Hadronics – part I

Implications for detector construction and physics lists

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Overview of the module

- What to observe, when constructing a detector for use with hadronics
- Physics lists for the use-cases of hadronic physics

On Material construction

- There are three ways to construct materials in geant4
  - From it's isotopic composition
  - From it's elements
  - As an effective material (Aeff, Zeff)

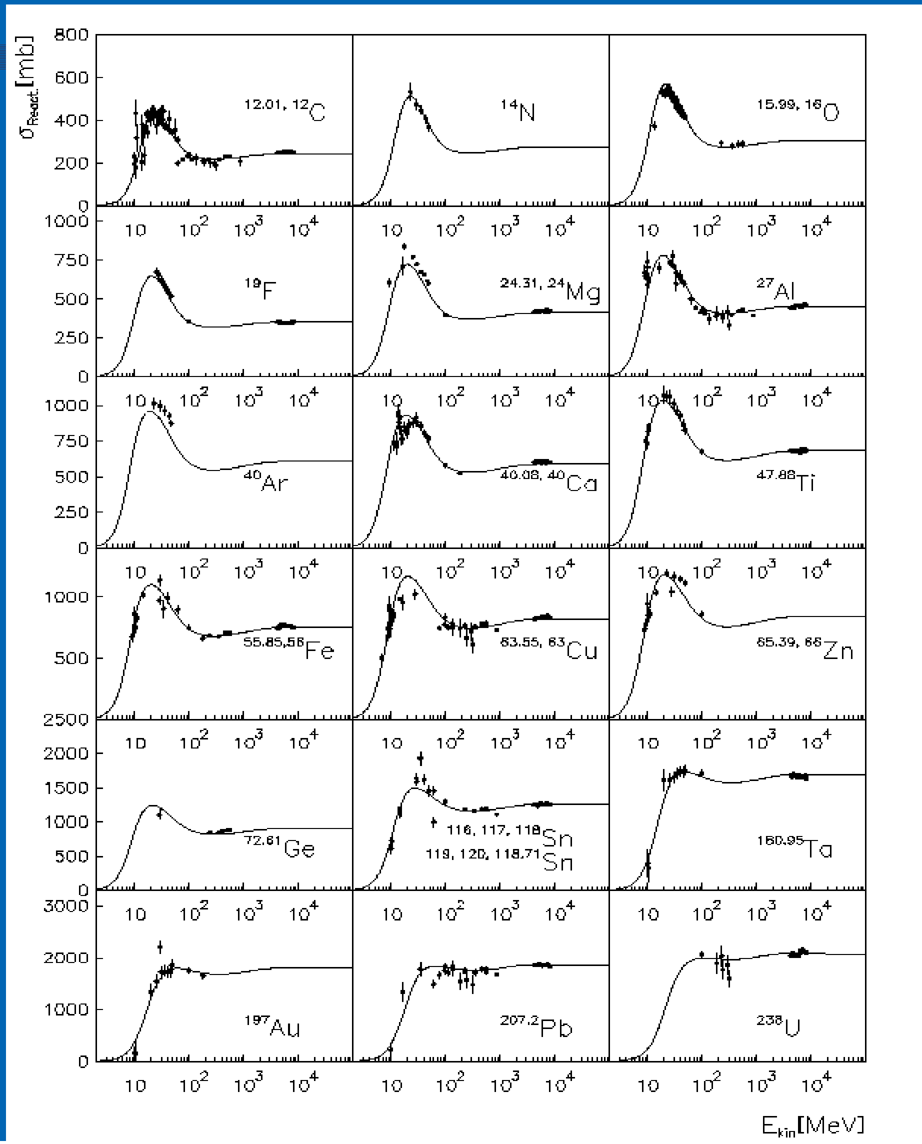
Effective materials

- Hadronics cross-section are not a function of material properties, but a function of nuclear properties.
- If you use effective numbers, the element composition cannot be automatically recovered.
- The cross-section will be ‘highly approximativ’ at best.
- The final states will have wrong properties.

- Never use this with hadronic physics

  (There are of course situations, here you will not be able to avoid it)

