Proton and anti-proton spectra and stopping

Peter Christiansen, NBI

1. Data selection and PID
2. Results
3. Publication

Data selection

Global cuts :

- Interaction point (BB & ZDC agrees, and close to nominal IP)
- Centrality : 0-5 %, (5-10 %, 10-20 %)

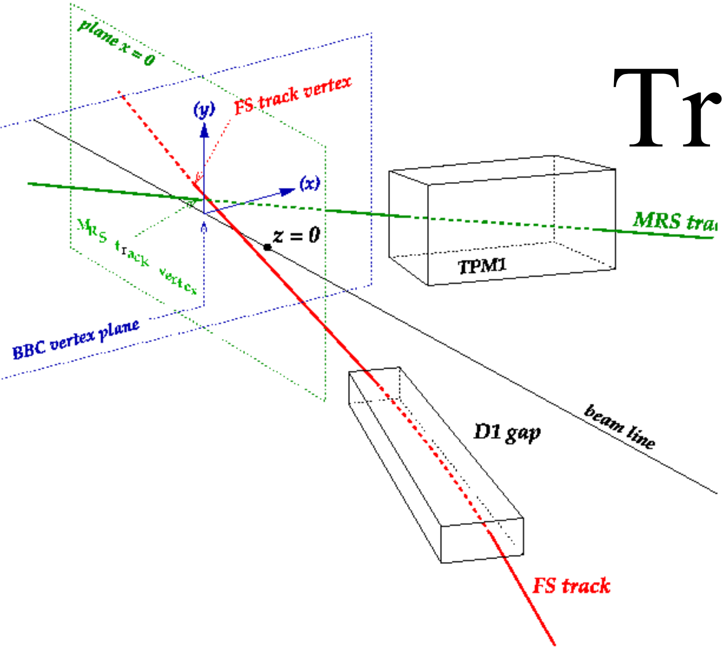
Track cuts :

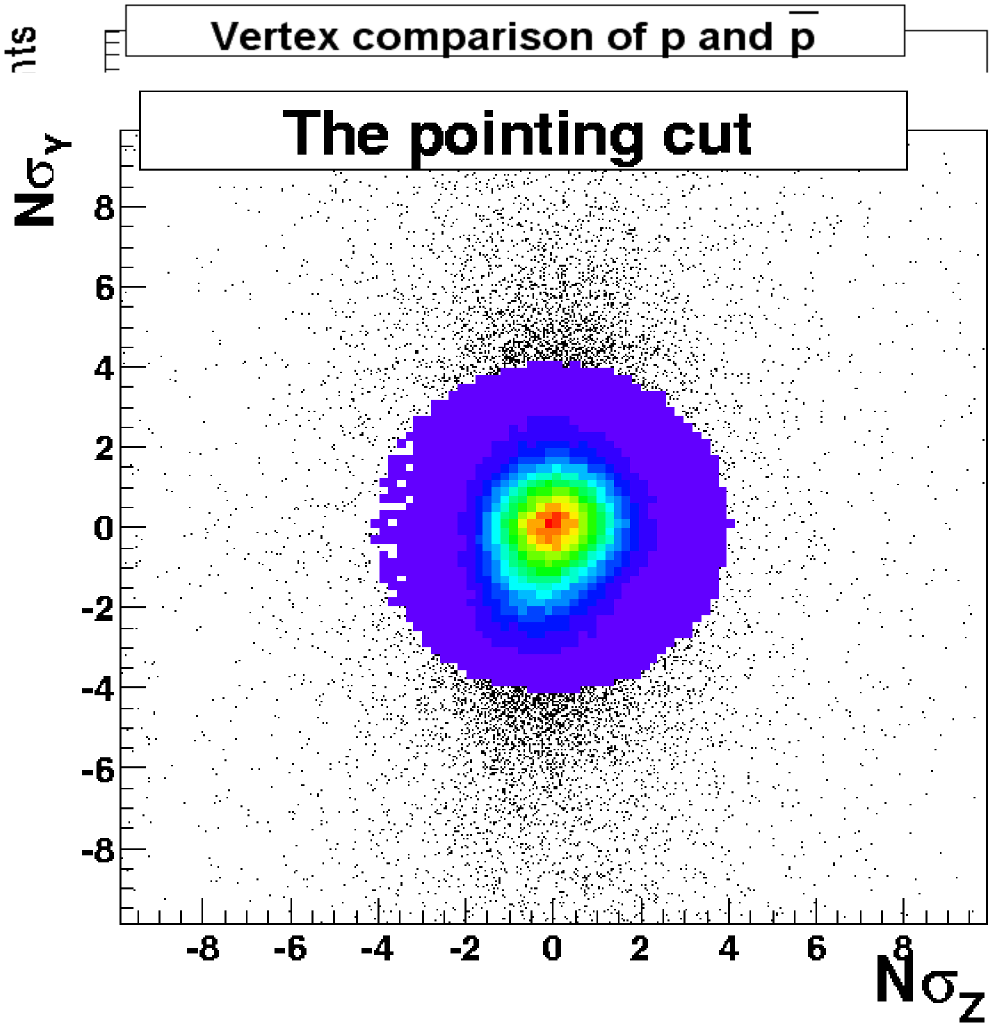
- Pointing (Track points back to the IP)
- Magnet fiducial cut (track status = 1)

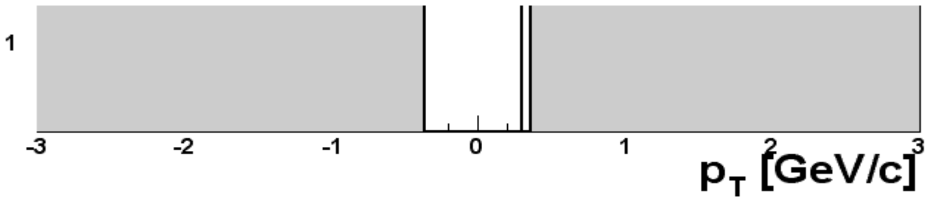
PID cuts :

- TOF (TOFW, H1, H2) and RICH

Track pointing





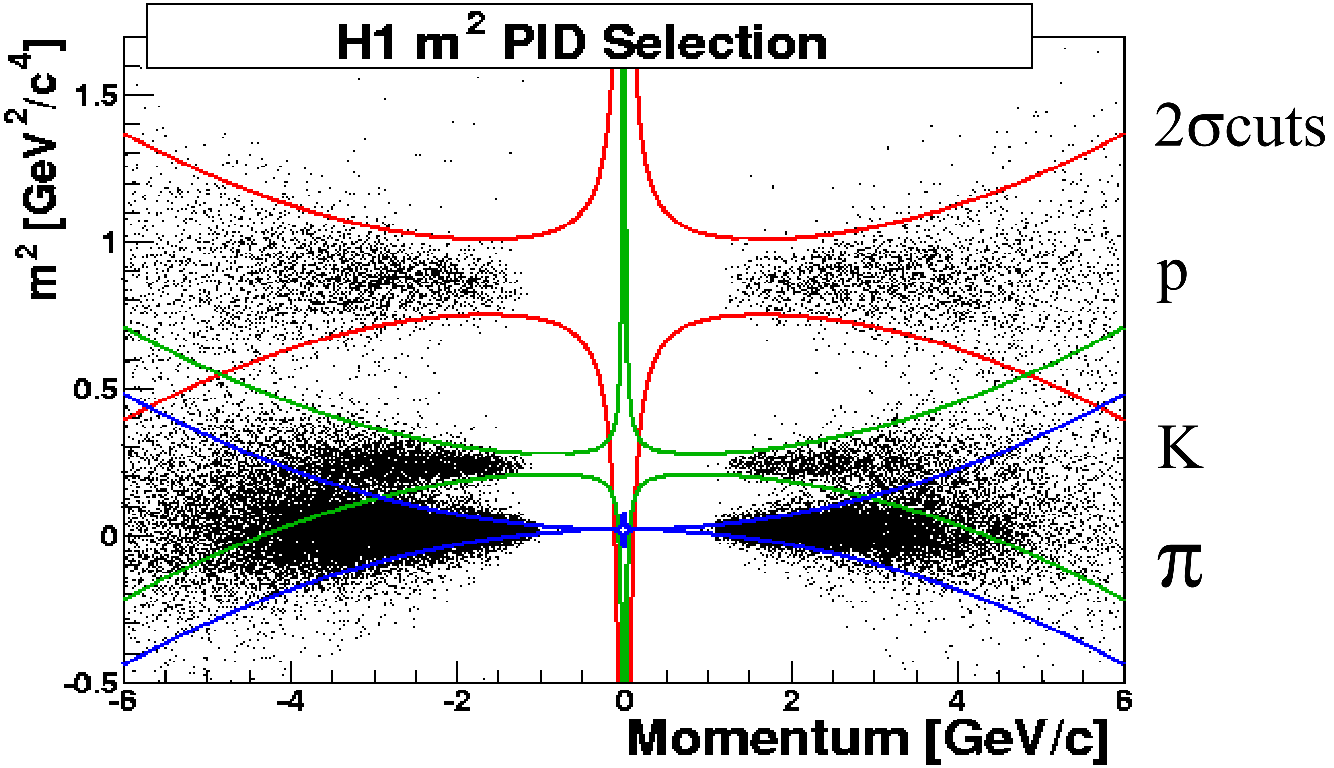


Pointing the track back to the interaction point to reject background tracks.

Might learn more from Monte Carlo simulations about where to set cut and momentum dependence.

Proton PID using TOF

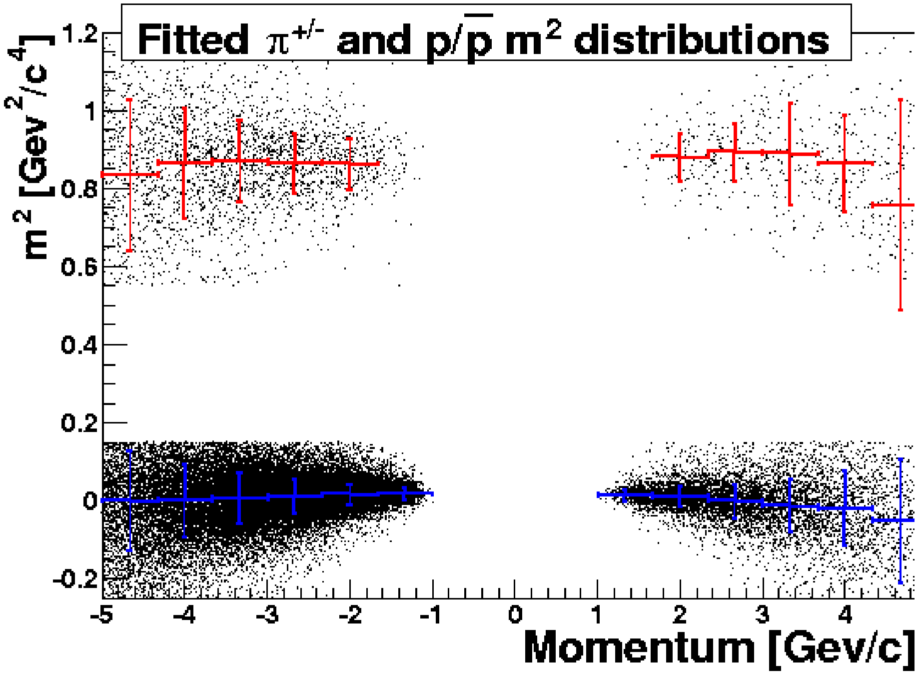
$$m^2 = p^2\left(\frac{1}{\beta^2} - 1\right)$$

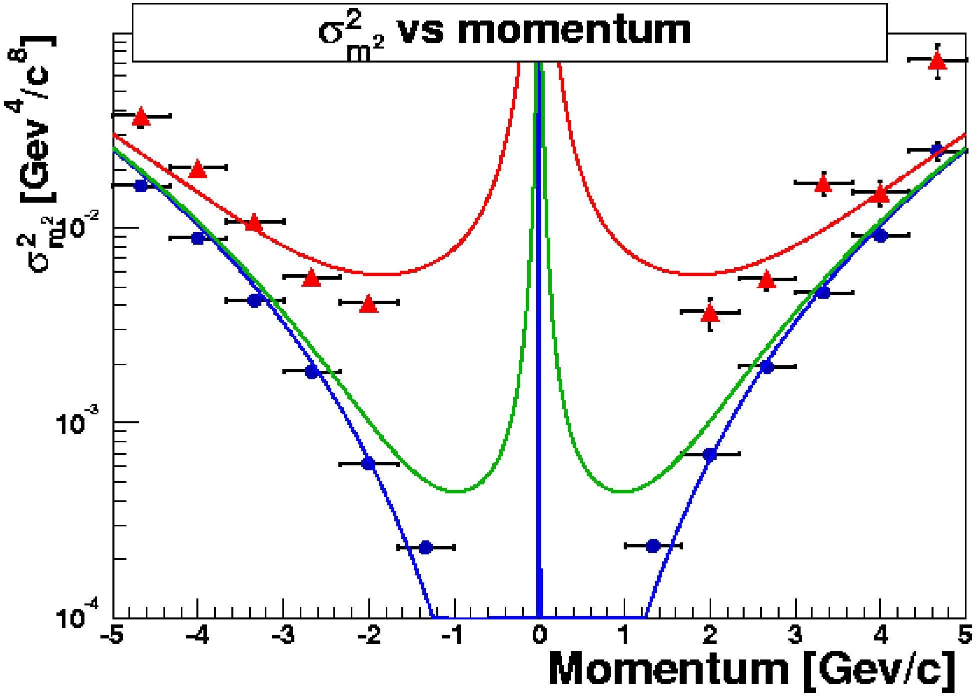


m² momentum dependence parameterized by :

$$\frac{\sigma^2_{m^2}}{4} = m^4 p^2 \sigma^2_{p_{angle}} + m^4 \sigma^2_{p_{multi}} \left(1 + \frac{m^2}{p^2}\right) + p^2 (m^2 + p^2) \sigma^2_{TOF}$$

