A Geant4 Physics List for Shielding Calculations

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Overview

- What is Physics List of Geant4
- Policy of Physics List
  in the Geant4 Collaboration
- Reference Physics List
- A Physics List for Shielding Calculation
- Possible Alternative Physics Lists for Shielding Calculation
- Comparison among the Physics Lists
- Summary

What is Physics List of Geant4

- Physics List is where user define all the particles, physics processes and cut-off parameters for his/her application.
- Geant4 offers multiple choices in many physics processes to users.
- The needed physics processes of Geant4 must be explicitly assigned to the particles used in the application by users.
- In hadronic framework of Geant4, concept of cross section and final state generator (model) are completely separated, therefore users can choice cross section and model independently.

Policy of Physics List in the Geant4 collaboration

- "Physics List" class is one of the three mandatory classes of Geant4, which user must prepare.
  - Other two classes are constructing geometry and generating primary vertex and particles.
- User has better knowledge about his/her problem than the developers of Geant4.
- At the beginning of Geant4, we only distributed physics lists as a content of examples.

Reference Physics Lists

- However, preparing a physics list is not a simple job even for non-novice user.
- There are many requests to support a default physics list by Geant4 collaboration.
- Reference physics lists are made in response to this request.
  - Reference physics lists vary by use case
  - These should be considered only as starting points which users may need to modify for their application
  - Most of examples still has its own physics list
- We currently offer 26 different physics lists and many builder classes helping implementation of user specific physics list.

Reference physics list cont.

- There are 26 physics lists available in the source/physics_list directory of v9.3.p01
  - CHIPS, FTFP_BERT, FTFP_BERT_EMV, FTFP_BERT_EMX, FTFP_BERT_TRV, FTF_BIC, LBE, LHEP, LHEP_EMV, QBBC, QBBC_XGG, QBBC_XGGSN, QGSC_BERT, QGSC_CHIPS, QGSP_BERT, QGSP_BERT_EMV, QGSP_BERT_EMX, QGSP_BERT_HP, QGSP_BERT_NOLEP, QGSP_BERT_TRV, QGSP_BIC, QGSP_BIC_EMY, QGSP_BIC_HP, QGSP_FTFP_BERT, QGS_BIC and QGSP_INCL_ABLA
- Physics List Naming Convention
  - "QGS" Quark gluon string model (>~20GeV)
  - "FTF" Fritiof Model (>~5GeV)
  - "LHEP" Low and High energy parameterisation model
  - "BIC" Binary Cascade Model (<~10 GeV)
  - "BERT" Bertini Cascade Model (<~10 GeV)
  - "INCL" INCL Cascade Model (< 3 GeV)
  - "HP" High Precision Neutron Model (<20MeV)
  - "PRECO" Pre compound Model (<~150MeV)
  - "EMV(X)" Variation of Standard EM package
  - "QEL" Qelastic
  - "CHIPS" CHiral Invariant Phase Space
- QGSP_BERT and QGSP_BERT_EMV is used by LHC ATLAS and CMS respectively.
  - Difference between two physics lists is parameters of electromagnetic processes

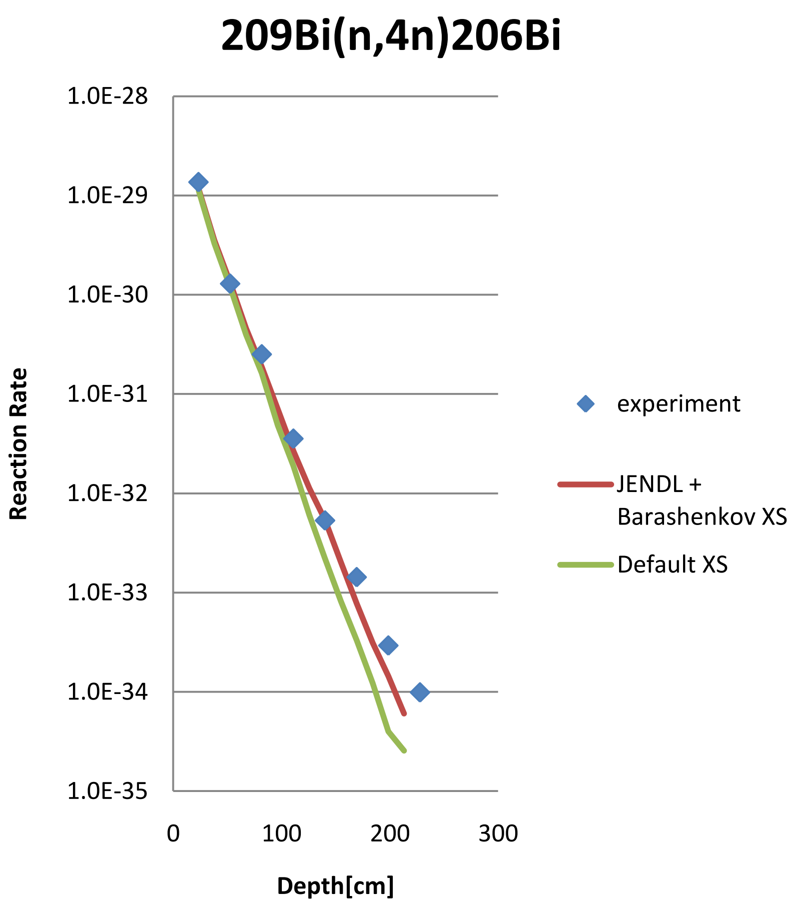
A Physics List for Shielding Calculations

- We have participated in the "Inter-comparison of Medium-Energy Neutron Attenuation in Iron and Concrete" project since SATIF8.
- QGSP_BERT was used for SATIF8
- QGSP_BERT + new cross sections were used for SATIF9.
- For submitting our result on SATIF10, we have included a set of recently improved physics models and cross sections into our physics list.

A Physics List for Shielding Calculations Cont.

