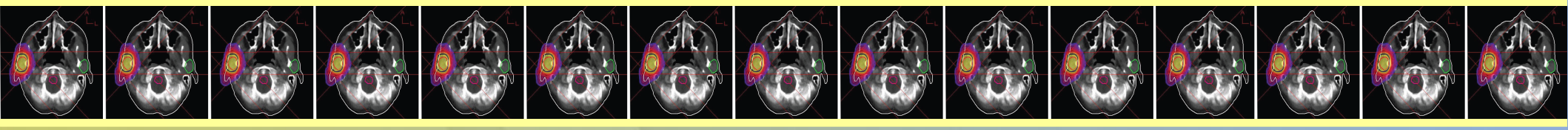
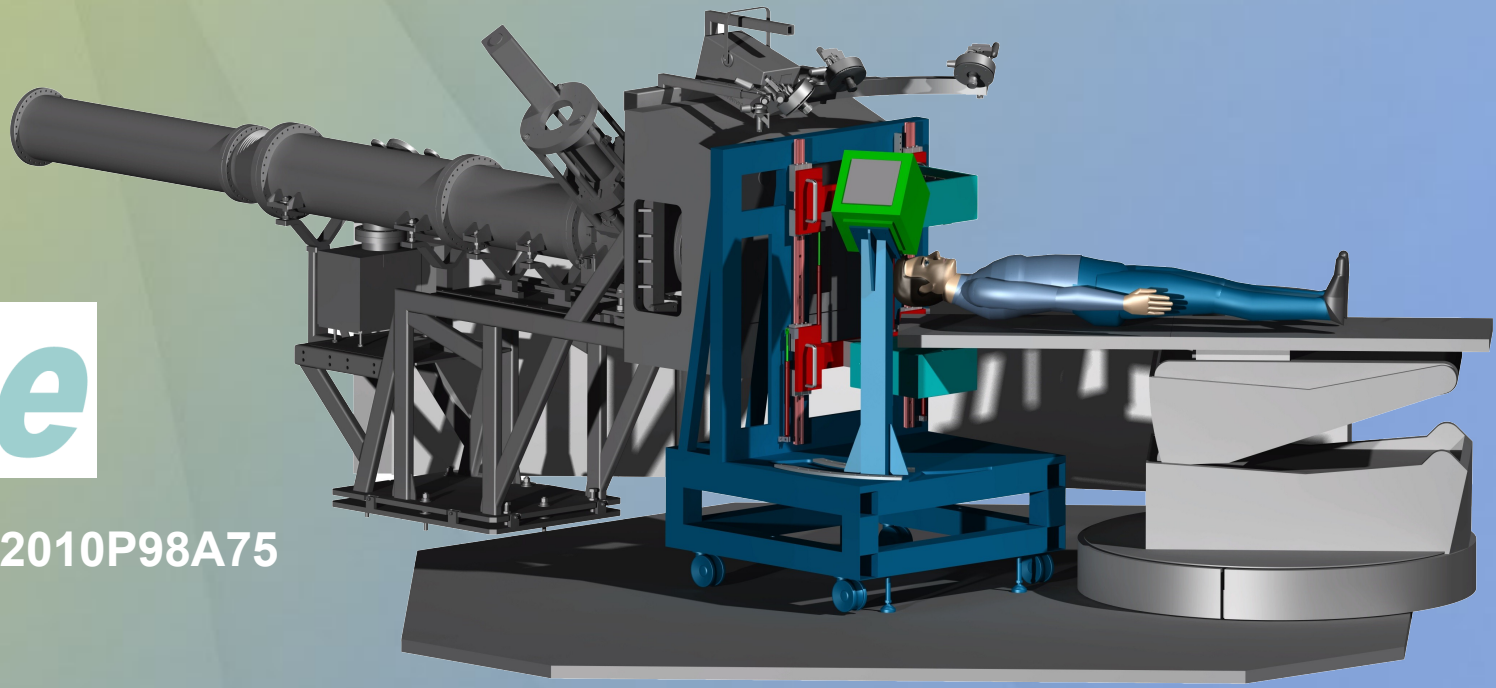
INSIDE project: a tool for the quality assurance of hadrontherapy treatments.



