The Search for New Physics in High-P_T Di-Electron Events at CDF

IoP HEPP Group Conference 2006

Talk Outline:

- Analysis Goals
- The CDF Detector
- Signature and Backgrounds
- Results
- Outlook

The Drell-Yan Process

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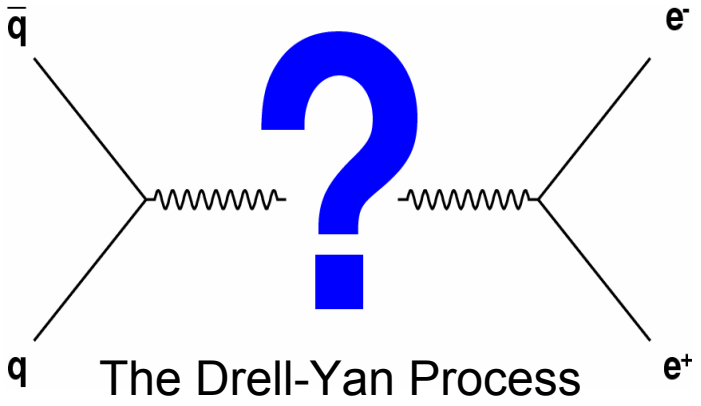
Analysis Introduction

- Analysis Goal:
  - to search for new physics beyond the Standard Model
- Achieve this by:



The Drell-Yan Process

  - measuring the Drell-Yan mass spectrum from $p\bar{p} \rightarrow e^+e^-$ events at $\sqrt{s} = 1.96\,\mathrm{TeV}$
  - interpreting the measured mass spectrum to search for and place limits on new physics processes in the 150 - 950 GeV/c^2 range
  - data sample: 2002-2005 → 820pb^{-1}

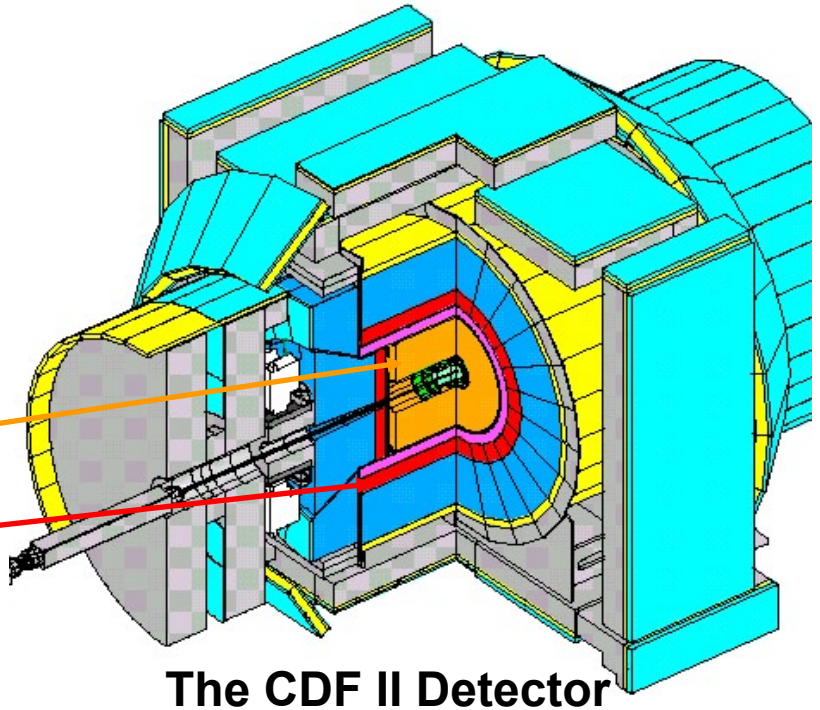
→ double the data of previous searches!

Why the Di-Electron Channel?

- Di-Electron channel relatively clean, low backgrounds
  - ideal channel to search for the small signals of a new physics process
- Di-Electron channel is sensitive to a wealth of new physics processes
  - Extra-dimensional gravity models, GUT theories, SUSY, Technicolor and yes even string theory
- New mass regime, produce e^+e^- pairs well above LEP II range

The CDF Detector

- situated at the Tevatron, observing $p\bar{p}$ collisions at $\sqrt{s}$=1.96TeV
- principally use the central outer tracker and EM calorimeters
- calorimeter resolution:



The CDF II Detector

$$\sim \Delta M_{ee}/M_{ee} \approx 3\%$$

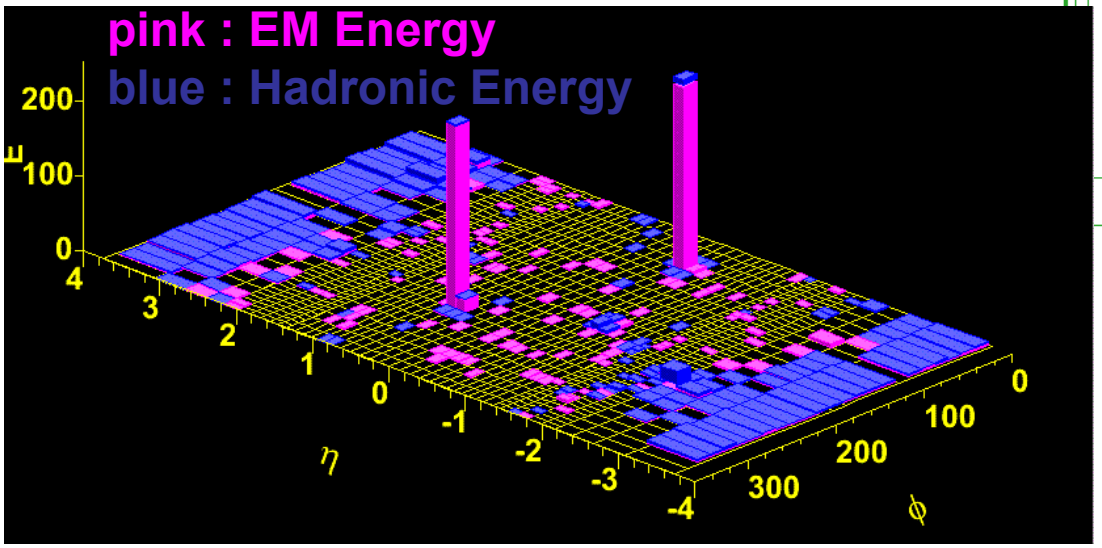
- CDF, together with D0, observes the highest energy collisions in the world, currently offers the best place to search for new physics

Analysis Strategy

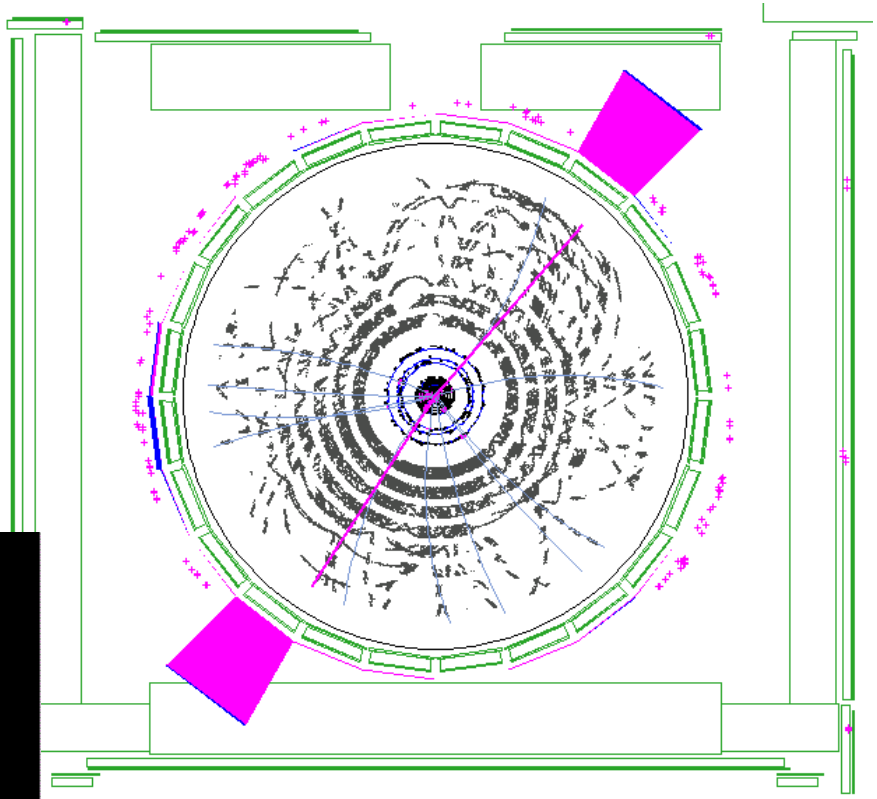
- data sample: 820pb^{-1}
- require two isolated electrons (E_T >25 GeV)
- two detector regions:
  - |η|<1.1 (central), 1.2<|η|<3.0 (plug)
  - require either central-central or central-plug
- blind analysis:
  - cuts were tuned on Monte Carlo and background samples before high mass region (>150 GeV) was looked at
  - only blind to data not previously published
- cuts were chosen to have high efficiency (>~90%) and good background rejection

A Good Electron Signature

- isolated EM calorimeter cluster with little hadronic energy
- associated track has p_T similar to cluster E_T
- profile of energy deposit consistent with test beam data



