Orthogonal Prompt-Gama Imaging (O-PGI) for Monitoring Proton Therapy

Feasibility Studies

Andrey Morozov[1], Hugo Simões[1], and Paulo Crespo[1,2]

[1] LIP LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSCA EXPERIMENTAL DE PARTÍCULAS

[2] 1 2 9 0 UNIVERSIDADE D COIMBRA

LIP JORNADAS 2020

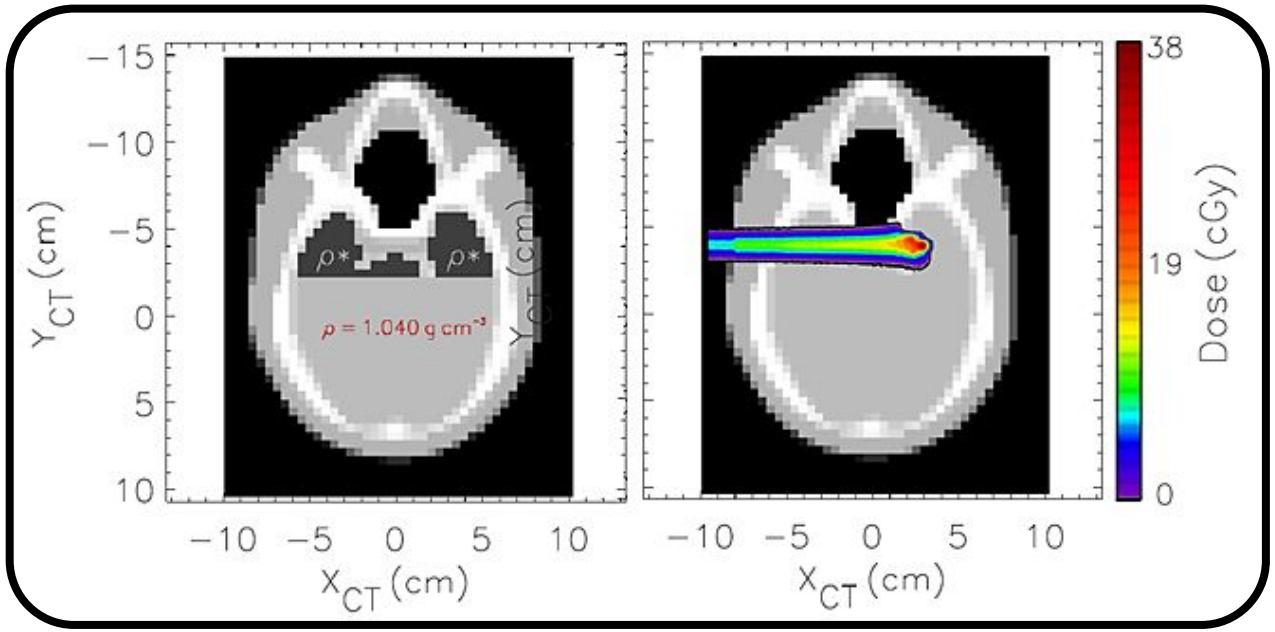
Braga – February 14-16, 2020

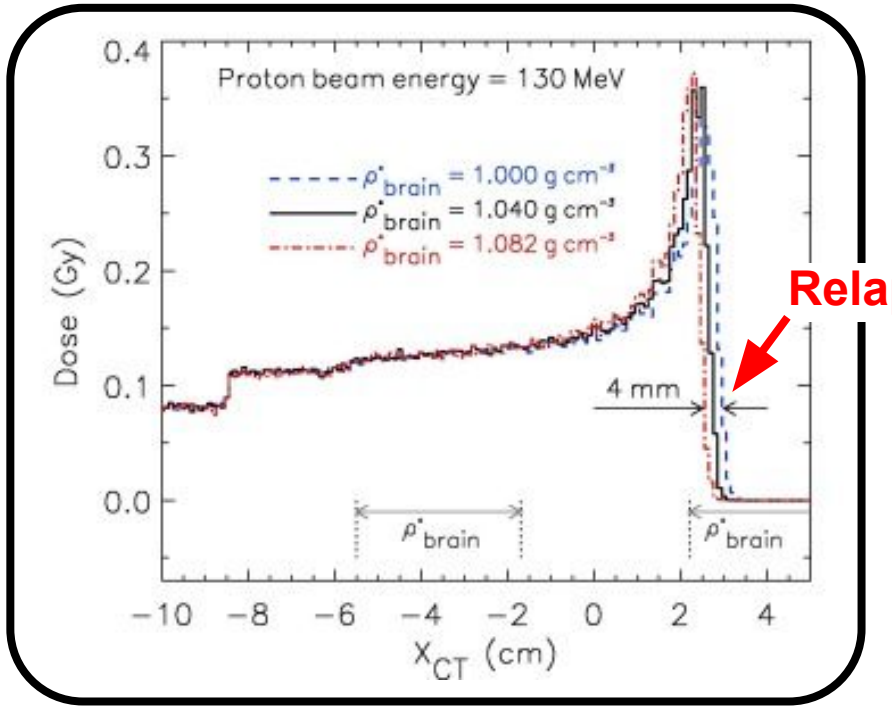
crespo@lip.pt

Challenges in proton RT

Change in brain density due to fractionated RT?

- Conjecture: brain tissue hypo/hyperdense due to fractionated RT



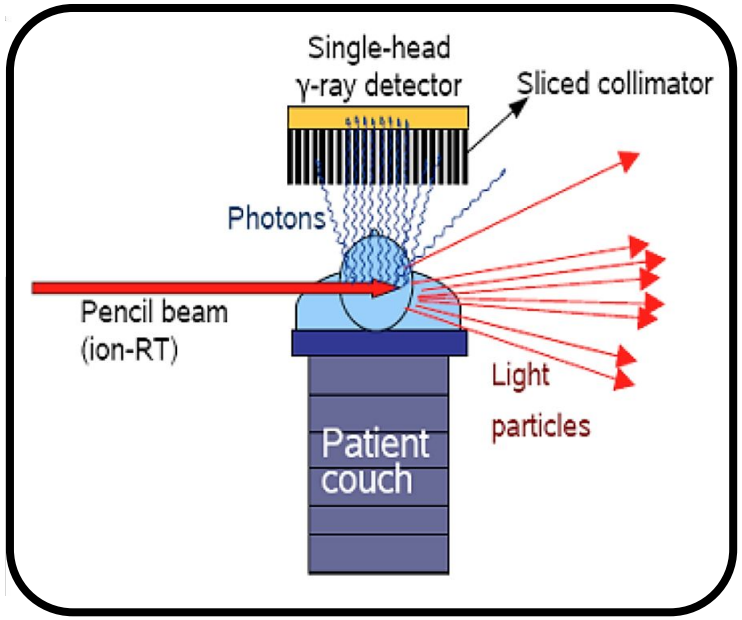


- A change of ± 4% in the brain density leads to a variation of ± 2 mm in the Bragg peak position

(Cambraia Lopes *et al*, Physica Medica 2018)

