Geant4 project

Makoto Asai (SLAC PPA/SCA)

OHEP Laboratory Scientific Computing Review

Feb.09.2011

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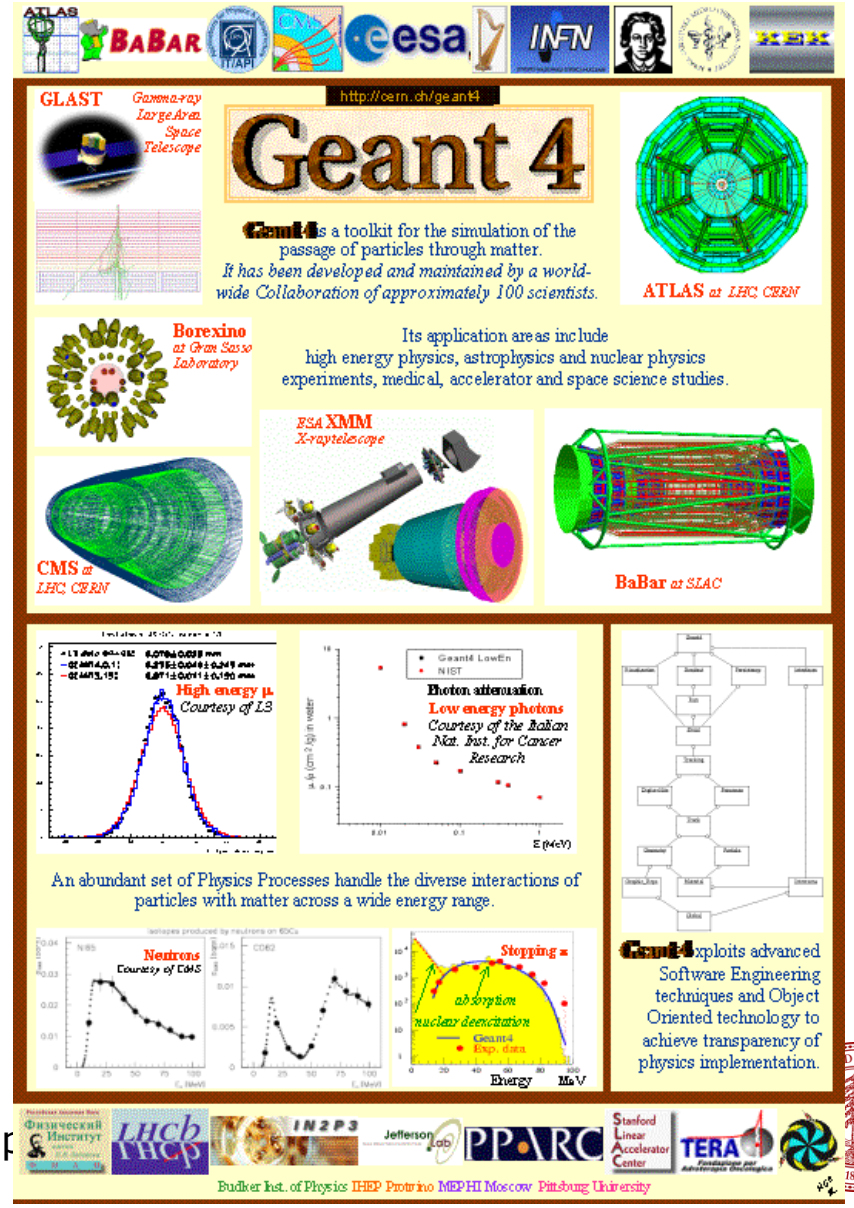
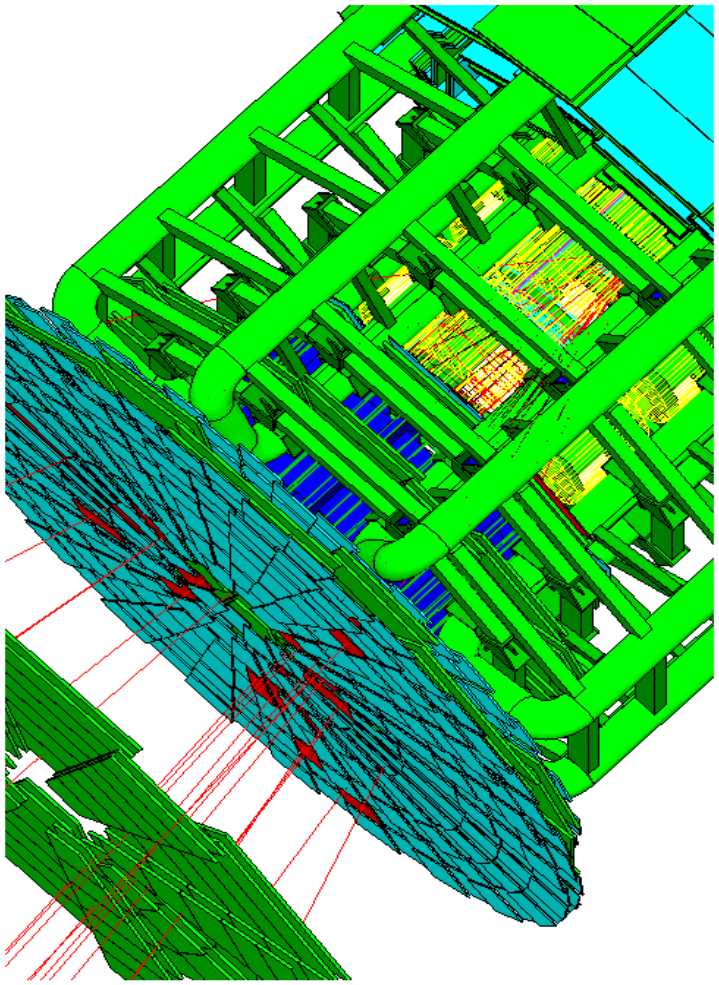


What is Geant4?

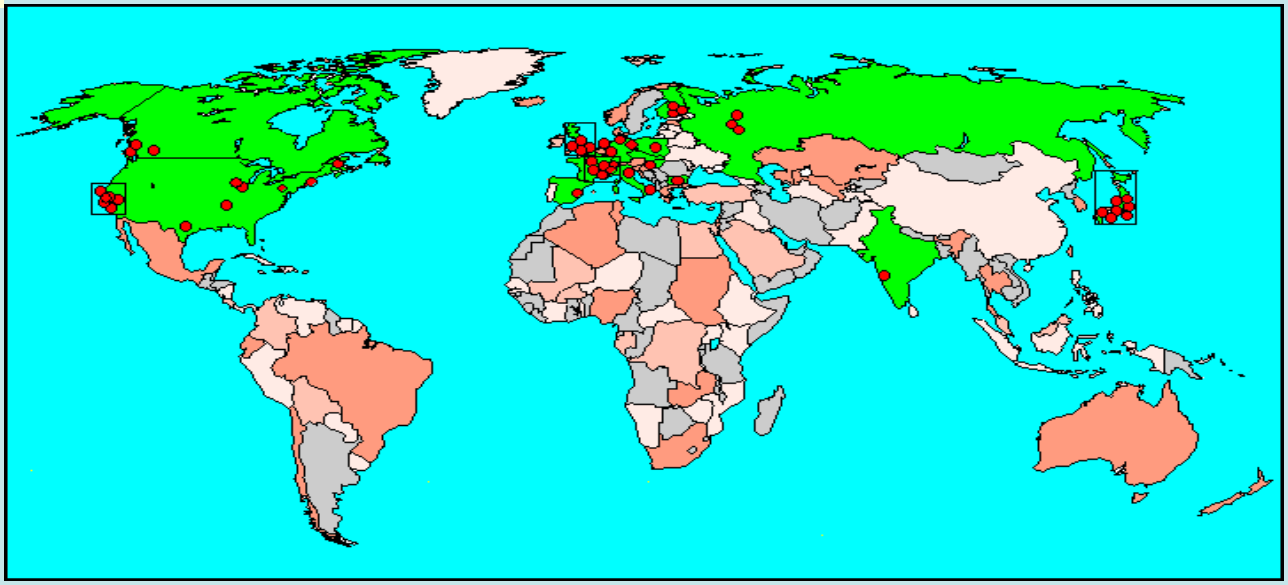
- Geant4 is the successor of GEANT 3, the world-standard toolkit for HEP detector simulation.
- Geant4 is one of the first successful attempt to re-design a major package of HEP software for the next generation of experiments using an Object-Oriented environment.
- Most of HEP experiments including all LHC experiments now rely on Geant4.
- A variety of requirements have also taken into account from heavy ion physics, CP violation physics, cosmic ray physics, astrophysics, space science and medical applications.



