

# Heavy Flavour Jets Production in Pb+Pb Collisions with the ATLAS Detector

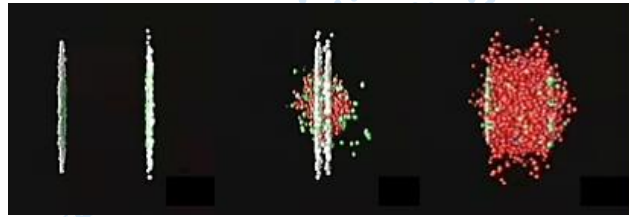
Vicente Mendes

Supervisor: Helena Santos



# Heavy Ions and the Quark Gluon Plasma

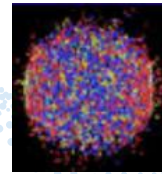
- Why study heavy ion collisions?



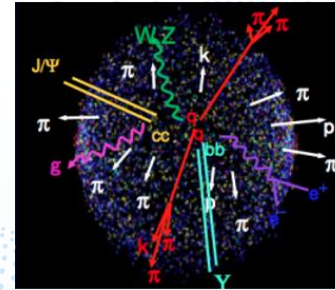
Incoming Nuclei

Collision

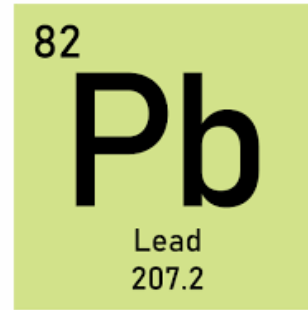
QGP



Mixed Phase

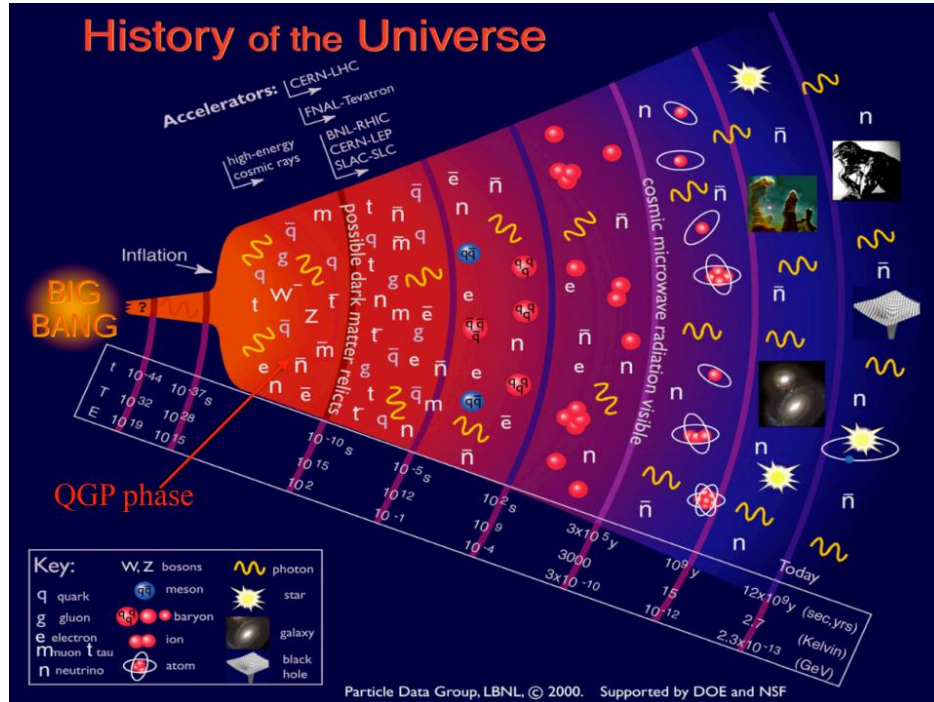


- Lead has 208 nucleons

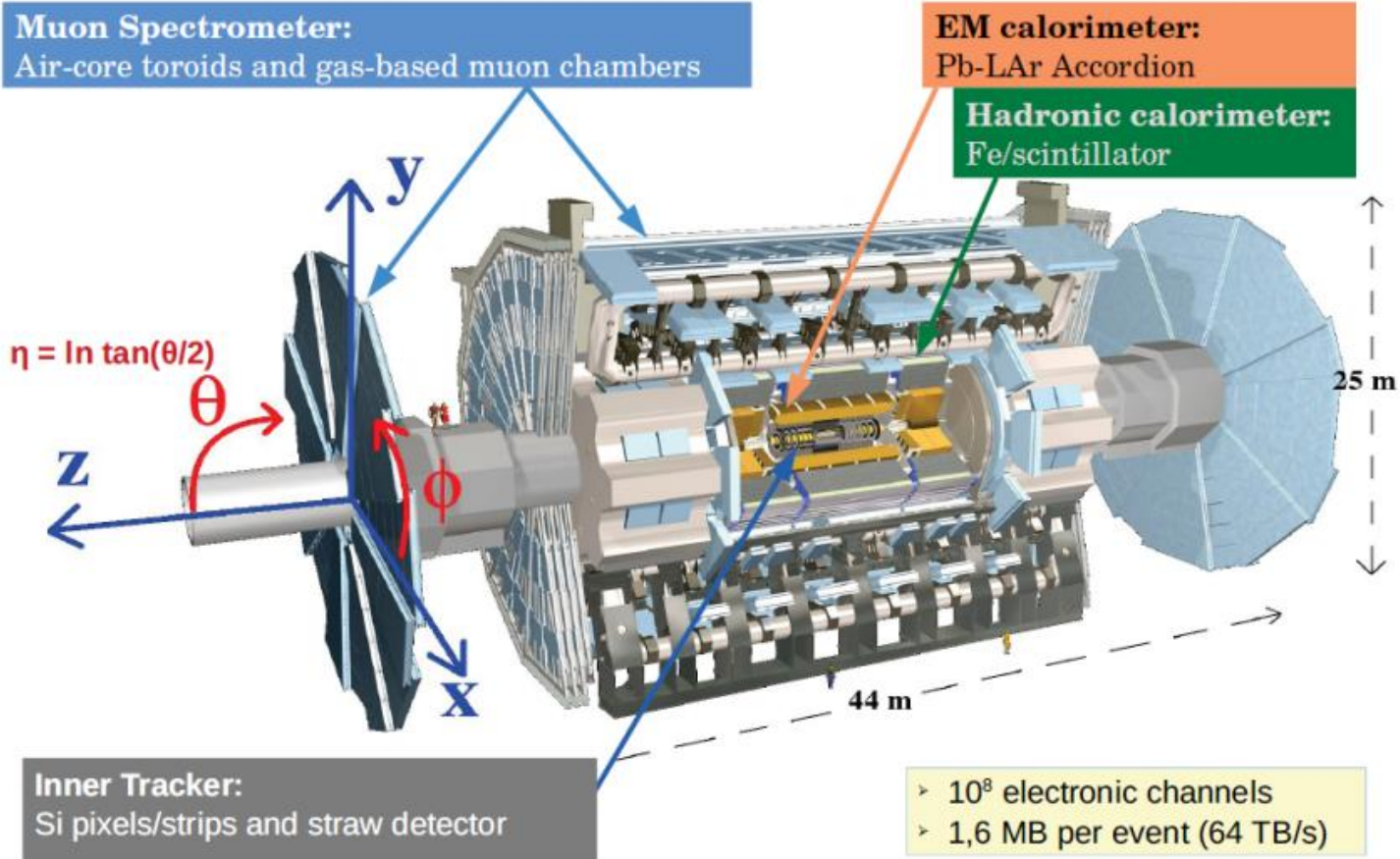


# Heavy Ions and the QGP

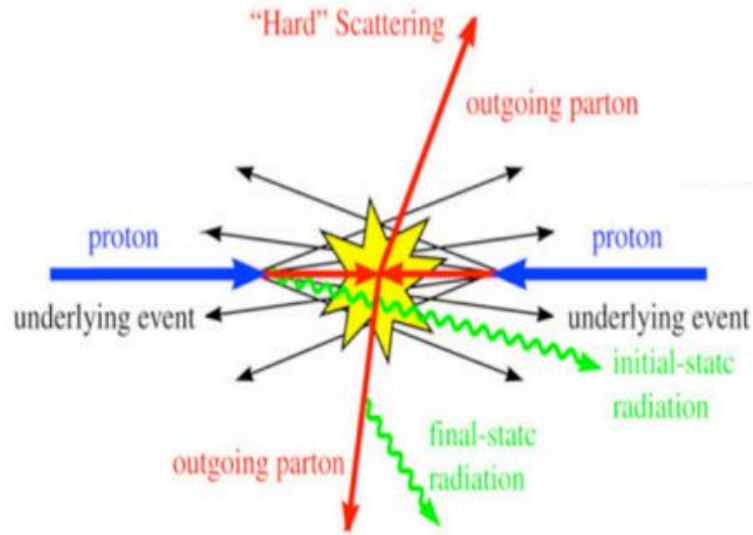
- Why study the Quark Gluon Plasma?



