Recent Results from the D0 Experiment

DIS 2009, Madrid

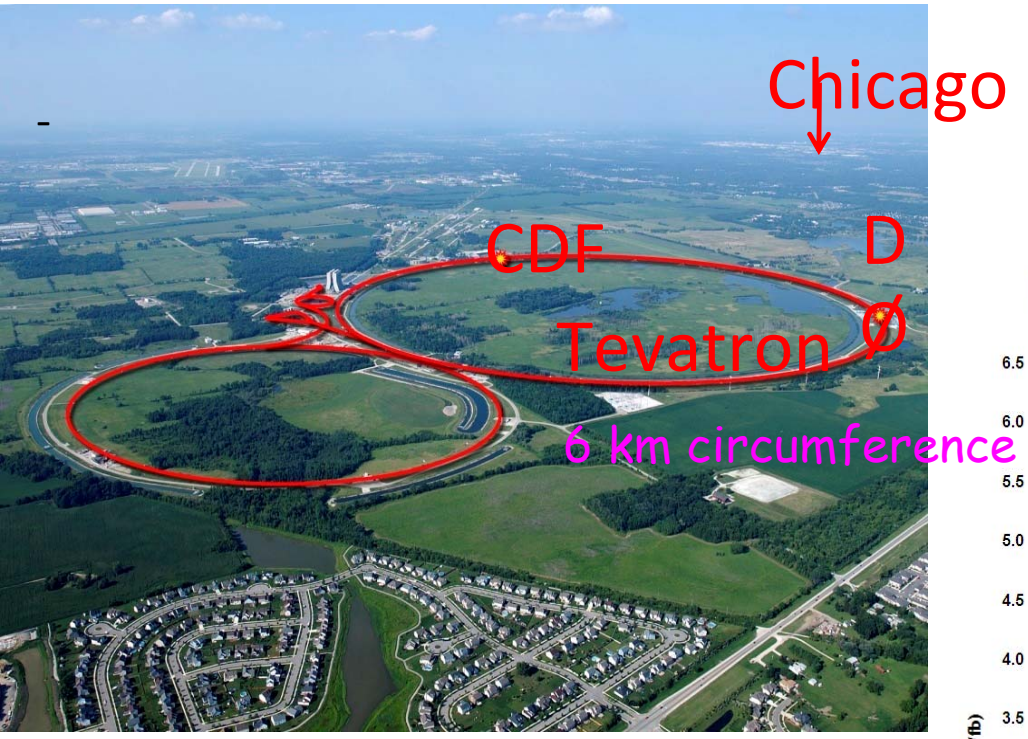
26-30 April 2009

R. Dean Schamberger

Outline

- Introduction
- Results with W's
  - W mass
  - W asymmetry
- Results in γ + Jets
- Results with Z's
  - Z $\rightarrow \nu\bar{\nu}$
- Results with Top's
  - Top Mass
  - Single Top
- Search for Susy in Tri-lepton final states
- Search for the Higgs
  - Multichannel combination Limit

Tevatron



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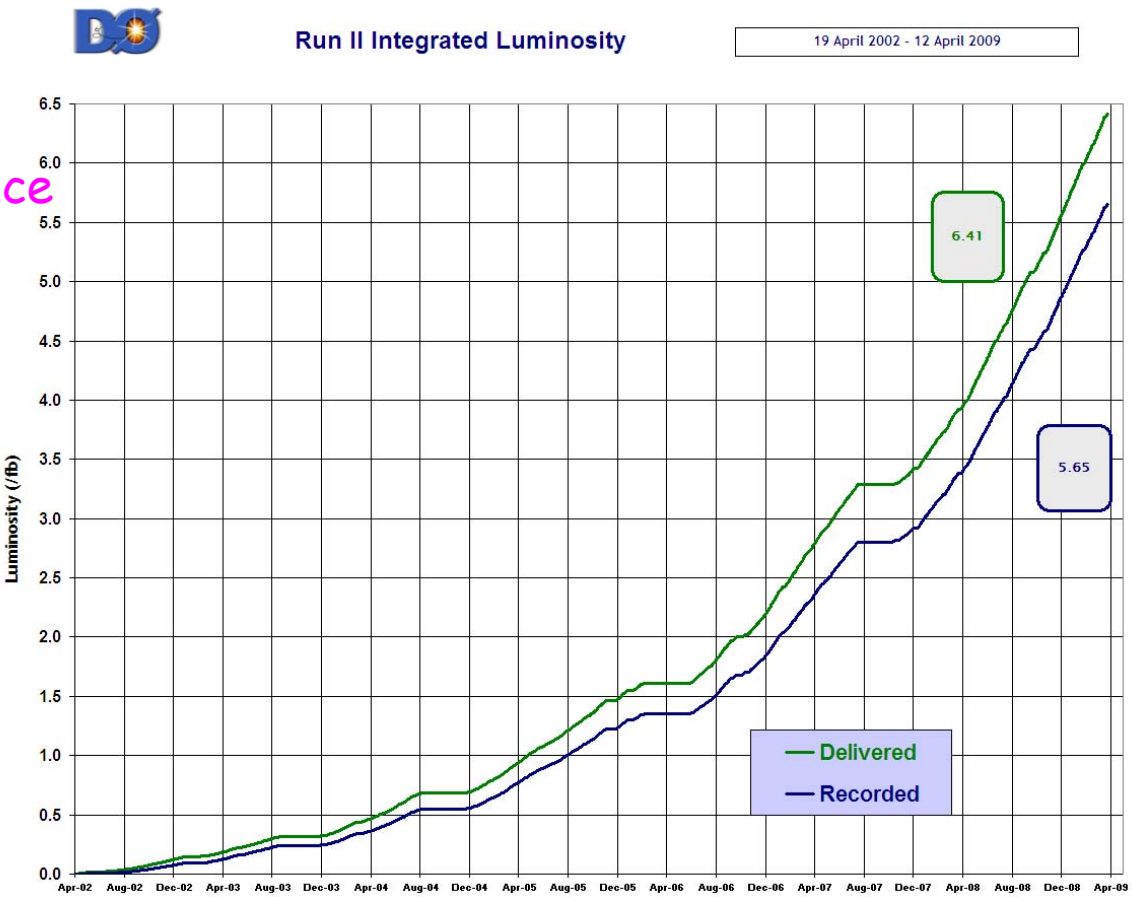
Proton-AntiProton collider at $\sqrt{s}$ =1.96 TeV

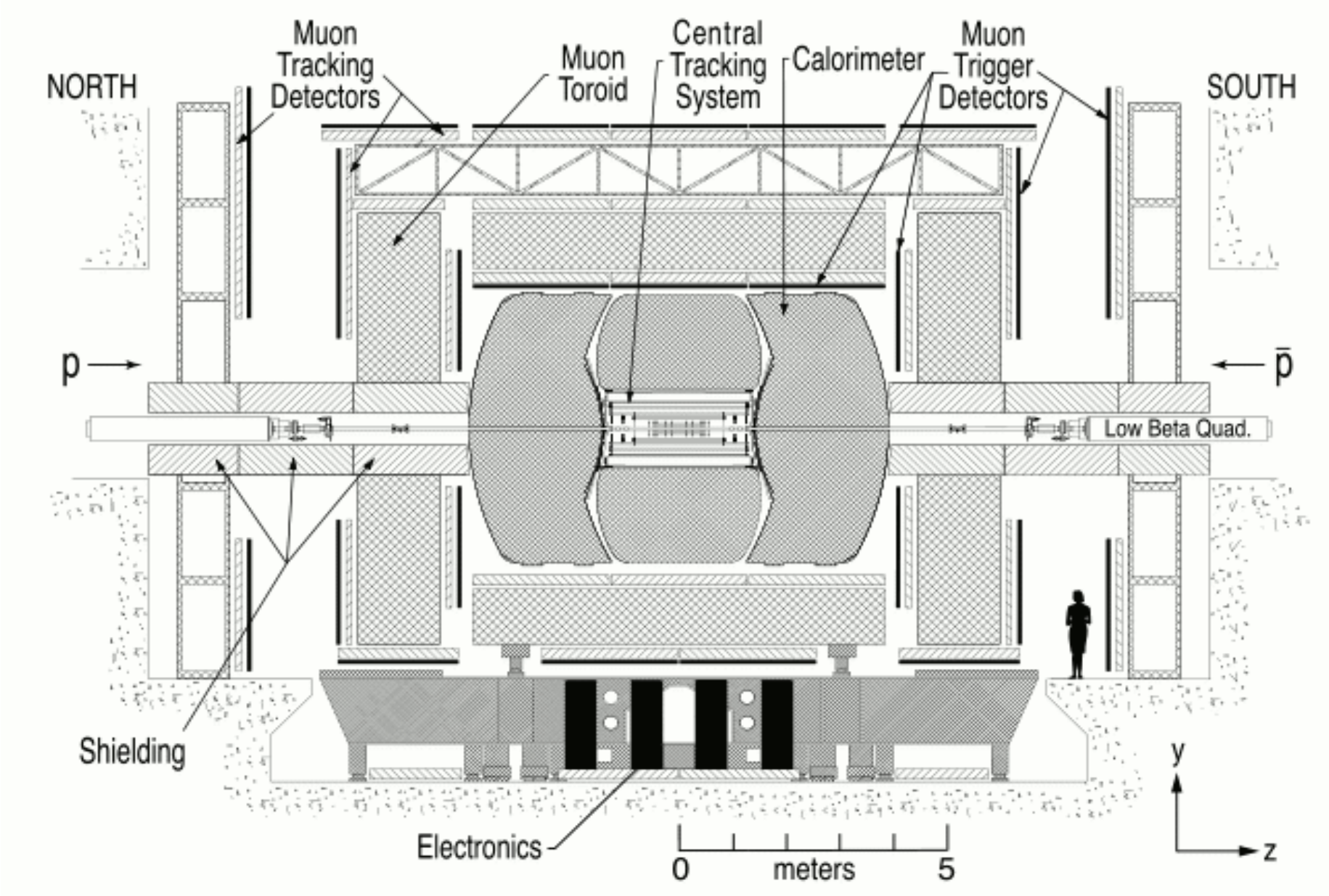
~6.5 fb^{-1} delivered

~5.7 fb^{-1} recorded

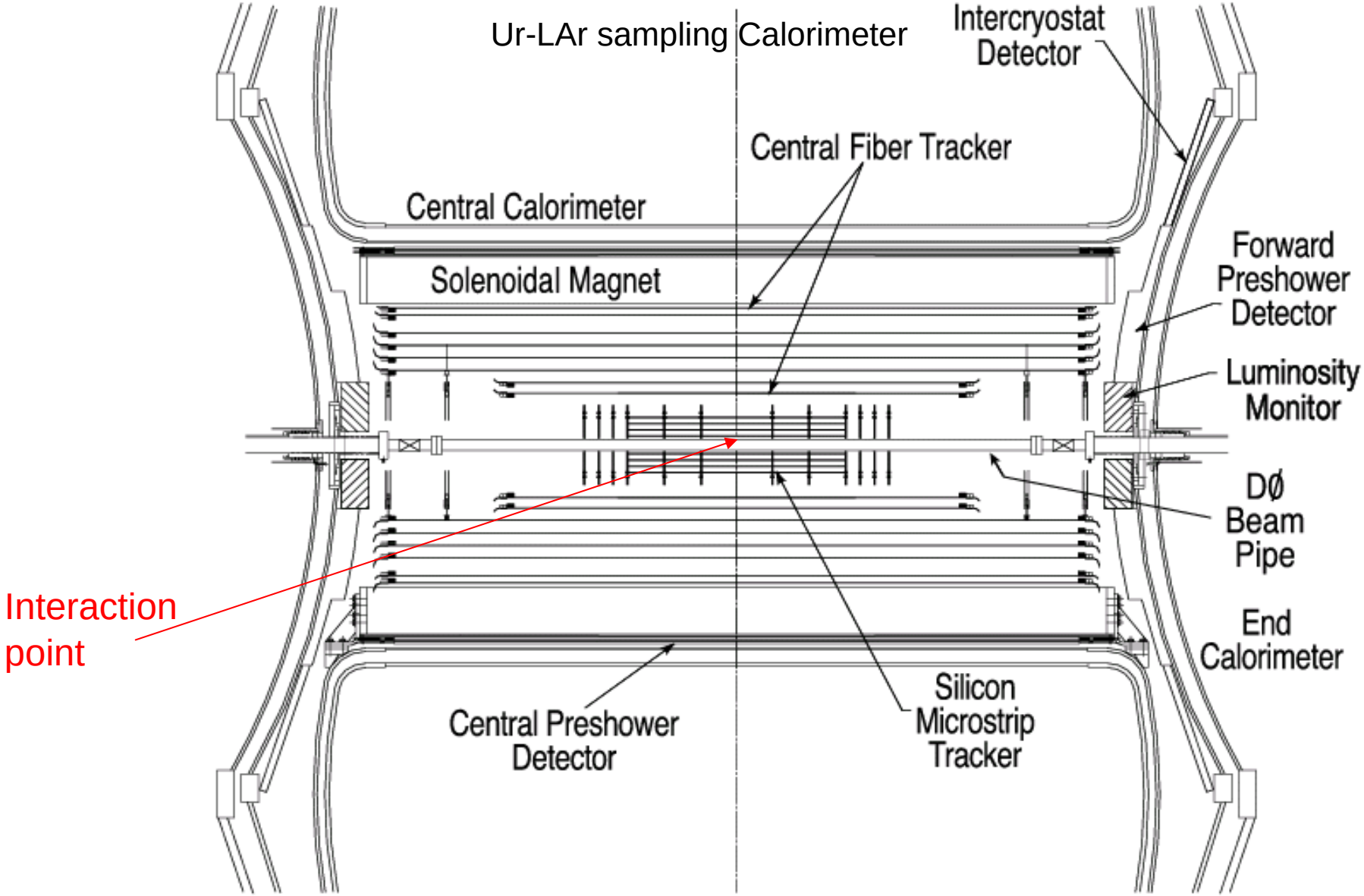
(~2 fb^{-1} in the last year alone)



