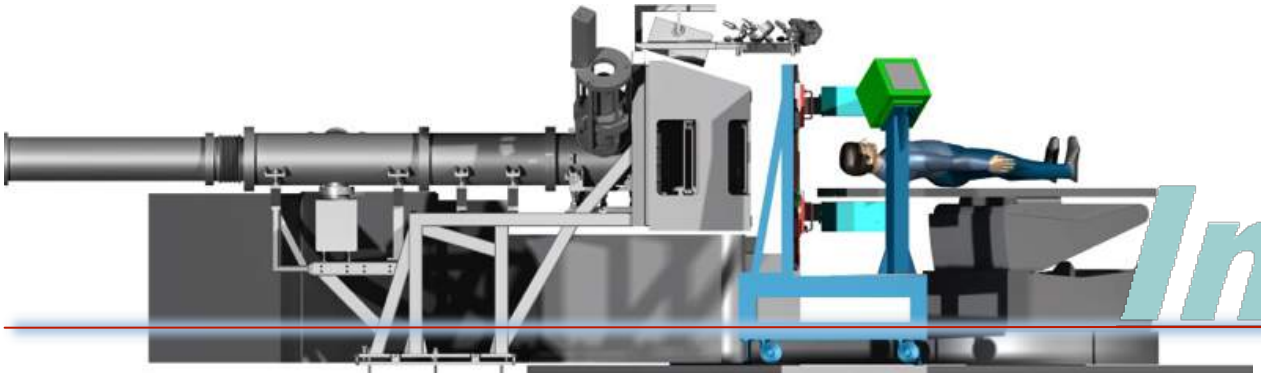
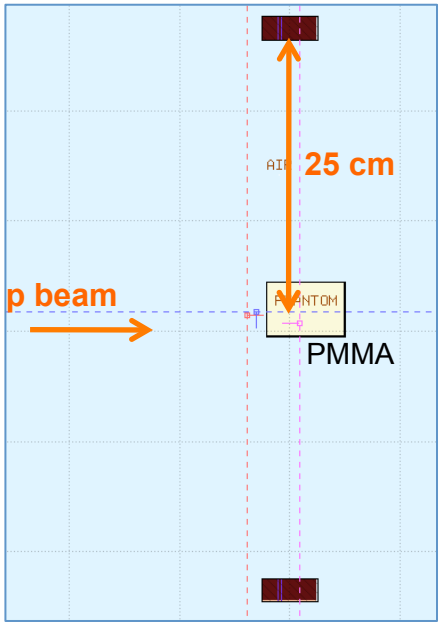


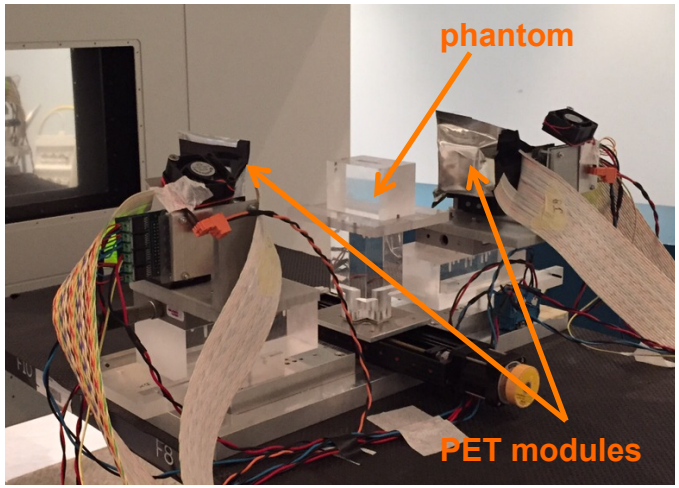
Validation of the MC In-beam PET simulation

Elisa Fiorina and Francesco Pennazio

INSIDE meeting, Pisa, June 9th 2015

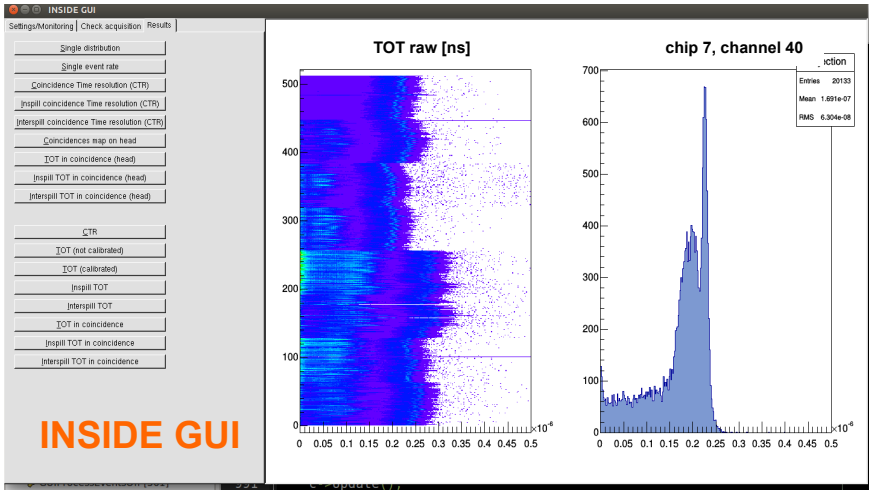
PET beam test May 2015 @ CNAO





Monoenergetic 1D proton treatments
Single spot, 2E+11 protons

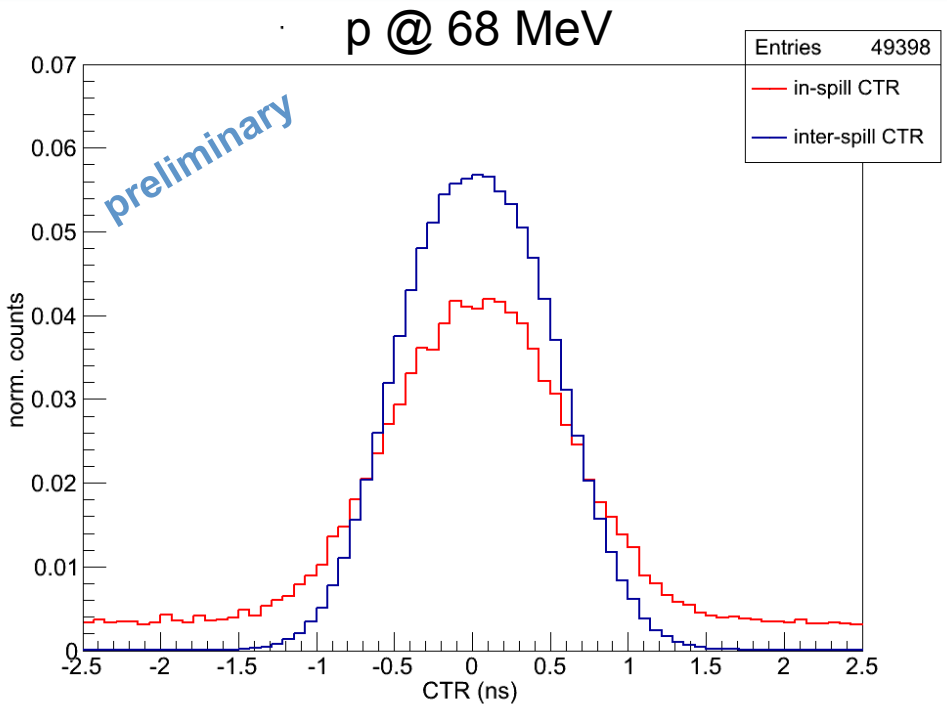
Energy [MeV]	68.3	72.03	84.3
spill	102	98	183
average protons/spill	1.96E+9	2.04E+9	1.09E+9



