

# New BERT Features for 10.0 Release



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Most of 2013 Work Plan implemented

- New angular distributions for two-body final states
- Stopping/capture of muons with generate cascade
- Forced first interaction validated, improved

Addressing thread safety and re-optimizing for MT

- Separate active code from shared (static) data
- Replace G4DynamicParticle (G4Ions) with G4Fragment

No progress moving toward “physical units” in nuclear model

# Technical Changes

## Kinematics moved to new “factory” interface

- Subclassed generator functions for different states
- Facilitate move from parametrizations to phase space model

## Several bugs introduced during development resolved

- Significant distortion of final-state spectra
- Thread collisions with buffers in shared objects
- Non-reproducibility in sequential and MT running

## Improvements for thread safety

- Don't mix active code using buffers with shared objects
- Replace global functions containing mutable objects with classes
- Replace function-local statics to file scope or class data

# Two-body Angular Generators

Dennis used data and calculations to produce binned distributions of  $\cos \theta$  vs. kinetic energy

- $\gamma p \rightarrow n \pi^+, p \pi^0$
- p-p, p-n, n-n elastic
- $\pi$ -N *still in process*

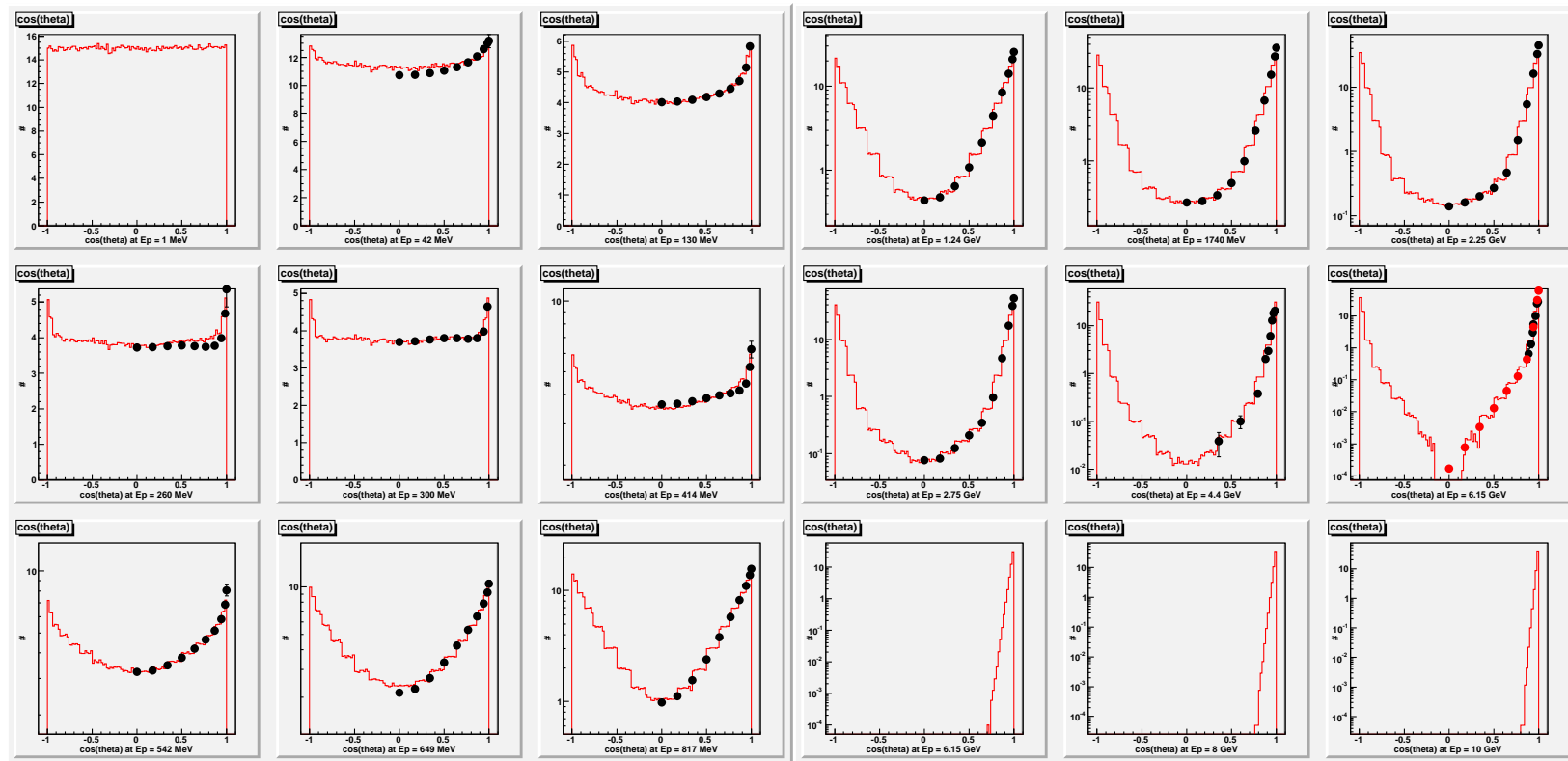
Implemented as two-dimensional interpolations

