Search for new neutral gauge bosons and leptoquarks at the Tevatron

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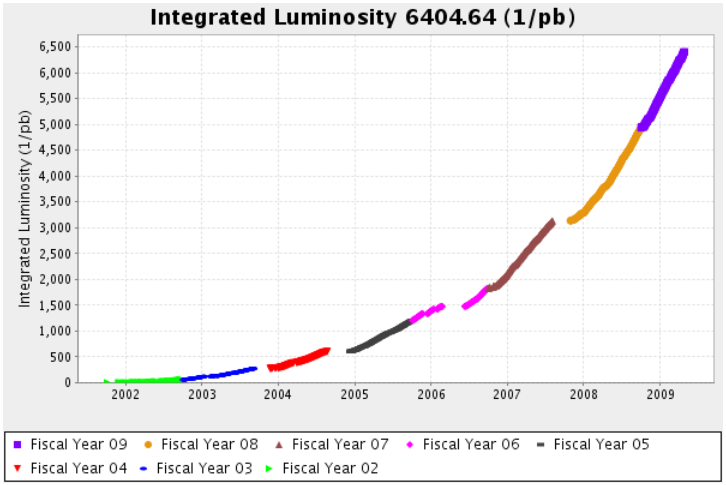
For CDF and D0 Collaborations

Outline

- New gauge boson searches:
  - Motivation
  - Status Of bread & butter dilepton searches
  - More elaborate signatures with di-jets, di-bosons and top
- Leptoquark searches
  - Motivation
  - Latest results
- Summary

Tevatron Status



- Pp-bar collisions
- E(cm)=1.96 TeV

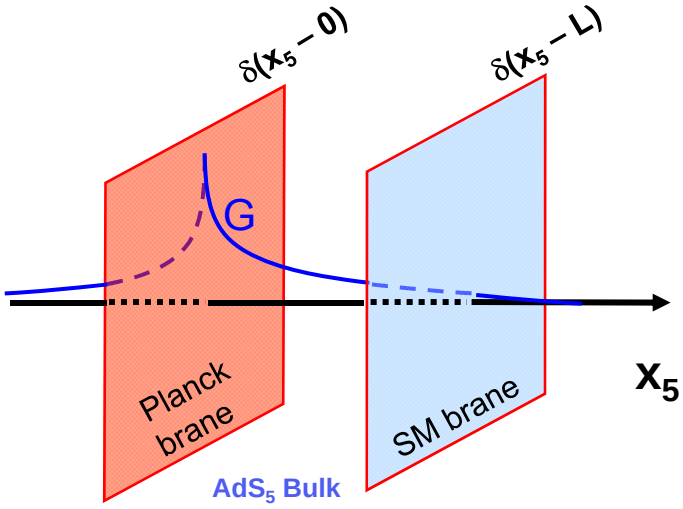
- Steady data taking
- About 5.5 fb^{-1} “on tape”

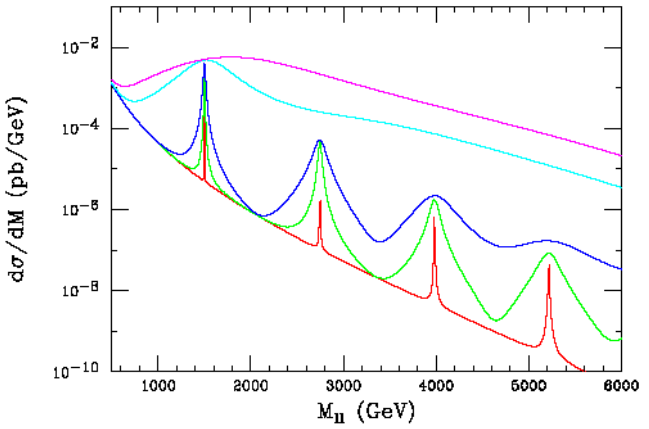
Why New Bosons?

- Many new physics models designed to resolve difficulties of Standard Model predict new bosons:
  - Randal-Sundrum and TeV^{-1} Models (KK gravitons or new gauge bosons)
  - Large Flat Extra Dimensions (gravitons)
  - Good old Z-prime bosons:
    - Sequential Standard Model
      - same couplings as in SM Z^0: Z_{SSM}
    - GUTs : $E6 \rightarrow SO(10)\times U(1)_\psi \rightarrow SU(5)\times U(1)_\chi \times U(1)_\psi$
      - Z_ψ, Z_η, Z_χ
    - Left-Right and Alternative Left-Right Models
      - assume $g_R = g_L$: Z_{LRM}, Z_{ALRM}

RS and TeV^{-1} Models

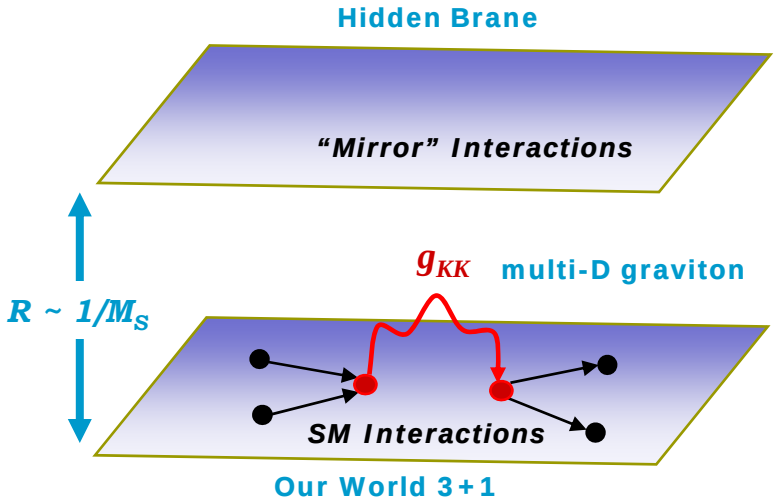
- Randall-Sundrum Model - a vigorous solution of hierarchy problem:
  - Small extra spatial dimensions
  - Curved bulk space: curvature k
  - Graviton propagates in the Bulk
  - All other particles live on SM "TeV" brane
  - Coupling constant depends on k/M_{PL}
    - Controls width of KK graviton resonances
- TeV^{-1} Extra dimension Models
  - Very similar to RS, but additional particles in the bulk (gauge bosons)
    - Many KK towers
  - Running of the couplings changed
    - Lowers GUT scale
  - Nearly equal energy level spacing of KK states
  - Natural to EW scale ED size ~1/TeV
  - But gravity is left out

