MOnitor for Neutron Dose for hadrOntherapy

SIMULATION & TRENTO TEST BEAM

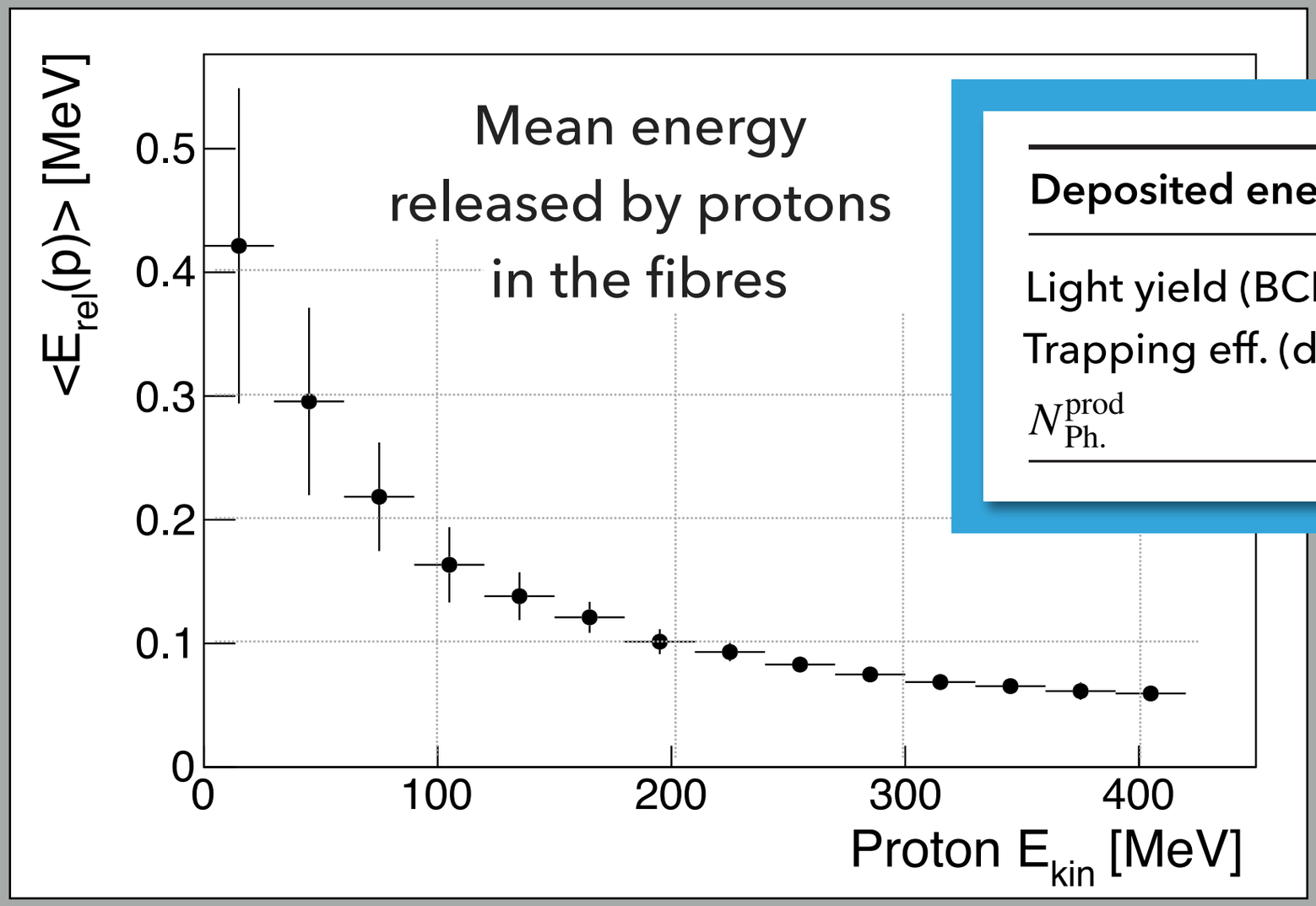
THE MONDO PROJECT

ARPG MEETING 11/07/17

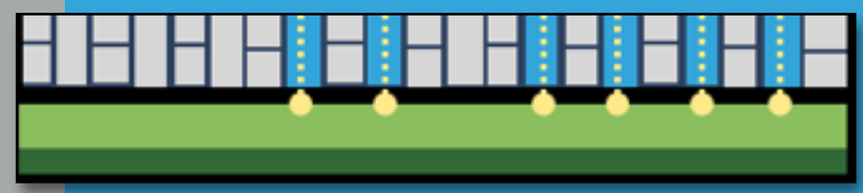
RICCARDO MIRABELLI FOR MONDO

EXPECTED SIGNALS AND SIMULATION

A **MonteCarlo simulation** has been developed using the **FLUKA code**. The matrix of fibres has been simulated in order to characterise the energy release of the protons in the fibres as a function of the neutrons (and proton) energy.



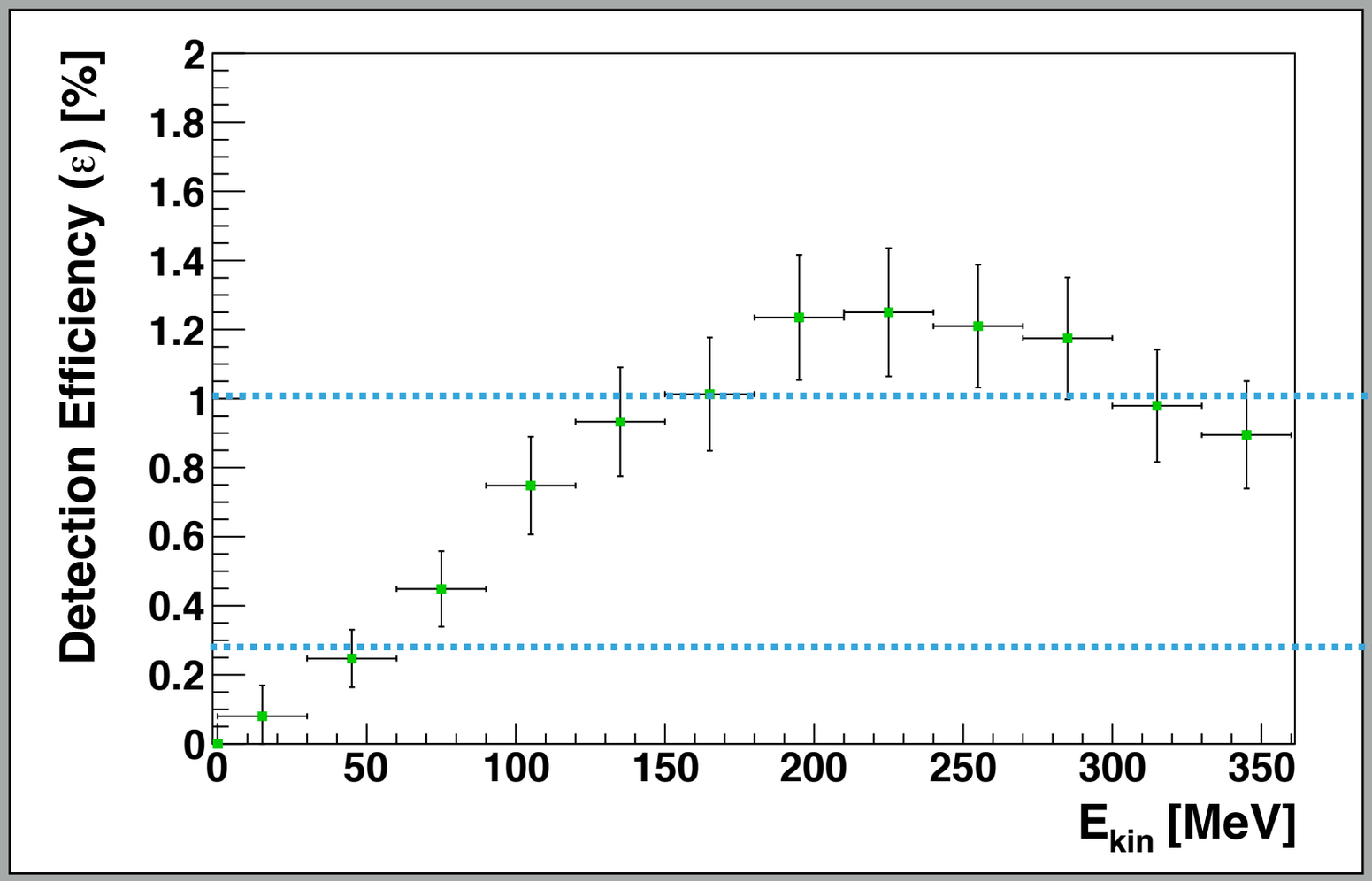
Deposited energy per fibre	100 keV in 250 μm
Light yield (BCF-12)	8000 ph. MeV^{-1}
Trapping eff. (double clad.)	7%
$N_{\text{Ph.}}^{\text{prod}}$	60 ph.



M.M et al. PMB doi: 10.1088/1361-6560/aa623a

EFFICIENCY

Defining the efficiency as the number of DES in which both protons are totally reconstructed (full containment) and cross at least 3 layers each, we have:



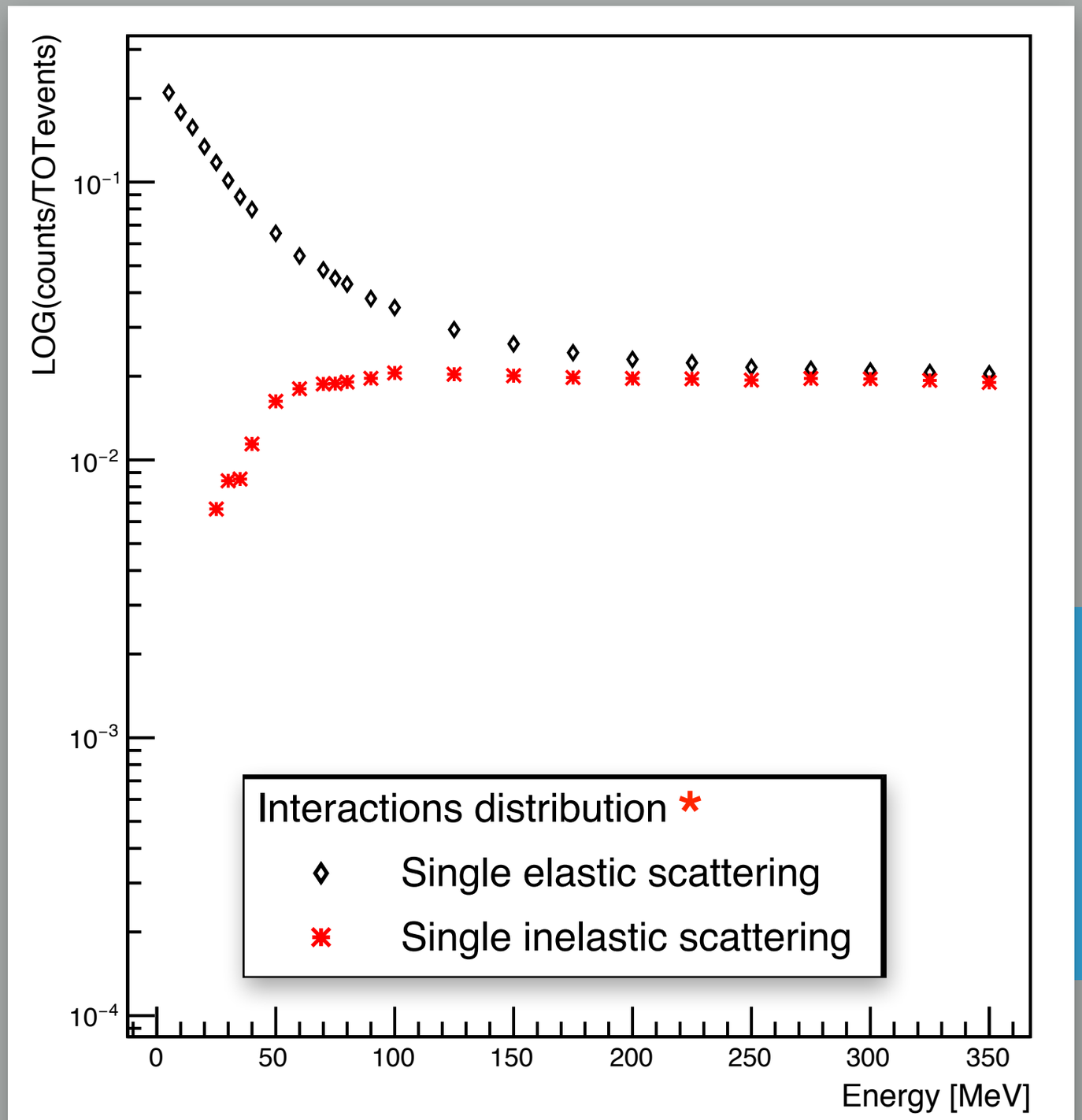
FLUKA Simulation

~ 10^{-2}

~ 3 x 10^{-3}

The assumption is conservative as we are requiring full proton containment; we expect to improve the detection efficiency using also the dE/dx information.

