Geant4 for HEP detector simulation

Highlights of Geant4's capabilities and recent developments

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Outline

1. Brief introduction to Geant4
2. A quick tour of Geant4
3. The collaboration

Apologies: Collaboration Meeting is tomorrow, and the request was in the last 10 days

Part 1

Introduction

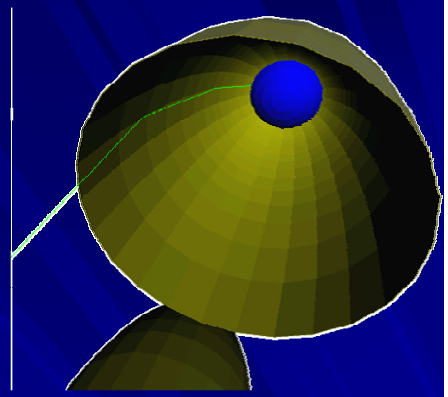
Context

Toolkit structure

GEANT 4 introduction

- Detector simulation tool-kit for HEP
  - offering alternatives, allowing for tailoring
- Software Engineering and OO technology
  - provide the method for building, maintaining it.
- Requirements from HEP & other domains:
  - LHC, heavy ions, CP violation, cosmic rays
  - medical and space science applications
- World-wide collaboration
  - RD44 1994-1998
  - MoU 1999-today

Geant4 Overview



- Powerful structure and kernel
  - tracking, stacks, geometry, hits, …
- Extensive & transparent physics models
  - electromagnetic
  - hadronic
  - decay, optical, …
- Interfaces
  - visualization, GUI, persistency.
- Efficiency enhancing techniques
  - Framework for fast simulation (shower parameterization)
  - Variance reduction / event biasing