Geant4 – Its history

- Dec ’94 - Project start
- Apr ’97 - First alpha release
- Jul ’98 - First beta release
- Dec ’98 - First Geant4 public release - version 1.0
- …
- Jun 29th, ’07 - Geant4 version 9.0 release
- …
- Dec 19th, ’08 - Geant4 version 9.2 release
  - Sep 24th, ’10 - Geant4 9.2-patch04 release
- Dec 18th, ’09 - Geant4 version 9.3 release
  - Sep 24th, ’10 - Geant4 9.3-patch02 release
- Dec 17th, ’10 - Geant4 version 9.4 release ← Current version
- We currently provide one public releases every year.
  - Beta releases are also publicly available.

Geant4 Collaboration



TRIUMF

Lebedev

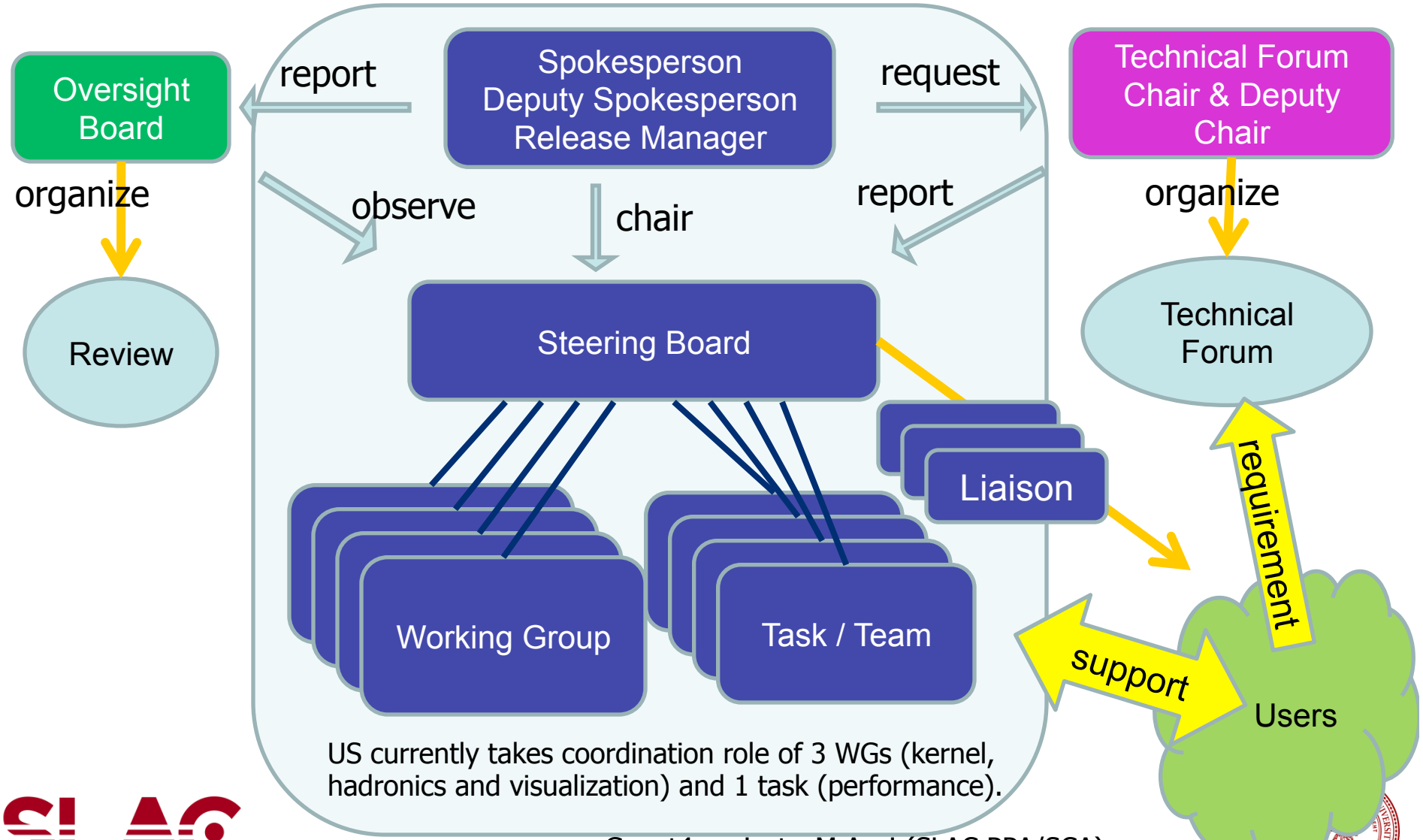
J.W.Goethe Universität

Collaborators also from non-member institutions, including
Budker Inst. of Physics
IHEP Protvino
MEPHI Moscow
Pittsburg University

Geant4 Collaboration

- The international Geant4 Collaboration develops and maintains Geant4 simulation toolkit. It also offers extensive user-supports.
- Geant4 Collaboration consists of 93 collaborators with 35 FTEs as of Oct.2010
  - 60% HEP-funded, 40% non-HEP funded
  - 17 US collaborators, 6.3 FTEs (11 collaborators, 4.0 FTEs OHEP funded)
- The collaboration is driven by the steering board and overseen by the oversight board.

Geant4 Collaboration structure

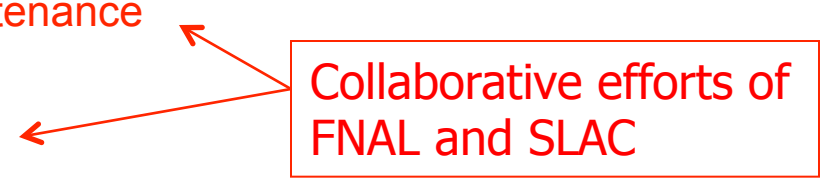


Geant4 - Issues

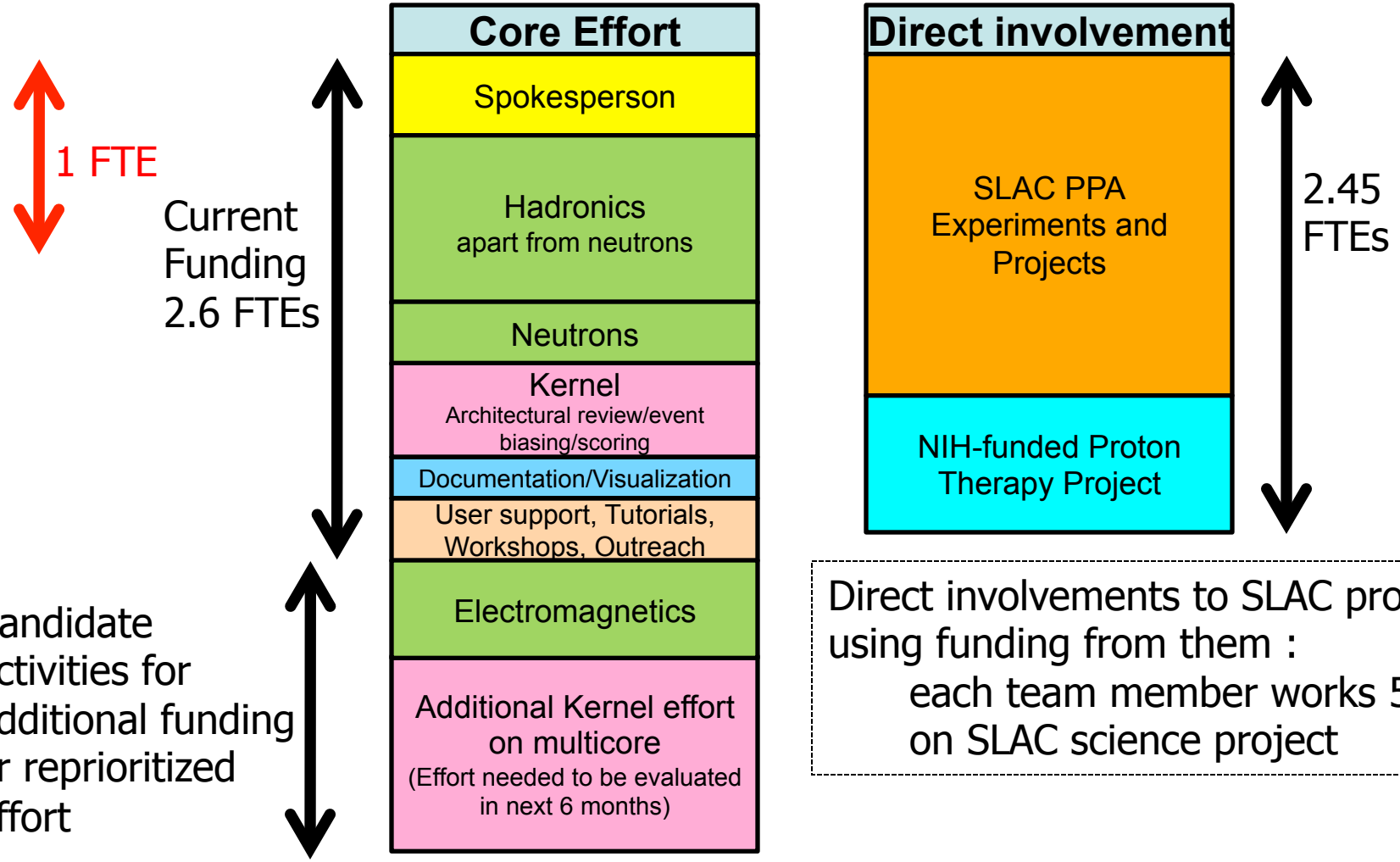
- Emerging needs of the LHC are the principal driver – they include:
  - Improving the precision and speed of hadronic shower modeling
  - Improving the precision and speed of electromagnetic modeling
  - Improving the precision, robustness and speed of transportation
  - Systematic validation, with input from existing sources plus LHC data, leading to usable estimates of precision
  - Efficient exploitation of multi-core (and perhaps later GPU) hardware
  - Ensuring maintainability for ~20 years
- Architectural revisions will be needed to address the multi-core and maintainability issues
- Estimating the likely return on effort investment for each area of need is difficult – plans and efforts should be reviewed annually