- $P(\cos \theta)$  integrated to make CDF at each energy
- Interpolate matching bins of  $CDF(\cos \theta)$  with energy
- Generate “intermediate”  $CDF(\cos \theta)$
- Use CDF to generate random polar angle

Calculations from SAID; histograms fitted for interpolation

1 MeV

1.24 GeV



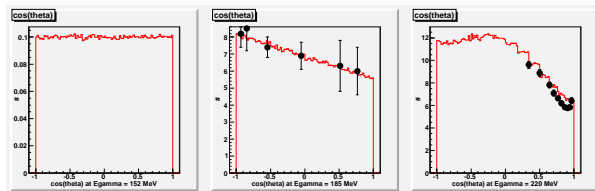
817 MeV

10 GeV

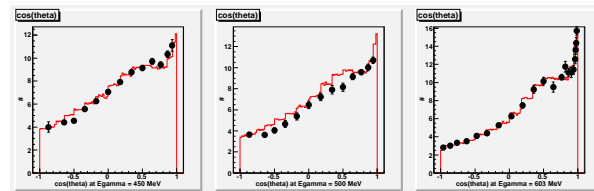


Data from numerous published sources; histograms fitted

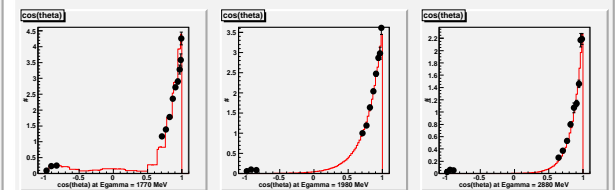
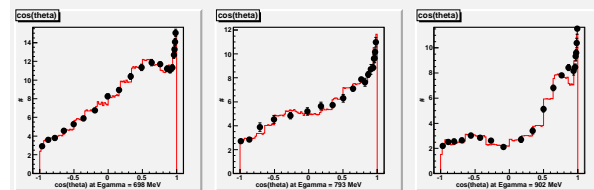
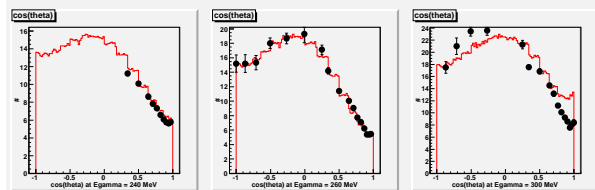
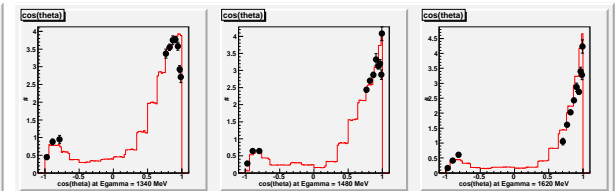
152 MeV



