STAR identified particle measurements at high transverse momentum in p+p at $\sqrt{s_{NN}}$ = 200 GeV

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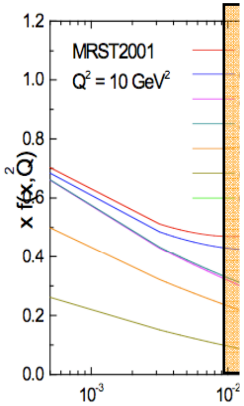
for the STAR Collaboration

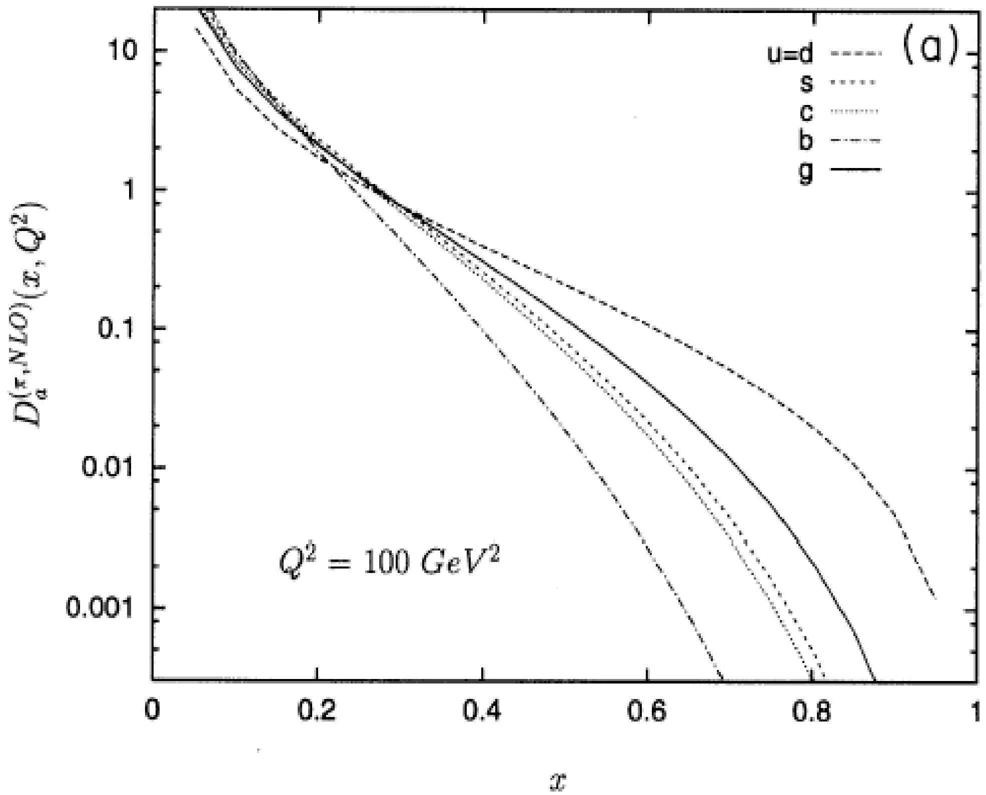
- Motivation
- STAR experiment
- Results
  - P_T-Spectra compared to NLO results
  - Quark vs Gluon jets
  - Particle ratios vs PYTHIA
- Conclusions

Perturbative QCD Ansatz

$$\frac{d\sigma^{h}_{pp}}{dy\,d^{2}p_{T}} = K \sum_{abcd} \int dx_a dx_b\, f_a(x_a,Q^2)\, f_b(x_b,Q^2)\, \frac{d\sigma}{d\hat{t}}(ab \rightarrow cd)\, \frac{D^{0}_{h/c}}{\pi z_c}$$

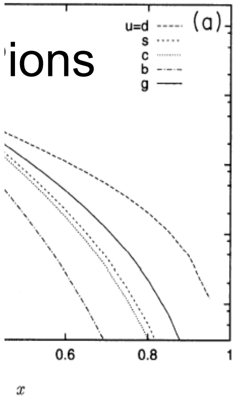
Parton Distrib
(non-pert.)





ion Function

ions

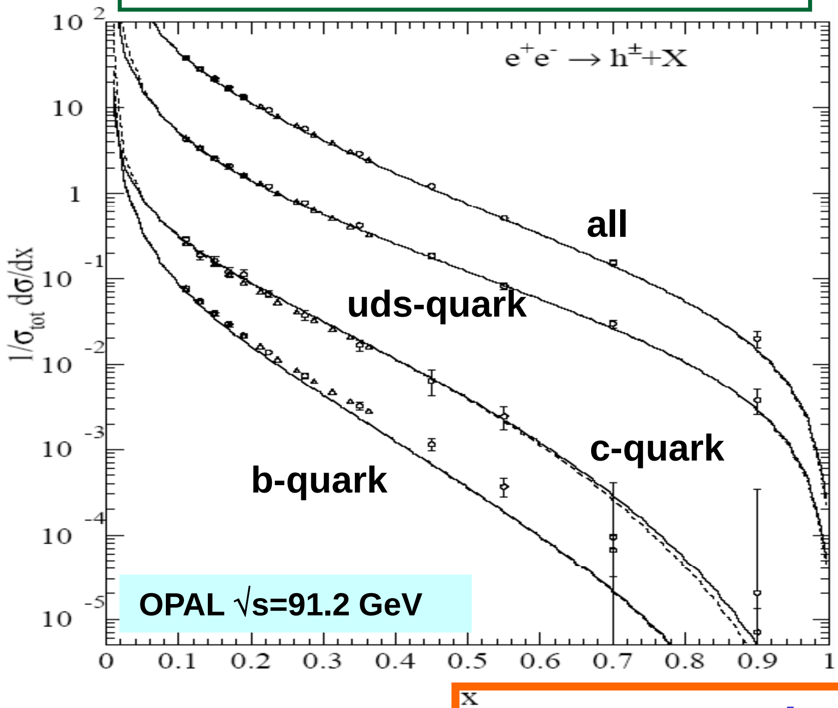


Rev D (1995)

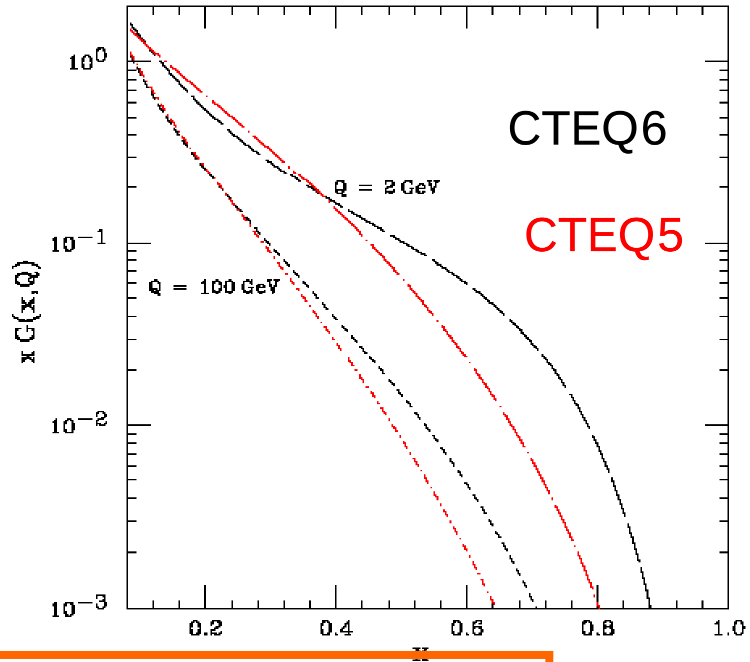
Universality of Fragmentation functions

- Suggested by Kniehl, Kramer & Poetter : *Nucl.Phys.B597(2001)*
- Experimental data from different collisions systems have been fit with the same fragmentation function (FF)
- Nevertheless the constraint on Gluon FF is much worse than for light quarks, and similar to heavy quark FF.

