Hadronic physics simulation engines for Geant4.

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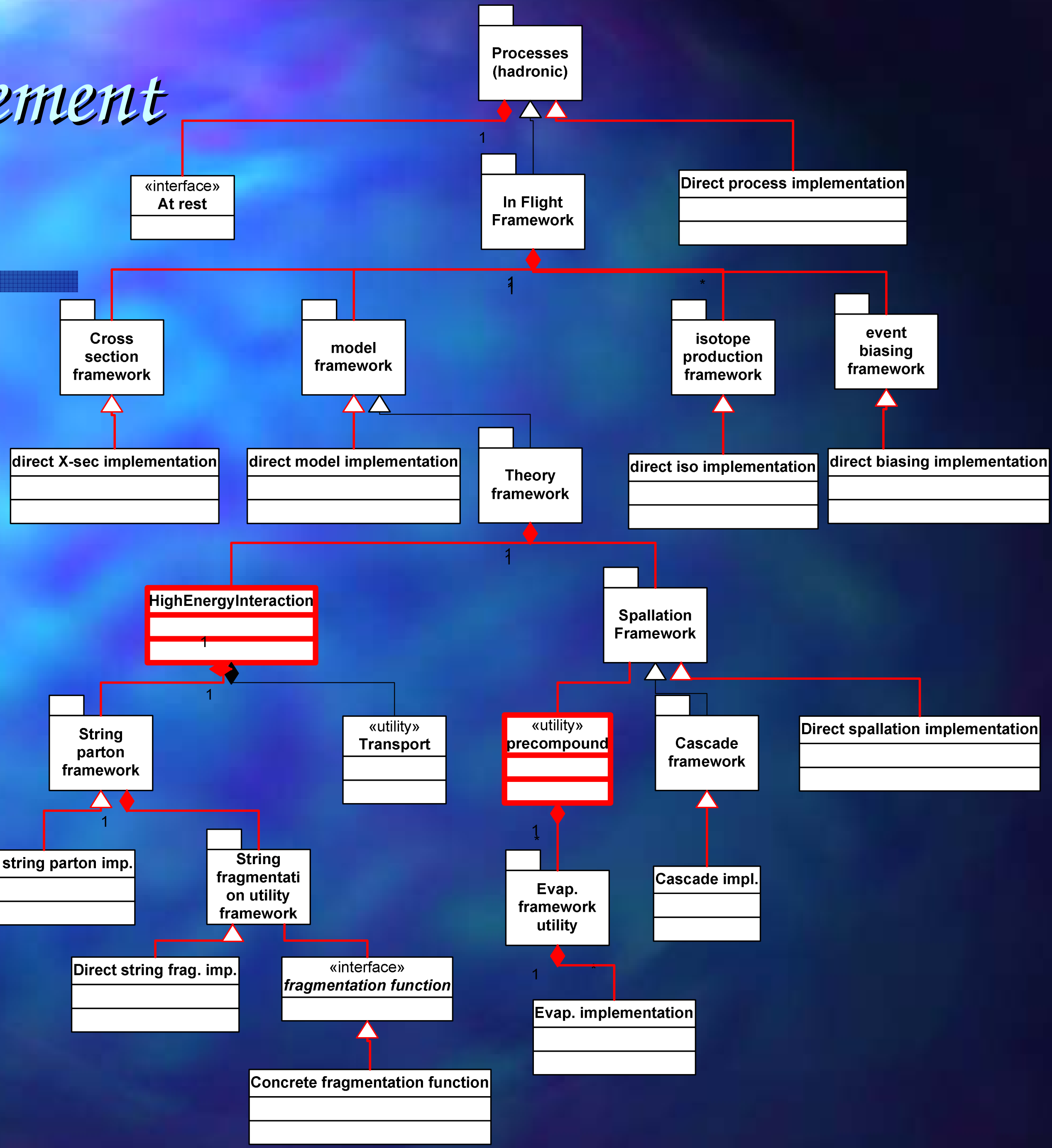
The problem I am solving is this: how to assemble a simulation engine.

- It took 5 levels of implementation framework to implement hadronic physics.
- These, and the 40 packages implementing them, will be used to assemble the hadronic physics for any given simulation engine.
- The number of possibilties is large.
- Each comes with trade-offs in descriptive power and performance.
- There are 25 particle species to be tracked, that need complete and consistent physics.

Model management in GHAD



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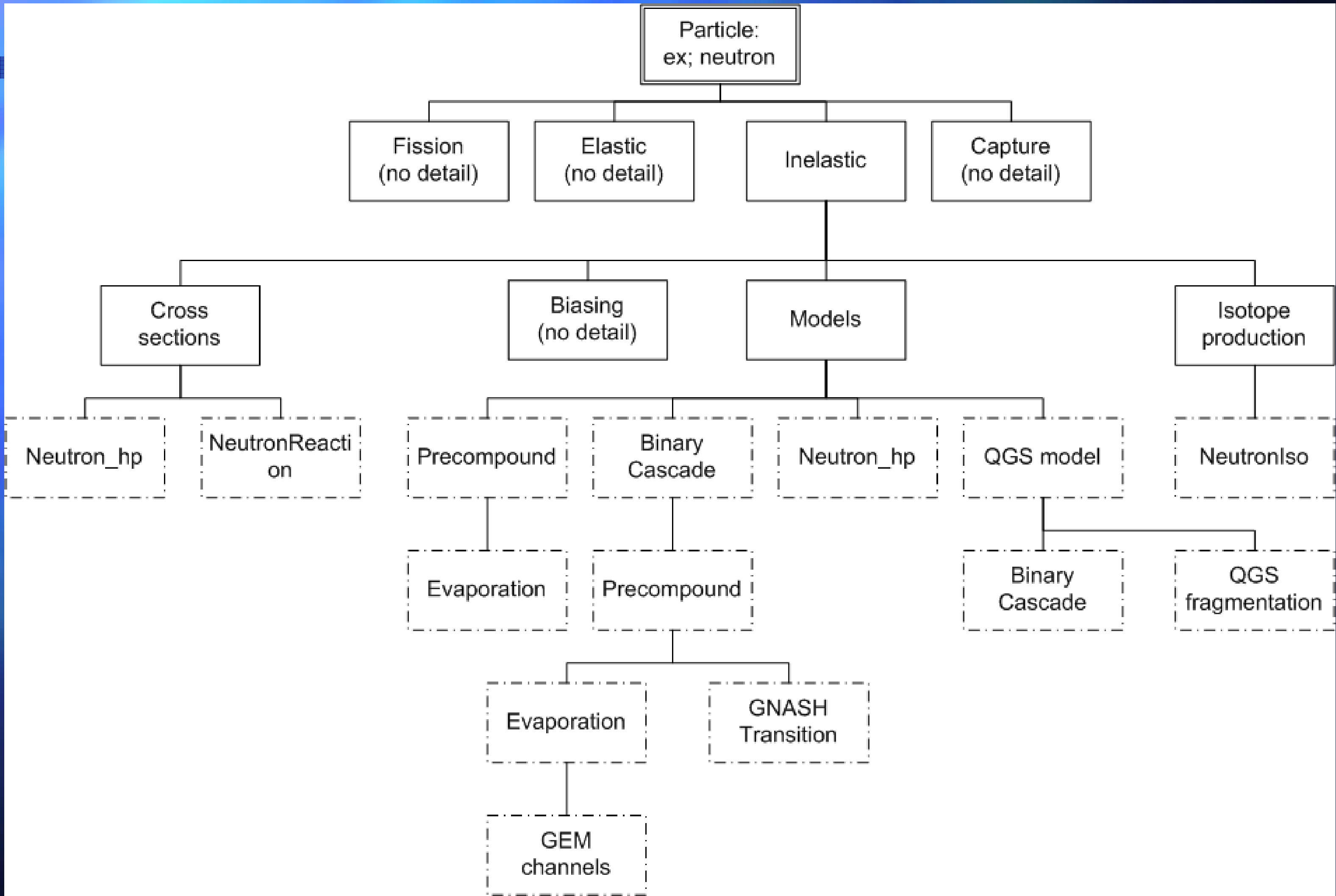
Assume we want to study activation.



Hence the educated guess physics lists/simulation engines

- It became clear early-on that writing a good physics list is tricky, 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, 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

- I have systematically accumulated experience with various combinations of cross-section and models over the last years.
- Today we provide a set of pre-packaged simulation engines institutionalizing this knowledge.

Use case packages of Physics Lists

- LCG simulation project.
- HEP calorimetry.
- HEP trackers.
- 'Average' collider detector
- Low energy dosimetric applications with neutrons
- Low energy nucleon penetration shielding
- Linear collider neutron fluxes
- High energy penetration shielding
- Medical and other life-saving neutron applications
- Low energy dosimetric applications
- High energy production targets
  e.g. 400GeV protons on C or Be
- Medium energy production targets
  e.g. 15-50 GeV p on light targets
- LHC neutron fluxes
- Air shower applications (still working on this)
- Low background experiments

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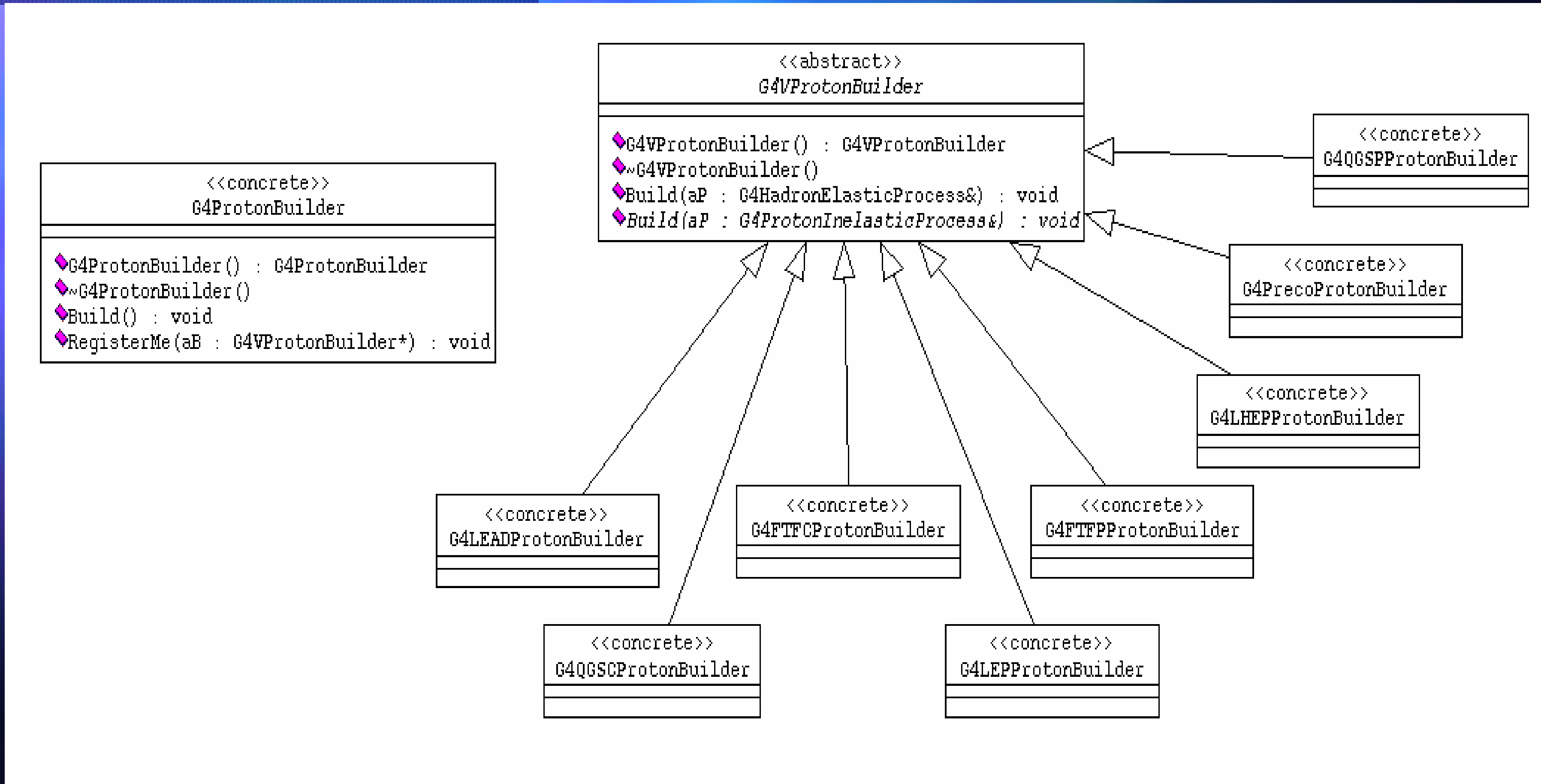
- http://cmsdoc.cern.ch/~hpw/GHAD/HomePage

