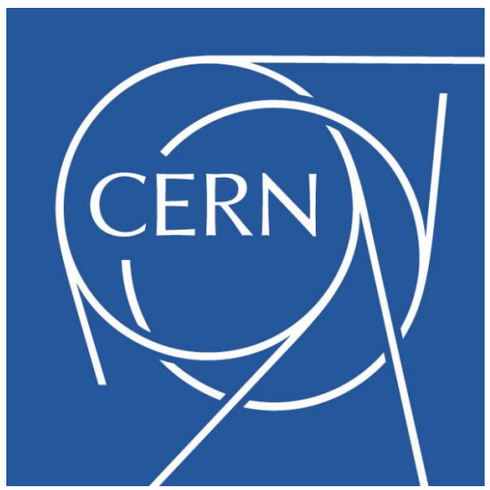
prospects for DPS and photon induced boson production at the HL LHC

workshop on the physics of HL-LHC
31st october 2017, CERN

marc dünser (CERN)
on behalf of ATLAS + CMS



introduction

DPS and photon induced processes usually ‘low-profile’ analyses

-> only very few studies related to the HL-LHC performed by the experiments

currently only one dedicated analysis for 3 ab^{-1} @ 14 TeV

-> studying the effects of the extended |eta| coverage in the CMS muon system on DPS WW

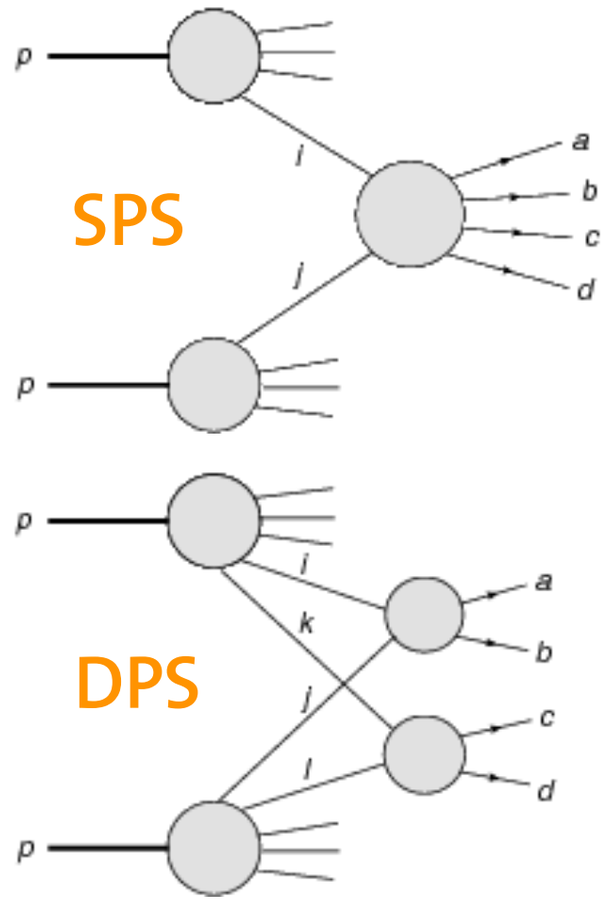
-> there is a lot more potential than that!

-> e.g. both phase-2 trackers will go to much higher |eta| perfect for electron channels in DPS (WW)

only little information on photon induced processes available

-> some considerations presented for AFP and CTPPS on the interesting topic of exclusive $\gamma\gamma$ ->bosons

DPS WW in a nutshell



looking for two Ws from two *separate* parton-parton interactions within a collision

-> theoretical models exist to describe this

simplest model assumes complete factorization of both hard scatters

-> go from this:

$$\sigma^D_{(A,B)} = \frac{m}{2}\sum_{i,j,k,l}\int \Gamma_{ij}(x_1,x_2,b;t_1,t_2)\hat{\sigma}^A_{ik}(x_1,x_1')\hat{\sigma}^B_{jl}(x_2,x_2') \times\Gamma_{kl}(x_1',x_2',b;t_1,t_2)dx_1dx_2dx_1'dx_2'd^2b$$

partonic cross sections

pdf terms

transverse distance between partons

-> to something much simpler, this:

$$\sigma^D_{(A,B)} = \frac{m}{2}\frac{\sigma^S_{(A)}\sigma^S_{(B)}}{\sigma_{\text{eff}}}$$

