Search for dark matter using monophoton final state

17TH INTERNATIONAL CONFERENCE ON INTERCONNECTIONS BETWEEN PARTICLE PHYSICS AND COSMOLOGY

PPC 2024

14 -18 October 2024, Hyderabad, India

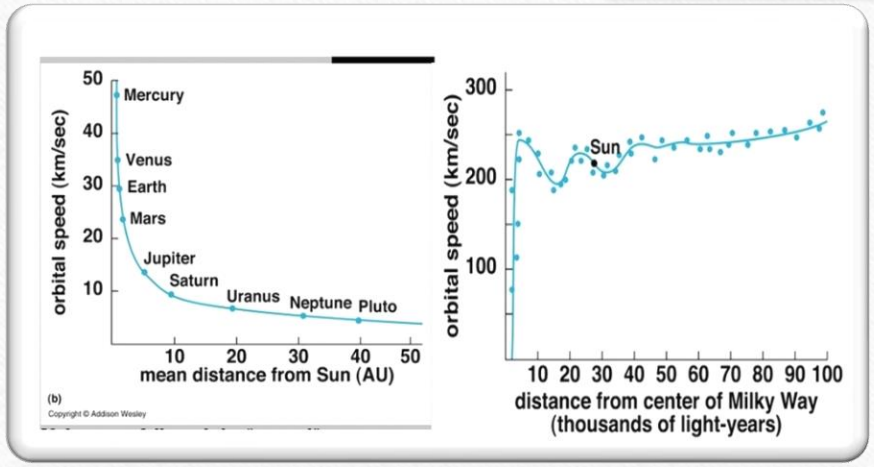
Shriniketan Acharya

University of Hyderabad

(On behalf of CMS collaboration)

Introduction:

- What is Dark matter
- Evidence of dark matter
- Properties
- How to search for dark matter



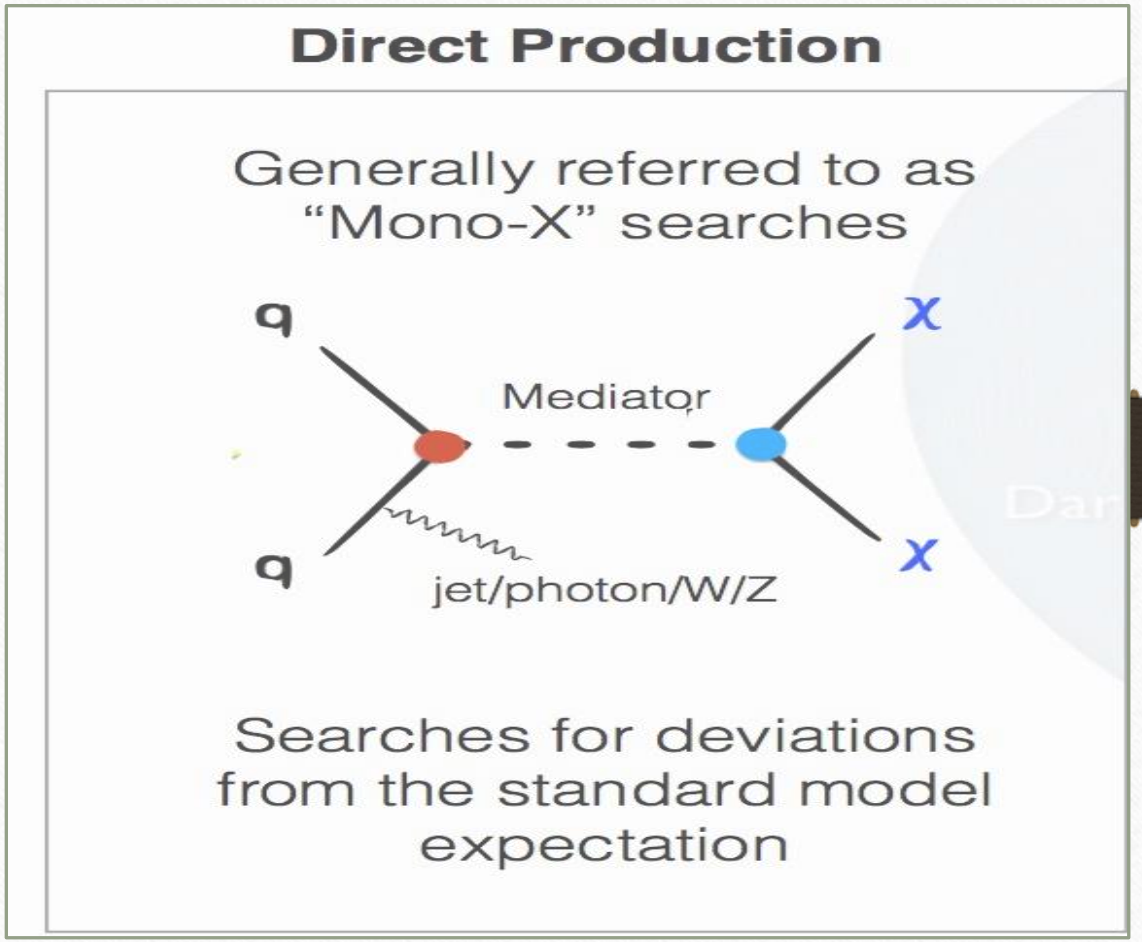
Rotational curve of the galaxy

Bullet Cluster

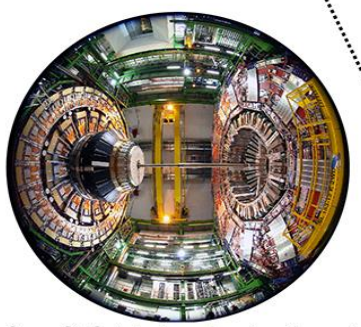
Images taken by Chandra X-Ray Observatory