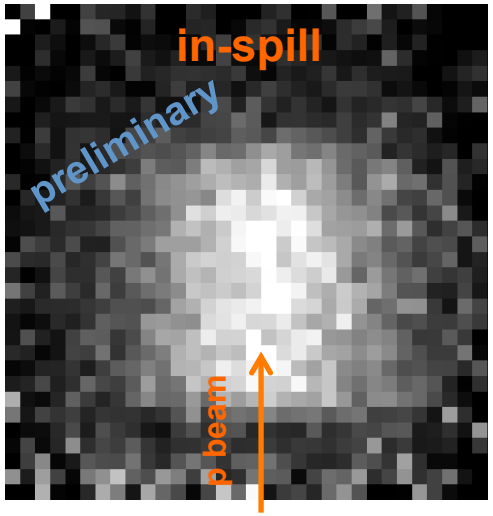
DATA ANALYSIS:

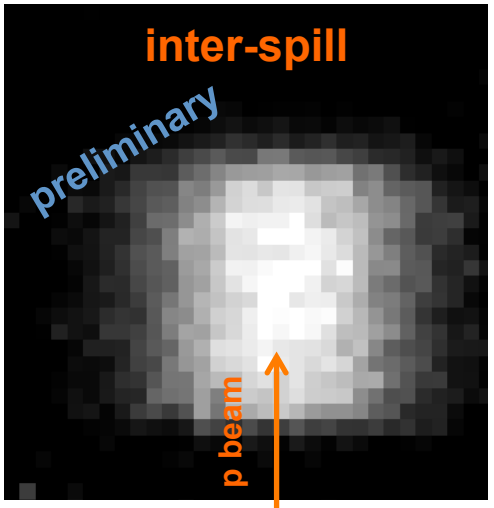
- Online/offline analysis
- For each channel, automated:
  - energy window selection
  - time delay calibration
- 3D PET image reconstruction
- Profile analysis

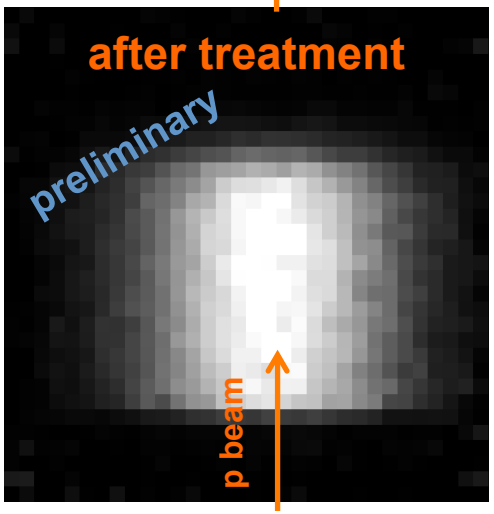
Data results



Coincidence Time Resolution (CTR)*
Interspill = 699 ps σ (blue)
Inspill = 851 ps σ (red)
***detector calibration to be optimised**



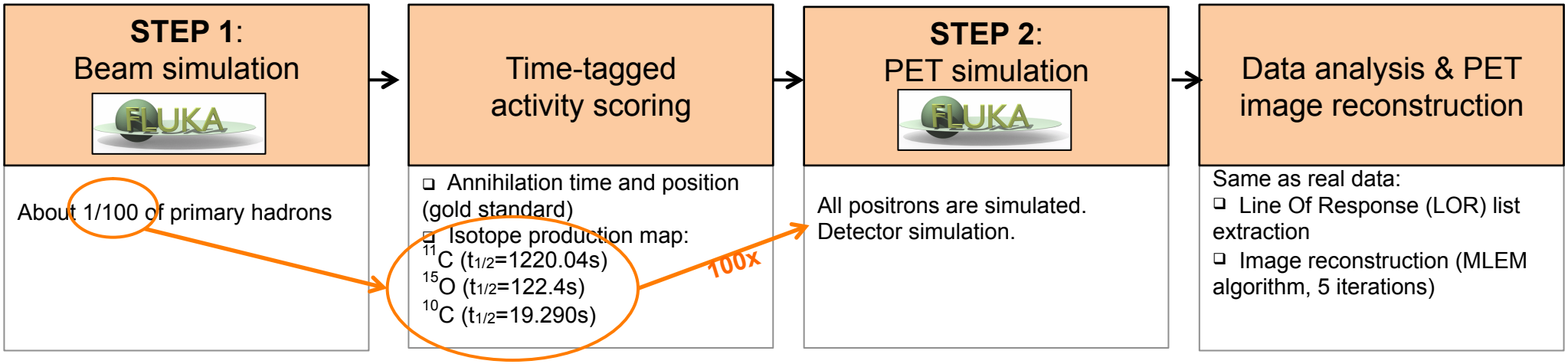




PET reconstructed images

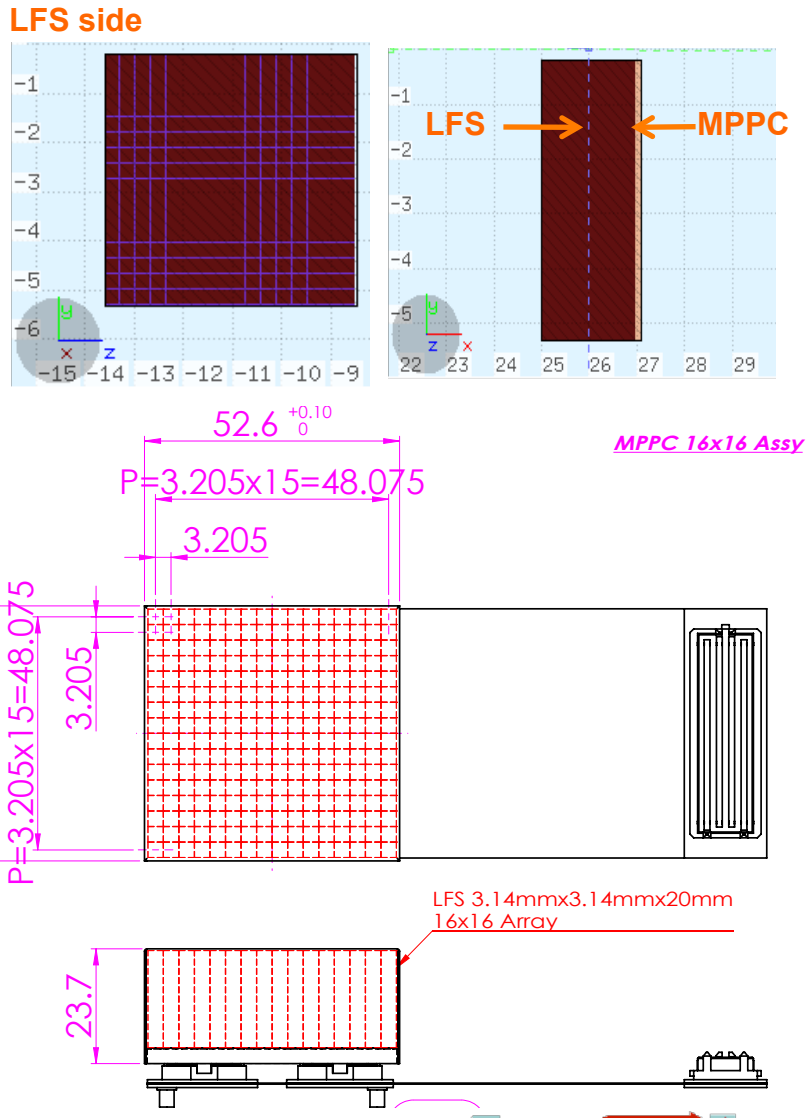
Let's validate simulation!

