Recent Results on New Phenomena and Higgs Searches at DZERO

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Outline

- Motivation for DØ Run II Detector at Fermilab
- The Fermilab Tevatron Collider
- Recent New Phenomena Results
- Prospects for Higgs Search at the Tevatron

Motivation

- **Run I DØ** → **Run II DØ**
  (1992-96) Began 1 March, 2001

Top Quark discovered in Run I

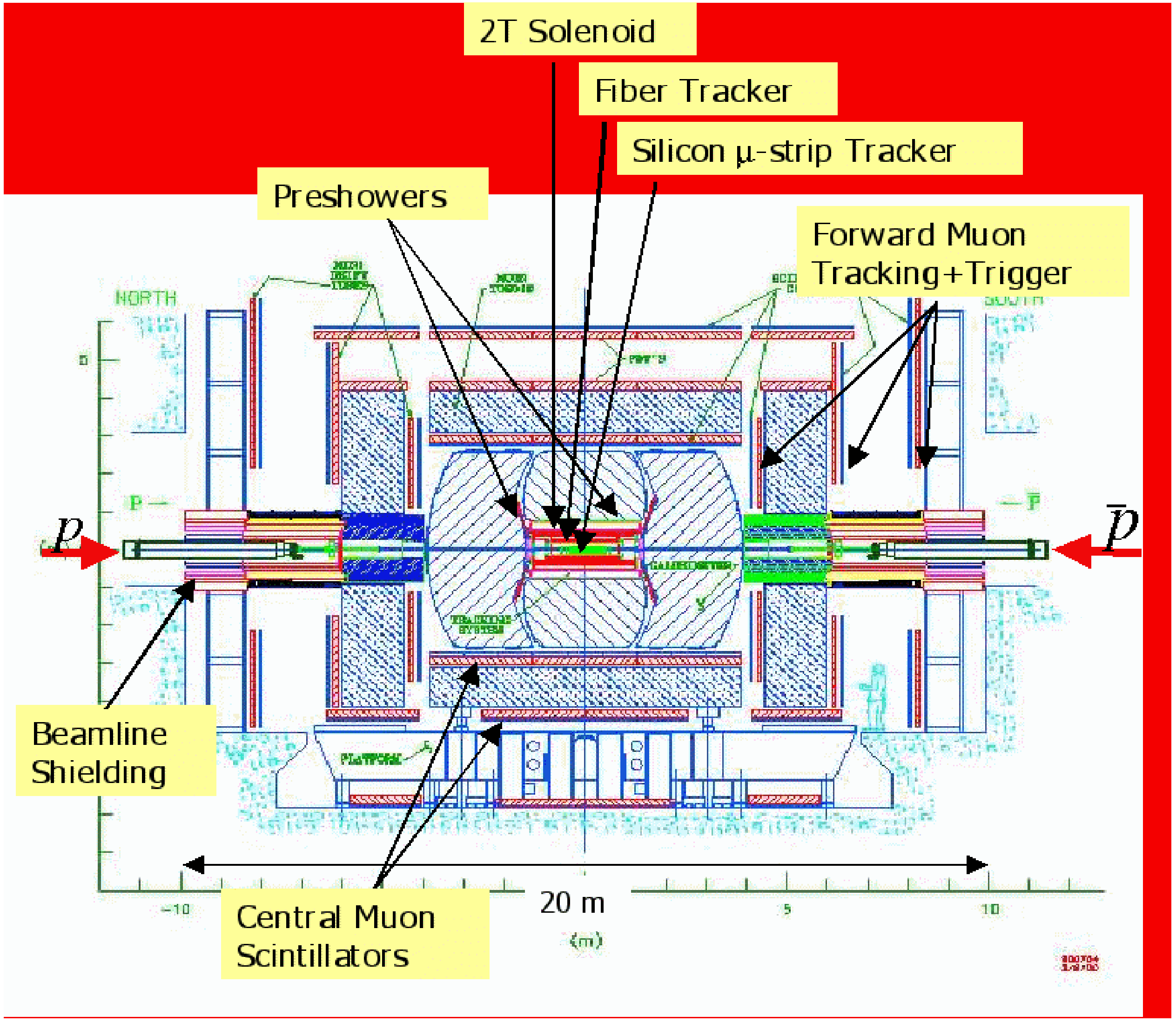
- Search for Higgs
- New Phenomena Searches
- Detailed Top quark Physics
- Electroweak Physics
- B Physics
- QCD

The DØ Collaboration

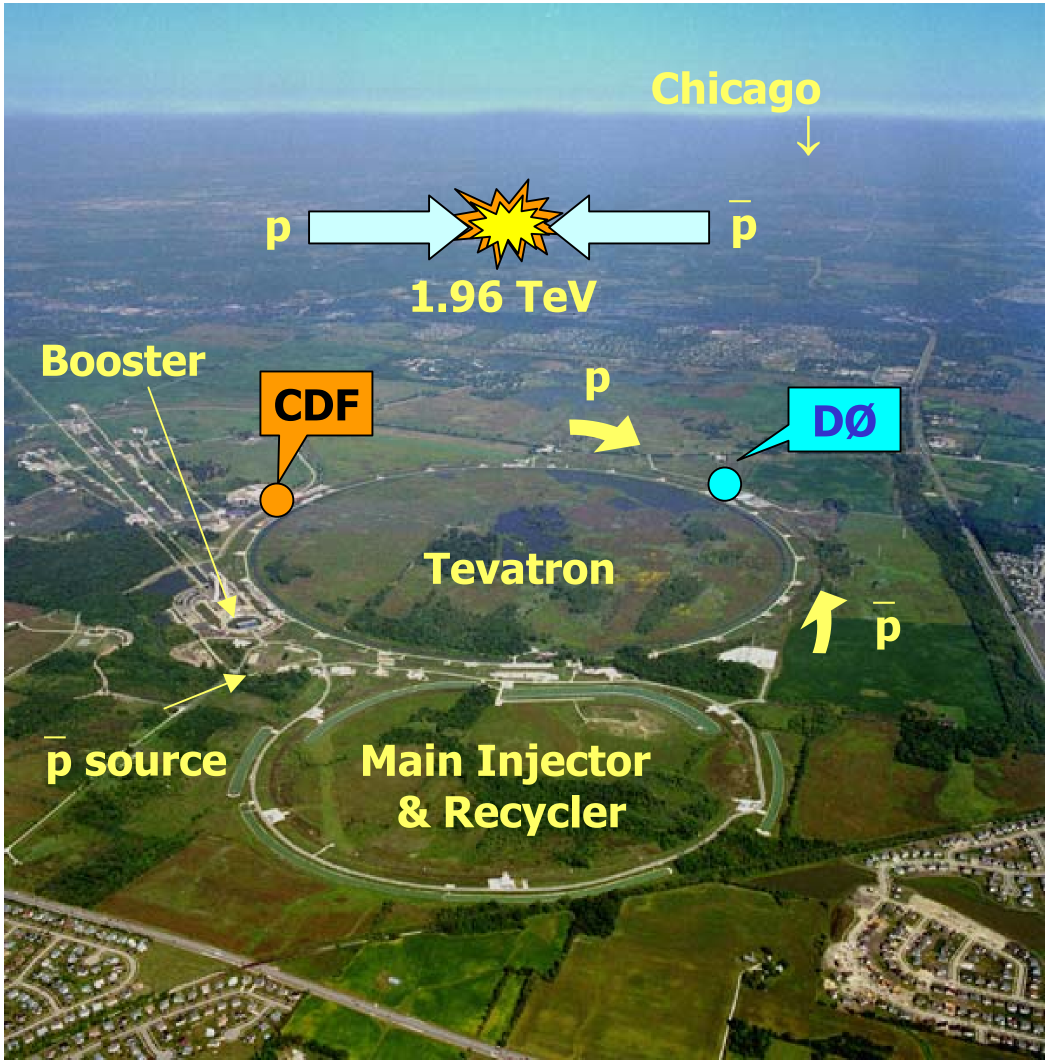
~ 650 physicists
76 institutions
18 countries

> 50% non-USA
~ 120 graduate students

The DØ Run II Detector



The Fermilab Tevatron Collider



Tevatron Upgrades

- Increase in Luminosity
  - $2\text{x}10^{31}$ -> $5\text{x}10^{32}$ cm^{-2} s^{-1}
- Bunch spacing
  - 3.5 μs -> 396 ns
- Increase in CM energy
  - 1.8 TeV -> 1.96 TeV

Detector challenges

- Large occupancies and event pile-up
- Radiation damage

Searching for New Phenomena

Different forms

- Observation of unseen particles predicted by SM
  - Higgs
- Discovery of particles not in the SM
  - SUSY, leptoquarks
- Identification of new gauge interactions
  - W'/Z', technicolor
- Unexpected complexities beyond the SM
  - Compositeness
- Fundamental changes to modern physics
  - Extra dimensions

Current DØ searches

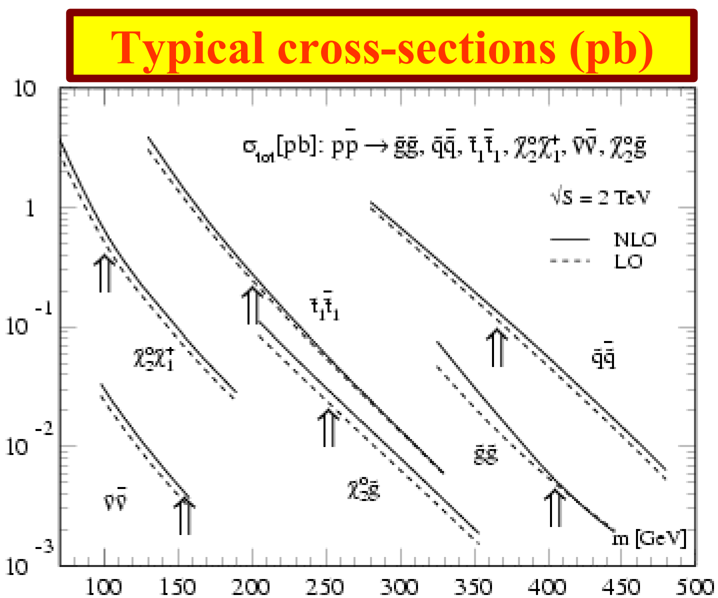
- Supersymmetry
  - Jets + missing E_T
  - Di- and Tri-leptons
  - GMSB: $\gamma\gamma$ + missing E_T
- Exotics
  - 2^{nd} Generation Leptoquarks
- Large Extra Dimensions
  - Dielectrons and diphotons
  - Dimuons

