Understanding the Quark-Gluon Plasma in Heavy-ion Collisions

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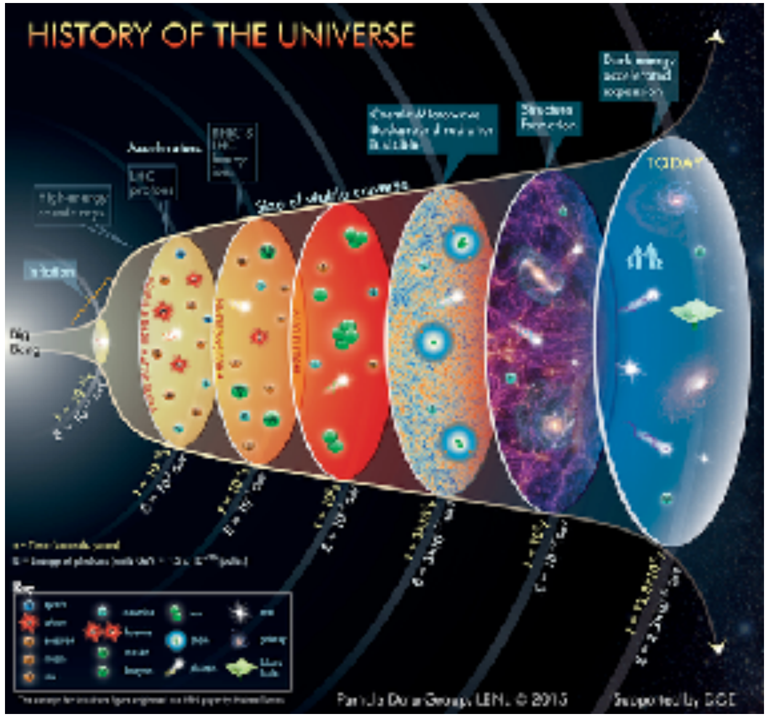
Supervisor: Liliana Apolinário

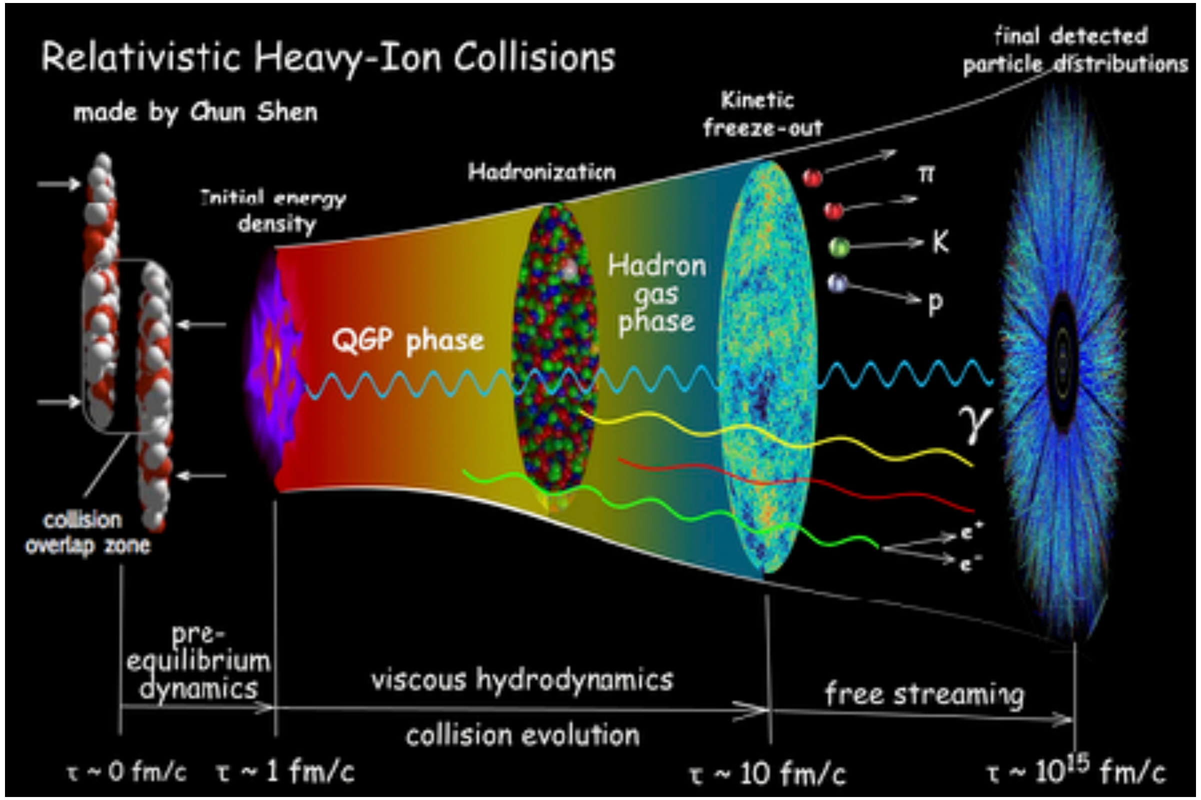
LIP – Summer Student Program

Introduction

The Quark Gluon Plasma

- Initial stage of the Universe
- Laboratory to study QCD (Quantum Chromodynamics)



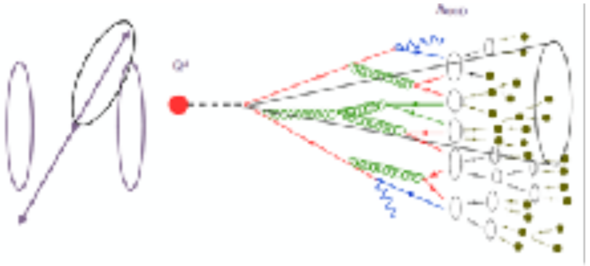


Hard Probes: Jets

- How to study QGP??

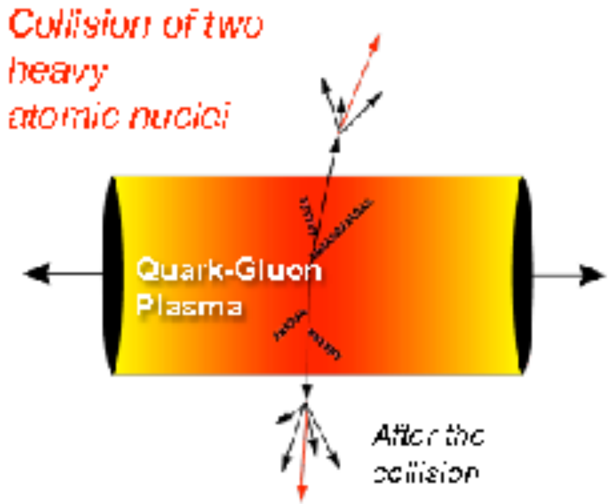
- Answer: Indirect Probing

Hard scattering

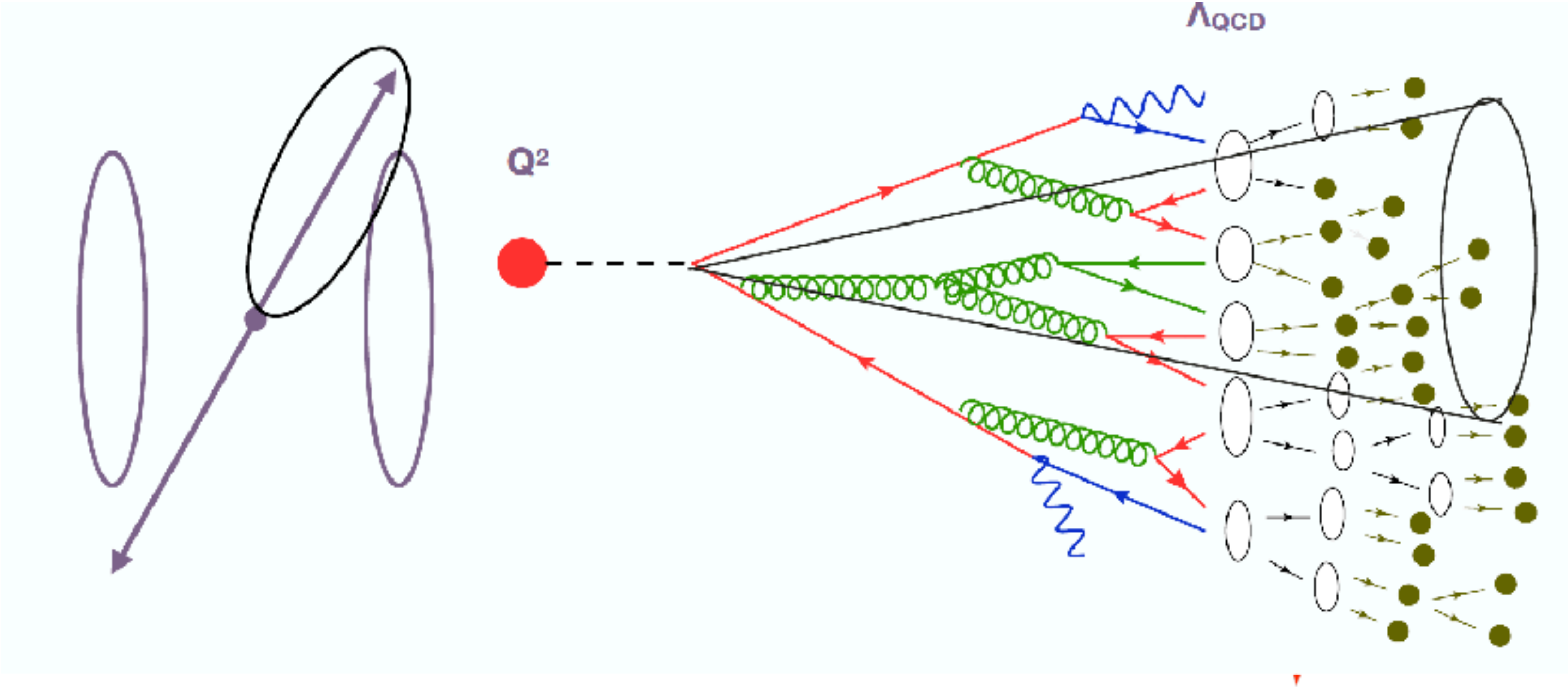


Hard probes

High momentum particles



Hard Probes: Jets

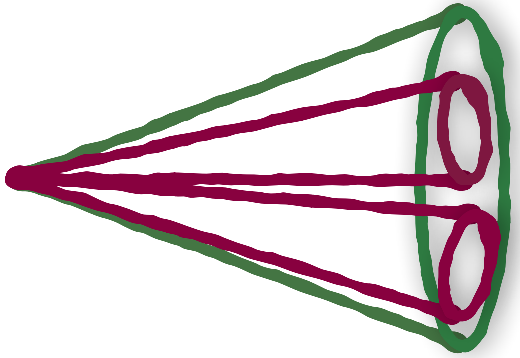


Study of background effects on ΔS_{12}

João Mesquita Lopes

Motivation

- Great deal of observables but more are needed to control the effect of background particles
- Recently published paper: Apolinário, L., Milhano, J.G., Ploskon, M. et al. Eur. Phys. J. C (2018) 78: 529.
- Introduces ΔS12 as a tool to distinguish between jet modification models