INSIDE PET simulation

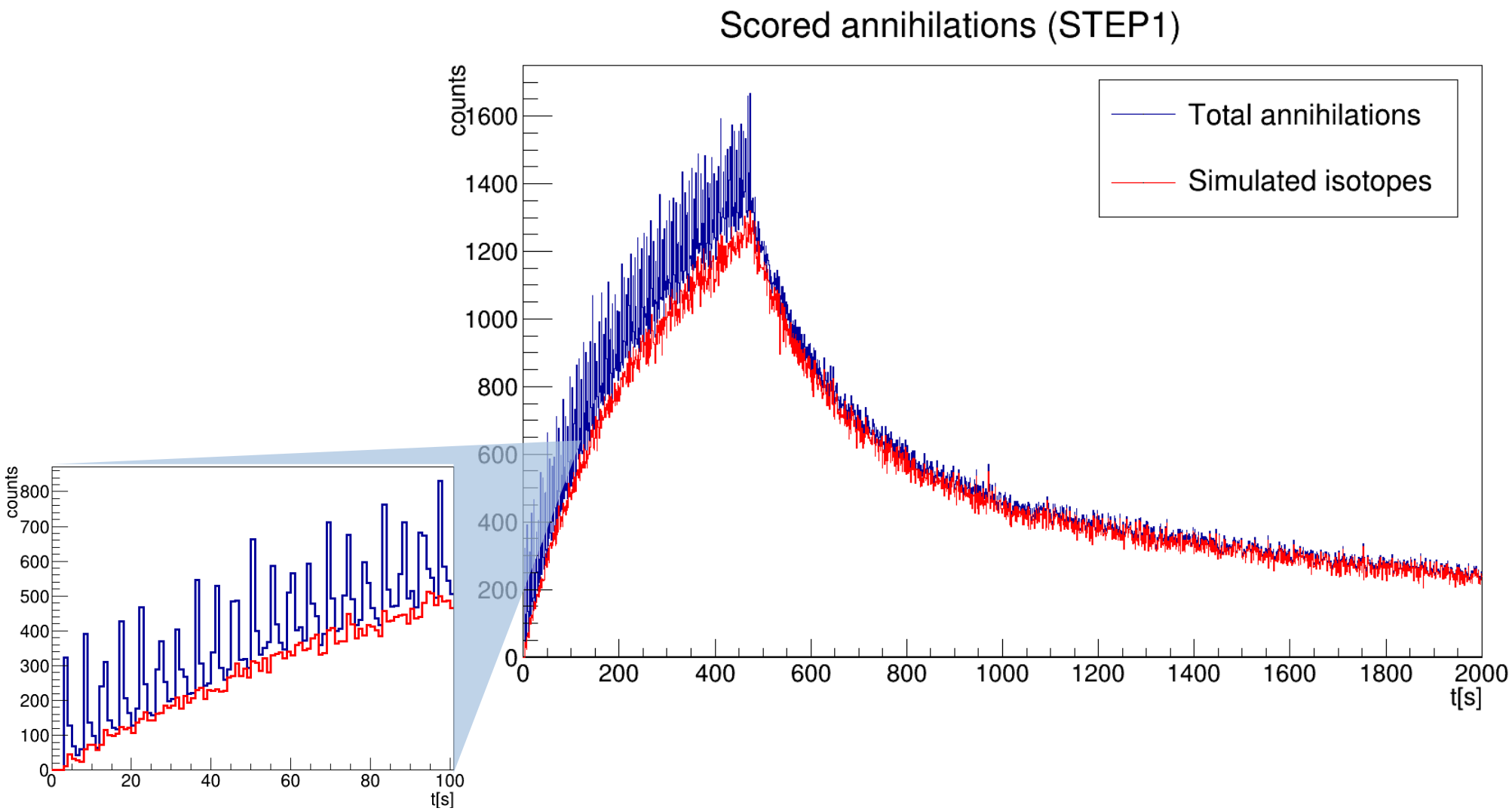


Detector simulation

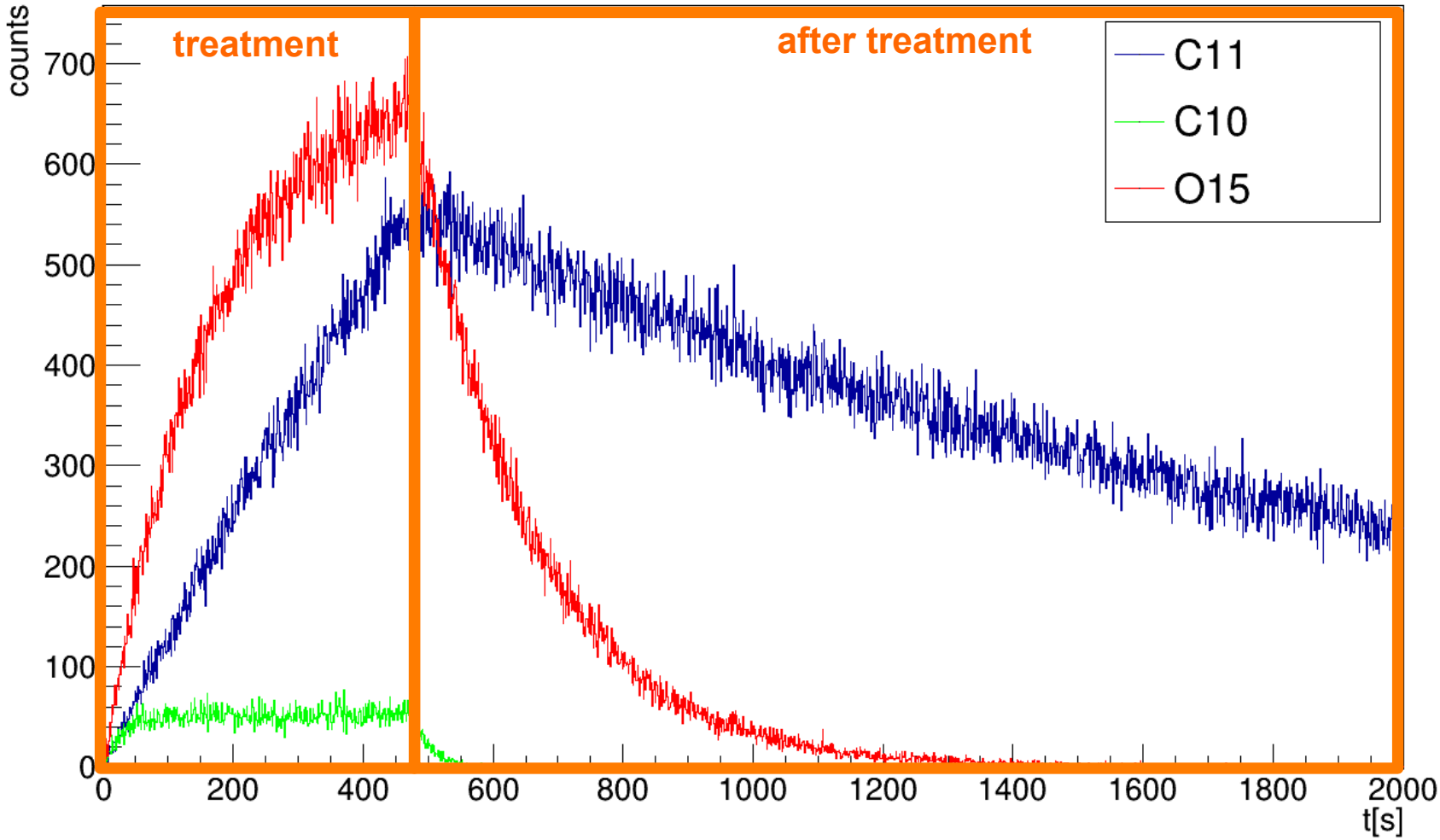
- LFS: no available chemical formula. Simulated from LSO with correct density
- Geometry from Hamamatsu data sheet
- Simulated detector response:
  - 10% σ ΔE/E
  - 460 ps σ time resolution
- 2.5 ns coincidence time window



