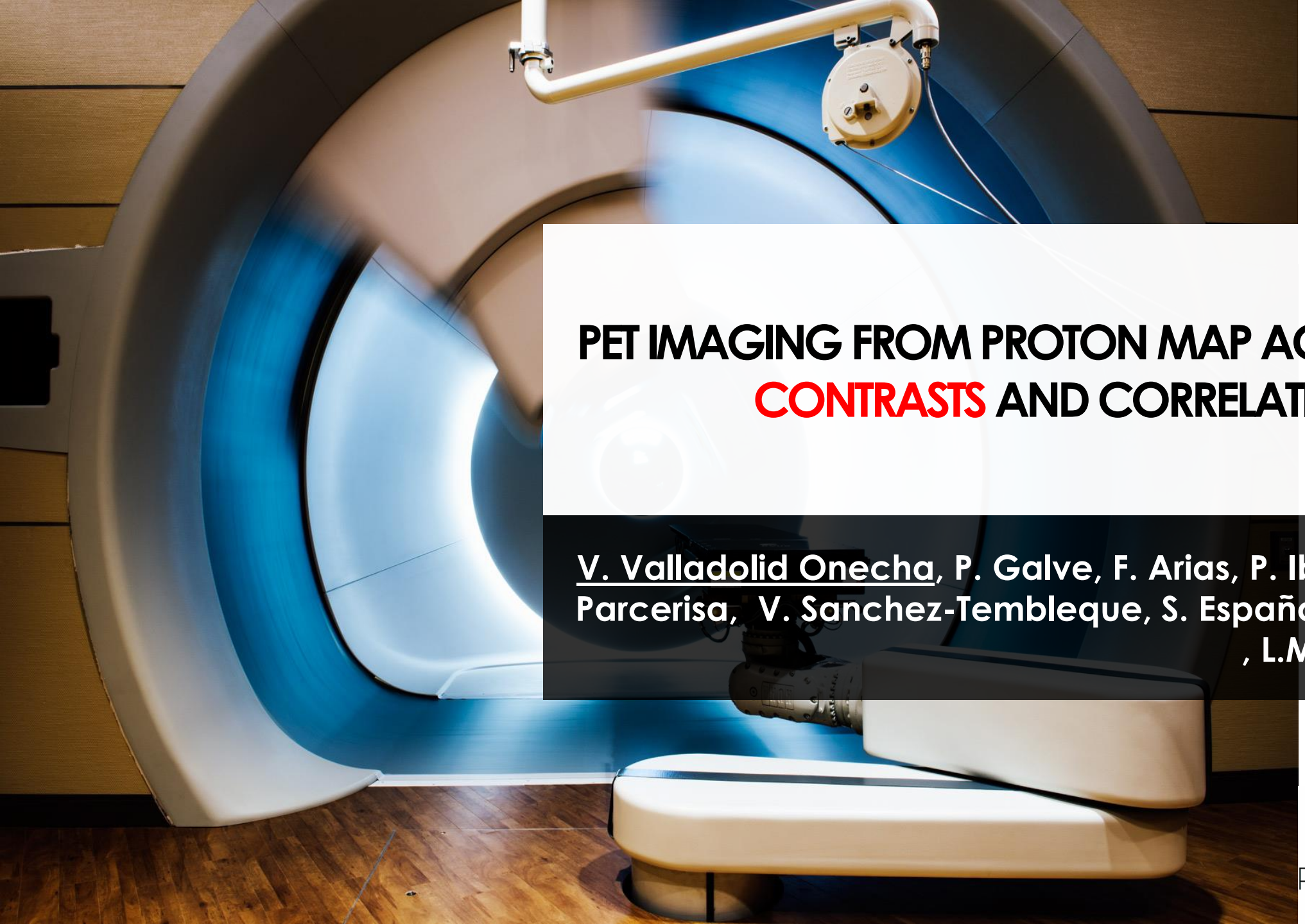
Grupo de Física Nuclear

PET IMAGING FROM PROTON MAP ACTIVATION AND CORRELATION WITH DOSE.

V. Valladolid Onecha, P. Galve, F. Arias, P. Ibañez, D. Sánchez-Parcerisa, V. Sanchez-Tembleque, S. España, A. Villa-Abaunza, L.M. Fraile, J.M.Udías.

Protontherapy and nuclear techniques for oncology



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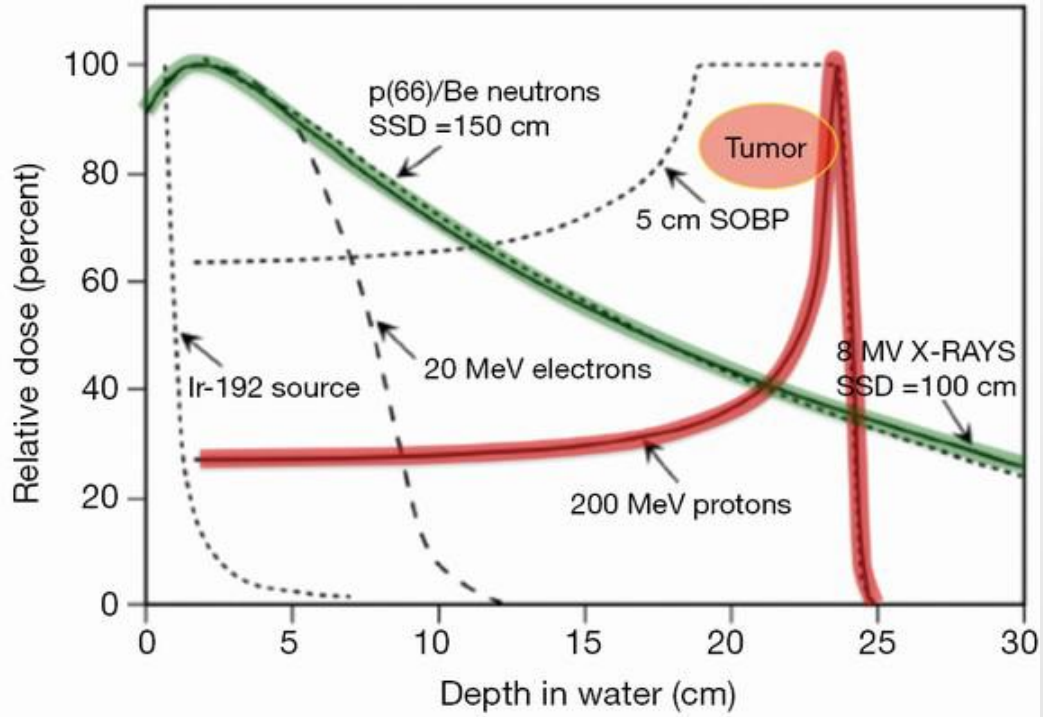
PET IMAGING FROM PROTON MAP ACTIVATION WITH CONTRASTS AND CORRELATION WITH DOSE.