grows strongly with $\sigma_{A,B}$

DPS WW in a nutshell

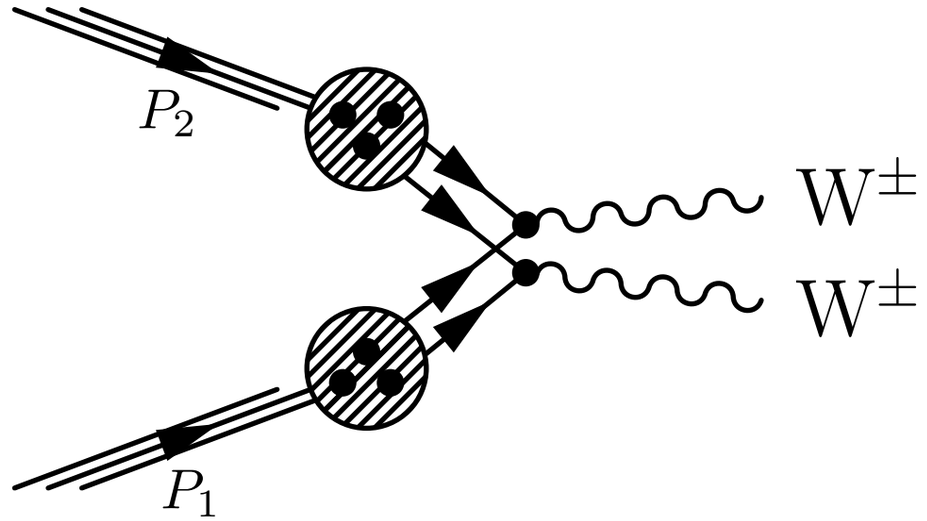
clearly this factorization approach must break down at some scale

-> momentum, spin, color effects...

DPS in WW production is (one of) the highest scale DPS processes which we can probe at the LHC

-> great process to study experimentally

-> especially in the $l^{\pm}l^{\pm}$ final state:
- low backgrounds
- clean final state
- SPS process negligible



expect an inclusive DPS WW cross section of around 1 pb at 13 TeV

-> large penalties on BR, charge, reco on top of that

DPS WW current status

analyses at 8 TeV and 13 TeV done at CMS

- -> 8 TeV : $\mu^{\pm}\mu^{\pm}$ and soon $\mu^{\pm}\mu^{\pm}$ + $e^{\pm}\mu^{\pm}$ combination
- -> 13 TeV: $\mu^{\pm}\mu^{\pm}$ + $e^{\pm}\mu^{\pm}$ public with 36 fb^{-1}

currently pushing towards observation levels with 100 fb^{-1} @ 13 TeV

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

CMS PAS FSQ-16-009

currently ~50% uncertainty on the cross section

- -> still very much statistically limited
- -> **need much more luminosity!**

DPS WW - physics case @ HL LHC

so why is this process interesting to begin with?

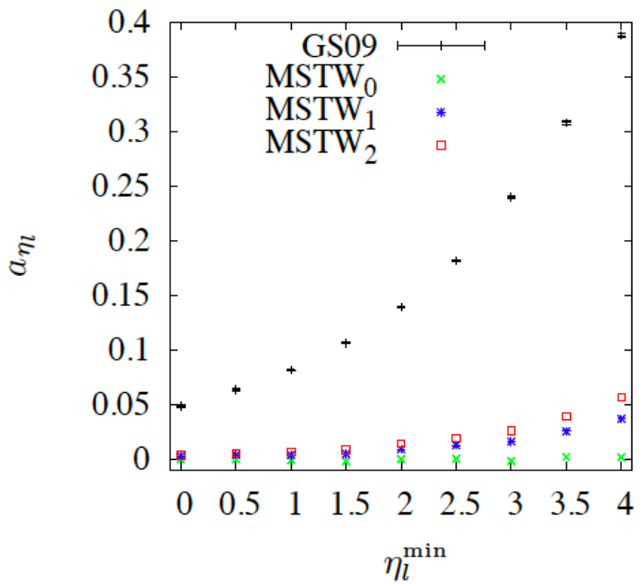
-> very sensitive to non-factorization models

-> we can learn something about the proton structure!
(and improve MC models)

non-factorization predicts observable differences w/r/t current MC models

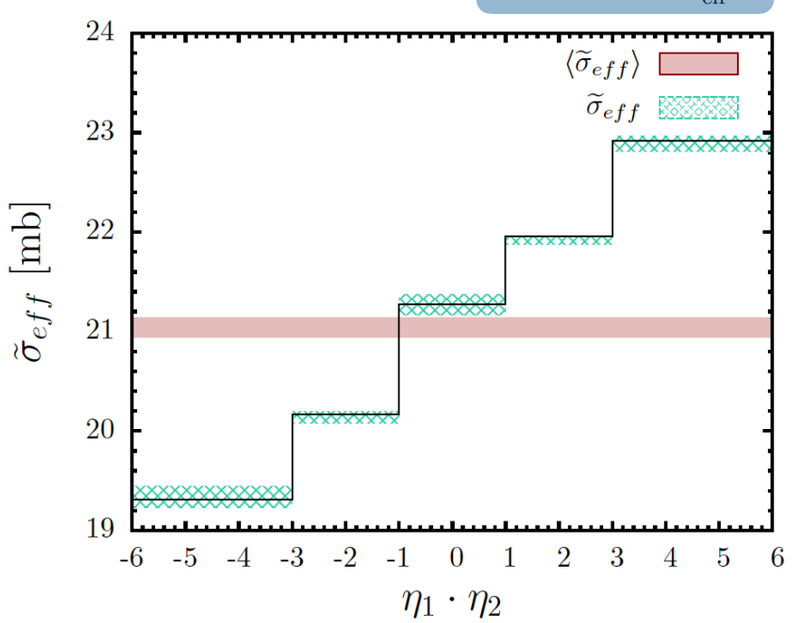
-> subtle overall change in cross section predicted