Multi-sliced detector for orthogonal prompt-gamma imaging

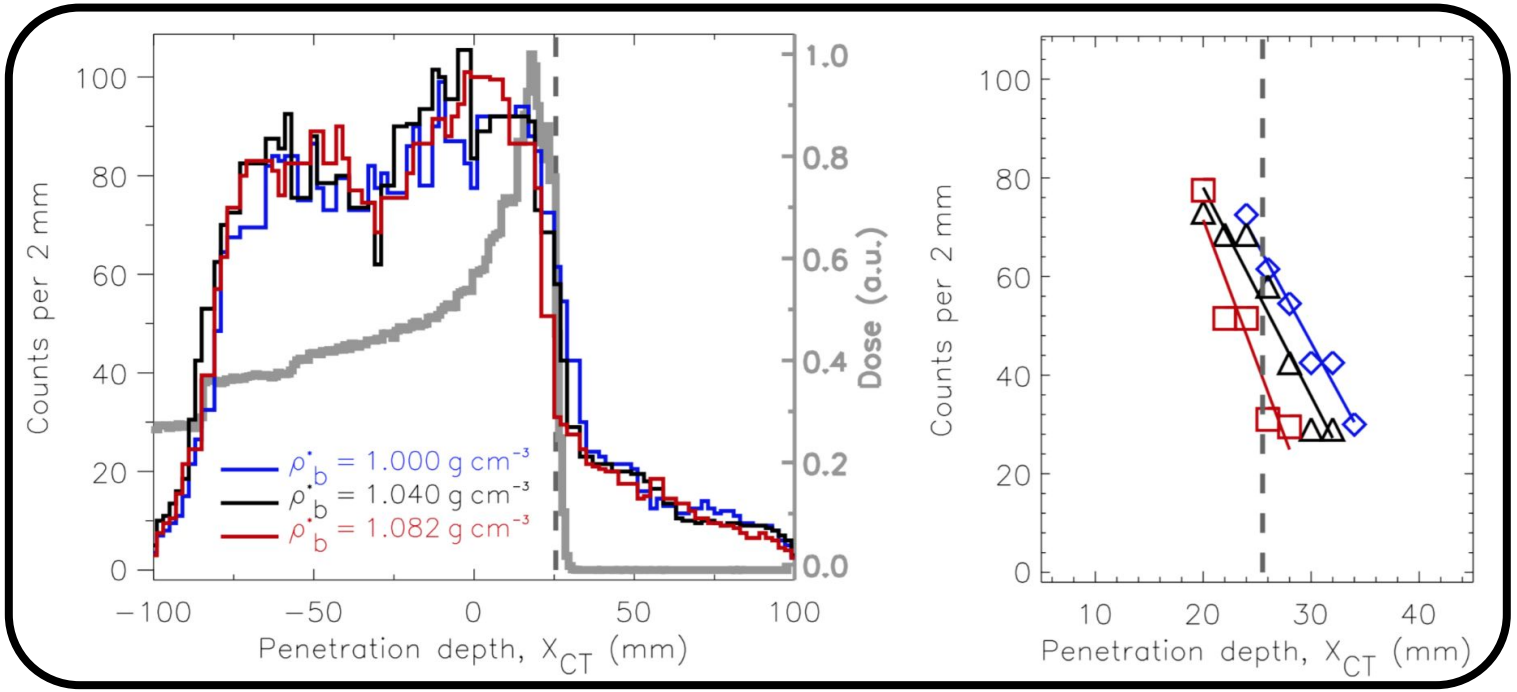
- O-PGI concept:



- Provides images of selected region without rotation of beam source

- Image with prompt gammas “stops” at beam range

- Monte Carlo results with proposed detector (Geant4):



- Deviations in the Bragg peak position are visible in the O-PGI counts profiles (perfect detectors)

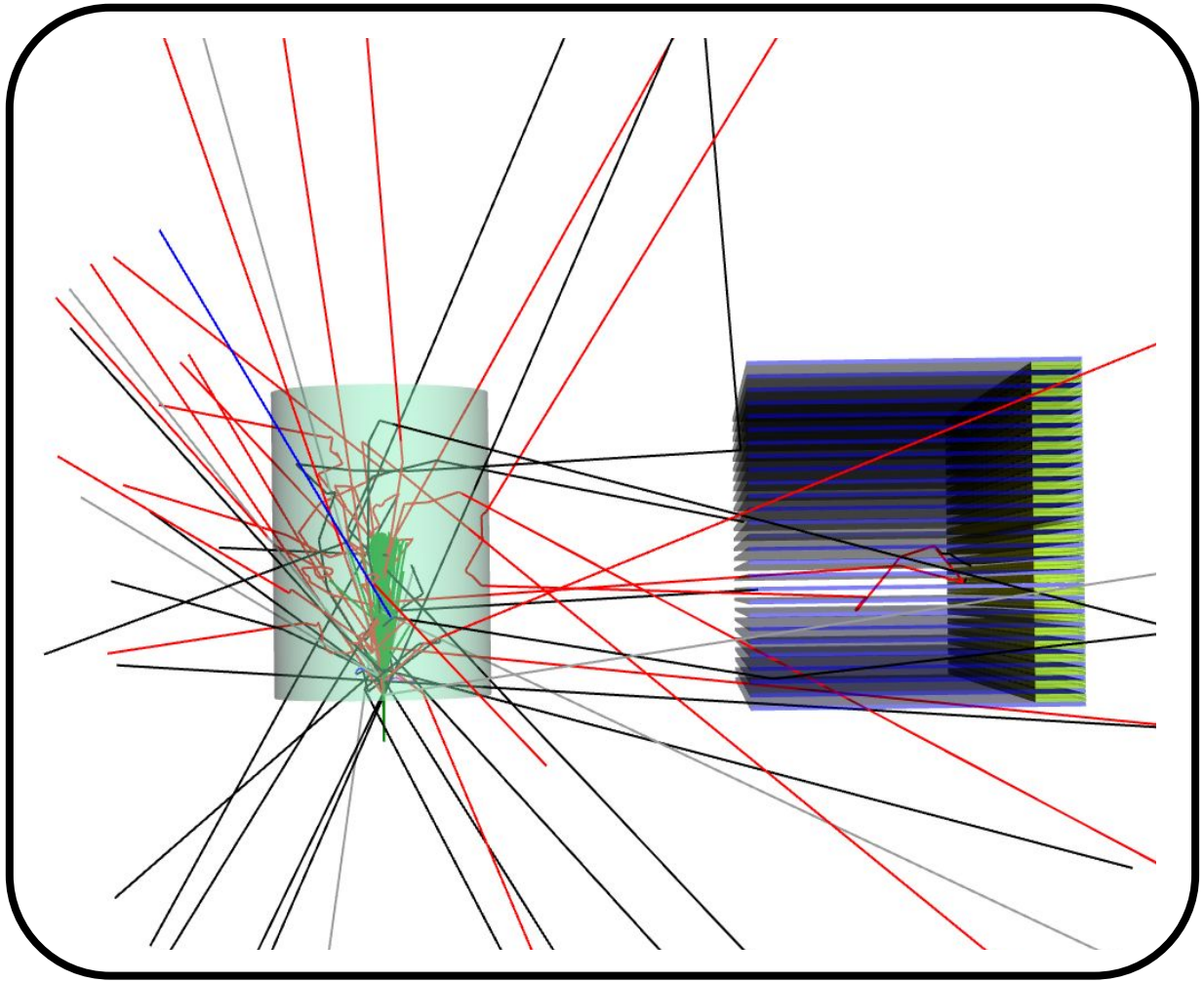
(Cambraia Lopes *et al*, Physica Medica 2018)

Validation phases: before, present, and future

- Three stages in the validation study based on Monte Carlo simulations
  - Collimator + ideal detectors of particles (e.g. Sensitive Detector of Geant4)
  - Collimator + scintillators: analysis of energy deposition
  - Collimator + scintillators + light sensors
- Experimental validation

