Hadronic Models
Problems, Progress and Plans

Gunter Folger

Geant4 Workshop, Lisbon 2006

Contents

- Hadronic shower shape issue
- Microscopic studies, mostly QGS..
- Neutron production
- Cascades
- Other topics

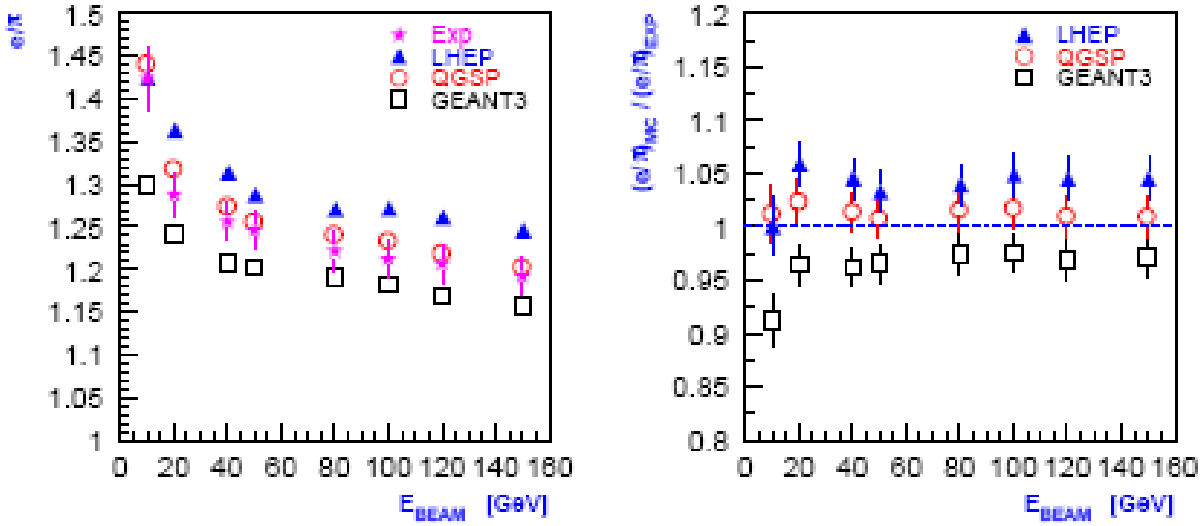
Hadronic shower shape issue

- Energy resolution $\sigma(E)/E$ well modeled by QGSP
- e/π - Ratio described very well by QGSP
- LHEP slightly worse for $\sigma(E)/E$ and e/π
- Shower shape best described by LHEP
  - QGSP produces shorter showers starting early
    - Some indication for narrower showers as well
  - Difference is more pronounced at high energies

Atlas HEC

GEANT4 physics validation with the HEC testbeam data / Energy scans with pions

Ratio e/π for GEANT4 version 8.0



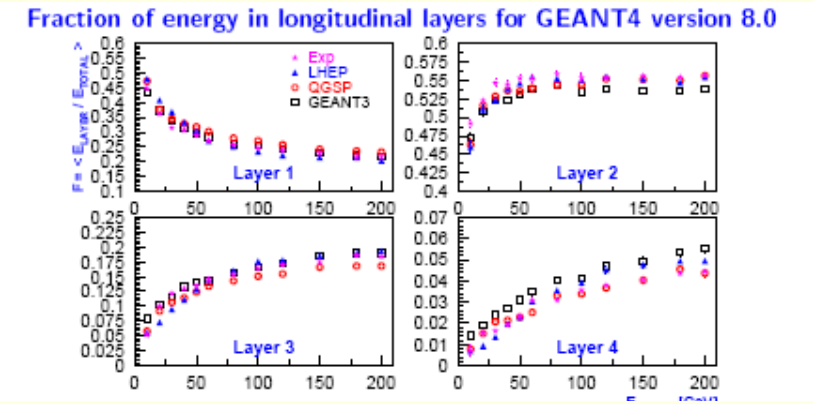
QGSP describes experimental values of e/π very well

