Simulation of the NEBULA detector using Geant4

Final presentation

Balázs Pál

Supervisor : Ákos Horváth, PhD
Eötvös Loránd University

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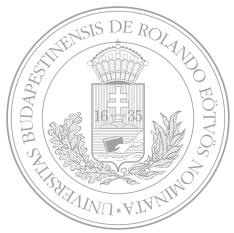


Tasks and achievements during the project

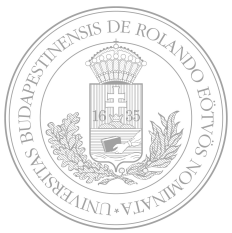
Goals and progress made so far

- ✓ Installing and setup Geant4 and other softwares and libraries needed
- ✓ Testing the configuration by running the examples provided in the Geant4 install
- ✓ Automate the complete setup pipeline of the environment for Geant4
- ✓ Implementing the simplified NEBULA detector geometry in Geant4
- ✓ Create neutron beam runs with real physical parameters
- ✓ Create macros for the project
- ✓ Create the data analysis and explore the distribution of the energy deposit of neutrons in the detector rods
- ✓ Test the finalized detector with pre-defined physics lists, containing different physical processes (built-in in Geant4)
- ✓ Measure the detector accuracy for different energies and physics lists

Geant4

Versatile simulation software

- Previous versions were developed since 1974, initial release of Geant4 is 1998
- Designed to be able to simulate every known physical aspect of matter-particle interactions
- Heavily bloated environment with **countless options**



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Nightmare

- ...or more like nightmare for anyone, who's not an actual software developer
- Serves as a software engine to develop actual simulation softwares on
- **Heavily bloated environment** with countless options

