Search for Randall-Sundrum Graviton's Decay to Two Photons in 7 TeV p-p collisions with the CMS detector

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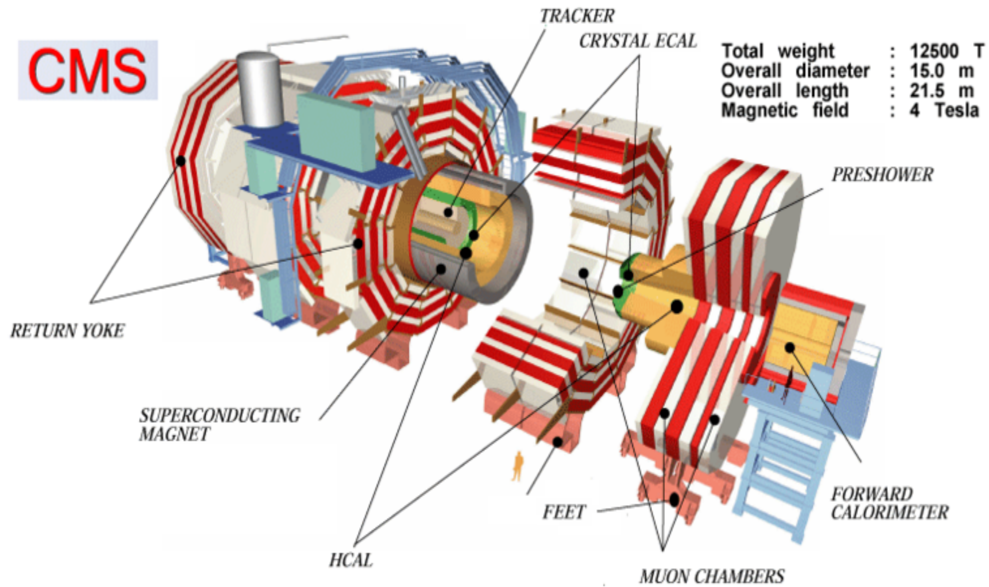
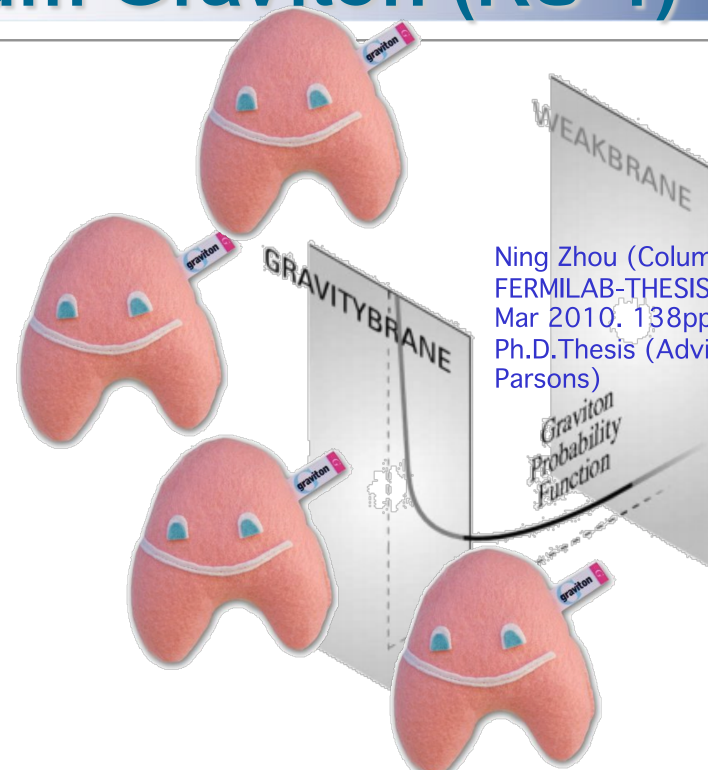
The Compact Muon Solenoid (CMS)

