Hadronic Physics Overview

Geant4 Users' Tutorial at CERN

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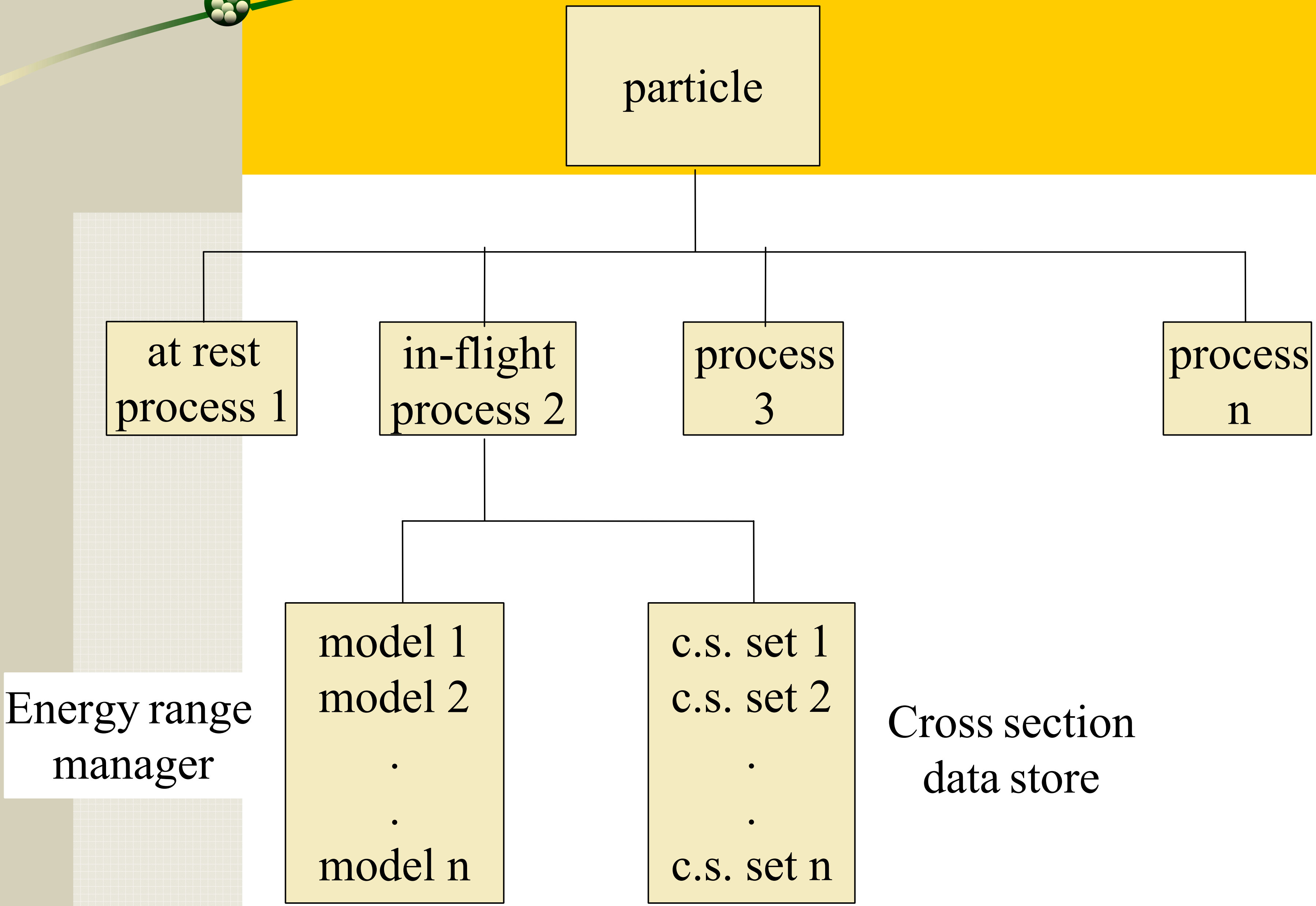
Outline