-> other observables related to the rapidities of the produced Ws



(b) Negatively charged leptons

$$\sigma^D_{(A,B)} = \frac{m}{2}\frac{\sigma^S_{(A)}\sigma^S_{(B)}}{\sigma_{\text{eff}}}$$



Gaunt, Stirling, arXiv:0910.4347v4, 2010
Double Parton Distributions Incorporating Perturbative QCD Evolution and Momentum and Quark Number Sum Rules

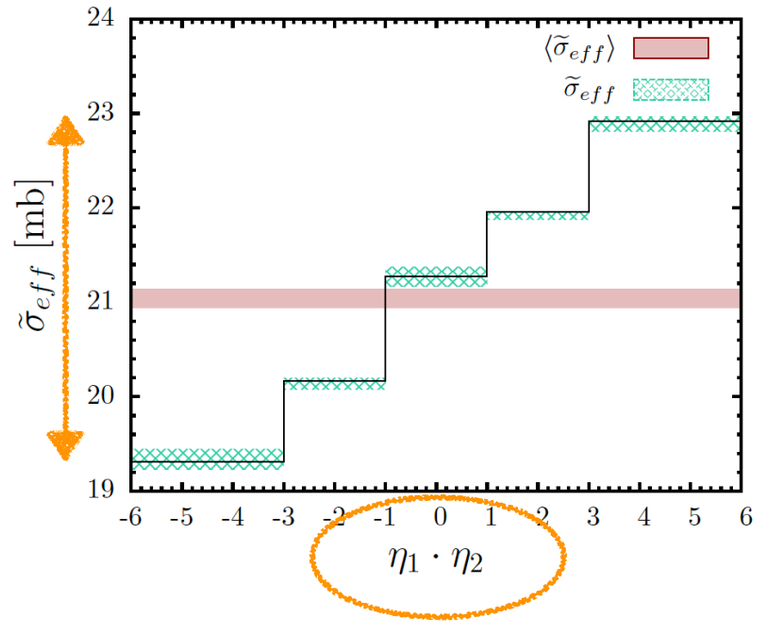
Ceccopieri, Rinaldi, Scopetta, arXiv:1702.05363v1, 2017
Parton correlations in same-sign W pair production via double parton scattering at the LHC

DPS WW and the HL-LHC

so why is this process interesting for the HL-LHC in particular?

-> statistics: effects are very subtle
need lots of lumi for diff x-sections

-> coverage: sensitive variables related to eta
need extended coverage for leptons



the HL-LHC provides CMS with both!

-> did a dedicated study of those effects in CMS

-> muon upgrade: coverage from |eta| < 2.4 to |eta| < 2.8

-> luminosity increase from 36 fb^{-1} to 3000 fb^{-1}

-> DPS WW is a process that is largely insensitive to PU!

study on DPS WW at the HL-LHC

this study is part of the muon upgrade TDR in CMS

-> in the public document

took the 13 TeV result, and extrapolated to HL-LHC

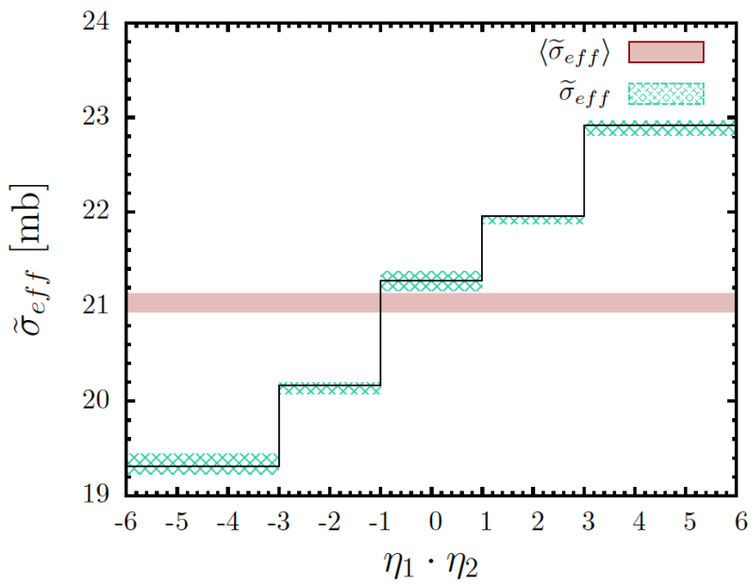
-> performed full simulation of the signal and background process with PU = 200

-> scaling of the cross section and luminosity to 3 ab^{-1} @ 14 TeV

-> scaling to extended coverage of the muon system

question: are we sensitive to non-factorized calculations?

-> e.g. can we see this subtle slope?



