Quark and Gluon jets at RHIC and LHC energies

Introduction

Jets and why they are important
Q/G jet differences

Historical outlook

Short summary of previous experiments

Jets in ALICE(LHC)

Three-jet events in ALICE

Dorffmaister: Pentecost

RHIC School '09
Zimanyi 2009
Winter School on Heavy Ion Physics

Nov. 30. – Dec. 04., Budapest Hungary

József Zimányi (1931 - 2006)

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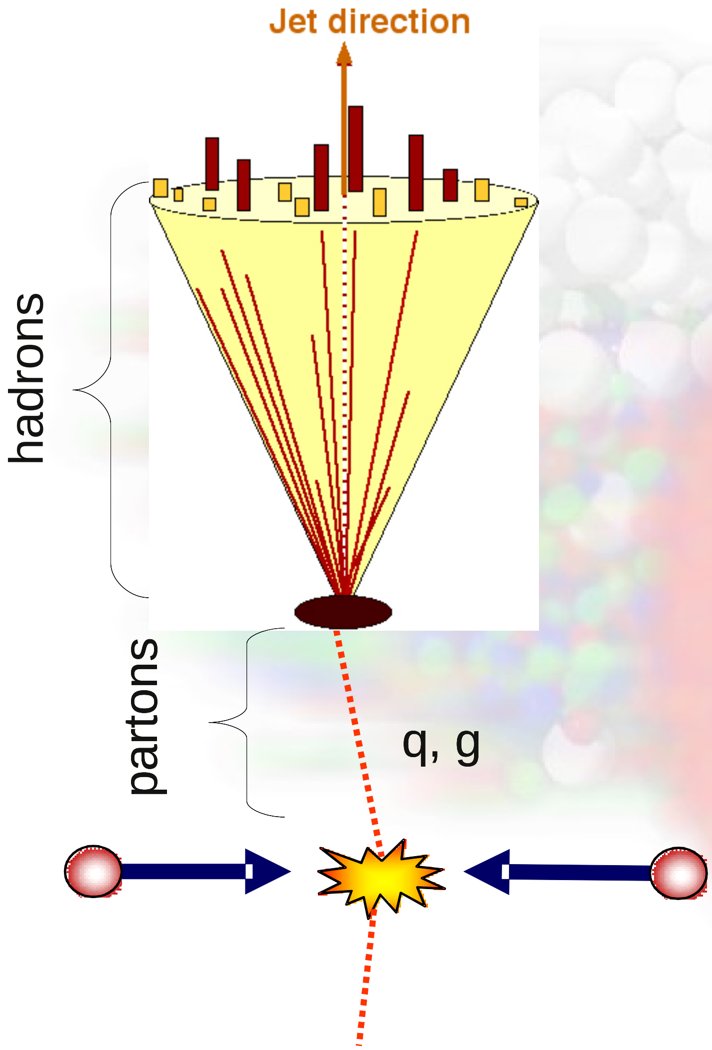
Introduction



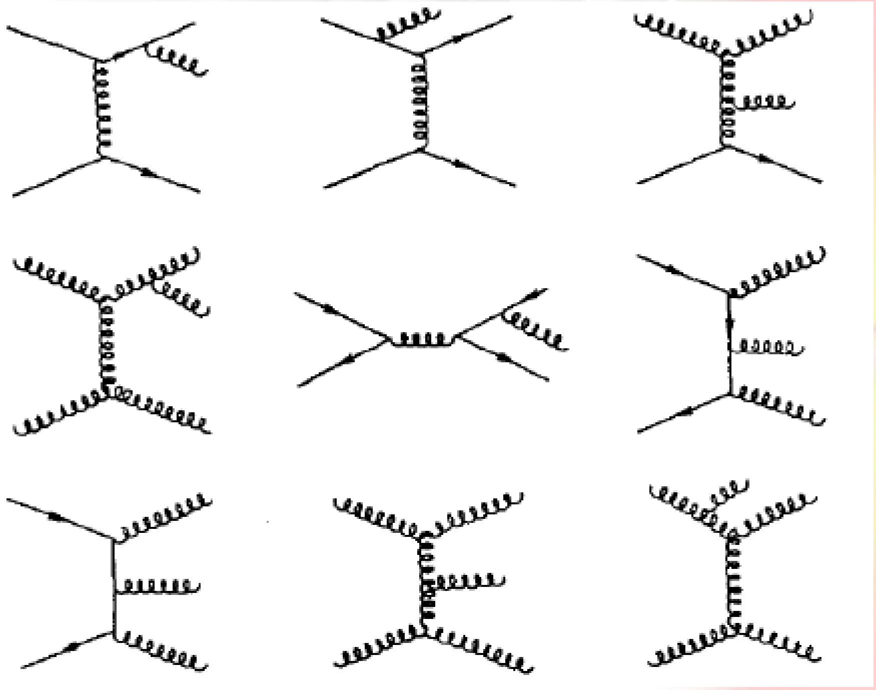
- In **hadron-hadron collisions**, partons may experience **hard scatterings**. The outgoing partons fragment – form **"showers"** - and eventually hadronise
- The hadronised showers can be observed as **jets containing high momentum particles**.

