

Simulation Software & Validation

- * Huge efforts worldwide in Geant4, Fluka, MCNP/MCNPX MARS PHITS
- * Various studies/comparisons, including with data, by simulation experts/teams
- * Comparisons with data usually done by/with collaborators in experiments
- * Lots of interests/needs for Geant4, Fluka, MCNP/MCNPX, MARS.
Many accelerator, experiment, medical, and space applications
- * Next generation accelerators/experiments/applications will require higher precision
- * Comparisons/validation among software packages and data would be beneficial
- * MARS Benchmark/Validation/Verification by N. Mokhov, the expert
- * Geant4 & Fluka most used for detector R&D
- * Virtual Monte Carlo Simulation and Analysis Framework
 - great for all high energy and nuclear accelerators/experiments/applications
 - Geant4, Fluka, Geant3 selected at run time
 - using same beam, detectors, geometry, user codes, same analysis
 - strongly supported by ALICE @ LHC and FAIR, CBM, Panda @ GSI
 - also used by CERN - Gran Sasso OPERA
 - and 4th Concept Detector for ILC, CLIC, Muon Collider
 - available on ilcsim.fnal.gov
 - can validate/verify with 4th/DREAM test beam data
 - best for the Validation Project

Introductions:

Challenges, Advances and Future needs in Shielding code developments

Nikolai Mokhov, 2008

<http://hpschapters.org/sections/accelerator/2008MidyearMorganLecturerNikolaiMokhovPresentation.pdf>

Report from the Hadron Shower Simulation Workshop

<http://conferences.fnal.gov/hss06>

<http://ilcagenda.linearcollider.org/getFile.py/access?contribId=62&sessionId=1&resId=0&materialId=slides&confId=1199>

CERN Simulation Project

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

Simulations in Detector Design and Future Prospects Harry W. K. Cheung

http://www.muonsinc.com/lemc2008/presentations/HWKC_MuCollWS2008_Apr23.ppt

Uncertainties in Energy Deposition Predictions Nikolai Mokhov

http://pubweb.bnl.gov/users/kirk/www/targetry03/thursday_am/mokhov-1.pdf

Examples of Validation:

Status of Atlas Simulation Project for the LHC Startup 2007

http://illaolmo.mib.infn.it/ICATPP10th_2007/High%20Energy%20Physics%20Experiments/Di_Simone.pdf

Geant4 Electromagnetic Physics and Readiness for the LHC Start

<http://indico.cern.ch/contributionDisplay.py?contribId=17&sessionId=6&confId=34666>

Hadronic Physics in Geant4: Improvements and Status for LHC Start

<http://indico.cern.ch/contributionDisplay.py?contribId=37&sessionId=10&confId=34666>

Ivantchenko, Vladimir

Physics Validation of Detector Simulation Tools for LHC

<http://www-conf.kek.jp/acat03/prog/presen/id0023.pdf>

LHC-wide validation of Geant4 and Fluka with data

<http://lcgapp.cern.ch/project/simu/validation/docs/Calor2004-talk.pdf>

<http://lcgapp.cern.ch/project/docs/hadronic-note.ps>

Physics validation and recent development in Geant4 and Fluka

<http://lcgapp.cern.ch/project/simu/validation/validation-AA05.ppt>

Physics Validation of simulation tools for LHC

<http://www-conf.kek.jp/acat03/prog/presen/id0023.pdf>

Inter-comparison of MARS and FLUKA: 2008

Predictions on Energy Deposition in LHC IR Quadrupoles

<http://lss.fnal.gov/archive/test-fn/0000/fermilab-fn-0819-apc.pdf>

A Cross-Comparison of MARS and Fluka Simulation Codes

M. Huhtinen and N.V. Mokhov Aug. 2000

<http://lss.fnal.gov/archive/2000/fn/FN-697.ps>

Hadron Working Group

http://geant4.cern.ch/collaboration/working_groups/hadronic/HadPlanPerson.ppt

Physics Validation of LHC Simulations

http://www.lip.pt/events/2005/hep2005/talks/hep2005_talk_AlbertoRibon.pdf

Geant4 validation with CMS calorimeters test-beam data

<http://cdsweb.cern.ch/record/1118697?ln=es>

<http://home.fnal.gov/~kunori/cms/meetings/00/001022-mc2000/mc2000-cms-hcal-a.ppt>

