INFN

Jet Reconstruction in Heavy Ion Collisions with ALICE

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for the ALICE Collaboration

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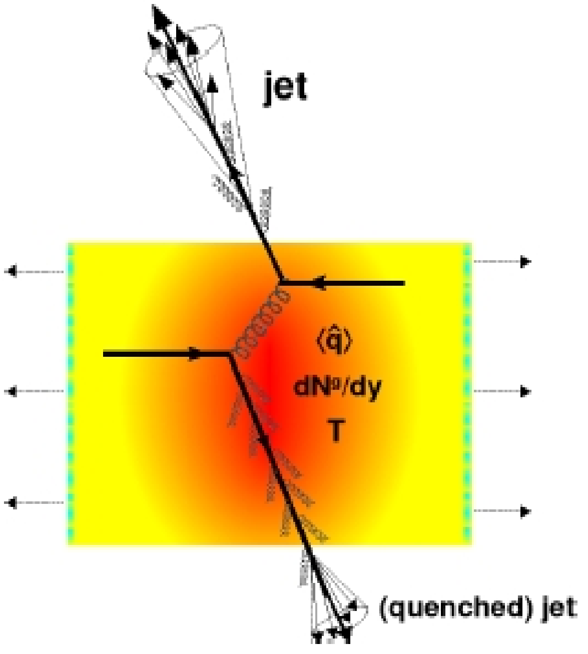
Jets in Heavy Ion Collisions

Understand how the radiation pattern of jets is changed in medium compared to vacuum.



-->What are the mechanisms of energy loss?

-->Medium induced gluon radiation is the dominant process?
Other mechanisms?

-->How is energy redistributed?

-->Energy loss vs broadening?

With full jet reconstruction we aim to capture the full dynamics of jet quenching

Infer fundamental properties of the medium

Jet Reconstruction in ALICE

2010 data:
Jet Reconstruction with charged particles only using:
Time Projection Chamber (TPC)+ Inner Tracking System (ITS)

2011 data: charged particles+neutrals measured in the Electromagnetic Calorimeter (EMCal)

-Transverse momentum track cut-off: p_t>150 MeV

--> Small bias towards hard fragmentation
--> **Large background & fluctuations**

-Uniformity in η-φ required for jet finding

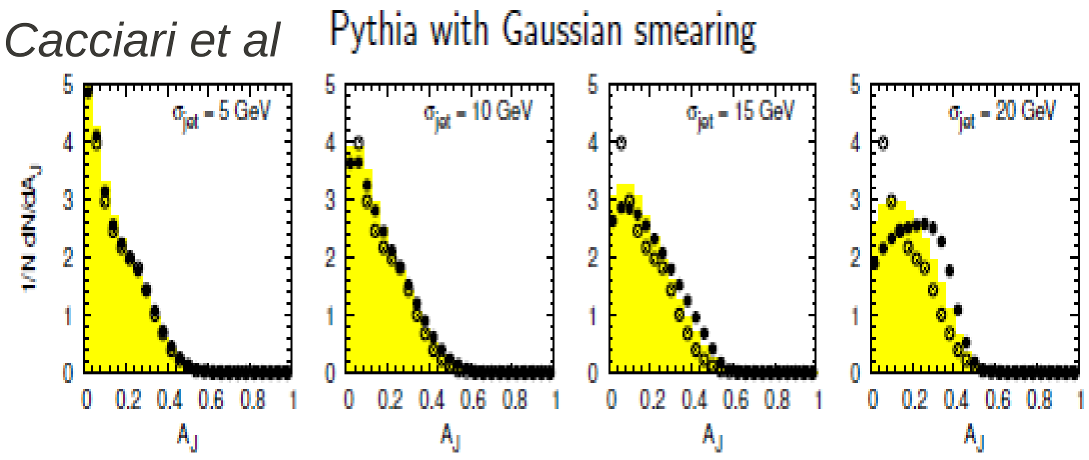
-The input to the jet finder are tracks-->very good jet area resolution