Dark matter searches at CMS

- Search for dark matter with monophoton final state
- 2016 published result :JHEP02(2019)074



Compact Muon Solenoid

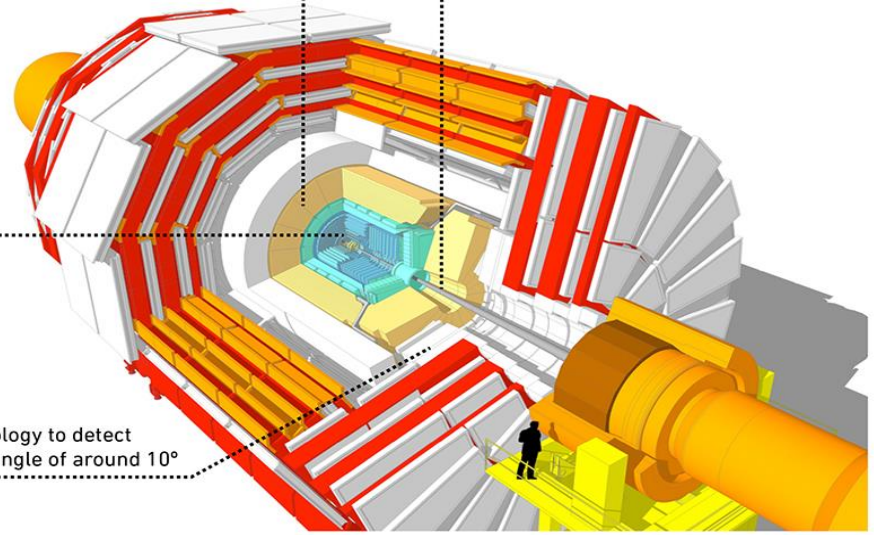


Open CMS detector, showing the endcap calorimeter sticking out, which will be replaced with the new **high granularity calorimeter (HGCAL)** around 2024-2026.

Hadron calorimeter
to reach a 5 Gb/sec readout

Pixel detector improvements at the core of the apparatus

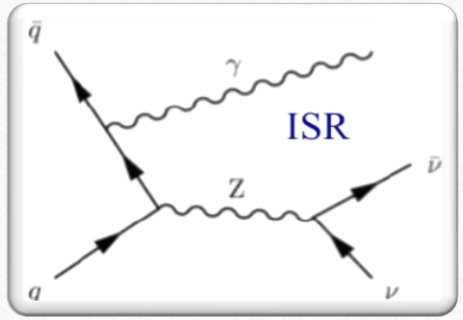
Beam pipe
with a new shape to get closer to the interaction point



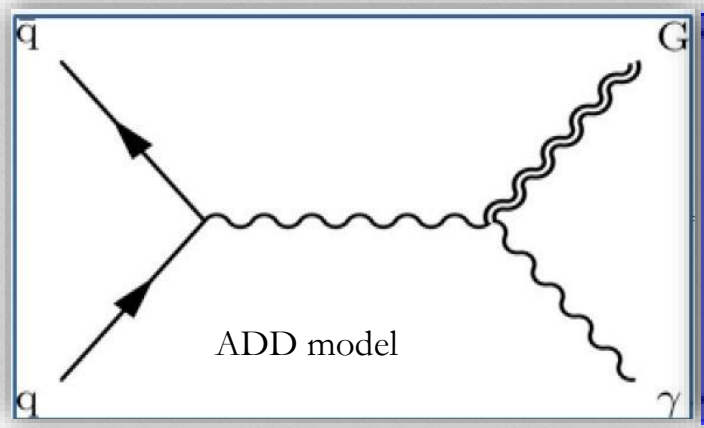
New **Muon System** technology to detect muons that scatter with an angle of around 10°

