

Improvements in Geant4 7.1 and Validation in BaBar

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BaBar Simulation Workshop
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Outline

- Differences between Geant4 6.1 and 7.1
- Changes required in BaBar
- Validation at Bogus level

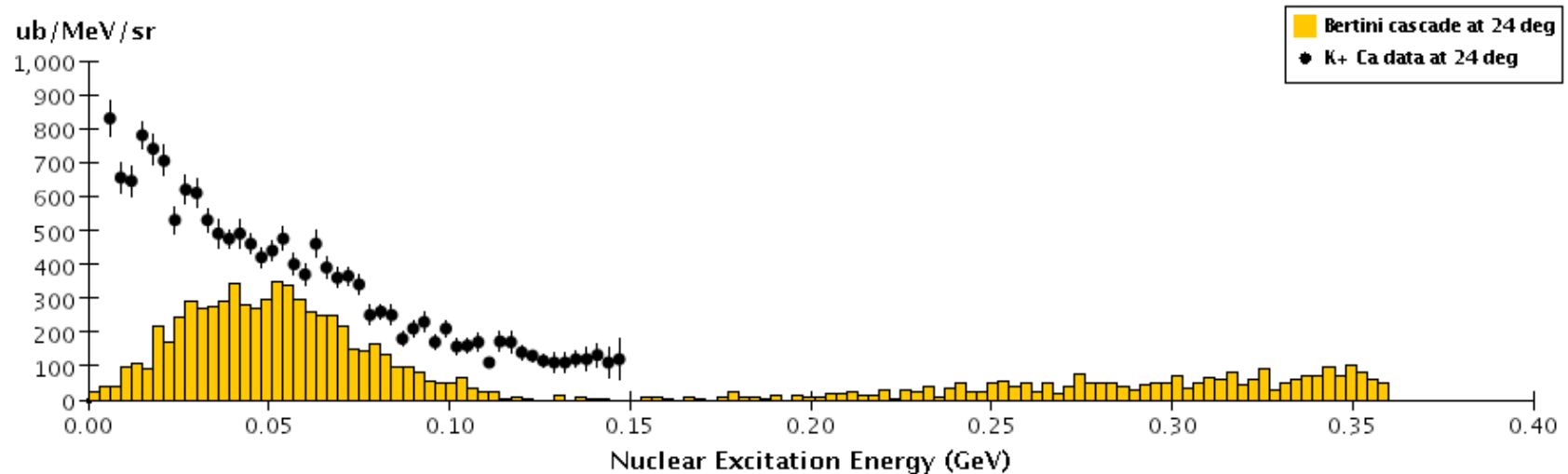
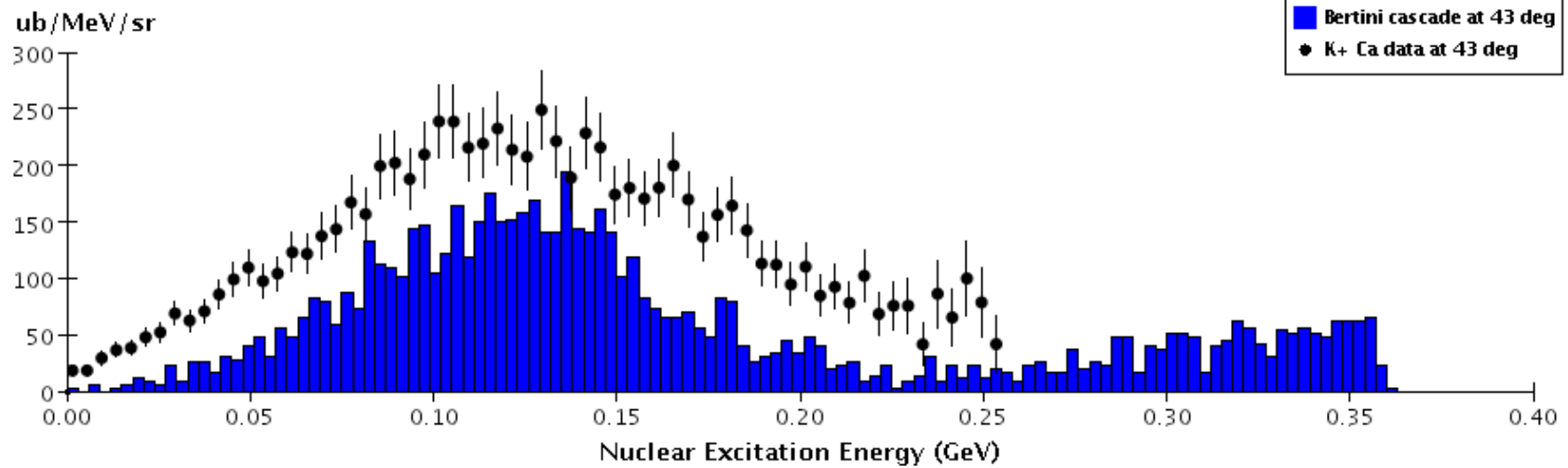
Geant4 Release 7.1 patch 01

- Geant4 6.1 used in 16-, 18-, 19-series BaBar releases
- Geant4 7.1 used in 19.4.1, 19.4.1a
- Old problem: faulty ionization code – now fixed
- New problem: bremsstrahlung process produces particles which have zero energy, but which are still considered “alive”
 - found and fixed locally in first round of validation
- New problem: crash due to NaN in ionization
 - found and fixed locally in first round of validation

