Shining Light on Dark Matter with the CMS Experiment

Zeynep Demiragli (Brown University), on behalf of CMS Collaboration

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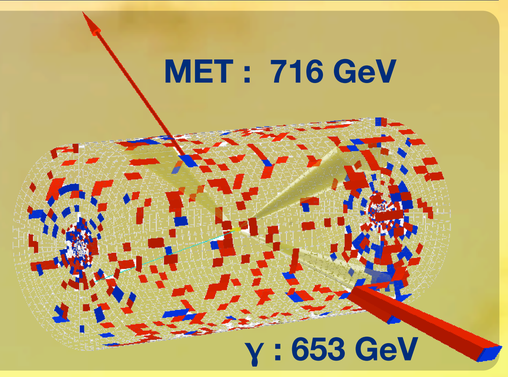
We present a search for ADD, Branon large extra dimensions and Dark Matter pair-production with a final state of γ + missing transverse energy (MET) in pp collisions at $\sqrt{s}$ =8 TeV. We find no deviation from the Standard Model prediction, and achieve an extension of the current limits. This search is done with the data taken by the CMS experiment at the LHC corresponding to an integrated luminosity of 19.6 fb^{-1}.

THE POWER OF LIGHT

- Dark Matter (DM) is the dominant contribution to the matter density of the universe and may be produced at the LHC through qq → γχχ, where the γ is radiated by an incoming quark and the DM particles escape detection.
- The ADD model provides a possible solution to the hierarchy problem and includes the process qq → γG, where the graviton G escapes detection.
- In the ADD model brane fluctuations may give rise to scalar particles called Branons which can be pair produced in association with SM particles.

ANALYSIS STRATEGY

- Events are required to pass a single photon or photon + MET trigger and have:
  - Isolated photon with energy > 145 GeV
  - MET > 140 GeV.
  - ΔΦ(γ,MET) > 2.0
- Events with leptons or more than one non-pile up jets are veto-ed.

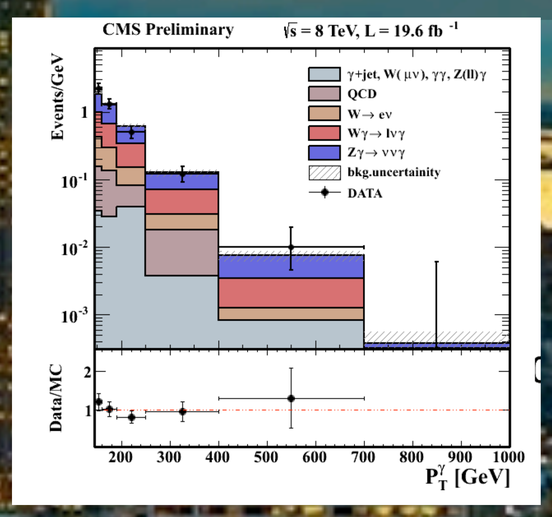


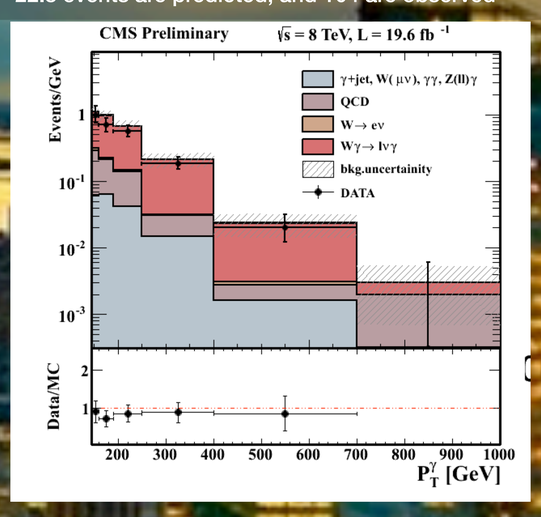
WHAT DO WE EXPECT?

- Backgrounds from (Zνν)γ, (Wlν)γ, γ+jet, Z(ll)γ and γγ events are estimated from simulation with NLO K-factors and Data/MC scale factors applied.
- The contamination from jets/electrons misidentified as photons, is estimated using control samples in data.
- Non-collision sources such as electronic noise, cosmic rays and beam induced backgrounds are estimated using timing information of the ECAL.
- Backgrounds with non-intrinsic MET are reduced by constructing and minimizing a X^2 function:

