Search for New Phenomena in Final States with Leptons, Photons, MET

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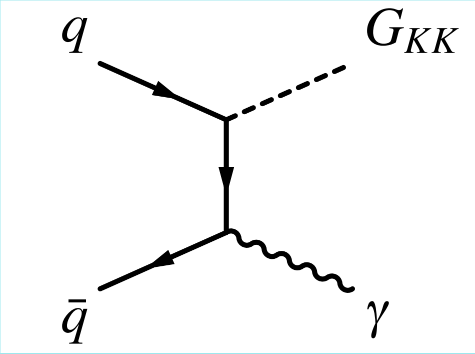
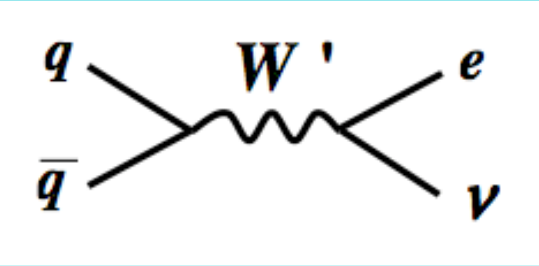
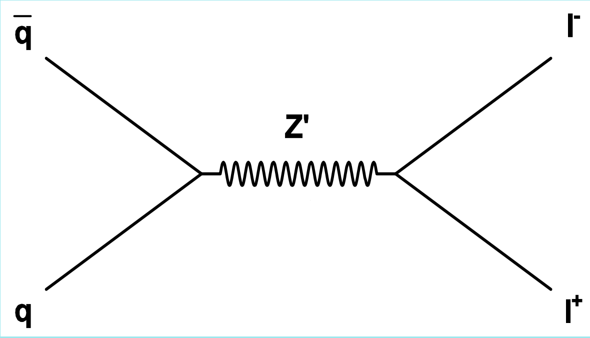
DPF 2009
2009 Meeting of the Division of Particles and Fields of the American Physical Society (DPF 2009)
26-31 JULY 2009
Wayne State University, Detroit, MI

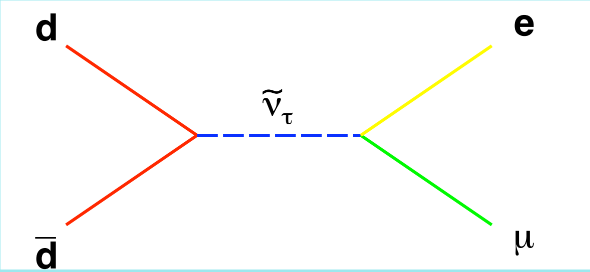
Outline

- Extensive program of searches for New Phenomena
  - Search for resonances and excesses in the production of SM particles
  - Signature based in addition to model based searches
- Signatures presented in this talk:
  - photon + MET (LED - $q\bar{q} \rightarrow \gamma G_{KK}$)
  - electron + MET (W')
  - Two EM objects - di-EM (LED)
  - Two electrons (Z' and RS graviton)
  - electron + muon (RPV sneutrino)







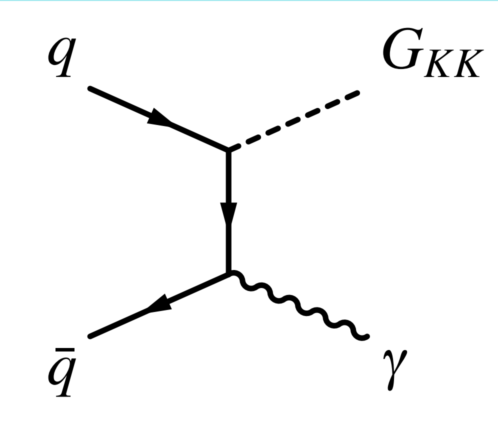


Motivation

- Heavy Resonances
  - Extra gauge bosons
    - $SU(3)\times SU(2)_L \times U(1)_Y$ embedded in a larger gauge group (SO(10), E6, ...) to achieve grand unification, after symmetry breaking, U(1) groups survive
    - L-R symmetry, “little Higgs” models
  - SUSY with RPV resonant production may occur with lepton pair of same or different flavor decay products
  - Randall-Sundrum model, one extra dimension $\Rightarrow$ excited KK modes G^*
- Excesses on the production of SM particles
  - LED models with n - extra dimensions can give rise to a real graviton emission, or virtual graviton exchange

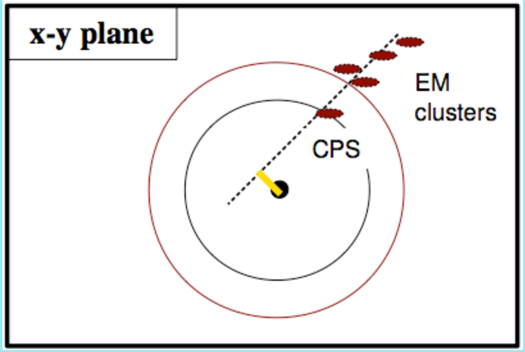
Photon + MET
Large Extra Dimensions

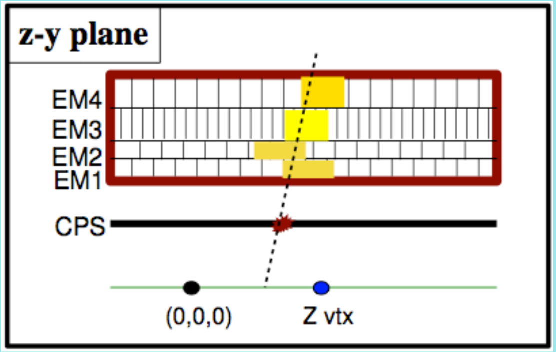
- Result based on 2.7 fb^{-1} of data
- Event Selection
  - Single Photon with $E_T > 90$ GeV
    - Central ($|\eta| < 1.1$)
    - Isolated in both the tracker and the calorimeter
  - MET > 70 GeV
  - Clean event
    - Veto on muons, jets, energetic tracks and other EM objects