Simulations in Geant4

Very short outline

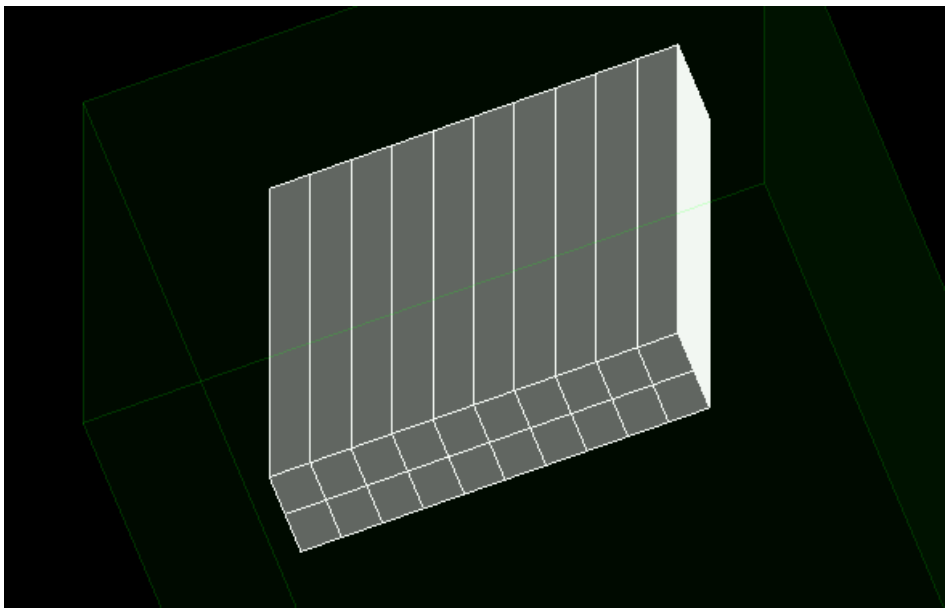
Usual components

- Detector construction
- Particle generation
- Data I/O
- Core loop

NEBULA detector in the simulation

Structure and composition

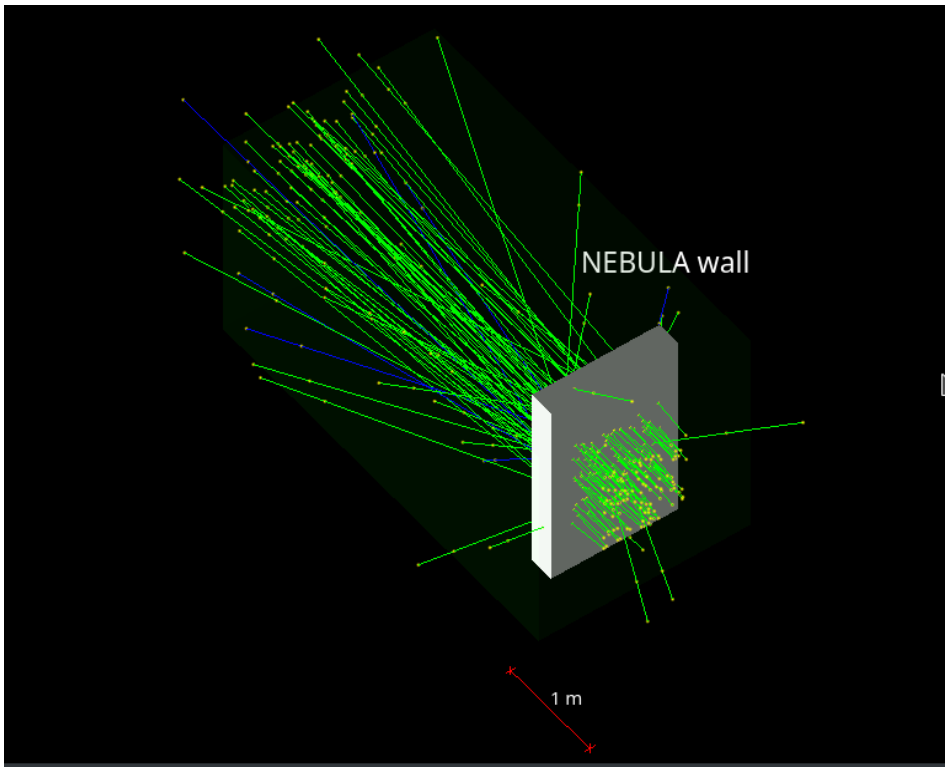
- 2×10 plastic scintillator rods in two layers
- Dimensions of rods are 12cm $\times$ 12cm $\times$ 180cm
- Filled with the BC-408 pastic scintillator material (52.45% H and 47.55% C)



Analysis of the simulation results

Examined topics

- Distribution of the energy deposition
- Processes and particles taken place in a simulation
- Detection accuracy



