# Measurement of $B\bar{B}$ Angular Correlations based on Secondary Vertex Reconstruction at $\sqrt{s}$ = 7 TeV

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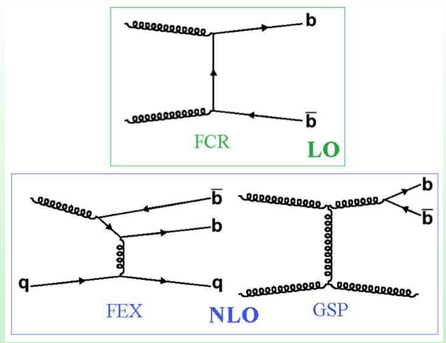
## B Physics at LHC

- Beauty quark pairs produced through strong interaction
- The $b\bar{b}$ cross section is very large
- b quarks are key ingredient at LHC
  $\rightarrow$ as signal (top, low mass Higgs)
  $\rightarrow$ as background to new physics searches




## B Production

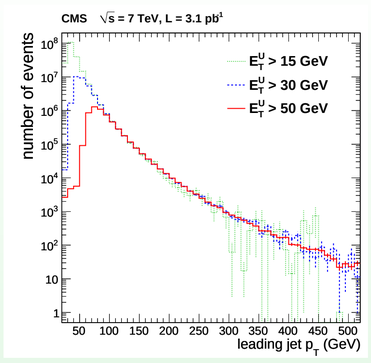
Three mechanisms:

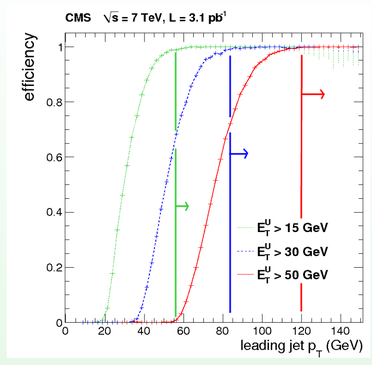
- Flavor creation (FCR): Leading order (LO) process, b and $\bar{b}$ back-to-back.
- Flavor excitation (FEX): Appears first at next-to-leading order (NLO).
- Gluon splitting (GSP): NLO process, small opening angles between b and $\bar{b}$ .

The goal of this study is to understand the underlying dynamics in B production by measuring the angular separation of B hadrons and to compare the results with Monte Carlo (MC) event generator predictions and NLO calculations.

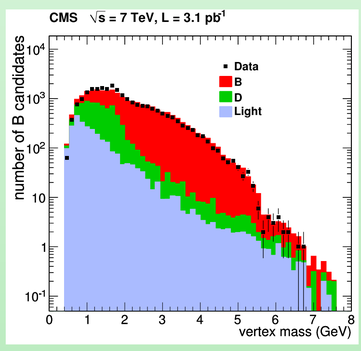
## Analysis Overview

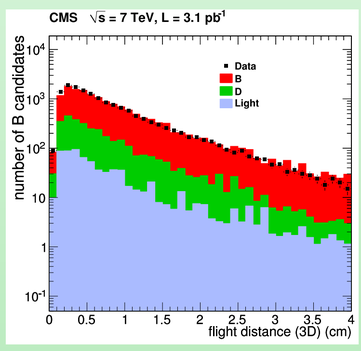
- **Trigger:**
  Single jet trigger above 15, 30 and 50 GeV, cut on $p_T$ of hardest jet, $>$ 99% efficiency: 56, 84 and 120 GeV.

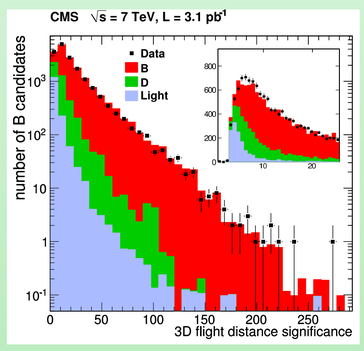


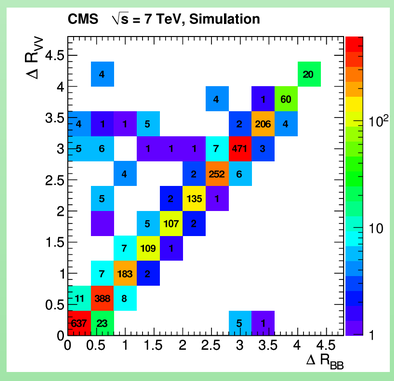

- **Monte Carlo:** Comparison with PYTHIA, MadGraph, MC@NLO, CASCADE
- **Analysis strategy**
  – Combine vertices from **B$\rightarrow$D$\rightarrow$X decays** into a single **B candidate**
  – Select events:
  $\rightarrow$with exactly two B candidates
  $\rightarrow$with sum of scalar mass of two B candidates larger than 4.5 GeV
- **B candidate properties** (Data/PYTHIA)

