Jet Quenching with ALICE

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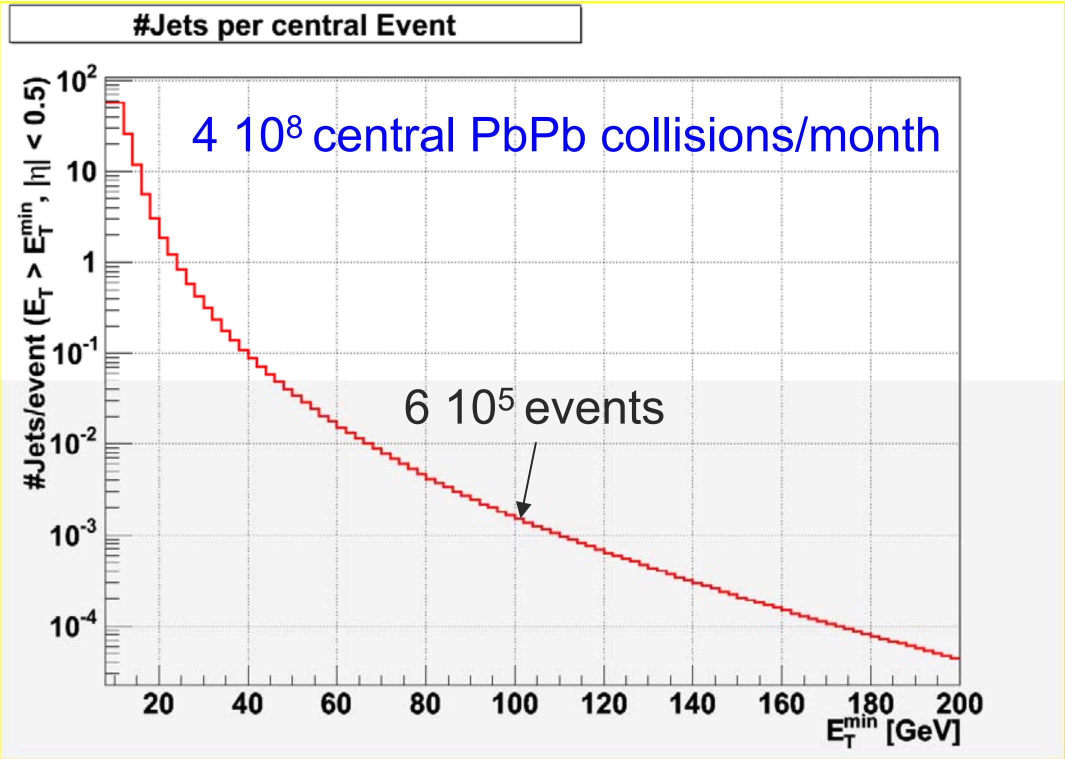
Physics at LHC
13-17 July 2004 . Vienna . Austria

Outline

- Rates
  - .... the need for triggering
- From particle correlations to jet measurements
  - .... the need for calorimetry
- Jet reconstruction in the LHC HI environment
  - ... small cone sizes for jet identification
- Quenching Models
  - ... the need for MC generators
- Quenching Measurements
  - ... lessons from theory predictions and toy-models
  - ... why low p_T is important to measure high-p_T phenomena

Jet Rates



- Several jets E_T < 20 GeV per central event
- Statistics limit ~ 200 GeV
- Minimum Bias E_T > 100 GeV
  - 1.5 10^6 jets/month produced
  - No trigger: 10^4 jets on tape
  - **Need Trigger !**

