A model for Net-Baryon rapidity

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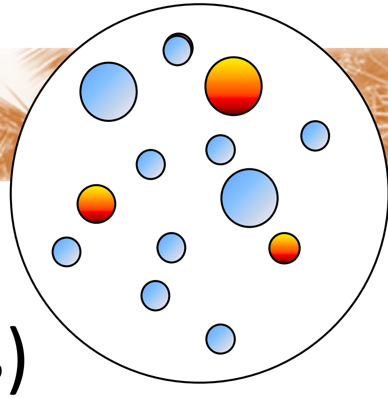
LIP

Motivation



- Net-Baryon = (Baryons - Anti-Baryons)
  - Valence quarks
  - As the baryon number is conserved, the net-baryon keeps track of the energy-momentum carried by the incoming particles
- How does the fraction of energy carried by the net-baryon evolve as a function of the centre-of-mass energy per nucleon?
  - At very high energy it is assumed that sea quarks dominate over the valence
- What is the role of the collision centrality?

What do we know?...

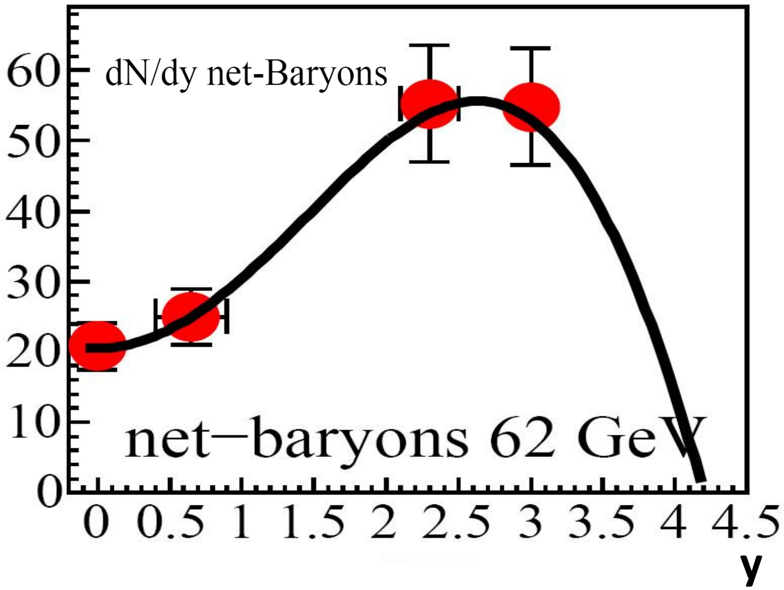
- ***Experimental Data***
  - AGS (5 GeV central collisions)
  - NA49 *(17 GeV several centralities)*
  - RHIC – (BRAHMS) *(62.4 GeV and 200 GeV central collisions)*

