Measurement of the b-jet Nuclear Modification Factors in PbPb Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with CMS

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Hard Probes
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Outline

- Motivation for heavy flavor analyses
- Jet reconstruction at CMS
- B-jet identification
- B-tagging performance
- B-jet R_{AA} measurements
  - NEW! Procedure
  - R_{AA} in p_T and centrality
- Conclusions

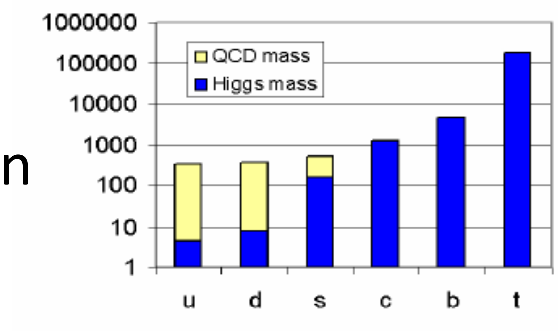
Since QM12…

- Greatly enhanced pp statistics
- Fully unfolded and corrected spectra
- True R_{AA} measurements

Additional details found in CMS PAS HIN-12-003

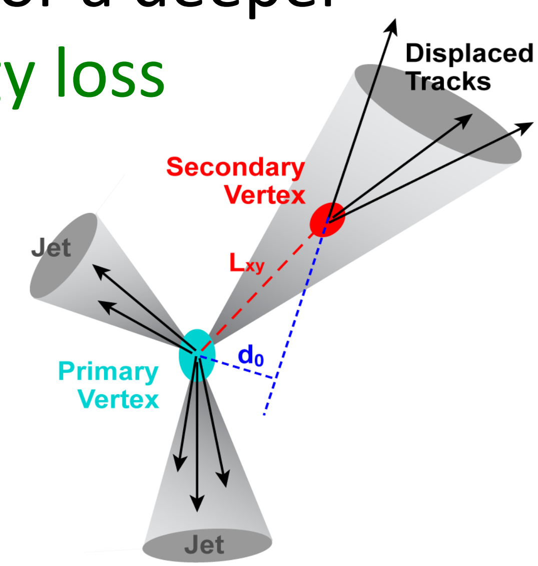
Motivation for Heavy Flavor Studies

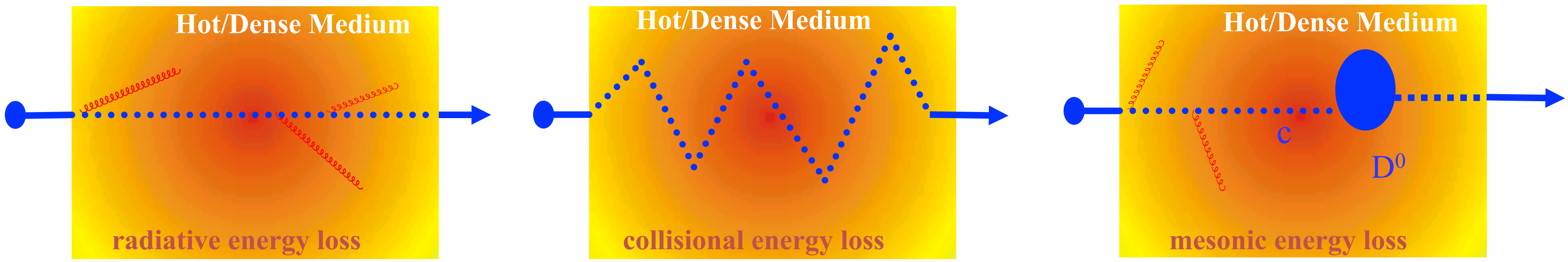
- Heavy quarks are:
  - ✓ Produced early in collisions
  - ✓ May interact with medium differently than light quarks
  - ✓ Sensitive to initial gluon density/gluon distribution



- Measurements of heavy quarks allow for a deeper understanding of the in-medium energy loss mechanisms

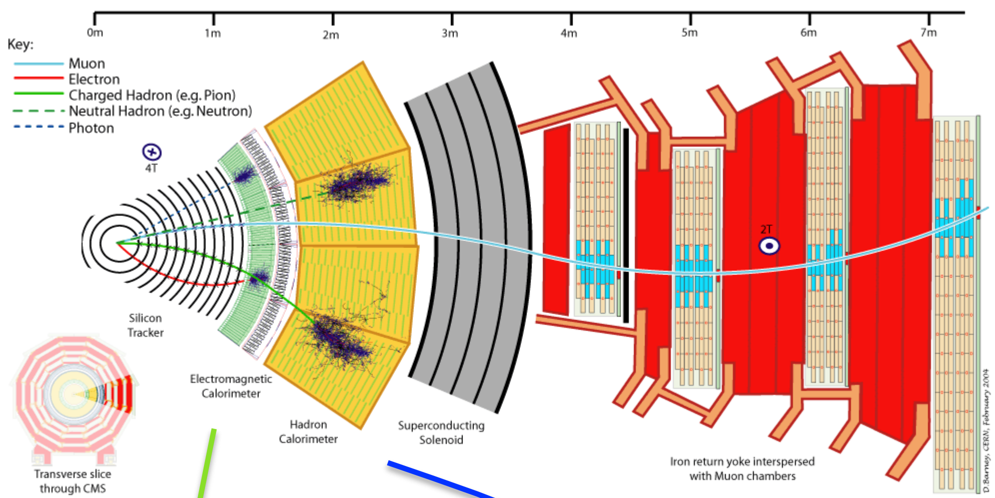
- Jets in particular are extremely useful:
  - ✓ Provide a high-p_T heavy flavor probe
  - ✓ Don't require any particle-ID to obtain heavy flavor measurements



