

Geant 4

Validation/Verification Activities in Geant4

11th Geant4 Collaboration Workshop
and Users Conference at LIP - Lisboa

SLAC/SCCS

Koi, Tatsumi



STANFORD LINEAR ACCELERATOR CENTER

Outline

- Hadron Validation
 - From low energy to high energy
 - CHIPS
 - Low Energy Neutron Transportation
 - Ions
- EM Validation
 - Standard
 - Low Energy
- Validation of Use Cases
 - Space Applications
 - Medical Applications
- Other information

Precompound model

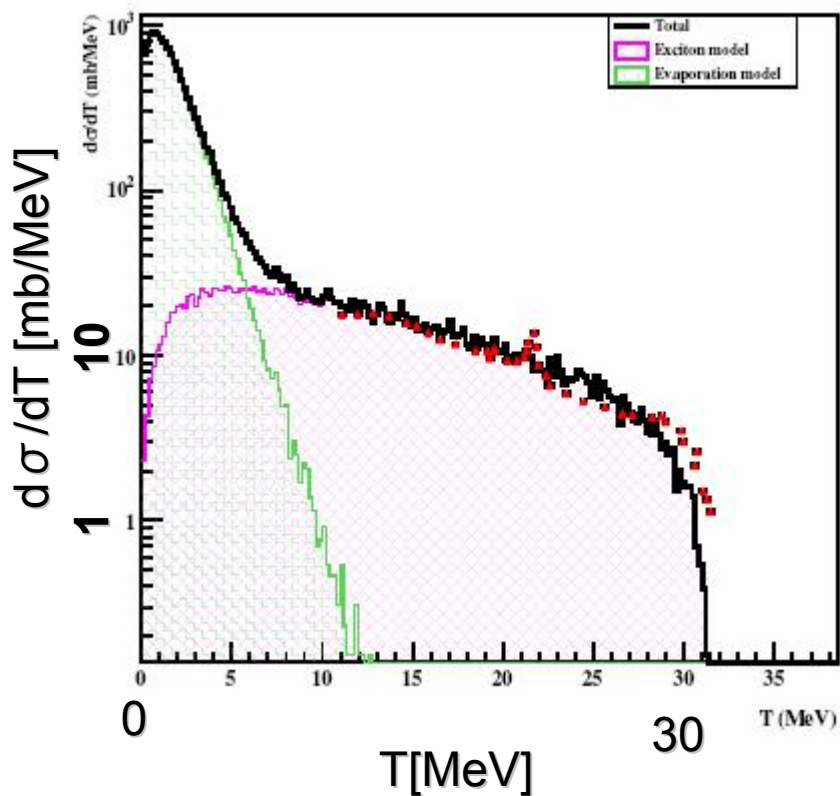
- This model handles lowest energy (below 170 MeV) hadron interactions
- In following plots the Geant4 precompound model coupled with evaporation model to handle low energy de-excitation of nucleus
- Precompound is exciton model

Neutron Production Cross Section

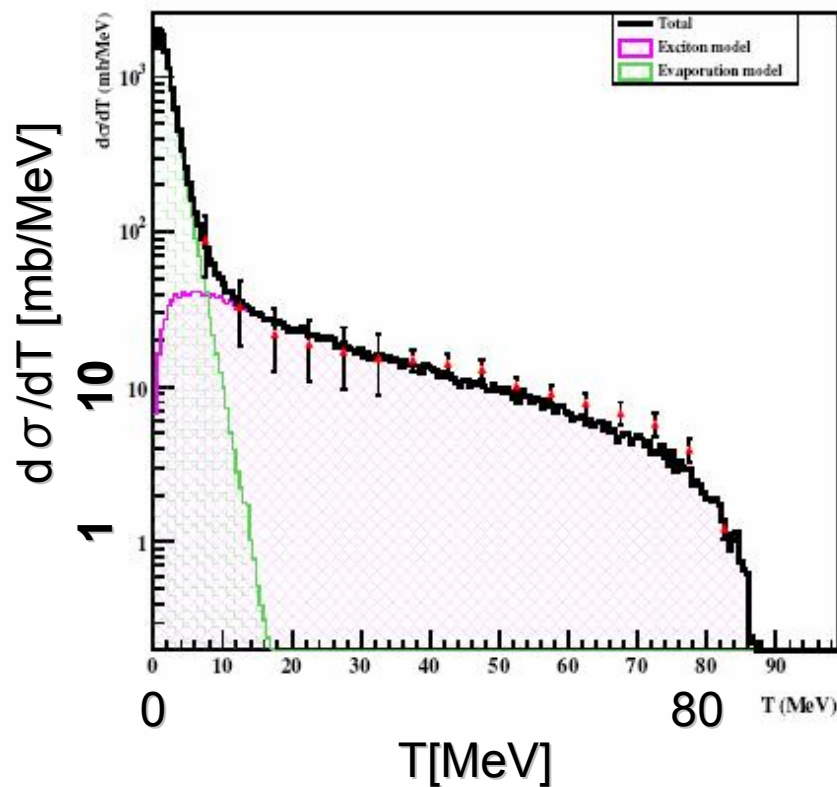
Secondary neutrons are created in

█ Exciton (Precompound)

█ Evaporation



Sn (p, X n) 35MeV



Bi (p, X n) 90MeV

Intermediate energies (170 MeV < E < 3.0 GeV)

**Binary Cascade
Bertini Cascade
and
LEP**



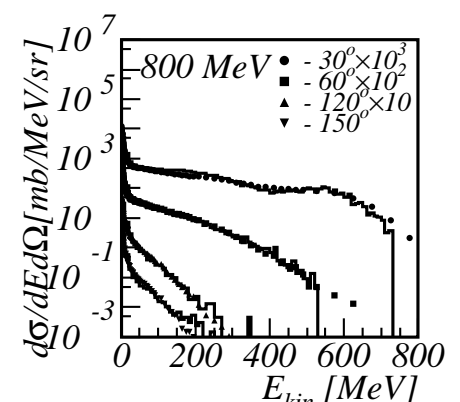
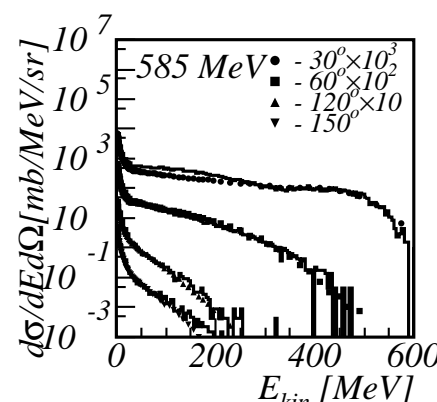
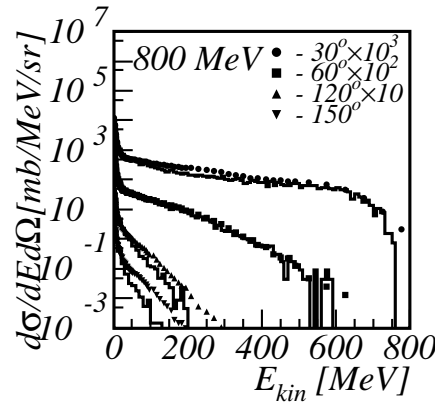
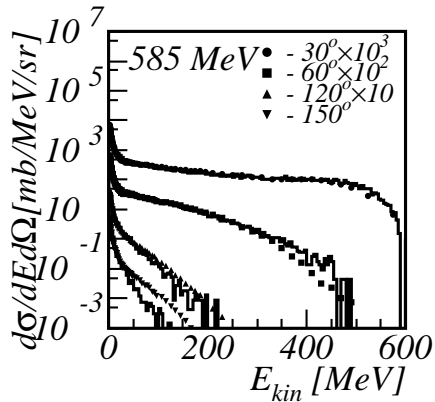
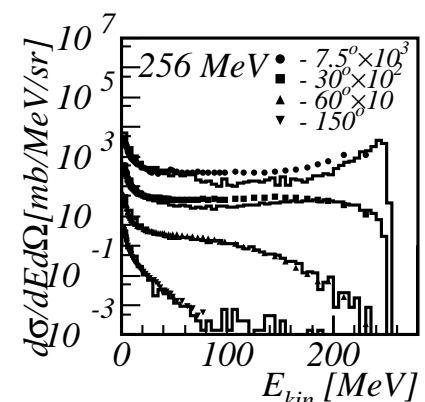
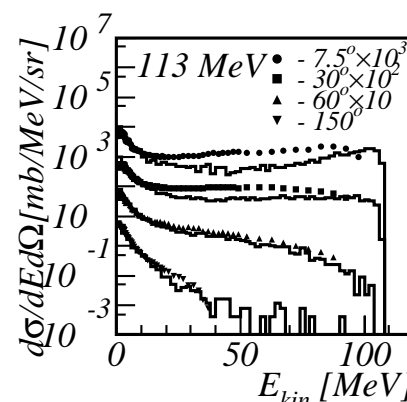
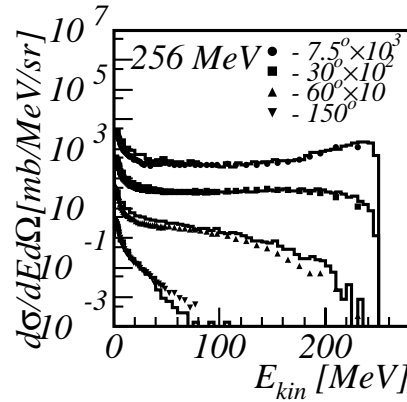
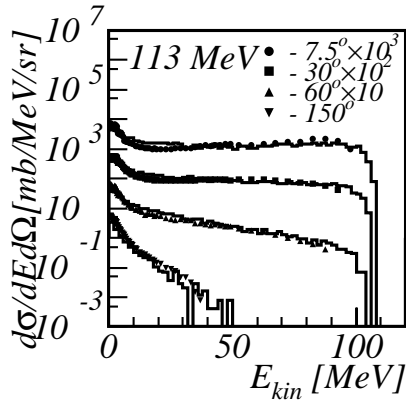
Verification Suite for the Cascade Energy Region

- We have developed since 2002 as test30
- Neutron production by p, d, α , ^{12}C with $E < 3 \text{ GeV}$
 - $P + A \rightarrow n + X$
 - $d + A \rightarrow n + X$
 - $\alpha + A \rightarrow n + X$
 - $^{12}\text{C} + A \rightarrow n + X$
- Pion production
 - $P + A \rightarrow \pi^{\pm} + X$
- 73 thin target experiments with reasonably small systematic
- Control on differential spectra (63 histograms)
- Models under testing:
 - Binary Cascade
 - Binary Ion cascade
 - Bertini Cascade
 - Wilson-Abrasion model
 - CHIPS
 - LHEP
- Additionally to double differential spectra for comparisons with the data a set of histograms with inclusive spectra is produced

Neutron spectra by protons in Aluminum

Binary Cascade

Bertini Cascade

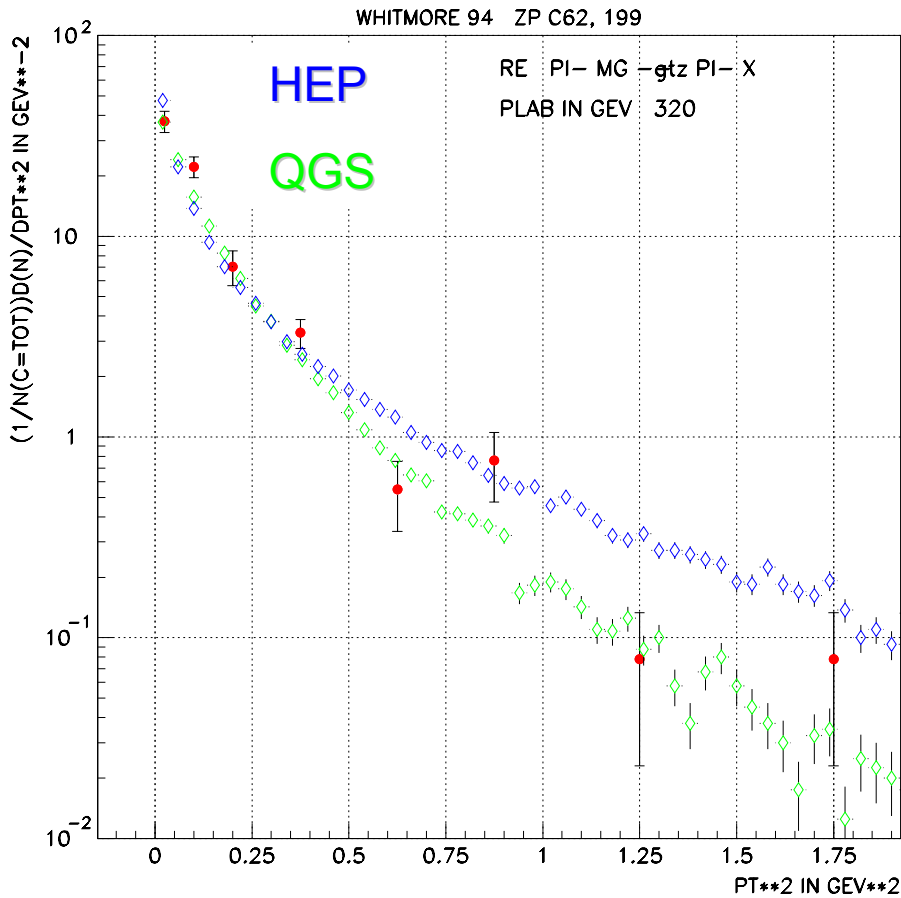


High Energy $>50\text{GeV}$

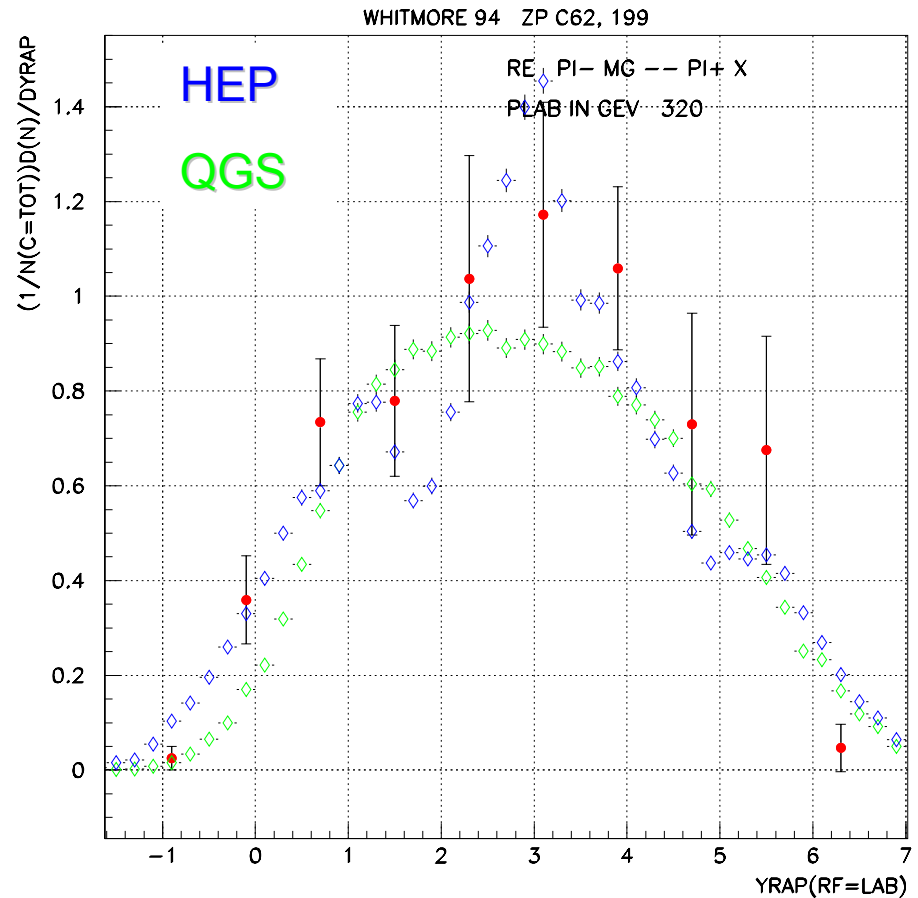
We have 3 models
(QGS, FTF and HEP)
for these energies.