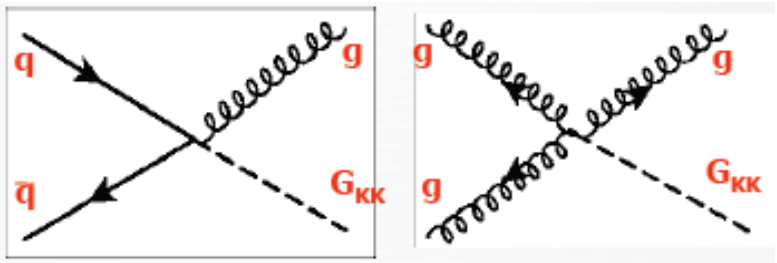




Large Extra Dimensions

- Large flat Extra-Dimensions (ADD model)
  - Could be as large as a few μm (n = 1) or as small as a fm (n = 6)
  - Bulk only accessible by gravity
  - SM particles restricted to 3D brane
    - Gauss' Law: $M_{PL}^2 = M_S^{2+n} R^n$
    - $M_S \sim O(1)$ TeV → Hierarchy problem translated from UV to IR
  - Winding modes with energy spacing 1 meV – 100 MeV
    - Can't resolve experimentally, look for enhancement in the spectrum
- Virtual Graviton Exchange → modifies (e.g. dilepton) mass continuum
- Direct production also possible: look for mono-jet or mono-photon signature (not in this talk)

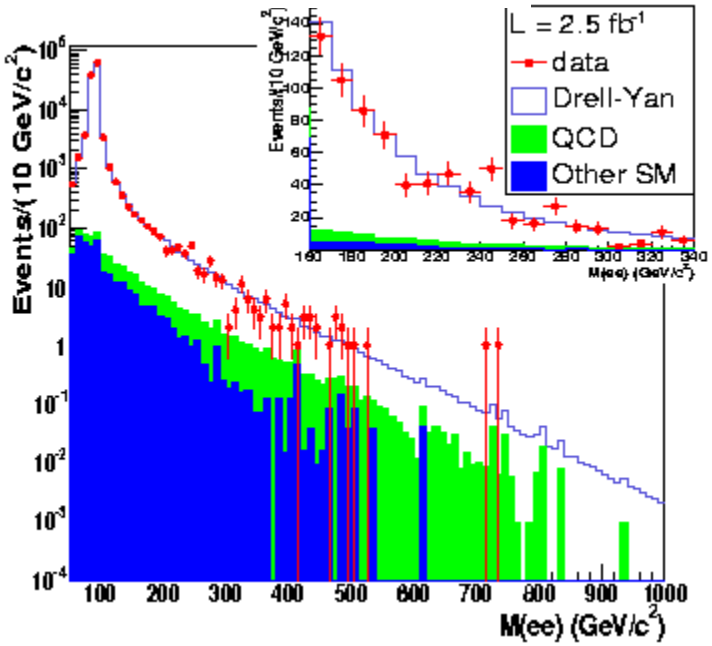


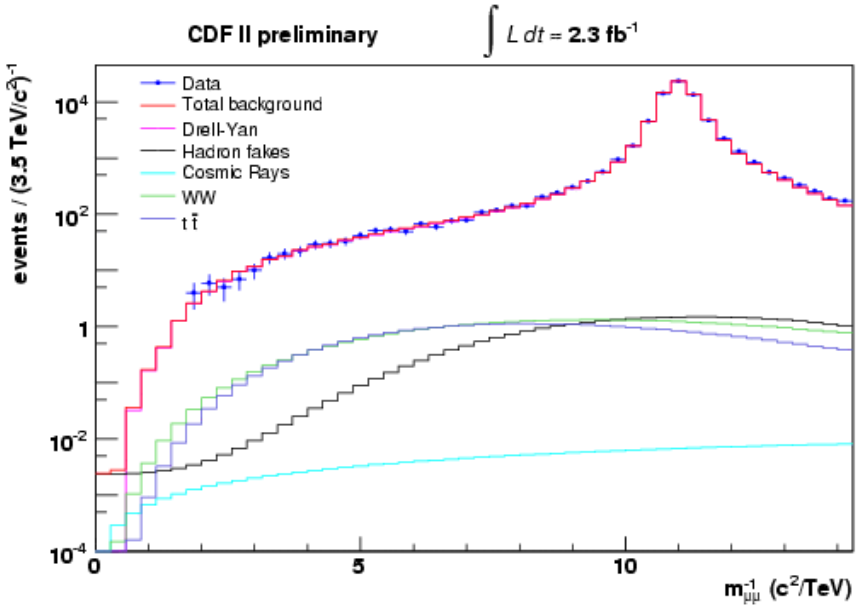


Z-prime in ee/μμ

- Traditional bread & butter dilepton searches
- CDF updates with L=2.3 - 2.5 fb^{-1}
  - Two searches: di-electron and di-muons
- Use Z peak as a control region, look for excess at the higher mass

PRL 102, 031801 (2009)





Limits on Z' and RS Graviton

- With no excess, we set limits:
  - Z'→ee: M>0.8-1 TeV
  - RS G→ee:
    - ~900 GeV for k/M=0.1
    - ~750 GeV for k/M=0.05

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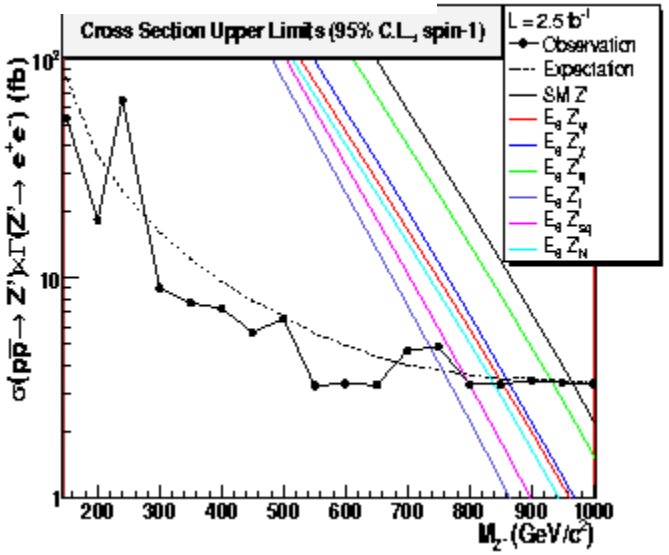
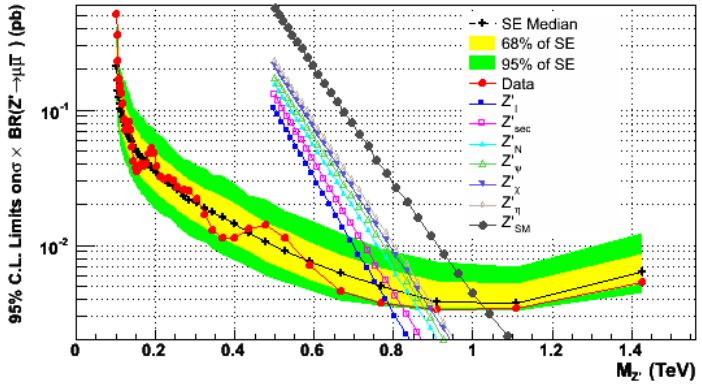