Part 2

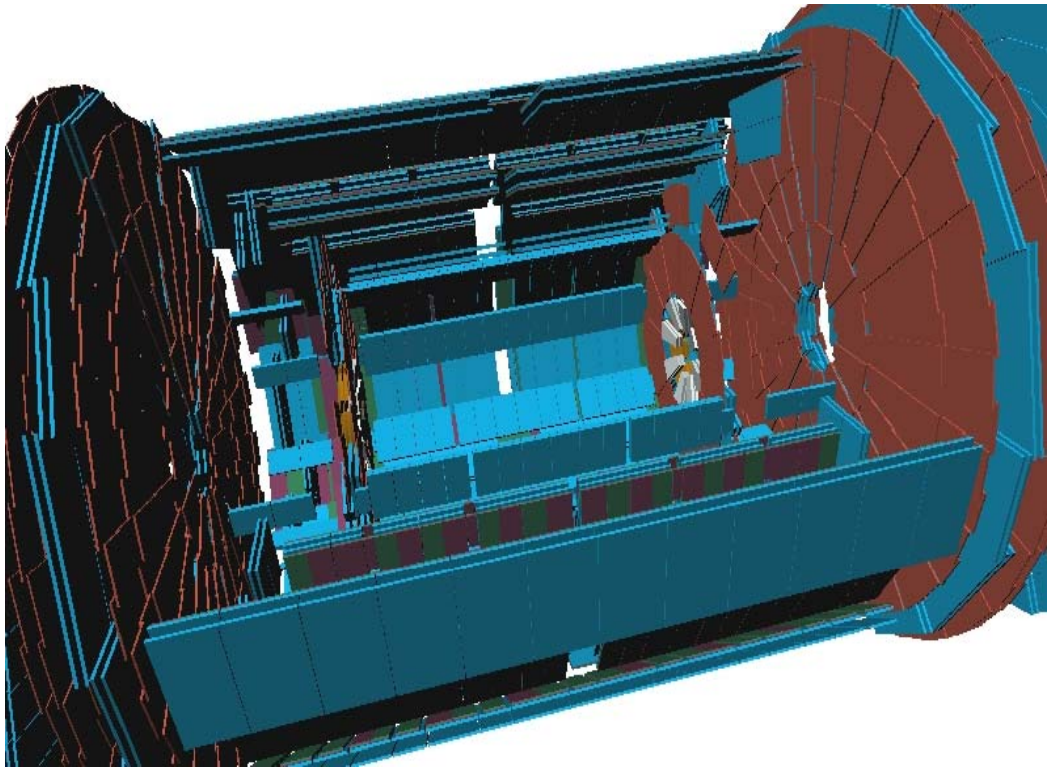
A quick tour of the Geant4 toolkit

Geant4 General Notes

- Geant4 is an object-oriented C++ toolkit
  - the goal is to provide all that is needed to build a wide variety of physics simulation applications
    - range of physics models,
    - tracking, geometry hit collection and scoring
    - and auxiliary components
  - code is open, modular – available for all to download
    - Anyone can inspect, understand, tailor, revise, … improve.
  - extensive documentation and tutorials provided
- Principal references:
  - NIM A506, 250 (2003) and IEEE Trans. Nucl. Sci. 53, 270 (2006)

Geant4 Geometry

- Extremely versatile
- Large number of volume shapes (CSG + BREP)
- Hierarchical combination of volumes
- Materials
  - isotopes, elements, compounds, phase, temp
  - user-created or use NIST database



Further capabilities

- External EM fields affect charged particles
- Tracks ‘hit’ user-written detectors
- Scoring radiation observables
- Event biasing

- Auxiliary capabilities
  - Visualisation via several systems
  - Input/Output (‘persistency’) for geometry, events

Physics Choices and ‘Physics Lists’

- User has the final say on the physics chosen for the simulation. He/she must:
  - select the relevant particles and physics processes from those provided, for each particle type
  - validate the selection for the application area
- ‘Physics Lists’ represent this collection
- Deciding or creating the physics list is the user's responsibility
  - reference physics lists are provided by Geant4
    - are continuously-tested and widely used configurations (eg QGSP)
  - other ‘educated-guess’ configurations for use as starting points.

