Hard Probes of Heavy Ion Collisions with ATLAS

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PANIC 2021, Portugal
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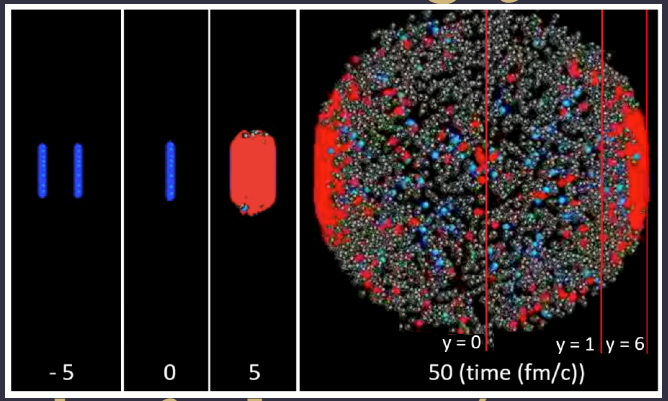
Producing Quark Gluon Plasma

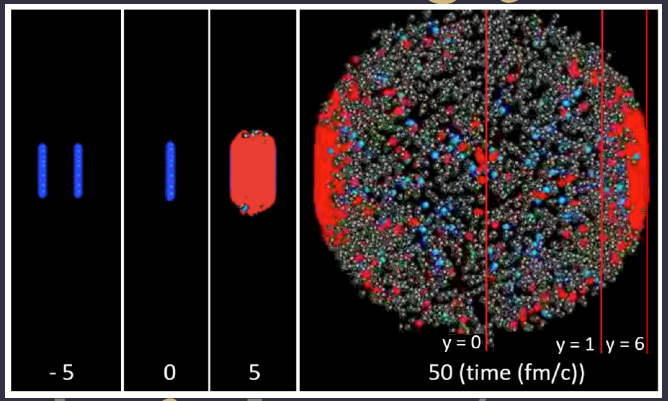


Still via Ann.Rev.Nucl.68 (2018)

Full video via Yen-jie Lee, Wit Busza, and Andre Yoon

1. Lorentz-contracted nuclei inbound
2. Initial collision; Hard-probes formed here
3. After some formation time, Quark Gluon Plasma (QGP)
4. After some longer time, freezeout and hadronization

Producing Quark Gluon Plasma



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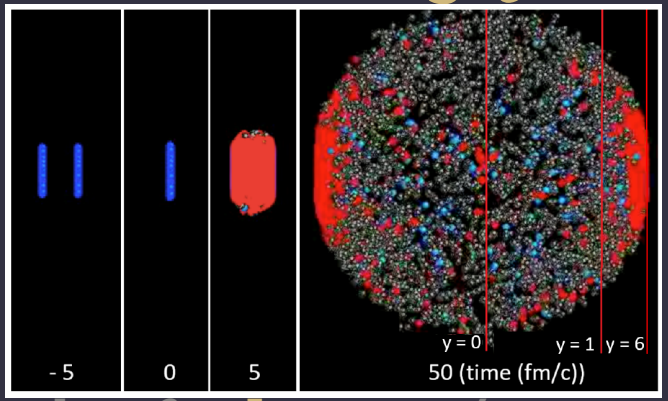

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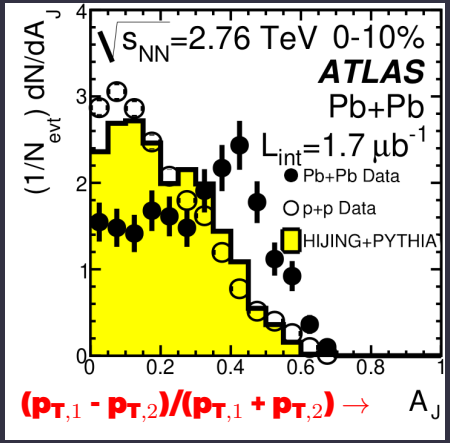
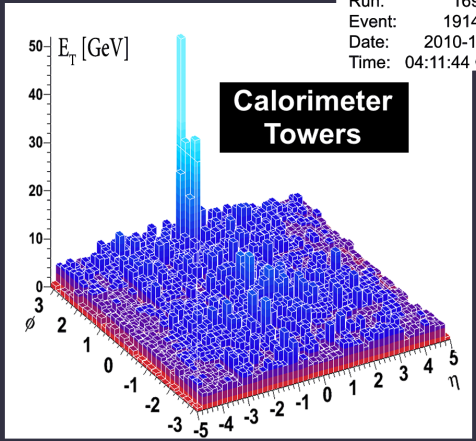
Jets in QGP

