Geant4 hadronic physics.

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Overview

- Some (not all) aspects of geant4 hadronic physics
- Additions to appear this year
- A word on model validation
- What about neutrons
- Building hadronic physics lists

Some aspects of GHAD (5.0) modeling

- Theoretical model – high energies
  - Diffractive string model (FTF)
  - Quark-gluon string model (QGS)
- Theoretical model – lower energies:
  - Binary cascade (BC)
  - Classical cascade (CC)
  - Chiral invariant phase-space decay (CHIPS)
- Parametrized model:
  - Low energy and high energy parametrized (LEP)
  - Mars rewrite
- Data driven models:
  - Neutron transport and G4NDL.

Quark gluon string model

- Hadron nuclear interactions at high energies
- The algorithm
  - A 3-dimensional nuclear model is built up
  - It is collapsed into 2 dimensions
  - The impact parameter is calculated
  - Hadron-nucleon collision probabilities calculated based on eiconal model, using Gaussian density distributions for hadrons and nucleons.
  - Sampling of the number of pomerons exchanged in each collision
  - Unitarity cut, string formation and decay.

The nuclear model

- The nuclear density distributions used are the Saxon-Woods form for high A (Grypeos 1991)

$$\rho(r_i) = \frac{\rho_0}{1+\exp[(r_i - R)/a]}$$

- And the harmonic oscillator form for light nuclei (A<17, Elton 1961)

$$\rho(r_i) = (\pi R'^2)^{-3/2} \exp(-r_i^2 / R'^2)$$

- The nucleon momenta are randomly chosen between zero and the fermi momentum

The nuclear model, cont.

- The sampling is done in a correlated manner
  - such the local phase-space densities stay within what is allowed by Pauli's principle, and
  - such that the sum of all nucleon momenta equals zero.

Collision criterion

- In the Regee Gribov approach, the collision probability can be written as

$$p_{ij}(\delta b_{ij}, s) = 1/c(1 - \exp[-2u(\delta b_{ij}, s)]) = \sum_{n=1}^{\infty} p_{ij}^{(n)}(\delta b_{ij}, s)$$

- where

$$p_{ij}^{(n)}(\delta b_{ij}, s) = 1/c\,\exp[-2u(\delta b_{ij}^2, s)]\frac{[2u(\delta b_{ij}^2, s)]^n}{n!}$$

- And

$$u(\delta b_{ij}^2, s) = \frac{z(s)}{2}\exp(\delta b_{ij}^2 / 4\lambda(s))$$

(Capella 1978)

Diffraction

- Diffraction is split off using the shower enhancement factor c (Baker 1976).

$$p_{ij}^{diff}(\delta b_{ij}, s) = \frac{1-c}{c}\left(p_{ij}^{tot}(\delta b_{ij}, s) - p_{ij}(\delta b_{ij}, s)\right)$$

String formation

- String formation is done via the partons exchange (Capella 94, Kaidalov 82) mechanism, sampling the parton densities, and ordering pairs of partons into color coupled entities.

$$f^h(x_1, x_2, \ldots, x_{2n-1}, x_{2n}) = f_0 \prod_{i=1}^{2n} u^h_{p_i}(x_i)\, \delta\Big(1 - \sum_{i=1}^{2n} x_i\Big)$$

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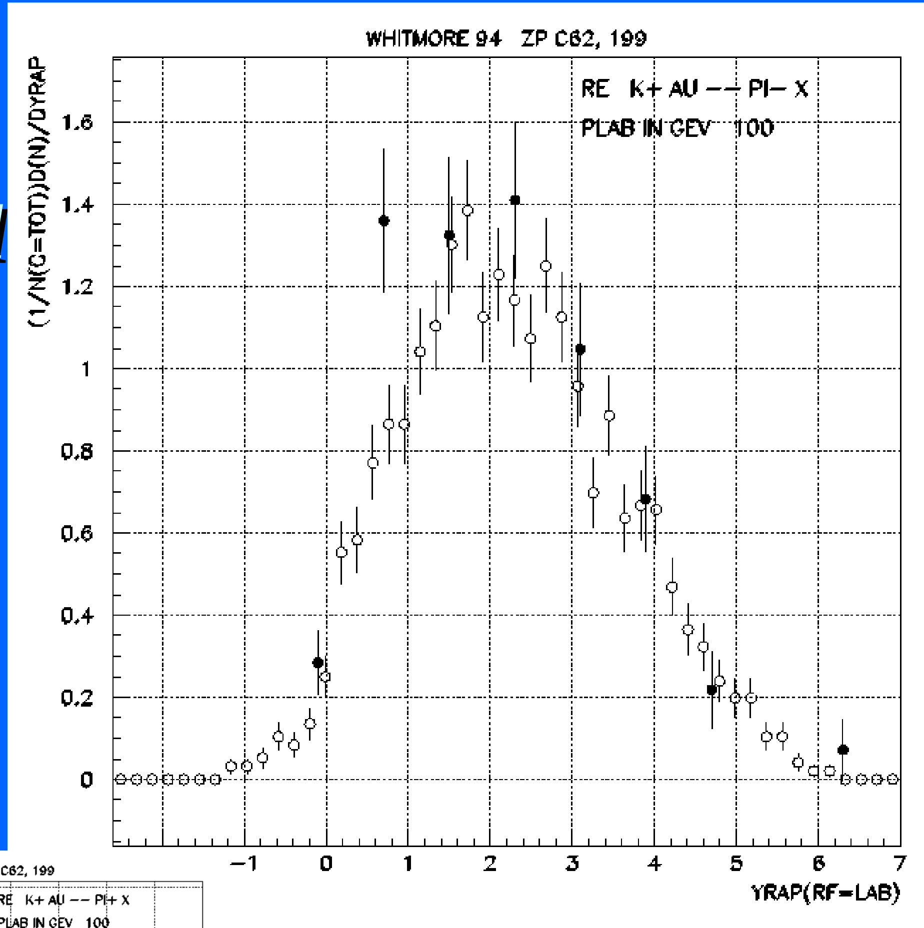
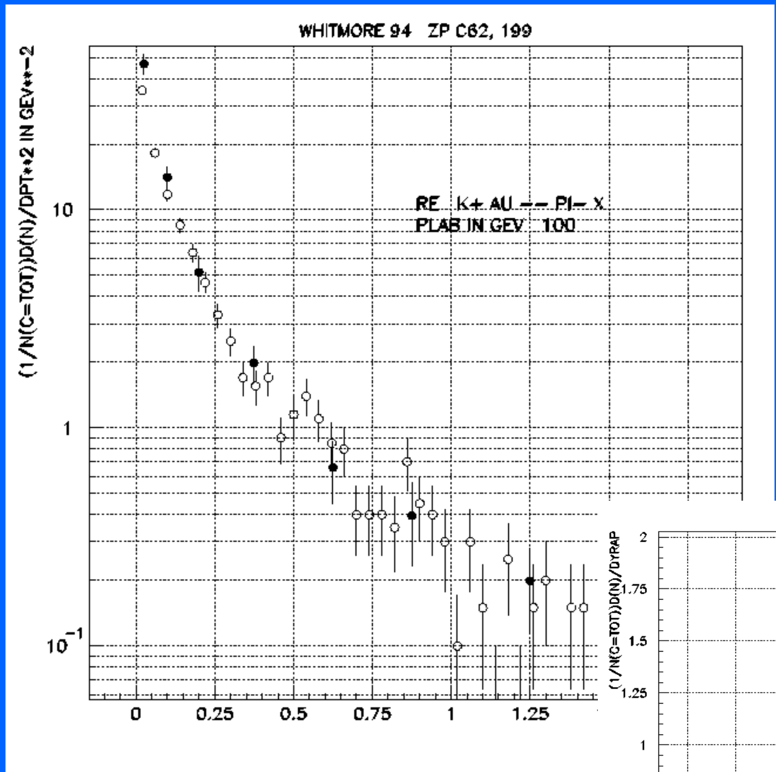
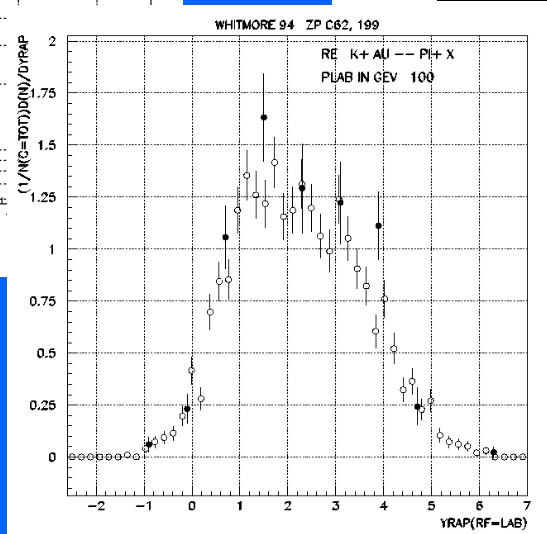
QGS model for π, N, *and K induced reactions*

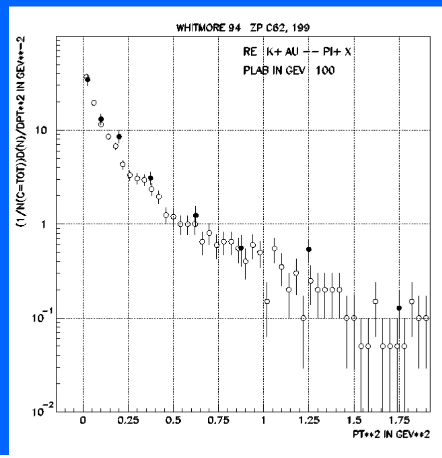
- Pomeron trajectory and vertex parameters found in a global fit to elastic, total and diffractive (6% assumed) cross-sections for nucleon, kaon and pion scattering off nucleons.

K+, scattering off Au









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Chiral Invariant Phase-space Decay.

- A quark level 3-dimensional event generator for fragmentation of excited hadronic systems (quasmons) into hadrons.
- Based on the QCD idea of asymptotic freedom
- Local chiral invariance restoration lets us consider quark partons massless, and we can integrate the invariant phase-space distribution of quark partons and quark exchange (fusion) mechanism of hadronization
- The only non-kinematical concept used is that of a temperature of the quasmon.

Vacuum CHIPS

- This allows to calculate the decay of free excited hadronic systems:
- In an finite thermalized system of N partons with total mass M, the invariant phase-space integral is proportional to M^{2N-4}, and the statistical density of states is proportional to $e^{-M/T}$. Hence we can write the probability to find N partons with temperature T in a state with mass M as

$$dW \propto M^{2N-4} e^{-M/T} dM$$

- Note that for this distribution, the mean mass square is $\langle M^2 \rangle = 2N(2N-2)T^2$

Vacuum CHIPS

- We use this formula to calculate the number of partons in the quasmon, and obtain the parton spectrum

$$\frac{dW}{kdk} \propto \left(1 - \frac{2k}{M}\right)^{N-3}$$

- To obtain the probability for quark fusion into hadrons, we can compute the probability to find two partons with momenta q and k with the invariant mass μ.

$$P(k, M, \mu) = \int \left(1 - \frac{2q}{M\sqrt{1 - 2k/M}}\right)^{N-4} \times \delta\left(\mu^2 - \frac{2kq(1-\cos\theta)}{\sqrt{1-2k/M}}\right) q\,dq\,d\cos\theta$$

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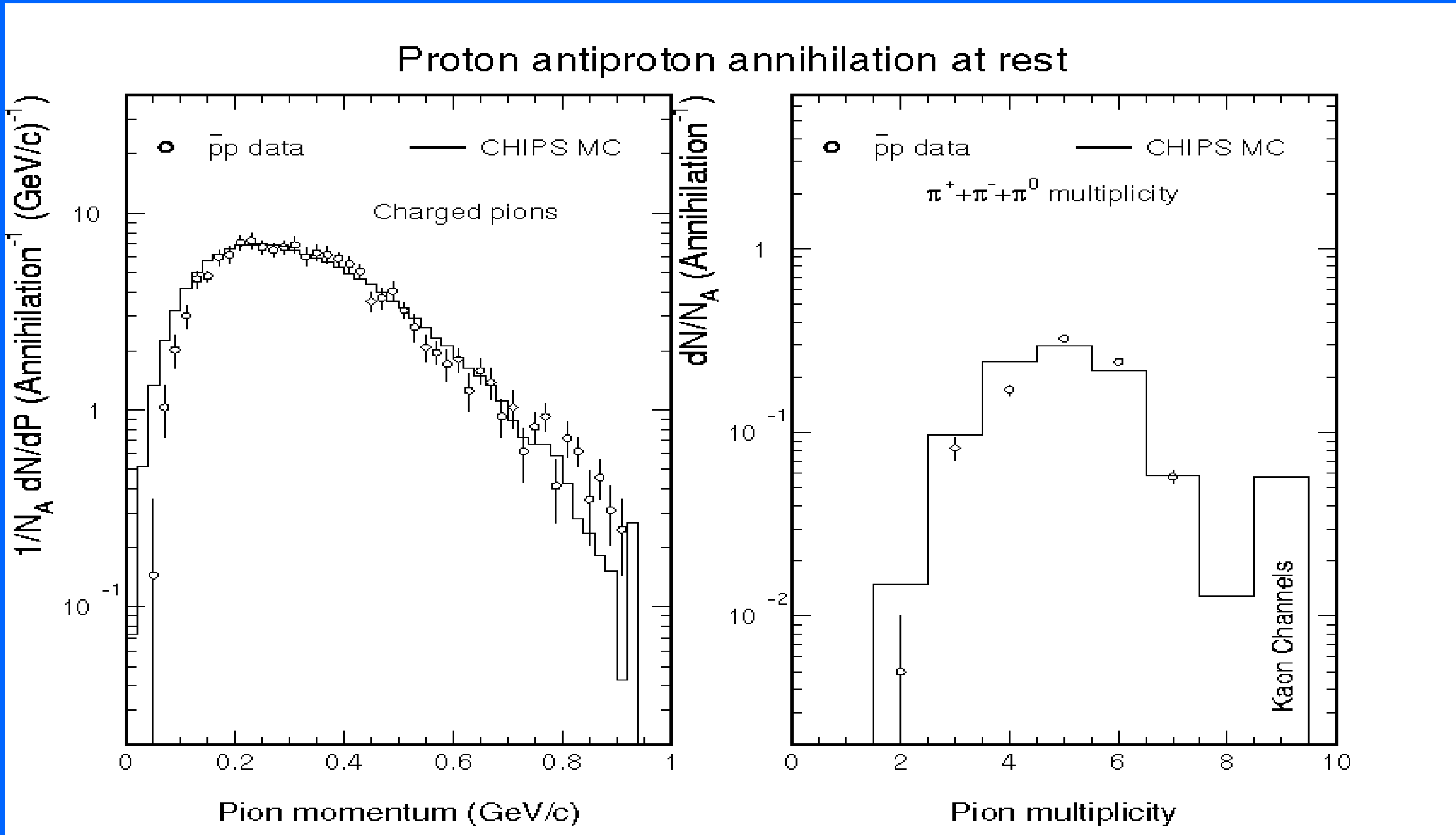
Vacuum CHIPS

- Using the delta function to perform the integration and the mass constraint, we find the total kinematical probability of hadronization of a parton with momentum k into a hadron with mass μ:

$$\frac{M-2k}{4k(N-3)}\left(1-\mu^2/2kM\right)^{N-3}$$

- Accounting for spin and quark content of the final state hadron adds (2s+1) and a combinatorial factor.
- At this level of the language, CHIPS can be applied to p-pbar annihilation

