Strategies for the measurement of MPI at ATLAS

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on behalf of the ATLAS collaboration

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Introduction

MPI have been measured by a number of collaborations.

Essential ingredient of the description of the UE in all major Event Generators

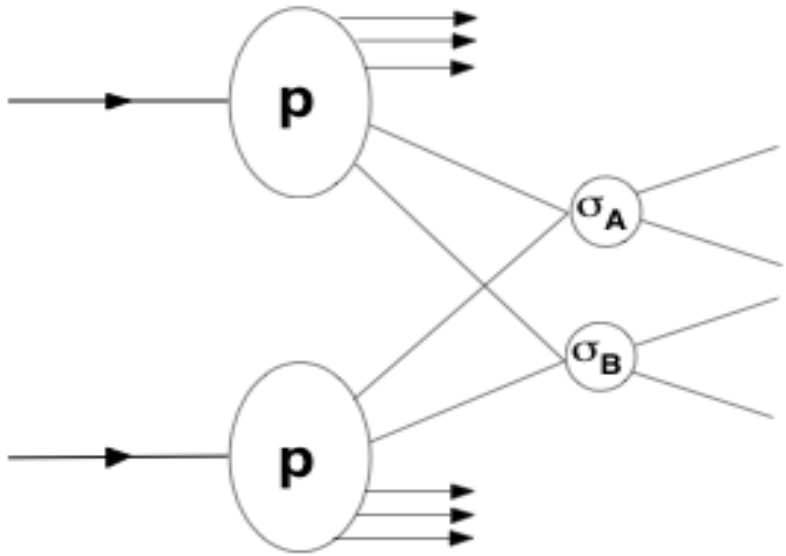
But: heavily tune dependent

Average number of (3−4 GeV p_T) multi-parton interactions per p−p collision for different Pythia tunes at 7 TeV:

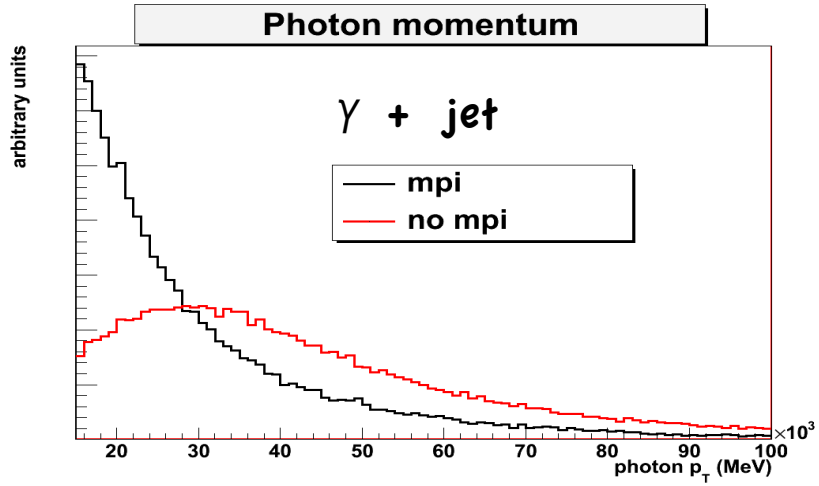
- Perugia0: 3.54
- DW: 7.37
- MC09c: 2.76
- AMBT1: 2.77

For comparison:

- Sherpa 1.2.2: 2.9 (pt>3 GeV)



$$\sigma_{DPI} = \frac{\sigma_A \cdot \sigma_B}{m\,\sigma_{eff}} \qquad m = \begin{cases} 2 & \text{if A,B indistinguishable} \\ 1 & \text{else} \end{cases}$$



Prior Art

- AFS collaboration: 63 GeV, $p_T > 4$ GeV
  - $\sigma_{eff} \sim 5$ mb
  - $\sigma_{DP}/\sigma_{dijet} = (6 \pm 1.5 \pm 2.0)$ %
- UA2: 630 GeV, $p_T > 15$ GeV
  - $\sigma_{eff} > 8.3$ mb
  - $\sigma_{DP} = (0.49 \pm 0.20)$ nb
- CDF: 1.8 TeV, 4 jets, $p_T > 25$ GeV
  - $\sigma_{eff} = (12.1\ ^{+10.5}_{-5.4})$ mb
  - $\sigma_{DP} = (63\ ^{+32}_{-28})$ nb
  - $F_{DP} = (5.4\ ^{+1.6}_{-2.0})$ %
- CDF: 1.8 TeV, γ + 3 jets, $p_T(\gamma) > 15$ GeV, p_T(jet) = 5-7 GeV
  - $\sigma_{eff} = (14.5 \pm 1.7\ ^{+1.7}_{-2.3})$ mb
  - $F_{DP} = (52.6 \pm 2.5 \pm 0.9)$ %
- DØ: 1.96 TeV, γ + 3 jets, 60 GeV < $p_T(\gamma)$ < 80 GeV, 1/fb
  - $\sigma_{eff} = (16.4 \pm 0.3 \pm 2.3)$ mb
  - $0.23 < f_{DP} < 0.47$

Motivation

- VBF Higgs analysis uses Jet veto
  - Irreducible background → Signal significance?
- How does f_{DP} depend on jet p_T
  - Looser cuts → more data
- Is the rate really independent of the processes?
- Number of multi-parton scattering events strongly dependent on generator tune
- (How) does σ_{eff} depend on the collision energy?