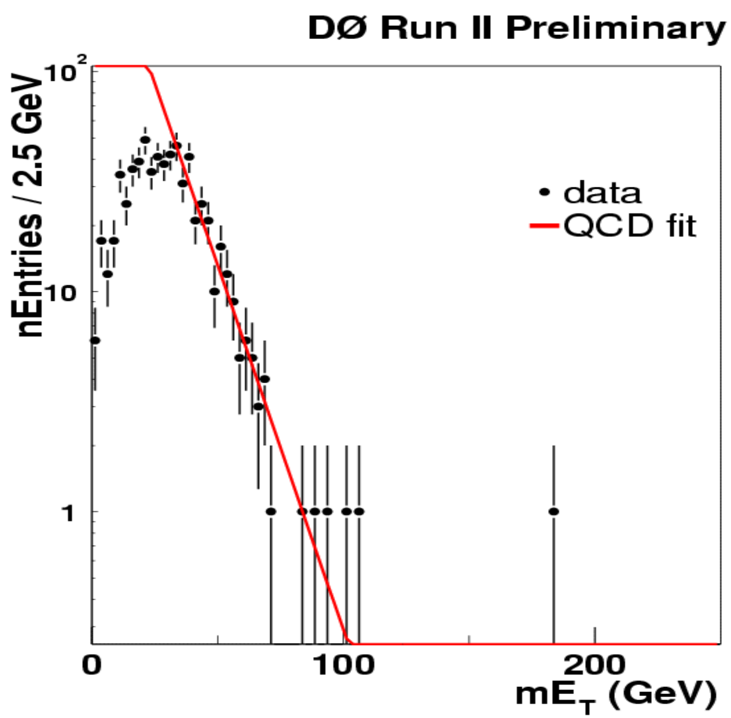
Jets + Missing E_T

➢Cascade decays end in quarks and/or gluons and missing transverse energy (Lightest Supersymmetric Particle escaping detector)

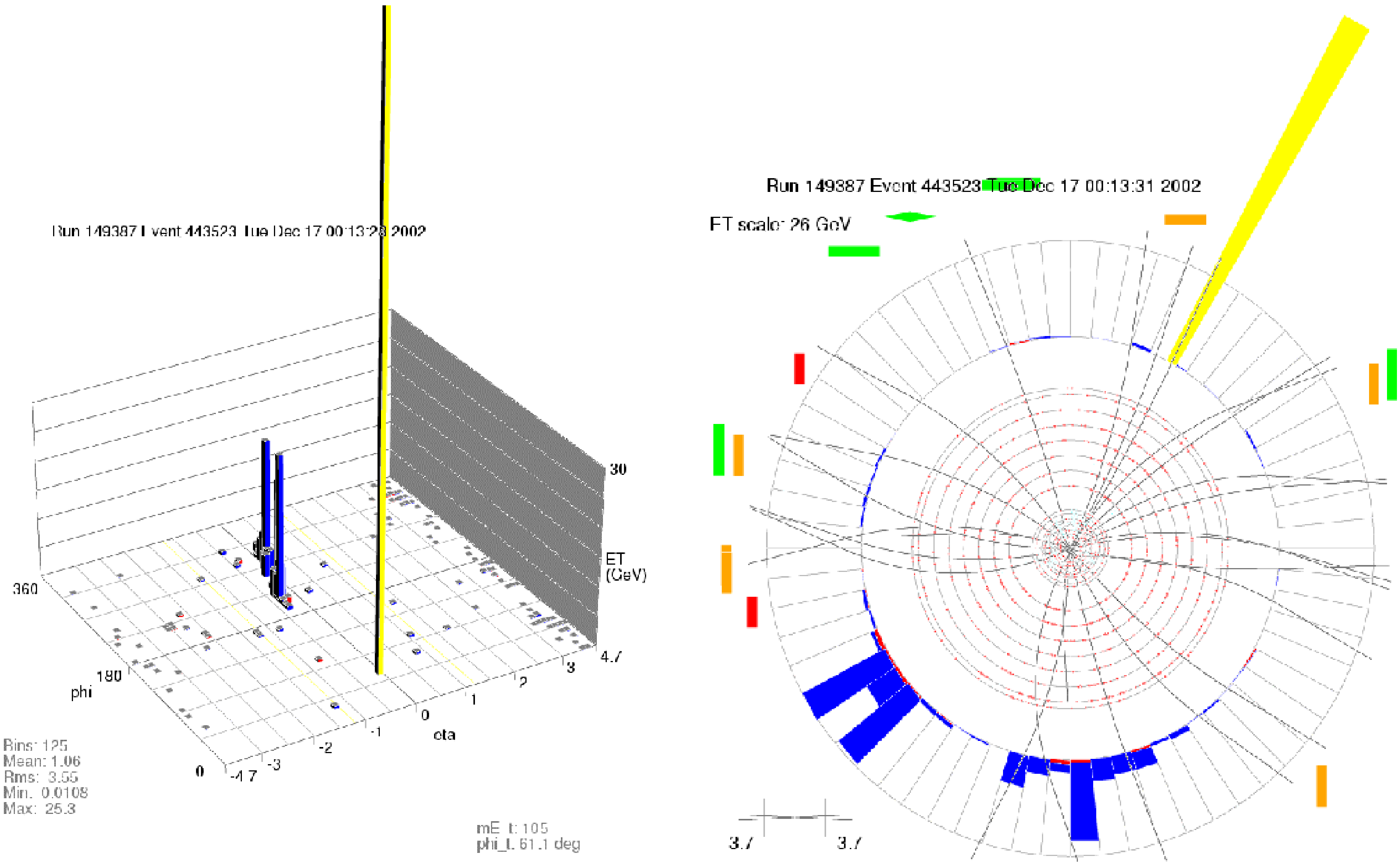
➢Generic signature for production of squarks and/or gluinos in SUGRA

Cut: Missing E_T >	70 GeV	80 GeV	90 GeV	100 GeV
Expected (events)	18.4 ± 8.4	9.5 ± 5.3	5.1 ± 3.2	2.7 ± 1.8
Data	7	6	4	3
Cross-section Limit (pb)	4.2	3.8	3.1	2.7





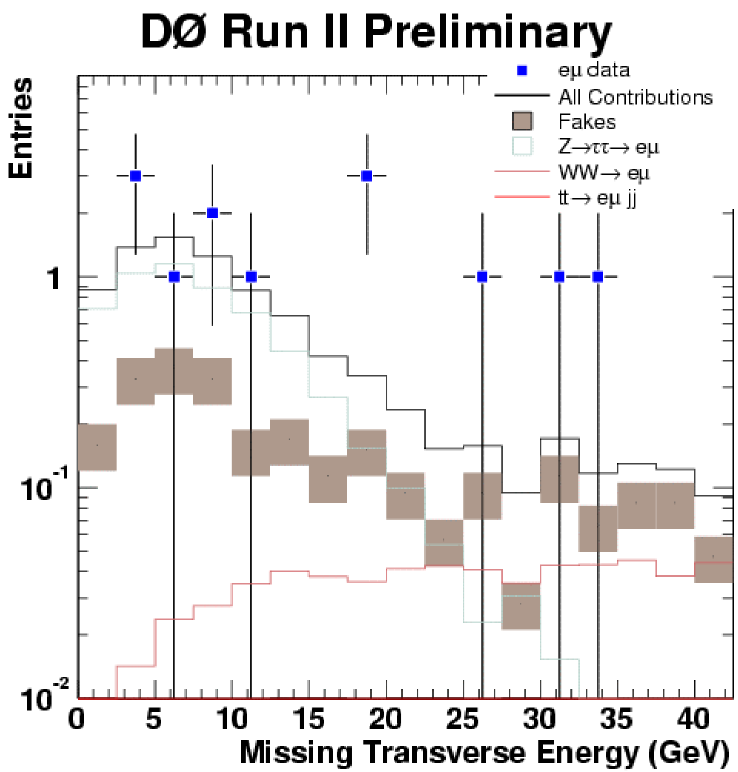
Jets + Missing E_T Event

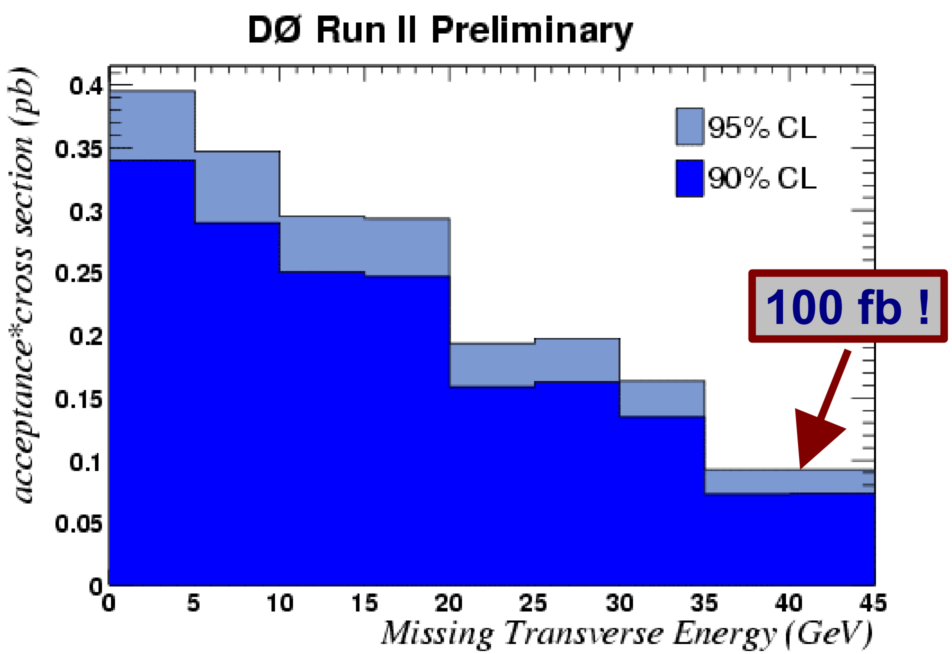


e μ + X

- **Very low backgrounds → pursue analysis in a model-independent way**
- **Require e, μ p_T > 15 GeV, estimate fake rates from data, physics backgrounds from simulation**
- **~30 pb^{-1}**

