b-dijets in CMS

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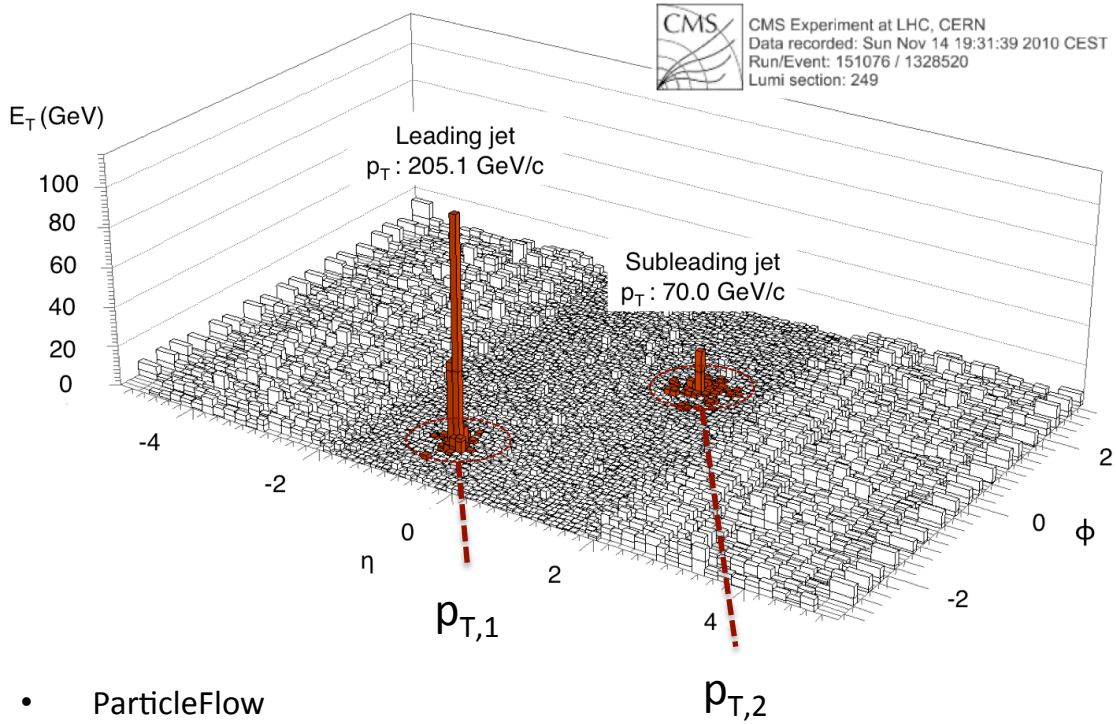
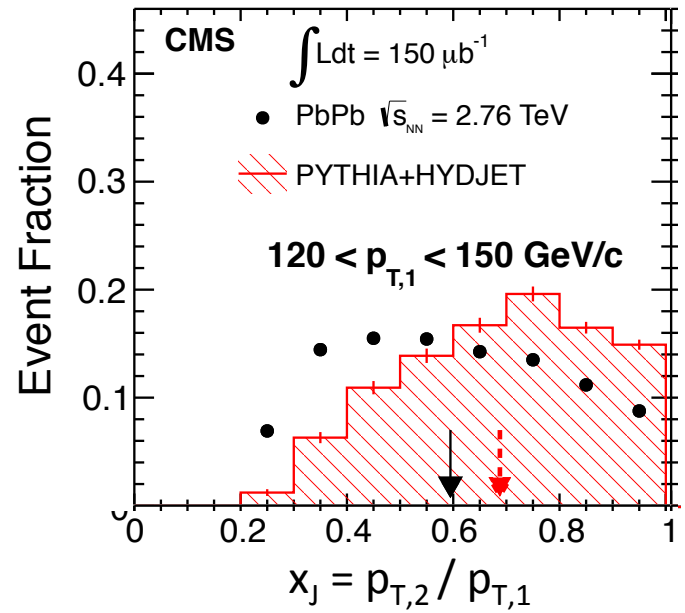
LLR

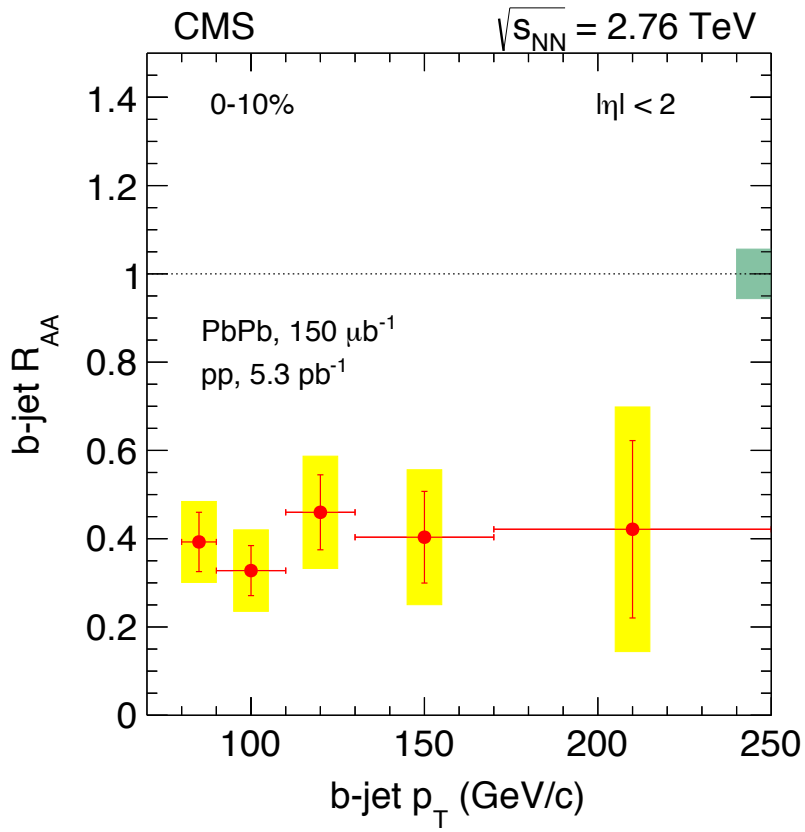
Dijets
since 2010...