Differences Between G4 6.1 and 7.1 (Kaons)

- Bertini cascade model extended to kaons and hyperons for 0 – 10 GeV
 - BaBar currently uses LEP (GHEISHA) model for K, Λ
- New model has many advantages over LEP:
 - conserves charge, strangeness, energy explicitly (LEP does so only on average)
 - exact final state multiplicity up to seven-body final states (LEP uses parameterized distribution of particle types)
 - angular distribution is wider for strange particles (too far forward in LEP)
 - K_L , K_S handled better (still not correct though)

705 MeV/c K^+ quasi-elastic scattering from C



Differences Between G4 6.1 and 7.1 (Pions - bugs)

- Pion total and inelastic cross sections currently used by BaBar are incorrect
 - bug in energy scale between 0.18 and 0.8 GeV results in cross sections ~20-30% too high
 - affects all elements between Sn and W (Cs, I)
 - bug in pi+ inelastic cross section in Pb: 90% too low
 - affects all elements between W and U for $160 < E < 200$ MeV
 - bug in pi+ inelastic cross section in W: 90% too low
 - affects all elements between Sn and U for $120 < E < 160$ MeV
- Now fixed in Geant4 7.1 (19.4.1)

Differences Between G4 6.1 and 7.1 (Pions - improvements)

- Pion inelastic cross sections recently updated in Geant4 7.1 from calorimeter beam tests
 - Ca π^+ cross section reduced 8%
 - affects all elements between Al and Fe for $1 < E < 3$ GeV
 - Fe π^- cross section increased 10%
 - affects all elements between Ca and Cu for $2 < E < 5$ GeV
 - a handful of other changes ($< 2\%$ change in cross section)

Differences Between G4 6.1 and 7.1 (Multiple Scattering)

- multiple scattering: change in angular distribution for e^+ , e^- due to correction of Highland formula for central part of distribution
 - showers should be slightly broader
- better treatment of back-scattering
 - important when particles travel from one material to a much denser one (IFR affected?)
 - in 7.1, more energy deposited in less-dense material
- process now much less dependent on step size

Differences Between G4 6.1 and 7.1 (Other Processes)

- improved stopping power corrections for hadrons and ions (now all within 2% of NIST)
 - 5 - 7% differences in 6.1
- photo-nuclear model improved to produce η , η' and other short-lived particles at a few GeV and above
 - resulted in a bug which was fixed locally
- Use relativistic kinematics for elastic scattering on H
 - non-rel used in 6.1