450 MeV



1.34 GeV



400 MeV

1.27 GeV

3.7 GeV

# Muon Capture

BERT now handles leptons as projectile particles

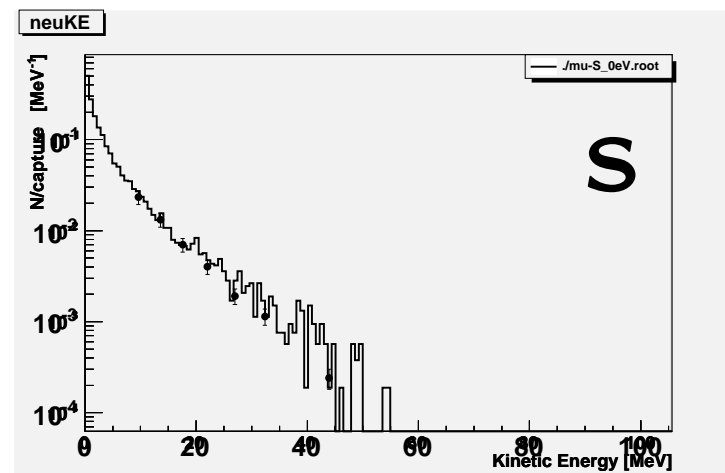
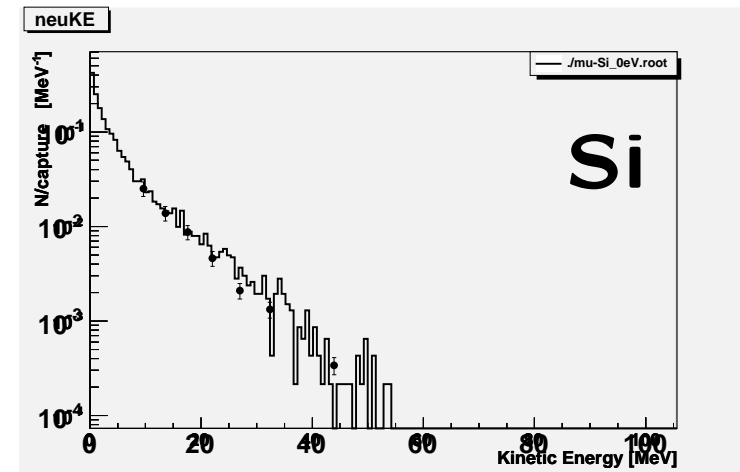
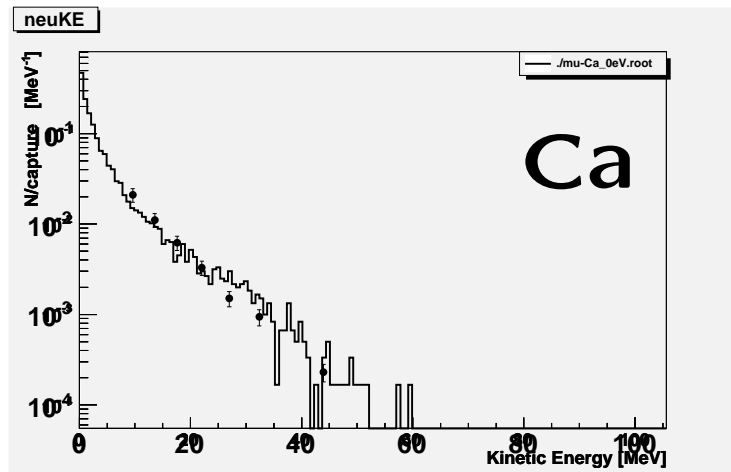
- $e, \mu, \tau$ , neutrinos and anti-neutrinos
- $\mu^- p, \mu^- (pp), \mu^- (pn)$
- Cross-section fixed at all energies
- Tables available for radiative final states

Outgoing neutron from  $\mu^- p \rightarrow \nu_\mu n$  may escape, become exciton, or induce small cascade

Final excited nucleus relaxed using `G4PrecompoundModel`

# Muon Capture

Neutron spectra available for Ca, Si, and S targets





## Forced First Interaction

Hadrons have large cross-sections in nucleus at all energies

- Projectile treated just as cascade secondary
- Throw interaction length for location of first interaction
- Rarely, doesn't interact initially, but after one "transportation" step

$\gamma$  N and  $\mu^-$  N cross-sections much smaller

- Projectiles often fail to interact
- Even with numerous (up to 20) retries
- Model returns "no interaction" state

### **Not correct behaviour!**

Once process manager has chosen interaction with nucleus, model should *always* generate cascade (unless kinematically forbidden)