US Geant4 efforts

- BaBar experiment at SLAC is the pioneer experiment in HEP in use of Geant4.
  - Production started in 2000
- FGST (GLAST) is one of the earliest astrophysics experiments in use of Geant4.
  - Some design studies with Geant4 started in 1999
- There are now thousands of users in US in all of HENP, astrophysics, accelerator, shielding, space, medical, security, education and industry application areas.
- SLAC created its local Geant4 team in 2001.
  - FNAL Geant4 team was launched in 2004 (joined to the collaboration in 2007).
  - We now have Geant4 collaborators also in JLab, LLNL and Northeastern U.
- US Geant4 efforts consist of
  - Kernel development/maintenance
  - Hadronic/nuclear physics development/maintenance
  - Visualization development/maintenance
  - Physics validation (EM/Hadronics)
  - Computing performance improvements
  - General user support / outreach
  - Collaboration management



SLAC Geant4 Effort



Core Geant4 effort at SLAC

- Core Geant4 effort = Direct commitment to the activities of the Geant4 Collaboration
- Core Geant4 effort at SLAC
  - Includes the founding architect of Geant4
  - Includes the Spokesperson, leader of Hadronics, leader of Visualization
  - Maintains expertise in kernel architecture, hadronic physics, nuclear physics, and visualization
  - Supports use of Geant4 by SLAC projects
    - General day-to-day supports
      - HEP projects such as ATLAS, SuperCDMS, EXO, ILC, astrophysics, etc. (BaBar, FGST supports fading out)
      - Non-HEP projects such as LCLS, radiation shielding for LCLS, etc.
  - Leads support for US HEP and outreach to US space, medicine, security and industry
    - Regular and popular tutorial courses on site and other locations

Goals of SLAC Geant4 efforts

- Tactical:
  - Achieve and maintain current leading roles in the Geant4 Collaboration.
  - Lead the effort to plan and execute architectural changes to Geant4 to ensure efficiency on new computing architectures and longevity on and beyond LHC.
  - Expand the SLAC role into Geant4 Electromagnetic simulation to ensure that this code meets US needs for precision, reliability and performance.
  - Take stewardship of the effort to quantify the validity of Geant4 by systematic comparison with relevant existing and emerging experimental data.
- Strategic
  - Leverage collaboration with HEP colleagues and with other disciplines, both national and international, to maximize the value of Geant4 to US science and commerce.
- Critical outcome
  - Provide the simulation toolkit essential to the world and to US HEP program that is required in maximizing the precision of physics measurements and sensitivity to new physics.

Geant4 project - M.Asai (SLAC PPA/SCA)