LHEP predicts larger values of e/π

GEANT3 – systematically lower

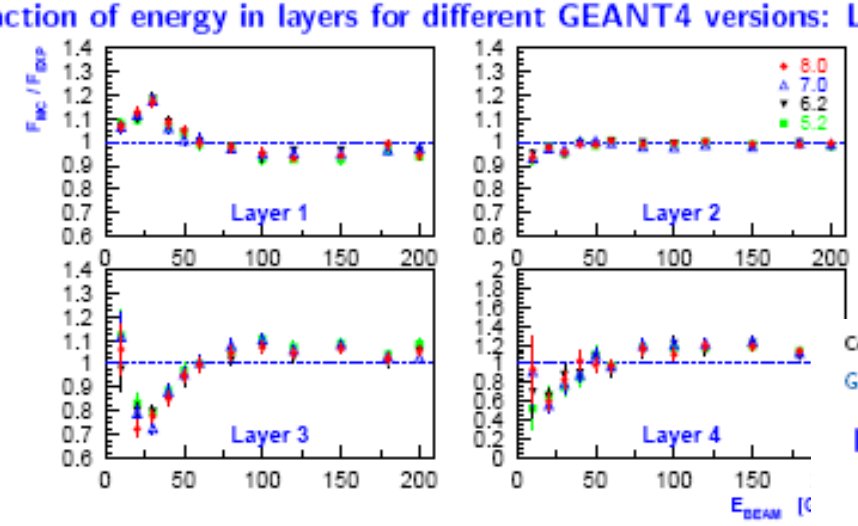
Slide by: A.Kiryunin (MPI Munich), Atlas Calibration workshop

Atlas – Shower shape



Costa Brava ACC Workshop September 5, 2006

GEANT4 physics validation with the HEC testbeam data / Energy scans with pions



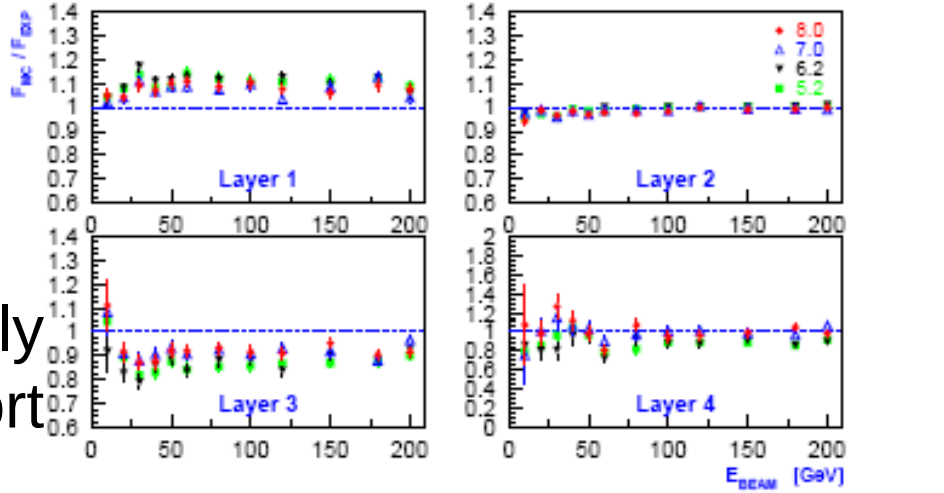
LHEP: No difference between GEANT4 versions

LHEP

- Shape well described for E>50GeV

Costa Brava ACC Workshop September 5, 2006

GEANT4 physics validation with the HEC testbeam data / Energy scans with pions



QGSP: Certain improvement between GEANT4 versions 6.2 and 7.0

QGSP

- Shower starts early
- Shower is too short

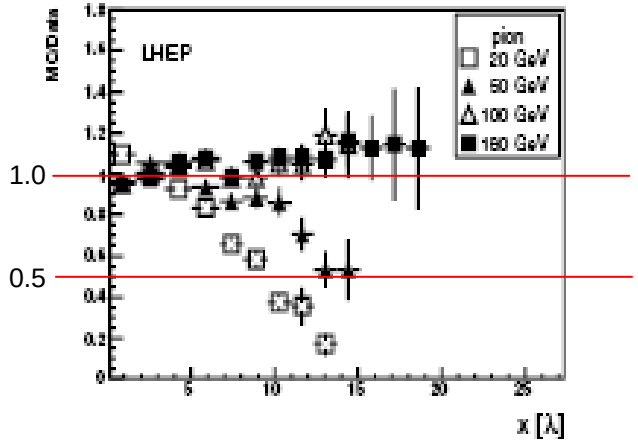
Plots by: A.Kiryunin (MPI Munich), Atlas Calibration workshop

