Study of identified particles oroginating from quark and gluon jets in proton-proton collisions

Outline:

- Introduction
- Q/G contribution to individual spectra
- Particle spectra in different event shapes

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PhD. studies in collab with

Peter Levai
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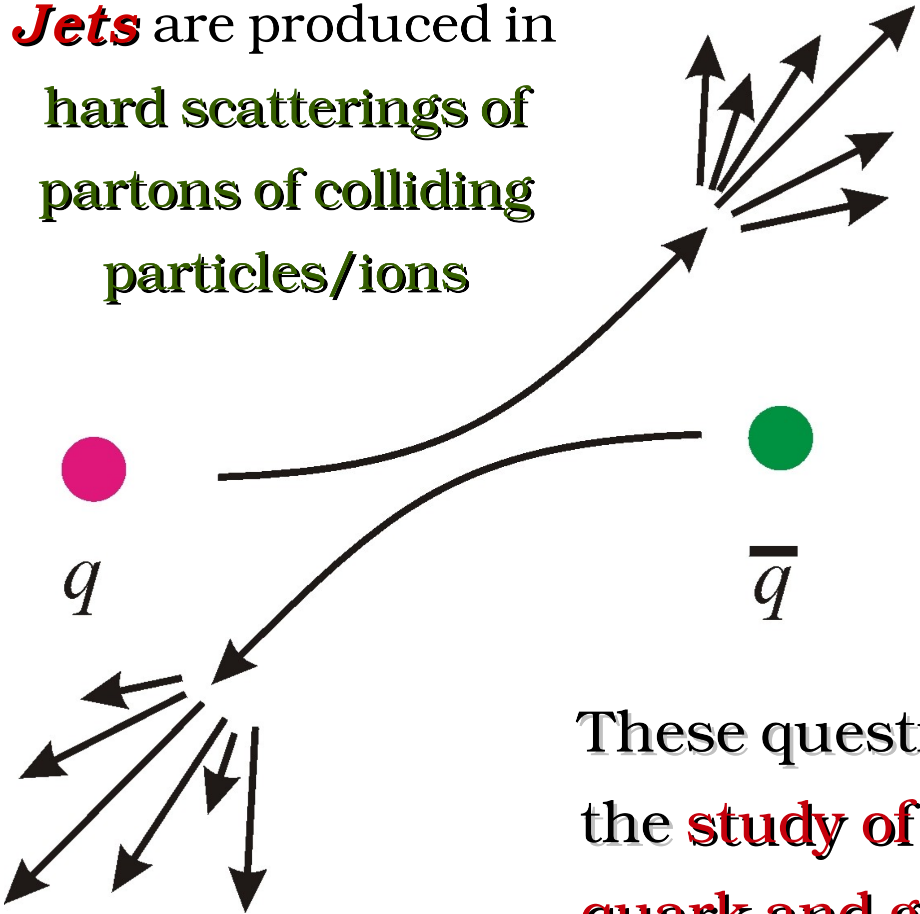
Introduction

Jets are produced in **hard scatterings of partons of colliding particles/ions**



Emerging from the very early stages of collisions they are ideal to study

Early stages of collisions
Hadronisation processes
Particle production

These questions can be addressed through the study of fragmentation properties of quark and gluon jets in different event shapes (2- and 3-jet events)

Quark and Gluon Jets

Quark and gluon jet carry <u>different colour factors</u>

$$\frac{C_A}{C_F} = \frac{9}{4} = 2{,}25 \left(Q \to \infty \right)$$

The colour factors are proportional to the **probability a parton radiates soft gluon**

<u>Gluons</u> branch more easily and are expected to form

Higher multiplicity jets

Broader jets

Jets with softer fragmentation function

Quark and Gluon Jets

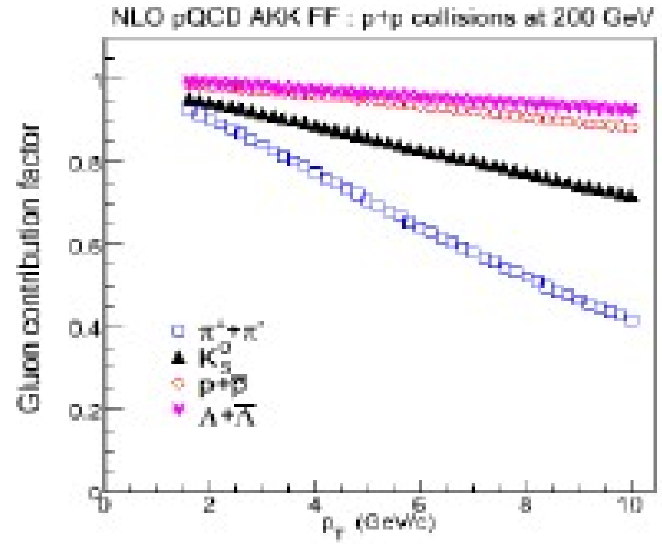
Particle production differences:

Gluons

Baryon production

Quarks

Meson production



S. Albino, B.A. Kniehl, and G. Kramer - NPB 725 (2005) 181

Higher multiplicity jets

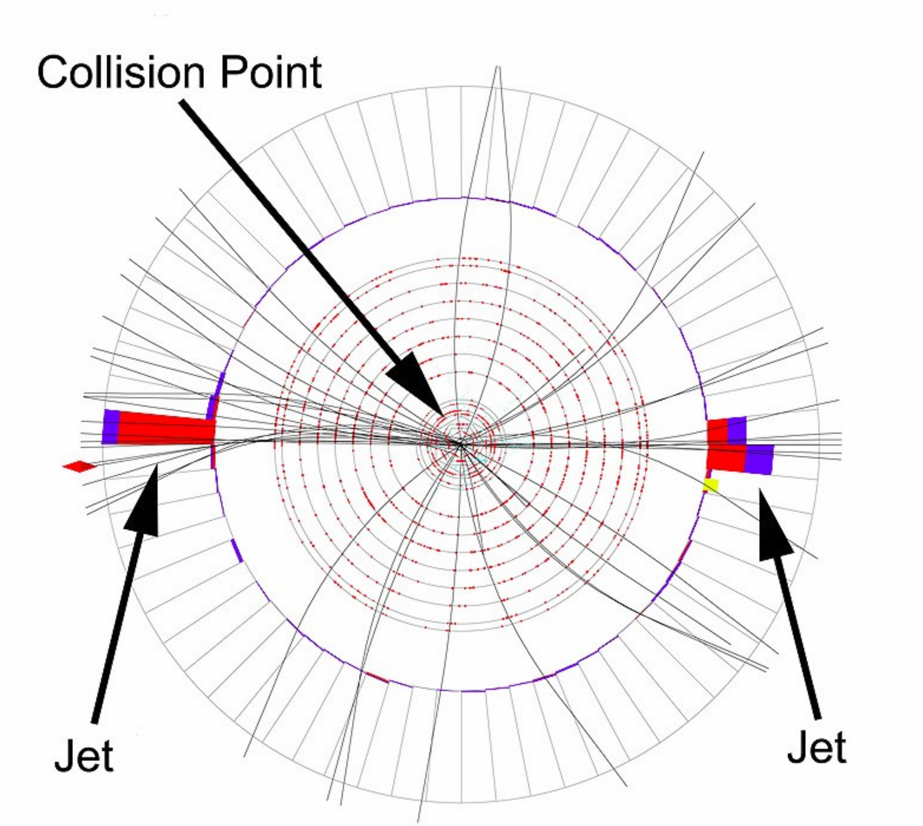
Broader jets

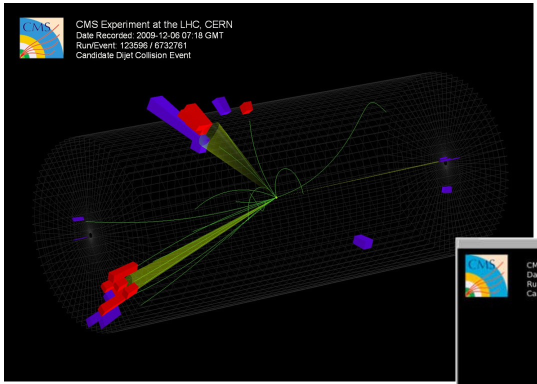
Jets with softer fragmentation function

Experimentally, jets are observed as showers of high-momentum particles in the detectors.