DOMINANT INTERACTIONS

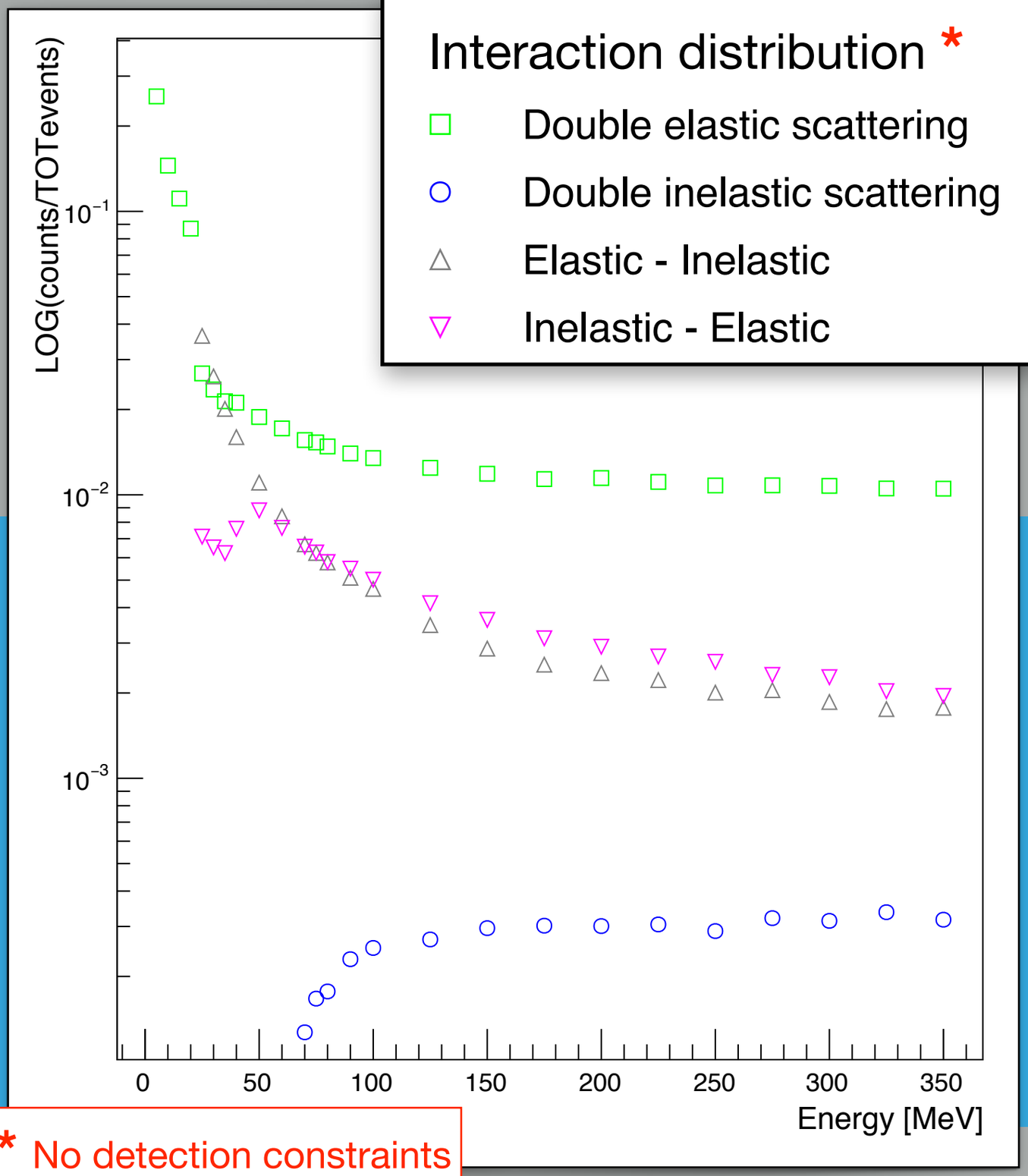


* No detection constraints

The elastic scattering is the dominant interaction in hydrogenated targets, however for high energies inelastic scattering contribution is not negligible.

The readout system allows to drastically reduce the impact of interactions the mis-identification.. work in progress!

BACKGROUND STUDY



* No detection constraints

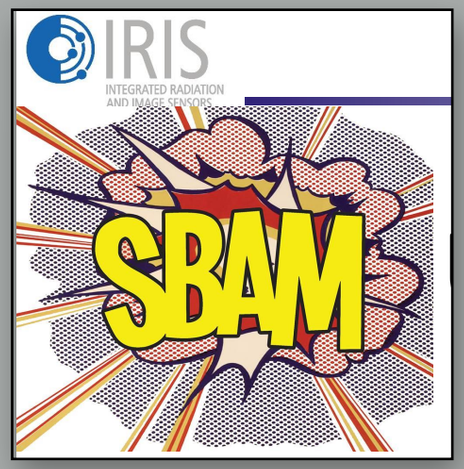
Below 50 MeV the probability mixed elastic and inelastic interactions is not negligible... we have to take it into account when we evaluate the performances of the detector and assign a systematic uncertainty to the measurements.

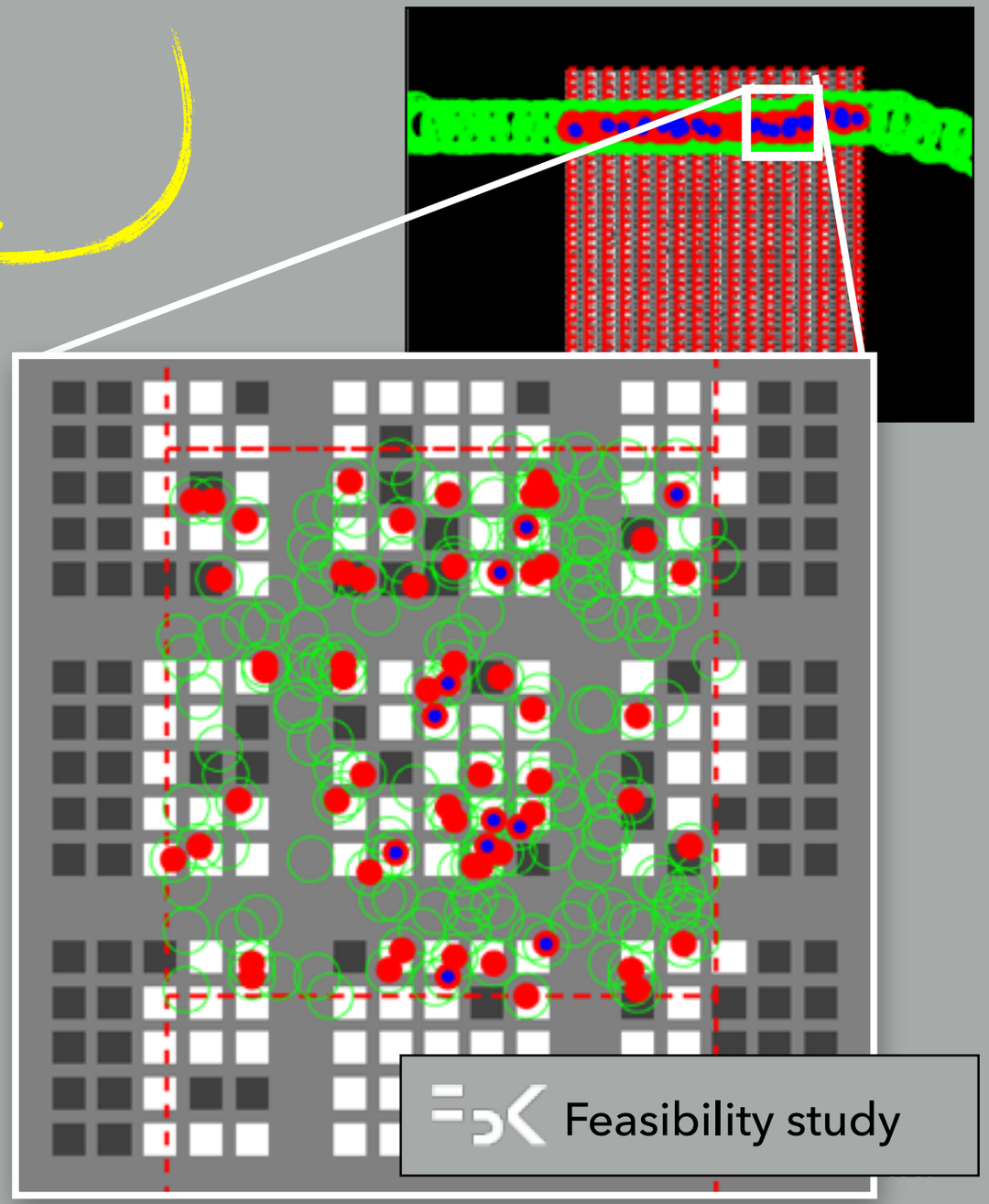
As **inelastic scattering** events are expected to produce more than one single proton per interaction **the track multiplicity at the interaction vertexes** will be used to **reduce** such unavoidable **background contamination** reject inelastic events.

