

Geant4 toolkit for simulation of HEP experiments

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From name of Geant4 collaboration

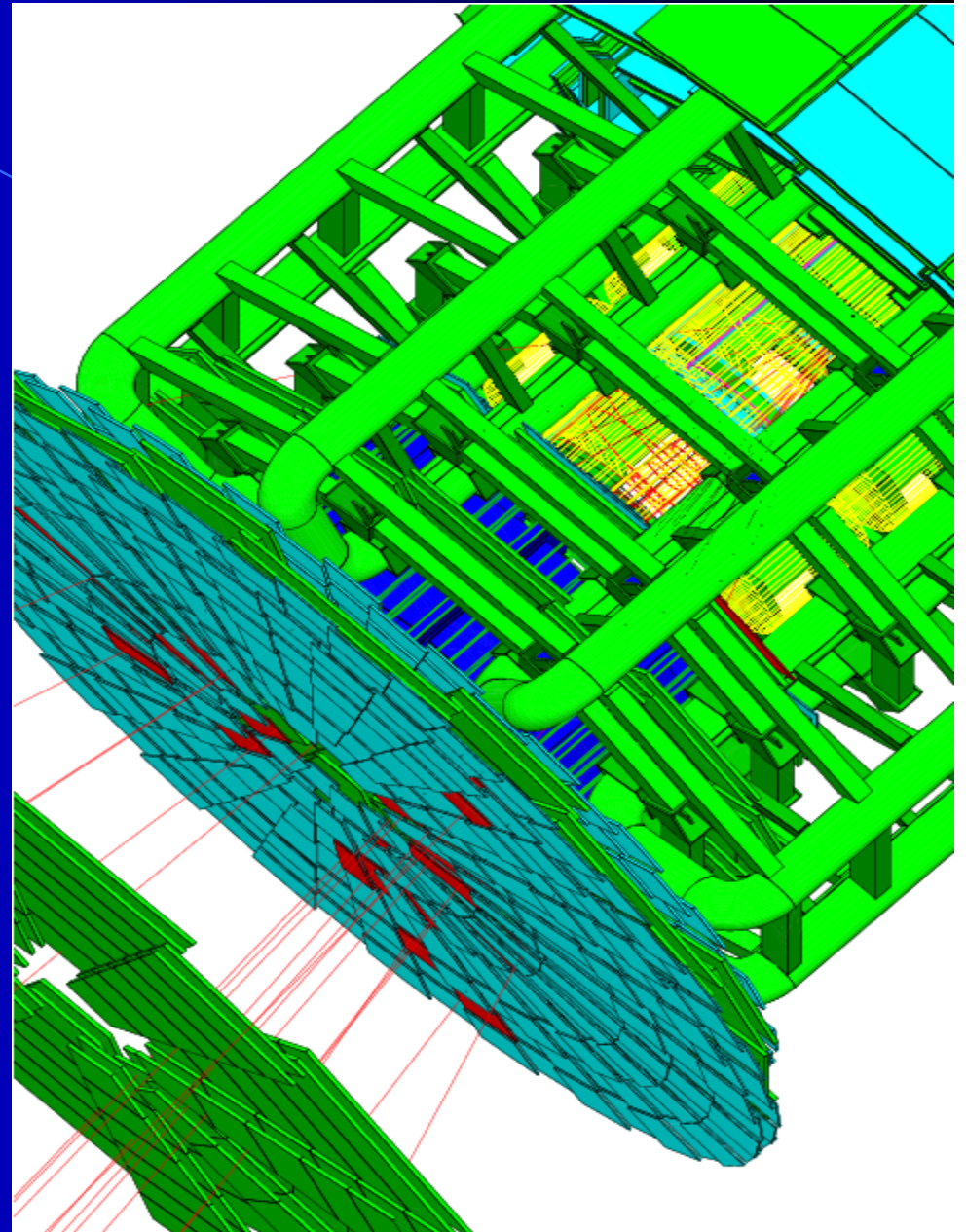
BINP, Novosibirsk, Russia

&

CERN, Geneve, Switzerland

Outline

- Geant4 history
- Design and tools
- Geant4 physics
- June 2002 release
- Prospects for future



History

- 90th: About 100 FORTRAN MC programs in the world. The most popular in HEP GEANT3.
- R&D project start in 1994 to develop a detector simulation toolkit for HEP
- Software Engineering, OO technology, and c++
- World-wide collaboration
- Requirements from:
 - LHC
 - heavy ions, CP violation, cosmic rays, medical and space science applications

History

- 1995 – prototype
- 1997 – alpha-version (main functionality)
- Dec '98 - Geant4 0.0 release
- Geant4 collaboration was created
- ...
- Dec '01 – Geant4 4.0 release
- June '02 – Geant4 4.1 release

Working Groups

- For G4 subdomains

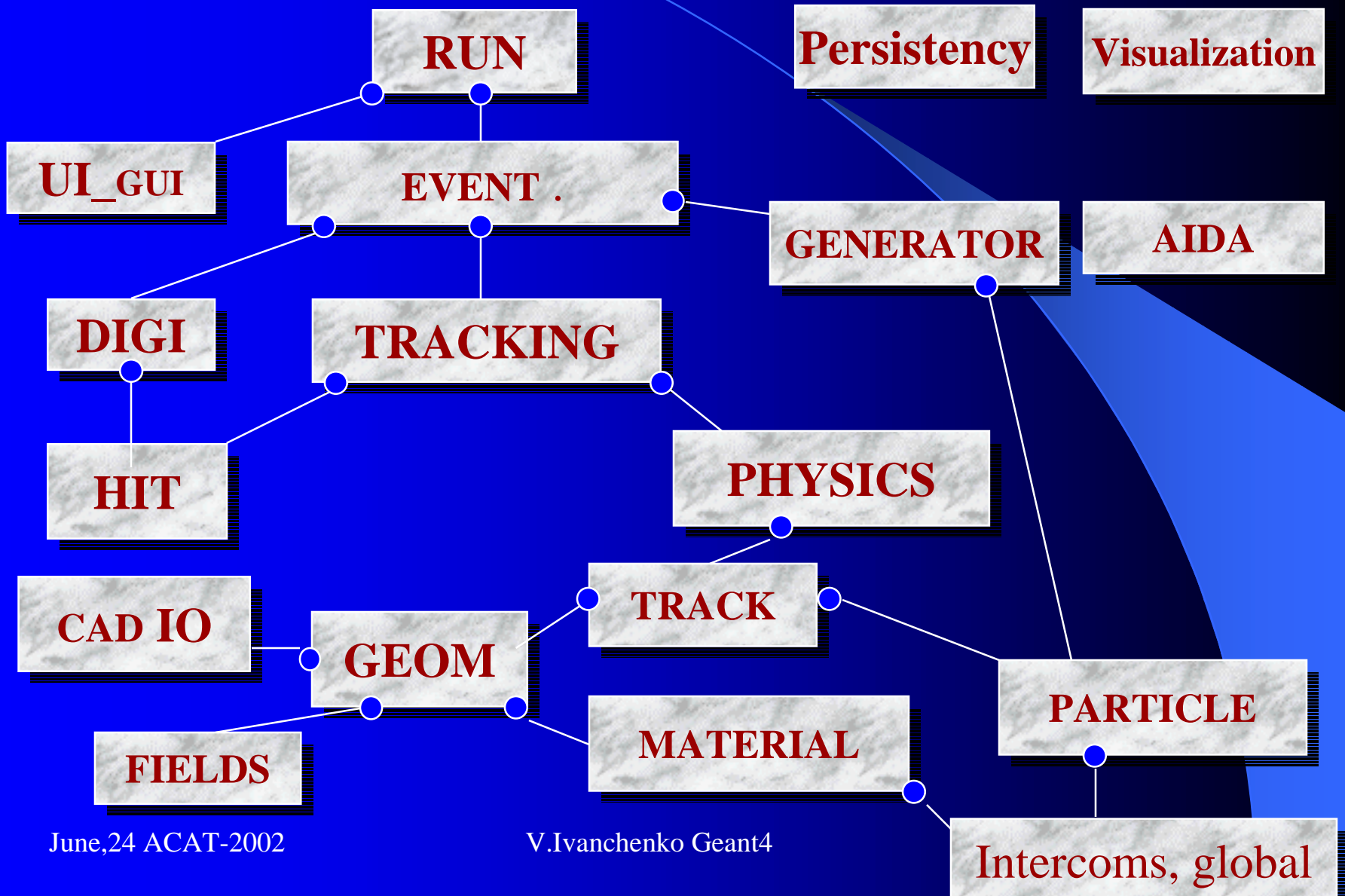
- Run, Events & Detector Response
- Tracking
- Geometry & Transportation,
- Generic Processes & Materials
- Hadronic Physics,
- E.M. Physics (“Standard”),
- Low Energy EM Physics (since 2000)