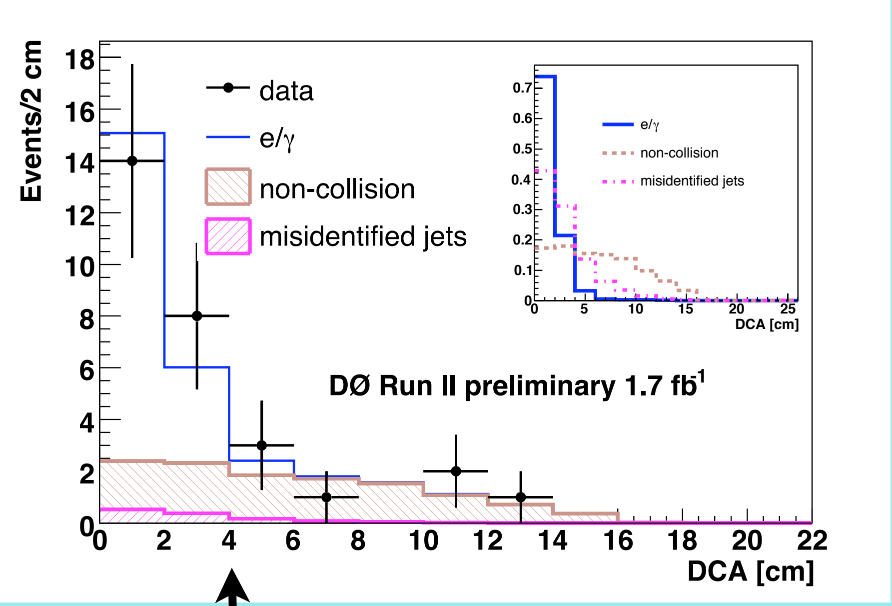


Photon + MET
Large Extra Dimensions

- Backgrounds
  - Zγ→ννγ, W+γ
    - Studied in Monte Carlo
  - W→eν, W/Z + jet, non-collision
    - Studied from data using distance of closest approach (DCA) templates
      - Pointing algorithm based on transverse and longitudinal segmentation of the calorimeter and the pre-showers
      - Fit sum of DCA templates to data



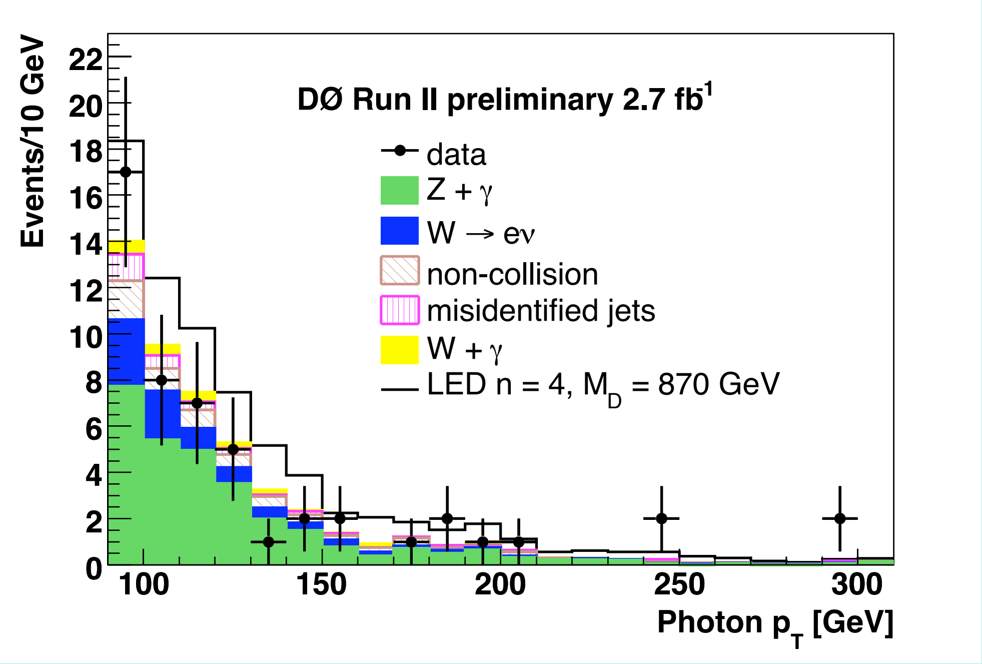




Cut

Photon + MET
Large Extra Dimensions

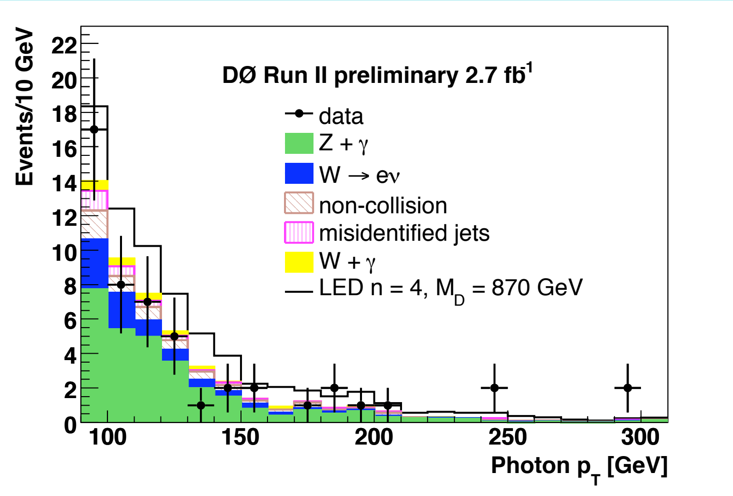
- Good agreement between data and background.
  - Proceed with setting limits on the fundamental Planck scale M_D



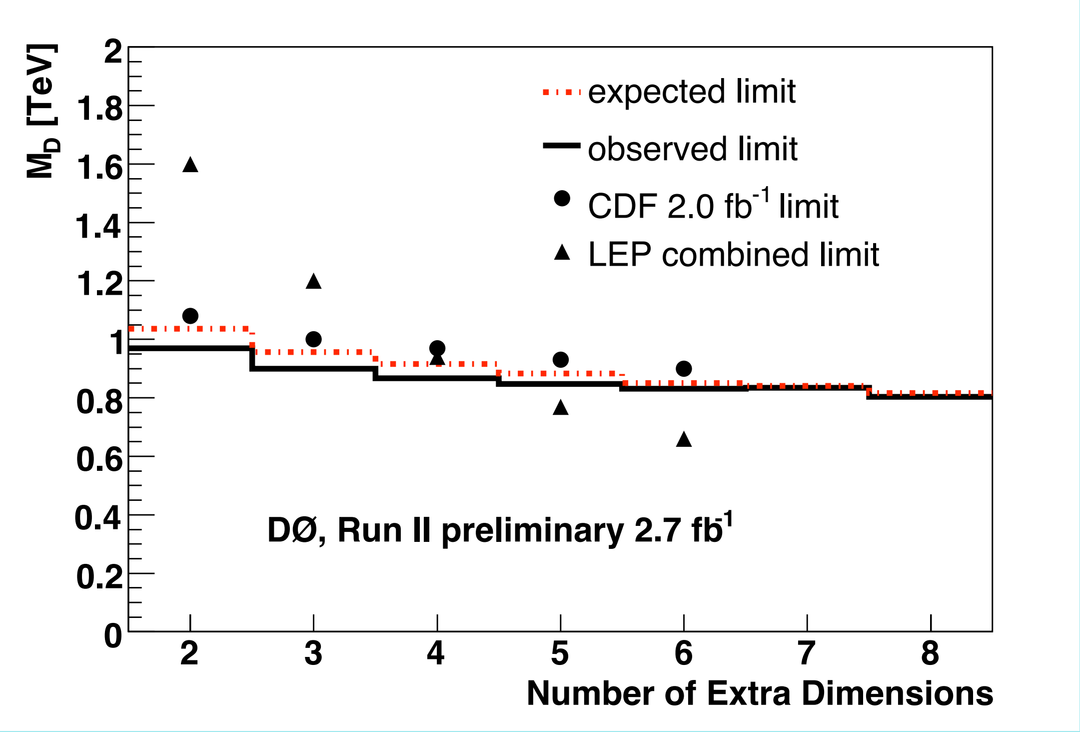
Backgrounds	
Z + γ	29.5 ± 2.5
W→eν	8.5 ± 1.7
W + γ	2.2 ± 0.3
Non-collision	6.6 ± 2.2
Mis-identified Jets	3.1 ± 1.5
Total Background	49.9 ± 4.1
Events	51