HEP Model

pi- Scattering on Mg, Plab 320 GeV/c



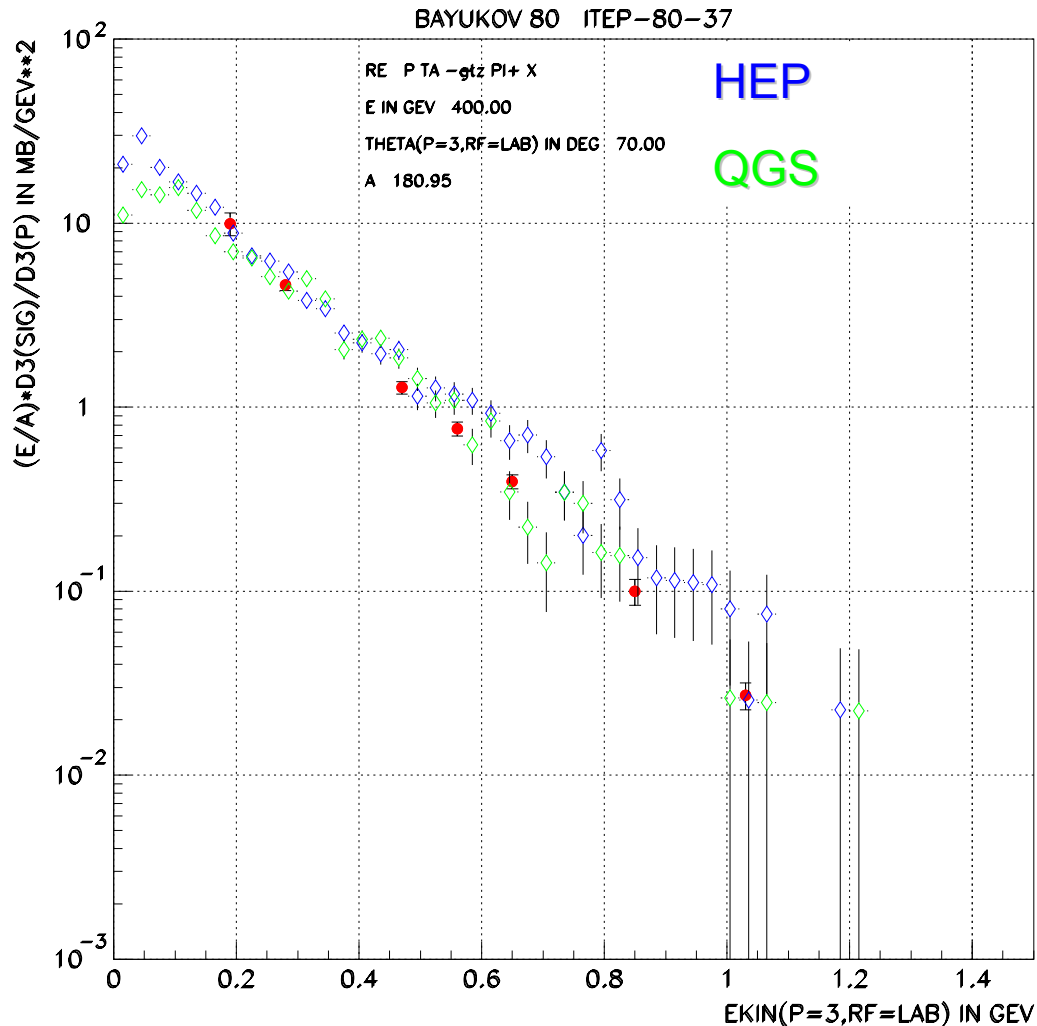
P_t^2 [GeV^2]



Rapidity $\eta = \frac{1}{2} \ln \left(\frac{E + p_z}{E - p_z} \right)$

HEP Model

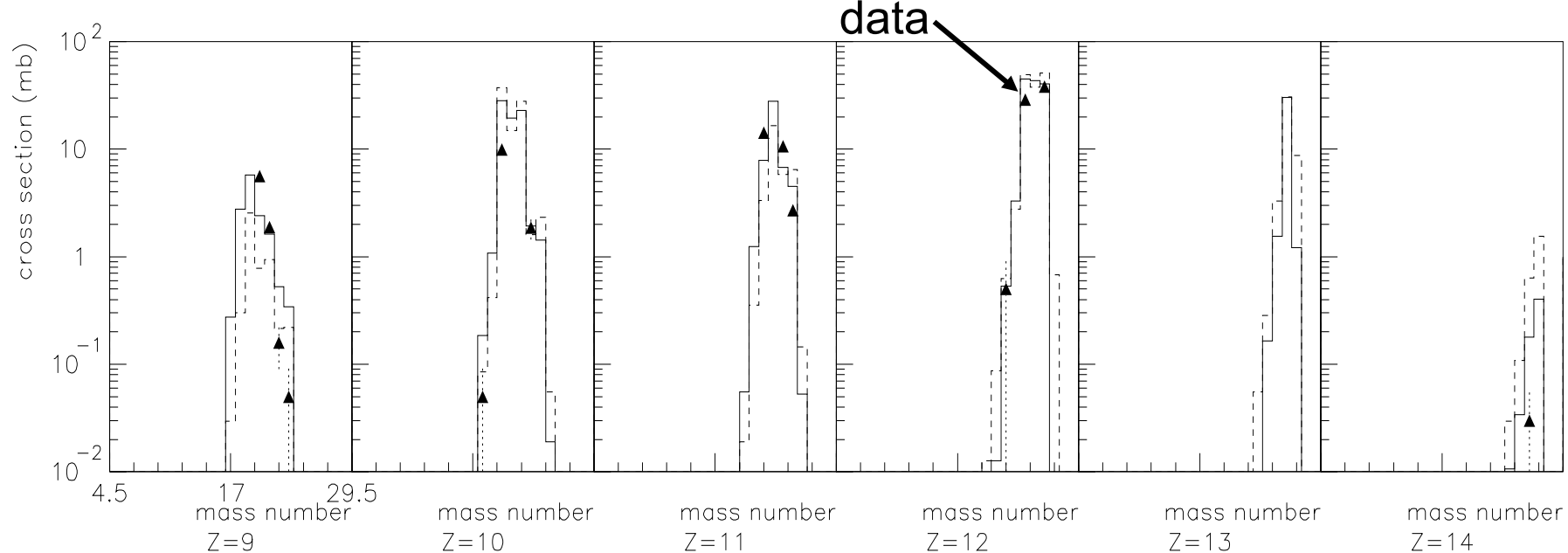
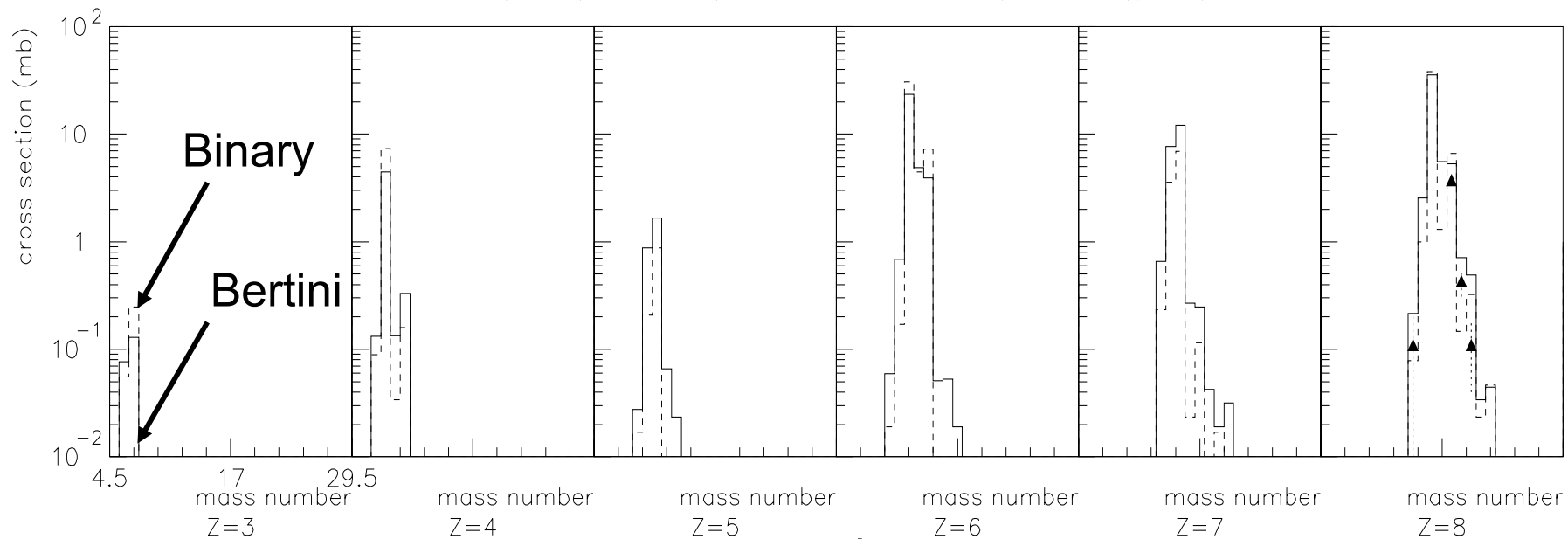
$\pi^+(70\text{deg})$ from proton (400GeV) on Ta



Isotope production by precompound models

- We have two precompound models.
 - One is currently integrated within Bertini Model
 - Another is implemented independently, so that it can be used by itself or coupled to Binary Model
- The range of nuclear excitation energies handled by these precompound models are most important to isotope production
- Next slide compare the two models to data.

Cross section(mb) vs A (for Element Z) in Al(p,X) at 800 MeV



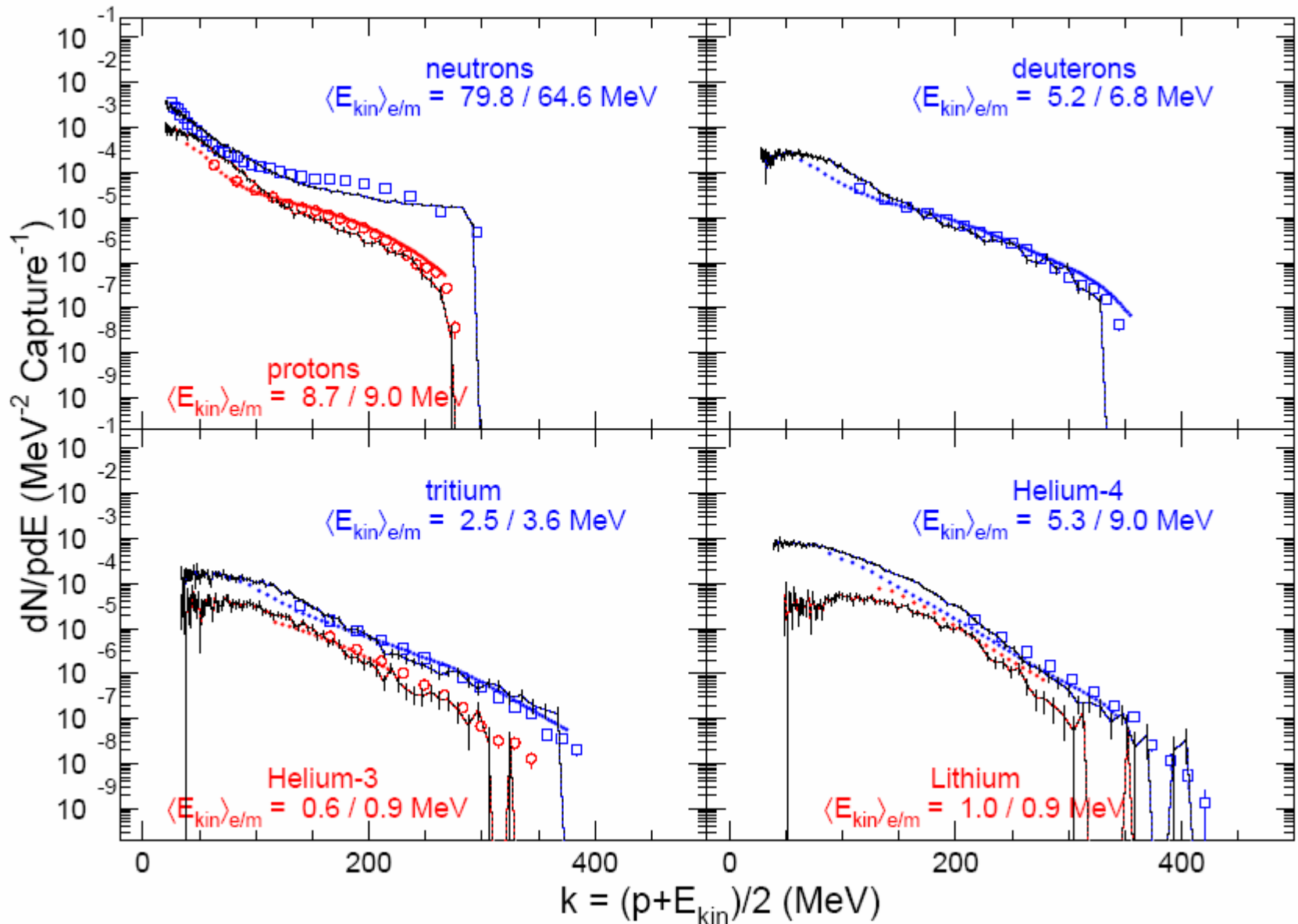
Validation of Chiral Invariant Phase Space decay (CHIPS) model