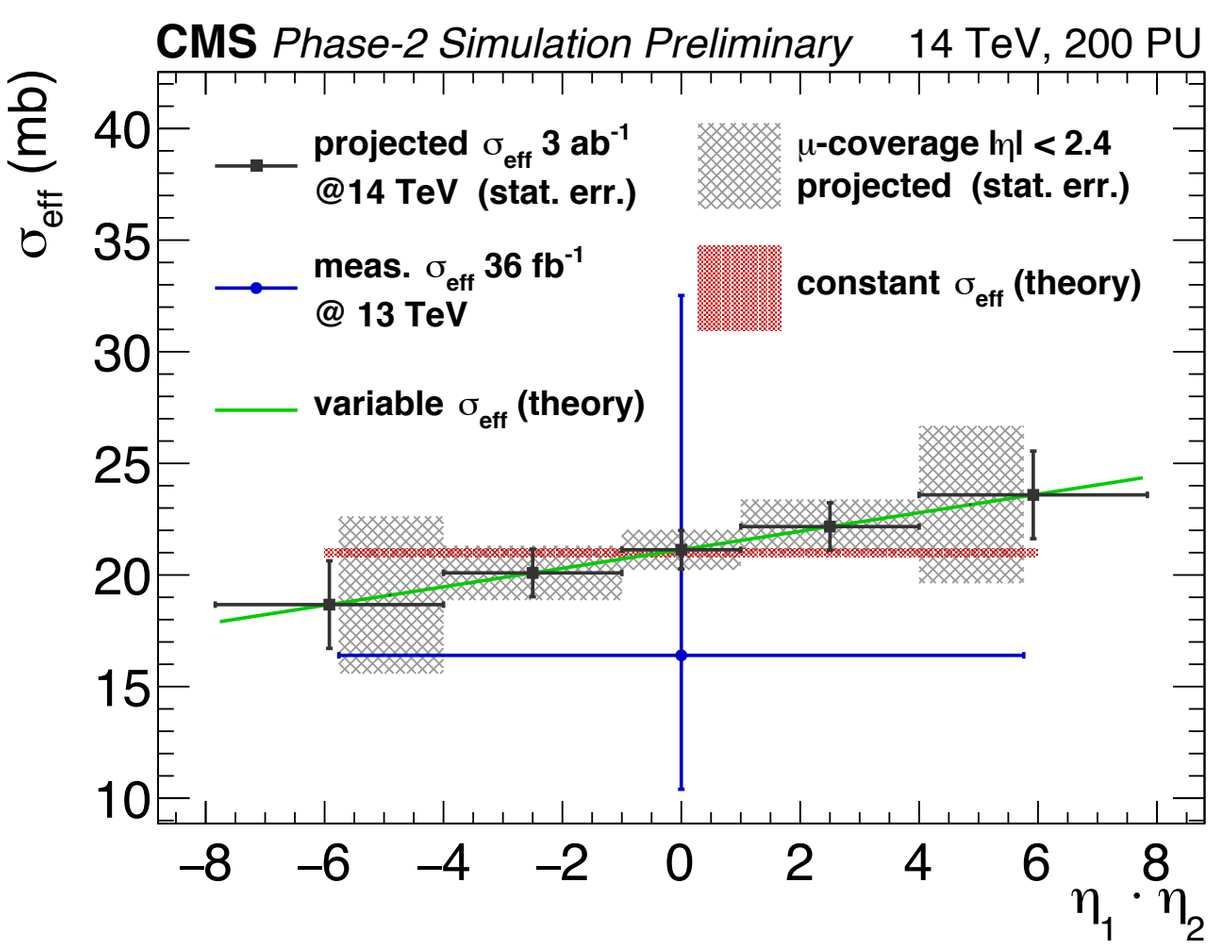
study on DPS WW at the HL-LHC

main result is this plot

-> sensitivity improved w/r/t 13 TeV result

-> extended coverage in |eta| really helps

-> combination of lumi + coverage will lead to sensitivity to these effects



CMS muon TDR

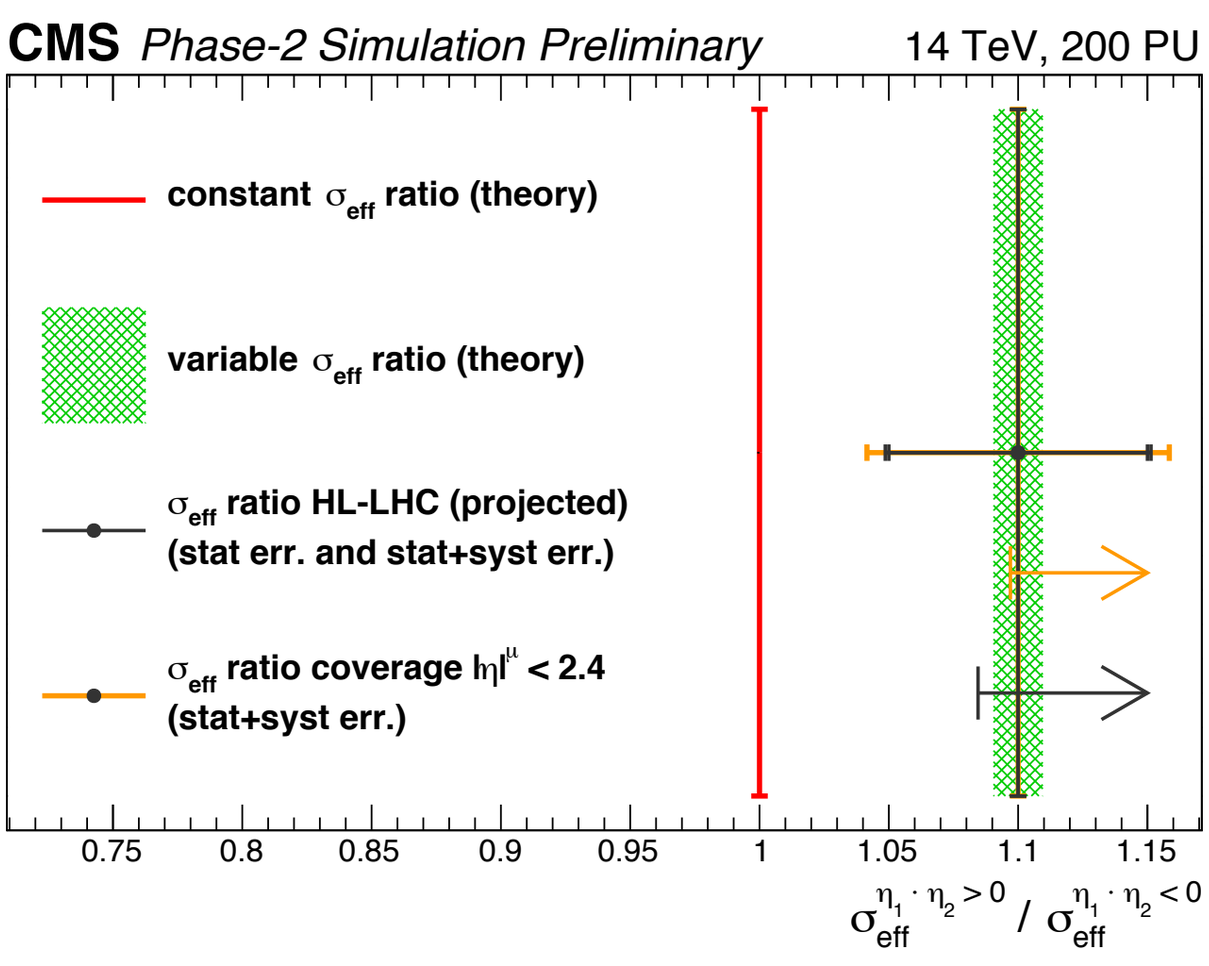
study on DPS WW at the HL-LHC

can also look at it in terms of a ratio (right over left)

-> sensitivity improved w/r/t 13 TeV result

-> extended coverage in |eta| really helps

