Bottom quark dijet momentum imbalance in PbPb collisions with CMS

GDR QCD 2016
Stas Lisniak for CMS collaboration

2016/11/08

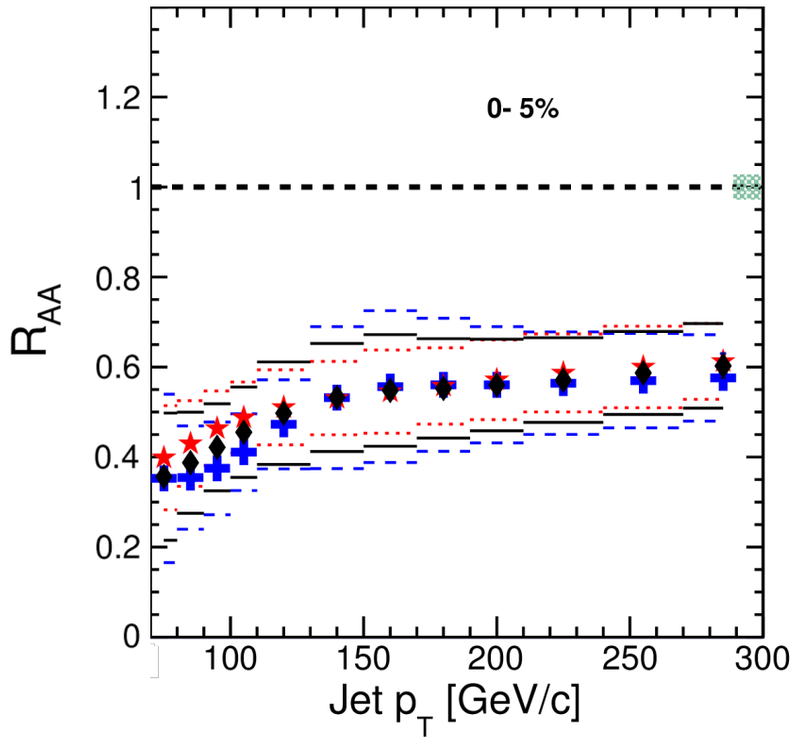
Physics Analysis Summary:
http://cds.cern.ch/record/2202805

What we already know

Inclusive jets

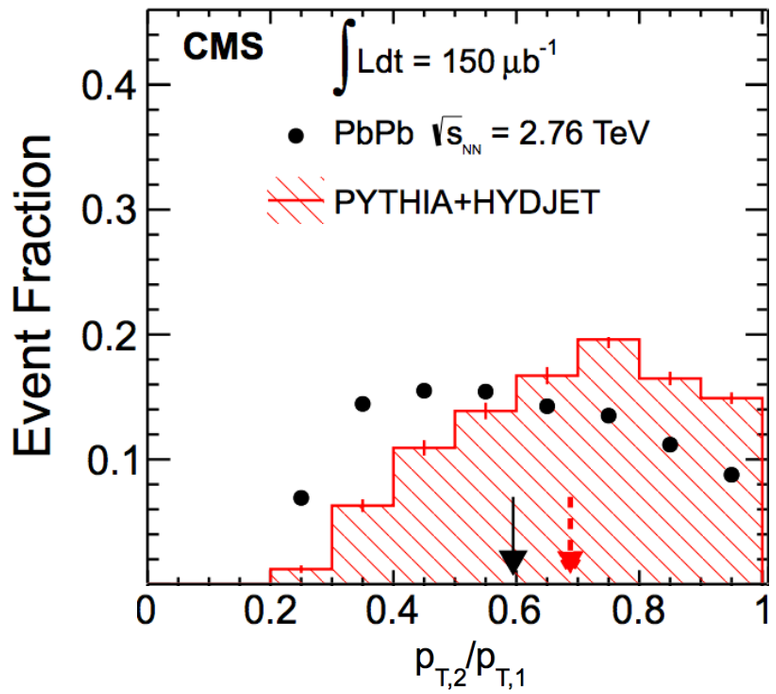
R_{AA}

arXiv:1609.05383

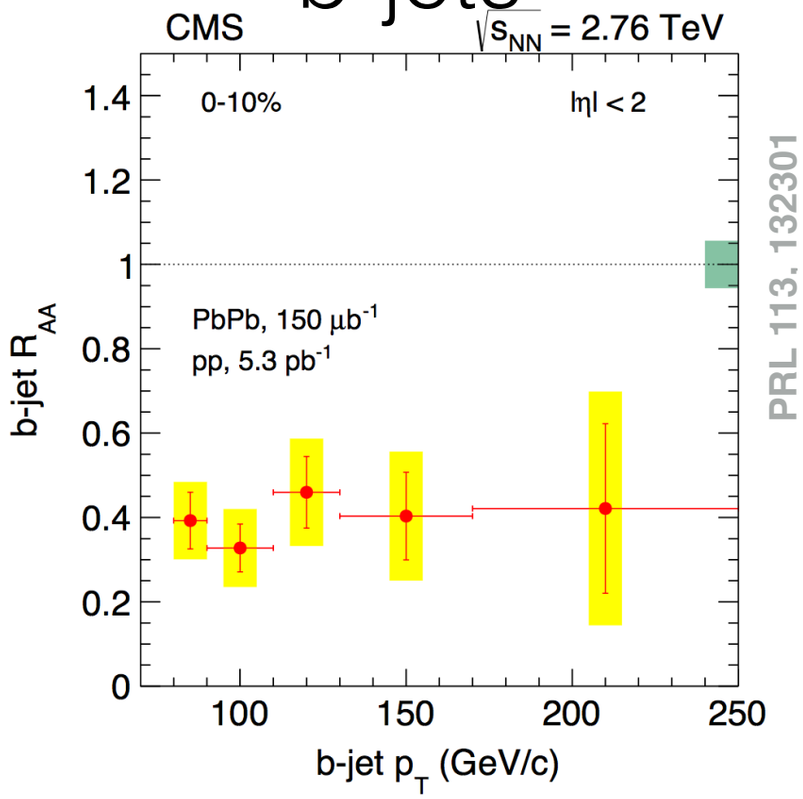


imbalance

PLB 712 (2012) 176



b-jets



PRL 113, 132301

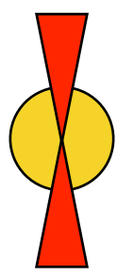
b dijet imbalance

?

Dijet momentum imbalance

- anti-k_T Particle Flow R=0.4 jets
- UE subtraction with iterative noise/ pedestal subtraction technique

- Dijet selection:



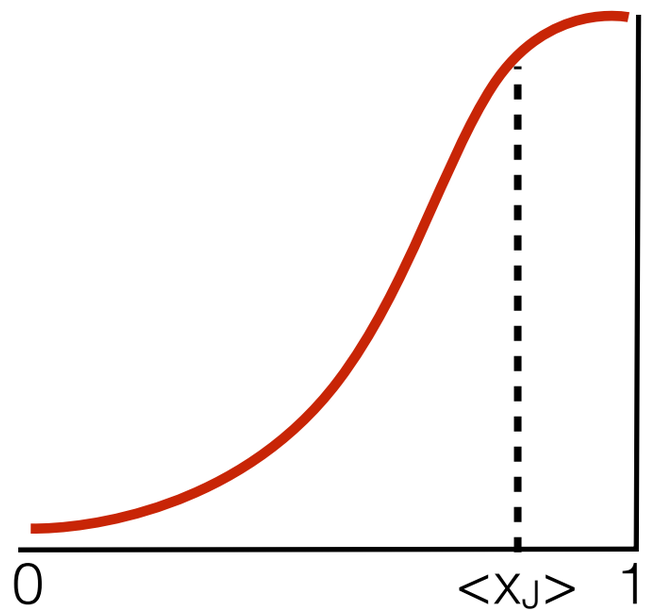
$|\eta|<1.5$

$p_{T,1}>100$ GeV/c

$p_{T,2}>40$ GeV/c

$\Delta\phi_{1,2}>2\pi/3$

balanced x_J

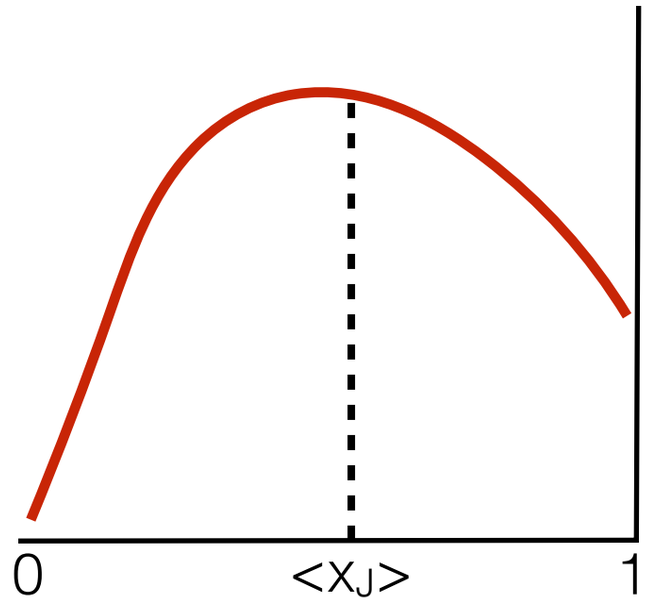


- Dijet imbalance

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

- Dijets are not *perfectly* balanced even in QCD
- +detector resolution effects
- b-dijets are the same with the requirement that both jets are **b-tagged**

