GEANT4 in LHC computing
- the Helsinki Institute of Physics Perspective

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Keywords: GEANT4, LHC, hadronic physics evaluation, cluster hardware, parallell GEANT4 computing

Outline

We'll give in this talk an overview of HIP GEANT4 LHC activities:

- Models developed for GEANT4
- GEANT4 evaluations by BaBar, ATLAS and CMS
- First finnish GEANT4 meeting at HIP, 30.10-31.10.2003
- Hardware for GEANT4 Monte Carlo
- Parallell GEANT4 computing

Background

- Helsinki Institute of Physics is committed to develop HETC and INUCL models for GEANT4
- High Energy Transport Code HETC in 1970's: part of models now released in GEANT4
- INUCL (1990's) hadronic code by N. Stepanov (now released in GEANT4

Bertini Cascade Models

http://arxiv.org/abs/nucl-th/0306008

- Intra-nuclear cascade model (INC) with exitons
- Pre-equilibrium model
- Nucleus explosion model
- Fission model
- Evaporation model
- De-exitation model

Covers γ, π, n, p, and nuclear isotopes in the energy range 100 MeV - 10 GeV.

Using Bertini cascade

Physics lists for a 'typical' HEP collider detector by J.P Wellisch: `http://cmsdoc.cern.ch/~hpw/GHAD/HomePage/geant4.5.2/hep_detector`

- QGSP_BERT and LHEP_BERT: Below 3 GeV the Bertini cascade is used for nucleon and pion induced reactions. The price to pay is reduced CPU performance. It does not include gamma and electro nuclear physics.
- BaBar or PANDA may want to start from one of the physcis lists including the Bertini cascade, once robustness tests are finalized

Bertini Cascade

- Speed comparision in thin targets (D. Wright, BaBar):
  - Standard physics settings (LEP): 0.06 ms/event (parametrical model based on GEANT3/GEISHA)
  - Bertini 0.64 ms/event (semi-empirical)
  - New Binary Cascade 3.78 ms/event (theoretical model)

BaBar evaluation of Bertini cascade

Dennis Wright, GEANT4 *in BaBar Simulation*,
GEANT4 Workshop, TRIUMF, Vancouver, September 2-7, 2003
(`http://www.triumf.ca/geant4-03/agenda.html`):

- Interest in hadrons: p, n, charged π and K
  ($p < 4GeV/c$, most $< 1GeV/c$)
- Currently using inelastic LEP model
- Only 5-7% increase in overall event time with new cascade models
- Hadronic processes validation continues
- New cascade models will replace LEP in production after robustness tests

Improved Physics Performance with Bertini Cascade

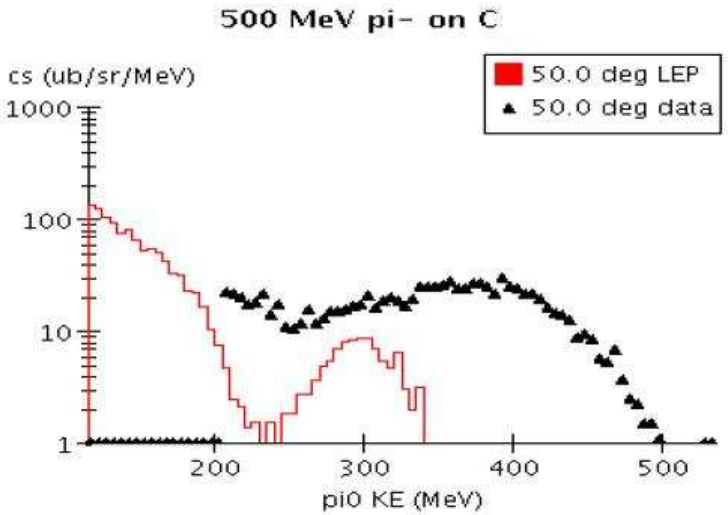

Figure 1: Current GEANT4 LEP physics list setting against data (Ouyang, Peterson 1992)

