TIMEPATH

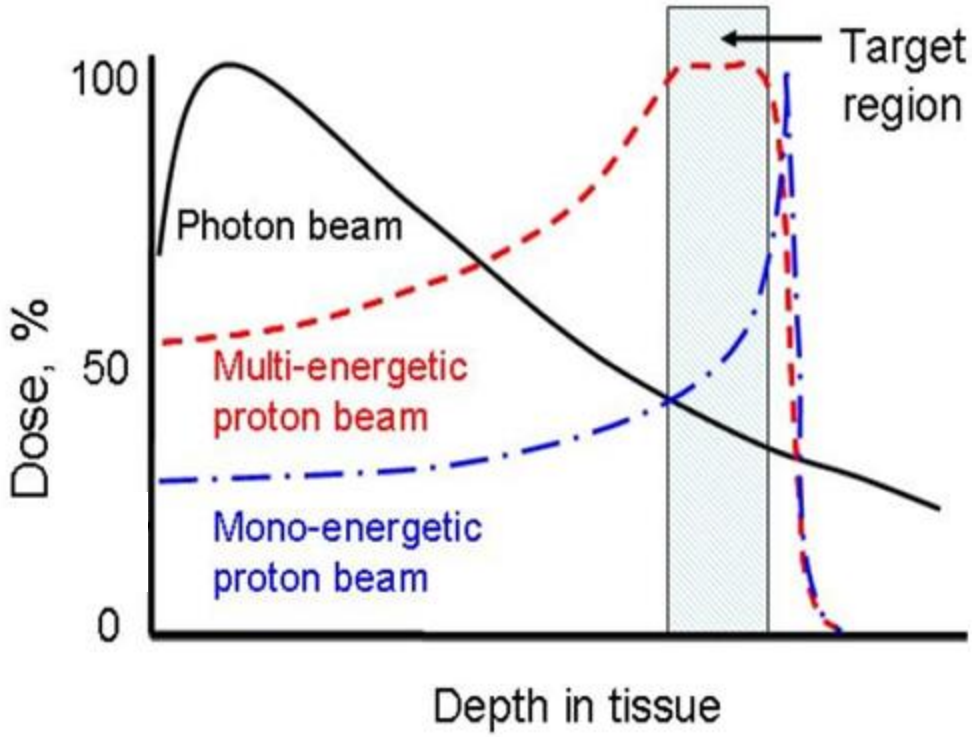
TIming MEasurements for Particle THerapy (& neutron detection)

Piergiorgio Cerello (INFN)

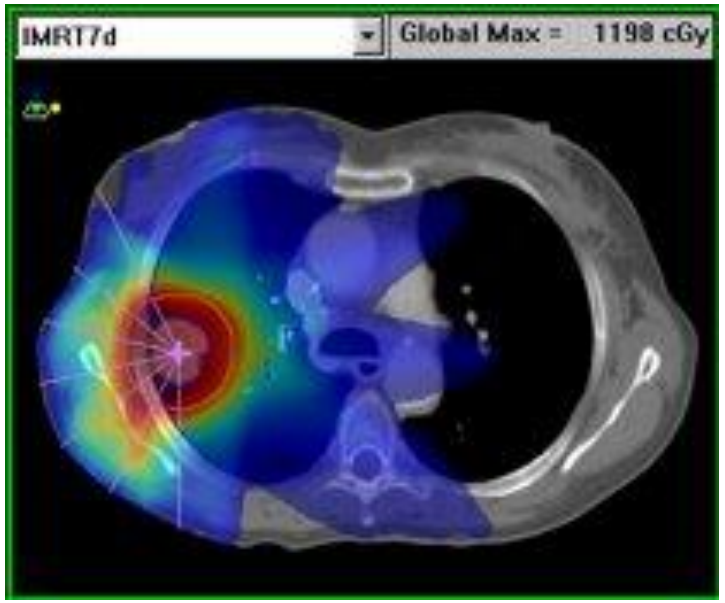
on behalf of the INFN and University of Torino groups

