Report on the hadronic working group

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GEANT4 activity review 2001

What I will do

- Lead through the principal considerations behind the design of the hadronic categories in geant4.
- Summarize briefly the activities and implementations existing
- Illustrate the functionality with concrete examples of implementations

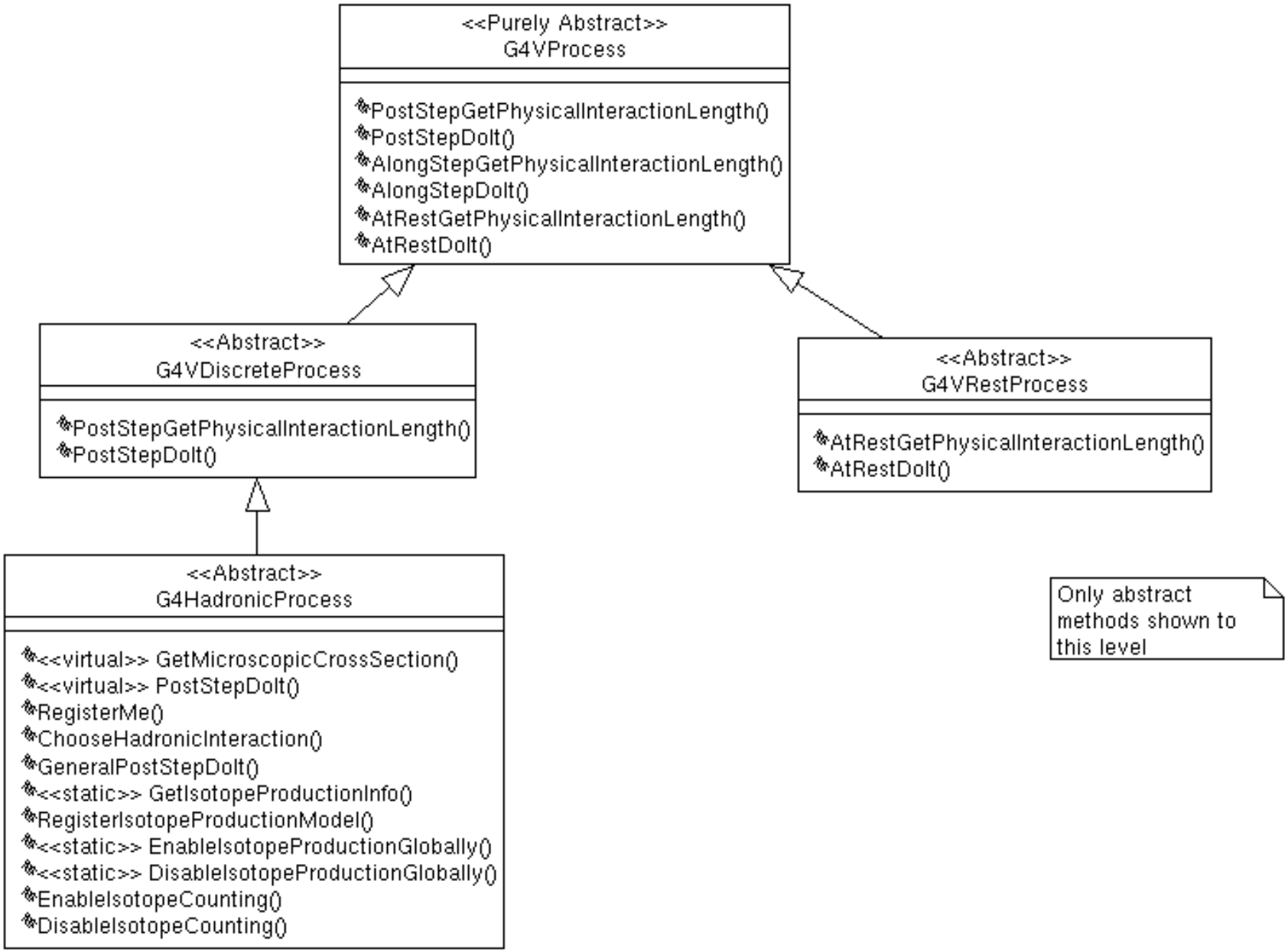
Principal considerations:

- Framework functional requirements are obtained through use-case analysis
- Framework components are found through grouping use-cases into independent bundles (cohesion)
- Complex problems require structured solutions
  - Keep abstractions general and implement in framework interfaces
  - Address more specific use-cases in specialized frame-works, that are implementing the interfaces of the more general frameworks
  - Repeat the pattern until all use-cases are covered

==> A ***Russian dolls*** approach to framework design
or “there are frameworks in frameworks in frameworks”

1st level framework requirement

- Provide the flexibility to allow for calculation of cross-sections and final states for particles in flight and at rest in a medium.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<<static>> DisableIsotopeProductionGlobally()
EnableIsotopeCounting()
DisableIsotopeCounting()
Only abstract methods shown to this level