- ***Current Model Predictions***
  - EPOS 1.61
  - QGSJET-II.03

Net-Proton Data

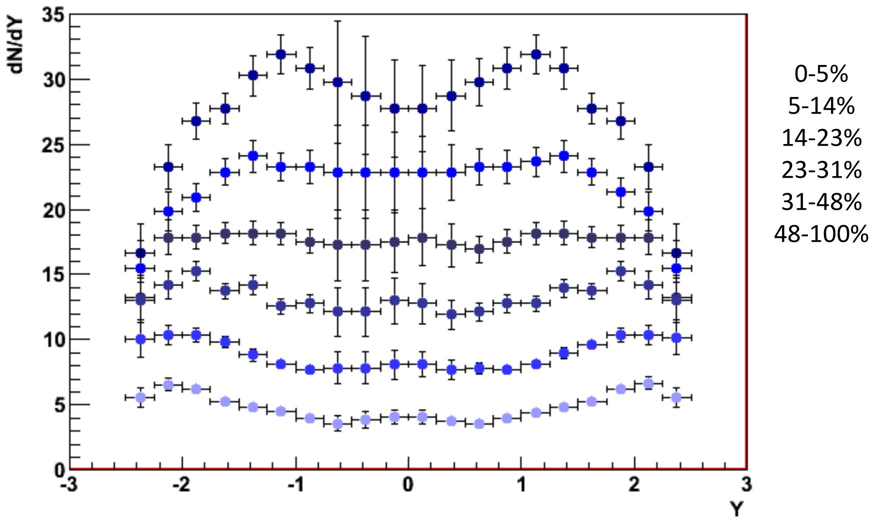
Energy Dependence

RHIC 62.4 GeV



Centrality Dependence

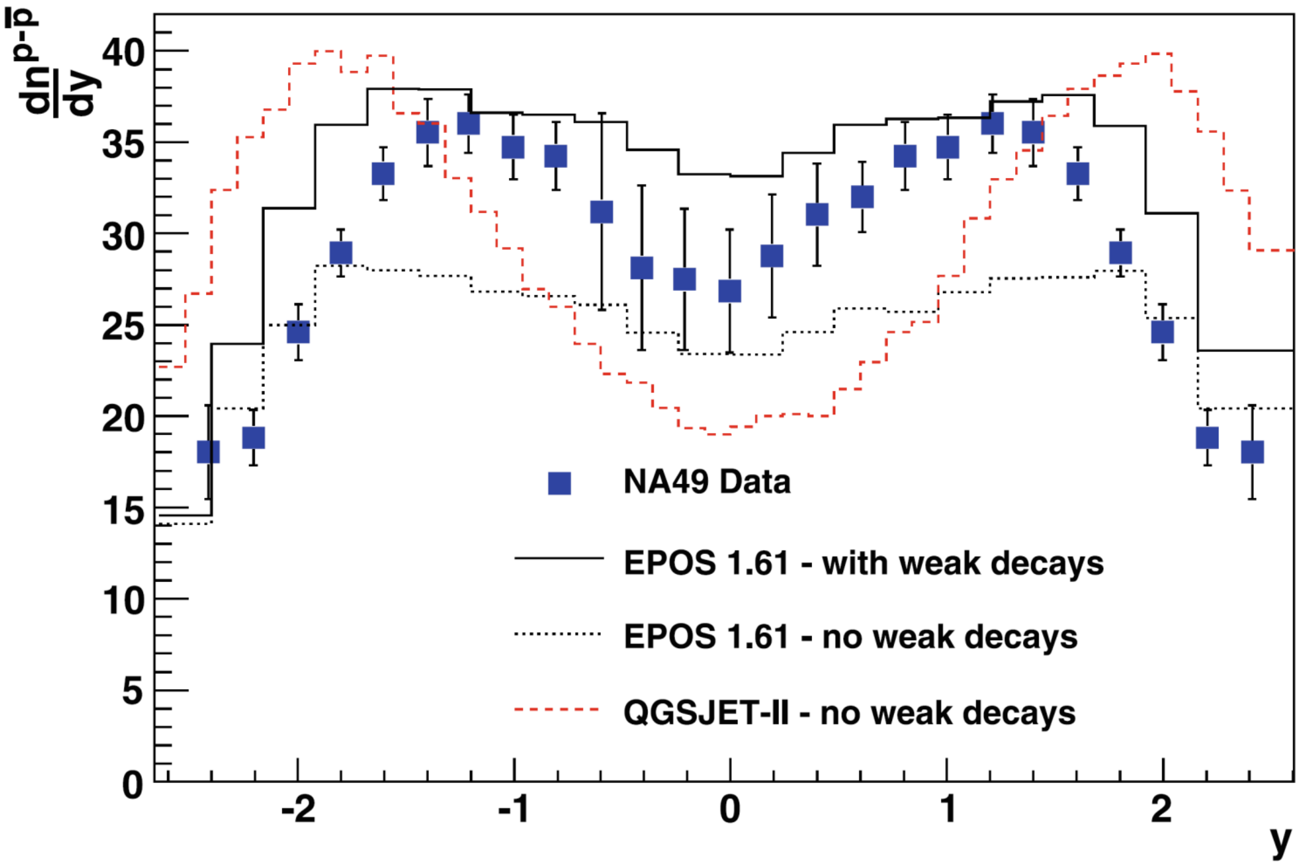
NA49 – 17 GeV



No Feynman scaling observed

SPS data have been corrected for weak decays

QGSJET-II and EPOS Predictions



- Weak decay Corrections Applied to Data
- QGSJET-II is not expected to perform very well at such low energies

Extra-Motivation

- The net-baryon has not been fully studied by Experiments
- In Monte Carlo hadronic models the physics of net-baryon production is very much obscured by the complexity of extensive and detailed codes

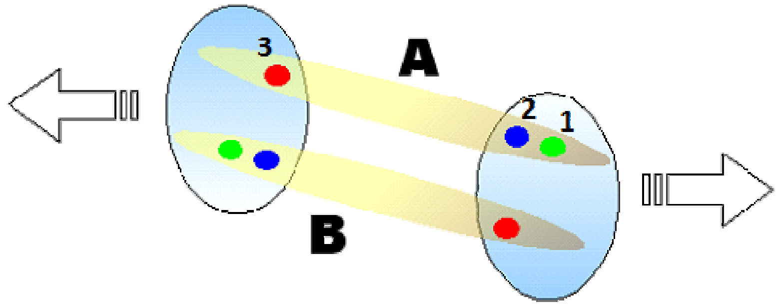
- Build a simple model to explain net-baryon data and predict the behaviour at higher energies

Our Model

- Description of the model
- Comparison with data
- Predictions for higher energies

Model – String Formation

- Formation of extended color fields or strings
  - Quark Combinatorial
- The string gets its energy-momentum from the valence quarks PDFs
  - Dependency of Q^2
  - CTEQ6
  - Nuclear effects taken into account (EKS98)



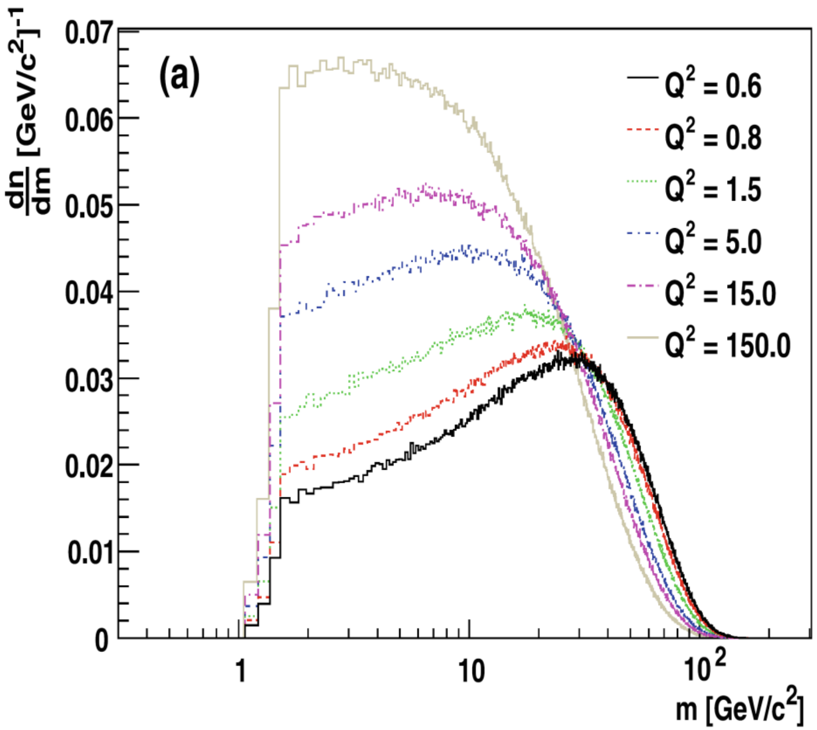
$$E_A = (x_1 + x_2 + x_3)\frac{\sqrt{s}}{2}$$