- One of the two general detectors at the LHC
- Main difference from ATLAS being its uniform magnetic 4 T magnetic field
- Main Studies:
  - Supersymmetry
  - Probing TeV scale physics
  - Discovery of Higgs Boson
  - Extra Dimensions



The Randall Sundrum Graviton (RS-1)

- In an attempt to solve the hierarchy problem (the large difference between the strength of the weak force and that of gravity) we introduce an extra dimension hence RS-1
- There are two (3+1)D branes separated by a (4+1)D "warped bulk"
- Gravitons exist mainly in one brane while "we" the standard model exist in the other
- The curvature of the bulk causes distance and mass to rescale exponentially causing gravity to appear weak



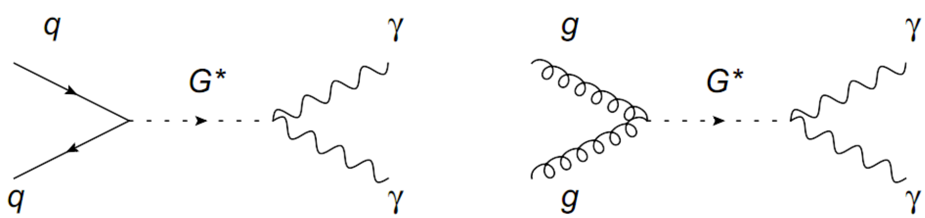
Ning Zhou (Columbia U.) . FERMILAB-THESIS-2010-14, Mar 2010. 138pp. Ph.D.Thesis (Advisor: John Parsons)

Two branes separated by "warped bulk"

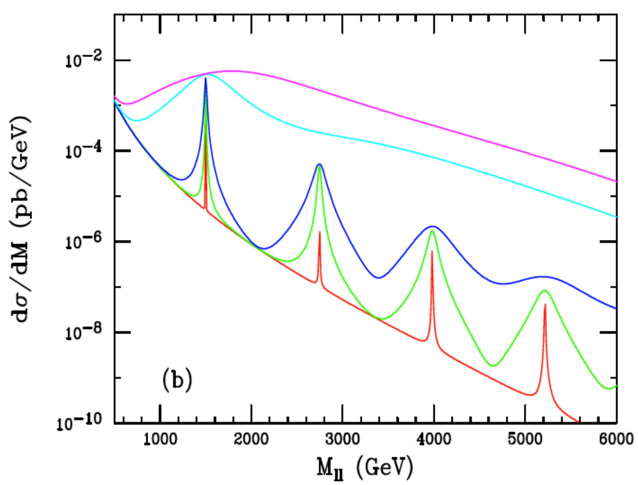
$$ds^2 = e^{-2kr_c y}\eta_{\mu\nu}dx^\mu dx^\nu - r_c^2 dy^2$$

RS-1 5 dimensional metric - note exponential warp factor described by k (the coupling of study in this search). r_c is the compactification radius of the extra dimension, η is the usual minkowski-space time metric, and y is the coordinate in the extra dimension $0 < y < \pi$

The Randall Sundrum Graviton (RS-1)



Graviton production and decay to diphotons
(dielectrons also a common study)

