INTER-FRACTIONAL MONITORING

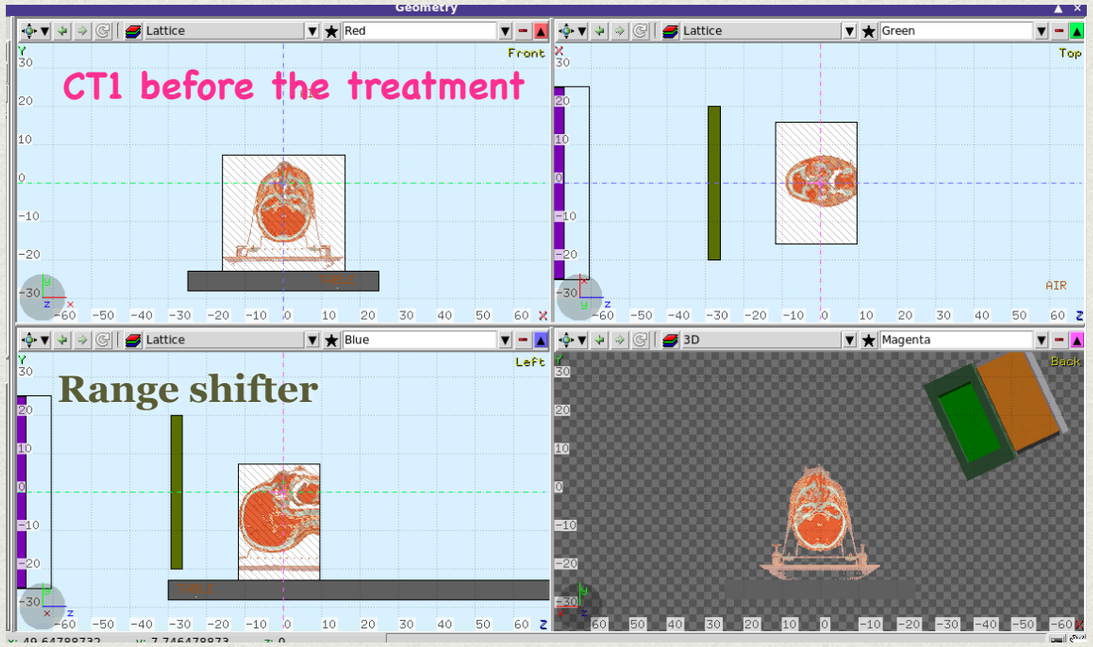
09/05/19

Marta Fischetti

IN THE LAST EPISODES…

The DP capability to spot the inter-fractional changes (during the treatment) in the dose deposition, using the charged fragments emission shape (POCA), has been investigated with a Monte Carlo simulation using the FLUKA software:

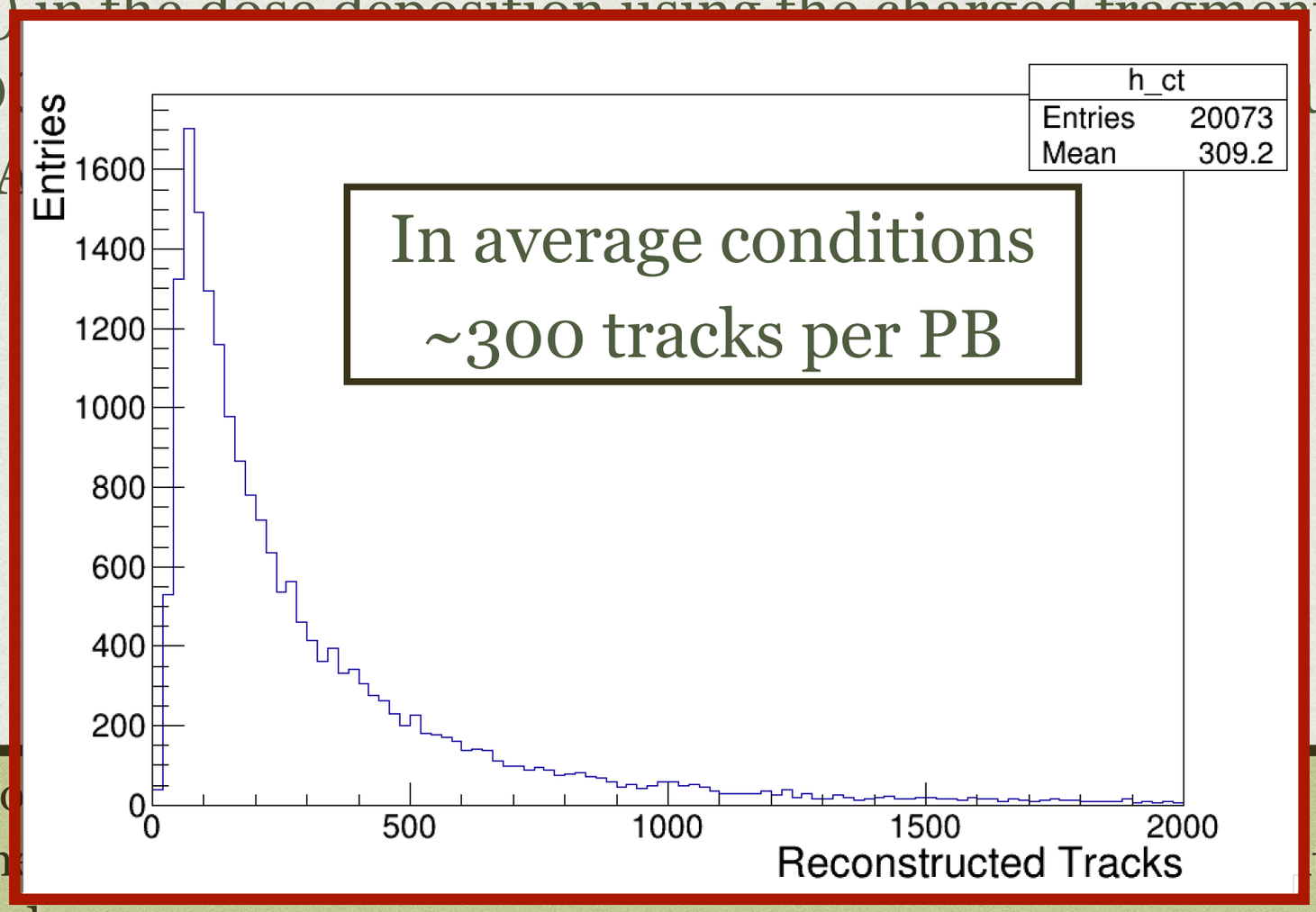
- Two CT: before the treatment and after the toxicity onset
- Same TP for each CT
- Real Positioning
- One fraction of ^{12}C ions



- We don't need to unfold the "matter effect"
- We have used the '1D' projections along the PB direction to perform a quantitative comparison ->Kolmogorv and χ^2 tests
- Low statistics for single PB (~300 tracks in most populated bins): Packing PB->5x5x3 = 75 PB (Volume = 1cm x 1cm x 6mm)

IN THE LAST EPISODES…

The DP capability to spot the inter-fractional changes (during the treatment) in the dose deposition using the charged fragments emission shape (PO… …ulation using the FLUKA…



- We don't need to…
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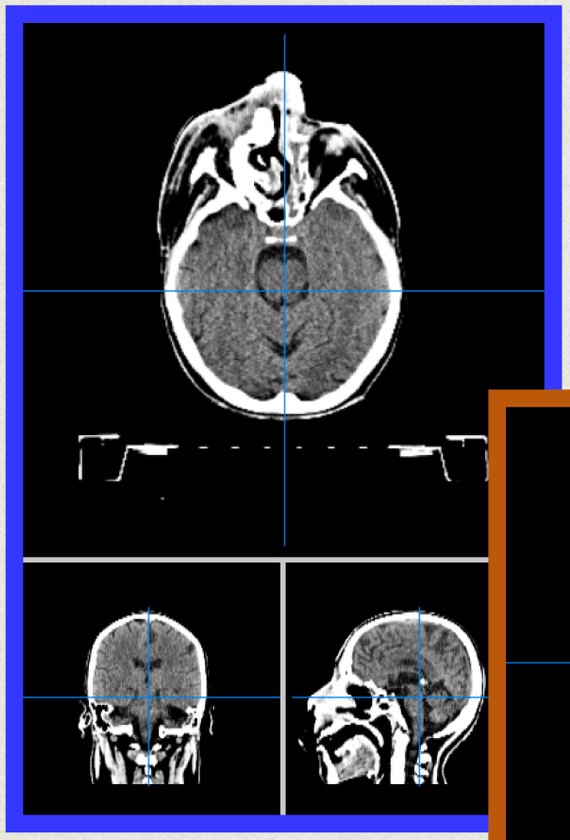
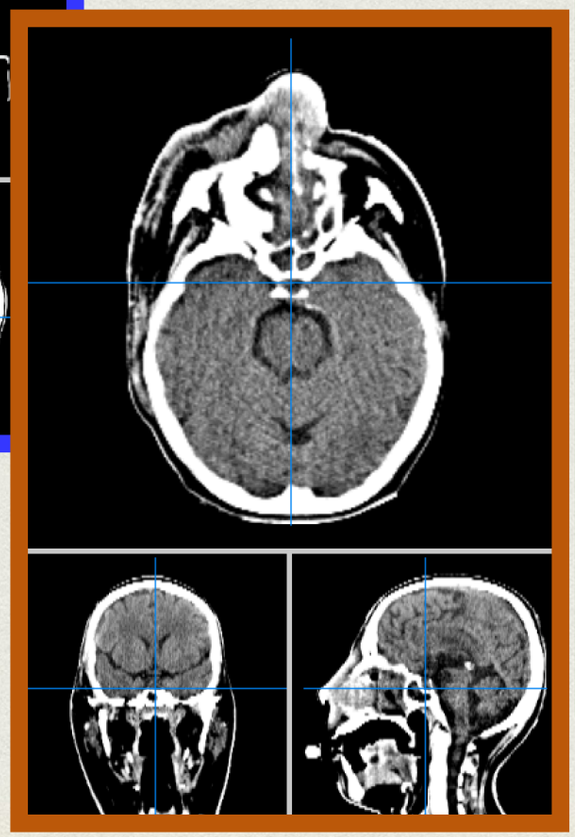
IN THE LAST EPISODES…