# Trajectory Emplacement

Forcing interaction at “edge” of nucleus not correct

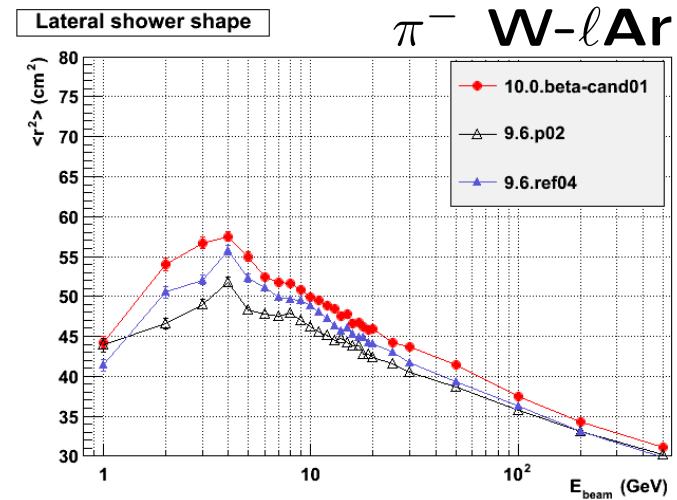
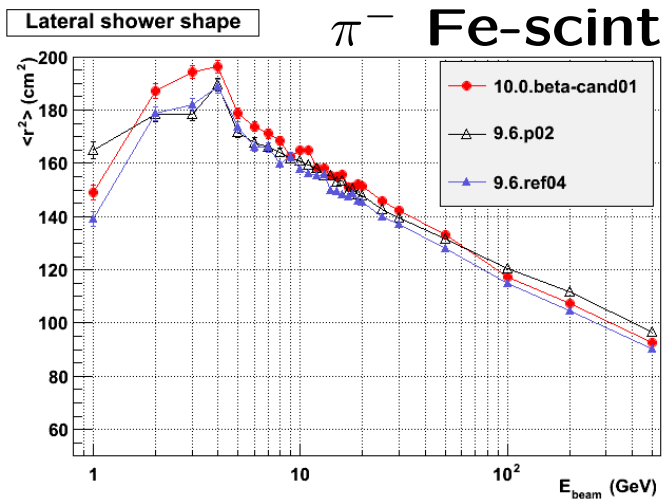
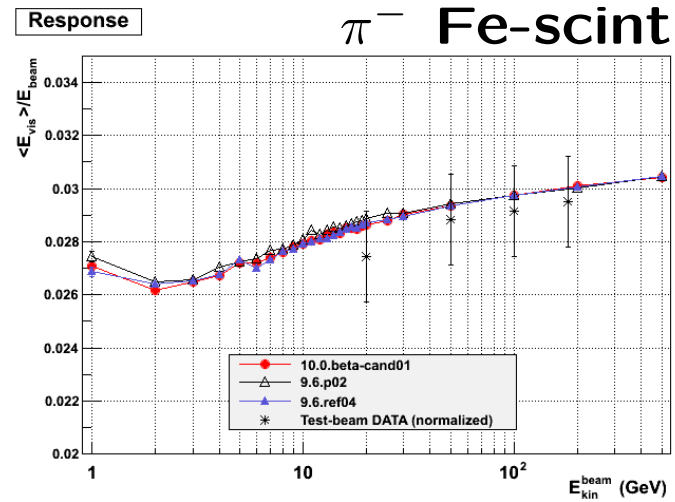
Use interaction length  $\exp(-s/\lambda)$  along trajectory through nucleus to choose point

- Relative cross-sections and nuclear density
- Separate calculations for each target (p, n, [pp], [pn], [nn])
- Resulting secondaries propagate cascade as usual