NEUTRON TRACKER

MAIN CHARACTERISTICS OF THE NEW SENSOR

- Pixels => 125 x 250 µm
- side-by-side sensors
- Fill Factor => ~33%
- Trigger logic tuned for <5ns signals
- Quantum efficiency (@435nm) ~40%
- Dark currents reduction (capability of turning off noisy SPADs)
- Possible EXT. Trigger





Feasibility study

NEUTRONS TRACKER

READOUT: SPAD Array

<u>Test PENELOPE prototype</u> :

- ^{90}Sr (electrons ~2 MeV);

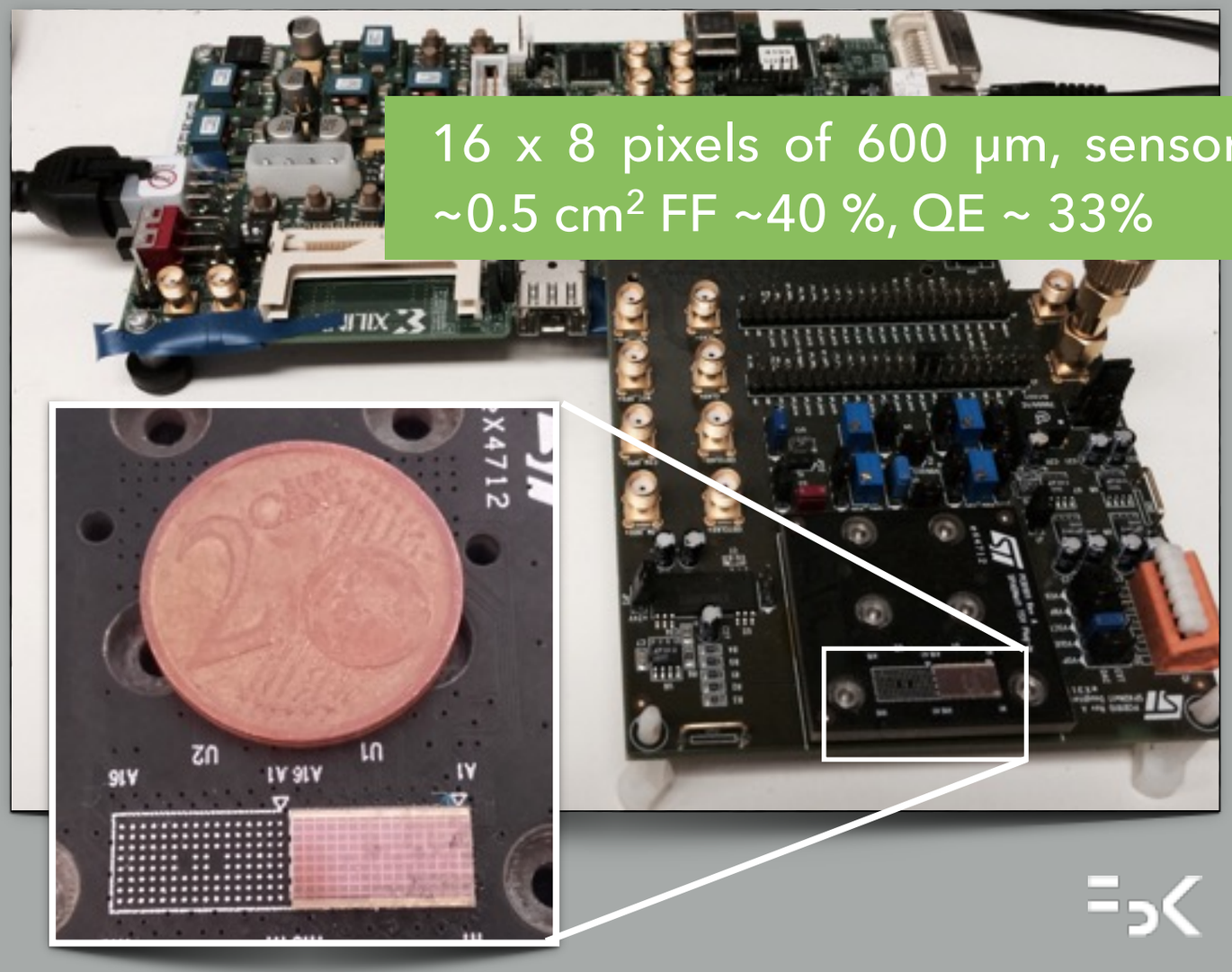
- cosmic rays (mip)

- electron beam (50-450 MeV)

- protons@CPTT* (60-230 MeV)

[*] Proton Terapia Center of Trento

The new sensor has been developed starting from the experience gained using an other sensor prototype: *spadnet [1]*. Practicing with *spadnet* allowed us to point out the critical issues to be addressed in the SBAM development phase.



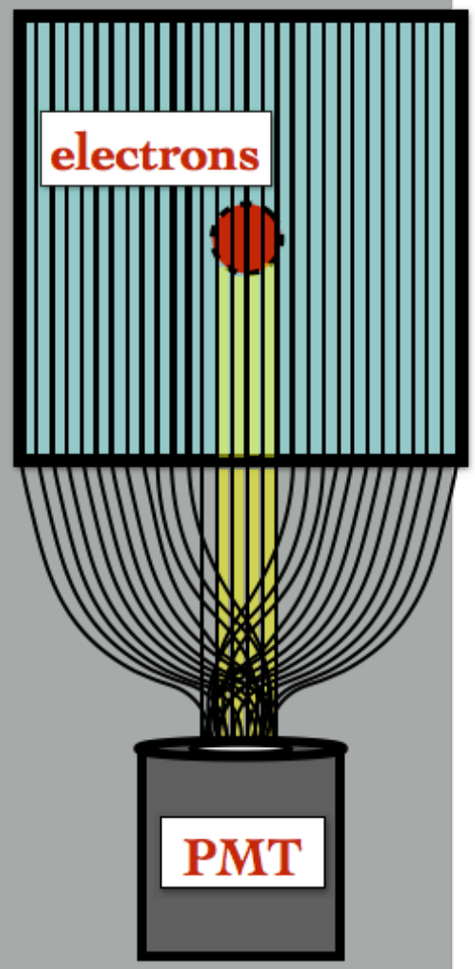
[1] http://iris.fbk.eu/projects/spadnet

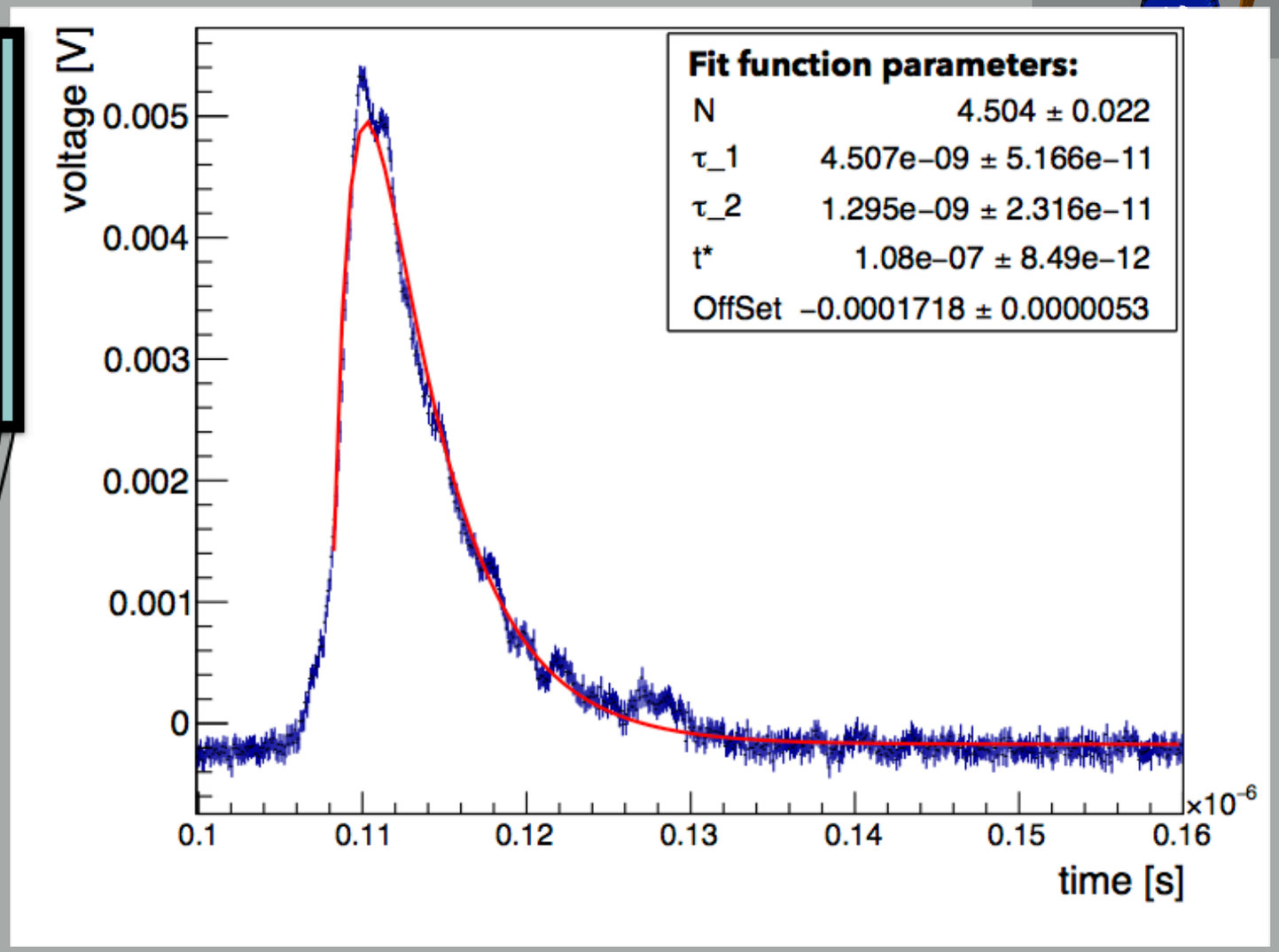
ULISSE

Test ULISSE :

- electron beam (50-450 MeV)

Measurements with traditional PMT readout



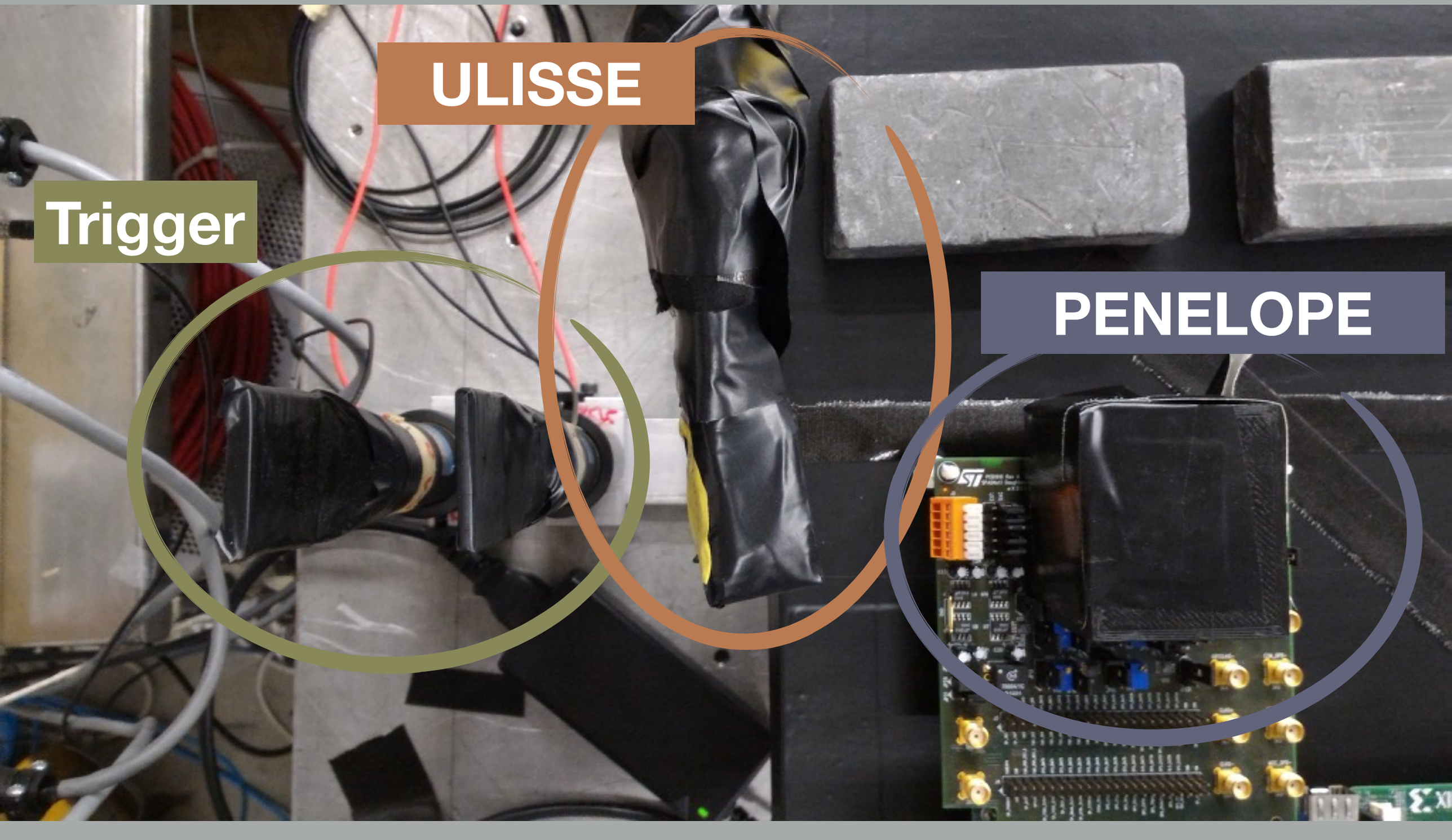


The scintillating time of the fibers (tau_1) is obtained fitting the signal waveform with:

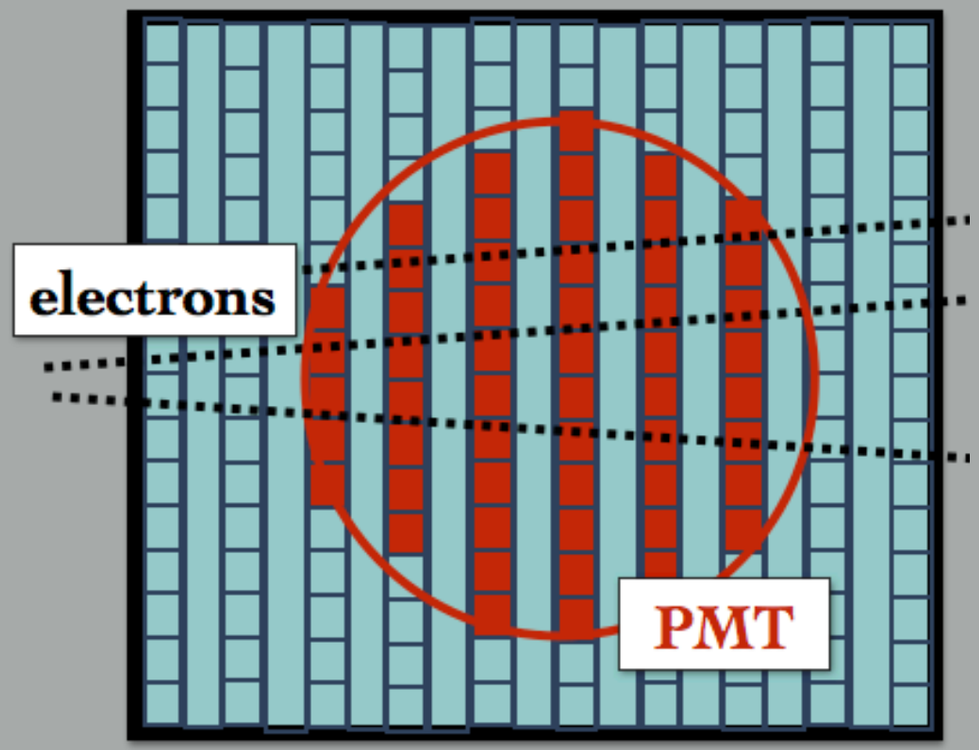
$$V(t) = -\left(\frac{GNeR}{\tau_1 - \tau_2}\right) \cdot [exp(-t/\tau_2) - exp(-t/\tau_1)]$$

the PMT rise time is given by tau_2

EXPERIMENTAL SETUP



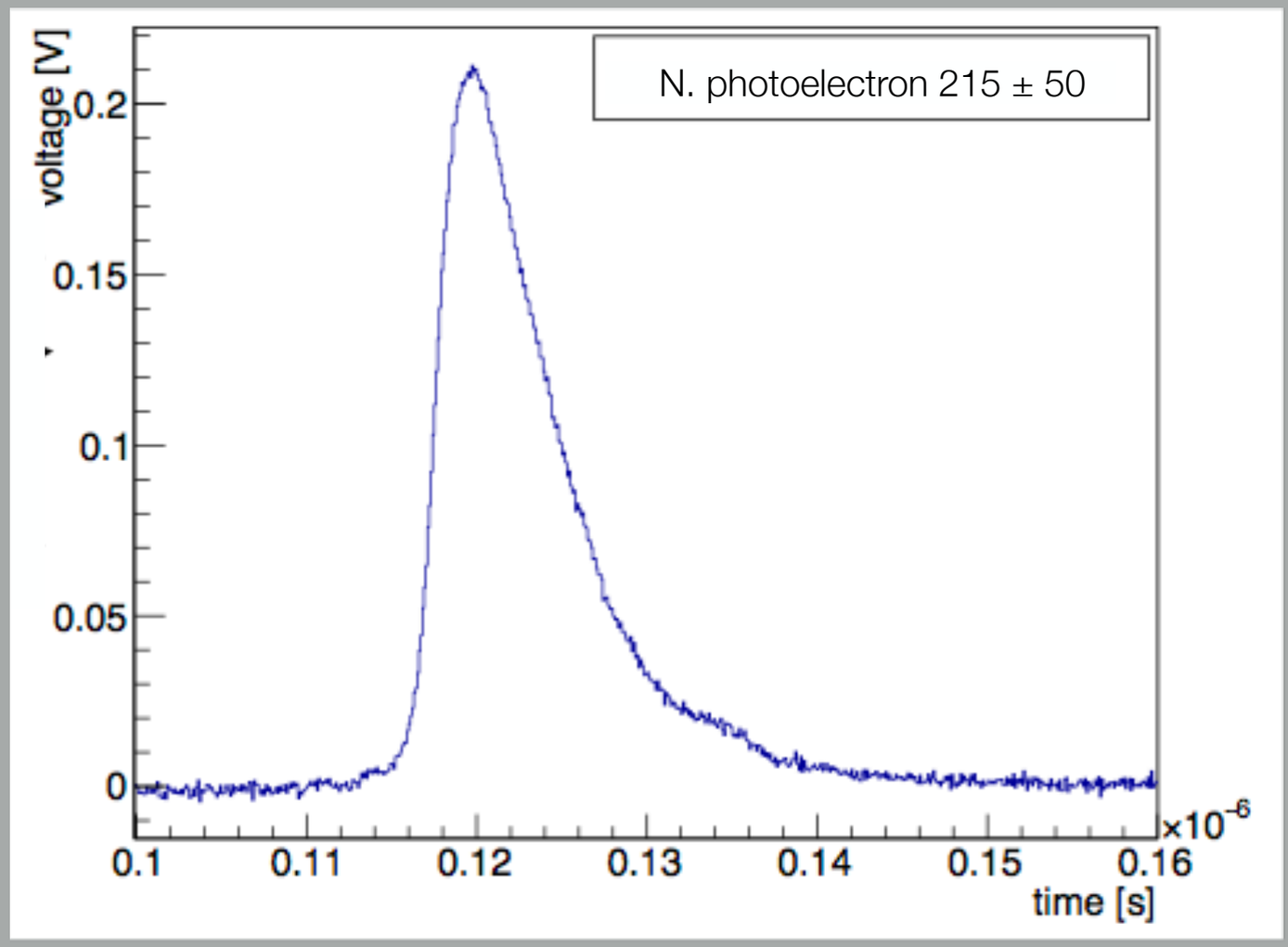
PENELOPE



Test PENELOPE prototype :

- electron beam (50-450 MeV)

Measurements with traditional PMT readout



- By integrating the signal, offset subtracted, is it possible to measure the total number of photoelectrons;
- The number of layer crossed by the particles = 30 ± 3;

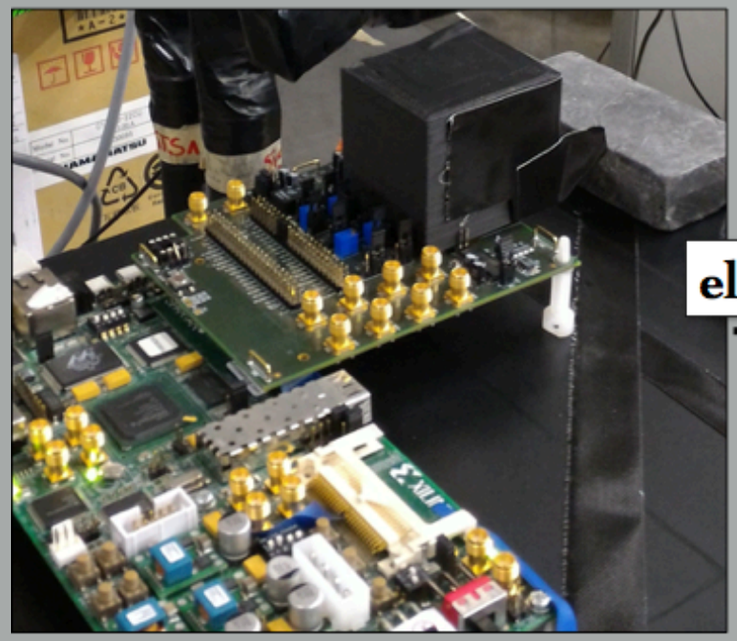
The average number of detected photoelectron per fibers is 7.2 ± 1.4

