CAP/ACP Congress
Université Laval, Québec

Latest Results of the DØ Experiment

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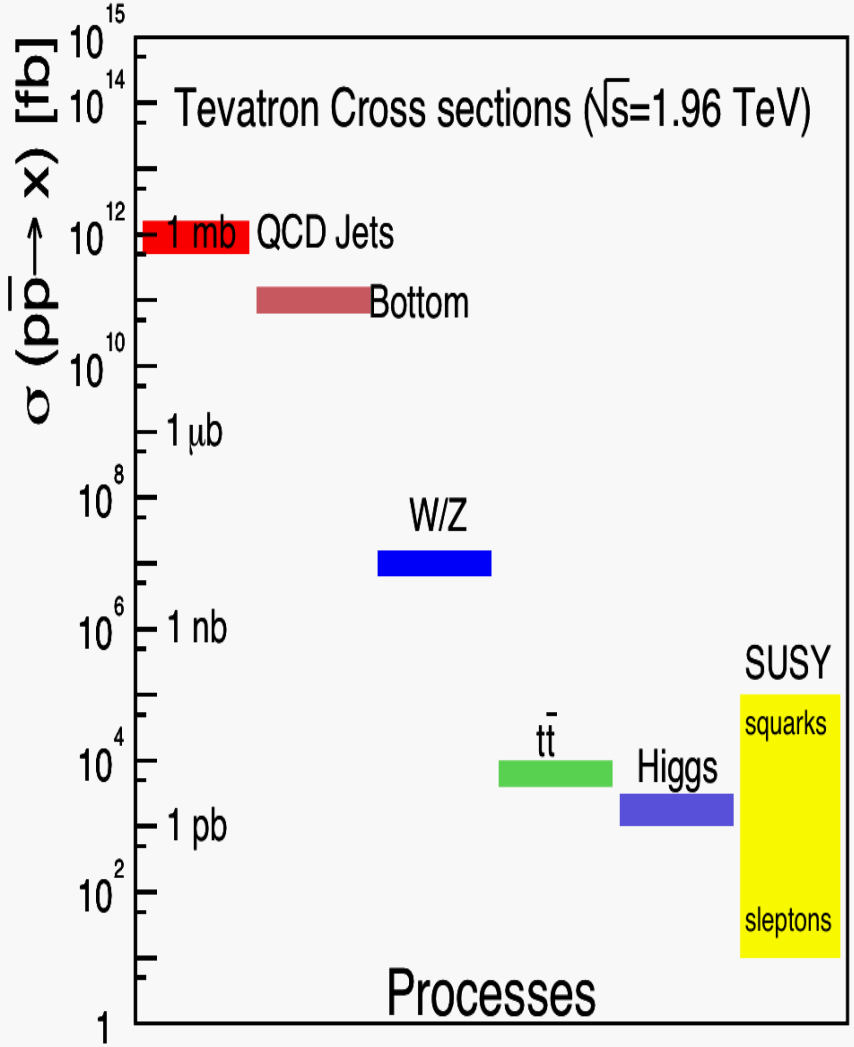
on behalf of the
DØ collaboration