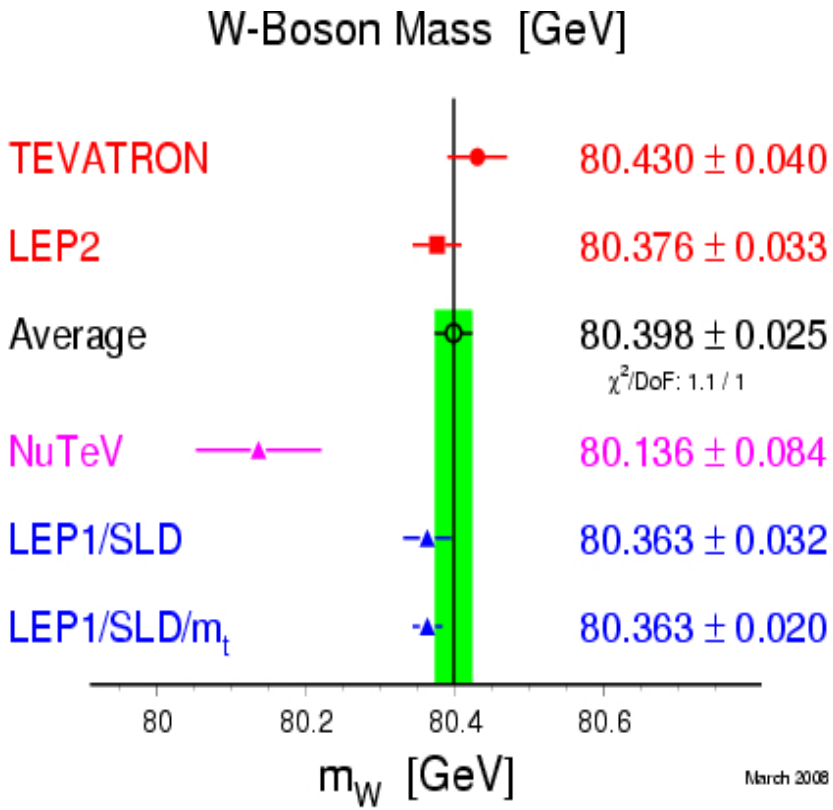
The upgraded Dzero detector

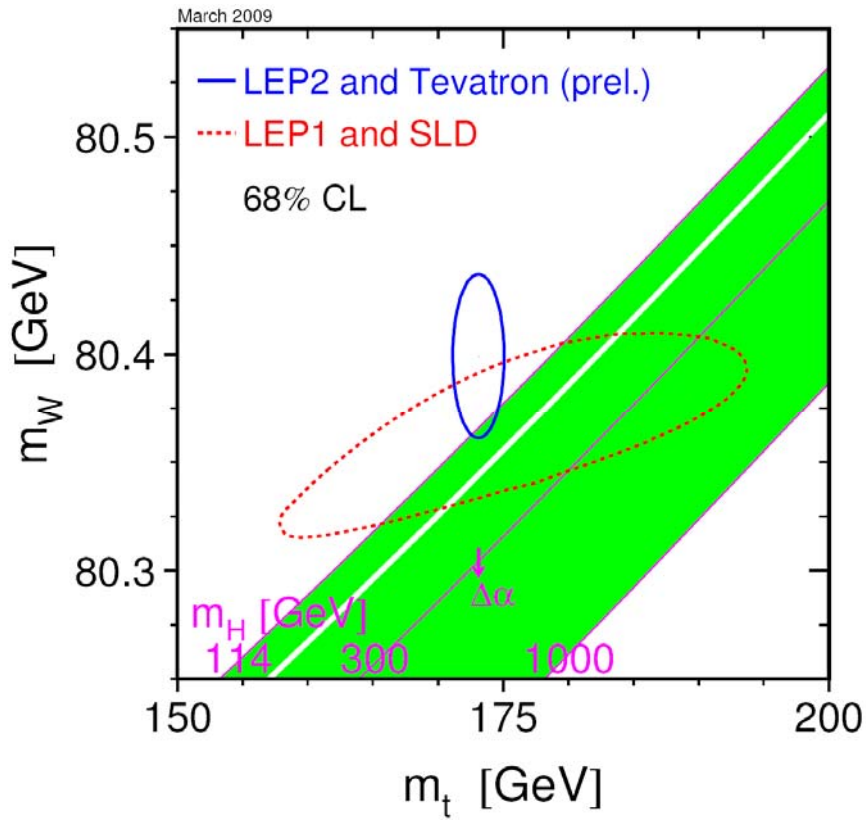


The upgraded Dzero detector



Precision W Mass



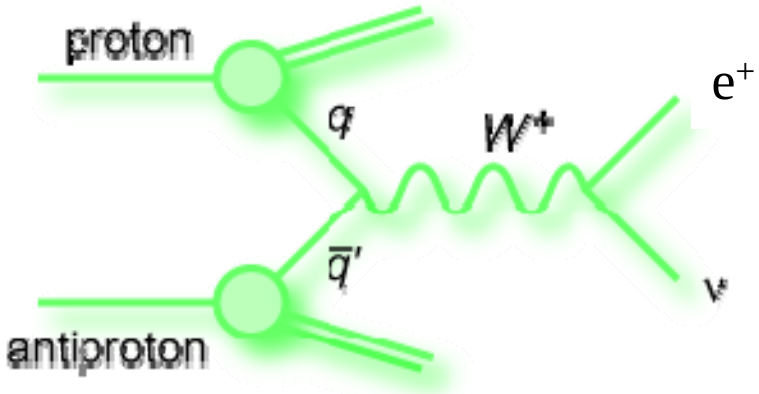


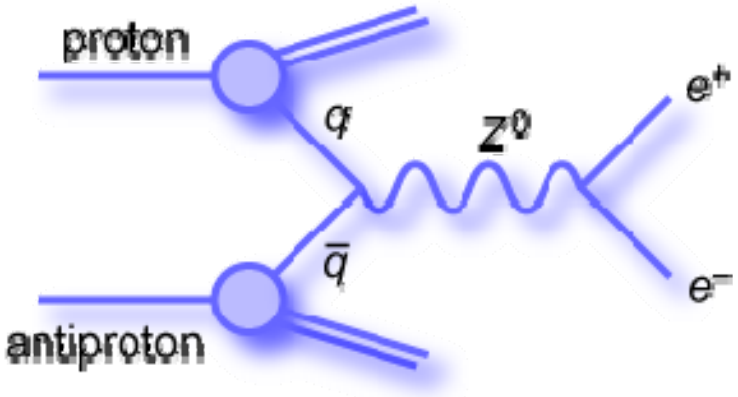
- **For equal contribution to the Higgs mass uncertainty we need:**
  $\Delta m_W \approx 0.006\ \Delta m_t$
- **Top quark mass is known with an uncertainty ~1.3 GeV, which requires $\Delta m_W \approx 8$ MeV, while currently $\Delta m_W \approx 25$ MeV. m_W is the limiting factor!**

$W \rightarrow e\nu$

1 fb^{-1} RunII data

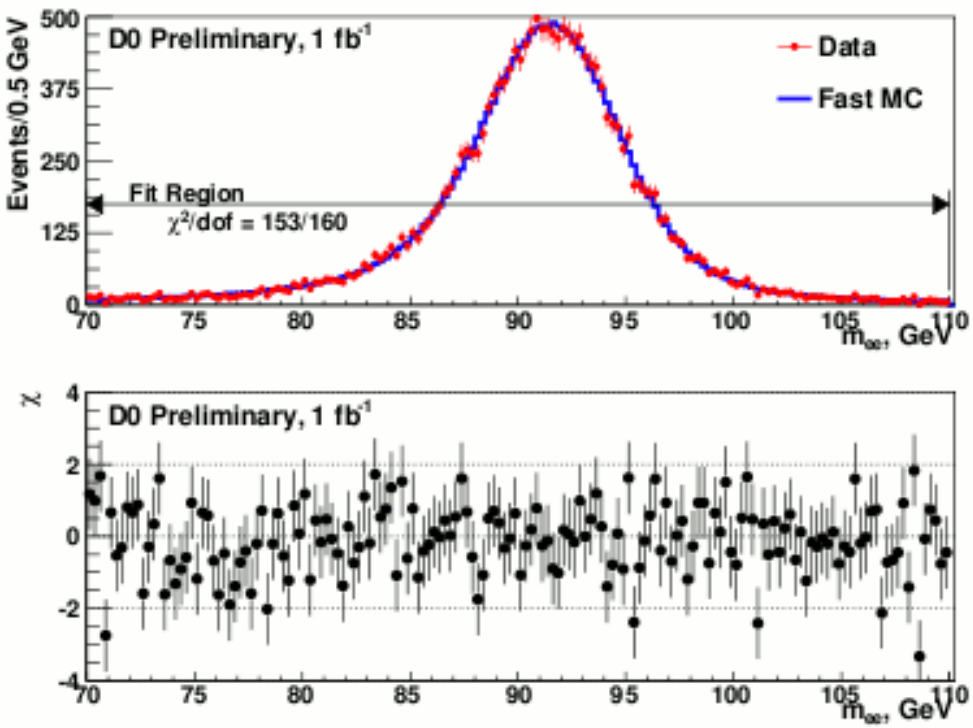
- Electron with $|\eta|<1.05$
- Track match
- $p_T^e > 25$ GeV
- Missing $E_T > 25$ GeV
- ~500K *W* and 18.7K *Z*
- Use the $Z \rightarrow ee$ to
  - Calibrate EM energy scale
  - Tune a fast parametrized Monte Carlo Simulation
- Fit the m_T, p_T^e, and MET distributions

