Evaluation of the new Map of Magnetic Field in FOOT MC simulation / Use of fluka2021.2.9 version

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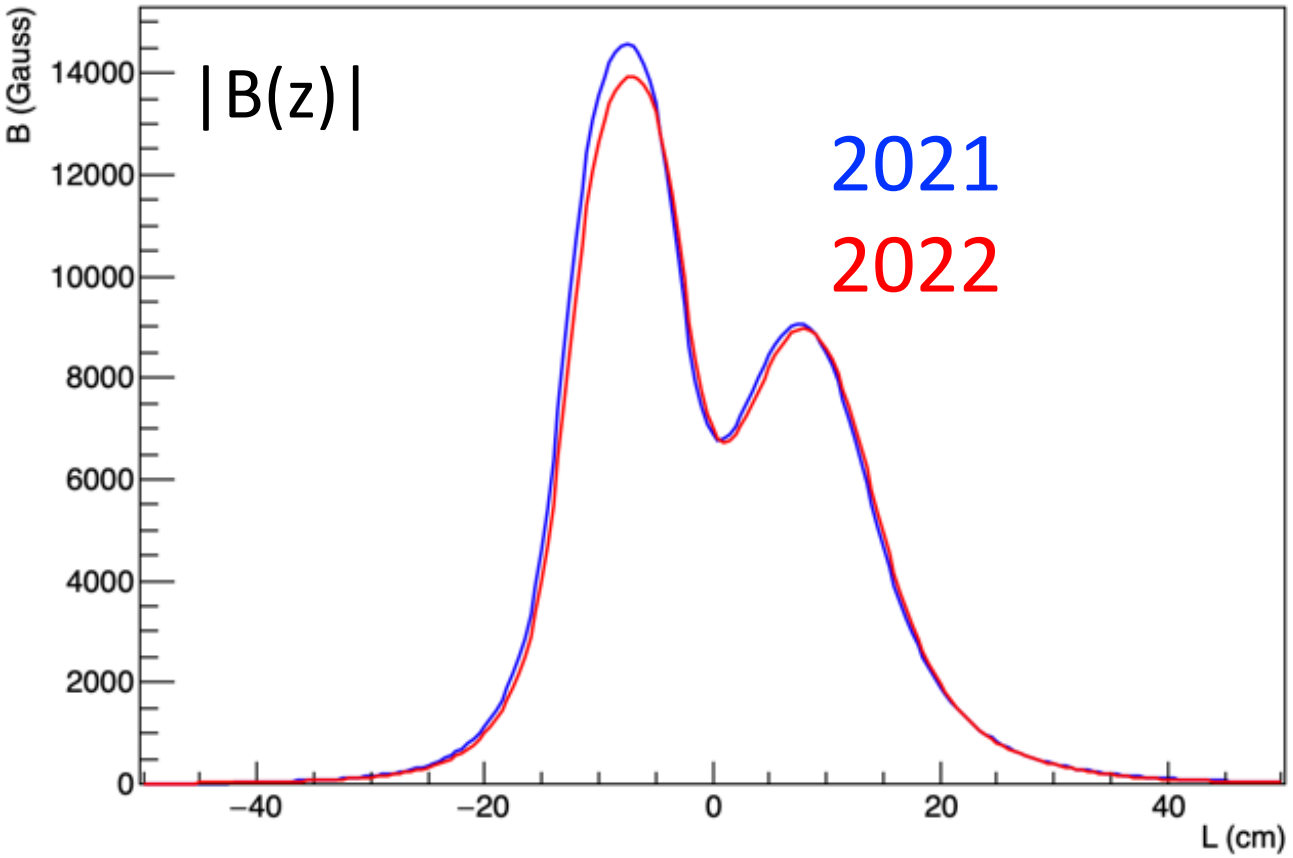
Introduction

- As presented in detail since Strasbourg meeting, a new design of the magnet system had to be considered by the Sigma-Phi firm. New mechanical arrangement, new ferromagnetic material: from Samarium-Cobalt to Neodymium-Iron-Boron, etc.
- The resulting field has differences. A new calculation of the 3-D map of the magnetic field was produced by Sigma-Phi. Two maps have been requested and received in Dec. 2022:
  1. The usual one in a volume of 10x10x100 cm^3 along the central axis of the magnets [x: -5,5; y: -5,5; z: -50,50]
  2. The map of field far below [x: -5,5; y: -5,5; z: -44,-34], which may be significant in the case we shift up the magnet system to perform alignment runs
- Here we present a first evaluation

B vs z: 2021-2022 Comparison of standard map



$\int B \cdot dl$ along the central z axis (x,y=0,0):