Anti proton annihilation



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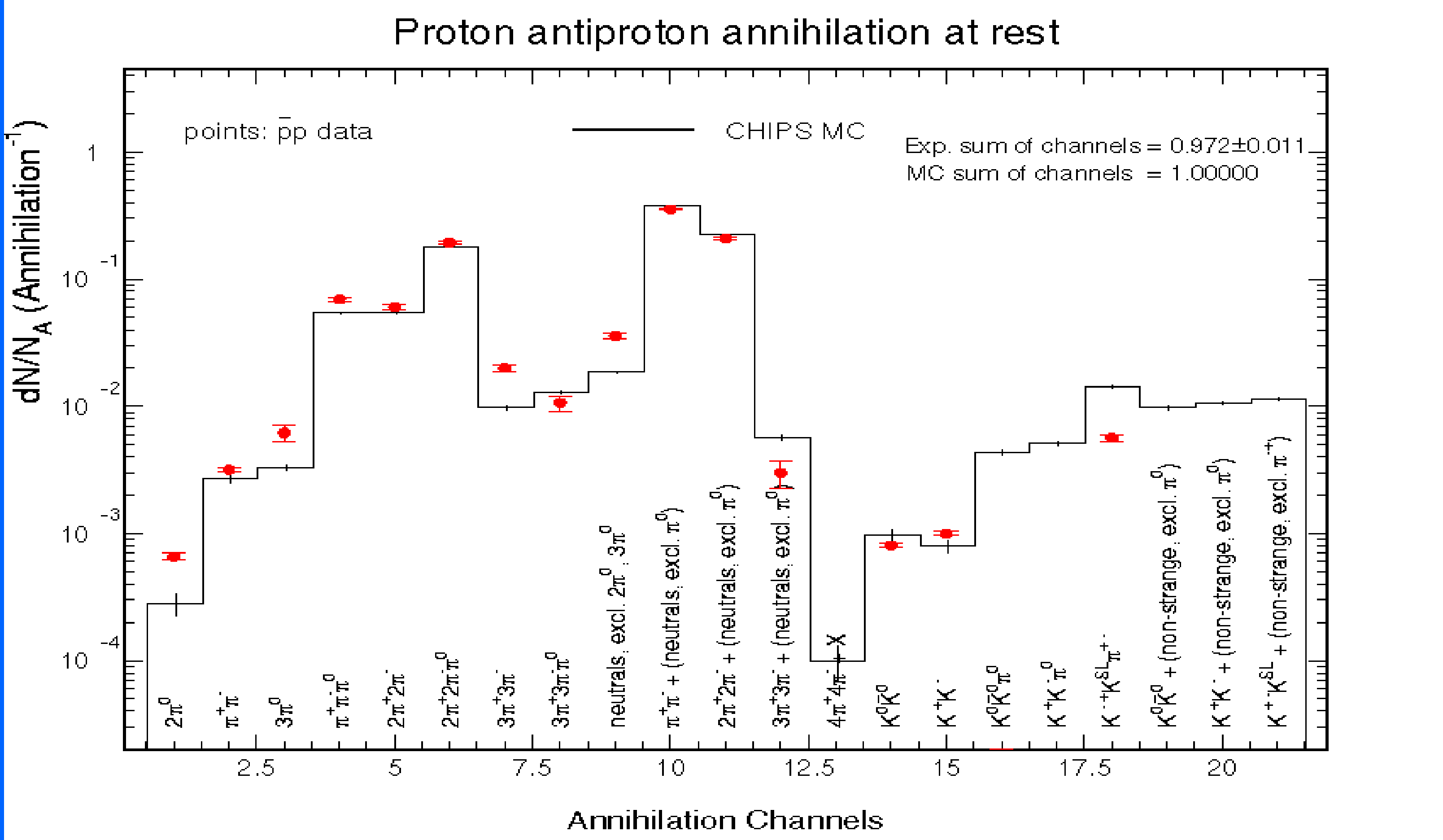
Anti proton annihilation



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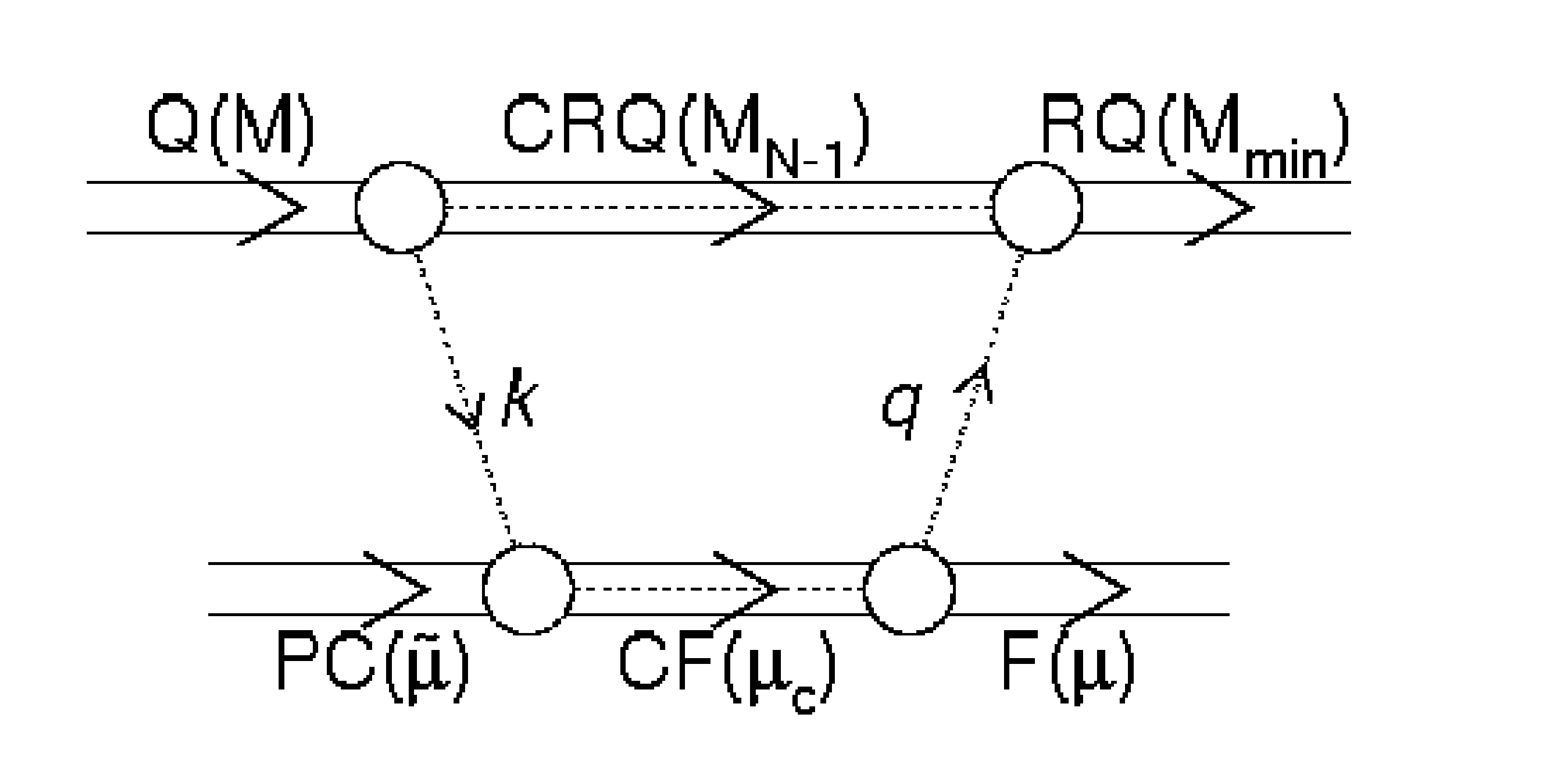
Nuclear CHIPS

- In order to apply CHIPS for an excited hadronic system within nuclei, we have to add parton exchange with nuclear clusters to the model
- The kinematical picture is, that a color neutral quasmon emits a parton, which is absorbed by a nucleon or a nuclear cluster. This results in a colored residual quasmon, and a colored compound.
- The colored compound then decays into an outgoing nuclear fragment and a ‘recoil’ quark that is incorporated by the colored quasmon.

The parton exchange diagram



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Nuclear CHIPS

- Applying mechanisms analogue to vacuum CHIPS, we can write the probability of emission of a nuclear fragment with mass μ as a result of the transition of a parton with momentum k from the quasmon to a fragment with mass μ′ as:

$$P(k,\mu',\mu) = \int \left(1 - \frac{2(k-\Delta)}{\mu' + k(1-\cos\theta_{kq})}\right)^{n-3} \frac{\mu'(k-\Delta)}{2\left[\mu' + k(1-\cos\theta_{kq})\right]^2} d\cos\theta_{kq}$$

- Here, n is the number of quark-partons in the nuclear cluster, and Δ is the covariant binding energy of the cluster, and the integral is over the angle between parton and recoil parton.

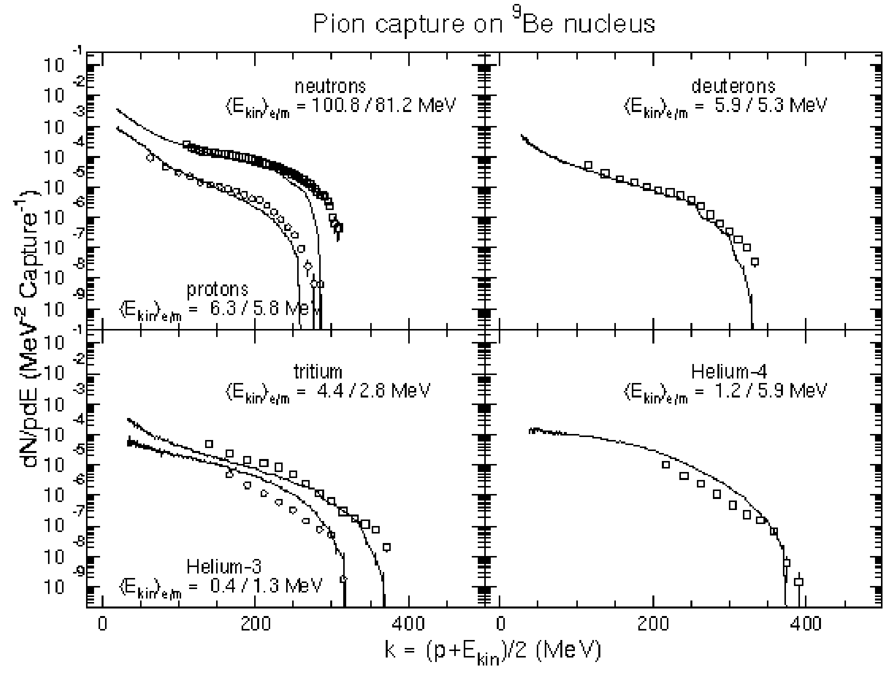
Nuclear CHIPS

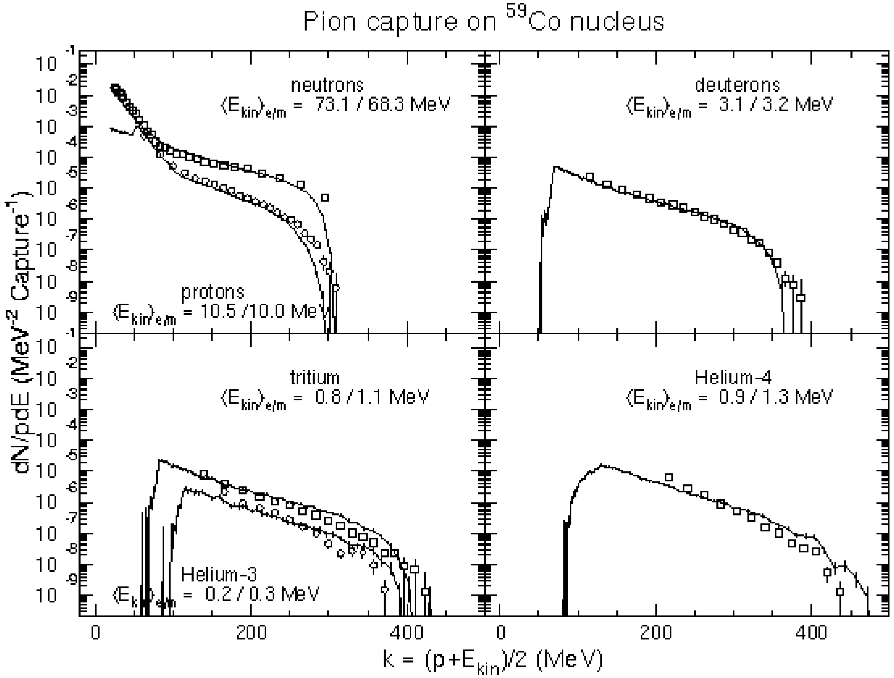
- To calculate the fragment yields it is necessary to calculate the probability to find a cluster of ν nucleons within a nucleus. We do this using the following assumptions:
  - A fraction $\varepsilon 1$ of all nucleons is not clusterising
  - A fraction $\varepsilon 2$ of the nucleons in the periphery of the nucleus is clustering into two nucleon clusters
  - There is a single clusterization probability ω
- and find, with 'a' being the number of nucleons involved in clusterization

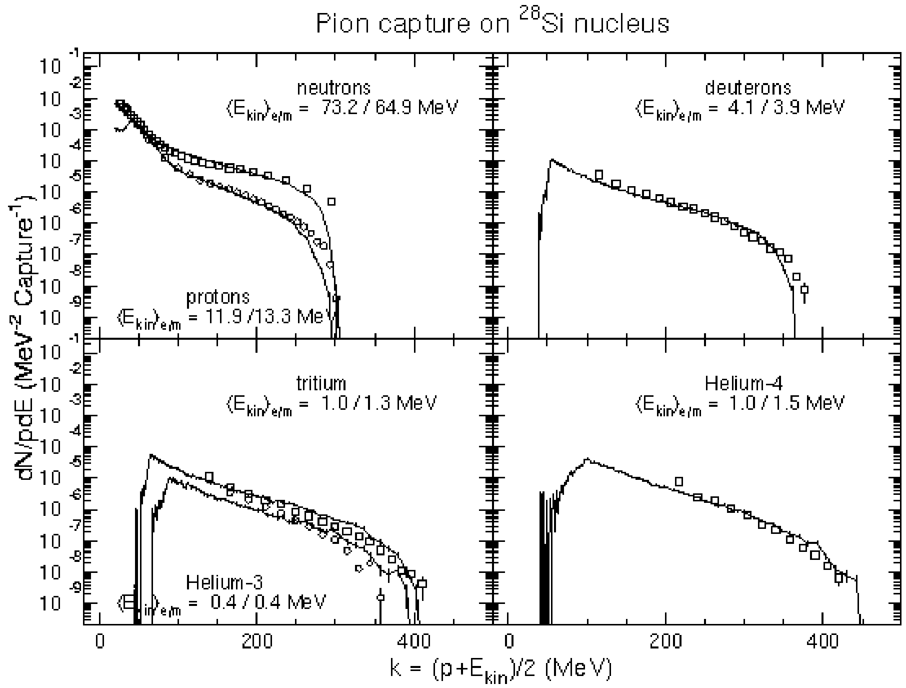
$$P_\nu = \frac{C_\nu^a \omega^{\nu-1}}{(1+\omega)^{a-1}}$$

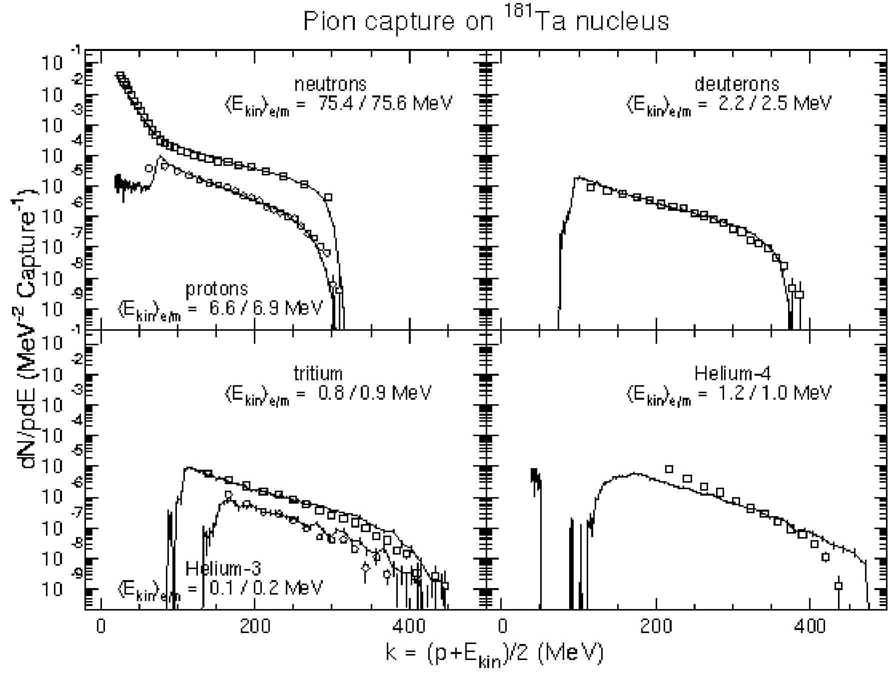
Nuclear CHIPS

- At this level of the language, CHIPS can be applied to reactions of pions and photo-nuclear reactions.