- User and Category Interfaces
- Visualization

- For software:

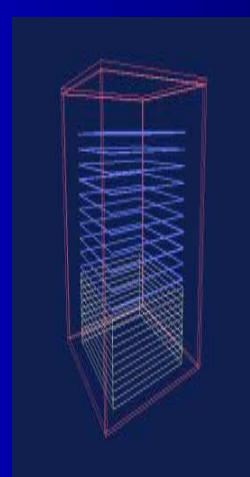
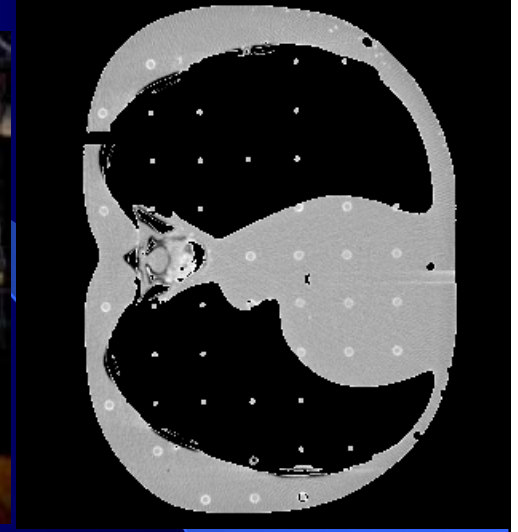
- Software Management
- Testing & QA
- Documentation Management

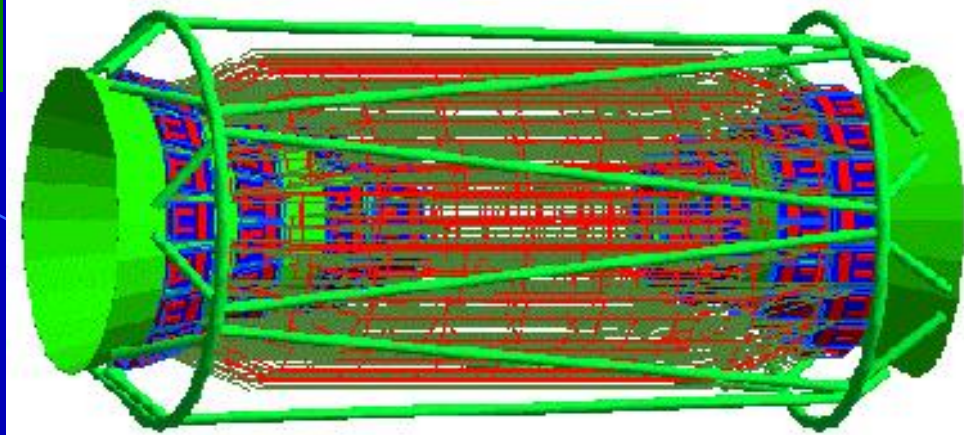
Class Category Diagram



Geant4 physics

- Main goal of G4 is good physics
- To achieve the goal OO approach is fundamental
- Independent, alternative physics models
- Existing components are integrated and new model continue to be developed



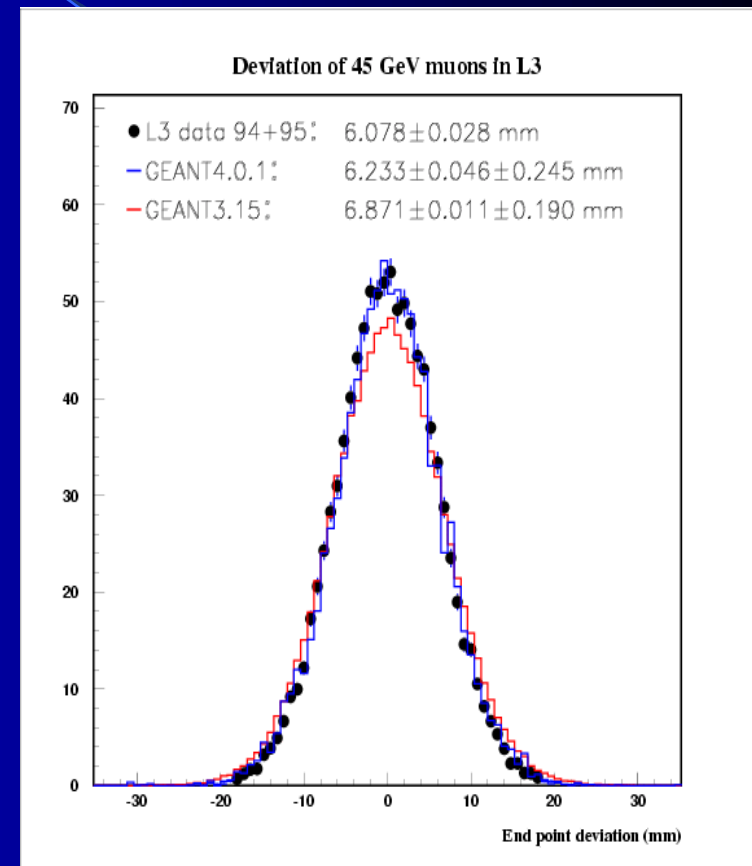


G4 processes

- Physics is described via abstract interface called *process* associated with *particles*
- Distinction between process and model – one process may includes many models
- Generation of final state is independent from the access and use of cross sections and from tracking
- Transparent access to cross sections and secondary generators
- Use of public evaluated databases

