Shielding benchmarks for Geant4 version 10

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Outline

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Geant4 version 10

Support of multi-threaded application

- Testing its performance

Geant4 results for SATIF12 Inter-comparison

- Neutron production on Al, Cu and Au targets

Geant4 results for SATIF BNL Benchmarks

Summary

Geant4 version 10

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The latest version of Geant4 is 10.00

- The first major release of Geant4 in 7 years
- Major release may require modification of user code.
- Patch Geant4.10.00.p01 is released the end of Feb 2014.

Multi-threading

- This release includes support for multi-threaded Geant4 applications.
- Parallelism is achieved at the event level, with events dispatched to different threads.
- The default build of Geant4 is still sequential.

Updated physics models and new physics lists

- The Fritiof(FTF) model can now handle nucleus-nucleus collisions.
- Three new physics lists (all making use of the intra-nuclear cascade INCLXX) have been introduced: QGSP_INCLXX_HP, FTFP_INCLXX, FTFP_INCLXX_HP.

Geant4 developments after SATIF11 (2012 Sep.)

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Two public releases since SATIF11

Geant4 v9.6 and Geant4 v10.00

Selected new developments and capabilities

- The INCL cascade model (INCL++) was updated and can now handle heavy-ion collisions.
- New model for lepton-nuclear interactions using Bertini and Fritiof/Pre-compound has been introduced in most physics list.
- Introduced Bertini model for nuclear capture at rest of pi-, K-, Sigma-, Xi- and Omega- in most physics lists.
- Fritiof/Pre-compound model for anti-proton, anti-Sigma+ and light anti-nucleus capture at rest in the same physics lists.
- Barashenkov-Glauber-Gribov nucleon-nucleus inelastic cross sections are now used in most physics lists
- In all physics lists, the neutron capture process has been significantly improved, both for the cross section (replacing Gheisha with G4NeutronCaptureXS) and the final-state modelling (now using G4NeutronRadCapture instead of G4LCapture). This affects the response and lateral width of hadronic showers in tungsten-based simplified calorimeters.
- A new biasing capability has been introduced to allow physics-based biasing --process interaction occurence biasing, process final state production biasing-- and non-physics-based biasing --e.g. splitting, killing-- to be handled through a set of common classes: G4VBiasingOperator, G4VBiasingOperation.

Geant4 MT

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Geant4 version 10.00 supports (optional) event-level parallelism for multi-threaded application

- In a multi-threaded application, at the end of first kernel initialization, worker threads are started and initialized.
- These worker threads are responsible for simulating events.

The objects that consume the largest fraction of memory (geometry and Electromagnetic physics tables) are shared among threads, while all other objects (in particular user-action and sensitive detectors) are thread-private.

- Exploits full performance of multi-core CPU(s) with less memory consumption

Testing MT performance on application for SATIF12 Inter-comparison problem

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CPUs

- Intel Xeon CPU E5620 @ 2.40GHz x 2
  - total 8 physical core

Memory size

- 48 GB

OS

- Red Hat Enterprise Linux 6.3-64

Compiler

- gcc 4.4.7

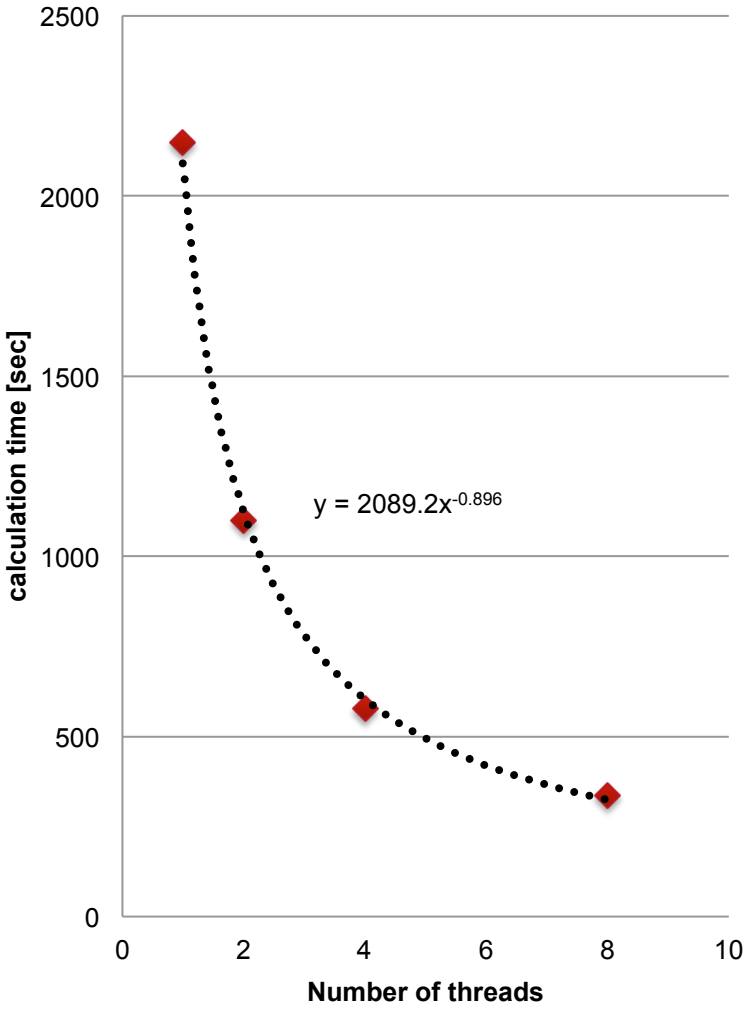
Testing application

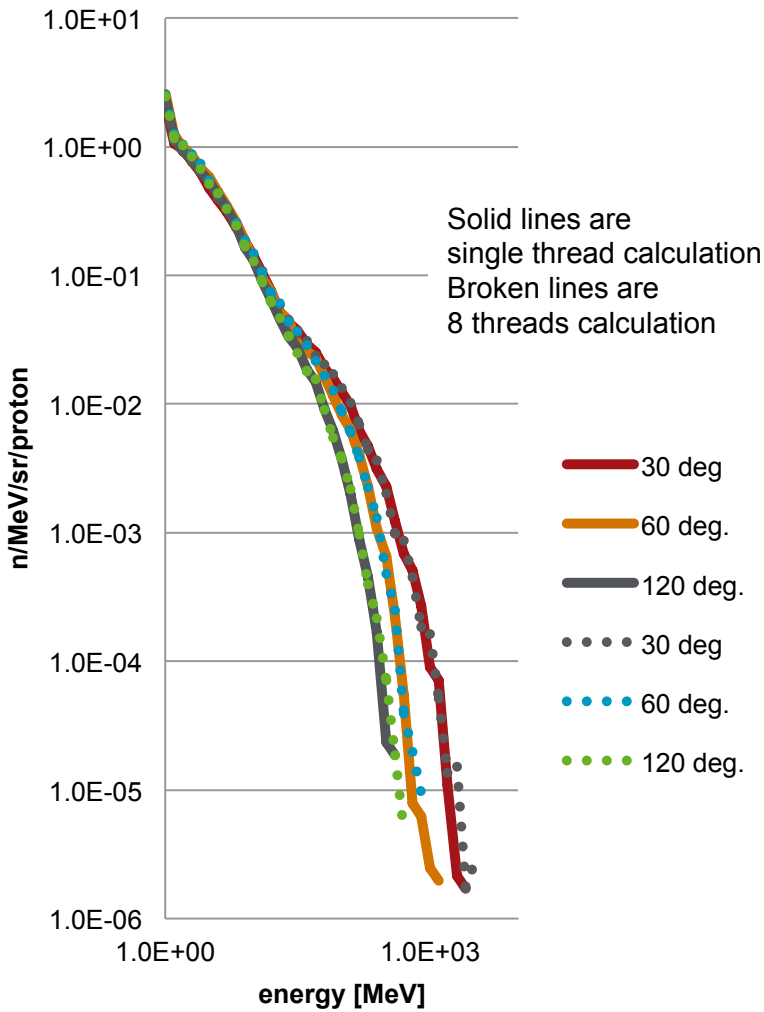
- Multi-threaded application for SATIF12 inter-comparison problem running on Geant4.10.00.p01
  - 16k events of 100GeV proton bombarding thick Au target

Result

- Single thread application uses 370MB at beginning and 290MB (80%) of them are shared in multithreading calculation
- Power law index of -0.896 (where -1 ideal) is is gotten in multithreading performance within the number of physical cores (see next slide)
- The result of single thread calculation is identical to the result of 8 threads (see next slide)

MT performances on Inter-comparison problem





SATIF12 Inter-comparison

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1. Incident particle

Pencil beam of protons with following energy

(a) 1 GeV

(b) 10 GeV

(c) 100 GeV

2. Target materials and their size

Targets geometry is the cylinder.