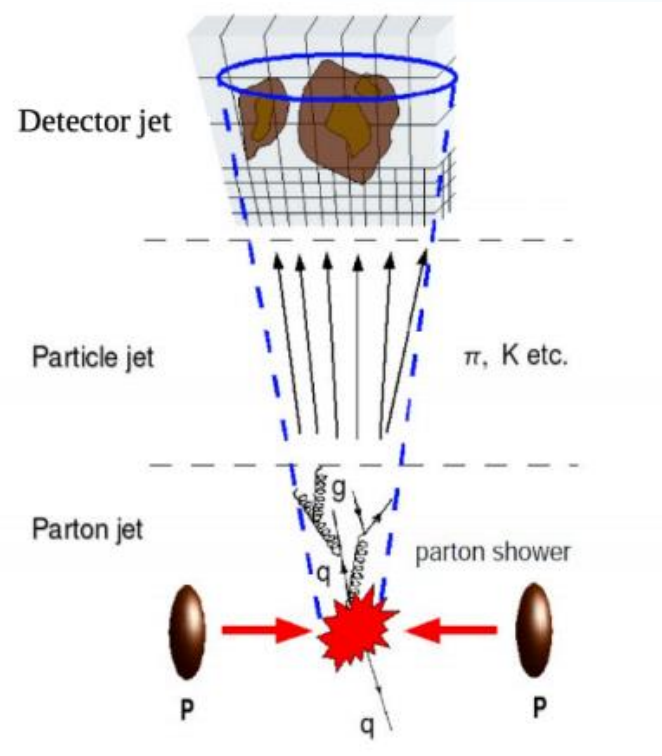
# ATLAS Detector



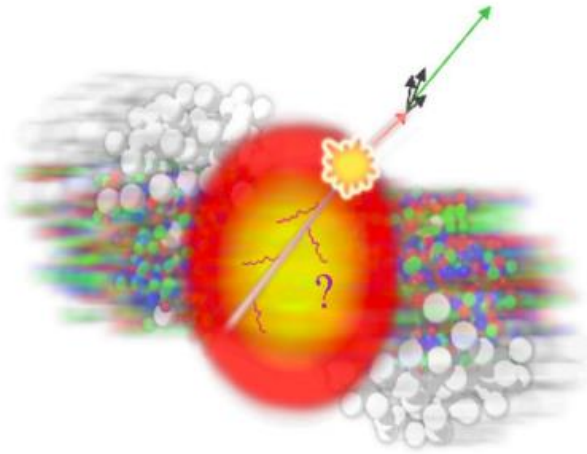
# Jets as the golden probes of the QGP



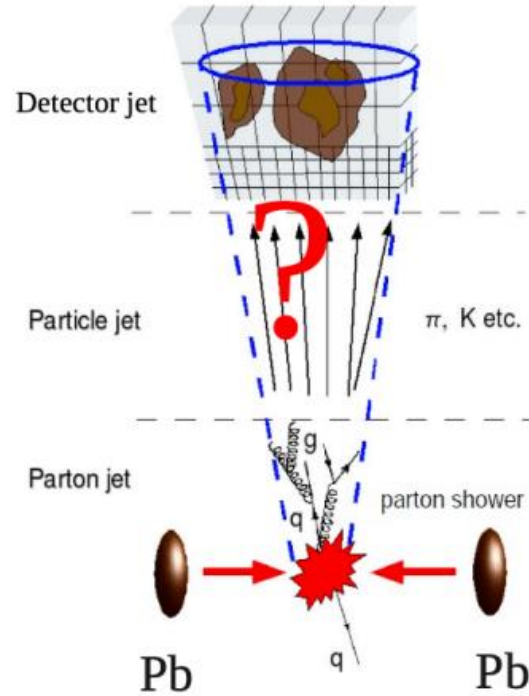
**Proton-Proton Collisions**



# Jets as the golden probes of the QGP



**Lead-Lead Collisions**



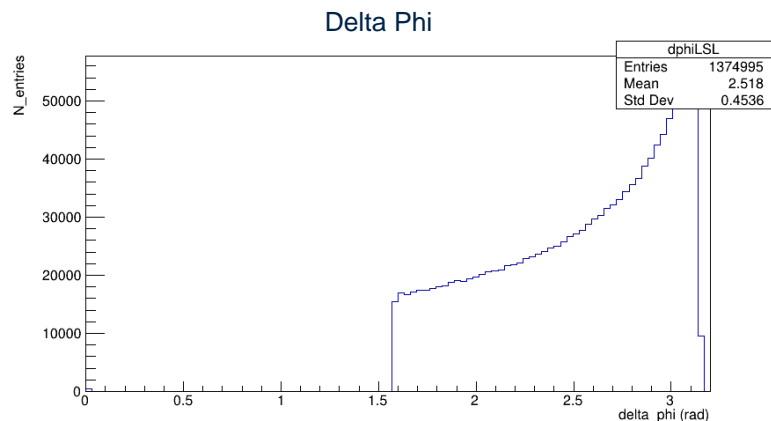
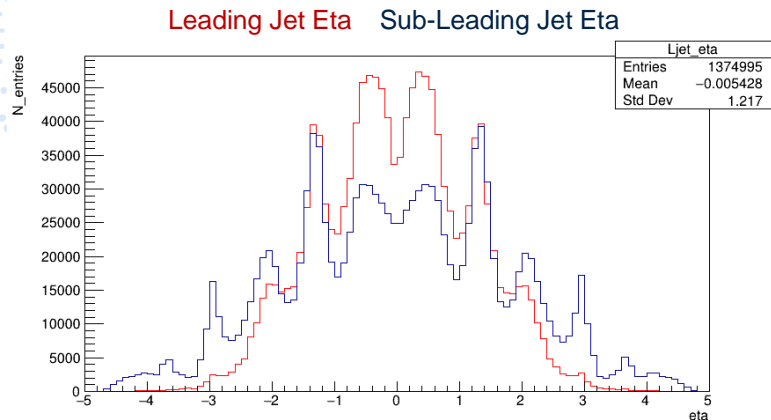
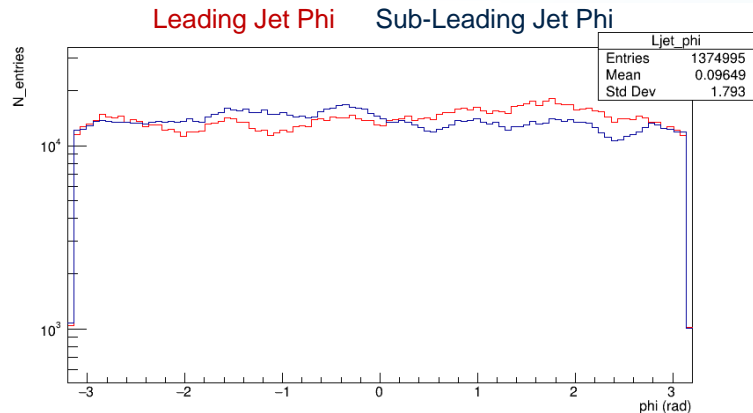