Nantes, July 2nd, 2025

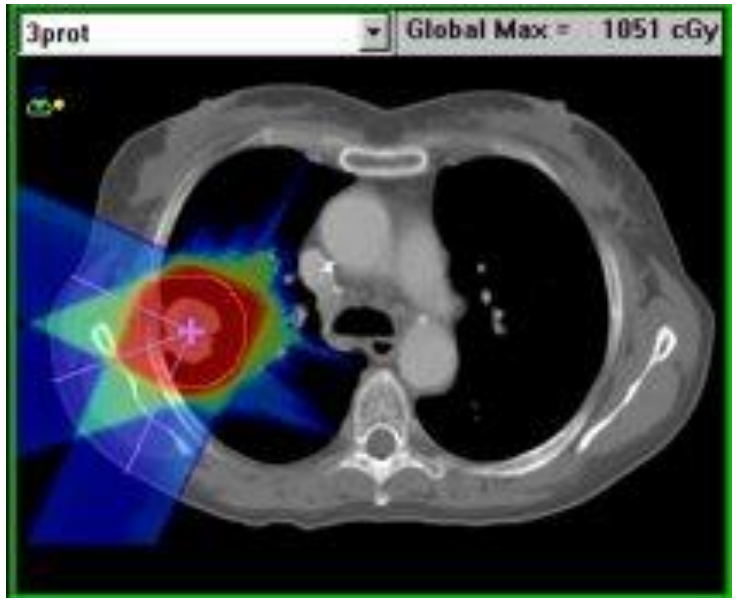
Why Particle Therapy?



Dose maps



Radiotherapy



Particle therapy

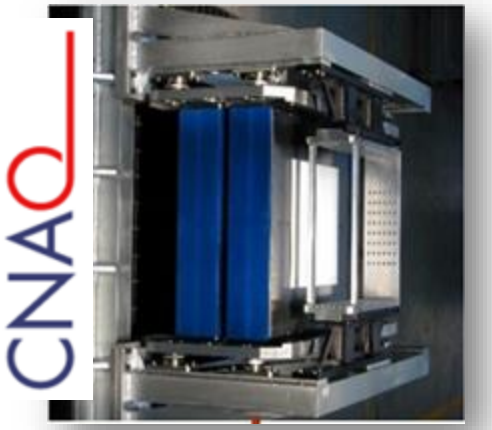
Compared to standard radiotherapy

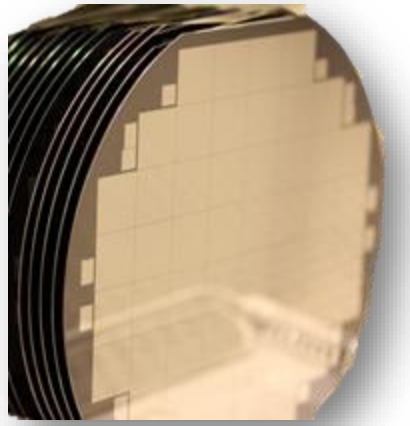
reduced toxicity
lower secondary malignancy risk
increased tumor local control