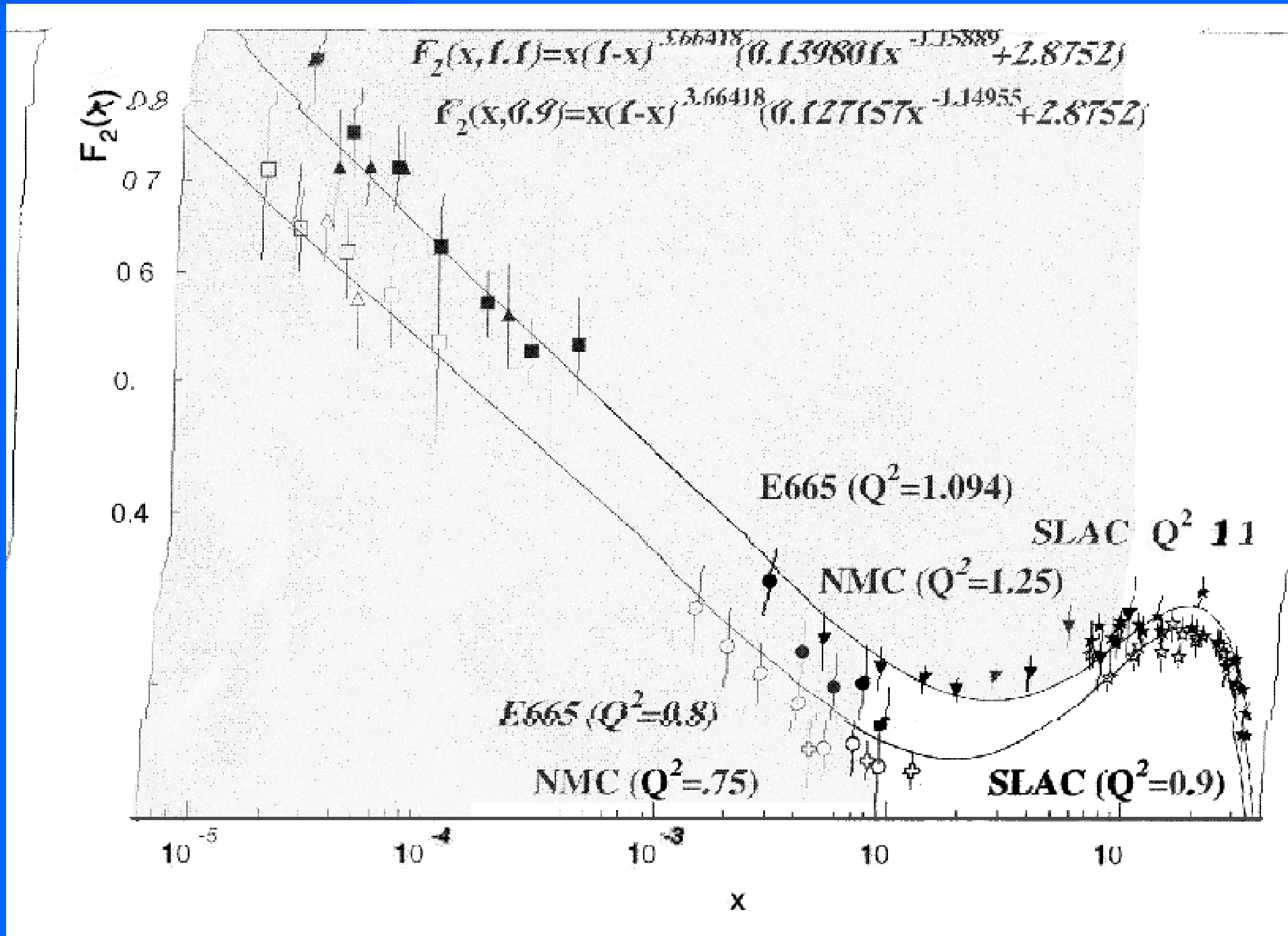

Pion capture on 9Be nucleus
neutrons
⟨E_kin⟩_e/m = 100.8 / 81.2 MeV
protons
⟨E_kin⟩_e/m = 6.3 / 5.8 MeV
deuterons
⟨E_kin⟩_e/m = 5.9 / 5.3 MeV
tritium
⟨E_kin⟩_e/m = 4.4 / 2.8 MeV
Helium-3
⟨E_kin⟩_e/m = 0.4 / 1.3 MeV
Helium-4
⟨E_kin⟩_e/m = 1.2 / 5.9 MeV
dN/pdE (MeV^-2 Capture^-1)
k = (p+E_kin)/2 (MeV)


Pion capture on 59Co nucleus
neutrons
⟨E_kin⟩_e/m = 73.1 / 68.3 MeV
protons
⟨E_kin⟩_e/m = 10.5 /10.0 MeV
deuterons
⟨E_kin⟩_e/m = 3.1 / 3.2 MeV
tritium
⟨E_kin⟩_e/m = 0.8 / 1.1 MeV
Helium-3
⟨E_kin⟩_e/m = 0.2 / 0.3 MeV
Helium-4
⟨E_kin⟩_e/m = 0.9 / 1.3 MeV
dN/pdE (MeV^-2 Capture^-1)
k = (p+E_kin)/2 (MeV)


Pion capture on 28Si nucleus
neutrons
⟨E_kin⟩_e/m = 73.2 / 64.9 MeV
protons
⟨E_kin⟩_e/m = 11.9 /13.3 MeV
deuterons
⟨E_kin⟩_e/m = 4.1 / 3.9 MeV
tritium
⟨E_kin⟩_e/m = 1.0 / 1.3 MeV
Helium-3
⟨E_kin⟩_e/m = 0.4 / 0.4 MeV
Helium-4
⟨E_kin⟩_e/m = 1.0 / 1.5 MeV
dN/pdE (MeV^-2 Capture^-1)
k = (p+E_kin)/2 (MeV)


Pion capture on 181Ta nucleus
neutrons
⟨E_kin⟩_e/m = 75.4 / 75.6 MeV
protons
⟨E_kin⟩_e/m = 6.6 / 6.9 MeV
deuterons
⟨E_kin⟩_e/m = 2.2 / 2.5 MeV
tritium
⟨E_kin⟩_e/m = 0.8 / 0.9 MeV
Helium-3
⟨E_kin⟩_e/m = 0.1 / 0.2 MeV
Helium-4
⟨E_kin⟩_e/m = 1.2 / 1.0 MeV
dN/pdE (MeV^-2 Capture^-1)
k = (p+E_kin)/2 (MeV)

Hard scattering in electro-nuclear



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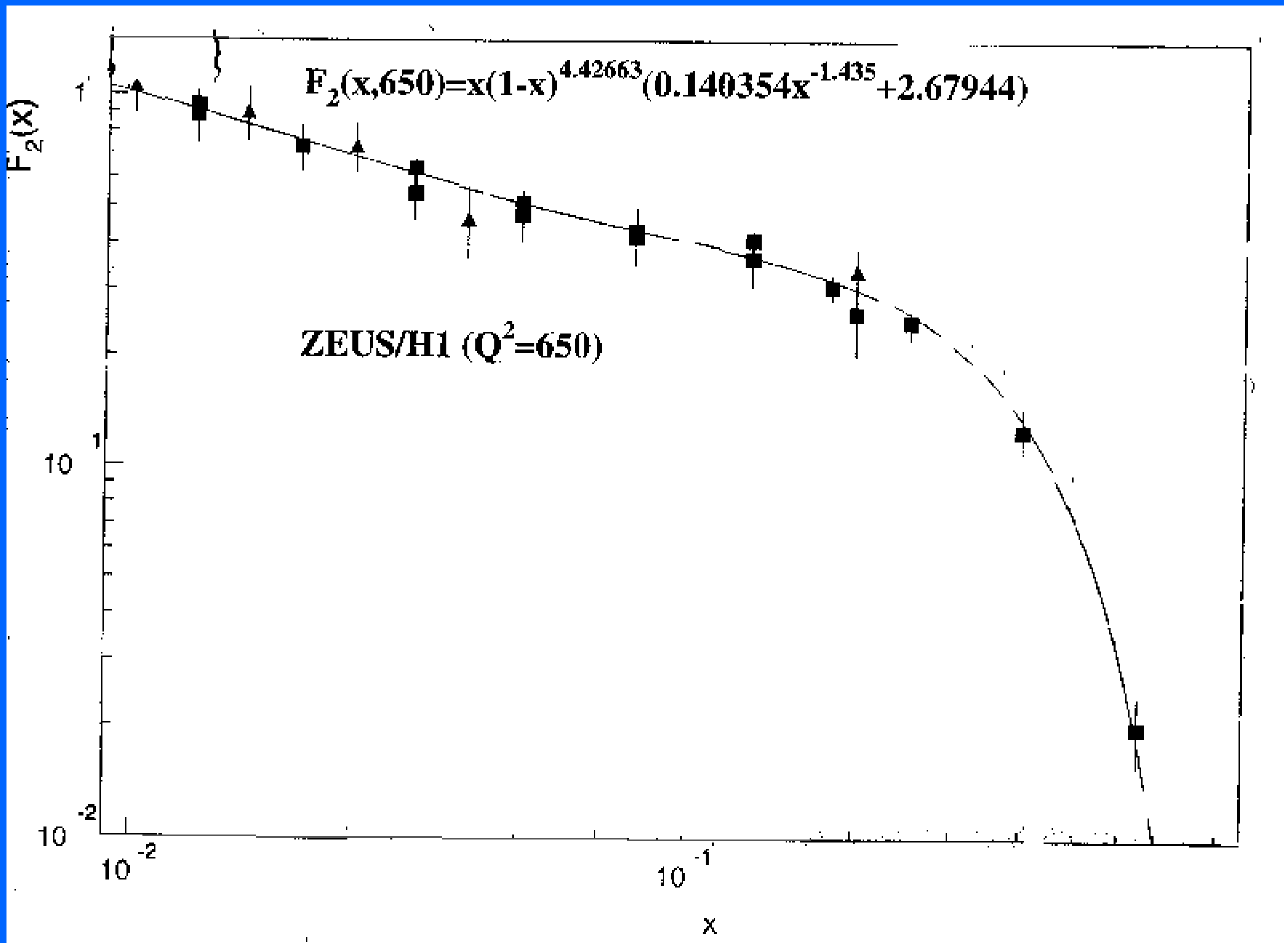
Hard scattering in electro-nuclear



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The binary cascade

- A 3-dimensional nuclear model is built up, as for quark gluon string model
- The impact parameter is sampled
- The time to closest approach to the nucleons in the nucleus is calculated
- Reactions are selected according to hadron nucleon cross-section
- The system is transported in the nuclear potential to the time of the earliest reaction or decay
- Products are created and subject to pauli's exclusion principle accepted.
- The procedure is repeated for all products, allowing for rescattering.

Why binary cascade?

- The name binary cascade comes from the fact that only binary collisions (and decay) are considered, like

$$pp \rightarrow \Delta_{1232} N^{*}_{2190} \quad or \quad K^{-} p \rightarrow \Sigma^{0}_{1775}$$

- No details on the mathematics, but this: the nucleon and delta resonances taken into consideration are these
  - Δ_{1232}, Δ_{1600}, Δ_{1620}, Δ_{1700}, Δ_{1900}, Δ_{1905}, Δ_{1910}, Δ_{1920}, Δ_{1930}, Δ_{1950}
  - N_{1400}, N_{1520}, N_{1535}, N_{1650}, N_{1675}, N_{1680}, N_{1700}, N_{1710}, N_{1720}, N_{1900}, N_{1990}, N_{2090}, N_{2190}, N_{2220}, N_{2250}

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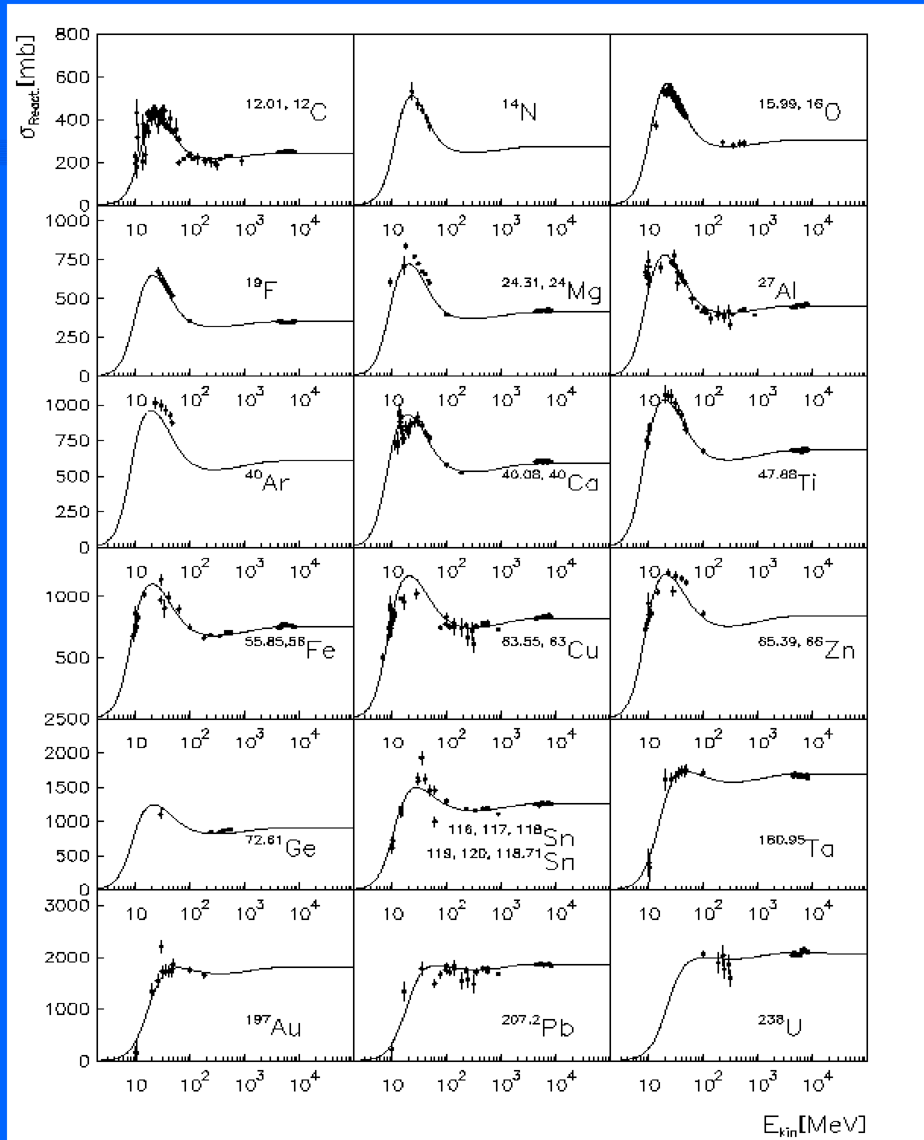
The potentials, transport equation, cross-section calculation, pauli-principle, etc..

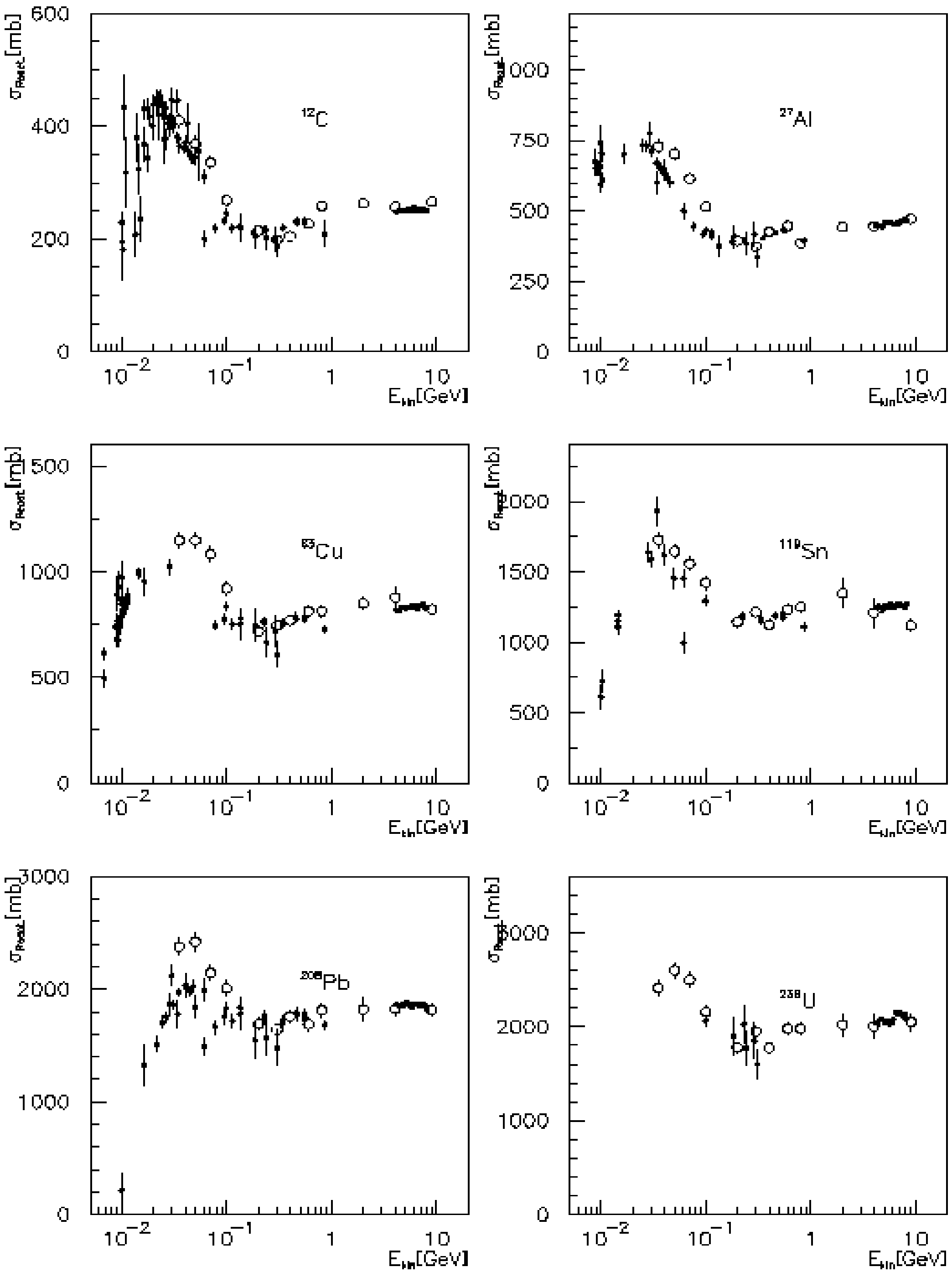
- All needed of course, but for the time being, just a few comparisons with existing data.