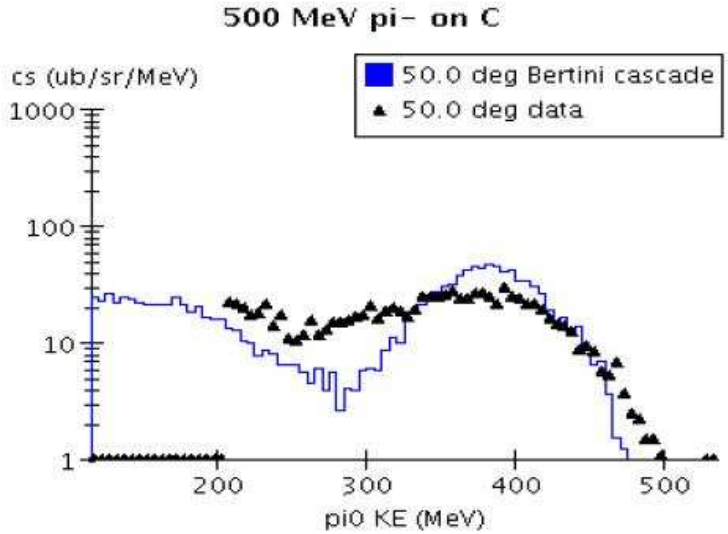

Figure 2: Bertini cascade model

ATLAS experience of GEANT4

A. Dell'Acqua, GEANT4 *Physics Validation in ATLAS*, GEANT4 Workshop, TRIUMF, Vancouver, September 2-7, 2003:

- GEANT4 physics benchmarking: try to understand differences in applied models, e.g.: effect of cuts on simulation parameters (range cut vs energy threshold)
- Use available experimental references from beam tests for various sub-detectors and particle types to determine prediction power of models
- GEANT4 simulates relevant features of muons, electrons and pions in various ATLAS detectors in most cases better than Geant3
- GEANT4 is definitely becoming a mature and useful product for large scale detector response simulation

CMS (1/5)

P. Arce, *Validation of* GEANT4 *in CMS*,
Geant4 Workshop, TRIUMF, Vancouver, September 2-7, 2003

- OSCAR (Object Oriented Simulation for CMS Analysis and Reconstruction) is (almost) ready to substitute GEANT3-based simulation in the official CMS production
- Extensive physics checking has been carried to test GEANT4 physics vs. GEANT3 and vs. TestBeam data where available (1.2 M single particle events + 300 k full events have been produced)

CMS (2/5)

The CMS DC04 challenge ($\mathcal{O}(100)$ M events) started in the summer 2003 with GEANT3 simulation

- CMS plans to generate a large part of this event sample with GEANT4
- November 2003: >2 M events have been simulated with GEANT4 for tests and validation
- 10 M events by the end of the year
- GEANT4 electromagnetic showers looks thinner than the GEANT3 showers, but test beam data seems to agree better with GEANT4

CMS (3/5)

- CPU time is acceptable: 1.5 - 2 x GEANT3
- Memory is acceptable: 220 MB OSCAR vs. 100 MB GEANT3 simulation
- Crashing rate is acceptable: 1 / 20000 events
  - Becoming smaller at each GEANT4 release
  - Still some problems in tracking and hadronic physics

CMS comparison of GEANT3 and GEANT4 (4/5)

