CNAO2020 campaign simulation and status of FLUKA development

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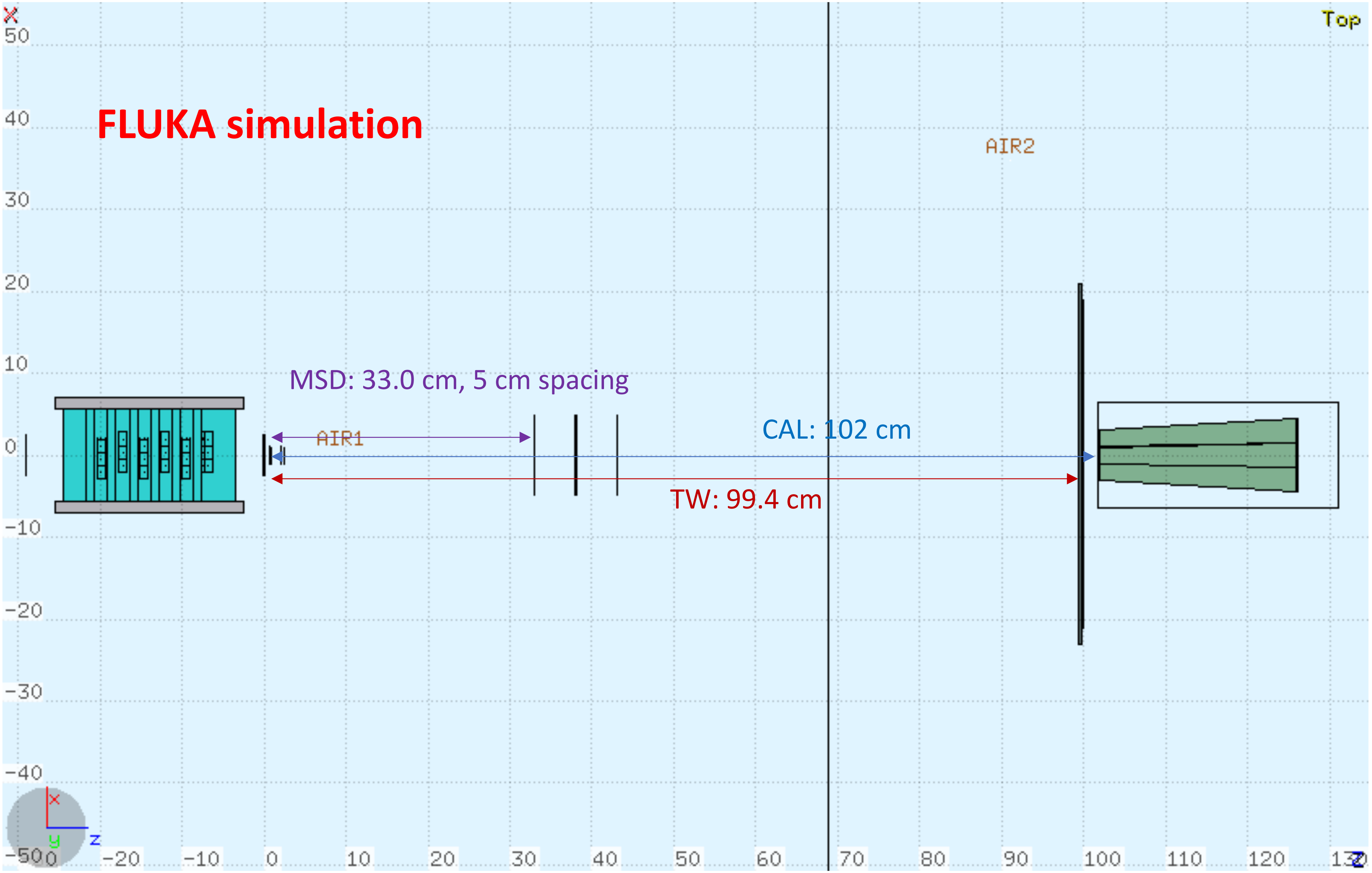
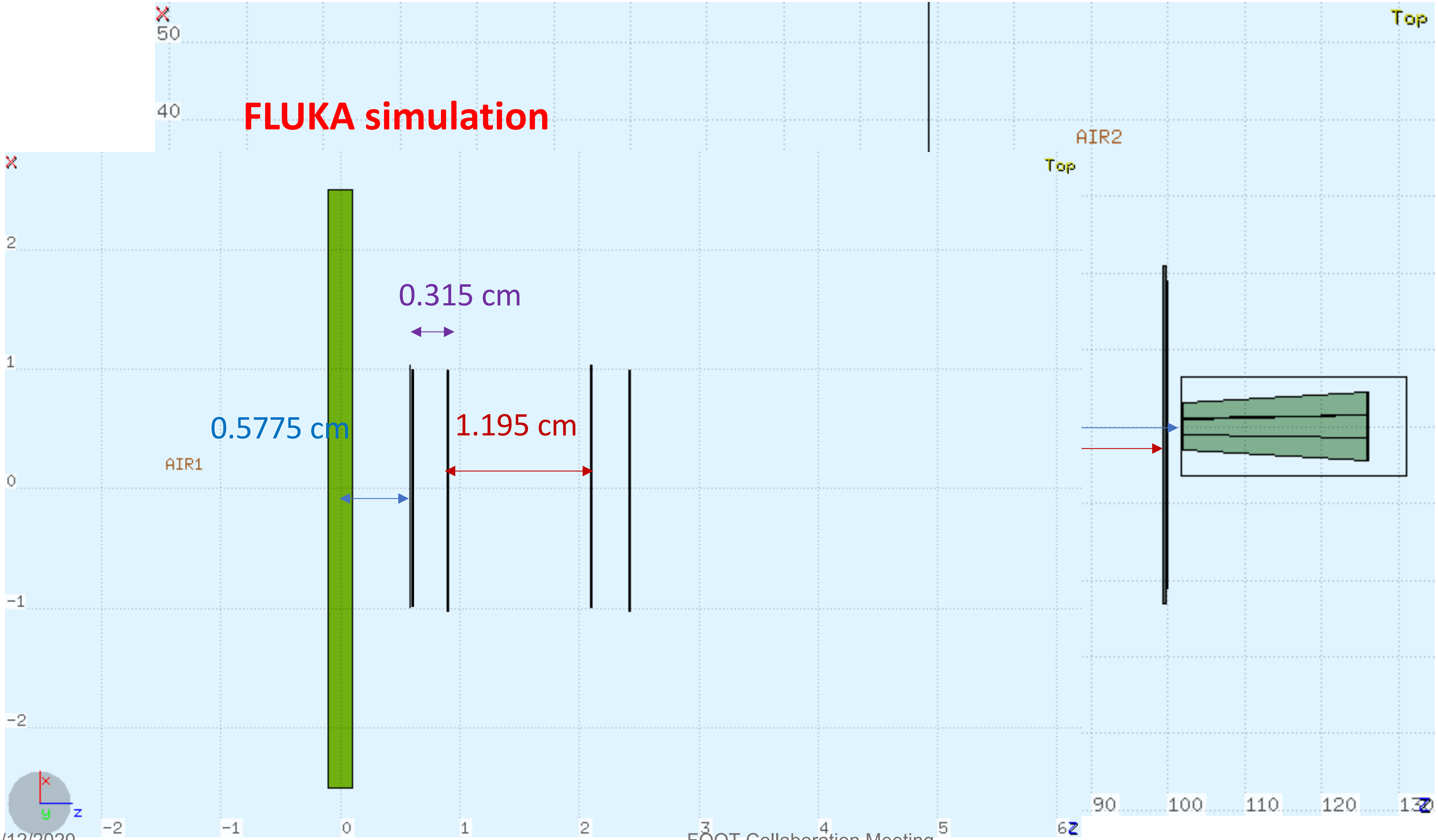
FOOT Collaboration Meeting

December 2020

Geometry: campaign CNAO2020



Geometry: campaign CNAO2020



Available files

usual root tree with the EVENT_STRUCT structure (~170 branches)

/gpfs_data/local/foot/Simulation/CNAO2020

^{12}C at 200 MeV/u on C (5 mm ρ=1.83 g/cm^3):

12C_C_200_1.root 10^7 primaries, 284246 events on file

^{12}C at 200 MeV/u on C_2H_4 (5 mm ρ=0.94 g/cm^3):

12C_C2H4_200_1.root 10^7 primaries, 198215 events

12C_C2H4_200_2.root 10^7 primaries, 197621 events

Warning: for the time being we have not activated e^+e^-/γ transport

CNAO2020 Campaign

In both *master* and *newgeom* branches of SHOE the campaign switch CNAO2020 is available

For example, MC data should be readout using:
yourpath/bin/DecodeMC –exp CNAO2020 –run 1

Available files

***Shoe** root tree*

New!!