Introduction

Jets are important probes of initial conditions they evolved in

Hard probes and their modification in HI collisions w.r.t pp can be used to study the properties of medium created in such collisions

- During the fragmentation, one of the partons may radiate a hard gluon – ***three-jet event***



Three-jet events are ideal for:

Testing higher order QCD

Studying quark and gluon jet properties based on the event's topology and flavour content

(Both in pp and HI colisions)

Quark and Gluon Jets

Quark and gluon jet carry different colour factors

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

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

Gluons branch more easily and are expected to form

Higher multiplicity jets

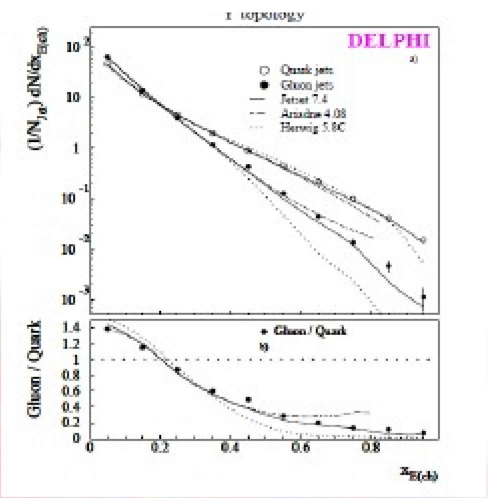
Broader jets

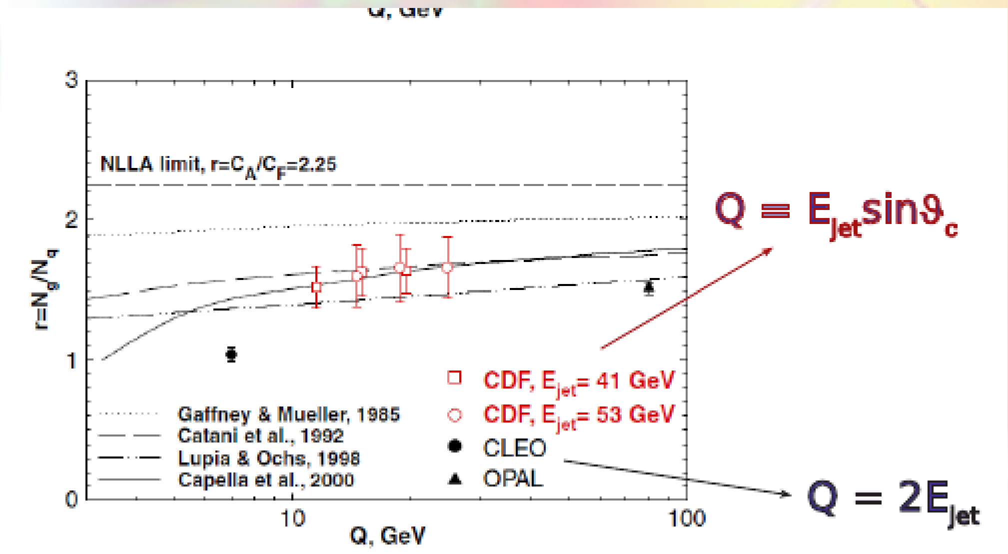
Jets with softer fragmentation function

Historical outlook

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

arXiv:hep-ex/0110084

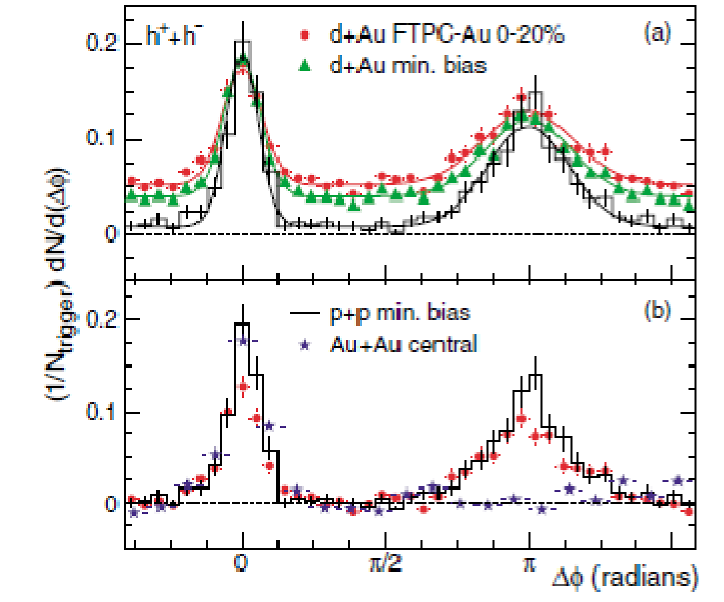




Qualitatively, differences were observed, however, <u>asymptotic limit was not</u>

RHIC

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



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

Many interesting and unexpected observations

Away side jet suppression

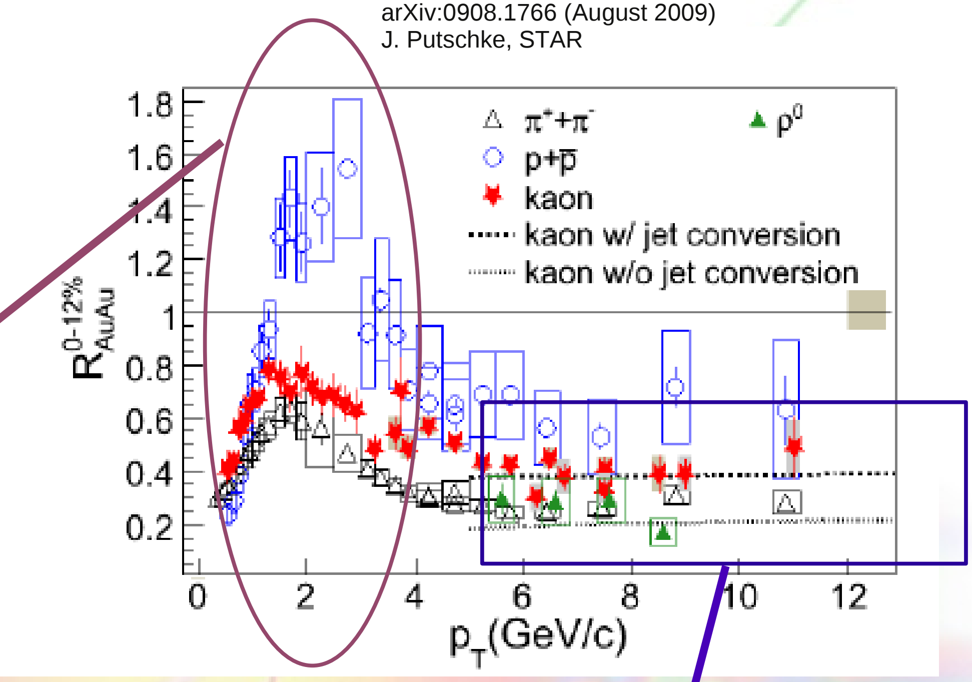
⇒ Dramatic softening of jet fragmentation through rapid energy loss while traversing the medium – soft gluon radiation. Particle spectra are sensitive to such behaviour