V. Valladolid Onecha, P. Galve, F. Arias, P. Ibañez, D. Sánchez-Parcerisa, V. Sanchez-Tembleque, S. España, A. Villa-Abaunza, L.M. Fraile, J.M.Udías.

Protontherapy and nuclear techniques for oncology

Proton therapy

- Proton radiotherapy provides physical advantages which permit a more conformal dose distribution than photon / electron radiotherapy.
- These benefits come from the typical dose distribution of charge particles (red), which is characterized by the dose peak at the distal part of the range (Bragg Peak).

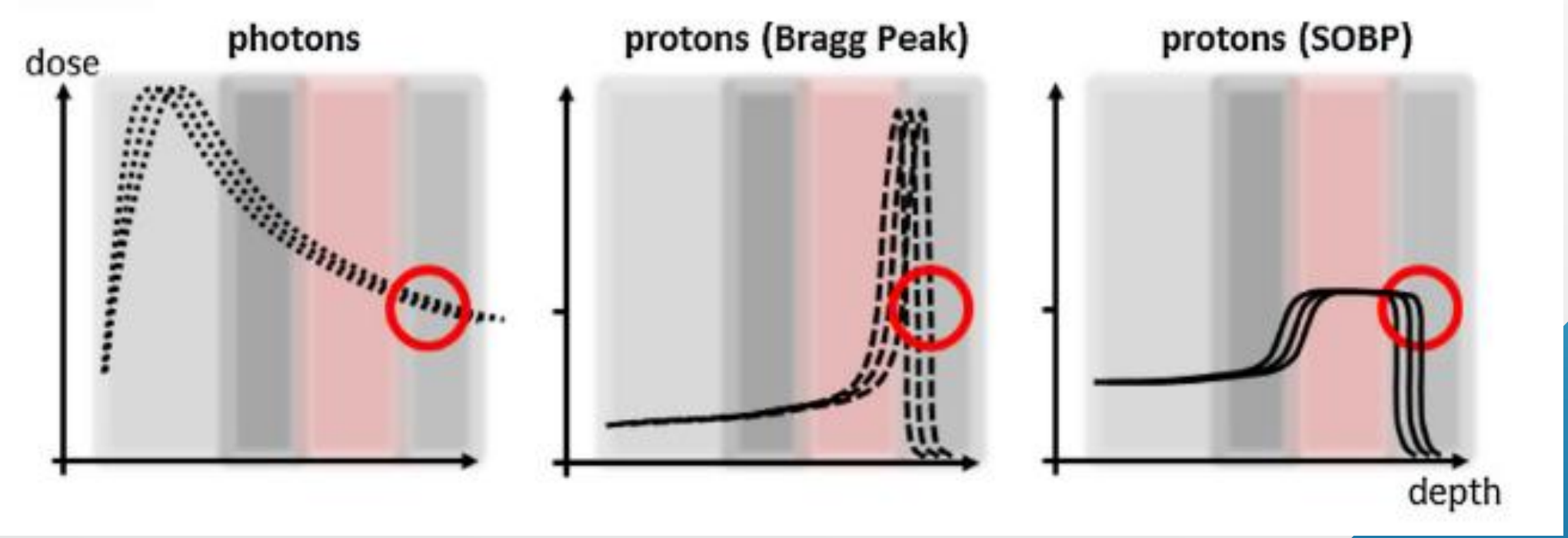


H.Diap et Al, Can proton beam therapy be clinically relevant for the management of lung cancer?,doi: 10.3978/j.issn.2218-676X.2015.08.15

1. Dose concentrated at the tumor.
2. No dose beyond the distal edge.
3. Lower dose in healthy tissues.

Proton Range Problem

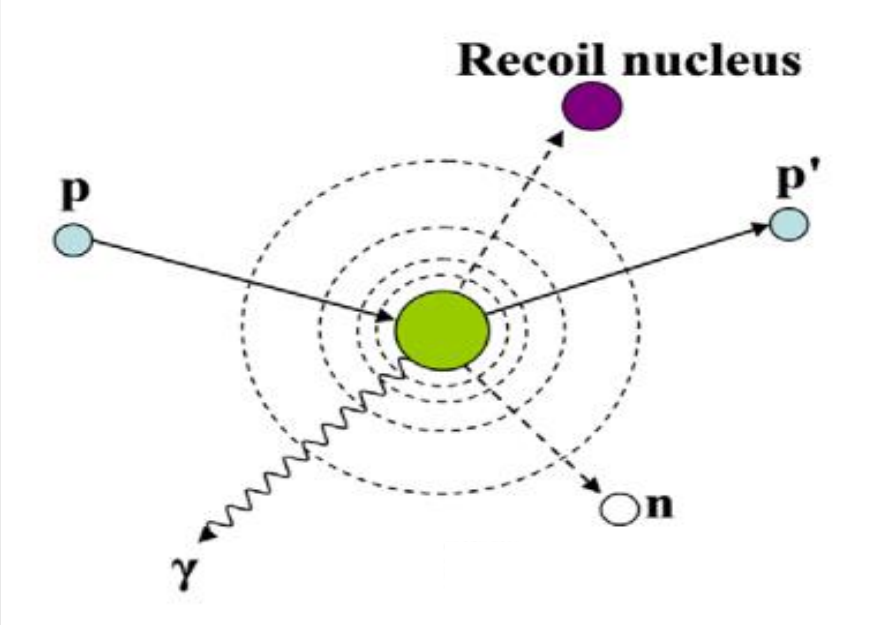
- Uncertainties in proton therapy are more problematic than in conventional radiotherapy because of the Bragg peak.
- The proton range is one of the most problematic issues in proton therapy.
- Current uncertainties ~3 % of range, limiting dose conformity in tumor.



Knopf Antje Christin, Lomax Antony. In vivo proton range verification: A review Physics in Medicine and Biology. 2013. 58, 15. 131–160.