Treatment Verification in Particle Therapy

2D: BEAM MONITOR - from ionization chambers to thin silicon detectors

IONISATION CHAMBERS



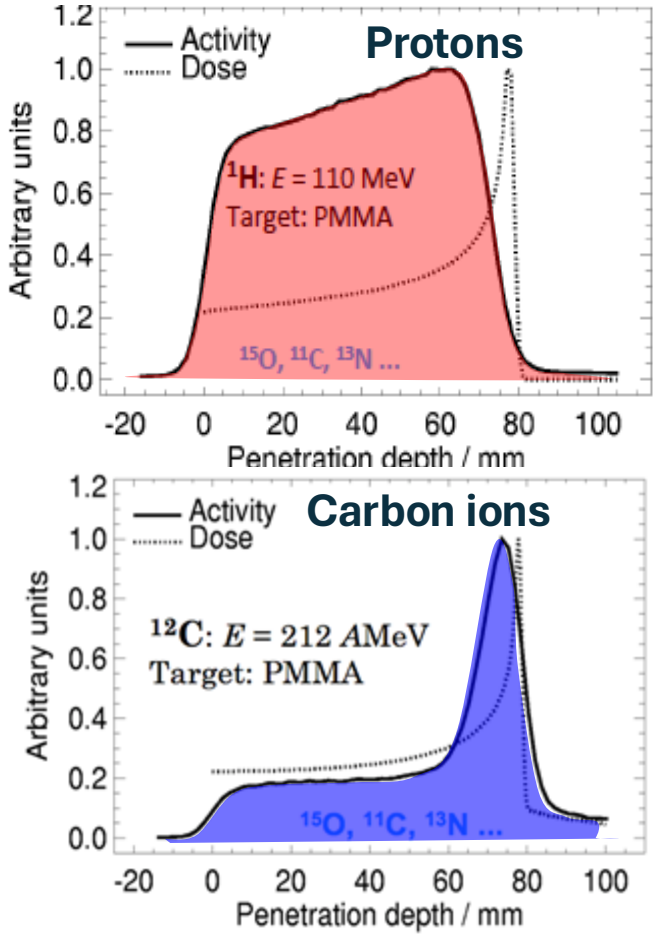


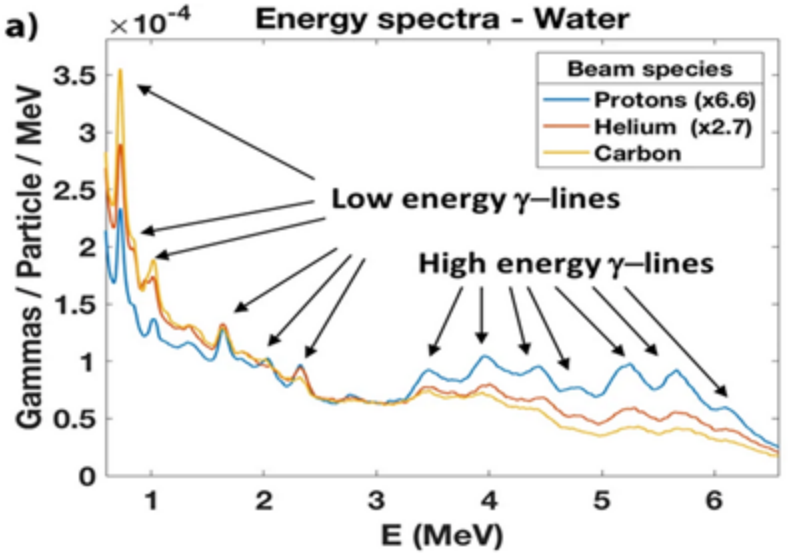
SOLID STATE DETECTORS

Collection Time	~ 100 µs	~ ns
Sensitivity	~ 10^4 particles	Single particle
Time resolution	Poor	< 50 ps
Application	Not suitable for fast counting modalities	Direct counting at clinical fluence (~ 10^8 cm^{-2} s^{-1})

Treatment Verification in Particle Therapy

3D: RANGE VERIFICATION SYSTEM - PET, Prompt Photon Imaging





- Collimated Gamma Camera
- Compton Camera
- **Prompt Gamma Timing**

Treatment Verification in Particle Therapy

2016: first in-vivo measurement

Recruiting

Innovative SolutIons for DosimEtry in Hadrontherapy (INSIDE) (INSIDE)

ClinicalTrials.gov ID NCT03662373

Sponsor CNAO National Center of Oncological Hadrontherapy

Information provided by CNAO National Center of Oncological Hadrontherapy (Responsible Party)

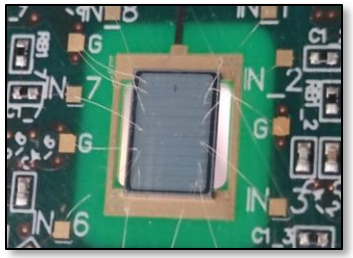
Last Update Posted 2024-08-21

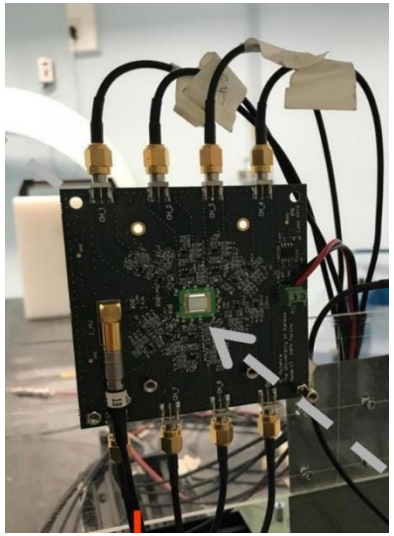
Ferrero et al., Sci.Rep 2018; Fiorina et al., EJMP, 2018

Prompt Gamma Timing: I3PET & MERLINO

BEAM MONITOR:

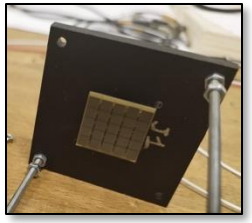
- 11-strips sensor with **gain=1**
- 8-channels amplifier board

