Geant4 Developments

AARM Meeting
4 March 2013
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Outline

- General Issues
- Phonon/electron hole propagation
- Electromagnetic physics
- Hadronic physics
- Radioactive decay

Multi-threaded Geant4

- To take advantage of multiple-core machines a multi-threaded version of Geant4 (Geant4MT) has been developed

- The current Geant4MT is a prototype
  - event-level parallelism
  - excellent scaling from 2 up to 40 cores

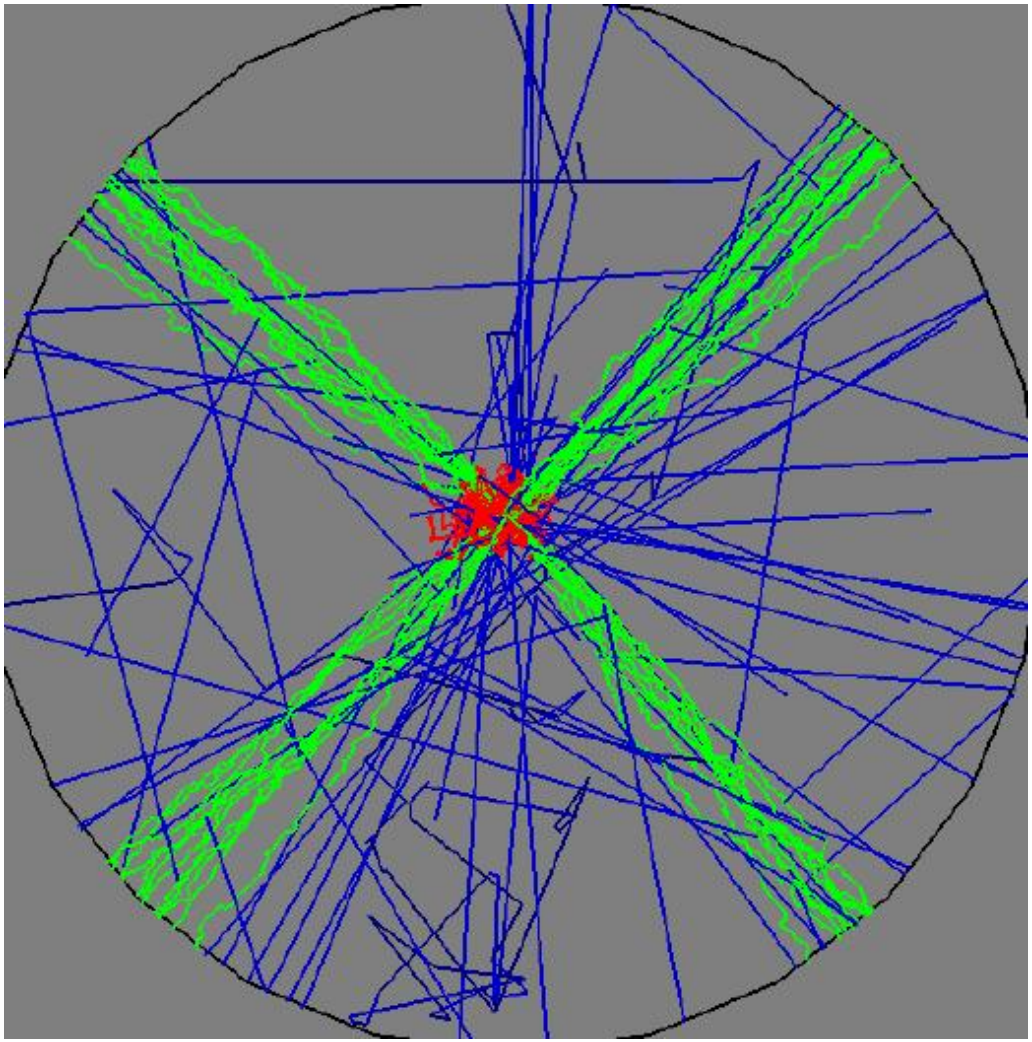
- Geant4MT will be merged with the main branch of Geant4
  - merger completed by Geant4 10.0 (December 2013); after that all Geant4 will be multi-threaded
  - nearly all code affected, but most changes to physics code are trivial
- Current user code will be broken
  - instructions for conversion will be provided at time of release

