String Parton Models in Geant4

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String Parton Models

- Models for inelastic interactions of primary hadrons with nuclei
- for particles of high incident energies
- Models split into
  - String excitation
  - String fragmentation

String Parton Models

- Two models for string excitation
  - FTFModel, a diffractive scattering model
  - Quark Gluon String Model
- String fragmentation common, but
  - fragmentation function specific for string model
- Secondaries passed on to lower energy models
- Nucleus passed to models for fragmentation, deexcitation, ...

Applicability of models

- *QGS* Model
  - Incident energies above 5-20 GeV up to 50 TeV
  - Incident particles: pion, Kaon, proton, neutron, and gamma
- FTF Model
  - Energies as above
  - Incident particles: all (longlived) hadrons

Quark gluon string model (QGSM)

- 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 calculation 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 (shared)

- 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.

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

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.

QGS Model for electro nuclear reactions

- Cross section see previous talk.
- Small cross section, gamma interacts with one (random) nucleon
- Using vector dominance model

FTF model

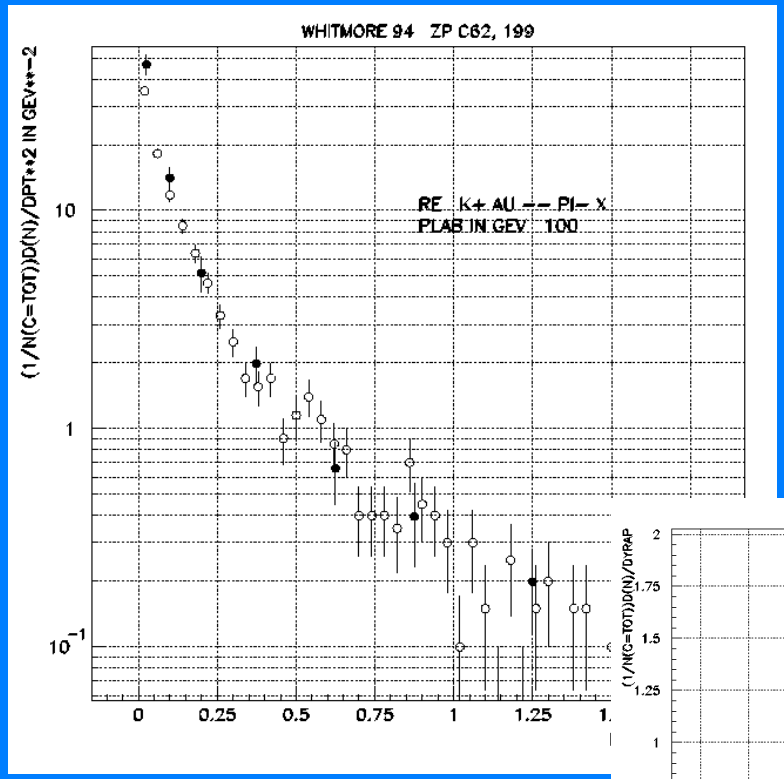
- The algorithm
  - Build 3-dimensional nucleus
  - Calculate impact parameters with all nucleons
  - Hadron-nucleon collision probabilities
    - using inelastic cross section from eiconal model
  - Collision between partons modeled as momentum exchange
  - Momentum exchange *q* excites hadron and nucleon
  - Condition on exited masses $m^2 > m^2_{Hadron} + q^2_t$
  - Strings formed from exited particles