- Capture
- Anti Proton Annihilation
- Gamma-Nucleus
- Elastic Scattering

Verification of nuclear capture at rest

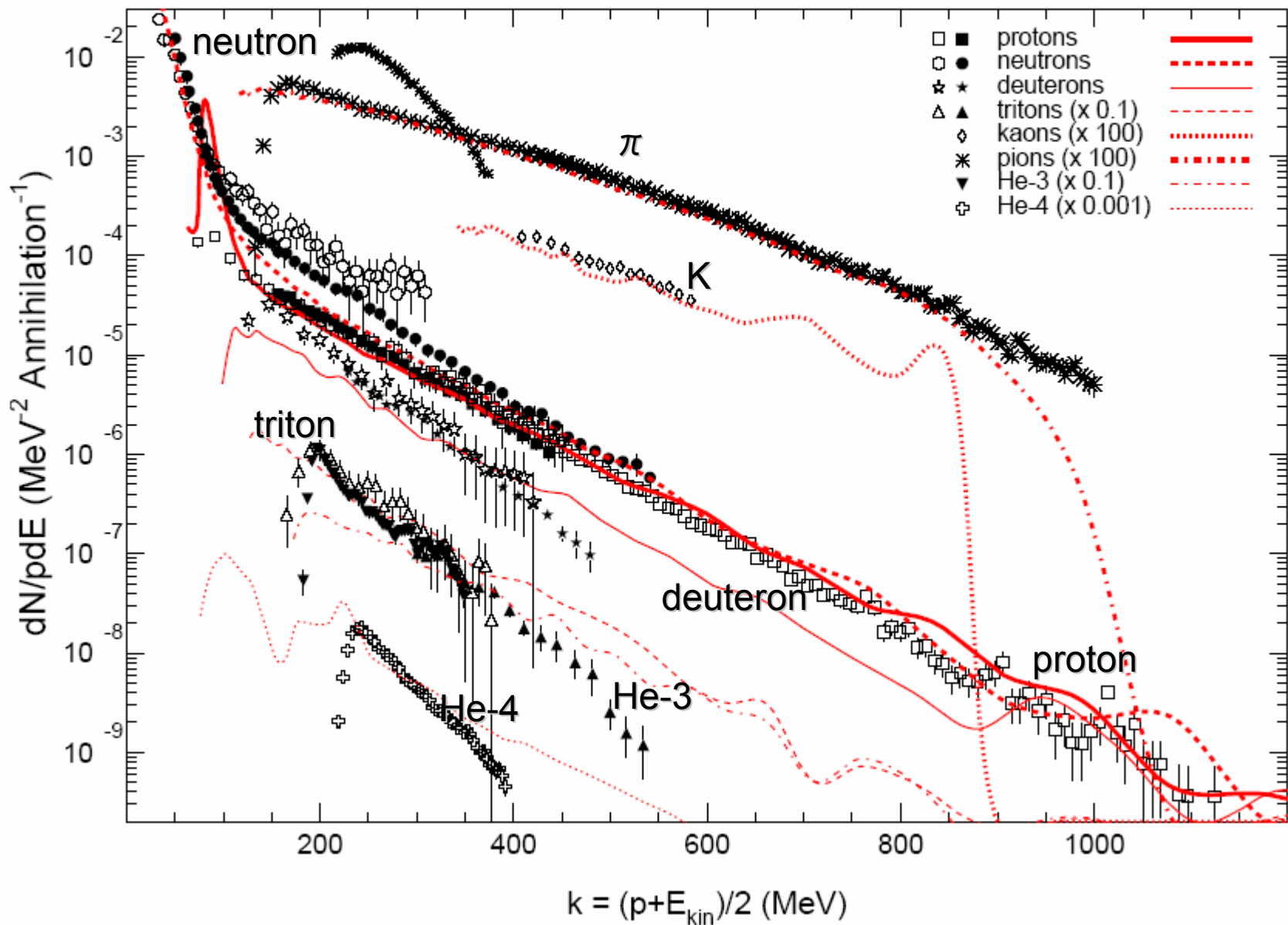
CHIPS Model

Pion capture on ^{12}C nucleus



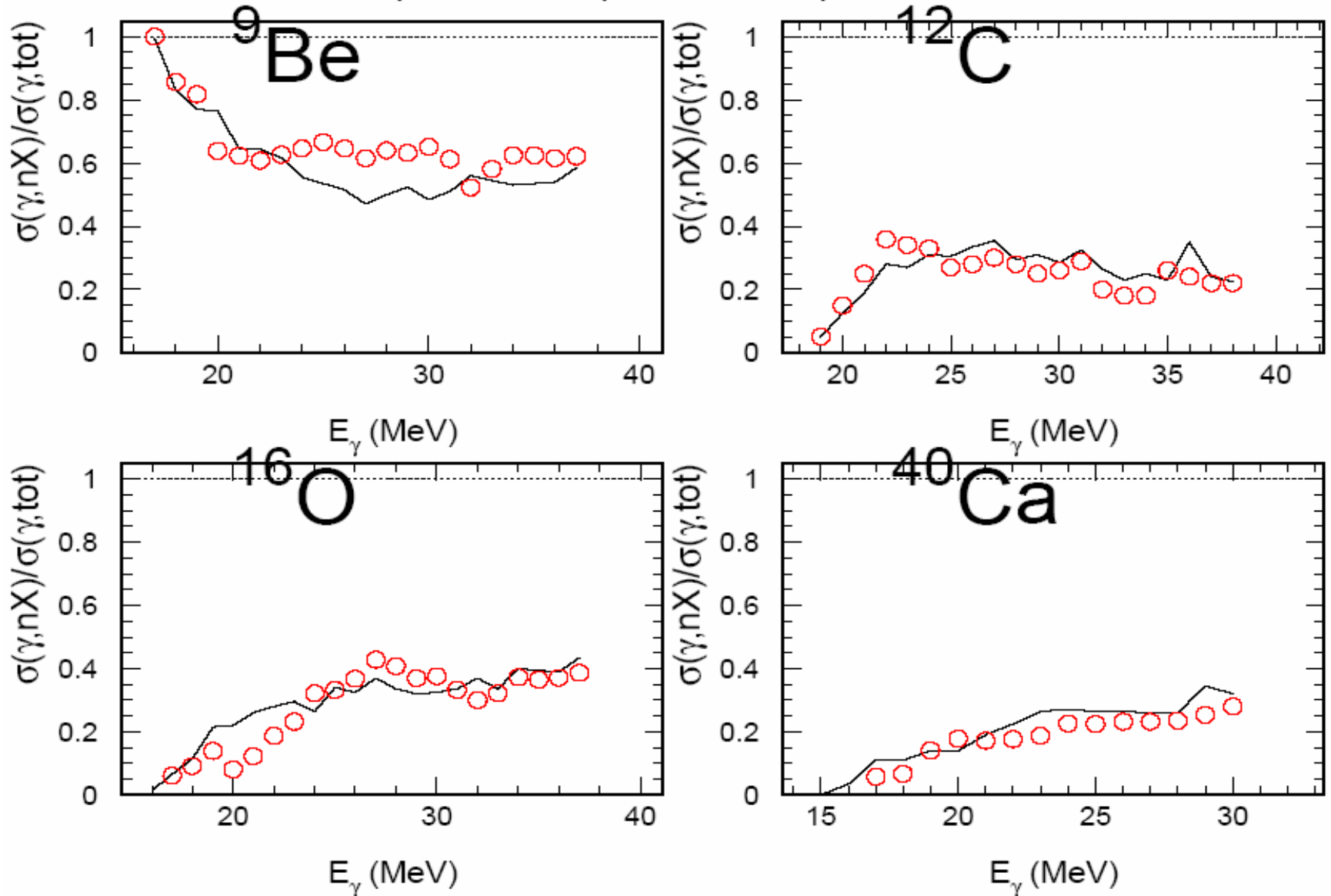
CHIPS Model

Antiproton annihilation on ^{238}U nucleus



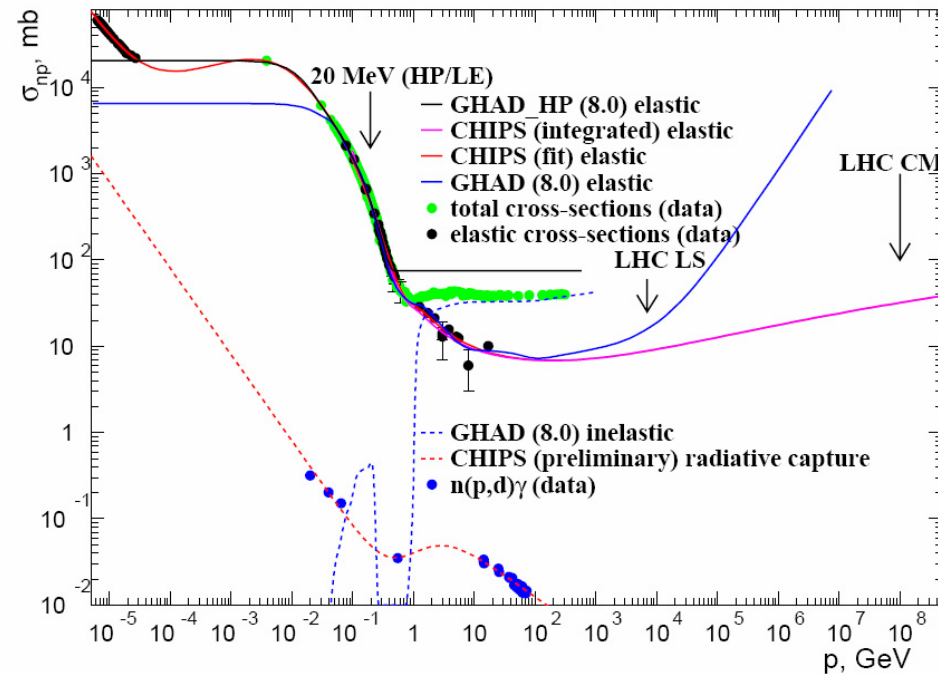
Verification of gamma-nuclear reactions CHIPS Model

Photoneutron production part of total photonuclear cross section

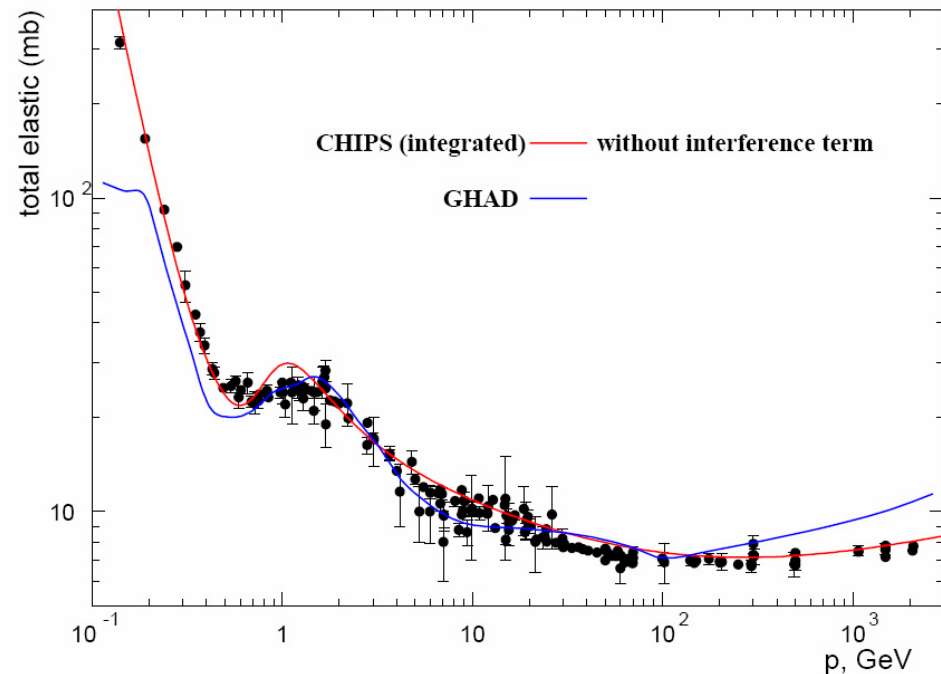


np and pp Elastic Cross Section

np



pp

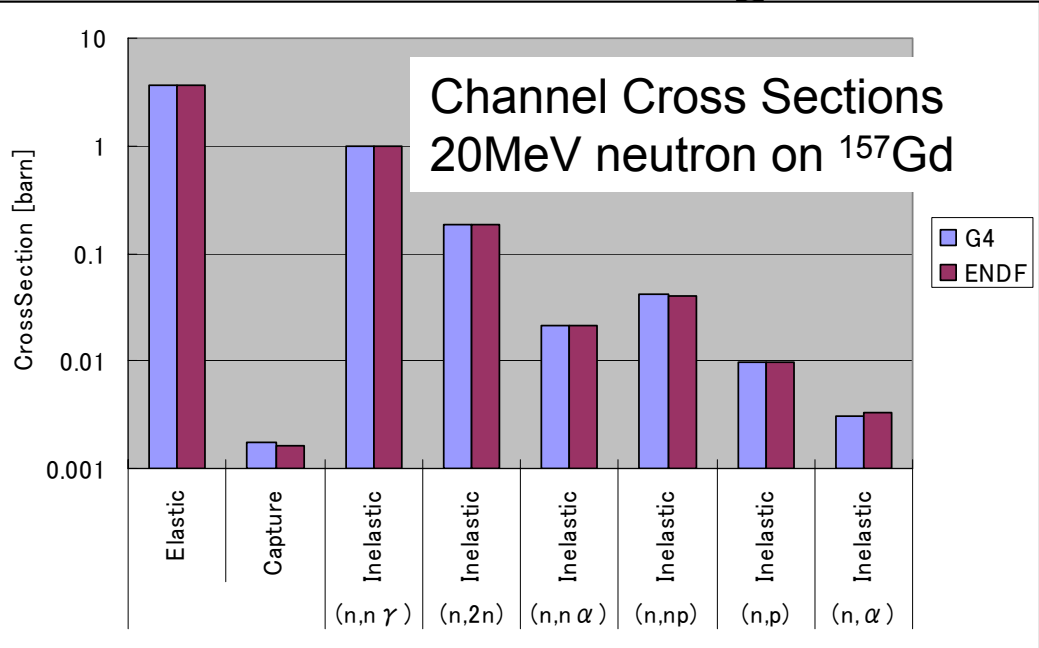


Low Energy (<20MeV) Neutrons

Neutron High Precision Models and
Data Sets

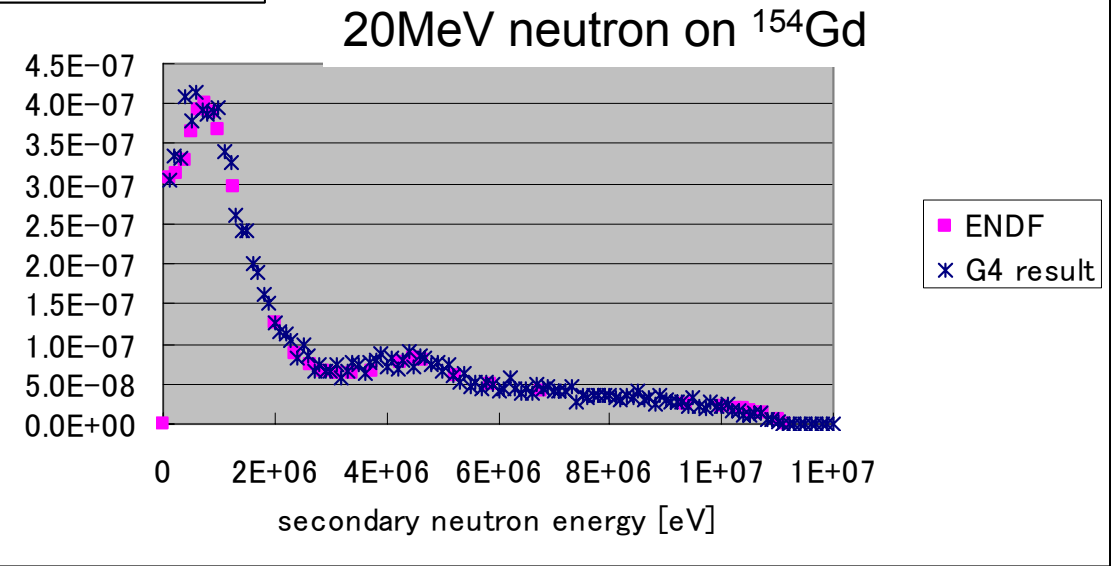
These are data driven models,
therefore comparison results to the
ENDF data should be very close.