Fragmentation function for Quarks



Parton Dist function for Gluons

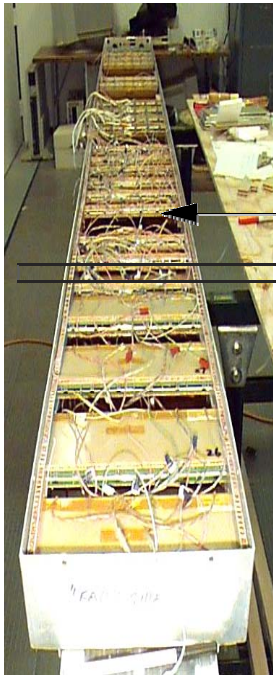


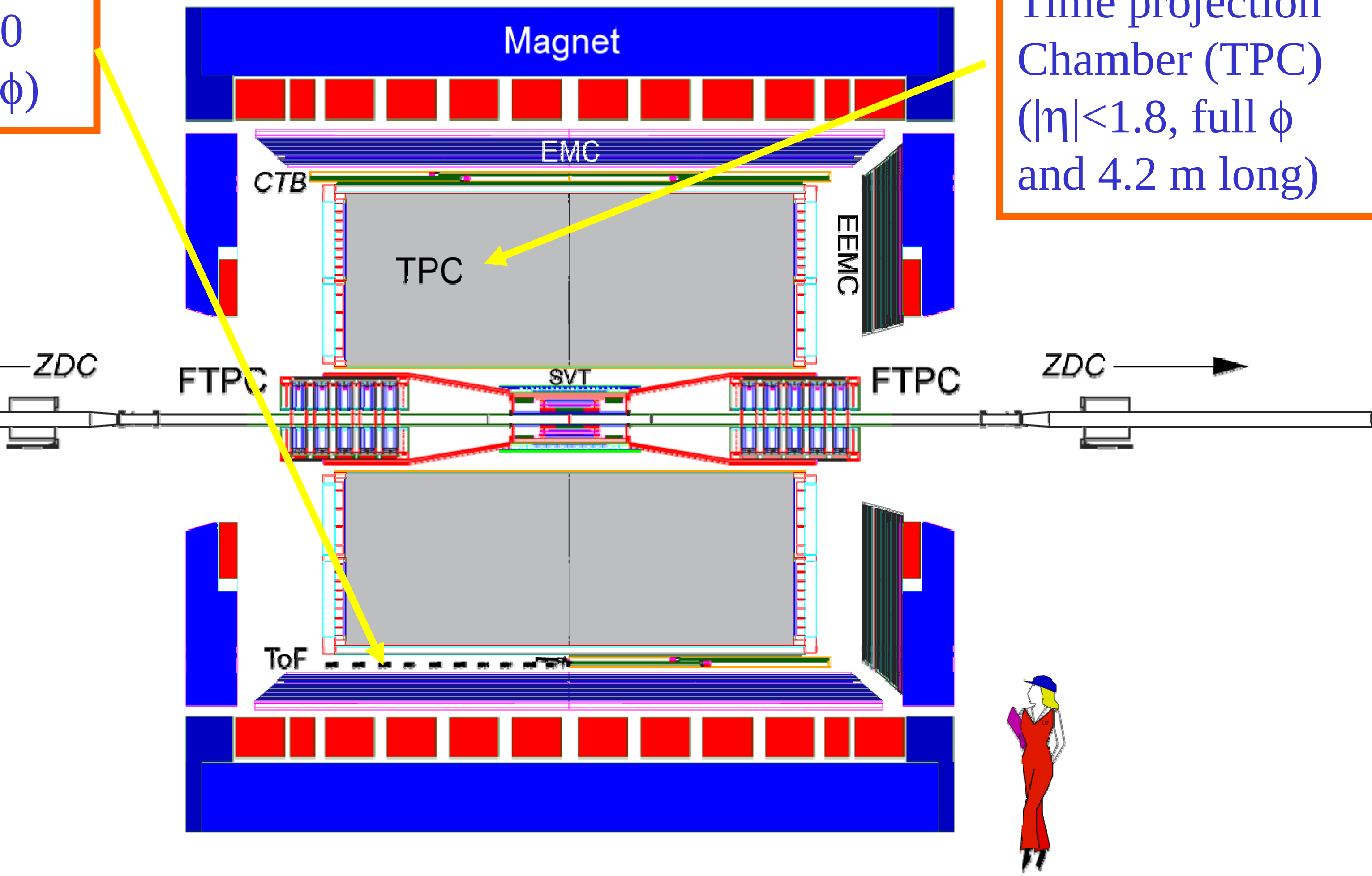
KKP, Nucl.Phys.B582(2000)

Large uncertainties remain for the gluon distributions & fragmentation functions

STAR experiment - Detectors

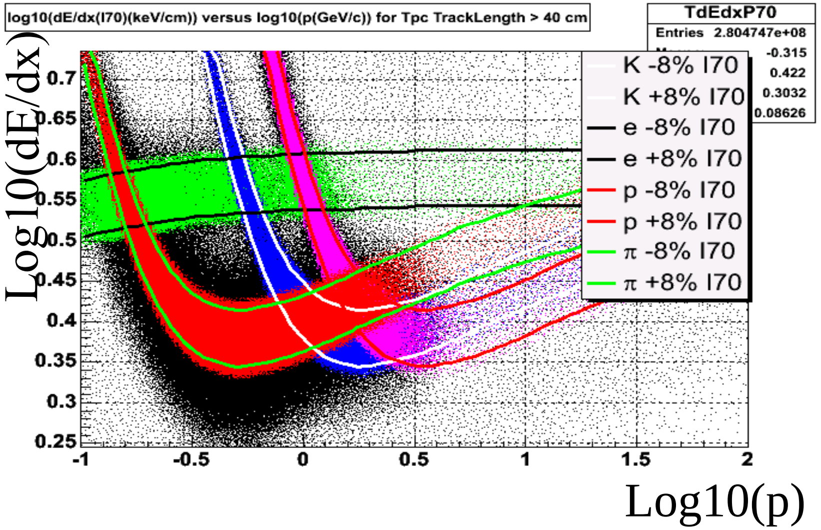
Time-Of-Flight
($-1.0 < \eta < 0$
and $\pi/30$ in ϕ)