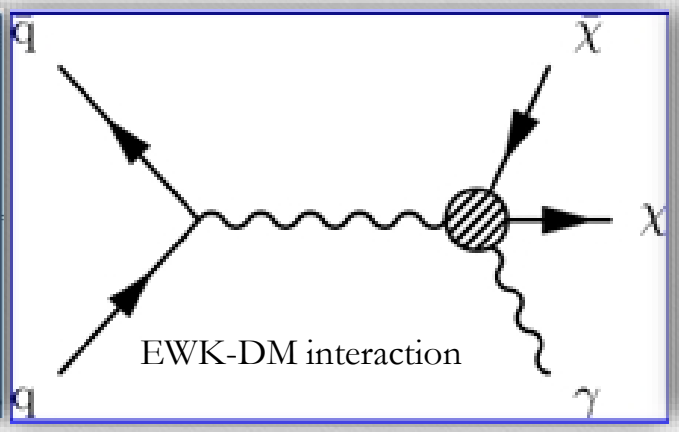
Monophoton Analysis

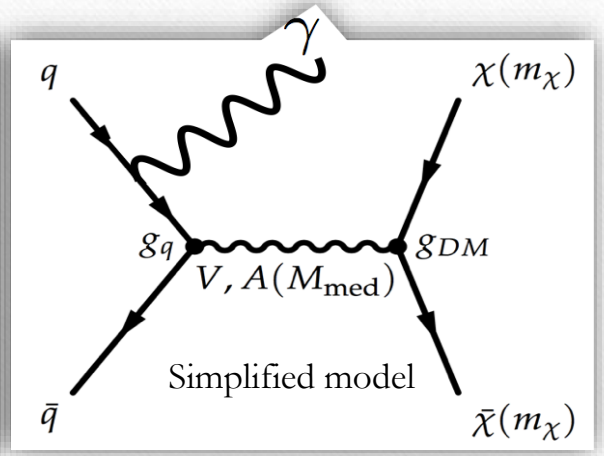
- Monophoton channel: High p_T photon against a large missing transverse energy
  - In Standard model, it is mostly through $Z(\nu\nu)+\gamma$
- New Physics model predicts excess in this channel above SM background
- Model considered in this analysis are:
  - ADD model for extra dimension
  - EWK-DM interaction model
  - Simplified model