-Recombination algorithms from FastJet Package [*Phys.Lett.B:.641 (2006) 57]*

---->antik$_t$ for the signal jets
---->k$_t$ to estimate background density

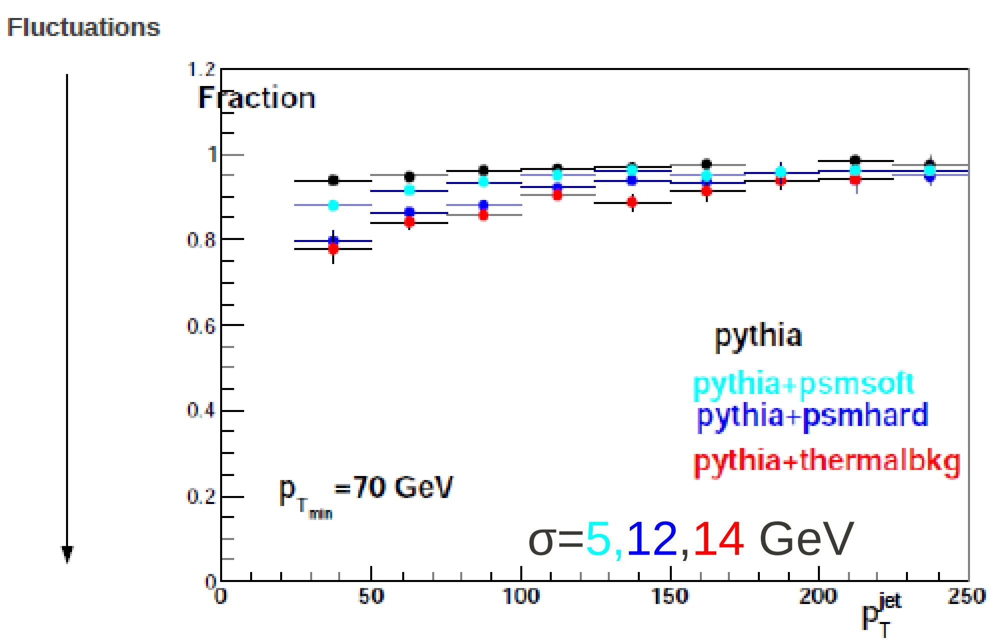
The influence of background fluctuations: 2 examples

Cacciari et al



Background fluctuations are the main source of uncertainty in our jet measurements.

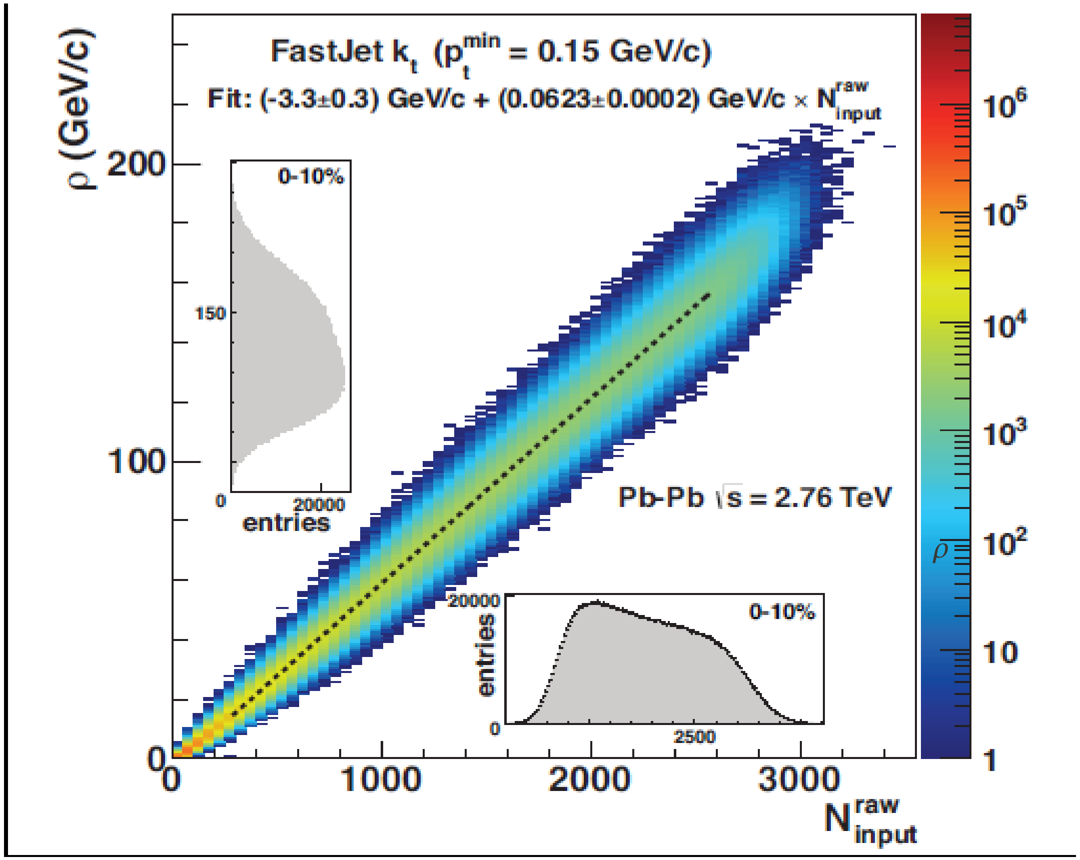
Jet core: pythia jets embedded



We need to have bkg under control before assessing the degree of quenching of the data