$$P_A = (-x_1 + x_2 + x_3)\frac{\sqrt{s}}{2}$$

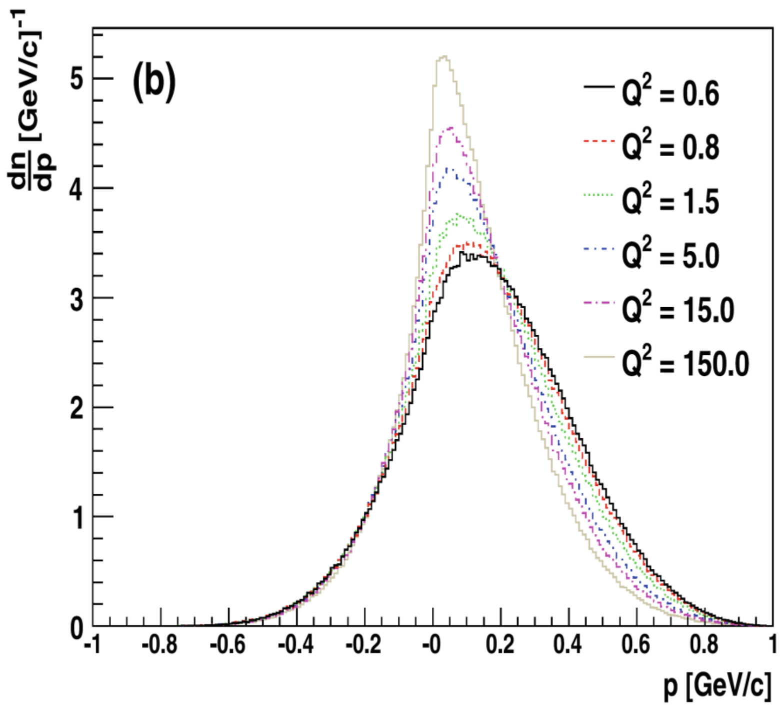
$$M = \sqrt{E^2 - P^2} = \sqrt{x_1\,(x_2 + x_3)\,s}$$

String Characteristics (200 GeV)

Mass Spectrum of strings



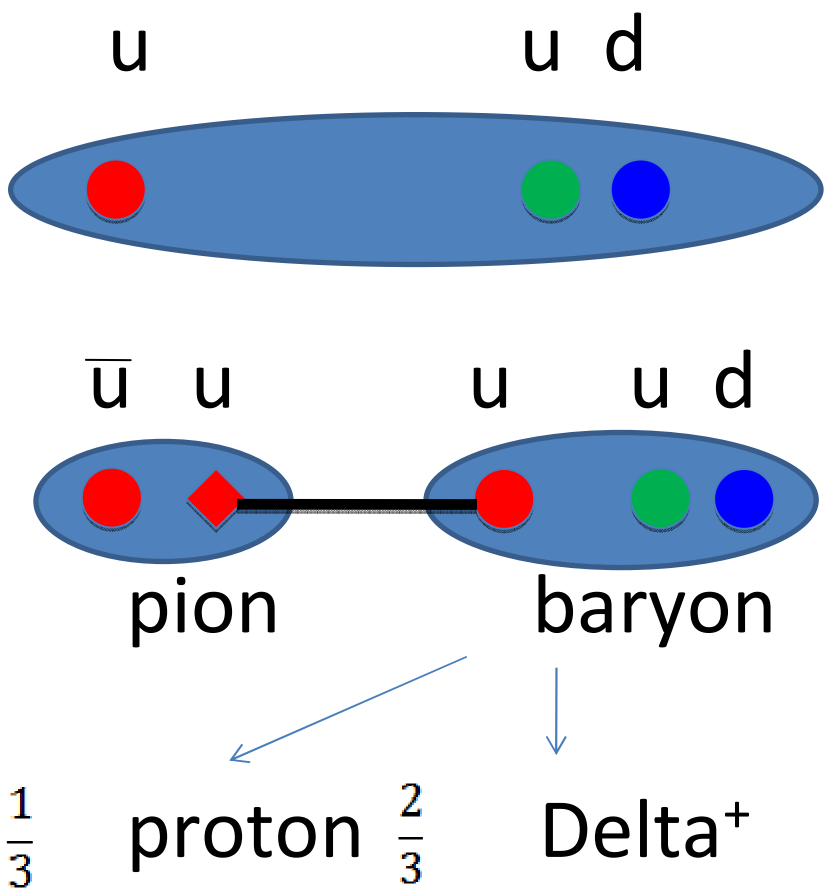
Momentum of string A



Model – String Fragmentation

- Mechanism of String Fragmentation:
  - It is assumed that the string decays into a baryon and a meson
  - Kinematic Constraints
  - Both fundamental and excited states were considered taking spin-dependent weights (2j+1)
  - Unstable baryon were forced to decay in order to enter in net-baryon calculations
  - The contribution of s quarks was not considered at this point

- Example:



Model – String Fragmentation II

- Mechanism of String Fragmentation:
  - The baryon produced will have the direction of the two nearest quarks in momentum
    - Diagram 1 is predominant at low energies
    - At high energies Diagram 2 will be as important as Diagram 1
- Can reproduce some features of string baryon junction and pop corn

$$x_3 < x_2 < x_1$$

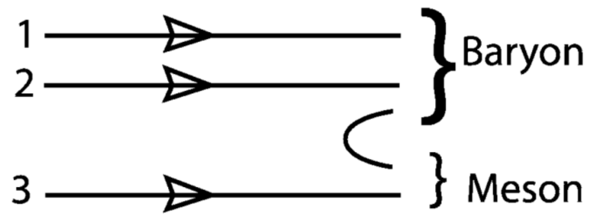


Diagram 1

$$x_1 - x_2 < x_2 - (-x_3)$$

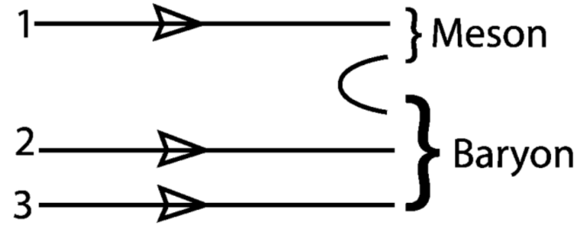
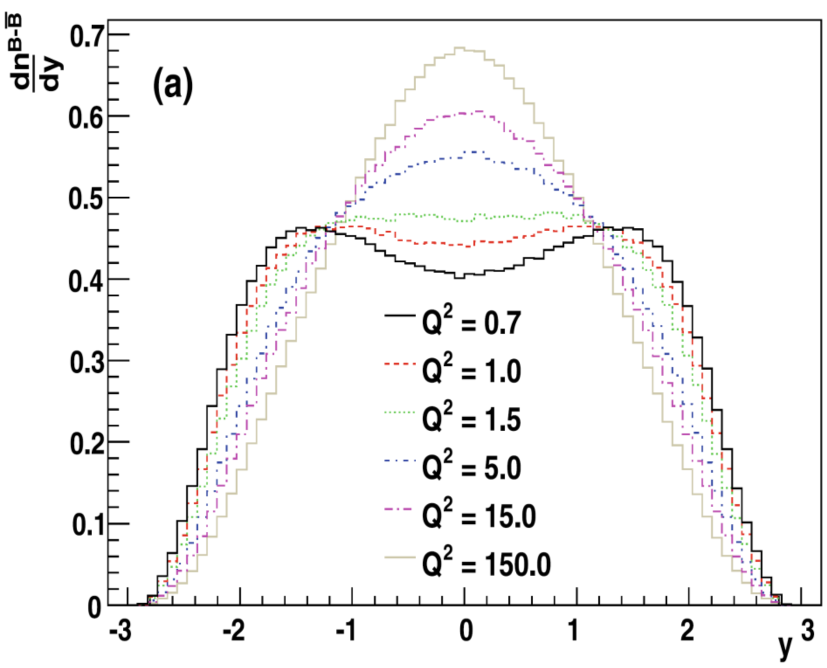


