LHC Sensitivity to Wbb Production via Double Parton Scattering at 7 TeV

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Outline

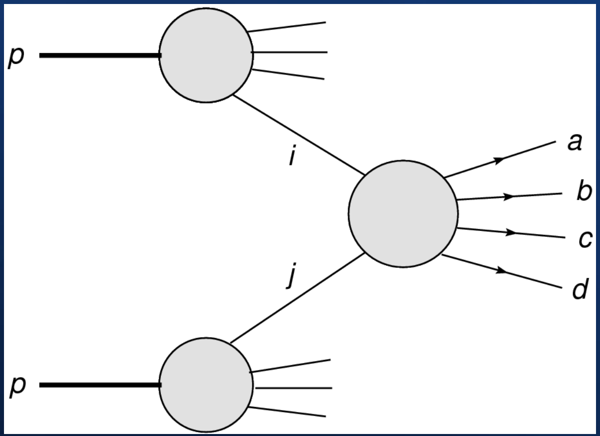
- What is Double Parton Scattering?
- Motivation
- Analysis details and backgrounds
- How to tell DPS from SPS
- Results
- Summary

What is Double Parton Scattering?

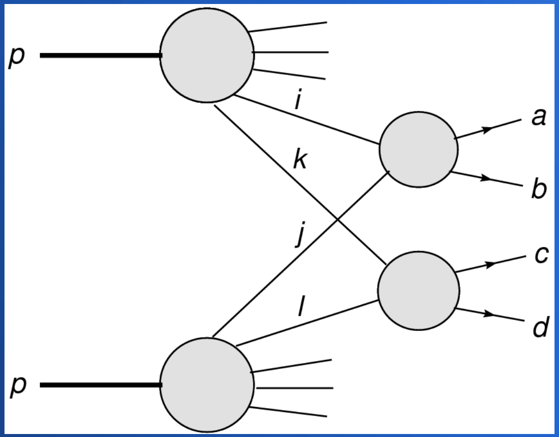
- Proton made of many partons
- More than one can scatter when struck
- Double parton scattering (DPS): 2 partons from one proton on 2 partons from another (2 nearly independent high scale interactions)

What is Double Parton Scattering?

SPS



DPS



Double parton distributions

- Assuming some kind of factorization holds,

$$d\sigma_{pp}^{DPS}=\frac{m}{2\sigma_{eff}}\sum_{ikjl} H_p^{ik}(x_1,x_2,\mu_A,\mu_B)\,H_p^{jl}(x'_1,x'_2,\mu_A,\mu_B)$$
$$\times\, d\sigma^{ij}(x_1,x'_1,\mu_A)\,d\sigma^{kl}(x_2,x'_2,\mu_B)\,dx_1\,dx_2\,dx'_1\,dx'_2$$

- We work in an approximation where scatterings are independent

$$H_p^{i,k}(x_1,x_2,\mu_A,\mu_B)=f_p^i(x_1,\mu_A)\,f_p^k(x_2,\mu_B)$$

  – Real goal is to measure

Why DPS?

- QCD beyond 1-1 scatterings and parton distributions
- Structure of proton?
- Additional background to complicated final states
  - Measuring one final state gives insight into size of other DPS contributions (σ_{eff})

Why Wbb?

- bb has large cross section (μb) $\rightarrow$ large probability of second scattering
- W $\rightarrow$ lepton easy to identify
- Simplest topologies of DPS (2 to 2)
- Possible background to new physics (WH)

Analysis details

- Most samples, including Wbb DPS and SPS generated with POWHEG-BOX processes
  - NLO tests how robust variables are in distinguishing DPS from SPS
- Cuts and simple detector effects (smearing) through analysis progam PEAT (G. Shaughnessy)

Basic cuts

- $p_{Tb} > 20$ GeV, $|\eta_b| < 2.5$
- 20 GeV $< p_{T\mu} <$ 50 GeV, $|\eta_\mu| < 2.1$
- $E_t^{miss} > 20$ GeV
- $\Delta R_{bb} > 0.4$, $\Delta R_{b\mu}$

Backgrounds

- Other processes contribute to or fake this final state

Process	Generator-level Cuts	Acceptance Cuts	$\not{E}_T \leq 45$ GeV	$S'_{p_T} \leq 0.2$
$W^\pm b\bar{b}$ (DPS)	10000	247	231	173
$W^\pm b\bar{b}$ (SPS)	44000	1142	569	114
$t\bar{t}$	225000	1428	290	13
$W^\pm jj$ (DPS)	476000	43.5	37.7	27.3
$W^\pm jj$ (SPS)	20300000	101	55.7	19.6
Single top	20000	492	168	15
$W^\pm bj$	153000	152	53.1	8.2