Photon + MET
Large Extra Dimensions

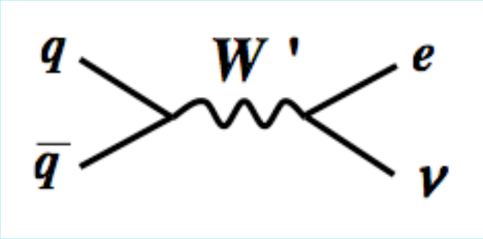
- For limit setting, photon E_T distribution in data is compared to signal + backgrounds looking for discrepancies
  - For signal study LED with number of extra dimensions, n, ranging from 2 to 8



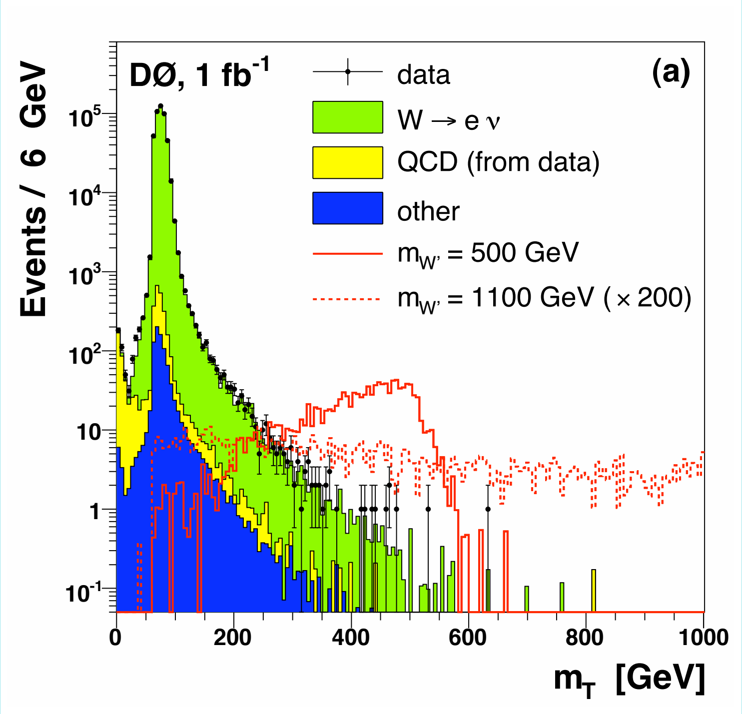
n	Observed (Expected) cross section limit (fb)	Observed (Expected) M(D) limit, GeV
2	19.0 (14.6)	970 (1037)
3	20.1 (14.7)	899 (957)
4	20.1 (14.9)	867 (916)
5	19.9 (15.0)	848 (883)
6	18.2 (15.2)	831 (850)
7	15.9 (14.9)	834 (841)
8	17.3 (15.0)	804 (816)



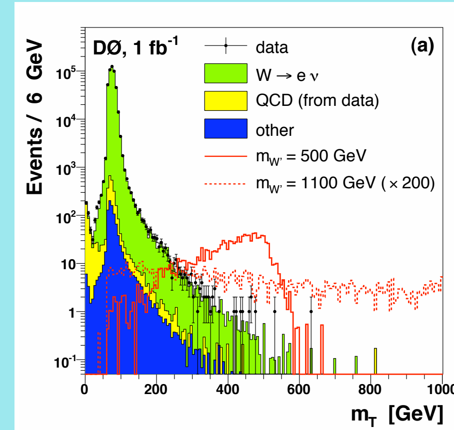
Electron + MET
W′ Bosons



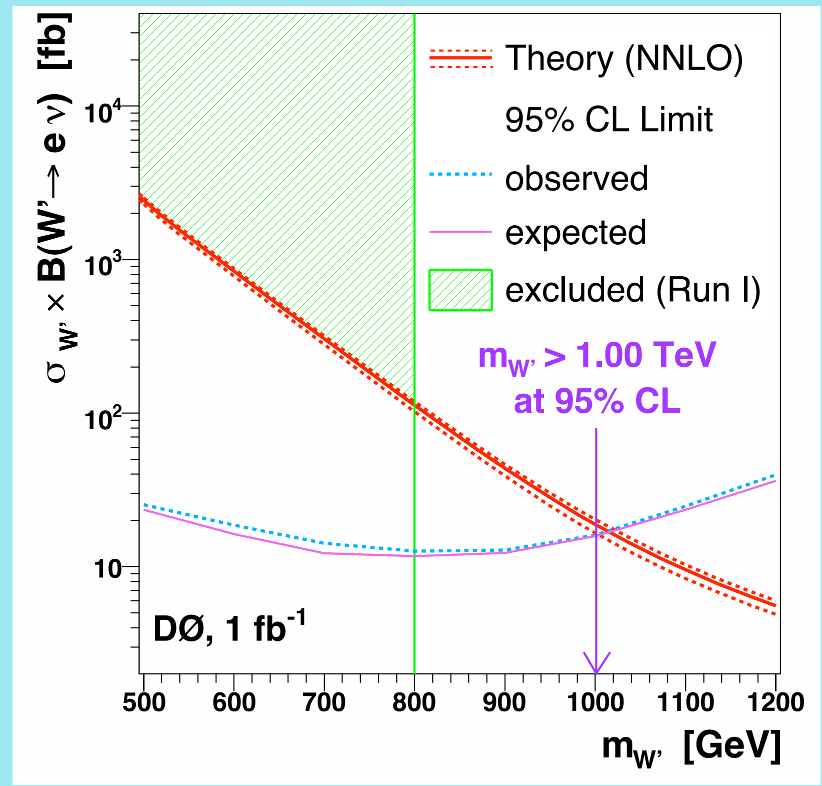
- Published result based on 1 fb^{-1} of data
- Event selection
  - An isolated EM candidate with E_T > 30 GeV
    - Shower shape consistent with that of an EM object
    - Track matched
  - MET > 30 GeV
- Backgrounds
  - Physics:
    - W→eν (dominant), WW, ZZ, WZ, Z
    - Are studied in Monte Carlo
  - Instrumental Background
    - Jet mis-identified as electron
    - Studied from data, by selecting a sample of fakes
- Fit M_T spectrum in data with the sum of backgrounds