PRL 105 (2010) 252303

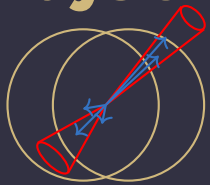


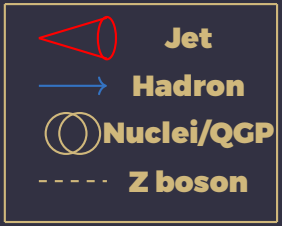


- Observe significant modification to dijet asymmetry (A$_J$)!
- Interpret as jet energy 'lost' to medium interactions
  - For latest ATLAS dijet asymmetry measurements, see here

Three Ways of Study (I)

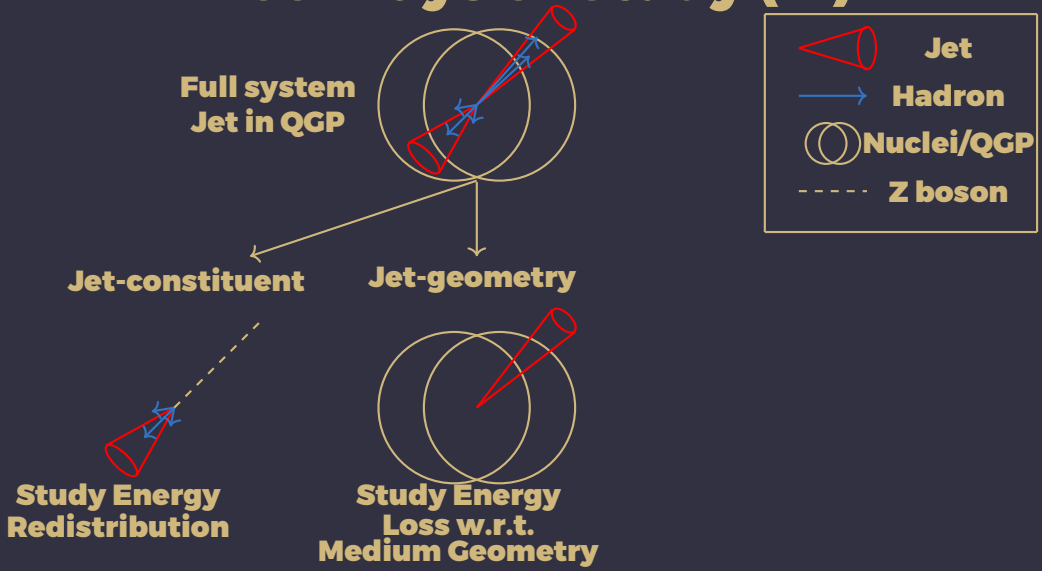
Full system
Jet in QGP



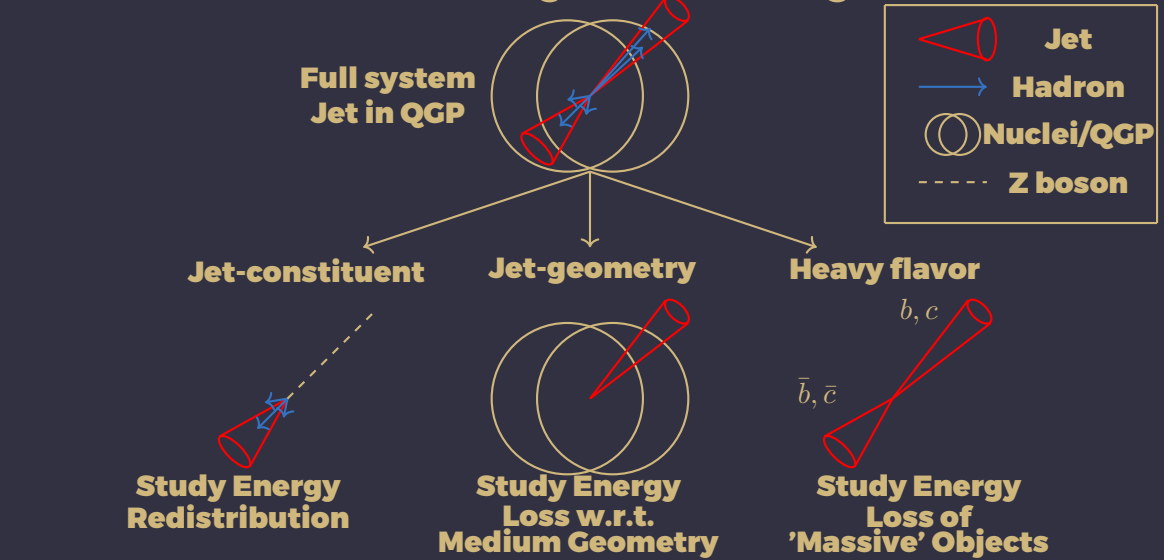


Three Ways of Study (II)

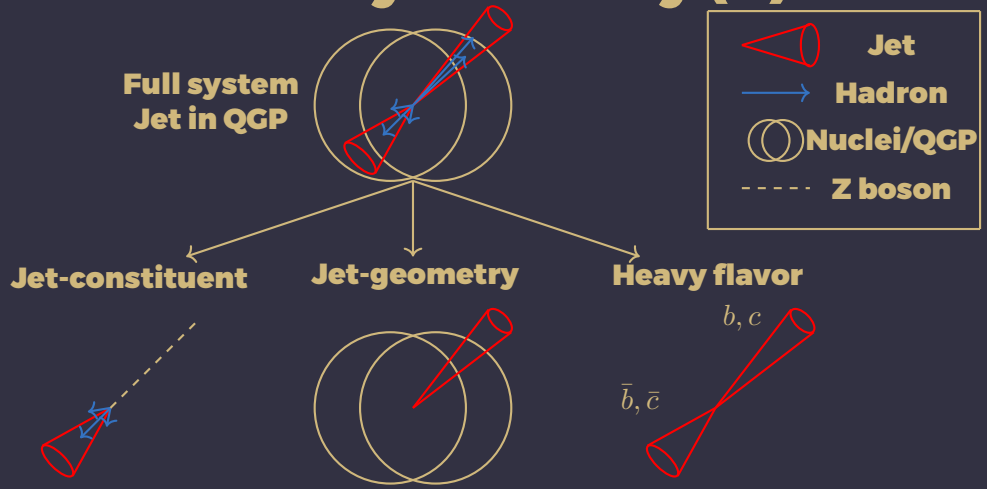