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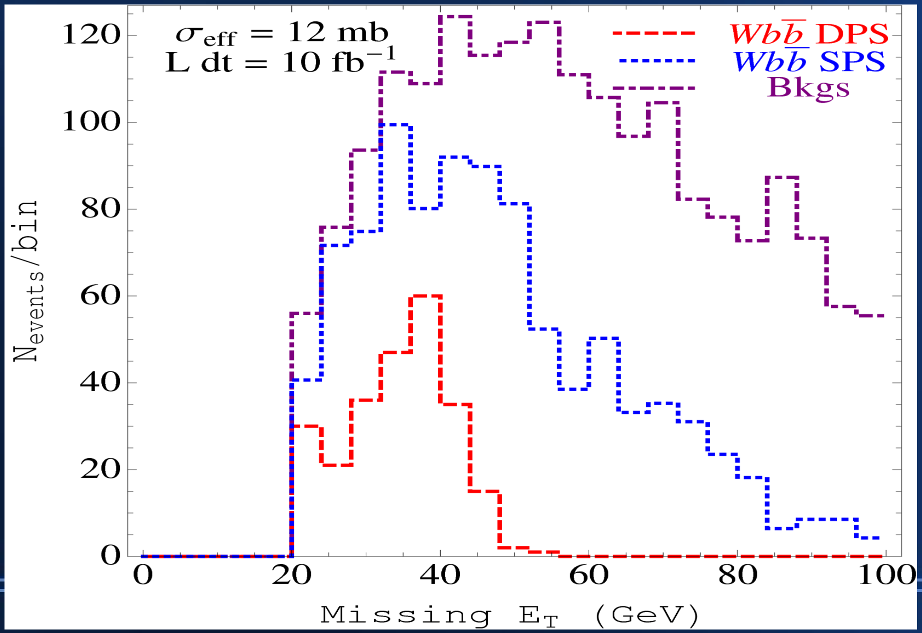
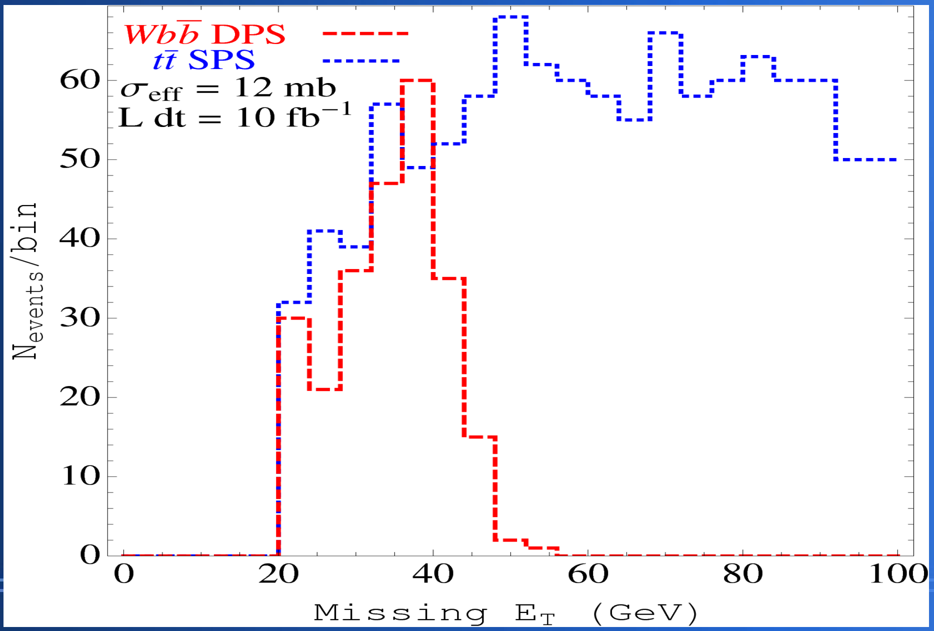
Tough!