Source protons incident on the center of the cylinder bottom.

Target detector distance from the center of the cylinder is 500cm.

(a) Al : length 40cm, diameter 4.0cm and density 2.7g/cm^3

(b) Cu : length 16cm, diameter 1.6cm and density 8.63 g/cm^3

(c) Au : length 10cm, diameter 1.0cm and density 19.3 g/cm^3

3. Quantities to be calculated

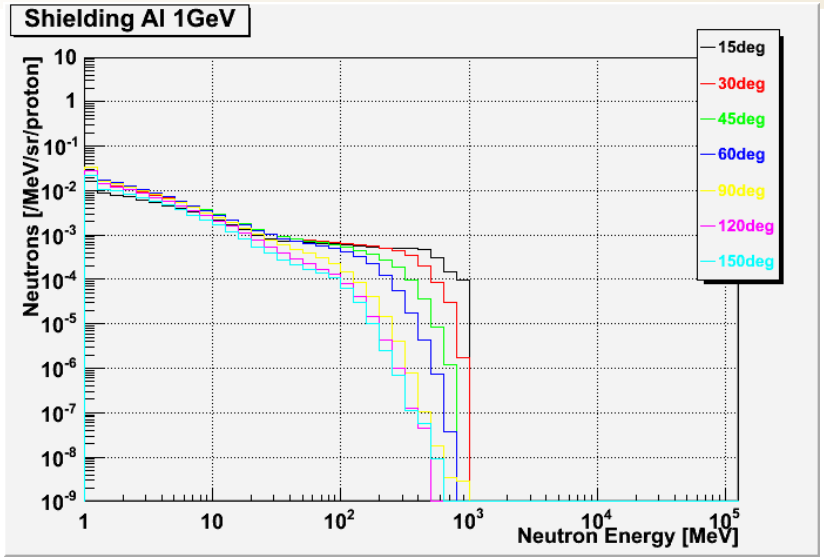
Neutron spectrum above 20 MeV in n/MeV/sr/proton

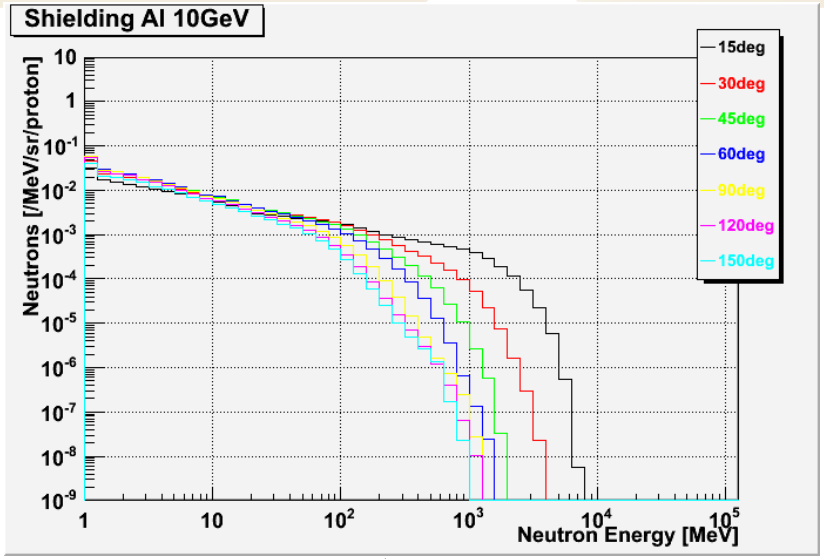
at 15, 30, 45, 60 ,90,120,150 degrees with angular width ±0.5 degrees.

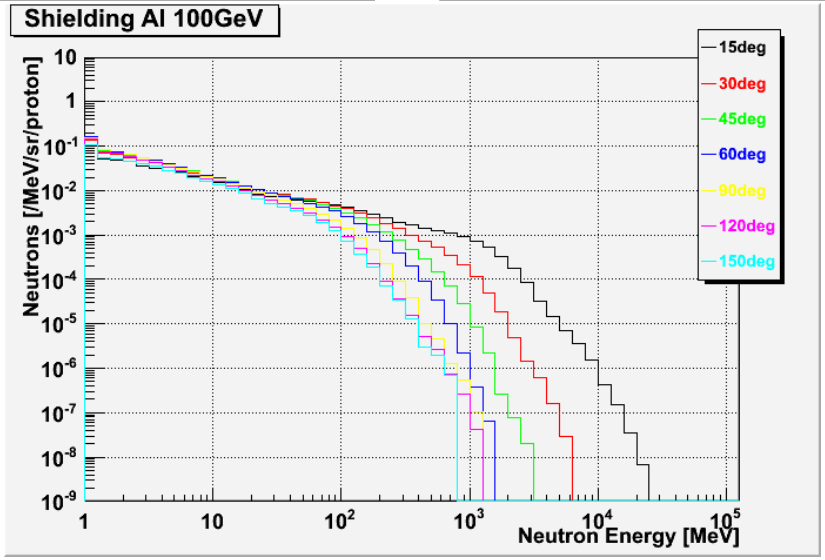
Submitted Geant4 results are calculated on Geant4 10.00.p01 with Shielding physics list

Configuration of Shielding physics list now close to FTFP_BERT_HP which uses BERT style cascade, FTF model in high energy and neutronHP models for low energy (<20MeV) neutron transportation

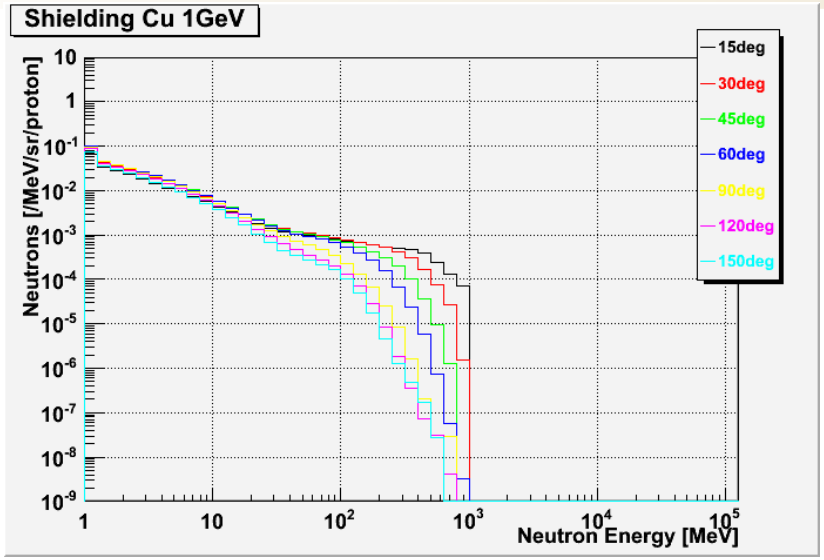
Geant4 results for SATIF12 inter-comparison
Al target

