Comparison of Direct Electron and Photon Activation Measurements with FLUKA Predictions

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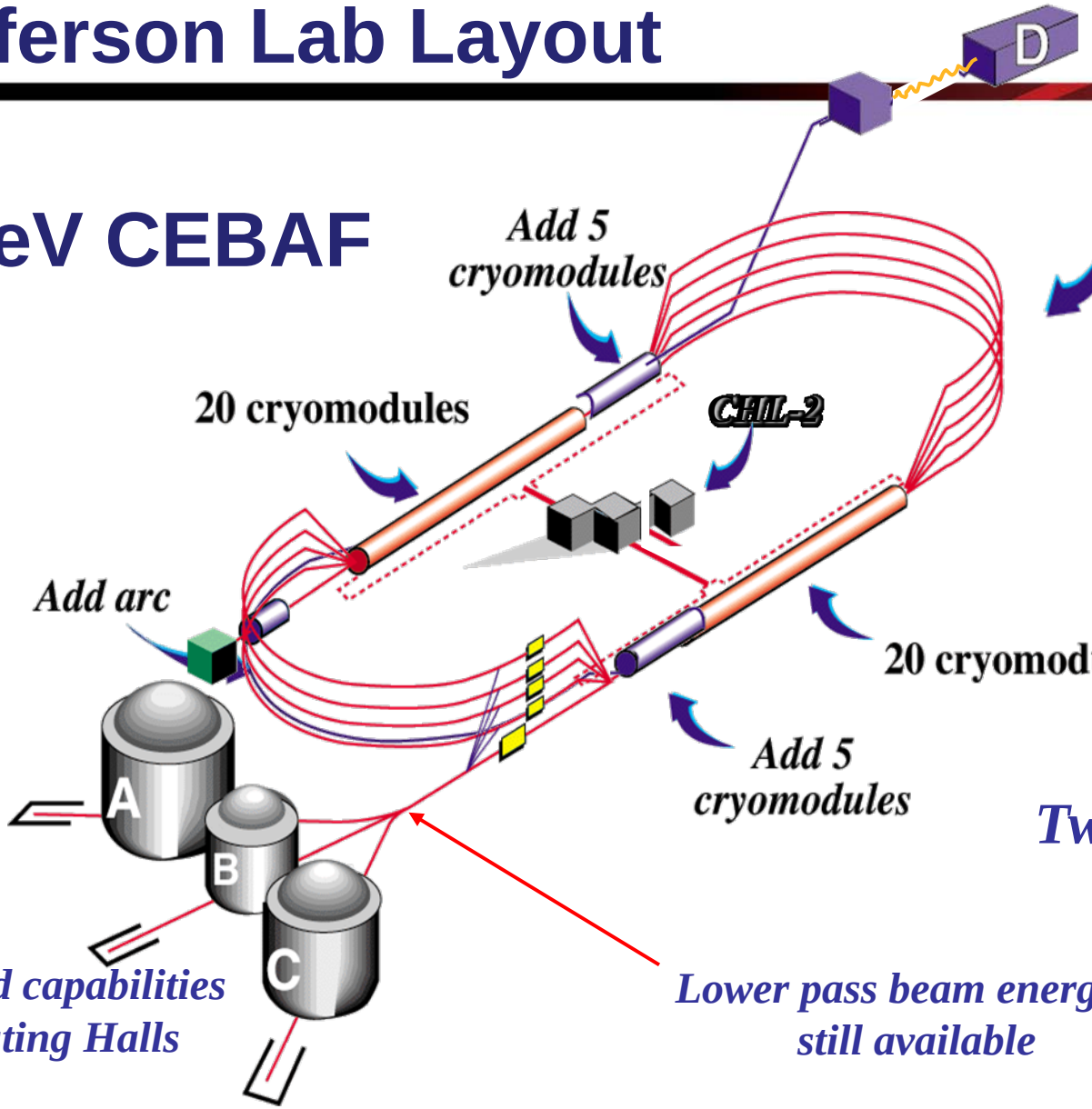
Jefferson Lab

Jefferson Lab Layout

12 GeV CEBAF



Two 1.1 GeV linacs

Enhanced capabilities in existing Halls

Lower pass beam energies still available

FLUKA at Jefferson Lab

- Modeling interaction of up to 12 GeV e^- and γ beams with targets, beamline components, etc.
  - Background;
  - Radiation damage;
  - Shielding;
  - Activation and subsequent exposure levels.
- Electronuclear interaction mechanism is not included in FLUKA
  - Closely related to photonuclear interaction;
  - Is of significant importance in thin targets

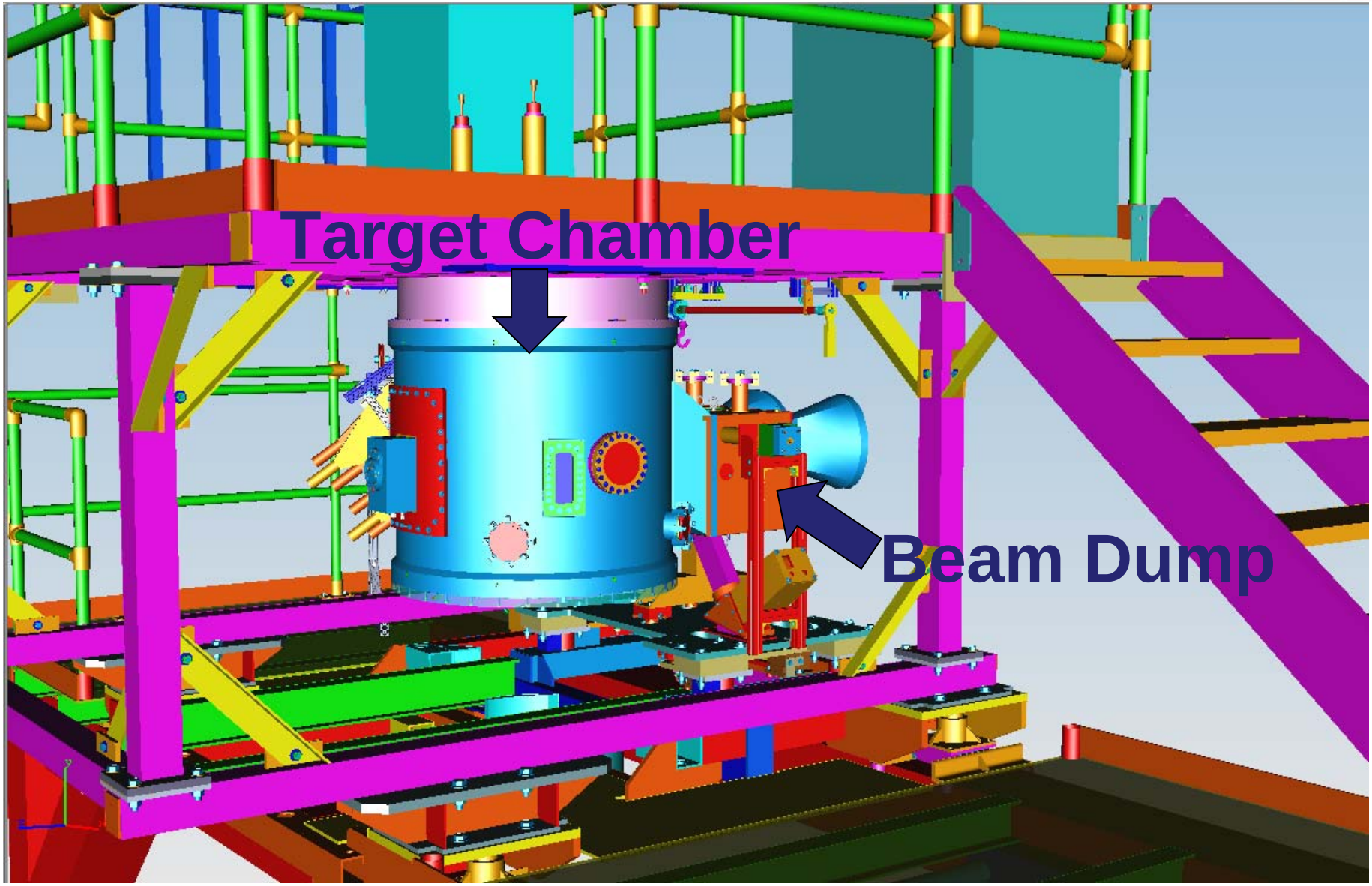
(<5% X_0)

Motivation and Opportunity

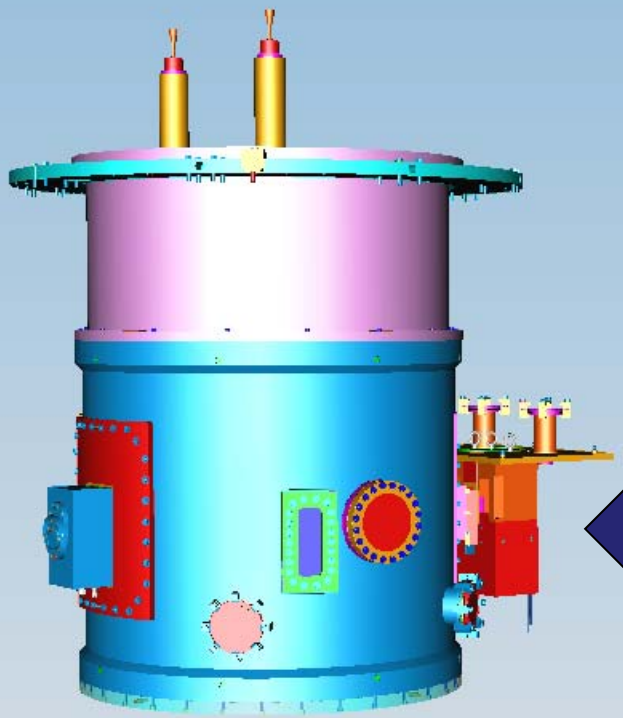
- Photon and neutron activation:
  - Check FLUKA (and our use of it!).
- Direct electron activation:
  - Evaluate relative importance for radiation environments typical to Jefferson Lab.