Proton induced reactions cross-sections



Binary cascade prediction

Sample the
Impact parameter over
A large area.
Make the ratio of 'hits'
To trials, times the area
sampled



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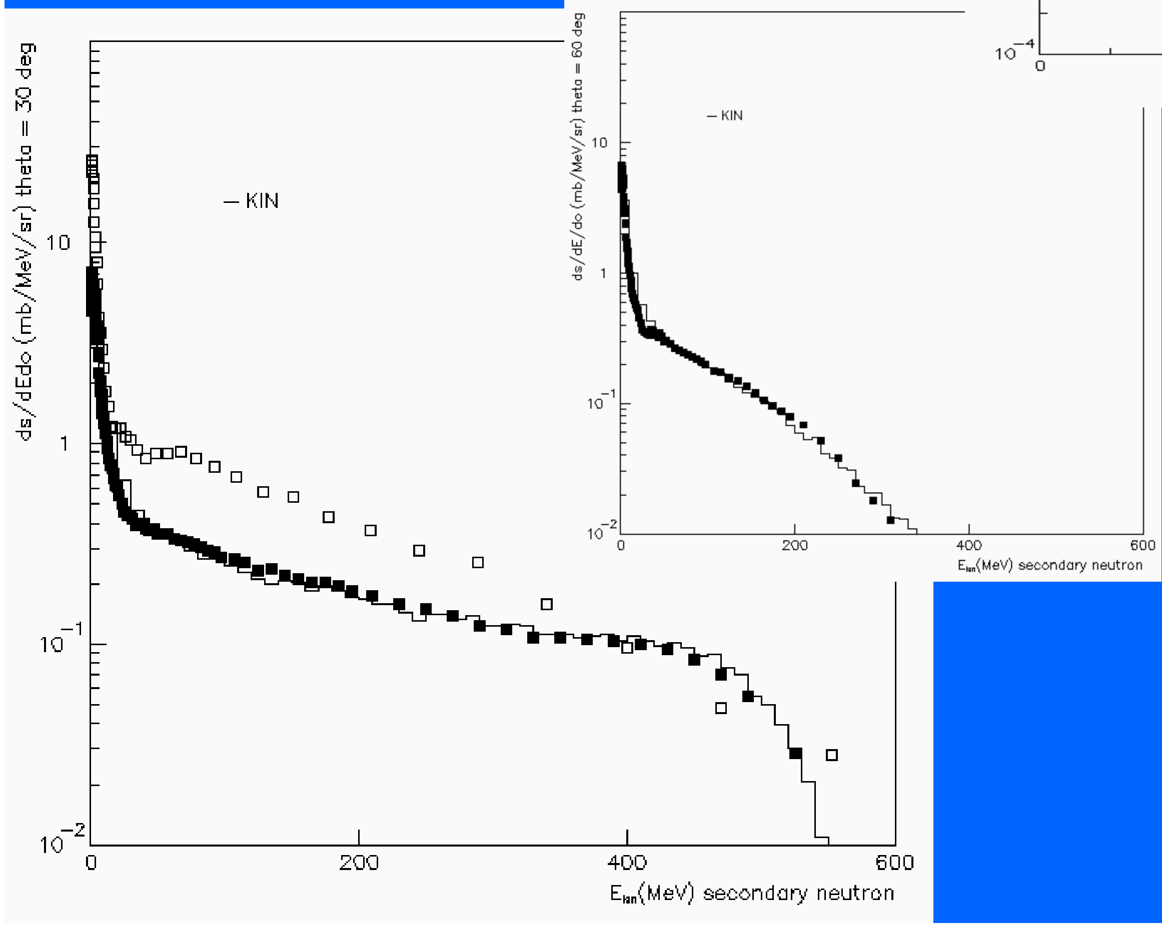
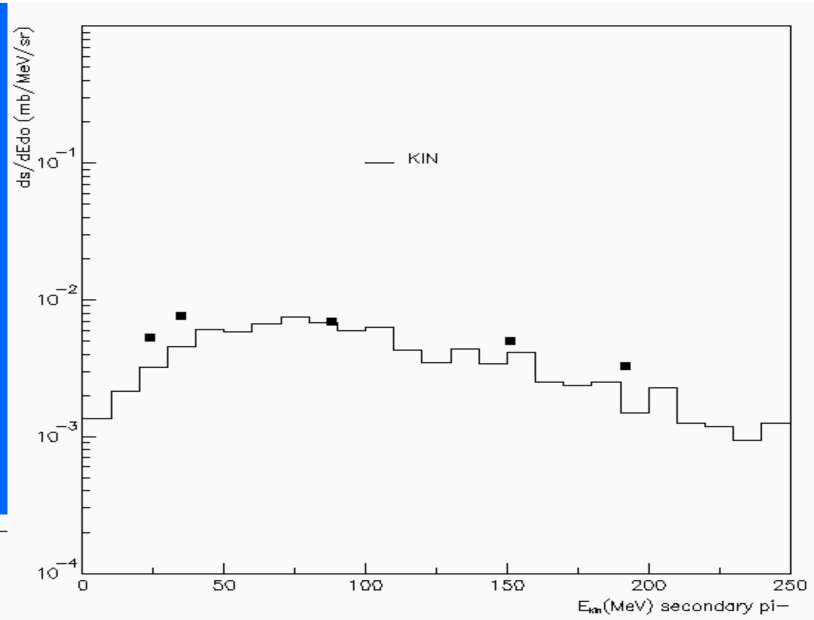
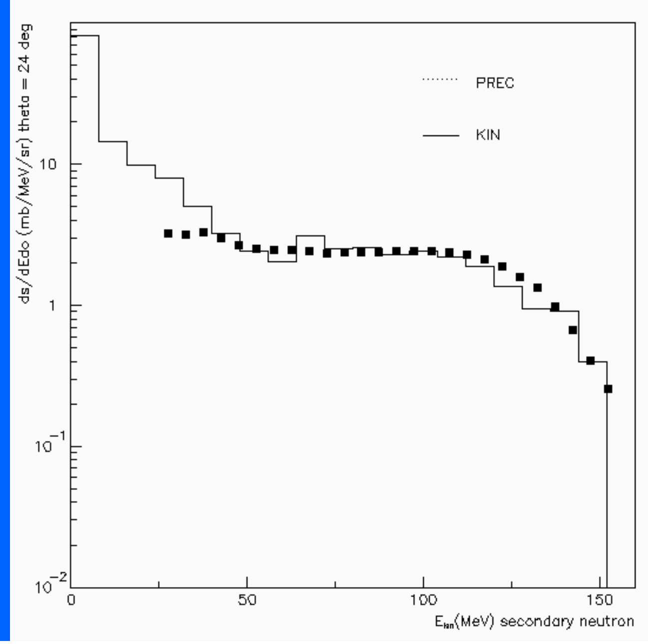
Binary cascade

585MeV p on Al, forward
And backward n and π

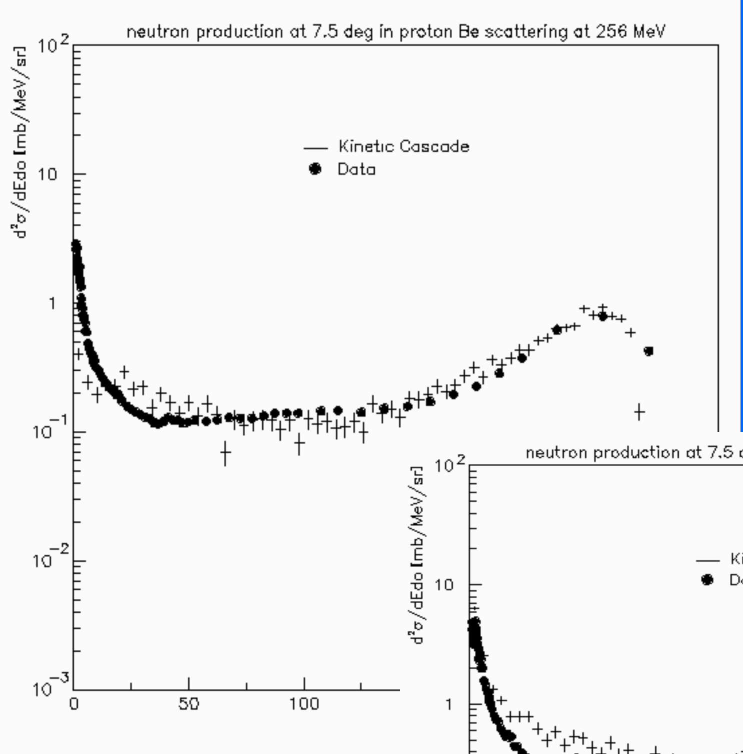


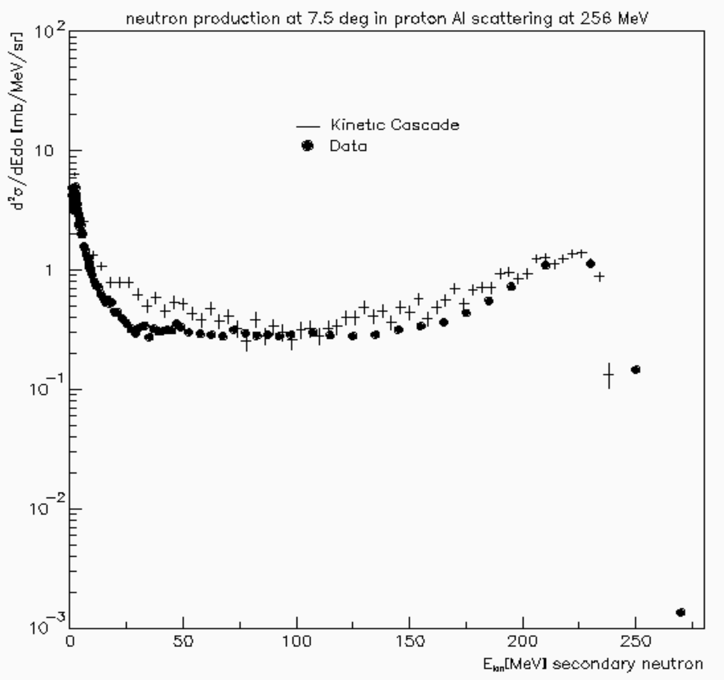


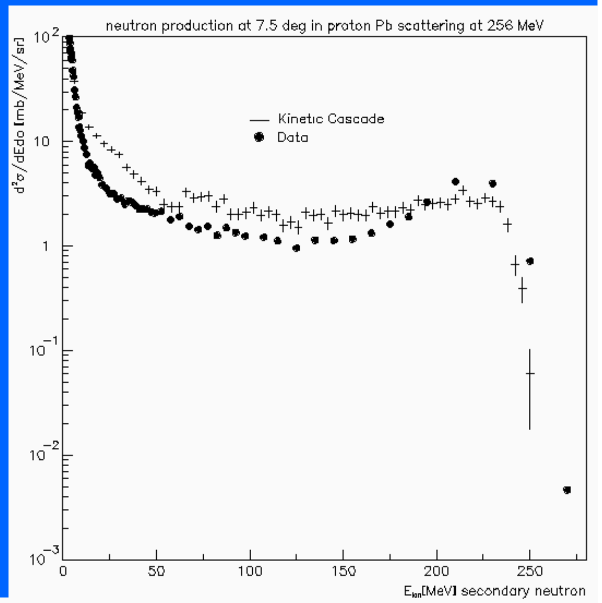
160 MeV p on Pb, forward neutrons

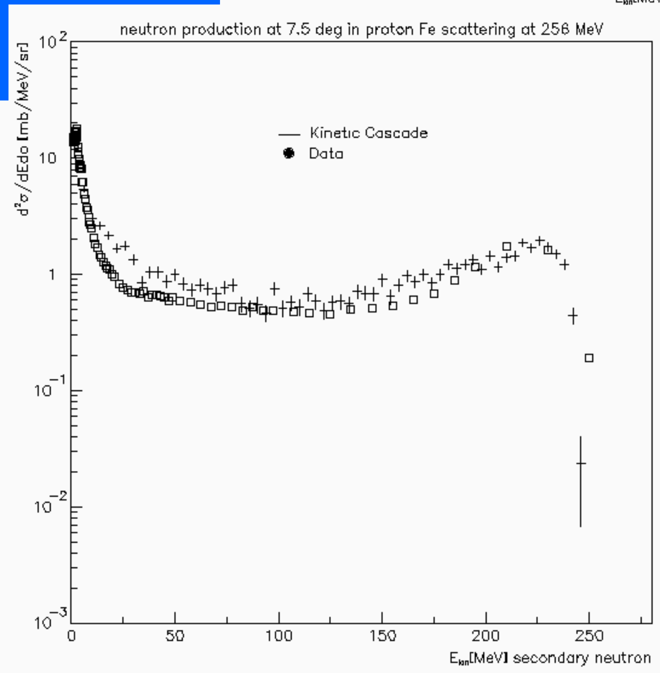


Quasi-elastic peaks in proton scattering (256 MeV)









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QMD currently under development

- Some characteristics of QMD:
  - A kinematical, binary cascade with detailed modeling of the nucleus.
  - Nuclear Hamiltonian calculated from 2 and 3 body potentials of all hadrons present in the system.
  - Solving the equation of motion by integrating this time-dependent Hamiltonian.
  - Scattering term in terms of localized interactions and decays.
  - Etc..

Well, this will have to do…

- There is a small fleet of additional models (including also a newly released classical cascade), over which for the moment I'll pass silently…

GHAD Validation&Verification

- Our validation strategy is deployed since spring 1999. It was also submitted as paper to CHEP2001.
- It was subsequently presented again in the CMS and ATLAS experiments at CERN, at the LHC-geant4 validation meeting, and the recent ACAT conference in Moscow, etc.…
- I would have been pleased to also present it in invited talks at the SATIF workshop (SLAC), and the IDM2002 workshop, but I had to turn these down due to lack of travel-money at CERN.