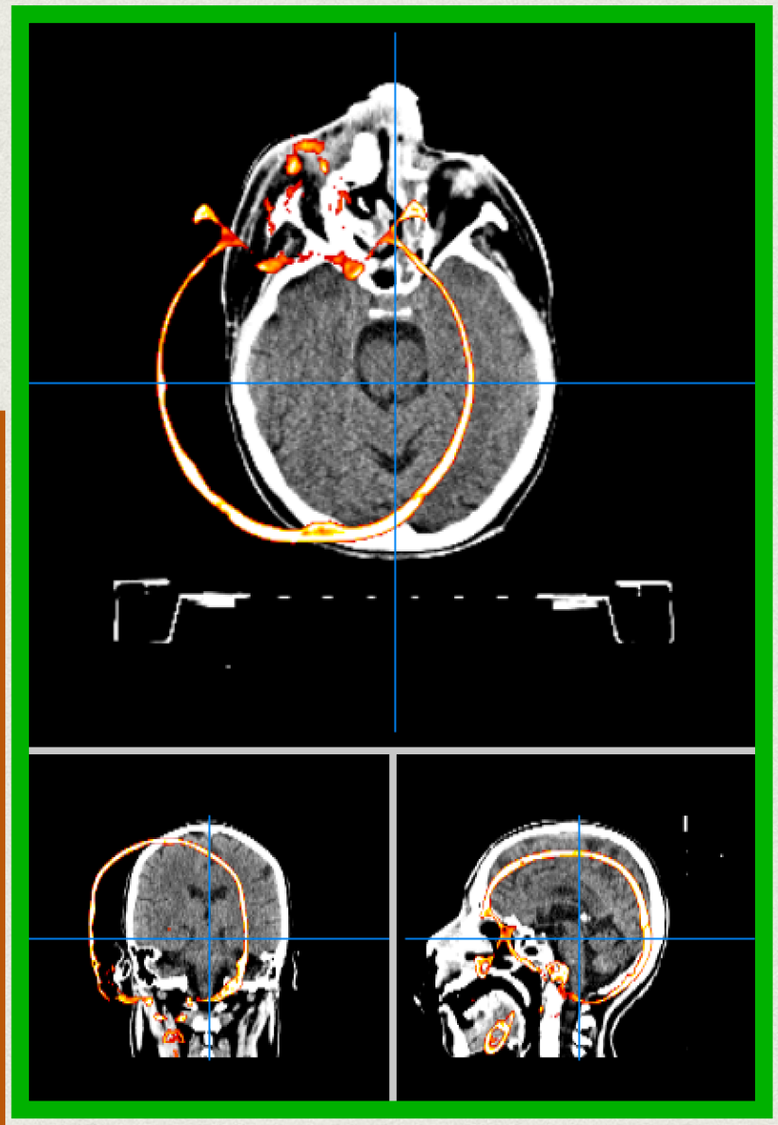
CT1 before the treatment



CT2 after the toxicity onset



CT2 overlaid to CT1

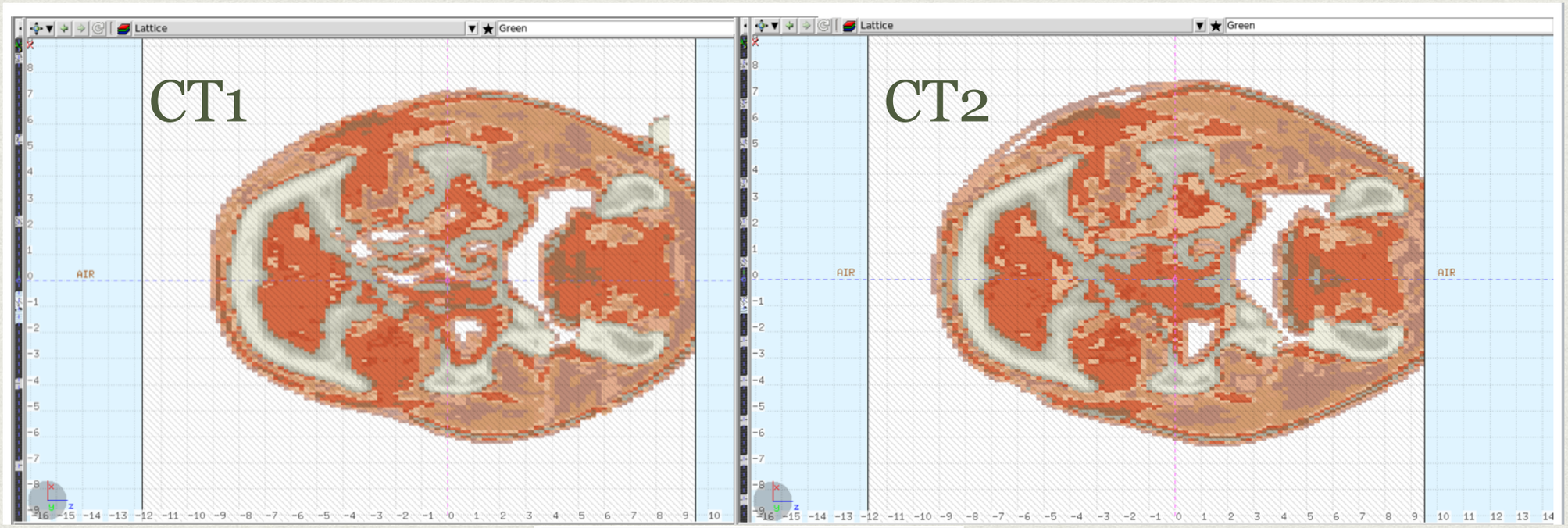


We have to align the two CT to use the same TP

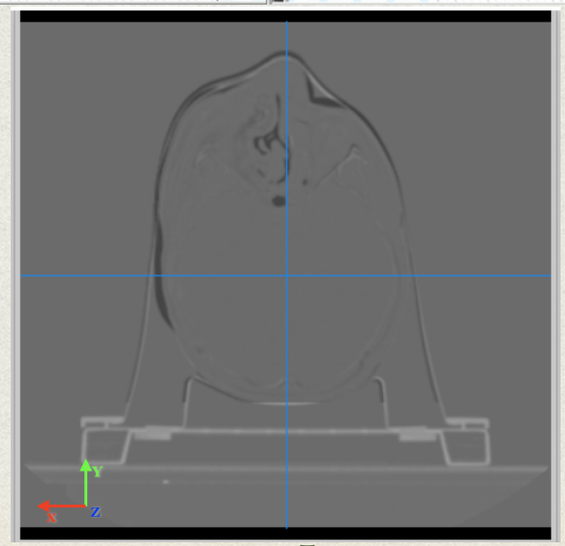
Manual alignment isn't enough accurate

IN THE LAST EPISODES…

We solved the alignment problem of the two CT using flirt software!!!!



The subtraction between CT1 and CT2 is shown in gray scale



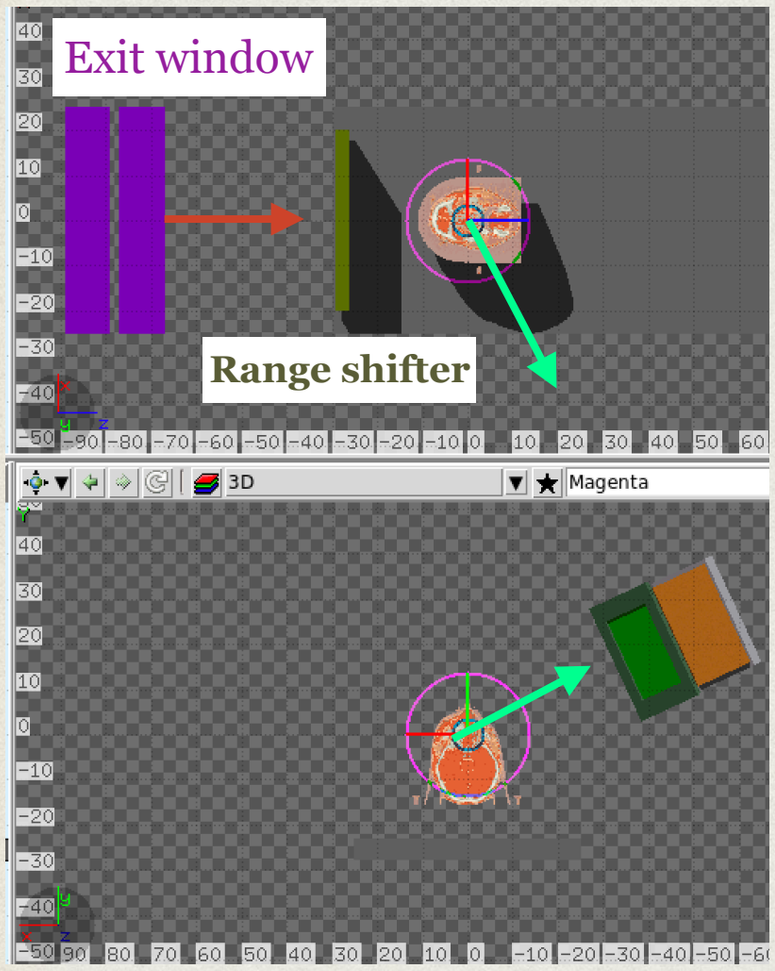
GOOD agreement

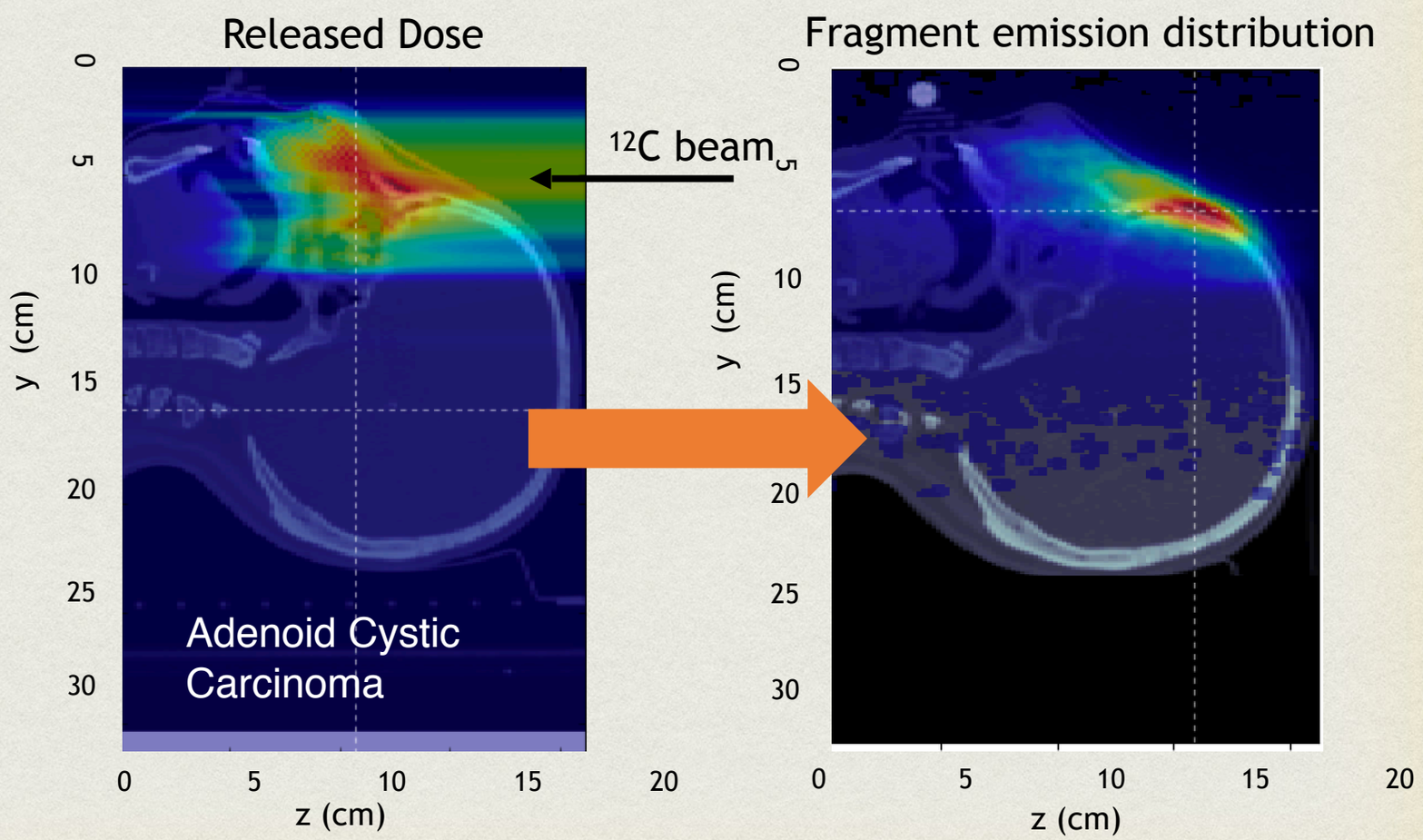
SECONDARY FRAGMENT PRODUCTION

This treatment is composed by 3 fields: B1, B2, B3.

Firstly I analyzed B3:
the best condition for us

→ Fragments are mostly produced at the entrance point inside the patient and are absorbed by the patient body in their exit path towards the detector





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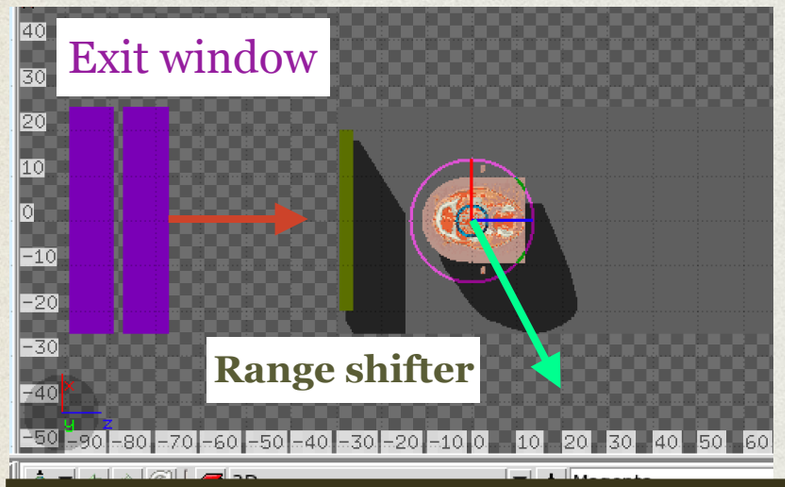