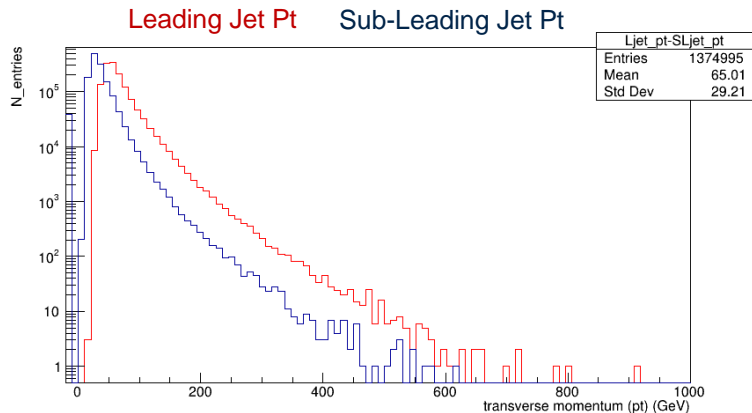
# b-jets and the QGP

- Why study b-jets in the QGP?
- What is the expected behaviour of b-jets in the QGP?

A periodic table of particles showing their mass, charge, and spin. The particles are organized into groups: Quarks, Leptons, and Gauge Bosons. A blue arrow points from the top row of quarks to the bottom row of quarks.