/gpfs_data/local/foot/Simulation/CNAO2020

^{12}C @ 200 MeV/u on C (5 mm ρ=1.83 g/cm^3):

12C_C_200_1_shoe.root

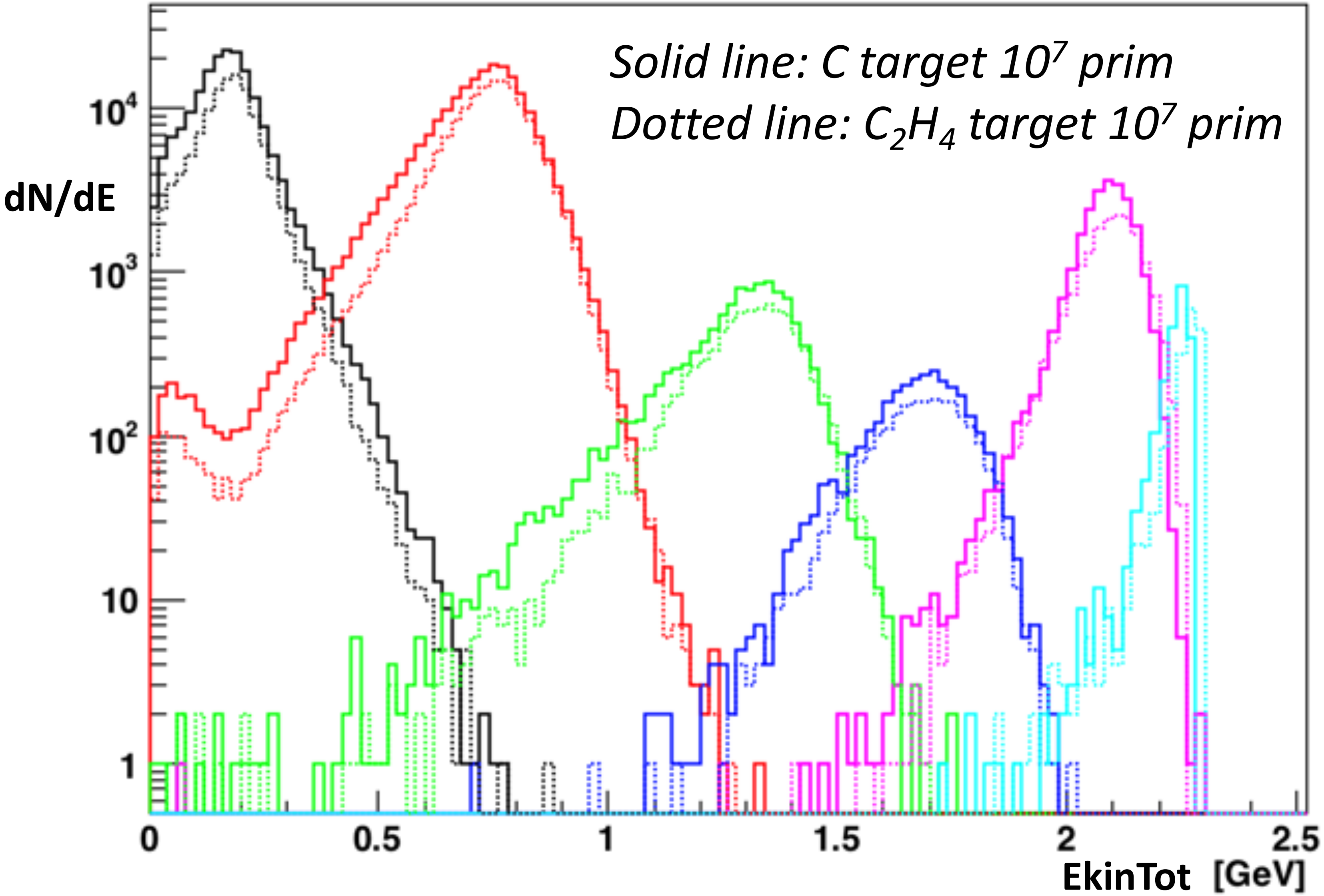
^{12}C @t 200 MeV/u on C_2H_4 (5 mm ρ=0.94 g/cm^3):

12C_C2H4_200_1_shoe.root
12C_C2H4_200_2_shoe.root

In the future the SHOE root-ple files will be always be produced directly and shared for everybody

