FISSION FRAGMENT GENERATOR

Development of a Data-Based Fission Fragment Generator using the Geant4 Framework

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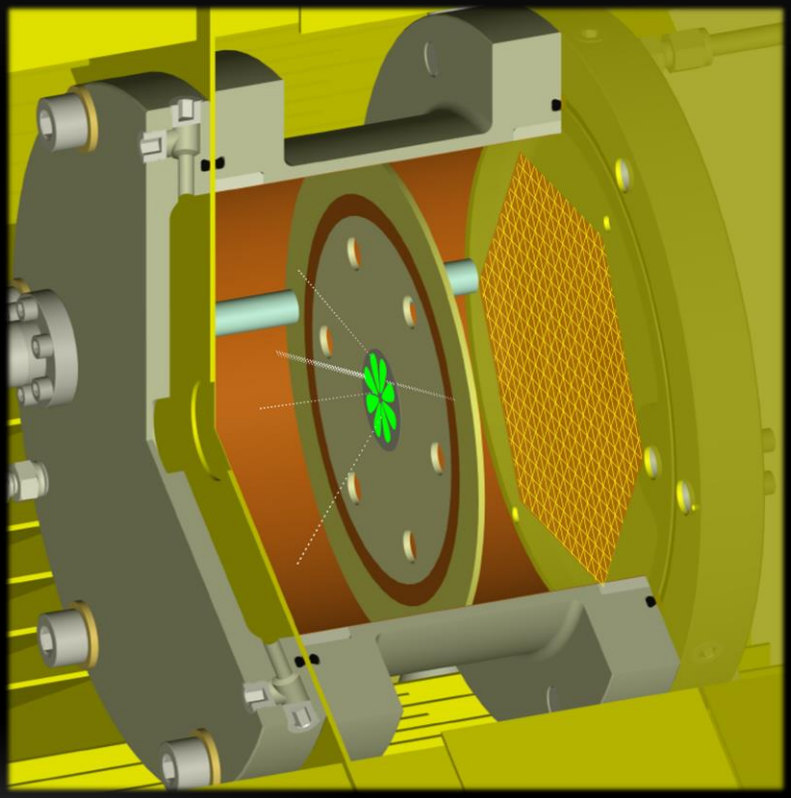
Use in the NIFFTE (Neutron-Induced Fission Fragment Tracking Experiment) Collaboration

ORIGINS

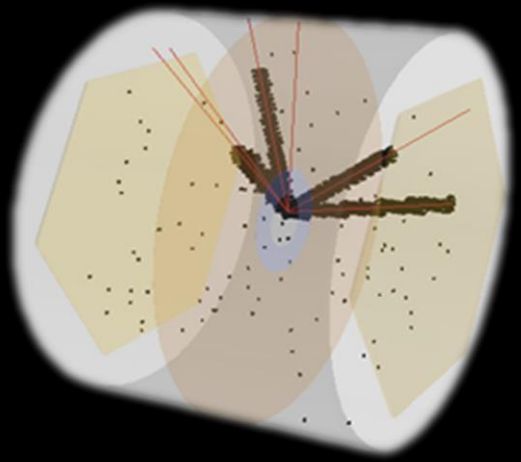
CONTEXT – THE NIFFTE TPC

- Nuclear Data Measurements via TPC
  - Small – 15 cm diameter
  - Pressurized fill gas
  - Central Cathode
    - Target placed in center
    - 1 ns cathode readout resolution
  - Two Outer Anode Planes
    - ≈2000 detector pads per plane
    - 16 ns or better charge collection resolution



MOCK DATA CHALLENGE

- Validation of the custom reconstruction software
  - Compare input vs. reconstructed track length, direction, charge, etc…
  - Geant4-based to provide single framework for entire simulation, from particle and field interactions to geometry
- Original process was manual entering of particles – very tedious
- Fission Fragment Generator was conceptualized – data based simulation of fission events
- Implemented as a custom module in our “TPCPrimaryGeneratorAction.cc”



Fission Fragment Generator Data and Simulation Design

CAPABILITIES

DATA SOURCES

- File based
  - ***NOTE*** Uses pre-existing Geant4 data in G4ENDL neutron data files
  - Fission product yields distributions in: `${NEUTRONHP}/Fission/FF`
  - Watt fission spectrum constants in: `${NEUTRONHP}/Fission/FS`
- Hard-coded values
  - v – Prompt neutron production in: `G4FPYNubarValues.hh`
  - Alpha particle angular distributions in: `G4FissionProductYieldDist.cc`