Verification of High Precision Neutron models



Energy Spectrum of secondary neutrons from (n,2n) channel
20MeV neutron on ^{154}Gd

Geant4 results are derived from thin target calculations



Ions

Binary Light Ions Cascade

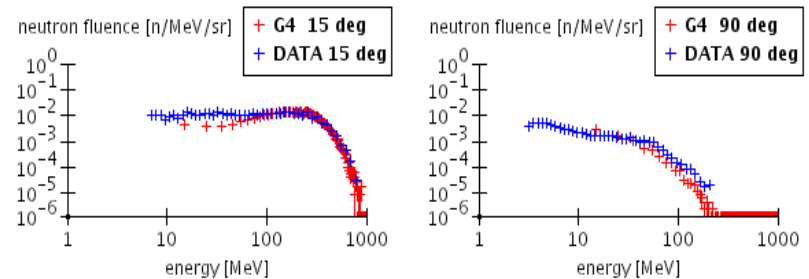
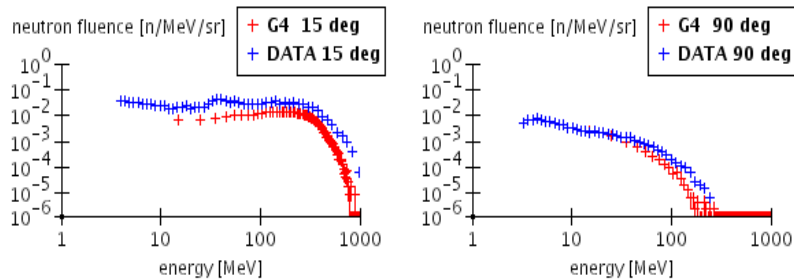
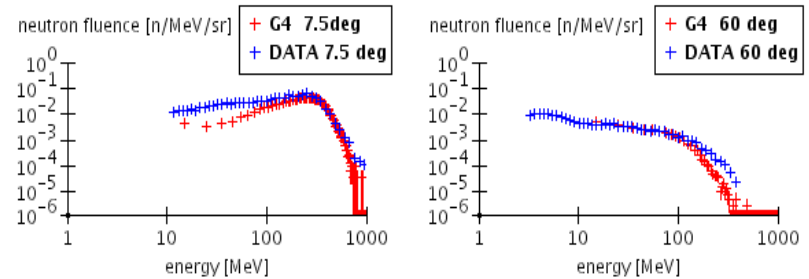
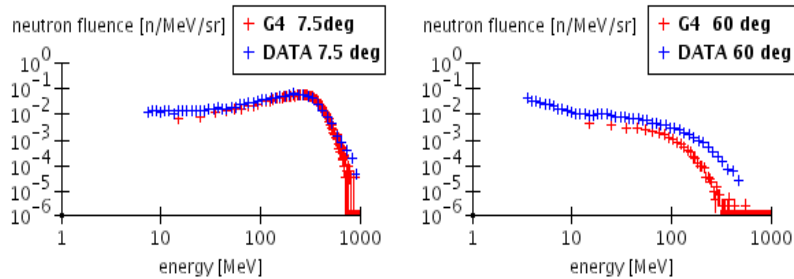
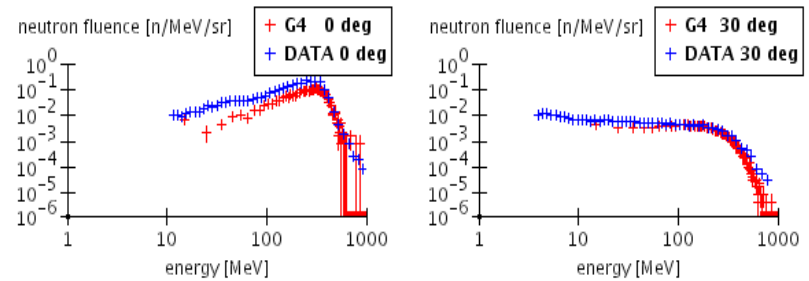
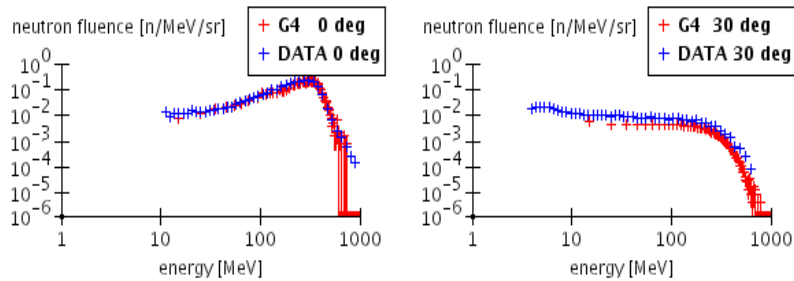
Wilson Abrasion Ablation

Electromagnetic Dissociation

Neutron Yield Fe 400 MeV/n beams

Carbon

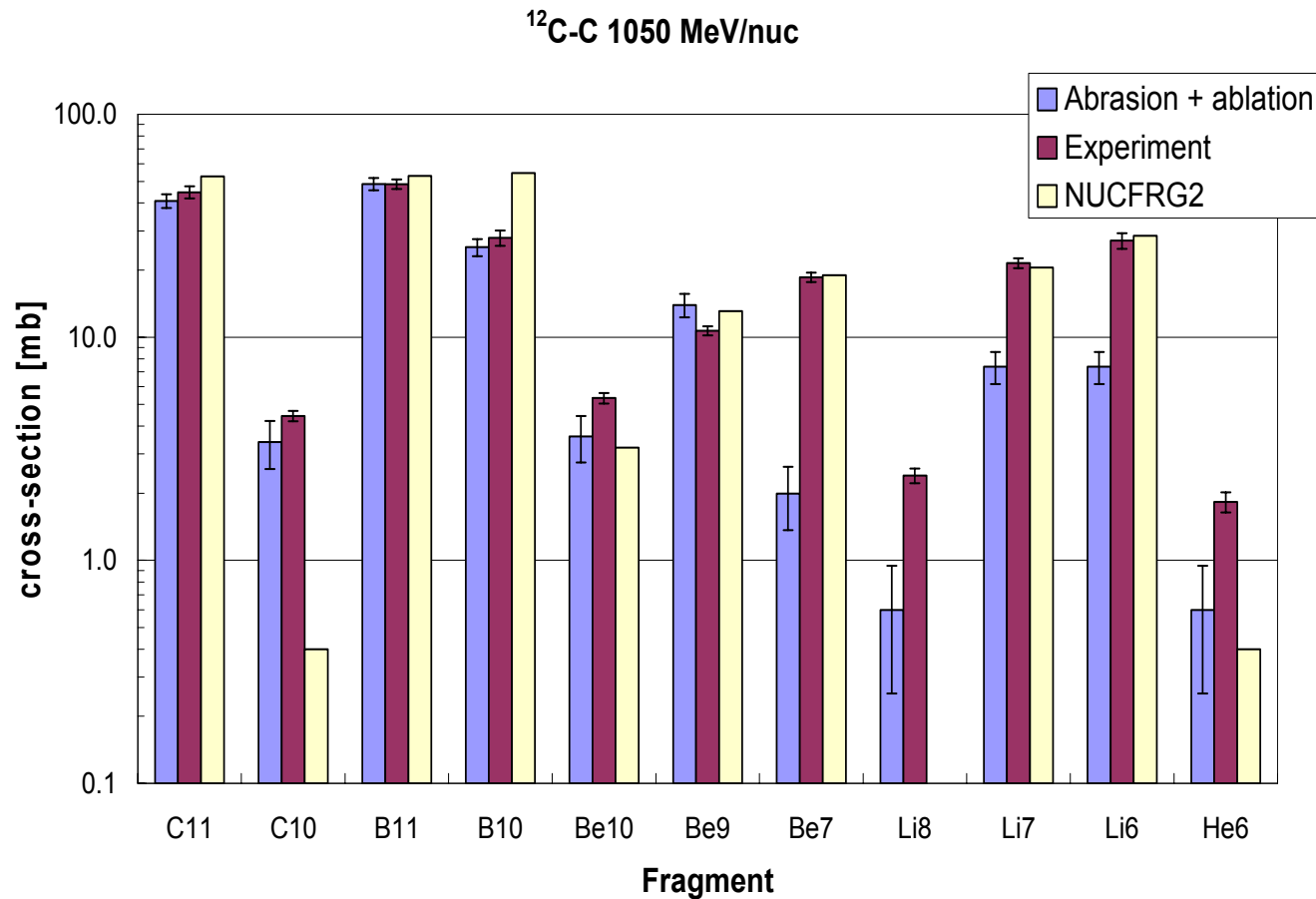
Aluminum



Binary Light Ions Cascade

T. Kurosawa et al.,
*Phys. Rev. C*62
pp. 04461501 (2000)

Validation of Wilson Abrasion Ablation Model



J W Wilson et al., "NUCFRG2: An evaluation of the semi-empirical nuclear fragmentation database," NASA Technical Paper 3533, 1995.

Validation of G4EMDissociation Model and Cross Section

Target Emulsion nuclei: Ag 61.7%, Br 34.2%, CNO 4.0% and H 0.1%

Projectile	Energy [GeV/nuc]	Product from ED	G4EM Dissociation [mbarn]	Experiment [mbarn]
Mg-24	3.7	Na-23 + p	124 ± 2	154 ± 31
Si-28	3.7	Al-27 + p	107 ± 1	186 ± 56
	14.5	Al-27 + p	216 ± 2	$165 \pm 24^\dagger$ $128 \pm 33^\ddagger$
O-16	200	N-15 + p	331 ± 2	$293 \pm 39^\dagger$ $342 \pm 22^*$

M A Jilany, "Electromagnetic dissociation of 3.7 A GeV 24Mg and 28Si projectiles in nuclear emulsion," *Nucl Phys*, **A705**, 477-493, 2002.

Validation of EM Standard Physics

The background is a solid teal color. In the bottom right corner, there is a dark teal silhouette of a mountain range with jagged peaks.

Validation of Standard EM Physics

- ◆ Unit tests by developers
- ◆ Comparisons with Geant3
- ◆ Comparison against theoretical predictions
- ◆ Comparison against evaluated data
- ◆ Testing suite:
 - About 20 G4 examples are used for different tests
 - More than 100 macro files
 - Limited statistic is regularly executed by sst
 - Large statistic tests are executed by the EM group
 - Results for each reference version of G4 are archived
- ◆ User validation

EM standard test suite

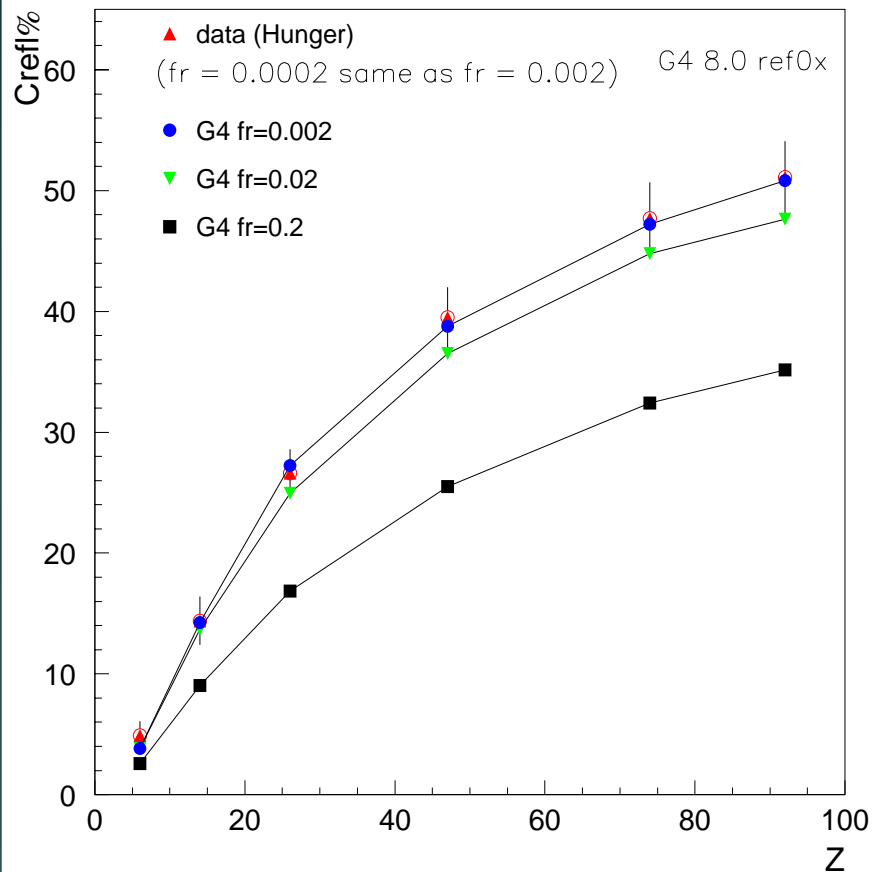
examples/extended/electromagnetic

Test	Purpose	Responsible	N macro	G3
TestEm0	G4EmCalculator	M.Maire	5	
TestEm1	Tracking/EM physics in infinite media	M.Maire	15	+
TestEm2	EM shower in homogeneous media	M.Maire	7	+
TestEm3	Sampling calorimeter	M.Maire	23	+
TestEm4	Gamma interactions	M.Maire	3	+
TestEm5	Multiple scattering	L.Urban	18	+
TestEm6	High energy muons	H.Burkhardt	6	
TestEm7	Bragg peak	M.Maire	6	
TestEm8	PAI models	V.Grishine	2	
TestEm9	Crystal Calorimeter	V.Ivanchenko	5	
TestEm10	TRD models	V.Grishine	2	

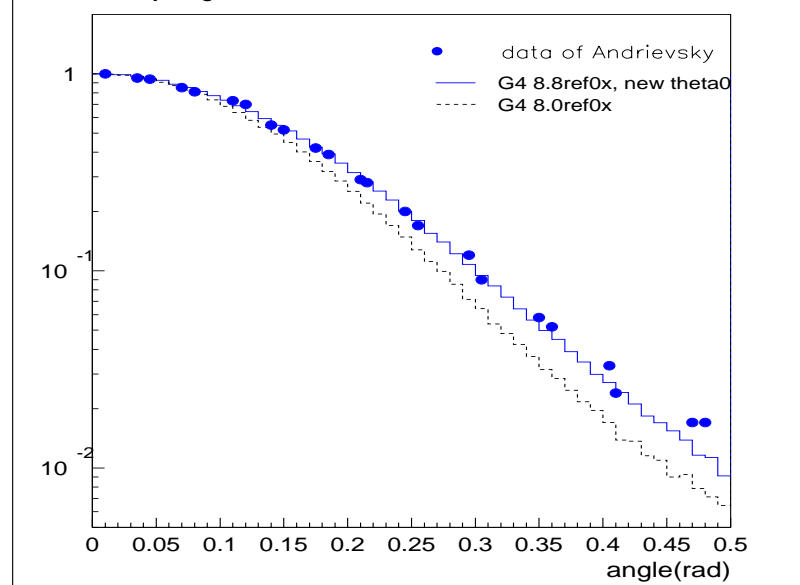
TestEm11	Deep dose profile (plane)	M.Maire	5	+
TestEm12	Deep dose profile (spherical)	M.Maire	4	
TestEm13	Gamma interactions	M.Maire	6	+
TestEm14	Cross sections and mfp	M.Maire	5	+
TestEm15	Multiple Scattering	M.Maire	4	
TestEm16	Synchrotron radiation	H.Burkhardt	3	
TestEm17	Muon processes	R.Kokoulin, A.Bogdanov	6	
GammaTherapy	Bremsstrahlung beam	V.Ivanchenko	5	
test31	Sliced media	V.Ivanchenko	5	

Multiple Scattering Update for the release 8.1 (CHEP'06)

backscattering coeff. of 41 keV e- in diff. materials



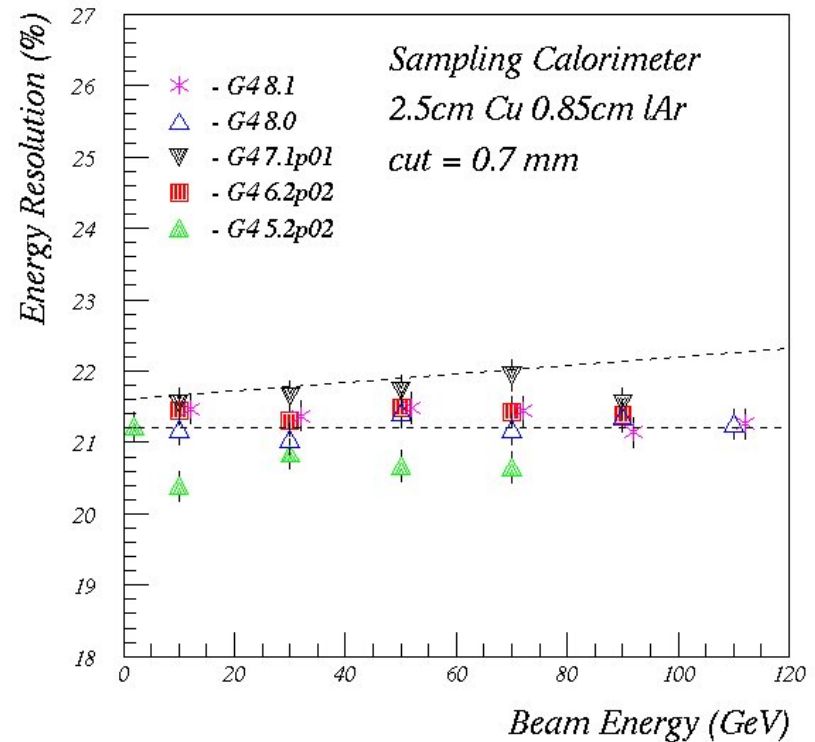
Proj. angle distribution of 2.7 MeV/c e- after 1.8 mm Li