Jet studies in PbPb

Trigger Limit

2GeV — 20 GeV — 100 GeV — 200 GeV

Event structure and properties p_T > 2GeV
'Underlying' Event Fluctuations

Event-by-event well distinguishable objects

Resolution limit

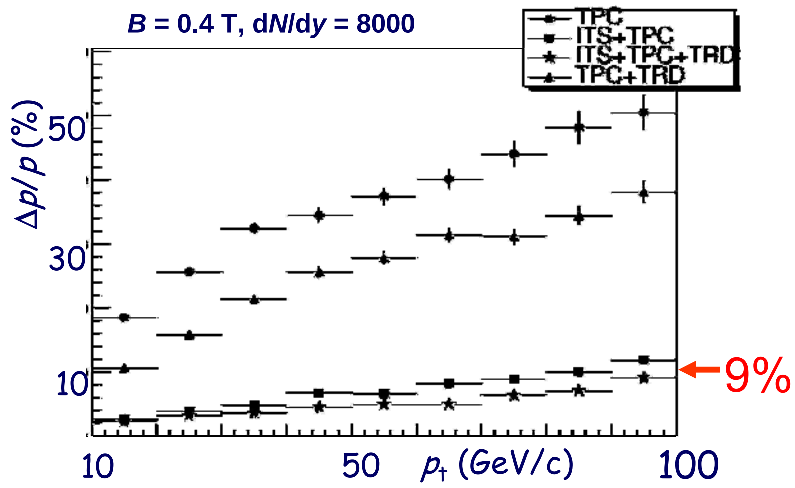
Inclusive (correlation) studies

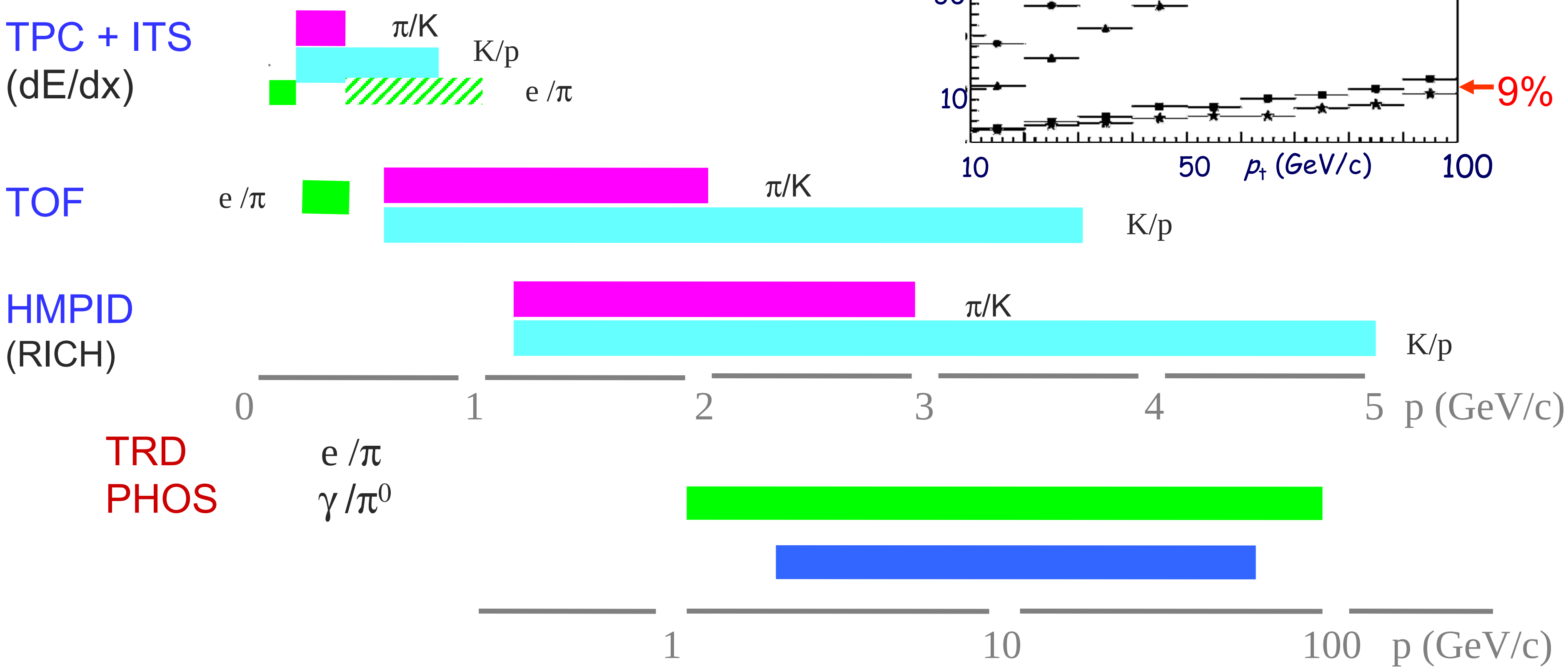
Charged tracks (TPC) + PID

Reconstructed Jets

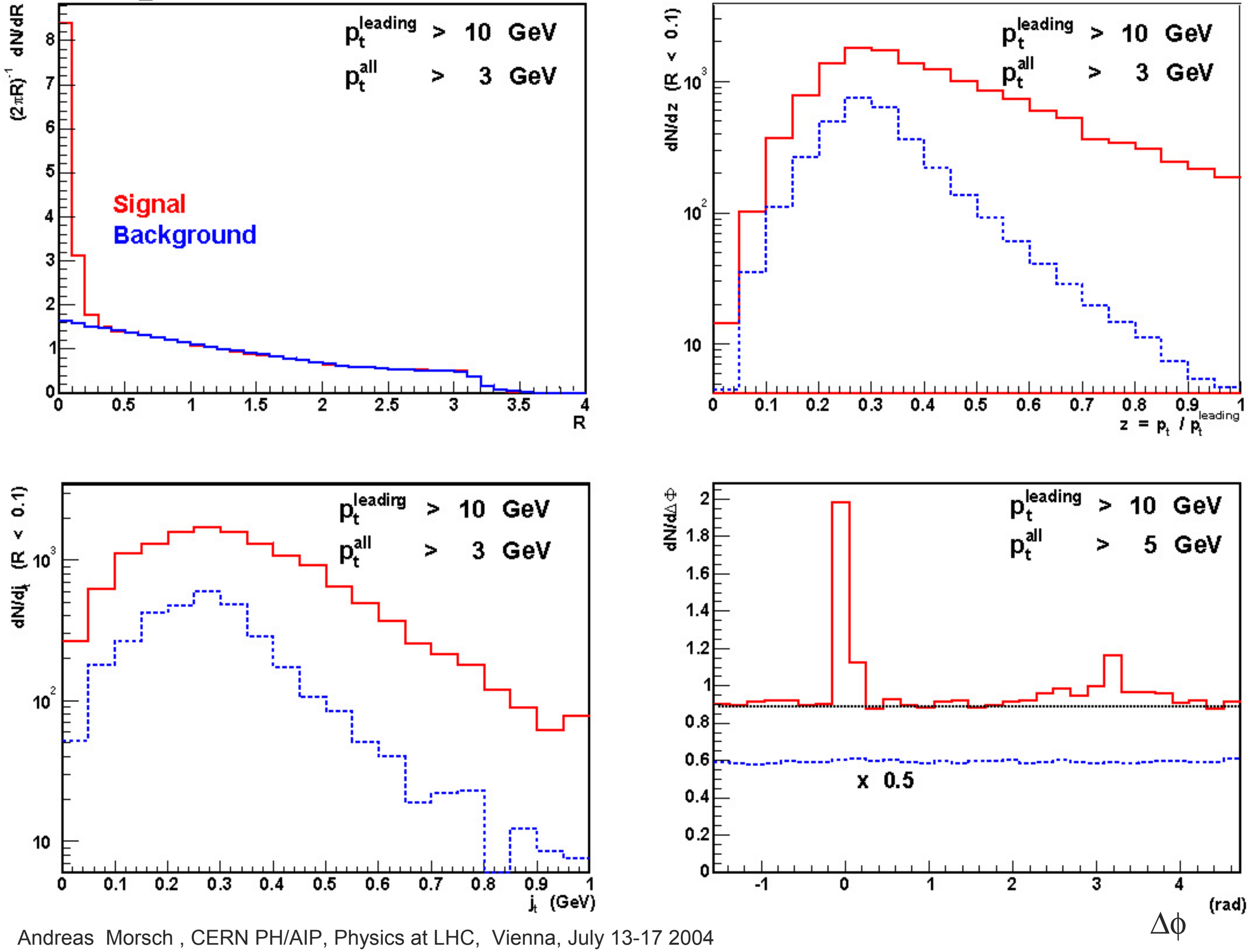
Needs Calorimetry (EMCAL)