imbalanced x_J



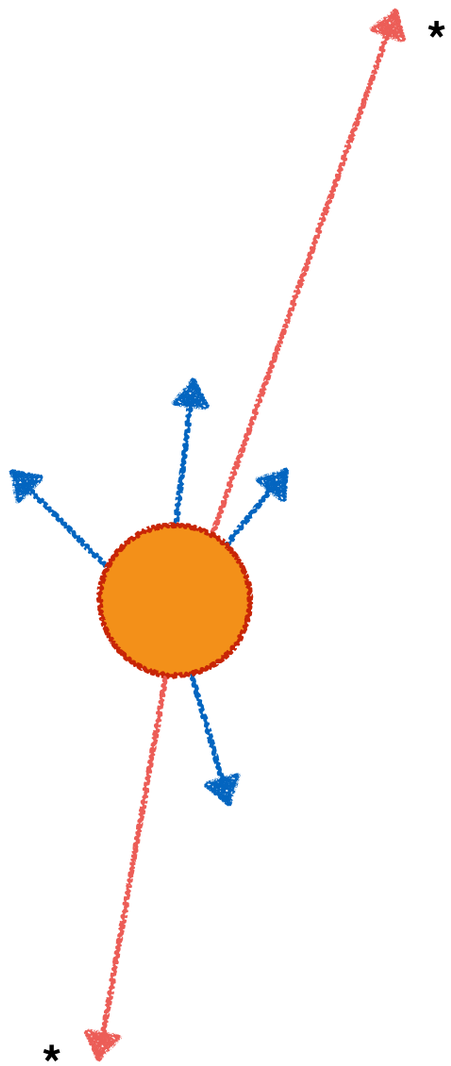
Jets in pp and PbPb

signal jet

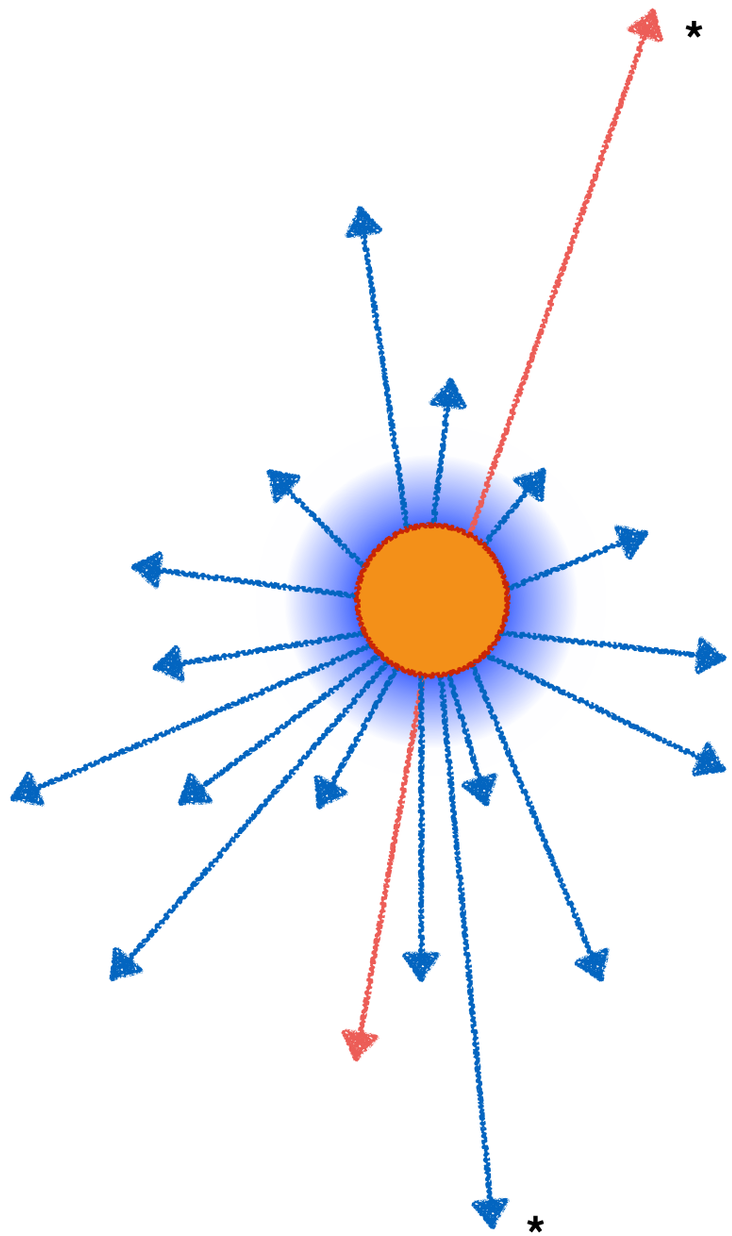
background jet

* selected pair

pp collisions

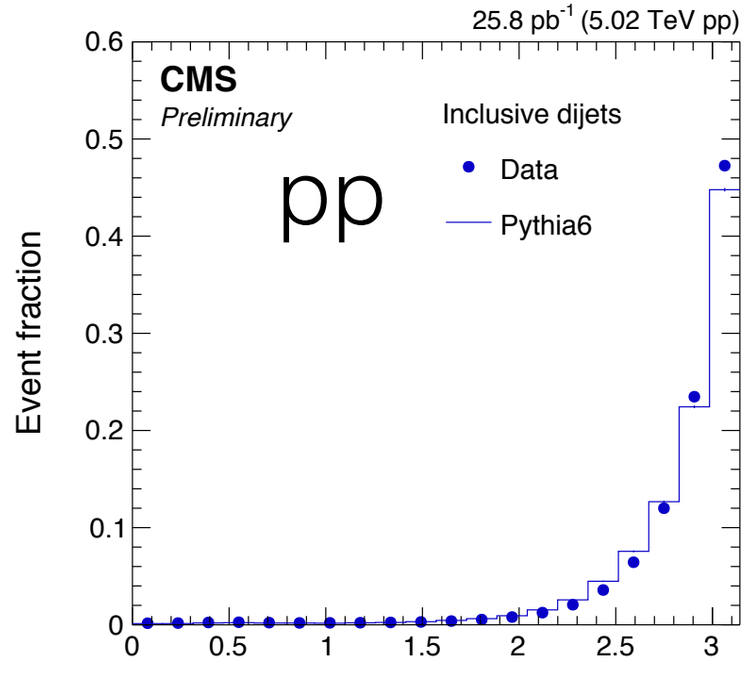


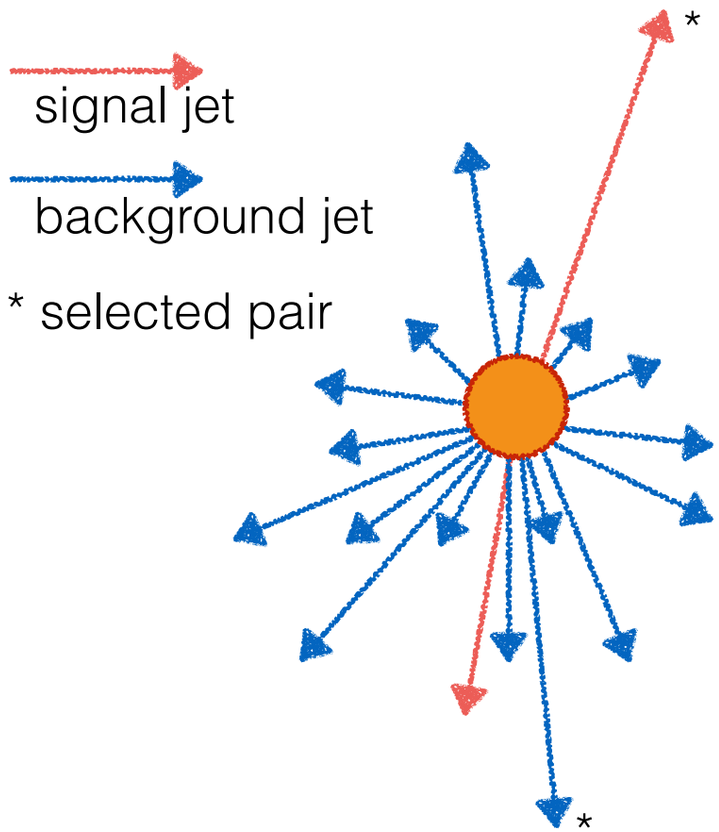
PbPb collisions

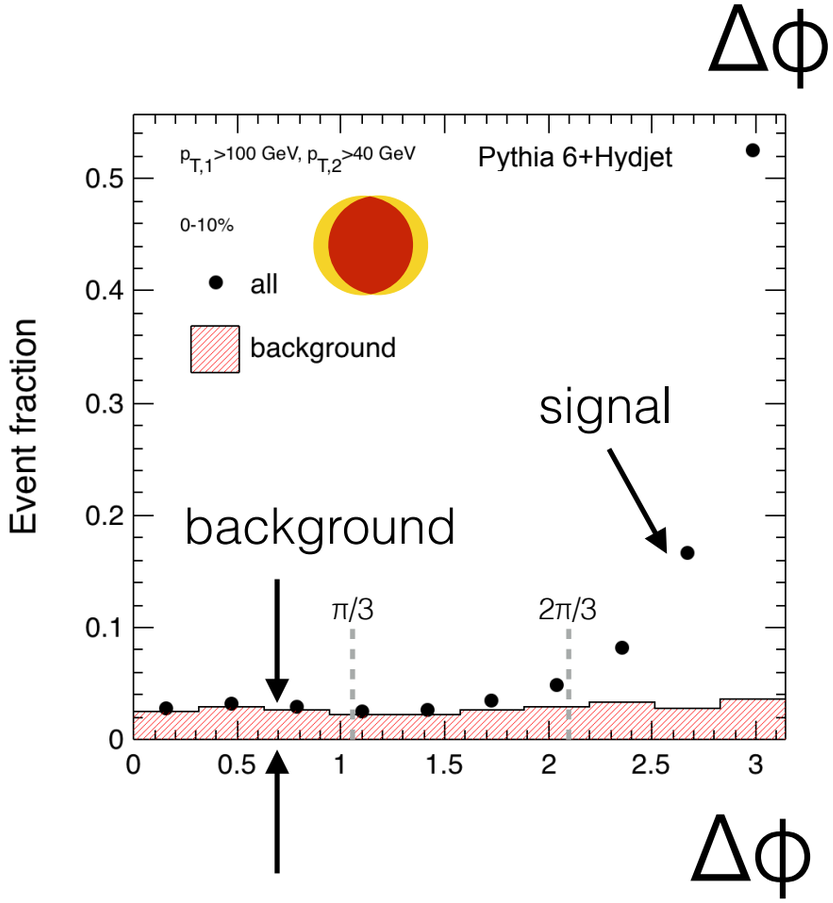


Combinatorial background **subtraction**

- Combinatorial background is **subtracted** with Δϕ sideband
- This introduces **inefficiency** for subleading jets