Graviton k/M_{Pl}	Mass Limit, 95% CL (GeV/c^2)
0.1	921
0.07	824
0.05	746
0.035	651
0.025	493
0.015	409
0.01	293

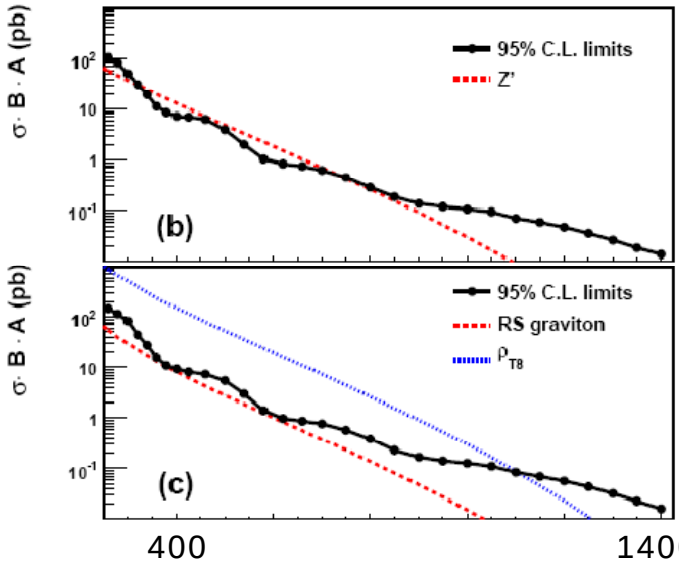
Di-muon channel results

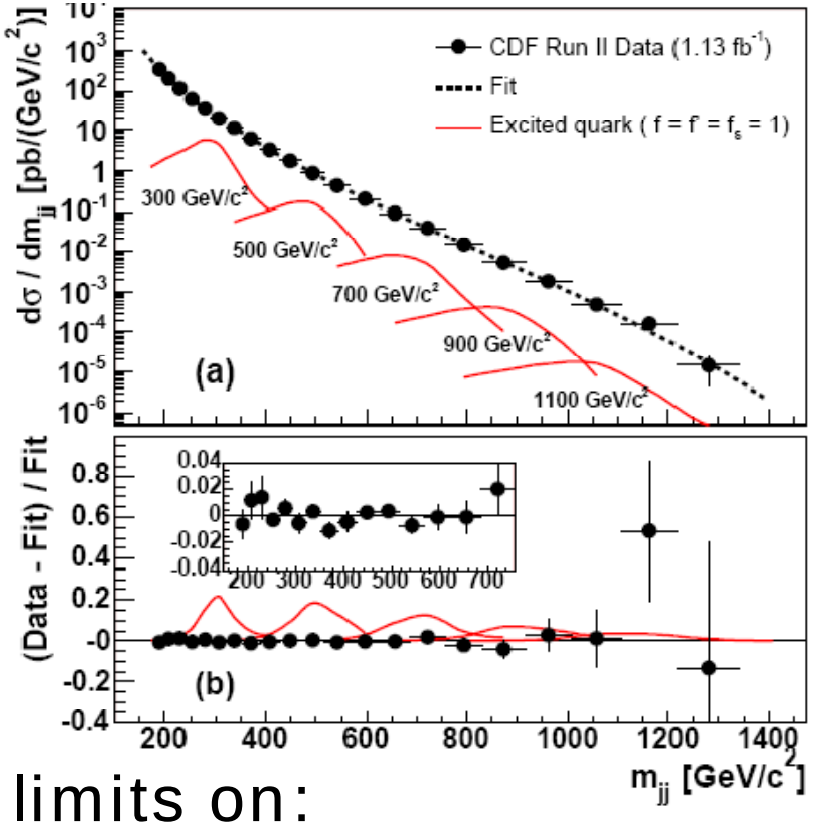
CDF Run II Preliminary L=2.3 fb^{-1}



Search with Dijets

- L = 1.1 fb^{-1}
- Search for generic bumps in dijet spectrum
  - Worse resolution and larger backgrounds but much larger rate!

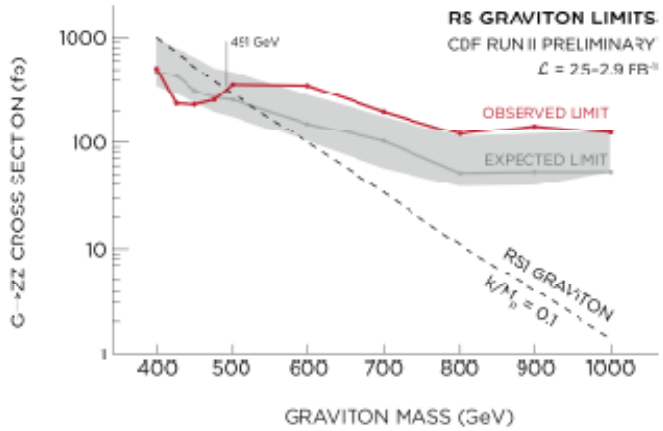




- Set limits on:
  - Z', W', RS graviton
  - q', technirho, contact interactions

RS Graviton in ZZ Channel

- L=2.5-2.9 fb^{-1}
- Put in many improvements:
  - Special forward tracking, loose lepton categories
- Multiple channels to improve acceptance:
  - eell, μμll, ll+jj