Central ALICE: Momentum Resolution and PID





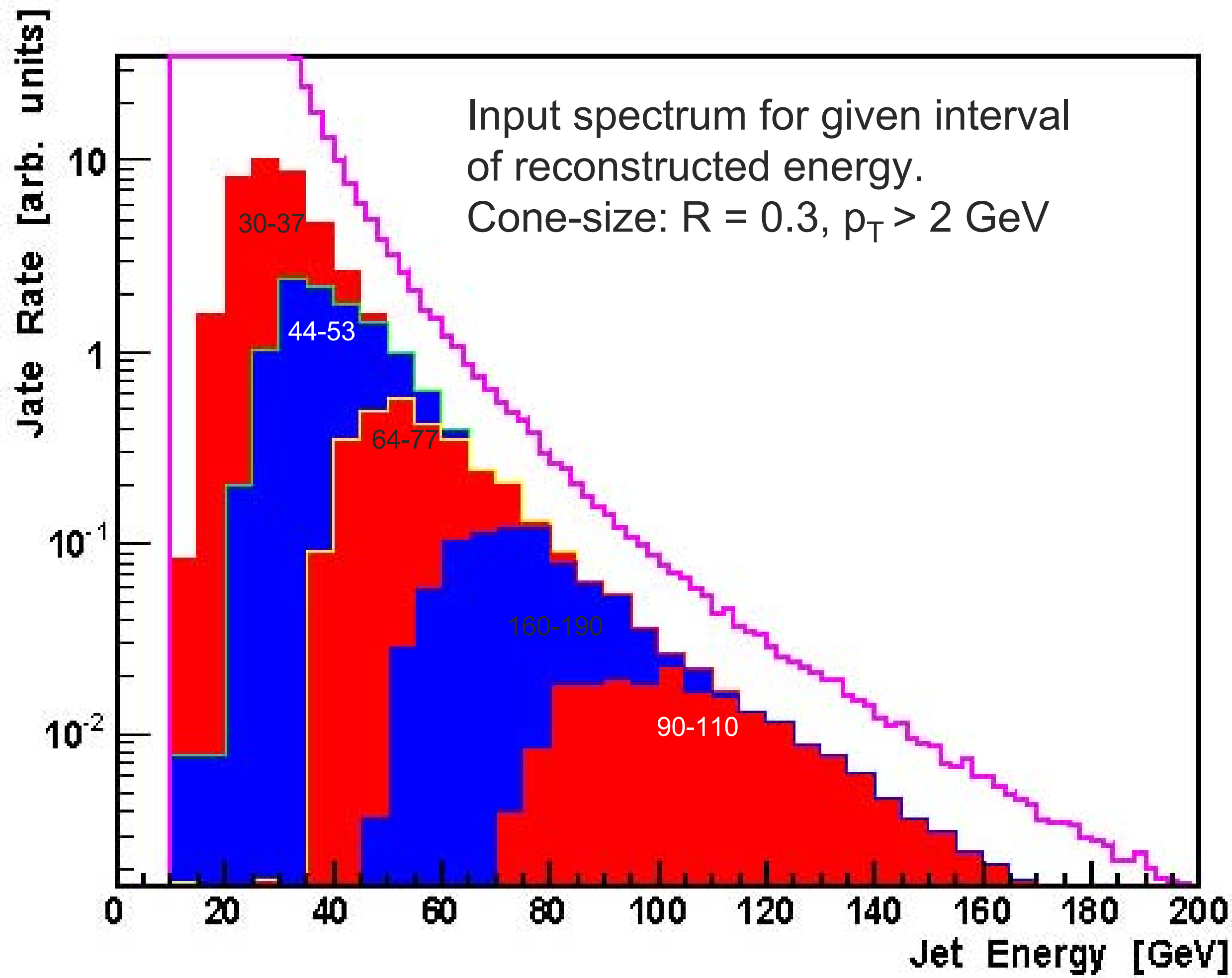
Leading Particle Correlation



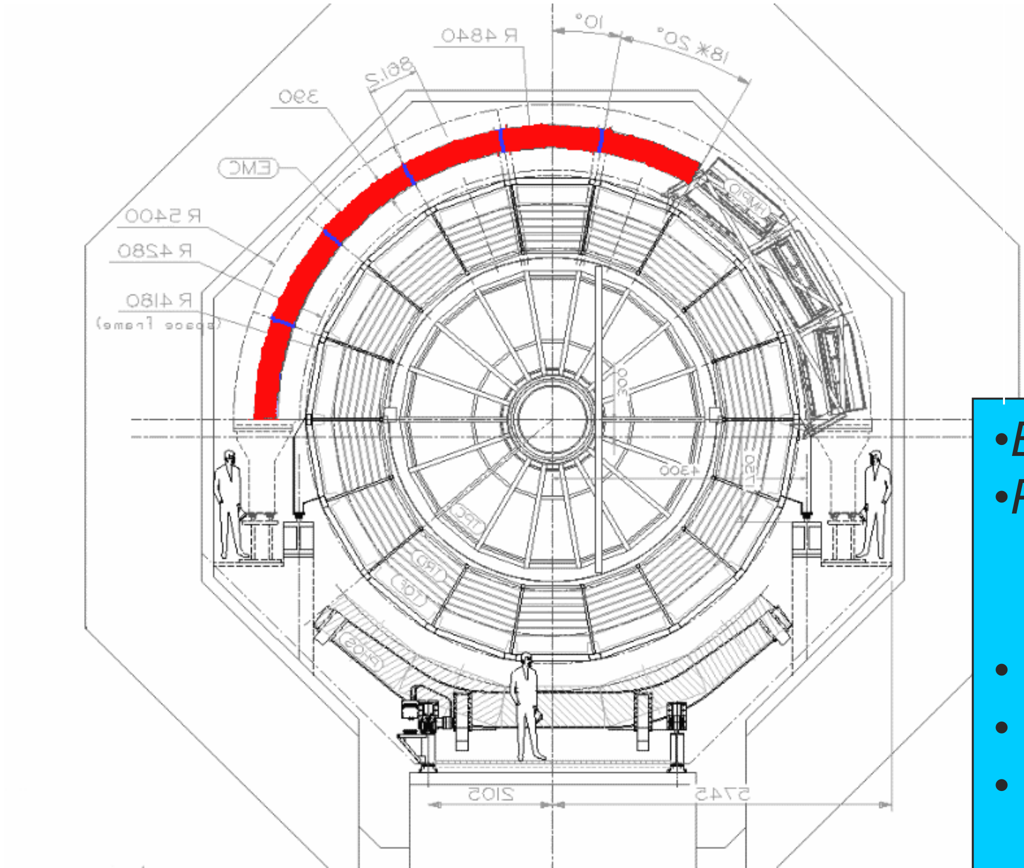
HIJING Simulation
PbPb b=0-5 fm

Background estimated
from random combinations

Jet energy resolution using charged particles



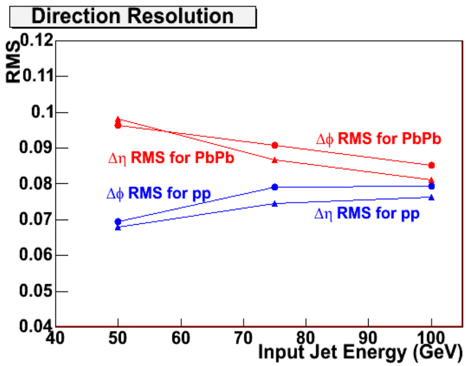
Proposed ALICE EMCAL

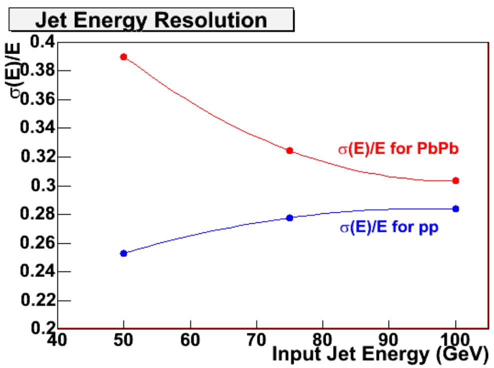


- *EM Sampling Calorimeter (STAR Design)*
- *Pb-scintillator linear response*
  - $-0.7 < \eta < 0.7$
  - $\pi/3 < \Phi < \pi$
- *12 super-modules*
- **19152** *towers*
- *Energy resolution ~15%/√E*

EMCAL
Directional and Energy Resolution

- Modified UA1 cone algorithm
- Uses combination of tracking and calorimeter information
- Cone Radius: R = 0.3, Seed 4.6 GeV, Minimum Jet energy 14 GeV
- Background HIJING PbPb b = 0-5 fm