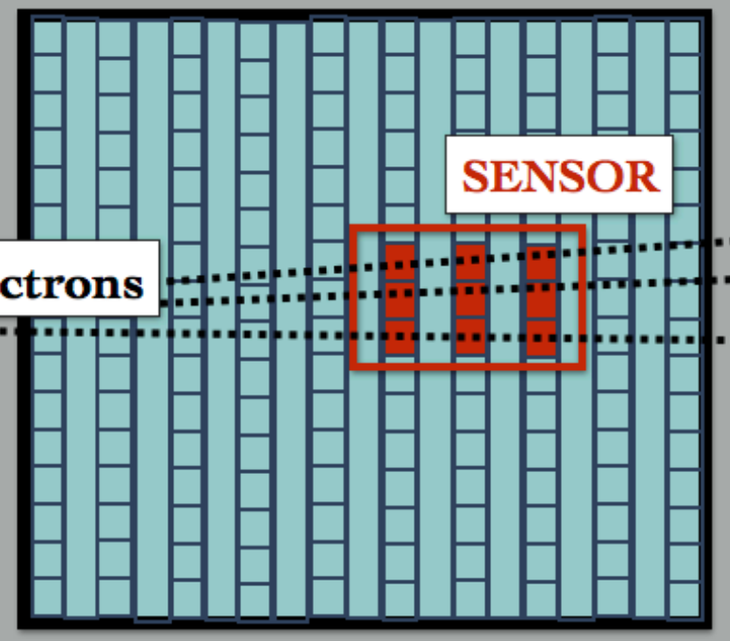
PENELOPE

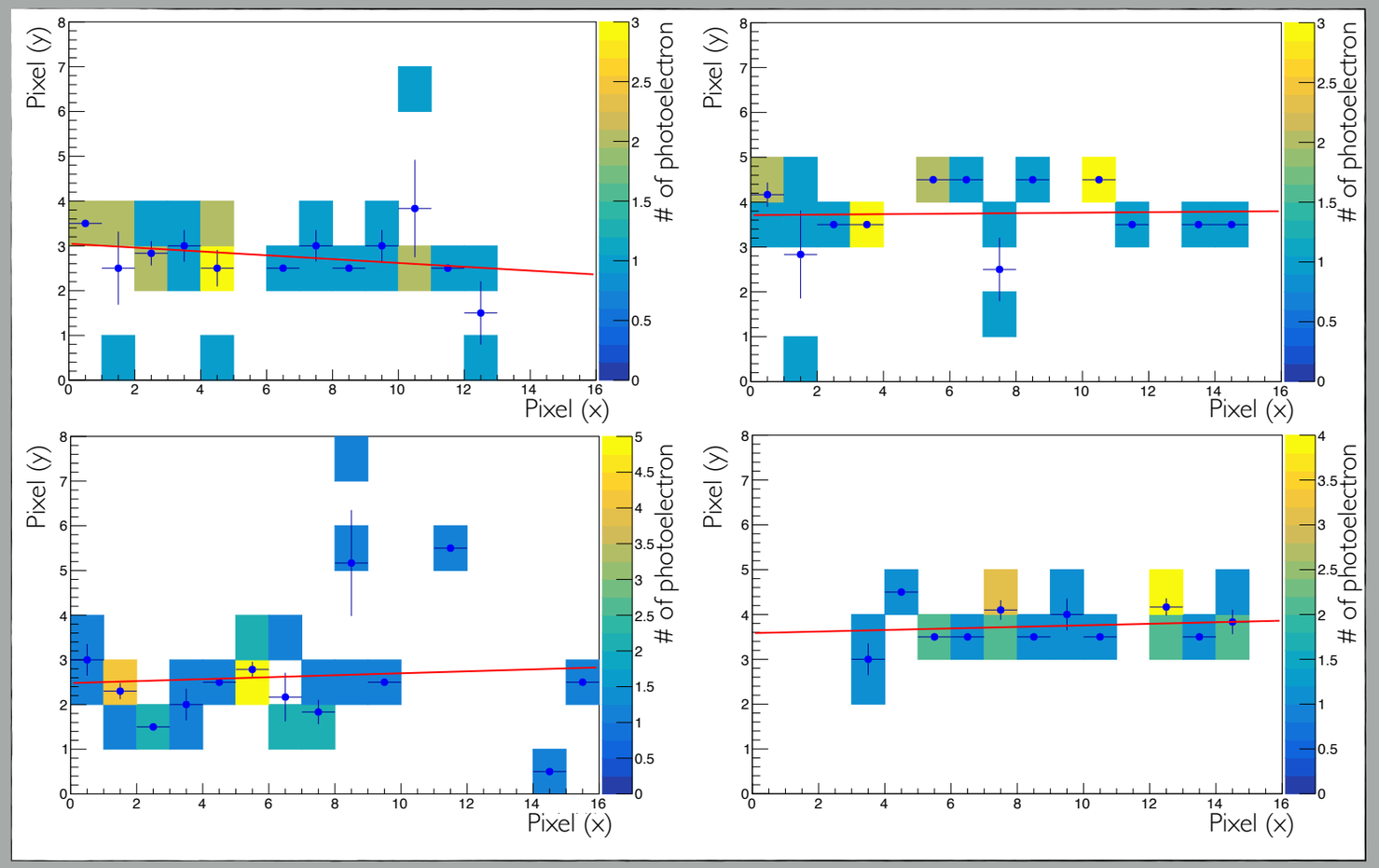
<u>Test PENELOPE prototype</u> :

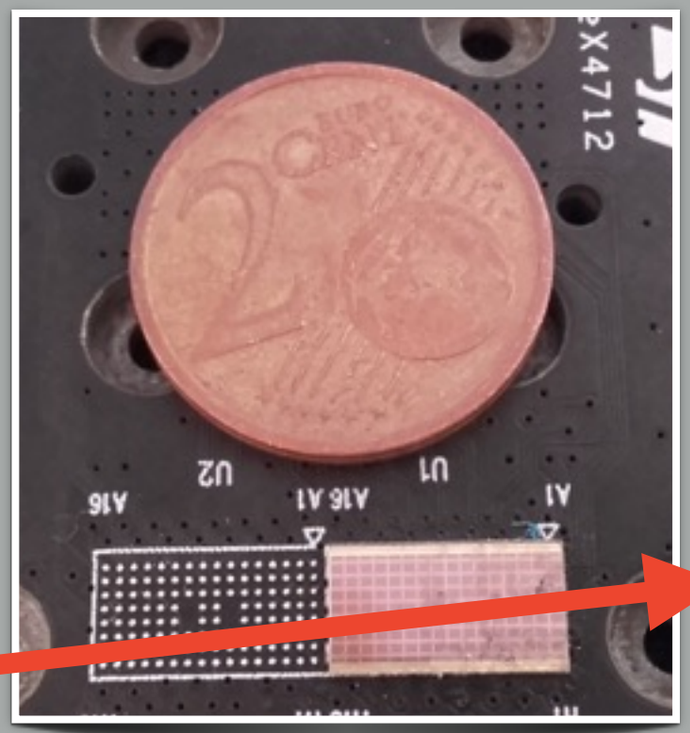
- electron beam
(50-450 MeV)

Measurements with *spadnet* sensor: only a small fraction of surface is acquired

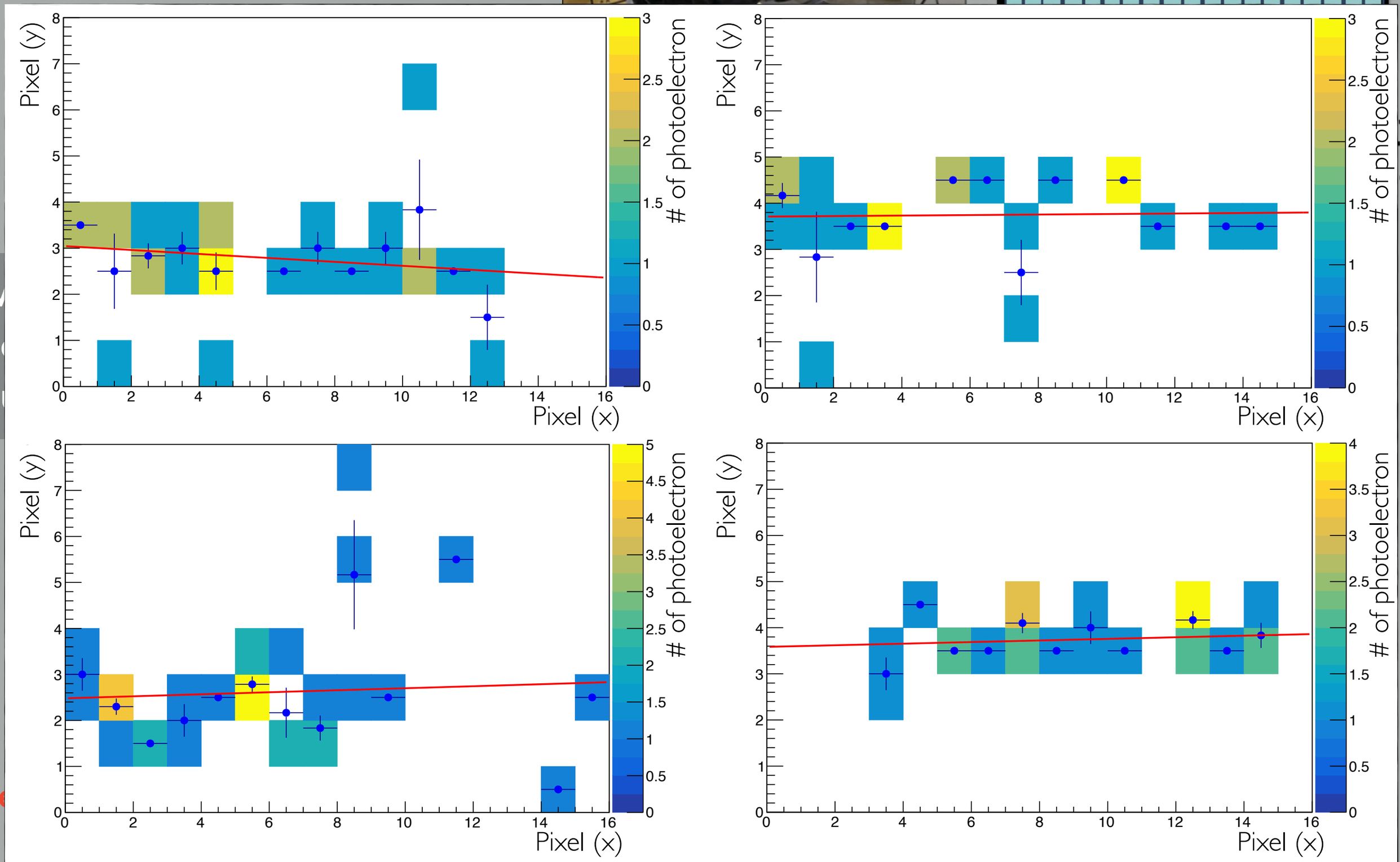




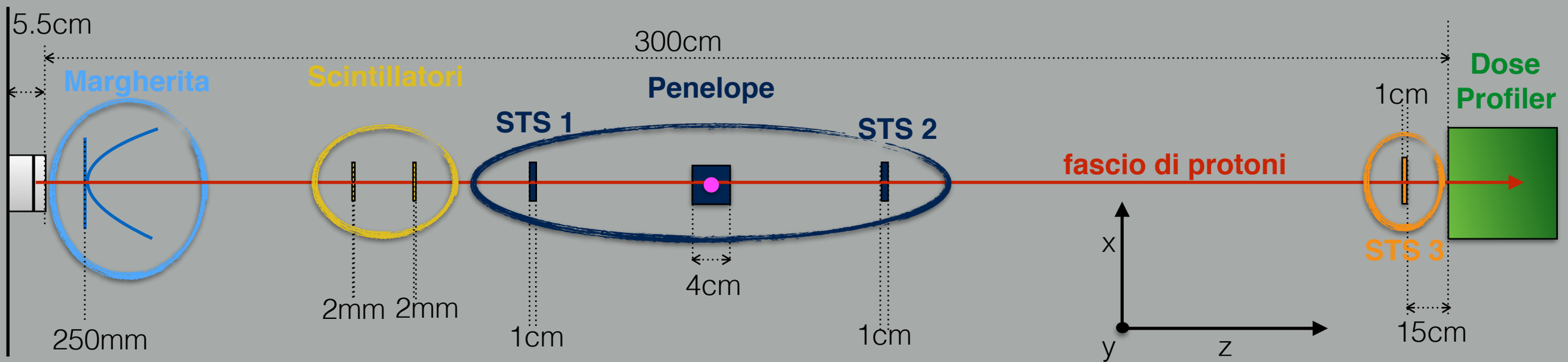


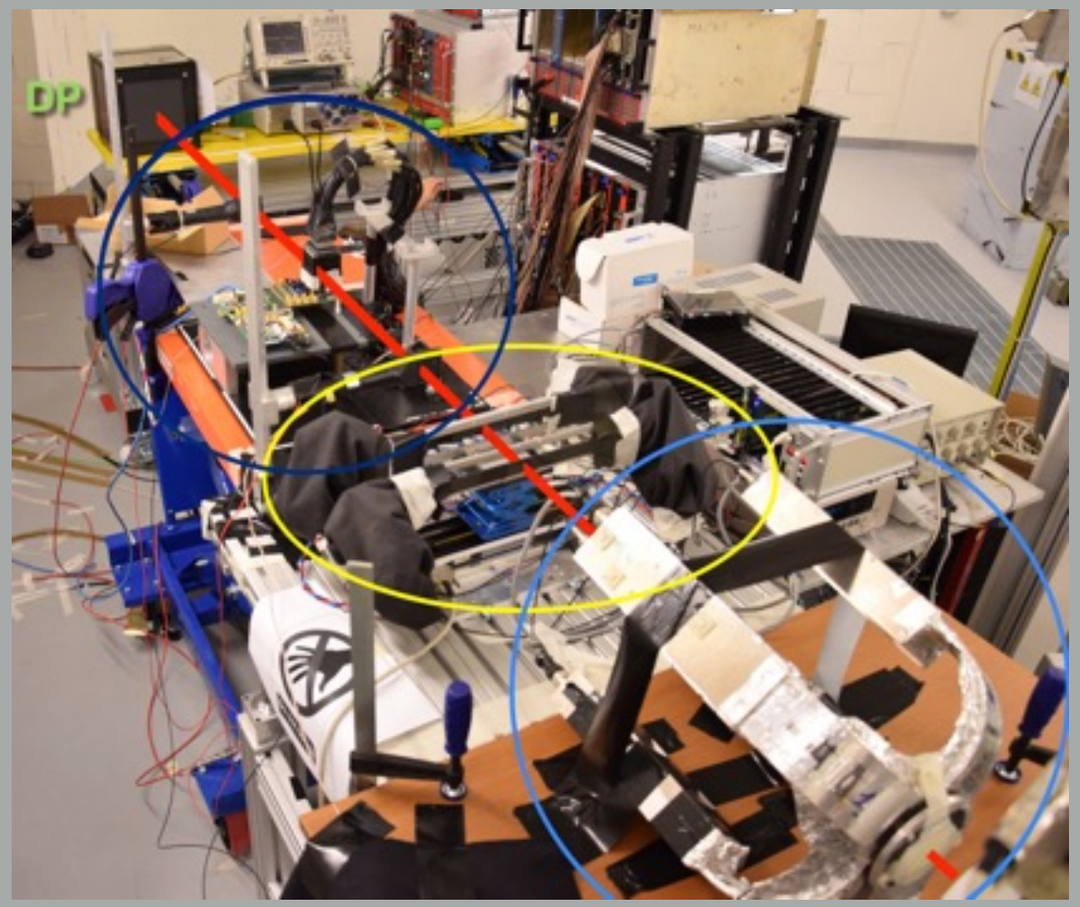


PENELOPE


Pixel (y)
Pixel (x)
# of photoelectron
Pixel (y)
Pixel (x)
# of photoelectron
Pixel (y)
Pixel (x)
# of photoelectron
Pixel (y)
Pixel (x)
# of photoelectron