G4 processes

- Standard interface: a process provides *Interaction Lengths*, *StepLimits*, and *DoIt* methods
- Processes active *AlongStep*, *PostStep*, *AtRest*
- There are following processes:
 - ☀ Electromagnetic
 - ☀ Hadronic
 - ☀ Decay
 - ☀ Optical
 - ☀ Transportation
 - ☀ Parameterized



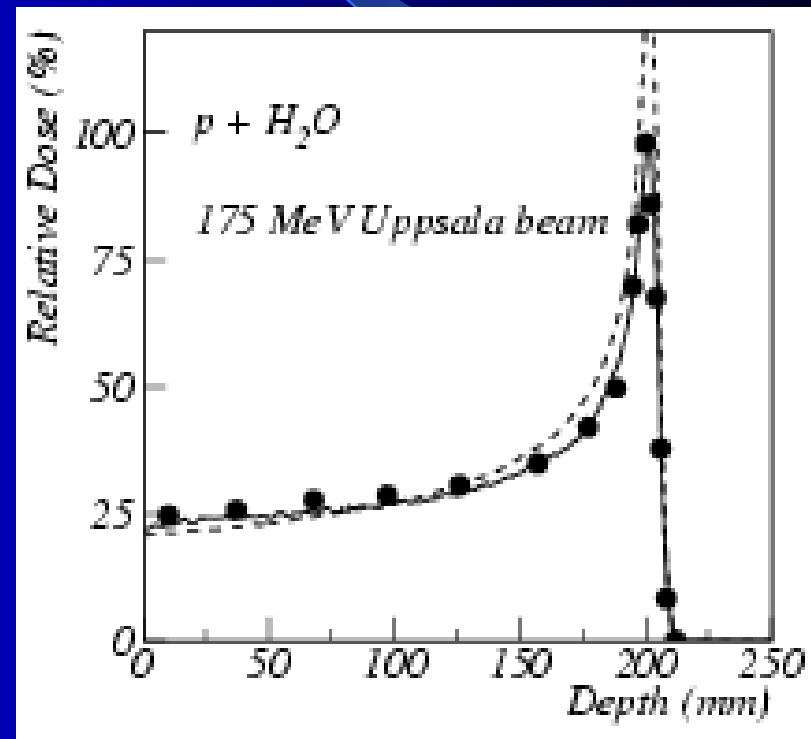
Electromagnetic physics

● Subcategories:

- Muons
- Lowenergy
- Standard
- Xrays

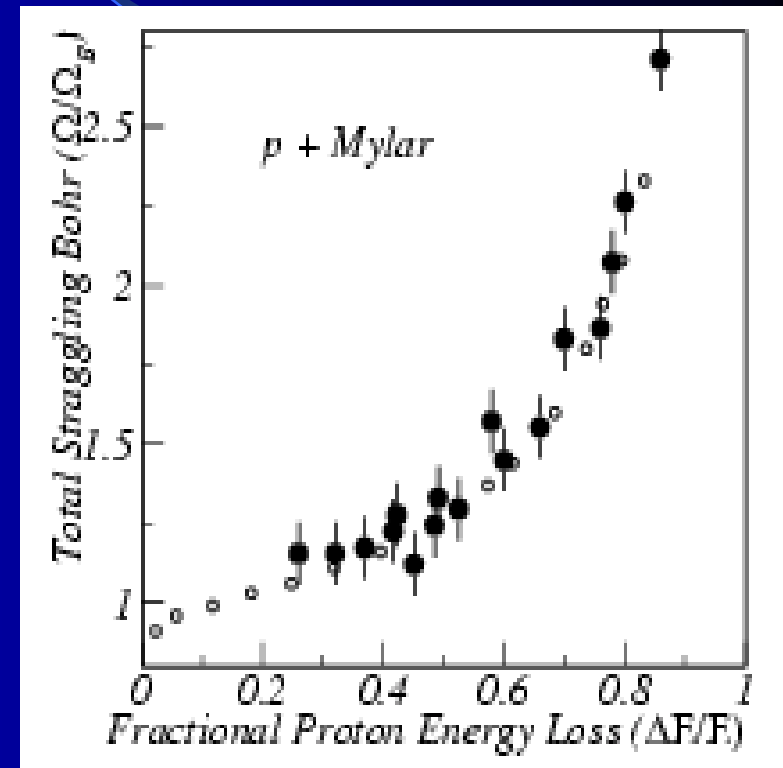
● Main processes:

- Ionisation
- Bremsstrahlung
- Multiple Scattering
- Gamma Conversion
- Compton Scattering
- Photoelectric effect
- Synhrotron radiation
- Transition radiation
- Cherenkov radiation
- Rayleigh effect



Geant4 cuts

- No tracking cuts, only production thresholds
- Default G4 – thresholds for production secondaries are expressed in range, universal for all media,
 - Range 10 keV gamma in Si ~ 2 cm
 - Range of 10 keV electron in Si ~ 2 microns
- Energy thresholds for a material is calculated from this cut in range.
- In 2002 a possibility to set a cut by logical volume will be implemented