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Virtual Monte Carlo Simulation and Analysis :

ALIROOT	ALICE	@ LHC	
CBMROOT	CBM	Compressed Baryonic Matter	@ FAIR
PANDAROOT	PANDA	Proton ANtiproton DArmstadt	@ FAIR
OpROOT	OPERA	Oscillation Project	CERN-GranSiasso
ILCROOT	4th	ILC, CLIC,	Muon Collider

ALIROOT

<http://aliceinfo.cern.ch/Offline/AliRoot/Manual.html>

<http://www.hep.lu.se/alicesoft/aliroot/gettingstarted.php>

<http://www.physi.uni-heidelberg.de/~shukla/aliroot.html>

[http://anakin.kisti.re.kr/mediawiki/index.php/Alice\(LHC\), AliEn, AliRoot](http://anakin.kisti.re.kr/mediawiki/index.php/Alice(LHC), AliEn, AliRoot)

Facility of Antiproton and Ion Research FAIR @ GSI Billion Euros

http://www.gsi.de/fair/index_e.html

http://www.gsi.de/fair/experiments/index_e.html

FairRoot

CbmRoot <http://cbmroot.gsi.de>

<http://www.gsi.de/informationen/wti/library/scientificreport2006/PAPERS/INSTRUMENTS-METHODS-16.pdf>

<http://esmane.physics.lsa.umich.edu/wl/cern/computing/2007/root/20070328-umwlc0010-02/realaudio/f001.htm>

PandaRoot <http://www-panda.gsi.de/html/panda.htm>

<http://www.fz-juelich.de/ikp/menu2007/Talks/talk-Wronska.pdf>

OpRoot <http://operameeting.sa.infn.it/Talks/PhysCoord/EmulsionReconstructionWG.ppt>

<http://operaweb.web.cern.ch/operaweb/internal/exchanger/home/software/documentation/OpRelease/packages/OpRoot.html>

<https://operaweb.web.cern.ch/operaweb/internal/exchanger/home/software/packages/documentation/OpRoot/HowTo.html>

ILCRoot

<http://ilc.fnal.gov/detector/rd/physics/detsim/ilcroot.shtml>

<http://www.fisica.unile.it/~danieleb/IlcRoot/>

ILCRoot FrameWork: Offline Simulation Program

A STEER module provides steering, run management, interface classes, and base classes to the entire framework. The detectors are independent modules that contain the code for simulation and reconstruction while the analysis code is progressively added.

Detector response simulation can be performed via different transport codes like GEANT3, GEANT4, and FLUKA.

The user can decide which one to load at runtime and, thanks to the Virtual Monte Carlo abstract interface, the transition from GEANT3 to GEANT4 and to FLUKA is seamless, since no user code has to be changed; only a different shared library has to be loaded.

GEANT4

<http://www.geant4.org>

http://www.geant4.org/geant4/collaboration/working_groups.shtml

<http://www.geant4.org/geant4/collaboration/members.shtml>

Fermilab: Sunanda Banerjee, Daniel Elvira, Mark Fischler,
Jim Kowalkowski, Marc Paterno, Julia Yarba.
Lynn Garren and others also install/maintain Geant4.