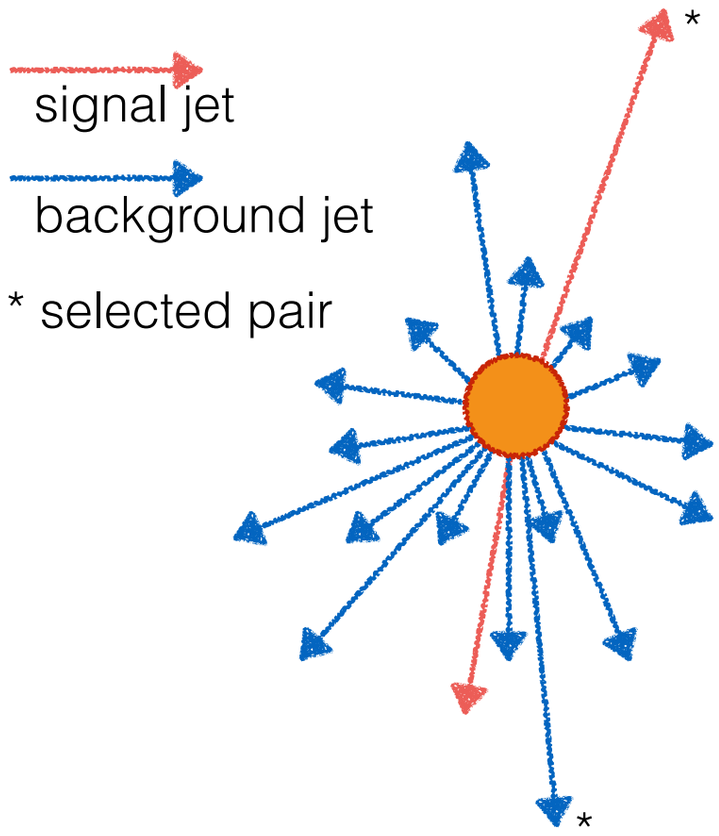


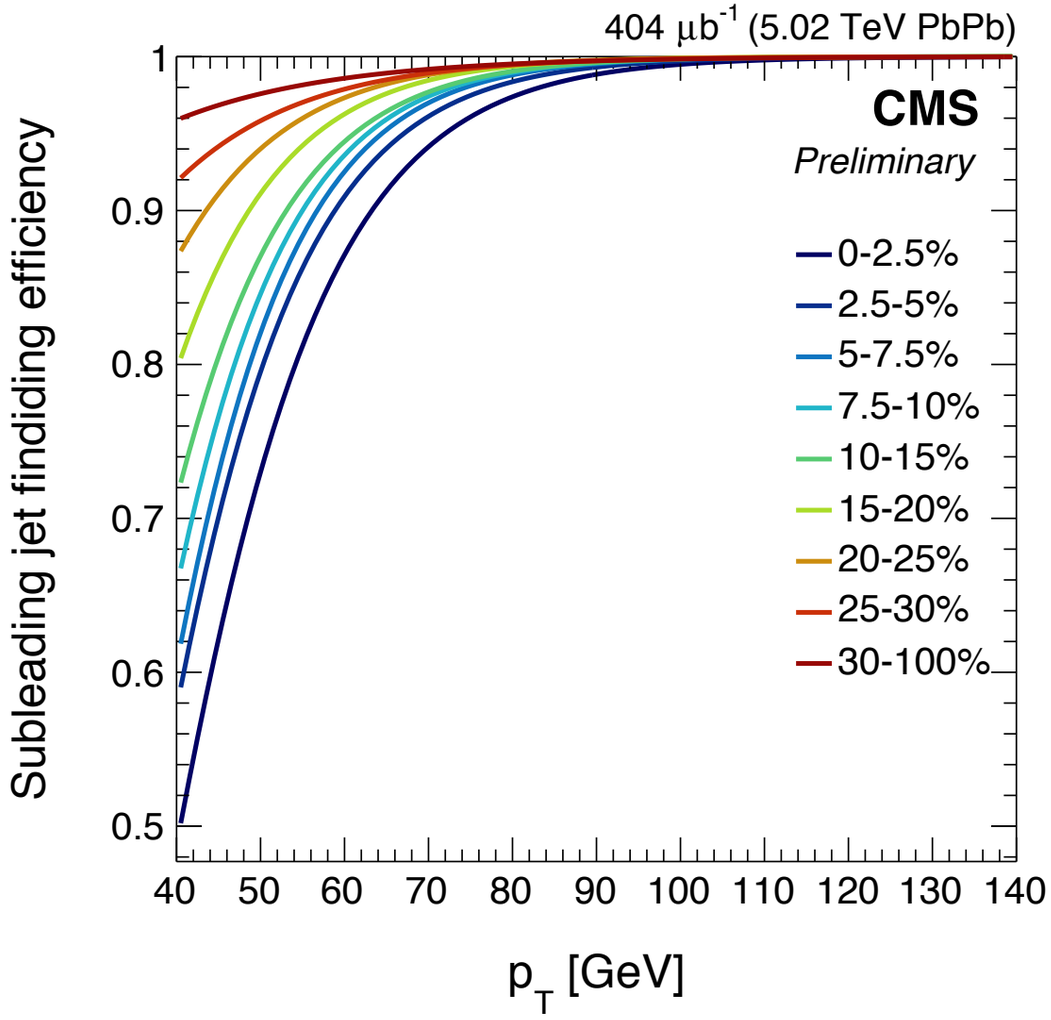


Combinatorial background **correction**

- Derived from the spectrum of the background jets

- After correction - **unbiased** dijet imbalance





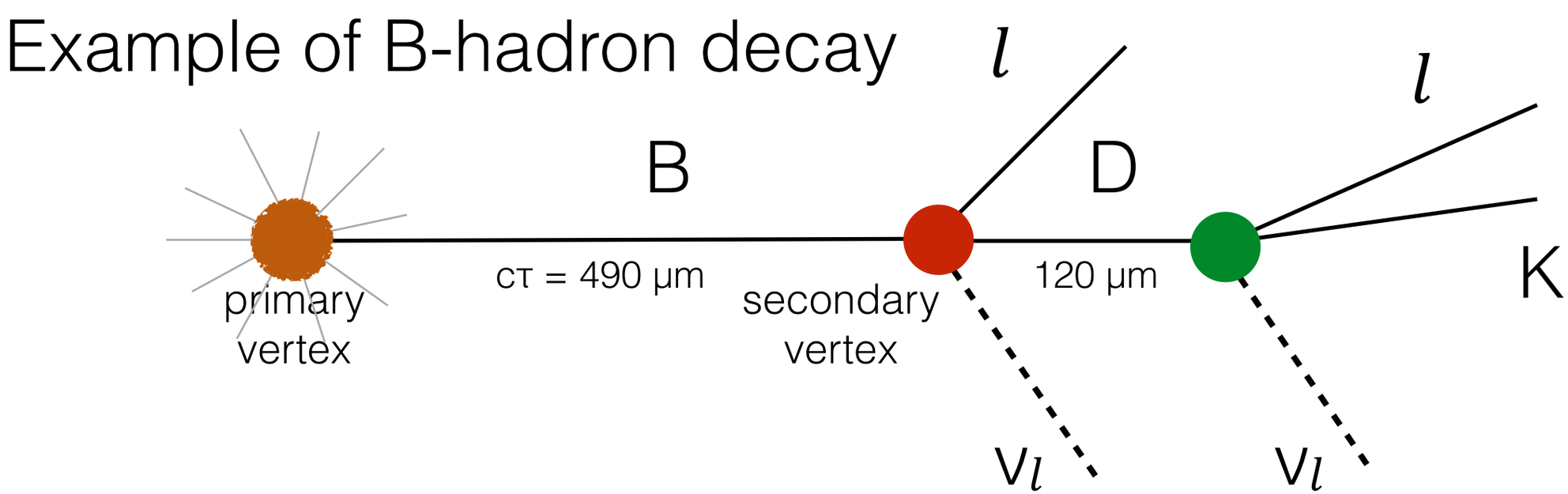
- e.g. 40 GeV jets in most central bin are lost 50% of the time, so we correct x2

b-tagging

- we define b-jet as a jet which has b-hadron in the vicinity of jet axis
- b-tagging ≠ b-hadron reconstruction

- there are two ways to perform identification of b-hadrons:
  - weak decay into leptons
  - b-hadron lifetime results in a displaced vertex

- The tagging of b-jets **in this analysis** is performed with identification of secondary vertex and displacement of tracks in the jet

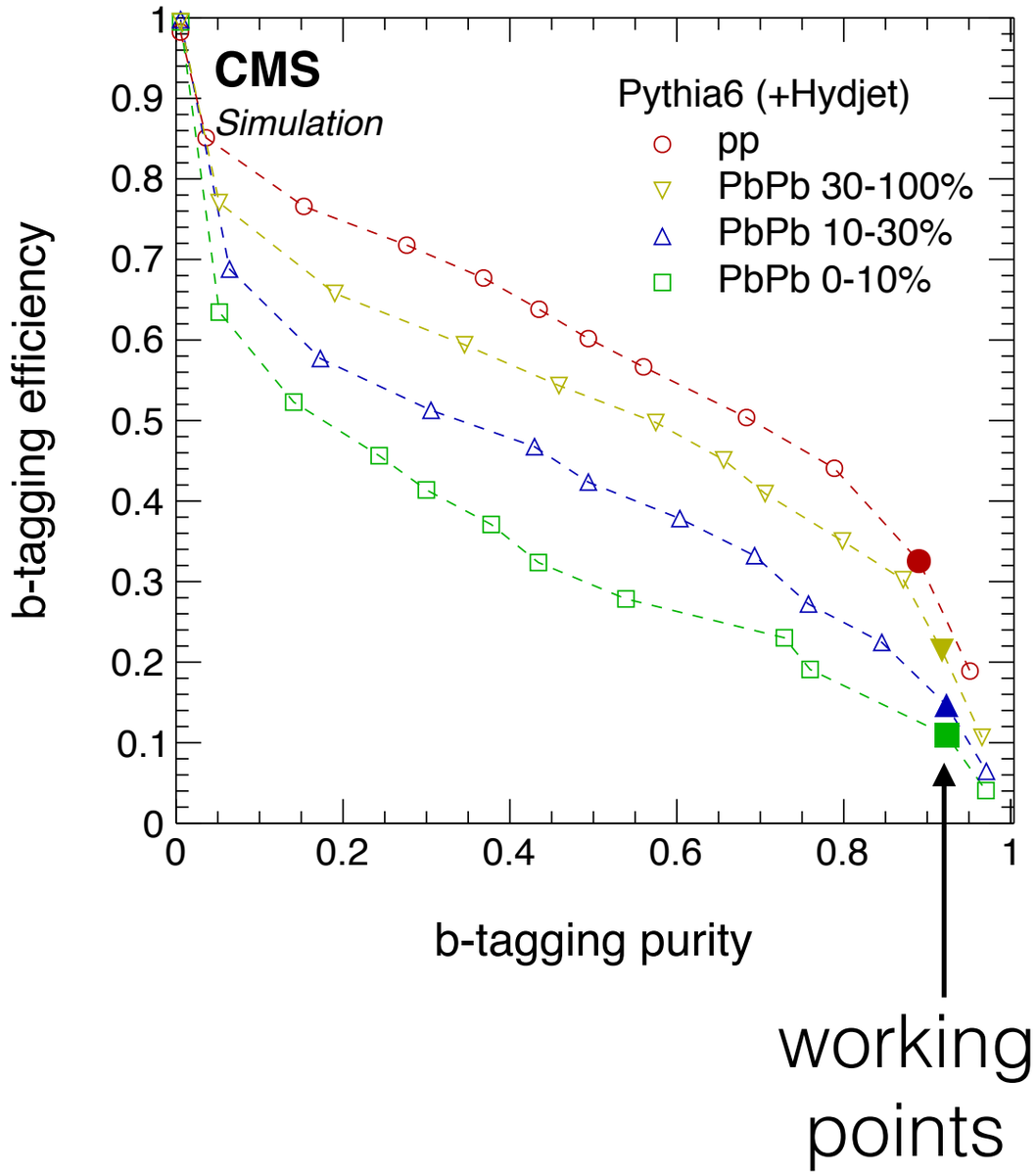


b-tagging in PbPb collisions @ 5 TeV

- We use CSV[1] discriminator to identify b dijets
- Working point is selected to obtain 90% pure sample