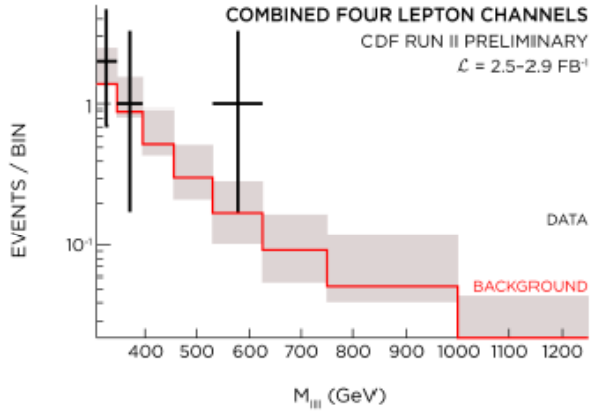
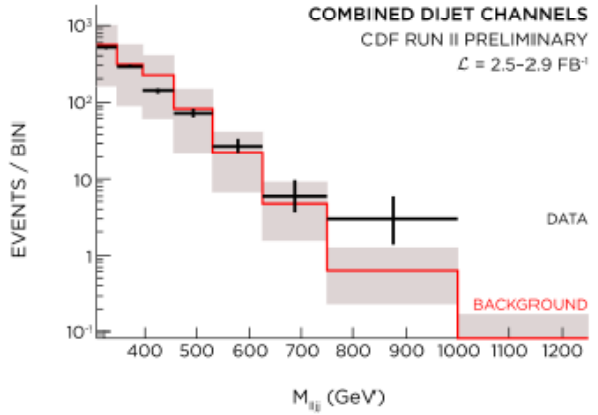
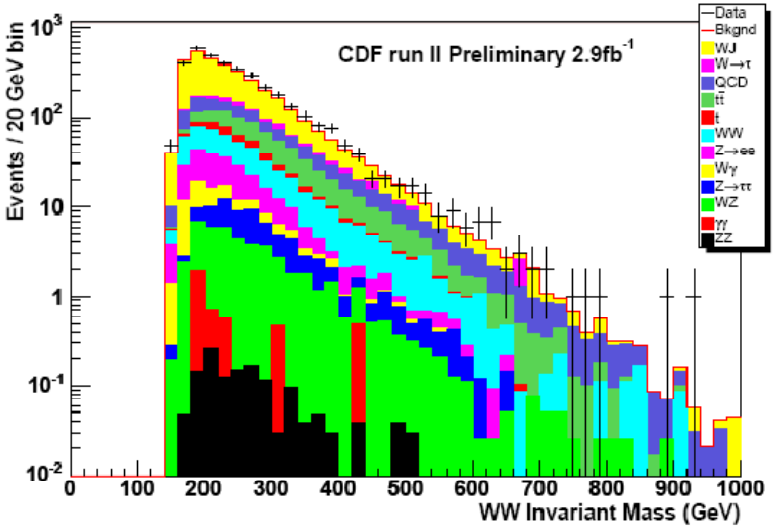


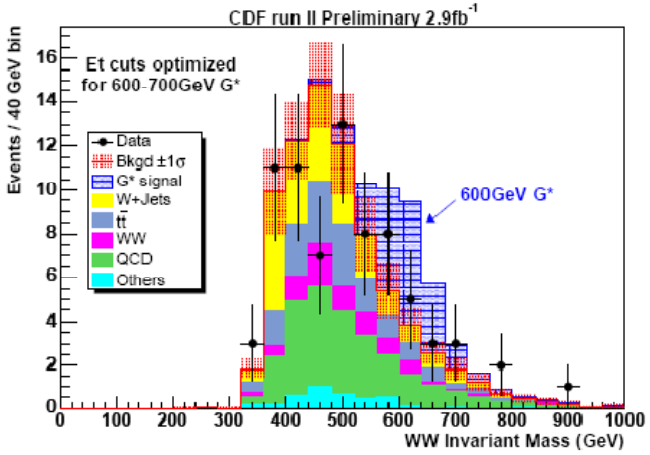
FIG. 4: Prediction and unblinded data for all four-lepton channels combined.

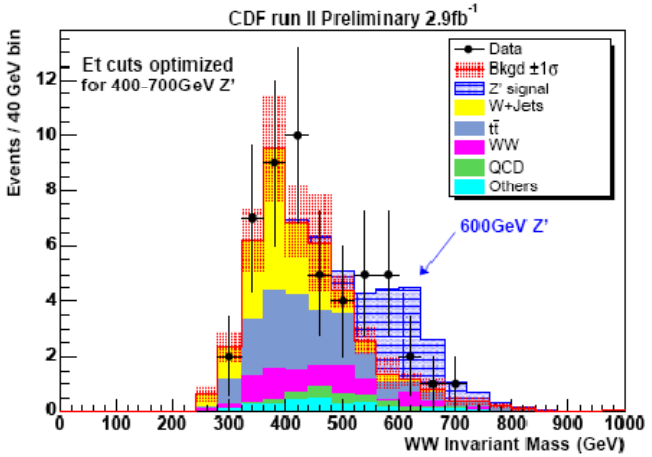


Search in WW Channel

- L = 2.9 fb^{-1}
- Optimize to increase sensitivity in high mass region
  - Separate for Z' or RS Graviton