To make tailoring easier, and the code more readable, we introduced Builders.



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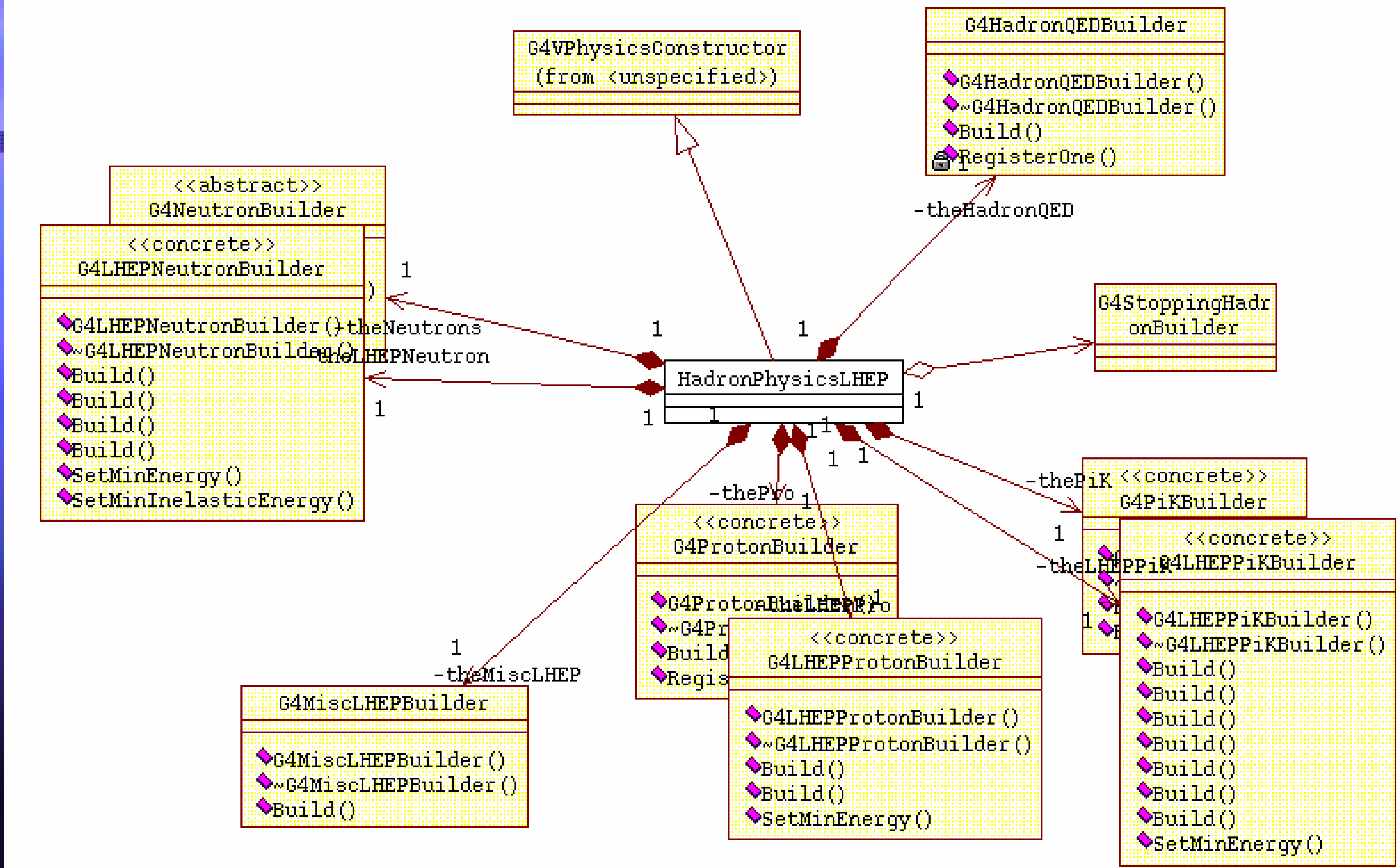

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Now, what does this mean ?

- You can
  - Just pick a physics list from my '*menu*'.
  - Aggregate your own cocktail from limited complexity of the builders
  - Use all 5 framework levels and 40 packages with their full power and flexibility.

➔ A layered reduction in the level of complexity exposed.

A sample use-case: HEP calorimetry

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(get the plots) (get the plots) (get the plots) (get the plots) (get the plots) (get the plots)

Physics lists for calorimetry.

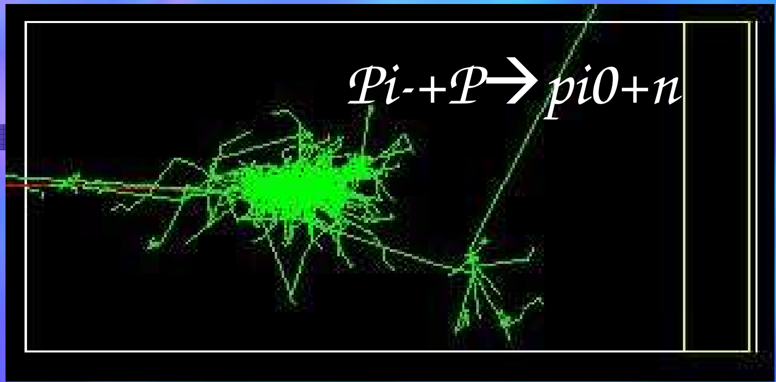
For calorimetry, we provide four alternative physics lists. The basic idea is to provide alternatives concerning the most important aspect of modeling calorimeter response; i.e. the initial interation, as well as leading paticle interactions further in the calorimeter material.

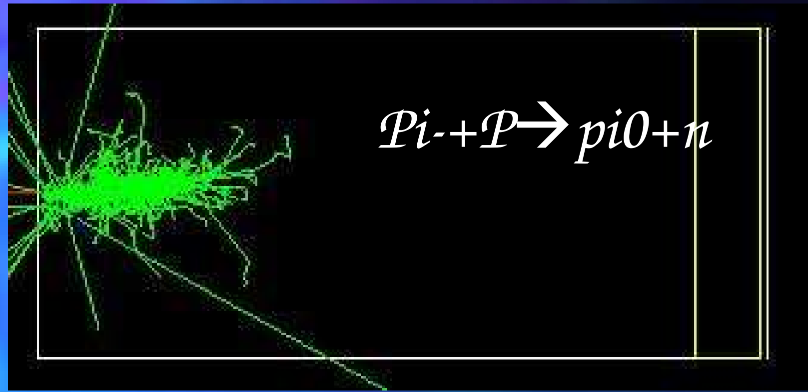
- The first physics list, LHEP, is the fastest, when it comes to CPU. It uses the LEP and HEP parametrized models for inelastic scattering. The modeling parametrizes the final states individual inelastic reactions, so you will not see resonances, and the detailed secondary angular distributions for O(100MeV) reactions may not be described perfectly. The average quantities will be well described.
- The second physics list, QGSP, uses theory driven modeling for the reactions of energetic pions, kaons, and nucleons. It employs quark gluon string model for the 'punch-through' interactions of the projectile with a nucleus, the string excitation cross-sections being calculated in quasi-eikonal approximation. A pre-equilibrium decay model with an extensive evaporation phase to model the behavior of the nucleus 'after the punch'. It uses current best pion cross-section.
- The third list, QGSC, is as QGSP for the initial reaction, but uses chiral invariant phase-space decay (multi-quasmon fragmentation) to model the behavior of the system's fragmentation.
- The fourth list, FTFP, is similar to QGSP for the treatment of the fragmentation, but the string excitation/fragmentation is changed from quark-gluon string model to a diffractive string excitation similar to that in FRITJOF, and the Lund fragmentation functions.

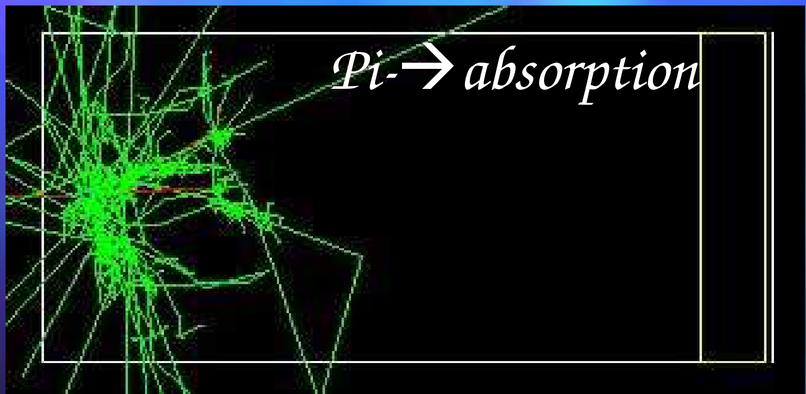
Note that the models used in lists 2,3,4 in general give somewhat better descriptions of microscopic cross-section data than list 1, and will produce the resonances. Once the electromagnetic part of the shower is parametrized, you will see a marked difference in CPU performance, though. The moment we can convince ourselves that LHEP can describe the test-beam data, it will therefor be the preferred solution for calorimeter simulation. Note also, that the optimization was done mainly on sampling calorimetry.