36 users subscribe to geant4-users@fnal.gov

Fermilab Simulation

<http://cepa.fnal.gov/cepa/simulation.shtml>

G4beamline Geant4 based simulation for beamlines

<http://g4beamline.muonsinc.com>

<http://nufact06.physics.uci.edu/Workshop/Slides/Roberts-G4Beamline.ppt>

FLUKA

Release notes for Fluka2008.3

<http://www.nea.fr/html/dbprog/RELEASE-NOTES.fluka2008.3.txt>

<http://www.fluka.org>

<http://www.fluka.org/fluka.php?id=citations>

<http://www.slac.stanford.edu/econf/C0303241/proc/pres/155.PPT>

<http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-11506.pdf>

Fluka Lectures

<http://info-fluka-discussion.web.cern.ch/info-fluka-discussion/pages/Talks.htm>

The FLUKA Code

<http://fluka.phys.uh.edu/course/Legnaro-07/Lectures/Introduction07.pdf>

LHCf

<http://www.particle.cz/conferences/c2cr2005/talks/Adriani.pdf>

MCNP / MCNPX

Fermilab-based cancer center gets \$6 million boost

http://www.fnal.gov/pub/today/archive_2008/today08-11-07.html

<http://foster.house.gov/News/DocumentSingle.aspx?DocumentID=104735>

<http://mcnp.lanl.gov/documents.html>

MCNPX Overview

<http://mcnp.lanl.gov/opendocs/misc/LA-UR-06-6206.pdf>

MCNP - A General Monte Carlo N-Particle Transport Code

<http://mcnp-green.lanl.gov>

MARS

<http://www-ap.fnal.gov/MARS/>

http://www-ap.fnal.gov/MARS/intro_manual.htm

<http://www-ap.fnal.gov/MARS/applications.htm>

<http://www-ap.fnal.gov/MARS/references.htm>

<http://arxiv.org/pdf/nucl-th/0404084>

PHITS Particle and Heavy Ion Transport code System since 2003

<http://phits.jaea.go.jp/>

<http://phits.jaea.go.jp/Benchmark.html>

<http://www.cap.bnl.gov/mumu/conf/target-051010/talks/KNiita1b.pdf>

<http://www.dsls.usra.edu/meetings/radiation2004/pdf/12/1105Niita.pdf>

<http://www-conf.kek.jp/geant4/1213/koji.niita.pdf>

Virtual Monte Carlo

<http://root.cern.ch/root/vmc/VirtualMC.html>

ALICE-FAIR Computing

<http://indico.cern.ch/conferenceDisplay.py?confId=30789>

Geant4 VMC

<http://indico.cern.ch/contributionDisplay.py?contribId=126&sessionId=23&confId=3580>

Fluka VMC

<http://indico.cern.ch/contributionDisplay.py?contribId=387&sessionId=3&confId=048>

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Sample applications:

Embarrassingly parallel framework for EGSnrc, FLUKA, MCNP, Geant4

<http://www.marychin.org/ICCRmarychin.pdf>

<http://www.grid-support.ac.uk/files/Presentations/marychin2.ppt>

<http://wwwasd.web.cern.ch/wwwasd/geant/>

Experimental test of Monte Carlo proton transport at grazing incidence
in GEANT4, FLUKA and MCNPX

<http://www.iop.org/EJ/abstract/0031-9155/53/4/020>

An interface for Geant4 using ROOT geometry navigation

Alice: allows running Geant4, Fluka, Geant3

http://www.iop.org/EJ/article/1742-6596/119/4/042014/jpconf8_119_042014.pdf

Physics Validation of simulation tools for LHC

<http://www-conf.kek.jp/acat03/prog/presen/id0023.pdf>

Flugg: Fluka + Geant4

<http://www.fluka.org/content/tools/flugg/index.html>

ALICE Analysis Framework

<http://indico.cern.ch/contributionDisplay.py?contribId=174&sessionId=4&confId=34666>

ACAT 2008

http://acat2008.cern.ch/index.php?option=com_content&task=view&id=13&Itemid=27

Geant4 Electromagnetic Physics and Readiness for the LHC Start

<http://indico.cern.ch/contributionDisplay.py?contribId=17&sessionId=6&confId=34666>

Hadronic Physics in Geant4: Improvements and Status for LHC Start

<http://indico.cern.ch/contributionDisplay.py?contribId=37&sessionId=10&confId=34666>