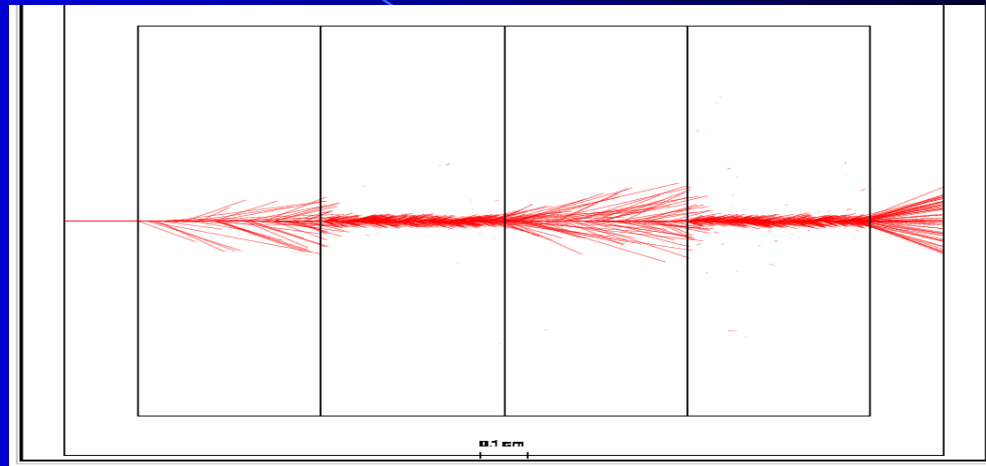


G3/G4 cuts in Pb/Ar calorimeter

Protons 500 MeV

G3

Cut 450 keV

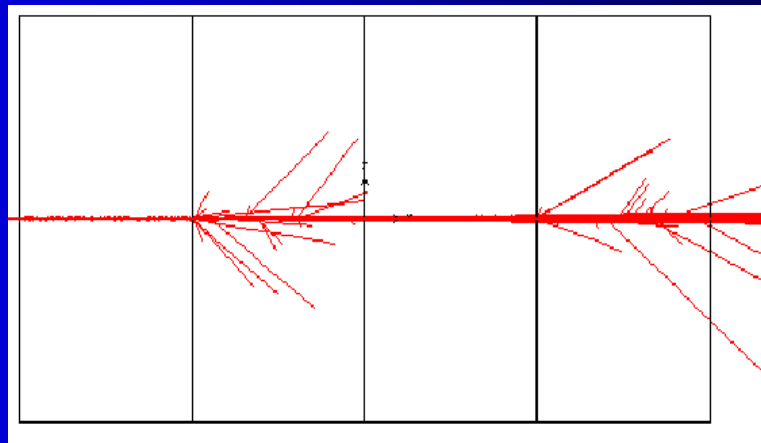


Ar Pb Ar

G4

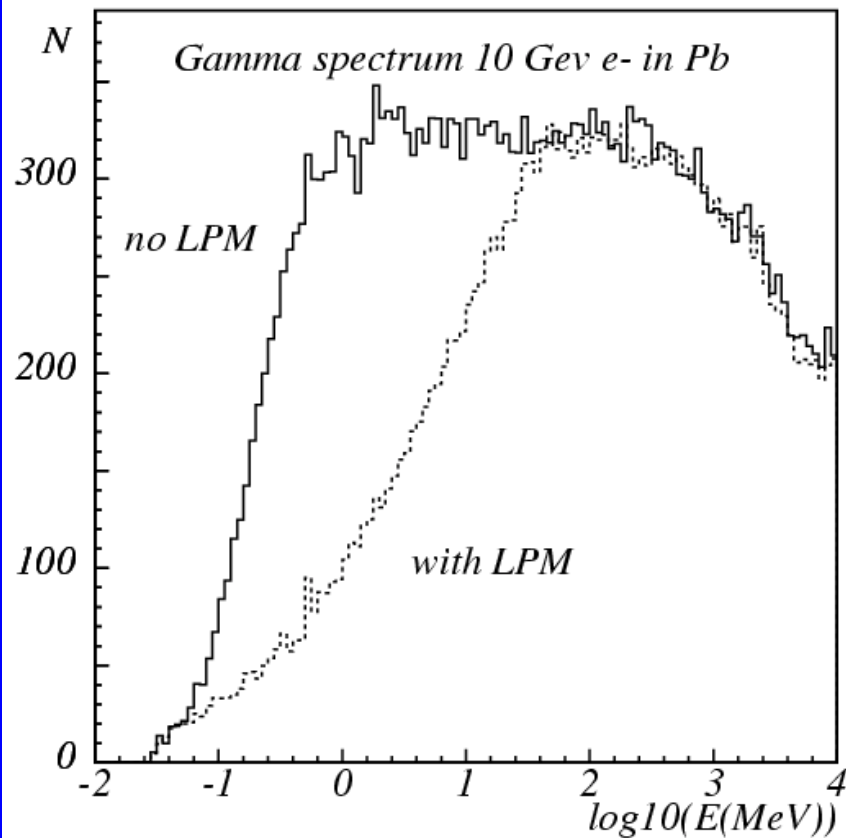
1.5 mm - 450 keV LAr

2 MeV Pb

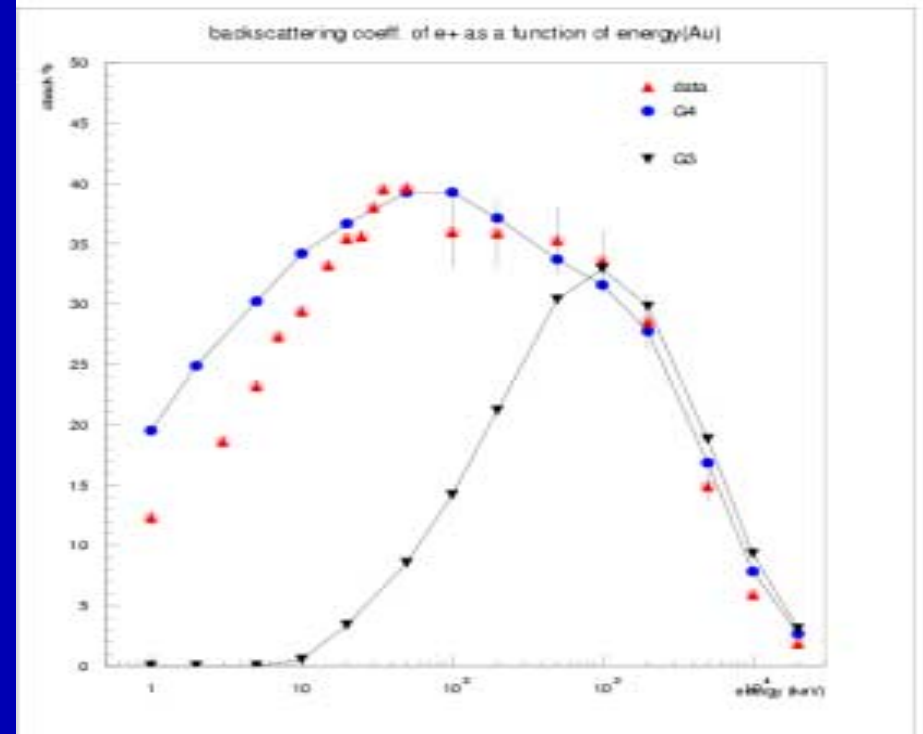


G4 electromagnetic physics

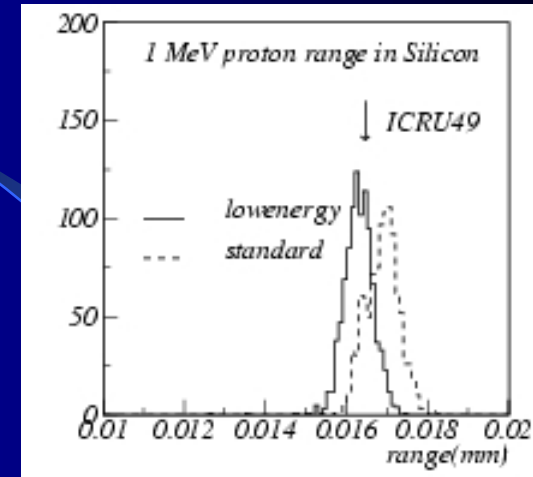
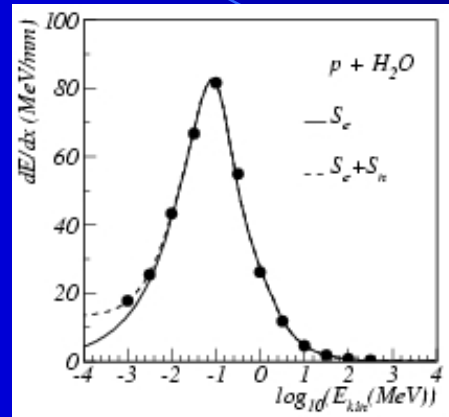
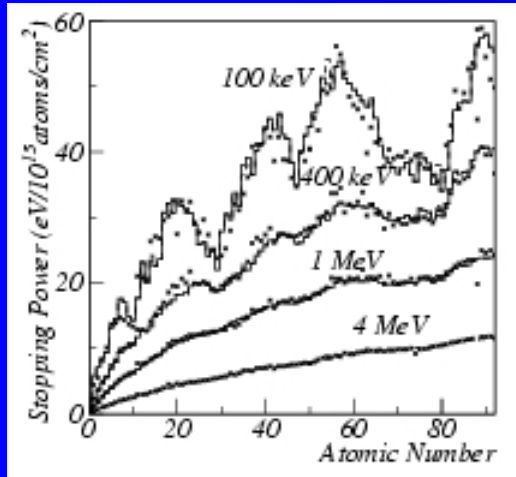
LPM effect for Bremsstrahlung