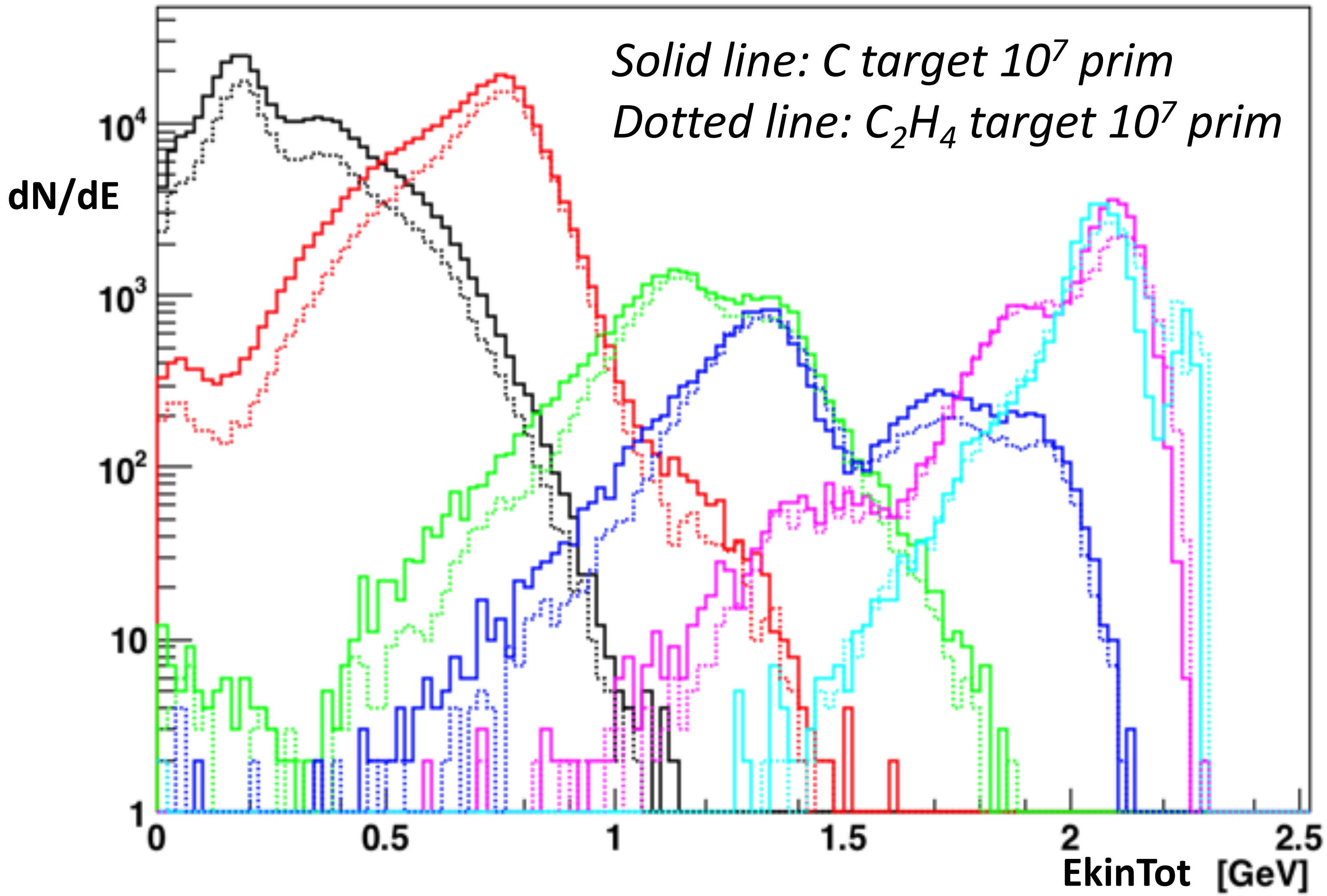
Preliminary checks

dN/dE for fragments of different Z (**1st generation**) arriving at TW



Preliminary checks

dN/dE for fragments of different Z (All generations) arriving at TW



Preliminary checks: re-interactions

In ~4.4% of events there is at least one secondary fragment interacting on VTX

In ~1.5% of events there is at least one secondary fragment interacting on MSD

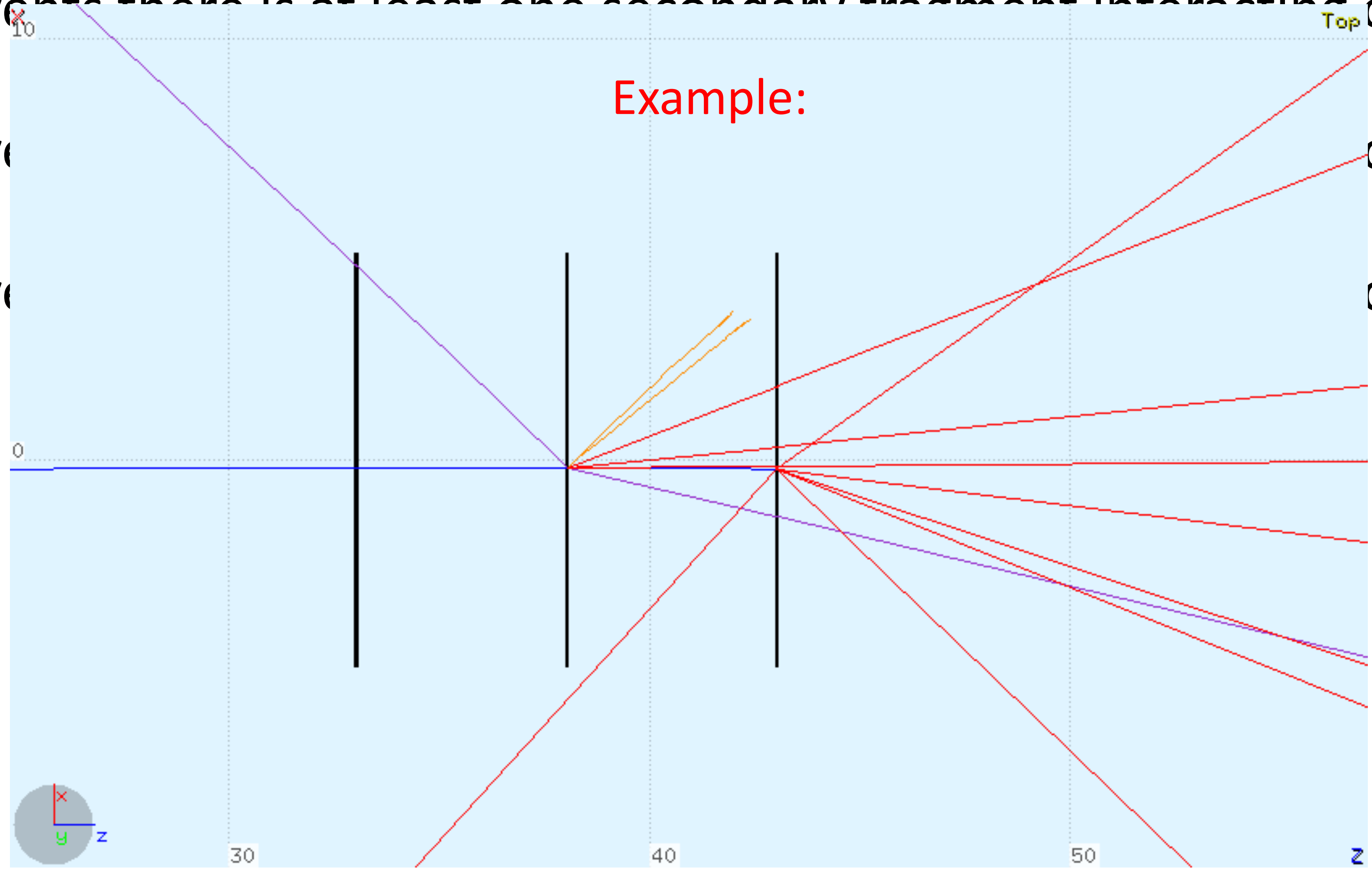
In ~5.9% of events there is at least one secondary fragment interacting on SCN

Preliminary checks: re-interactions

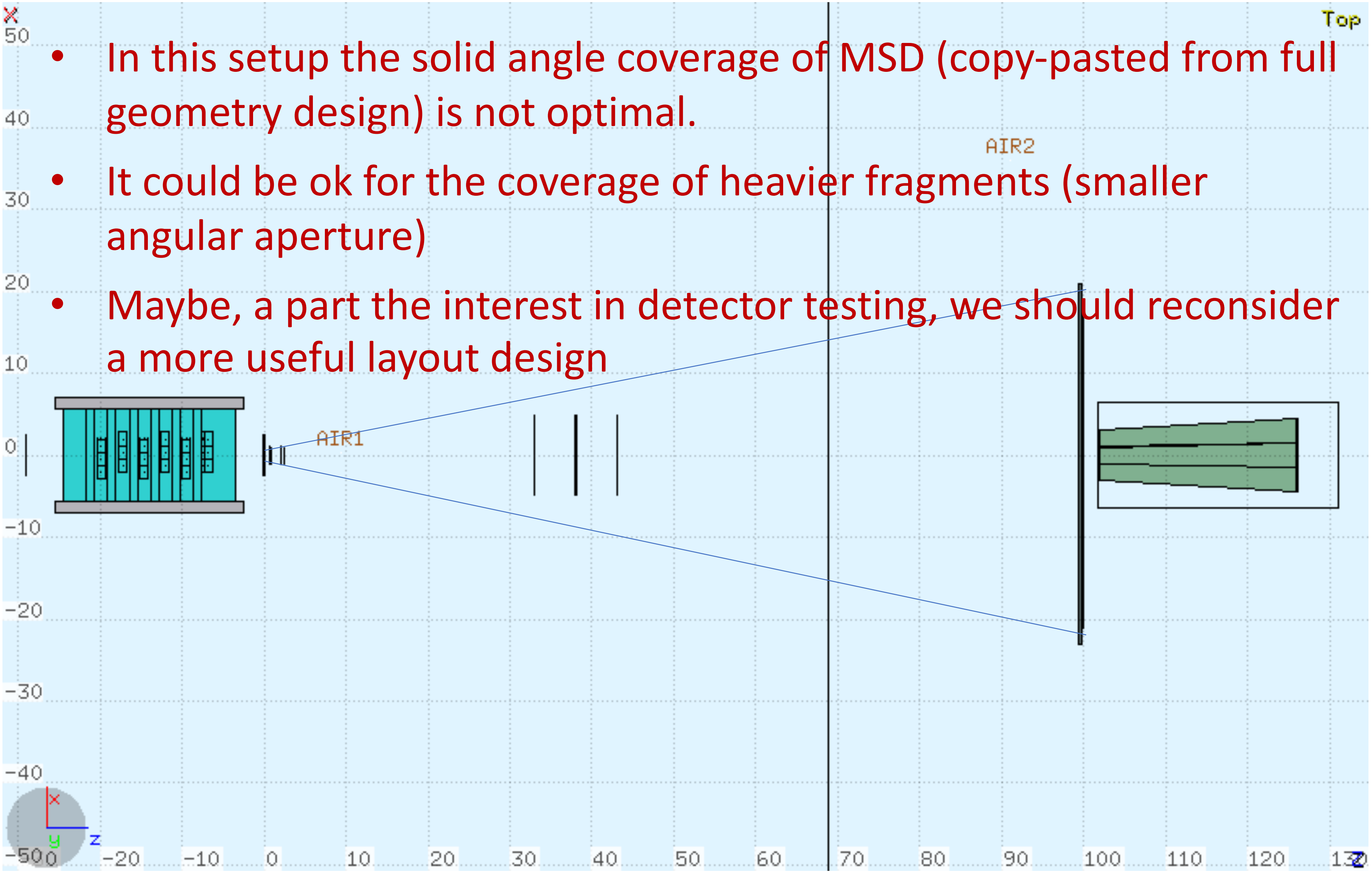
In ~4.4% of events there is at least one secondary fragment interacting on VTX