- ParticleFlow
- anti-k_T R=0.4
- UE subtraction with iterative noise/pedestal subtraction
- $|\eta|<1.5$
- $p_{T,1}>100$ GeV/c
- $p_{T,2}>40$ GeV/c
- $\Delta\phi_{1,2}>2\pi/3$

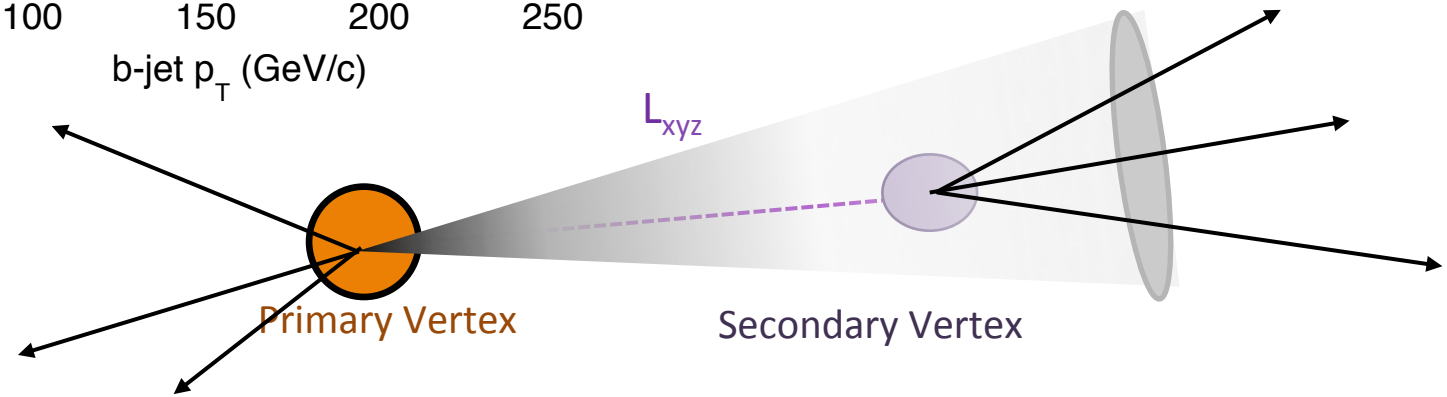
Beyond light dijets



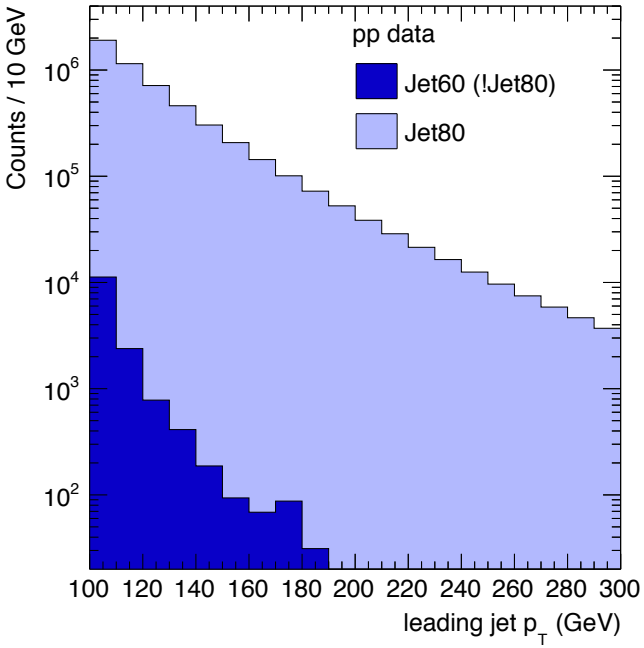
Nuclear modification factor (R_{AA})

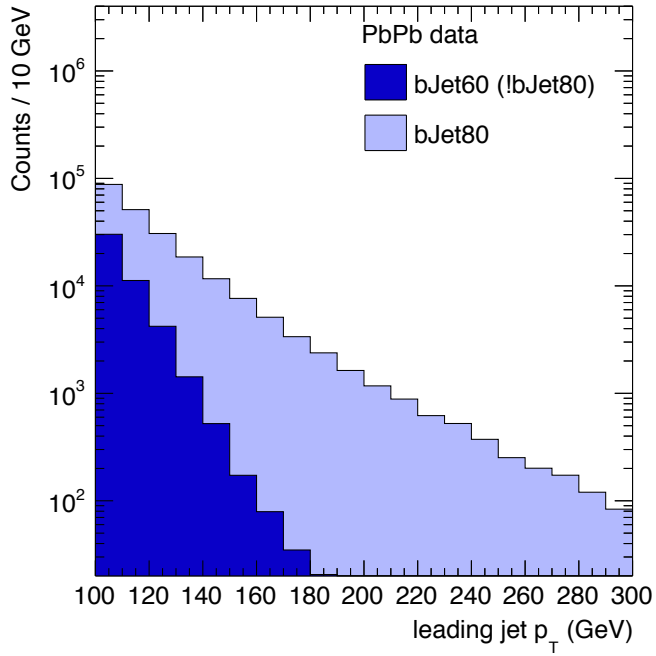
- Measured for inclusive & b-jets
- No difference seen yet, but uncertainties still large