[STEP1] Annihilation distribution (I)



[STEP1] Annihilation distribution (II)

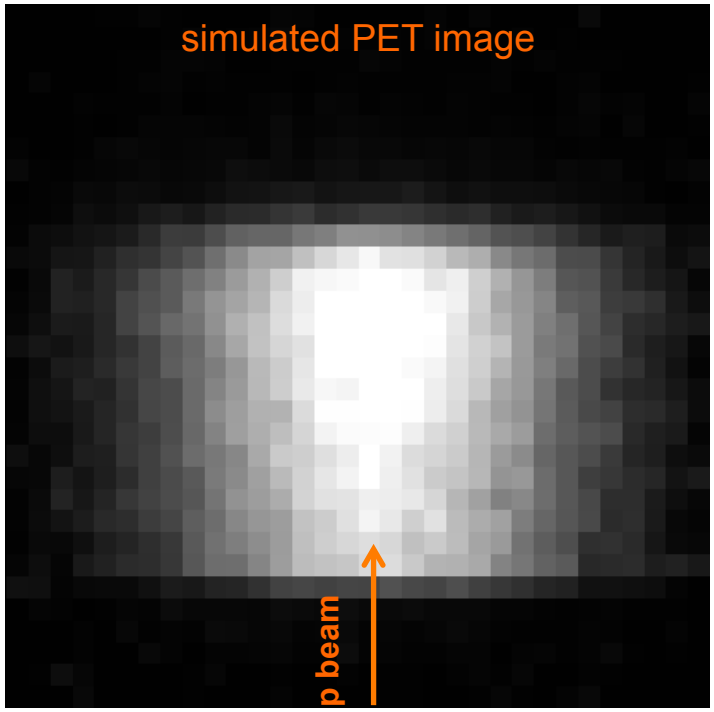


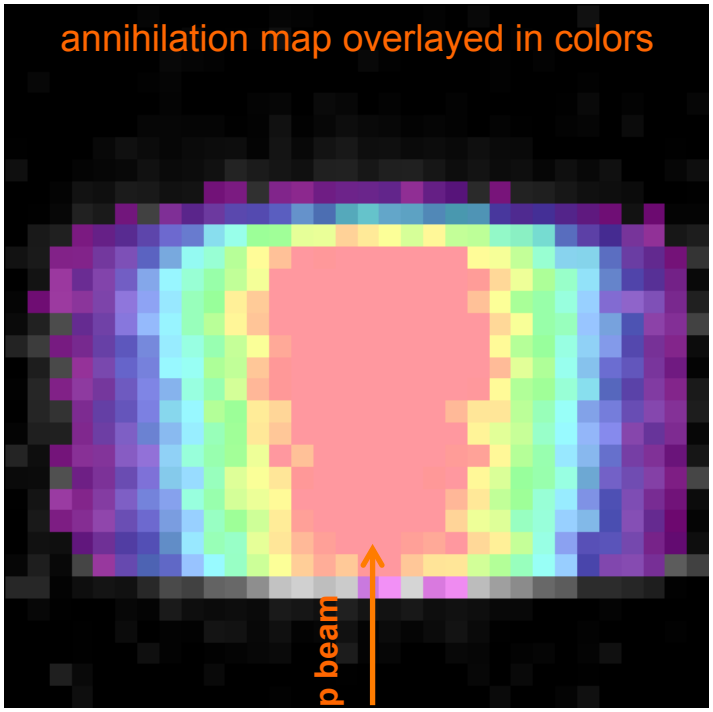
Simulated isotopes: about 86% during treatment, about 95% after treatment

[STEP2] Activity profile check (I)

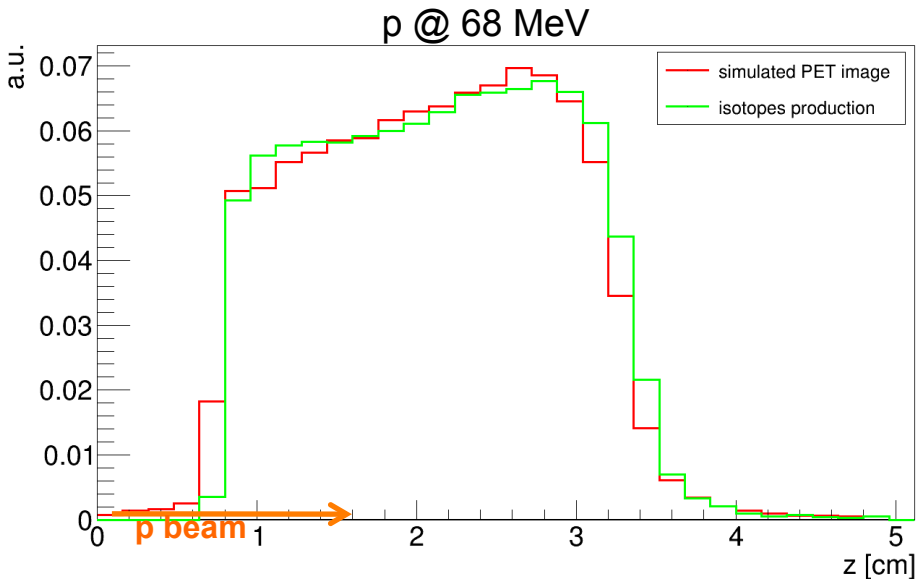
Comparison between simulated image and annihilation map scored in STEP1

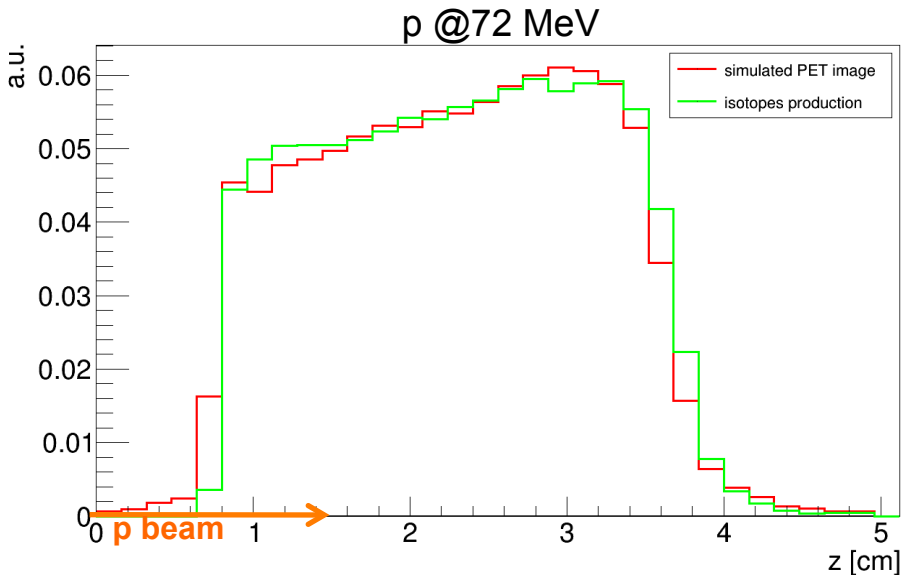
To check the reliability of the two step simulation technique, no artifacts