-> combination of lumi + coverage will lead to sensitivity to these effects



CMS muon TDR

DPS WW in ATLAS

ATLAS muon coverage is already up to |eta| < 2.7

-> reduced effect therefore expected

however: ATLAS will get a new muon system

-> much better performance at higher |eta| than current system

-> will clearly benefit such an analysis although quantitative studies are not available

a thing to keep in mind: ATLAS high-η muon tagger!

-> μ-tagger for $|\eta| < 4$

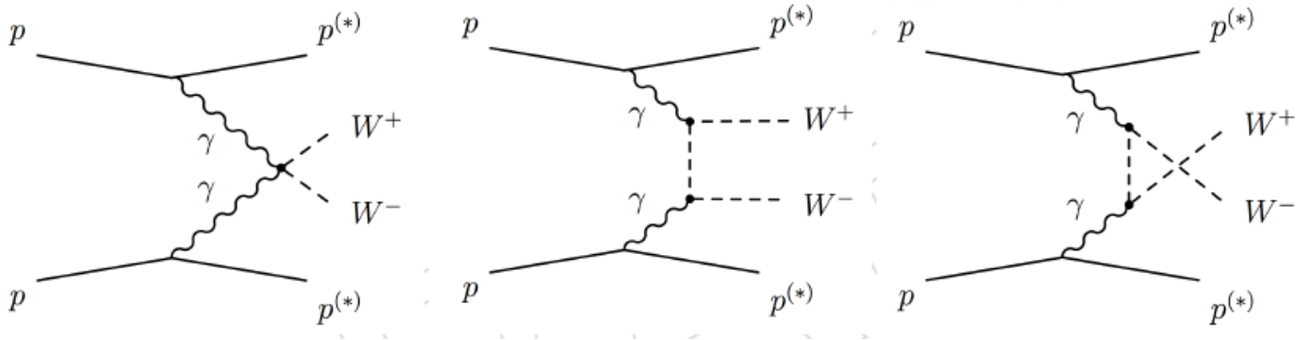
-> in a region without B-field, but with tracking