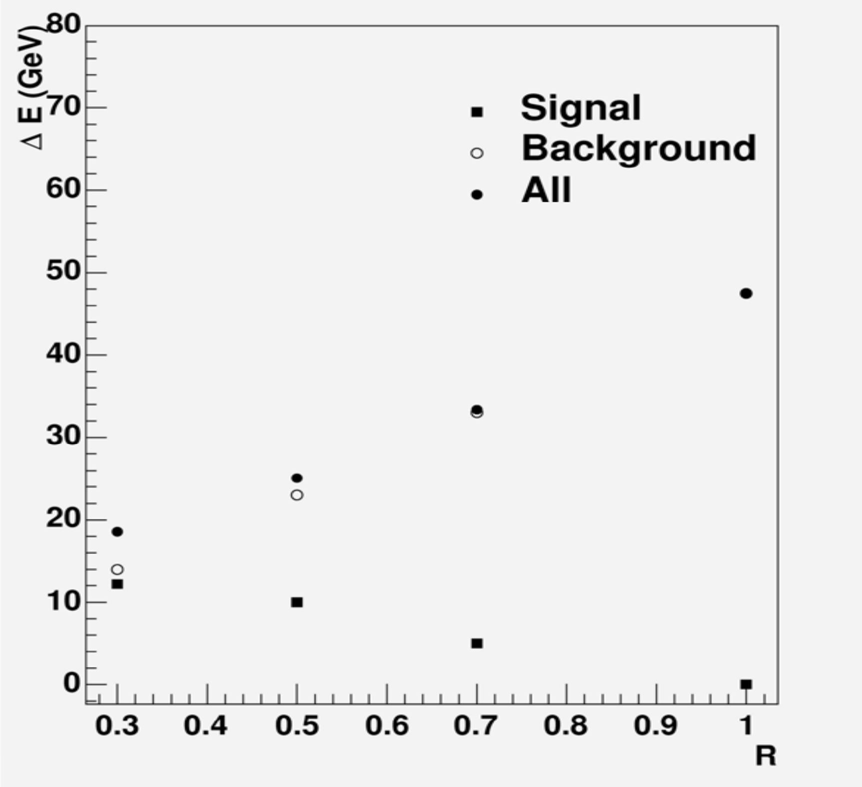


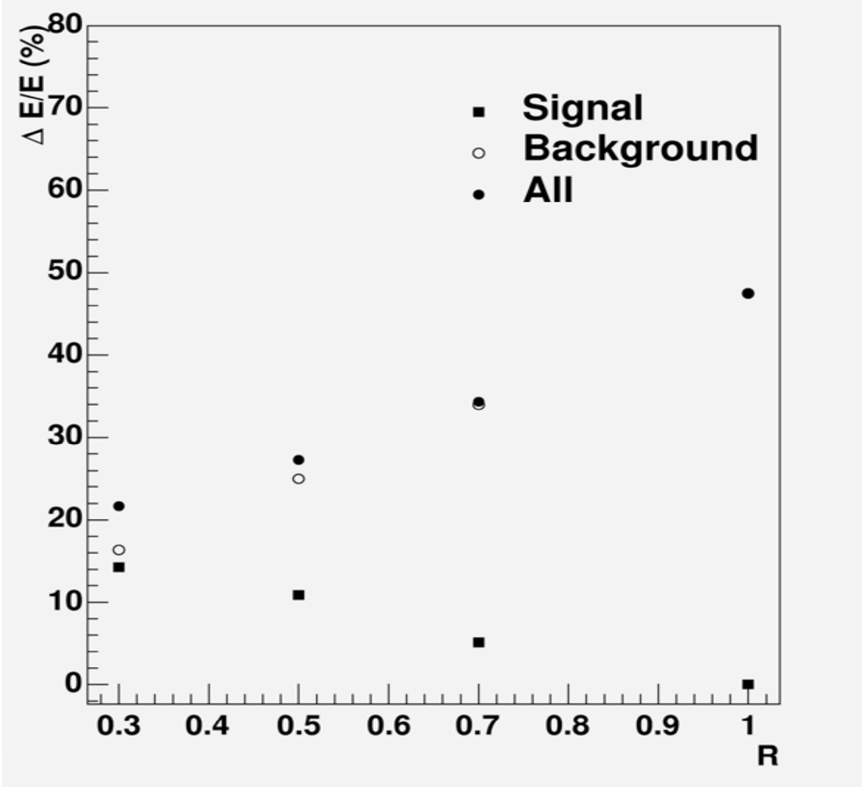
Jet Reconstruction in the LHC Heavy Ion Environment

Irreducible Fluctuations: Out-of-cone and Background

Fluctuations are evaluated relative to energy in cone *R*<1 "parton energy"

E = 100 GeV

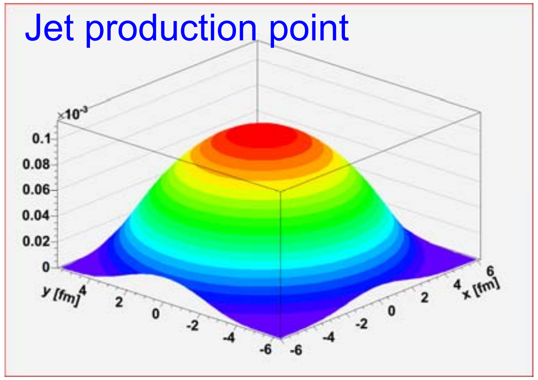


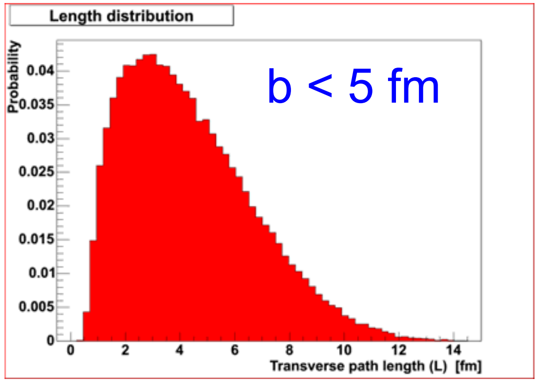


Quenching Measurement

- Goals (long term)
  - Measure $\Delta E(E,L, \{q, g\})$
  - Distribution of radiated energy in phase space (angle, momentum)
  - Constrain model parameters
- Goals (short term)
  - Understand the influence on jet observables:
    - Background
    - Limited cone-size
    - out-of-cone fluctuations
    - out-of-cone radiation

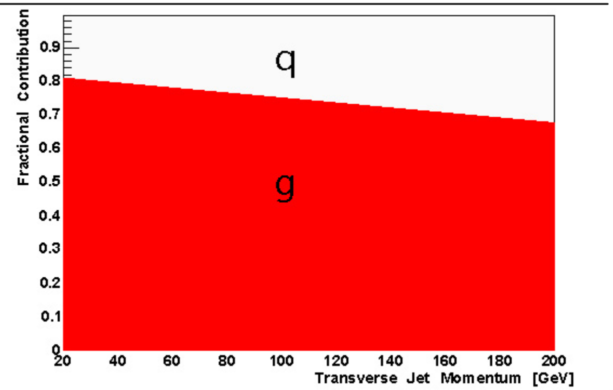
In medium path length (*L*) cannot be fixed:





Vary impact parameter and perform measurements relative to reaction plane

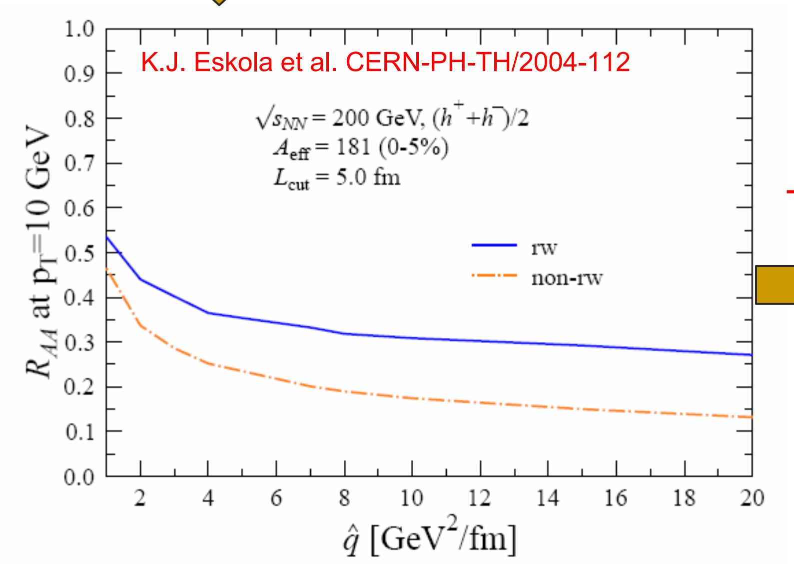
Gluons dominate !