JET INTERACTION WITH MEDIUM

mid p_T hadron yield enhanced

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

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



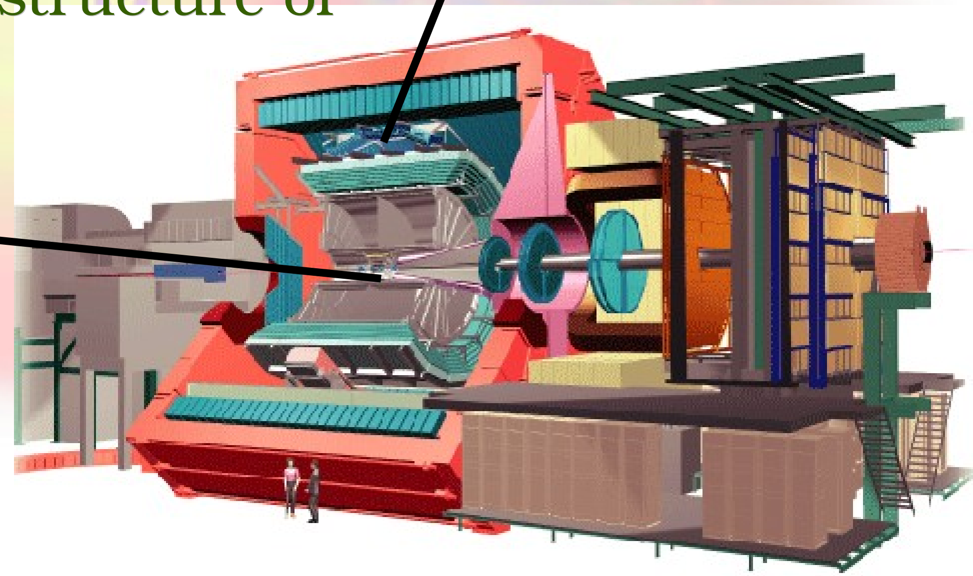
The observed ordering of R_{AA} of identified hadrons is consistent with predictions from calculations including jet flavor conversion in the hot dense medium

COLOR CHARGE EFFECT OF PARTON ENERGY LOSS

Jets at ALICE (LHC)

- High pT capabilities + excellent low pT tracking and PI at high particle densities
- Jet energies up to 250 GeV
  - Jets in HI collisions can be reconstructed above the background from the underlying event
  - Pure QCD regions
- Experimental conditions are suitable for studying modification of the structure of fully reconstructed jets

EMCAL
Neutral particles
DeltaPhi = 107, |eta| < .7
Energy res. 10 %
Trigger capabilities