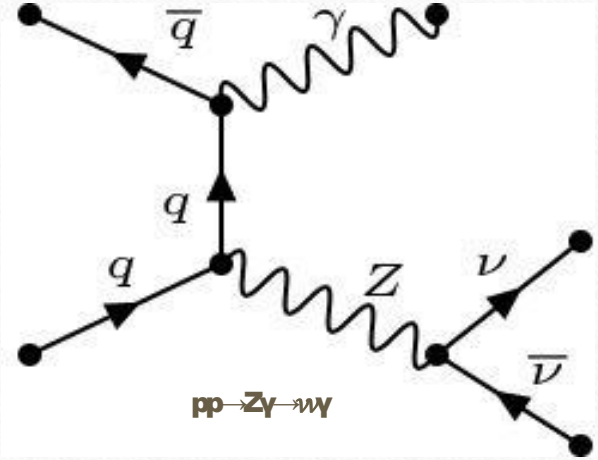
Standard model process

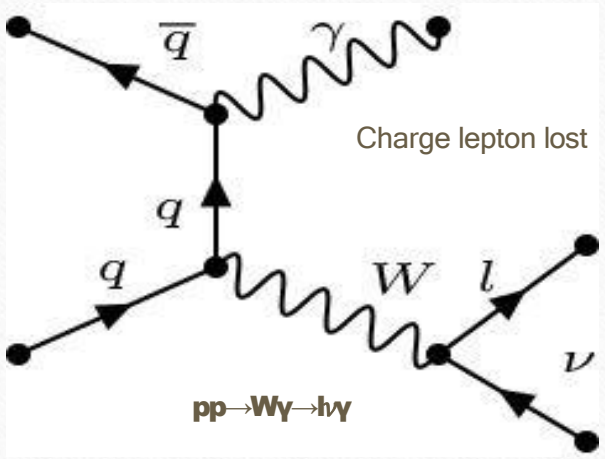


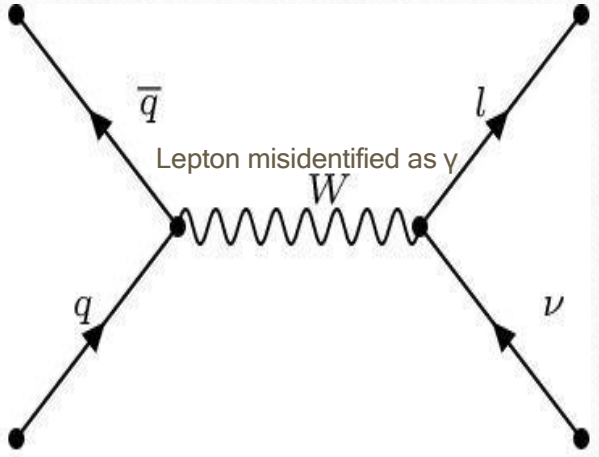




Background Composition

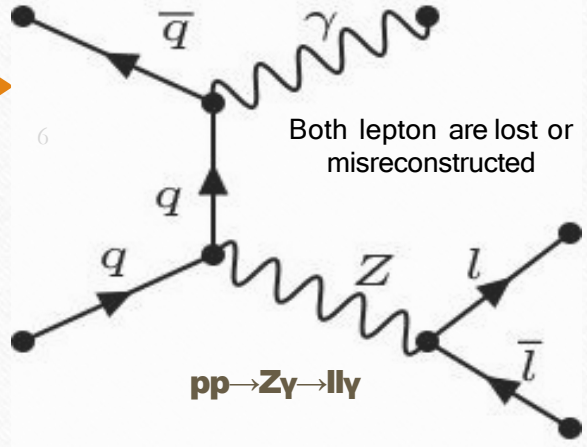


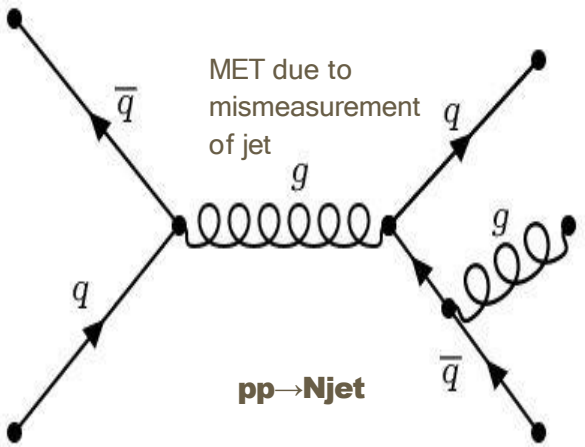


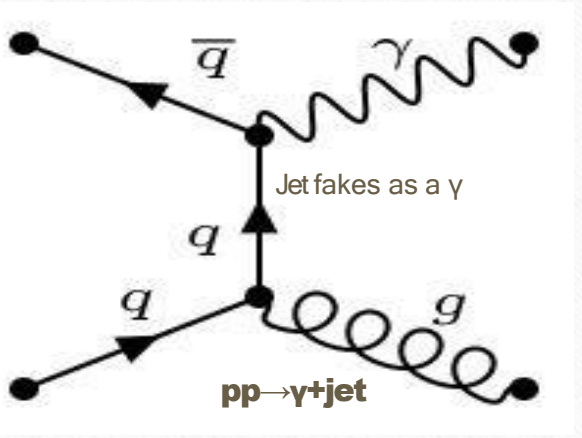


Major Backgrounds

- Backgrounds are estimated using a combination of data-driven and monte-carlo techniques





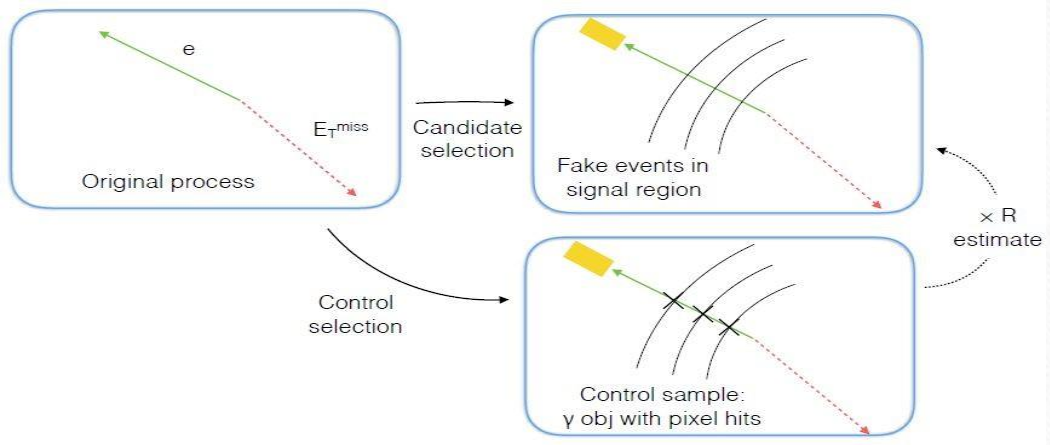


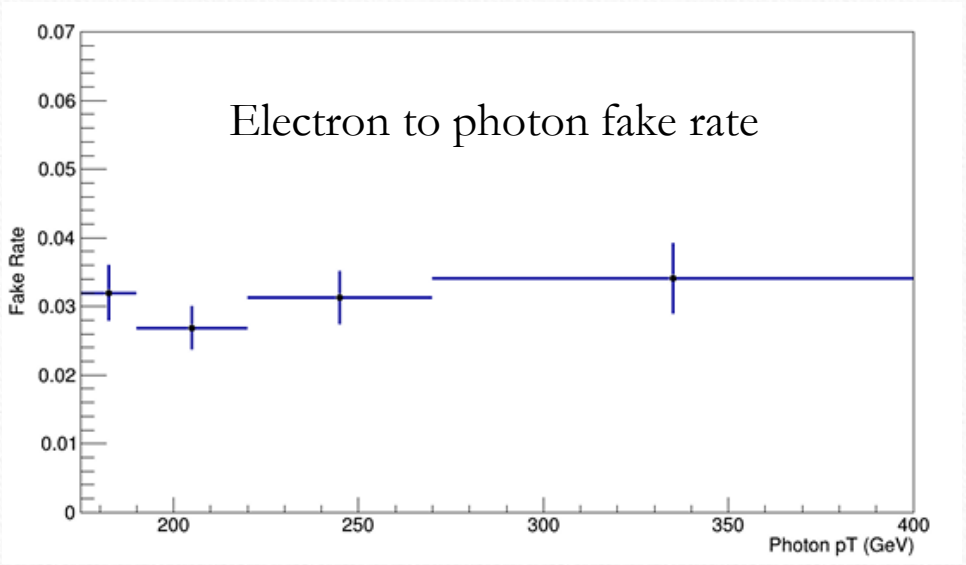
Minor Backgrounds

Background Estimation

Electron faking photon

- Data driven strategy
  - Z->ee event
  - Tag is an electron (passing tightID)
  - Probe is a photon (passing medium photon ID)
  - Fit ee and eγ distributions and estimate fake rate
  - Fake rate = $N_{e\gamma}$/ N_{ee}
  - Method for obtaining uncertainty with electron faking photon is in backup