Need for MC

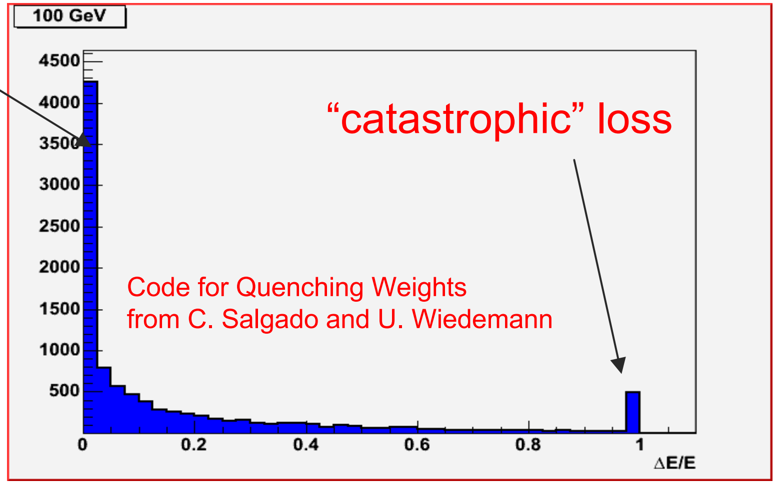
Discrete, "no loss", part dominates leading particle Spectrum: R_{AA} and high-momentum fraction in Fragmentation Function.

Small dependence on Model parameters.



Quenching Weights "Bremsstrahlung" Spectrum

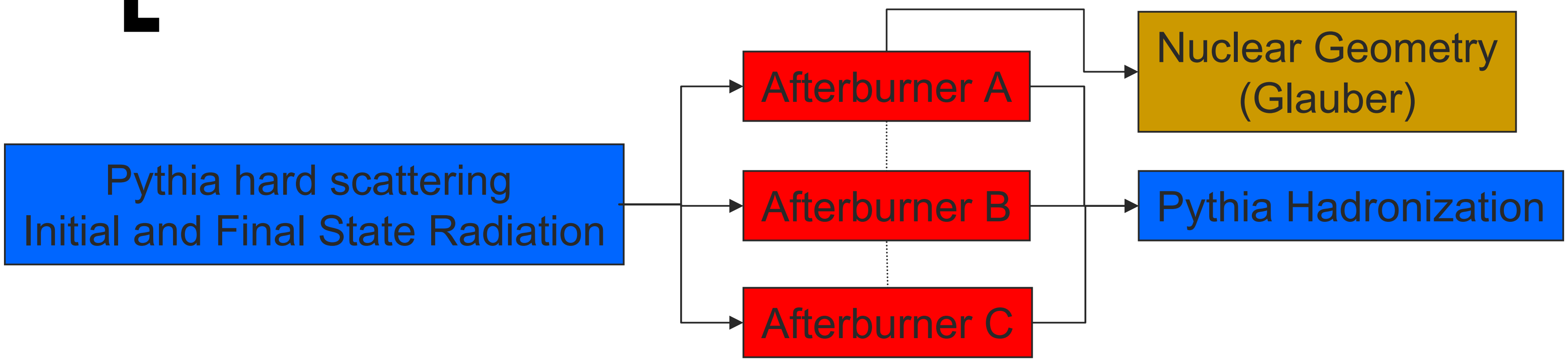
no loss



The way out

- Measure original parton (jet), parton after energy loss and radiated energy (jet structure).
- No trivial relation between energy loss and jet observables.
- Need MC combining consistently parton shower and medium induced energy loss to interpret data.

Simplified Models



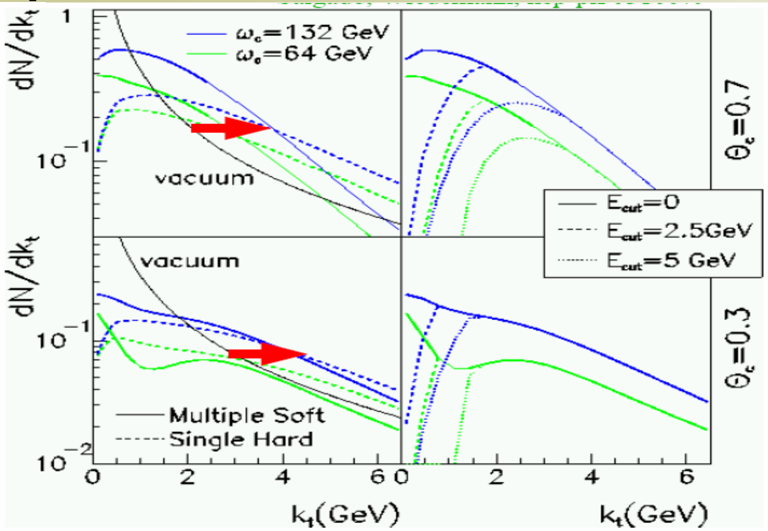
Jet (E) → Jet (E-ΔE) + n gluons (“Mini Jets”)

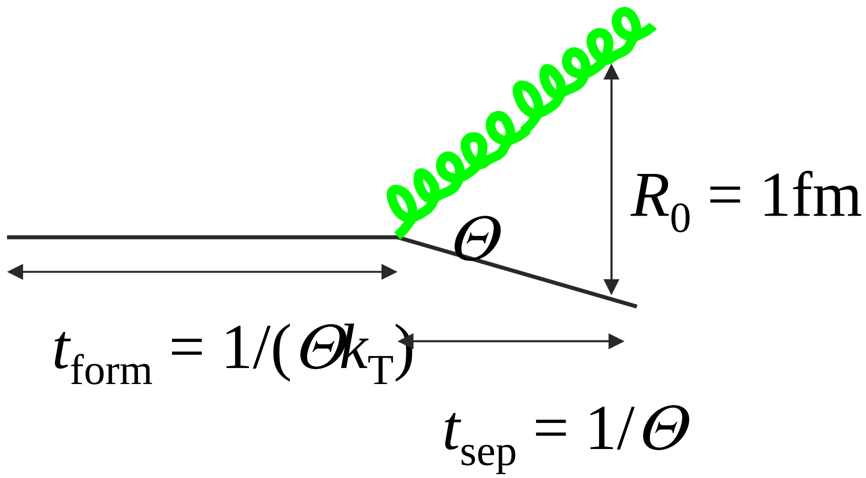
- **Two extreme approaches**
  - Quenching of the final jet system and radiation of 1-5 gluons. (AliPythia::Quench + Salgado/Wiedemann - Quenching weights with q= 1.5 GeV^2/fm)
  - Quenching of all final state partons and radiation of many (~40) gluons (I. Lokhtin, Pyquen)*
- **Can we learn something from these toy MCs ?**

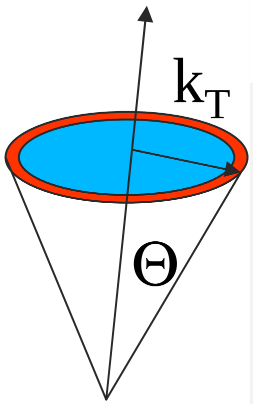
)* I.P. Lokhtin et al., Eur. Phys. J C16 (2000) 527-536
I.P.Lokhtin et al., e-print hep-ph/0406038
http://lokhtin.home.cern.ch/lokhtin/pyquen/