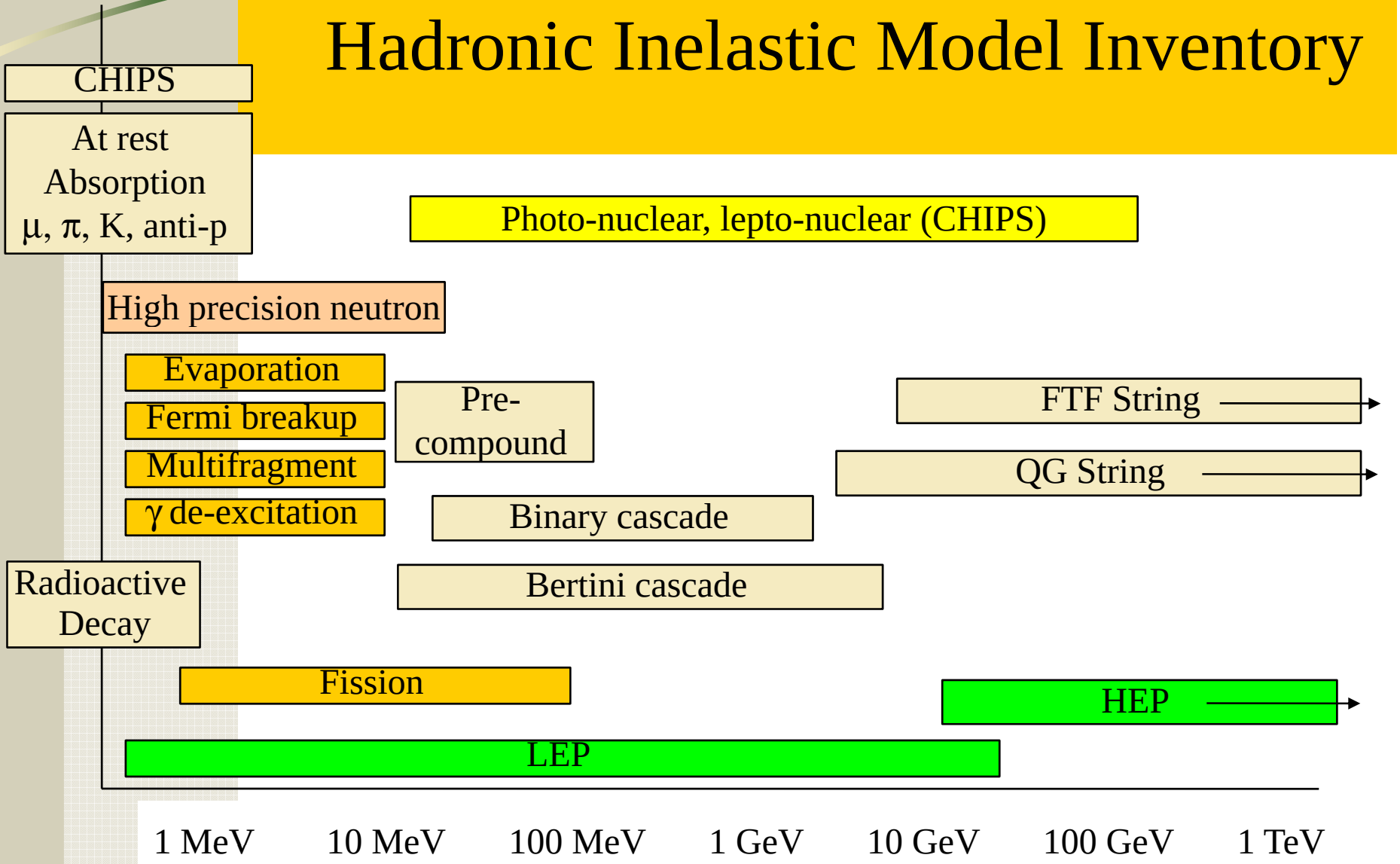
Electromagnetic Physics in Geant4

- "standard" package (1 keV and up)
  - multiple scattering, ionization, bremsstrahlung
  - Compton, pair production, photo-electric, annihilation
  - synchrotron, Cerenkov, transition radiation, high energy muon processes
- "low energy" package
  - uses database information to extend interactions below 1 keV
  - many of the same processes as offered in "standard"
- optical photons
  - reflection/refraction, absorption, Rayleigh, wavelength shifting

Propagation in EM/other fields

- External fields
  - Are created by user code
    - Choice of simple fields provided in toolkit (eg solenoid)
    - User can create own field (analytic or map)
  - Are applied to all charged particles
    - Being extended to particles with dipole moments

Hadronic Inelastic Model Inventory



Part 3

The Geant4 Collaboration

Geant4 Collaboration

CERN

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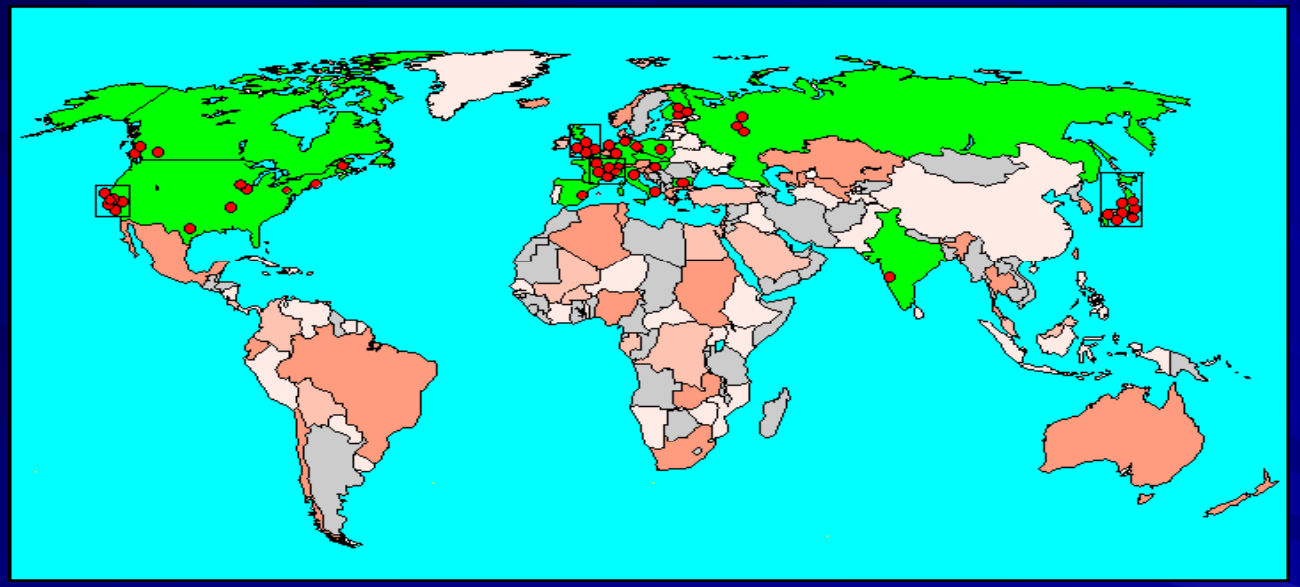

