Shielding Code Comparison: A Simple Benchmark Problem

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EJSM Instrument Workshop
January 18-20, 2010

ACKNOWLEDGEMENT: Part of the research described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

Presentation Summary

- Objective of Study
- Geometry Setup: Ta and Al slabs
- Simulation Status
- Geant4 Physics and Scoring
- Calculations:
  - Aluminum and Tantalum
    - Electron spectrum
    - Photon spectrum
    - Neutron spectrum
- Conclusions

Objectives

- To compare and better understand the predictive capability of commonly used radiation transport tools

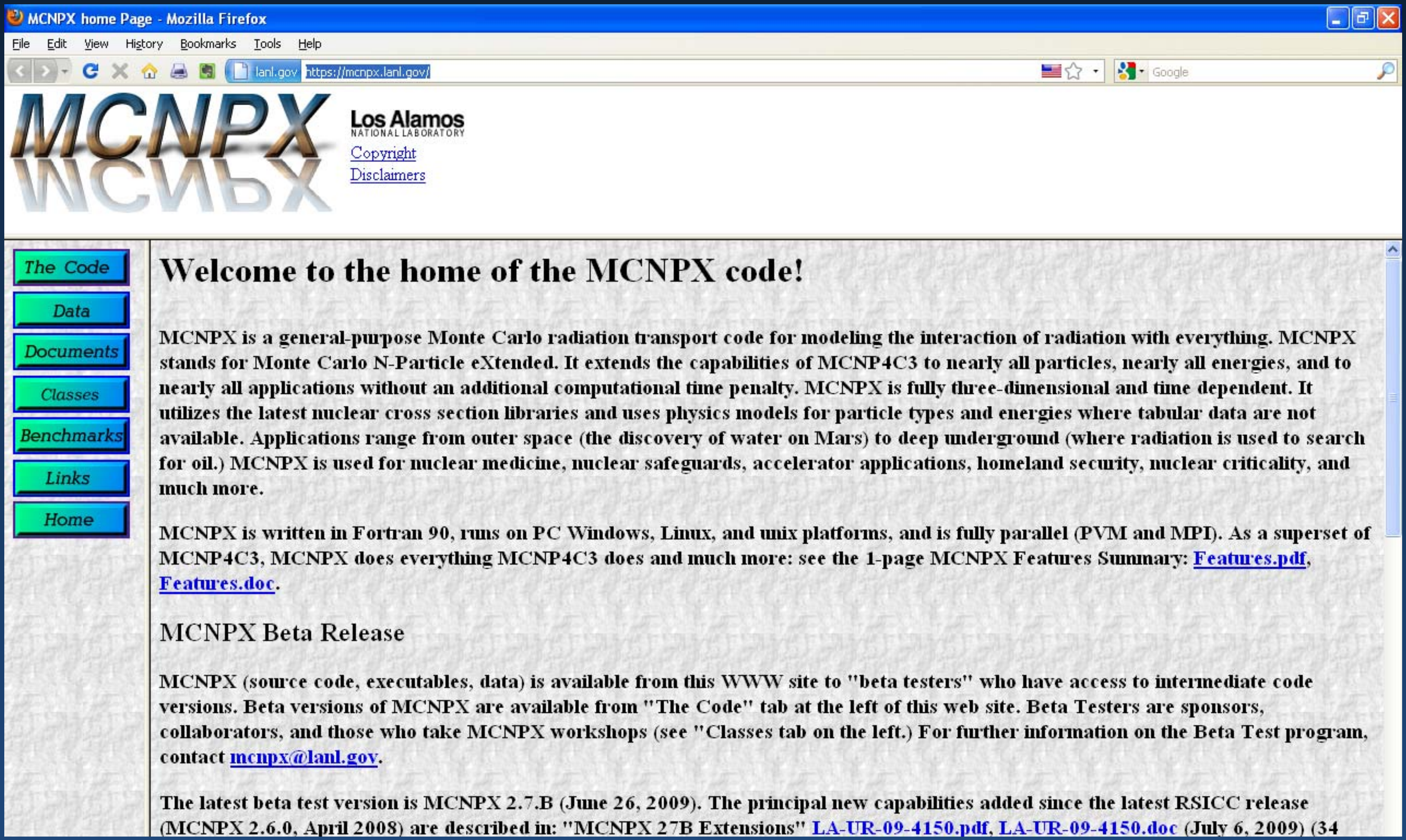
- To provide a set of benchmark problems that potential instrument providers can use to validate their own choice of transport tools

- For this initial benchmark study, we are focusing on the high energy electron transport, as they are dominating contributor in the Jovian radiation environment.

- Two codes used: MCNPX and Geant4. For Geant4, two sets of results are given, for a native Geant4 application at JPL and for GRAS (Geant4 Radiation Analysis for Space application)

MCNPX

- https://mcnpx.lanl.gov


MCNPX home Page - Mozilla Firefox

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lanl.gov https://mcnpx.lanl.gov/

MCNPX

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The Code

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Home

Welcome to the home of the MCNPX code!

MCNPX is a general-purpose Monte Carlo radiation transport code for modeling the interaction of radiation with everything. MCNPX stands for Monte Carlo N-Particle eXtended. It extends the capabilities of MCNP4C3 to nearly all particles, nearly all energies, and to nearly all applications without an additional computational time penalty. MCNPX is fully three-dimensional and time dependent. It utilizes the latest nuclear cross section libraries and uses physics models for particle types and energies where tabular data are not available. Applications range from outer space (the discovery of water on Mars) to deep underground (where radiation is used to search for oil.) MCNPX is used for nuclear medicine, nuclear safeguards, accelerator applications, homeland security, nuclear criticality, and much more.

MCNPX is written in Fortran 90, runs on PC Windows, Linux, and unix platforms, and is fully parallel (PVM and MPI). As a superset of MCNP4C3, MCNPX does everything MCNP4C3 does and much more: see the 1-page MCNPX Features Summary: Features.pdf, Features.doc.

MCNPX Beta Release

MCNPX (source code, executables, data) is available from this WWW site to "beta testers" who have access to intermediate code versions. Beta versions of MCNPX are available from "The Code" tab at the left of this web site. Beta Testers are sponsors, collaborators, and those who take MCNPX workshops (see "Classes tab on the left.) For further information on the Beta Test program, contact mcnpx@lanl.gov.

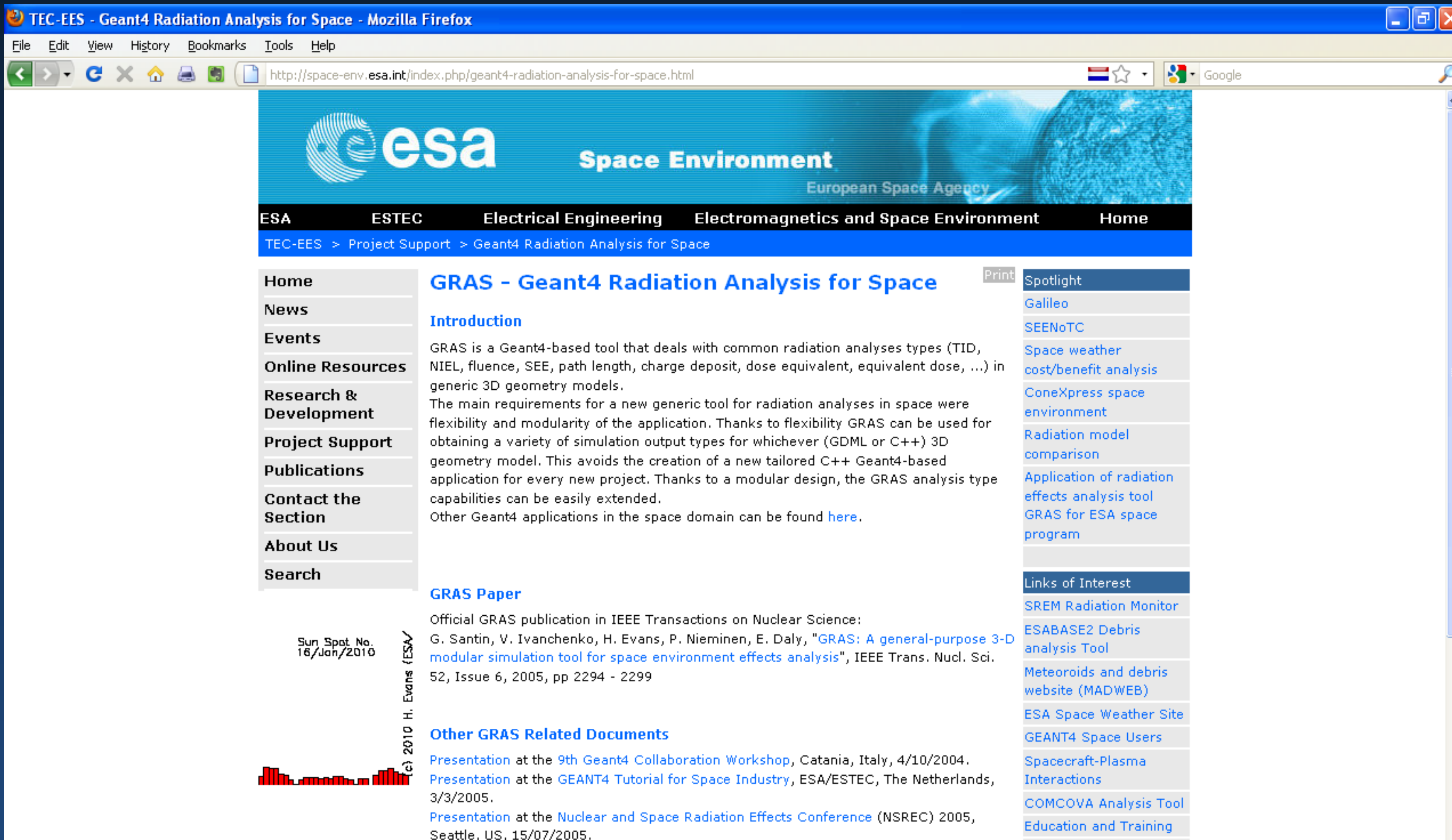
The latest beta test version is MCNPX 2.7.B (June 26, 2009). The principal new capabilities added since the latest RSICC release (MCNPX 2.6.0, April 2008) are described in: "MCNPX 27B Extensions" LA-UR-09-4150.pdf, LA-UR-09-4150.doc (July 6, 2009) (34