Channels

- Jet-based (look for 2 back-to-back pairs)
  - 4 jets (produced in abundance)
  - γ + 3 jets
    - σ(prompt photon) ≈ 30xTevatron
  - bbjj

Two approaches within ATLAS.

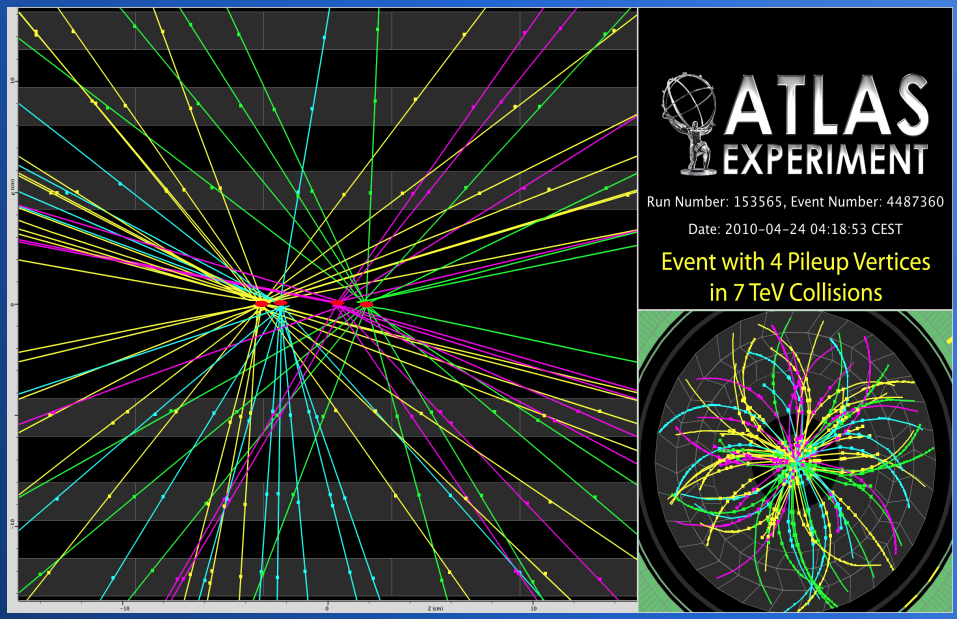
Showing the one relying more on MC here

- Heavy Vector Bosons (same sign leptons)
  - $W^+ W^+$
- Focus on jet-based searches

Model for Signal

- Looking for 4 jet (photon + 3 jets) signature
- 2 independent parton interactions

  back-to-back final states from each

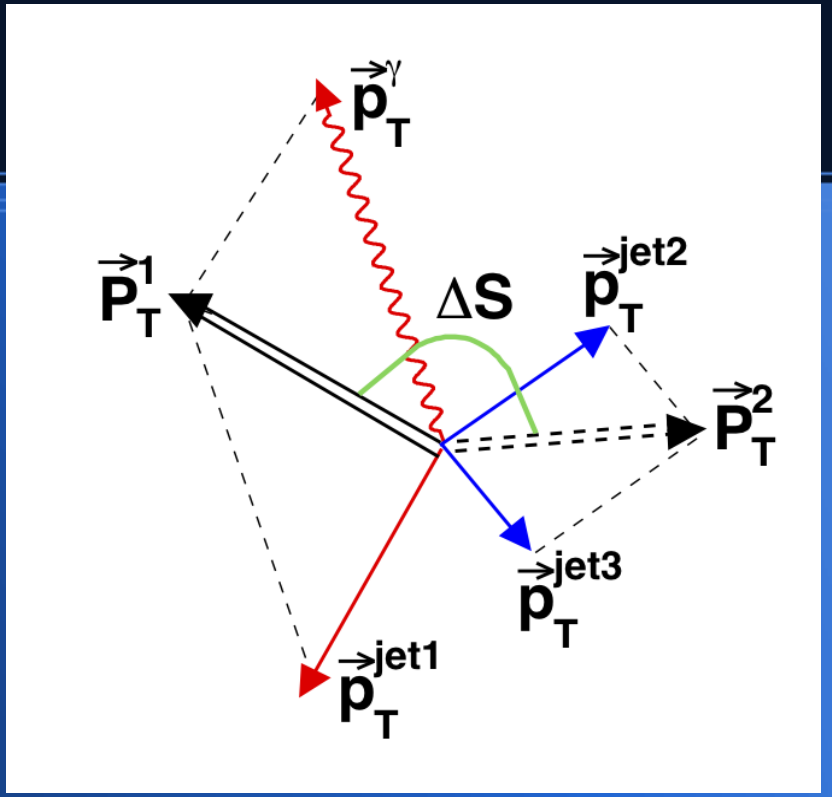


- Use 2 independent proton interactions (pileup)

  (modelled merging events from different samples here)