In ~1.5% of eve … on MSD

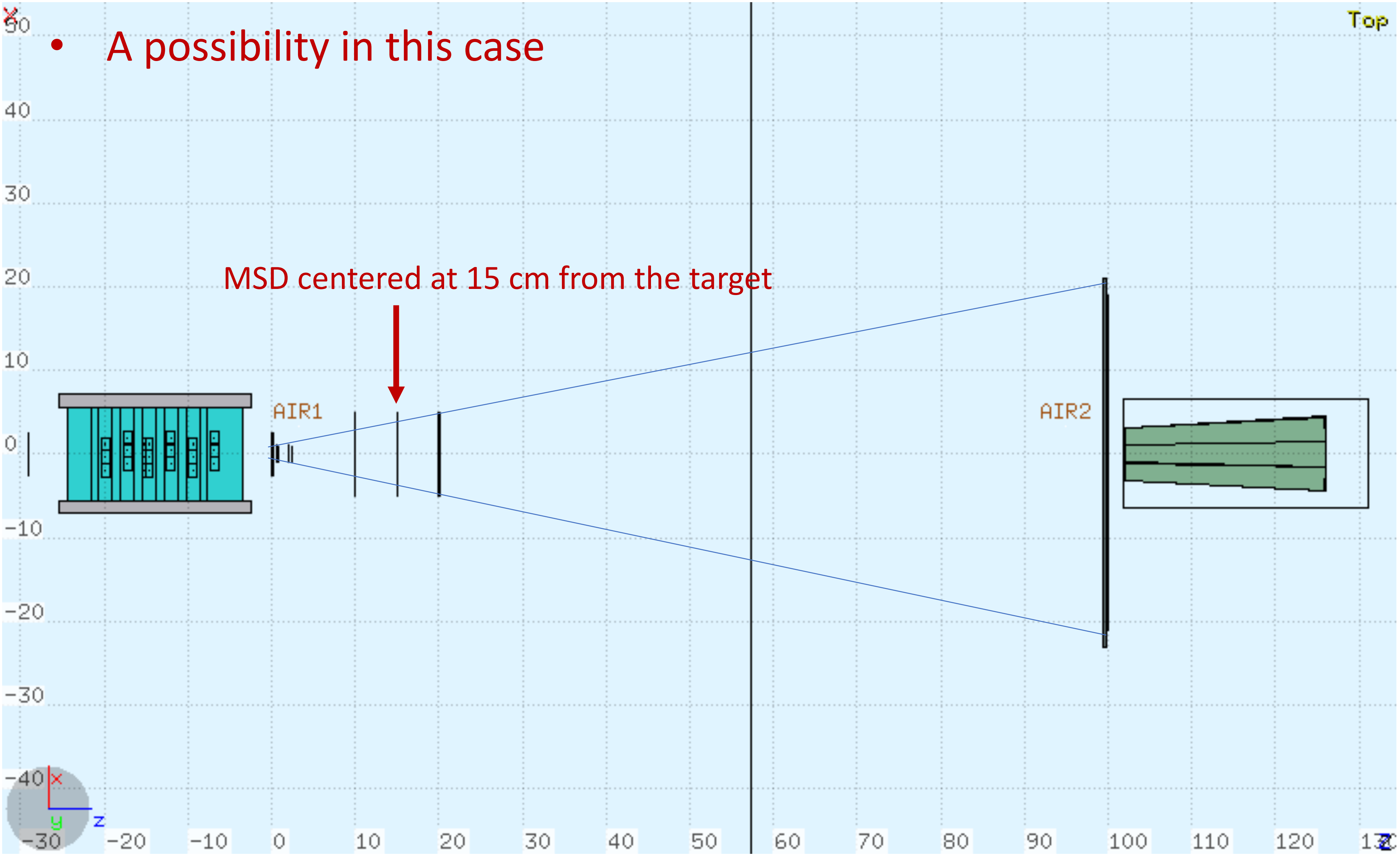
In ~5.9% of eve … on SCN



- In this setup the solid angle coverage of MSD (copy-pasted from full geometry design) is not optimal.
- It could be ok for the coverage of heavier fragments (smaller angular aperture)
- Maybe, a part the interest in detector testing, we should reconsider a more useful layout design



- A possibility in this case



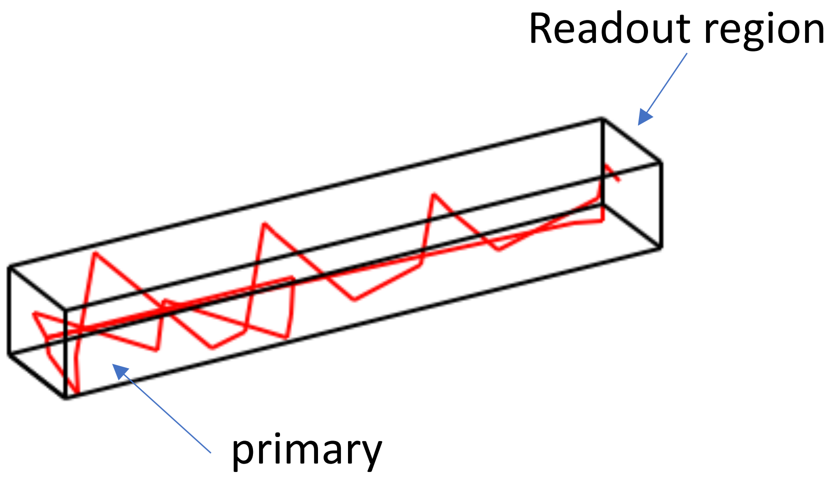
New work in progress

Simulation of light propagation in BGO crystals (To, L. Scavarda)

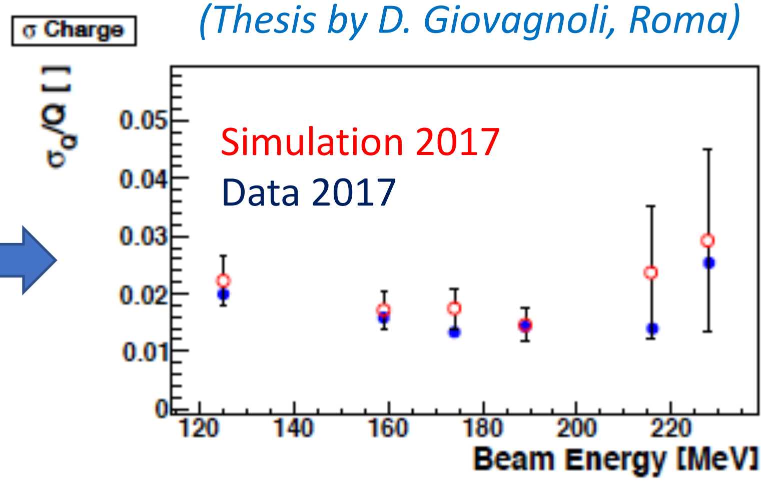
Purpose: understand the mechanism underneath the results of latest test beam results

Difficulty: determine the correct parameters for light absorption, refraction, diffusion and reflection of different materials (BGO, Tyvec), and their possible dependence on wave-length (+ detection efficiency, etc.)