2021

$\int |B(z)| \cdot dl = 0.327$ T m

2022

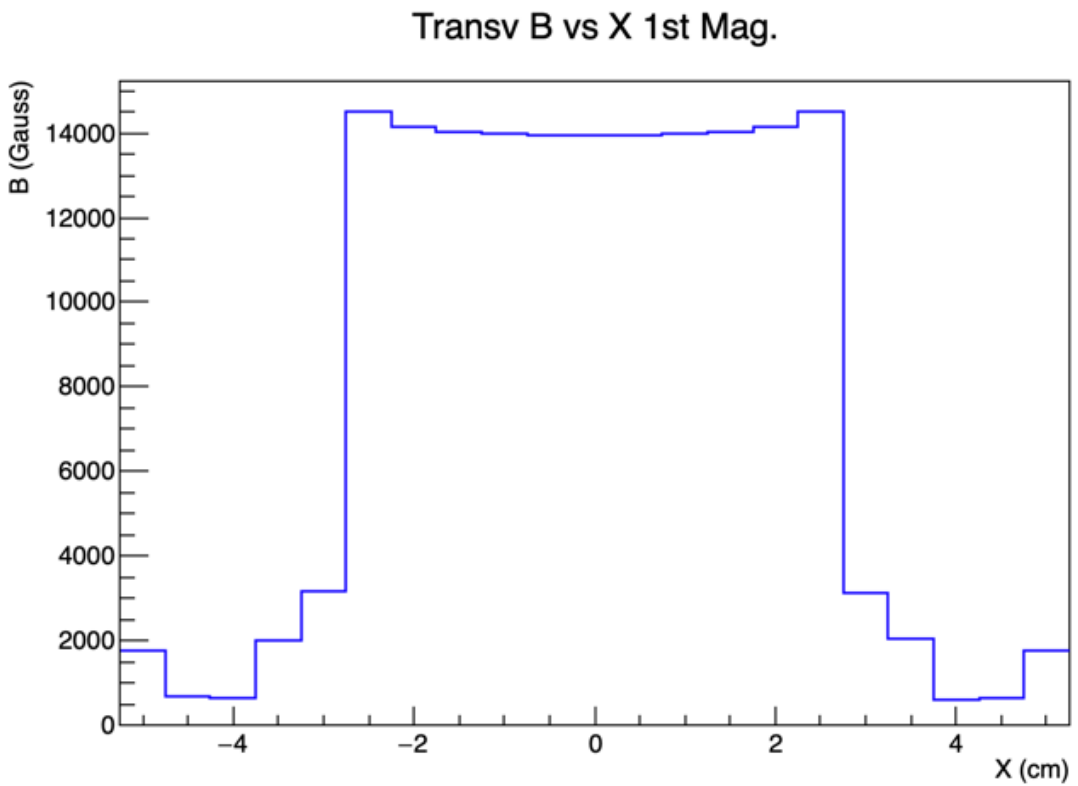
$\int |B(z)| \cdot dl = 0.318$ T m

B intensity as a function of Z (local reference frame) as measured along the z axis (x=0, y=0):

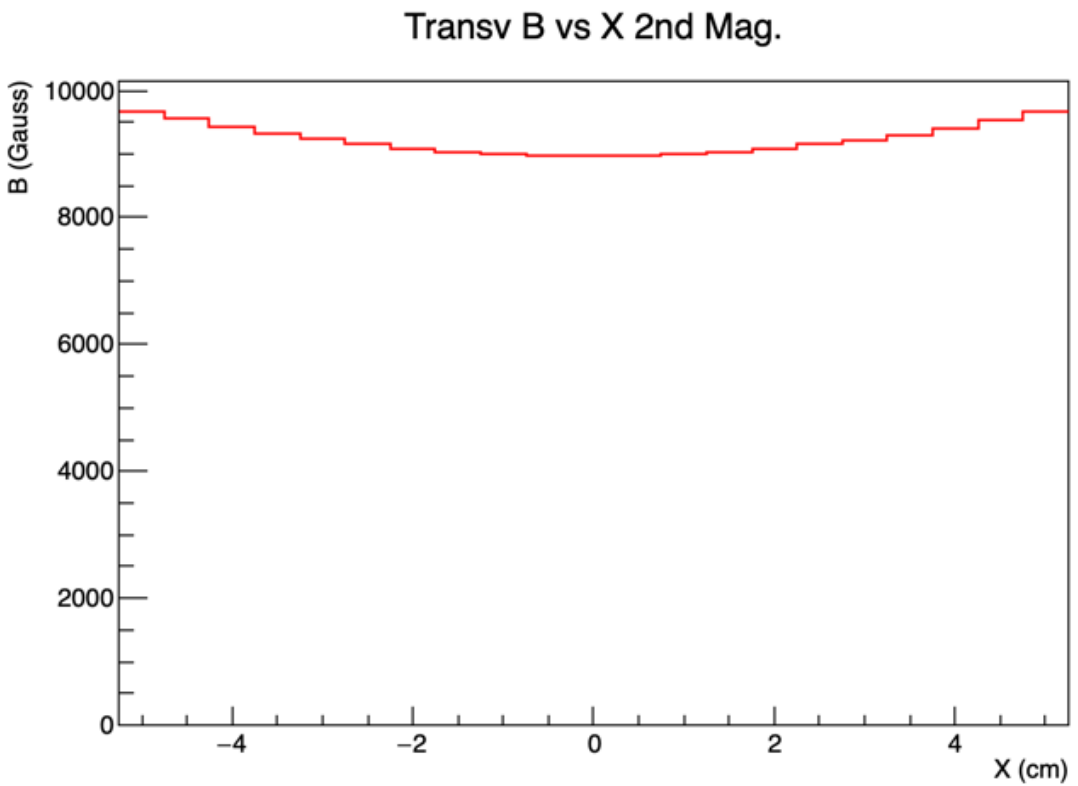
Notice: here, and in the following, z=0 is the center of the magnet system

In our MC magnetic campaigns this is usually positioned at 16.7 cm from the target (our origin of global coordinates)

B vs x-coordinate (across the magnet bores)