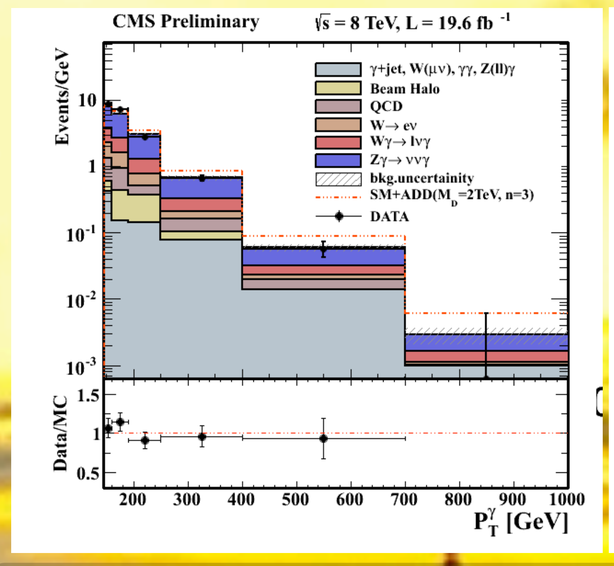
$$\chi^2 = \sum_{i=objects} \left(\frac{(p_T^{reco})_i - (\hat{p}_T)_i}{(\sigma_{p_T})_i} \right)^2 + \left(\frac{\hat{\not{E}}_x}{\sigma_{\hat{\not{E}}_x}} \right)^2 + \left(\frac{\hat{\not{E}}_y}{\sigma_{\hat{\not{E}}_y}} \right)^2$$

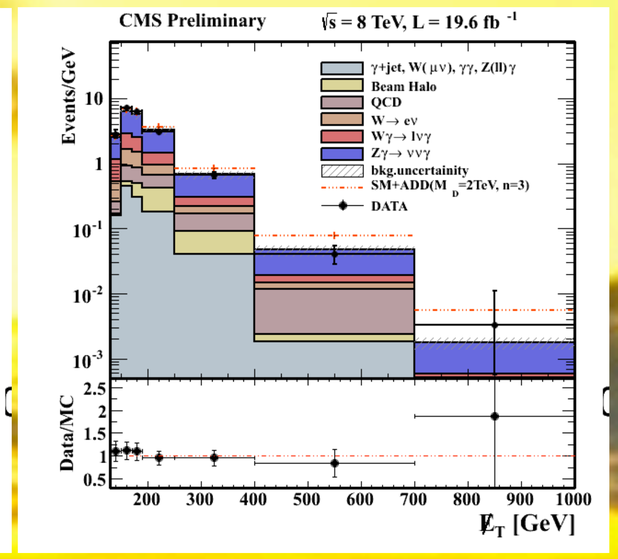
- Zg region: Inverting the ΔΦ(γ,MET). 124.8 \pm 12.8 events are predicted, and 123 are observed.
- Wg region: Inverting the lepton veto. 126.1 \pm 22.8 events are predicted, and 104 are observed





WHAT DO WE SEE?

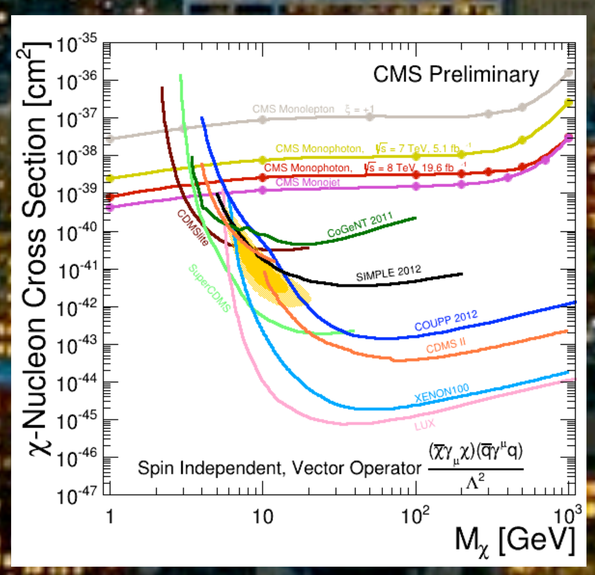


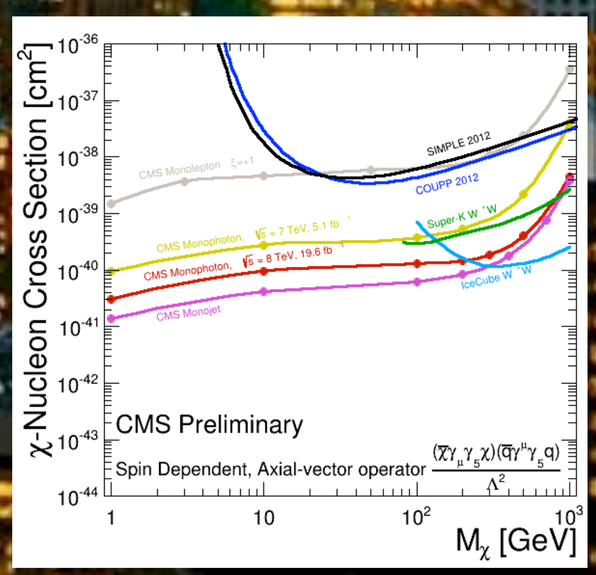


- These distributions show the γ pT and MET distribution in the signal region, compared with the estimated background contributions as well as the prediction from the ADD model with M_D = 2 TeV and n = 3. The background uncertainty includes statistical and systematic errors.
- The number of events observed in data is consistent with the background estimation.