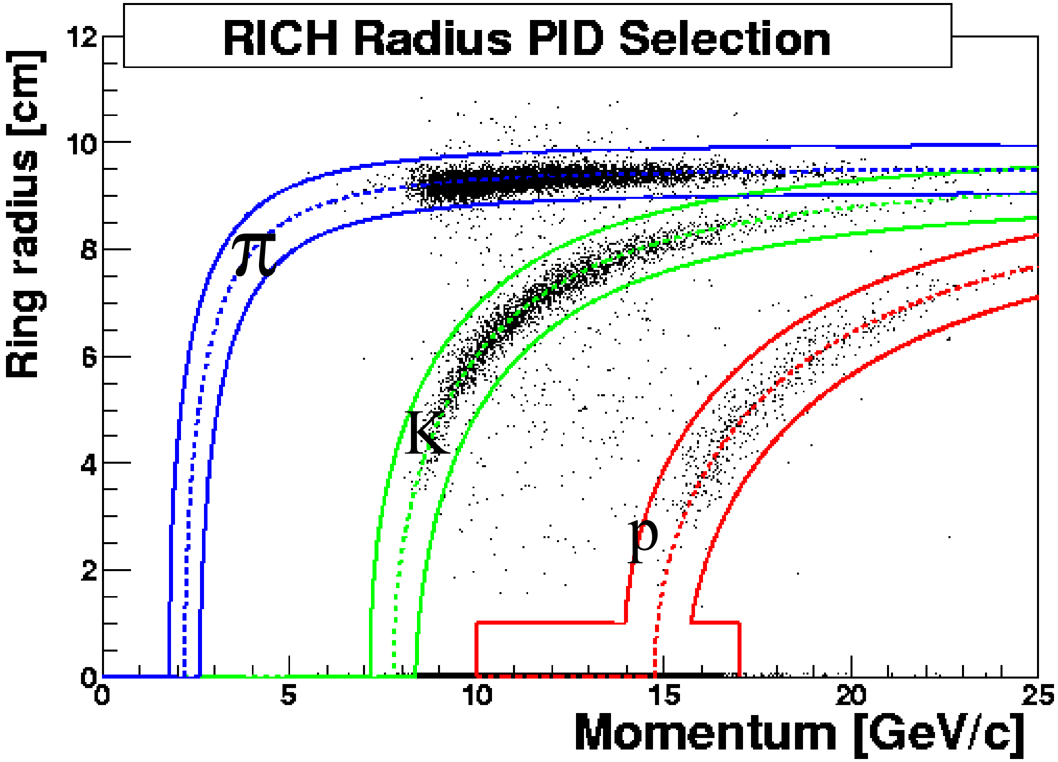
How to parameterize TOF

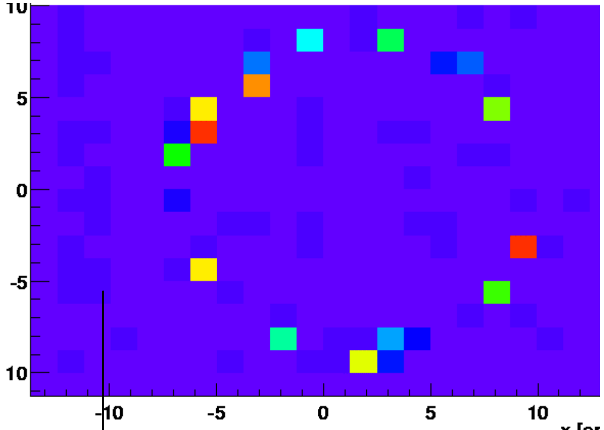


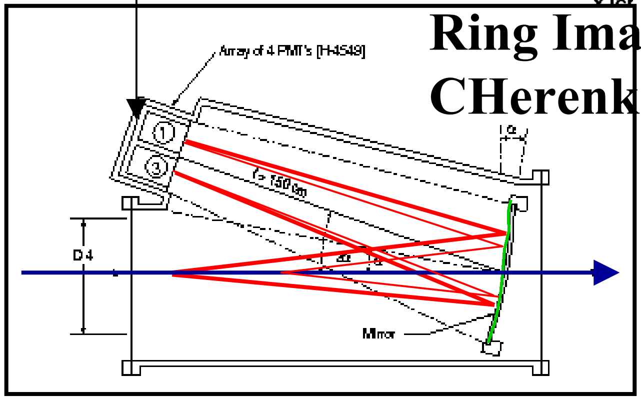


Can we determine the parameterization without fitting ???

Proton PID in the FS





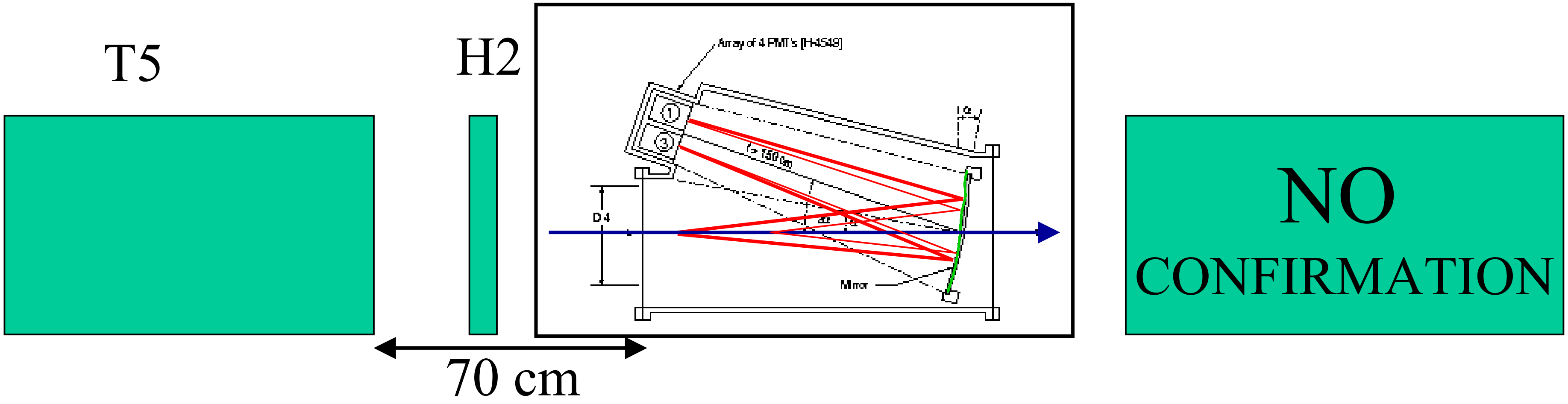


Ring Imaging CHerenkov

The ring radius in the RICH depends on the velocity.

We could take same approach as for TOF since the radius gives us the velocity => mass2 cuts.

Rich efficiency 1



T5

H2

70 cm

NO
CONFIRMATION

Focus on veto method (essentially all yield) :

1) Particle absorption or decay after T5 and decay product is not identified in the RICH.

p=10GeV/c, length=1m, P(pi)=0.2%, P(K)=1.3%

But decay product could be identified

2) Algorithm inefficiency.

Rich efficiency 2

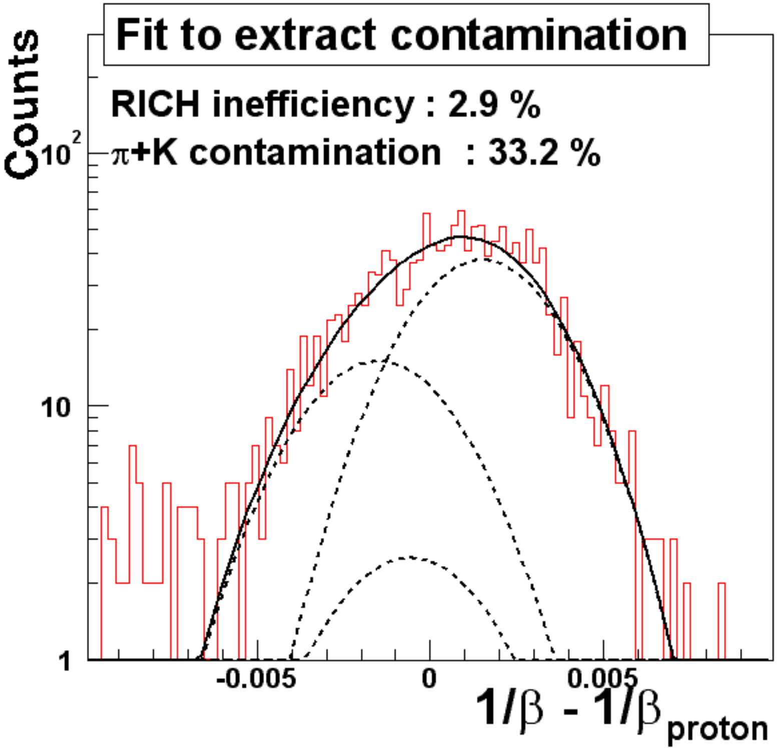
Use H2 to estimate contamination. 1/beta-1/beta(proton).

Shape of pion and kaon dist from those identified by the RICH.

Shape of protons from directly identified at higher momentum.

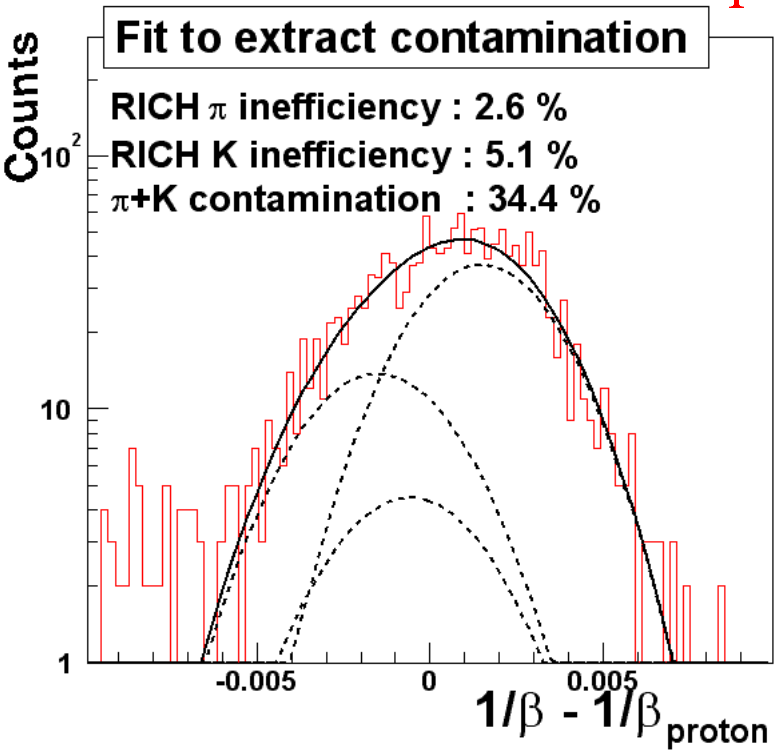
Fit H2 distribution of vetoed protons with sum of pi,K, p.

Fixed pi+K contamination(thesis)

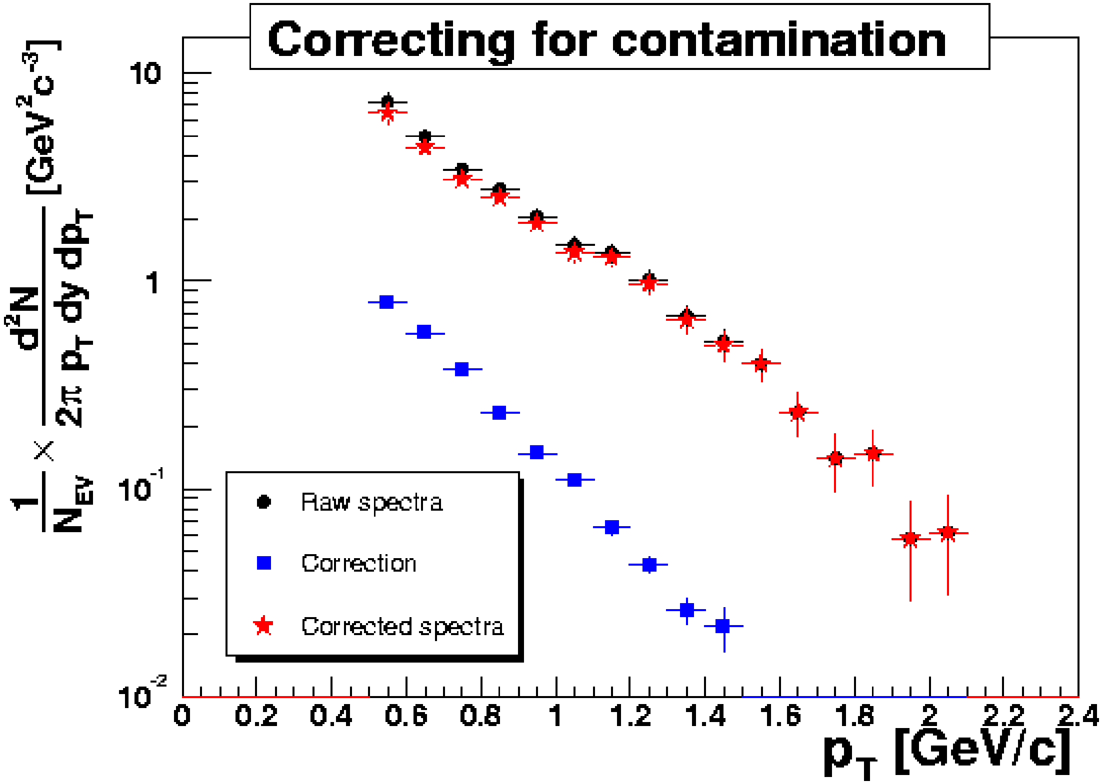


neeting

Different contamination of pi,K

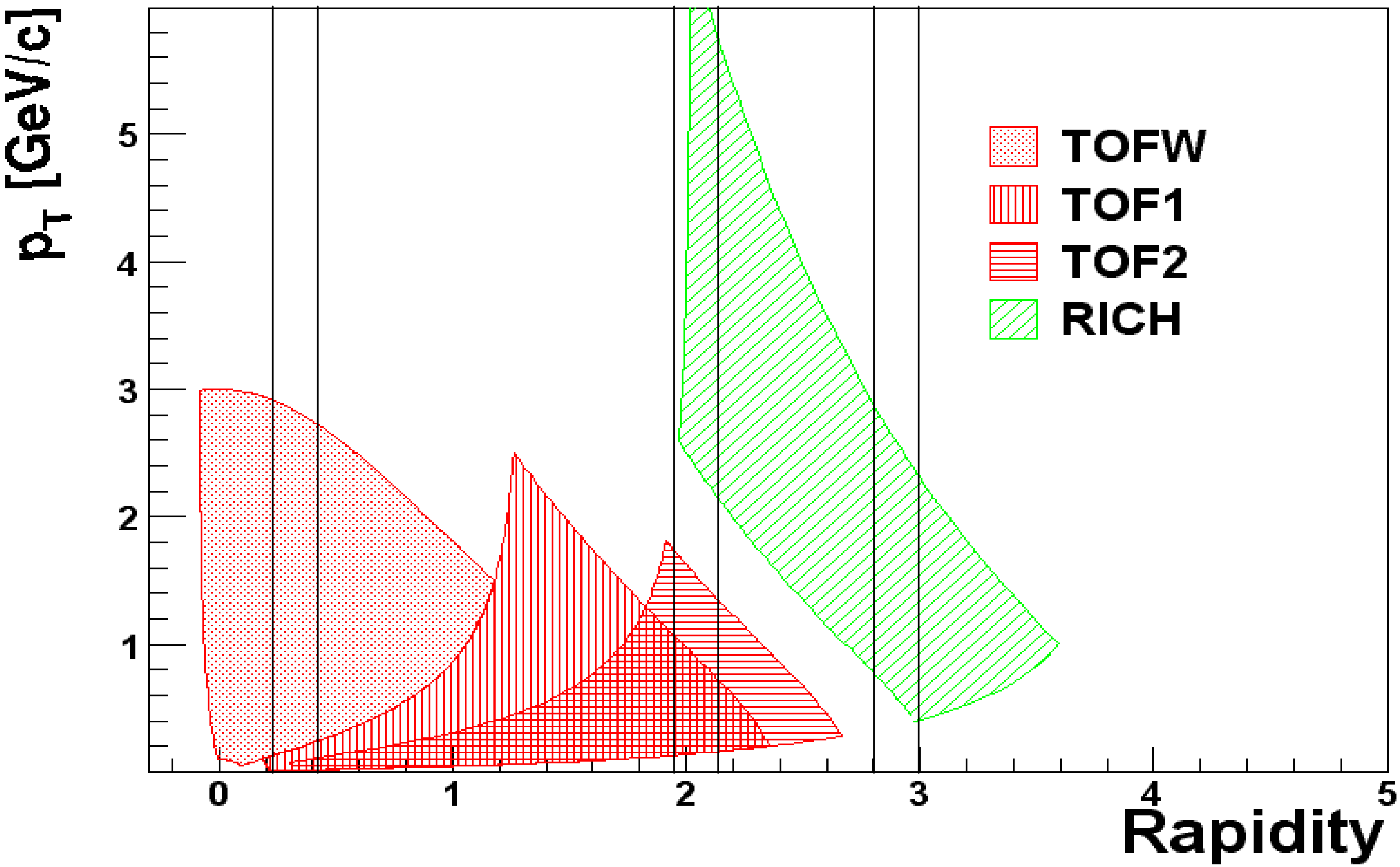


Rich efficiency 3



Do we understand the RICH (algorithm) performance and could it be enhanced ???? Does it depend on momentum. The effect of the correction is small for net-protons.