- Overview of processes, models and cross sections
- Hadronic cross sections and their management
- Hadronic models and their management
- Coding example

Hadronic Processes, Models and Cross Sections

- In Geant4 physics is assigned to a particle through processes
- Each process may be implemented
  - directly as part of the process, or
  - in terms of a model class
- In Geant4 hadronic physics there are sometimes many models for a given process
  - user must choose
  - can have more than one per process
- A process must also have cross sections assigned
  - here too, there are options


particle
at rest process 1
in-flight process 2
process 3
process n
model 1
model 2
.
.
model n
c.s. set 1
c.s. set 2
.
.
c.s. set n
Energy range manager
Cross section data store

Hadronic Processes

- At rest
  - stopped μ, π, K, anti-proton
  - radioactive decay
- Elastic
  - same process (but several models) for all long-lived hadrons
- Inelastic
  - different process for each hadron
  - photo-nuclear, electro-nuclear, muon-nuclear
  - ions
- Capture
  - neutron capture
- Fission
  - Neutron-induced, de-excitation

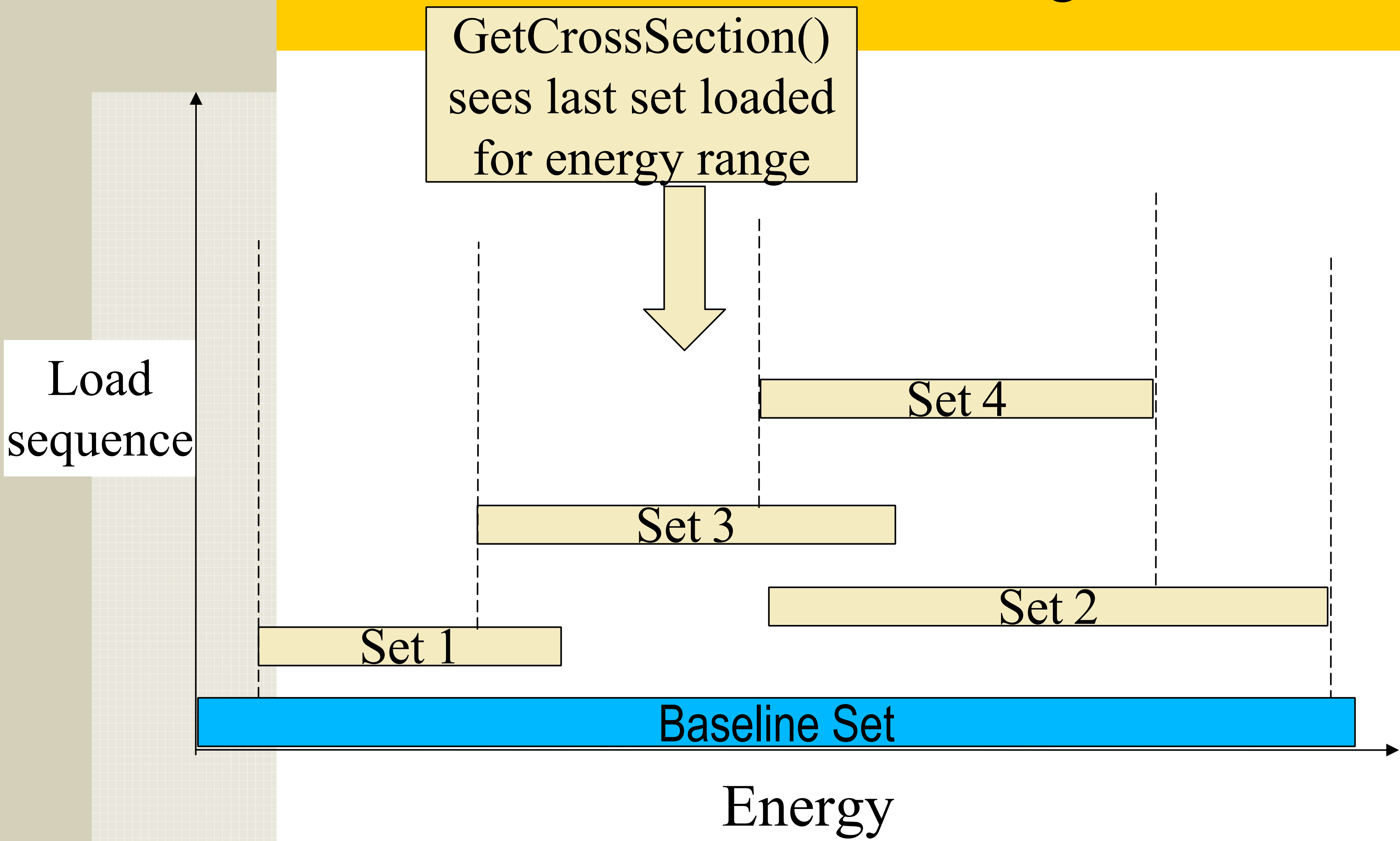
Cross Sections

- Default cross section sets are provided for each type of hadronic process
  - fission, capture, elastic, inelastic
  - can be overridden or completely replaced
- Different types of cross section sets
  - some contain only a few numbers to parameterize c.s.
  - some represent large databases
  - some are purely theoretical

Alternative Cross Sections

- Low energy neutrons
  - G4NDL available as Geant4 distribution data files
  - Available with or without thermal cross sections
- "High energy" neutron and proton reaction σ
  - 14 MeV < E < 20 GeV
- Ion-nucleus reaction cross sections
  - Good for E/A < 10 GeV
- Pion reaction cross sections

Cross Section Management



Hadronic Models – Data Driven

- Characterized by lots of data
  - cross section
  - angular distribution
  - multiplicity
  - etc.
- To get interaction length and final state, models interpolate data
  - cross section, coef of Legendre polynomials
- Examples
  - neutrons (E < 20 MeV)
  - coherent elastic scattering (pp, np, nn)
  - Radioactive decay