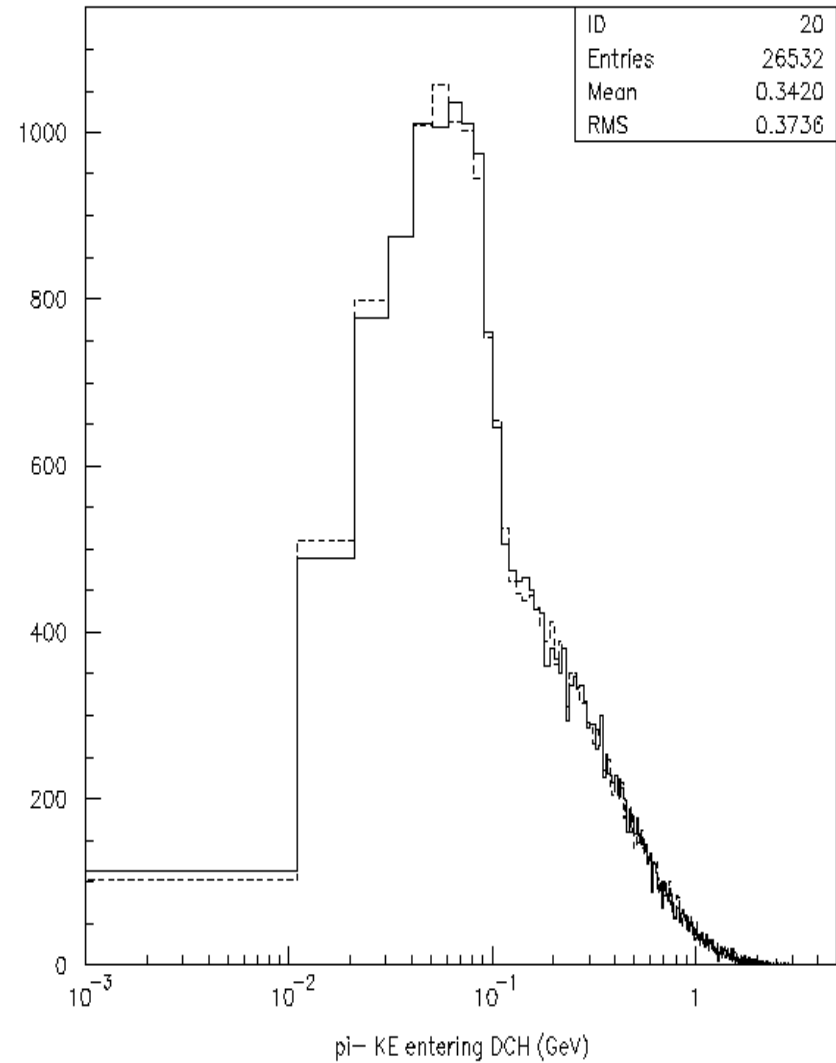
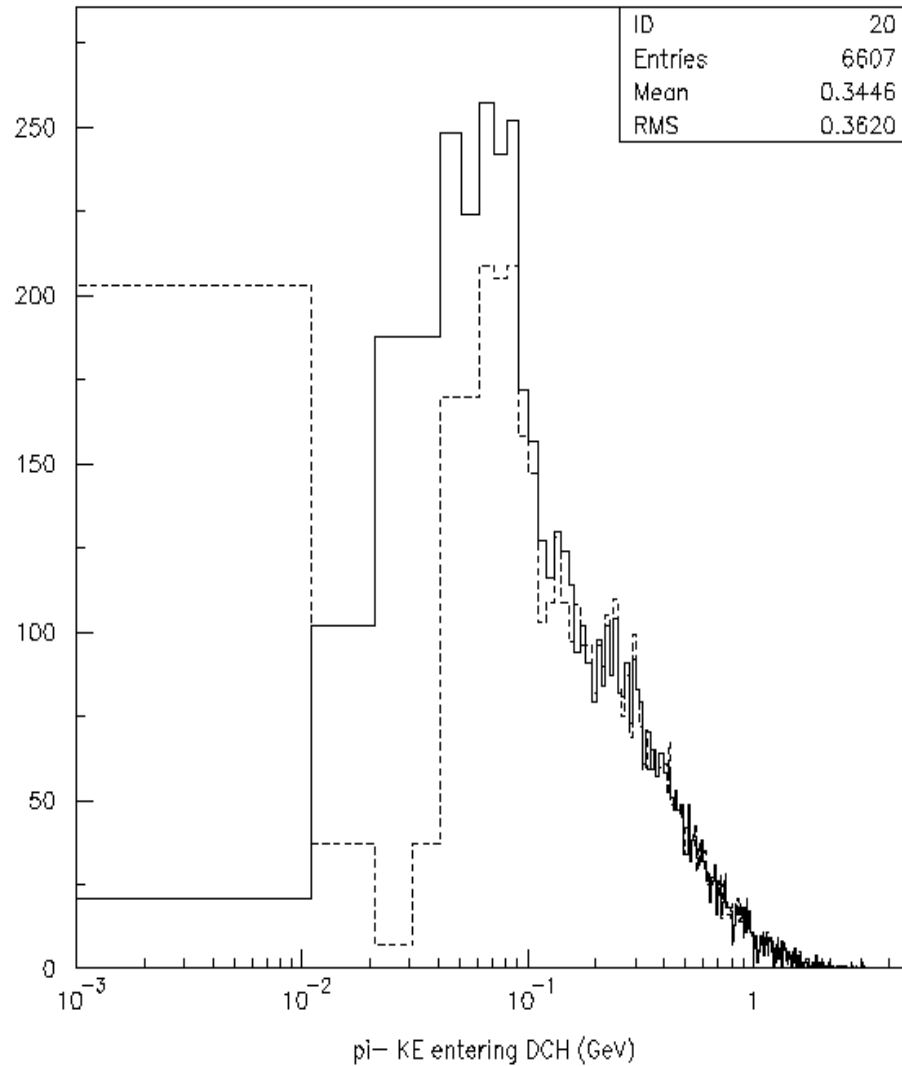
BaBar Changes Required by Geant4 7.1

- Bogus
 - add Bertini model for kaons to physics list
 - removal of David W.'s ionization work-around
 - migration to new G4 method names for setting final state particle properties
- BgsG4Extension
 - migration to new G4 method names for setting final state particle properties
 - set Sensitive Detector pointer in PostStepDoIt of BgsTransportation (required by G4 transportation upgrade)