- Opportunity:
  - JLab Hall A experiment: measurement of the proton's transverse spin structure function - g^p_2;
  - 2.2 and 3.3 GeV e^- beams dumped on a specially designed beam dump;
  - Allowed us to place thin foils on the face of the dump.

g^p_2 Layout



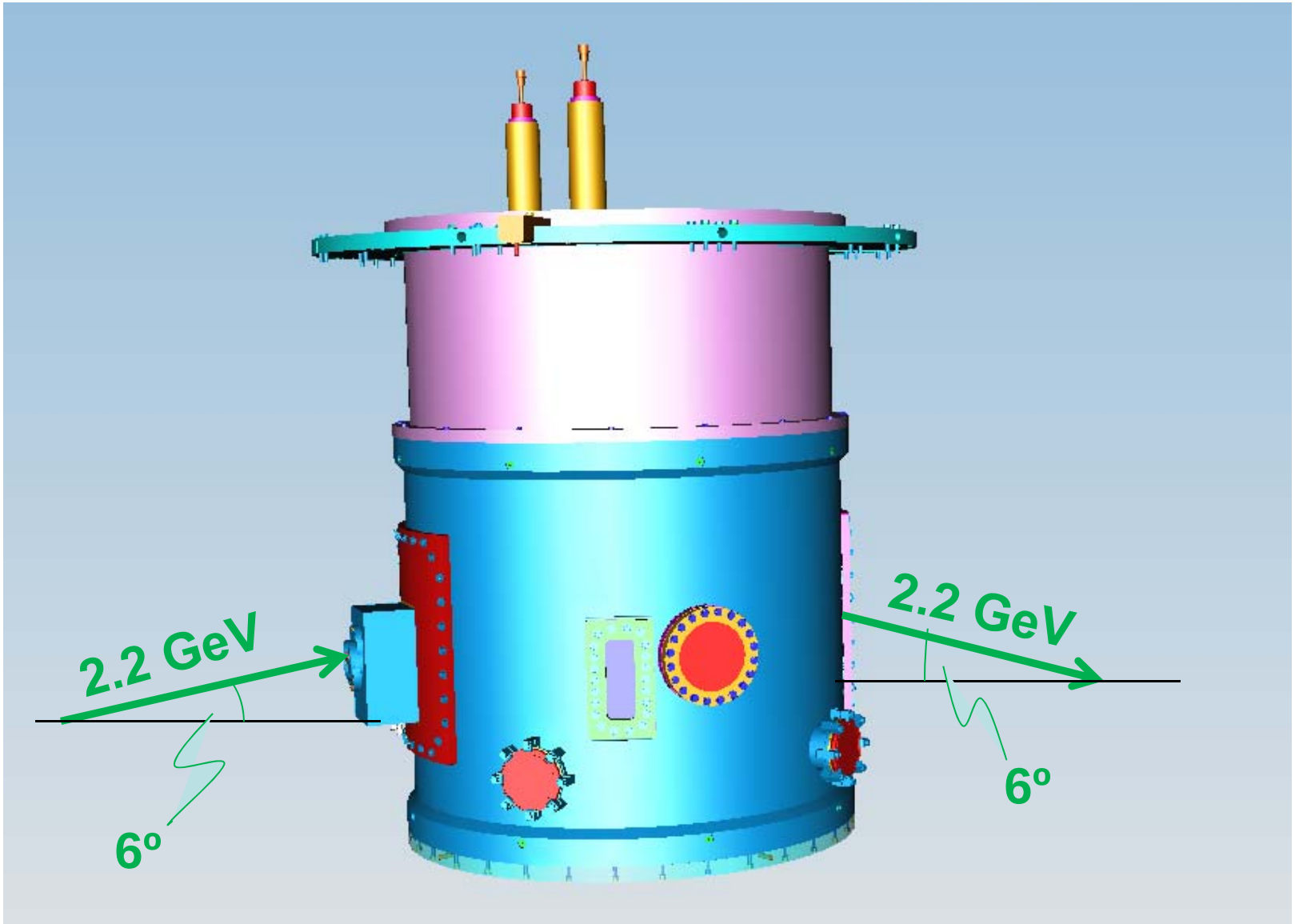
g^p_2 Target Chamber and Beam Dump



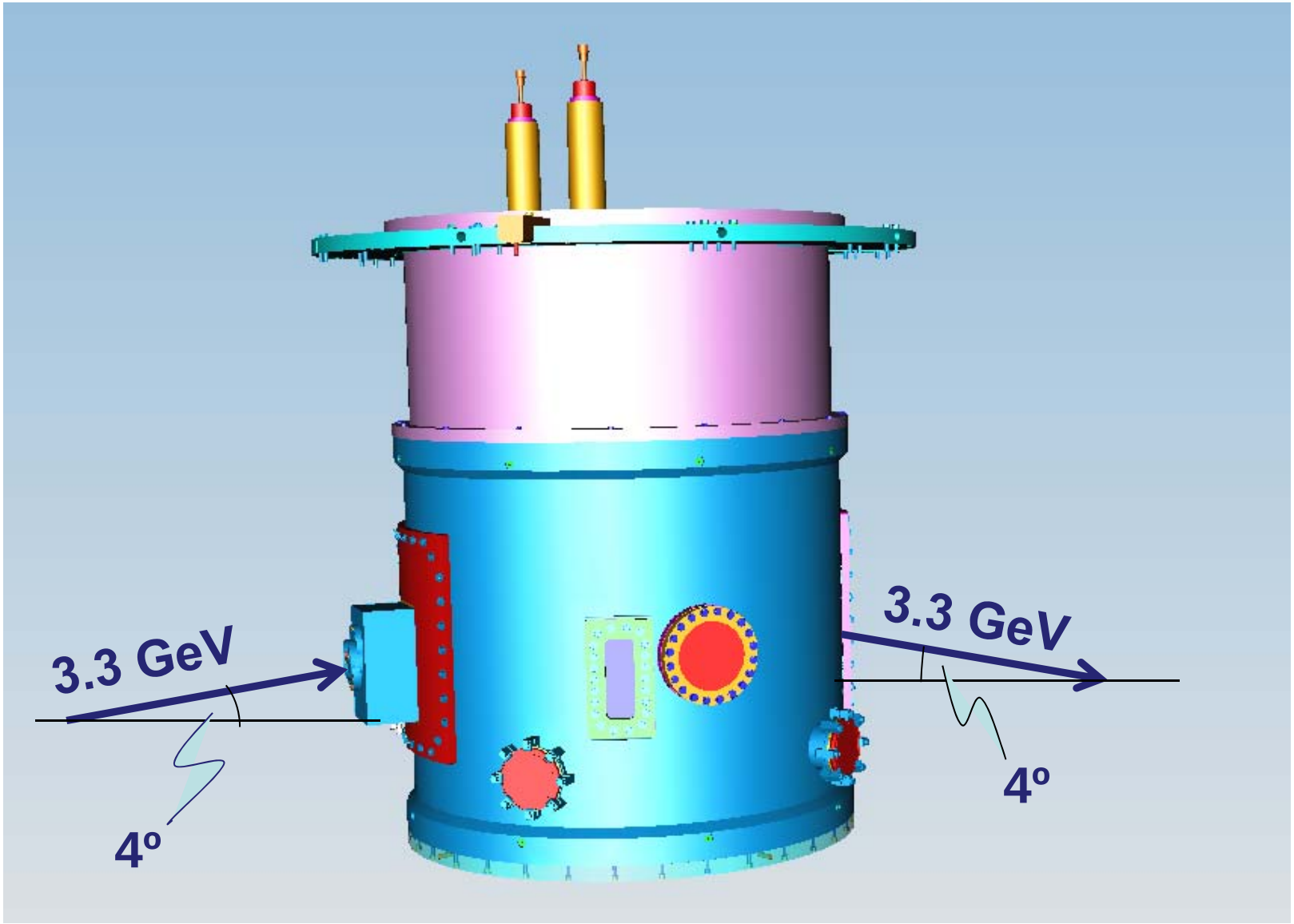