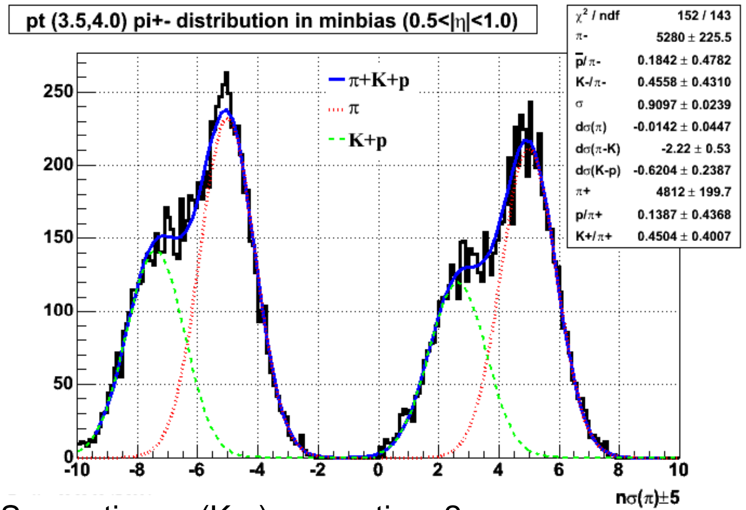




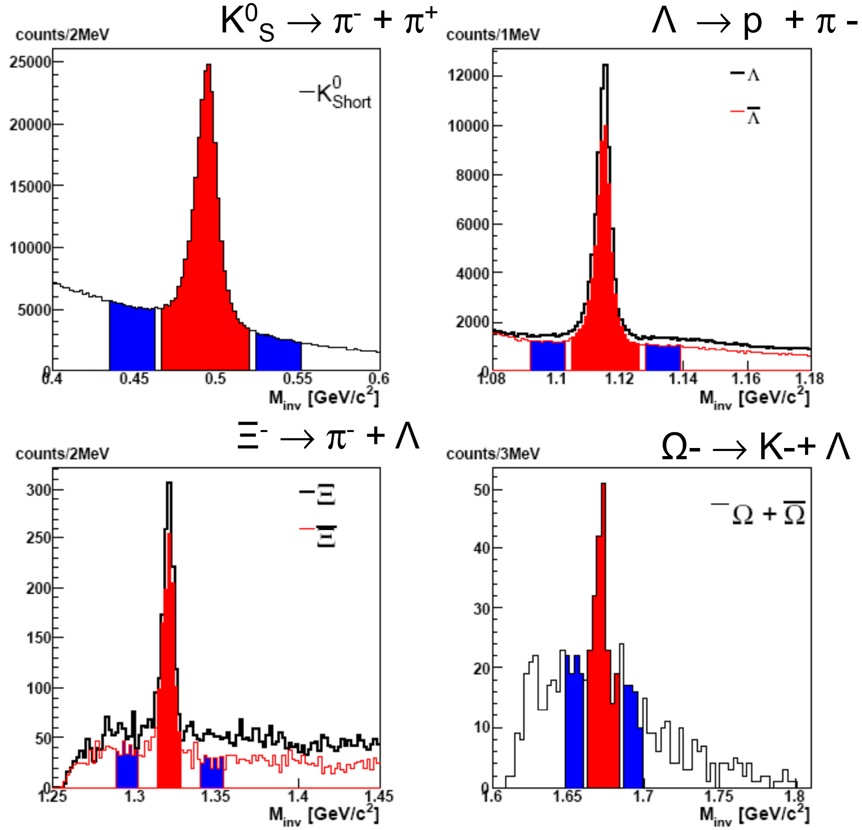
Time projection
Chamber (TPC)
($|\eta|<1.8$, full ϕ
and 4.2 m long)

Particle Identification





■Separation: p (K,p) separation: 2s



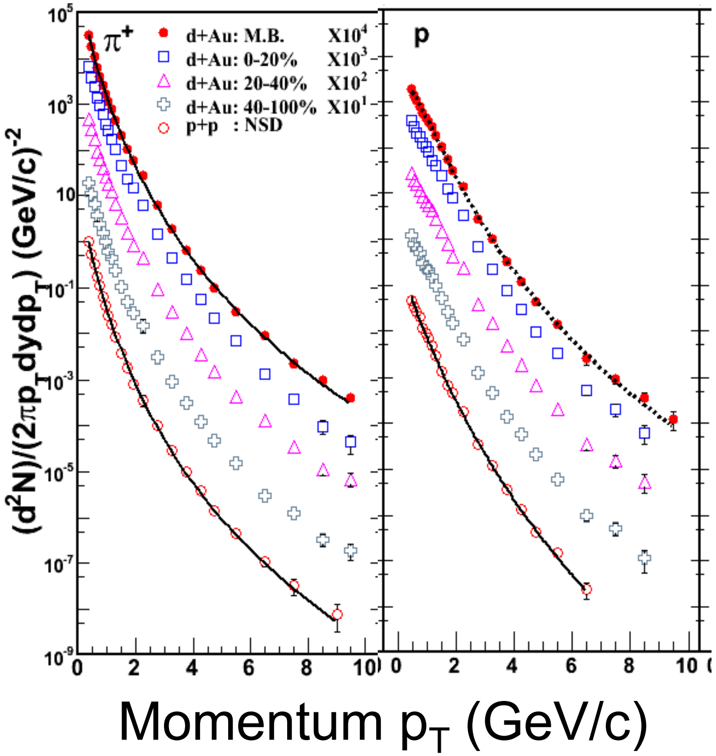
Weak decay vertices (strange particles):

- Charged daughters identified by dE/dx

Relativistic Rise dE/dx:

- Identify high pt π,k, p for momenta of: 3 < p < 10 GeV/c

Transverse Momentum Spectra



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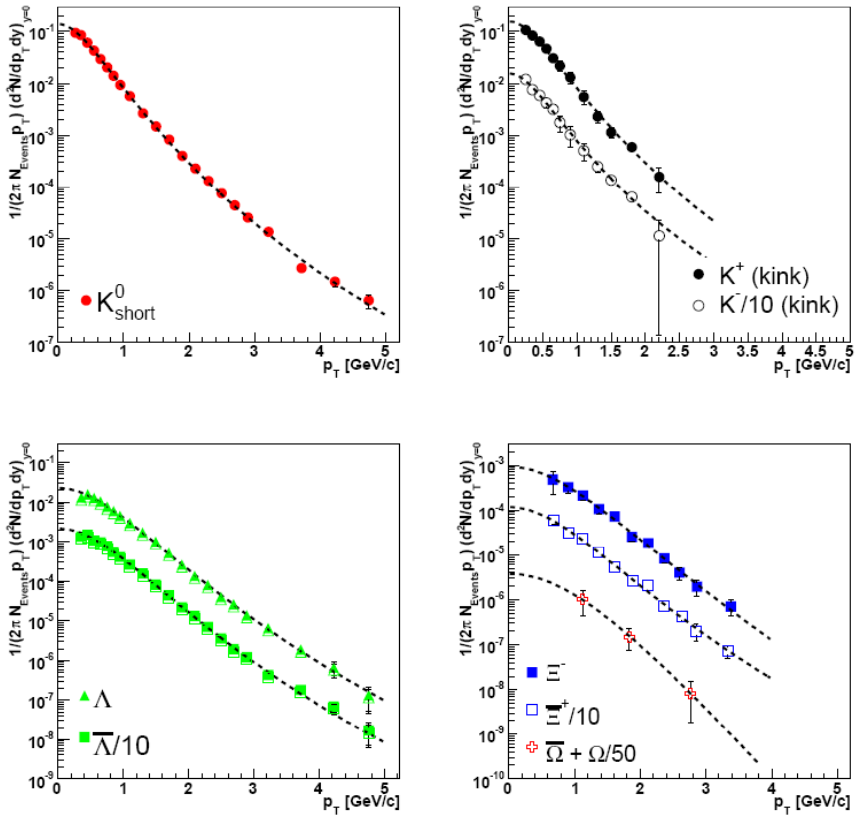


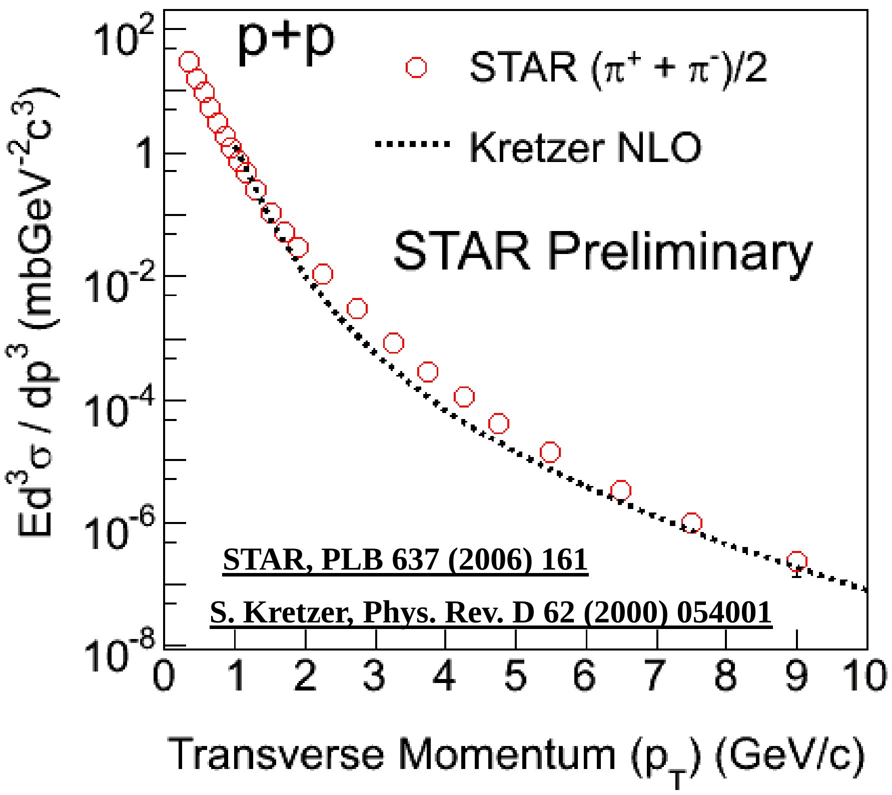
Fitted curves to data are Levy-functions $A_s/(1+\beta_0\,(m_t-m_0)/n)^n$