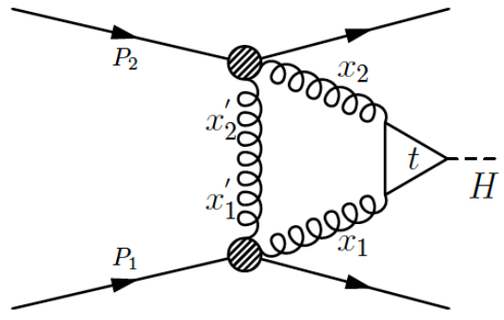
-> depending on p_T resolution, this would be a great detector for a DPS WW analysis

photon induced (vector) bosons

the physics: looking for *exclusive* production of γγ ->bosons

-> both ATLAS and CMS have 7/8 TeV analyses

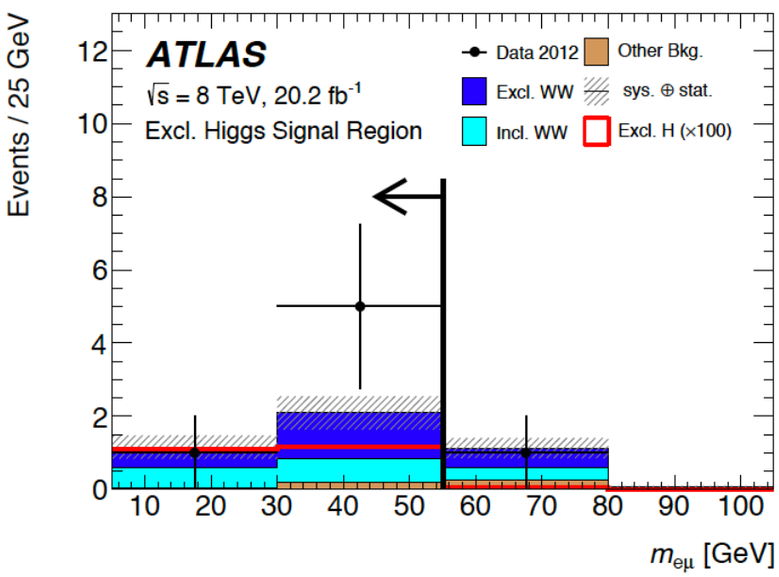


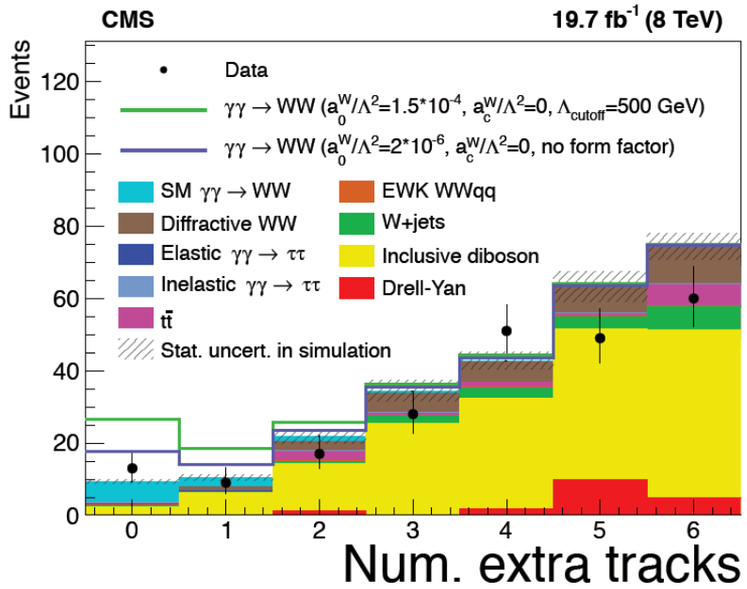


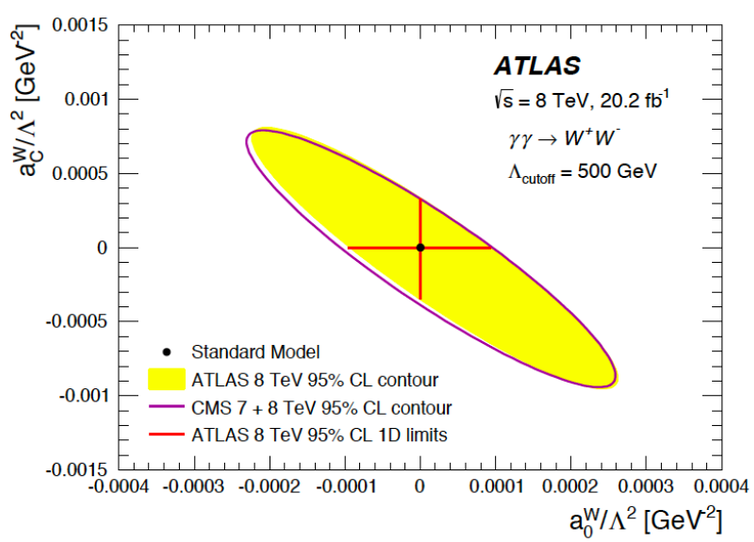
protons stay largely intact in this processes - elastic

-> spectacular distributions in these analyses

-> very much statistically limited: can it be done at HL LHC?