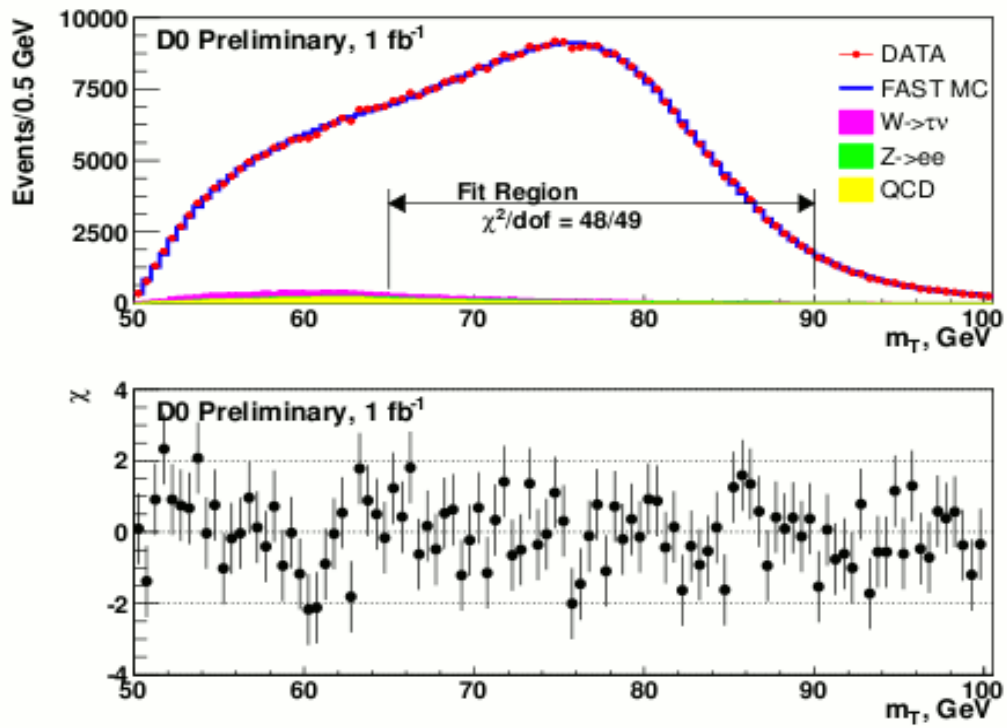




$$m_T = \sqrt{2E_T^l \not{E}_T (1 - \cos\Delta\phi)}$$

Mass fits (m_{ee} and m_T)





m_Z = 91.185 ± 0.033 GeV (stat)

(Z mass value from LEP was an input to electron energy scale calibration, PDG: m(Z) = 91.1876 ± 0.0021 GeV)

m_W = 80.401 ± 0.023 GeV (stat)

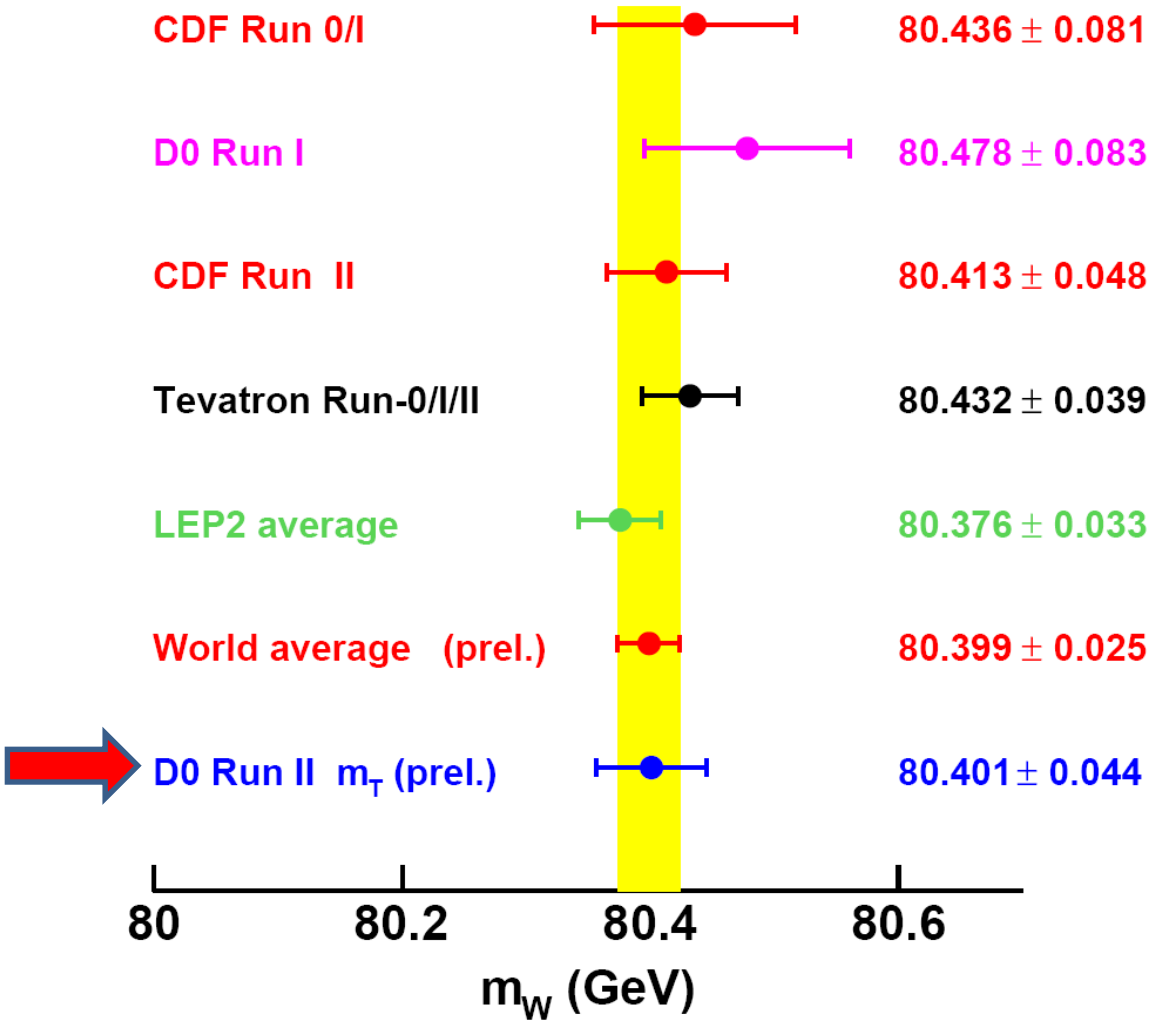
Summary of Uncertainties

systematic uncertainties

Source	$\sigma(m_W)$ MeV m_T	$\sigma(m_W)$ MeV p_T^e	$\sigma(m_W)$ MeV $\not{E}_T$
Experimental			
Electron Energy Scale	34	34	34
Electron Energy Resolution Model	2	2	3
Electron Energy Nonlinearity	4	6	7
W and Z Electron energy loss differences	4	4	4
Recoil Model	6	12	20
Electron Efficiencies	5	6	5
Backgrounds	2	5	4
Experimental Total	35	37	41
W production and decay model			
PDF	9	11	14
QED	7	7	9
Boson p_T	2	5	2
W model Total	12	14	17
Total	37	40	44
statistical	23	27	23
total	44	48	50

W Mass Results

80.401 ± 0.023(stat) ± 0.037(syst) GeV= 80.401 ± 0.044 GeV (M_T)
80.400 ± 0.027(stat) ± 0.040(syst) GeV= 80.400 ± 0.048 GeV (p_T^e)
80.402 ± 0.023(stat) ± 0.044(syst) GeV= 80.402 ± 0.050 GeV (MET)



- **Single most precise measurement of the *W* boson mass to date**
- **D0 result is in good agreement with previous measurements.**
- **PRL paper in the works**
- **Based on 1/6 of the data we already have recorded**

Electron Charge Asymmetry in $W \rightarrow e\nu$ + X events

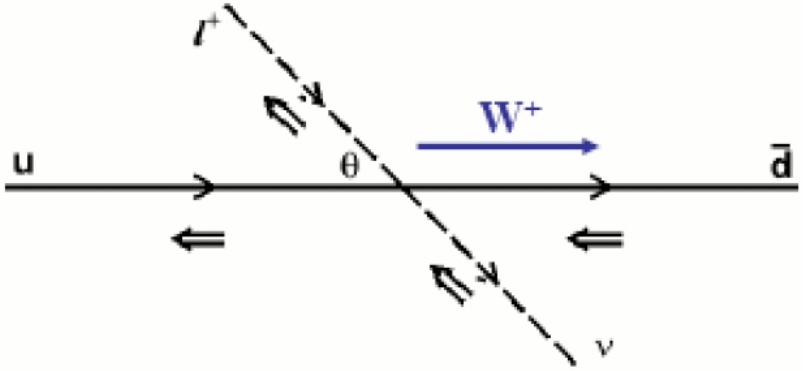
$W^{\pm}$ rapidity measurement constrains PDF of u and d quarks.

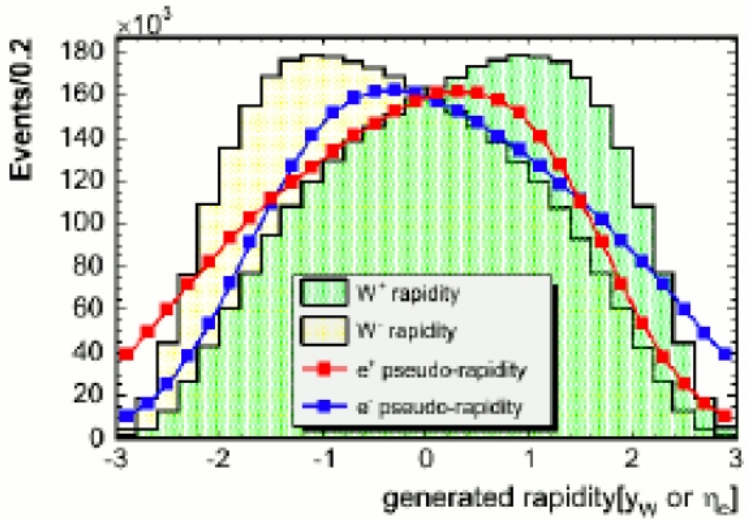
$$x_{1,2} = \frac{M_W}{\sqrt{s}} e^{\pm y}$$

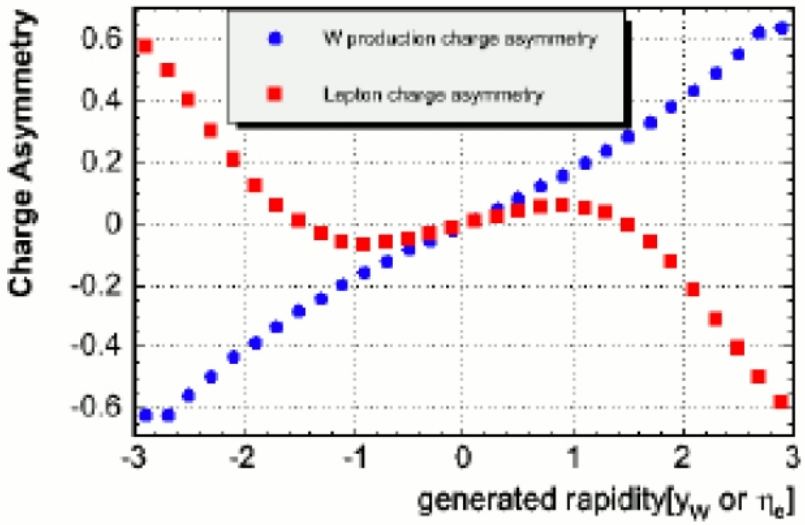
Different u, d momentum:
$W^{\pm}$ produced asymmetrically.

→ charge asymmetry of l, ν from W decay

But V-A interaction: **reduces** the observable **asymmetry** in the lepton rapidity distributions.