Proton induced reactions



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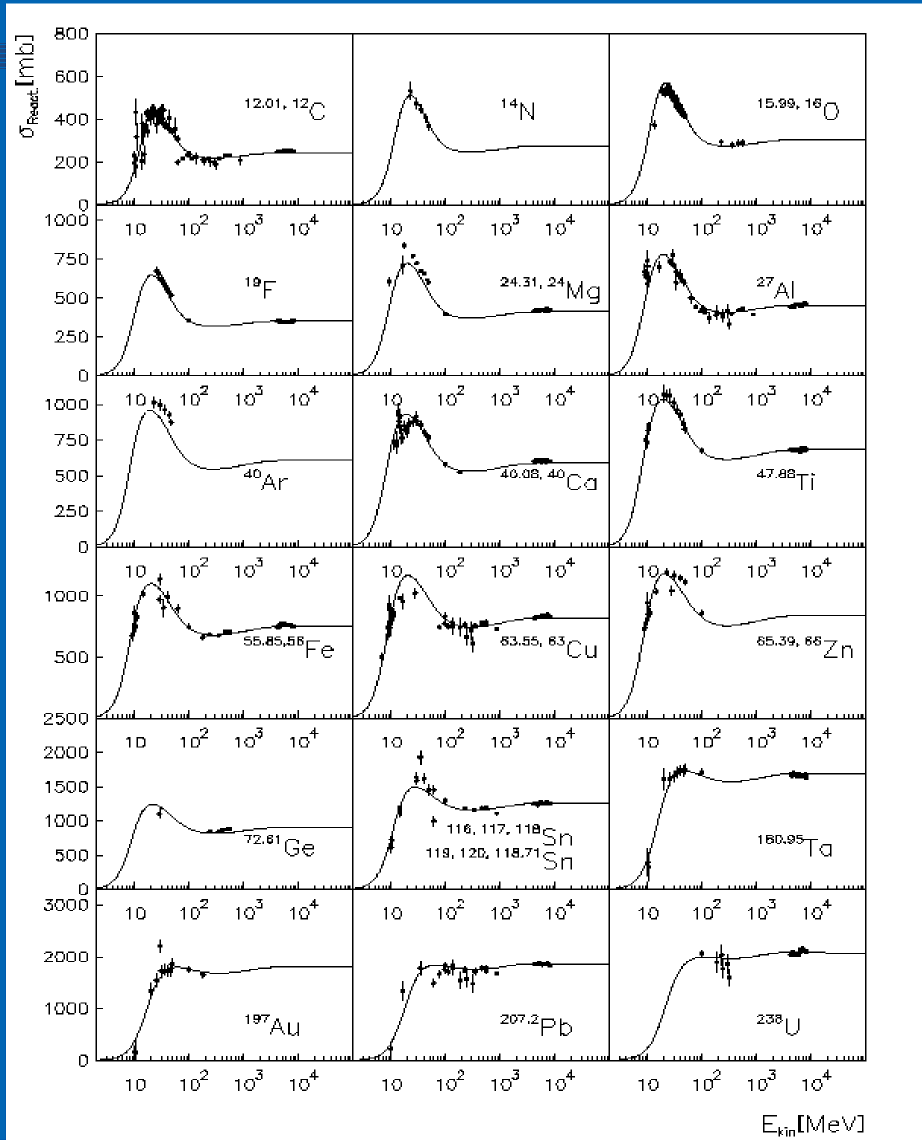
From elementary composition

- This is good enough for most high energy applications.

Proton induced reactions



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Isotope wise composition

- When detailled simulation of low energy neutrons is important, element info is not sufficient (E<15MeV) to get the cross-section and final states right.
  - For different isotopes, the neutron nuclear resonances will be at entirely different positions
  - For different isotopes, the final state channels open can differ drastically.
- ➔ You may be tempted to construct your materials from Isotopes in this case

Isotope wise composition

- In case the neutron_hp models are used (detailed neutron transport below 20MeV), geant4 recovers the natural isotopic composition, in case materials and mixtures are specified in terms of their constituting elements.
- If you have enriched isotopes (like Uranium-238), please use the isotopes directly, to specify your material.

➔ Normally you do not need to use the G4Isotope in your detector construction

Example: Neutrons in Lithium

- Neutron inelastic cross-section at 150eV:
  - Li-7: 0.00 millibarns
  - Li-6: 12.2 barns !
- Open inelastic channels:
  - Li-7: none
  - Li-6: nLi➔tα

  (which makes Li-6 a well known shielding isotope)

Part-2 physics lists

What is a physics list?

- A physics lists specifies the complete physics modeling necessary for your application.
  - Particles
  - Transportation
  - Decays
  - Electromagnetic physics
  - ...
  - Hadronic physics

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Geant4 physics lists versus geant3 packages

- In geant4, the physics lists (LHEP, QGSP, FTFC, etc.) serve the same purpose as the "packages" (GHEISHA, FLUKA, GCALOR) in geant3.
- Conceptually, the two are identical !
  - They both give a complete set of hadronic modeling to an application.
  - Each "package" is built of a set of models
- In RD44, the idea was that each user would (have to) build 'his' package.

In the case if hadronic physics lists, the problem is complexity.

- It takes 5 levels of implementation framework in geant4 to implement hadronics.
- These, and the models implementing them, are then used to assemble the physics lists.