2D lego plot of energy deposits in the calorimeters towers



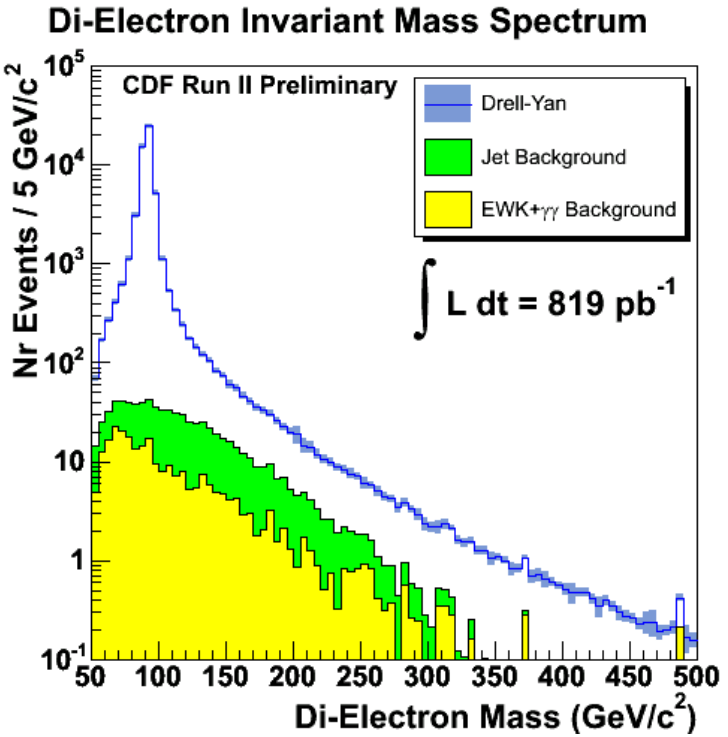
Face on view of the Central Outer Tracker

Highest mass di-electron event (M_{ee} = 491 GeV/c^2)

Backgrounds

In order of significance:

- SM Drell-Yan ($\gamma^*/Z \rightarrow e^+e^-$):
  - irreducible background
- Jet background:
  - jets faking electrons
  - very small fraction pass cuts
- Di-Photon:
  - photon converted or incident outside tracking coverage
- EWK background ($t\bar{t}, \tau^+\tau^-$, WW, WZ) :
  - genuine electrons produced through W decay