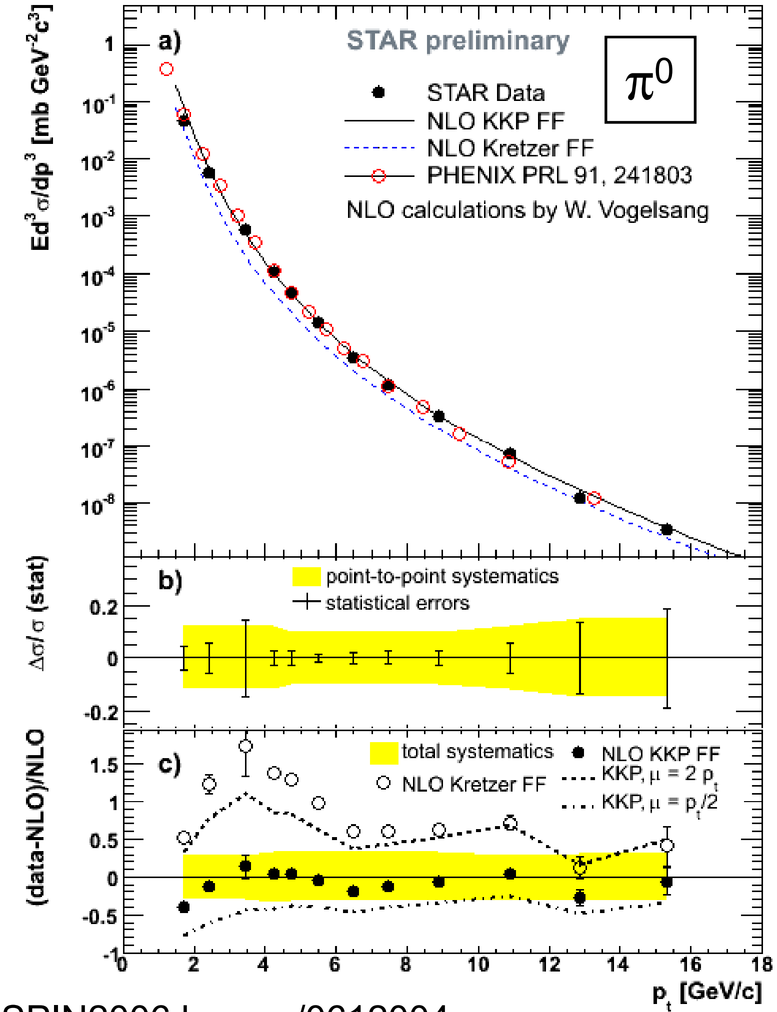
p_T spectra for protons and pions up to 10 GeV/c and strange particles up to 5 GeV/c

STAR (nucl-ex/0607033) accepted by Phys Rev C

Understanding the p+p collisions

Sensitivity to choice of fragmentation function (FF)





SPIN2006,hep-ex/0612004

NLO pQCD calculations with ***Kretzer*** FF **inconsistent** with data at midrapidity

Sensitivity to gluon contribution of FF

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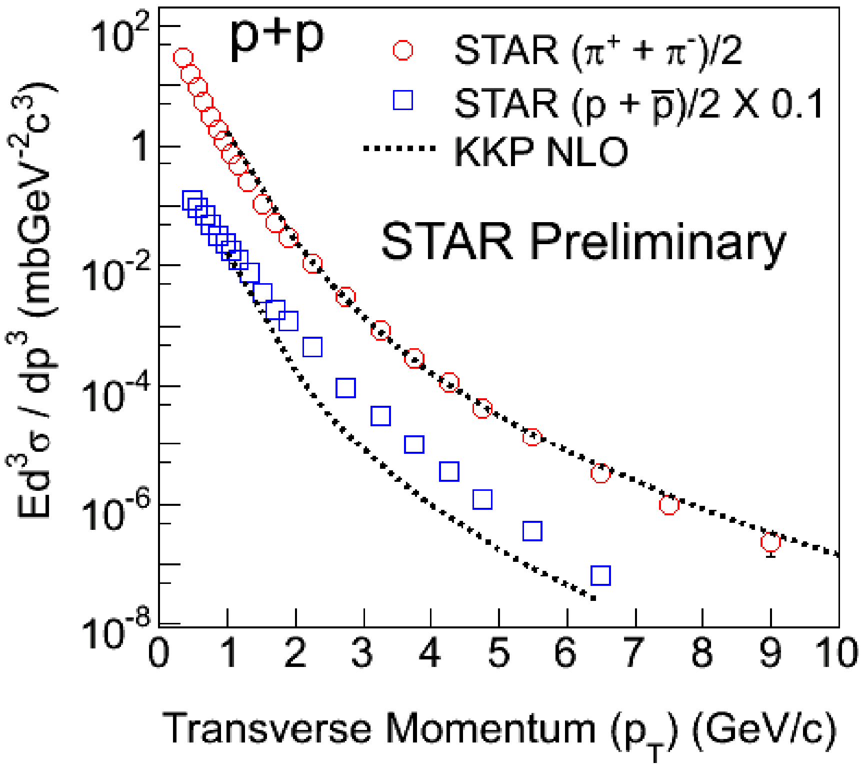
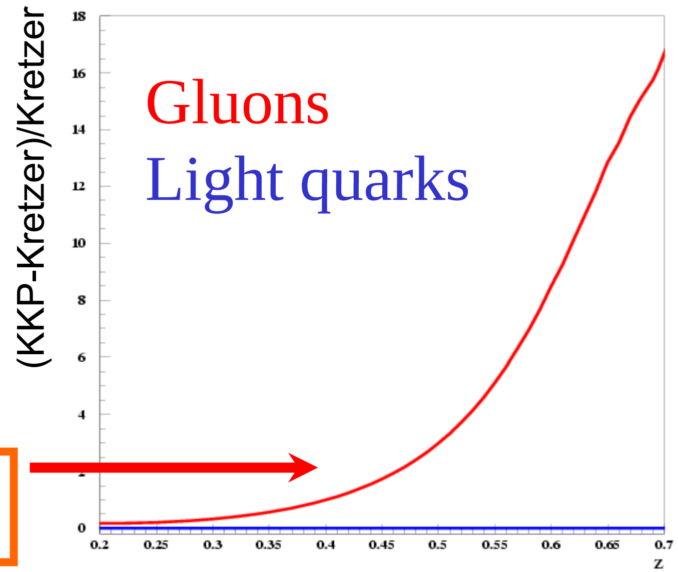


NLO pQCD calculations by W. Vogelsang
KKP : B. A. Kniehl, G. Kraner and B. Potter,
Nucl. Phys. B 597 (2001) 337

NLO pQCD calculations with ***KKP FF*** are **consistent** with pion data at **high** p_T **(> 2 GeV/c)**