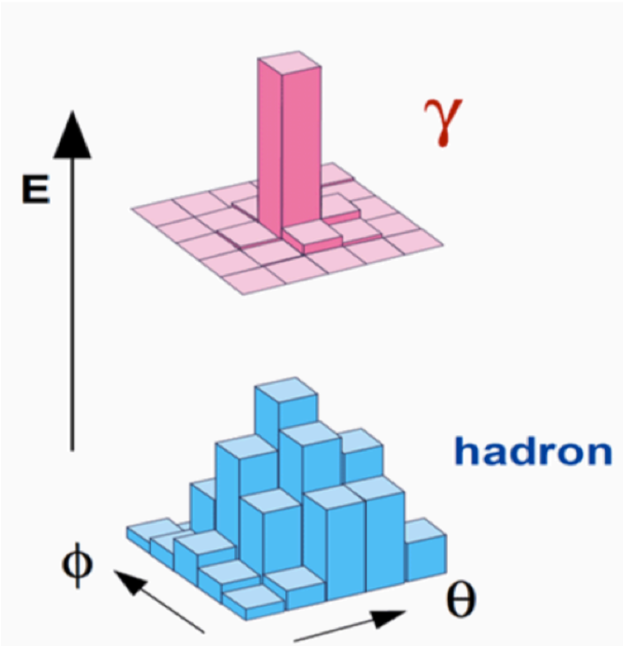


We look for the first (M1) Kaluza Klein excitation

H. Davoudiasl, J.L. Hewett, T.G. Rizzo
Phys.Rev.D63:075004,2001

- We search for high mass resonances that would not have been seen at Tevatron at the level of ~1 TeV
- Gravitons appear as a tower of excitations and we search for the first excitation
- The spacing and width of excitations is given by the coupling factor k/M_{pl} constraining the search for resonances

Selection

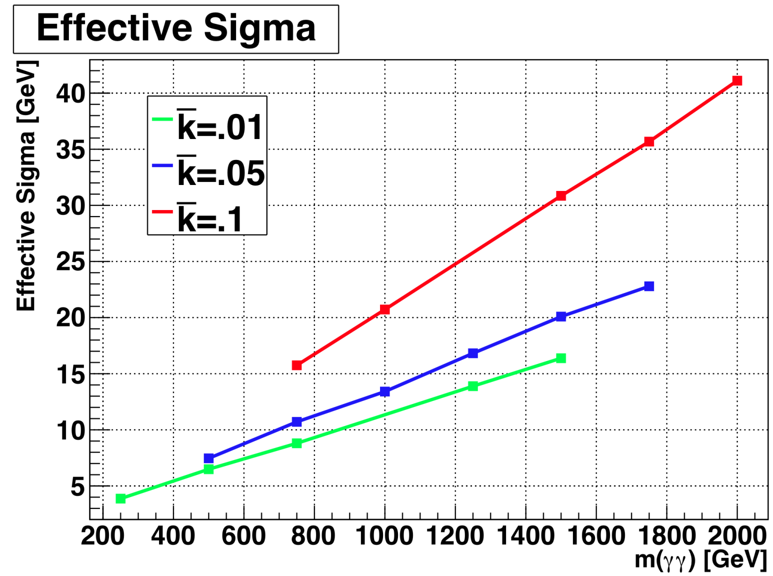


Criteria	Requirement
HLT	HLT_DoublePhoton33_v* OR HLT_DoublePhoton50_v*
p_t	> 70 GeV
$M_{\gamma\gamma}$	> 120 GeV
η	$\|\eta_{det}\| < 1.4442$
EB, EE categories	EB-EB
H/E	$< .05$
ECAL Isolation	$(.06 < \Delta R < .4) < 4.2 + .006 \cdot p_t$
HCAL Isolation	$(.15 < \Delta R < .4) < 2.2 + .0025 \cdot p_t$
Track Isolation	$(.04 < \Delta R < .4) < 2.0 + .001 \cdot p_t$
$\sigma_{i\eta i\eta}$	$< .013$
Track Veto	No Pixel Seed

- Selection is restricted to the barrel (endcaps provide little power)
- Regular photon identification recommendations using hollow isolation cones with corrections for pileup
- Slightly looser cuts as the high mass region is SM background limited

Signal Sample and Selection

M_1 (GeV)	$\bar{k}$	$\sigma_{tot}\times$ BR (pb)	N_{events}
250	0.01	1.4e+00	22000
500	0.01	4.8e-02	21040
750	0.01	6.0e-03	22000
1000	0.01	1.0e-03	22000
1250	0.01	2.5e-04	22000
1500	0.01	6.7e-05	21040
500	0.05	1.4e+00	21120
750	0.05	1.6e-01	21520
1000	0.05	2.8e-02	20080
1250	0.05	6.8e-03	21600
1500	0.05	2.0e-03	22000
1750	0.05	6.3e-04	22000
750	0.1	6.3e+00	22000
1000	0.1	1.2e-01	21520
1250	0.1	2.8e-02	20080
1500	0.1	8.0e-03	20320
1750	0.1	2.5e-03	21760
2000	0.1	8.0e-04	21760