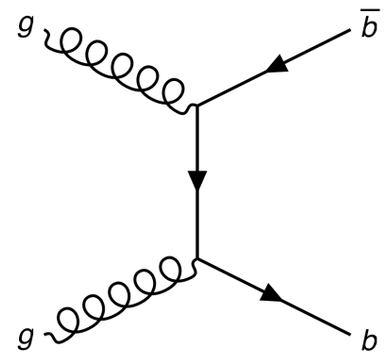
- *Relative* tagging efficiency corrections are applied in centrality, p_T, η
- 10% contamination as systematics

dijet b-tagging ROC curve



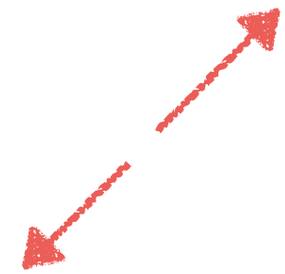
[1]JINST 8 (2013) P04013

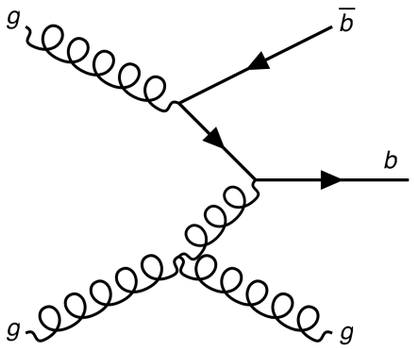
Heavy flavor production



Flavor Creation

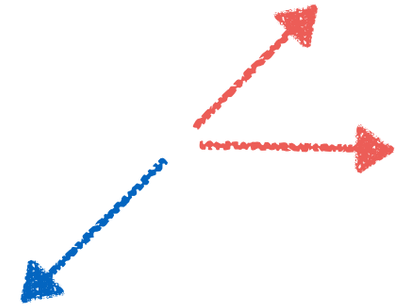
gluon fusion or
$q\bar{q}$ annihilation

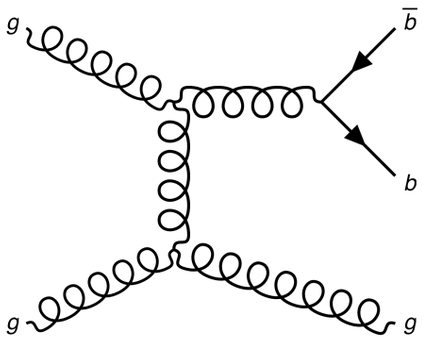




Flavor Excitation

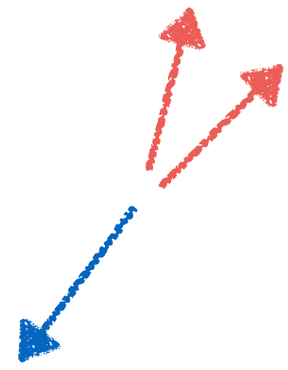
sea $b\bar{b}$ pair is excited
by gluon or light quark





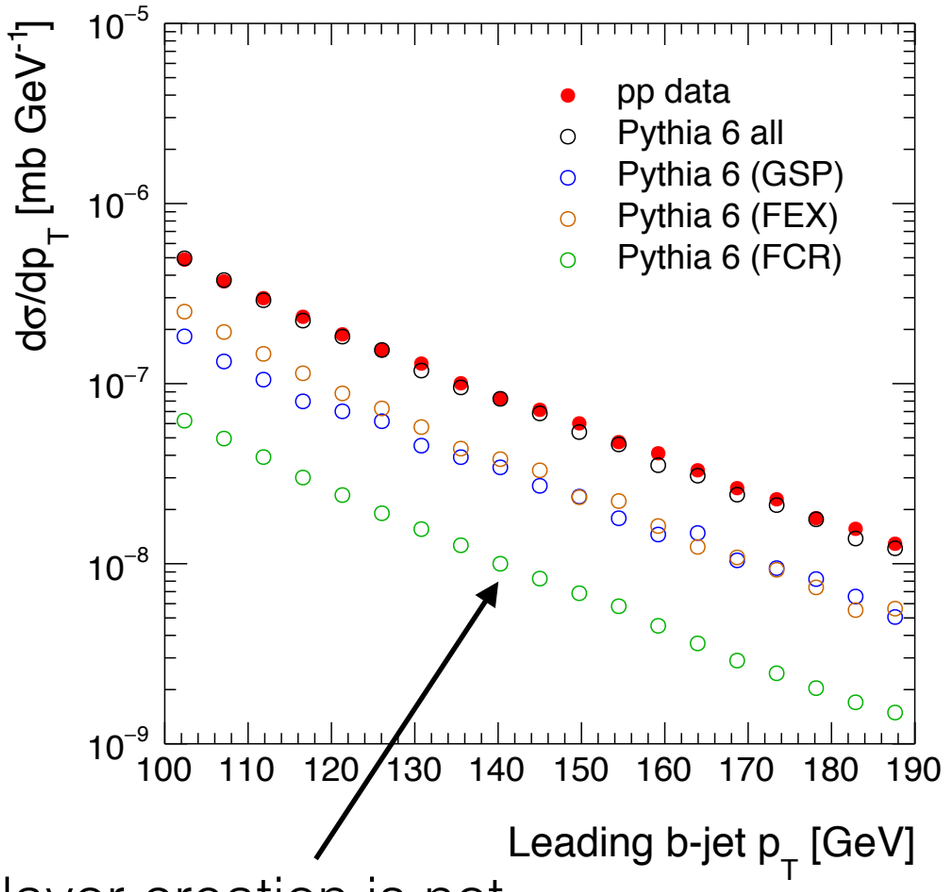
Gluon Splitting

gluon splits into $b\bar{b}$



b-jets in pp and Pythia

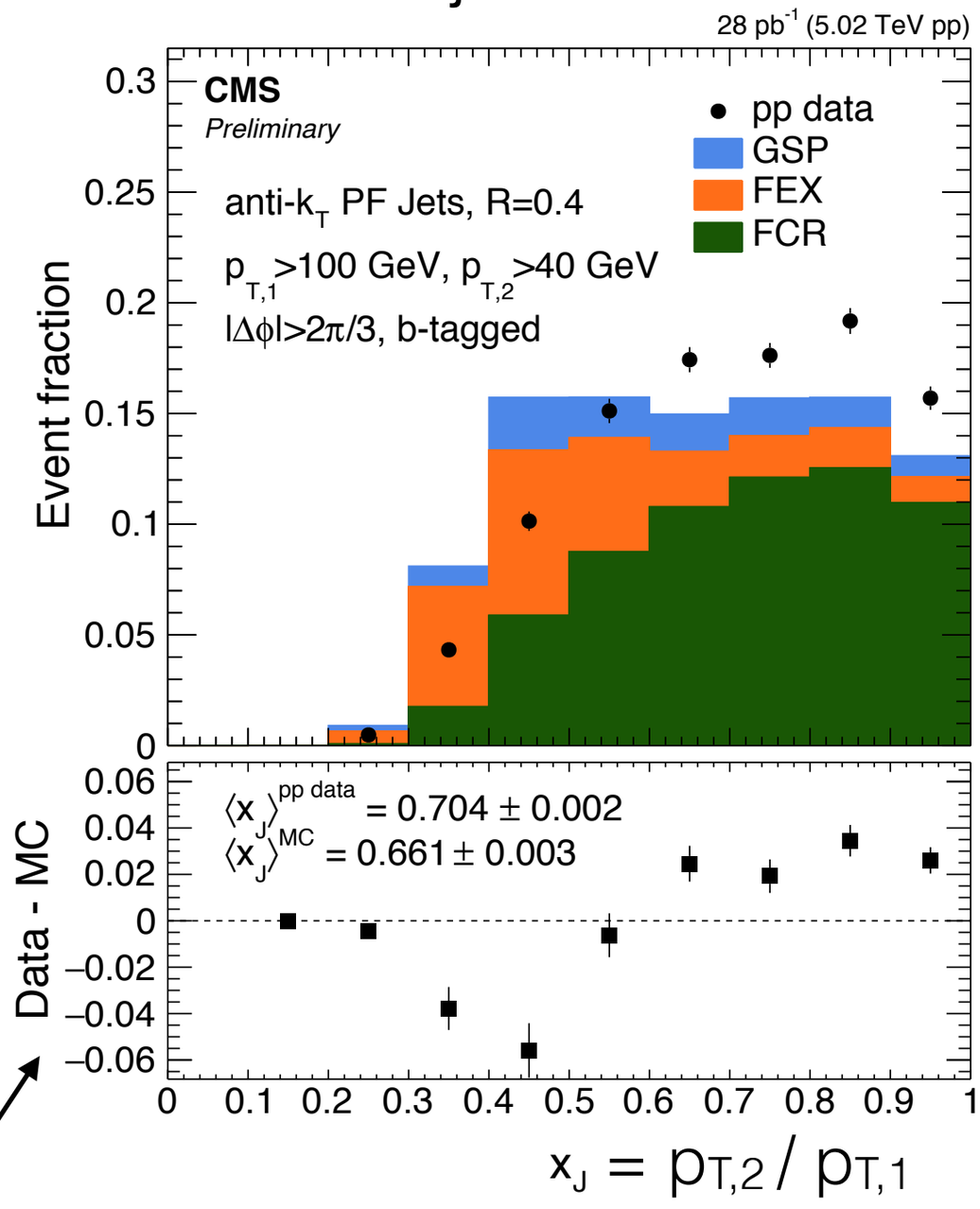
single b-jet cross-section



flavor creation is not
a dominant contribution

- Single b-jet cross-section is described well by Pythia
- Pythia6 has poor description of b dijet imbalance