Event Reproducibility in Geant4

- Results of two runs were not always identical when using the same random seed
  - also the case that you could not take the seed from the end of one run, start another run, and get the same answer as when only a single run of combined statistics was done
  - physics was OK, but this caused problems for debugging
  - a long-standing problem due to caching in hadronics

- This is now fixed for the most part in 9.6
  - only physics lists involving high precision neutrons (HP) are still a problem
  - work continues

Phonon/Electron/Hole Propagation in Geant4



Ge crystal simulation
by D. Brandt (SLAC)

blue – phonon
green – electron
red – hole

Electric field
direction into page

Phonon/Electron Hole Propagation

- As of 9.6, phonon capability available to general user
  - geant4/examples/extended/exoticphysics/phonon
  - Ge crystal at ~40mK with Al endcaps
  - executable must be run from within example directory
- Electron hole transport now undergoing testing
  - example ready for use in 10.0
- New projects
  - channeling of protons and ions in crystals
  - crystal-to-crystal phonon transfer using elasticity tensor

Electromagnetic Physics

- Improved multiple scattering model (WentzelVI) with Geant4 9.6
  - better simulation of both large and small angle scattering
  - now the default for all physics lists
  - however, there's a bug: final track momentum is overwritten by initial momentum + delta P, which is only correct if other physics processes don't shorten the step length
  - affects mostly muons and protons in air
  - don't use G4 9.6, instead use G4 9.6 patch 01 which contains fix

- New EM builder now selects most accurate models for each process: G4EMStandardPhysics_option4
  - Models from both standard and low energy regimes used