Beam Dump

Target Chamber

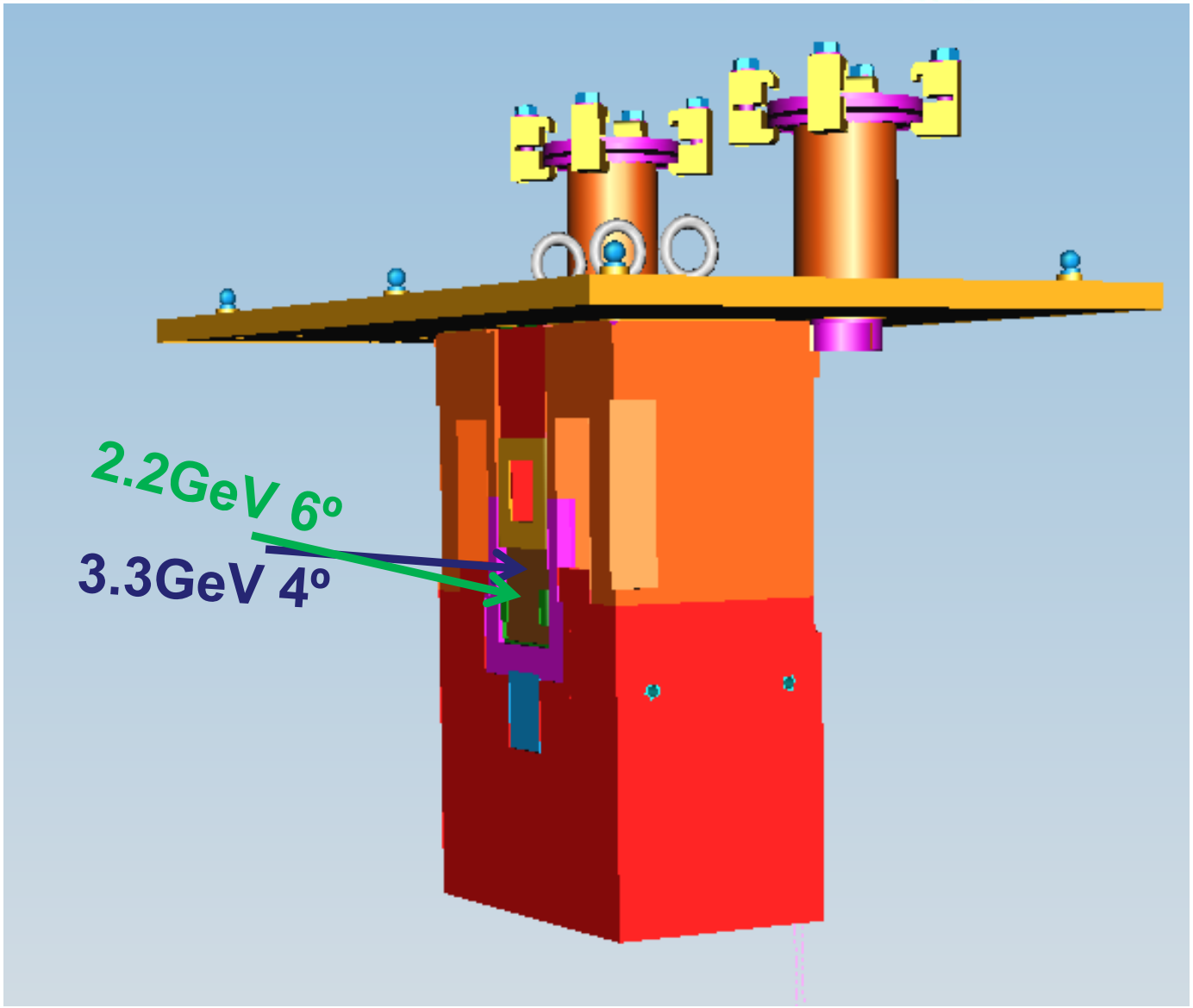
g^p_2 Target Chamber



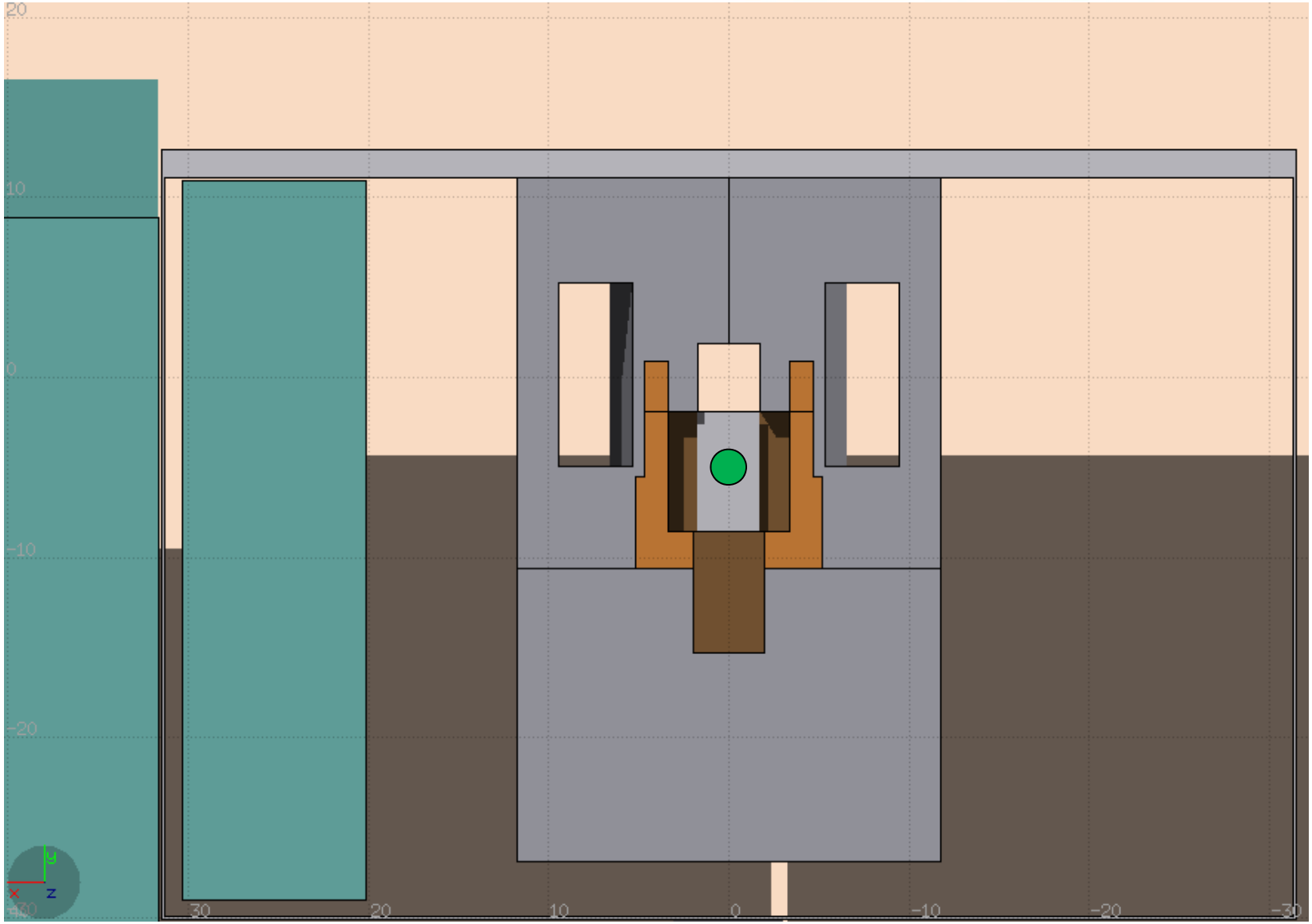
g^p_2 Target Chamber



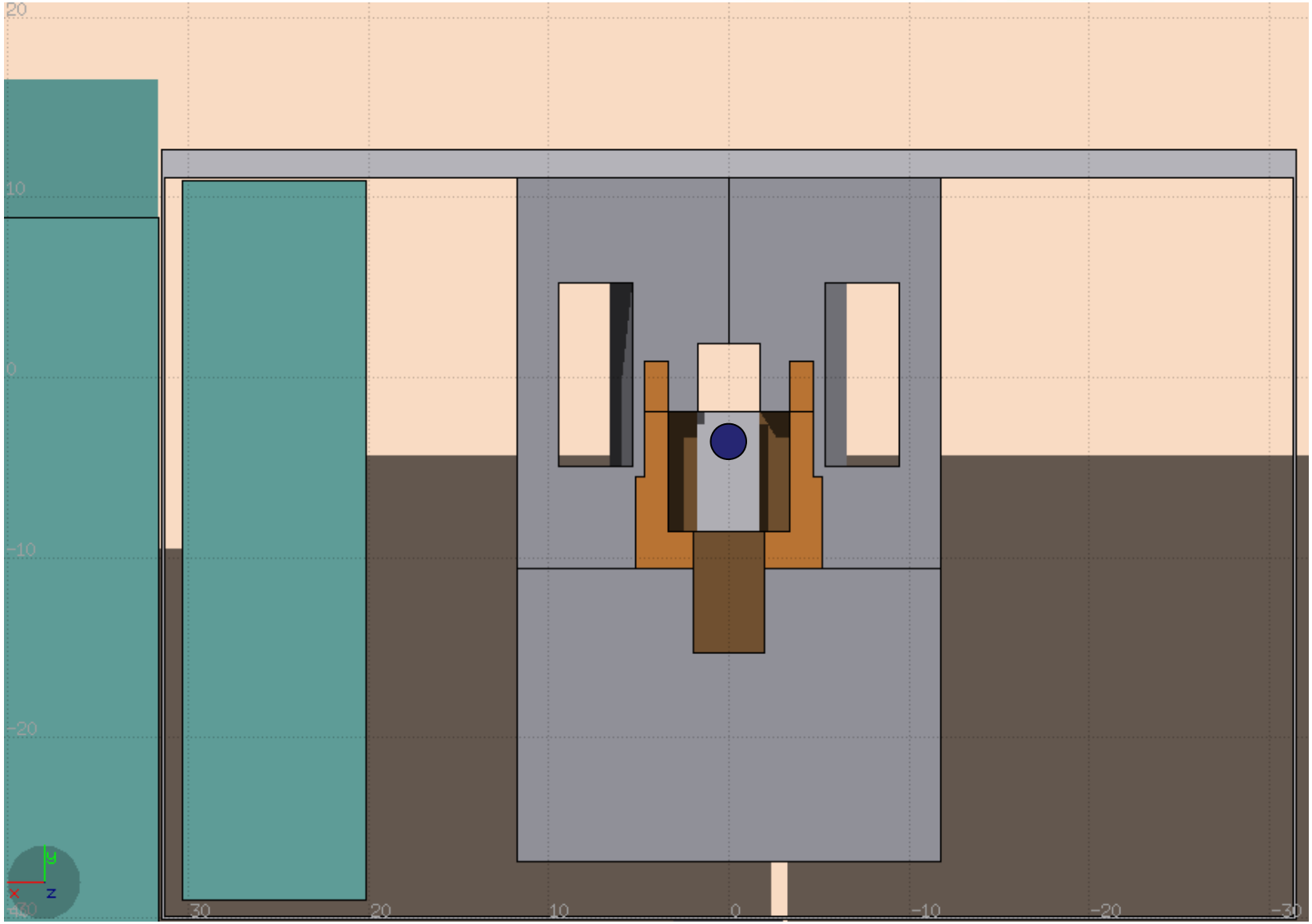
g²p Beam Dump



g^p_2 Beam Dump – FLUKA Model

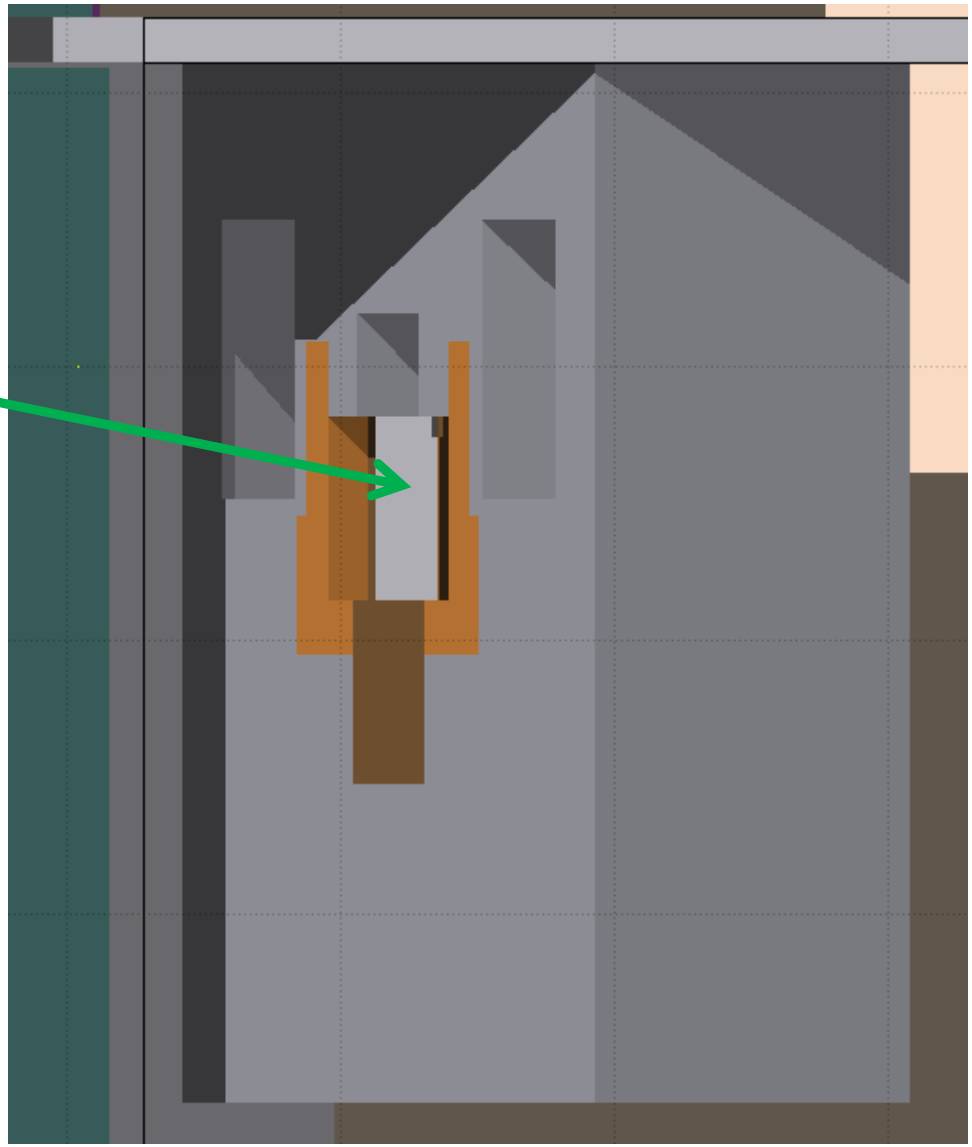


g^p_2 Beam Dump – FLUKA Model



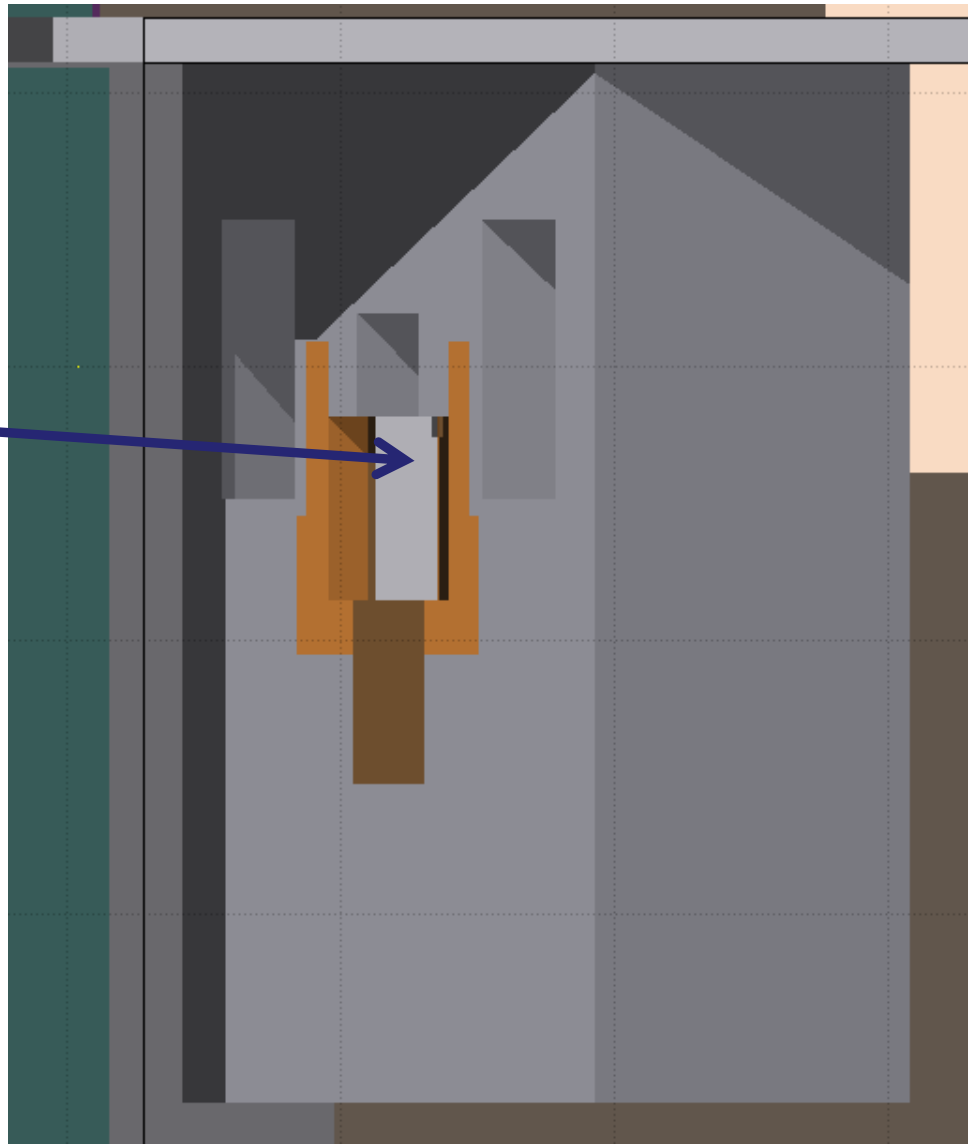