G. Pirrone and M.A. Piliero on behalf of the INSIDE Collaboration



InSide

PRIN MIUR 2010-2011 - 2010P98A75

UNIVERSITÀ DI PISA

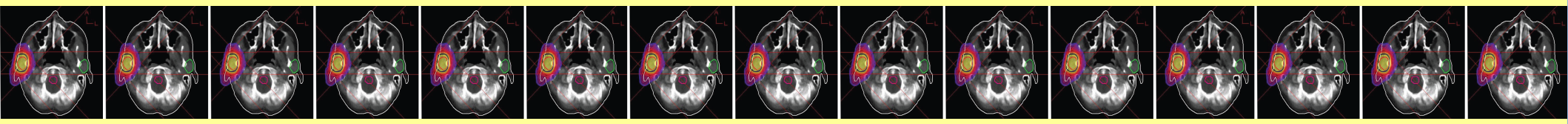
POLITECNICO DI BARI

SAPIENZA UNIVERSITÀ DI ROMA

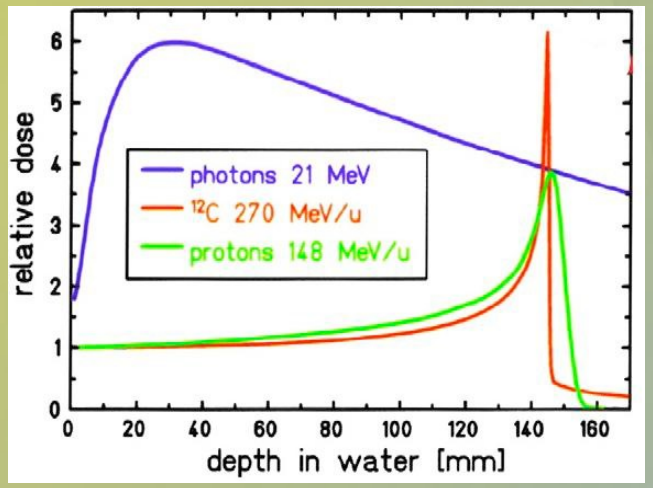
UNIVERSITÀ DEGLI STUDI DI TORINO

INFN Istituto Nazionale di Fisica Nucleare

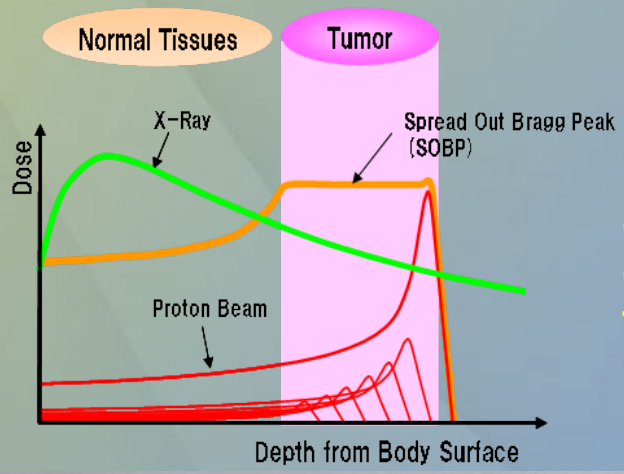
INSIDE project: a tool for the quality assurance of hadrontherapy treatments.



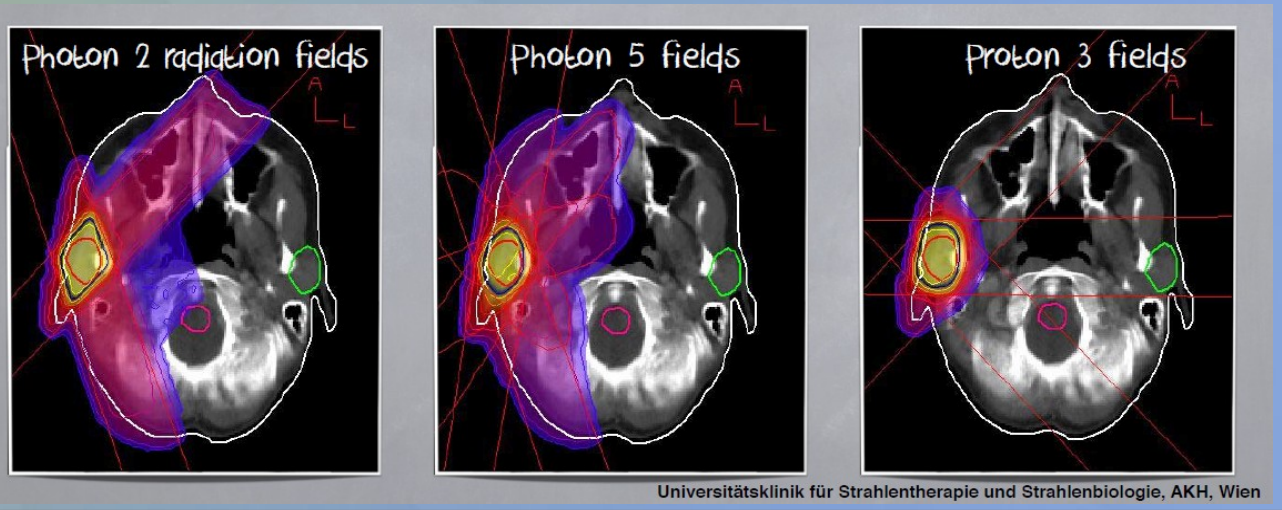
Particle therapy



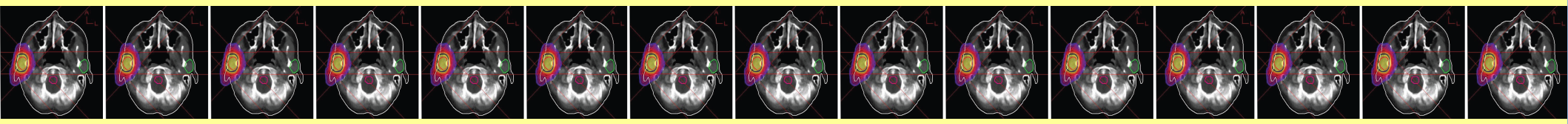
The dose released follows the Bragg-Peak distribution, that can be calculated from the well known Bethe-Bloch equation



Using beams of different energies it is possible to conform the dose to the tumor shape



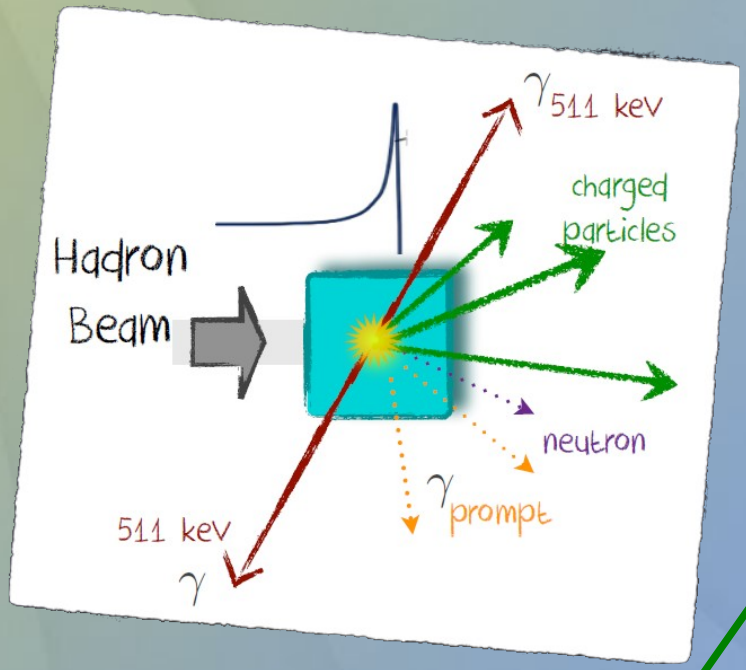
INSIDE project: a tool for the quality assurance of hadrontherapy treatments.



