Non-SUSY Exotics Searches at the Tevatron

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for the CDF and D0 Collaborations

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La Thuile, Aoste Valley, Italy
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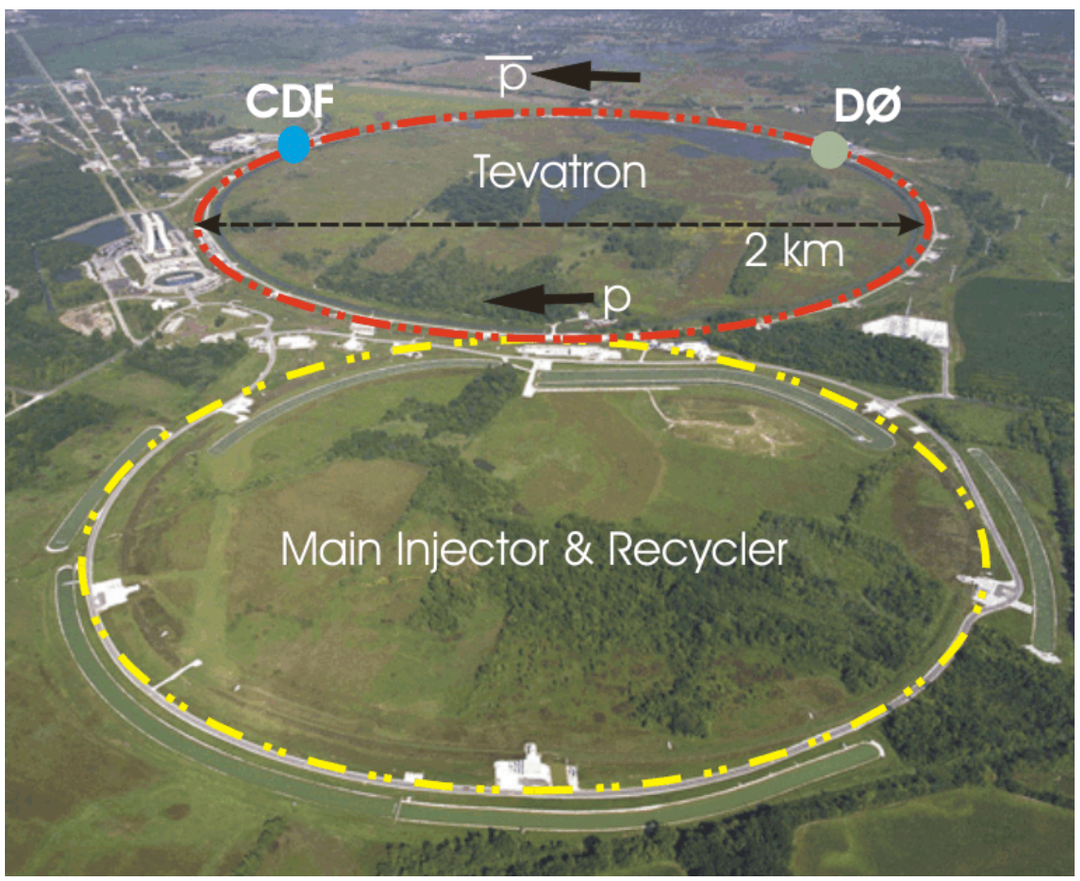
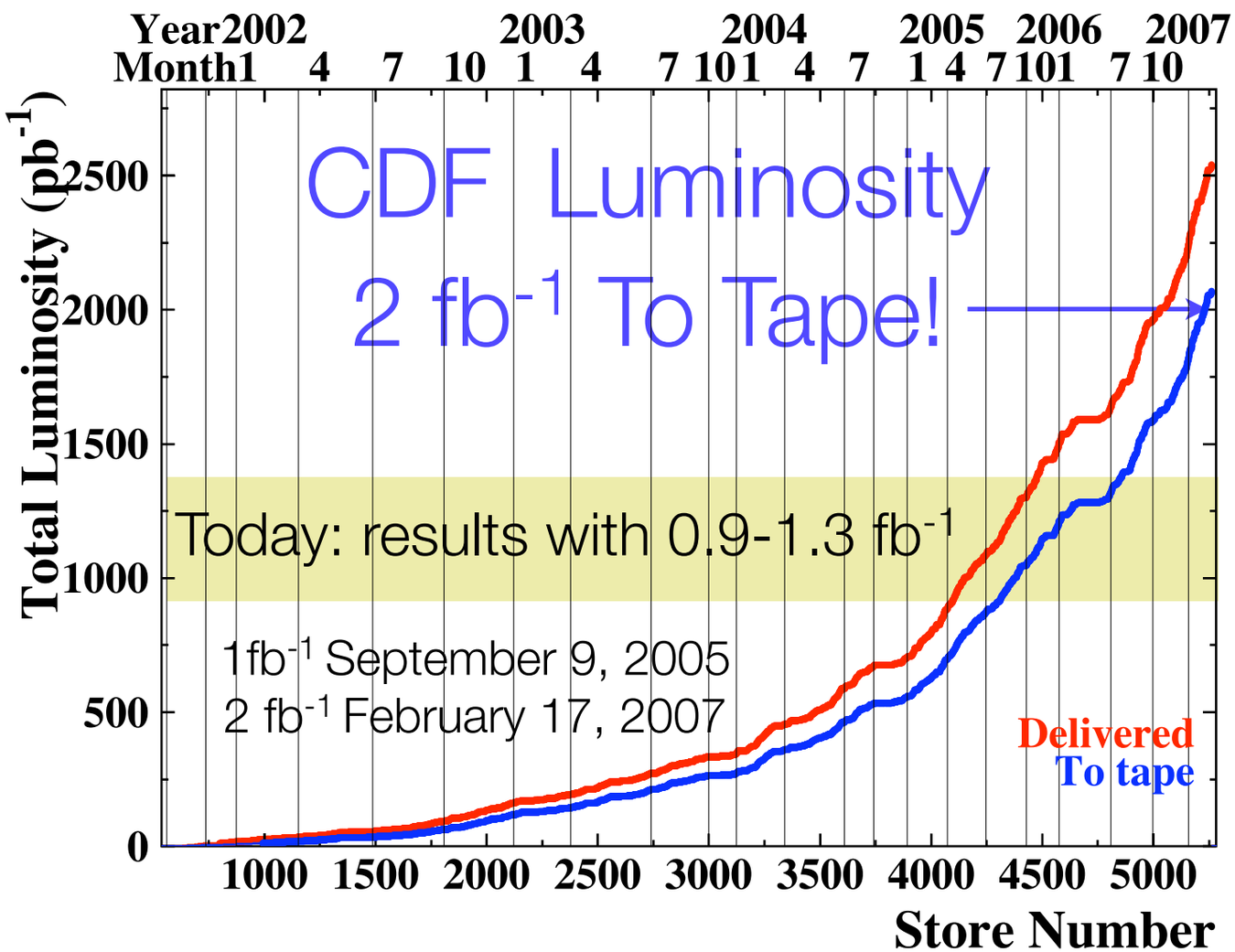
Overview

- Tevatron, CDF & DØ
- Model-inspired searches
  - Theory driven
  - Standard model and new physics known; optimize for sensitivity.
  - Extra Dimensions, Extra Gauge Bosons (Z', W'), New quarks (b'), Leptoquarks
- Signature-based searches
  - Final-state driven
  - Standard model is known. Look for any deviations everywhere
  - Because we can
- Today: Emphasis on 1 fb^{-1} results
- Outlook

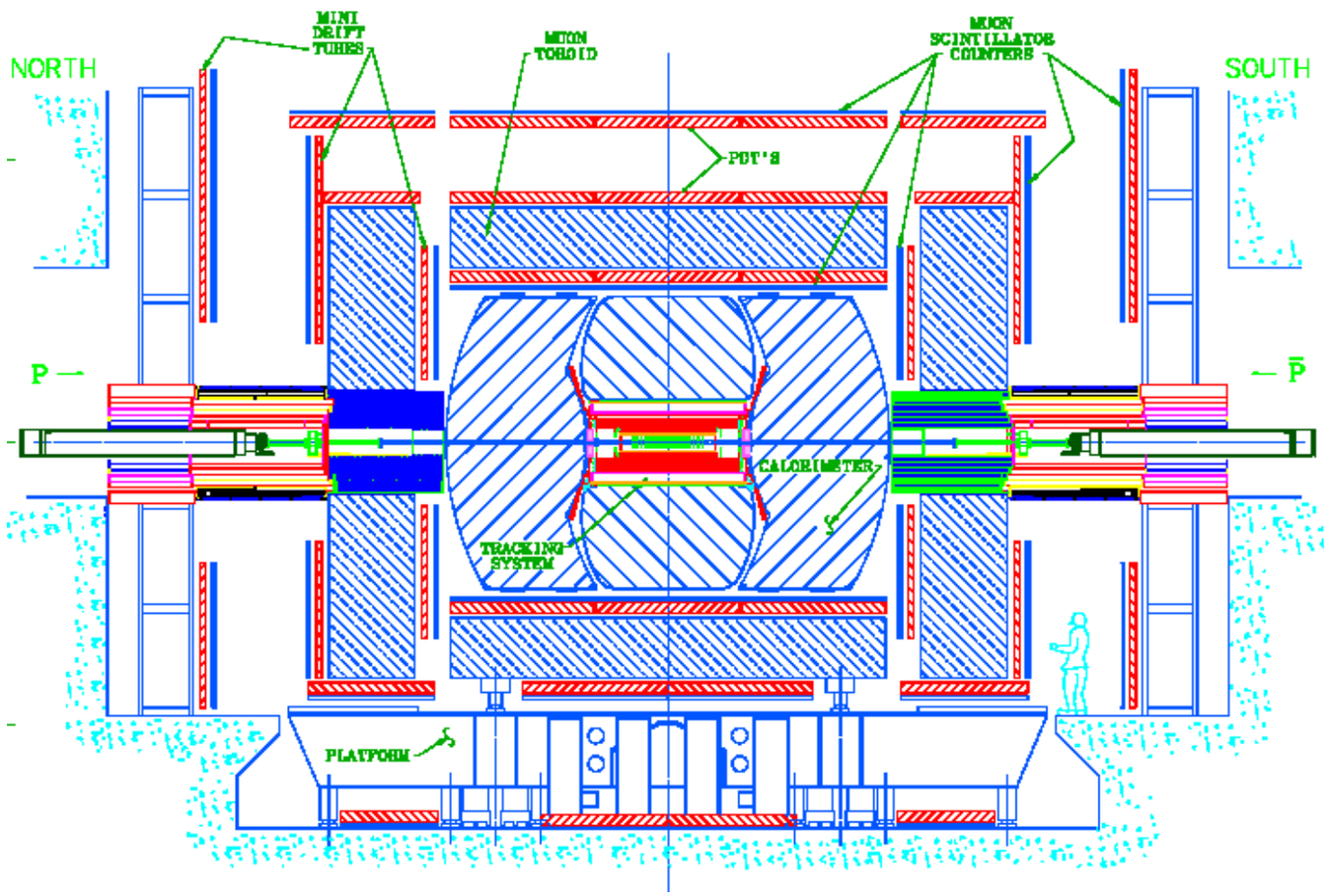
Tevatron Performance

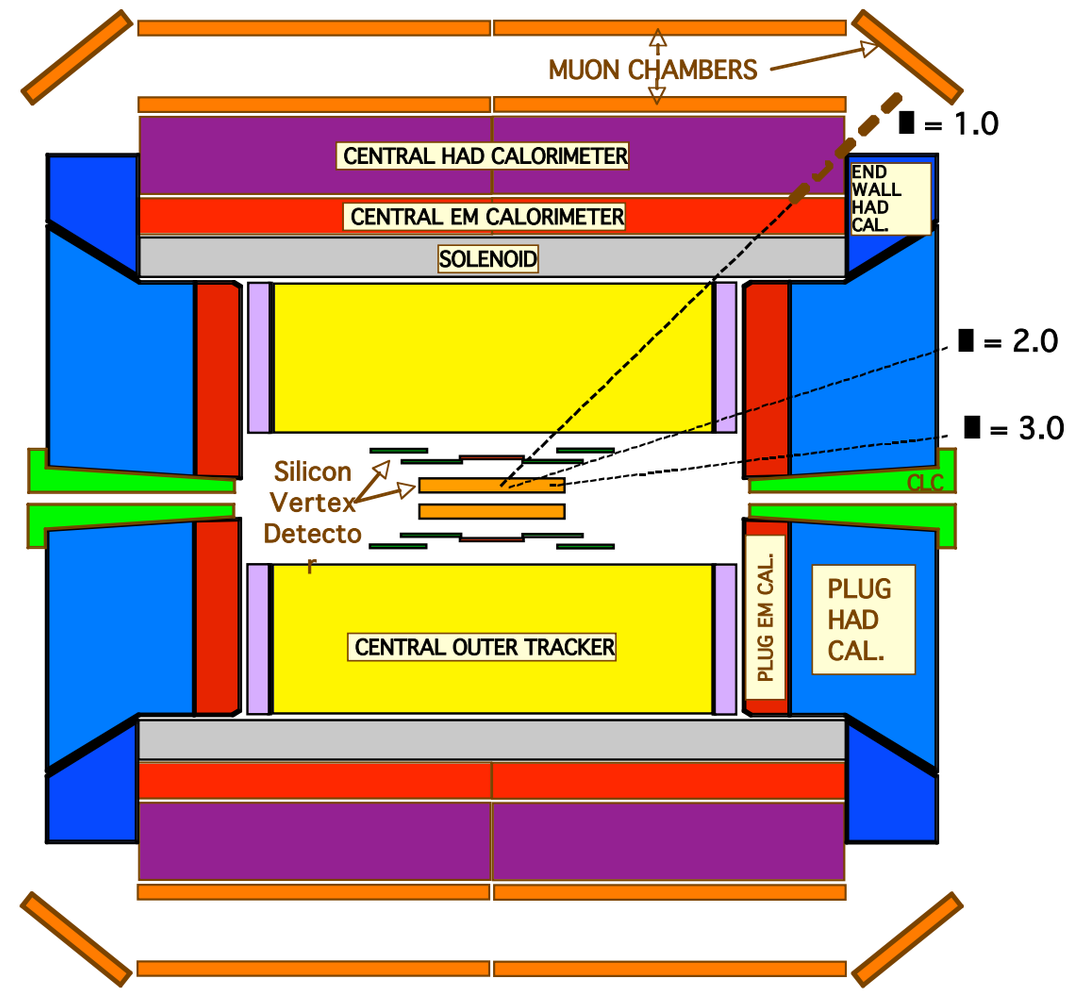
- DØ and CDF each have >2 fb^{-1} recorded; expect 4-8 fb^{-1} by 2009
- Records: Initial Luminosity: 292.3 $\times 10^{30}$ $cm^{-2}s^{-1}$





D0 and CDF Detectors



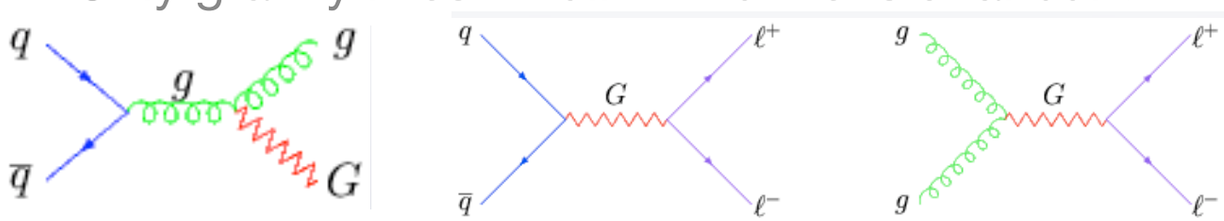


- Multipurpose Charged Tracking Spectrometers with Microstrip Silicon Vertex Detectors, Electromagnetic and Hadronic Calorimetry and Muon chambers.
- Reconstruct e,μ,τ,γ,jets,b-jets, missing E_T (MET)

