Prompt gamma camera developments at CNAO

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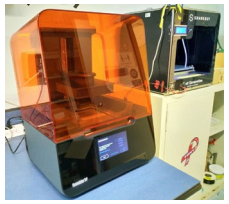
The RADLAB team

RadLab

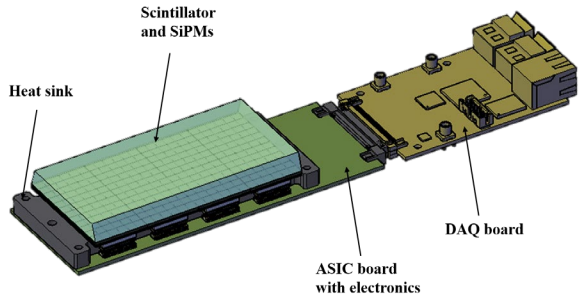
POLITECNICO MILANO 1863

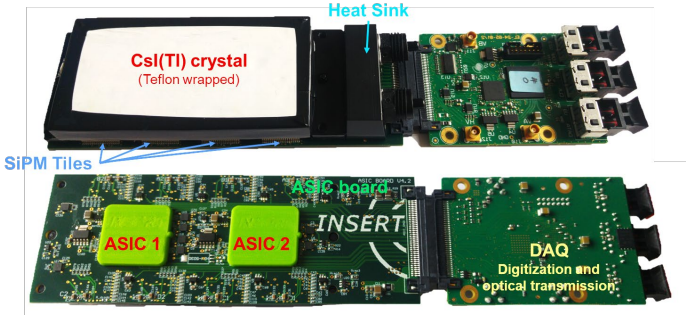
INFN

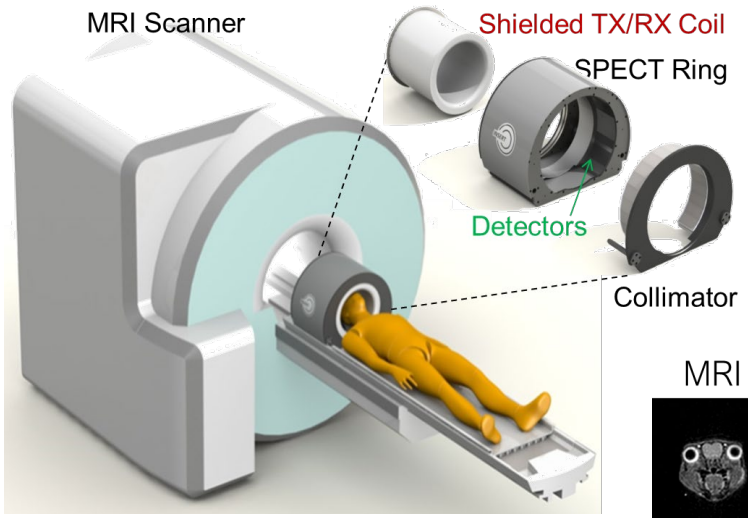
- 2 staff, 10 Ph.D. students and post-docs, 20 M.Sc. thesis students
- CAD workstations, detectors and electronics assembly and test instrumentation, Wire bonding and Flip Chip, 3D printers, vacuum and climatic chambers, photon sources,…

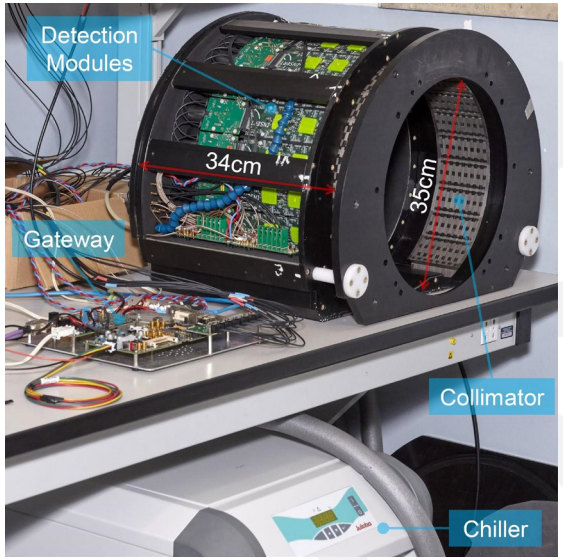


Focus: development of radiation detectors and readout electronics, full detection modules and instrumentation for physics, medical imaging and industry