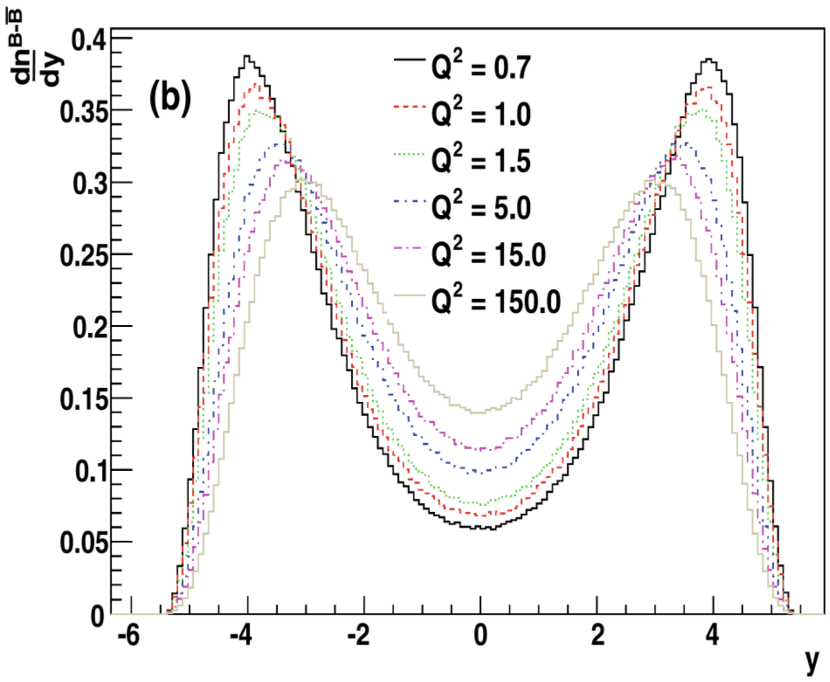
Diagram 2

$$x_1 - x_2 > x_2 - (-x_3)$$

Net-Baryon Rapidity

17 GeV	200 GeV





Evolution with energy is a consequence of QCD evolution of the PDFs and kinematic constraints in the string fragmentation

Effective Q² – Data Fits

- Fits were performed to the available net-proton data
  - Effective Q²
    - Quark PDFs input
  - Normalization factor
    - Proportional to the number of participants

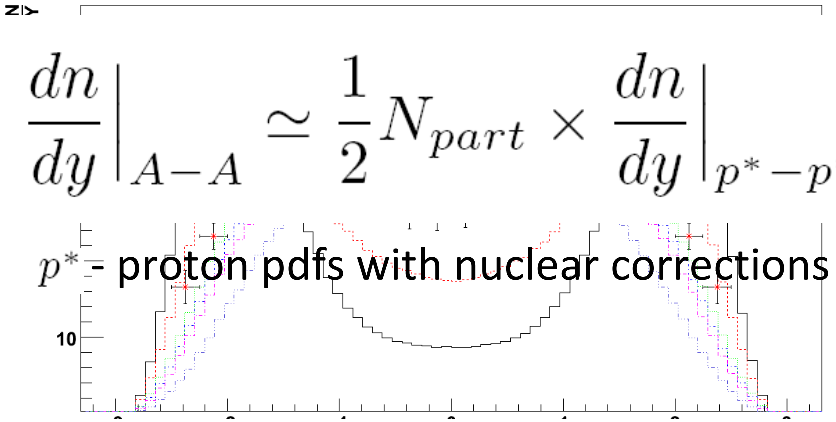
Net-Proton

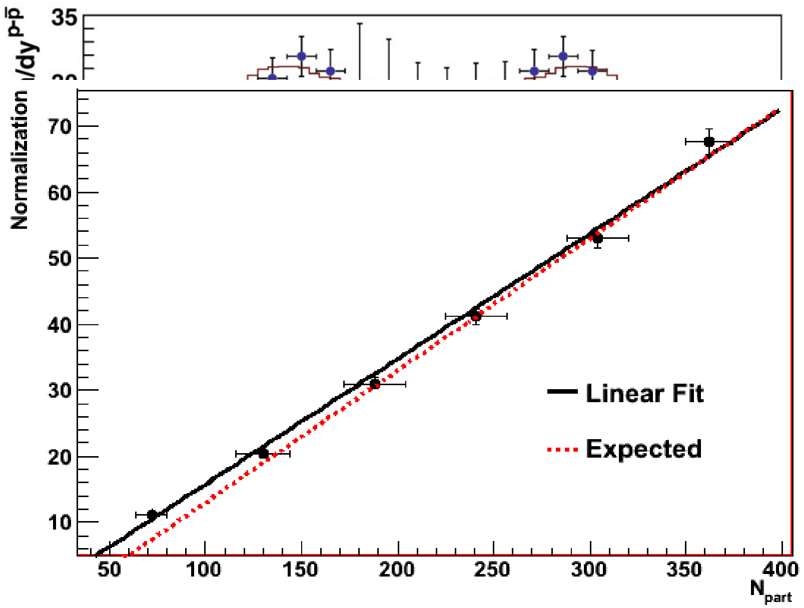
Net-Baryon

- pp → AA collisions
  - Factor 2
- net-baryon → net-proton
  - ≈ Factor 2
- strange baryons contribution
  - About 25%
- Use 17 GeV points at several centralities to verify this assumption

$$\frac{dn}{dy}\bigg|_{A-A} \simeq \frac{1}{2} N_{part} \times \frac{dn}{dy}\bigg|_{p^*-p^*}$$