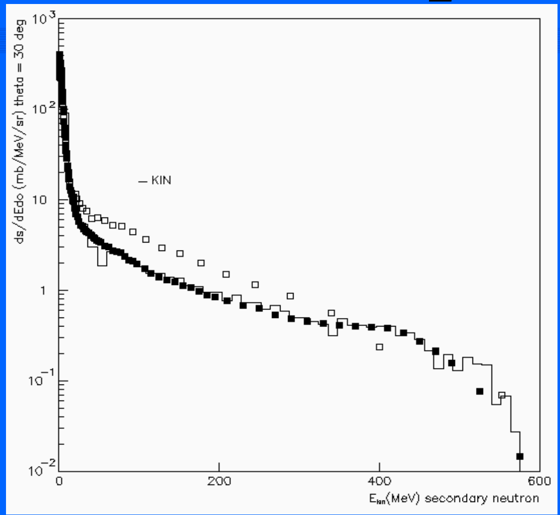
Model validation

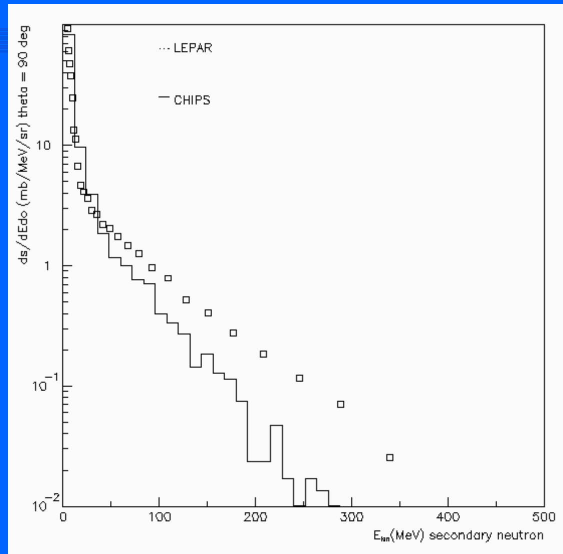
- Four tier strategy
  - Author validation plots for the individual models
    - Precondition for a model to be a candidate for inclusion.
  - Independent validation on thin target data with regression suites by the working group
    - Verified before every release
  - Independent validation on benchmarks, where these are available
    - Verified before every release, where possible
  - Validation on full simulation programs
- I take model validation much more seriously than it was in the times of geant3.

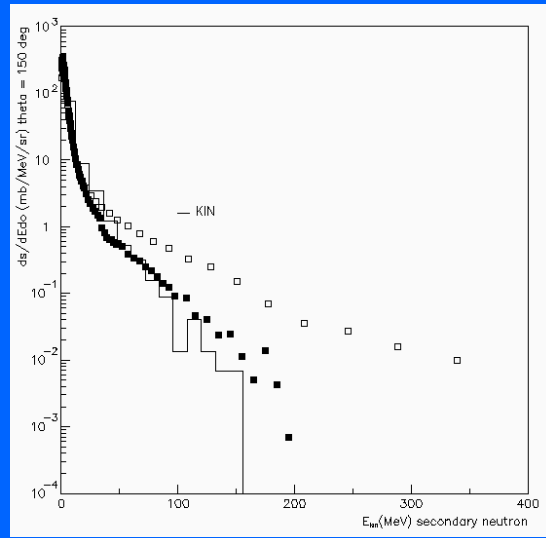
The cascade verification suite (CERN/SLAC)

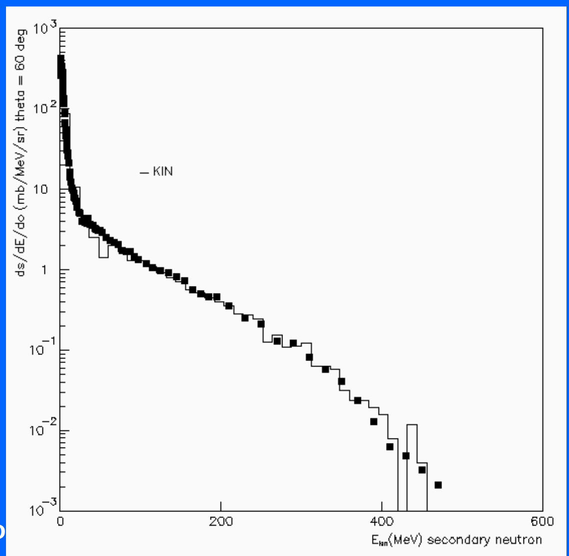
- Materials: H, d, Be, C, Al, Fe, Ni, Zr, Pb.
- Be: 113, 256, 585, 800 MeV
- C: 113, 590, 800 MeV
- Al: 22, 39, 90, 113, 160, 256, 585, 800 MeV
- Fe: 22, 65, 113, 256, 597, 800 MeV
- Ni: 200, 585 MeV (for pion production)
- Zr: 22, 35, 50, 120, 160, 256, 800 MeV
- Pb: 35, 65, 120, 160, 256, 597, 800 MeV
- H, d: pion production at 585 MeV
- More being added as we speak.

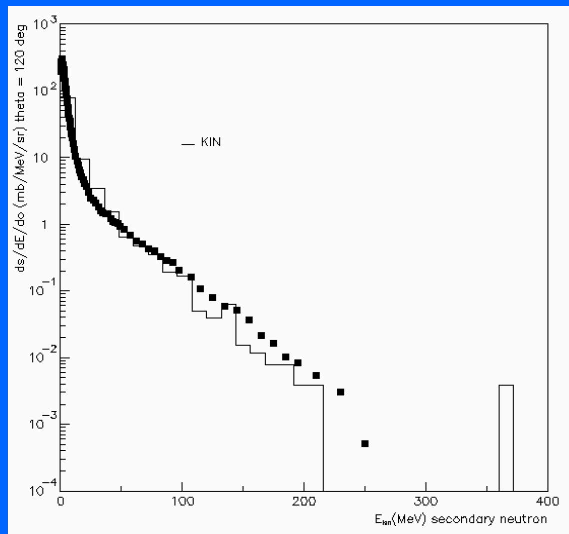
One complete example: 597 MeV p on Pb











Neutron production
At 30, 60, 90, 120
And 150 degrees

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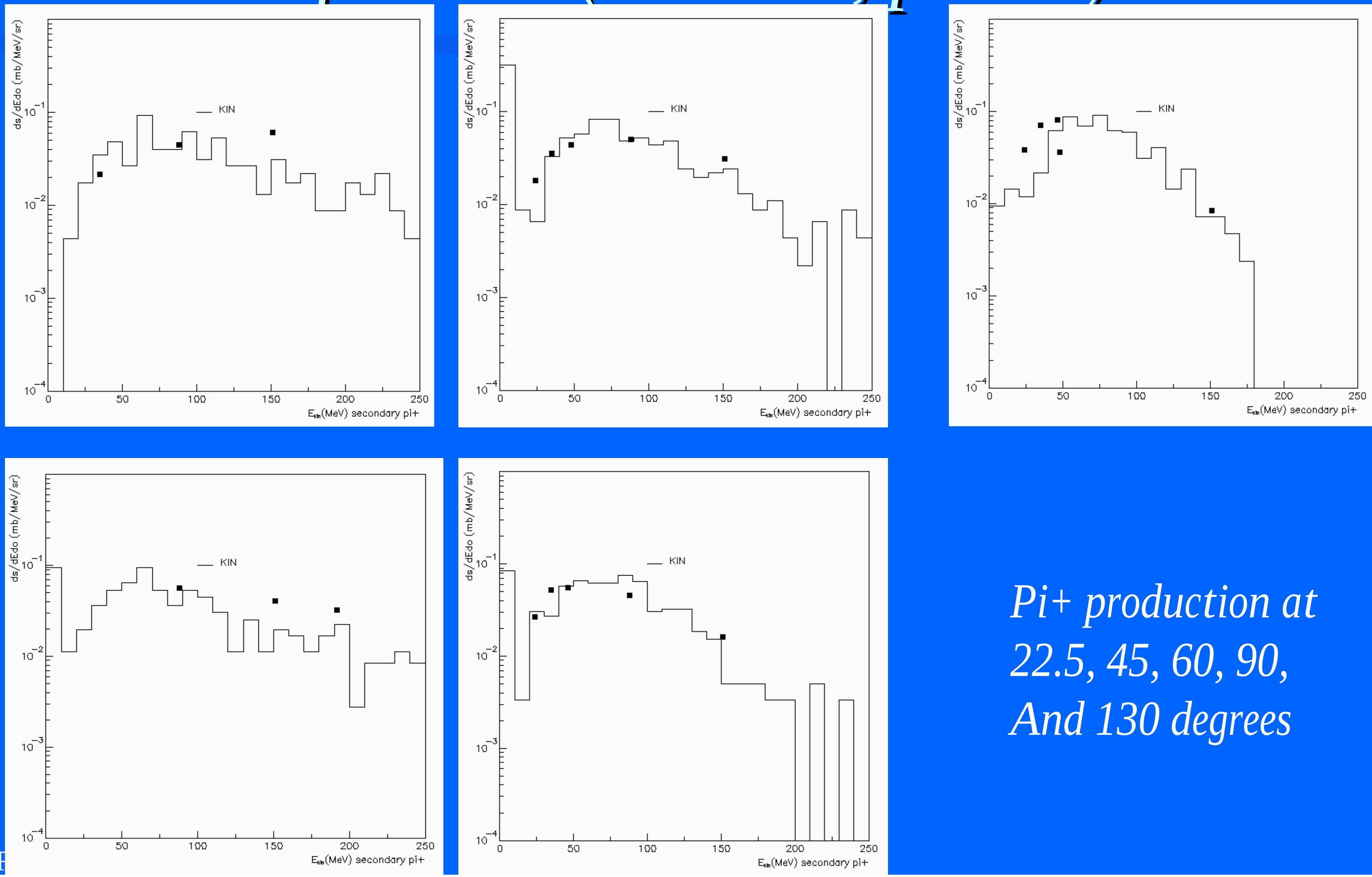
One complete example:
597 MeV p on Pb (PRC 22, p1184)



Pi+ production at 22.5, 45, 60, 90, And 130 degrees

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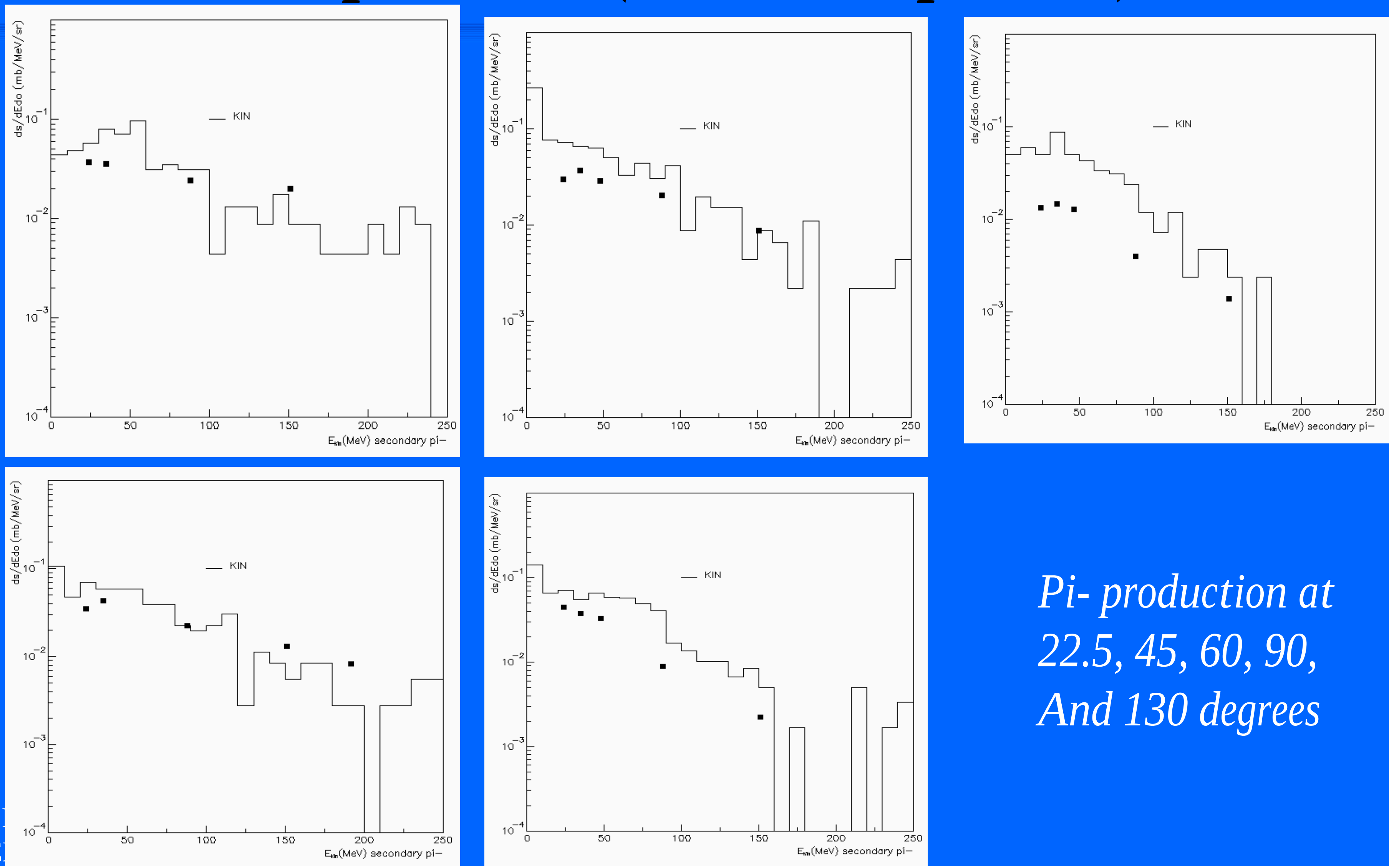
One complete example:
597 MeV p on Pb (PRC 22, p1184)



Pi- production at
22.5, 45, 60, 90,
And 130 degrees

J.
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Low energy neutrons: G4NDL0.2, 3.7

- Are granular selections of data from (alphabetic)
  - Brond 2.1
  - CENDL 2.2
  - EFF-3
  - ENDF/B (VI.0, VI.1, VI.5)
  - ENSDF
  - FENDL/E2.0
  - JEF 2.2
  - JENDL (3.1, 3.2, FF; 3.3 currently under study)
  - MENDL-2(P)
- Large parts of the selection is guided by the FENDL-2 selection
- G4NDL0.2 for non-thermal application

The neutron_hp transport models

- Simulate the cross-sections and interactions of neutrons with kinetic energies below 20 MeV down to thermal energies .
- The upper limit is set only by the evaluated data libraries the code is based on.
- We consider elastic scattering, fission, capture and inelastic scattering as separate models
- Neutron_hp sampling codes for the ENDF/B-VI derived data formats are completely generic (not including general R-matrix for the time being)
- Note that for fission there is a quite competitive theory driven alternative model, G4ParaFissionModel.

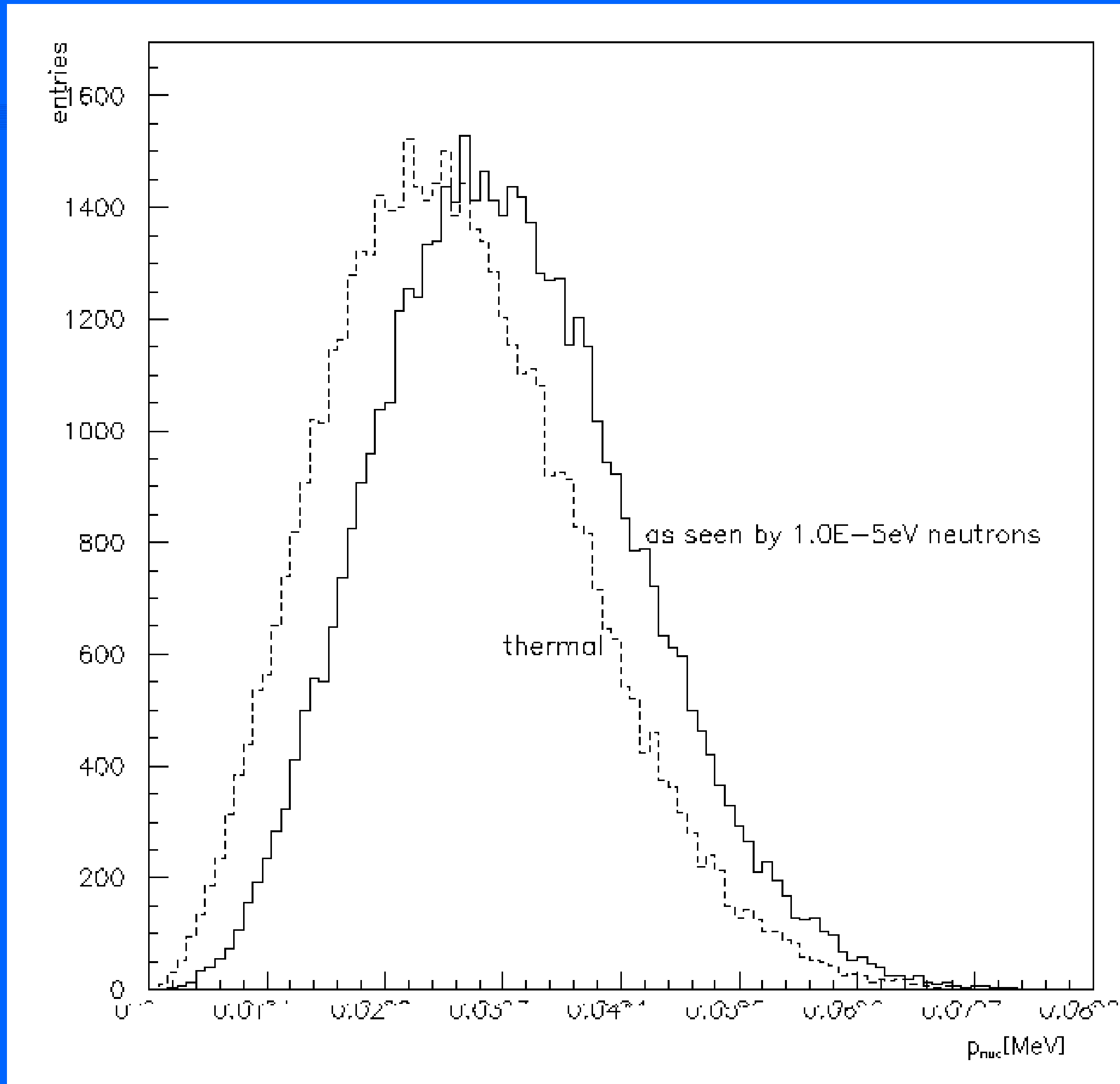
Models for neutron interaction and thermalization.

