The University of Kansas

Tests of an LGAD detector using a Linac for radiotherapy

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Torino PicoSecond Workshop 16 - 18 May 2018

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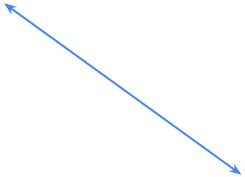
Medical Physics needs High Energy Physics ...

need of fast detectors to monitor high rate medical accelerators and evaluate instantaneous dose absorbed by the patient

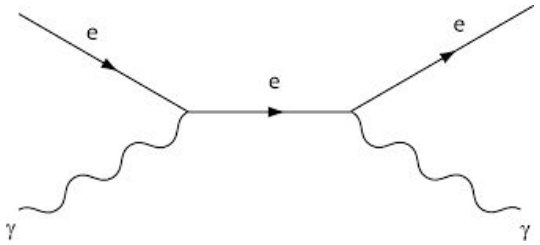


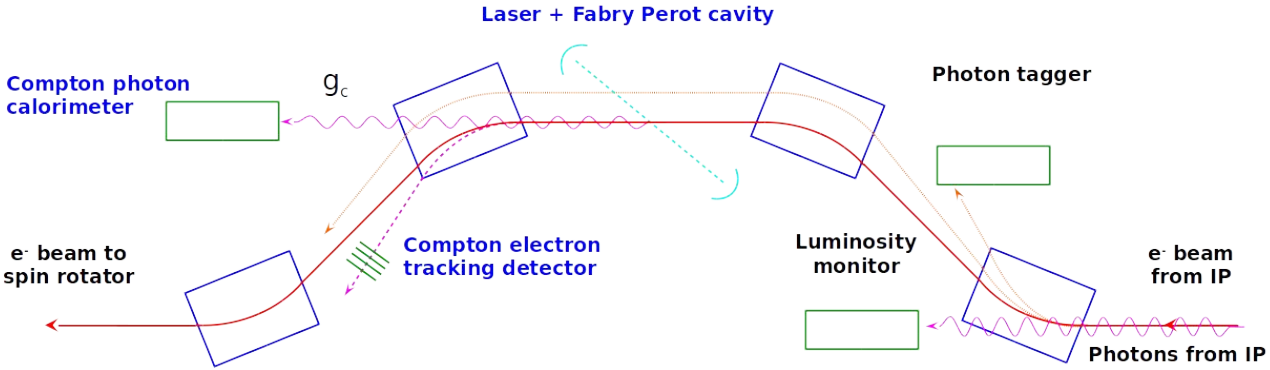
... High Energy Physics needs Medical Physics

characterization of fast detectors to discriminate single electrons pulses in high rate facilities (polarimetry @ EIC)

HEP applications: high rate in particle colliders

Study of the polarization of the electron beam





$$\sigma(\vec{e} + \gamma \rightarrow e' + \gamma') \neq \sigma(\overleftarrow{e} + \gamma \rightarrow e' + \gamma')$$

The Compton effect cross section (Laser on electrons) changes with the electron spin state!

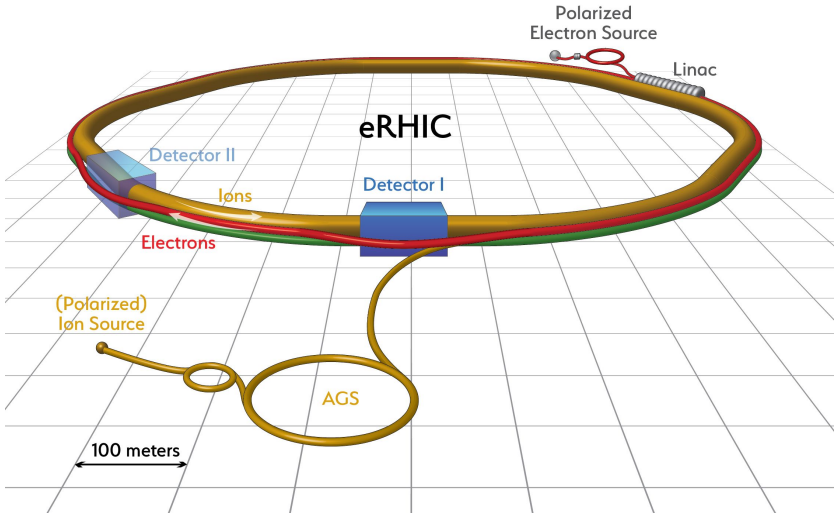
$$A_{EXP} = \frac{N^+ - N^-}{N^+ + N^-} = P_e \cdot P_\gamma \cdot A_{QED}(E_e, k_\gamma, k_{\gamma'})$$

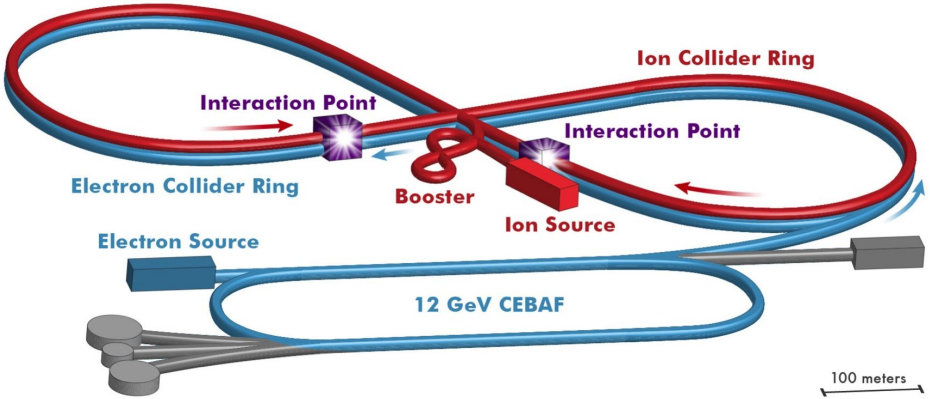
NOTE:
For electron beam asymmetry measurements polarization can be the dominating error. Aiming for 1% or better electron polarization accuracy and 0.5 % for parity violation program

Need of a detector capable of single electron pulse counting...

HEP applications: high rate in particle colliders

...However the measurements have to be performed bunch-by-bunch





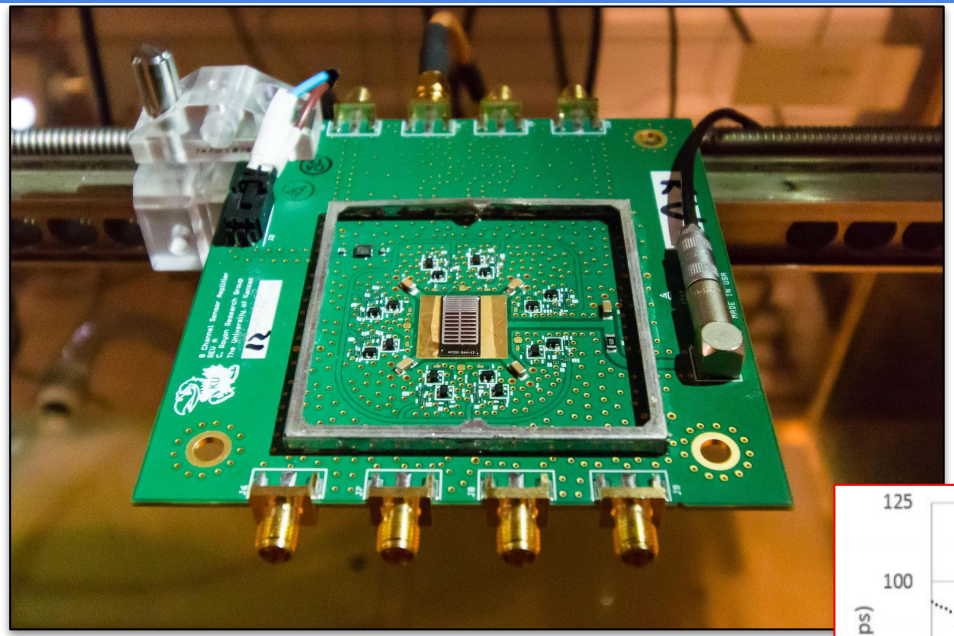
Lower luminosity
560 MHz RF
330 bunches
33 ns between bunches
Electron current up to 1.2A
Ion current up to 0.46 A