|B|(x, y=0, z=-7)
center of the 1st magnet



|B|(x, y=0, z=8)
center of the 2nd magnet

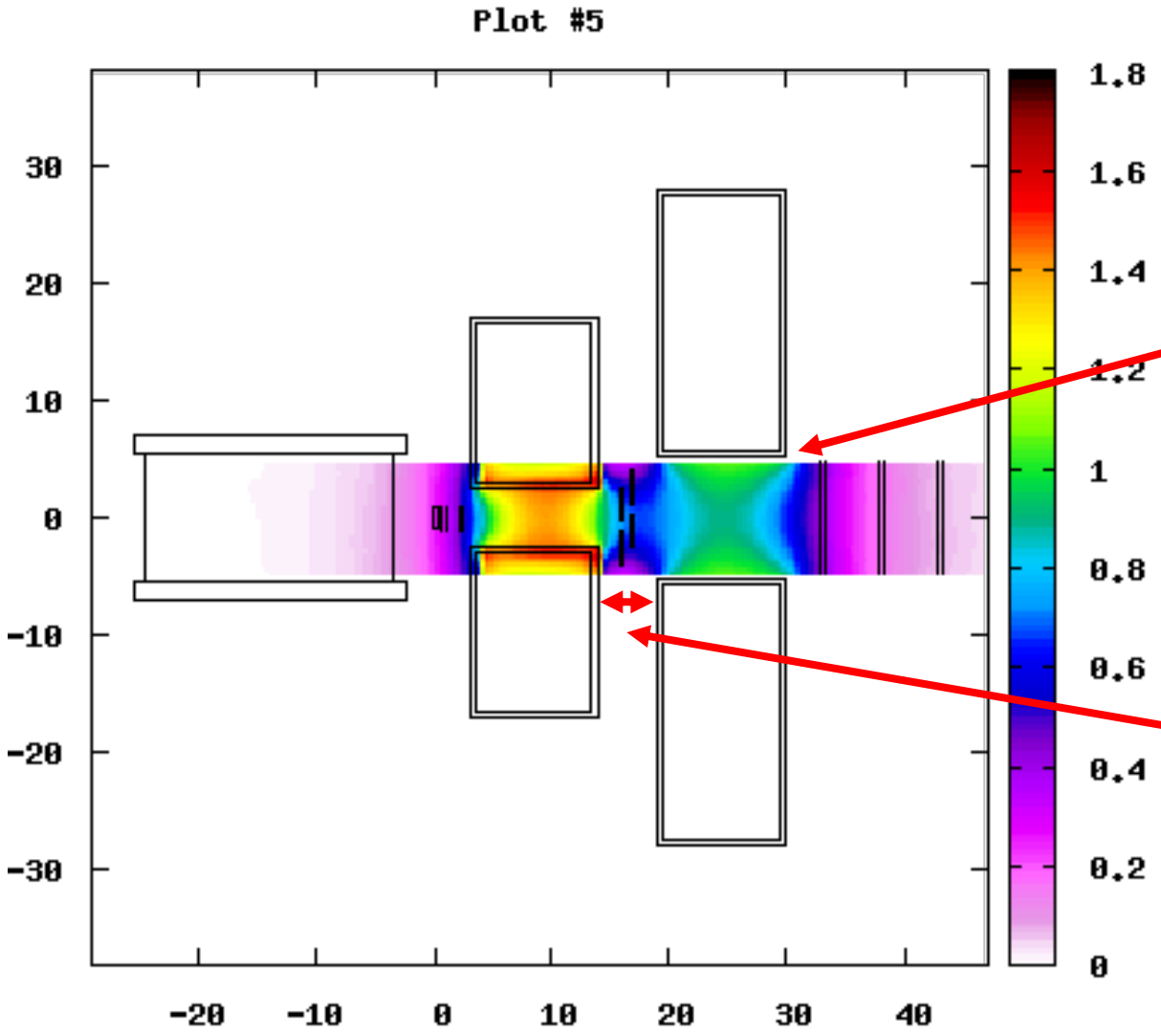
Use of map in simulation

The magnetic field map is located in the Reconstruction/level0/data directory.

It is read out by FLUKA in the user routine magfld.f
The map file name is provided in an include file written by makeGeo for a given campaign. The file name is read from the file geomaps/TADIdetector.geo

The map is shifted to the actual global coordinate system within magfld.f using the coordinates of the center of the magnet system in the global frame, as obtained from the values written in geomaps/FOOT.geo

At run time, the B field components at any given (x,y,z) location are obtained using a 3-linear interpolation among the grid points of the stored map.

