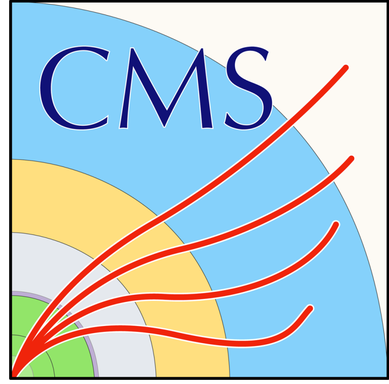


$\gamma+E_T^{miss}$ Searches

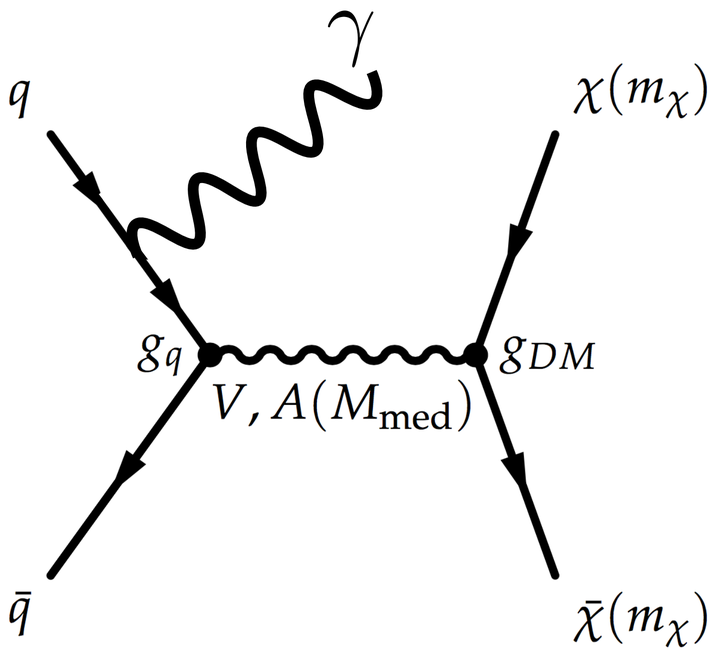
New Experimental Techniques

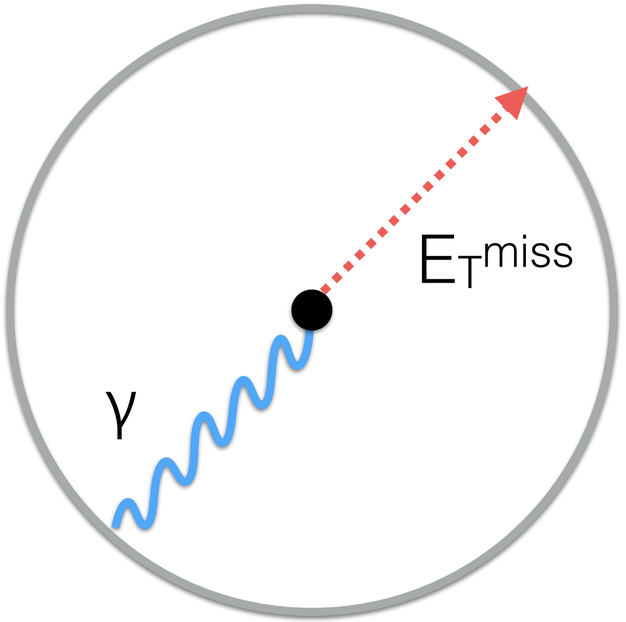
Brandon Allen

on behalf of the

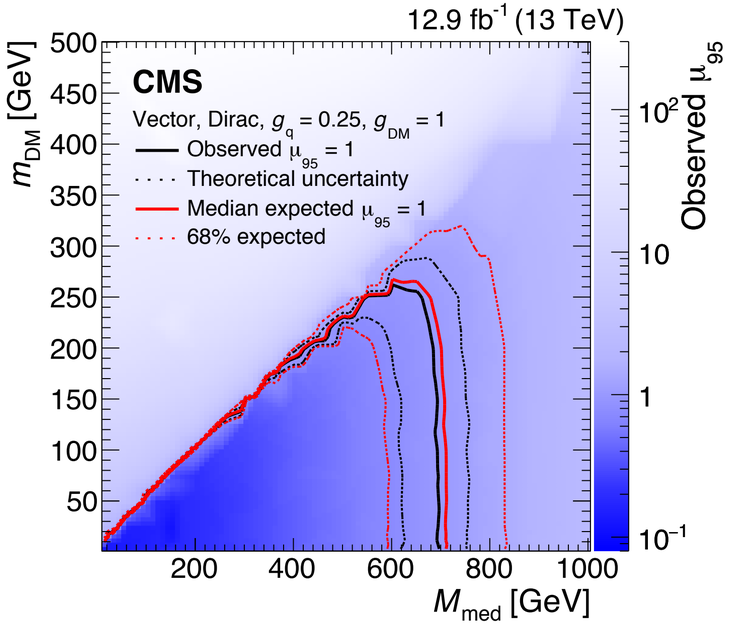
CMS Collaboration

Current Status



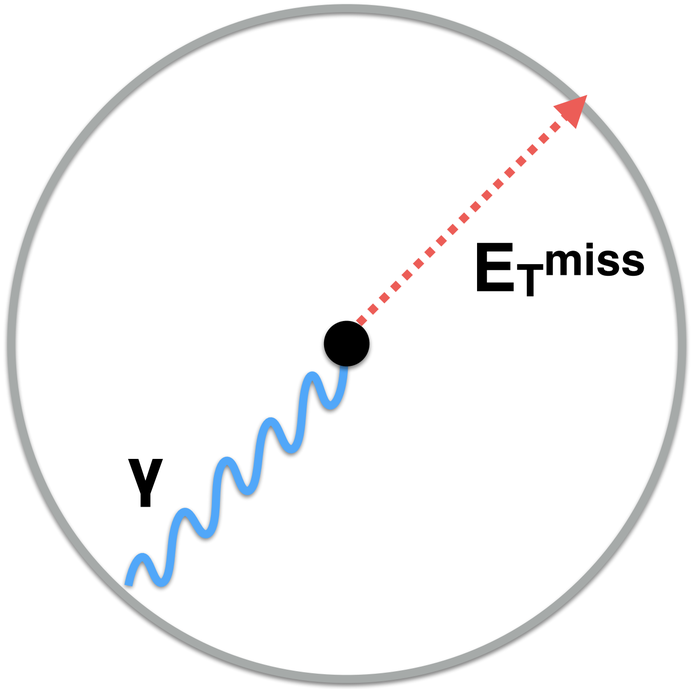


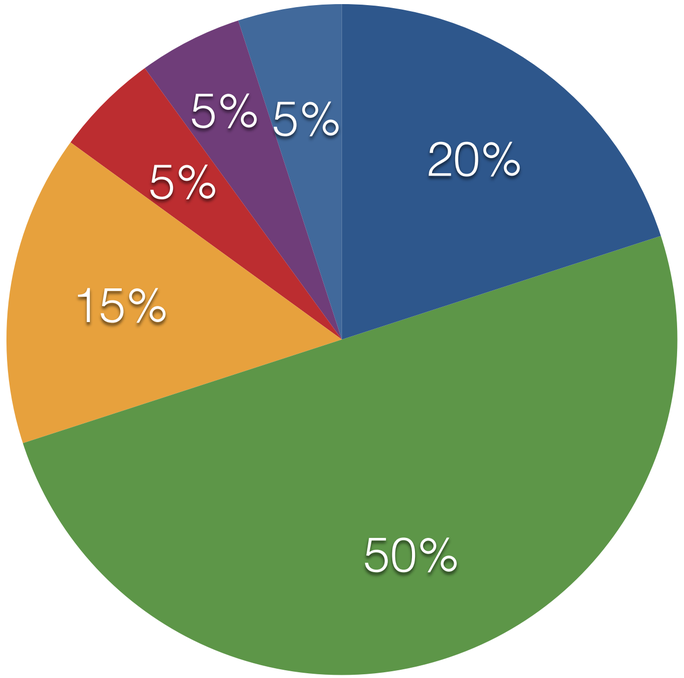
arXiv:1706.03794v2



- Previous CMS result was a single bin cut and count analysis
  - Dominant backgrounds estimated only from MC
- Forthcoming result will be a shape analysis on E_T^γ
  - Dominant backgrounds estimated through data-driven control regions