Muon-induced neutron production with Geant4 and Fluka

<http://www-iliac.cea.fr/scripts/home/publigen/content/templates/Show.asp?P=167&L=EN>

Simulating neutron propagations with Fluka, Geant4, MCNP

<http://ieeexplore.ieee.org/iel5/4436263/4436479/04436548.pdf?arnumber=4436548>

Shower simulations, comparisons of Fluka, Geant4, EGS4

<http://www.eurotev.org/e158/e1365/e1378/e2196/EUROTEV-Report-2006-034.pdf>

Fluka + Geant4 Simulations of CALICE

<http://www.hep.ph.ic.ac.uk/calice/others/040419lcws04/watson.ppt>

Simulation of muon-induced background in astroparticle physics

Mu2e Geant4

<https://mu2e-docdb.fnal.gov:440/cgi-bin/ShowDocument?docid=64>

Geant4 Lecture Notes 2004

<http://www.ge.infn.it/geant4/events/nss2004/geant4lectures.html>

Monte Carlo event generators and generator services in the LHC era

<http://indico.cern.ch/contributionDisplay.py?contribId=8&sessionId=27&confId=34666>

Monte Carlo generators in CMS

<http://indico.cern.ch/contributionDisplay.py?contribId=41&sessionId=27&confId=34666>

Tools for systematic event generator tuning and validation

<http://indico.cern.ch/contributionDisplay.py?contribId=187&sessionId=27&confId=34666>

Geant4 Physics List Forum

<http://hypernews.slac.stanford.edu/HyperNews/geant4/get/phys-list.html>

SLAC Offline Team

<http://www.slac.stanford.edu/grp/scs/pes/offlineteam/>

The new ROOT Geometry Package

<http://acat02.sinp.msu.ru/presentations/brun/geom.ppt>

Raja

<http://ilcagenda.linearcollider.org/getFile.py/access?contribId=222&sessionId=45&resId=0&materialId=slides&confId=1556>

<http://nufact06.physics.uci.edu/Workshop/Slides/raja-NUFACT06.ppt>

FP7 Detector R&D MICE.pdf

<http://dpnc.unige.ch/users/blondel/BENE/detectors/NEUDET-Blondel-04-12-2007.ppt>

Low Energy neutron propagation in MCNPX and Geant4

<http://www.citeulike.org/user/kaixuan/article/3486503>

Geometry and GEANT4

http://nuclear.unh.edu/~maurik/GEANT4/GEANT4_GEOM.html

A Monte Carlo dose calculation algorithm for proton therapy

<http://link.aip.org/link/?MPHYA6/31/2263/1>

Presentations of Geant4 and related topics

<http://www.ge.infn.it/geant4/talks/index.html>

M.G. Pia

Geant4 for microdosimetry & ...

Radiobiology at INFN Workshop, Trieste, February 2008

OpenGATE Geant4 Application for Tomography Emission

<http://opengatecollaboration.healthgrid.org/>

Visualization drivers for Geant4

Andy Beretvas

<http://www-spires.fnal.gov/spires/find/hep?key=6434940>

[arXiv:0806.4887] FERMILAB-TM-2329-CD (Oct 2005) 57p.

Fermilab-based cancer center gets \$6 million boost

http://www.fnal.gov/pub/today/archive_2008/today08-11-07.html

<http://foster.house.gov/News/DocumentSingle.aspx?DocumentID=104735>

Illinois' Bold Technology Bet: 2 new Hadron Therapy Centers near Fermilab

http://www.fnal.gov/pub/today/archive_2008/today08-09-23.html

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GEANT4

Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The two main reference papers for Geant4 are published in Nuclear Instruments and Methods in Physics Research A 506 (2003) 250-303, and IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278.

FLUKA

FLUKA is a fully integrated particle physics MonteCarlo simulation package.

It has many applications in high energy experimental physics and engineering, shielding, detector and telescope design, cosmic ray studies, dosimetry, medical physics and radio-biology.