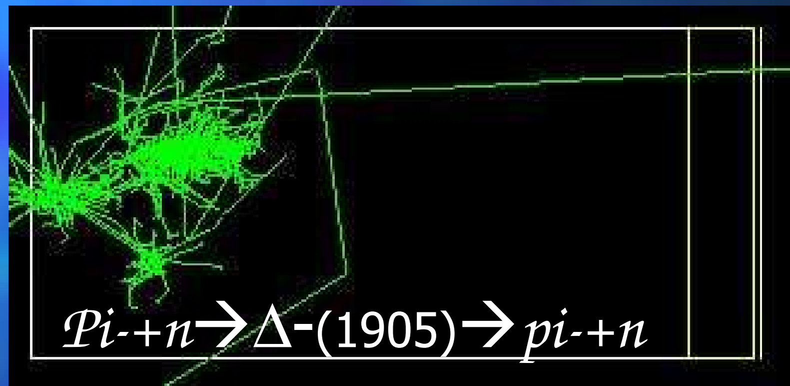
In case of questions, please contact J.P Wellisch. J.P. Wellisch, 2002

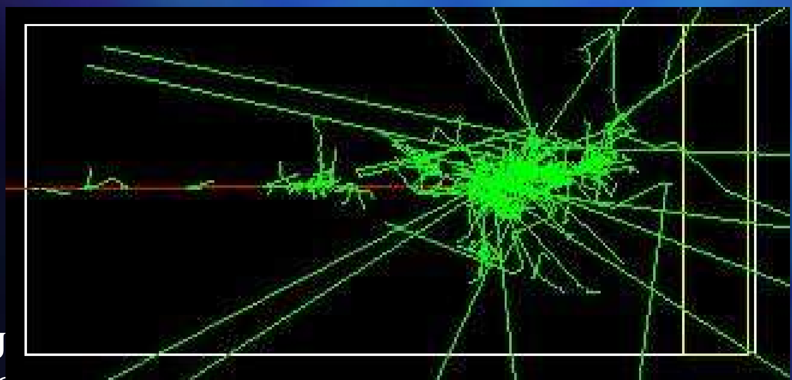
5 GeV pi- in copper

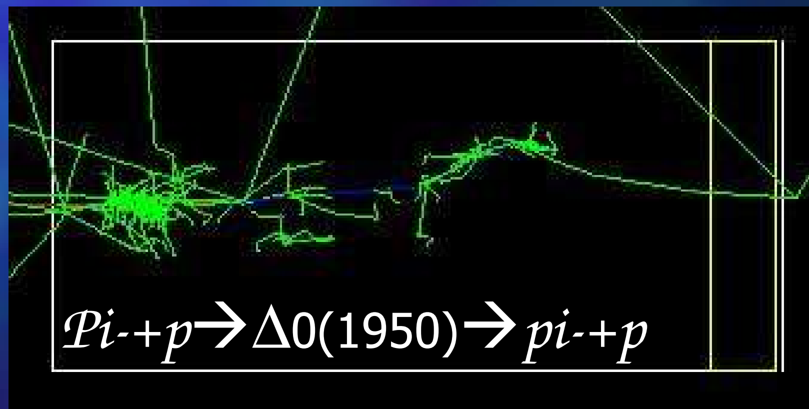








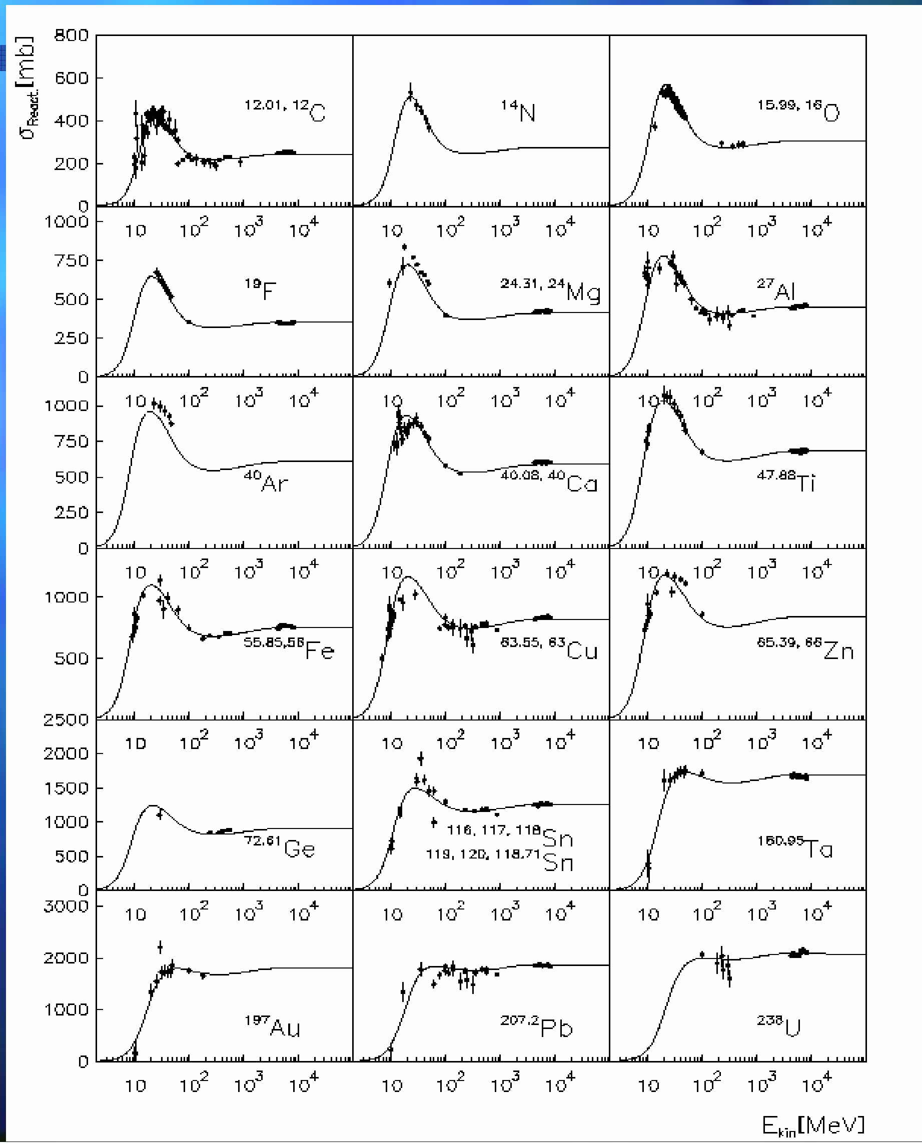




Improvements are based on interplay of application results and model verification

- The verification/validation effort of GHAD is grouped into several sections:
  - Inclusive cross-sections
  - Verification of model components
  - Differential cross-section comparisons
  - Code comparisons
  - Complete application tests (per use-case)
  - Robustness.

Proton reaction cross-section



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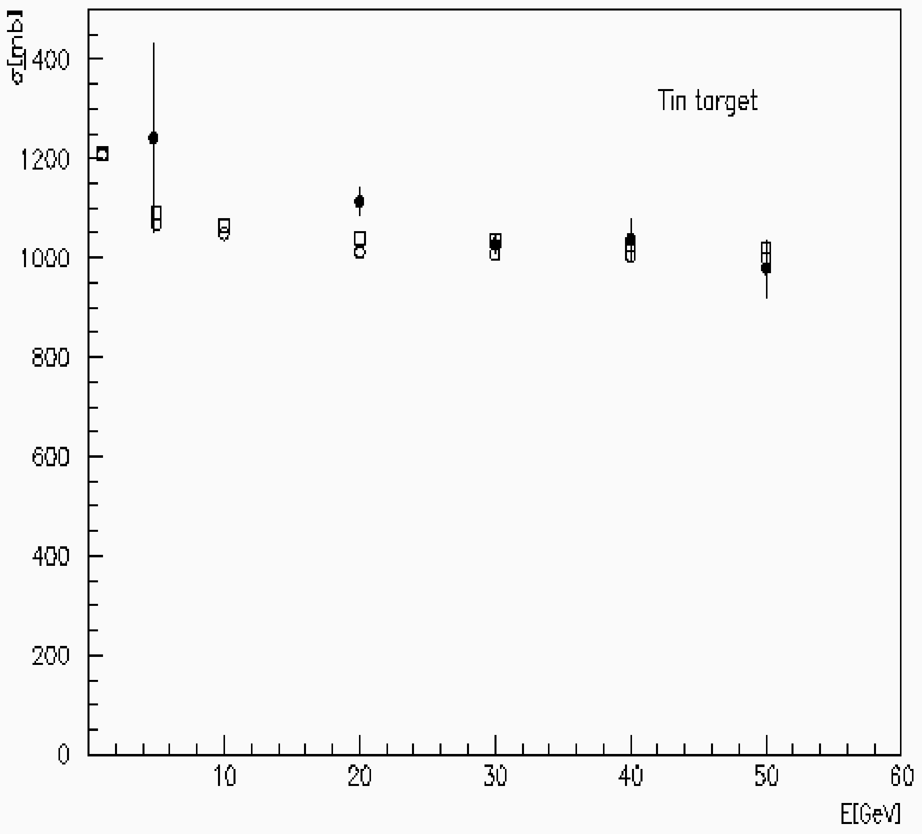
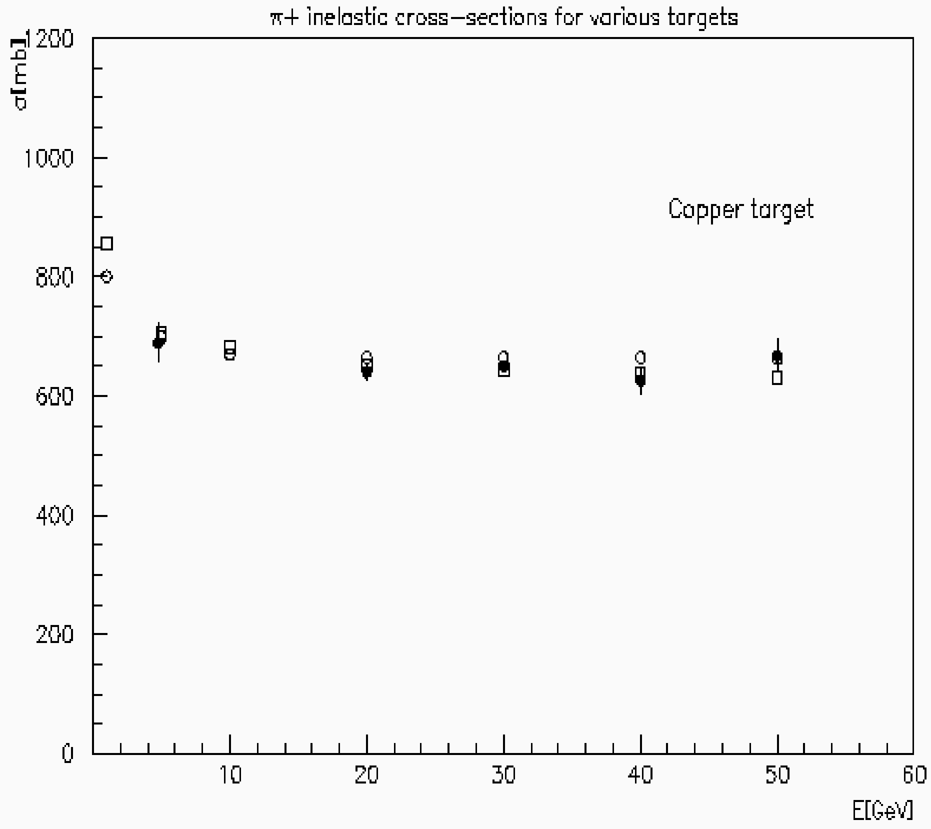
Pi+ reaction cross-sections: dots: data, open symbols: two different parameterization





