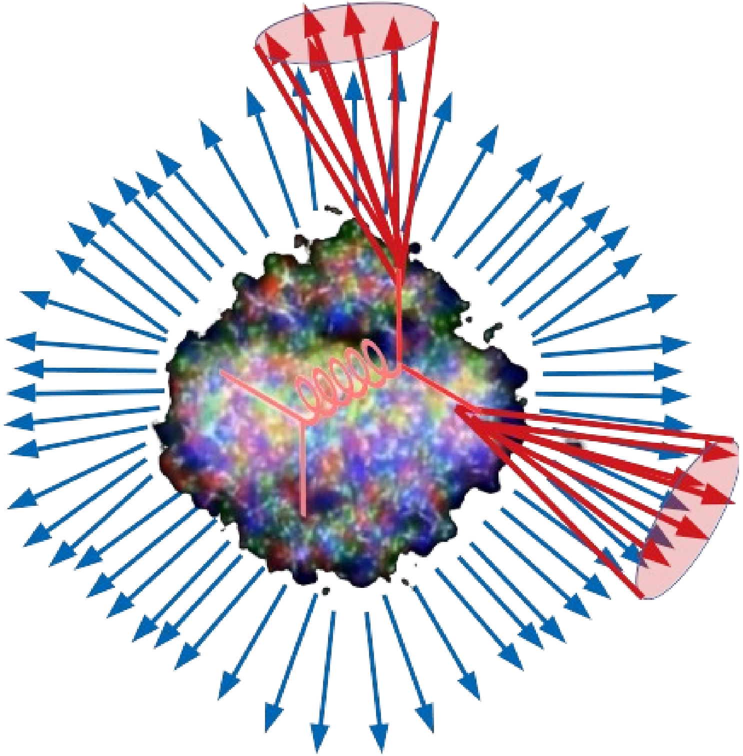
Background fluctuations in jet studies in heavy ion collisions

Antonio Da Silva



Charles Hughes

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University of Tennessee, Knoxville

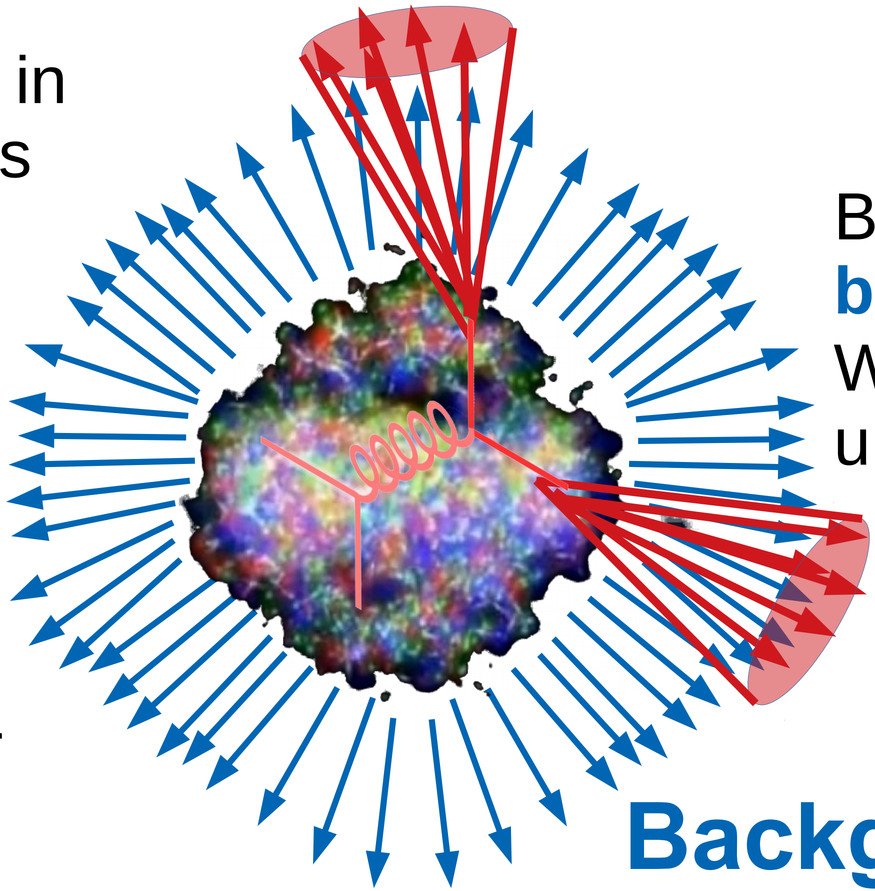
Motivation

Want to study **jets** in heavy ion collisions

ALICE Random cones JHEP 03 (2012) 053

compared to

- *TennGen* background generator
- PYTHIA Angantyr



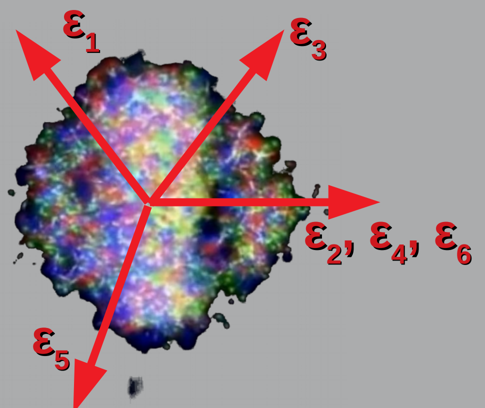
But there's a large **background**. We need to understand it.

Signal

Background

TennGen background generator

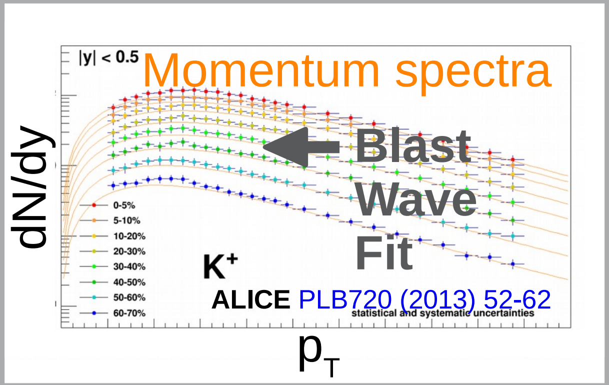
Event properties



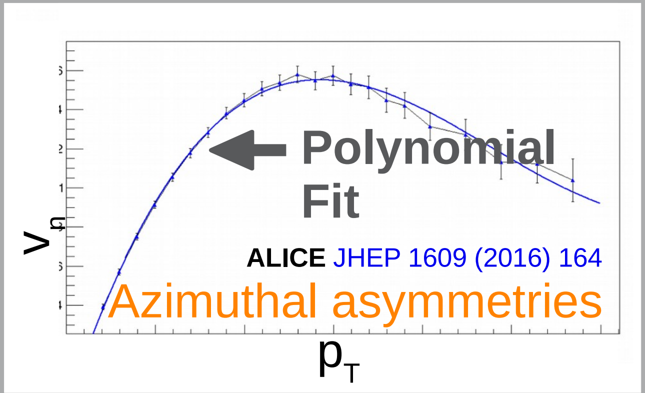
- Even event planes fixed at Ψ=0
- Odd planes at random φ
- Multiplies from ALICE PRC88 (2013) 044910