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The starting point

- It is well recognized since quite some time that writing a good physics list is no trivial, in particular when hadronic physics is involved.
- It is nice to be able to exploit the full power in the flexibility and variety of hadronic physics modeling in geant4, but being forced to do so is not what we want.
- It is also nice to have the physics transparently in front of you and be able to exploit it in the best possible way, but being forced to understand it all is (very understandably) not what people want, either.

Because of this

- We have systematically accumulated experience with various combinations of cross-section and models over the last years.
- Today we can provide a set of physics lists institutionalizing this experience.
- Publishing them to the general audience was one of the main milestones of the hadronic working group for 2002.

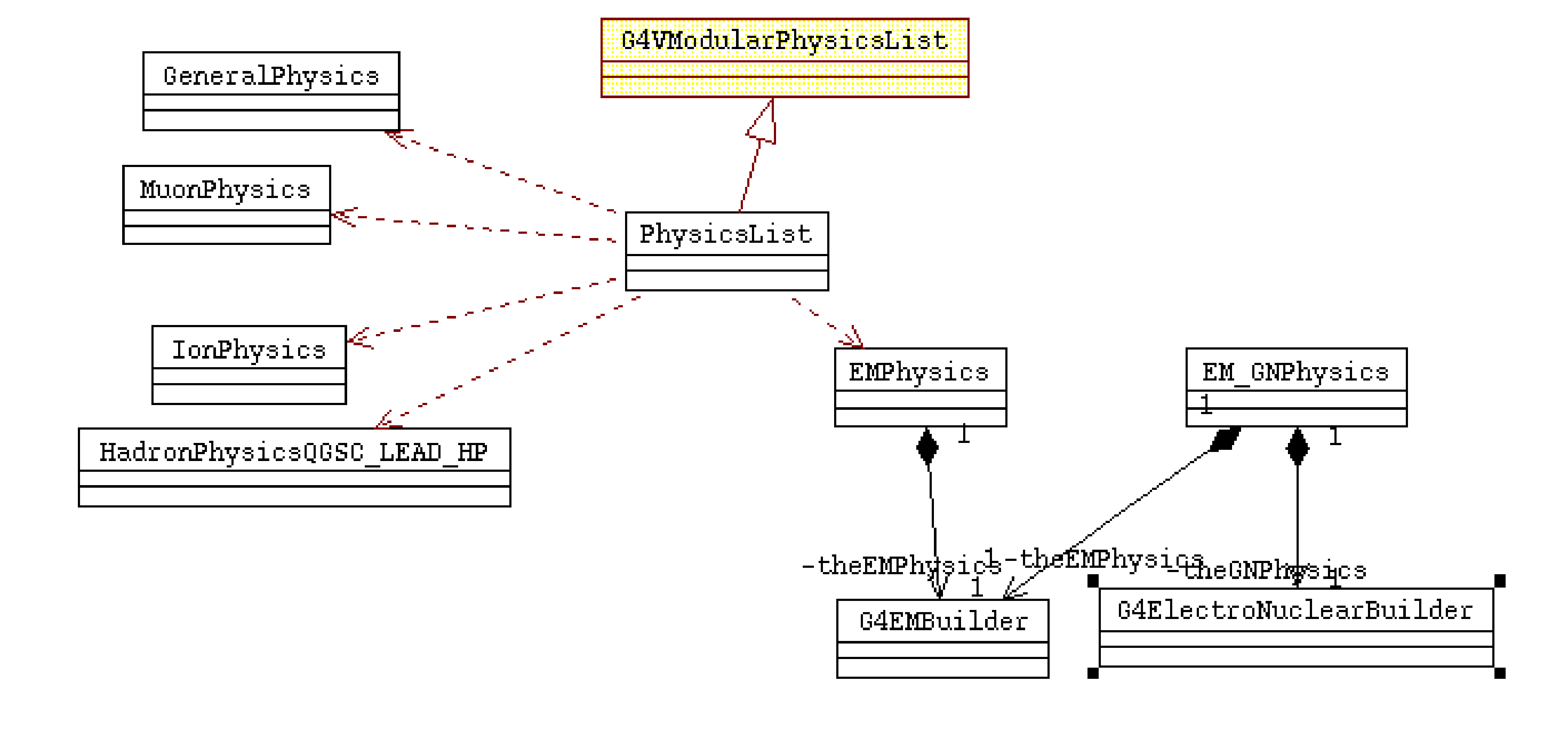
The purpose of the physics lists

- Give an ‘educated guess’ that can be used as starting point by any user and/or give meaningful alternatives for physics lists for the various use-cases of hadronic physics.
- Provide a brief description of the modeling used in the different physics lists.
- Find a natural organization for the verification/validation results, so people can find the part of the information they are interested in; whether they do calorimeter design or neutron dosimetry.
- Provide for areas where users can contribute their findings.
- Provide a distribution mechanism for both physics lists and verification results.
- Make physics lists source code more readable.