2nd level framework requirements

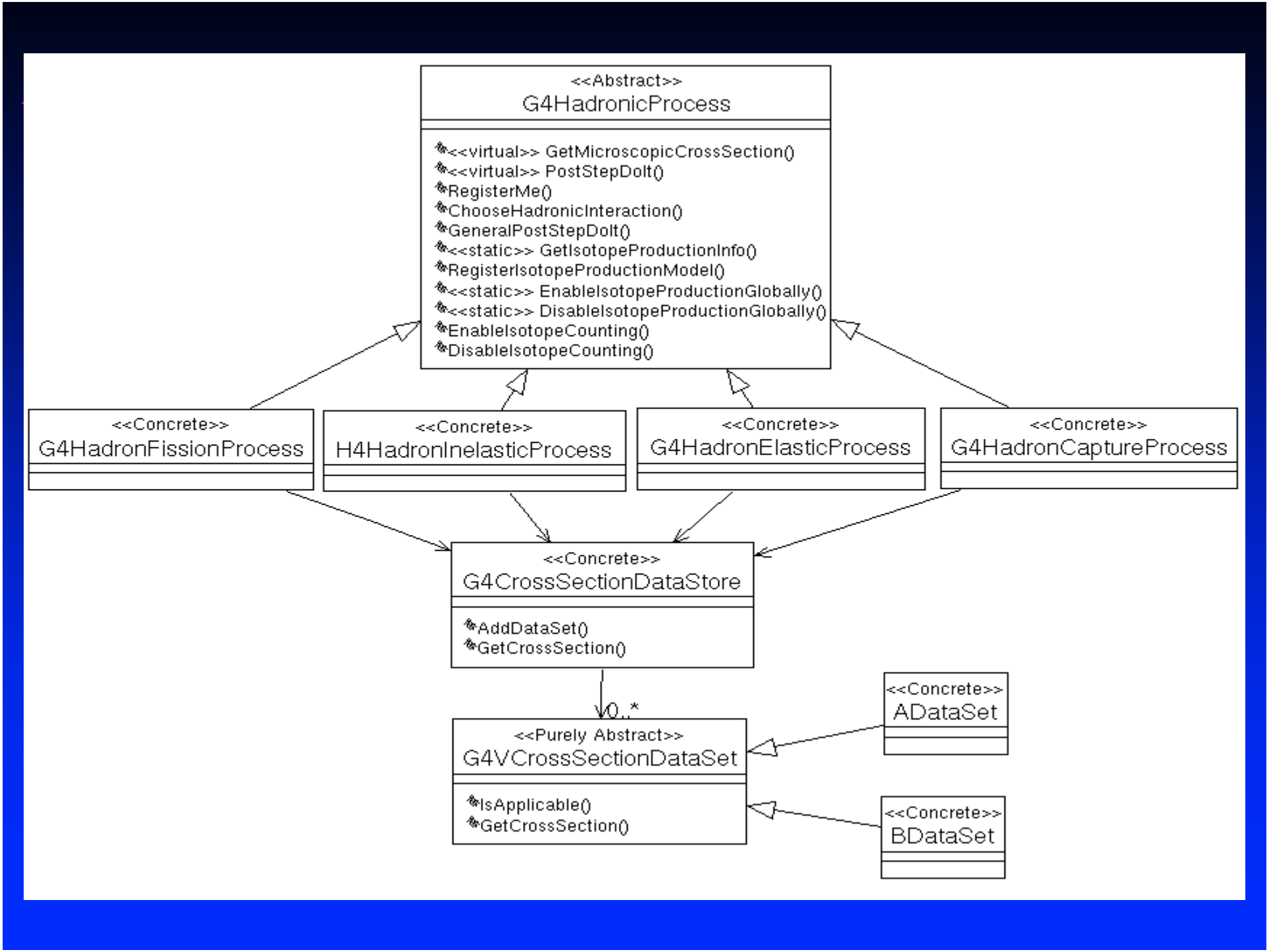
- Flexible choice of inclusive scattering cross-sections
- Possibility to use different data-sets for different parts of the detector
- User shall be able to run geant4 against his own data in a seamless manner

- Flexible choice of final state production code.
- Ability to use different codes in one run, depending on the conditions at the point of interaction
- Ability to use user-defined models in a seamless manner

2nd level framework requirements

- Flexible choice of isotope production codes, to run parasitically to any kind of transport codes
- Ability to use different codes in one run, depending on the conditions at the point of interaction
- Ability to use user-defined isotope production codes