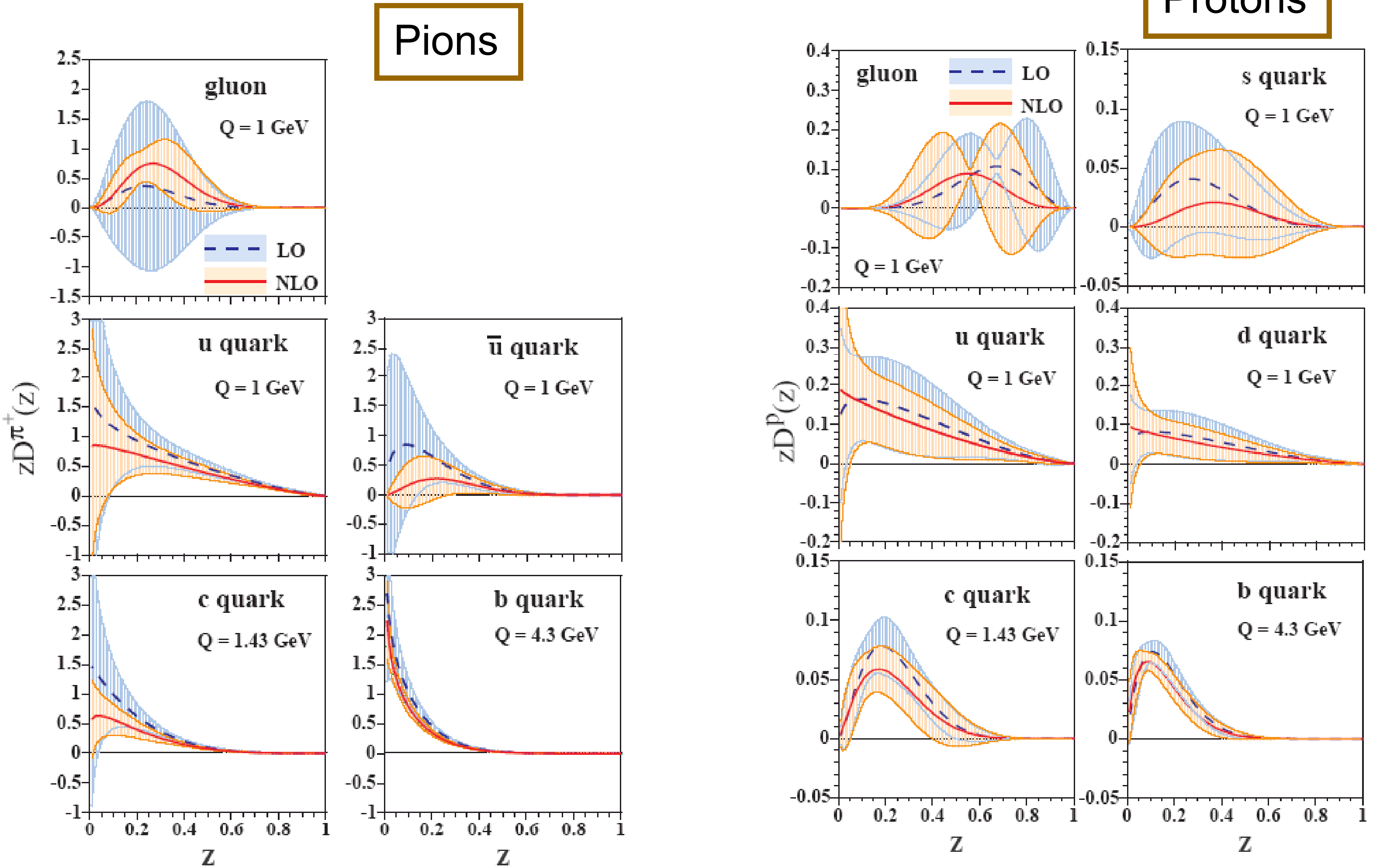
They are **inconsistent** with the **proton+anti-proton** data

Difference between KKP and Kretzer FF is the way g→π
g→π fragmentation is more in KKP

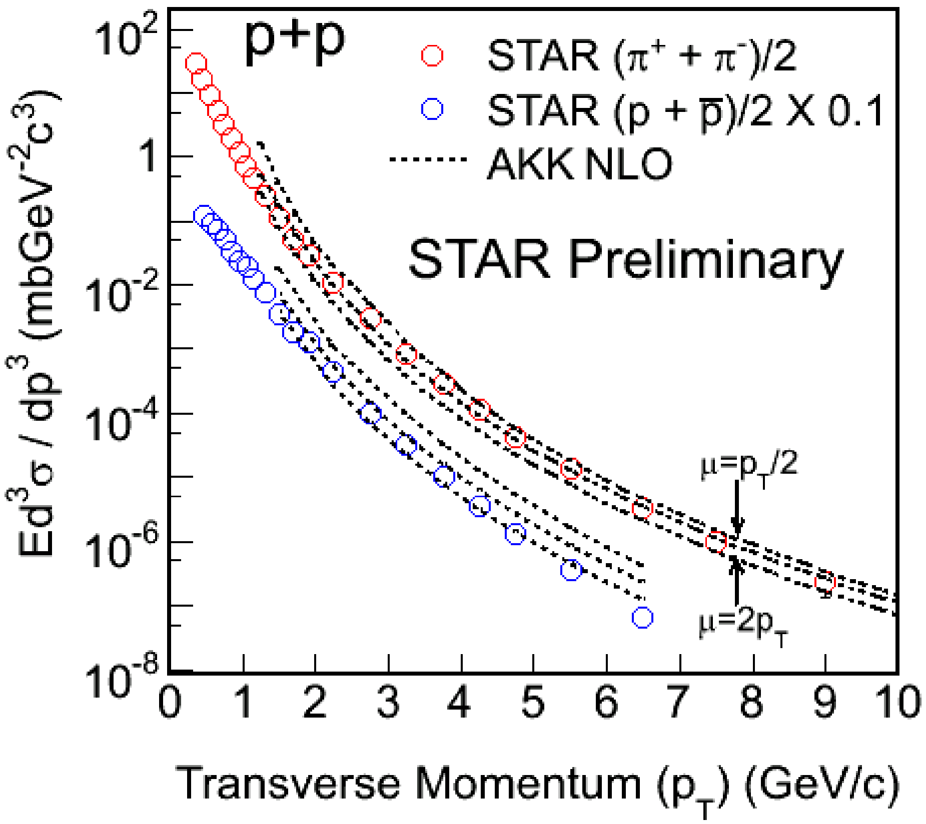


Uncertainties in FF

- Recent compilation and error analysis of available fragmentation functions by (KKP,Kretzer, AKK) by Hirai et al. (hep-ph/0702250)



Light flavor separated FF



AKK : S. Albino, B. A. Kniehl, and B. Potter, Nucl. Phys. B 725 (2005) 181

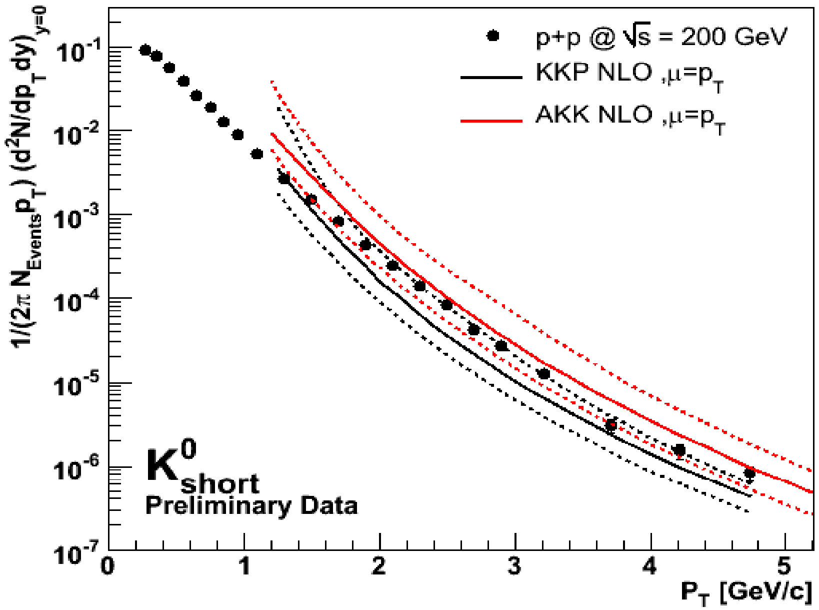
OPAL: Eur. Phys. J. C 16 (2000) 407

NLO pQCD calculations with ***AKK FF*** are **consistent** with pion data at **high p_T (> 2 GeV/c)**

NLO pQCD calculations with ***AKK FF*** **compares relatively better than** ***KKP*** for the **p+ $\bar{p}$ data**

⇒ **AKK** differ from ***KKP***, in the way the **light flavor FF** are obtained from the light flavor separated measurements in e+e- collisions by OPAL

What about strange particles ?