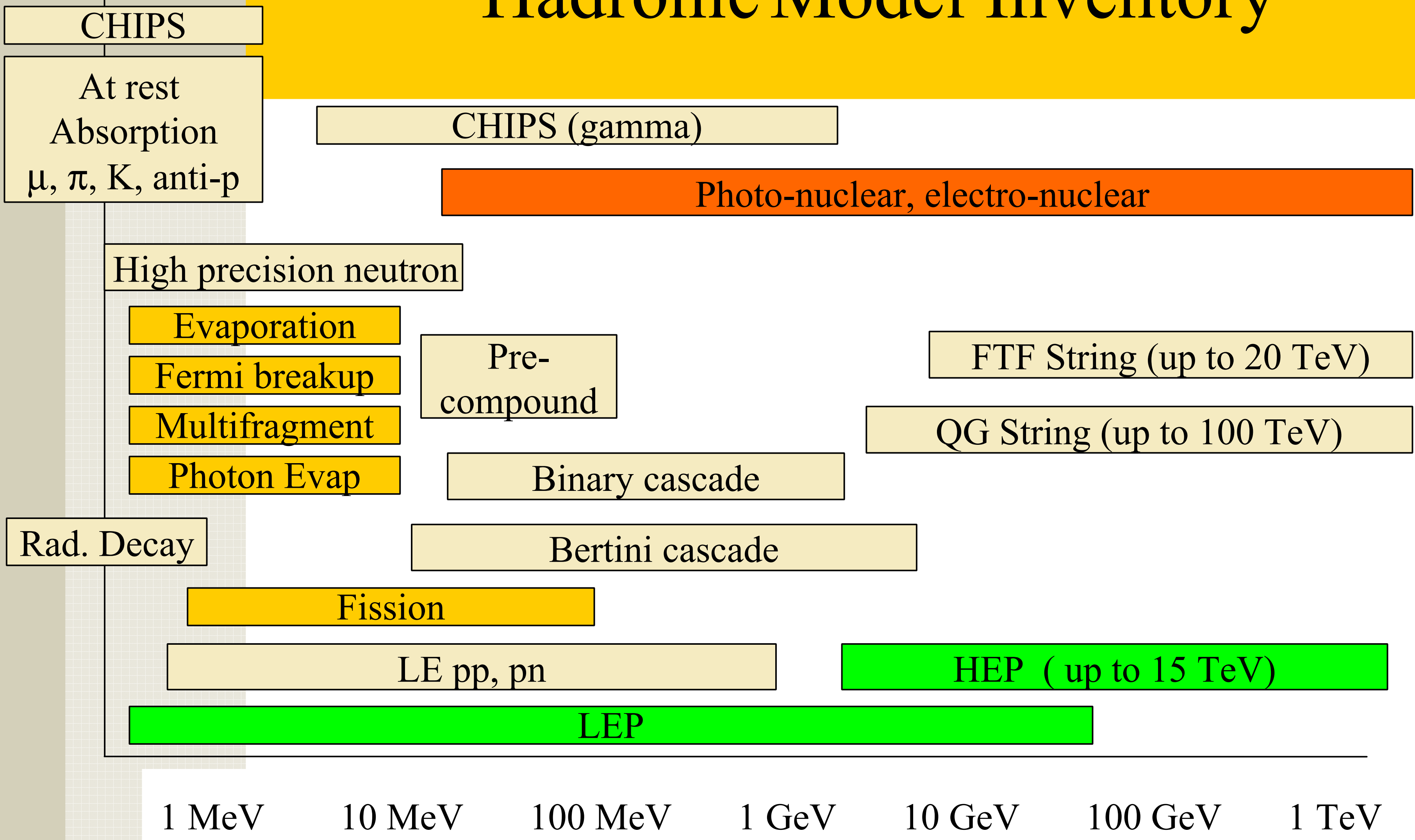
Hadronic Models – Theory Driven

- Dominated by theory (quark-gluon strings, chiral perturbation theory, ...)
  - not as much data to tie things down
- Final states determined by sampling theoretical distributions
- Examples:
  - quark-gluon string (projectiles with E > 10 GeV)
  - intra-nuclear cascade (intermediate energies)
  - nuclear de-excitation and breakup
  - chiral invariant phase space (up to a few GeV)