! This grouping of requirements according to related use-cases results quite naturally in three almost independent framework components at the same level of abstraction.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G4HadronCaptureProcess
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AddDataSet()
GetCrossSection()
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G4VCrossSectionDataSet
IsApplicable()
GetCrossSection()
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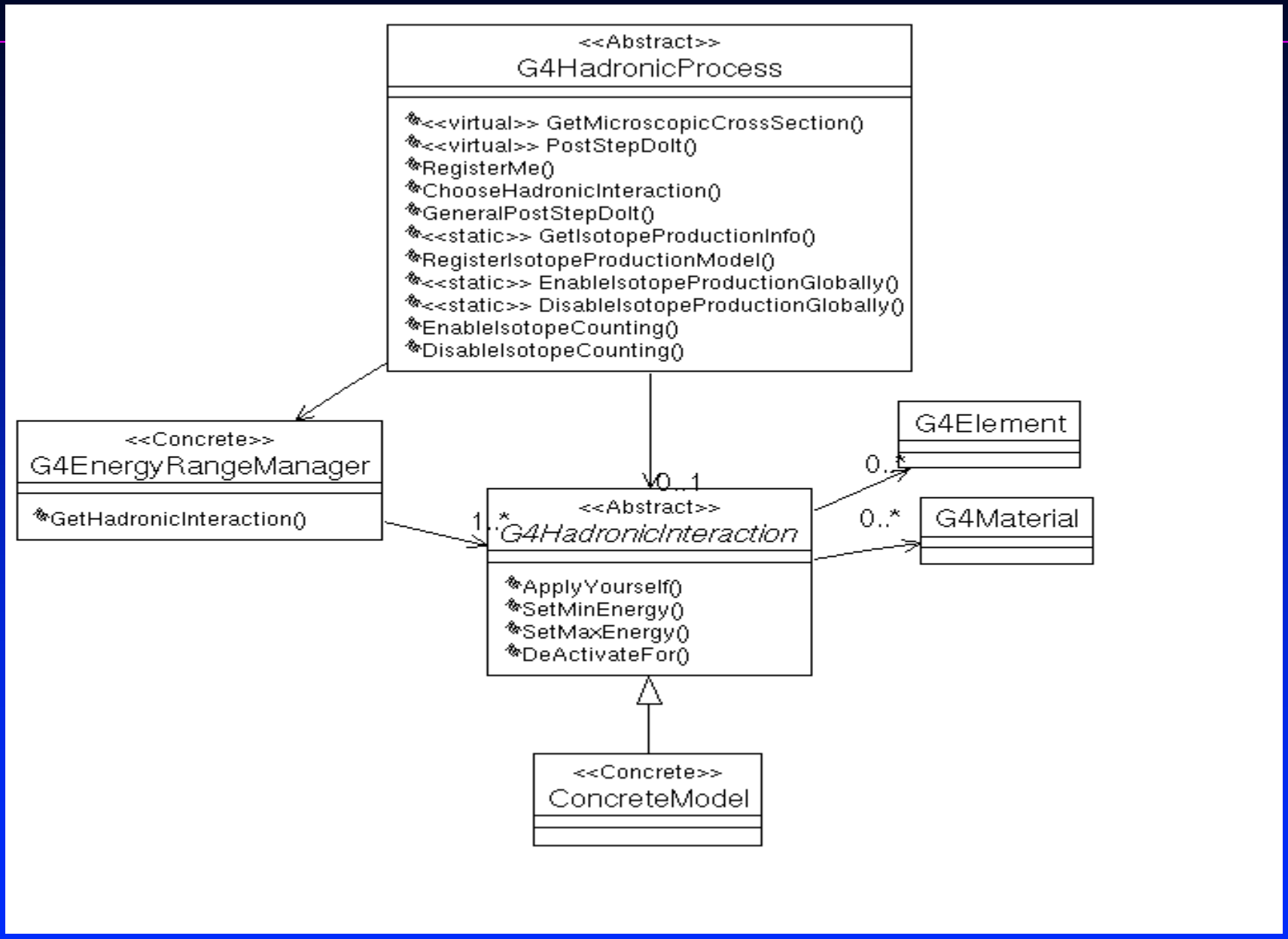