- neutron_hp models and cross-sections:
  - Uses the unix file-system to ensure granular and transparent access/usage of data sets.
  - More than 10^10 events run.
  - Uses point-wise cross-sections → no artifacts due to multi-group structure.

Doppler broadening

- Does exact doppler broadening on the fly, based on 0K data → no pre-formatting of data to fixed temperatures, and easy simulation of set-ups with mixed temperatures.
- Adds the doppler bias to the nuclear momentum distribution
- Point one is to the best of our knowledge not available from any other transport code (the second is also in MCNP).

The doppler bias illustrated for Carbon



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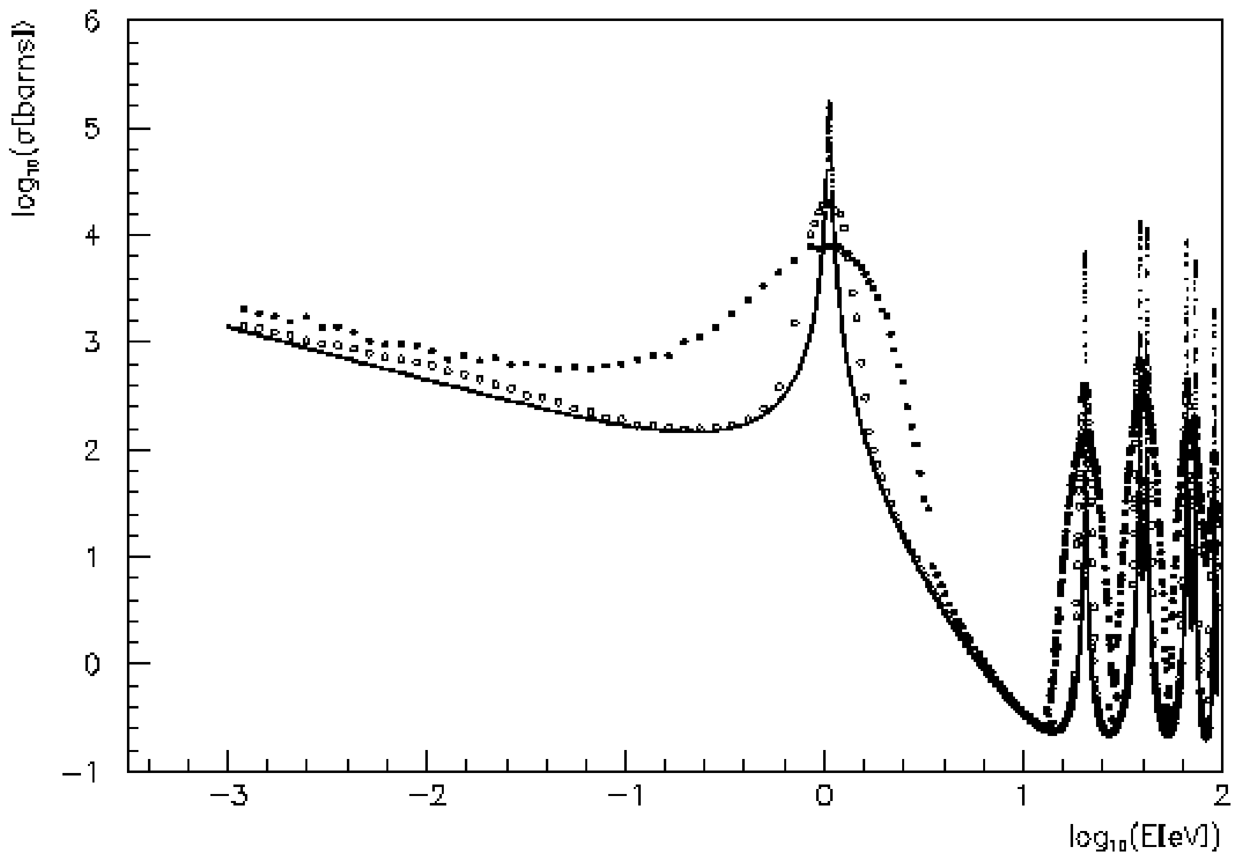
Doppler broadening



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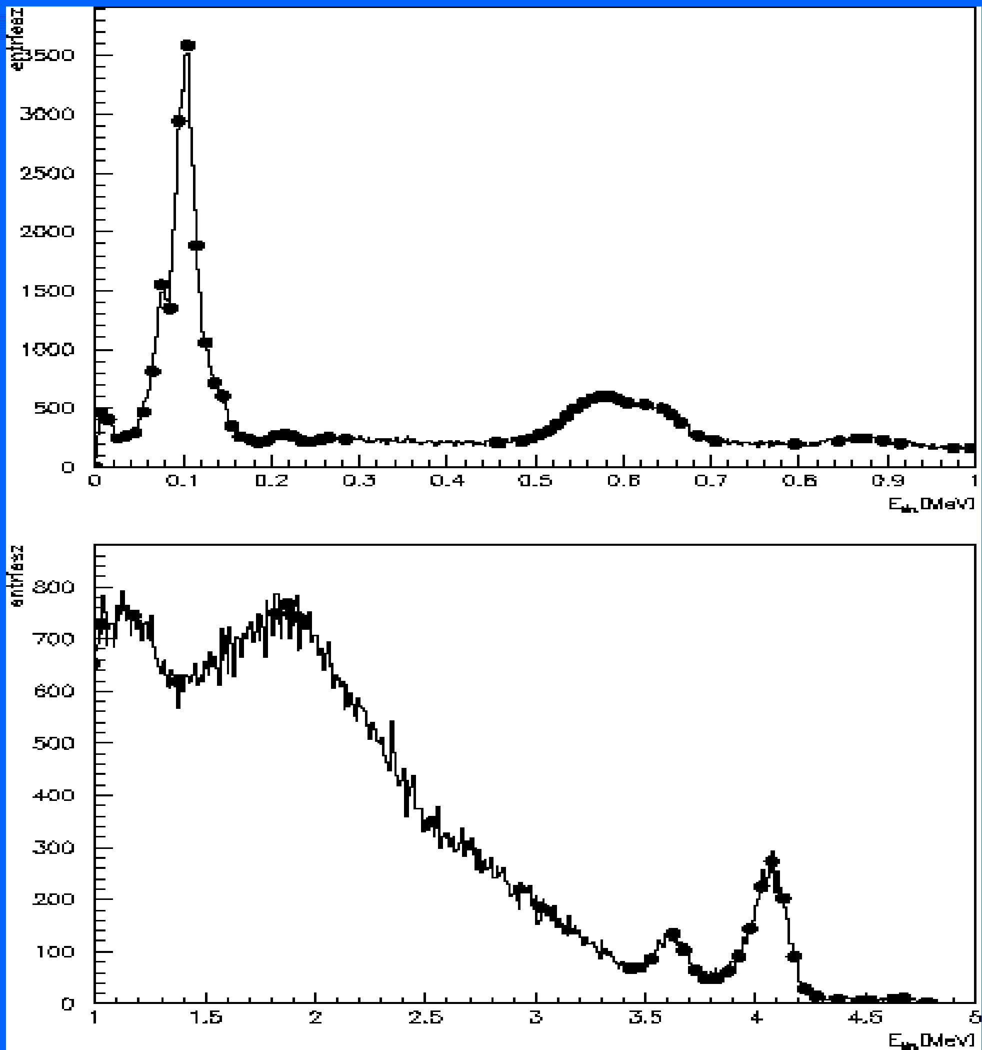
Low energy neutron capture



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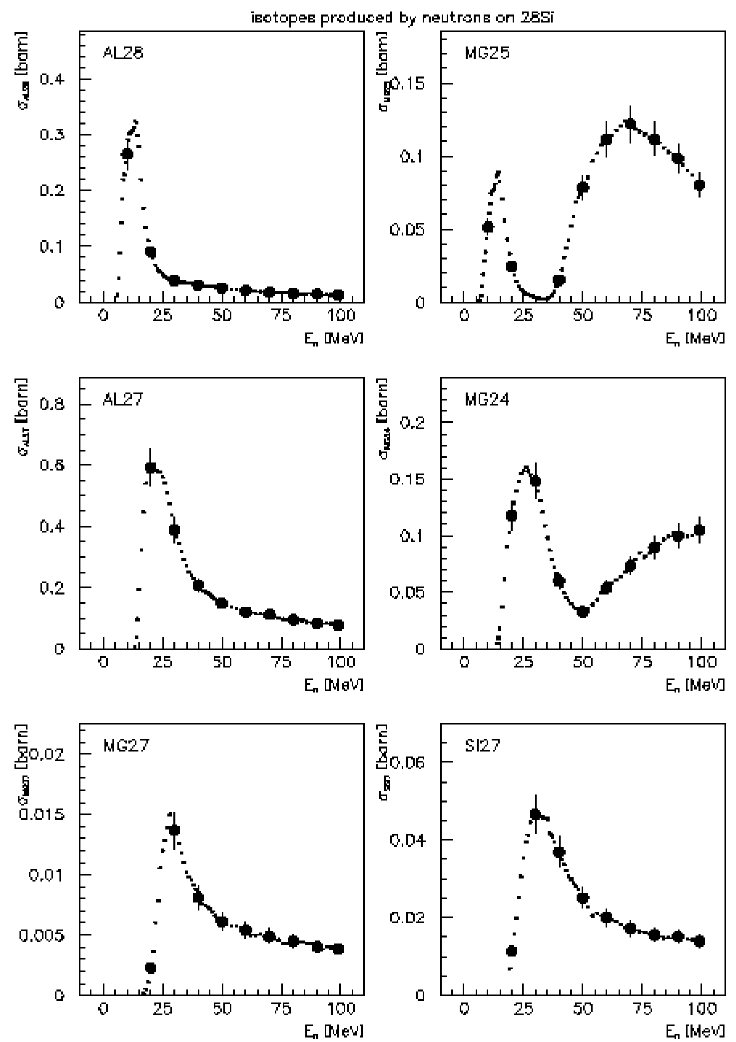
Neutron induced isotope production



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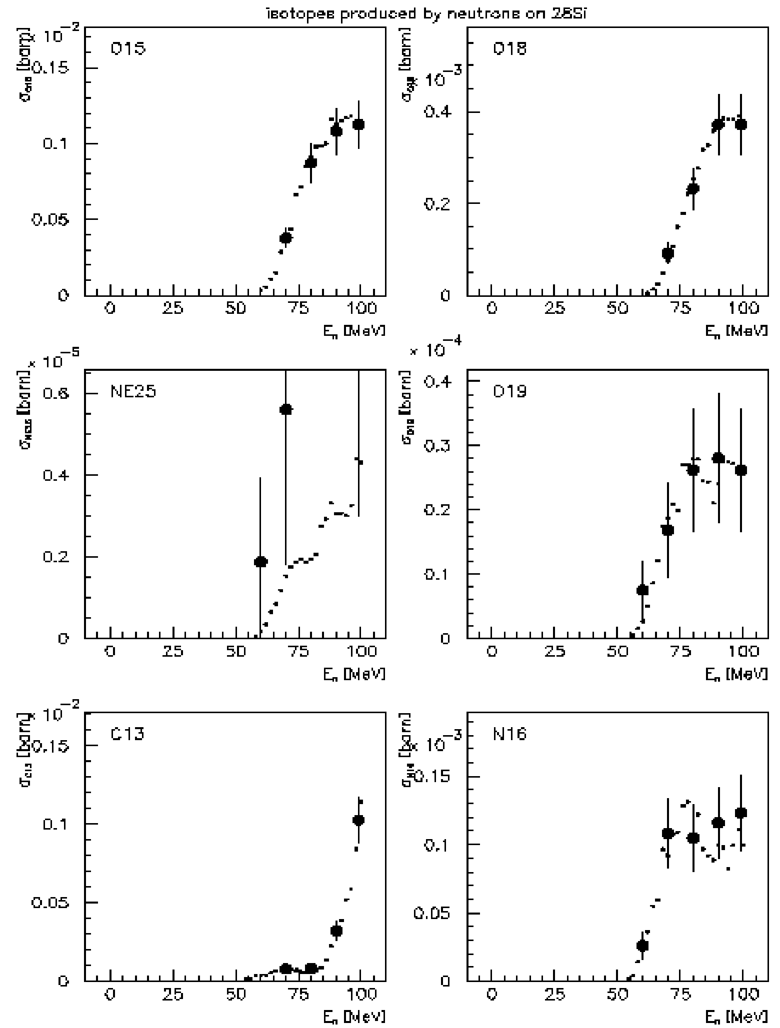
Isotope production



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Additions to appear this year

- Elastic recoils
- Ion induced reactions
- Extension of binary cascade to higher energies
- Evaluation of level densities in pre-compound model

More to be added after this workshop.

A few words on physics lists

- The problem(s) we tried to solve with the ‘educated guess’ physics lists
- The use-cases and some realizations
- The designs
- Some code samples
- The contents –The web page

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.

