IMPROVING GRETINA/GRETA PERFORMANCES VIA NEUTRON DAMAGE CORRECTION

MARCO SICILIANO
Argonne National Laboratory
Physics Division

4th AGATA-GRETINA/GRETA Collaboration meeting
ANL, 20-22 November 2024

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(TENTATIVE) NEUTRON DAMAGE CORRECTION FOR GRETINA/GRETA

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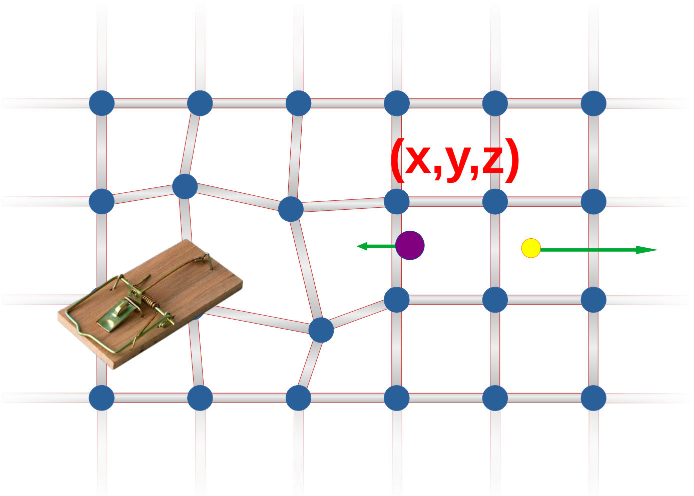
Neutron Damage

The interaction of fast neutron with germanium crystals induces lattice defects, which acts as efficient **charge-carrier traps**.

The effects can be worsened by thermal or power cycles.



Problem typically solved by “cooking” (aka annealing) the HPGe crystal, restoring the lattice structure.

- ✗ Limited number of iterations, due to the diffuseness of passivation layer
  (change of energy bands, reduction of the *intrinsic* volume)
- ✗ For segmented detectors, dangerous procedure for the delicate electronics

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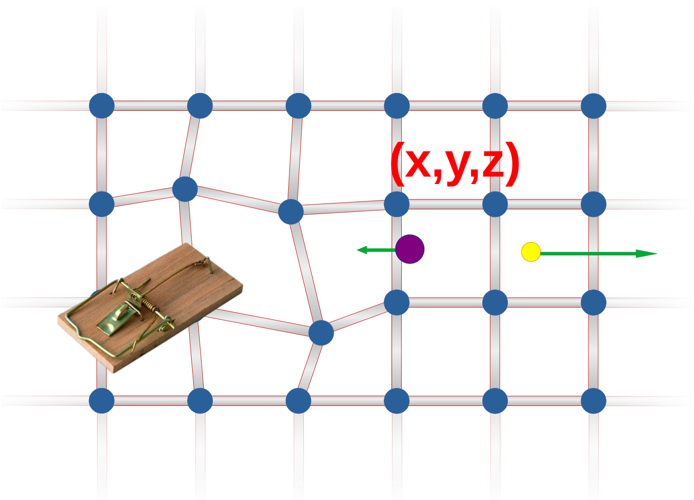


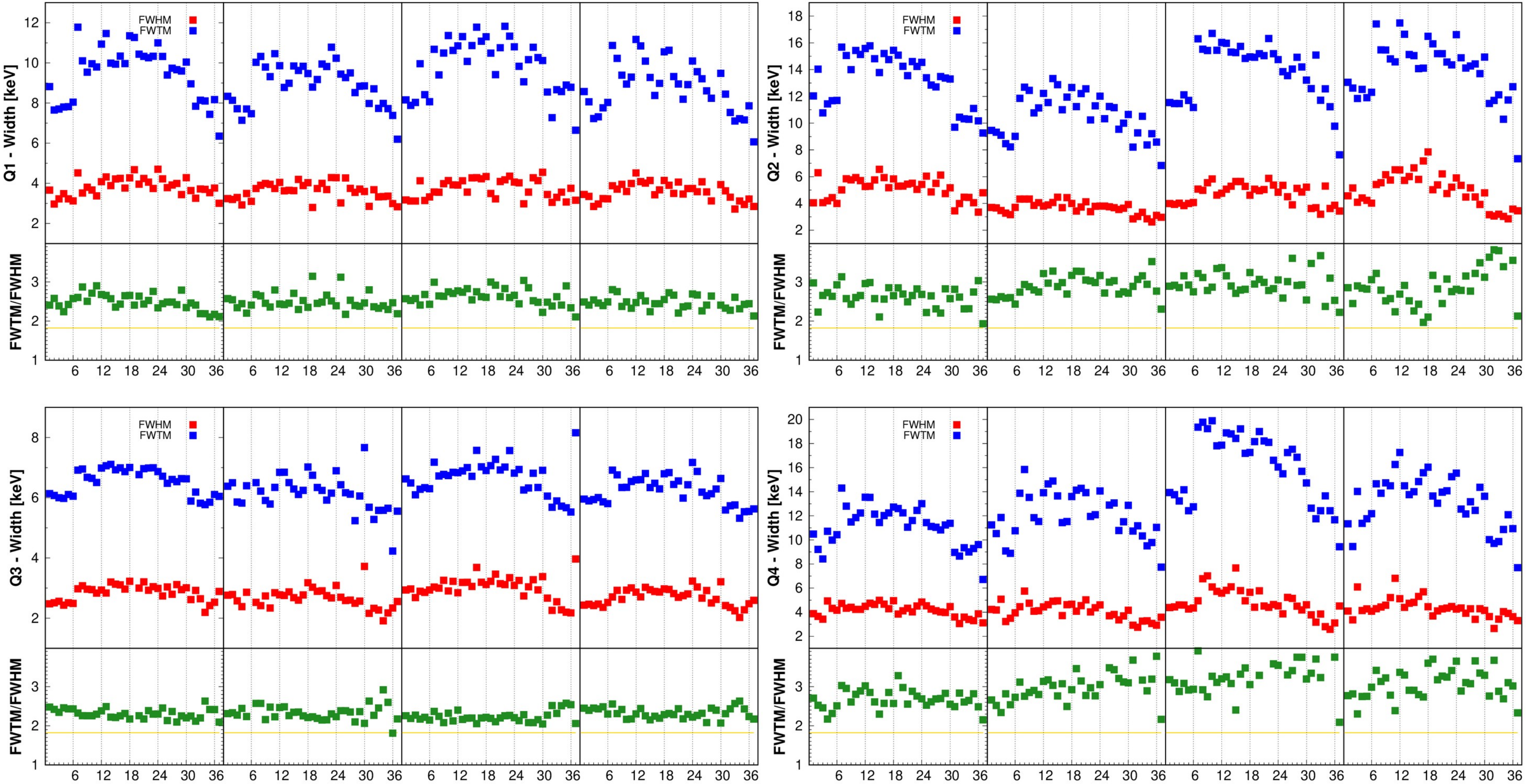
Taking advantage of the position sensitivity to correct the effects of the neutron damages

The amplitude of the signal (aka the energy) can be corrected by estimating the mean-free path of the charge carries.

In general, holes are more affected by the presence of lattice defects.

Depending on interaction-point position, the probability for electrons and holes to be trapped change drastically.