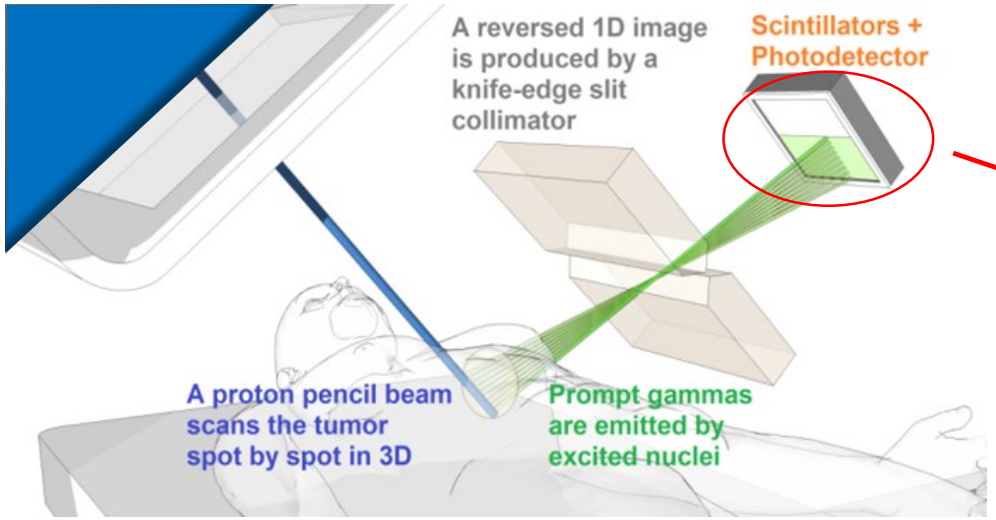


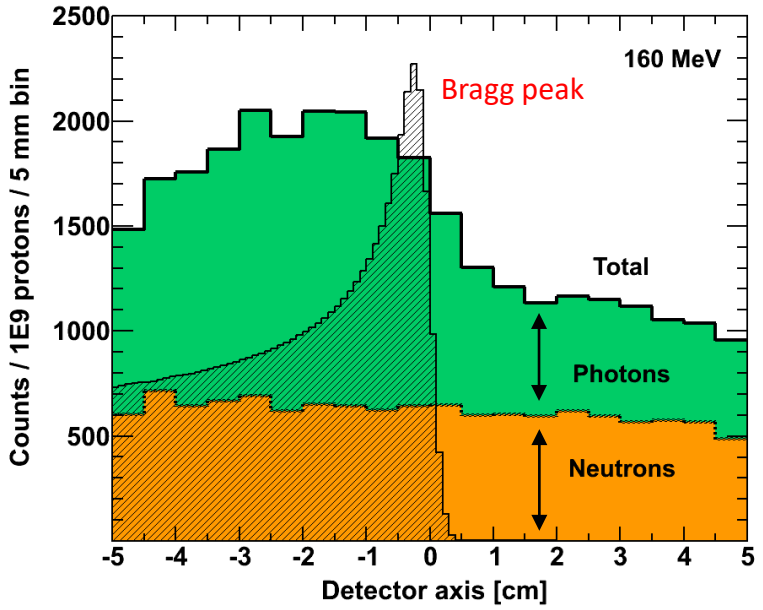


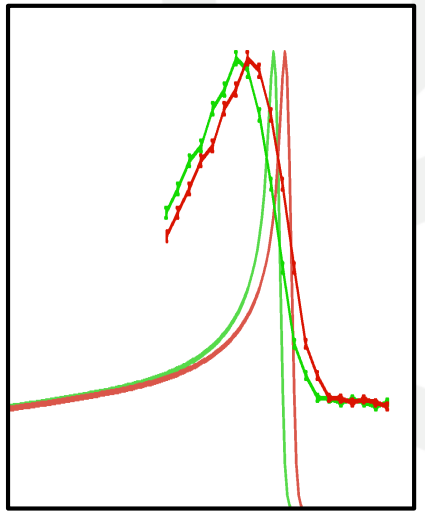




Range verification through Prompt Gammas Imaging (PGI)

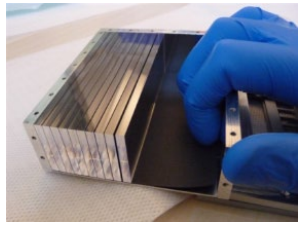




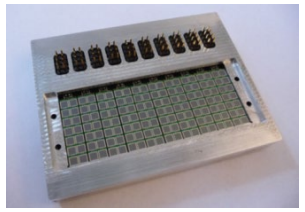


Principle of **prompt-gamma** measurement through a 1D imaging camera. The measured profile of gamma rays shows correlation with the fall-off of the Bragg peak. Contribution from secondary radiation, as neutrons, do not show relevant correlation and contribute mainly to background noise.
A potential tool to **real-time range verification** during irradiation against deviations with respect to the treatment planning, such as patient mis-positioning, organ motion or anatomic changes between fractions.