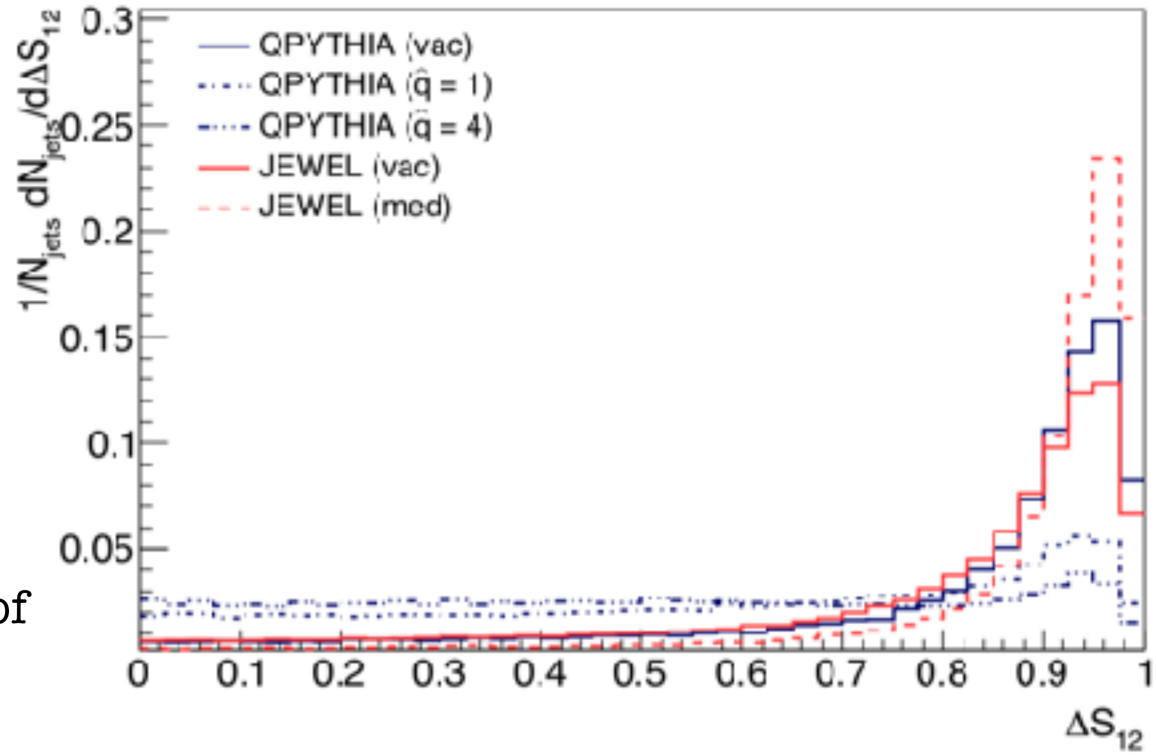


$$\Delta S_{12} = z_1 - z_2\,,$$

$$z_i = p_{\mathrm{T},i}/p_{\mathrm{T,jet}}\,.$$

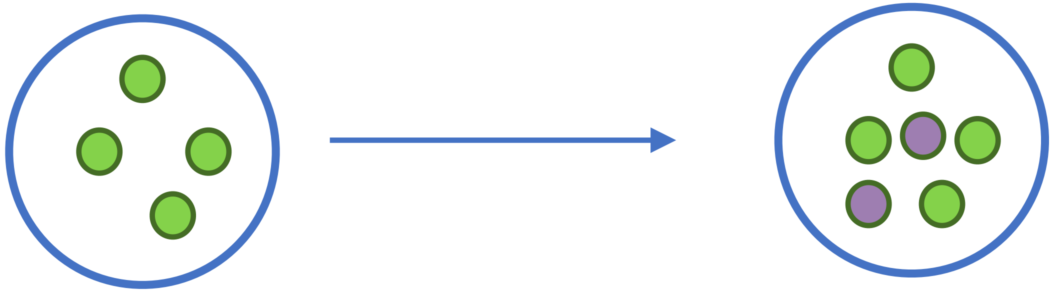
Transverse momentum of subjet i

Transverse momentum of the jet

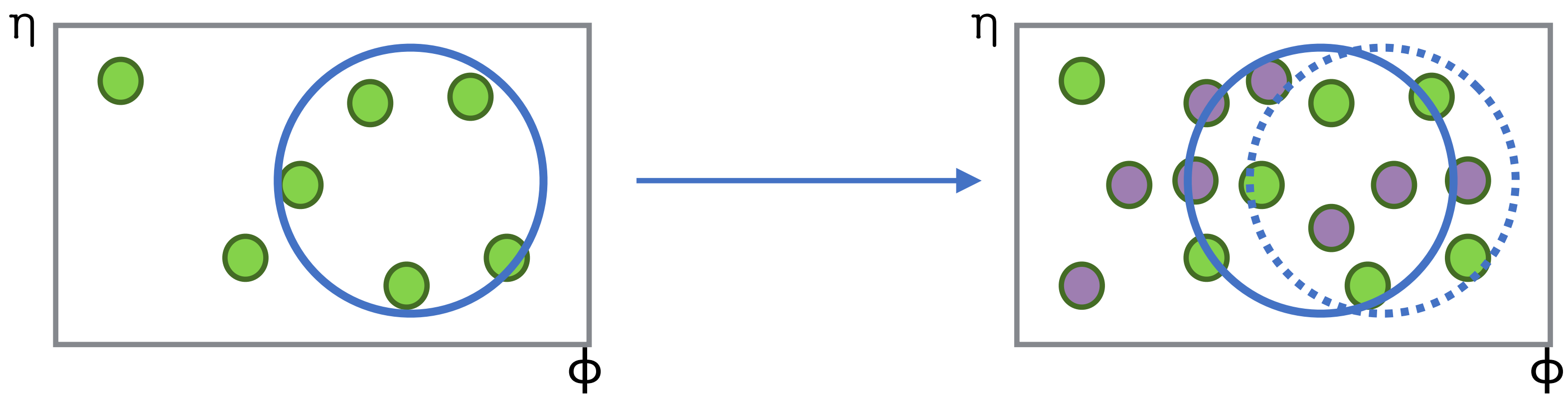


Methodology

- Pt Smearing of the subjets (background particles inside the jet)



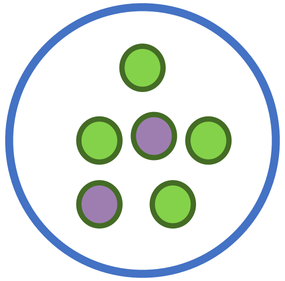
- Embedding of a pp event into a "real" underlying event (QGP particles) (background over the whole event)



Tools:
ROOT
Pythia
FastJet

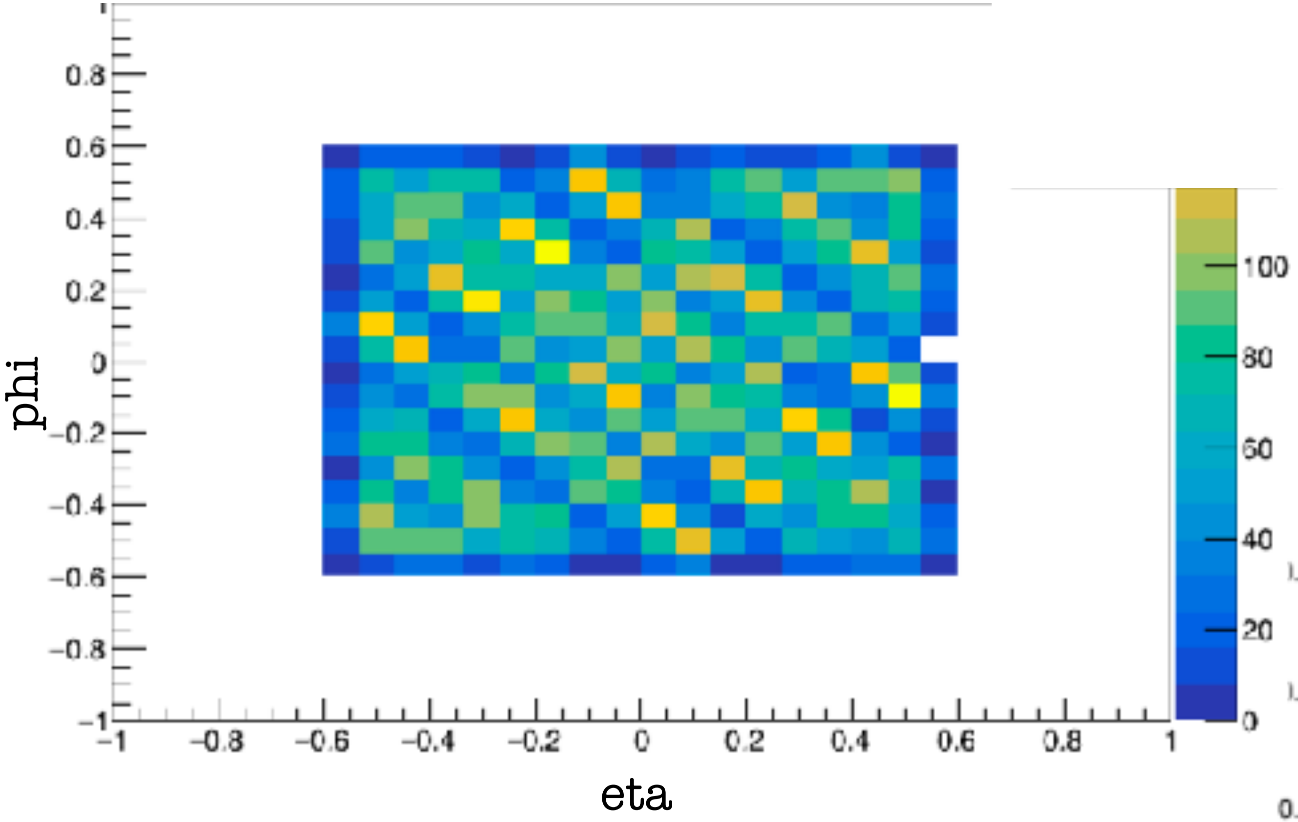
Cuts
Transverse momentum >150 GeV
Jet Radius (R) = 0.4.
Subjets radius (R) = 0.15
Subjets per jet > 2

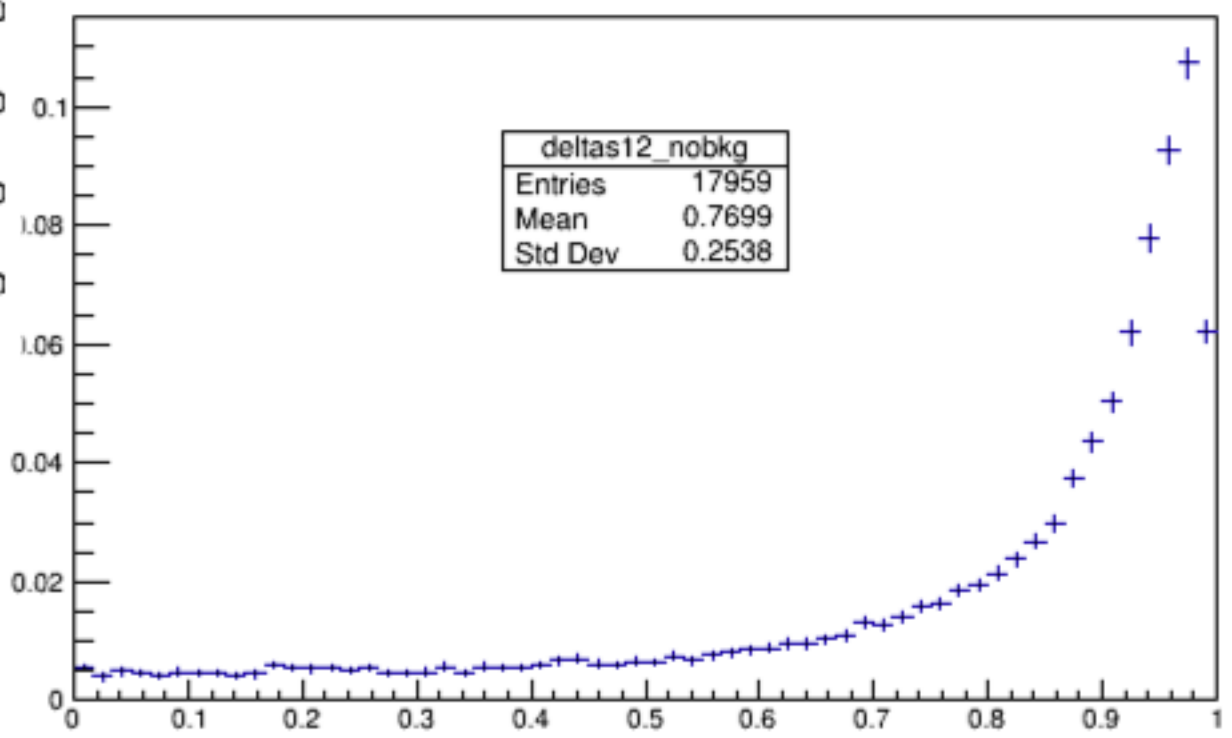
Eta: Pseudorapidity
Phi: Azimuthal Angle (range 0-2π)