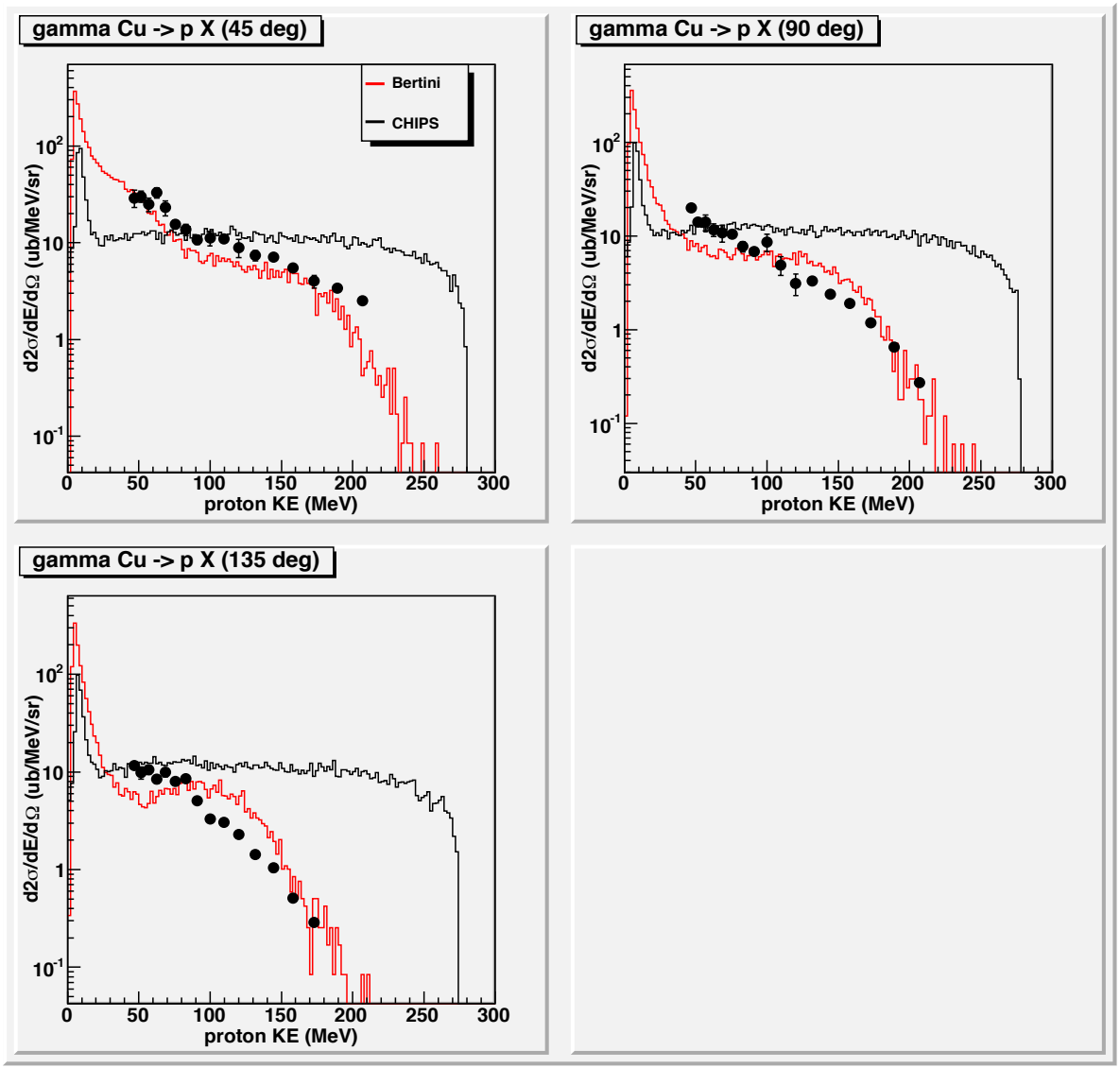
Hadronic Physics Developments

- Improved photo-nuclear process
  - gammas from ~10 MeV to 10 GeV now interact directly with nuclei using the Bertini-style cascade
  - above 10 GeV, the FTF string model is used, but first the gamma is converted to a pion

- Improved mu-nuclear model (G4MuonVDNuclearModel)
  - no longer need to replace virtual photon with 50% π+, 50% π-

- New electro-nuclear model (G4ElectroVDNuclearModel)
  - as in old model, uses CHIPS cross sections and virtual gamma generation
  - now uses Bertini-style cascade to interact gamma below 10 GeV, FTF above 10 GeV

γ Cu -> p X


gamma Cu -> p X (45 deg)
Bertini
CHIPS
d2σ/dE/dΩ (ub/MeV/sr)
proton KE (MeV)
gamma Cu -> p X (90 deg)
d2σ/dE/dΩ (ub/MeV/sr)
proton KE (MeV)
gamma Cu -> p X (135 deg)
d2σ/dE/dΩ (ub/MeV/sr)
proton KE (MeV)

Hadronic Physics Developments

- Ion-ion collisions
  - INCL++ cascade model can now handle ion collisions up to 3 GeV (projectiles/targets up to mass 12)
  - The FTF string model can now be used for all ions at energies from ~ 3 GeV to ~ TeV
    - although validation is still underway
- For the first time in Geant4, we can consider doing heavy ion collisions at all energies
  - QMD (or INCL++ or Binary cascade) coupled with FTF model
  - should now address all cosmic ray needs

Hadronic Physics Developments

- LEP, HEP (Gheisha-style) models are deprecated
  - better models now available to cover all particles, all energies formerly handled by LHEP
  - after Geant4 10.0, physics lists using LEP, HEP models will not work – for underground physics applications, we recommend the Shielding list