Energy distribution

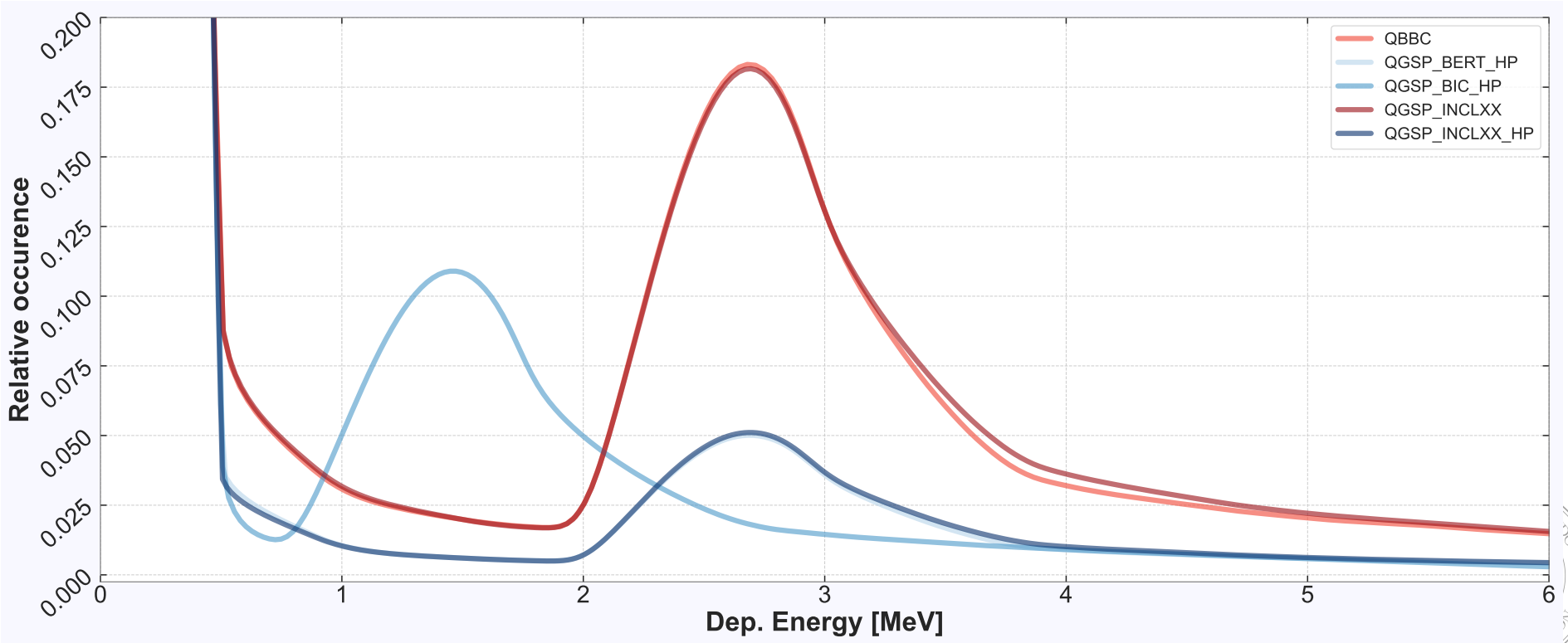
Distribution of total energy per rods

- Slightly different image for each physics list
- As energy grows, neutrons tend to pass through without depositing energy