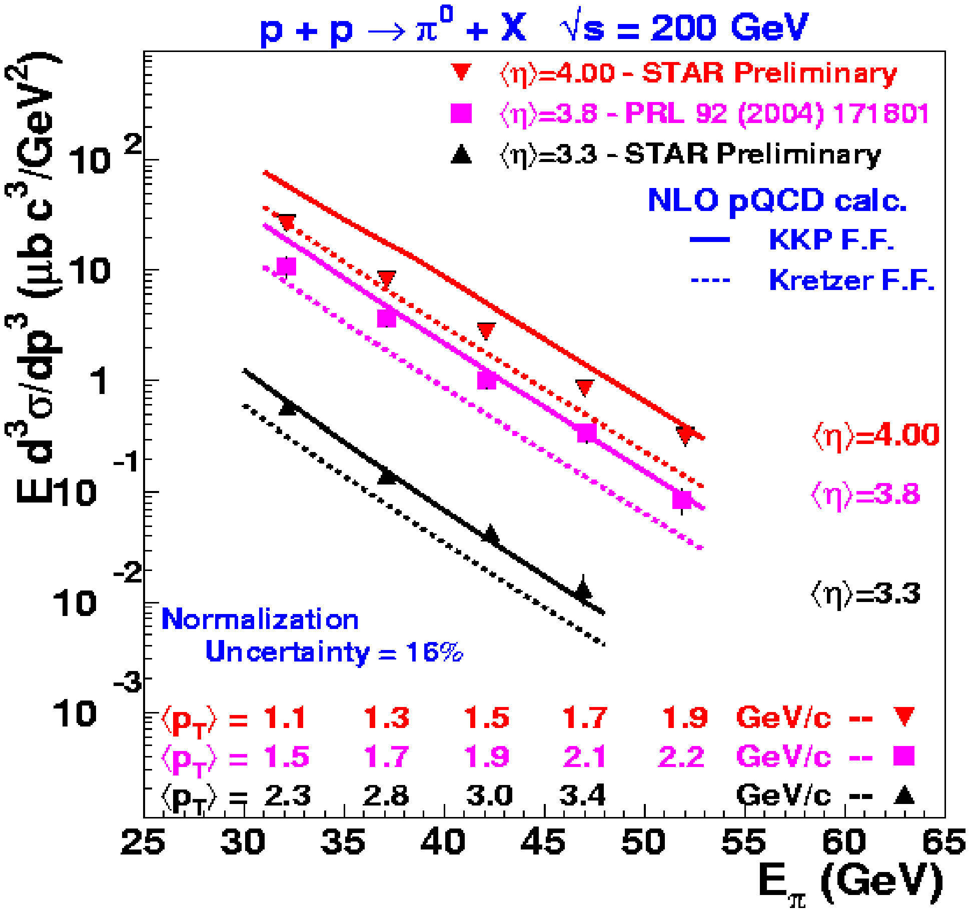


STAR (nucl-ex/0607033) accepted for Publication in Phys Rev C

- **NLO pQCD** calculations with **AKK FF compares relatively better than *KKP*** for the strange particle data
- Lambda **gluon FF** was constrained using STAR data

π^0 production at forward rapidity

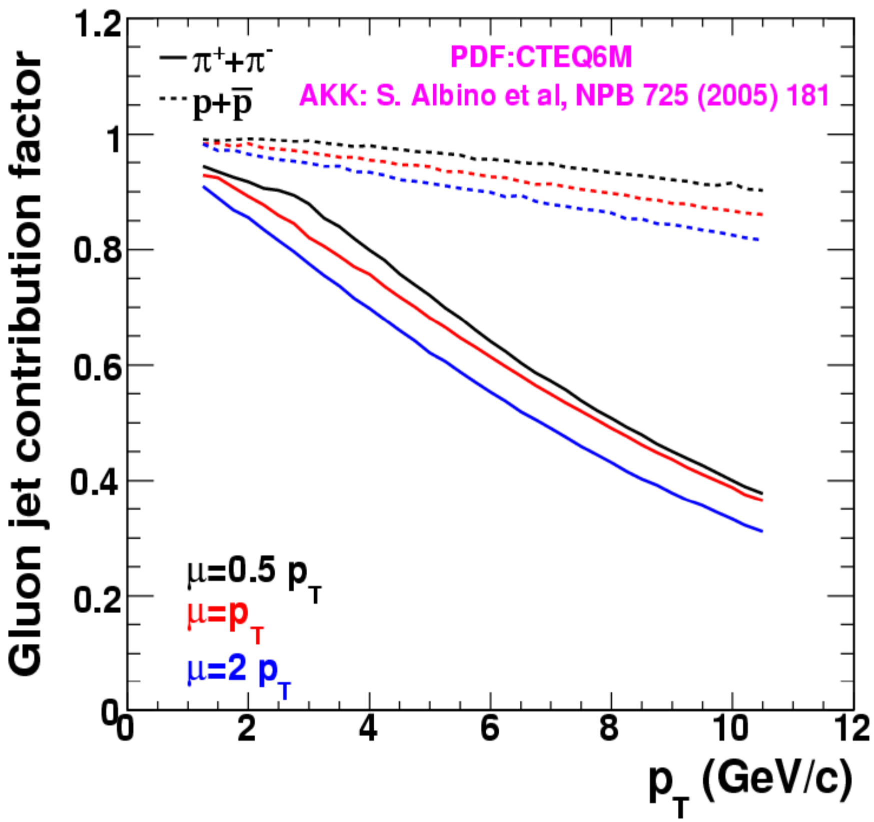
probing the initial gluon densities

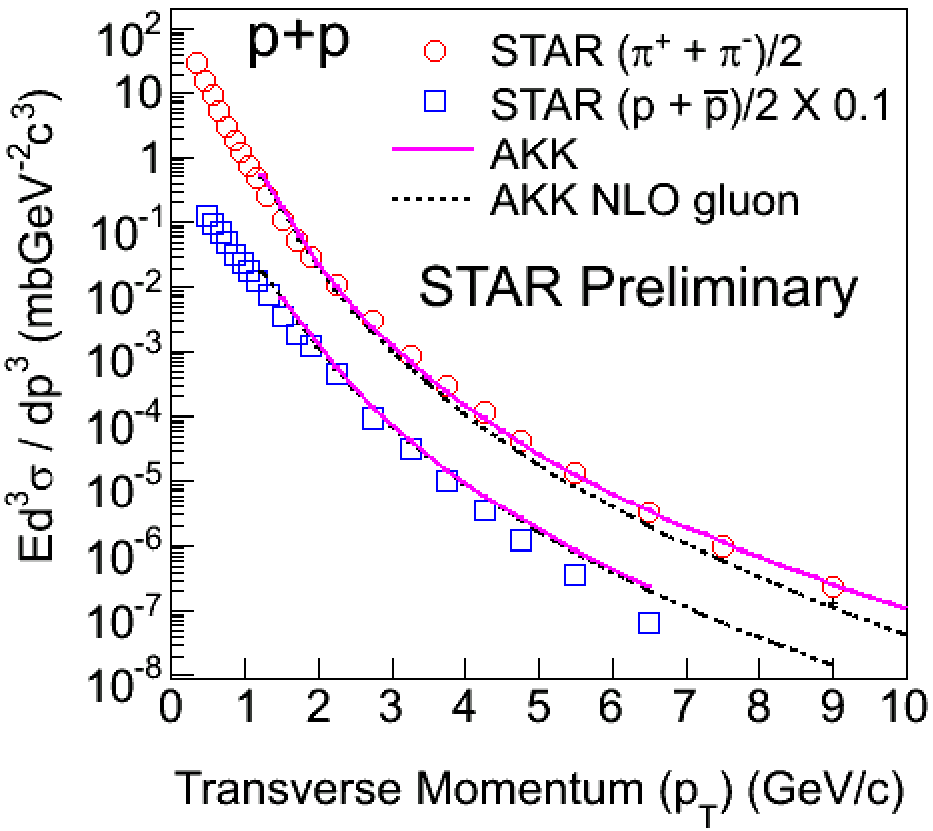


- ✓ Inclusive forward p[0] production in p+p collisions at 200 GeV consistent with NLO pQCD calculations
- ✓ At small h, data consistent with KKP, as h increases data approaches cal. with Kretzer set of FF

STAR, Phys.Rev.Lett.97,152302 (2006)

Gluon Jets Vs. Quark Jets





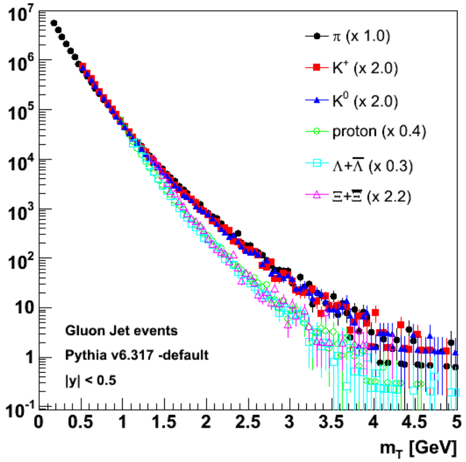
Gluon jet contribution to protons is significantly larger than to pions at high p_T in p+p collisions at RHIC.