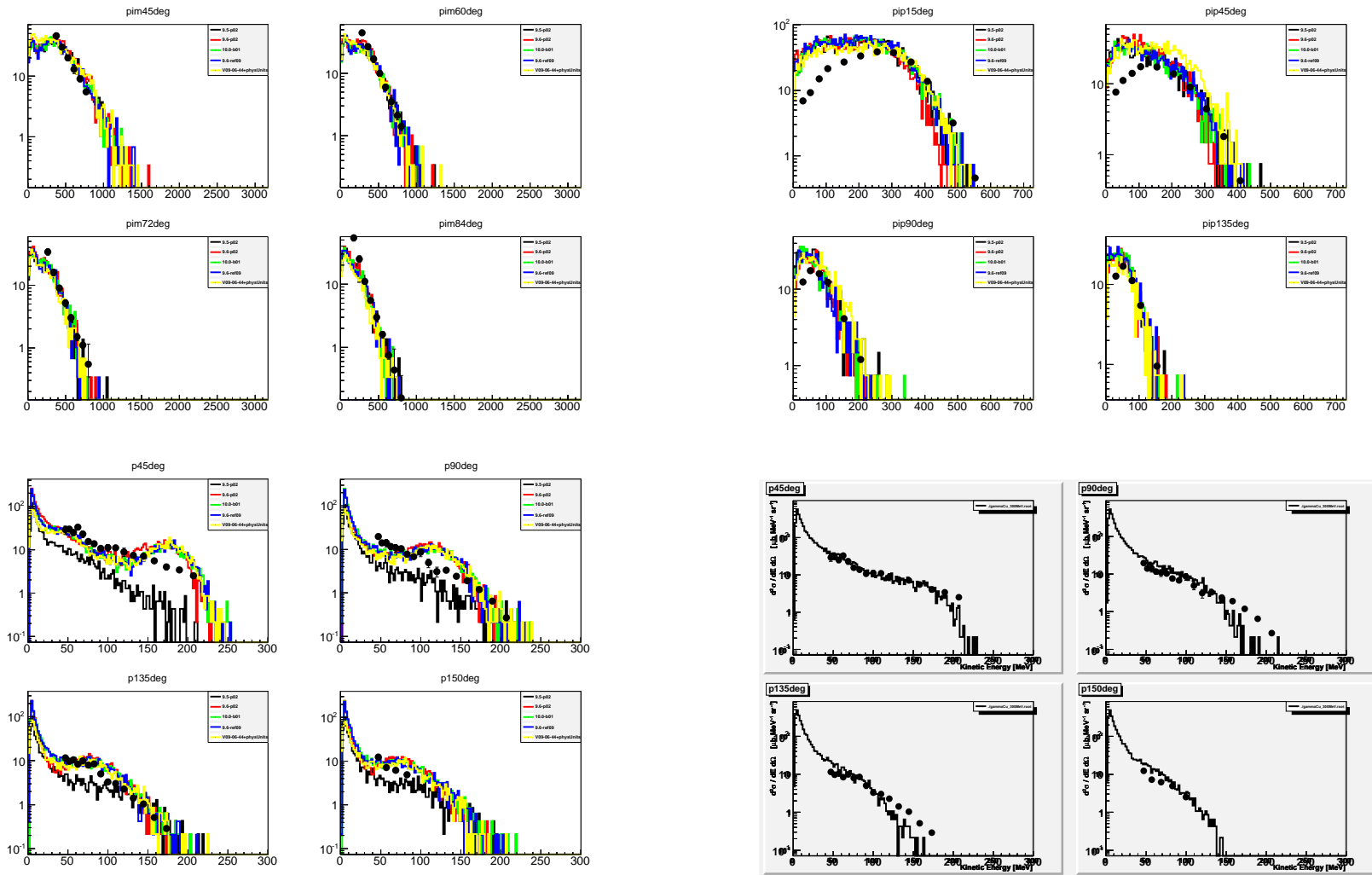
For stopped  $\mu^-$ , “trajectory” is chord along  $z$  axis from chosen impact-parameter point, uniform random

Applies to  $\gamma$  and  $\mu^-$  projectiles only, not hadrons

- Should treat all particles equivalently
- Applying to hadrons degrades validation vs. data



Black: 9.5p02    R/G/B: 9.6p02++    Yellow: Physical units



*Incorrect force-first code*

## Remaining Issues

Continue struggle with “better” nuclear model parametrization

Why are  $\gamma$  interactions better with “wrong” code?

Remaining items from 2013 Work Plan

- Produce and deploy new-style angular distributions for  $\pi$ -N
- Enable post-cascade clustering for light-ion production
- Use PreCompound as default for all de-excitation
- Extend kaon and hyperon final-state tables to 32 GeV  
⇒ deferred to 2014