We made an "educated guess" for you.

- What it needed was
  - Sufficient richness in modeling
  - A user base, that is willing to iron things out (I.e. beta testers)
  - Experience in the various areas of application.
  - Sample use-case realizations

Design – an extension of what I had proposed during one of the last workshops, and Hisaya had realized.



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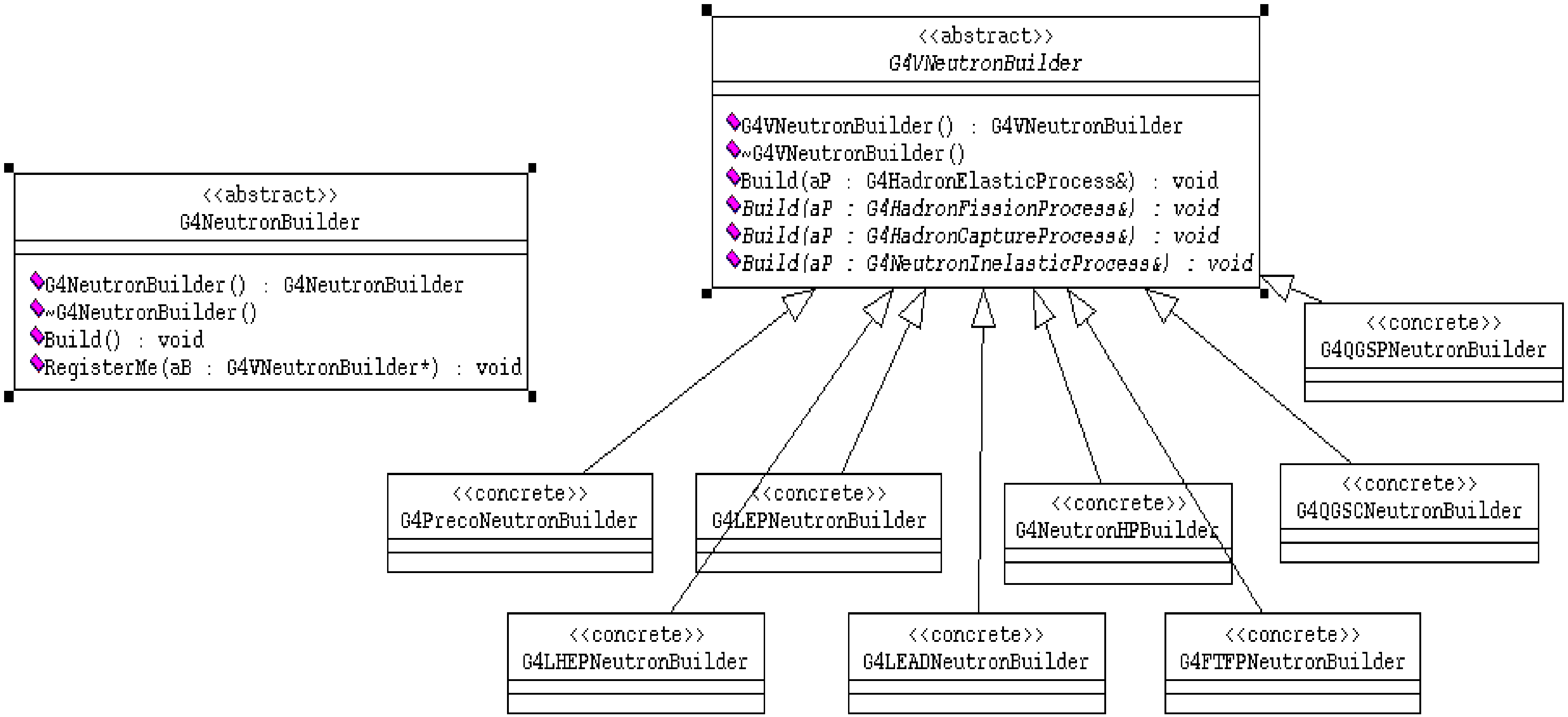
Design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G4VNeutronBuilder
G4VNeutronBuilder() : G4VNeutronBuilder
~G4VNeutronBuilder()
Build(aP : G4HadronElasticProcess&) : void
Build(aP : G4HadronFissionProcess&) : void
Build(aP : G4HadronCaptureProcess&) : void