Pt smearing method

- 50.000 events 50 background particles per event





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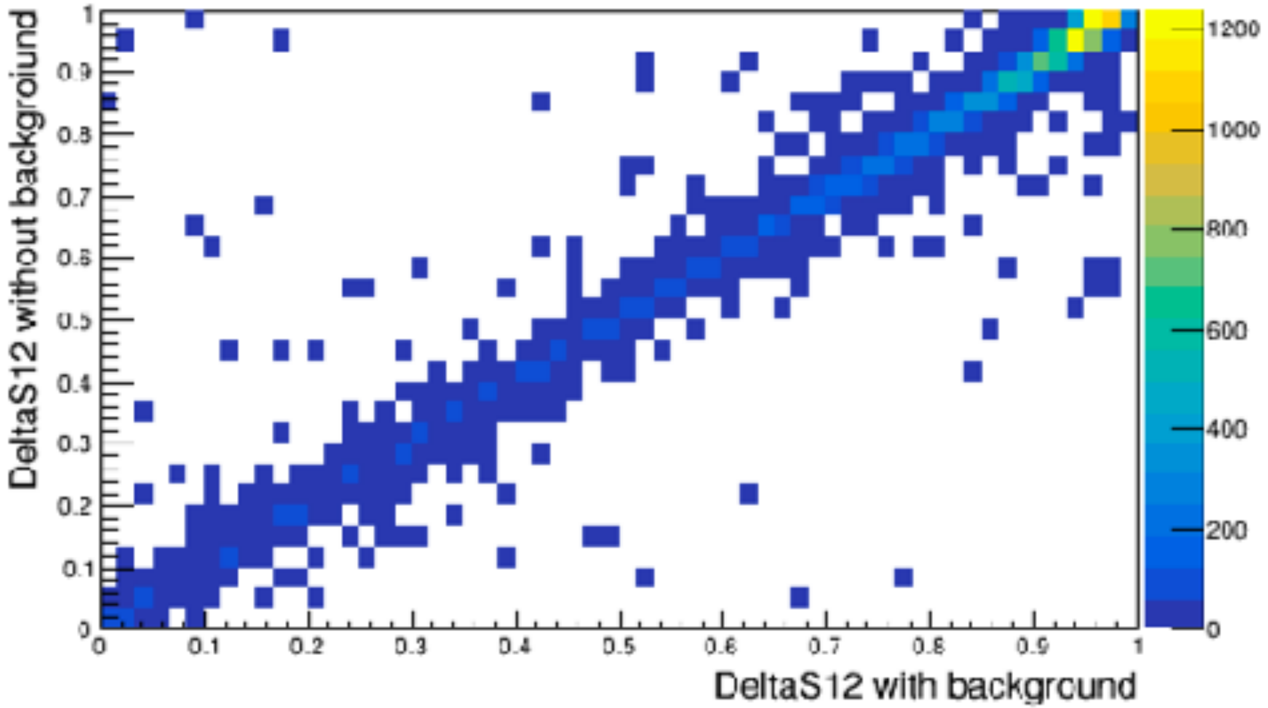

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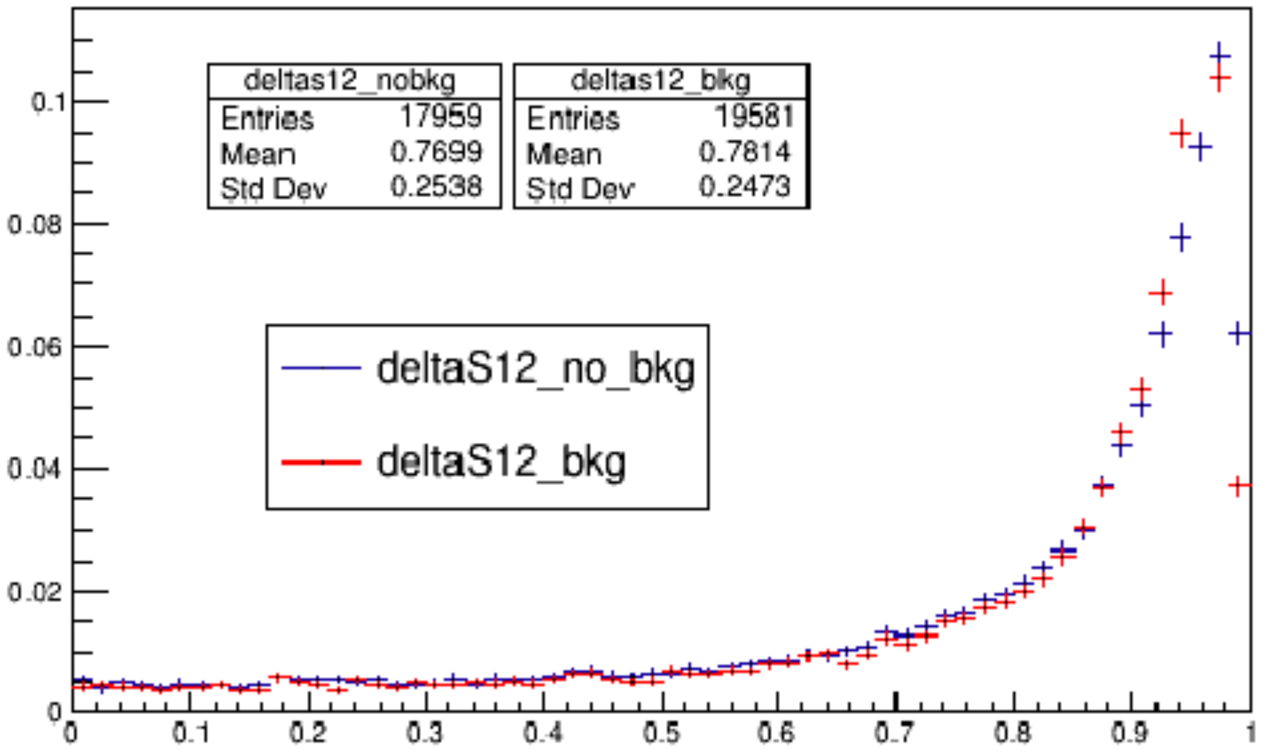
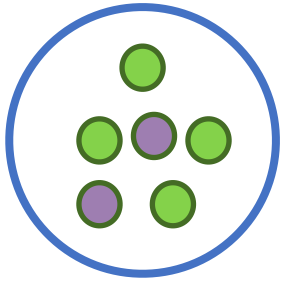
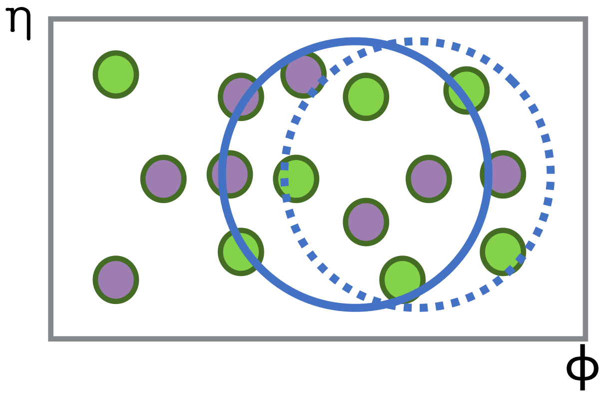
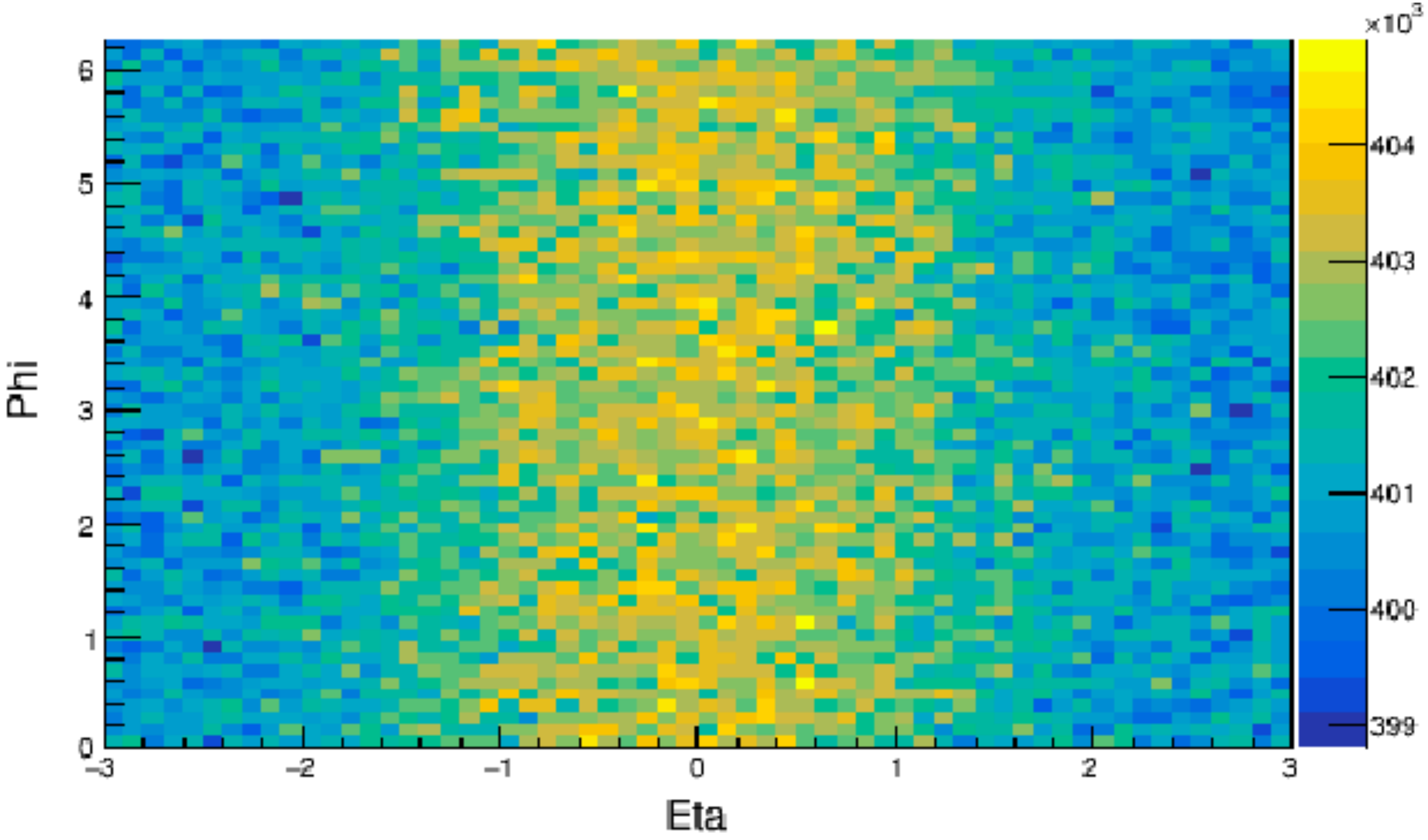