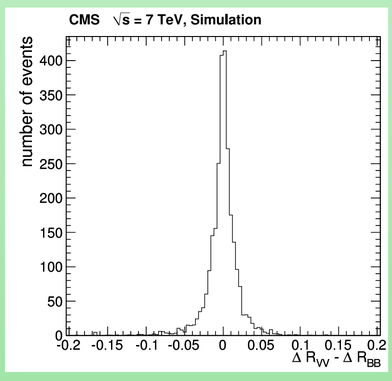



- **Resolution and efficiency:**




1.7% of events out of diagonal ($|\Delta R_{VV} - \Delta R_{BB}| > 0.4$)
$\rightarrow$ very small compared to overall analysis uncertainty
$\rightarrow$ bin-to-bin correction sufficient, no unfolding needed
$\rightarrow$ calculate efficiency on MC as function of leading jet $p_T$ and $\Delta R$.

## Conclusions

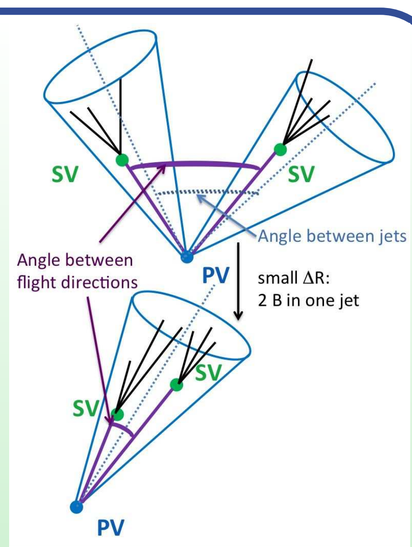
- B hadron angular correlations measured using vertexing in full range, down to very small opening angles.
- Novel technique independent of jet reconstruction used.
- Comparison to perturbative QCD predictions at LO and NLO done.
- Collinear B production is sizable fraction of total cross section and increases at larger $p_T$ of the leading jet.

## Finding B Hadrons

The study is based on a b-tagging algorithm exploiting the long B hadron life time and reconstructing the B hadron decay vertex.

Note:

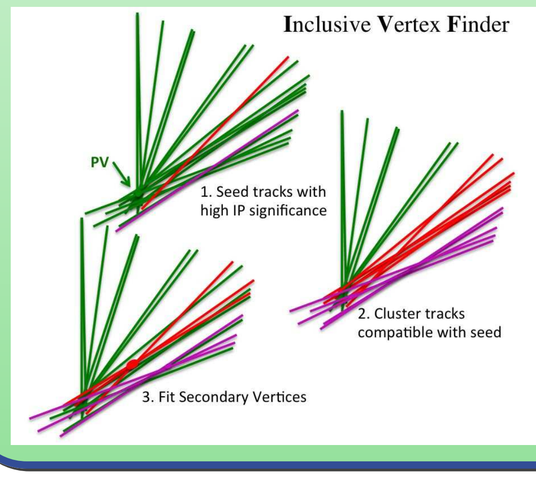
- The resolution is limited to jet cone size ($\Delta R$ = 0.5) when measuring $\Delta\phi$ between *jets*.
- At 7 – 14 TeV: GSP dominant
  $\rightarrow$ Two B hadrons merged into same jet.
  $\rightarrow$ Using jets for correlation study not ideal.

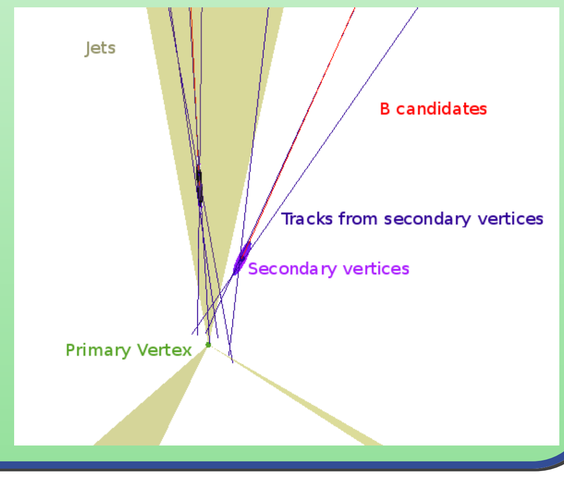



⇒ *Measure angle ($\Delta R$ and $\Delta\phi$) between **flight directions of the B hadrons***

- For two B in one jet the jet direction is no good estimate of the B flight direction.