g^p_2 Beam Dump – FLUKA Model

2.2GeV at 6º

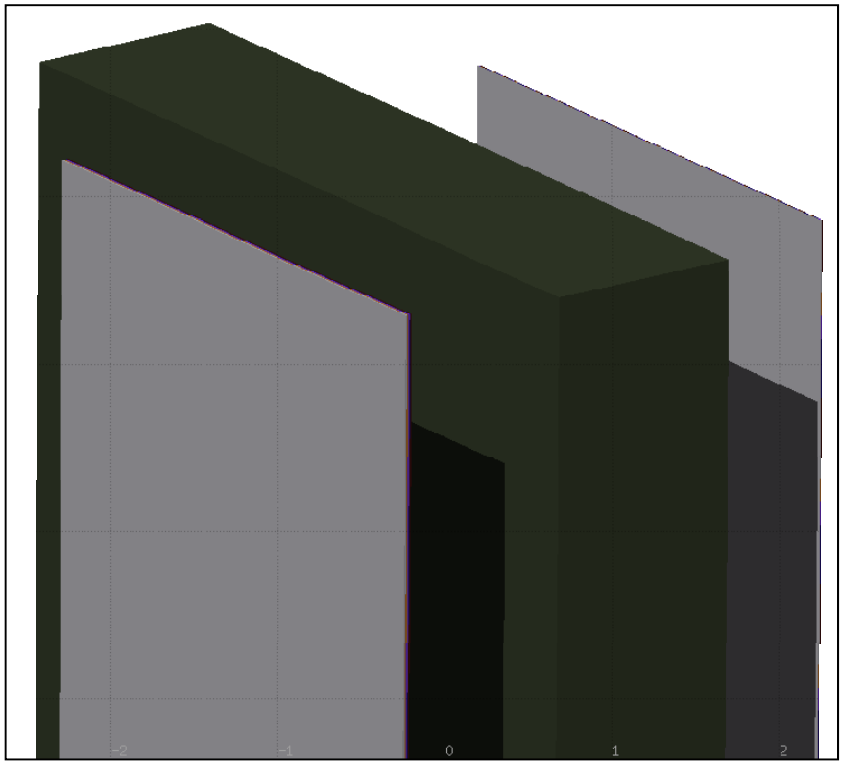


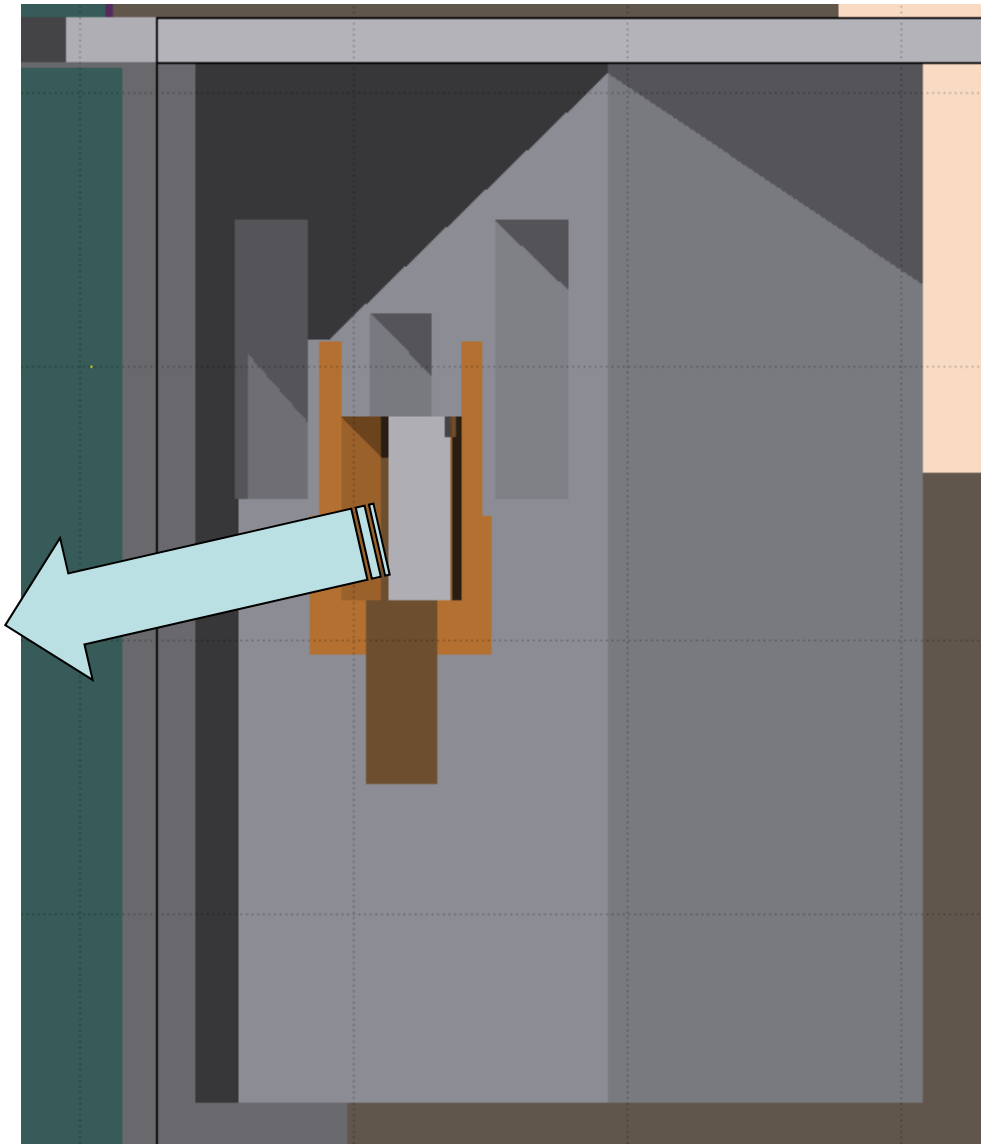
g^p_2 Beam Dump – FLUKA Model

3.3GeV at 4º

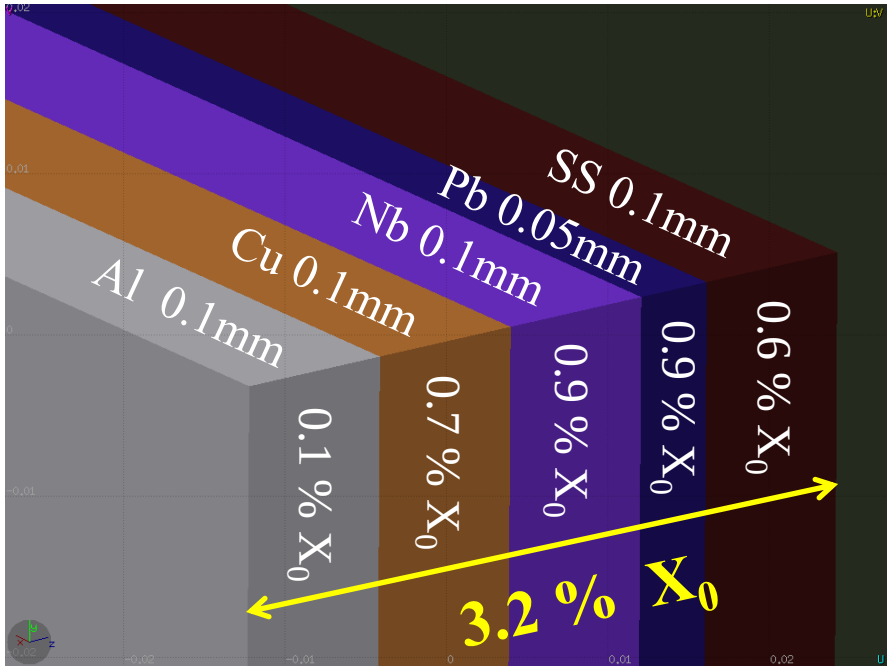


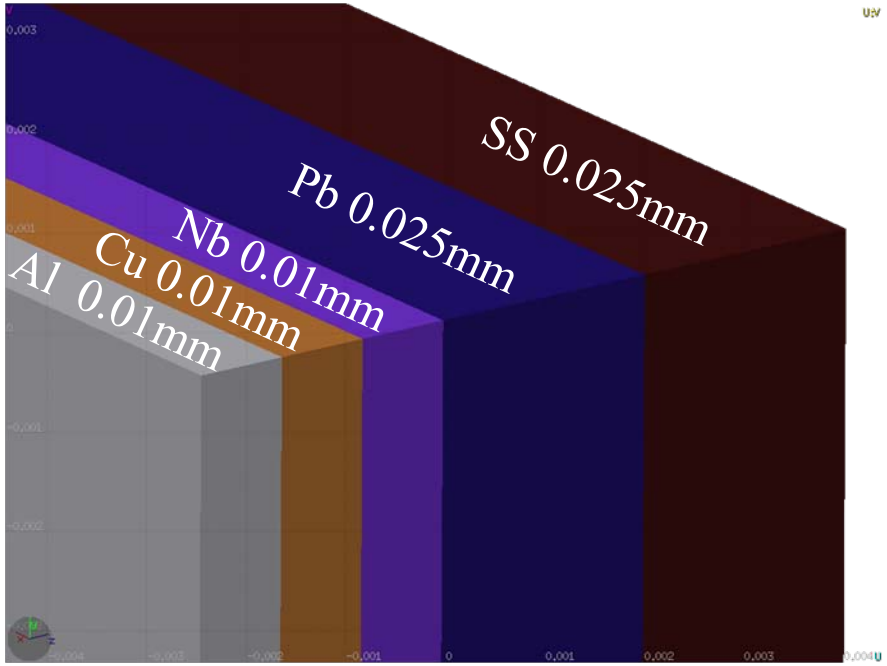
g^p_2 Beam Dump – FLUKA Model

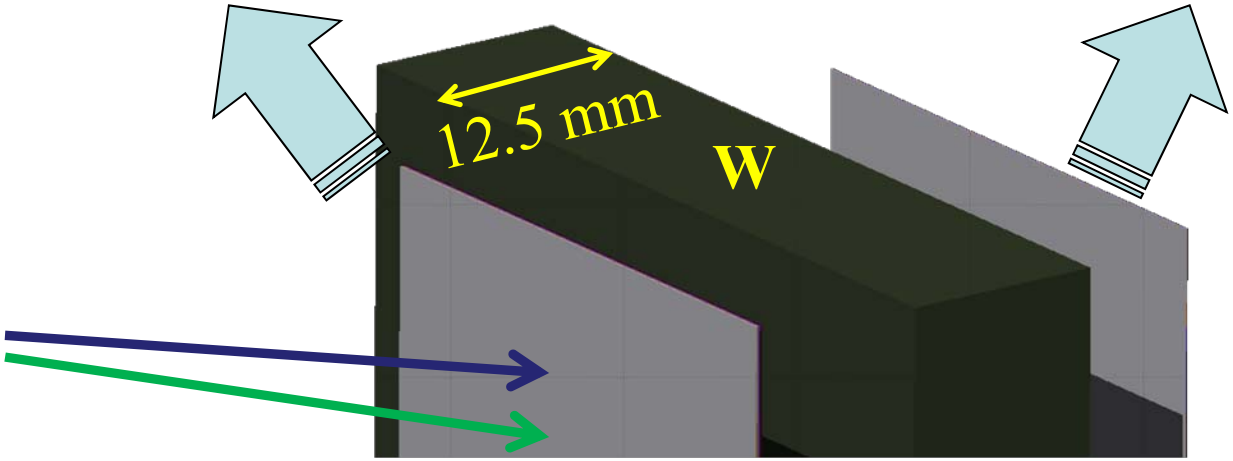




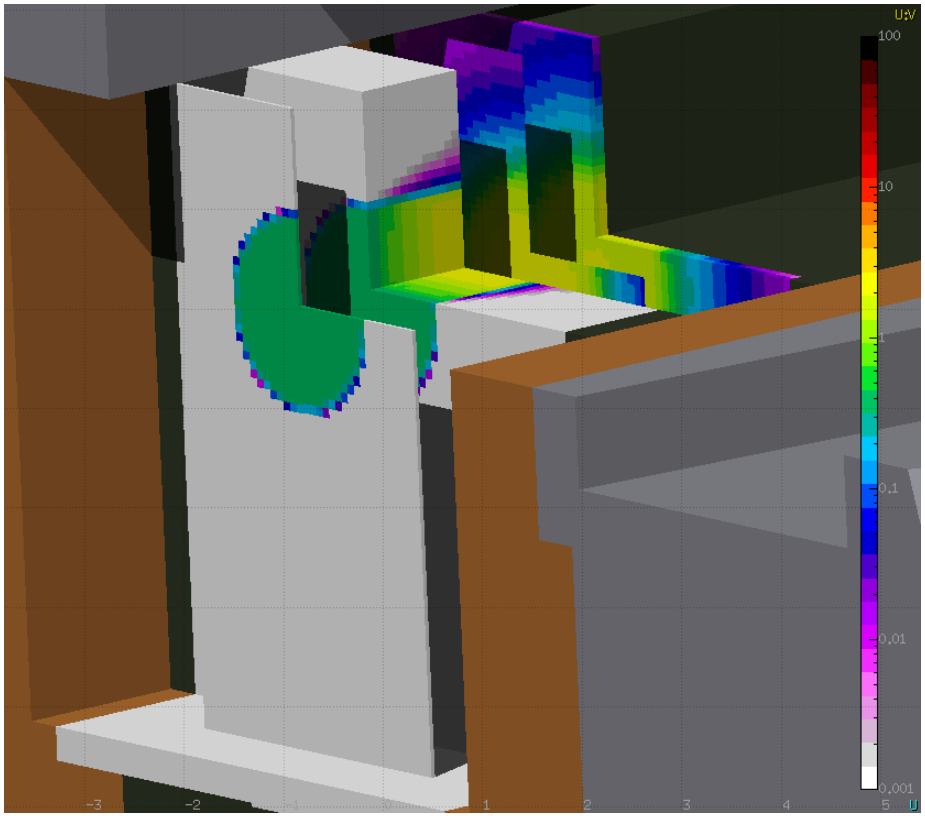