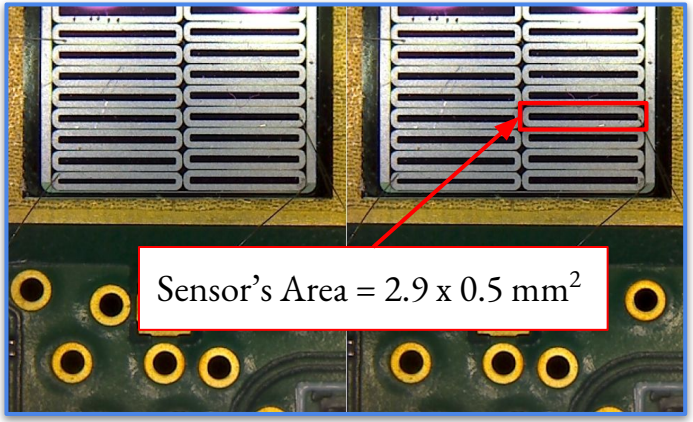
High luminosity
560 MHz RF
1320 bunches
10 ns between bunches
Electron current up to 2.4 A
Ion current up to 0.92 A

Low and Medium energy
476 MHz RF
1540(x2) bunches
2 .1 ns between bunches
Electron current up to 2.8 A
Ion current up to 0.75 A

High energy
476 or 119 MHz RF
385 x 2 bunches
8.4 ns between bunches
Electron current up to 0.75 A
Ion current up to 0.71 A

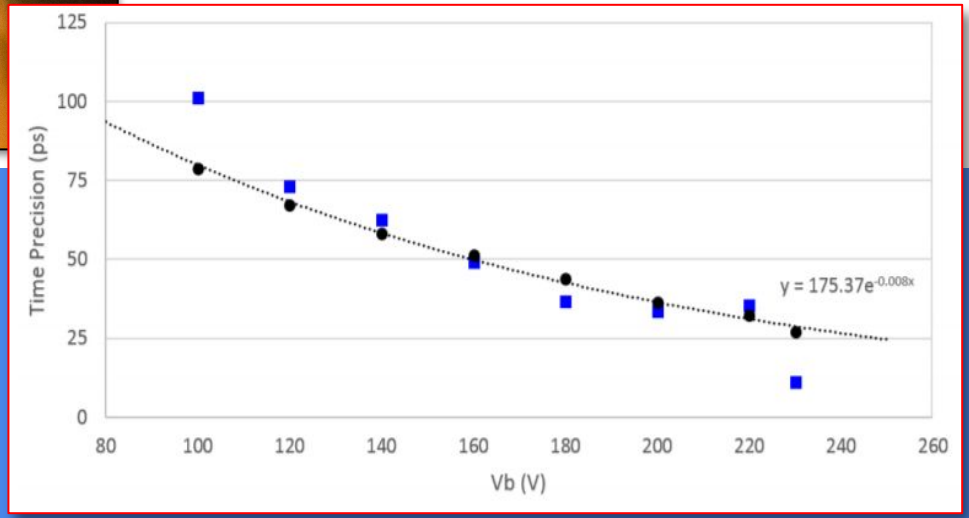
The sensors & detectors' board





The boards designed @ KU were characterized with a 50 µm UFSD using a particle beam at CERN

Time Precision < 30 ps on the chosen pixel

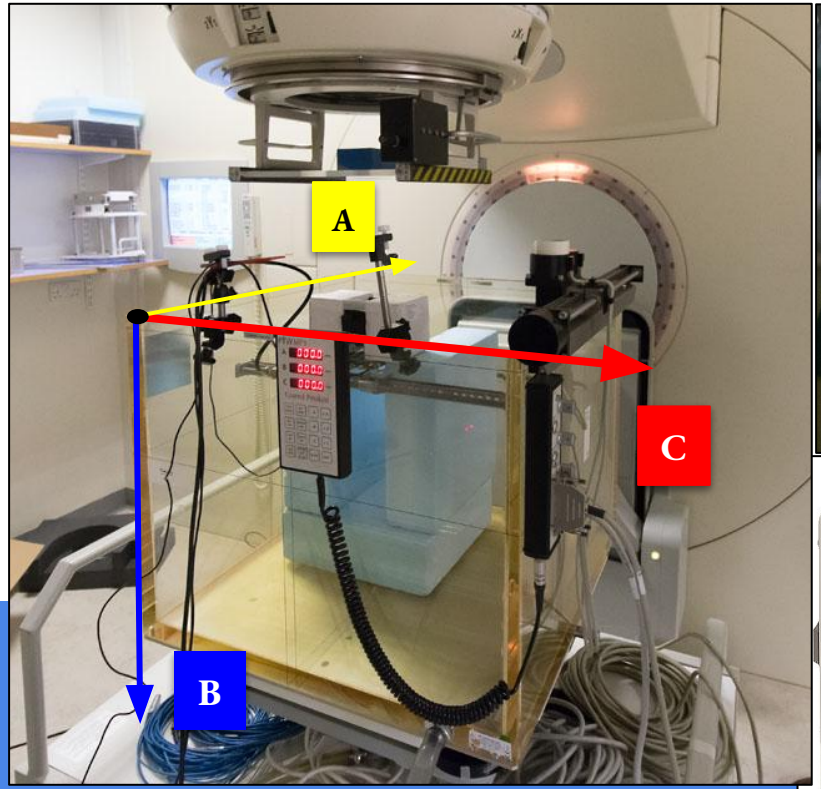


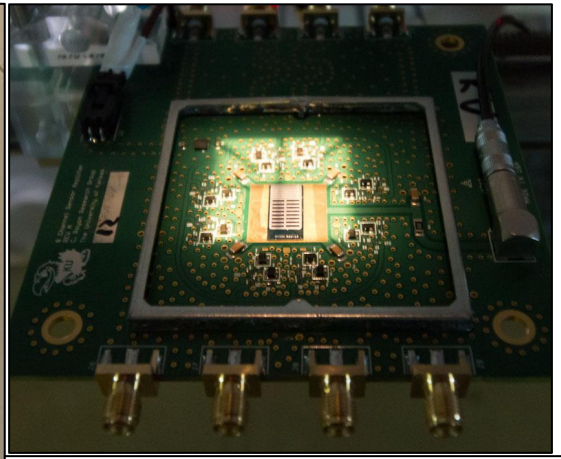
"Test of Ultra Fast Silicon Detectors for Picosecond Time Measurements with a New Multipurpose Read-Out Board"

St. Luke's Hospital, Dublin

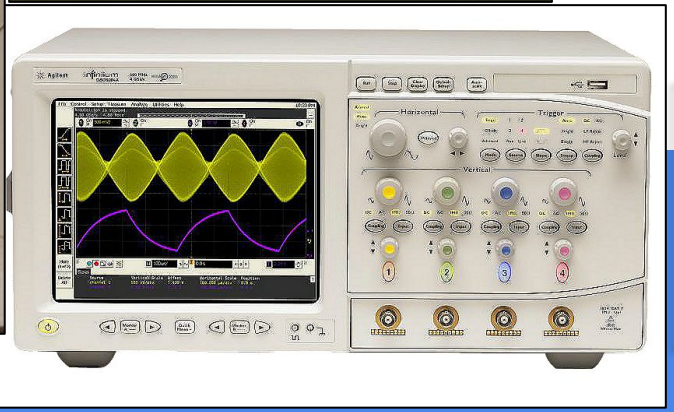
An LGAD has been installed under the X-ray beam (electrons accelerated with a linac (ELEKTA), then X-rays produced using a lead target) to study its performance and characterize the beam rate and composition

The Set-up





32 channels **LGAD** originally design to be integrated inside **CT-PPS** forward detectors (**U**ltra **F**ast **S**ilicon **D**etector)