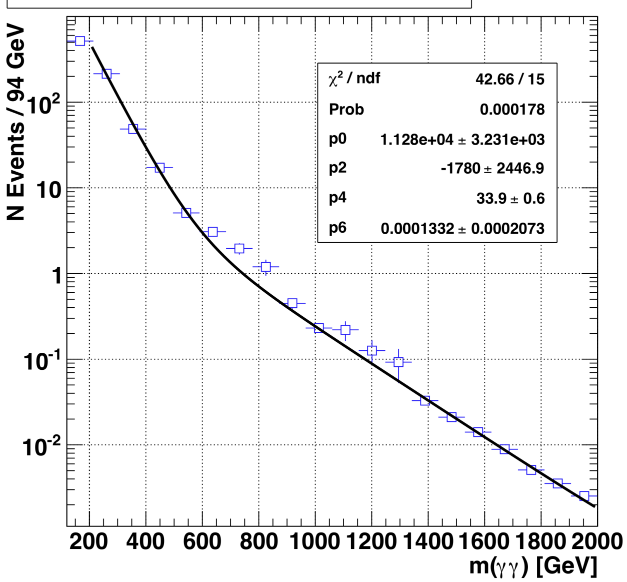


- Signal sample are generated in Pythia and reconstructed in CMSSW_4_2_X
- We determine mass windows based on the signal peak's effective sigma (+/- 5 σ_{eff})
- The effective sigma is the smallest window containing 68% of the signal

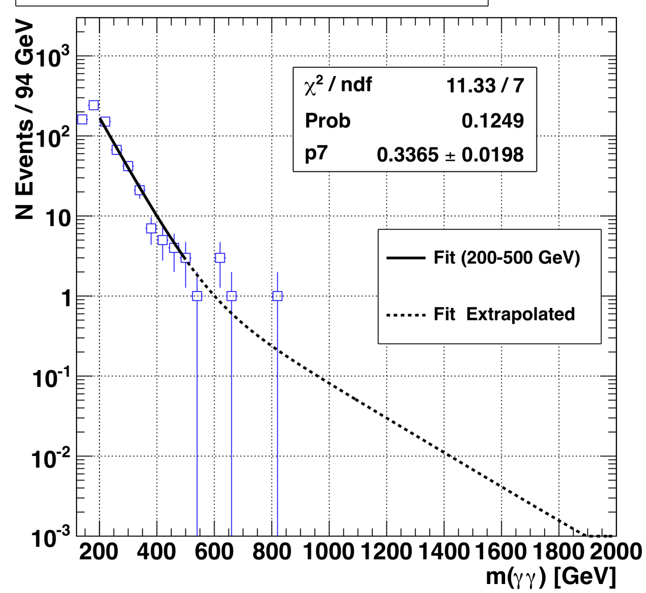
Background MC and Estimation

	Dataset	$\hat{p}_t$ (GeV)	Cross-section (pb)	N_{events}	Equiv Luminosity (pb^{-1})
γγ	DiPhoton Born	$25 < \hat{p}_t < 250$	2.237×10^1	537445	24025
		$25 < \hat{p}_t < \infty$	8.072×10^{-3}	546355	6.78×10^7
	DiPhoton Box	$25 < \hat{p}_t < 250$	1.237×10^1	777725	62871
		$250 < \hat{p}_t < \infty$	2.080×10^{-4}	789470	3.795×10^9
j+γ	PhotonJet (EM Enriched)	$20 < \hat{p}_t < \infty$	$.0064 \cdot (7.71 \times 10^4)$	1182075	2395.5
j+j	QCD Jets (Double EM Enriched)	$30 < \hat{p}_t < 40$	$0.00023 \cdot (4.18 \times 10^7)$	3550408	369.3
		$40 < \hat{p}_t < \infty$	$0.00216 \cdot (1.87 \times 10^7)$	21301935	527.3