Range Verification

- There are several techniques whose objective is to reduce the uncertainties of the proton range calculation in the clinical planning.
- Some of them focus in the calculation of the dose distribution from the secondary radiation emitted after protons interact with target.
- There are three types of interaction between protons and matter:
  1. Elastic Colisions
  2. Multiple Coulomb Scattering
  3. Nuclear Reactions

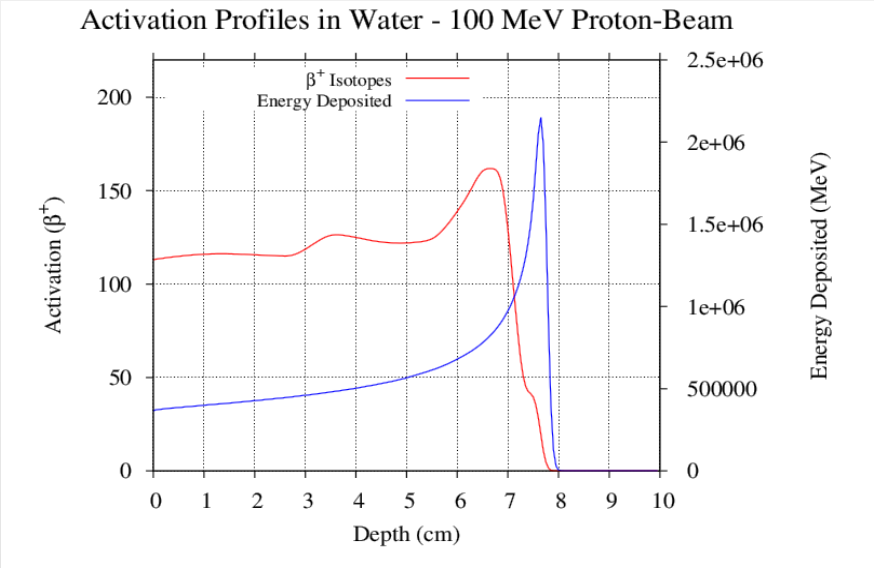


Wayne D Newhauser and Rui Zhang 2015 *Phys. Med. Biol.* **60** R155

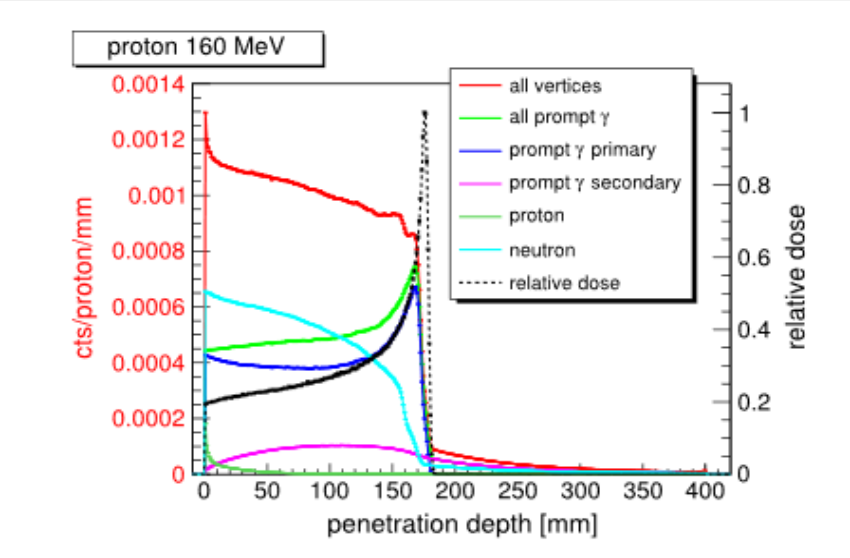
Range Verification

- Positron Emission Tomography (PET) for 2D and 3D imaging (in-vivo or offline).
  - β^+ isotopes are produced in nuclear reactions A(p,X)B.
  - PET scans measure the activity and produce the activation image distribution.
  - Dose distribution is obtained from measured activity distribution.

- Prompt-Gamma (PG) in-vivo.
  - Nuclear reactions produce PG (time emission ns-ps).
  - The intensity of this PG is higher under the BP.



PET

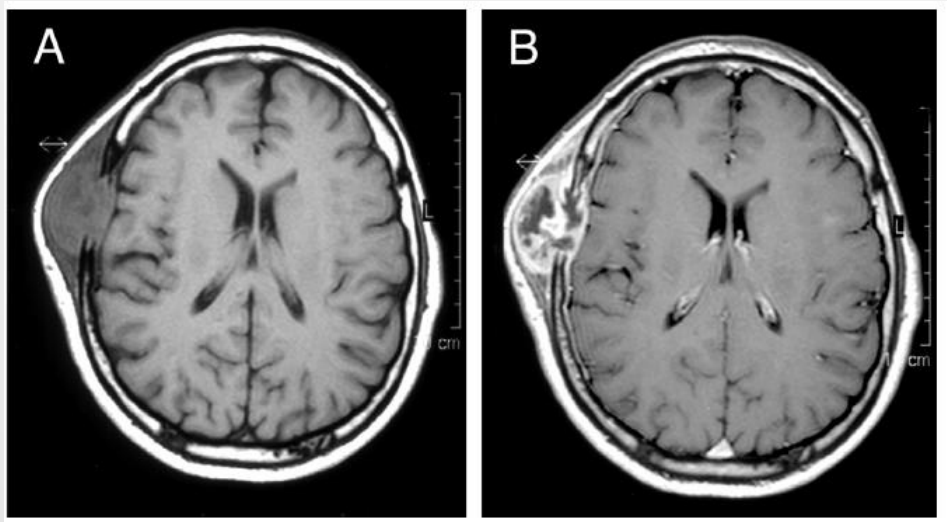


PG

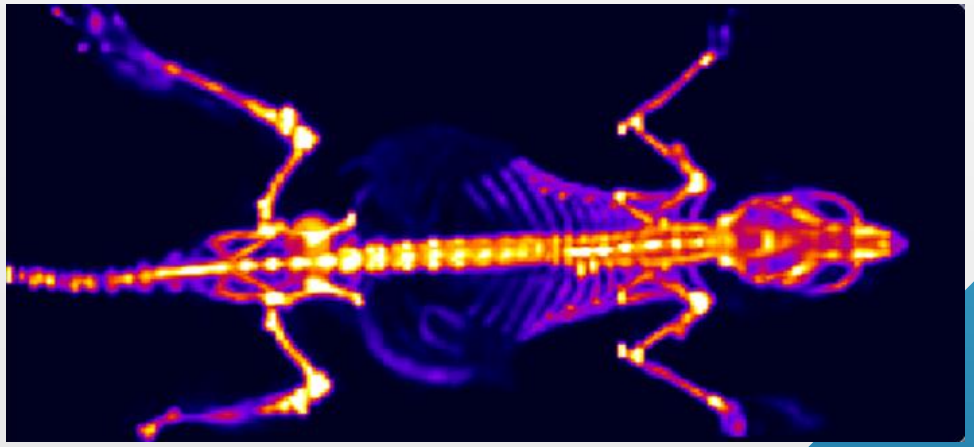
Contrasts in Medicine

- A contrast is an element which is introduced in the human body to get a better quality in a medical image.