Two examples:
-Bkg can generate asymmetry in dijet events.
-Bkg changes the jet shapes, i.e. reducing the energy fraction in the jet core

The Average Background Level in ALICE



The background density is measured event-by-event using the area based method [*Phys.Lett.B659:119-12682008)*]

$$\rho = median\left(\frac{p_T^{jet,i}}{A_i^{jet}}\right)$$

To further reduce the influence of true jets on the background estimate, the **2 hardest structures are excluded from the median calculation.**

0-10% central class: <ρ>~140 GeV/area
-->70 GeV of contamination in a cone of R=0.4

The spread of ρ for fixed multiplicity underlines the need for an event-by-event subtraction.

Background region-to-region fluctuations

Region-to-region background inhomogenities (deviations from the average background density) cause large uncertainty in the reconstructed jet energy.

We **quantify those fluctuations by embedding** different probes in real Pb-Pb events and by studying their response:

$$\delta_{p_T} = p_{T,jet}^{rec} - \rho A - p_T^{probe}$$

The different probes are:

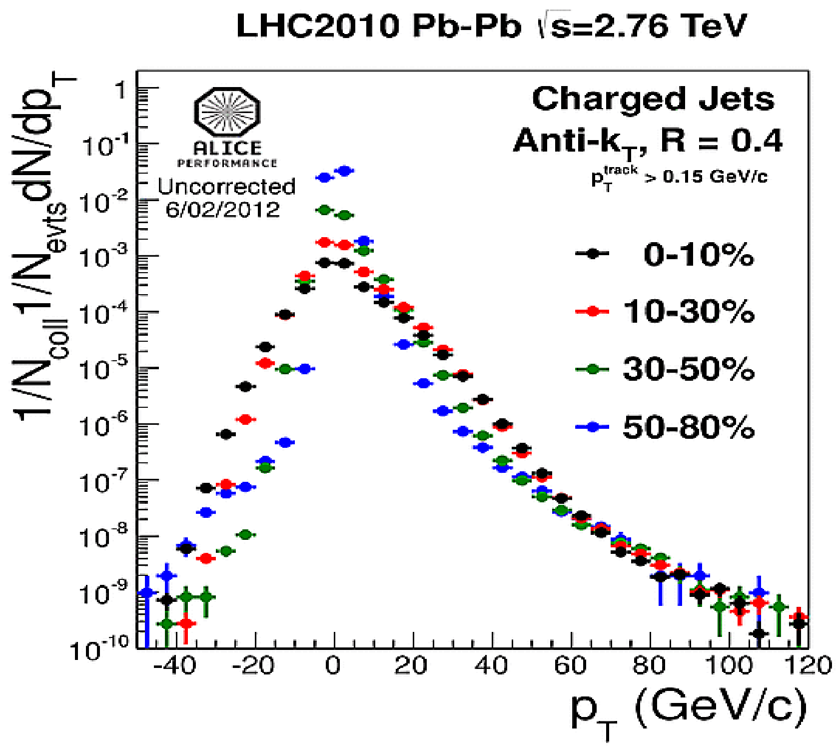
-**Random Cones**: non overlapping cones of fixed area randomly distributed over the acceptance.
-->fluctuations on the scale of a jet

-**Single tracks**:
-->explore interplay between fluctuations & jet finding

-**Pythia jets**
-->interplay between flucutations& jet finding& fragmentation pattern