- Based on FTFP_BERT
- High energy model: FTF (FriToF string model)
  - Precompound model is used as nuclear de-excitation model
  - FTF model uses down to 4 GeV
- Medium energy model: BERT
  - Based on Classical Bernini and INUCL cascade model
  - Many improvement are done related to treatment of nuclear medium
  - BERT model has its own low energy model below cascading energy
  - BERT model is used up to 5 GeV
- Mix and match of FTF and BERT will take place at transition region.
- Cross section of neutron:
  - FTFP_BERT uses a parameterization based on the Axen and Wellisch systematic
  - Instead we use the following
    - JENDL HE-2007 cross section up to 3 GeV
    - Barashenkov evaluated cross section beyond 3 GeV

Iron 24GeV



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Reaction Rate
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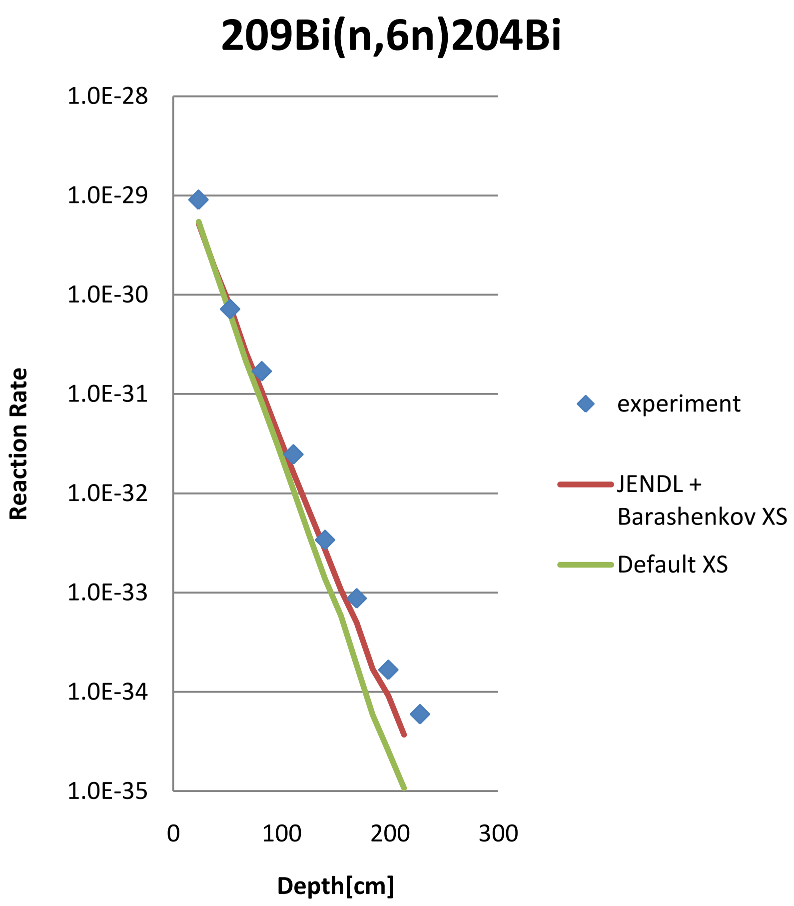
Depth[cm]
experiment
JENDL + Barashenkov XS
Default XS



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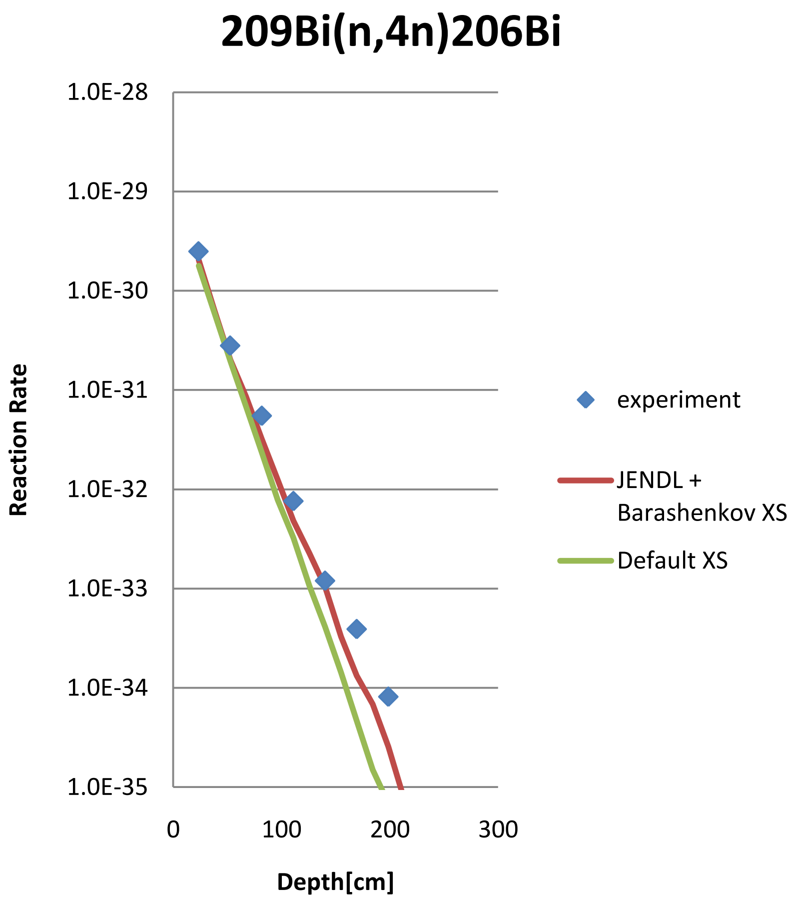
Default XS