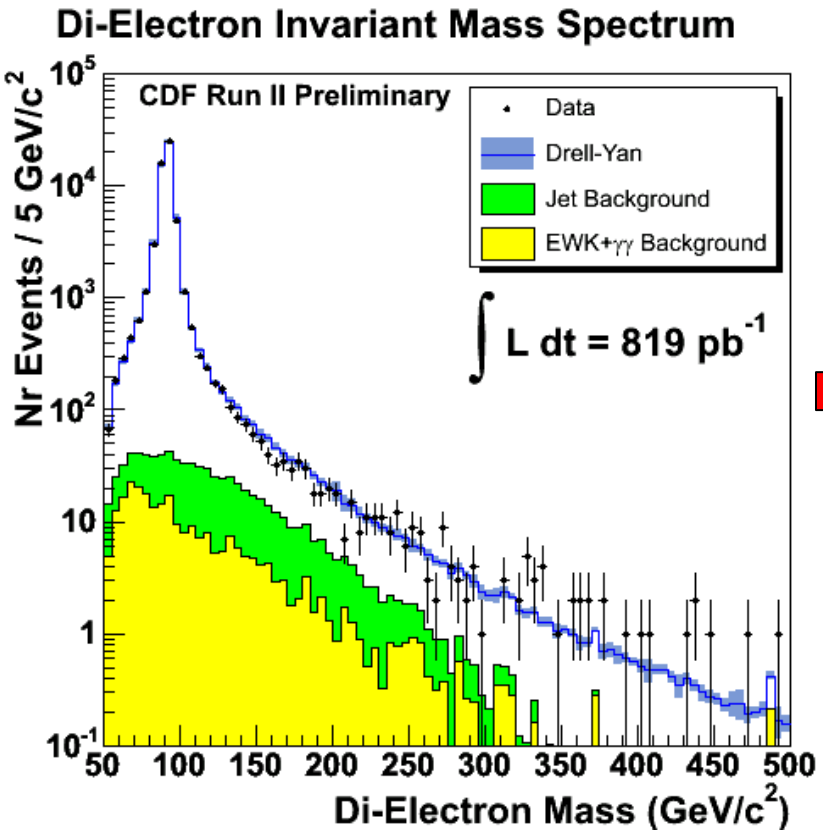


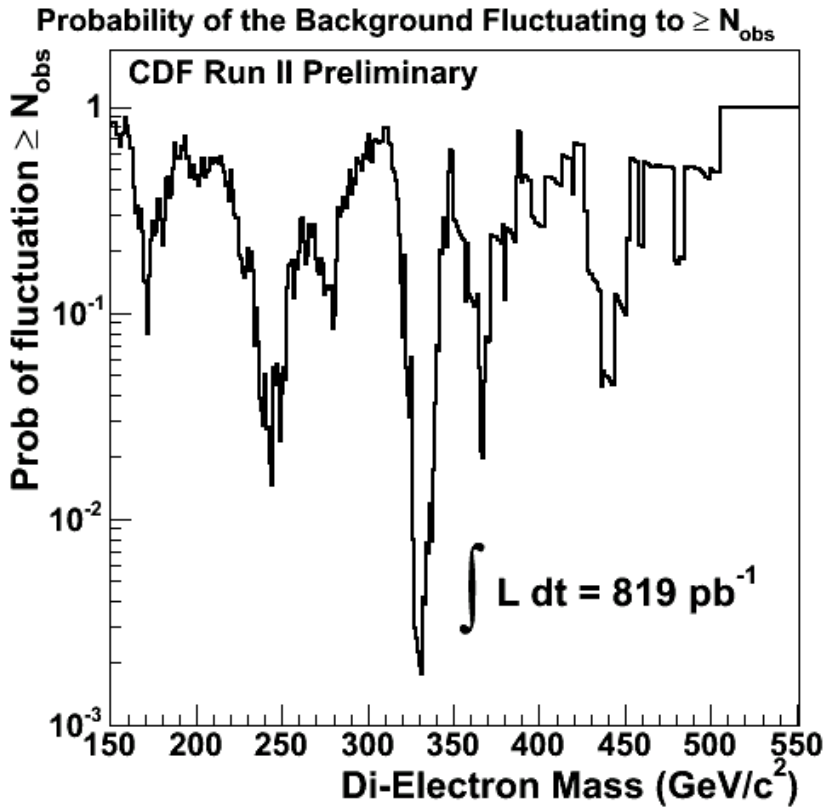
Searching For New Physics

- Search strategy:
  - Scan across the entire mass spectrum from 150GeV to 950GeV
  - At each point calculate P(bkg≥data) in a window equal to the width of a narrow* resonance in the CDF detector
  - Include systematics by smearing probability with a Gaussian
    - μ = bkg expectation
    - σ = error on bkg expectation
- model independent
  - only assumes a narrow resonance
- method and parameters chosen before looking at the data
  - statistically unbiased

*narrow = resolution of detector dominates width

Results





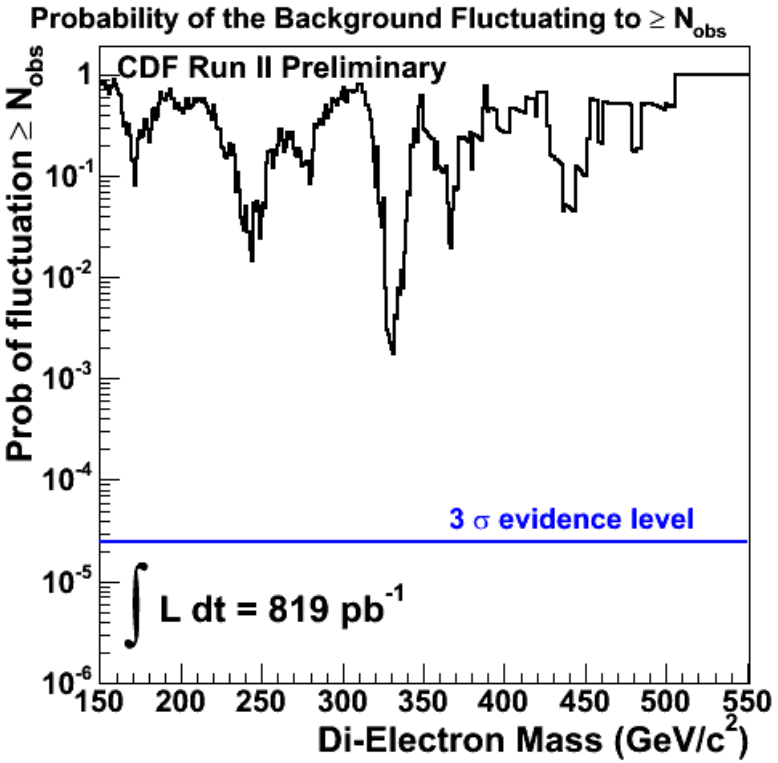
- Large possible excess at 330GeV!?
- Prob of bkg fluctuating to data level at 330: <0.2%
- Do we have evidence for new physics at 330?

Evidence for New physics?

NO!

Quantifying the Probability

- searching over a large range
  - 100s of points, correlated in a complicated way
  - throw pseudo-experiments based on background to determine how often a particular probability or less will occur
  - find that a 0.2% probability will occur somewhere ~19% of the time
  - not only is a prob<1% likely to occur but its unlikely not to occur



minimum probability:

- expected : 0.3%
- 68.3% range: 0.06%→1.0%

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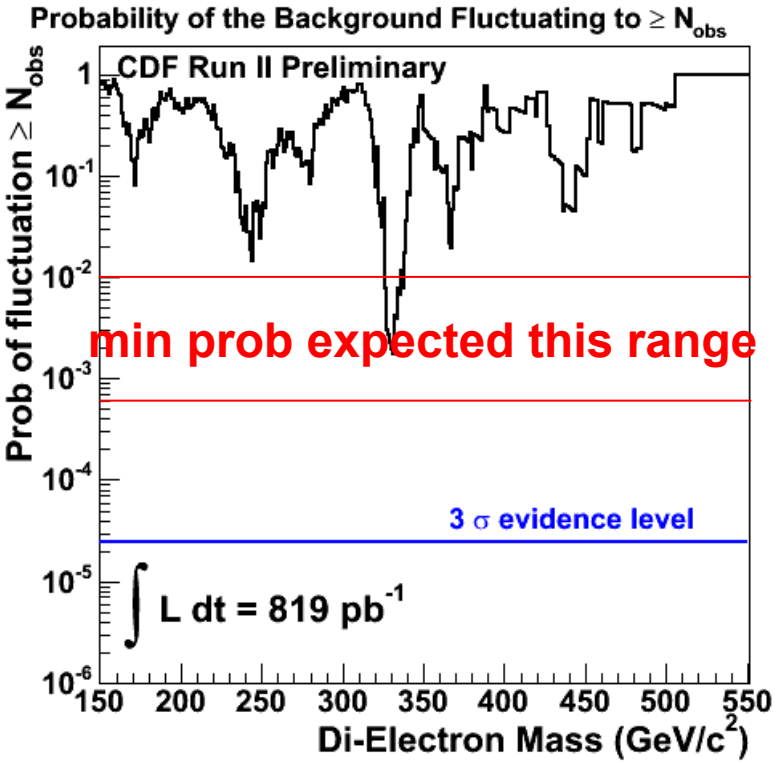