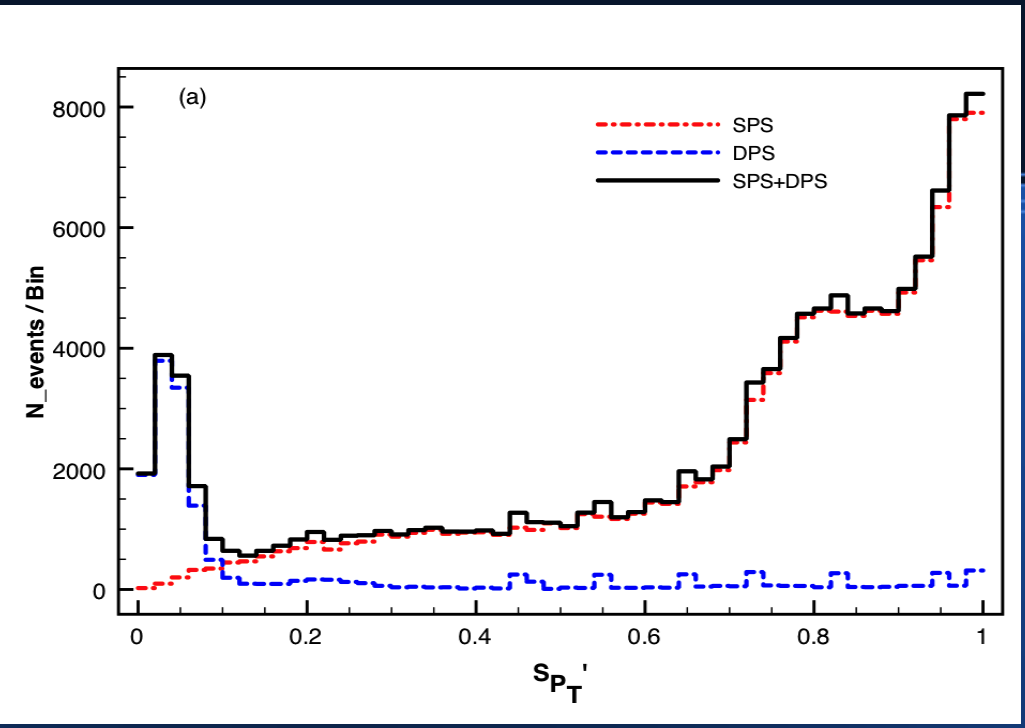
Search strategy

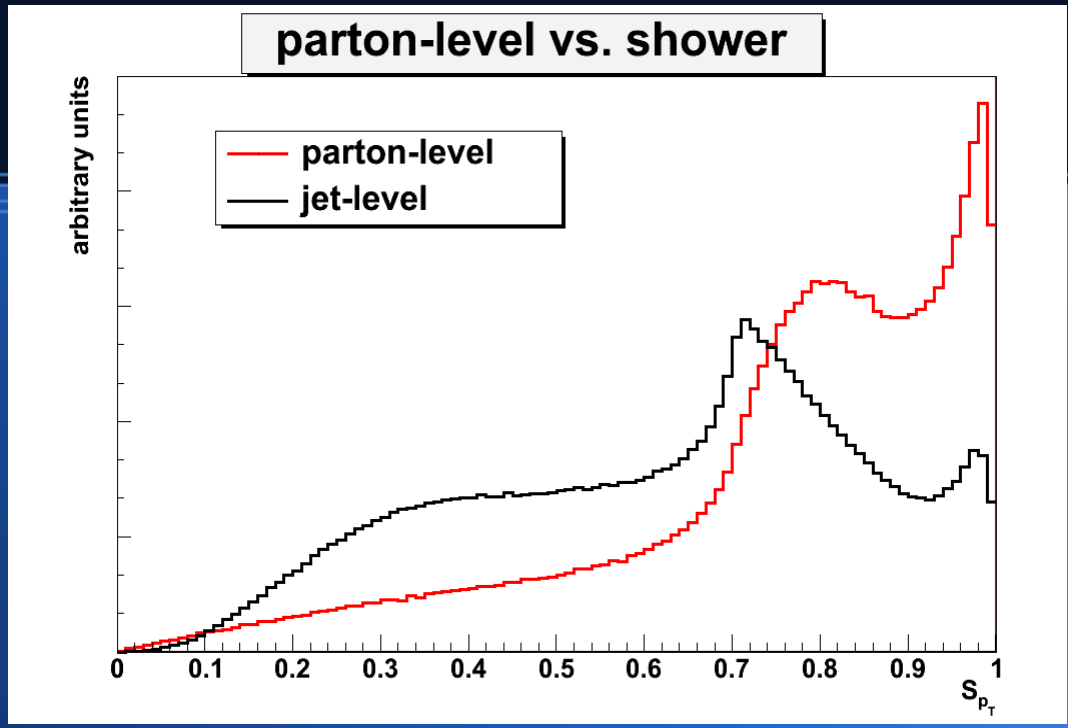
- Use pile-up to model kinematics of multi-parton interactions
  - 2 jets (photon+jet) from primary parton scatter
  - 2 jets from pile-up vertex
- Background modelled by Monte Carlo (MPI off)
- Use pairwise pt-imbalance in template fit to determine rates



$$s_{p_T} = \frac{1}{\sqrt{2}} \sqrt{\frac{\vec{p}_T(\gamma\, j_0)}{p_T^{\gamma} + p_T^{j_0}} + \frac{\vec{p}_T(j_1\, j_2)}{p_T^{j_1} + p_T^{j_2}}}$$

Distinguishing variable in bbjj





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Reproducing the parton-level distribution in Sherpa, and comparing to hadron shower