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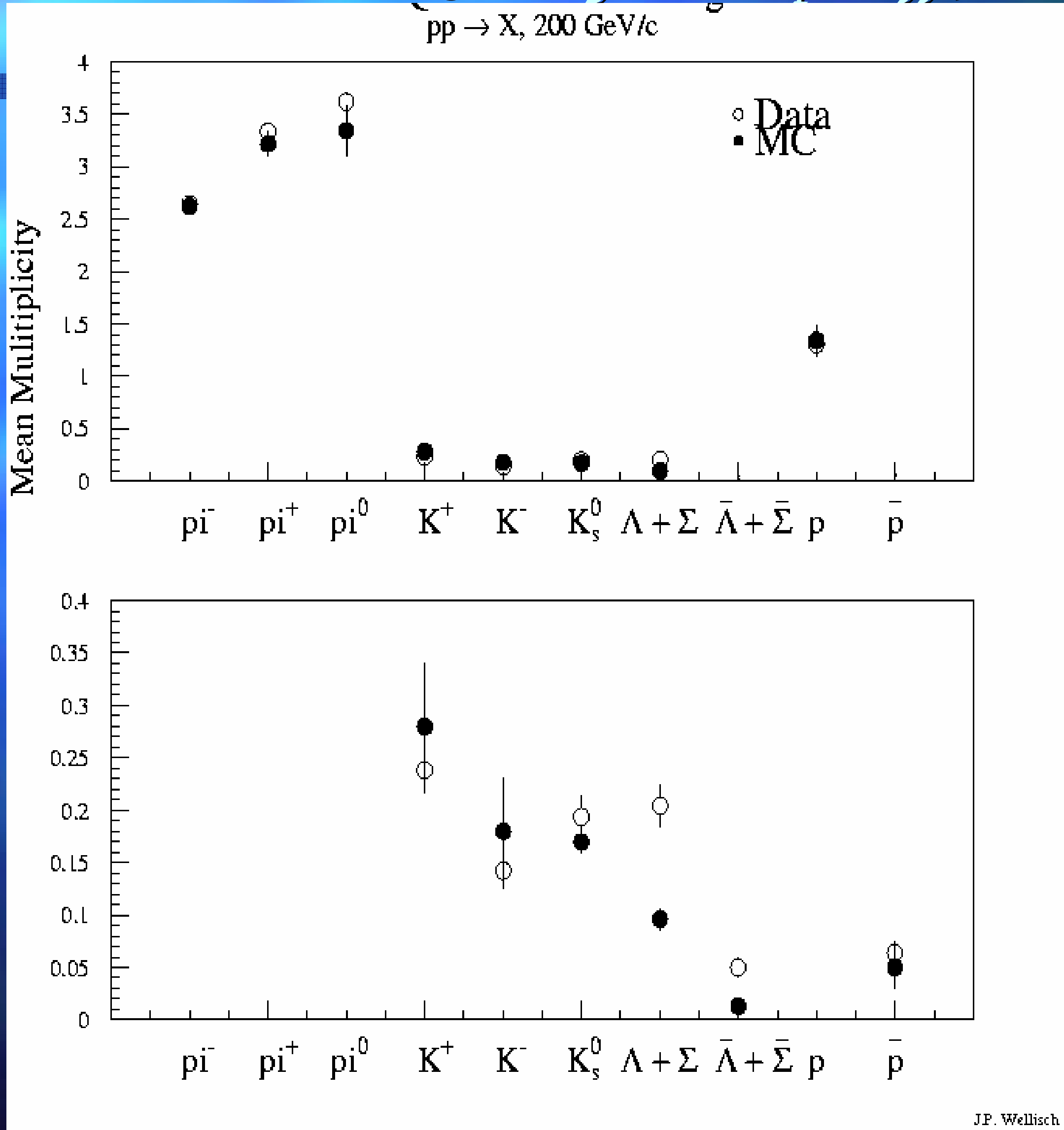
Particle multiplicities, QGS model

(dots are data, circles are MC, Nucl.Phys.A,528,p754ff(1991))



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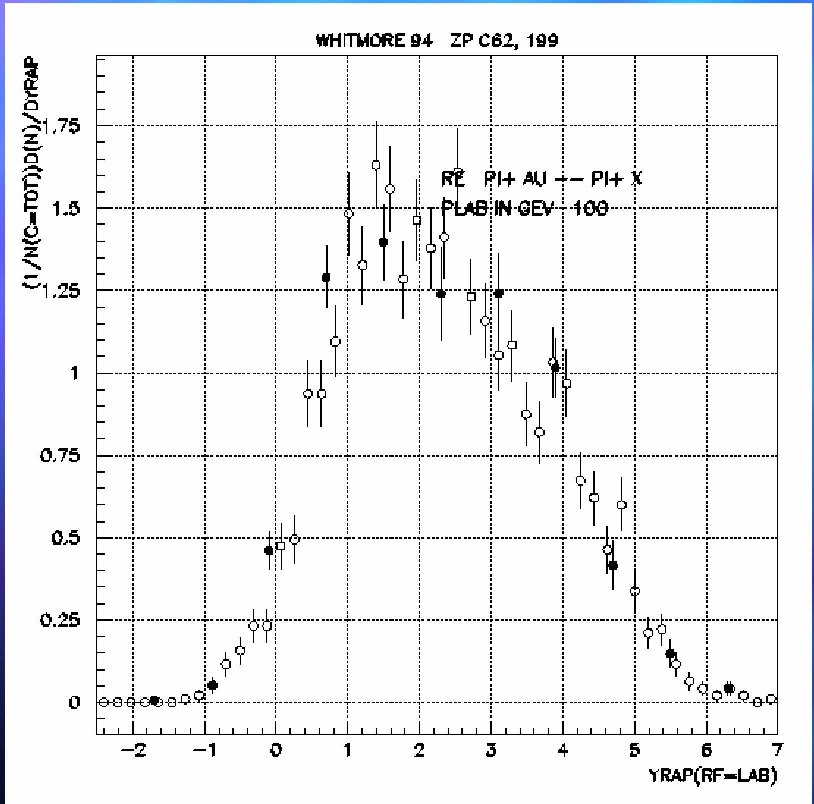
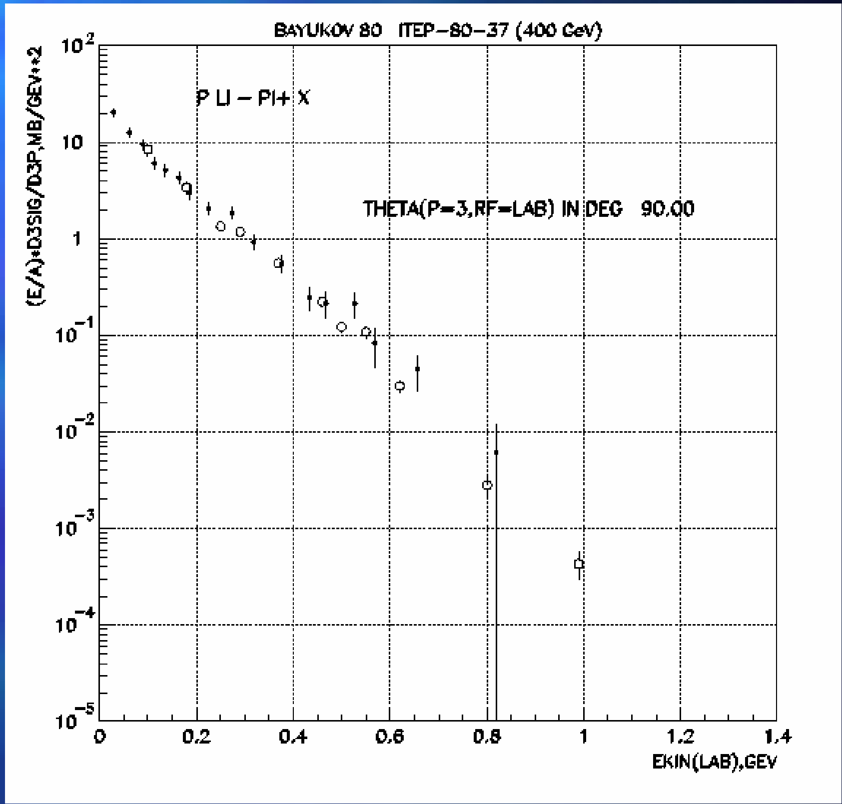
Pion production examples, QGS:

Rapidity distributions and invariant cross-section predictions in quark gluon string model