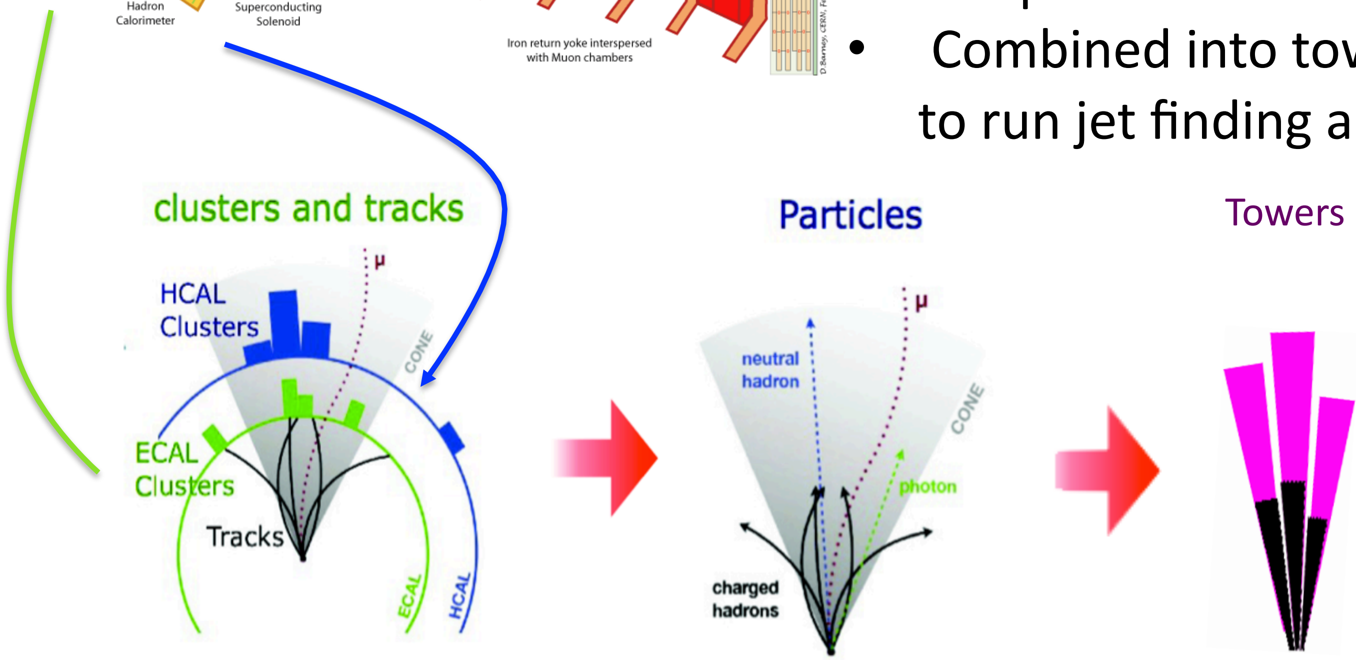


- Different possibilities for in-medium energy loss mechanisms
  - Heavy quarks suffering **radiative energy loss** suppressed by dead-cone effect
  - **Collisional energy loss** affected by forced radiation from acceleration in collisions
  - **Mesonic energy loss** affected by modified meson dissociation probabilities (shorter meson formation time)
- These three energy loss mechanisms all depend on the higher b-quark mass *differently*

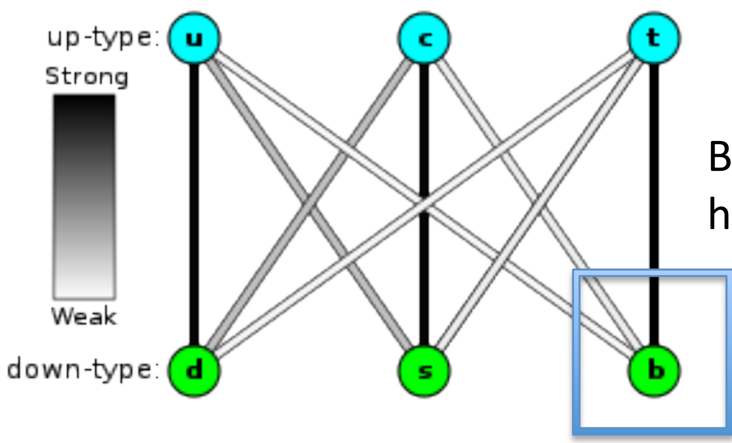
Jet Reconstruction at CMS



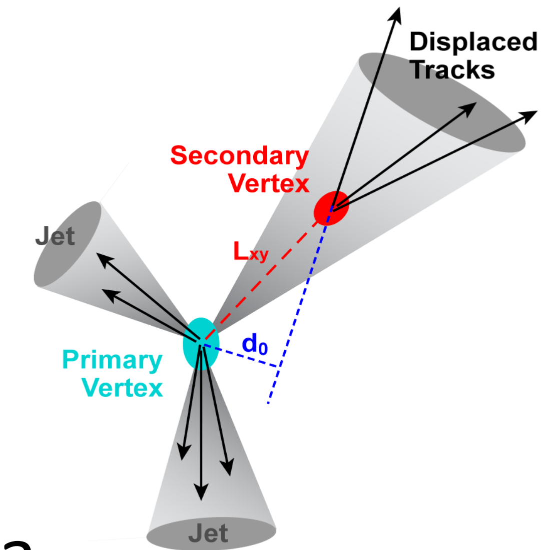
- Jets are reconstructed via the "Particle Flow" algorithm
- Allows for the exploitation of the excellent tracker resolution for the charged hadron jet components
- Combined into towers in order to run jet finding algorithms