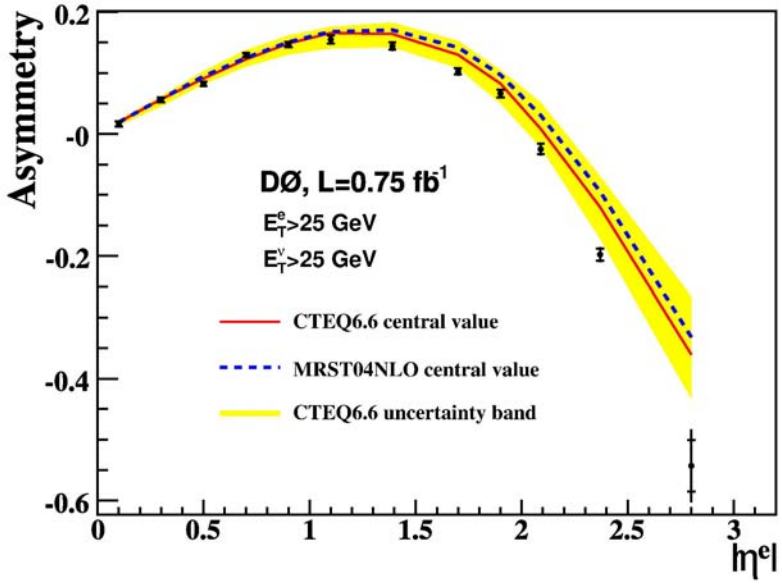


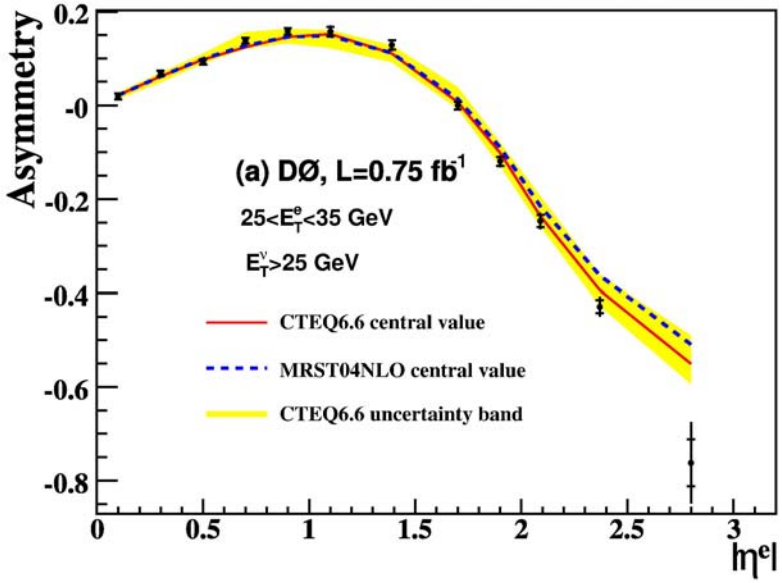


Electron Charge Asymmetry in $W \rightarrow e\nu$ + X events

PRL **101**, 211801 (2008)

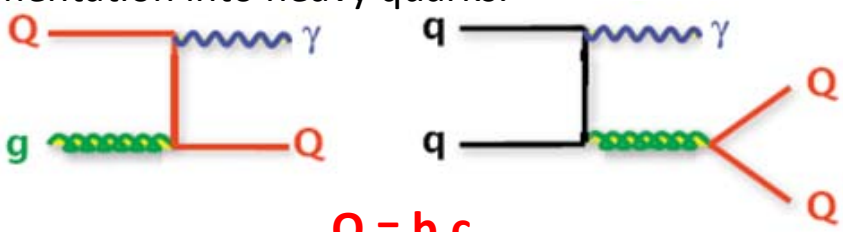
- 0.75 fb^{-1} RunII data
- $|\eta^e| < 3.2$
- Electron and Met > 25 GeV
- Track match for the electron
- $m_T > 50$ GeV
- Asymmetry measured in 24 η bins and two E_T^e bins
- Our data prefer a u(x)/d(x) ratio 5%-10% below PDF central values for x > 0.2





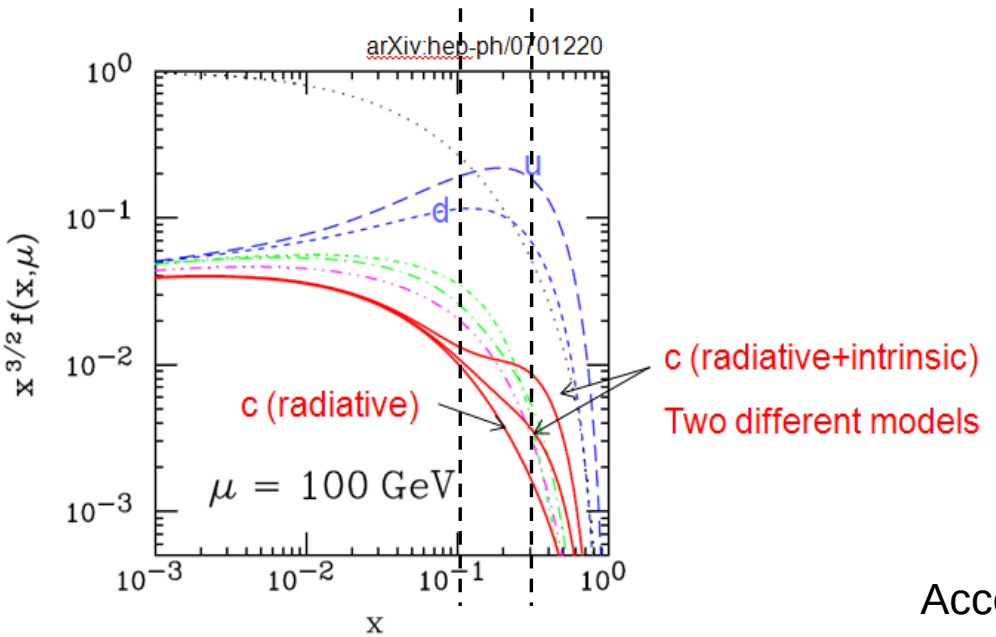
Vector Boson + Heavy Flavor Jets

- Sensitive to production mechanism and the heavy quark content of the proton. Also probes fragmentation into heavy quarks.

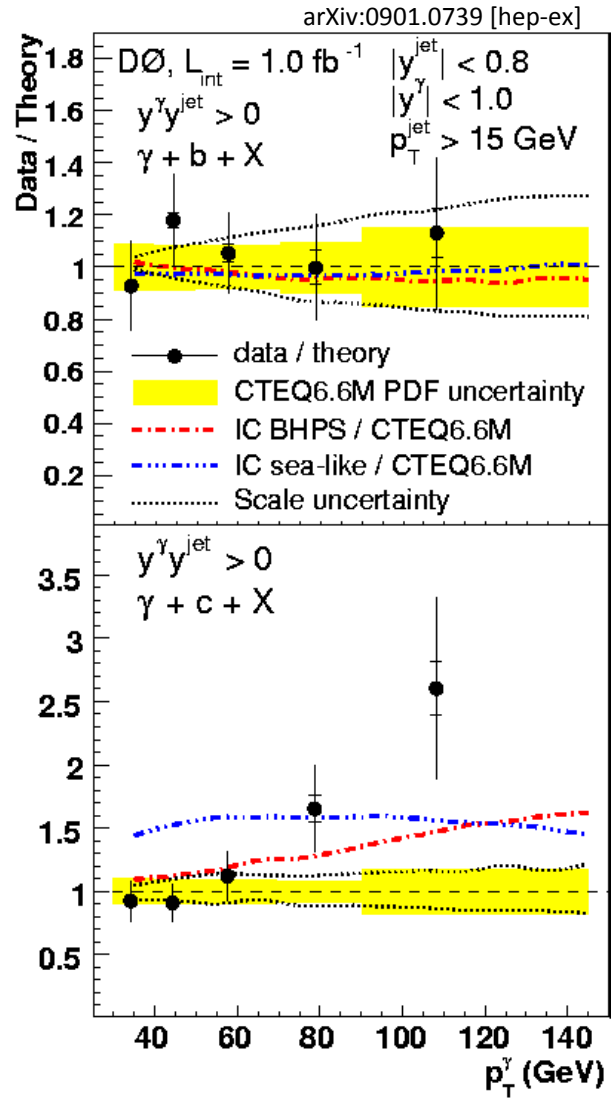


Q = b,c

- Is there an "intrinsic charm" (non-perturbative) component of the proton?



Region probed: $0.1<x<0.3$, $0.9\times10^3<Q^2<2\times10^4$ GeV^2



Accepted by PRL (2009), arXiv:/0901.0739

$Z\gamma \rightarrow \nu\bar{\nu}\gamma$ Observation

- First Observation of $Z\gamma \rightarrow \nu\bar{\nu}\gamma$ production at a hadron collider
- ~3.6/fb RunII data

SM NLO: $\sigma_{Z\gamma} = 39 \pm 4$ fb

Selected $Z\gamma$ candidate events:

Photons: Single EM object, E_T>90 GeV

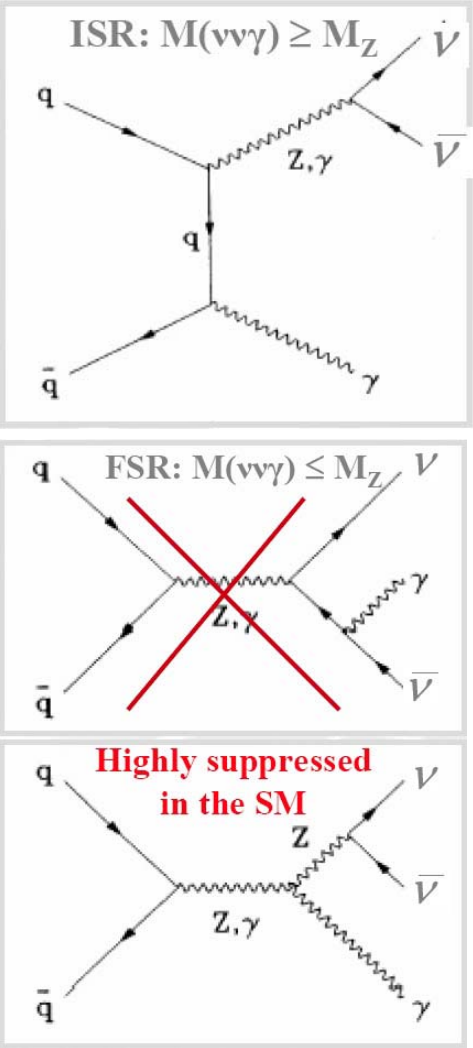
(central, $|\eta|<1.1$)

no second EM object E_T>15 GeV

no jets with E_T>15 GeV

MET > 70 GeV

Shower pointing to primary vertex



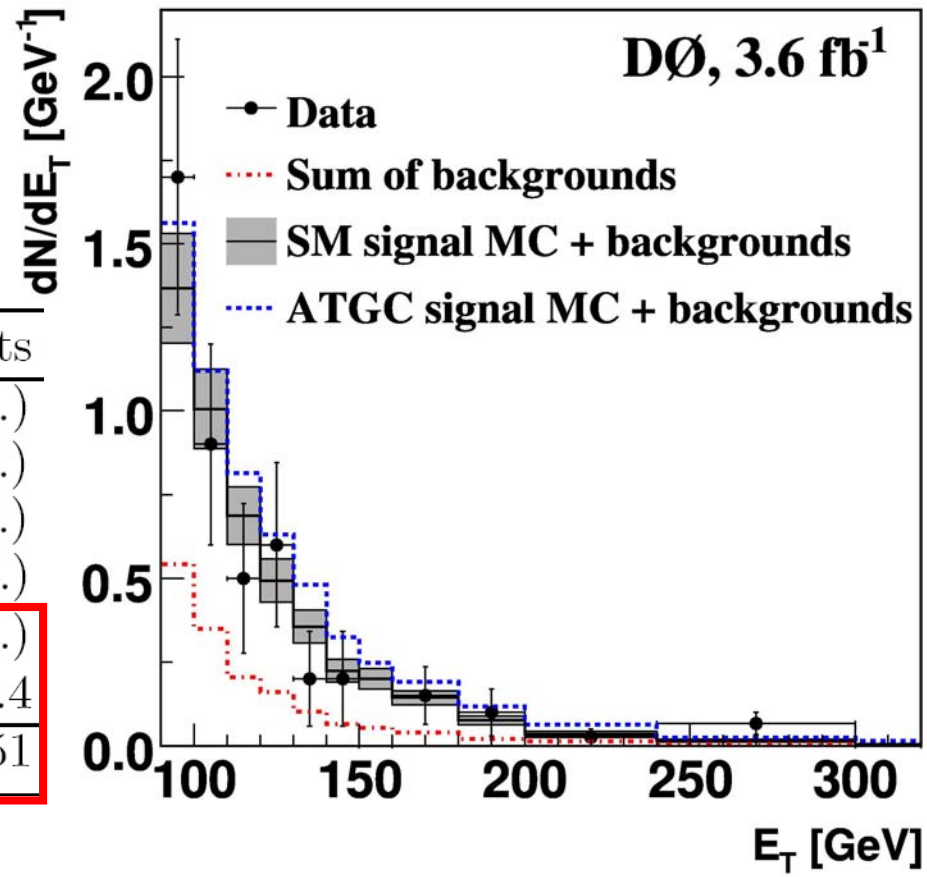
$Z\gamma \rightarrow \nu\bar{\nu}\gamma$ Observation