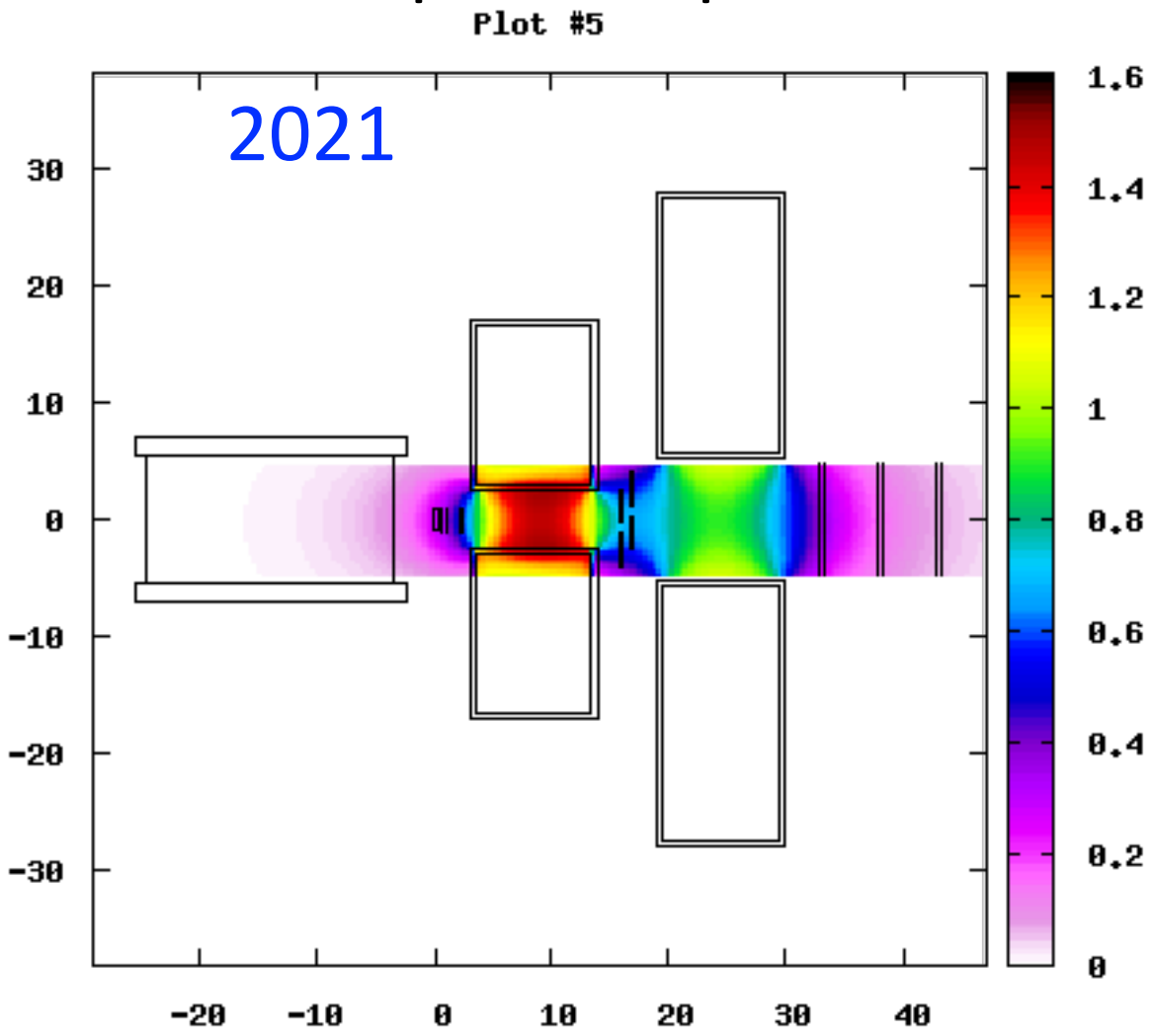


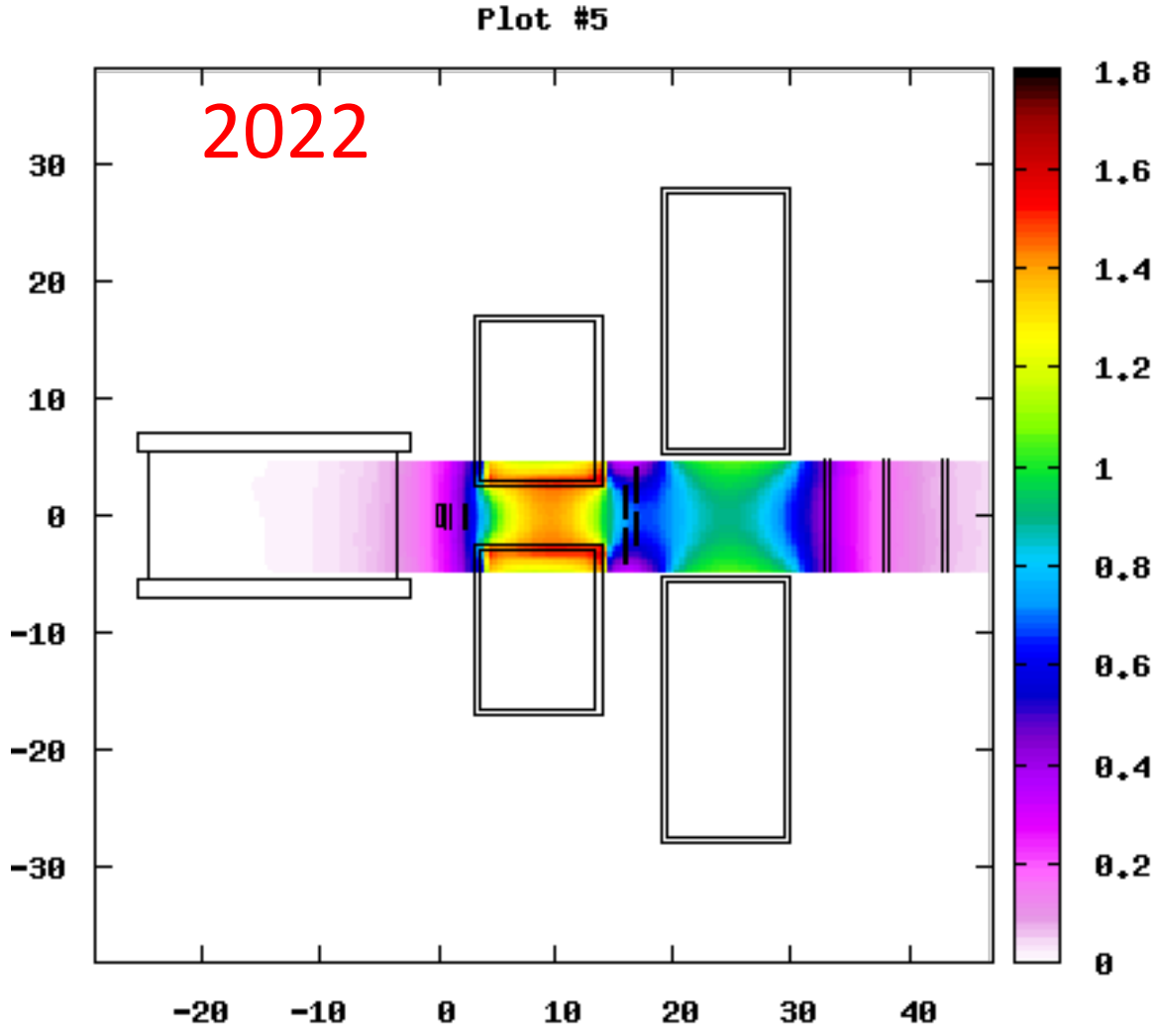
B-intensity map superimposed to the FOOT geometry (y vs z view)

➔ It can be seen that:

1) since the bore diameter of the 2nd magnet is larger than 10 cm, (10.6 cm) we should require a map which extends in range wider than (-5,5) in the X and Y dimensions
2) The new design of magnets has a horizontal gap of 55 mm between the 2 magnets, while the previous design had 50 mm. Does the new map received in december take this into account? (to be checked with Sigma-Phi)

