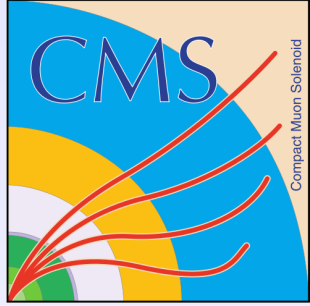

Extra Dimensions: CMS

S. A. Schmitz

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on behalf of the CMS Collaboration

LPCC BSM Jamboree
2011, CERN

Overview

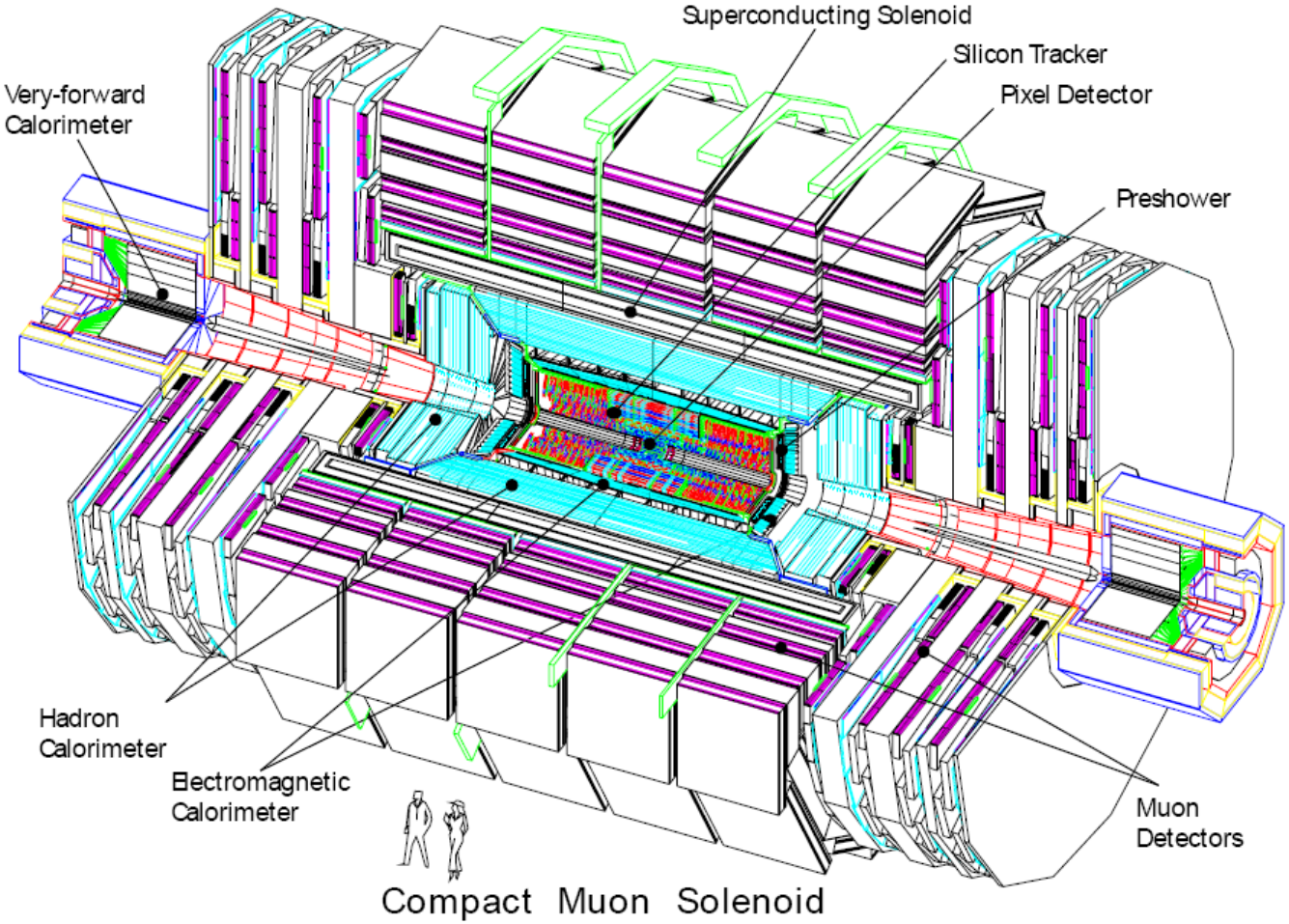
- Introduction
- Search for Microscopic Black Hole Signatures (first published collider limits)
- Search for New Physics with a Mono-Jet and Missing Transverse Energy (extends Tevatron results)
- Search for Large Extra Dimensions in the Diphoton Final State (extends Tevatron results)
- Search for Large Extra Dimensions in Dimuon Events (extends Tevatron results)
- Search for Randall-Sundrum Gravitons Decaying into Two Photons (close to Tevatron results)

Outlook: 2011 and Beyond

CMS: 2010 Data Taking

proton-proton collisions in 2010:

$35-40\ \mathrm{pb}^{-1}$ of data recorded for analyses at $\sqrt{s}=7\ \mathrm{TeV}$

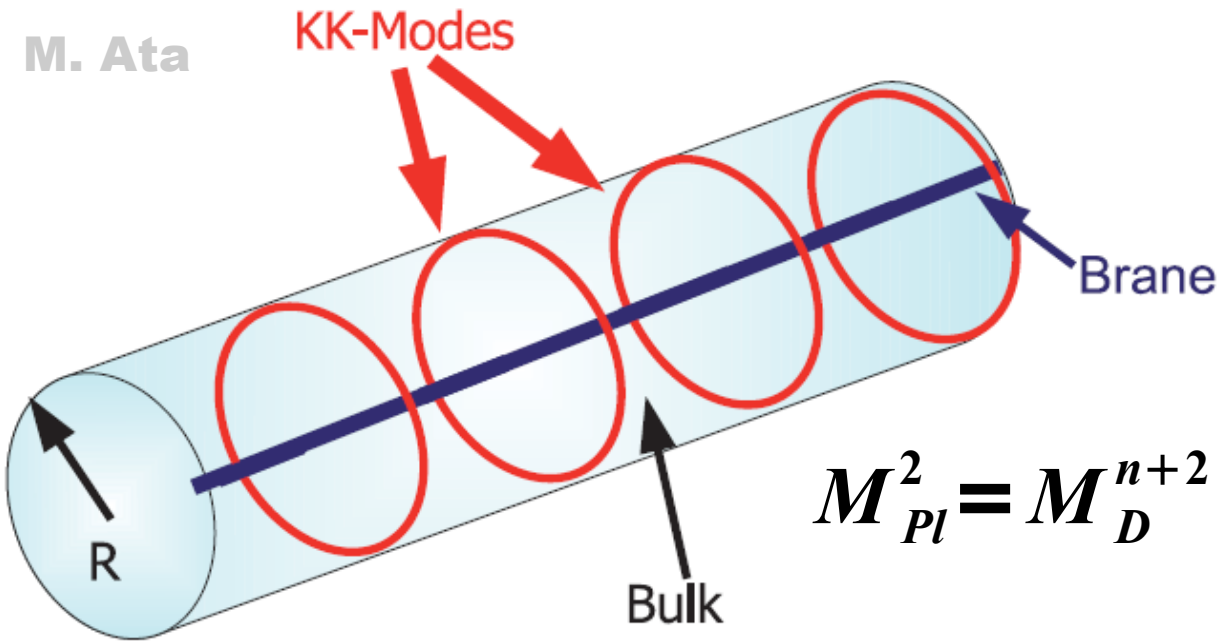


A Window towards Extra Dimensions?