To identify such showers, one uses various **jet-finding algorithms**

- **Cone**
- **KT**
- **Anti-kT**





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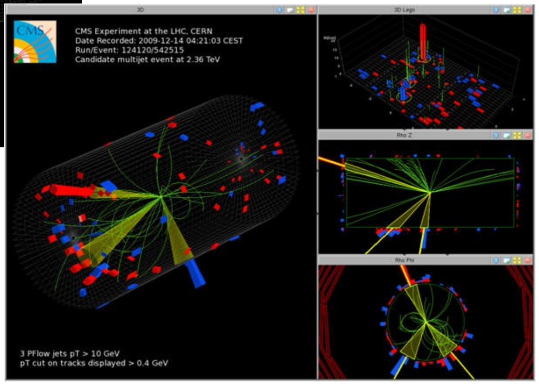


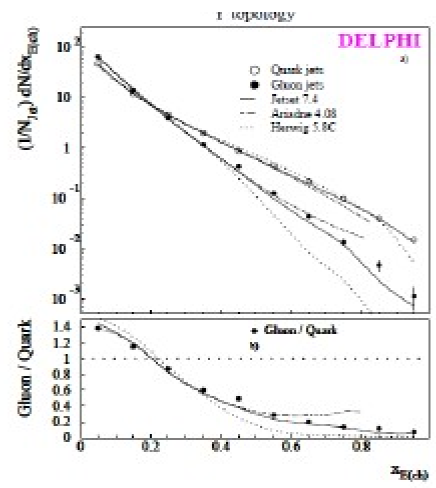
Event shape study:

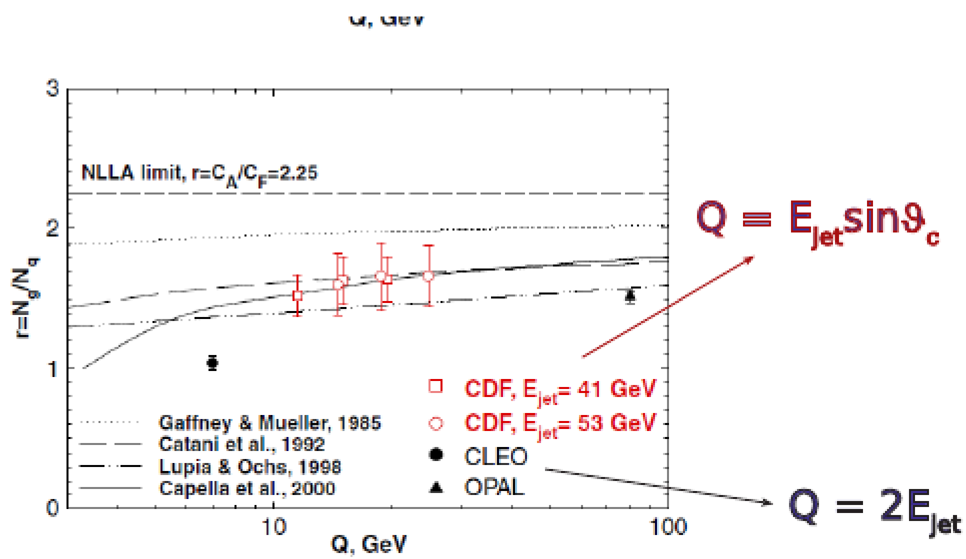
- **anisotropical/isotropical events**
- **Di-Jet/Multi-Jet events**

Historical outlook

- First studies looking at properties of jets were conducted in e^+e^- (LEP)
- **Tevatron – pp @ 2 TeV**

arXiv:hep-ex/0110084



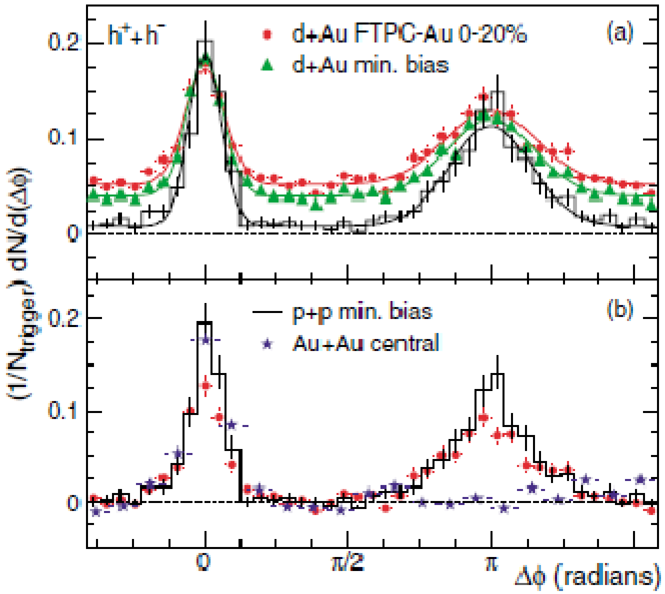


Qualitatively, differences were observed, however, <u>asymptotic limit was not</u>

RHIC

RHIC – colliding HI; possibility to investigate matter formed in such collisions through modification of jet

Many interesting and unexpected observations



J. Adams *et al.*, Phys. Rev. Lett. 91 (2003) 072304

Away side jet suppression

⇒ Dramatic softening of jet fragmentation through rapid energy loss while traversing the medium – soft gluon radiation. Particle spectra are sensitive to such behaviour

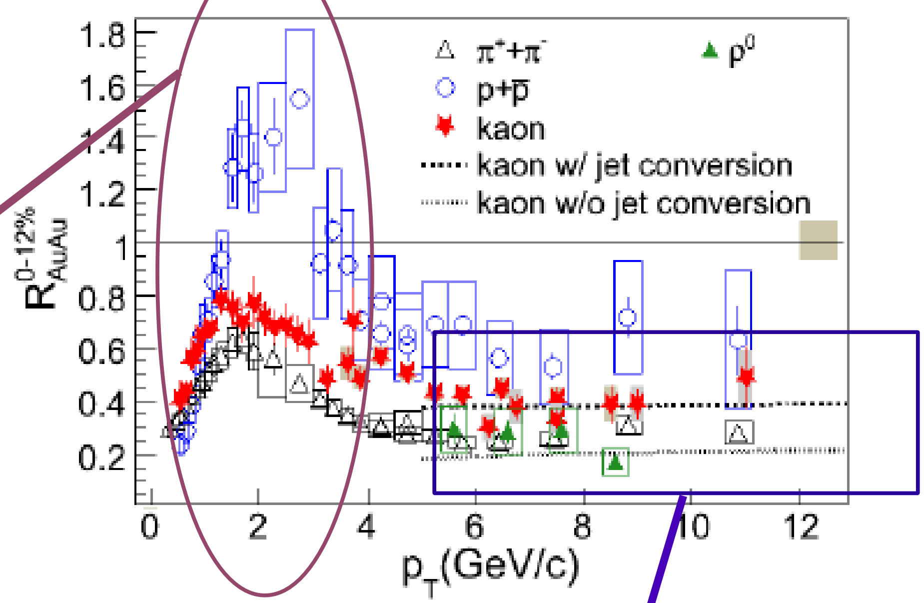
JET INTERACTION WITH MEDIUM

mid p_T hadron yield enhanced

⇒Coalescence of hard partons from jets with soft partons from medium

V. Greco, C.M. Ko, P. Levai, PRL90 (2003) 202302.

arXiv:0908.1766 (August 2009)
J. Putschke, STAR



The observed ordering of R_{AA} of identified hadrons is consistent with predictions from calculations including jet flavor conversion in the hot dense medium