- Its use is very common in different techniques, such as ^{127}I in CT, Gd in Magnetic Resonance and ^{18}F in PET.

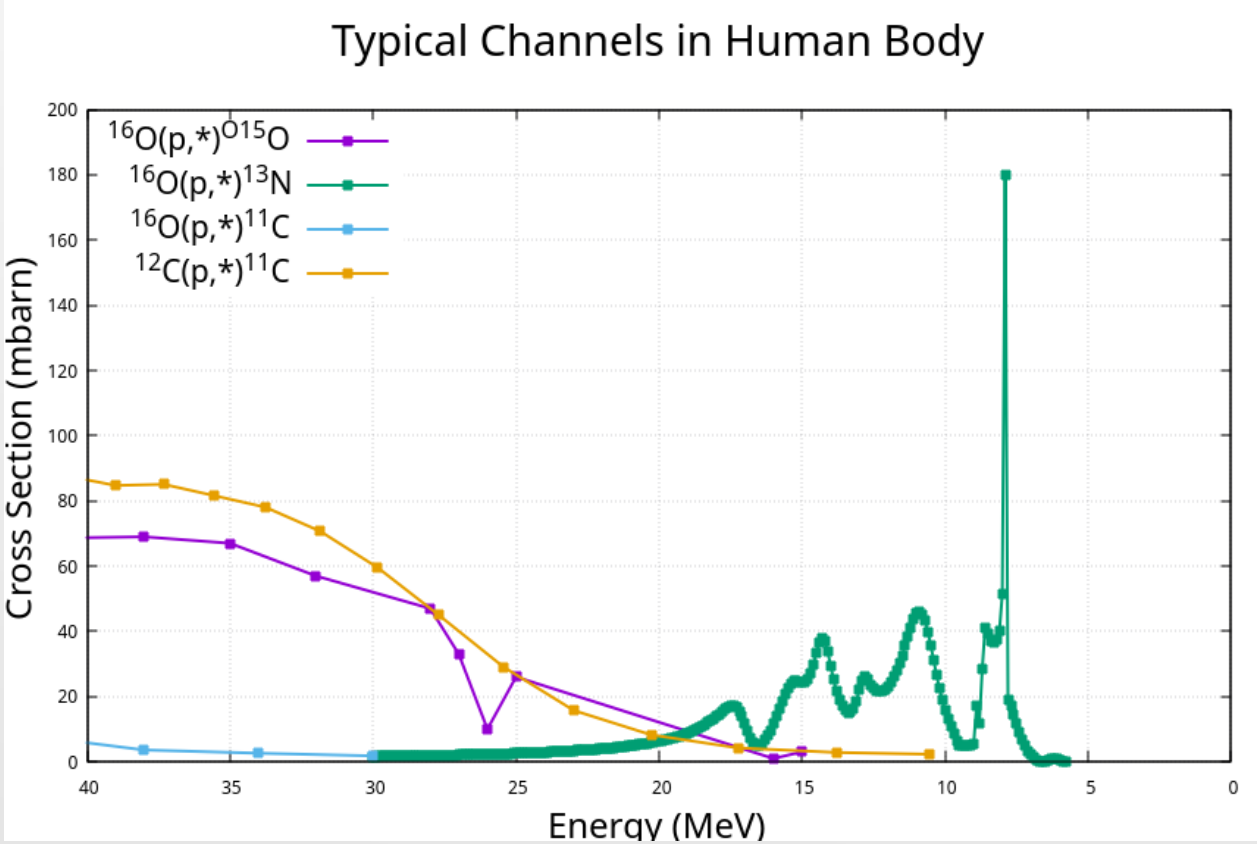


El Saghir, Nagi & I Elhajj, Ihab & Geara, Fady & Hourani, Mukbil. (2005). Trauma-associated growth of suspected micrometastasis. BMC cancer. 5. 94. 10.1186/1471-2407-5-94.



Contrast in Proton therapy

The principal function of a contrast is to improve the quality of a medical image.
→ In PT, that means a stronger signal near the BP.



Contrast in Proton therapy

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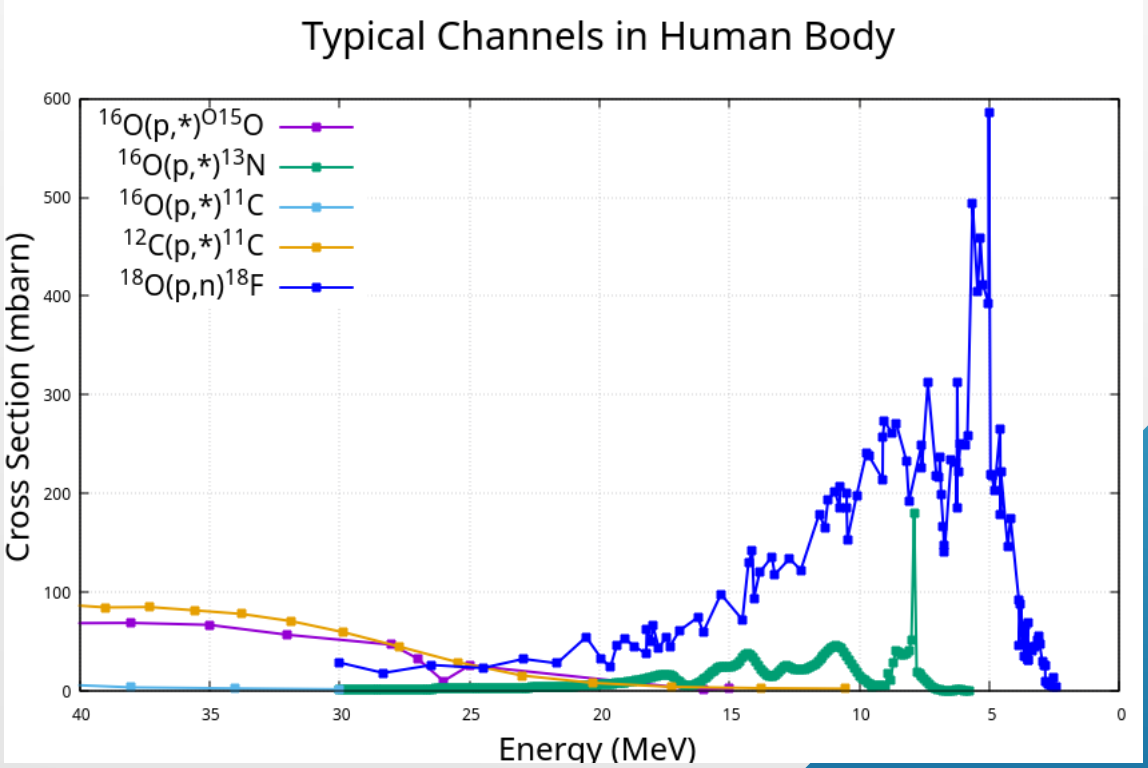
Because of that we are looking for contrasts produced in a reaction (p,X) which satisfied this conditions:

1) Energy Threshold of the reaction must be low.