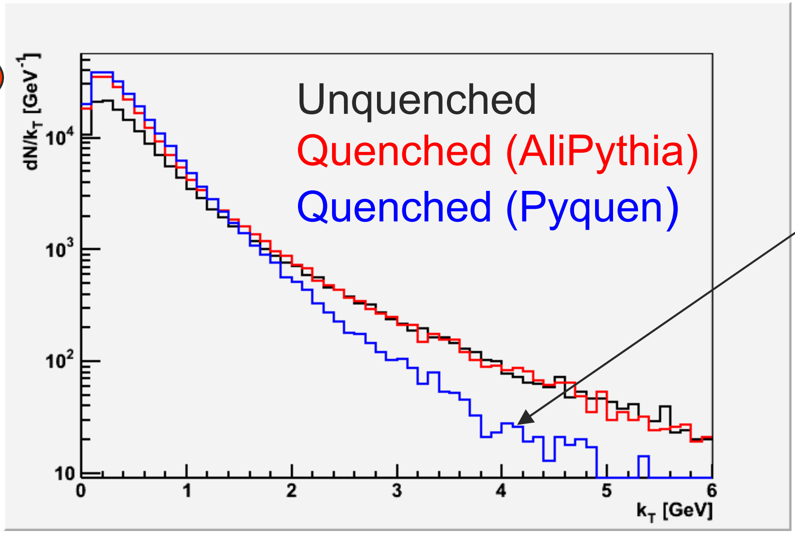
k_T – Spectra

Salgado, Wiedemann, hep-ph/0310079





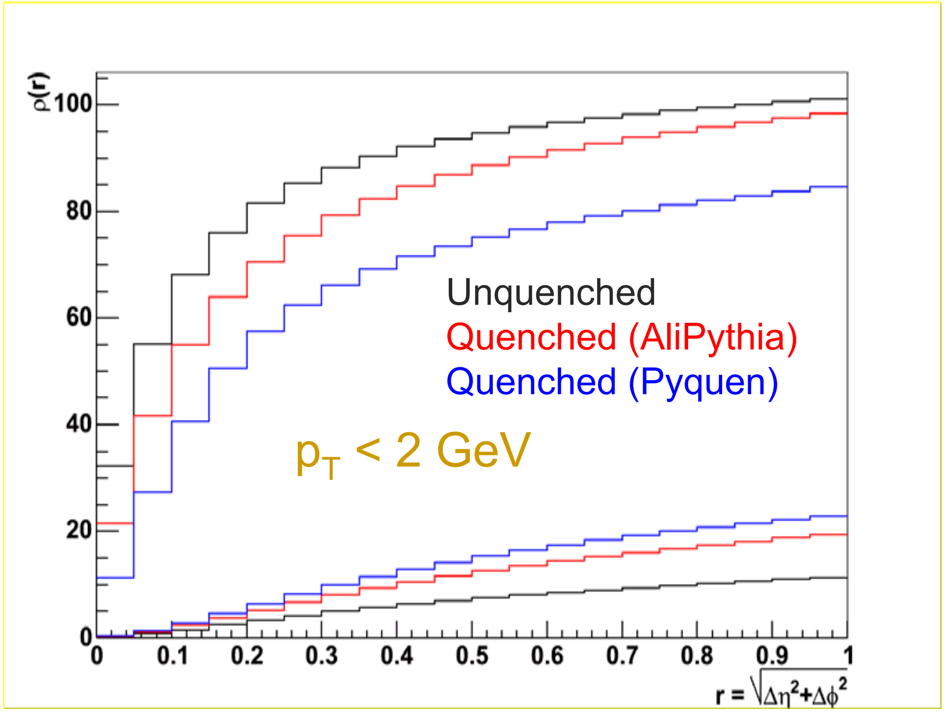




- PYQUEN: Strong quenching of radiated gluons leads to a softening of the k_T distribution.
- Formation Time: Gluons at high k_T and/or high Θ are emitted at early times and might indeed be quenched.

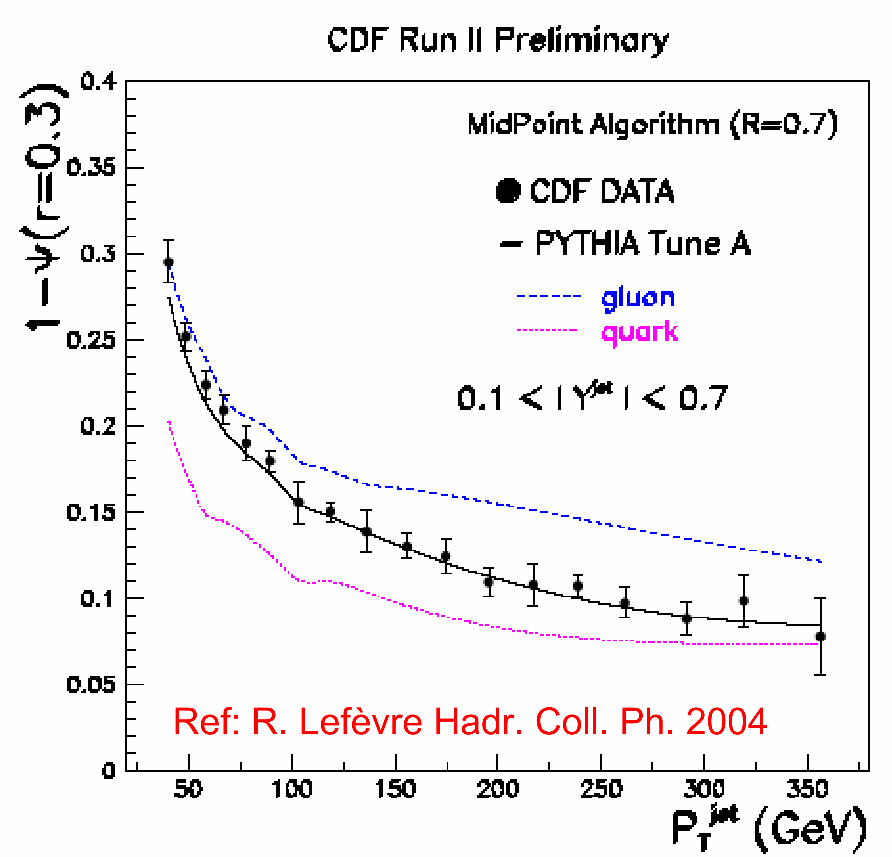
Jet shapes

Note: $\Theta = \sin^{-1}(k_T/p_l)$
Theory predicts increase of k_T
and decrease of p_l !