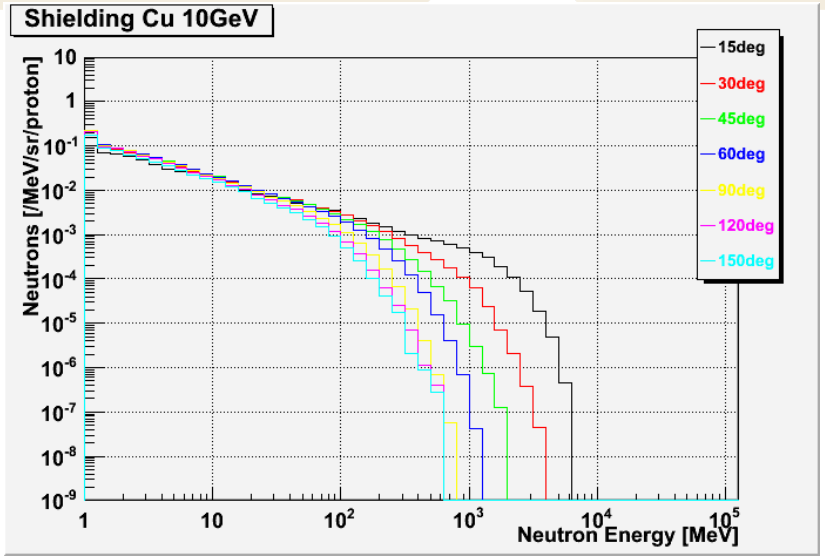


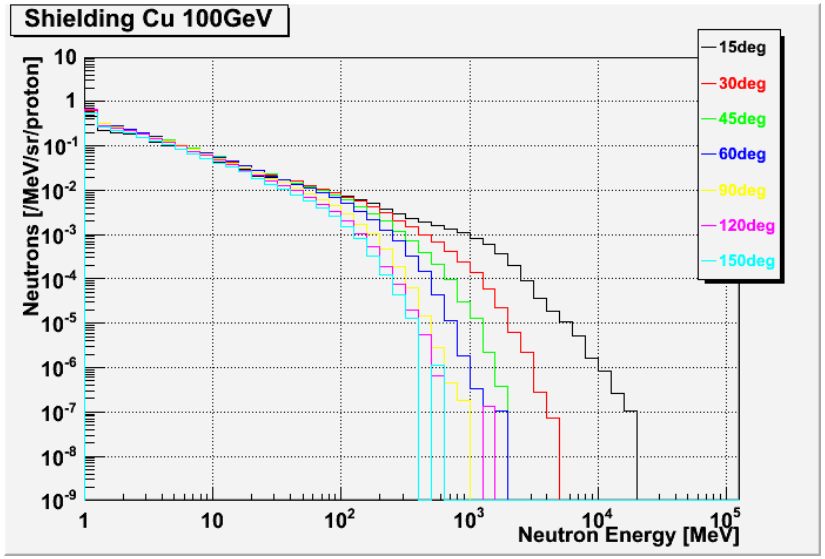




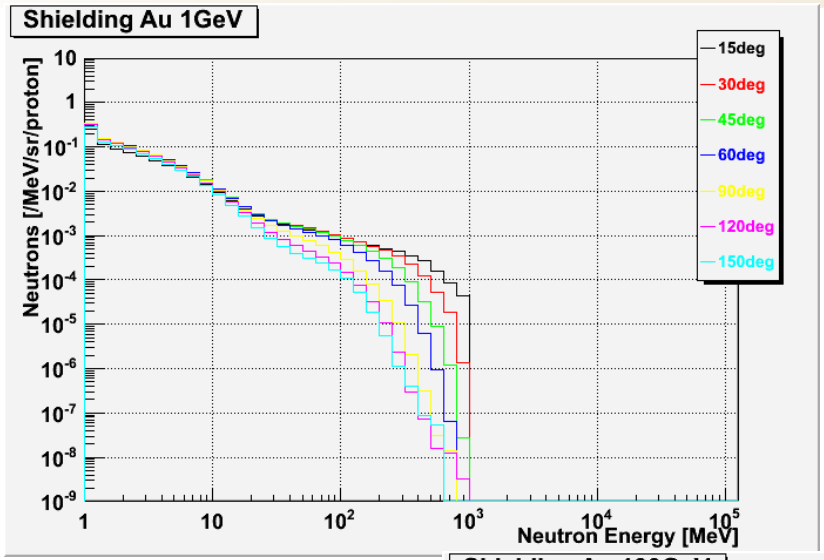
Geant4 results for SATIF12 inter-comparison
Cu target

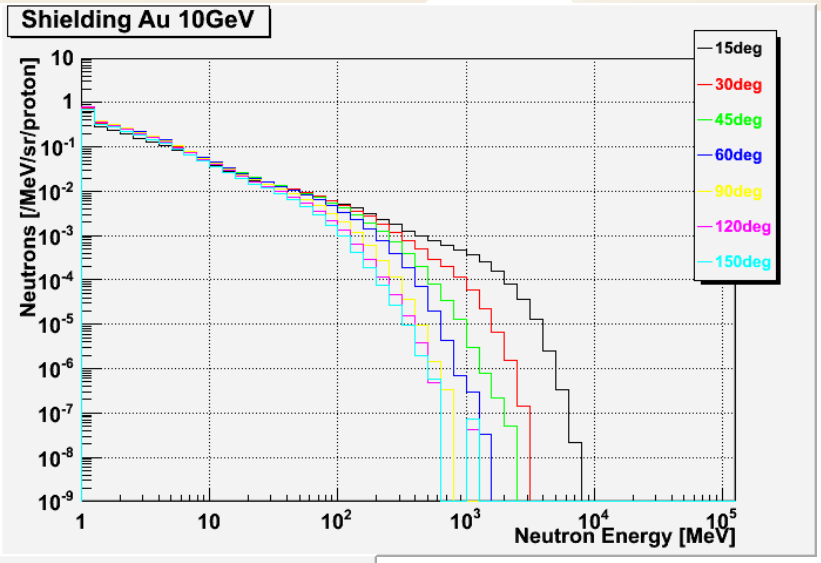


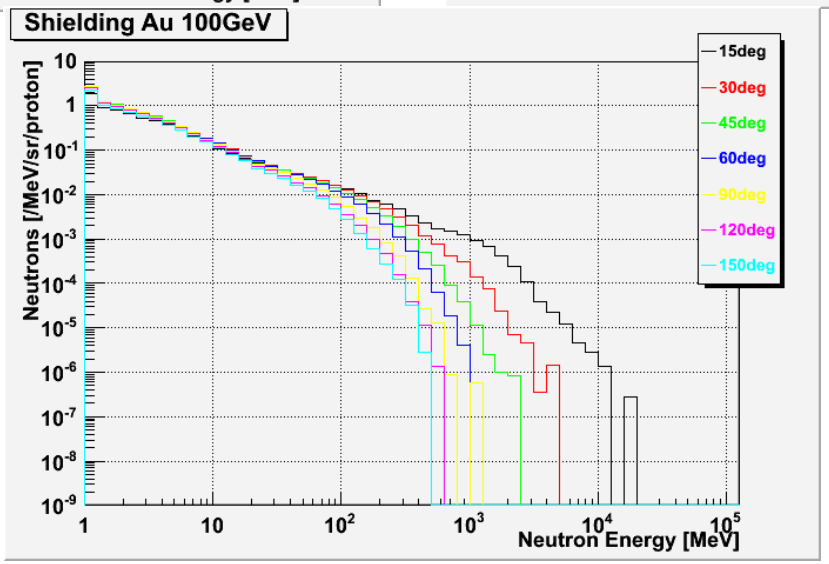




Geant4 results for SATIF12 inter-comparison
Au target







SATIF BNL Benchmark

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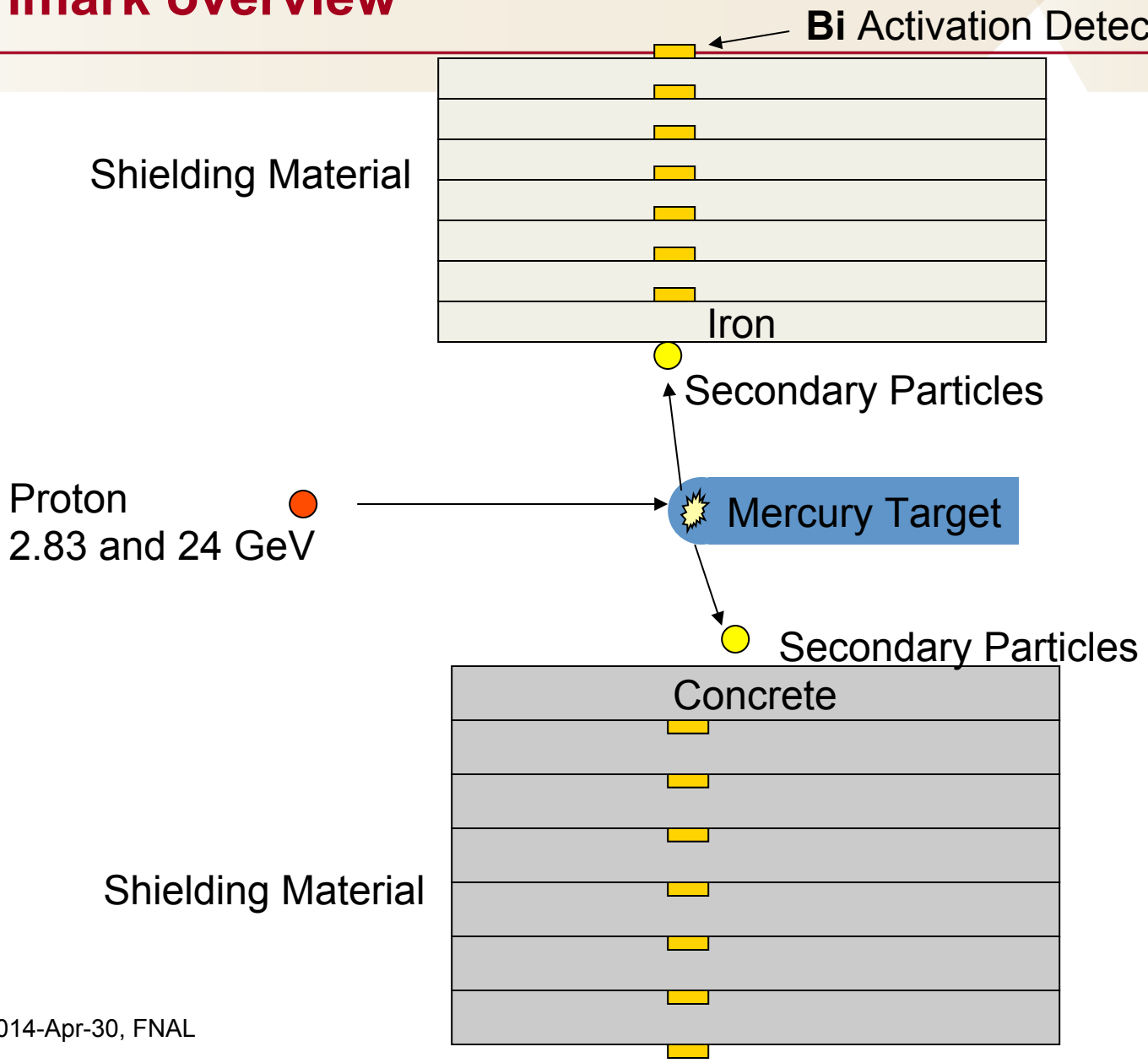
Deep penetration experiments through steel and concrete shields for neutrons generated at mercury target irradiated by 2.83-and 24-GeV protons