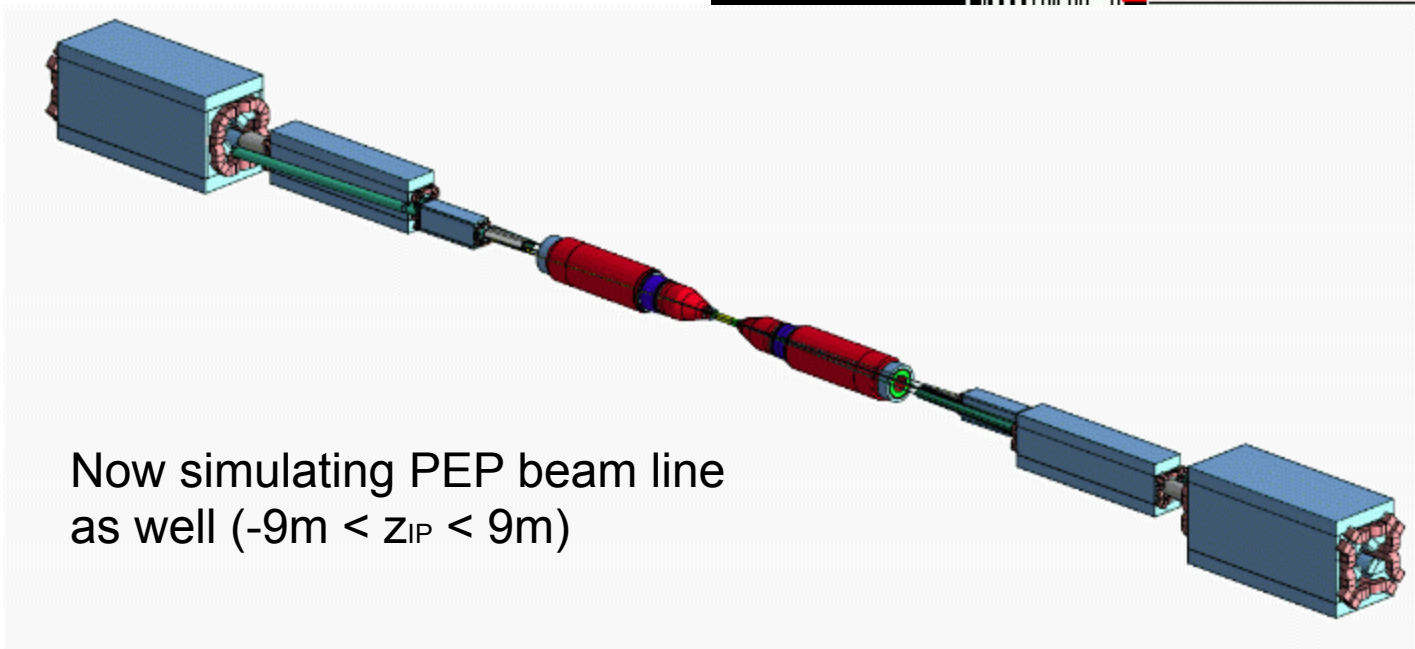
Backup slides

Geant4 Steering Board

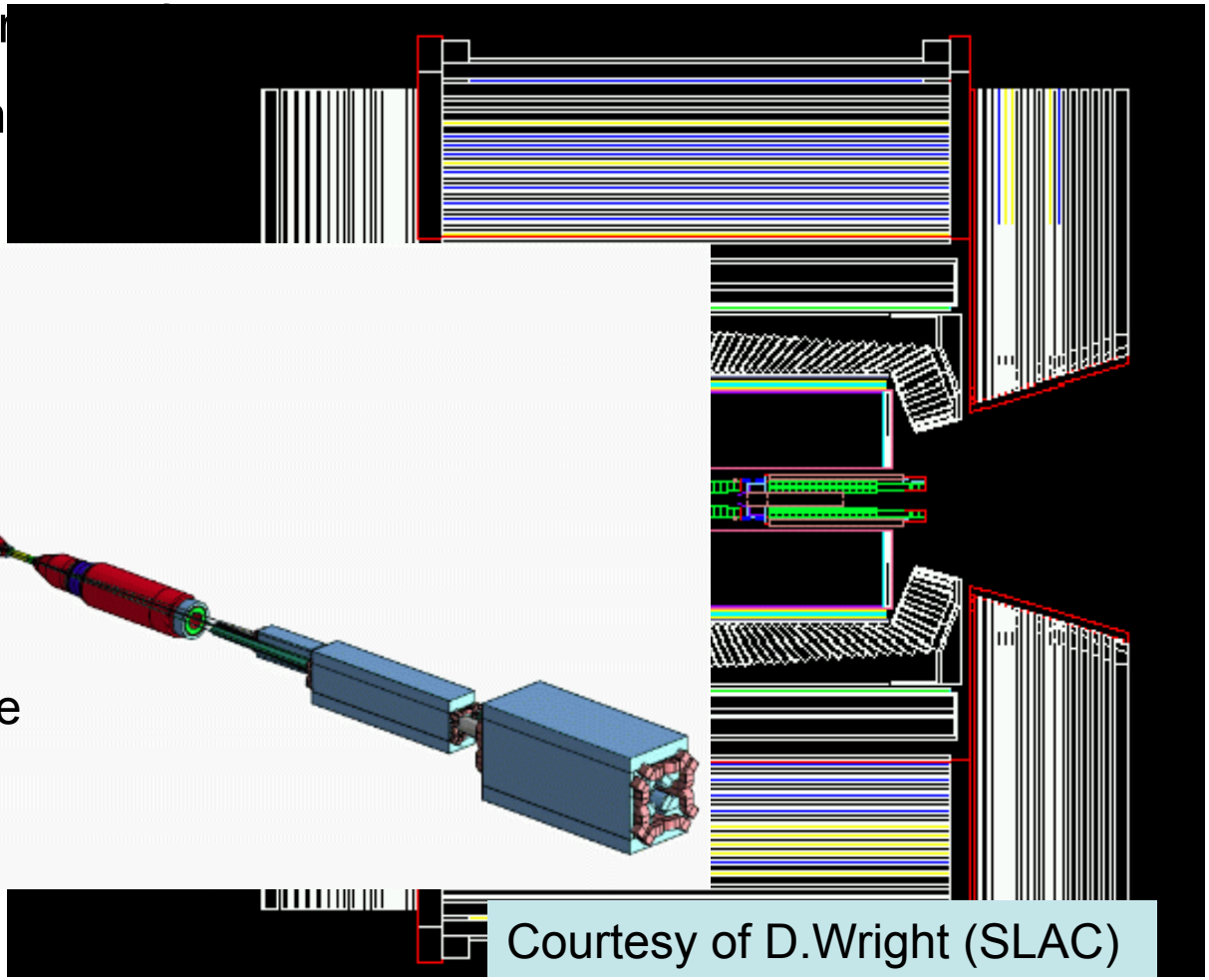
Role	Name	
Chair of SB and Spokesperson of Geant4	Makoto Asai	
Deputy spokesperson of Geant4	Marc Verderi	
Chair Technical Forum	Andreas Morsch	
Deputy Chair Technical Forum	Bruce Faddegon	
Release Manager	Gabriele Cosmo	
Working Group	**Coordinator**	**Deputy and Representatives**
Advanced Examples	G. A. Pablo Cirrone	Luciano Pandola
Documentation Management	Katsuya Amako	Dennis Wright
Electromagnetic Physics	Vladimir Ivanchenko	Michel Maire Peter Gumplinger
Geometry and Transport	Gabriele Cosmo	John Apostolakis
Hadronic Physics	Dennis Wright	Gunter Folger Sunanda Banerjee, Giacomo Cuttone
Low Energy Electromagnetic Physics	Sebastien Incerti	Giacomo Cuttone Paul Gueye, Christina Zacharatou
Particles and Track	Hisaya Kurashige	Makoto Asai
Persistency	Gabriele Cosmo	Witold Pokorski
Processes and Materials	Marc Verderi	Vladimir Ivanchenko
Run, Event and Detector Responses	Makoto Asai	Hisaya Kurashige
Software Management	Gunter Folger	Gabriele Cosmo
Testing and Quality Assurance	Gunter Folger	Andrea Dotti
Tracking	Takashi Sasaki	Katsuya Amako
User and Category Interfaces	Koichi Murakami	Hajime Yoshida
Visualisation	Joseph Perl	John Allison

BaBar

- BaBar at SLAC is the pioneer experiment in HEP in use of Geant4
  - Started in 2000
  - Simulated ~$2*10^{10}$ ever
  - Produced at 20 sites in



Now simulating PEP beam line as well ($-9m < z_{IP} < 9m$)



Courtesy of D.Wright (SLAC)

Geant 4

Geant4 at the LHC Today

Now Geant4 has become the standard simulation for ATLAS, LHCB, and CMS

	ATLAS	CMS	LHCb
Transition to Geant4 (G3 stopped)	DC02 '04	Nov '03	May '04
Produced # of events in DC	12 M	40 M	80 M
CPU time (sec)/ event (2.8 Ghz)	600 (pp→Z→ee) 700 (SUSY)	200 (QCD jets) 60 (min bias)	22-65
Memory used	400 Mb	220 Mb	220 Mb
# of placed volumes	5 M	1.2 M	18 M

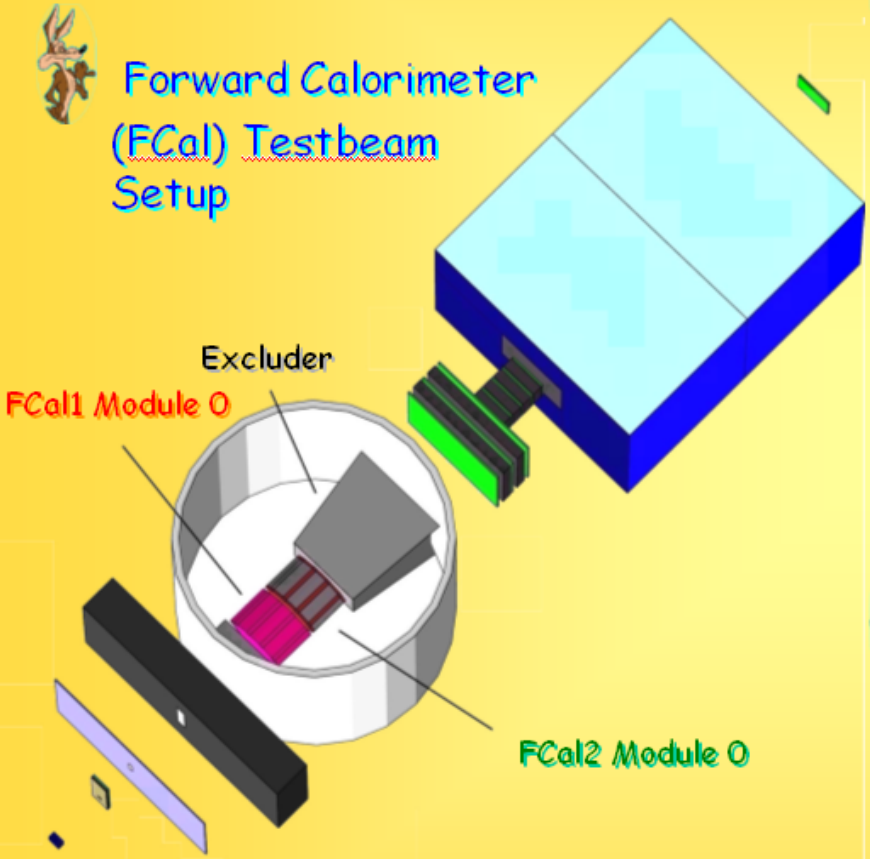
No memory leaks!!

⇒ Observations:

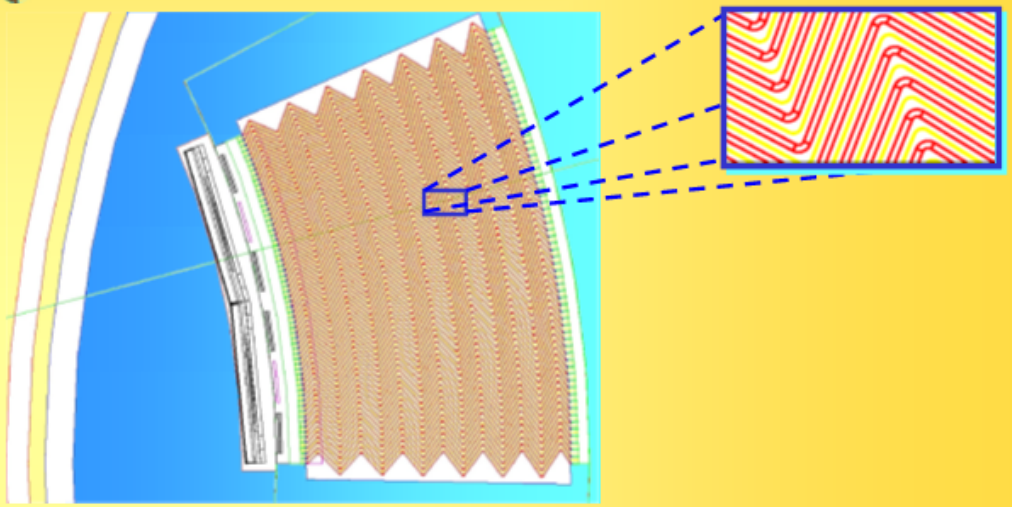
- Geant4 in production is running now very stable/very few problems (~ 10^{-5})
- Transition to Geant4 has been a very smooth process for all experiments

Geant4 Setups (2)

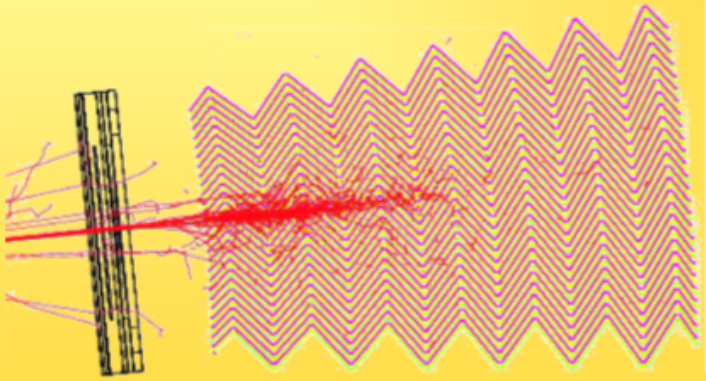
Forward Calorimeter (FCal) Testbeam Setup