Geant4

- http://cern.ch/geant4
- http://geant4.esa.int (space users' community)

GRAS

- http://space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html



TEC-EES - Geant4 Radiation Analysis for Space - Mozilla Firefox

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http://space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html

esa Space Environment European Space Agency

ESA | ESTEC | Electrical Engineering | Electromagnetics and Space Environment | Home

TEC-EES > Project Support > Geant4 Radiation Analysis for Space

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GRAS - Geant4 Radiation Analysis for Space

Print

Introduction

GRAS is a Geant4-based tool that deals with common radiation analyses types (TID, NIEL, fluence, SEE, path length, charge deposit, dose equivalent, equivalent dose, ...) in generic 3D geometry models.
The main requirements for a new generic tool for radiation analyses in space were flexibility and modularity of the application. Thanks to flexibility GRAS can be used for obtaining a variety of simulation output types for whichever (GDML or C++) 3D geometry model. This avoids the creation of a new tailored C++ Geant4-based application for every new project. Thanks to a modular design, the GRAS analysis type capabilities can be easily extended.
Other Geant4 applications in the space domain can be found here.

GRAS Paper

Official GRAS publication in IEEE Transactions on Nuclear Science:
G. Santin, V. Ivanchenko, H. Evans, P. Nieminen, E. Daly, "GRAS: A general-purpose 3-D modular simulation tool for space environment effects analysis", IEEE Trans. Nucl. Sci. 52, Issue 6, 2005, pp 2294 - 2299

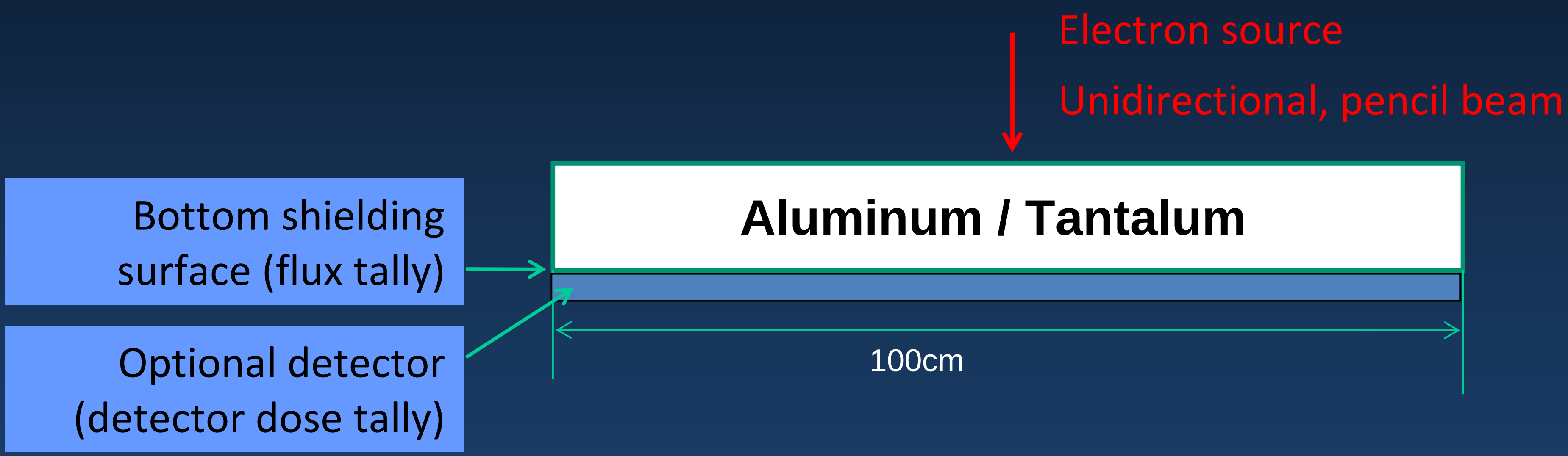
Other GRAS Related Documents

Presentation at the 9th Geant4 Collaboration Workshop, Catania, Italy, 4/10/2004.
Presentation at the GEANT4 Tutorial for Space Industry, ESA/ESTEC, The Netherlands, 3/3/2005.
Presentation at the Nuclear and Space Radiation Effects Conference (NSREC) 2005, Seattle, US, 15/07/2005.

Spotlight
Galileo
SEENoTC
Space weather cost/benefit analysis
ConeXpress space environment
Radiation model comparison
Application of radiation effects analysis tool GRAS for ESA space program

Links of Interest
SREM Radiation Monitor
ESABASE2 Debris analysis Tool
Meteoroids and debris website (MADWEB)
ESA Space Weather Site
GEANT4 Space Users
Spacecraft-Plasma Interactions
COMCOVA Analysis Tool
Education and Training

Geometry Setup



- Electron, photon, and neutron fluxes at the bottom surface of the slab.
- Energy deposition in the shielding volume is also calculated.
- For GRAS, energy deposition after the shielding also tallied

Simulation Case Summary

Tools

- MCNPX 2.5
- Geant4
  - Geant4 application @JPL
  - GRAS 2.4.1

Material	Thickness (g/cm^2)	Energy (MeV)
Al and Ta	5, 16.6, and 50	1, 2, 3, 5, 10, 20, 30, 50, and 100