Submitted to PRL (2009),
hep-ex/0902.2157v1

$\Rightarrow$ Observed Significance 5.1 σ

$\sigma_{Z\gamma} = 32 \pm 9$ (stat+syst) ± 2 (lumi) fb

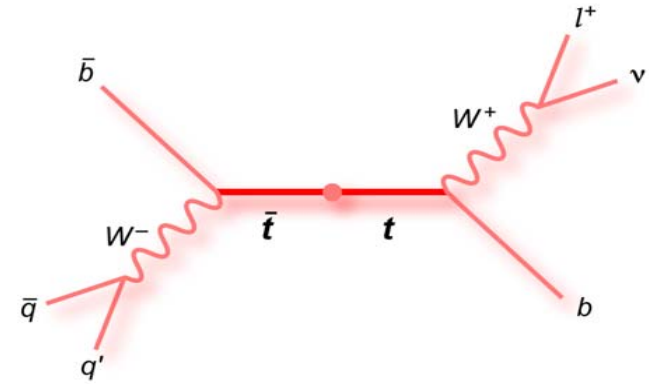
	Number of events
$W \rightarrow e\nu$	$9.67 \pm 0.30(\text{stat.}) \pm 0.48(\text{syst.})$
non-collision	$5.33 \pm 0.39(\text{stat.}) \pm 1.91(\text{syst.})$
W/Z + jet	$1.37 \pm 0.26(\text{stat.}) \pm 0.91(\text{syst.})$
$W\gamma$	$0.90 \pm 0.07(\text{stat.}) \pm 0.12(\text{syst.})$
Total background	$17.3 \pm 0.6(\text{stat.}) \pm 2.3(\text{syst.})$
$N^{\text{SM}}_{\nu\bar{\nu}\gamma}$	33.7 ± 3.4
N_{obs}	51



We have also looked for anomalous trilinear gauge boson couplings using this data and have set limits in the 10^{-2} to 10^{-3} range for Λ = 1.5 TeV

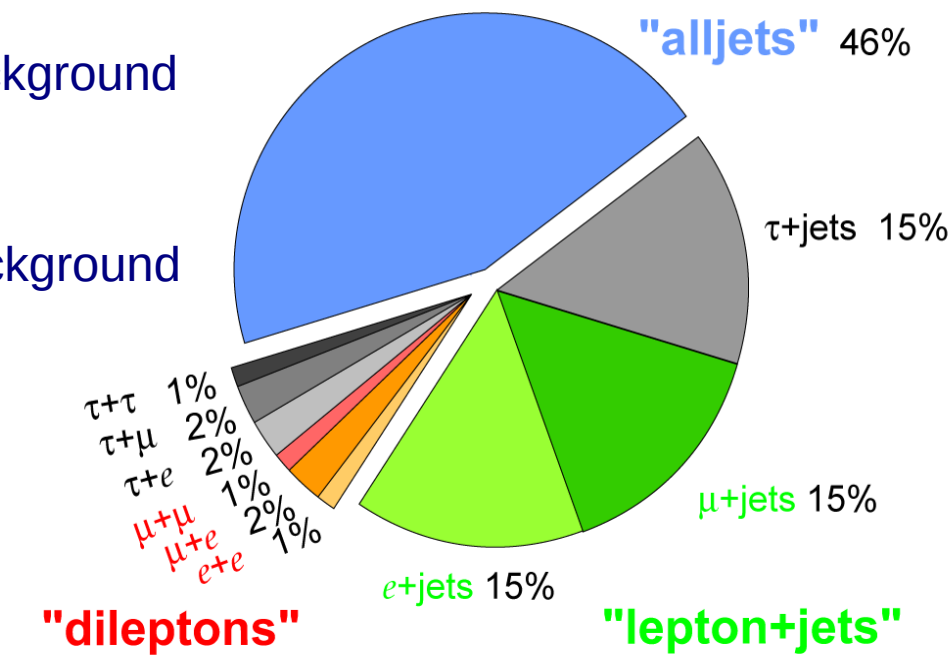
Top Quark Mass

- Top quark has a very short life-time ~ 10^{-25} sec
  $\Rightarrow$ decay before hadronisation
- In SM $|V_{tb}| \sim 1 \Rightarrow Br(t \rightarrow Wb) \sim 100\%$



- Dileptons:
  - e, μ, τ → e (μ) : ~ 6.5%, low background
  - τ → had + e (μ) : ~ 3.6%, reasonable background
- Leptons + jets,
  - e, μ, τ → e (μ) + jets ~ 35%, reasonable background
  - τ → had + jets ~ 9.5%, high background
- All jets ~ 46%, high background

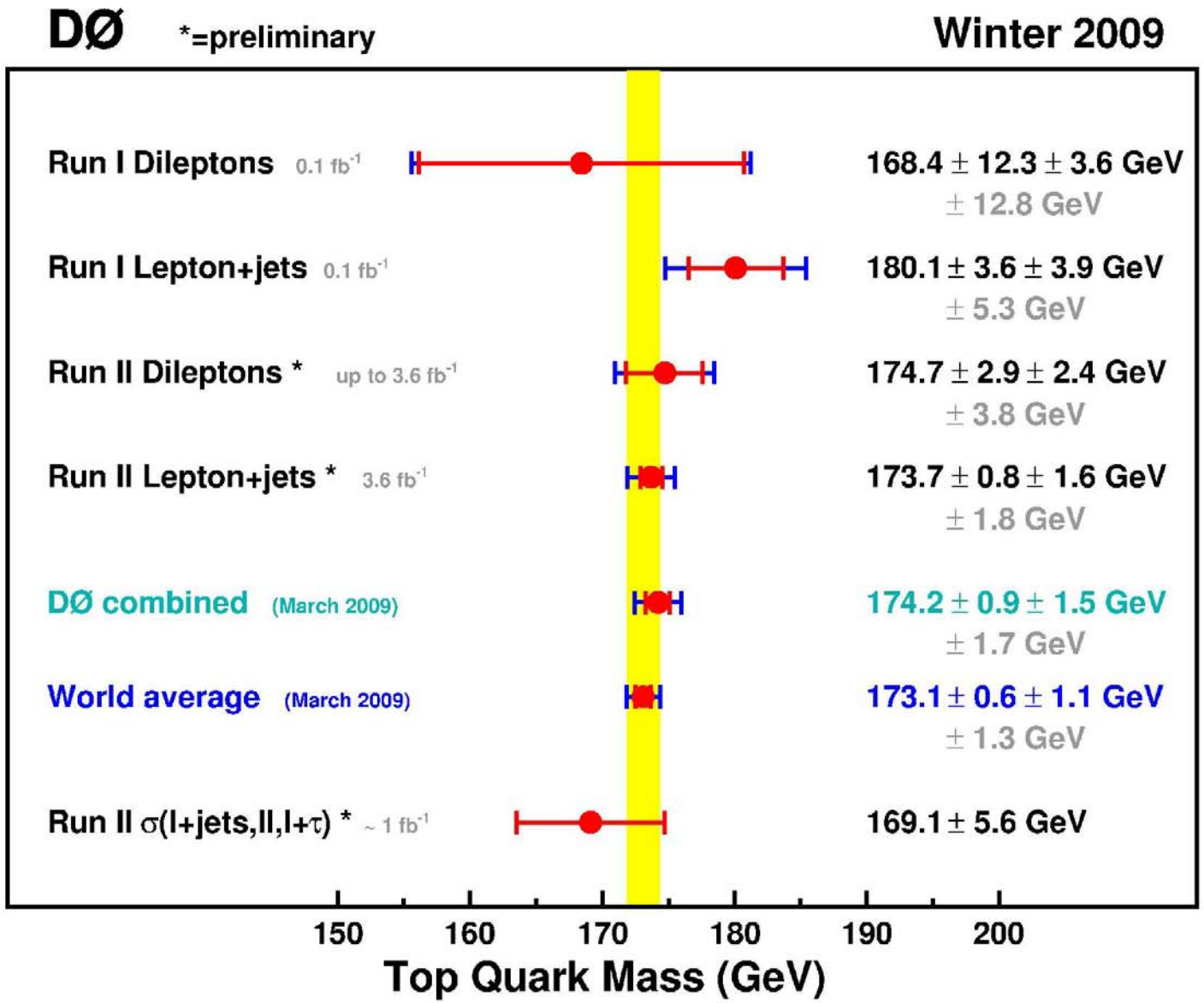
Top Pair Branching Fractions



Top Mass Measurement

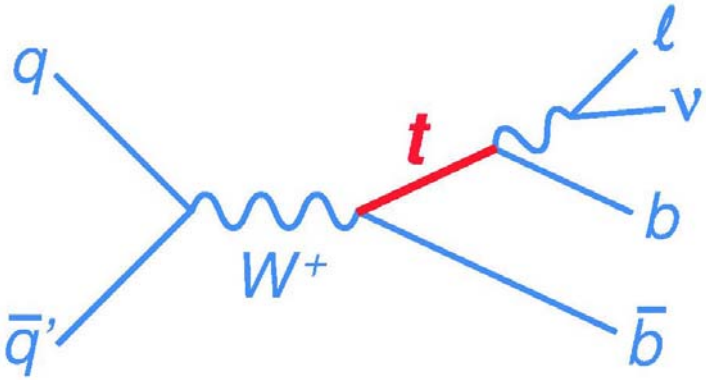
- Up to 3.6 fb^{-1} used
- Combined ℓ + jets channels
  - $m_{top}^{\ell + jets} = 173.7 \pm 0.8(stat) \pm 1.6\ (syst)$ GeV or $m_{top}^{\ell + jets} = 173.7 \pm 1.8$ GeV
- Combined di-lepton channels (*ee*, *e*μ, μμ and lepton + track)
  - $m_{top}^{\ell\ell} = 174.7 \pm 2.9(stat) \pm 2.4\ (syst)$ GeV or $m_{top}^{\ell\ell} = 174.7 \pm 3.8$ GeV

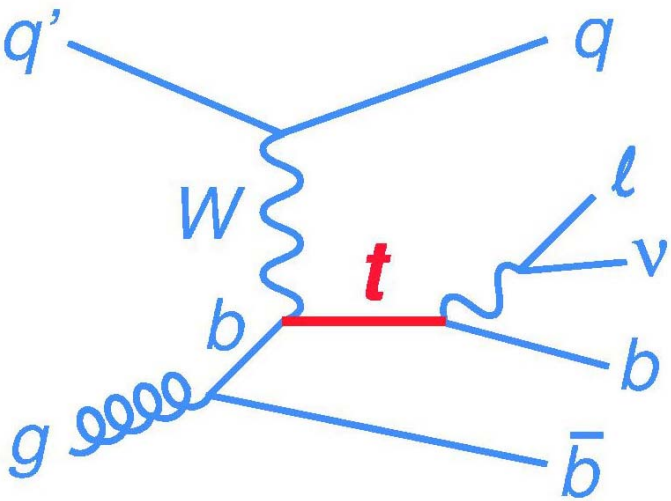
Combined Top Mass



Observation of Single Top

- About a factor of 2 below the t-tbar production
- Event selection
  - Isolated *e* or μ (p_T>15 GeV)
  - Missing E_T (20<MET<200) GeV
  - b jets (leading p_T>20 GeV)
- Consider 2,3 and 4 Jet events