Iron 2.83GeV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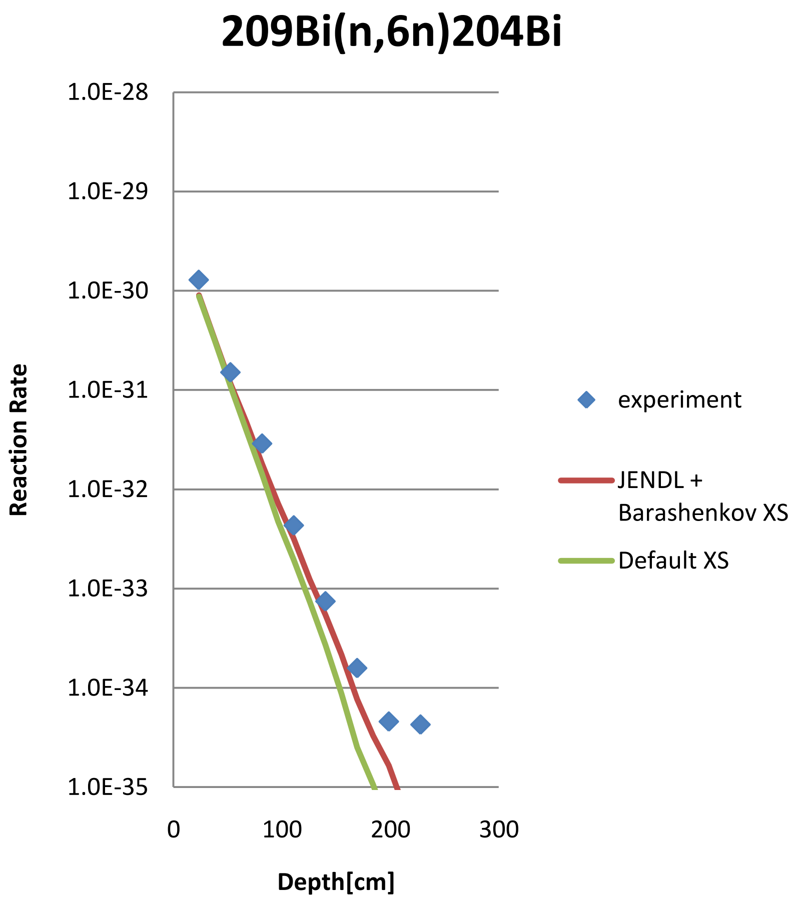
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