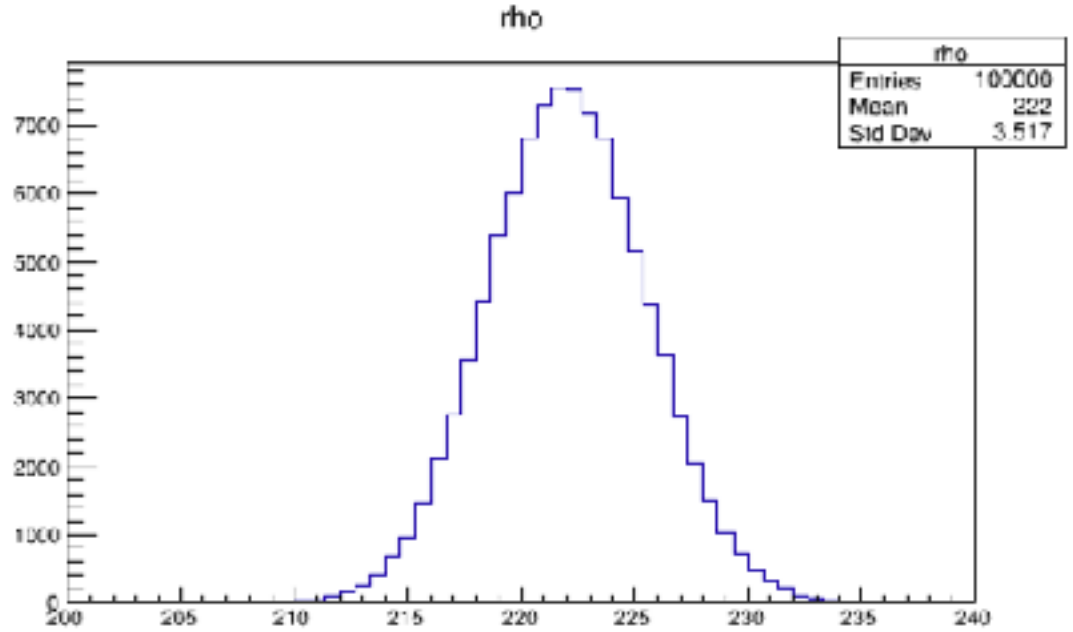
Embedding method

- 100.000 events with background subtraction

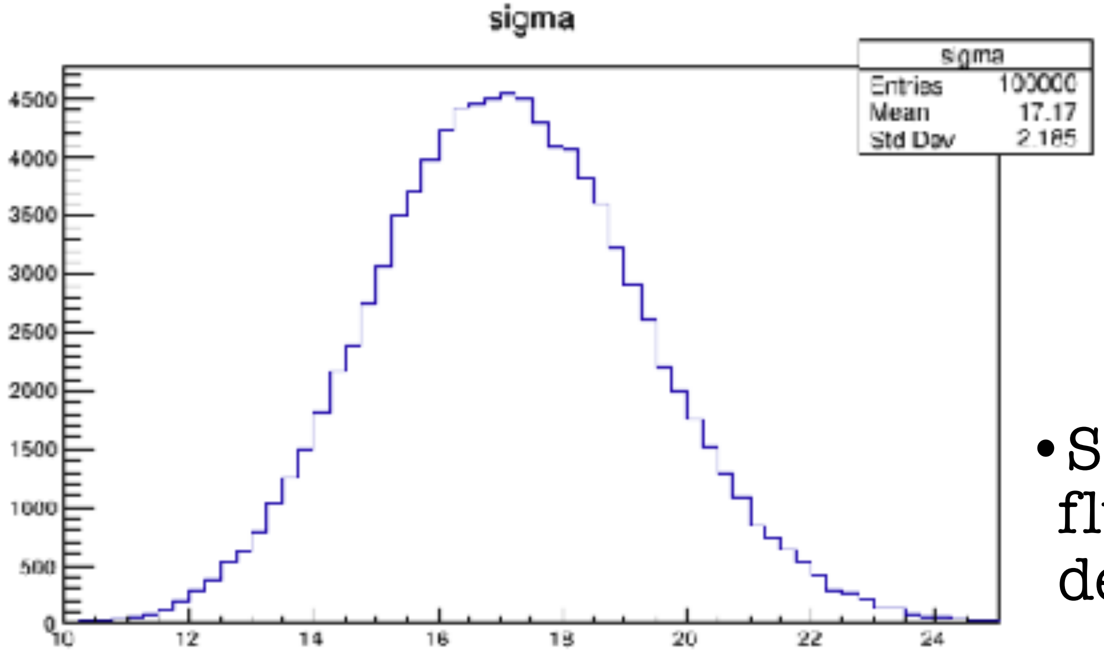


Background estimation

Grid Based Method



- Rho-> Pt/area, for jets that pass the selection cut



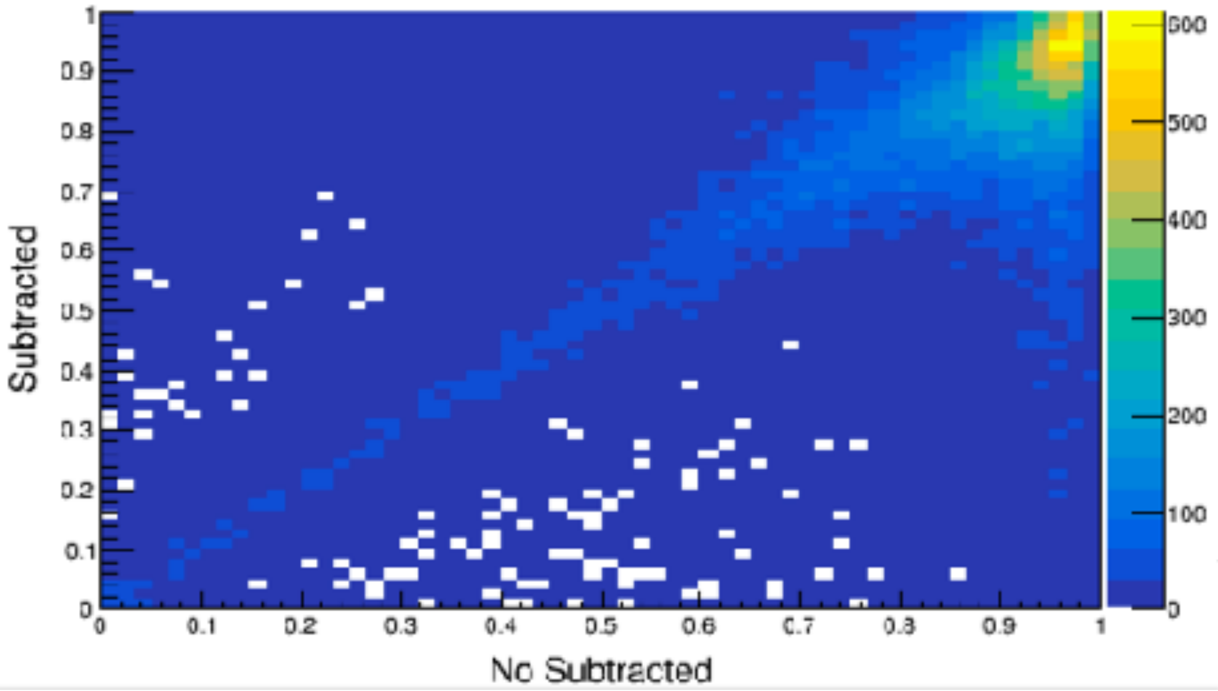
- Sigma->estimate of the fluctuations in the pt density per unit √A

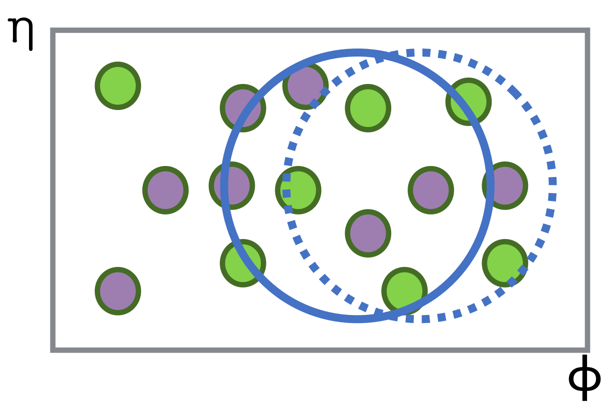
Average values ALICE
Sigma = 15 GeV
Rho=180 GeV

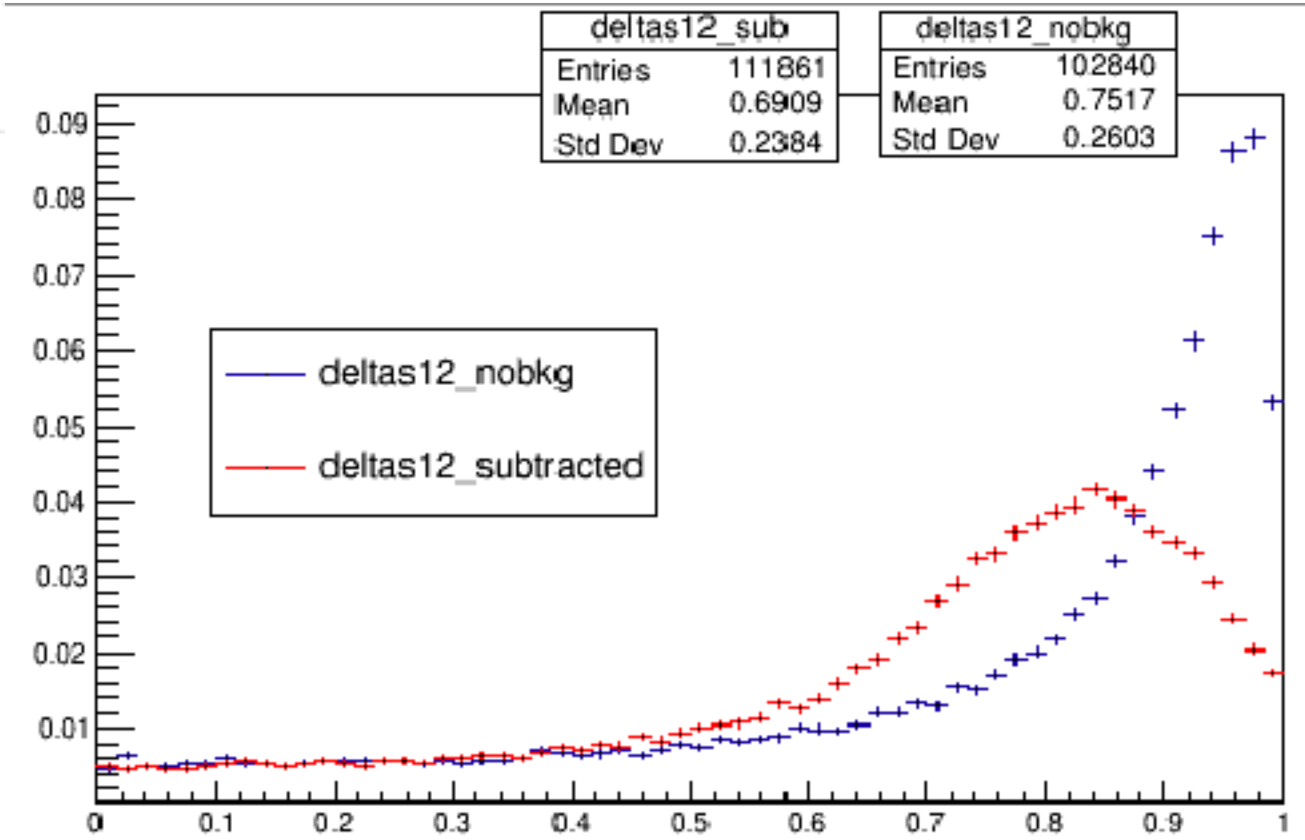
Correction of the background

Embedding method

- 100.000 events with background subtraction







Conclusions

- DeltaS12 resilient against a pt smearing (this effect is cancelled in its definition - it is a subtraction and a ratio). - First method
- DeltaS12 is indeed distorted when embedded into a “simple” fluctuating background - Second method
- Nevertheless the results are very promising: the response matrix is quite diagonal
- DeltaS12 can be indeed a good tool to study real heavy-ion collisions