In-beam monitoring

TREATMENT UNCERTAINTIES IN ION BEAM THERAPY

- Difference TP/Delivery
  - Daily setup variation
  - Internal organ motion
  - Anatomical/physiological chages
- TPS dose calculation errors
  - Inhomogeneities, metallic implants
  - Conversion HU ion range
  - CT artifacts

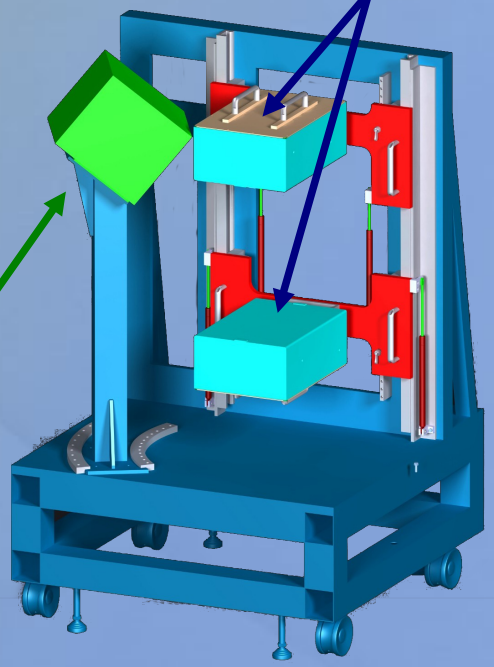


A dose monitoring is needed!

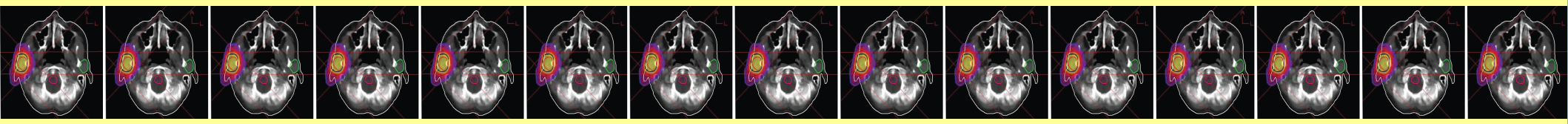
fondazione CNAO
Centro Nazionale di Adroterapia Oncologica per il trattamento dei tumori

PET heads

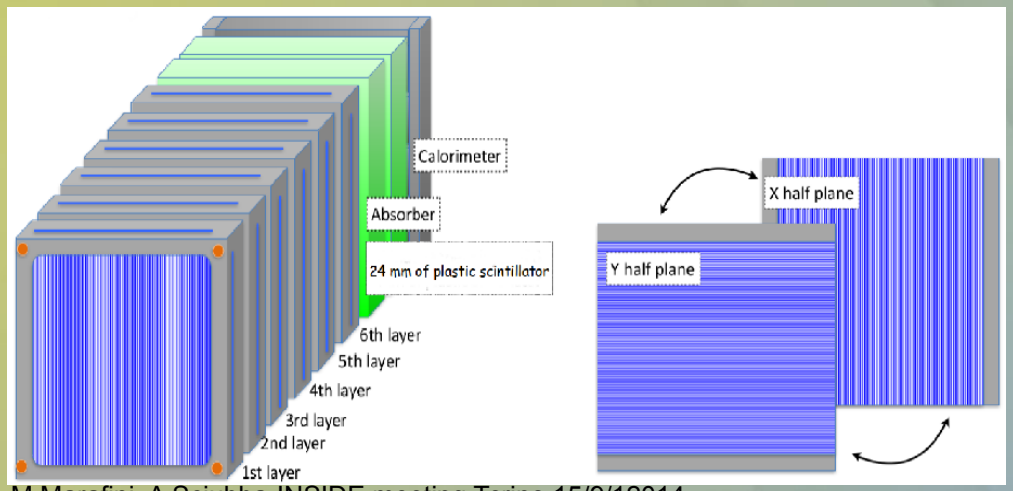
Dose Profiler



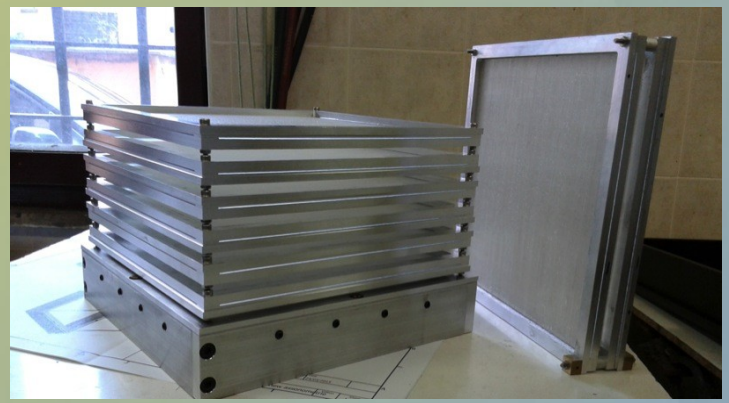
INSIDE project: a tool for the quality assurance of hadrontherapy treatments.