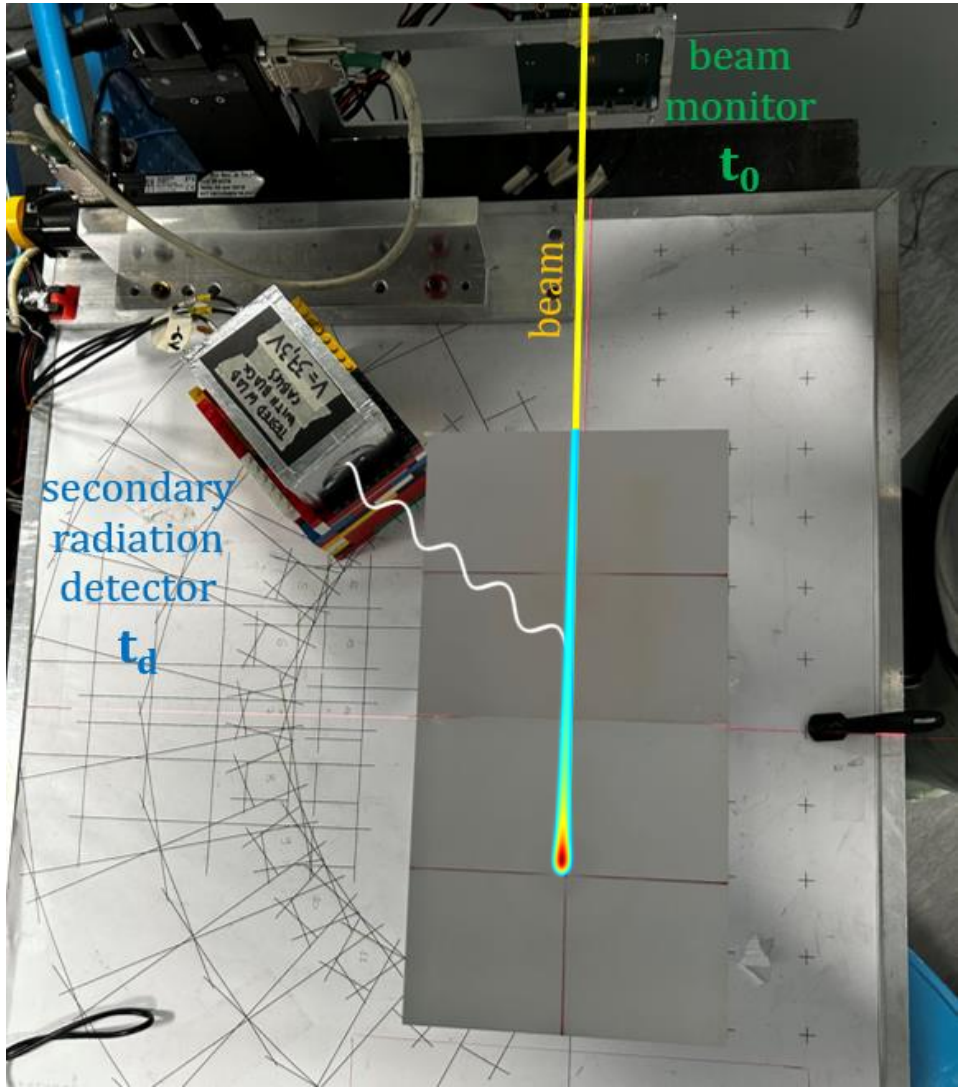




Prompt Gamma DETECTOR:

- 1.5 inch cylindrical LaBr3(Ce) crystal
- Readout by a SiPM matrix (or PMT)
- Custom board to sum all SIPM signals