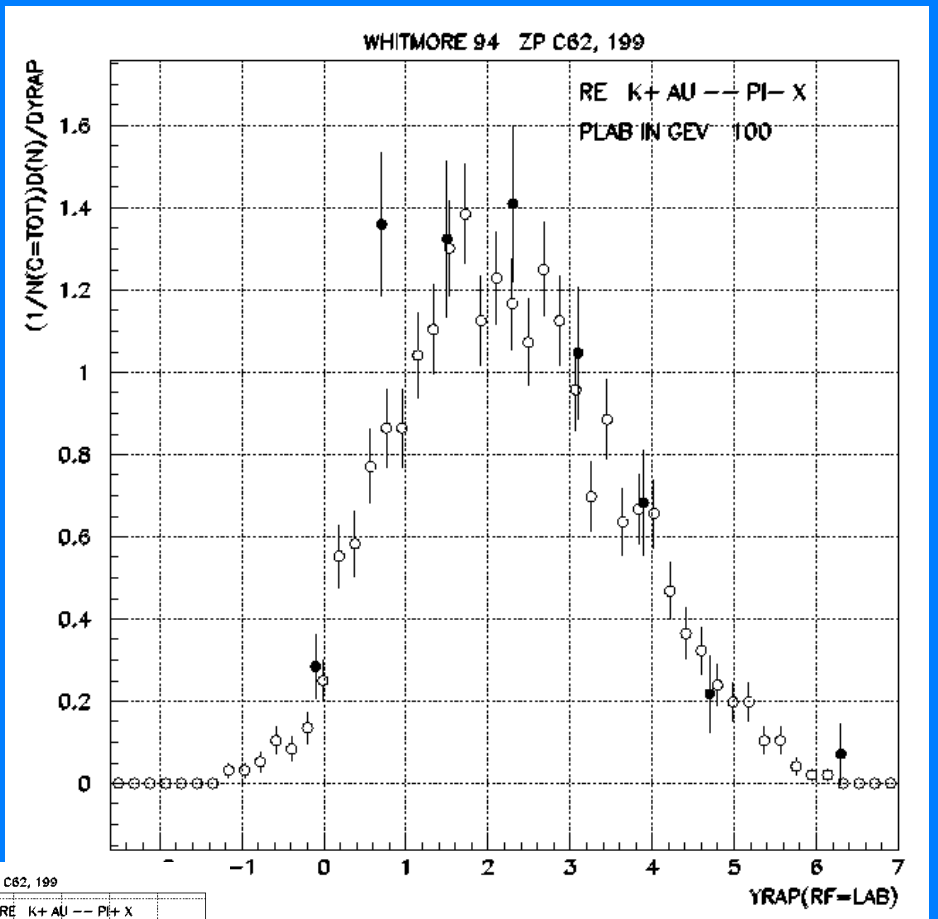
Longitudinal String Fragmentation

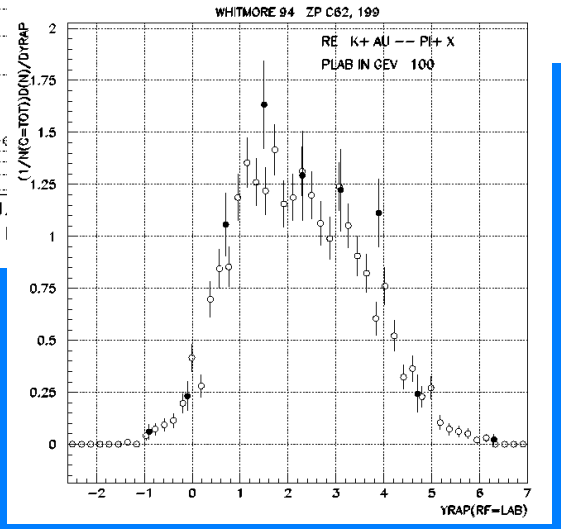
- Algorithm
  - String between constituents
  - Break string by inserting *q-qbar* pair
    - *u : d : s : qq = 1 : 1 : 0.27 : 0.1*
  - Break string at pair ➡ new string + hadron
  - Gaussian P_t, $\langle P_t^2 \rangle = 0.5$ GeV
  - Split longitudinal momentum using Lund or "QGSM" fragmentation functions