Build(aP : G4NeutronInelasticProcess&) : void
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G4NeutronBuilder
G4NeutronBuilder() : G4NeutronBuilder
~G4NeutronBuilder()
Build() : void
RegisterMe(aB : G4VNeutronBuilder*) : void
<<concrete>>
G4QGSPNeutronBuilder
<<concrete>>
G4PrecoNeutronBuilder
<<concrete>>
G4LEPNeutronBuilder
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G4NeutronHPBuilder
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G4QGSCNeutronBuilder
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G4LHEPNeutronBuilder
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G4LEADNeutronBuilder
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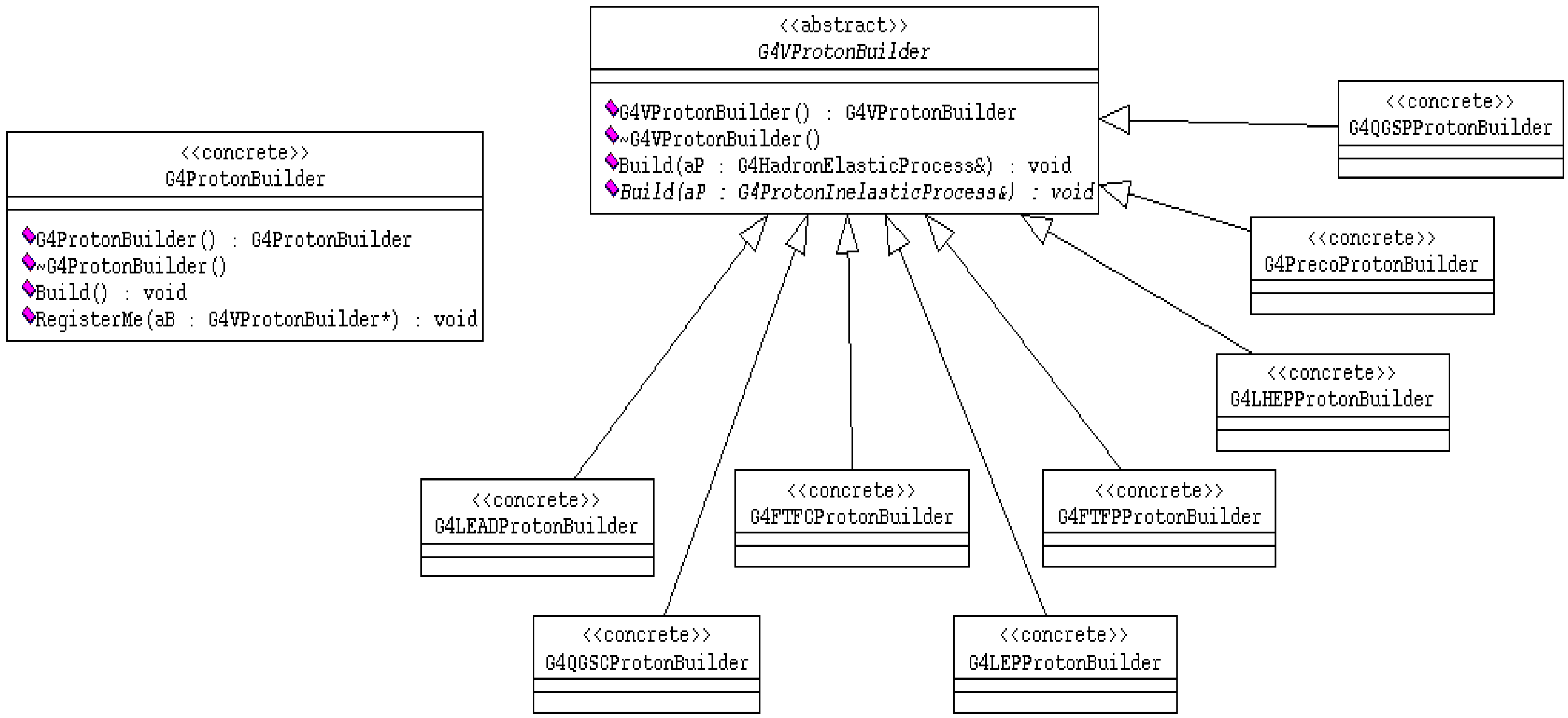
G4FTFPNeutronBuilder