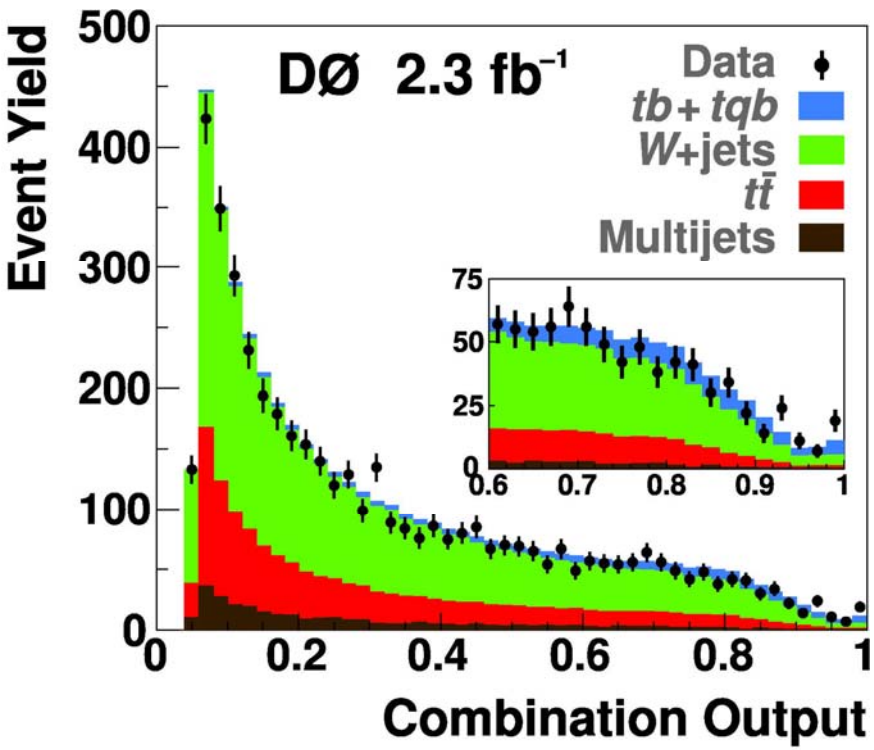


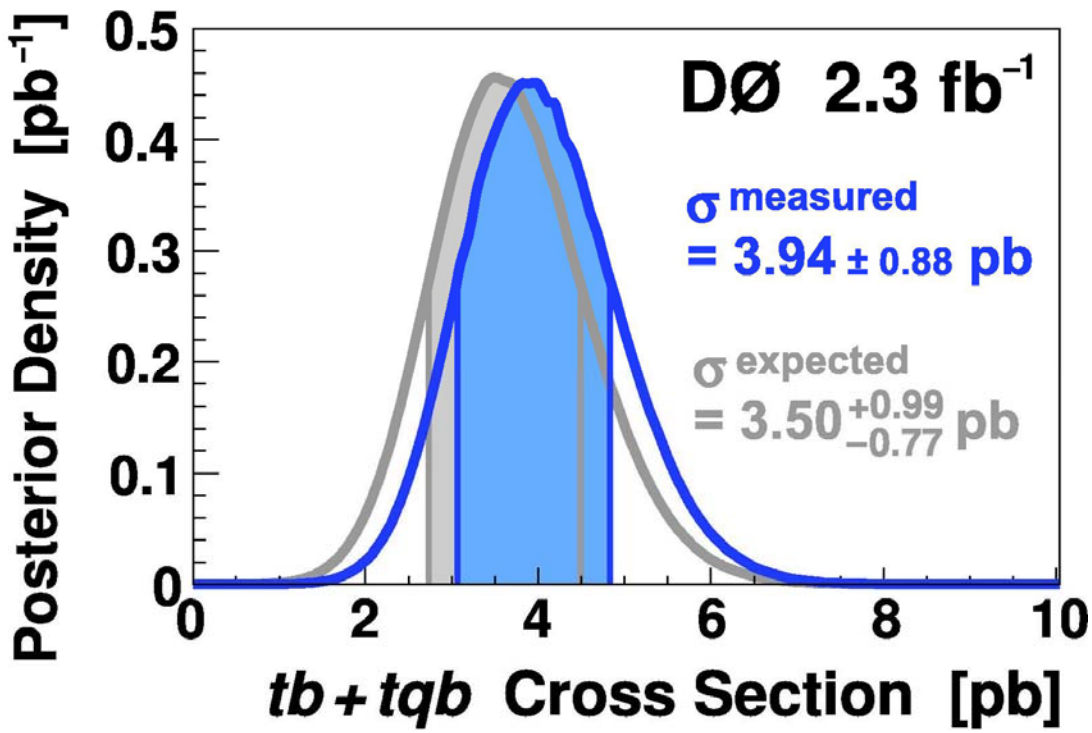


Observation of Single Top

$$\sigma(p\bar{p} \to tb + X, tqb + X) = 3.94 \pm 0.88 \text{ pb}$$

The probability of measuring a cross section at this value in the absence of signal is 2.5×10^{-7}, corresponding to a 5.0 standard deviation significance





$|V_{tb}| > 0.78$ at 95% C.L. When the upper constraint is removed we measure $|V_{tb} f_1^L| = 1.07 \pm 0.12$, where f_1^L is the strength of the left-handed Wtb coupling

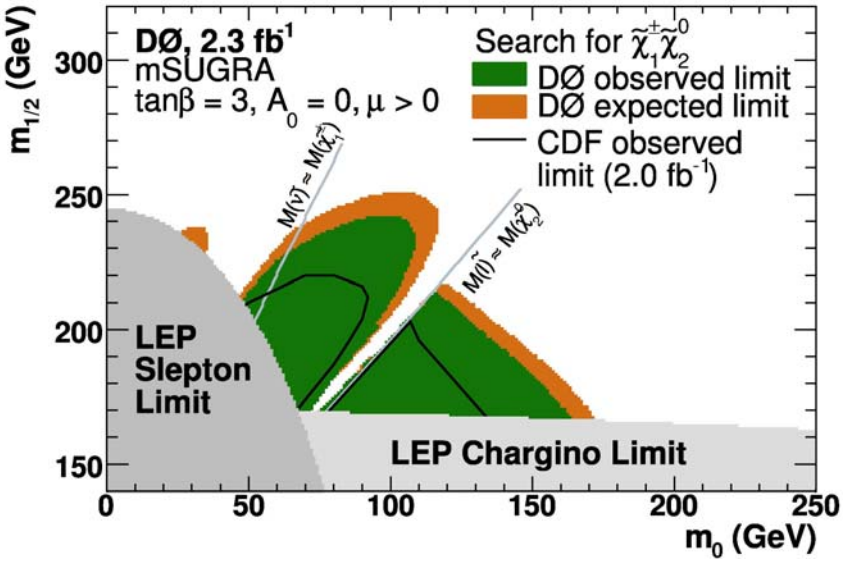
Submitted to PRL (2009), hep-ex/0903.0850

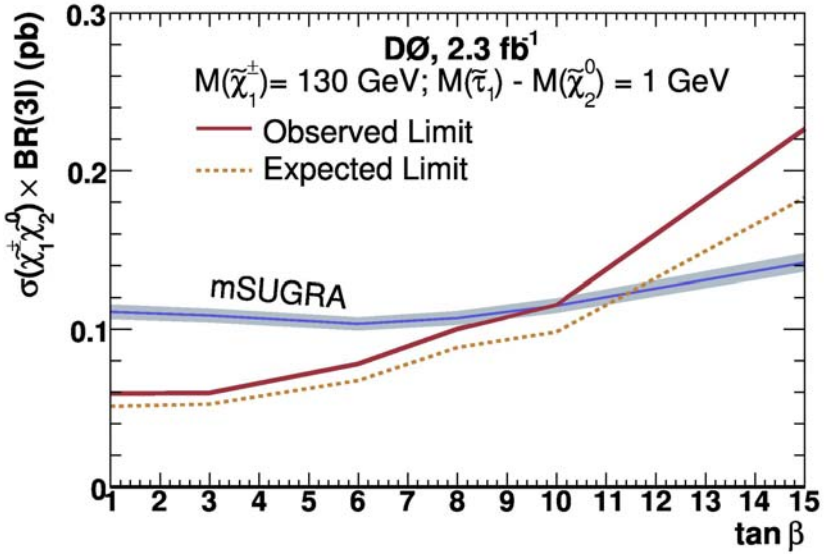
Submitted to PLB

arXiv:/0901.0739

Tri-lepton + Missing E_T

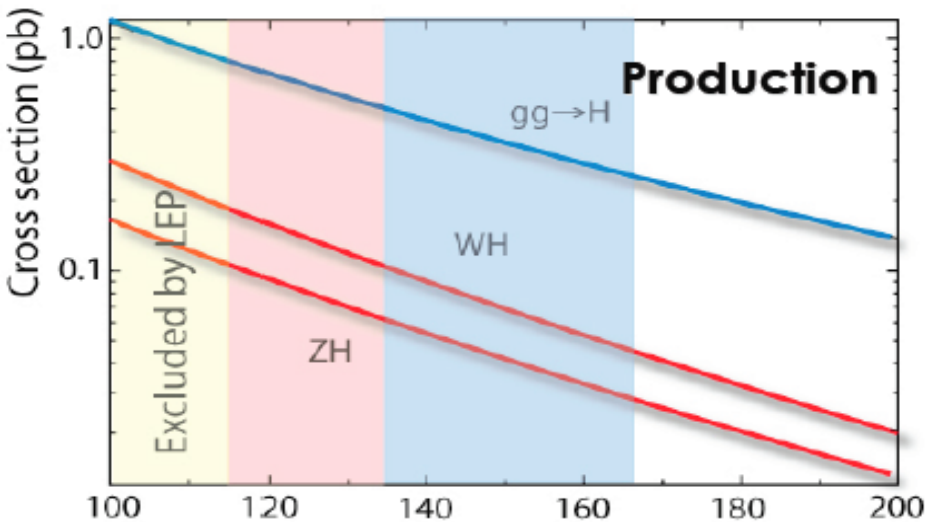
- 2.3 fb^{-1} RunII data
- 4 channels
  - Di-electron plus ℓ
  - Di-muon plus ℓ
  - Electron, muon plus ℓ
  - Muon, τ Lepton plus ℓ
- Highest p_T lepton >12 GeV
- Second lepton > 8 GeV
- ℓ =Isolated track only to keep high lepton efficiency

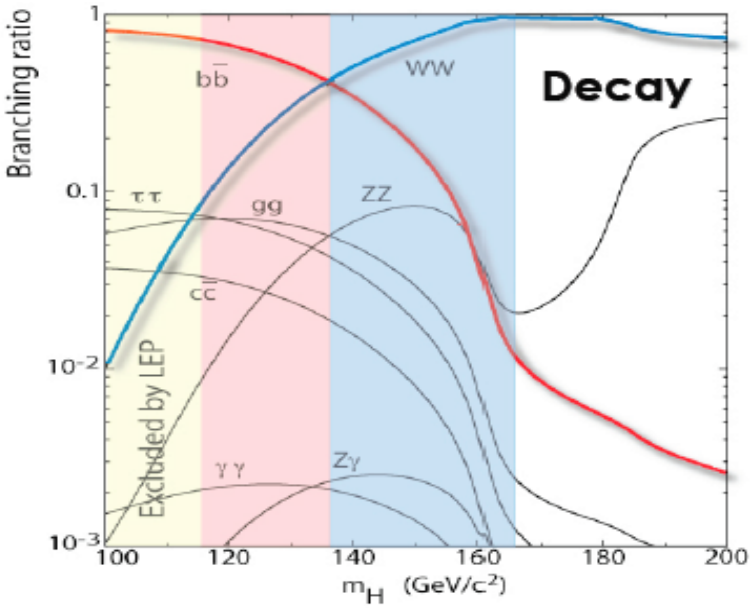




Searching for the Higgs

Expect M_{higgs} between 115 and 185 GeV
Accessible to the Tevatron





- High mass: H→WW→ℓνℓν decay available
  - Take advantage of large gg→H production cross section, ZZ in progress
- Low Mass: H→bb, QCD bb background overwhelming
  - Use associated production with W or Z for background discrimination
  - WH→ℓνbb, ZH→ννbb (MET+bb), ZH→ℓℓbb
  - Also: VBF Production, VH→qqbb, H→ τ τ(with 2jets), H→γγ, WH->WWW, ttH