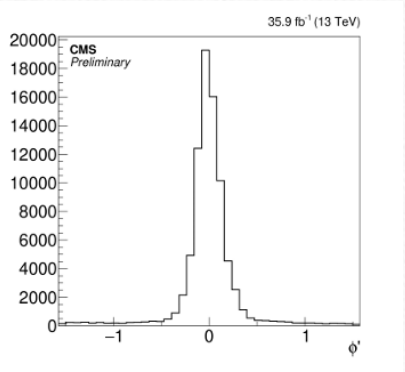




Event Selection In Signal Region

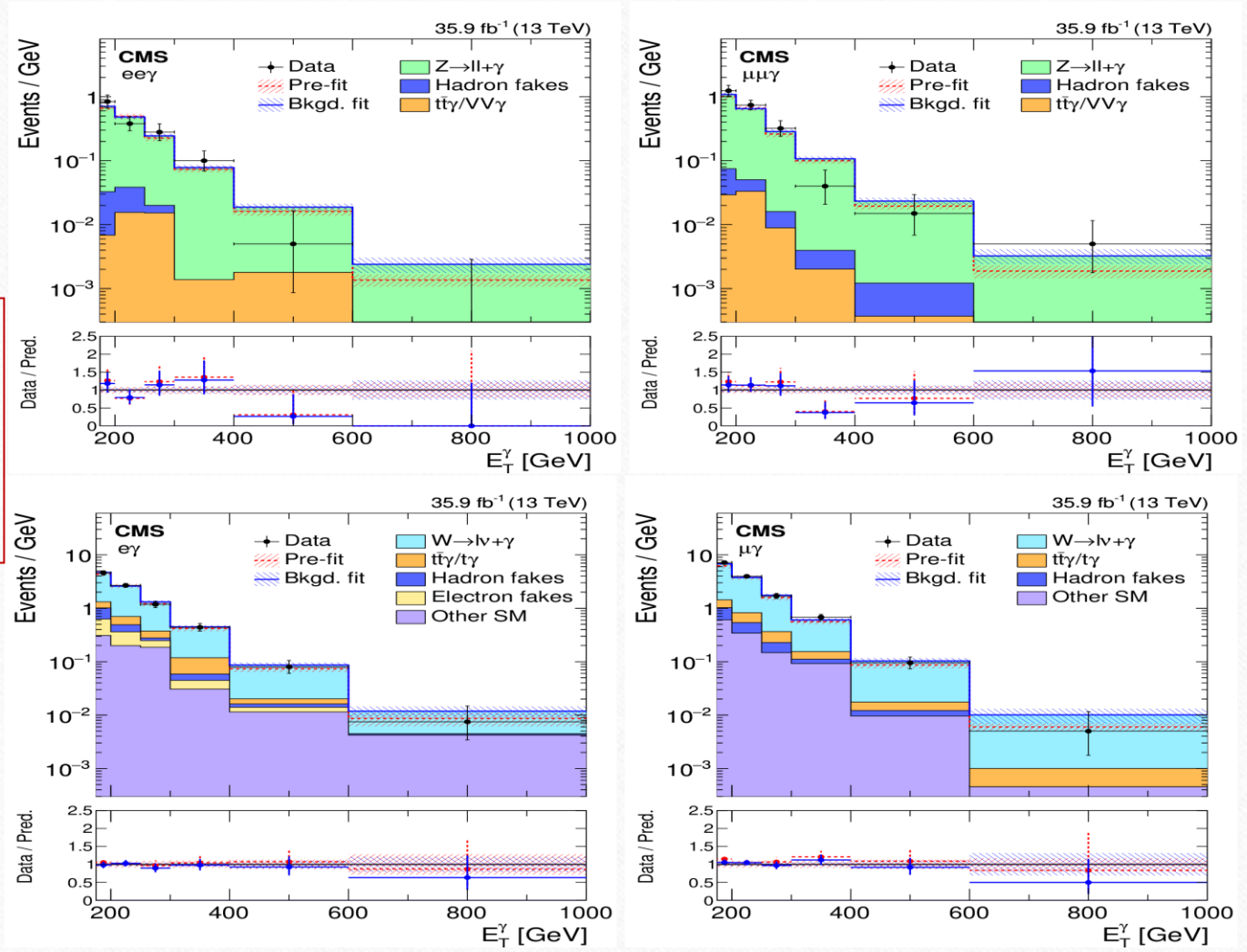
- Event are selected with P_T > 165 GeV at trigger level
- Photon
  - Pt>175 & $|\eta|$<1.4442
  - Passing 80% Signal Efficiency
- MET
  - MET>170
  - MET filters are applied
- Lepton Veto if electron or muon is found
  - LooseID
  - pt>10 GeV
  - ΔR(lepton, photon)>0.5

- Δϕ(photon,MET)>0.5
- Jet
  - Δϕ(jet,MET)>0.5
- To reject γ+Jets background
  - Photon Pt/MET <1.4
- Split SR into vertical and horizontal region to constrain beam halo normalisation
  - $|\Delta\phi|$>0.5 (Vertical region)
  - $|\Delta\phi|$<0.5 (Horizontal region)