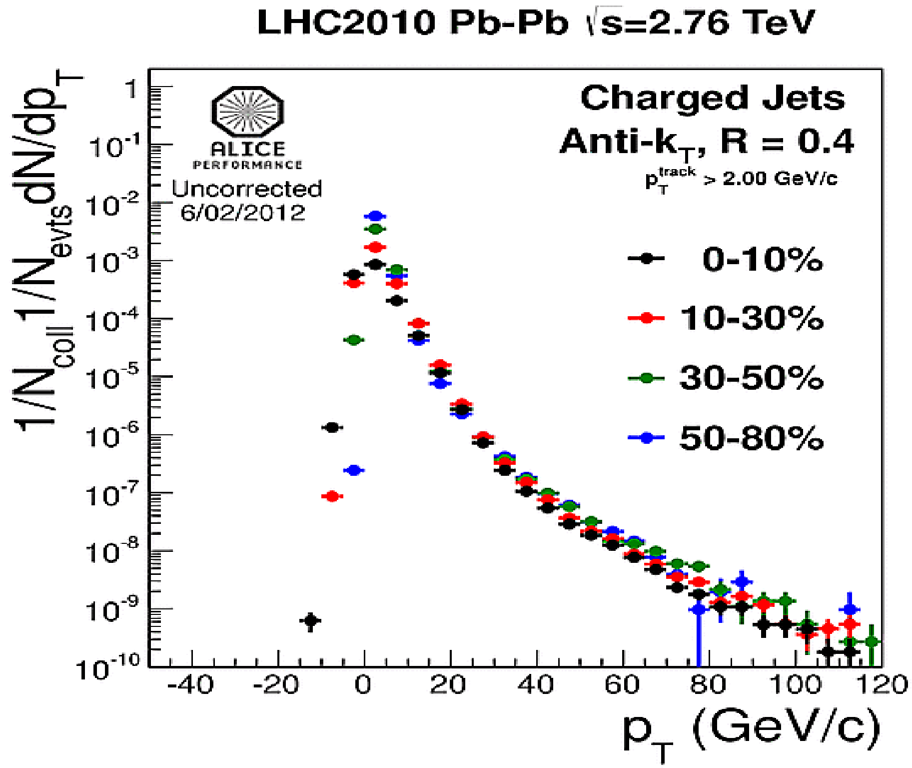
Background fluctuations: subtracted jet spectrum