Three Ways of Study (III)



Three Ways of Study (IV)

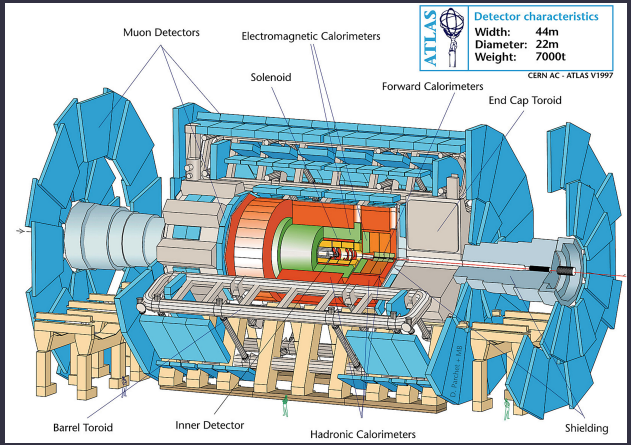


Three Ways of Study (V)



- Not a comprehensive view of the ATLAS HI jet program!
- All ATLAS HI results (including jets) can be found here

ATLAS Detector and Data



Via CDS

p p

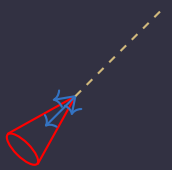
p+p collected in 2017 (2015)
260 pb^{-1} (1.16 pb^{-1}) lumi.

Pb Pb

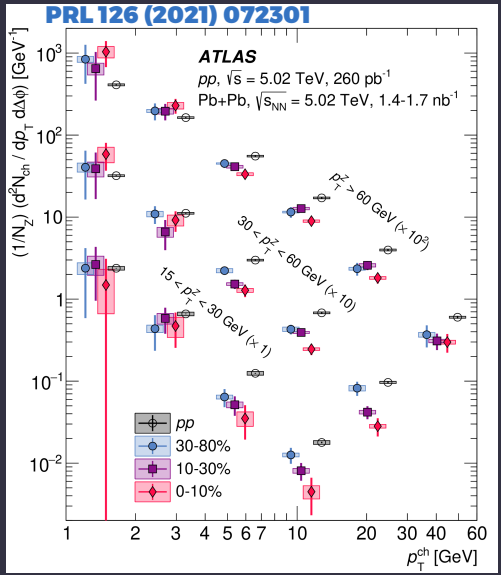
Pb+Pb collected in 2018 (2015)
1.72 nb^{-1} (246μb^{-1}) lumi.