g^p_2 Beam Dump – FLUKA Model

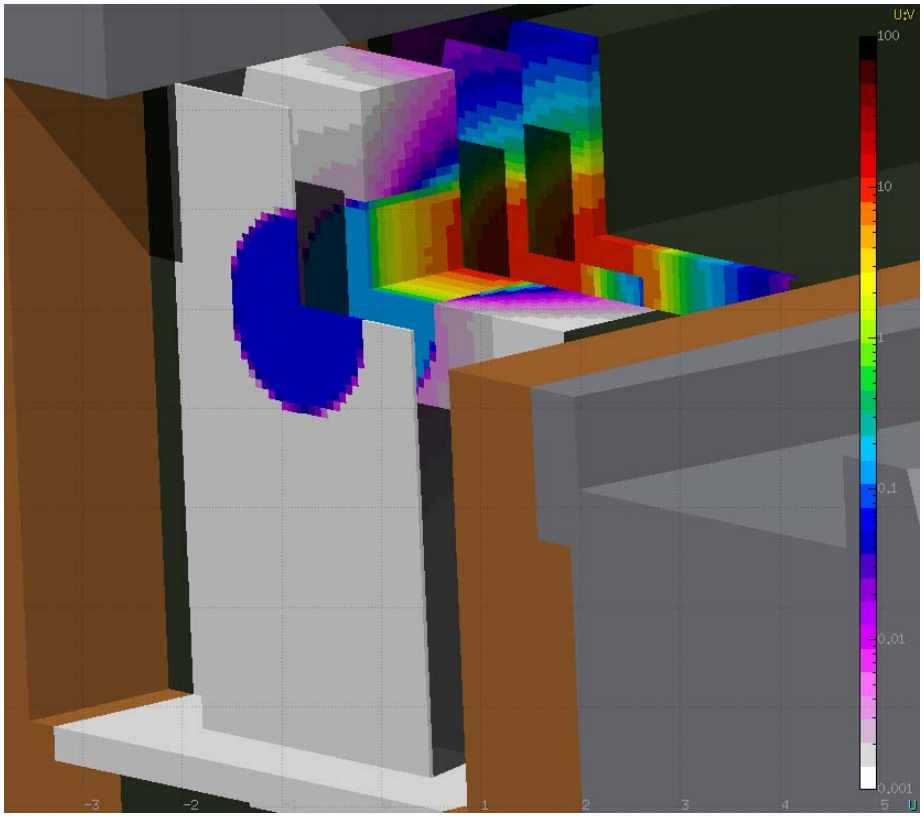






Electron and Photon Fluences

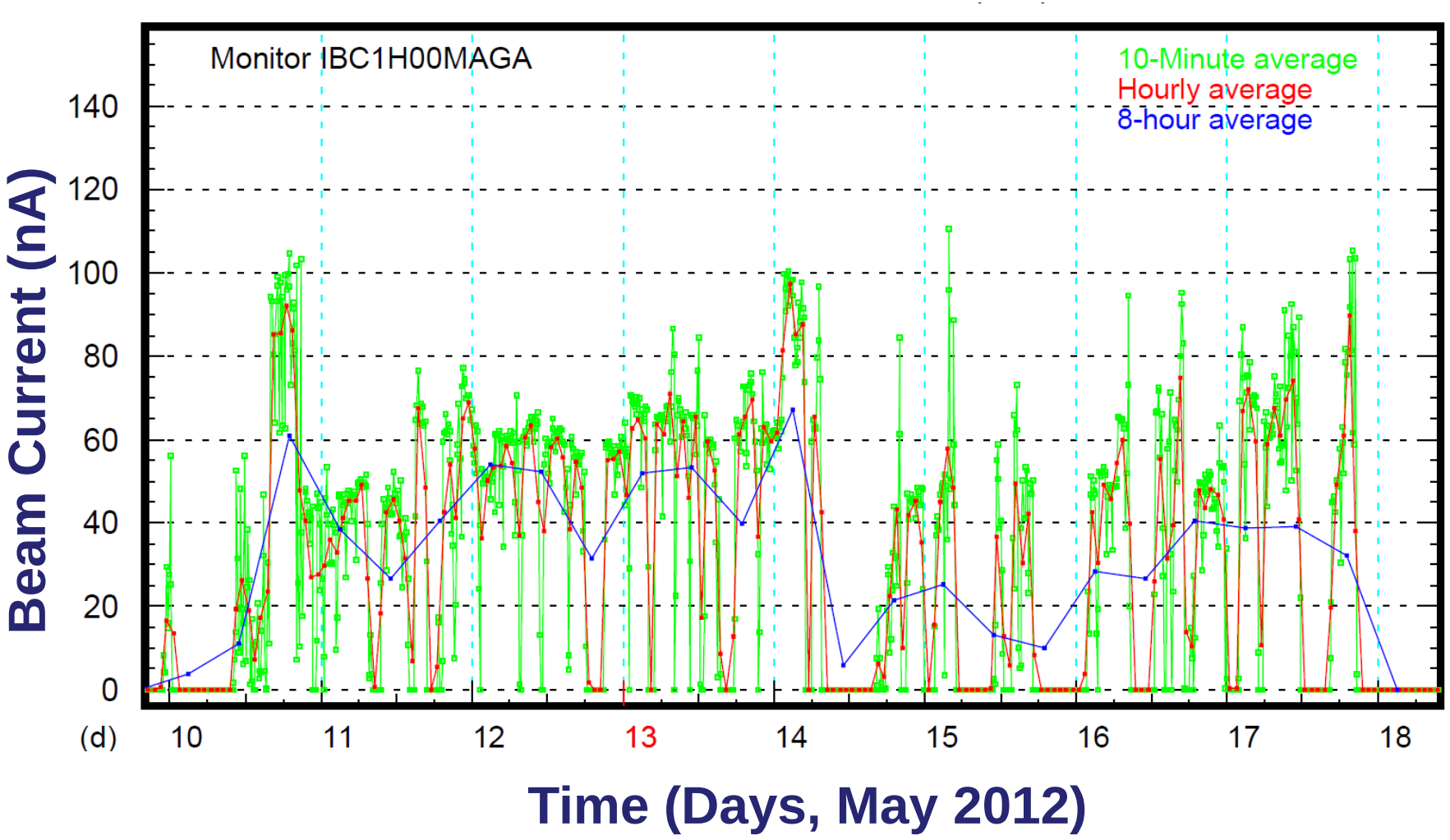




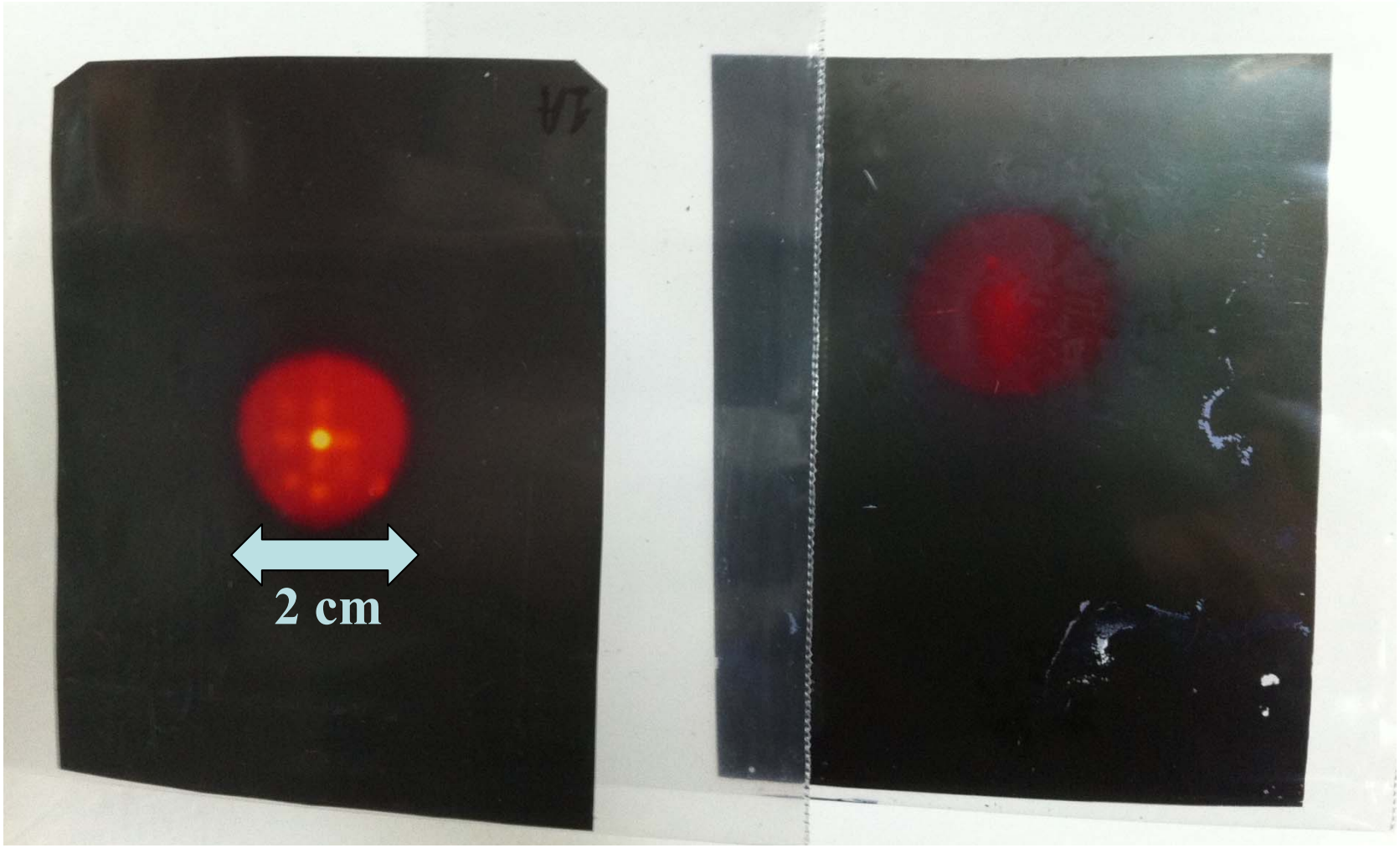
Electron fluence **Photon fluence**

3.35-GeV e^- beam incident with 4º angle

Beam Monitoring During Sample Irradiation



Radiochromic Films Used to Monitor Beam Spot