See also
http://mpi10.desy.de/

Convenient channel

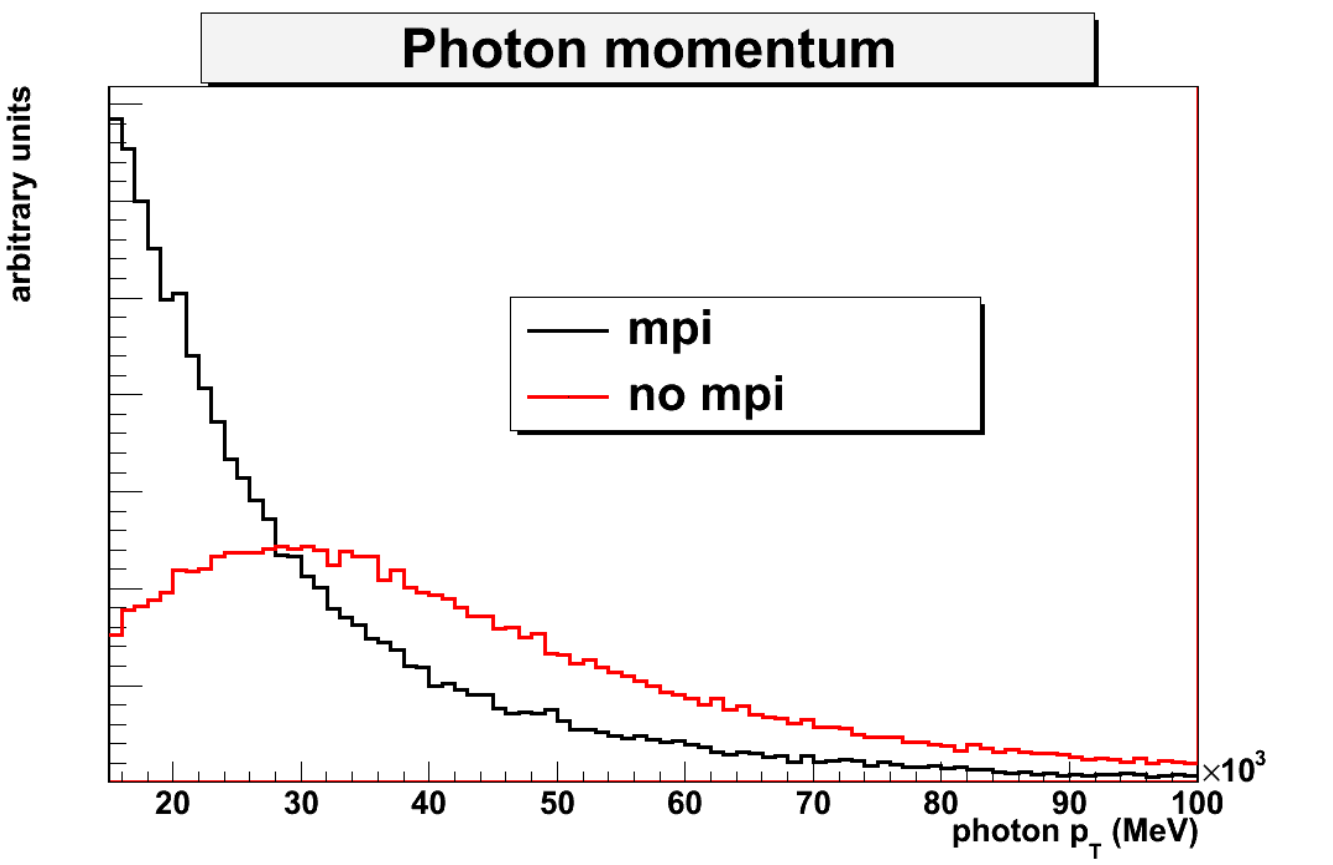
No ambiguity in matching

Immediate relevance to other channels

VH, Wbb, Zbb

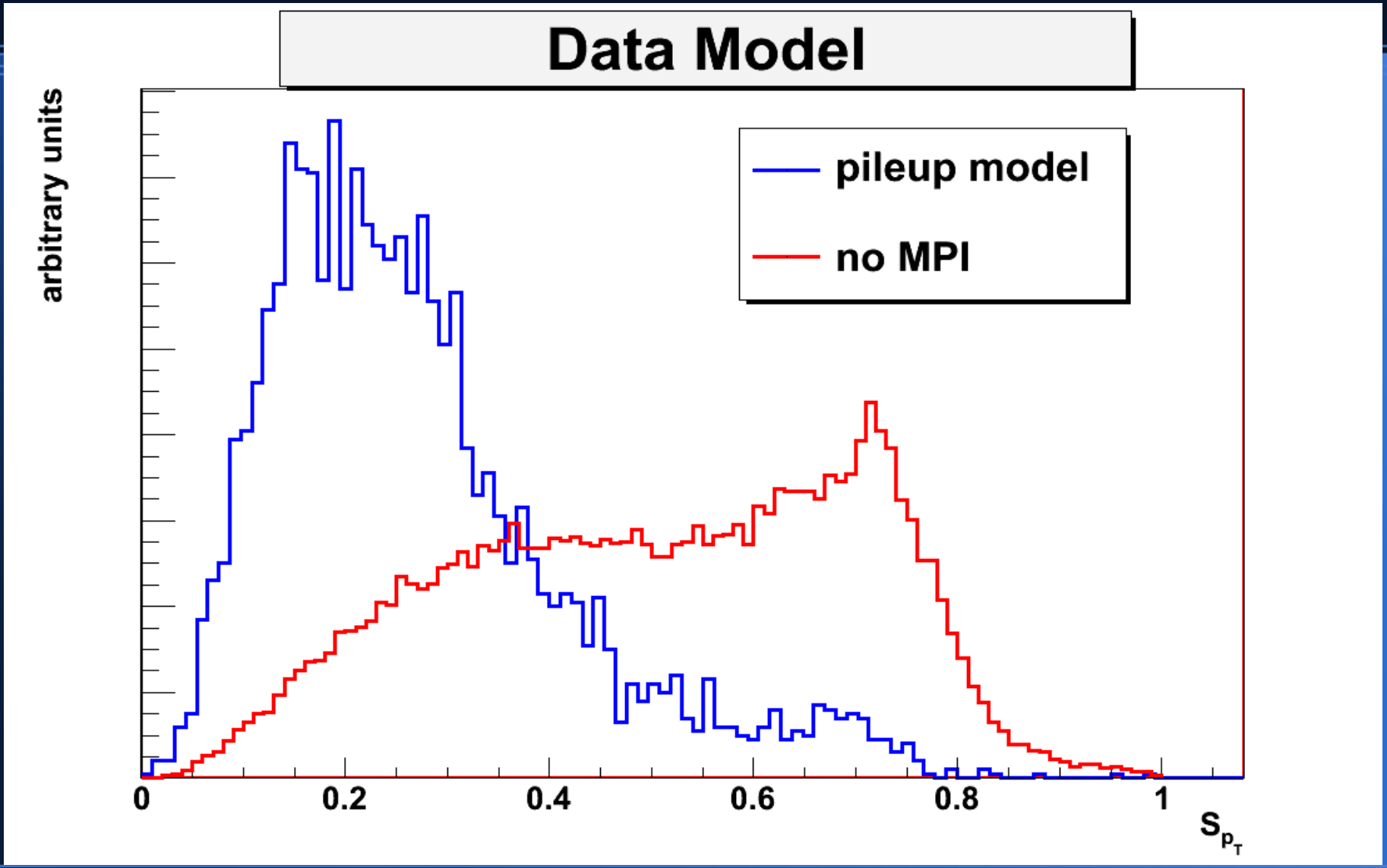
γ + 3 jets

Need to find balance between efficient trigger and enough MPI

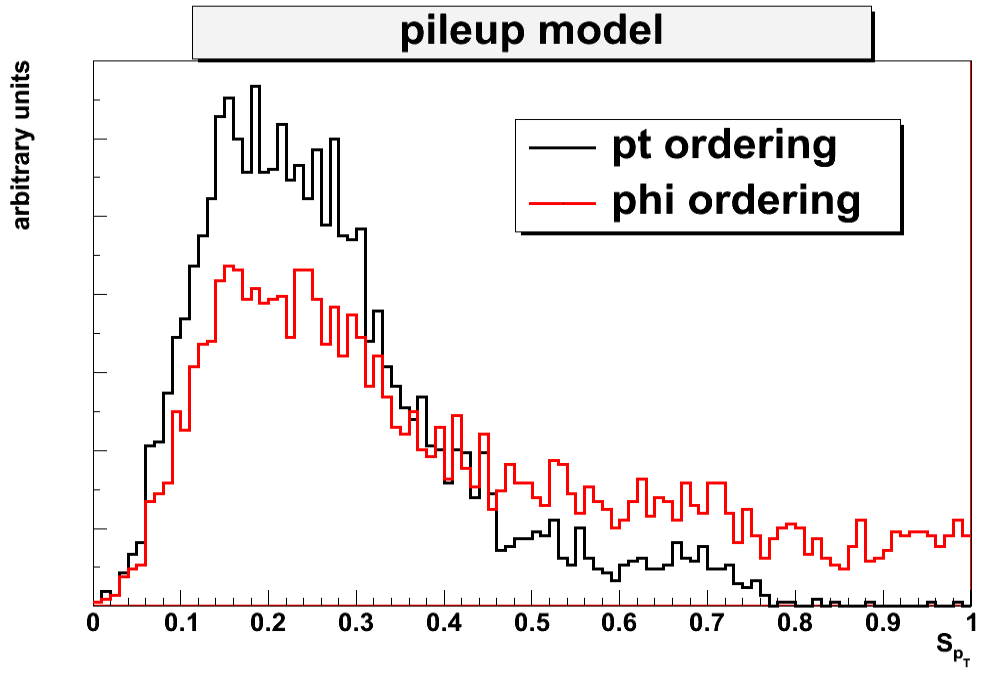


Trigger	Total Luminosity: (±11 %)
All	36.6 pb^{-1}
10 GeV photon	1.2 pb^{-1}
20 GeV photon	7.1 pb^{-1}
2x 10 GeV photon	15.8 pb^{-1}

Modelling signal and background



Possible selection bias



Different ways to resolve the ambiguity in pairing can lead to vastly different distributions

