Geant4 in HARP

The Hadron Production Experiment at the PS, CERN

P. Arce and V. Ivanchenko
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HARP Collaboration

Università degli Studi e Sezione INFN, Bari, Italy
Rutherford Appleton Laboratory, Chilton, Didcot, UK
Institut für Physik, Universität Dortmund, Germany
Joint Institute for Nuclear Research, JINR Dubna, Russia
Università degli Studi e Sezione INFN, Ferrara, Italy
CERN, Geneva, Switzerland
Section de Physique, Université de Genève, Switzerland
Laboratori Nazionali di Legnaro dell' INFN, Legnaro, Italy
Institut de Physique Nucléaire, UCL, Louvain-la-Neuve, Belgium
Università degli Studi e Sezione INFN, Milano, Italy
P.N. Lebedev Institute of Physics (FIAN), Russian Academy of Sciences, Moscow, Russia
Institute for Nuclear Research, Moscow, Russia
Università "Federico II" e Sezione INFN, Napoli, Italy
Nuclear and Astrophysics Laboratory, University of Oxford, UK
Università degli Studi e Sezione INFN, Padova, Italy
LPNHE, Université de Paris VI et VII, Paris, France
Institute for High Energy Physics, Protvino, Russia
Università "La Sapienza" e Sezione INFN Roma I, Roma, Italy
Università degli Studi e Sezione INFN Roma III, Roma, Italy
Dept. of Physics, University of Sheffield, UK
Faculty of Physics, St Kliment Ohridski University, Sofia, Bulgaria
Institute for Nuclear Research and Nuclear Energy, Academy of Sciences, Sofia, Bulgaria
Università di Trieste e Sezione INFN
HARP goals

- Cross sections for protons and pions in the energy range (1.5-15) GeV
- The data for the neutrino factory source optimization
- The data for calculation of meson flax from atmospheric neutrino
- The data for K2K and MiniBooNE experiments
- The data for Geant4 hadronic models
Large Acceptance and Particle ID

Detector layout

PS East Area beams: 1.5-15 GeV

Neutrino Factory: ~2-24 GeV
Atmospheric meson flux: 2-100 GeV

Geant4 in HARP
The HARP Experiment

- Beam Instrumentation and Trigger
  - Beam Cherenkova
  - Beam TOFs
  - Tracker MWPC
  - Inner Trigger
  - Forward Trigger
  - Muon Catcher

- Large Angle Detectors
  - TPC
  - Barrel RPC

- Forward Spectrometer
  - Forward RPC
  - Drift Chambers
  - Cherenkov
  - TOF Wall
  - EM Wall

- Software
  - Offline
  - Online

Large Parallel Effort in Design and Construction
Large Angle detectors
HARP at T9
HARP History & Strategy

- Approved in 1999
- Construction from 2000
- 1st run 2001 (~10^8 triggers)
- 2nd run 2002 (~10^8 triggers)
- Software project from 2000
- Component approach, OO design and c++
- Geant4 is one of the main external packages for HARP

- Positive and negative beams
- Momentums: 1.5, 3, 5, 8, 10, 12.2, 15 GeV/c
- Solid targets: Be, C, Al, Cu, Sn, Ta, Pb
- Target depth in nuclear interaction length 2%, 5%, 100%
- Special targets: Al(K2K), Be (MiniBooNE)
- Liquid targets: H_2O, H_2/D_2, O_2/N_2
Geant4 in HARP

- Gaudi Framework (LHCb) for all HARP offline applications
- G4 UI interface is provided by Gaudi UI
- Any combination of subdetectors and sensitive detectors can be defined for a given run
- User have several choices for
  - Event generator
  - Hadronic physics
  - Stepper algorithm
  - TPC and Dipole magnetic field parameterizations
  - Hadronic generator for the target
HARP geometry

- Geant4 geometry description is used for simulation, reconstruction, and event display
- Extrapolator provides propagation of reconstructed tracks between subdetectors
- PS T9 beam line is described and implemented

ASCII files with a few tags (CMS):

- Logical volume
- Boolean operation
- Positioning
- Replica
- Positioning of parameterized volumes
- Rotations
- Materials
- Mixtures
HARP Geant4 simulation

- Sensitive Detectors, Stepping and Tracking actions are defined for subsystems independently
- Hits are stored in Gaudi Event Store
- Digitization is separated from hit production
- Digi are stored in Gaudi Event Store in the format of Reconstruction hits and can be processed as experimental data
- Two types of persistency exist for simulation: ASCII files and ObjectivityDB
NDC Detector Response

GEANT4

HdrNdcSD

HdrNdcMCHitAlg

HdrNdcMCDigiAlg

McVertex

McParticle

McBaseHit

McNdcHit

NdcHit

Gaudi
Detector Response Simulation

Ndc 3 GeV

Data

MC

EM Calorimeter

Geant4 in HARP

09.10.02
HARP event generators

- Standard generator “HARPgun”
- G4GeneralParticleSource
- ASCII input, filled from experimental events
- T9 beam line simulation – 72 meters of PS beam transport from the target to T9 hall have been performed. The main goal: to control beam parameters.
HARP background study

- In 2001 experiment background was 4 times higher than expectations
- In order to understand the background special Geant4 study was performed
- Beam parameters were extracted from the data using MWPC and beam counters
- Simulation were done with and without target
- Background events were traced back
Results of background study

- Main sources of background are following:
  - Multiple scattering on beam counters and TPC walls (29 %)
  - Bremsstrahlung of beam electrons/positrons on beam counters and TPC walls with further conversion on other walls (33 %)
  - $\delta$-electron production on beam counters and TPC walls (26 %)
  - $\delta$-electrons production in air (12 %)

- Simple shielding is not effective!

- As a result the program to optimize HARP trigger for 2002 run have been formulated
Hadron Production

- The process of hadron production is designed. It is active only in the target and only for primary track
- Interaction point is forced to be distributed along the target
- One of the following secondary generators can be used:
  - “Elastic” – user defined angular distribution
  - “Exclusive” – user defined final state
  - Parametrised (GHEISHA)
  - Chiral invariant phase space (CHIPS)
  - String fragmentation + CHIPS
Benchmark for G4 hadron physics

- A benchmark is designed to study G4 hadronic generators
- The goals:
  - Analysis strategy
  - Acceptance calculation
  - Studying hadronic generators
- Gaudi framework is used
- No secondary interactions
- One can study:
  - Multiplicity of final states
  - Inclusive spectra
  - Angular distributions
  - Invariant masses
Conclusions

- HARP data taking will be completed in 10 days
- Currently the calibration and alignment of HARP subsystems are in progress
- Geant4 simulation of HARP is working and used as for calibration and for subdetector studies
- Geant4 was used for trigger optimization
- The results of HARP experiment will be utilized in Geant4 for testing and tuning of hadronic models in the energy range 1.5-15 GeV
- The collaboration between HARP and Geant4 is fruitful and effective