Atlas HEC Calorimeter (Monte Carlo' 2005)

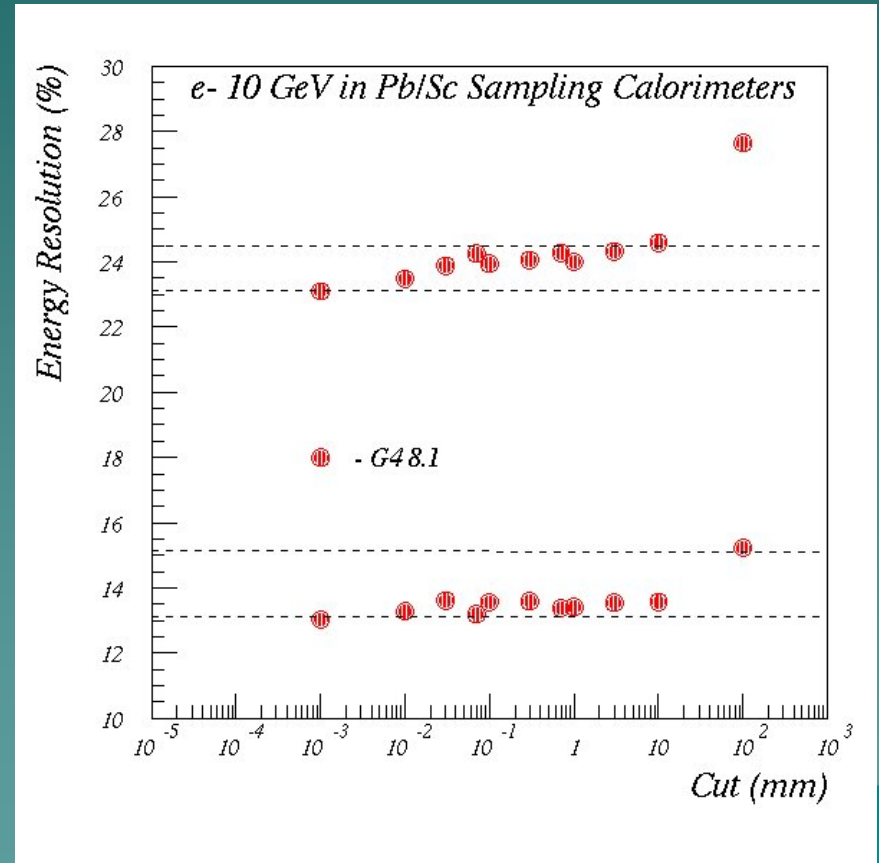
- ◆ The first setup for the suite
- ◆ ATLAS HEC structure is used as a reference since release 5.2
- ◆ Based on TestEm3
- ◆ Resolution is compared with the data
- ◆ 30 GeV e^- were chosen (Gaussian spectrum)

Default EM physics



Comparison with Published Data (preliminary)

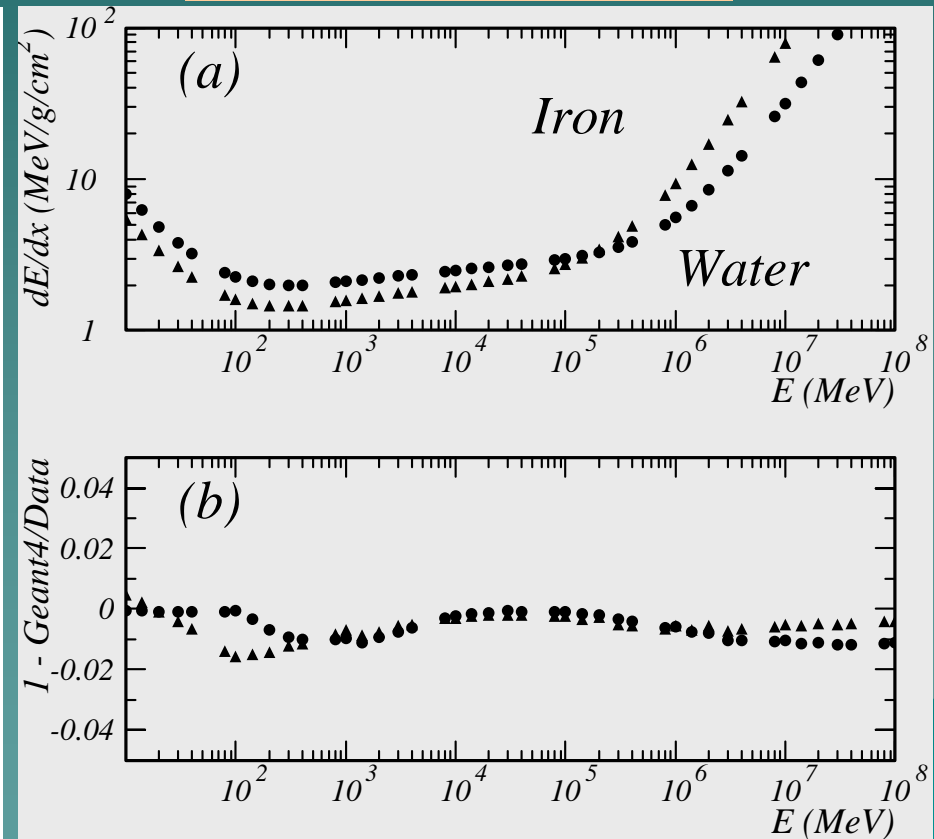
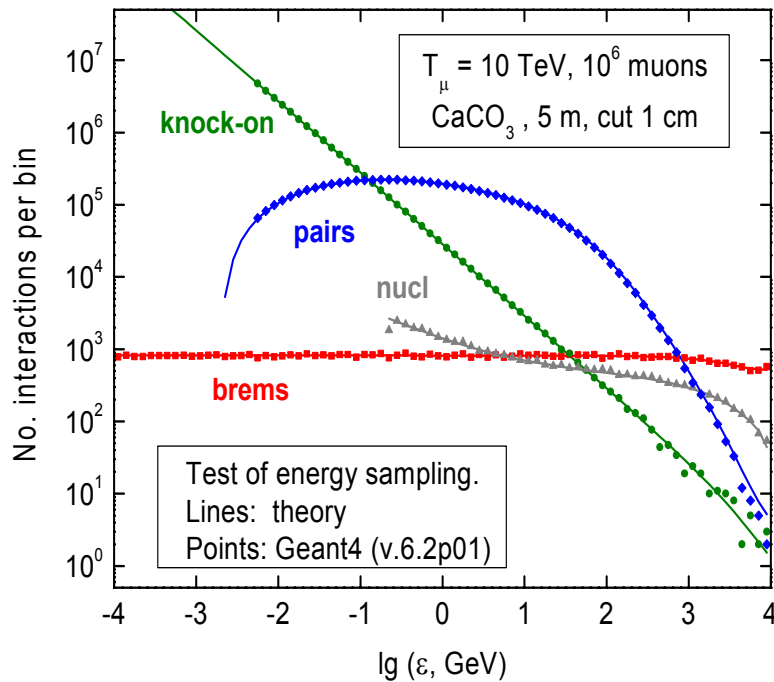
- ◆ ZEUS calorimeter test beam data
 - NIM A262 (1987) 229
 - NIM A274 (1989) 134
 - E. Bernardi thethis
 - PS CERN measurements
- ◆ Two calorimeter structures:
 - ◆ 5mm Pb/5mm Sc
 - ◆ 10 mm Pb/2.5 mm Sc
- ◆ Accurate description of sizes and materials was needed



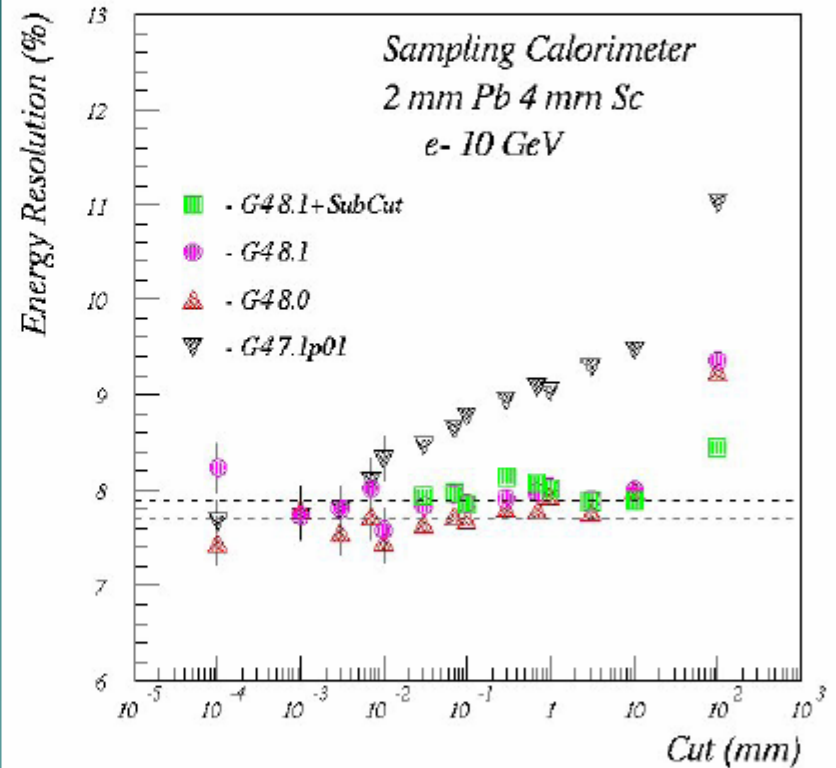
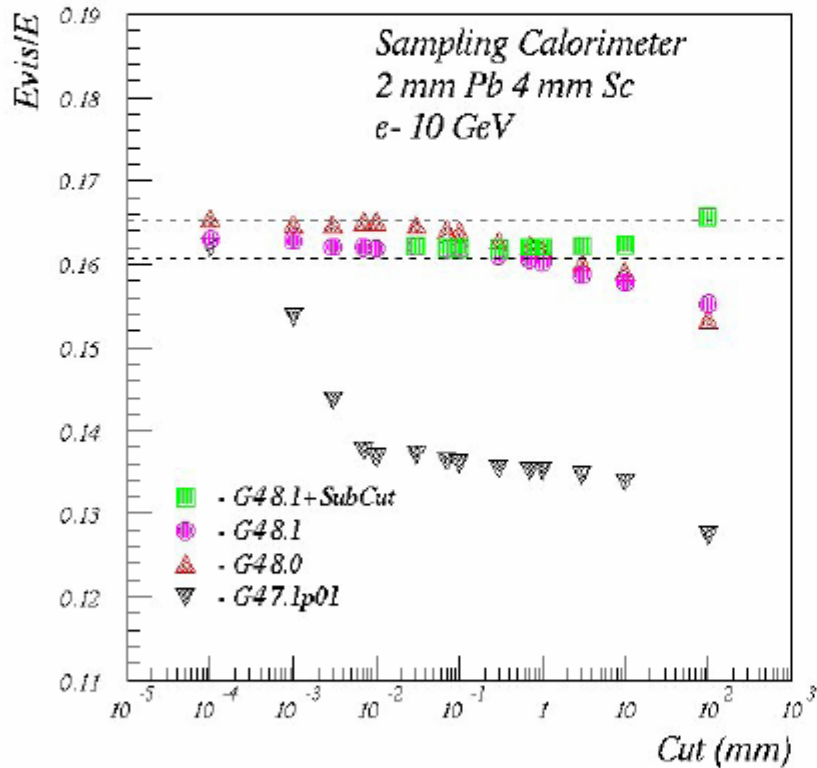
Verification theory/Geant4 (IEEE Trans. Nucl. Sci. 53(2006)270)

Differentiation cross sections
precision better 5%

Muon stopping power
Precision about 2%



LHCb Type Calorimeter



**Validation Activities
of
Low Energy EM group**

Lines of activity

- **Basic physics quantities of Geant4 models**
 - Cross sections, angular distributions, final state spectra etc.
 - In progress: Bremsstrahlung, Atomic Relaxation
- **Experimental use cases**
 - Related to the assessment of basic physics quantities
 - In progress: Bragg peak of protons, LHC radiation monitors
- **LowE Electromagnetic specific models**
 - Models with no other counterpart in Geant4
 - e.g. new Geant4-DNA models at the eV scale

Validation of EM physics

An example of activity: **ALL** Geant4 Bremsstrahlung models

The sets of cross section models for γ have already been extensively and successfully validated

K. Amako et al.,
published in IEEE
Trans. Nucl. Sci.

Now **e^-/e^+ EM processes** to be taken into account

more difficult to find reference data and to disentangle effects
(because of the continuous part)

For **Bremsstrahlung**, 3 sets of models:

G4eBremsstrahlung

G4LowEnergyBremsstrahlung

G4PenelopeBremsstrahlung

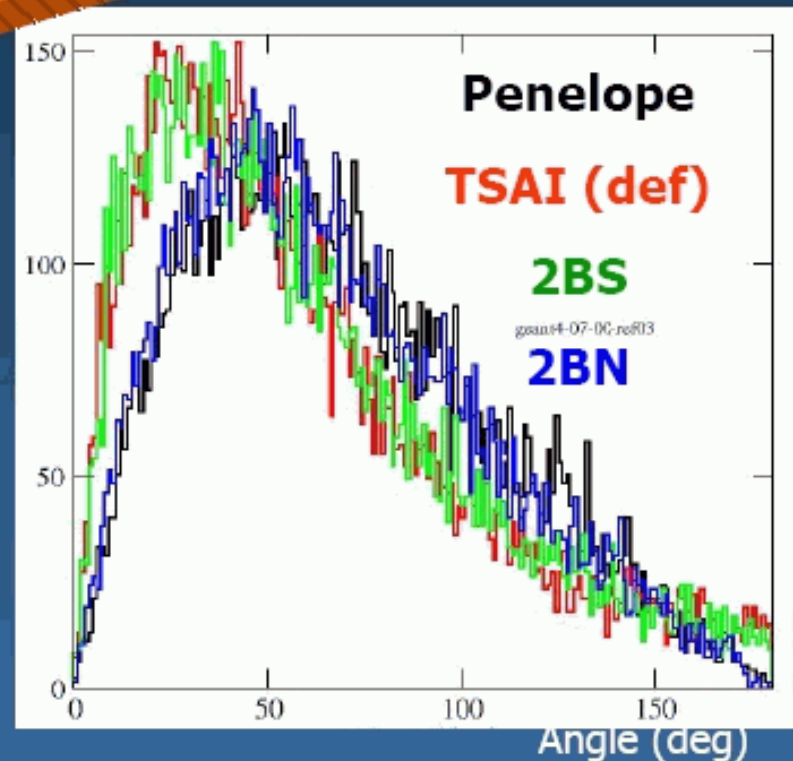
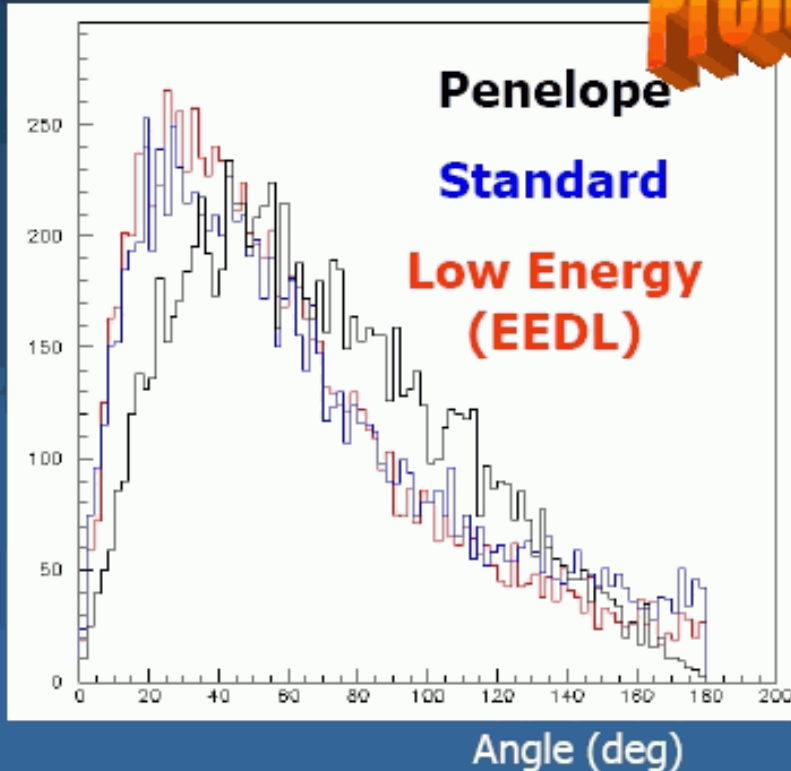