Identifying B-Jets



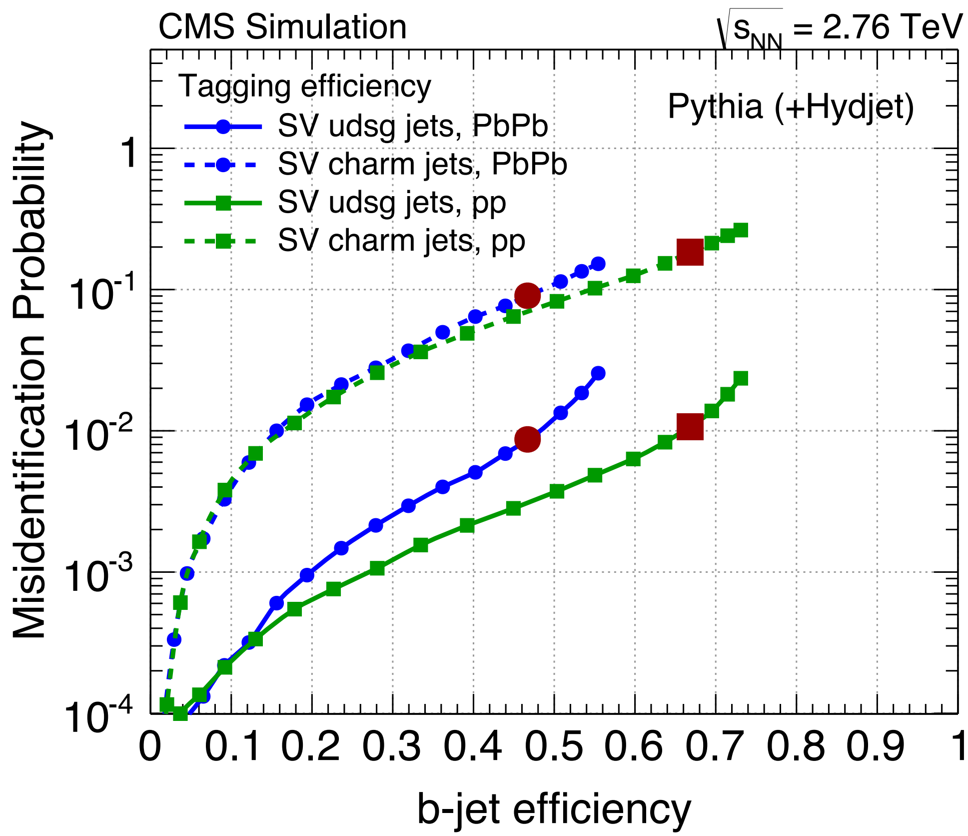
B-quark decays are heavily CKM-suppressed



- Primary identification method is using a **Secondary Vertex**
  - Long lifetime of b = mm or cm vertex displacement
- Flight distance (L_{xy}) of the secondary vertex used as a discriminating variable
- Also use displacement of jet tracks (impact parameters) as a cross-check

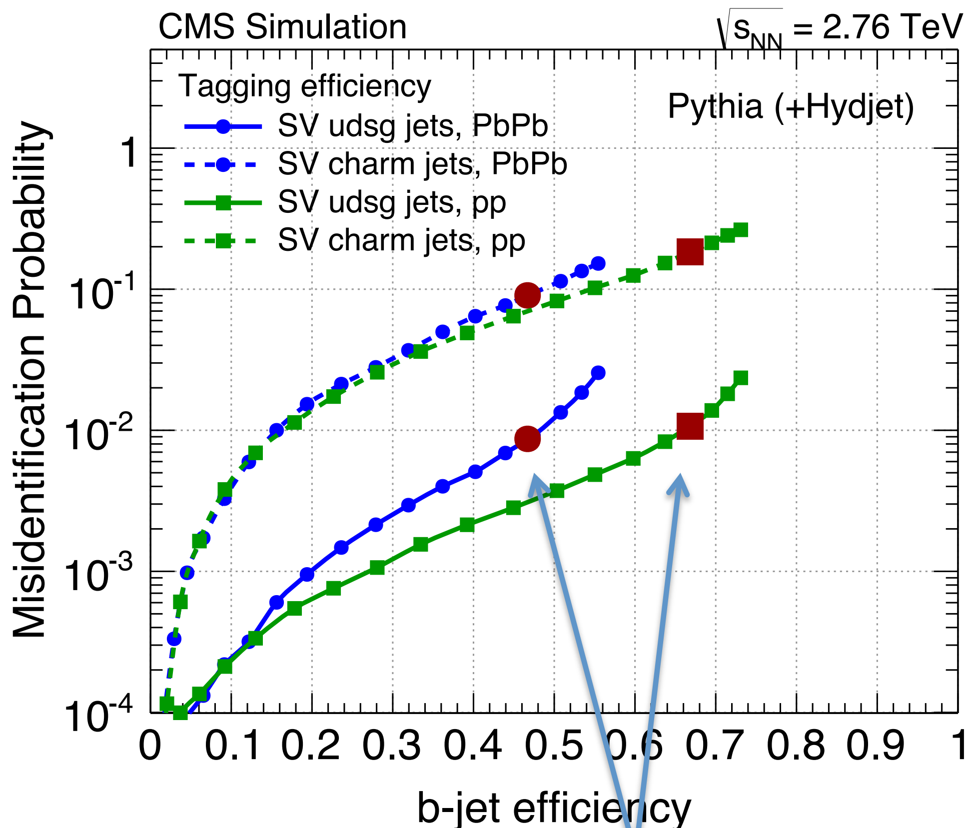
Algorithms described in:
JINST 8 (2013) P04013

B-Tagging Performance



- Performance is benchmarked by comparing tagging efficiency of b-jets to other jets (usdg)
- Performance vs charm jets is also shown
- SV tagger (relies on a secondary vertex) used throughout this analysis