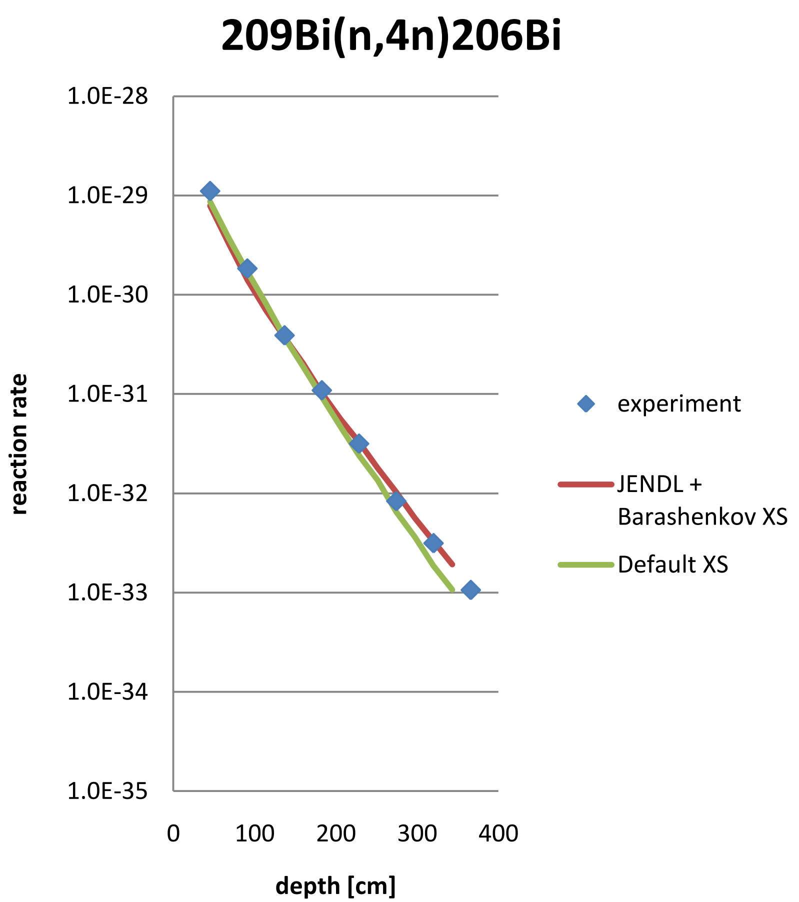
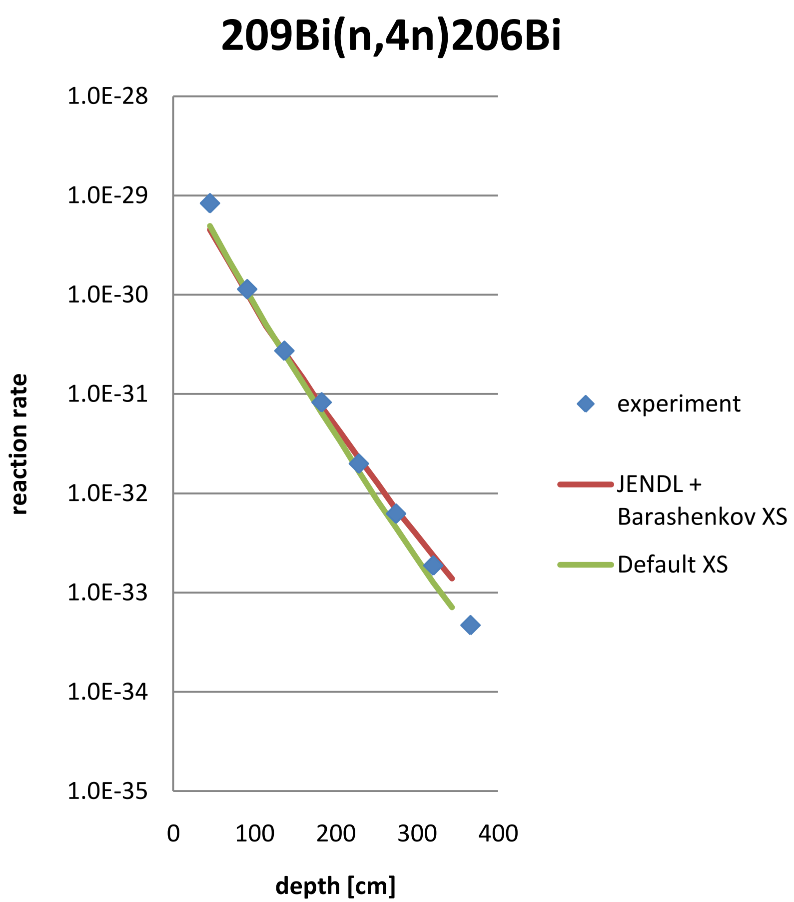
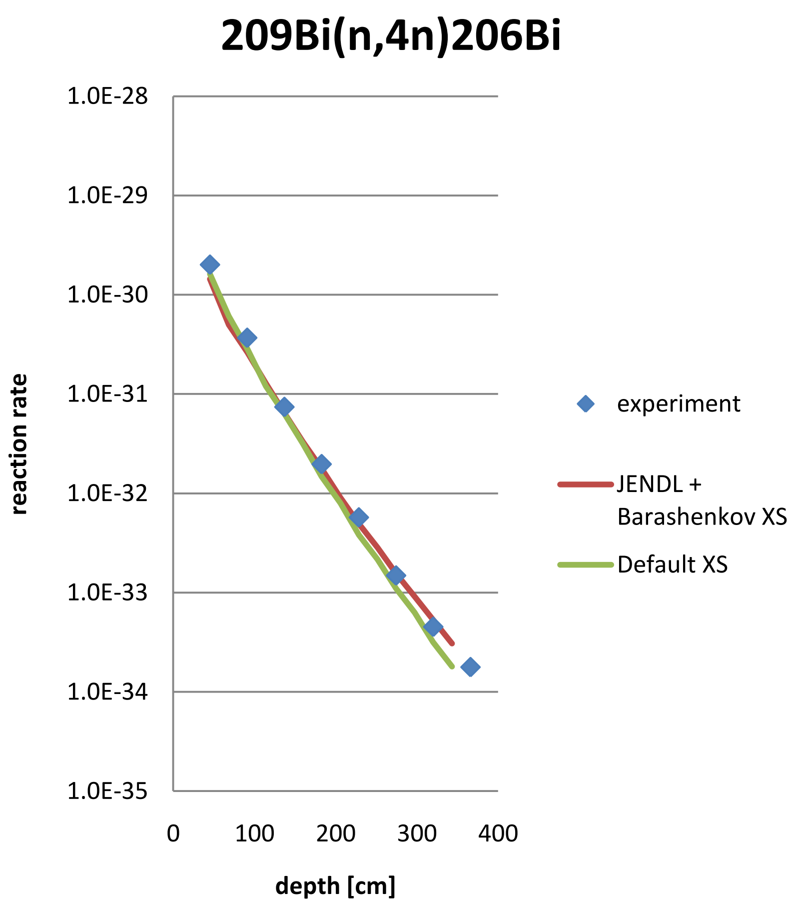
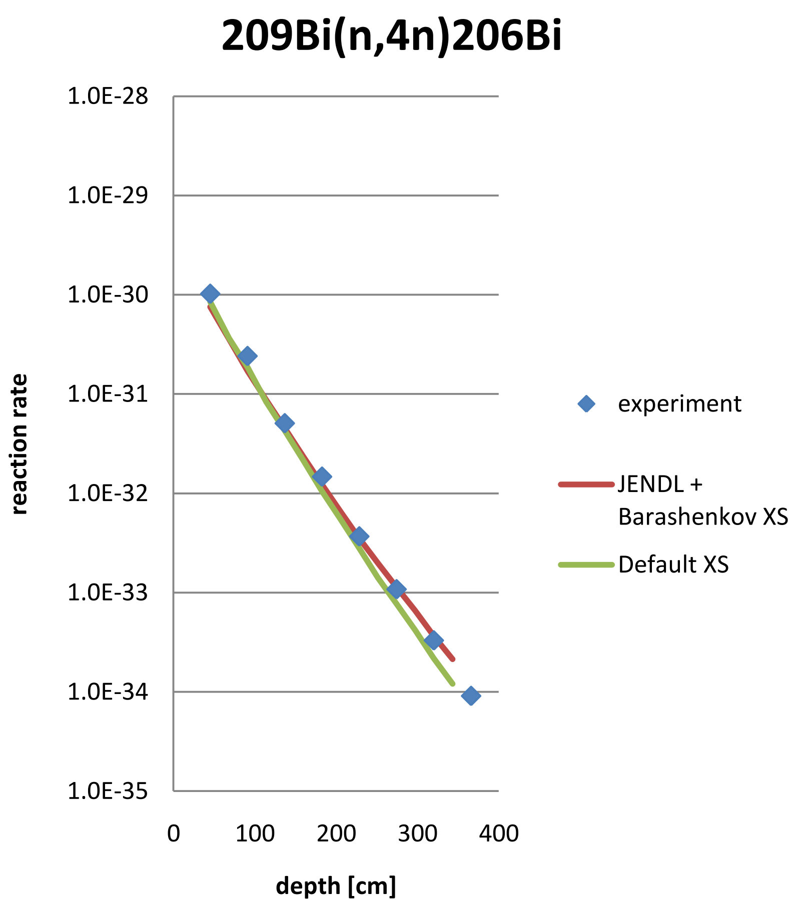
Concrete 24GeV