- Jets are reconstructed w/ EMCal and HCal
- Charged particles via inner tracking detectors
- Centrality (nuclear overlap) is determined by FCal
- Z boson reconstructed w/ muon detectors and EMCal+track

Z-Tag w/ Jet Fragments (I)



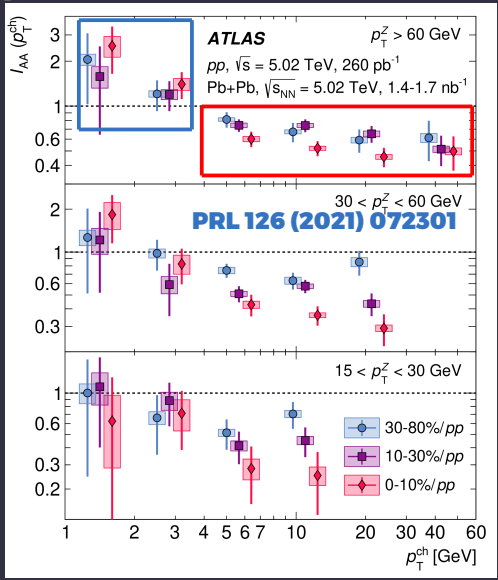
- Colorless tag (Z) unmodified by medium
  - Initial scattering proxy
- Study charged particles opposite the Z
  - These are produced by the jet
- Right: Charged particles produced in hemisphere opposite Z in Pb+Pb, p+p



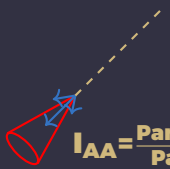
Z-Tag w/ Jet Fragments (II)

$$I_{AA} = \frac{\text{Particles per Z in Pb+Pb}}{\text{Particles per Z in p+p}}$$

- How does energy loss modify jet constituents?
- Observe suppression of high-p_T particles
- Excess of low p_T particles
- Medium interactions attenuate+redistribute

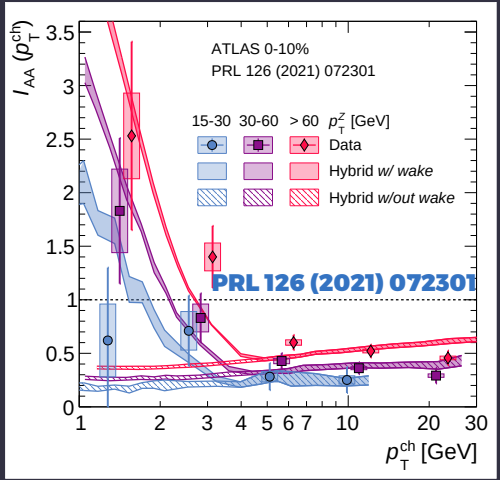


Z+hadrons Theory Comparison

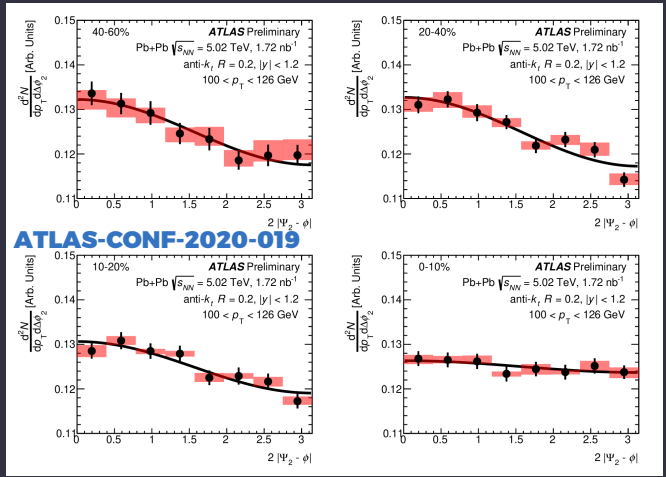


$$I_{AA} = \frac{\text{Particles per Z in Pb+Pb}}{\text{Particles per Z in p+p}}$$