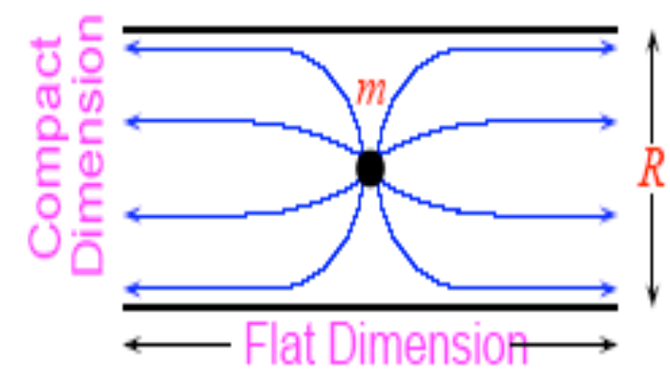
Extra Dimensions

Extra dimension models provide a solution to the hierarchy problem

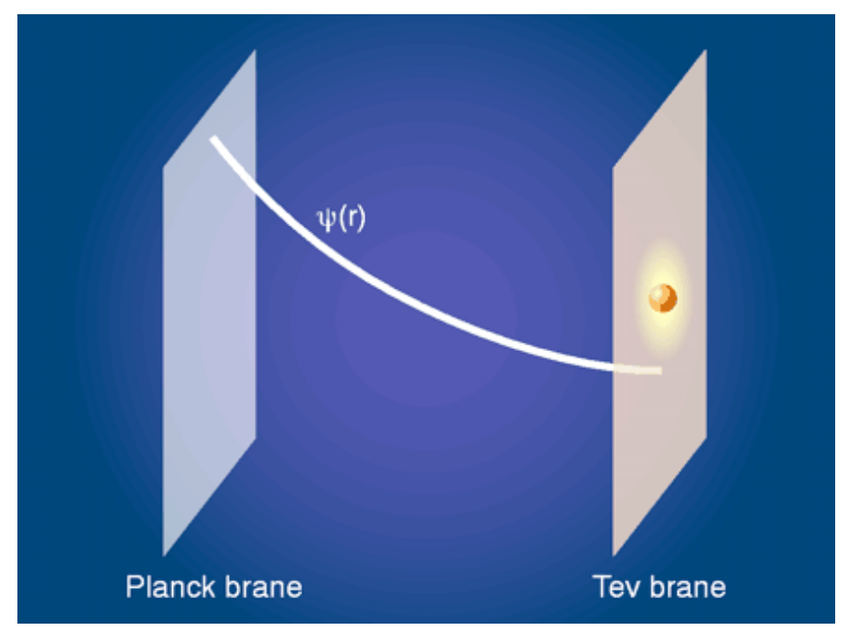
- Arkani-Hamed, Dimopoulos, Dvali (ADD)
  - *n* compact extra dimensions; $M_{Pl}^2 \sim R^n M_D^{2+n}$
  - Standard Model confined to a 4-dimensional brane
  - Only gravity lives in full 4+n dimensional bulk



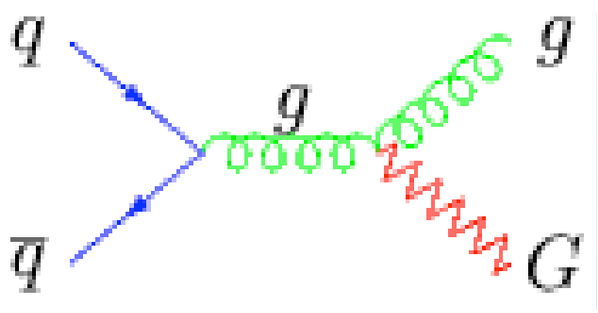
– Weakness of gravity due to being diluted by volume of extra dimensions

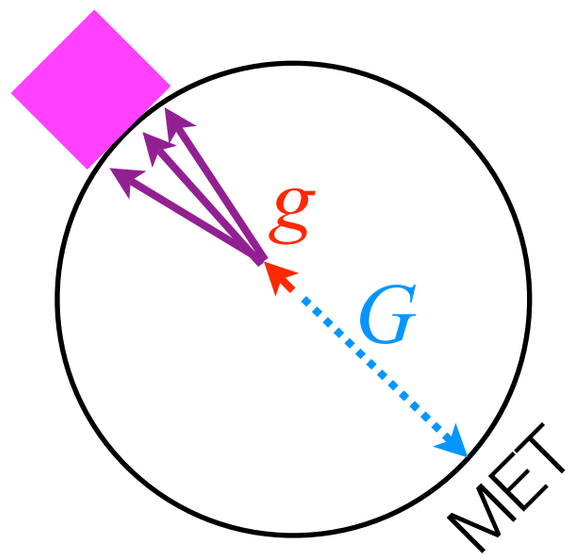


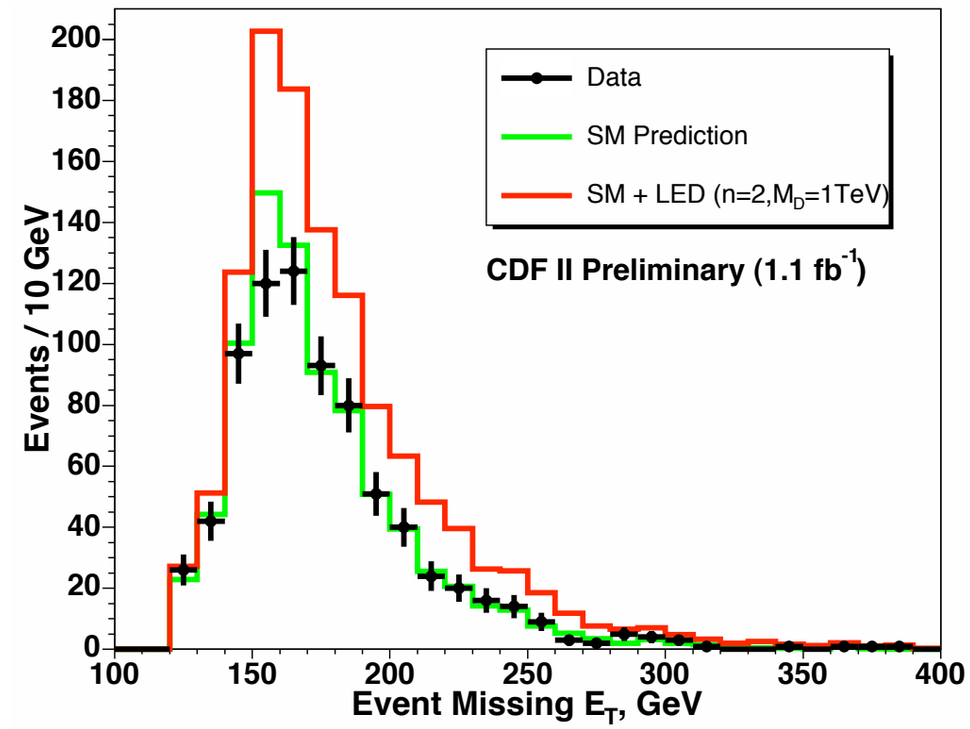
- Randall-Sundrum I (RS)
  - Warped extra dimension(s), exponential warp factor solves hierarchy problem
  - Two branes, TeV and Planck. Gravitons live everywhere, SM confined to TeV brane.
  - Signature: High-Mass Graviton Resonances
    - $pp \rightarrow G_n$, $m_n \sim x_n k/M_{Pl}$



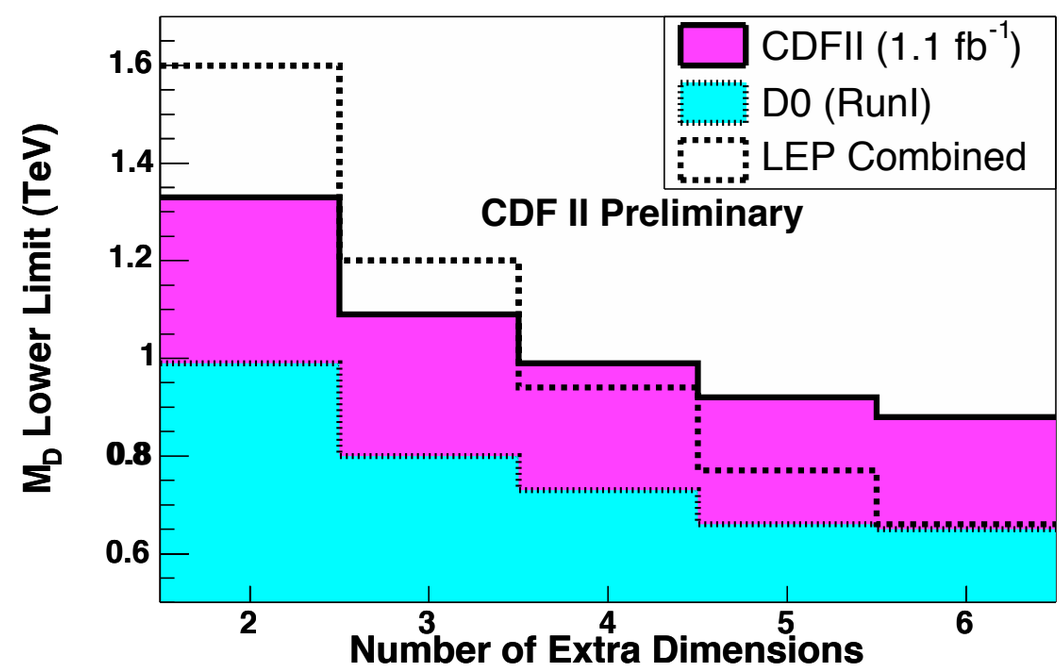
Search for Large Extra Dimensions: Monojet + Missing E_T



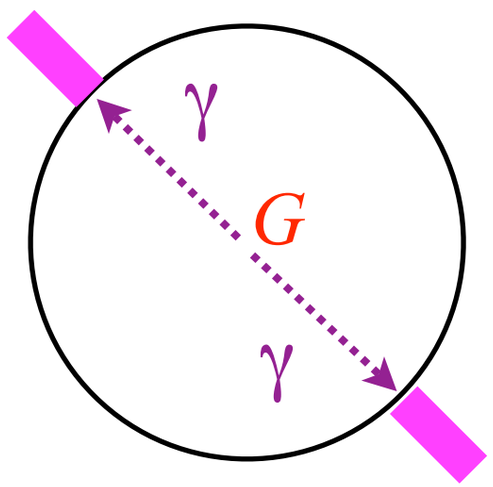


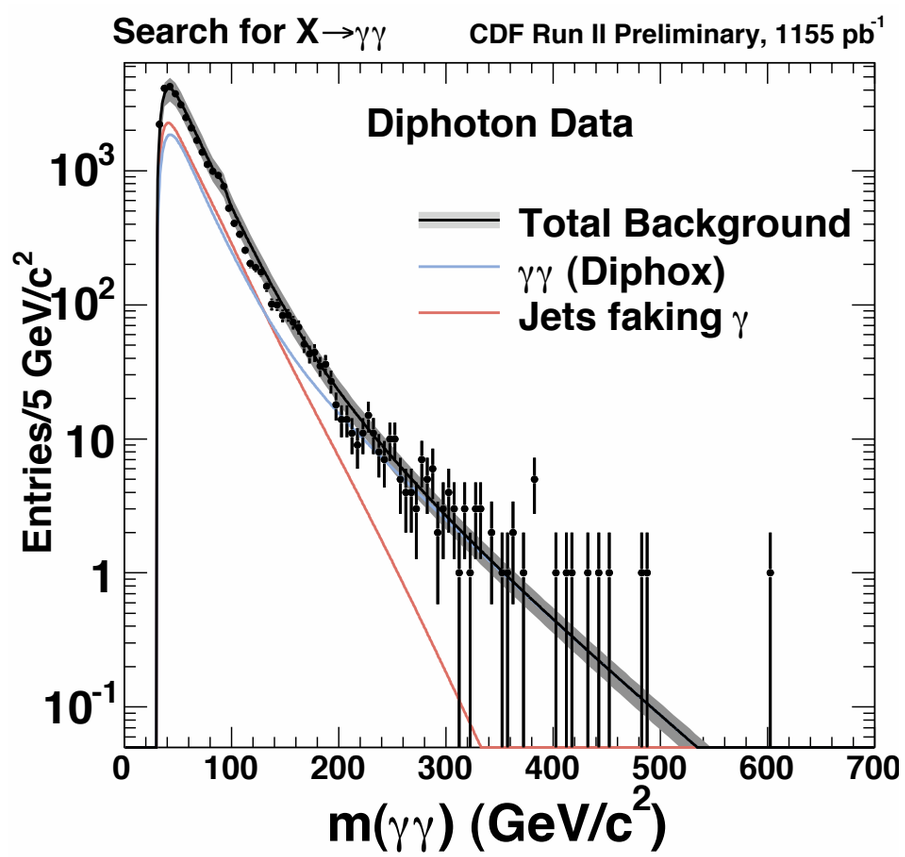


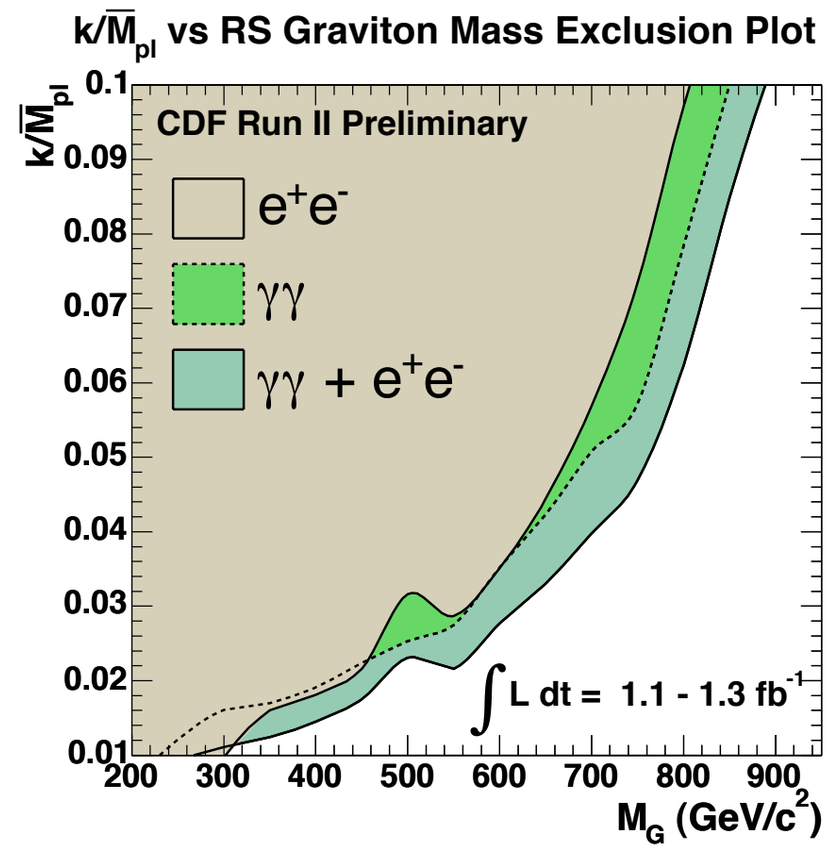
- Direct production qq→Gg, qg→Gq, gg→gG
- Jet E_T>150 GeV, MET > 120 GeV
- Backgrounds: Z→νν+jets, W→lν+jets, QCD dijet. Measured with data.
- Expected 819±71, Observed 779.