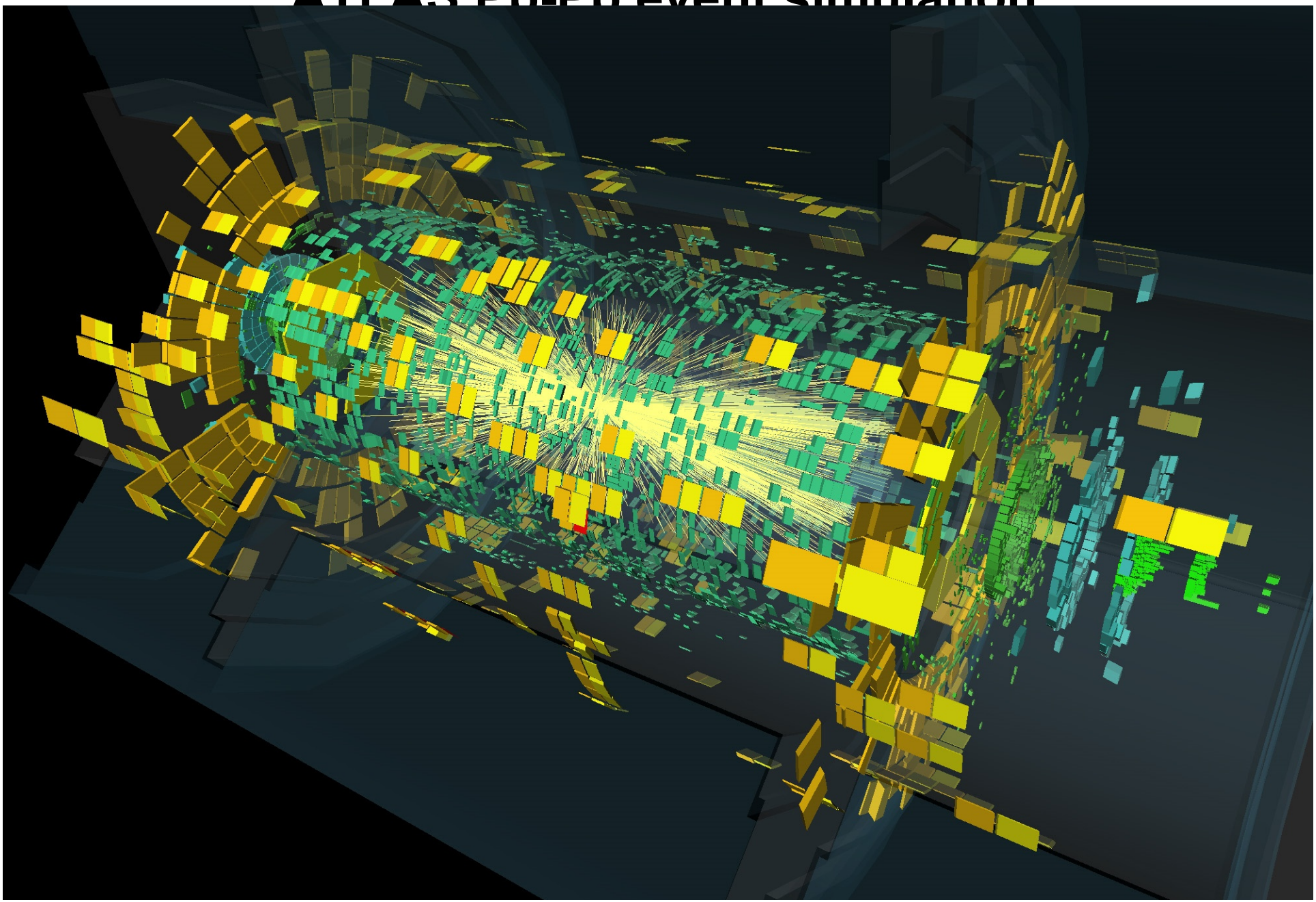
Electromagnetic Barrel Accordion Calorimeter



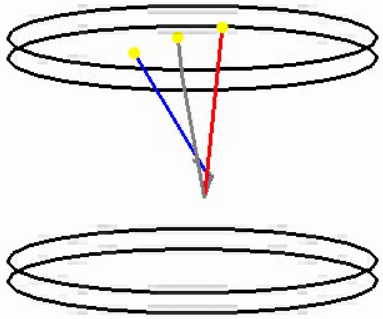
10 GeV Electron Shower



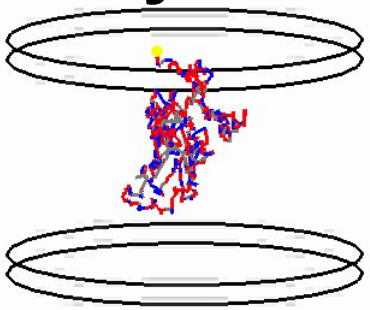
ATLAS Pb-Pb event simulation



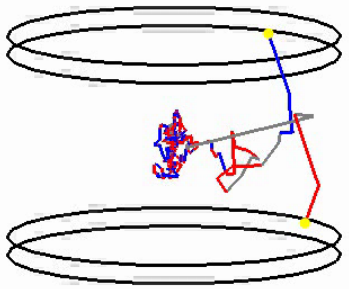
Phonon transport simulation in SuperCDMS Ge crystal



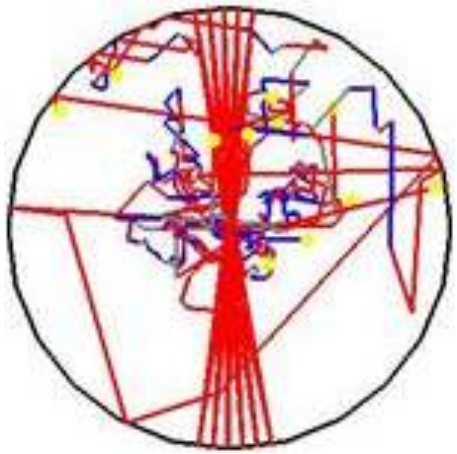
Down conversion

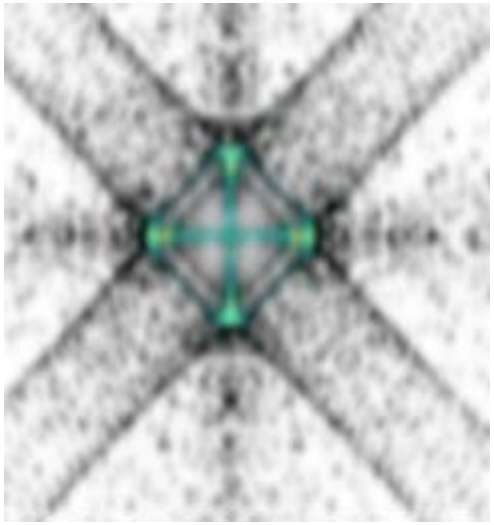


Scattering/Mode Mixing



Integrated

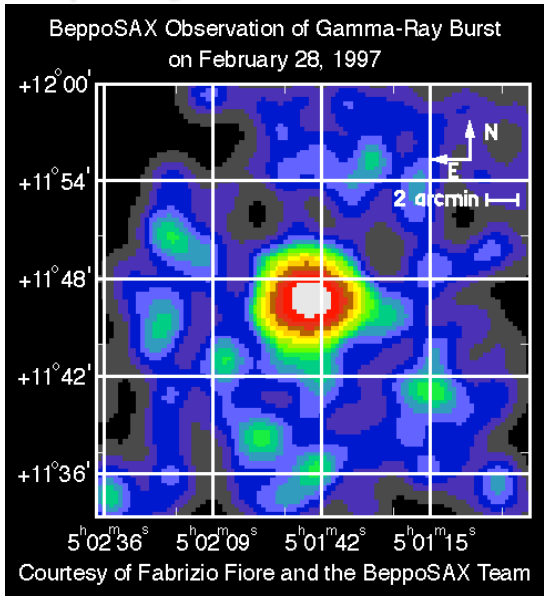


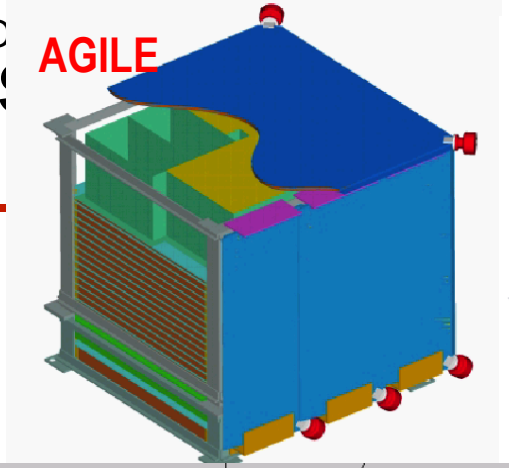


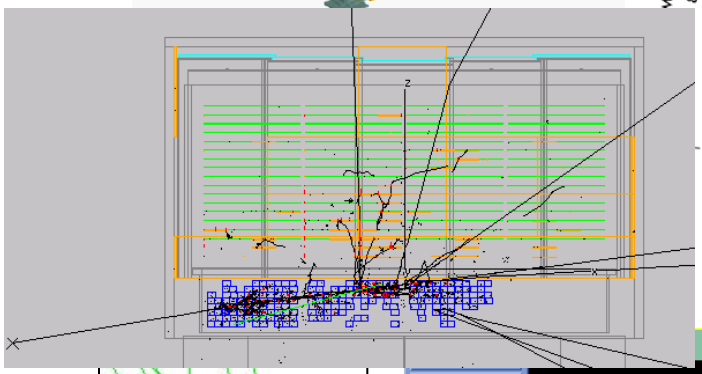
SuperCDMS phonon simulation (left) and simulated caustic pattern on Ge crystal (right)