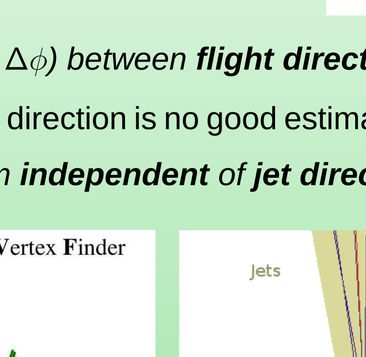
⇒ *Use **seeding** mechanism **independent** of **jet direction**:*

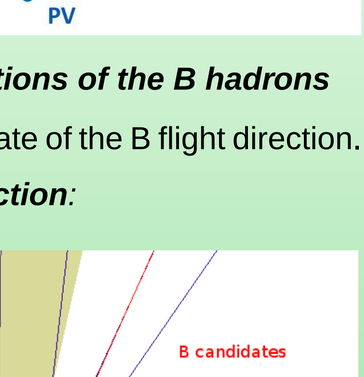



## Systematics

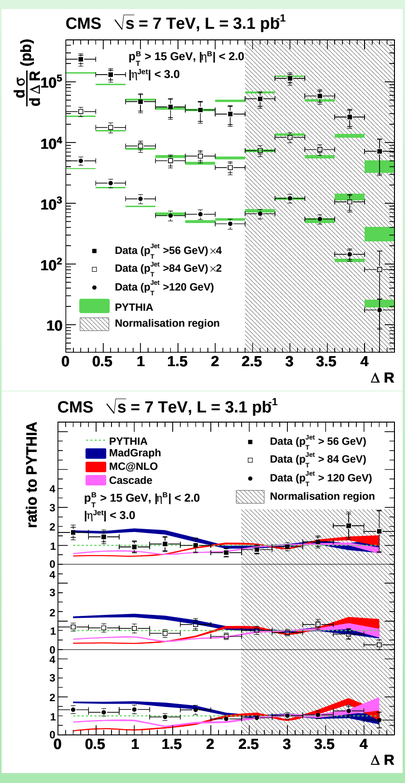
Data driven check using event mixing done to measure relative vertex reconstruction efficiency and the effect on shape of angular distribution.

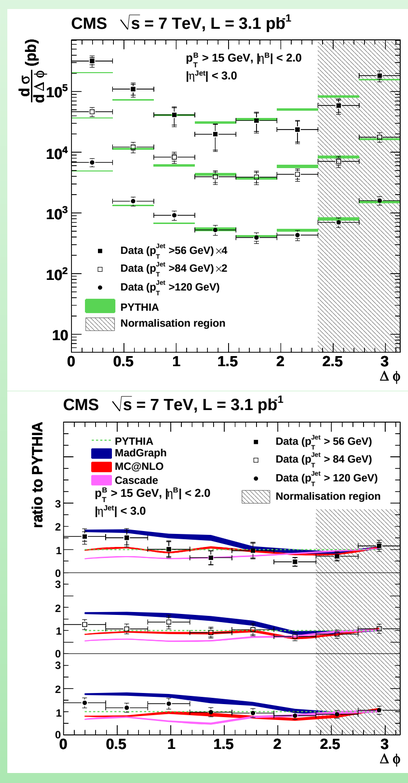


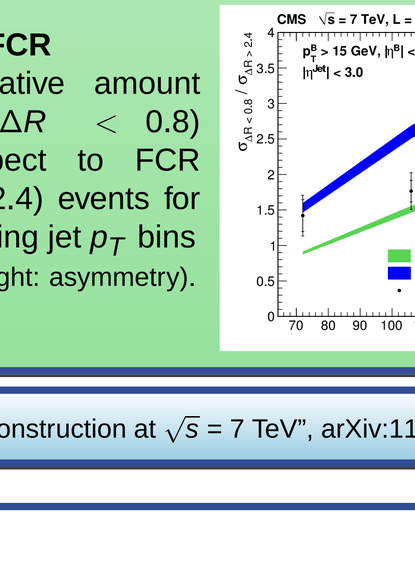



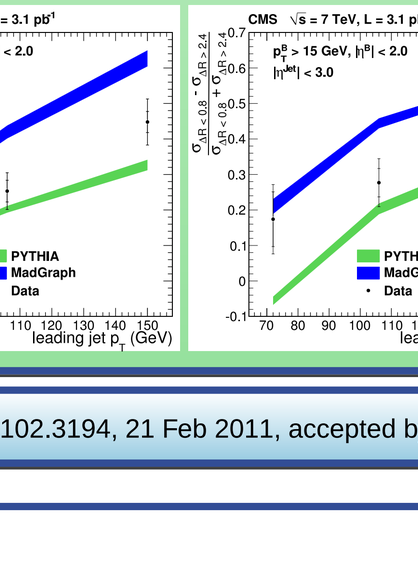

## Results

- Phase space: $|\eta| < 3$ for leading jet, $p_T > 15$ GeV and $|\eta| < 2$ for B hadrons.
- MC normalized to number of events with $\Delta R > 2.4$ or $\Delta\phi > 2.4$ (back-to-back topology, FCR region, indicated by shaded bands).
- For data the statistical (inner) and total (outer) errors are shown.




**GSP vs. FCR**
Show relative amount of GSP ($\Delta R < 0.8$) with respect to FCR ($\Delta R > 2.4$) events for three leading jet $p_T$ bins (left: ratio, right: asymmetry).







**Reference:** The CMS Collaboration, "Measurement of $B\bar{B}$ Angular Correlations based on Secondary Vertex Reconstruction at $\sqrt{s}$ = 7 TeV", arXiv:1102.3194, 21 Feb 2011, accepted by JHEP.