B-Tagging Performance



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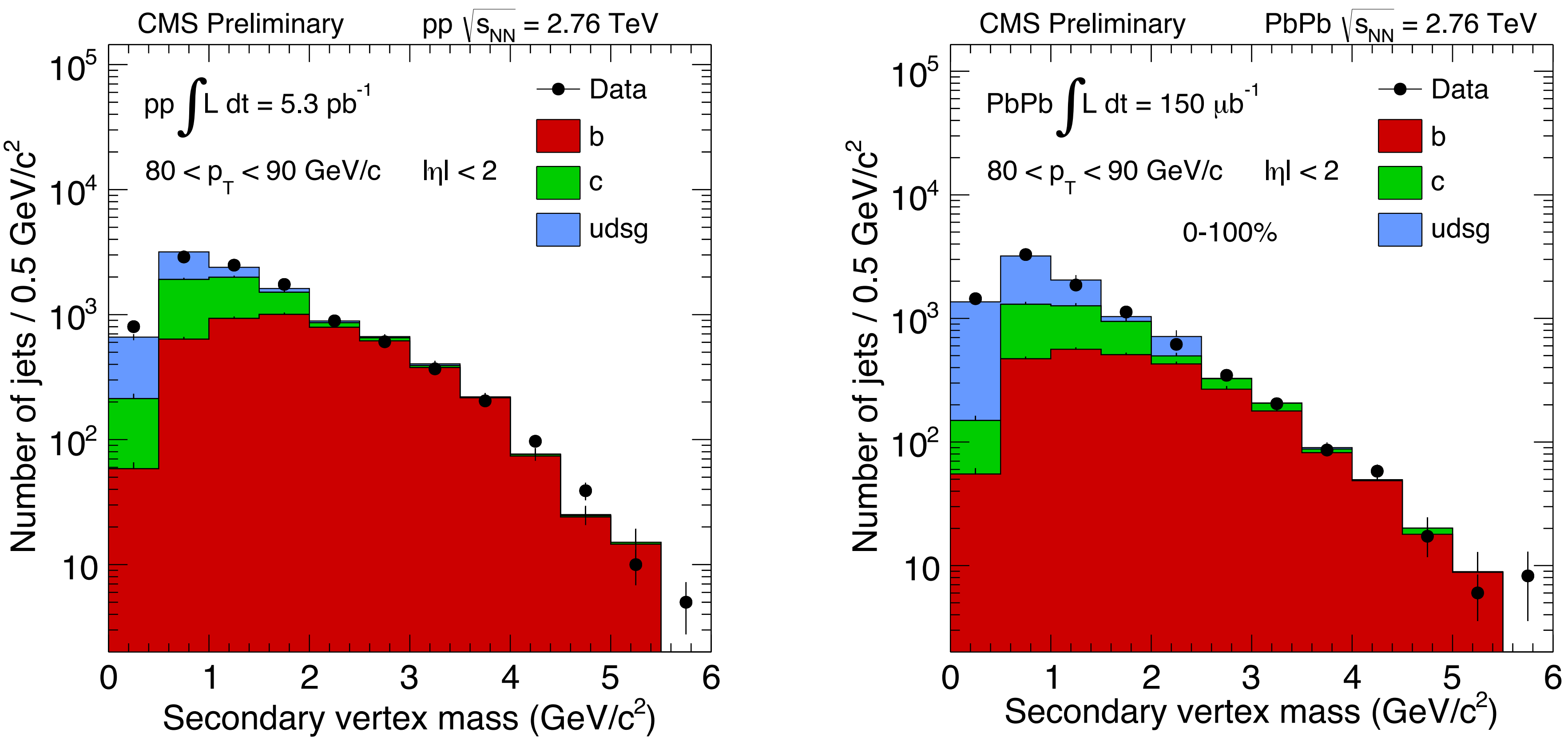
This analysis uses a working point which has a rejection factor for ~100 in pp and PbPb, while the efficiency for b-jets remains at about 65% for pp, and 45% for PbPb

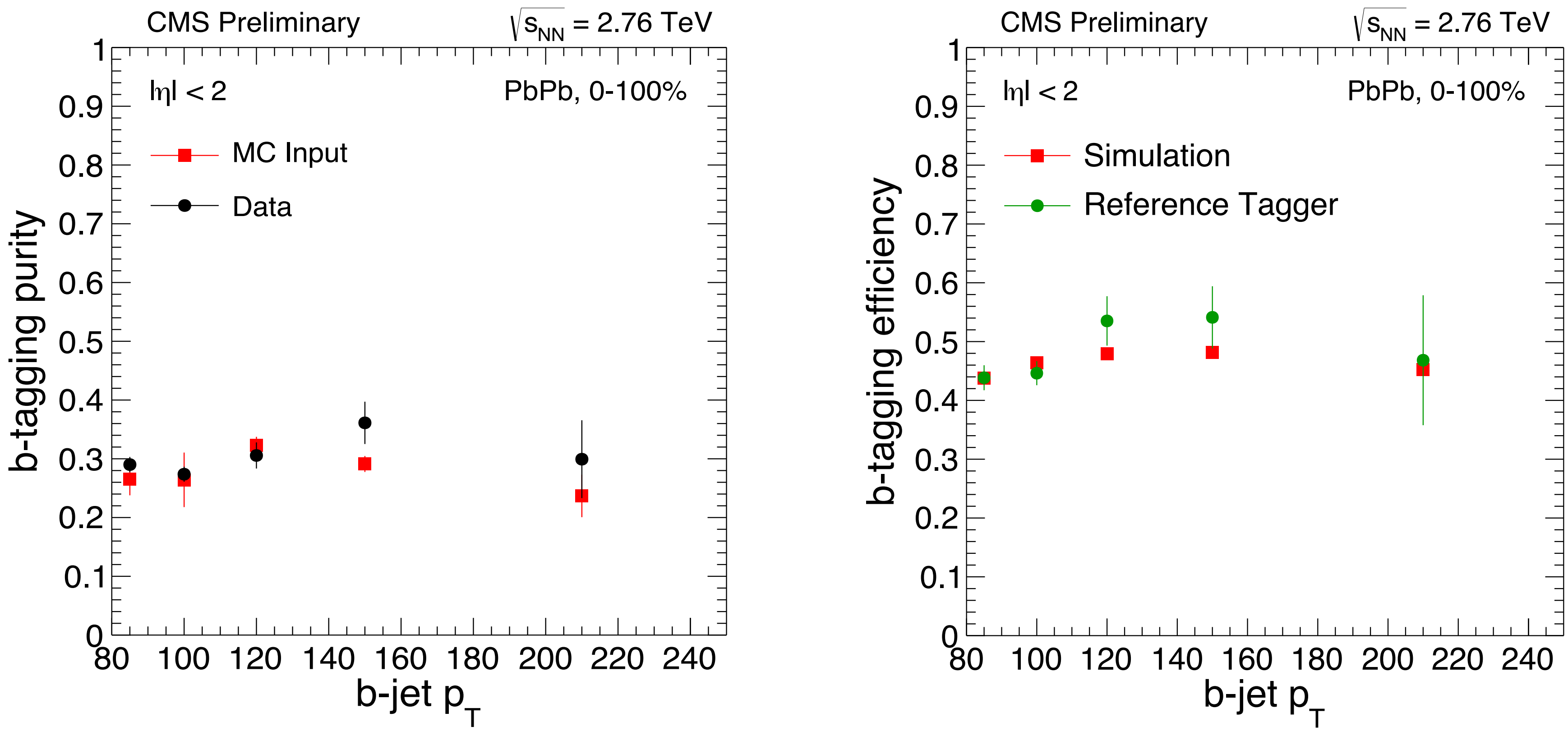
Extracting b-Jet Purity

- B-tagging purity obtained via unbinned greatest likelihood fits to the secondary vertex mass