ATLAS: Phys. Rev. D94 (2016) 032011 **CMS:** JHEP 08 (2016) 119

photon induced production @ HL ?

naively speaking, more lumi helps a lot here

-> however, *huge* deterioration with pileup

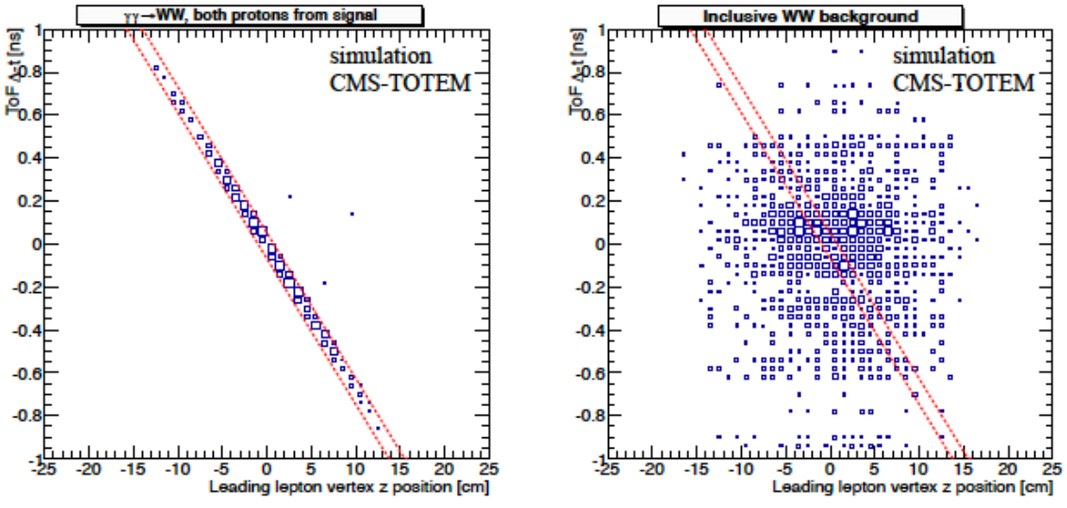
-> both CMS and ATLAS designed new detectors for this

ATLAS **AFP -** ATLAS Forward Protons

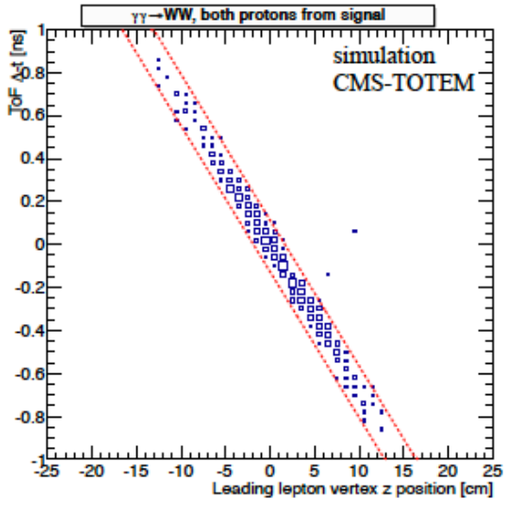
CMS **CTPPS -** CMS TOTEM Precision Proton Spectrometer

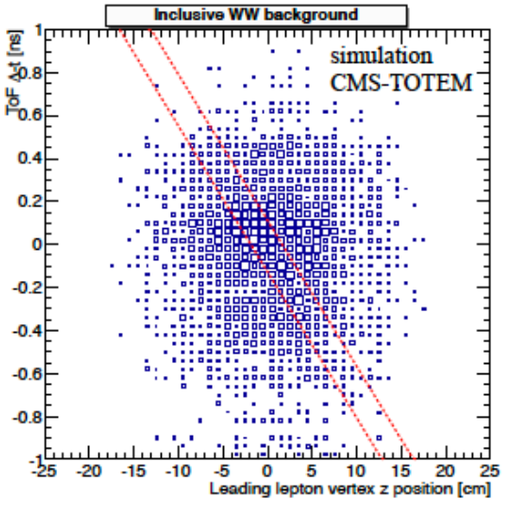
-> precision timing and tracking at 210m from IP1/IP5

