Same sign WW production via DPS: 8 TeV and preliminary results from Run-II

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ON BEHALF OF CMS COLLABORATION

Introduction

- Why Multi Parton Interaction?
  - information on the spatial structure of the hadrons
  - correlations in the hadronic wave-function
  - production of high mass particles from MPI are backgrounds for NP searches

- Measure MPI with large Q^2 and compare with model derived from Low Q^2 measurements

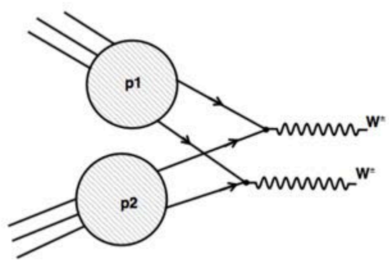
- Simple hypothesis for DPS:
  - No (or negligible) momentum correlations, the two scatters are independent
  - DPS cross section expressed as function of single cross section and an effective cross section
    - σ_{eff} characterize the transverse area of hard partonic interaction

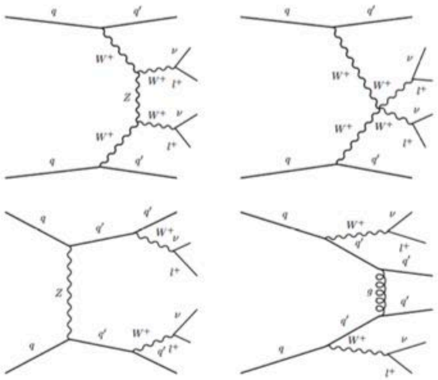
$$\sigma_{A+B}^{DPS} = \frac{m}{2} \frac{\sigma_A \cdot \sigma_B}{\sigma_{eff}}$$

- σ_{eff} theoretically independent of energy
  - Existing measurements at different energies have large systematics
  - No coclusions on the energy trend can be extracted
  - Measured σ_{eff} in the range 15-20mb

DPS same sign WW

- same-sign WW DPS to leptons is very promising theoretically
  - Single parton scattering ssWW production suppressed

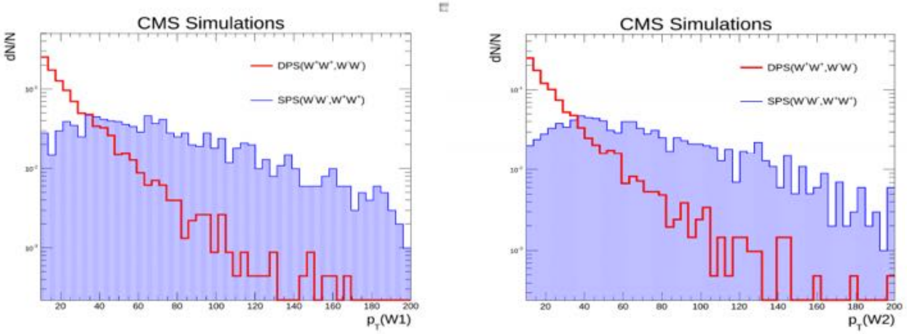




  - Very clean final states: two leptons with missing E_T
  - Good probe for correlation in the proton's pdf structure

Analysis overview

- DY process and WW production from SPS reduced by requesting same-sign bosons
  - Number of jets is another discriminant between SPS and DPS
- Moderate leptons p_T and Missig E_T
  - Difficult phase-space



- No b-jets at all
- Event selection
  - Essentially based on leptons momentum and isolation cuts
    - p_T (leading) >20GeV & p_T (sub-leading) >10GeV
    - Reject leptons from hadronic activities in the event
    - Third lepton veto (p_T > 10GeV)