MCNPX <http://mcnpx.lanl.gov/documents.html>

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, nuclear criticality, and much more.

MCNPX is written in Fortran 90, runs on PC Windows, Linux, and unixn 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.

MCNP - A General Monte Carlo N-Particle Transport Code - Version 5

<http://mcnp-green.lanl.gov>

Diagnostics Applications Group - Los Alamos National Laboratory

MCNP is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. Specific areas of application include, but are not limited to, radiation protection and dosimetry, radiation shielding, radiography, medical physics, nuclear criticality safety, Detector Design and analysis, nuclear oil well logging, Accelerator target design, Fission and fusion reactor design, decontamination and decommissioning. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and fourth-degree elliptical tori.

Pointwise cross-section data typically are used, although group-wise data also are available. For neutrons, all reactions given in a particular cross-section evaluation (such as ENDF/B-VI) are accounted for. Thermal neutrons are described by both the free gas and S(alpha,beta) models. For photons, the code accounts for incoherent and coherent scattering, the possibility of fluorescent emission after photoelectric absorption, absorption in pair production with local emission of annihilation radiation, and bremsstrahlung. A continuous-slowing-down model is used for electron transport that includes positrons, x-rays, and bremsstrahlung but does not include external or self-induced fields.

Important standard features that make MCNP very versatile and easy to use include a powerful general source, criticality source, and surface source; both geometry and output tally plotters; a rich collection of variance reduction techniques; a flexible tally structure; and an extensive collection of cross-section data.

MCNP5 contains numerous flexible tallies: surface current & flux, volume flux (track length), point or ring detectors, particle heating, fission heating, pulse height tally for energy or charge deposition, mesh tallies, and radiography tallies.

MARS

MARS is a Monte Carlo code for inclusive and exclusive simulation of three-dimensional hadronic and electromagnetic cascades, muon, heavy-ion and low-energy neutron transport in accelerator, detector, spacecraft and shielding components in the energy range from a fraction of an electronvolt up to 100 TeV.

Recent developments in the MARS15 physical model of 0.1 MeV to 100 TeV hadron, heavy-ion and lepton interactions with nuclei and atoms include a new nuclear cross section library, a model for soft pion production, the cascade-exciton model, the dual parton and quark gluon string models, deuteron-nucleus and neutrino-nucleus interaction models, detailed description of negative hadron and muon absorption and a unified treatment of muon, charged hadron and heavy-ion electromagnetic interactions with matter. New algorithms are implemented into the code and benchmarked against experimental data. The code capabilities to simulate cascades and generate a variety of results in complex media have been also enhanced. Other changes in the current version concern the improved photo- and electro-production of hadrons and muons, improved algorithms for the 3-body decays, particle tracking in magnetic fields, synchrotron radiation by electrons and muons, significantly extended histogramming capabilities and material description, and improved computational performance.

In addition to direct energy deposition calculations, a new set of fluence-to-dose Conversion factors for all particles including neutrino are built into the code. Completely new object-oriented geometry module provides user-friendly geometry description, verification and powerful visualization. The MARS15 code include links to the MCNP4C code for neutron and photon production and transport below 20 MeV, to the ANSYS code for thermal and stress analyses and to the STRUCT code for multi-turn particle tracking in large synchrotrons and collider rings.

PHITS <http://phits.jaea.go.jp/>

PHITS (Particle and Heavy Ion Transport code System) supports your researches in the fields of accelerator technology, radiotherapy, space radiation, and in many other fields which are related to particle and heavy ion transport phenomena.

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GENERAL PURPOSE ALL-PARTICLE CODES

1. **FLUKA** - since 1970, currently FLUKA-2006.3b, CERN & INFN
2. **GEANT** - since 1974, currently GEANT4-9.1, CERN, SLAC et al.
3. **MARS** - since 1974, currently MARS15 (2007), FNAL
4. **MCNPX** - since 1994, originated from earlier MCNP, currently MCNPX-2.5.0 (beta 2.6E), LANL
5. **PHITS** - since 2003, currently PHITS-2.13, JAEA, RIST, GSI

Particle energies from hundreds TeV (with some exceptions) down to thermal neutron energy, $10^{-3} < E < 10^{14}$ eV.