Previous experience using PGI with protons irradiation



500 cm³ LYSO slabs



SiPMs readout

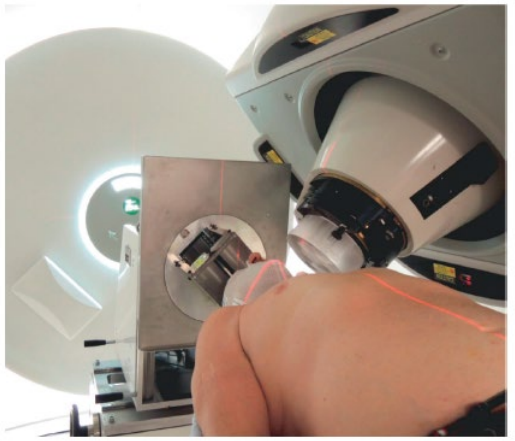
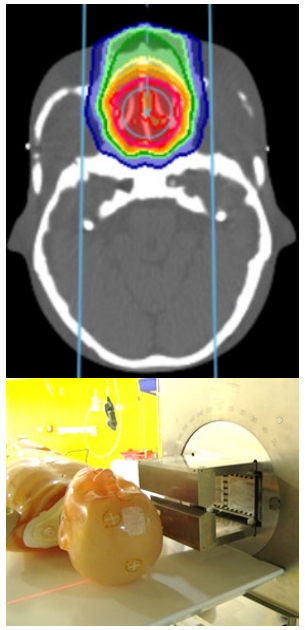
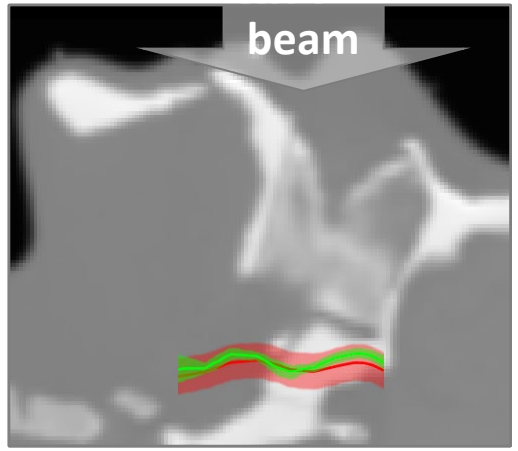
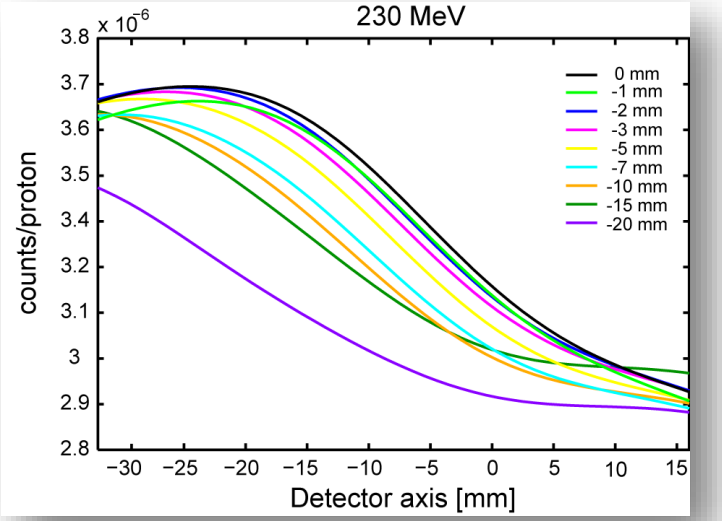


Fig. 1. PGI slit camera trolley (upper row) and its application during patient treatment (lower row).





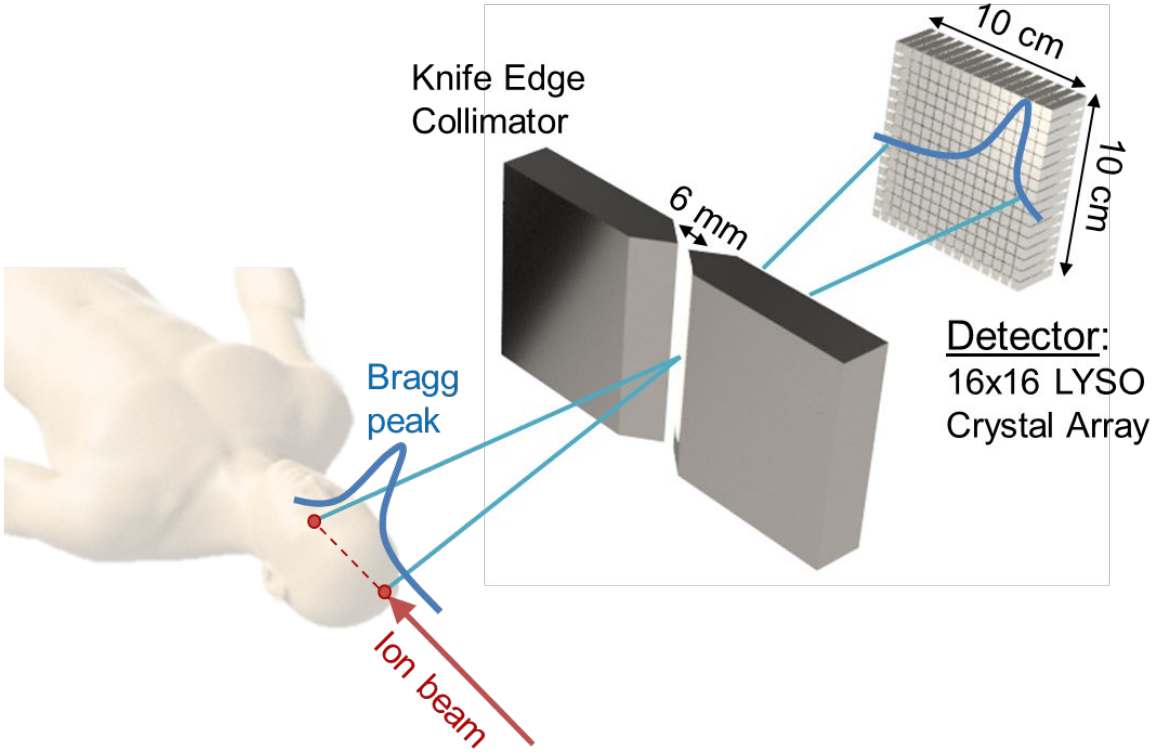
Planning uncertainty **> 5 mm**
(margin of 3.5% + 2 mm)
Measurement uncertainty (1.5σ)
≈ 2.0 mm