No jets! No resonances
Emulates hydro correlations

Track properties



→ Random p_T

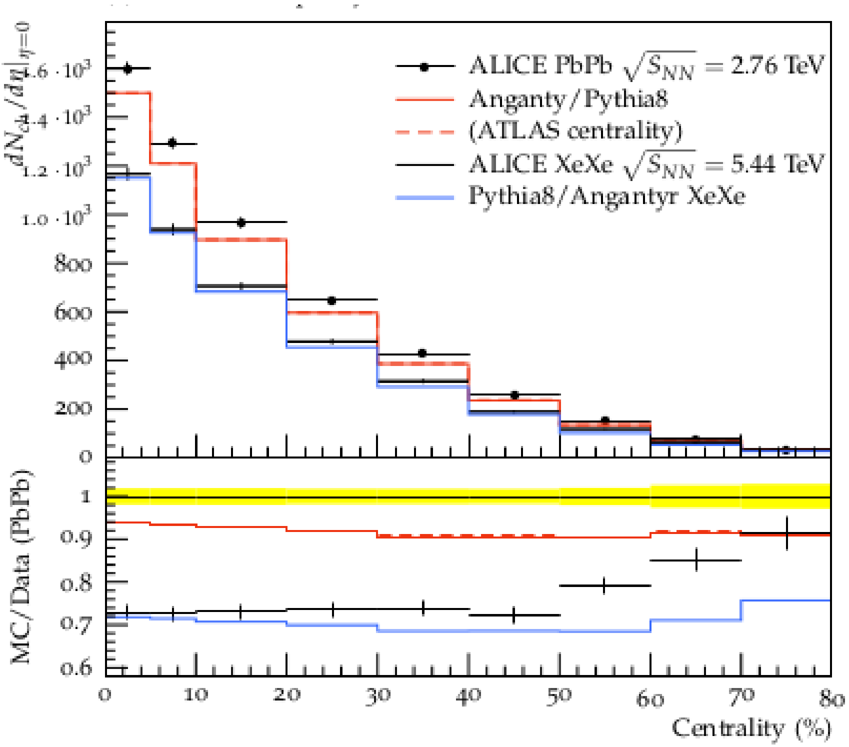


→ v_n → Random φ

PYTHIA Angantyr

JHEP (2018) 2018: 134

- Based on PYTHIA 8
  Sjöstrand, Mrenna & Skands,
  JHEP05 (2006) 026
  Comput. Phys. Comm. 178 (2008) 852.
- Based on Fritiof & wounded nucleons
- N-N collisions w/fluctuating radii → fluctuating σ



Lots of jets! And resonances!
No hydrodynamics, no jet quenching

Area-based background subtraction

Cacciari & Salam, PLB659:119–126,2008

Particles, clusters

↓

k_T algorithm

$$k_T = p_T, \Delta R_{ij} = \sqrt{(\eta_i - \eta_j)^2 + (\phi_i - \phi_j)^2}$$

- For all *i,j* calculate:

$$d_{ij} = min(p_{T,i}^2, p_{T,j}^2)\Delta R_{ij}^2$$

$$d_{iB} = p_{T,i}$$

- Combine smallest d_{ij}.