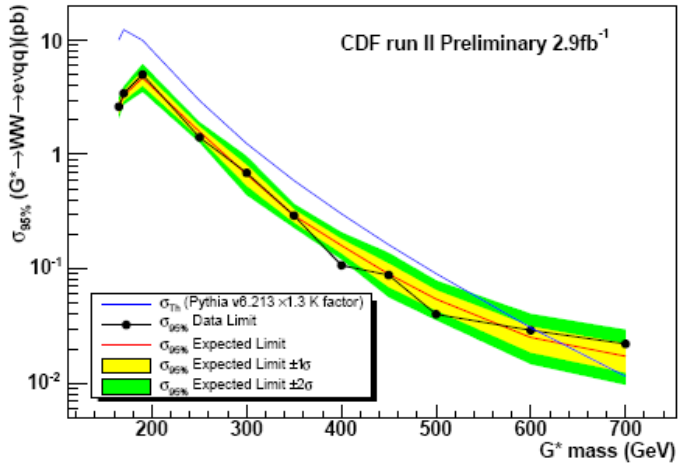


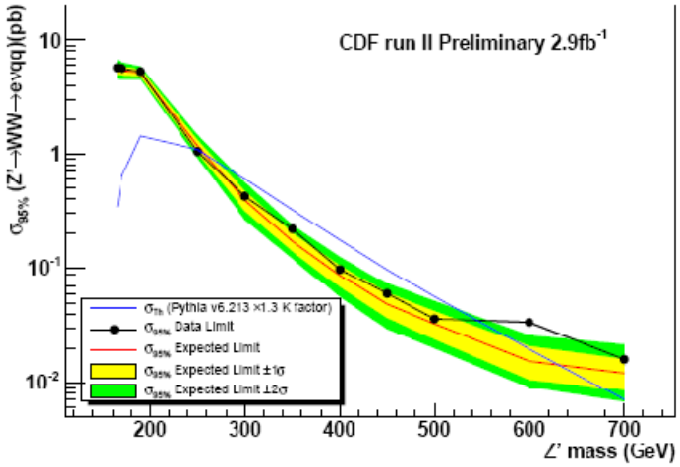




Limits from WW Search

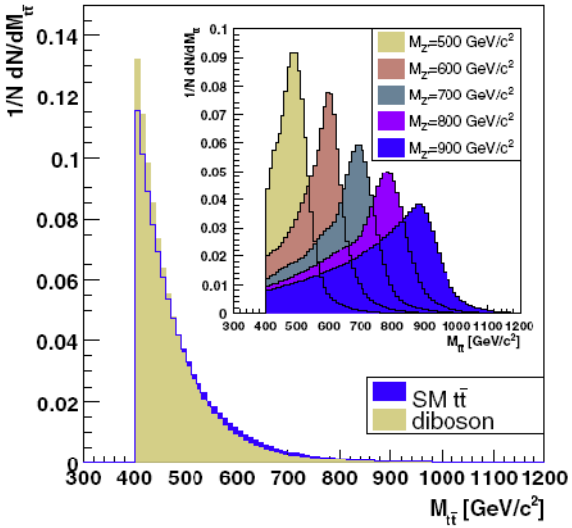
- Sequential Z-prime
  - Mass of 260-550 GeV excluded
- RS Graviton:
  - Anything below ~600 GeV excluded for k/M=0.1
- Stronger limits if for some reason fermion coupling is suppressed (e.g. lepto/fermio-phobic Z')

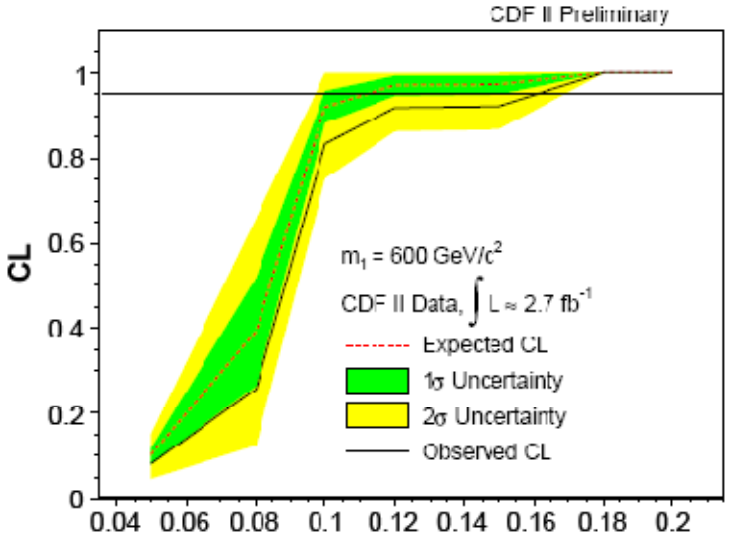




Search for new bosons in tt-bar

- Several new results from CDF and D0:
  - Details in talk by E. Agulio on top
- Not competitive with dileptons in standard benchmarks, but new physics can pop up here if leptonic decays are suppressed
  - Signal: one (Z' or heavy gluon) or multiple (RS) bumps in the spectrum
- Advanced analyses:
  - JES systematics from in-situ W constraint
  - Unfolding of the m_{tt} spectrum

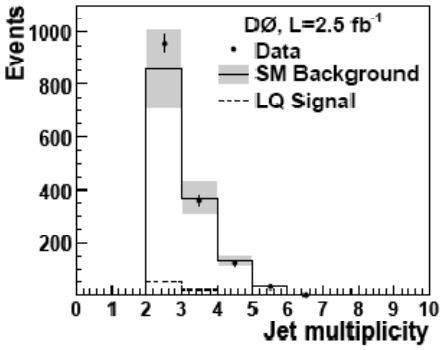


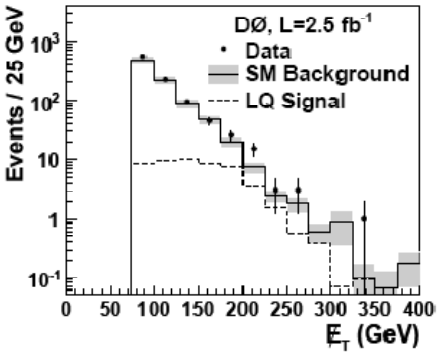


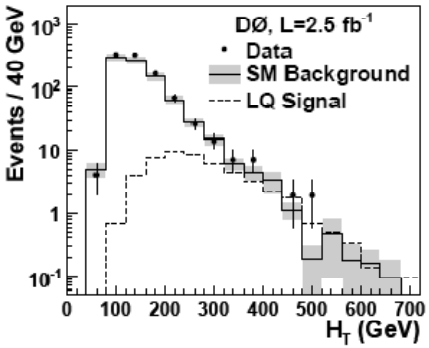
Leptoquarks

- Provides “missing” link between leptons and quarks in SM
- Scalar (standard benchmark) and vector (larger x-section, harder spectrum) variety
- FCNC severely limits coupling across generations
- Additional interest inspired by a few HERA events
- Jargon in benchmarking:
  - 3rd generation as example: LQ can decay to τb or tν
  - Define parameter β as BR to neutrinoless decays