Concrete 2.83GeV

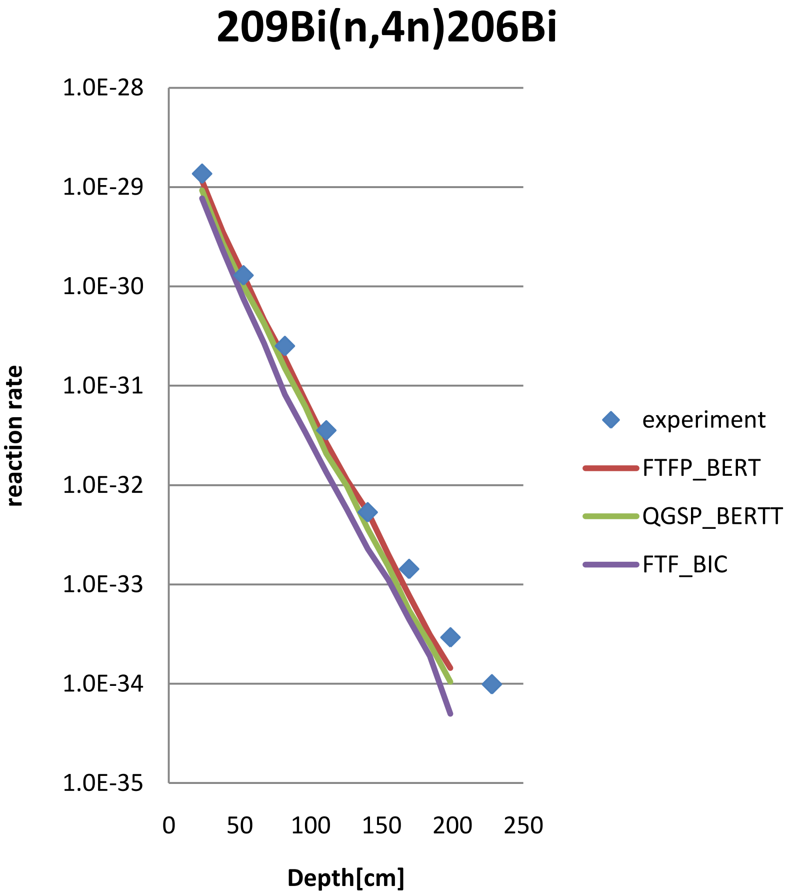




Alternative Physics Lists for Shielding Calculation

- Change high energy model to QGS
  - QGSP_BERT
- Change cascade model to Binary cascade and also use it as a re-scattering model of high energy model
  - FTF_BIC
- Use Neutron High Precision Model and Cross Sections, if necessary
  - QGSP_BERT_HP
- We recommend JENDL and Barashenkov cross sections for Shielding Calculation

Steel 24GeV



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1.0E-35
reaction rate
0
50
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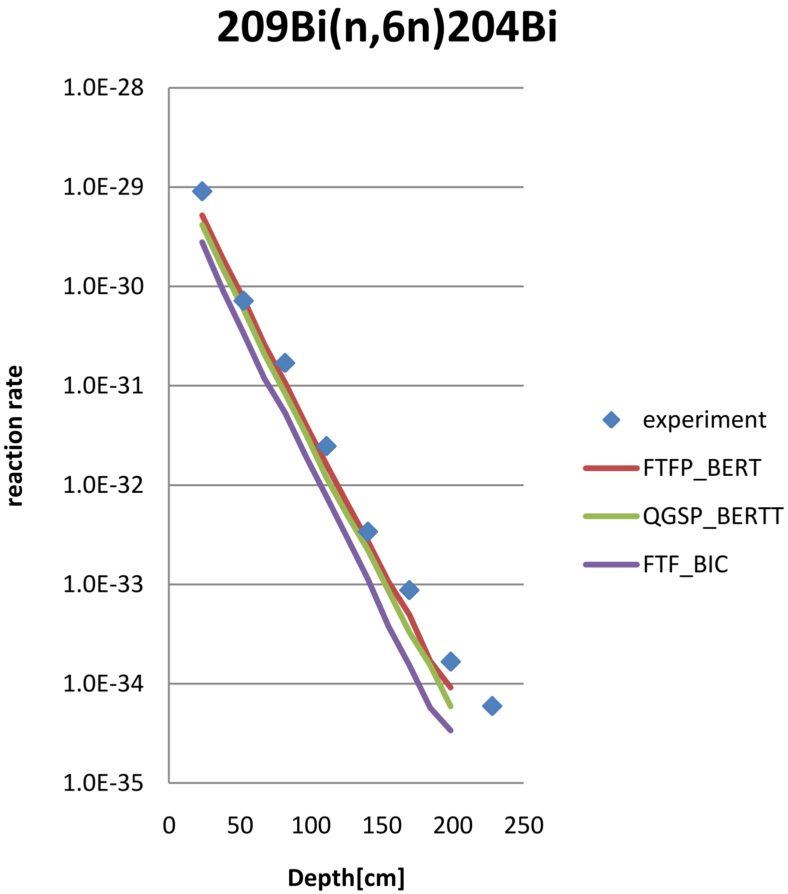
Depth[cm]
experiment
FTFP_BERT
QGSP_BERTT
FTF_BIC