  If d_{iB} smallest, $d_{iB} \rightarrow$ jet

Repeat until no particles left

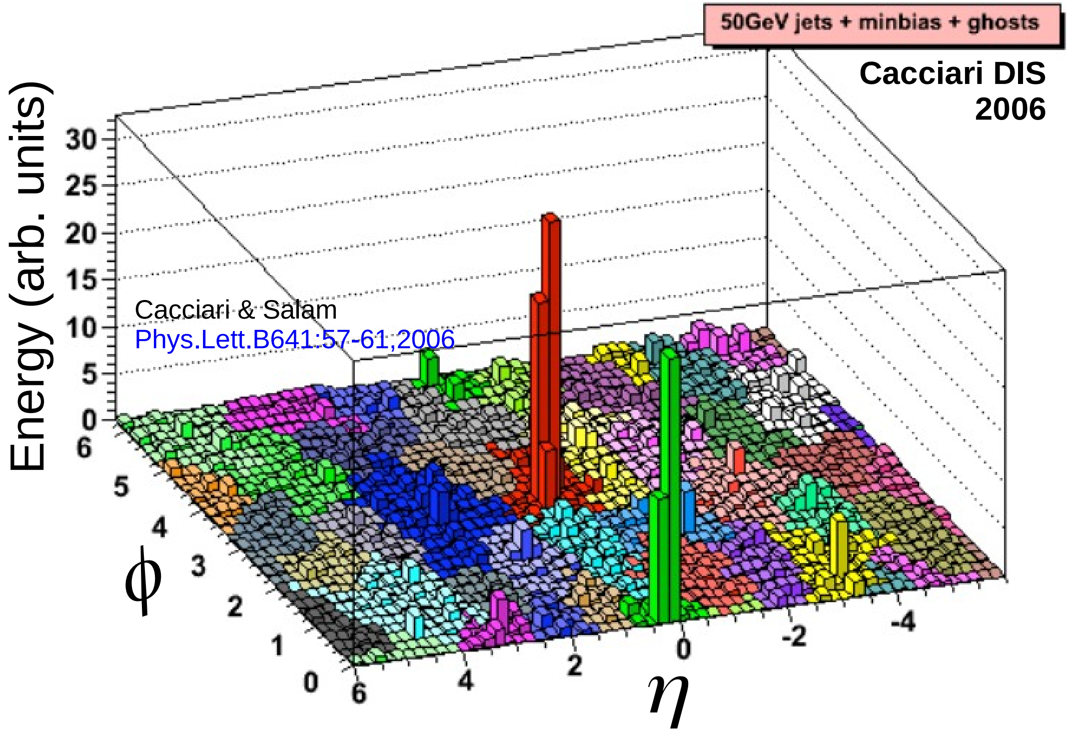
↓

Jet candidates

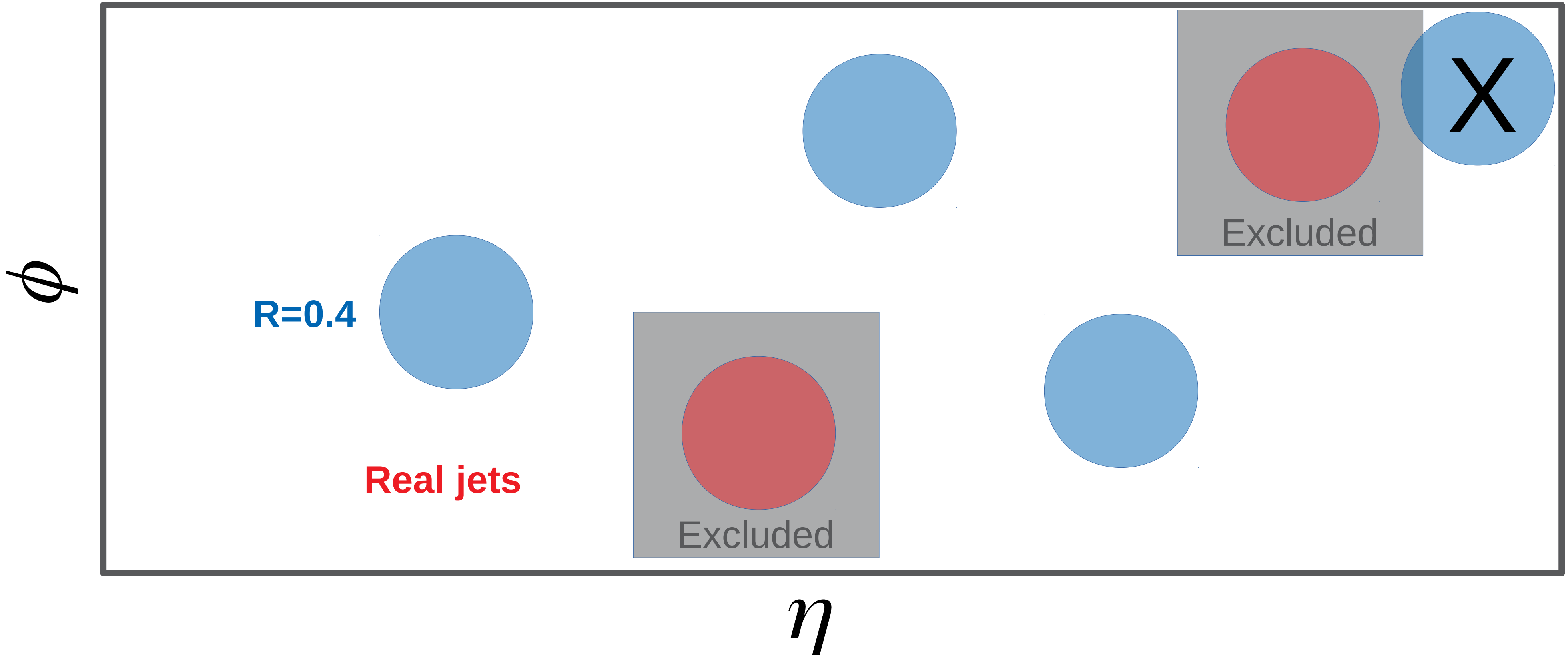
↓

Median $\rho = p_T/A$

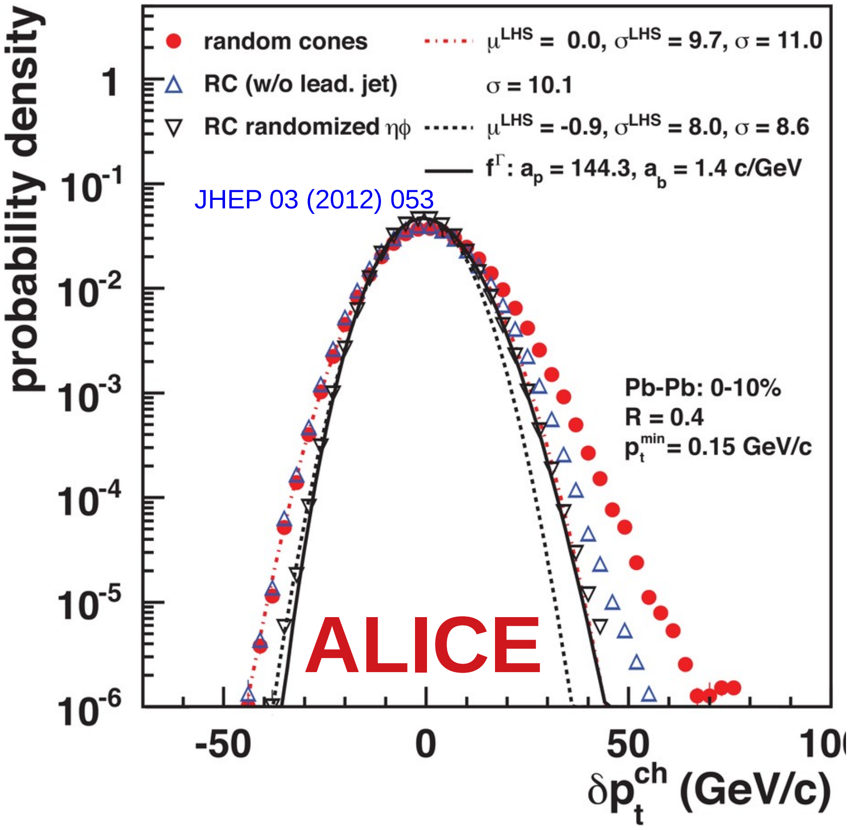
$$p_T^{jet} = p_T^{reco} - \rho_{median} A^{jet}$$