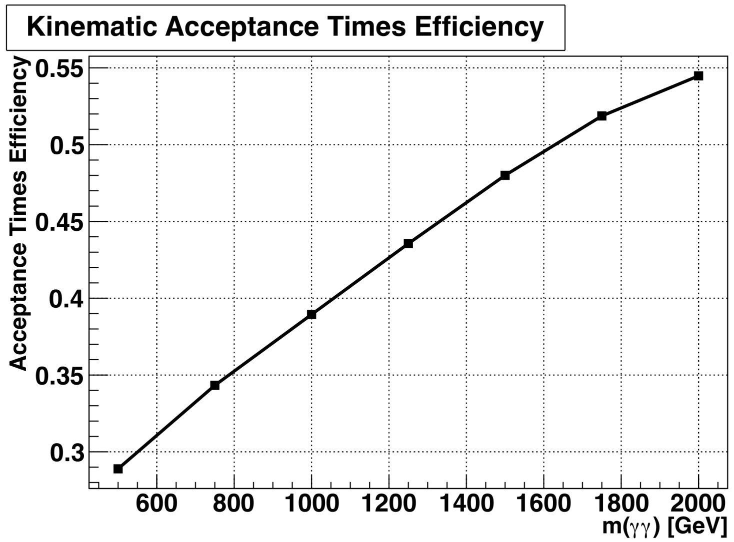
Full Background Fit to 3 Exponentials

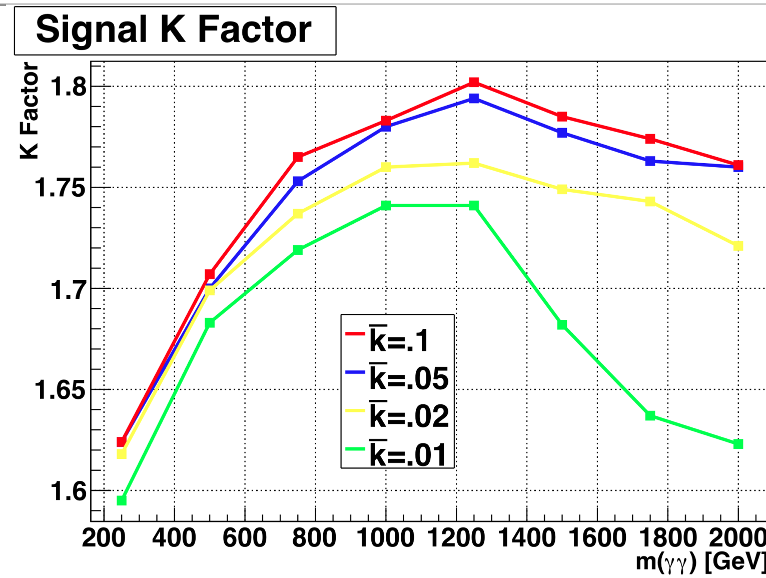


Data Fit Normalization

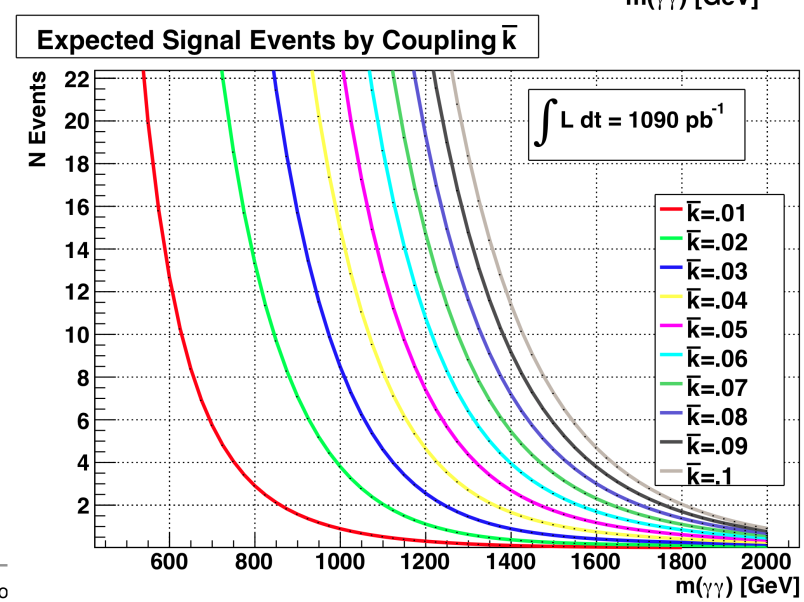


Signal Estimation





- K factors (NLO) are applied generated from a ratio of Diphox to Pythia cross sections
- Acceptance times efficiency determined across mass range (coupling independent)
- Through linear interpolation expected events are determined by mass and k-factor



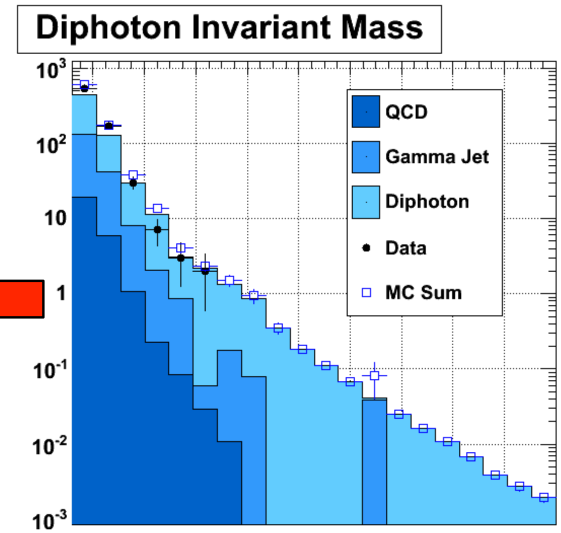
Yield Calculations

$\tilde{k}$	M_1	Mass Window	Expected Signal	Expected Background	Data
0.01	500	469.6 to 530.3	32	4.5	4
0.01	750	707.1 to 792.8	4.0	0.71	0
0.01	1000	944.6 to 1055.3	0.89	0.23	0
0.01	1250	1182.2 to 1317.7	0.23	0.082	0
0.01	1500	1419.7 to 1580.2	0.066	0.028	0
0.01	1750	1657.2 to 1842.7	0.018	0.0097	0
0.01	2000	1894.7 to 2105.2	0.0053	0.0034	0
0.05	500	463.6 to 536.3	760	5.4	5
0.05	750	698.2 to 801.7	110	0.87	0
0.05	1000	932.7 to 1067.2	23	0.28	0
0.05	1250	1167.2 to 1332.7	5.6	0.10	0
0.05	1500	1401.8 to 1598.1	1.7	0.035	0
0.05	1750	1636.3 to 1863.6	0.71	0.012	0
0.05	2000	1870.9 to 2129.1	0.36	0.0042	0
0.10	750	668.8 to 831.1	410	1.4	1
0.10	1000	893.6 to 1106.4	90	0.46	0
0.10	1250	1118.3 to 1381.6	23	0.16	0
0.10	1500	1343.1 to 1656.9	7.2	0.059	0
0.10	1750	1567.8 to 1932.1	2.5	0.021	0
0.10	2000	1792.6 to 2207.4	0.91	0.0075	0

- Data is found in strong agreement with expectation (in the absence of signal)
- Where we expect more than one event we see the integer number of events
- Where we expect less than one event we see none
- Apply CLs method for upper limits on the cross section

CLs Based Exclusions

- Accordingly CLs is computed and an upper limit on the cross section derived at 95% conf.
- From this we exclude the graviton when it is less than the theoretical cross section. The ratio is referred to as r95
- Errors on the expectation are derived from errors on luminosity, background estimation, energy resolution, etc..)