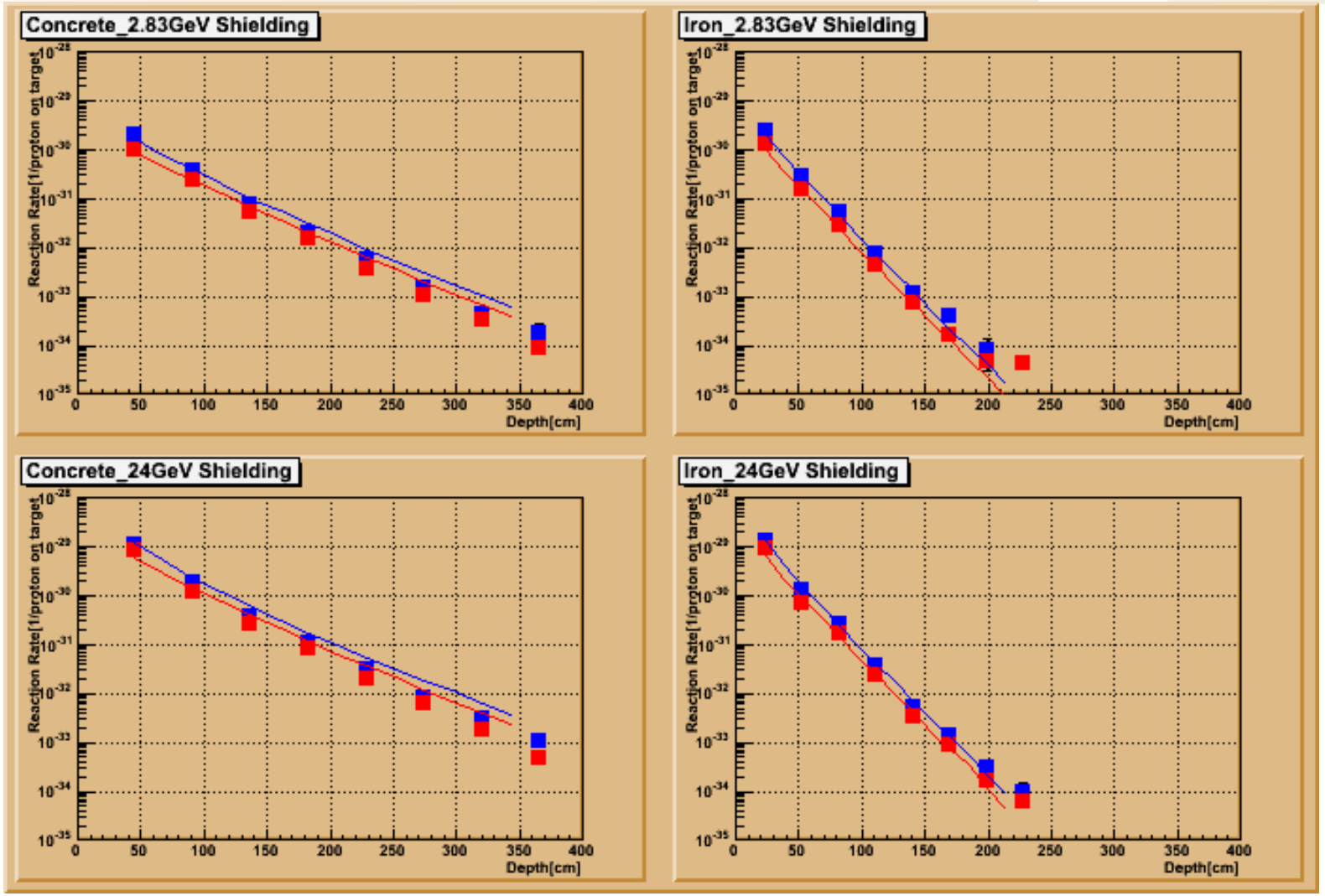
Benchmark problem

- 1) Accelerator (Organization): AGS (Brookhaven National Laboratory)
- 2) Projectile (Energy): Proton (2.83 and 24 GeV)
- 3) Target Material : Mercury
- 4) Shielding Material : Steel and Concrete
- 5) Geometry : Slab Geometry
  - implemented as Cylindrical Geometry for better simulation efficiency
- 6) Instruments : Activation Detector (Bi) with HP-Ge Detectors
- 7) Measured Quantities : Neutron Reaction Rate
  - 209Bi(n,4n)206Bi Threshold Energy of 22.6 MeV
  - 209Bi(n,6n)204Bi Threshold Energy of 38.1 MeV
  - Reaction rate of them are given as a function of neutron flux from SATIF organizer

Benchmark overview



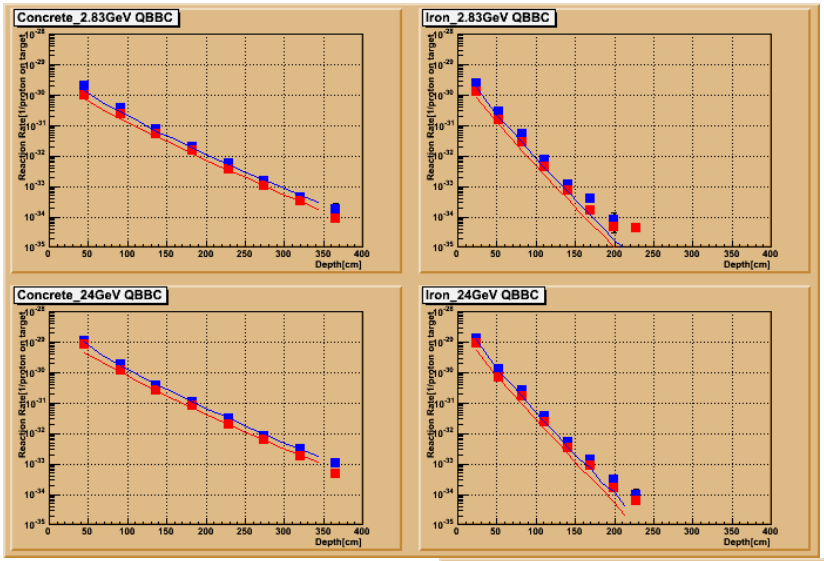
Results of Shielding Physics List



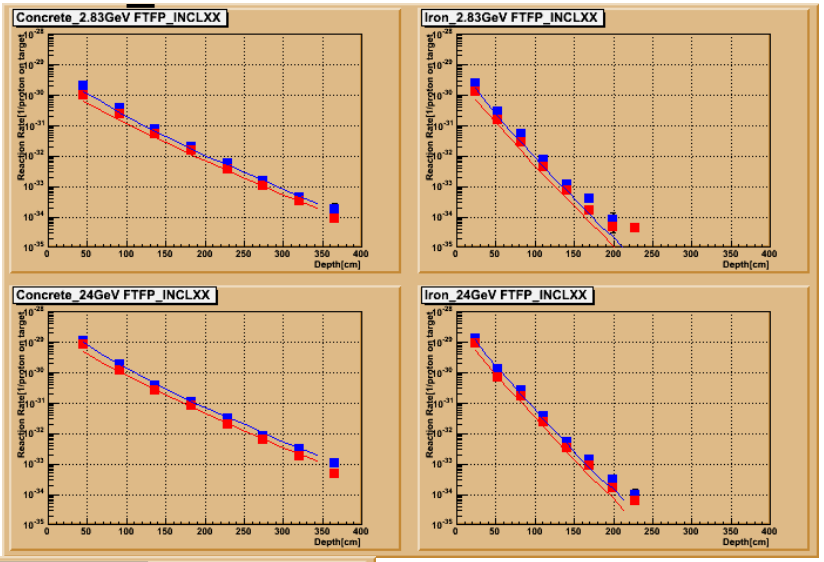
209Bi(n,4n)206Bi Threshold Energy of 22.6 MeV ■ data — simulation
209Bi(n,6n)204Bi Threshold Energy of 38.1 MeV ■ data — simulation