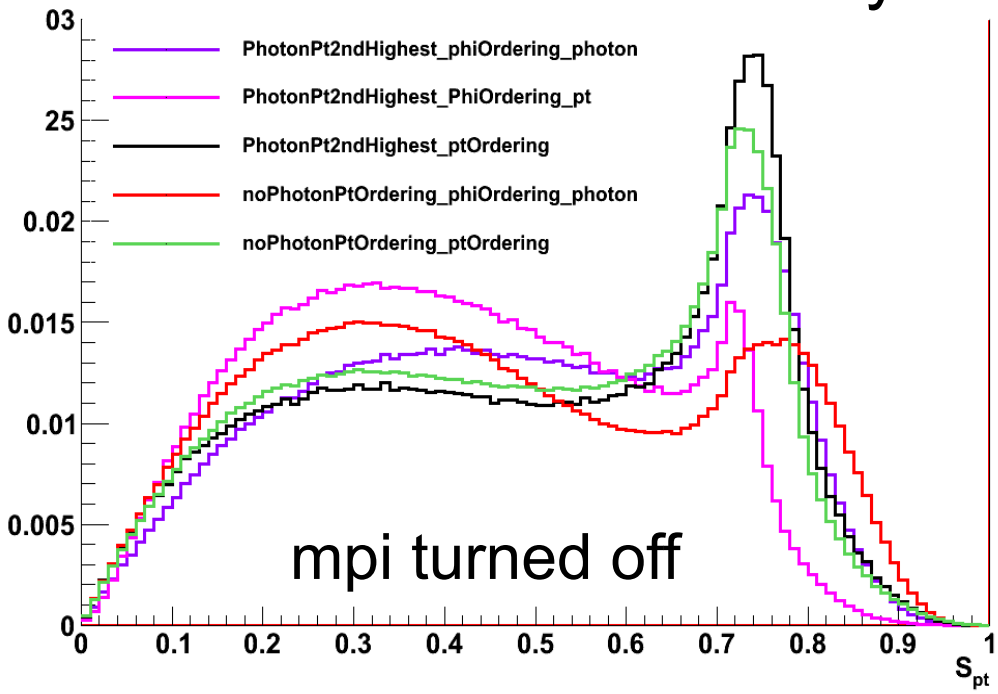
Difference between pairing

hard photon and hardest jet

versus

photon with most opposite jet

Parton shower-level study

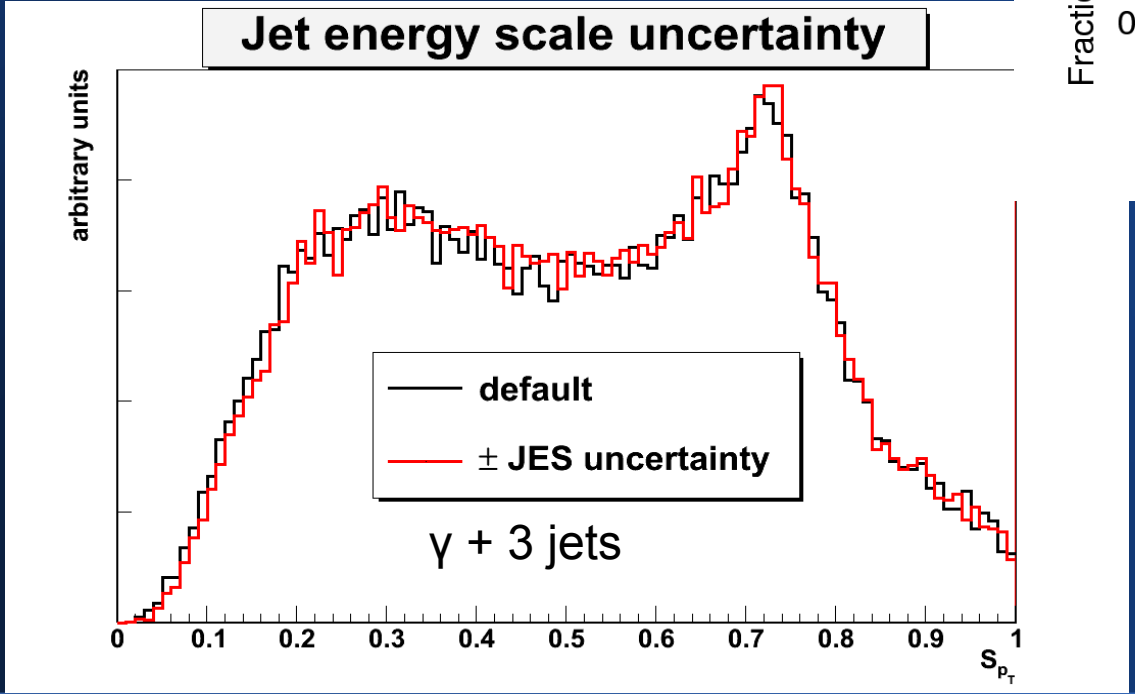


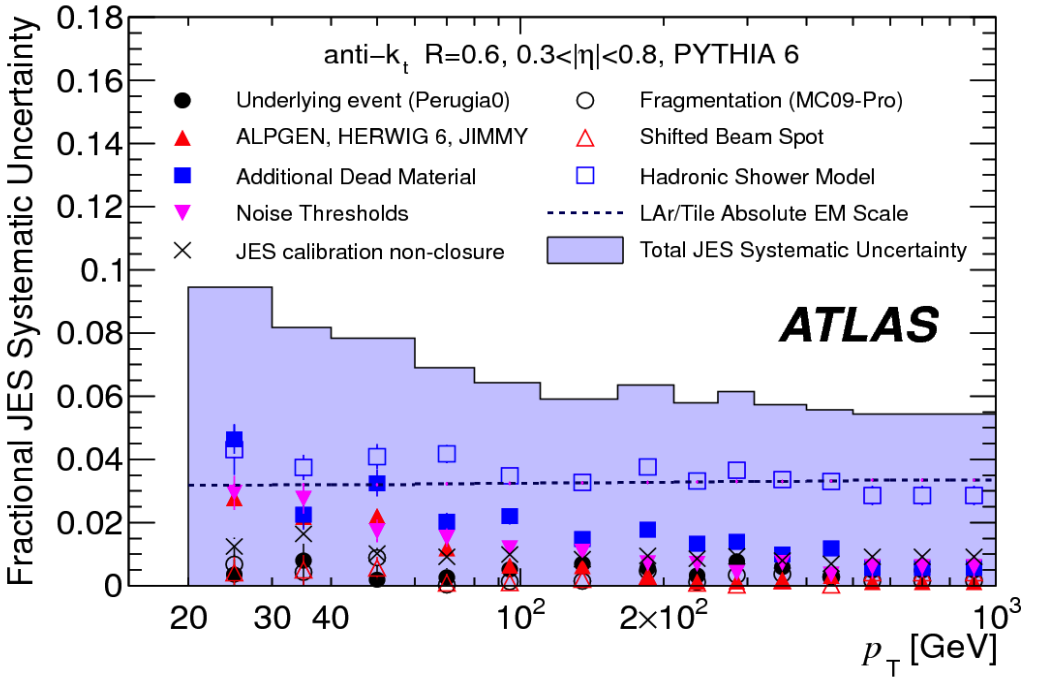
Selection

- Start with hard photon (pt > 15 GeV)
  - 80 % purity of the photon selection
- Sort jets by pt
  - Hardest jet > 20 GeV
  - All other jets > 15 GeV
  - Photon pt > second-hardest jet
  - $|\eta| < 2.5$