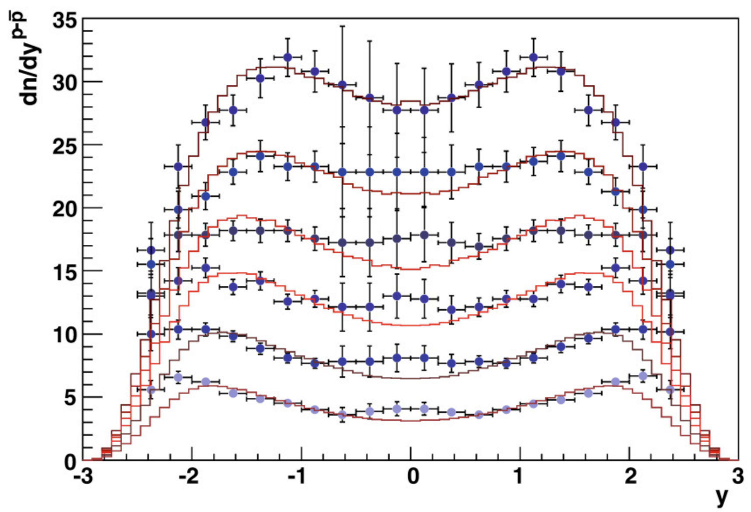
p^* - proton pdfs with nuclear corrections

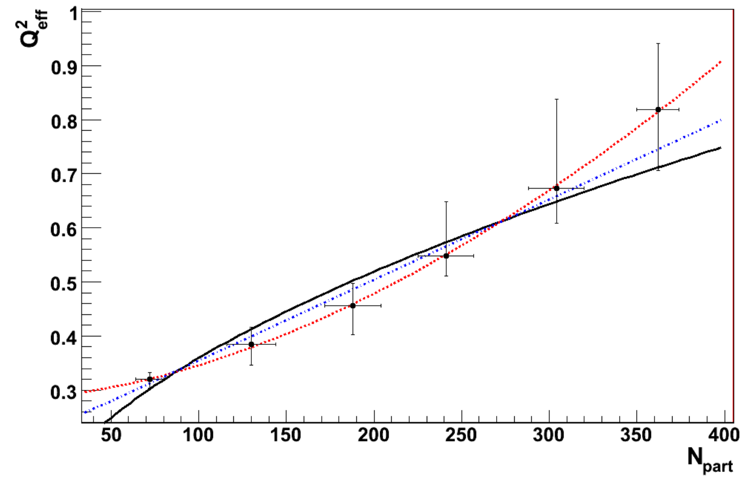




Q^2 Centrality Dependence

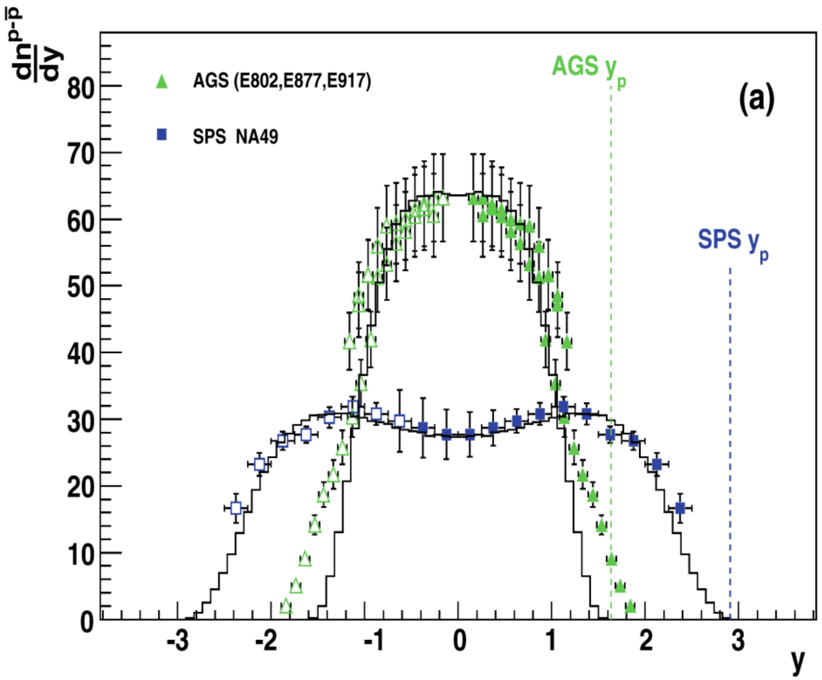
- NA49 data
- Evolution of Q^2 with centrality
  - Fitted functions:
    - $Q^2 = Q_0^2 \left(\frac{A}{2}\right)^{\alpha}$ [GeV^2]
      - $\alpha = 0.53 \pm 0.13$
    - Using same formula but not imposing zero when A=0
      - $\alpha = 1.70 \pm 0.62$
    - Linear Fit
      - $\alpha = 1.0$
  - Since N_{part} of central collisions does not vary much we just need an interpolation function