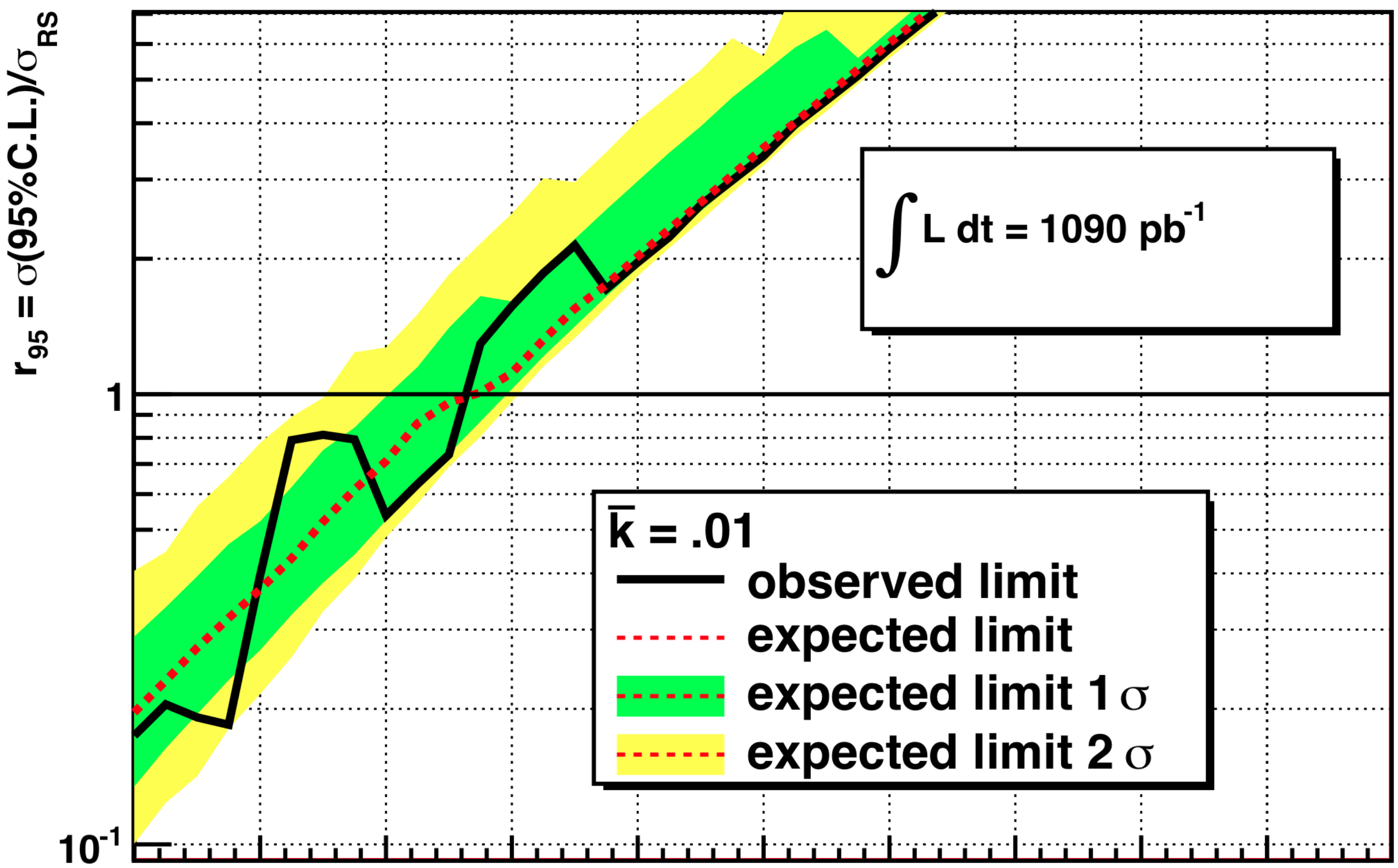


$$Q = \prod_i^M \exp(-s_i) \left(\frac{s_i + b_i}{b_i} \right)^{n_i} \qquad q \equiv \ln Q$$