81 cases total, each with ~10M histories

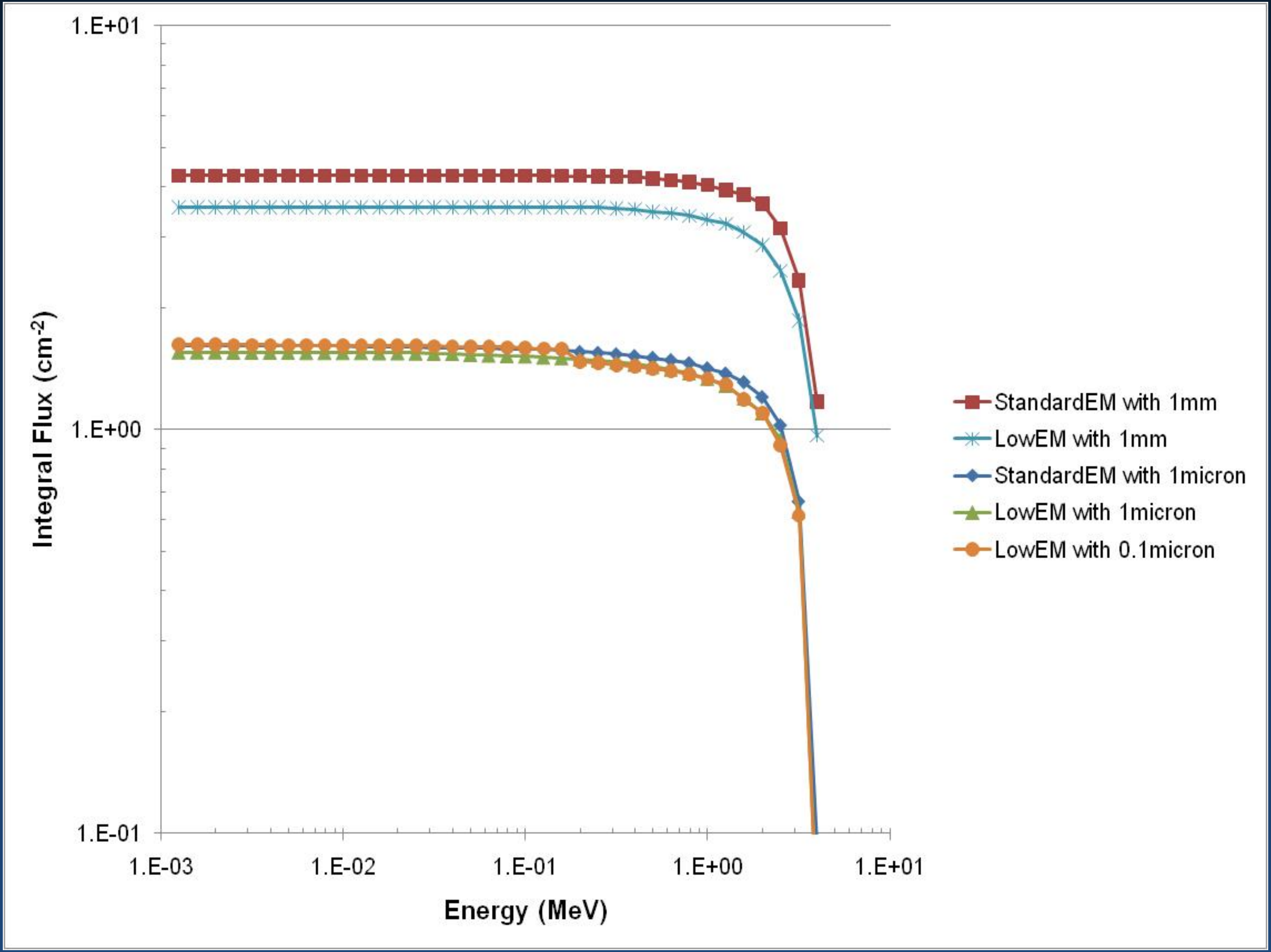
Geant4 Physics and Scoring

		Geant4 @JPL	GRAS (Geant4)
Physics	Electrons and Gammas	LowEMPhysics	Standard EM
Physics	Secondary neutrons	G4PhotoNuclearProcess G4GammaNuclearReaction	
Physics	Production cut	1 micron	
Scoring	Flux for e^-, γ, n (equiv. to MCNPX F2 Tally)	G4PSFlatSurfaceFlux	GRAS Fluence module (w/ “surf. correction”)
Scoring	Dose (all particles) (equiv. to MCNPX +F6 Tally)	G4PSEnergyDeposit	GRAS Dose module

Multiple scattering and Geant4 production cuts

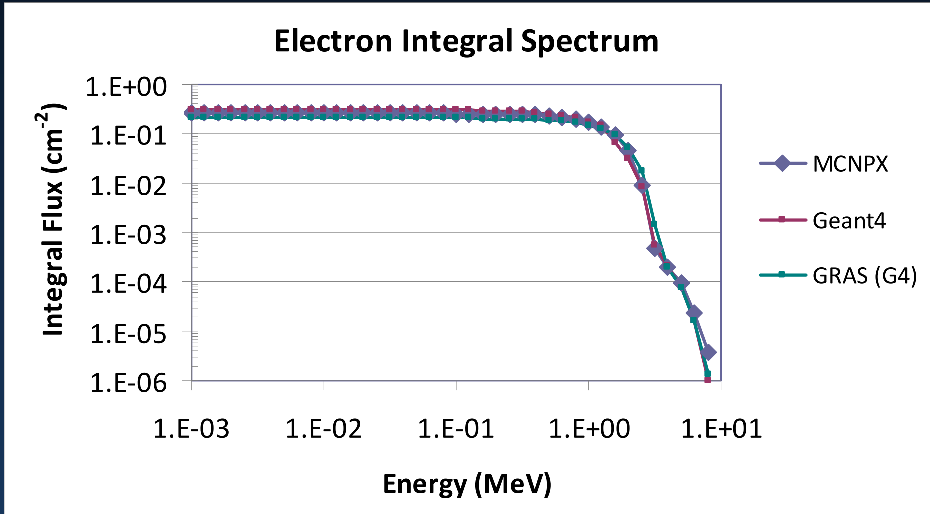
- "Condensed history" for electron transport
  - "Multiple" small angle scatterings -> can not practically follow each individual scatterings: "condensed history" or "condensed random walk"
  - In condensed history modelling of electron transport, the electron paths are broken into many steps in each of which numerous interactions occur
- In Geant4
  - Production cut for secondary e^- and γ in ionisation and Bremsstrahlung (to avoid "infrared divergence")
  - Also affects step length and therefore multiple scattering

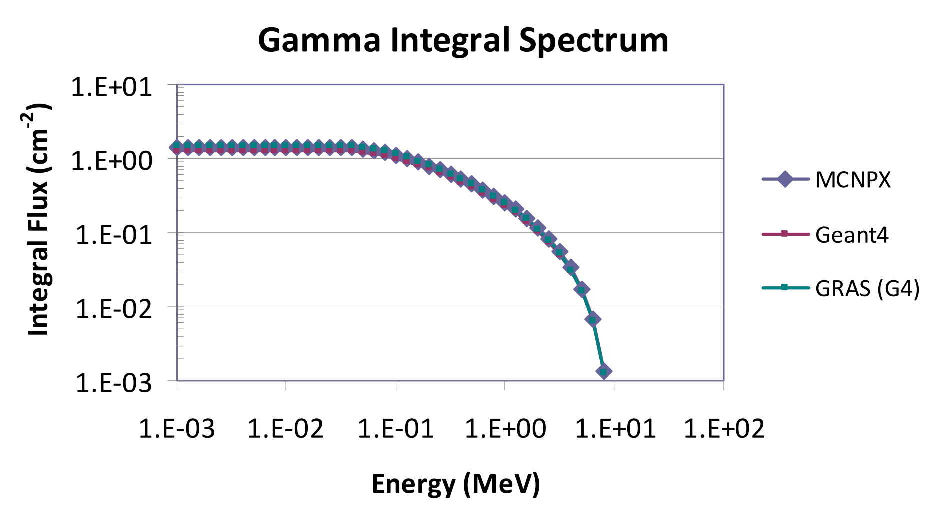
Geant4: physics models and production cuts



- LowEM and StandardEM produced similar results for our application
- Setting up the "cut" value is much more important