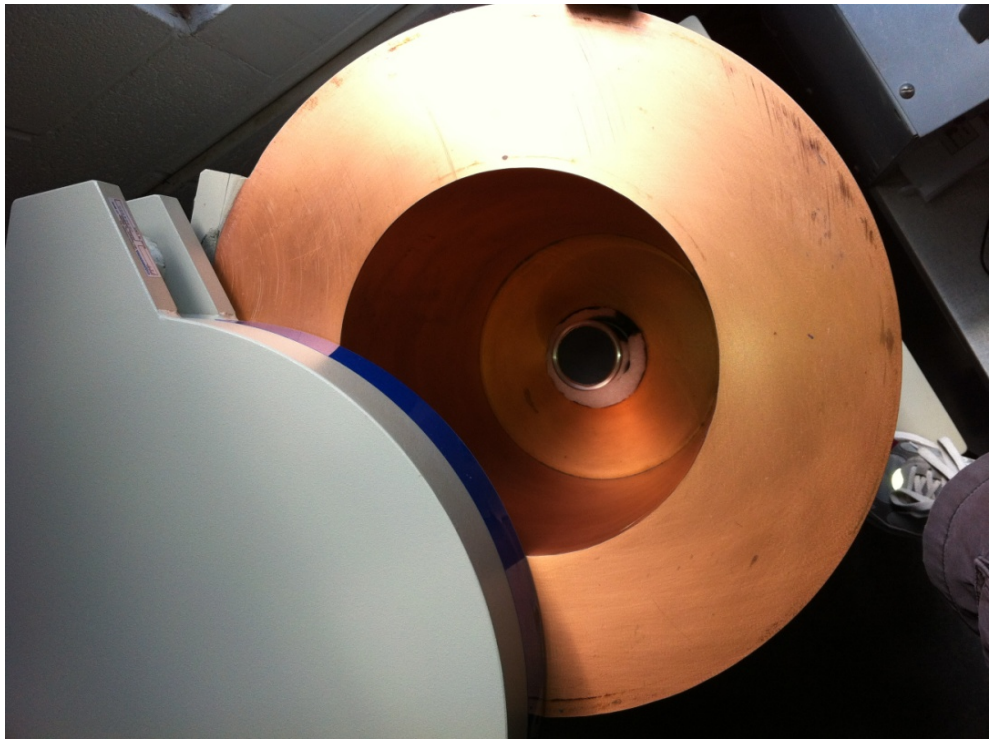


2.2 GeV

3.3 GeV

Gamma Spectroscopy Analysis

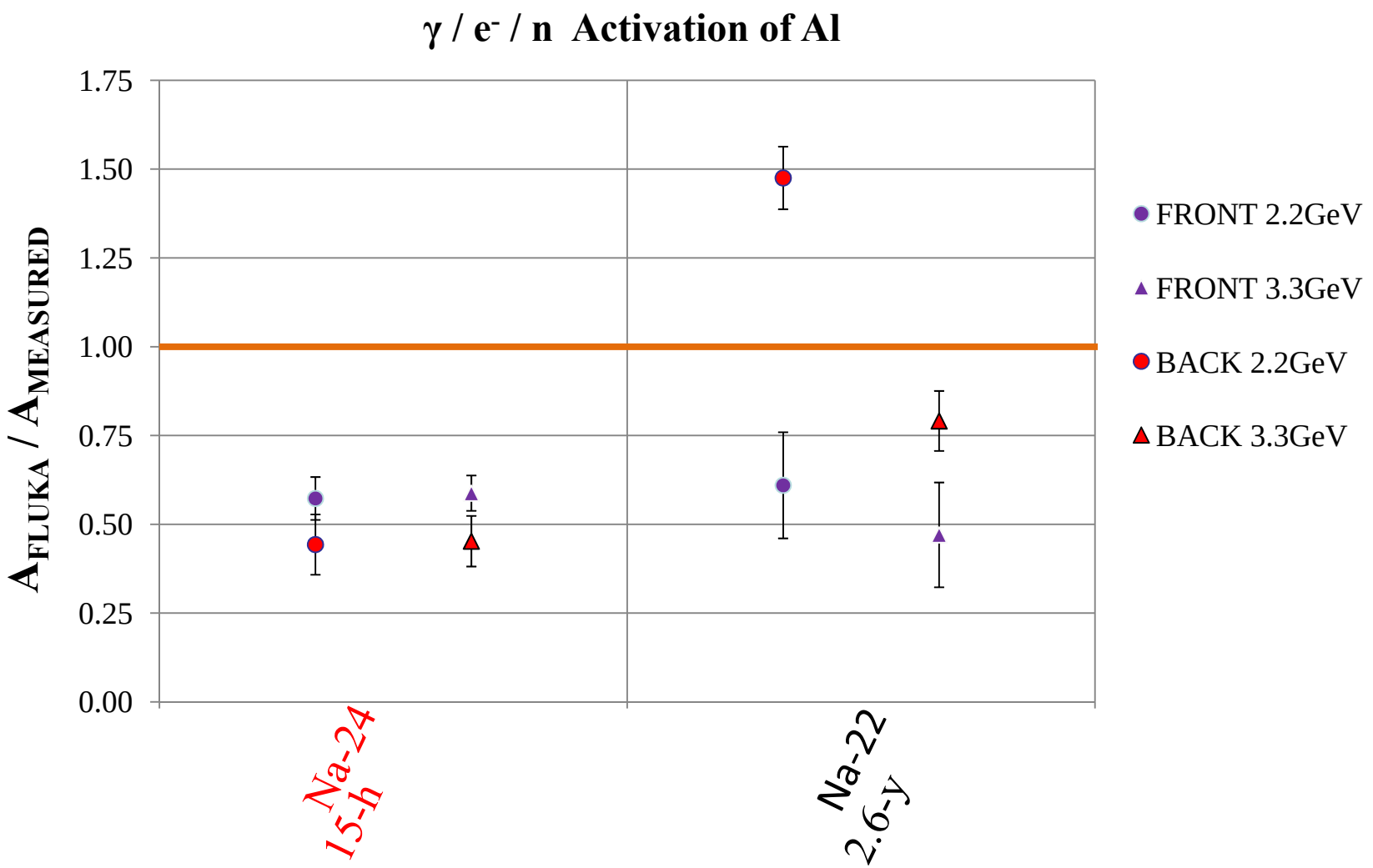
- Samples were analyzed with high-purity germanium detector using GENIE 2000 spectroscopy software and ISOCS/LabSOCS calibration software by Canberra.
- Proper QC procedures were implemented: characterization source checks, spiked sample counting, etc.



