Geant4 for HEP detector simulation

Highlights of Geant4's capabilities and recent developments

John Apostolakis, CERN
for the Geant4 collaboration

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

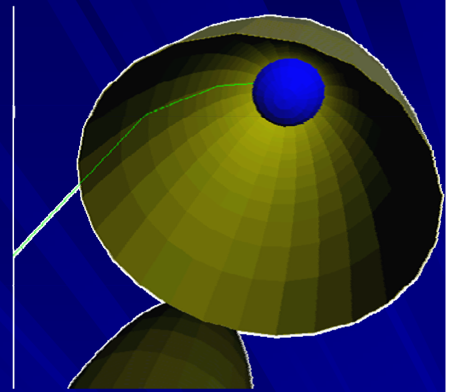
Context

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

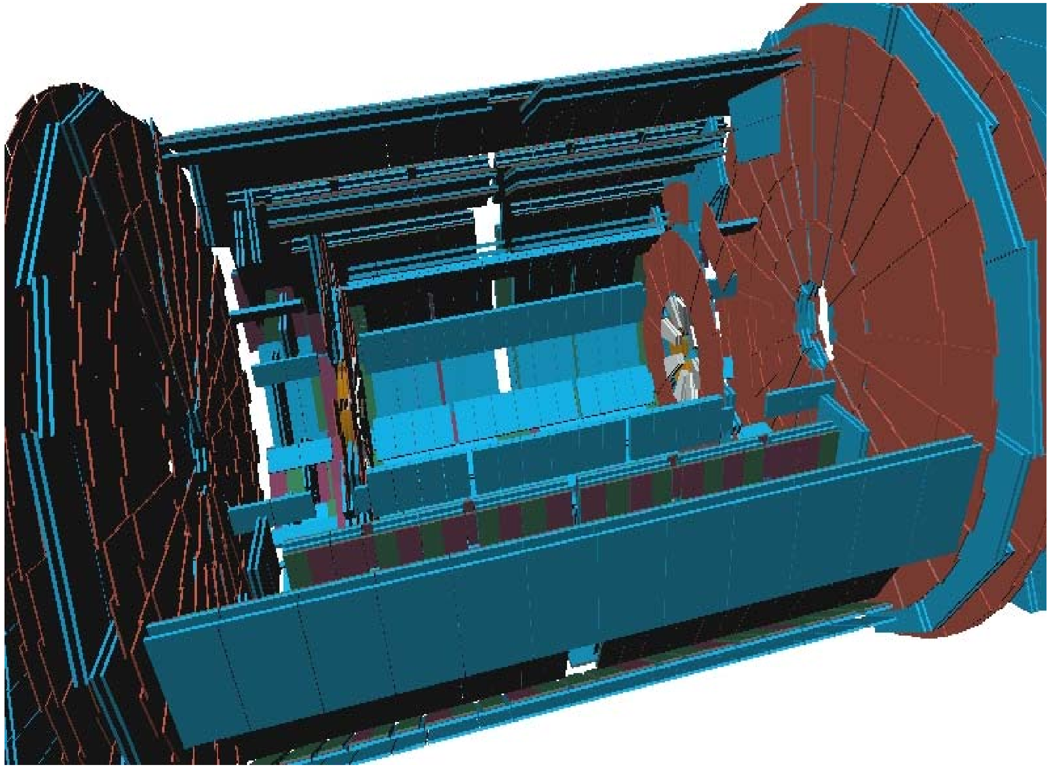
- Geant4 is an object-oriented C++ toolkit
  - the goal is to provide all that is needed to build a wide variety of physics simulation applications
    - range of physics models,
    - tracking, geometry hit collection and scoring
    - and auxiliary components
  - code is open, modular – available for 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 Architecture

- The Kernel is the backbone of the toolkit
  - A ‘physics’ process can affect the state of a track
    - E, p, x, charge, weight, ..
    - Transport, biasing, scoring, shower parameterization are ‘processes’ too
  - Each particle type has a set of processes
  - Geometry is separate module
    - one mass geometry accessible via G4Navigator
    - optional parallel geometries
  - Additional properties can be attached to many objects