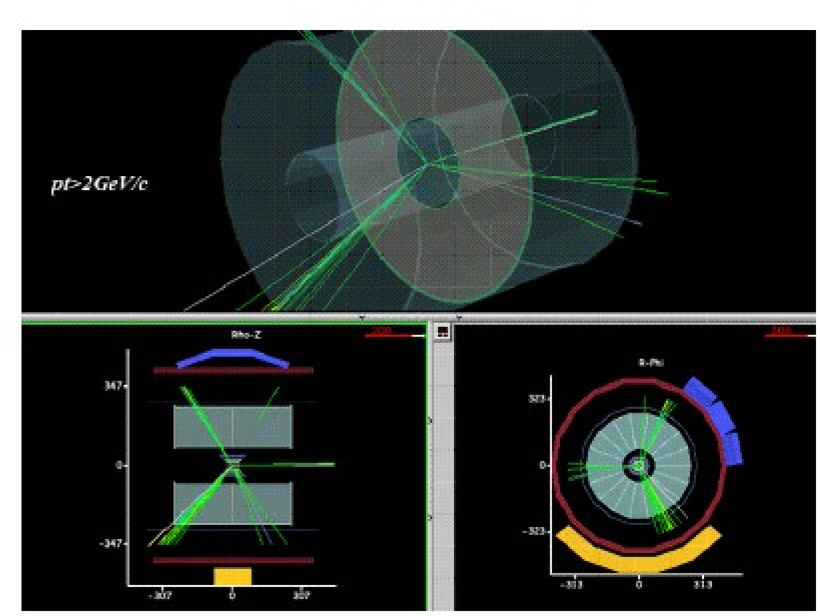


ITS+TPC+(TOF, TRD)
Charged particles |eta| < 0.9
Excellent momentum resolution up to 100 GeV/c (6%)
Tracking down to 100 MeV/c
Excellent PID and heavy flavour tagging

Three-jet events

- Observables of interest
  - ***Cross-section***
  - ***Event shape variables***
    - Dalitz variables
    - Transverse thrust