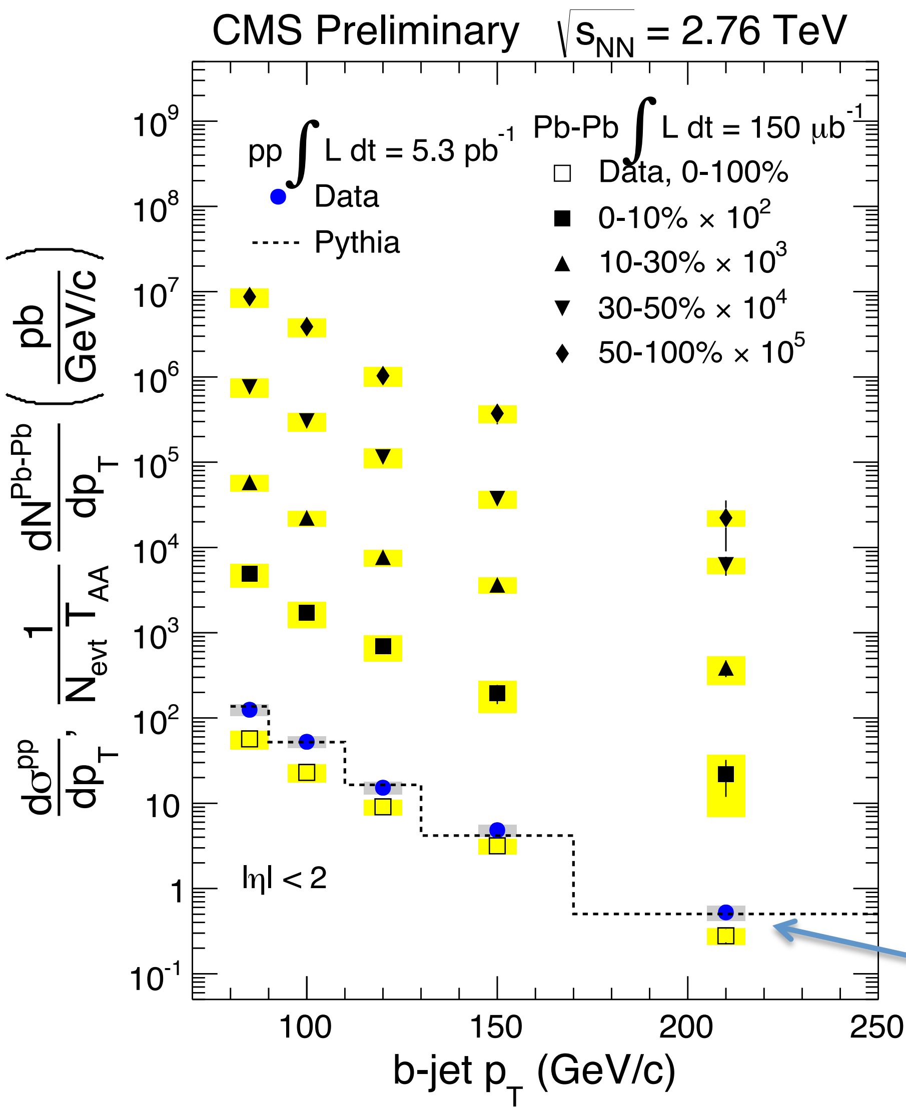
Extracting Efficiency and Purity

$$N_{bjets} = N_{incl} \frac{\text{purity}}{\text{efficiency}}$$



- PbPb efficiency and purity very consistent between MC truth and template fits

B-Jet Spectra



- Fully *corrected* and *unfolded* spectra plotted for both PbPb and pp
- B jets in PbPb scaled by T_{AA}
  ➔ normalized to pp spectra
- B-jet spectra shown for different PbPb centrality classes
- pp reference data in blue, consistent with PYTHIA prediction

B-jet suppression clear already from this plot

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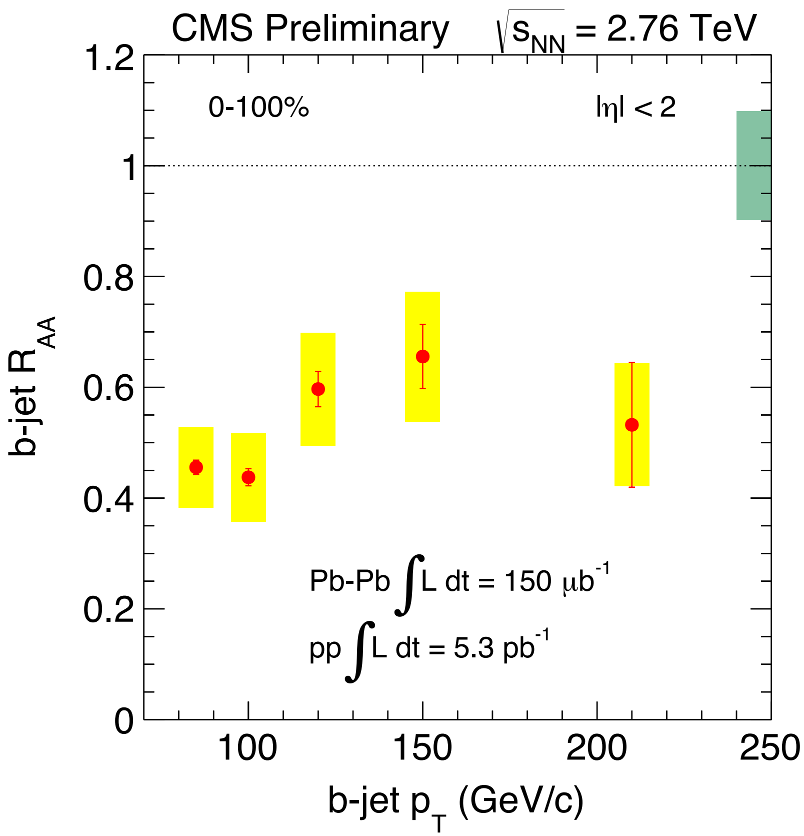
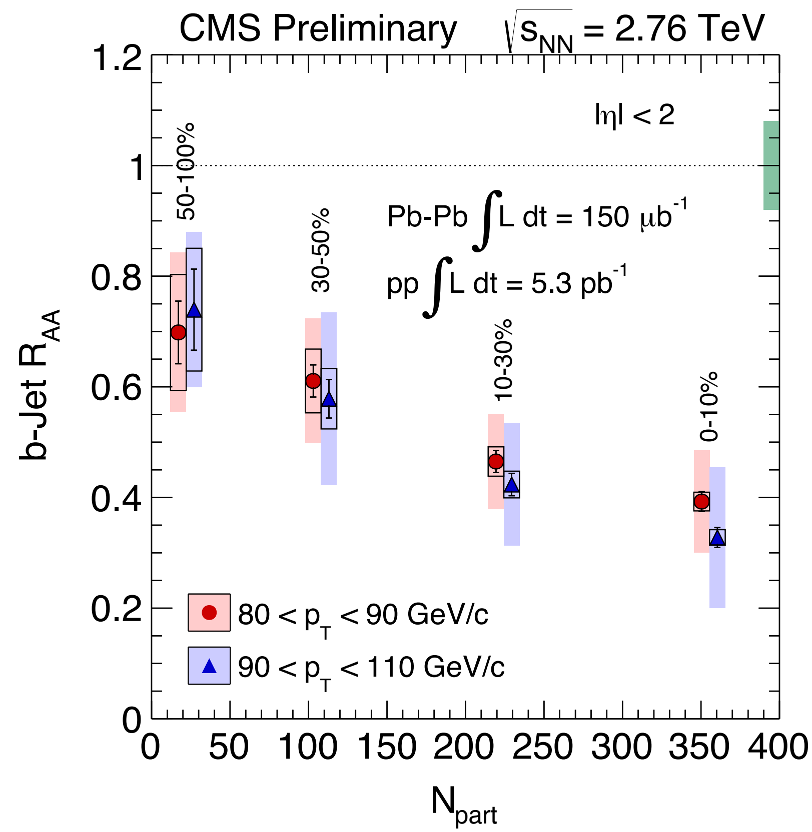
B-Jet R_{AA}