2) Cross Section must have a peak at low energies.

3) Half-life of the produced isotope must be short.



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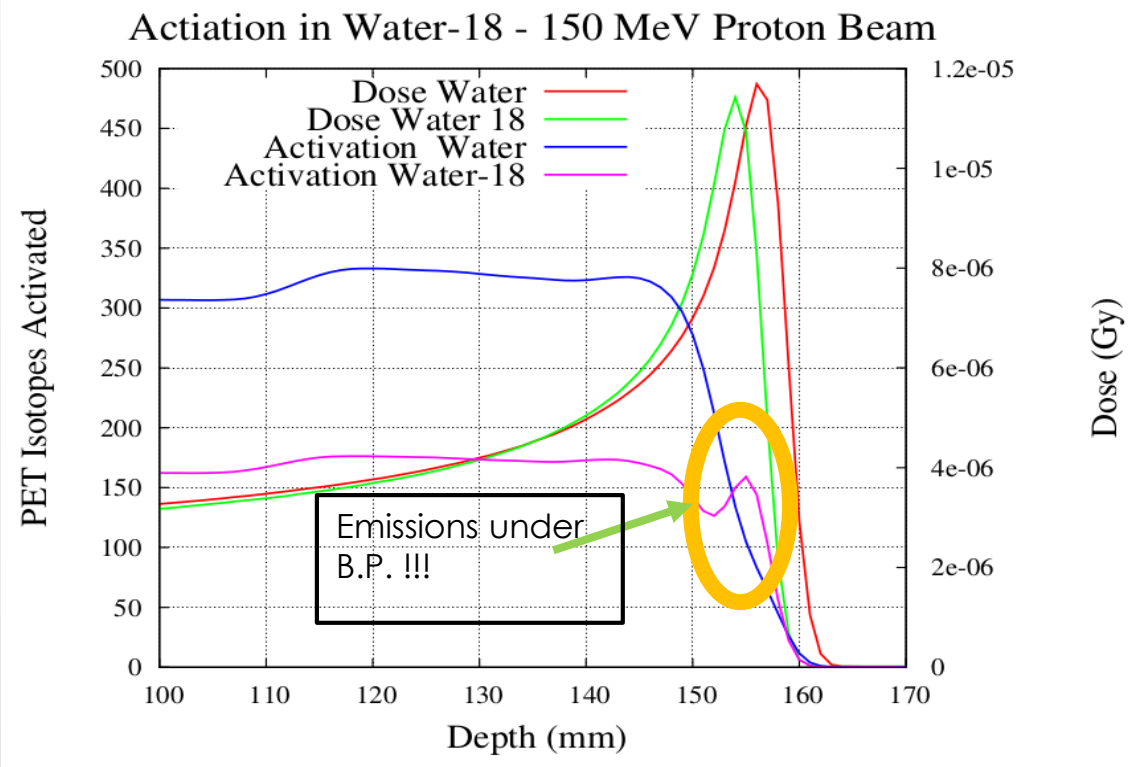
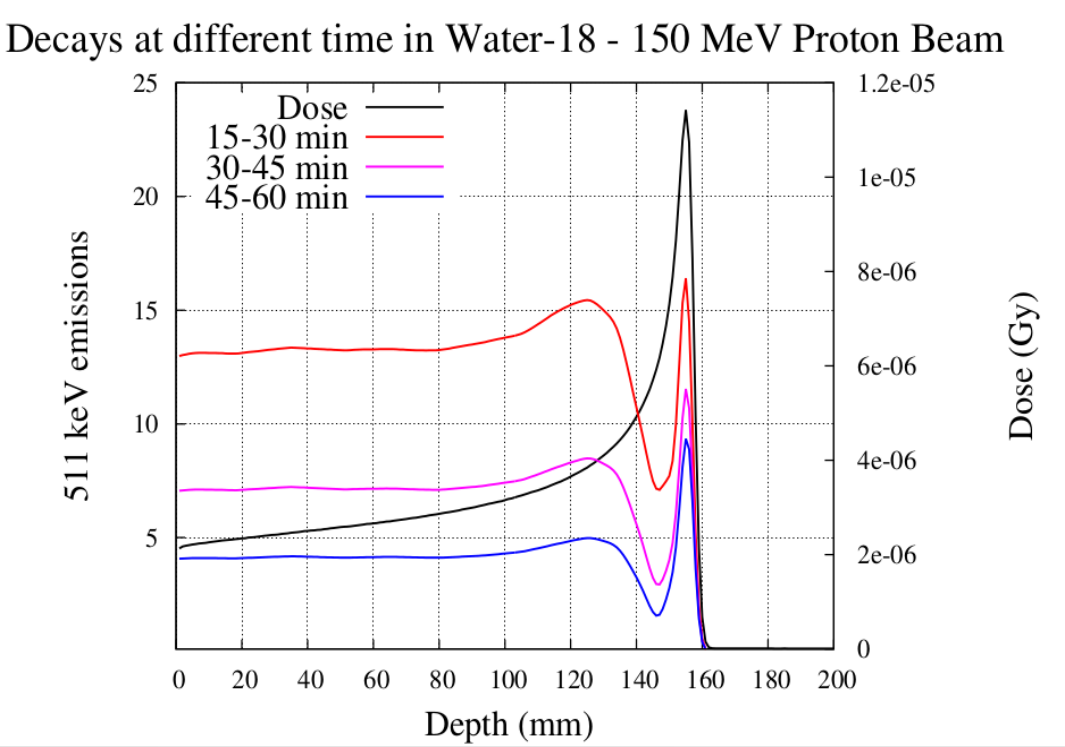


Water-18

- ^{18}F is a β^+ isotope with 109.77 min of half-life which is generated in $^{18}O(p,n)$ reaction. Water-18 is a mix of normal water and water with ^{18}O, in this simulation the amount of each one is 50%.
- In normal water the β^+ isotopes produced are ^{15}O (122 s), ^{11}C (20min) and ^{13}N (12 min).