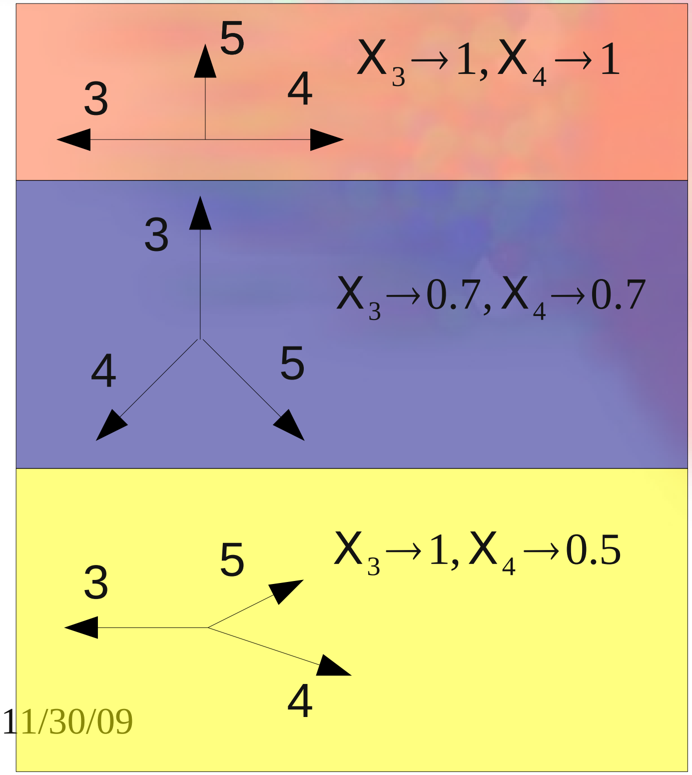
Global characteristics of an event

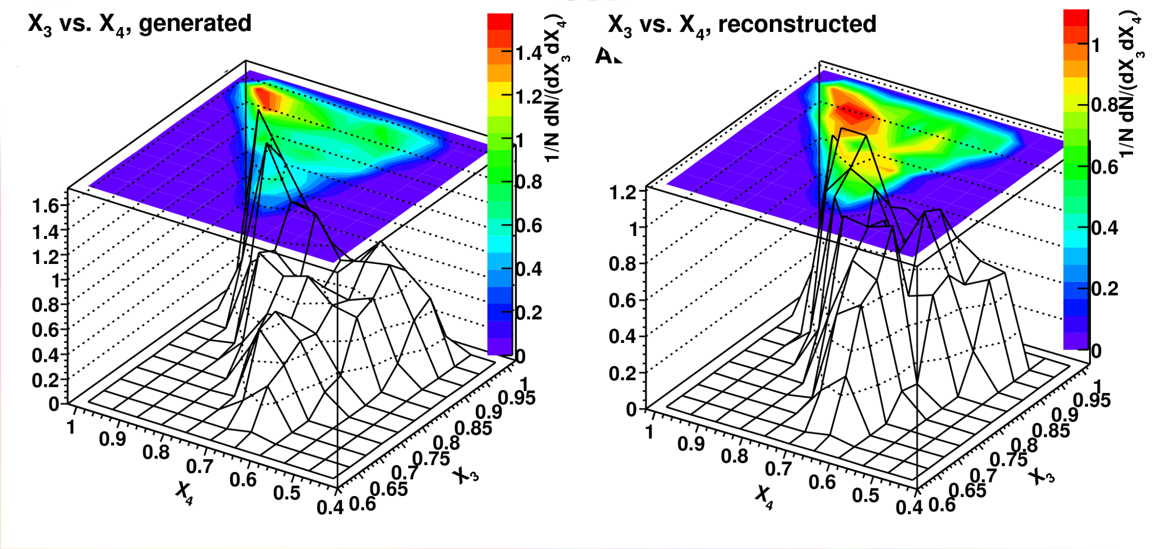


  - ***Jet-by-jet observables***
    - Flavour composition
    - Fragmentation function

Dalitz variables

$$X_i = \frac{2\,E_i}{\sum_{i=3}^{5} E_i},\; E_3 > E_4 > E_5$$

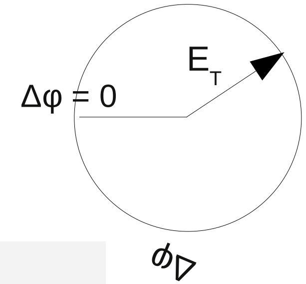