Hadronic shower shape - Atlas

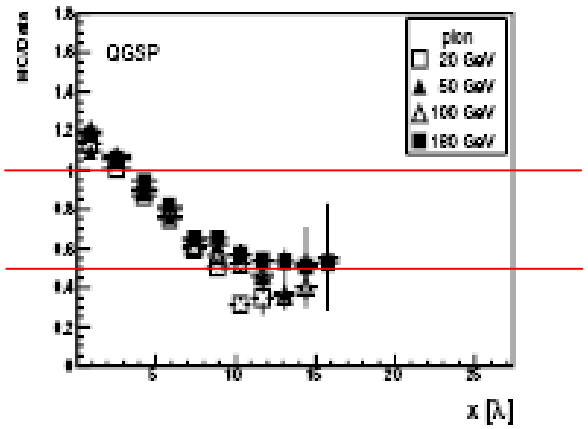
- Atlas TileCal rotated by 90° - M. Simonyan

MC and Data comparison

Good description at high energies.



Showers are too short.



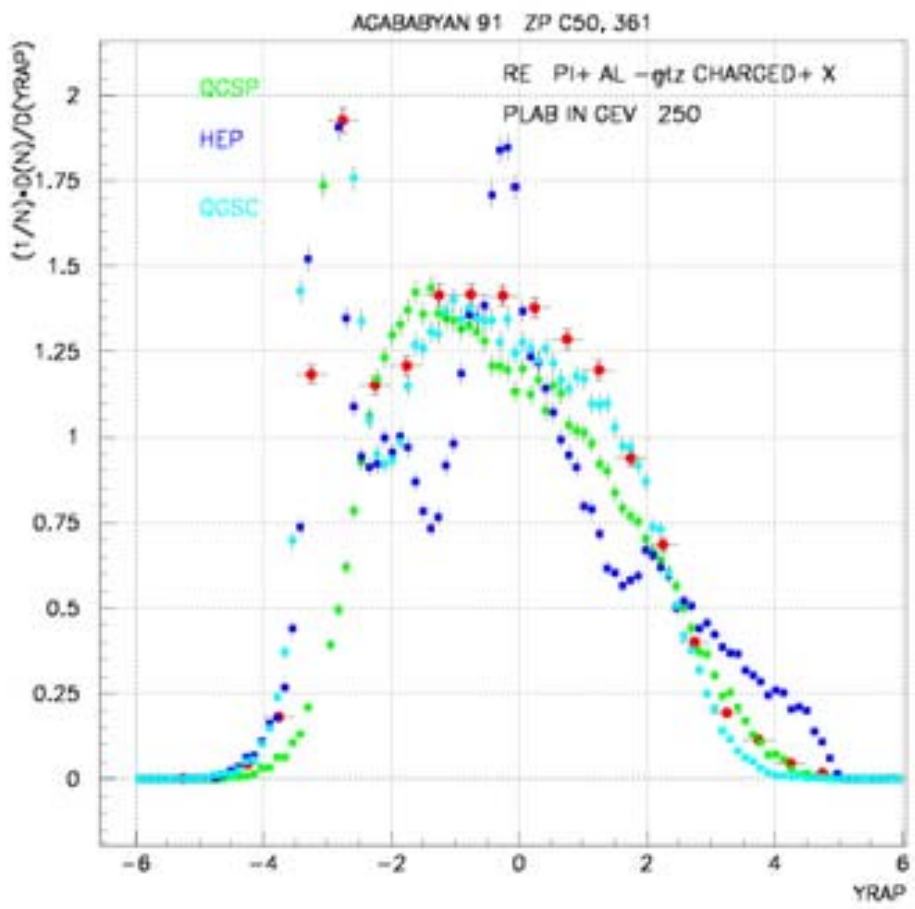
How to solve this issue?