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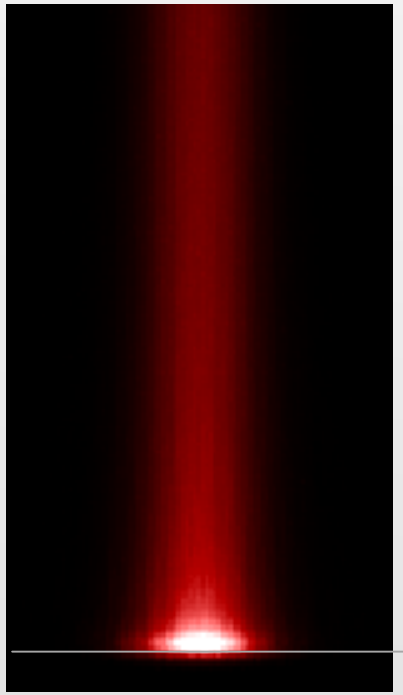
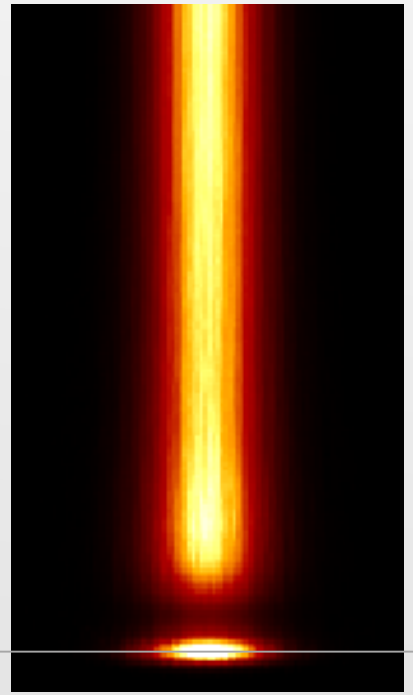
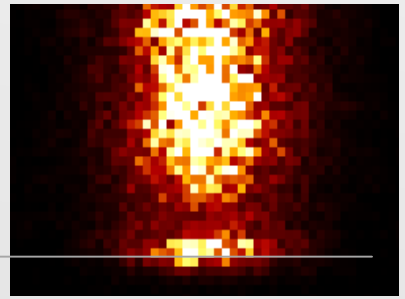
DOSE DISTRIBUTION



β^+ EMISSION DISTRIBUTION

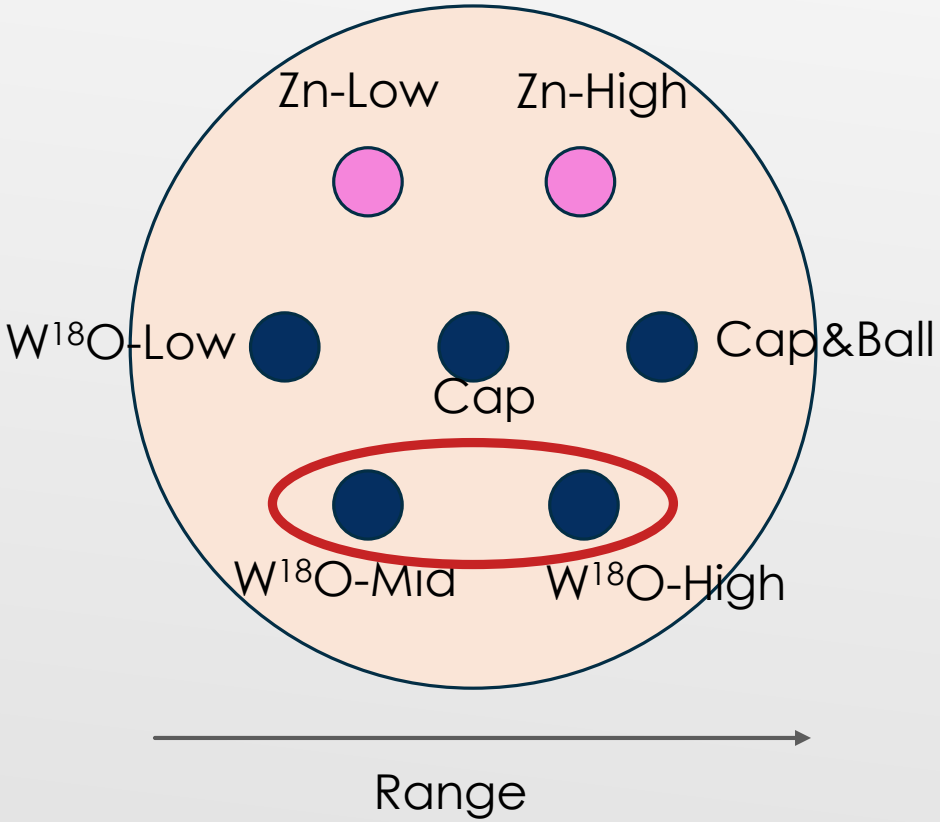


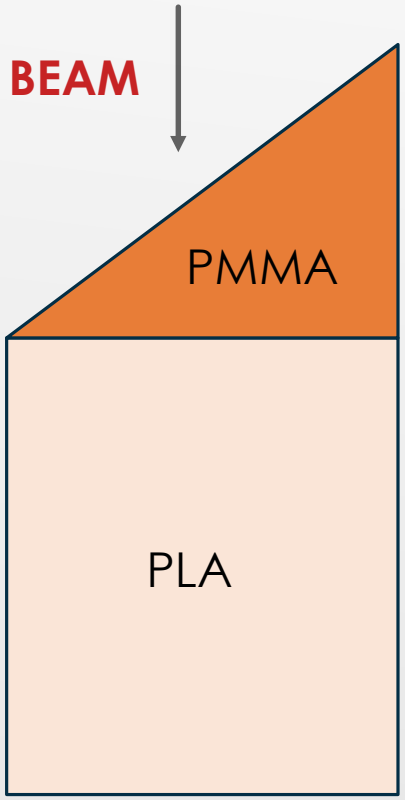
ACTIVATION PET IMAGE



Experimental Phantom

- In this experiment **Water-18 has a 9% of $H_2{}^{18}O$.**
- Each cylinder was irradiated with $1.675 \cdot 10^7$ protons.