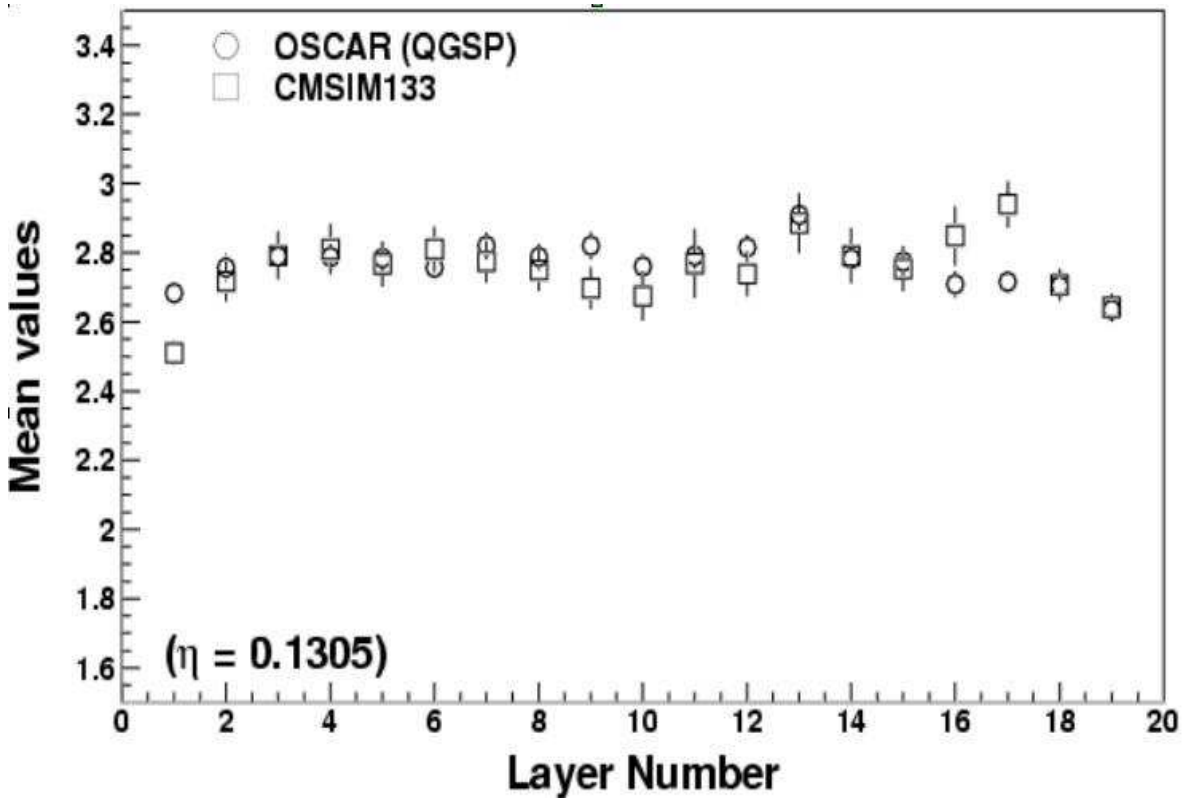

Figure 3: Energy deposited in each layer of hadron calorimeter shows good agreement between GEANT3 and GEANT4.

CMS detector geometry in GEANT4 (5/5)

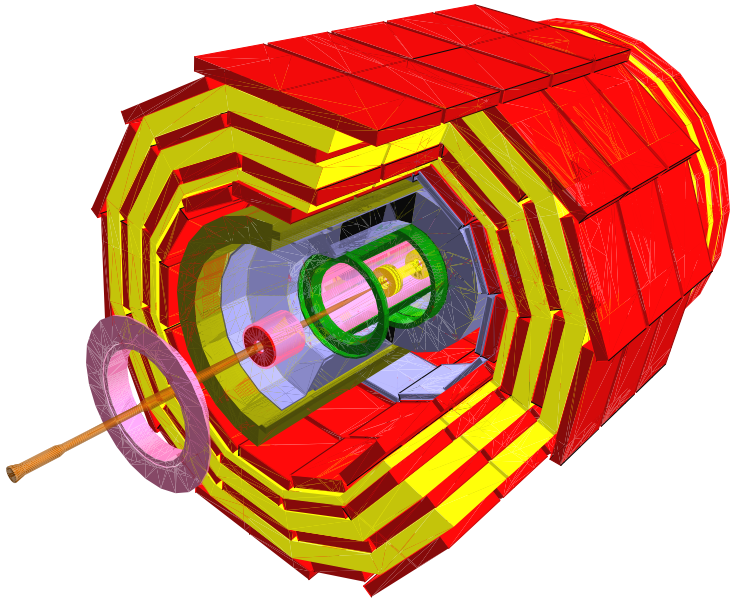

Figure 4: XML description of the CMS detector geometry.