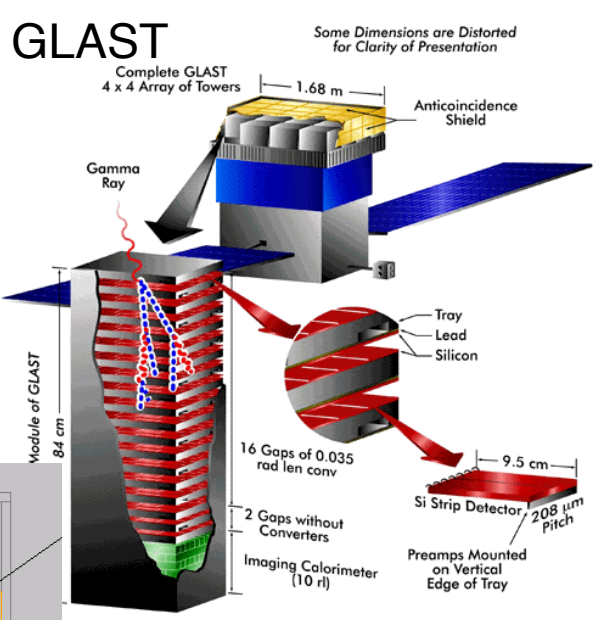
γ astrophys

γ-ray bursts

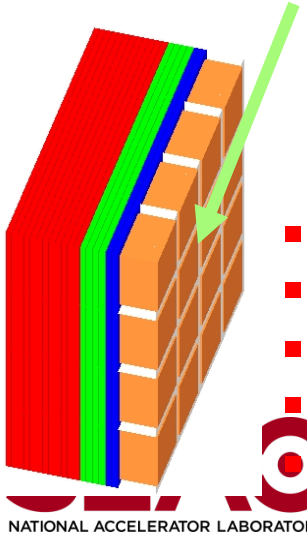






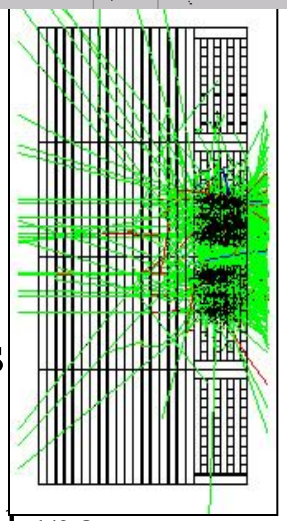


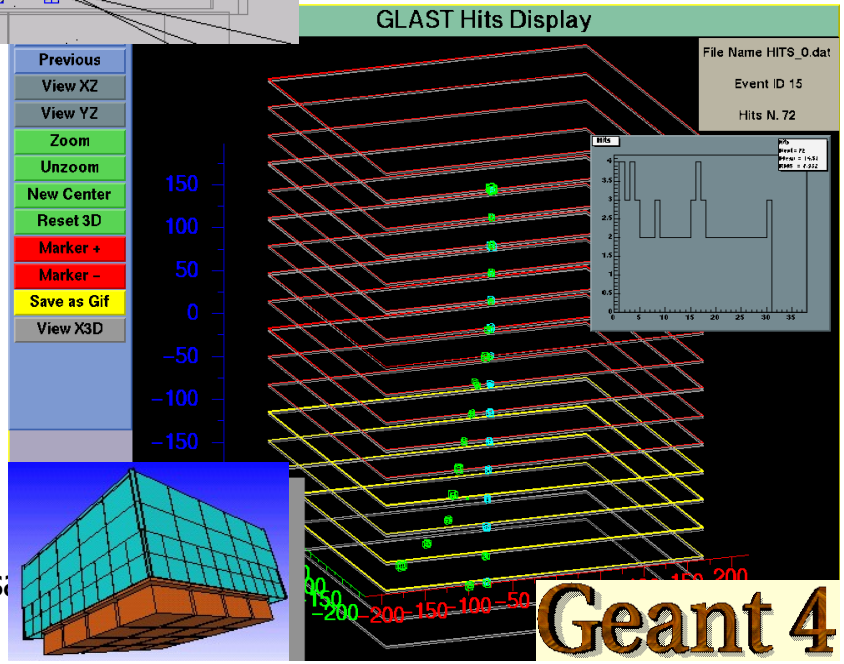
GLAST



Typical telescope:
Tracker
Calorimeter
Anticoincidence

- γ conversion
- electron interactions
- multiple scattering
- δ-ray production
- charged particle tracking



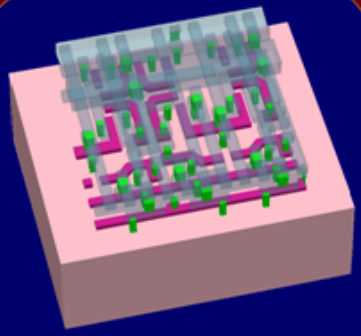


NATIONAL ACCELERATOR LABORATORY

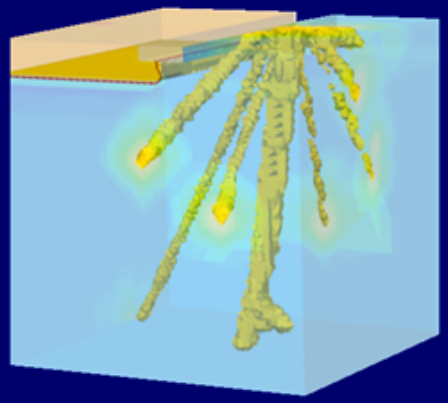
Geant4 project - M.As

Geant 4

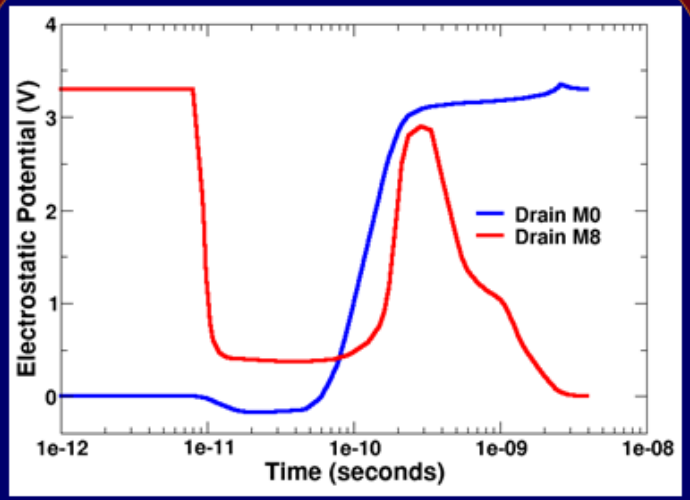
RADSAFE on SEE in SRAMs



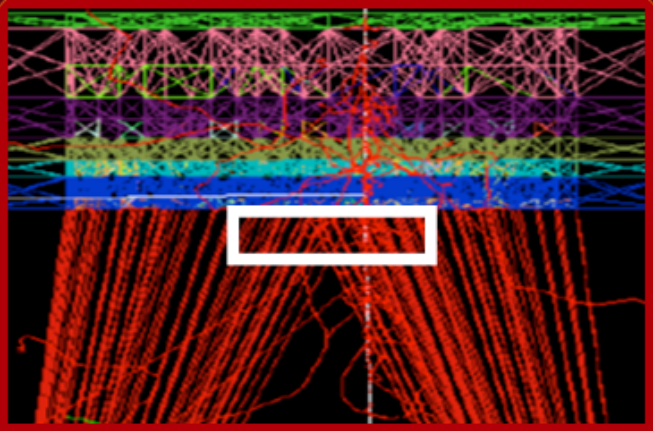
TCAD Cell Structure: SRAM Cell



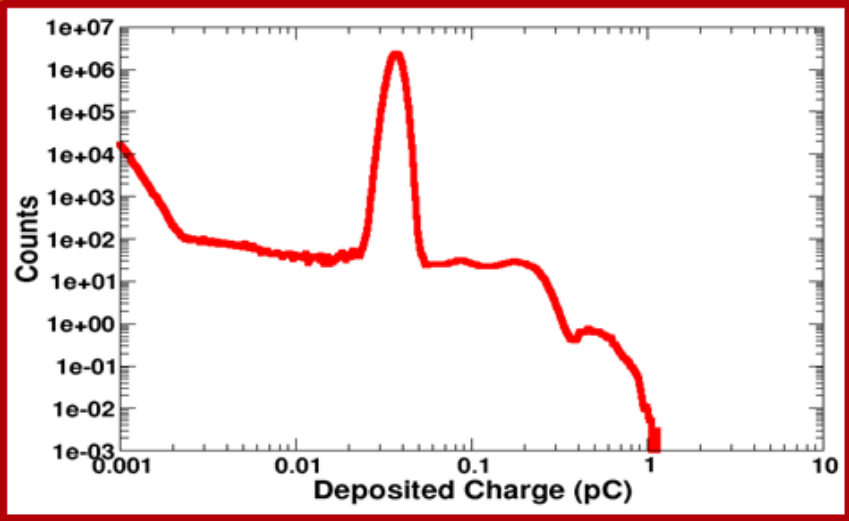
Single Charge Deposition in TCAD: Ne+W Event