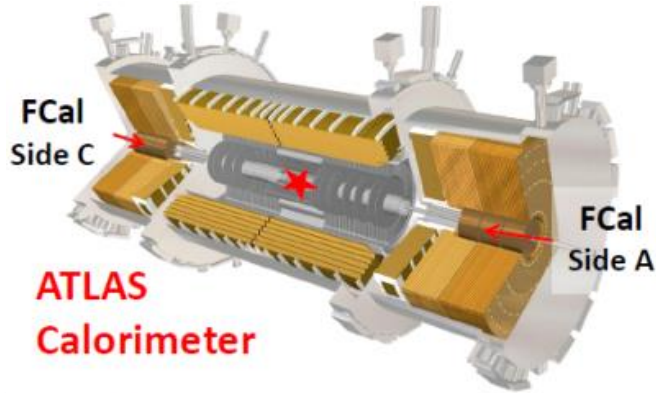
mass →	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge →	$2/3$	$2/3$	$2/3$	0	0
spin →	$1/2$	$1/2$	$1/2$	1	0
<b>QUARKS</b>	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-1/3$	$-1/3$	$-1/3$	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon	
<b>LEPTONS</b>	$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
	-1	-1	-1	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson	
	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
	0	0	0	$\pm 1$	
	$1/2$	$1/2$	$1/2$	1	
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson	
					<b>GAUGE BOSONS</b>

# The sample used in this project

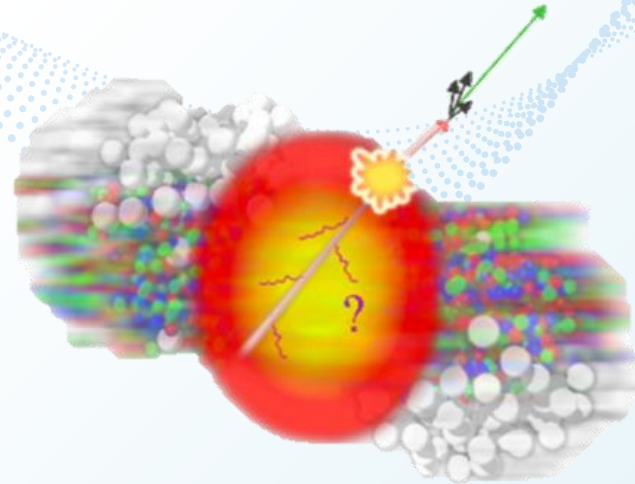
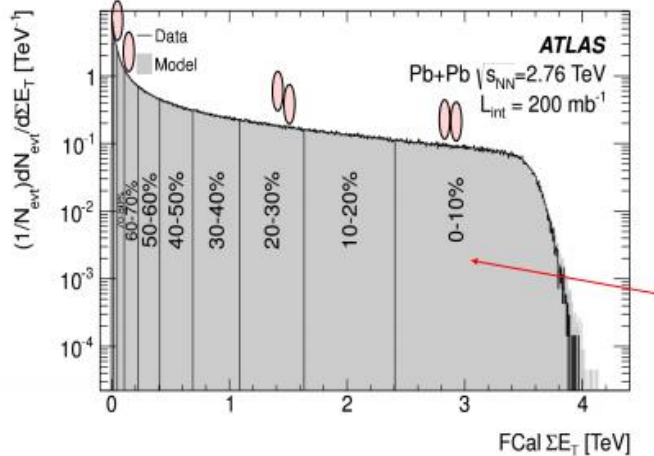