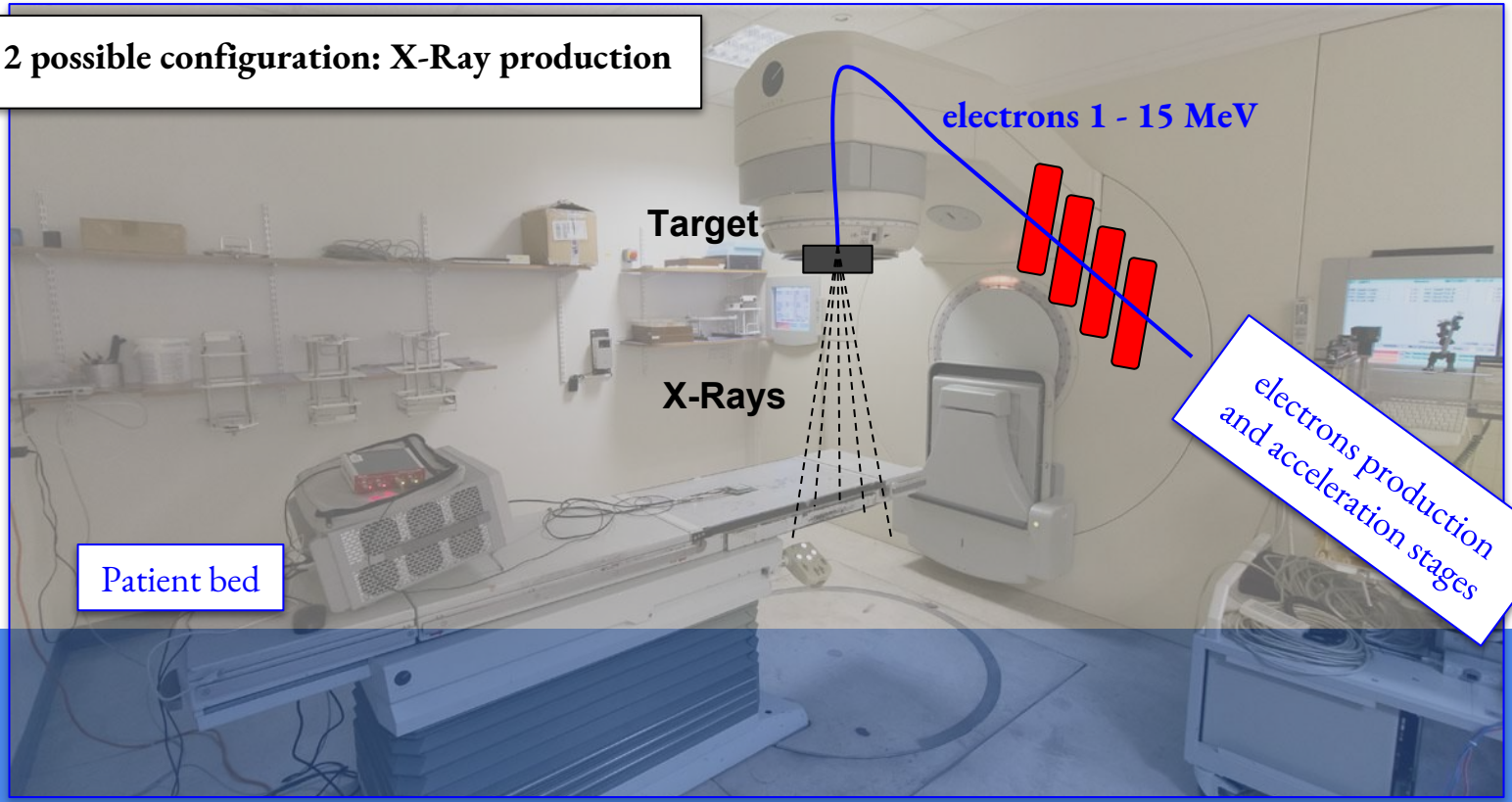


DSO8104A Infiniium

1 GHz
4 Channels
1 GSa/s

Detector mounted on a moving support contained inside the plexiglass box used to **reduce the back-scattering** during photon runs

St. Luke's Hospital, Dublin: X-ray

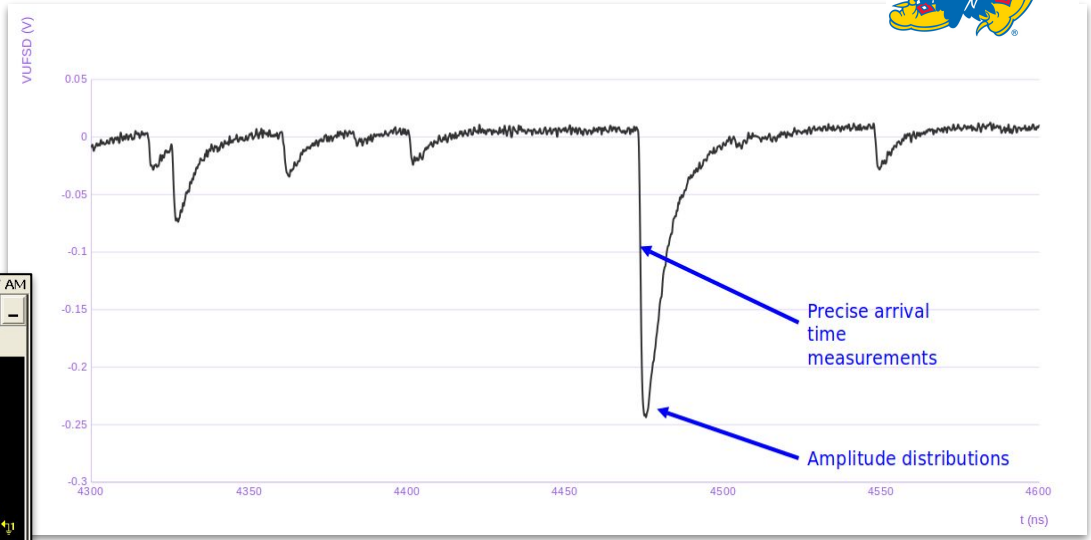


Note: Elekta Linac machine has a characteristic frequency of ~ 3GHz and produces spills ~ 2 μs long.

The signals

ENVELOPE:
rough idea of the intensity of the beam within a single pulse

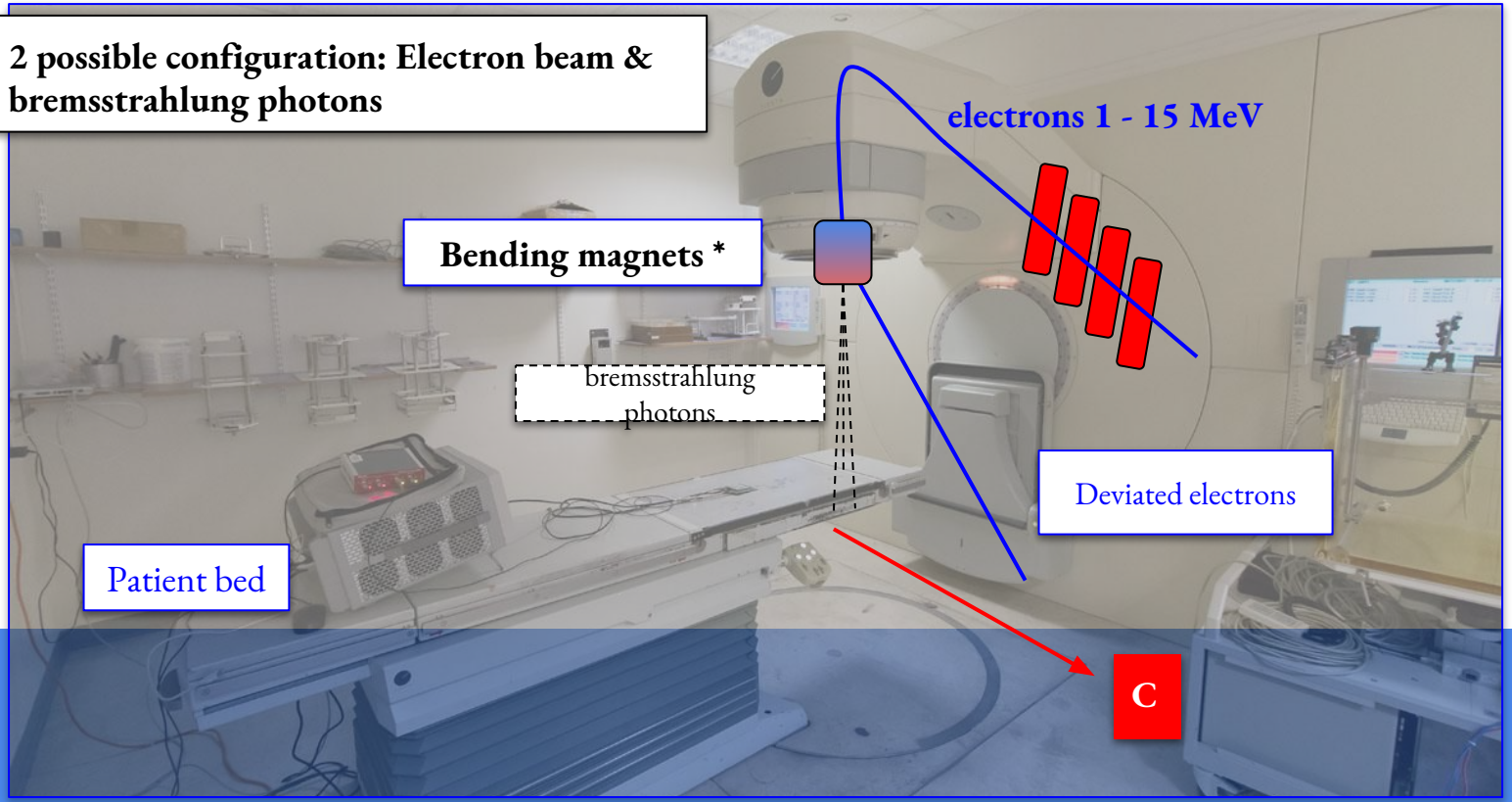
BASELINE:
rough idea of energy released (charge collected) by the particles