GRETINA performances (December 2021)



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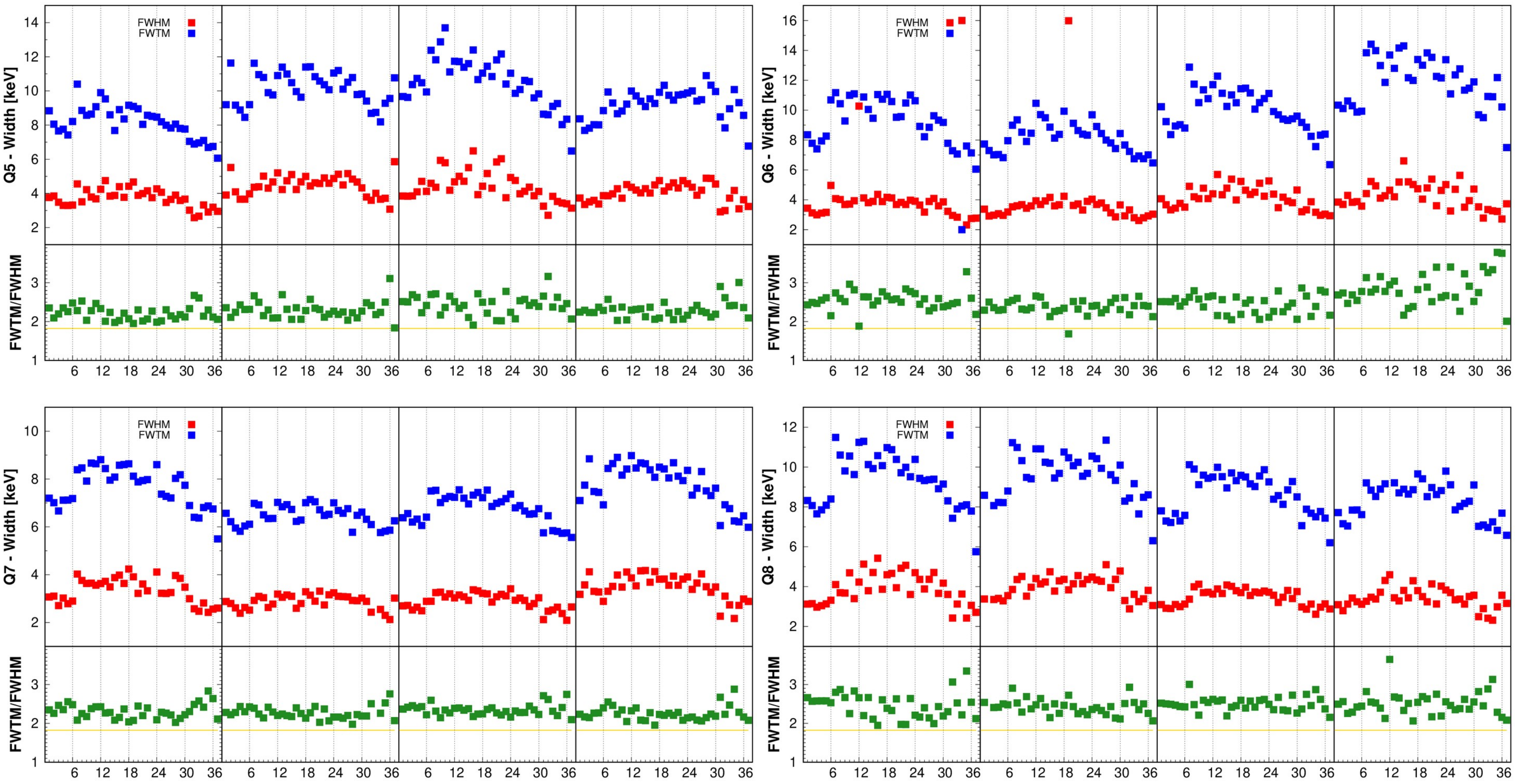

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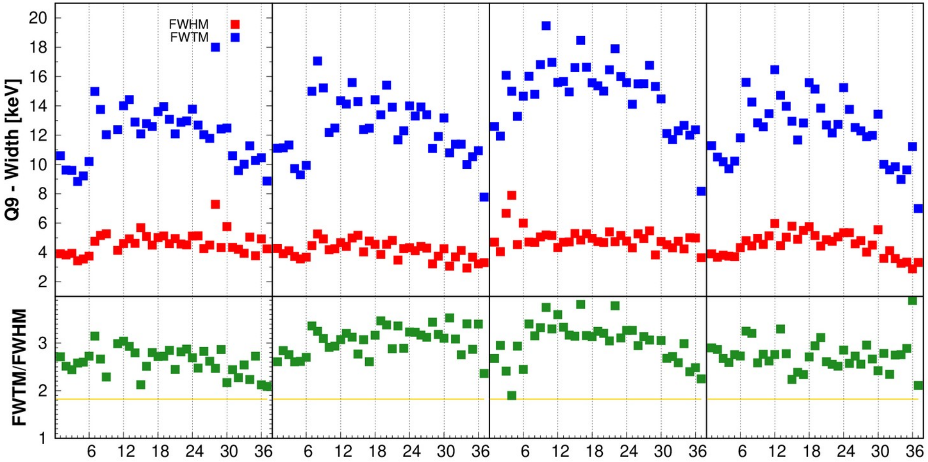