Electron + MET W′ Bosons



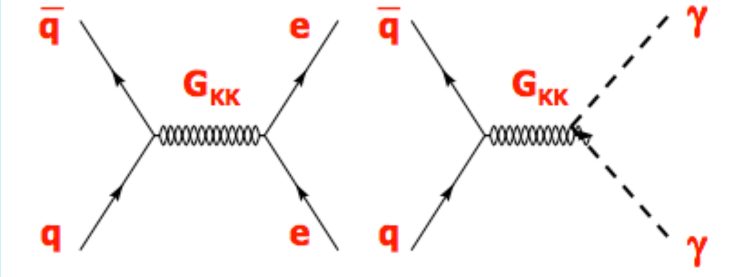
- No evidence of W′ in data, so proceed with setting a limit
  - Use M_T distribution above 140 GeV to compare between data and signal + backgrounds
  - Set 95% confidence level upper limit on the production cross-section × BR
    - Convert to a lower mass limit for a SSM W′ of 1.00 TeV



PRL **100**, 31804 (2008)

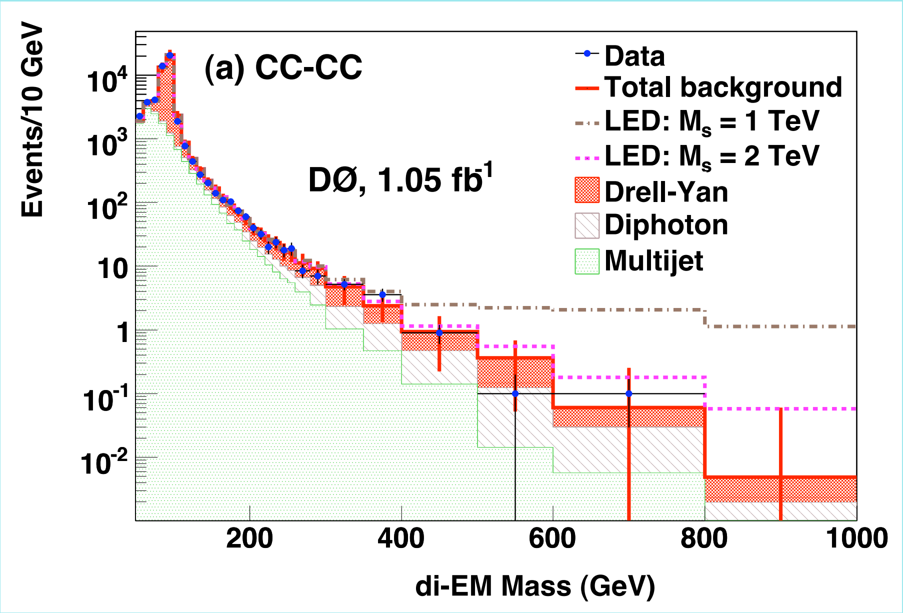
Di-EM
Large Extra Dimensions

- Published result based on 1 fb^{-1} of data
- Looking for excess on the production of SM particles
- Event selection
  - Two isolated EM objects
    - $E_T > 25$ GeV
    - Shower shape consistent with that of EM objects
    - Central ($|\eta| < 1.1$) and forward ($1.5 < |\eta| < 2.5$) cluster
  - Do not distinguish between electrons and photons



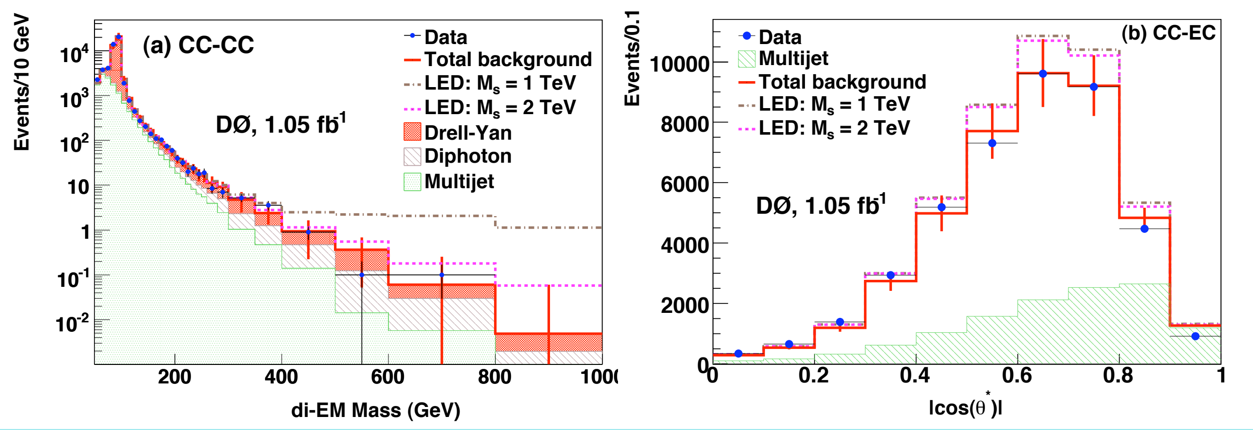
Di-EM
Large Extra Dimensions

- Backgrounds
  - Physics
    - $Z/\gamma^* \rightarrow ee$
    - Direct $\gamma\gamma$ production
      - Studied in MC
  - Instrumental
    - Jets misidentified as EM objects
      - Studied from data by inverting the shower shape criteria to estimate the shape of the instrumental background
- Fit the di-EM invariant mass spectrum to the sum of the backgrounds