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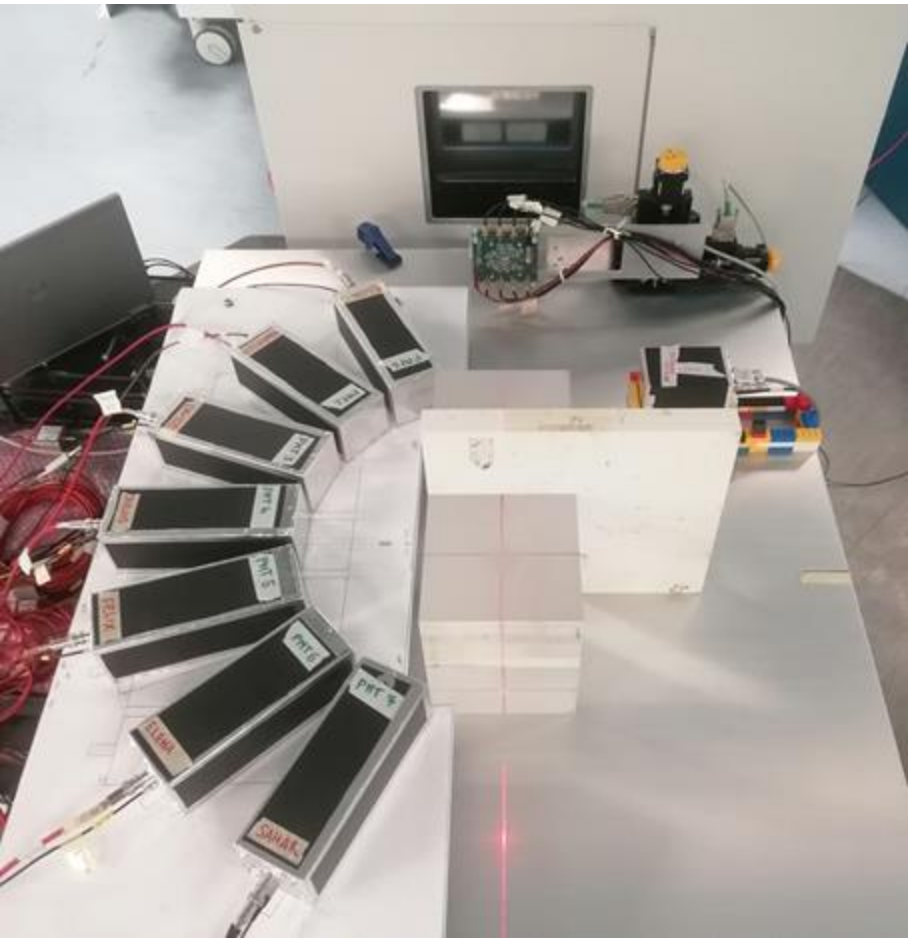
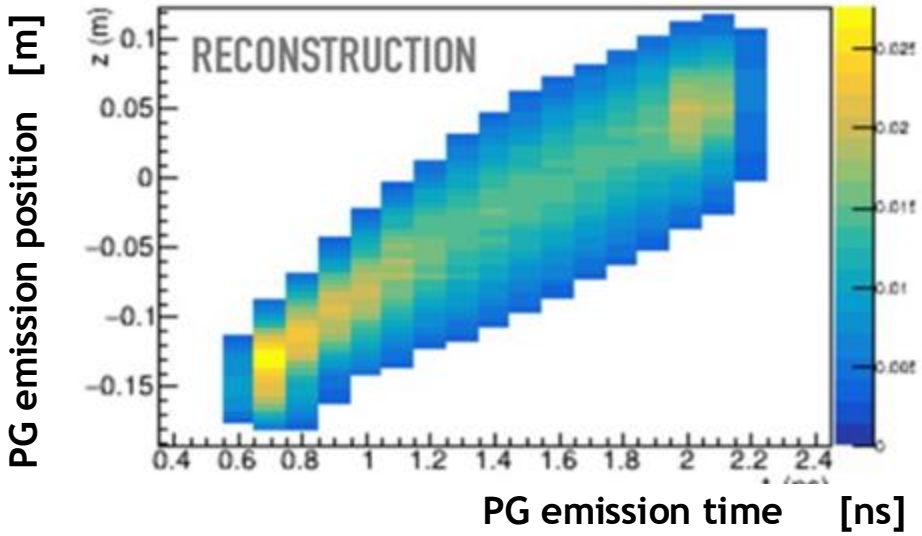
Bragg Peak in-vivo measurement: PoC

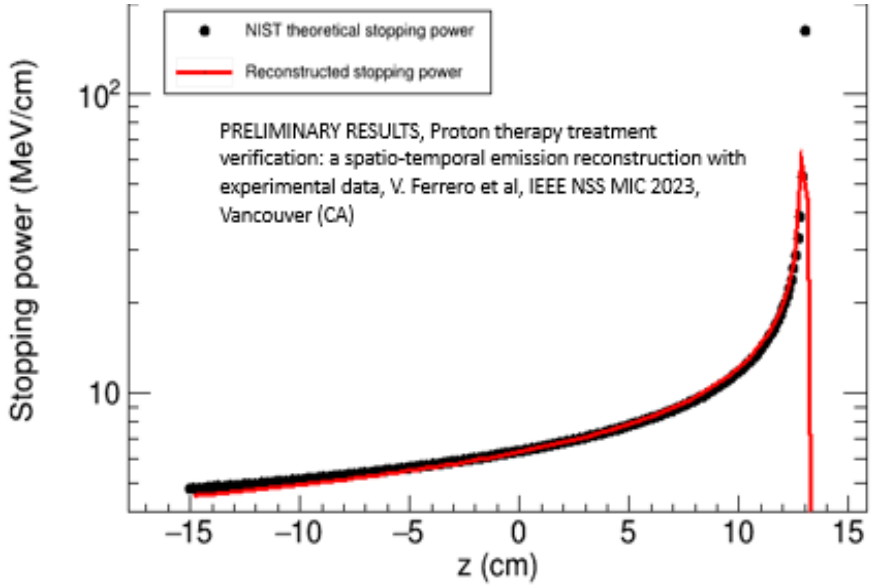


Ferrero et al.
Front Phys (2022)