BDataSet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ApplyYourself()
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SetMaxEnergy()
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G4Element
0..*
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G4Material
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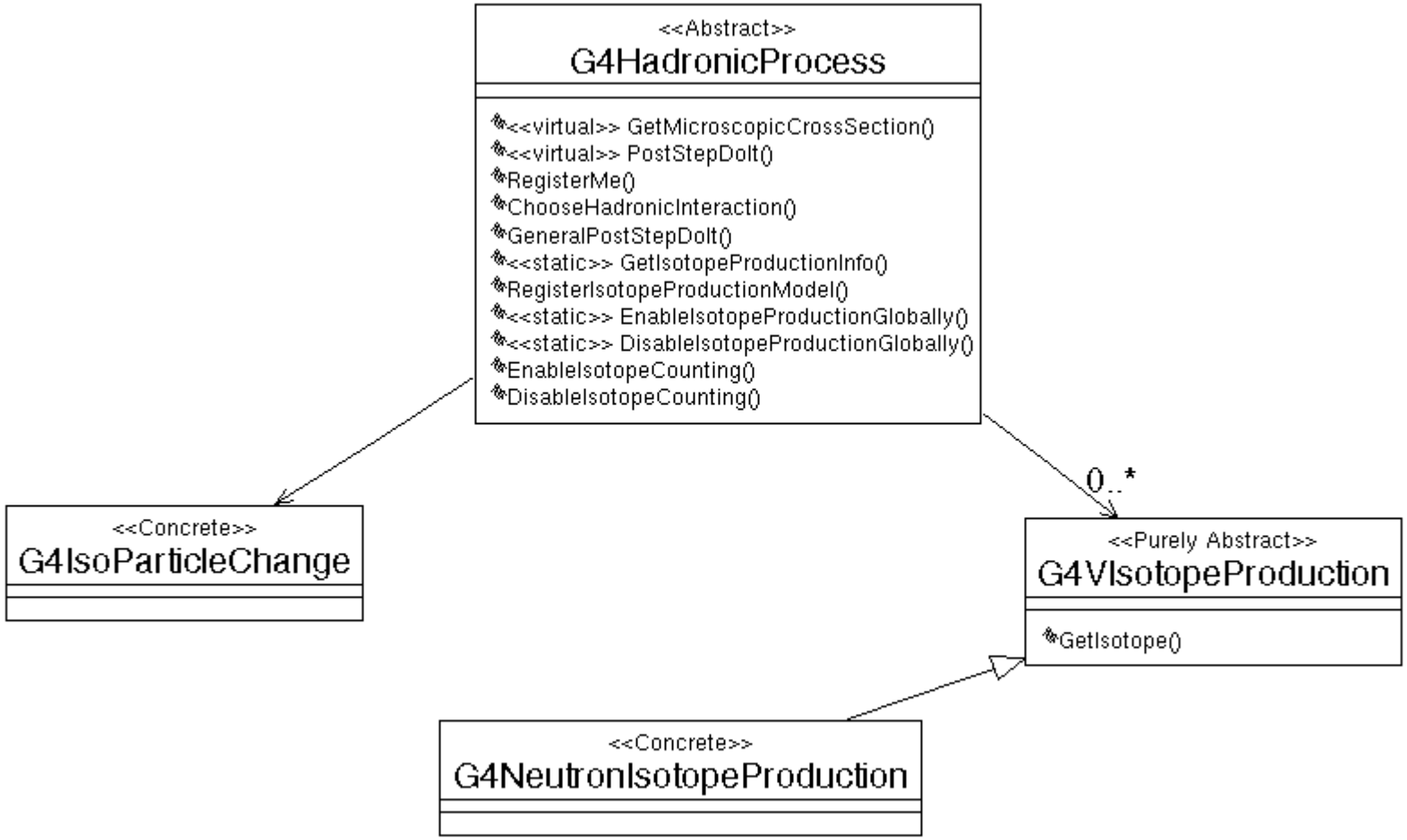
ConcreteModel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G4VIsotopeProduction
GetIsotope()
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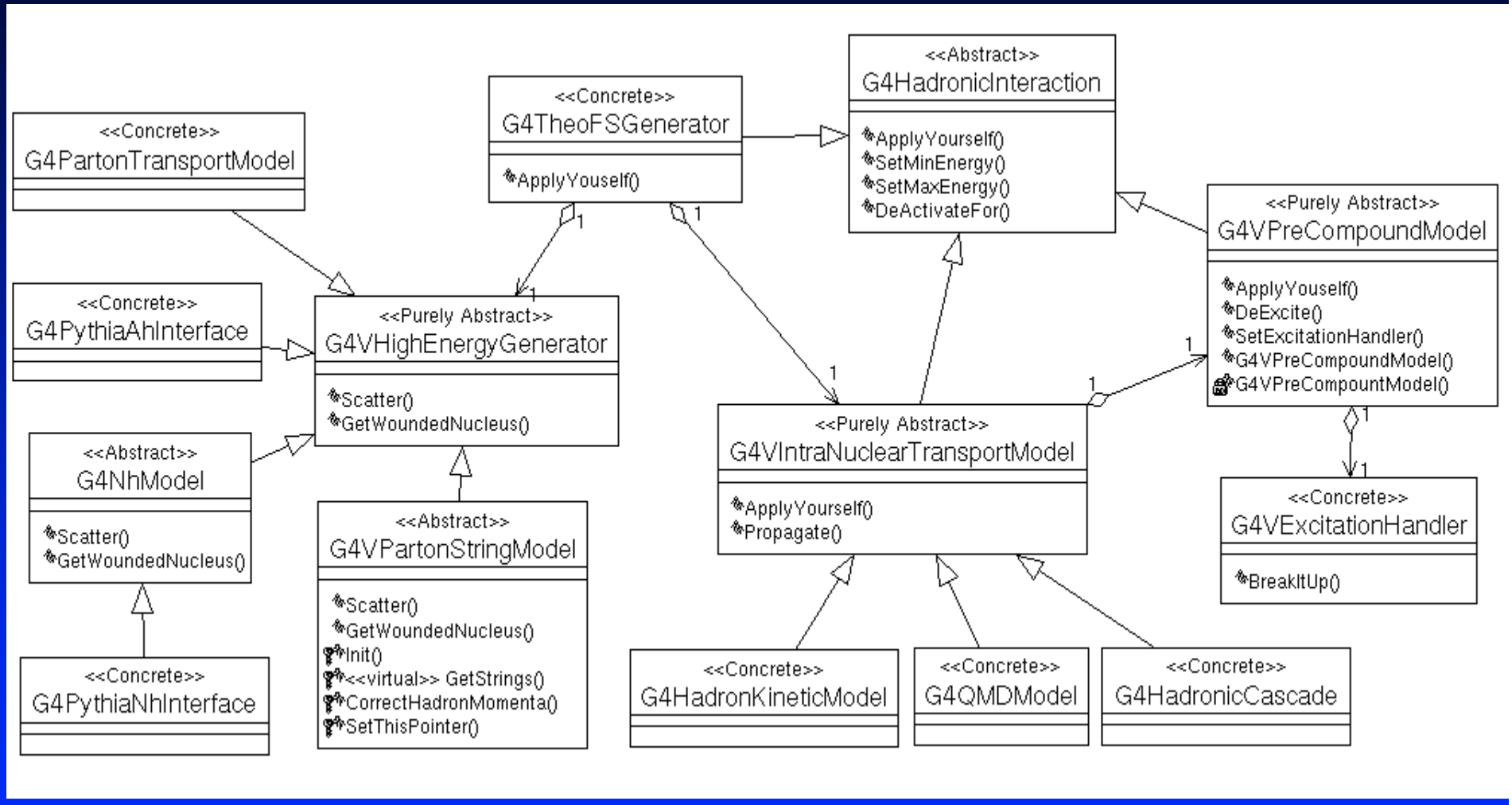
G4NeutronIsotopeProduction