Preliminary Results

- Some potential sources of systematic errors need to be looked at:
  - Gamma spectroscopy – more QA/QC checks;
  - Improve FLUKA model;
  - Beam current monitoring – FLUKA normalization.
- Radionuclides are plotted with increasing half-lives.
- Radionuclides with significant contribution from neutron activation are shown in red.

Comparison FLUKA vs. Measurement



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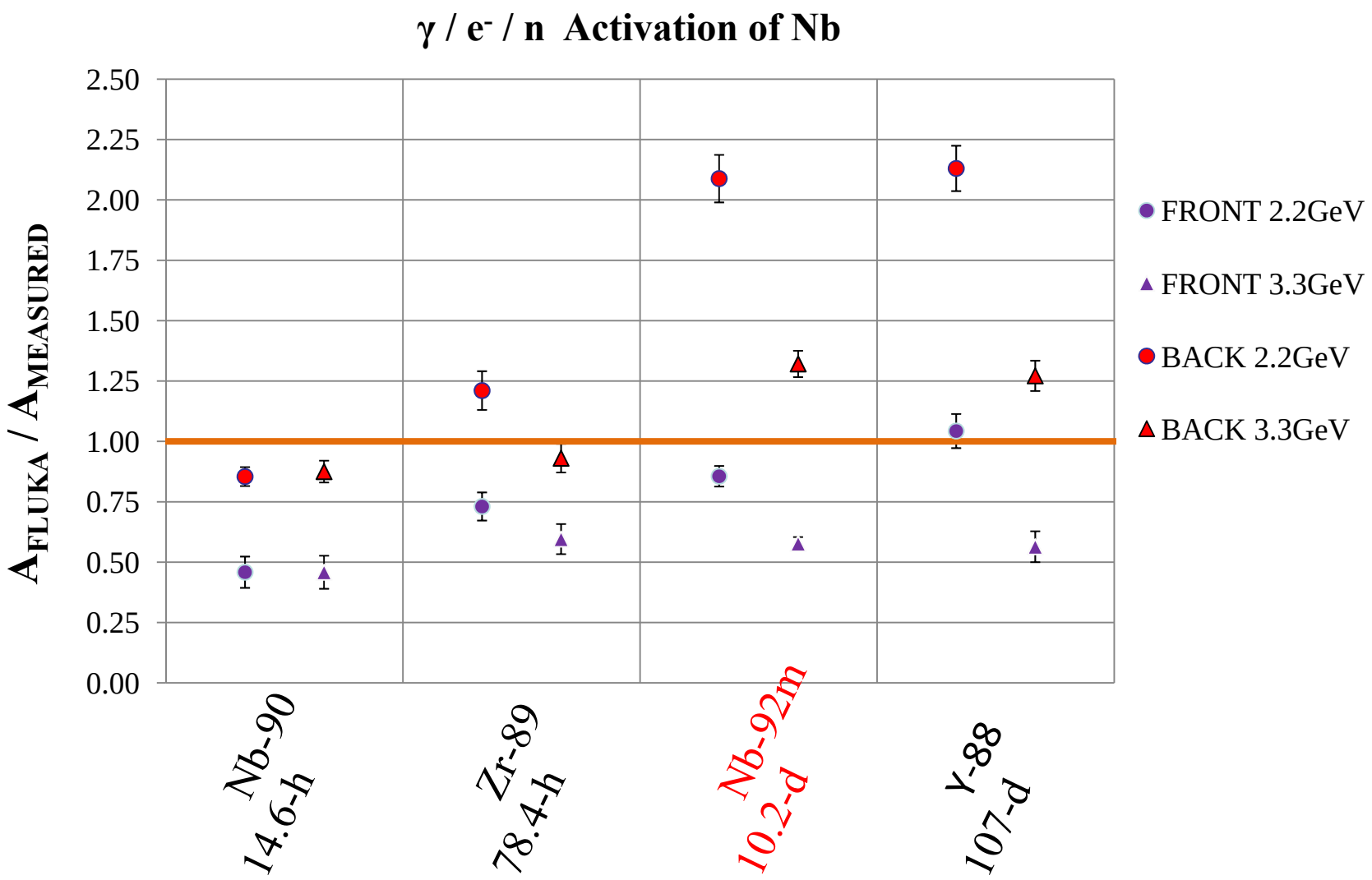

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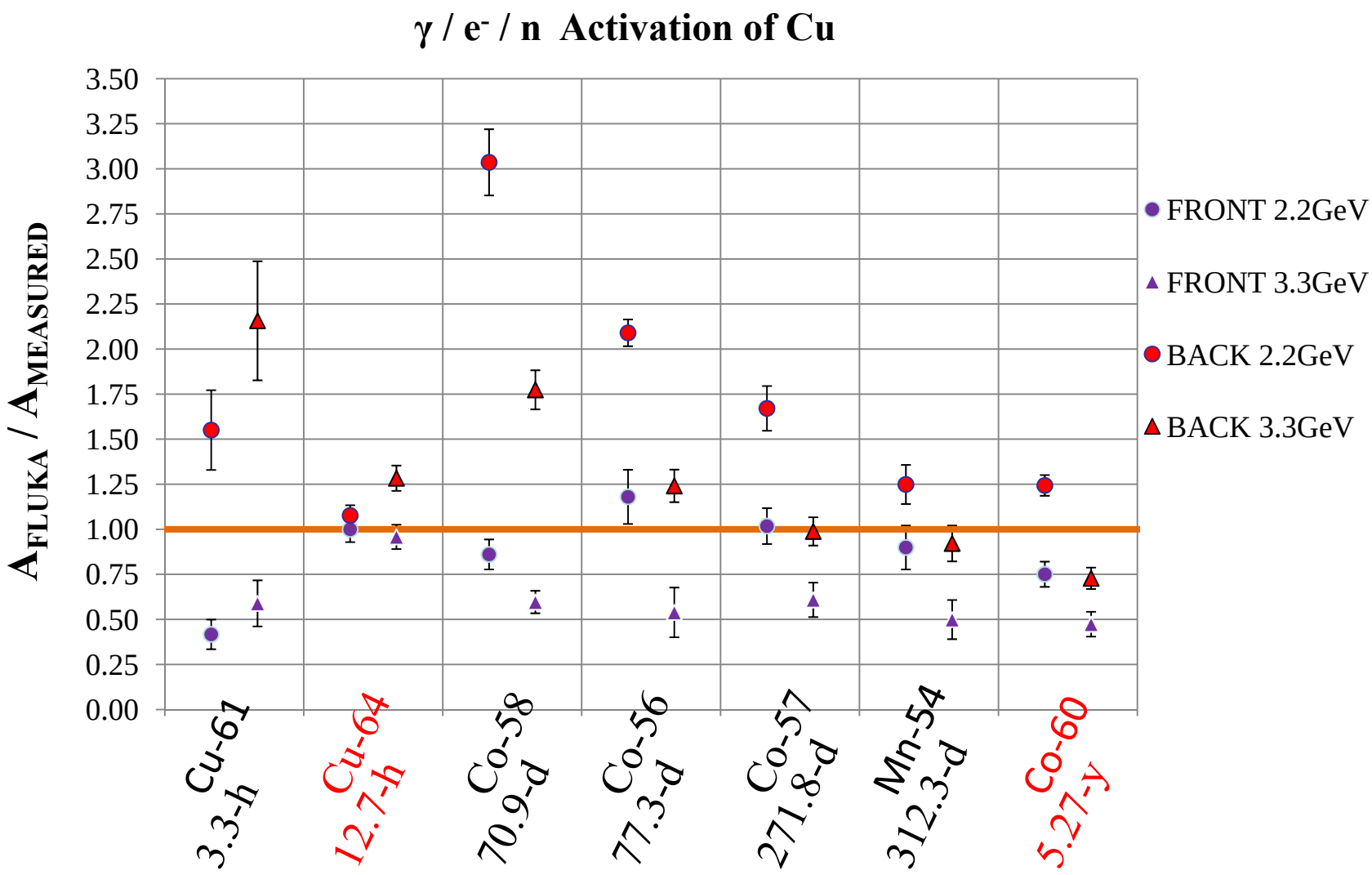