Electron backscattering

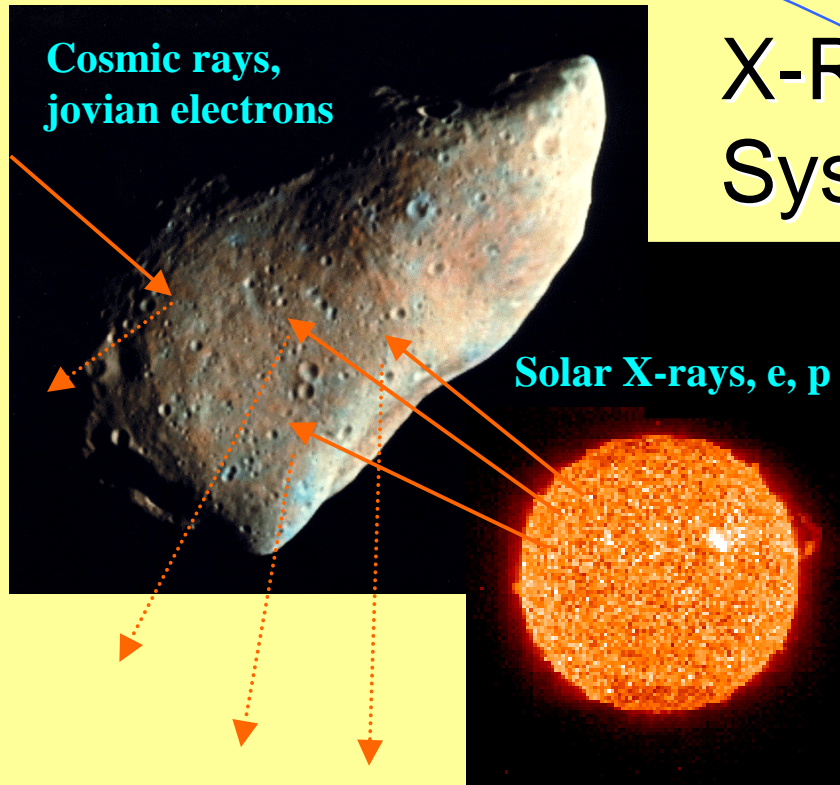


Low energy EM physics



- Low energy EM physics required using detailed information about atomic shells
- Instrumentation studies, space, and medical applications
- Cross sections and energy spectrums are taken from EEDL, EADL, EPDL, ICRU, and others databases
- The state of media (solid, liquid, gas) and chemical structure is taken into account