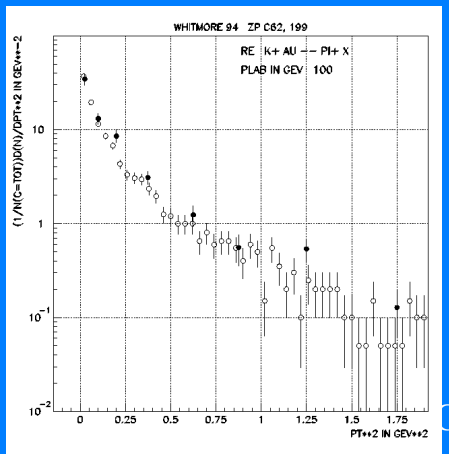
QGS Model

K+, scattering off Au









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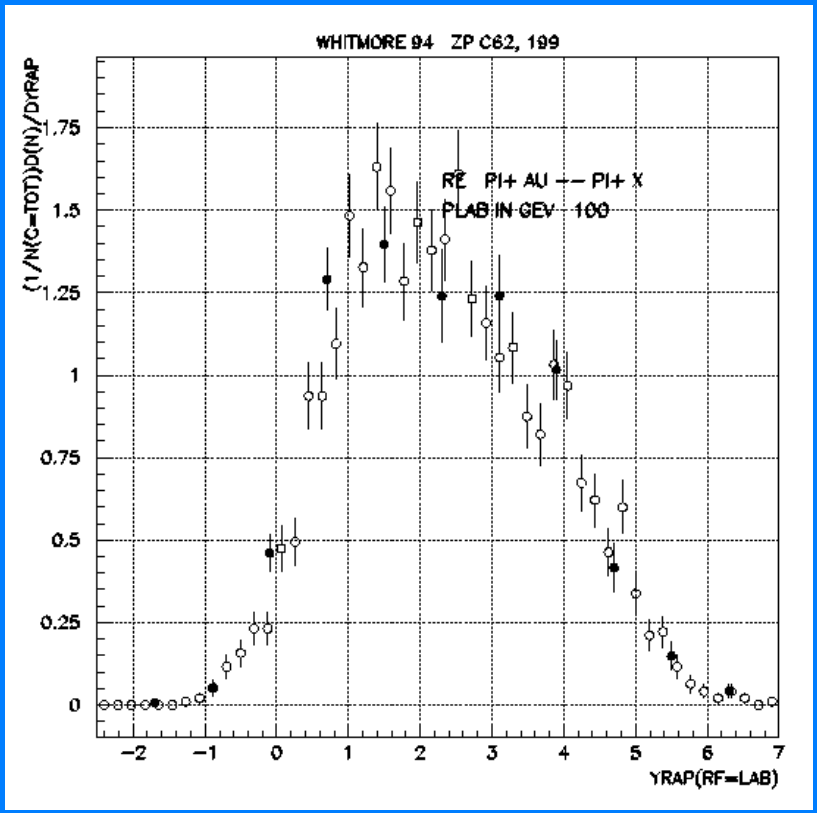
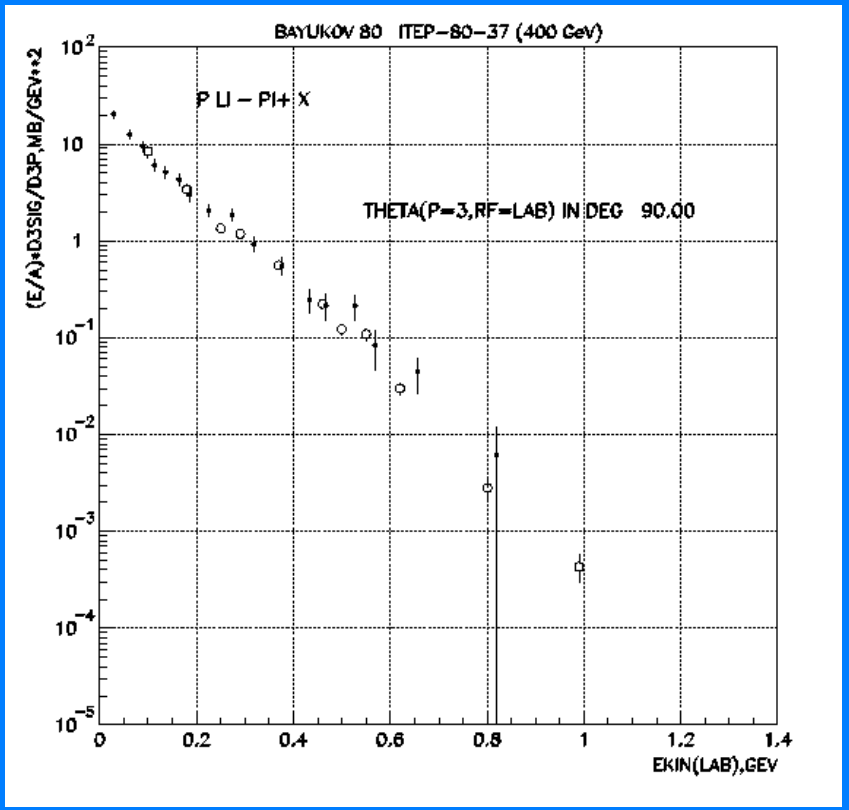
QGS Model