The ADD model

The ADD (Arkani-Hamed, Dimopoulos, Dvali) model leads to an effective field theory based on the ideas of

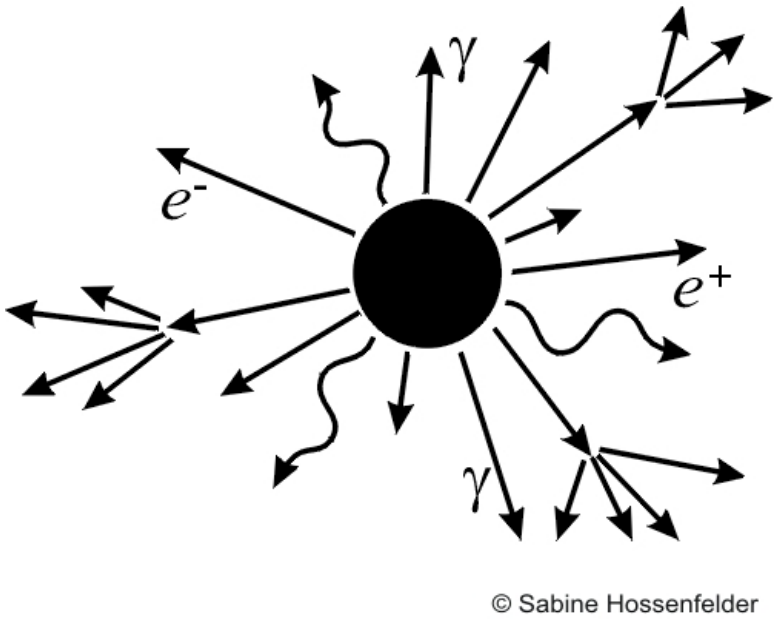
- **Compactified Large Extra Dimensions**
- **Brane Physics**



$$M_{Pl}^2 = M_D^{n+2} V_n$$

- **The Standard Model (SM) is confined to a brane**
- **Graviton can propagate in the bulk**
- **Effective field theory at "low" energies**

Microscopic Black Holes



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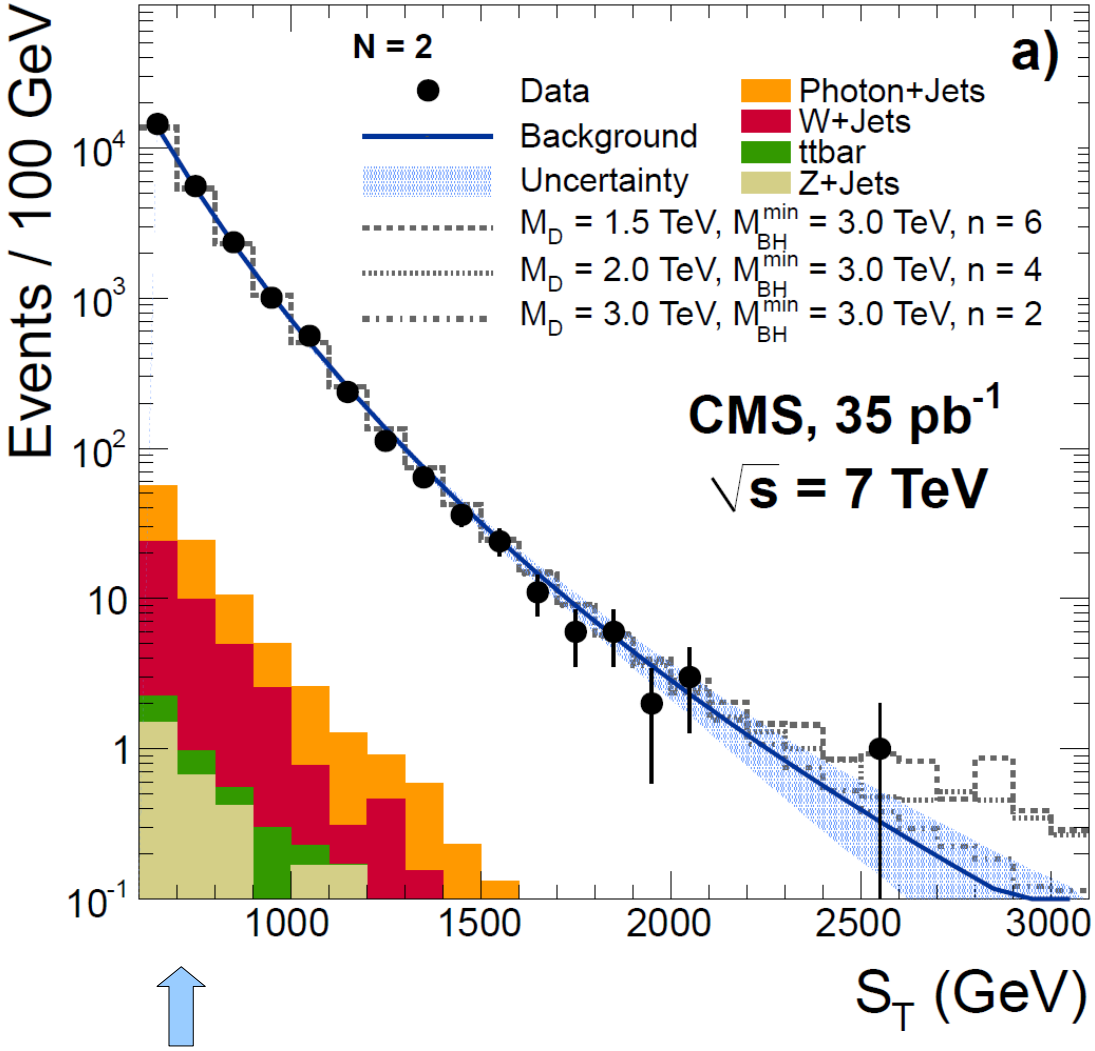
- Reduced Planck scale due to large extra dimension → increased Schwarzschild radius
- Large cross-sections possible $O(100\ pb)$
- Ansatz: $\sigma \sim \pi r_s^2$
- Signature: events with high particle multiplicities and high transversal momentum

simulation of signal events with:
a) BlackMax (no brane tension, rotating/non-rotating, no graviton)
b) Charybdis2 (rotating, stable remnant)

MBH: Background Estimation



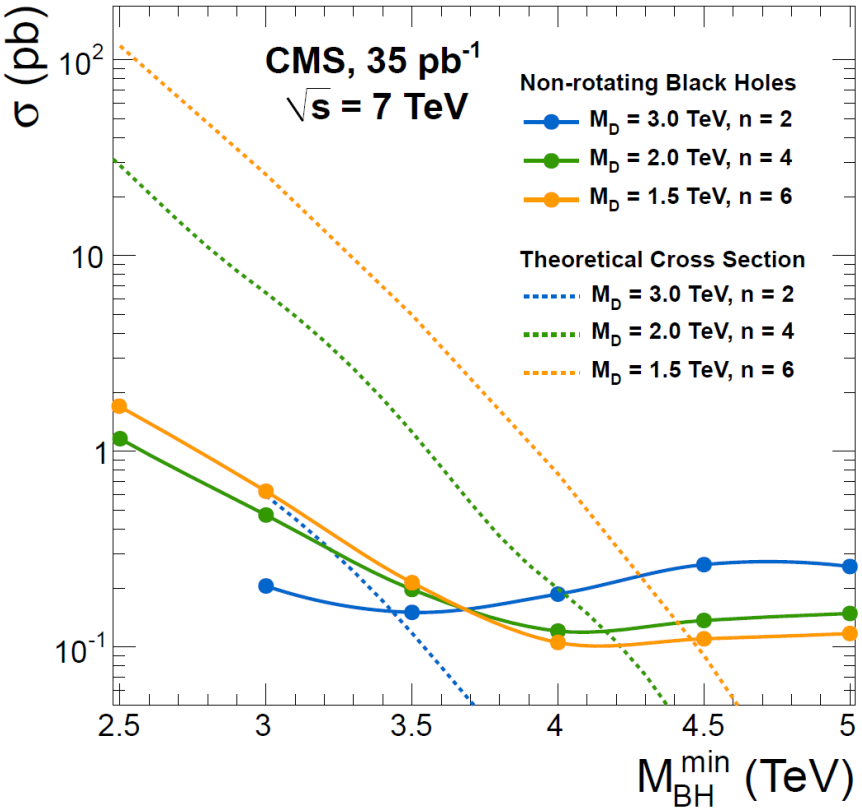
sum of transverse momenta S_T for object multiplicity N=2