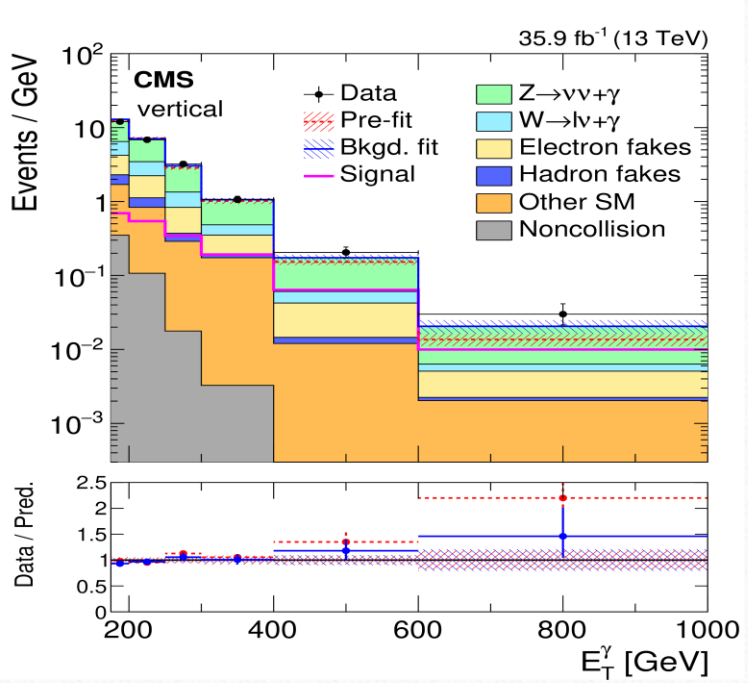
Control Region

Comparison between data and MC simulation in the four control regions: Zeeγ(upper left), Zμμγ(upper right), Weνγ (lower left), Wμνγ (lower right) before and after performing the simultaneous fit across all the control samples and signal region, and assuming absence of any signal.

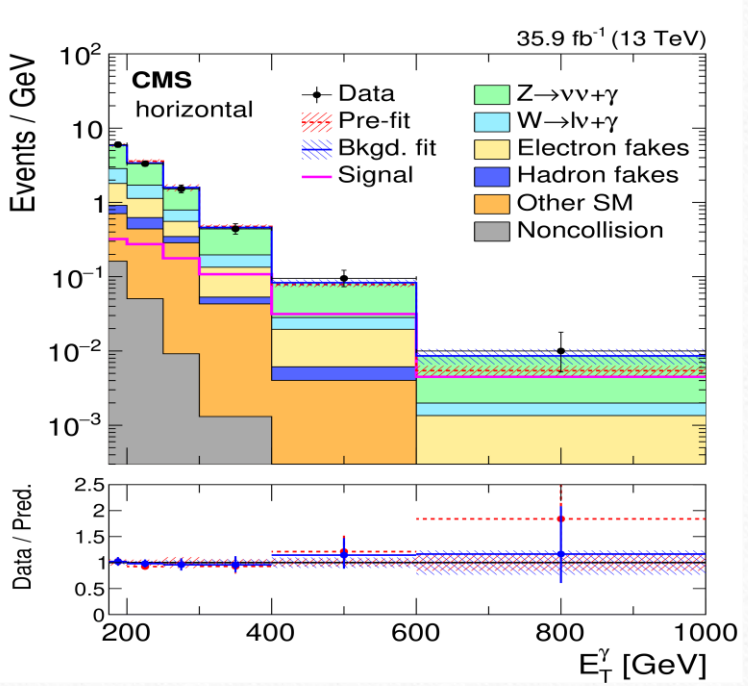


Signal Region

Observed E_T^γ distributions in the horizontal (left) and vertical (right) signal regions compared with the post-fit background expectations for various SM processes