- At smaller energies, neutrons simply bounce off the outer wall

Energy distribution

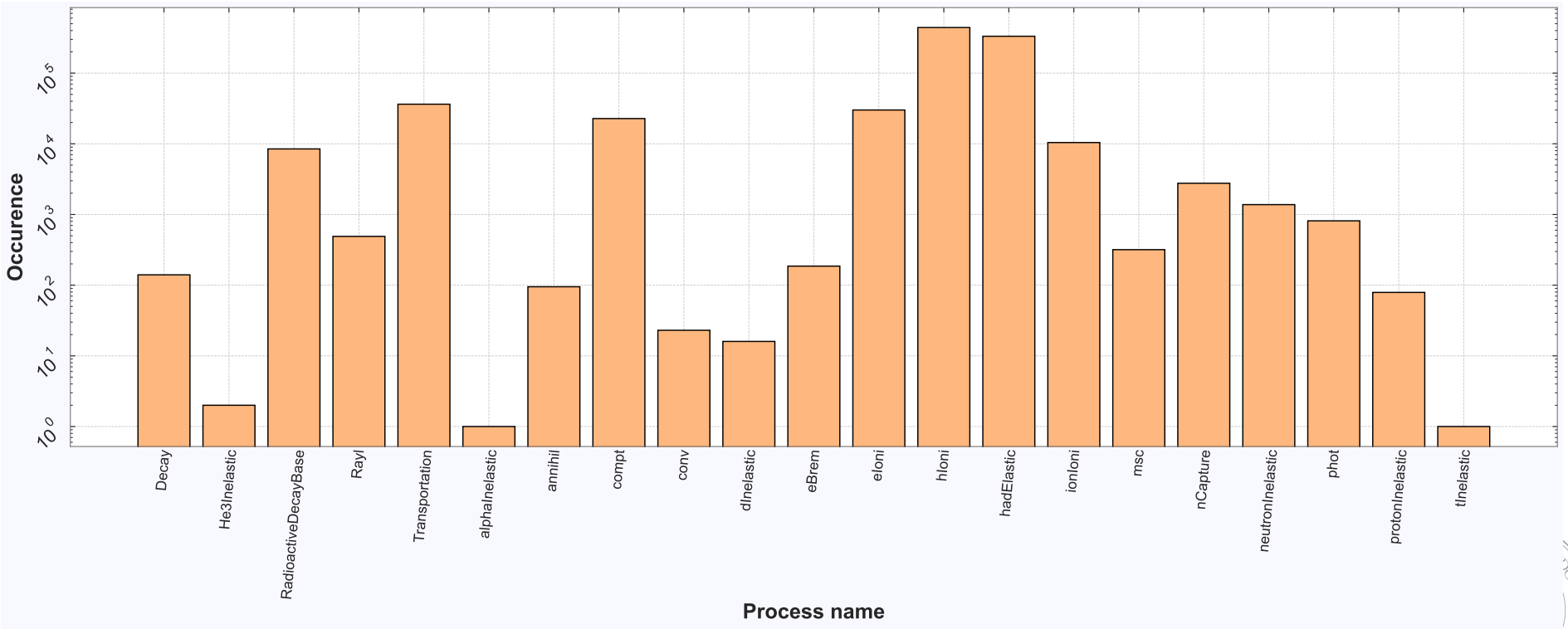
Usual components

- NeutronHP package produces smaller peak around 2.7 MeV
- The `QGSP_BIC_HP` physics list exhibits totally different characteristics