Results from other physics lists

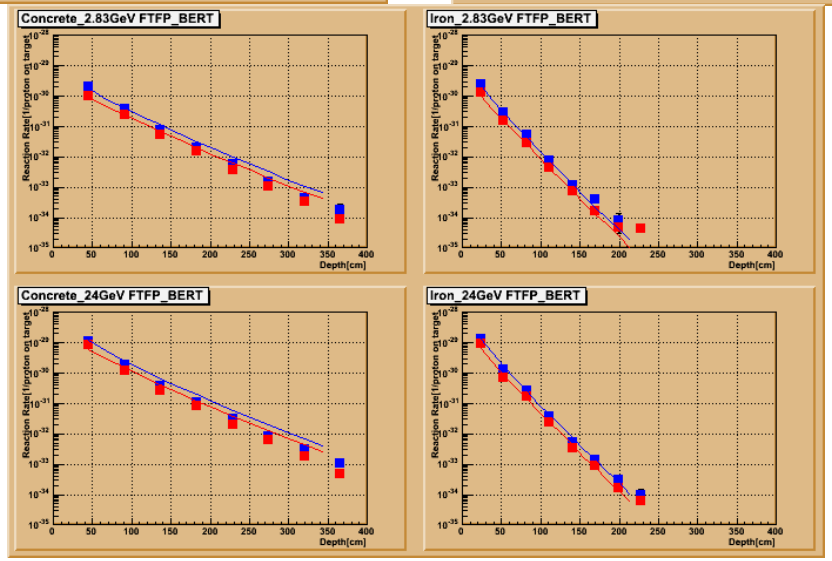
QBBC



FTFP_INCL++



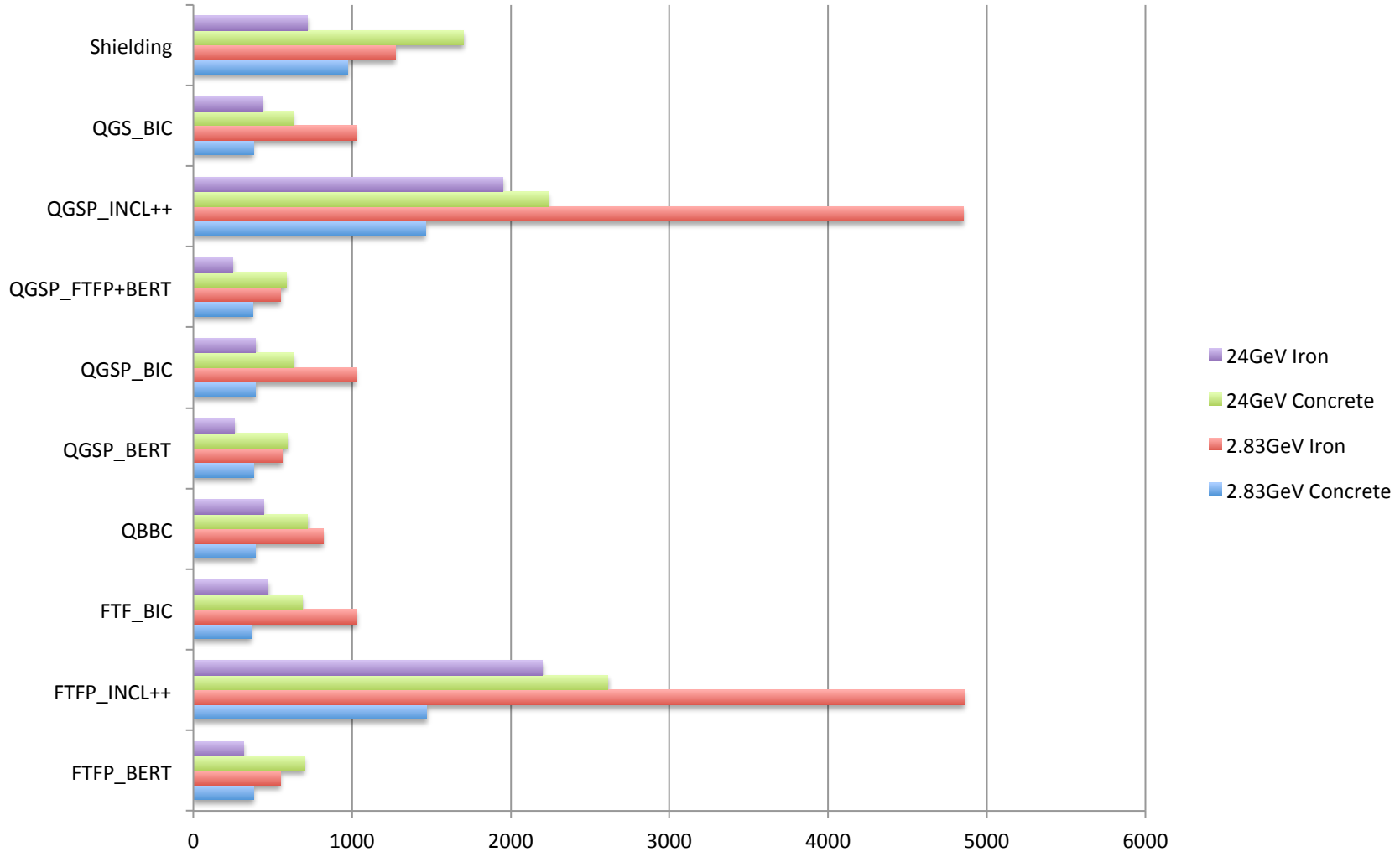
FTFP_BERT



209Bi(n,4n)206Bi
■ data — simulation

209Bi(n,6n)204Bi
■ data — simulation

CPU usages among Geant4 physics lists



Summary

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Geant4 version 10 is released

- This is a major update after 7 years

Multi-threaded applications are supported on this version

- Easily use full CPU power with smaller amount of memory

Tested performance of multi-threaded application for SATIF12 inter-comparison problem

- Power law index of 0.896 for multi threading performance
- 80% of memory consumption are shared on beginning
- Result of 8 threads calculation is equivalent to 1 thread calculation

We submitted results from Shielding physics list, however, judging from results of BNL benchmark

- QBBC and INCLXX gives even better result in concrete shielings

Newly introduced INCL cascade shows promising physics performance, however, it requires more CPU power than other cascade models

Appendix

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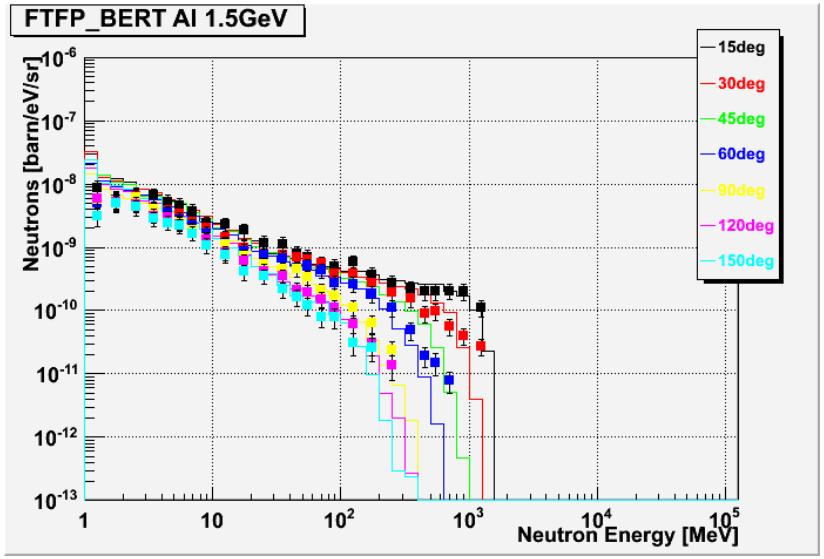
Comparison against measurement of thick target neutron production