Search for Randall Sundrum Gravitons: $G \rightarrow \gamma\gamma$



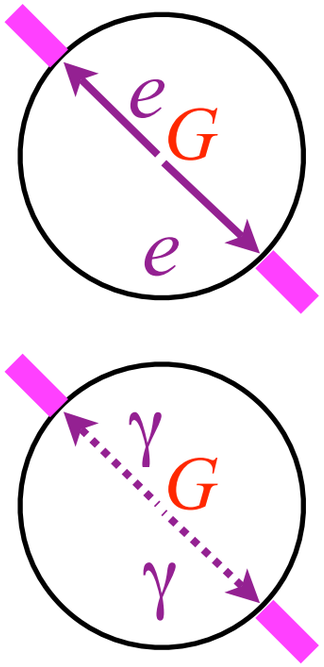


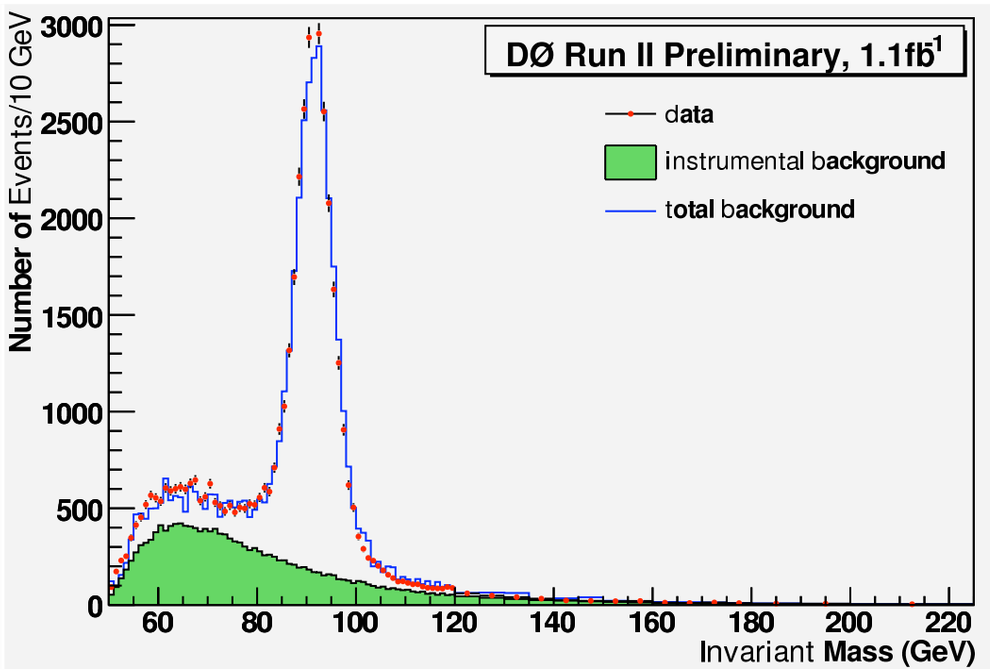


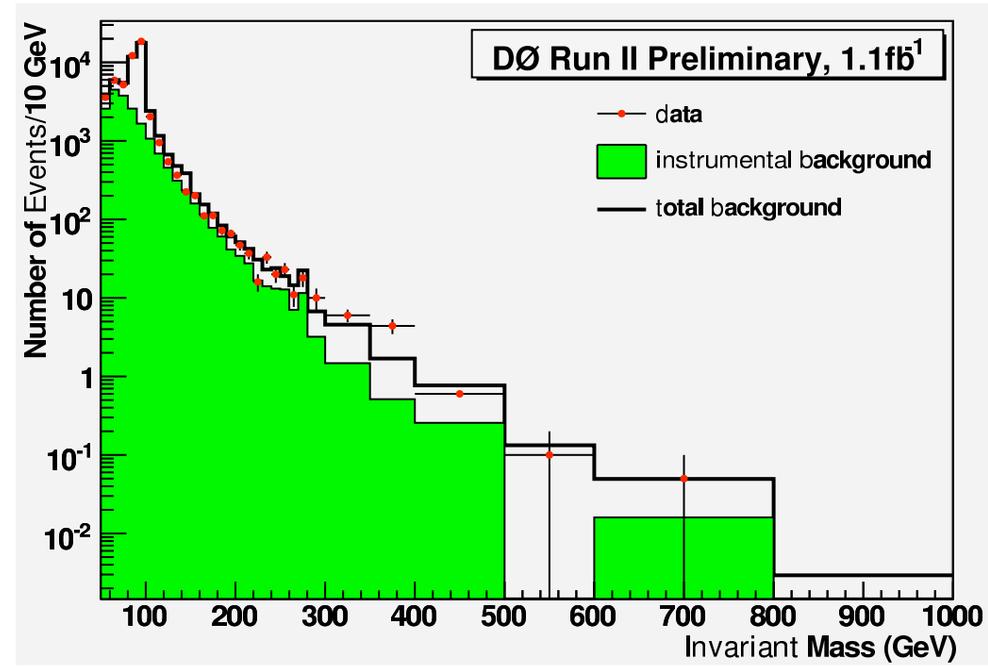
- Direct search for a bump in $\gamma\gamma$ mass spectrum
- Data-based fake background estimation

- Randall-Sundrum Graviton limits
  - $k/M_{PL}=0.1$, $m_G > 850$ GeV
- Combination $\gamma\gamma + ee$,
  - $k/M_{PL}=0.1$, $m_G > 889$ GeV

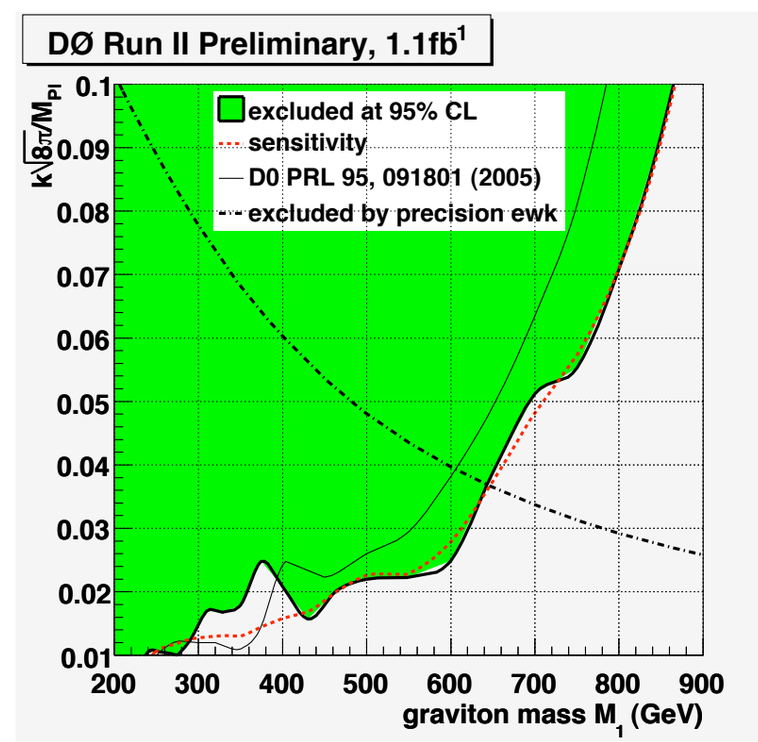
Search for Randall-Sundrum Gravitons: Combined ee,γγ



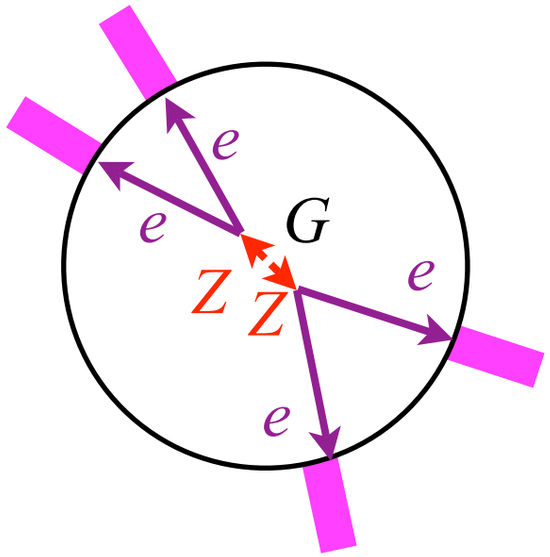


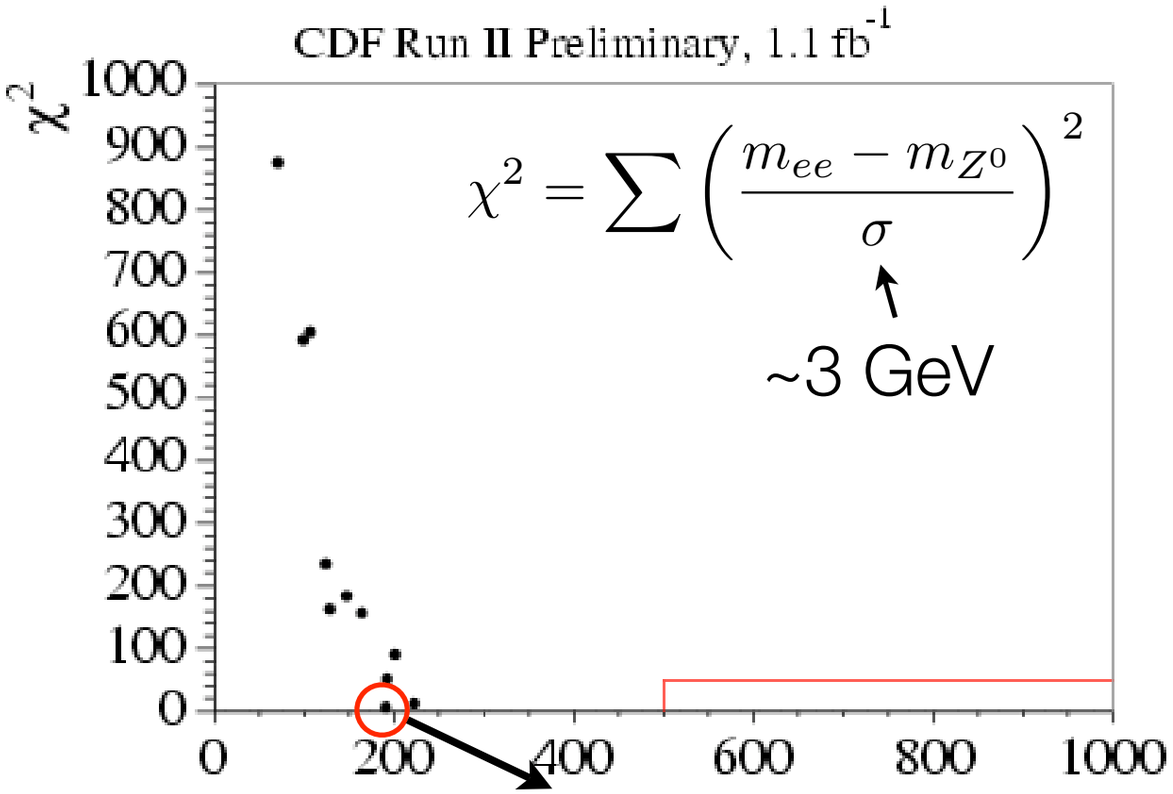


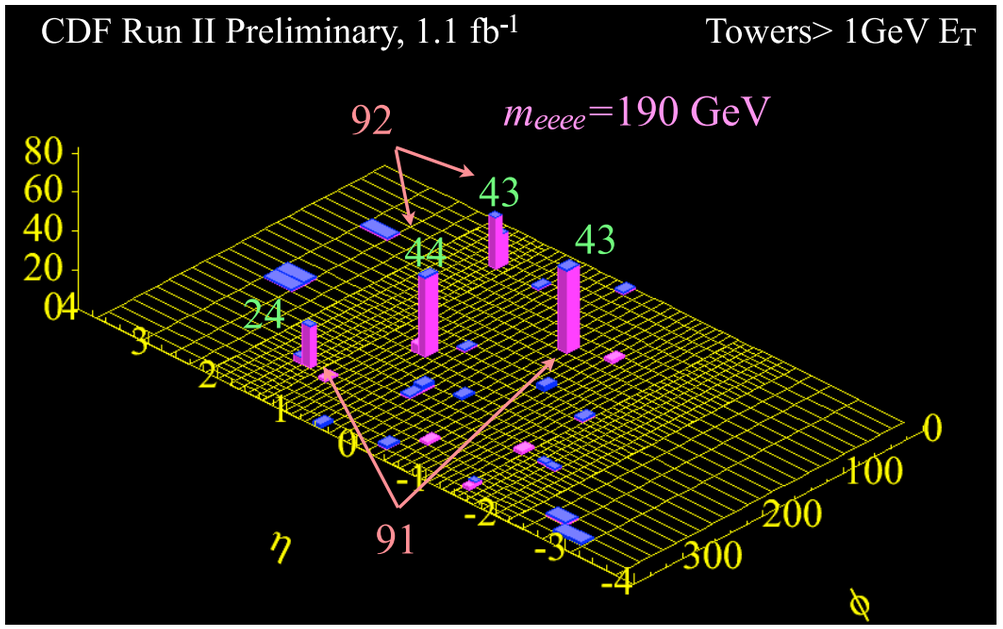
- ee and γγ are combined for maximum sensitivity
- Data-based mis-id background estimate
- For $k/M_{Pl} = 0.1$, $m_G < 865$ GeV excluded at 95% CL