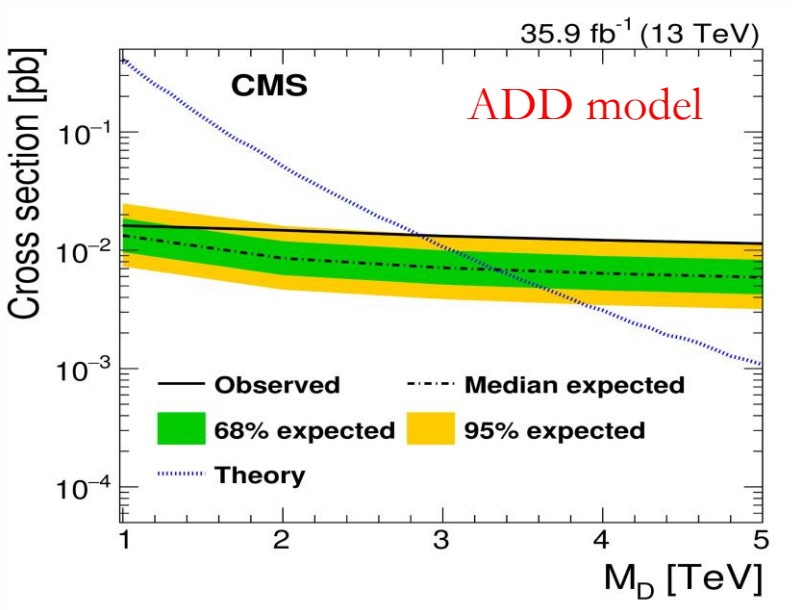


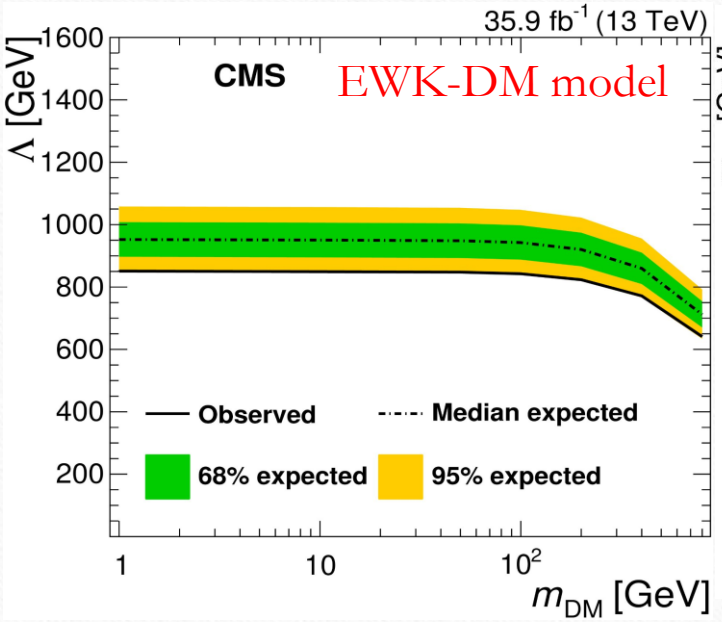
Vertical Region

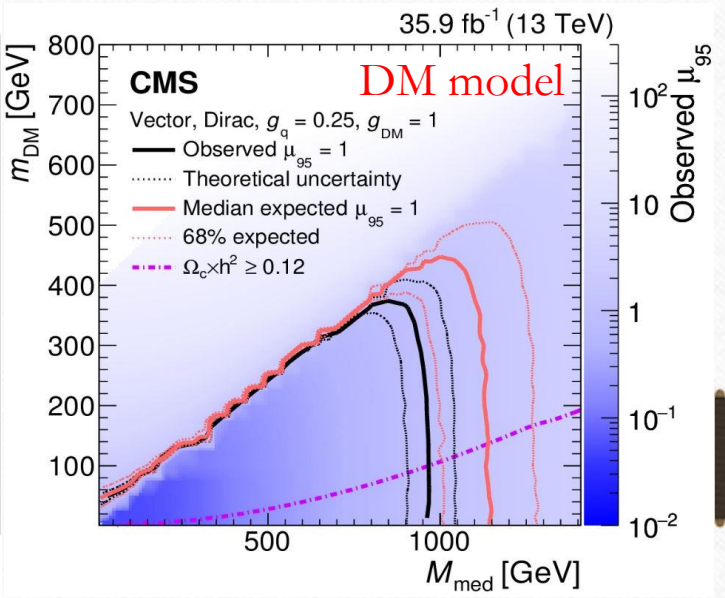


Horizontal Region

Results







12

Using 35.9 fb^{-1} of integrated luminosity, Upper limit is determined for the production cross-section of three models which are mention below

- For the ADD model: Planck mass up to 2.90 TeV has been excluded
- For EWK-DM model: Expected limit on suppression scale Λ is 850 GeV
- For DM simplified model: Mediator mass 950 GeV has been excluded

Summary

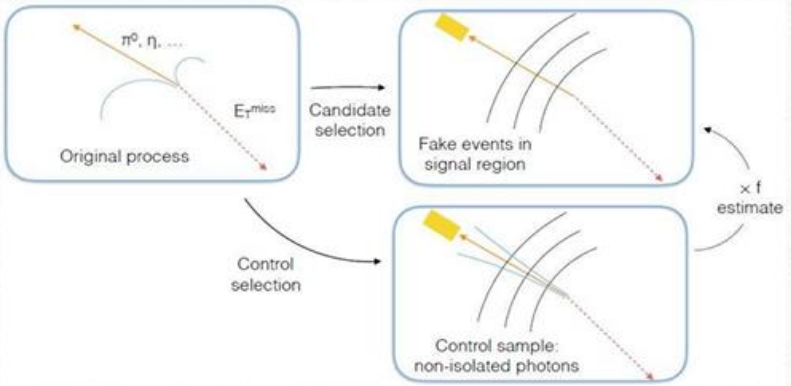
- Presented a monophoton analysis using 35.9 fb^{-1} integrated luminosity
- Working on finalizing the monophoton analysis for the dark matter simplified model, ADD model for extra dimension and EWK-DM interaction model using full Run2 data


THANK
YOU

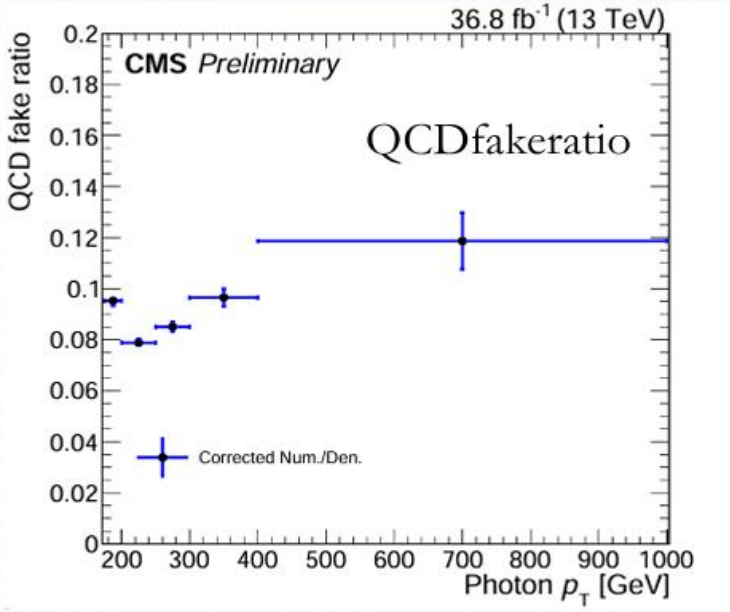
Background Estimation

QCD Fake rate

- Data driven strategy
  - Count the number of jets behaves as a photons, which fails loose isolation cut
  - Multiply by a fake ratio to get number of jets mistakenly identified as photons
  - Fake ratio is evaluated in MET<30 GeV control sample