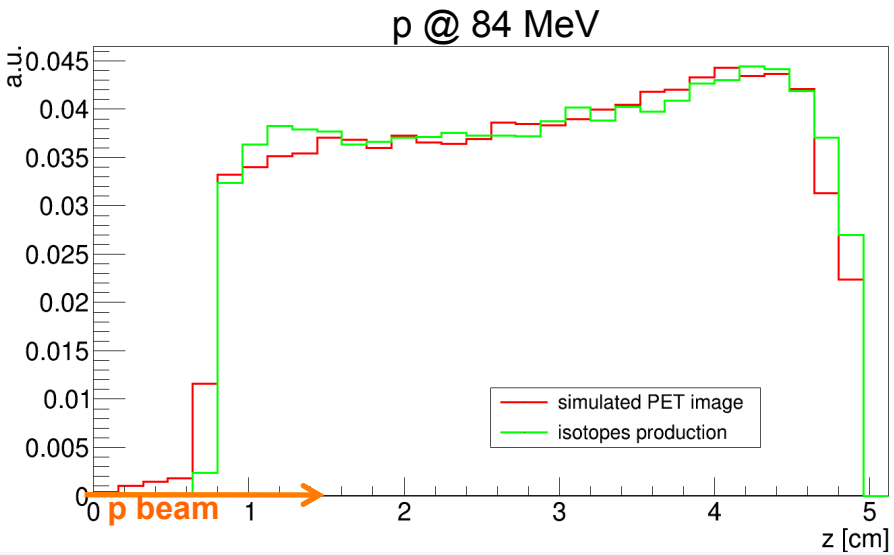




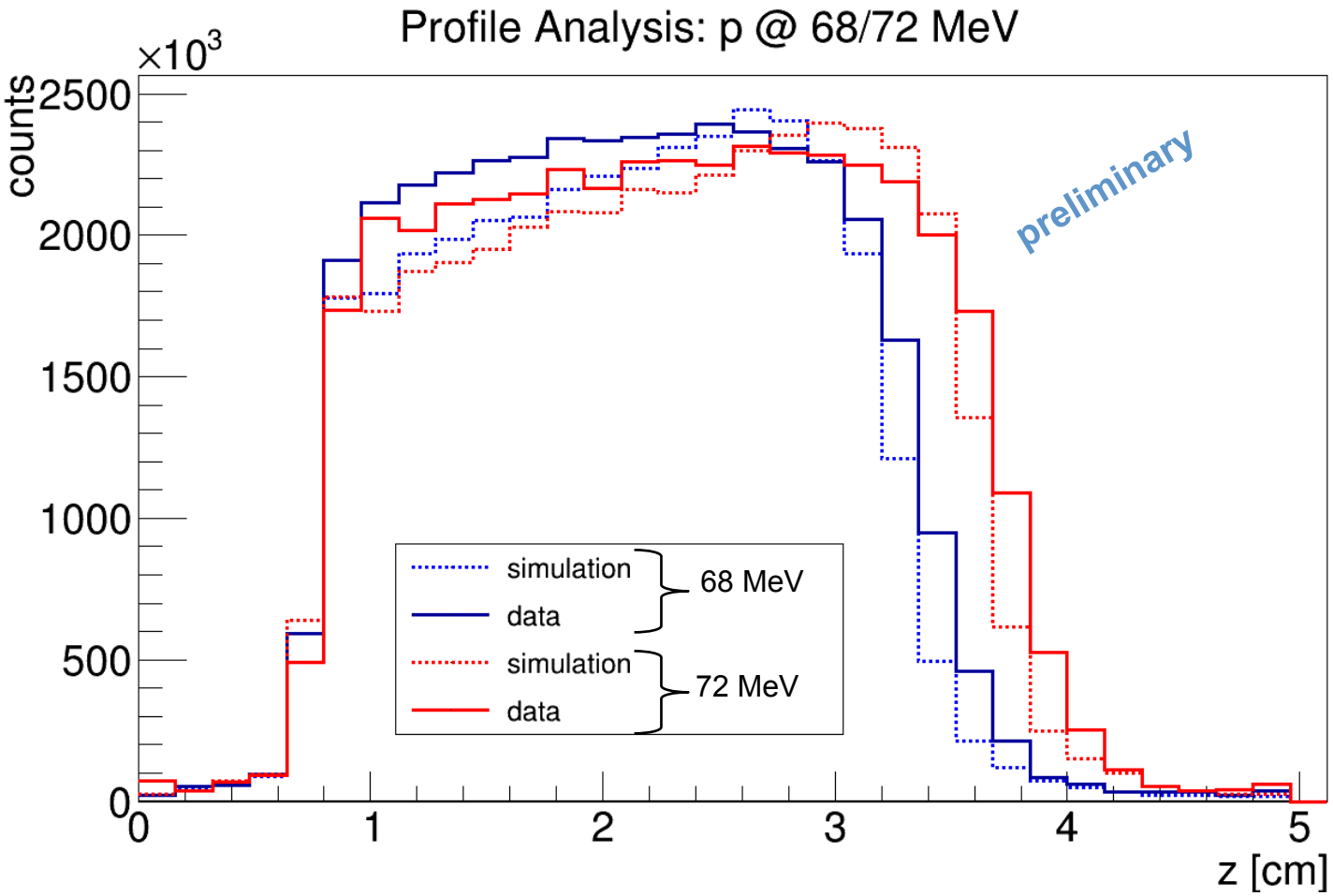
[STEP2] Activity profile check (II)







[STEP2] Profile Analysis (II)



Correction for isotopes not simulated
(14% during, 5% after treatment)