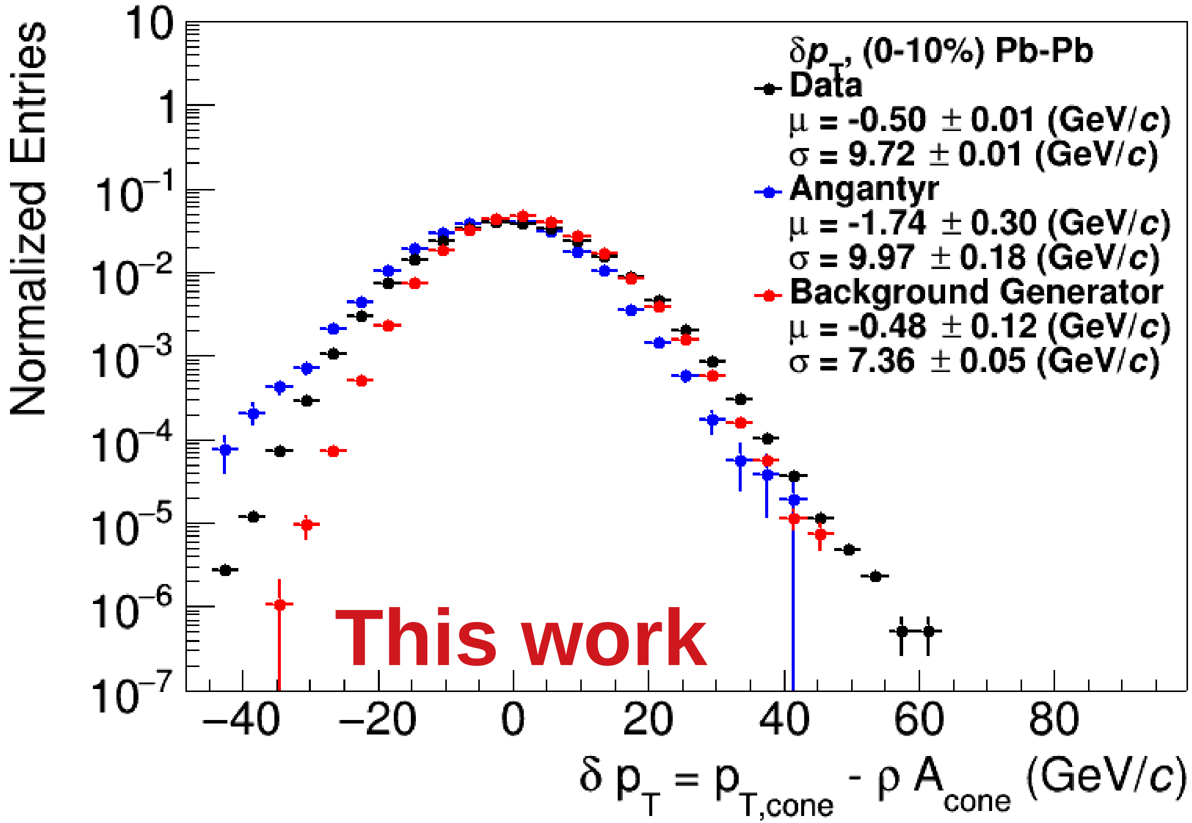


Random cones



Random cones





Shape of width of the distribution

Single particle spectra

$$f_\Gamma(p_T, p, b) = \frac{b}{\Gamma(p)} (b\, p_T)^{p-1} e^{-bx}$$

$$\frac{dN}{dy} \propto f_\Gamma(p_T, 2, b) = b^2 p_T e^{-k p_T}$$

$$\mu_{p_T} = \frac{p}{b}, \sigma_{p_T} = \frac{\sqrt{p}}{b}$$

Tannenbaum, PLB(498),1–2,Pg.29-34(2001)

Σp_T of N particles → N-fold convolution:

$$f_N(p_T, p, b) = f_\Gamma(p_T, Np, b) \qquad \frac{dpT^{total}}{dy} \propto f_N(p_T, Np, b)$$

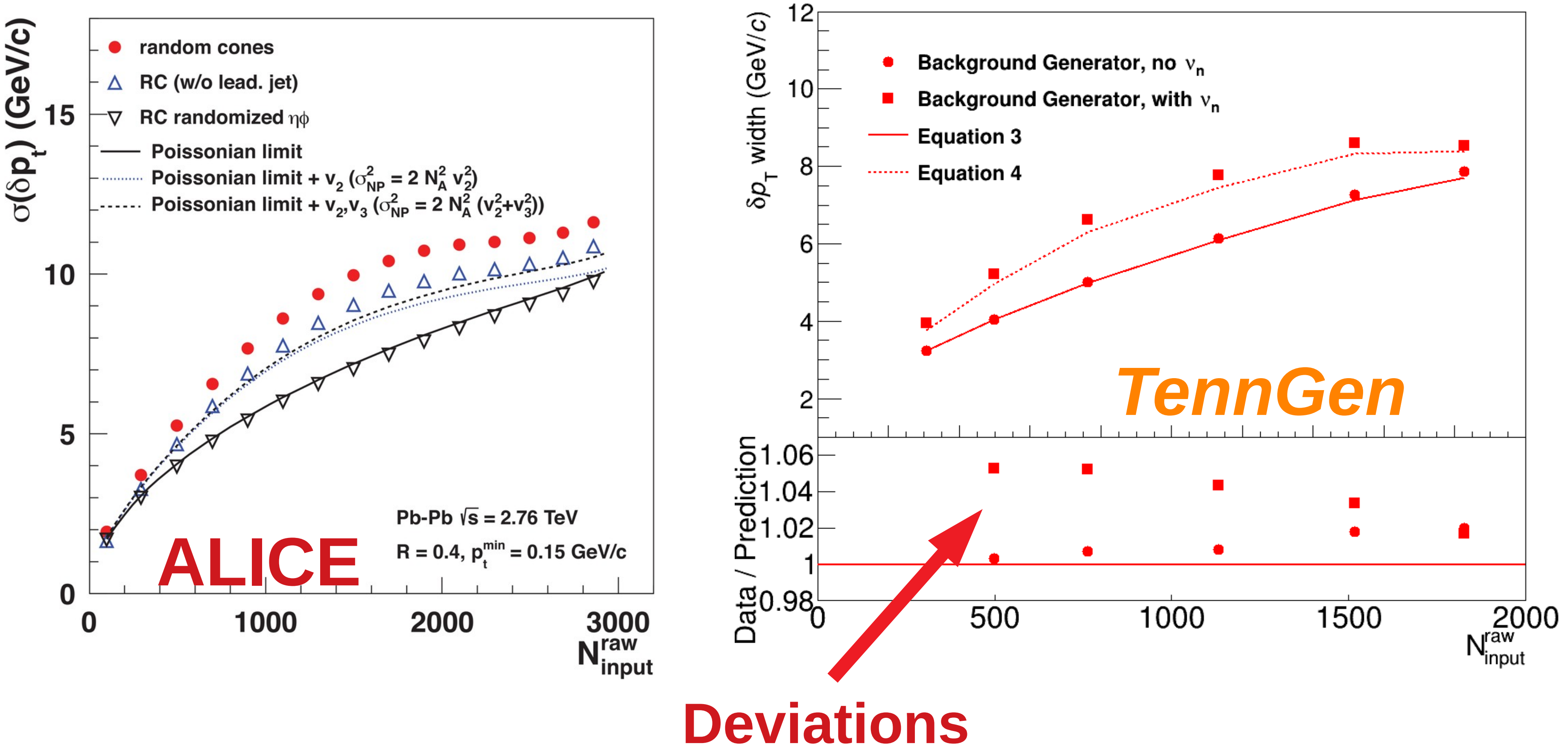
$$N = \frac{N_{total}}{A_{total}} \pi R^2 \quad \mu_{total} = \frac{Np}{b} = N \mu_{p_T}, \sigma_{total} = \frac{\sqrt{Np}}{b} = \sqrt{N} \sigma_{p_T}$$