X_3 -> 1, X_4 -> 1 dominant

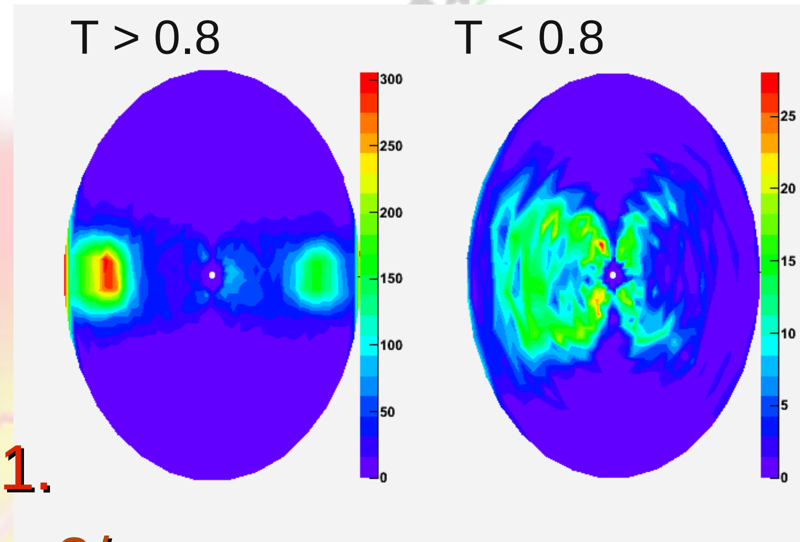
Consistent with previous studies (CDF)

Event Shape



- Transverse thrust

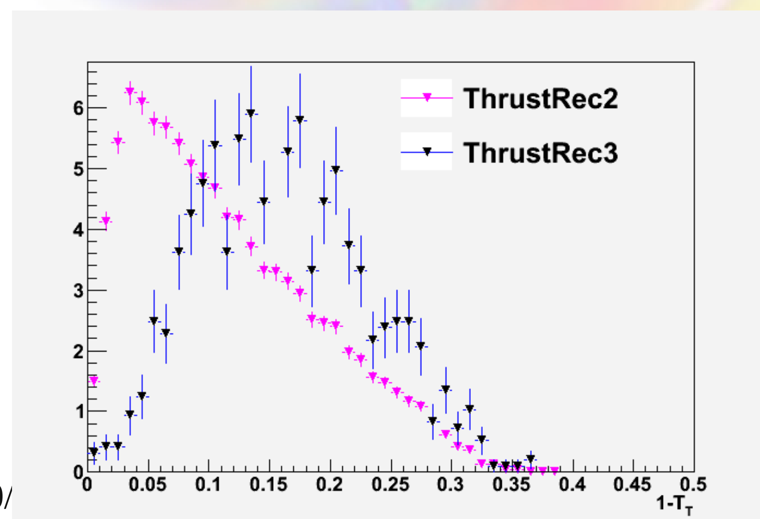
$$T_T = \max_{|\vec{n}|=1} \frac{\sum_i \vec{p}_{Ti} \cdot \vec{n}}{\sum_i |p_{Ti}|}$$



<u>Limits:</u>

Planar event (eg. 2-jets) $T_T \to 1$.