EXPERIMENTAL SETUP





Two different readout for PENELOPE:

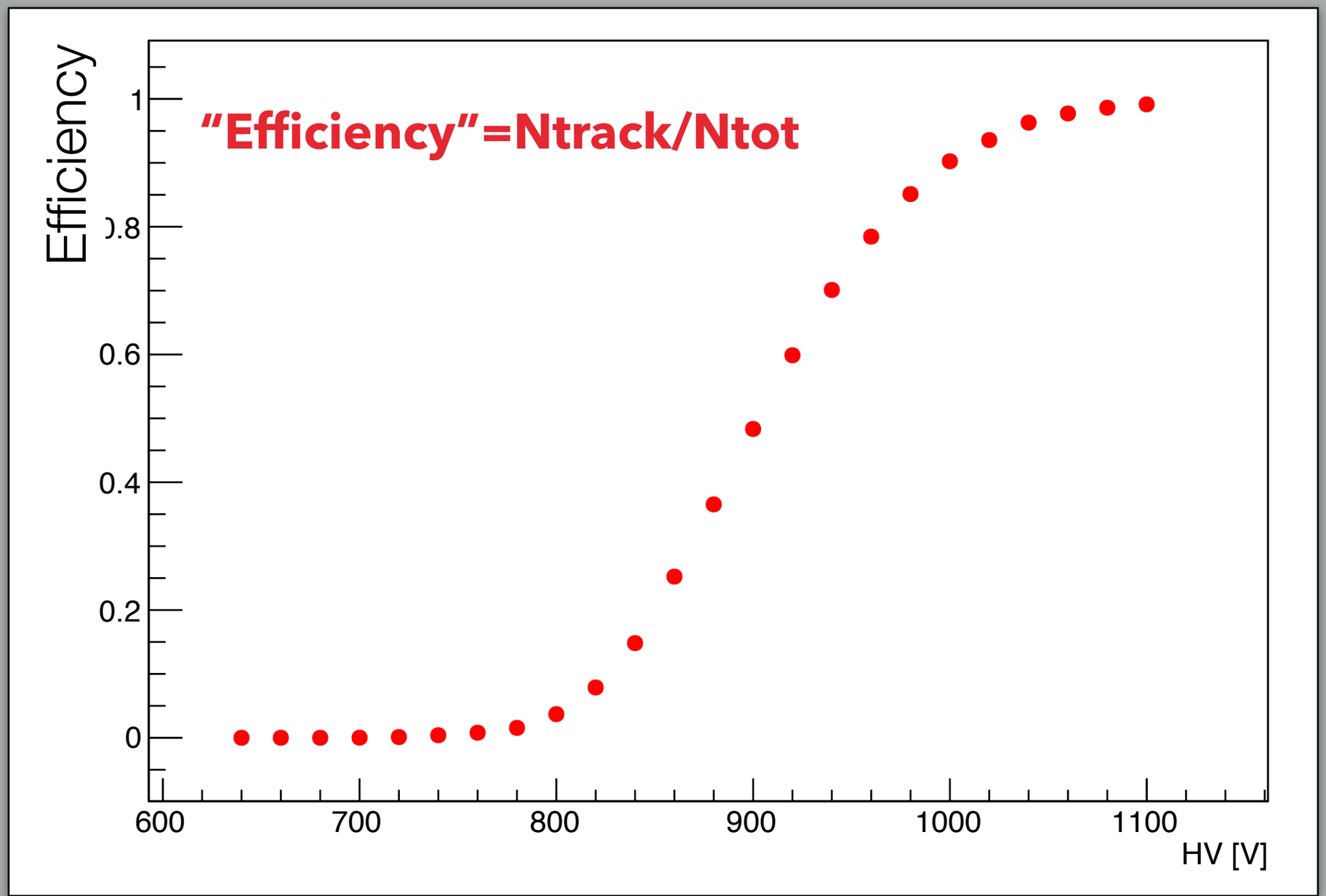
HAMAMATSU Multianode (64 ch., 6mm per pixel)

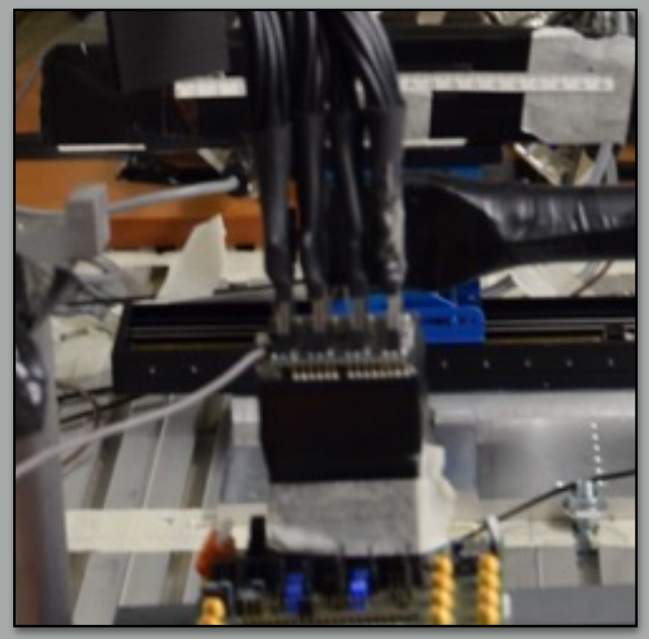
FBK spadnet sensor (128 ch., 600μm per pixel)

PROTON THERAPY CENTER TRENTO WITH PROTONS

Mono-energetic proton beam impinging on PENELOPE matrix

2° PENELOPE readout: HAMAMATSU Multianode (64 ch., 6mm per pixel)





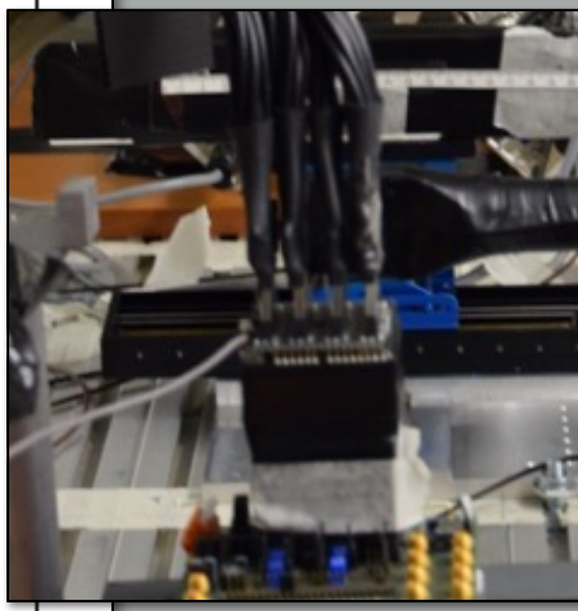
1 TDC per each ch.
No pixel charge info
only average total charge released

HV scan => Thr. scan

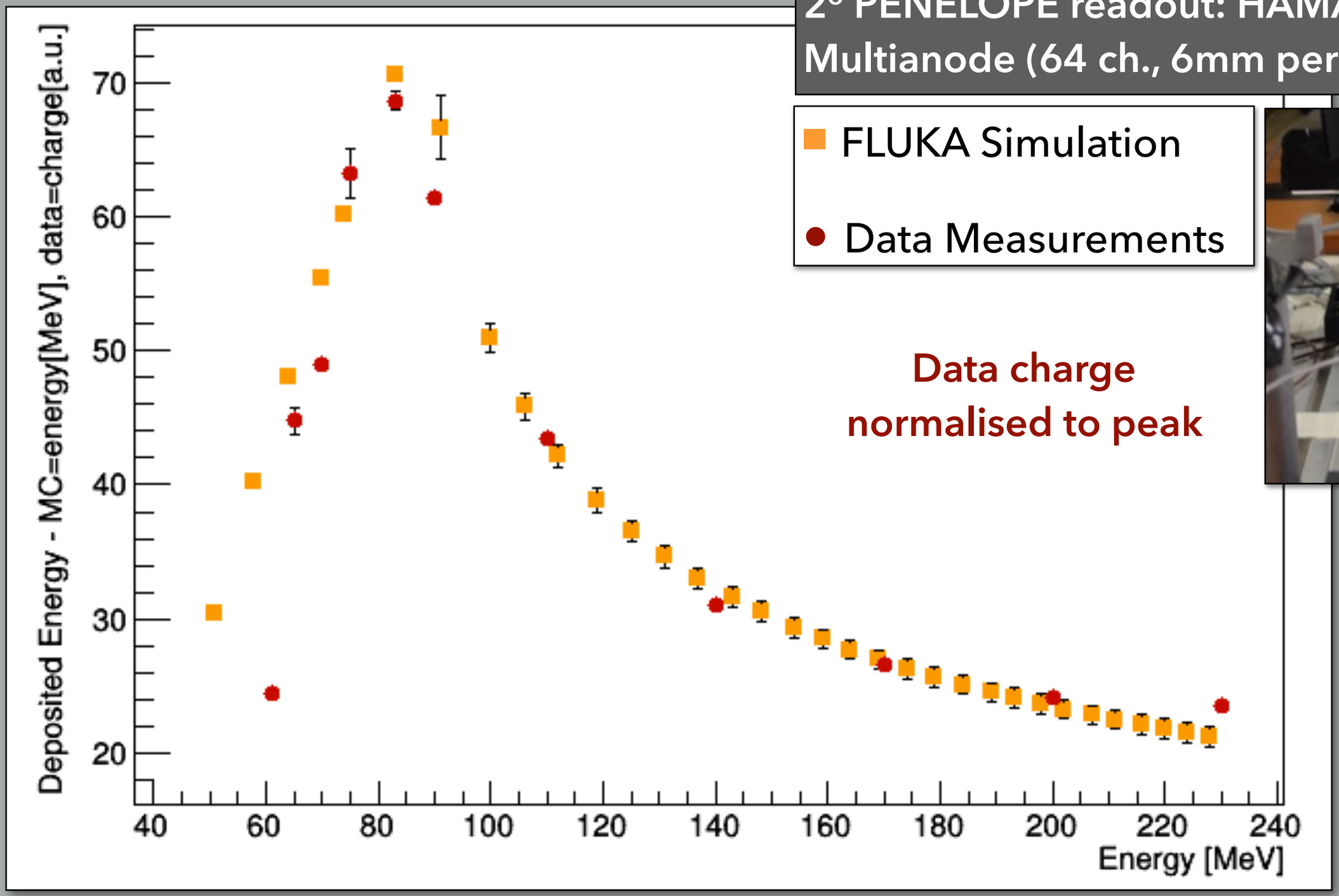
PROTON THERAPY CENTER TRENTO WITH PROTONS

2° PENELOPE readout: HAMAMATSU Multianode (64 ch., 6mm per pixel)