Design



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~G4ProtonBuilder()
Build() : void
RegisterMe(aB : G4VProtonBuilder*) : void
<<abstract>>
G4VProtonBuilder
G4VProtonBuilder() : G4VProtonBuilder
~G4VProtonBuilder()
Build(aP : G4HadronElasticProcess&) : void
Build(aP : G4ProtonInelasticProcess&) : void
<<concrete>>
G4QGSPProtonBuilder
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G4PrecoProtonBuilder
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G4LHEPProtonBuilder
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G4LEADProtonBuilder
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G4FTFCProtonBuilder
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G4QGSCProtonBuilder
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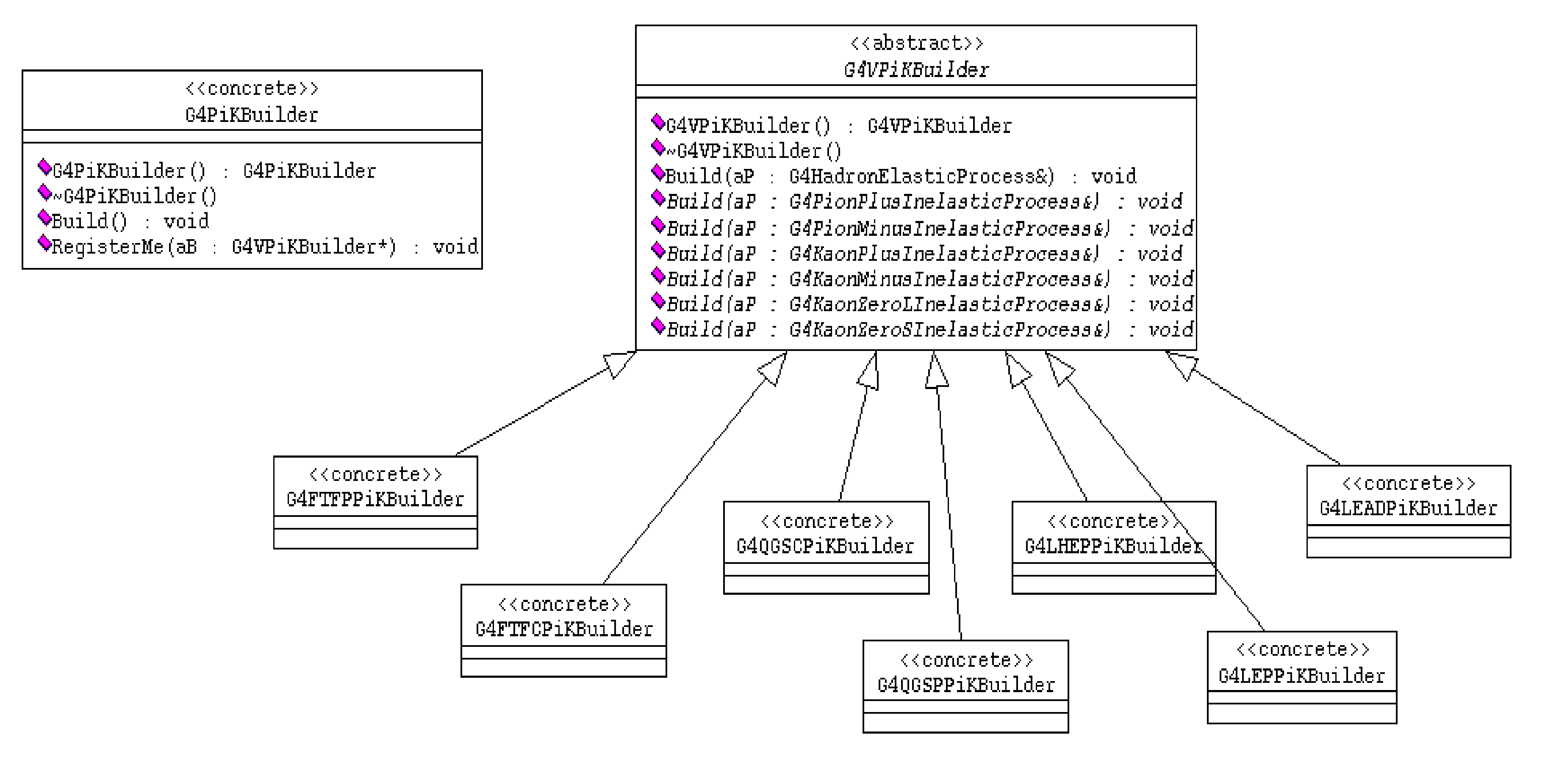
G4LEPProtonBuilder