- First measurement of heavy flavor jet R_{AA}
- Clear suppression of b-jets
  - R_{AA} as a function of p_T shows significant suppression to very high p_T
  - R_{AA} shows clear trend as a function of centrality

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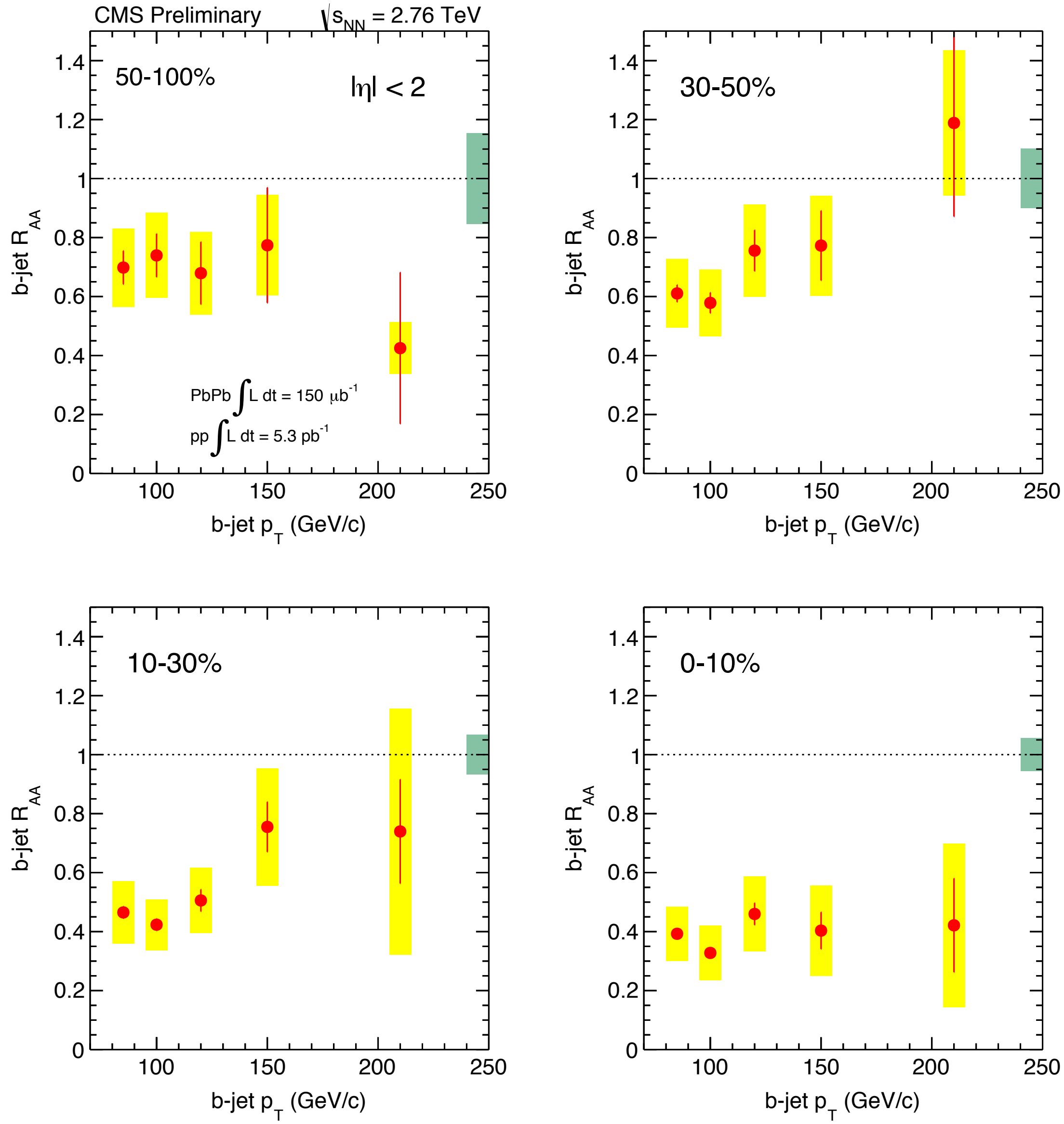
B-jet R_{AA} (centrality)