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- expected : 0.3%
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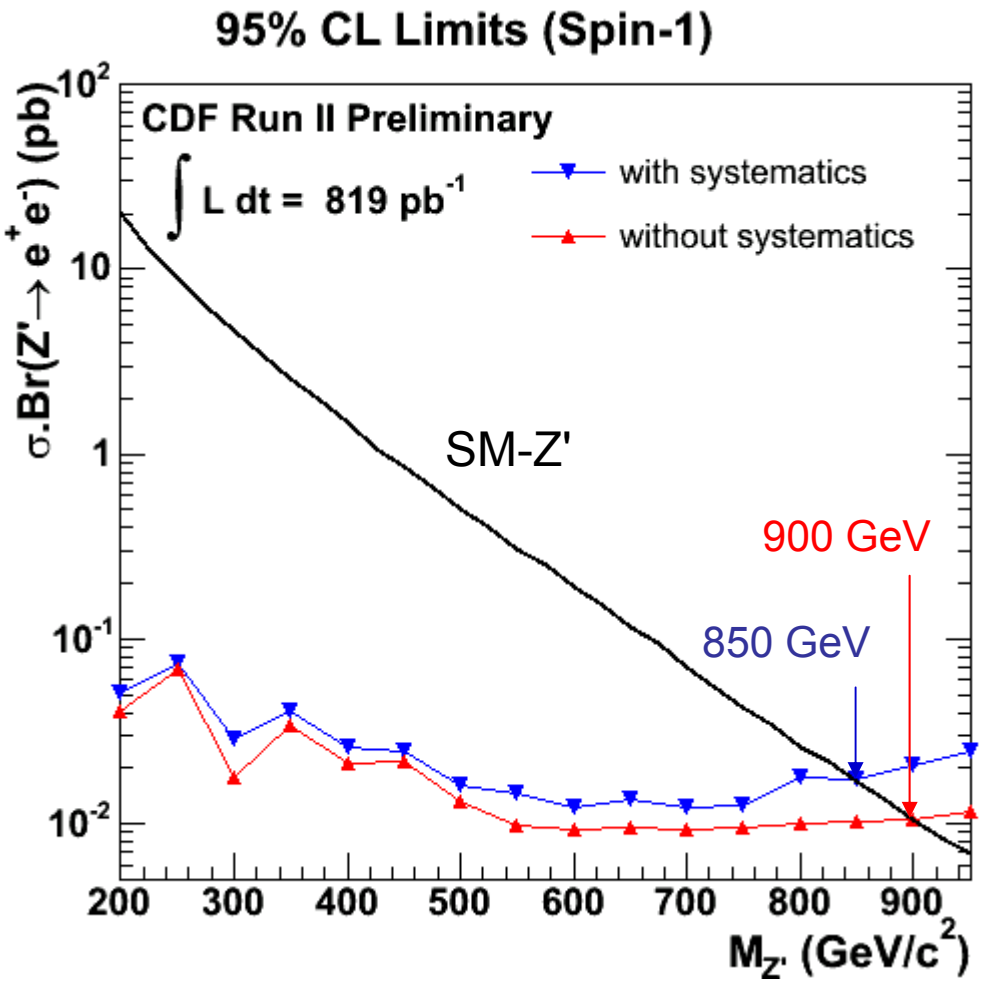
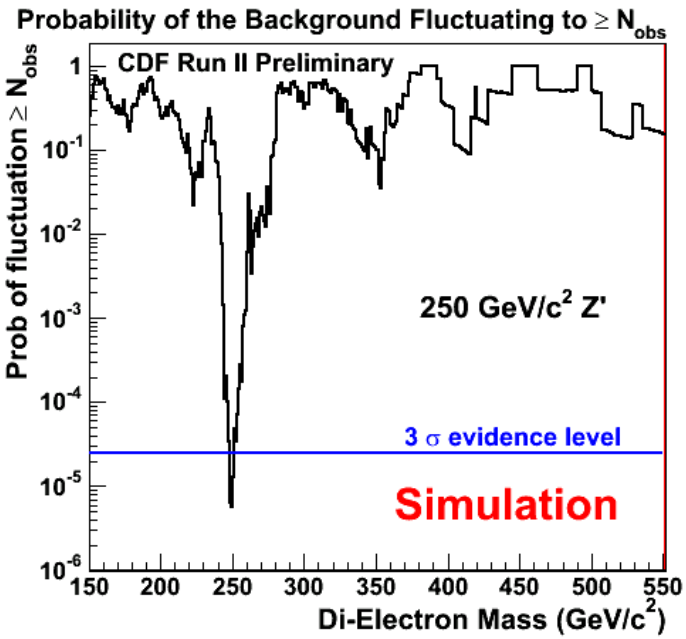
Limits

- highest direct mass spectrum only limit in the world
- previous results
  - 200pb^{-1} (ee+μμ) : 820 GeV
  - D0 (200pb^{-1}) : 780 GeV
- can improve by ~25% by adding in angular info
- more models and spins coming soon



Outlook

- search statistics limited
  - improve with 4-8fb^{-1} expected in run II
- improve sensitivity by
  - adding in angular information
  - combining with di-photon analysis
- maybe just maybe one of the excesses will cross the 3 sigma line next year....



maybe for real next year?