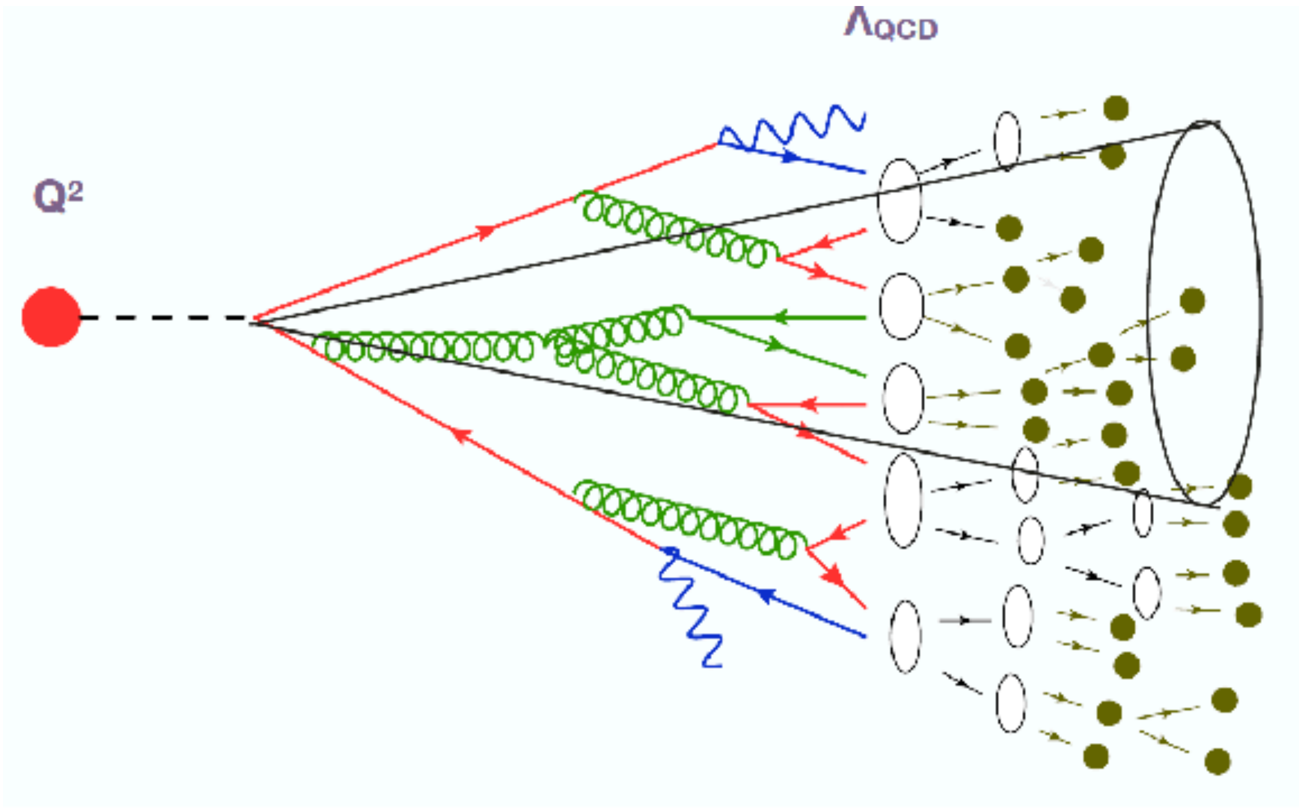
Further research is essential…

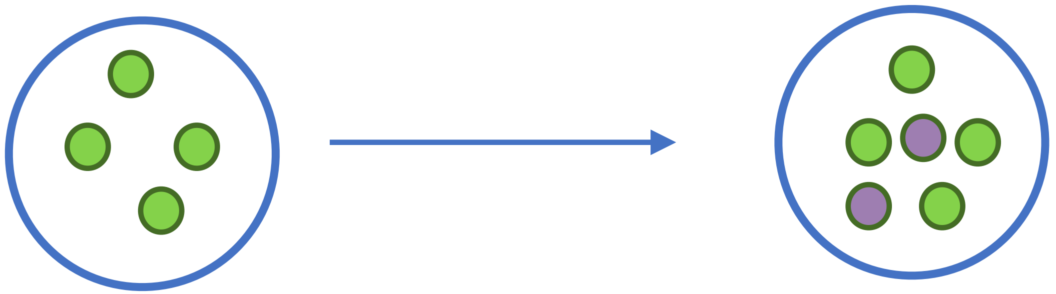
Evaluating Background Fluctuations on intra-jet observables

Luís Bugalho

Motivation

- Evaluate how the presence of a fluctuating background can affect parton shower evolution





Observables that were tested:
- Jet Splitting function (z_G)
- Jet Fragmentation Functions
- Number of Soft Drop splittings (n_G)

Jet Quenching effects on lighter systems

Rafael Orelhas

Motivation

$$R_{AA} = \frac{\text{Number of particles in pp}}{\text{Number of particles in PbPb}}$$

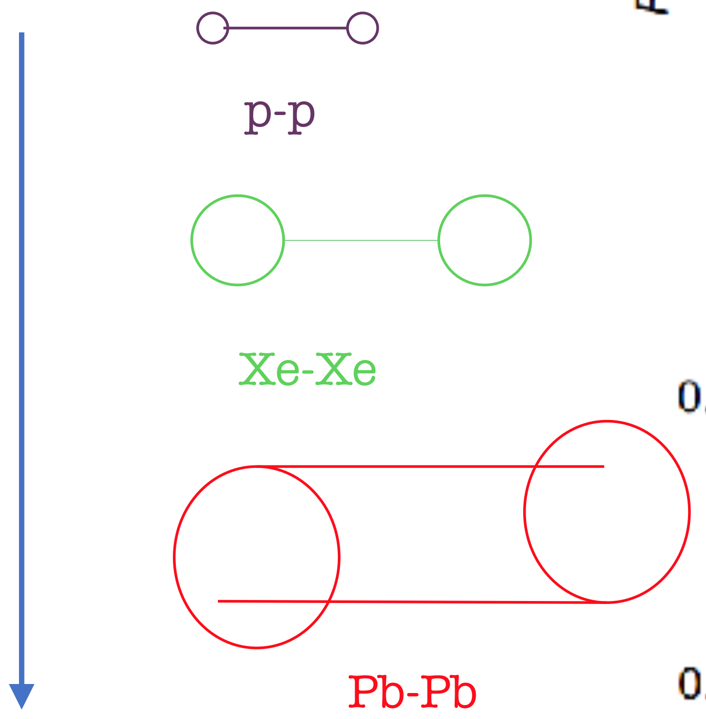
$R_{AA} < 1 \Rightarrow$ Energy Loss!

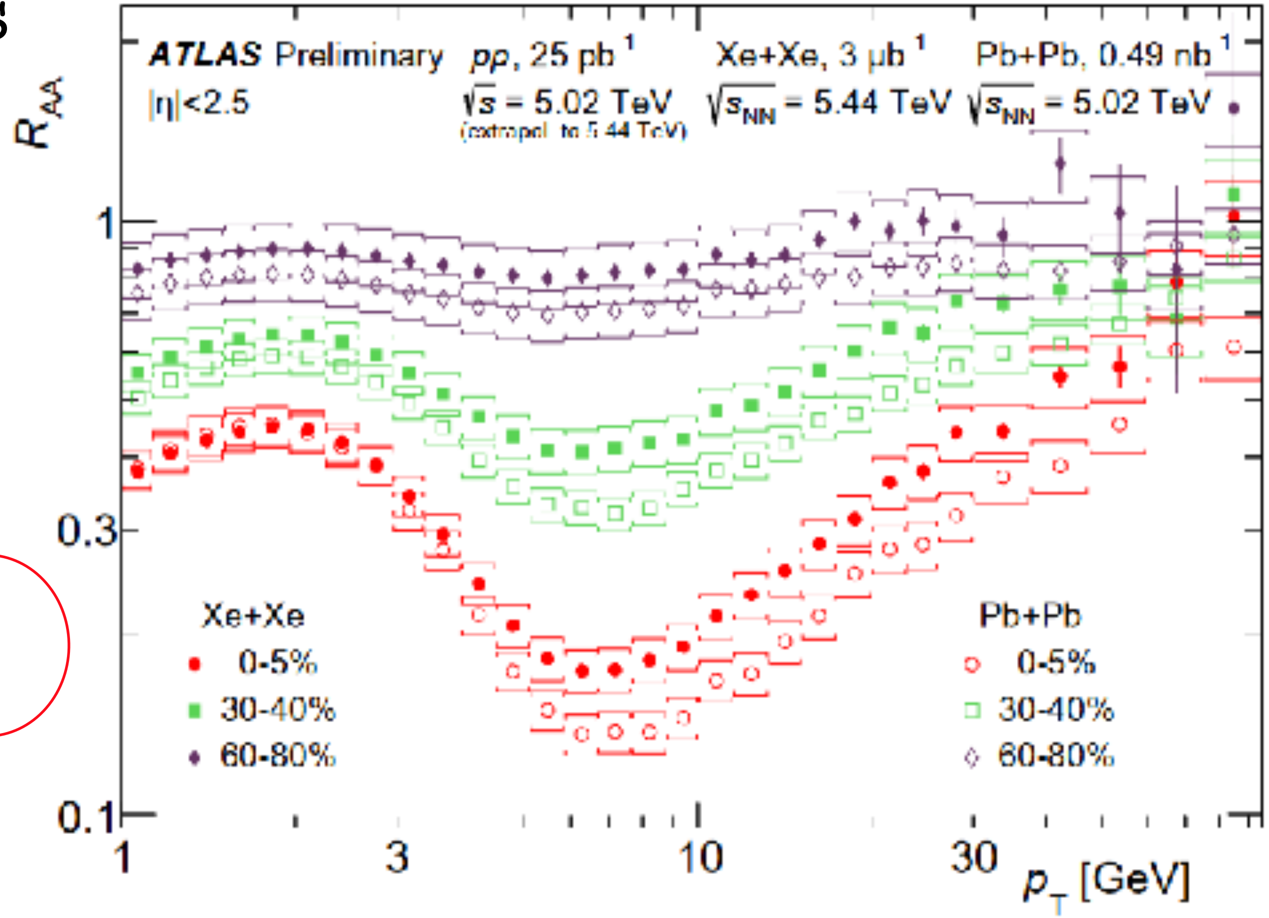
- Study different magnitudes of jet quenching
- Probe different QGP lifetimes

More QGP extent

$\Rightarrow$ More Energy Loss

$\Rightarrow$ Smaller R_{AA}

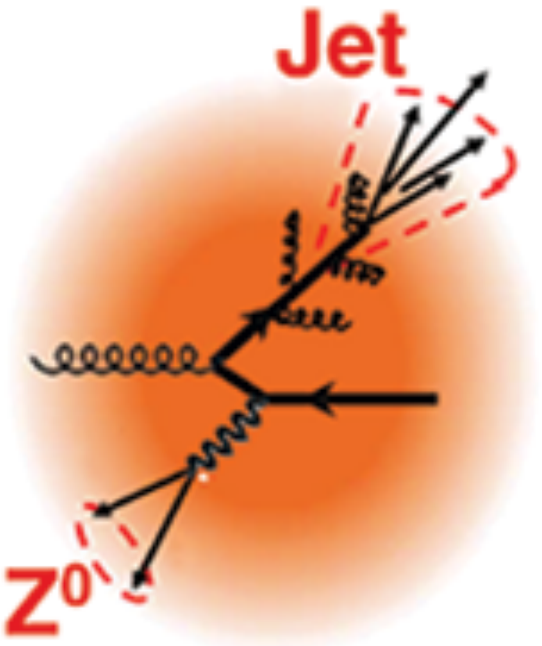




Methodology

- Analysis: Z + Jet
  - $Z \rightarrow \mu^+\mu^-$
  - Calibrated probe

Interaction with the QGP
⇒ Energy Loss



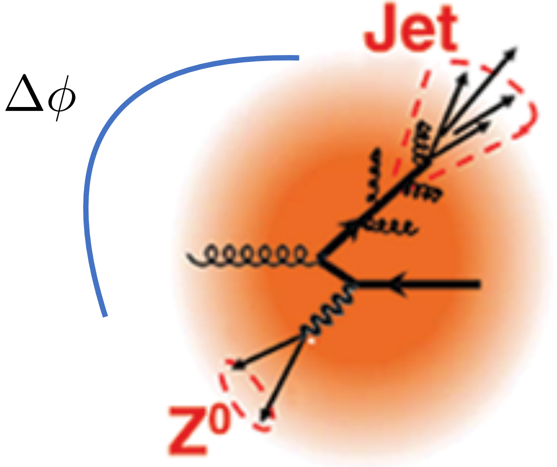
No Interaction with the QGP
⇒ No Energy Loss