Backgrounds

- Few backgrounds contribute after events selection

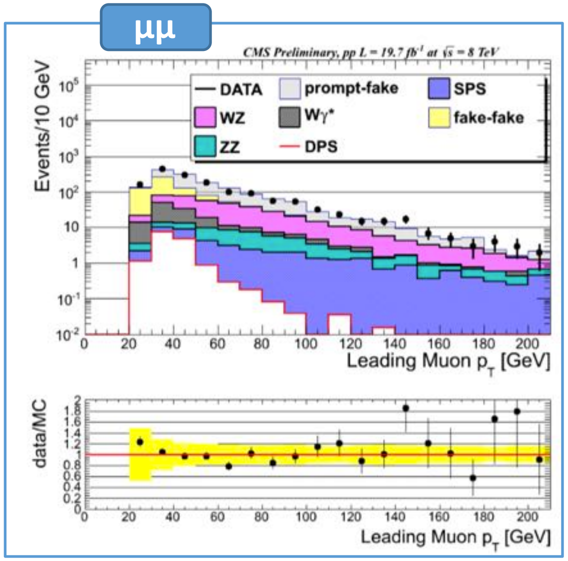
- Improve rejection is challenging
  - WZ production
    - Kinematically most similar to DPS ssWW
  - "fake leptons", mainly QCD and W+jets
    - Experimentally complicated
  - Smaller contribution from Wγ*, ZZ, WWW, charge-flip (mainly e)
  - DY and tt production (mainly eμ)

DPS in WW at 8TeV

- First search at CMS in RunI data
- Center of mass energy 8TeV
- Integrated luminosity 19.7fb^{-1}
- First performed only on μμ channel
- Then added also the eμ channel
- “Fake leptons” estimated from data
  - Leptons generated by heavy flavour decays reconstructed as prompt
  - Fake-rate method
- Boosted Decision Tree (BDT) trained in order to maximize sensitivity
- Public analysis: CDS 2103756 (only Dimuon) http://cds.cern.ch/record/2103756?ln=en
  - *Combined μμ and eμ channel will be published soon*

BDT

- BDT trained on 8 variables
  - **μμ**
    - p_Ts, Missing E_T, $\Delta\phi(\mu_{1/2},ME_T)$, $M_T(\mu_{1/2},ME_T)$, $M_T(\mu_1, \mu_2)$
  - **eμ**
    - p_Ts, Missing E_T, $p_T(l_1+l_2)$, $\Delta\phi(l_2,ME_T)$, $\Delta\eta(\mu_1, \mu_2)$, $\Delta\phi(l_1l_2,ME_T)$, $\Delta\phi(l_1, l_2)$
- Training sample
  - Signal : DPS MC (Pythia8 + CTEQ6L1 pdf set)
  - Backgrounds: WZ MC , QCD-W+jets (fake leptons) form data, Wγ*-ZZ-WWW MC

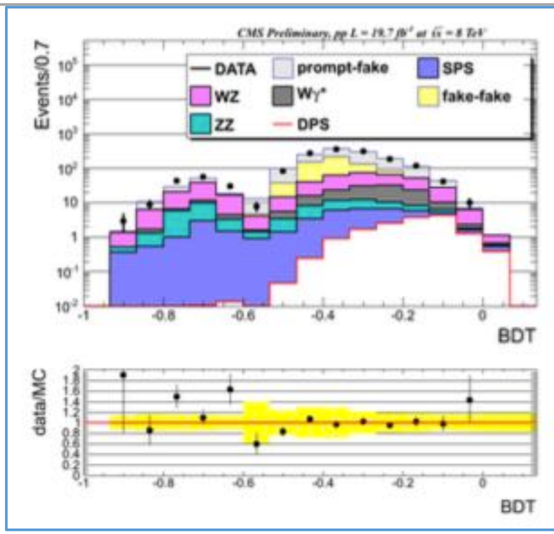


Systematic uncertainties

- Uncertainties on MC yield arise from
  - Luminosity Calib (2.6%)
  - Pileup reweight (4.5%)
  - Data/MC scale factor uncertainties from triggers, lepton ID and b-jet veto (~6-10%)
  - Theoretical uncertainties on PDFs, α_S and high-order corrections
    - Between 1 and 10%, depends on the particular proces