List of analysis channels

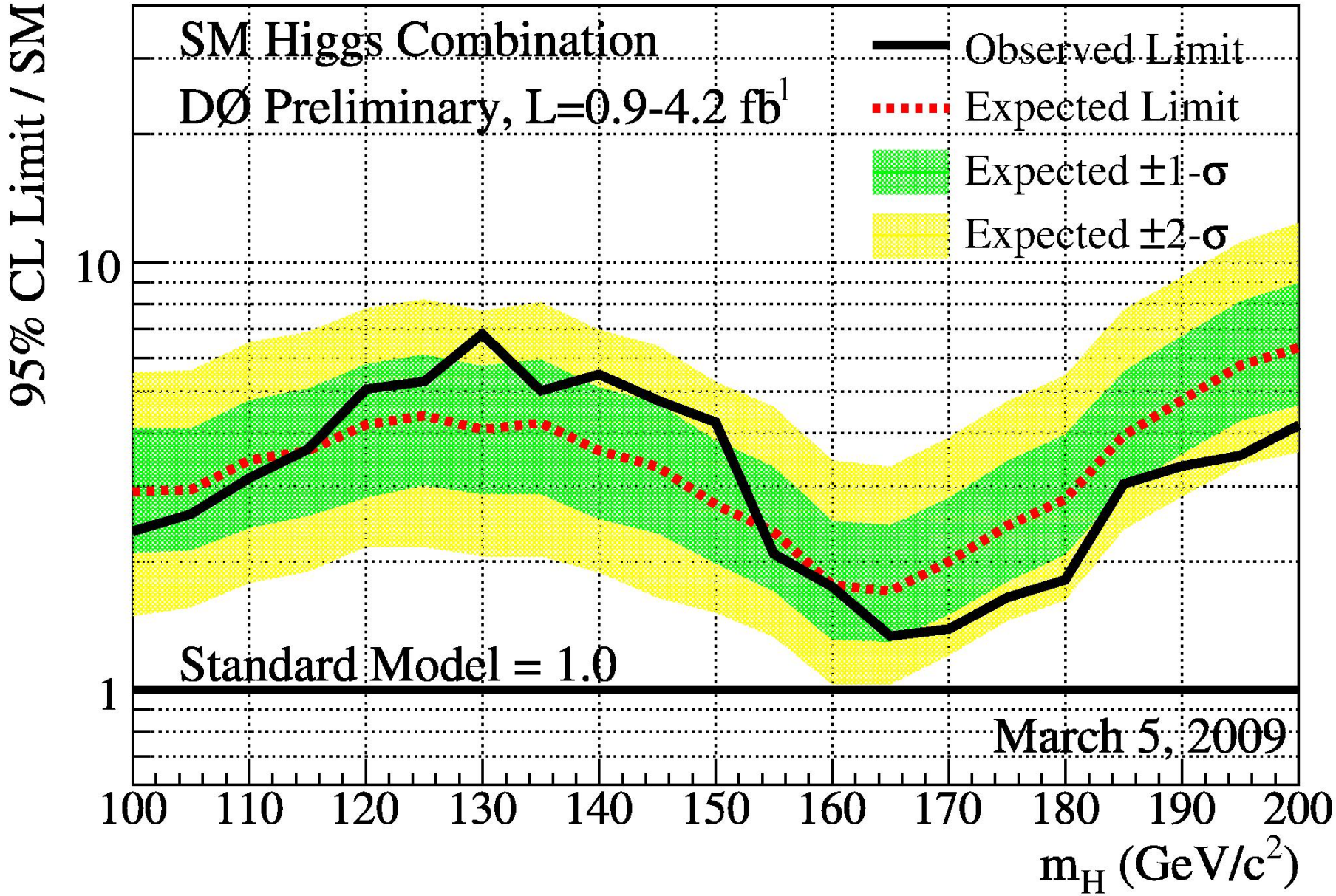
Channel	Data Epoch	Luminosity (fb^{-1})	Final Variable	# Sub-Channels
$WH \to \ell\nu bb$, ST/DT, W+2 jet	Run IIa+Run IIb	2.7	NN discriminant	8
$WH \to \ell\nu b\bar{b}$, ST/DT, W+3 jet	Run IIa+Run IIb	2.7	Dijet Mass	8
$WH \to \tau\nu b\bar{b}$	Run IIa	0.9	Dijet Mass	5
$H+X \to \tau\tau b\bar{b}/q\bar{q}\tau\tau$	Run IIa	1.0	NN discriminant	1
$ZH \to \nu\bar{\nu}b\bar{b}$, DT	Run IIa+Run IIb	2.1	DTree discriminant	2
$ZH \to e^+e^-b\bar{b}$, ST/DT	Run IIa	1.1	NN discriminant	2
$ZH \to \mu^+\mu^-b\bar{b}$, ST/DT	Run IIa	1.1	DTree discriminant	2
$ZH \to e^+e^-b\bar{b}$, ST/DT	Run IIb	3.1	DTree discriminant	6
$ZH \to \mu^+\mu^-b\bar{b}$, ST/DT	Run IIb	3.1	DTree discriminant	2
$ZH \to \mu^\pm$+track $b\bar{b}$, ST/DT	Run IIa+Run IIb	4.2	DTree discriminant	2
$WH \to WW^+W^-$	Run IIa	1.1	2-D Likelihood	3
$WH \to WW^+W^-$	Run IIb	2.5	1-D Likelihood	3
$H \to W^+W^-$ ($\mu^+\mu^-$)	Run IIa+Run IIb	3.0	NN discriminant	1
$H \to W^+W^-$ ($e^\pm\mu^\mp$)	Run IIa+Run IIb	4.2	NN discriminant	1
$H \to W^+W^-$ (e^+e^-)	Run IIa+Run IIb	4.2	NN discriminant	1
$H \to \gamma\gamma$	Run IIa+Run IIb	4.2	Di-photon Mass	1
$t\bar{t}H \to t\bar{t}b\bar{b}$	Run IIa+Run IIb	2.1	Scaled H_T	12

Total Sub-Channels 60

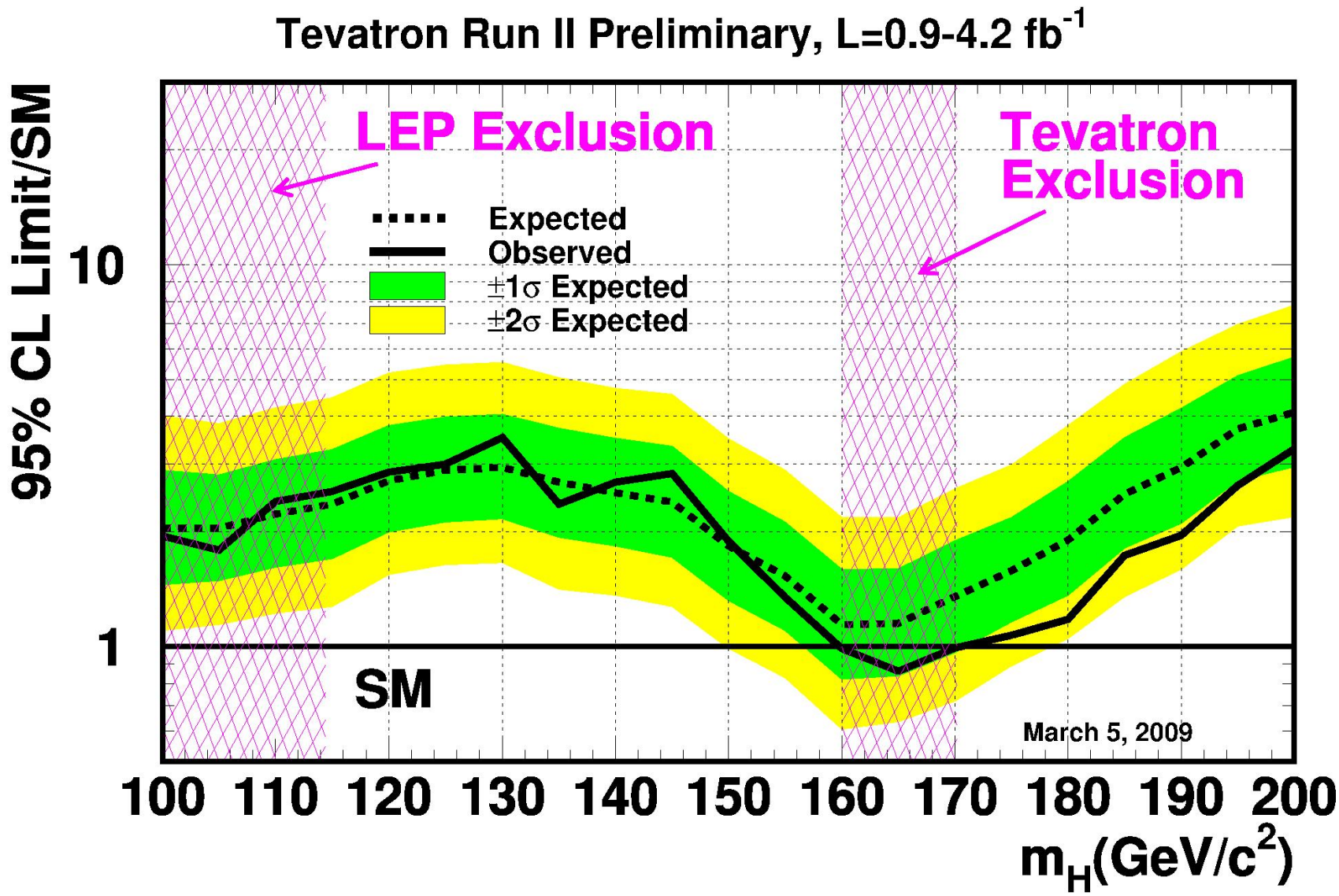
TABLE I: List of analysis channels, corresponding integrated luminosities, and final variables. The final variable used for several analyses is a neural-network or boosted decision-tree discriminant output which is abbreviated as “NN discriminant” and “DTree discriminant”, respectively.

Also usefully for Beyond the Standard Model Searches

D0 Combine Higgs Limit



TeV Combined Higgs limit

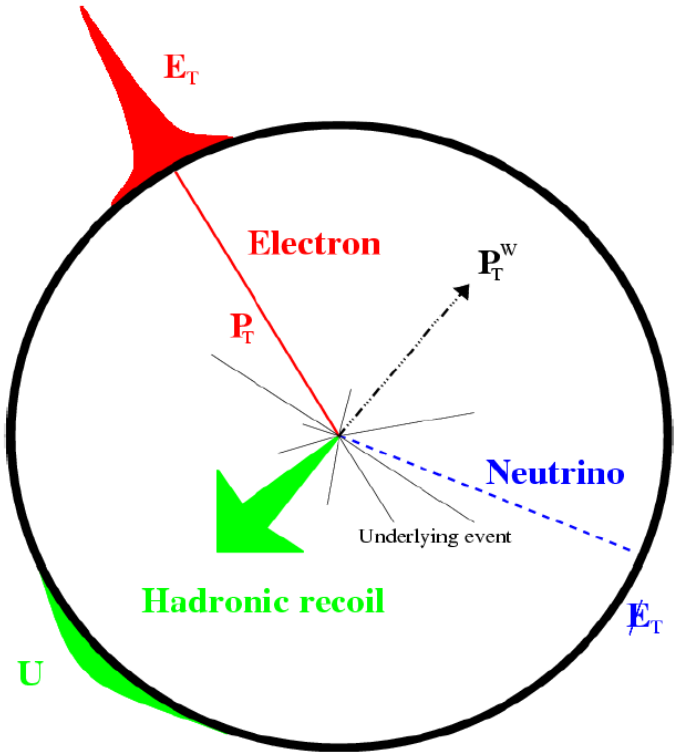


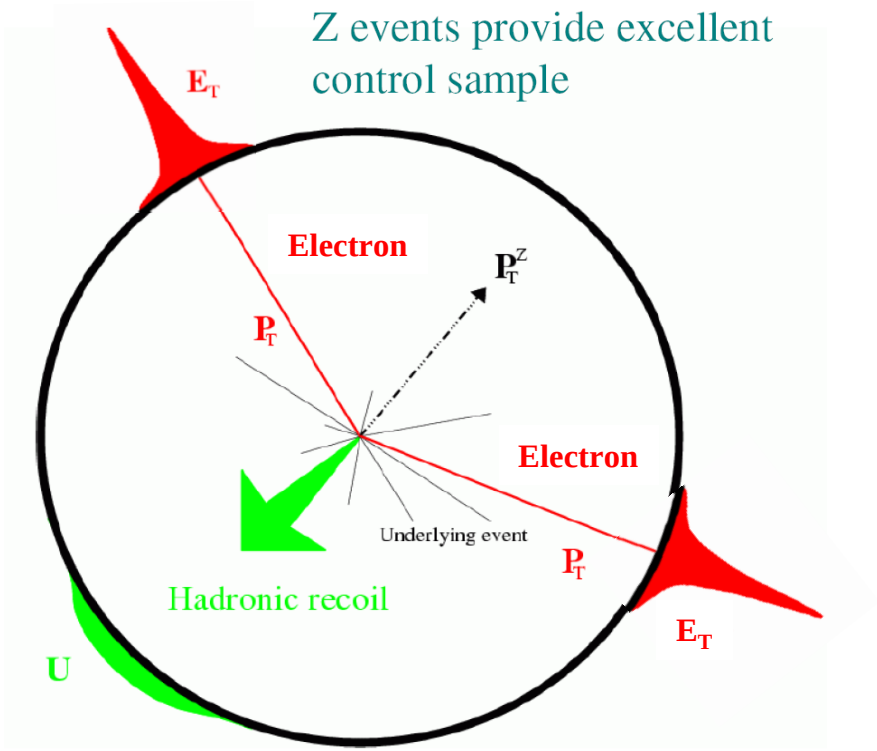
Summary and Outlook

- D0 is accumulation lots of good data.
- The detector is understood and performing well.
- Getting lots of precision results
- Establishing benchmark measurements
- Stay tuned for much more to come