Validation at the Bogus Level

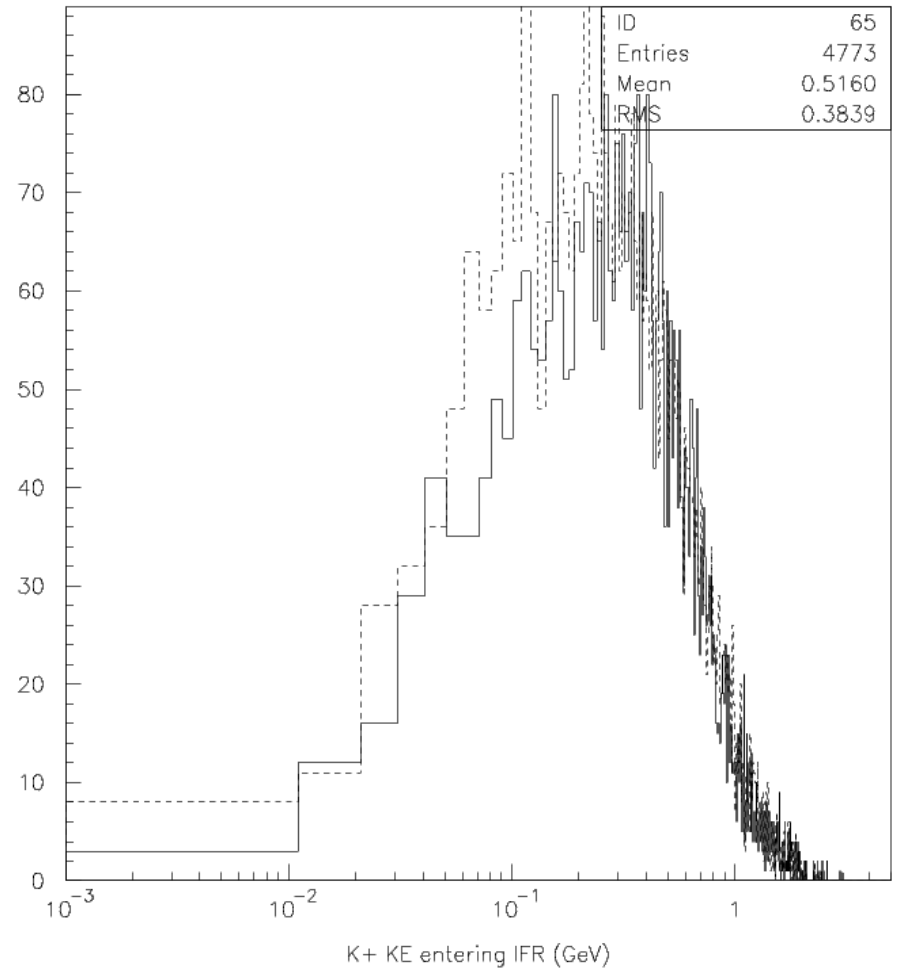
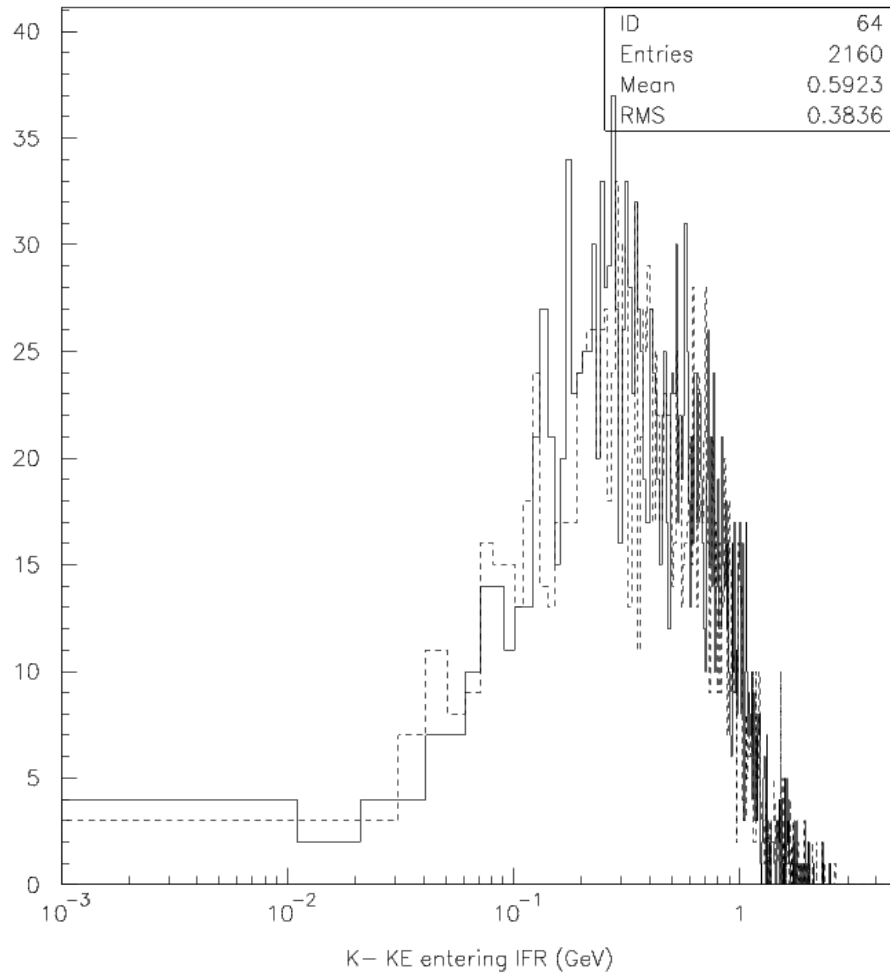
- Comparison of particle spectra using
 - Geant4 6.1 (19.4.0)
 - Geant4 7.1 (19.4.1)
- Use B-Bbar events (7500 in this sample)
- Look at kinetic energy spectra of particles as they enter each subsystem
 - all particle types
 - this will pick out major changes between releases, but not detailed ones