Cross-section Limit as a function of missing E_T



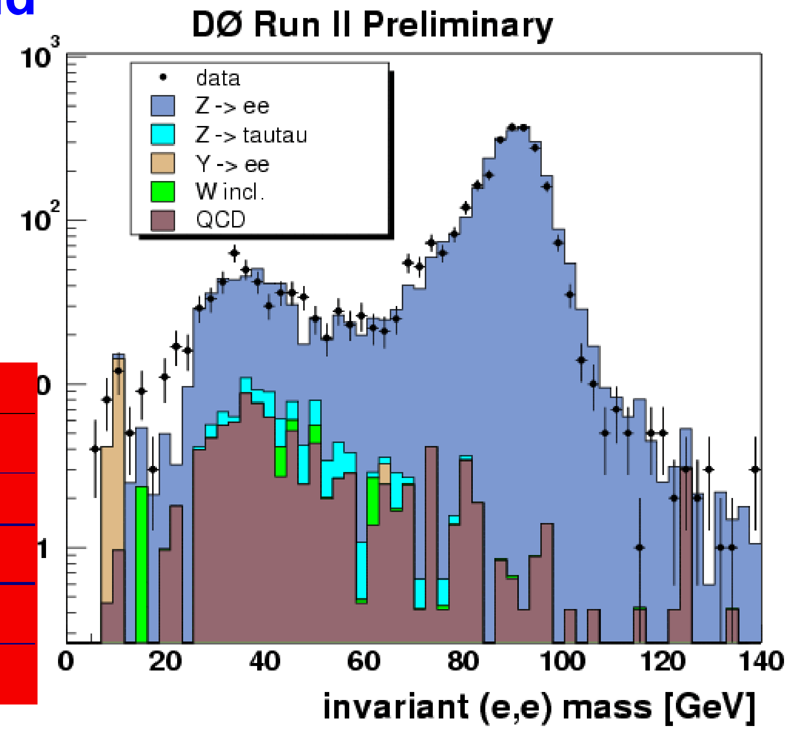


eel + X

- **Start from dielectron sample: understand trigger, reconstruction, simulation**
- **Also verify determination of QCD fake background (from data)**

~40 pb^{-1}

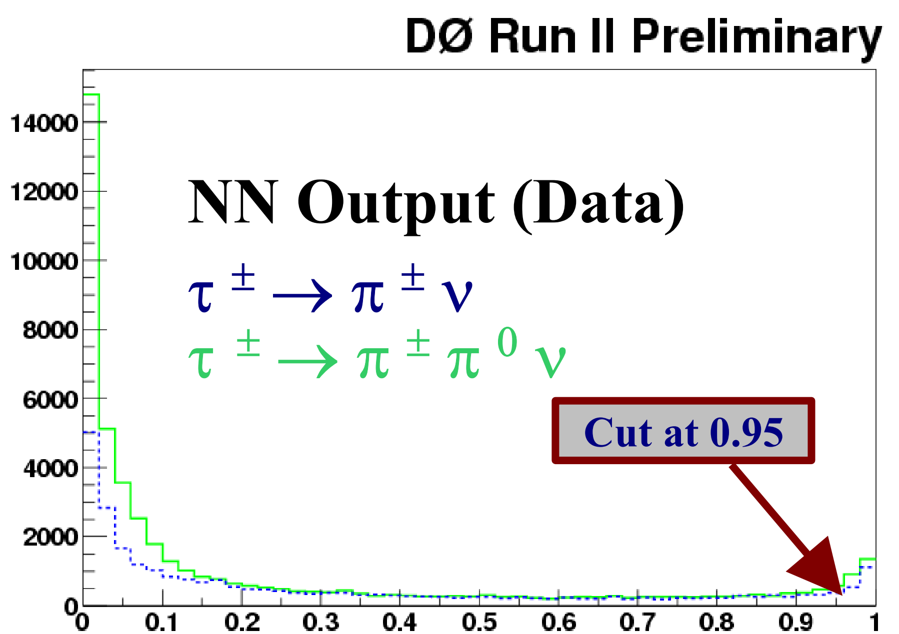
	Backgrounds	Data
$p_T(e_1) > 15$ GeV, $p_T(e_2) > 10$ GeV	3216 ± 43.2	3132
10 GeV < M(ee) < 70 GeV	660.2 ± 19.1	721
$M_T > 15$ GeV	96.4 ± 8.1	123
Add. Isolated Track, $p_T > 5$ GeV	3.2 ± 2.3	3
Missing $E_T > 15$ GeV	0.0 ± 2.0	0

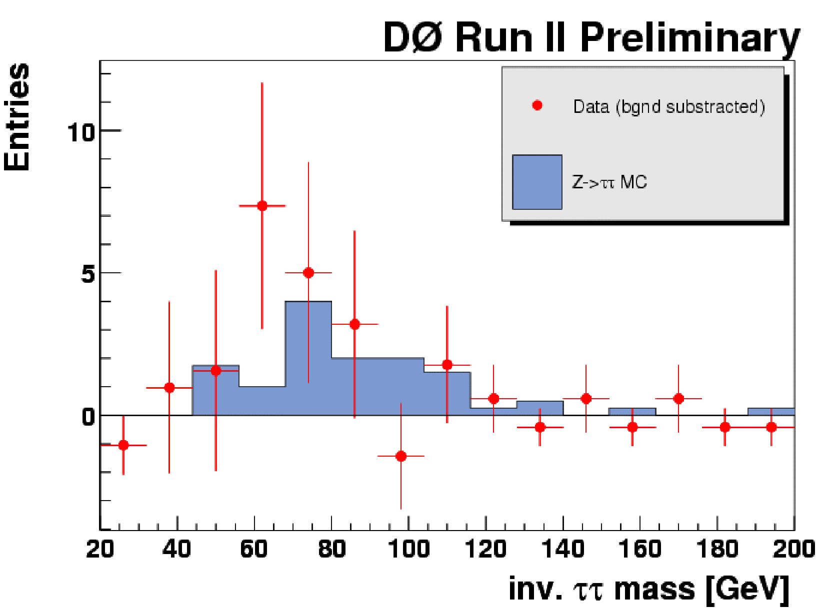


- **Typical selection efficiency for SUGRA 2-4%**
- **Sensitivity still about factor 7 away from extending excluded area in parameter space → working on improving efficiency, adding channels**

$Z \rightarrow \tau\tau \rightarrow e\,h\,X$

- In ~50 pb^{-1}, select events with an electron ($p_T(e)$ > 12 GeV) and a narrow jet of p_T > 7 GeV with a single track of p_T >1.5 GeV
- Use neural net to further discriminate between QCD and tau jets
- Reconstruct di-tau invariant mass using the assumption that the tau direction = visible tau daughter direction
- Finally, subtract same- sign e- τ events from opposite sign

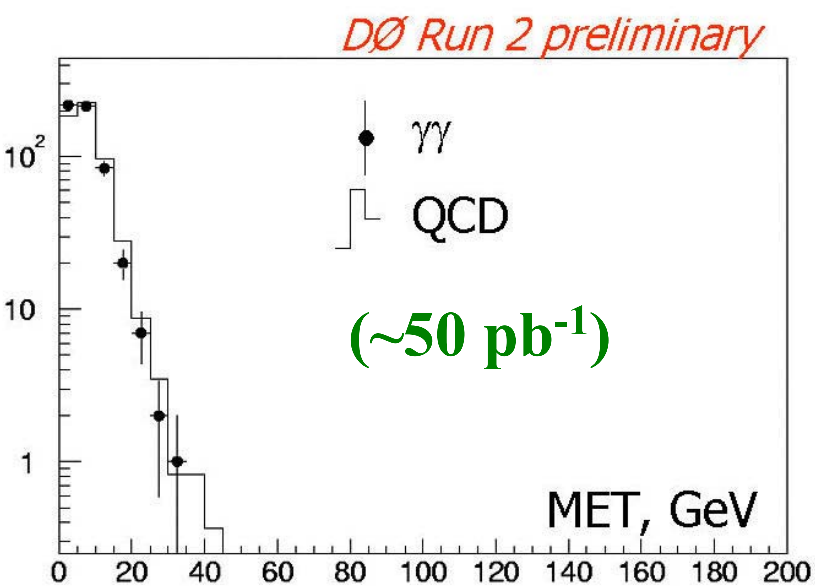


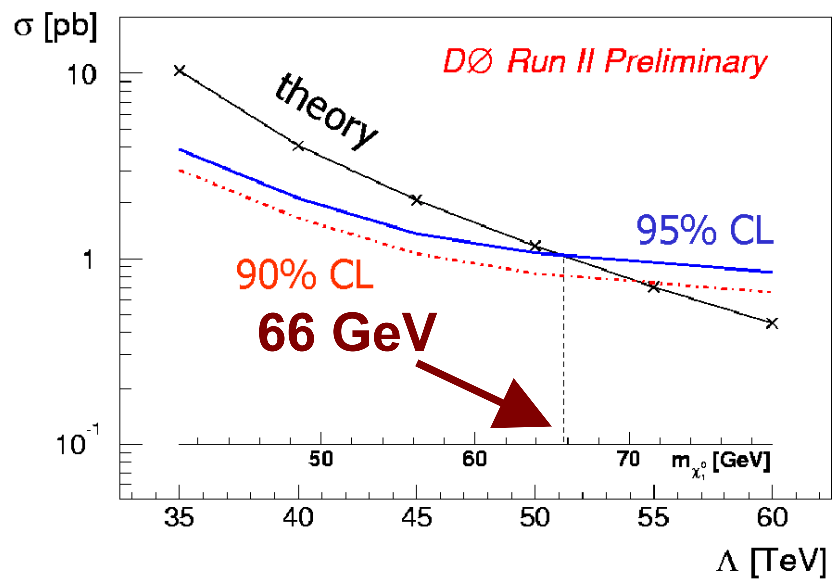


Gauge Mediated SUSY Breaking

- LSP is a light (<< 1 eV)) gravitino, phenomenology driven by nature of the NLSP
- "Bino" NLSP will lead to signatures with 2 photons and missing E_T
- ~50 pb^{-1}, close to Run I limit!