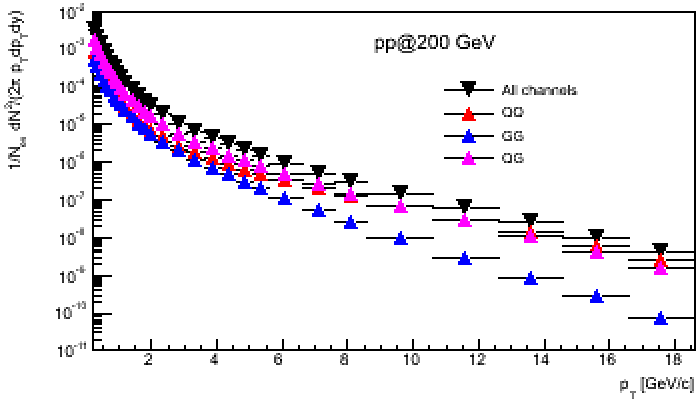
Wei Liu, Che Ming Ko, Ben-Wei Zhang
Int.J.Mod.Phys.E16:1930-1936,2007.

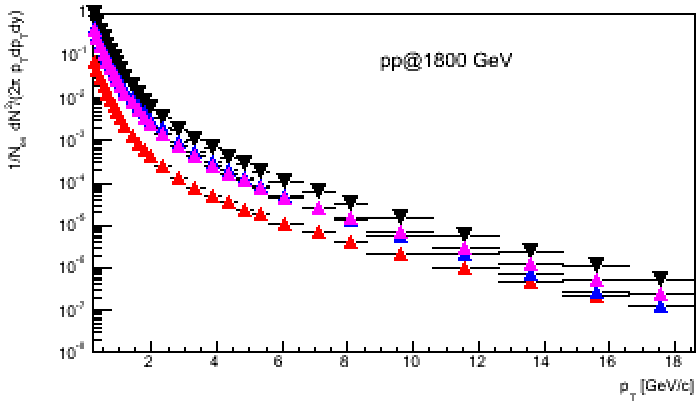
COLOR CHARGE EFFECT OF PARTON ENERGY LOSS

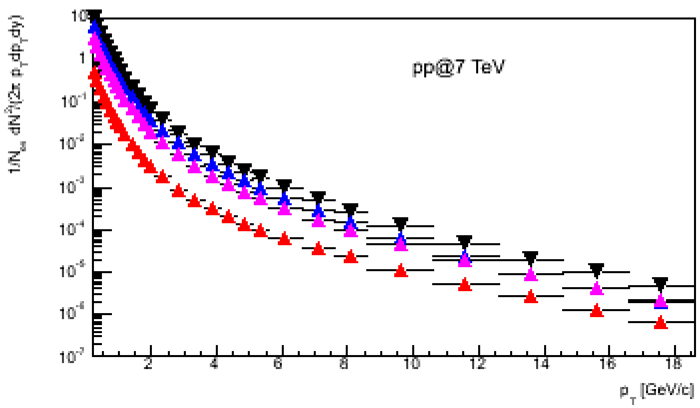
Aim of our work:

- We are looking at identified particle production based on whether these are coming from quarks or gluons
- We compare collision energies (RHIC, CDF, LHC)
- Simulations – PYTHIA Tune P0
  - QCD processes:
    - QQ (+G)
      - $qq \rightarrow qq$
      - $q\bar{q} \rightarrow q\bar{q}$
      - $gg \rightarrow q\bar{q}$
    - GG (+G)
      - $q\bar{q} \rightarrow gg$
      - $gg \rightarrow gg$
    - QG (+G)
      - $qg \rightarrow qg$
  - Look at production w/o jet finding algotrithm
  - We distinguish between 2- and 3-jet events using the thrust variable

Identified particle spectra





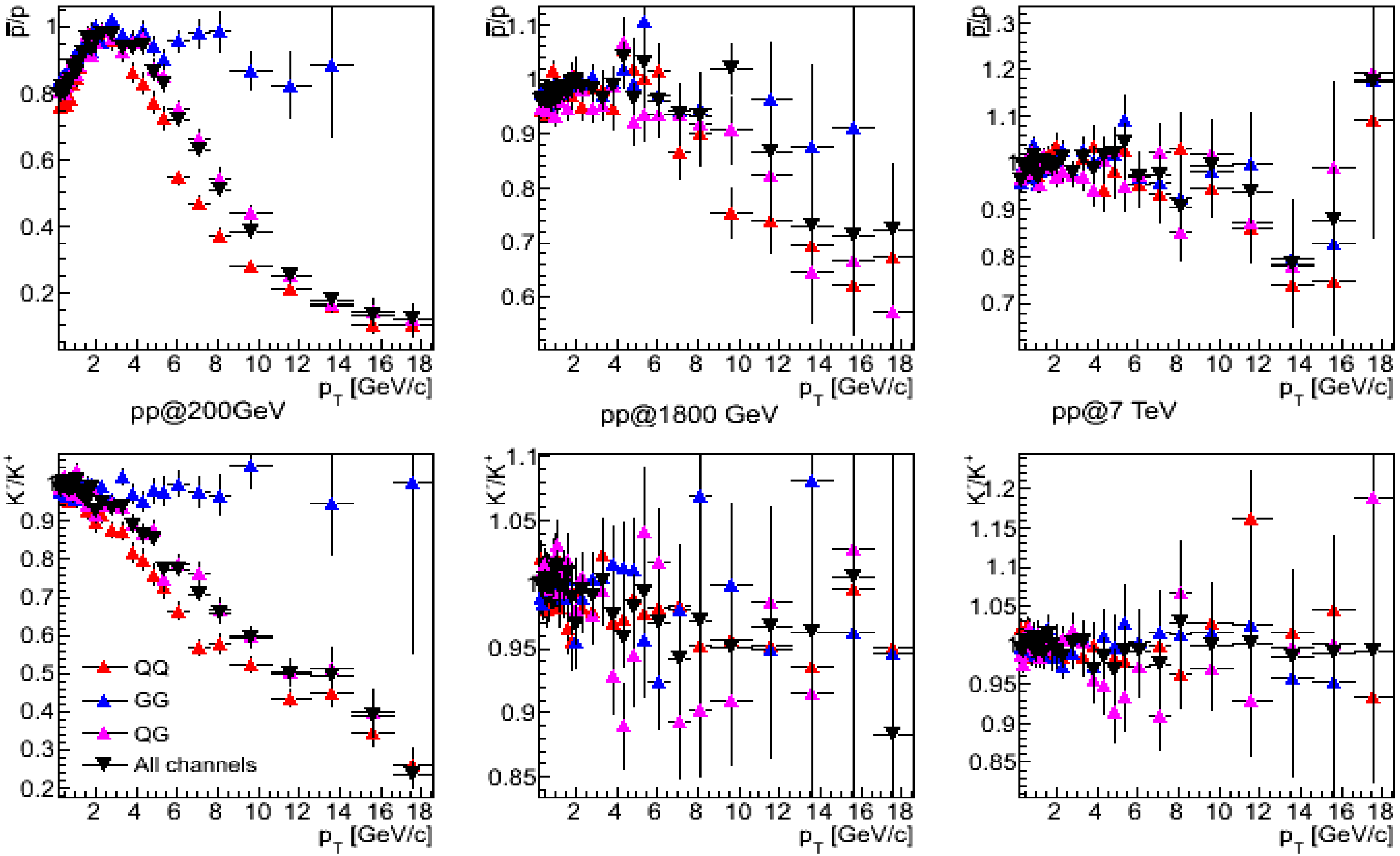


- Higher collision energy
  - QQ channel becomes suppressed
  - GG becomes dominant