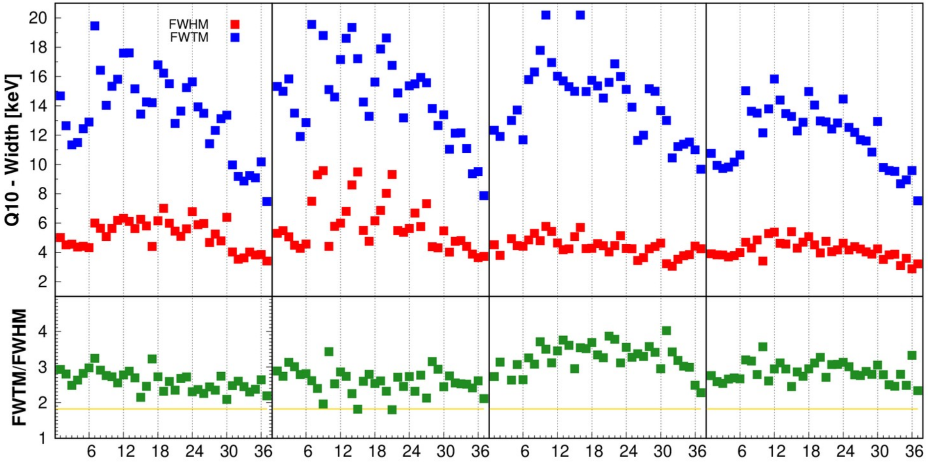

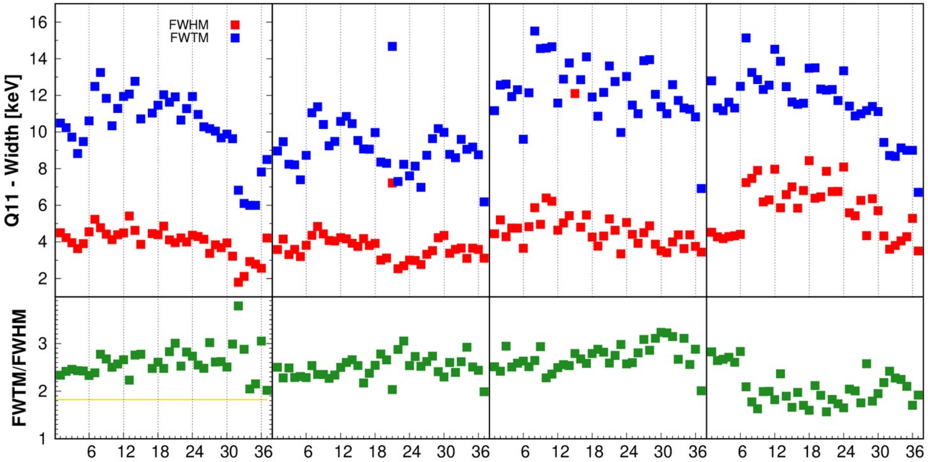

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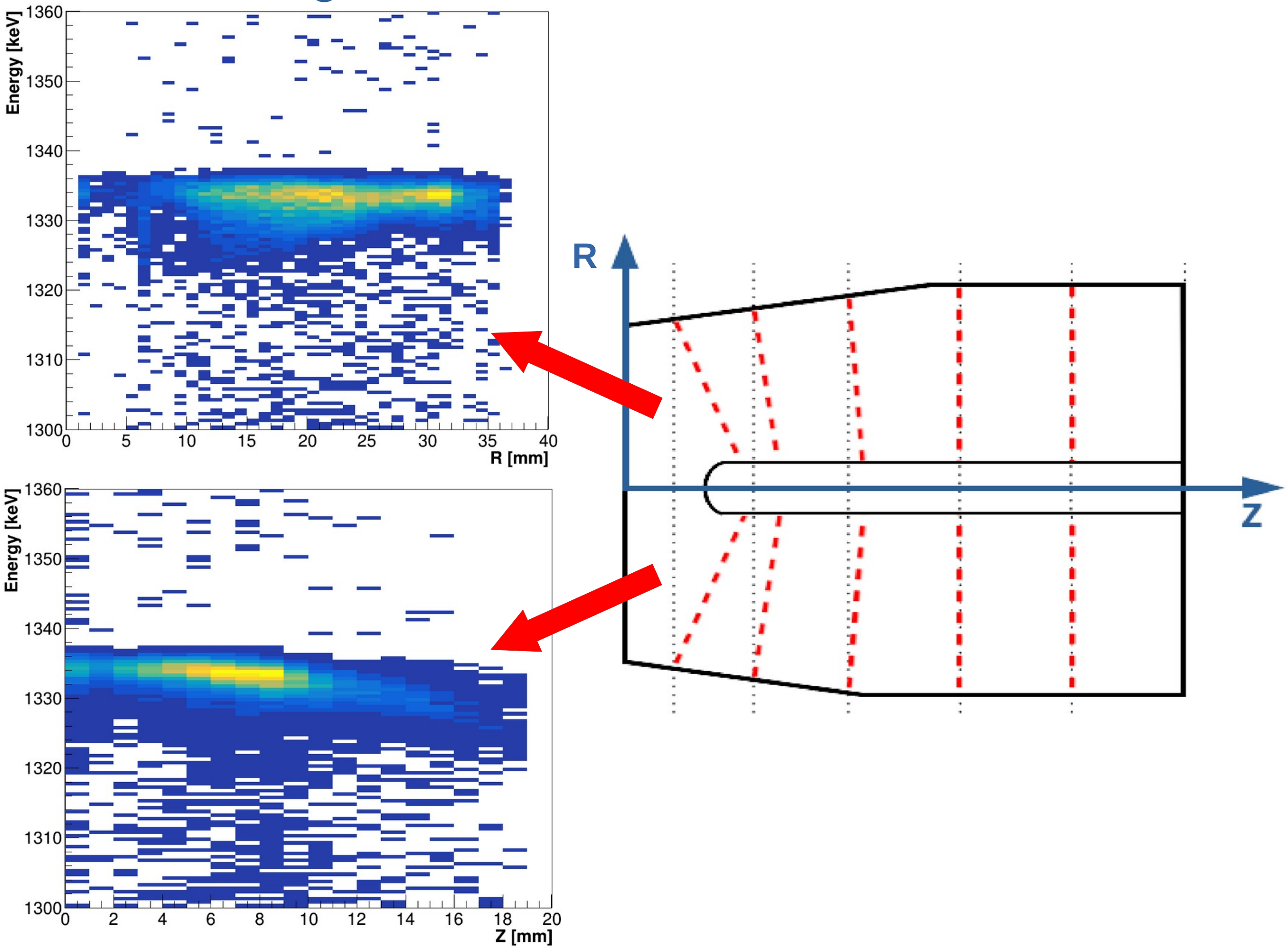
Neutron Damage vs Position



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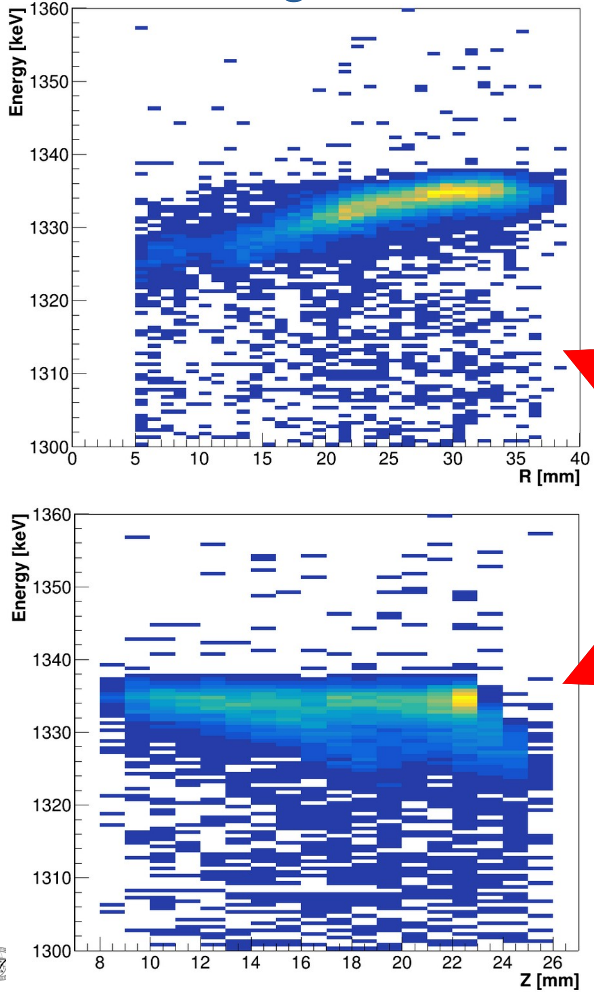