Algorithms described in : **JINST 8 (2013) P04013**



b-jet identification at HLT



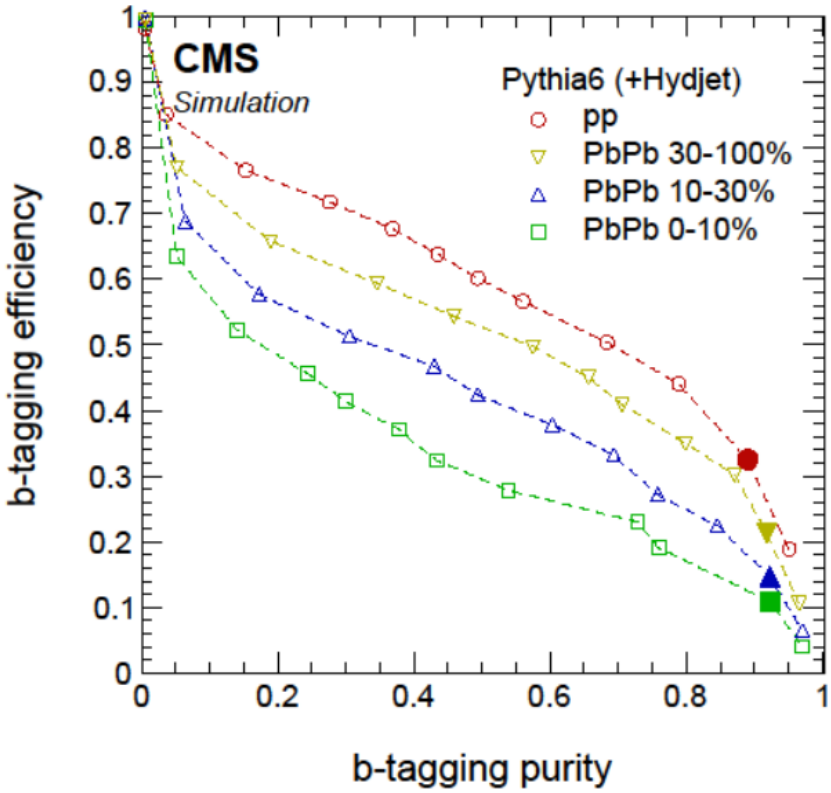


	pp	PbPb
Jet60 prescale	6.3	1.59
Jet80/ total (%)	99.7	87.5

- For both pp and PbPb, 80 GeV Jet triggers are unprescaled
- To reach full efficiency for p_T > 100 GeV, we merge with 60 GeV triggers
- b-jet trigger helps to preserve statistics at 60 GeV

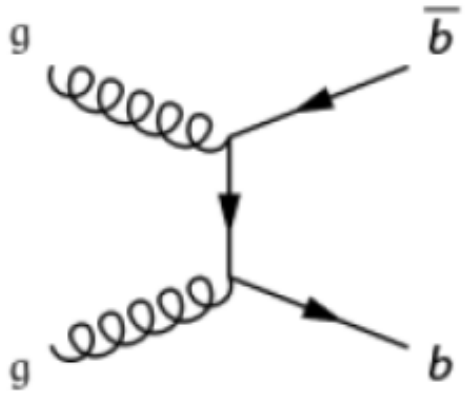
b-tagging in PbPb collisions at 5 TeV

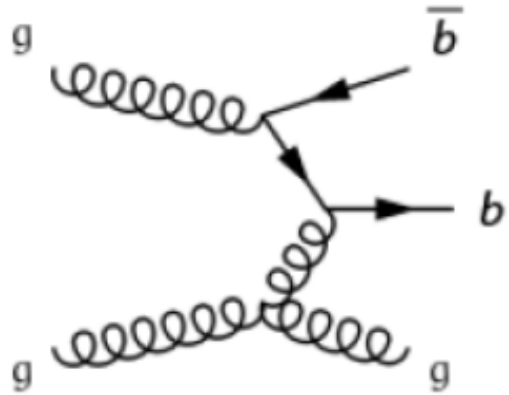
- Combined Secondary Vertex discriminator is constructed by vertex and track information to identify b dijets
- The working point is selected to obtain 90% pure sample
- Tagging efficiency corrections are applied in : p_T , η, Centrality
- ~10% contamination is taken into account as a systematic uncertainty

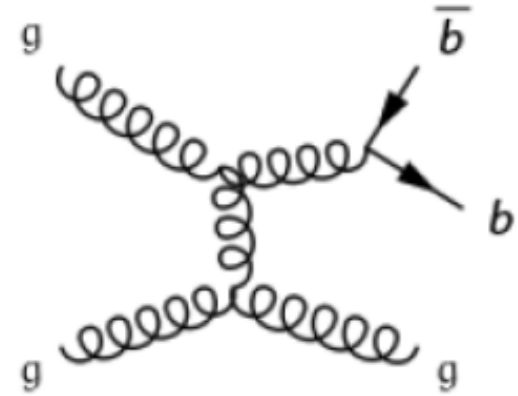


CMS PAS HIN-16-005 , CDS:2202805

Heavy flavor production







Flavor Creation (FCR)

- Gluon fusion or $q\bar{q}$ annihilation
- Heavy quarks are back-to-back

Flavor Excitation (FEX)

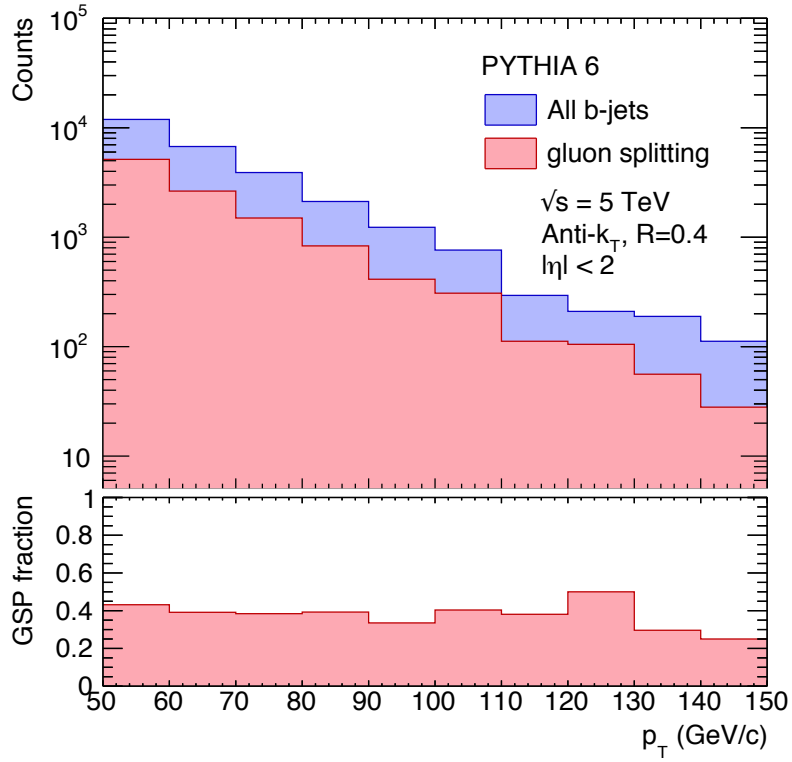
- Sea $b\bar{b}$ pair is excited by gluon or light quark
- Heavy quark is back-to-back with light parton