Protons dominated by ***gluon FF*** & pions by ***quark FF*** at RHIC

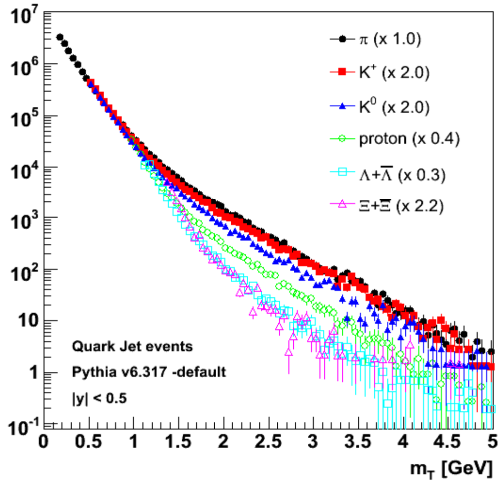
m_T-scaling

STAR (nucl-ex/0607033)

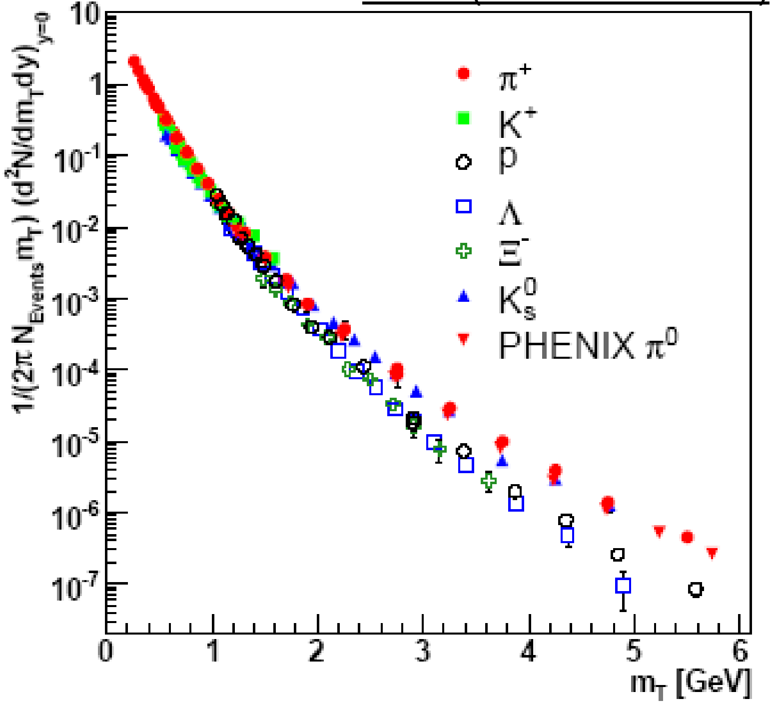
PYTHIA 6.3



Gluon jet



Quark jet



In PYTHIA gluon jets produce baryon-meson splitting whereas quark jets produce mass splitting.

STAR data shows baryon-meson splitting, hence supports dominance of gluon jets at RHIC

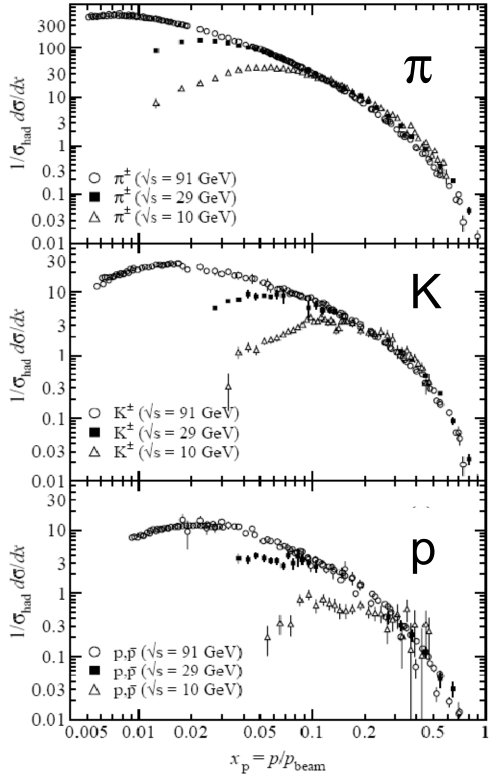
x_T-Scaling

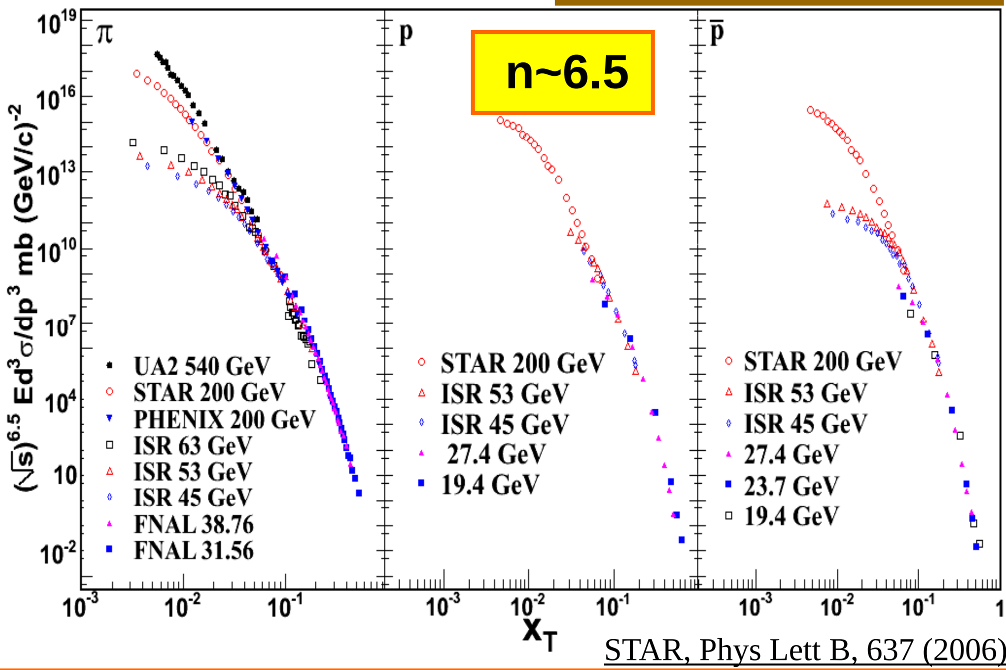
e+ e- collisions

$$E\frac{d^3\sigma}{dp^3} = \frac{1}{\sqrt{s}^n} g(x_T)$$

$x_T = 2p_T/\sqrt{s}$

p+p / $\bar{p}$+p collisions





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Cross-section are multiplied by $(\sqrt{s_{NN}})^2$ factor

TPC, PRL 61(1988)
ALEPH,ZPC66(1995)
ARGUS,ZPC44(1989)

n ~ 4 for basic scattering process
n ~ 5-8 depending on evolution of structure function and fragmentation function (as seen in data)
⇒ Suggests transition from soft/hard processes ~p_T=2GeV