SRAM Cell Upset

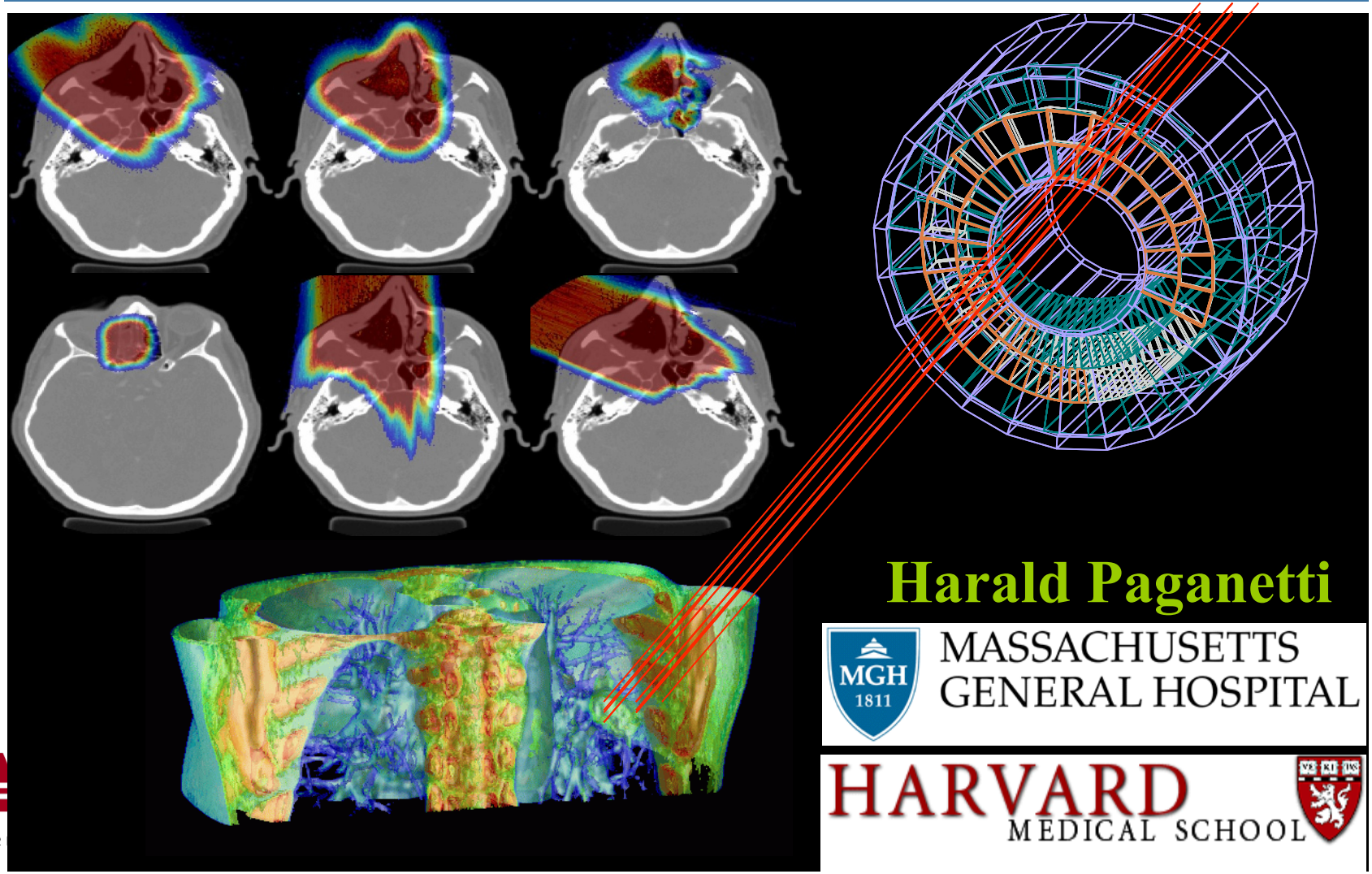


Geant4 Geometry and 523 MeV Neon Event



MRED Energy Deposition for 10^8 Events

GEANT4 based proton dose calculation in a clinical environment: technical aspects, strategies and challenges



Harald Paganetti

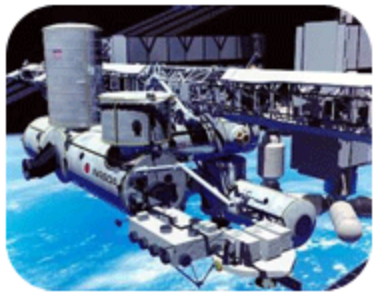
MASSACHUSETTS GENERAL HOSPITAL

HARVARD MEDICAL SCHOOL

SLA
NATIONAL ACCELERATOR

Geant 4

BOEING



Geant4 Space Users Workshop 2010

Conference Name:GEANT4 Space Users Workshop
Dates: Wednesday August 18 - Friday August 20, 2010
Location: Hilton Hotel Seattle Downtown, Seattle, WA
Point of Contact:Makoto Asai

Geant4 Space Users' Workshop –**G4SUWS**– is focused on new results on space radiation interaction with components, sensors and shielding analysis, as well as on Geant4-based tools and developments applicable to any Space mission. The workshop includes some working sessions and open discussions for topical collaborative efforts and for future plans.

The Geant4 particle transport toolkit is jointly developed by a world-wide Collaboration and is intended for a wide range of applications in HEP, medical field, and space physics and engineering. In recent years, space and astrophysics has become a significant user domain, with applications ranging from instrument and detector response verification to space radiation shielding optimization, component effects, support of scientific studies, and analysis of biological effects. The various domains include:

- Space electronics and Space Science detector systems.
- Single Event Effect analysis tools such as CRÈME-MC
- Simulations of astronaut radiation hazards.
- Planetary exploration applications.
- Interfaces and tools to space environment analysis tools such as SPENVIS.
- Cosmic ray magnetospheric propagation analysis.
- Microdosimetry.
- Large-scale simulations requiring event biasing and GRID capabilities.
- General shielding optimization applications.

This 7th GEANT4 Space Users' workshop follows events organized at

Home
Important Dates
Scientific Program
Abstract Submission
Social Events
Registration
Accomodation & Travel Info
Committees

For questions, contact:

Local Organizing Committee
or
Makoto Asai
SLAC National Accelerator Laboratory
2575 Sand Hill Road, Menlo

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   Journal of Physics and Chemistry of Solids, Volume 65, Issue 8-9, 1 August 2004, Pages 1501-1506
   Chong, K.P.
2. Geant4-a simulation toolkit • **Article**
   Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 506, Issue 3, 1 July 2003, Pages 250-303
   Agostinelli, S.; Allison, J.; Amako, K.; Apostolakis, J.; Araujo, H.; Arce, P.; Asai, M.; Axen, D.; Banerjee, S.; Barrand, G.; Behner, F.; Bellagamba, L.; Boudreau, J.; Broglia, L.; Brunengo, A.; Burk
3. Radiation pneumonitis and pulmonary fibrosis in non-small-cell lung cancer: Pulmonary function, prediction, and prevention • **Article**