- Main systematic on data driven "fake leptons" (~40%)
  - Differences on the background shape (from control region)
  - Statistical uncertainties on fake rate

Results



- Yields extracted with a fit to the BDT output
  - Separately for μμ and eμ channels
- Major background from "fake leptons"

- CLs on DPS σ_{WW} extracted from fit results
- Dimuon and Electron-Muon combined results not yet approved
  - Only dimuon results

$$\sigma^{DPS}_{W^\pm W^\pm} < 1.12 pb$$

$$\sigma_{eff} > \frac{(\sigma_{W\to l\nu})^2}{2\cdot(\mathcal{B}^2_{W\to l\nu})\cdot\sigma^{DPS}_{W^\pm W^\pm}} = 5.91$$

DPS in WW at 13TeV

- DPS ssWW search extended to 13TeV RunII data
- $\sqrt{s} = 13TeV$
- $\mathcal{L}$=35.9fb^{-1}
- Both Dimuon and Electron-Muon channel exploited
- Almost same structure as the RunI analysis
  - Events selection
  - Data-driven method for “fake leptons”
  - BDT to maximize sensitivity

- Public analysis : CDS 2257583
  http://cds.cern.ch/record/2257583?ln=en

Comparison with previous analysis

- Different pdf tuning in pythia8

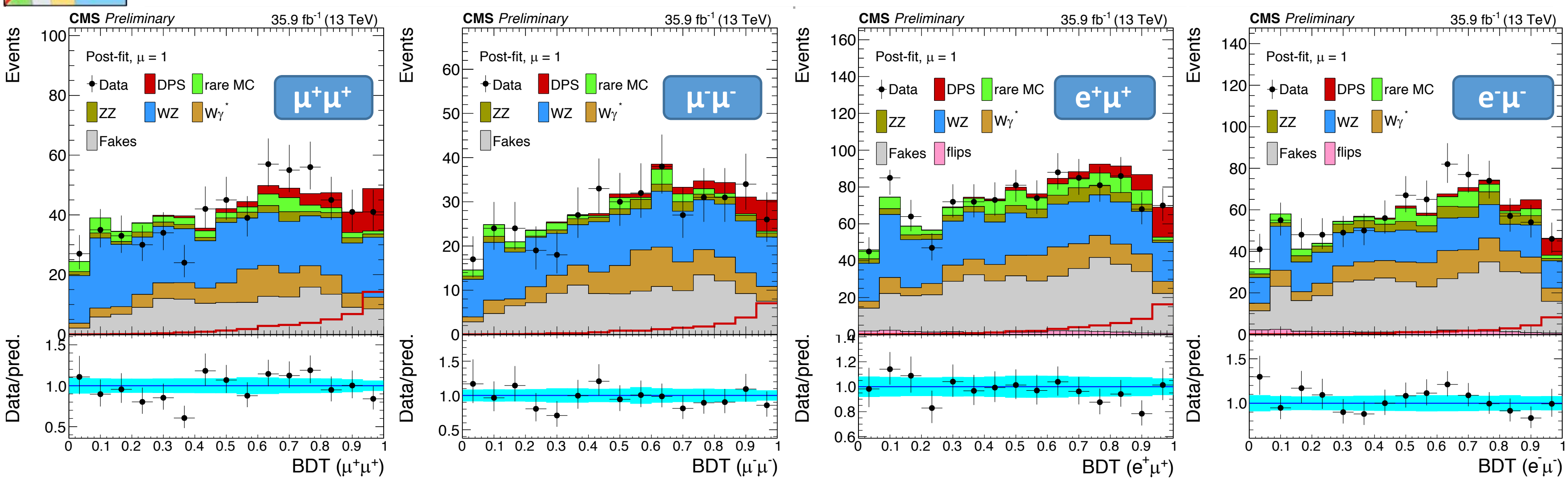
- Slightly different events selection
  - Harder cut on p_T : form 20(10) to 25(20) GeV for leading (sub-leading) lepton
  - Added a cut on the number of jets : $N_{jet}<2$ ($p_T>$ 30GeV)
  - Lowered the p_T threshold for third lepton veto (form 10 to 5 GeV)