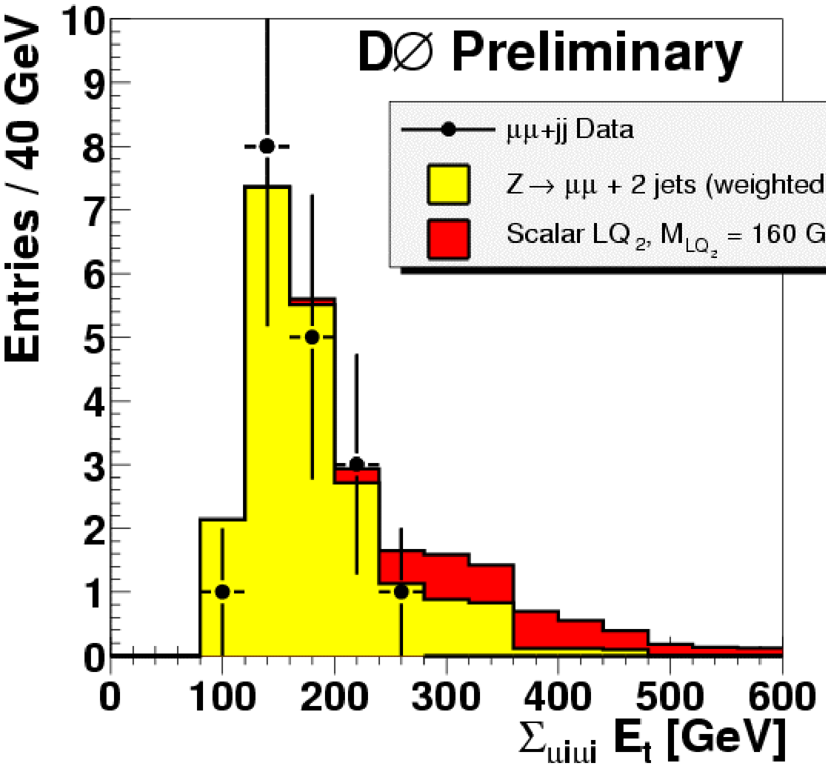
Theory = "Snowmass" slope:
$M = 2\Lambda$,
$N_5 = 1$,
$\tan\beta = 15$,
$\mu > 0$

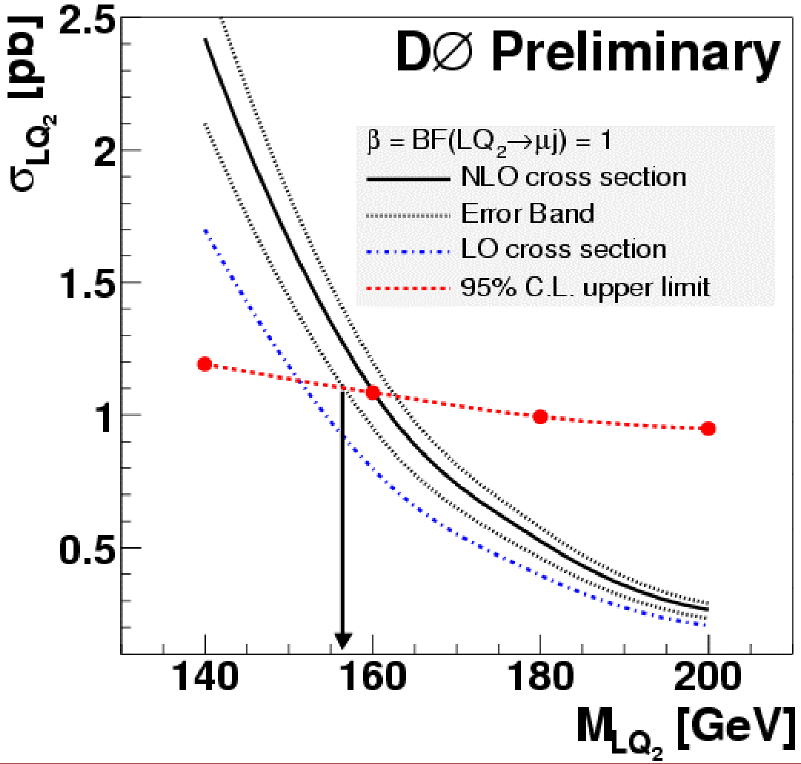




Second Generation Leptoquarks

- In this analysis, assume $\beta = 1$,, i.e. leptoquarks decay to μ + c or s
- Pair production → 2 muons + 2 jets

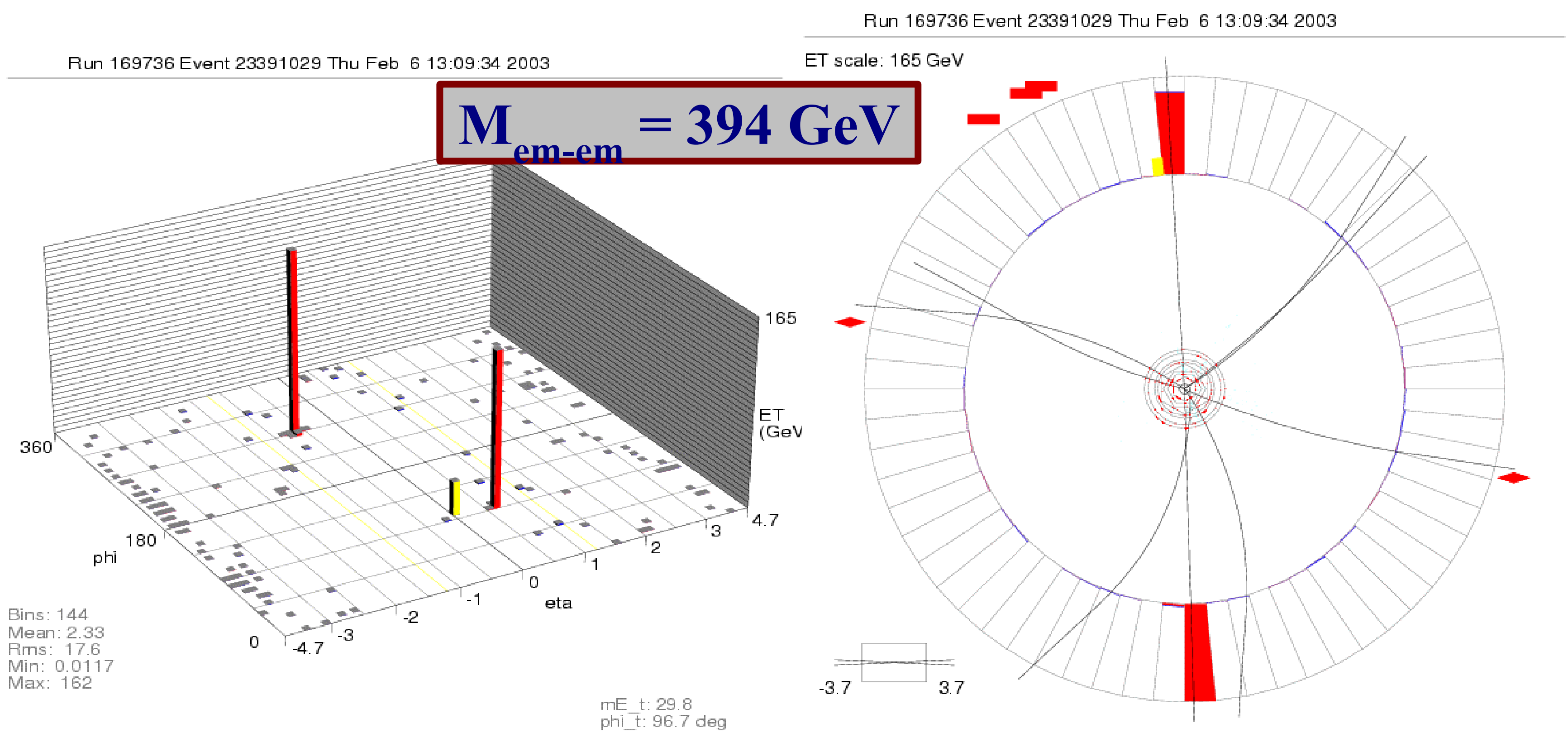




M_{LQ2} > 157 GeV (~30 pb^{-1}) (Run I: 200 GeV)

Dielectrons and diphotons

- Require 2 electromagnetic objects with p_T > 25 GeV, missing E_T < 25 GeV
- Estimate physics backgrounds from MC, fake rates from data