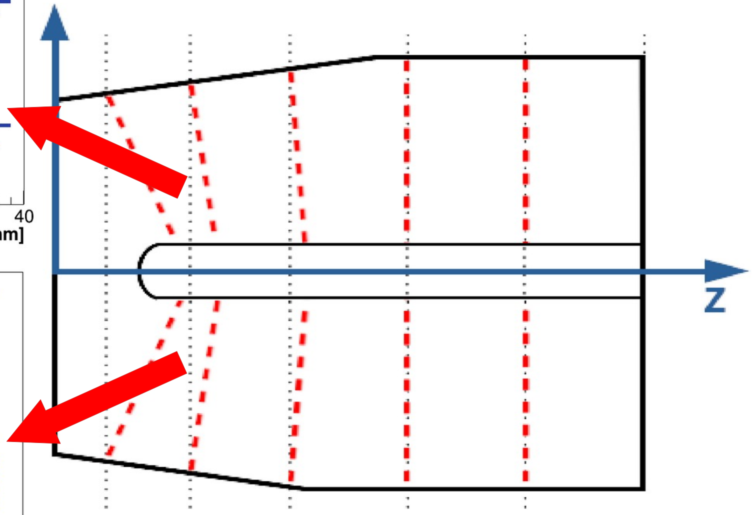

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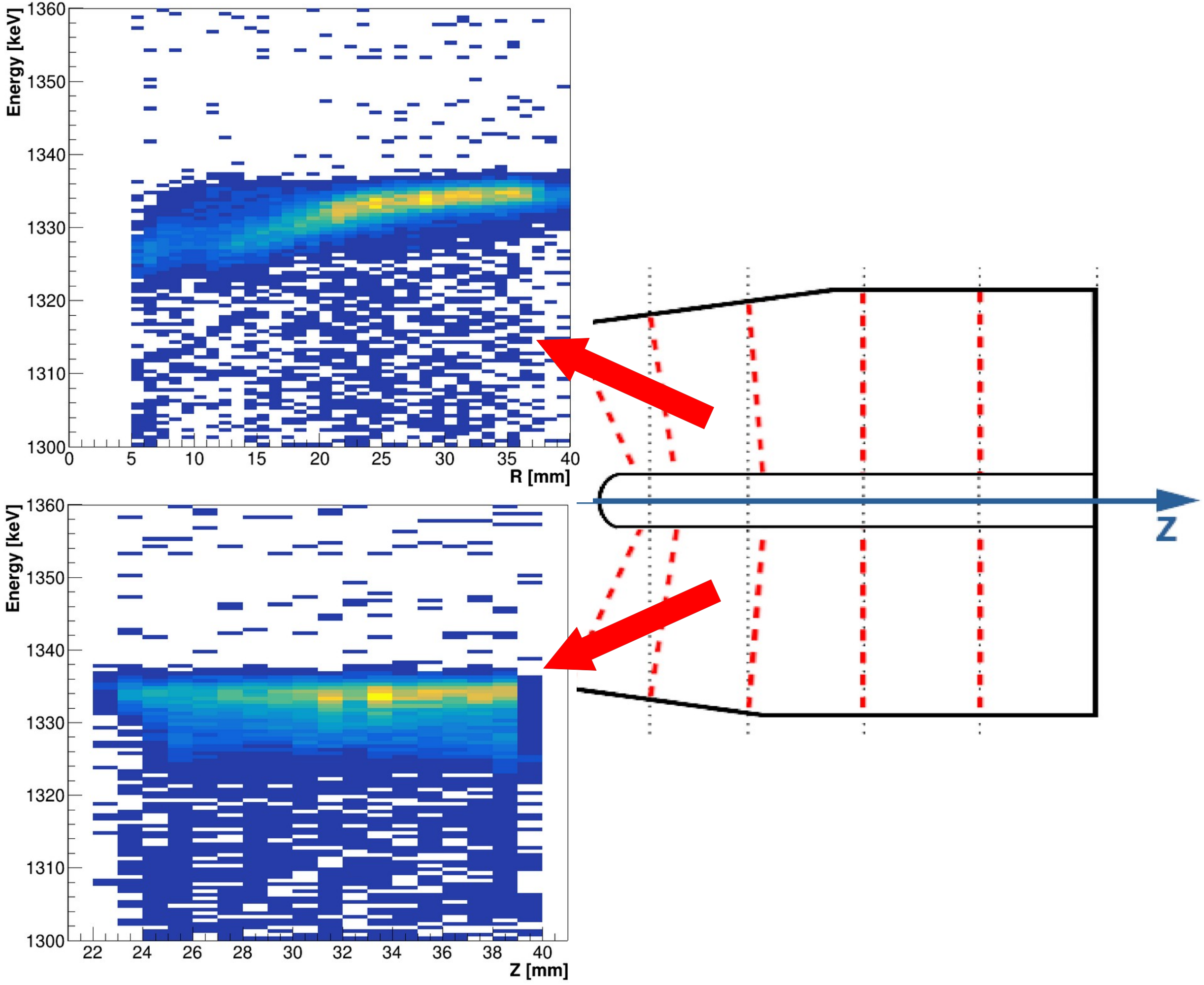

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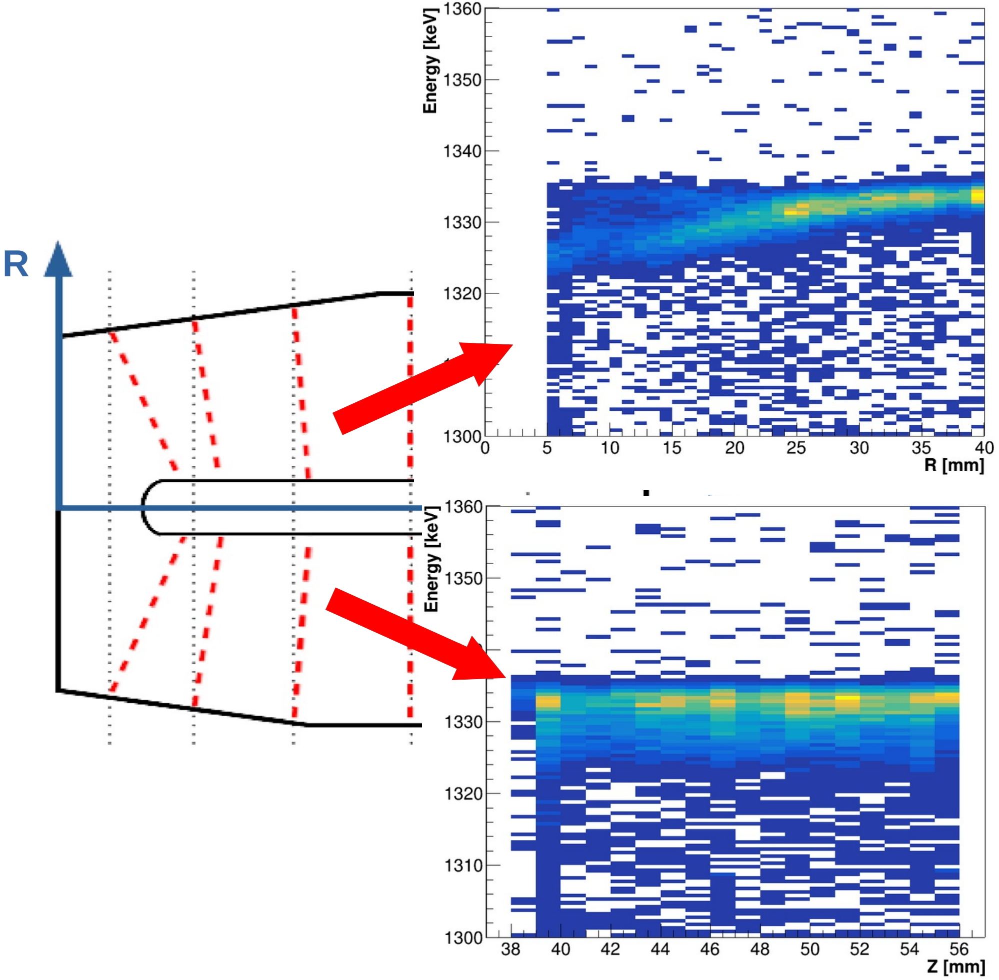