- BDT trained only against WZ background
  - gives biggest separation to most similar background

- BDT trained on 11 variables
  - Added
    - $|\eta_1 x \eta_2|$
    - $\eta_1+\eta_2$
    - $M_{T2(l1,l2)}$

$$M_{T_2}=\min(\max(m_{T,1},m_{T,2}))$$

BDT output



High sensitivity → Low sensitivity

- BDT trained on the 4 different channel togheter
  - Then the output is analyzed separately
- Expected ~135 events on top of 2900 backgrounds
- Simultaneous Likelihood fit to all the channels

Systematic uncertainties

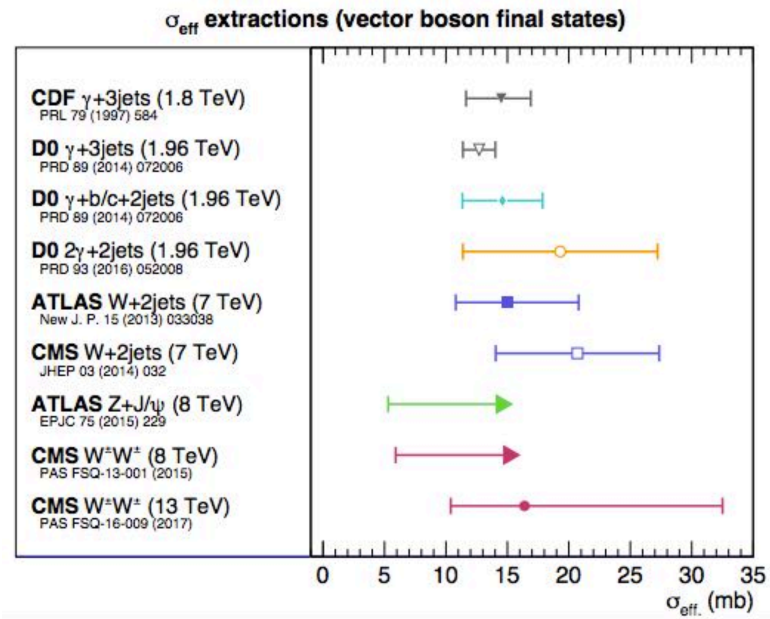
- Three main background components
  - **WZ production (~16%):**
    estimated from MC, shape and normalization uncertainty from MC simulation and data-MC comparison in 3l
  - **fake leptons (~30%):**
    estimated from data with fake-rate method, shape and scale uncertainty from variations in fake-rate and MC closure
  - **rare MC contributions (~50%):**
    $W\gamma^*$, ZZ, WWW, etc. from MC simulation estimate scale and shape uncertainties from variations in MC
- Theoretical uncertainties on PDFs
- Uncertainties constrained by likelihood fit

Results at 13TeV

- From likelihood fit expected and observed cross section (from pythia8 and/or factorization approach) are extracted
  - As well as significance and UL (no signal hypothesis)

	expected	observed
σ_{DPSWW}^{pythia}	1.64 pb	$1.09^{+0.50}_{-0.49}$ pb
$\sigma_{DPSWW}^{factorized}$	0.87 pb	
significance for σ_{DPSWW}^{pythia}	3.27 σ	2.23 σ
significance for $\sigma_{DPSWW}^{factorized}$	1.81 σ	
UL in the absence of signal	< 0.97 pb	< 1.94 pb

- First 3σ sensitivity measurement
- Observed an inclusive cross section of 1.09±0.50pb with a significance of 2.23 σ
- Interpreting the results as σ_{eff} measurement
  - $\sigma_{eff}=16.4^{+16.1}_{-6.0}$mb