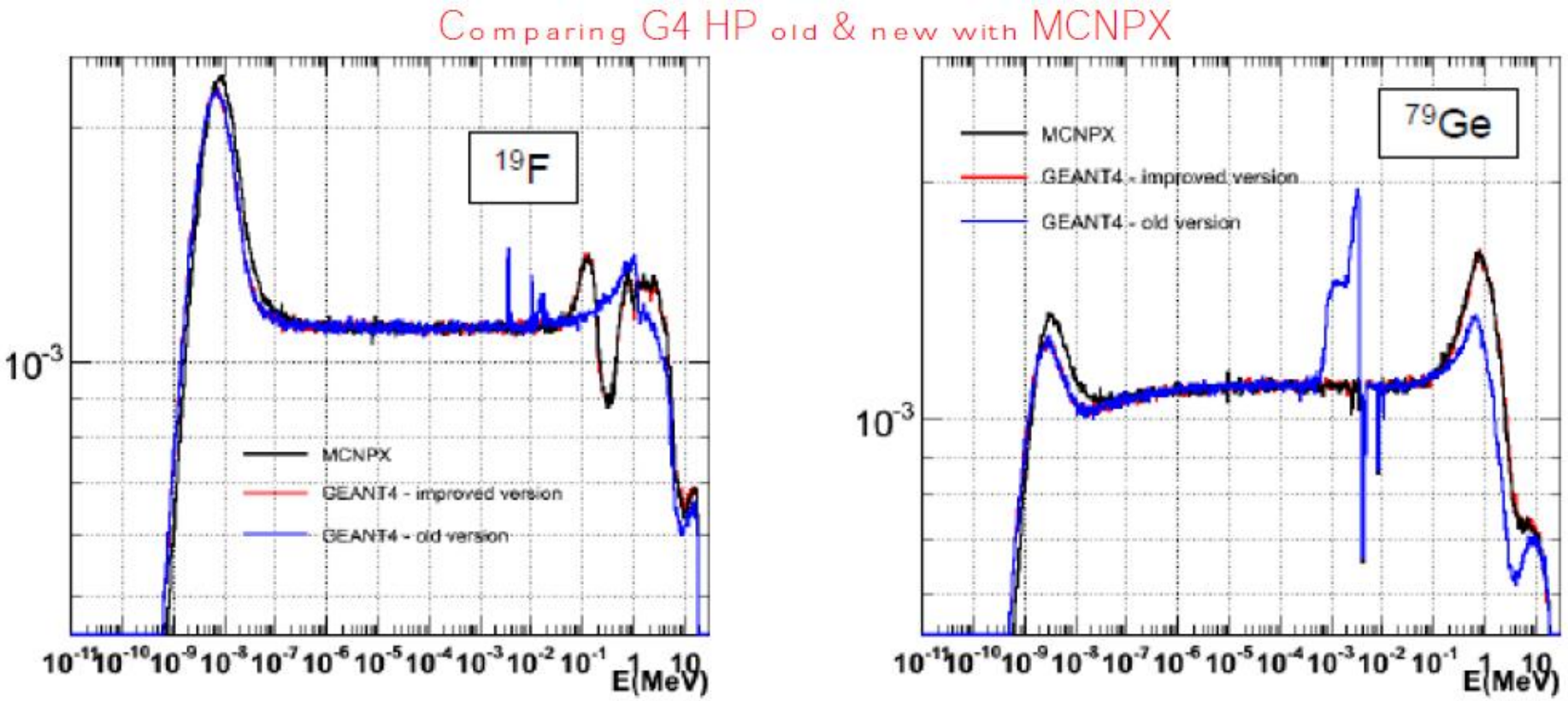
- CHIPS (Chiral Invariant Phase Space) code deprecated
  - cross sections and other important pieces of code extracted into other models
  - physics lists using original CHIPS code will disappear
    - this includes some stopping and nuclear de-excitation code

Hadronic Physics Developments

- Two high precision neutron models available (E < 20 MeV)
  - neutronHP
    - the old standard, but now more data library options
    - data sources are no longer mixed
  - LEND
    - newer and faster model based on Livermore database
    - so far, fewer isotopes than neutronHP, but will improve

- High precision charged particle models (p, d, α)
  - prototype for protons available, still being tested
  - α model expected sometime this year
  - will have same data sources as neutronHP