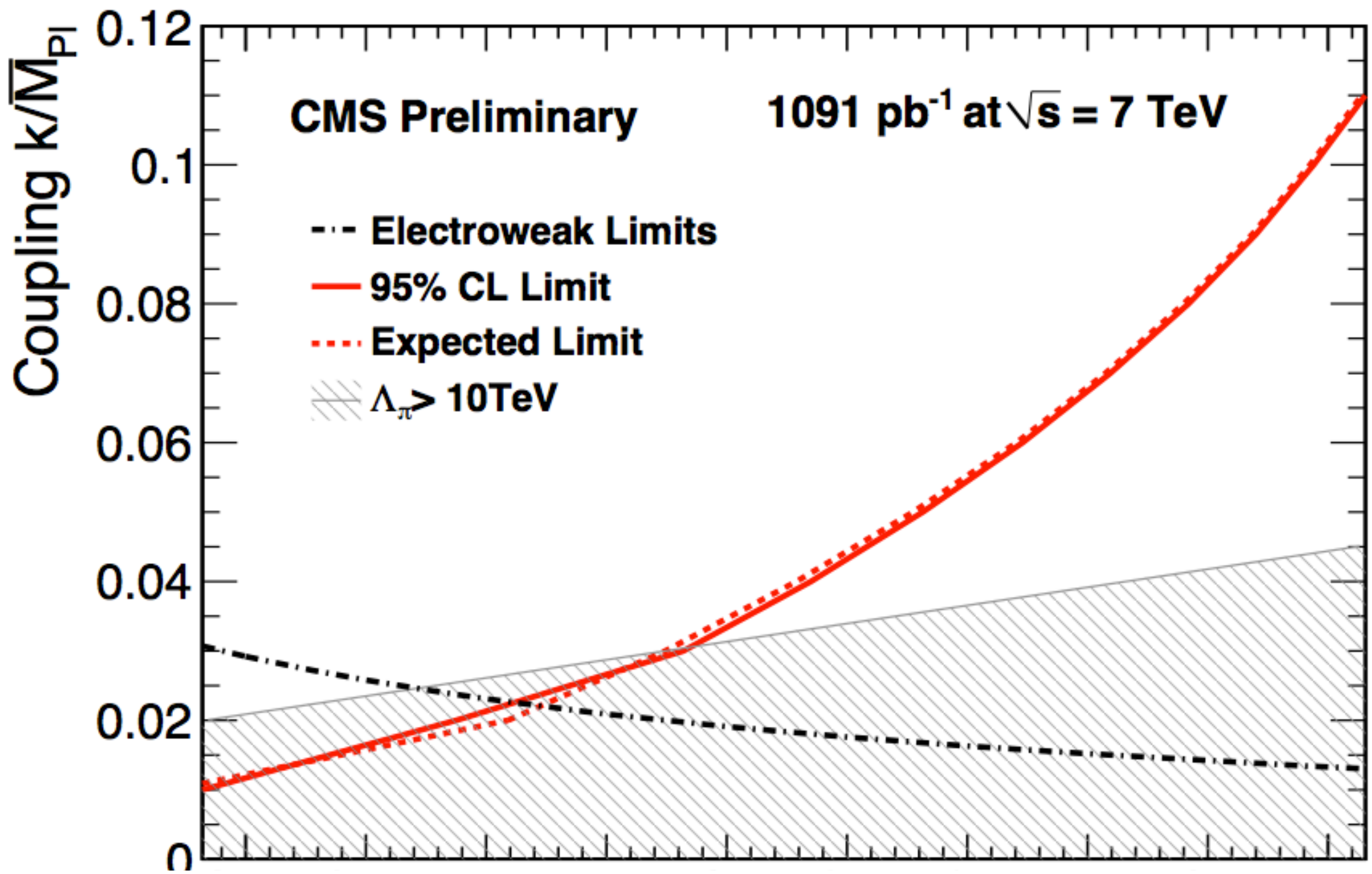
$$CL_s = \frac{CL_{s+b}}{CL_b} \equiv \frac{P_{s+b}(q_{s+b} \leq q_{obs})}{P_b(q_b \leq q_{obs})}$$

$$\sigma(C.L.\ 95\%)/\sigma(SM) < 1$$

Example Result k=.01



Compilation of Results



Nature One Music Festival Germany

Thanks!

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Questions?