Killing tt

- Attempts to remove tops via mass reconstruction messy, can remove signal
- Upper missing energy cut (45 GeV) very effective (tops have transverse momentum, mass to give)





Discriminating DPS and SPS

- We want kinematic variables that expose 2 to 2 processes from 2 to 4 processes
- Define (Berger, Jackson, Shaughnessy)

$$S'_{p_T} = \frac{1}{\sqrt{2}} \sqrt{\left(\frac{|p_T(b_1, b_2)|}{|p_T(b_1)| + |p_T(b_2)|} \right)^2 + \left(\frac{|p_T(l, \nu)|}{|p_T(l)| + |p_T(\nu)|} \right)^2}$$

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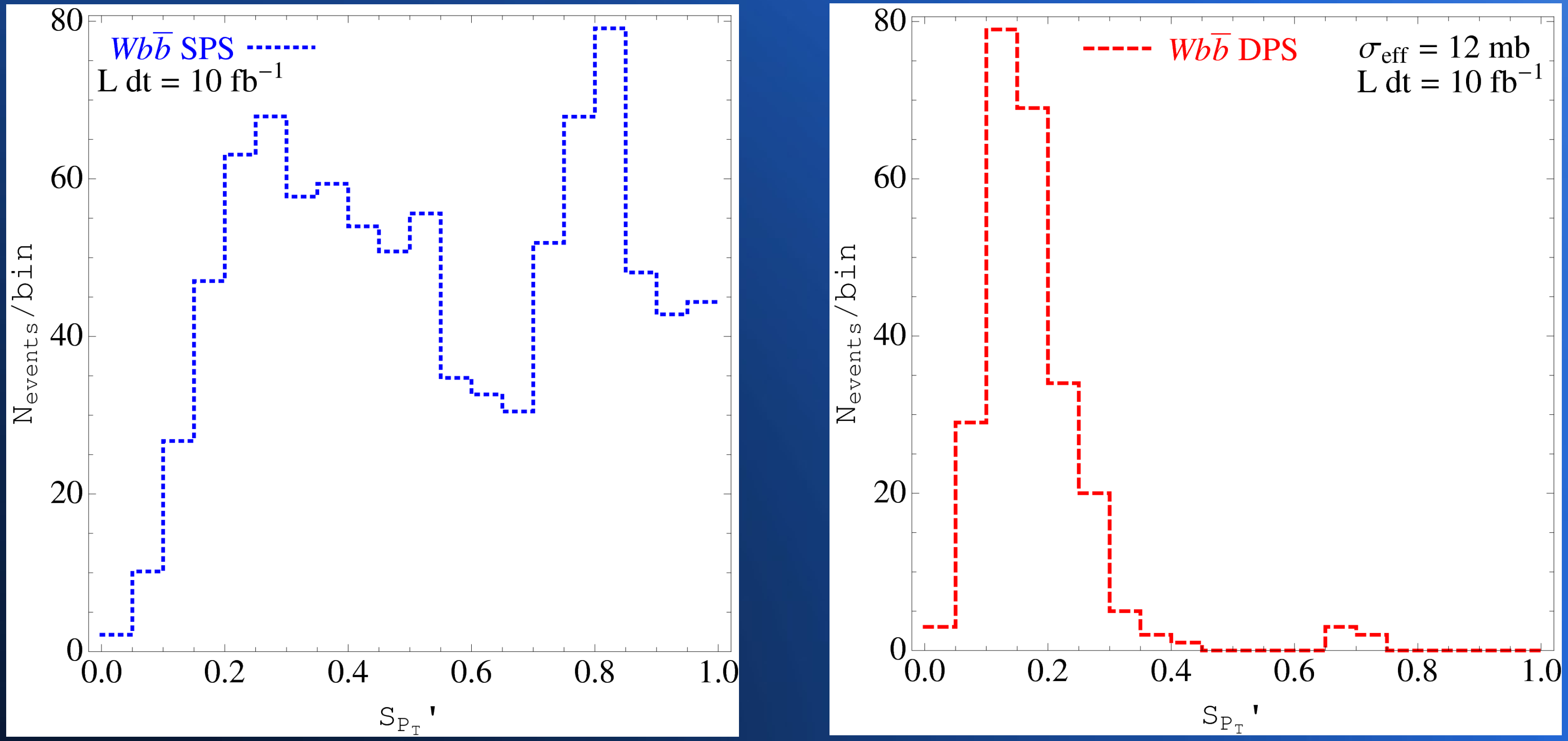
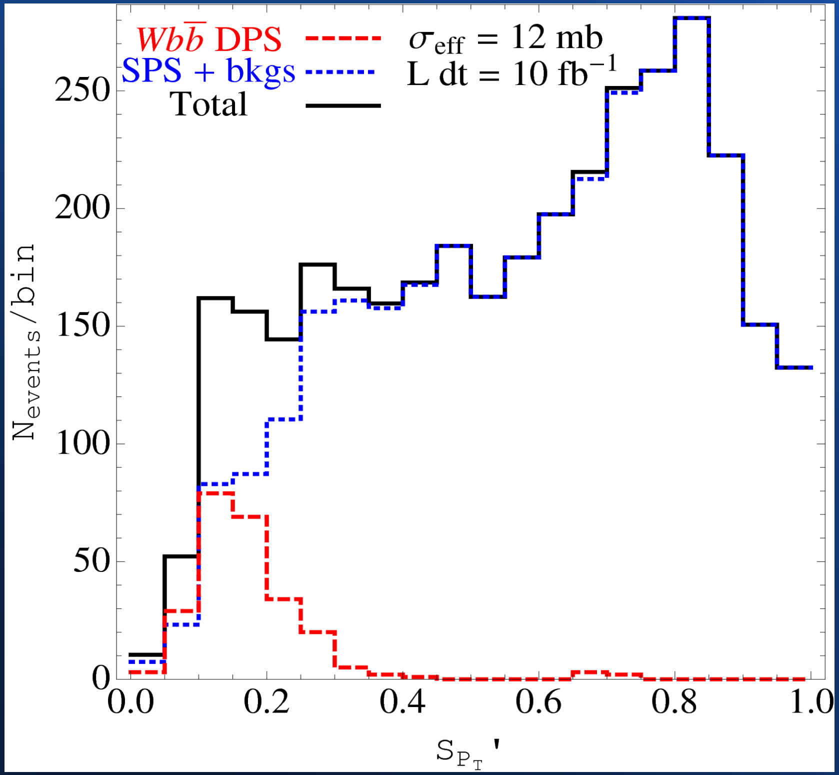
Go to zero for 2-2 in LO limit