↓

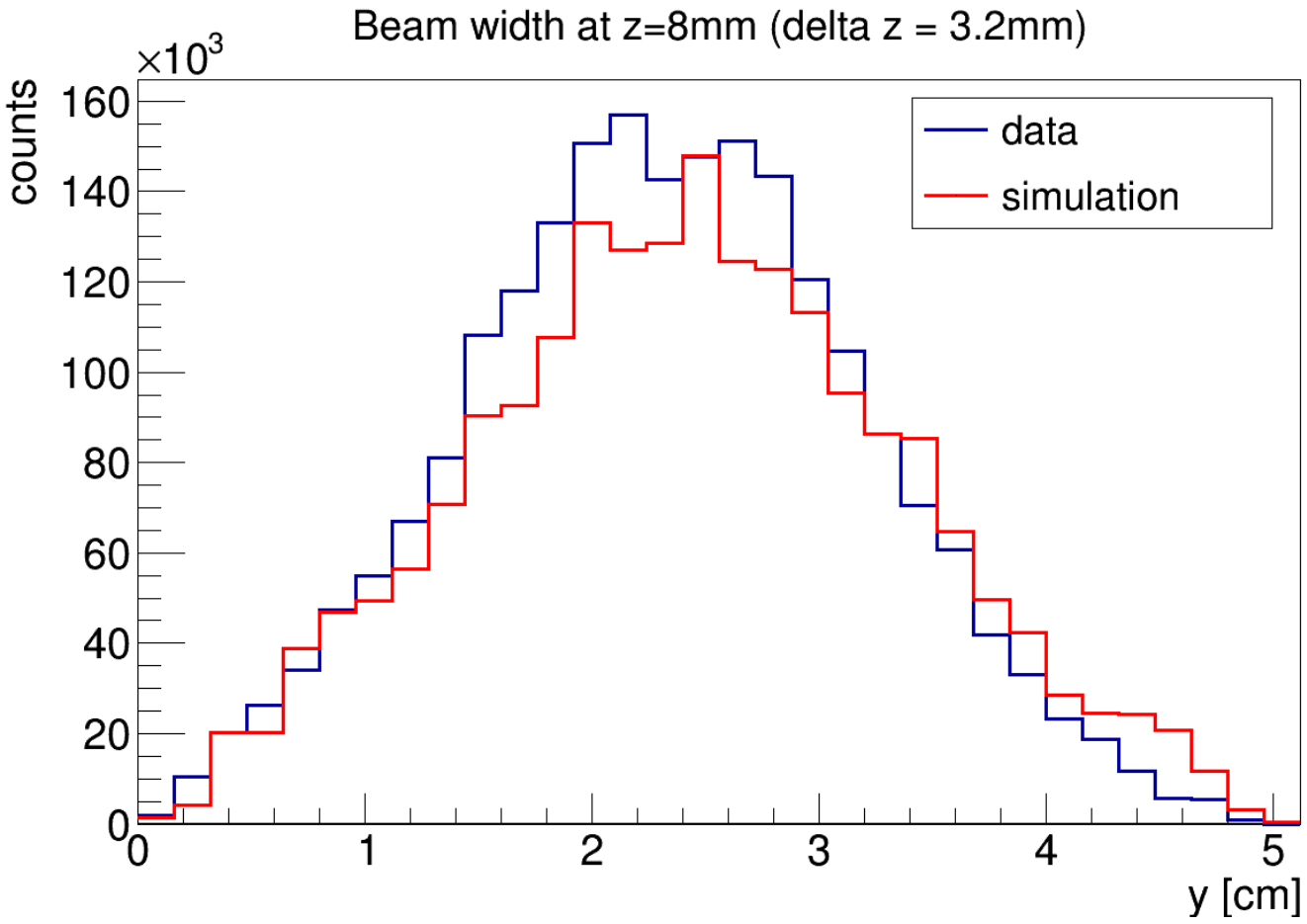
Quantitative compatible simulation and real data profiles.
Distal fall off evaluation: simulation and real data difference < 1 mm

↓

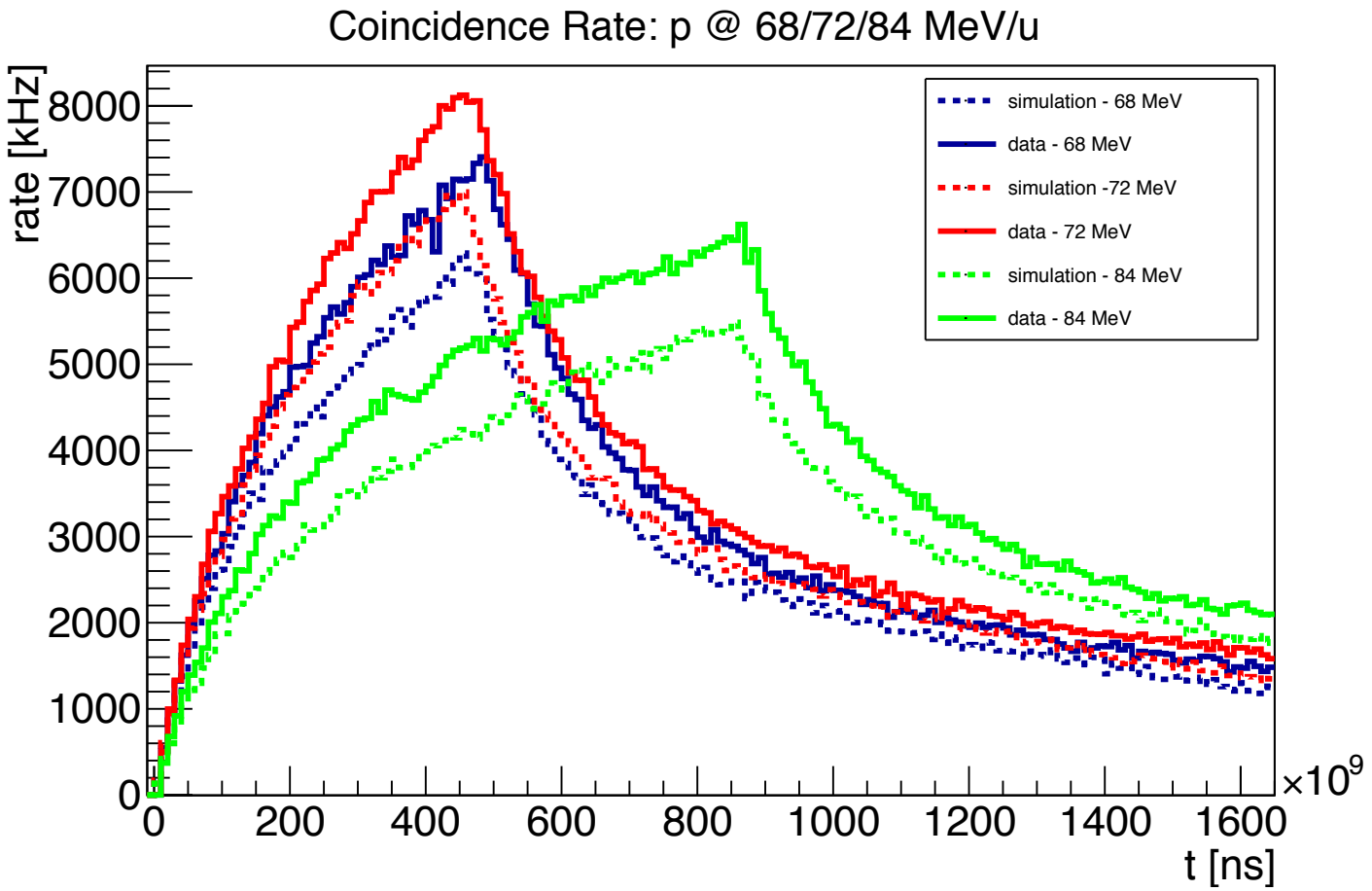
The MC simulation is a reliable tool to evaluate the performance of the full in-beam PET system.