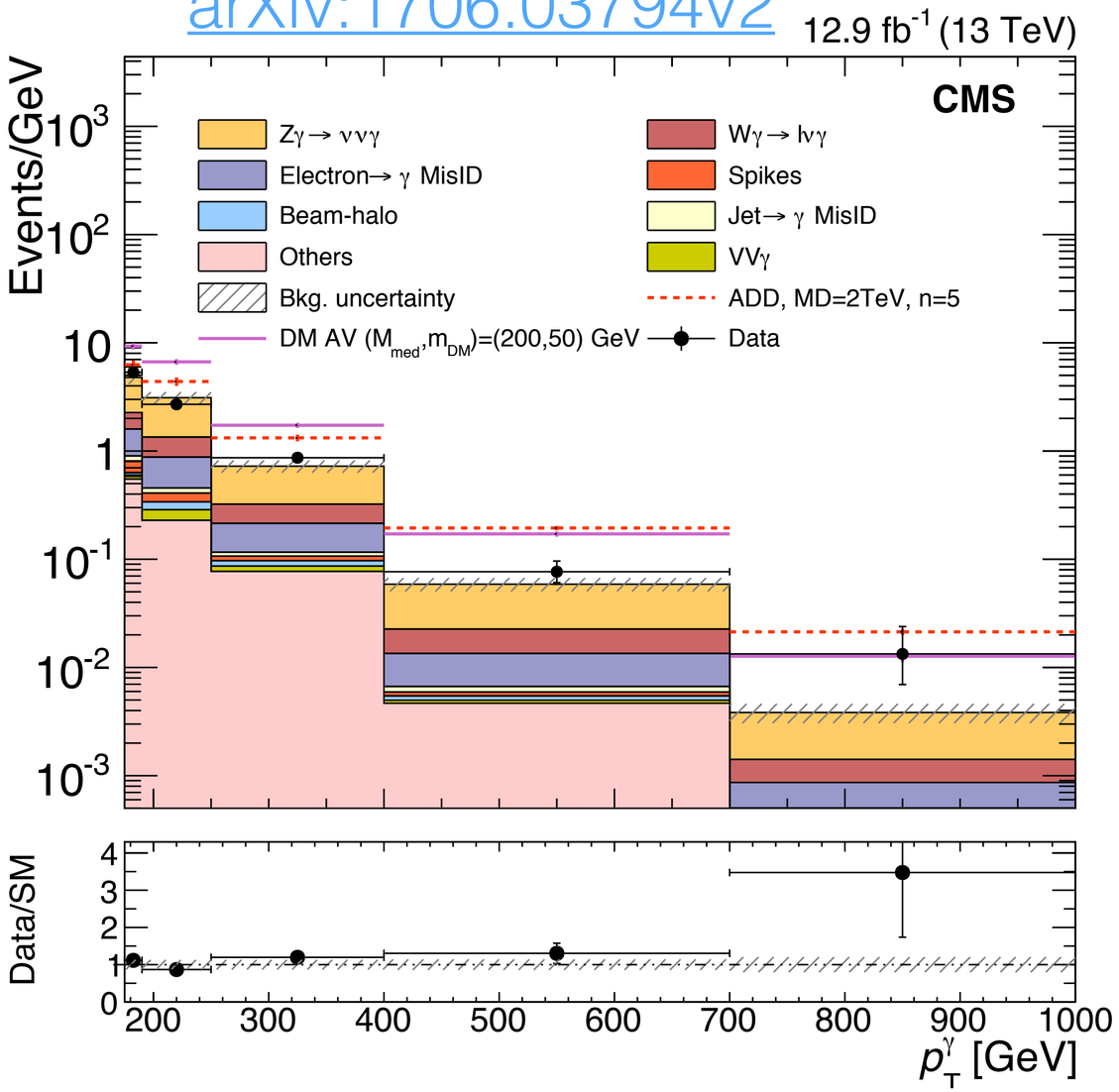
Backgrounds



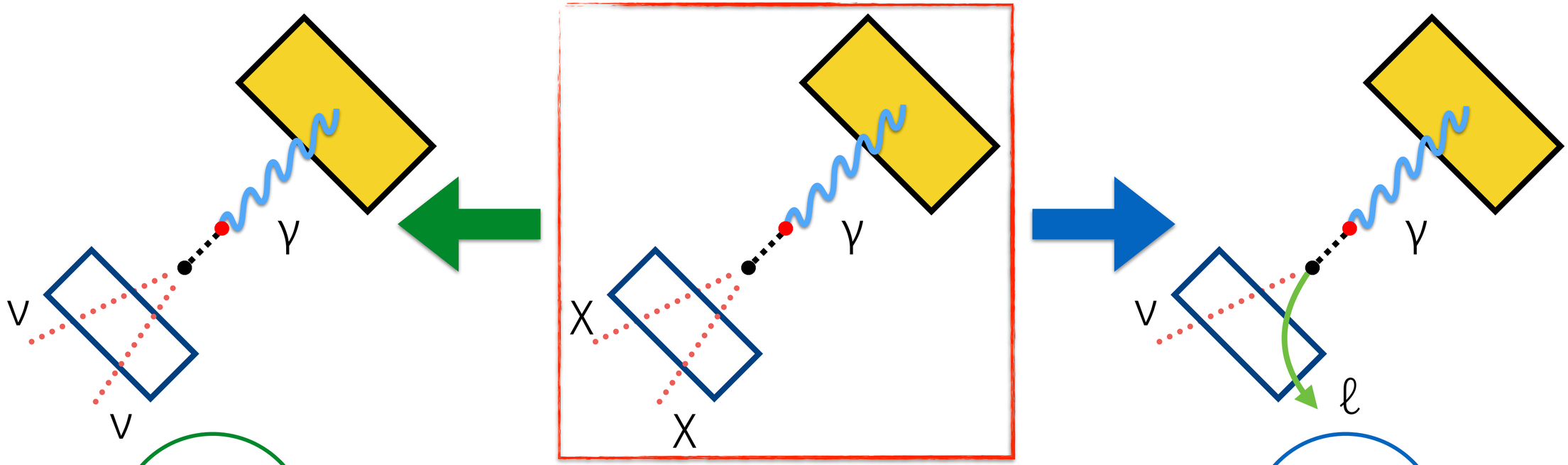


Irreducible	γ + Z(νν)	γ + W(ℓν)
Fakes	Electrons	Hadrons
Anomalous	Beam Halo	Spikes