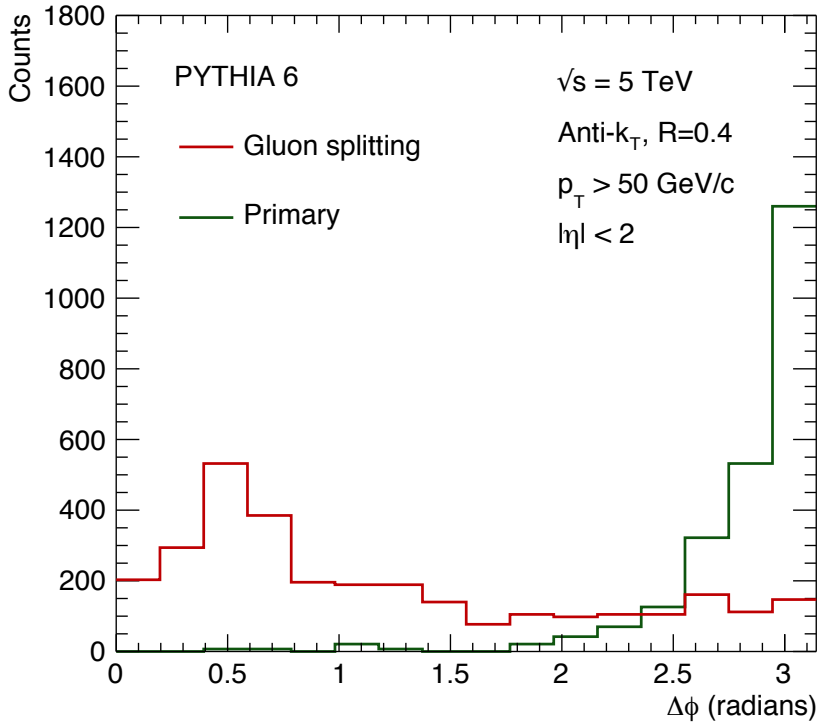
Gluon Splitting (GSP)

- Gluon splits into $b\bar{b}$
- Small angle between heavy quarks

Single b-jets vs b-dijets

- Rate is about an order of magnitude lower than single b-jets
- On the other hand, double tagging can give quite high purity



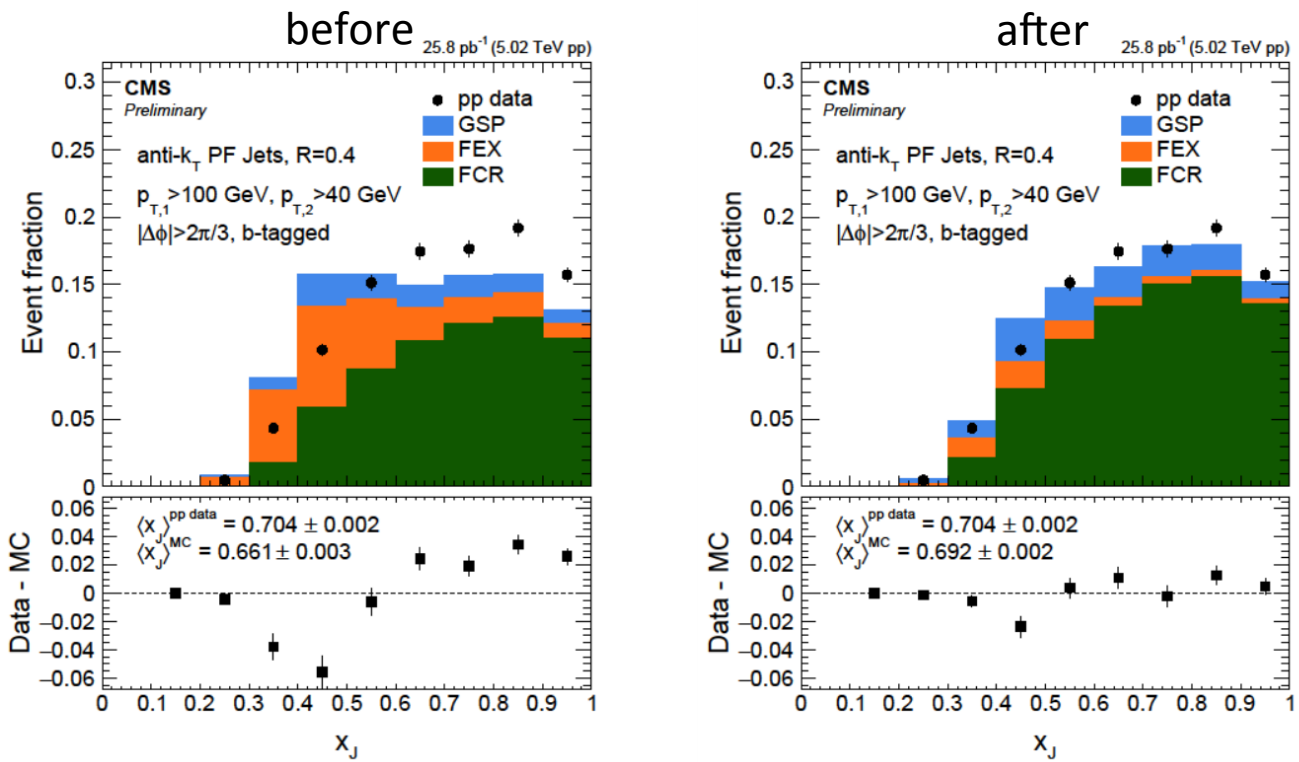


Additional motivation: About 40% of single b-jets from "GSP"