  - $\Delta R > 0.6$ pairwise between photon and 3 jets
  - $\Delta R > 1$ between soft pair

Jet Energy Scale uncertainty

- Jet Energy Scale uncertainty of 9% has a small effect on S_{pt}
- Notice systematic shift of low region



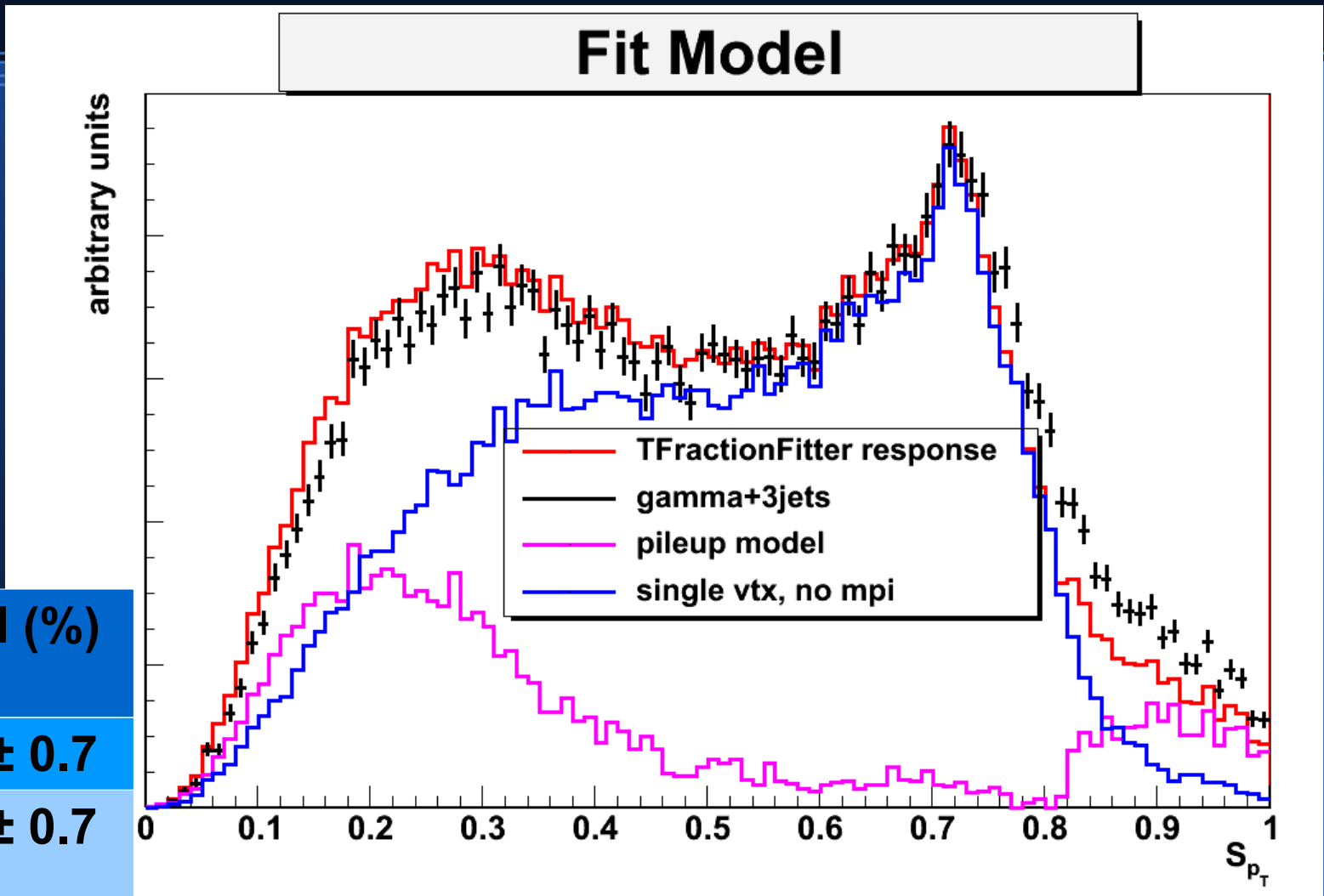


Folding Gaussian distribution (width=JES uncertainty) with px, py

Fit Results

Systematic study: Results for different data sets

Model	f_MPI (%)
baseline	22.5 ± 0.7
JES variation	21.1 ± 0.7
Phi ordering	48.7 ± 1.5