- Does a jet in medium leave a wake?
- Check in Hybrid model - jet quenching theory with strong-coupling
- Hybrid model does not describe low-p_T excess in data w/o such a backreaction



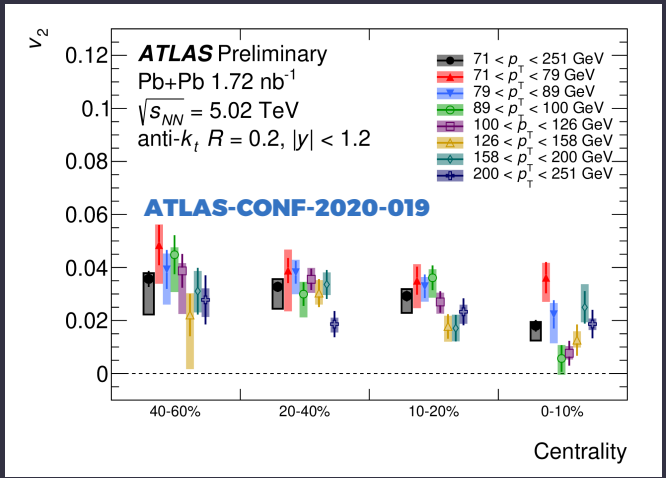
Jet-Geometry Correlations (I)



- **Simple counting of jets in-and-out-of-plane**
  - **We observe more jets in the final state in-plane!**

Jet-Geometry Correlations (II)

v_2: 2nd Fourier Coef.
$A(1 + 2v_n \cos(n(\Psi_n - \phi)))$

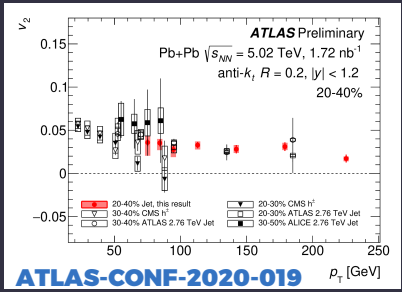


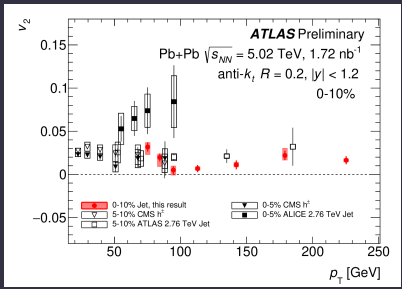
- Significant v_2 observed, with expected centrality dependent trend
  - Implies a path-length dependence in energy loss!

Cross-experiment Comparison

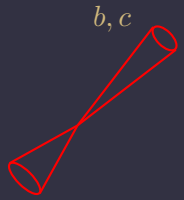
v_2: 2nd Fourier Coef.
$A(1 + 2v_n \cos(n(\Psi_n - \phi)))$

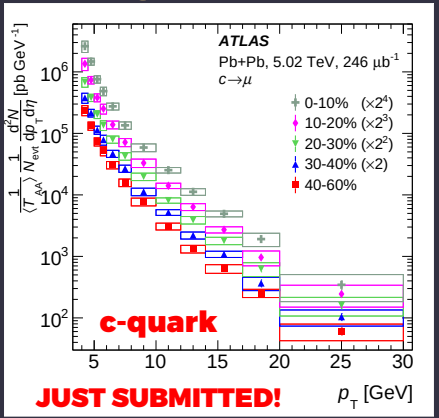
- Good agreement in semi-central (20-40%)
- Modest tension in 0-10% w/ ALICE
  - ATLAS 5.02 TeV result consistent with 2.76 TeV

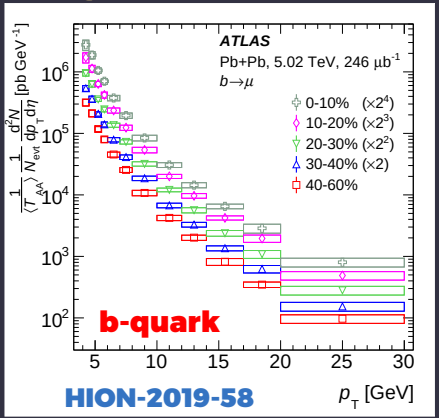




Heavy Flavor Study (I)