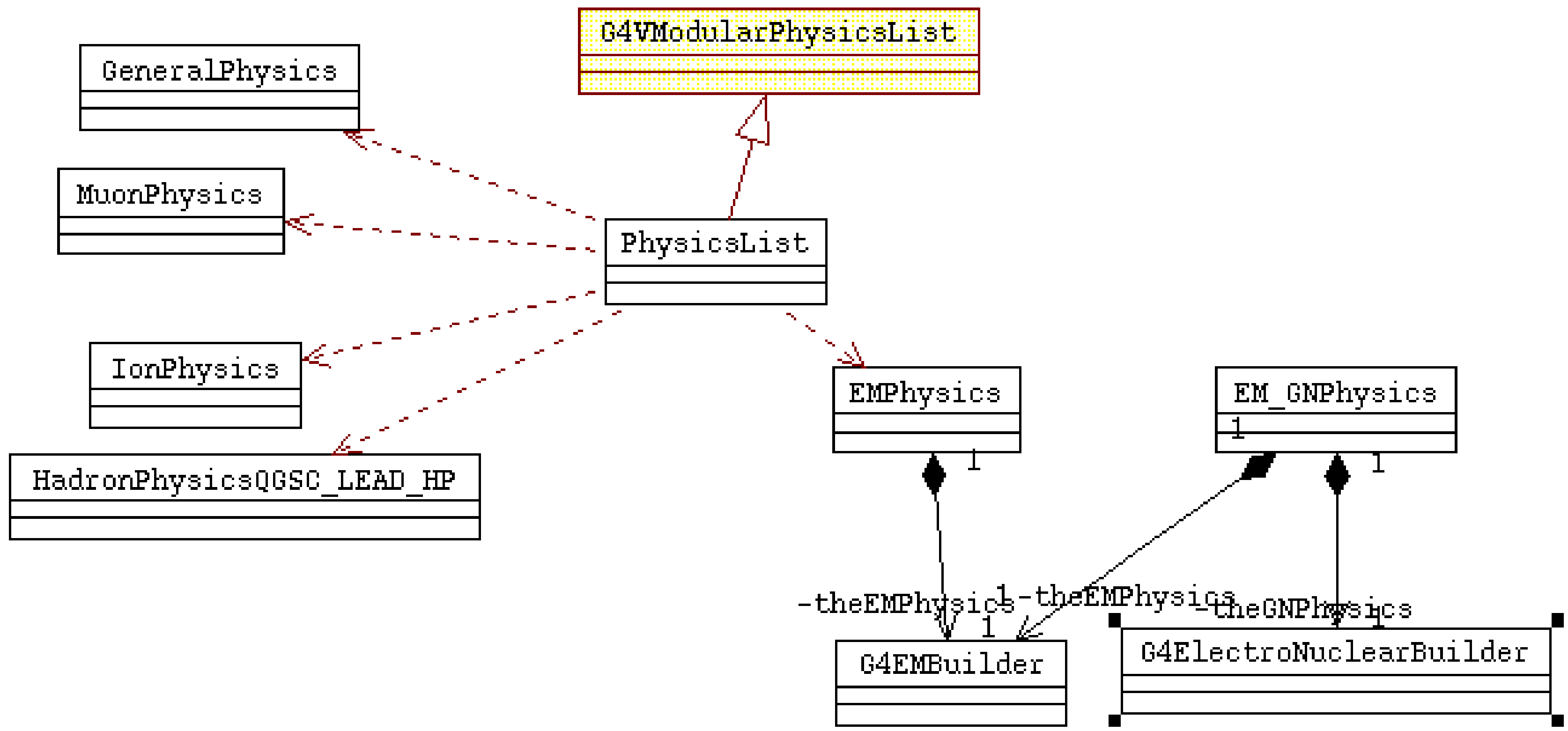
Because of this

- We have systematically accumulated experience with various combinations of cross-section and models over the last years.
- Today we 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

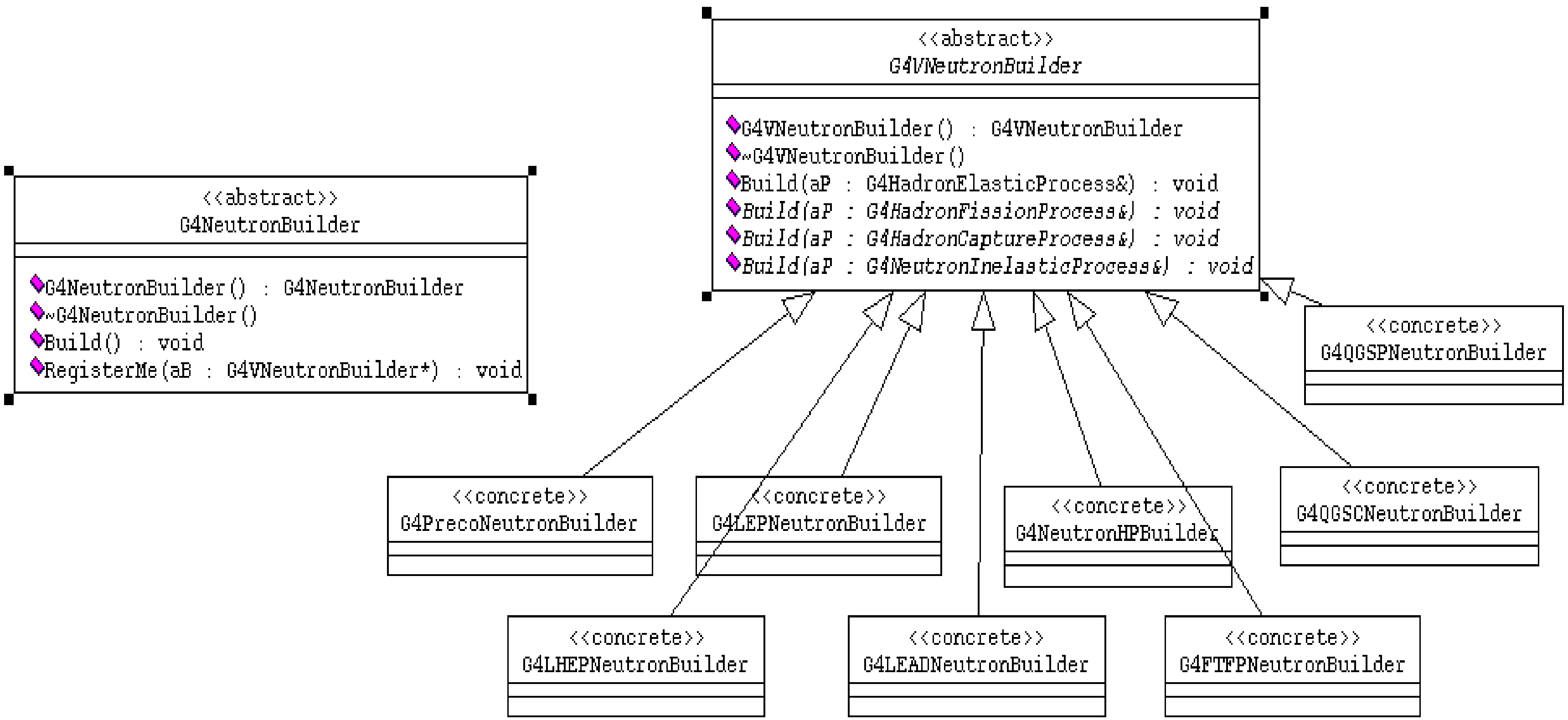
- Give an ‘educated guess’ to be used as starting point and/or give meaningful alternatives for physics lists for the various use-cases of hadronic physics.
- Provide a brief description of the modeling used in the different physics lists.
- Make physics lists more readable.
- Find a natural organization 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 shielding.
- Provide for areas where users can contribute their findings.
- Provide a distribution mechanism for both physics lists and verification results.

Design



G4VModularPhysicsList
GeneralPhysics
MuonPhysics
PhysicsList
IonPhysics
HadronPhysicsQGSC_LEAD_HP
EMPhysics
EM_GNPhysics
1
1
1
-theEMPhysics
1
-theEMPhysics
-theGNPhysics
1
1
G4EMBuilder
G4ElectroNuclearBuilder

Design



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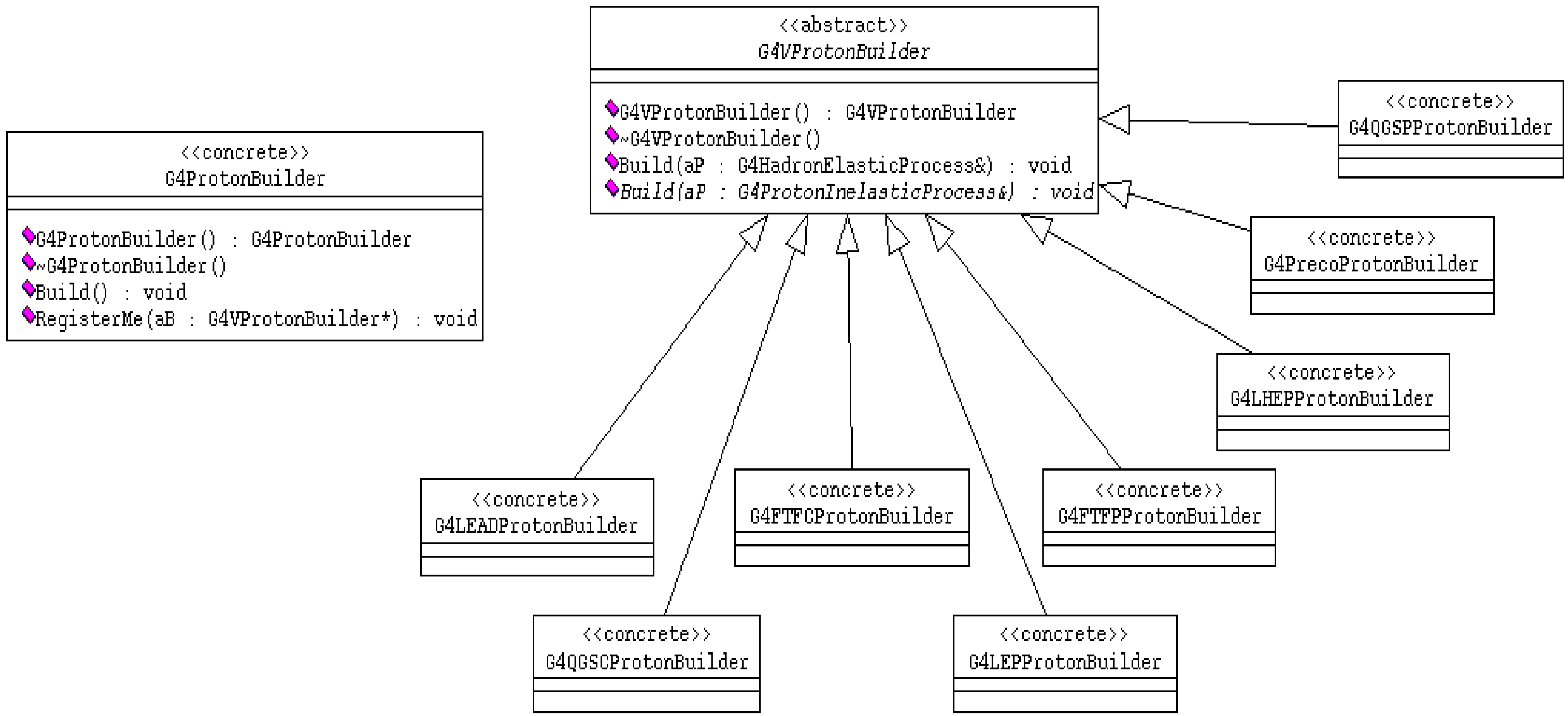
Design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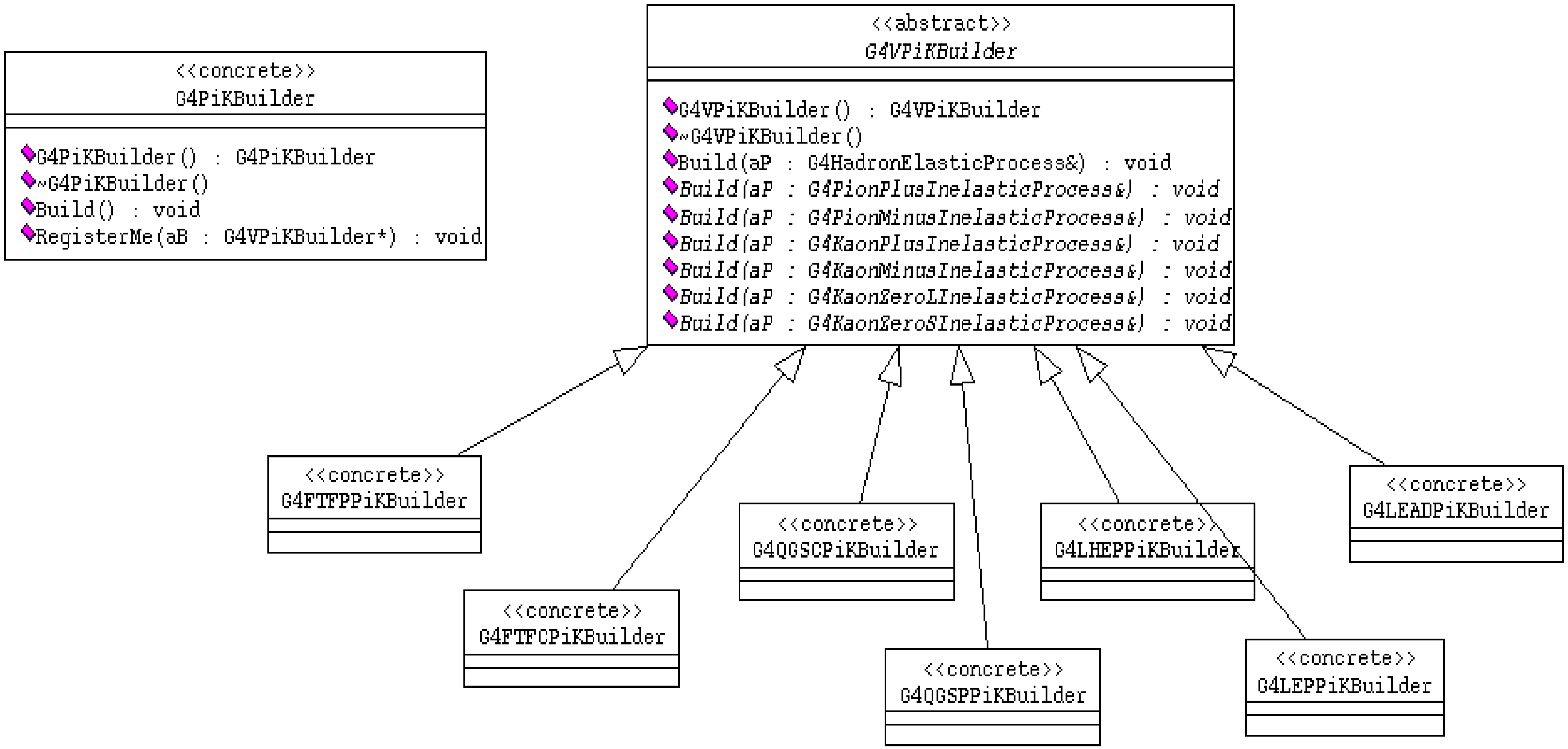
G4ProtonBuilder
G4ProtonBuilder() : G4ProtonBuilder
~G4ProtonBuilder()
Build() : void
RegisterMe(aB : G4VProtonBuilder*) : void
<<abstract>>
G4VProtonBuilder
G4VProtonBuilder() : G4VProtonBuilder
~G4VProtonBuilder()
Build(aP : G4HadronElasticProcess&) : void
Build(aP : G4ProtonInelasticProcess&) : void
<<concrete>>
G4QGSPProtonBuilder
<<concrete>>
G4PrecoProtonBuilder
<<concrete>>
G4LHEPProtonBuilder
<<concrete>>
G4LEADProtonBuilder
<<concrete>>
G4FTFCProtonBuilder
<<concrete>>
G4FTFPProtonBuilder
<<concrete>>
G4QGSCProtonBuilder
<<concrete>>
G4LEPProtonBuilder

Design



<<concrete>>
G4PiKBuilder
G4PiKBuilder() : G4PiKBuilder
~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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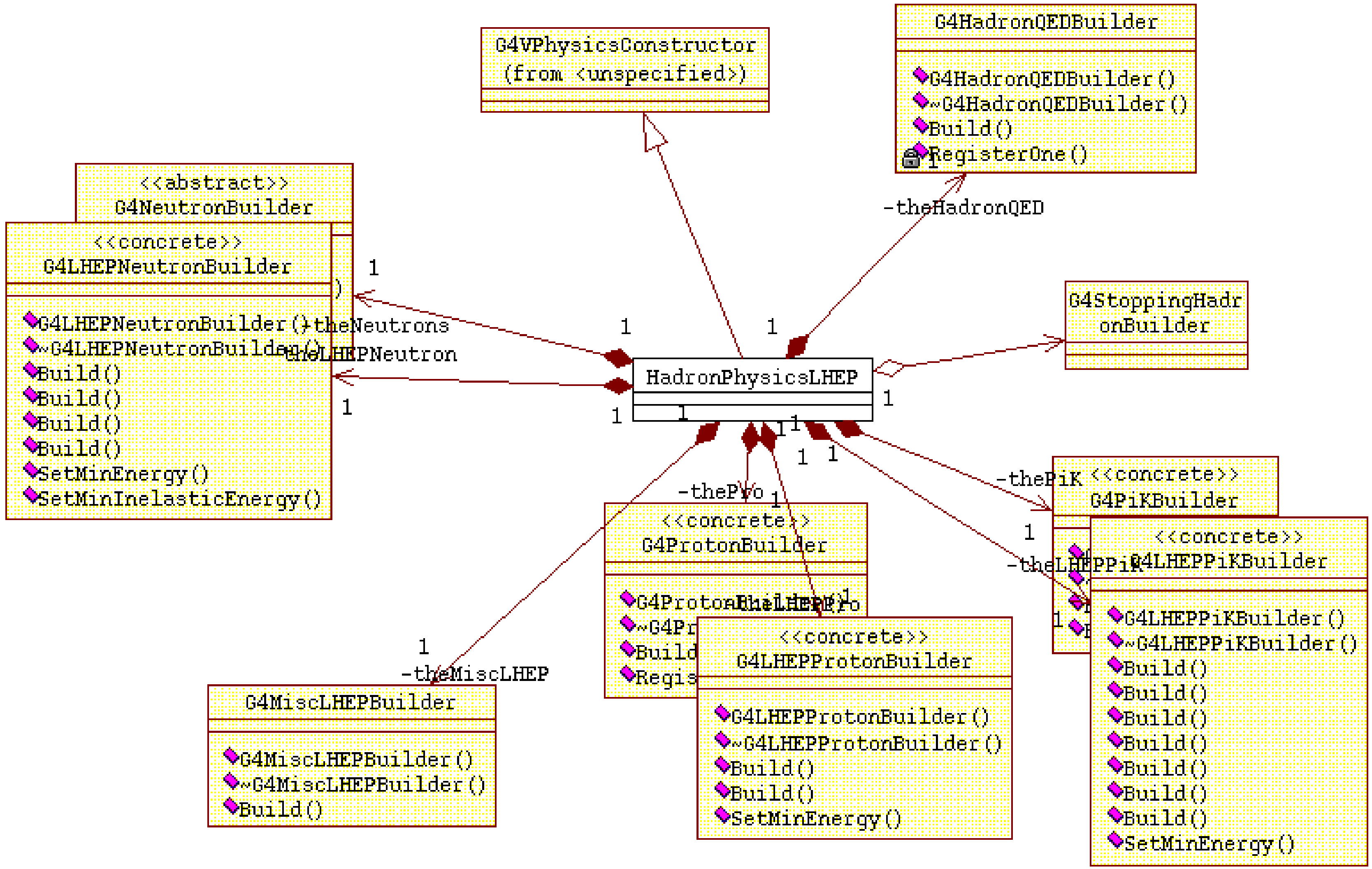
G4LHEPPiKBuilder
<<concrete>>
G4LEPPiKBuilder
<<concrete>>
G4LEADPiKBuilder