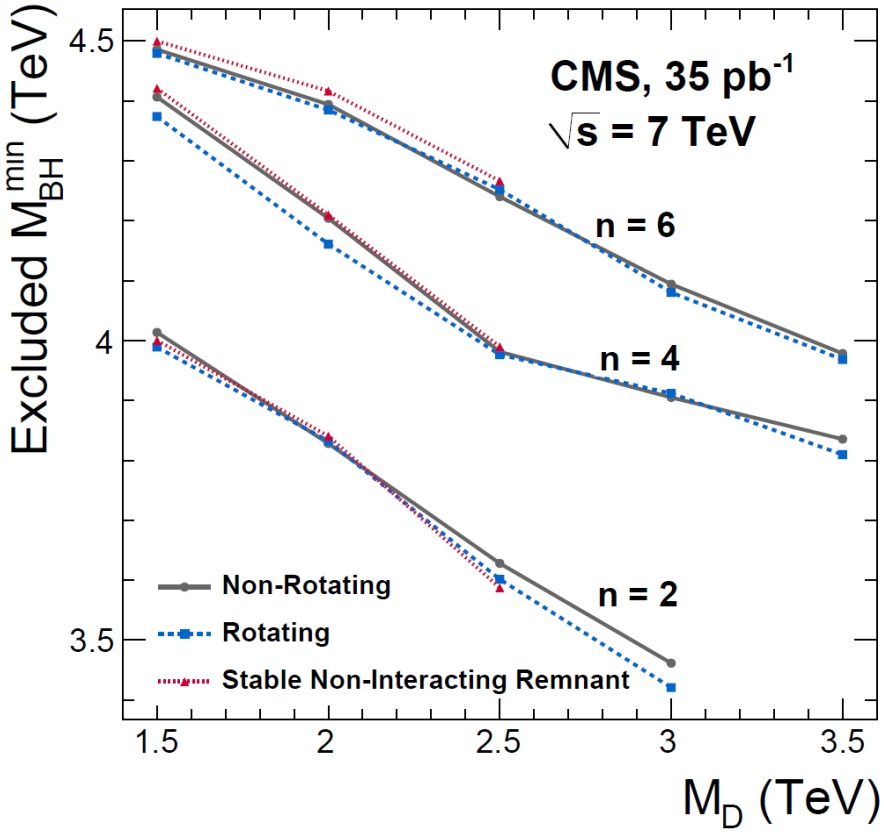
Search variables: S_T , N
(sum of transverse momenta, object multiplicity)
Considered objects:
(jets,photons,electrons,muons)

Derive dominant QCD multijet bkg from data:

a) analytic fit for N=2 and N=3 in signal free region
b) use that S_T shape independent of N
c) normalize fitted shapes in signal free regions to estimate bkg for $N \geq 3..5$

Microscopic Black Holes: Results





Bayesian 95% Upper Limits (Counting Exp.), parameter dependent optimization

Dominant Systematics: differences between considered fit functions, normalization for higher multiplicities

ADD Signatures

The coupling of the graviton to the Standard Model energy-momentum tensor results in (also other channels possible) :

a) monojet events

via graviton emmission

b) enhanced non-resonant diphoton production

via virtual Graviton exchange

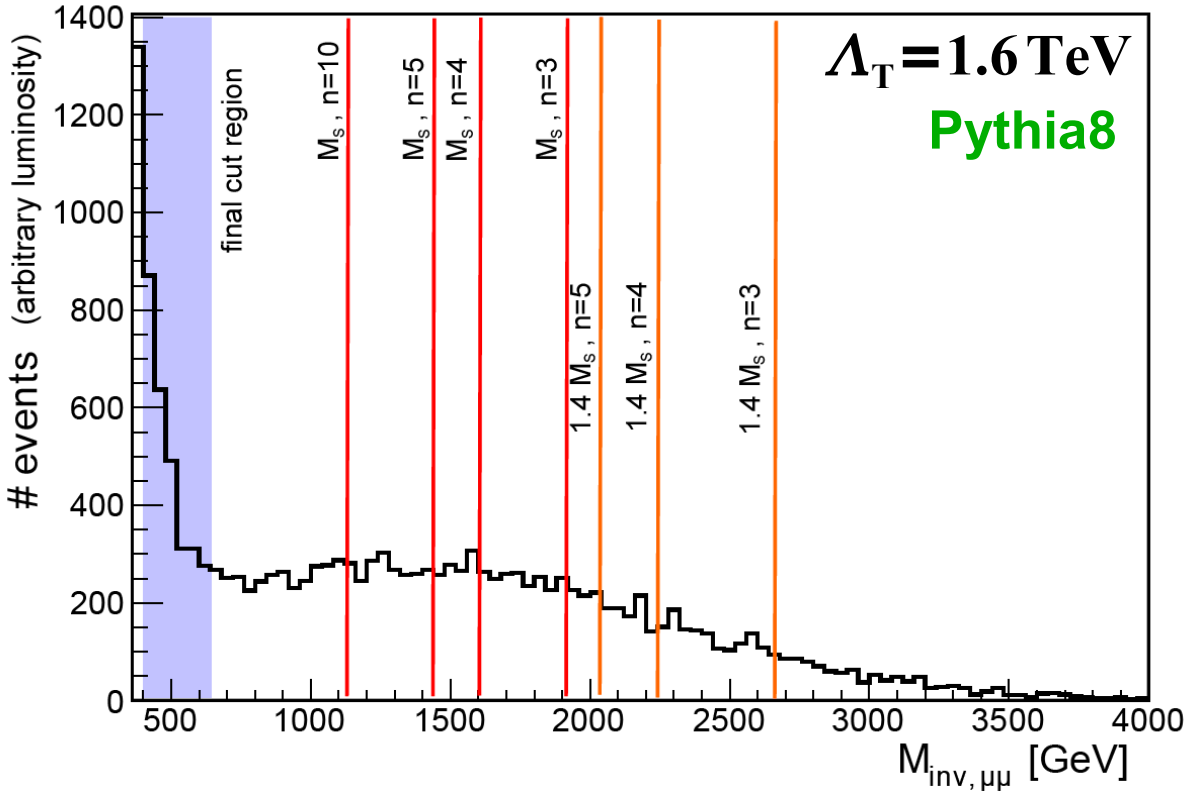
c) enhanced non-resonant dimuon production

via virtual Graviton exchange

Discussion: High Energy Completion

The validity range of the effective field theory is not directly predicted by the ADD model ...