arXiv:1706.03794v2



Combined Fit for Zγ and Wγ



Theory only

$$\mu^{W\gamma\to\ell\nu\gamma} = f(\theta)\cdot\mu^{Z\gamma\to\nu\nu\gamma}$$

Zγ SR

Exp. only

Zγ μμ CR

Zγ ee CR

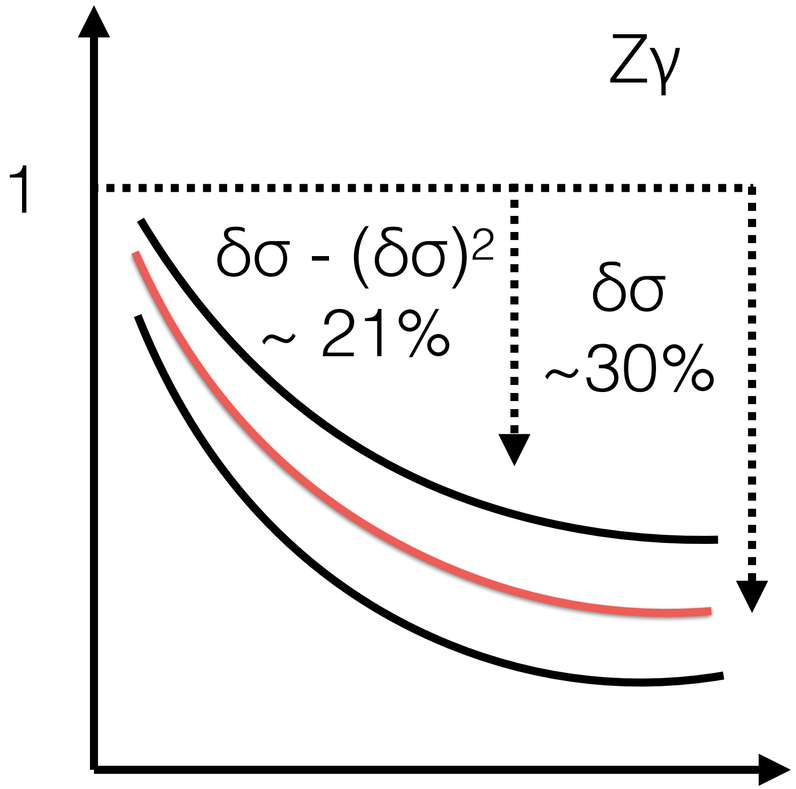
Wγ SR

Exp. only

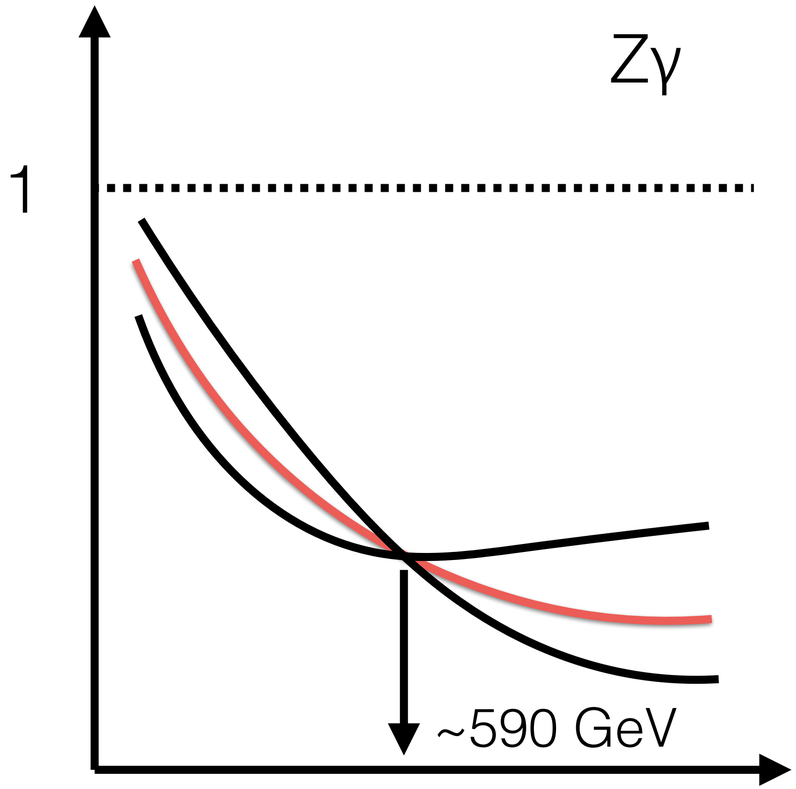
Wγ μ CR

Wγ e CR

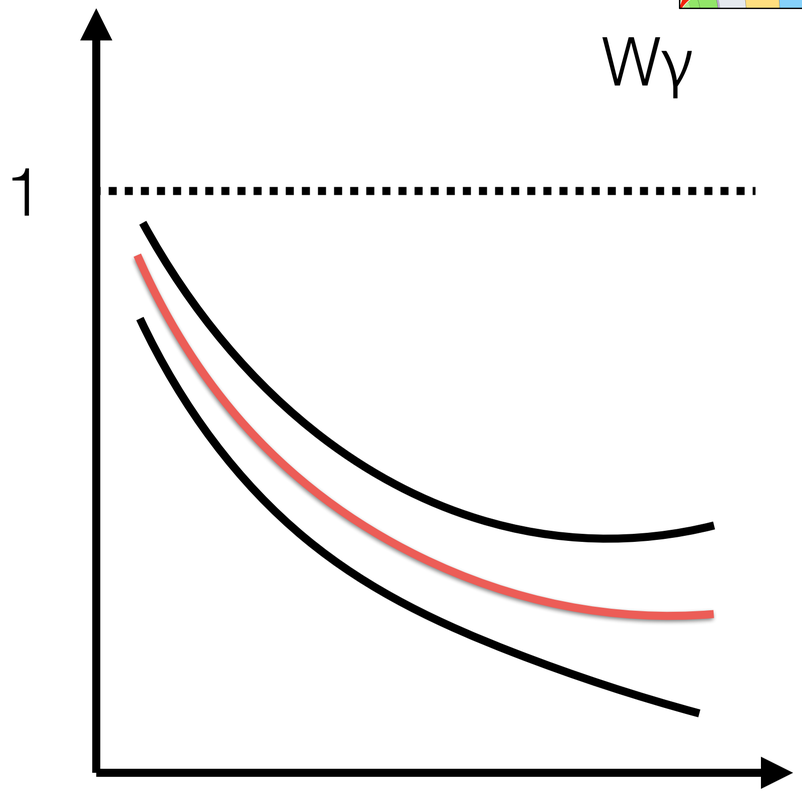
EWK Uncertainties for Zγ and Wγ



Sudakov scale
Amp ~ $(\delta\sigma)^2/\sqrt{2}$



Sudakov shape
Amp ~ $(\delta\sigma)^2/\sqrt{2}$



Photon induced
Amp ~ δσ

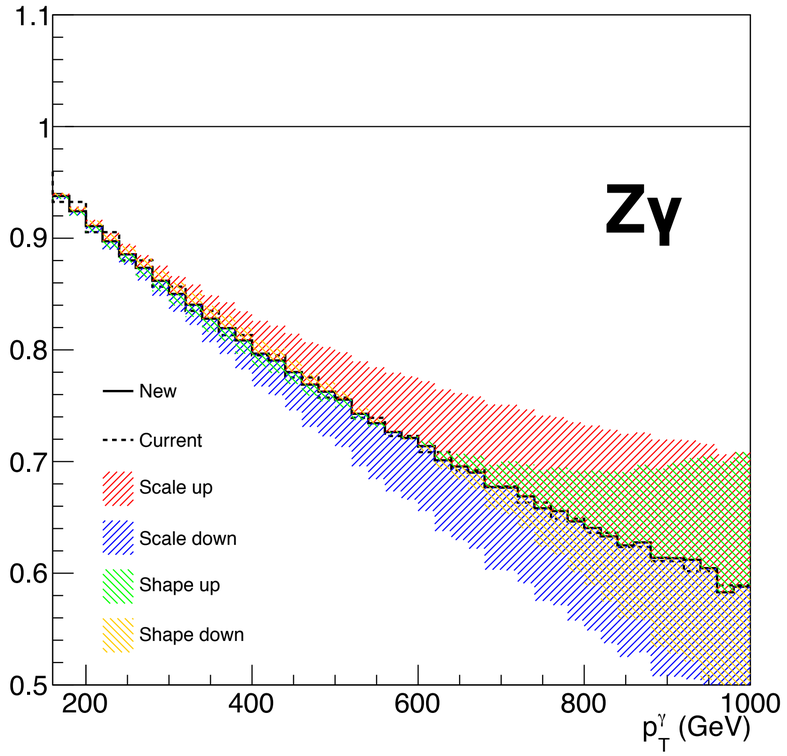
$\delta\sigma_{EWK}$ dominated by Sudakov suppression

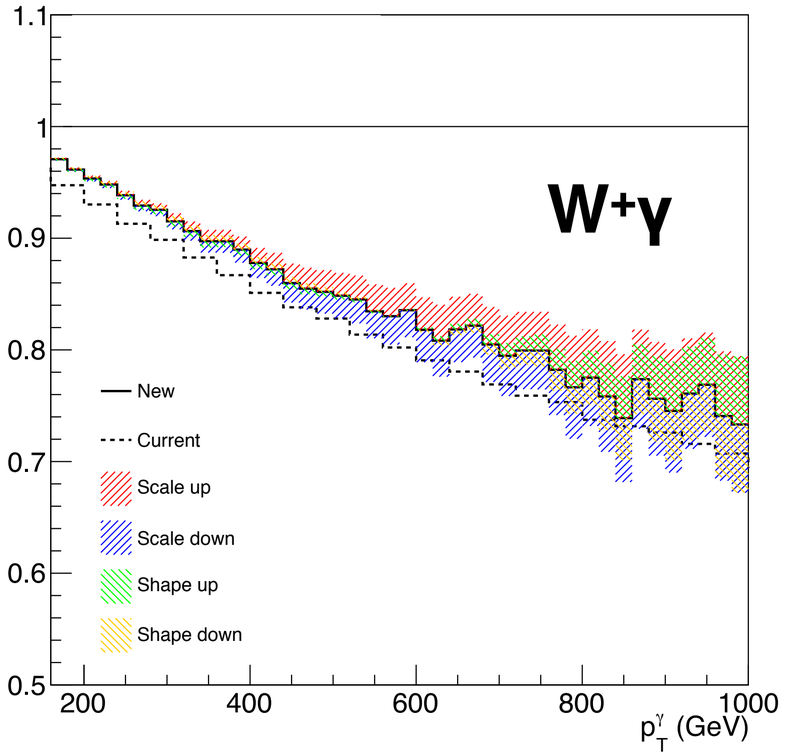
This exponentiates → $(\delta\sigma)^2$ captures higher orders

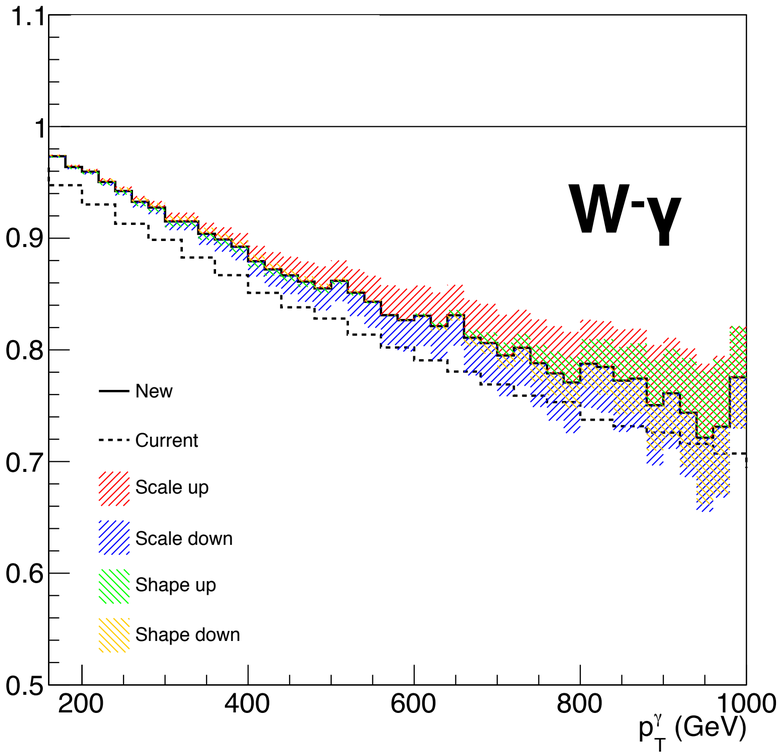
$\delta\sigma_{\gamma}$ mostly from γ PDF