The dose profiler



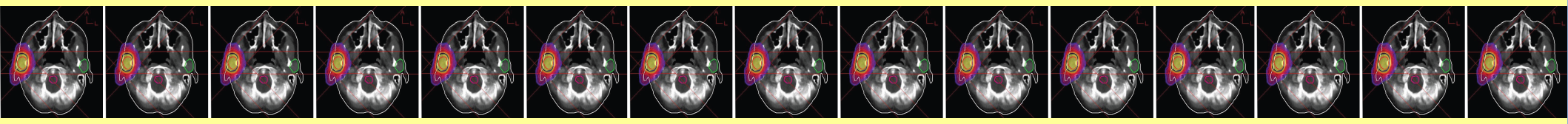
M.Marafini, A.Sciubba-INSIDE meeting Torino 15/9/12014



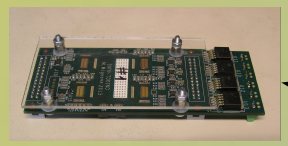
V. Patera - INSIDE meeting Pisa 9/6/12015

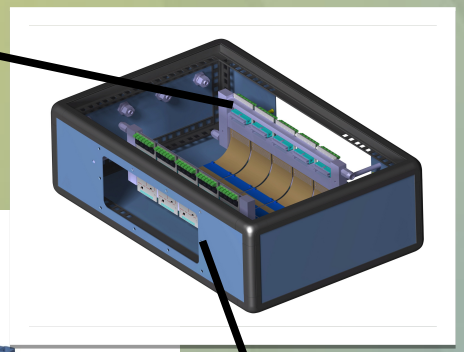
- **Tracker:**
  - 6 XY planes of scintillating fibers
- **Absorber**:
  - 2.4 mm of plastic scintillator
- **Calorimeter:**
  - 4x4 matrices of pixellated LYSO crystals read by a multi-anode H8500 PMT

INSIDE project: a tool for the quality assurance of hadrontherapy treatments.



The PET scanner

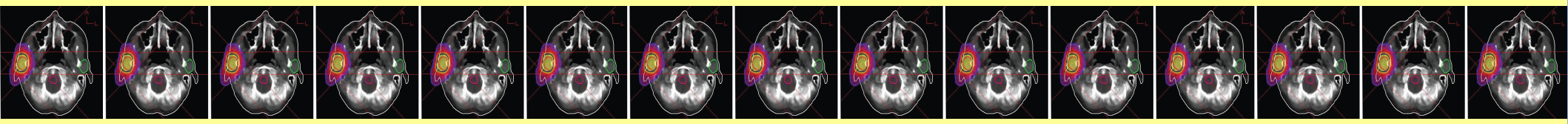




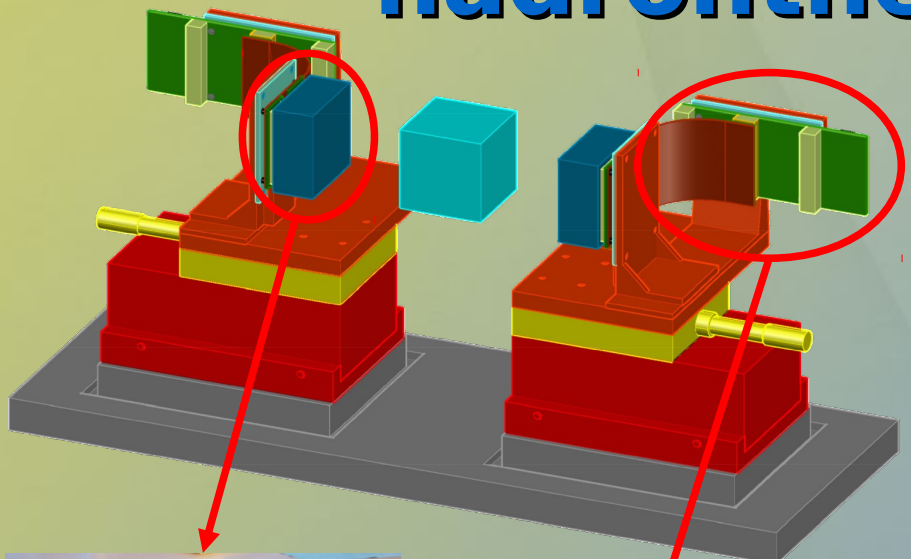
Detection module

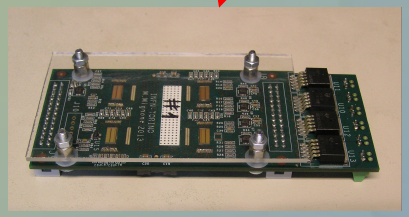
- Two planar panels, 10 cm x 25 cm
- Each panel is composed of 2 x 5 detection modules
- The detection module is composed of:
  - pixelated LFS scintillator matrix of 51,2 x 51,2 mm^2
  - 16 x 16 pixels (3 x 3 x 20 mm^3) of 3.2 mm pitch
  - 16 x 16 Multi-Pixel Photon Counters (MPPC) arrays from Hamamatsu
- 4 custom-design 64 channels TOF-PET ASIC for the read out of one detection module
- 50 cm head-to-head distance

INSIDE project: a tool for the quality assurance of hadrontherapy treatments.



Beam test at the CNAO hadrontherapy facility





Detection module, 51.2 x 51.2 mm^2 cross section

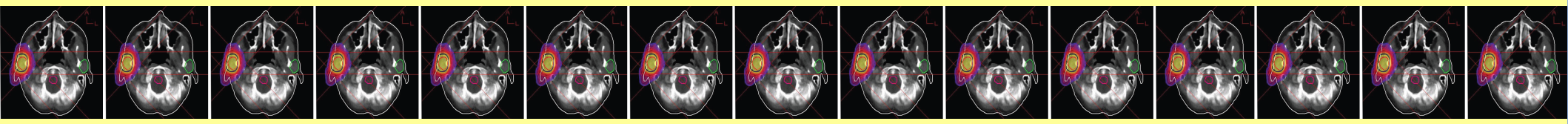
- 50 cm head-to-head distance
- Proton beam on a PMMA phantom, single spot irradiation
- 49 x 49 x 70 mm^3 PMMA phantom
- Four monoenergetic beams:

  - 68 MeV, 72 MeV, 84 MeV, 100 MeV
- 2 *10^{11} protons

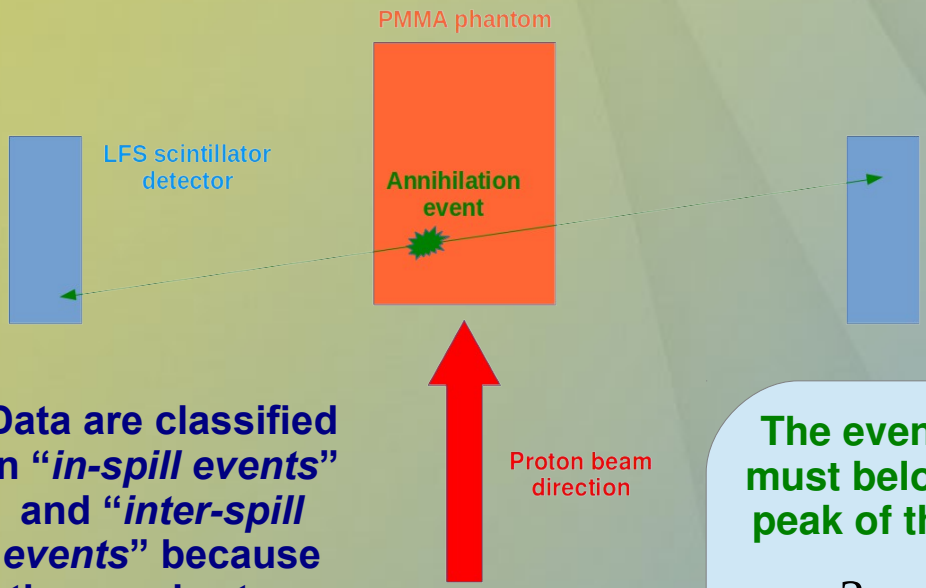
Monoenergetic proton beams on PMMA

Energy (MeV)	Nr. of protons	Nr. of spills	Average protons number per spill	PMMA range (mm)
68	$2.0 \cdot 10^{11}$	102	$1.96 \cdot 10^{9}$	34
72	$2.0 \cdot 10^{11}$	98	$2.04 \cdot 10^{9}$	37
84	$2.0 \cdot 10^{11}$	183	$1.09 \cdot 10^{9}$	49
100	$2.0 \cdot 10^{11}$	139	$1.44 \cdot 10^{9}$	66

INSIDE project: a tool for the quality assurance of hadrontherapy treatments.

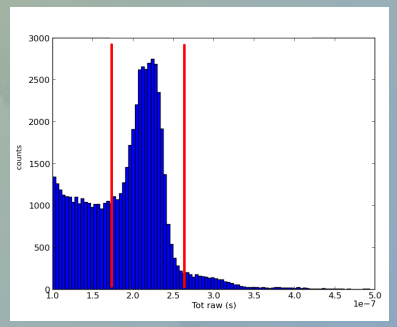


Coincidence signals and CTR



Data are classified in "*in-spill events*" and "*inter-spill events*" because the synchrotron particles emission

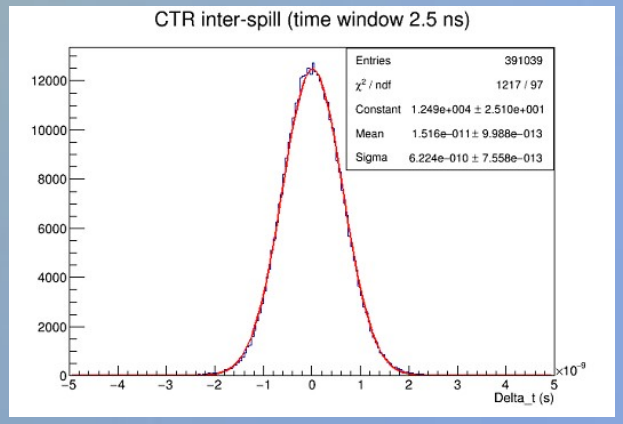
Energy measured by the ASIC through the Time-Over-Threshold technique

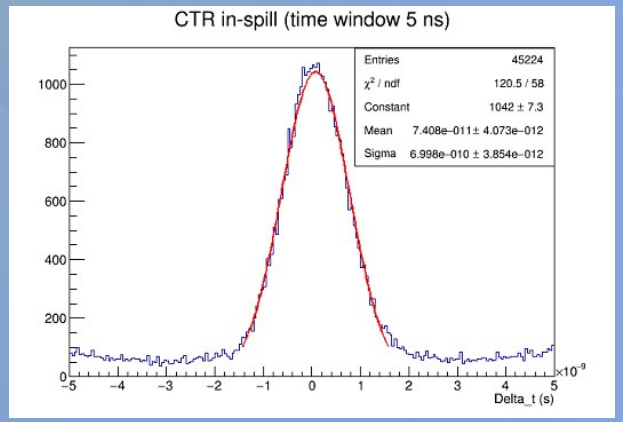


The events to be selected must belong to the 511 keV peak of the TOT spectrum.

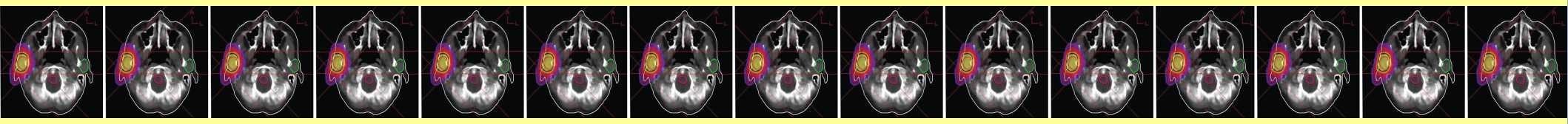
$$\mu_i - 3\sigma_i < TOT_i < \mu_i + 3\sigma_i$$

Where μ_i and σ_i are the the values of mean and standard deviation obtained for the i^{th} channel with the gaussian fits on the inter-spill data.