Starting point: work done for a BGO test in *“PhoSwich”* configuration performed in Trento in 2017



BGO+scint charge resolution vs proton energy
(Thesis by D. Giovagnoli, Roma)

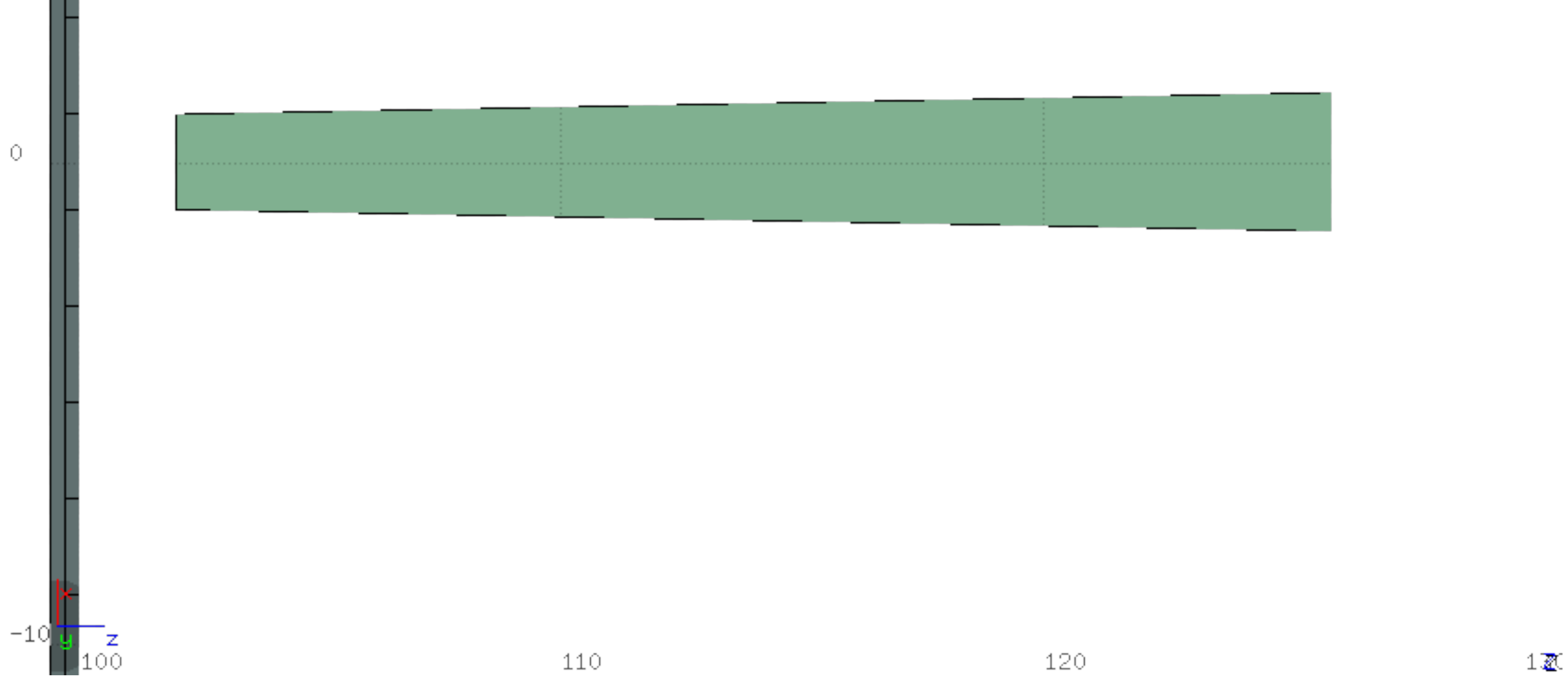


Some FLUKA developments of possible interest for FOOT

- Geometry of pyramids (already in production, not yet used in FOOT)
- Improvement of low energy neutron cross sections
- Neutrons from spontaneous fission
- Elastic scattering model
- In flight nuclear γ-decays
- New features for optical photon simulations

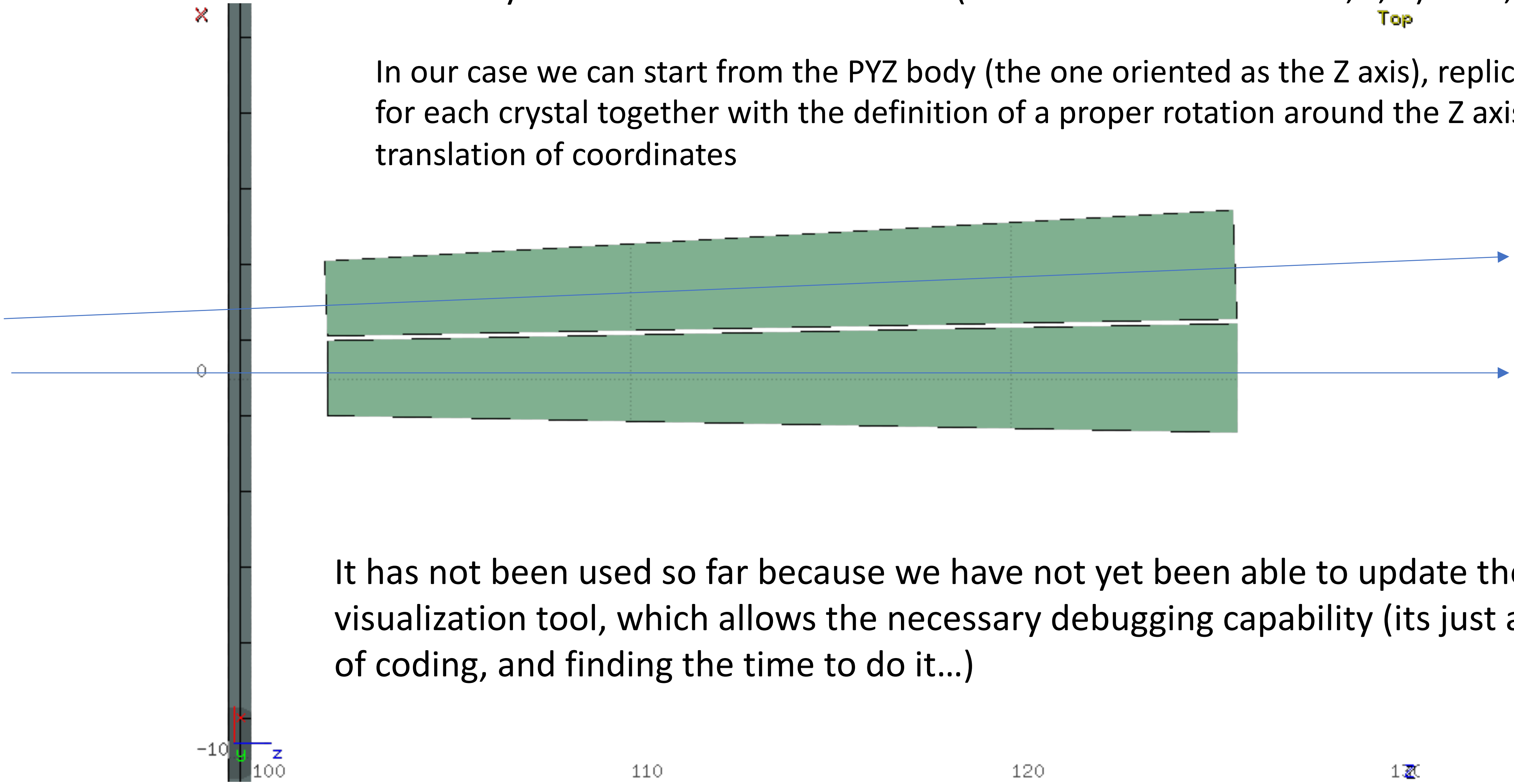
In the development version, not publically distributed yet

As already announced time ago, a new pyramidal body is available (after FOOT request)
It would allow to define one of our crystals withous using 6 planes, as we are currently doing: it would be a significant simplication in geometry management



The body is defined in 3 orientations (one for each main axis X, Y, Z): PYX, PYY, PYZ

In our case we can start from the PYZ body (the one oriented as the Z axis), replicate it for each crystal together with the definition of a proper rotation around the Z axis and translation of coordinates



It has not been used so far because we have not yet been able to update the visualization tool, which allows the necessary debugging capability (its just a problem of coding, and finding the time to do it…)

Improvement of low-energy neutron cross-sections - 1

There has been a lot of work towards the overcome of the "Multigroup" treatment of neutrons for E<20 MeV *(thanks also to C. Morone)*

Now we have "point-wise" cross sections.

