Fermilab U.S. DEPARTMENT OF ENERGY | Office of Science

Celeritas Physics Perspectives

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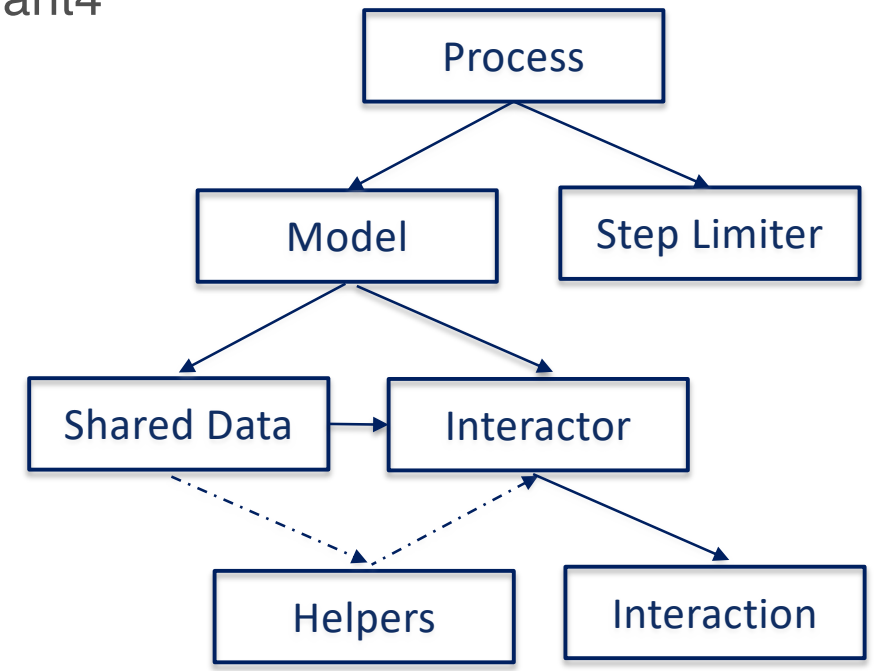
Celeritas Physics: Available Processes

- Celeritas physics models are based on Geant4 10.6 or 10.7 and significantly restructured, but functionally equivalent to Geant4.
- Most processes rely on imported data from Geant4 (interaction xsecs, range and energy loss tables) - ImportProcessAdapter
- Currently available processes and models:

Particle	Process	Model(s)	Status
γ	photon conversion	Bethe-Heitler	implemented
	Compton Scattering	Klein-Nishina	verified
	photoelectric effect	Livermore	implemented
	Rayleigh scattering	Livermore	implemented
$e^{\pm}$	ionization	Moller-Bhabha	implemented
	bremsstrahlung	Seltzer-Berger, relativistic	implemented
	pair annihilation	EPlusGG	implemented
	multiple scattering	Urban	implemented
$\mu^{\pm}$	muon bremsstrahlung	UrbanVI	implemented