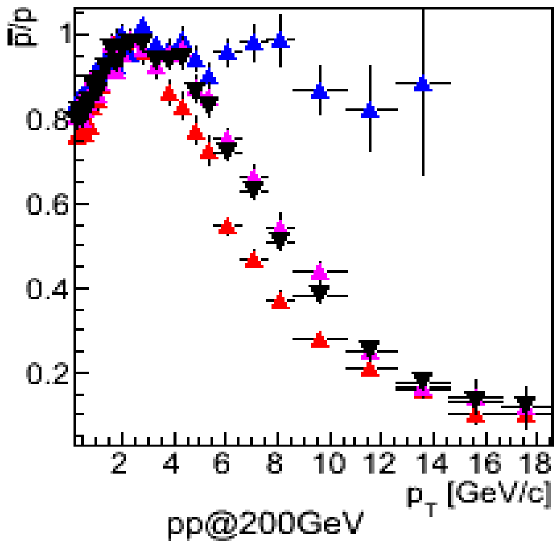
√sNN [TeV]	**QQ/Jet**	**GG/Jet**	**QG/Jet**
0.2	*27.3%*	*17.7%*	*55%*
1.8	*7.6%*	*49.7%*	*42.7%*
7	*5.3%*	*60%*	*34.7%*

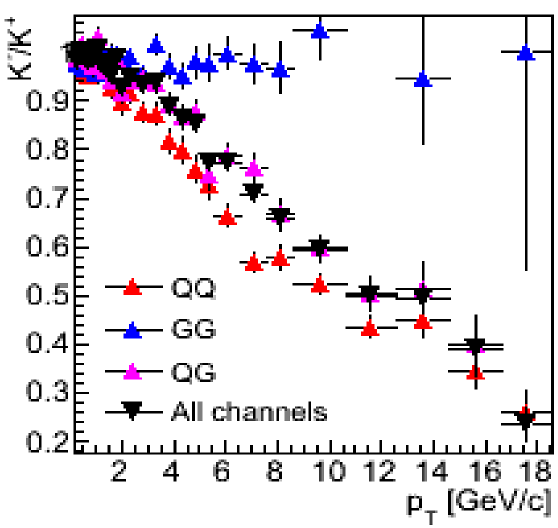
Particle ratios

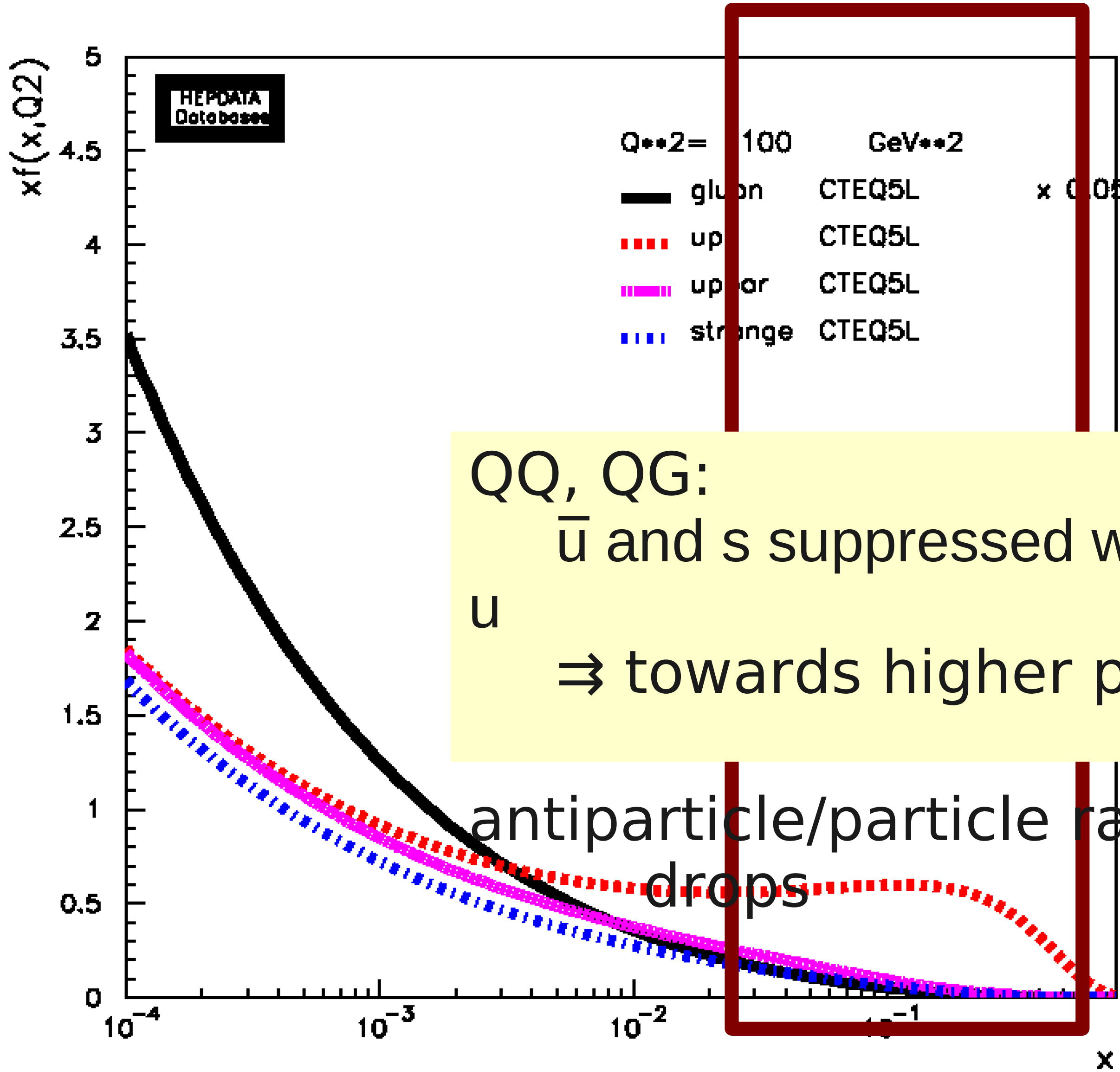
Antiparticle/particle ratios



Antiparticle/particle ratios







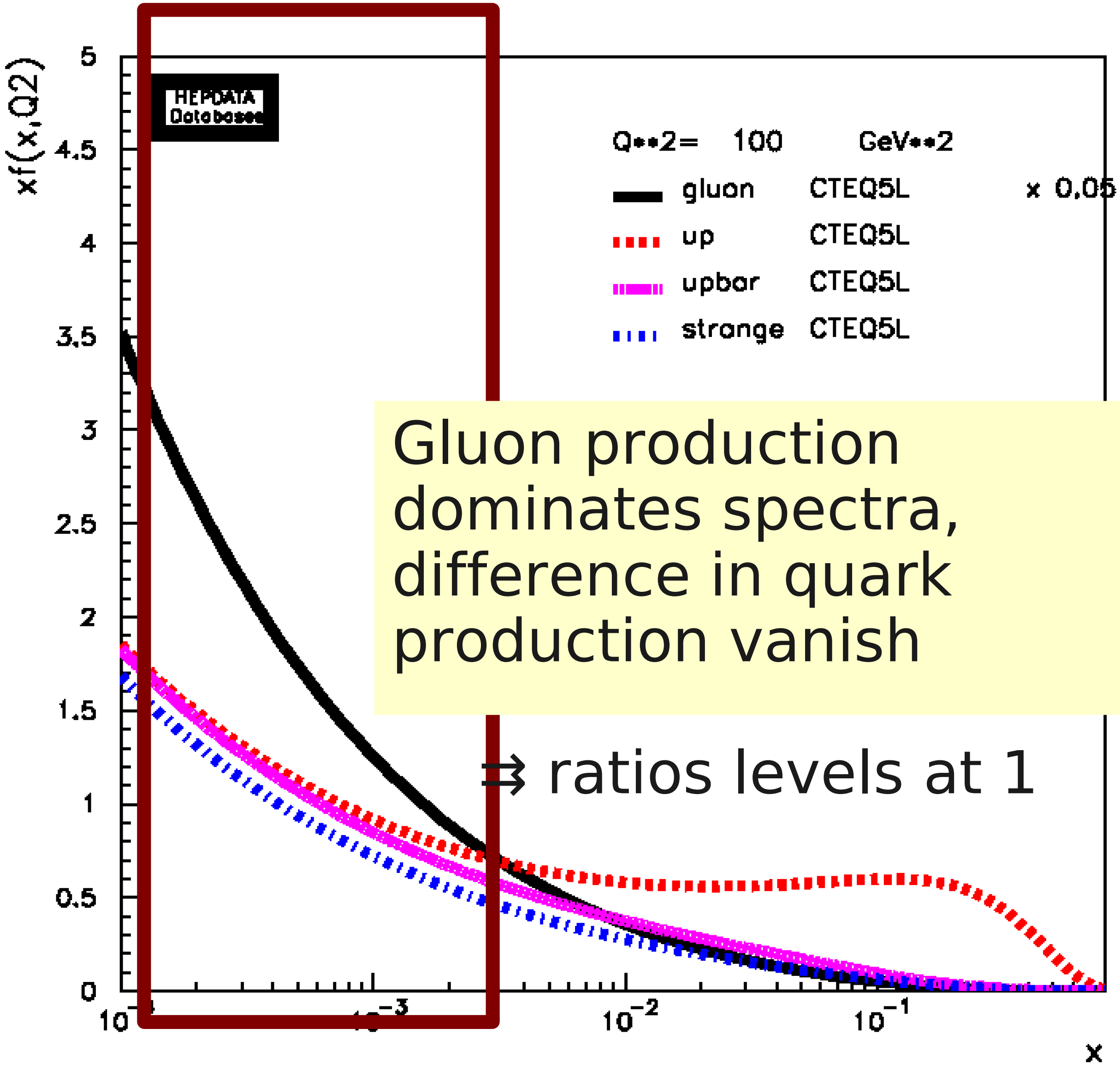
QQ, QG:

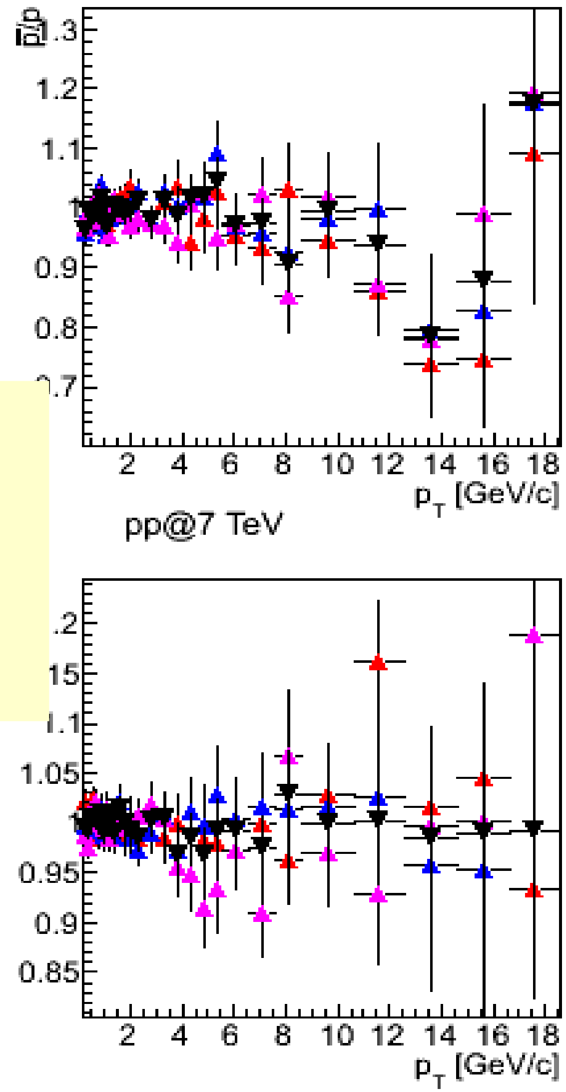
$\bar{u}$ and s suppressed w.r.t u

$\Rightarrow$ towards higher p_T

antiparticle/particle ratio drops

Antiparticle/particle ratios

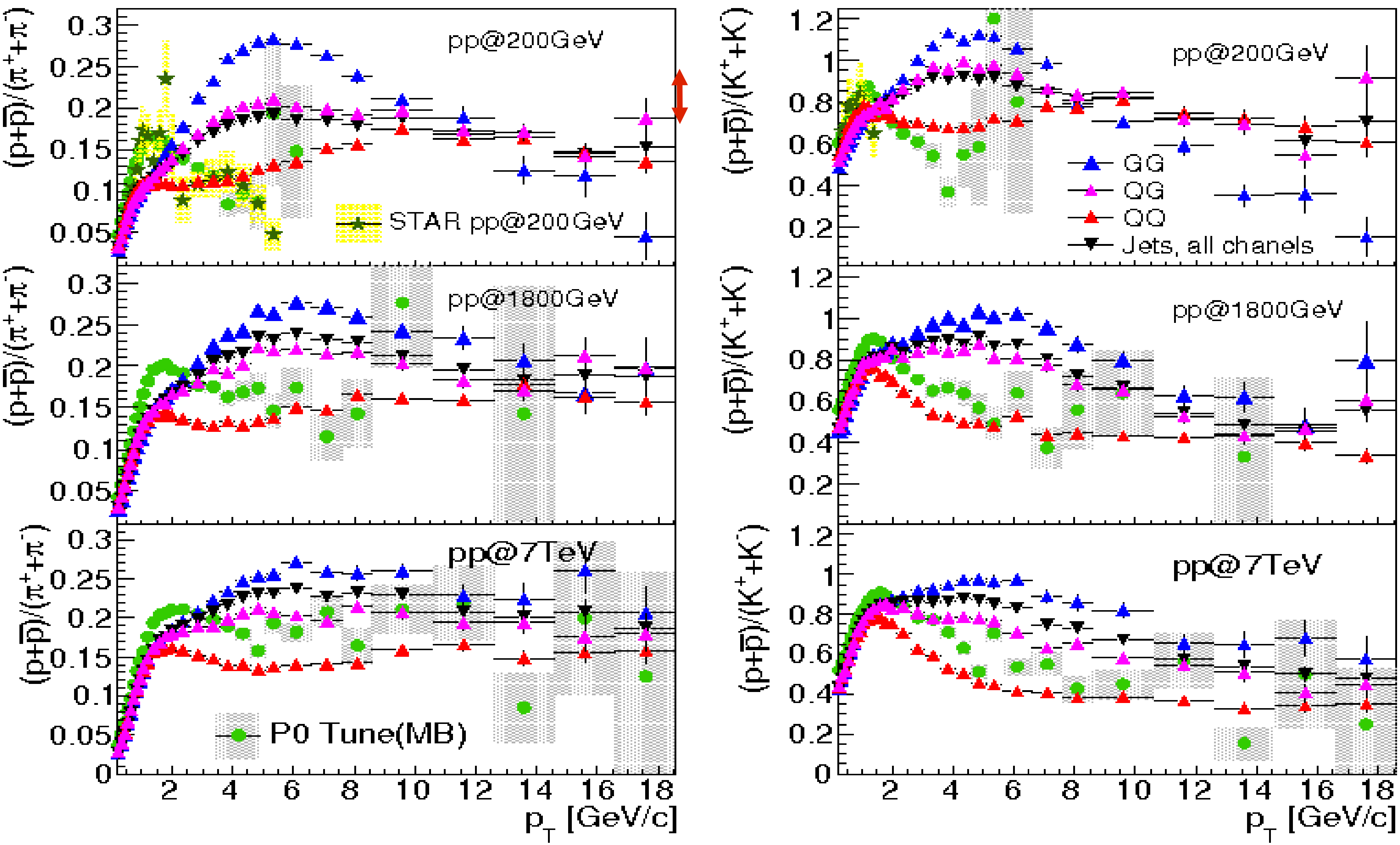




Gluon production dominates spectra, difference in quark production vanish

⇉ ratios levels at 1

p/π, p/K

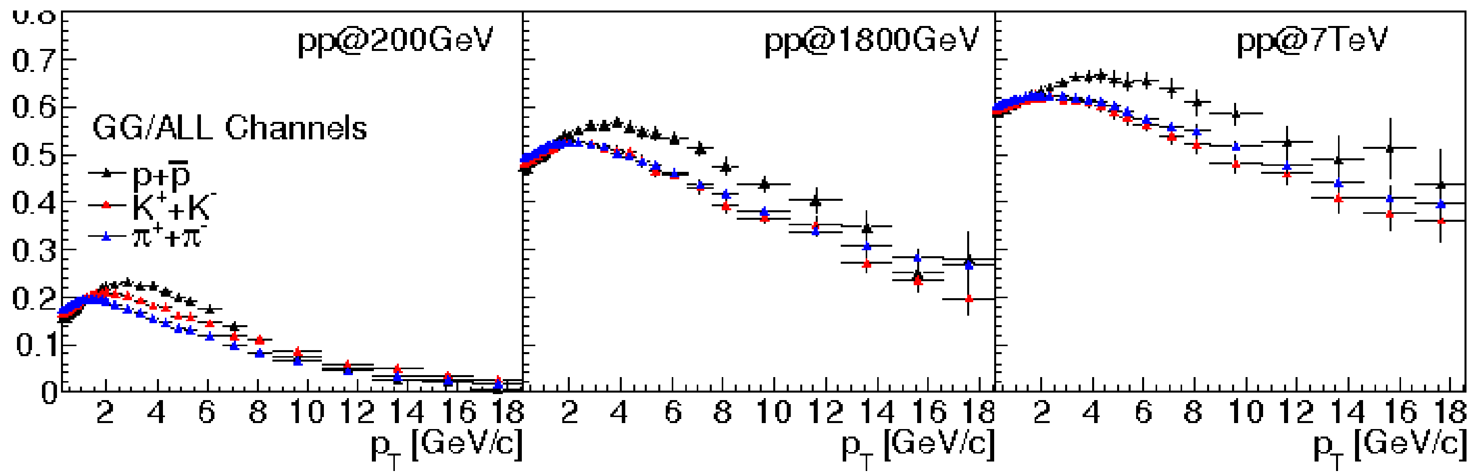


pp@200GeV
STAR pp@200GeV
pp@1800GeV
pp@7TeV
P0 Tune(MB)
GG
QG
QQ
Jets, all chanels
$(p+\bar{p})/(\pi^++\pi^-)$
$(p+\bar{p})/(K^++K^-)$
p_T [GeV/c]

p/π, p/K

- p/π, p/K ratios highest for GG channel (mid-p_T)
- All production channels combined
  - Follow QG channel
  - Merging to GG value with collision energy