Processes – Counts

- Different physics list include different set of processes
- Ionization strongly dominates



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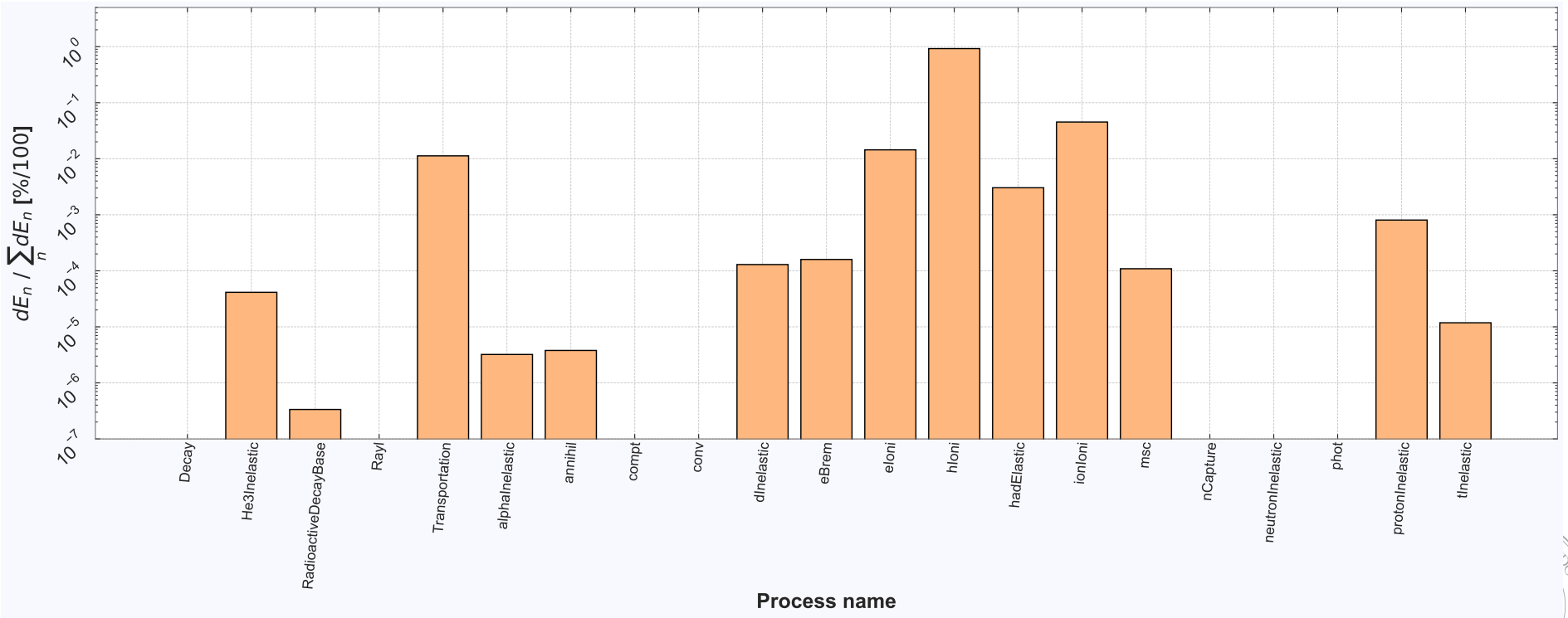
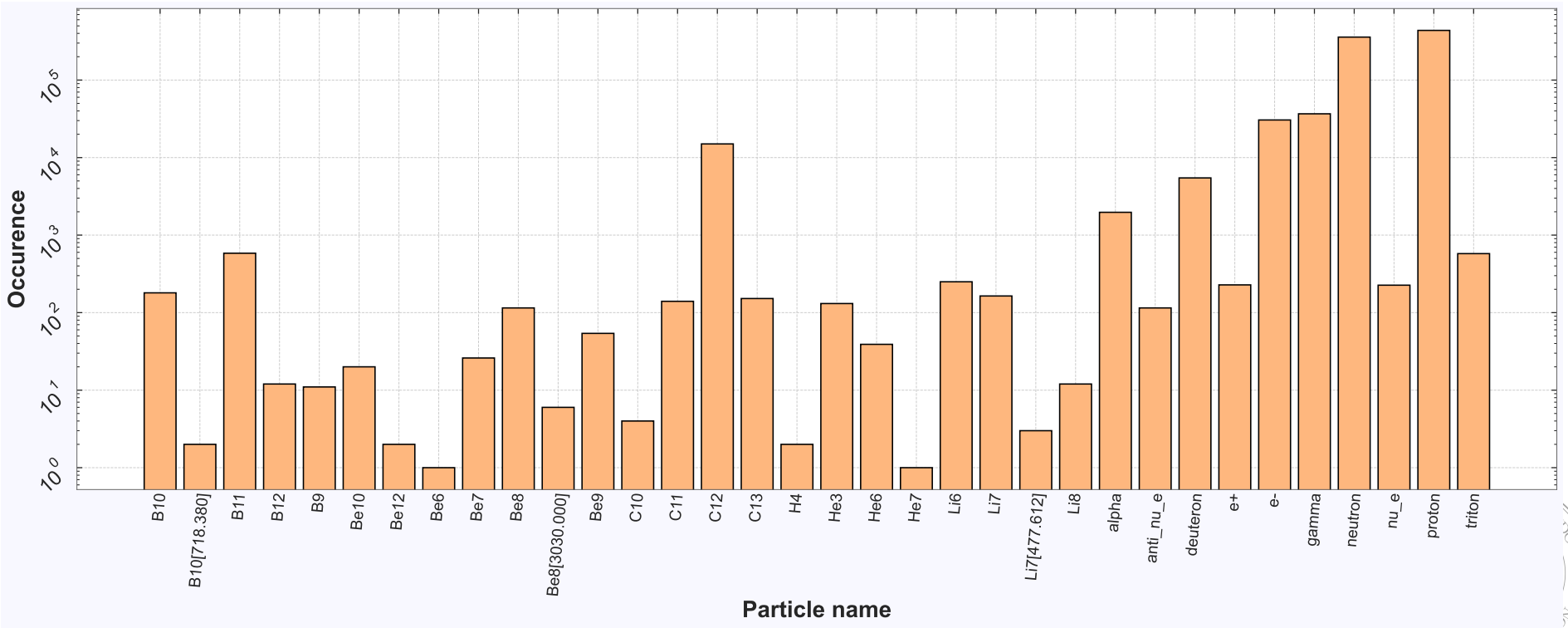


