BaBar & Geant4
(hadronic)
interaction

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Why are hadronic interactions relevant for BaBar?

- *Delenda Carthago!*
  - BaBar Note 305
  - Dresden Collaboration Meeting, July 1996
  - Simulation Review, October 1996
  - Various HyperNews postings
  - ...
- **Affect PID**
  - e/π, μ/π, K/π
  - *a lot of our PID is based on the discrimination between different* ***interaction patterns*** *(e/π in EMC, μ/π in EMC+IFR)*
- **Charge asymmetry affects B-tagging**
- **J/ψ K^0_L CP channel** is based on detection and reconstruction of hadronic interaction
- An unrealistic simulation of hadronic interactions can generate additional systematic effects in our measurement

We'd better do it right!

From GEANT3 museum

- ***Crystal Barrel studies***
  - Charged K in CsI: data and Gheisha/Fluka
- ***BaBar Note 305***
  - charged π and K^0_L in Gheisha, Fluka, Calor
- ***A look at Gheisha and Fluka hidden secrets***
  - π, K, n, K^0_L cross sections
- ***Two examples in detail***
  - stopping K^-
  - stopping π^-

Comments

You have been warned!

PID selections

charge-dependent PID algorithms

shower libraries

neutral hadron reconstruction algorithms

etc.

currently developed on bbsim data are based on the wrong, unrealistic behaviours you have just seen

(and on those you have not seen...)

- ***Note***:*That's OK if one just wants to test the design of the code, or to verify that the job runs without crashing*

Is there anything we can **do** ?

apart complaining about GEANT3...

Hadronic physics in GEANT4
The design

- Completely different approach w.r.t. the past
  - **transparency**
  - clear **separation between data and their use** in algorithms
- **Cross-section data sets**
  - transparent and interchangeable
- **Final state computation**
  - models per <u>particles</u>, <u>materials</u>, <u>elements</u>, <u>energy</u>
- **Data-driven and theory-driven models**
  - mix and match!
    - with a fine granularity

- ***Consequences for users***
  - *not confined any more to picking one comprehensive package for everything*
  - *greater responsibility for users*
    - *we should choose what is best to use at a fine level*

Hadronic physics in GEANT4
Data-driven models

- Based on parameterisations of experimental data
- Two domains
  - Low energy
  - High energy
- What's new
  - **stopping particles**
  - new parameterisations
  - refinement of existing parameterisations
  - extensions

- *Warning for users*

  experimental data do <u>not</u> cover <u>all</u> materials, <u>all</u> particles, <u>all</u> energies

  experimental data are often old, of poor quality, conflicting

  data driven models imply interpolations, extrapolations, average of data, discarding suspicious data etc.

  to be tested!

Hadronic physics in GEANT4
Theory-driven models

- Wide variety of models will be available
  - the most complete hadronic simulation kit on the market!
- **Parton String Models** (soft and hard collisions)
  - Lund String Model
  - Dual Parton Model
  - Pythia(7) Model
- **Hadron Kinetic Model**
  - QMD Model
  - Hadronic Cascade + Precompound Model
- **Deexcitation**
  - Evaporation
  - Fission
  - Fermi break-up
  - Fragmentation

- *Warning for users*

  theoretical models require testing on experimental data

Hadronic physics in GEANT4
Neutrons

- Exploitation of published cross-sections data sets
- Multiple data sets can be used concurrently according to needs
  - isotopes
  - low Z
  - etc.
- Exploitation of file system to ensure granular and transparent access
- Millions of events run, results available
  - inelastic, elastic, fission etc.

New hadronic physics already implemented

- pp elastic differential cross-section
- nN total cross-section
- pN total cross-section
- np elastic differential cross-section (including charge exchange)
- πN total cross-section
- πN coherent elastic scattering
- nuclear fragmentation
- low E neutron transport
- theory-driven models (in progress)
- stopping K^-
- stopping π^-

How big is the difference?