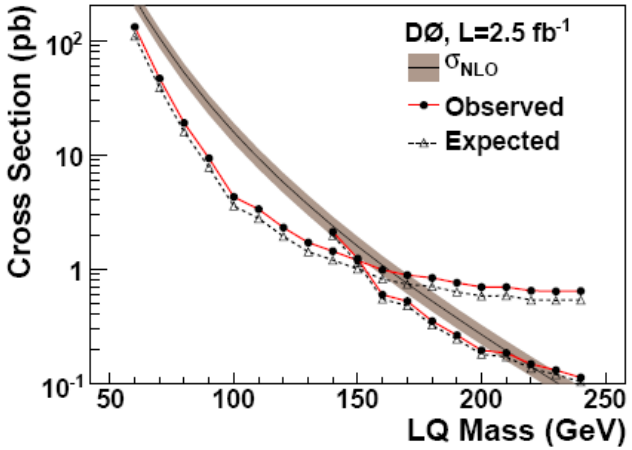
LQs in Jets+MET Channel





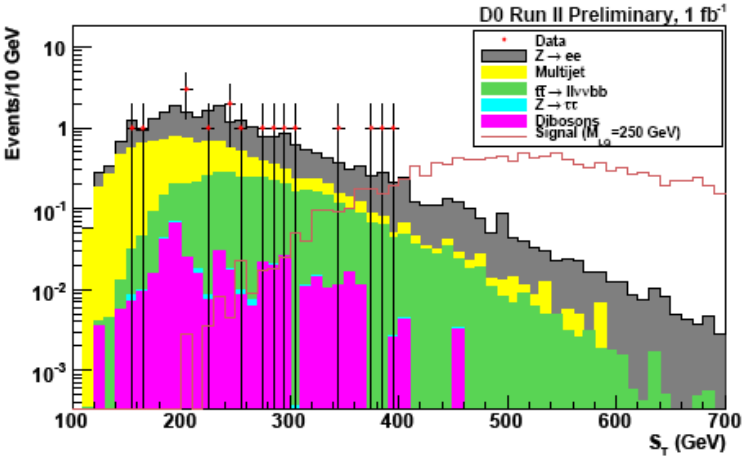


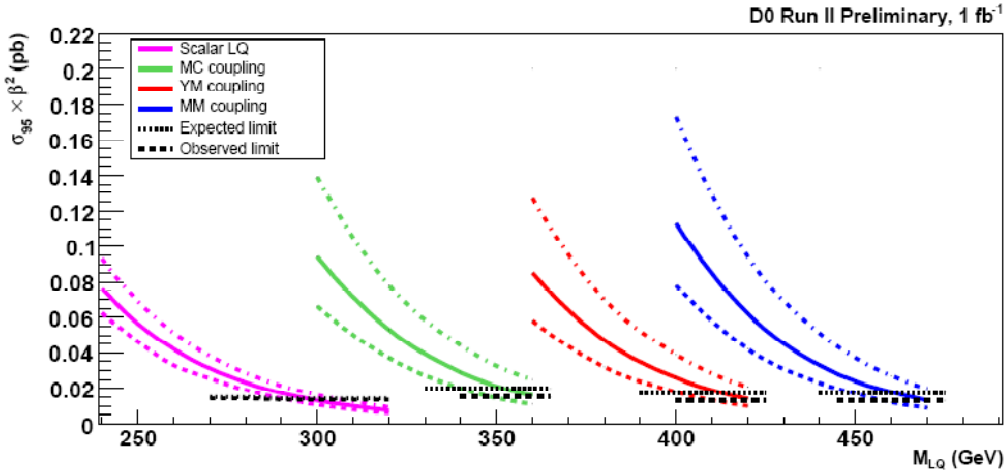
- New D0 analysis L=2.5 fb^{-1}
- Designed to be sensitive to small β for all generations
  - Exactly 2 acoplanar jets
  - Separately optimize for high and low masses



Search for 1st gen LQ in ee+jets+MET

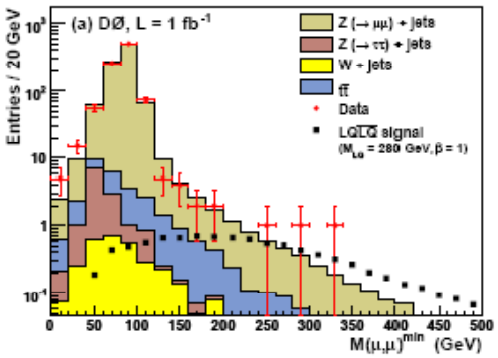
- D0 analysis with L=1 fb^{-1}
- Limits on scalar and vector LQ
  - Minimal: k=1, lambda=0
  - YM: k=0, lambda=0
  - MM: k=-1, lambda=-1