PDF uncertainties 100%

Scale and Shape

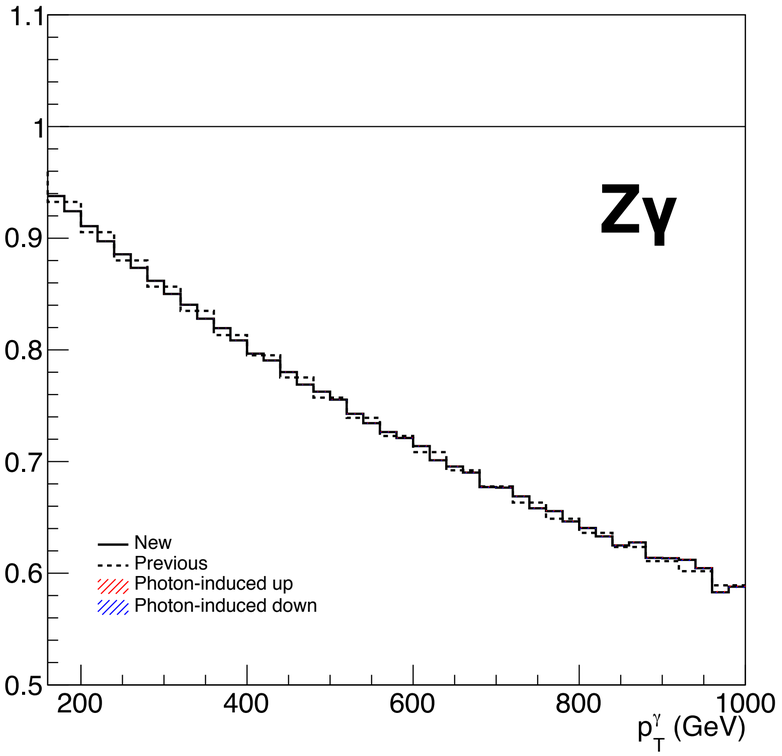


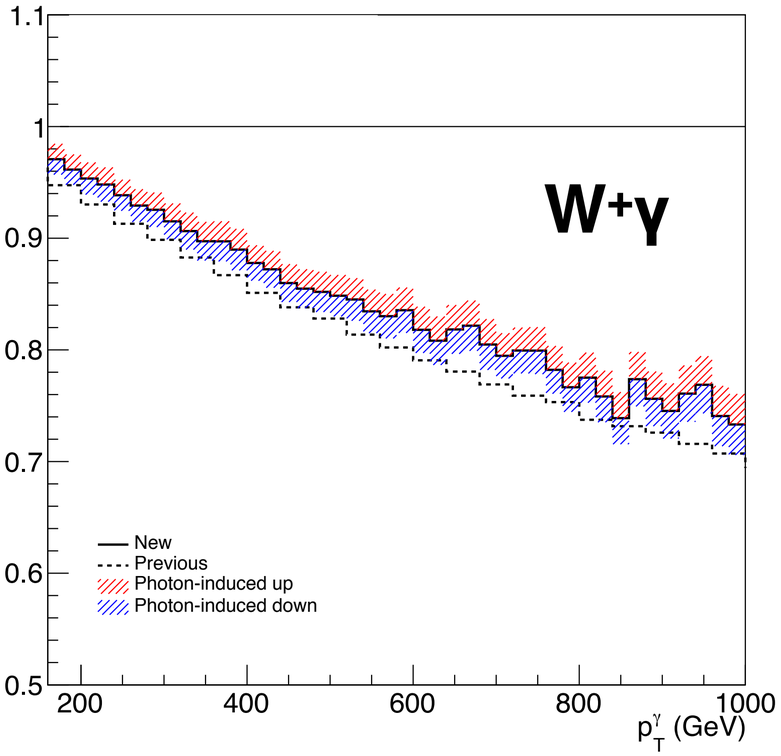


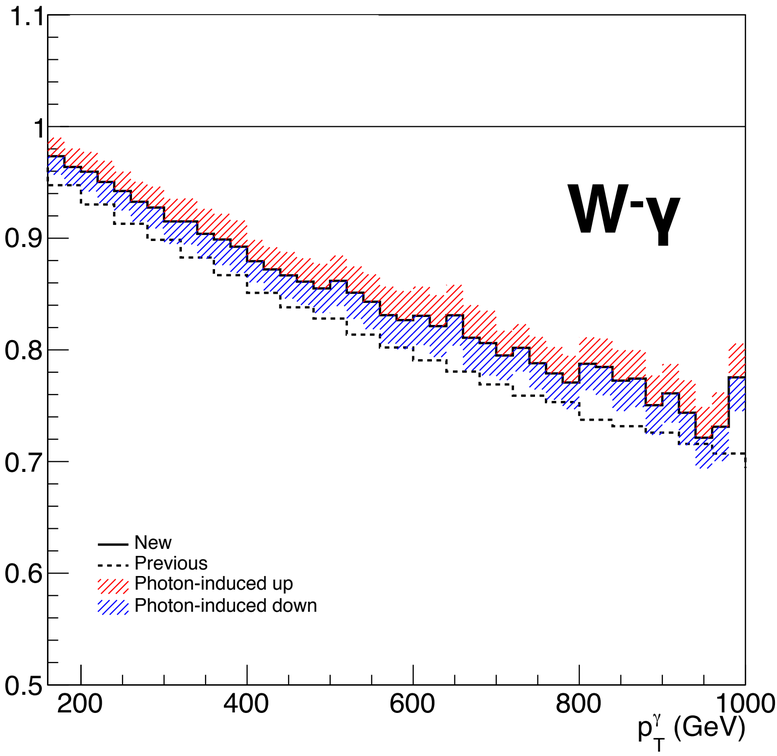


- Based on arXiv:1412.7421v2 and arXiv:1510.08742 from Denner et al.
  - Updates from private communication to adapt to 13 TeV and NNPDF3.1