10 MeV input on 5 g/cm^2 of Al





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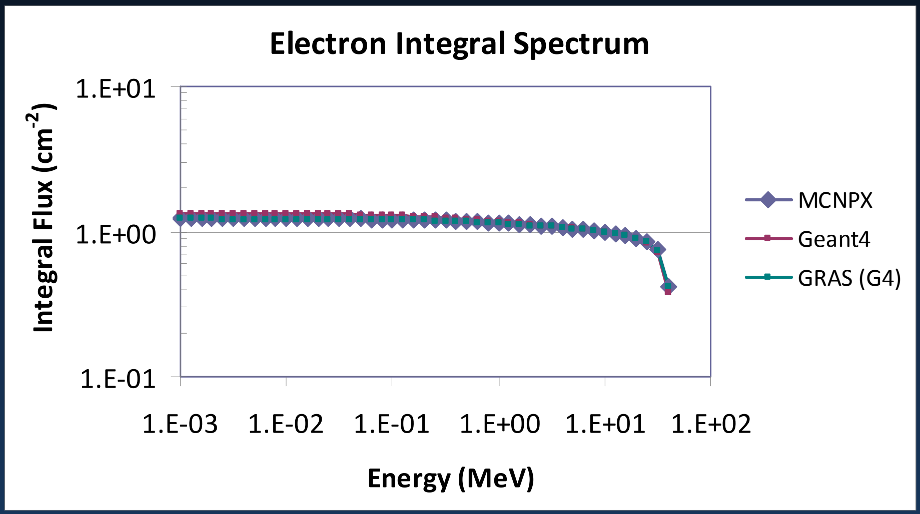
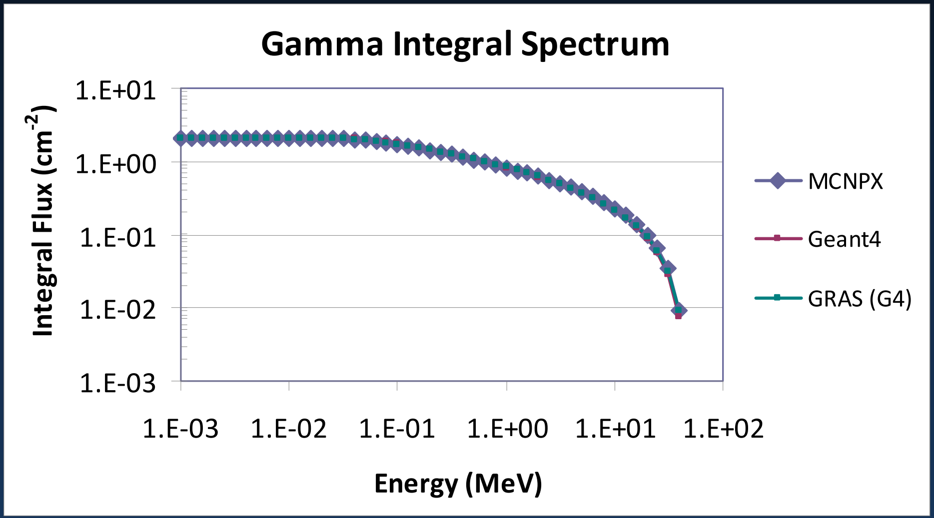
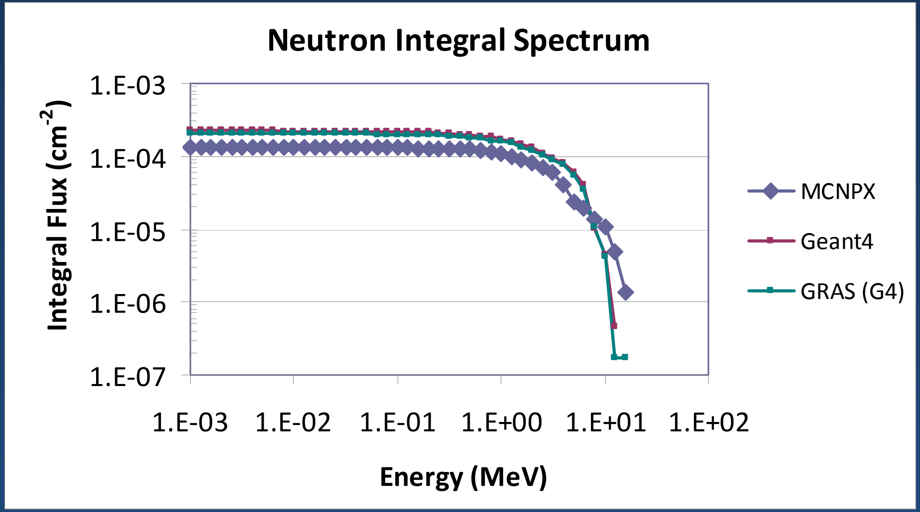
	Energy Deposit (MeV
MCNPX	9.06
Geant4	9.16

50 MeV input on 5 g/cm^2 of Al

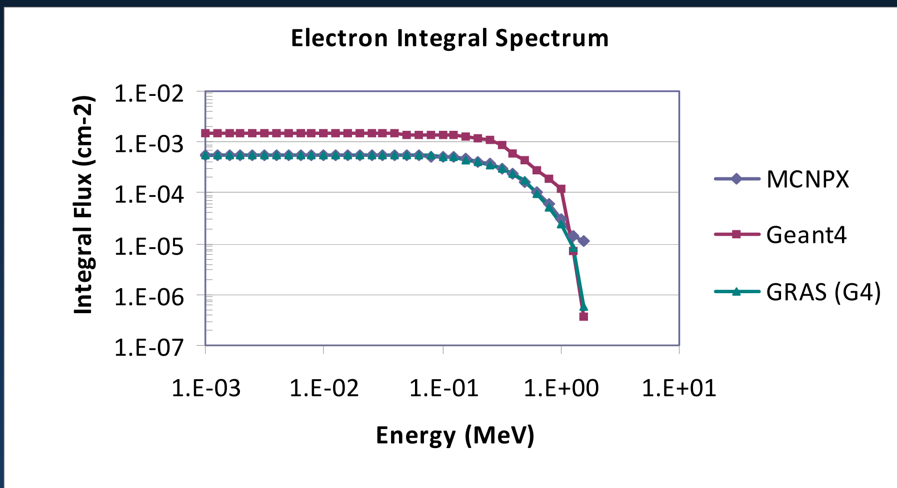


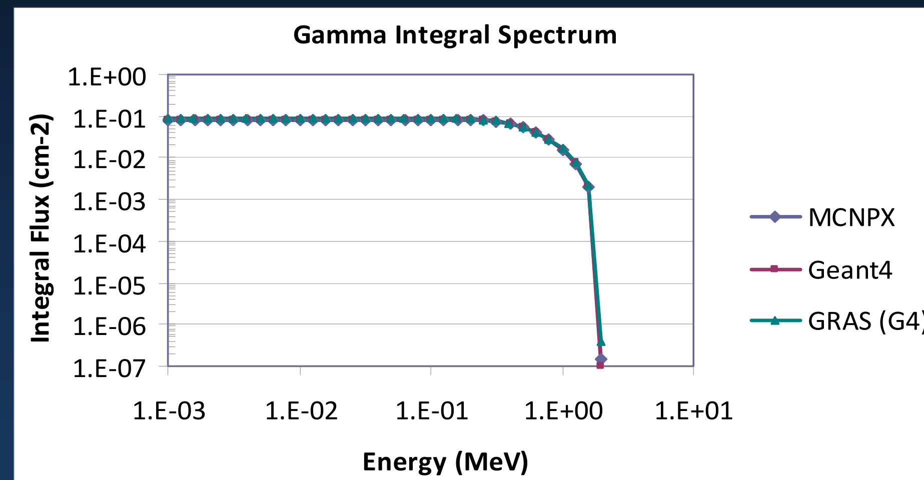




	Energy Deposit (MeV)
MCNPX	8.40
Geant4	9.16

2 MeV input on 5.0 g/cm^2 of Ta





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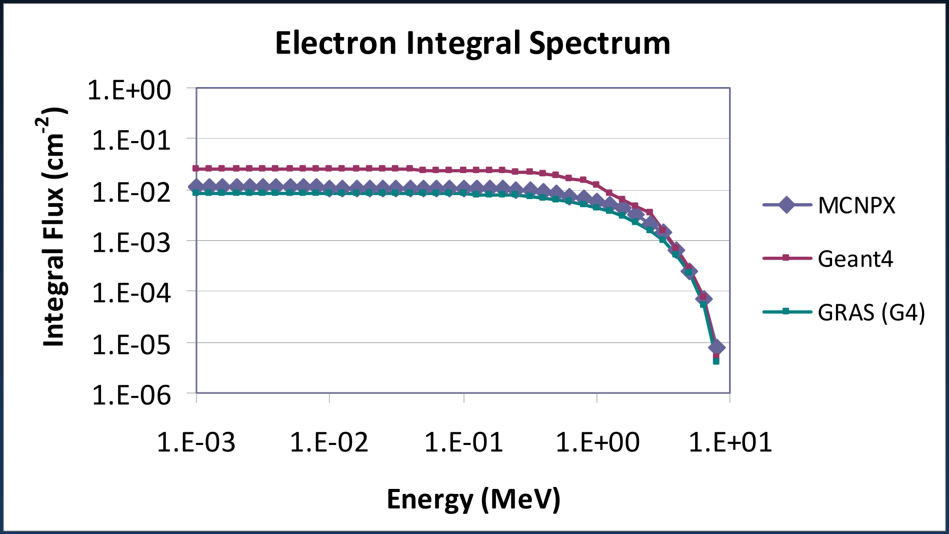
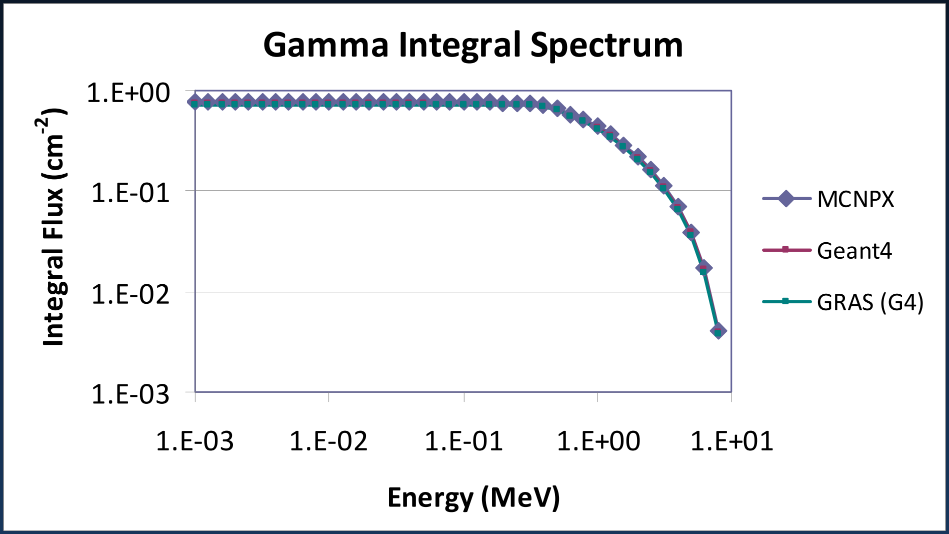
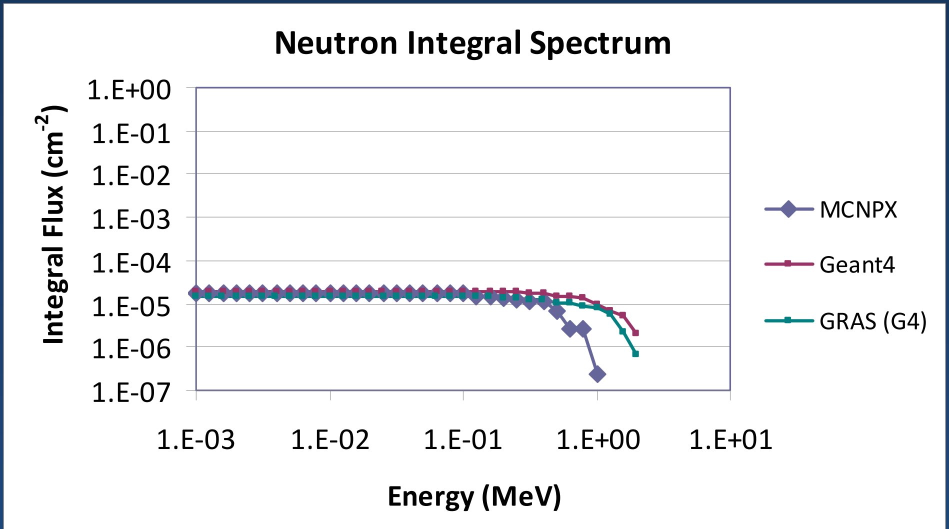
	Energy Deposit (MeV)
MCNPX	1.41
Geant4	1.45