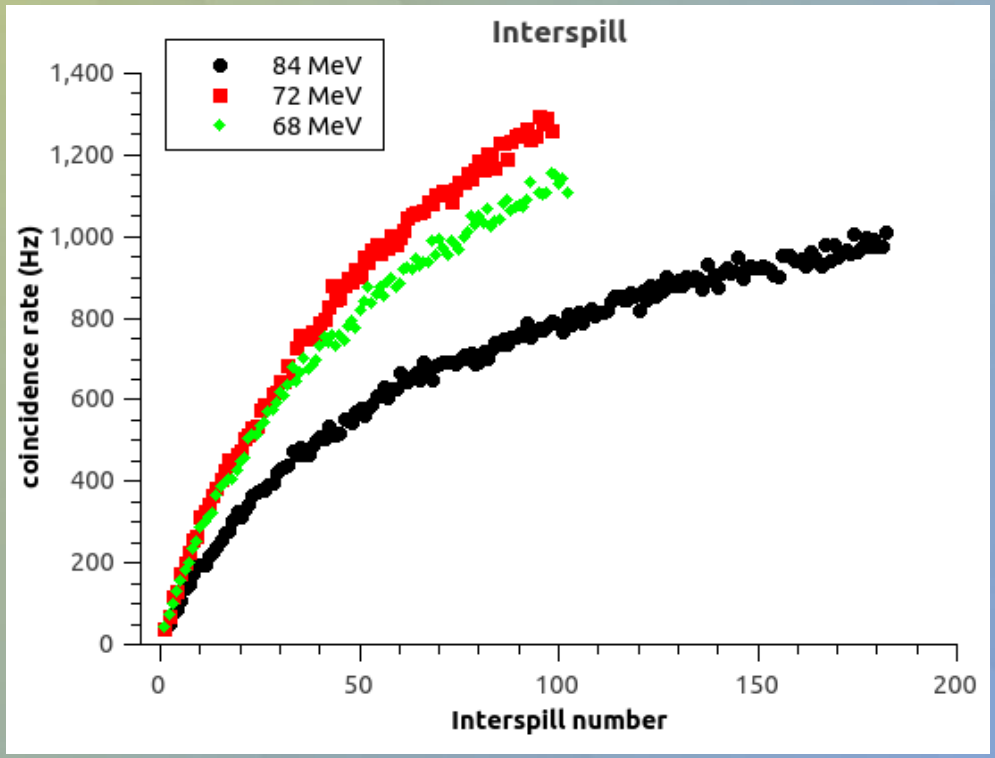




INSIDE project: a tool for the quality assurance of hadrontherapy treatments.

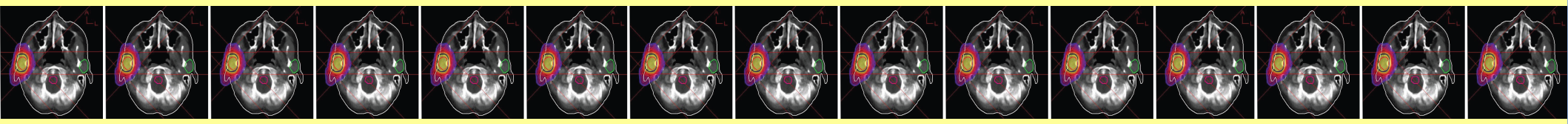


Coincidence rate



At 84 MeV the number of spills delivered was double the number of spills at 68 MeV and 72 MeV. A lower coincidence rate is plausible.

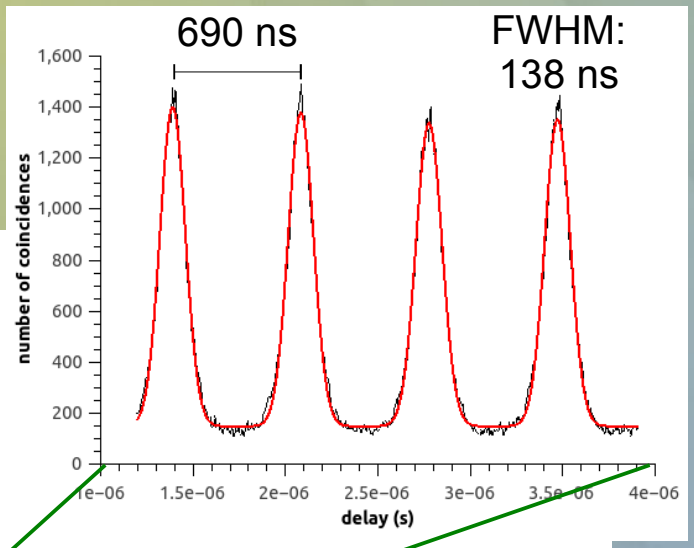
INSIDE project: a tool for the quality assurance of hadrontherapy treatments.