Example: dimuon signal

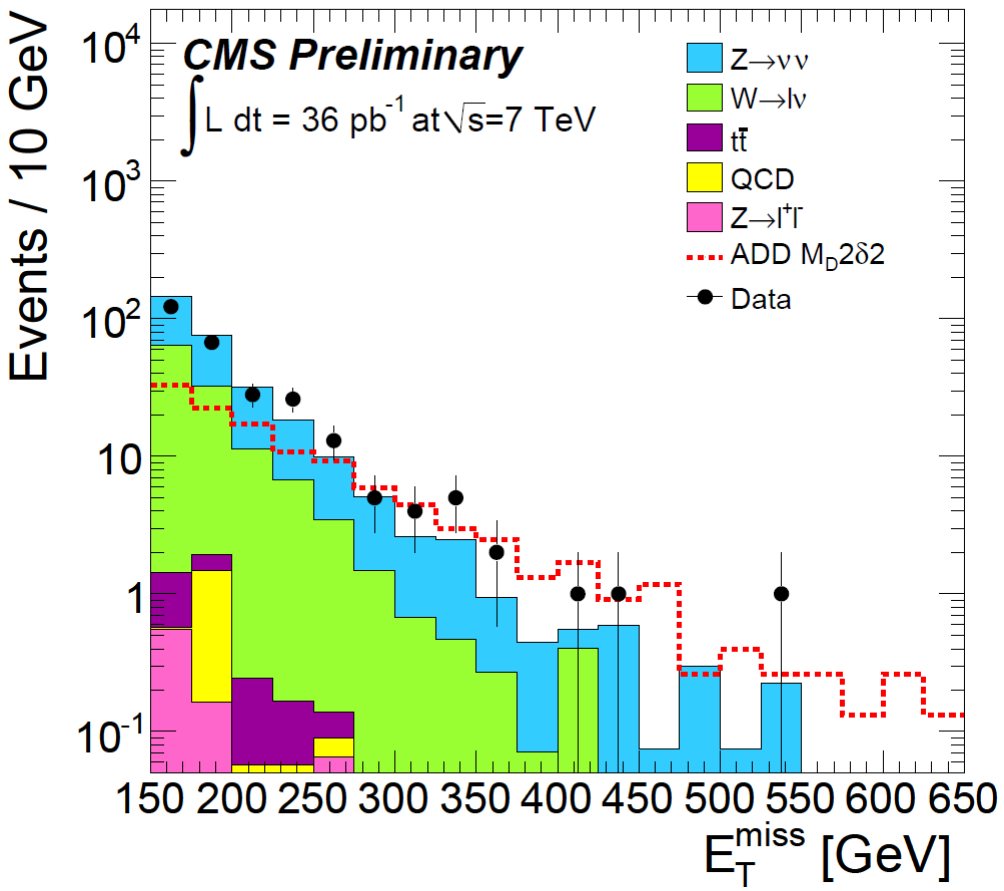


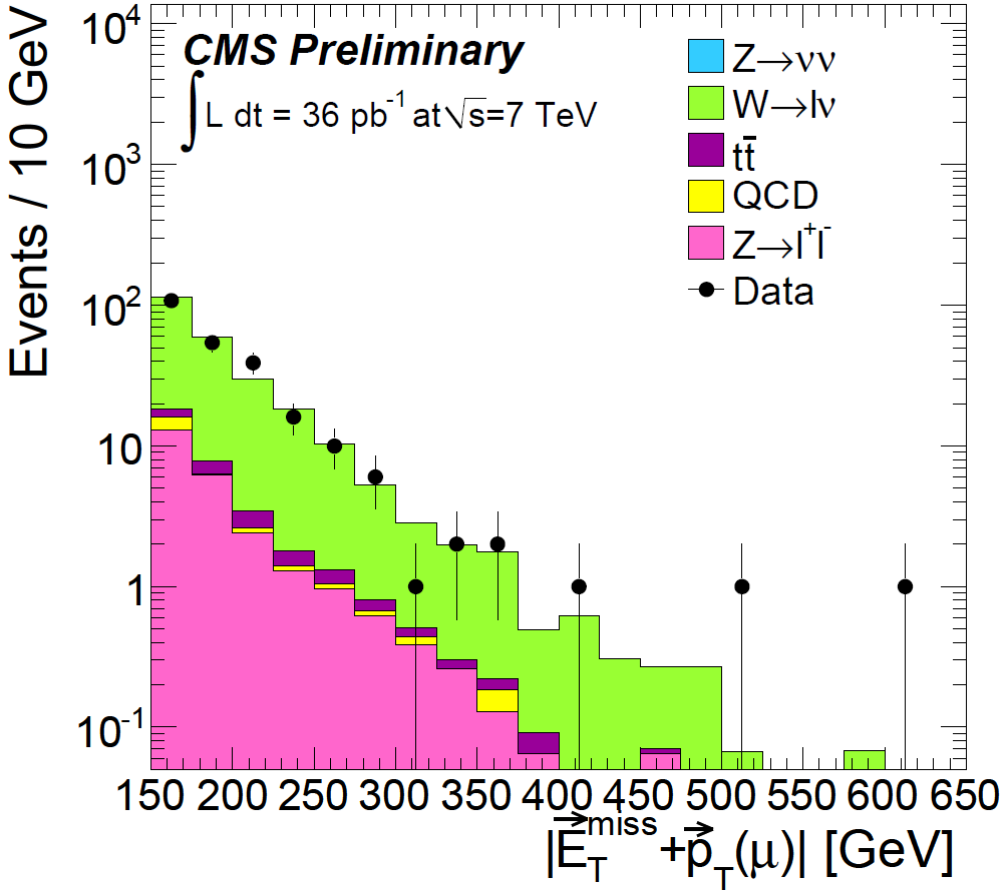
Validity ranges of down to 1 TeV need to be considered to include the possibility of a cutoff at $\hat{s} = M_S$

LO: $\hat{s} \approx M_{\mu\mu}$

No general agreement yet on how to proceed ...

ADD Monojet Analysis

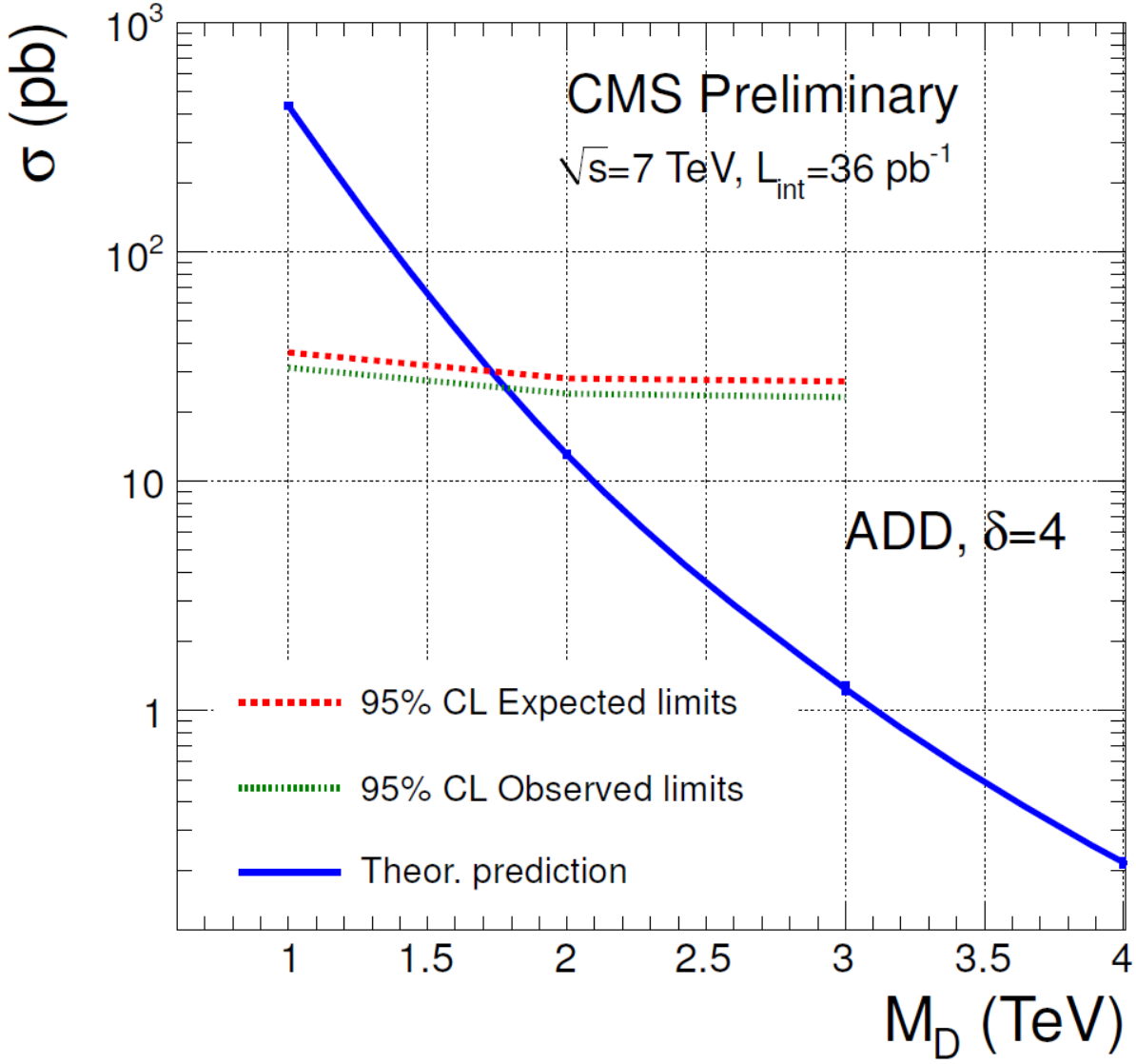




Missing transverse energy for
- veto on isolated lepton
- $p_{T,j1}>110$ GeV

W dominated sample for data driven bkg estimation

ADD Monojets: Results



dominant backgrounds $Z \to \nu\nu + \text{jets}$, $W \to l\nu + \text{jets}$ estimated with data driven methods