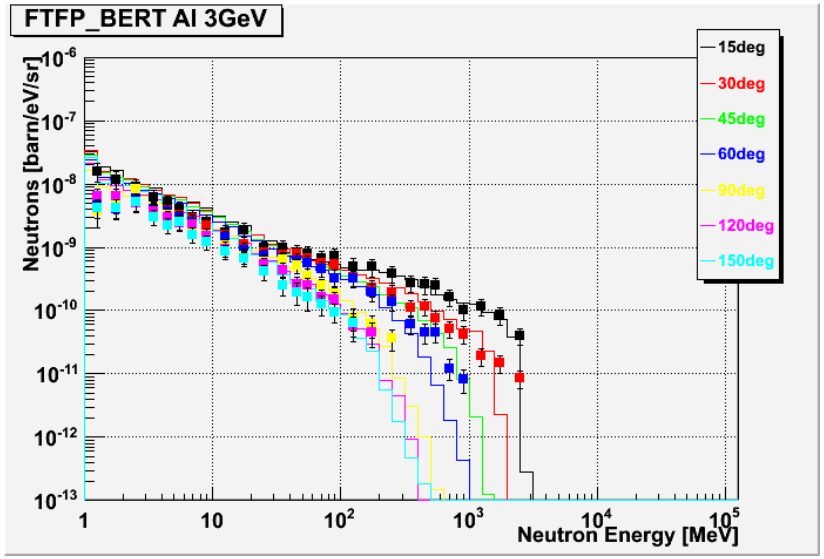
- "Measurement of Neutron-Production Double-Differential Cross Sections for Nuclear Spallation Reaction Induced by 0.8,1.5 and 3.0 GeV Protons", K. Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)
- Thickness of target
  - Al 4cm
  - Fe 2cm
  - Pb 1.2cm

- FTFP_BERT
- QGSP_BIC
- FTFP_INCLXX

FTFP_BERT
neutron production from proton on Al

Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)



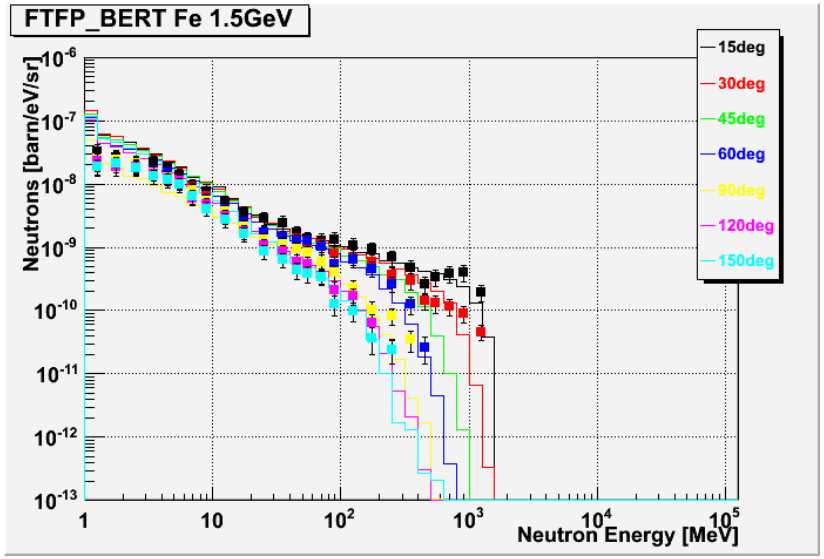


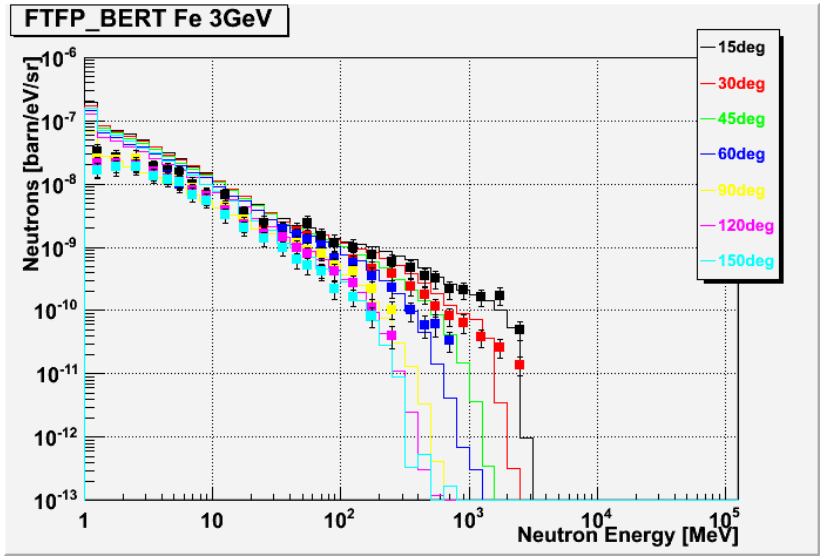
Lines are results of simulation Geant4 v10.00.p01
Boxes are result of measurement
- data 15deg.
- data 30deg.
- data 60deg.
- data 90deg.
- data 120deg.
- data 150deg.

No measurement data on 45 deg.

FTFP_BERT
neutron production from proton on Fe

Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)





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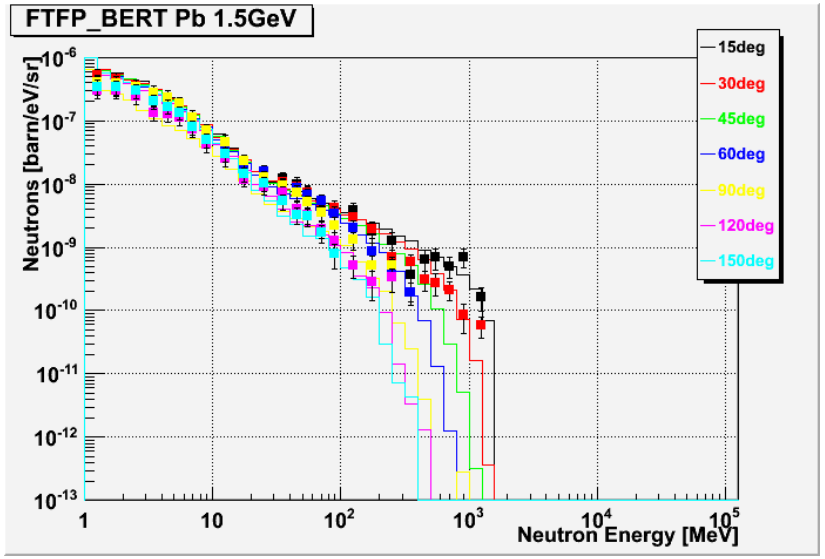
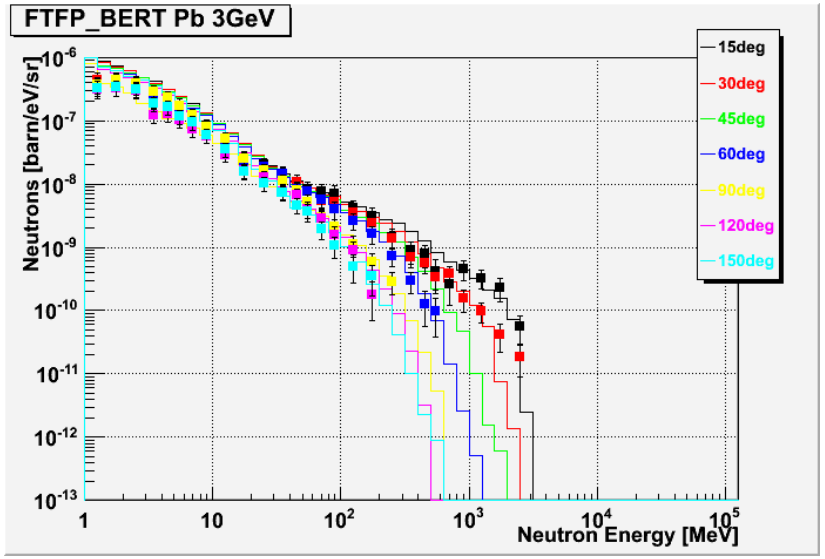
FTFP_BERT
neutron production from proton on Pb

Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)