- Understand development of showers
  - particles important for energy deposit
    - Electrons ← pi0
  - particles important for shape
    - proton
- Verify models on thin target experiment
  - single interactions
  - Differential cross sections, angular distributions, …
- Cross sections

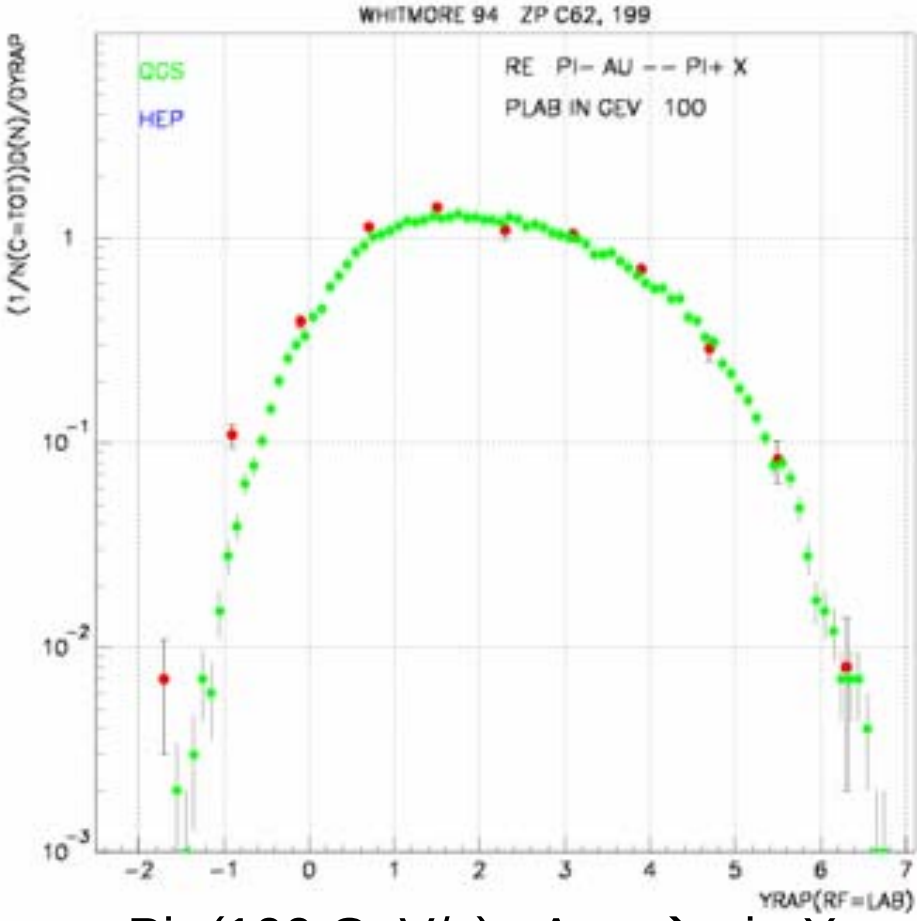
QGS.. model

- QGSP and QGSC
  - Differ in ‘nuclear de-excitation’
- Many comparisons to experiment at high energies (>100 GeV)
  - Rapidity, pt, Et, mulitiplicities
  - Much more data, including recent more precise data exist.
- Examples…
  - More e.g. on http://cern.ch/gunter/thin_tgt

