Searching for the elusive graviton!!

A Search for Large Extra Dimensions via Single Photon plus Missing Energy Final States

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1. INTRODUCTION: Large Extra Dimensions (LED) ..... what? ..... why?

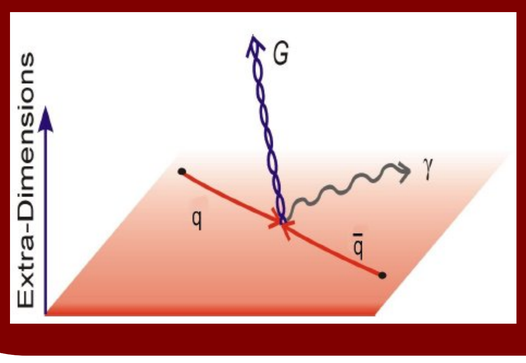
The World of LED

• Standard Model (SM) particles are confined to a 4D (time+space) brane.

• The gravitational field is diluted in a large compactified extra volume.

• This could explain why gravity appears so much weaker than the other forces of nature.

• The presence of LED solves the hierarchy problem of the Standard Model.



How large is LARGE?

Not very..... These extra dimensions are large compared to the electroweak scale:

$$1\ \text{TeV}^{-1} \approx 10^{-19}\ \text{m}$$

n: number of extra dimensions,
$\mathbf{M_{Pl}}$: effective Planck scale (4D),
$\mathbf{M_D}$: fundamental Planck scale [(4+n)D],
R: size of extra dimensions, related by [1]:

$$M_{Pl}^2 = 8\pi\, M_D^{n+2} R^n$$

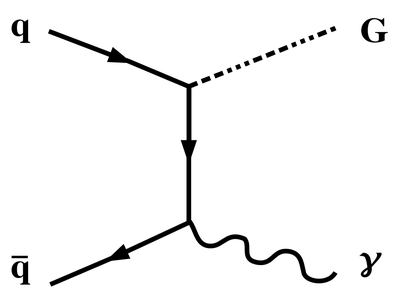
Sizes of LED

At M_D = 1 TeV:

n = 1 → R ≈ 10^{13} cm (solar system)
n = 2 → R ≈ 1 mm
n = 3 → R ≈ 1 nm
n = 7 → R ≈ 1 fm (proton)

What would we see?

We search for a single photon (monophoton) and missing energy (missing transverse energy) [2].

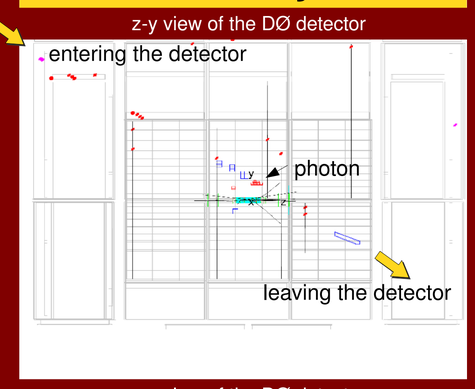


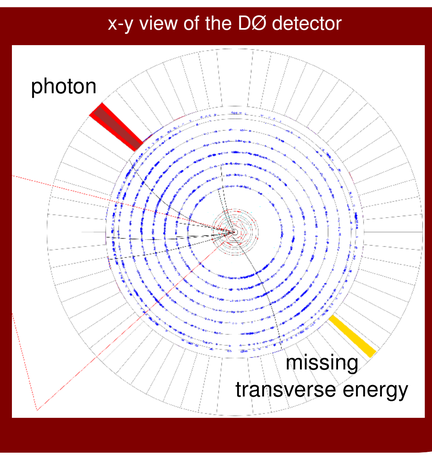
What looks the same? (backgrounds)

$Z+\gamma \to \nu\,\bar{\nu}+\gamma$
$W \to e\,\nu$
$W+\gamma \to l\,\nu+\gamma$
$W/Z+$ jet

Large background from non-collision events: **cosmic rays and/or beam halo particles** which leave energy in the calorimeter..