10 MeV input on 16.6 g/cm^2 of Ta







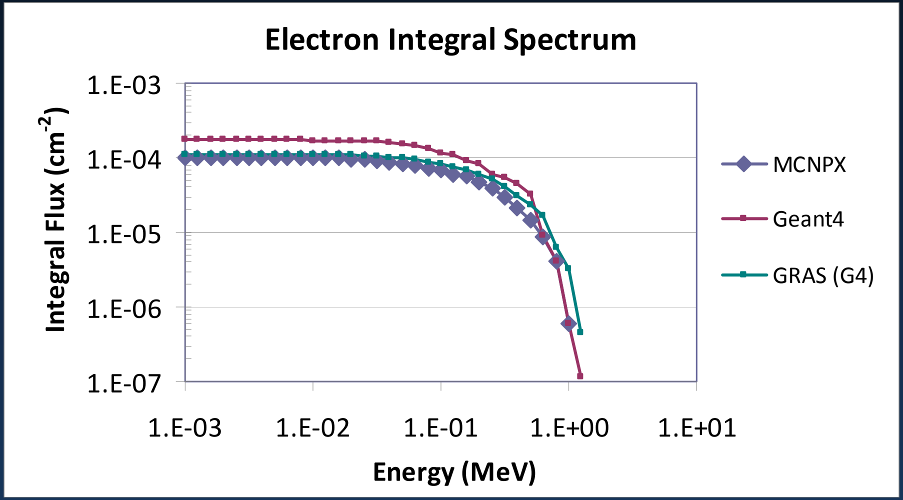
	Energy Deposit (MeV)
MCNPX	7.99
Geant4	8.10

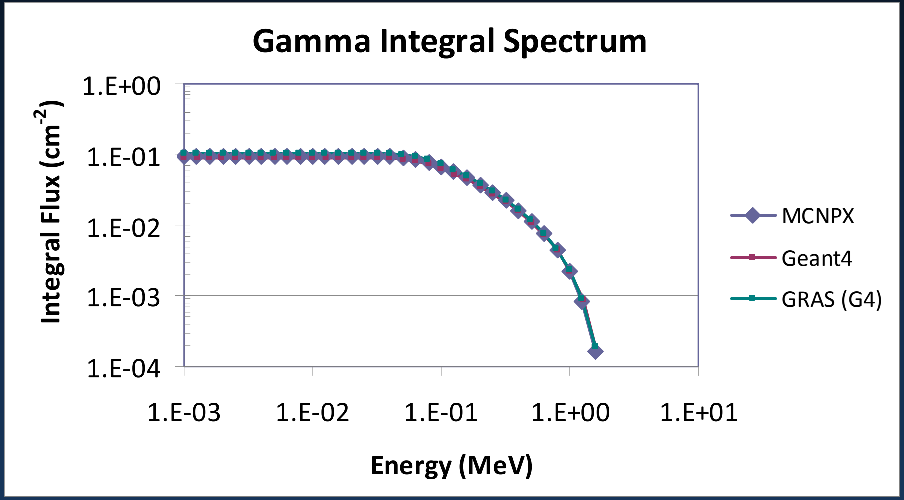
Conclusions

- The agreement between the three codes is generally good for all cases
  - However, the selection of correct input parameters is important. For example, the Geant4 results strongly depend on the choice of "cut" value
  - More detailed analyses of differences in preparation
  - Need for experimental coordinated validation programme
- More benchmark cases about to start including
  - Representative detector material (e.g., Silicon or HgCdTe) behind the shielding
  - Representative layered shielding options

Backup slides

2 MeV input on 5 g/cm^2 of Al





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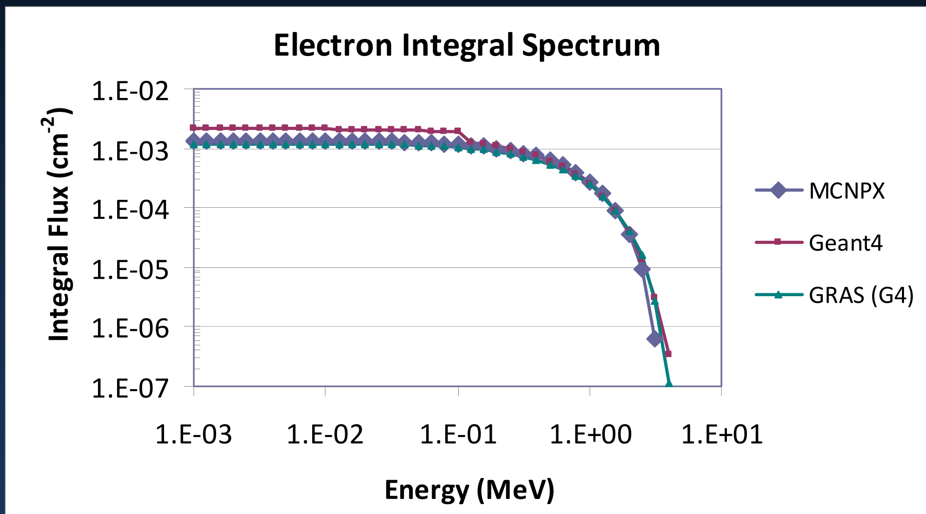
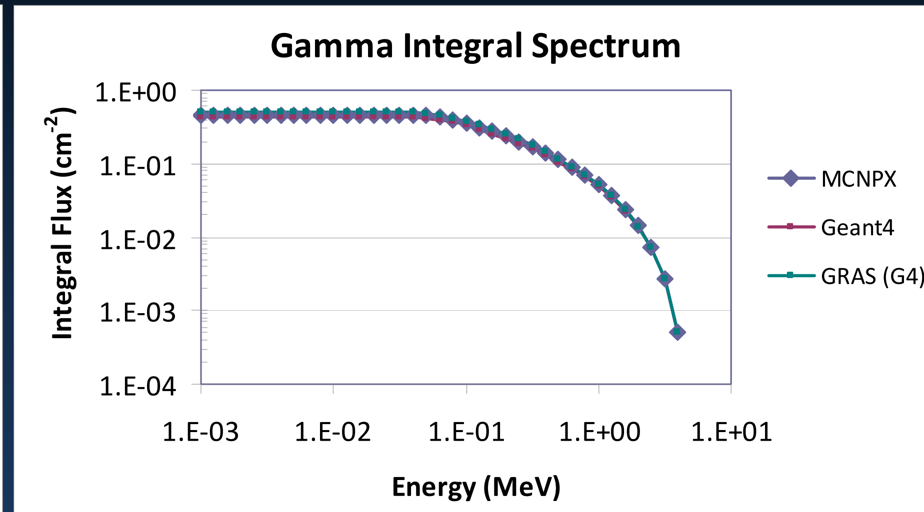
	Energy Deposit (MeV
MCNPX	1.93
Geant4	1.93