3rd level framework requirements

- For data driven models
  - Possibility to change the data used by the models in a seamless manner.
- For theory driven models
  - Allow to use any string-parton or parton-cascade model
  - Allow to use event generators for final state generation
  - Allow for combination with any intra-nuclear transport
  - Allow stand-alone use of any intra-nuclear transport
  - Allow for combination with any pre-compound model
  - Allow stand-alone use of any pre-compound model
  - Allow for use of any evaporation code

Level 3 framework design

- The requirement on data driven models is fulfilled by using standard data formats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ApplyYourself()
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SetMaxEnergy()
DeActivateFor()
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ApplyYouself()
DeExcite()
SetExcitationHandler()
G4VPreCompoundModel()
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Scatter()
GetWoundedNucleus()
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ApplyYourself()
Propagate()
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BreakItUp()
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Init()
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SetThisPointer()
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G4QMDModel
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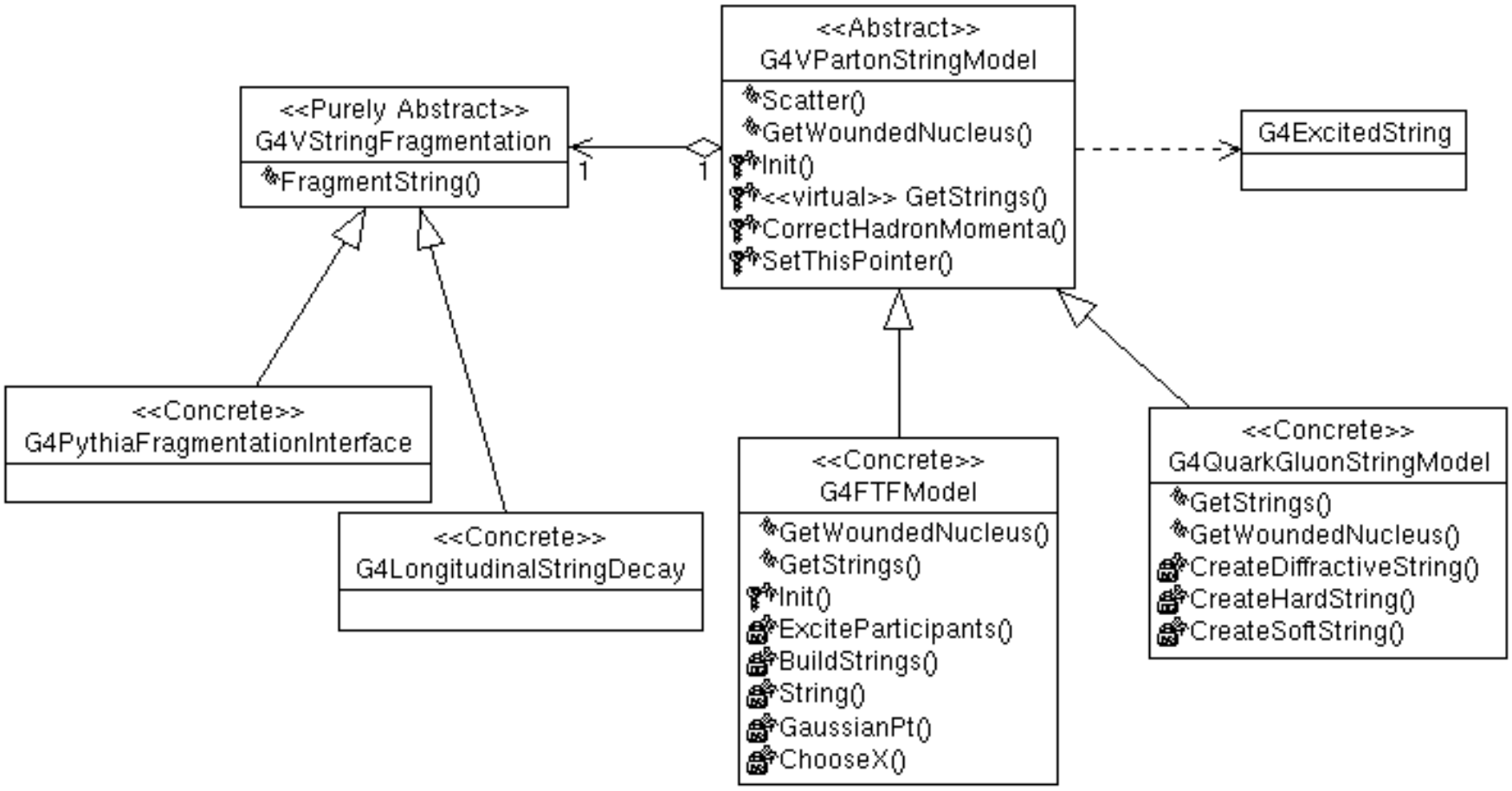
G4HadronicCascade
1