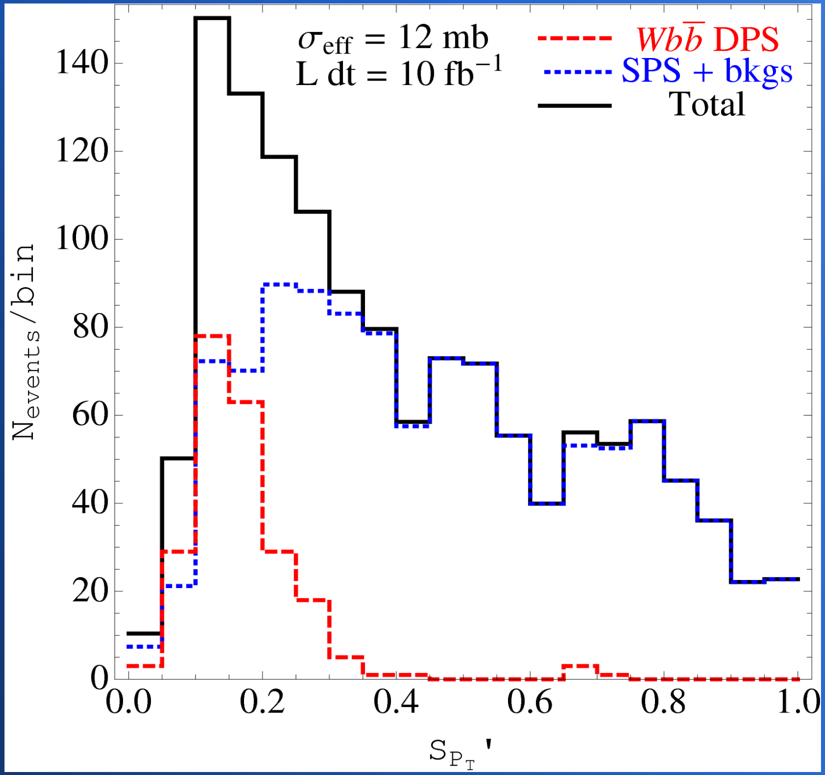
S_{pT}'