- FLUKA Simulation
- Data Measurements



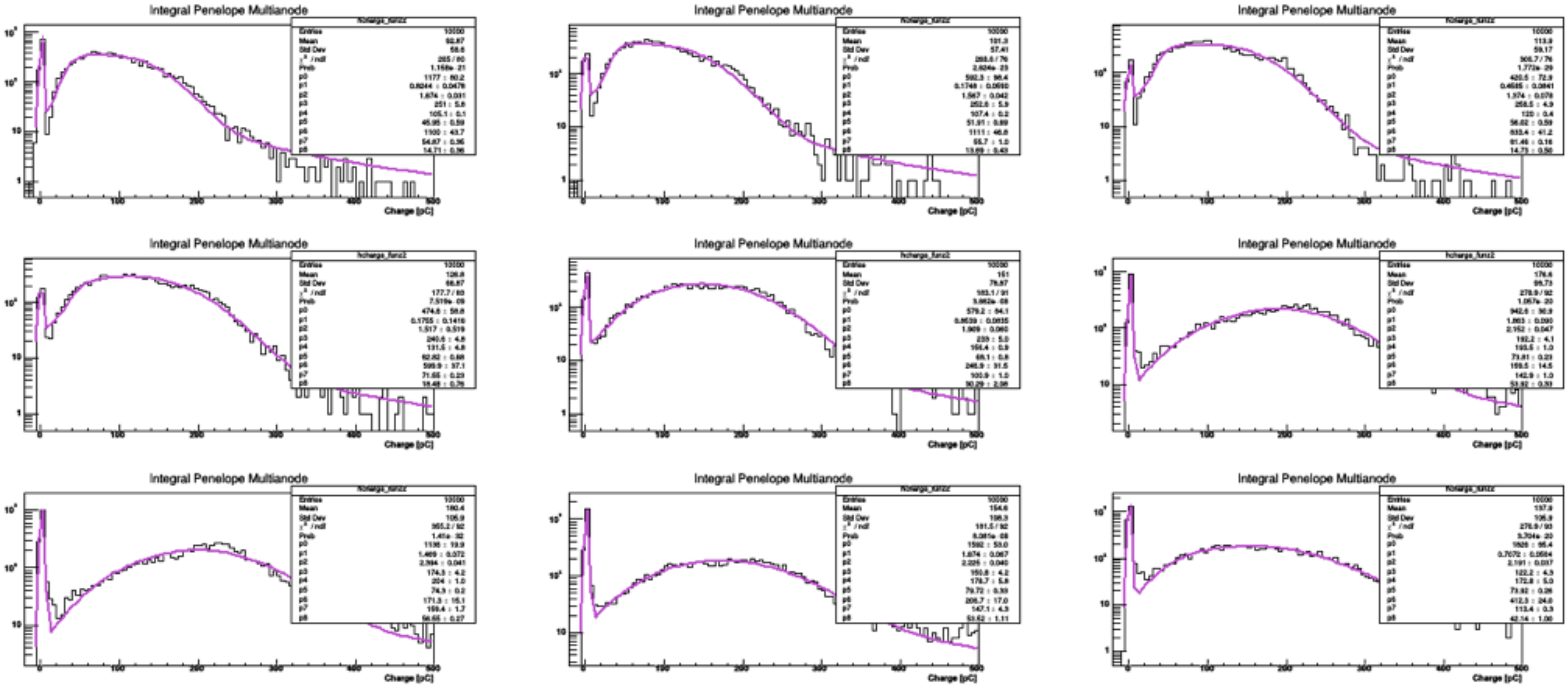
Data charge normalised to peak

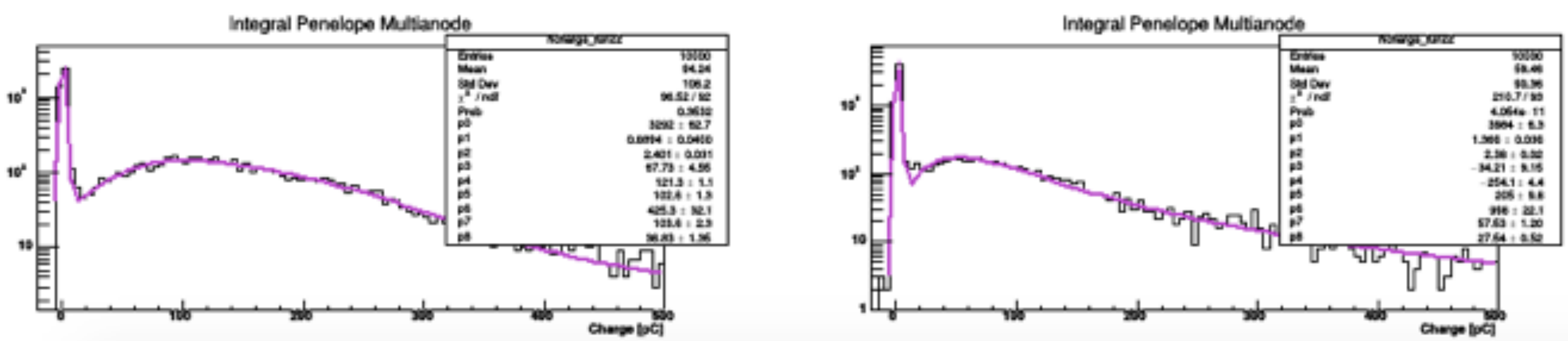


Only average total charge

Preliminary (No syst. errors has been evaluated jet)

PROTON THERAPY CENTER TRENTO WITH PROTONS

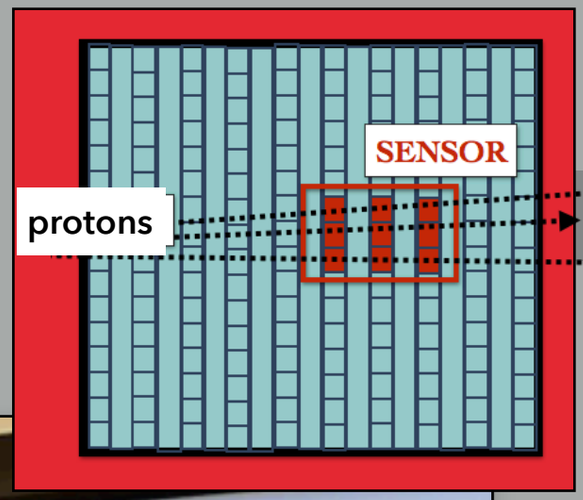




2° PENELOPE readout: HAMAMATSU Multianode (64 ch., 6mm per pixel)

TRENTO TEST BEAM

PROTON THERAPY CENTER TRENTO WITH PROTONS



1° PENELOPE readout: FBK spadnet sensor (128 ch., 600µm per pixel)

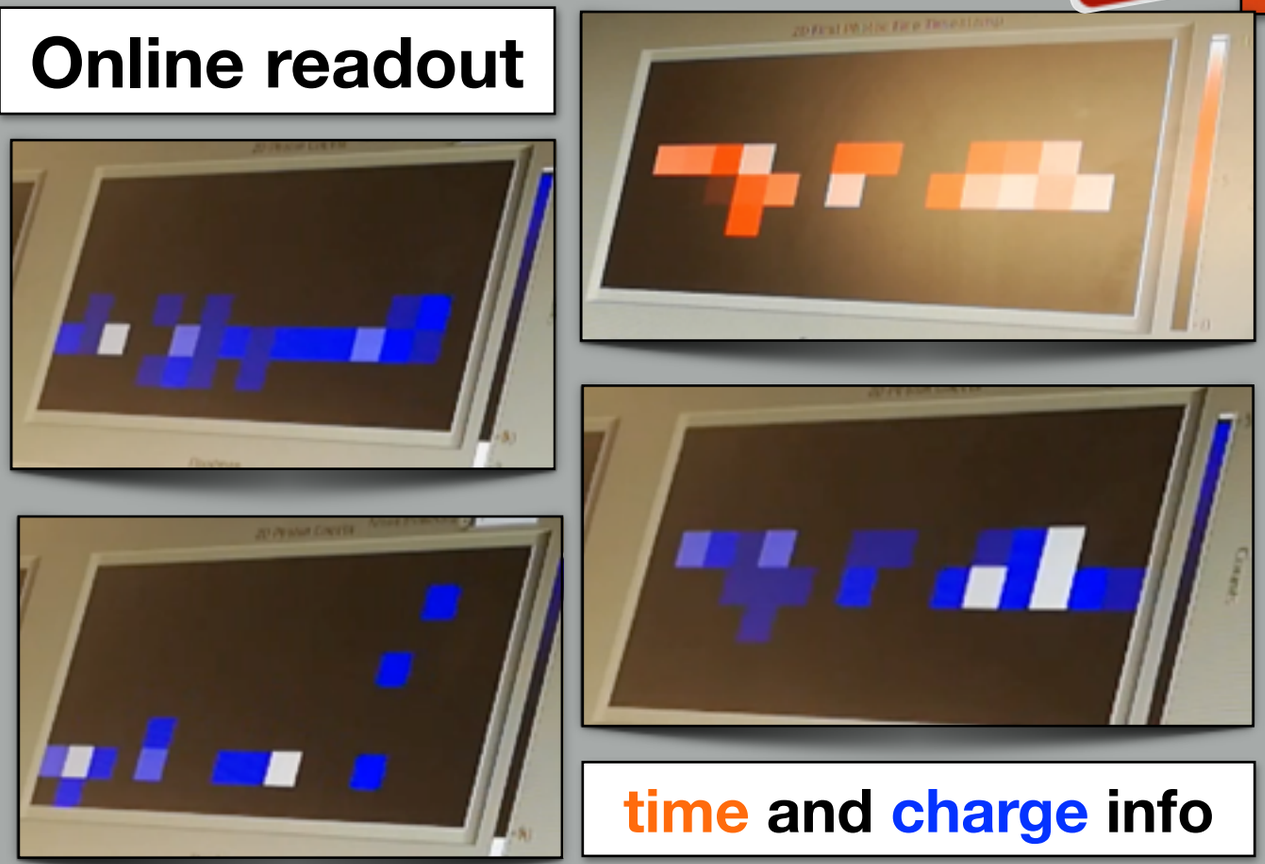
PROTON THERAPY CENTER TRENTO WITH PROTONS

1° PENELOPE readout: FBK spadnet sensor (128 ch., 600μm per pixel)