RMS:
rough idea of the number of particles per pulse

THYRATRON PULSE:
Fast trigger signal from the linac

St. Luke's Hospital, Dublin: electron beam



*** Bending magnets**

Block magnet :

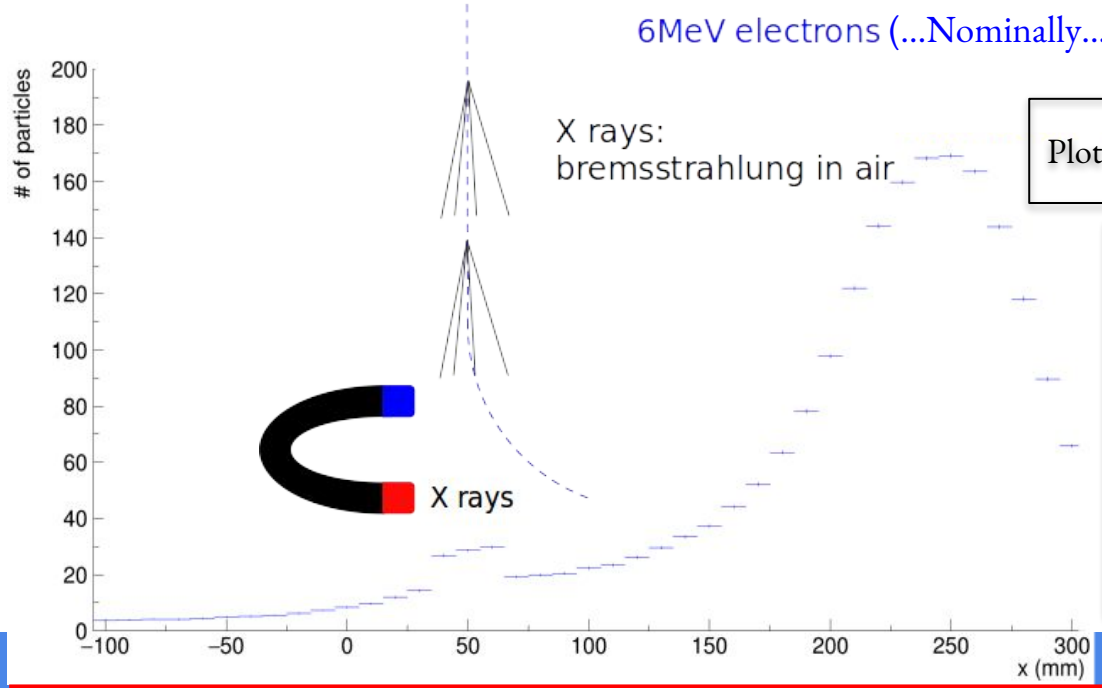
70 x 70 x 30 mm

Neodymium, N40, nichel-plated

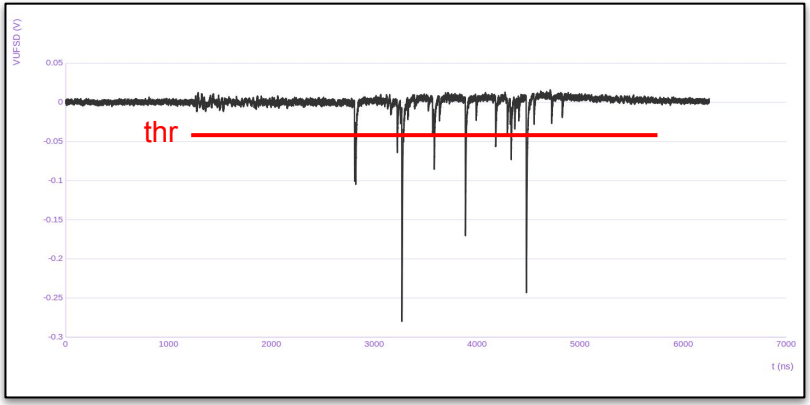
The sample of data chosen for the analysis was acquired using:

- Electrons energy: 6 MeV
- Distance Gantry gun - detector: 100cm
- presence of the Magnet → **USING THE SYSTEM AS A SPECTROMETER**

The signals



Plot of # of particles detected vs Xaxis position (C coordinate)

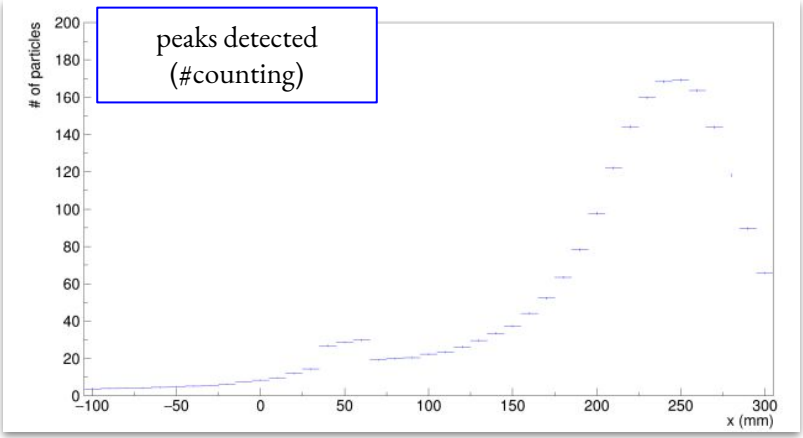


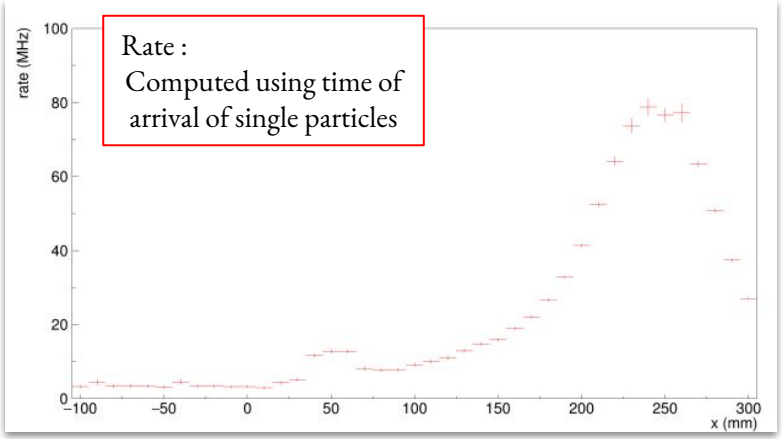
Once defined an offline threshold...

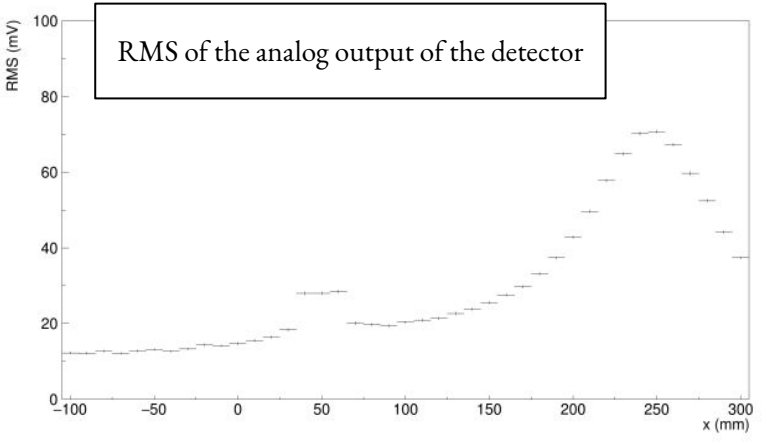
- we can acquire the profile of the **number of detected peaks along the defined axis.** (The moving support allowed us to scan the various horizontal position, verifying the magnet effect)
- We expect to see the 6 MeV electron peaks displaced from the beam's central position.