Add Poissonian fluctuations in N: $\sigma_{total} = \sqrt{N \sigma_{p_T}^2 + N \mu_{p_T}^2}$

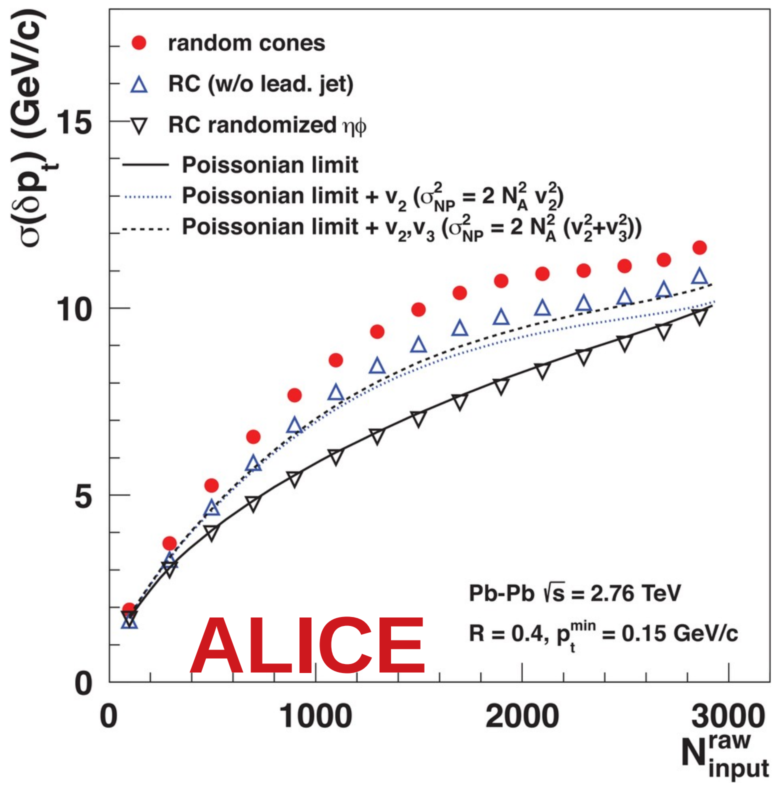
Add non-Poissonian fluctuations in N due to flow

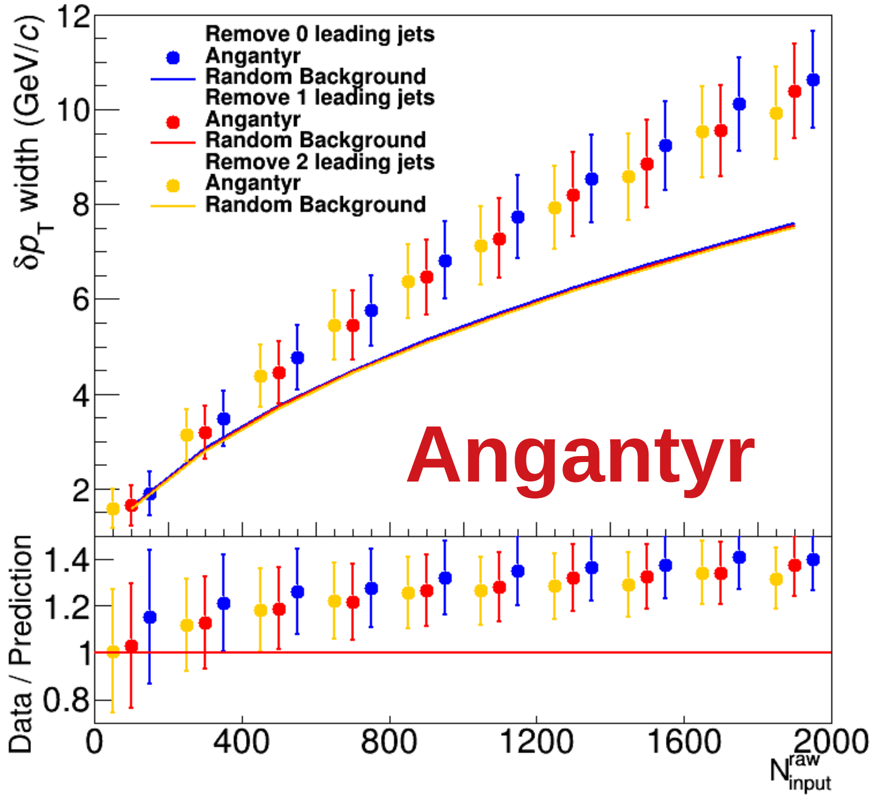
$$\sigma_{total} = \sqrt{N \sigma_{p_T}^2 + \left(N + 2 \sum_n v_n^2\right) \mu_{p_T}^2}$$