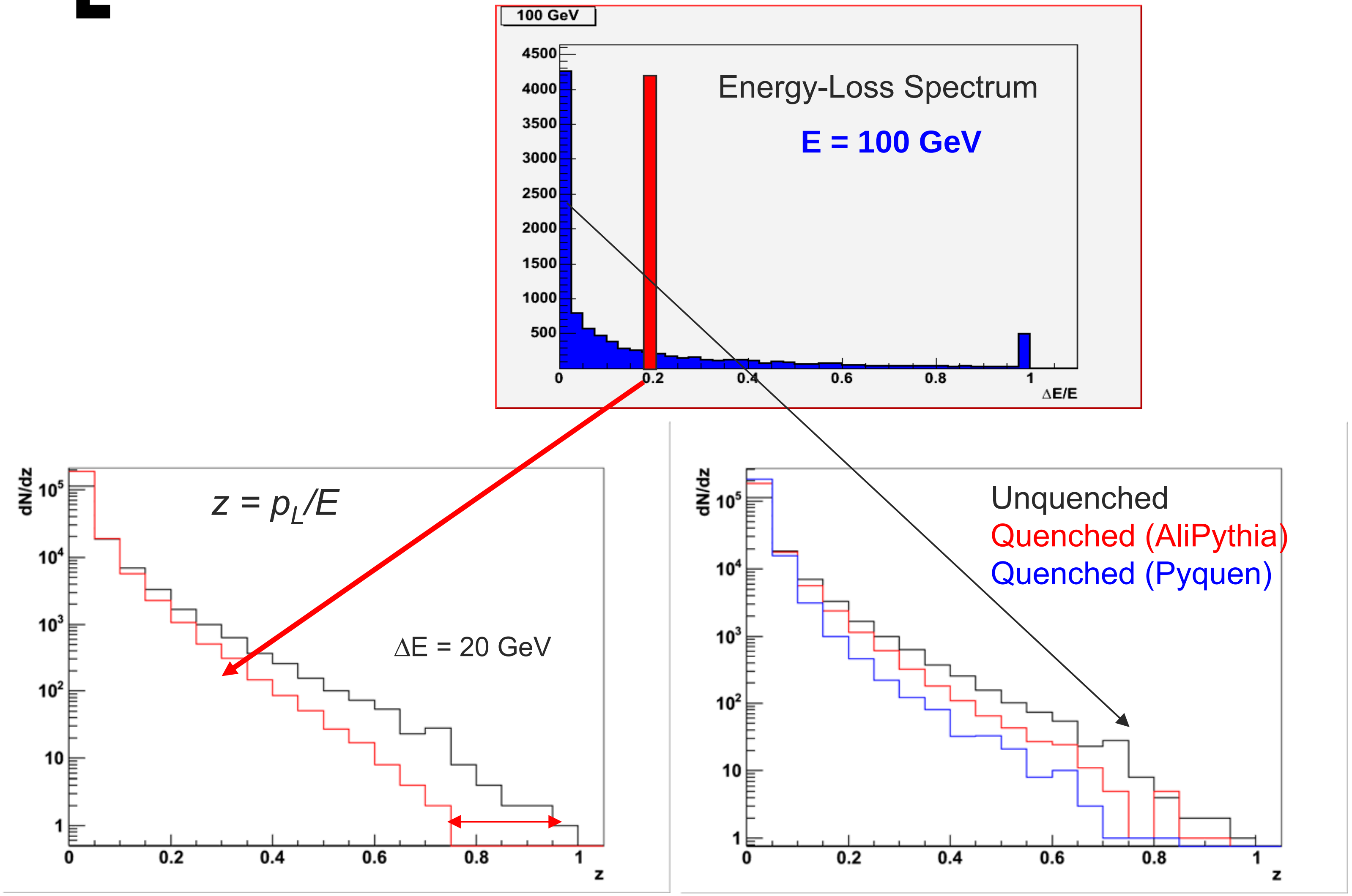


Largest effect seen in low-p_T particles.

pp: Energy outside cone of 0.3 as function of jet energy.

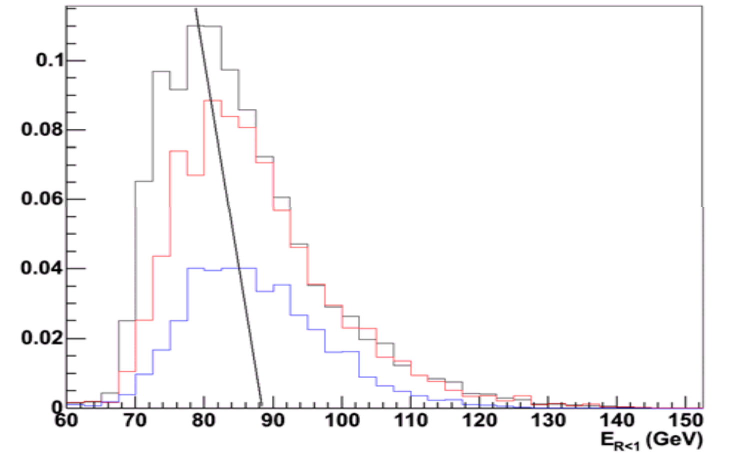


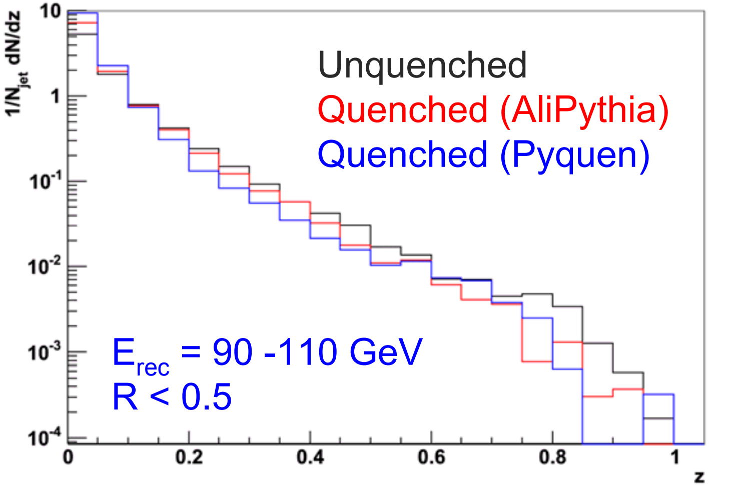
Interpreting Fragmentation Functions



Out of cone radiation

- Consequence of out-of-cone radiation
  - At fixed parton energy: Energy (E_c) in reduced cone decreases $z = p_L/E_c$ increases
  - At fixed reconstructed energy: bias towards higher parton energies: p_L and consequently z increase.
  - Softening of fragmentation function is masked.