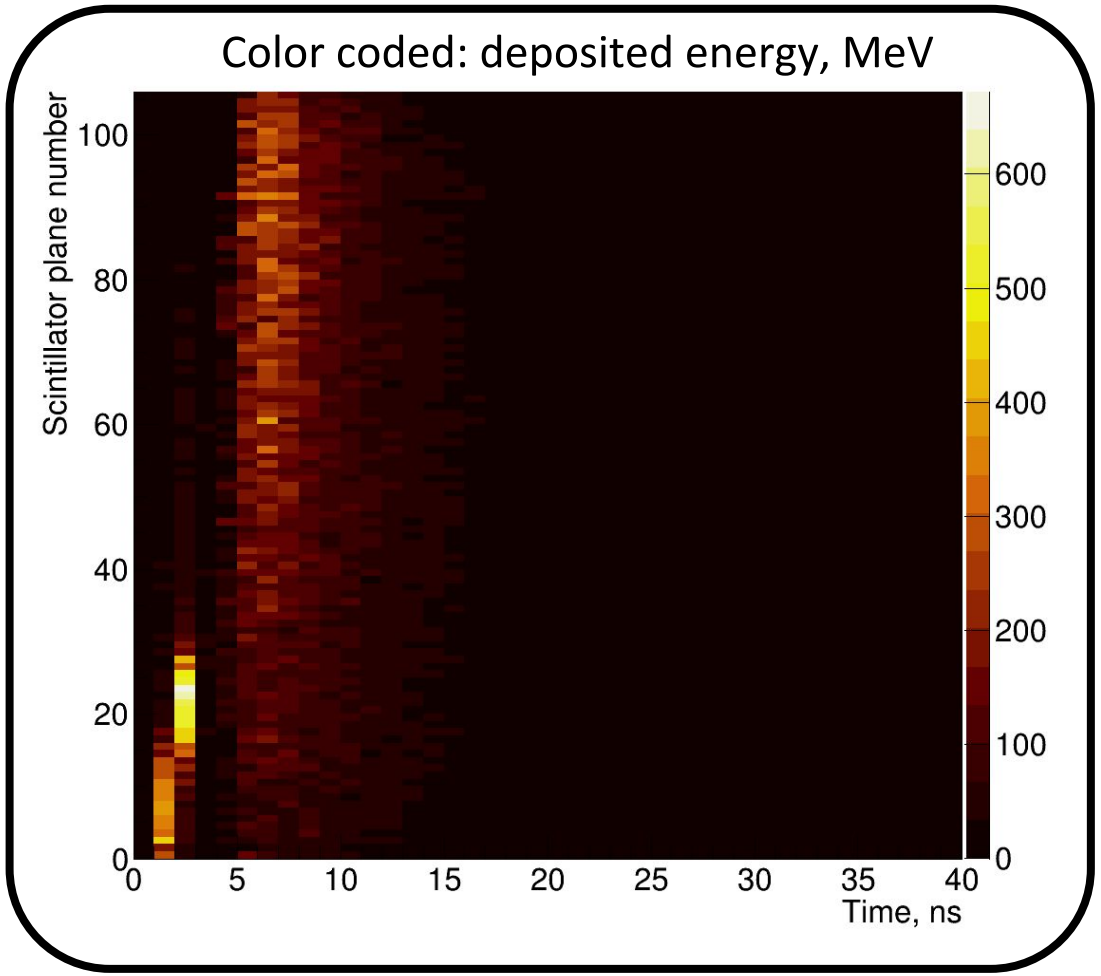
Ongoing Monte Carlo simulation studies

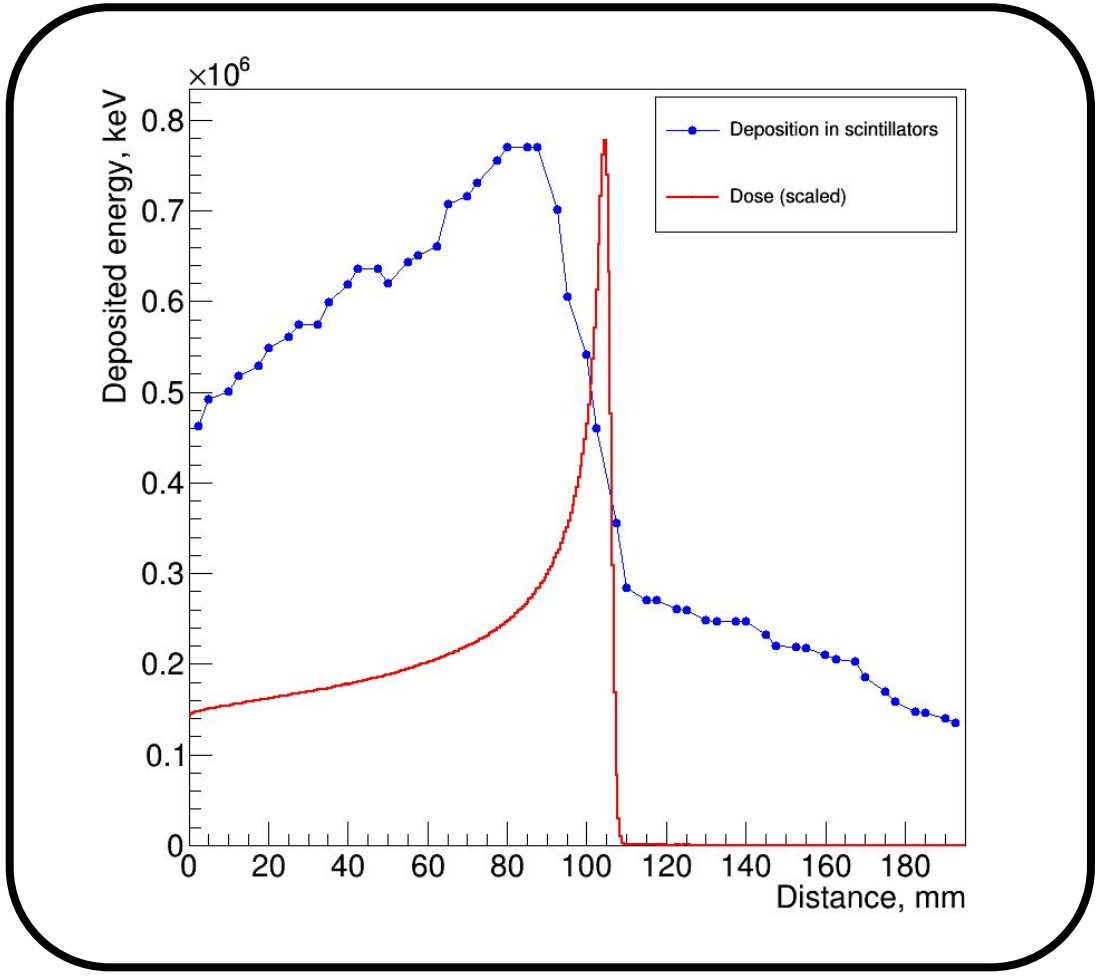
- Simulated proton beam:
  - 130 MeV
  - 300 protons per bunch
  - 1 ns FWHM bunch width
  - 10 ns repetition rate
- Emission of prompt gammas correlates with the linear dose density
- There is a strong background (secondary gammas induced by neutron reactions)
- Gamma yield is relatively low



Ongoing Monte Carlo simulation studies

- Results with simulated proton beam:

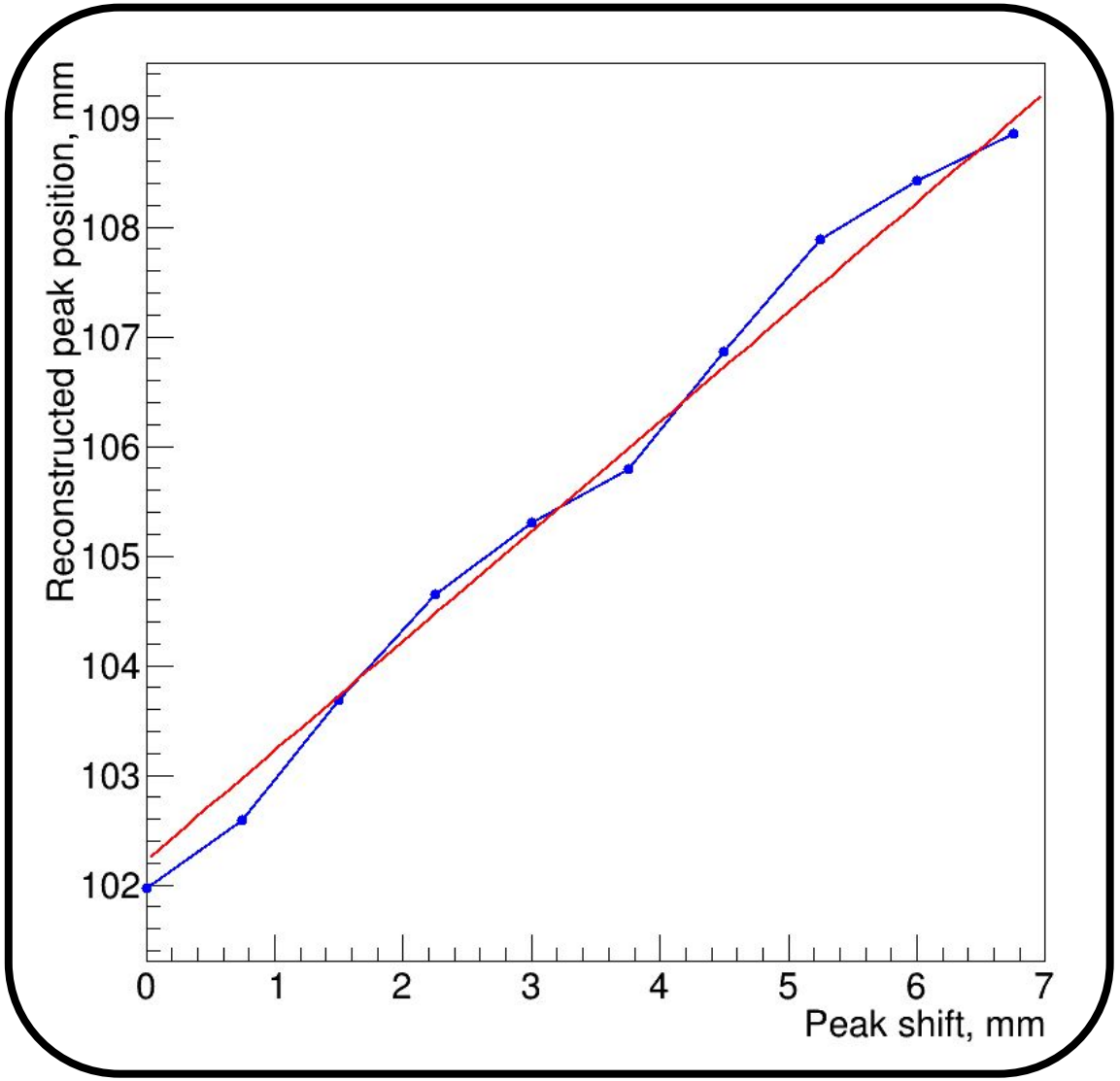




Ongoing Monte Carlo simulation studies

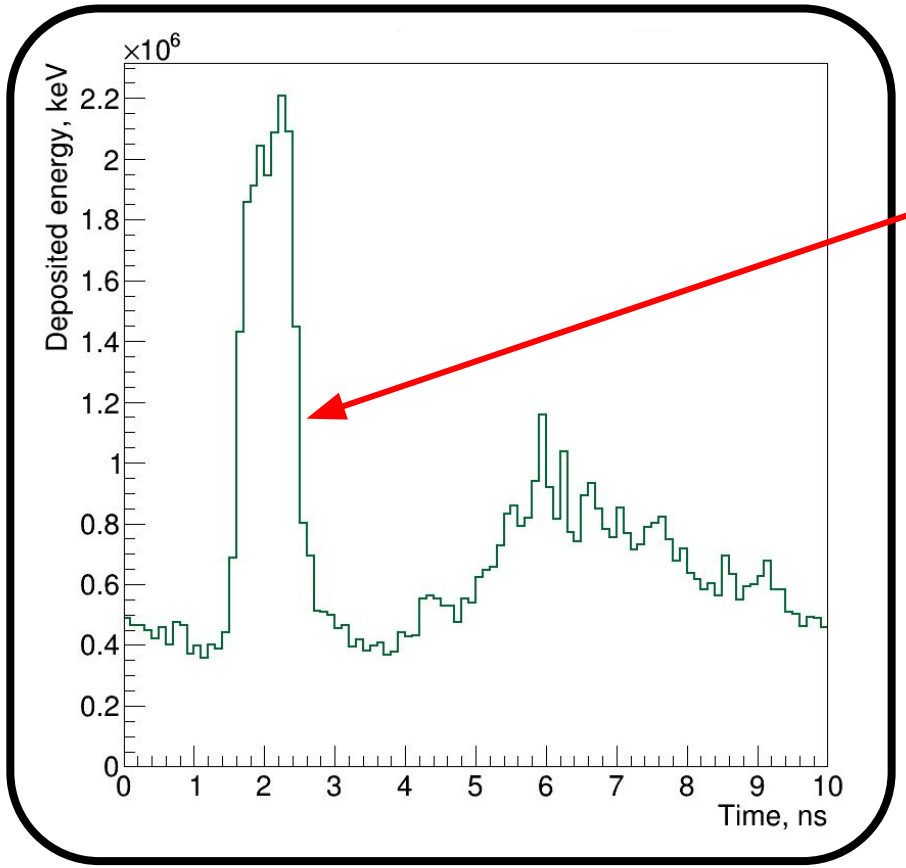
Ideal detector:

- Extracted edge position vs true edge position
- Data for several relative positions of the Bragg peak and the collimator's first blade are processed
- Sigma = 0.24 mm => 0.564 mm FWHM

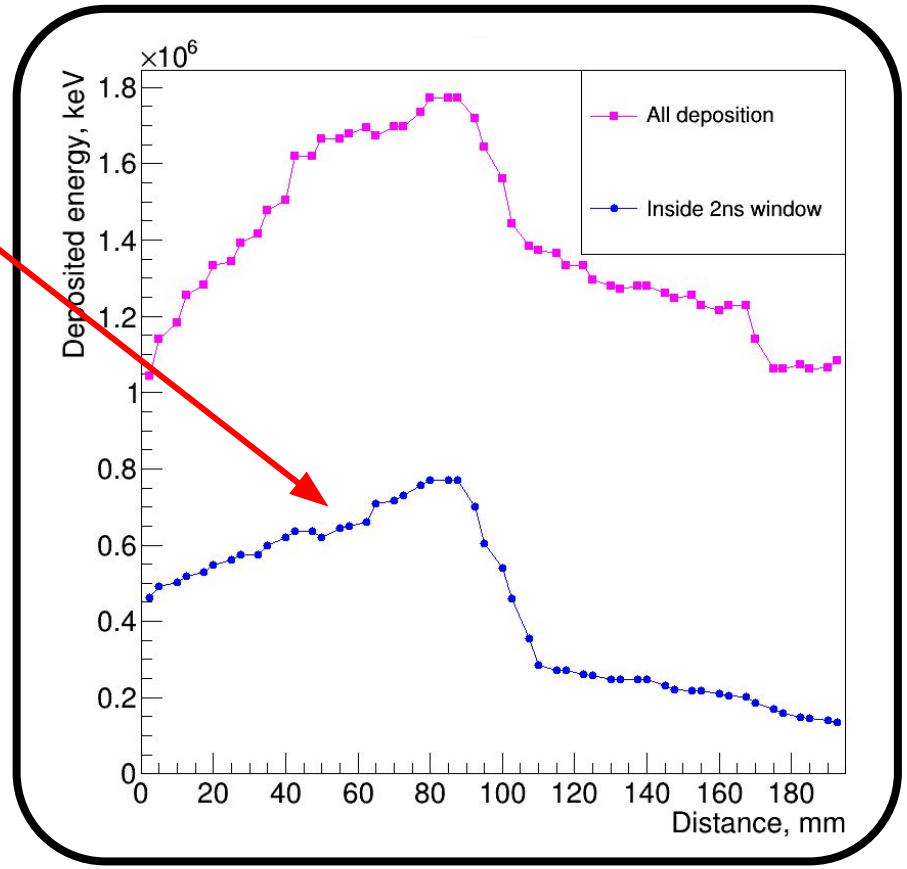


Ongoing Monte Carlo simulation studies

Energy deposition (GSO crystals):