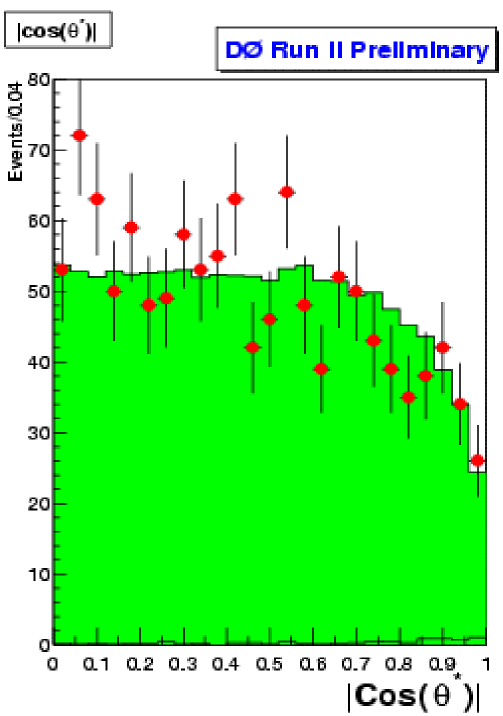


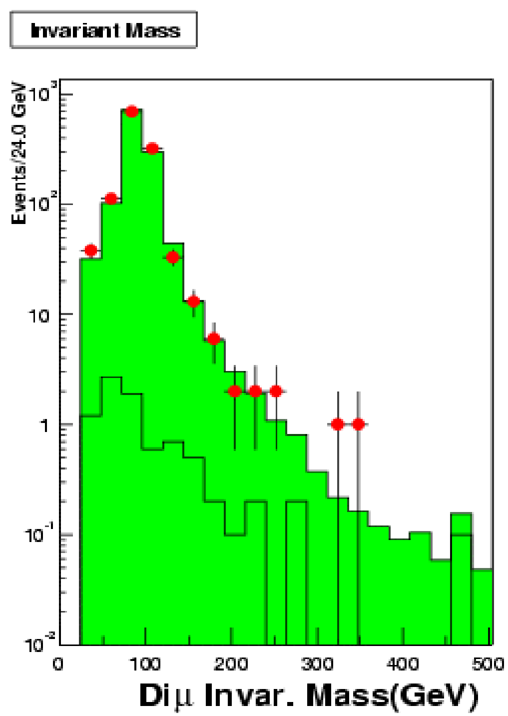
Large Extra Dimensions

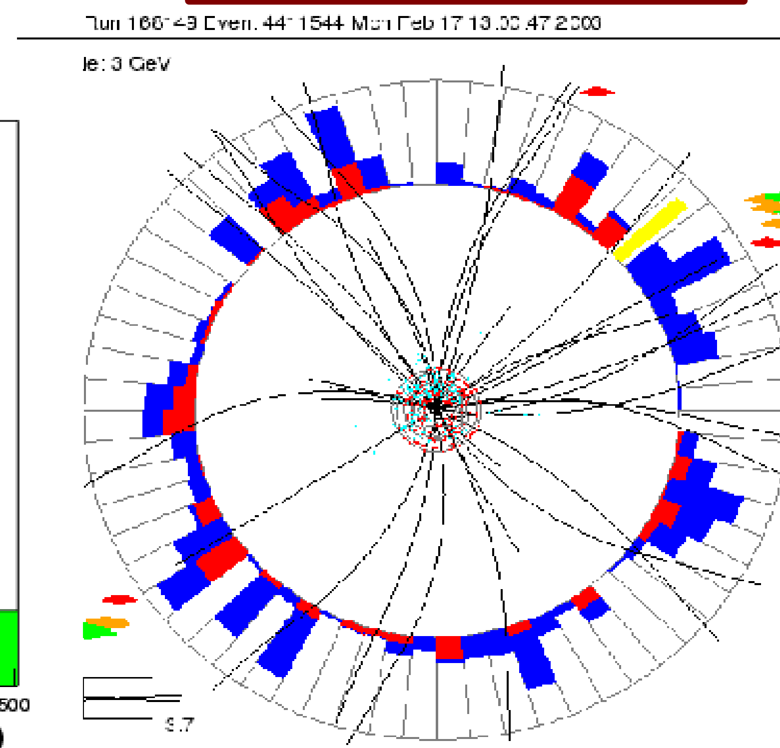
Dimuons

- Require two muons with p_T > 15 GeV, impose $M_{\mu\mu}$ > 40 GeV

$M_{\mu\mu}$ = 460 GeV

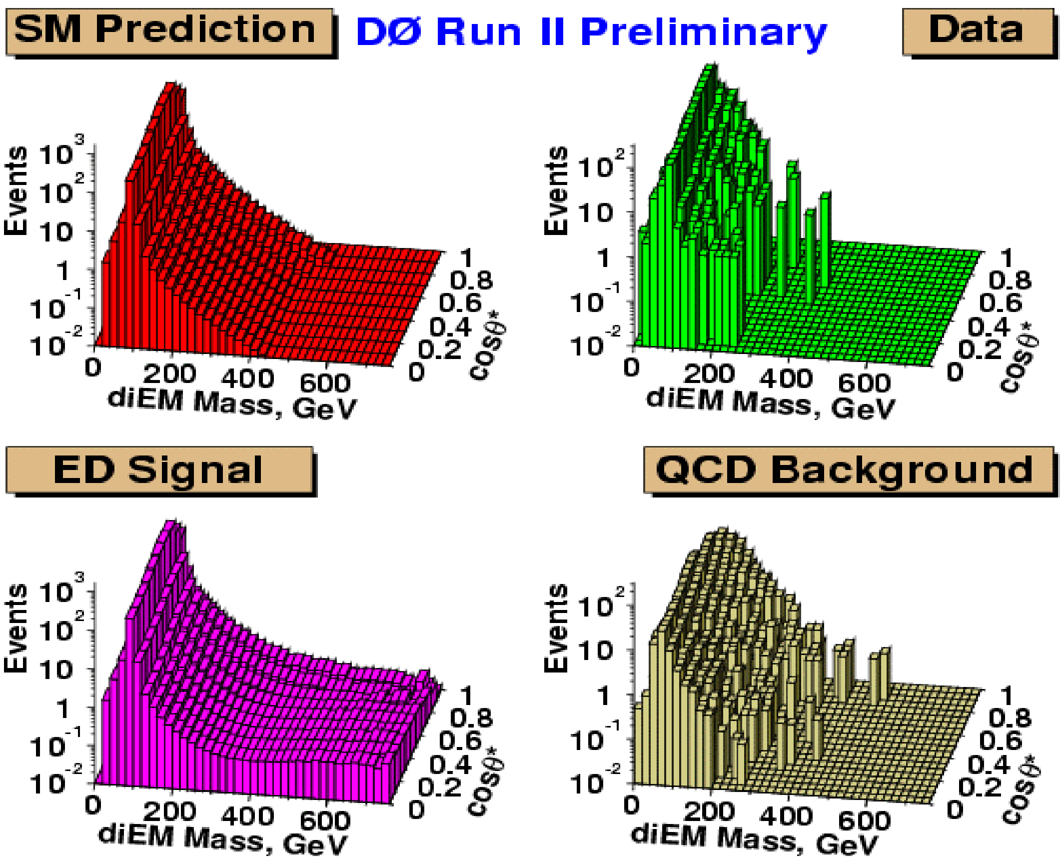






0 500 GeV

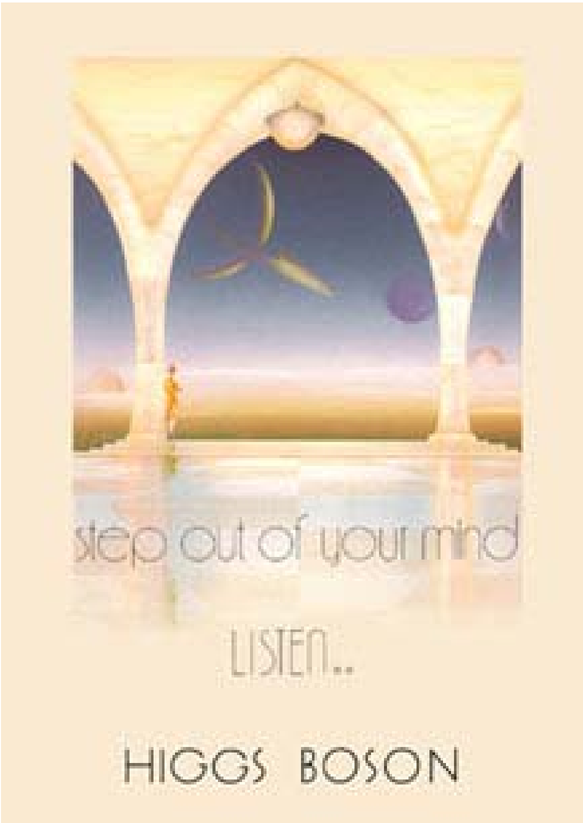
Large Extra Dimensions

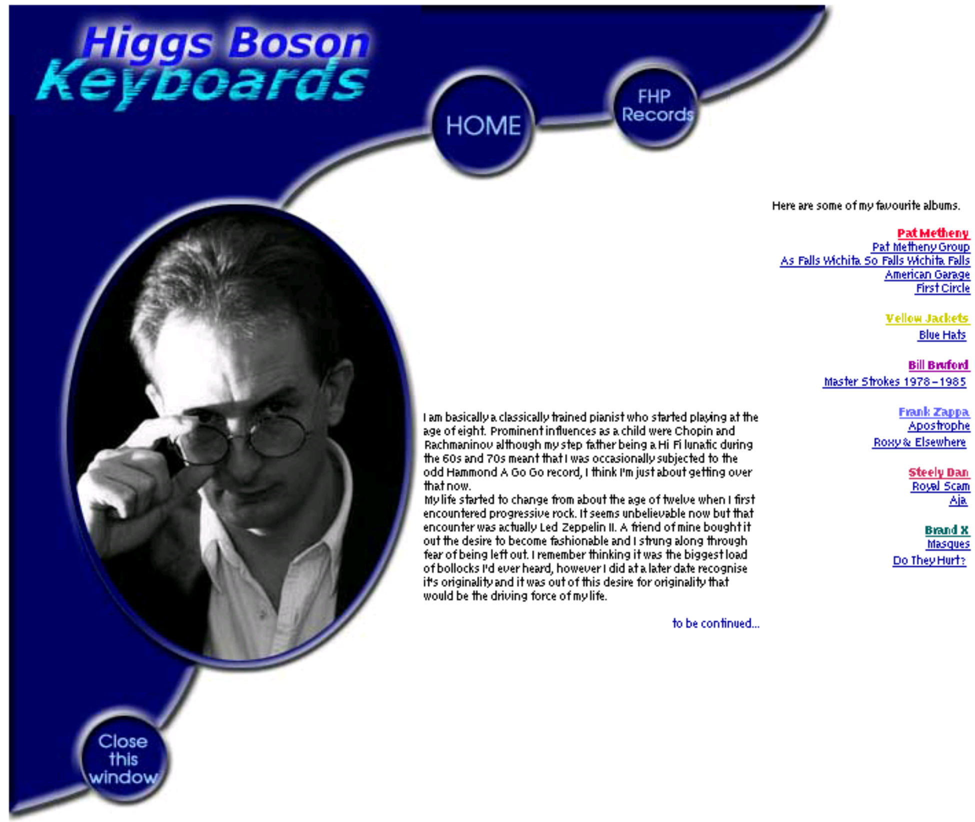


Di-em result is close to Run 1
Dimuon is a new channel
Both similar to individual LEP limits