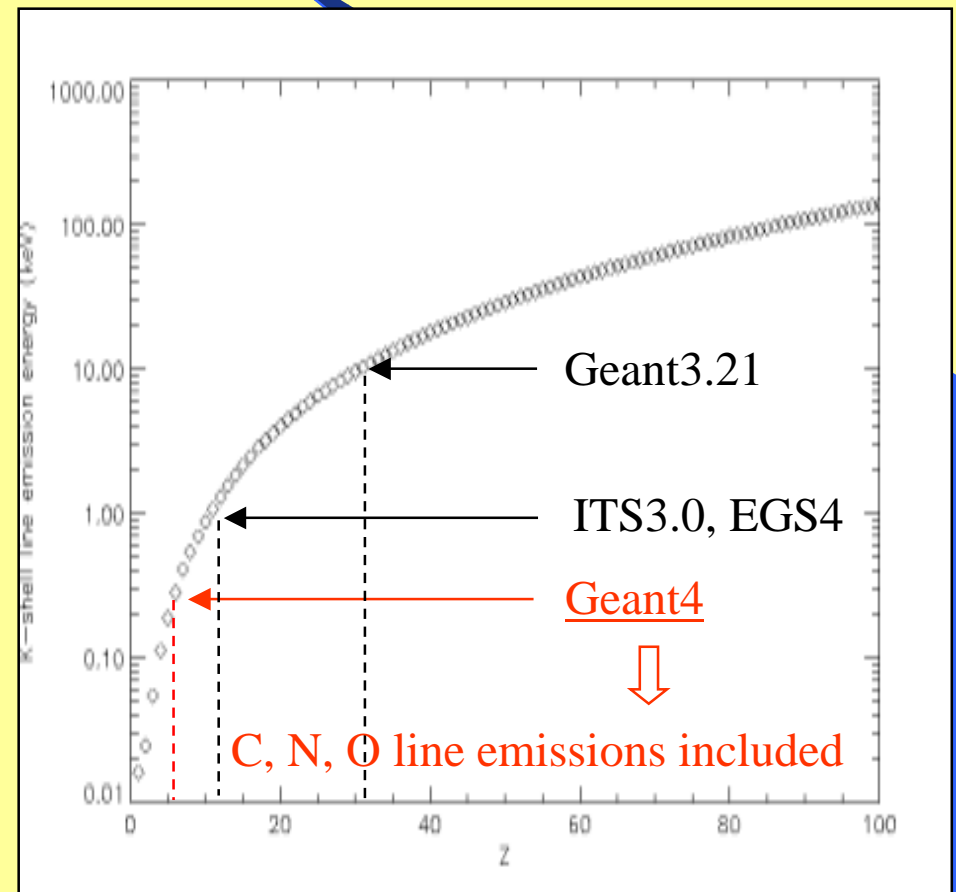
Geant4 space applications



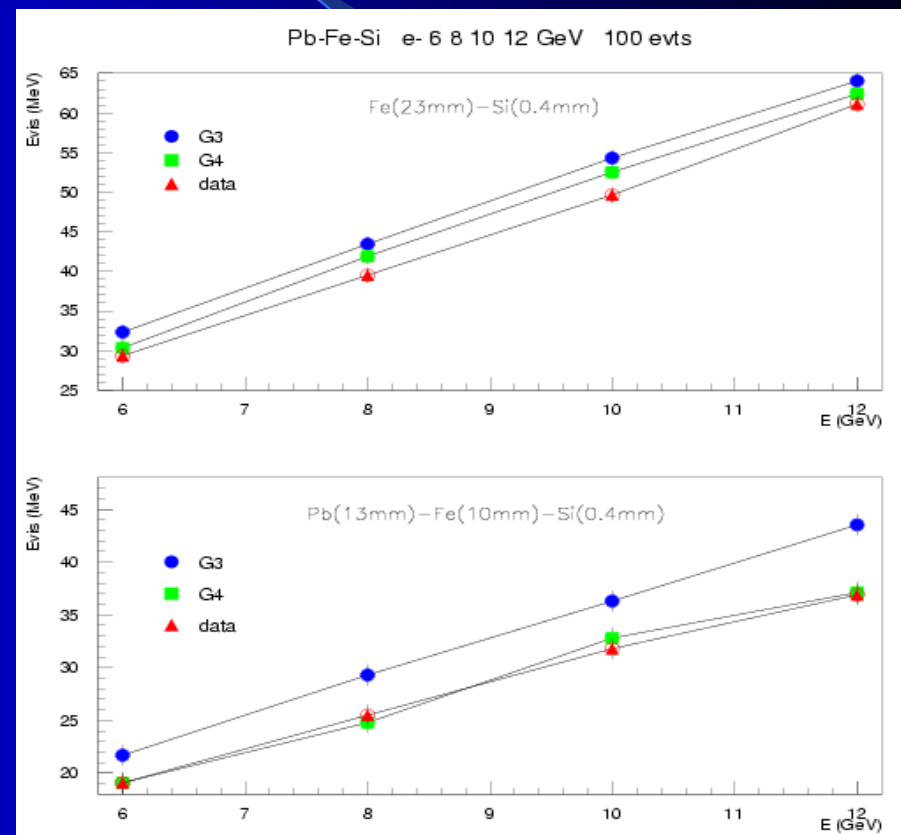
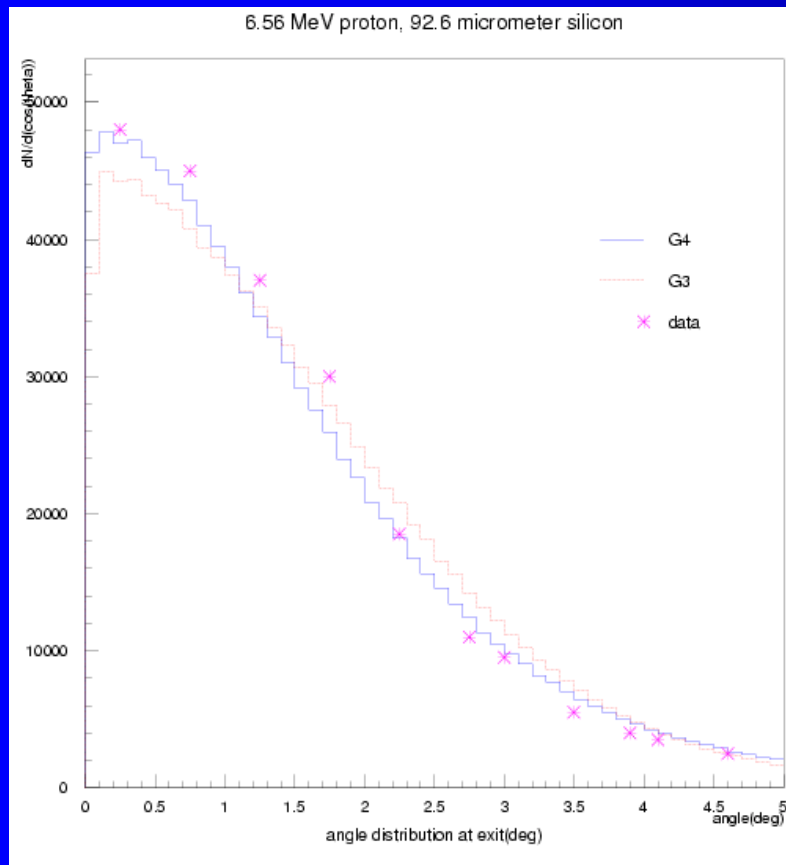
Courtesy SOHO EIT

X-Ray Surveys of Solar System Bodies

Induced X-ray line emission:
indicator of target composition
(~100 μm surface layer)

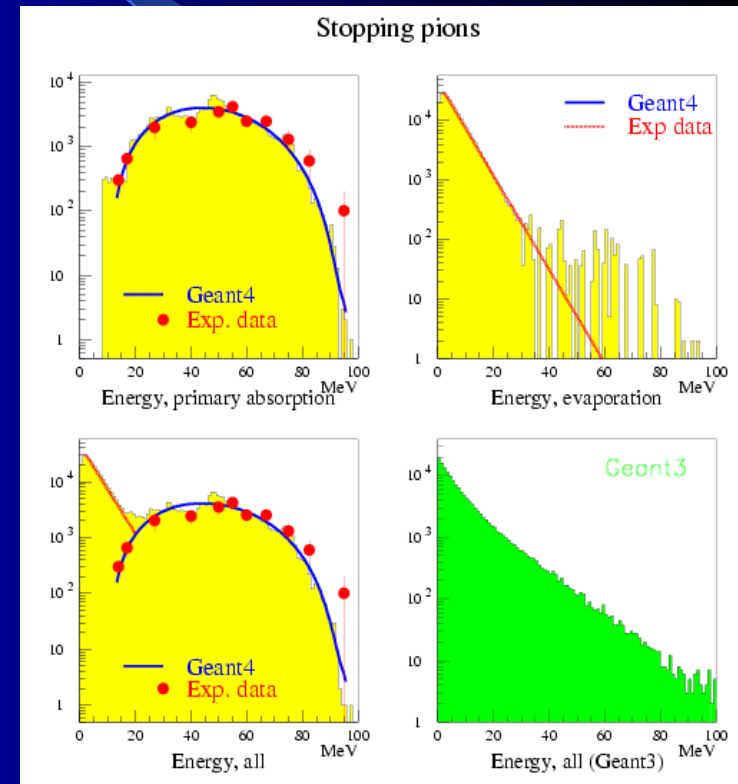


G3/G4/Data comparison



G4 hadronic processes

- Model approach – cross sections and secondary generation are separated.
- Based of evaluated data libraries: ENDF, Jef, EFF, JENDL, FENDL, CENDL, ENSDF, Brond, and MENDL.
- Following models are exist now:
 - Elastic
 - Cascade
 - Chiral_inv_phase_space
 - Pre-equilibrium
 - High_energy parameterized
 - Low_energy parameterized
 - Isotope_production
 - Neutron_hp
 - Stopping
 - Radiative_decay