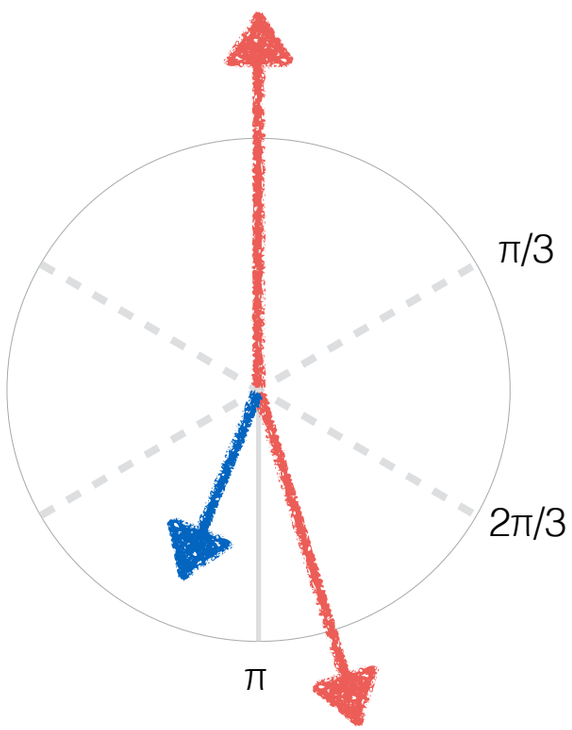
b-dijet imbalance

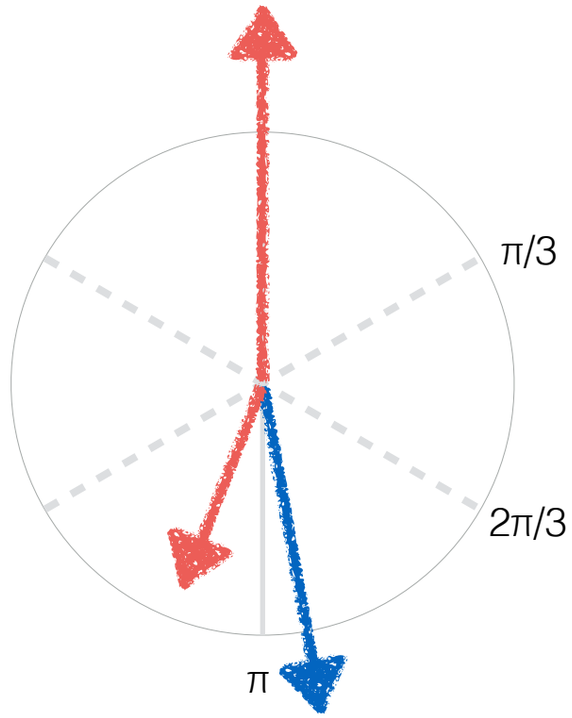


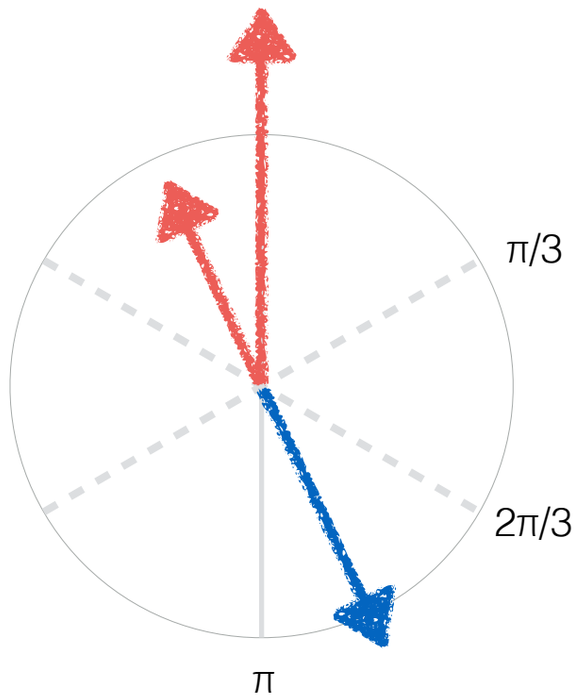
- b dijets from Flavor Excitation (FEX) are more imbalanced than from Flavor Creation (FCR)

Flavor process reweighting

- The two highest pT jets are b-tagged and back-to-back ($|\Delta\phi_{1,2}|>2\pi/3$)
- The first and third highest pT jets are b-tagged and back-to-back ($|\Delta\phi_{1,3}|>2\pi/3$)
- The first and third highest pT jets are b-tagged and nearby ($|\Delta\phi_{1,3}|<\pi/3$)





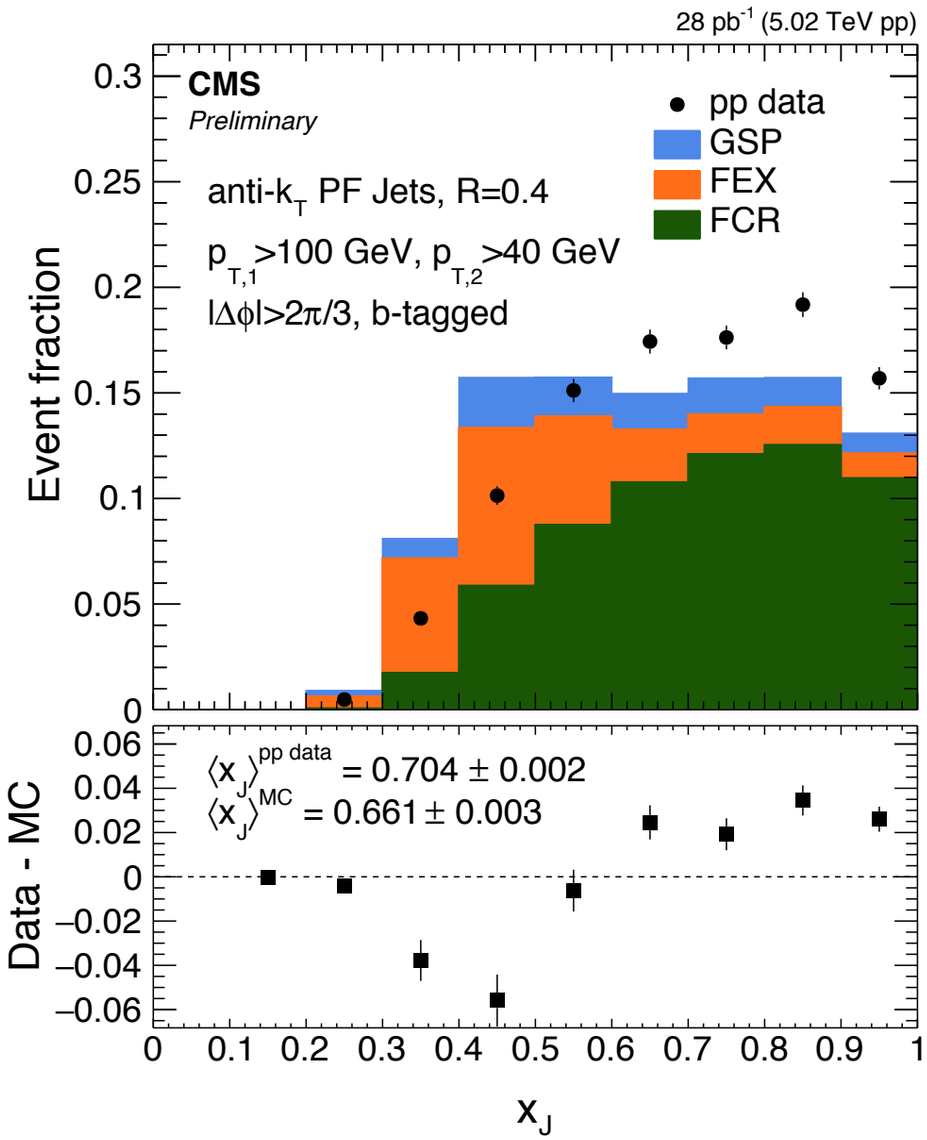


Category	FCR	FEX	GSP
$\|\Delta\phi_{1,2}\|>2\pi/3$	**57%**	26%	17%
$\|\Delta\phi_{1,3}\|>2\pi/3$	11%	**62%**	27%
$\|\Delta\phi_{1,3}\|<\pi/3$	0%	17%	**83%**

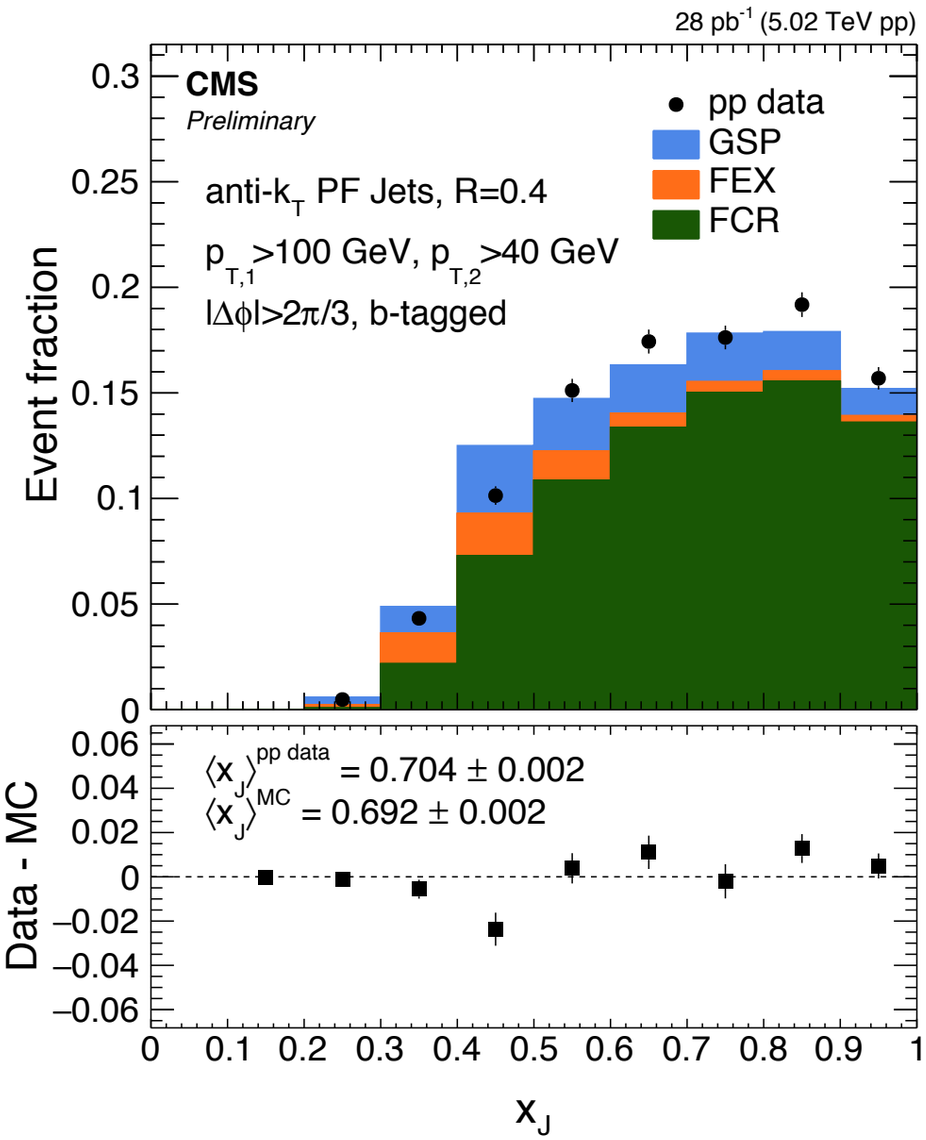
Category	MC	Data
$\|\Delta\phi_{1,2}\|>2\pi/3$	46%	56%
$\|\Delta\phi_{1,3}\|>2\pi/3$	49%	37%
$\|\Delta\phi_{1,3}\|<\pi/3$	5%	7%