Formalism	GRW	HLZ, n=2	HLZ, n=7	Hewett, λ = +1
di-EM (~50 pb^{-1})	1.12	1.16	0.89	1
dimuon (~30 pb^{-1})	0.79	0.68	0.63	0.71

www.higgsboson.com





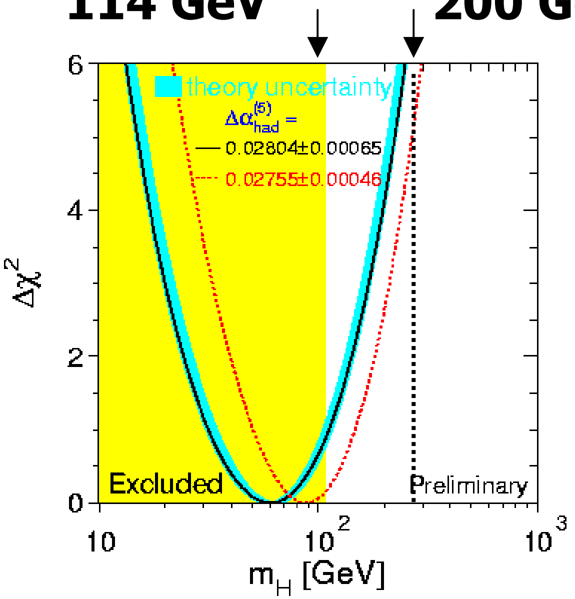
Higgs Boson is the name of a British musician

Searching for the Higgs

- Focus has been on experiments at the LEP e^+e^- collider at CERN
  - precision measurements of parameters of the W and Z bosons, combined with Fermilab's top quark mass measurements, set an upper limit of $m_H \sim 200$ GeV
  - direct searches for Higgs production exclude $m_H < 114$ GeV

114 GeV

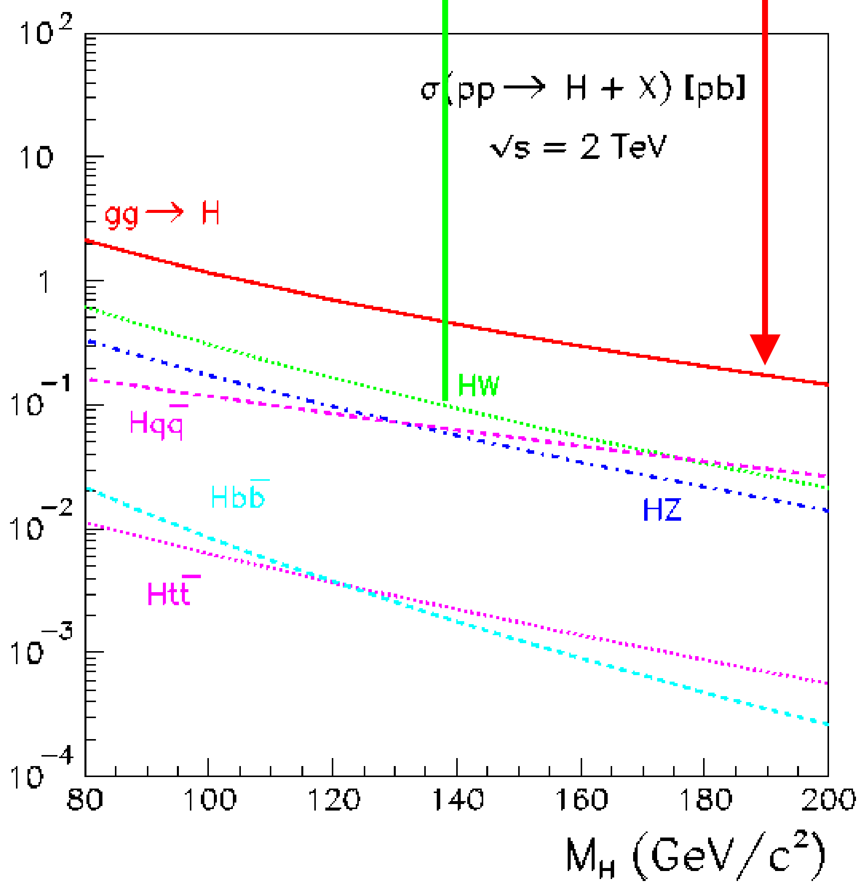
200 GeV



Higgs Production and Decay

Gluon Fusion: **high background**

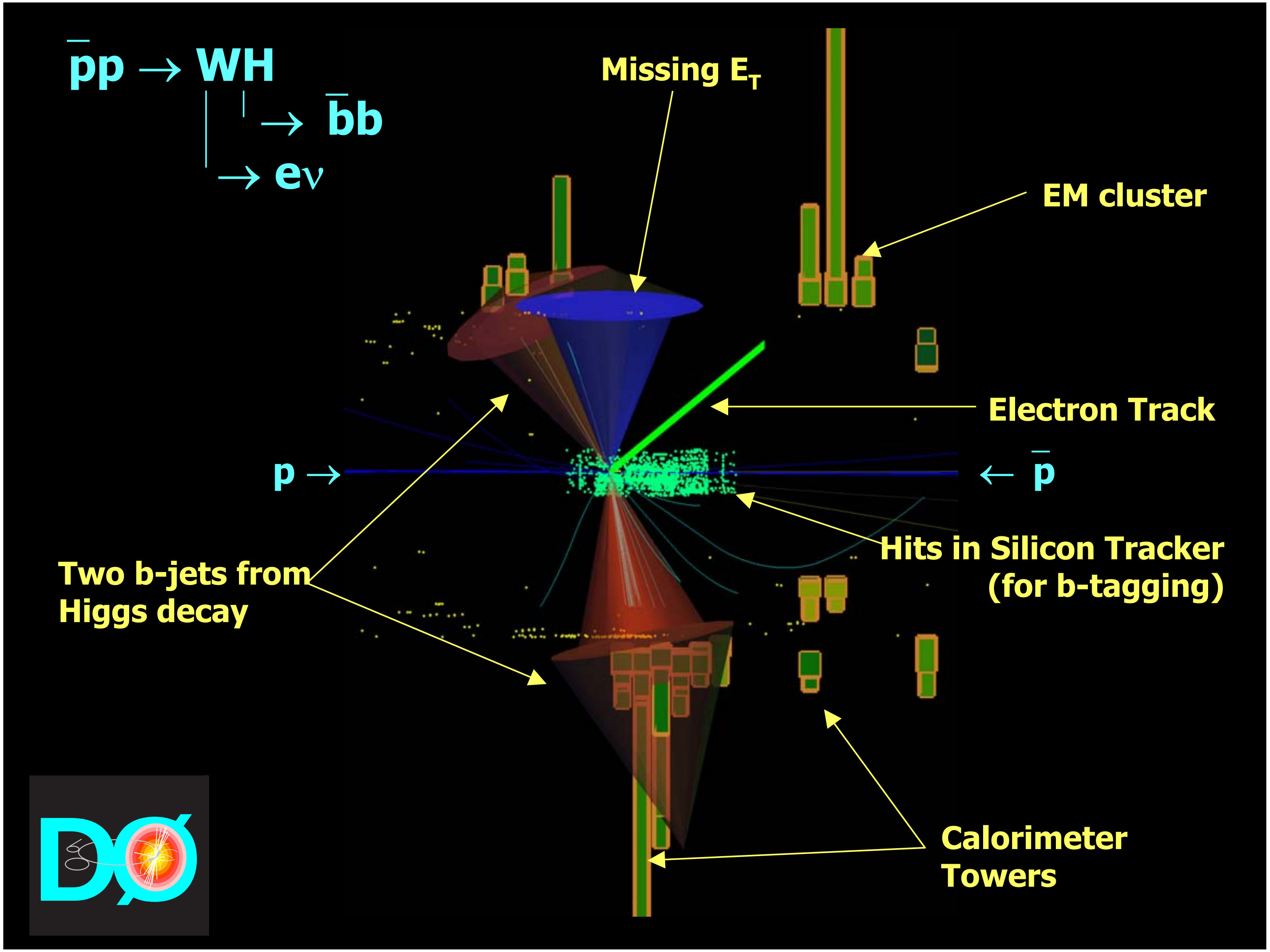
Associated Production:
better rejection



- **For M_H < 135 GeV, H → bb dominates**
  - **WH → $l\nu$ bb**
    - **backgrounds: Wbb, WZ, tt, single t**
  - **WH → qqbb**
    - **overwhelmed by QCD background**
  - **ZH → ll bb**
    - **backgrounds Zbb, ZZ, tt**
  - **ZH → $\nu\nu$ bb**
    - **backgrounds QCD, Zbb, ZZ, tt**
- **For M_H > 135 GeV, H → WW dominates**
  - **gg → H → WW***
    - **backgrounds: Drell-Yan, WW, WZ, ZZ, tt, tW, $\tau\tau$**

Tools: **b-tagging efficiency**
Di-jet mass resolution

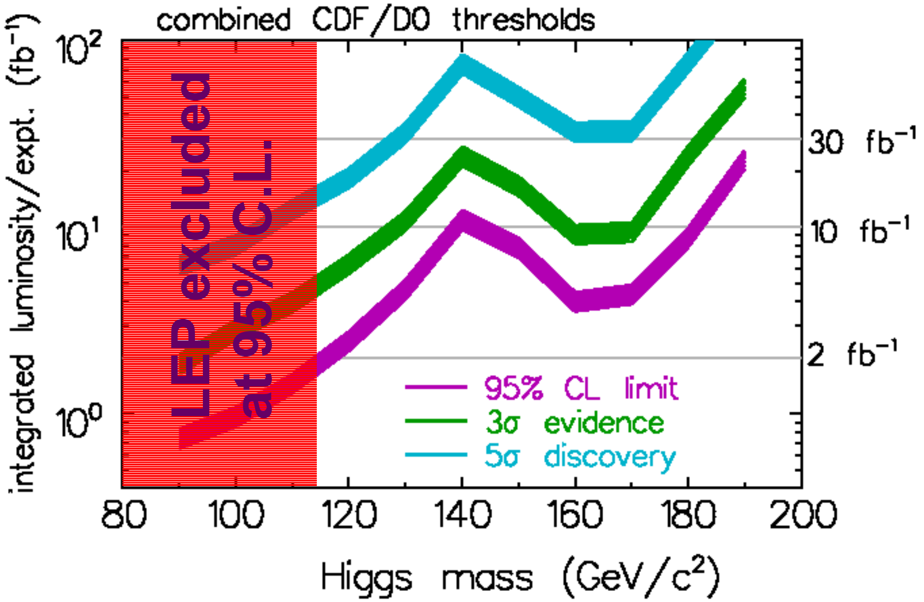
SM Decay Higgs Signature



Tevatron Higgs Working Group

- The Higgs discovery potential for Run II has been evaluated (hep-ph/0010338, using a parameterized fast detector simulation)