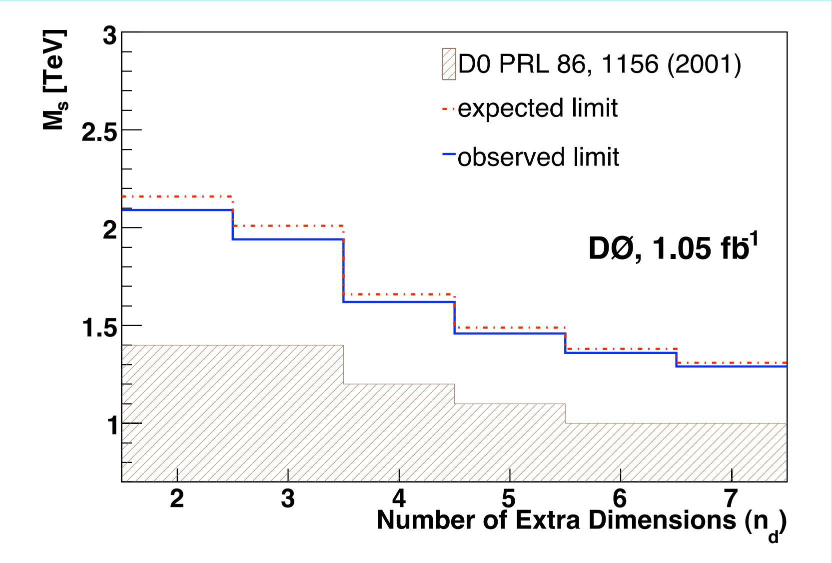


Di-EM
Large Extra Dimensions

- Good agreement between data and background
  - Compare di-EM invariant mass spectrum and |cosθ*| distribution for data and signal + background
  - Set 95% CL limits for LED with n = 2, …, 7 and extract limits on the effective Planck scale Ms



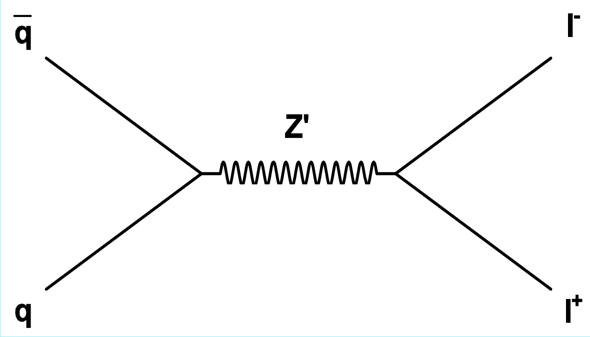
n	2	3	4	5	6	7
Observed Limit M(s) (TeV)	2.09	1.94	1.62	1.46	1.36	1.29
Expected Limit M(s) (TeV)	2.16	2.01	1.66	1.49	1.38	1.31



PRL **102**, 051601 (2009)

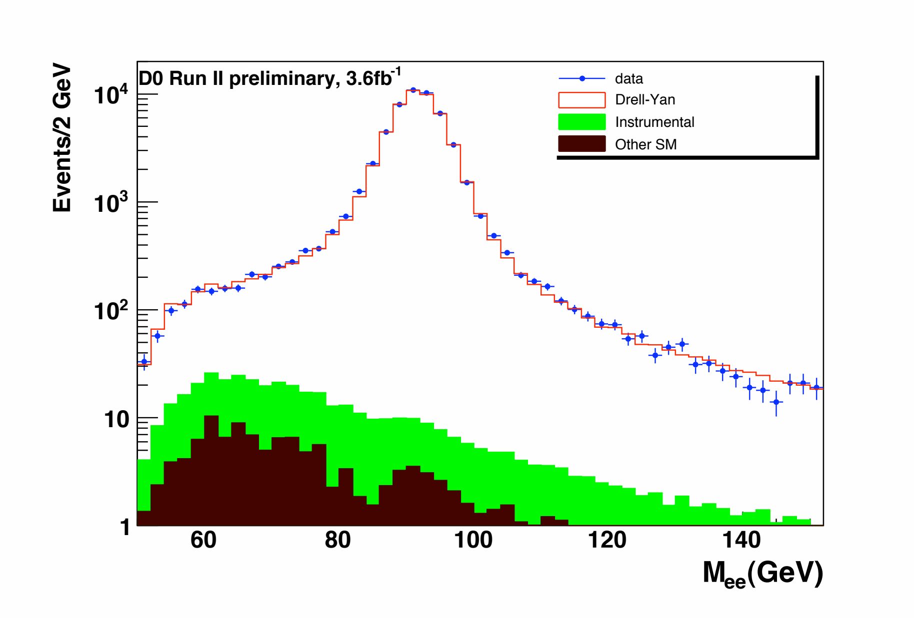
Di-electron
Heavy Neutral Resonances

- Preliminary result based on 3.6 fb^{-1} of data
- Looking into the high E_T di-electron mass distribution
- Event selection
  - Two isolated EM objects
    - $E_T > 25$ GeV
    - Shower shape consistent with that of the EM objects
    - Central ($|\eta| < 1.1$)
    - Track matched