Tools:
Sim: Pythia (pp)
JEWEL (PbPb & ArAr)
Reco: FastJet
Plots: ROOT

Cuts
p_T (Z) > 60 GeV
p_T (Jet) > 30 GeV
$|\eta| < 1.6$
Jet Radius (R) = 0.5

p_T: Transverse momentum
η: Pseudorapidity
Φ: Azimuthal Angle (range 0-2π)

Results

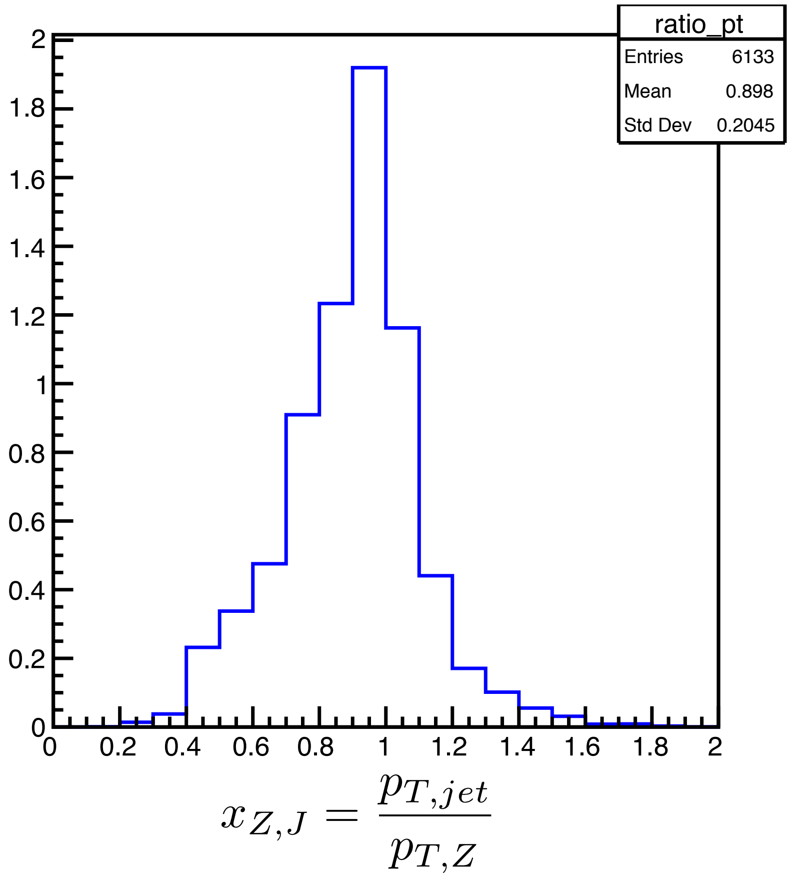


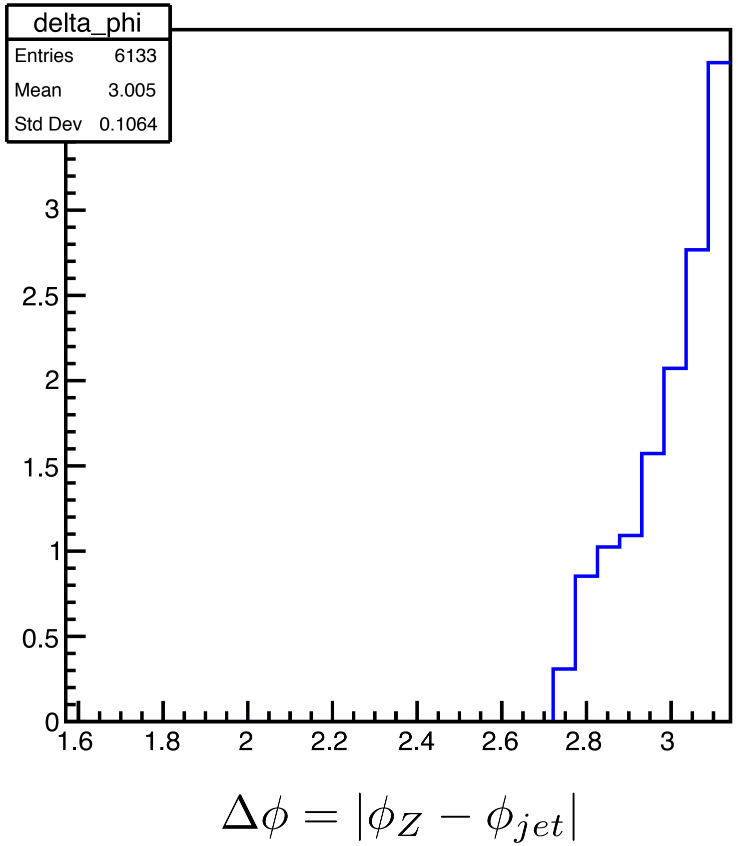
pp: Cross-check

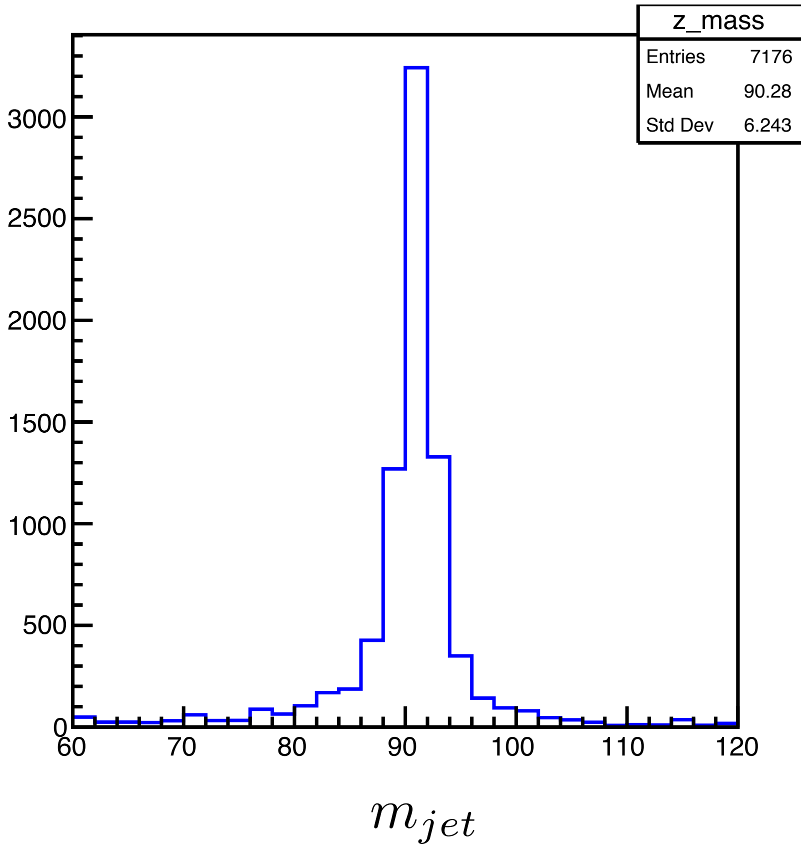
$m_Z = 91.1876$ GeV

$\langle x_{Z,J} \rangle^{pp} \sim 0.9$

$\langle m_Z \rangle^{pp} \sim 90.3$







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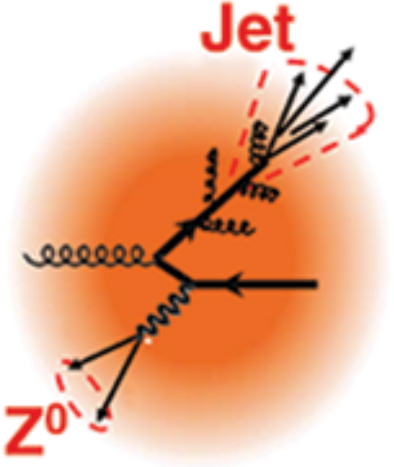
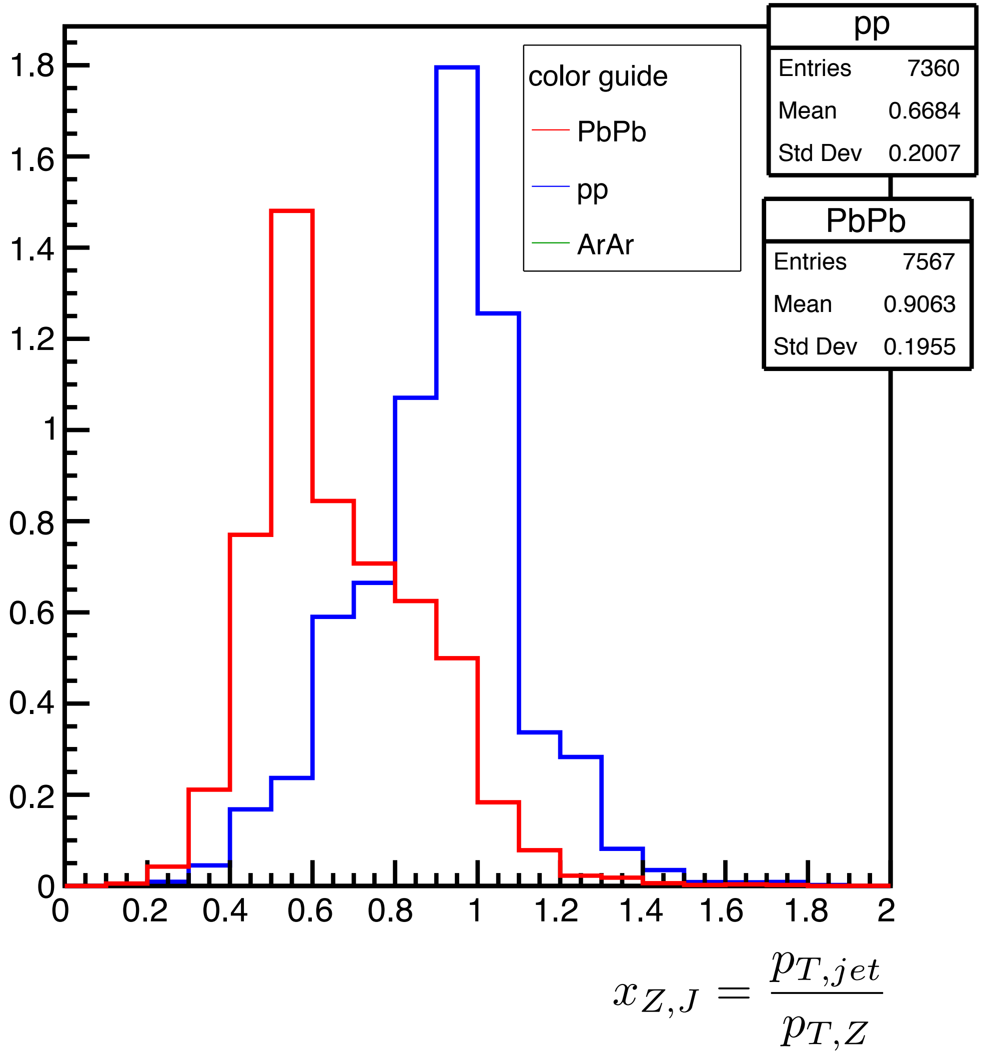


PbPb (256)

$\langle x_{Z,J} \rangle^{pp} \sim 0.9$

$\langle x_{Z,J} \rangle^{PbPb} \sim 0.66$



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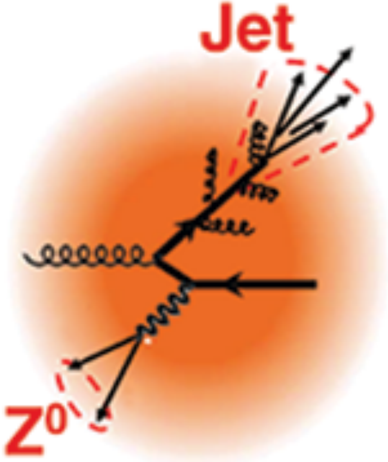