Backup Slides

Selection Cuts

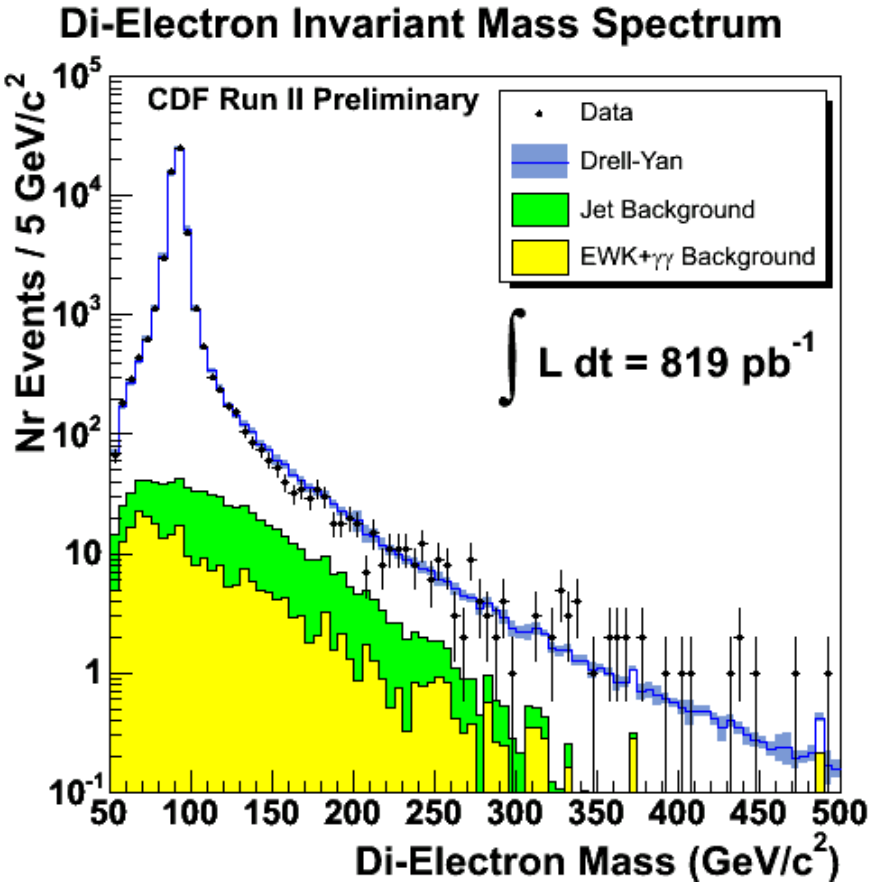
Variable	CEM	PEM
Fiducial	Fid = 1 or 2	$1.2<\|\eta_{PES2D}\|<3.0$
E_T	> 25 GeV	> 25 GeV
|Track Z_0|	≤ 60 cm	n/a
P_T	> 15 GeV	n/a
E_{had}/E_{em}	≤ 0.055 + 0.00045 x E	≤ 0.05 + 0.026xln(E/100)
Isol E_T	≤ 3 + 0.02xE_T GeV	≤ 1.6 + 0.02xE_T GeV
E/P	≤ 2.5 + 0.015xE_T E_T<100 P_T >25 GeV E_T>100	n/a
CES |ΔX|	≤ 3 cm	n/a
CES |ΔZ|	≤ 5 cm	n/a
L_{shr}	≤ 0.2	n/a
χ^2_{Pem3x3}	n/a	<25
conversion	!=1 (CP events only)	n/a