Flavor process reweighting

before



after



- Result: FCR fraction in analysis selection 50% → 70%
- Pythia overestimates the FEX contribution to back-to-back topologies.
- After reweighting - same data/Pythia agreement as for inclusive jets
- Similar conclusion in CDF PRD71 (2005) 092001

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

Absolute systematic uncertainties on ⟨xJ⟩ for **inclusive dijets**

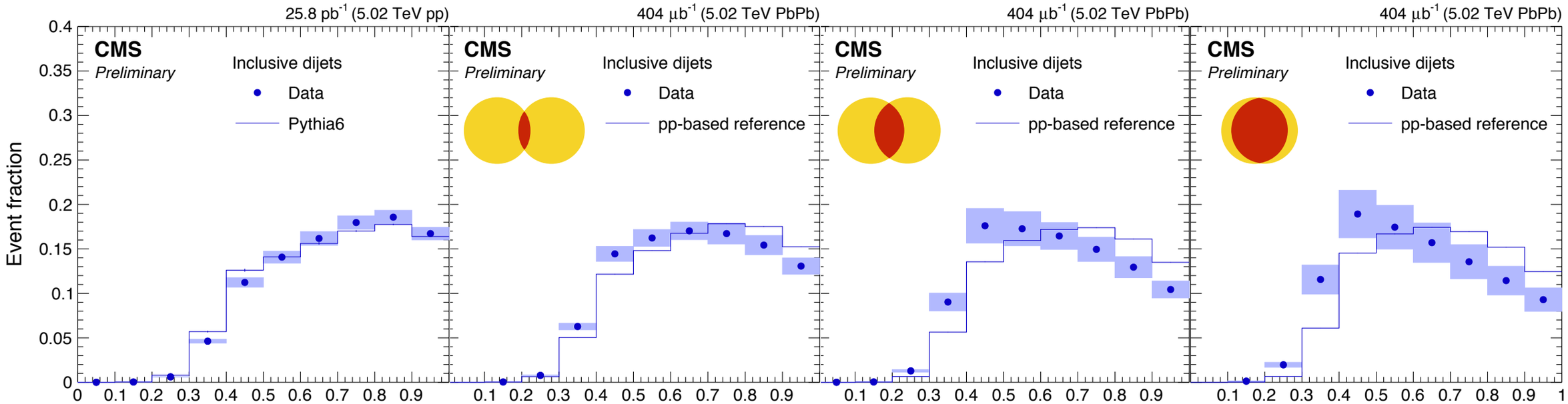
Source	pp	30-100%	10-30%	0-10%
Combinatorial subtraction	-	0.008	0.008	0.008
Subleading jet finding	-	0.002	0.004	0.004
Tagging efficiency	0.002	0.003	0.003	0.009
Signal mistagging	0.002	0.004	0.006	0.006
Jet energy scale	0.001	0.006	0.010	0.013
Jet resolution	0.007	0.008	0.010	0.012
total	0.008	0.014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