- OK, Geant4 is a fancy tool, but...
  - is its hadronic physics ***really*** different from Geant3?
  - ***how big*** is the difference?

- A look at stopping K^- and π^-...

Bogus and Geant4-hadronic validation

- **Physics has changed a lot from G3 to G4!**

- Validating Bogus+Geant4 hadronics against bbsim+ Gheisha/Fluka does not make any sense
  - validation against bbsim may be sensible for what concerns geometry and tracking, **not** for what involves **hadronic interactions**

- Bogus validation for what concerns hadronic physics can only be done from **real data**
  - compare tagged particle samples with simulation
  - *not a new idea for BaBar...*
  - *same for PID, tagging etc.*
  - *most of the tools to do the work are actually the same*
  - *just their application is different*

Homework for BaBar (and for Geant4 too...)

- Choose among Geant4 available hadronic models
  - fine granularity
- Compare simulation with data *(BaBar)*
- Tune Geant4 hadronic physics models from BaBar experimental data *(Geant4)*

  Let's not forget that
  - Geant4 developers do not have direct access to experimental data of their own
  - Data for Geant4 physics validation and optimization can only come from collaborating experiments

    (or from published papers...)

- Benefits of the BaBar-Geant4 collaboration
  - ***for BaBar:*** get a reliable hadronic simulation, consistent with data
  - ***for Geant4:*** provide a better tool to the users' community

What to do next?

- Need tagged hadron samples
  - covering a wide momentum range
    - variety of source calibration channels needed
  - must know the momentum at each detector, not only at origin
    - swum tracks needed (are they in the event store?)
- Make sure that what gets into a detector is the original particle
  - not a secondary decay or interaction product
- Identify
  - occurrence of interaction, particle stopping
- Characterize the effects of the interaction
  - secondary tracks produced, cluster shape, energy deposit, split-offs etc.
  - make sure they don't get mixed with other effects
    - overlaps, ghosts, unmatched secondaries, e.m. etc.
- 4-vectors are not enough for this kind of studies
  - (nor for PID studies either...)
- Many tools for such studies are still to be developed
  - that is, code must be written, tested, committed to CVS and used

Let's get started...

- We need code, not words only
- A practical example of what could be done with some small projects around an initial existing tool
- *We have an initial tool for 4-vector calibration K^0_s*
- *How do we make 4-vector K^0_s into detector K^0_s?*
- Want the original π track
  - need decay tool (**kink-finding**)
  - does it come from IP/K^0_s? (some **track filtering** - χ^2, d_0, z_0)
- Does anything occur in the support tube?
  - a blessing!
  - look at **SVT-only tracks**
- Does it **reach the DIRC**?
  - does it interact there?
- Does it **reach the EMC**?
  - is it **matched**?
  - are **secondaries** (decay, conversions etc.) identified/matched?
  - what features does it make there?
- Does it get out of EMC or does it die there?
  - **look at innerRPC**
- Does it **reach the IFR**?
  - are **secondaries** (decay muons) matched/identified?
  - what features does it make there?

Conclusions

- There is a lot of **new hadronic physics** in Geant4
  - effort to make it better than what whas in Geant3
- There are several hadronic models to choose from
- New physics needs validation/optimization
- Bogus validation for what concerns hadronic interactions cannot come from bbsim comparisons
  - physics input is different
  - can only come from <u>comparisons with data</u>
  - **should be part of 1st year programme**
- Bogus-Geant4 hadronic validation/optimization is a **joint BaBar-Geant4 project**
  - both sides will benefit from such collaboration
- **Reconstruction/analysis tools** are needed for Bogus-Geant4 hadronic validation
  - mostly the same as for PID, B-tagging etc.
  - 4-vectors are not enough
  - go in depth into **detector features**
- It's time to start **<u>working</u>** at such tools...

Nil sine magno vita labore dedit mortalibus.

Horatius