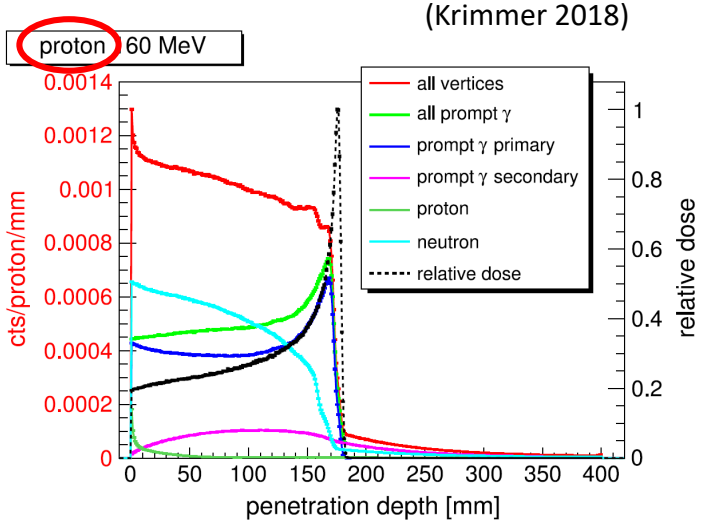
Shift measurements

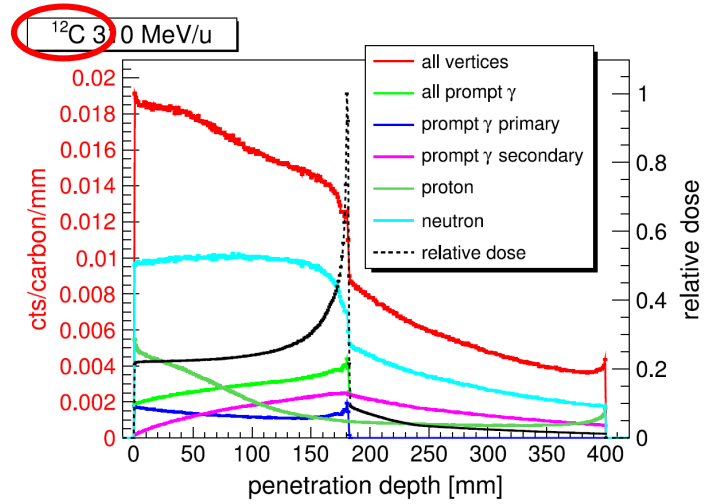
- C.Richter, et al., "First clinical application of a prompt gamma based in vivo proton range verification system", Radiother Oncol 2016;118:232–7.
- Y.Xie, et al., "Prompt gamma imaging for in vivo range verification of pencil beam scanning proton therapy", Int J Radiat Oncol Biol Phys 2017;99:210–8.

Study of PGI with carbon irradiation at CNAO



(Krimmer 2018)