Absolute systematic uncertainties on ⟨xJ⟩ for **b dijets**

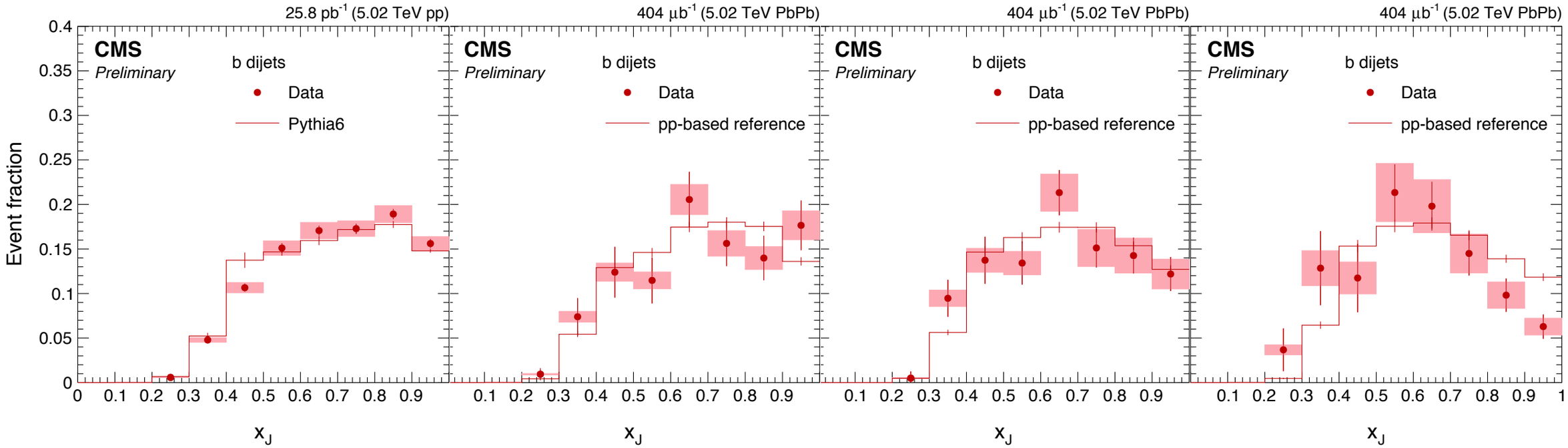
Inclusive and b dijet imbalance @ 5 TeV

pp 30-100% 10-30% 0-10%

inclusive dijets

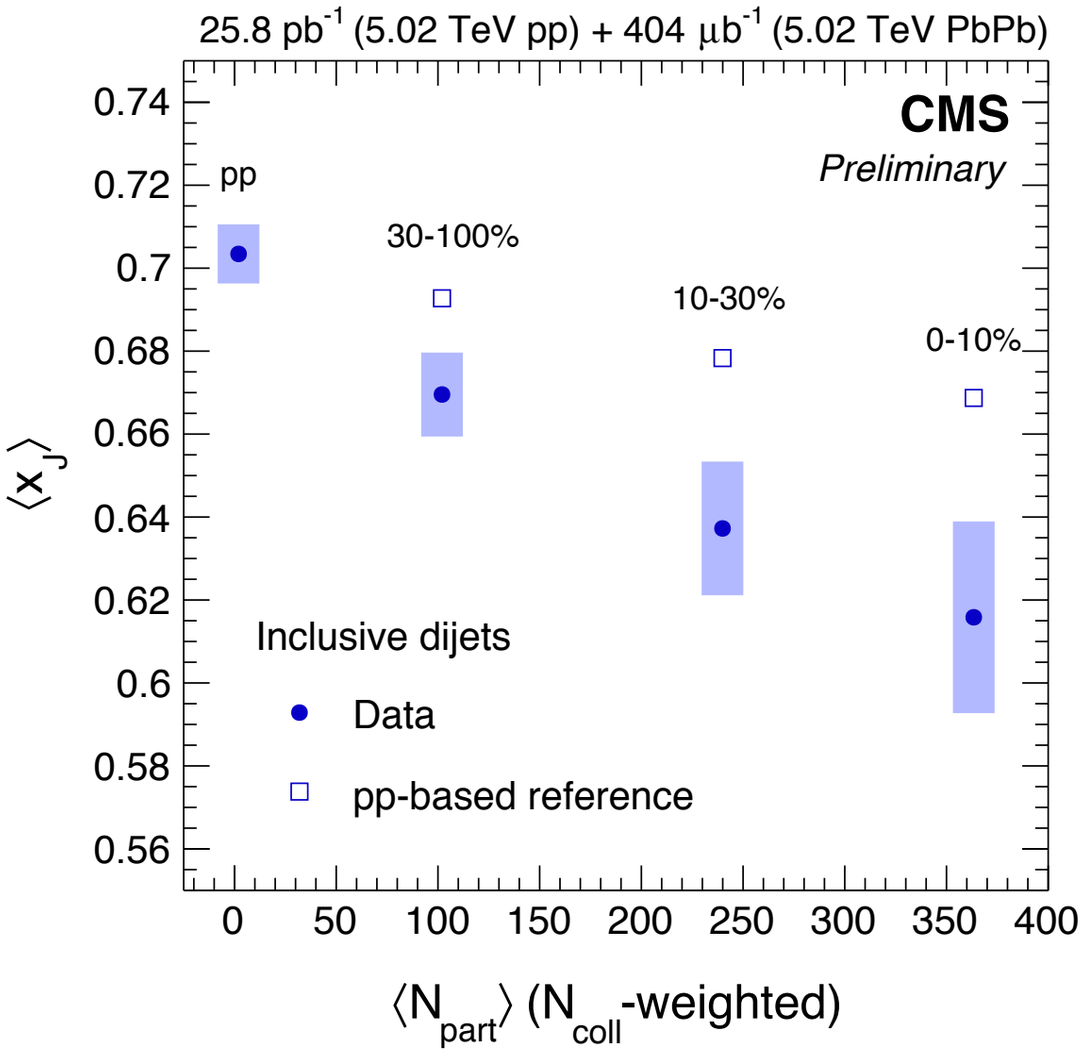


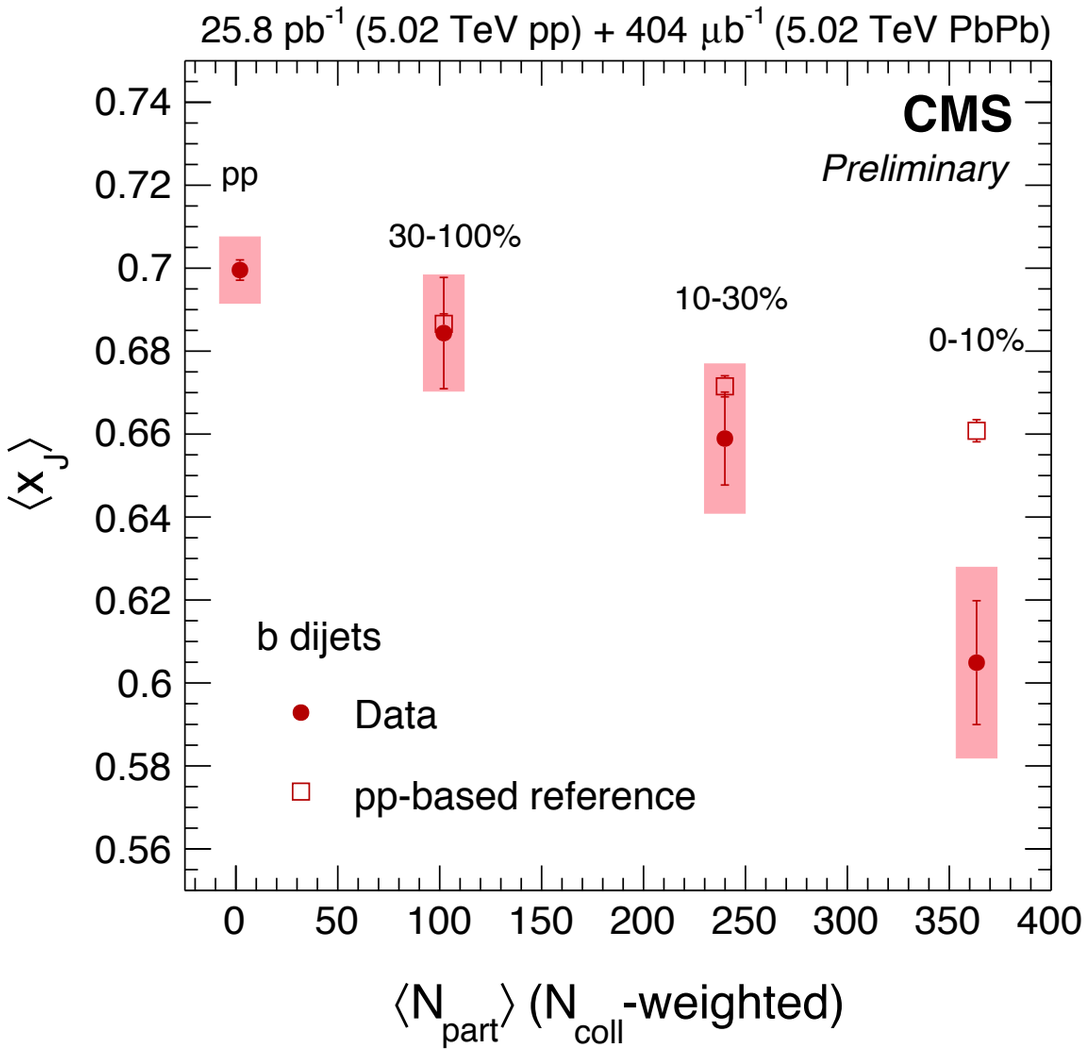
b dijets



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

Results summary

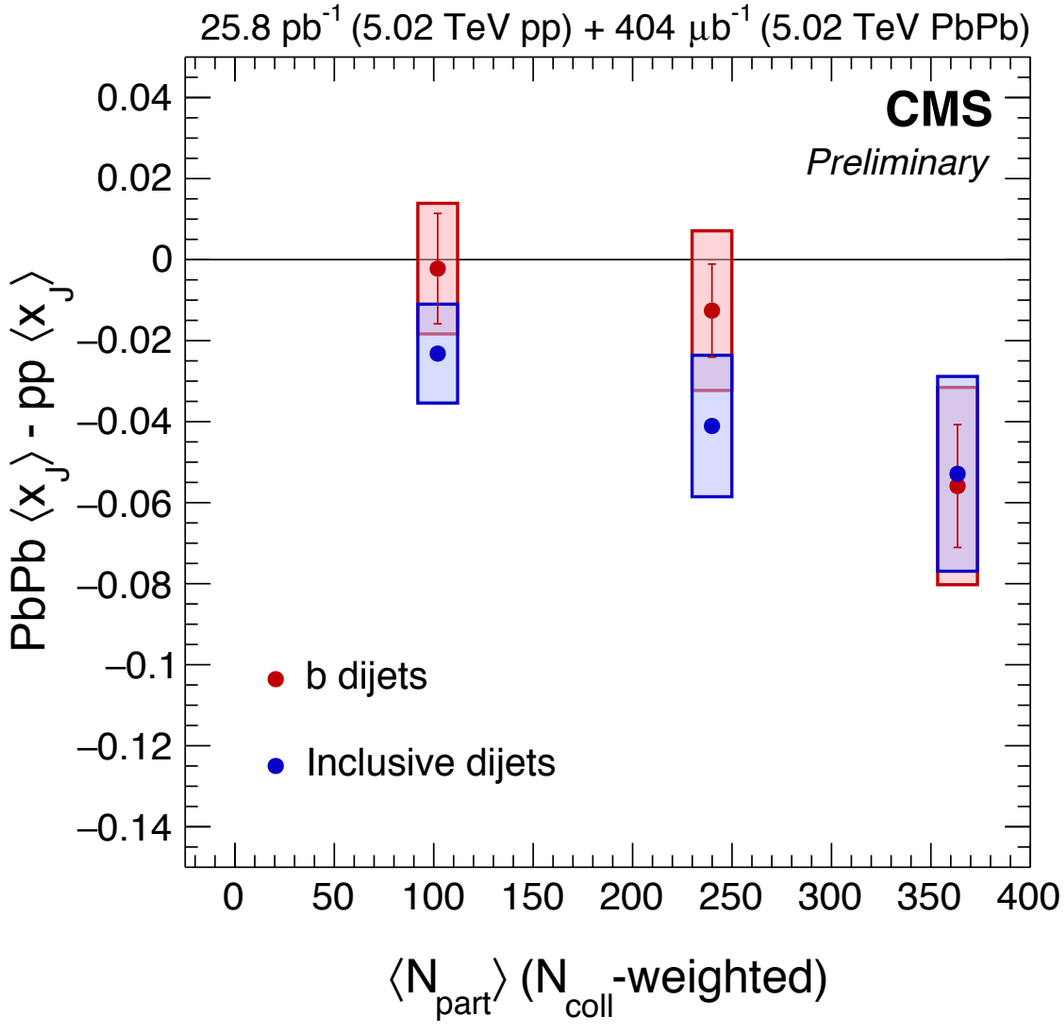




- The increase of imbalance of inclusive dijets from pp to central PbPb collisions has been confirmed @ 5 TeV
- The imbalance of b dijets has been observed for the first time