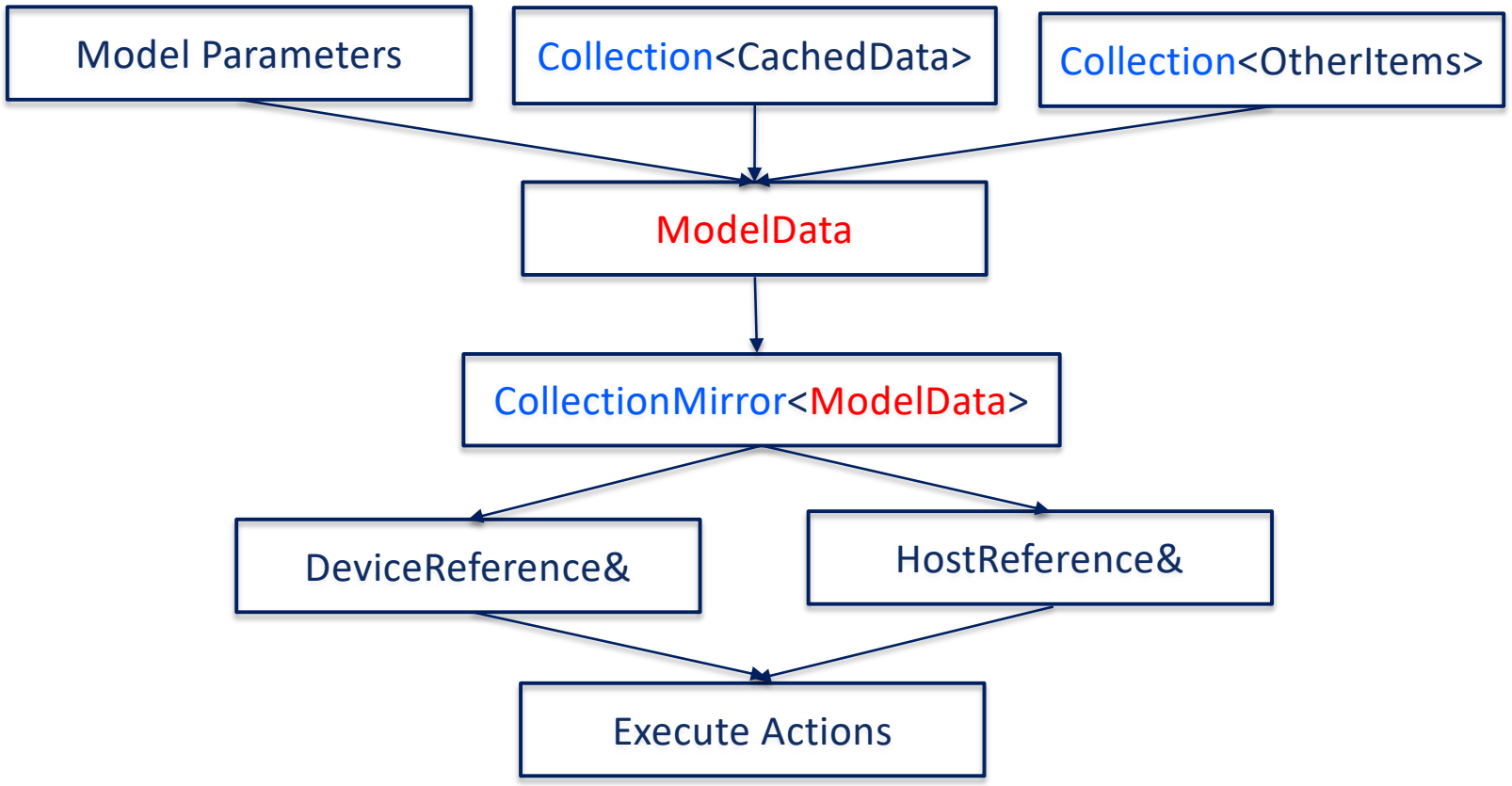
Basic Structure of Process and Model Interactor

- (Host only) Process
  - Import process data from Geant4
  - Build model(s)
  - Build step limiter
- (Host only) Model
  - Build shared model data
  - Set applicability
  - Execute (action to kernels)
- (Device/Host) Interactor
  - Final state interaction
- (Device/Host) Helper classes
  - Calculators (diff. cross sections, range, dE/dx, lpm, etc. …)
  - Samplers (distributions)
  - Utilities



Layout of Physics Model Data

- Rely on celeritas Collection<T, Ownership, Memspace, ItemId<T>>
  - Collection: generic array-like data (T) with ownership and memory type
  - CollectionMirror: helper copying Collection groups to host and device



Interfaces for Physics Kernels

- View: interface to properties of an individual object
- List of views associated with physics

View	Description
Cutoff View	Particle- and material- dependent cutoff values
Element/Material View	Properties of element and material
Material Track View	Material properties of a particle track
Particle View	Properties of a particle
Particle Track View	Physical properties of a particle track
Physics Track View	interface for data and operations common to models