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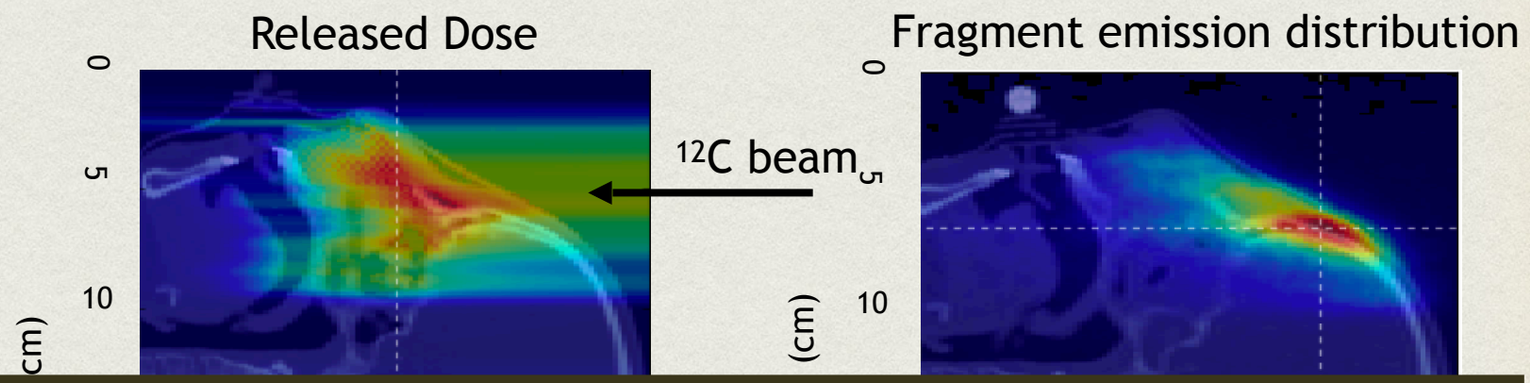
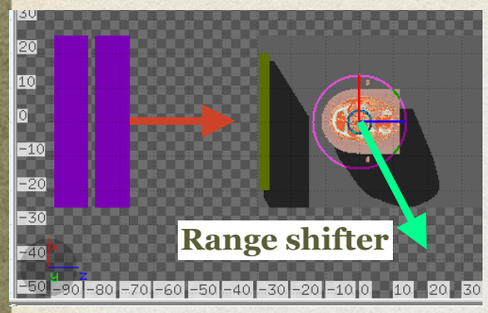
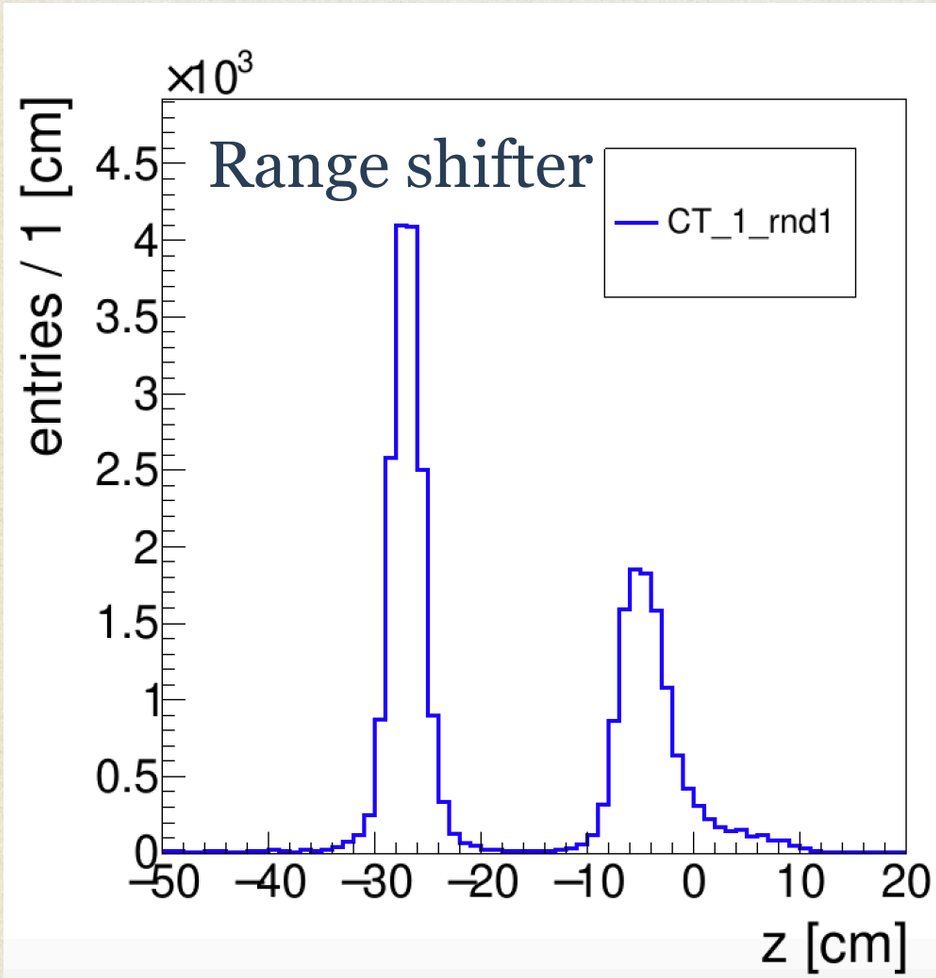


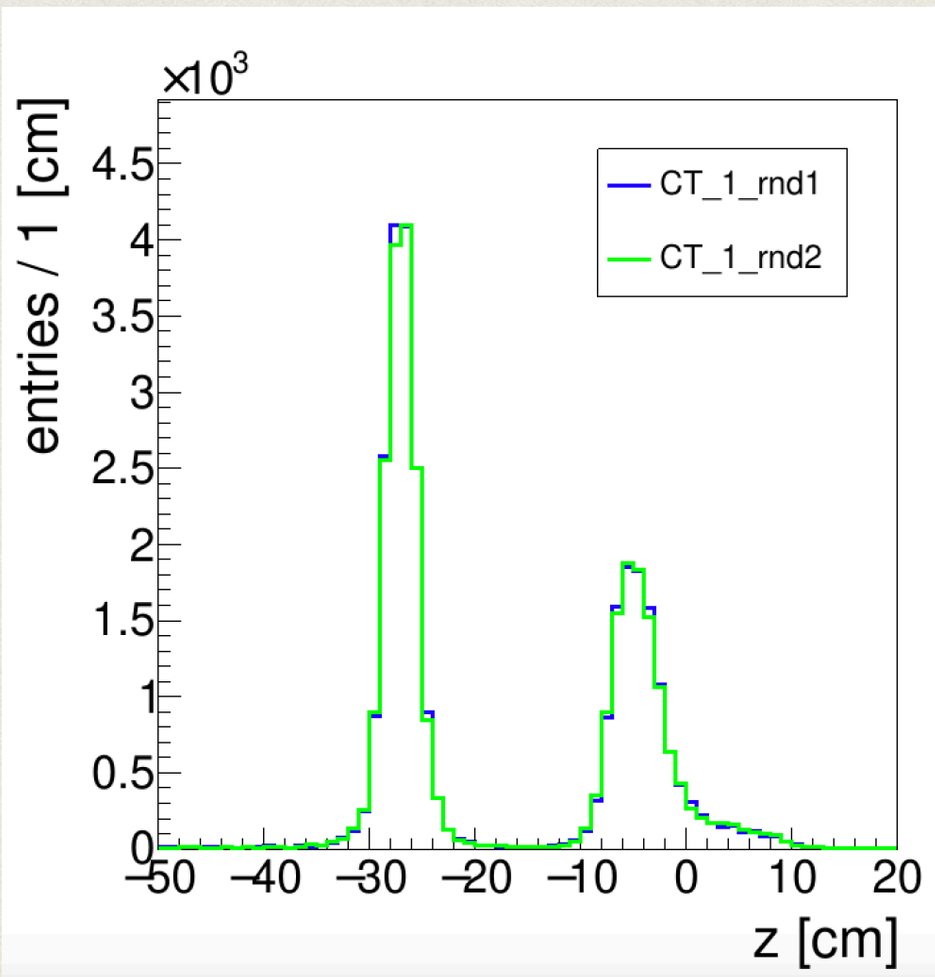
- Inter-fractional monitoring in dose deposition is done using the '1D' projections of secondary fragments emission vertex (POCA) along the PB direction
- More detailed method of '3D' comparison will be studied soon

SECONDARY FRAGMENT PRODUCTION

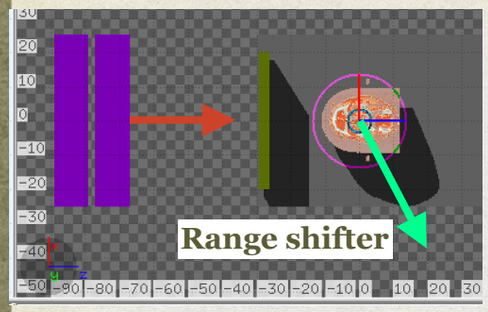


Reproducibility study of the method was done producing the same MC simulation (using the same CT1 scan and the same treatment plan) with different random seeds and comparing, super PB per super PB, the resulting profiles of secondary particles

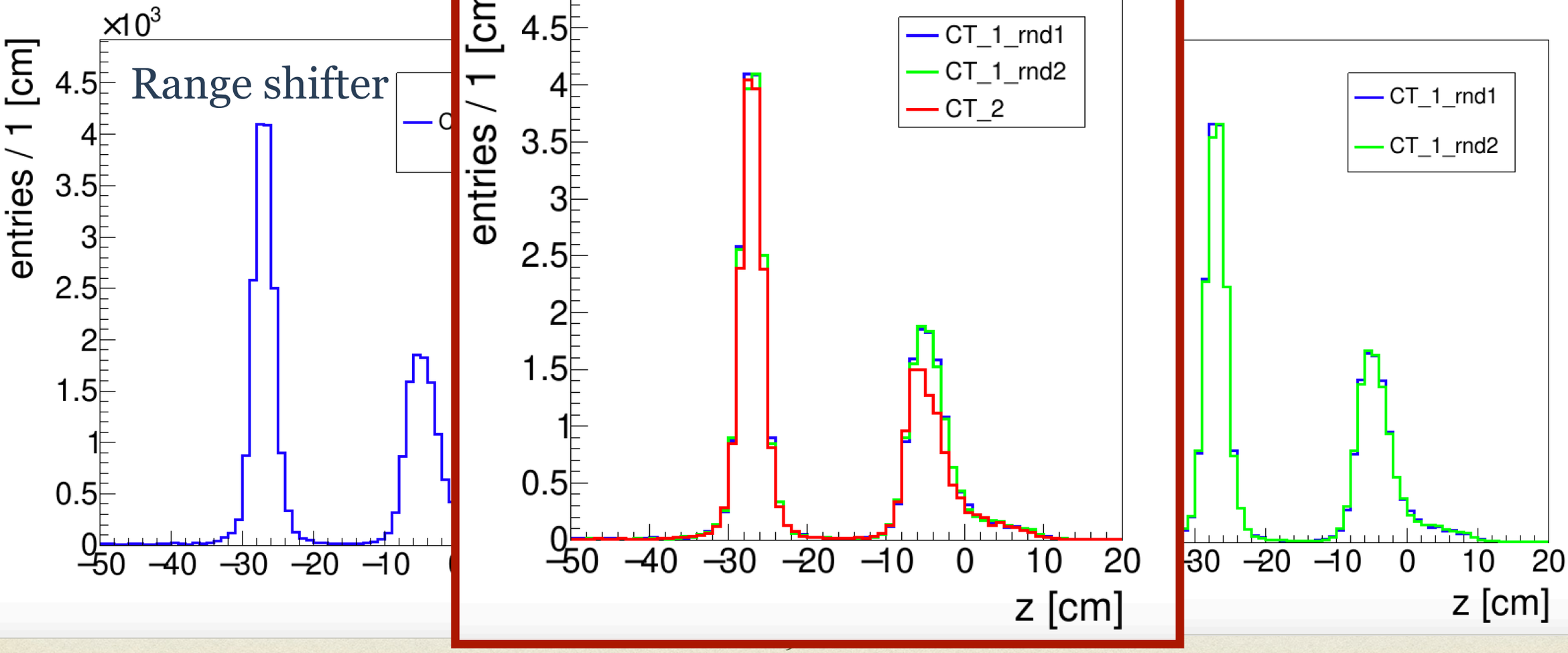




SECONDARY FRAGMENT PRODUCTION



Comparing the reconstructed profiles along z axis for the two different CT scans (CT1 and CT2) difference are observed



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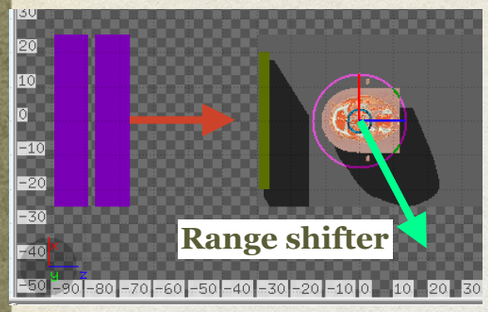