Proton and anti-proton acceptance



Constructing p_T-spectra

Invariant yield : $E\frac{d^3N}{dp^3} = \frac{d^3N}{p_T dp_T d\phi dy}$

$$\frac{1}{2\pi \mathrm{p_T}}\frac{\mathrm{d}^2N}{dy\,dp_T} = \frac{1}{2\pi \cdot \mathrm{p_T} \cdot \mathrm{N_{events}} \cdot \mathrm{NORM_{bin}}} \cdot \frac{\mathrm{CORR} \cdot \mathrm{DATA}}{\mathrm{ACC}}$$

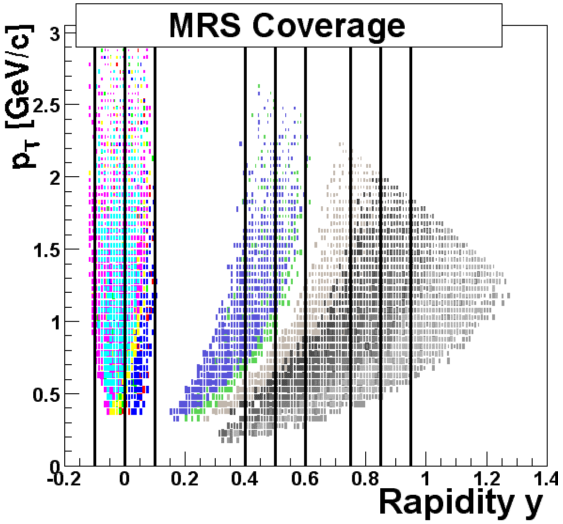
DATA : Measured protons and anti-protons

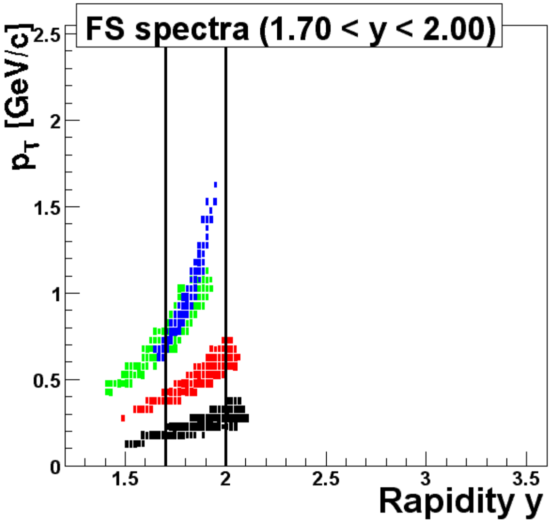
ACC : Geometrical acceptance

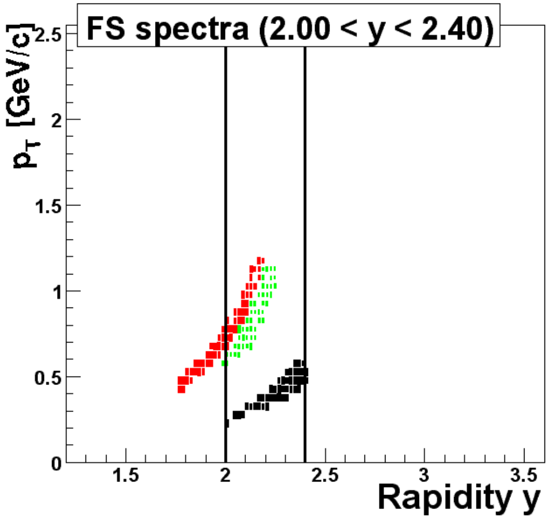
CORRections

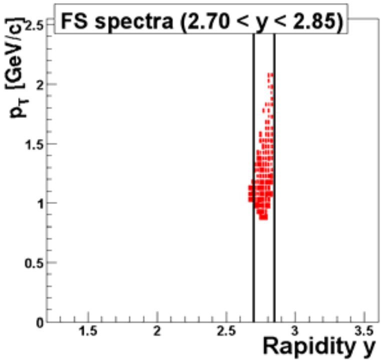
- •Tracking efficiency
- PID efficiency (slat efficiency)
- Multiple scattering and nuclear absorption correction

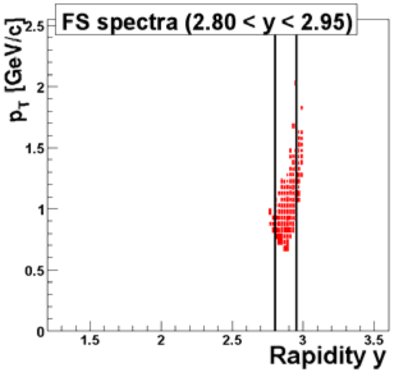
Rapidity Coverage

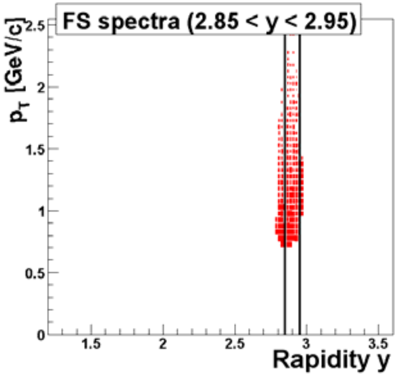


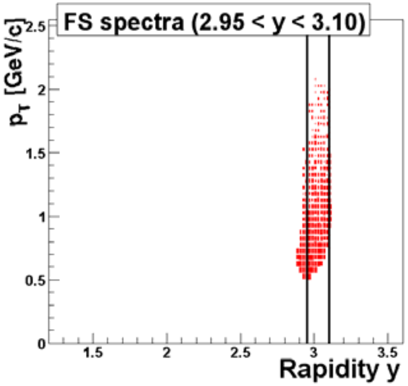




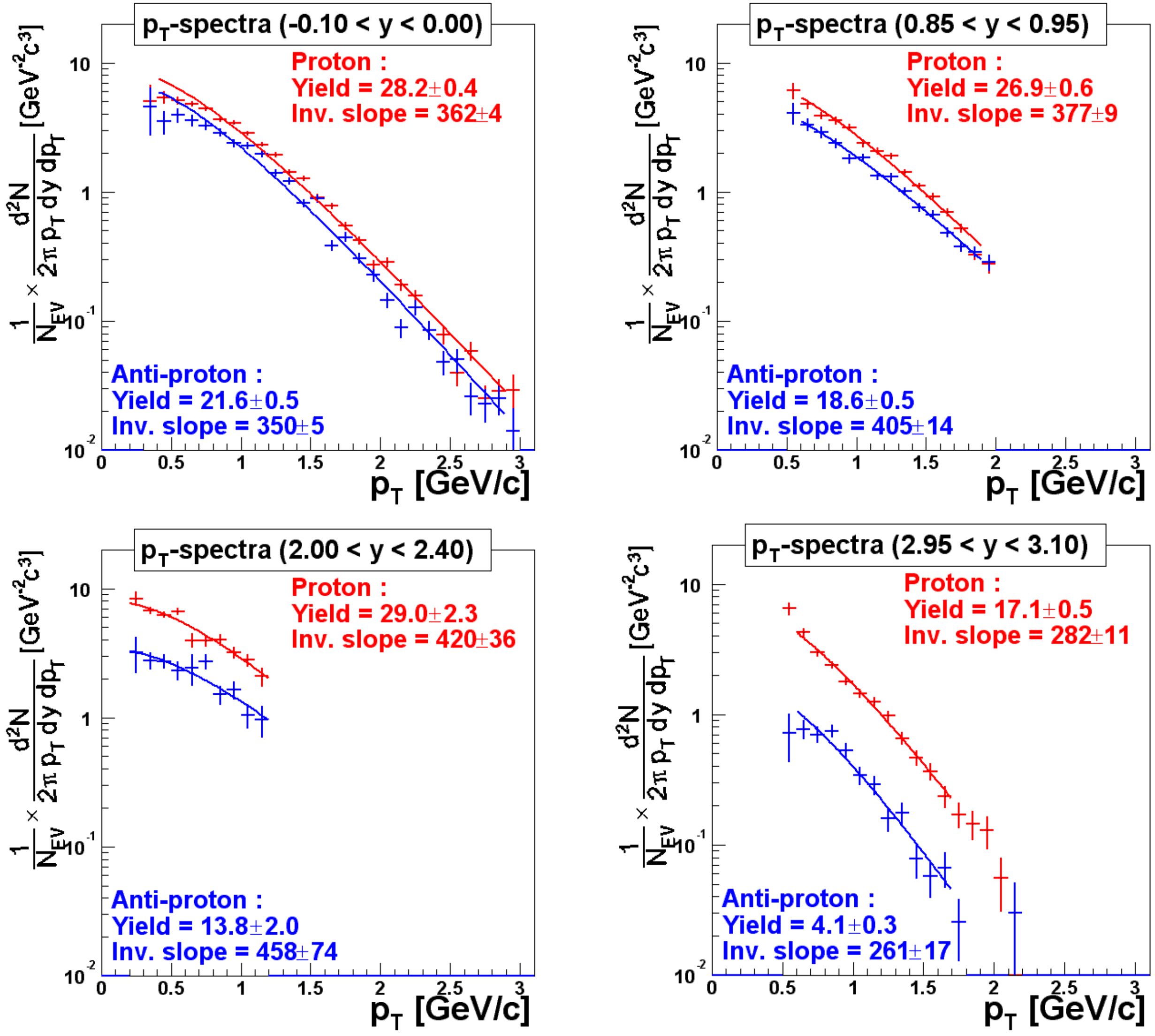






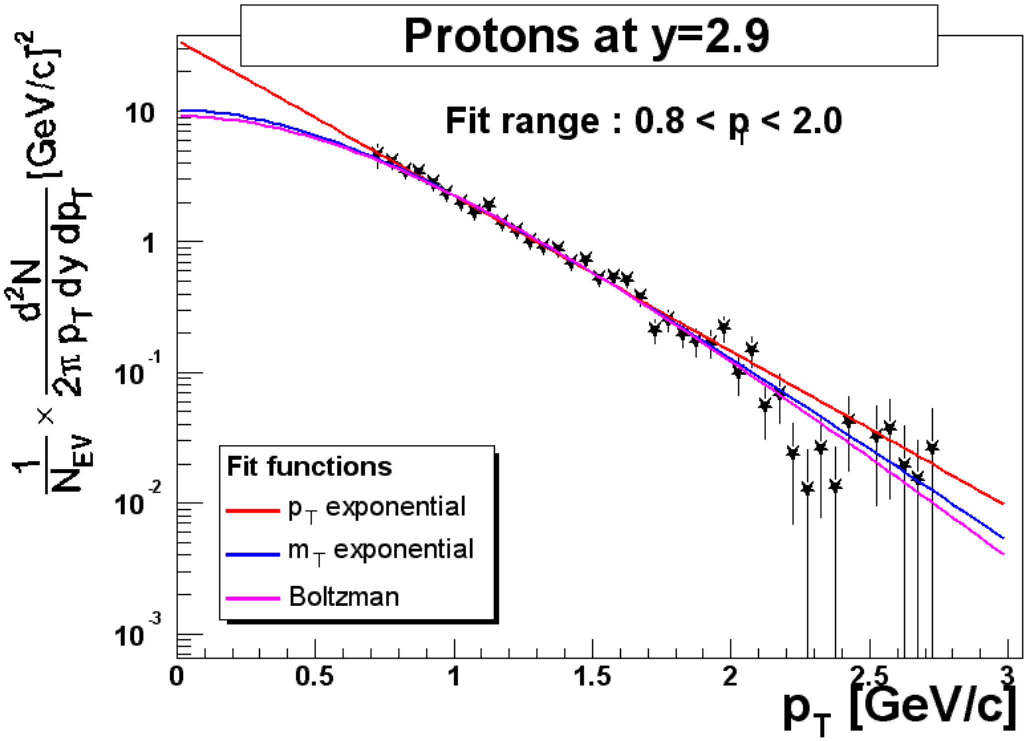


Examples of p_T-spectra



0-5%
central
collisions

Extracting dN/dy



Fit p_T spectra and use the fit to extrapolate into regions where we don't measure to get dN/dy.

$$m_T = \sqrt{m^2 + p_T^2}$$

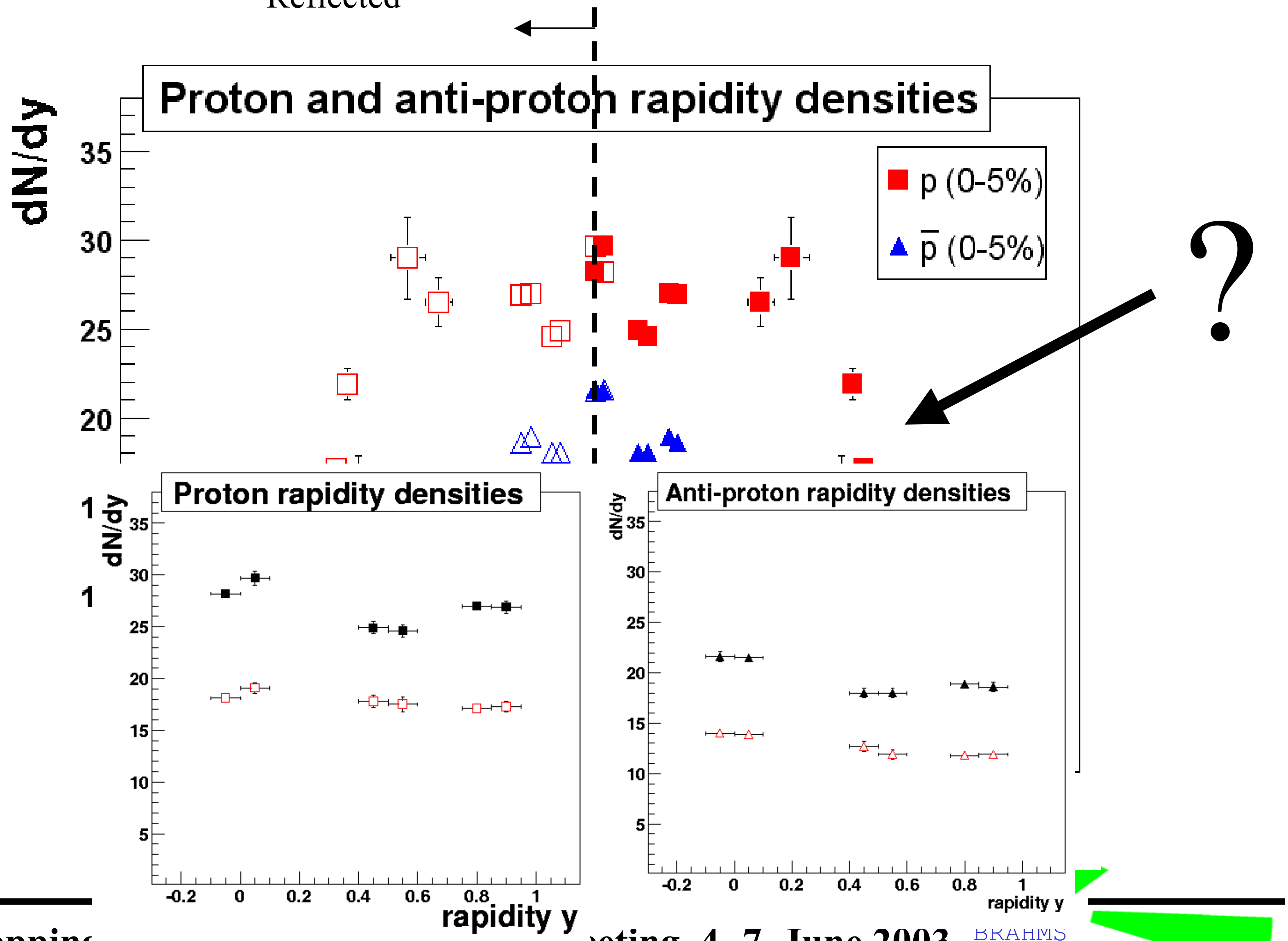
$$f(p_T) = N \cdot e^{-p_T/T}$$

$$f(p_T) = N \cdot e^{-m_T/T}$$

$$f(p_T) = N \cdot m_T \cdot e^{-m_T/T}$$

Here m_T-exponentials are used at all rapidities, but could we do better : Blast wawe or free mT exponent