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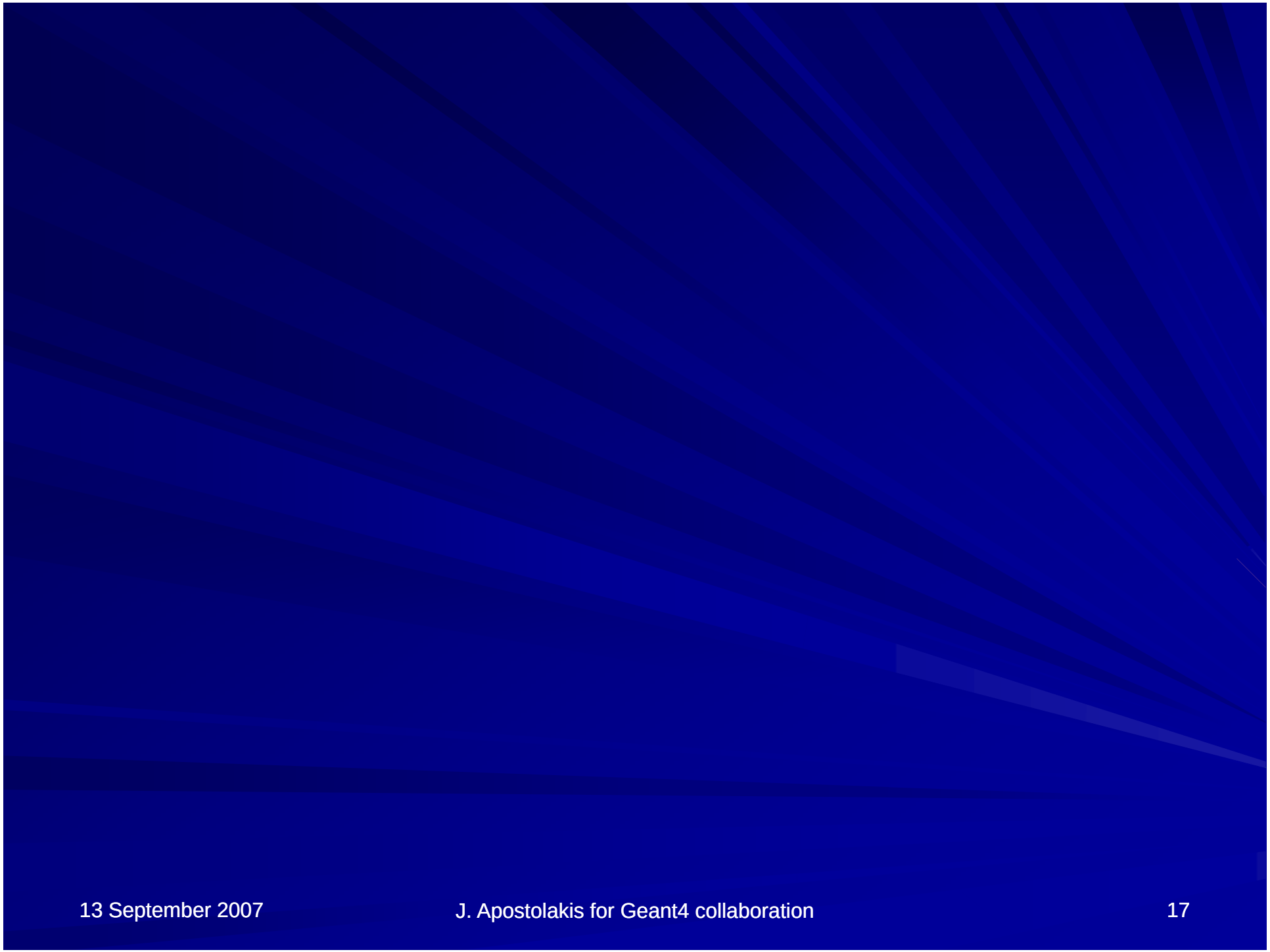
Collaborators also from several other (non-member) institutions, including
Budker Inst. of Physics
IHEP, KFKI Budapest
CIEMAT, MEPHI Moscow