High Precision Neutrons
Comparing Geant4 and MCNPX

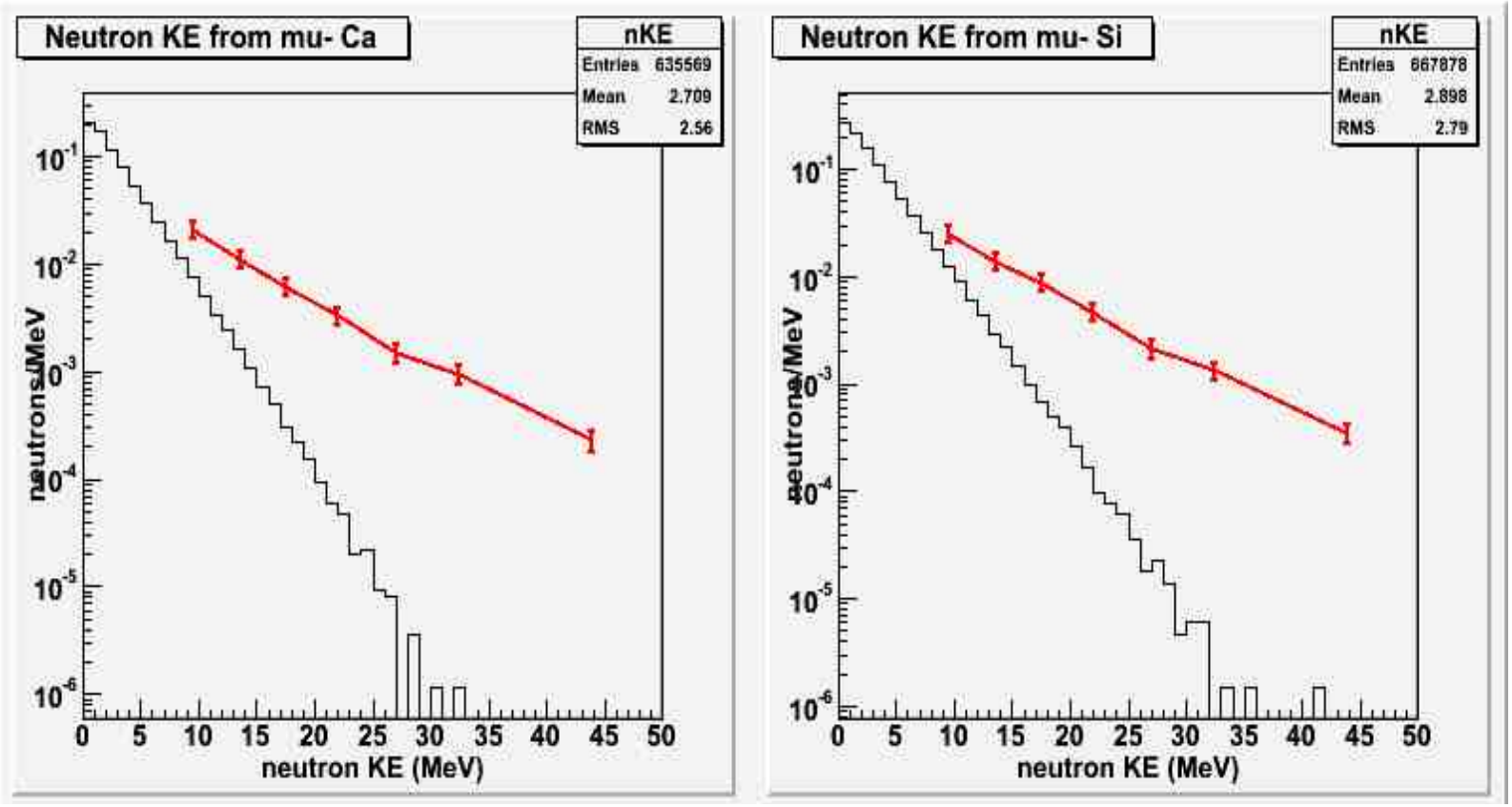


Particle Stopping and Capture

- New stopping models (to replace old CHIPS models)
  - G4PiMinusAbsorptionBertini
  - G4KaonMinusAbsorptionBertini
  - G4SigmaMinusAbsorptionBertini
  - G4AntiProtonAbsorptionFritiof

- Improved mu-stopping
  - current model is quite simple, with too-soft neutron spectrum
  - replace with Bertini using both one and two nucleon muon absorption
  - expected by 1st half of this year

Neutron Energies from Muon Capture

- 

Radioactive Decay

- New data set required
  - RadioactiveDecay3.6 (available in download area)
  - 534 nuclear states now have precise beta decay spectrum shapes (classified as 1^{st}, 2^{nd}, or 3^{rd} unique forbidden)

- Activation now added
  - good agreement with proton activation data

- Directional biasing of decay daughters
- Production and propagation of isomers/metastable nuclear states
  - coming 1^{st} half of this year

Summary

- Many improvements relevant to low-background experiments in Geant4 9.6
  - EM, hadronic radioactive decay, gamma- and lepto-nuclear
  - but use patch01 of Geant4 9.6
- Geant4 is moving to multi-threading by the end of 2013
  - user code will need to be modified
- Reproducibility
  - all Geant4-provided physics lists now give fully reproducible runs, with the exception of those involving low energy neutrons