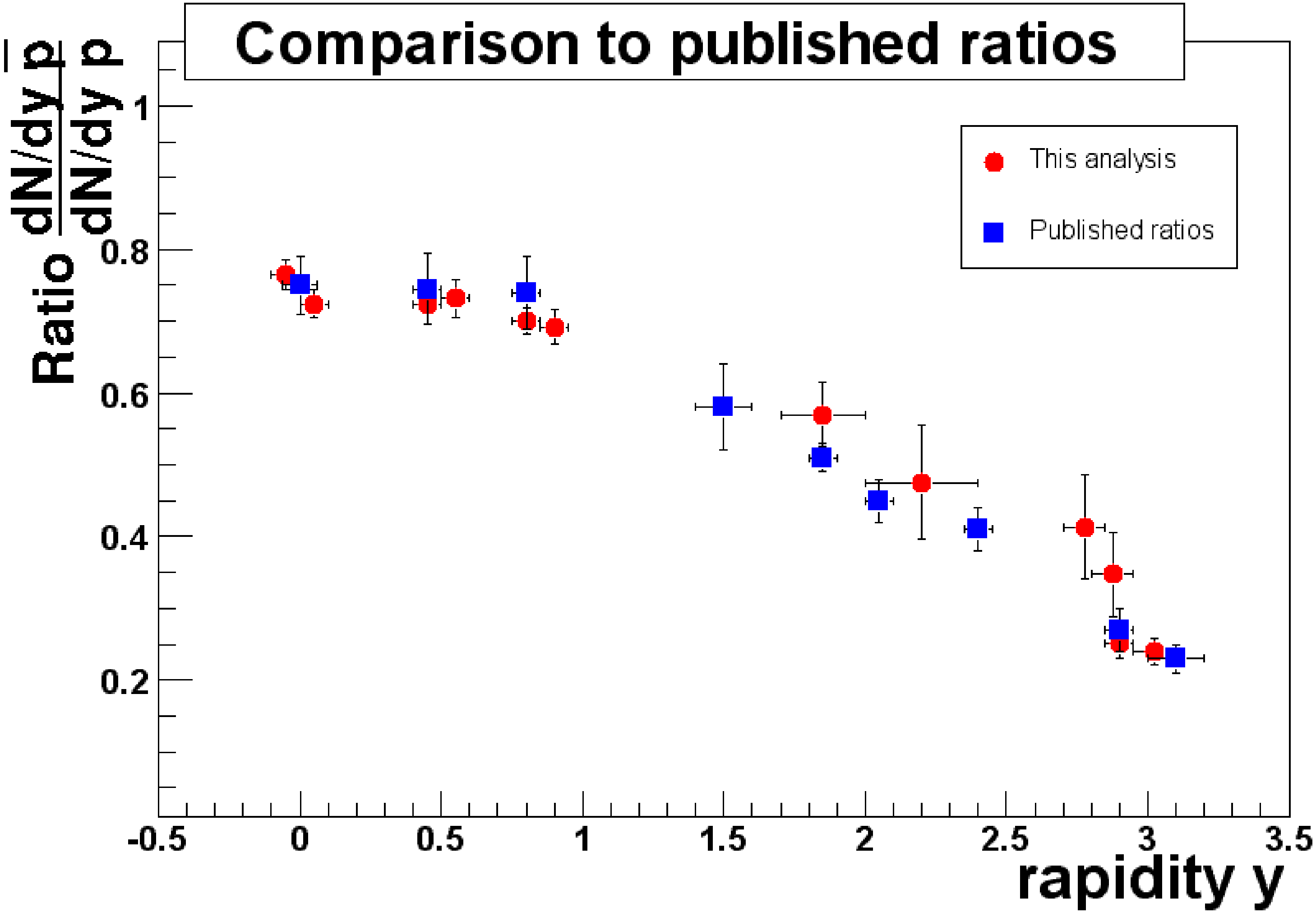
Rapidity densities dN/dy



Reflected

?

Compare to ratios



Systematic errors

Quality of data => Can we improve. Y=3 needs this

- Data : Discrepancy between measurements in the same phase space
- Fit : Variations

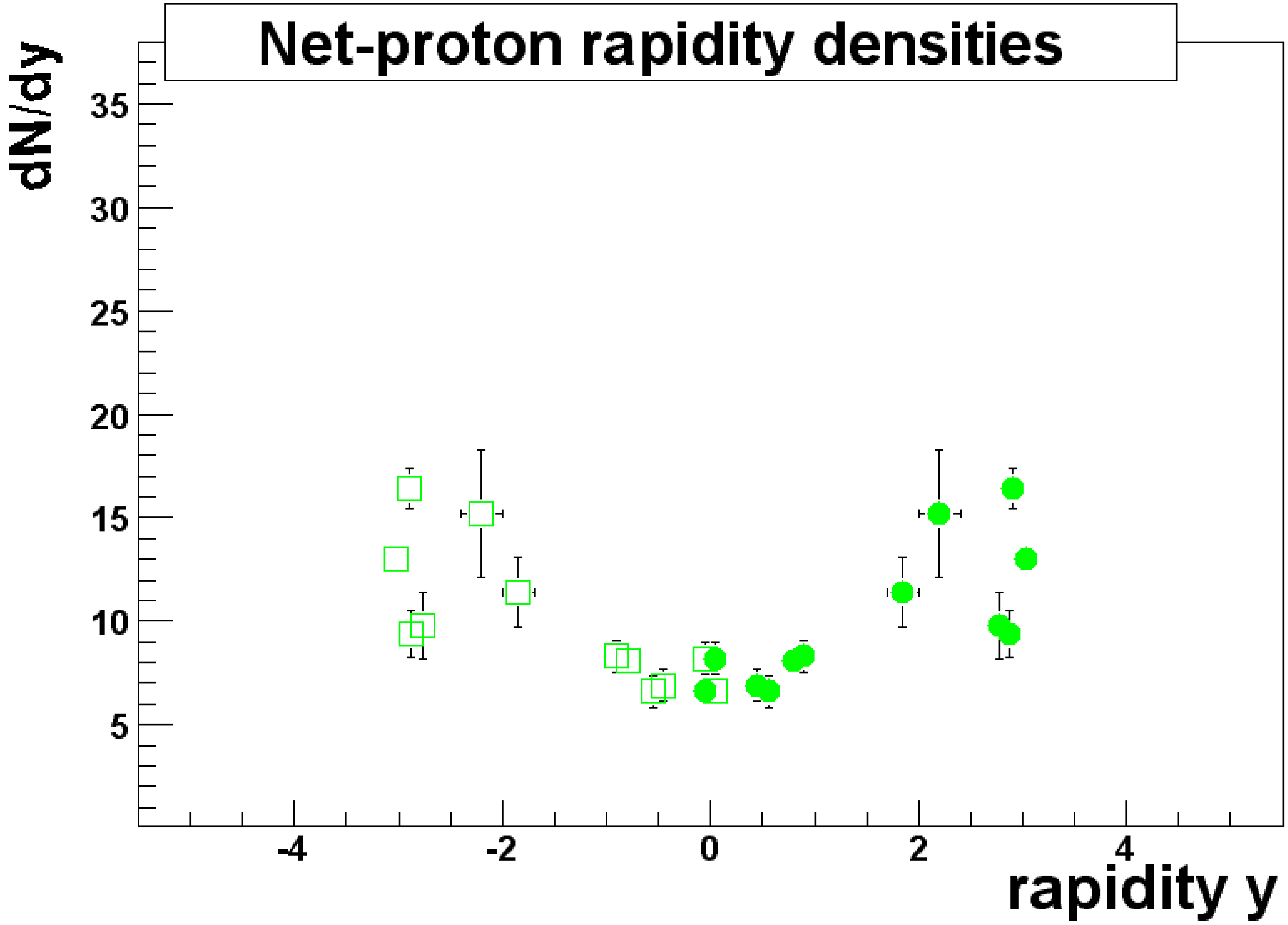
10% difference between efficiency methods. Do we understand our efficiencies = tracking. MC might tell us more

Do we understand TPC drift well enough

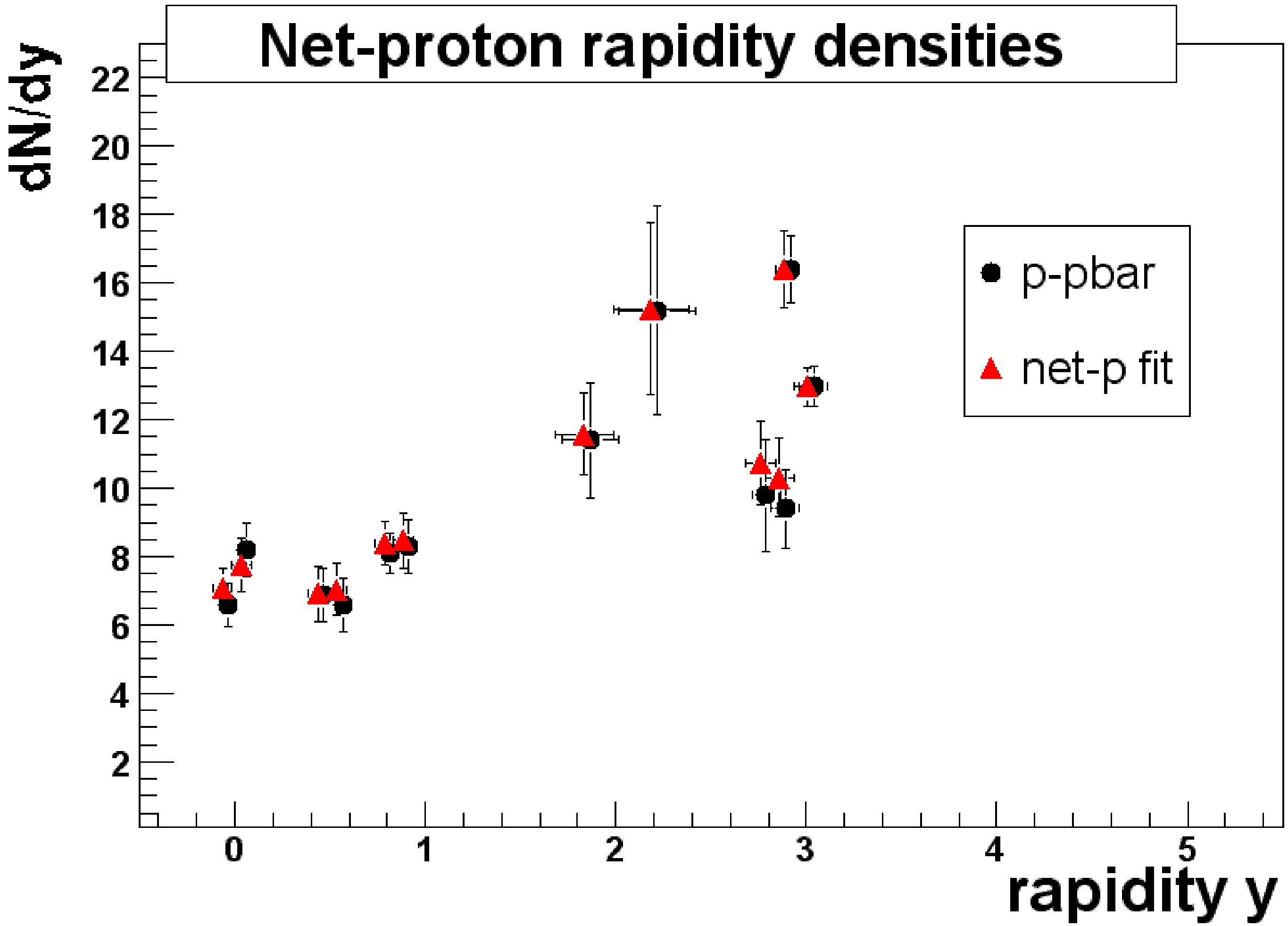
Sigma cut ?

How does yields vary with cuts ?

Net-proton dN/dy

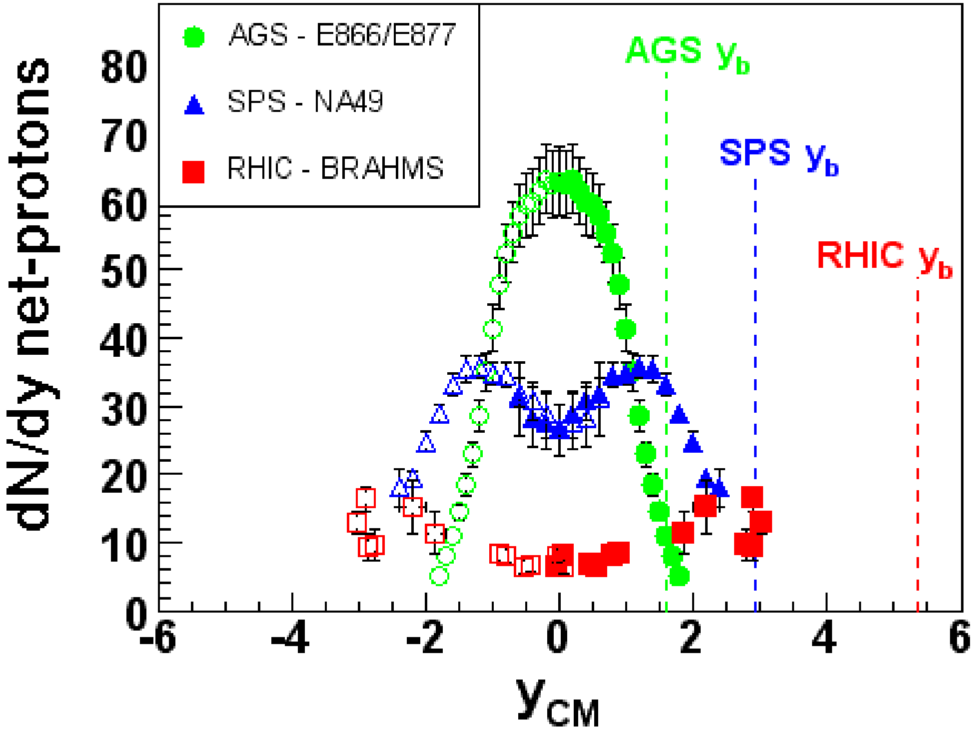


Test



Net-p fits has better chi2

Net-proton energy dependence



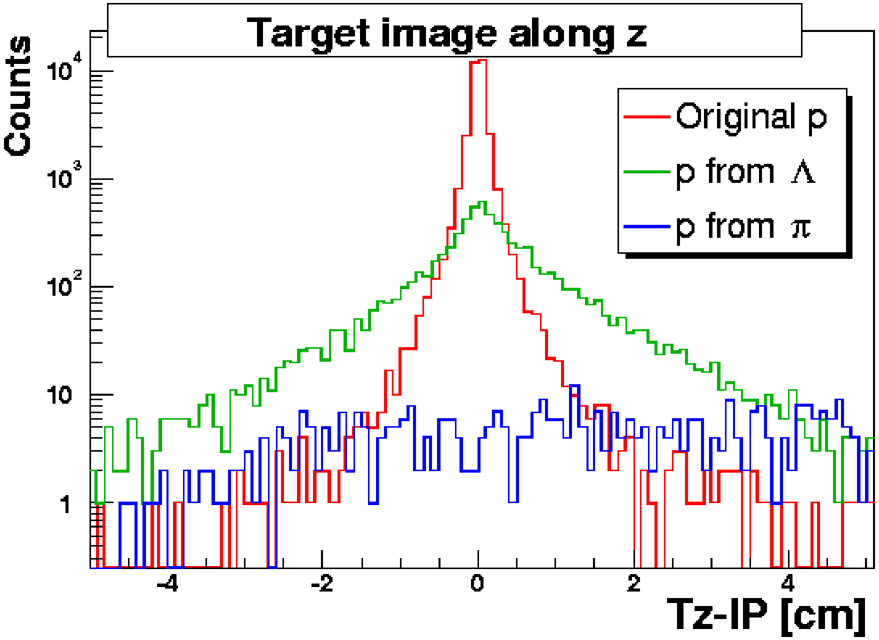
The shape of the net-proton distribution measured at RHIC is different from what is observed at lower energies.