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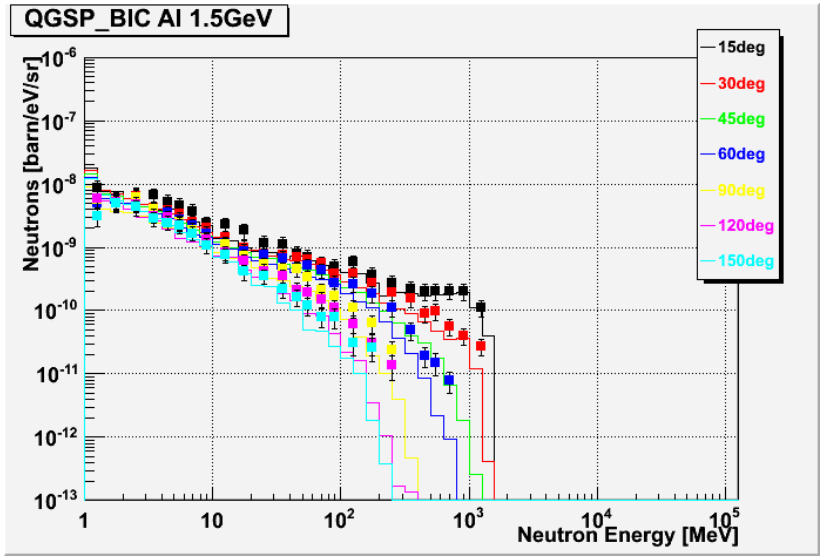
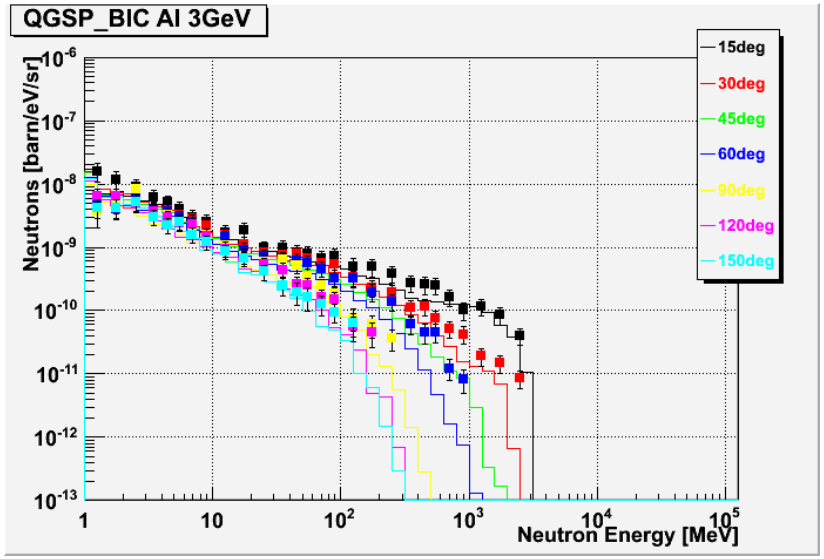
QGSP_BIC
neutron production from proton on Al

Ishibashi et al., Jour. of Nuclear Science and Technology; Vol.34, Issue.6, p.529 (1997)





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QGSP_BIC
neutron production from proton on Fe

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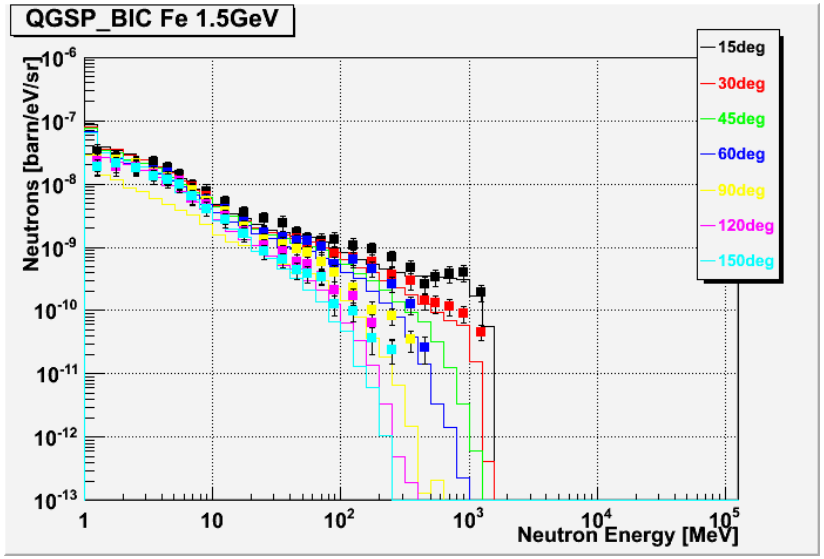

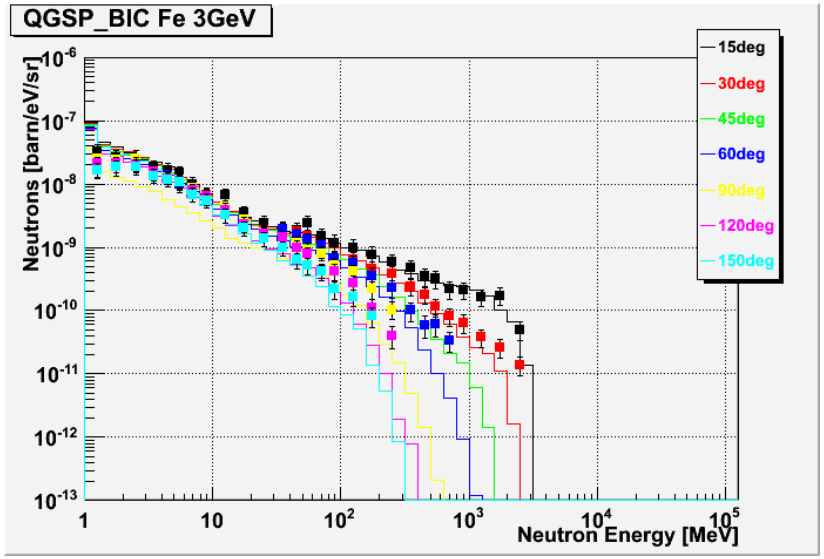

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QGSP_BIC
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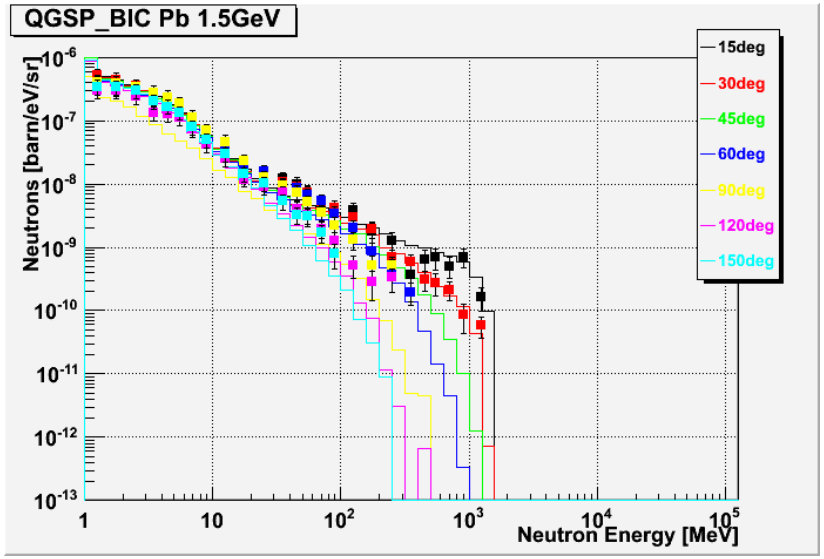

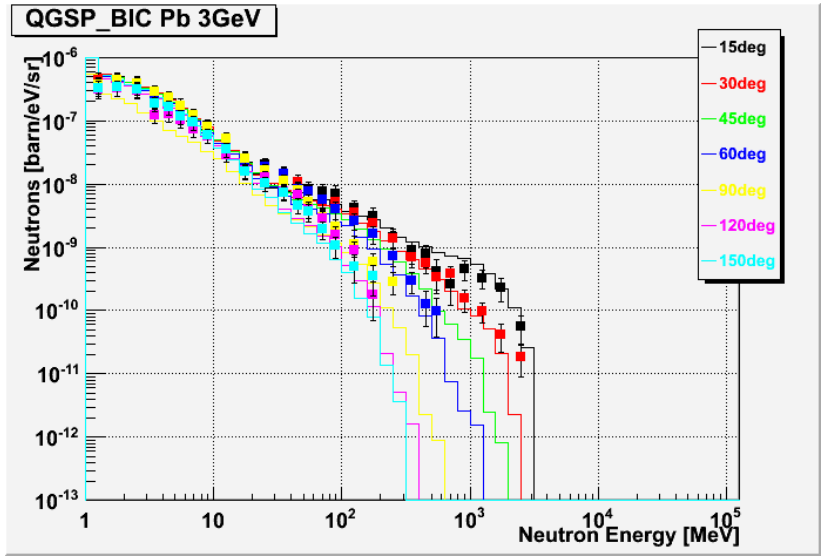

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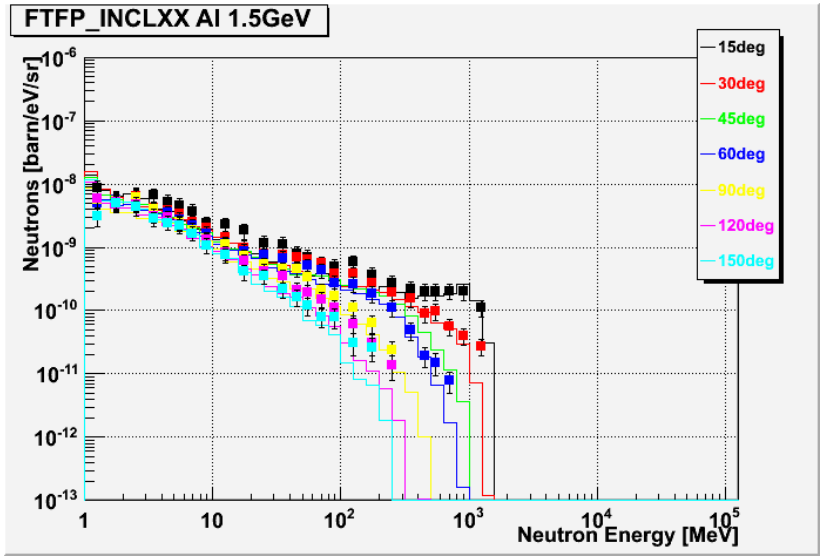