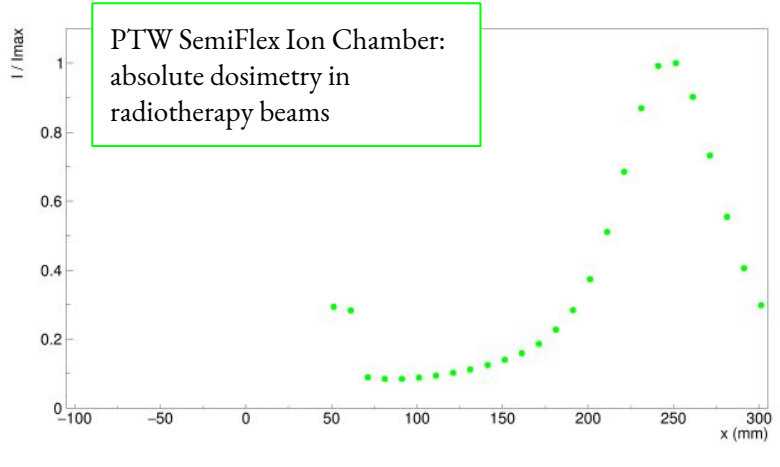
Data analysis

...Some data comparison vs Xaxis position (C coordinate)

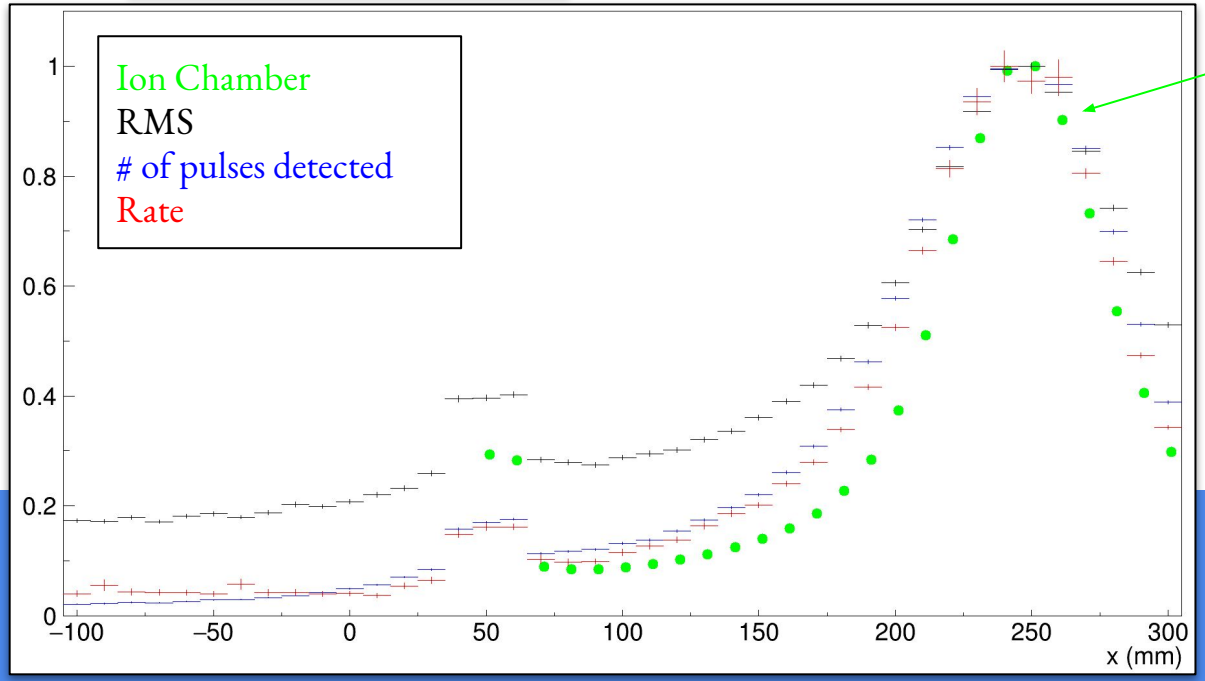








... Superimposing the data...



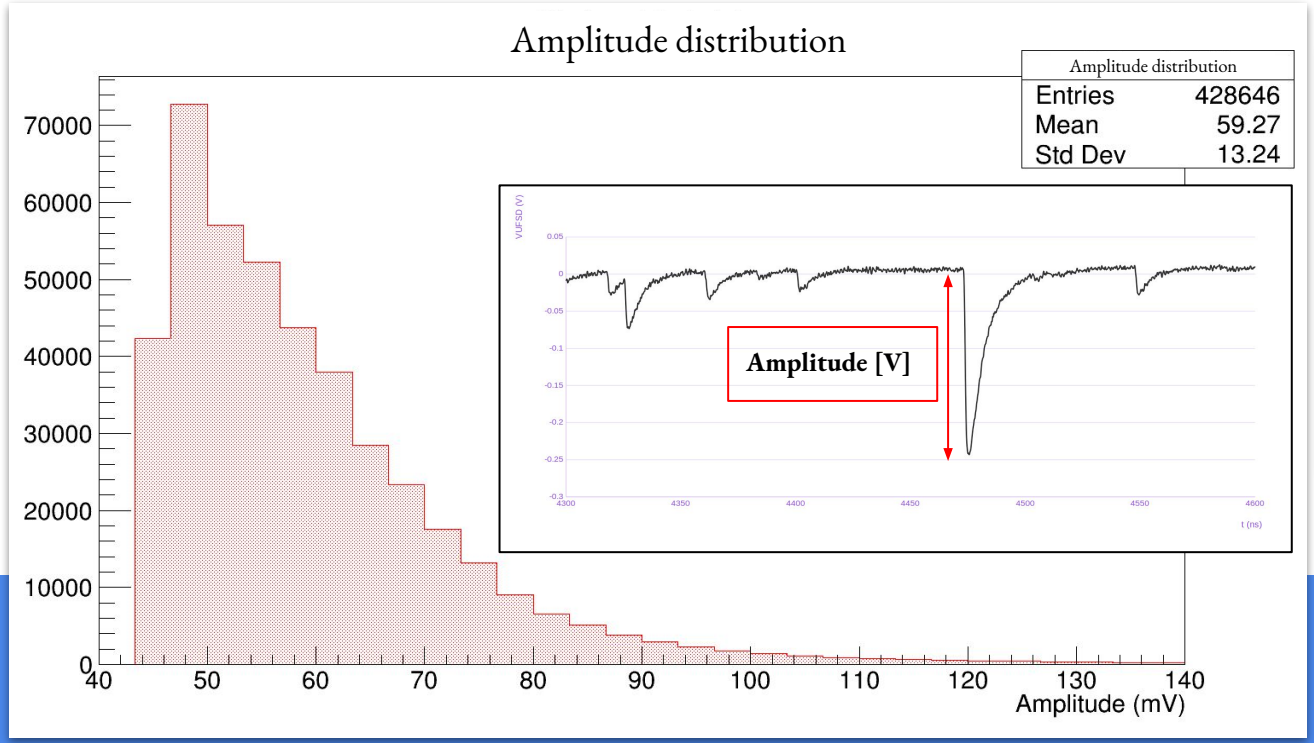
ION CHAMBER

PTW SemiFlex Ion chamber

WALL: 0.57 mm PMMA 1.19 g/cm^3
0.09 mm graphite, 1.95 g/cm^3

The superimposition of the 4 curves shows a similar behaviour for the 4 data set. → Energy calibration of the UFSD

Data analysis: amplitude distributions



The contribution of several effects reflects into the peaks amplitude distribution:

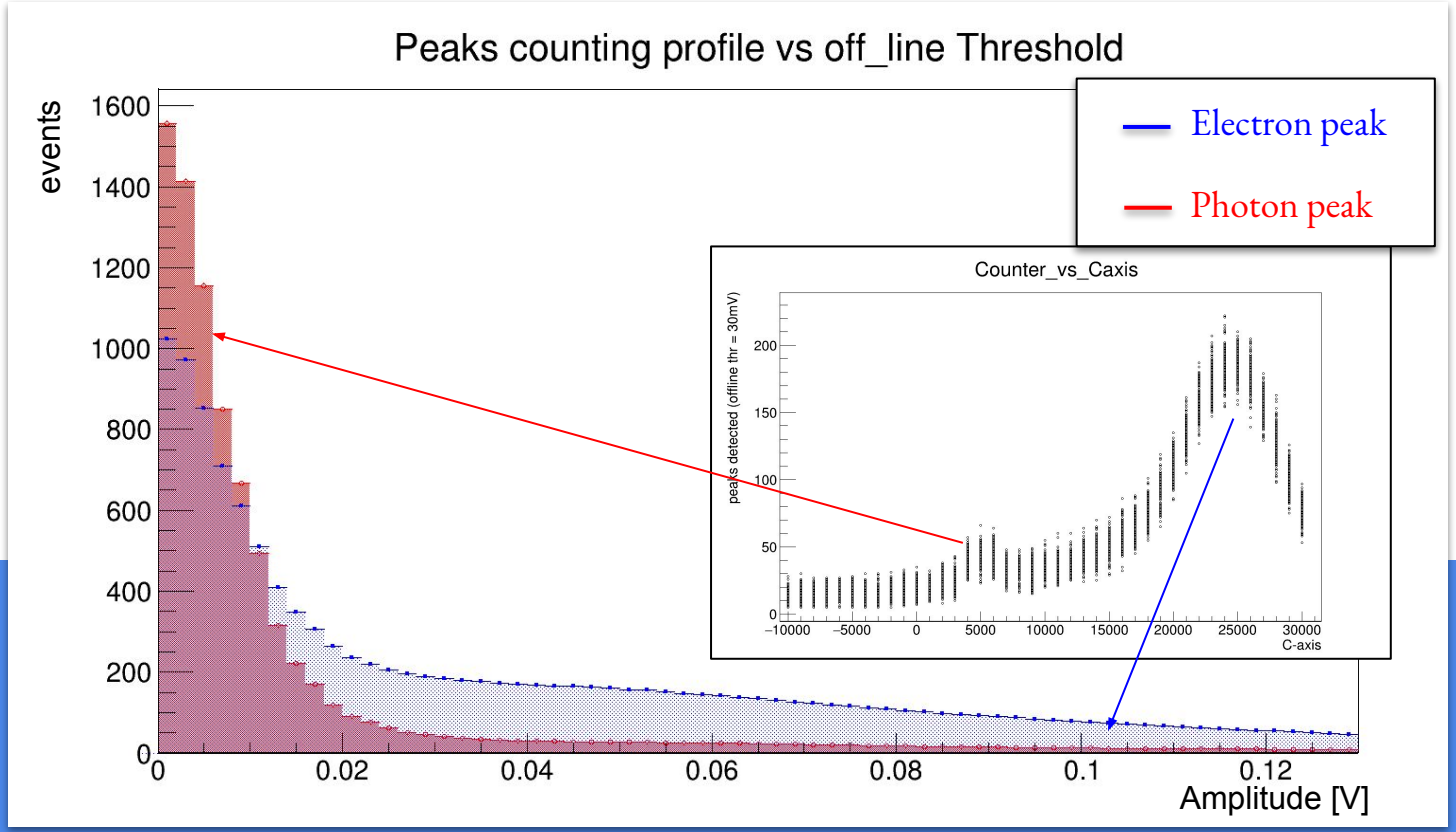
(bremsstrahlung photon converting in the sensor? double counting?...)

Impossible to extract a Landau distribution

Simulations needed!!

We can select and study the plot, dividing the zones where we expect to have the photons and electrons peaks

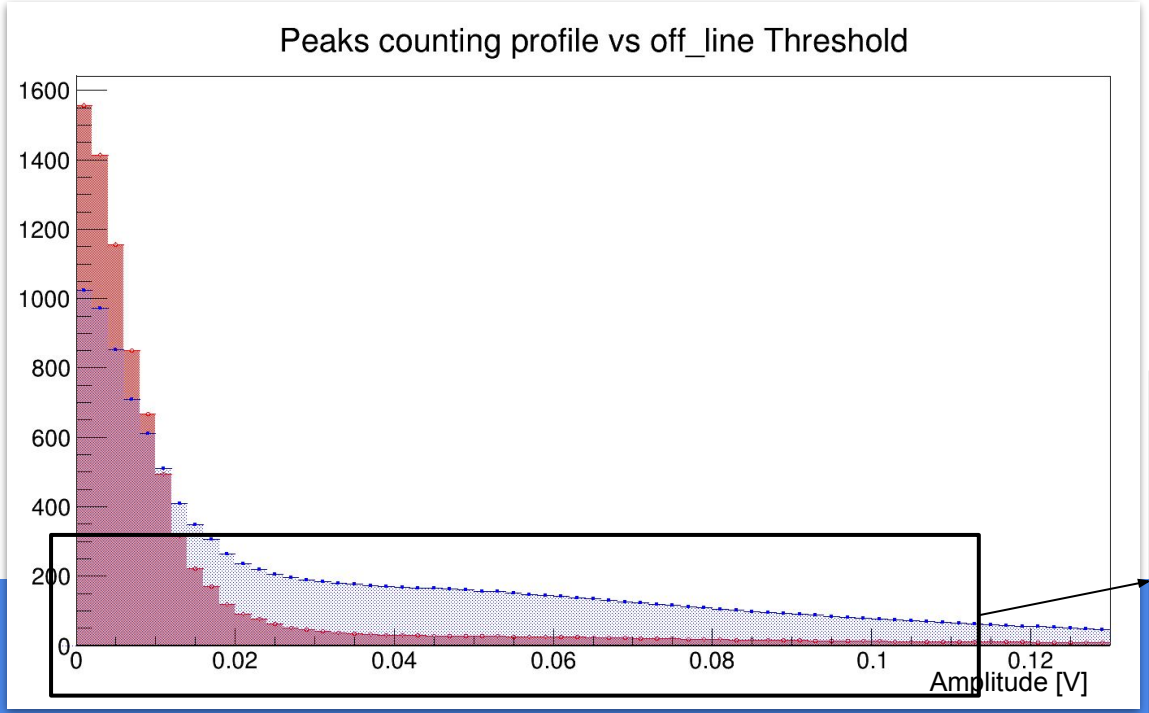
Data analysis: amplitude distributions



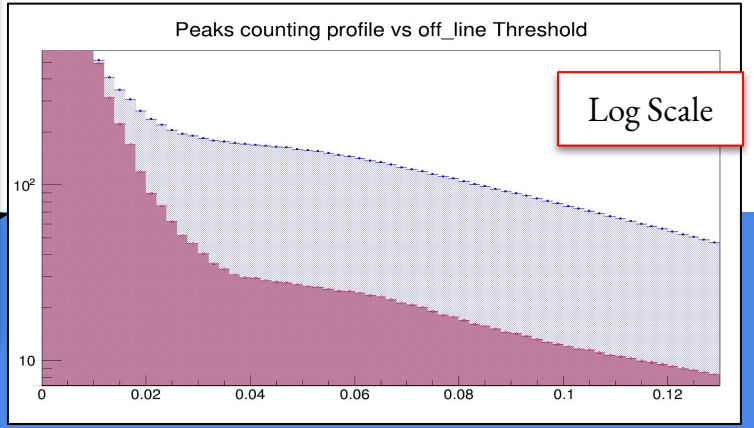
First attempt to divide between the contribution of collinear **bremsstrahlung photons** (due to to the beam deviation) and the **Electron Landau**

Operate a selection on the CAxis

Data analysis: amplitude distributions



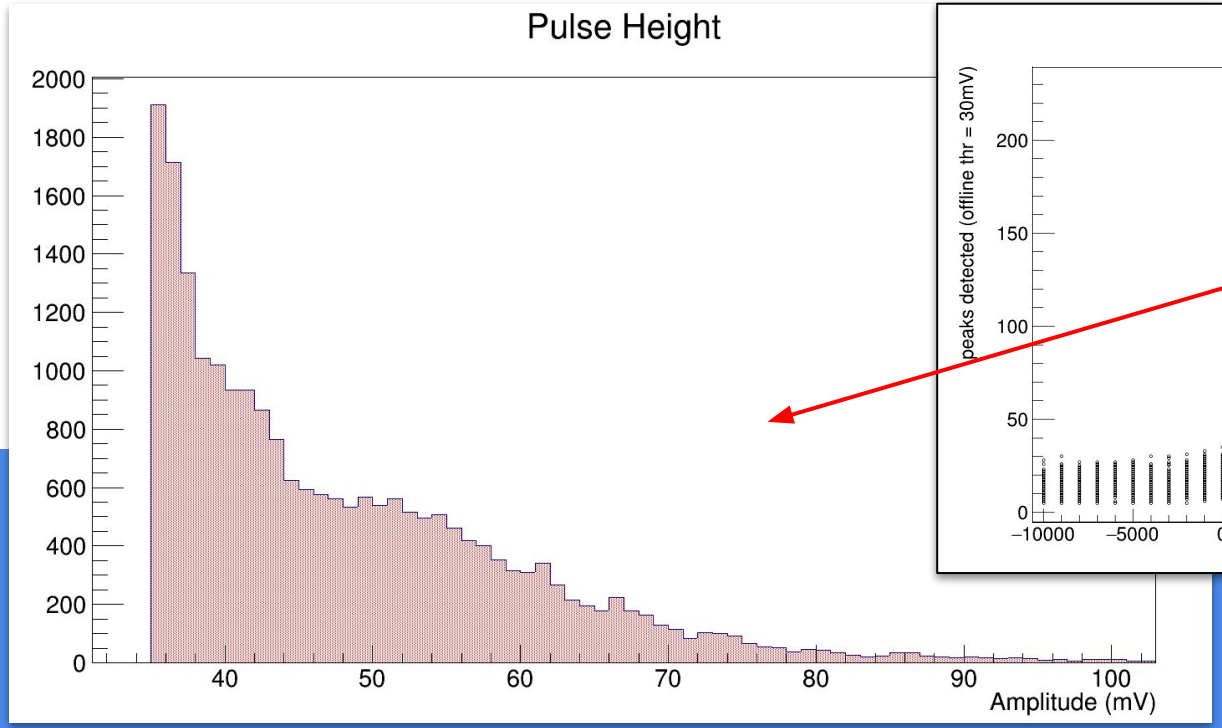
...Observing only a portion of the full graph...