Search for New Heavy Particles in Z^0Z^0



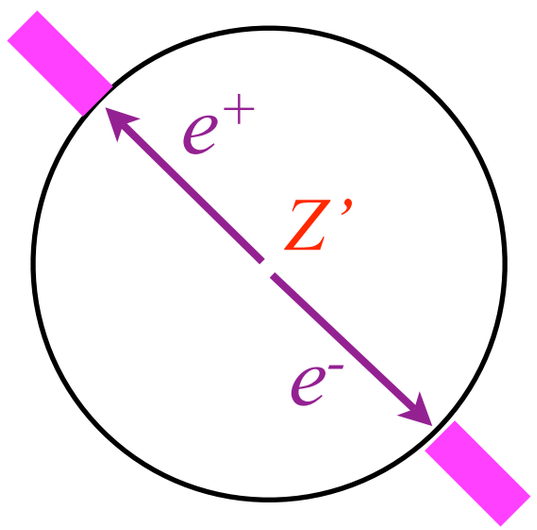


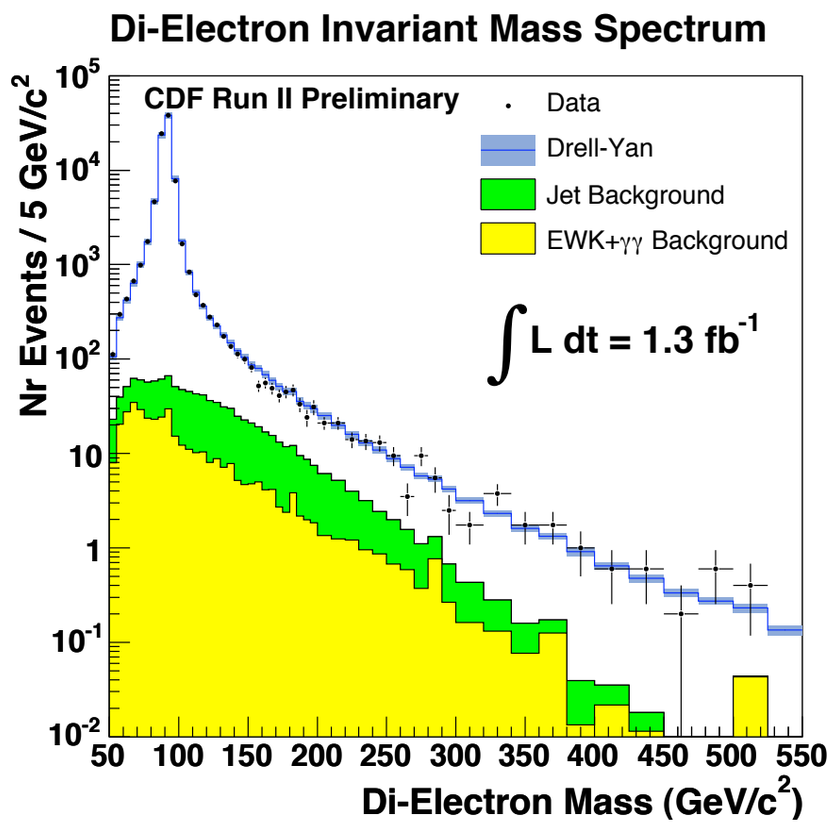


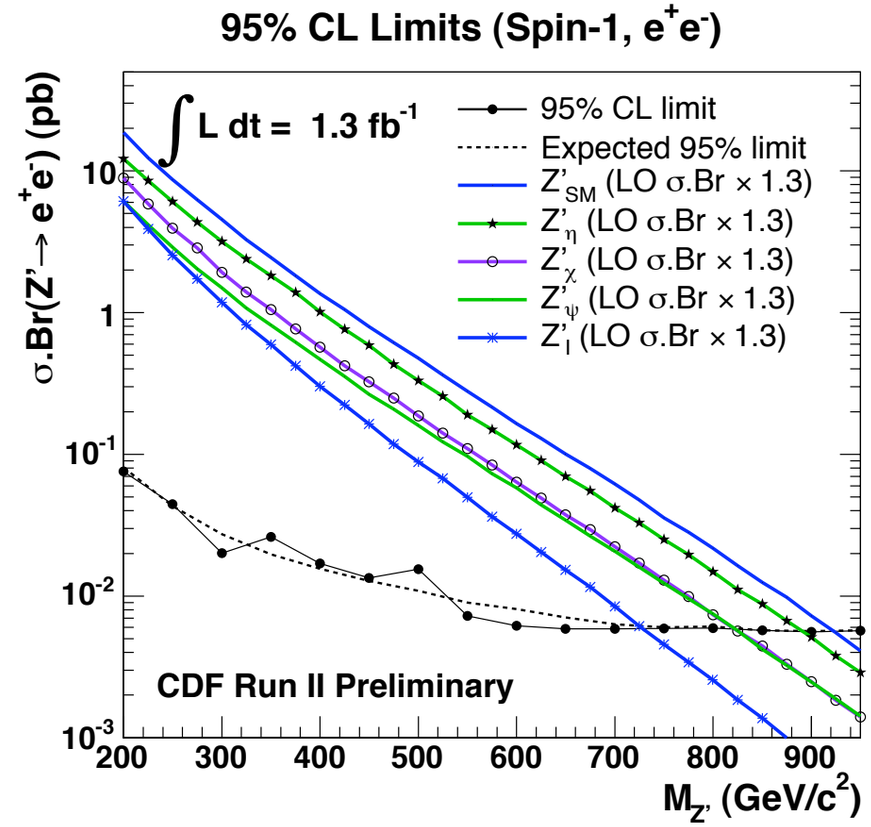
- RS Graviton Model: for m_G = 500 GeV, k/M_{Pl} = 0.1 σ = 292 fb
- Four isolated very loose electrons
- Very clean; almost no background
- Expect 0.02, see 0 events with

  M > 500 GeV

Search for Z' → ee



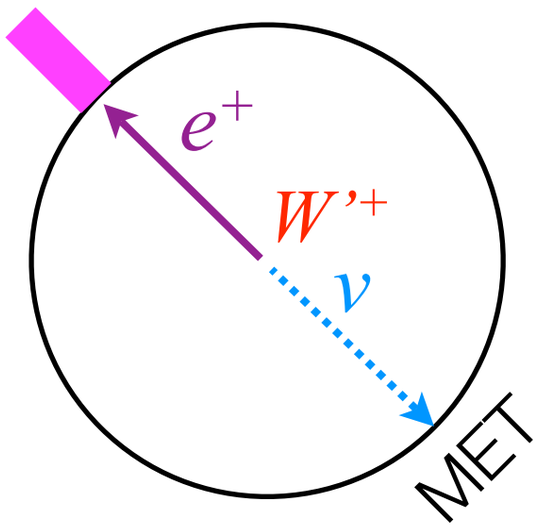


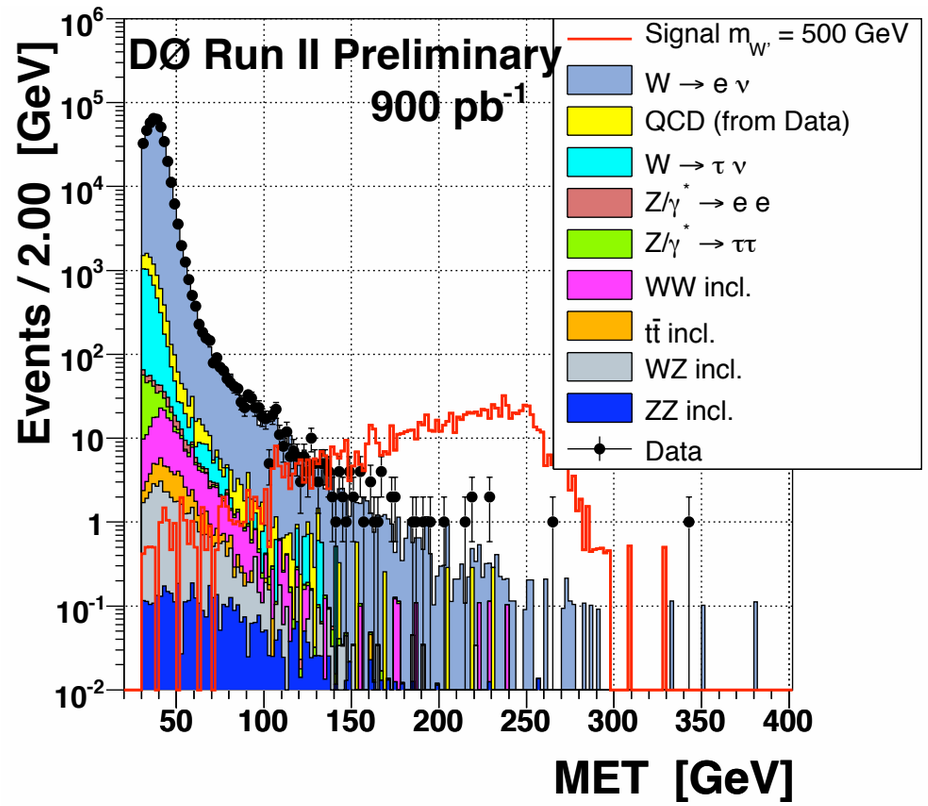


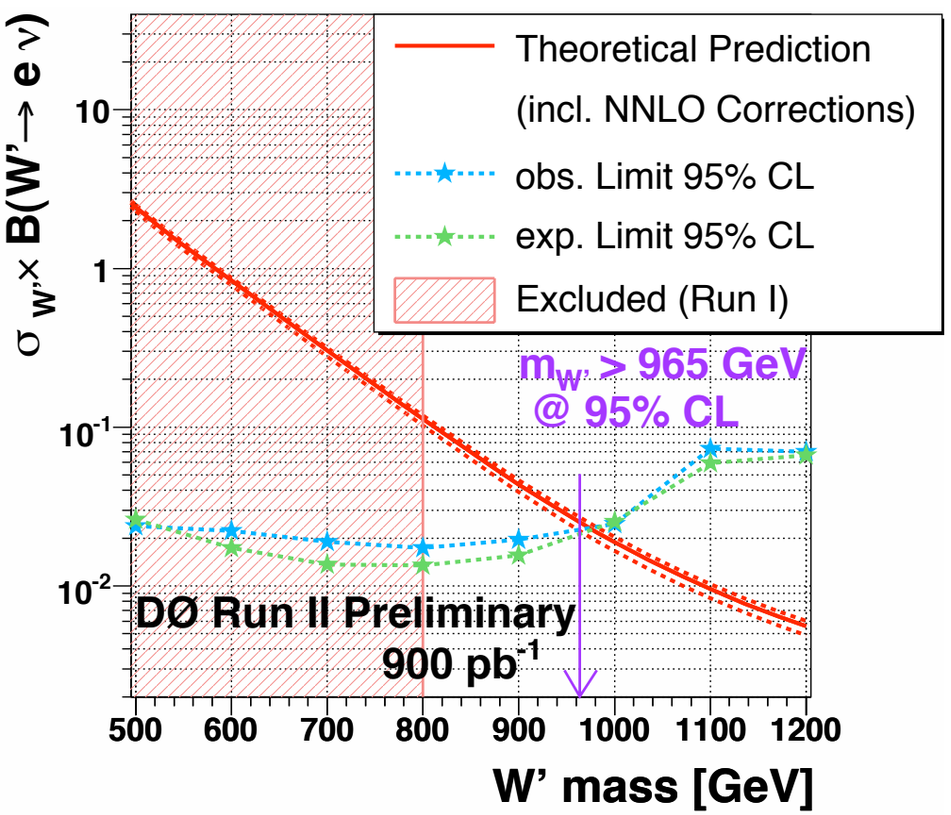
- Many SM extensions introduce additional gauge bosons
- Di-Electron Search in $|\eta| < 3.0$, 1.3 fb^{-1}
- Dominant backgrounds from Drell-Yan, QCD
- $Z'_{SM} > 923$ GeV

E_6 Z'	Z'_I	Z'_ψ	Z'_χ	Z'_η
Mass Limit (GeV)	729	822	822	891

Search for W' → eν

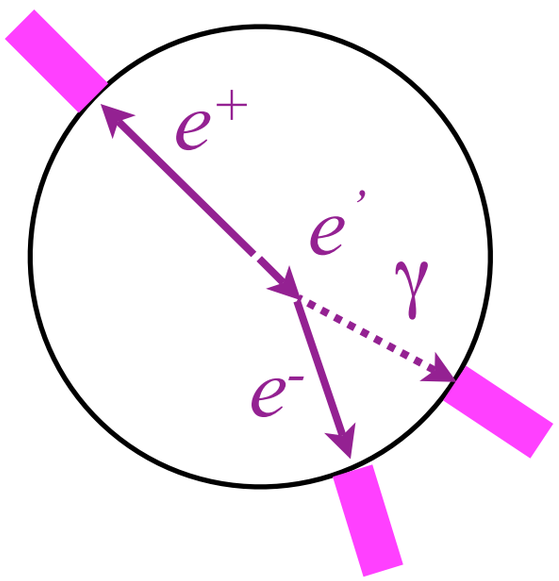


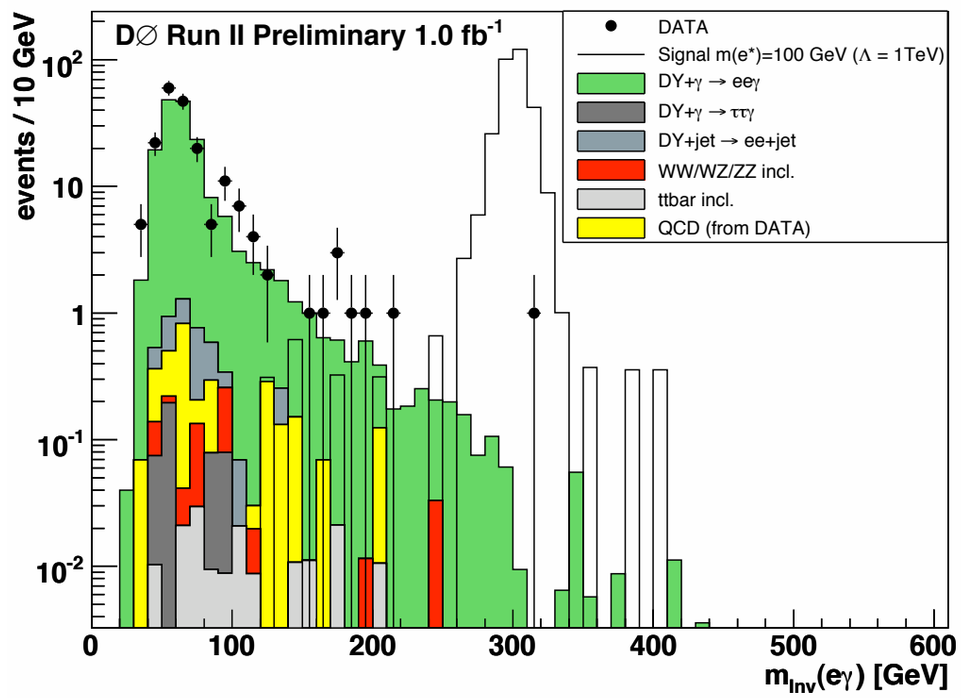


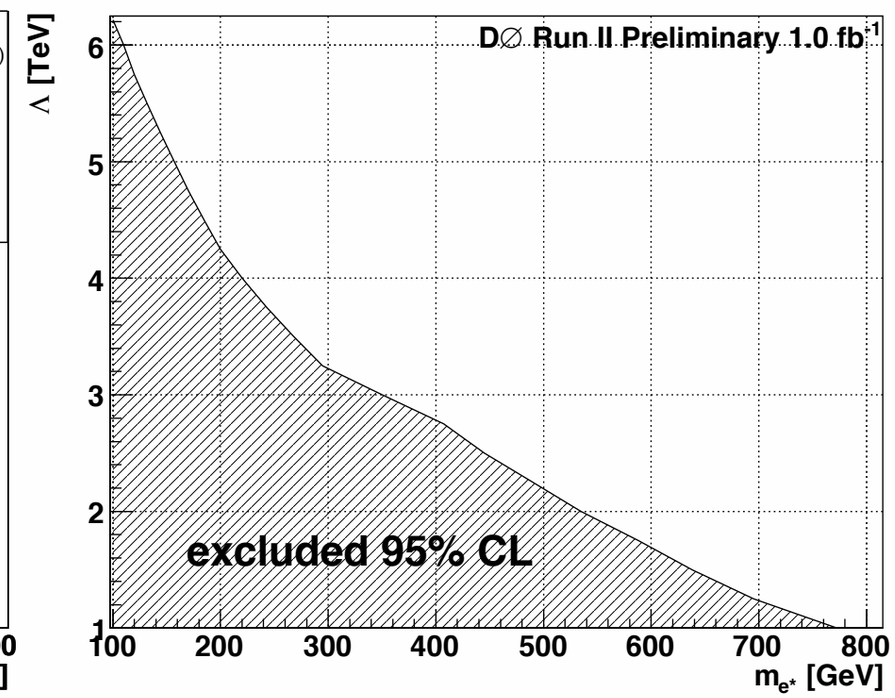


- Signature: >30 GeV e^+, $0.7 < E_T/MET < 1.3$
- Main background is SM W
- Assuming SM Couplings to fermions, exclude $m_{W'} < 965$ GeV (95%CL)