Width vs multiplicity



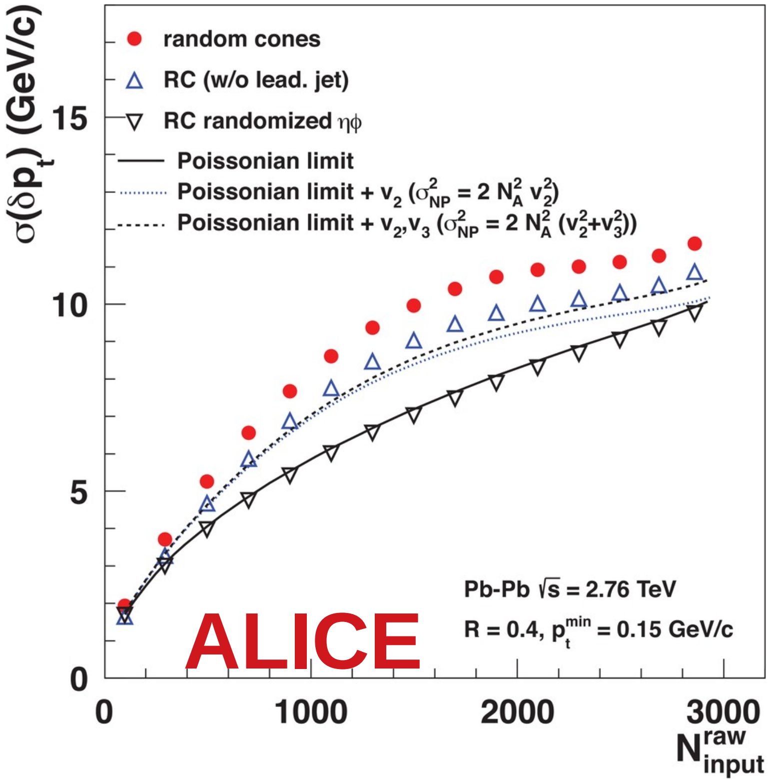
Width vs multiplicity

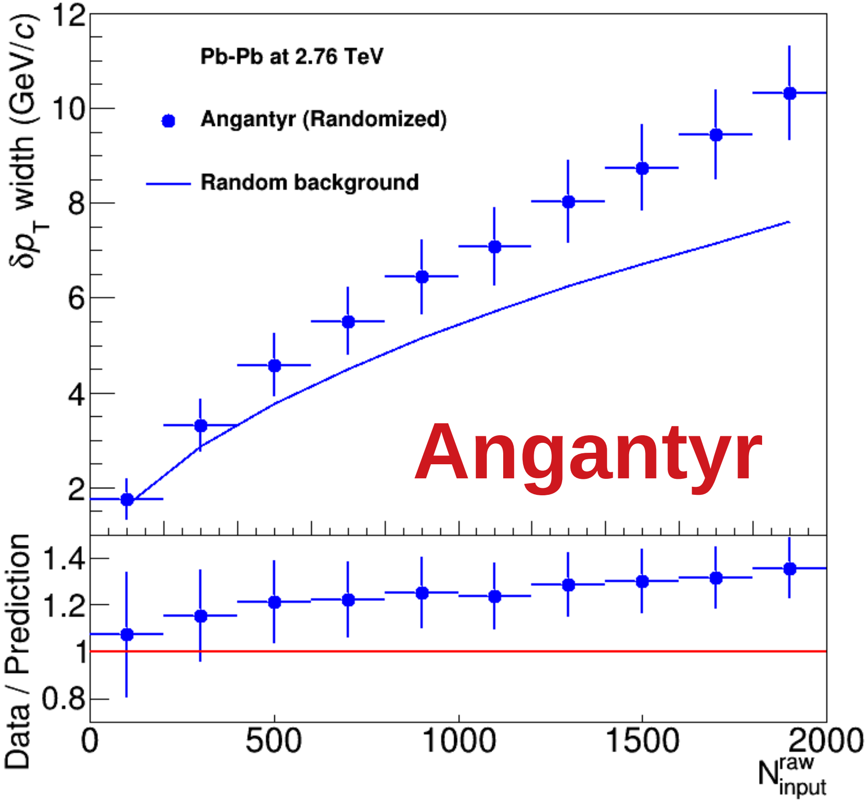




Discrepancy not from an excess of jets!

Width vs multiplicity





Doesn't go away with random track orientation!

Shape of width of the distribution

Single particle spectra

$$f_\Gamma(p_T,p,b)=\frac{b}{\Gamma(p)}(b\,p_T)^{p-1}e^{-bx}$$

$$\frac{dN}{dy}\propto f_\Gamma(p_T,2,b)=b^2\,p_T\,e^{-k\,p_T}$$

$$\mu_{p_T}=\frac{p}{b},\ \sigma_{p_T}=\frac{\sqrt{p}}{b}$$

Tannenbaum, PLB(498),1–2,Pg.29-34(2001)

Assumes shape

Σp_T of N particles → N-fold convolution:

$$f_N(p_T,p,b)=f_\Gamma(p_T,Np,b) \qquad \frac{dpT^{total}}{dy}\propto f_N(p_T,Np,b)$$

$$N=\frac{N_{total}}{A_{total}}\pi R^2 \qquad \mu_{total}=\frac{Np}{b}=N\,\mu_{p_T},\ \sigma_{total}=\frac{\sqrt{Np}}{b}=\sqrt{N}\,\sigma_{p_T}$$

Add Poissonian fluctuations in N: $\sigma_{total}=\sqrt{N\,\sigma_{p_T}^2+N\,\mu_{p_T}^2}$

Add non-Poissonian fluctuations in N due to flow

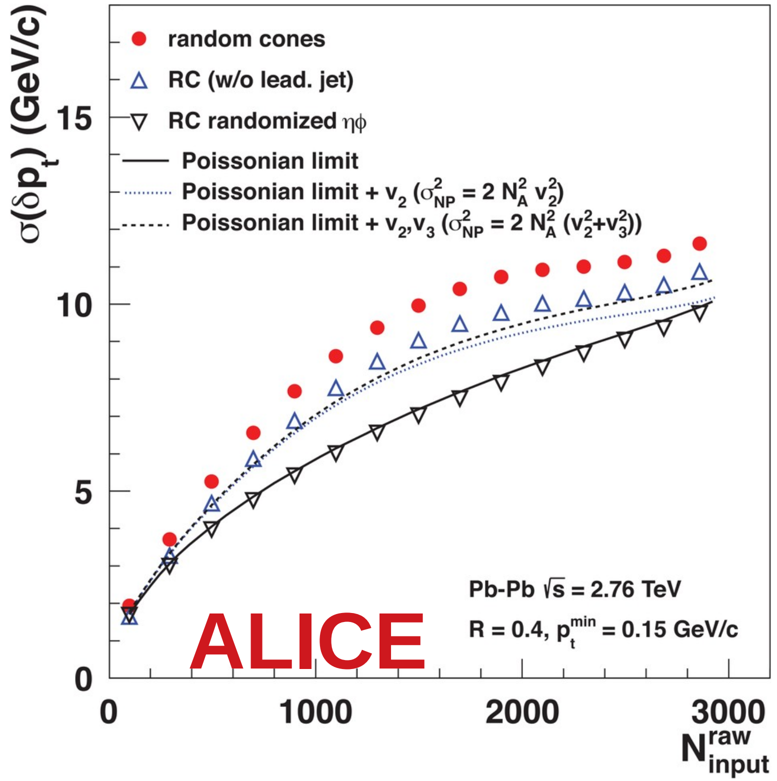
$$\sigma_{total}=\sqrt{N\,\sigma_{p_T}^2+\left(N+2\sum_n v_n^2\right)\mu_{p_T}^2}$$