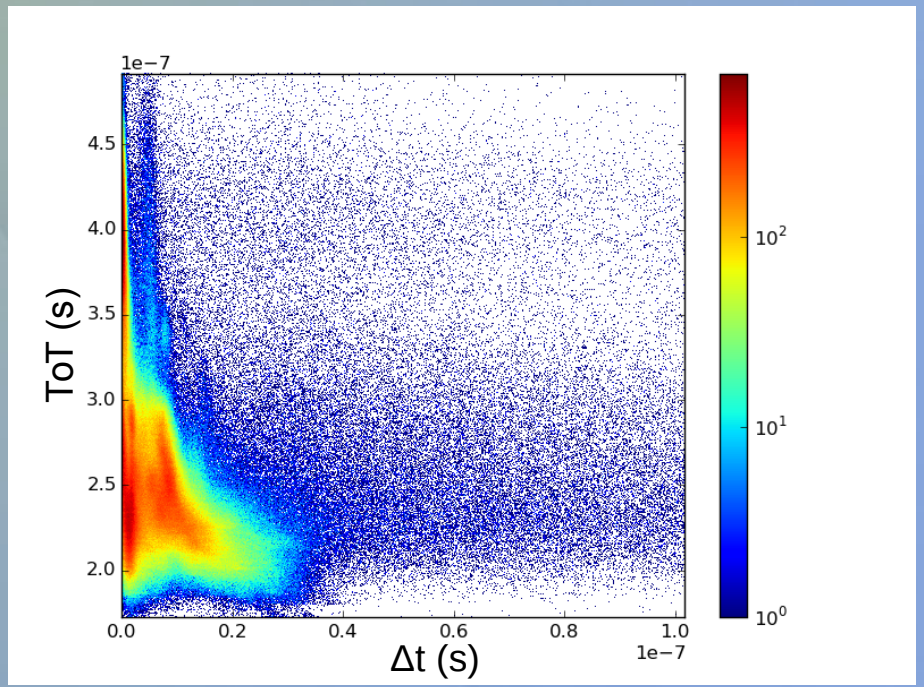


Random coincidences

Coincidence rate

$$C_R = 2\Delta t\, C_1 C_2$$





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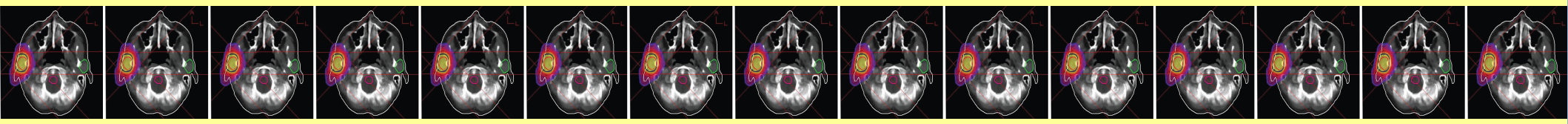


Reconstruction software

MLEM image reconstruction algorithm has been used to get the activity distribution in the FOV of the PET-scanner from the coincidence signals

$$\vec{f}^{k+1} = \frac{1}{\|A\|} \vec{f}^{k} \cdot A^{T} \frac{\vec{p}}{A\vec{f}^{k}}$$

Retro projection:

Forward projection

- Start with an uniform image
- Forward projection: For each LOR gets the number of events expected if X was the true activity
- Retro projection: Compare the acquired value of the LOR with the forward projection and retroproject it on the image
- Divide by the sensitivity
- Update the image

- Number of modules 2
- Face to face distance 50 cm
- Number of crystals per module 256
- Crystal size 3 x 3 mm^2
- Pitch 3.2 mm
- FOV size 51.2 x 51.2 x 51.2 mm^3
- Voxel size 1.6 x 1.6 x 1.6 mm^3
- Model size 102 Mb

INSIDE project: a tool for the quality assurance of hadrontherapy treatments.

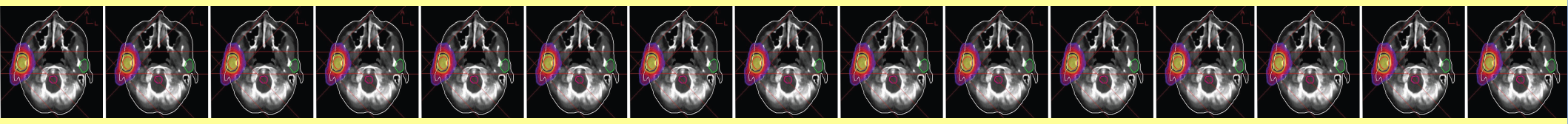
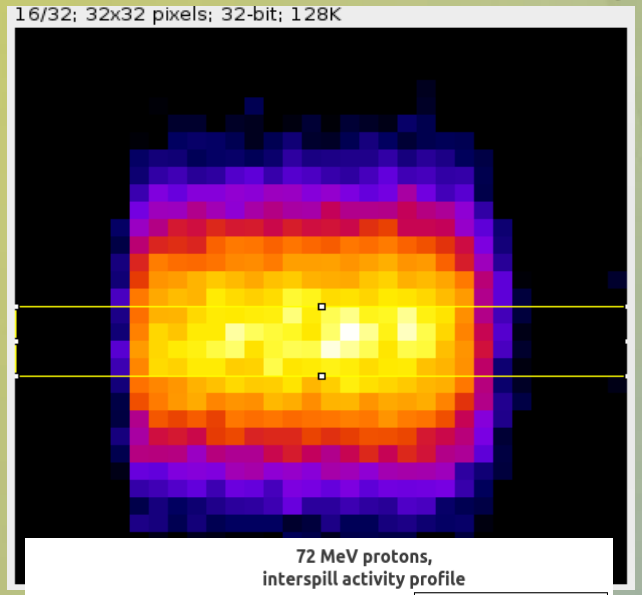
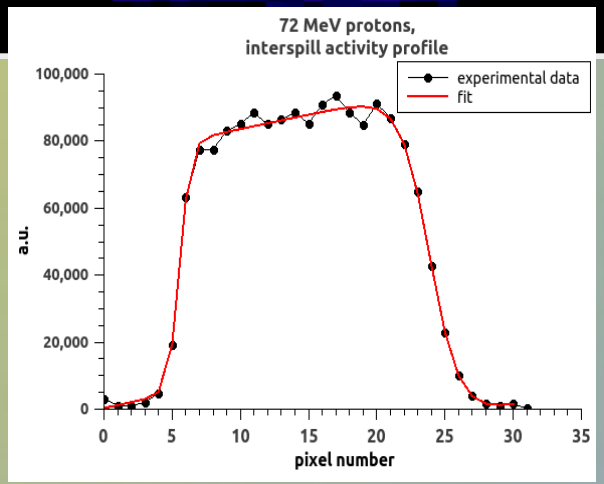
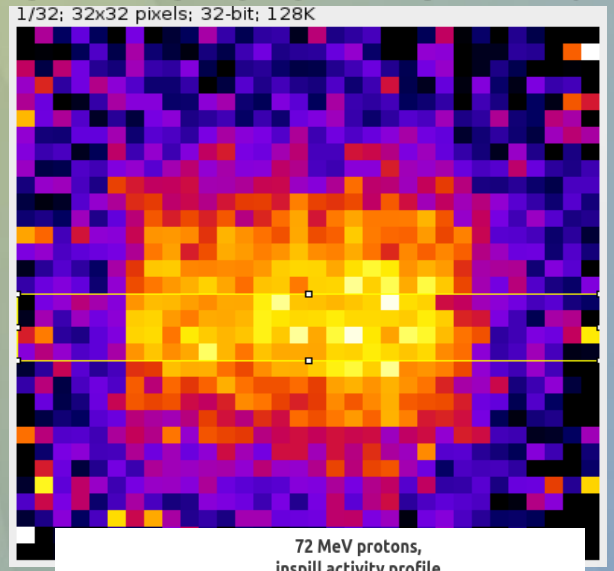
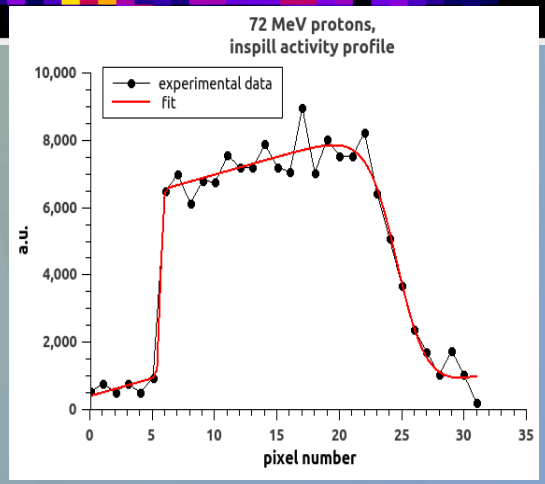