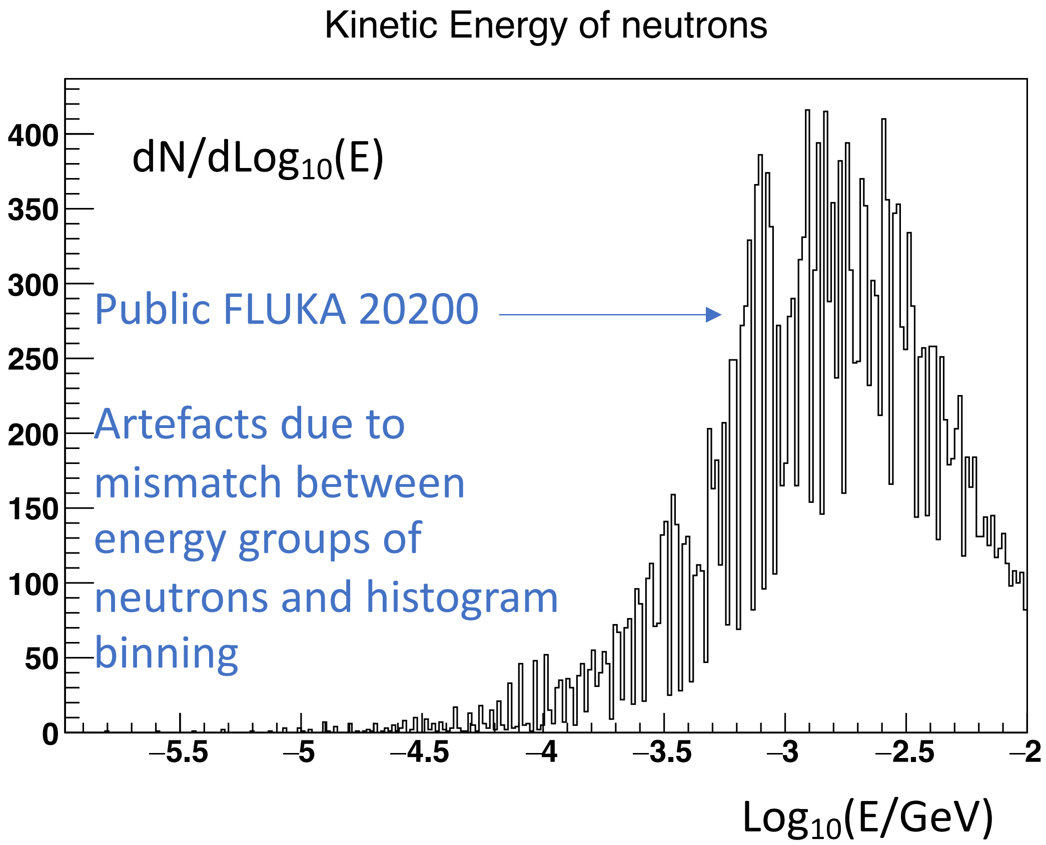
This allows to have a full treatment, with all correlations in their reactions: *(n,n), (n,n'), (n,2n), (n,3n), (n,p), (n,d), (n,t), (n,^{3}He), (n,α), (n,γ)*

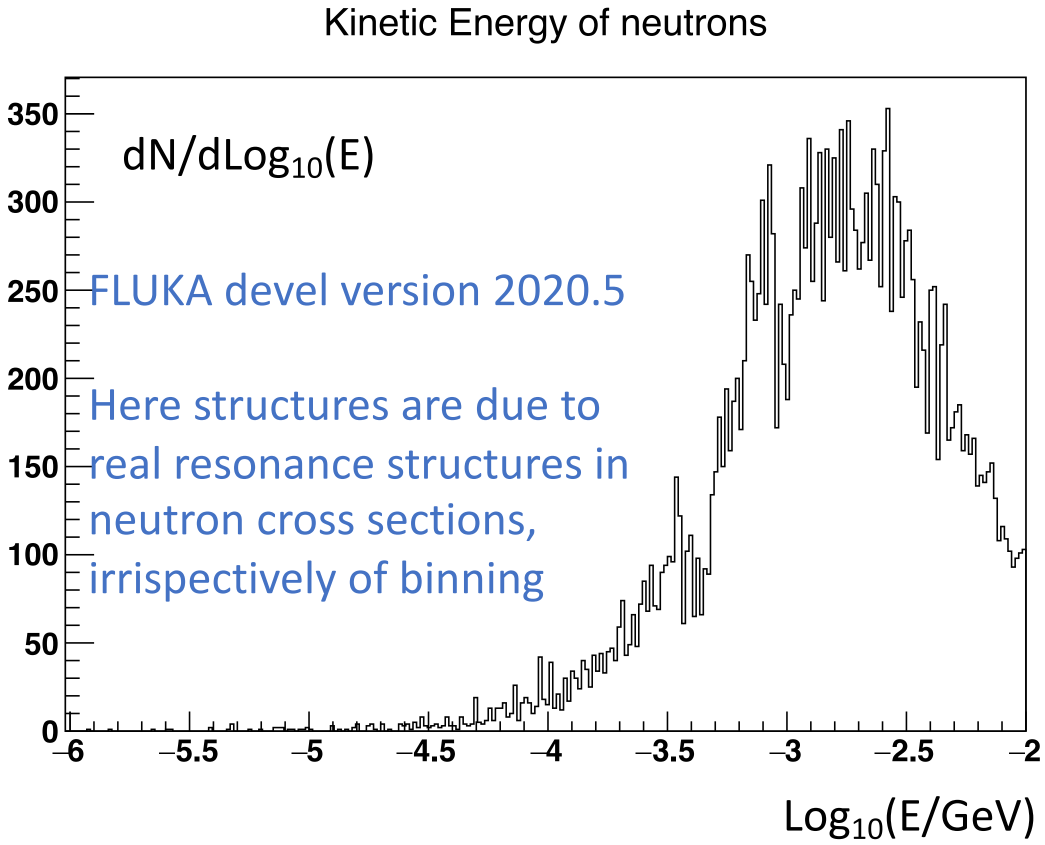
Warning: Point-wise follows cross section precisely but it can be time and memory consuming. Group approach is fast and gives good results for most application

For all isotopes, the cross sections, total and partial ones, are always taken from Endf database, and the reaction channel selected accordingly

Improvement of low-energy neutron cross-sections - 2

“Lethargy” distribution of Neutrons E<20 MeV arriving at TW in CNAO2020 geometry





A variabile binning matching the 260 FLUKA energy groups for neutrons with E<20 should be used

Improvement of low-energy neutron cross-sections - 3

But the main advantages are:

- *Elastic and inelastic reactions are now simulated as exclusive processes with full correlations.*

- *All secondary particles produced in low energy neutron reactions are now fully transported. No more kerma factors for local energy deposition.*

For interested people (outside the FOOT scope) → this allows to consider in the proper way the radiobiological effects of neutrons

In-flight nuclear de-excitation

So far and in present version (public 2020.0)

De-excitation of excited nuclear states is performed “instantaneously” during a nuclear interaction

Drawback at “therapy” energies: Doppler broadening of both target/projectile emitted γ lines is overestimated.

In development version2020.5:

By default excited nuclei with measurable/known mean life will not de-excite during the nuclear interaction which produced the excited state, but rather will fly until decay according to the level mean life

Isotope E^*(MeV) $T_{1/2}$(s)

- $^{7}Be^{1*}$ 0.43 $1.33\ 10^{-13}$
- $^{10}B^{1*}$ 0.72 $7.07\ 10^{-10}$
- $^{10}B^{3*}$ 2.25 $1.48\ 10^{-12}$
- $^{10}B^{4*}$ 3.59 $1.02\ 10^{-13}$
- $^{10}C^{1*}$ 3.35 $1.07\ 10^{-13}$
- $^{11}C^{4*}$ 6.34 $7.62\ 10^{-14}$
- $^{12}C^{1*}$ 4.44 $4.22\ 10^{-14}$
- $^{12}C^{3*}$ 3.85 $8.60\ 10^{-12}$
- $^{14}C^{2*}$ 6.59 $3.00\ 10^{-12}$
- $^{14}C^{3*}$ 6.73 $6.60\ 10^{-11}$