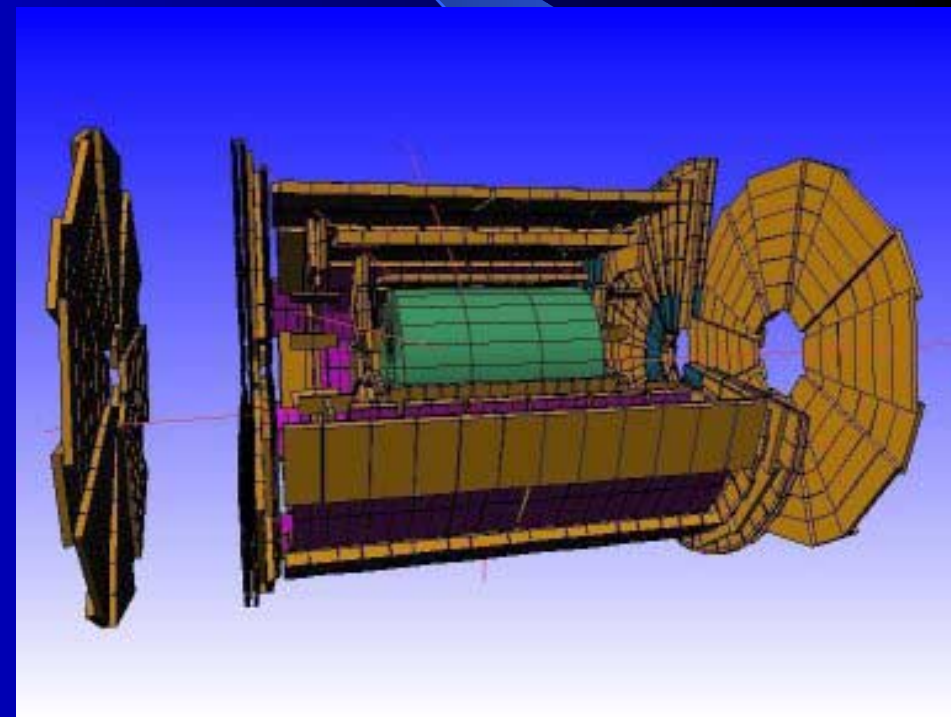
G4 hadronic processes

- The set of models provides simulation of neutron transport, elastic and inelastic nuclear interactions of photons, leptons, and hadrons
- Results of comparison project, for example ATLAS pion testbeam (A.Kiryunin, Calor'2002), demonstrates reasonable agreement with G4 predictions
- All details about G4 hadronic in talks of J.P.Wellisch and M.Kosov

Status of G4 HEP applications

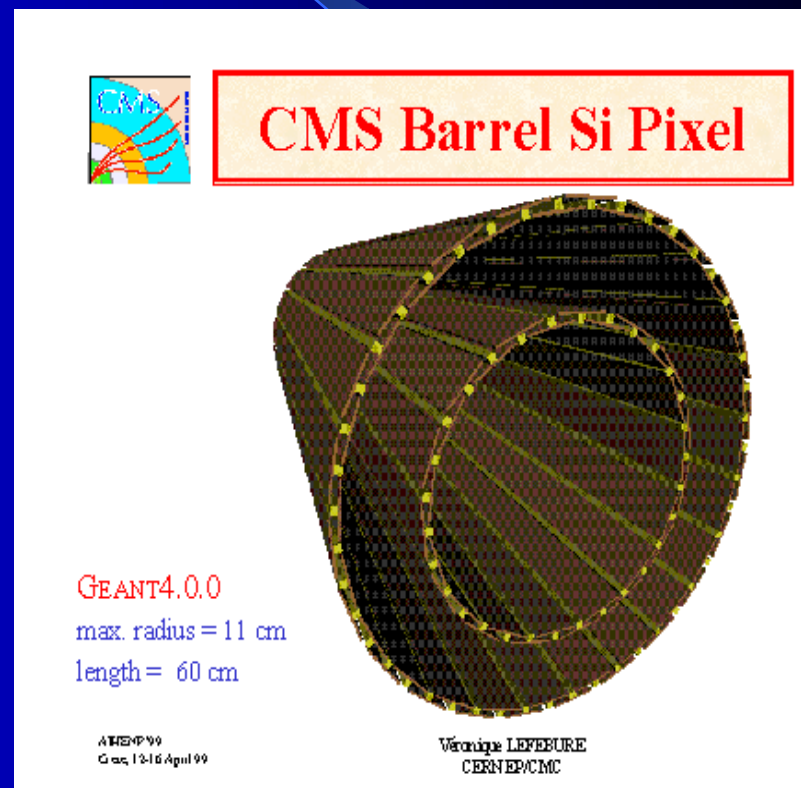
ATLAS

- In 2001 BABAR dropped G3 and is using G4 for production, $>3 \cdot 10^8$ events are generated
- GLAST accept G4
- ATLAS – geometry, transition radiation, accordion type calorimeter, comparison projects



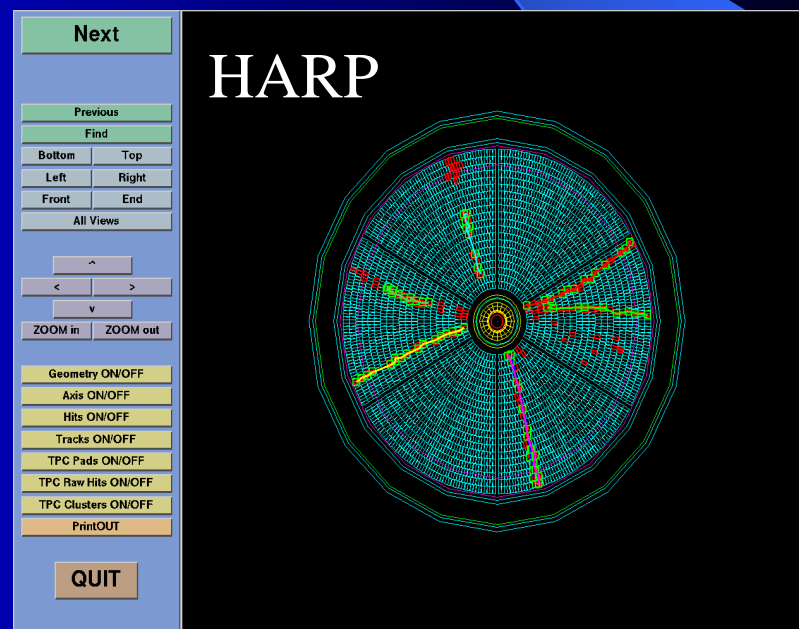
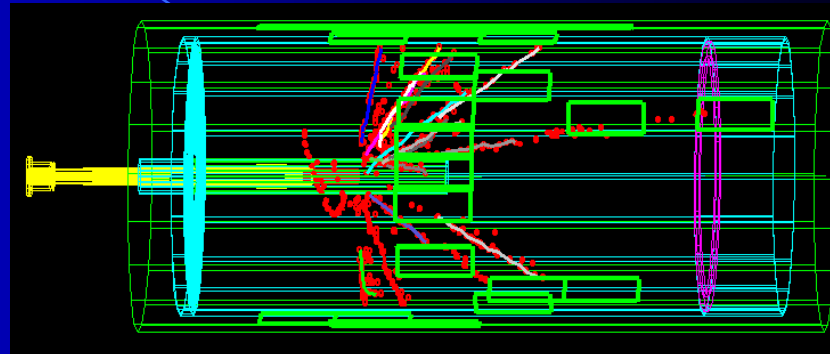
Status of G4 HEP applications

- CMS – geometry is ready, production is planned for 2002
- ALICE – comparisons of hadronic physics
- LHCb – Gaudi framework, geometry, Airogel detailed model
- TESLA - R&D / detector optimization