# Collision centrality and the QGP



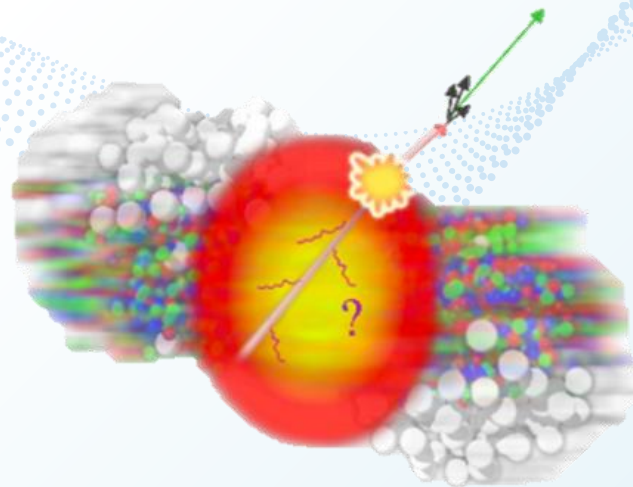
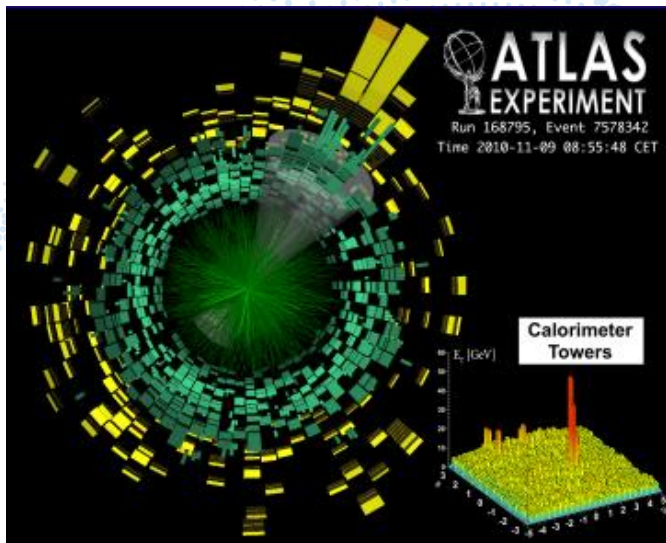
- QGP is formed only if the collision is central enough
- We can determine centrality with the energy deposited in the Forward Calorimeters



# Di-jet asymmetry in heavy ion collisions

- The transverse momentum asymmetry observable is a great way to see the effect of the QGP on jets

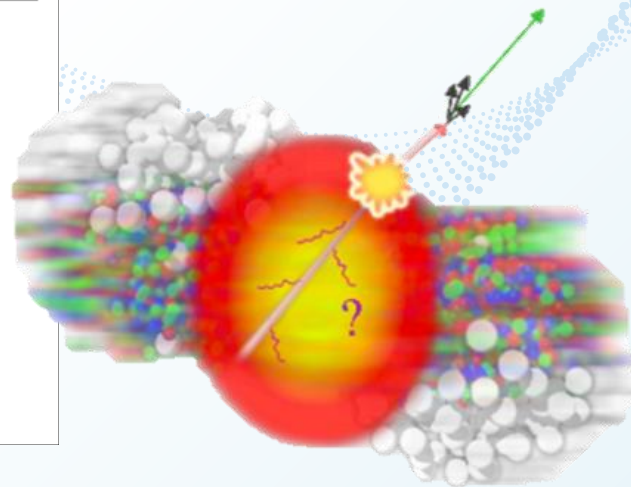
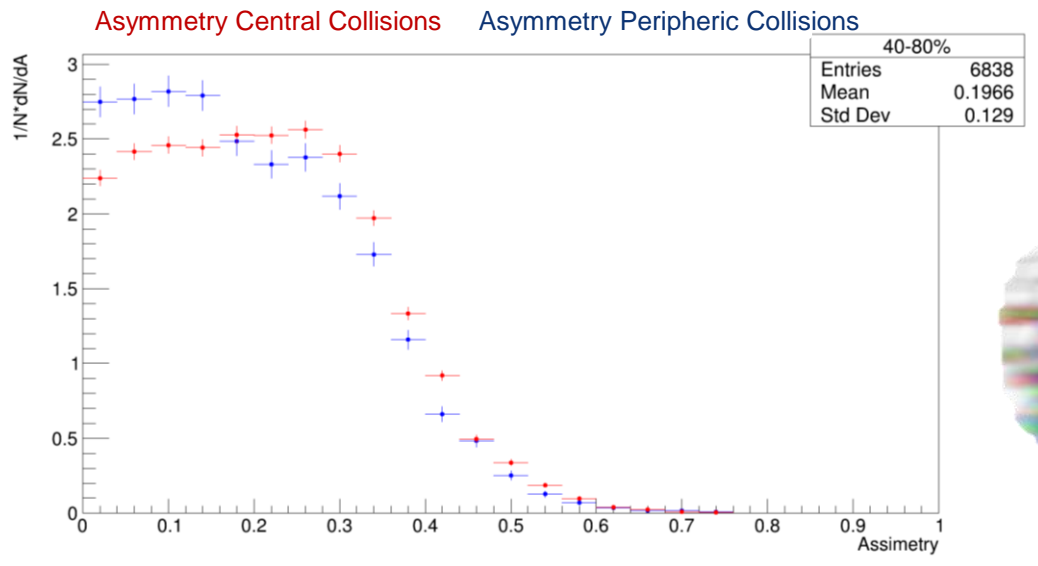
$$A = \frac{L_{jet\_pt-} - S L_{jet\_pt}}{L_{jet\_pt+} + S L_{jet\_pt}} \quad (1)$$