Plans for 2018

- Wait for more data (end of 2017 – middle 2018) in order to improve significance on DPS ssWW
  - Higher statistics could make parton correlations visible
  - Other final states could become accessible
- In the meanwhile
  - Review and optimized selection and MVA method to improve sensitivity
- Preliminary study for other final states DPS
  - i.e. Open charm production could give a high separation between DPS and SPS

Conclusions

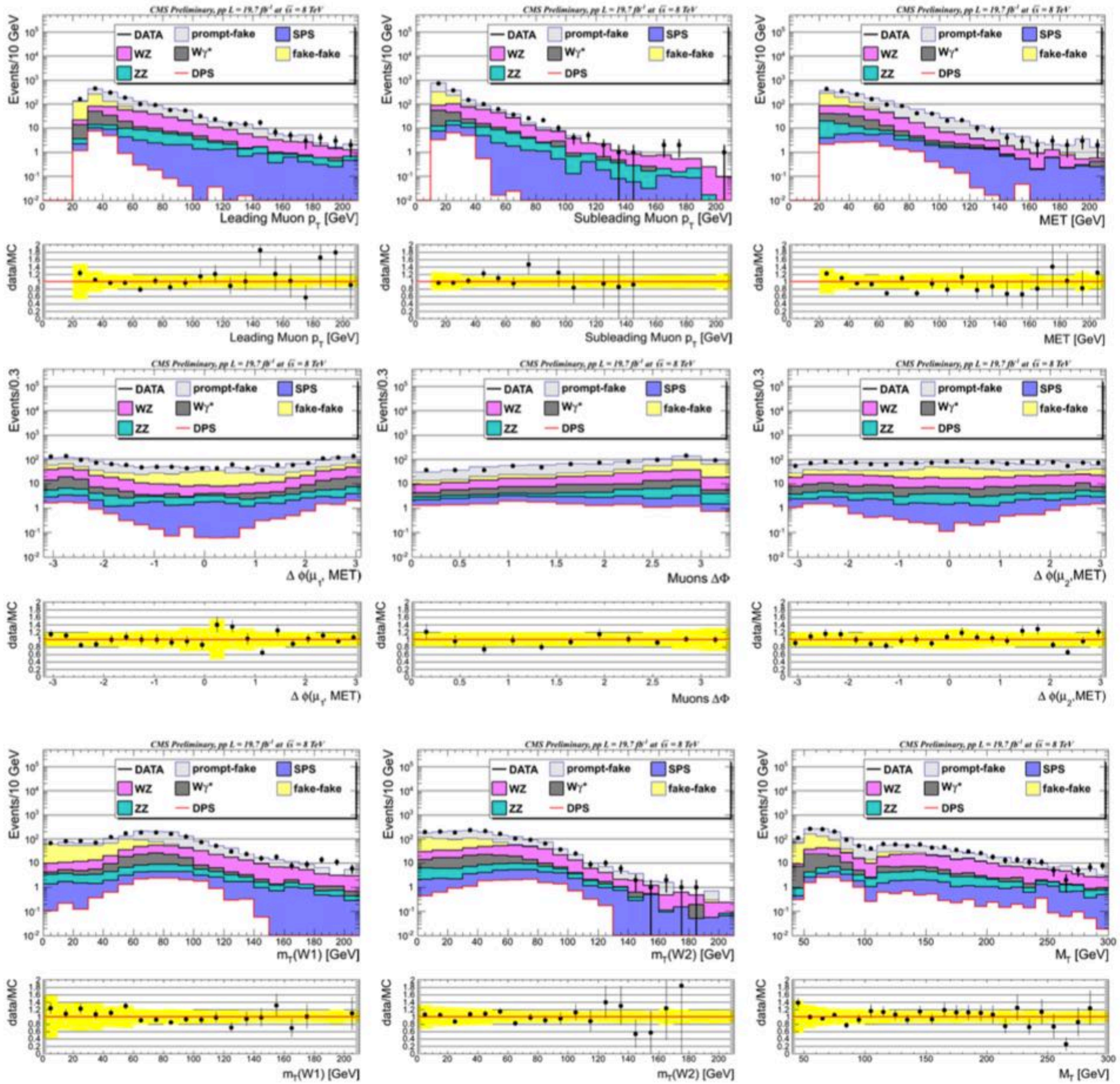
- DPS same-sign WW has been analyzed on both 8TeV and 13TeV data
  - Dimuon and dilepton channel
  - UL setted up at 8TeV on DPS cross section
  - 2.23σ significance reached ad 13TeV : DPS σ_{WW}=1.09±0.5pb
    - First MPI measurement at 13TeV