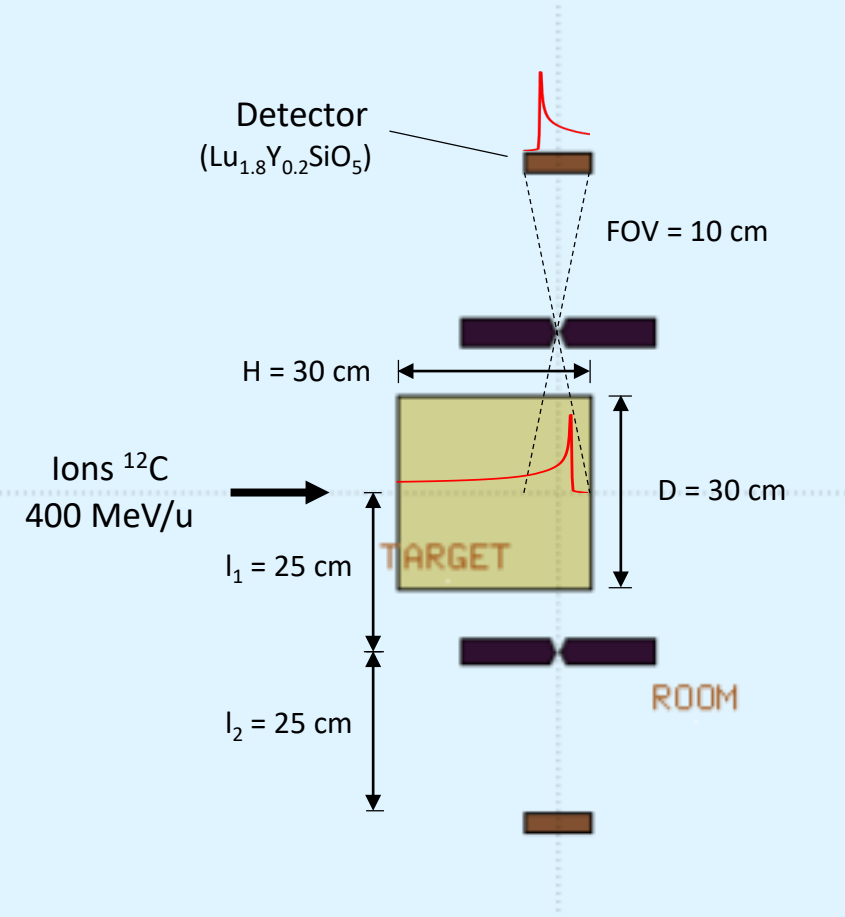




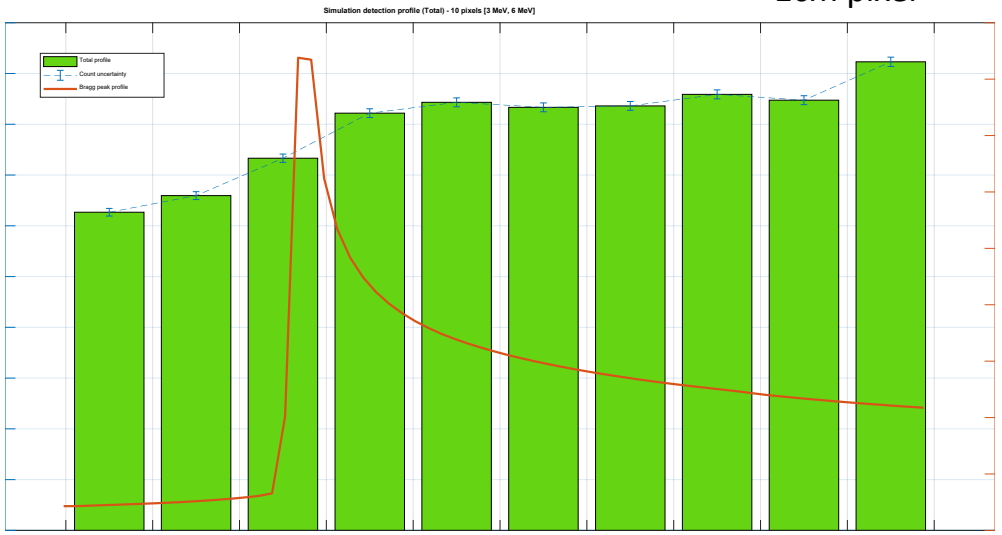
Challenges:

- Two orders of magnitude less carbon ions than protons used for irradiation (issue partially compensated by higher PG yield of carbon vs. proton)
- Secondary gammas reduces the range-end falloff
- Higher neutron background (vs. proton irradiation)