Pion and proton scattering





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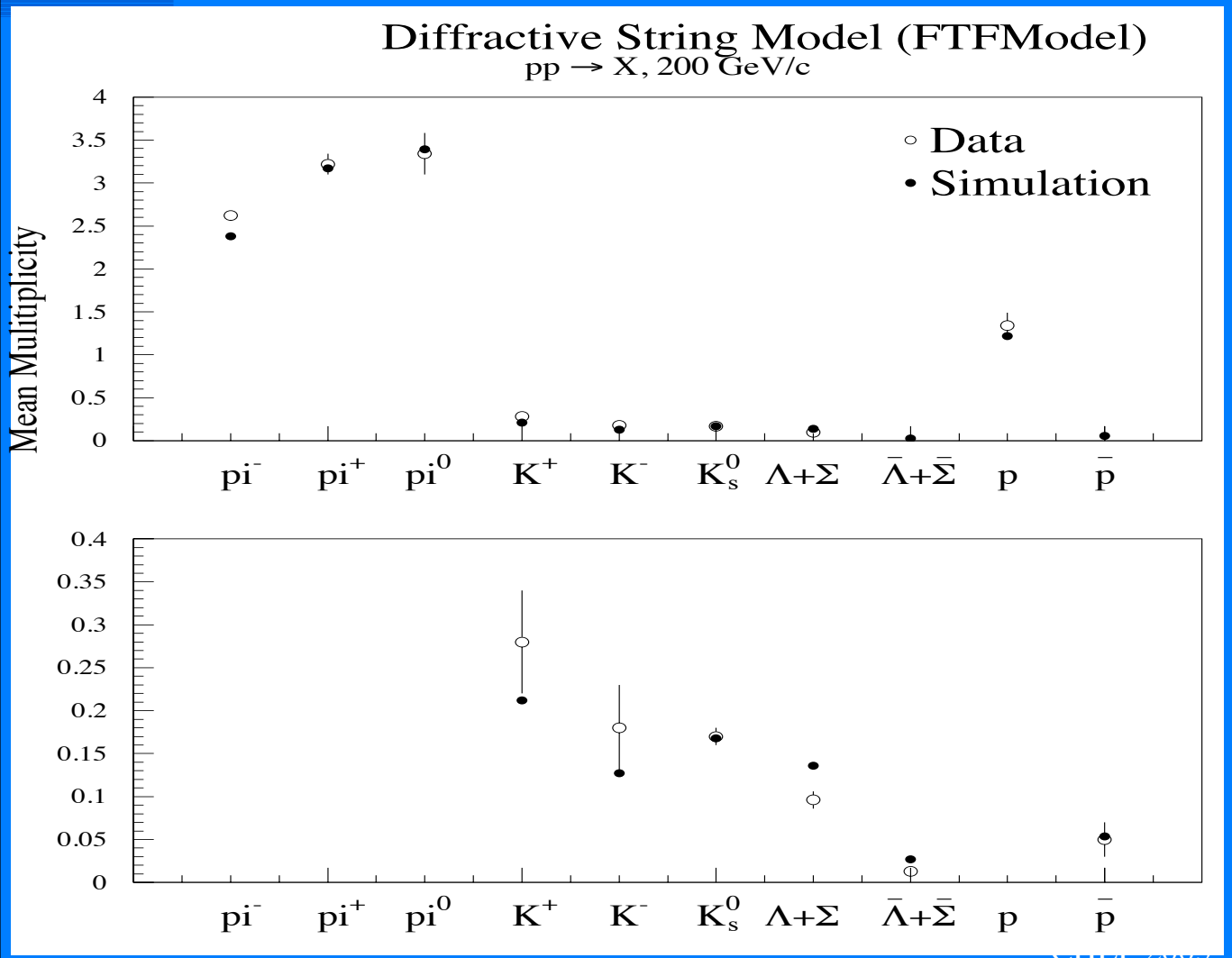
FTF Model

p H → X
200 GeV/c



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Summary

- Two parton string models are available with geant4.
- Both models are at present heavily used in test-beam simulation.