Photon Induced

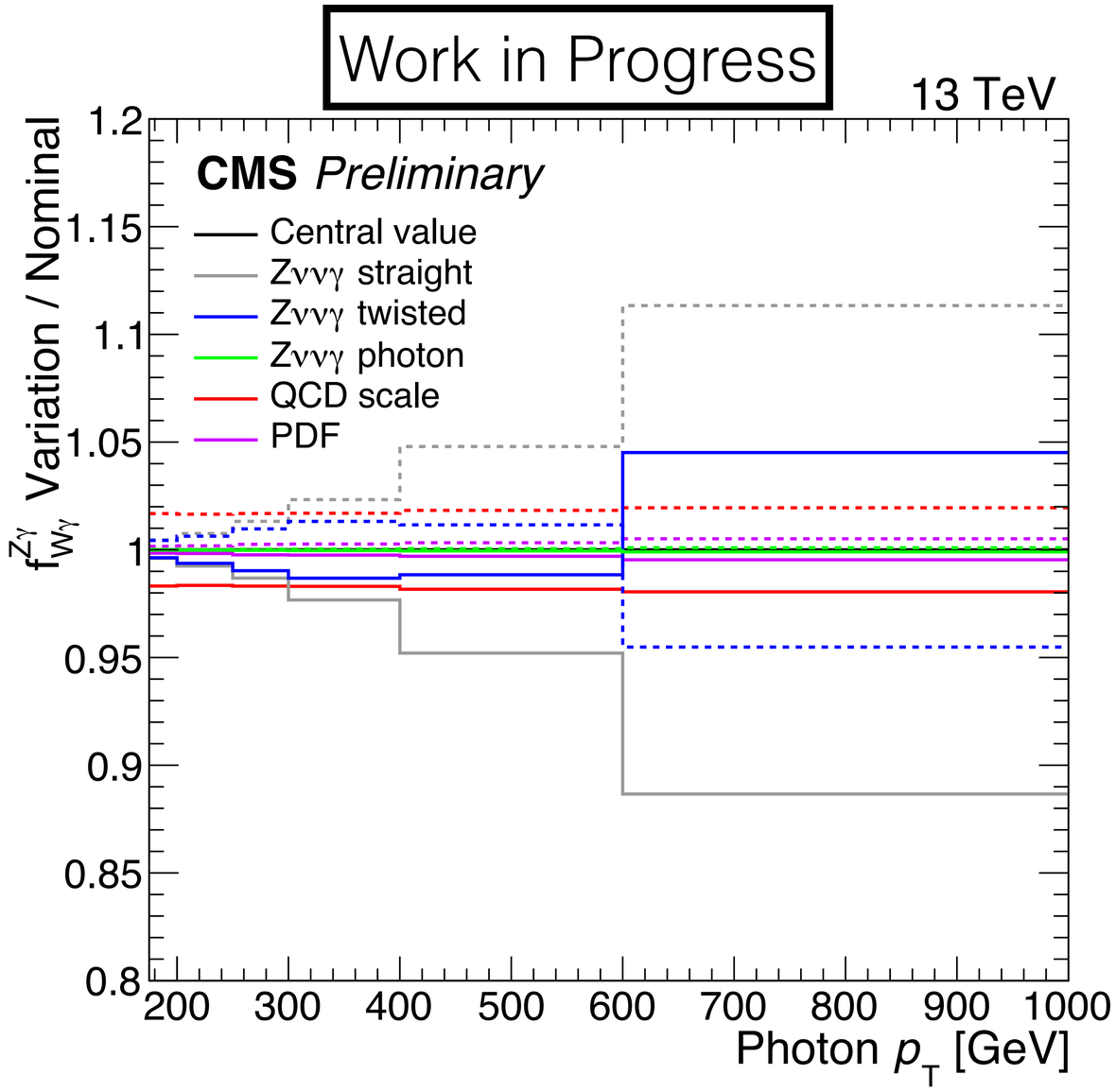


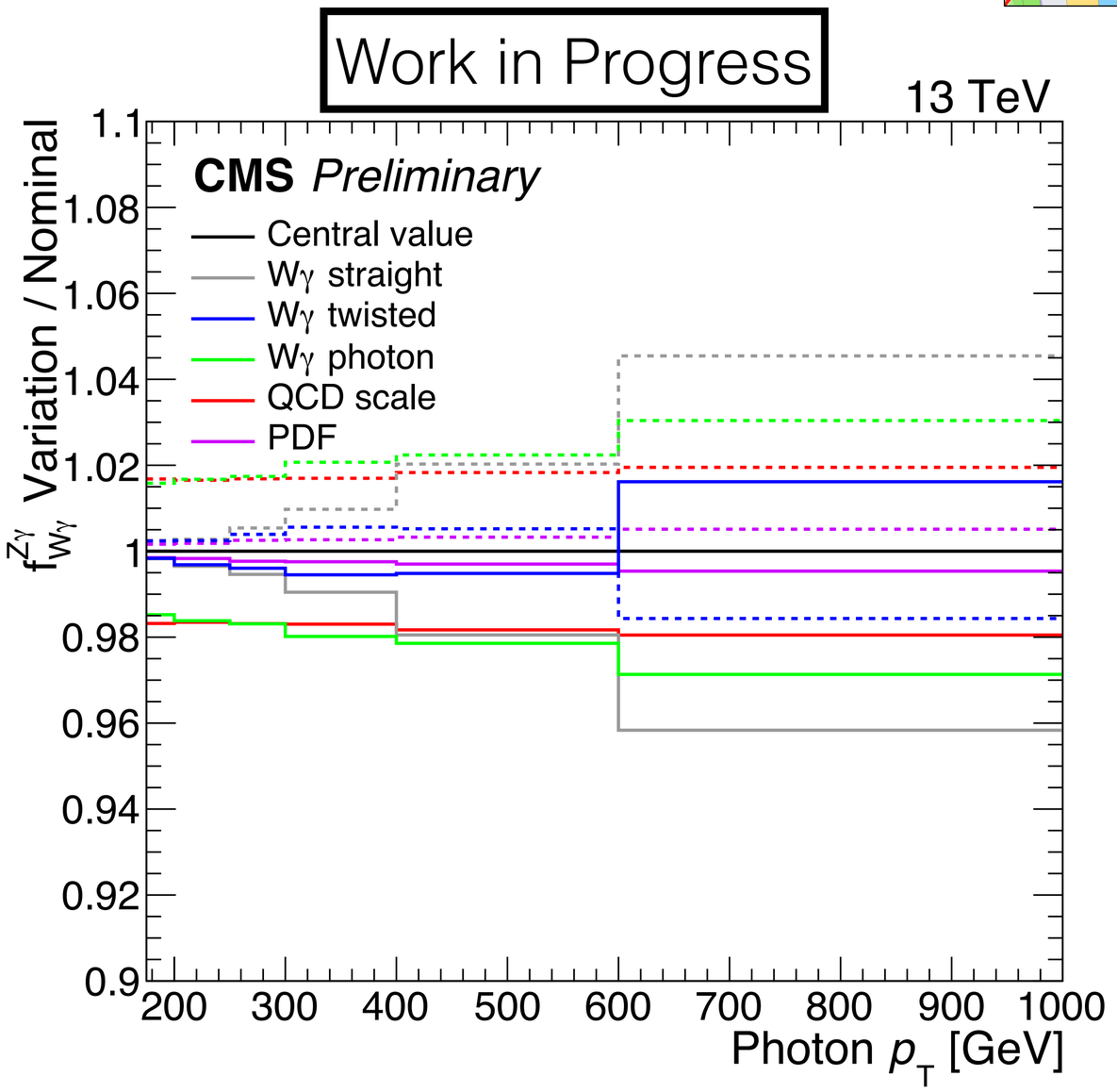




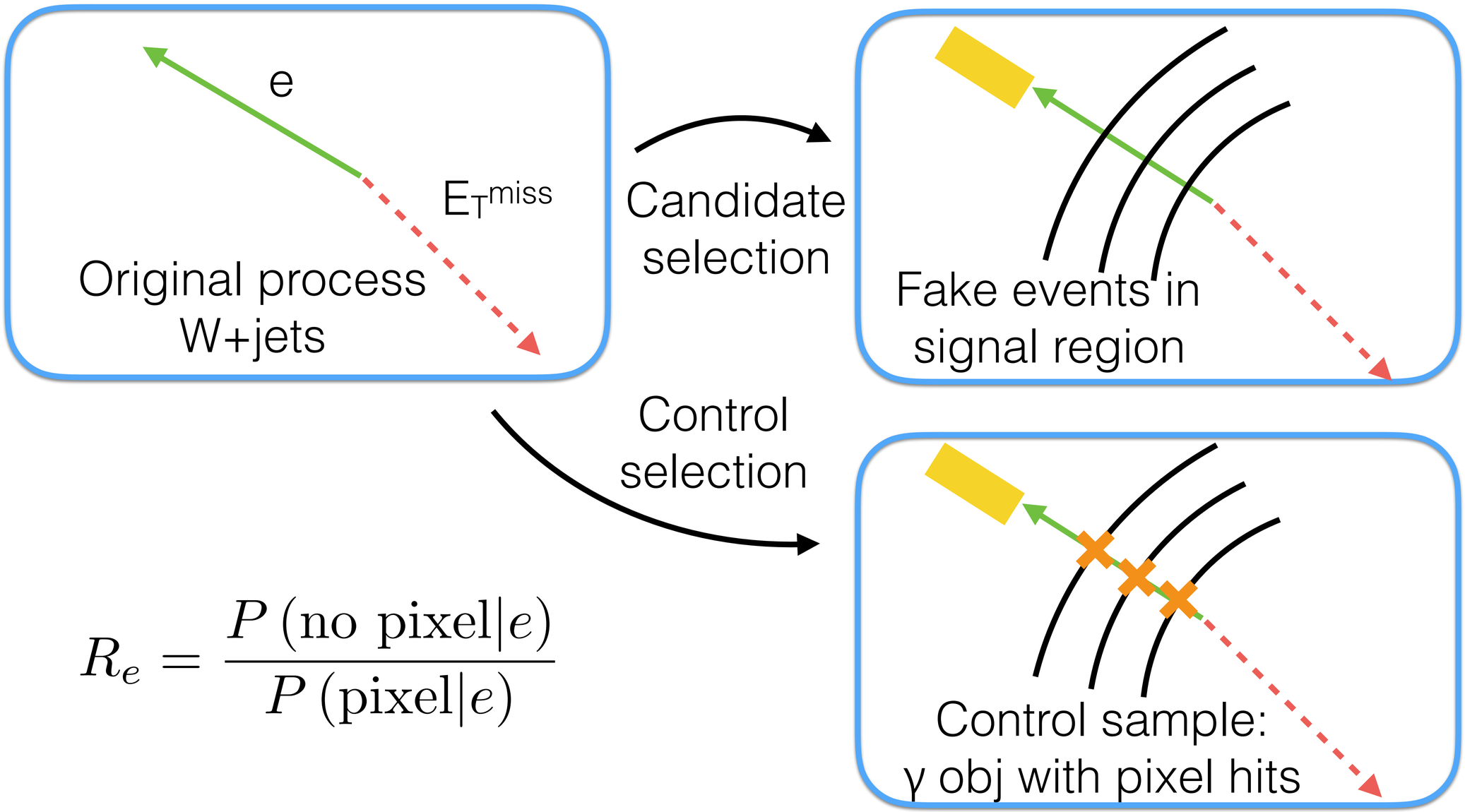
- Based on arXiv:1412.7421v2 and arXiv:1510.08742 from Denner et al.
  - Photon PDFs constrained by luxQED fits from arXiv:1708.01256v2

Zγ / Wγ Ratio


Work in Progress
13 TeV
CMS Preliminary
Central value
Zνγ straight
Zνγ twisted
Zνγ photon
QCD scale
PDF
$f^{Z\gamma}_{W\gamma}$ Variation / Nominal
Photon p_T [GeV]