Which is consistent with GG channel contribution to individual hadron spectra:



GG channel mainly contributes to proton spectra

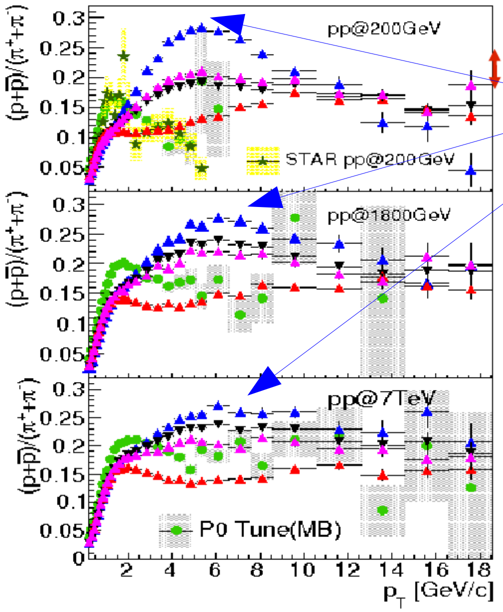
Going higher in p_T the differences vanish

Different point worth mentioning:

Monday; J-P Revol – ***p/π ratio underestimated by PYTHIA when compared to data***

7 TeV – Gluon domination – proton production enhance w.r.t to pions

? PYTHIA tunes parameters may lead to underestimation of proton production in the gluon channel when looking at the full event



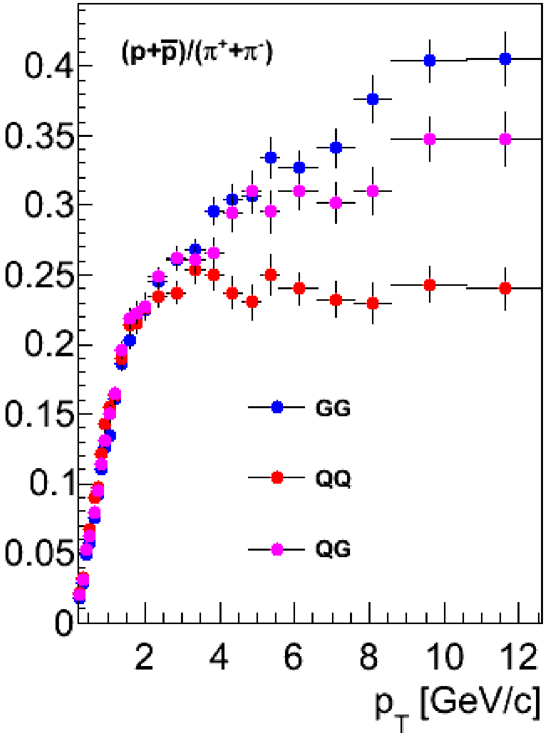
The gluon contribution to the ratios changes to lower values with energy (0.3 - 0.25).

