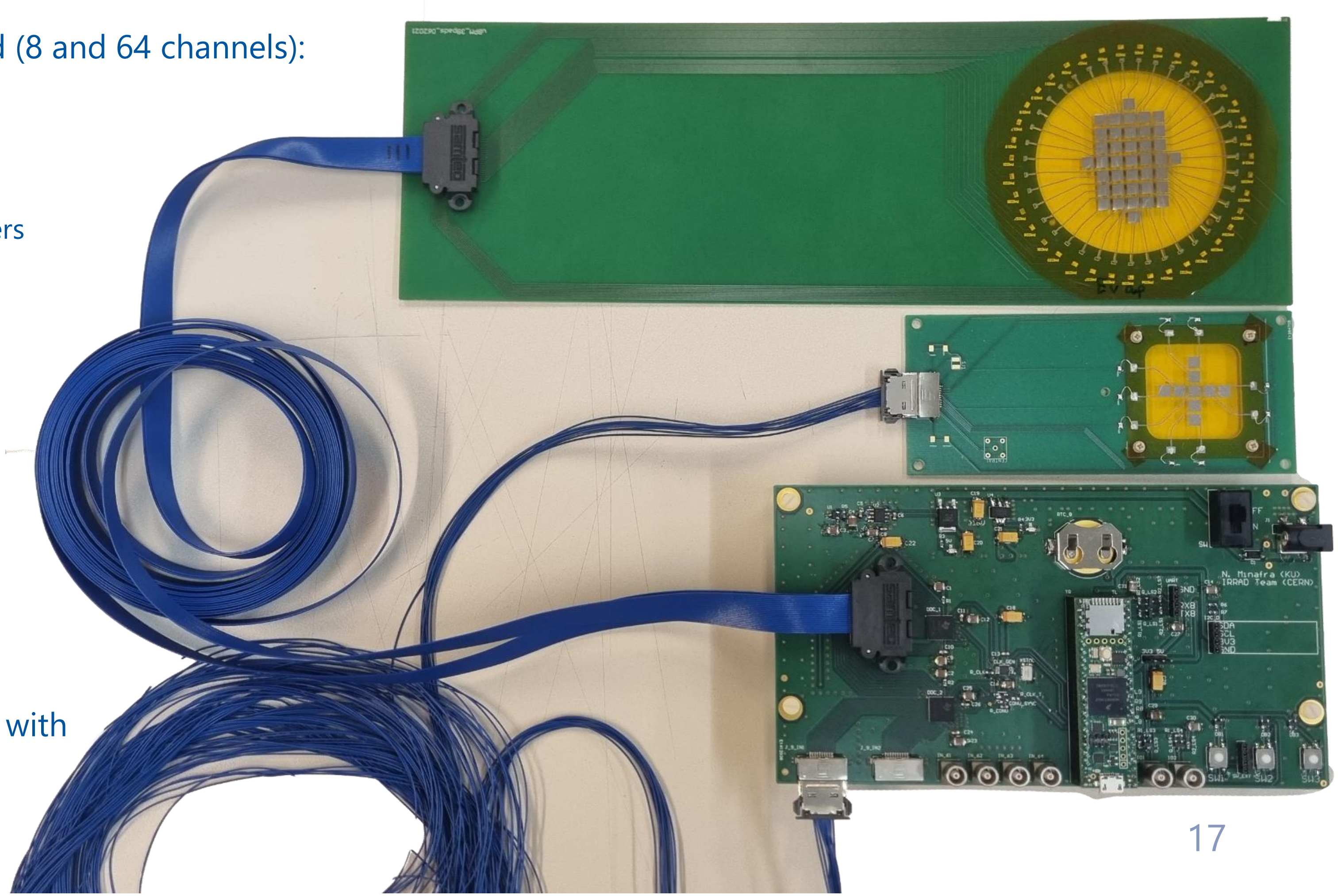


A "structure" is visible on the right side of the beam

The Molfetta effect

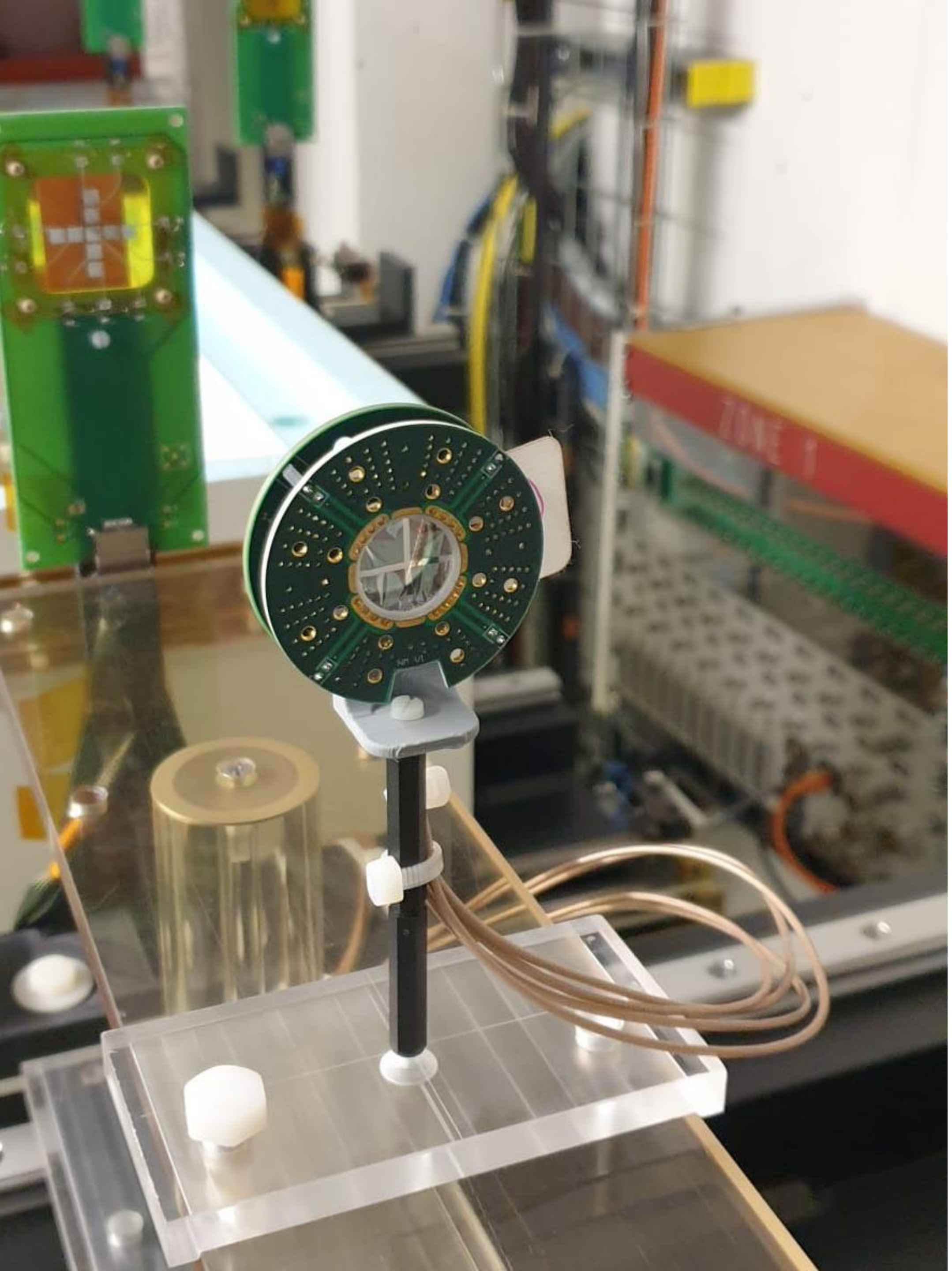
Conclusion and next steps

- Degrader/nanoBPM designed, manufactured
- Degrader/nanoBPM tested at IRRAD and performance compared with reference sensors
- New read-out electronics designed and produced (8 and 64 channels):
  - faster amplifier
  - lower noise
  - more control on amplifier parameters
  - Floating



Next steps:

- Test of the new Mylar nanoBPM
- Test of the nanoBPM with new FE electronics
- Test of the new 64 ch board
- Test of the nanoBPM inside the Aegis Experiment with Antiproton beams



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