Assumes uncorrelated number fluctuations

Conclusions

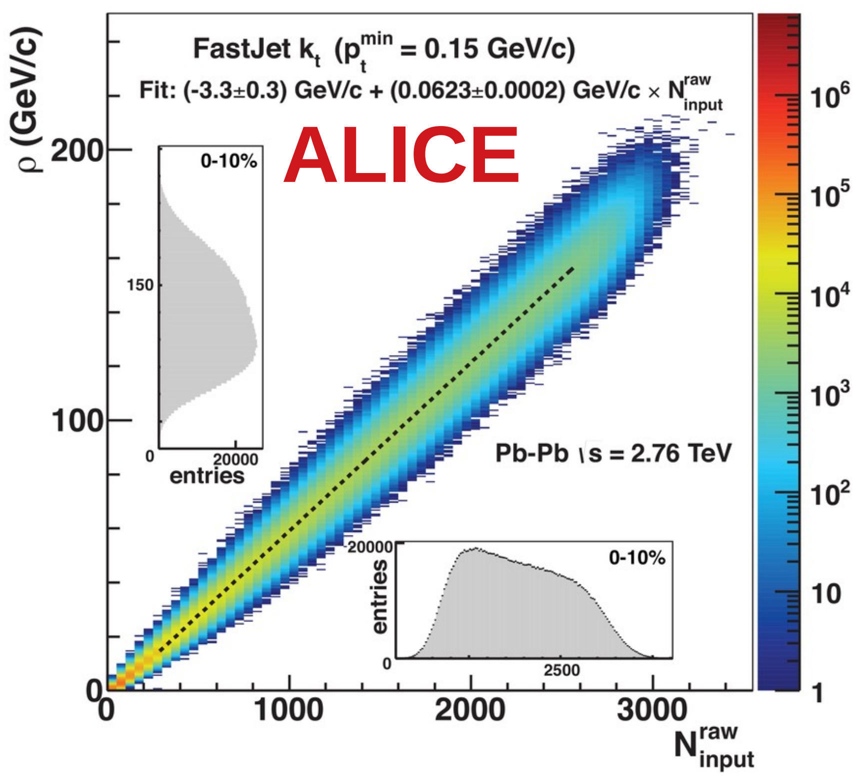
- Comparisons with ***TennGen*** and Angantyr broadly support ALICE conclusions: random background
  - Both studies indicate sensitivity to shape of spectrum
  - ***TennGen*** studies indicate trivial flow correlations also import
- Important for model studies to treat background the same way as data!
  - Rivet 3.0 heavy ion capable!!

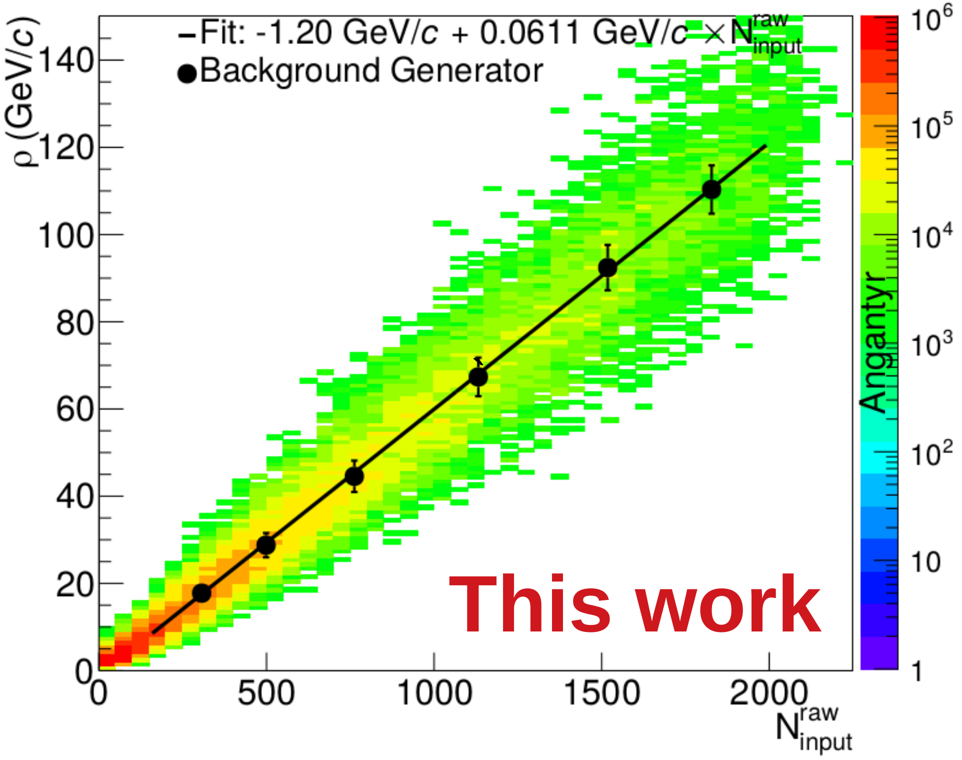
Width vs multiplicity



- Consistent with random fluctuations
- Slight deviations
  - Other sources of correlations...?