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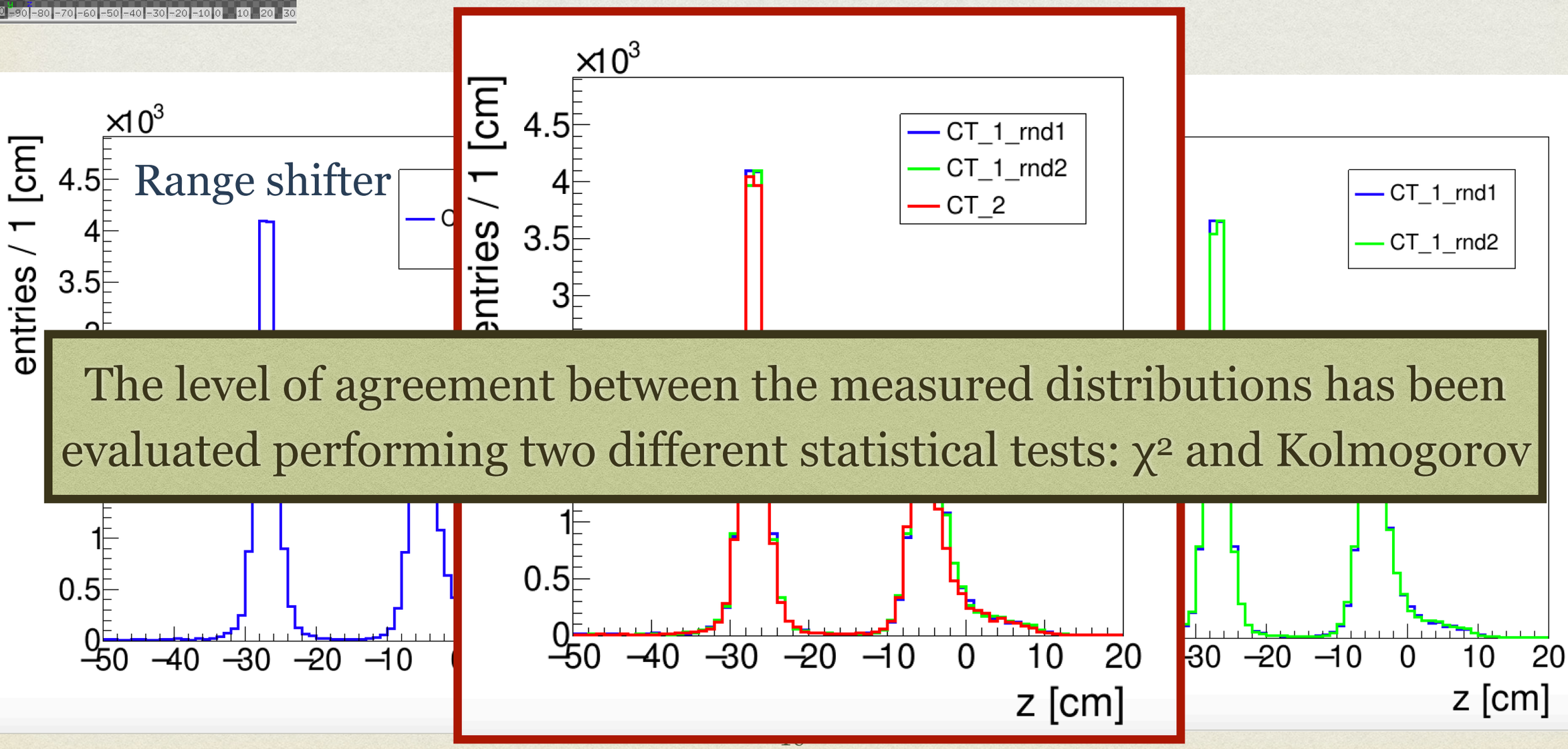
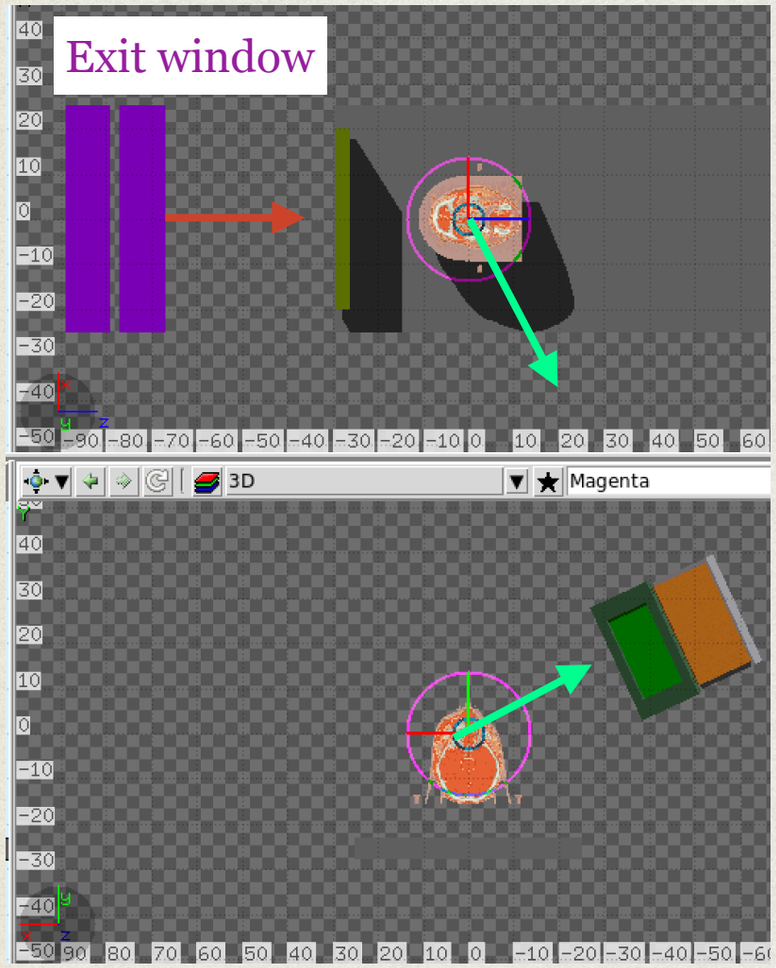


The level of agreement between the measured distributions has been evaluated performing two different statistical tests: χ^2 and Kolmogorov

SECONDARY FRAGMENT PRODUCTION

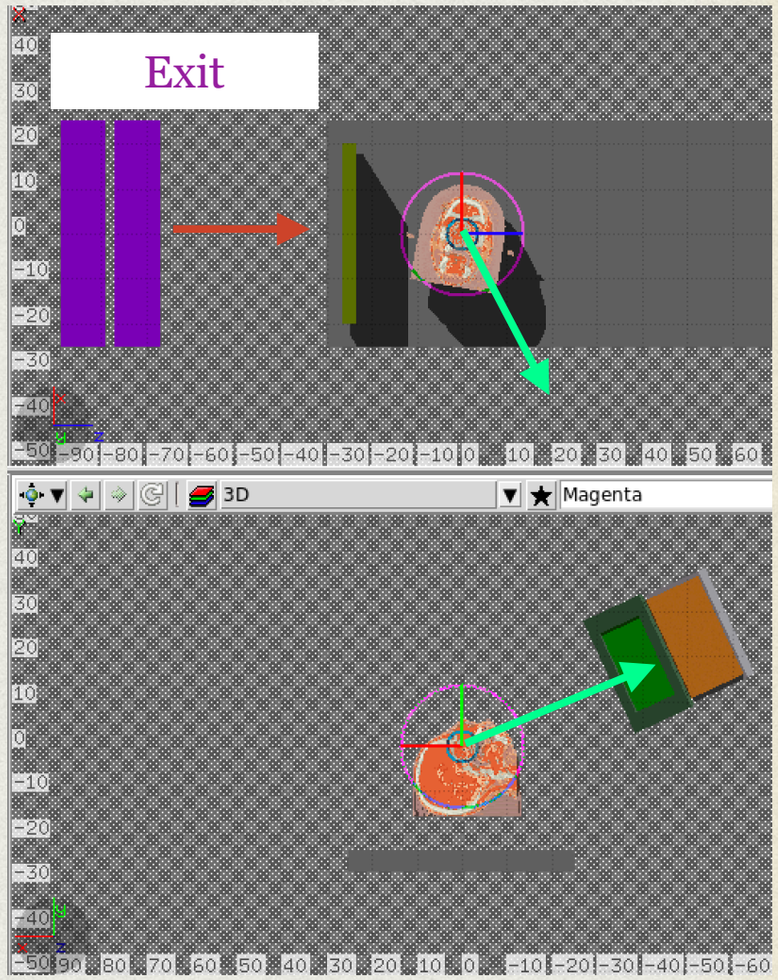
Firstly I analyzed B3:
the best condition for us



Another test in a worst condition has been done

Fragments have to travel a bigger path inside the body before reaching the detector