2D-map comparison

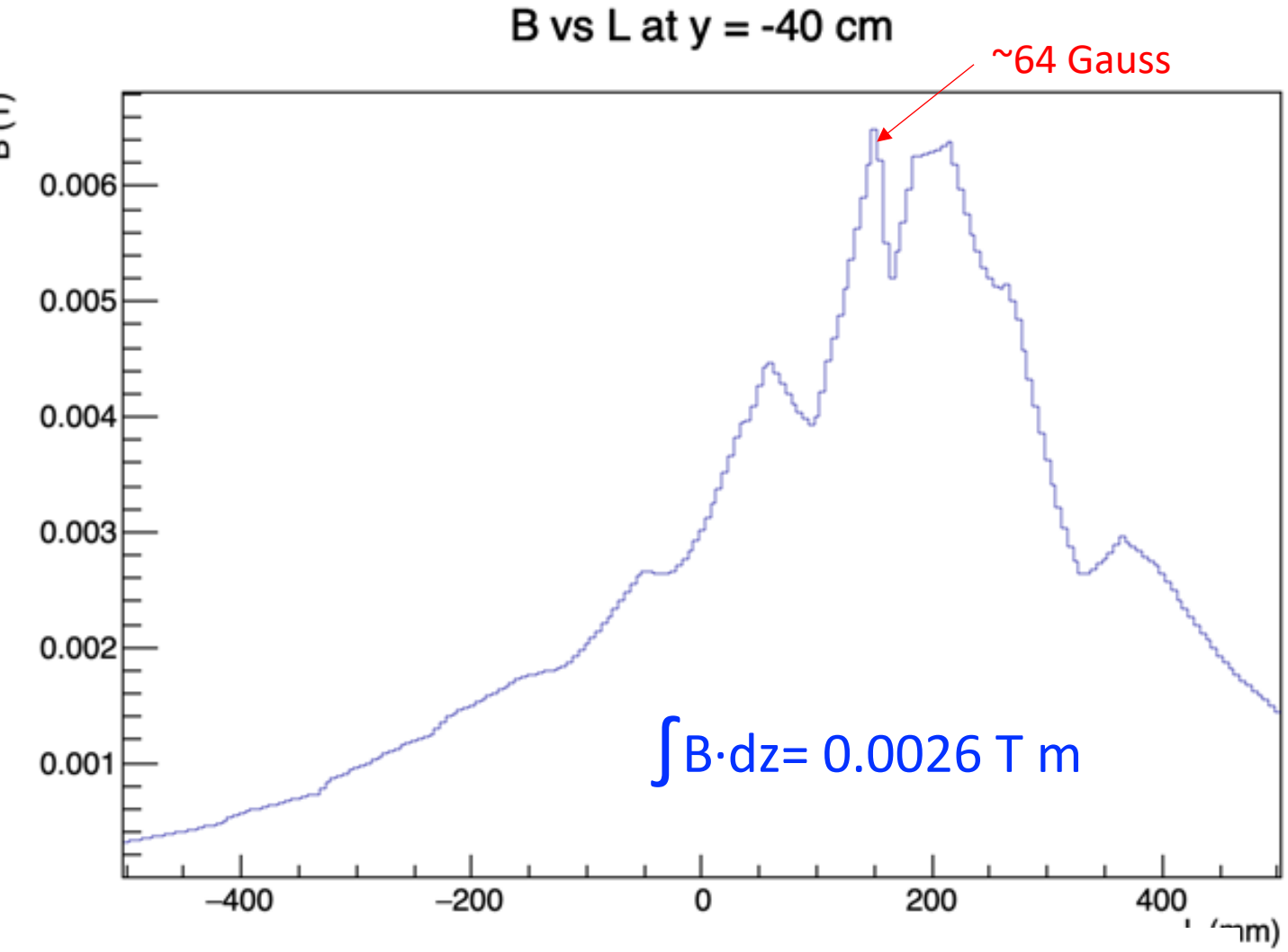




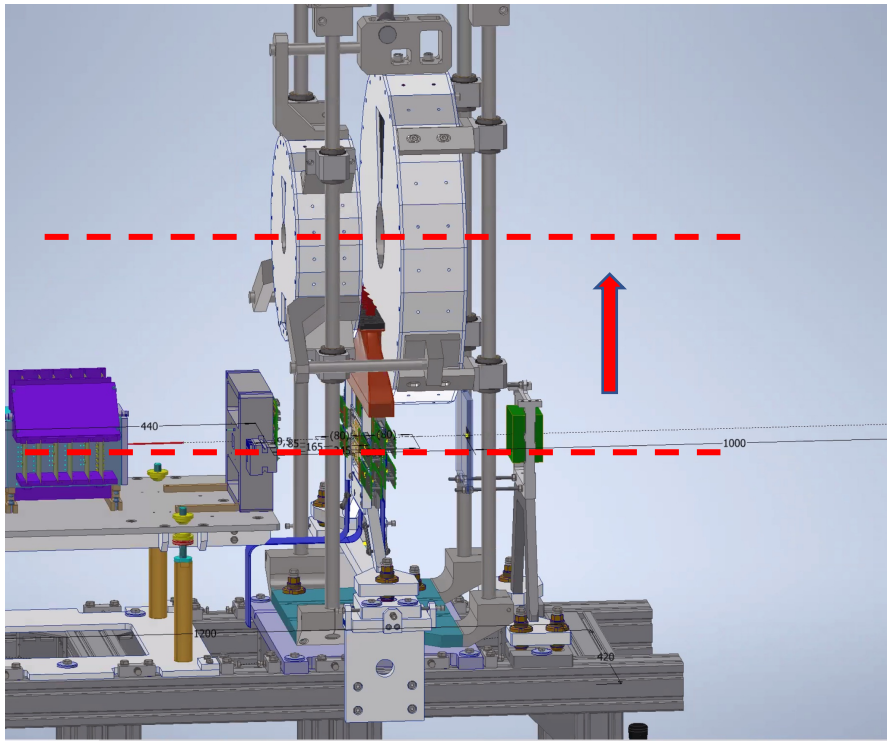
Warning: the color palette is not the same!

However some differences are visible

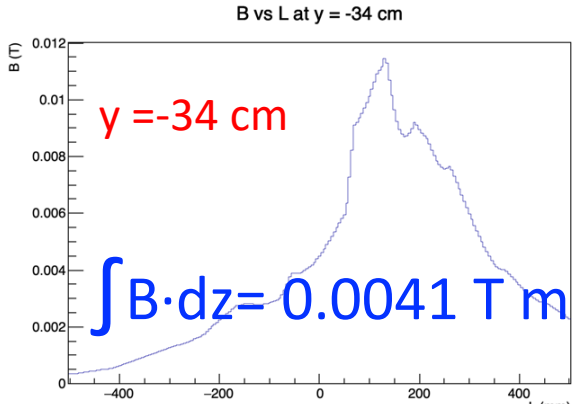
B vs z if the off-center map

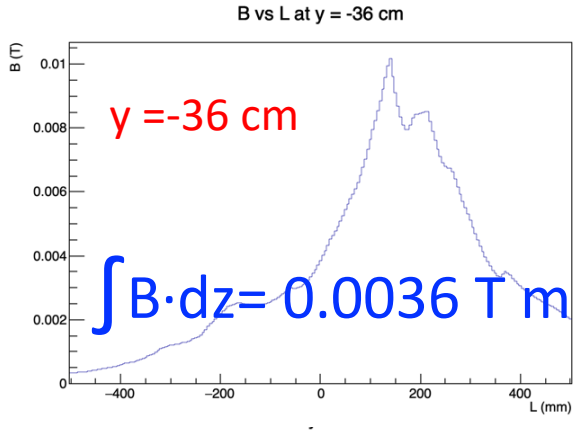


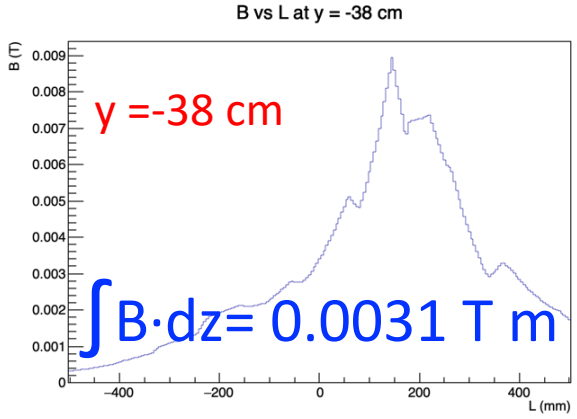
[B_{earth}(Pavia) ~ 0.47 Gauss]