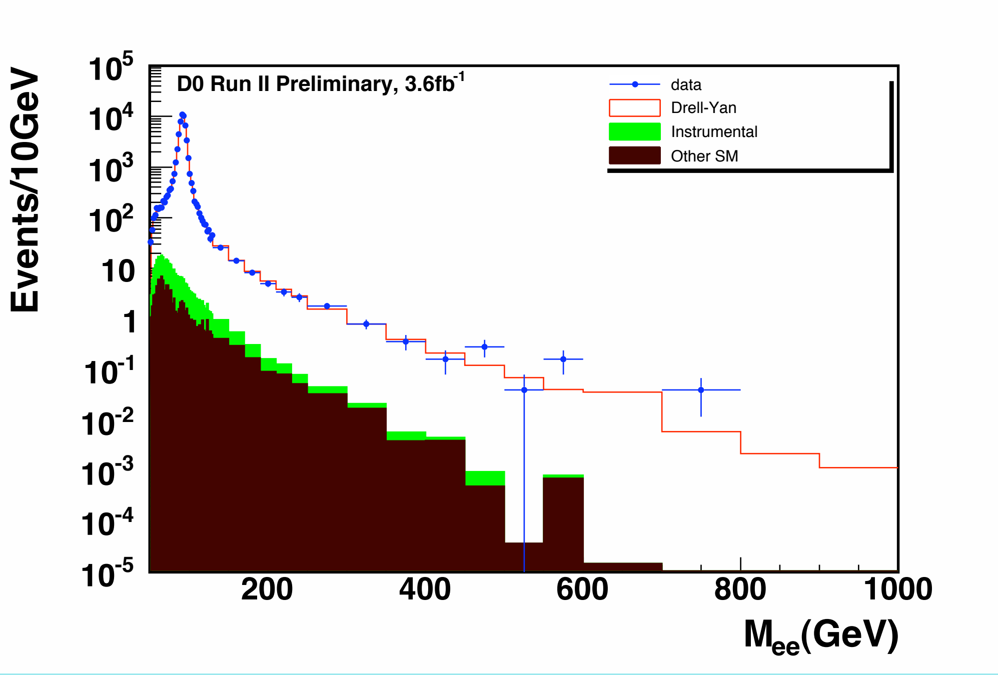
Di-electron Heavy Neutral Resonances

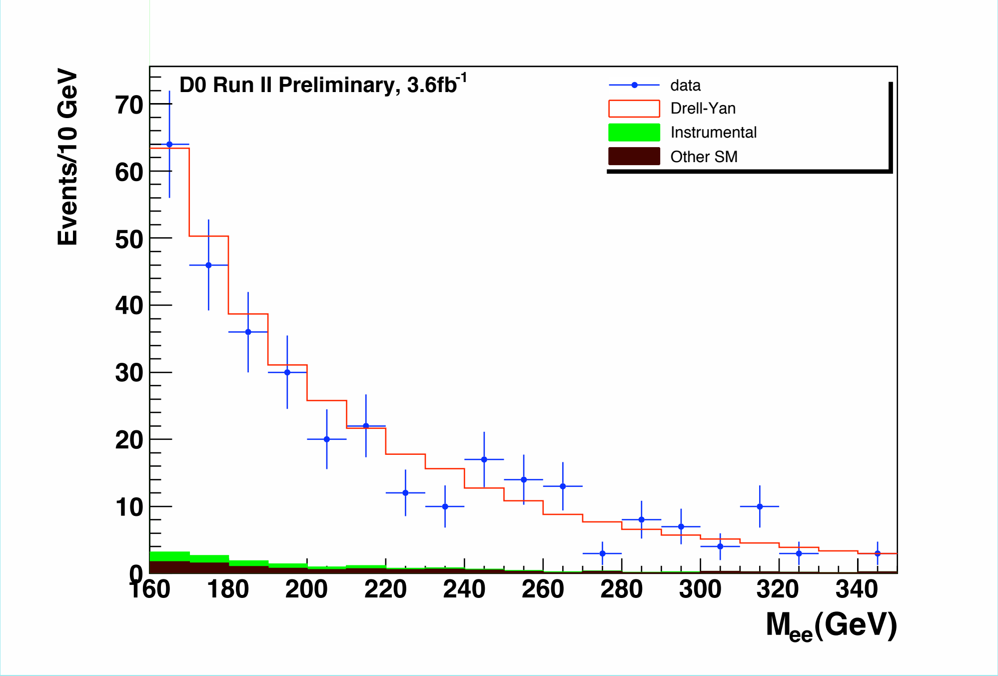
- Backgrounds
  - Physics
    - $Z/\gamma^* \rightarrow ee$ (Dominant Background)
    - $Z/\gamma^* \rightarrow \tau\tau$, $W+X \rightarrow e\nu+X$, $WW \rightarrow ee\nu\bar{\nu}$, WZ where $Z \rightarrow ee$, $t\bar{t} \rightarrow ee\nu\nu b\bar{b}$ ("Other SM")
      - Studied in MC
  - Instrumental
    - Jets misidentified as EM objects
    - Studied from data by inverting the shower shape criteria to estimate the shape of the instrumental background
- Fit di-electron invariant mass spectrum to the sum of the backgrounds



Di-electron
Heavy Neutral Resonances

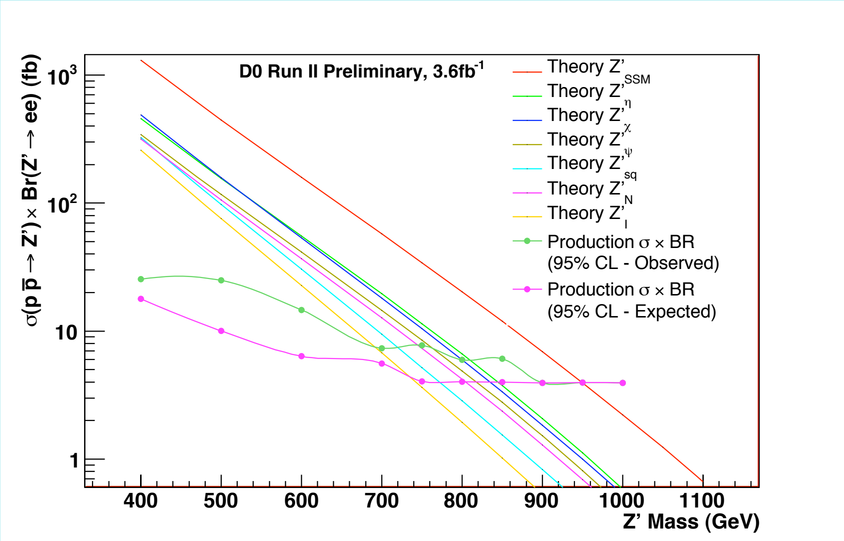
* There is a good agreement between data and expected total background for the full mass range studied
  * Since no significant excess is observed, proceed with setting limits

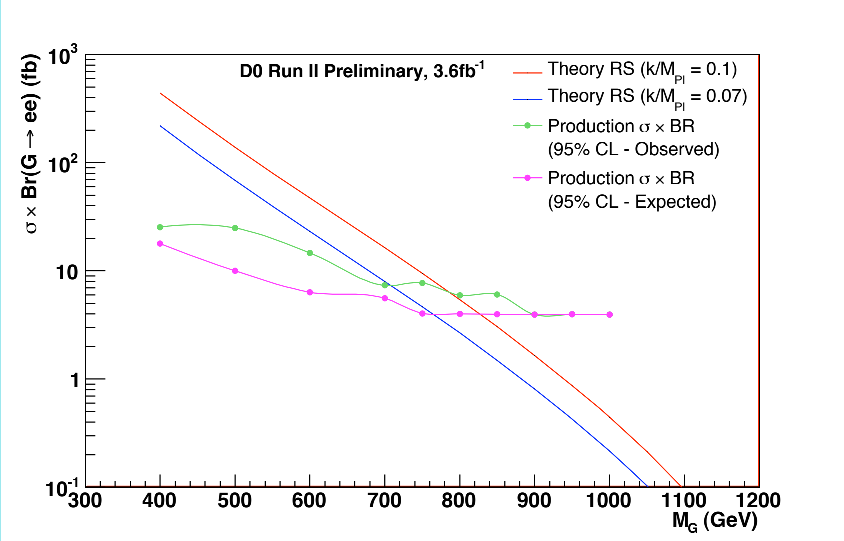




Di-electron
Heavy Neutral Resonances

- Set 95% CL upper limits on σ × BR(X→ee), where X is a heavy resonance with spin 1 (Z′), or 2 (G_{RS}) for $M_X \geq 400$ GeV
  - Interpret this limit to lower mass limits for a variety of models