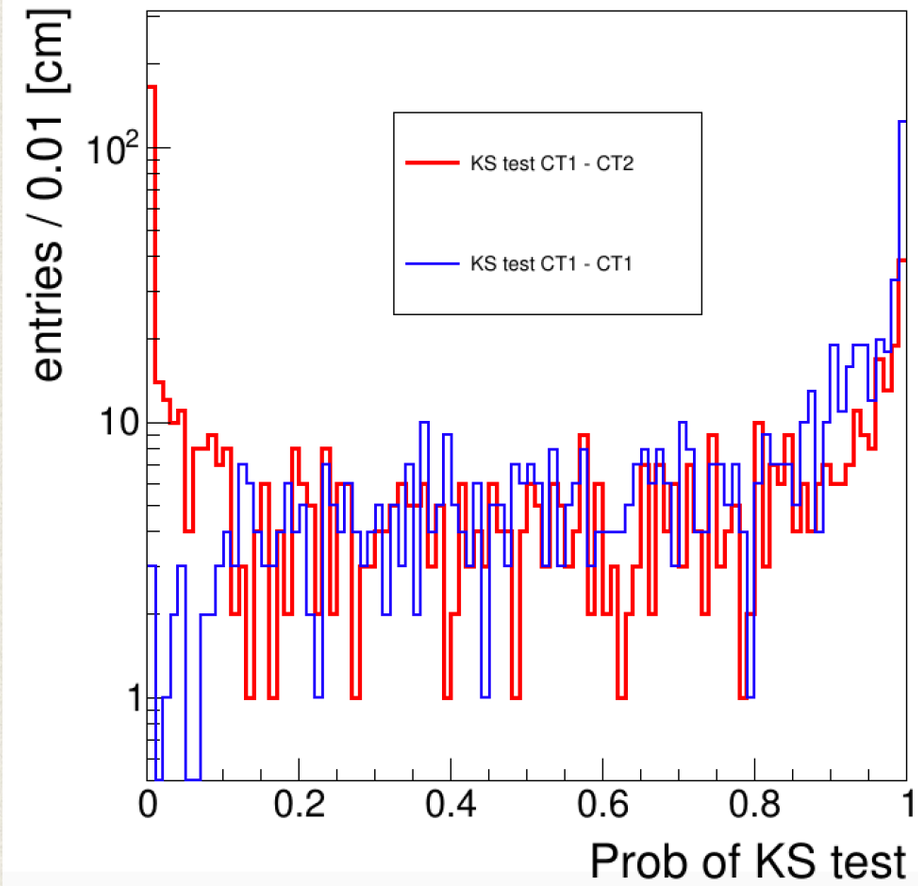
Secondly I analyze also B2



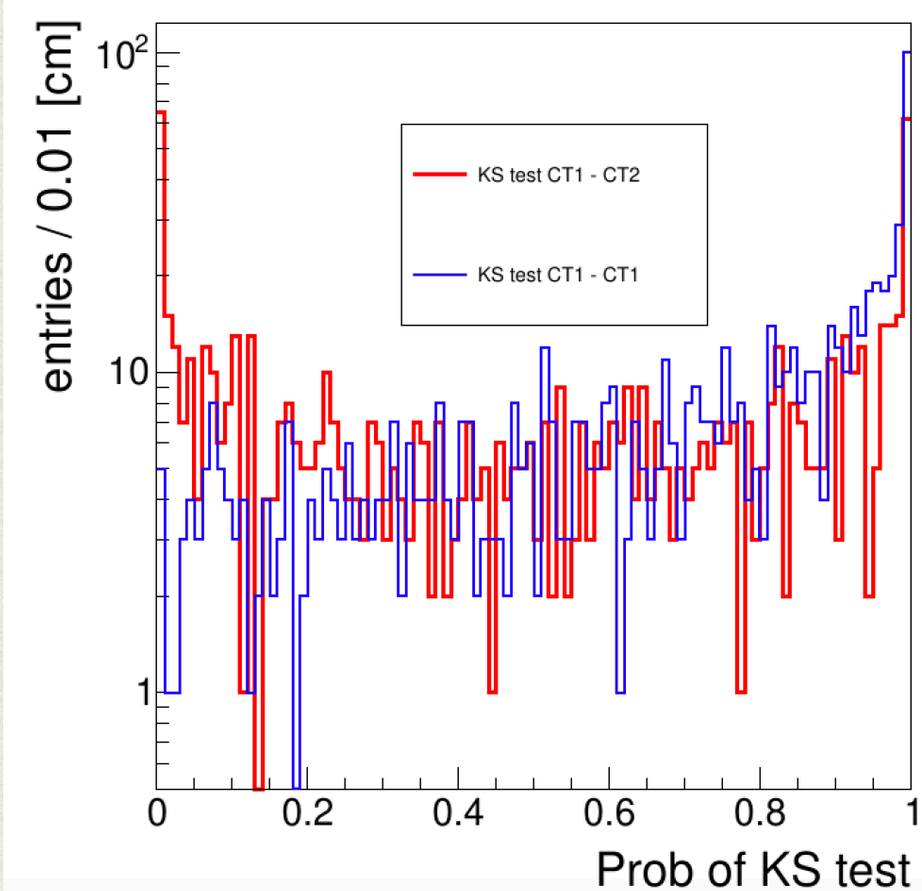
STATISTICAL TEST: KOLMOGOROV & χ^2 TEST

Kolmogorov

B3



B2

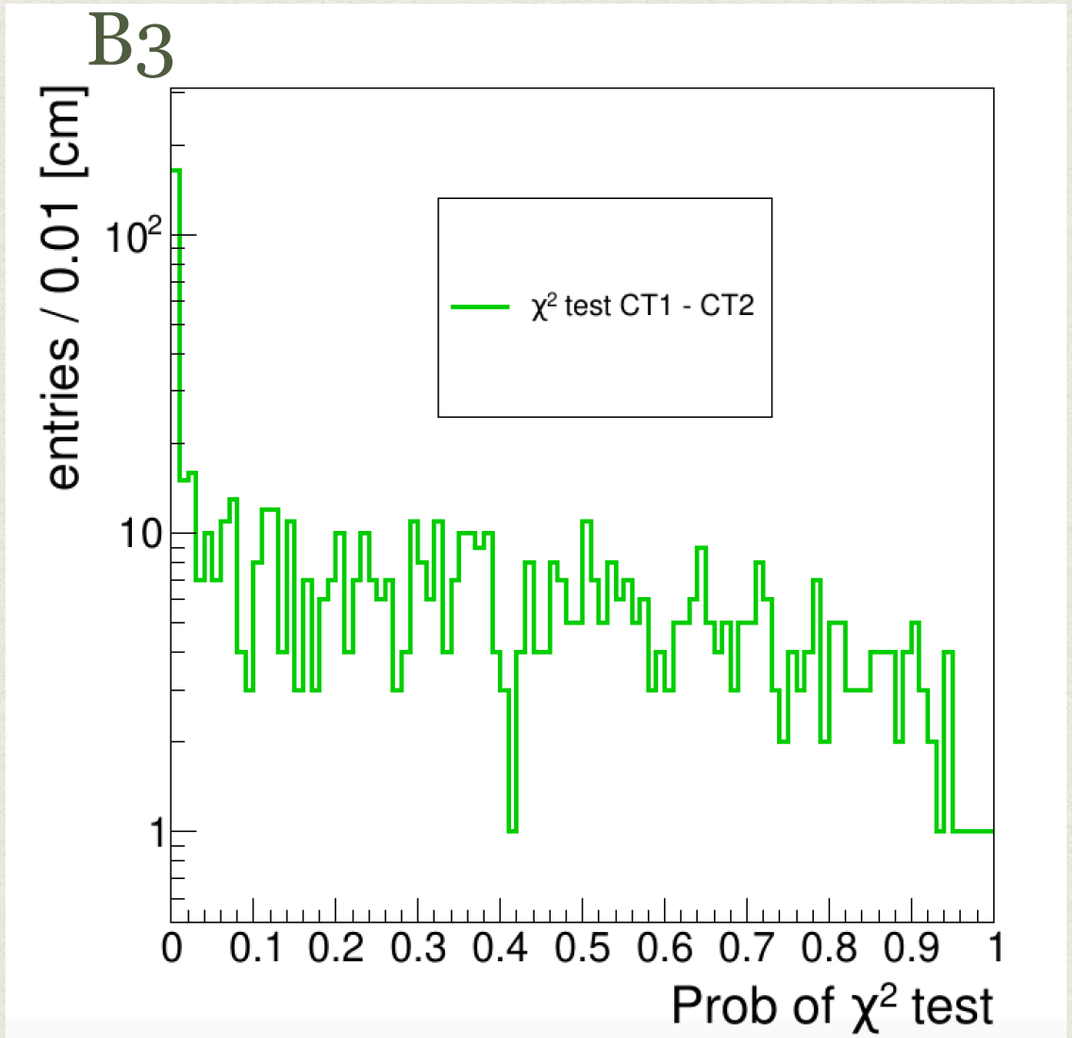


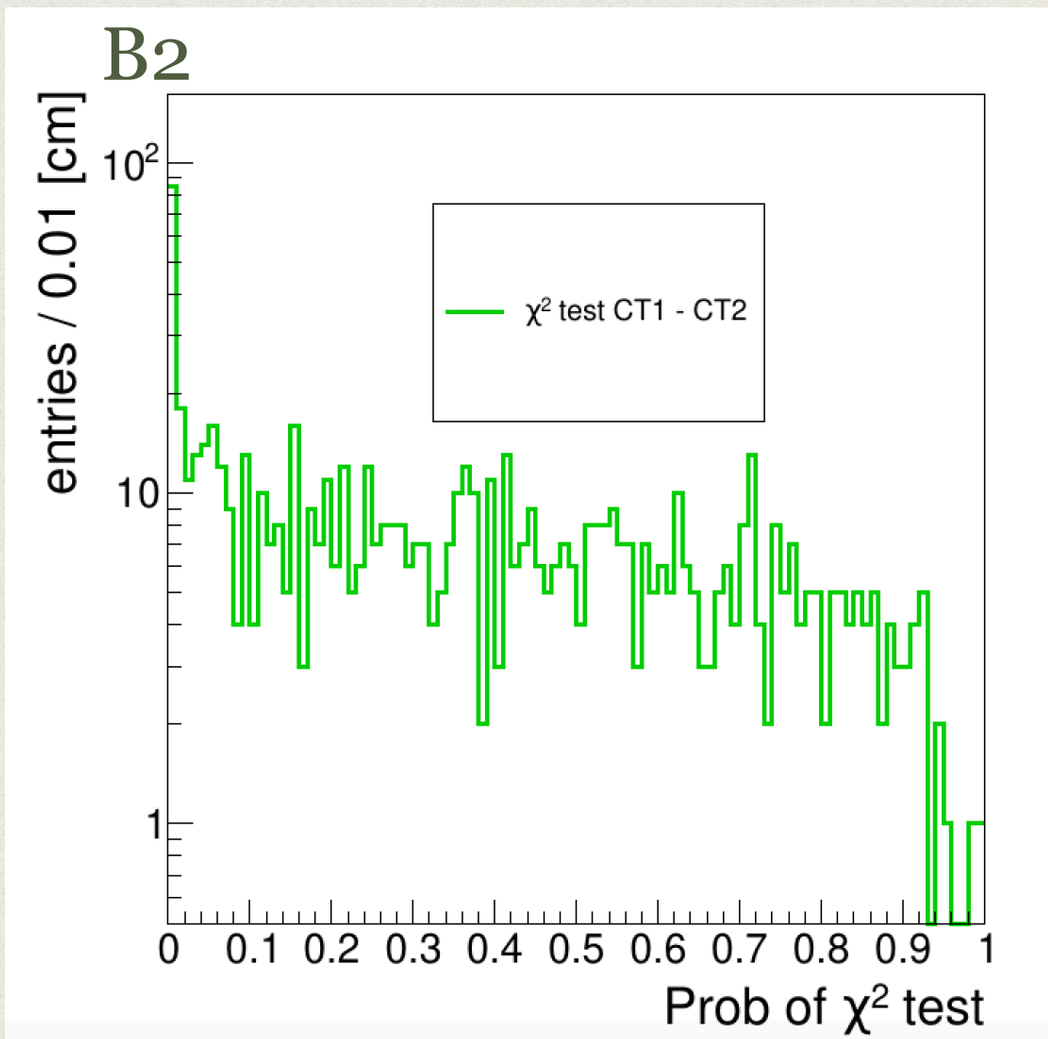
When CT1 and CT2 are compared (red) , there's a clear evidence that in some superPB there's no agreement btw the measured distributions. Instead, when just checking the statistical fluctuations (blue) such peak at low p(KS) disappears

STATISTICAL TEST: KOLMOGOROV & χ^2 TEST

The χ^2 test was also studied because the results provided are binning dependent → Kolmogorov test are bin independent. It compares the cumulative of the distribution

χ^2

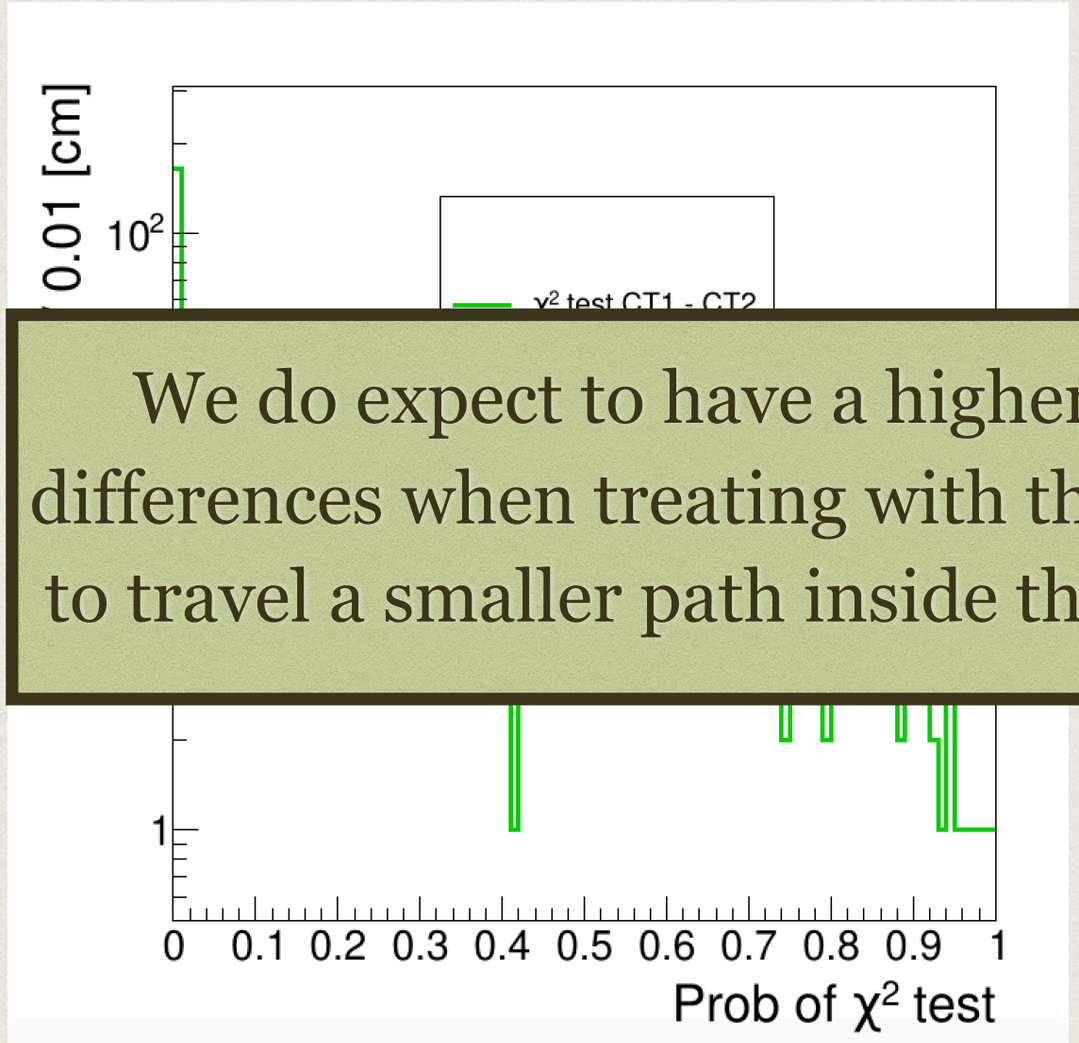




STATISTICAL TEST: KOLMOGOROV & χ^2 TEST

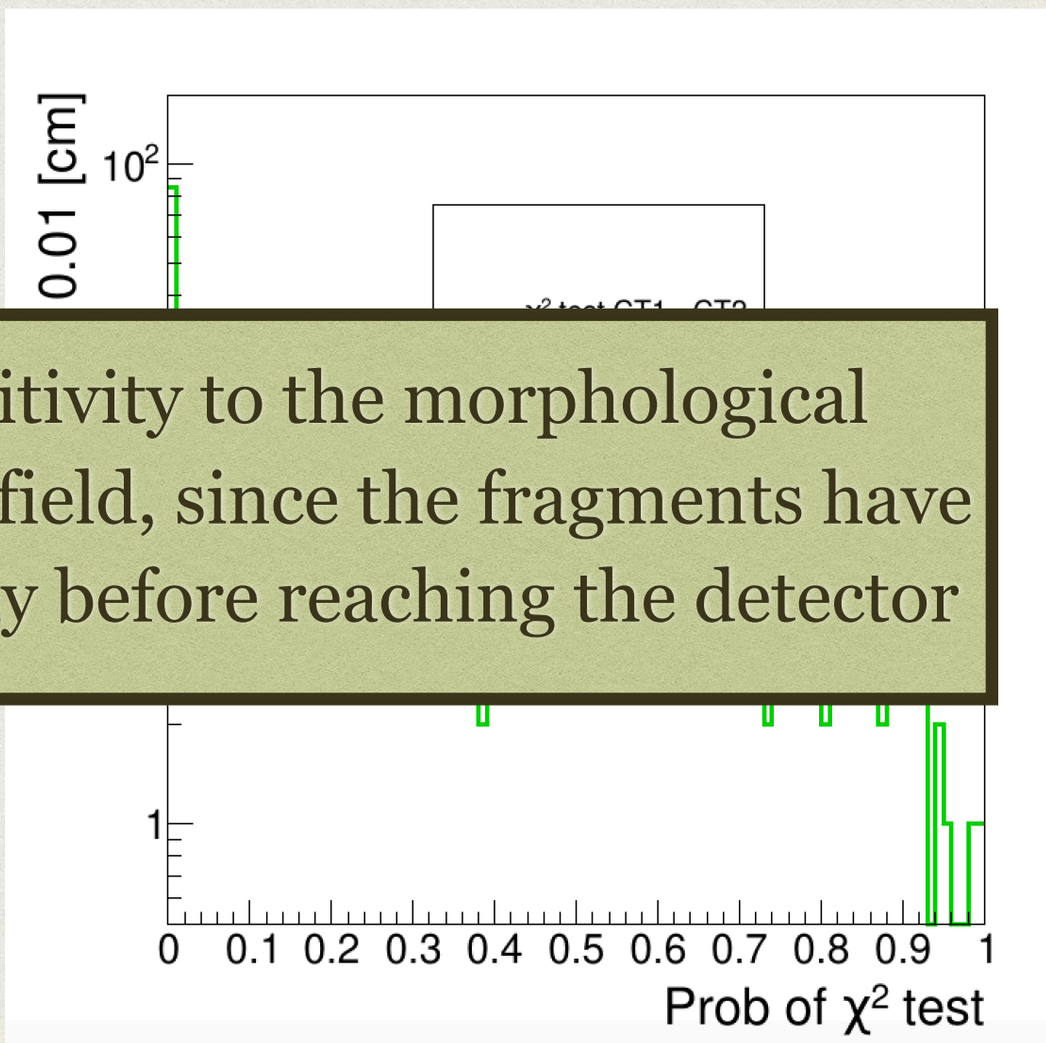
The χ^2 test was also studied as a further test to verify the robustness of the results provided by the statistical analysis done with the kolmogorov test