5 MeV input on 5 g/cm^2 of Al





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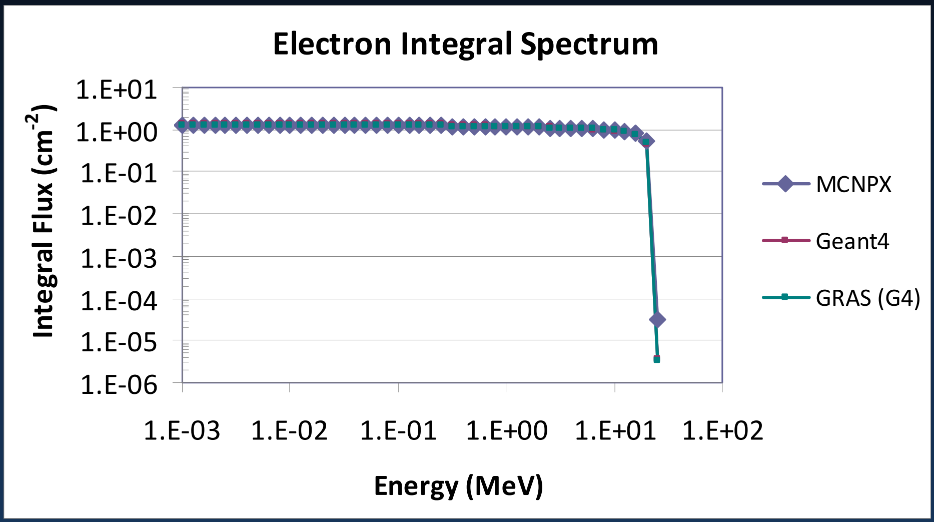
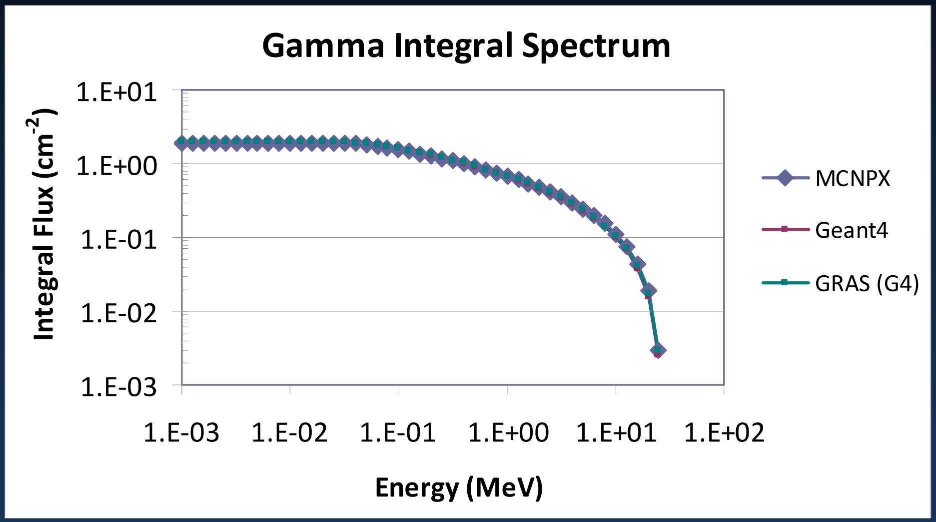
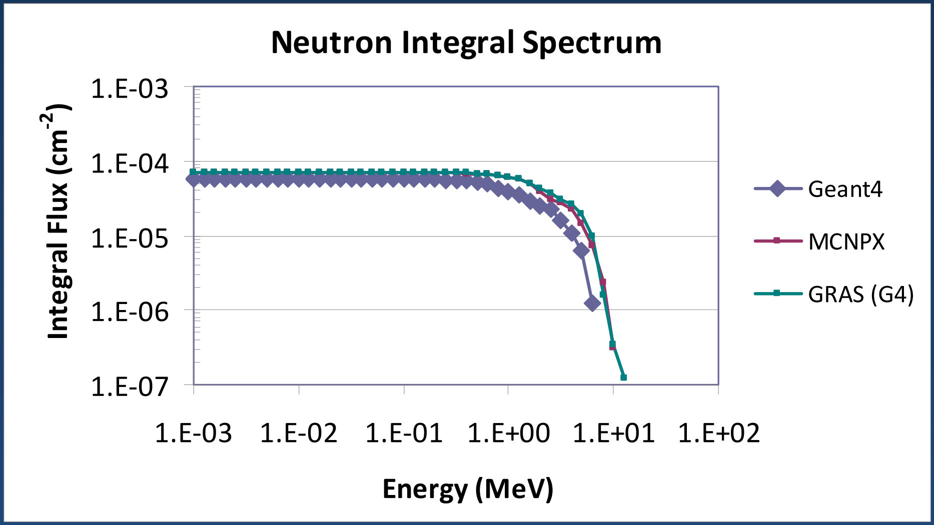
	Energy Deposit (MeV
MCNPX	4.81
Geant4	4.80