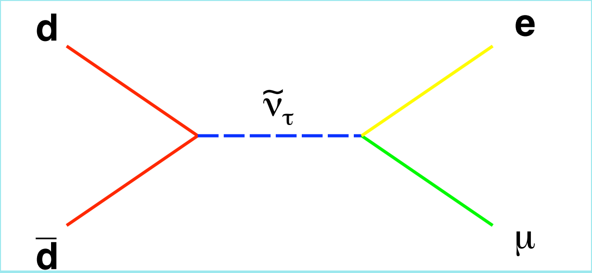




Model	Z'_{SSM}	Z'_{η}	Z'_{χ}	Z'_{ψ}	Z'_{sq}	Z'_{N}	Z'_{I}	RS (k/M_{Pl} = 0.1)	RS (k/M_{Pl} = 0.07)
Expected Lower Mass Limit (GeV)	949	844	834	817	774	803	732	826	767
Observed Lower Mass Limit (GeV)	950	810	800	763	719	744	692	786	708

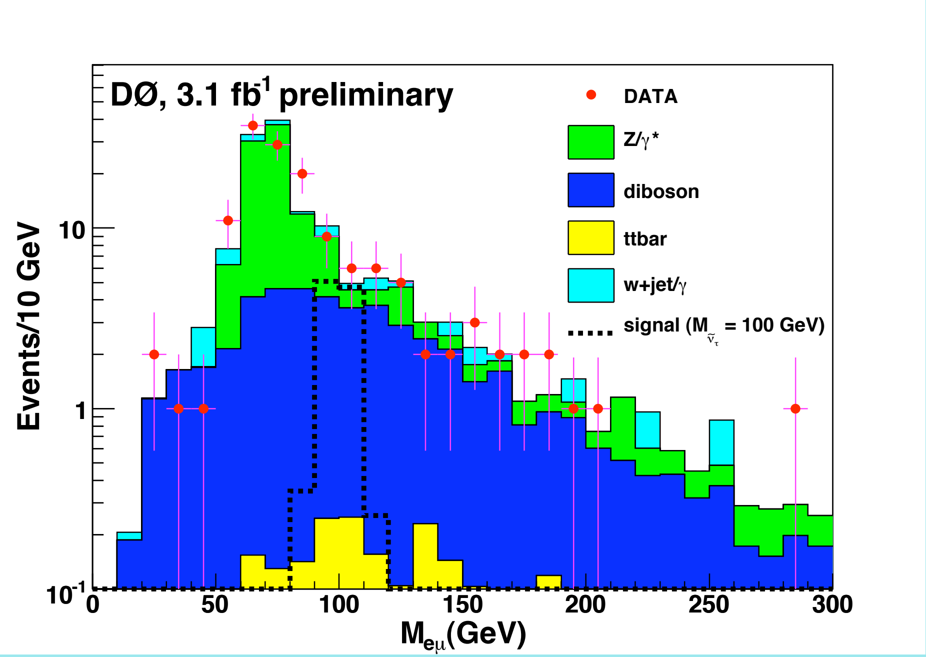
Electron + muon RPV sneutrino

- Preliminary result based on 4.1 fb^{-1} of data
- Looking for high E_T leptons, where electron and muon are back-to-back, and no MET is present
- Event selection
  - Electron
    - Isolated EM candidate
      - $E_T > 30$ GeV
      - Shower shape consistent with that of an electron
      - Central ($|\eta| < 1.1$)
      - Track matched
  - Muon
    - Isolated muon candidate in both calorimeter and tracker
      - $E_T > 25$ GeV
      - $|\eta| < 2.0$
      - Track matched



Electron + muon RPV sneutrino

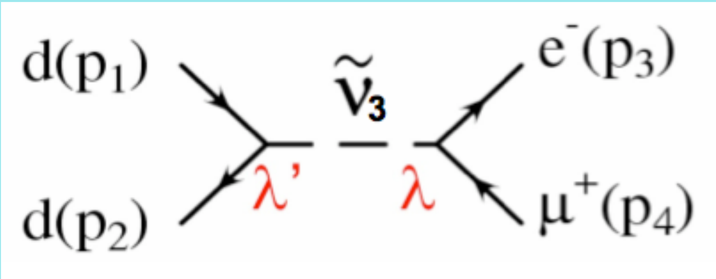
- Backgrounds:
  - Physics
    - $Z/\gamma^* \to \tau\tau$
    - WW, WZ, ZZ
    - $t\bar{t}$
  - Instrumental
    - W+jet/γ
    - $Z/\gamma^* \to ee, \mu\mu$
    - multijet
  - All background contributions except for the multijets are studied in MC. Multijets are studied from data, by selecting a sample rich in fakes