EXAMPLE: PHISICS CAPBILITIES IN PHITS

neutrons	protons	hadrons <small>$\pi, \mu, K, \Sigma, \dots$</small>	nucleus	photons electrons
200 GeV	200 GeV	200 GeV	100 GeV/u	100 GeV
← JAM, Hadron cascade model → (JQMD) (JQMD) (JQMD) (Bertini) (Bertini)			JQMD	In progress
← GEM, Evaporation process →				
← SPAR, ATIMA, Ionization process →				
20 MeV ↑	1 MeV	1 MeV	10 MeV/u	1 GeV ↑
MCNP with nuclear data	only transport with dE/dx (SPAR, ATIMA)			MCNP with nuclear data
thermal ↓	0 MeV	0 MeV	0 MeV/u	1 keV ↓

CODES: General Information

Compiled by G. McKinney with contributions from 5 code teams

General	MCNPX	GEANT4	FLUKA	MARS	PHITS
Version	2.5.0 (beta: 26E)	9.1	2006.3b	15 (2007)	2.13
Lab. Affiliation	LANL	CERN IN2P3 INFN KEK SLAC TRIUMF, ESA	CERN INFN	FNAL	JAEA RIST GSI Chalmers Univ.
Language	Fortran 90/C	C++	Fortran 77	Fortran 95/C	Fortran 77
Cost	Free	Free	Free	Free	Free
Release Format	Source & binary	Source & binary	Source & binary	Partial source & binary	Source & binary
User Manual	470 pages	280 pages	387 pages	150 pages	176 pages
Users	2500	~2000	~1000	300	220
Web Site	mcnpx.lanl.gov	cern.ch/geant4	www.fluka.org	www-ap.fnal.gov/MARS	Under const.
Workshops	~7/year	~4/year	~1/year	~2/year	~1/year
Input Format	Free	C++ main Fixed geometry	Fixed or free	Free	Free
Input Cards	~120	N/A	~85	~100	~100
Parallel Execution	Yes	Yes	Yes	Yes	Yes

CODES: Physics Capabilities

Compiled by G. McKinney with contributions from 5 code teams

Physics	MCNPX	GEANT4	FLUKA	MARS	PHITS
Particles	34	68	68	41	38
Charged particles	CSDA	CSDA	CSDA	CSDA	CSDA
Energy loss	Bethe-Bloch	Bethe-Bloch	Bethe-Bloch	Bethe-Bloch	Bethe-Bloch
Scatter	Rossi	Lewis	Moliere	Moliere*	Moliere
Straggling	Vavilov	Urban	Custom	Custom	Vavilov
XTR/Cherenkov	No	Yes	No/yes	No	No
Baryons					
Neutron					
Low	Cont. (ENDF)	Cont. (ENDF)	Multigroup(72)	Cont. (ENDF)	Cont. (ENDF)
High	Models	Models	Models	Models	Models
Proton					
Low	Cont. (ENDF)	Models	Models	Models	Models
High	Models	Models	Models	Models	Models
Other	Model List: Bertini ISABEL CEM INCL FLUKA89>3 GeV LAQGSM (2.6.D)	Model list: Hadron-nucleous GHEISHA* INUCL(Bertini) BIC CHIPS QGS/FTF>8 GeV	Model list: PEANUT(GINC) DPM+Glauber > 5 GeV	Model list: Custom CEM LAQGSM DPMJET	Model list: Bertini JAM>3 GeV
Leptons					
Electrons	ITS 3.0	EEDL, EADL	Custom	Custom	ITS 3.0
Muon	CSDA/decay	Models	Models	Models	CSDA/decay
Neutrino	Production	Production	Models	Producti/Models	Models
Other	Decay	Decay	Decay	Decay	Models