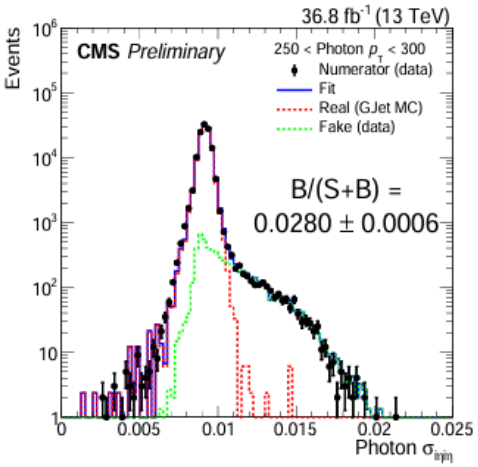


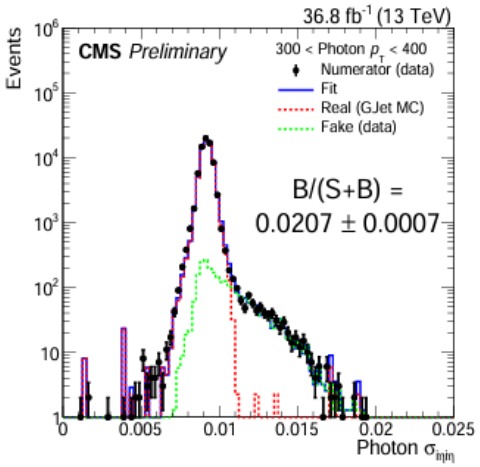
$$f = \frac{N_{iso}(\text{EM Object})}{N_{non\text{-}iso}(\text{EM Object})}$$



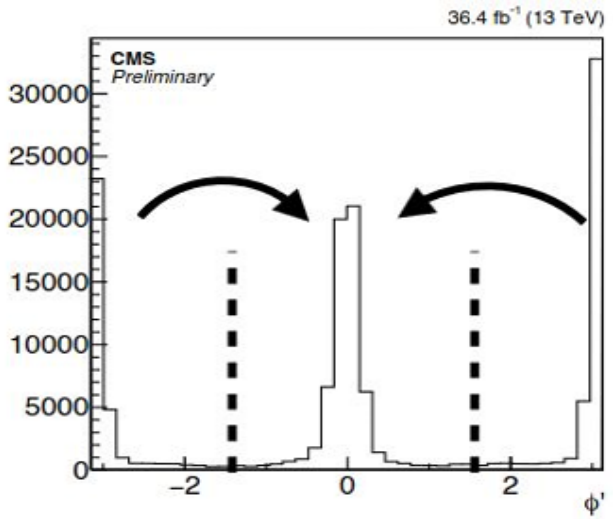
Jet faking photon

- Numerator of fake ratio:
  - QCD fake events passing the medium ID selections
  - Subtract real photon contribution, obtained from template fit based on $\sigma_{i\eta i\eta}$
  - **Real photon template:** γ+jets MC
  - Fake photon template: charged worst hadron isolation sideband in data

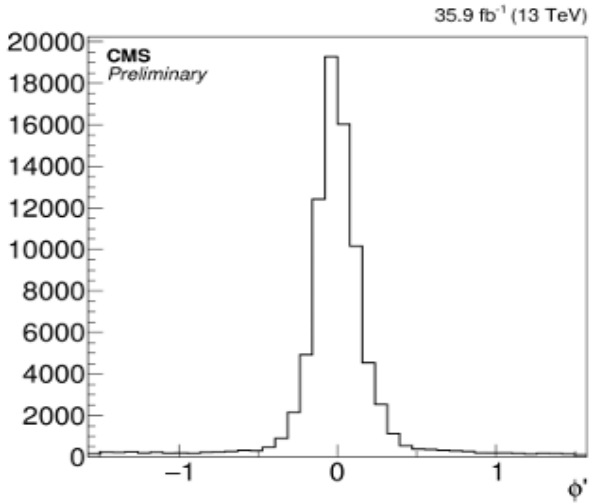


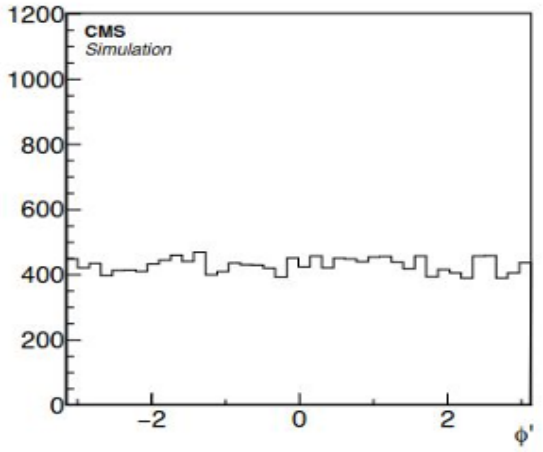


Beam Halo Estimation



Fold





- Beam halo is anisotropic in ϕ
  - Φ′ ="folded ϕ" into one peak
- Final beam halo estimate from simultaneous fit
  - Halo normalisation floated freely
  - Horizontal regions constraints halo
- Top is Bhalo and bottom plot is Zνν̄γ

Splits SR into $|\Phi'|<0.5$ (horizontal) and $|\Phi'|>0.5$ (vertical region)

Nuisances parameters

	W TF	Z TF	W/Z Link	e fake	h fake	halo	spike	MC
Vγ Theory			SHAPE					
lepton ID SF	SHAPE	SHAPE						
fake rates				FLAT	SHAPE			
halo shape						SHAPE		
spike norm							FLAT	
photon ID SF								FLAT
jet/γ energy scale								SHAPE
luminosity								FLAT
MC and CR statistical	BIN BY BIN							