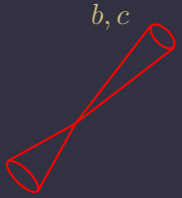




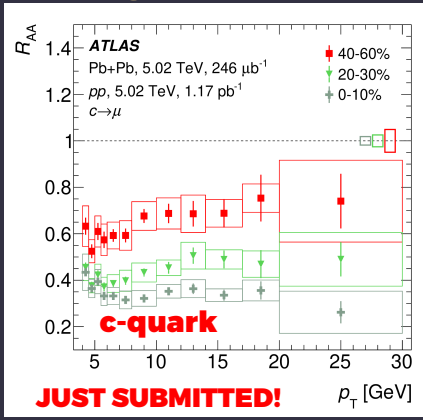


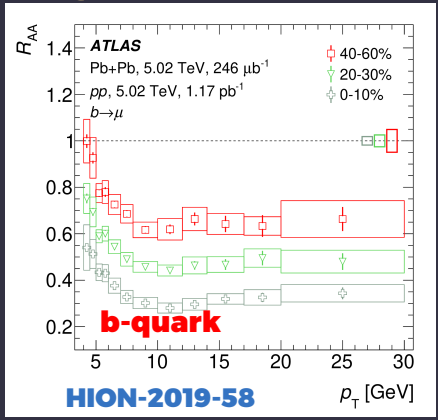
- **Does mass (c/b quark) modify medium interactions?**
- **Measure production of via muon decay channel**
  - **Produce spectra above, binned in centrality**
- **Construct scaled Pb+Pb ratios w/ p+p as:** $R_{AA} = \frac{N_{AA}/N_{evt}}{\langle T_{AA} \rangle \times \sigma^{pp}}$

Heavy Flavor Study (II)



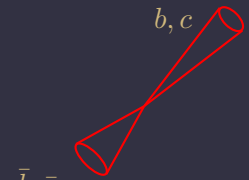
$$R_{AA} = \frac{N_{AA}/N_{evt}}{\langle T_{AA} \rangle \times \sigma^{pp}}$$

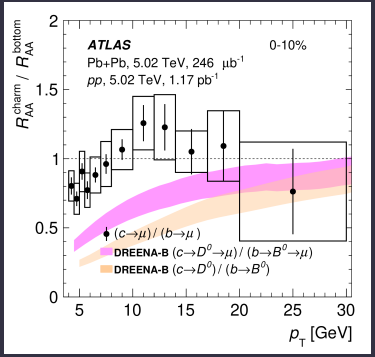


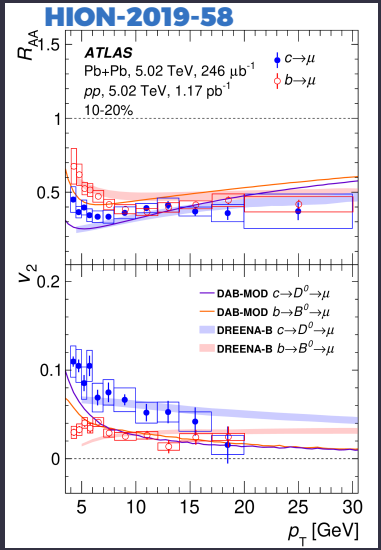


- We observe flat charm suppression across all p_T
- b-suppression is flat at high-p_T
  - Recovered partially at low-p_T
- Mass ordering to suppression?

Heavy Flavor Study (III)

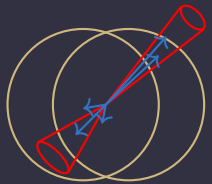






- **Double ratio of c/b suppression**
  - **Additional error cancellation**
- **Simultaneously compare R_{AA} and v_2**
  - **Greater constraint on theory**
- **For more on heavy flavor flow, see Dominik's talk**

Conclusion

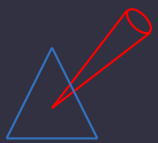


- Jets are an excellent probe for learning the properties of QCD matter
- Jet constituents are preferentially softer in Pb+Pb
- The path length of jet thru medium impacts suppression
- Heavy flavor reveals mass dependencies to medium interactions

Backup

Jet-Geometry Correlations v_3

ATLAS-CONF-2020-019



0

v_3 In-Plane

π

v_3 Out-Plane

$3|\Psi_3 - \phi|$