p_t cut-off=150 MeV



ALI-PERF-13266

p_t cut-off=2 GeV

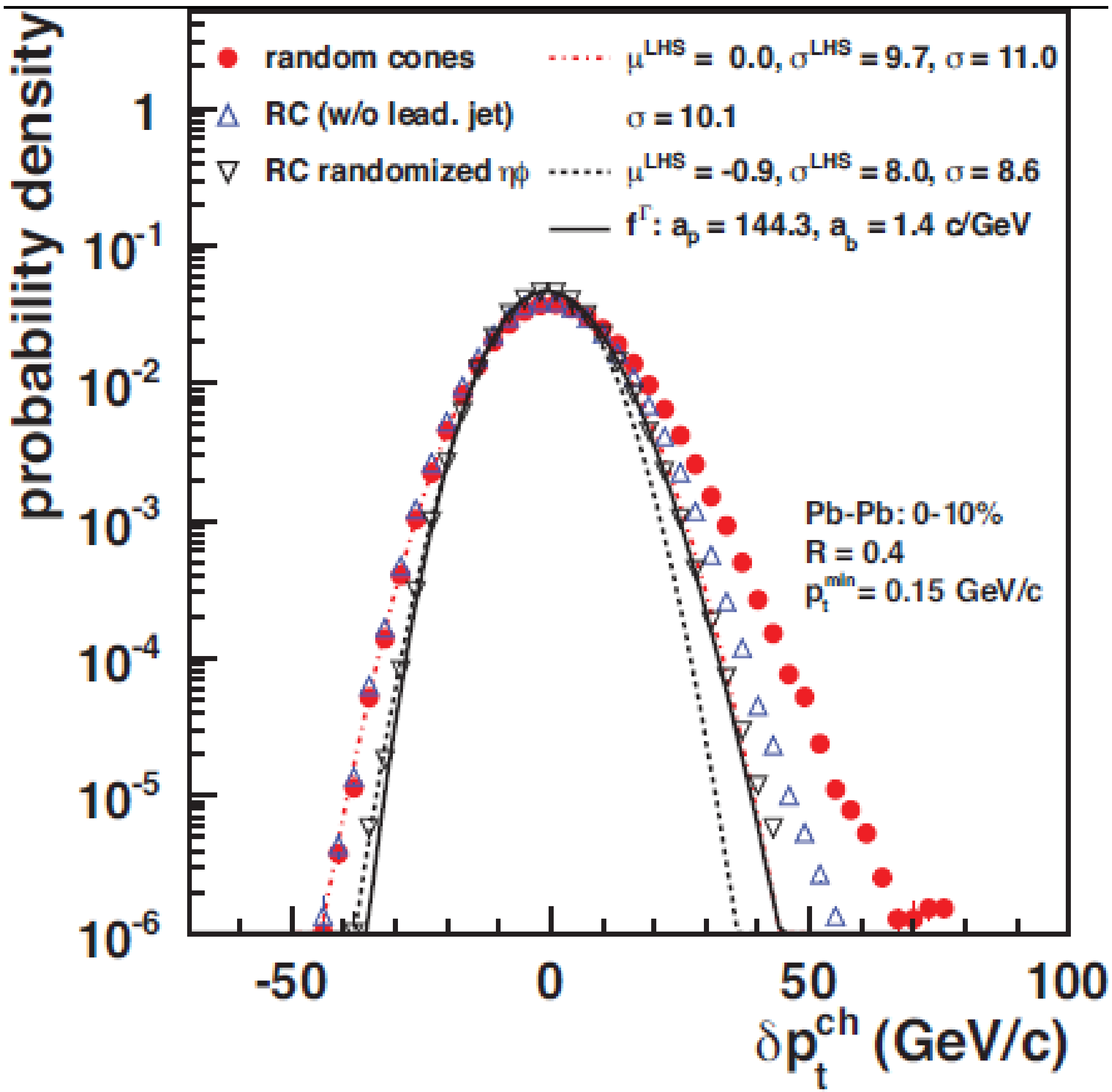


ALI-PERF-13274

Clear change of shape of the raw subtracted spectra in central collisions:
evidence of strong effect of background fluctuations up to high jet p_t

With a minimum cut-off of 2 GeV the influence of bkg is drastically reduced.
--> may introduce a bias towards hard/unmodified fragmentation.

Background fluctuations: Random Cones



Fluctuations centered at zero
->quality check for the bkg subtraction

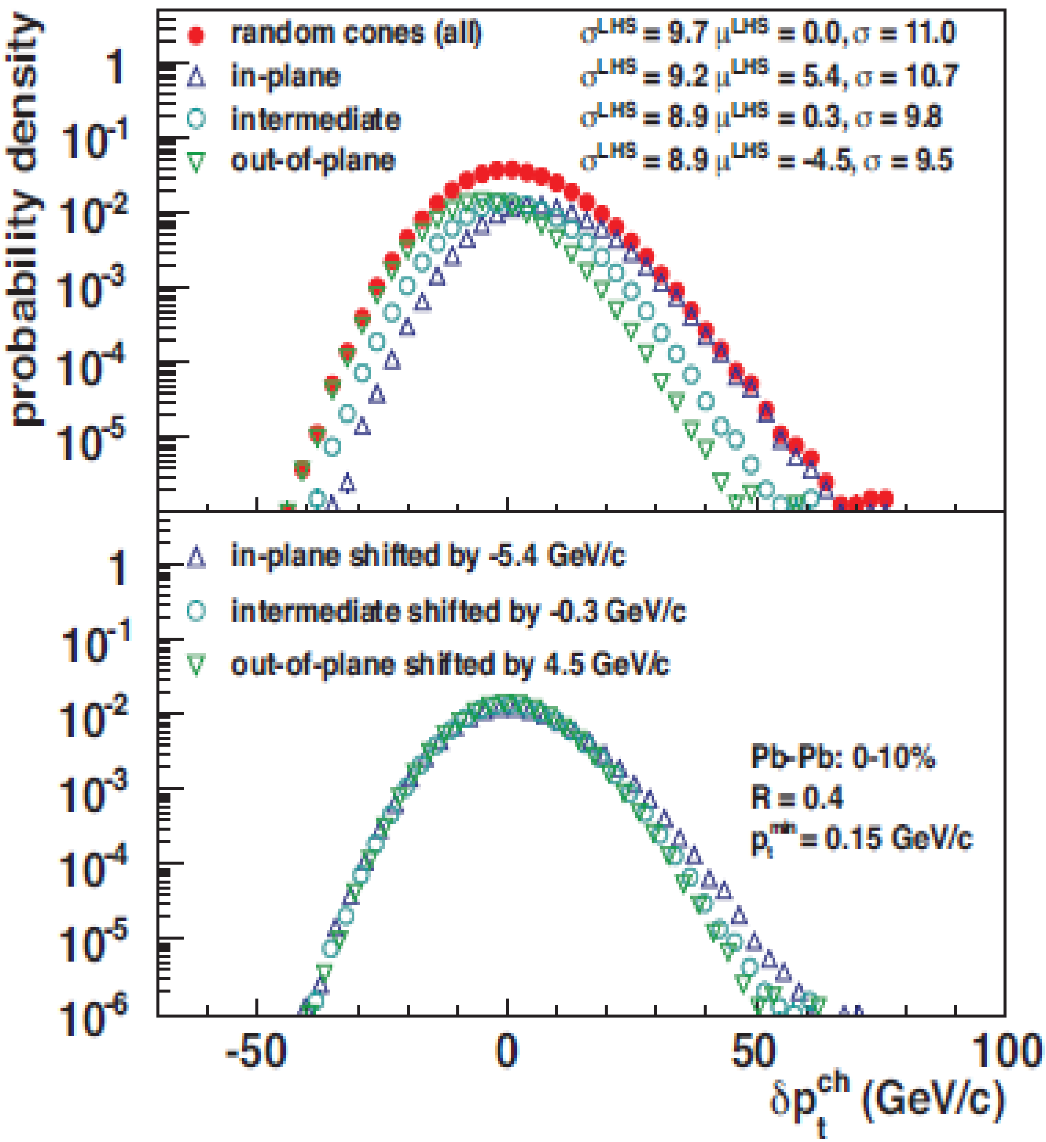
Differentiate random& correlated sources:

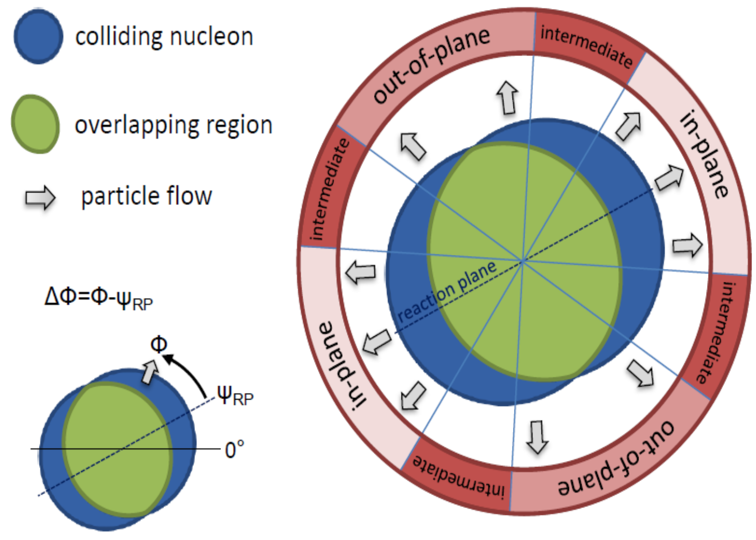
-RC

-RC excluding region close to leading jet
(reduce contribution from hard process)
RHS tail is suppressed

-RC on randomized events: correlations are destroyed, left with purelly statistical fluctuations only:
RHS tail is suppressed
Also LHS is narrower
→ other sources of fluctuations like flow

Event plane dependence of fluctuations





~5 GeV shift in the average background density for in-out-of-plane, ~v2*<ρ>

LHS narrower out of plane, qualitatively consistent with less particles out of plane.

More pronounced tail on the RHS in plane:

-dependence of the jet spectrum with RP?

-autocorrelations?

-->more systematic studies needed

Sources of fluctuations

Purelly statistical fluctuations, ~sqrt(NA)

$$\sigma(\delta p_t) = \sqrt{N_A \cdot \sigma^2(p_t) + N_A \cdot \langle p_t \rangle^2}$$