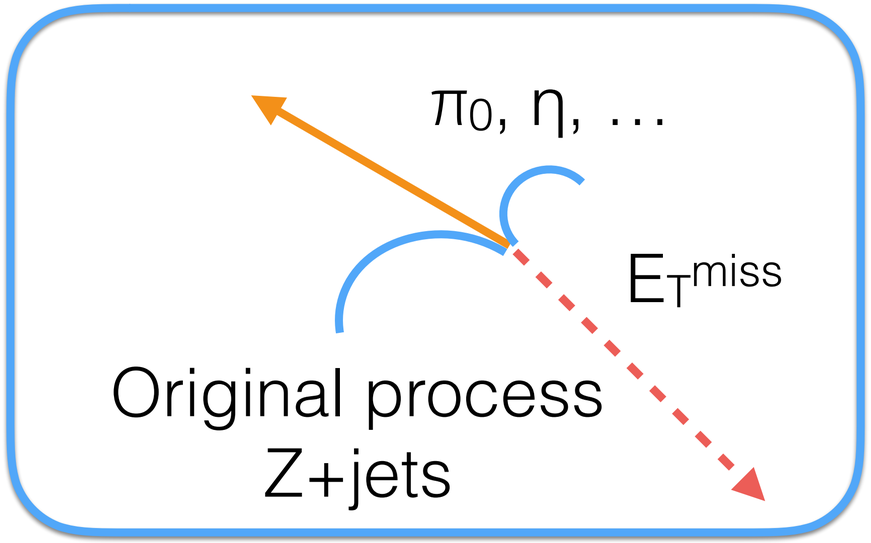

Work in Progress
13 TeV
CMS Preliminary
Central value
Wγ straight
Wγ twisted
Wγ photon
QCD scale
PDF
$f^{Z\gamma}_{W\gamma}$ Variation / Nominal
Photon p_T [GeV]

Electron Fakes

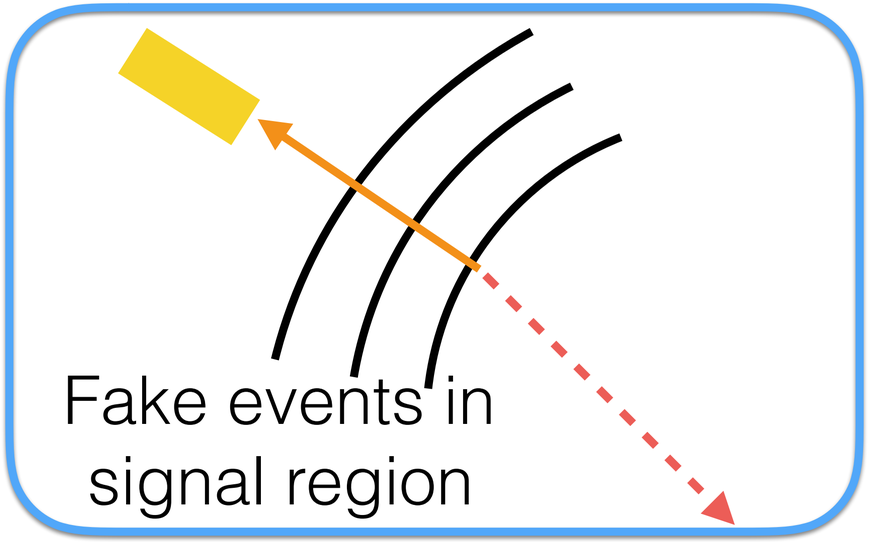


$$R_e = \frac{P\left(\text{no pixel}|e\right)}{P\left(\text{pixel}|e\right)}$$

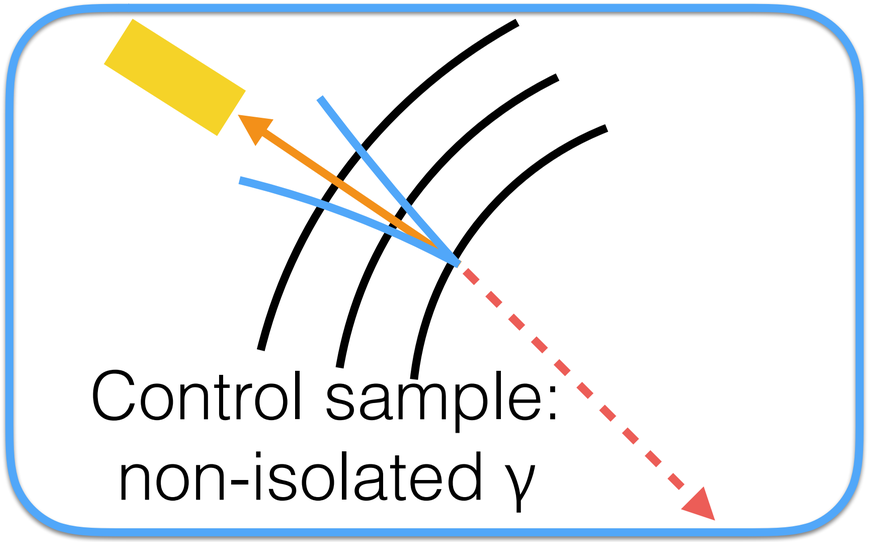
Hadron Fakes



Candidate selection



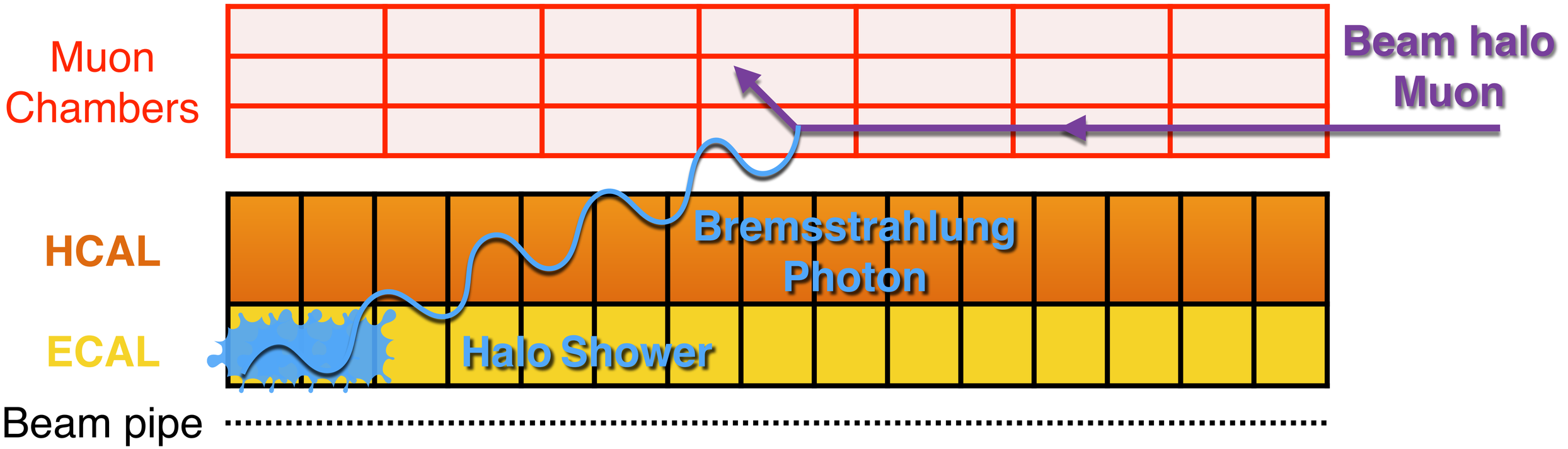
Control selection



× f

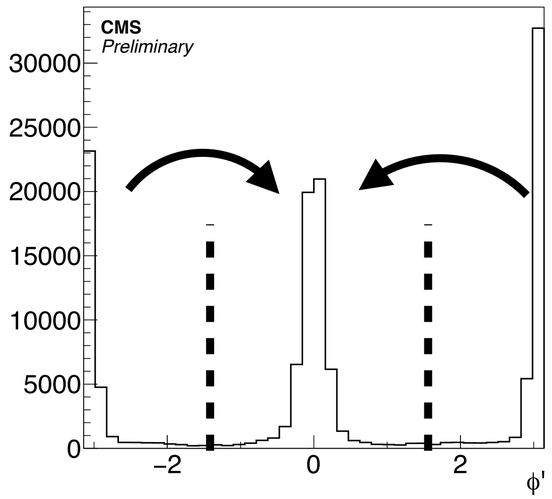
$$f = \frac{N_{\text{iso}}(\text{EM Object})}{N_{\text{non-iso}}(\text{EM Object})}$$