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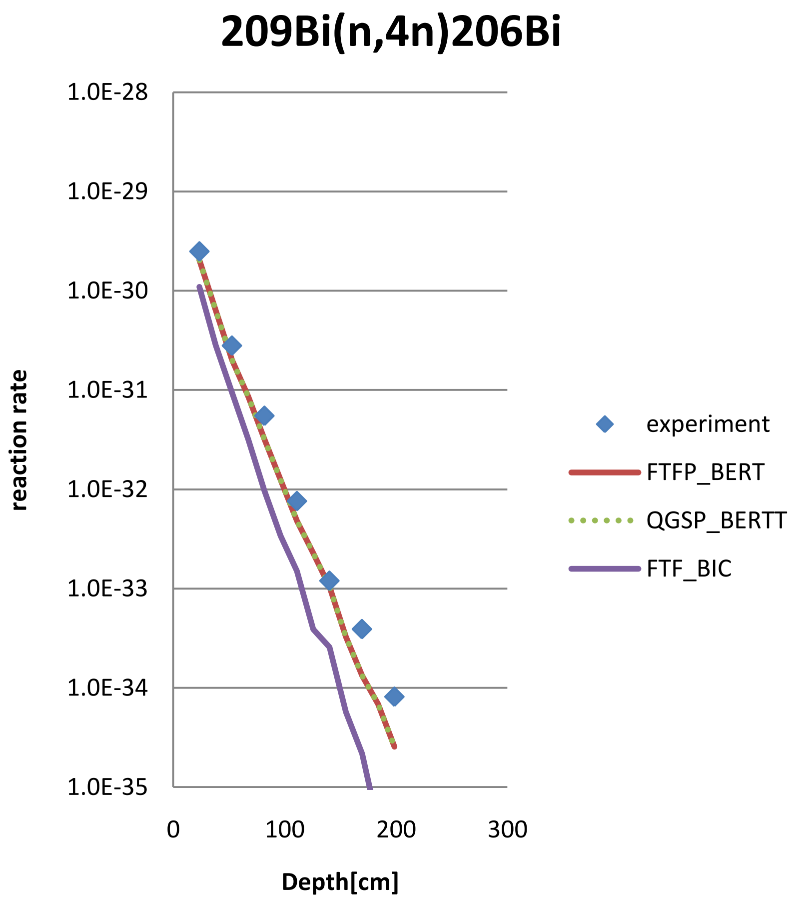
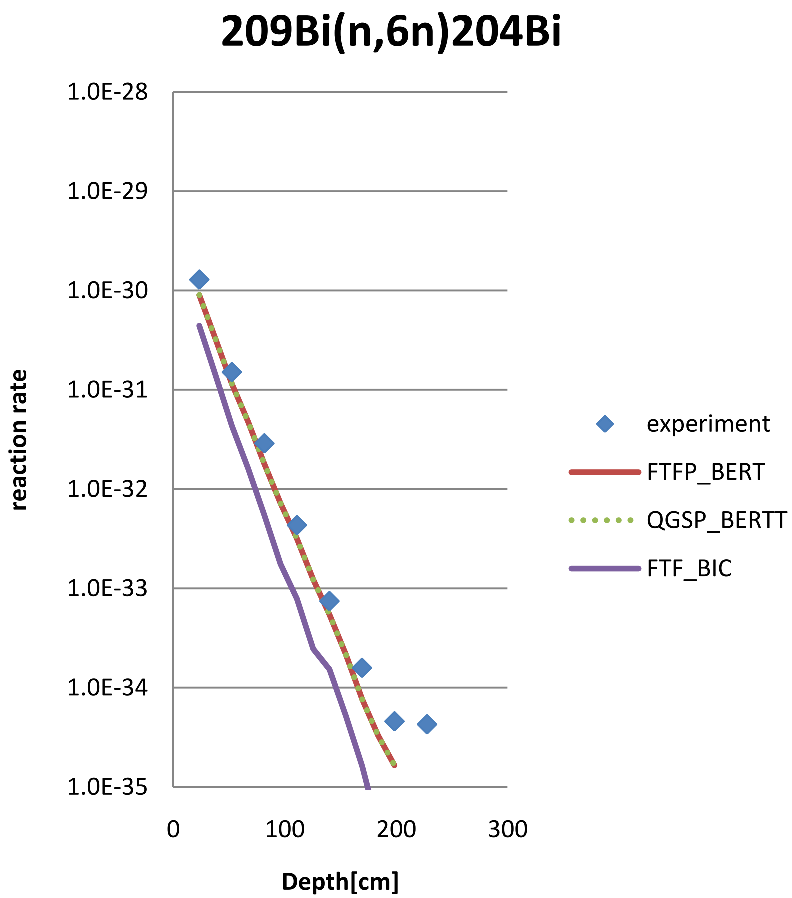