Isotorpic event (eg. 3-jets) $T_T \to 2/\pi$



Higher thrust values – balance – 2-jet events

Lower thrust values - 3-jet structure

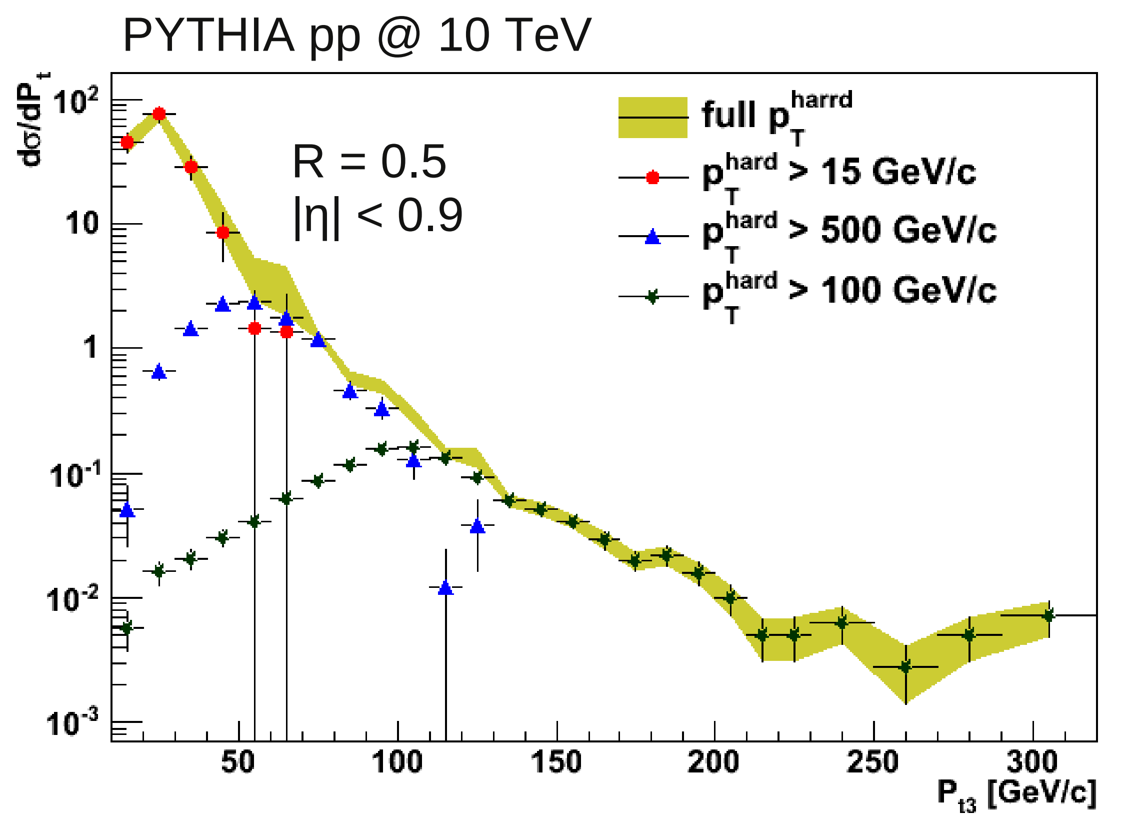
Three-jet events rates

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

σ_{ine}[mb]	Event rate[Hz]	N_{trig}/8 months
69	10^4	3×10^{10}

$p_T > 10$ GeV/c :

$\approx 10^5$ three-jet events/8 months



Summary

Jets - key to understanding interactions between partons and formation of hadrons in both pp and HI collisions

Results from pp collisions are so far consistent with QCD picture

HI - RHIC saw new, unexpected phenomena, which have a place in LHC research to study and understand them better