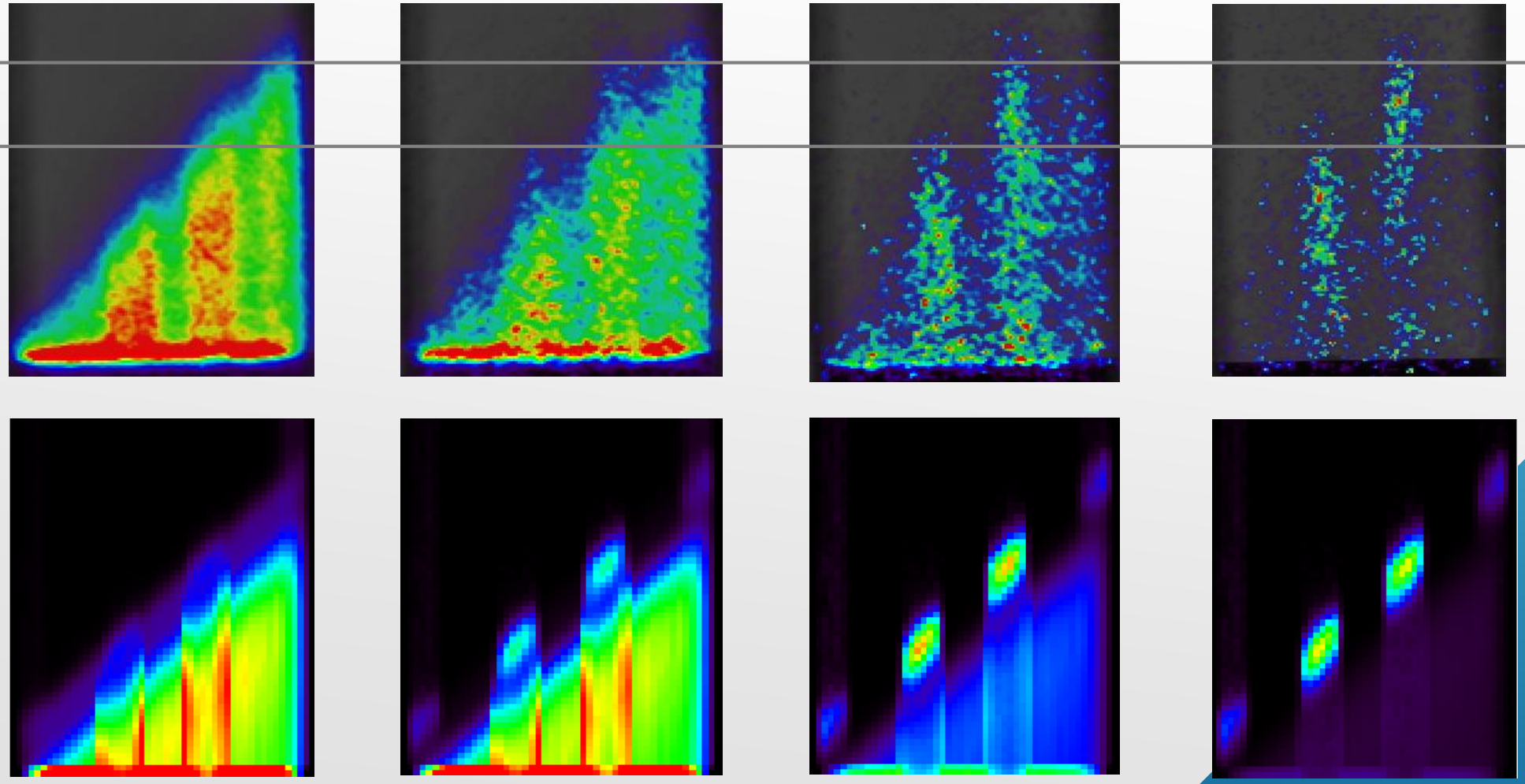


Experimental Phantom

1 hour after irradiation | 2 hour after irradiation | 3 hour after irradiation | 4 hour after irradiation