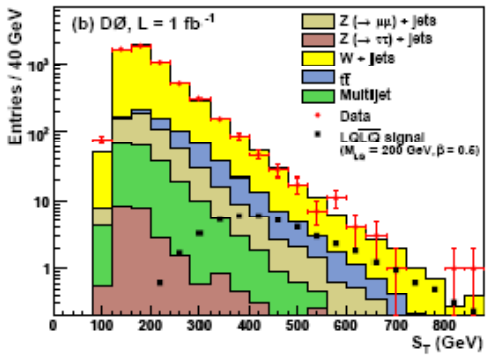


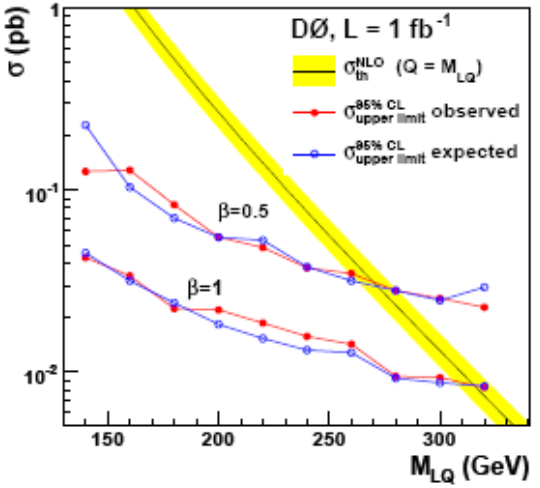


LQ type	Mass limit
Scalar	292
Vect. Minimal	350
Vect. YM	410
Vect. MM	458

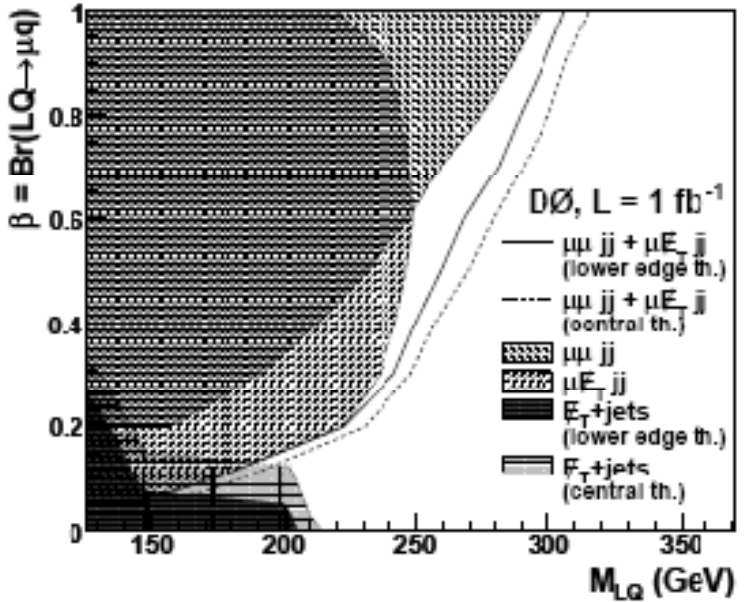
Search for 2nd Gen LQs



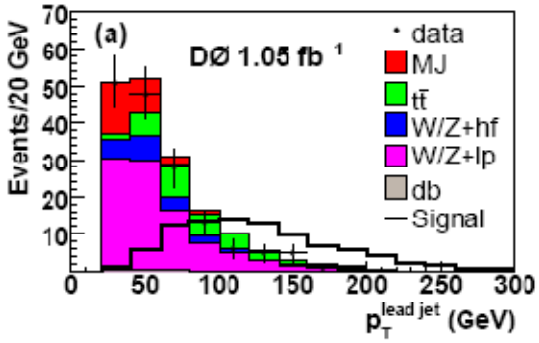


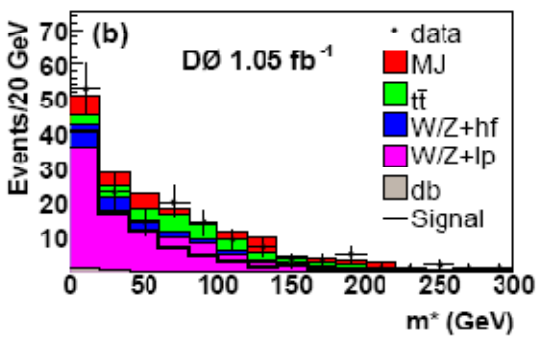


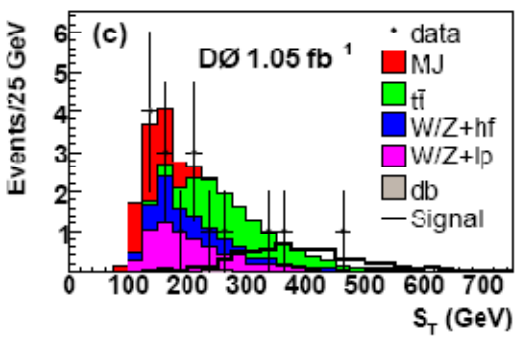
- D0 analysis with L=1 fb^{-1}
- Designed to target both high and medium β ranges
  - Both μμjj & μ+METjj
  - NN-based analysis
- Very low beta from acoplanar jets+MET analysis



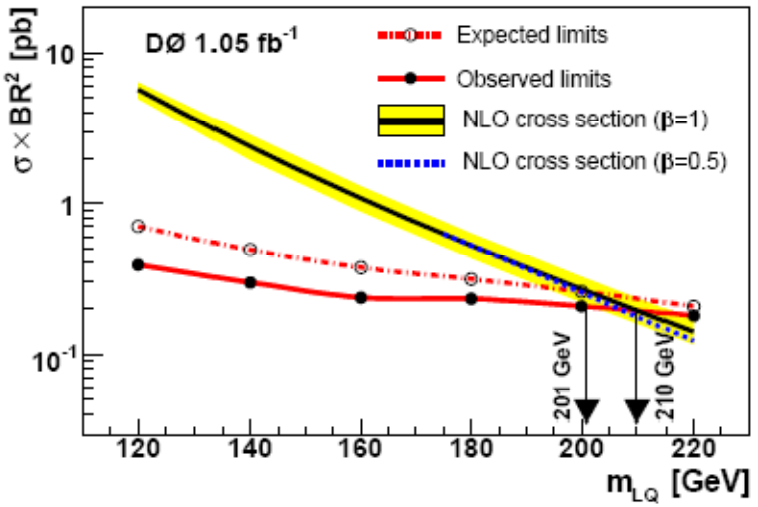
Search for 3rd gen LQs







- L=1 fb^{-1}
- Signature: $\mu\tau_{had}$+jj
- Two subsets:
  - Two b-tagged jets
  - One b-tag (sec. vertex)
    - More backgrounds, but allows recovering extra acceptance

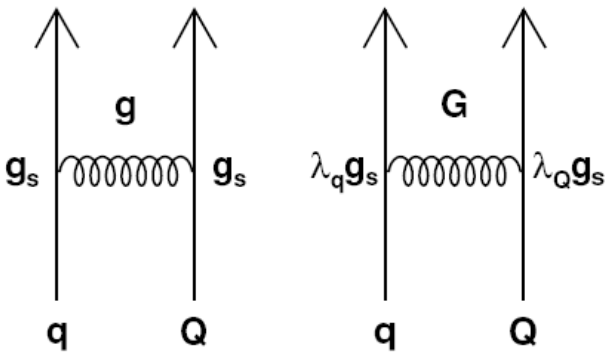


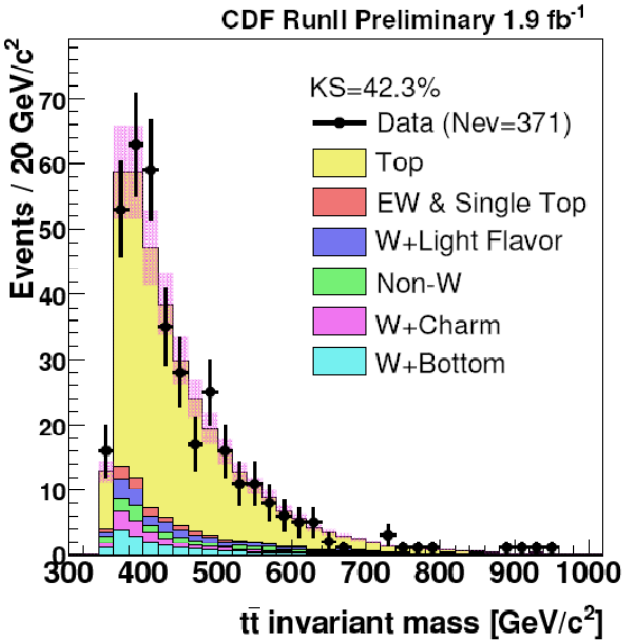
Summary

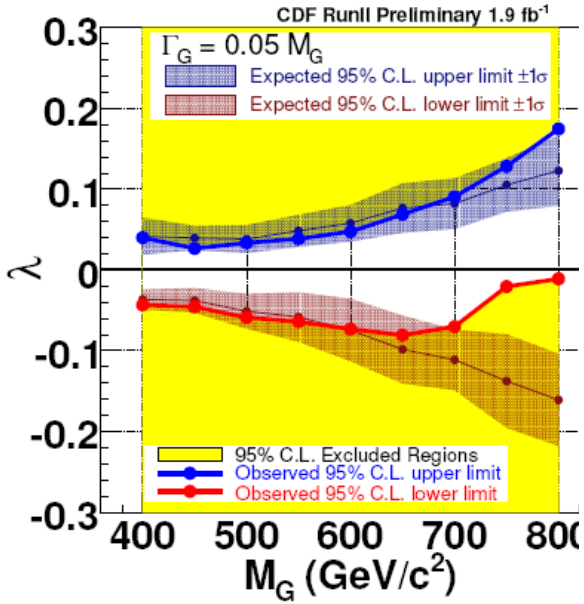
- Both CDF and D0 are in excellent shape and maintain vibrant and active programs on searches for new physics
- New data are regularly used to update analyses
- More elaborate techniques lead to better sensitivity with the same amounts of data
- Large top and diboson samples and detailed understanding allow broadening searches beyond standard dilepton scenarios