Process	Estimate
$Z(\to \nu\bar{\nu}) + \gamma$	344.8 ± 42.5
$W(\to \ell\nu) + \gamma$	102.5 ± 20.6
$W \to e\nu$	59.5 ± 5.5
jet → γ fakes	45.4 ± 13.9
Beam halo	24.7 ± 6.2
Others	35.7 ± 3.1
Total background	612.6 ± 63.0
Data	630.0

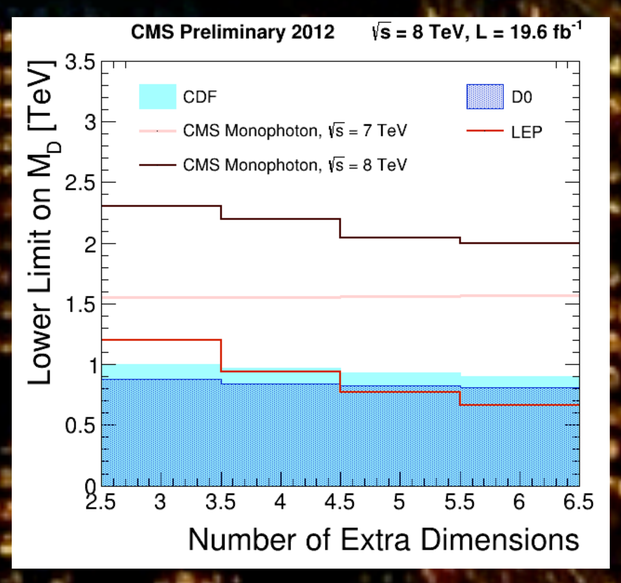
WHAT DOES IT ALL MEAN?

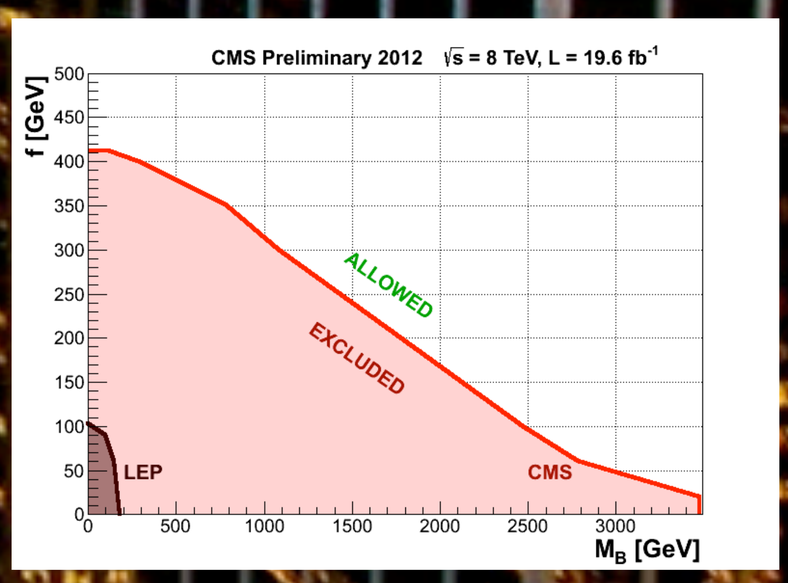




- 90% CL upper limits are placed on the DM production cross sections, as a function of M_χ, assuming vector and axial-vector operators. These are converted into lower limits on the cutoff scale Λ. The Λ values are then translated into upper limits on the χ-nucleon cross sections, calculated within the effective theory framework.
- These limits are compared to direct and in-direct detection of dark matter experiments. In the case of spin dependent couplings, the CMS results are the most stringent over a wide range of DM mass hypothesis.
- 95% CL upper limits are placed on the ADD cross sections and translated into exclusions on the model parameters MD and n. Masses MD < 2.30 TeV are excluded at 95% CL for n = 3.

- For massless branons the brane tension f is found to be greater than 412 GeV. Branon masses M_B < 3.5 TeV are excluded at 95% CL for low brane tension (20 GeV). These bounds are the most stringent to date on the possible existence of branons.





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