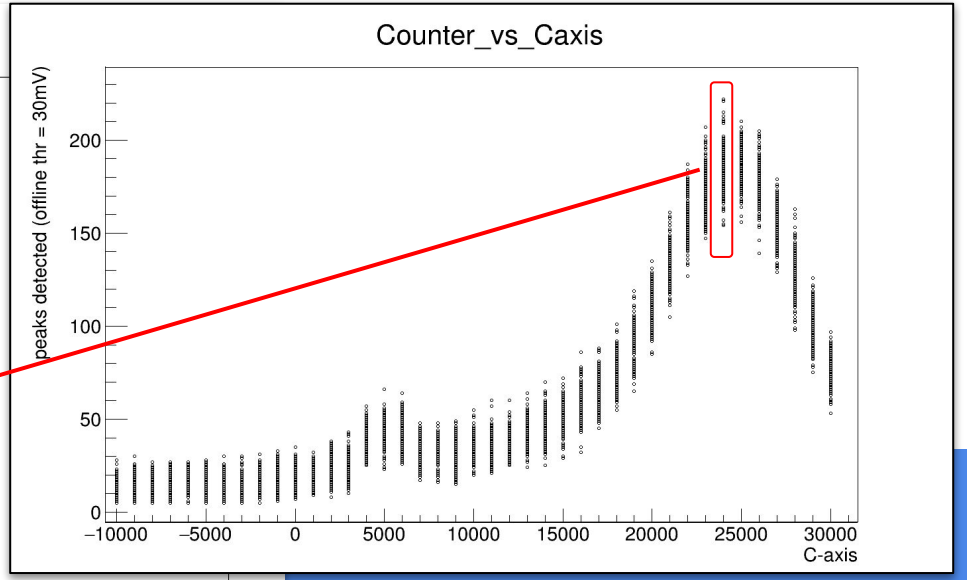


The preliminary results highlight a difference between photons and electron peaks

Data analysis: amplitude distributions

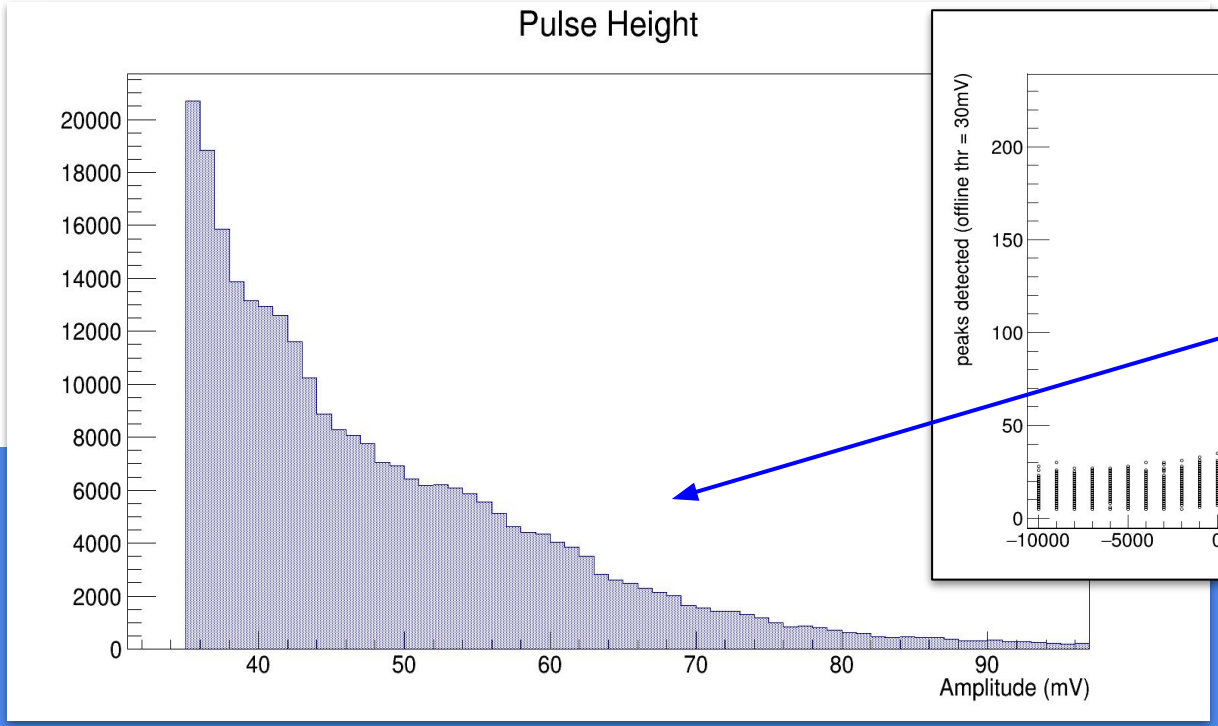
Analyzing only the trigger corresponding to the Caxis position with the maximum number of detected pulses …

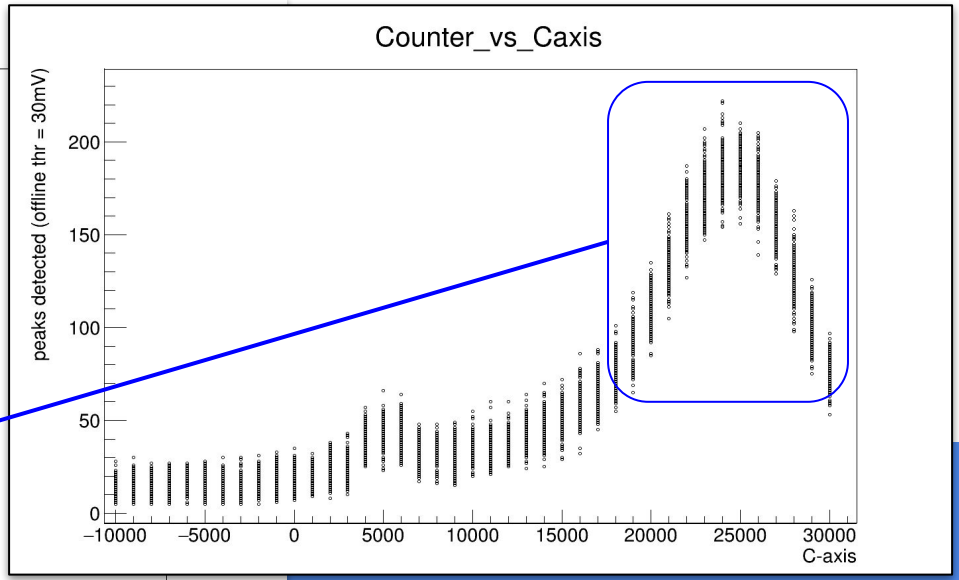




Data analysis: amplitude distributions

..To increase the statistics (and range in energy spectrum) we merged all the triggers with 20000 < Caxis < 30000...