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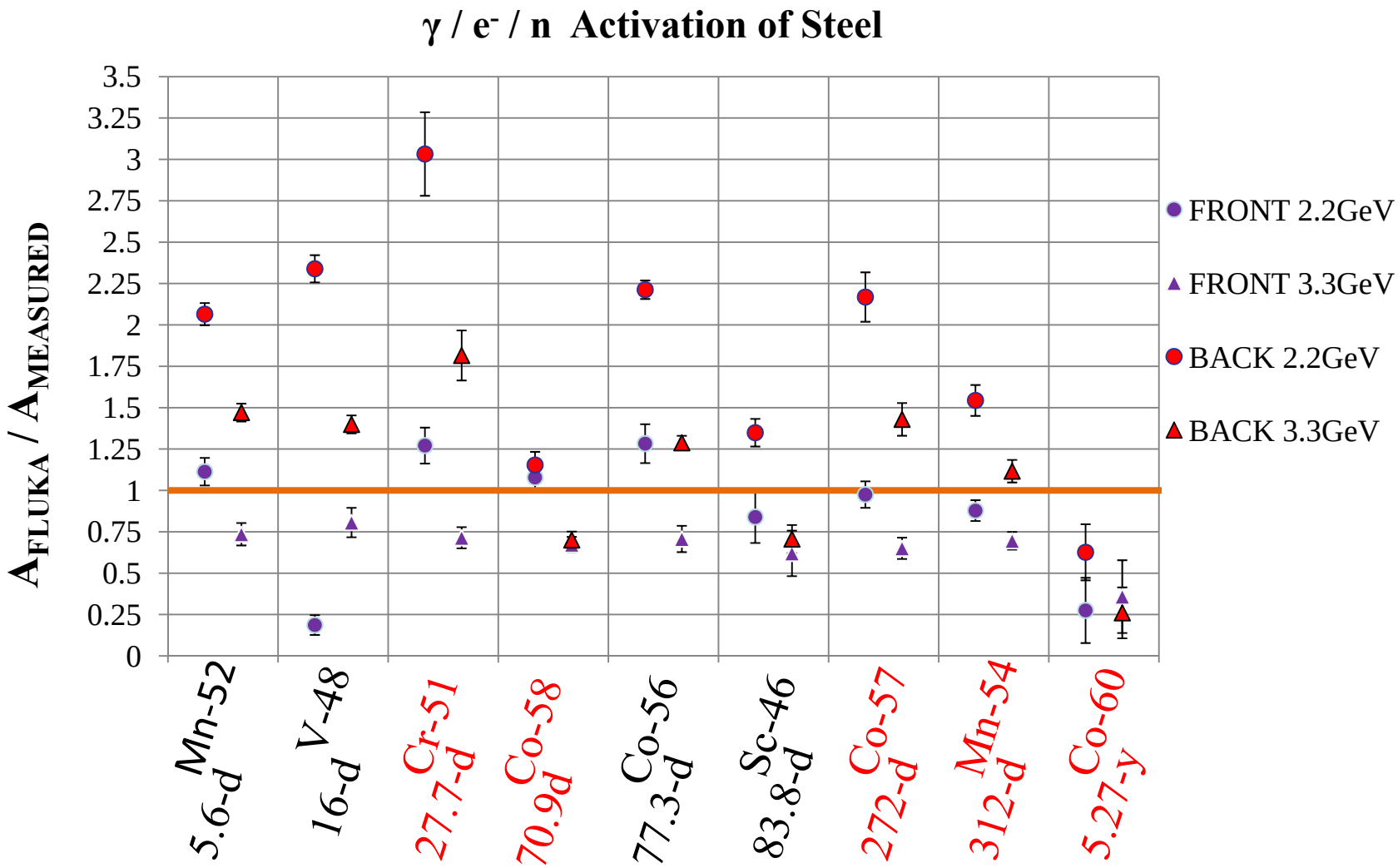

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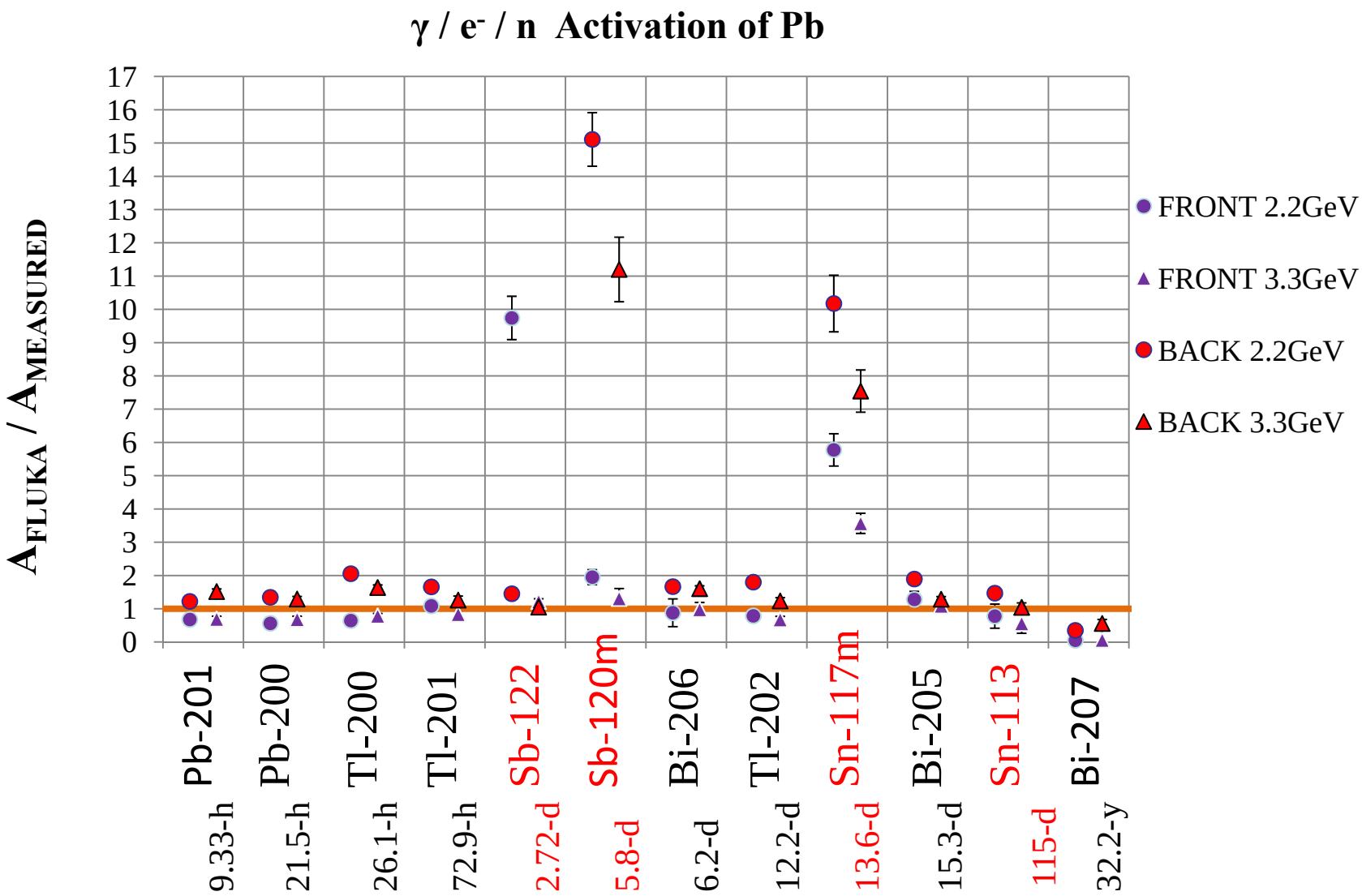

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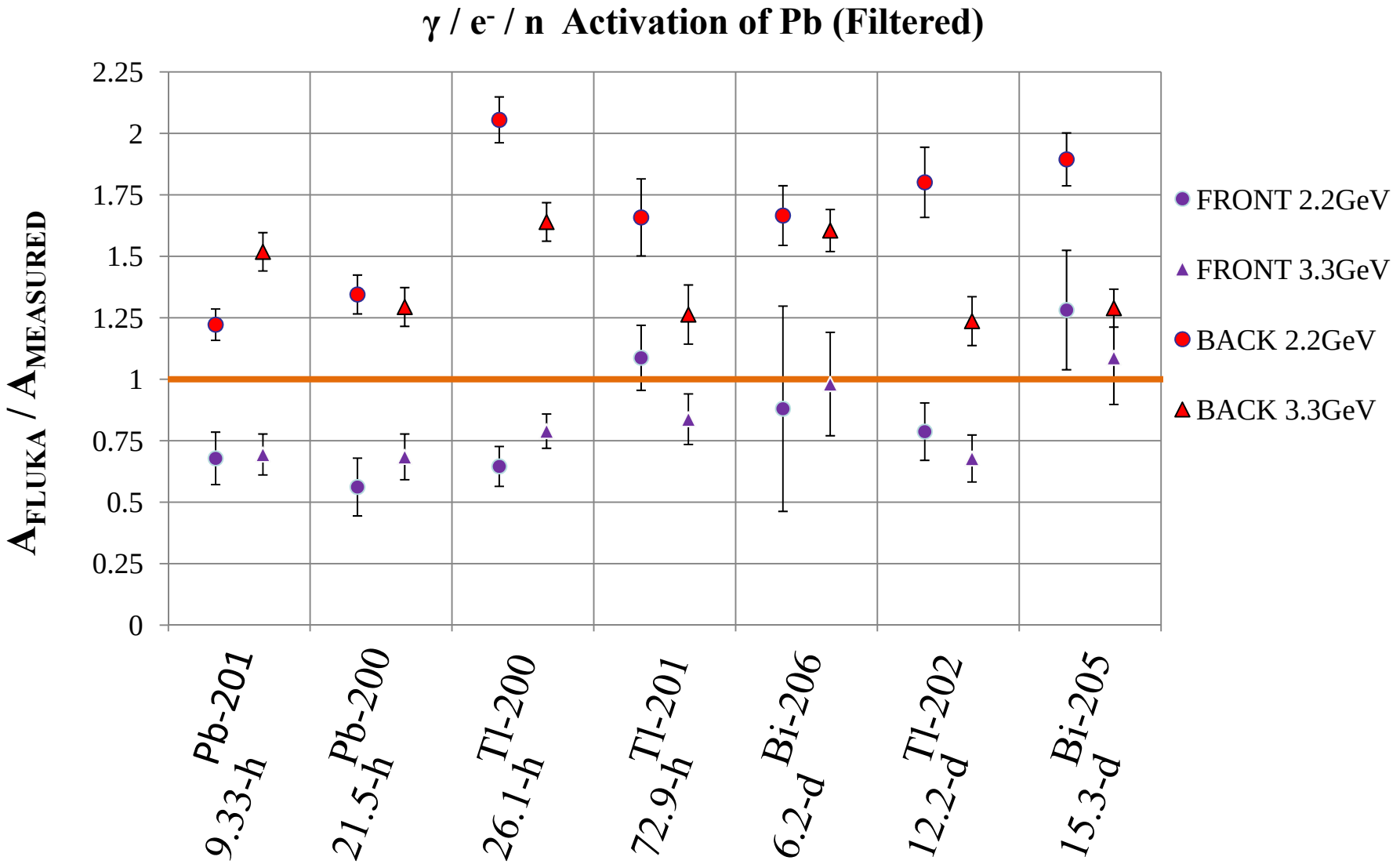

Conclusions

- 2-3 GeV e^- interaction with matter: FLUKA tends to predict induced activity within a factor of 2-3 !!!
  - More often than not – better than a factor of 2 !!!
  - Some gross under/overestimations may be attributed to insufficient knowledge of sample composition – impurities.
- In general FLUKA tends to:
  - Overestimate induced activities in the samples placed in the well developed EM cascade;
  - Underestimate induced activities in the samples exposed to direct e^- beam before EM cascade is well developed (< 3.2 X_0)

Our Wishes

- **Electronuclear interactions in FLUKA**
- **Proper benchmarking**

Acknowledgements

- **Thanks to the 2nd FLUKA Advanced Course and Workshop for inviting me!**
- **Special thanks to Alberto Fassò for his advise and guidance!**
- **Thanks to Adam Hartberger, David Hamlette, Keith Welch, Jixie Zhang, Alan Gavalya, Ed Folts, Karl Slifer, J. P. Chen, and g^2_p collaboration for their contributions!**

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