B3



χ^2

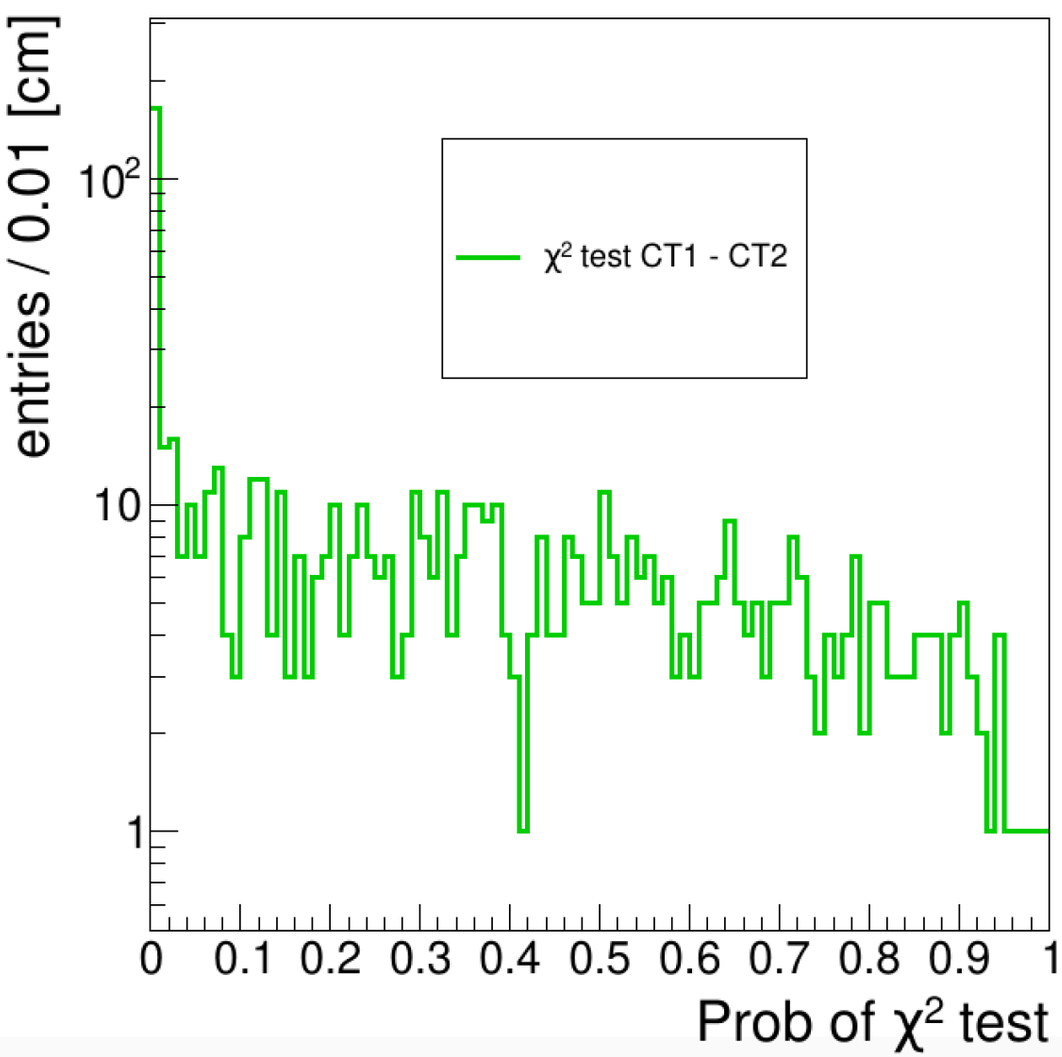
B2

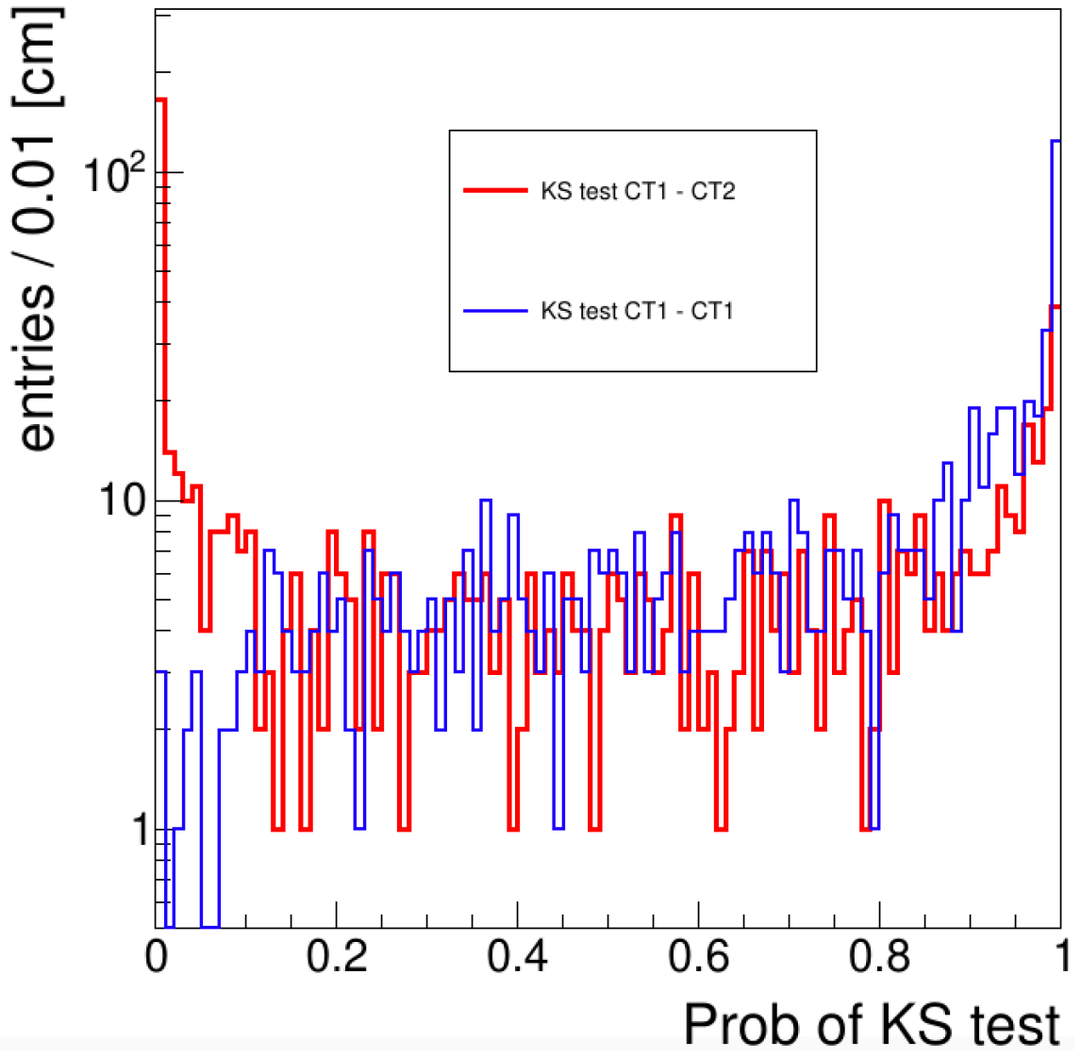


We do expect to have a higher sensitivity to the morphological differences when treating with the B3 field, since the fragments have to travel a smaller path inside the body before reaching the detector