G4 Ionization Problem Fixed



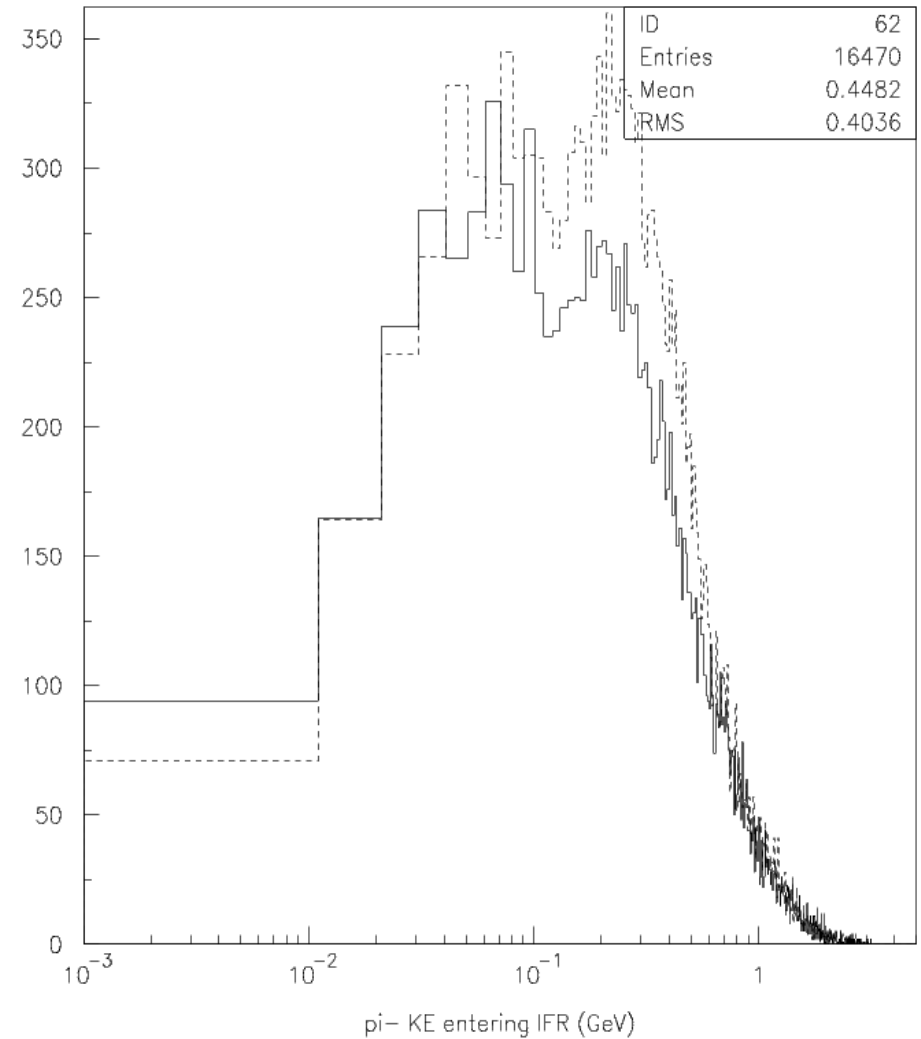
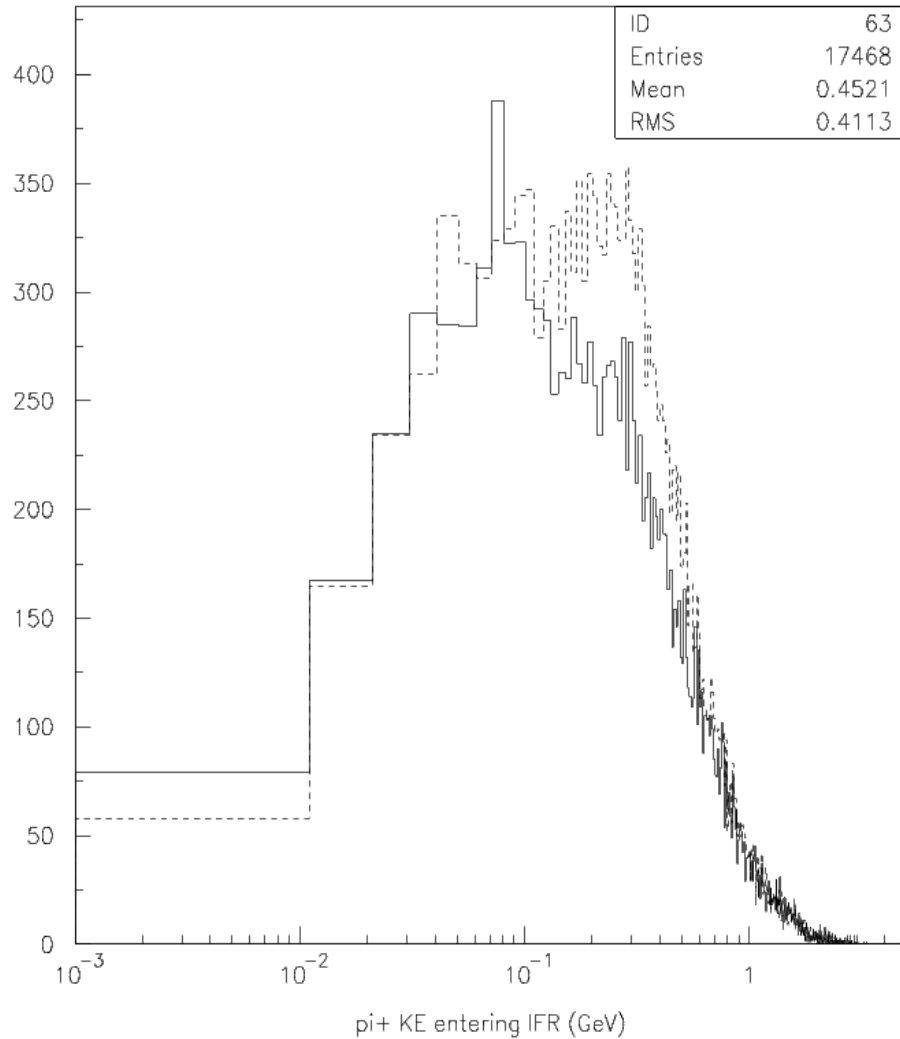
Kaons Entering IFR