- See NLO effect on DPS, but clearly still peaked low

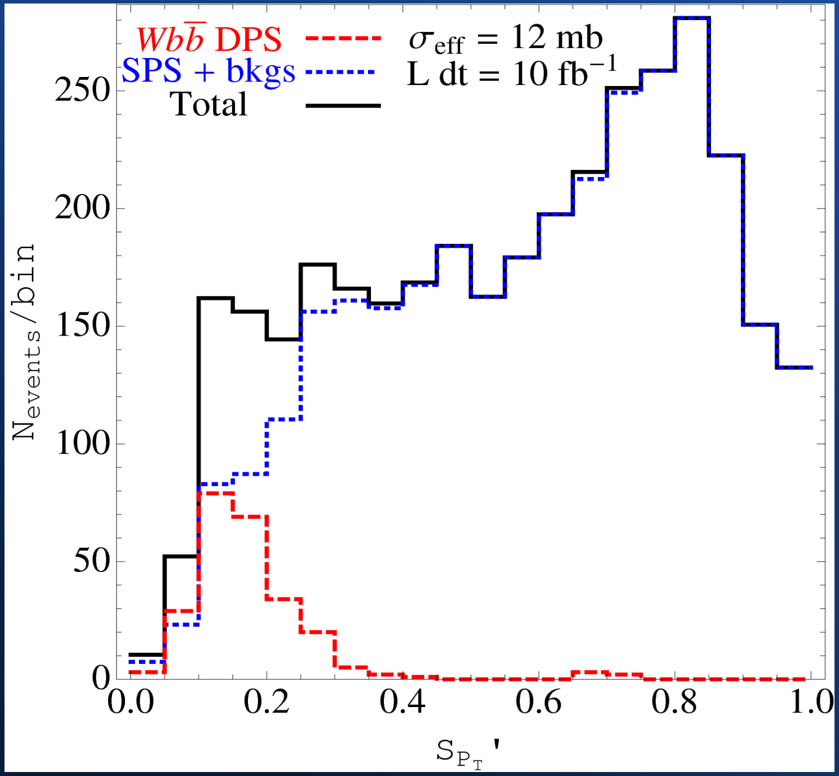
S_{pT}' (with backgrounds)

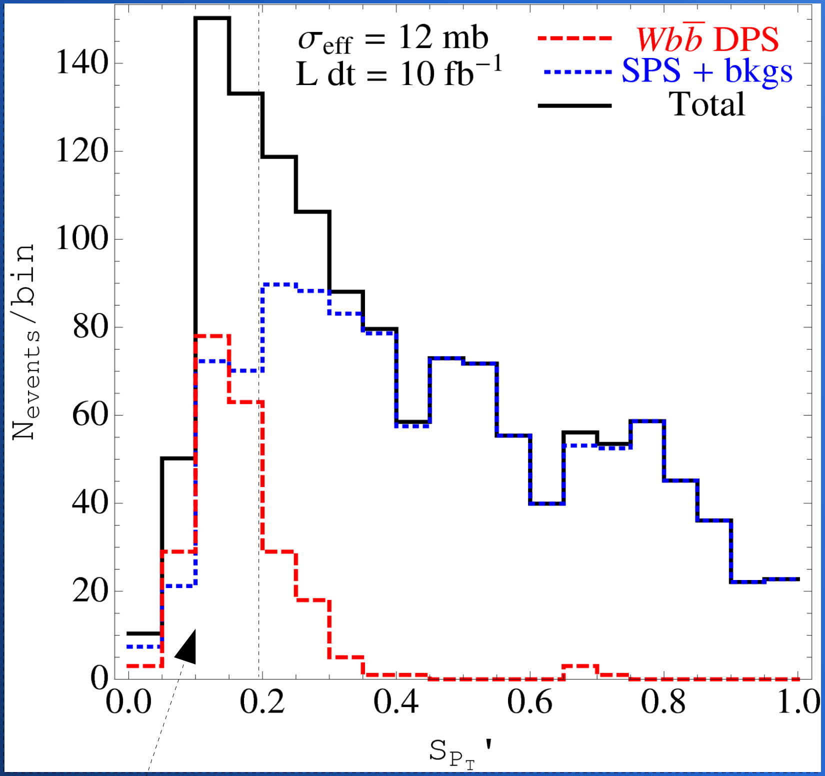




- Missing transverse energy cut sculpts to some extent; Wjj DPS dominates low S_{pT}' region