Particles – Counts

- Figure just vaguely represents the actual number of particles
- These are actually the number of steps calculated for specific particle types



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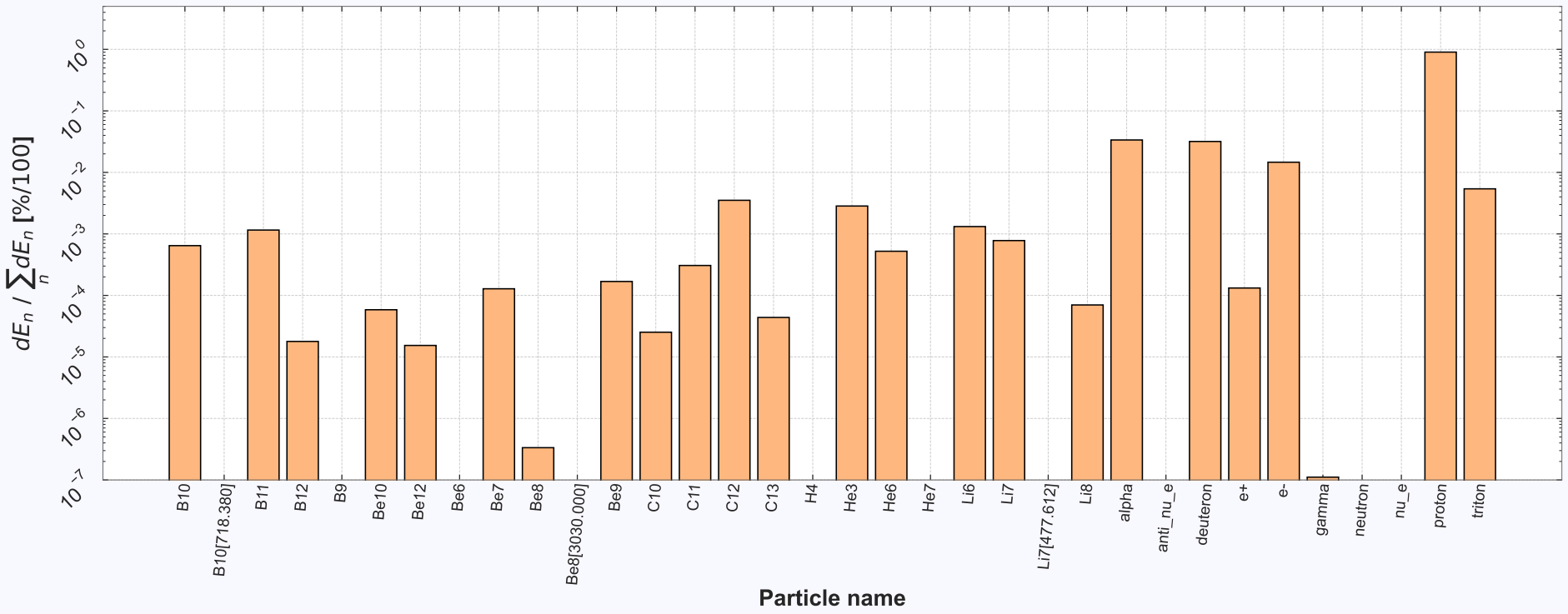
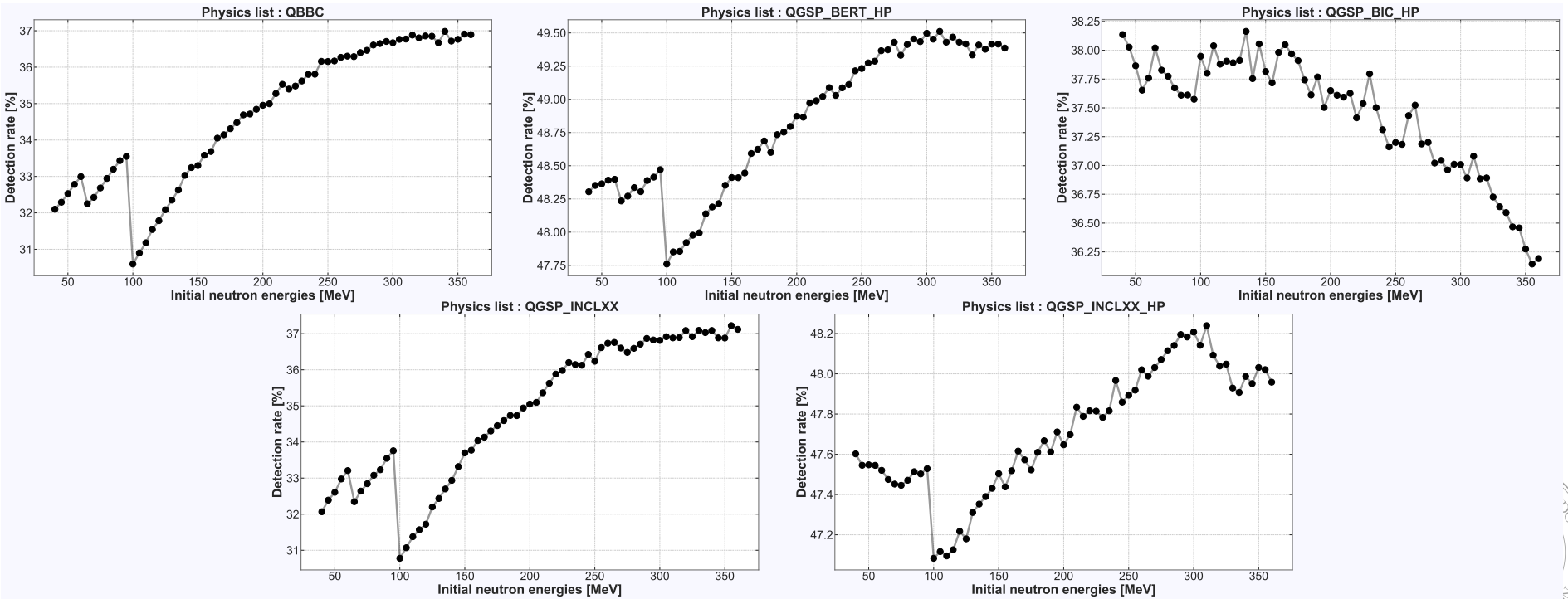