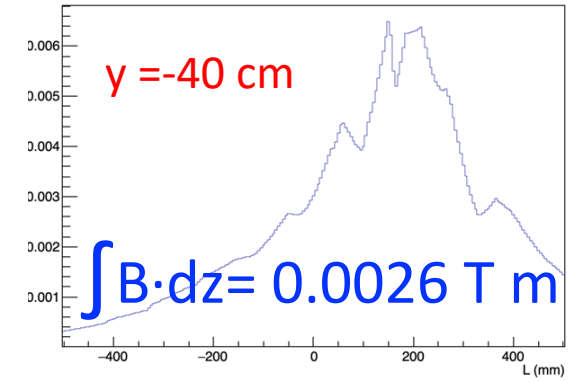


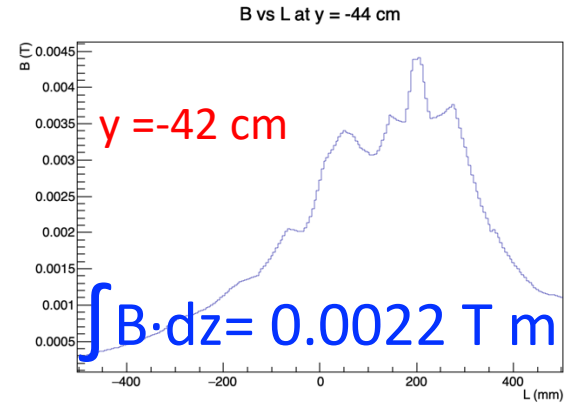
B vs z at different distances below the central axis

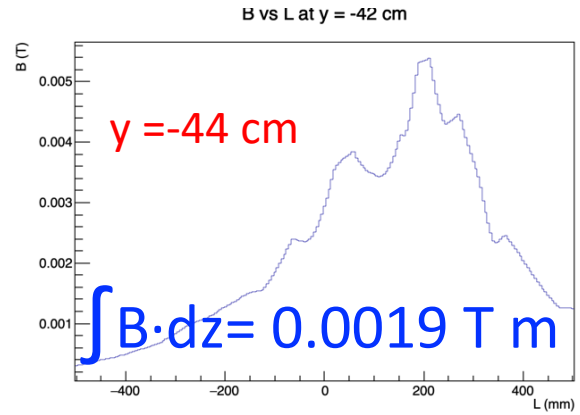


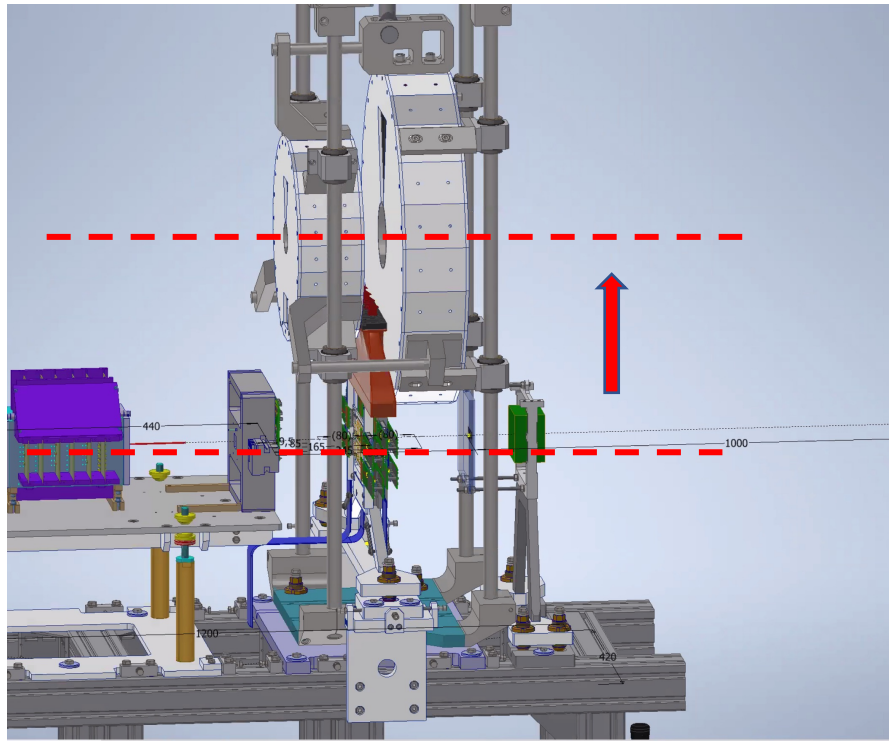












Use of map in simulation - 2

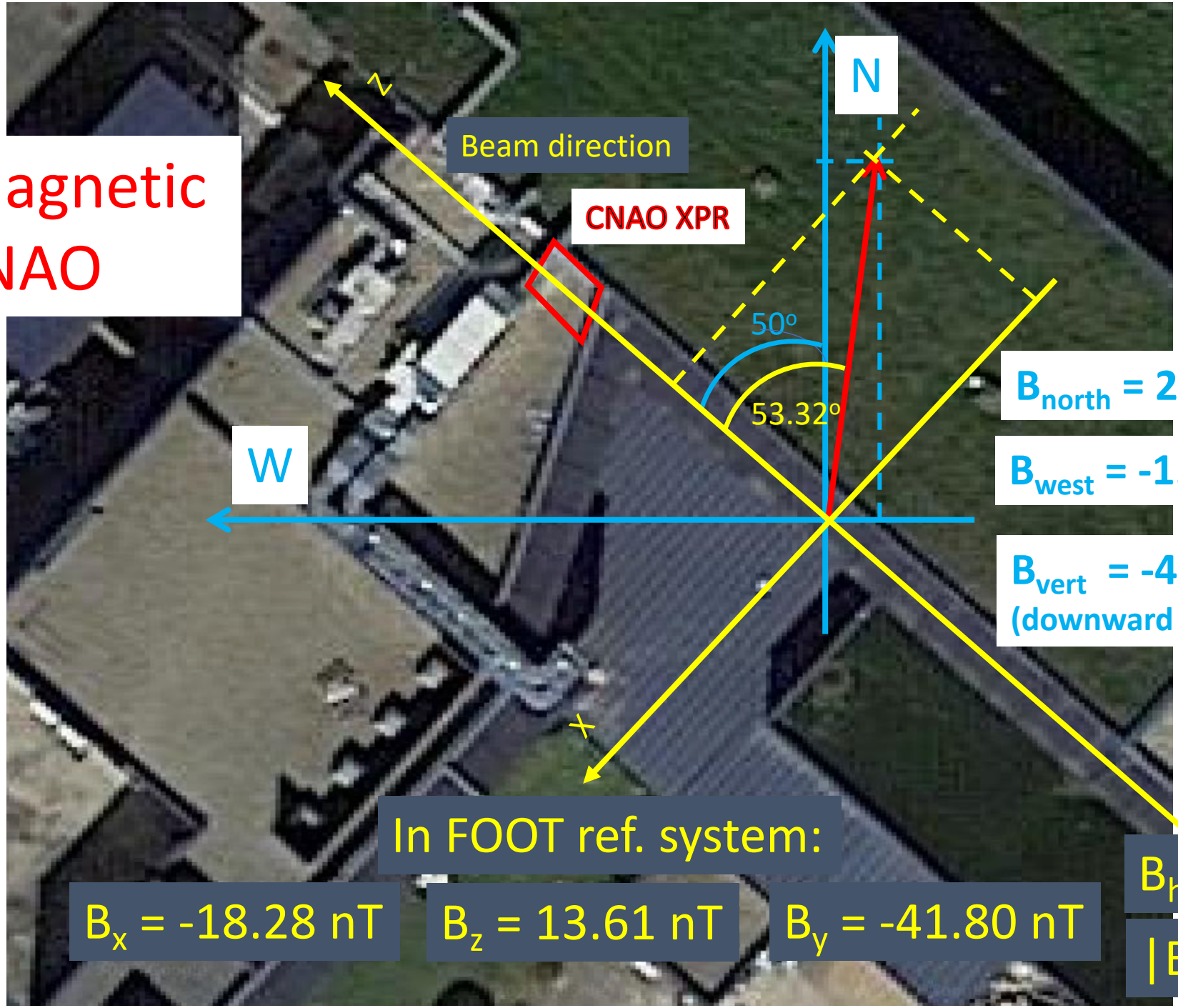
At present the magfld.f routine returns a non-zero B field only in the volume where the map exists.