30 MeV input on 5 g/cm^2 of Al

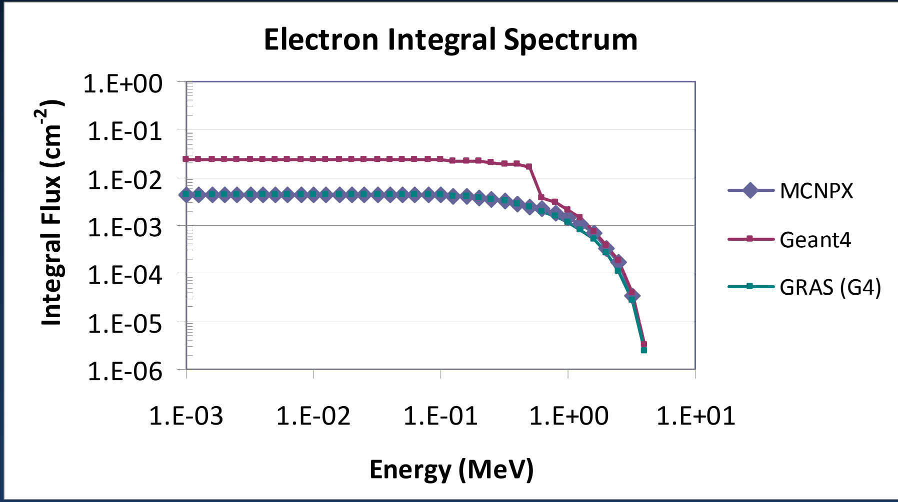


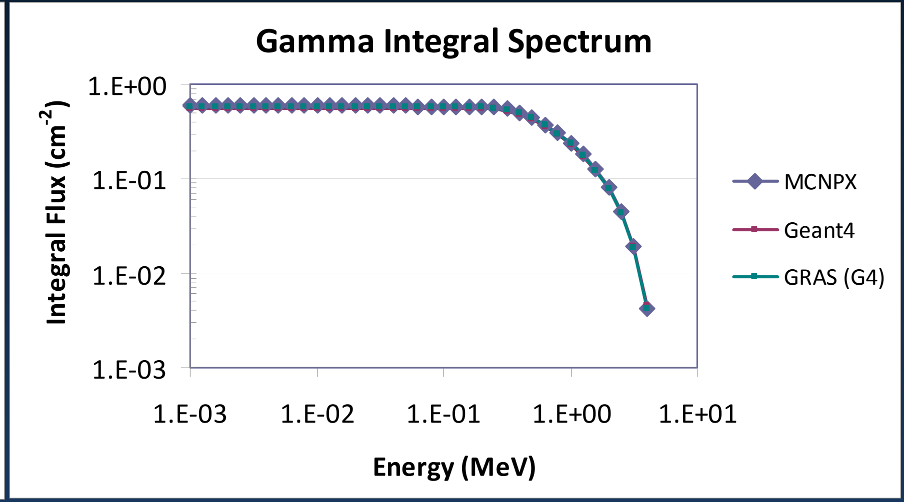




	Energy Deposit (MeV
MCNPX	8.44
Geant4	9.30

5 MeV input on 5.0 g/cm^2 of Ta

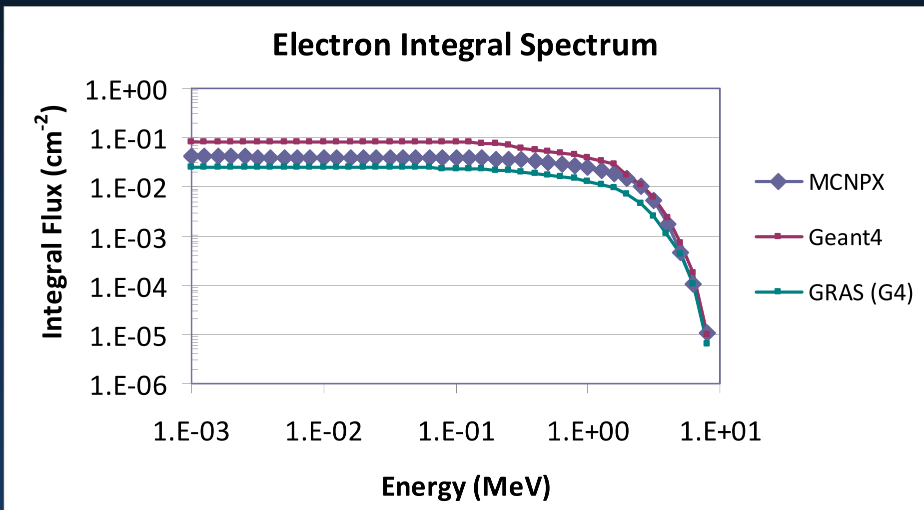


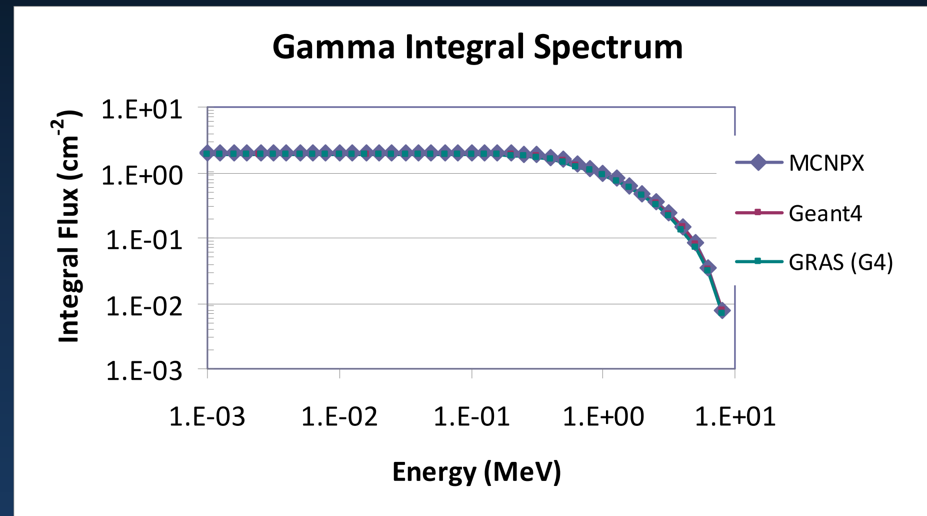


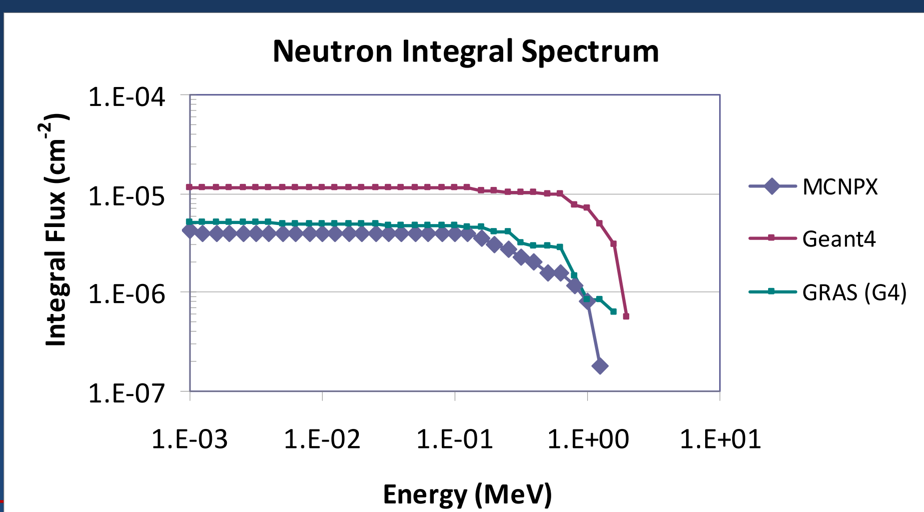
No Neutron Generated

	Energy Deposit (MeV)
MCNPX	3.76
Geant4	3.81

10 MeV input on 5.0 g/cm^2 of Ta

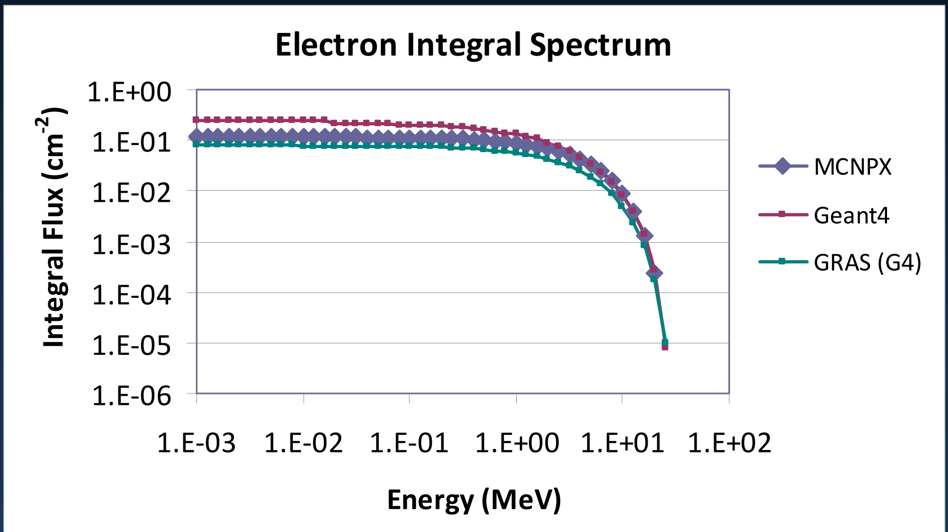


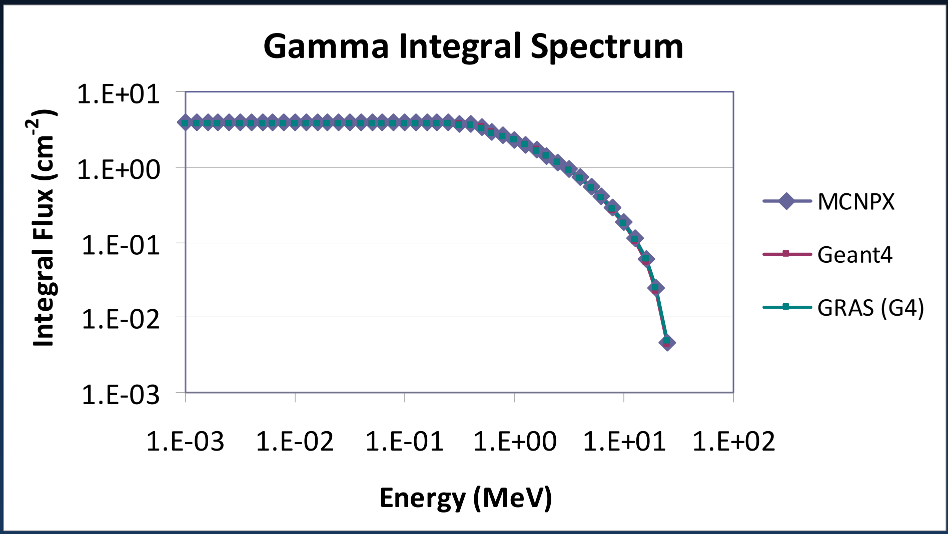


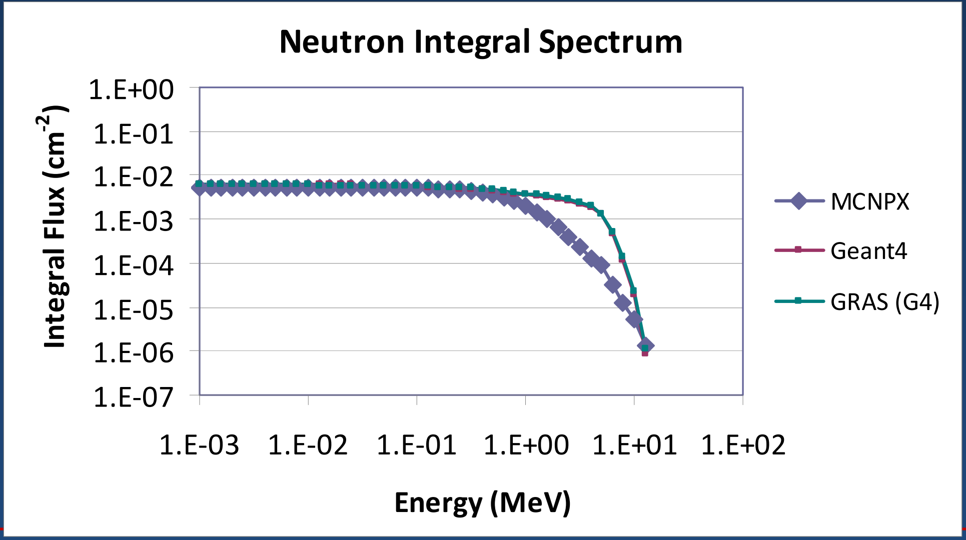