At RHIC the mid-rapidity region is almost net-proton free. Pair production dominates at RHIC.

Comparison to Models I

Net-protons measured includes protons from hyperon decays e.g. $\Lambda \rightarrow p + \pi^-$.

To compare with models the protons from hyperon decays have to be removed. BRAHMS does not measure Λ, instead we use models and simulations to correct :

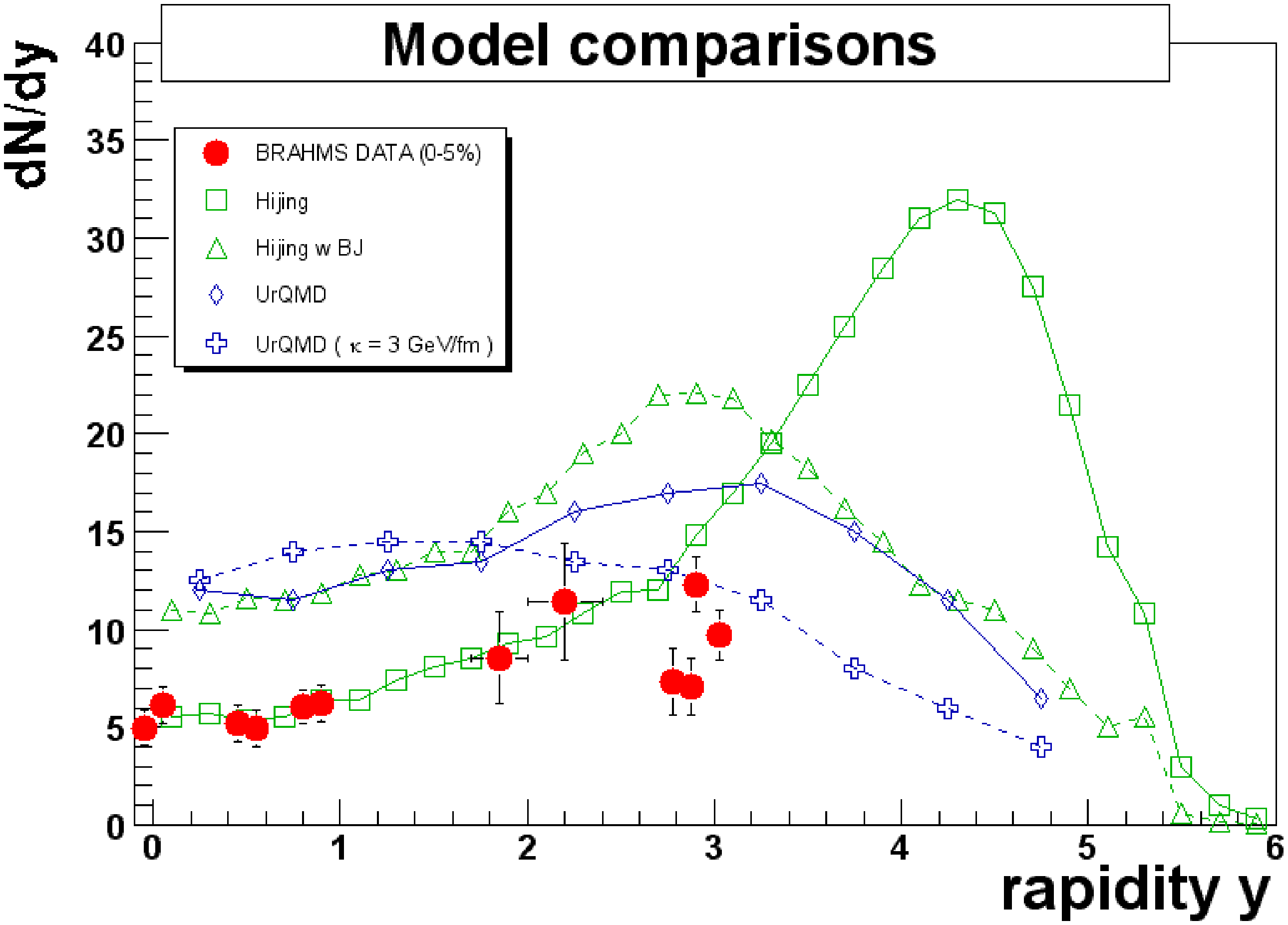


$$C = \frac{N_p}{N_p + s \cdot N_\Lambda + s \cdot N_{\Sigma^+}}$$

HIJING : s = 0.9/0.4

C~0.75 at all rapidities

Comparison to Models II

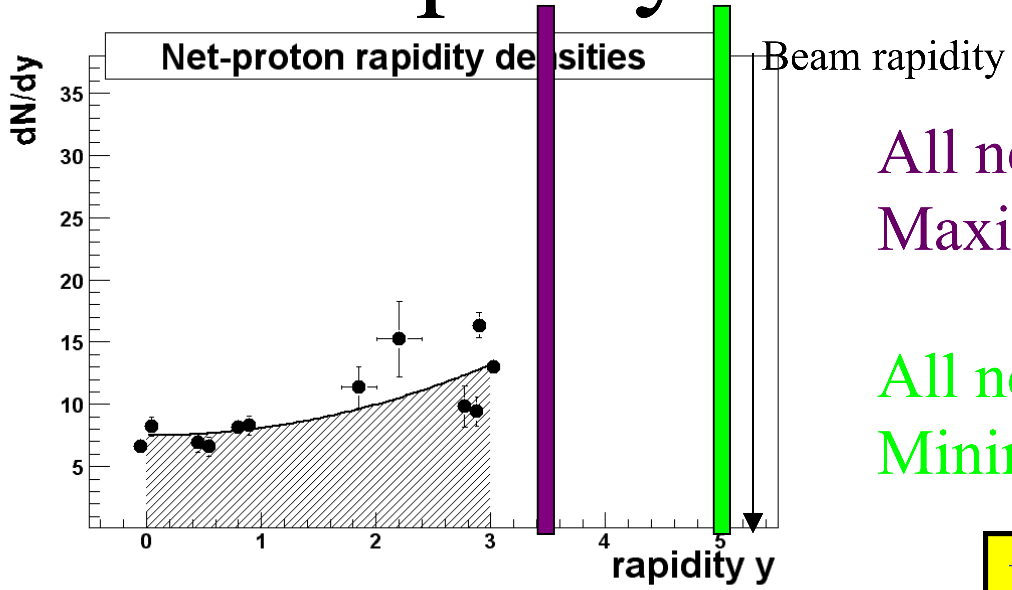


Hijing (Strings, no rescattering)

UrQMD (Transport calculation, resonance excitations, rescattering)

Hijing describes the data best, BUT Hijing does not reproduce Λ/p (y=0) or p-bar/p (0<y<3)

Rapidity Loss Estimates



All net-protons at $y = 3.5$
Maximal rel. rap. loss = 0.24

All net-protons at $y = 5.0$
Minimal rel. rap. loss = 0.16

29 net-protons measured ($0 < y < 3$)

Estimate total :

350 participants 140 initial protons

Assume 140 total ⇒ 70 ($y>0$)

⇒ 41 outside acceptance ($y>3$)

Example of processes :

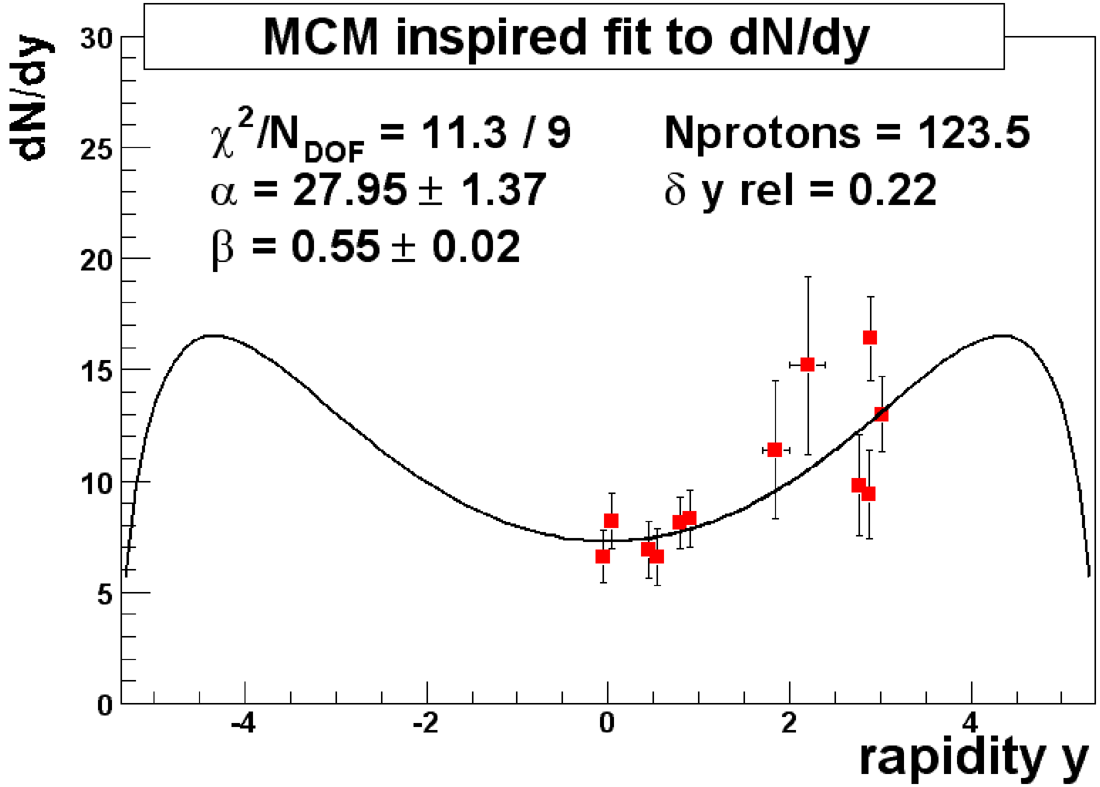
$p+p \rightarrow n+p+\pi^+$ ($p \rightarrow n$)

$n+n \rightarrow n+p+\pi^-$ ($n \rightarrow p$)

$p+N \rightarrow \Lambda + K^+ + N$ ($p \rightarrow \Lambda$)

$\Lambda \rightarrow p + \pi^-$ ($\Lambda \rightarrow p$)

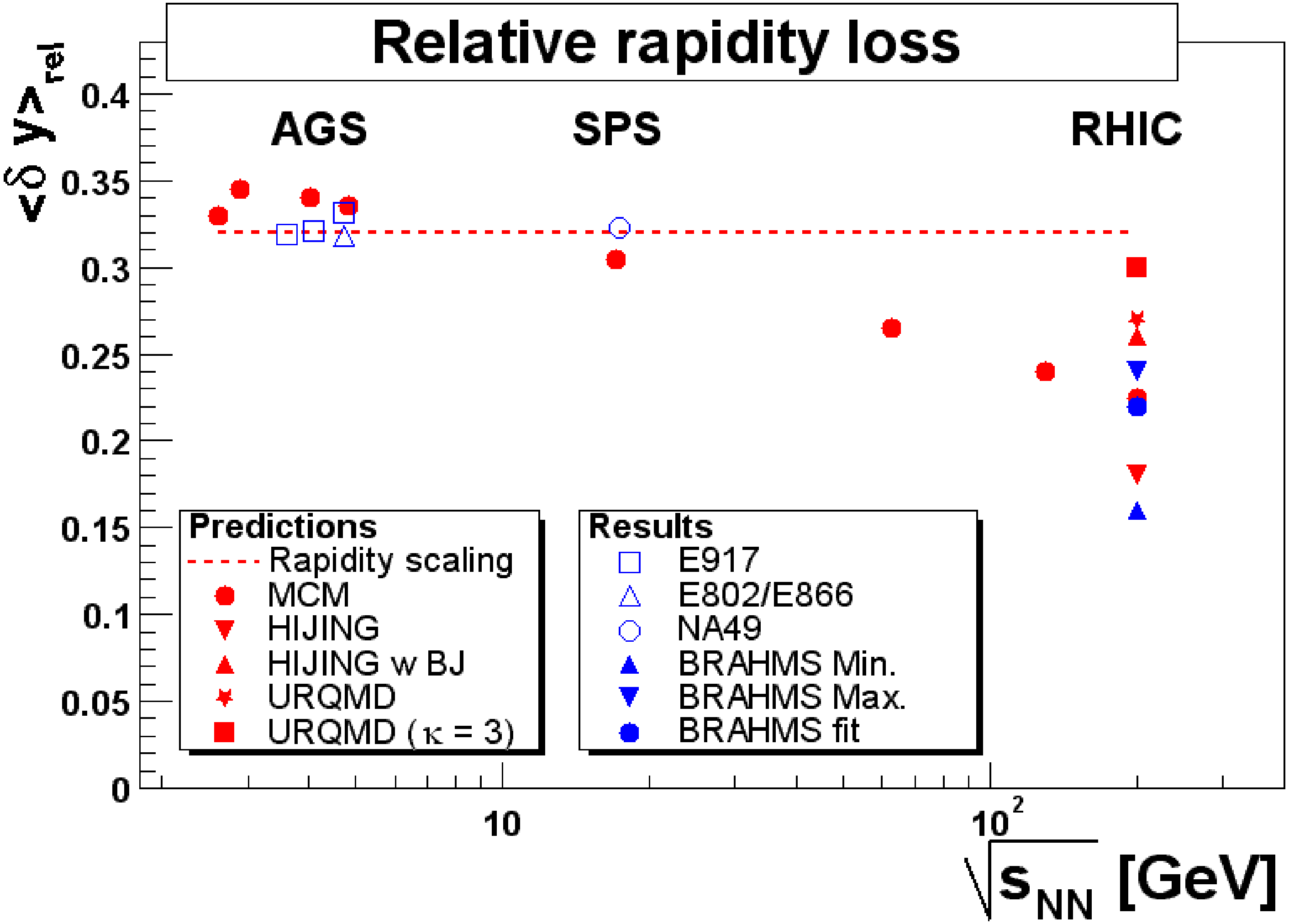
Rapidity Loss (MCM fit)



Fit the data with the MCM inspired function :

$$f(x) = N(x^{\alpha}e^{-\alpha} + (Y-x)^{\alpha}e^{-\alpha(Y-x)}) \text{ where } x = y + y_{beam}$$