(solid G4 6.1, dashed G4 7.1)



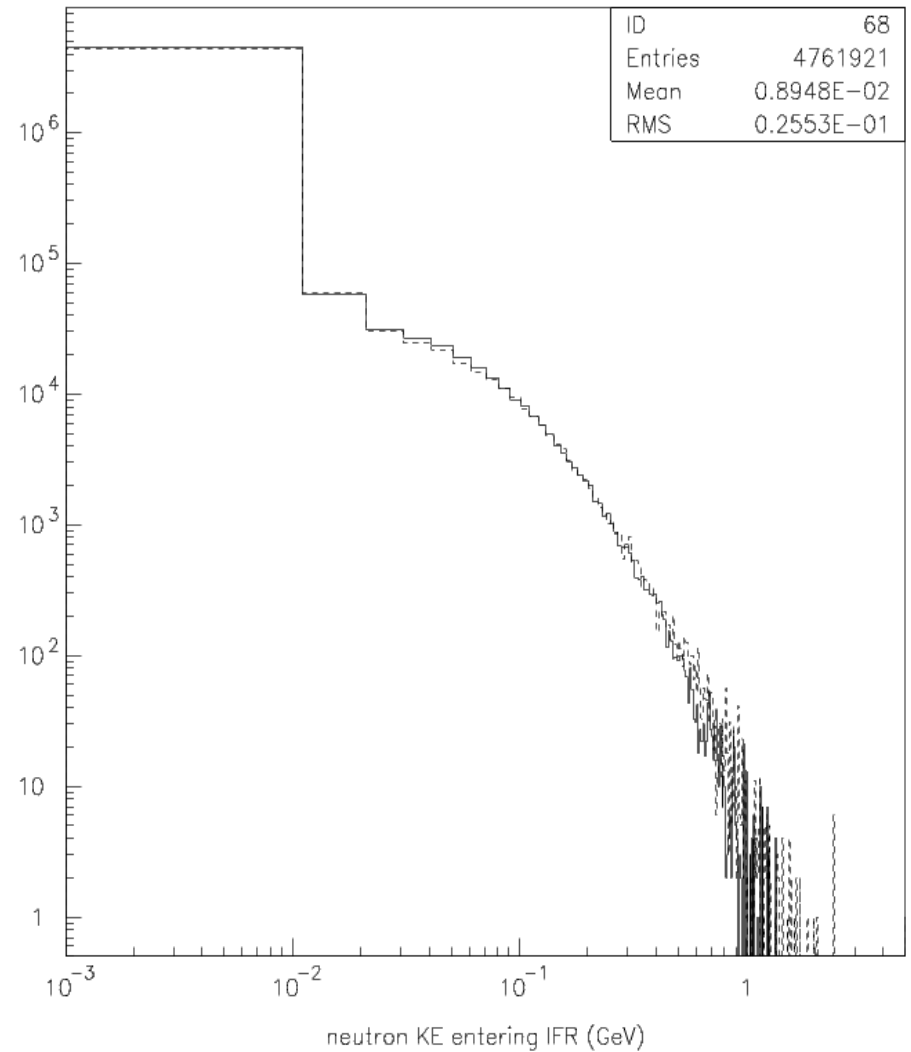
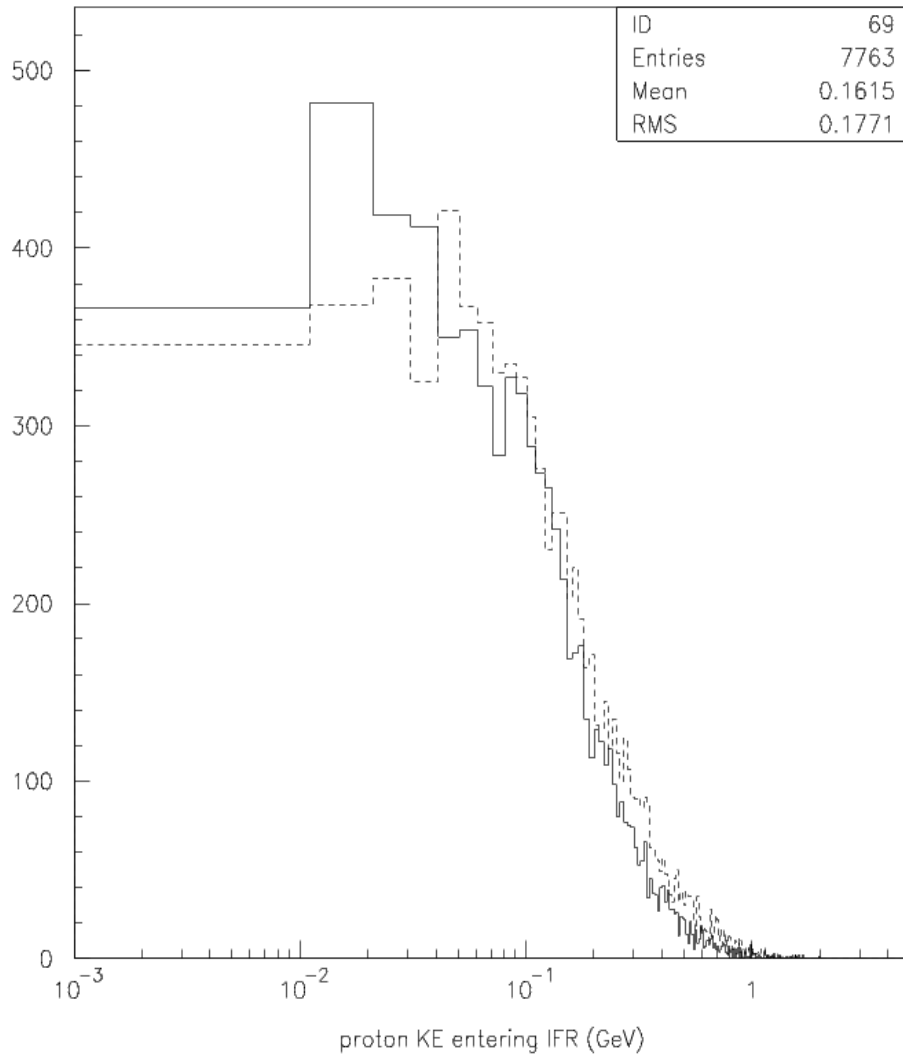
Pions Entering IFR