# Di-jet asymmetry in heavy ion collisions

- Cuts used for this graph:  $SLjet\_pt > 50\text{GeV}$ ,  
 $Ljet\_pt > 100\text{GeV}$ ,  $|\eta| < 2.8$ ,  $d\phi > 2.5$

$$A = \frac{Ljet\_pt - SLjet\_pt}{Ljet\_pt + SLjet\_pt} \quad (1)$$



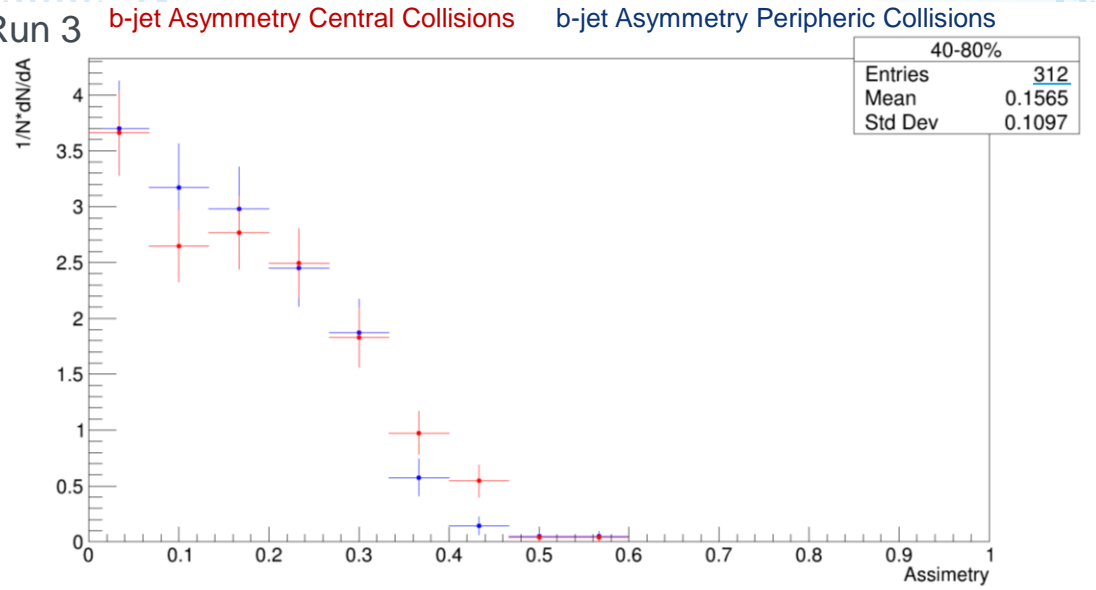
# Di-jet asymmetry for b-jets

- To study the b-jet asymmetry, the ideal events are the back-to-back  $b\bar{b}$
- However, there is too little statistic as these are only 0.6% of all events
- Something to be looked at in Run 3