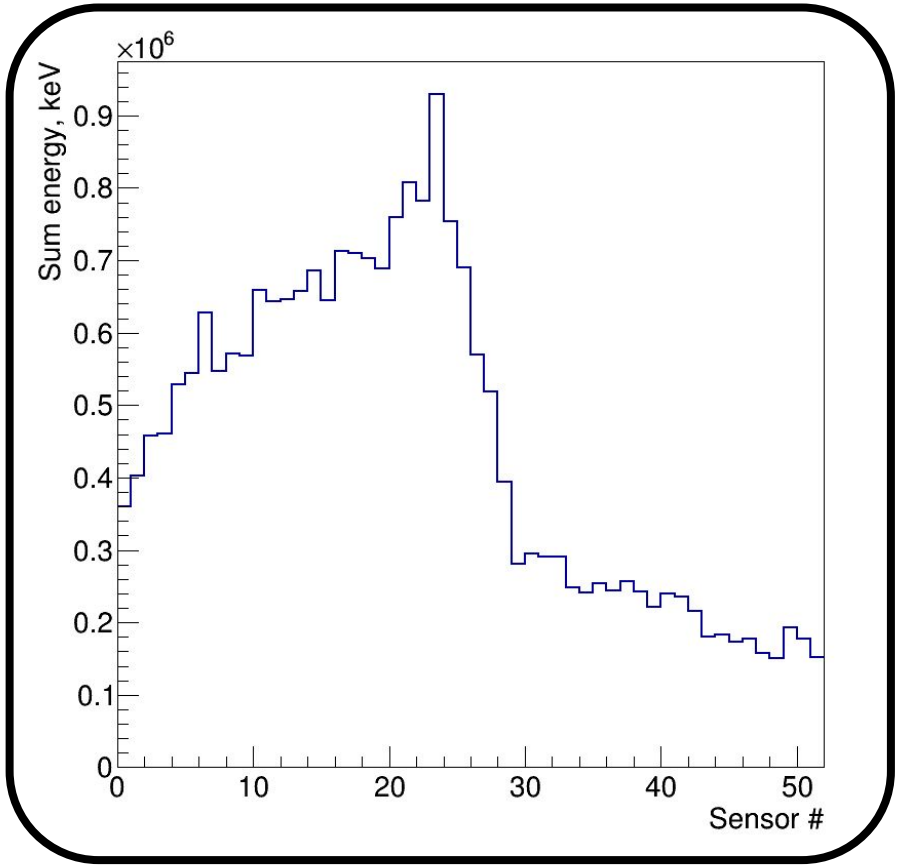
Prompt gammas



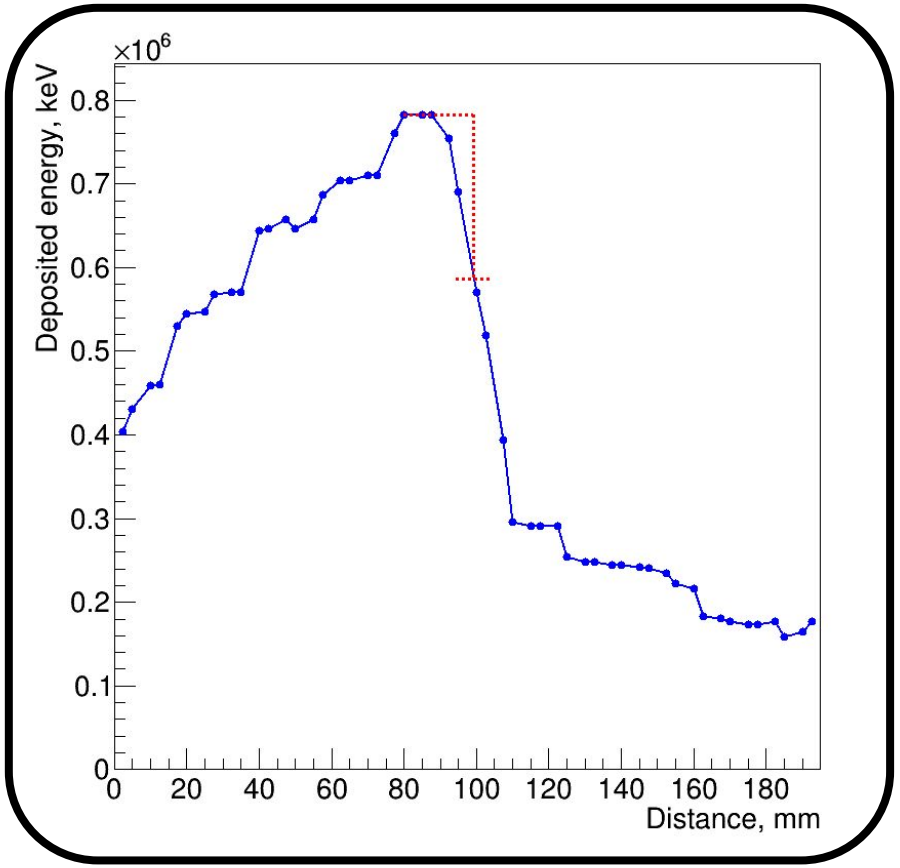
Ongoing Monte Carlo simulation studies

Energy deposition (GSO crystals):