Geant4 collaboration 1994-today

- RD44 (1994-1998)
  - DRDC project
- Geant4 'MoU' Collaboration (1999-2005)
  - Labs, experiments, univ. groups .. agencies
- Geant4 new Collaboration Agreement (2006-now)
  - Individual as members
  - Labs, institutes, funding agencies



http://cern.ch/geant4/

Summary

- Geant4 has demonstrated important strengths:
  - stability of results, flexibility, transparency.
  - it is in production use today in running HEP experiments (BABAR, HARP, ATLAS, CMS, LHCb, ..)
- Geant4 is evolving
  - With the feedback from HEP experiments, users in space and medical application domains.
- Refinements & further development are ongoing.

THE END

Thanks to all

- Contributors
- Users

Physics lists for calorimetry

- LHEP is the fastest for CPU
  - uses the LEP and HEP parameterized models for inelastic scattering.
- QGSP,
  - uses theory-driven modeling for reactions of πs, Ks, and nucleons.

  It employs
  - Quark Gluon String Model
    - for the 'punch-through' interactions of the projectile
  - A Pre-equilibrium decay model
    - with an extensive evaporation phase to model the nucleus 'after the punch'.
- QGSC, is similar to QGSP but uses CHIPS for fragmentation
  - The CHiral Invariant Phase-Space decay (CHIPS)
- FTFP starts with QGSP and replaces instead the string
  - with a diffractive string excitation
    - similar to that in FRITJOF, and the Lund fragmentation functions.

Comparison projects

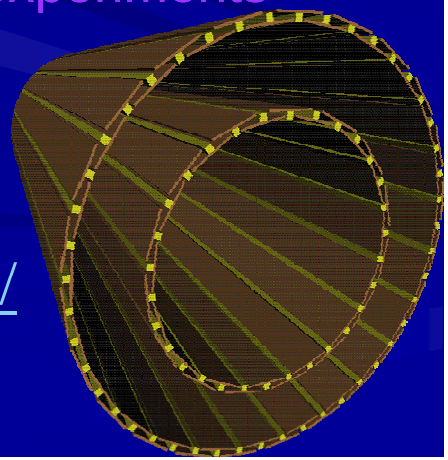
- Joint efforts for comparing Geant4 with experiment & test-beam data.
  - Results of EM comparisons: 'peak' between 2000-2002.
  - Hadronic comparisons: 2002-ongoing.
- Collaboration with experiments
  - ATLAS (numerous projects with data of test beams)
  - BaBar (one project with data for tracker, drift chamber)
- Many results have been presented at
  - conferences & workshops,
    - Eg lately at Calor 2002 and CHEP 2003 (last March).
  - at regular meetings experiments-Geant4 physics comparisons
    - 1999-2001 with Atlas
    - Since 2002 jointly with all LHC experiments

Review and Releases

- δ Review October 2002
  - Report available at http://cern.ch/geant4
- Developments available in β releases
  - Every two months
  - Latest β release (February)
    - Included cuts per region
- Upcoming releases
  - 'Scheduled' release Geant4 5.2 for end-June
    - Further fixes, refinements, performance improvements
    - A few new developments
  - 2003 work items & planned release contents to be available soon
    - Started from User & Experiment Requirements and Requests
    - Next major release Geant4 6.0 is scheduled for December 2003.

Use cases of Physics Lists

- HEP calorimetry.
- HEP trackers.
- 'Average' HEP collider detector
- Low energy dosimetric applications with neutrons
- low energy nucleon penetration shielding
- linear collider neutron fluxes
- high energy penetration shielding
- medical and life-saving neutron applications
- low energy dosimetric applications
- high energy production targets
  - e.g. 400GeV protons on C or Be
- medium energy production targets
  - e.g. 15-50 GeV p on light targets
- LHC neutron fluxes
- Air shower applications
- low background experiments



Contributors: http://cern.ch/geant4/organisation/working_groups.html#wg.Had