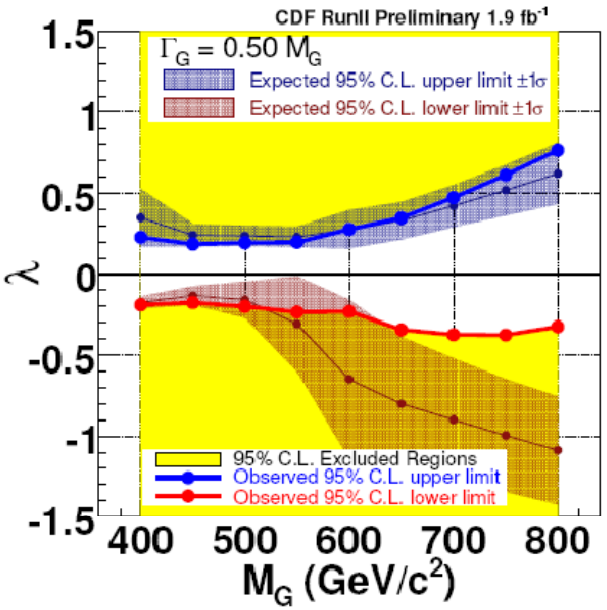
Massive Gluon

- Similar search, based on L=1.9 fb^{-1}
- Strong coupling, possibly enhanced by $\lambda=\lambda_Q*\lambda_q$
- Look for a bump in the spectrum
- With no excess, set limits





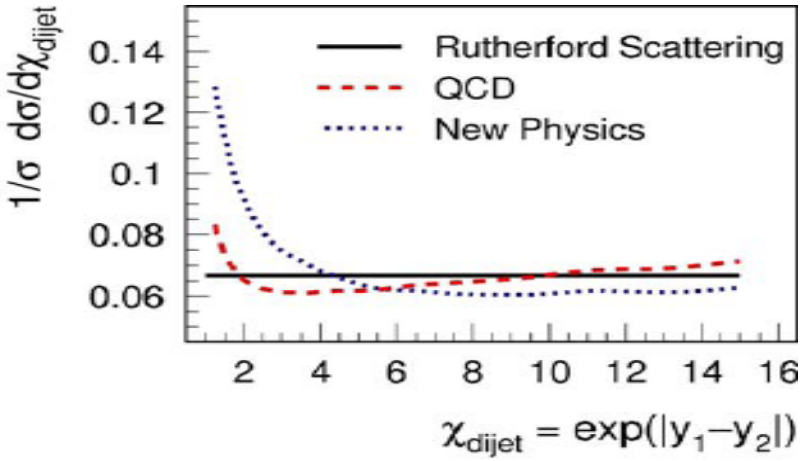


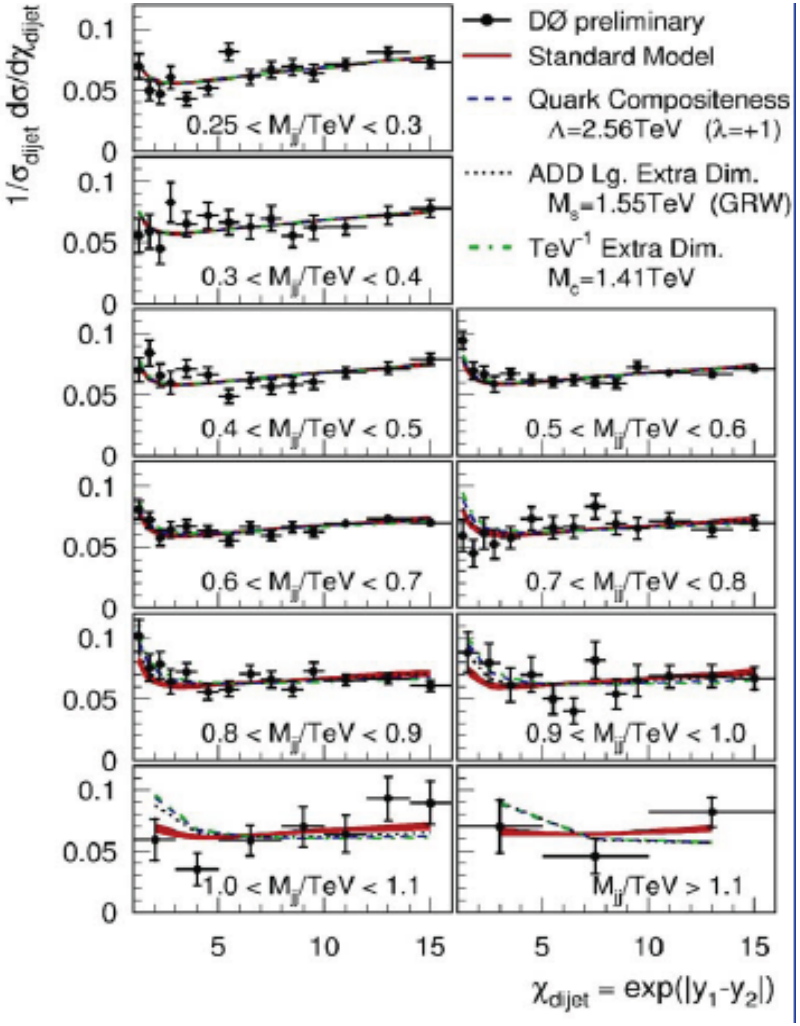


Dijet final states

- Can look at resonances in Mjj but also at angular distributions:
- Deviation from SM could be hint of:
  - Compositeness
  - ADD extra dimensions
  - TeV-1extra dimensions
- Measure χ_{dijet} as a function of Mjj

$$\chi_{dijet} = \exp(|y_1 - y_2|)$$





Compositness (Λ): ~**2.6 TeV**
ADD LED (M_s in GRW formalism): **1.54 TeV**
TeV-1 ED (M_c): **1.42 TeV**