100 GeV pi+ on Gold



400GeV protons on Lithium

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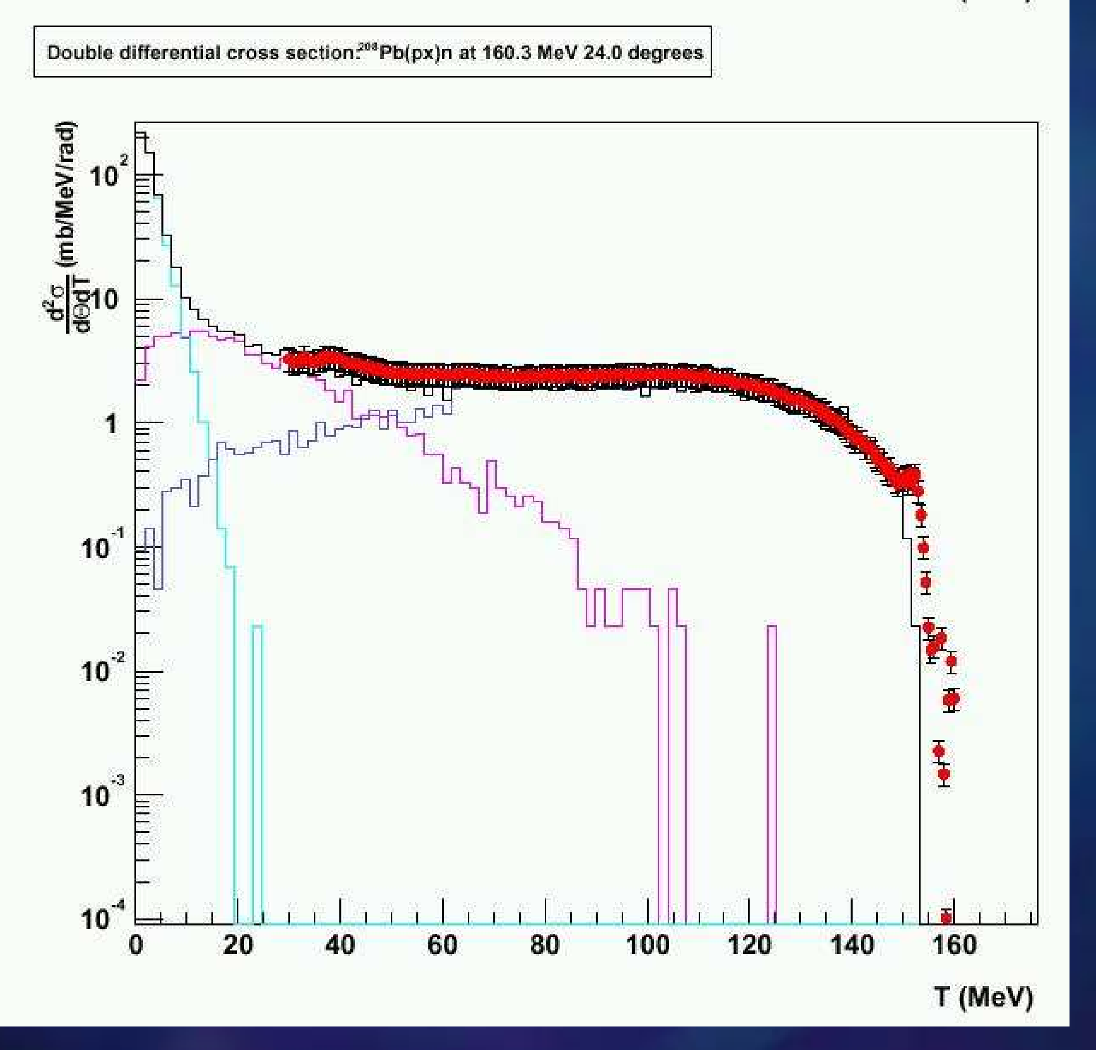
Contributions of the model components to the neutron spectrum



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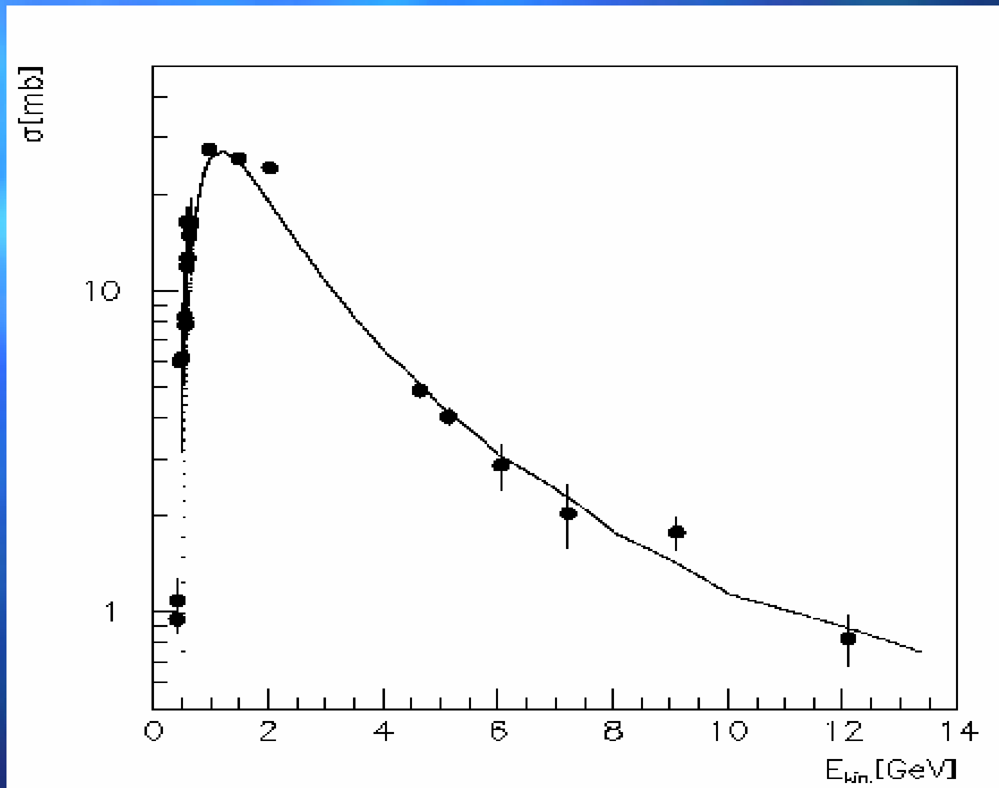
Predicting the Delta production cross-section in pp scattering by binary casacde

(kinks due to caching)



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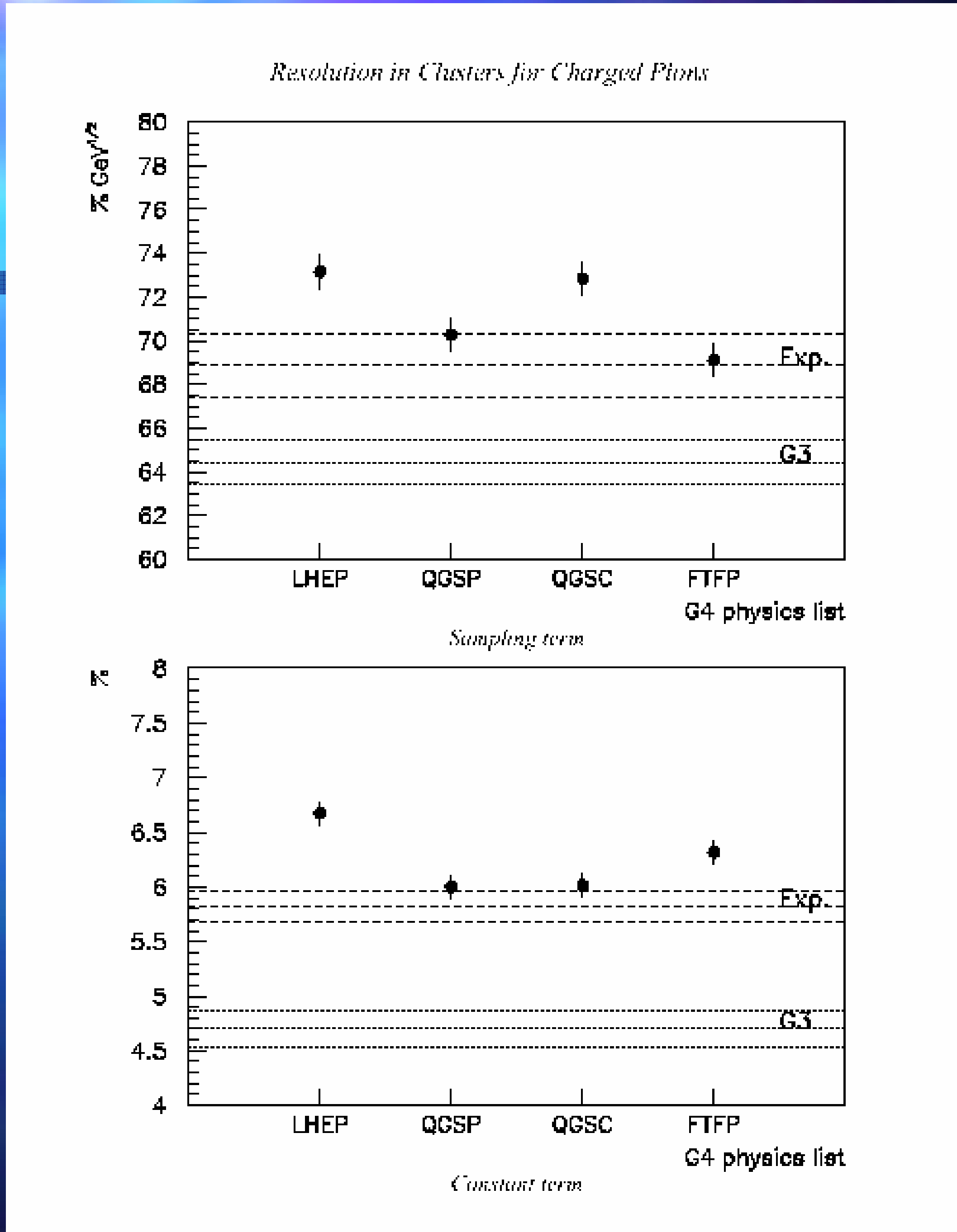
Some results

- Optimization is done in close collaboration with the various communities



Courtesy of
The ATLAS
HEC community

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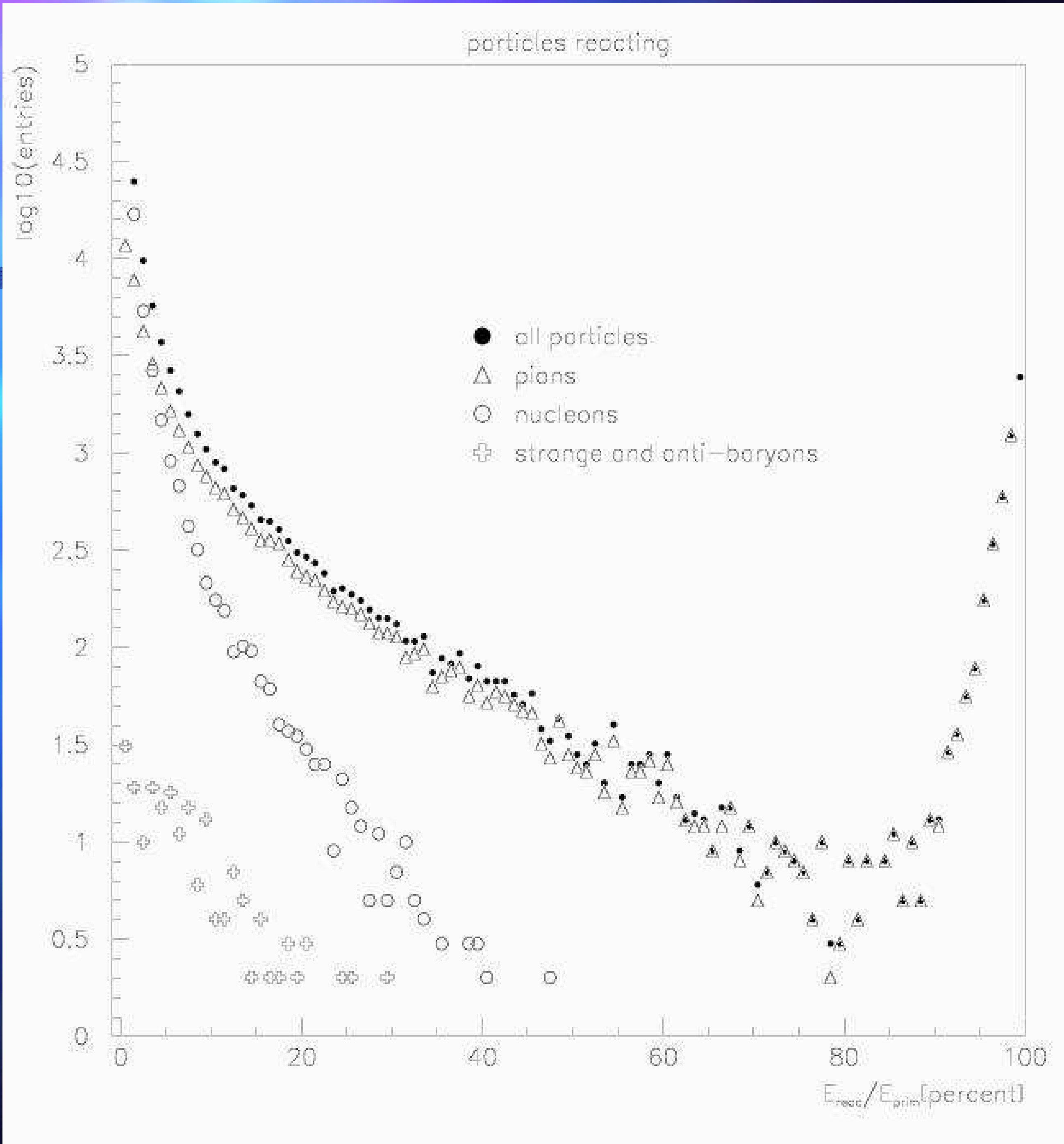
20 GeV pi- in Copper