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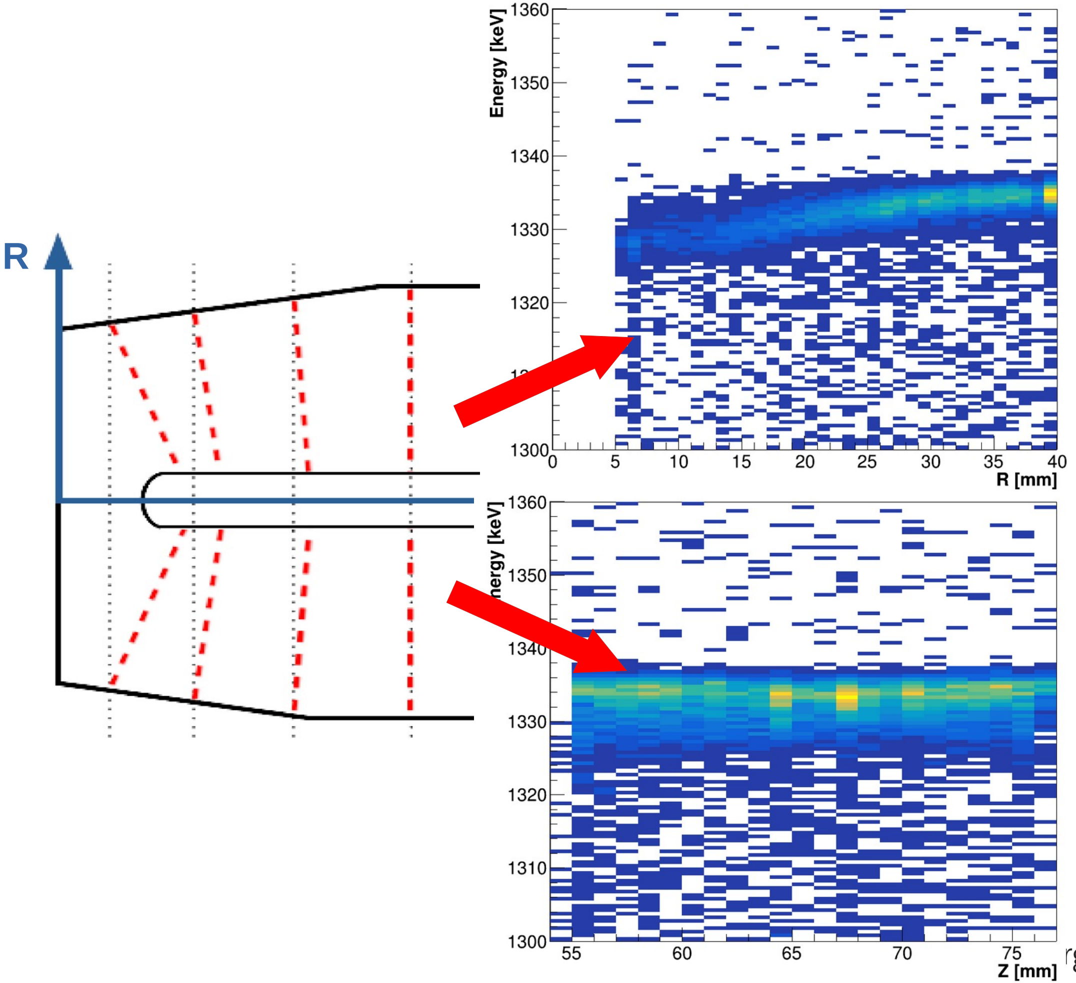

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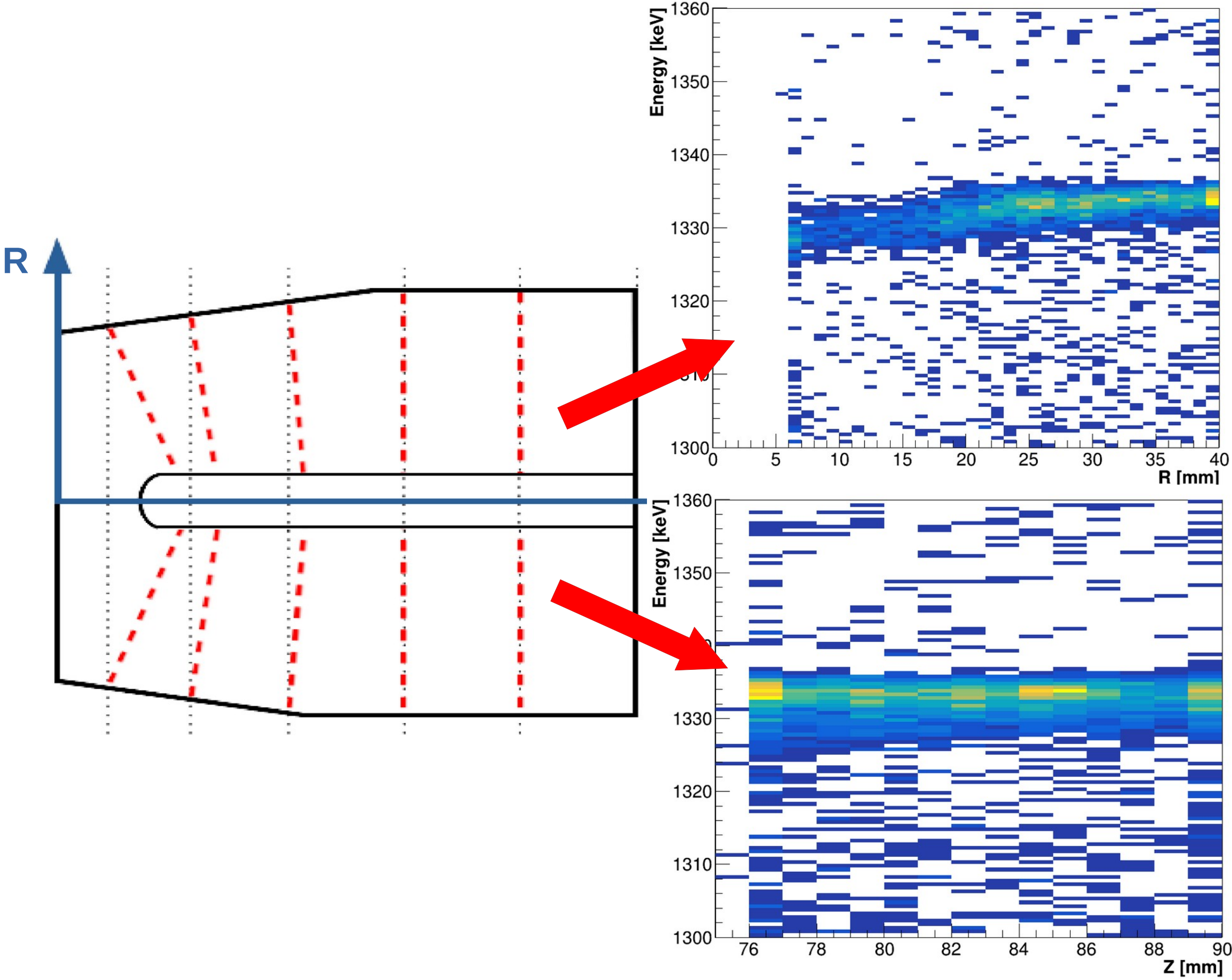