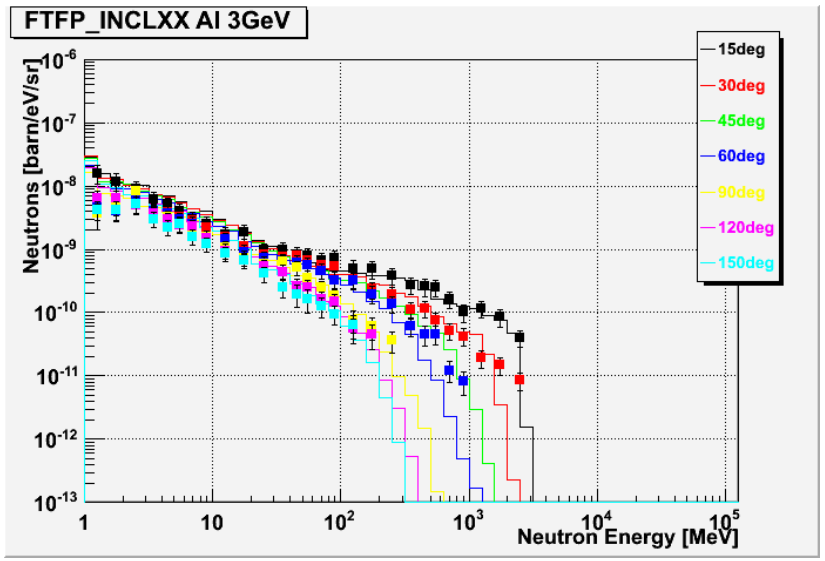

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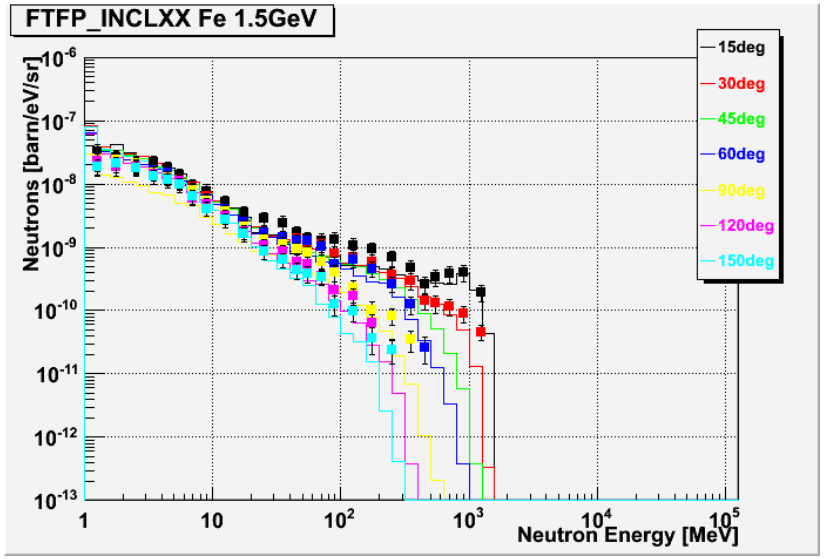

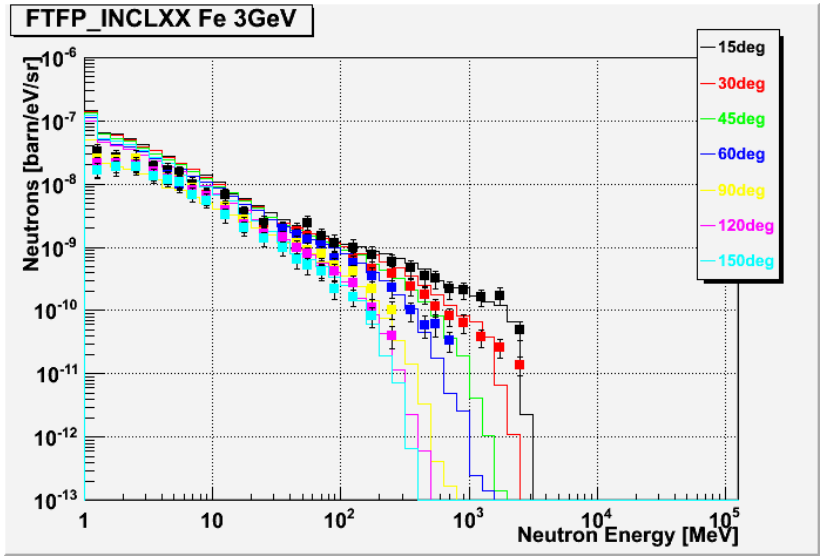

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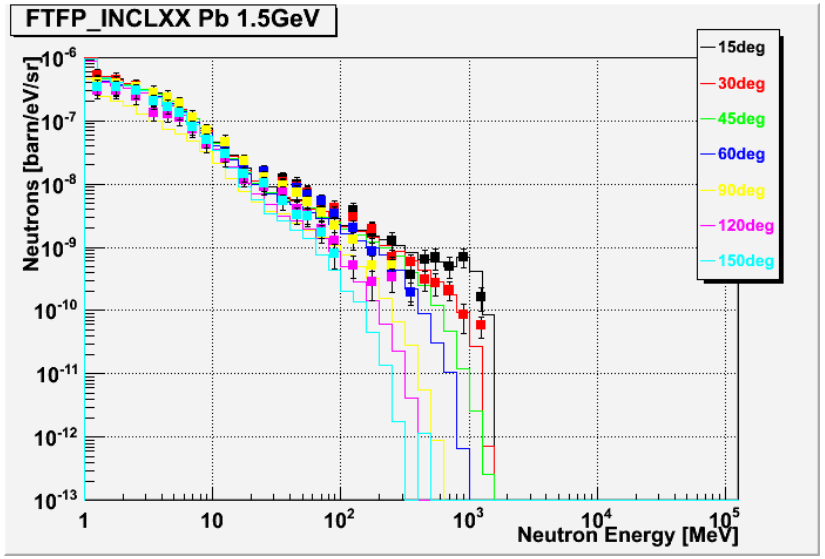

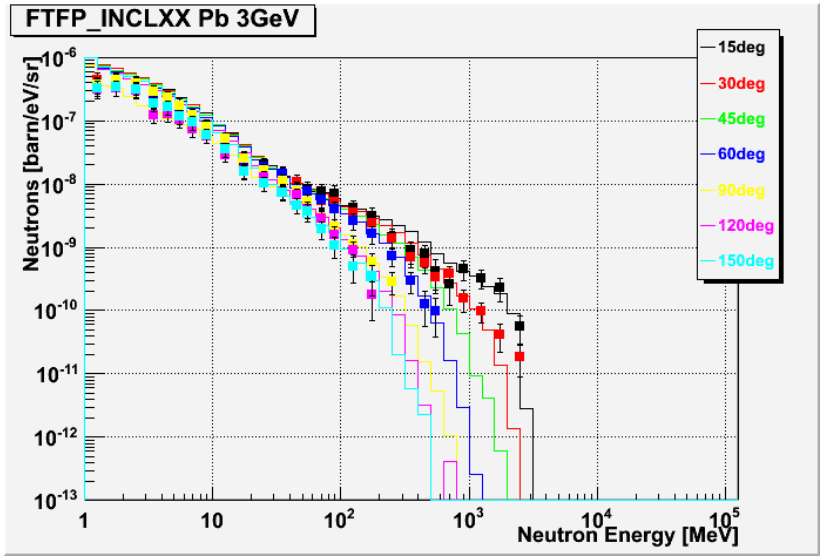

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