Rapidity distribution



Pi (250GeV/c) Al → x+ X



Pi- (100 GeV/c) Au → pi+ X

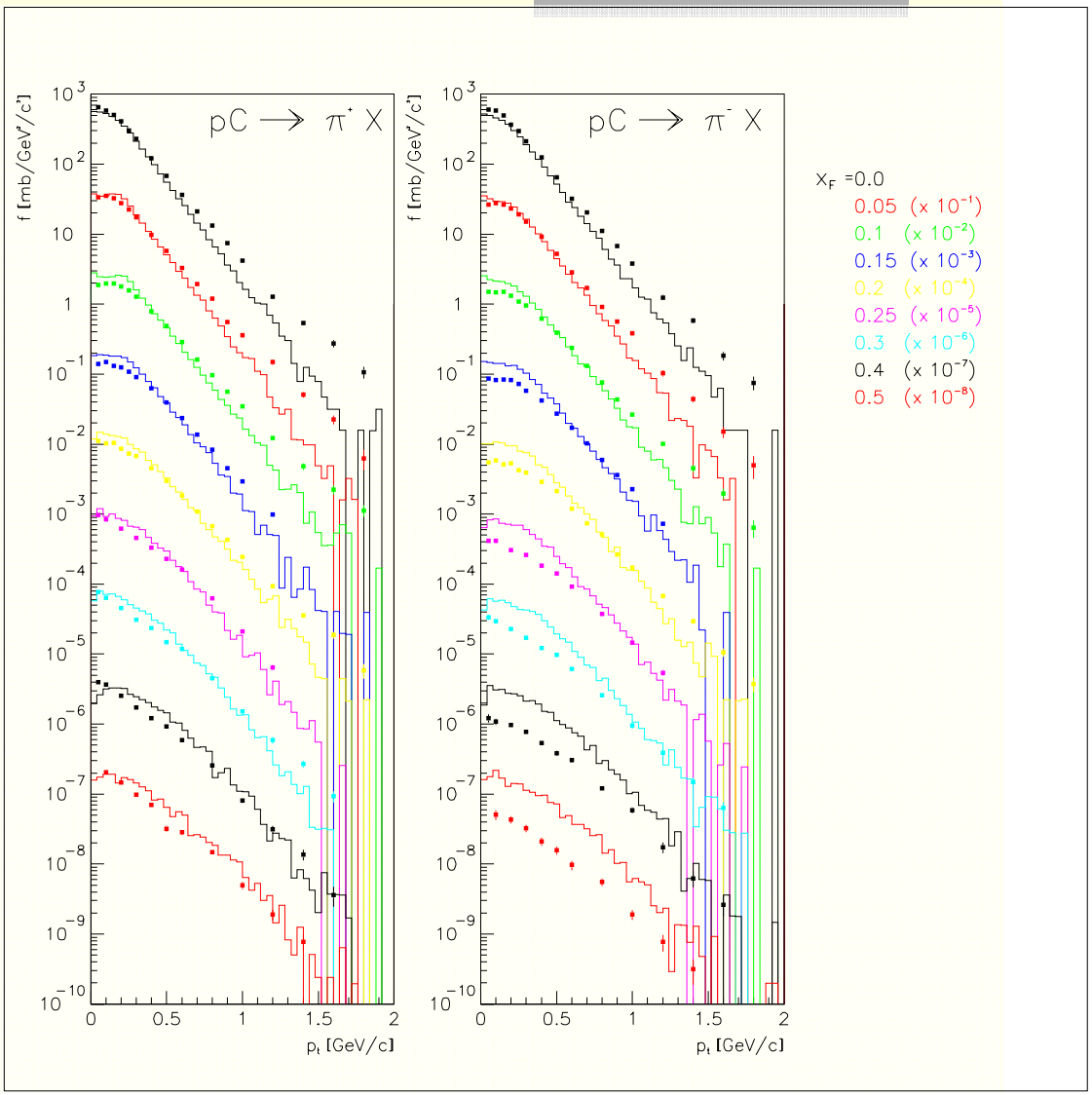
Rapidity $y=0.5 \ln((E+p_z)/(E-p_z))$

Transverse momentum p_t
pi+/pi- from proton (158GeV/c) on Carbon

- Data NA49:

arXiv:hep-ex/0606028 v1

- Distribution for small x_F too narrow for
  - pi+ (left)
  - pi- (right)
- Too many pi- for high x_F