Hadronic Models - Parameterized

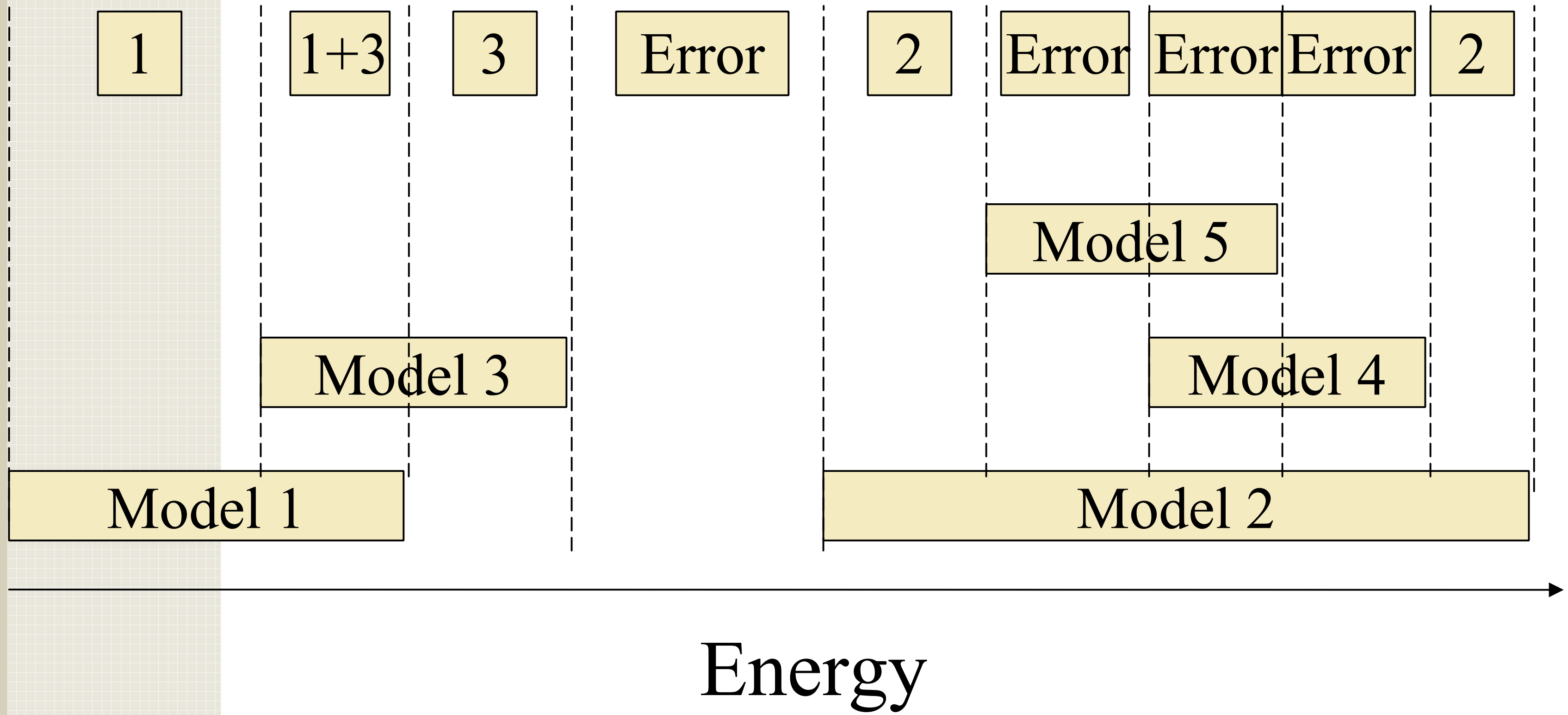
- Depends on both data and theory
  - multiplicities, angular distributions, etc. parameterized to get rough agreement with trends in data
  - theoretical treatments not as detailed
- Final states determined by theory, sampling
  - use conservation laws to get charge, energy, etc.
- Examples
  - LEP
  - HEP