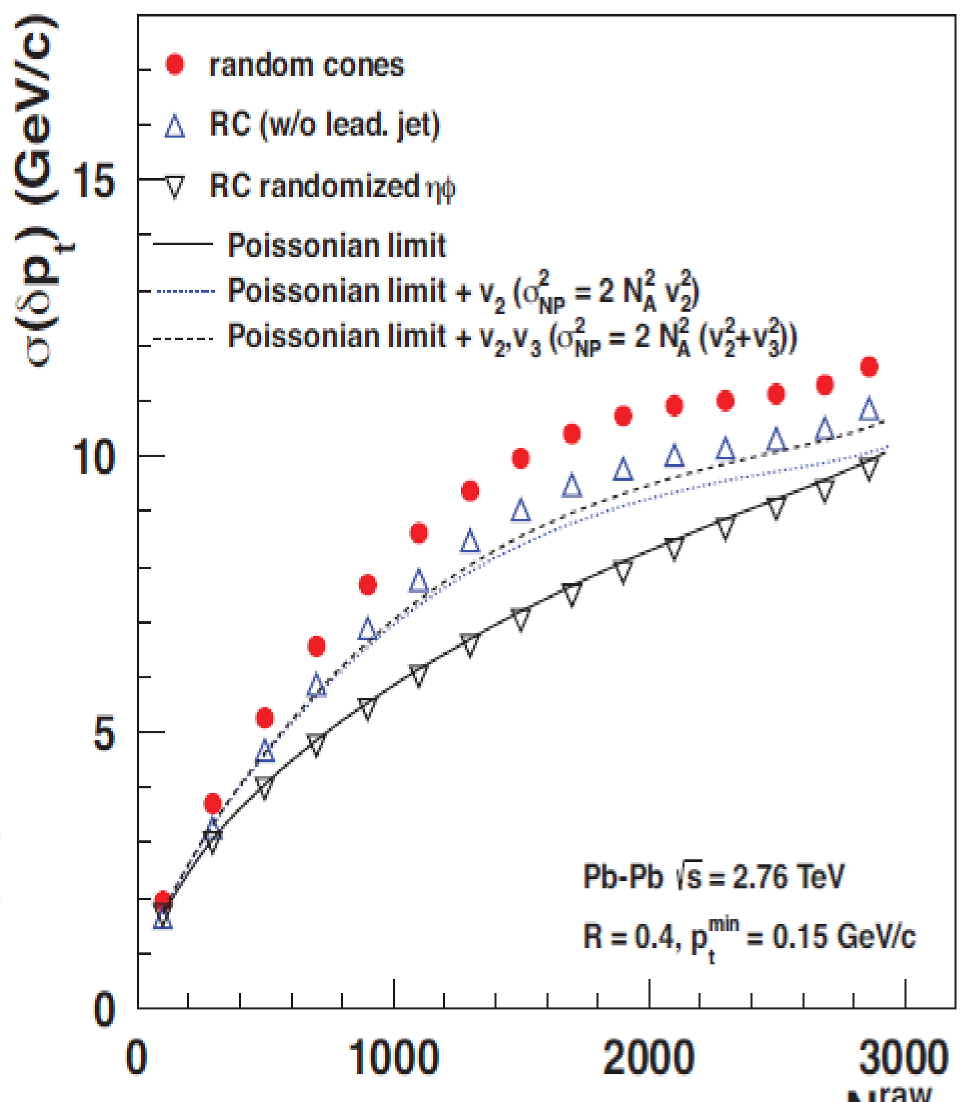
Randomized event fluctuations well described

Non statistical fluctuations added as variations of the average multiplicity inside the cone

$$\sigma(\delta p_t) = \sqrt{N_A \cdot \sigma^2(p_t) + (N_A + \sigma^2_{NP}(N_A)) \cdot \langle p_t \rangle^2}$$