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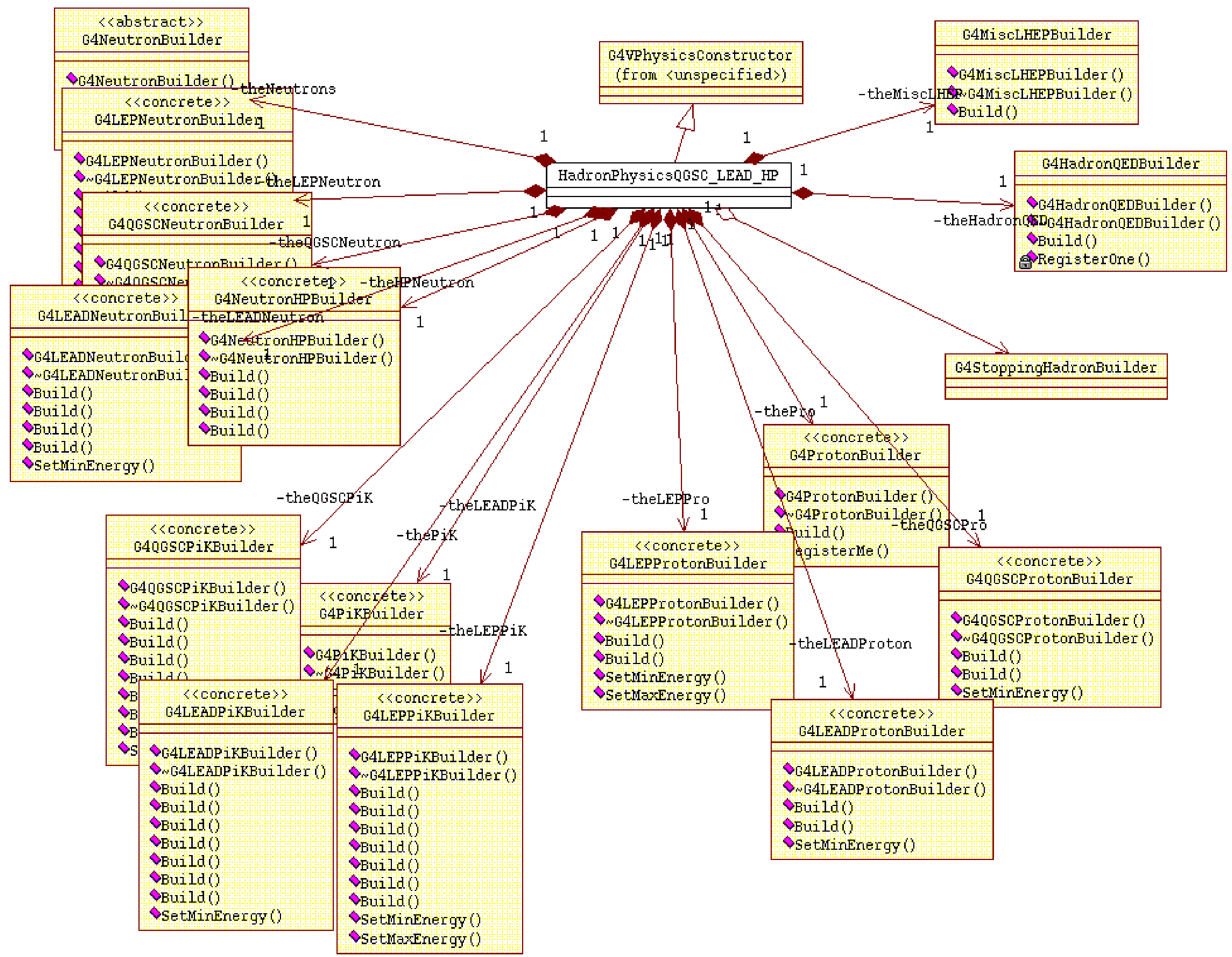

HadronPhysicsQGSC_LEAD_HP
G4VPhysicsConstructor (from <unspecified>)
<<abstract>> G4NeutronBuilder
G4NeutronBuilder()
<<concrete>> G4LEPNeutronBuilder
G4LEPNeutronBuilder()
~G4LEPNeutronBuilder()
<<concrete>> G4QGSCNeutronBuilder
G4QGSCNeutronBuilder()
<<concrete>> G4LEADNeutronBuilder
Build()
SetMinEnergy()
<<concrete>> G4NeutronHPBuilder
G4NeutronHPBuilder()
~G4NeutronHPBuilder()
Build()
G4MiscLHEPBuilder
G4MiscLHEPBuilder()
~G4MiscLHEPBuilder()
Build()
G4HadronQEDBuilder
G4HadronQEDBuilder()
~G4HadronQEDBuilder()
Build()
RegisterOne()
G4StoppingHadronBuilder
<<concrete>> G4ProtonBuilder
G4ProtonBuilder()
~G4ProtonBuilder()
<<concrete>> G4LEPProtonBuilder
G4LEPProtonBuilder()
~G4LEPProtonBuilder()
Build()
SetMinEnergy()
SetMaxEnergy()
<<concrete>> G4QGSCProtonBuilder
G4QGSCProtonBuilder()
~G4QGSCProtonBuilder()
Build()
SetMinEnergy()
<<concrete>> G4LEADProtonBuilder
G4LEADProtonBuilder()
~G4LEADProtonBuilder()
Build()
SetMinEnergy()
<<concrete>> G4QGSCPiKBuilder
G4QGSCPiKBuilder()
~G4QGSCPiKBuilder()
Build()
<<concrete>> G4PiKBuilder
G4PiKBuilder()
~G4PiKBuilder()
<<concrete>> G4LEADPiKBuilder
G4LEADPiKBuilder()
~G4LEADPiKBuilder()
Build()
SetMinEnergy()
<<concrete>> G4LEPPiKBuilder
G4LEPPiKBuilder()
~G4LEPPiKBuilder()
Build()
SetMinEnergy()
SetMaxEnergy()
-theNeutrons
-theLEPNeutron
-theQGSCNeutron
-theHPNeutron
-theLEADNeutron
-theMiscLHEP
-theHadronQED
-thePro
-theLEPPro
-theQGSCPro
-theLEADProton
-theQGSCPiK
-theLEADPiK
-thePiK
-theLEPPiK
1

Now, what does this mean ?

- Complex problems need structures solutions.
- There are 5 levels of implementation framework.
- In the builders, we have collapsed these to level 1 and/or level 2 complexity.

- Anybody 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.

The WWW pages – a small demo.

- We go to:
  - http://cmsdoc.cern.ch/~hpw/GHAD/HomePage

Use-cases considered

- Goto the physics lists page.

Code samples

- Go to the physics list page.

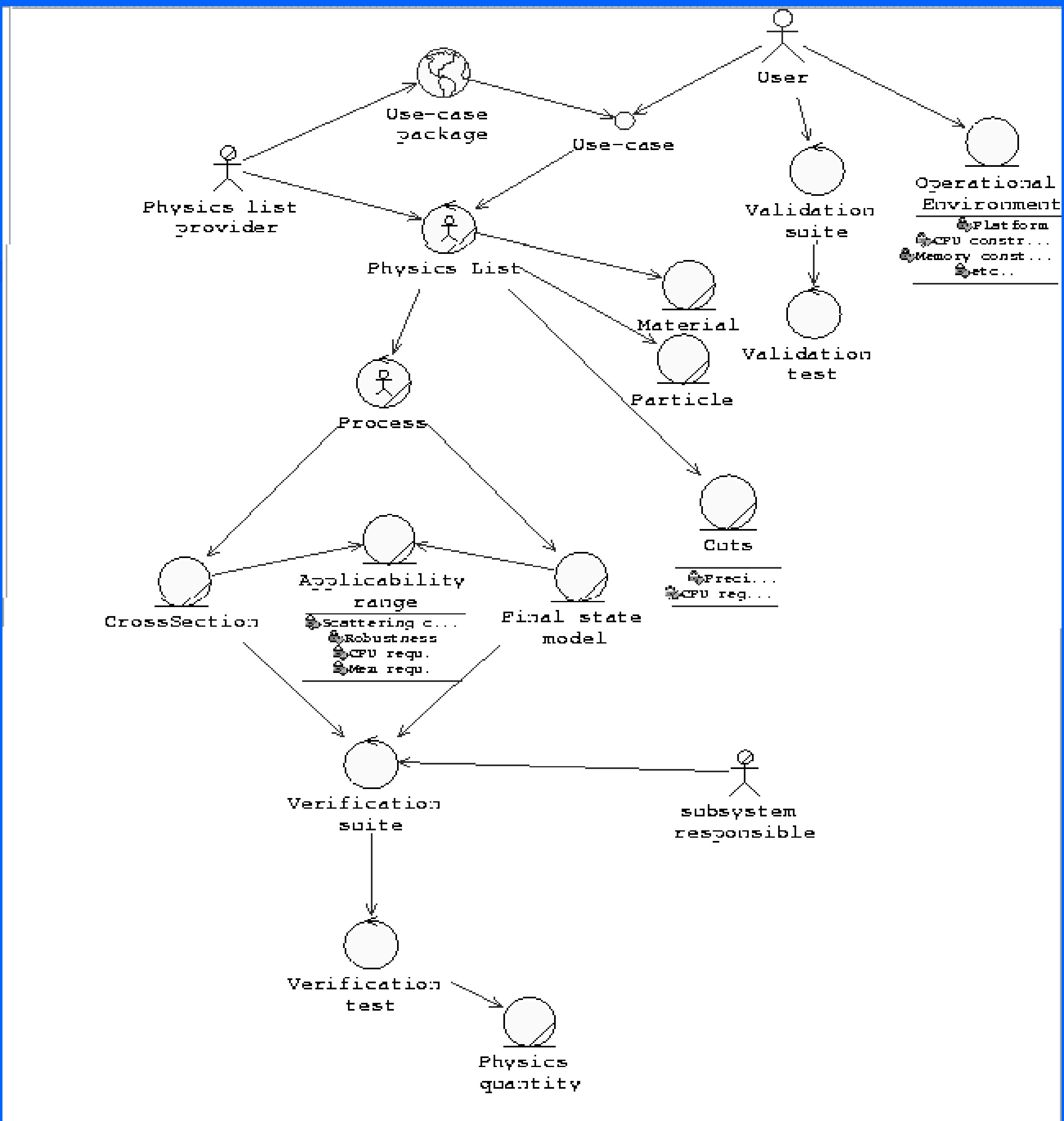
A non trivial effort

- We support 15 use-case packages
- We support 16 physics lists
- They comprise 74 classes
- Their implementation needed 8740 lines of code (comments discounted)

User feed-back

- Verbatim cut and paste from some of the mails…
  - “Please accept my great congratulations to you and all members in hadronic working group”
  - “So, to make a long story short: very USEFULL. As well, I like the idea of distributing and orgenizing the information through web pages.”
  - “There are just a few obvious mistapes, especially your name ‘J.P. Wellisch’.
  - “Thank you for this site. It is really useful.”

The support process – static view



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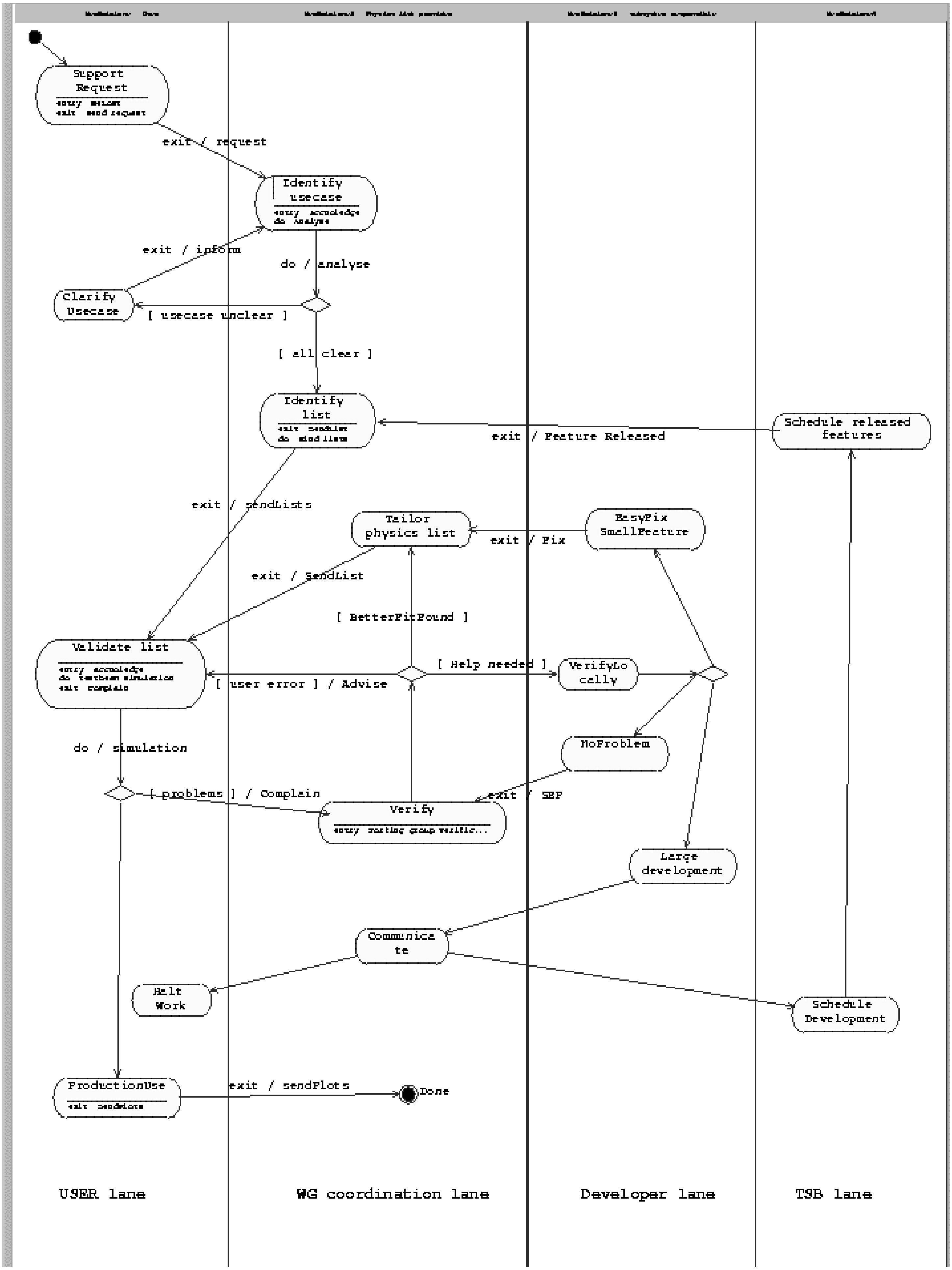
Support Request
exit / request
Identify usecase
exit / inform
do / analyse
Clarify Usecase
[usecase unclear]
[all clear]
Identify list
exit / Feature Released
Schedule released features
exit / sendLists
Tailor physics list
exit / Fix
EasyFix SmallFeature
exit / SendList
[BetterFitFound]
Validate list
[Help needed]
VerifyLocally
[user error] / Advise
do / simulation
NoProblem
[problems] / Complain
exit / SBP
Verify
Large development
Communicate
Halt Work
Schedule Development
ProductionUse
exit / sendPlots
Done
USER lane
WG coordination lane
Developer lane
TSB lane