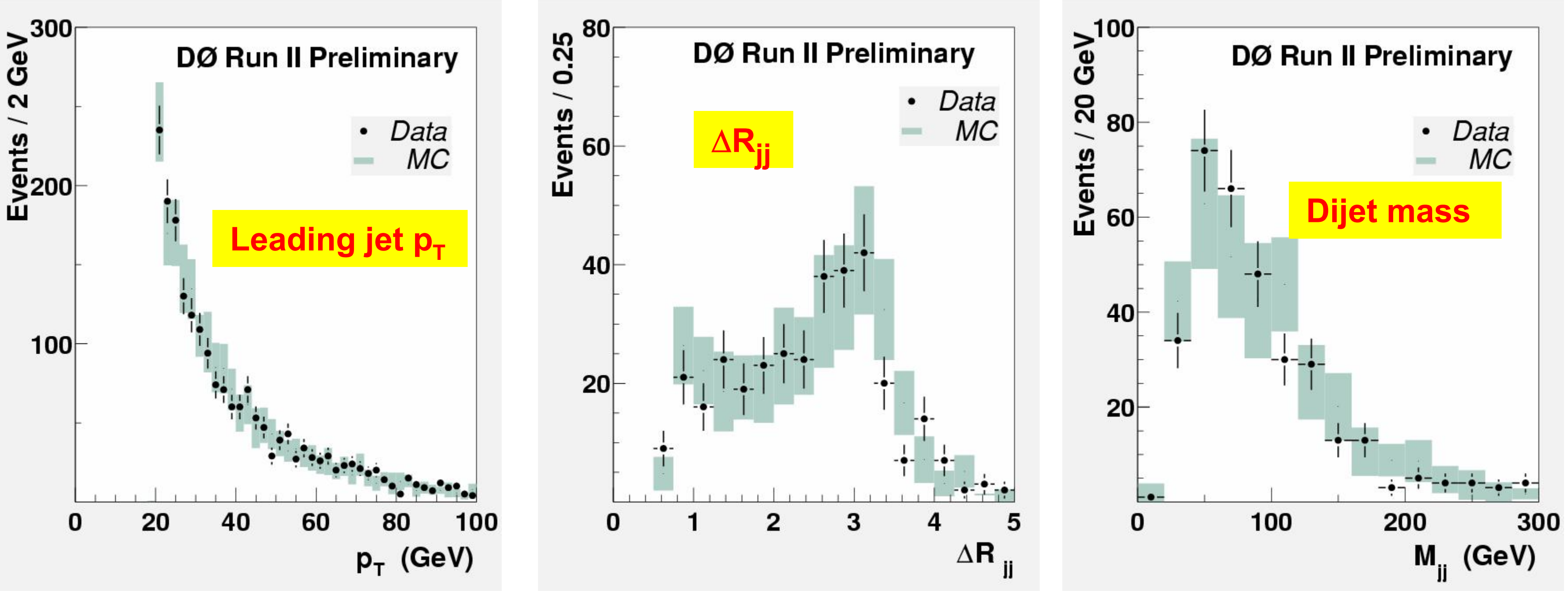
- Discovery at 3-5σ can be made
  - Combine all channels, data from both D0 and CDF
  - Improve understanding of signal and background processes
    - b-tagging, resolution of M_{bb}



- Advanced analysis techniques are vital
- Largest luminosity required to discover Higgs
- Results of simulations consistent with SHWG expectations

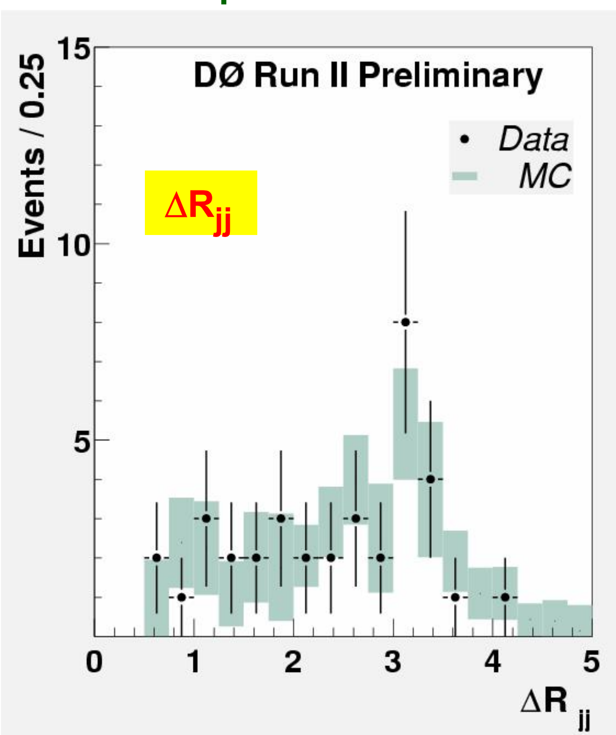
W + jets

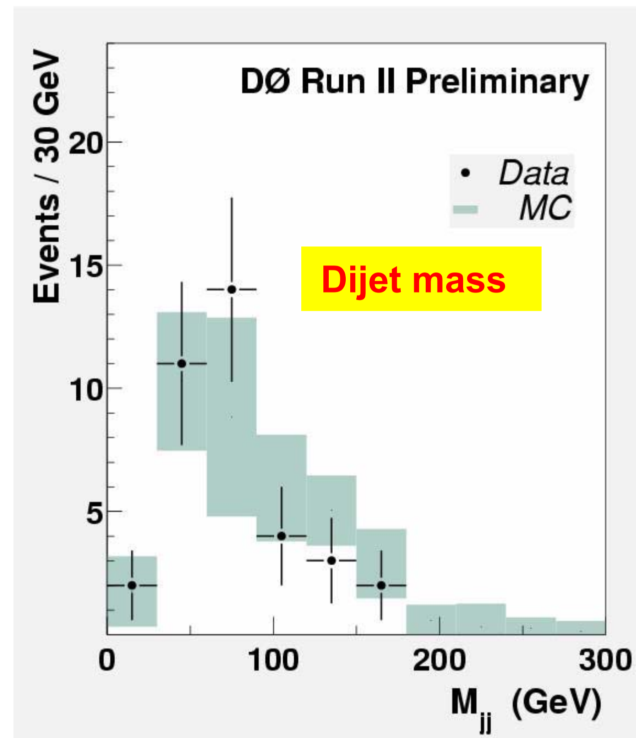
- First step towards W(→ℓν) + H(→bb) measurement
- Major background source from W + di-jets
- Basic selection, based on 35 pb^{-1}
  - Isolated high p_T lepton (e or μ) with large missing E_T
  - Jets p_T > 20 GeV in |η| < 2.5



Z + jets

- First step towards Z(→leptons) + H(→bb) measurement
- Major background source from Z + di-jets
- Basic selection, based on 35 pb^{-1}
  - 2 high p_T leptons (ee or $\mu\mu$)
  - Mass of dileptons consistent with Z mass
  - Jets p_T > 20 GeV in $|\eta|$ < 2.5

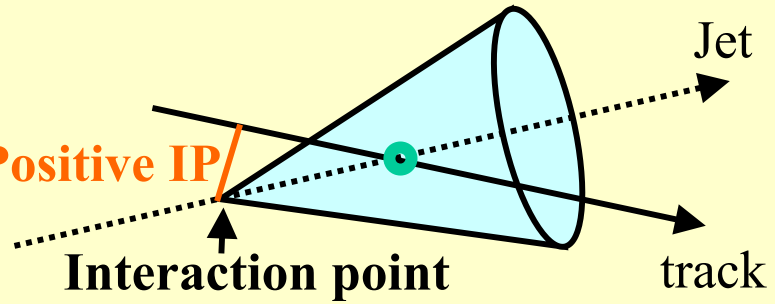




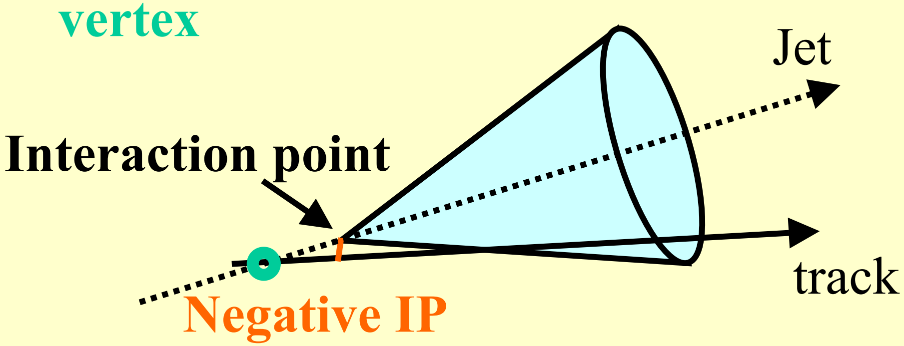
b-tagging

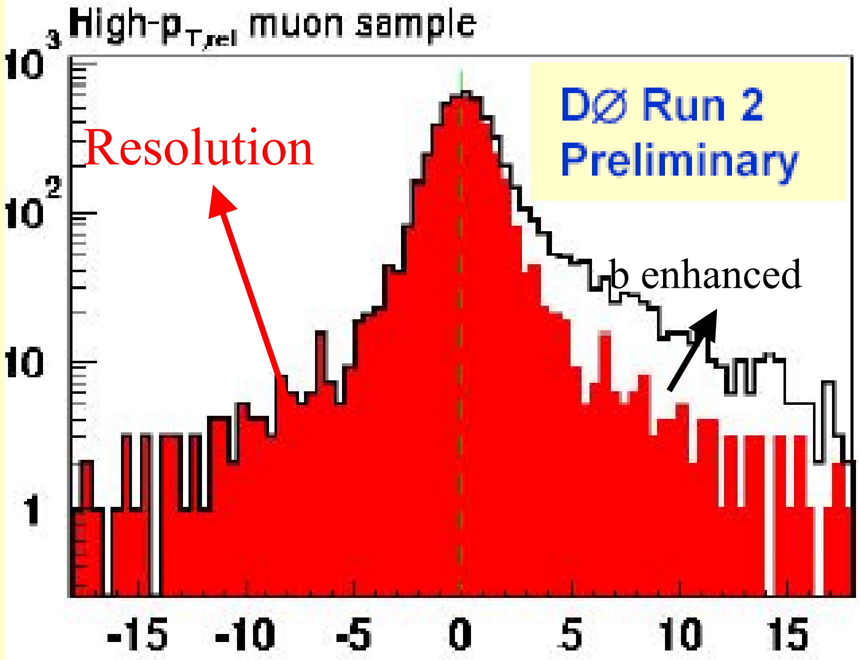
- b-tagging explores IP significance method
- Lepton from semileptonic decay of b is very useful