S_{pT}' (with backgrounds)





$$\frac{S}{\sqrt{B}} = 12.3$$

Other observables

- Interplane angle (Berger, Jackson, Shaughnessy)

  $$\cos(\Delta\Theta_{b\bar{b},l\nu}) = \hat{n}_3(b_1, b_2)\cdot\hat{n}_3(l,\nu)$$

  Uncorrelated in DPS

  - Requires reconstruction of neutrino longitudinal momentum

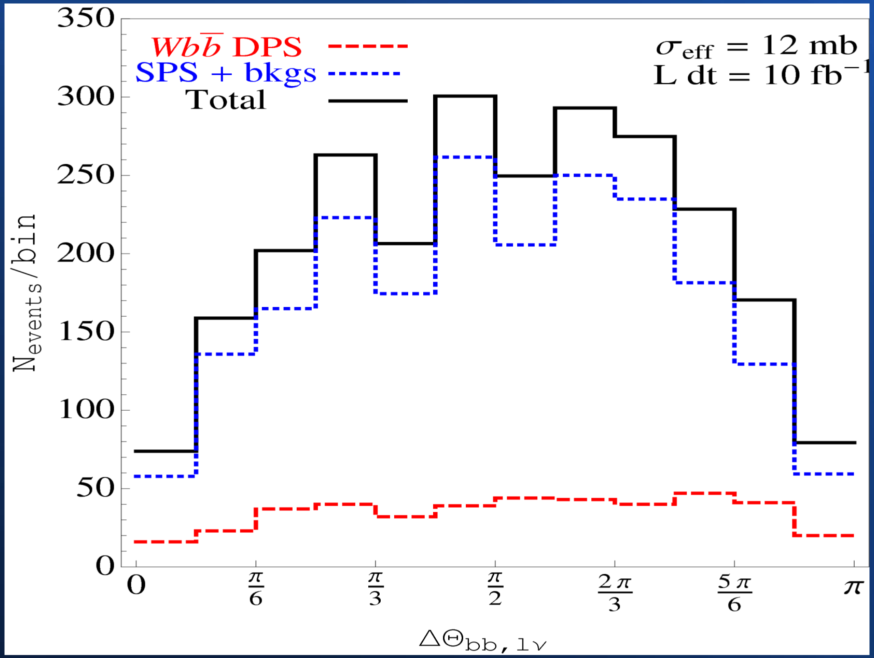
- Azimuthal angle between bb and lv systems

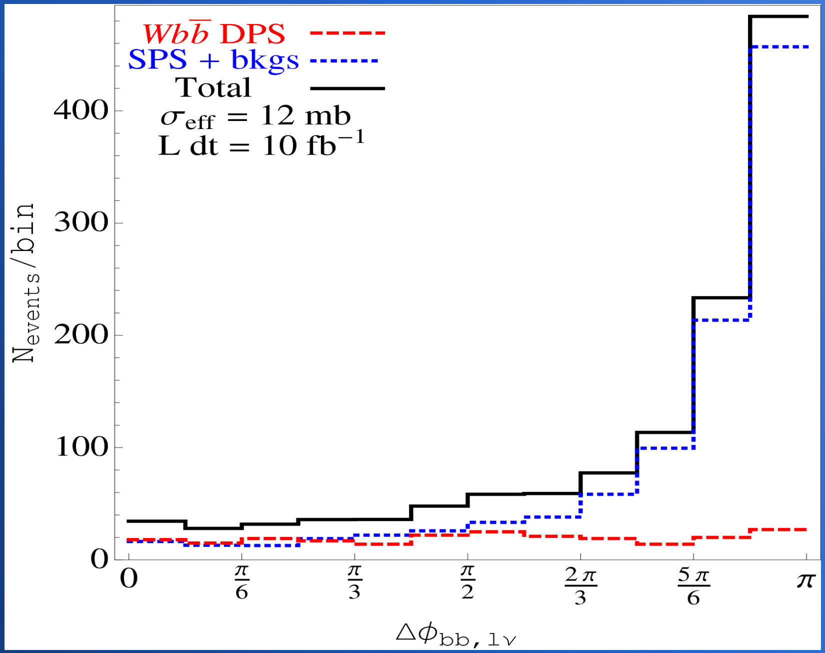
  $$\cos(\Delta\phi_{b\bar{b},l\nu}) = \hat{p}_T(b_1, b_2)\cdot\hat{p}_T(l,\nu)$$