Rapidity Loss Results

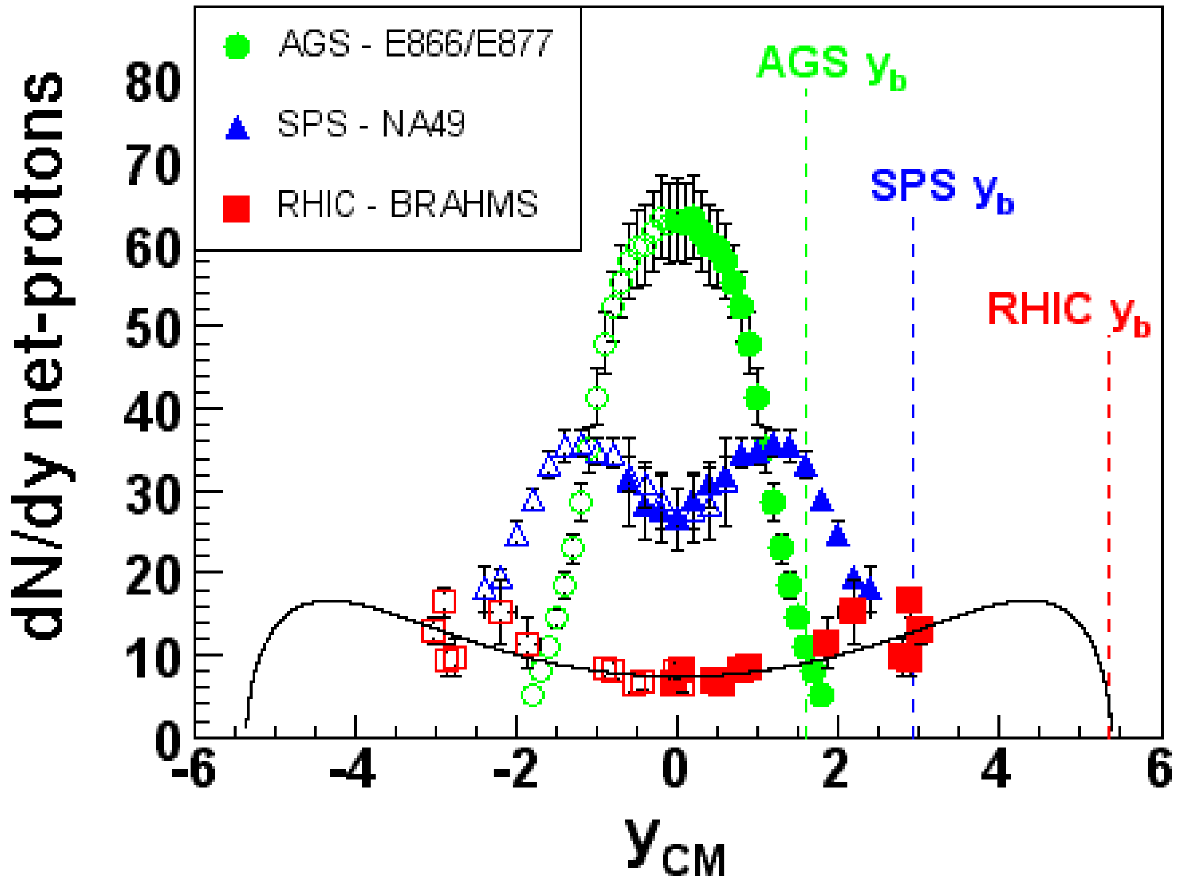


BLUE is DATA

RED is MODELS

Constant relative rapidity loss is broken at RHIC.

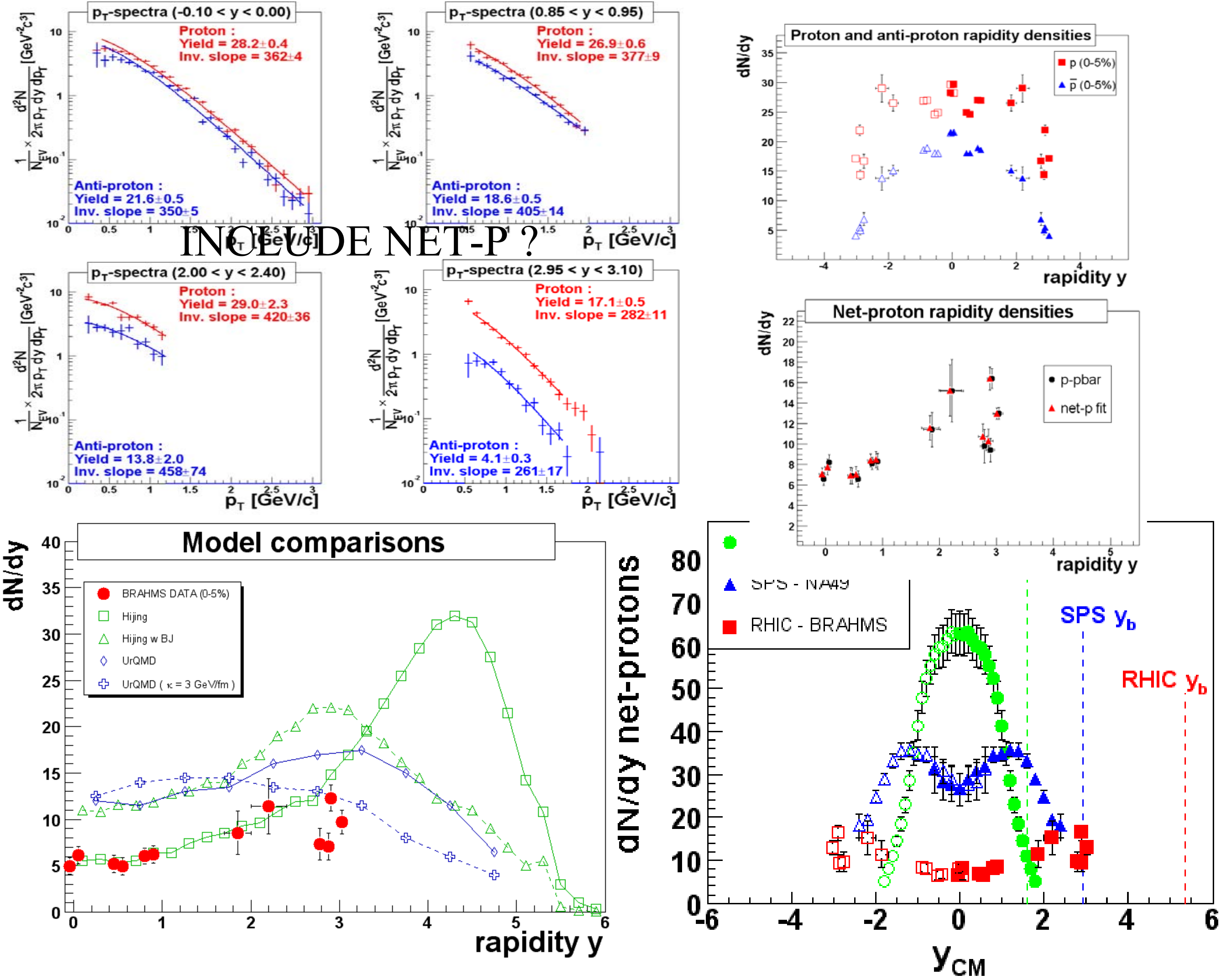
Net-proton energy dependence



Four plots for a PRL

1. pT spectra
2. Proton and anti-proton yields and Net-proton yields 2 methods
3. Net-p vs models
4. Net-proton vs energy
5. Net-baryons ? Rapidity loss

Should we try to get net-baryons ala NA49. The advantage is that then we know there is 350 from Glauber calculations.



INCLUDE NET-P ?

Conclusions

There should be a BRAHM web page with thesis's!!!!!

Data shows :

Transparency (Bjorken)

Rapidity scaling broken

Problems :

Y=3 discrepancy

Estimating systematic errors

SHOULD WE PUBLISH SOON ?????????? Make plan.

Model predictions

- Geometric Glauber model calculations can be used to calculate the collision geometry.
- Most interactions are *soft* so pQCD can not be used.
- The physics learned from p+p collisions can be used as a starting point, but there are important differences :

  Formation times, Off-shell cross sections, Rescattering

The models chosen are :

- MCM (Simple)
- Hijing (Strings)
- UrQMD (Transport)

Multi Chain Model I

$$\frac{dN^{BA\to pX}}{dy}(y) = r_B W_B \sum_{n=1}^{N_A} P_{B/A}(n) Q_n(Y-y) + r_A W_A \sum_{m=1}^{N_B} P_{A/B}(m) Q_m(y)$$

B is the projectile(y=Y),
A is the target(y=0)

r is the ratio of protons to nucleons

W is the number of participants

P(n) is the fraction of nucleons that has n binary collisions

Q are the fragmentation functions that contains the physics

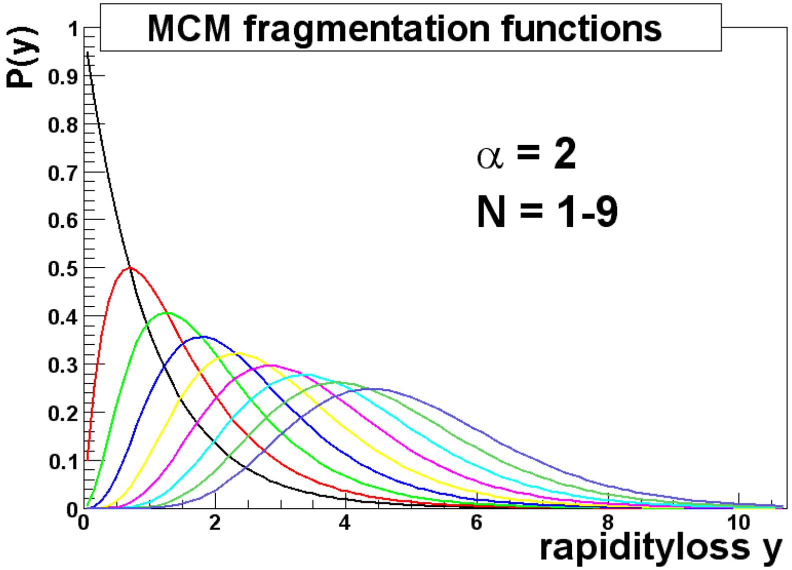
$Q_1(y)$ is the p+p fragmentation function $Q_1(y)=e^{-y}$

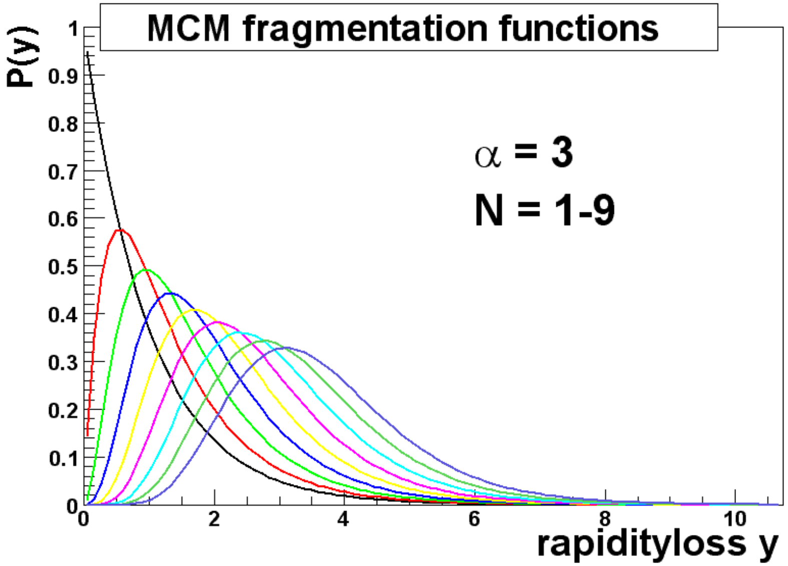
$Q_2(y)$ is in the simplest case made from $Q_1(y_1)Q_1(y-y_1)$

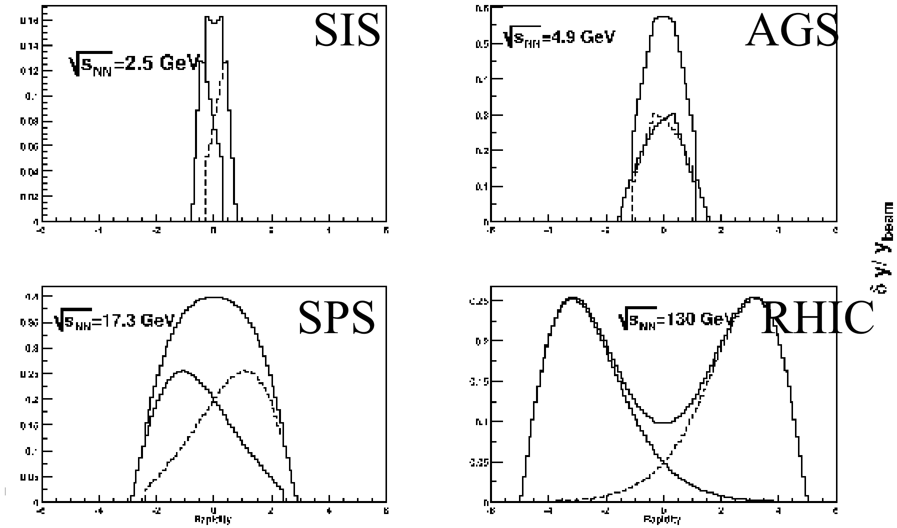
But in general a different fragmentation function is used for collisions after the first $Q_1^*(y)=e^{-\alpha y}$. This gives the general

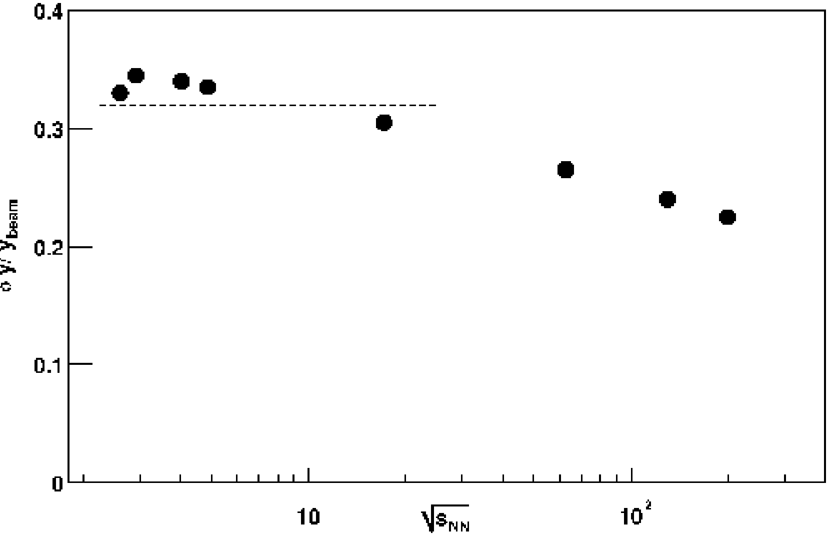
$$Q_n(y) = \left(\frac{\alpha}{\alpha-1}\right)^{n-1}\left[e^{-y} - e^{-\alpha y}\sum_{m=0}^{n-2}\frac{1}{m!}(\alpha-1)^m y^m\right]$$

Multi Chain Model II









Bottom picture calculations done by F. Videbæk, nucl-ex/0106017

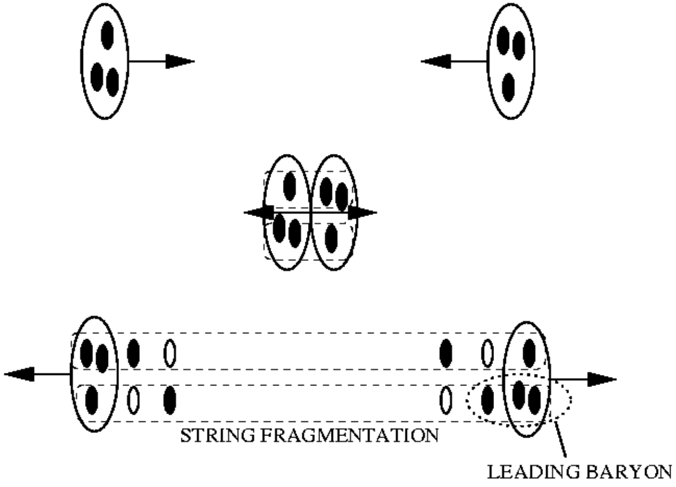
Hijing

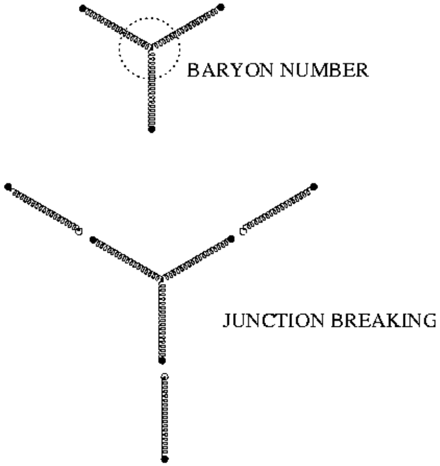
Energy lost in hard scatterings is resolved first.