Energy deposition profile vs scintillator index



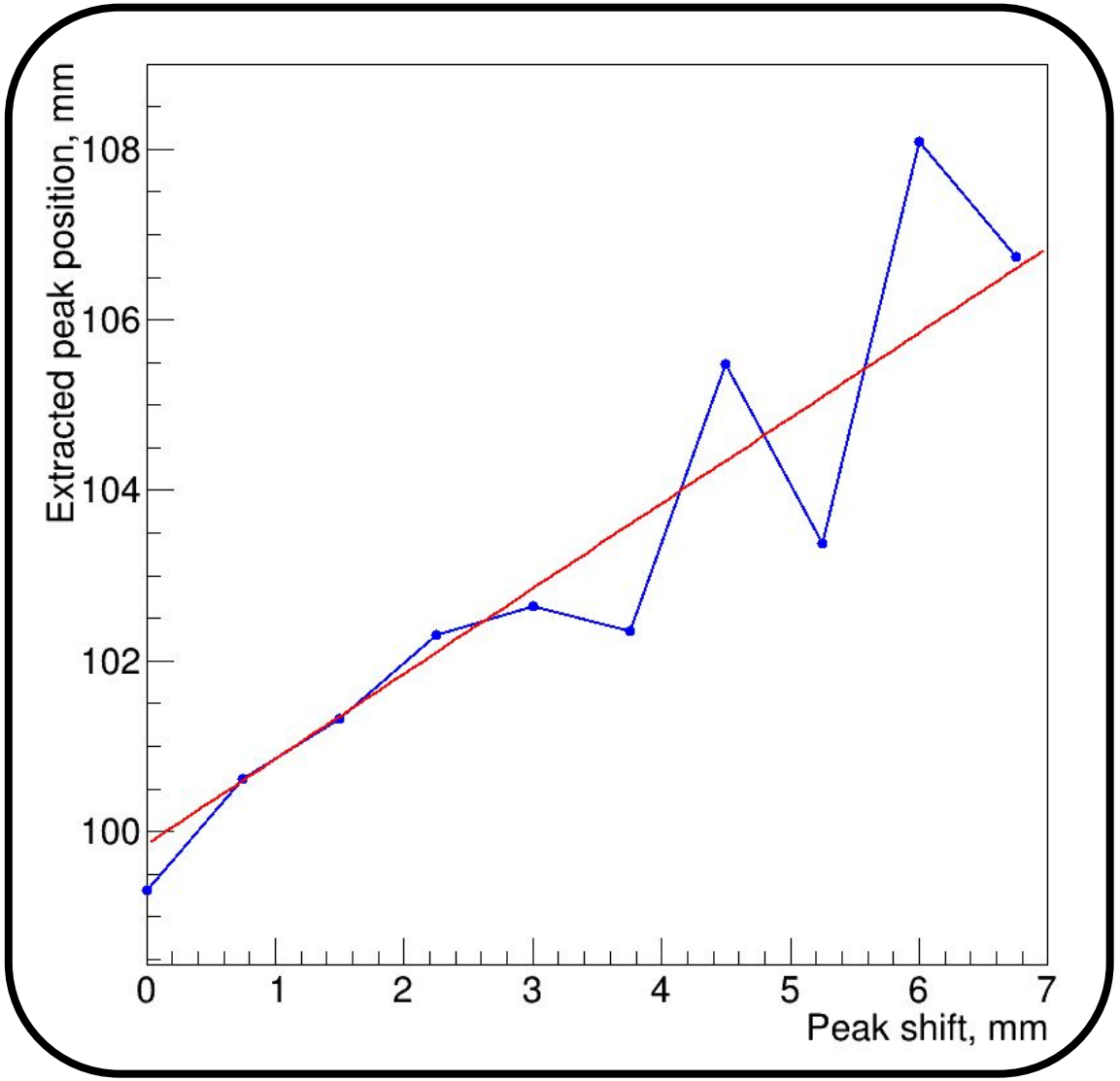
Bragg peak extraction procedure



Ongoing Monte Carlo simulation studies

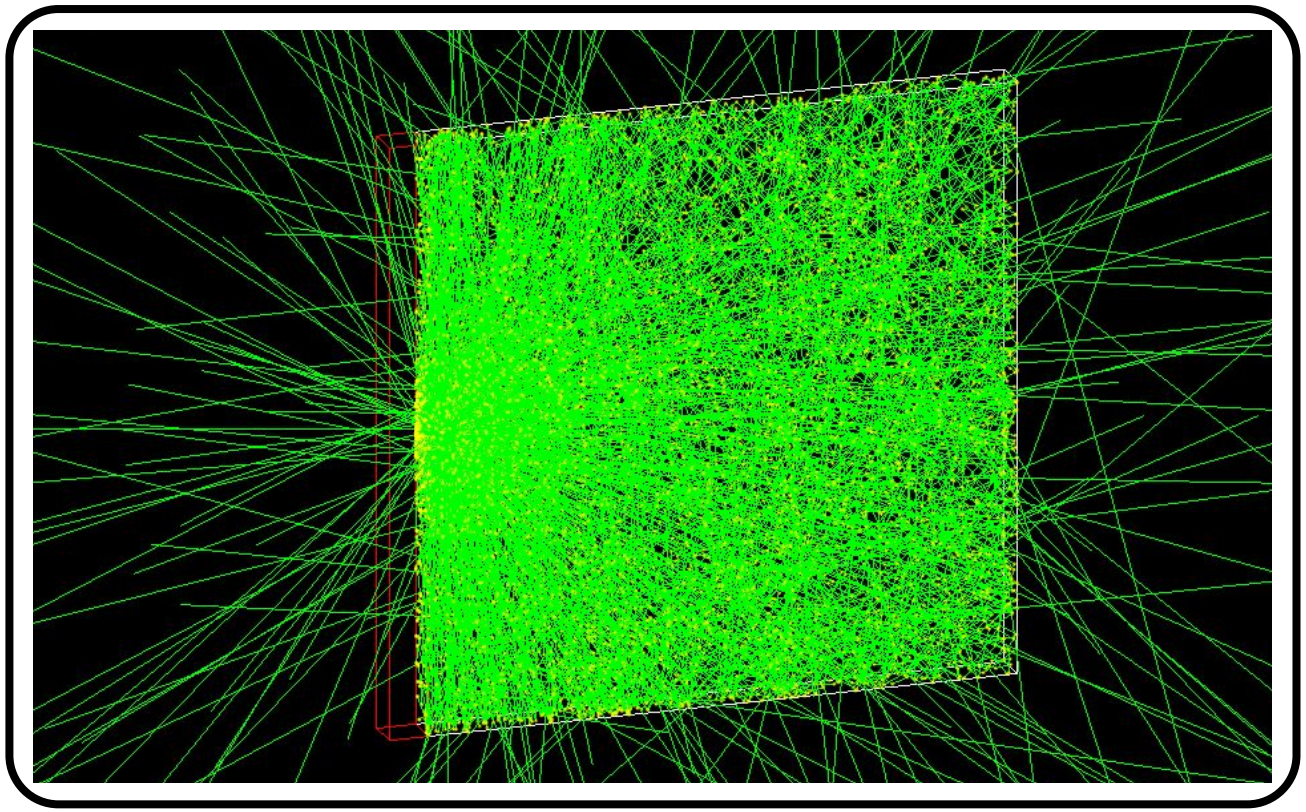
Energy deposition (GSO crystals):

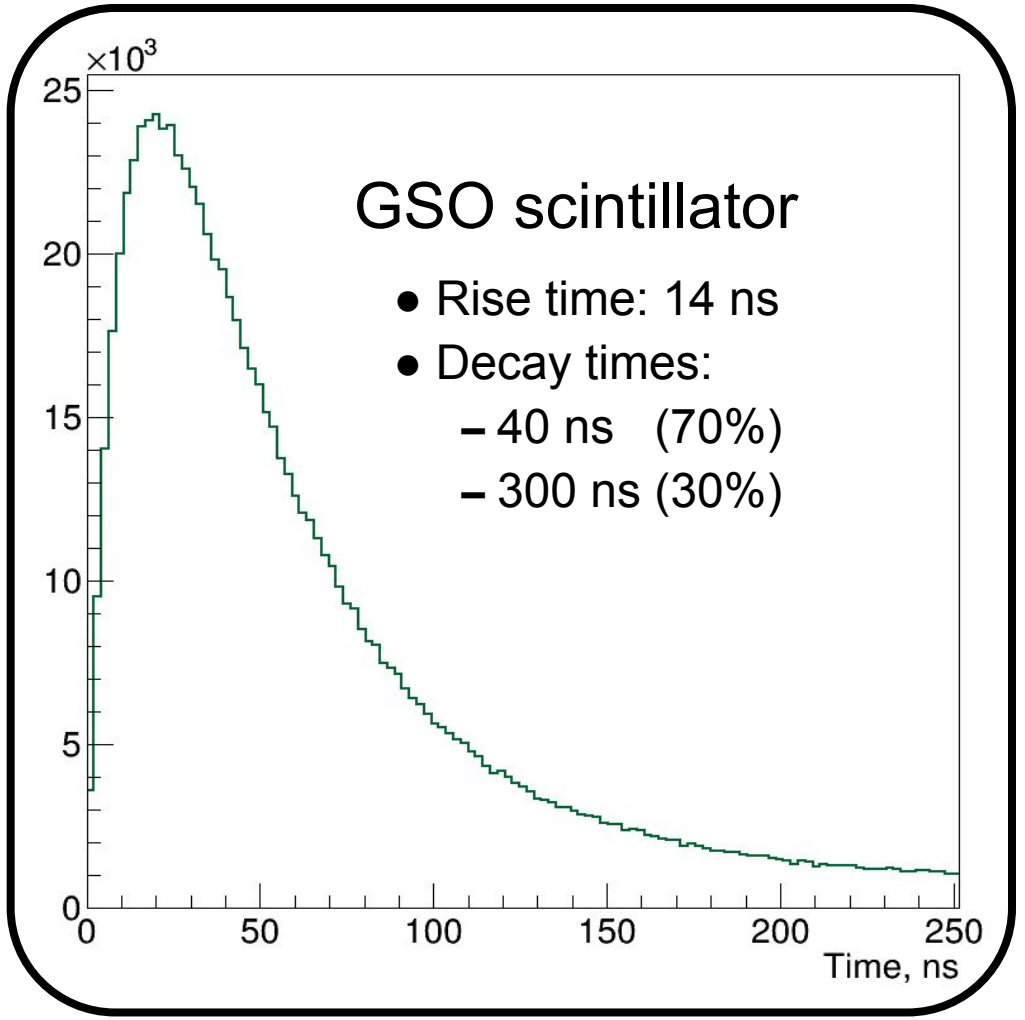
- Extracted edge position vs true edge position
- Data for several relative positions of the Bragg peak and the collimator's first blade are processed
- Sigma = 1.1 mm => 2.6 mm FWHM



Ongoing Monte Carlo simulation studies

Optical photons (GSO crystals):