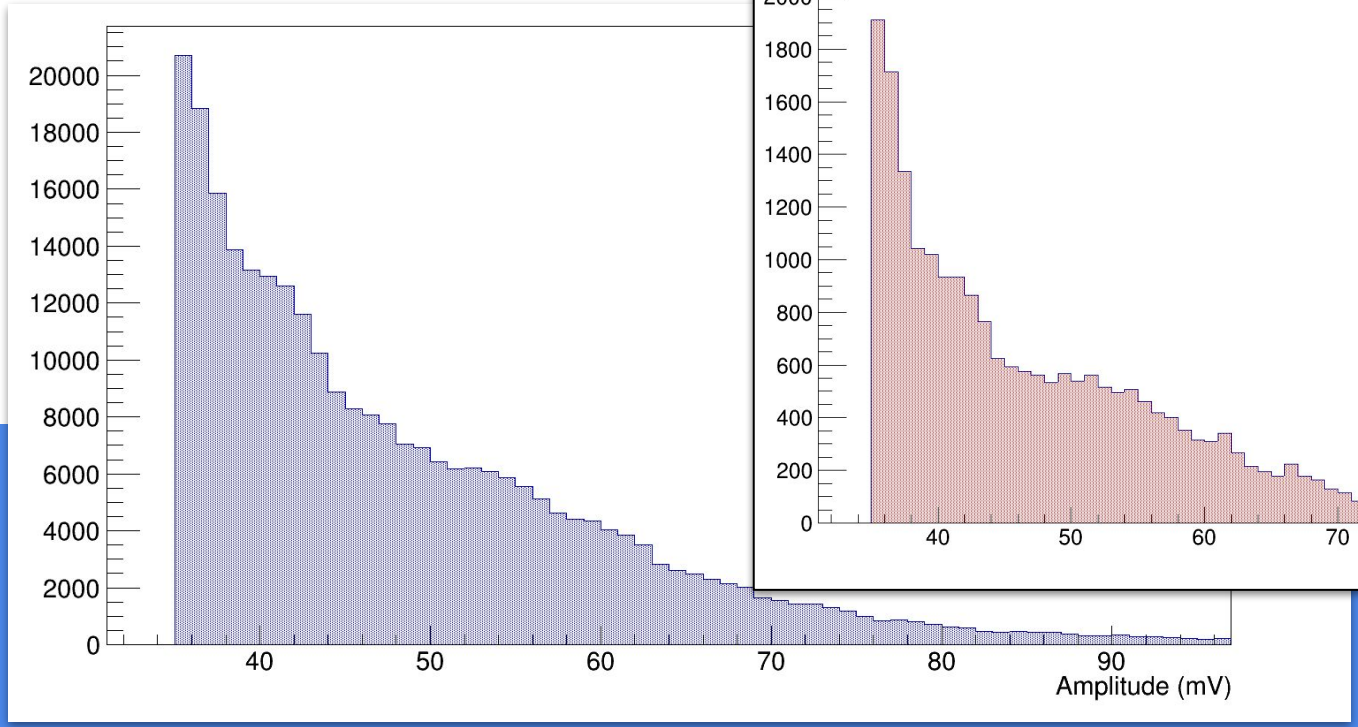


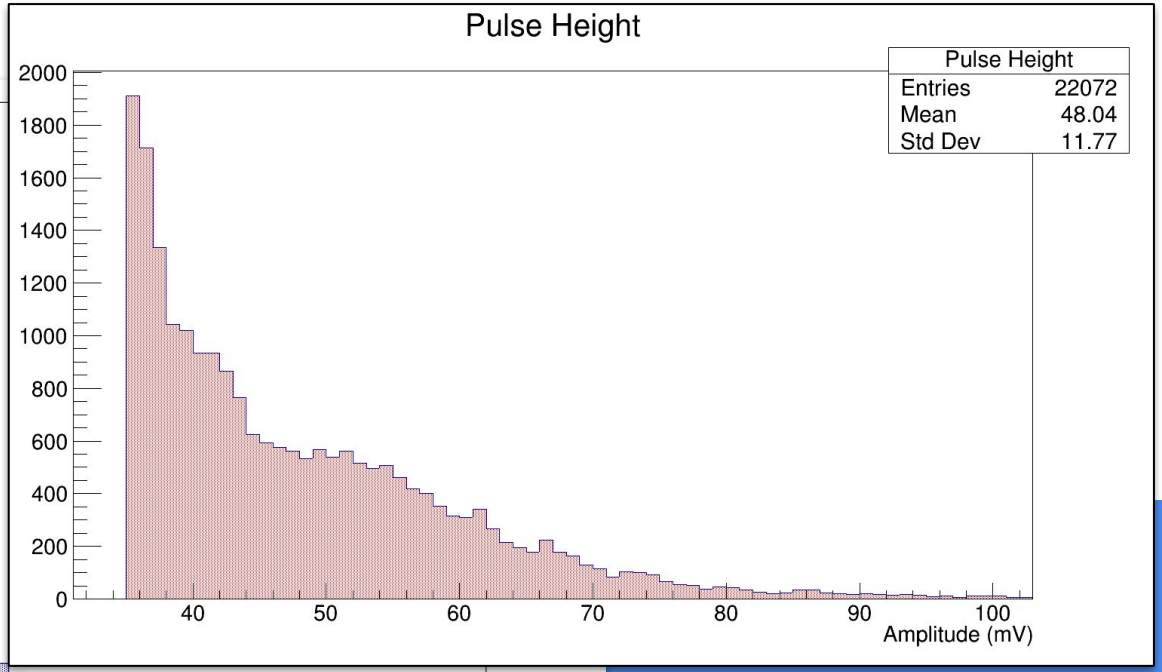


Data analysis: amplitude distributions

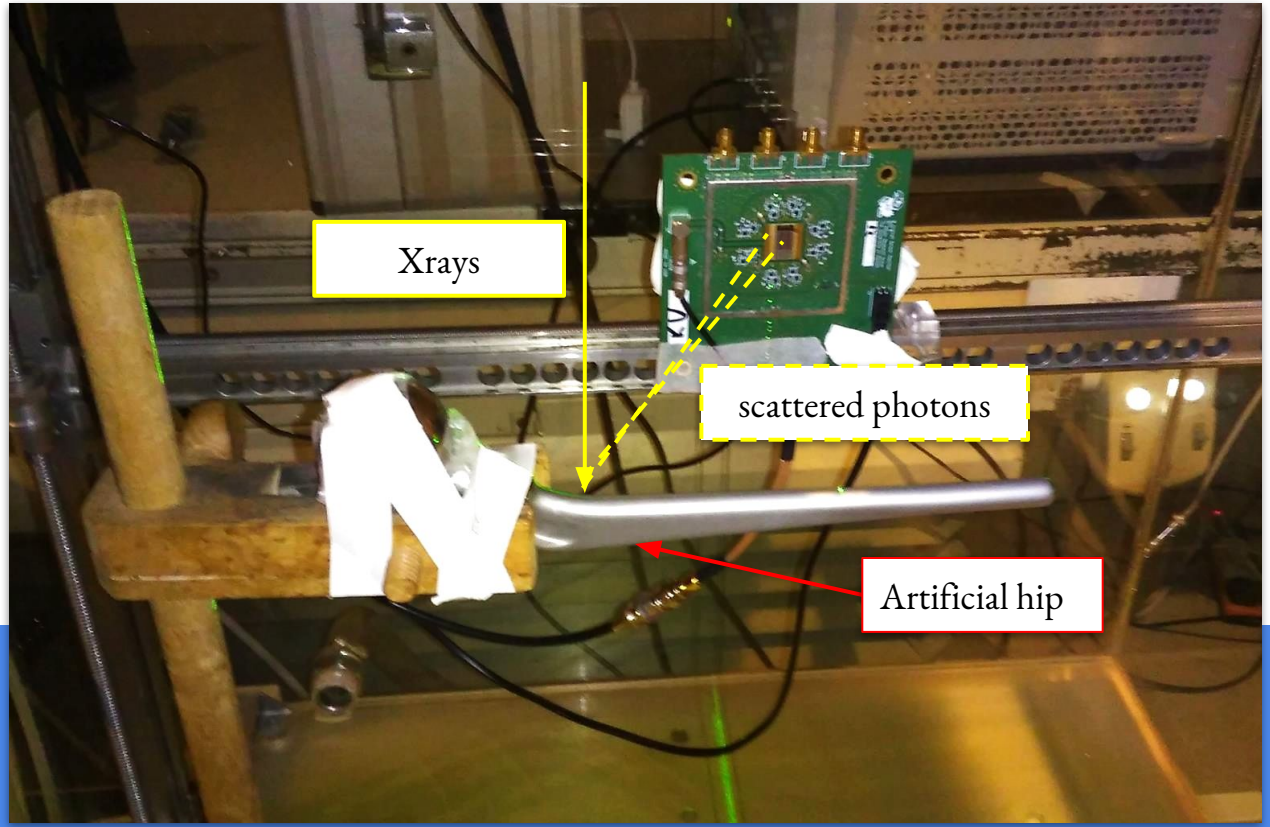
In both cases we observed a similar profile in the amplitude distributions.

Work in progress to better understand the structure





Other studies: backscattering from prosthesis



Integrating over small time interval (~ns) allow the study of little amount of absorbed dose

Study of the dose released to the patient due to backscattering on metal implants and prosthesis!

Conclusions

- UFSD detector deployed in medical Linac (Elekta)
- Data taken for electron and photon beams with energy 1 -15 MeV
- Clear pulse observed with a time resolution of the order of ~ 100 ps
- Work in progress to fully understand the beam's structure
- Applications in beam monitoring and imaging for medical facilities
- Measuring dose with timing intervals of order of ~ ns would allow better computation of the dose absorbed by the patient (very low dose sensitivity)

Analysis and simulation in progress ...

Thank you for the attention

... To be continued