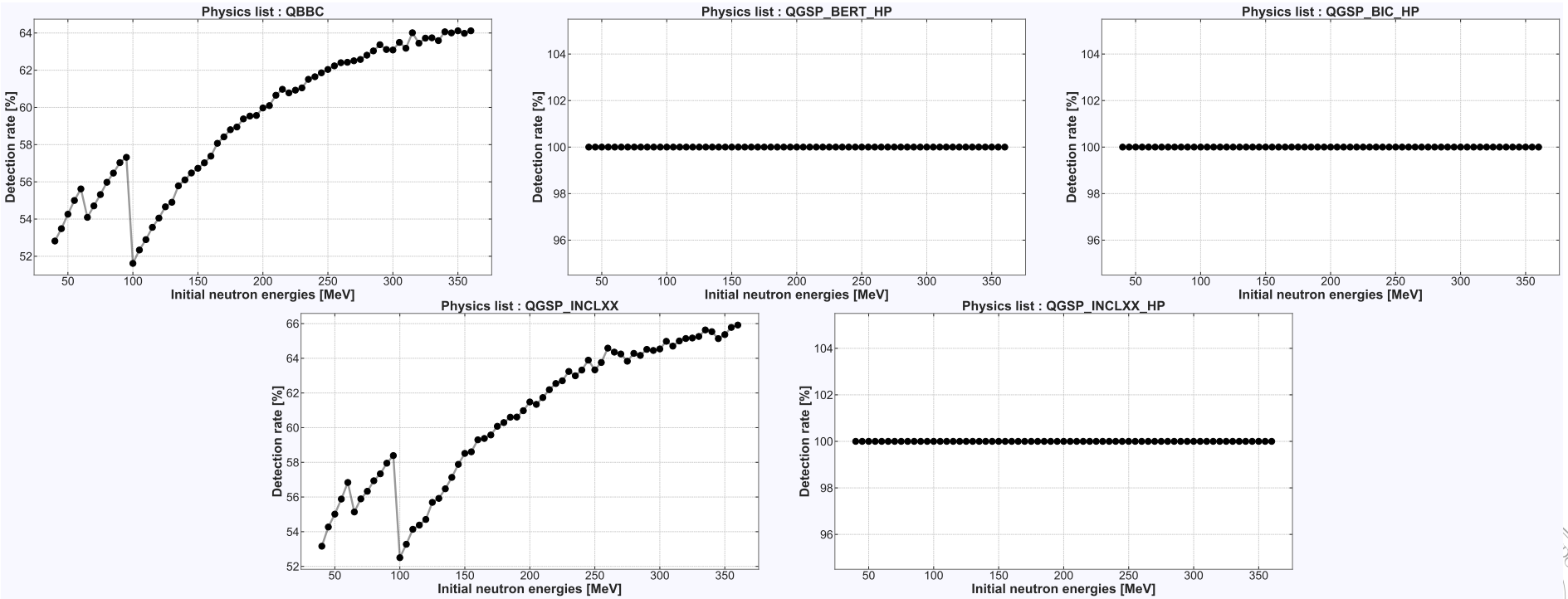
Detector accuracy – All particles

- Accuracy were measured for energies between 55 MeV and 355 MeV
- Artifact at 100 MeV
- Different characteristics for `QGSP_BIC_HP` (again)



Detector accuracy – Neutrons only

- NeutronHP package produces 100% detection rate on an energy levels
- For other physics lists, characteristics are similar to the general case



Summary

Achievements

- As a reference work I've used the BSc thesis of Dávid Pesznyák
- Successfully reproduced his results and figures...
- ...and also extended them with my own work and ideas

Reflections on the project

- The project took a lot of time and was relatively hard to keep up with it, but I think I did handle it relatively well
- Extra difficulties were arisen, when I had to interpret some results
- Overall it was still an interesting and challenging topic to work on