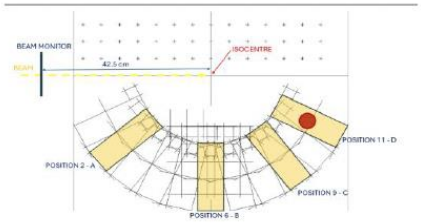
Pennazio et al. PMB (2022)
Werner et al. PMB (2024)

Stopping Power distribution

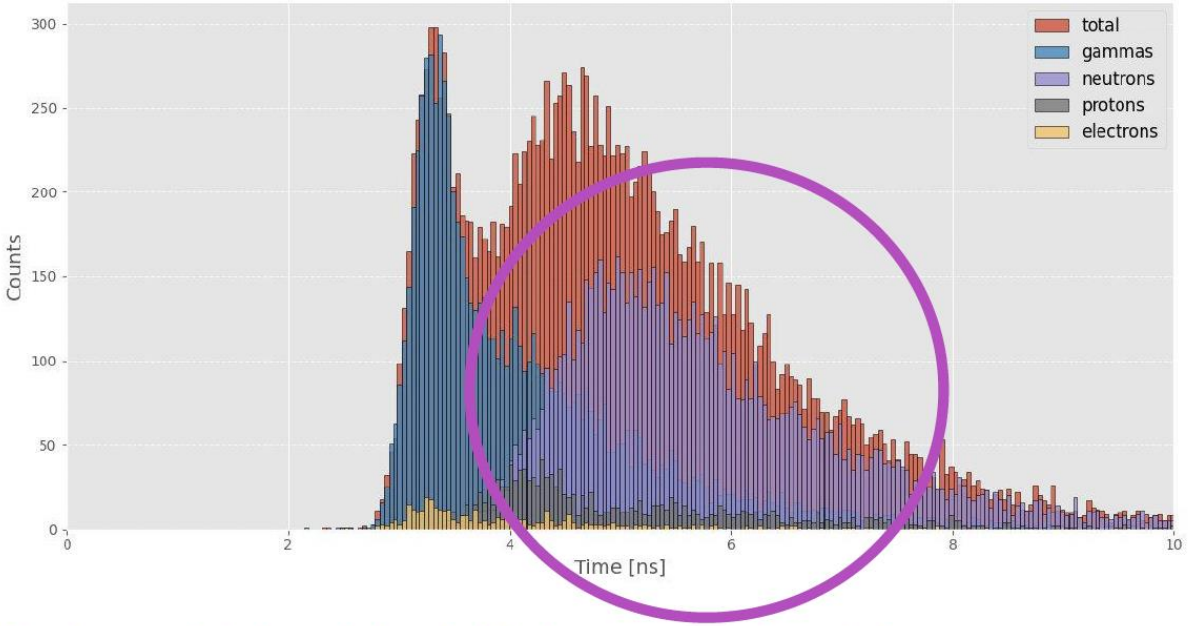


Prompt Gamma Timing with carbon ions

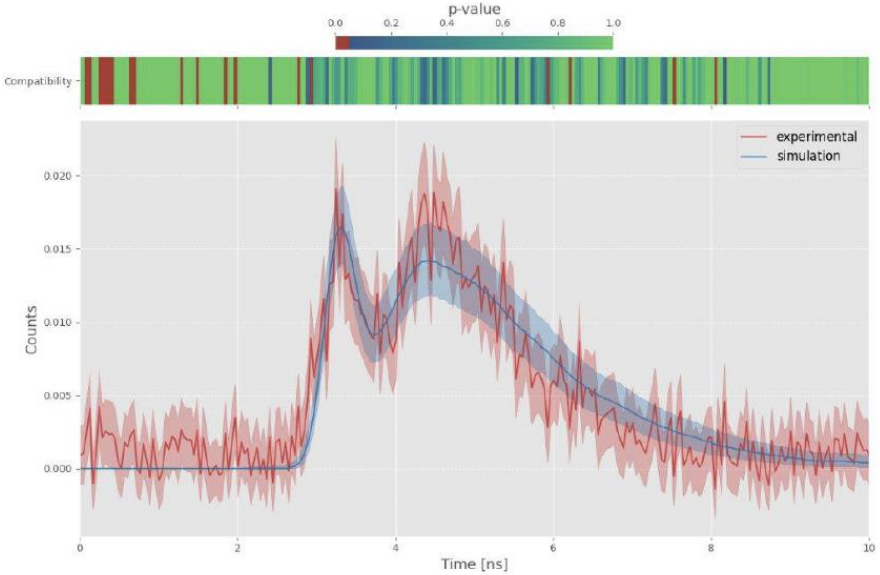
Beam: 166.41 MeV/u Carbon Ion