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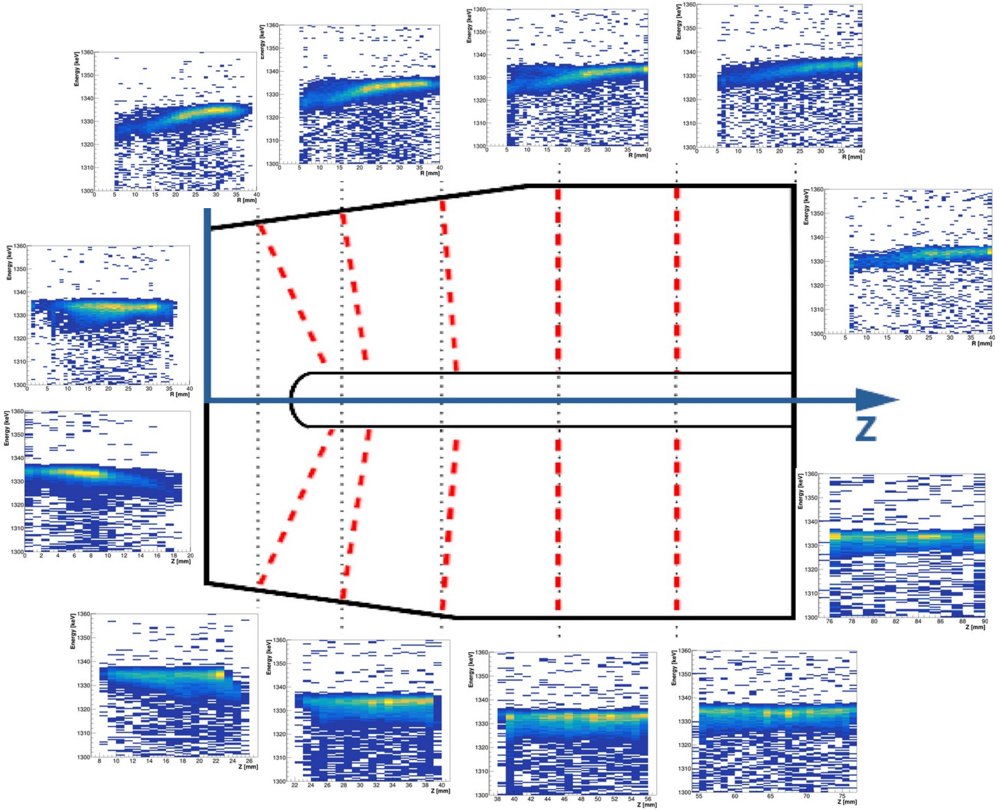


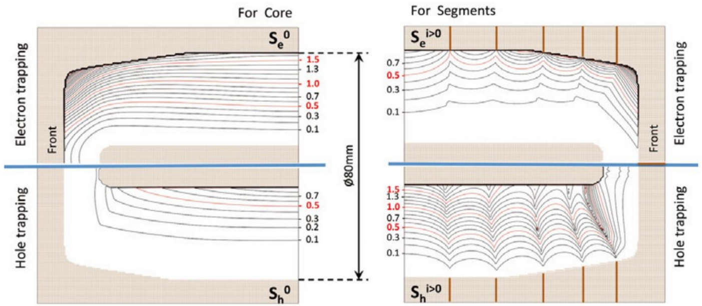
$$E = f\left(E_0, \vec{r}\right)$$

Introducing the possibility of trapping in the description of the detector electric field.

- Account for the different effect on the charge carriers

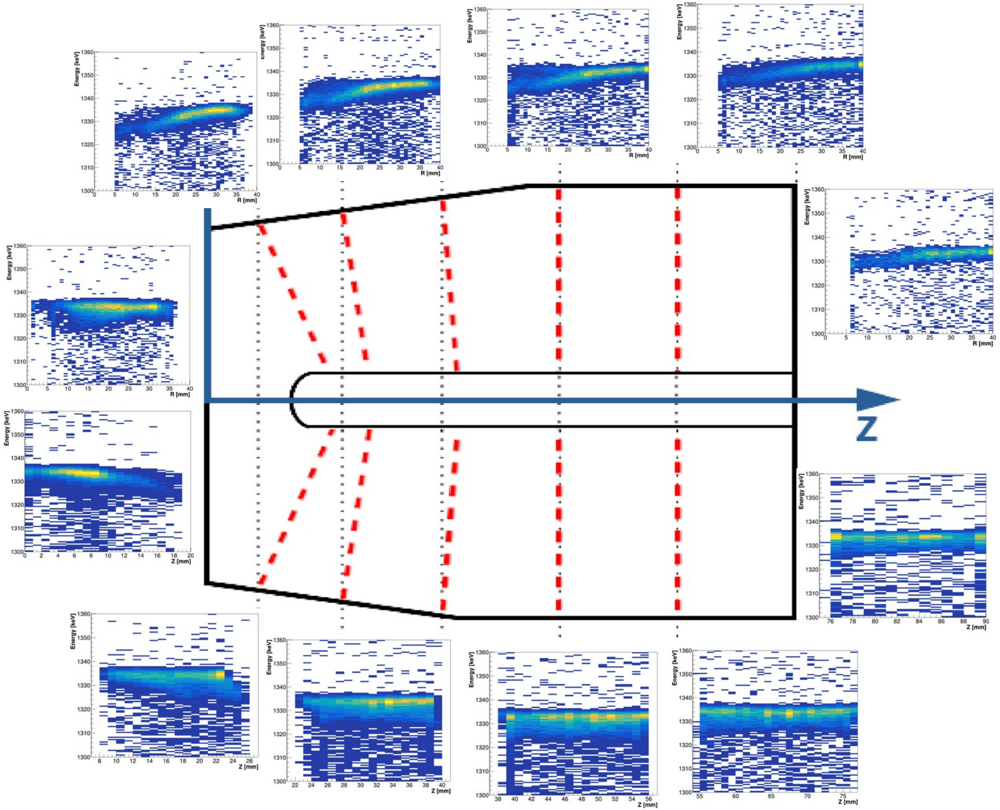
- A scalable "sensitivity field" permits to simplify the correction

$$\eta^i_{tot}\left(\vec{r}_0\right) = 1 + \left[N_e s^i_e\left(\vec{r}_0\right) + N_h s^i_h\left(\vec{r}_0\right)\right] + \ldots$$



B. Bruyneel et al., *Eur. Phys. J. A* ***49*** *(2013) 61*

Neutron Damage vs Position



$$E = f\left(E_0, \vec{r}\right)$$

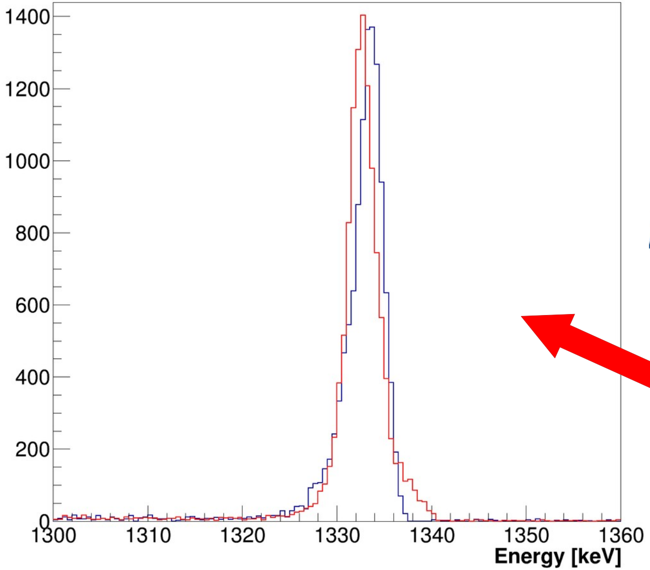
Empirical correction based on the collected source data.