Beam Halo: Features

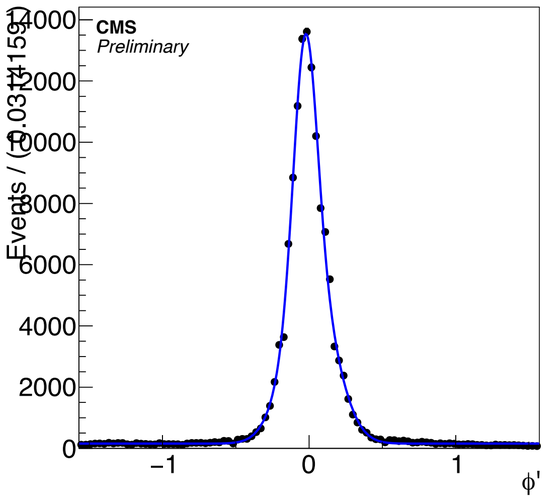


- Beam halo muons originate from protons colliding with LHC collimators
  - Travel parallel to the beam pipe and pass through detector at constant ϕ
- TeV scale muons radiate photons with energies hundreds of GeV
  - Enter the ECAL from outer detectors → wider in ϕ than prompt showers

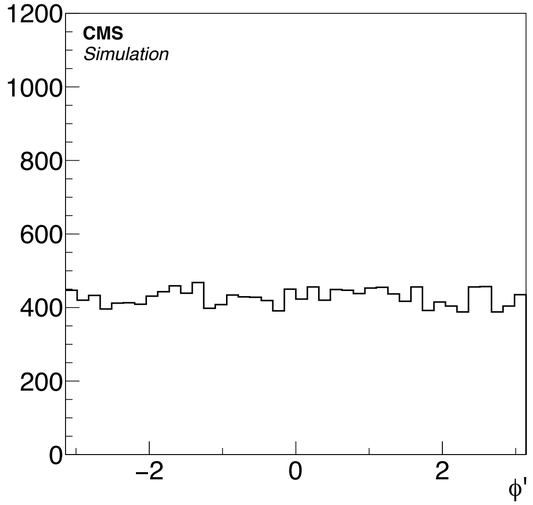
Beam Halo: Estimation



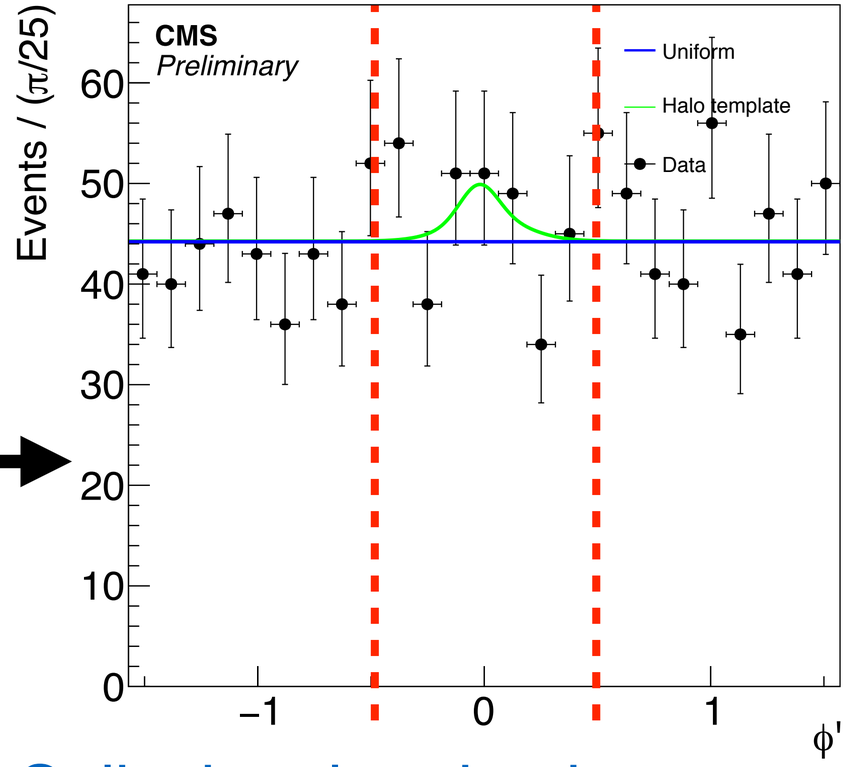
fold



+



Work in Progress



Beam halo anisotropic in ϕ

ϕ’ = “folded” ϕ → One peak

SM events isotropic in ϕ

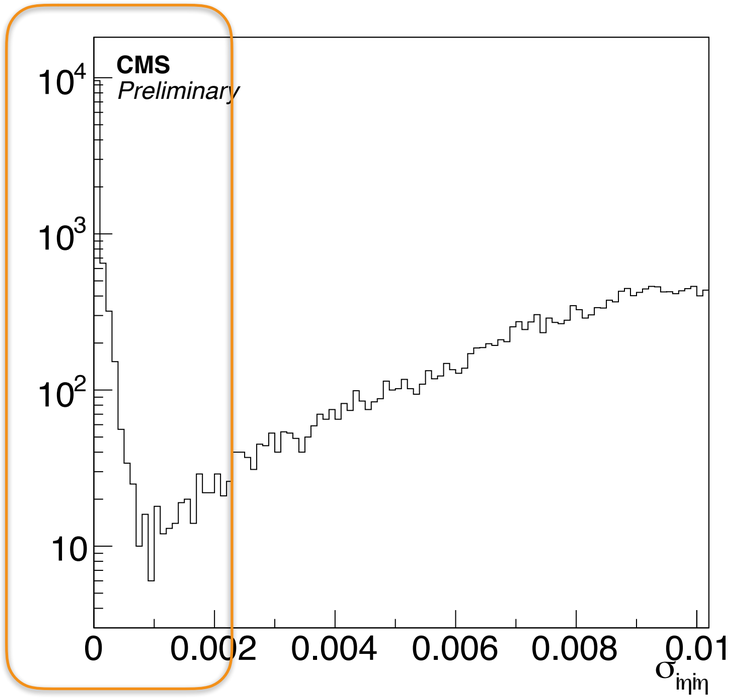
High discriminating power

Split signal region in two

|ϕ'| < 0.5 - Beam halo rich

|ϕ'| > 0.5 - SM + BSM rich

Spikes



All energy in single crystal

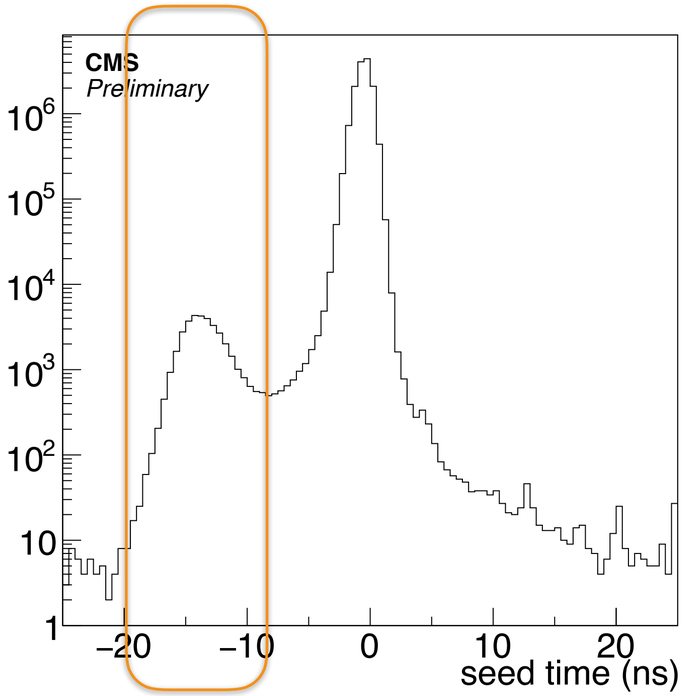
→

Very narrow shower shape

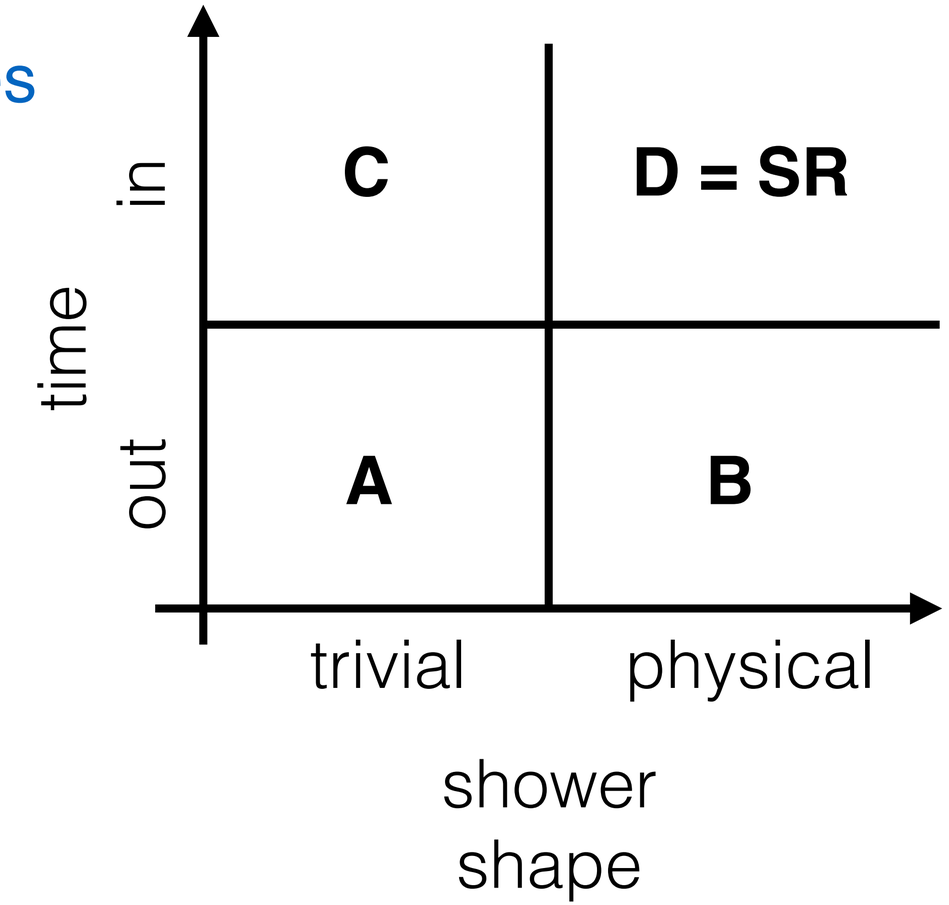
Anomalous pulse shape

→

Reconstructed at early times



For further details
See doi:10.1088/1748-0221/8/03/C03020