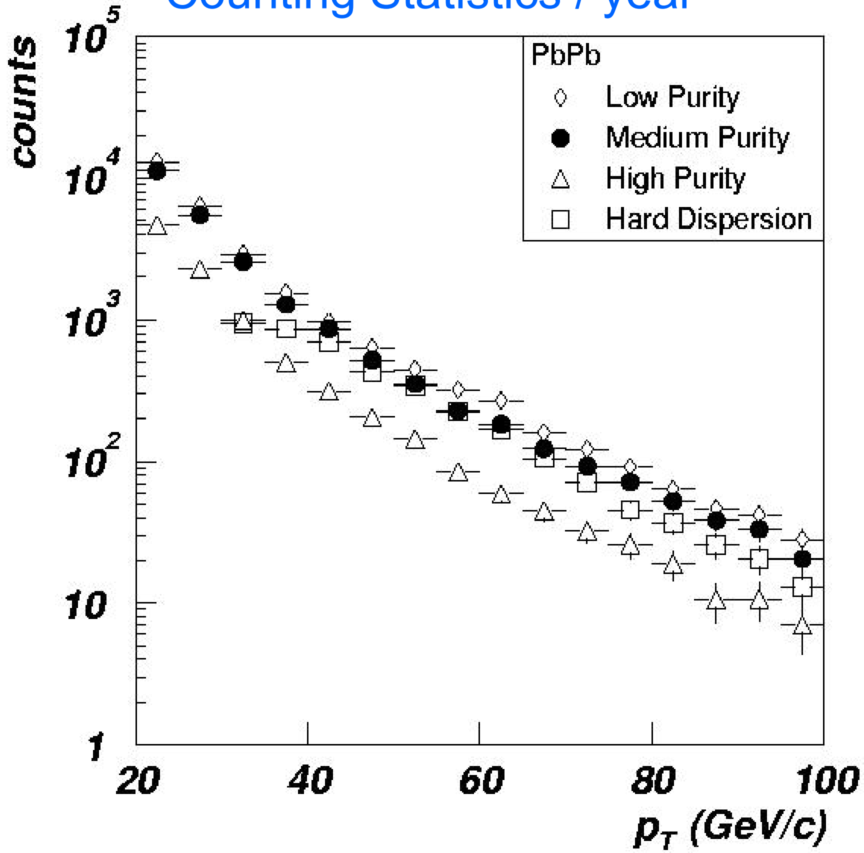




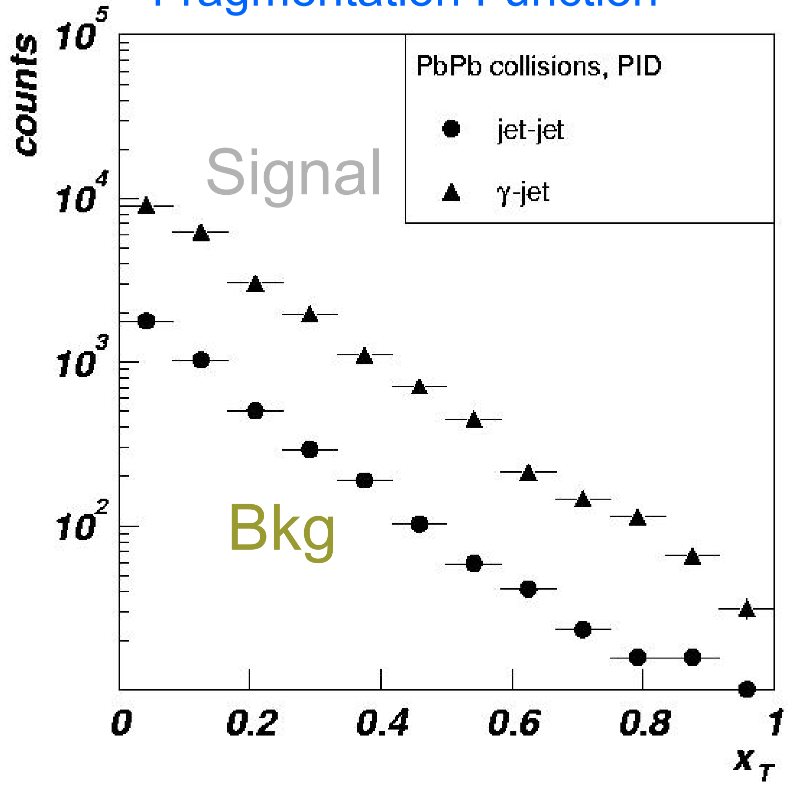
γ-Jet Analysis

Advantage: Strong Correlation between γ and Jet Energy

Counting Statistics / year

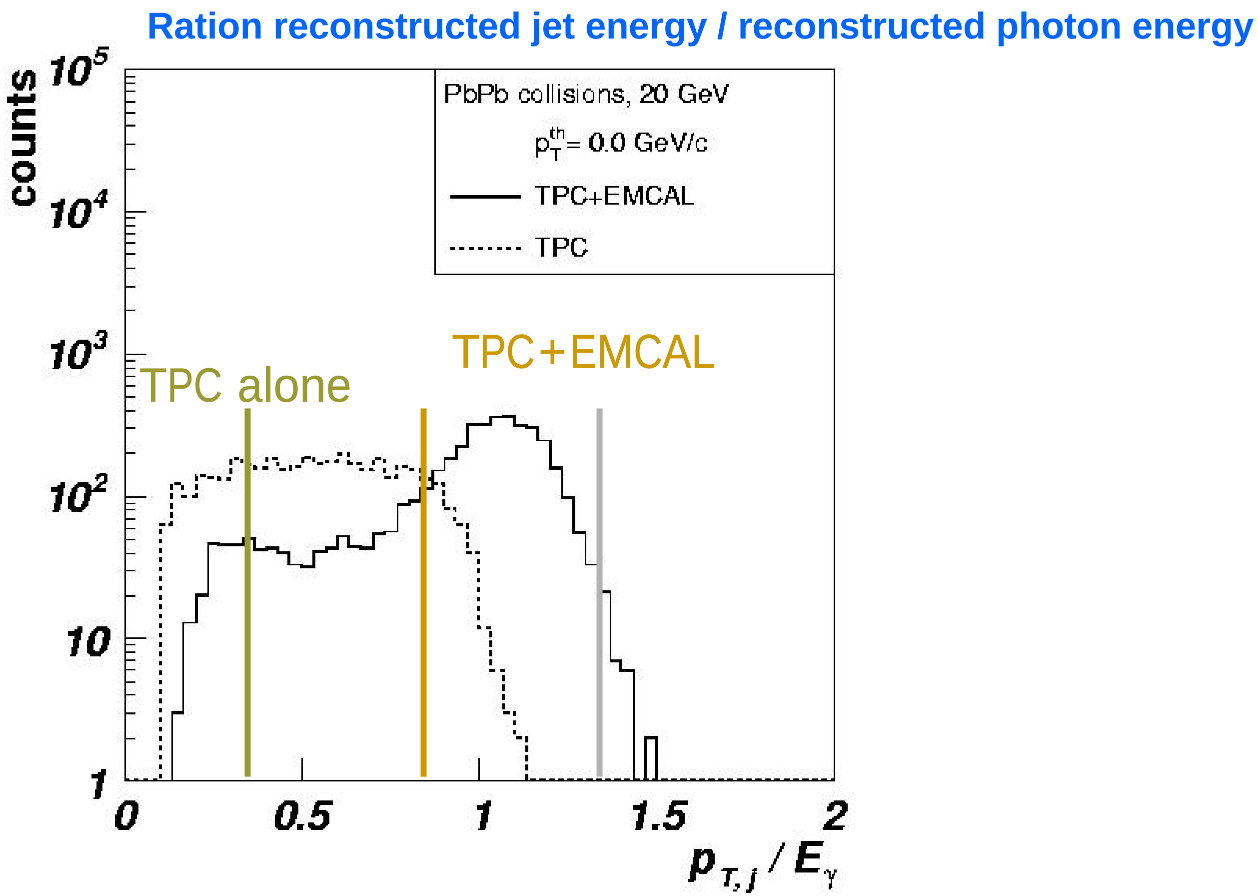


Fragmentation Function



Gustavo Conesa and Y. Schutz

TPC vs TPC+EMCAL



Conclusions

- Copious production of jets in PbPb collisions at the LHC
  - < 20 GeV many overlapping jets/event
    - Inclusive leading particle correlation
  - > 100 GeV Triggering necessary
- Background conditions require jet identification in reduced cone R < 0.3-0.5
- ALICE needs calorimetry (EMC) for triggering and jet reconstruction
- Signals for jet quenching in jet structure observables (k_T, fragmentation function, jet-shape)
  - One observable is not enough, in particular jet-shapes have to be understood (out of cone radiation)
  - Radiated energy is observed in low-p_T particles.
    - Good low-p_T tracking capabilities are needed
  - Interpretation of data requires MC combining consistently in medium energy loss and parton showers.