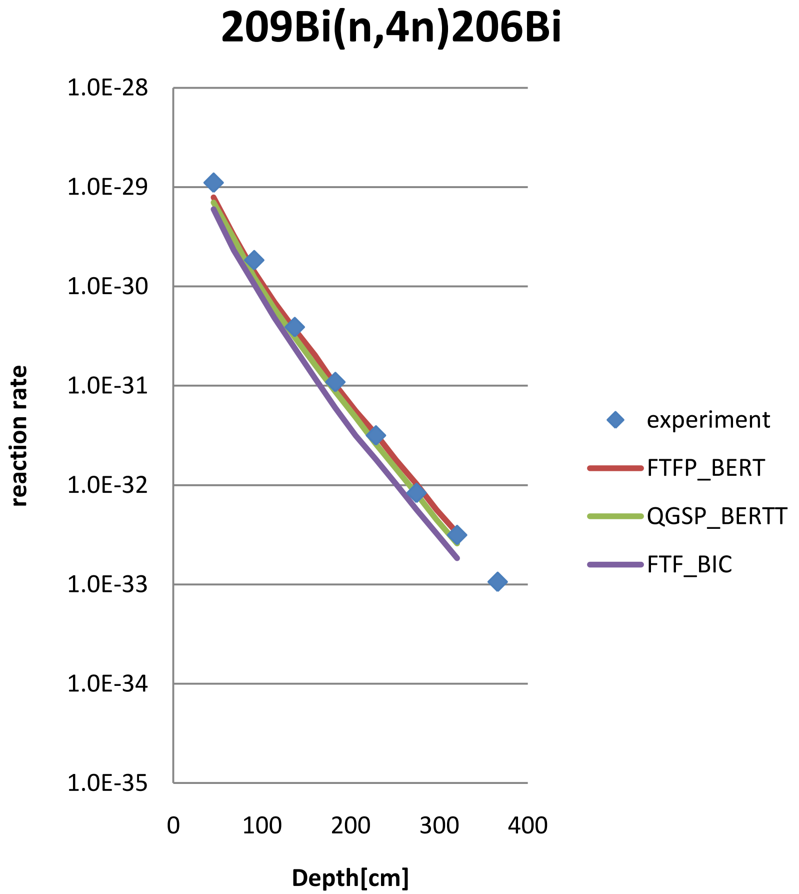
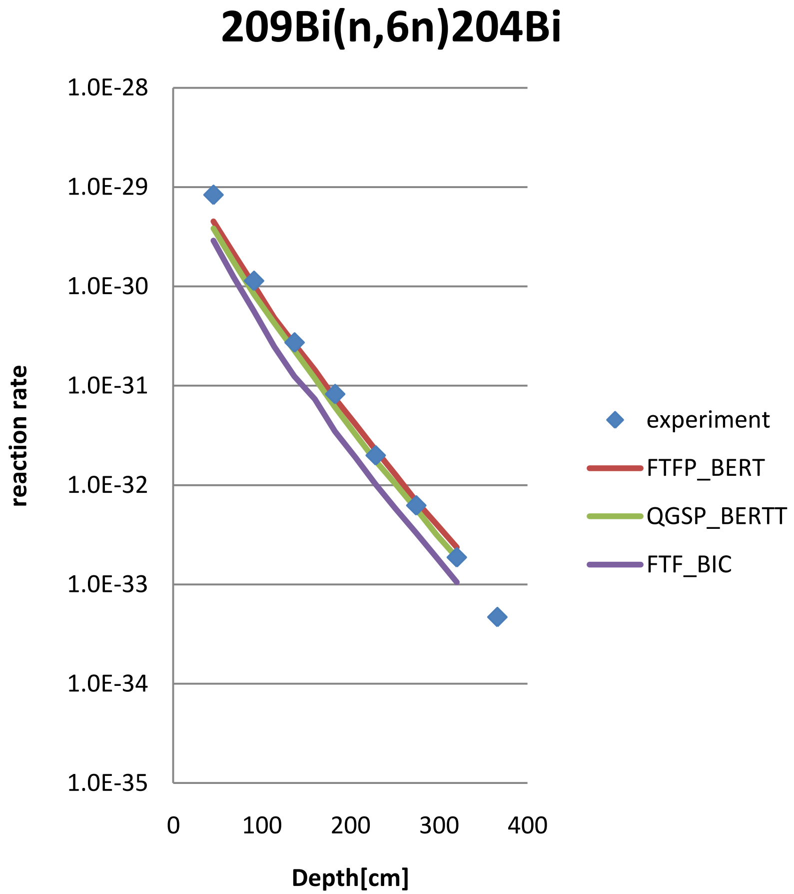
Steel 2.83GeV