3 alternative angular
distributions:

Tsai, 2BS, 2BN

Angular distributions

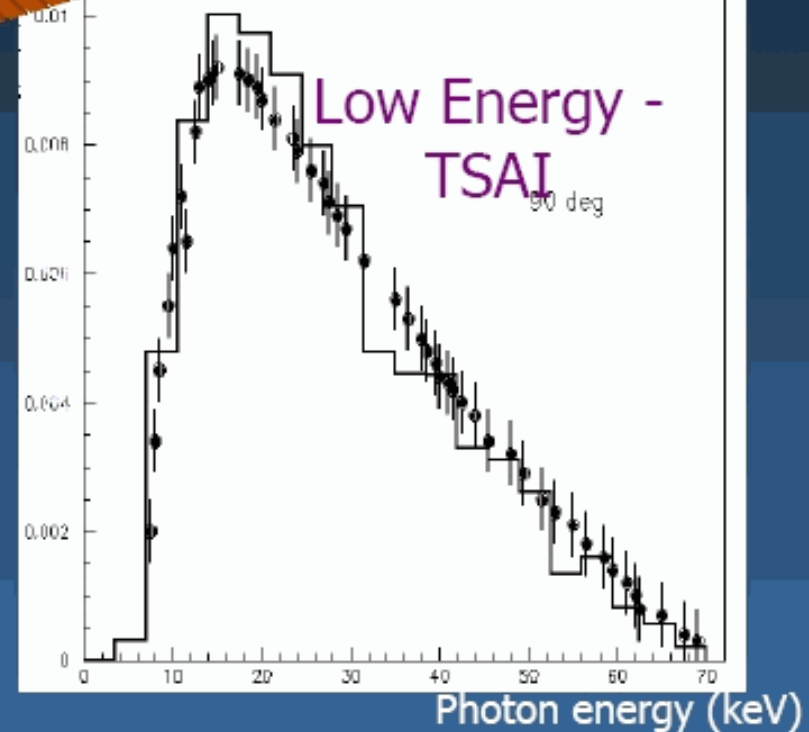
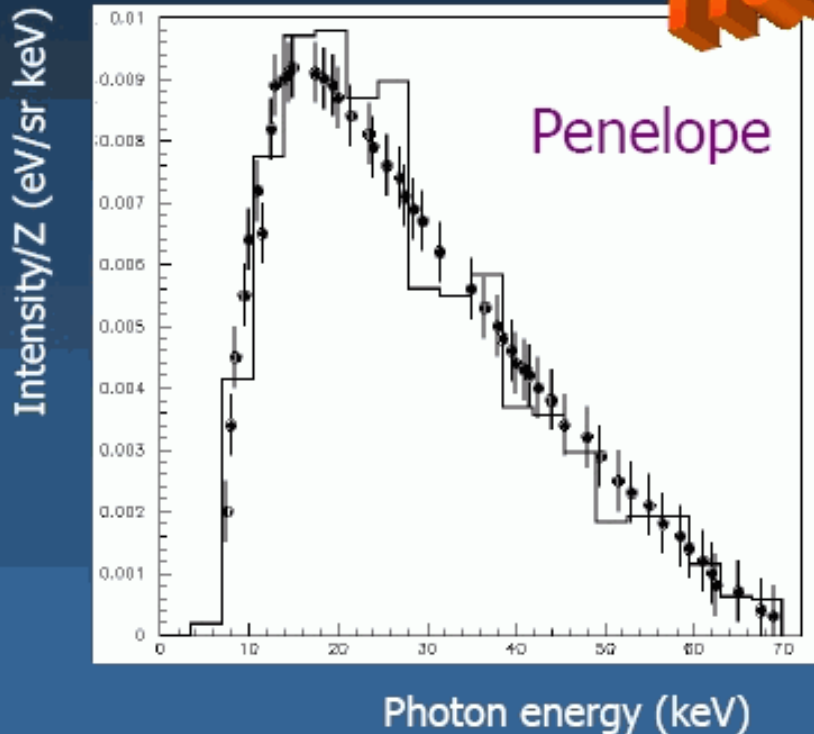
Preliminary



Angular distribution of photons is **strongly model-dependent**

Comparison

Preliminary



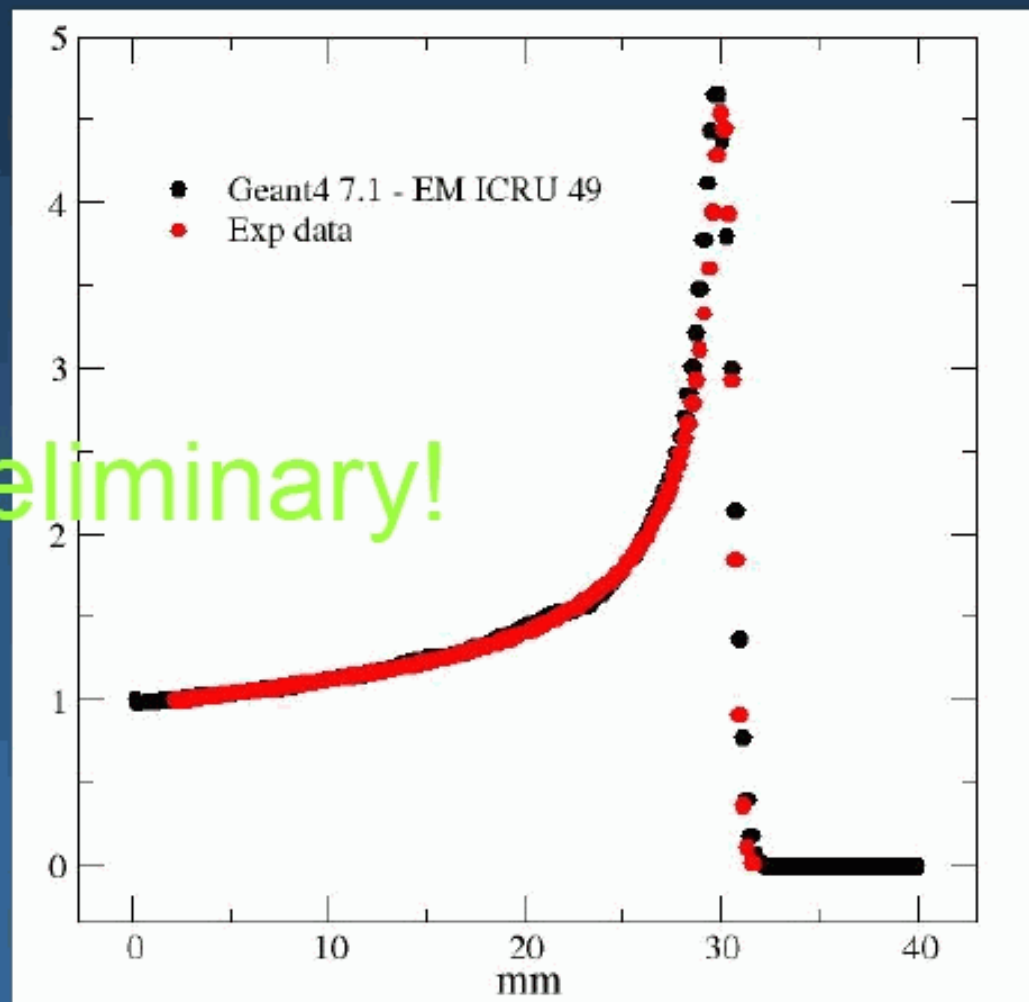
Relative comparison (90 deg dir). The shapes ~agree →

More work in progress
Statistical analysis to be done

EM - ICRU 49 + Elastic + Precompound + default Nuclear Deexcitation

ENTIRE PEAK	Exp	G4
S	2.89	3.39
T	3.26	3.46
GoF test	CVM-AD	

Preliminary!



$N_E=149$ $N_{G4}=150$	Test statistics	p
KS	0.0368	0.999944
CVM	0.0131	0.999887
AD	0.0993	0.999974

Comparison of Geant4 Electromagnetic Physics Models Against the NIST Reference Data

910

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 52, NO. 4, AUGUST 2005

Comparison of Geant4 Electromagnetic Physics Models Against the NIST Reference Data

Katsuya Amako, Susanna Guatelli, Vladimir N. Ivanchenko, Michel Maire, Barbara Mascialino, Koichi Murakami, Petteri Nieminen, Luciano Pandola, Sandra Parlati, Maria Grazia Pia, Michela Piergentili, Takashi Sasaki, and Laszlo Urban

Abstract—The Geant4 Simulation Toolkit provides an ample set of physics models describing electromagnetic interactions of particles with matter. This paper presents the results of a series of comparisons for the evaluation of Geant4 electromagnetic processes with respect to United States National Institute of Standards and Technologies (NIST) reference data. A statistical analysis was performed to estimate quantitatively the compatibility of Geant4 electromagnetic models with NIST data; the statistical analysis also highlighted the respective strengths of the different Geant4 models.

Index Terms—Geant4, Monte Carlo, NIST, validation.

I. INTRODUCTION

GEANT4 is an object oriented toolkit [1] for the simulation of the passage of particles through matter. It offers an ample set of complementary and alternative physics models for electromagnetic and hadronic interactions, based on theory, experimental data or parameterizations.

The validation of Geant4 physics models with respect to authoritative reference data is a critical issue, fundamental to establish the reliability of Geant4-based simulations. This paper is focused on the validation of Geant4 electromagnetic models, with the purpose to evaluate their accuracy and to document their respective strengths. It presents the results of comparisons of Geant4 electromagnetic processes of photons, electrons, protons and α particles with respect to reference data of the United States National Institute of Standards and Technologies (NIST) [2], [3] and of the International Commission on Radiation Units and Measurements (ICRU) [4], [5].

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Digital Object Identifier 10.1109/TNS.2005.852691

TABLE I
GEANT4 ELECTROMAGNETIC MODELS IN THIS COMPARISON STUDY

Particle	Geant4 Models in Electromagnetic Packages
Photon	Geant4 Low Energy - EPDL Geant4 Low Energy - Penelope Geant4 Standard
Electron	Geant4 Low Energy - EEDL Geant4 Low Energy - Penelope Geant4 Standard
Proton	Geant4 Low Energy - ICRU 49 Geant4 Low Energy - Ziegler 1985 Geant4 Low Energy - Ziegler 2000 Geant4 Standard
α	Geant4 Low Energy - ICRU 49 Geant4 Low Energy - Ziegler 1977 Geant4 Standard

The simulation results were produced with Geant4 version 6.2. The Geant4 test process verifies that the accuracy of the physics models will not deteriorate in future versions of the toolkit with respect to the results presented in this paper.

II. OVERVIEW OF GEANT4 ELECTROMAGNETIC PHYSICS PACKAGES

The Geant4 Simulation Toolkit includes a number of packages to handle the electromagnetic interactions of electrons, muons, positrons, photons, hadrons and ions. Geant4 electromagnetic packages are specialised according to the particle type they manage, or the energy range of the processes they cover.

The physics processes modeled in Geant4 electromagnetic packages include: multiple scattering, ionization, Bremsstrahlung, positron annihilation, photoelectric effect, Compton and Rayleigh scattering, pair production, synchrotron and transition radiation, Cherenkov effect, refraction, reflection, absorption, scintillation, fluorescence, and Auger electrons emission [1].

Alternative and complementary models are provided in the various packages for the same process. The Geant4 electromagnetic models studied in this paper are listed in Table I.

A. Standard Electromagnetic Package

The Geant4 Standard electromagnetic package [8] provides a variety of models based on an analytical approach, to describe the interactions of electrons, positrons, photons, charged hadrons and ions in the energy range 1 keV–10 PeV.

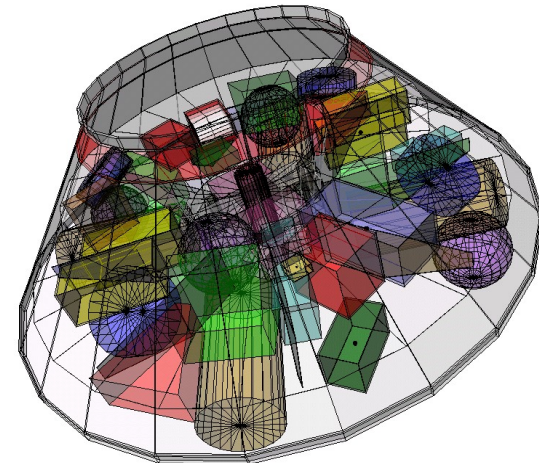
- IEEE Trans. Nucl. Sci. 52- 4 (2005) 910-918
- Covering all available EM models of Geant4
- Rigorous statistical methods for the comparison of simulated and experimental data distributions

Validations activities
in
Space Applications

Comparison of Geant4 Sector-shielding and Monte Carlo Analyses for Space Applications¹

R. Lindberg, G. Santin, P. Nieminen, H. Evans, E. Daly, June 2006

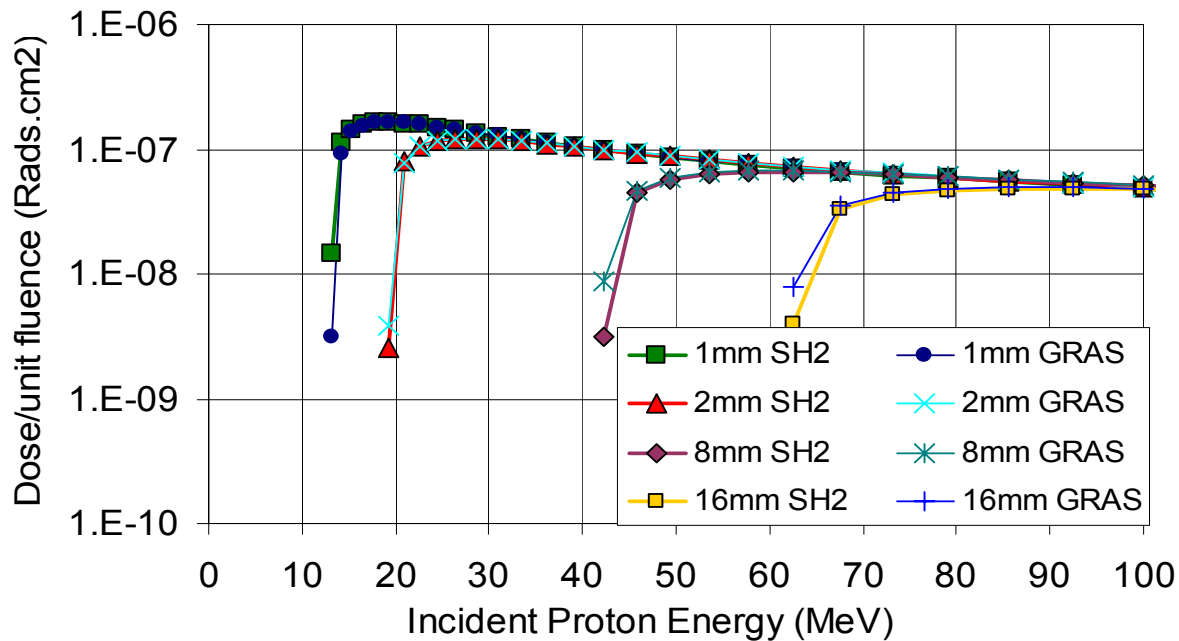
- Compared Total Ionising Dose using Sector-shielding method (SSAT^{*,2}) and Monte Carlo method (GRAS^{** ,3}).
- Geant4 version: 8.0.p01 using standard and hadronics physics
- Comparisons performed on geometries with increasing complexity:
 - Slab
 - Solid Sphere
 - Hollow Box.
 - Realistic Satellite Geometry (ConeXpress ~100 volumes)
- Space environment based on 200-day geostationary transfer orbit and ~12 year geostationary orbit.
 - Trapped protons: < 400 MeV
 - Solar protons: < 200MeV
 - Trapped Electrons: < 7 MeV



ConeXpress satellite, modelled in GDML.