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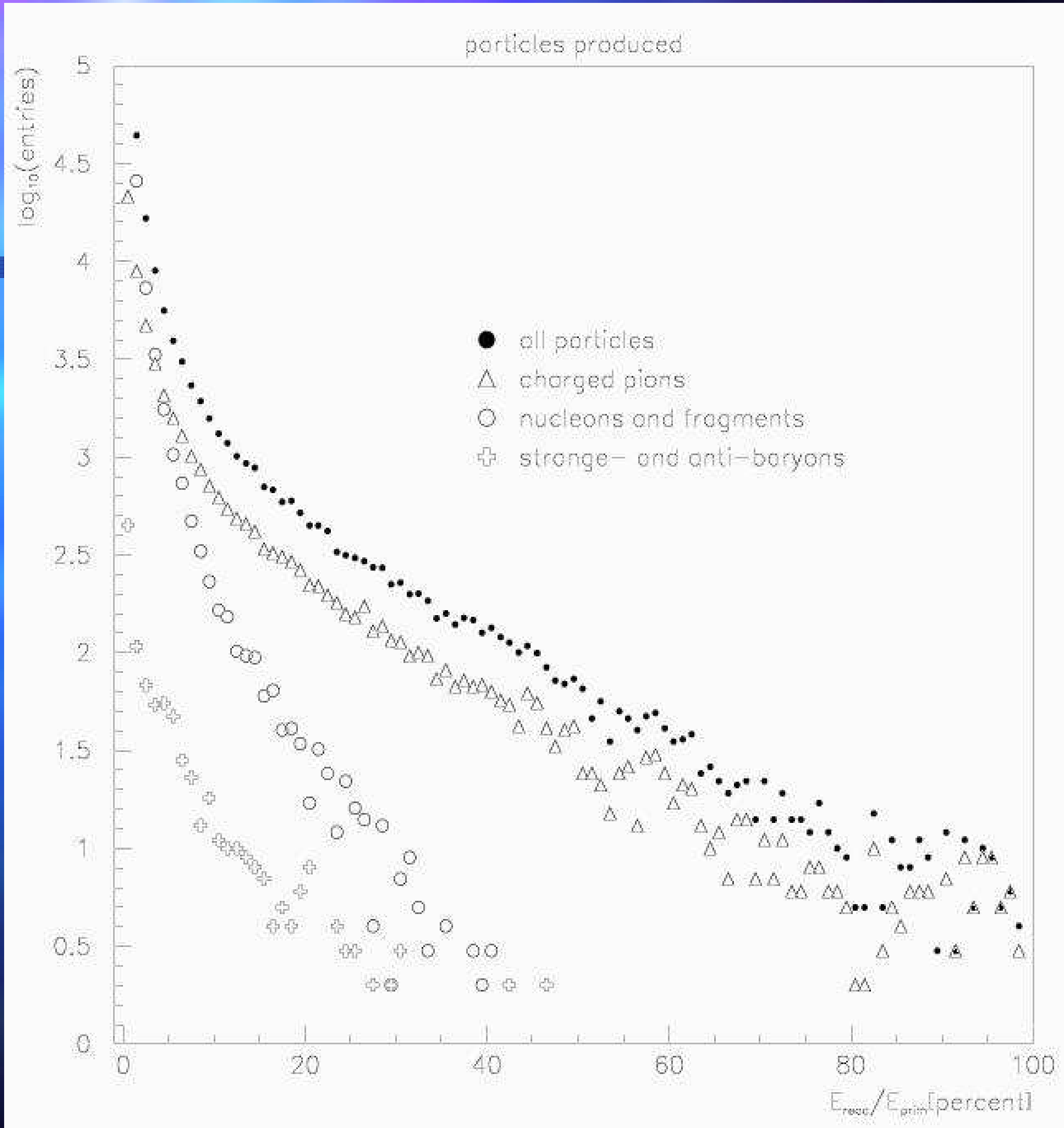
20 GeV pi- in Copper



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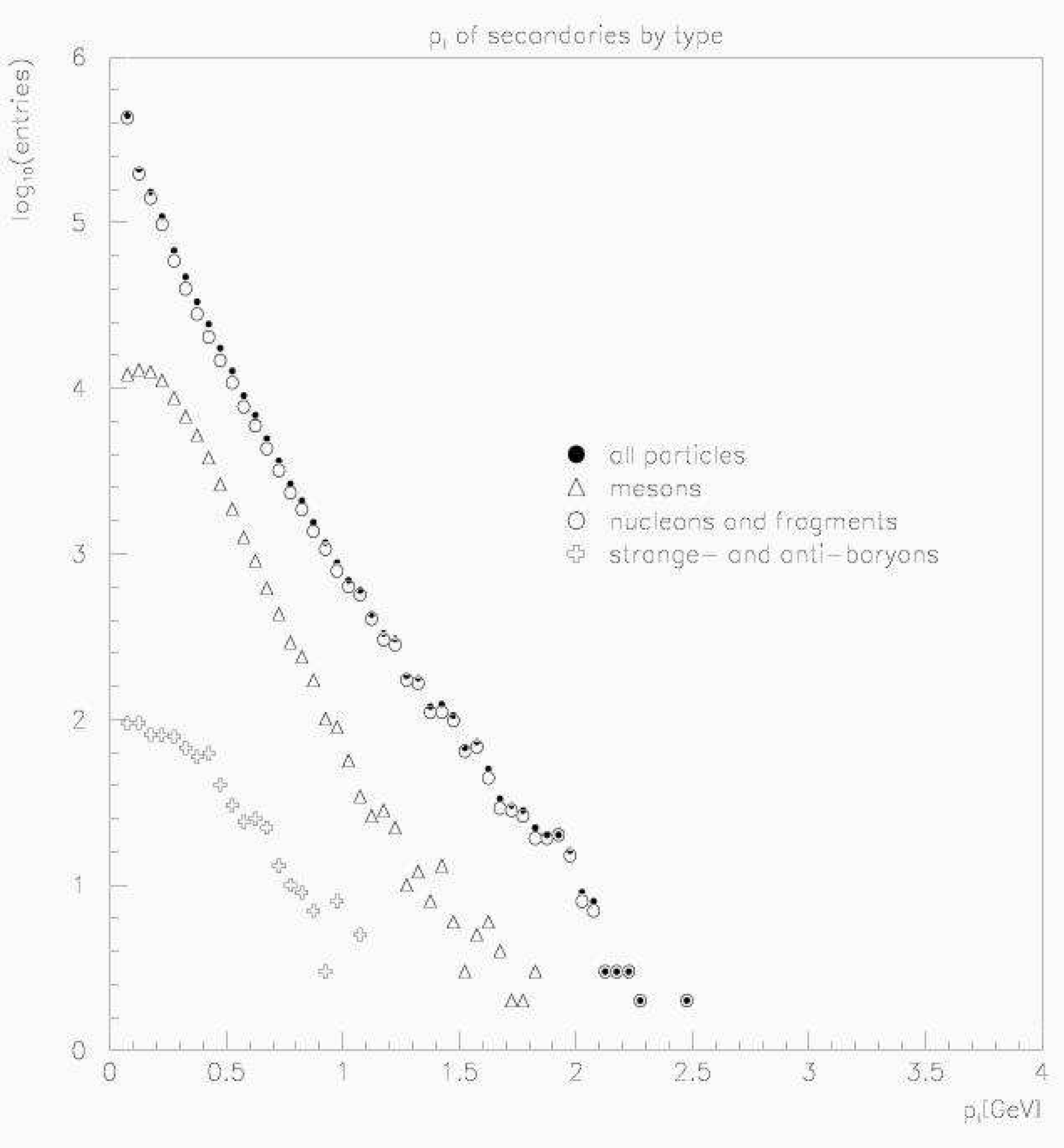
20 GeV pi- in Copper