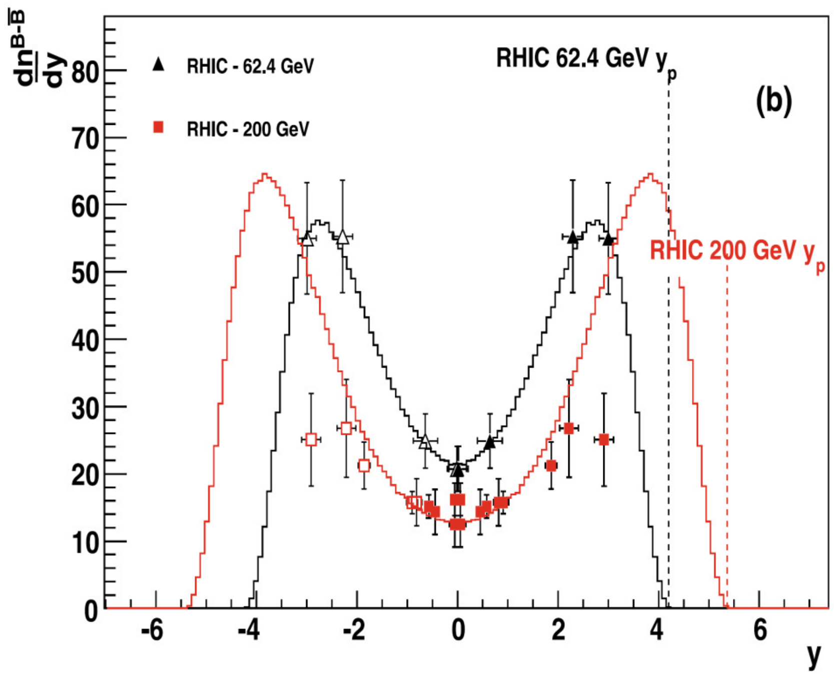


Energy Dependence

Net-Proton



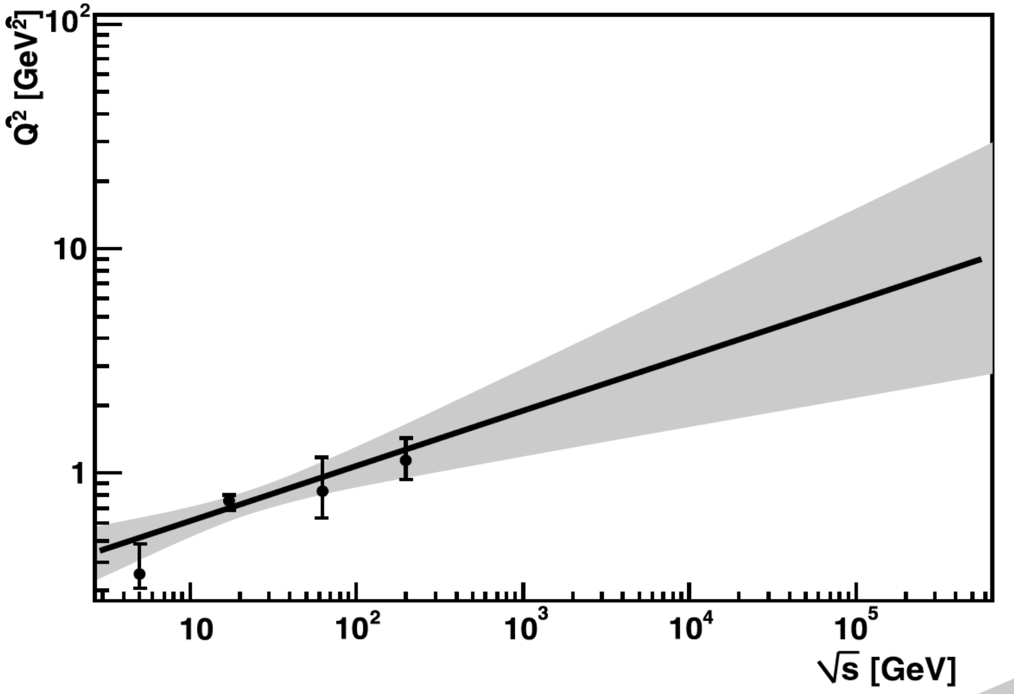
Net-Baryon



At central collisions

Evolution with collision energy ($\sqrt{s}$)

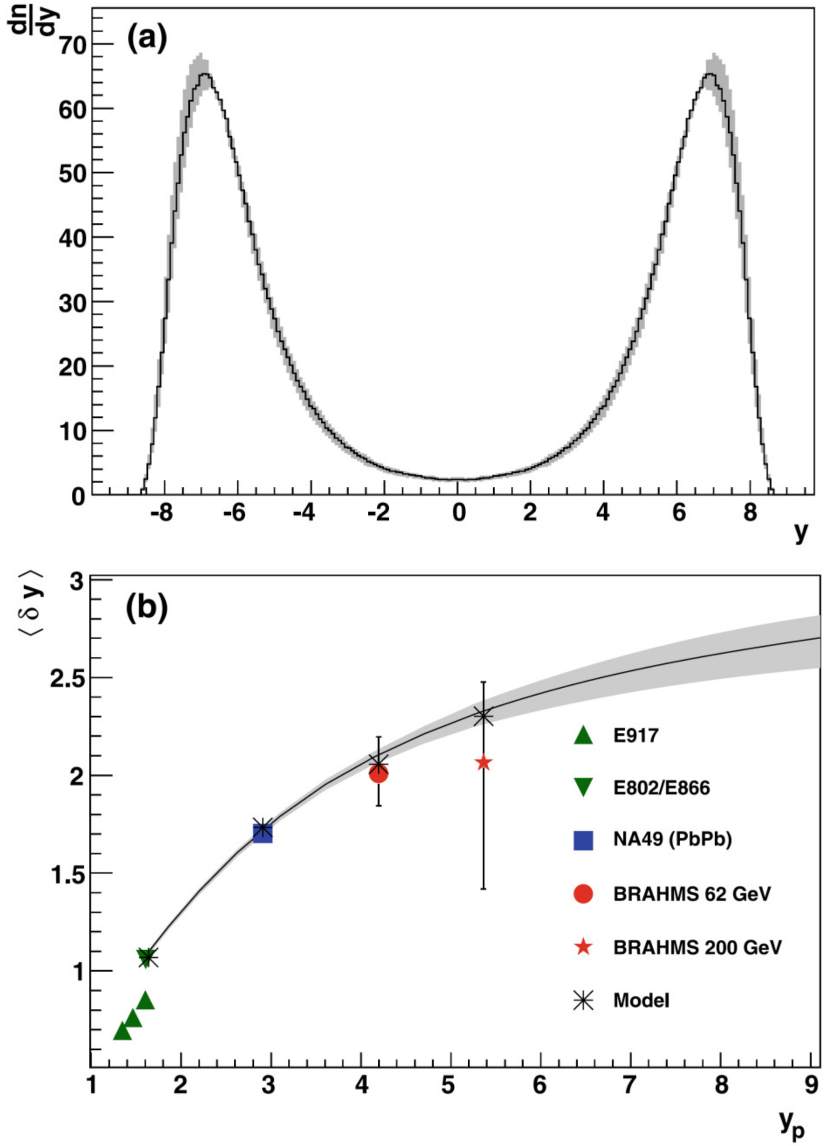
- Relate effective Q^2 with collision energy using:
  - $Q_A^2 = Q_0^2 \left(\frac{N_{\text{part}}}{2}\right)^{\alpha} \left(\frac{s}{s_0}\right)^{\lambda_v} \, [\text{GeV}^2]$
- Using,
  - $\sqrt{s_0} \simeq 17$ GeV.
  - $\alpha = 0.53^{+0.12}_{-0.13}$
- One gets,
  - $\lambda_v = 0.25^{+0.12}_{-0.11}$



With this law we can try to make some predictions for higher energies!