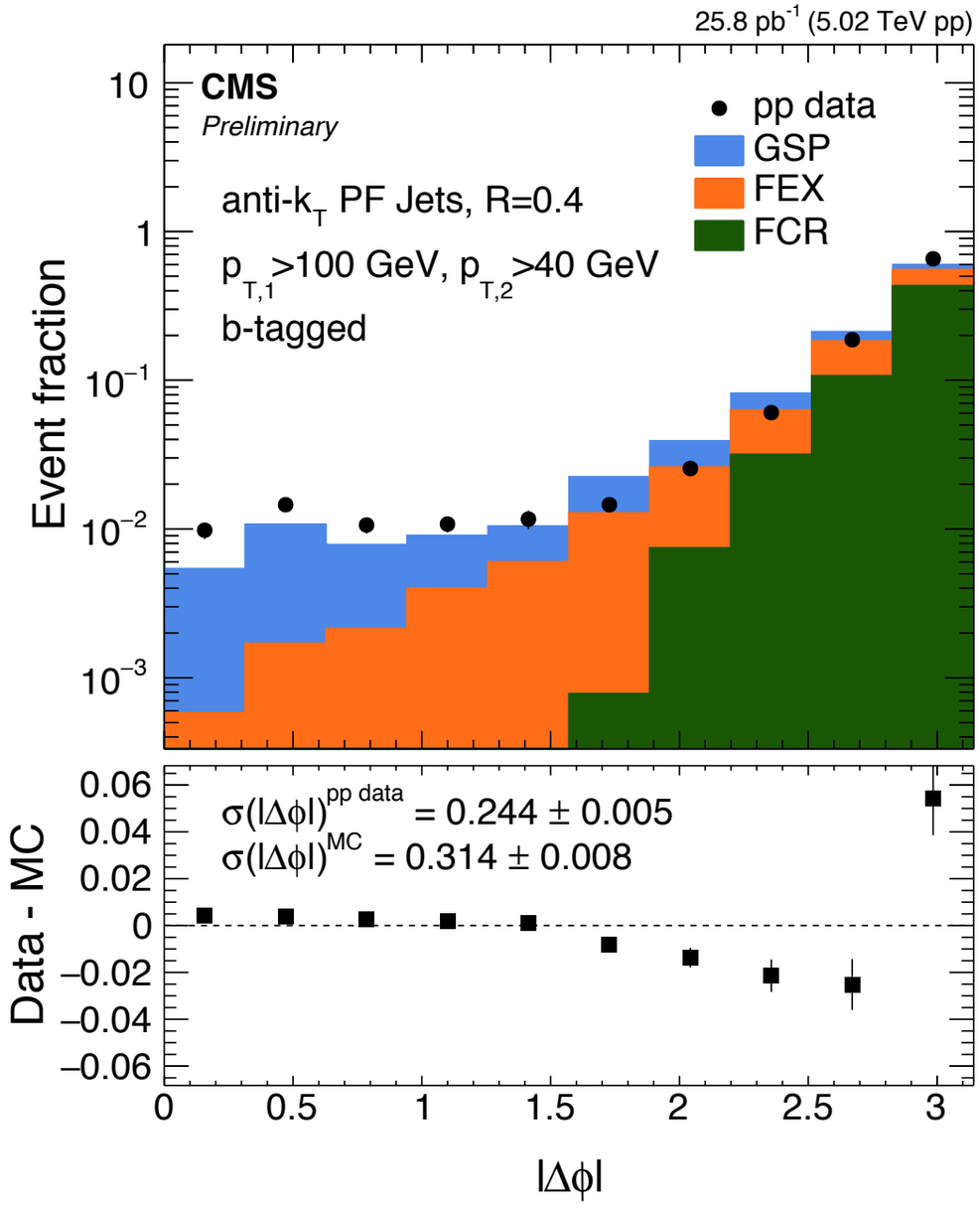
Conclusions

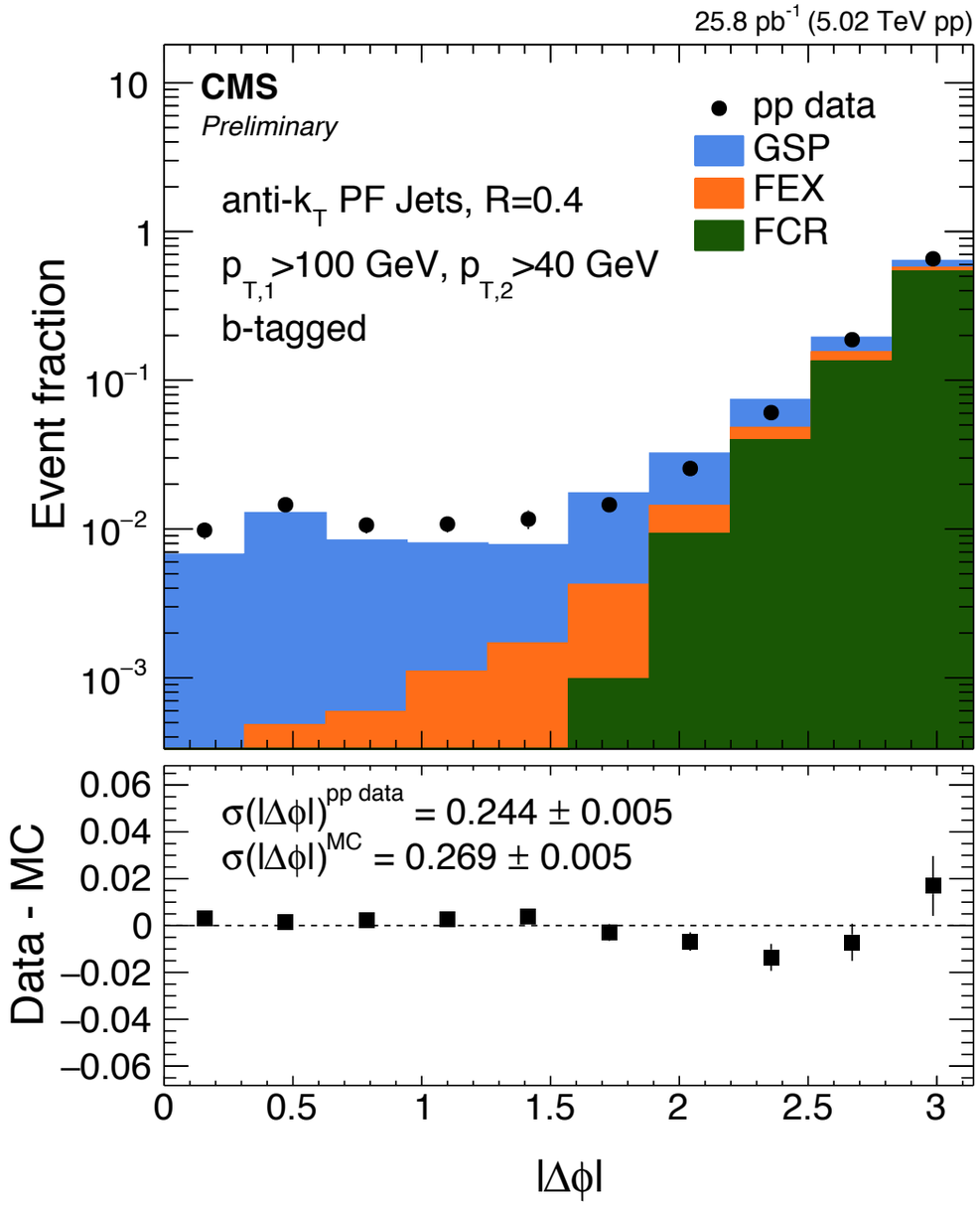
- Dijet measurement is improved with better treatment of combinatorial background
- b dijet imbalance x_J is described well in pp after flavor process reweighting
- The imbalance of b dijets is measured for the first time
- We observe the imbalance of b dijets on the same level as for non-identified jets



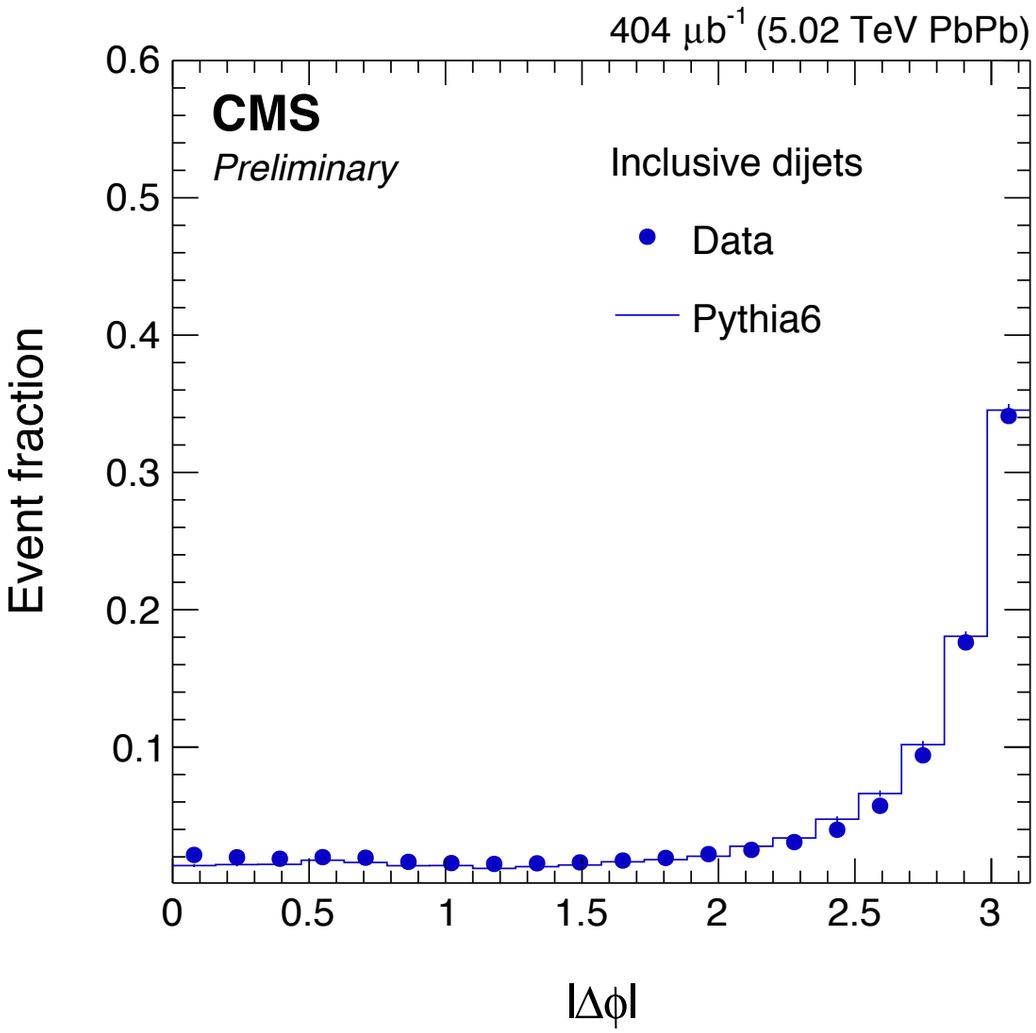
- Back up

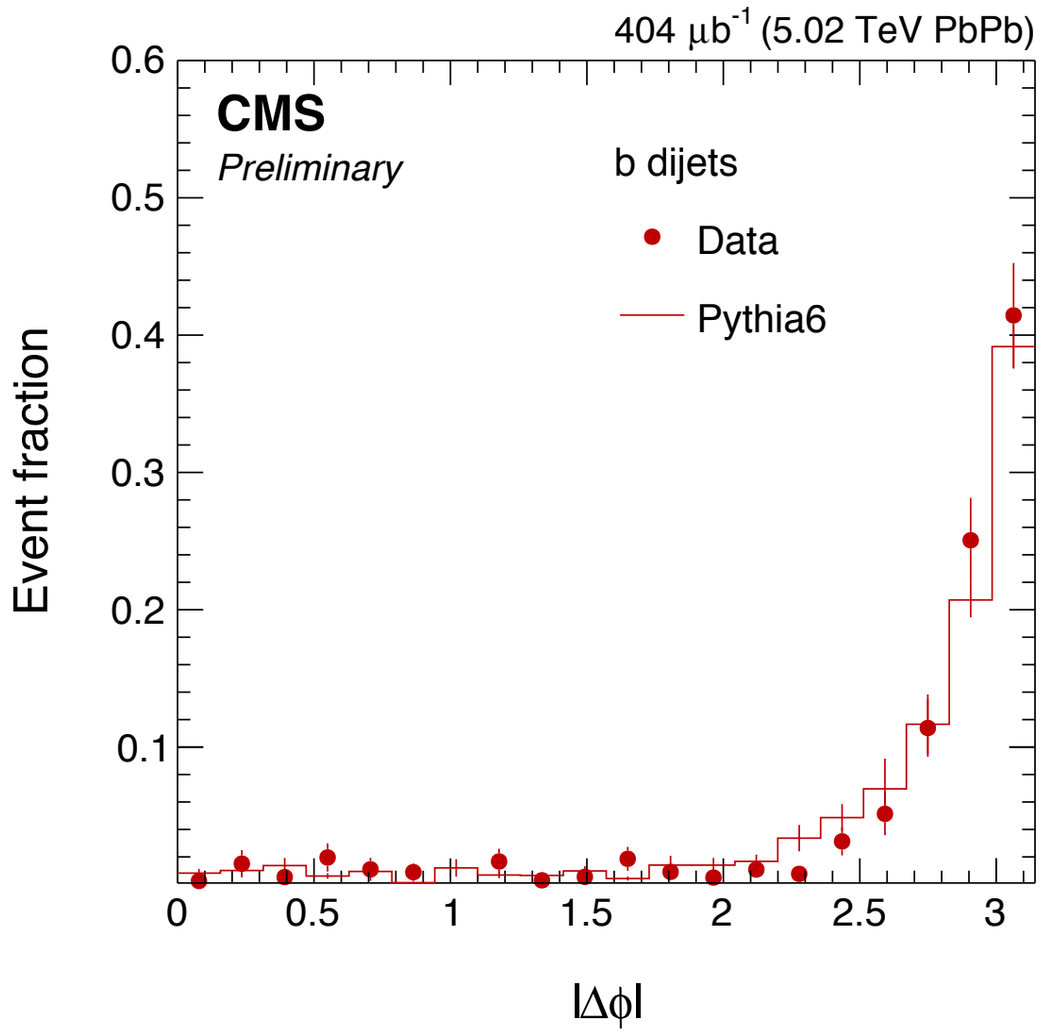
process reweighting Δϕ





Δϕ 0-10%


404 μb^{-1} (5.02 TeV PbPb)
CMS
Preliminary
Inclusive dijets
Data
Pythia6
Event fraction
0.6
0.5
0.4
0.3
0.2
0.1
0
0.5
1
1.5
2
2.5
3
|Δϕ|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b-jet / inclusive jets