-> aim for ~10 ps and or less: still not there



10 ps timing



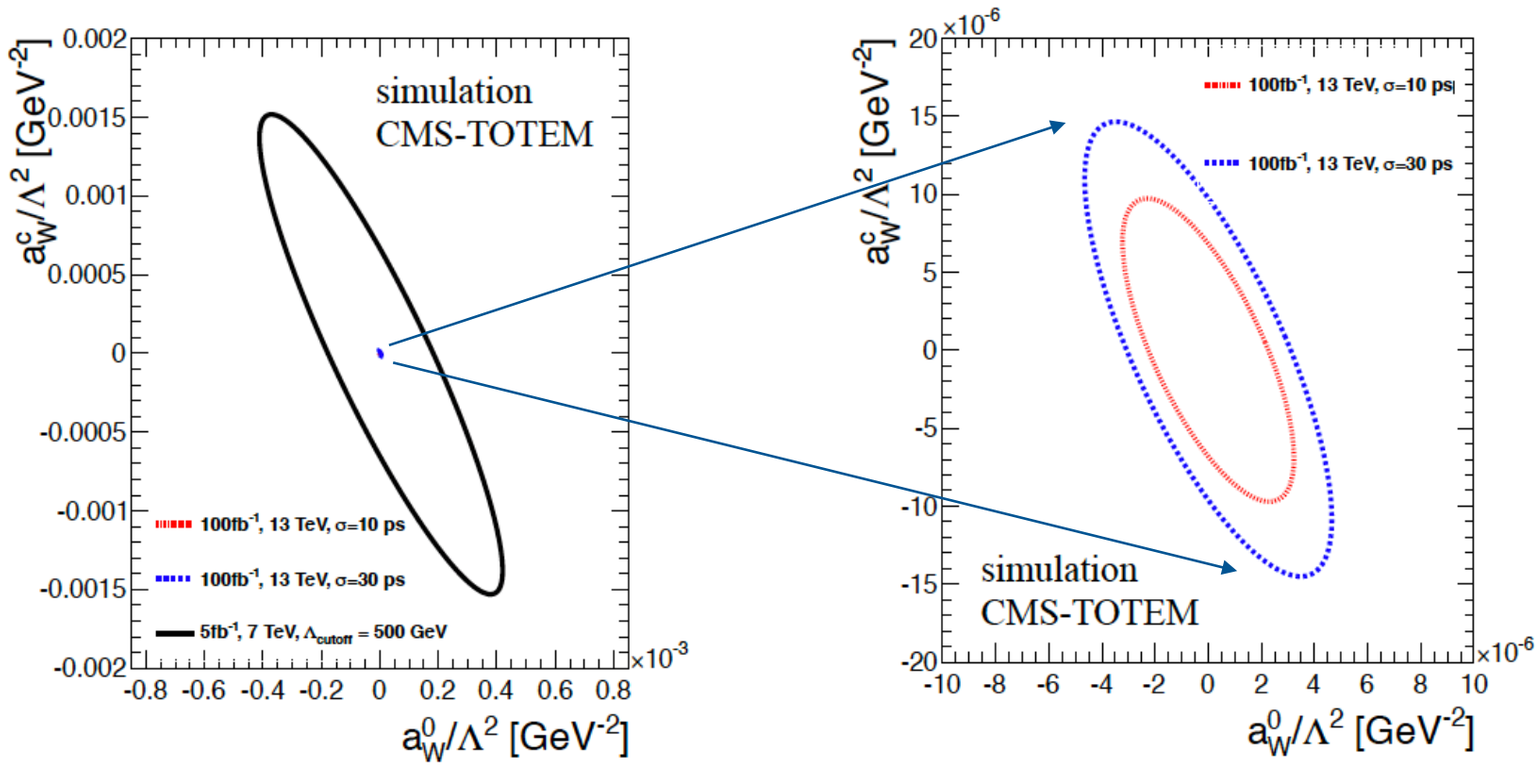


30 ps timing

photon induced production @ HL ?

studies so far only for 100 fb^{-1} at 13 TeV

-> so far timing of 10 ps not reached in operation of CTPPS



ATLAS AFP TDR

CTPPS TDR

from the ATLAS AFP TDR:

-> need timing resolution of 10 ps or better

-> Run2 physics and detector performance will be crucial for potential Run3 program with AFP

-> similar things are valid for CMS/CTPPS

summary & what else?

DPS an interesting topic for HL-LHC

-> first studies for the physics reach coming in

-> will profit a lot from upgraded detectors
in many production modes and final states!

exclusive production via γγ challenging from the PU point of view

-> are AFP/CTPPS able to get to design timing?

what else? exclusive light-by-light scattering

-> i.e. γγ -> γγ

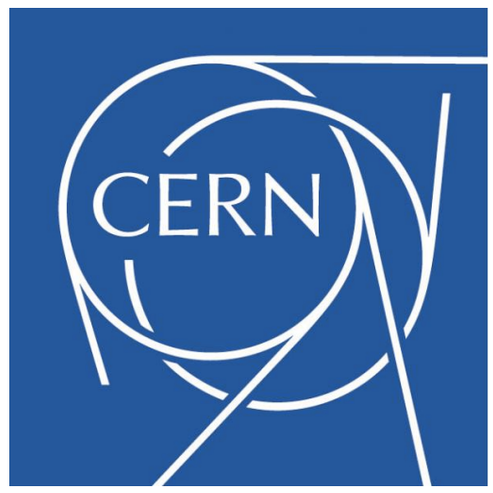
-> interesting for pp and PbPb (or XeXe?)
EM 'pileup' might be a problem at HL

-> similar physics can be probed with this process

-> large benefits from extended trackers as well

the end

marc dünser



extras