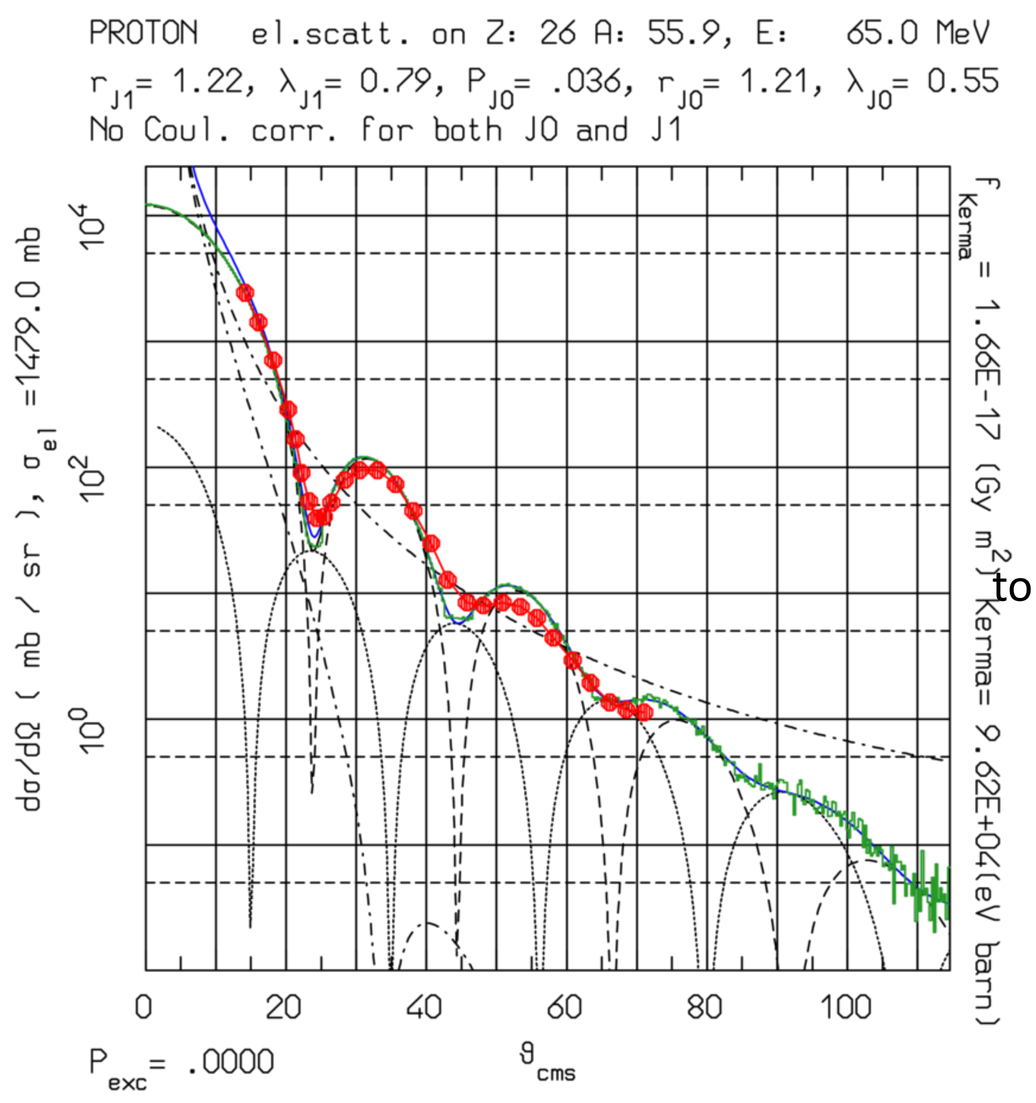
Isotope E^*(MeV) $T_{1/2}$(s)

- $^{14}N^{1*}$ 2.31 $6.80\ 10^{-14}$
- $^{14}N^{4*}$ 5.11 $4.35\ 10^{-12}$
- $^{15}N^{1*}$ 5.27 $1.79\ 10^{-12}$
- $^{16}N^{1*}$ 0.12 $5.25\ 10^{-06}$
- $^{16}N^{2*}$ 0.30 $9.13\ 10^{-11}$
- $^{16}N^{3*}$ 0.40 $3.90\ 10^{-12}$

Isotope E^*(MeV) $T_{1/2}$(s)

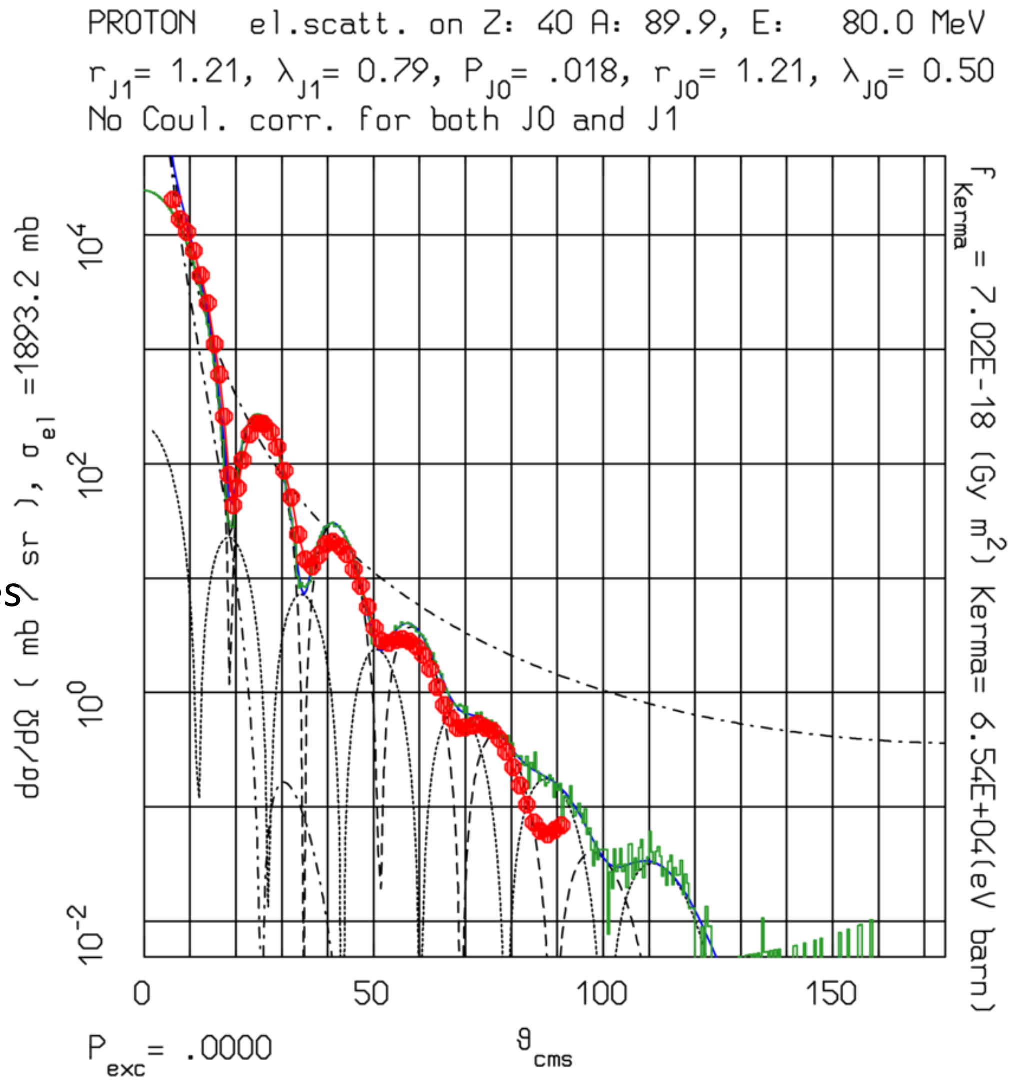
- $^{15}O^{2*}$ 5.24 $2.25\ 10^{-12}$
- $^{15}O^{6*}$ 7.28 $4.90\ 10^{-13}$
- $^{16}O^{2*}$ 6.13 $1.84\ 10^{-11}$
- $^{16}O^{7*}$ 8.87 $1.25\ 10^{-13}$
- $^{17}O^{1*}$ 0.87 $1.79\ 10^{-10}$
- $^{17}O^{2*}$ 3.06 $8.00\ 10^{-14}$
- $^{18}O^{1*}$ 1.98 $1.94\ 10^{-12}$
- $^{18}O^{2*}$ 3.55 $1.72\ 10^{-11}$
- $^{18}O^{3*}$ 3.63 $9.60\ 10^{-13}$