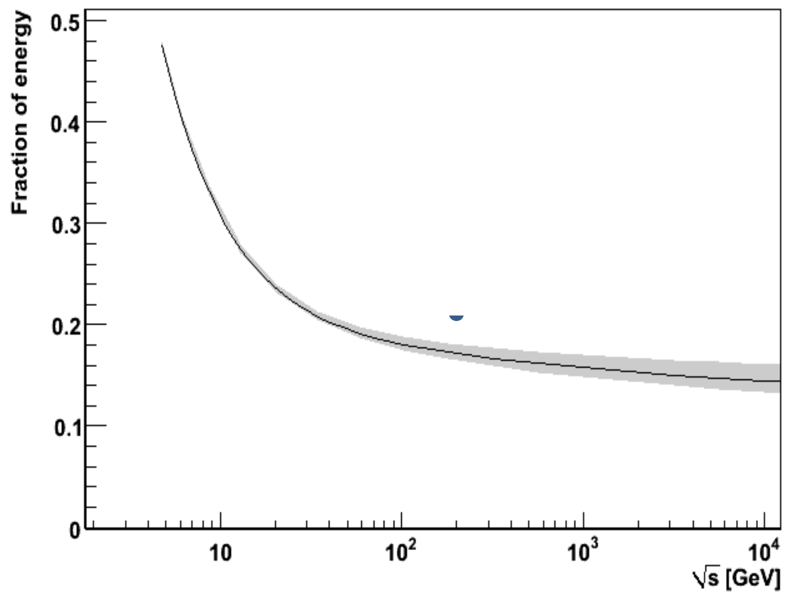
Net-Baryon Predictions

- Net-Baryon rapidity for central Pb–Pb collisions at *√s = 5.5 TeV*
- Rapidity loss as function of beam rapidity
  - $\langle \delta y \rangle = y_p - \langle y \rangle$
  - Used to give information about nuclear stopping
- Small uncertainty is due to the slow evolution of valence quark PDFs



Net-Baryon Predictions

- Fraction of energy carried by the net-baryon
  - The fast evolution at low energy is a consequence of kinematic constraints in the string fragmentation
  - At high energies the fraction of energy carried by the net-baryon depends on how fast Q^2 grows with it
  - Transverse momentum not taken into account



$$E = \frac{1}{N_{part}} \int_{-y_p}^{y_p} \langle m_T \rangle \cdot \cosh y \cdot \frac{dN_{B-\bar{B}}}{dy} \cdot dy$$

Conclusions

- The role of the Net-Baryon is not negligible
- EPOS 1.61 and QGSJET-II have problems in reproducing the Net-Baryon data at low energies
- Our simple model can reproduce the Net-Baryon's main features including centrality dependence
- New (and forward) data needed!!
  - In particular from pp collisions

Thank you!!

Backup slides

Rapidity Loss

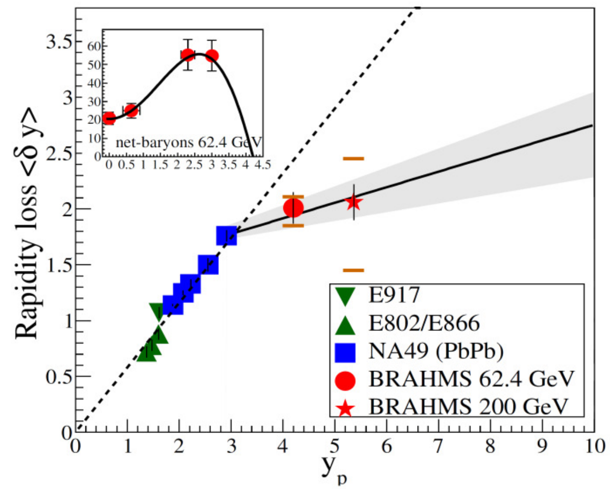
- Rapidity loss given by

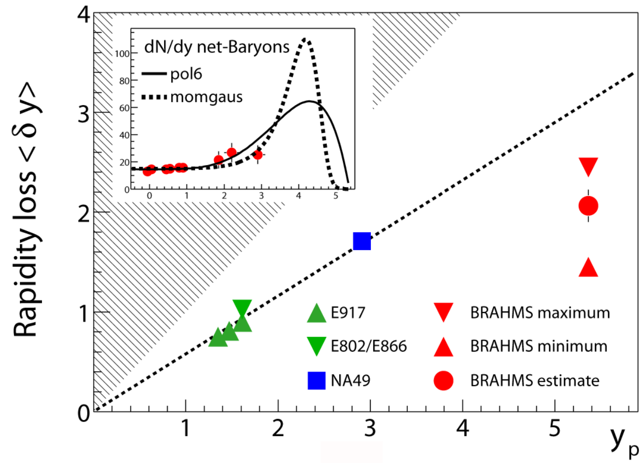
  - $$\langle \delta y \rangle = y_p - \langle y \rangle$$