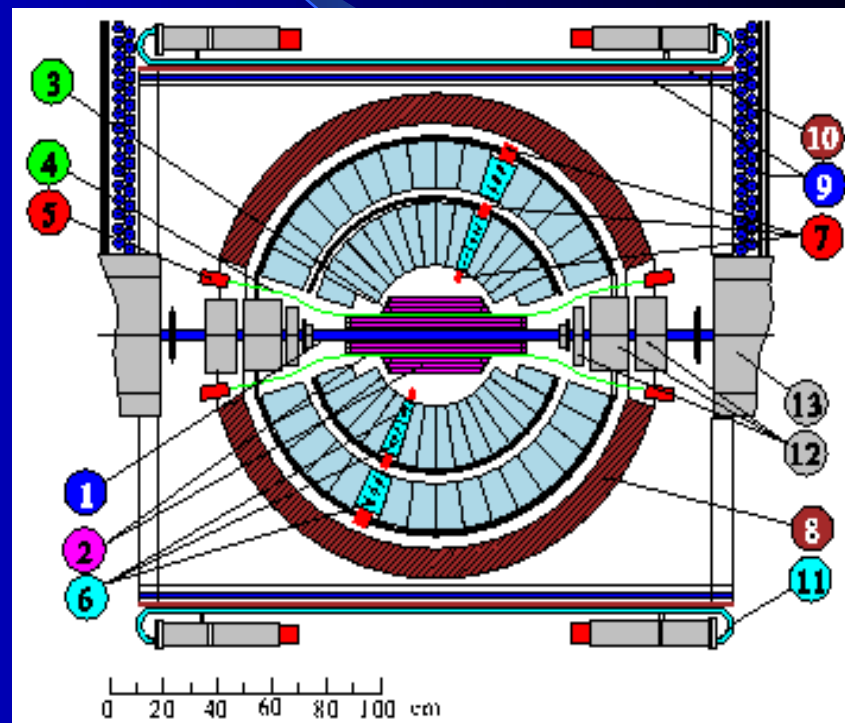
Status of G4 HEP applications

- HARP (CERN) is based on G4, TPC detailed study, validation of hadronic models, T9 beam line simulation
- BTeV – testbeam
- FNAL – R&D on muon beam transport and muon culling
- ... others



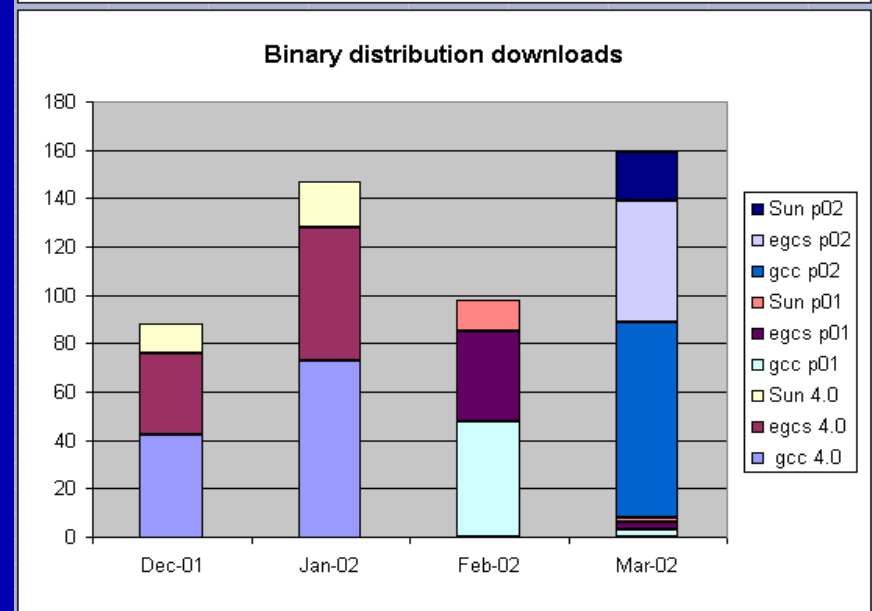
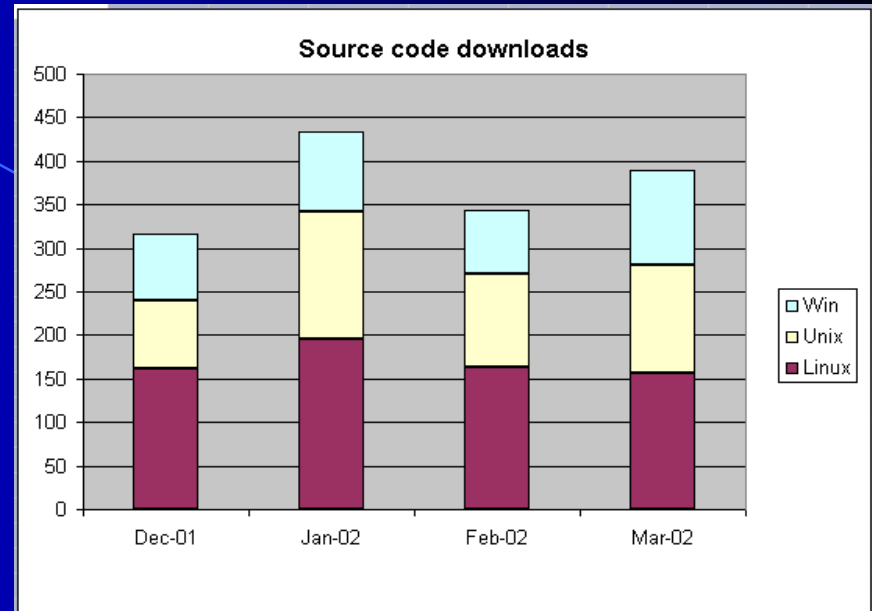
Geant4 in Novosibirsk

- Optimization of detectors for medicine
- SND at VEPP-2000 required transition UNIMOD2 → G4
- R&D on detailed model of tracker
- Comparison of G4 and SND data for π , K



User support

- Two public releases per year
- Intermediate releases available for G4 members and for beta-testers
- About 30 integration tests and about 20 examples
- Regression suit in progress
- HyperNews system (SLAC)
- Automatic bug report system
- Documentation review



June'2002 release

- GDML: consolidate implementation of XML browser
- Parameterized 3D voxelisation
- Consolidation of solid/volume reflections
- Gamma into muon pair conversion
- Updated multiple scattering
- Ionisation for fragments
- Auger effect
- MARS-13 re-write – leading particle biased code for energies below 5 GeV
- Include heavy fragments to evaporation
- Update of gamma – nuclear and electro-nuclear cross sections/ models

Future perspectives

- Cut per region – key design iteration for LHC
- Design iteration in EM processes
- New electromagnetic processes for TeV energies
- Improvement of low energy EM models
- Continued improvement of hadronic models
- Providing ‘educated guess’ physics lists for major use-cases (like LHC detector simulation)
- Validation of G4 physics – first priority
- Close collaboration with HEP experiments