* Sector Shielding Analyses Tool (SLANT method)

** Geant4 Radiation Analyses for Space.ver 1.3

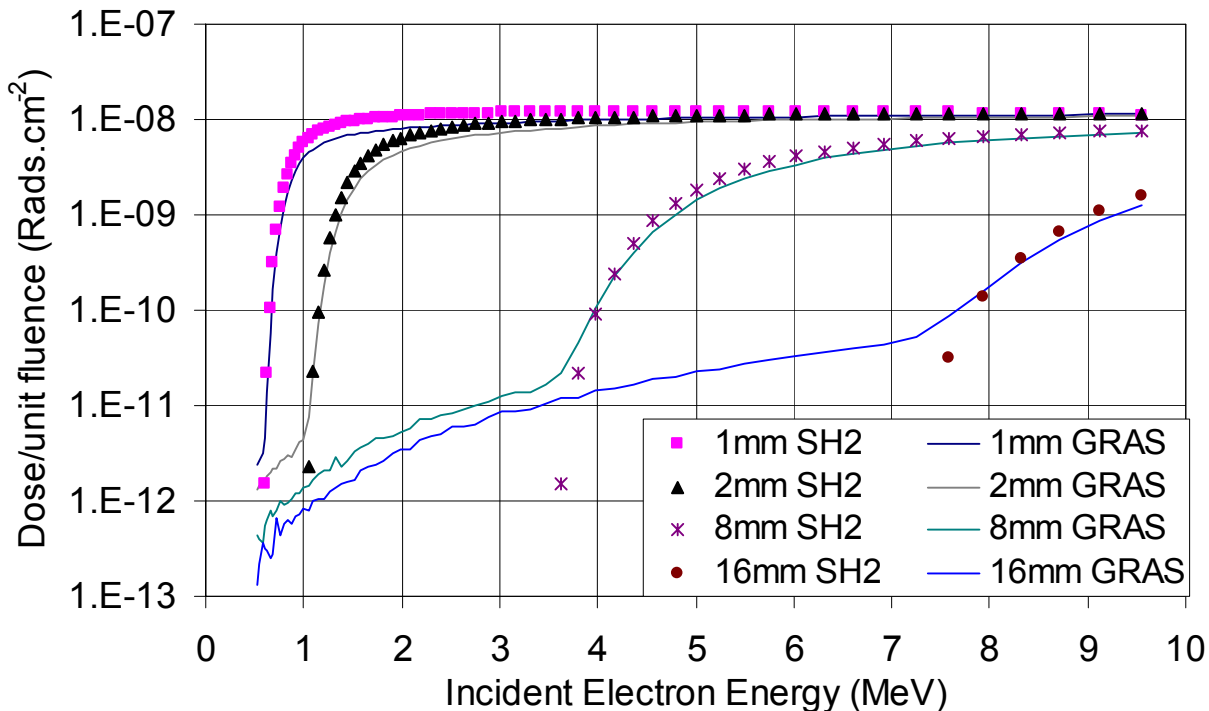


- Compared results from mono-energetic particles between GRAS and Shieldose2 (used as dose-depth curve in SSAT)

- Detector is 2 mm Si slab behind 3 mm Aluminium slab.

- As would be expected, protons show very good agreement to within 3%

- For electrons, as incident particle energy increases, agreement is better. Shieldose2 predicting higher dose.



RATIO OF GRAS/SSAT FOR SIMPLE GEOMETRIES IN GTO

	Thickness	Tr. p (%)	Tr. e (%)	Solar p (%)	Total dose (%)
Slab	2 mm	92±0.3	60±0.2	101±0.1	62±0.3
	7 mm	81±0.6	63±2	102±0.2	74±2
	20 mm	82±0.8	61±3	102±0.3	75±4
Sphere	2 mm	110±0.7	100±0.9	111±0.3	85±3
	7 mm	75±1	114±11	89±0.5	86±11
	20 mm	86±2	82±39	110±1	72±12
Box	2 mm	77±2	34±1	91±1	36±2
	7 mm	85±6	31±5	97±2	59±18
	20 mm	83±8	57±15	103±4	85±28

TOTAL DOSES ON CONEXPRESS SUBSYSTEMS IN GTO

Subsystem	GRAS	SSAT	Difference (%) (Dssat-Dgras)/Dgras
	TID [rad]	TID [rad]	
PCDU	398	824	110
DHS Master	330	655	100
PPU1	637	1602	150
PPU3	473	1598	240
Star-Tracker1	1077	5838	440
Star-Tracker2	1243	5871	370
DockCamera1	470	1639	250
CaptureTool	272	2539	830
Sun-Sensor	29632	47113	60

Simple 3D geometries:

- Reasonable correlation – between a few per cent (solar protons) to a factor 3 (trapped electrons).

ConeXpress:

- Difference of up to factor 8 for most heavily shielded subsystems

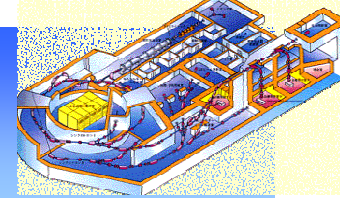
General remarks:

- Protons show better results than electrons → electrons scatter in a more irregular way
- Trend can be seen where higher shielding increases differences
- Largest influence on results seem to be geometry complexity

References:

1. R. Lindberg et al., “Detailed Comparison of Monte Carlo Sector-Shielding Analyses for Space Applications”, IEEE Trans. Nucl. Sci., accepted for publication.
2. G. Santin et al., “GRAS: A general purpose 3D simulation tool for space environment effects analysis”, IEEE Trans. Nucl. Sci. 52, Issue 6, 2005, pp. 2294 – 2299
3. G. Santin et al., "New Geant4 based simulation tools for space radiation shielding and effects analysis", Nuclear Physics B (Proc. Suppl.) 125, pp. 69-74, 2003

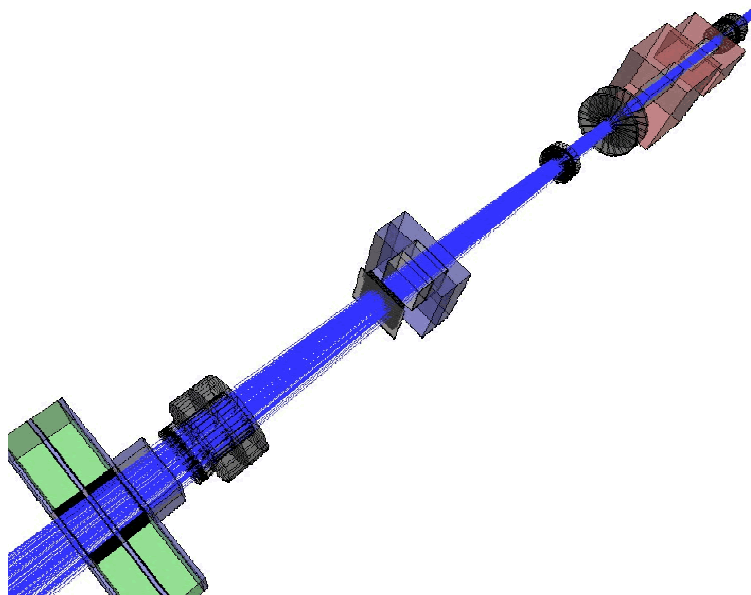
Validation Activities in Medical Applications



Results from the recent carbon test beam at HIMAC

Koichi Murakami
Satoru Kameoka

KEK CRC

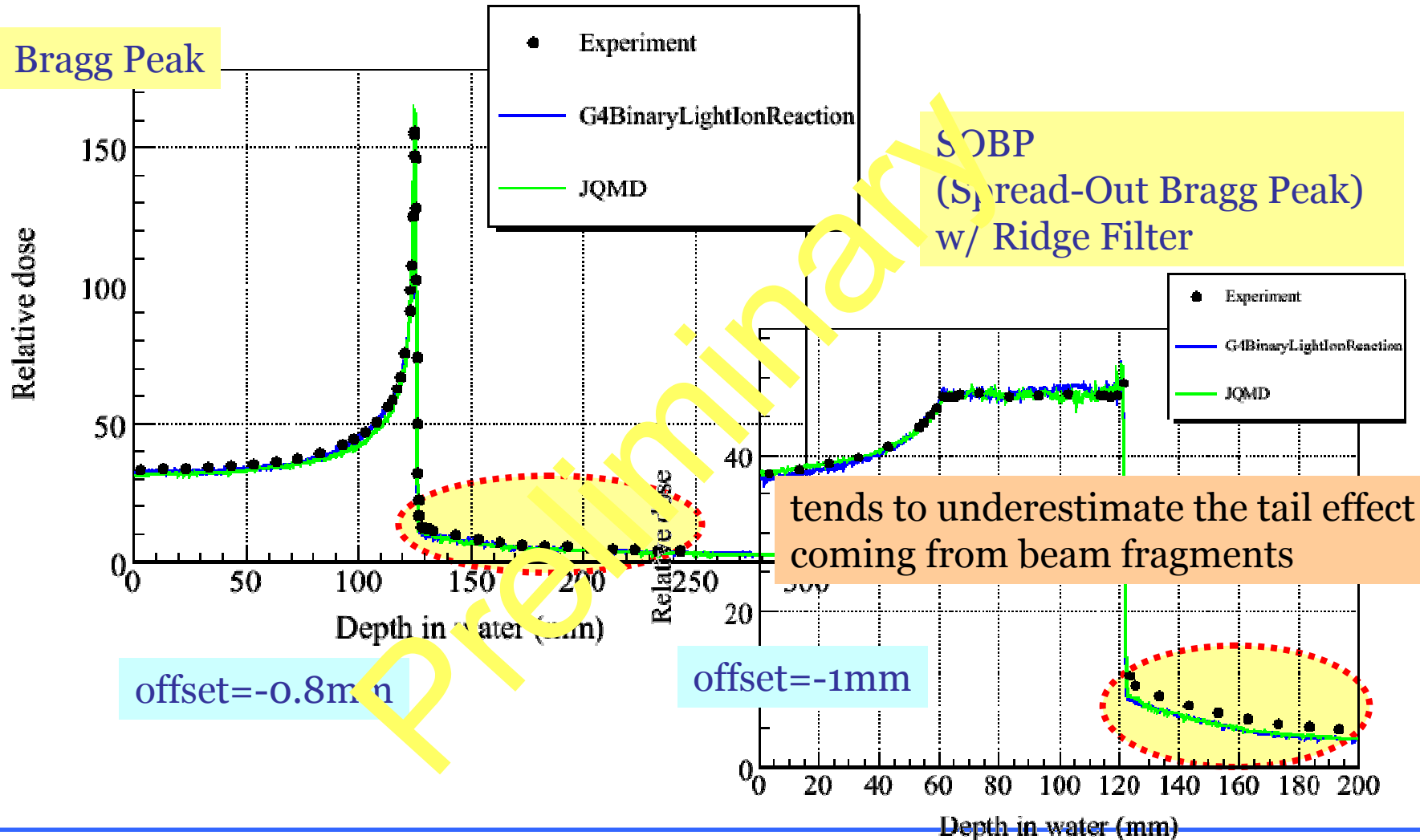


Introduction

- A joint project among Geant4 developers, astrophysicists and medical physicists in Japan
 - ✓ *Development of software framework for simulation in radiotherapy*
 - » funded by the Core Research for Evolutional Science and Technology (CREST) program organized by Japan Science and Technology Agency (JST) from 2003 to 2008
- The project goal
 - ✓ provides a set of software components for simulation in radiotherapy (especially hadrontherapy),
 - » well designed general purpose software framework
 - » DICOM/DICOM-RT interface
 - » application of GRID computing technology
 - » visualization tools
 - ✓ *In addition, physics validation is one of key issues.*

Comparison between Experiment and Simulation (290 MeV/u)

Bragg Peak



Many validations are also done by HEP peoples and presented in CHEP06, Calor06, Hadron Shower Simulation Workshop and so on.

Following slides will introduce
web pages where help users to
find valuable information about
Geant4 validations

<http://geant4.web.cern.ch/geant4/results/results.shtml>

Geant 4

[Download](#) | [User Forum](#) | [Gallery](#) | [Site Index](#)
[Contact Us](#)

Search Geant4

[Home](#) > [Results & Publications](#) > [Testing and Validation](#)

Testing and Validation

Listed here is a sample of Geant4 testing and validation results.

Electromagnetic Physics

- [Detailed electromagnetic physics results](#), M.Maire (LAPP) and L.Urban (RMKI Reserch Institute, Budapest, Hungary)
- [Photon attenuation coefficients in water](#): NIST data, Geant4 standard processes and Geant4 Low Energy processes (statistical errors on simulation < 1%), S. Agostinelli, F. Foppiano, S. Garelli, M. Tropeano, National Institute for Cancer Research, IST Genova, Italy
- [CMS Barrel ECAL](#), S. Nikitenko (CMS), CMS Week at PSI
- [Boraxino simulation results](#), S. Magni e E. Meroni (INFN Milano, Italy)
- [Geant4 simulation of Low Activity Detectors at the Gran Sasso Laboratory](#), S. Cremonesi et al. (INFN Milano, Italy)
- [Multiple Scattering on single materials](#), L. Urban (RMKI Reserch Institute, Budapest, Hungary)
- [Muons, comparisons of Geant3/Geant4 simulation and data, Part 1 and Part 2](#), P. Arce (University of Santander, Spain, CMS)
- [L3, 45 GeV muons: GEANT3.15, GEANT4.0.1 and data](#) P. Arce (University of Santander, Spain, CMS)
- Detailed Geant3-Geant4 comparison of muons in L3, P. Arce (University of Santander, Spain, CMS):
 - [End point deviation](#), [Continuous energy lost](#), [Energy lost by ionisation](#),
 - [Total energy lost by delta rays per event](#), and [Delta rays energy](#),
 - [Total energy lost Bremsstrahlung per event](#), and [E of Bremsstrahlung's gamma](#),
 - [Total energy lost by pair production per event](#)

Hadronic Physics

- [Simulation of the CMS HCAL test-beam setup H2-1996 with Geant4](#), V. Lef' bure, CMS Note
- [Neutron Induced Isotope Production with Geant4 in CMS](#), J.P. Wellisch, CMS Note, 1999
- [Results from the photon evaporation process](#) in Geant4, M.G. Pia *et al.* (INFN Genova, Italy)
- [Test of pi0 production in GEANT4](#), D. Dannheim, CERN Summer Student Report, 1999
- [Nuclear deexcitation and preequilibrium multiplicity \(Pb\)](#), V. Lara (University of Valencia, Spain)
- [Nuclear deexcitation and preequilibrium multiplicity \(Zr\)](#), V. Lara (University of Valencia, Spain)
- [Results on stopping pions](#), including Geant3-Geant4 comparison, M.G. Pia (INFN Genova, Italy)

- Official Testing and Validation page of Geant4 collaboration
- However most contents are
 - Out of link
 - Out of date
- Should be update soon and must be well maintained.

<http://www.ge.infn.it/geant4/lowE/>

Geant 4 Low Energy Electromagnetic Physics

Geant4 Low Energy Electromagnetic Physics

A set of models are available in the **CLHEP** package for the interactions of photons, electrons, hadrons and ions.