    y_p is the beam rapidity

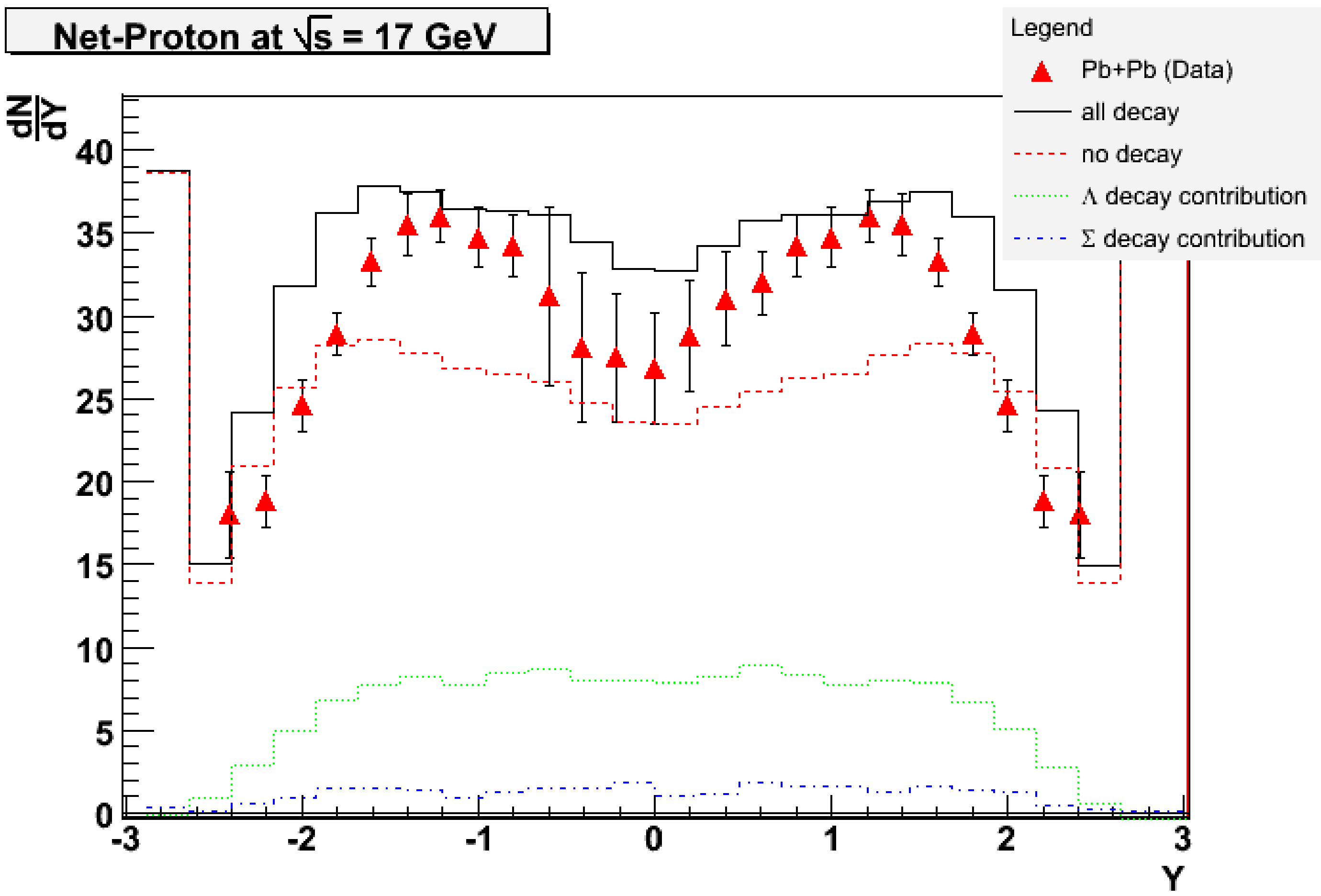
    $$\langle y \rangle = \frac{2}{N_{part}} \int_0^{y_p} y \frac{dN_{B-\bar{B}}(y)}{dy} dy$$

- Large uncertainties



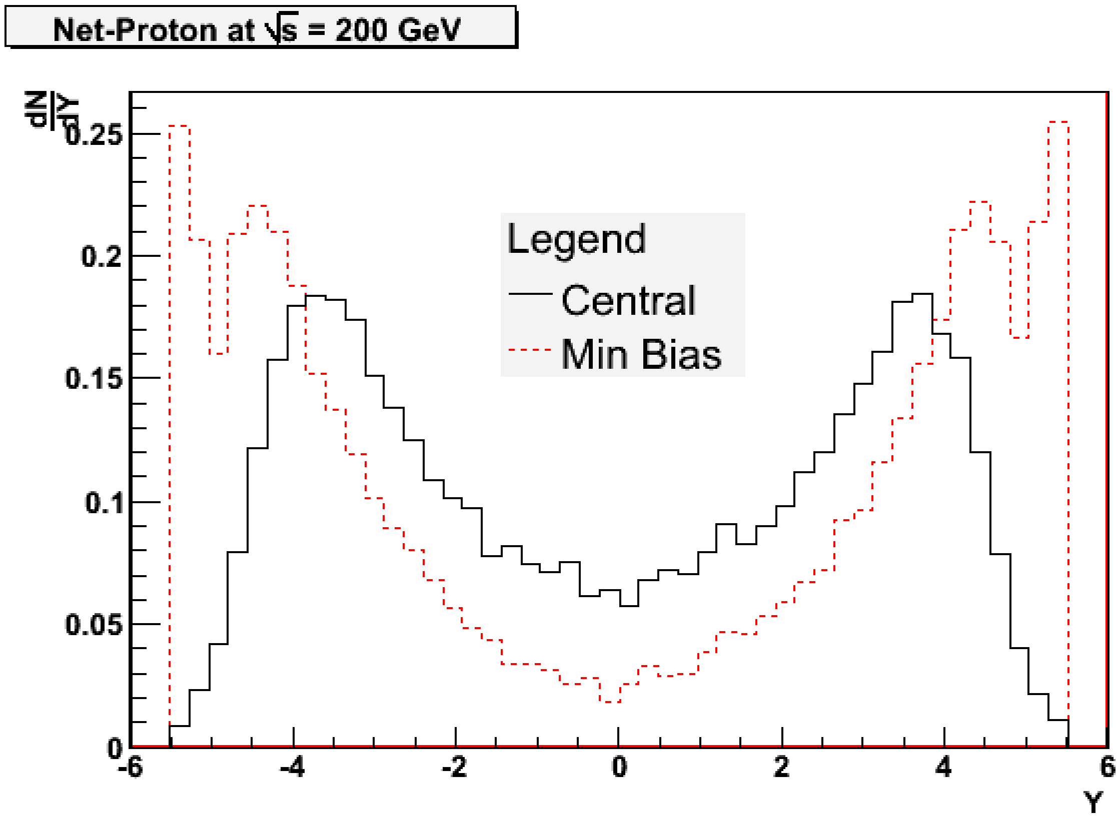


Weak decays



EPOS 1.61

Centrality Dependence



Minimum Bias vs Central Collisions

EPOS 1.61