Elastic (and quasi-elastic) scattering - 1

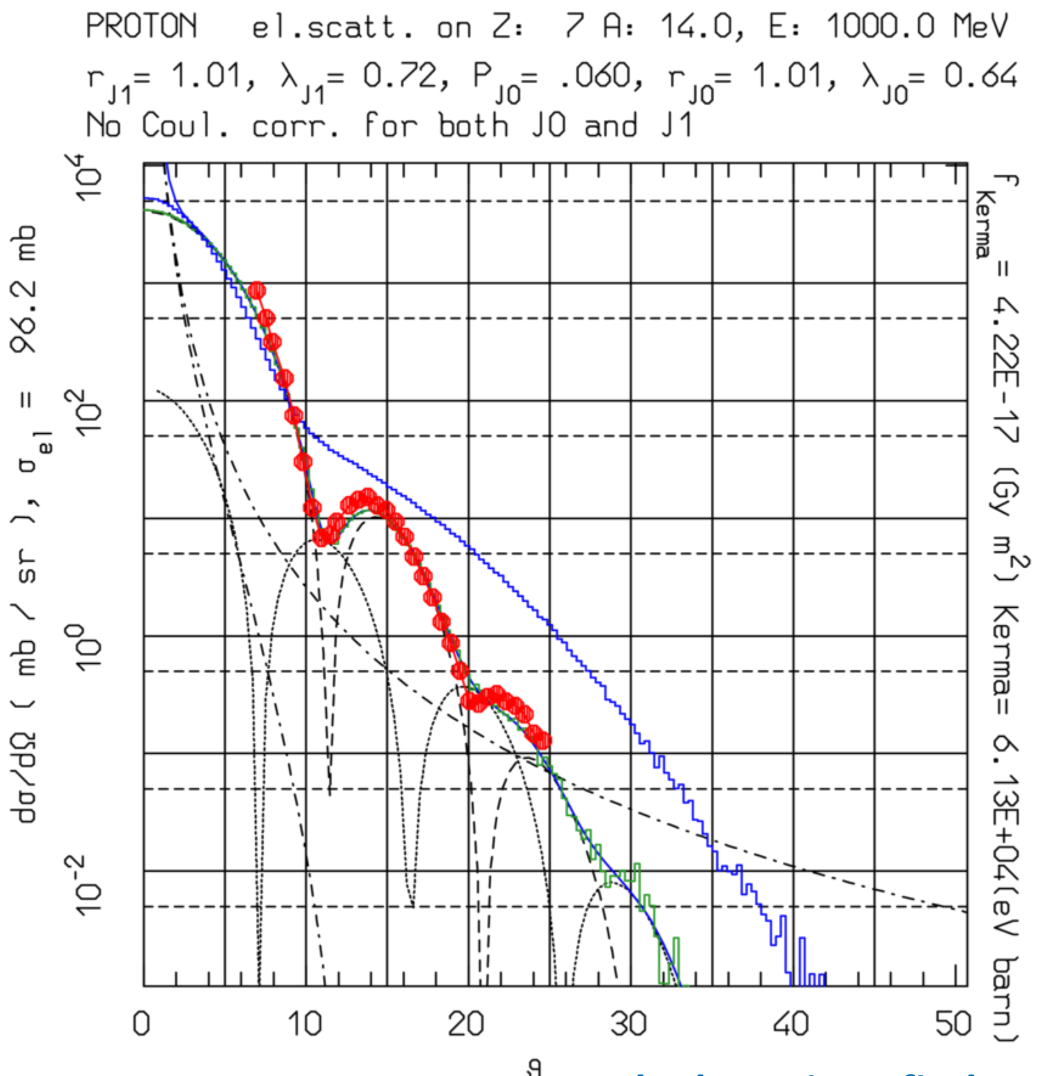


Green: Fluka Ferrari-Sala Model: p/n up to 200 MeV extended to all proj/targ/energies for E>1 GeV

Red: exp. data

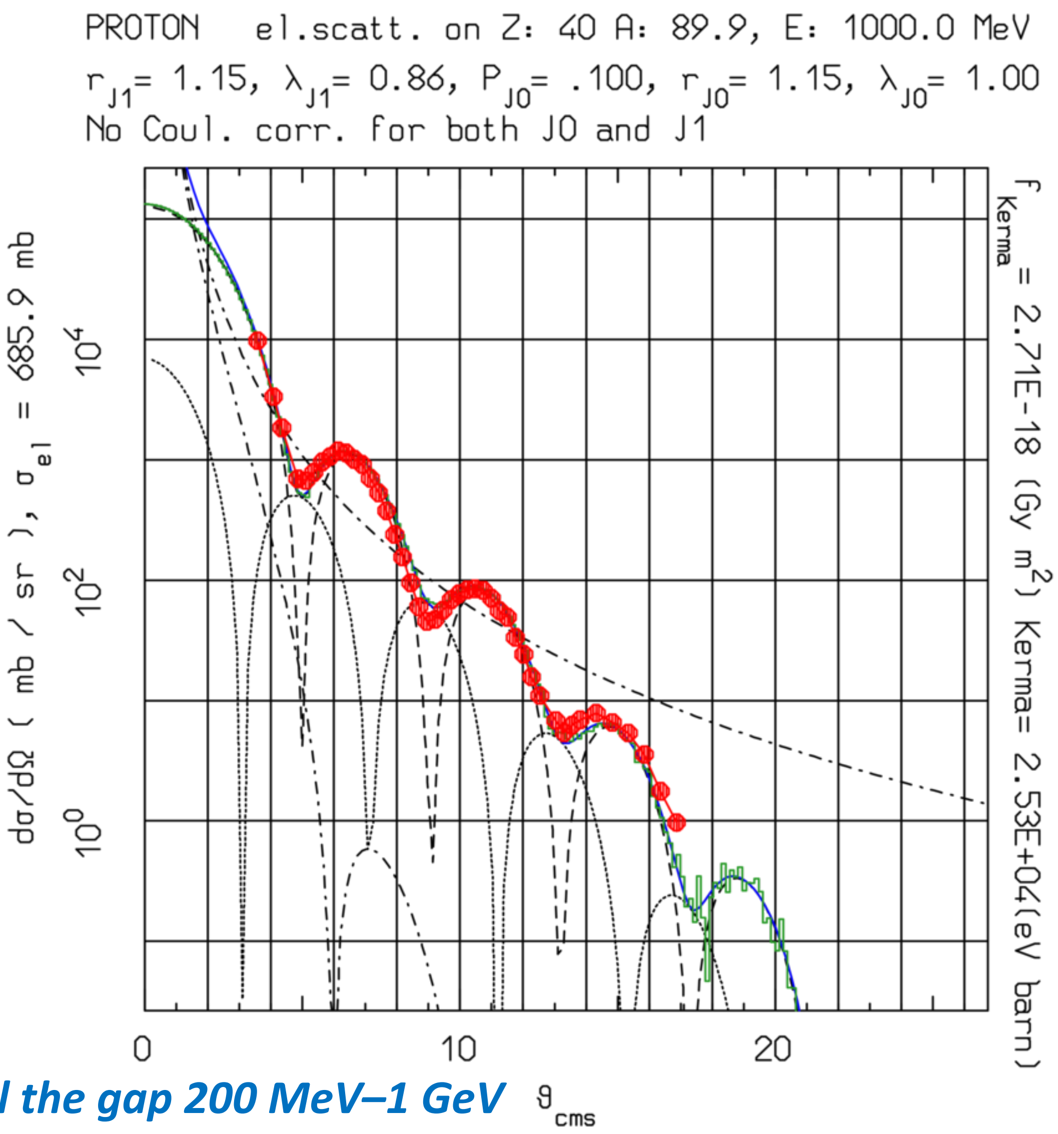


Elastic (and quasi-elastic) scattering - 2



Green Fluka
Red: exp. data

Blue:
“old”, Ranft,
model



The hope is to find enough exp. data to fill the gap 200 MeV–1 GeV

Developments for optical photon simulation

Current version: only emission lines (up to 3 for each material) are possible (see the example now in progress for FOOT)

Development version: now added the possibility to input a spectrum or even a combination of line + spectrum through a couple of user routines. Also a user-defined intensity is requested.

Now optical photons take away part of the energy otherwise accounted as ionization

Some conclusions and To-do List

- All interested people is invited to perform detailed checks and analyses on the CNAO2020 production
- Should we rethink the layout?
- Other simulation runs can be produced if needed:
  - More statistics
  - «Untriggered» production
  - …
- We are assisting the Calo group to run optical simulation in BGO crystals
- A meeting with people interested in neutron detection has still to be organized in view of the addition of other detector elements