Target: PMMA (15x15x30 cm3)
Deposited energy : (1, 10) MeV
Sub-clinical rate: average 5e6 pps; instantaneous 2e8 pps



Simulation



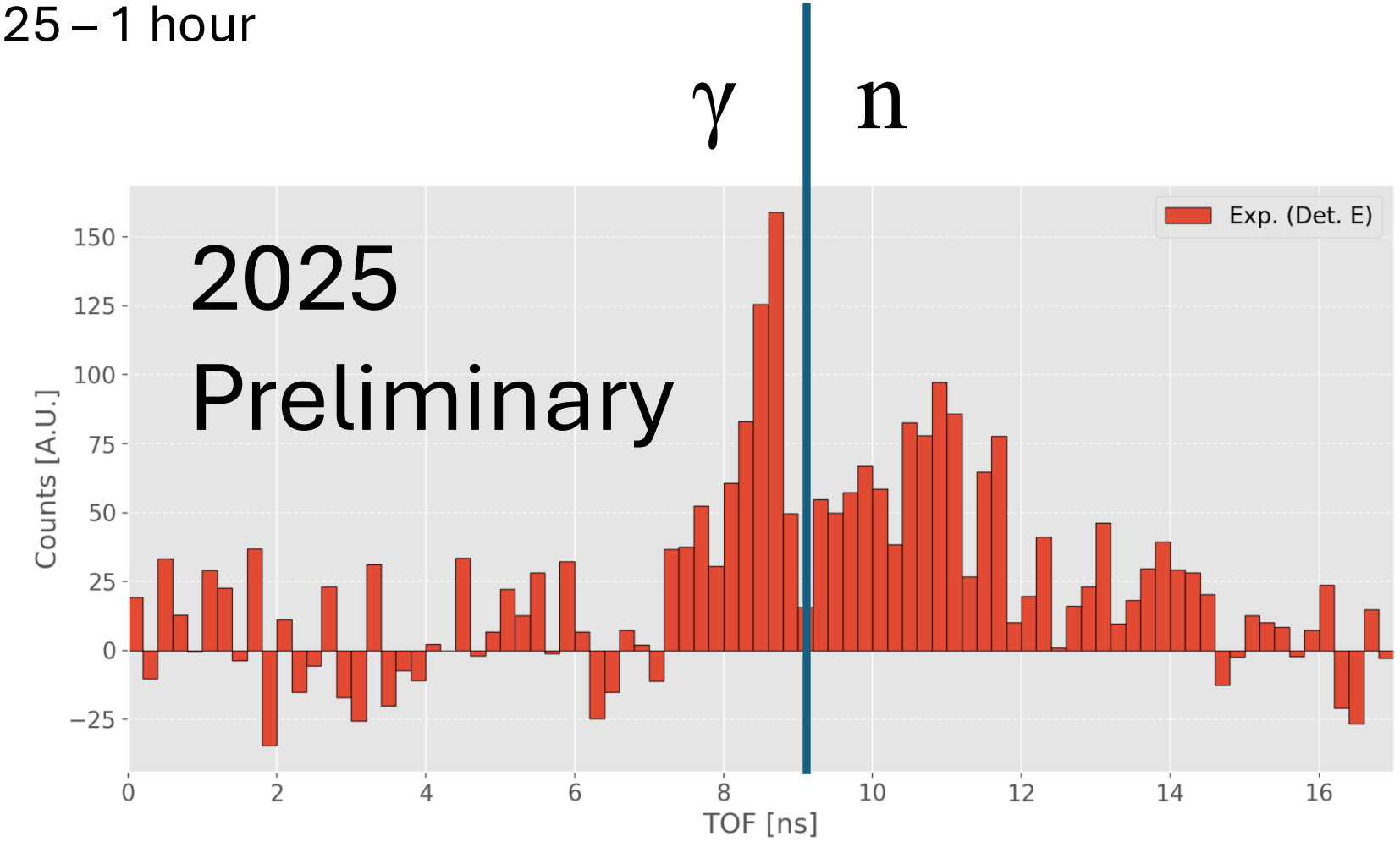
Data



Neutron related peak is visible in our experimental measurements in agreement with simulation.