→ some of these more gluon-like than b-quark-like from QGP perspective

Back-to-back pairs, on the other hand, tend to be primary

Flavor process reweighting



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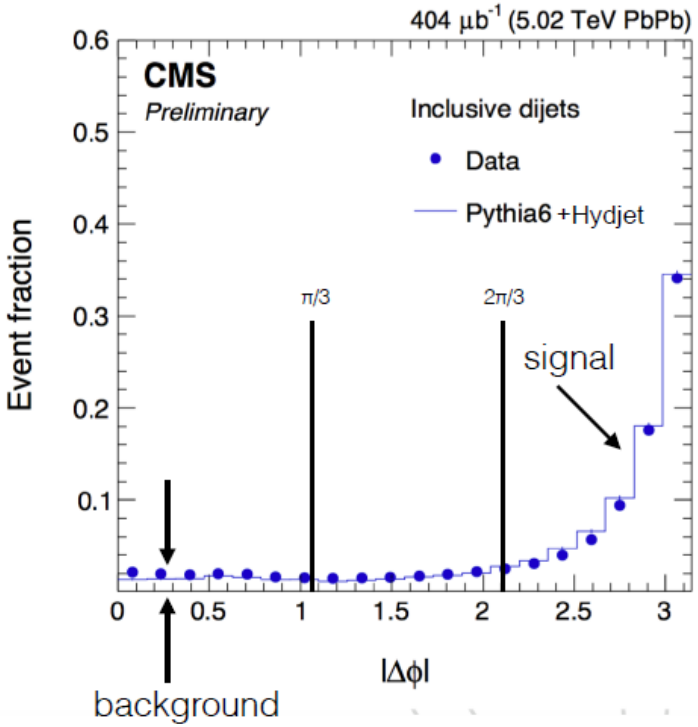
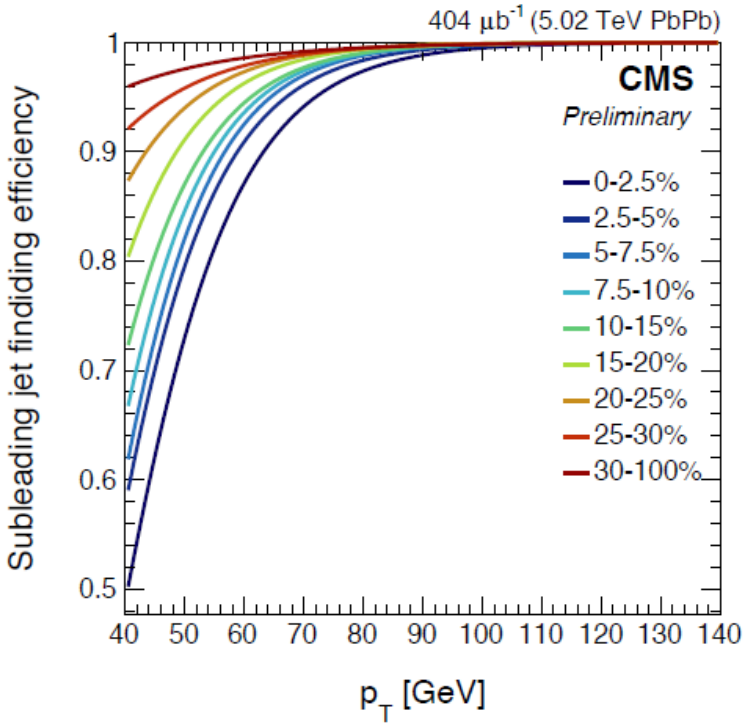
- Data/PYTHIA discrepancy is found in b dijet momentum imbalance.
- After reweighting, Data/PYTHIA in agreement
- FCR in analysis selection 53% → 70%
- Similar conclusion in CDF PRD71 (2005) 092001

Combinatorial background subtraction & correction





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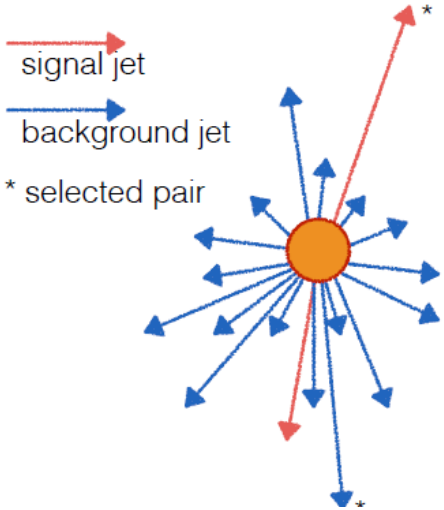
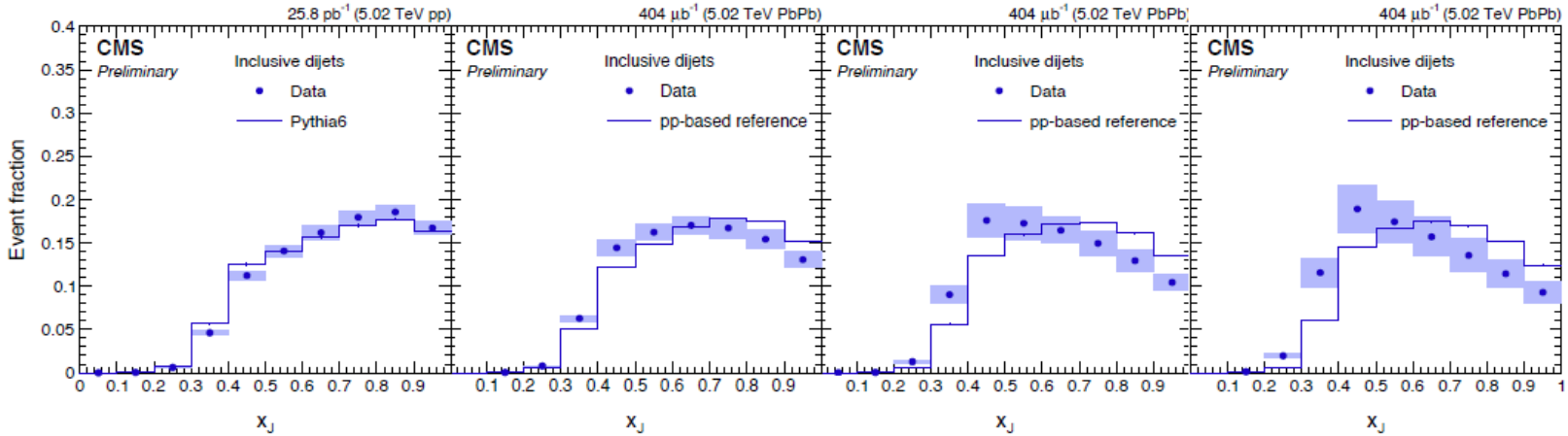