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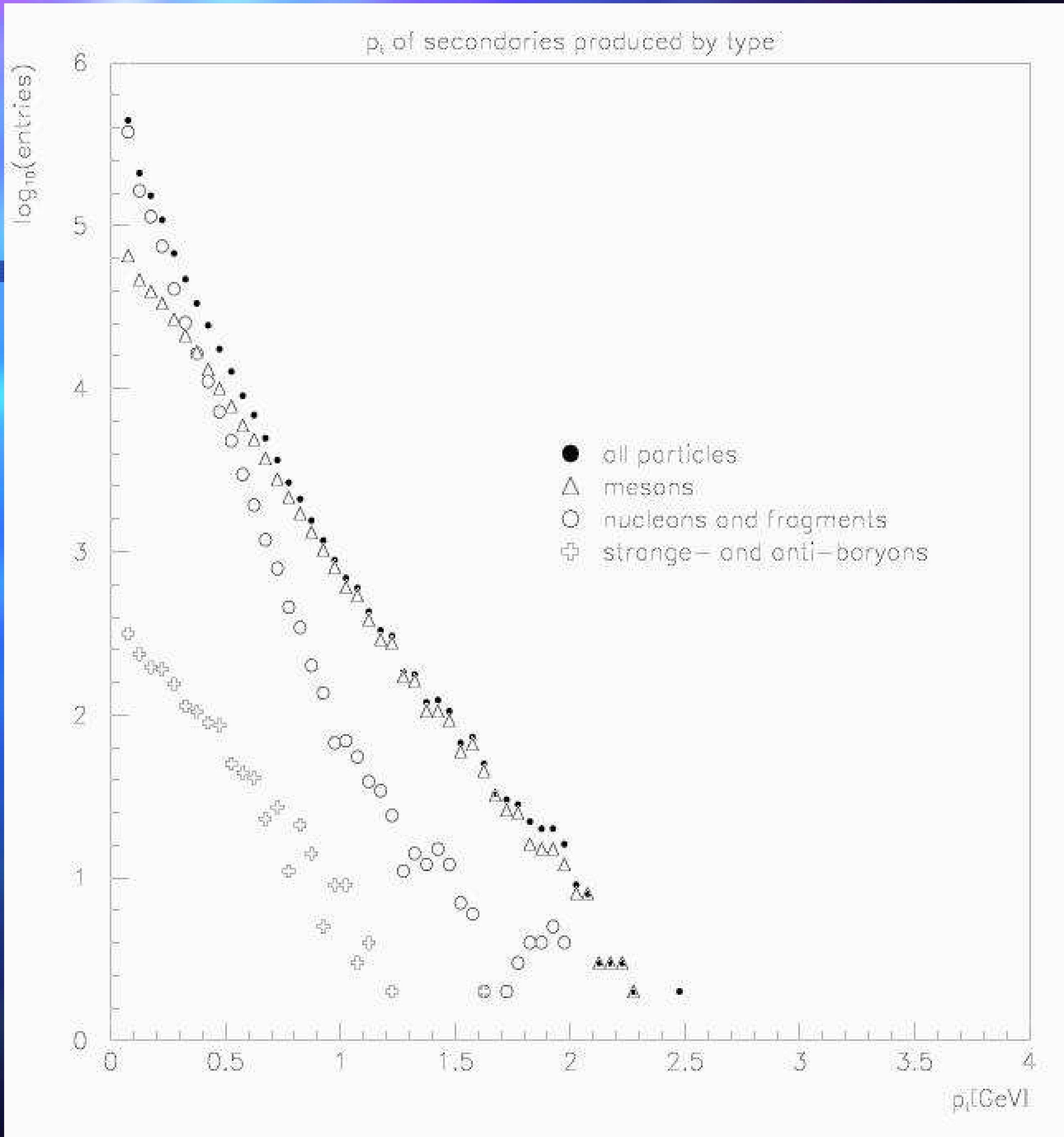
20 GeV pi- in Copper



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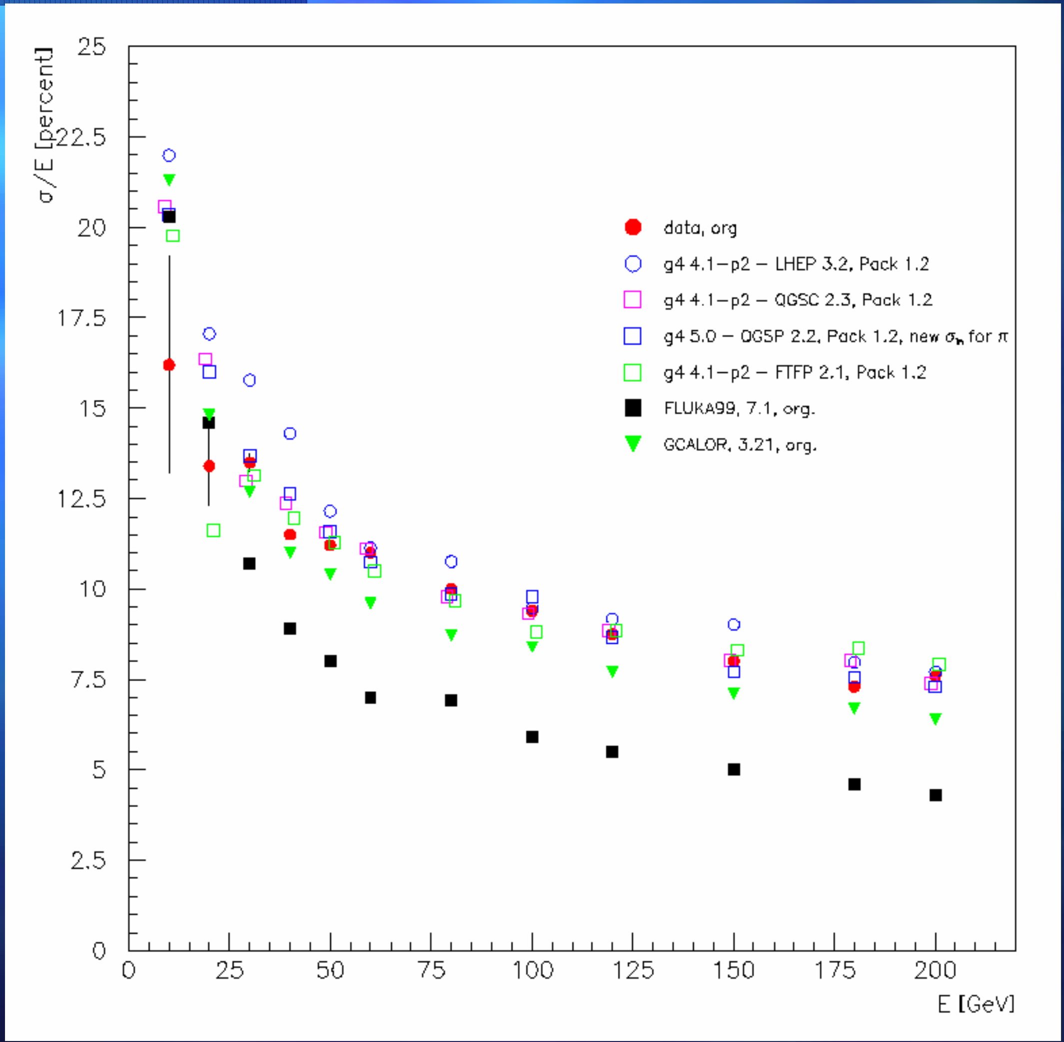
HEC G4 5.0 (true geometry, my toy analysis) data from NIM, A482,94ff.



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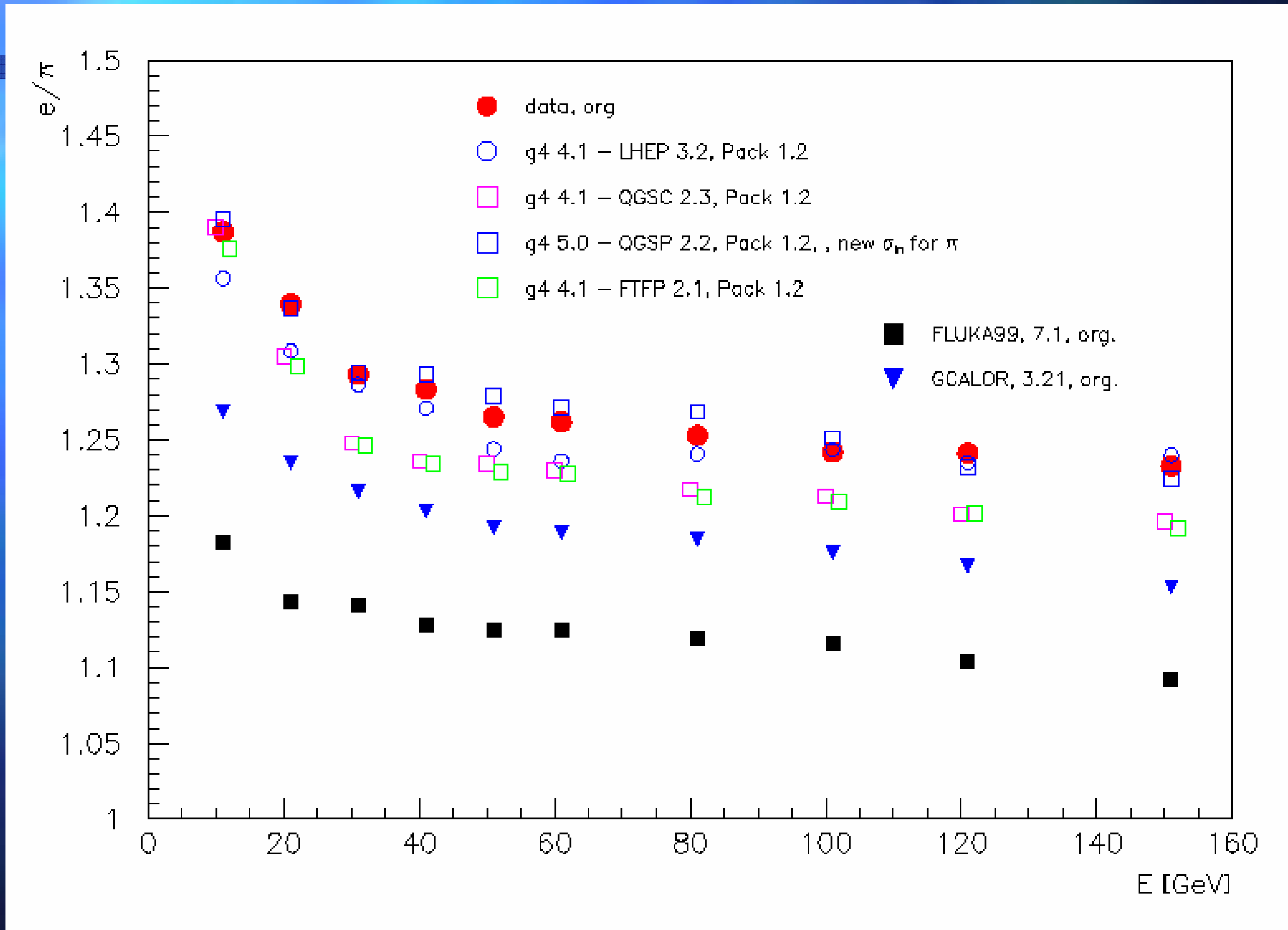
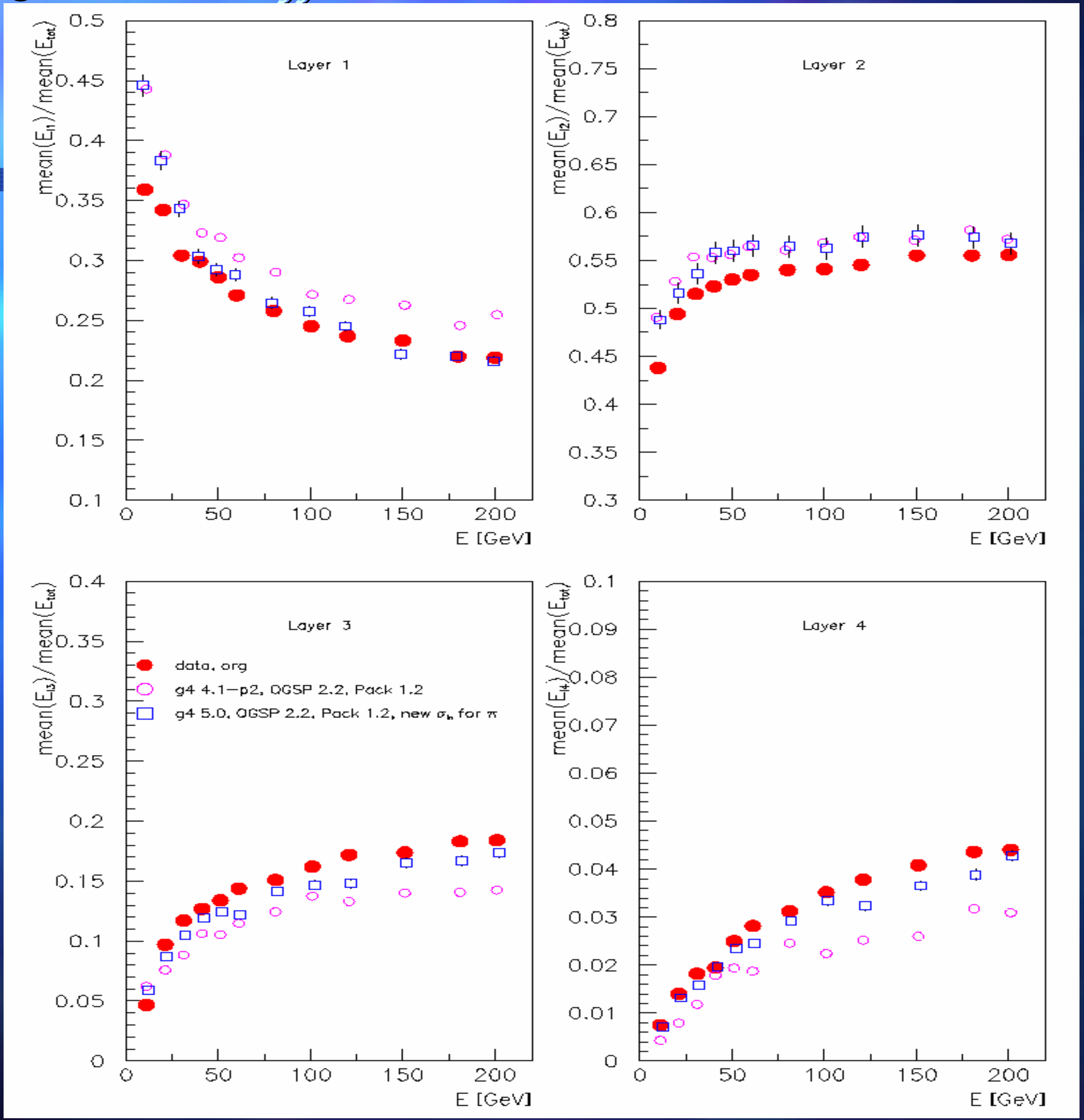
ATLAS HEC G4 5.0 (true geometry, my toy analysis) data from NIM, A482,94ff.