(solid G4 6.1, dashed G4 7.1)



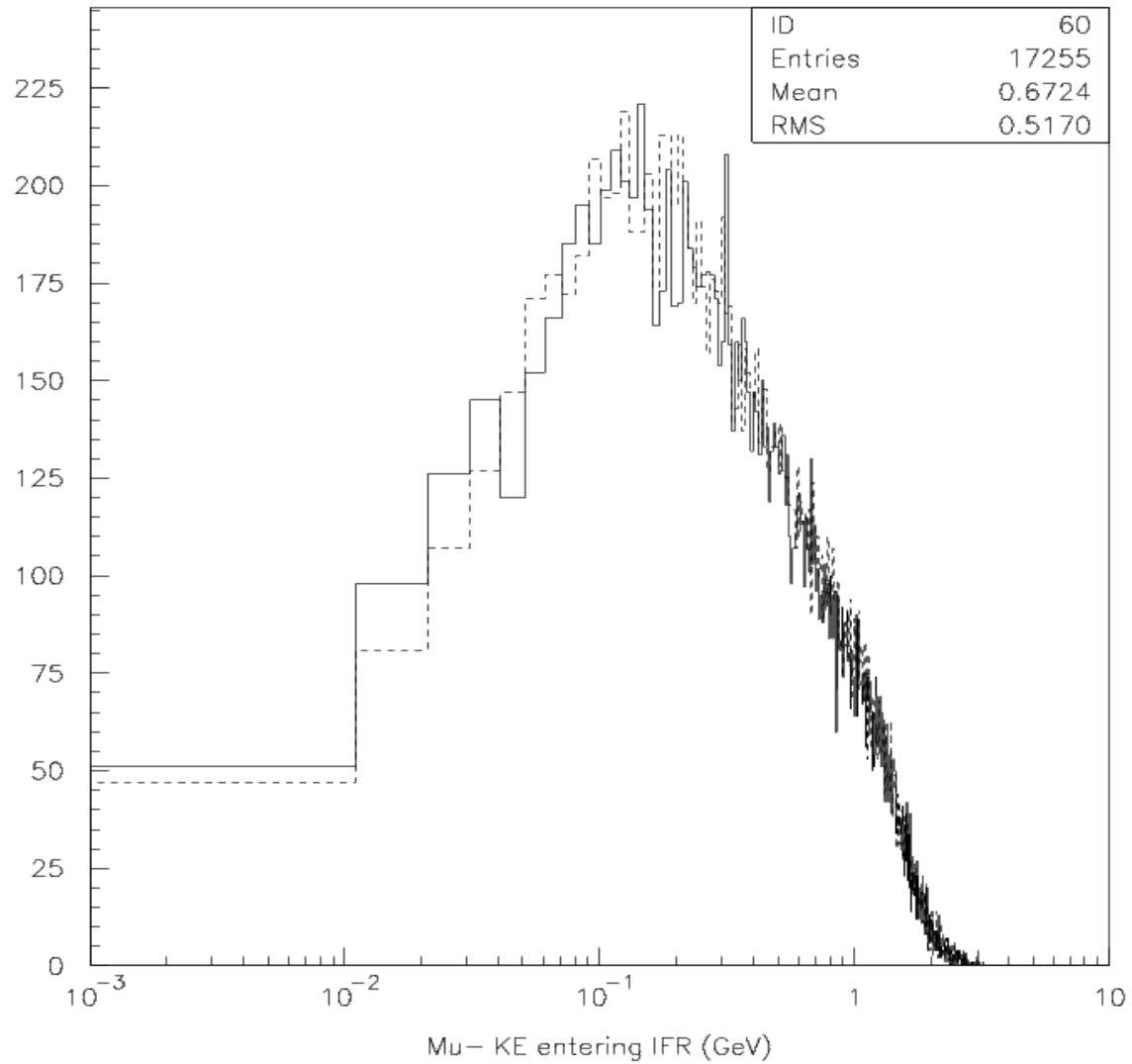
p, n Entering IFR

(solid G4 6.1, dashed G4 7.1)