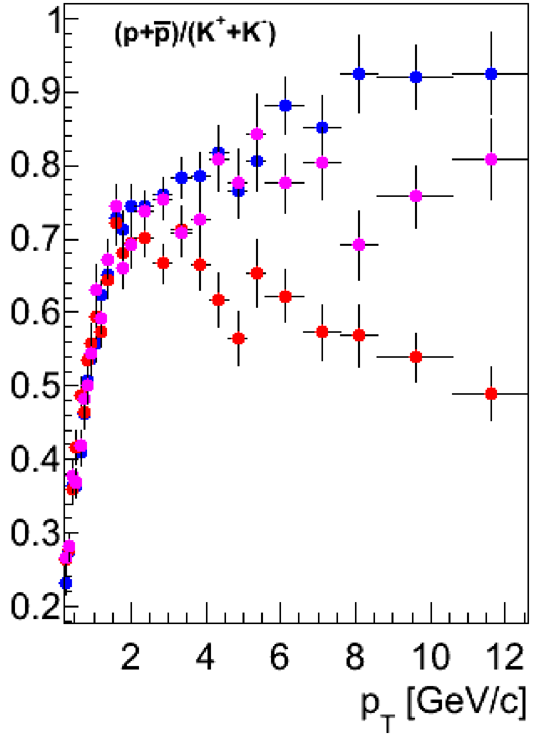
Ratio from all prod.channels on the other hand at ~ TeV energies stays the same (~ 0.25).

! Important to look at separate prod.channels for tuning purposes as well.

Jet algorithm implementation

7 TeV





Anti-kT algorithm (*fastjet.fr*)
R = 0.7

Separating jets from the surronding event - ratio rises

Experimental study of Q/G jets

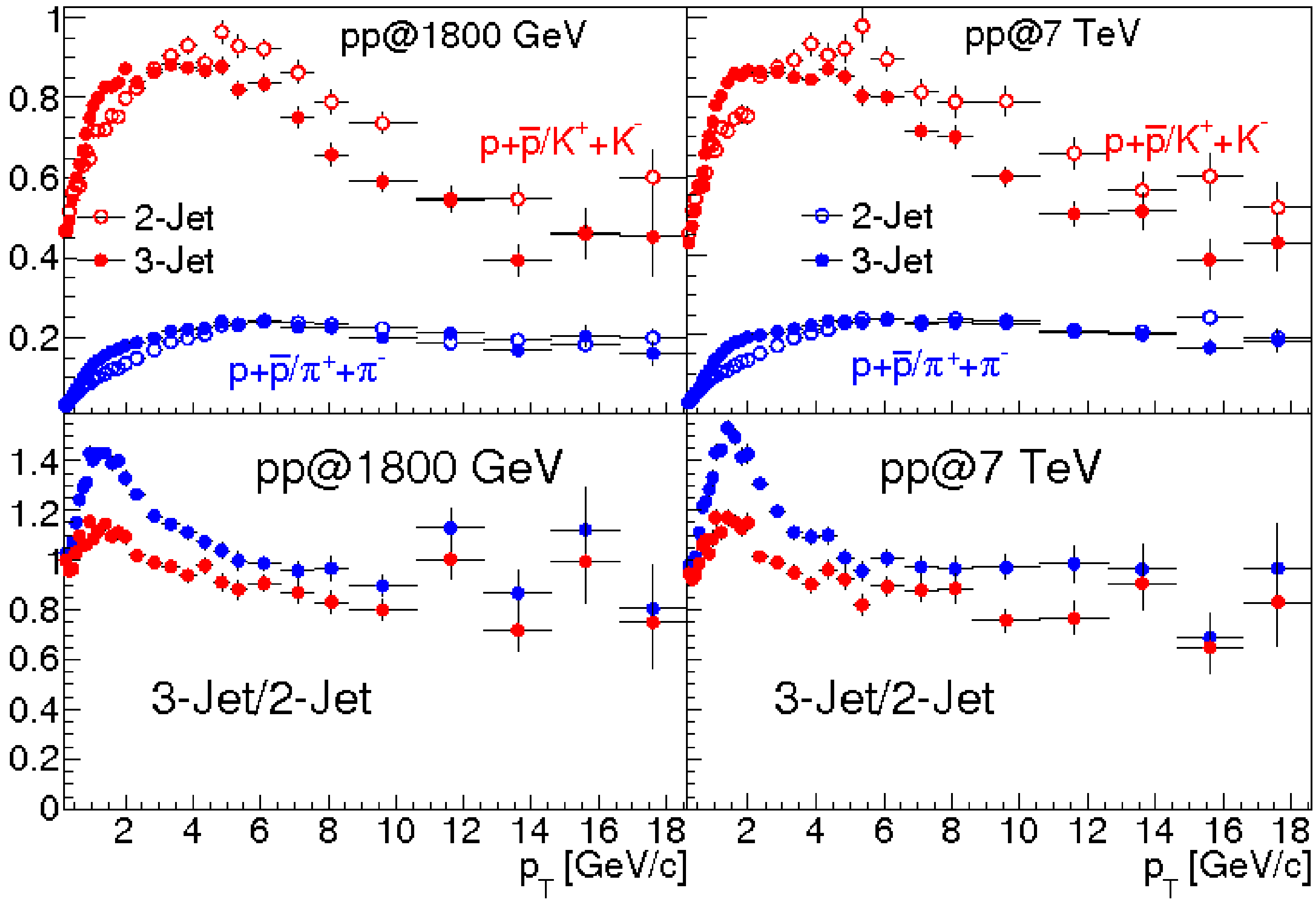
- Using variable cuts based on MC
  - ***Charged multiplicity*** *(Herme's talk)*
  - ***Average pT, radial energy distribution***
  - All based on some prior assumptions in MC >> **BIASED Q/G SELECTION**
- **Multi-jet events**
  - **Additional *hard gluon radiation***
  - **Might provide cross-checks for selection based on MC**

Event shapes

Event shape selection:

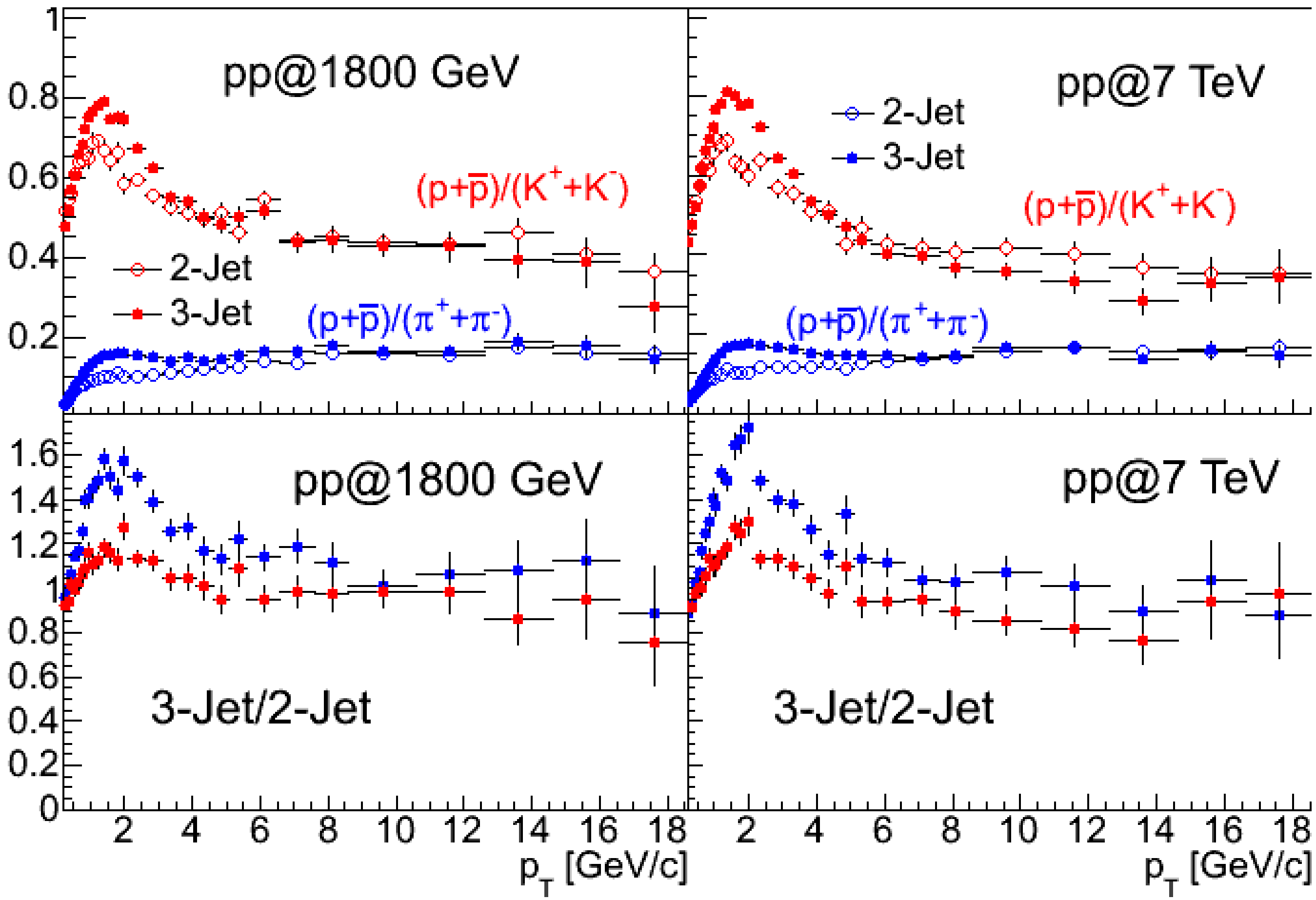
$T > 0.9$ – anisotropic (2-Jet like)

$T < 0.9$ -isotropic (3-Jet like)



Ratios for all production channels
3-Jet events – additional hard gluon radiation
Effect ~ 20-40 %
Effect stronger for pions

QQ (+G)

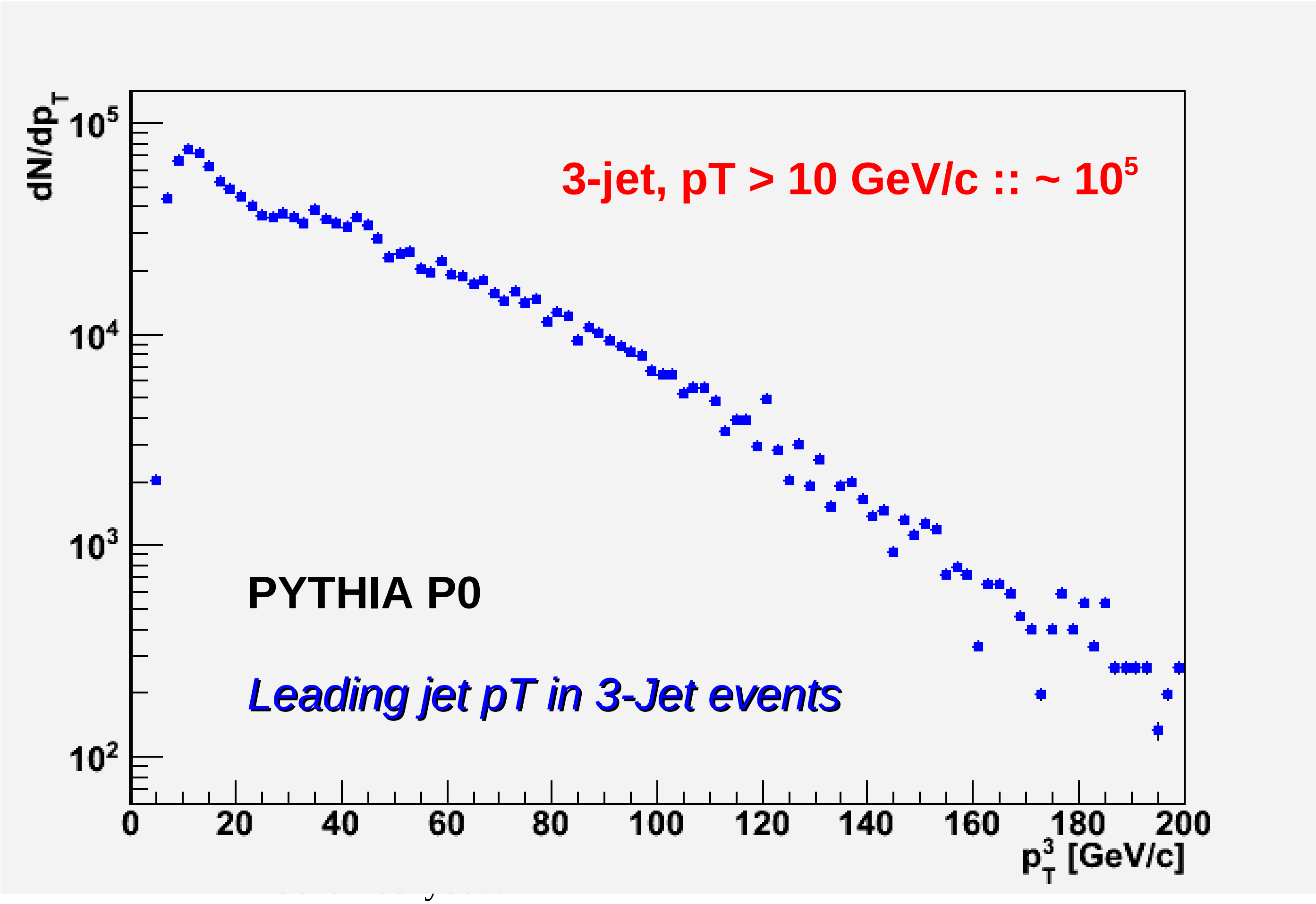


Selecting on QQ channel makes the effect bigger- up to 60 % for pions

3-Jet yield

$$\frac{1}{\sigma_{ine}}\frac{d\sigma}{dp_T} = \frac{1}{N_{trig}}\frac{dN}{dp_T}$$

Ntrig: 700 M. Events
σ (inel): 69 mb



Summary

- *The presented analysis is suitable to study fragmentation properties of quarks and gluons*
- *Selection:*
  - **QQ, GG, QG**
  - **2/3 Jet-like shape**
- *Going to higher $\sqrt{s}_{NN}$*
  - **Sample becomes gluon dominated**
  - **differences between Antiparticle/particle production vanish**
- *Additional gluon radiation*
  - **baryon/meson ratio influenced**