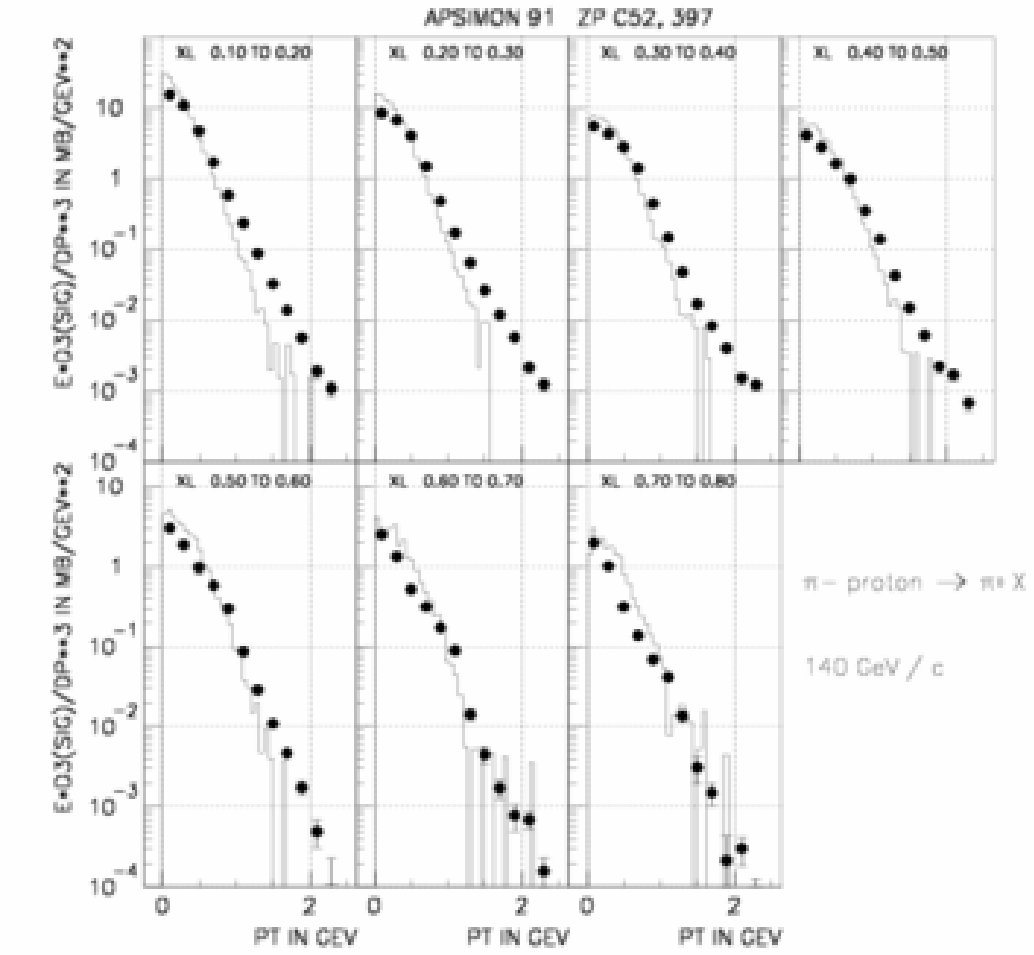
Pi0 production

- Pi0 production in

Pi- (140 GeV/c) proton

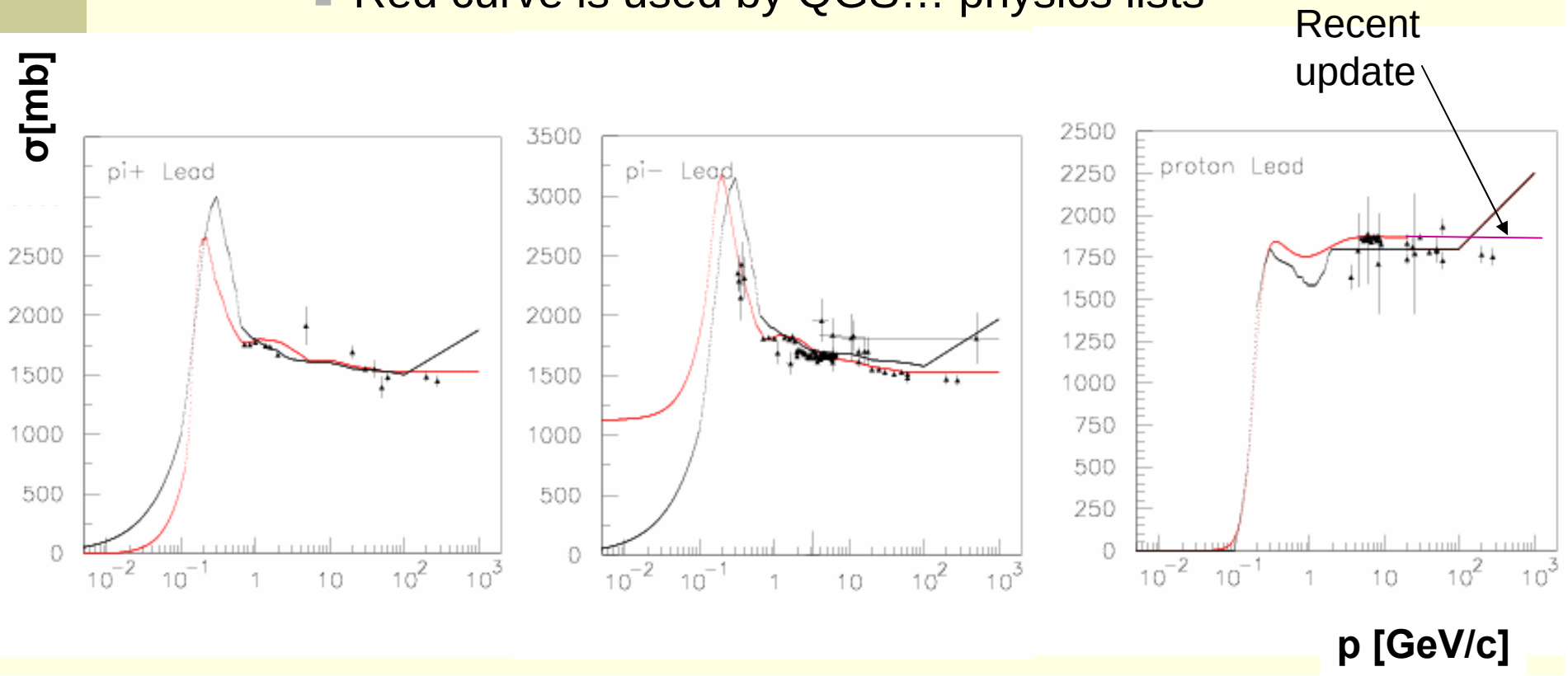
- For various x_L
- p_T can be improved
- Low x_L excess at small p_T