- Combinatorial background removed with sideband method

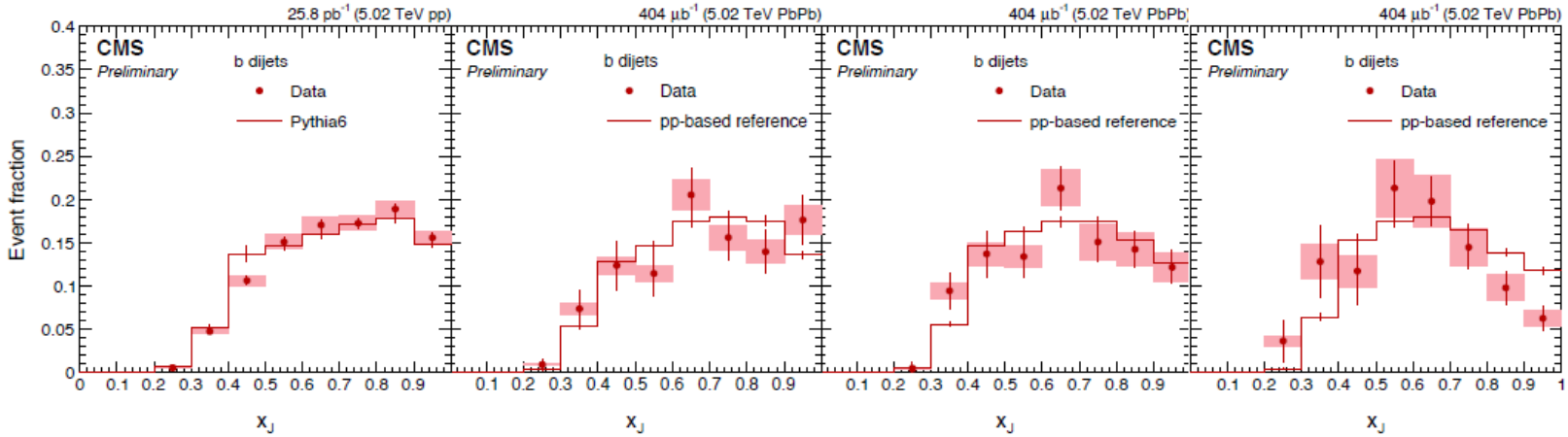
Imbalance distributions

pp | PbPb 30-100% | PbPb 10-30% | PbPb 0-10%

Inclusive dijets



b dijets



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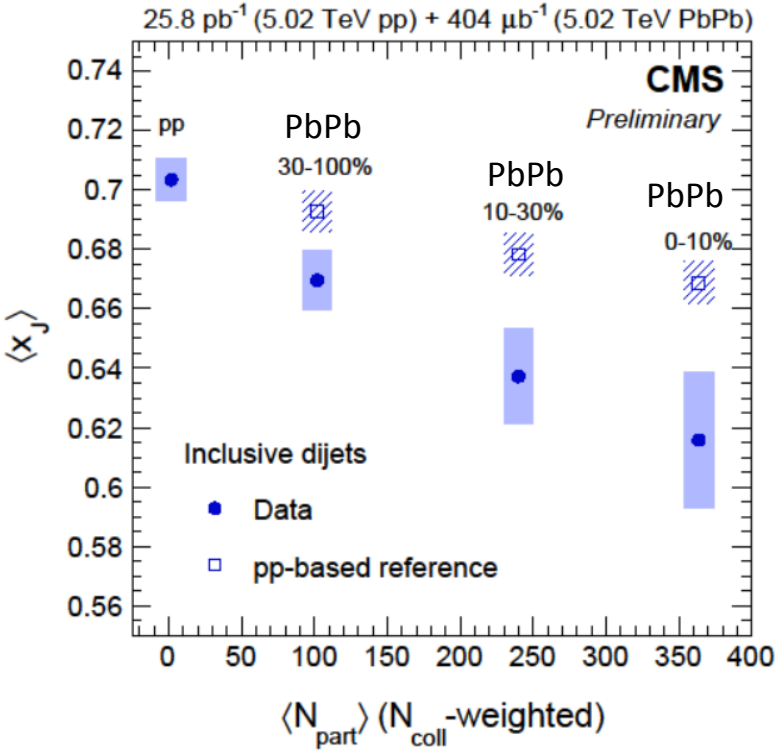
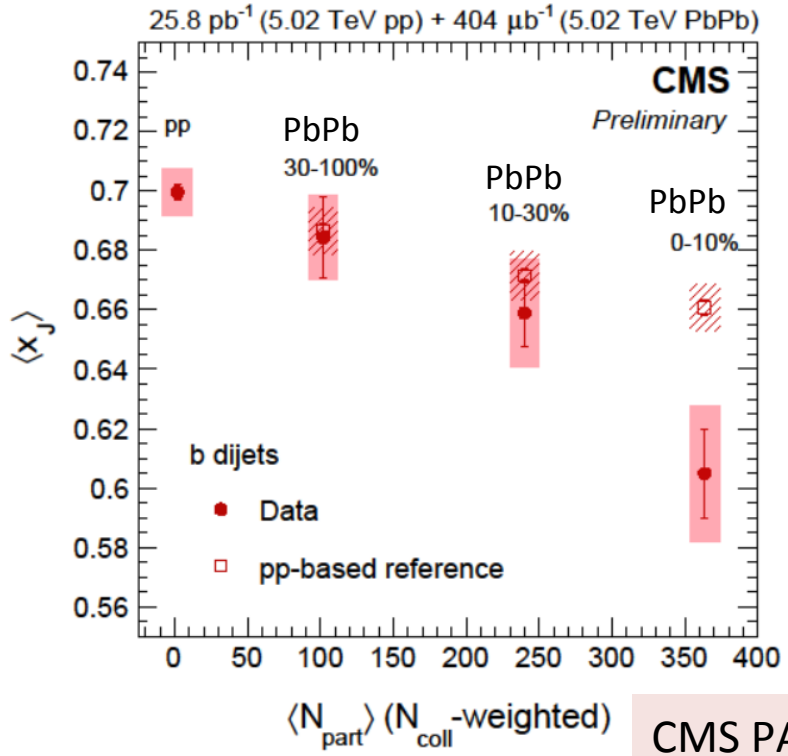
Imbalance summary

Inclusive dijet



b dijet



$Xj = p_{T,2}/p_{T,1}$

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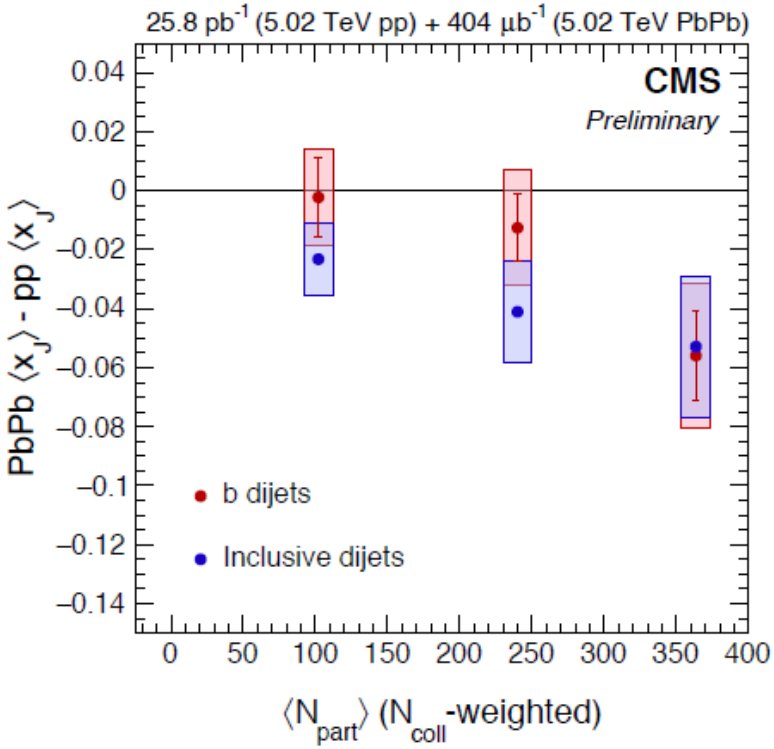
- The imbalance of b dijets has been observed for the first time
- The increase of imbalance of inclusive dijets from pp to central PbPb collisions has been confirmed at 5TeV
- Inclusive dijet and b dijet imbalance are within uncertainty