• Impact Parameter > 0
→ track crosses jet axis after primary vertex



• Impact Parameter < 0
→track crosses jet axis before primary vertex





Significance = IP/σ_{IP}

$H \to WW^{(*)} \to e^+e^-\nu\nu$ final states

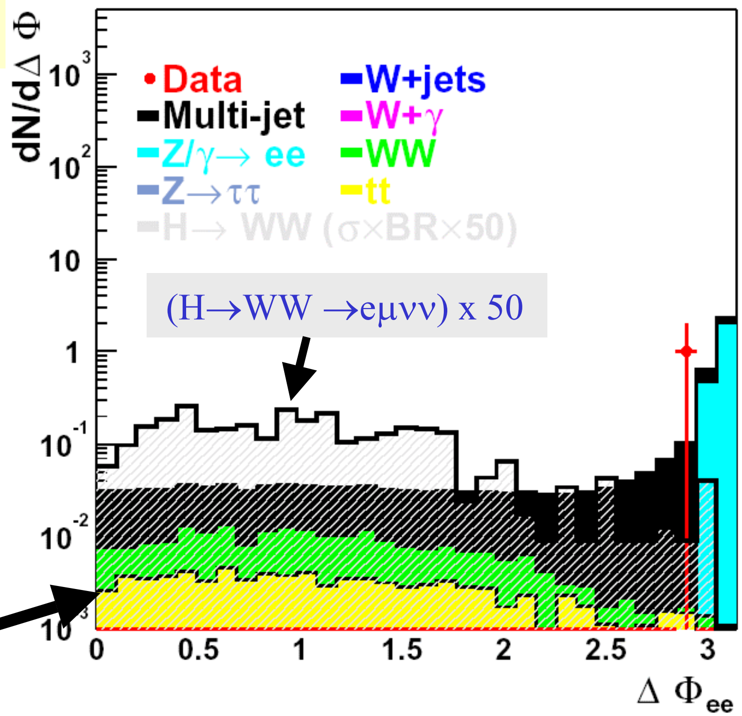
L=44.5 pb^{-1}

Selection optimized for m_H = 120 GeV

Efficiency = ~ 8%

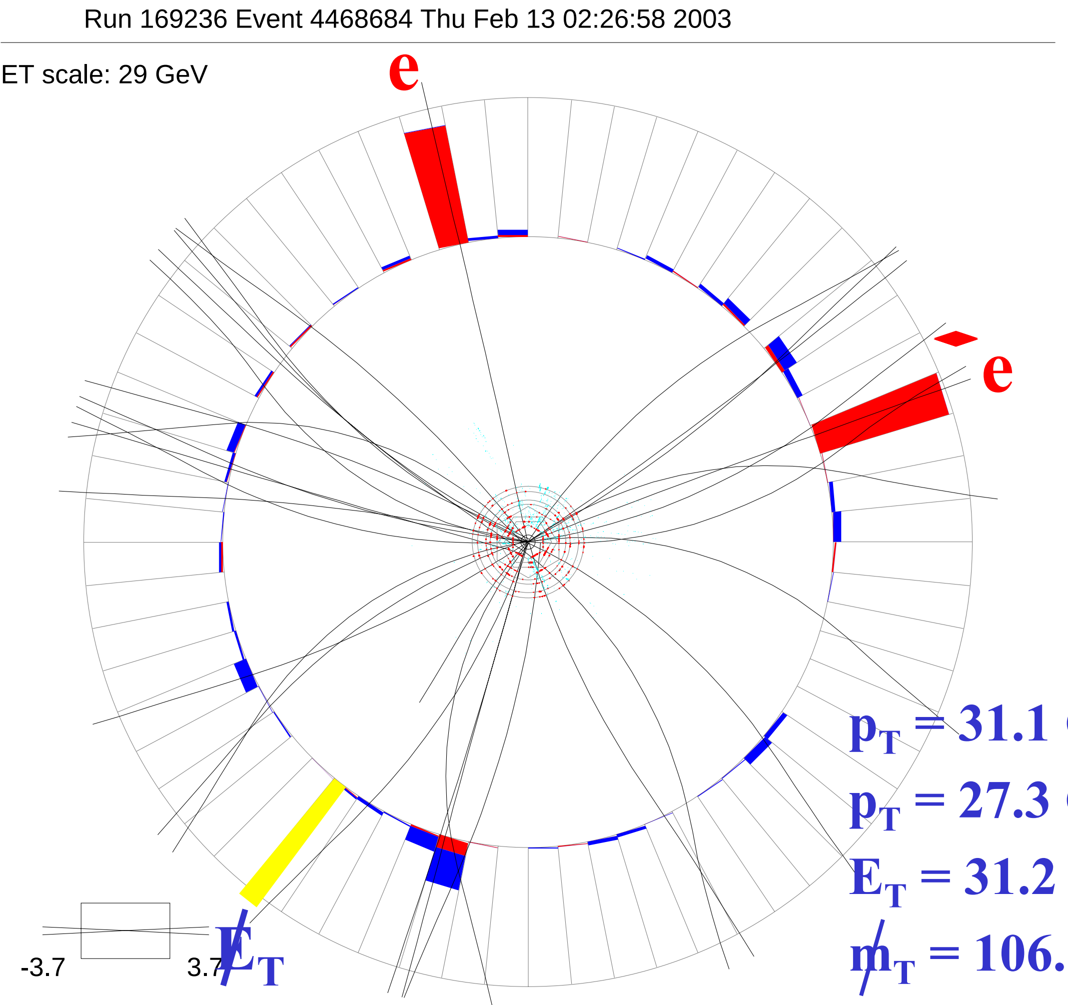
Event selection	Expected background	DATA
Lepton ID, p_T>10, 20 GeV	2748 ± 42 ± 245	2753
$m_{ee} < m_H/2$	264 ± 18.6 ± 4.3	262
$\not{E}_T$ > 20 GeV	12.3 ± 2.5 ± 0.7	11
$m_T < m_H$ + 20 GeV	3.6 ± 1.4 ± 0.2	1
$\Delta\Phi_{ee}$ < 2.0	0.7 ± 1.4 ± 0.1	0

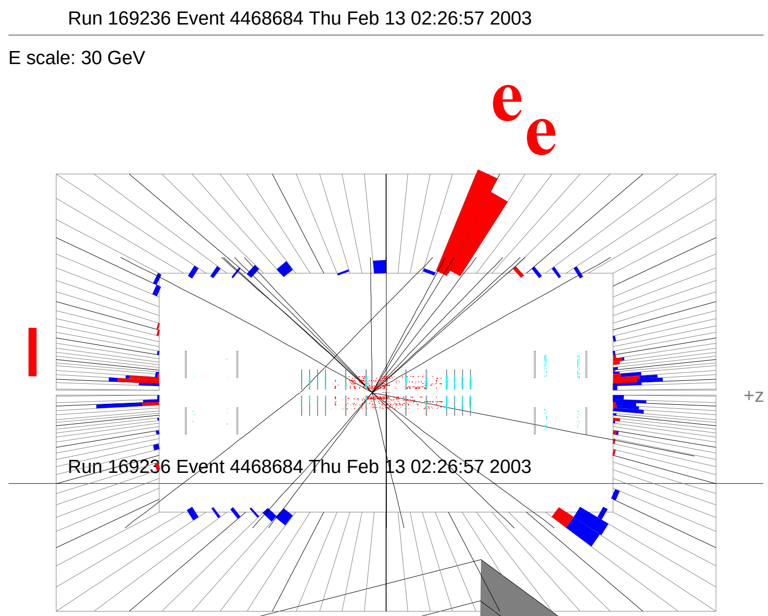
After all selection but $\Delta\Phi_{ee}$

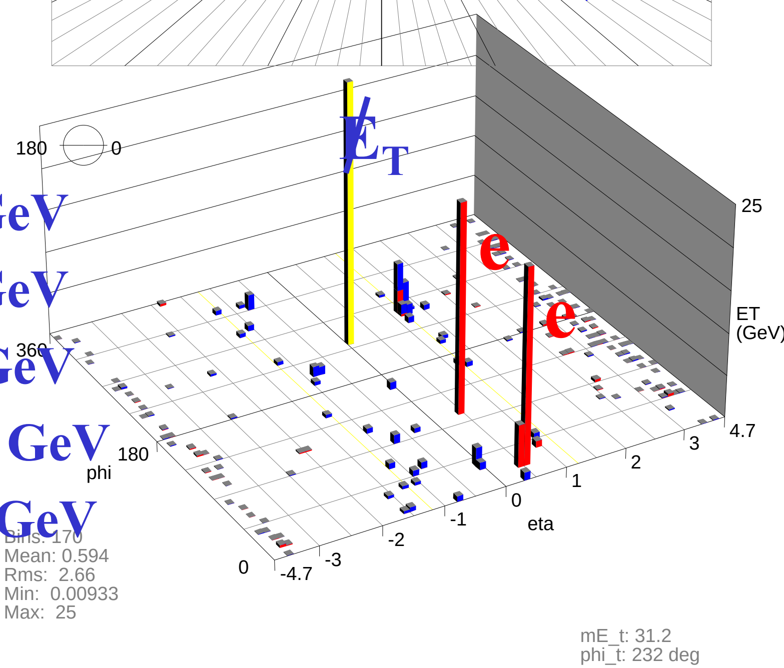


Expected Background

Candidate of $H \rightarrow WW^{(*)} \rightarrow e^+e^-\nu\nu$







$p_T = 31.1$ GeV

$p_T = 27.3$ GeV

$\not{E}_T = 31.2$ GeV

$\not{m}_T = 106.8$ GeV

$M_{ee} = 36.1$ GeV

$\Delta\Phi_{ee} = 1.43$

Summary

- DØ has been taking data since March 1, 2001
- The effects of increased center-of-mass energy and an improved detector can now be seen in improved sensitivity
- DØ continues to search for New Physics and Higgs