[STEP2] Beam width check

Quantitative compatible simulation and real data profiles.
Beam width evaluation: simulation and real data difference of about 1 mm



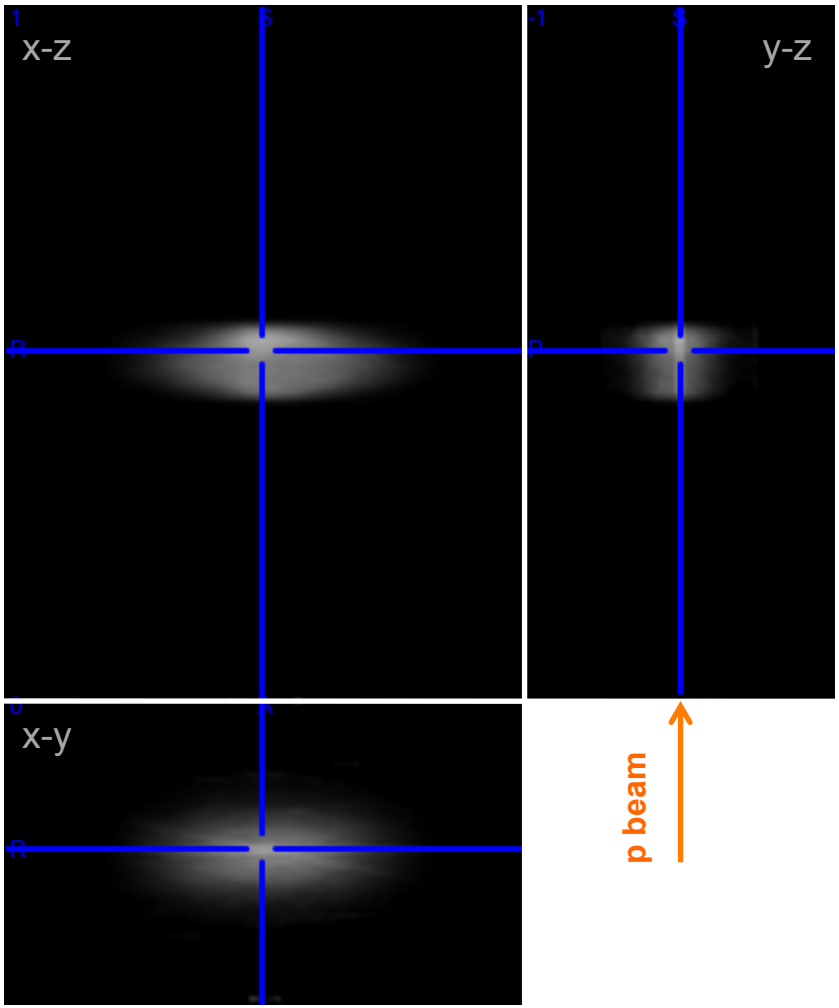
Coincidence Event Rate

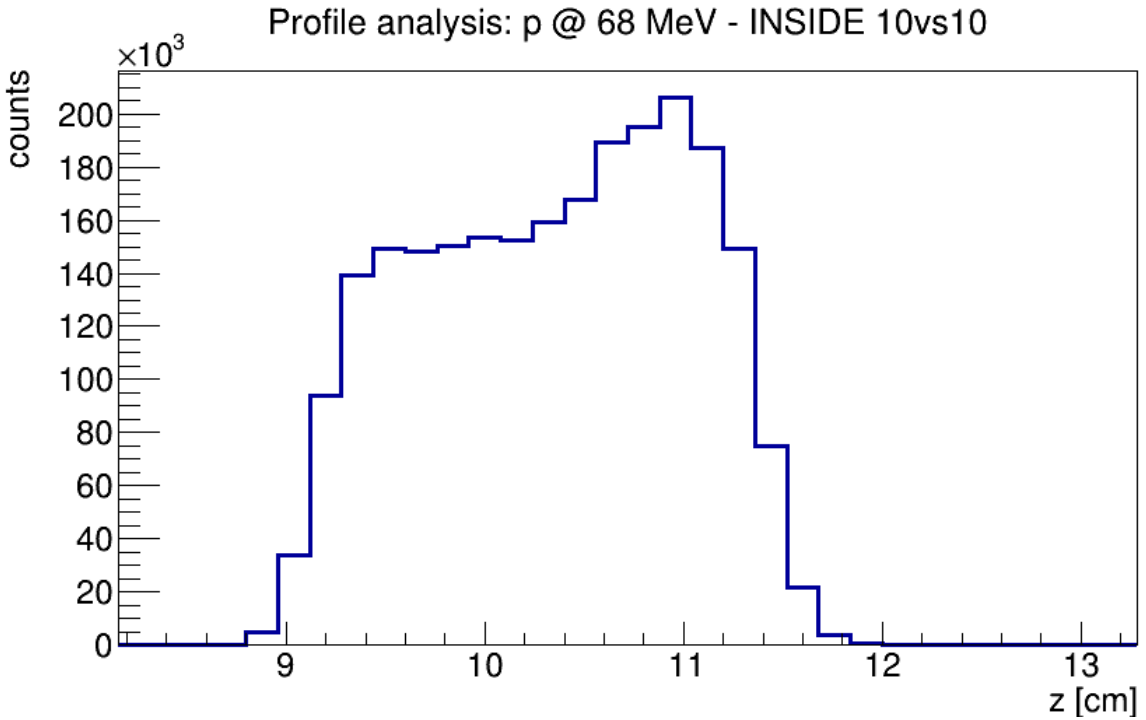


- Delayed coincidence window on acquired data: negligible random coincidence contribution in beam off
- Single channel figures of merit from experimental data
- Space and time beam structure from CNAO Dose Delivery System