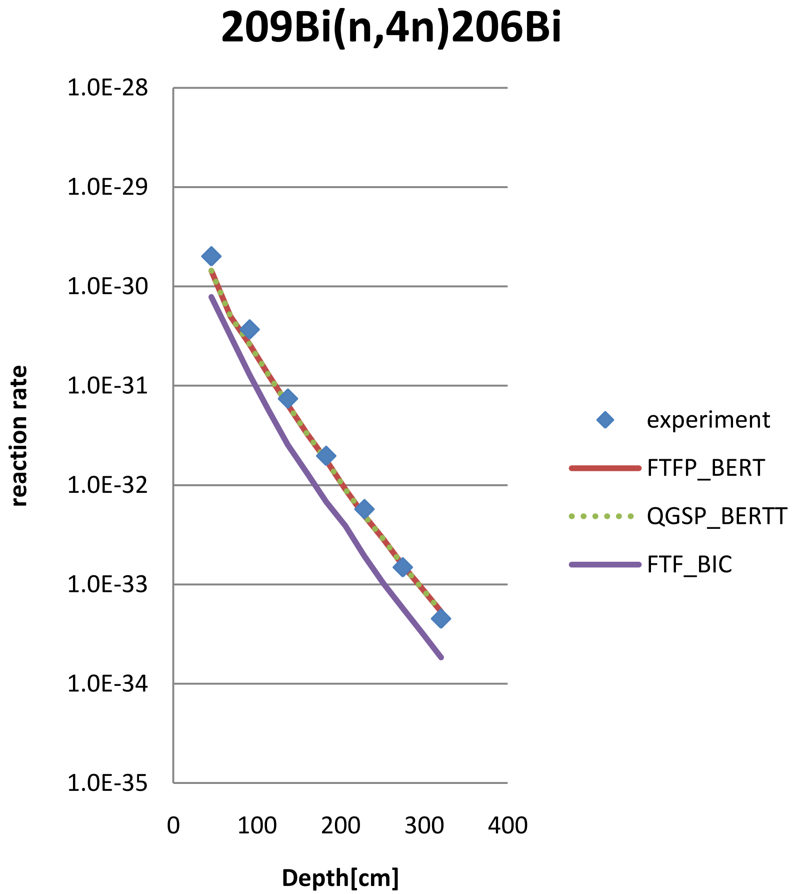


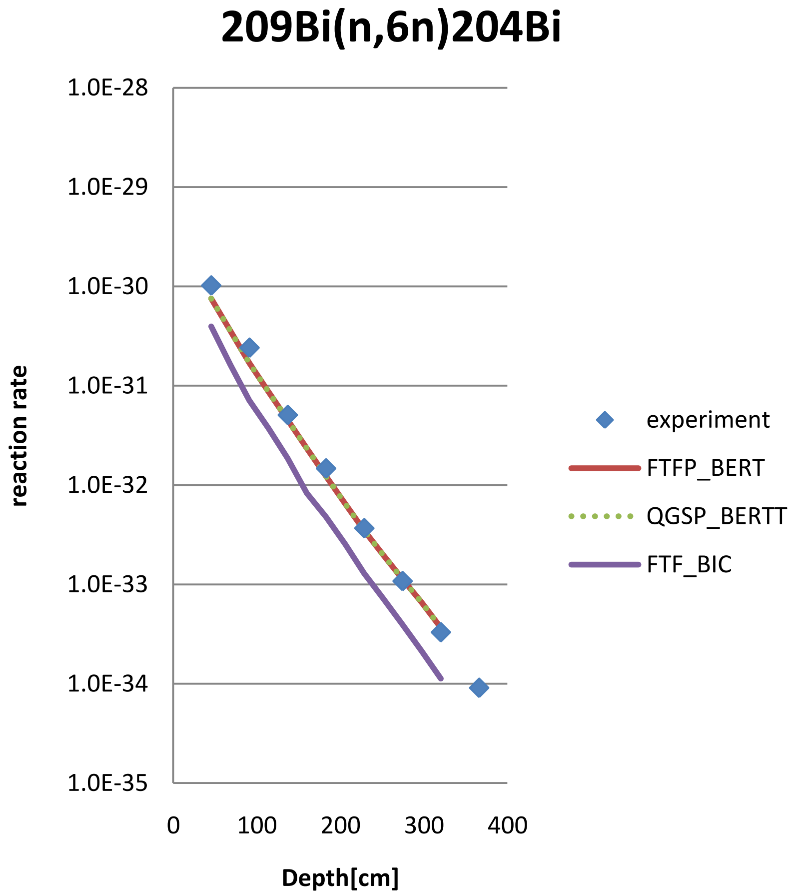
Concrete 24GeV





Concrete 2.83GeV





CPU performance

	Concrete		Iron	
	2.83GeV	24GeV	2.83GeV	24GeV
QGSP_BERT	1.09	0.75	0.98	0.77
FTF_BIC	2.58	2.05	4.08	3.24

FTFP_BERT = 1
A lower number represents better CPU performance

	Concrete		Iron	
	2.83GeV	24GeV	2.83GeV	24GeV
FTFP_BERT	1.00	6.83	0.39	3.75

Concrete 2.83GeV = 1
A higher number represents longer calculation time

All calculation is done on lfs batch system of Dell Poweredge 1950
dual quad-core 2.66GHz Xeon CPUs, 16GB memory

Summary

- Many reference physics lists are offered by Geant4 collaboration now.
- However they should be considered as a base of further modification by each user
- A FTFP_BERT based physics list is proposed for Shielding calculation.
  - Neutron cross section is modified to JENDL + Barashenkov
- QGSP_BERT based physics list gives comparable results and slightly faster.
- Because of detailed treatment of interactions FTF_BIC based physics list is slower than others and the attenuation is significantly larger.

Backup slides

- Difference between QGS and FTF model
- Difference in mean free path among FTFP_BERT default, JEBDL + Barashenkov+JENDL and LHEP
  - XS plots for Concrete and Iron from 20MeV to 100 GeV

FRITIOF model

B. Andersson et al., Nucl. Phys. B281 (1987) 289;
B. Nilsson-Almquist and E. Stenlund, Comp. Phys. Commun. 43 (1987) 387.

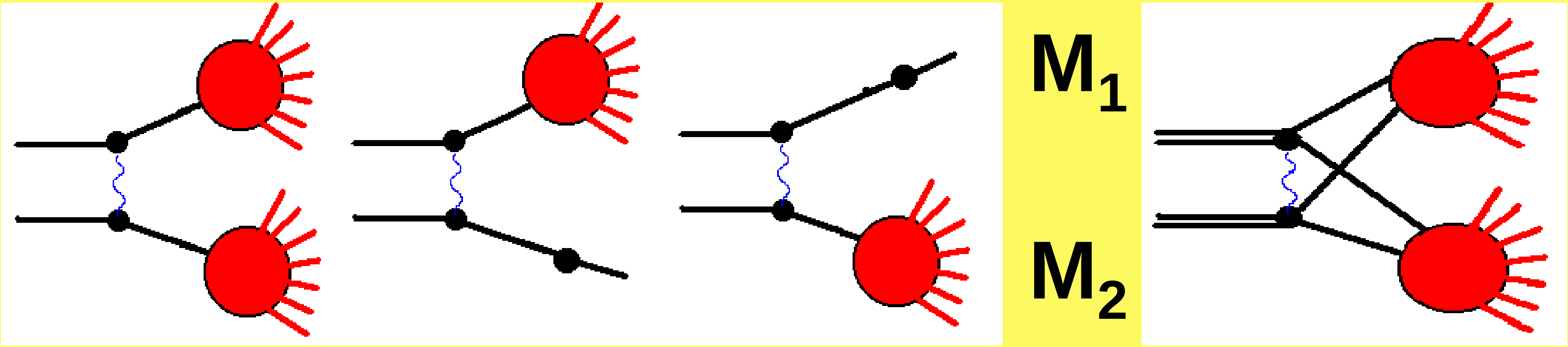
Hadron-hadron interactions are modeled as binary kinematics

$a + b \rightarrow a' + b'$, $m_a' > m_a$ $m_b' > m_b$

where a' and b' are excited states of the initial hadrons a and b.

Courtesy of V. Uzhinsky (JINR-CERN)

FRITIOF model QGSM



$$dW \propto \frac{dM_1}{M_1}, \qquad dW \propto \frac{dM_2}{M_2}$$

Key parameters

$$M_{string} = 1.1\ GeV\ (N), \quad 1\ GeV\ (\pi), \quad 1.1\ GeV\ (K)$$

$$M_{sampling} = 0.94\ GeV\ (N), 0.75\ GeV\ (\pi), 0.85\ GeV\ (K)$$

Changes in FTF model

Courtesy of V. Uzhinsky
(JINR-CERN)

Quark exchange is introduced. Good description of hadron-nucleon interaction is reached.

Reggeon cascading is implemented. Good description of proton spectra is reached.

Nuclear excitation energy is estimated roughly.

Common notation:
Deficit of mesons with T=100 – 300 MeV in all hardonic models.

We urgently need a good low energy cascading model!

Improved FTF model can be smoothly coupled with the Bertini model at Plab 3 – 5 GeV/c erasing discontinuity in model predictions!

Neutron Mean Free Path in Concrete and Iron