4th level framework requirements

- For string-parton models
  - Be able to choose string decay algorithm, and string excitation
  - Be able to use user-defined string excitation and decay
- For Intra-nuclear cascades
  - Be able to use user-defined models for a nucleus
  - Be able to use user-defined final state and cross-sections data for the intra-nuclear scattering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Init()
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CorrectHadronMomenta()
SetThisPointer()
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FragmentString()
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1
G4ExcitedString
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G4PythiaFragmentationInterface
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G4LongitudinalStringDecay
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G4FTFModel
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GetStrings()
Init()
ExciteParticipants()
BuildStrings()
String()
GaussianPt()
ChooseX()
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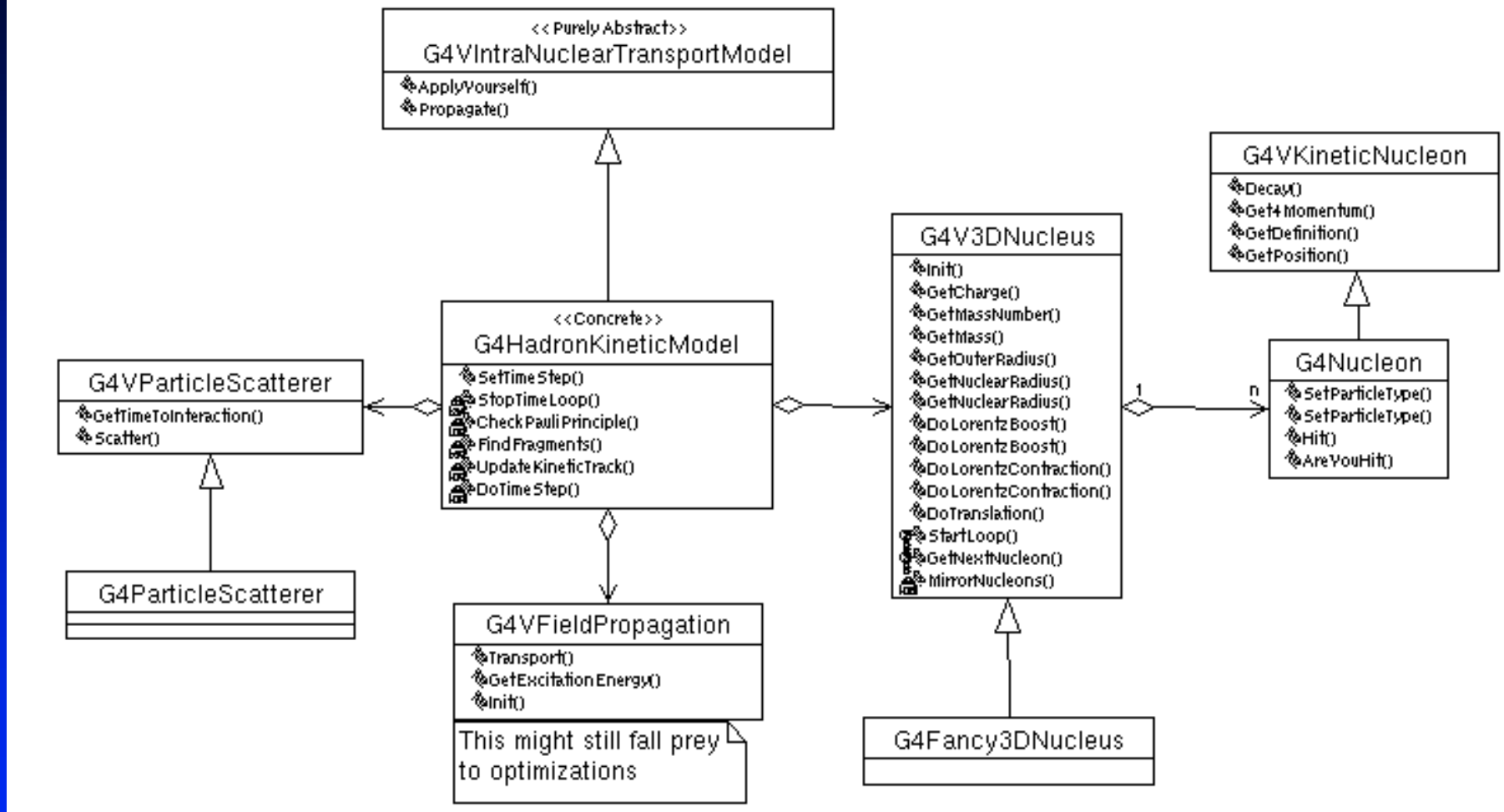
G4QuarkGluonStringModel
GetStrings()
GetWoundedNucleus()
CreateDiffractiveString()
CreateHardString()
CreateSoftString()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ApplyYourself()
Propagate()
G4VKineticNucleon
Decay()
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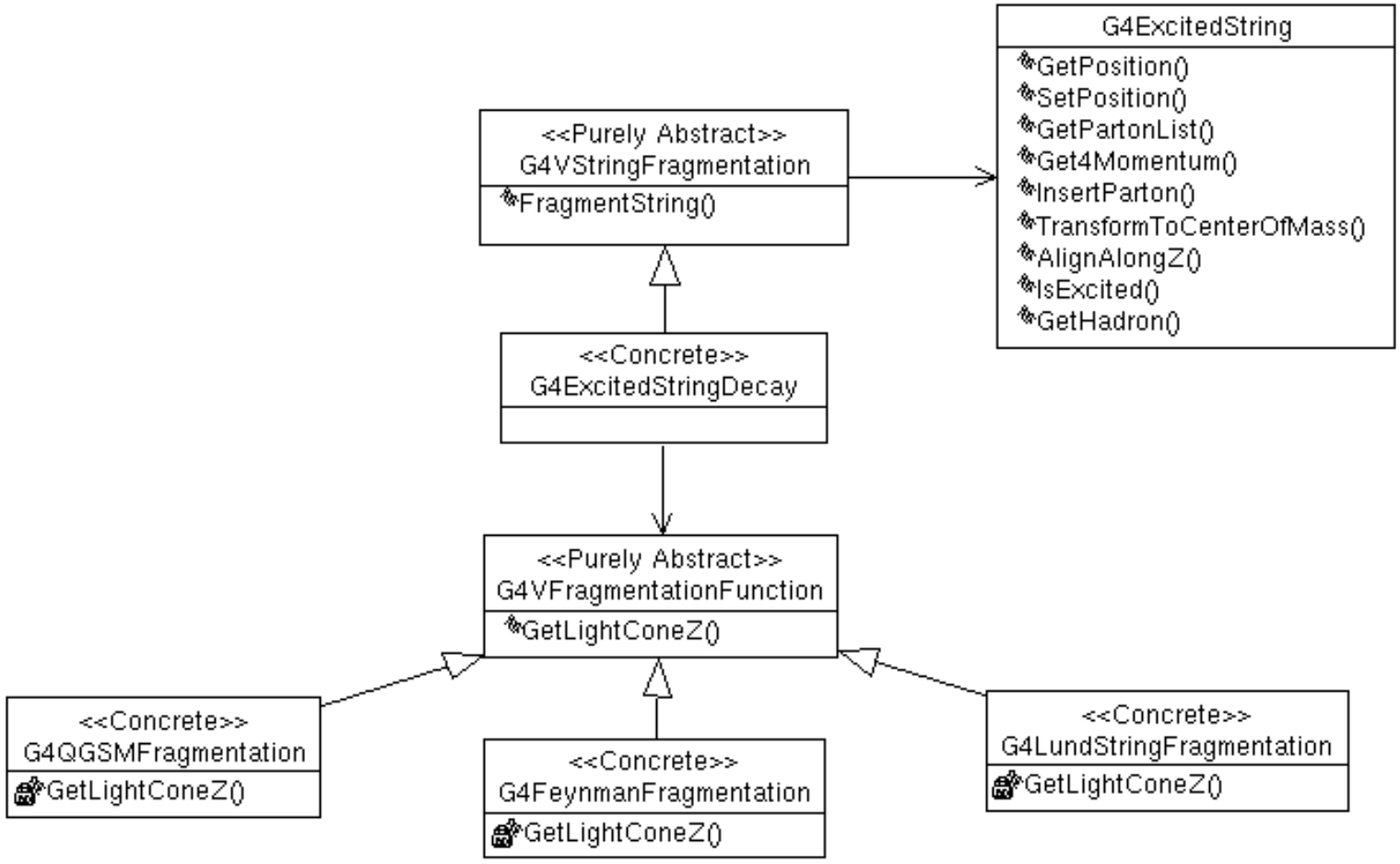
GetDefinition()
GetPosition()
G4V3DNucleus
Init()
GetCharge()
GetMassNumber()
GetMass()
GetOuterRadius()
GetNuclearRadius()
GetNuclearRadius()
DoLorentzBoost()
DoLorentzBoost()
DoLorentzContraction()
DoLorentzContraction()
DoTranslation()
StartLoop()
GetNextNucleon()
MirrorNucleons()
1
n
G4Nucleon
SetParticleType()
SetParticleType()
Hit()
AreYouHit()
<<Concrete>>
G4HadronKineticModel
SetTimeStep()
StopTimeLoop()
CheckPauliPrinciple()
FindFragments()
UpdateKineticTrack()
DoTimeStep()
G4VParticleScatterer
GetTimeToInteraction()
Scatter()
G4ParticleScatterer
G4VFieldPropagation
Transport()
GetExcitationEnergy()
Init()
This might still fall prey to optimizations
G4Fancy3DNucleus