FISSION EVENT SIMULATION

- Whole-event perspective
- Conservation principles
  - Mass, momentum, charge
- Process
  1. Generate ternary fission particles (not used by default)
  2. Select fission fragment from data
  3. Generate neutrons
  4. Sample particle energies (ternary, neutrons)
  5. Generate fission γ's
  6. Sample angles for γ's and light ions (assume isotropic distribution)
  7. Calculate fission fragment angles

FISSION EVENT SIMULATION

- Geant4 kernel defines isotope / isomer
- Incident particle provides:
  - Fission type (currently only data for neutron-induced)
  - Energy
- Default parameters
  - Sample over entire yield distribution
  - No ternary fission
  - Neutron induced
- Configurable parameters
  - Fission fragment sampling methodology
  - Ternary fission probability and yields

Structure and Documentation

CODE

CORE CALCULATIONS

- Inheritance provides for selection of sampling scheme
  - G4FissionProduceYieldDist
    - G4FPYNormalFragmentDist
    - G4FPYBiasedLightFragmentDist
- G4FPYSamplingOps
  - Specialized class for sampling continuous distributions (neutron/alpha production) as integer values
  - Maintains overall mean
  - Assumes Gaussian-shaped distribution

DOCUMENTATION

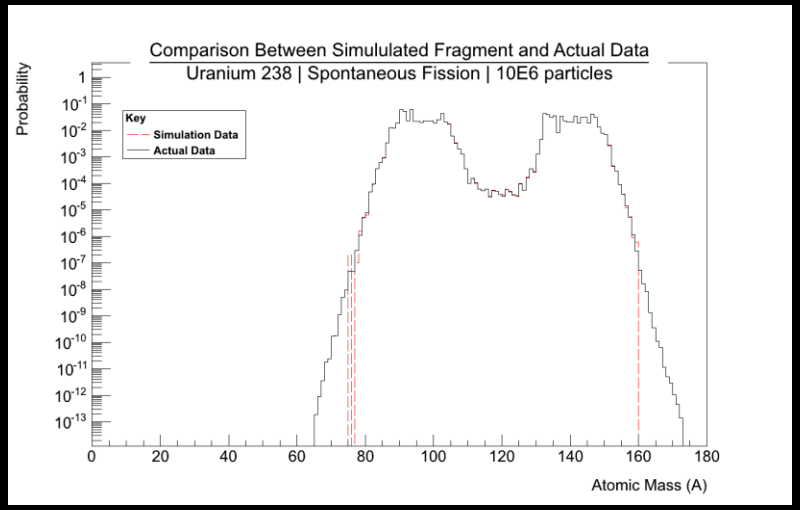
- Extensive use of comments to explain processes and reasoning
- Code structure currently documented for use with Doxygen
- “Users Manual” in rough draft
  - Overview of code layout
  - Input parameters
  - Sampling methods/algorithms
  - Missing discussion of results