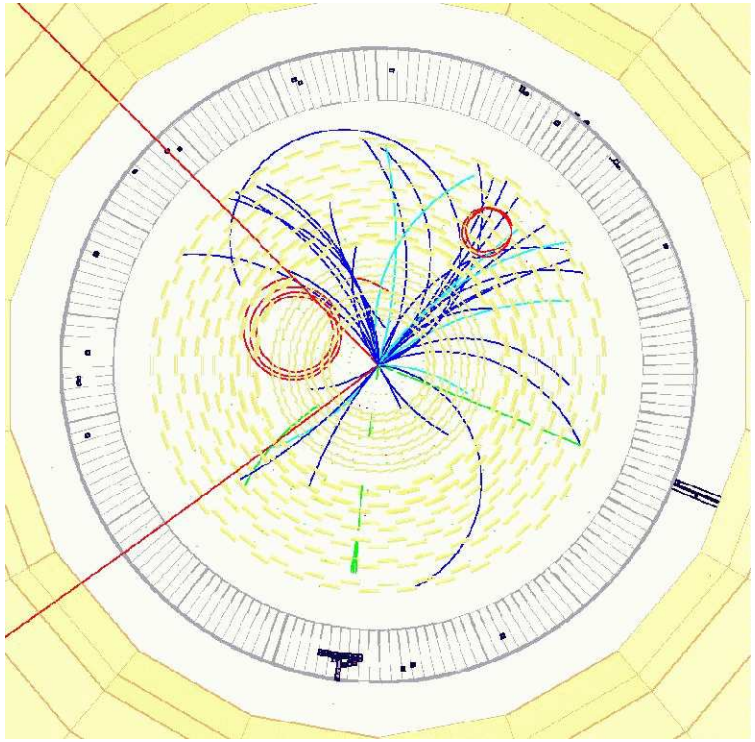

Figure 5: GEANT4 simulated Higgs event in the CMS Tracker.

HIP GEANT4 Workshop in Helsinki, October 30–31, 2003 (1/2)

`http://www.hip.fi/geant4/workshop/`

- The first Finnish meeting for users was devoted to practical studies of GEANT4
- 18 participants from several different fields of application
  - Semiconductor industry
  - Space science
  - Underground cosmic radiation experiments
  - Nuclear physics
  - Radiation safety
  - High Energy Physics

HIP GEANT4 Workshop in Helsinki (2/2)

- P. Nieminen from ESA: *Geant4 Space Applications* (many interesting applications e.g. Space Station and Mars modelled with GEANT4)
- Maria Grazia Pia from INFN: *Geant4 Low Energy Physics Applications* (medical applications, such as GEANT4 in treatment planning)

Parallell computations with GEANT4

- GEANT4 will be the largest CPU time consuming application in the near future.
- Using computer clusters is therefore essential.

Since GEANT4 is a *pleasently parallell* application the simplest way to run GEANT4 in parallell on a cluster is to:

- Use scripts that split large event samples into independent subsamples and recombine the results after the calculation.
- This is used in CMS Monte Carlo Production runs by the McRunJob script generator.
- We have also done this on the *moonshine* "night" openMosix cluster.

Using GEANT4 on an openMosix PIII cluster

Moonshine idea: Try to use CPU cycles on NT workstations in four computer classes on the Kumpula kampus that are idle during nights and weekends.