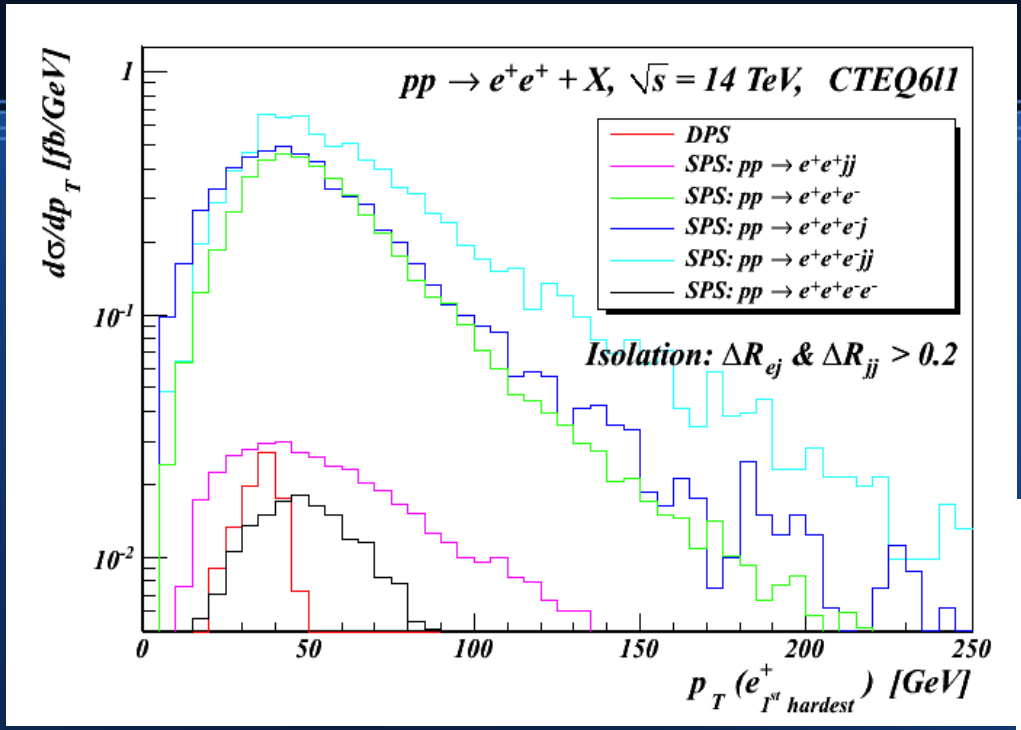


$W^+ W^+$

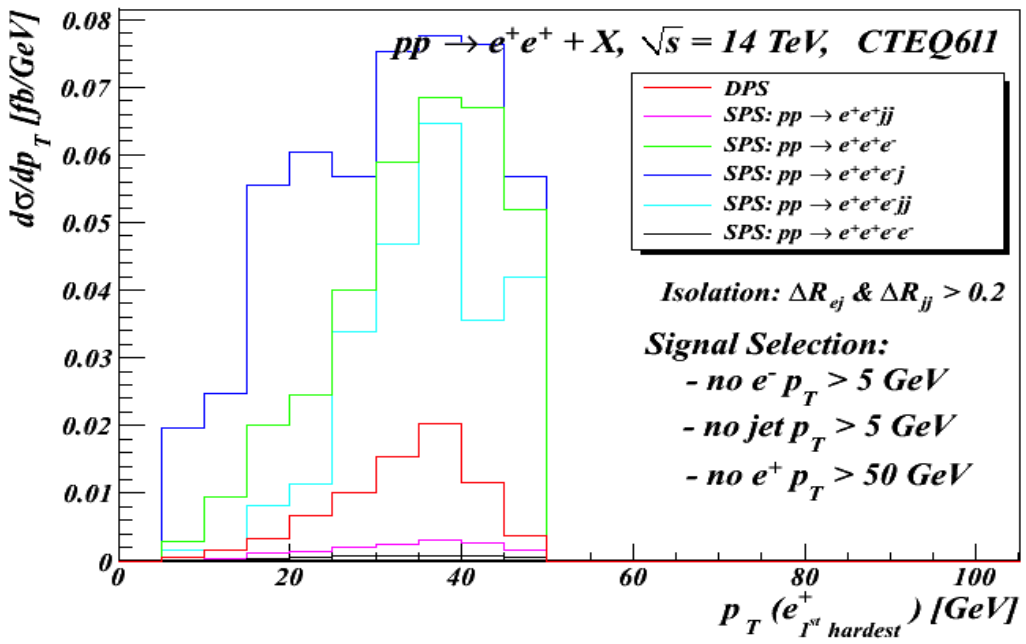
- Unique signature
  - Not much background to be expected from real physics
- Not accessible at other machines

  But
- Background estimation:
  - Same-sign / opposite-sign?

Very preliminary look ahead



- Preliminary set of cuts make this look feasible in simulation



- Also see Steve Kom's talk

  "Probing double parton scattering with same-sign W pairs at the LHC"

Summary

- ATLAS is actively investigating multi-parton interactions in various channels
  - Important to try different channels for cross-check
- Trying to take advantage of high luminosity and large beam energy
  - Using pileup to reduce reliance on generators
  - Investigating new heavy final states that weren't accessible before

Thank you

Questions?