STATISTICAL TEST: KOLMOGOROV & χ^2 TEST

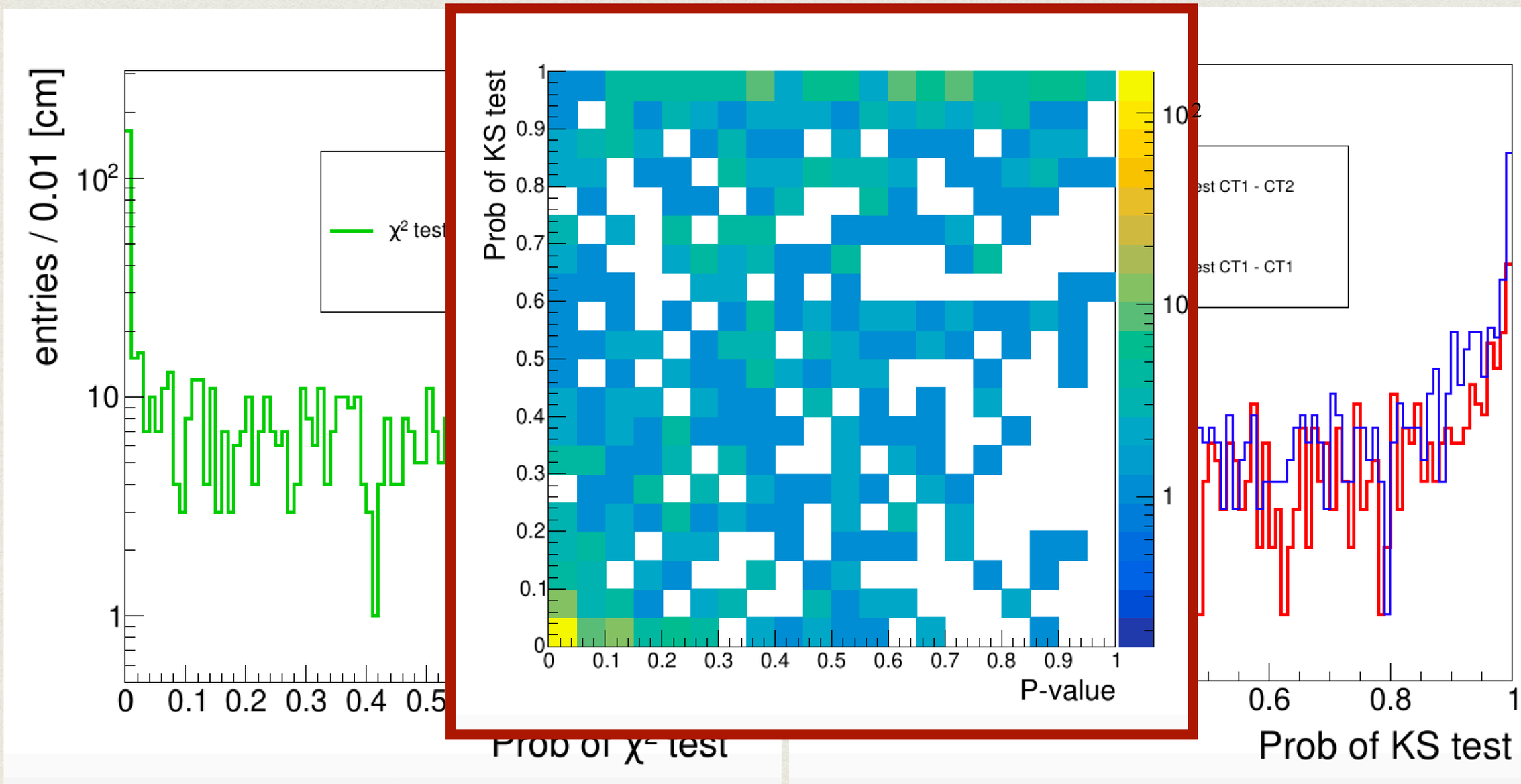
B3





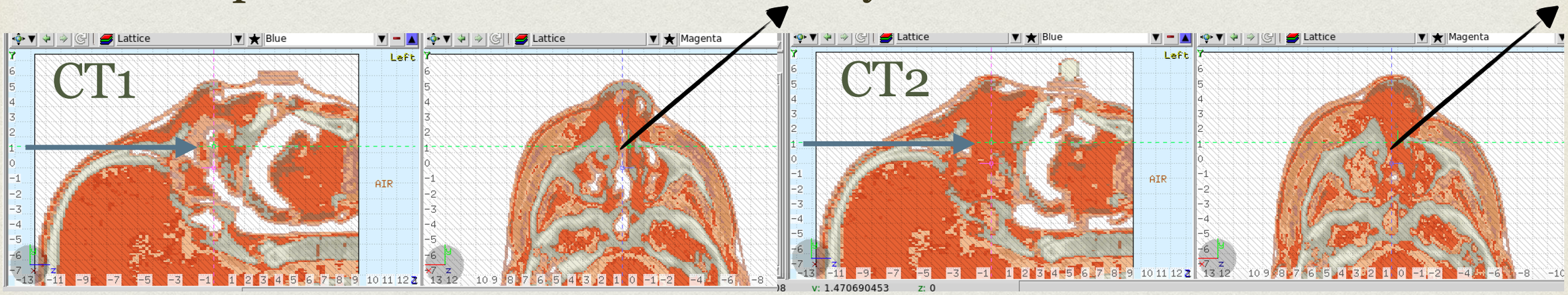
STATISTICAL TEST: KOLMOGOROV & χ^2 TEST

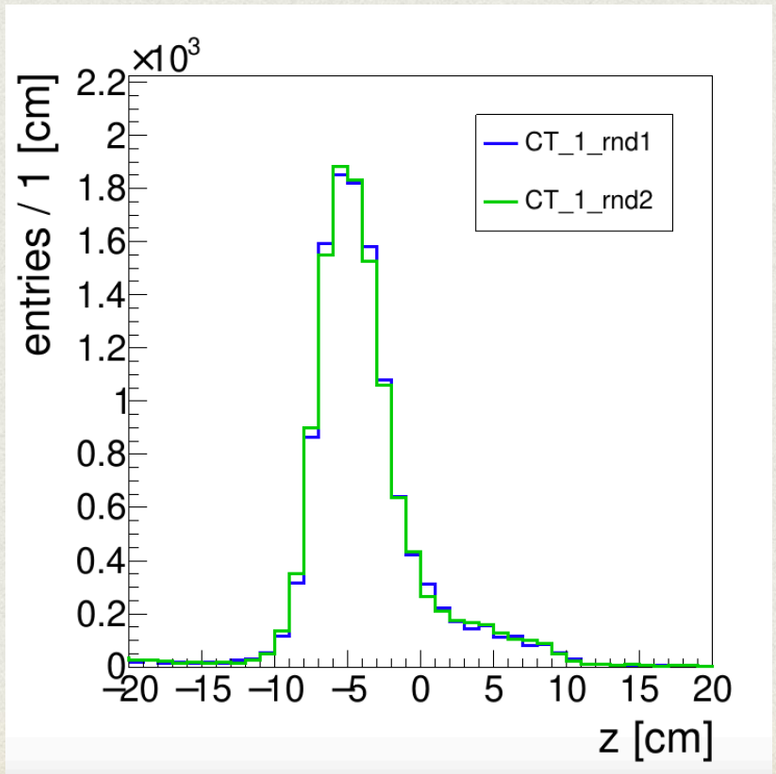
The bidimensional visualization of the χ^2 and KS probability shows a population of super PB with p(χ^2) and p(KS) <1%

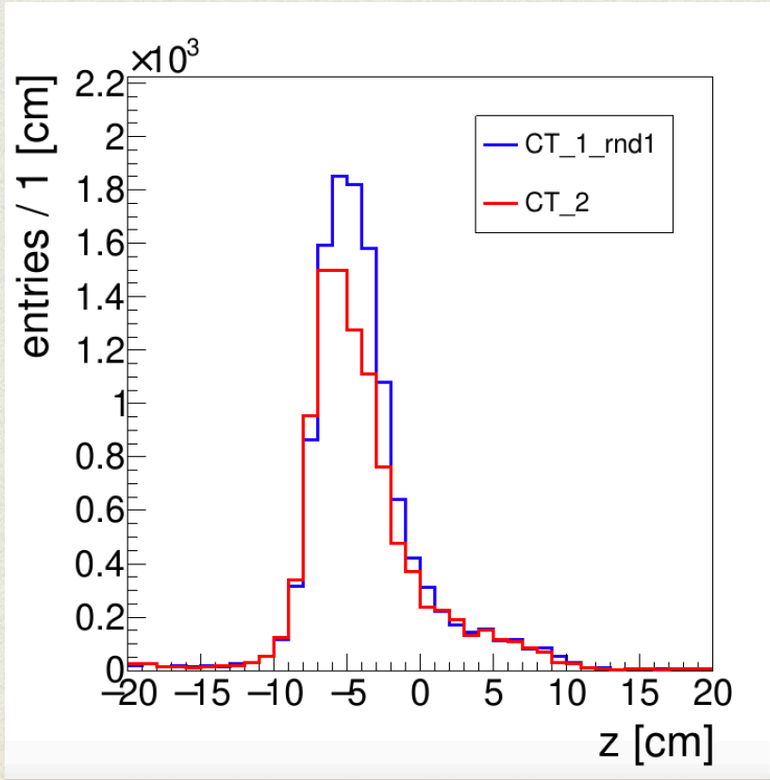


PB WITH KS AND χ^2<0,01

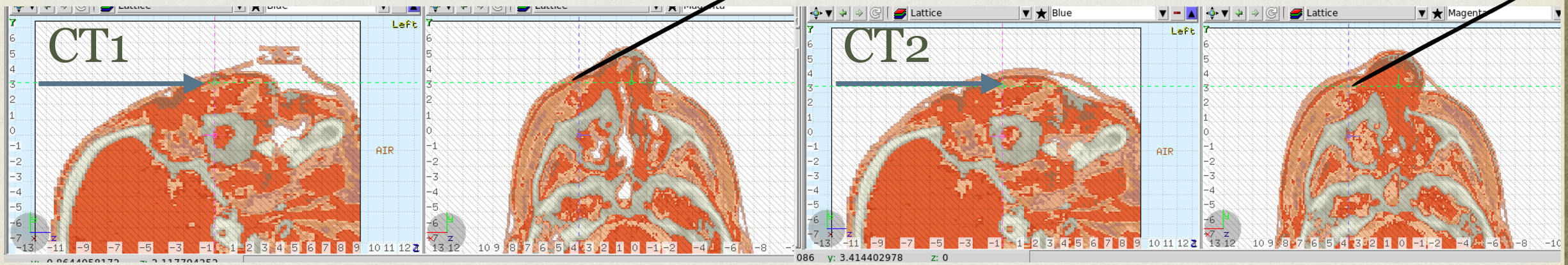
A detailed study of individual super PBs has been done to show how the different spectra are related to the toxicity onset…