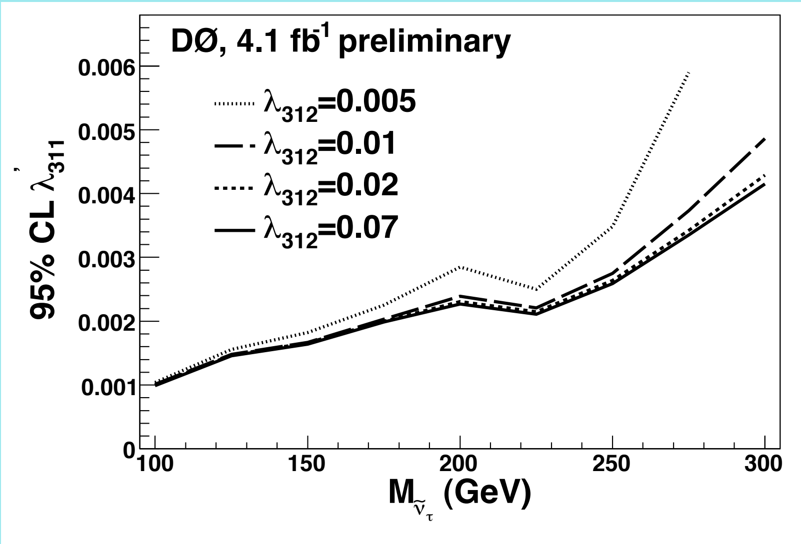


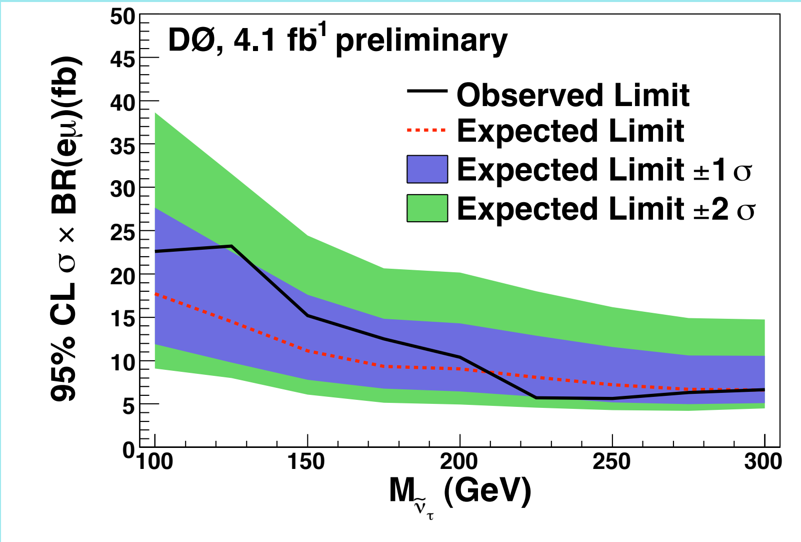
Background	
Z/γ*	83 ± 3
di-boson	46 ± 2
W + jet/γ	13 ± 2
$t\bar{t}$	3 ± 0
Total Background	145 ± 4
Data	143

Electron + muon RPV sneutrino

- Good agreement between data and background
- Proceed with setting 95% CL limits on the production cross-section and RPV couplings as a function of the sneutrino mass
  - Assume that all RPV couplings are zero except for λ'_{311} and $\lambda_{312} = \lambda_{321}$, and $\lambda'_{311} \leq 0.12$, $\lambda_{312} \leq 0.07$ for $M \geq 100$ GeV







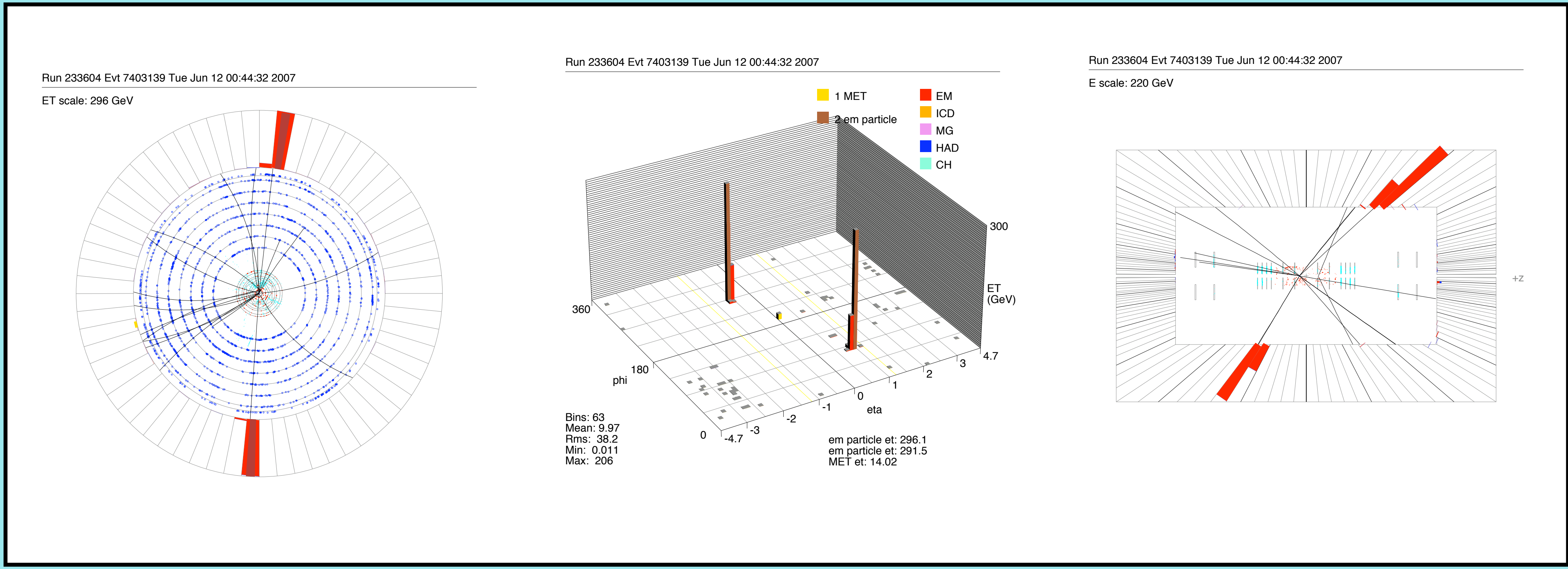
Summary and Outlook

- Presented searches for New Phenomena with the D0 detector using final states with leptons, photons, and MET
- No excess of events over the SM expectations observed up to 4.1 fb^{-1} of data analyzed
- Search for sign of new physics continues
  - D0 detector is well understood
  - Already about 6 fb^{-1} have been recorded and are being analyzed
  - Expect to collect 10 - 12 fb^{-1} of data in the next couple years
- http://www-d0.fnal.gov/Run2Physics/WWW/results/np.htm

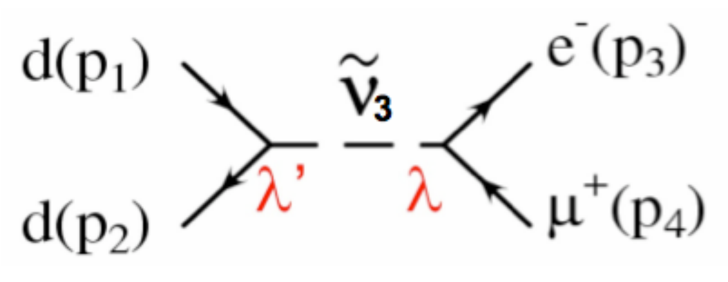
- BACKUP SLIDES

Di-electron Event

M_{ee} = 766GeV



Electron + muon RPV sneutrino



- The cross-section of the signal only depends on the third generation sneutrino mass and the LQD and LLE couplings:

$$\hat{\sigma}_{e\mu} \propto (\lambda'_{311})^2 \times (\lambda'_{312})^2 \cdot \frac{1}{\left| S - M^2 + \Gamma M \right|^2}$$

where the total width of the sneutrino can be written as:

$$\Gamma = \left[3 \cdot (\lambda'_{311})^2 + 2 \cdot \lambda_{312}^2 \right] \cdot \frac{M}{16\pi}$$