A Cosmic Ray Event





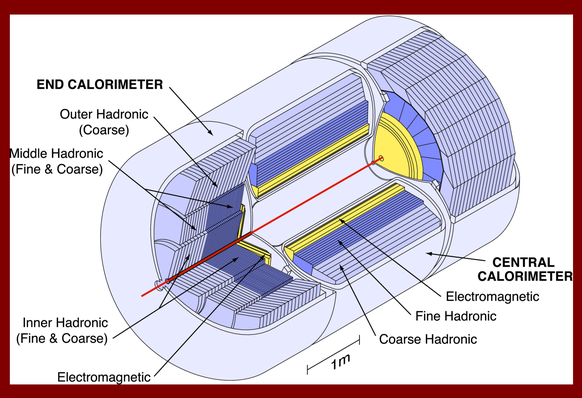
2. THE METHOD: The EM pointing algorithm..... how?

DØ Calorimeter [3]

• Fine segmentation.

• Topology of electromagnetic (EM) objects can be used to select photons from interaction region.

• Non-collision photons still present after clean-up requirements.

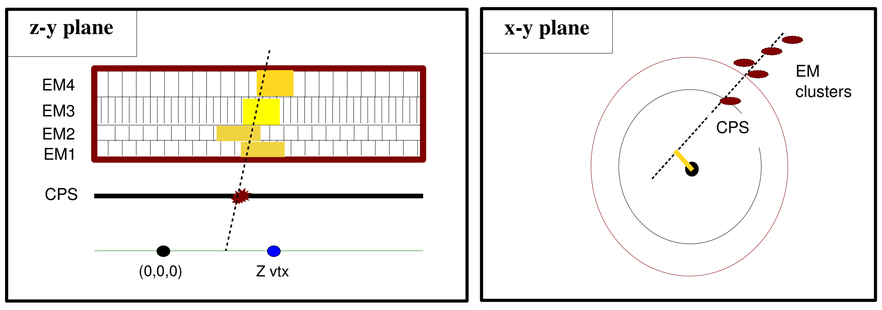


The EM Pointing Algorithm at DØ

• Calculates the direction of an EM shower using only EM calorimeter and central preshower (CPS) information.

• A straight line fit is performed to predict:

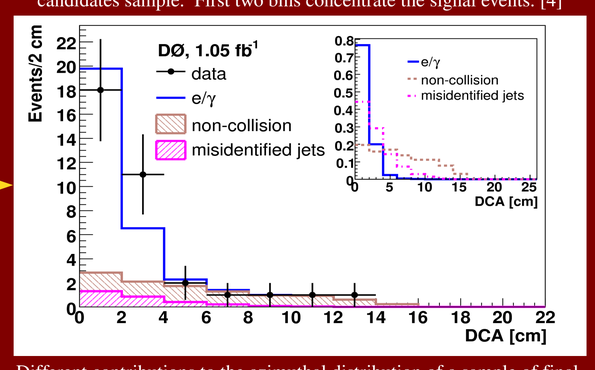
the **z-position of primary vertex** in the polar plane,
and the distance of closest approach (**DCA**) in the azimuthal plane.



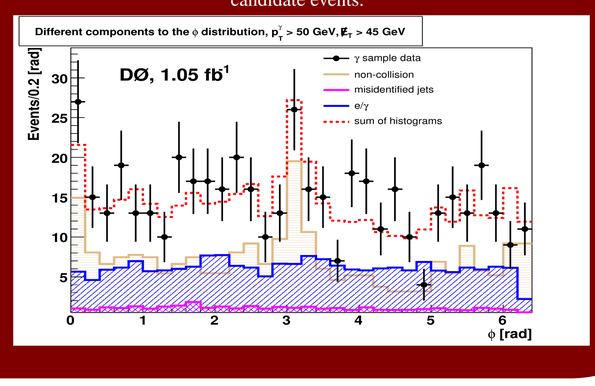
Photons from non-collision events, misidentified jets and signal photons have different DCA distributions. They can be used to construct templates for a linear histogram fit to the final candidate events to determine their fractional contribution.

DCA Template Shapes & Fit

Different DCA shapes of background and signal are used to fit the final candidates sample. First two bins concentrate the signal events. [4]



Different contributions to the azimuthal distribution of a sample of final candidate events.