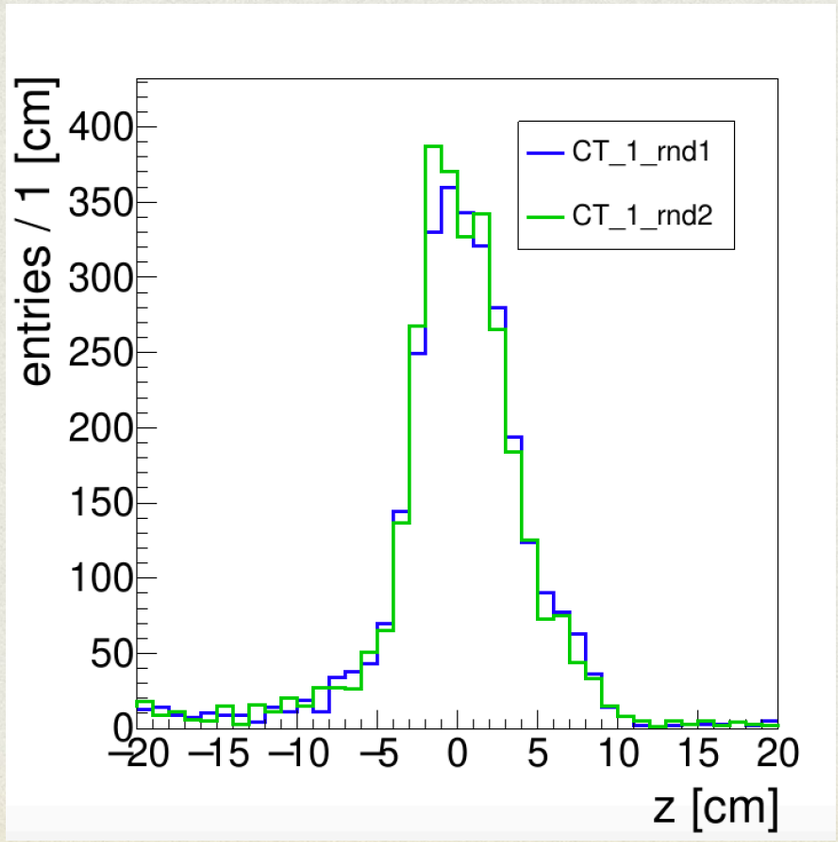


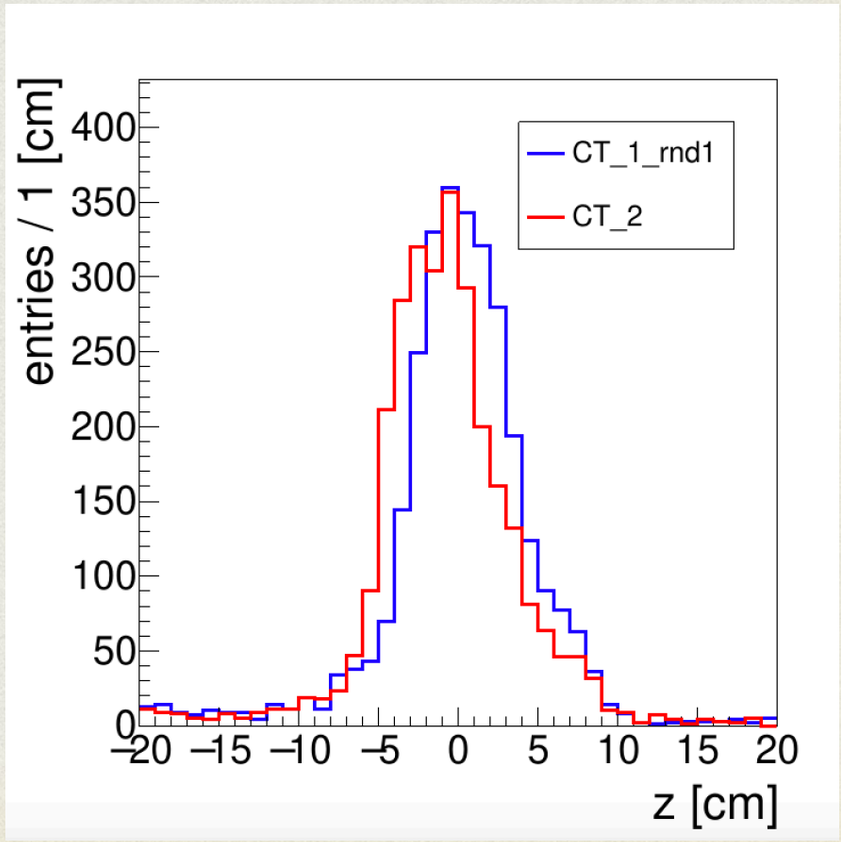




PB WITH KS AND χ^2<0,01

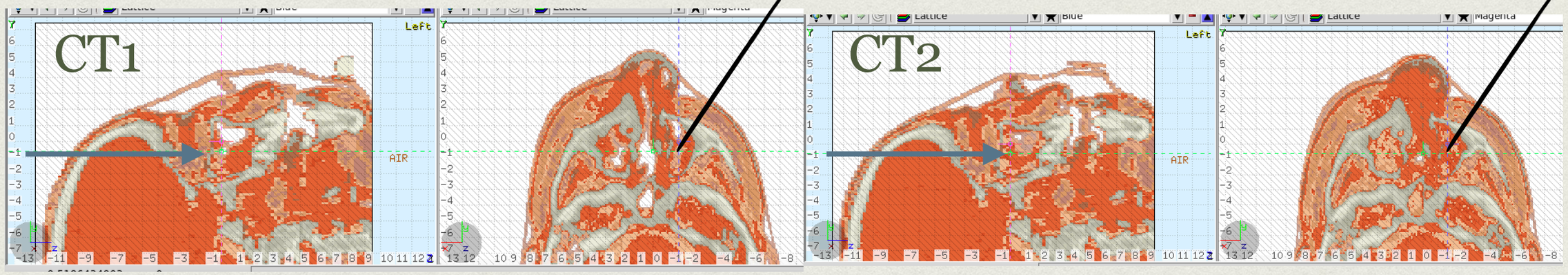


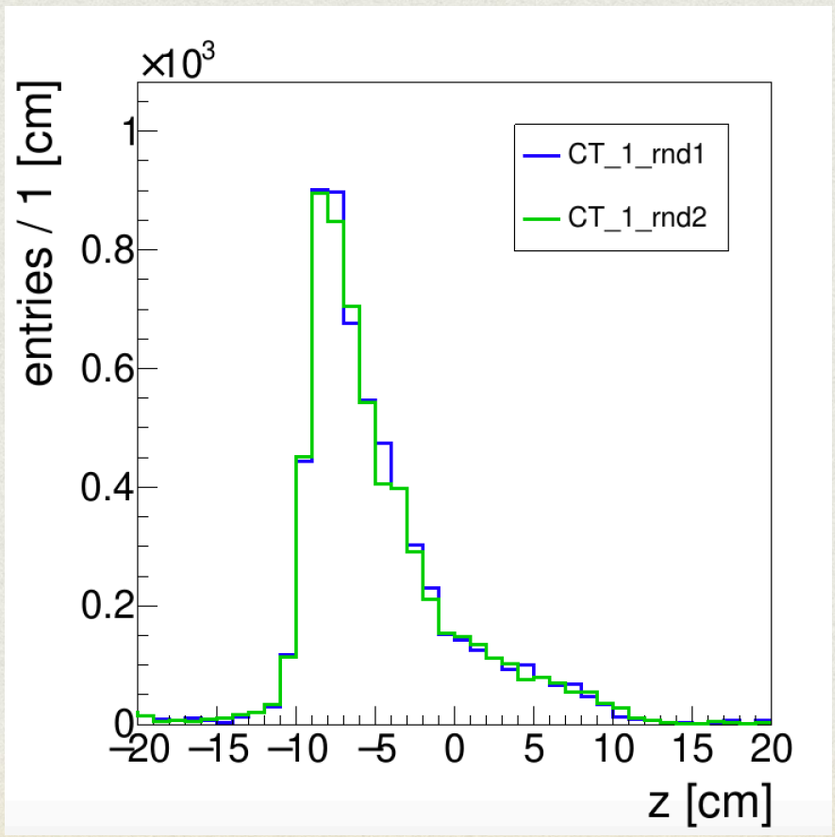


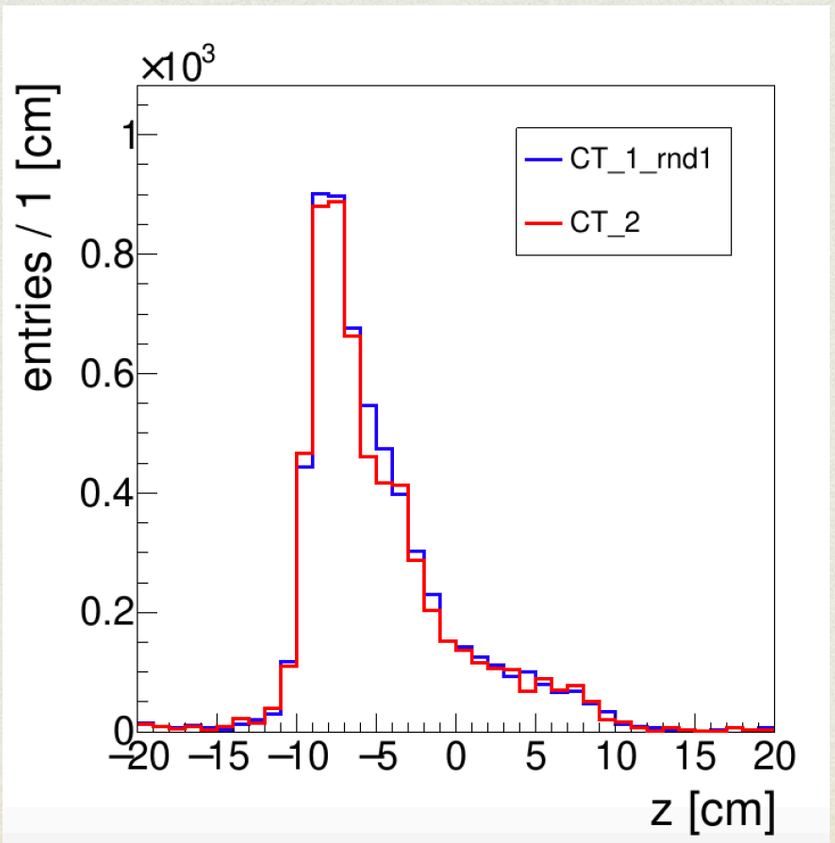


PB WITH KS AND χ^2 BETWEEN 0,6 AND 0,9

Individual super PBs that have spectra compatible have been analyzed







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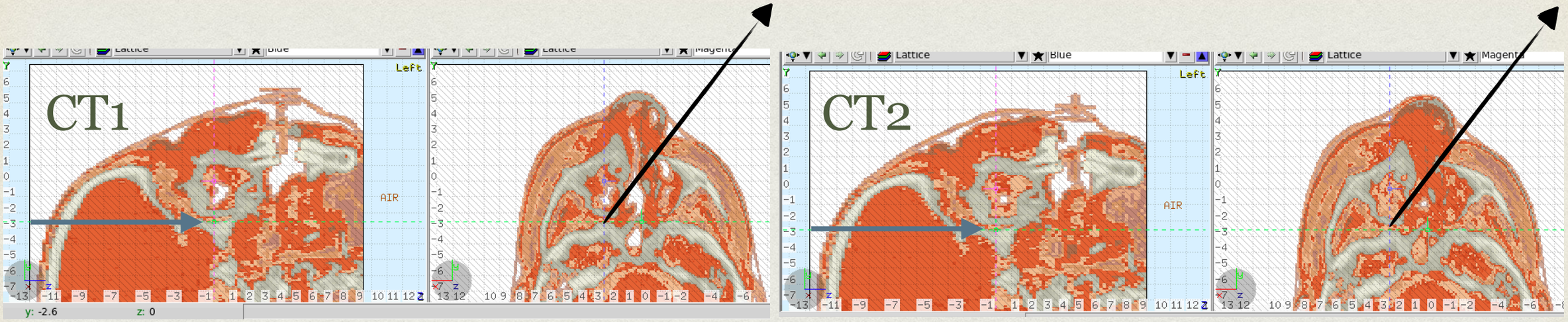
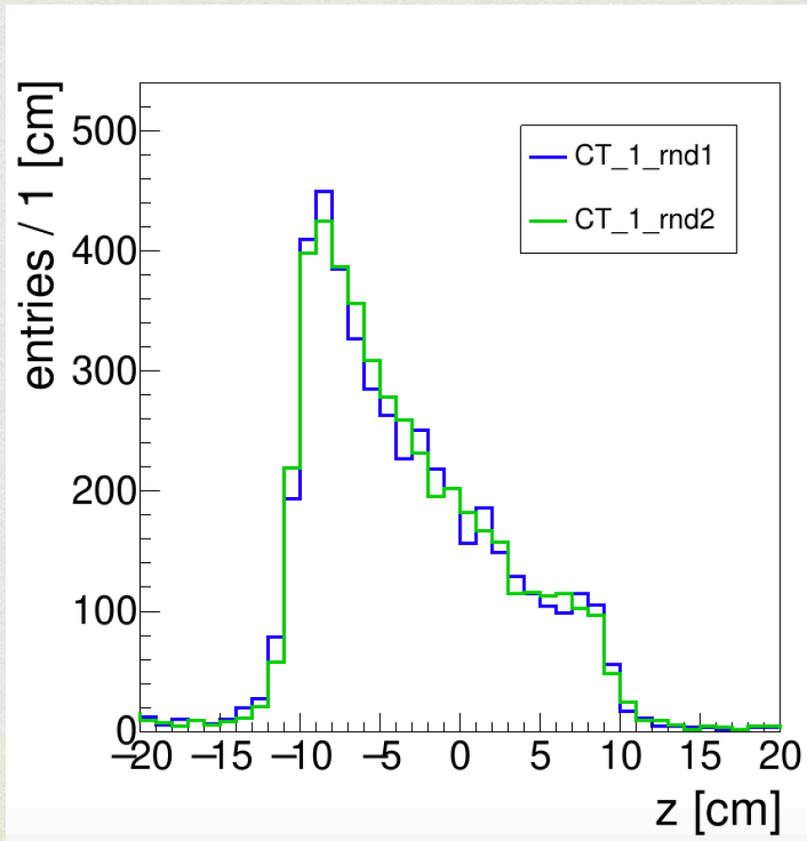
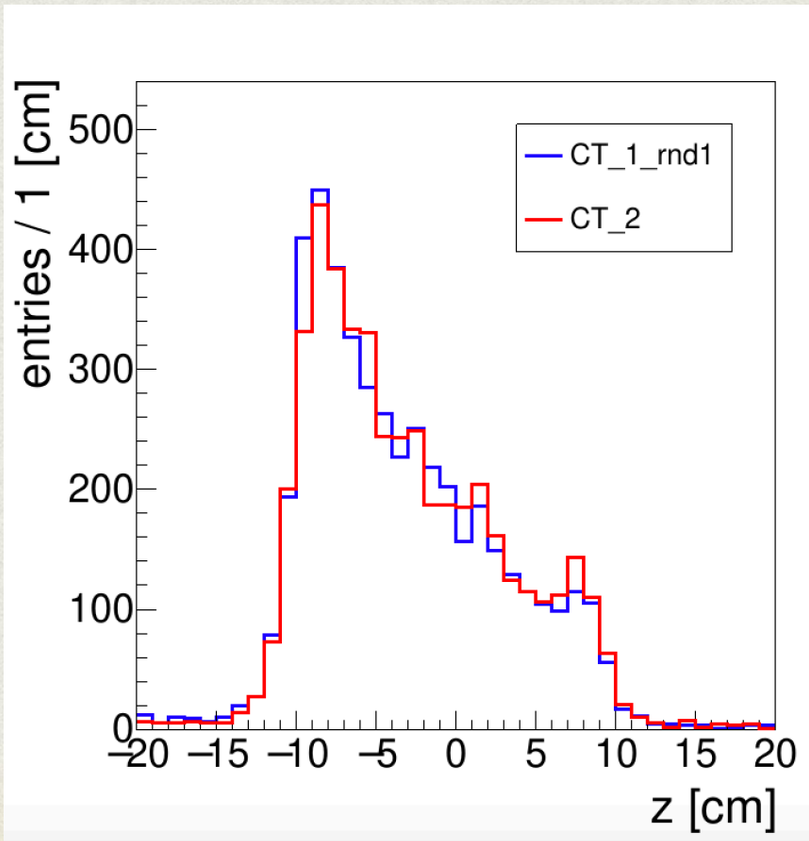




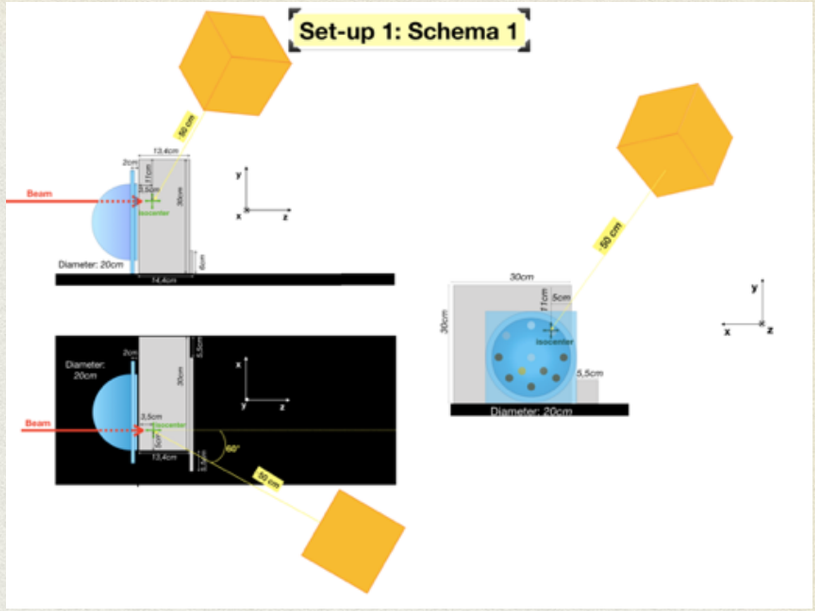


CONCLUSION

- The inter-fractional monitoring capability of the DP has been tested in the case of an ACC and the preliminary MC results seems to be promising
- As expected we are more sensitive in some fields due to the relative positioning of the DP wrt the target volume and the absorption inside the body
- A paper is in preparation documenting the DP capability on the basis of the FLUKA MC simulation

NEXT STEPS

- Perform the analysis of the data collected at CNAO @ end of 2018 with “phantom" with insets of different density



- Finalize the study of B1 of a different patient where no sensitivity to the toxicity was observed -> redo the study with the proper “CT morphing” and check the results
- Beautify the plots and finish the article preparation