5th level requirements

- For string decay
  - Allow to change the fragmentation function
  - …more under study…

! At this level, the framework approach has essentially exhausted the complexity of the topic, but note that ***concrete implementations are possible at any level of the Russian doll***. Each doll could be the last.


G4ExcitedString
GetPosition()
SetPosition()
GetPartonList()
Get4Momentum()
InsertParton()
TransformToCenterOfMass()
AlignAlongZ()
IsExcited()
GetHadron()
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G4VStringFragmentation
FragmentString()
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G4VFragmentationFunction
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G4QGSMFragmentation
GetLightConeZ()
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G4FeynmanFragmentation
GetLightConeZ()
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G4LundStringFragmentation
GetLightConeZ()

Activities and implementations

- Particles at rest:
  - One complete set of processes ‘a’la Geant3’
  - Alternative process implementations for stopping pi-, K-, mu-
  - Included the electromagnetic transitions of the exotic atom prior to capture, and effects of atomic binding.
  - Upgrade for anti-protons in progress

Activities and implementations

- Inclusive cross-sections:
  - Complete set of cross-section classes ‘a la’ Geant3.21
  - Specialized data-sets for neutron and proton induced reactions below 20 GeV
  - Specialized data set for ion induced reactions
  - Data sets for neutron induced reactions, elastic scattering, capture and fission of neutrons for energies below 20 MeV.
  - Upgrade for strange particle induced reactions underway.

Data libraries

- Systematic collection and evaluation of experimental data from many sources worldwide
- Databases
  - ENDF/B, JENDL, FENDL, CENDL, ENSDF, JEF, BROND, EFF, MENDL, SAID, EPDL, etc.
- Distribution centres
  - NEA, LANL, LLNL, BNL, KEK, IAEA, IHEP, TRIUMF, FNAL, Helsinki, Durham, etc.
- The use of evaluated data is important for the validation of physics results of the experiments

Activities and implementations

- In flight
  - Coherent elastic scattering
    - One set ‘ala’ Geant3.21
    - Regge theory based alternative implementation for incoming pi, K, nucleon.
    - Data driven specialized models for low energy nucleon scattering off Hydrogen on the way.
    - Alternative data driven model for low energy (<20 MeV) neutron coherent elastic scattering with possibility to run against any formatted data library (ENDF/B, FENDL, JENDL, G4NDL, etc..)

Activities and implementations

- Capture of neutral particles
  - One set ‘ala’ Geant3
  - Alternative data driven model for low energy (<20 MeV) neutron capture with possibility to run against any formatted data library (ENDF/B, FENDL, JENDL, G4NDL, etc..)

Activities and implementations

- In flight
  - Fission
    - One model ‘ala’ Geant3
    - Alternative data driven model for low energy (<20 MeV) neutron induced Fission (1st, 2nd, 3rd and 4th chance) with possibility to run against any formatted data library (ENDF/B, FENDL, JENDL, G4NDL, etc..)
    - Alternative theory driven model.

Activities and implementations

- In flight
  - Inelastic scattering
    - Two models ‘ala’ Geant3
    - Alternative data driven model for low energy (<20 MeV) inelastic neutron nuclear scattering (36 exclusive final states are considered) with possibility to run against any formatted data library (ENDF/B, FENDL, JENDL, G4NDL, etc..)
    - Alternative theory driven models, see next slides

Activities and implementations

- In flight, inelastic scattering
  - Theory driven models
    - One parton transport model (concept)
    - Two alternative string model (released)
    - Two types of string fragmentation (released)
    - One quantum molecular dynamics model (release expected 2002)
    - Two alternative intra-nuclear cascades (time-driven - 2002, space-driven - 2001)
    - One chiral invariant phase-space decay model (release imminent)
    - Three alternative nuclear descriptions (2 released, one 2002)
    - Two alternative pre-equilibrium decay models (1 released, one 2002)
    - Three alternative evaporation implementations (2 released, one 2001)

Apologies

- My apologies for this flat list of activities without citations or making reference to the people doing/having done the work.
- This is solely for the sake of briefness.
- Note that many of the concrete implementations were done by others, and much consultancy was provided in many areas by numerous theorists that have invented the models employed.
- Currently 33 people are actively contributing with some of their creativity to the effort in the hadronic working group of geant4.

Notes:

- It should be noted that the use-case driven approach to implementing modeling possibilities is also open for misuse.
- Some non geant4-members are often observed using models in use-cases for which they have not been made.

Examples

- See the transparencies