Backup Slides

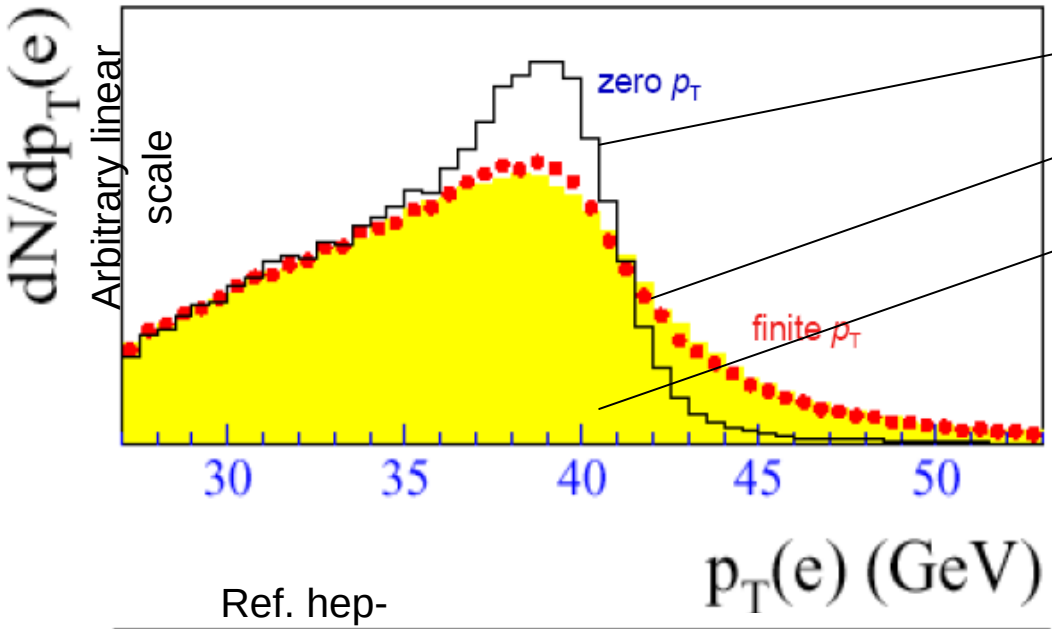
18 countries, 77 institutions, 522 scientists





- **Calorimeter energy response is calibrated using *Z->ee* events**

Experimental observables



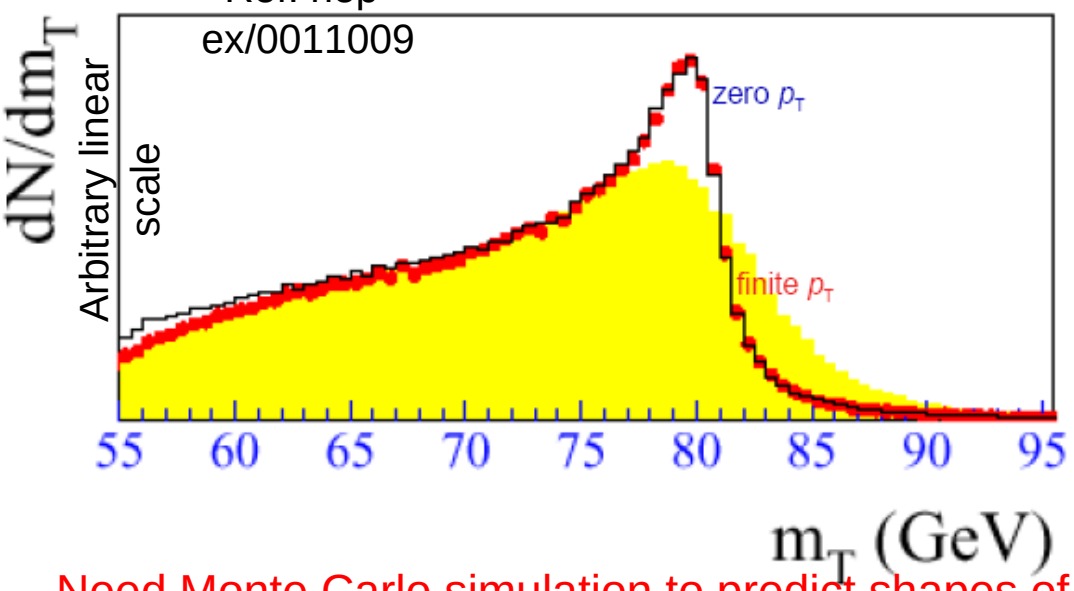
No $P_T(W)$

$P_T(W)$ included

Detector Effects added

$p_T(e)$ most affected by $p_T(W)$

Ref. hep-ex/0011009



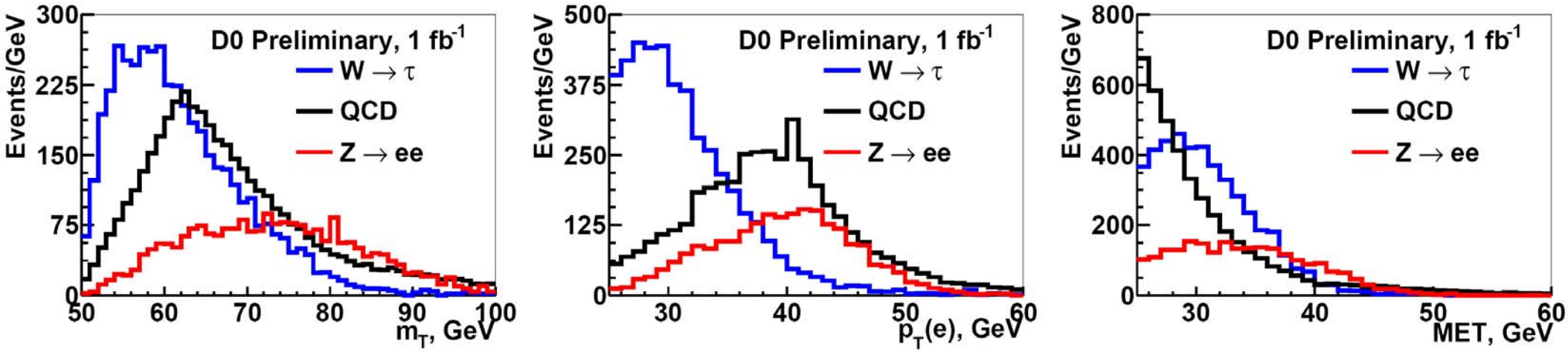
$$M_T = \sqrt{2E_T^l \not{E}_T (1 - \cos\Delta\phi)}$$

M_T most affected by measurement of missing transverse momentum

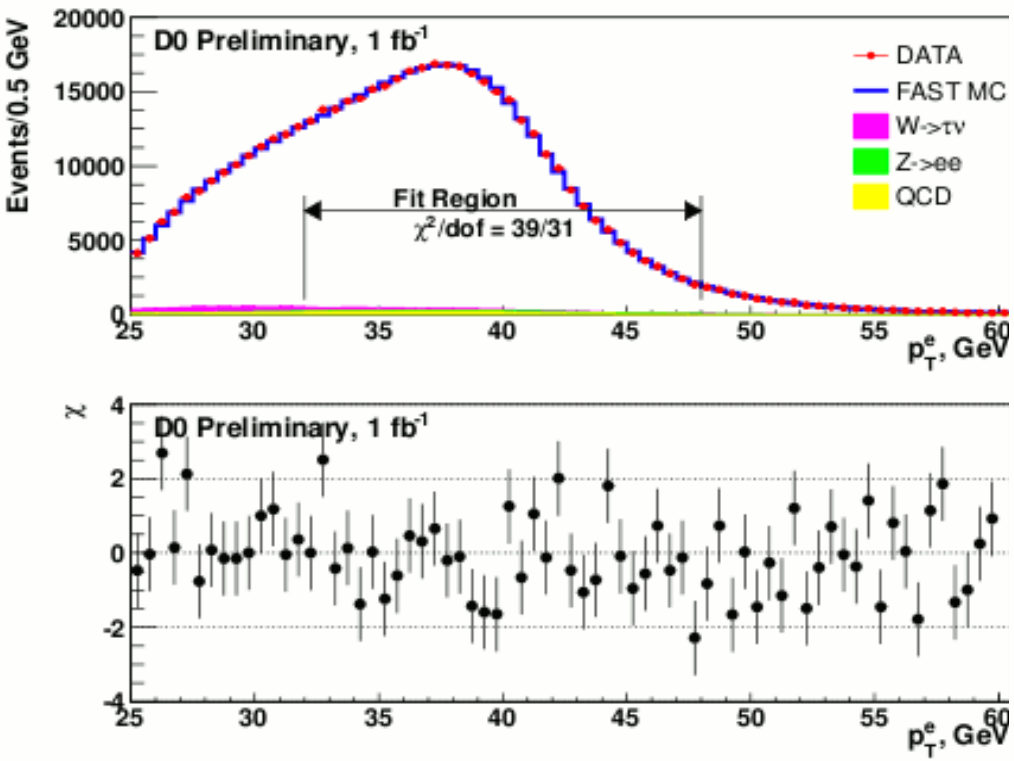
Need Monte Carlo simulation to predict shapes of these observables for given mass hypothesis. DØ use **ResBos** [Balazs, Yuan; Phys Rev D56, 5558] + **Photos** [Barbiero, Was, Comp Phys Com 79, 291] for W/Z production and decay, plus **parameterised detector model**.

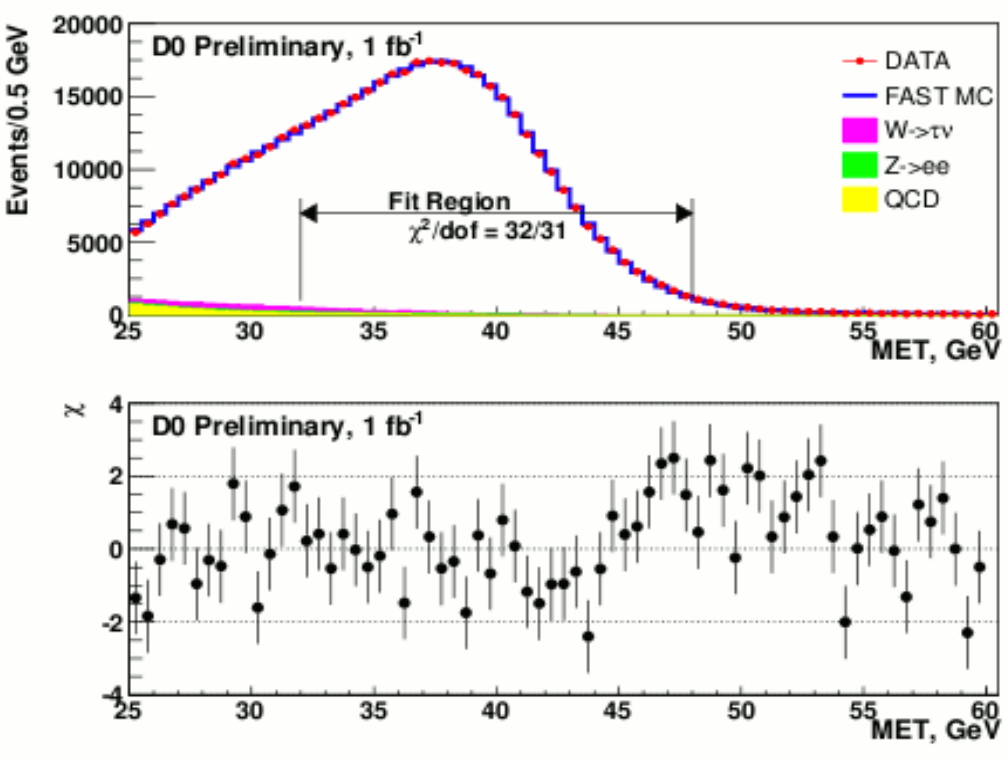
Backgrounds to W->eν

- **QCD (di-jet)((1.49±0.03)%):** one jet faked as electron
- **Z -> ee((0.80±0.01)%):** one electron lost in ICR(between CC and EC CAL)
- **W -> τν((1.60±0.02)%)**: mostly from τ decays into "eνν"



Mass fits (p^e_T and p^ν_T)





m(W) = 80.400 ± 0.027 GeV (stat)

m(W) = 80.402 ± 0.023 GeV (stat)