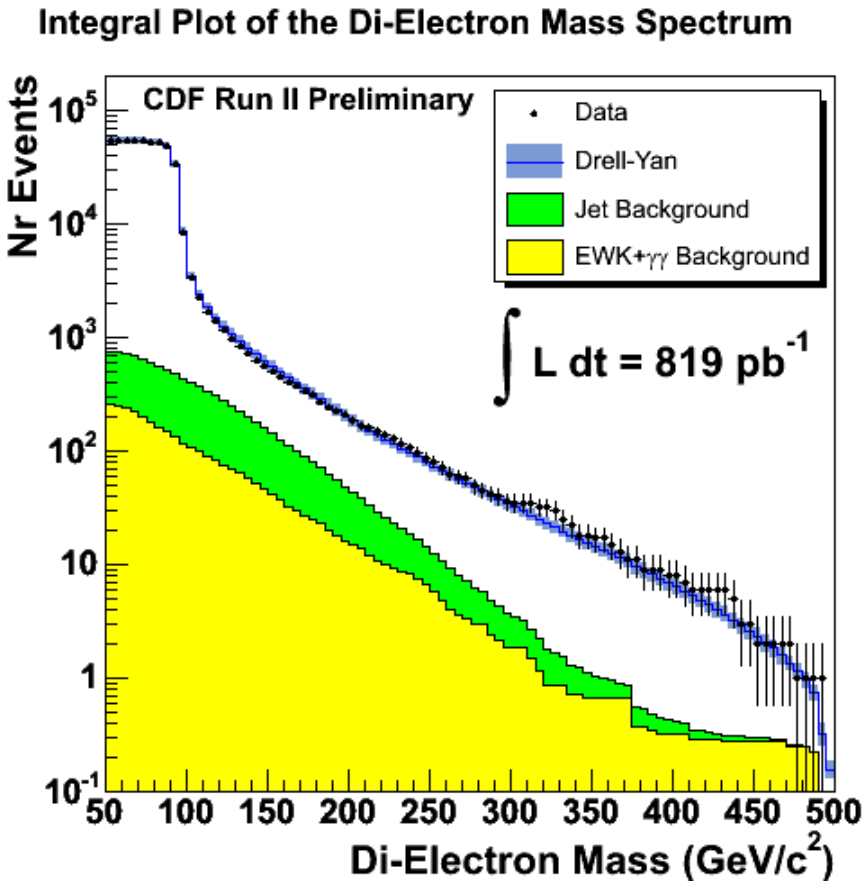
Systematics

Quantity	Uncertainty	Channels Effected
Luminosity	6%	CC + CP
Nr QCD Background (CC)	85.8%	CC
Nr QCD Background (CP)	32.0%	CP
EWK Cross-Section	10.8%	CC + CP
Z^0/γ^* MC Normalisation (CC)	3.8%	CC + CP
Energy Scale (CEM)	1.0%	CC + CP
Energy Scale (PEM)	1.0%	CP
Energy Resolution (CEM)	0.7%	CC + CP
Energy Resolution (PEM)	0.5%	CP
Photon Conversion	10%	CC + CP
Efficiency Scale Factor (CEM)	0.3%	CC + CP
Efficiency Scale Factor (PEM)	0.4%	CP
High Mass Efficiency (CEM)	2.0%	CC + CP
High Mass Efficiency (PEM)	2.0%	CP

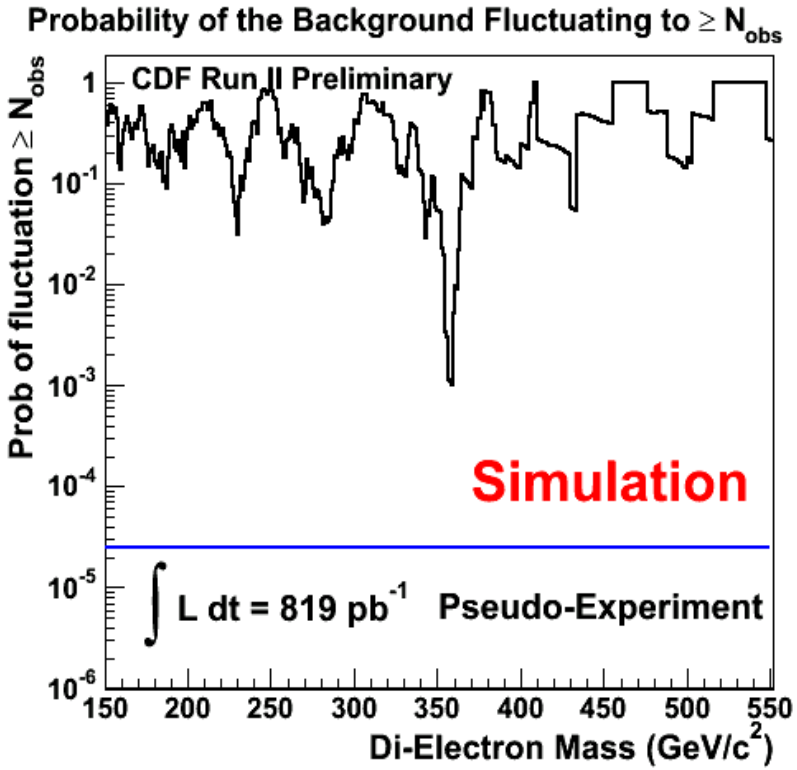
PDF errors not shown as cannot be expressed easily as a single number