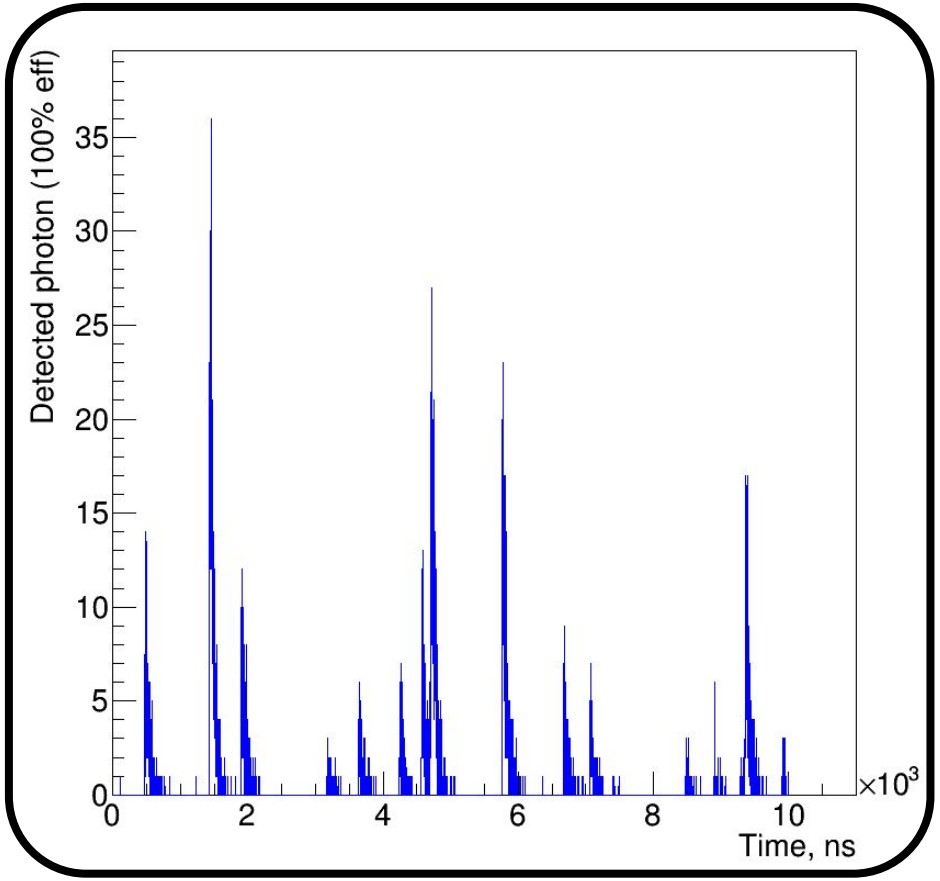




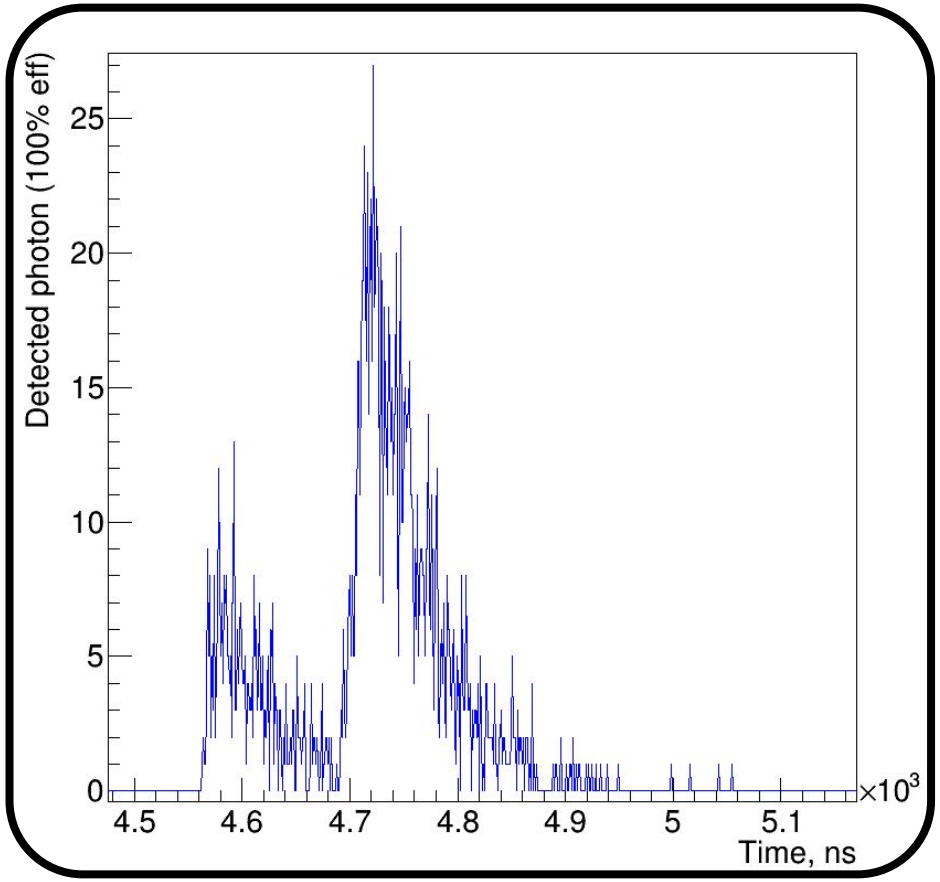
Ongoing Monte Carlo simulation studies

Optical photons (GSO crystals):

- "Waveform": light sensor signal vs time for one of the scintillator plates



Zoom of the central region



Ongoing Monte Carlo simulation studies

Optical photons (GSO crystals):

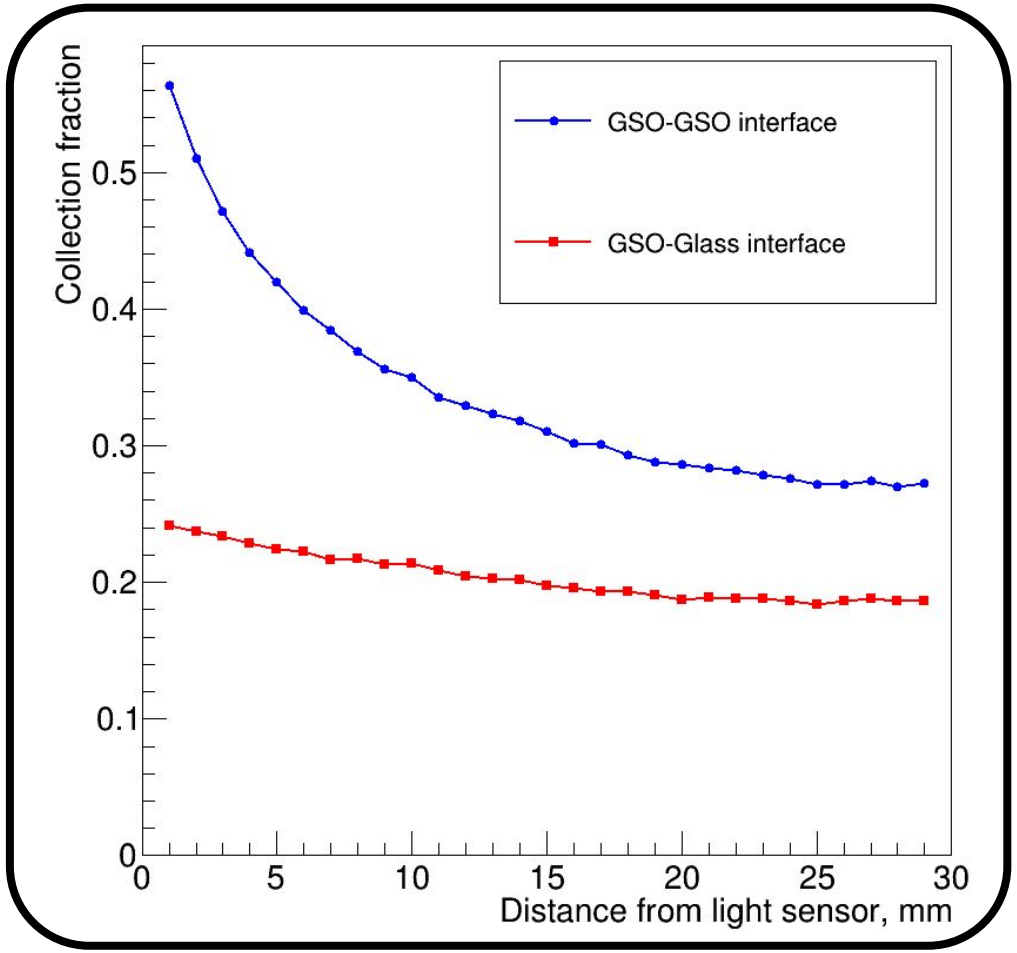
- Optical trapping collection efficiency reduces with the depth of interaction (DoI)