Real Pet Image

Simulation Activation Image



Experimental Phantom

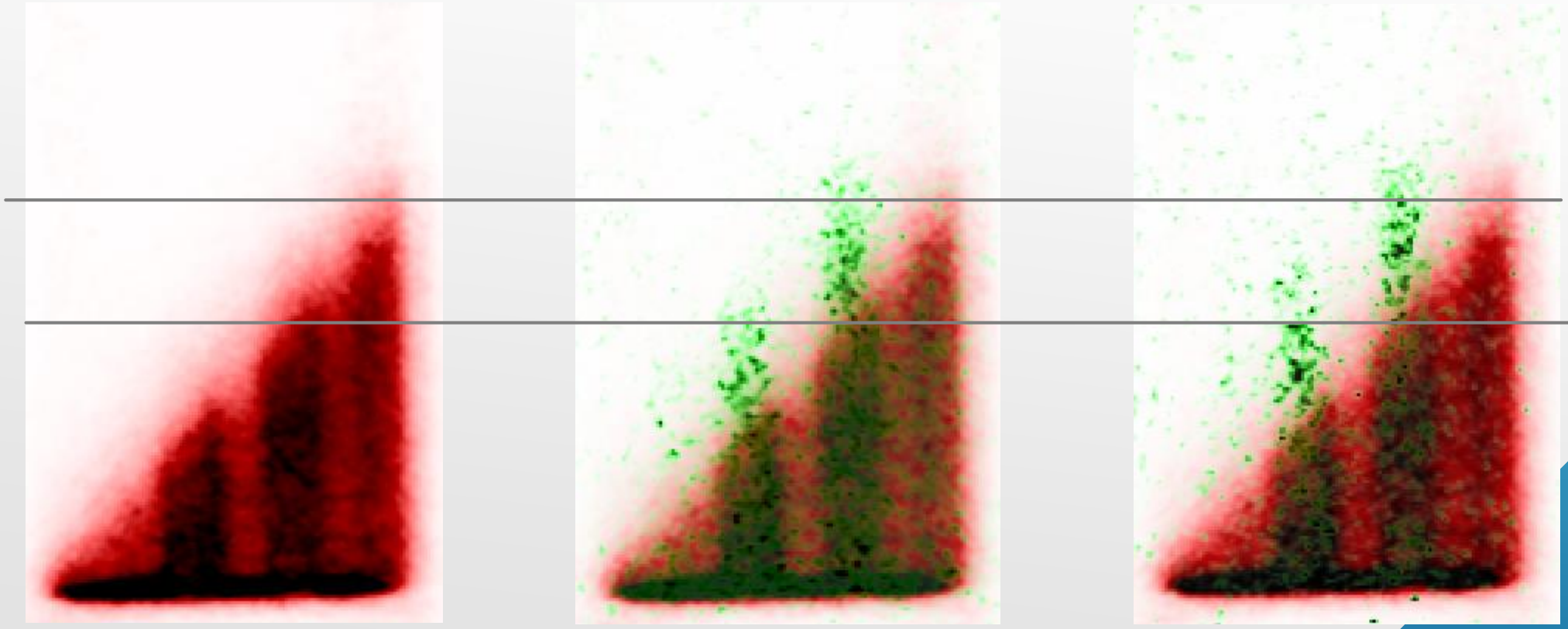
1 hour after irradiation

1 & 3 hour after irradiation

1 & 4 hour after irradiation

Range 80MeV

Range 40MeV



Conclusions

- Contrasts improve activation distributions and they can be used to calculate the proton range with better accuracy , and therefore the dose deposition.
- Contrasts with a short half-life may be used to make in-vivo image. Contrast with long half life (such as ^{18}F) could be used to verify Monte Carlo simulations or even for proton beam and beam transport quality assurance.
- We have obtained experimental results which prove the viability of the use of ^{18}O as a contrast agent in proton therapy.
- We have performed some experiments whose goal is to calculate the Cross Sections of other promising contrasts at CMAM and Essen. And in the future we will try to obtain more PET results but using different contrast agents with shorter lives.

Acknowledgements

Grupo de Física Nuclear and IPARCOS,
Facultad de Ciencias Físicas,
Universidad Complutense de Madrid, CEI Moncloa; Instituto de Investigación Sanitaria del Hospital Clínico San Carlos (IdISSC), Madrid, España.

Spanish Government (FPA2015-65035-P, RTC-2015-3772-1)

Comunidad de Madrid (S2013/MIT-3024 TOPUS-CM, B2017/BMD-3888 PRONTO-CM). European Regional Funds.

“This is a contribution for the Moncloa Campus of International Excellence. ”
“Grupo de Física Nuclear-UCM”,Ref.: 910059.

Pet Reconstruction Details

NUMBER OF DECAY PROCESS 7256887

-> **SINGLES:** 5131758

SINGLES RATE: 5701.95 SINGLES/SEC

EFFICIENCY: 35.36 %

TRIGGERS SING/TRIG: 5350224 0.96

COINCIDENCE SINGLES: 484579

ENERGY LOST: 460018 -- 94.93 %

PILE-UP: 14 -- 0.00 %

GAMMAS: 0 -- 0.00 %

-> **COINCIDENCES:** 140360

COINCIDENCIE RATE: 155.96 COINC/SEC

EFFICIENCY: 1.93 %

TRUES: 100396 -- 71.53 %

RANDOMS: 0 -- 0.00 %

SCATTER: 39960 -- 28.47 %

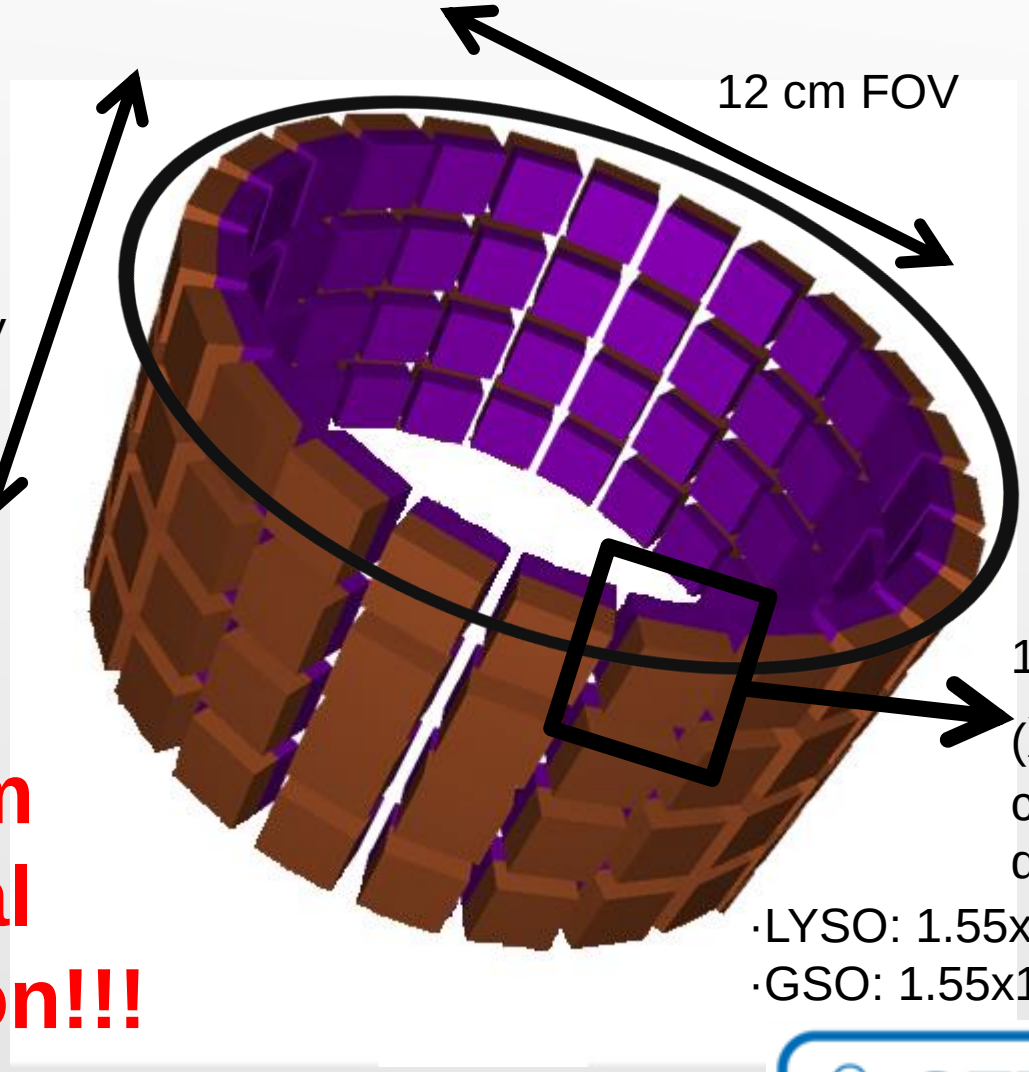
PILE-UP: 4 -- 0.00 %

SELF-COINC: 0 -- 0.00 %

NEC: 79.79

The SuperArgus PET/CT

Super Argus



12 cm FOV

10 cm FOV
axial
4 rings

96 LYSO-GSO detector blocks (24x4)

13x13
(x2 layers)
crystals per detector block

·LYSO: 1.55x1.55x0.7 mm^3
·GSO: 1.55x1.55x0.8 mm^3

<1 mm spatial resolution!!!