Preliminary simulations

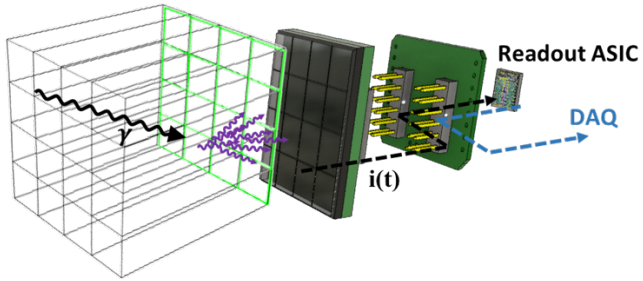


1cm pixel

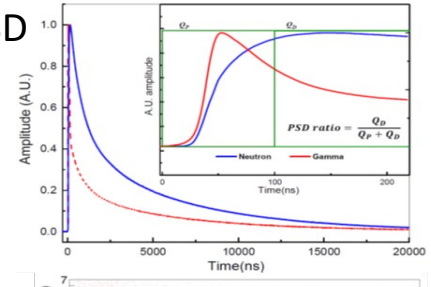


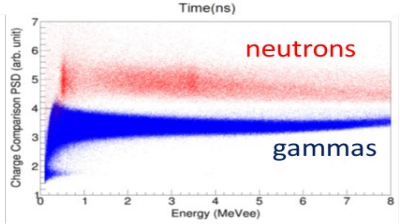
Next…detector development

LYSO-SiPM-ASIC unit



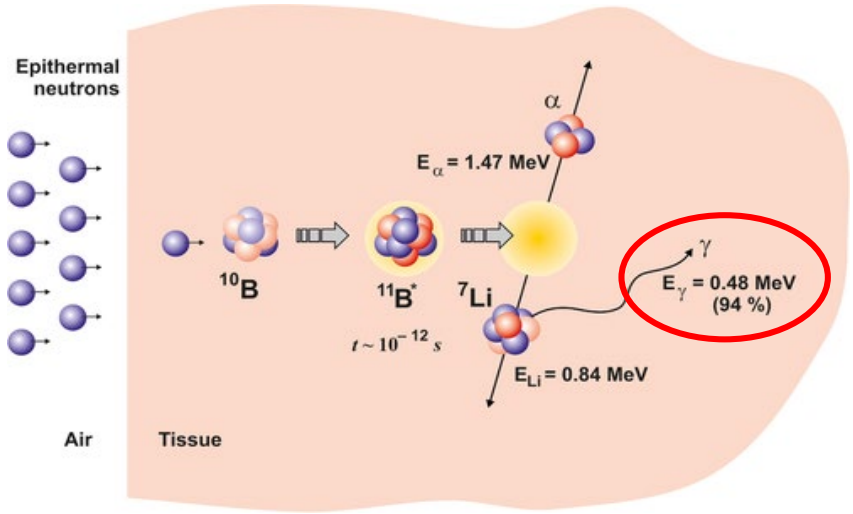
PSD



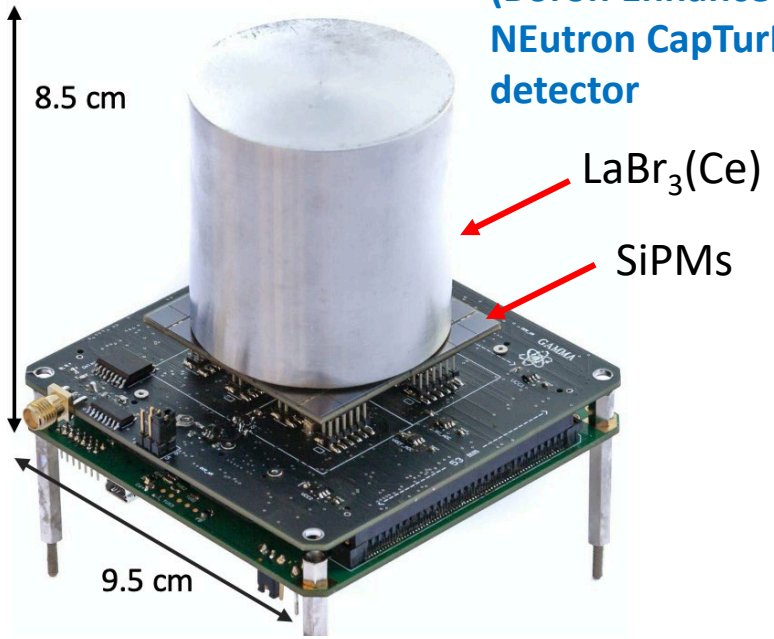


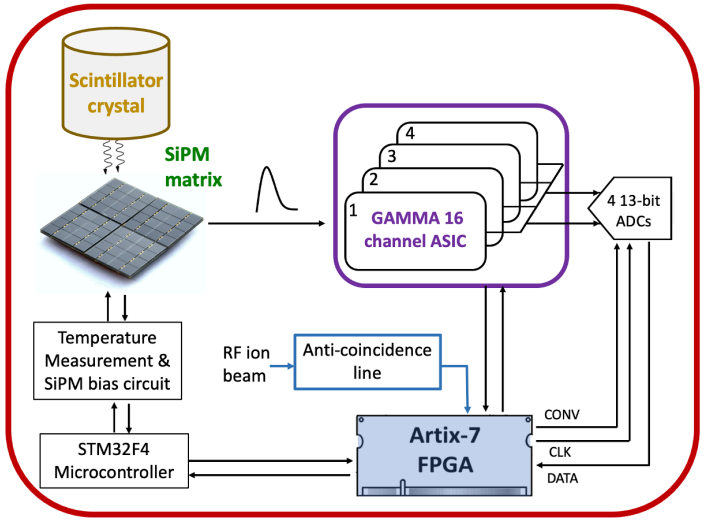
Activity in collaboration with POLIMI Energy Department
(S.Agosteo, F.Casamichiela, …)