Kai Arstila (Accelerator laboratory of the Physics department) has setup this *openMosix cluster* (**M**ulticomputer **O**perating **S**ystem for Un**IX**):

- Frontend 1.8 GHz P4 running RedHat 7.x with kernel 2.4.x
- 60 nodes (no local disk): 800 MHz PIII 256 MB 100 Mb/s
- Availability: 65 % / week, computing power $\approx$ **1,3 kSI95**.

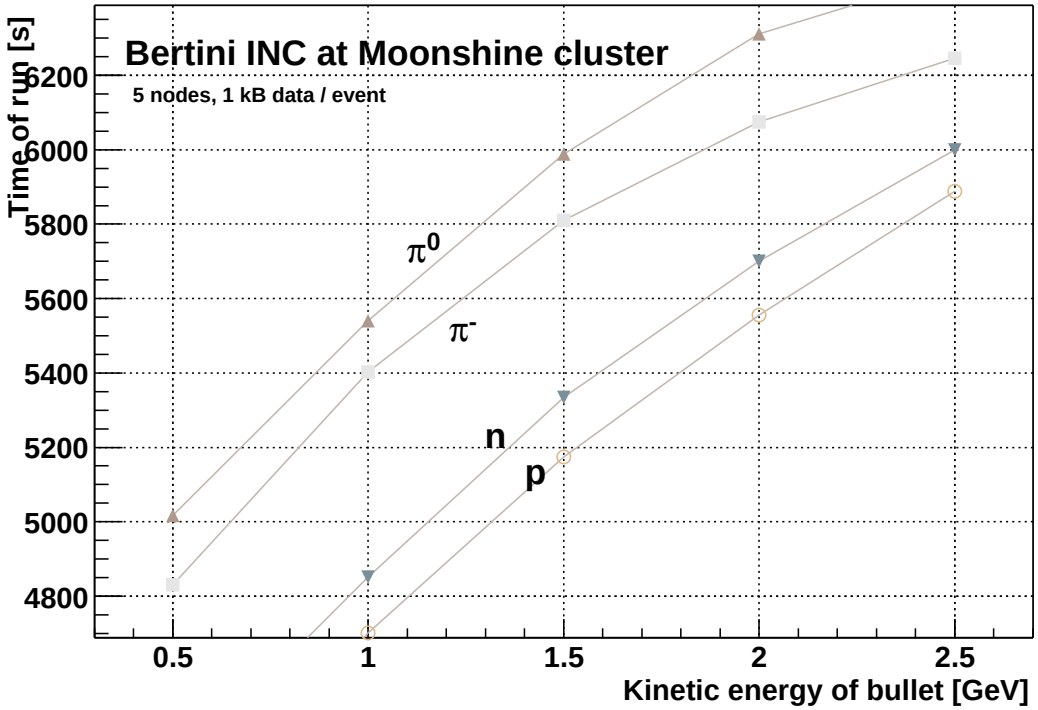

Figure 6: CPU time for simulation of 1 M collisions of π^0, π^-, n and p with Al using GEANT4 writing 1 kB output data / event.

Parallell computations with GEANT4

GEANT4 supports intrinsic parallellism:

- There is the possibility of letting GEANT4 generate new subprocesses using the TOP-C package distributing the data over available slave CPUs.

For details have a look in the GEANT4 examples directory *extended/parallell* and the Parallell GEANT4 web page: `http://www.ccs.neu.edu/home/gene/pargeant4.html`.

We plan to try this way of running GEANT4 in parallell on the new 64+2 CPU Linux cluster *mill* in Helsinki.

Conclusions

- GEANT4 is becoming a mature and useful product.
- It is being used in the largest HEP detectors like ATLAS, BaBar, and CMS to simulate the detector response.
- GEANT4 is also being used in a wide area of applications outside HEP.
- In CMS all physics groups agree in switching to GEANT4 as the official simulation tool.
- GEANT4 processes migrate nicely under openMosix.
- GEANT4 applications demanding huge amounts of CPU time can be distributed over cluster nodes, using scripts or by letting GEANT4 generate subprocesses using TOP-C.