- R_{AA} is smallest for most central collisions and moves toward unity for peripheral collisions
- Most central b-jets show consistent suppression with inclusive jets (next slide)

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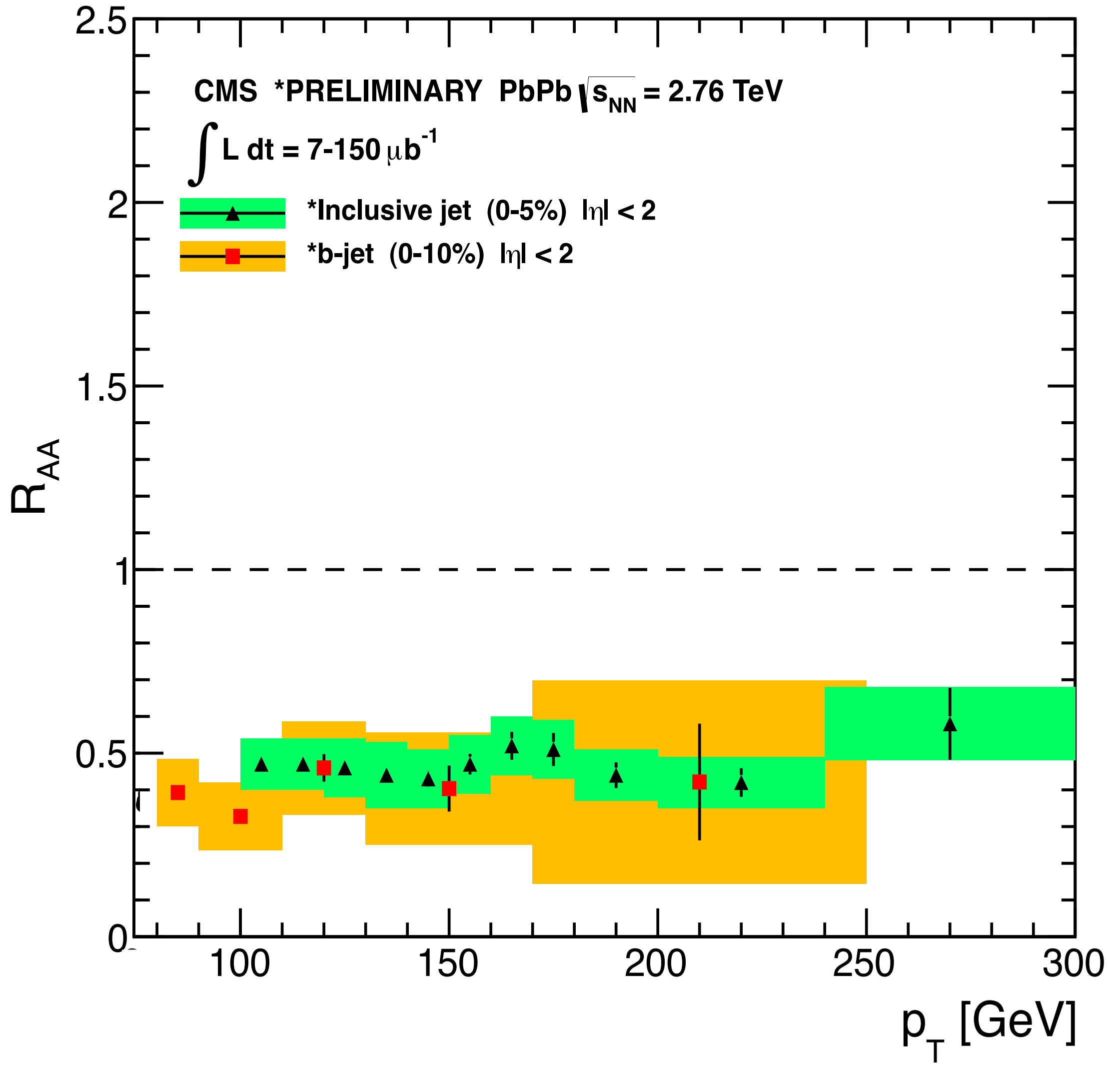
Comparisons to Inclusive Jets



- B-Jet suppression (0-10%) is consistent with inclusive jet (0-5%) suppression to within systematic error
- Systematics between inclusive and b-tagged jets are mostly uncorrelated

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CMS PAS HIN-12-003

Conclusions

- Measurements of b-Jet R_{AA} obtained for the first time
- Observe larger suppression in b-jets with increasing centrality
- B-jet suppression is quite significant vs jet p_T
- Observe a central b-jet suppression consistent with that in inclusive jets