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1 Citations: 133
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Authors: AGOSTINELLI S; ALLISON J; AMAKO K; APOSTOLAKIS J; ARAUJO H; ARCE P; ASAI M; AXEN D; BANERJEE S; BARRAND G; BEHNER F; BELLAGAMBA L; BOUDREAU J; BROGLIA L; BRUNENGO A; BURKHARDT H; CHAUVIE S; CHUMA J; CHYTRACEK R; COOPERMAN G; COSMO G; DEGTYARENKO P; DELL'ACQUA A; DEPAOLA G; DIETRICH D; ENAMI R; FELICIELLO A; FERGUSON C; FESEFELDT H; FOLGER G; FOPPIANO F; FORTI A; GARELLI S; GIANI S; GIANNITRAPANI R; GIBIN D; CADENAS JJG; GONZALEZ I; ABRIL GG; GREENIAUS G; GREINER W; GRICHINE V; GROSSHEIM A; GUATELLI S; GUMPLINGER P; HAMATSU R; HASHIMOTO K; HASUI H; HEIKKINEN A; HOWARD A; IVANCHENKO V; JOHNSON A; JONES FW; KALLENBACH J; KANAYA N; KAWABATA M; KAWABATA Y; KAWAGUTI M; KELNER S; KENT P; KIMURA A; KODAMA T; KOKOULIN R; KOSSOV M; KURASHIGE H; LAMANNA E; LAMPEN T; LARA V; LEFEBURE V; LEI F; LIENDL M; LOCKMAN W; LONGO F; MAGNI S; MAIRE M; MEDERNACH E; MINAMIMOTO K; DE FREITAS PM; MORITA Y; MURAKAMI K; NAGAMATU M; NARTALLO R; NIEMINEN P; NISHIMURA T; OHTSUBO K; OKAMURA M; O'NEALE S; OOHATA Y; PAECH K; PERL J; PFEIFFER A; PIA MG; RANJARD F; RYBIN A; SADILOV S; DI SALVO E; SANTIN G; SASAKI T; SAVVAS N; SAWADA Y; SCHERER S; SEIL S; SIROTENKO V; SMITH D; STARKOV N; STOECKER H; SULKIMO J; TAKAHATA M; TANAKA S; TCHERNIAEV E; TEHRANI ES; TROPEANO M; TRUSCOTT P; UNO H; URBAN L; URBAN P; VERDERI M; WALKDEN A; WANDER W; WEBER H; WELLISCH JP;

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Agostinelli S., Allison J., Amako K., Apostolakis J., Araujo H., Arce P., Asai M., (...), Savvas N.

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(2003) *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 506 (3), pp. 250-303.

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Nuclear Instruments and Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment (296)	Lees, J.P. (247)	2011 (4)	Istituto Nazionale Di Fisica Nucleare, Frascati (281)	Physics and Astronomy (1,655)
IEEE Nuclear Science Symposium Conference Record (244)	Aubert, B. (240)	2010 (308)	UC Berkeley (271)	Engineering (549)
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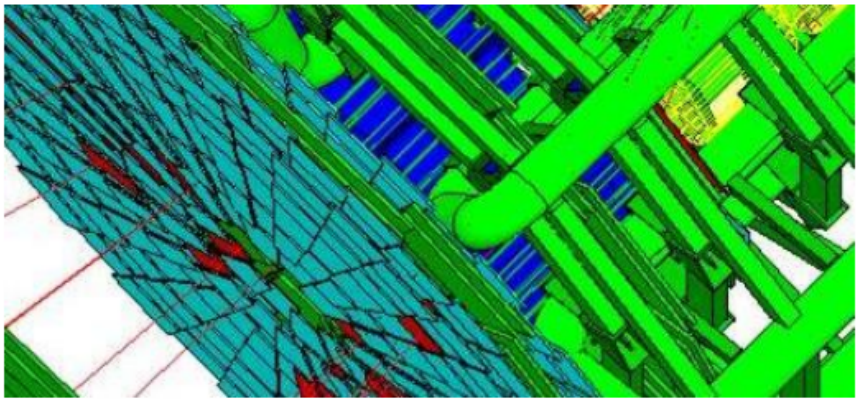

Geant4 at SLAC

Geant4 is a toolkit for the simulation of particles passing through and interacting with matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. Geant4 is developed and maintained by the international Geant4 Collaboration. Members of the SLAC Geant4 team have been actively participating in the Geant4 collaboration since its beginning, and currently take leading roles in several key areas of the collaboration. SLAC Geant4 members made significant contributions in simulation development for the BaBar experiment at SLAC, which pioneered the use of Geant4 in the simulation of high energy physics experiments. The SLAC Geant4 Team supports the use of Geant4 for on-site users including ATLAS, BaBar, Cryogenic Dark Matter Search (CDMS), Enriched Xenon Observatory (EXO), Fermi Gamma-ray Space Telescope, and International Linear Collider. The team also supports general Geant4 users of all application domains in North America and beyond.

News

- *Dec. 31, 2010* - Step by step installation guide is updated for Geant4 v9.4.
- *Dec. 16, 2010* - Geant4 version 9.4 is now available at SLAC standard installation.
- ***Dec. 16, 2010* - Geant4 version 9.4 is released.**
- *Dec. 15, 2010* - Registration for Geant4 / SWORD training workshop @ Oak Ridge is now open.

Events

- *Mar. 7-11, 2011* - Geant4 / SWORD training workshop @ Oak Ridge

Visitors

Visitors

2,850	234	99
638	220	79
363	184	71
357	148	65
342	146	63
257	103	59

FLAG counter

since Apr.24,2009

Activities of SLAC Geant4 Group – FY 2010

Geant4 Core	Other Group Activities
• Makoto Asai Elected Spokesperson	• ATLAS full simulation realized a 30% speedup (mainly from FY 2009 work)
• Geant4 Architectural Review	• Cleanup of ATLAS muon simulation – volume clashes etc. (mainly FY 2009)
• Bertini Cascade rewritten for physics and speed improvements	• ATLAS cavern background simulation (Geant4 geometry + Fluka physics)
• Development and maintenance of other hadronic and nuclear models	• CDMS simulation – especially germanium detector and phonons!
• Event biasing and scoring	• Ongoing support for BaBar and FGST simulation code
• Users' Workshops and outreach to new science areas	• Support for EXO, ILC and accelerator studies
• Extending/improving visualization	• NIH-funded proton therapy simulation (TOPAS)
	• Other externally funded space/medical projects (NASA(Vanderbilt), Varian …)

Activities of SLAC Geant4 Group – FY 2011

Geant4 Core	Other Group Activities
• Spokesperson and other leadership roles	• ATLAS – limited consultancy
• Develop plans for vital architectural improvements	• ATLAS cavern background simulation – maturing/decreasing effort
• Address (mainly hadronic) issues revealed by increasing LHC data	• CDMS simulation – especially germanium detector and phonons!
• Upgrading Bertini and radioactive decay	• Ongoing support for BaBar, FGST, EXO and ILC simulation code
• High-precision neutron code maintenance and improvement	• Ongoing support for LCLS, LCLS shielding
• Event biasing and scoring	• NIH-funded proton therapy simulation (TOPAS)
• Users' Workshops and outreach to new science areas	

SLAC Geant4 Group – Core Activities FY 2011

Activity		SLAC efforts	Richard Mount	Makoto Asai	Dennis Wright	Tatsumi Koi	Joseph Perl	Mike Kelsey	Norman Graf	Administrative Support
Geant4 Spokesperson		40.0%		40%						Included in Program Support
Hadonics	Leadership of G4 hadronics	10.0%			10.0%					
	RPG/LEP/HEP models	10.0%			10.0%					
	Bertini model	47.0%			10.0%			37.0%		
	CHIPS model	3.0%			3.0%					
	HP Neutron and its alternative models	30.0%				30.0%				
	QMD model	7.0%				7.0%				
	HadronicValidation	4.0%			4.0%					
	New Models and Features									
Electromagnetics										
Kernel	Leadership of G4 kernel	10.0%		10.0%						
	Event biasing	20.0%		5.0%		5.0%		10.0%		
	Scoring	5.0%		5.0%						
Geometry										
Performance	Profiling for speed/memory improvement									
	Code Robustness and QA (reviews)	10.0%		5.0%	5.0%					
Documentation		10.0%			5.0%	5.0%				
Visualization		10.0%					10.0%			
Outreach to new science areas		31.0%	2.0%	5.0%	3.0%	3.0%	15.0%	3.0%		
Project Management		13.0%	3.0%	10.0%						
Totals per person for FY 2011		**260.0%**	**5.0%**	**80.0%**	**50.0%**	**50.0%**	**25.0%**	**50.0%**	**0.0%**	
Total Staff Cost (incl benefits and overhead)		759								
M&S (desktops etc.) fully burdened $k		8								
Travel ($50k from 2010 experience + $10k for Spokesperson role) fully burdened		91								
Total Cost $k		**858**								

Collaborative efforts with other domains

- The SLAC Geant4 group actively promotes "outreach" to non-SLAC or non-HEP domains (space, medicine and related industries):
  - One or two workshops or tutorials each year (participation of HEP-funded staff)
  - SLAC work on specific collaborative applications (e.g., medicine/Harvard, industry/Varian, space/Vanderbilt) funded at no cost to HEP
  - Not yet receiving non-HEP US funding for core Geant4, but this remains a goal (in Europe ESA does fund core Geant4)
  - Benefits, to HEP, of being seen to contribute valuable technology are real, but hard to quantify in dollars.