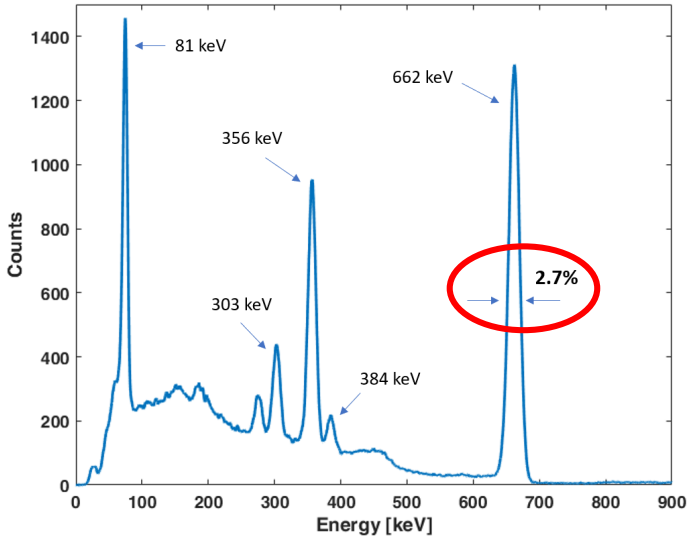
Gamma detection in BNCT

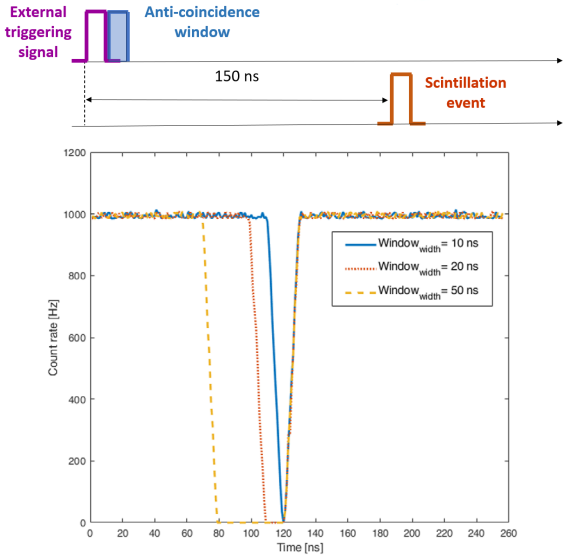


The BENEdiCTE (Boron Enhanced NEutron CapTurE) detector



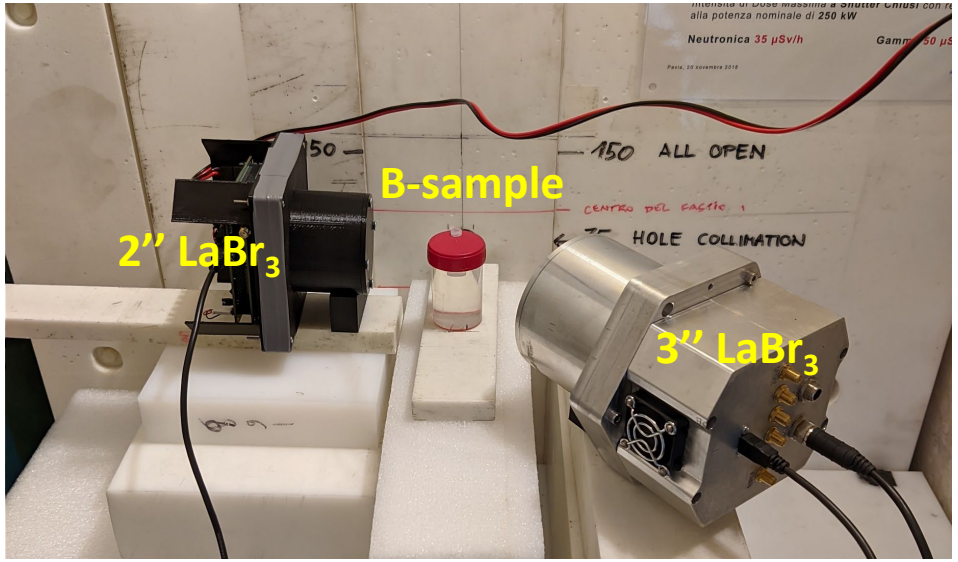




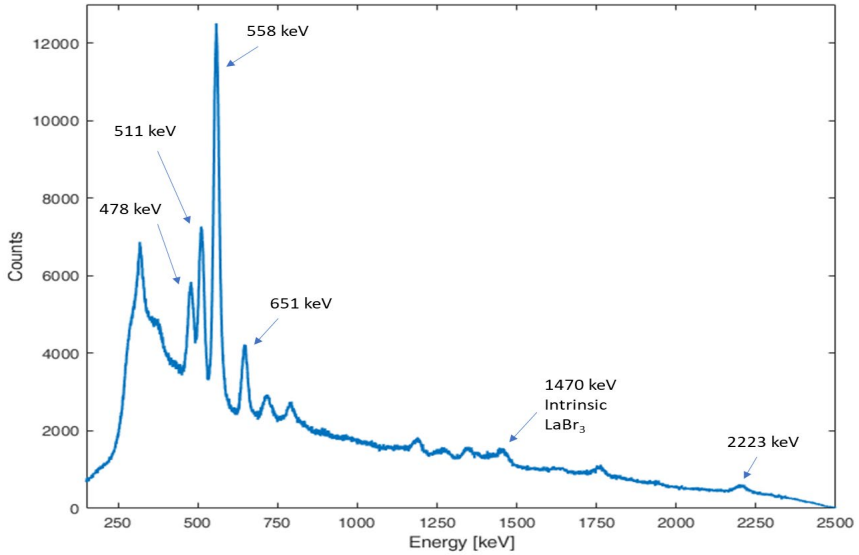


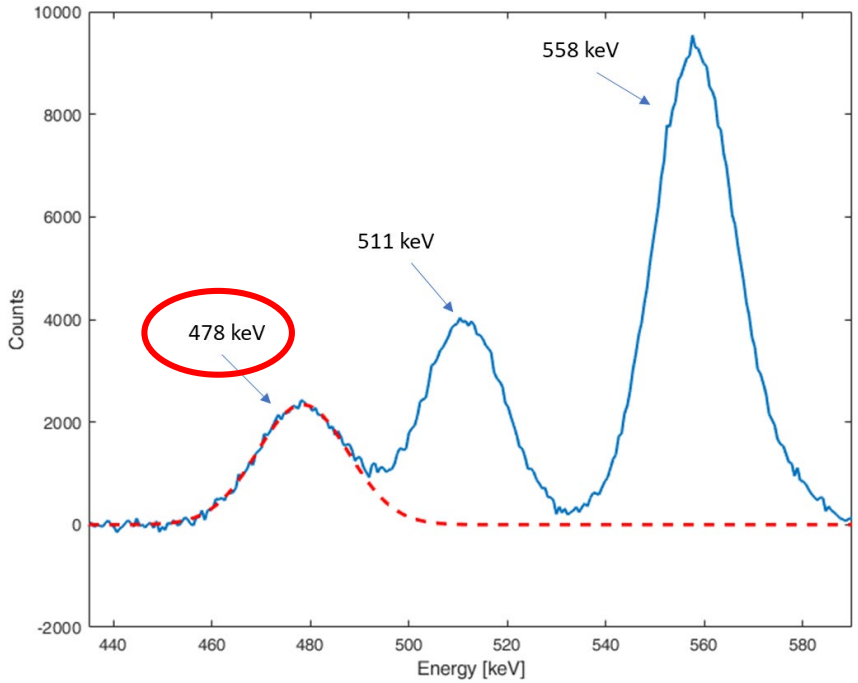
First measurements

Measurements at LENA reactor
University of Pavia (S.Altieri, N.Protti)