Preliminary: final INSIDE PET image

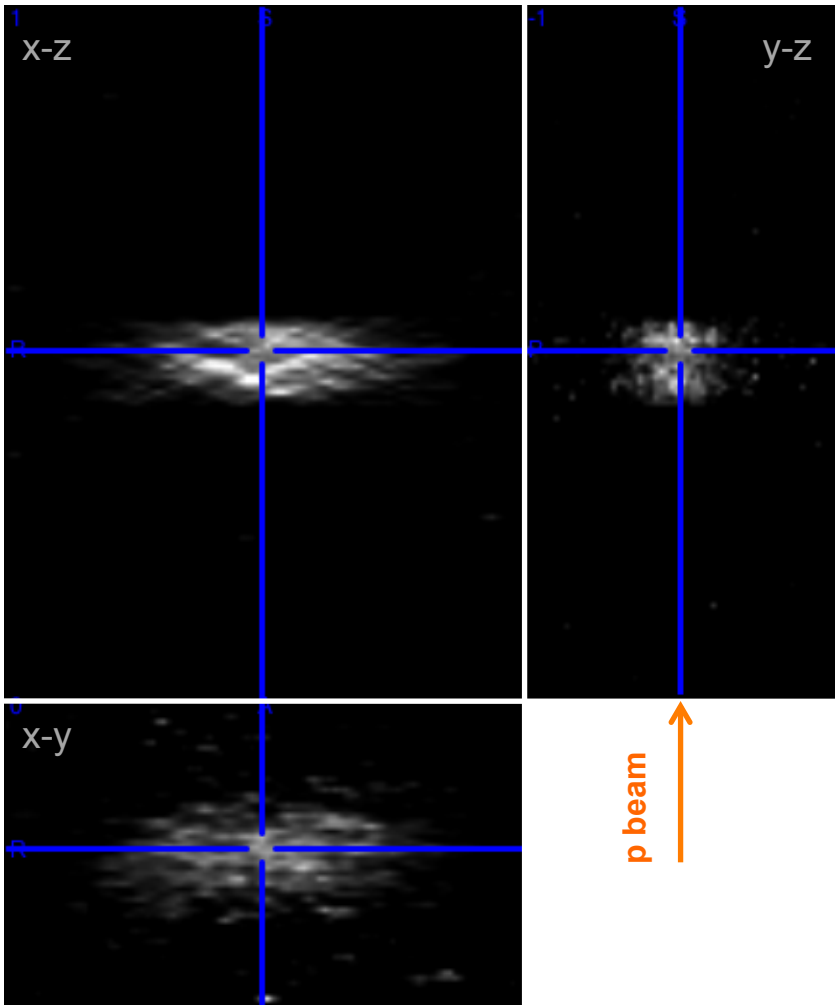
Interspill + after treatment

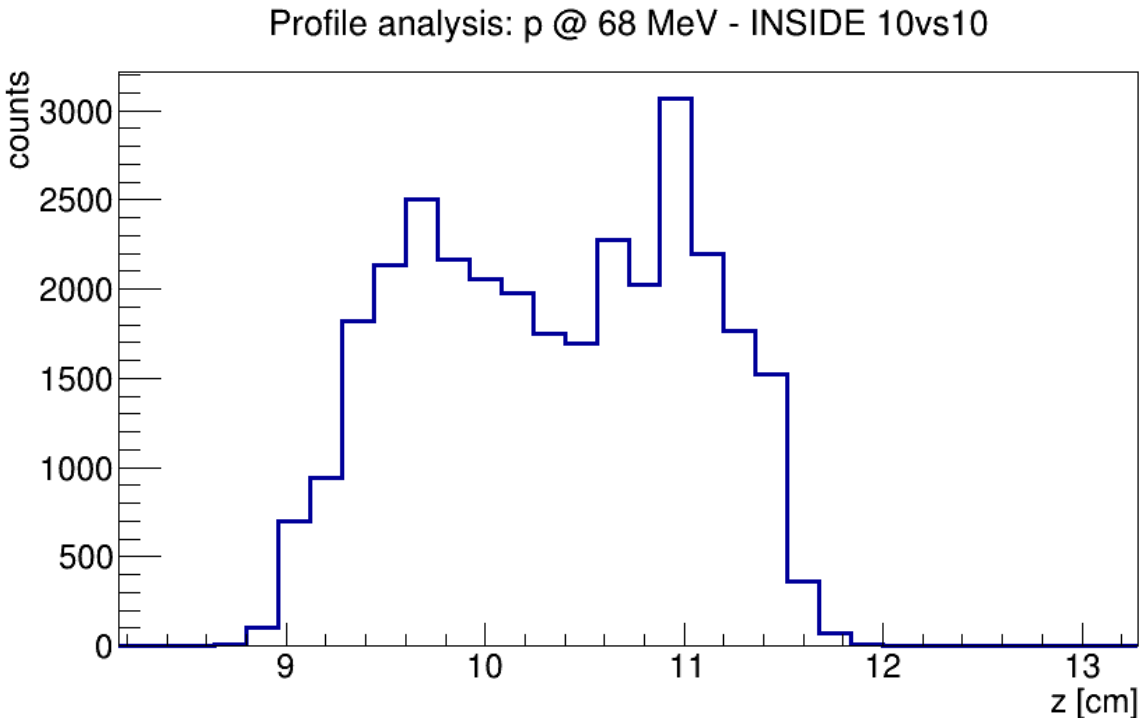




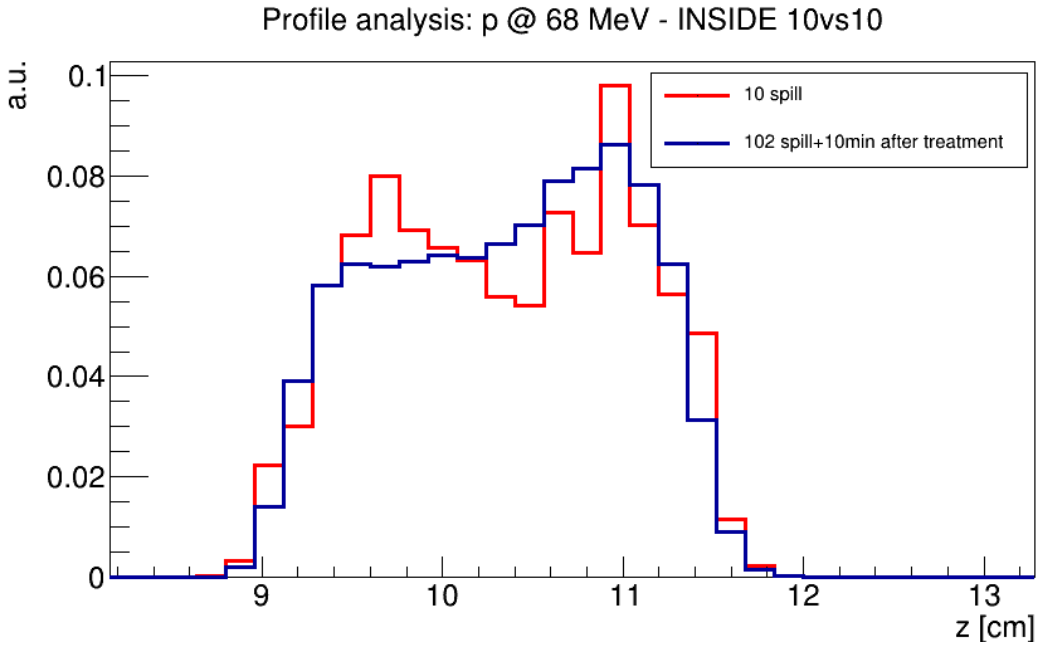
Preliminary: final INSIDE PET image

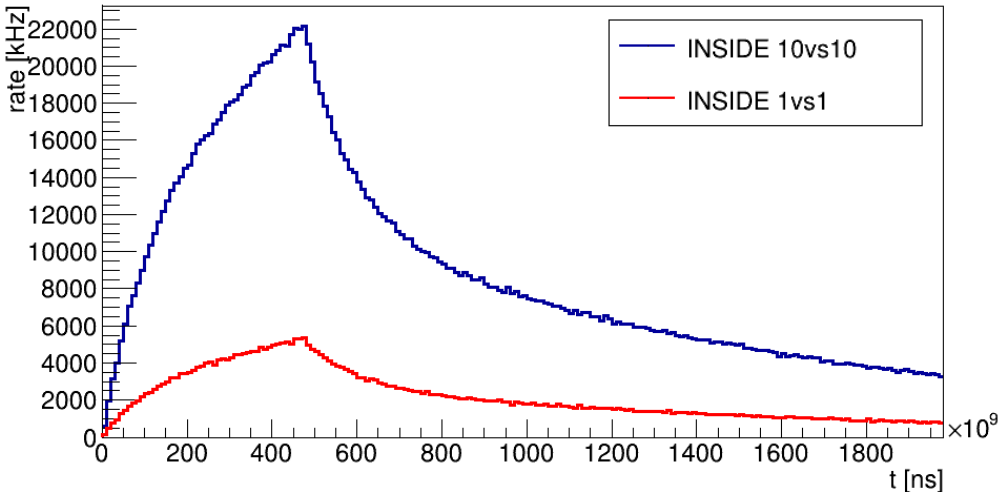
Interspill + after treatment





Preliminary: final INSIDE PET image





Compatible Z profiles with 102 and 10 spills.
Preliminary Coincidence Event Rate evaluation: 10x10 rate about 4 times wrt 1x1 INSIDE geometry

Conclusions & Next steps

- Simulated PET image profiles are quantitative compatible with the acquired ones.
- In the distal fall off evaluation, a difference between simulation and experimental data < 1 mm is found
- Further improvements needed for simulated Coincidence Event Rate validation/ calibration

- Simulation of a ^{18}F-FDG planar source and point sources
- Check beam features
- Further analysis on data (apart of any DAQ issue):
  - time delay calibration (each couple of channel)
  - planar source for LOR equalization
- Treatment plan and monitoring reliability evaluation (after the validation…)