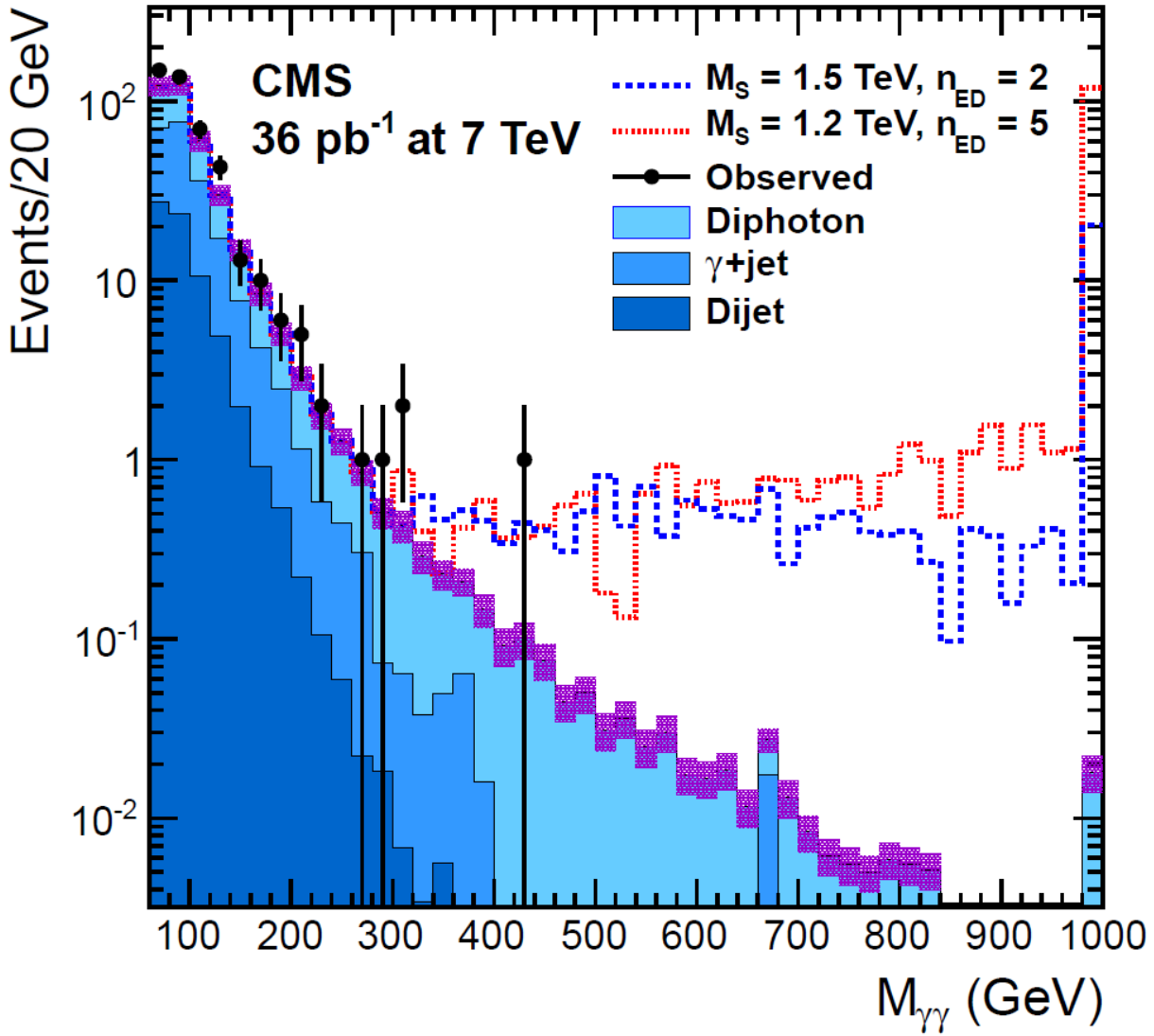
most important systematics:
- **jet energy scale**
- **jet resolution**
- **PDF uncertainty**

interpretation in the context of unparticle models also possible

simulation of signal events with Pythia8

Bayesian 95% Upper Limits (counting exp.)

ADD Diphoton Analysis



Optimized Signal region:

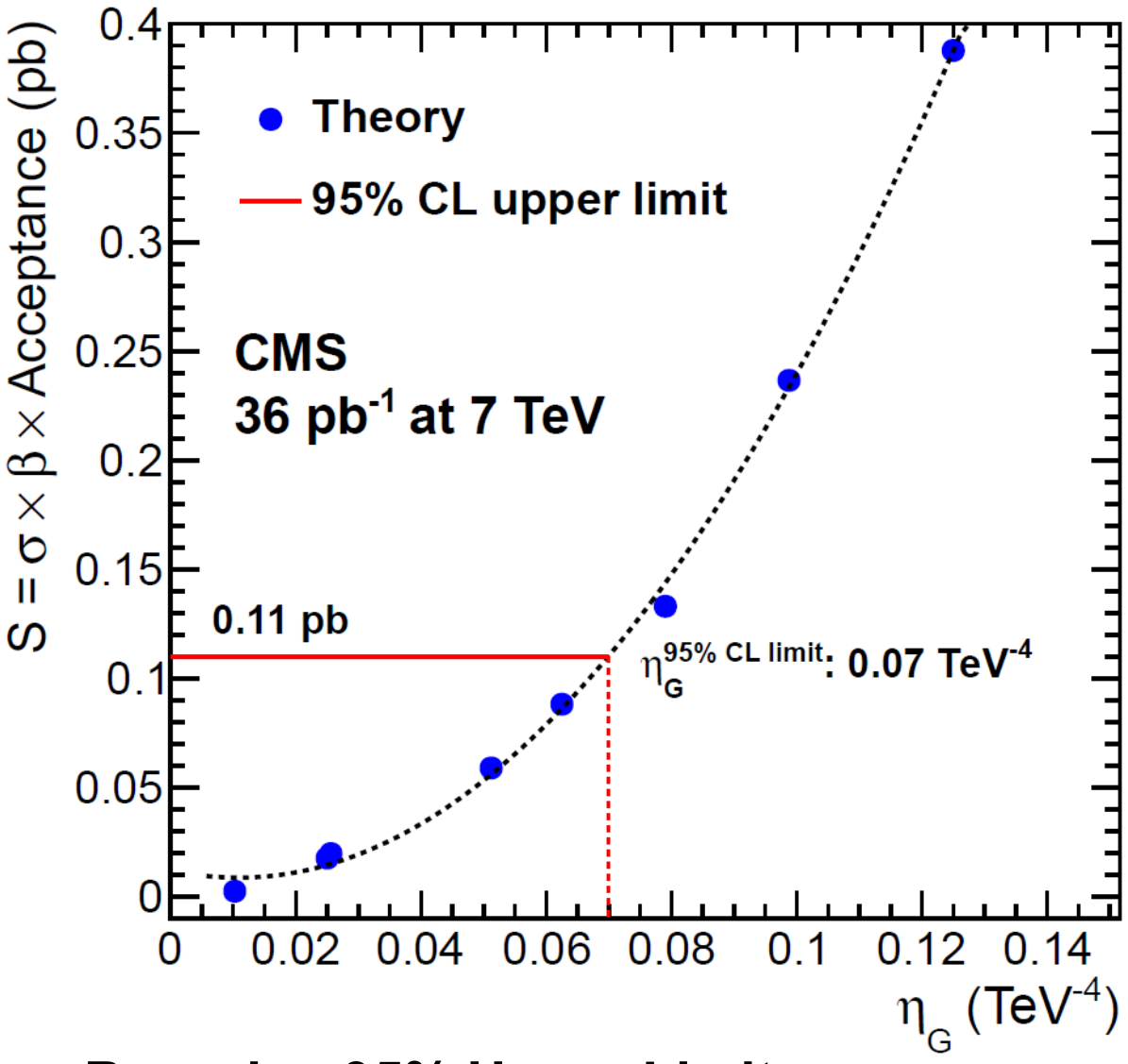
$$M_{\mu\mu} > 500 \text{ GeV}$$

$$|\eta| < 1.4$$

SM background from Diphoton events based on Sherpa (and full CMS simulation) and Diphox

data driven study of jet → photon fake rate used to study bkg from dijet and photon+jet events