- We may ask for a calculation in a more extended volume
- In which volume will we measure B for the experimental situation?

Just for kidding:
to be uselessly and exaggeratedly picky, instead of giving B=0 outside the map, we could provide the geomagnetic field…

The geomagnetic field at CNAO

IGRF model
Jan 2023



Next steps

A Reconstruction/level0/data/SigmaPhi_FOOT2023.table is ready as **temporary** study case

We are waiting for:

- a possible new map extending radially beyond 5 cm
- Confirmation that the new gap of 5.5 cm between magnets is being considered

New FLUKA respin: *FLUKA2021.2.9*

At the FOOT collaboration Meeting 2021 we already announced the release of a new production version of FLUKA (2021.2), which includes some new features.

see: https://agenda.infn.it/event/23294/contributions/137303/attachments/81756/107240/Simulation_Updates_20210524.pdf

Some may be important for FOOT. Among them:

Before 2021 release. this was available only in the version reserved to developers

1) **Pointwise transport of low energy neutrons with correlated interactions**
2) Runge-Kutta based transport in electric fields is implemented for vacuum and gas regions
3) **Optional Runge-Kutta based transport in magnetic field in vacuum and gas regions**
4) **New physics model for elastic scattering of hadrons on nuclei**
5) **Transport and in-flight decay of excited residual nuclei**
6) **Improved nuclear mass/decay/deexcitation database**
7) **Revised hadron-nucleus interaction cross sections**
8) **Revised cross sections for proton - light ion interactions**
9) **Non monochromatic scintillation light emission and transport**

Comparison *FLUKA2020* vs *FLUKA2021.2.9*

So far, we did not make use of the new version. Very recently there was the realease of a new respin of 2021.2 version (2021.2.9), with some bug corrrections and at least 2 improvements which in principle are important for FOOT:

Nucleus interations E>120-130 MeV/u

"…This Fluka respin includes two physics improvement:

- a rare condition in rQMD could produce an excess of "cold" fragments when approaching the lowest energy threshold of rQMD. The excitation energy computation has been improved in order to avoid these pathological cases (thanks to Walter Ikegami Andersson for pointing it);

Nucleus interations E<120-130 MeV/u

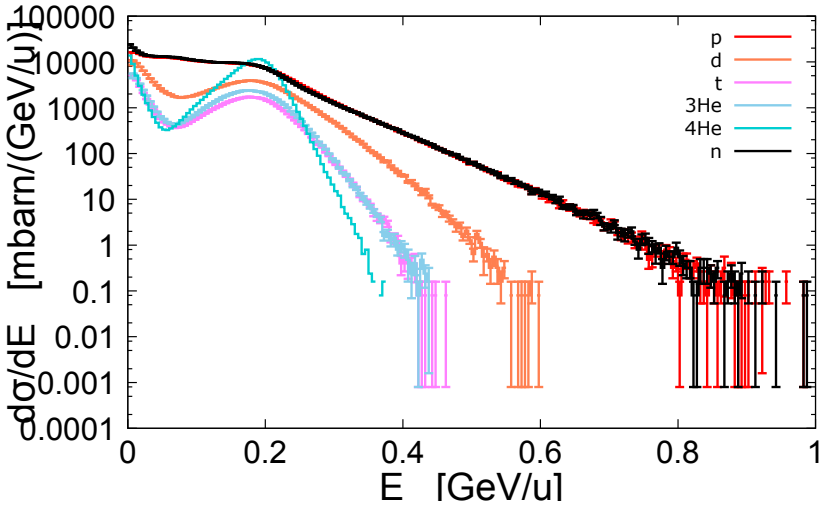
- at the same time a reworking of several BME routines, in particular those dealing with the preequilibrium interface, has been performed significantly improving the fragment distribution in similar cases."

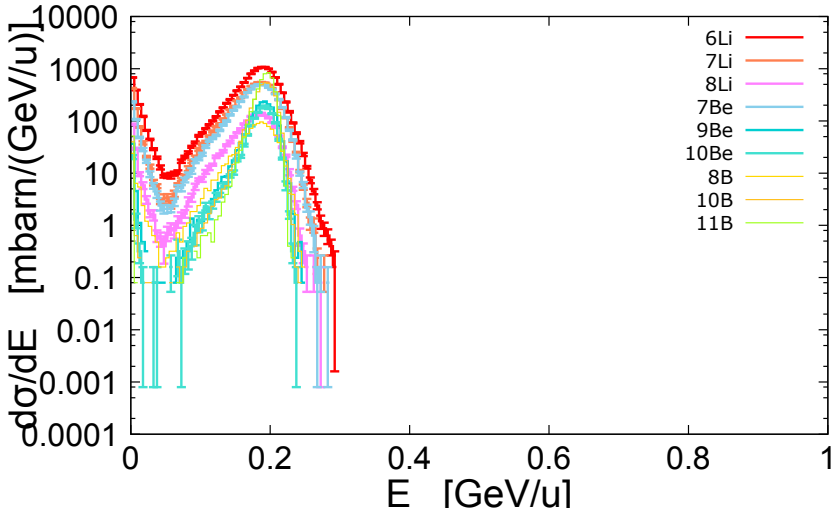
We tested it against version 2020.0.10 and previous 2021.2 respins to search for possible differences in cross sections:

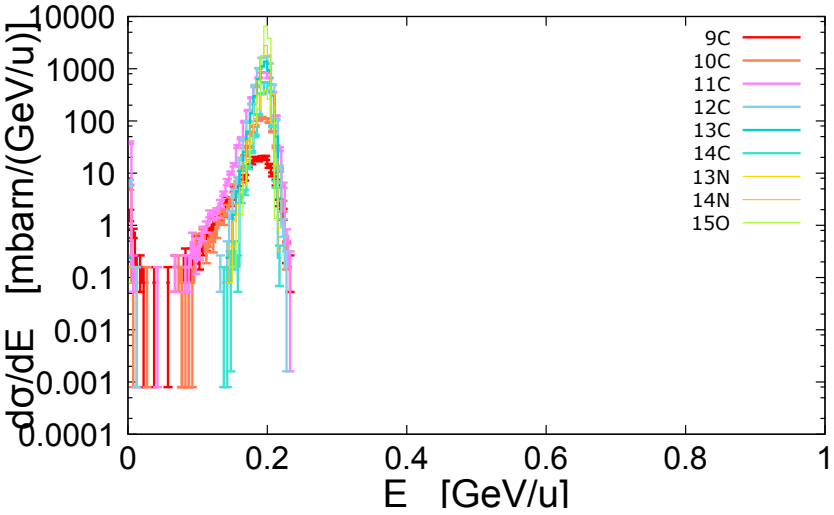
➔ **No significant difference comes out from our comparison**

^{16}O+C @ 200 MeV/u

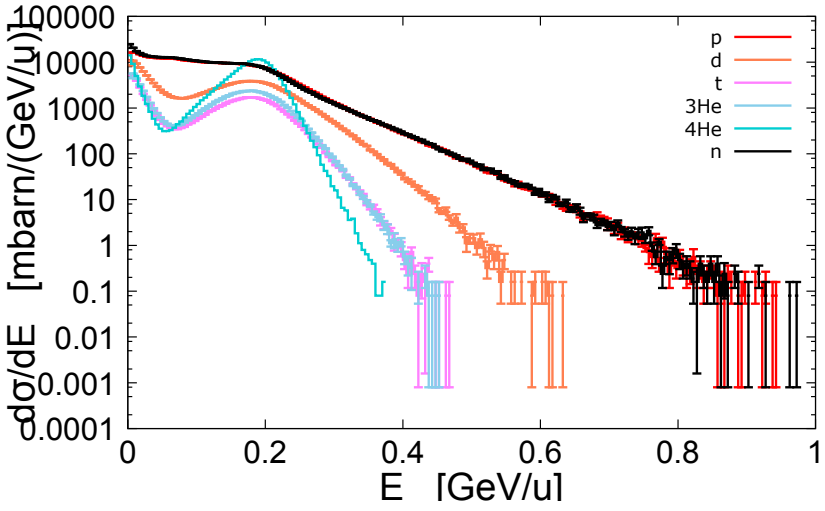
Fluka 2020.0.10

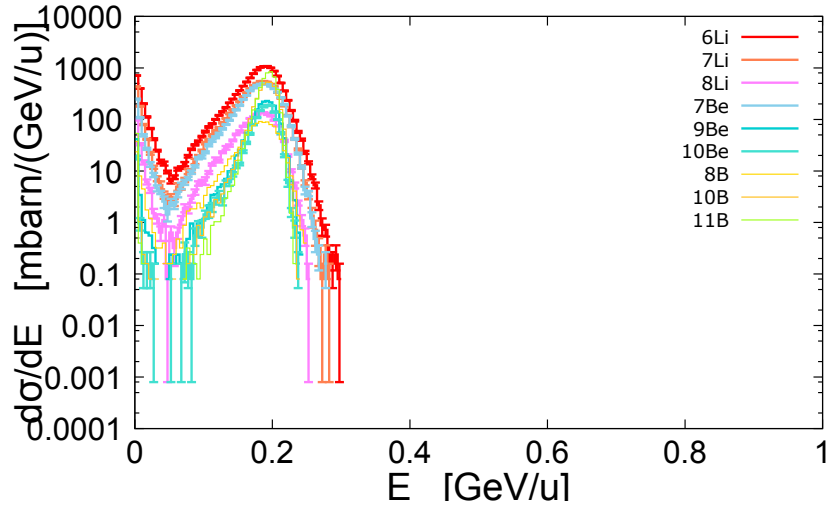


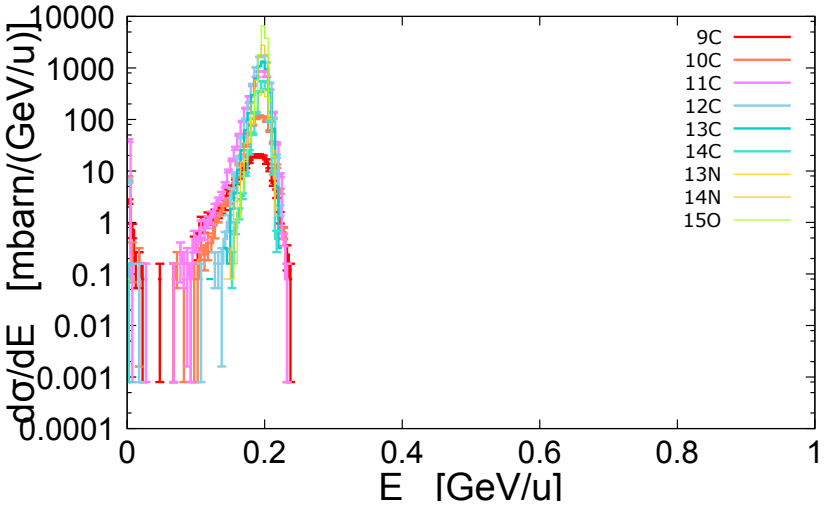




Fluka 2021.2.9







Future production runs:

From now on we intend to make use of the **FLUKA 2021.2.9 version**.

To this purpose a small change in the magfld routine is required.

All this will be completely transparent for end users in FOOT: there is no impact on the way in which simulated data files are decoded and analyzed.

One potential **advantage** of using this version, is the possibility of using **point-wise cross sections for E<20 MeV neutrons** (continuous dependence on energy instead of multi-group energy transport): based on ENDF/B-VIIIR0 and TENDL-2019 evaluated cross-sections.

If considered important by the neutron group, this option will allow not only to have exact neutron energy at every step, but also to get energy and directions of reaction products, including nuclear recoils, correlated among themselves so that energy-momentum conservation is ensured in an event-by-event basis.