Particle Ratios – PYTHIA comparison

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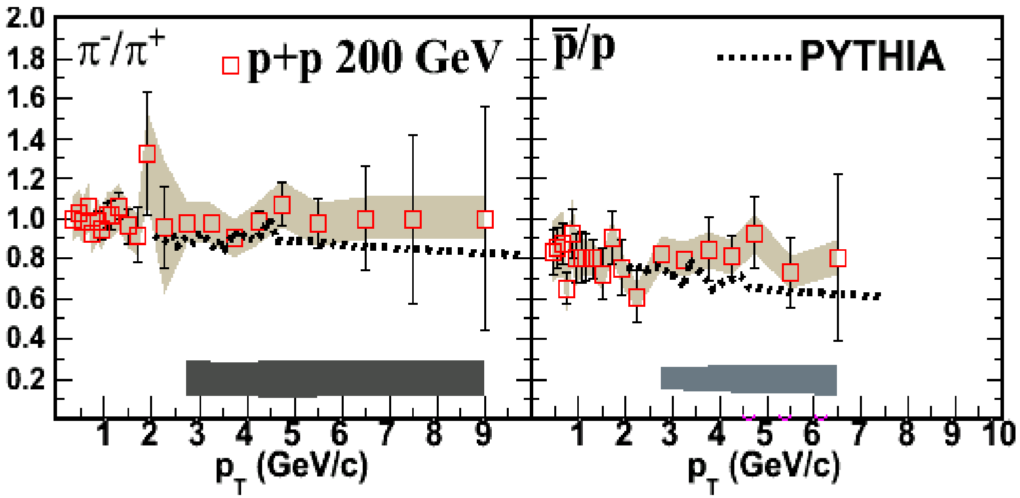

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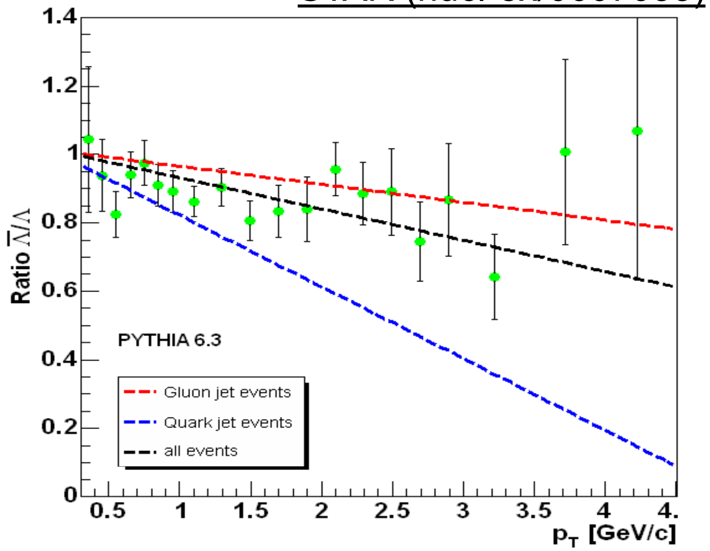
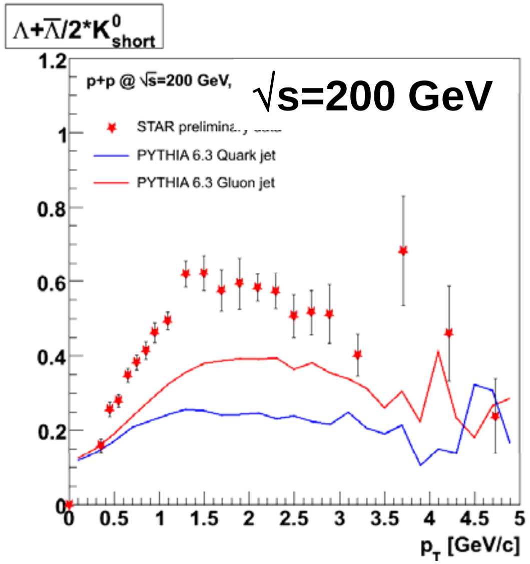


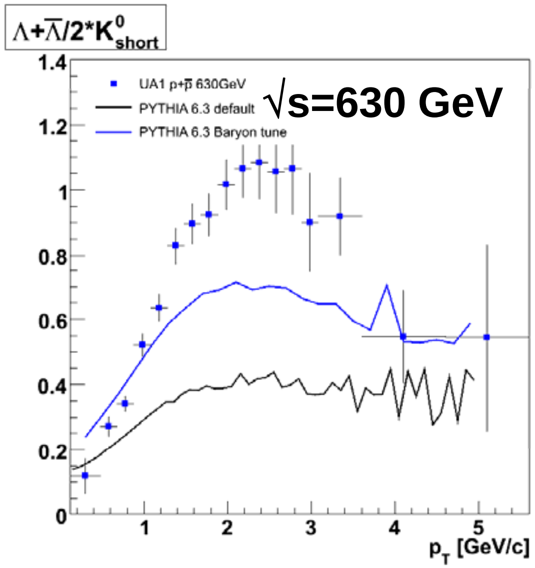
PYTHIA

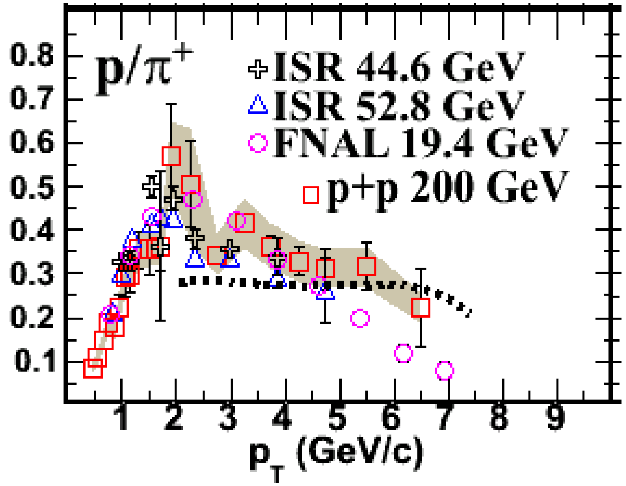
- predicts a more prominent p_T dependence for $\bar{p}/p$ and a flat dependence at high p_T for π^-/π^+
- predicts an even stronger dependence for $\bar{\Lambda}/\Lambda$. Current data does not allow to conclude, but is consistent with gluon jet dominated production.

Baryon-meson ratios

- Gluon Jets will produce a larger Baryon/Meson ratio than quark-jets in the region of interest
- PYTHIA cannot describe Baryon-Meson ratio at intermediate p_T even with tuned K-factors. In addition di-quark probabilities need to be tuned.







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STAR (nucl-ex/0607033)

PYTHIA also under-predicts the Baryon-meson ratio other energies:

- Λ/K^0 UA1, √s= 630 GeV
- p/π at ISR and FNAL: 19-53 GeV

Conclusions

- NLO pQCD describes the proton and Λ p_T spectrum for the first time in p+p collisions
- Importance of the significant improvement of FF for baryons and strange particles from the light-flavor separated measurements in e+e- collisions (OPAL)
- Neutral pion p_T spectra at forward rapidity provides unique data to study pQCD processes and understand the gluon vs. quark jet contributions
- m_T-scaling together with x_T scaling in p+p collisions shows that the dominance of hard process (related to PDF and FF) over soft process for minbias collisions starts at $p_T \sim 2$ GeV/c
- Splitting of high baryon-meson m_T spectra confirms gluon jet dominance at RHIC
- Anti-particle to particle ratio is show little dependence to p_T for the studied p_T range again indicating gluon jet dominance at RHIC for these processes
- Baryon-to-meson ratios not well reproduced by LO pQCD (PYTHIA), over a broad range of energies in p+p collisions

STAR Collaboration

U.S. Labs:
Argonne, Lawrence Berkeley, and Brookhaven National Labs

U.S. Universities:
UC Berkeley, UC Davis, UCLA, Caltech, Carnegie Mellon, UIC, Creighton, Indiana, Kent State, MIT, MSU, CCNY, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale

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Czech Republic:
Nuclear Physics Institute

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University of Birmingham

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Pusan National University

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