	Energy Deposit (MeV)
MCNPX	7.13
Geant4	7.23

30 MeV input on 5.0 g/cm^2 of Ta

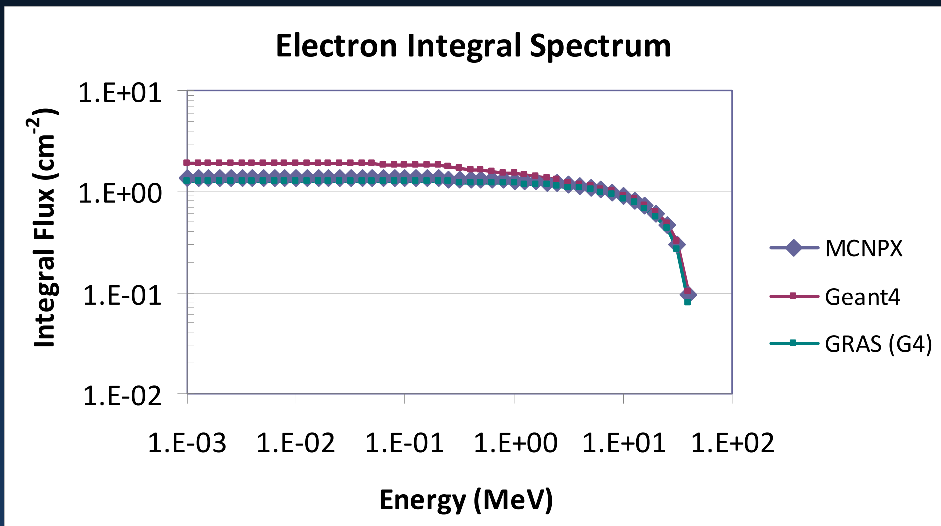


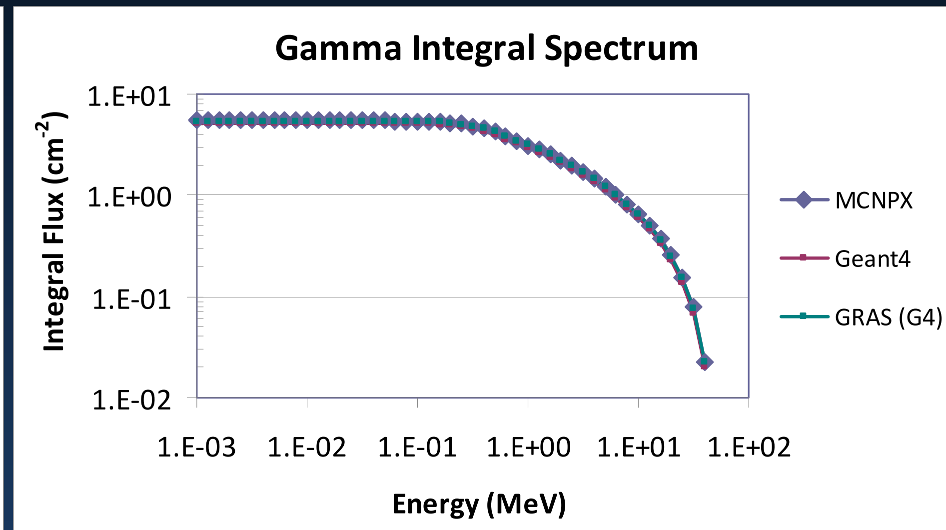


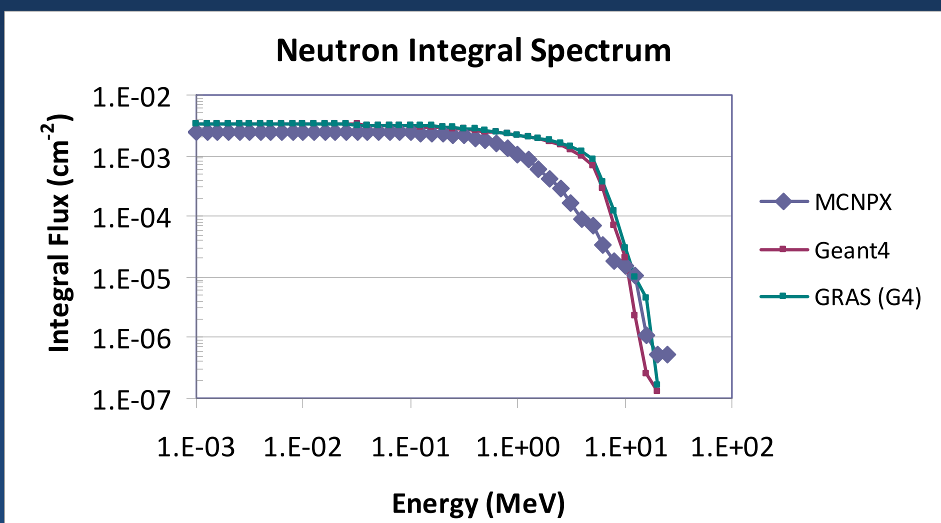


	Energy Deposit (MeV
MCNPX	9.13
Geant4	9.87

50 MeV input on 5.0 g/cm^2 of Ta

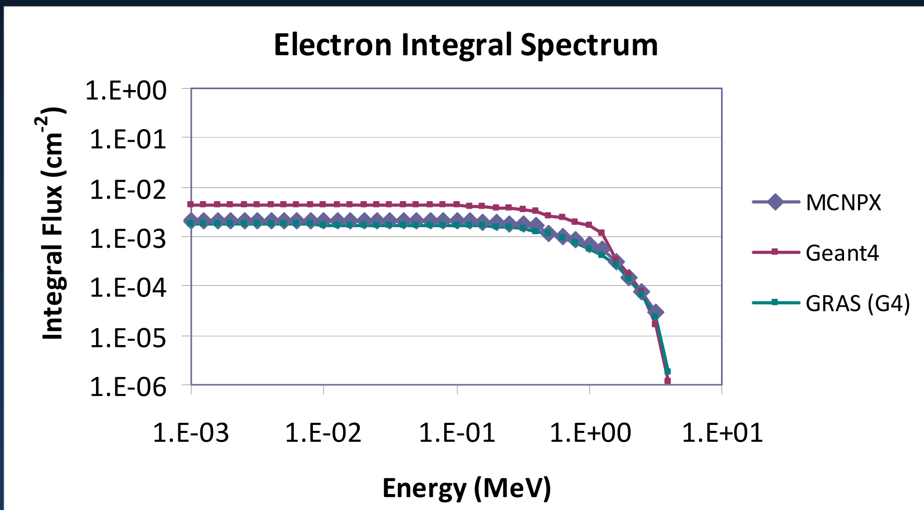


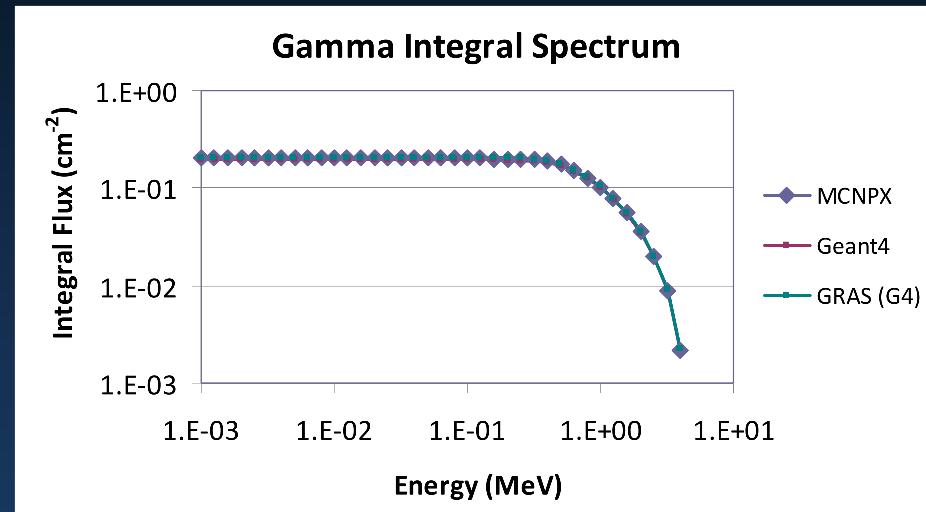




	Energy Deposit (MeV
MCNPX	8.75
Geant4	8.62

5 MeV input on 16.6 g/cm^2 of Ta





No Neutron Generated

	Energy Deposit (MeV
MCNPX	3.96
Geant4	4.00