Search for Excited Electrons in eeγ

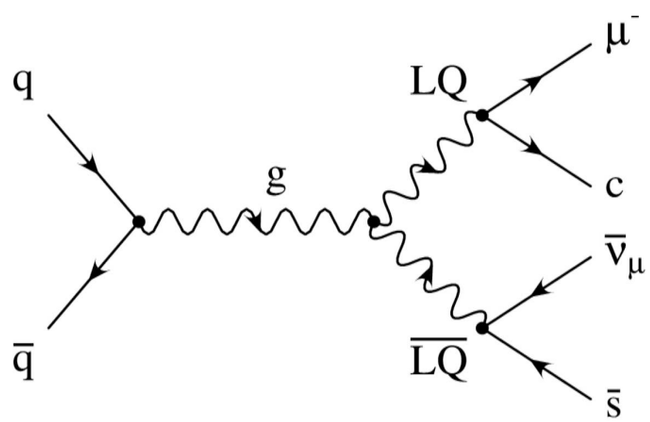


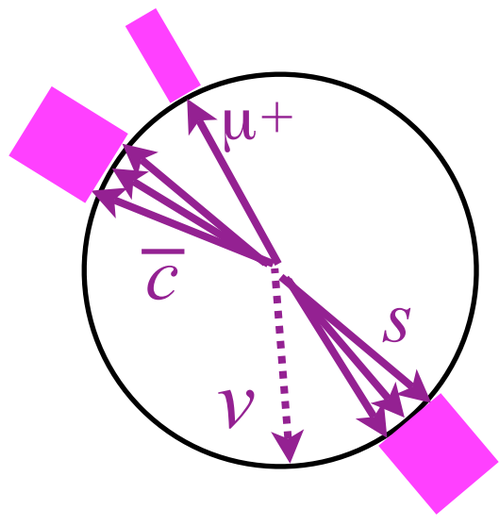


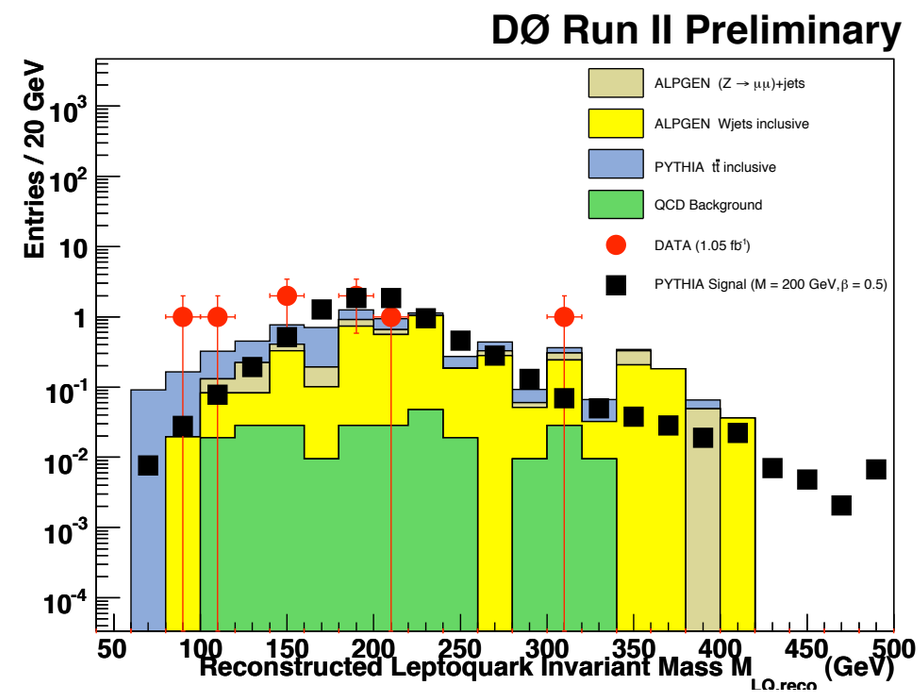


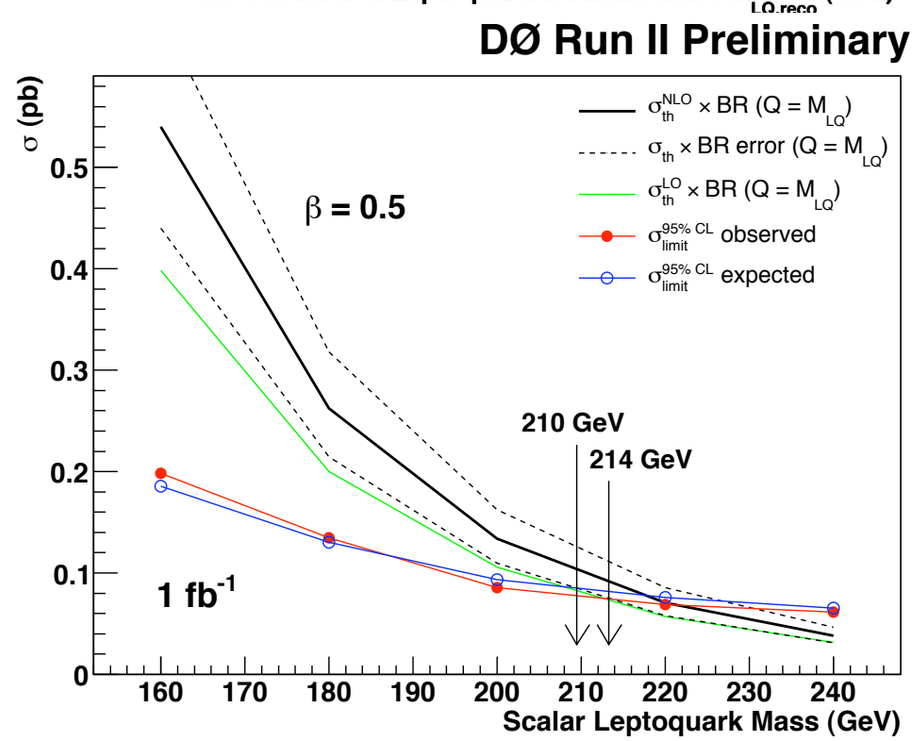
- Possible sign of compositeness
- Produced in contact interactions pp→ee'→eeγ
- Sets limit $m_{e'}$ > 756 GeV (95% CL) for compositeness scale Λ = 1 TeV

Search for second-generation leptoquarks μνqq



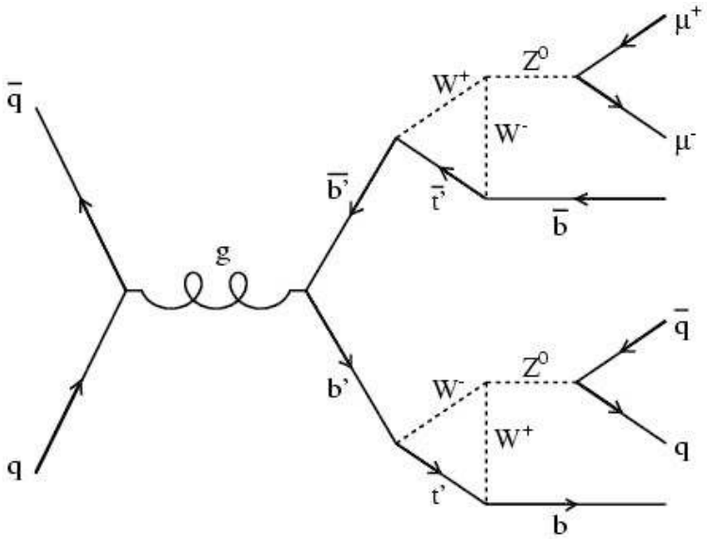


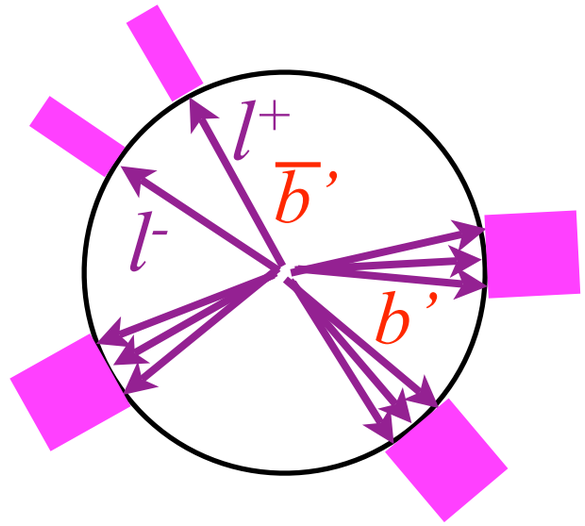


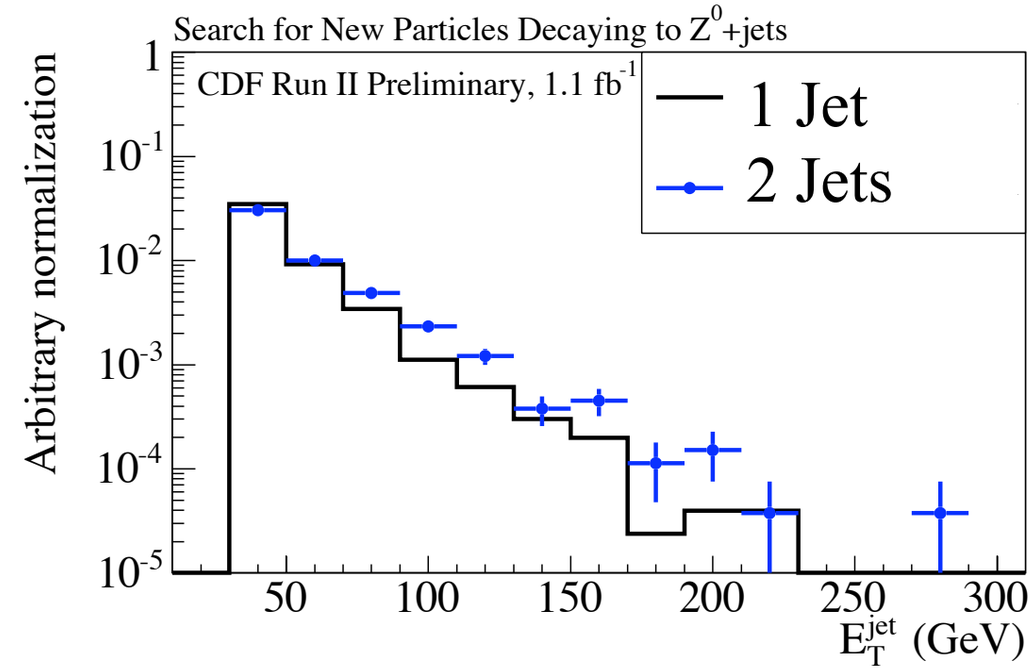


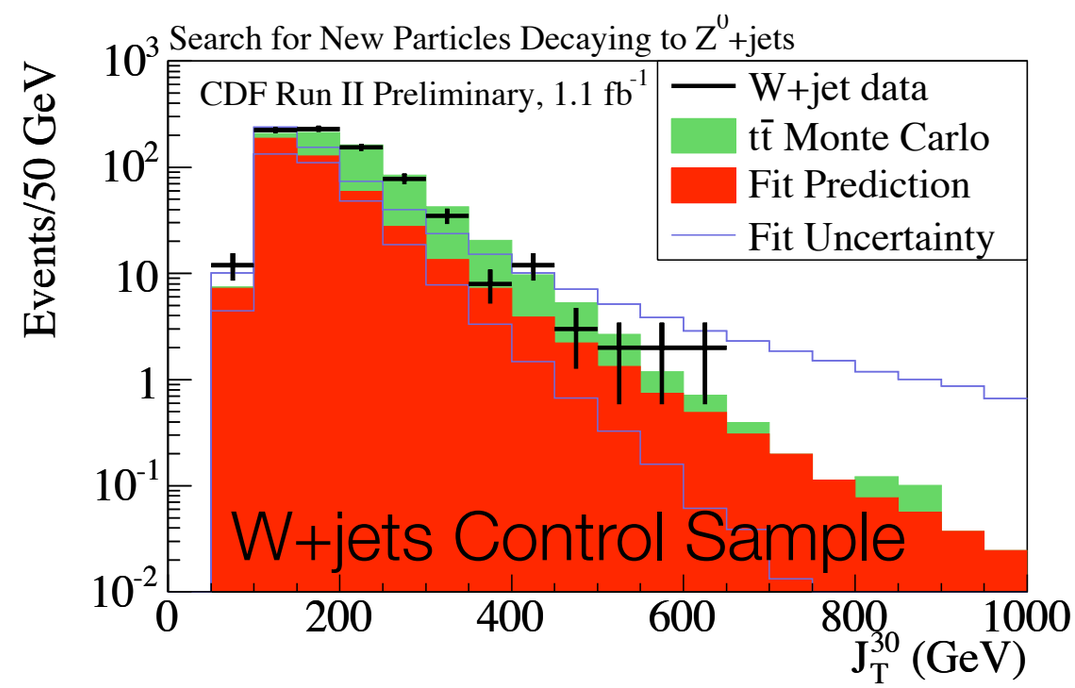
- Signature: μ+ 2 jets + MET
- Normalizes W+jets to data before LQ selection
- Sets limit m_{LQ} > 214 GeV (95% CL) for β= 0.5

