Using Geant4 in the BaBar Simulation

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Outline

BaBar overview
  – physics
  – building a Geant4-based simulation

MC/data comparison
  – EM process validation
  – hadronic process validation

Performance
CP violation in B0B0bar system

EM interactions
– must reconstruct $B^0 \rightarrow J/\psi K_s$, $J/\psi K^*$, $D^+D^-$, ...
– typical decay product energies:
  • lepton pairs $0.3 < p < 2.3$ GeV/c
  • $\pi^0$ $0.3 < E < 2.5$ GeV
  • $\gamma$ $0.1 < E < 4.5$ GeV

hadronic interactions
– charged $\pi$ s and K s interacting in beam pipe, calorimeters
  • $p < 4$ GeV/c, most $< 1$ GeV/c
The BaBar Detector

- Instrumented Flux Return
- Drift Chamber
- Cherenkov PID detector
- CsI calorimeter
- Vertex Tracker
Simulation Design Requirements

Simulation must run in BaBar Framework
- tracking, physics, hit scoring (GEANT4) implemented as a Framework module
- Geant4 must give up run control to the Framework

Work with existing event generators, detector response and reconstruction codes

Use Objectivity database for persistence
- even though Geant4 does provide persistence

Simulation must be detailed but fast enough to keep up with high-luminosity production
BaBar Simulation Overview

- Tracking, physics, hit scoring
- Event generation
- Background mixing and digitization
- Event reconstruction
- Objectivity database
Use of Geant4 in BaBar

BaBar uses:

– Geometry
– Hit-scoring
– Decay processes
– EM physics processes (< 10 GeV)
– Low energy hadronic processes (< 10 GeV)

BaBar does not use:

– Detector response
– Persistence
– Standard particle transport/navigation
Since October 2000, several validation test runs generated, compared to data
- total of 20 million events
- 25 different event types: B0B0bar, bhabhas, dimuons

Examined:
- Detector material model
- Tracking, resolution, reconstruction
- Particle ID
- EM processes
- Hadronic processes
- performance/robustness
EM Process Validation: dE/dx

Min. ionizing e+, e- from rad. Bhabhas (0.2 < p < 8 GeV/c)

- mean energy loss in He-ISO gas reproduced
- widths agree \(\rightarrow\) fluctuations are reproduced

ADC counts
EM Validation: shower shapes
EM Validation: \( \pi^0 \) Reconstruction

- \( \pi^0 \) mass – test of tracking, energy scale, containment in calorimeter
- \( \pi^0 \) width – depends on shower simulation, detector response to photons
- Looked at \( \pi^0 \) s with energies 0.3 to 2.1 GeV from \( K_s \rightarrow \pi^0 \pi^0 \)
EM Validation: $\pi^0$ Reconstruction

data

- peak: 0.1352 +/- 0.0003
- width ($\sigma$): 0.0062 +/- 0.0002

MC

- peak: 0.1344 +/- 0.0002
- width ($\sigma$): 0.0054 +/- 0.00014
Hadronic Validation

Currently using low energy parameterized (LEP) model
  – re-engineered version of GHEISHA
  – not especially appropriate for BaBar energies (50MeV – 5 GeV)

Cascade models now being tested as alternatives
  – binary cascade
  – Bertini cascade looks promising

Thin target tests used for validation
  – using BaBar data
  – using other data
Hadronic Validation: Models
Hadronic Validation: Models
BaBar “Thin Target” Hadronic Tests

[Diagram of a particle accelerator setup with labels: p, Drift Chamber, Be, Vertex Tracker, CF support tube]
Performance

Simulation stage of generic B0-B0bar event includes event generator, tracking, hit-scoring

- On 866 MHz PIII takes 5.0 s/evt
- Used Geant4 4.0

Currently running MC production at ~20 sites (1440 M events so far)

Run failures due to Geant4 getting rare
- < 1 per million events
Conclusions

- BaBar is the first large experiment to develop and use a Geant4-based simulation
- EM validation well in hand
  - Some differences between MC and data but so far probably due to detector response simulation
- Hadronic validation beginning in earnest
  - Testing low energy parameterized, binary cascade, Bertini cascade models
  - BaBar thin target tests just beginning
- Simulation is robust and reasonably fast