Hadronic Model Inventory

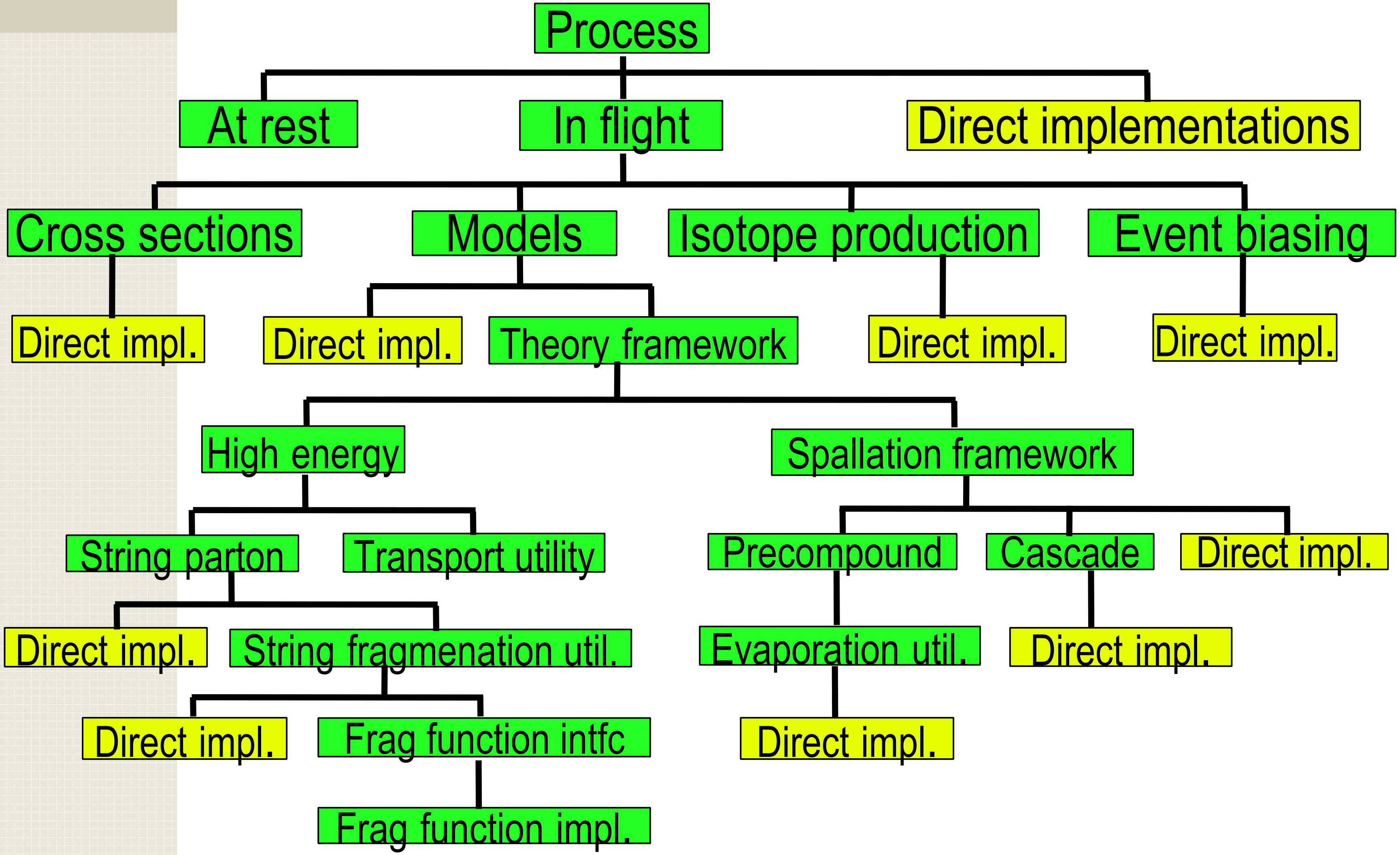


Model Management

Model returned by GetHadronicInteraction()



Hadronic Model Organization



Code Example

```
void MyPhysicsList::ConstructProton() {
    G4ParticleDefinition* proton = G4Proton::ProtonDefinition();
    G4ProcessManager* protMan = proton -> GetProcessManager();
    // Elastic scattering
    G4HadronElasticProcess* protelProc
                                    = new G4HadronElasticProcess();
    G4LElastic* protelMod = new G4LElastic();
    protelProc -> RegisterMe(protelMod);
    protMan -> AddDiscreteProcess(protelProc);
```

Code Example (continued)

```
// Inelastic scattering
G4ProtonInelasticProcess* protinelProc =
                                  new G4ProtonInelasticProcess();
G4LEProtonInelastic* proLEMod = new G4LEProtonInelastic();
protLEMod -> SetMaxEnergy(20.0*GeV);
protinelProc -> RegisterMe(protLEMod);

G4HEProtonInelastic* protHEMod = new G4HEProtonInelastic();
protHEMod -> SetMinEnergy(20.0*GeV);
protinelProc -> RegisterMe(protHEMod);
}
```

Conclusions

- *Hadronic processes require physics models and cross sections*
  - *user must choose (carefully)*
  - *more than one model and/or cross section allowed*
- *Many models offered – three main types:*
  - *data-driven*
  - *parameterized*
  - *theory-driven*
- *Most cross section sets provided by default*
  - *alternative cross sections are available*