All the soft scatterings results in string excitations.

The strings decays after all collisions have been resolved according to Lund string model (JETSET).

The strings can be (de)excited by more scatterings after they are created with a modified probability.





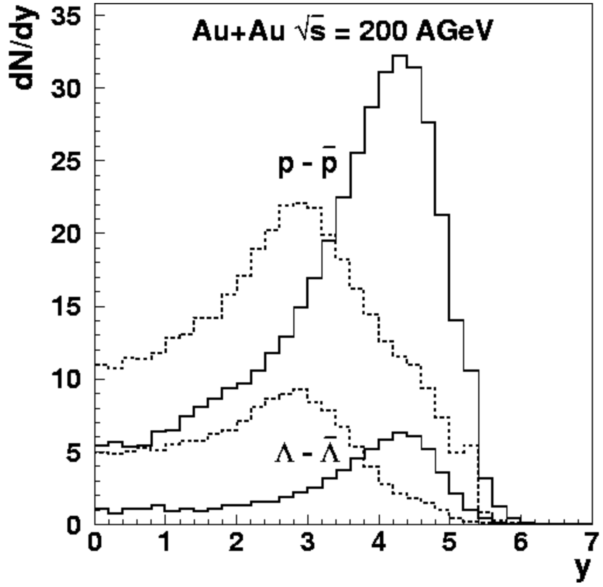
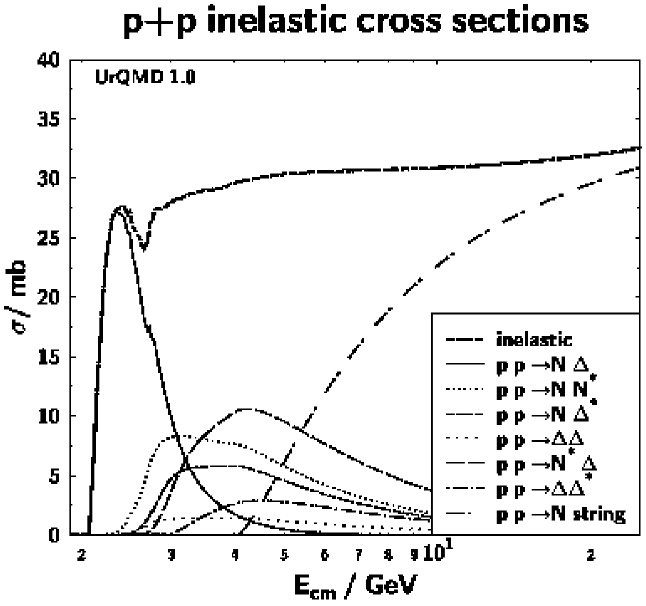


Figure is taken from Phys. Lett. B 443, p 45

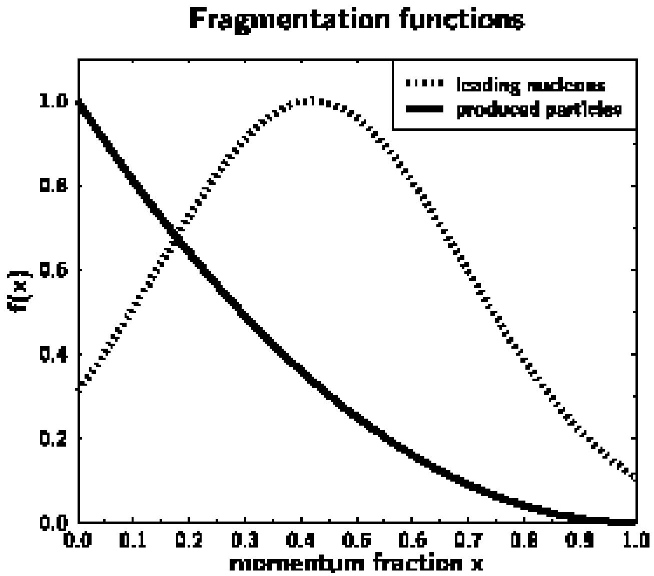
UrQMD

Transport theory. Only 12→34 scatterings. All particle production from decays. Propagate as free particle between scatterings.

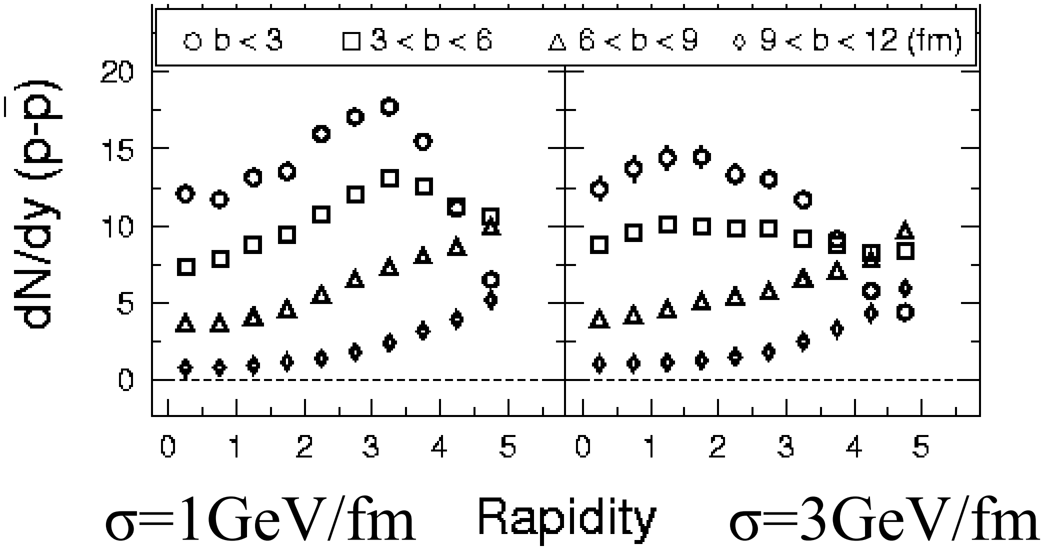
Reduced cross section of strings and decay time of strings is important. Strings decay time $\propto 1/\sigma$.



p+p inelastic cross sections

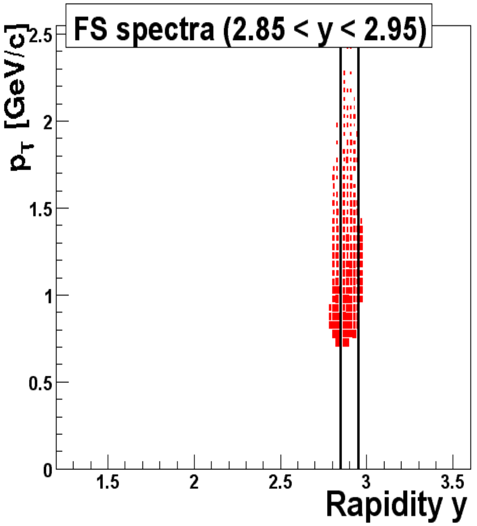


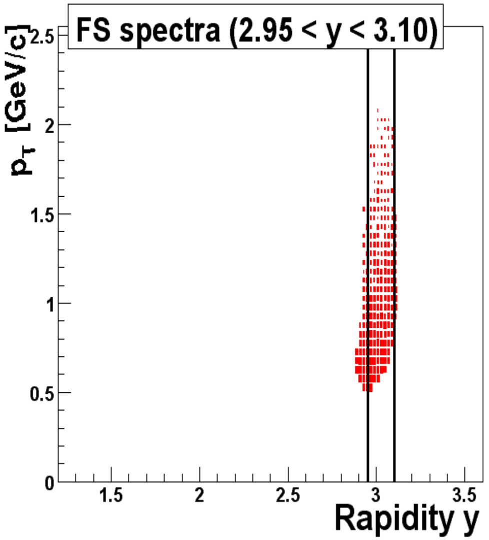
Fragmentation functions



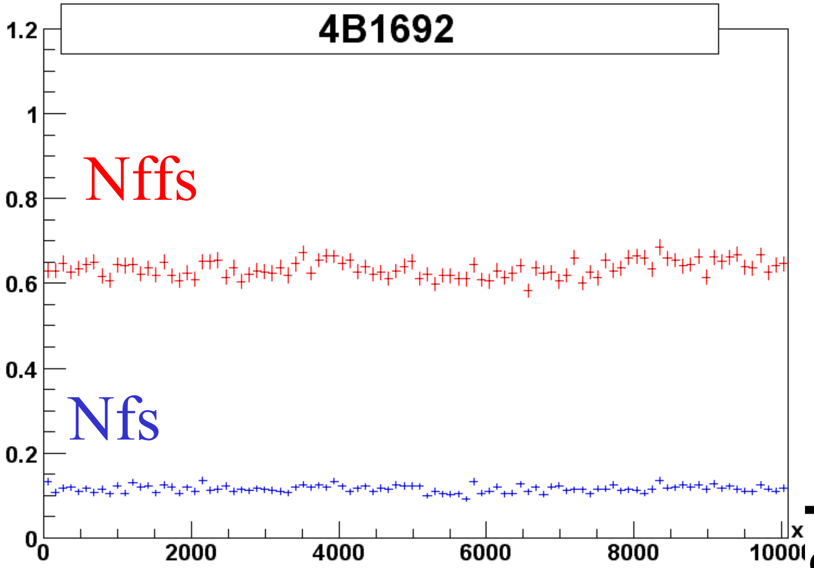
Y=3 discrepancy 1

4 deg
HIGH value

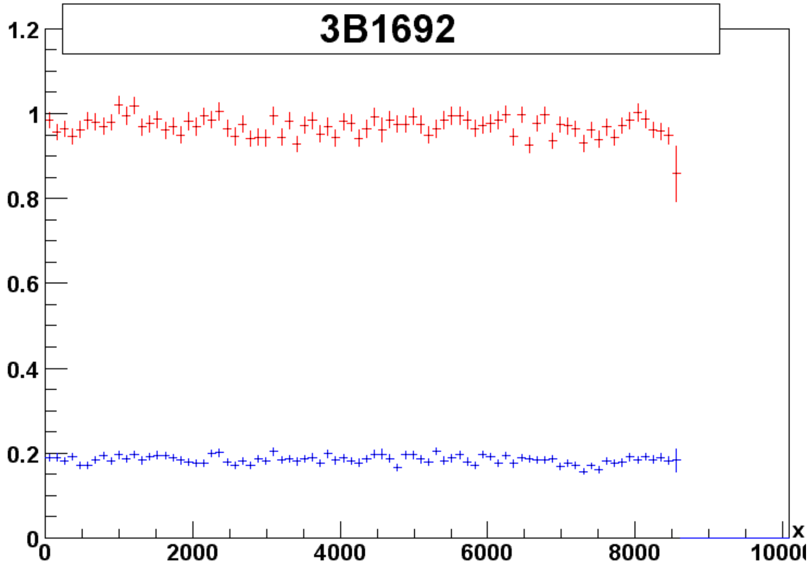




3 deg
LOW value



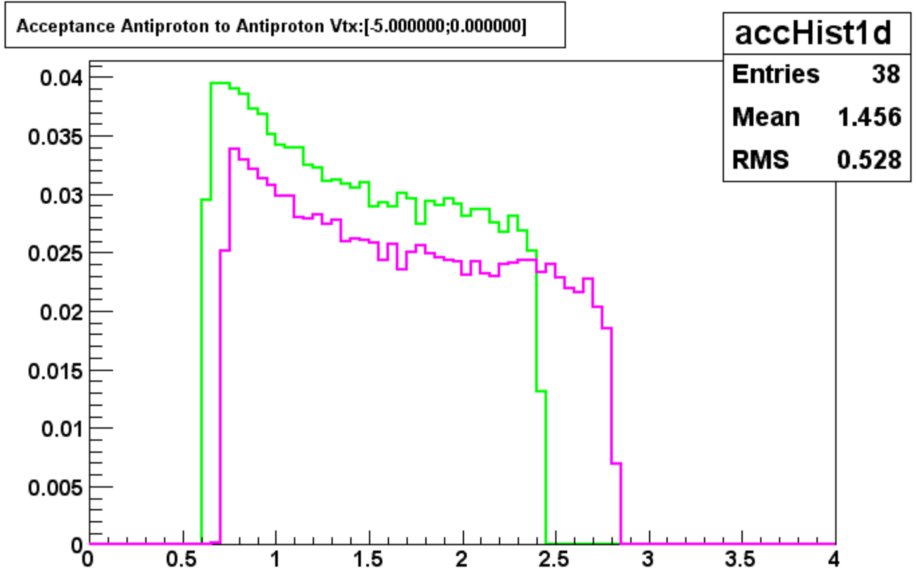
eet

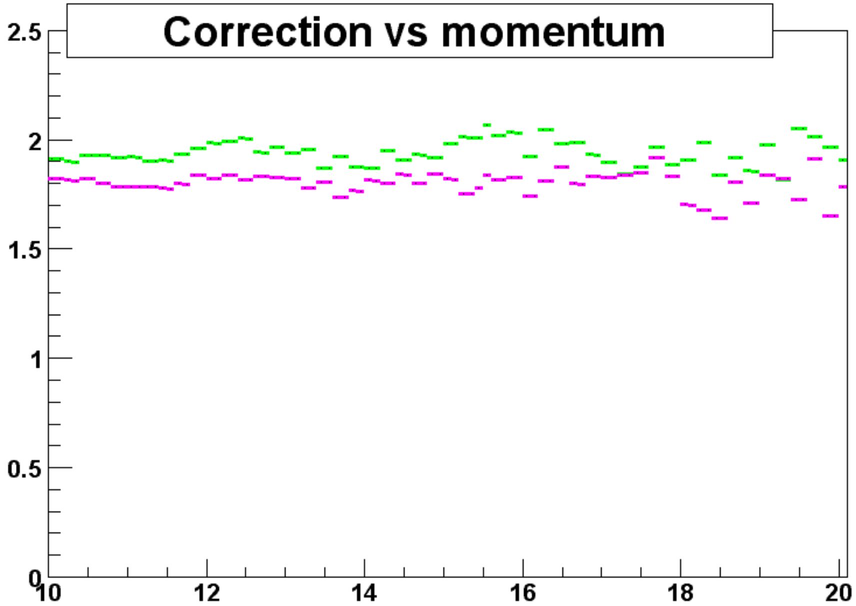


Y=3 discrepancy 2

4 deg
HIGH value

3 deg
LOW value





Net-protons vs Net

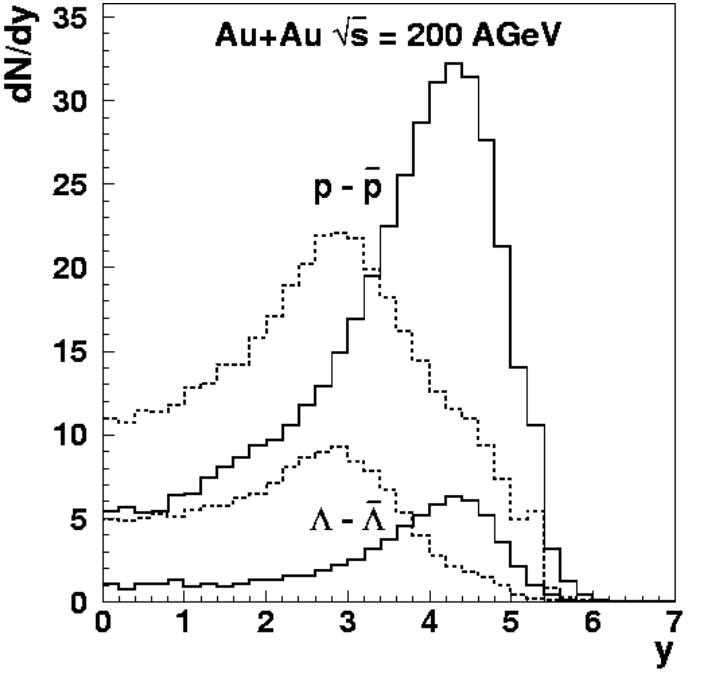
The effect of lambdas.