- Waveform fit precision depends on statistics need to apply a threshold on the amplitude

- To be explored:

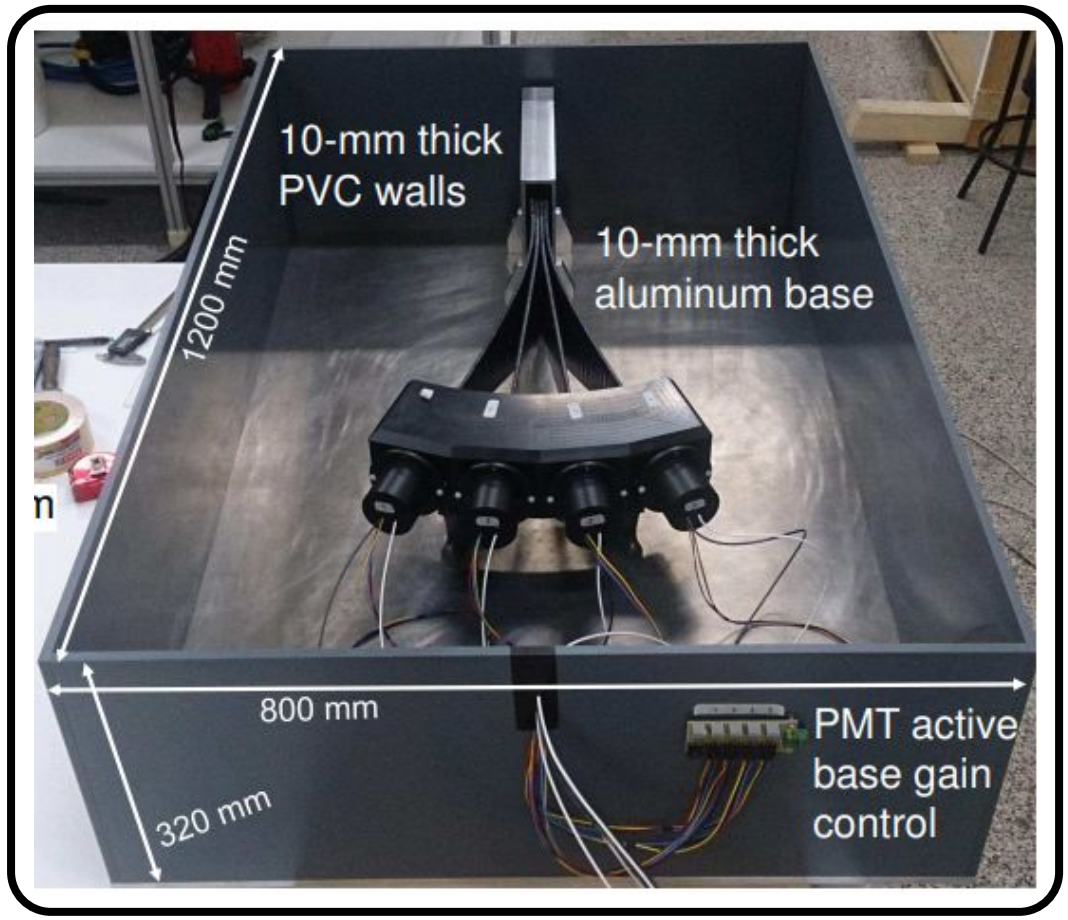
  - YAP (instead of GSO): rise time ~ 0.5 ns
  - Semi-supervised collimator optimization in ANTS2
  - 200 MeV protons (pelvic irradiation)

- Collection efficiency vs DoI for two cases: sensor has GSO-matching window and realistic glass window

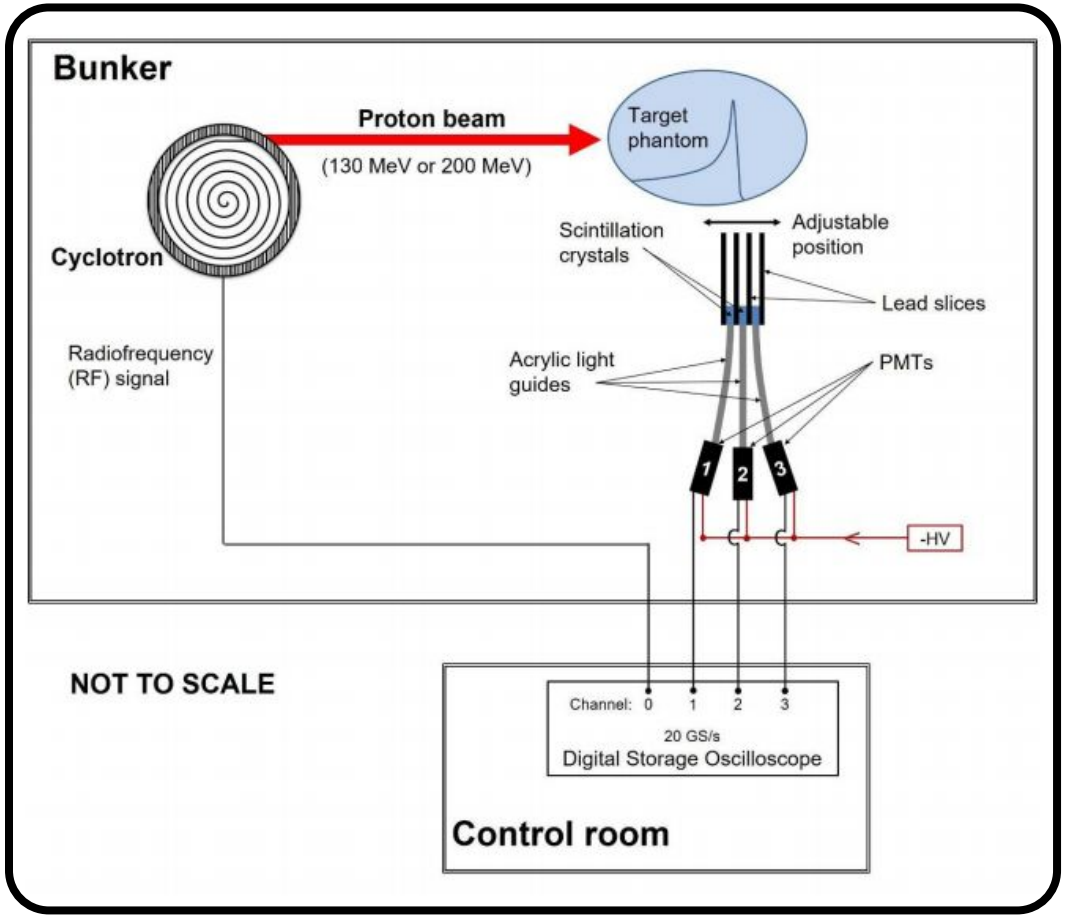


Planned experiment for Monte Carlo validation

- First version of a validation prototype (already constructed) to be tested at PCTHolland facility



- Planned experimental setup (oscilloscope missing)



Thank you for your attention.

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR
Lisb@20[20]
COMPETE 2020
PROGRAMA OPERACIONAL COMPETITIVIDADE E INTERNACIONALIZAÇÃO
PORTUGAL 2020
UNIÃO EUROPEIA
Fundos Europeus Estruturais e de Investimento