Search for b' in Z+Jets



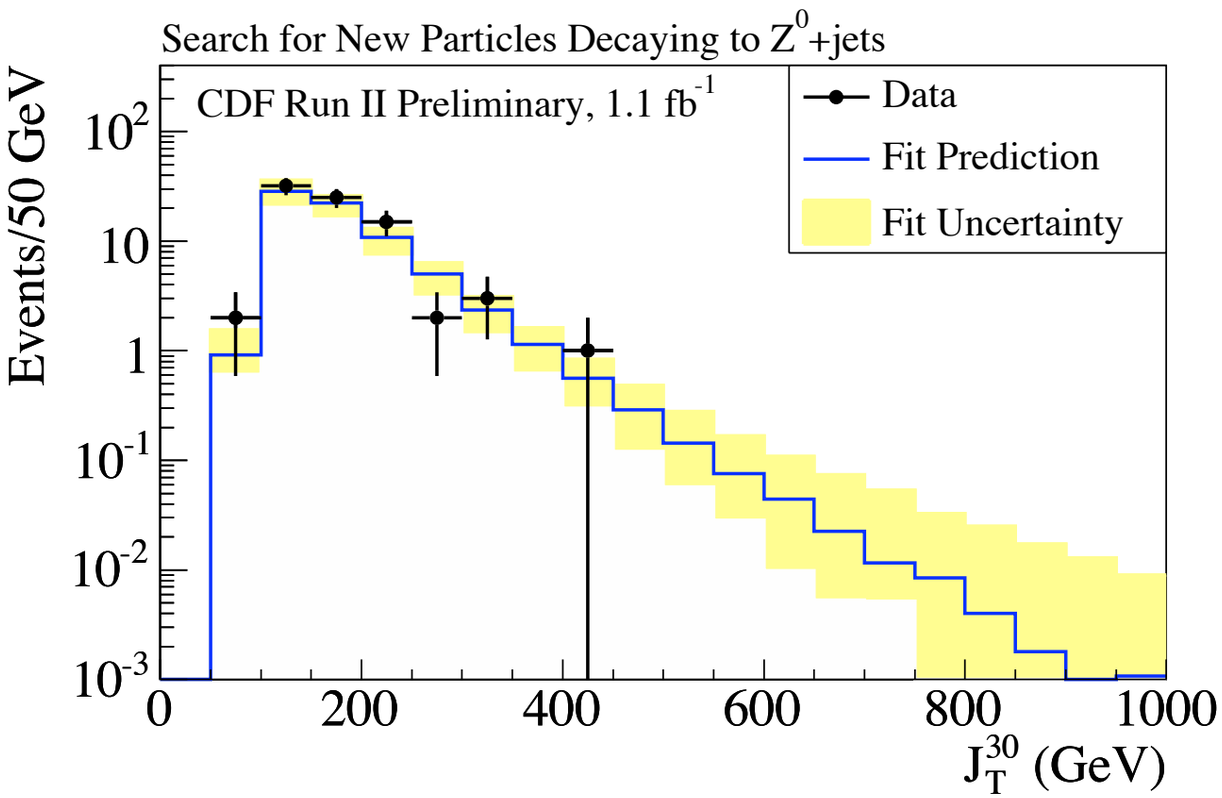


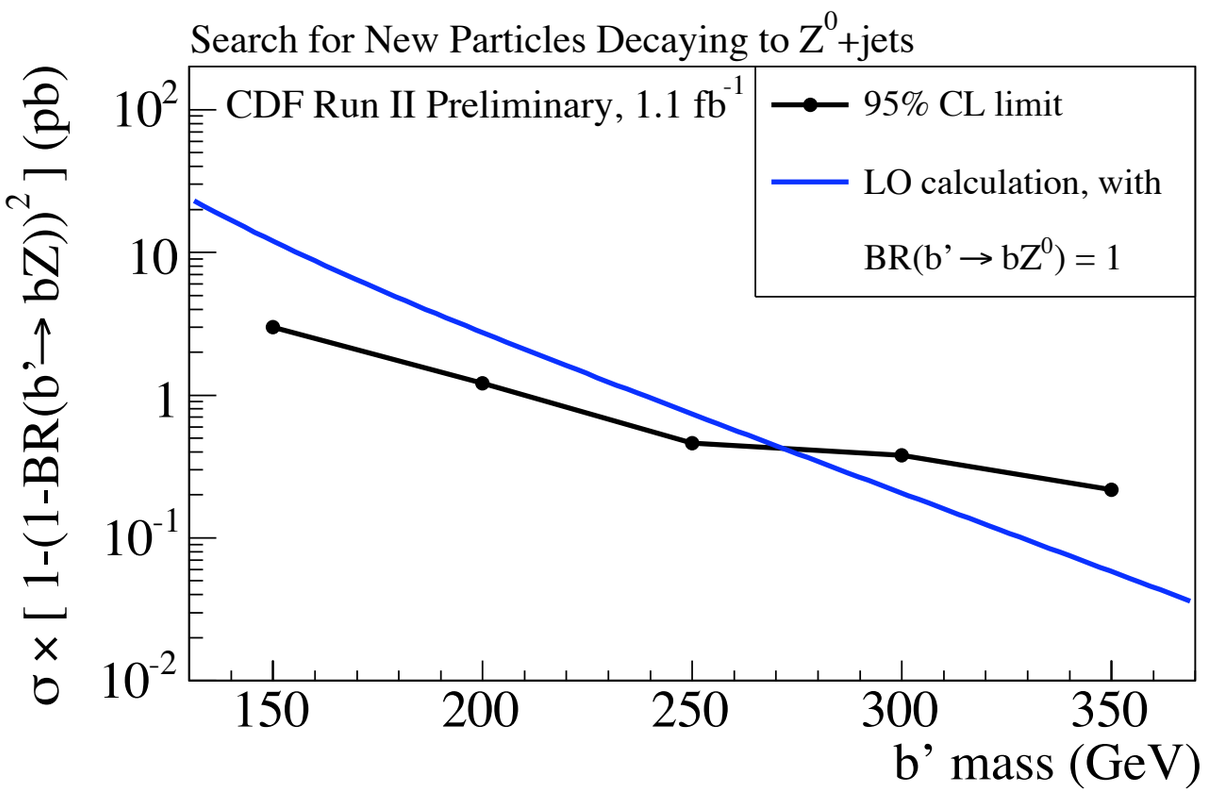




- Signature: pair-produced b' → bZ, Z → ll
- Signal region: 3 Jets with E_T > 30GeV; discrimination in sum of jet E_T (J_T)
- Fit data in n_{Jet} < 3 bins; extrapolate to $n_{Jet} \geq 3$ signal region
- Method developed with MC
- Background method verified in W+jets by measuring t-tbar cross section

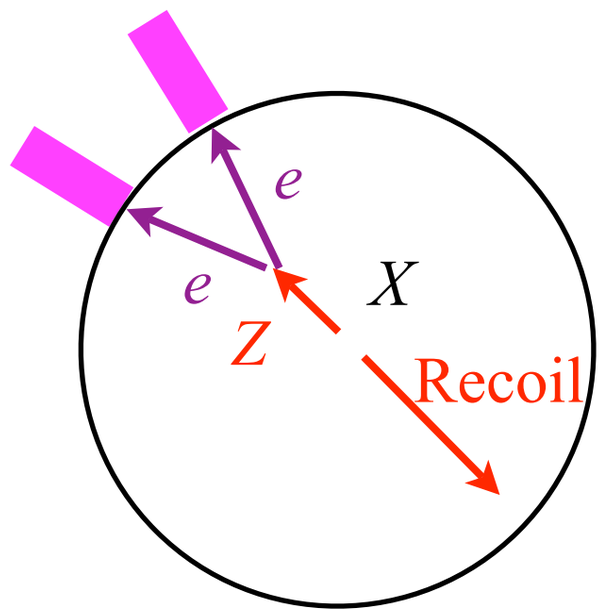
Search for b' in Z+Jets

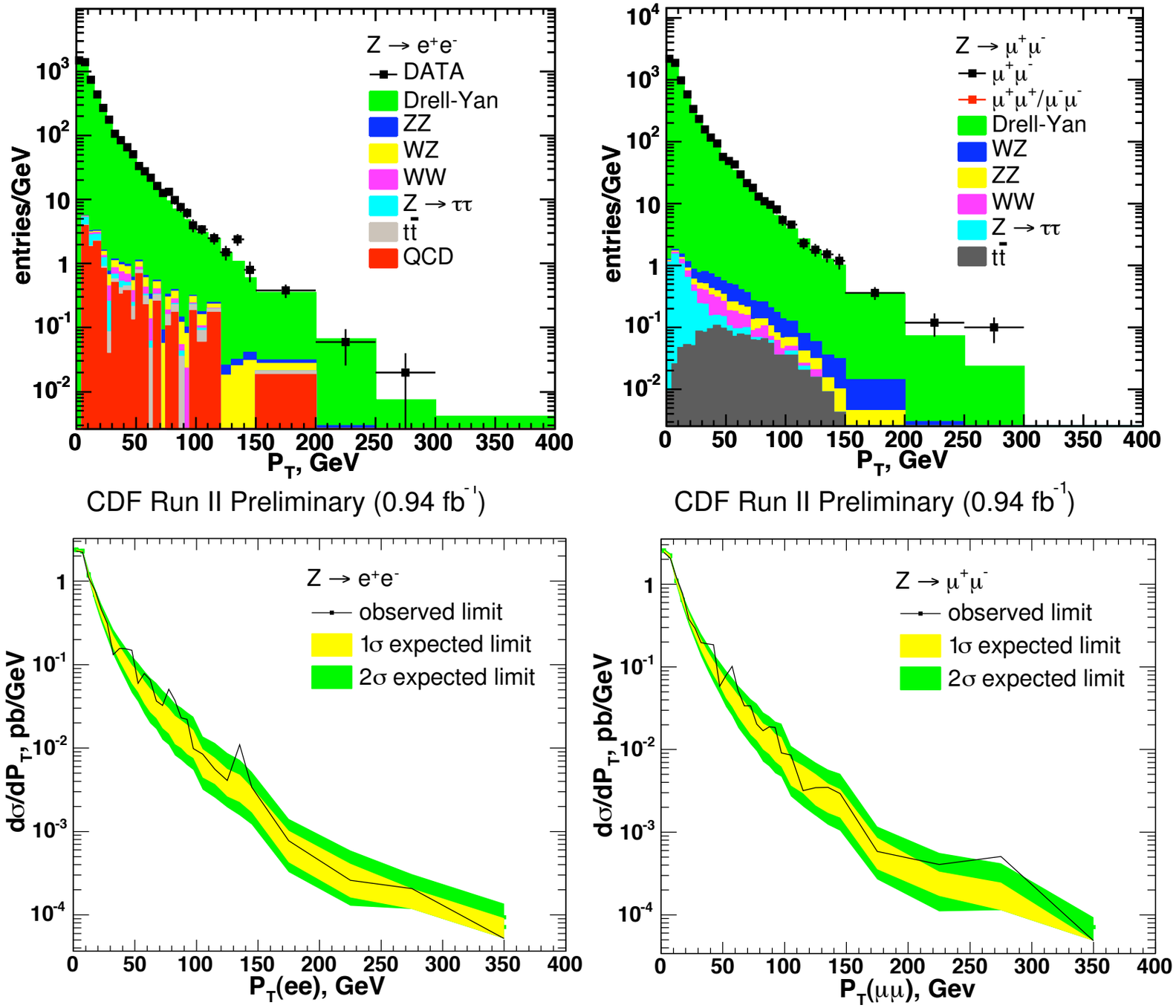




- Look in data in Z+jets ≥ 3 jet bin
- No excess observed; set limit $m_{b'} > 271$ GeV

Signature-Based Search for High-p_T Z



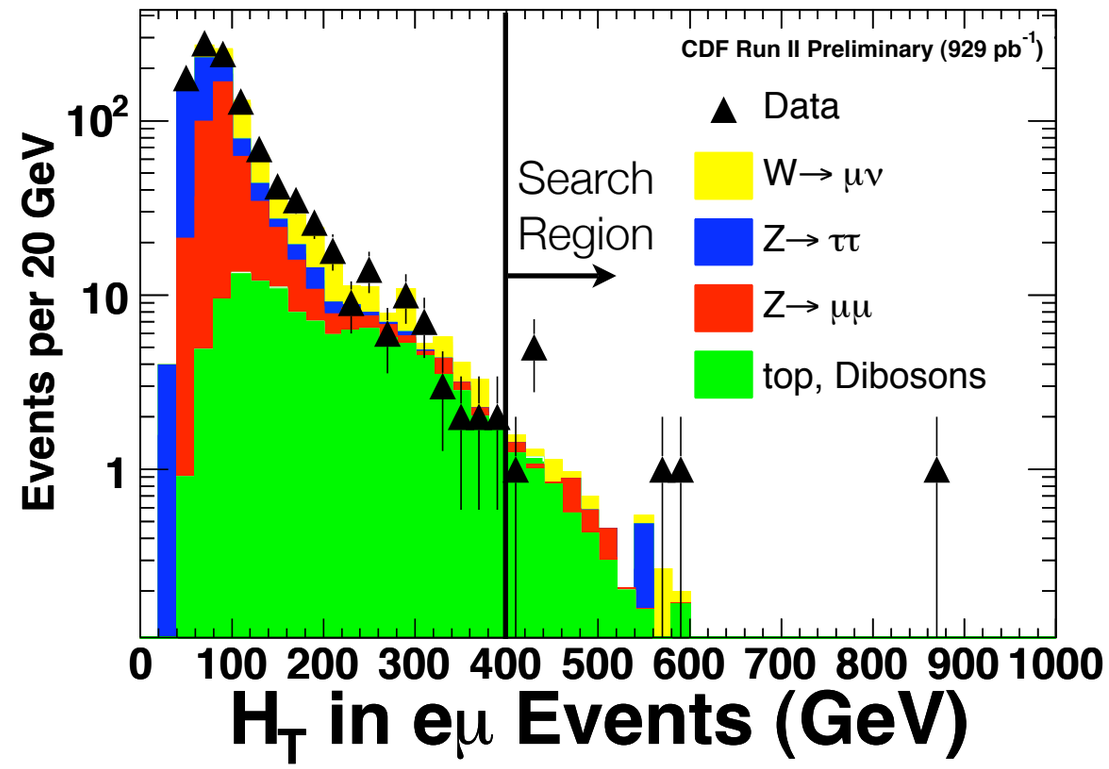


- Sensitive to heavy particles decaying to Z
- Set limits on anomalous Z production versus p_T

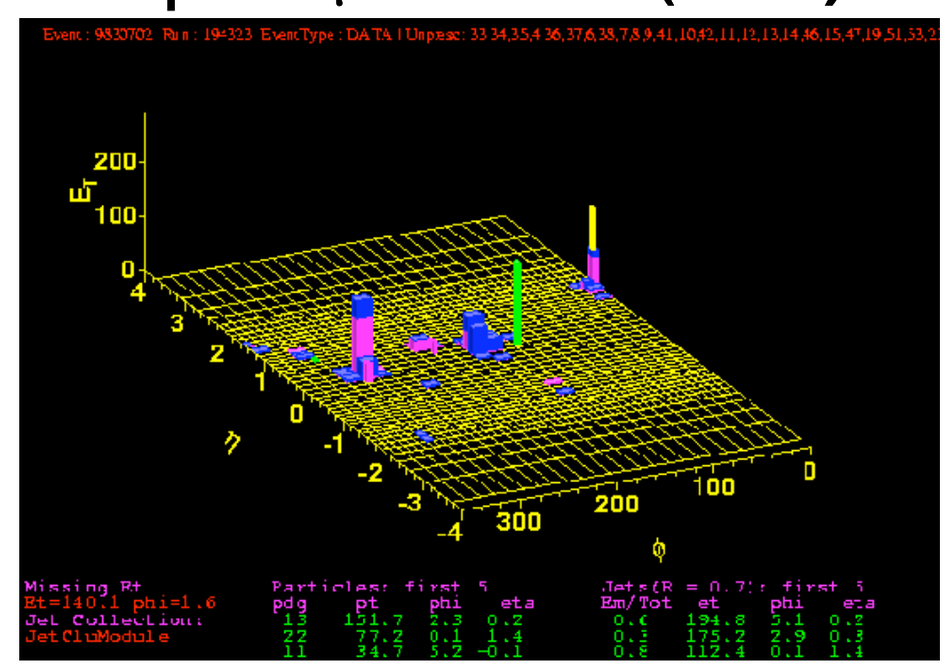
Signature-Based Search for Dilepton + X

- Search for anomalous production of ll+X, with X = γ, H_T, MET, high E_T jets, lepton
  - Results in eμ and same-sign ee,$\mu\mu$
- $H_T = \sum E_T$ + MET

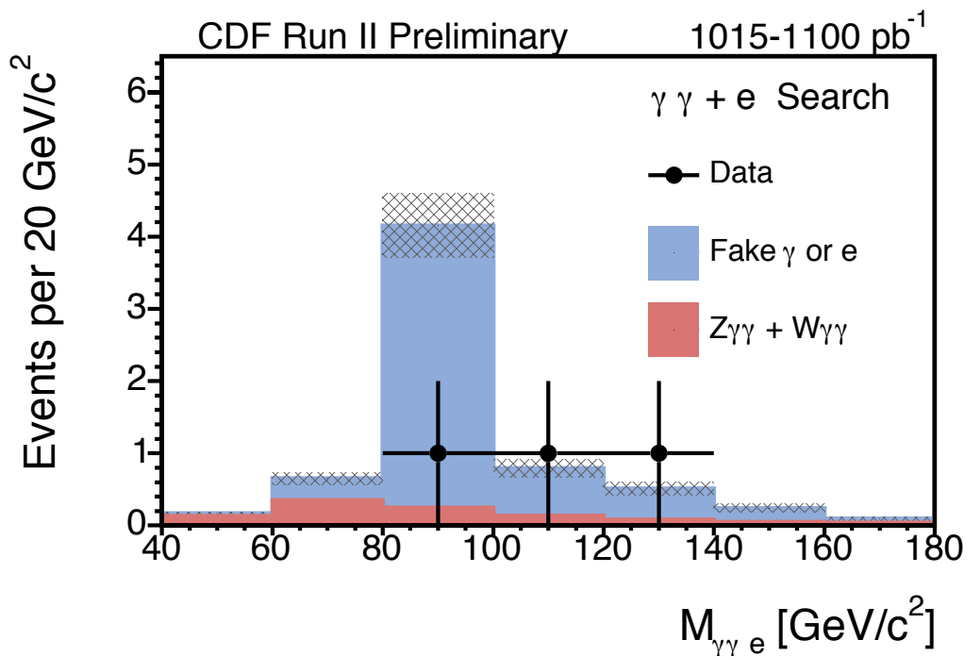
≥2 jets	eμ	Same sign ee/$\mu\mu$
SM	2.9±1.5	1.5±0.8
Data	2	0