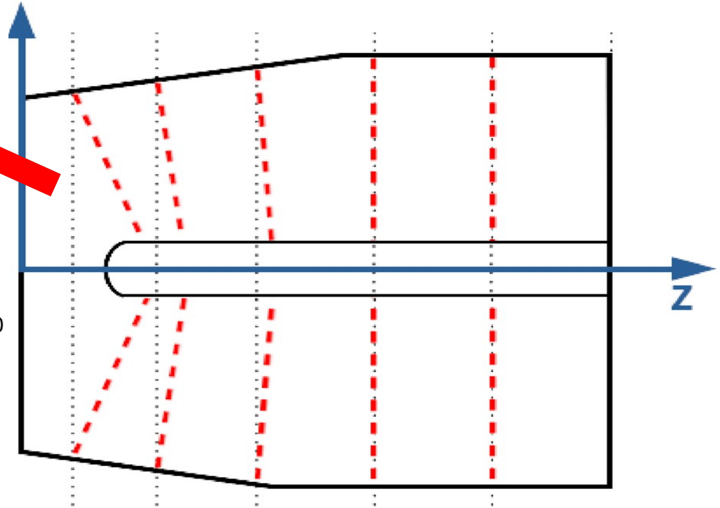
$$E = E_0 \cdot f\left(\vec{r}\right)$$

✔ The correction is not "constrained" by the modeling of the detector response
✔ "customable"
✗ No sensitivity to the different charge carriers
✗ Extracting the correction requires very high statistics

$$E = E_0 \cdot p_n(R) \cdot p_m(z)$$

Neutron Damage vs Position





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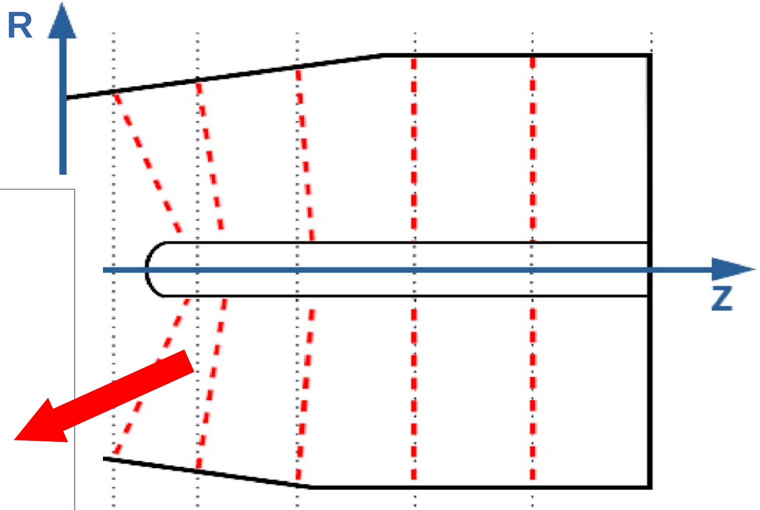

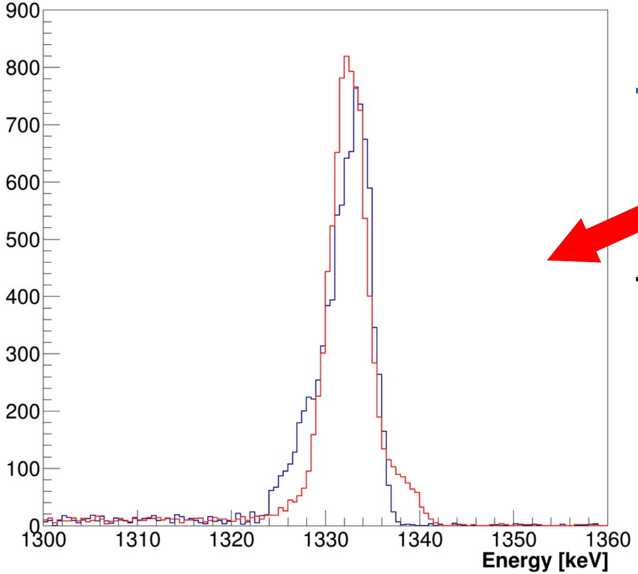

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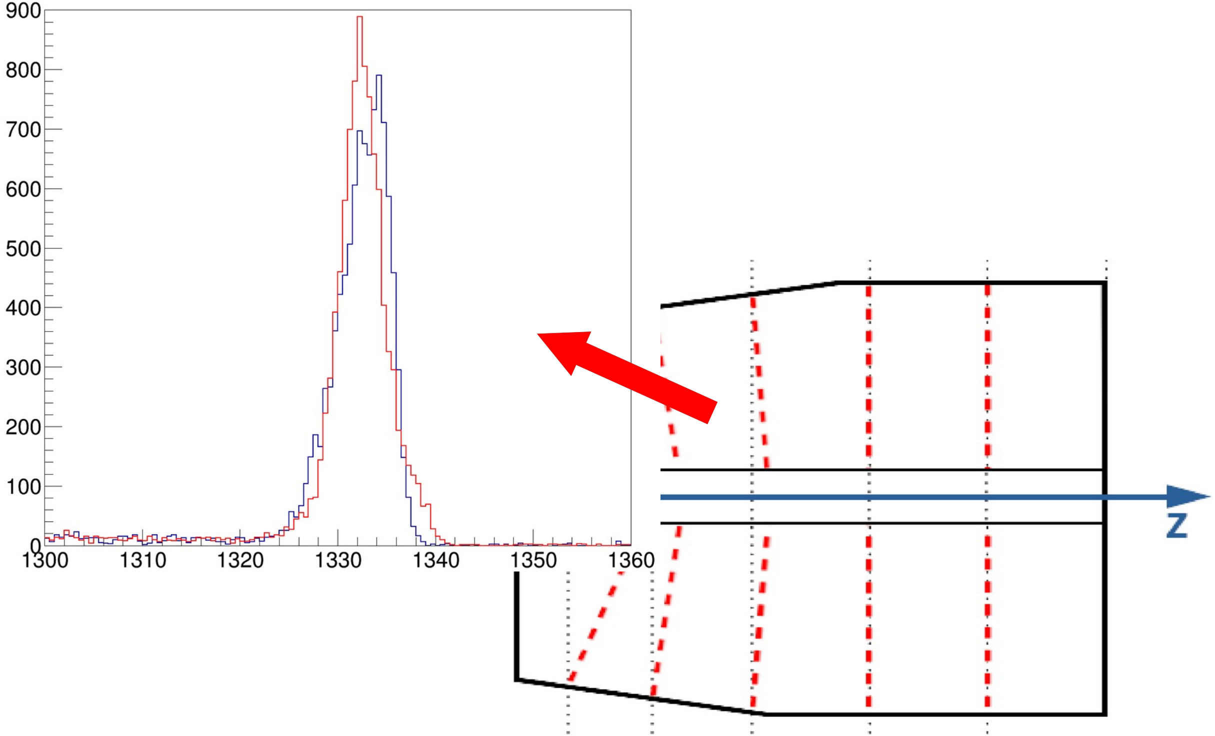

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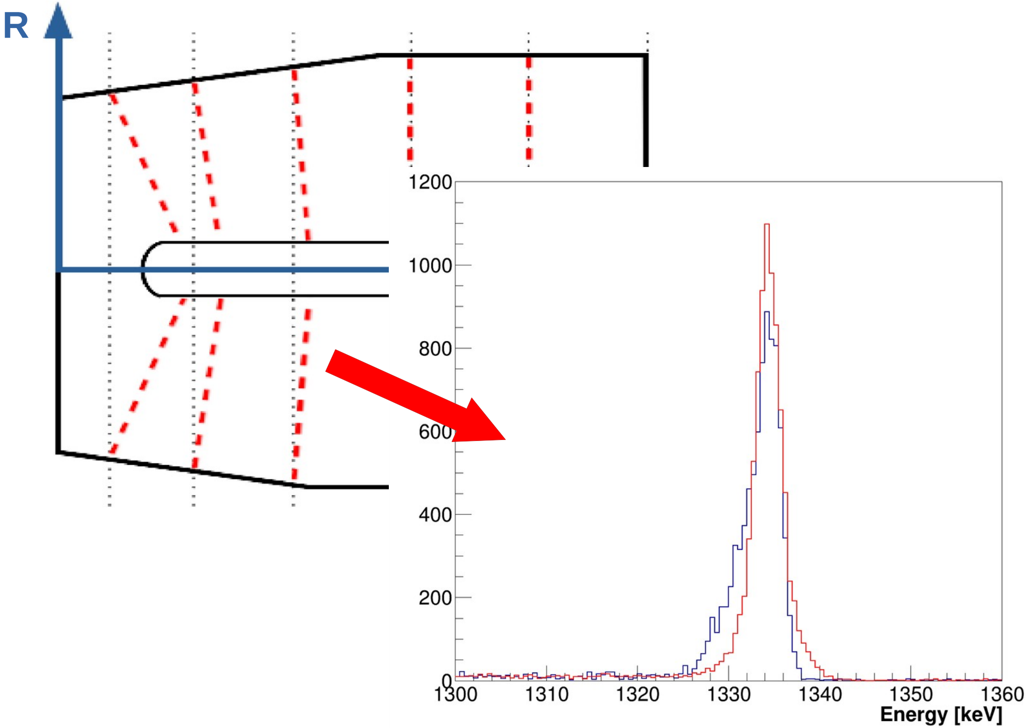