$$(\sigma^2_{NP}(N_A) \approx 2N_A^2(v_2^2 + v_3^2))$$

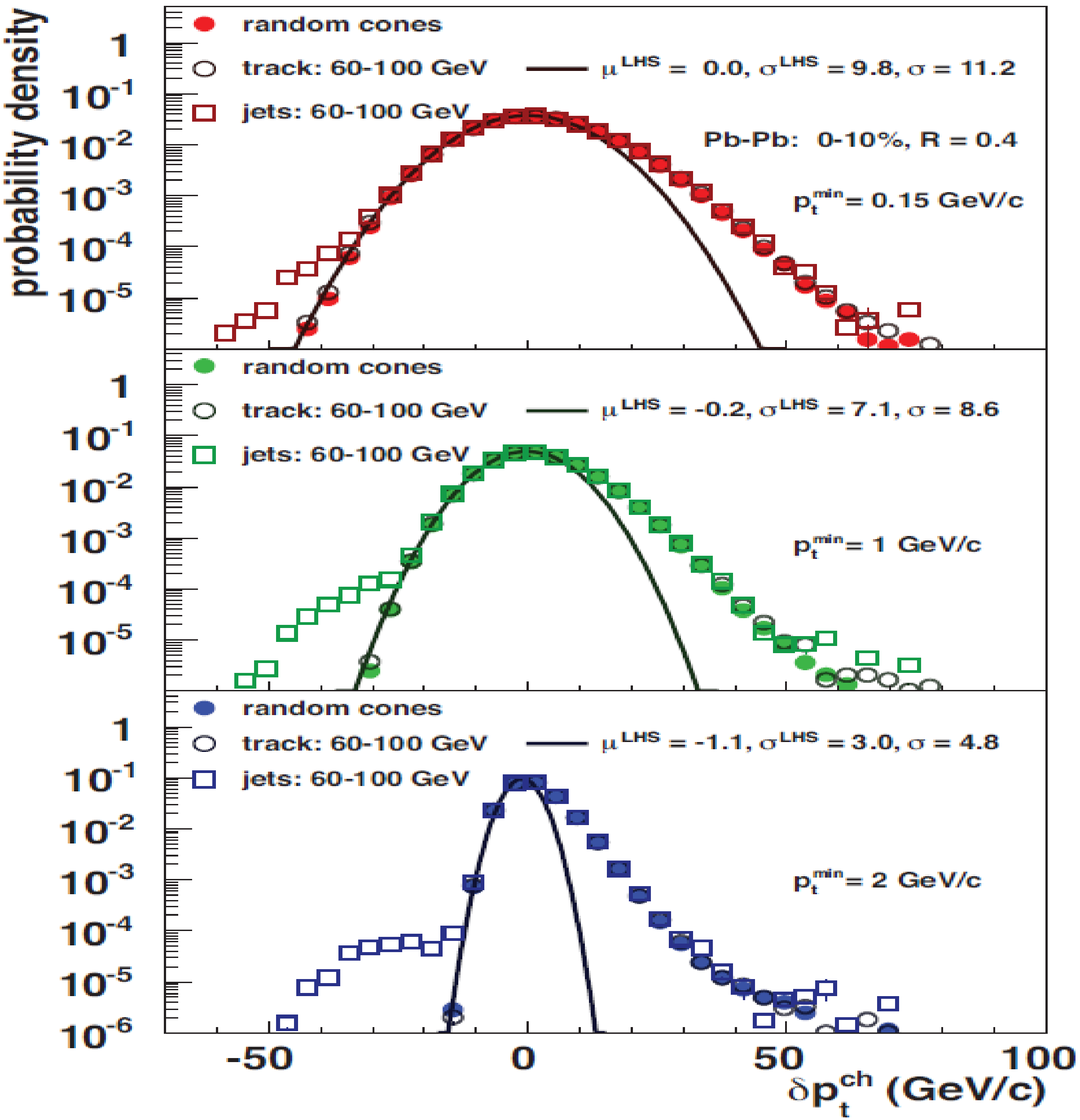
Adding flow--> close to RC wo the leading jet



$\sigma(\delta p_T)$ = standard deviation of δp_T distribution

Further differences with RC distribution: high p_t tail due to hard processes.

Background fluctuations and the type of probe



No significant differences in the response of the 3 probes:

No dependence on fragmentation pattern:
single tracks(extreme hard fragmentation) vs pythia jets.

Small back-reaction effects observed for the antik_t for jet probes caused by **jet splitting and merging**.

Increase of lower track p_t cut-off: large reduction of soft statistical correlations, visible in the LHS.

Impact on reconstructed jet spectrum

$f(p_t)$ folded with	relative yield for $p_t = 60 - 68\,\mathrm{GeV}/c$		
δp_t	RC	tracks	jets
$p_t^{min} = 0.15\,\mathrm{GeV}/c$	9.8 ± 1.7	11.4 ± 1.1	10.9 ± 3.4
$p_t^{min} = 2\,\mathrm{GeV}/c$	1.30 ± 0.02	1.31 ± 0.02	1.65 ± 0.25
Gauss			
$\sigma = 11\,\mathrm{GeV}/c$		1.82 ± 0.04	
$\sigma = 5\,\mathrm{GeV}/c$		1.05 ± 0.01	

Power law (with a lower cut at 4 GeV) folded with measured responses in 0-10% central and with R=0.4

Low p_t jets migrate to higher jet p_t bins due to the broad response

~factor 10 more jets at 60-68 GeV

To note: one order magnitude of difference between a Gaussian and the measured response of the same width

--->**strong impact of the asymmetric shape of fluctuations**

Summary

Region-to-region background fluctuations are largest source of uncertainty in the jet energy.

First detailed study of event background fluctuations:

- σ~11 GeV measured within a cone of R=0.4 in 0-10% central.

- Non statistical sources of background fluctuations are driven by flow and hard processes.

- Modest dependence of the procedure on jet finder, on fragmentation pattern.

The asymmetric shape of the response with a tail towards positive fluctutions has a large impact on the jet measurement up to high jet p_t --->challenging unfolding.

Stay tuned for upcoming ALICE jet results