Peak's origin	Energy [keV]	Resolution [%]
Boron neutron capture	478	5
Annihilation photons	511	4
Cadmium neutron capture	558	3.6
Cadmium neutron capture	651	3.1
Hydrogen neutron capture	2223	1.2





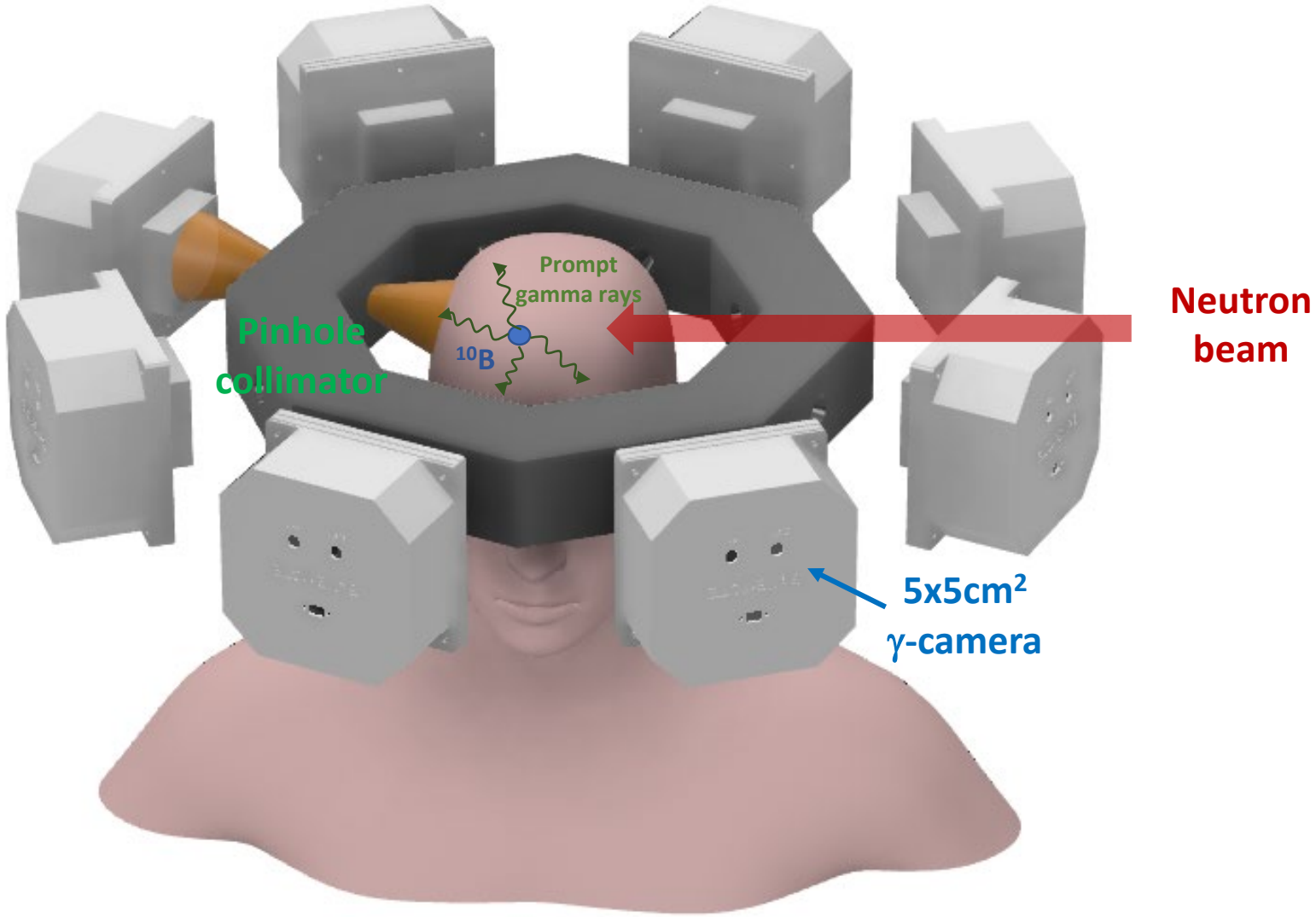
Neutron flux: ~10^5 $cm^{-2}s^{-1}$

1000ppm ^{10}B

15min. measurement

Minimum ^{10}B-concentration of **60ppm** detected (data analysis ongoing)

A first step towards a SPECT for BNCT?



Outlook

- Development of gamma-ray detectors, electronics and instrumentation for gamma-ray measurements applied to dose verification in carbon-ion irradiation and BNCT.
- This is a starting activity and it is open for collaborations!

Acknowledgments

A.Bourkadi Idrissi, A.Caracciolo, L.Buonanno, I.D'adda, D.Di Vita, M.Carminati
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