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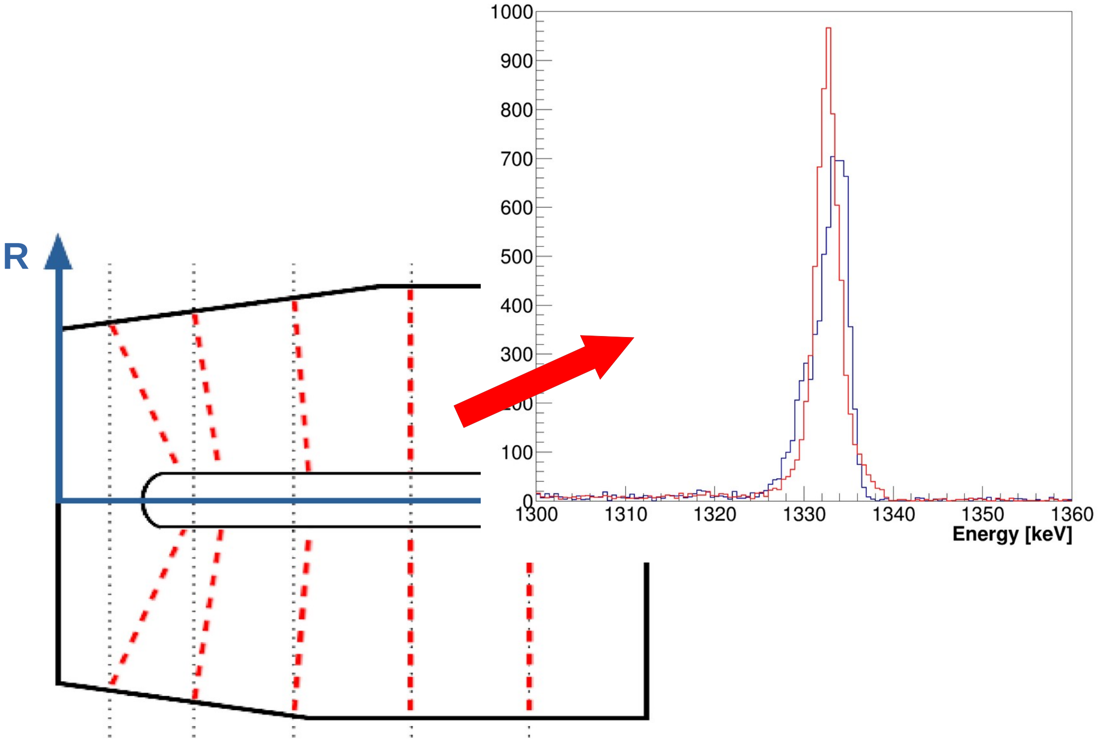

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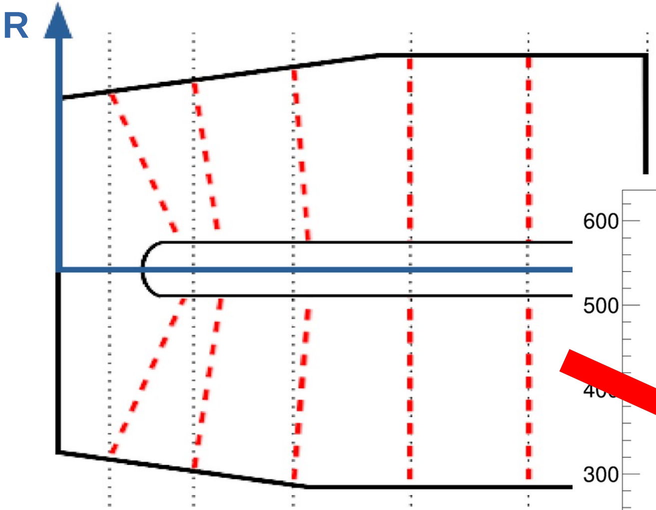
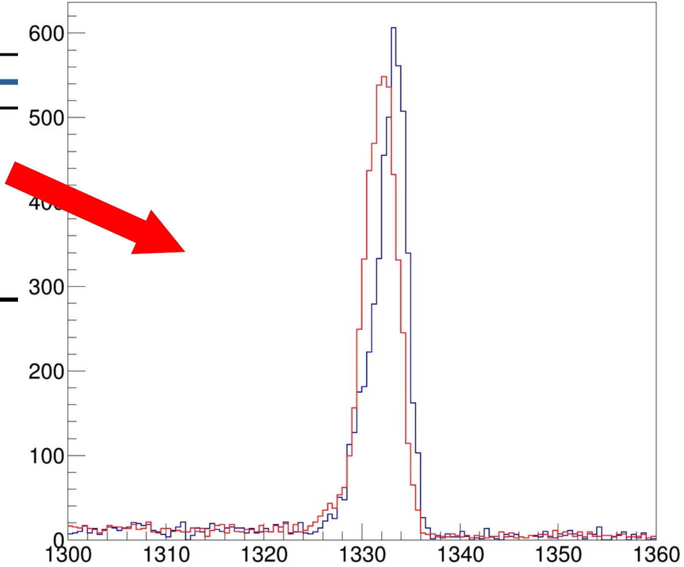




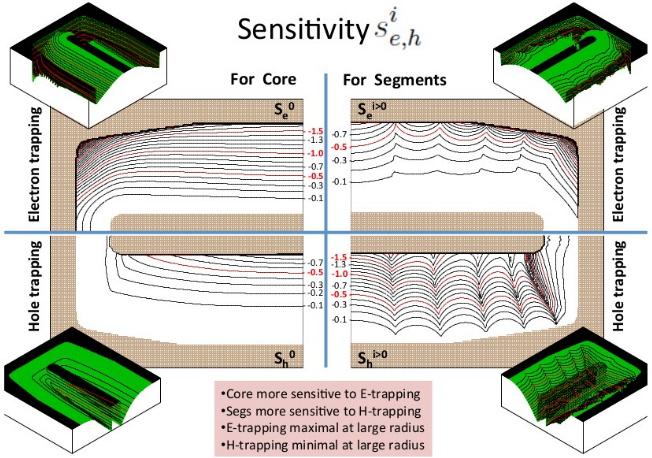
Further Work

- Preliminary results with the empirical neutron-damage correction are promising, but there is (a lot of) room for improvements
  - explore better solutions that account for both *R* and *z* position
  - even though the effects of the damage smaller, corrections for the CC should be explored

- Development of automated procedure

- Implementation on GRETINA/GRETA analysis code

- Treating electrons and holes separately
  - ✔ Shorter source runs
  - ✔ Finer correction



B. Bruyneel, EGAN school (2011)

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