Summary

- CMS measured b-dijets in PbPb collisions
- Momenta of b-dijets are imbalanced in central collisions
- No significant difference to light dijets
- Similar quenching



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back-up

CSV varibles

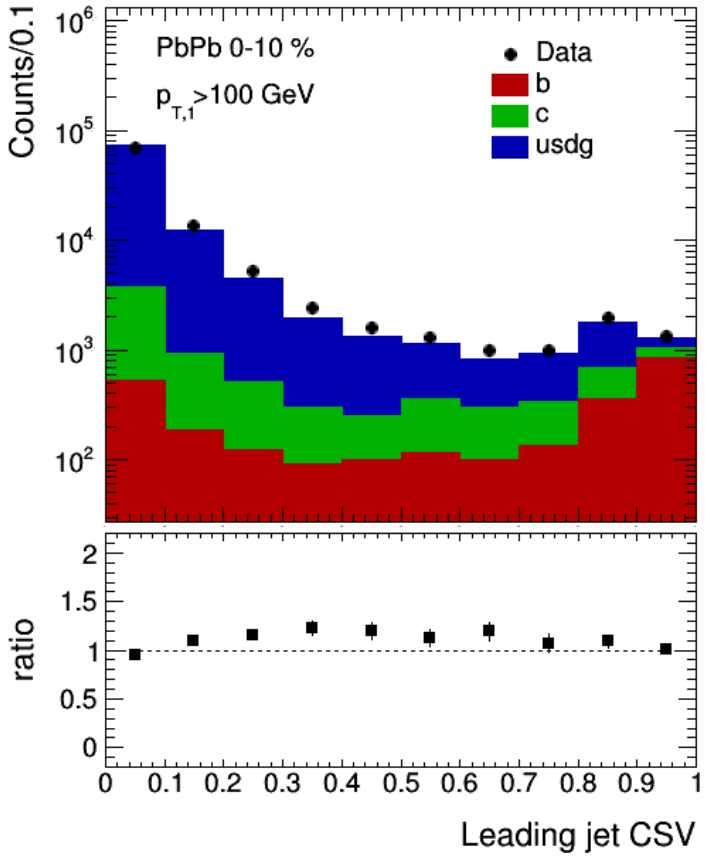
The following set of variables with high discriminating power and low correlations is used:

- the vertex category (real, “pseudo,” or “no vertex”);
- the 2D flight distance significance;
- the vertex mass;
- the number of tracks at the vertex;
- the ratio of the energy carried by tracks at the vertex with respect to all tracks in the jet;
- the pseudo-rapidity of the tracks at the vertex with respect to the jet axis;
- the 2D IP significance of the first track that raises the invariant mass above the charm threshold of 1.5 GeV when subsequently summing up tracks ordered by decreasing IP significance;
- the number of tracks in the jet;
- the 3D signed IP significances for each track in the jet

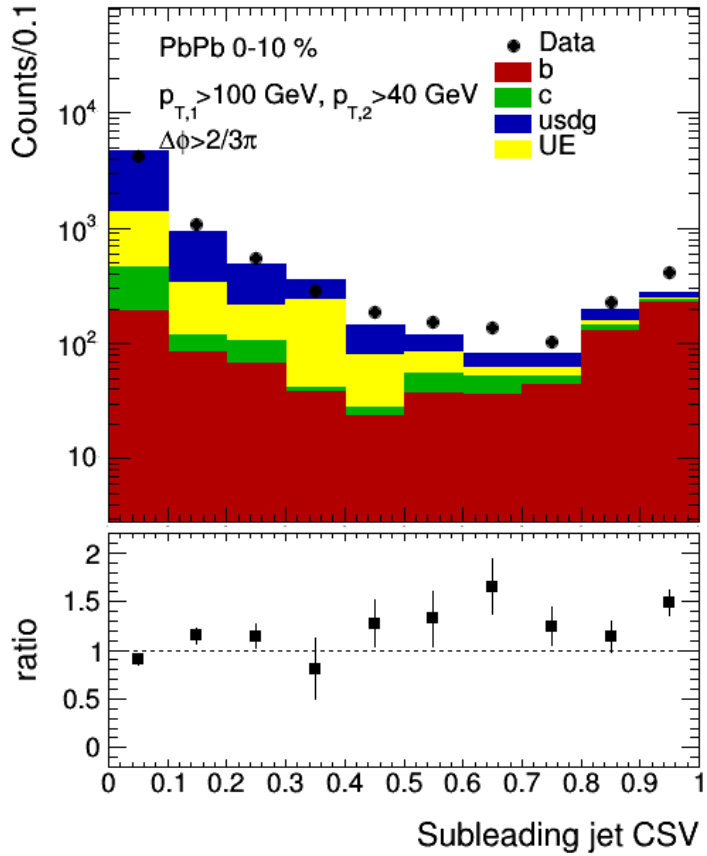
b-tagging

CSV distributions for 0-10% PbPb
NB: Not template fits

Leading jet



Subleading jet



- The discriminator shape is generally well described by simulation
- Similar case for other SV-related quantities (more plots in the AN)
- Relatively tight CSV working point of > 0.9 used in this analysis