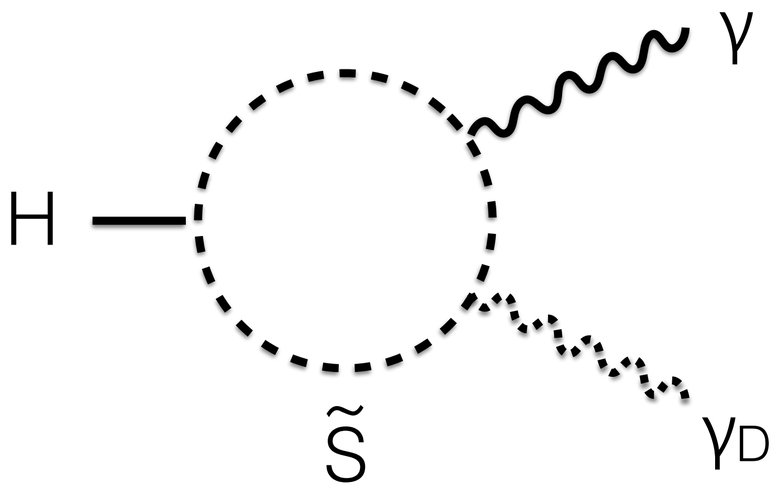
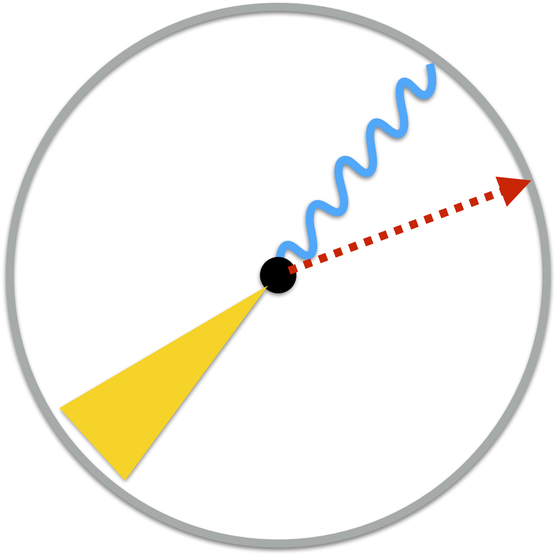
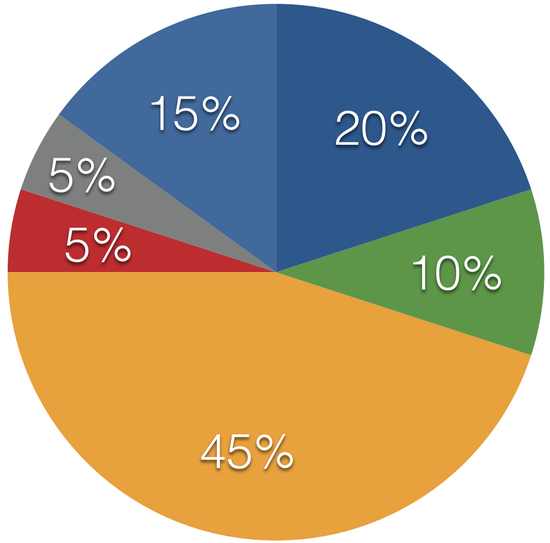
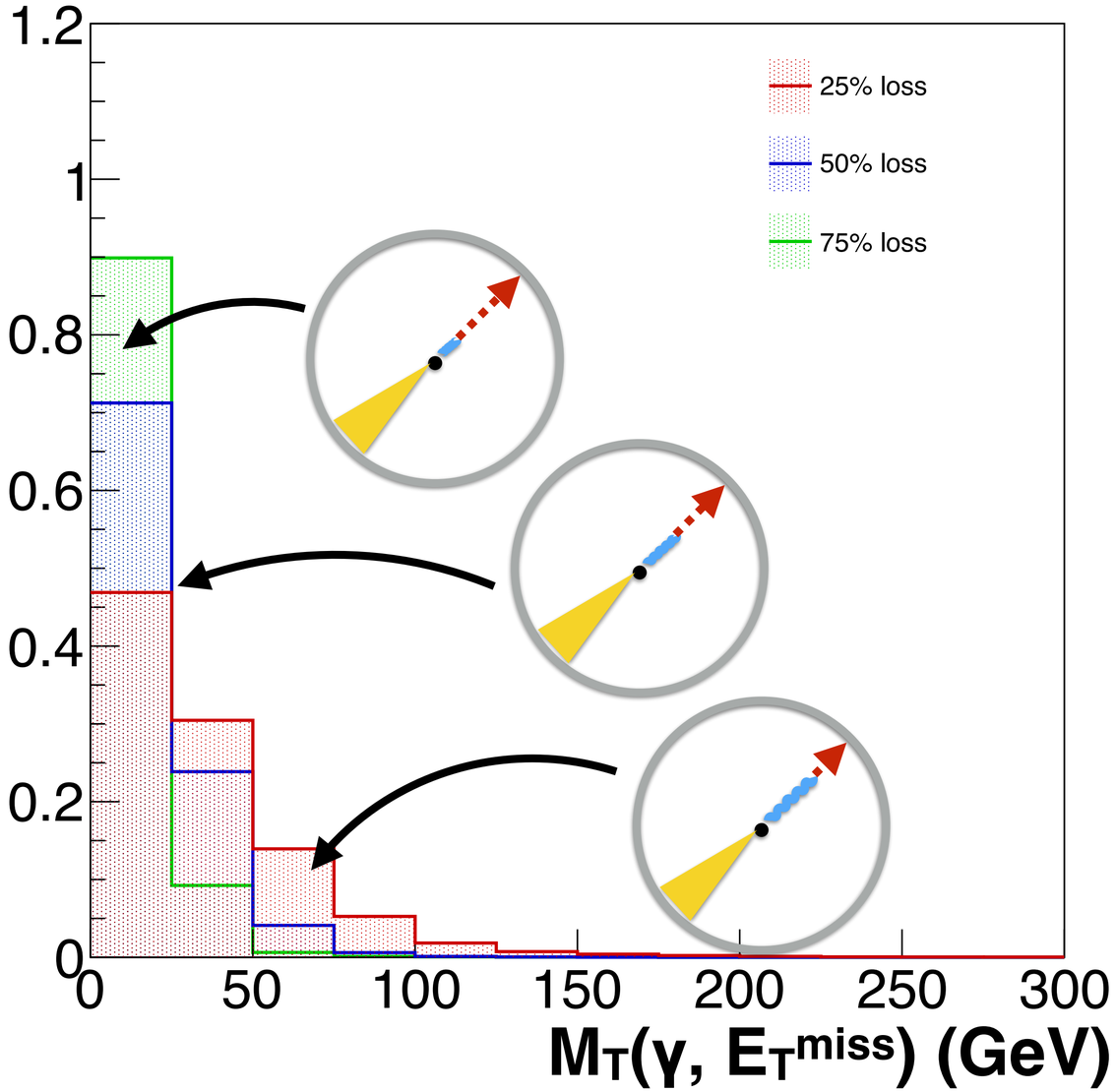


Summary and Outlook

- $\gamma+E_T^{miss}$ searches require data driven background estimation methods
  - Irreducible Zγ and Wγ decays
    - Leptonic control regions
    - State-of-the-art EWK uncertainties
  - Fakes from leptons and hadrons
    - Well understood at this point
  - Small contributions from non-collision sources
    - Tricky to estimate → Significant R&D
- Updated results with 35.9 fb^{-1} to be released in the next few months
  - Shape analysis will bring major gains
  - Control regions and Z/W provide further reach

Expected Gain for Exclusion	Marginal	Cumulative
EXO-16-039	0%	0%
Luminosity	12%	12%
Shape	40%	56%
Lepton Control Regions	20%	65%
Z/W Link	15%	70%

Boosted Resonances



Example model by Gabrielli et al.
arXiv:1310.1090, arXiv:1405.5196, arXiv:1603.01377