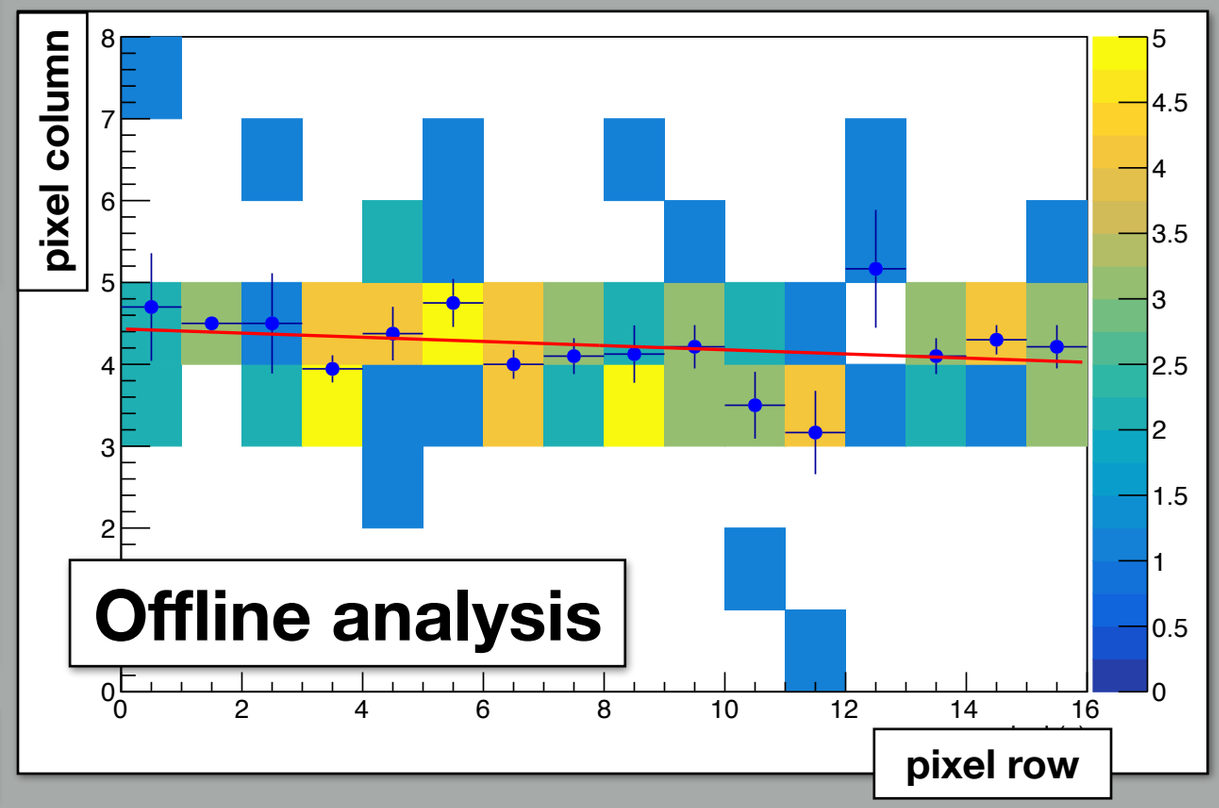
A detailed analysis of the proton tracks in the fibres readout by the *spad-net* sensor is ongoing

COMING SOON

Online readout



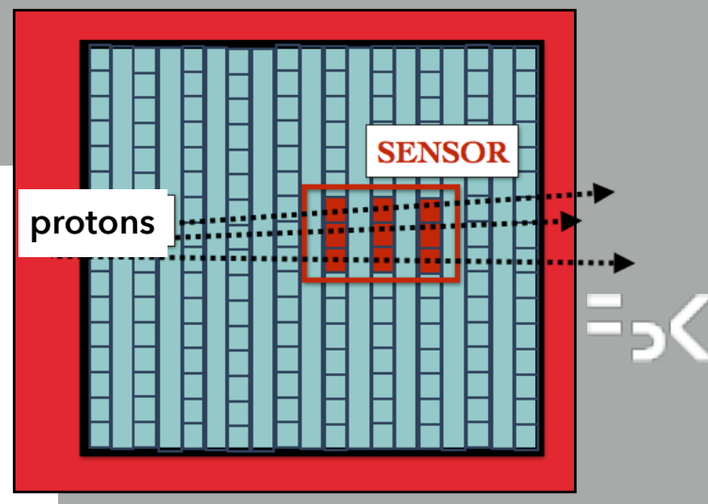
time and charge info

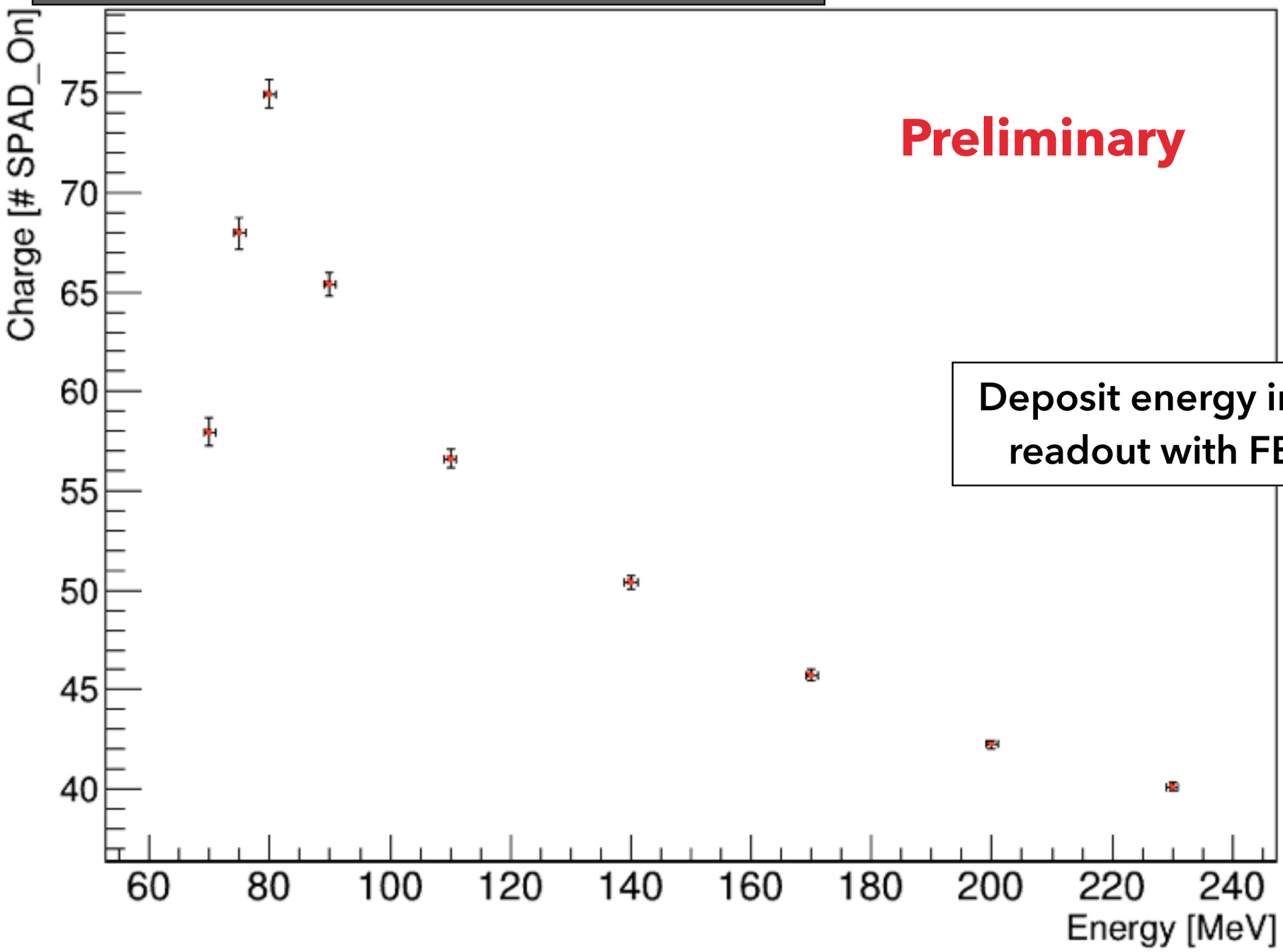


May 2017 Measurements

PROTON THERAPY CENTER TRENTO WITH PROTONS

1° PENELOPE readout: FBK spadnet sensor (128 ch., 600μm per pixel)

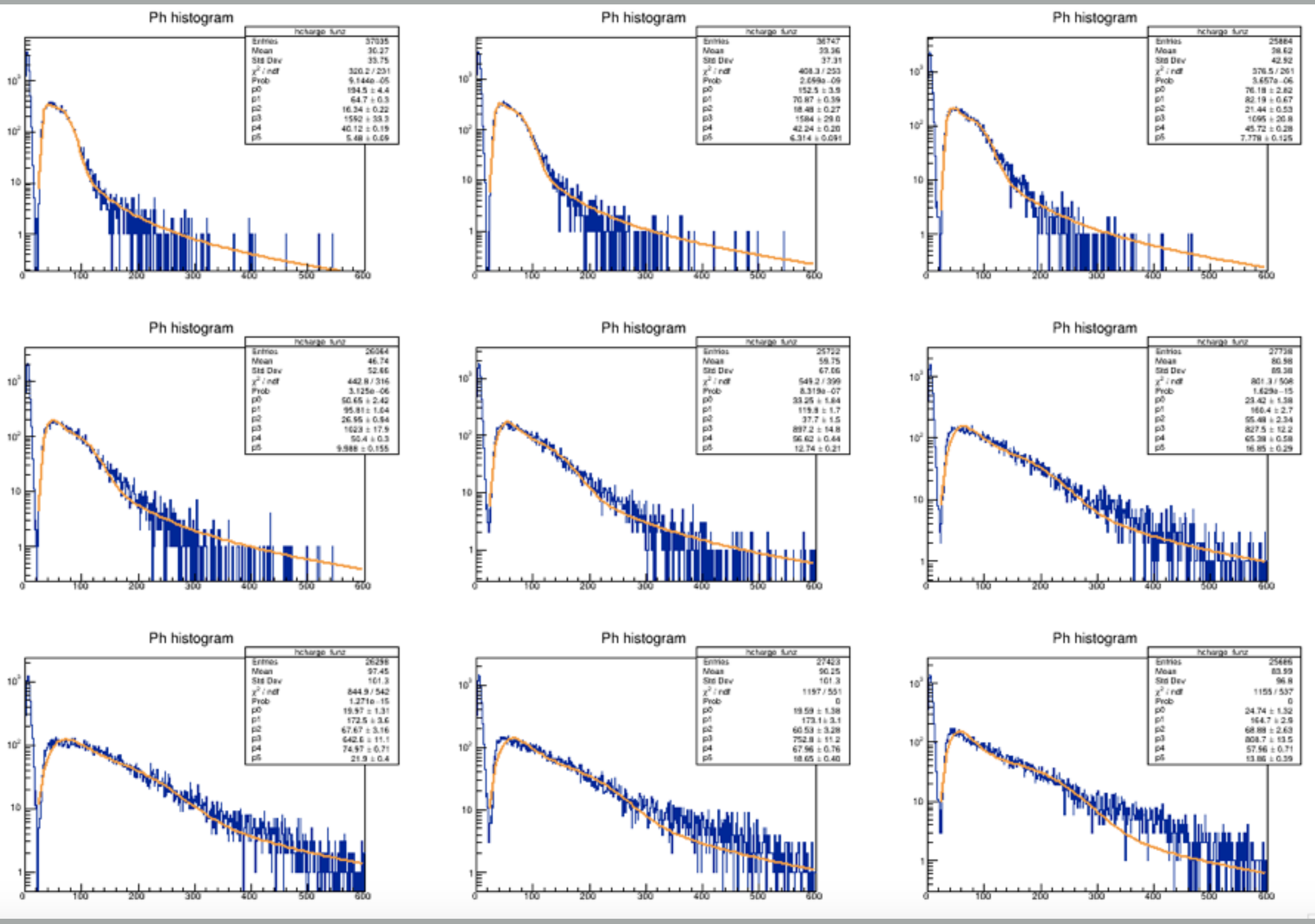




Preliminary

Deposit energy in the fibres readout with FBK sensor

PROTON THERAPY CENTER TRENTO WITH PROTONS



- **Summer Conferences**

We got 5 talks: Mirabelli, (YRM-Cagliari) Mattei (MEDAMI), Marafini (MLZ) Traini (iWorid), Giacometti (Strasburgo), 1 joined talk with the DP at Scint. and 1 poster at MC-Napoli; Still waiting from SIF.

- **To do:**

1. Full size detector => 10 x 10 x 20 cm^3;
2. SBAM sensors FBK => test chips;
3. Test with Protons (TIFPA) and Carbon ions (CNAO);
4. Software: implementation of the readout system, background study and evaluation of the resolutions (energy and angle);
5. New sensor SBAM (full run) FBK;
6. Measurements with secondary neutrons produced in PMMA with protons (TIFPA) and Carbon ions (CNAO) beams;

GRAZIE!!

ULISSE

Test ULISSE :

- electron beam
(50-450 MeV)