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

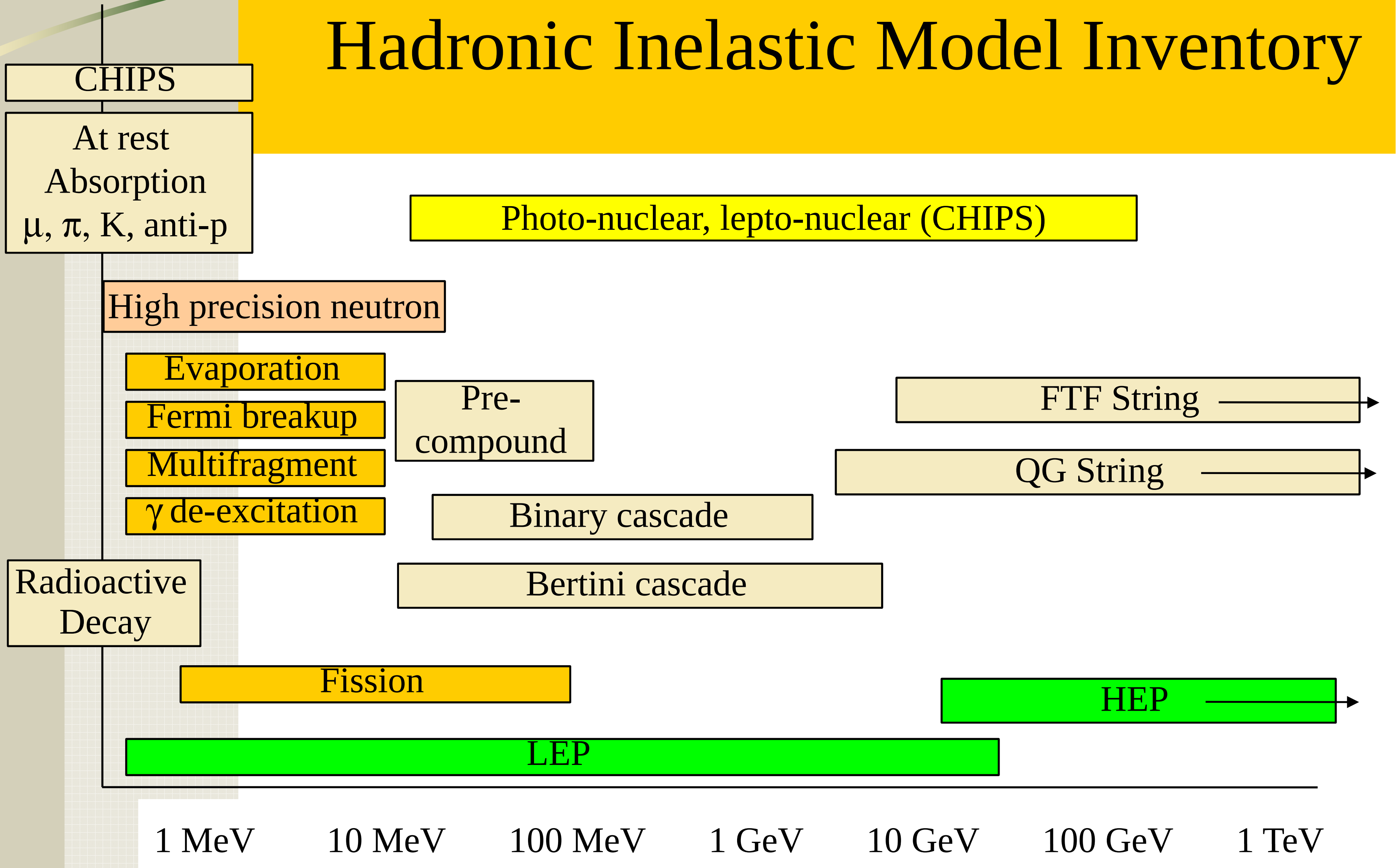
Ionization and energy loss

- ‘Standard’ ionization
  - Creates secondaries of E>1 KeV (production thresh.)
  - Tracks particles down to zero energy, range
- ‘Low-energy’ ionisation
  - Typical production threshold of 250 eV
  - De-excitation
- Photo-absorption Ionization model
  - For gases, silicon
  - User chooses which volumes or materials to use it in

Propagation in EM/other fields

- External fields
  - – Magnetic, electric and combined available
    - Can create custom gravity or custom field+equation
  - – Are created by user code
    - Can choose a simple field - 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

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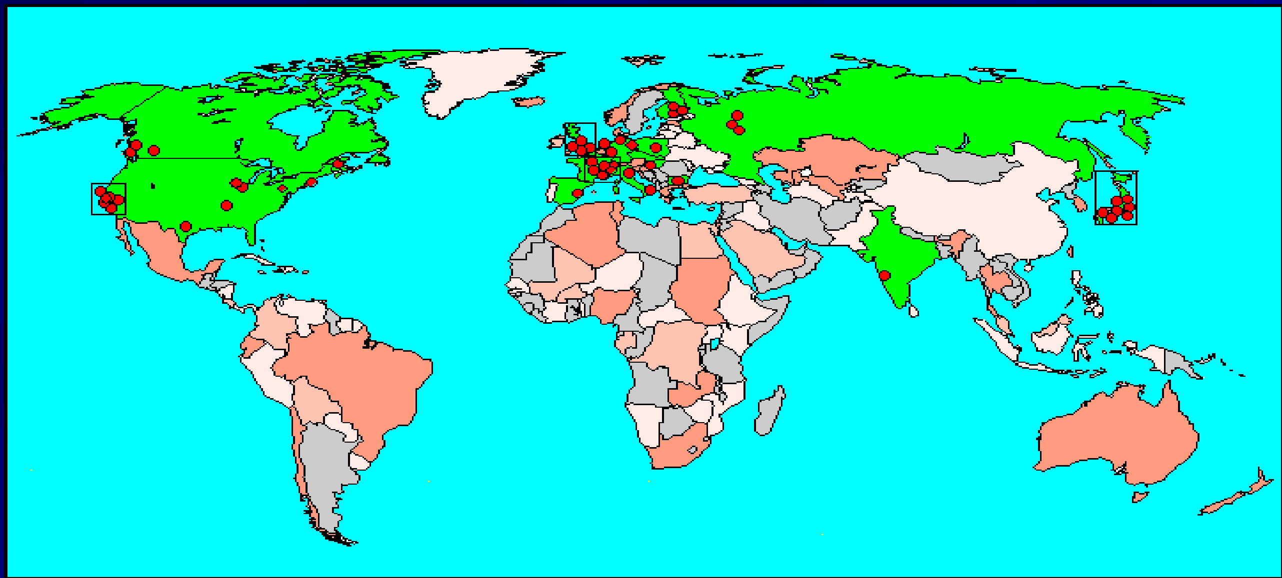

KEK

Российская Академия Наук
Физический Институт
имени П.Н.Лебедева
Ф И А Н

Lebedev

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

Stanford Linear Accelerator Center

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

Recent extensions

- GFLASH shower parameterisation
  - ATLAS/CMS initiative
- Geant4e error propagation module
  - Pedro Arce, CIEMAT
- Additions made by G4, others
  - New solids developed, donated
  - For major developments prefer to co-develop or at least establish good communication