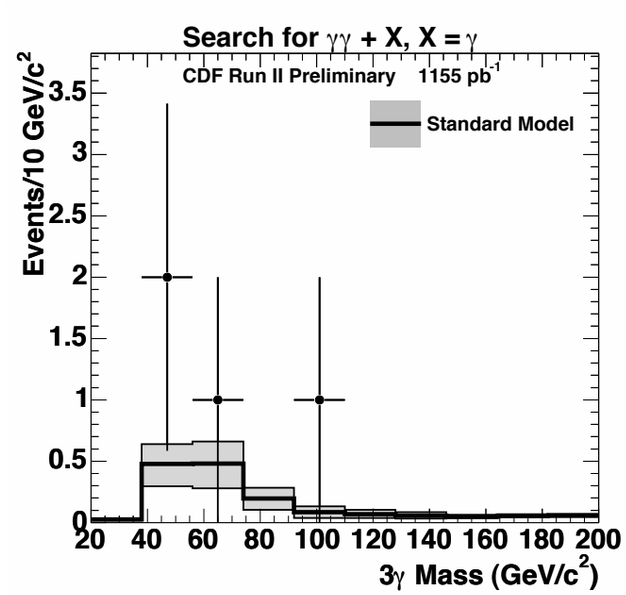


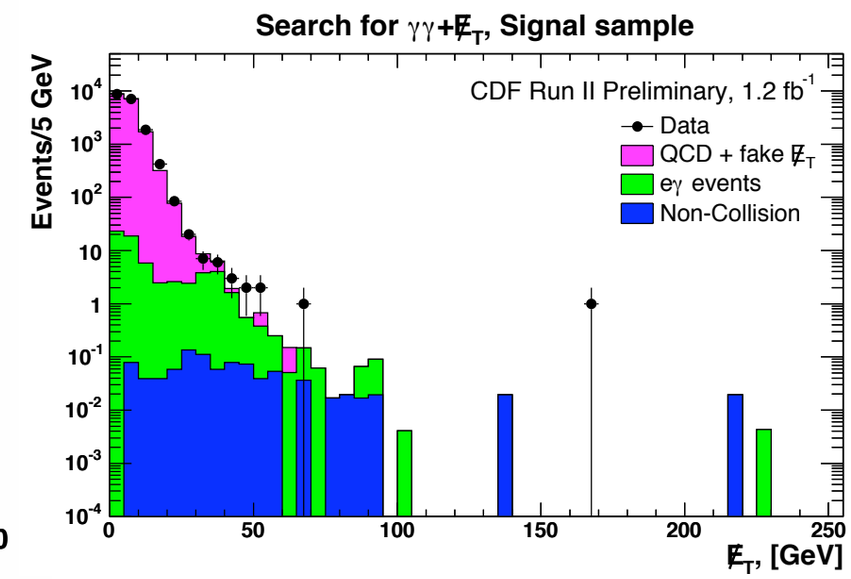
- Applied to BPT heavy quark model, hep-ph 0206116
  - $\sigma < 2.1\times\sigma_Q$ (90%CL) σ_Q=0.289pb, m_Q=300GeV
- One event has H_T=864 GeV; consistent with top dilepton + jets
  - e μ j j j b MET

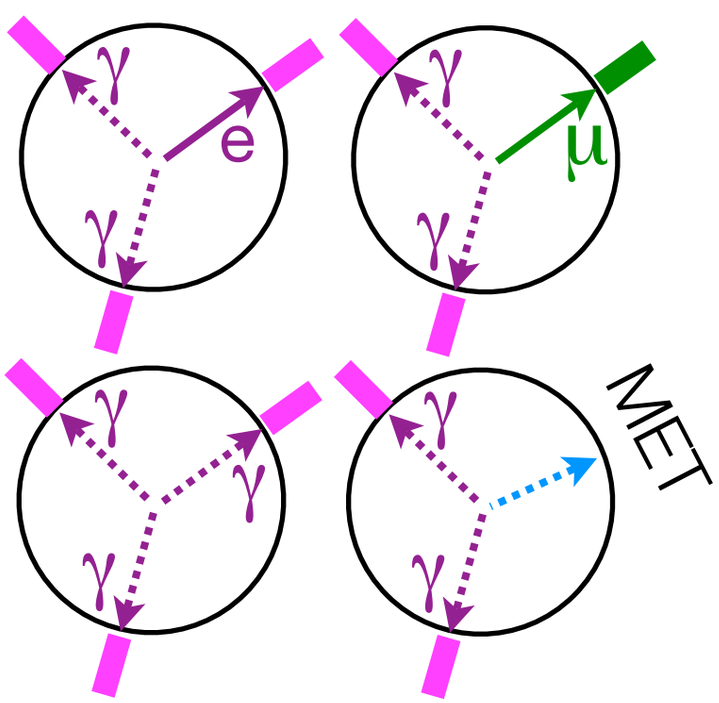


Signature-Based Search for γγ+e/μ/γ/MET





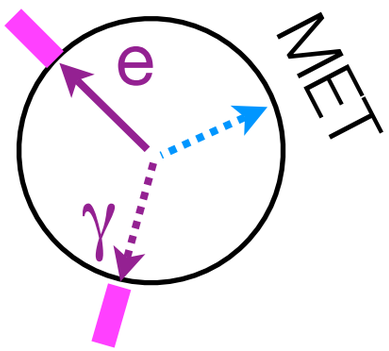


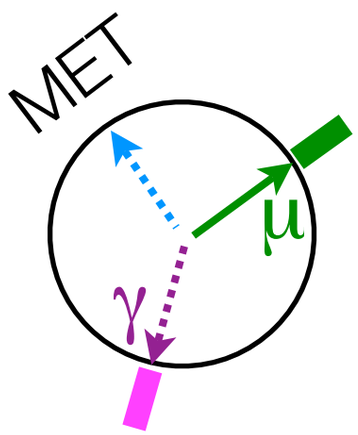


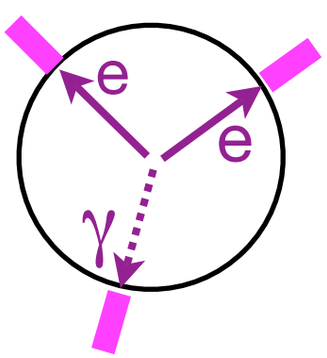
- Motivated by Run I ee+γγ+MET event
- No significant excess seen
- No ee+γγ events seen

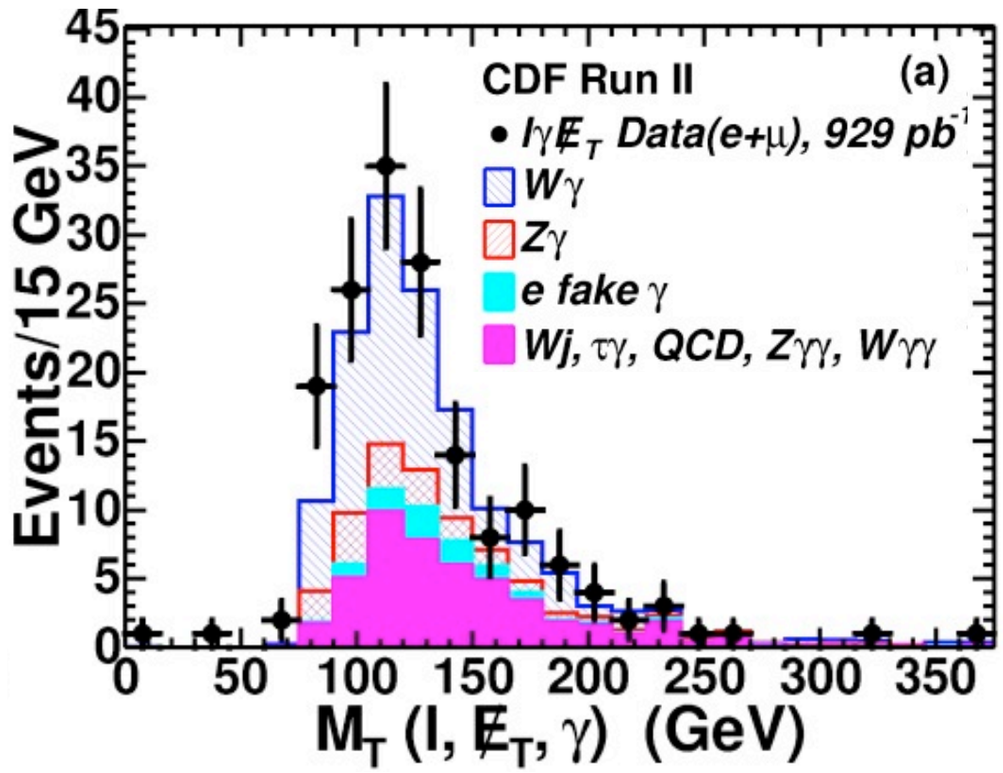
	γγe	γγμ	γγγ	γγ+MET MET>75
SM	6.8±0.8	0.8±0.1	2.2±0.7	0.24±0.22
Data	3	0	4	1

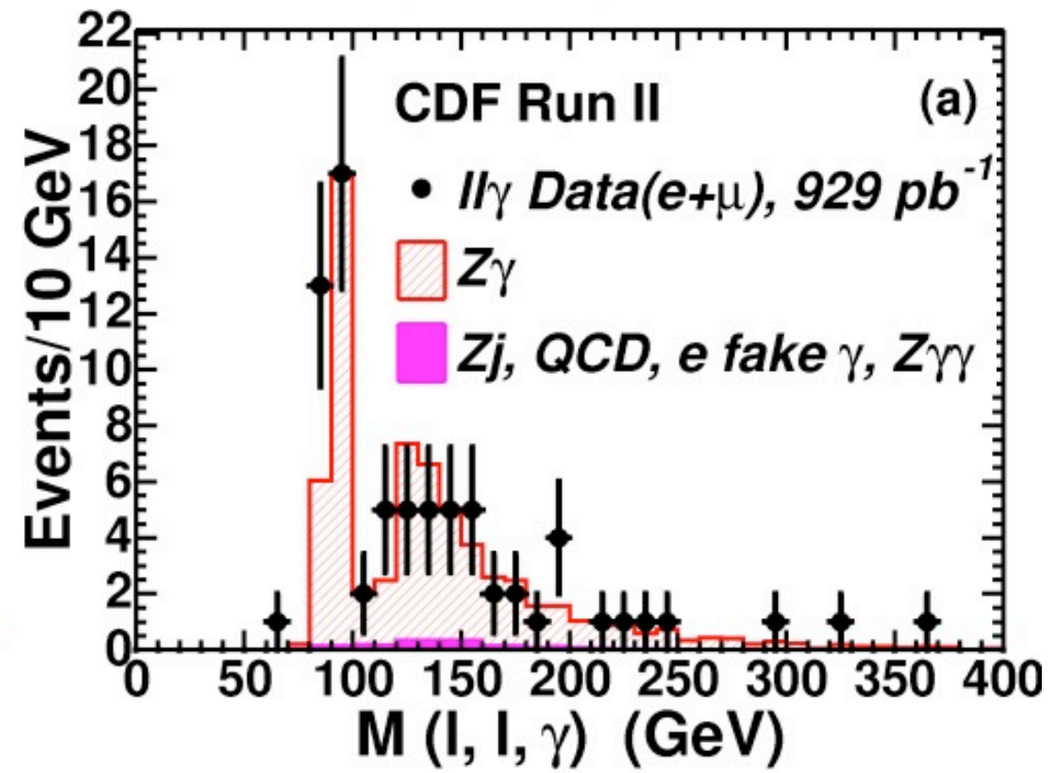
Signature-Based Search for lγMET and llγ









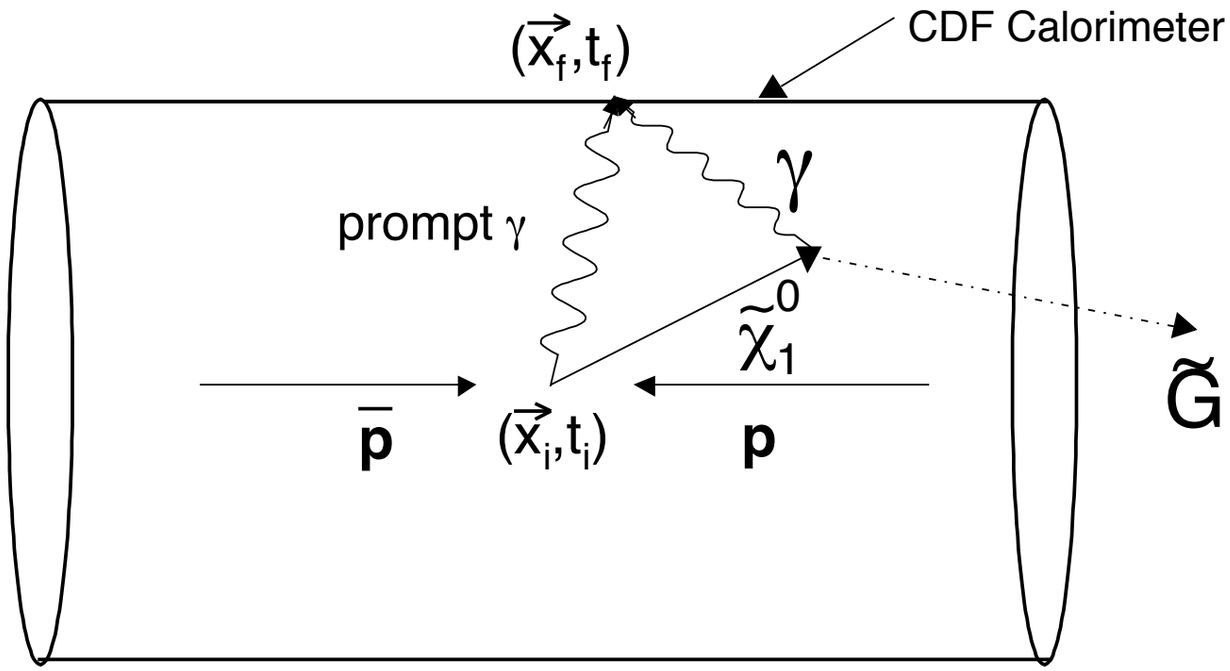


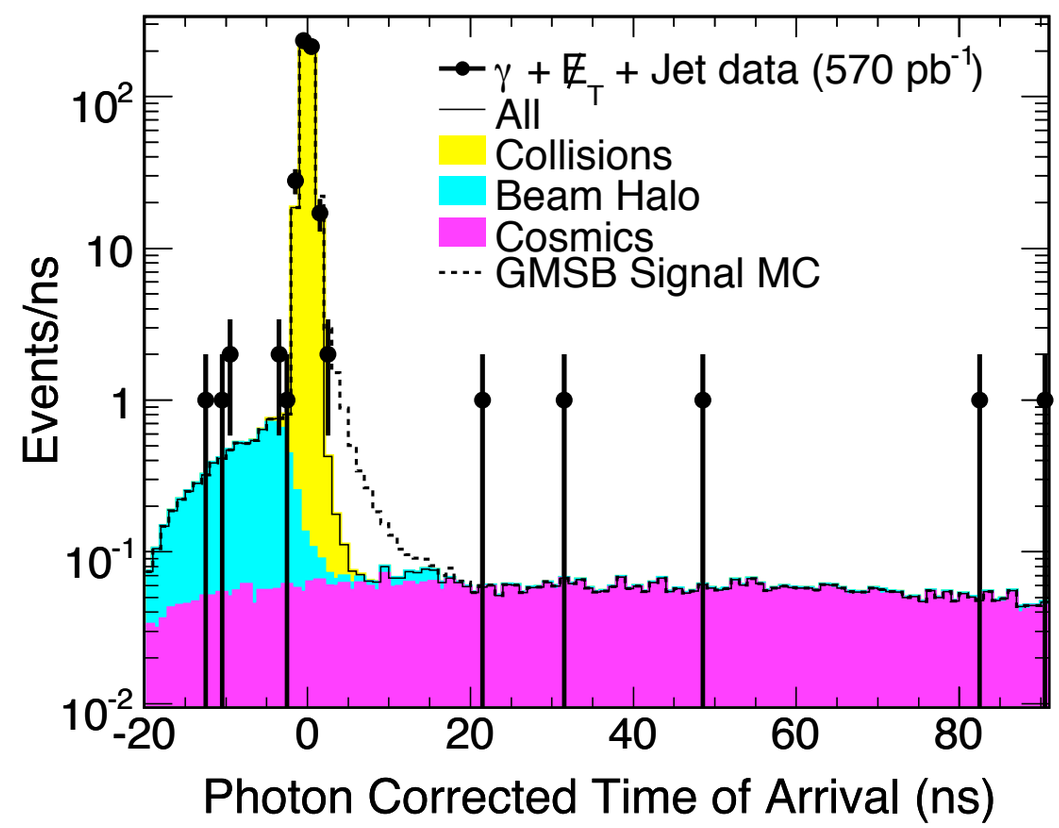
- Searches for lγMET and llγ
- Backgrounds from Wγ,Zγ
- No significant excess