HEC shower shapes G4 5.0 (true geometry, my toy analysis)

data from NIM, A482,94ff.



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The recommended procedure for using my simulation engines:

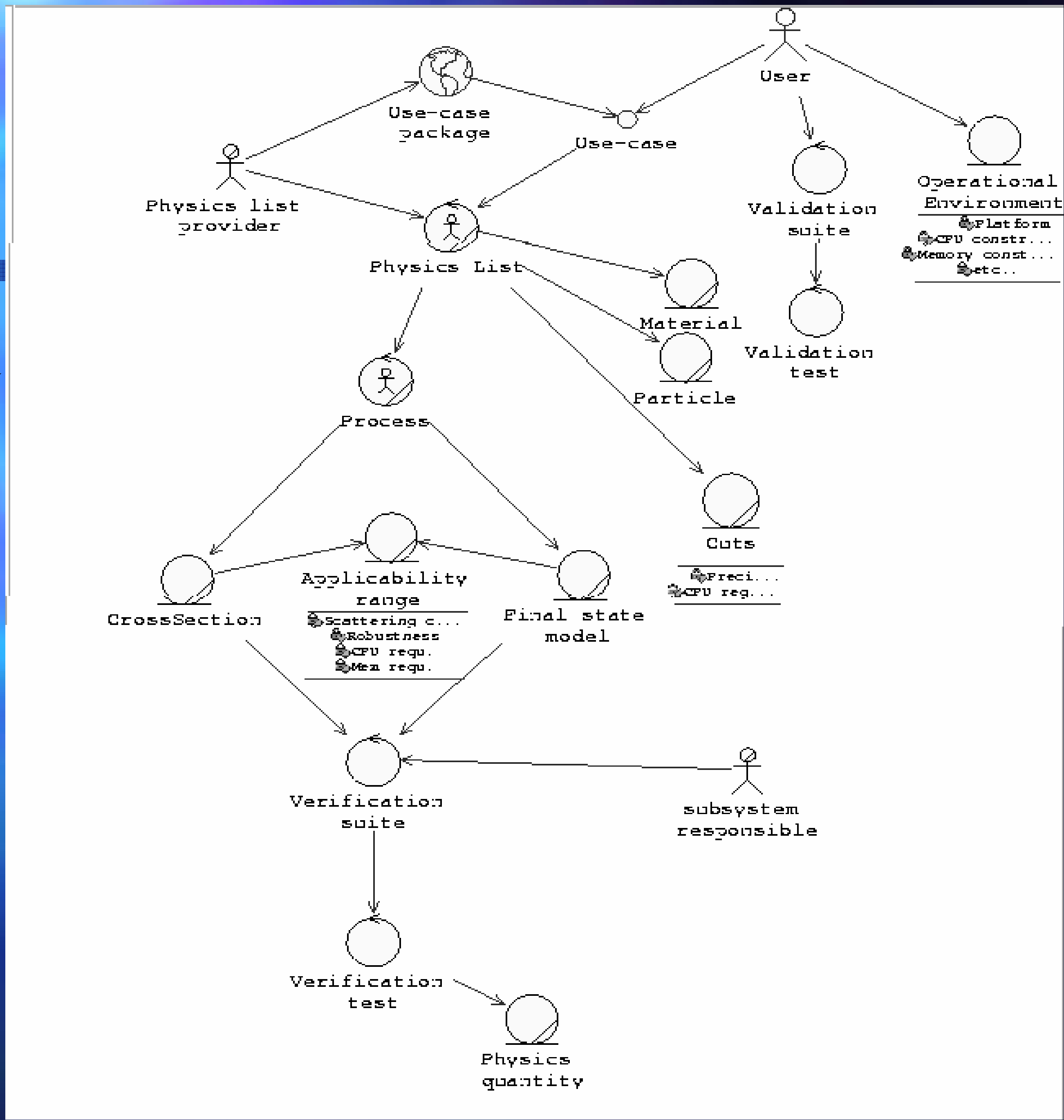
- Start by trying the simulation engines 'as is'.
  - It makes it such that results by different groups can be compared.
  - You will profit from validation and verification done by others.
- Of course you are still encouraged to tailor the physics lists that I provide, and/or build your own where you need.
- Please also let me know about your findings.
- Plots you may whish to provide can enter WWW for everyone's benefit.

➔Please do not use code from geant4 examples as example for a hadronic physics lists.

Conclusions:

- I have provided a set of simulation engines for use with geant4.
- It is continuously being improved in collaboration with a large and still growing user community.

The support process – static view



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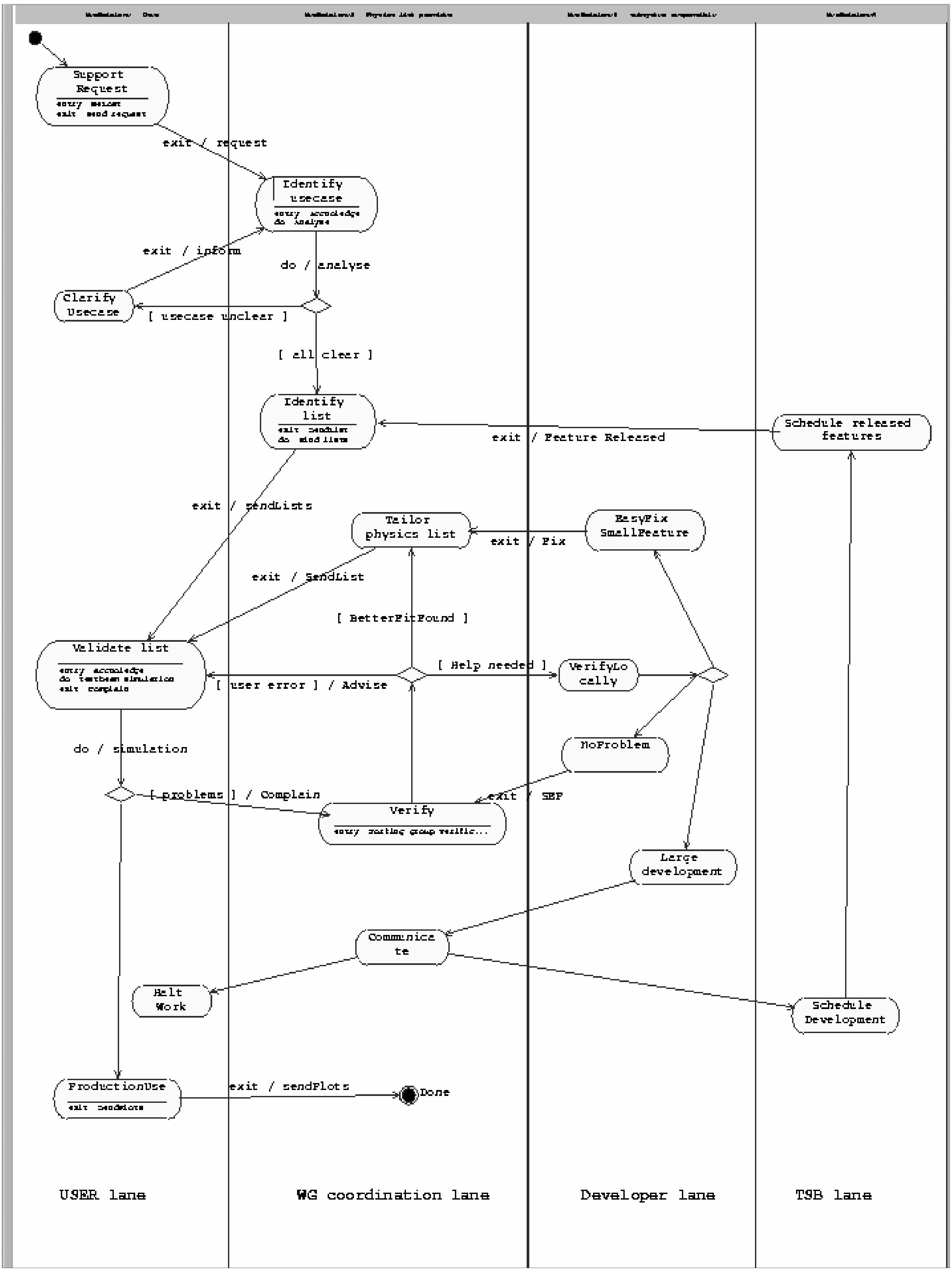

Support Request
exit / request
Identify usecase
entry acknowledge
do Analyse
do / analyse
exit / inform
Clarify Usecase
[usecase unclear]
[all clear]
Identify list
exit sendList
do mod lists
exit / Feature Released
Schedule released features
exit / sendLists
Tailor physics list
exit / Fix
EasyFix SmallFeature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