Backup

Results at 8TeV

Sample	Events ± stat. ± syst.
DPS	15.0± 0.5 ± 0.7
SPS	30 ± 1 ± 3
WZ	263 ± 3 ± 30
ZZ	40 ± 1 ± 2
$W\gamma*$	86 ± 3 ± 9
Prompt-Fake	709 ± 7 ± 213
Fake-Fake	381 ± 4 ± 229
Total	1523 ± 9 ± 314
Data	1539

BDT Variables (8TeV)

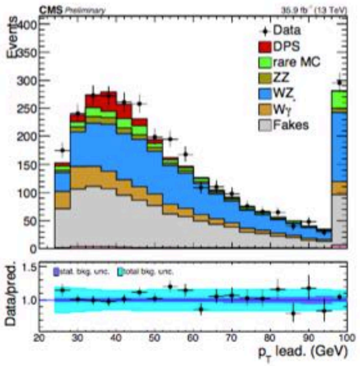


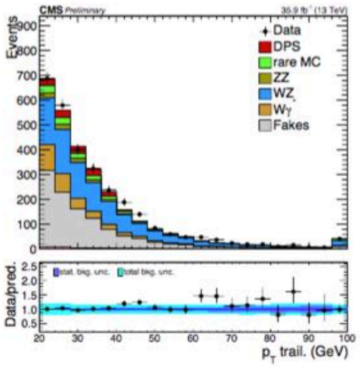
→ μμ

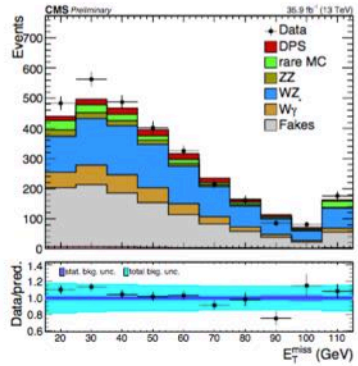
Results at 13TeV

	$\mu^+\mu^+$	$\mu^-\mu^-$	$e^+\mu^+$	$e^-\mu^-$
fakes	151.1 ± 26.6	132.7 ± 23.4	412.7 ± 47.2	341.4 ± 39.0
WZ	277.2 ± 28.1	164.5 ± 16.7	355.9 ± 36.1	228.1 ± 23.2
ZZ	24.8 ± 7.0	18.7 ± 5.3	57.8 ± 16.4	55.8 ± 15.8
$W\gamma*$	85.9 ± 27.5	73.1 ± 23.4	142.8 ± 45.7	127.7 ± 40.9
other rare	39.7 ± 15.0	20.2 ± 7.7	83.7 ± 31.7	49.4 ± 18.8
charge flips	—	—	20.4 ± 0.0	21.5 ± 0.0
background	578.6 ± 50.3	409.2 ± 38.2	1073.3 ± 83.0	824.0 ± 65.8
DPS WW	41.1 ± 1.0	20.6 ± 0.5	48.7 ± 1.2	24.1 ± 0.6
observed	604	411	1091	869

BDT Variables (13TeV)







→ **All channel togheter**