Simulation Data

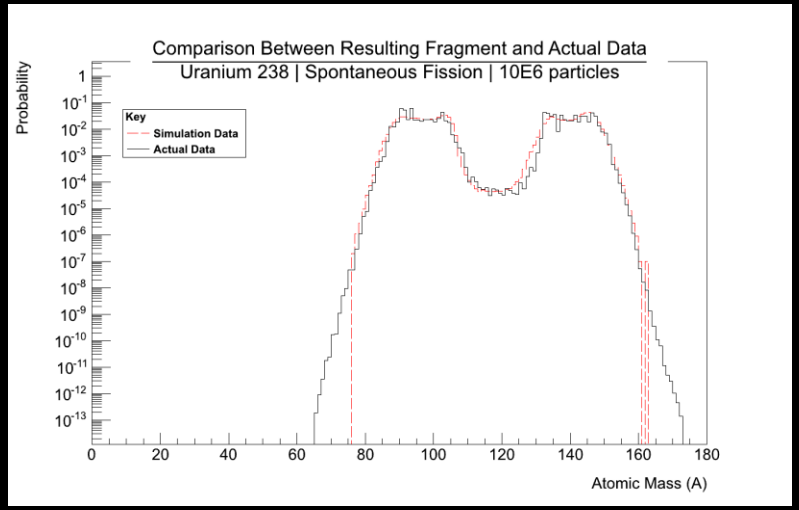
RESULTS

FRAGMENT DISTRIBUTIONS

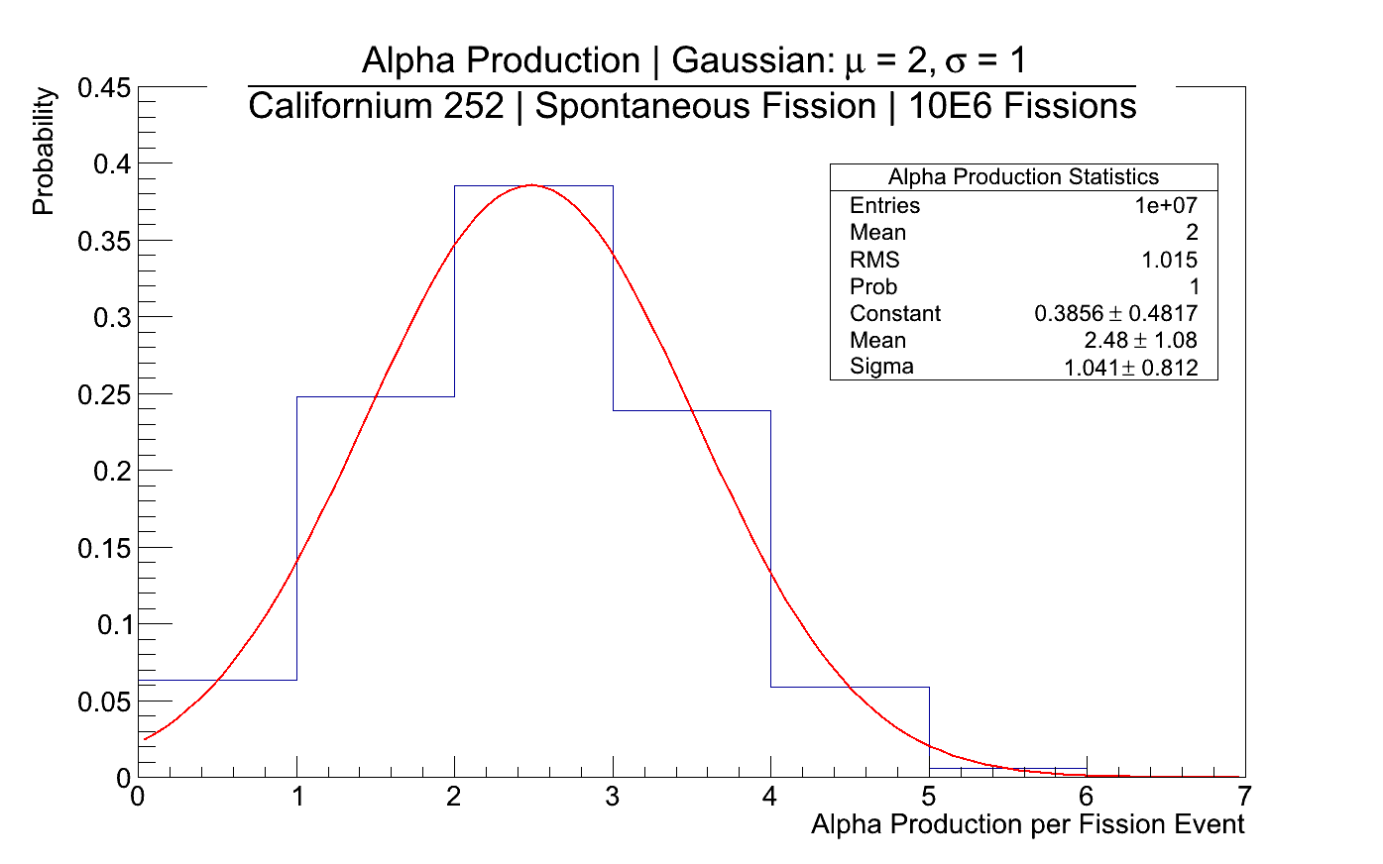
Sampled Fragment (from data)



Resultant Fragment (remaining mass)



CONVERSION OF A CONTINUOUS DISTRIBUTION INTO INTEGER VALUES



FINALLY…

INTEGRATION

- The “Fission Fragment Generator” will be available as a model of the Geant4 hadronic framework under the HP directory
- Timeline: completion and inclusion in the December release of Geant4 10

FUTURE WORK

- Physics
  - Ballistics using information from fission-inducing particle
  - Spontaneous fission as a stand-alone model
  - High energy neutron models (>10 MeV, I'm a nuclear engineer)
    - Symmetric fission
    - Asymmetric fragment angular distributions (more prominent at higher energies)
- Utility
  - Allow for a user-provided constraint on the initial fission fragment direction
  - User example of implementation
- Other
  - Photo fission, proton-induced fission
  - Update and complete manual
  - Update internal documentation to Geant4 standard
  - Paper/Publication