Preliminary plot



Inelastic Cross Sections

- Cross sections directly influence longitudinal shower development
- Inelastic (reaction) cross section in Lead
  - Red curve is used by QGS… physics lists



Current Understanding

- QGS describes thin target data rather well
  - Transverse momentum too narrow
  - Opposite charge seems to be produced to much
    - Handling of diffractive scattering?
  - QGSC gives better description (too much?) of nuclear fragmentation compared to QGSP
- LHEP has peak structures in rapidity distributions
  - p_T distributions well agree with data
- More validation below 100 GeV needed
  - Only comparison is to HARP data @ 12GeV in very limited forward angles

Neutron Production from Cascades

- Bertini and Binary are low in simulating neutron fluence when simulating TARC (x4 / x6)
- Thin Target comparison
  - Proton (0.8-1.6 GeV) on ^{208}Pb
  - Bertini produces too many neutrons
    - But comparing to isotope production at 1GeV, Bertini is about correct
  - Binary produces too few neutrons
    - And isotopes production confirms this.
- More tomorrow: Alex Howard,

Bertini cascade

- elastic interface was released first time, critical
  bug fix was made.
- Early 2007
  - separate interfaces for Bertini sub models will be provided
  - Coulomb barrier issue clarified - see talk by Aatos
  - optimized Bertini code – talk by Michael Hannus

With Input provided by
Aatos Heikkinen

INCL4+ABLA

- rewrite to Geant4 agreed in June with original authors.
- Translation started in September (now running in Fortran - C++ hybrid mode),
- first release hopefully in April 2007,
- full release late 2007 - see talk by Pekka Kaitaniemi

With Input provided by
Aatos Heikkinen

Other topics & developments

- Revision of hadron elastic scattering
  - Cross section and final state generation
  - Talk by M.Kosov
- Review of hadron nucleus cross sections
  - Improved interpolation for inelastic pion cross sections used by QGS
  - artificial a few percent biasing of inelastic pion cross-sections used by QGS for some elements (Copper)
- quasi-elastic
  - double counting LHEP Elastic,
- Coherent charge exchange model/process
- isotope selection

With Input provided by Mikhail Kosov and Vladimir Ivantchenko

Summary

- LHC experiments find hadronic showers are significantly too short using QGS.. physics lists
  - LHEP better, but worse in e/pi, response
- Understanding this issue is high priority
  - Looked at many distributions, reasonable agreement
    - Do we check the relevant distributions?
  - High statistic NA49 data is exception
    - Improve p_T distribution
    - Diffractive scattering ?
- Neutron production by cascade models needs improvement
  - Relevant for radiation background studies