Neutron detection: Silicon + Crystals

First data taking focused on neutron detection @ CNAO
April 2025 – 1 hour



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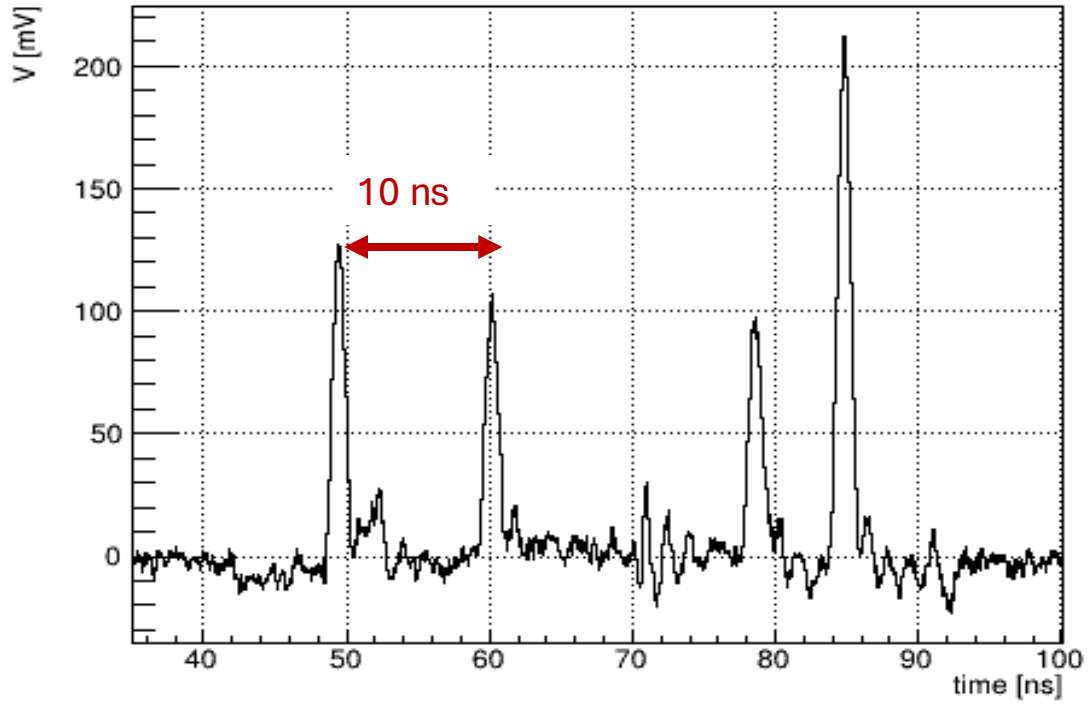
Neutron detection: Silicon + Crystals

Proton signals with LGAD for $5x10^8$ protons/sec



Thin UFSD sensors (50 μm)

Small signal duration (~1 ns) → single particle detection capability

MAIN CHALLENGES

- Readout
  - *Efficiency*
  - *Dead time*
  - *Number of channels*
  - *Data throughput*
- **Size**
- **Dead area**

Infrastructures, Team, Timeline

- Goal
  - building and validating a layout for measuring double differential neutron production cross section for Particle Therapy and Space Radioprotection applications
  - also useful to get closer to clinical application of the Prompt Gamma Timing technique

- Infrastructures
  - FBK: LGAD & SiPM - optimising time resolution
  - CERN: n detector characterisation
  - GSI: Proof of Concept (PoC) of n detection with ion beam(s) at 1 GeV

- Team: INFN & University of Torino

- Timeline: 4 years
  - R&D for Large Size Silicon Detector & n detectors (3 y)
  - PoC measurements (1 y)

Budget

Beam monitor	New (larger) LGAD sensor & frontend board	50 kE
Secondary radiation detectors	New scintillators & SiPMs	30 kE
DAQ + mechanics		20 kE
Travels	Beam tests & meetings	20 kE
Post-doc contracts	2 x 2y	200 kE
Total		**320 kE**