Design



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~G4PiKBuilder()
Build() : void
RegisterMe(aB : G4VPiKBuilder*) : void
<<abstract>>
G4VPiKBuilder
G4VPiKBuilder() : G4VPiKBuilder
~G4VPiKBuilder()
Build(aP : G4HadronElasticProcess&) : void
Build(aP : G4PionPlusInelasticProcess&) : void
Build(aP : G4PionMinusInelasticProcess&) : void
Build(aP : G4KaonPlusInelasticProcess&) : void
Build(aP : G4KaonMinusInelasticProcess&) : void
Build(aP : G4KaonZeroLInelasticProcess&) : void
Build(aP : G4KaonZeroSInelasticProcess&) : void
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G4FTFPPiKBuilder
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G4FTFCPiKBuilder
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G4QGSCPiKBuilder
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G4QGSPPiKBuilder
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G4LHEPPiKBuilder
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G4LEPPiKBuilder
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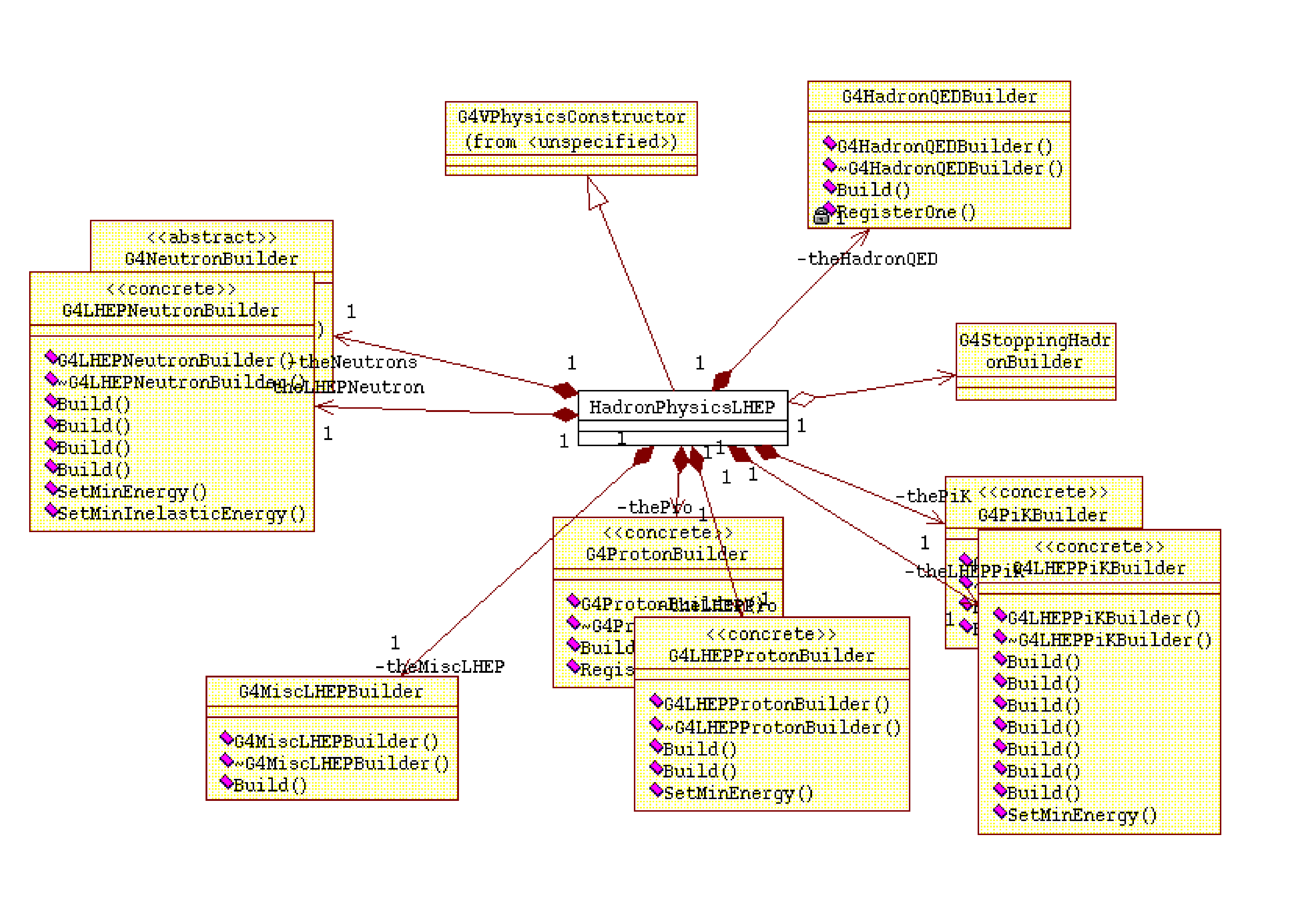
G4LEADPiKBuilder