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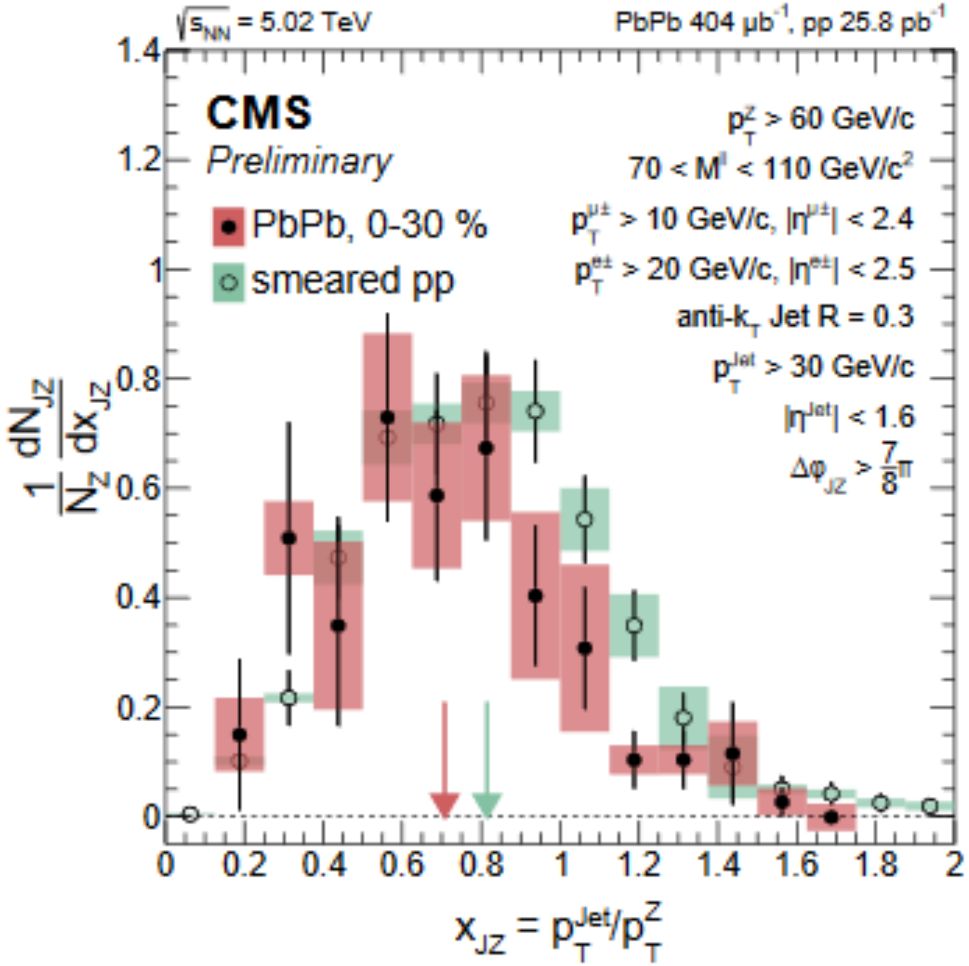

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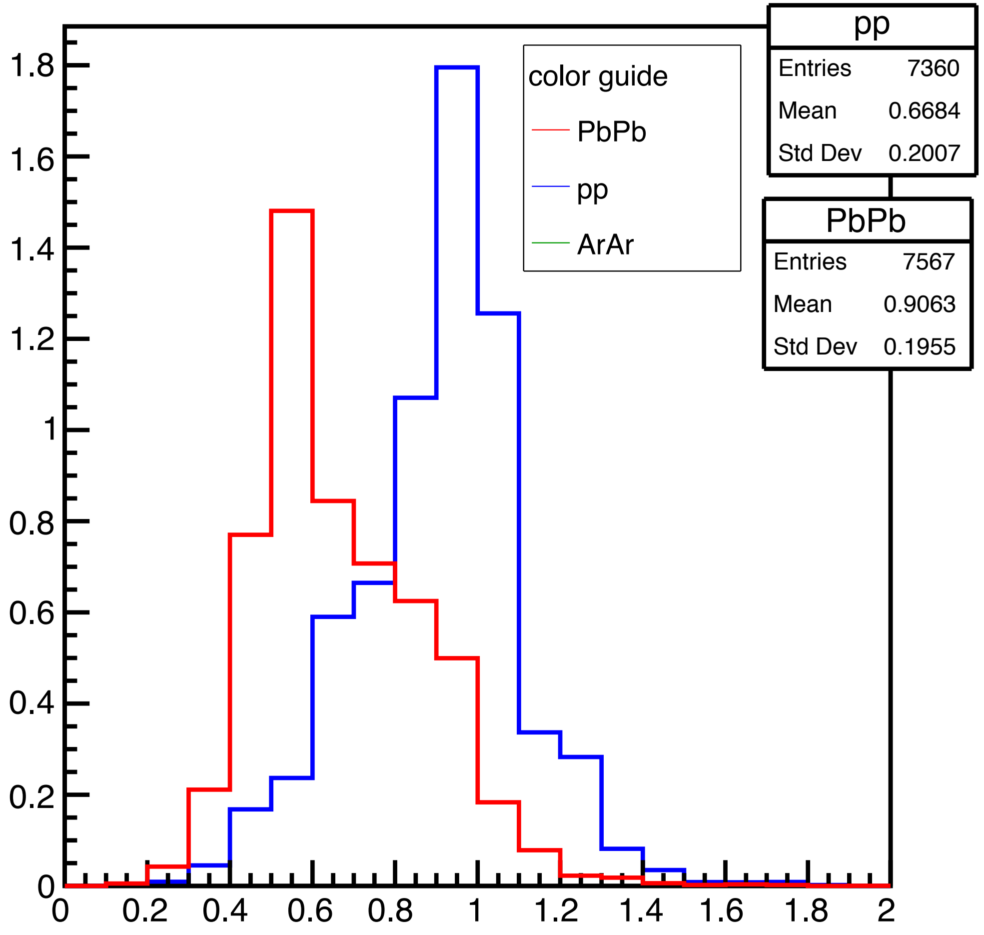
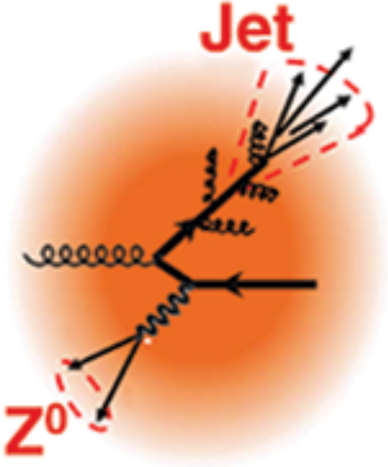


$$x_{Z,J} = \frac{p_{T,jet}}{p_{T,Z}}$$

Results

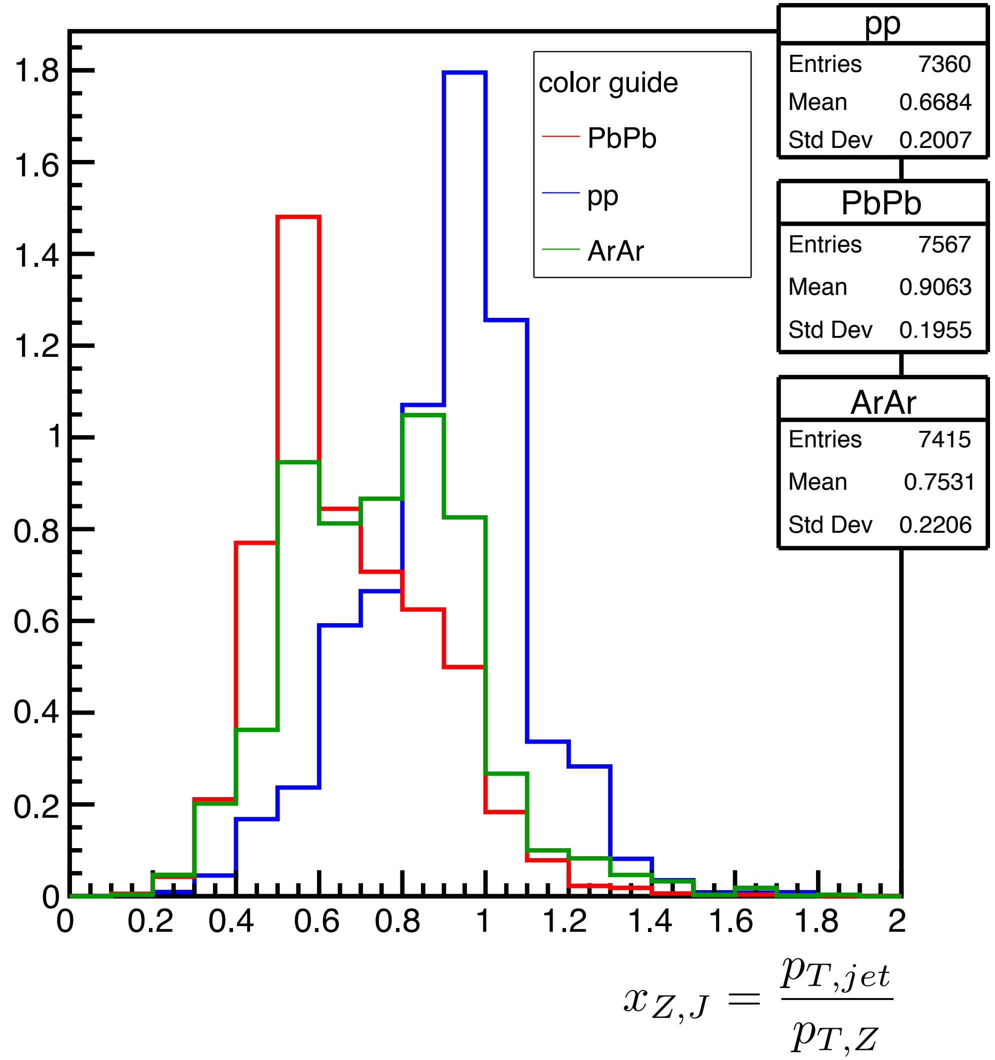


ArAr (40)

$$\langle x_{Z,J} \rangle^{pp} \sim 0.9$$

$$\langle x_{Z,J} \rangle^{PbPb} \sim 0.66$$

$$\langle x_{Z,J} \rangle^{ArAr} \sim 0.75$$



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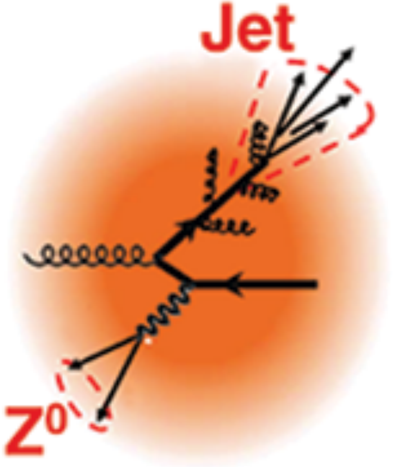
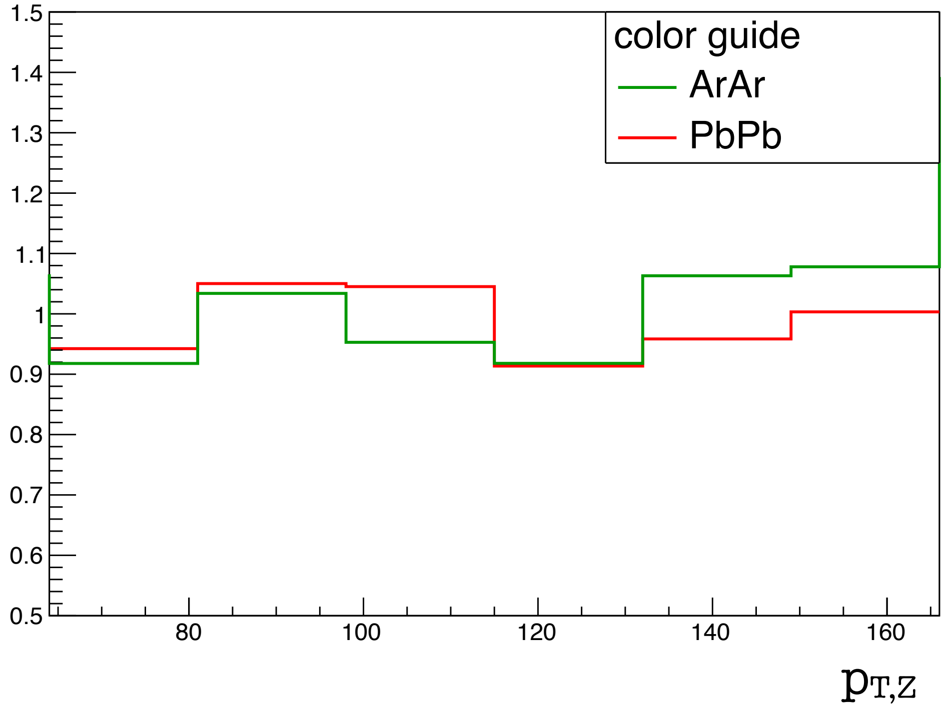