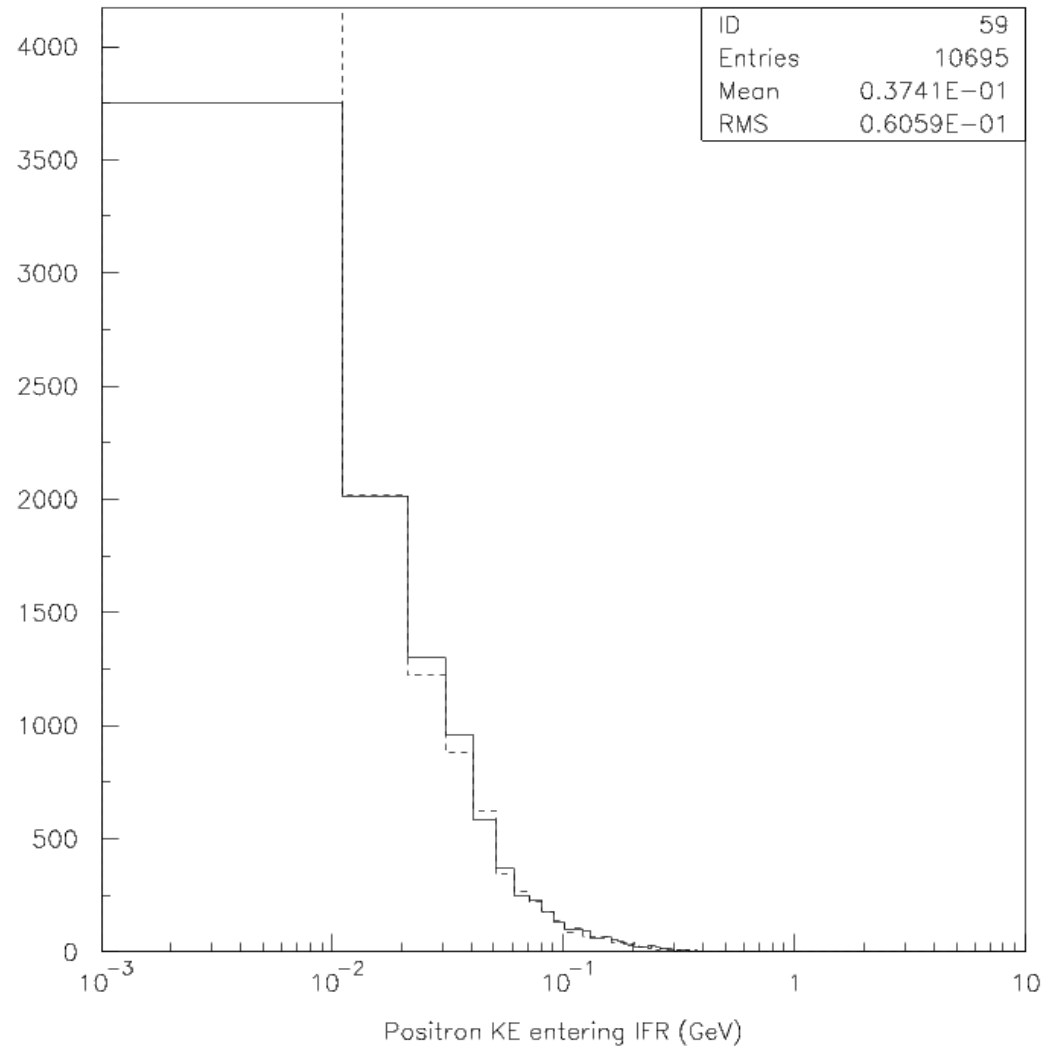
μ^- Entering IFR

(solid G4 6.1, dashed G4 7.1)



Positrons Entering IFR

(solid G4 6.1, dashed G4 7.1)



Validation Status

- Verified that ionization process in Geant4 was fixed
- Comparison of particle spectra using Geant4 6.1 and Geant4 7.1
 - significant differences at IFR (+19% for pions) now understood (cross sections)
 - all other particle types show smaller differences between 6.1 and 7.1
 - +15% for protons, < 5% all others
 - may still be differences showing up in detailed analyses

Validation Plans

- Continue subsystem validation in 19.4.2
 - any detailed changes visible?
- Continue testing at Bogus level
 - look at dimuons, bhabhas
 - use single particle generators to look for
 - differences in kaon spectra produced by pions
 - effects of pion cross section bug

Conclusions

- Several problems have been fixed during switch to Geant4 7.1
 - in Bogus, BgsG4Extension and Geant4 toolkit
 - 19.4.1 (now 19.4.1a) looks good so far
- Multiple scattering has been improved – but no changes in BaBar analysis so far
- Changes in pion cross section most significant change to BaBar
- Changes in kaon physics models will likely affect detailed analysis, but so far no large changes seen