These models are implemented in the **Geant4** package for the interactions of photons and electrons down to <1 keV.

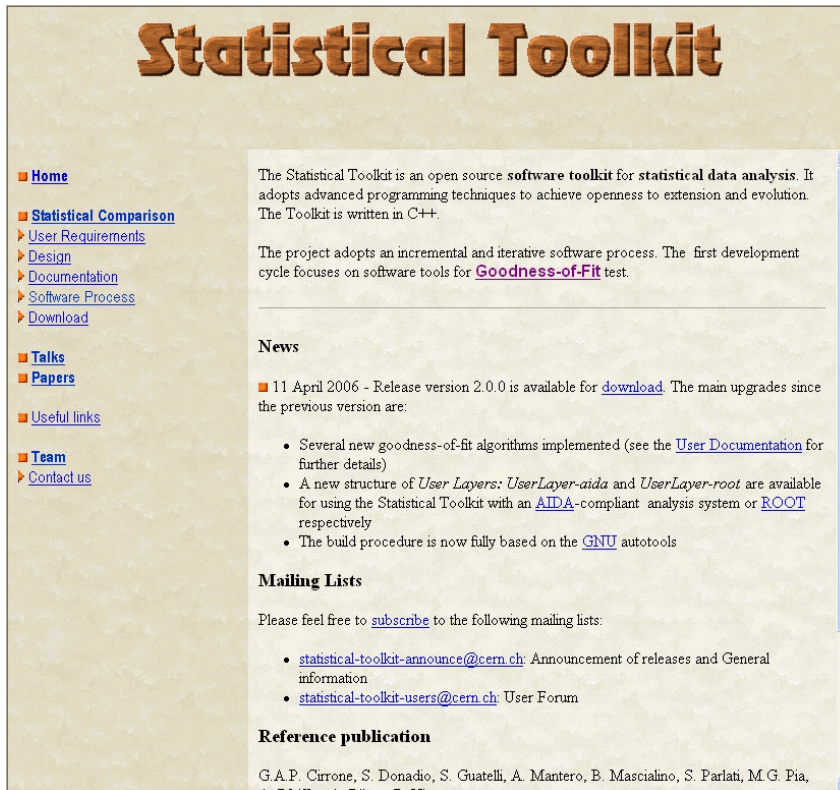
Specialised models taking into account the interactions of photons and electrons down to <1 keV.

Applications of such models range from astrophysics to the medical field.

Last modified 26 July 2004, Maria Grazia Pia

- Low Energy Electromagnetic Physics Working group web page
- Wide variety of information are available including validation results

<http://www.ge.infn.it/statisticaltoolkit/>



Statistical Toolkit

- Home
- Statistical Comparison
- User Requirements
- Design
- Documentation
- Software Process
- Download
- Talks
- Papers
- Useful links
- Team
- Contact us

The Statistical Toolkit is an open source **software toolkit** for **statistical data analysis**. It adopts advanced programming techniques to achieve openness to extension and evolution. The Toolkit is written in C++.

The project adopts an incremental and iterative software process. The first development cycle focuses on software tools for **Goodness-of-Fit** test.

News

- 11 April 2006 - Release version 2.0.0 is available for [download](#). The main upgrades since the previous version are:
 - Several new goodness-of-fit algorithms implemented (see the [User Documentation](#) for further details)
 - A new structure of *User Layers*: *UserLayer-aida* and *UserLayer-root* are available for using the Statistical Toolkit with an [AIDA](#)-compliant analysis system or [ROOT](#) respectively
 - The build procedure is now fully based on the [GNU](#) autotools

Mailing Lists

Please feel free to [subscribe](#) to the following mailing lists:

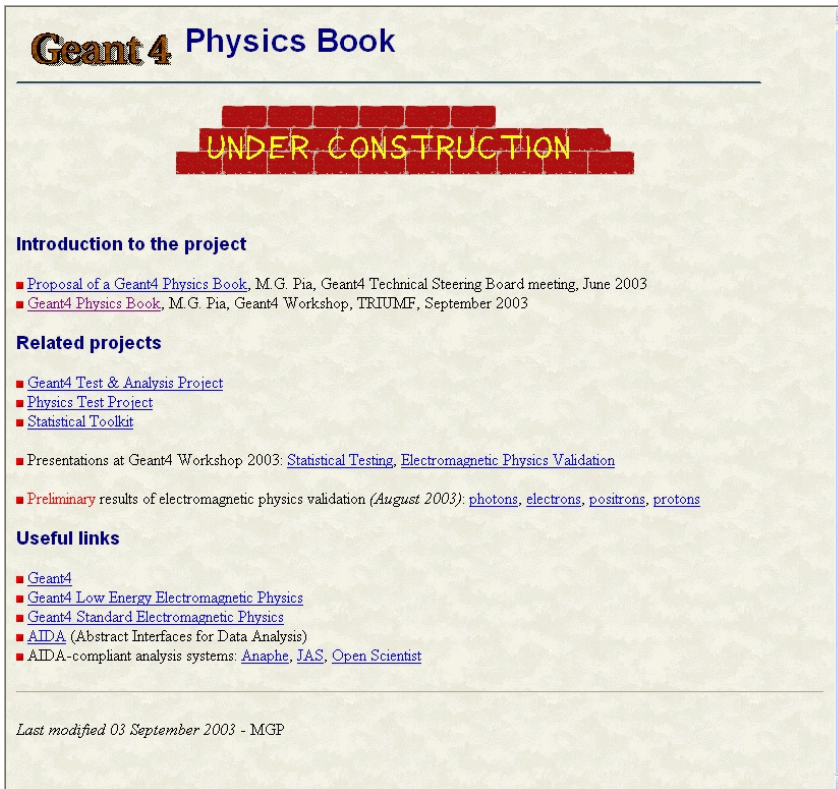
- statistical-toolkit-announce@cern.ch: Announcement of releases and General information
- statistical-toolkit-users@cern.ch: User Forum

Reference publication

G.A.P. Cirrone, S. Donadio, S. Guatelli, A. Mantero, B. Mascialino, S. Parlati, M.G. Pia, A. Pugliese, A. Riboldi, R. Uboldi

- Statistical Toolkit web page
- It is an open source software toolkit for statistical data analysis

Geant4 Physics Book



Geant4 Physics Book

UNDER CONSTRUCTION

Introduction to the project

- [Proposal of a Geant4 Physics Book](#), M.G. Pia, Geant4 Technical Steering Board meeting, June 2003
- [Geant4 Physics Book](#), M.G. Pia, Geant4 Workshop, TRIUMF, September 2003

Related projects

- [Geant4 Test & Analysis Project](#)
- [Physics Test Project](#)
- [Statistical Toolkit](#)

■ Presentations at Geant4 Workshop 2003: [Statistical Testing](#), [Electromagnetic Physics Validation](#)

■ **Preliminary** results of electromagnetic physics validation (*August 2003*): [photons](#), [electrons](#), [positrons](#), [protons](#)

Useful links

- [Geant4](#)
- [Geant4 Low Energy Electromagnetic Physics](#)
- [Geant4 Standard Electromagnetic Physics](#)
- [AIDA](#) (Abstract Interfaces for Data Analysis)
- AIDA-compliant analysis systems: [Anaphe](#), [IAS](#), [Open Scientist](#)

Last modified 03 September 2003 - MGP

- Provide the quality of Geant4 physics to users
- Focus to validations
- To complement Physics Reference Manual of Geant4
- Contents should have publication-level quality
- This project in progress

<http://lcgapp.cern.ch/project/simu/validation/>

Physics Validation Project

[LHC Computing Grid Project](#) [LCG Applications Area](#) [Simulation Project](#)

[ALICE](#) [ATLAS](#) [CMS](#) [LHCb](#)
[Geant4](#) [Geant3](#) [ELUKA](#)

General information

- Project leader: [Alberto Ribon](#)
- [Project plan](#)
- [Proposed work plan for 2005](#)
- For more general information about the physics validation and other parts of the simulation project, please refer to the main page of the [simulation project](#)

Meetings and mailing lists

- Mailing list: [project-lcg-simu](#) and [archive](#)
- Future meetings :

Date	Day	Time	Room
October 25	Wednesday	18:00-18:00	32-1-A24
November 29	Wednesday	18:00-18:00	32-1-A24

- [Kick-off meeting April 16, 2003](#)
- [May 14, 2003](#)
- [June 4, 2003](#)
- [July 30, 2003](#)
- [October 1, 2003](#)
- [November 5, 2003](#)
- [December 3, 2003](#)
- [February 4, 2004](#)
- [March 3, 2004](#)
- [April 7, 2004](#)
- [May 5, 2004](#)
- [June 2, 2004](#)
- [July 7, 2004](#)
- [December 1, 2004](#)
- [January 26, 2005](#)
- [February 23, 2005](#)
- [March 23, 2005](#)

- LCD Physics Validation Project Web page
- Slides library of previous meetings is quite useful
- Also has many useful links
- HEP oriented

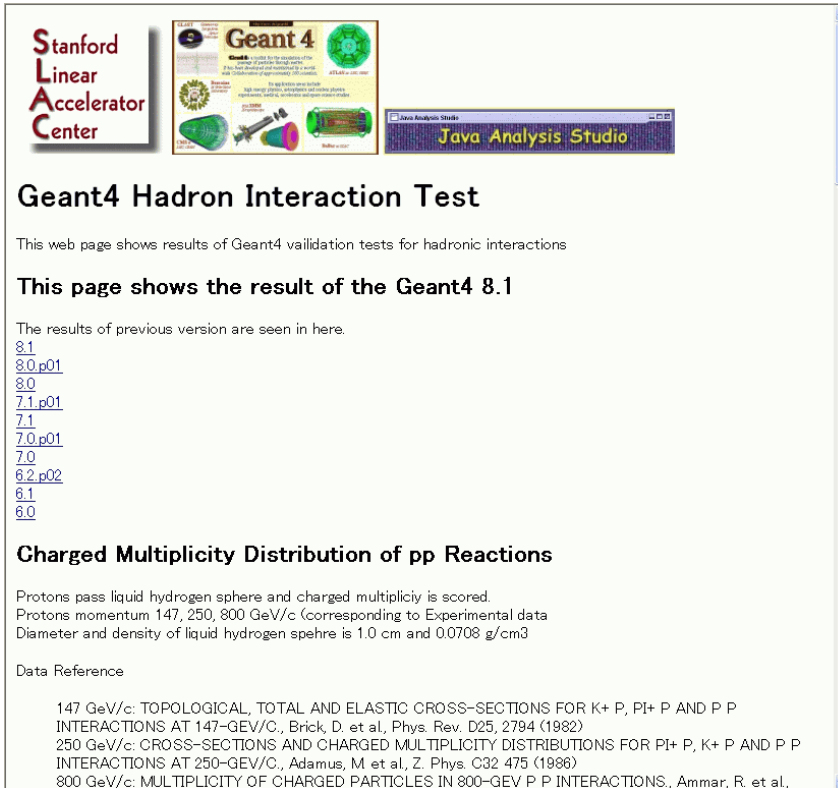
<http://indico.cern.ch/conferenceDisplay.py?confId=4532>

The screenshot shows the Indico interface for the "Geant4 Physics Verification and Validation" workshop. The page is titled "Geant4 Physics Verification and Validation" and includes a navigation bar with options like "category", "view", "focus on", "details", and "manage". A sidebar on the left provides summary information: Date/Time (Monday 17 July 2006 08:00 to Wednesday 19 July 2006 18:00), Chairperson (John APOSTOLAKIS), and Material (vrvs_1907, vrvs_1807, Videoconference, vrvs_1707). The main content area displays a schedule of sessions for Monday 17 July 2006 and Tuesday 18 July 2006. Each session entry includes the time, title, duration, and chairperson.

Date	Time	Session Title	Chairperson
Monday 17 July 2006	14:00-20:30	Experiment validation (32-1-A24)	Alberto Ribon (CERN)
Monday 17 July 2006	14:00	MUSCAT validation of Geant4 (30)	Malcolm ELLIS
Monday 17 July 2006	14:30	Geant4 validation with ATLAS calorimeter test-beams (45)	Tancredi CARLI
Monday 17 July 2006	15:15	Coffee break	
Monday 17 July 2006	15:45	ATLAS HEC test-beam validation of Geant4 (30)	Andrei KIRYUNIN
Monday 17 July 2006	16:15	CMS HCAL test-beam validation of Geant4 (30)	Stefan PIPEROV
Monday 17 July 2006	16:45	Results from the recent carbon test beams at HIMAC (20)	Koichi Murakami (KEK)
Tuesday 18 July 2006	09:30-11:00	EM physics verification validation (40-SS-D01)	Alberto Ribon (CERN)
Tuesday 18 July 2006	11:00-17:50	Hadronic verification & validation (40-SS-D01)	
Wednesday 19 July 2006	09:30-17:10	Hadronic verification & validation (40-SS-D01)	
Tuesday 18 July 2006	09:30-11:00	EM physics verification validation (09-30->11:00)	Alberto Ribon (CERN)
Tuesday 18 July 2006	09:30	Recent validation results for EM standard (20)	Vladimir Ivanchenko (CERN)
Tuesday 18 July 2006	09:50	Geant4 Simulation for E166 Experiment at SLAC (05)	Andreas Schaeicke (DESY)
Tuesday 18 July 2006	09:55	Comparison of G4 EM models with SANDIA data (15)	Omrane Kadri (CNSTN)
Tuesday 18 July 2006	10:10	Status of validations in the LowEnergy EM and Advance Example groups (20)	Maria Grazia Pia (INFN, Genova)
Tuesday 18 July 2006	10:30	Coffee break	

- Web page of “Geant4 Physics Verification and Validation Workshop” on July 2006
- Not only Geant4 developers but also several HEP experiment group presented their validations

<http://www.slac.stanford.edu/~tkoi/G4HadInt.html>



Stanford Linear Accelerator Center

Geant4

Java Analysis Studio

Geant4 Hadron Interaction Test

This web page shows results of Geant4 validation tests for hadronic interactions

This page shows the result of the Geant4 8.1

The results of previous version are seen in here.

- [8.1](#)
- [8.0.p01](#)
- [8.0](#)
- [7.1.p01](#)
- [7.1](#)
- [7.0.p01](#)
- [7.0](#)
- [6.2.p02](#)
- [6.1](#)
- [6.0](#)

Charged Multiplicity Distribution of pp Reactions

Protons pass liquid hydrogen sphere and charged multiplicity is scored.
Protons momentum 147, 250, 800 GeV/c (corresponding to Experimental data
Diameter and density of liquid hydrogen sphere is 1.0 cm and 0.0708 g/cm³)

Data Reference

- 147 GeV/c: TOPOLOGICAL, TOTAL AND ELASTIC CROSS-SECTIONS FOR K+ P, PI+ P AND P P INTERACTIONS AT 147-GEV/C., Brick, D. et al, Phys. Rev. D25, 2794 (1982)
- 250 GeV/c: CROSS-SECTIONS AND CHARGED MULTIPLICITY DISTRIBUTIONS FOR PI+ P, K+ P AND P P INTERACTIONS AT 250-GEV/C., Adamus, M et al, Z. Phys. C32 475 (1986)
- 800 GeV/c: MULTIPLICITY OF CHARGED PARTICLES IN 800-GEV P P INTERACTIONS, Ammar, R. et al,

- Hadron Physics
 - pp interactions
 - nucleus-nucleus interactions
- EM Physics
 - Multiple Coulomb Scattering
 - Thin Layer Energy Loss
 - Multi Layer Faraday Cup
- Medical related validations
- And so on

Summary

- Many validations are done by not only developers but also users.
- However, there is no place where are collecting those results and activities. This situation make it difficult that a user find a validation of his/her interested.
- “Testing and Validation” in Geant4 web site is the first candidate to become such a place. However it looks like left without maintenances. It should be re-organized and muse be maintained well in the future.
- The results are reasonably well in most cases, however we still discover unexpected disagreements. E.g. Visible Energy of Sampling Calorimeter.
- Future development of Geant4 should be pursed in a collaboration with these validation activities.