Results: ADD Diphoton Analysis



Bayesian 95% Upper Limits

Simulation of signal events with Sherpa

limits reported in different parameter conventions (see ADD summary slide)

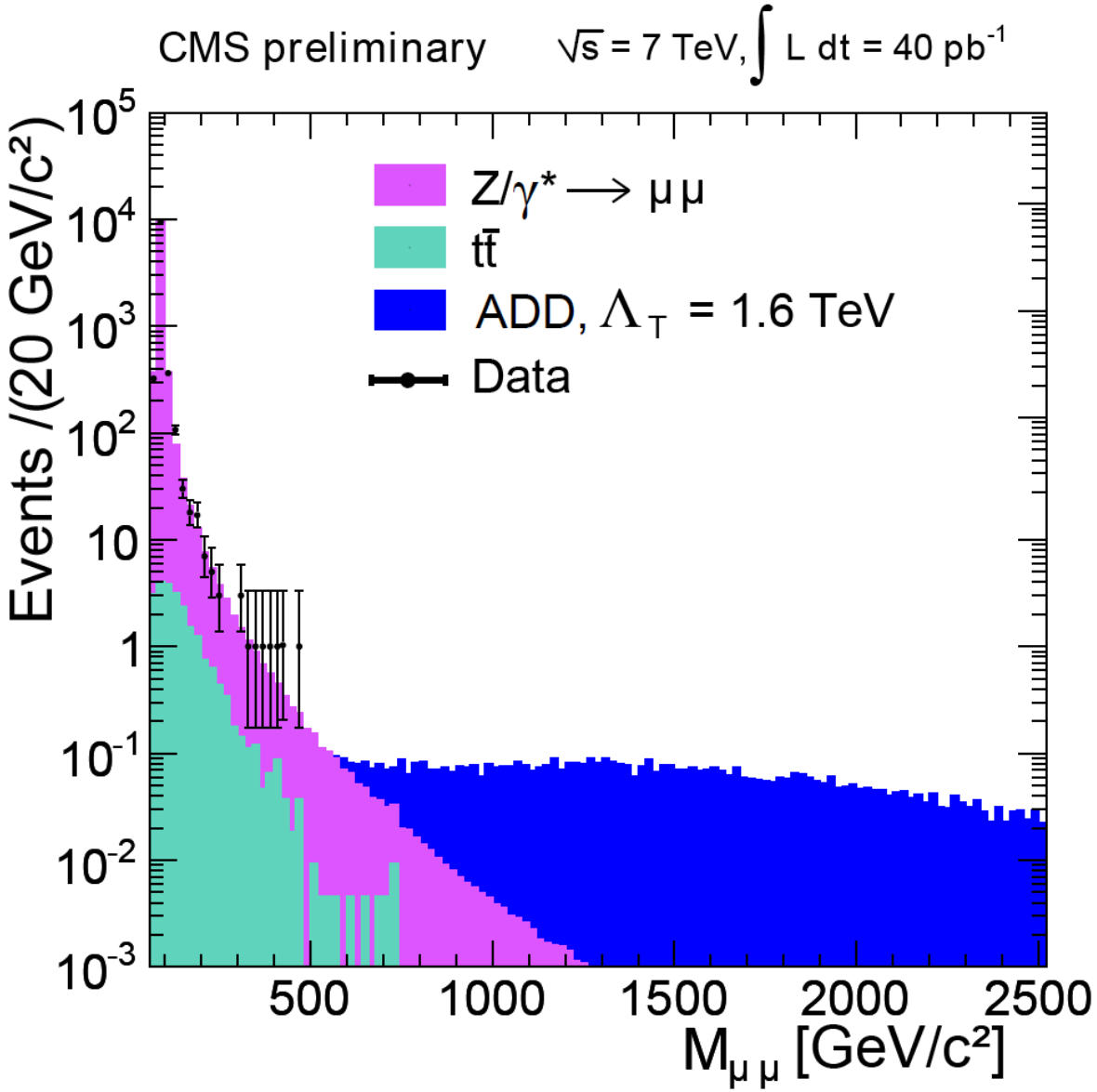
1) GRW: G. F. Giudice, R. Rattazzi, J. D. Wells $[\Lambda_T]$

2) HLZ: T. Han, J. D. Lykken, R. Zhang $[M_s, n]$

3) J. Hewett $[\eta_G]$

Dominant systematic uncertainties:
- Diphoton k-factor
- Signal Efficiency

ADD Dimuon Analysis



Drell-Yan high mass prediction based on MC@NLO (and full CMS simulation) and FEWZ

Optimized Signal region:

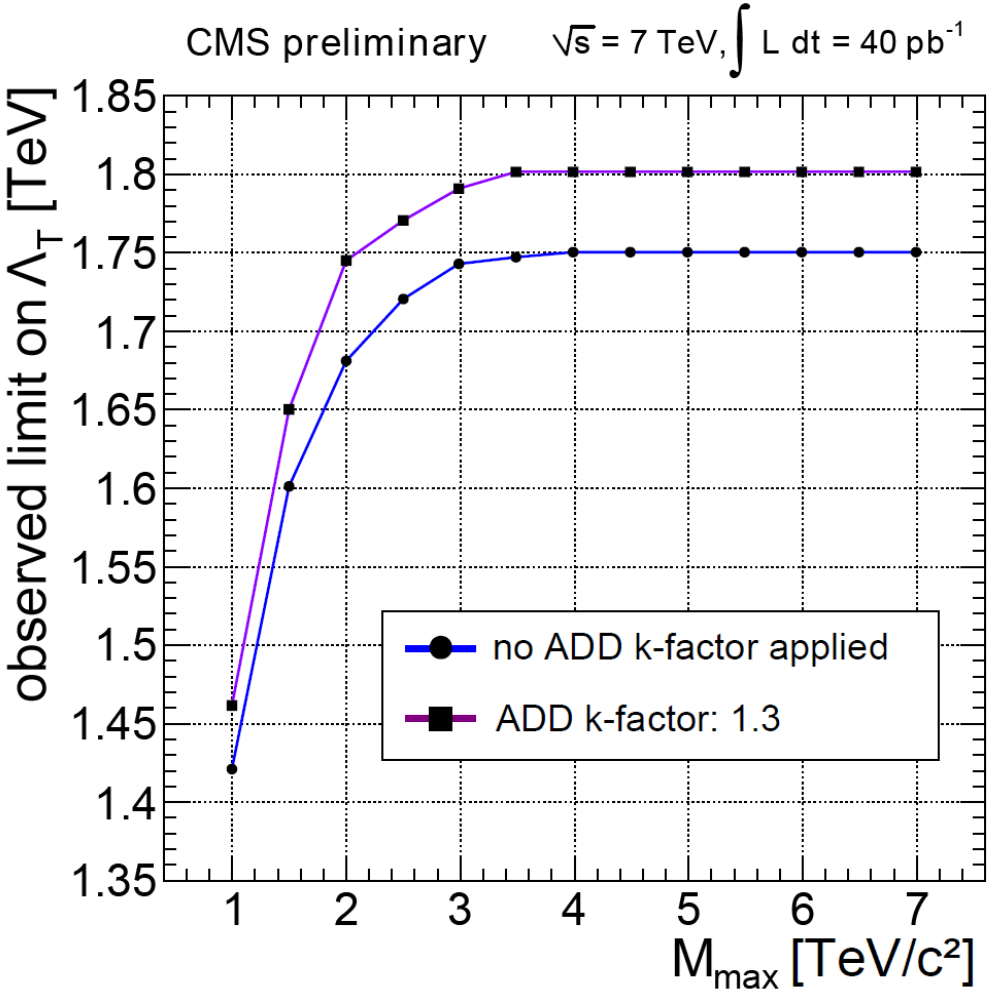
$$M_{\mu\mu} > 600 \text{ GeV}$$

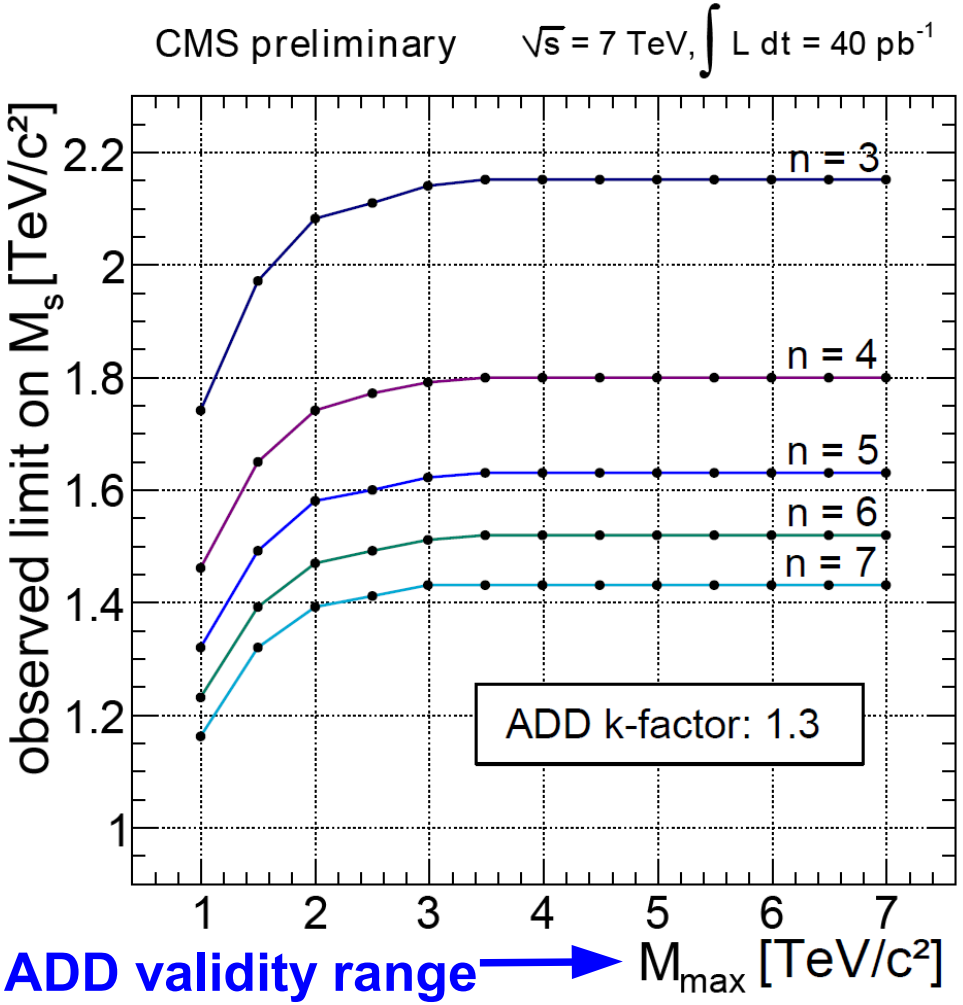
Dominant Systematics: DY theory prediction, muon reconstruction

Data driven techniques can be used to control $t\bar{t}$ and QCD multijet background

ADD Dimuons: Observed Limits

Bayesian 95% Upper Limits (Counting Exp.) on signal cross section





Limit for high validity range: $\Lambda_T = 1.80\ \mathrm{TeV}$

ADD Model: Summary Tables

All numbers are based on Bayesian 95% Upper Limits

CMS, Monojet:

	$n=2$	$n=3$	$n=4$	$n=5$	$n=6$
limit on M_D $[\mathrm{TeV}/c^2]$	2.37	1.98	1.77	1.68	1.62

CMS, Diphoton (limits in TeV):

	GRW	Hewett		HLZ					
		Pos.	Neg.	$n_{ED}=2$	$n_{ED}=3$	$n_{ED}=4$	$n_{ED}=5$	$n_{ED}=6$	$n_{ED}=7$
Full	1.94	1.74	1.71	1.89	2.31	1.94	1.76	1.63	1.55
Trunc.	1.84	1.60	1.50	1.80	2.23	1.84	1.63	1.46	1.31

CMS, Dimuon:

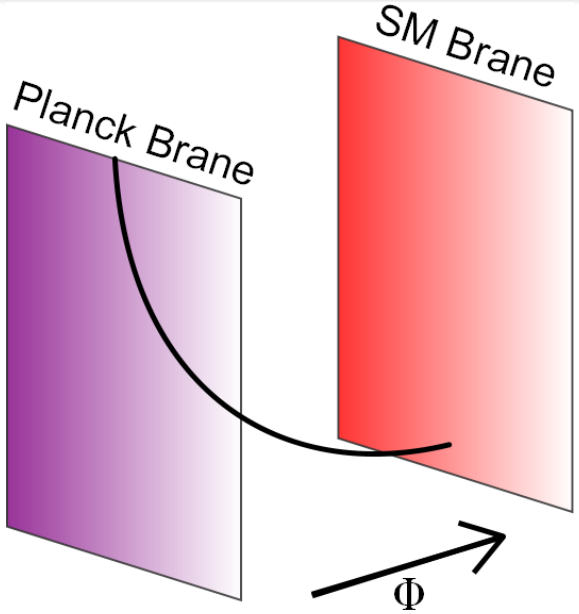
	Λ_T [TeV] (GRW)	M_s $[\mathrm{TeV}/c^2]$ (HLZ)					
		$n=2$	$n=3$	$n=4$	$n=5$	$n=6$	$n=7$
Full	1.80	1.75	2.15	1.80	1.63	1.52	1.43
Truncated	1.68	1.67	2.09	1.68	1.49	1.34	1.24