- Action output types: result of an interaction as an example

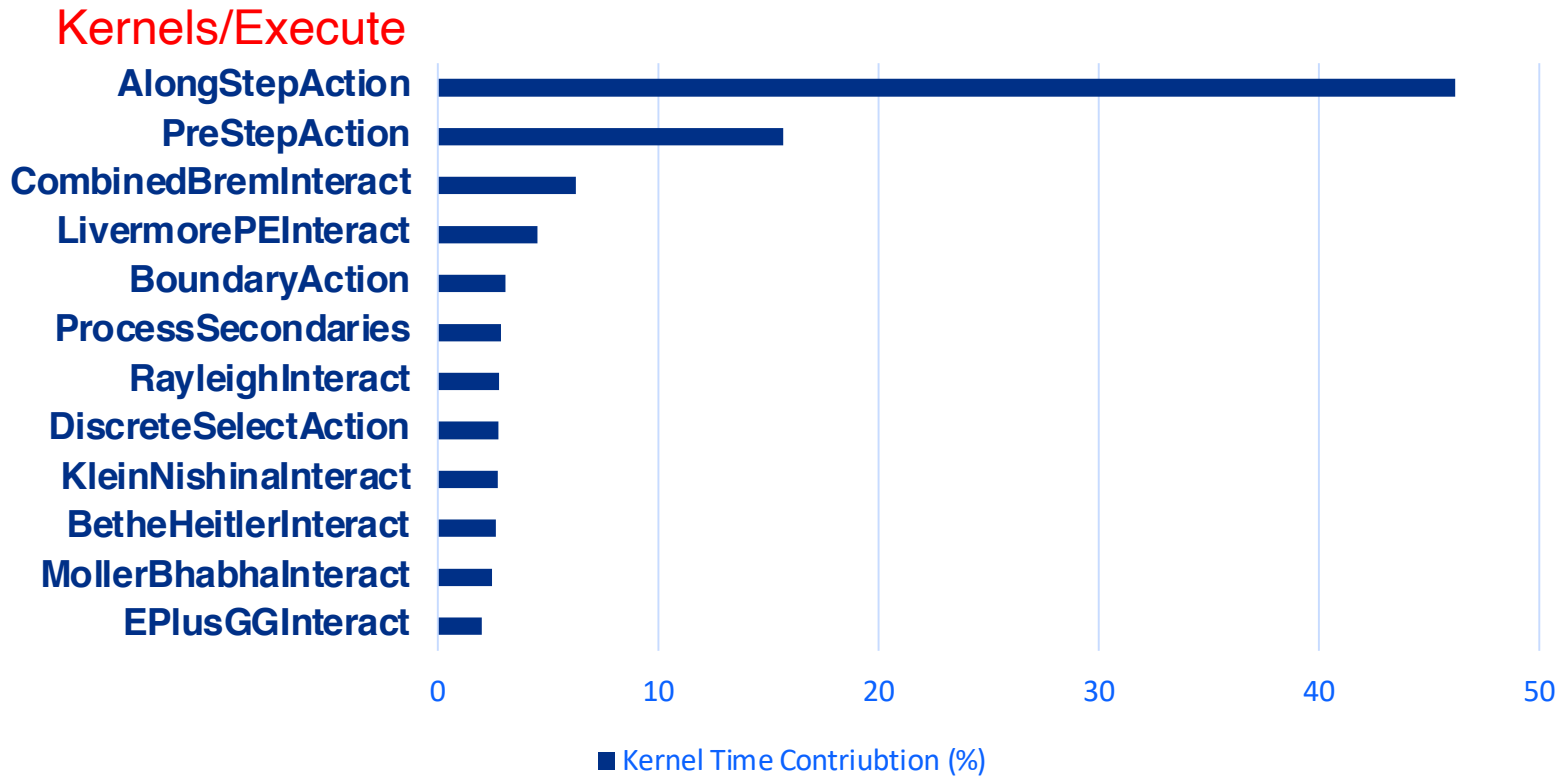
```
//! Change in state due to an interaction.
struct Interaction
{
    units::MevEnergy energy;              //!< Post-interaction energy
    Real3            direction;           //!< Post-interaction direction
    Span<Secondary>  secondaries;         //!< Emitted secondaries
    units::MevEnergy energy_deposition{0}; //!< Energy loss locally to material
    Action action{Action::scattered};     //!< Flags for interaction result
    // ...
};
```

Differences from Geant4

- Units (cgs) and physical constants (SI/CODATA): use of ‘Quantity’
- Using celeritas grid data type instead of G4PhysicsVector
- Following physics operations are independent actions (separated from physics processes or models)
  - Range limiter and energy loss calculator
  - MSC step limiter and scattering sampler
  - Propagator and boundary action (a.k.a G4Transportation)
- Variations and specific choices from Geant4 models
  - Seltzer-Berger model uses SB DCS data and rejection methods (i.e., does not use the SB sampling table)
  - UrbanMSC uses the ‘UseSafety’ stepping algorithm
- Components and models that will be added in this year
  - Spline interpolation and element selector for composite materials
  - WenzelVI MSC (and lepto-/photo-nuclear)

Performance of Physics Kernels

- (Preliminary) Computing performance of physics kernels with SimpleCMS and H→ZZ events (from acceleritas, without MSC)



  - None of discrete (physics model) interactors is a major contributor
  - AlongStepAction: (MSC limiter) + propagator + (MSC sampler) + dE/dx

Physics Perspectives: Next Milestones

- Detail physics verification for each physics model (by energy and material – see the **Stefano's talk**) and performance optimization, especially for multiple scattering (and energy loss calculation)
- The next major model extension: neutron transport (E < 10 GeV)
  - ~20% of the total number of steps (typical HEP), ~25% of CPU time