ArAr (40)

$$\text{Ratio} = \frac{\text{ArAr/PbPb}}{\text{pp}}$$



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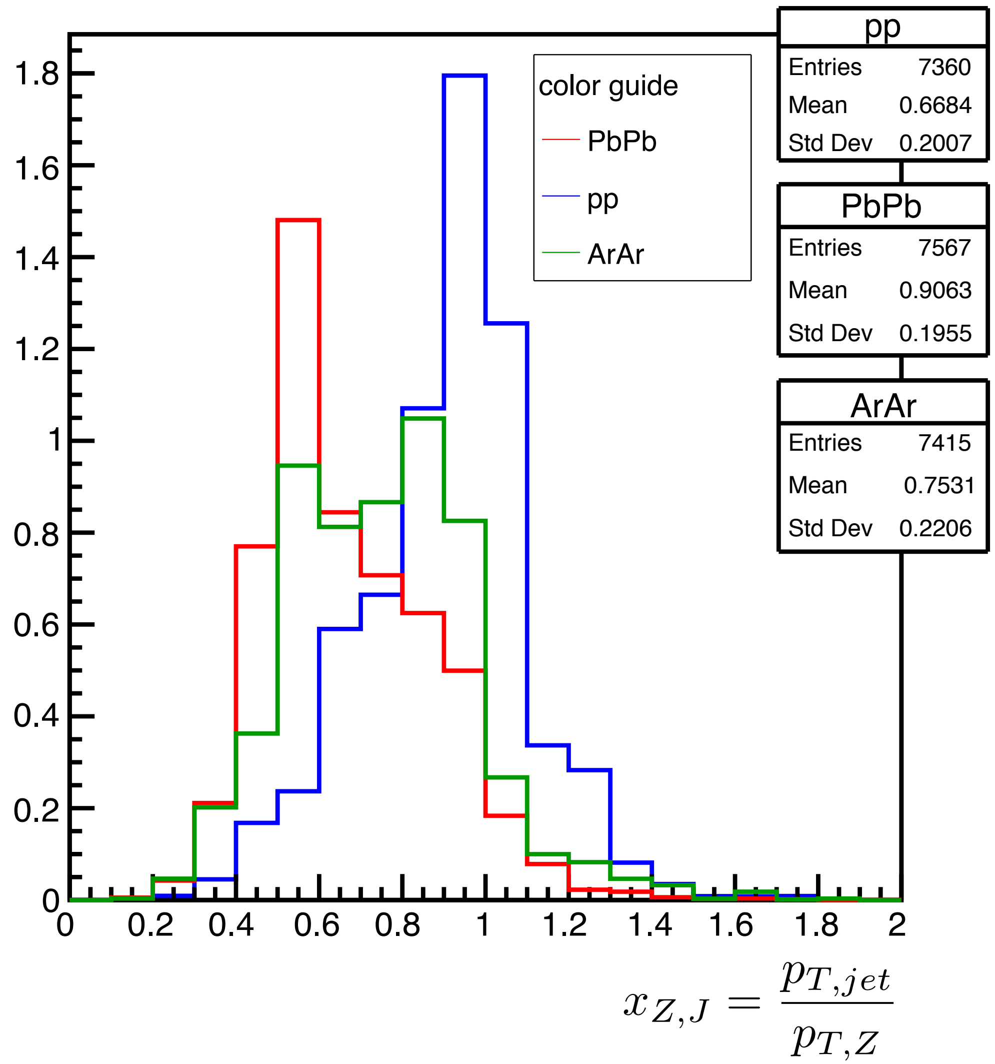

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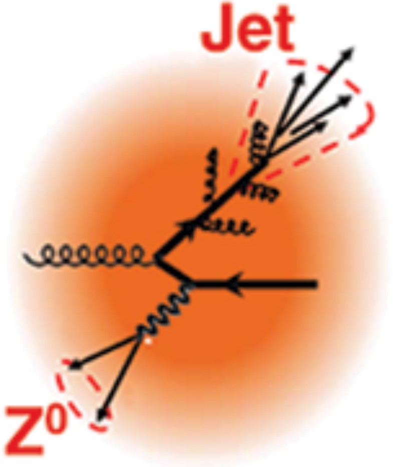

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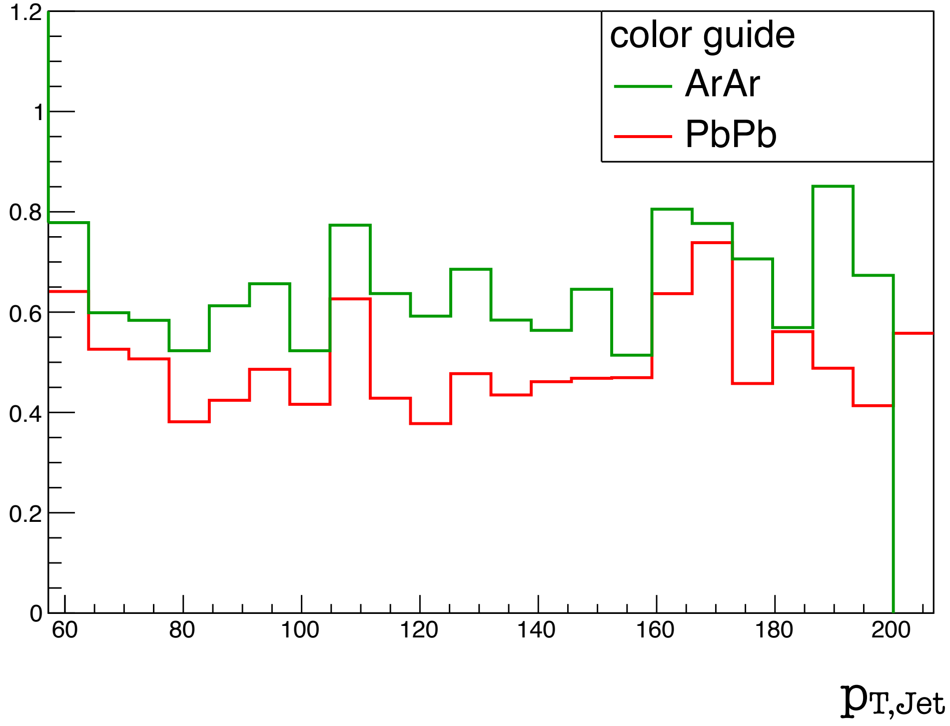
$$\text{Ratio} = \frac{\text{ArAr/PbPb}}{\text{pp}}$$



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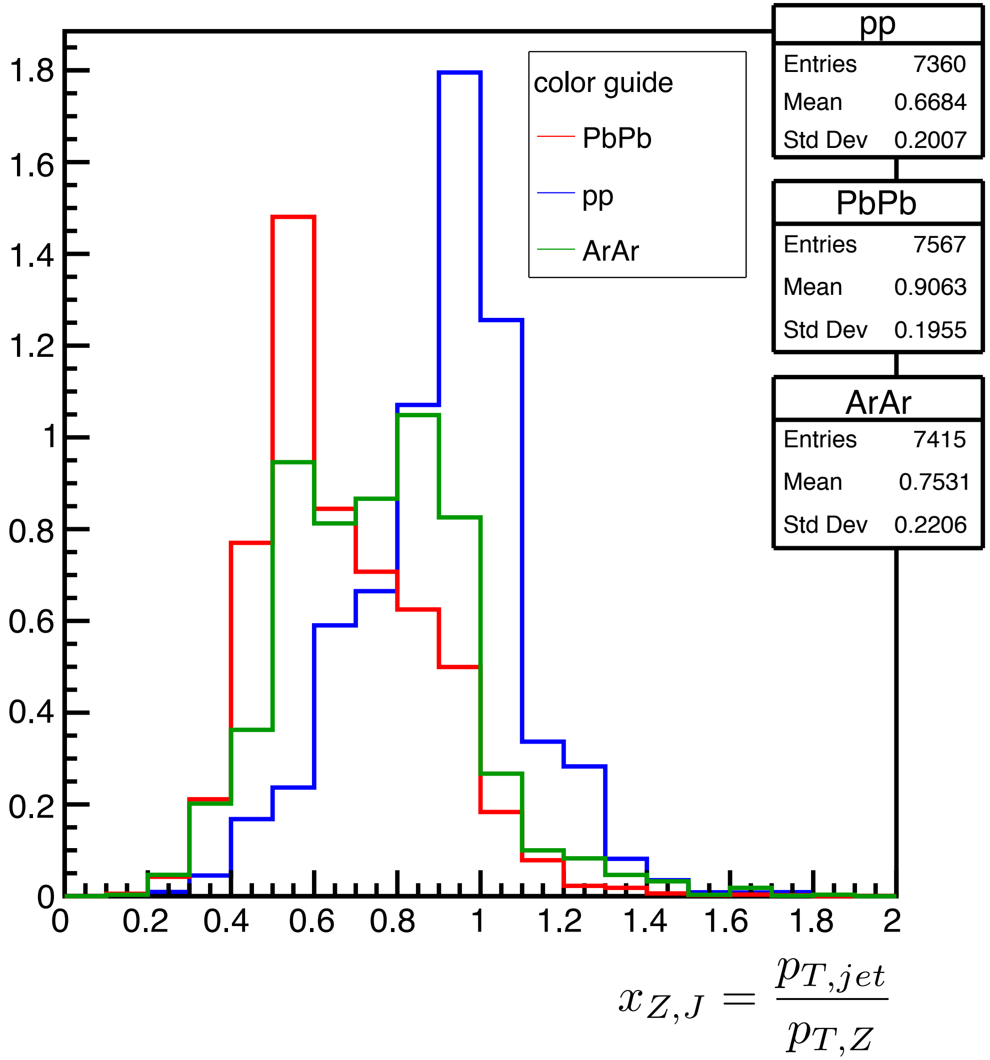

Conclusions

- Z+Jet channel calibrated probe to evaluate energy loss effects
  - Z Boson does not lose energy
  - Jet interacts with QGP
- Only one model tested: JEWEL
  - PbPb results compatible with PbPb data (by CMS)
  - ArAr fisrt predictions!
    - Preliminary results seem to show that ArAr will have sizeable energy loss effects

Thank you!

Backup Slides

(Backup)

Prospects

-Improve the \eta distribution of background particles, to get more realistic with data
-Get more statistics
- Improve response matrix by introducing a min pt on the reconstructed subjets; with this improve the performance of the observables in the presence of background particles

Prospects

- Check with another jet quenching models:
  - Perturbative: Q-PYTHIA, PYQUEN;
  - Holographic: AdS/PYTHIA
- Check other (technically preferable) ions
- Make additional ArAr predictions for intra-jet observables