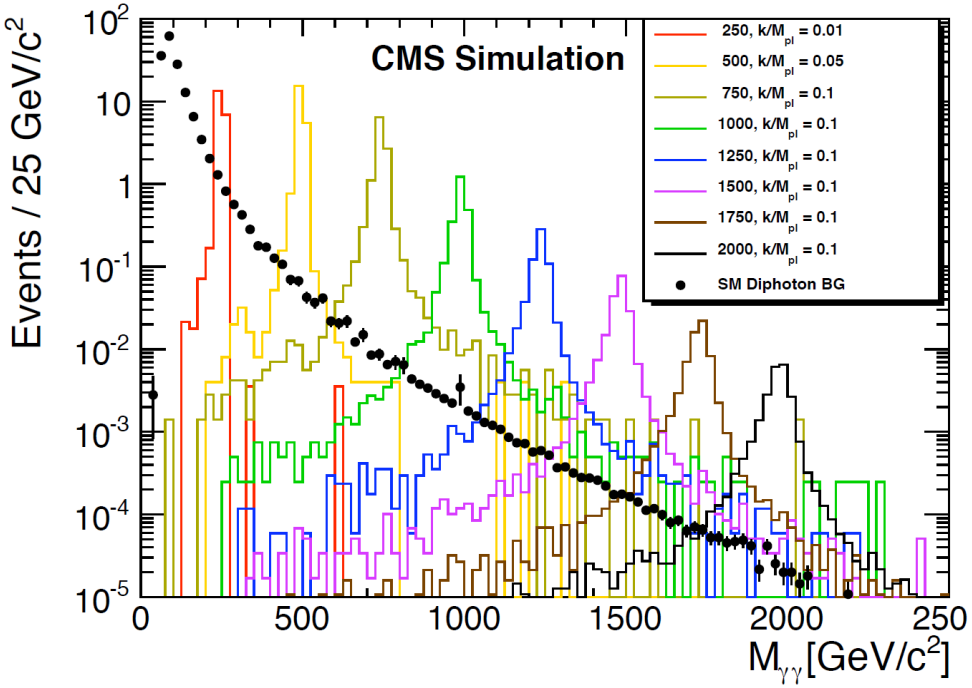
Randall Sundrum (RS-1) Scenario

Slice of AdS_5 space between two 3+1 branes

"warped" metric

$$ds^2 = e^{-2kr_c\phi}\eta_{\mu\nu}\,dx^{mu}\,dx^{nu} + r_c^2\,d\phi^2$$





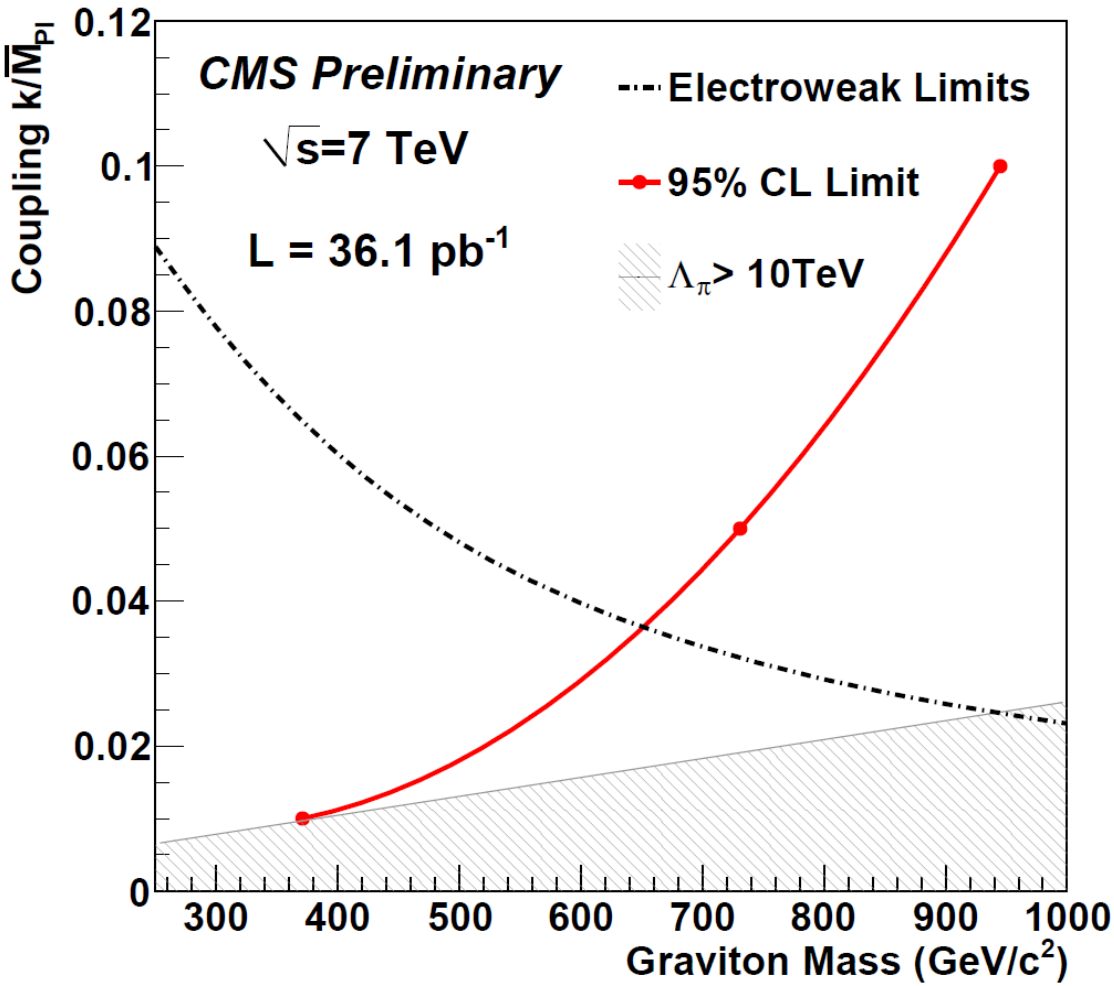
resonant diphoton signal from the first KK mode of the Graviton

Model parameters:

graviton mass M_1

coupling parameter $\tilde{k} = k/M_{Pl}$

Results: RS-1 Diphotons

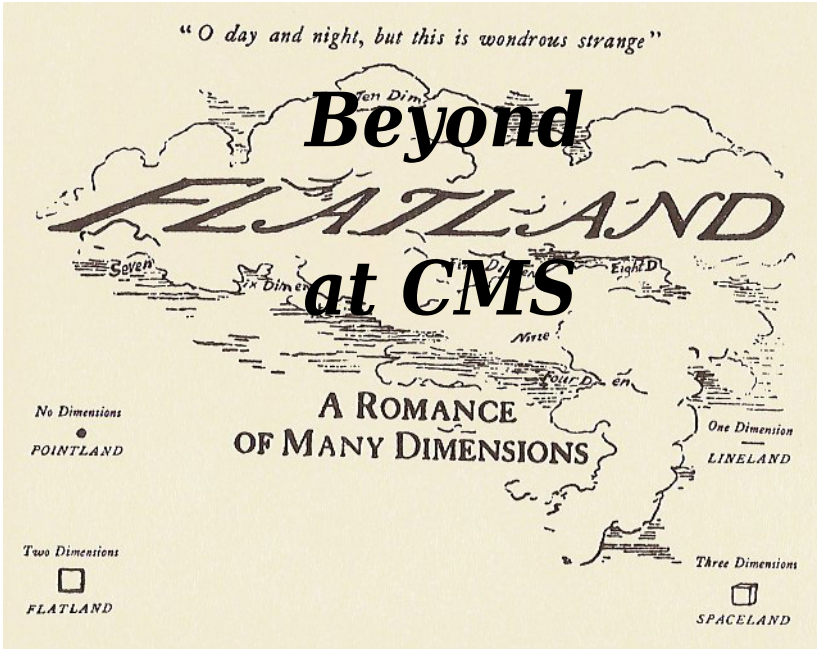


95% Bayesian upper limits in optimized (sliding) mass windows

- SM background shape from Diphoton events based on Pythia6
- simulation of signal events with Pythia6
- data driven study of jet → photon fake rate used to study bkg from dijet and photon+jet events
- dominant systematic uncertainty: SM diphoton k-factor

Outlook: 2011 and Beyond

- non-surprising plans:
  - results → updated results
  - preliminary results → results
  - shift focus from limits towards potential discoveries
- consider additional searches and/or combine channels to improve the results
- of course, we are always looking out for new phenomenological results from the theory side that could trigger new analyses or modify existing search strategies



Appendix: Links to Public Material

- **Search for Microscopic Black Hole Signatures**

  published in Physics Letters B

- **Search for Large Extra Dimensions in the Diphoton Final State**

  arXiv:1103.4279v1, submitted to JHEP

- **Search for Large Extra Dimensions in Dimuon Events**

  CMS-PAS-EXO-10-020, Physics Analsis Summary

- **Link to all public CMS Exotica results (including all approved plots)**

  CMSPublic/PhysicsResultsEXO