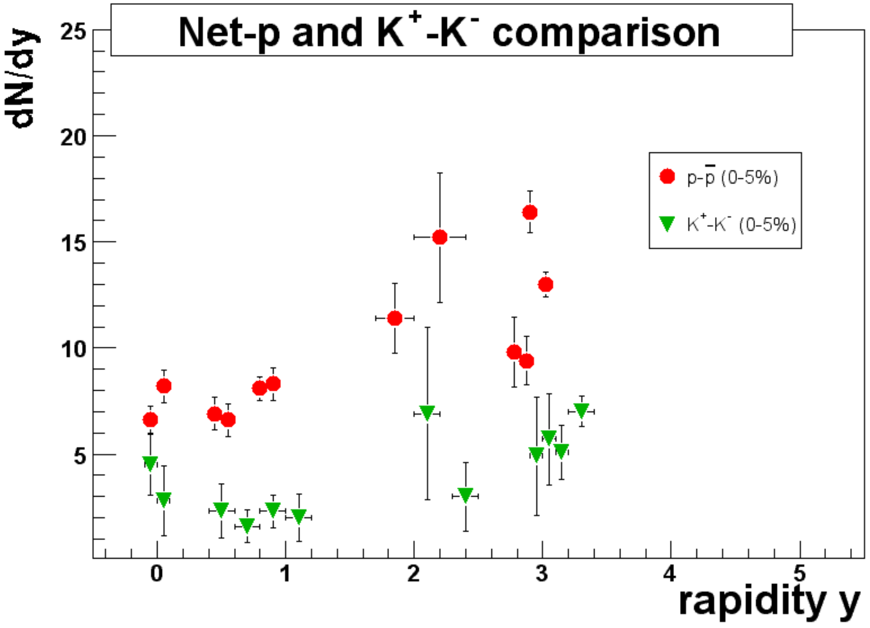
$\Lambda \rightarrow p+\pi^-$

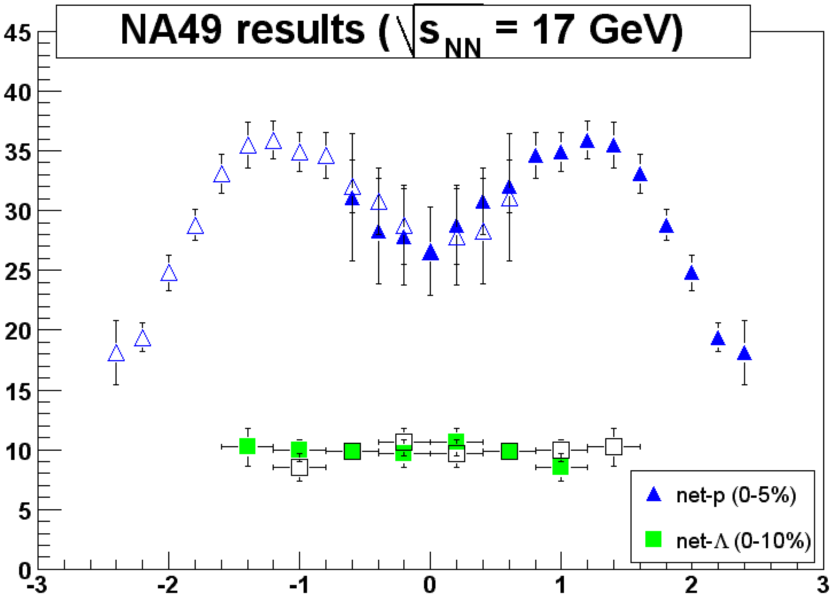
Associated production

$p \rightarrow \Lambda + K^+$

HIJING SIMULATION





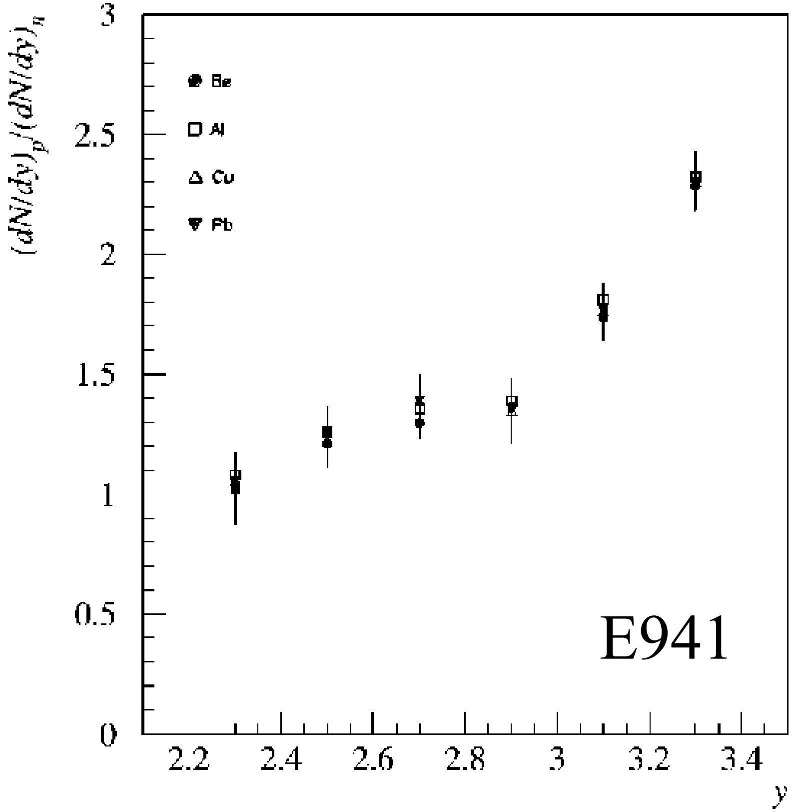


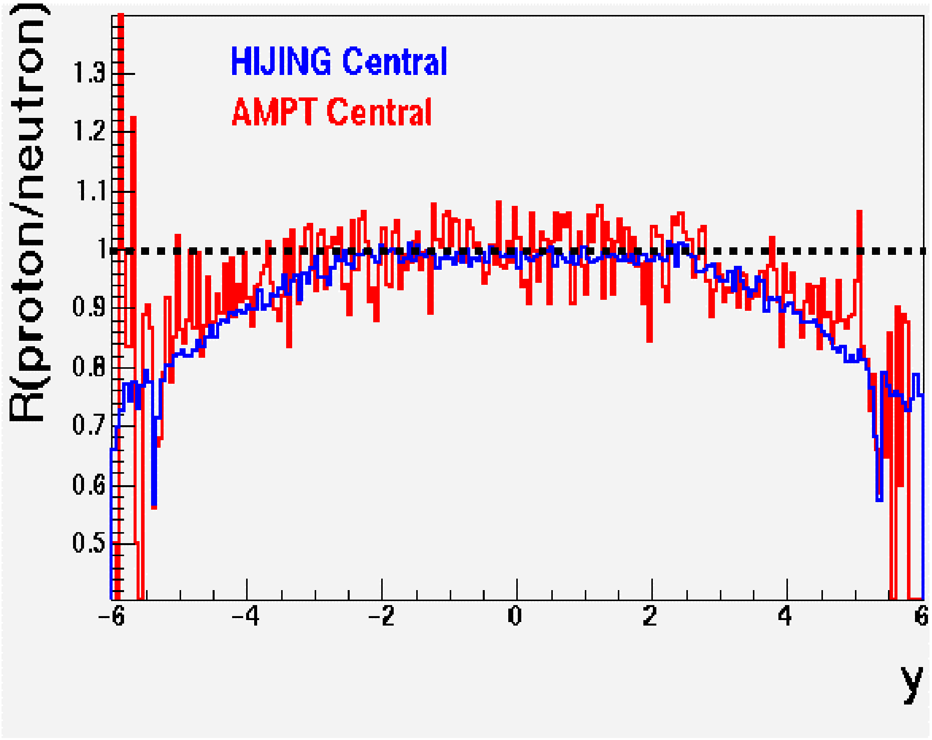
Net-protons vs Net-baryons 2

The effect of neutrons :

19GeVp+Be,Al,Cu,Pb (min. bias)

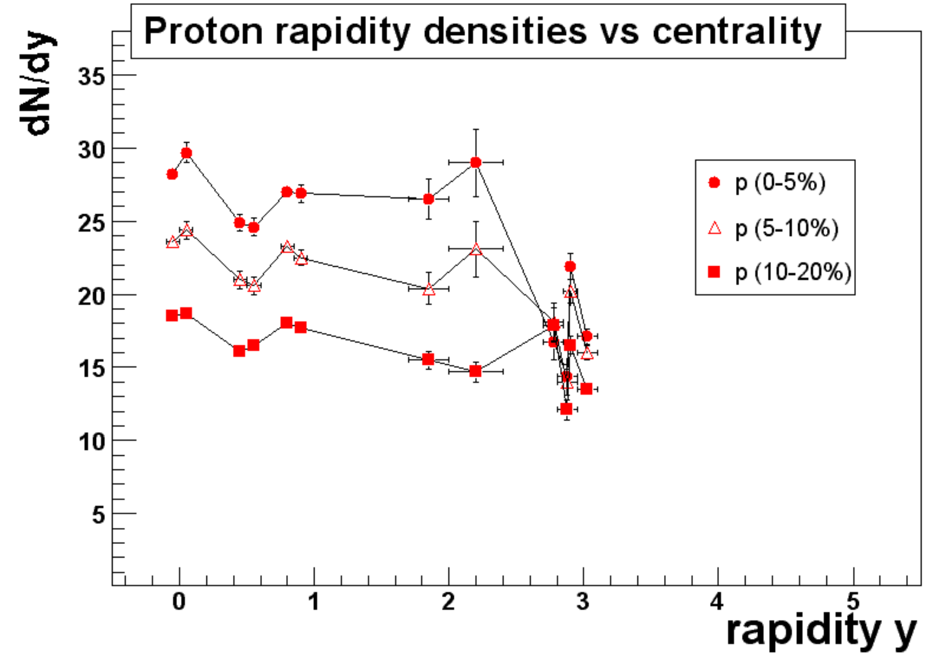
RHIC simulations



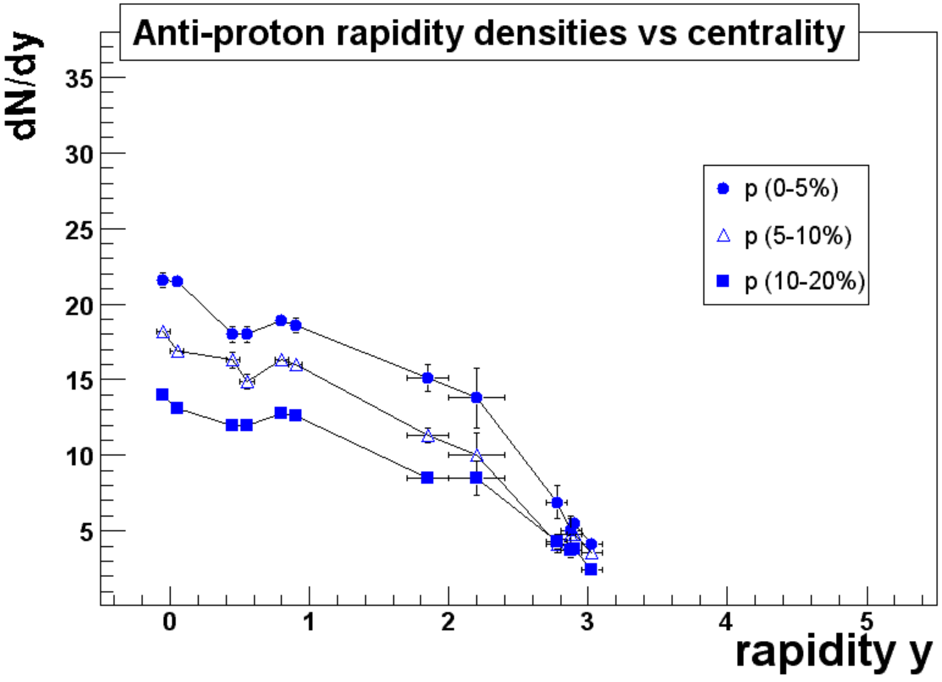


ybeam = 3.7

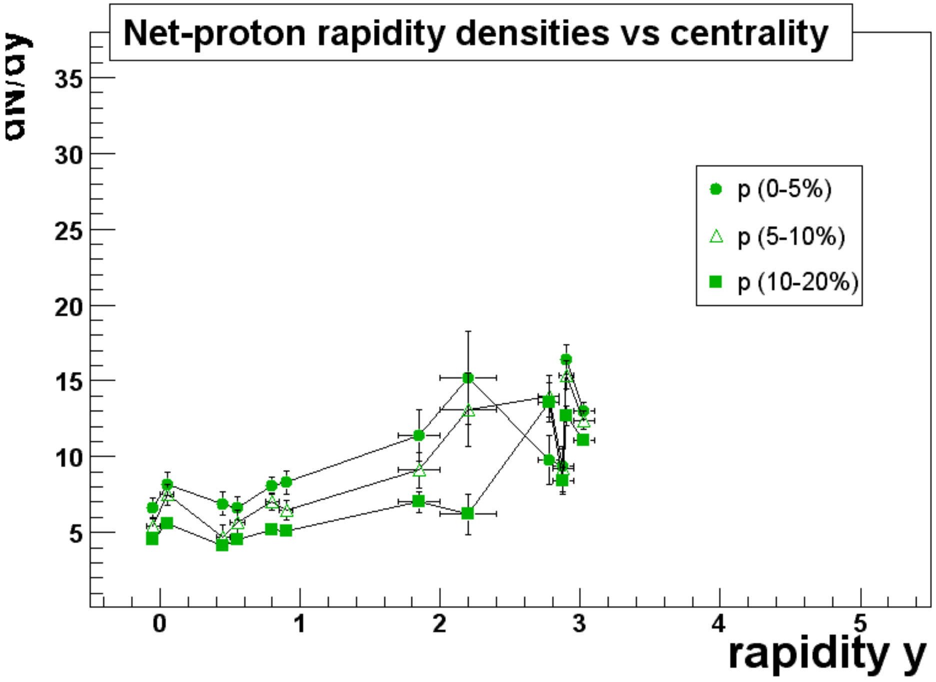
Cen l



Proton rapidity densities vs centrality



Anti-proton rapidity densities vs centrality



Net-proton rapidity densities vs centrality

Centrality dependence 2