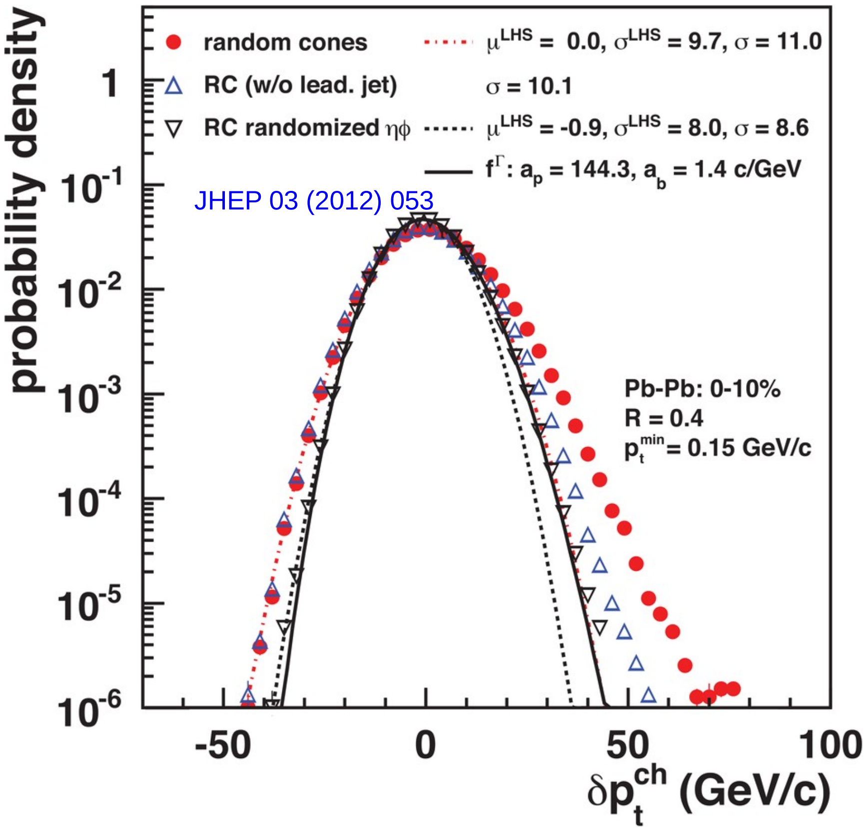
Background density ρ



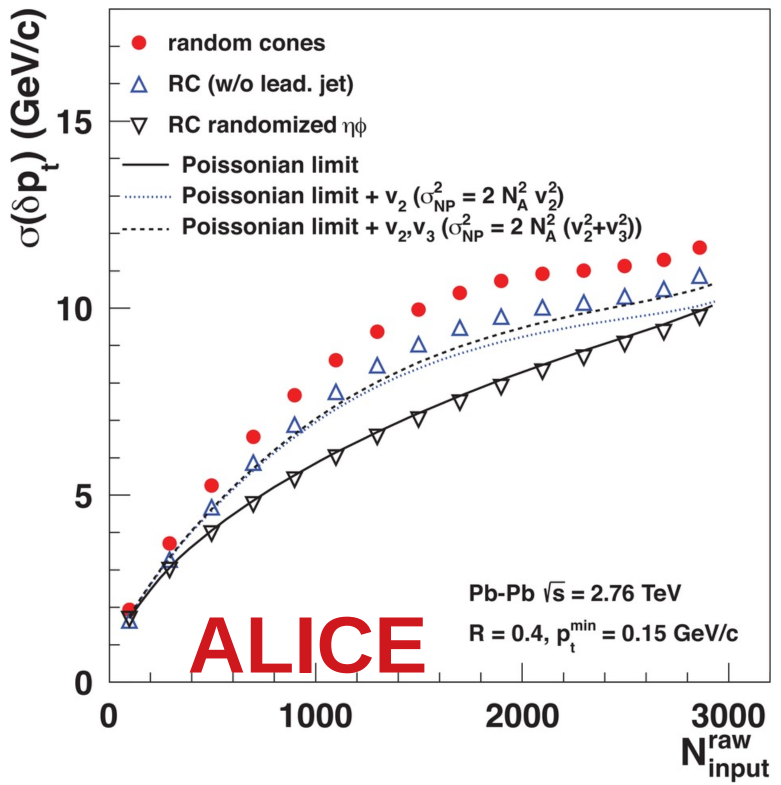


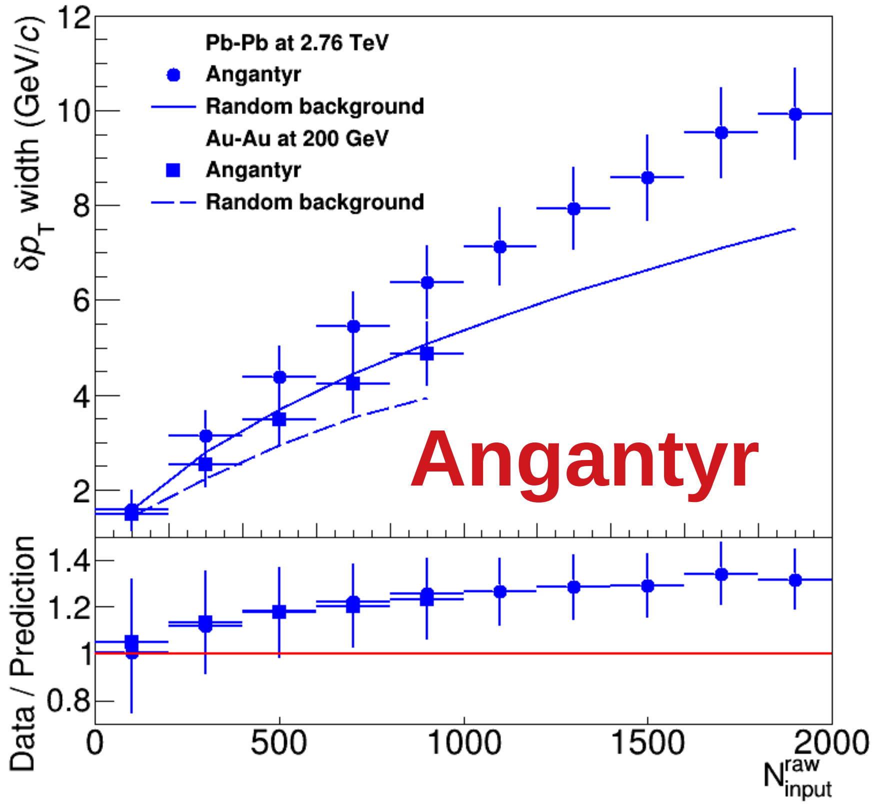
Random cones in ALICE

- Estimate ρ
  - k_T jet finder → jet candidates
  - $\rho = \text{Median}(p_T/A)$
- Draw Random cone
- $\delta p_T = p_T^{reco} - \rho A$



Width vs multiplicity





Little difference with collision energy!

Signal vs Background: the standard pa