3. RESULTS/CONCLUSIONS: .....so, what happened?

Data and estimated backgrounds

Results are shown for 2.7 fb^{-1} of data. They are an update to reference [4].

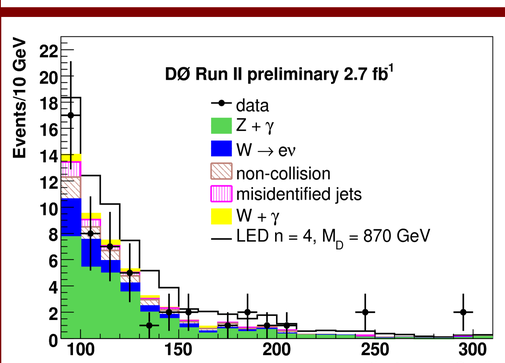
Remaining backgrounds:

$\mathbf{Z+\gamma \to \nu\,\bar{\nu}+\gamma}$
irreducible contribution estimated from Monte Carlo (MC). An excess of events could also indicate the presence of anomalous ZZγ couplings.

$\mathbf{W \to e\,\nu}$
electron misidentified as a photon due to tracking inefficiency or hard bremsstrahlung. Estimated from a sample of isolated electrons.

$\mathbf{W+\gamma \to l\,\nu+\gamma}$
the lepton is not reconstructed. Smaller contribution estimated from MC.

Background	Number of expected events
$Z+\gamma \to \nu\bar{\nu}+\gamma$	29.5 ± 2.5
$W \to e\nu$	8.5 ± 1.7
Non-collision	6.6 ± 2.3
Misidentified jets	3.1 ± 1.5
$W+\gamma$	2.22 ± 0.3
Total Background	49.9 ± 4.1
Data	51



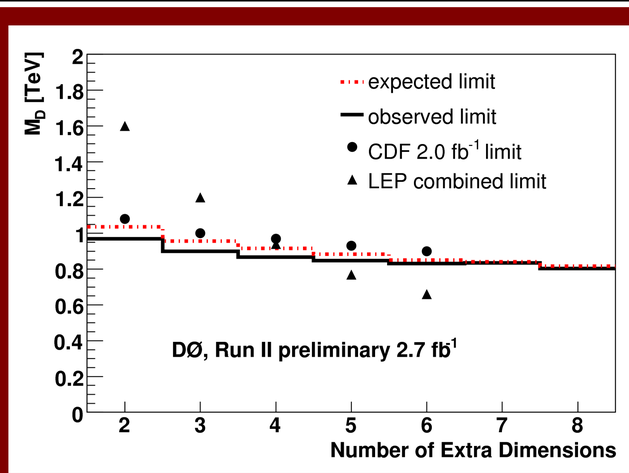
Limits

We set limits for the fundamental Planck scale M_D assuming the leading-order theoretical cross section for the signal.

n	DØ 2.7 fb^{-1} observed (expected) M_D lower limit (GeV)	CDF 2 fb^{-1}[5] ($\gamma + \not\!\!E_T$) observed M_D lower limit (GeV)	CDF 2 fb^{-1}[5] combined observed M_D lower limit (GeV)
2	970 (1037)	1080	1400
3	899 (957)	1000	1150
4	867 (916)	970	1040
5	848 (883)	930	980
6	831 (850)	900	940
7	834 (841)	−−	−−
8	804 (816)	−−	−−

Conclusions

We have conducted a search for LED in the monophoton channel, finding no evidence for their presence. The updated limits show significant improvement from our previous study.



REFERENCES

[1] N. Arkani-Hamed, S. Dimopoulos, G. Dvali, Phys. Lett. B 429, 263 (1998).
[2] G. Guidice, R. Rattazzi, and J. Wells, Nucl. Phys. B544, 3 (1999).
[3] V.M. Abazov et al. (D0 Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **565**, 463 (2006).
[4] V. M. Abazov et al. (D0 Collaboration), Phys. Rev. Lett. 101, 011601 (2008).
[5] T. Aaltonen et al. (CDF Collaboration), arXiv:0807.3132v1[hep-ex] (2008)

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