  Also uncorrelated in DPS;
  generated through higher order/shower

  - Tend to be back-to-back in SPS (momentum conservation)

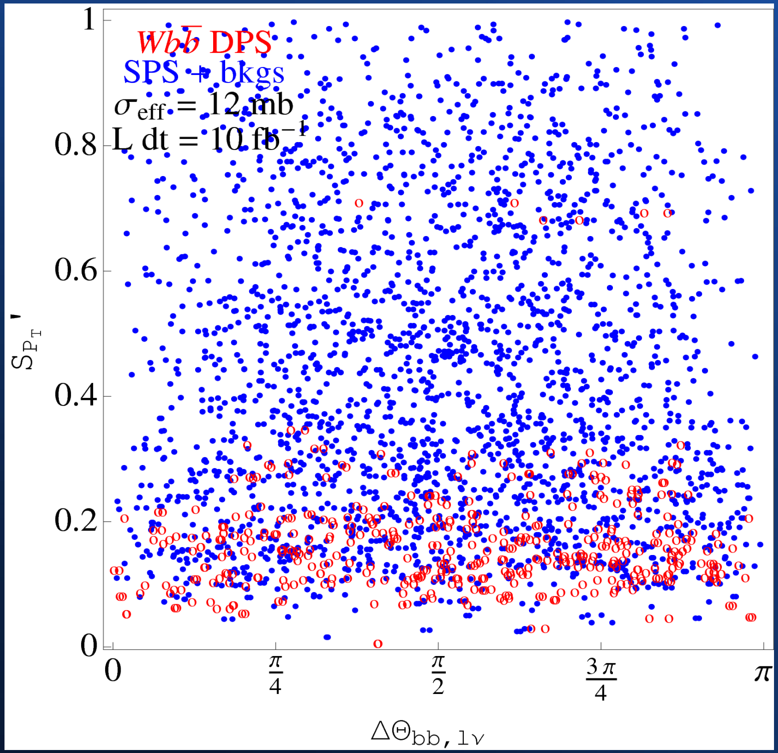
Other observables

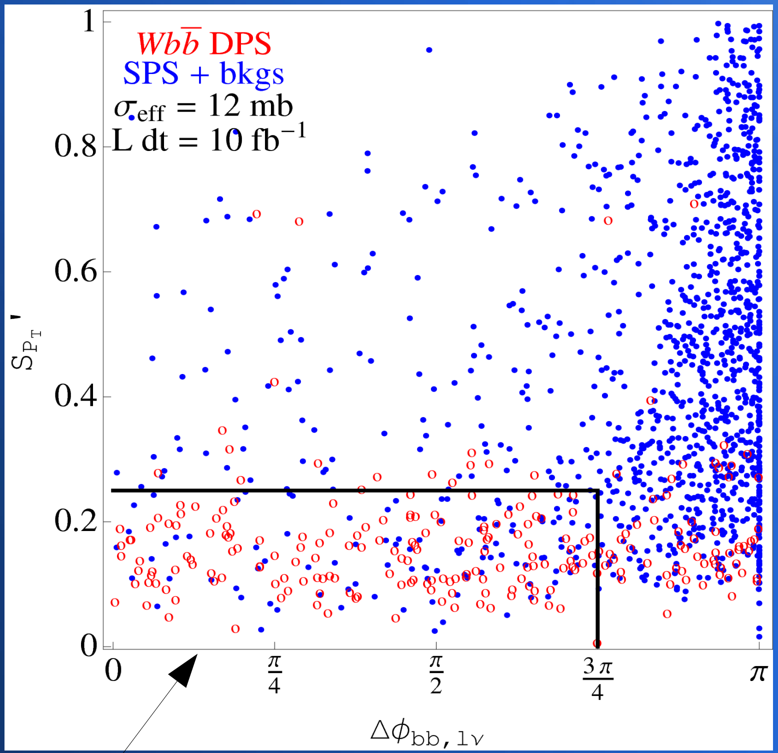




- Some correlation seen in SPS interplane angle; neutrino reconstruction ambiguity
- Very sharp distinction in azimuthal angle, even with NLO

2D distributions





$$\frac{S}{\sqrt{B}} = 15.2$$

Summary

- Double parton production can be important relative to single parton rate
- Variables designed to expose 2 to 2 processes can be used to differentiate DPS from SPS at excellent significance (12-15 σ)
- Once isolated, can determine σ_{eff} for this process, compare to others at LHC

New physics searches?