G4VPhysicsConstructor
(from <unspecified>)
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G4HadronQEDBuilder()
~G4HadronQEDBuilder()
Build()
RegisterOne()
-theHadronQED
<<abstract>>
G4NeutronBuilder
<<concrete>>
G4LHEPNeutronBuilder
G4LHEPNeutronBuilder()
~G4LHEPNeutronBuilder()
Build()
Build()
Build()
Build()
SetMinEnergy()
SetMinInelasticEnergy()
-theNeutrons
-theLHEPNeutron
G4StoppingHadronBuilder
HadronPhysicsLHEP
-thePro
-thePiK
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G4PiKBuilder
-theLHEPPiK
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G4LHEPPiKBuilder
G4LHEPPiKBuilder()
~G4LHEPPiKBuilder()
Build()
Build()
Build()
Build()
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G4ProtonBuilder
-theLHEPPro
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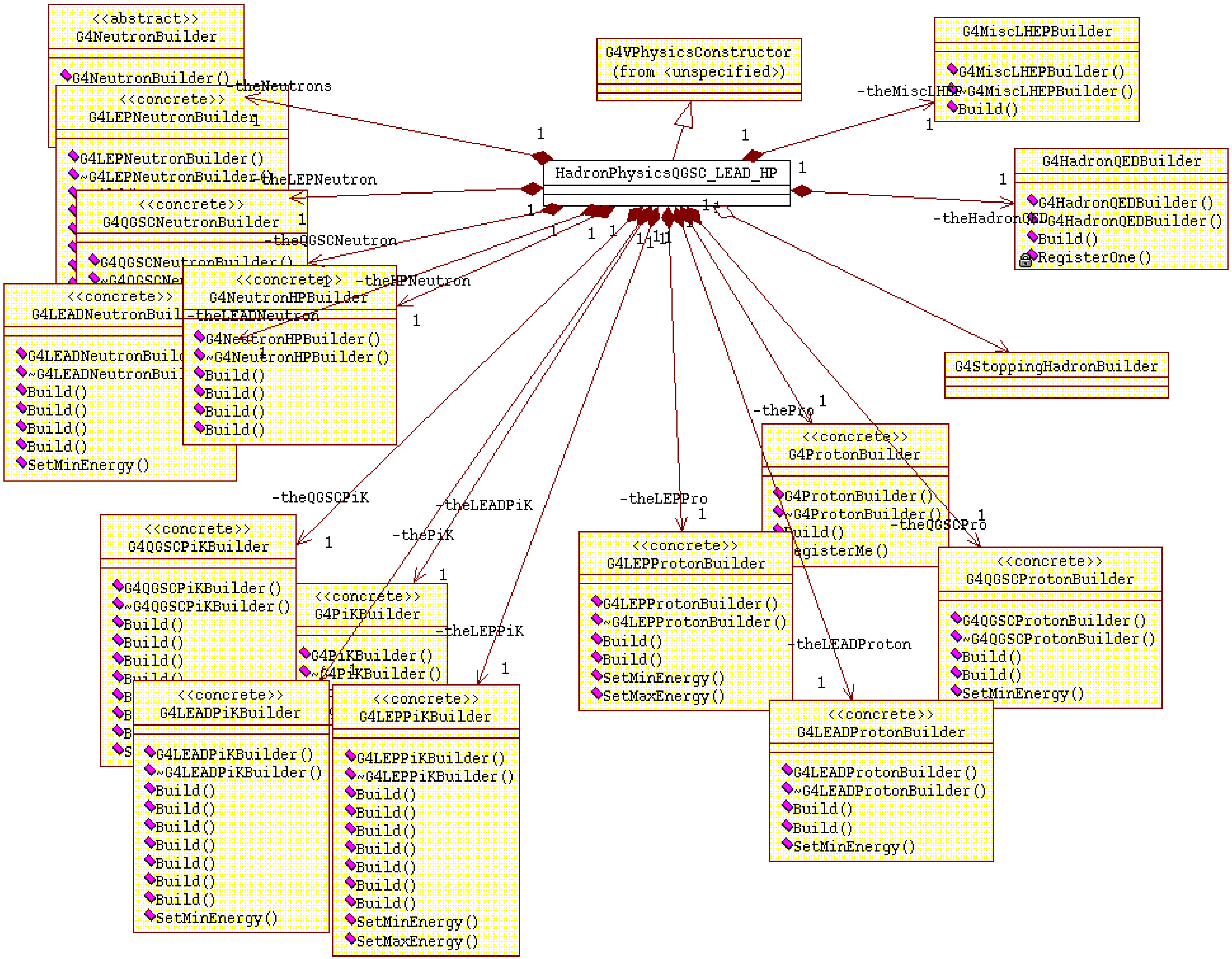
G4LHEPProtonBuilder
G4LHEPProtonBuilder()
~G4LHEPProtonBuilder()
Build()
Build()
SetMinEnergy()
-theMiscLHEP
G4MiscLHEPBuilder
G4MiscLHEPBuilder()
~G4MiscLHEPBuilder()
Build()



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Now, what does this mean ?

- Complex problems need structured solutions!
- There are 5 levels of implementation framework in geant4 hadronics.
- In the builders, we have collapsed these to level 1 and/or level 2 complexity.
- With the “educated guess” physics lists, we have re-introduced an equivalent of the geant3 “package” concept.

- You can now
  - Just pick a physics list from the '*menu'*.
  - Aggregate his own cocktail from limited complexity of the builders
  - Use all 5 framework levels with their full power.

➔ A structured reduction in the level of complexity exposed to our users.

- Of course you are still encouraged to tailor the physics lists that we provide, and/or build our own.

The WWW pages – a small demo.

- We go to:
  - http://cmsdoc.cern.ch/~hpw/GHAD/HomePage
- Note that there is also a 'physics lists' topic on the geant4 HyperNews.