$$A = \frac{L_{jet\_pt-} - S L_{jet\_pt+}}{L_{jet\_pt+} + S L_{jet\_pt-}}$$

BB - 0.6%  
BU - 6%  
BC - 0.5%

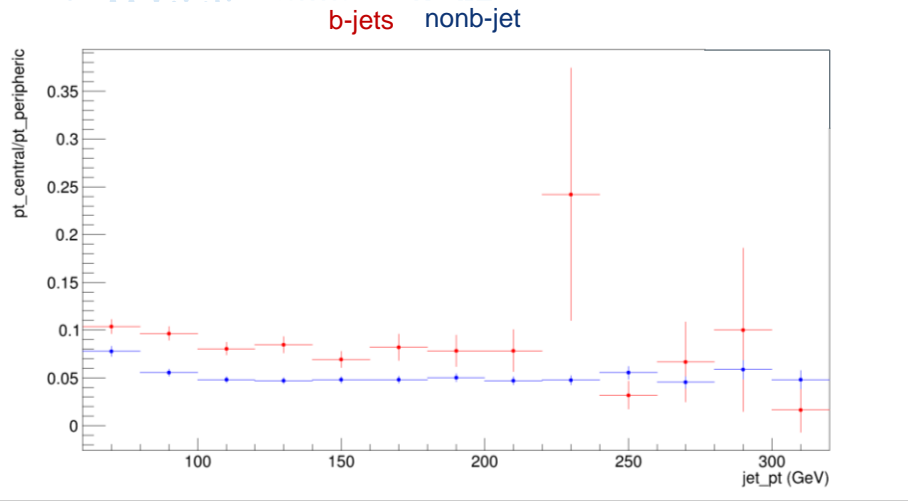
Inclusive di-jet production  
"U" stands for all light jets (2)



# $R_{cp}$

- $R_{cp}$  is the normalized ratio between the central pt histogram and peripheral pt histogram
- $R_{cp}$  analysis requires only one b-jet per event, so we can use more statistic (7.1% of the events)

$$R_{CP}^{\text{meas}}(p_T)|_{\text{cent}} = \frac{1}{R_{\text{coll}}^{\text{cent}}} \left( \frac{\frac{N_{\text{jet}}^{\text{cent}}(p_T)}{N_{\text{evt}}^{\text{cent}}}}{\frac{N_{\text{jet}}^{60-80}(p_T)}{N_{\text{evt}}^{60-80}}} \right) \quad (3)$$

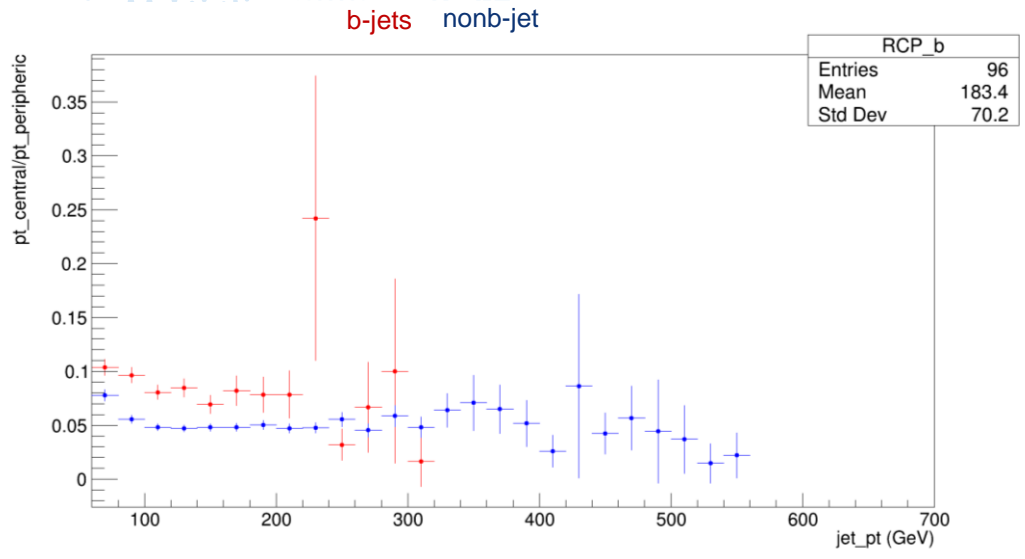


b-jets are less suppressed by the QGP

# RCP

- However, more statistic is still needed to reach higher values of transverse momentum
- Bias in sample has affected normalization

$$R_{CP}^{meas}(p_T)|_{cent} = \frac{1}{R_{coll}^{cent}} \left( \frac{\frac{N_{jet}^{cent}(p_T)}{N_{evt}^{cent}}}{\frac{N_{jet}^{60-80}(p_T)}{N_{evt}^{60-80}}} \right) \quad (2)$$



# Conclusions

- Jets in central collisions are suppressed by the QGP, as shown by the di-jet asymmetry
- b-jets are shown to be less suppressed by the QGP
- More statistics are necessary to study the effects of the QGP on b-jets → Run 3

The image features a solid blue background. A dark blue diagonal stripe runs from the top-left towards the bottom-right. A decorative wave of light blue dots, composed of multiple parallel lines of dots, flows across the frame from left to right, curving upwards and then downwards. Centered in the upper-middle portion of the image is the text "Thank You!" in a white, bold, sans-serif font.

**Thank You!**