Image reconstruction



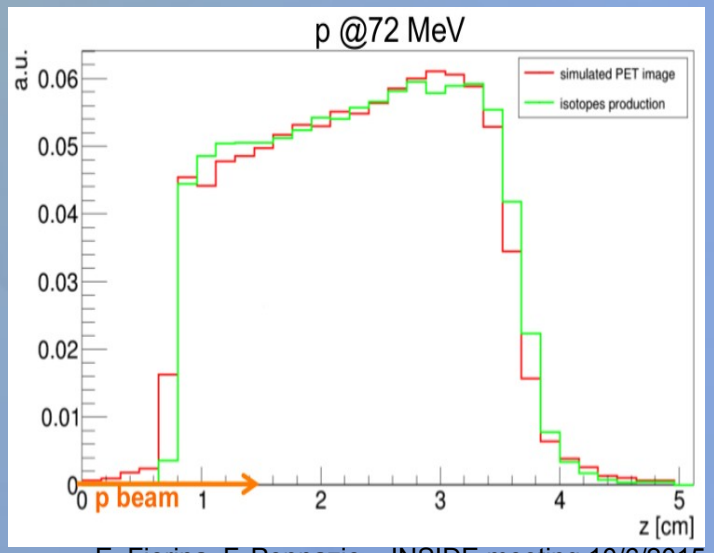






Interspill activity profile:

Comparison between experimentala data and FLUKA simulated data



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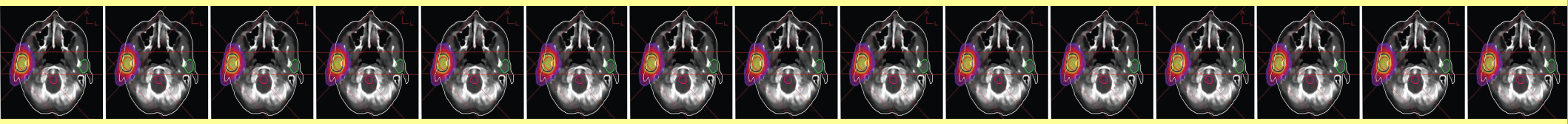
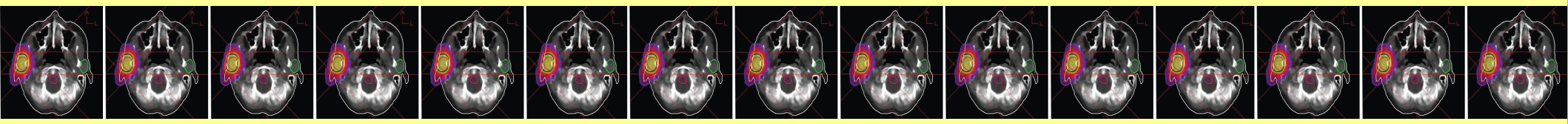


Conclusions

- Very promising results from CNAO test beam of the PET prototype
- Good agreement between simulated and acquired data
- Fast read-out electronics of the PET system allows the study of the prompt radiation

Within 2016 test on phantom at CNAO

INSIDE project: a tool for the quality assurance of hadrontherapy treatments.



Acknowledgments

The INSIDE collaboration:

Bari: F. Ciciriello, F. Corsi, F. Licciulli, C. Marzocca, G. Matarrese

INFN (Milano, LNS, LNF): G. Battistoni, M. Cecchetti, G.A.P. Cirrone, Pablo Cirrone, G. Cuttone, E. De Lucia, F. Romano, P. Sala

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Torino: P. Cerello, S. Coli, E. Fiorina, G. Giraudo, F. Pennazio, C. Peroni, A. Rivetti, R. Wheadon

Roma: E. De Lucia, R. Faccini, P.M. Frallicciardi, M. Marafini, C. Morone, V. Patera, L. Piersanti, A. Sarti, A. Sciubba, C. Voena

CNAO: M. Ciocca, M. Ferrarini, F. Gerardi, M. Pullia, A. Serra, M. Pelliccioni

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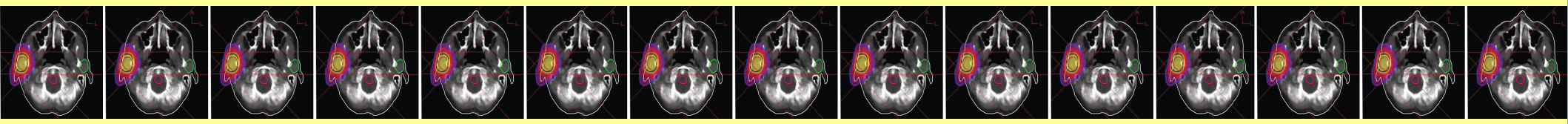

Grazie per l'attenzione!