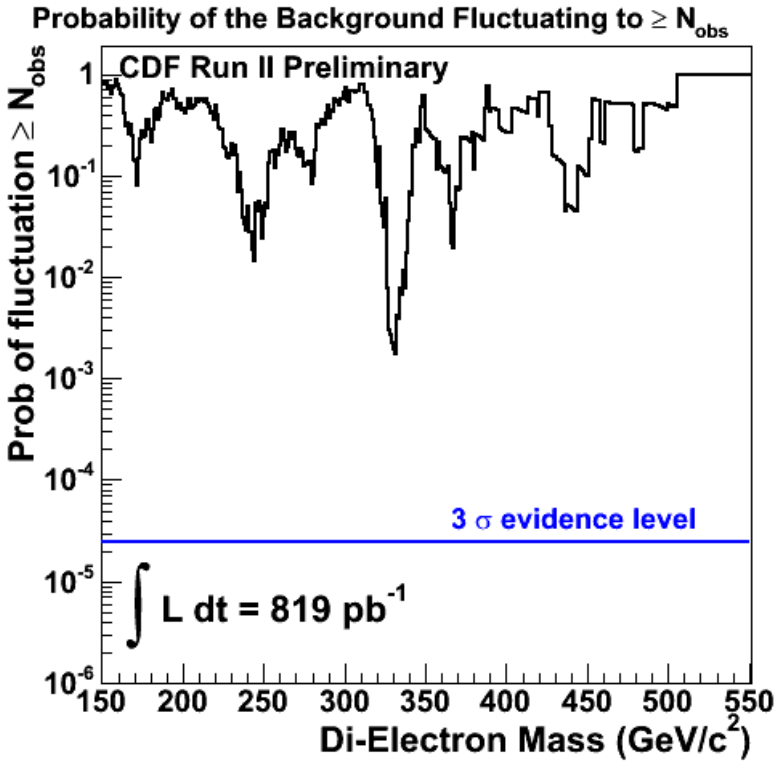
Mass Spectrum



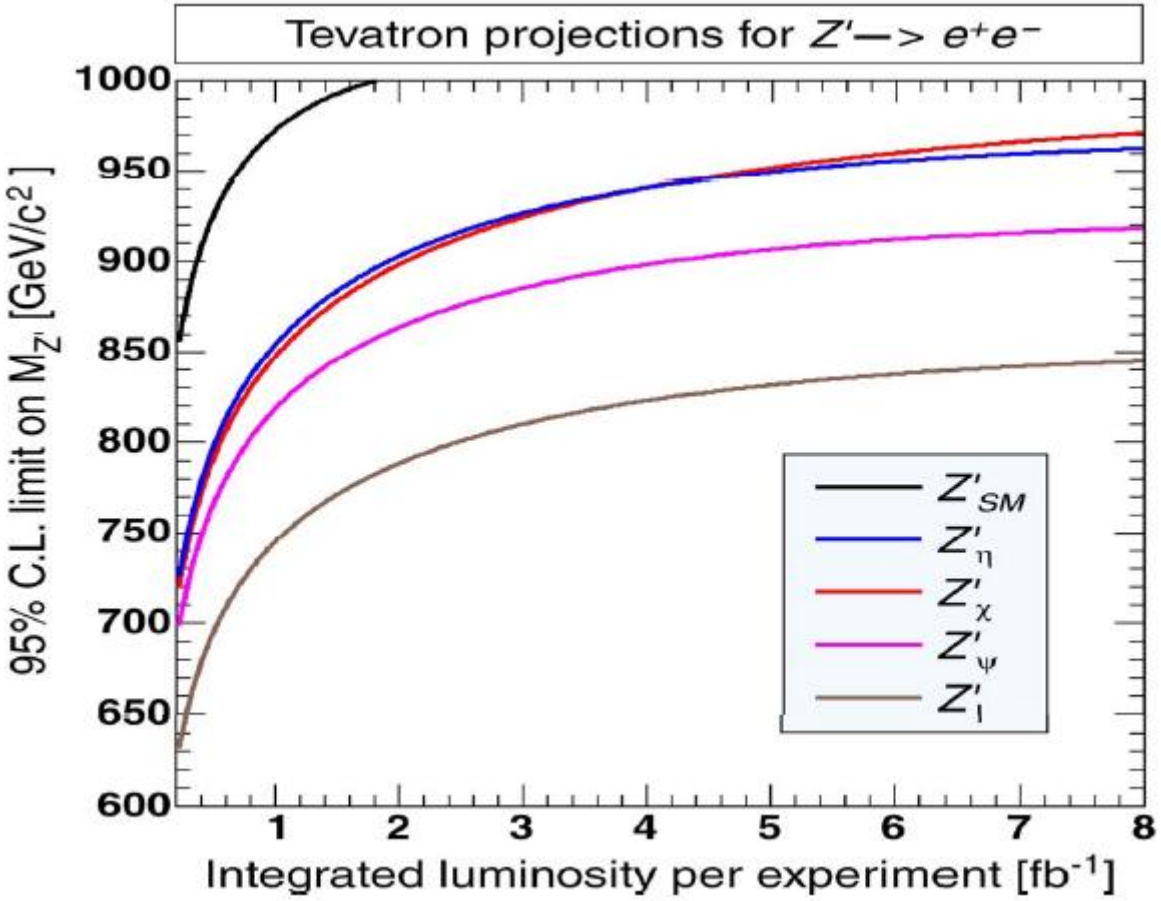


Typical Pseudo Experiment





Reach


Tevatron projections for Z'—> e+e−
95% C.L. limit on M_Z' [GeV/c²]
1000
950
900
850
800
750
700
650
600
1
2
3
4
5
6
7
8
Integrated luminosity per experiment [fb⁻¹]
Z'_SM
Z'_η
Z'_χ
Z'_ψ
Z'_I