Flavor process reweighting

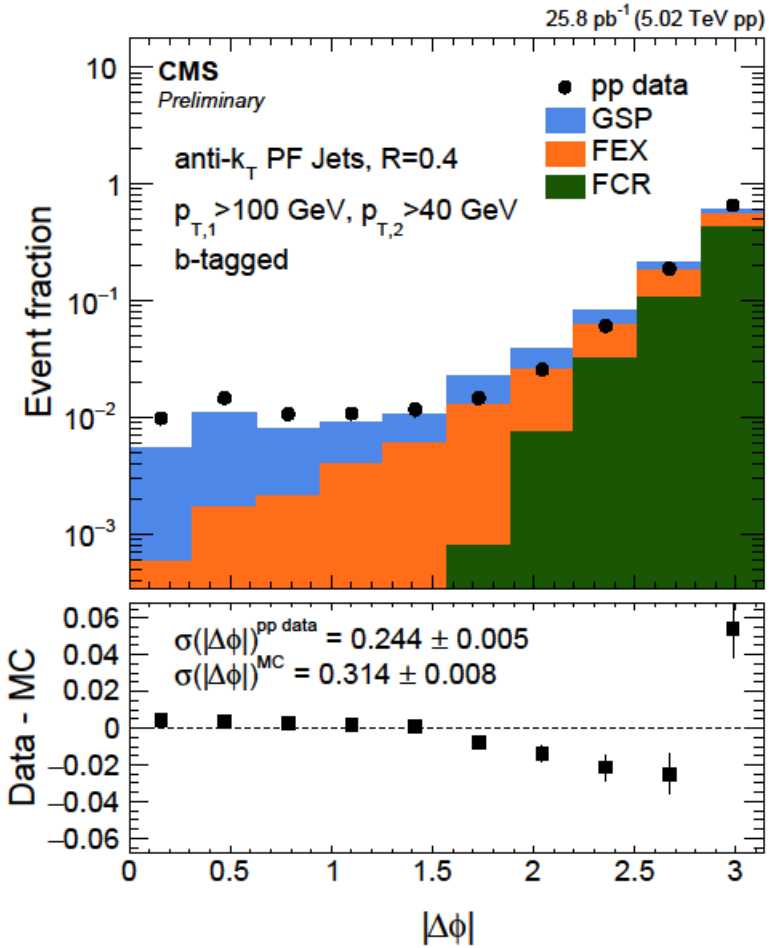
- Reweight the flavor process based on the difference of MC and Data in three Categories:

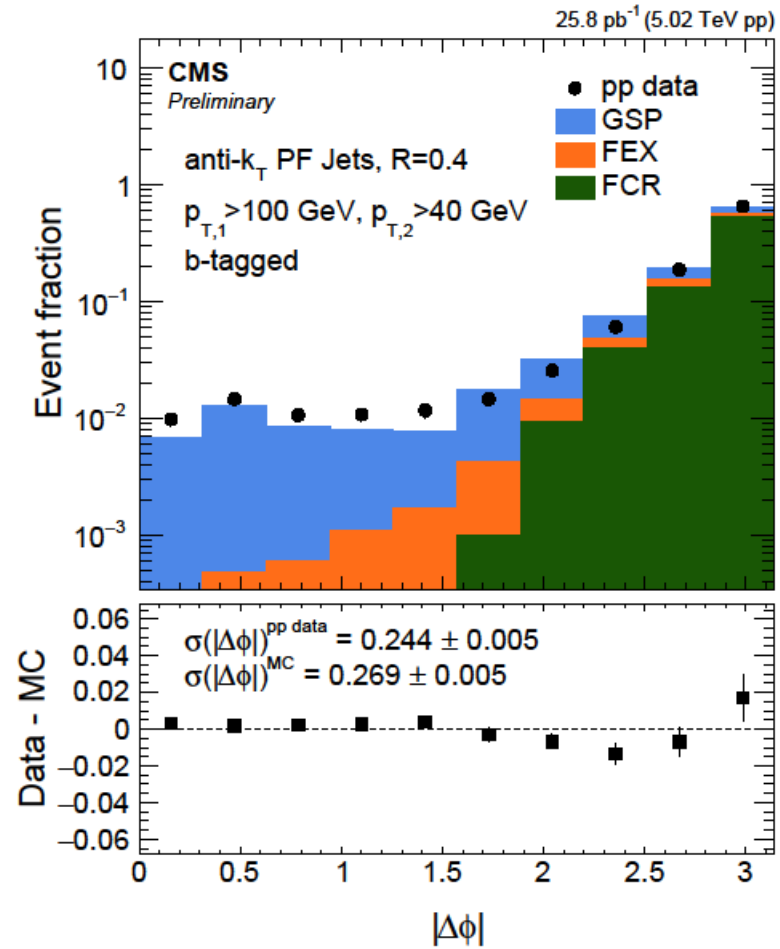
  - $|\Delta\phi 1,2|>2\pi/3$: The two highest p_T jets are b-tagged and back-to-back
  - $|\Delta\phi 1,3|>2\pi/3$: The first and third highest p_T jets are b-tagged and back-to-back
  - $|\Delta\phi 1,3|<\pi/3$: The first and third highest p_T jets are b-tagged and nearby

Category	FCR	FEX	GSP
$\|\Delta\phi 1,2\|>2\pi/3$	57%	26%	17%
$\|\Delta\phi 1,3\|>2\pi/3$	11%	62%	27%
$\|\Delta\phi 1,3\|<\pi/3$	0%	17%	83%

Category	MC	Data
$\|\Delta\phi 1,2\|>2\pi/3$	46%	56%
$\|\Delta\phi 1,3\|>2\pi/3$	49%	37%
$\|\Delta\phi 1,3\|<\pi/3$	5%	7%

Dijet Δϕ after reweighting





Dijet systematic uncertainties:

Source	pp	30-100%	10-30%	0-10%
Combinatorial subtraction	-	0.001	0.006	0.014
Subleading jet finding	-	0.002	0.004	0.004
Energy scale	0.001	0.006	0.010	0.013
Jet resolution	0.007	0.008	0.010	0.012
total	0.007	0.010	0.016	0.023

Table 4: Absolute systematic uncertainties on $\langle x_J \rangle$ for inclusive dijets.

Source	pp	30-100%	10-30%	0-10%
Combinatorial subtraction	-	0.008	0.008	0.008
Subleading jet finding	-	0.002	0.004	0.004
Tagging efficiency	0.002	0.003	0.003	0.009
Signal mistagging	0.002	0.004	0.006	0.006
Jet energy scale	0.001	0.006	0.010	0.013
Jet resolution	0.007	0.008	0.010	0.012
total	0.008	0.014	0.018	0.023

Table 5: Absolute systematic uncertainties on $\langle x_J \rangle$ for b dijets.

DRAFT

- pp results have been smeared according to the jet resolution in PbPb in order to make data-based reference