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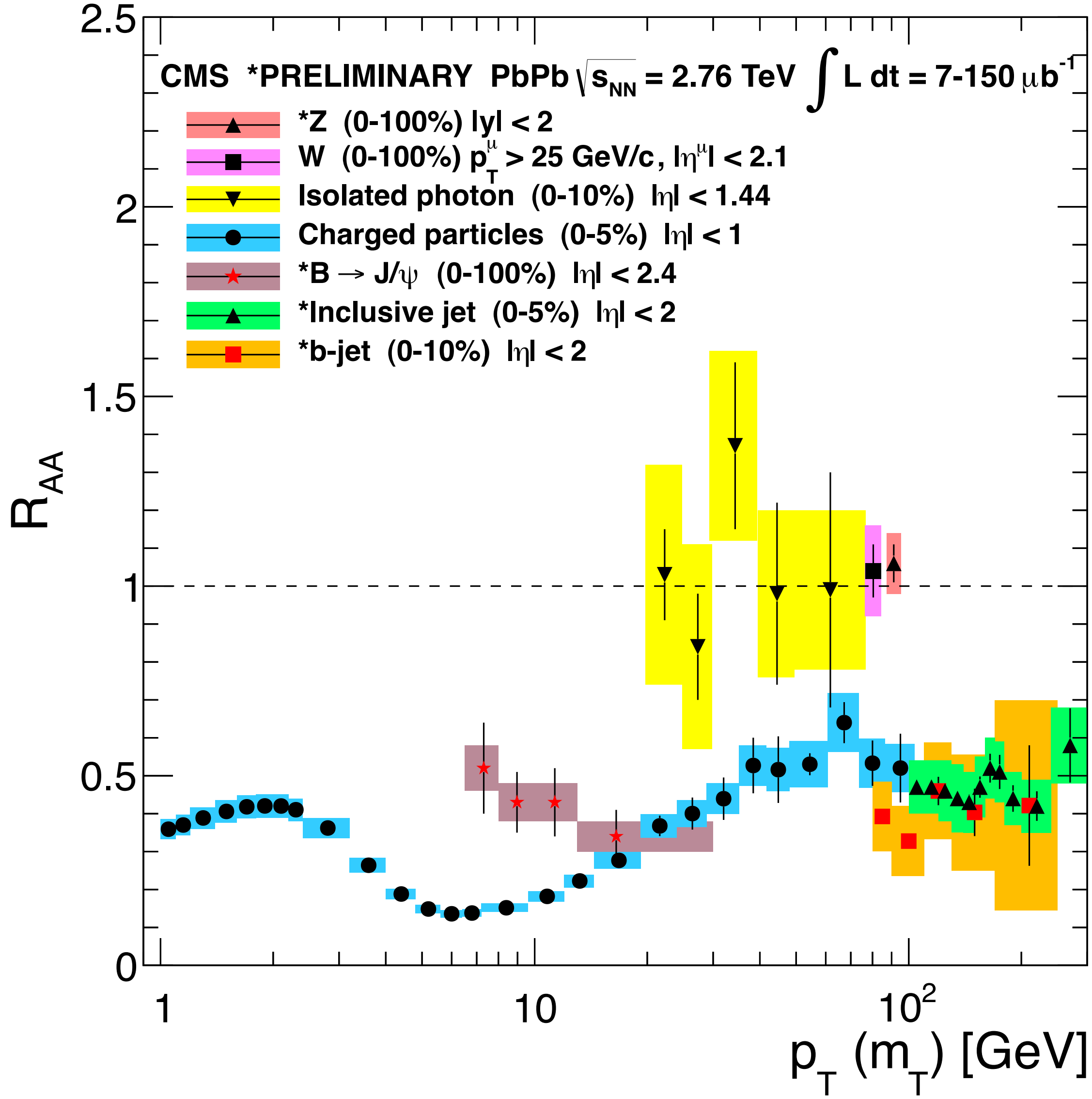
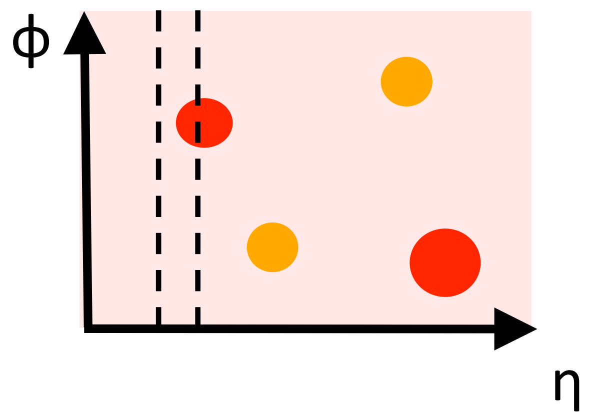
BACKUP

R_{AA} "Zoo"

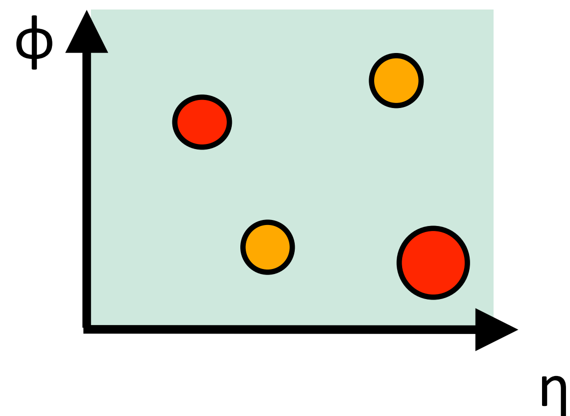


CMS *PRELIMINARY PbPb √sNN = 2.76 TeV ∫L dt = 7-150 μb-1
*Z (0-100%) lyl < 2
W (0-100%) pTμ > 25 GeV/c, lημl < 2.1
Isolated photon (0-10%) lηl < 1.44
Charged particles (0-5%) lηl < 1
*B → J/ψ (0-100%) lηl < 2.4
*Inclusive jet (0-5%) lηl < 2
*b-jet (0-10%) lηl < 2
RAA
pT (mT) [GeV]
2.5
2
1.5
1
0.5
0
1
10
10²

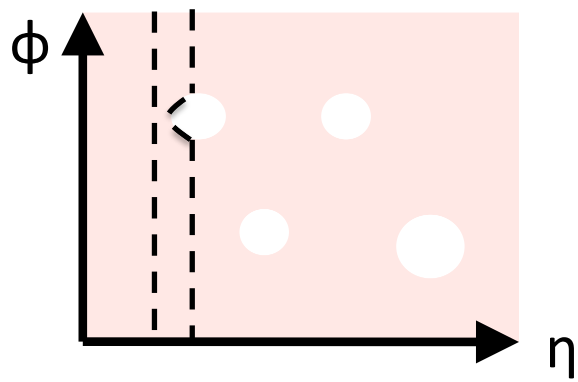
Underlying Event Subtraction



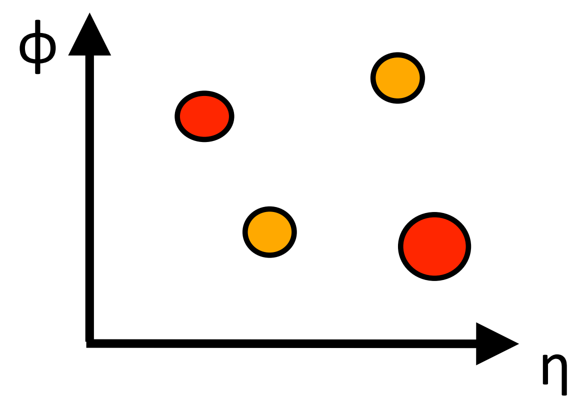
1. Background energy per tower calculated in strips of η. <E> + σ subtracted.



2. Run anti k_T algorithm on background subtracted towers



3. Exclude reconstructed jets
Recalculate the background energy



4. Run anti k_T algorithm again on background subtracted towers to get final jets