	eγ+MET	μγ+MET	lγ+MET
SM	95±8	56±7	151±13
Data	96	67	163

	eeγ	μμγ	llγ
SM	39±5	26±3	65±8
Data	53	21	74

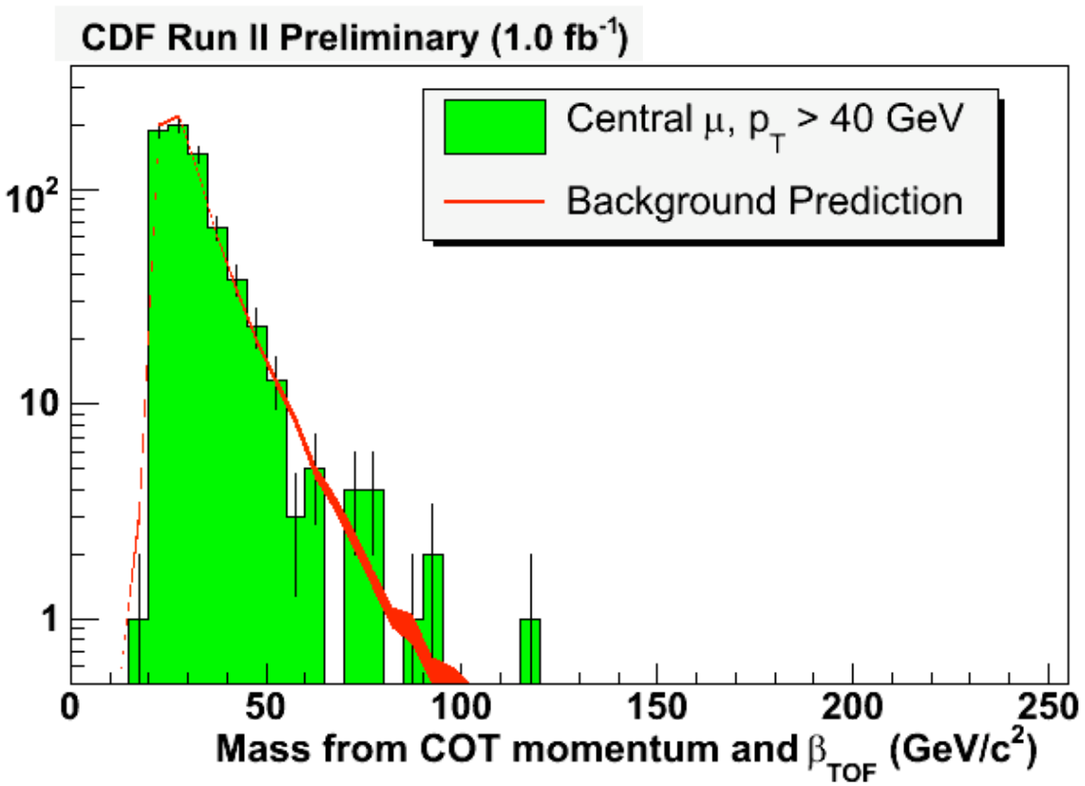
Search for Delayed Photons

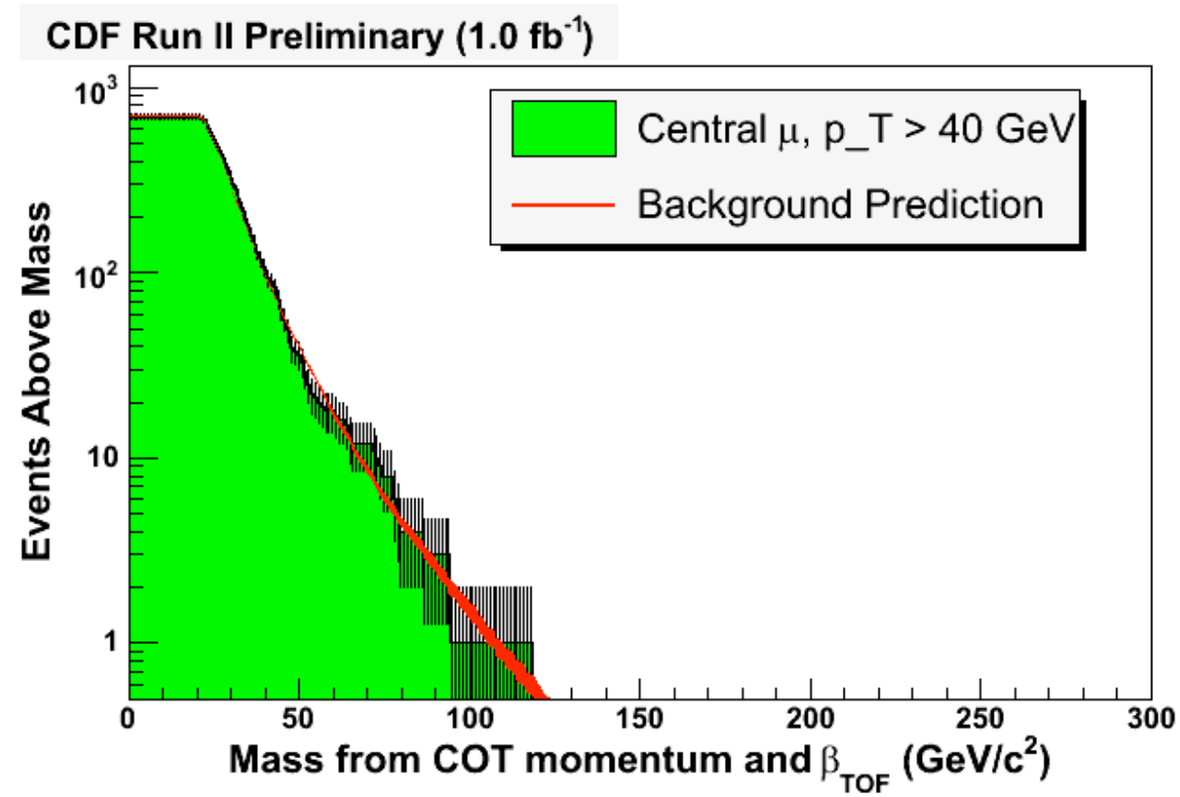




- Some models predict long-lived particles
  - Conventional searches assume prompt decays
- Use EM Timing system (installed mid Run-II)
- Signal region 2 < t < 10 ns.
- Expect 1.3±0.7, Observe 2.

Search for CHAMPS



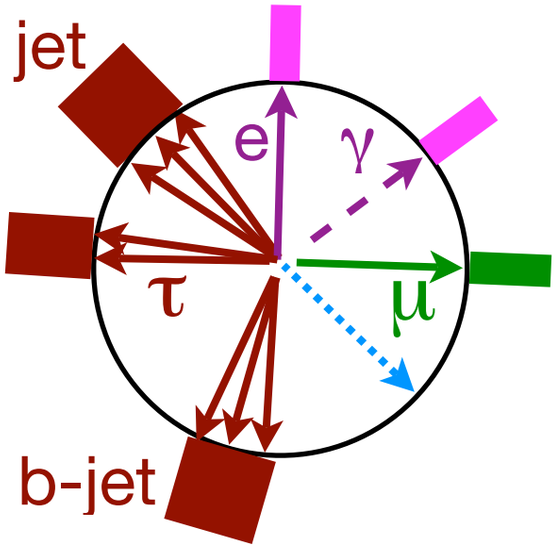


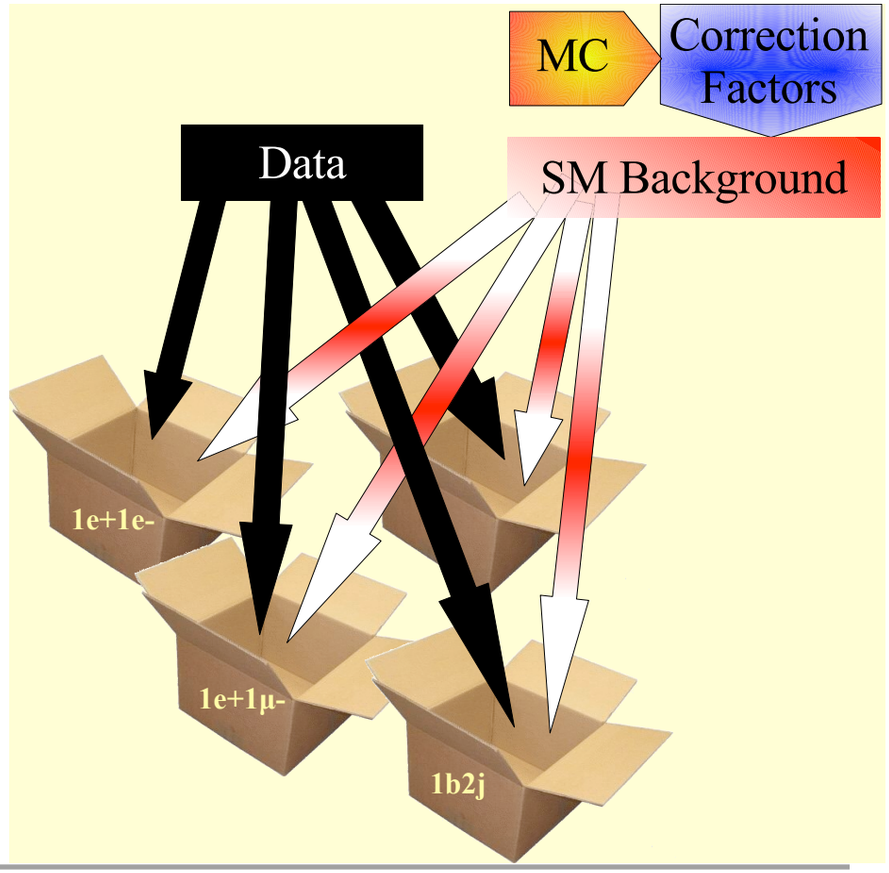
- Many extensions of SM predict Charge Massive Stable Particles
- Signature: slow, highly ionizing, penetrating (looks like muon)
- Use time-of-flight (TOF) system to measure particle velocity

- Reconstruct mass from v and p
- Model-independent limits: for CHAMP fiducial to TOF, $0.4<\beta<0.9$, $40<p_T<420$,
  - $\sigma<48$ fb if interacts with hadrons
  - $\sigma<10$ fb if no hadronic interactions

Model-Independent Algorithmic (Vista+Sleuth)

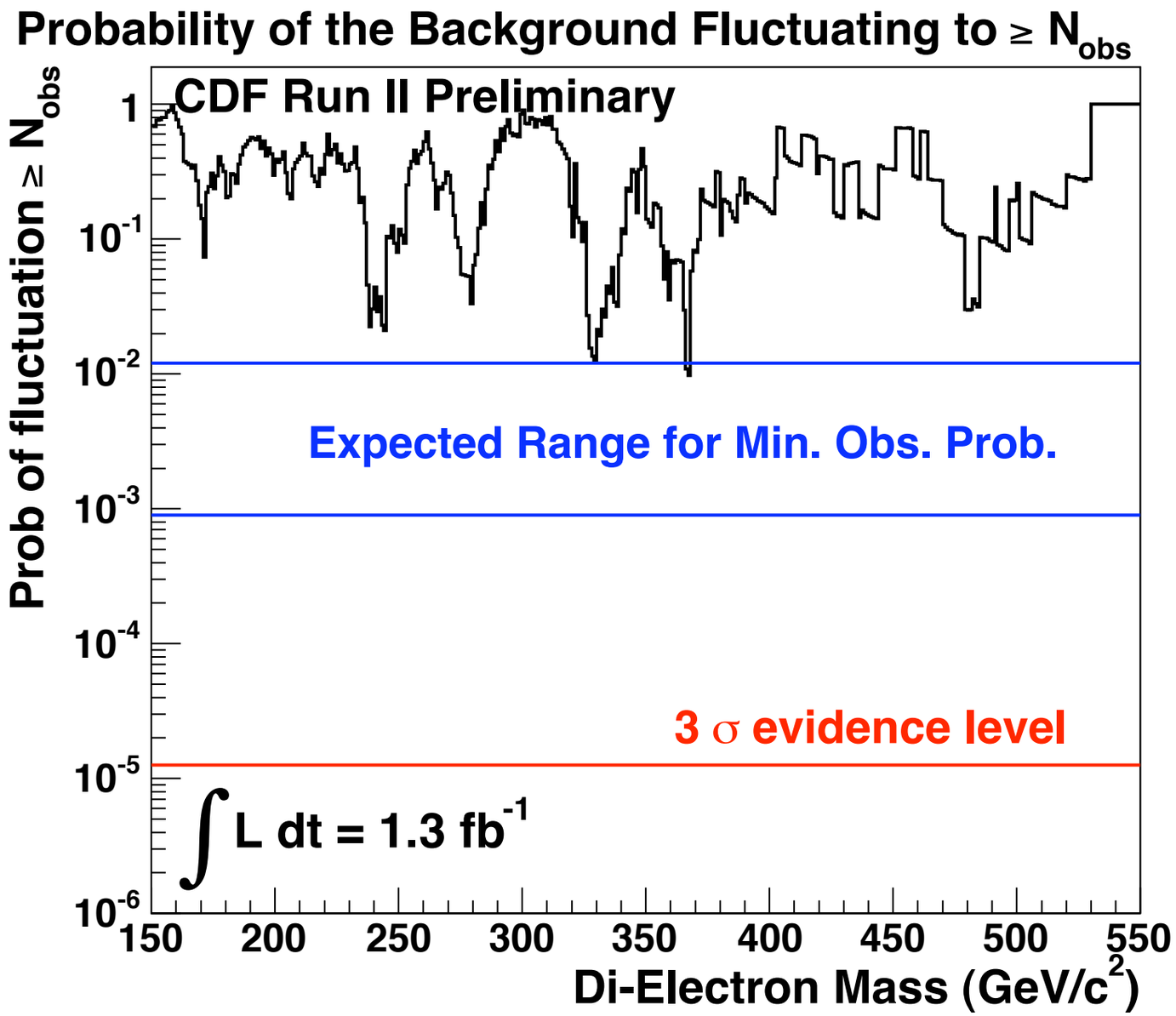
- Classify events by their object content (final state)
- Simulate standard model with Monte Carlo
- Global fit to extract correction factors (luminosity, k-factors, mis-id rates, trigger efficiencies, jet energy scale)
- Look for anomalies in distributions (bulk)
- Look for excesses in high sum E_T distributions
  - Assumes NP will be at high sum E_T and appear as an excess
- Order final states by how discrepant they are
  - Flag interesting states for further study
- Iterative procedure to identify and account for detector effects
- Sensitivity to new physics depends on details of final state
- Provides a safety net to avoid missing the obvious
- 1 fb^{-1} result expected soon





Outlook

- DØ and CDF are searching for many models and signatures of new physics
- No evidence of NP observed yet in Run II
- Both experiments have now recorded 2 fb^{-1}
  - Should soon have results with ~double the data
- Most of expected Run II data still to be collected and analyzed
  - Surprises could be just around the corner

Back-Up

Search for Z' in ee