University of Alberta
&
York University

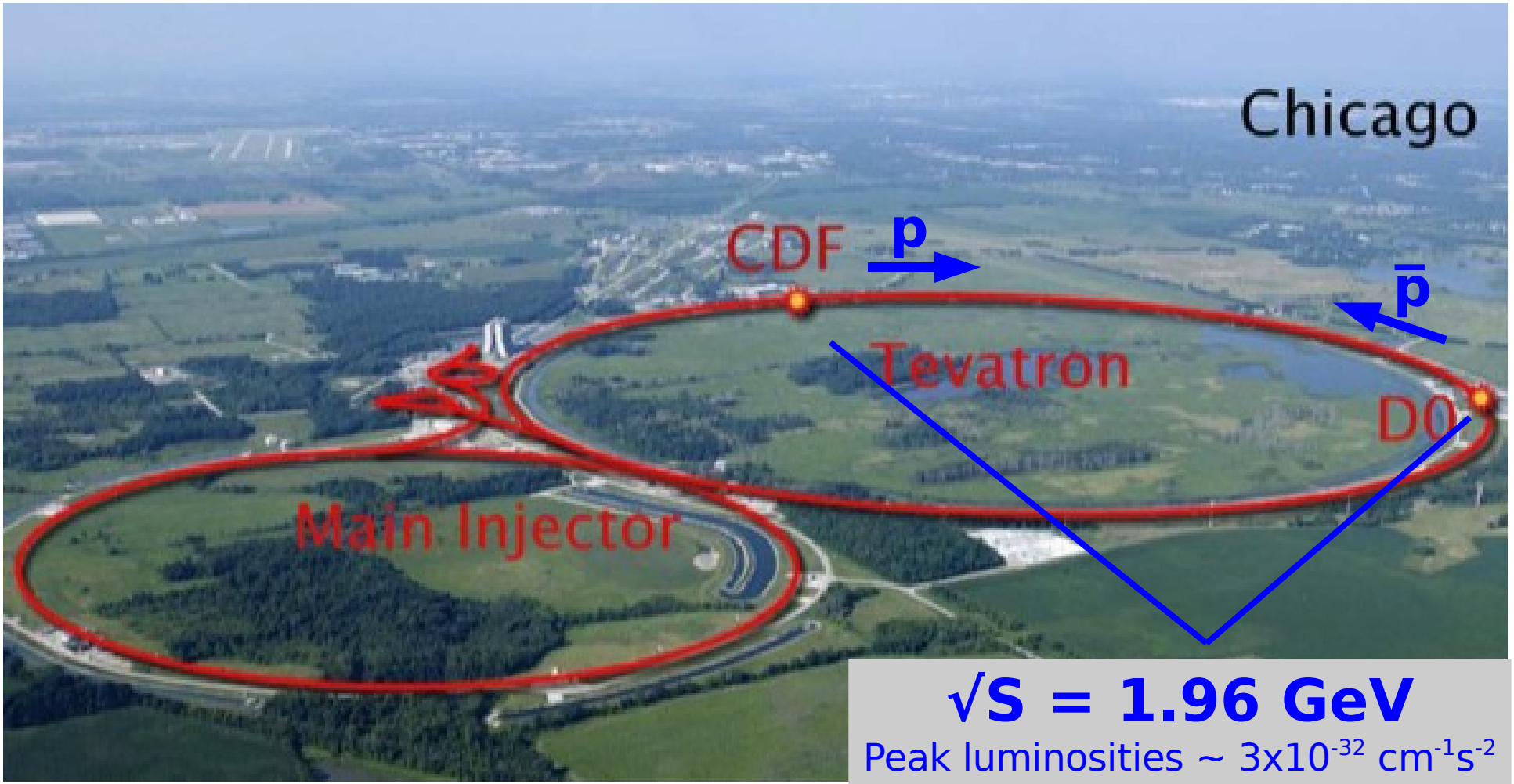
June 11th 2008

Outline

- The DØ Experiment
- QCD
- B Physics
- Electroweak Physics
- Top Physics
- Higgs Searches
- New Phenomena



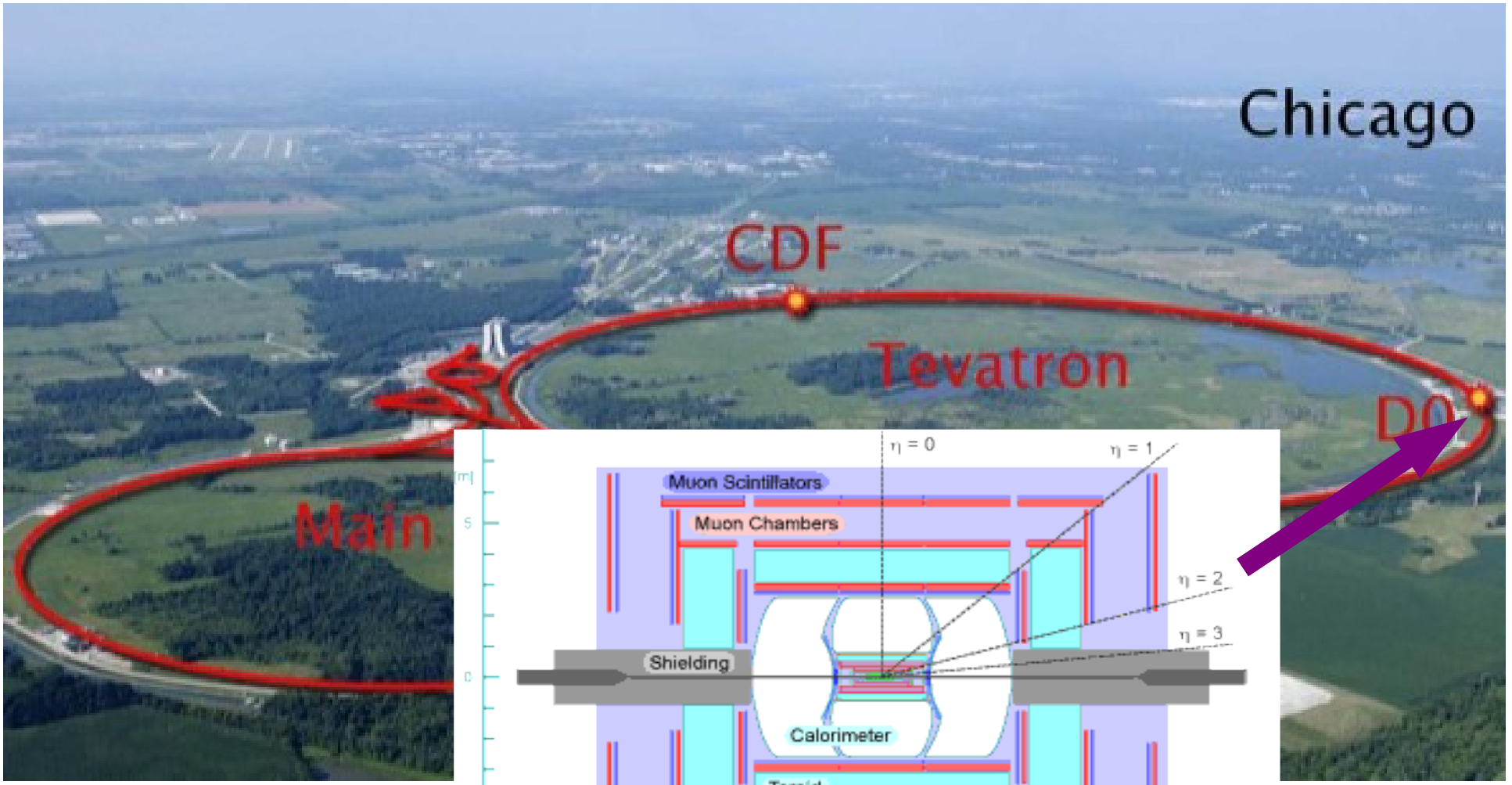
The DØ Experiment

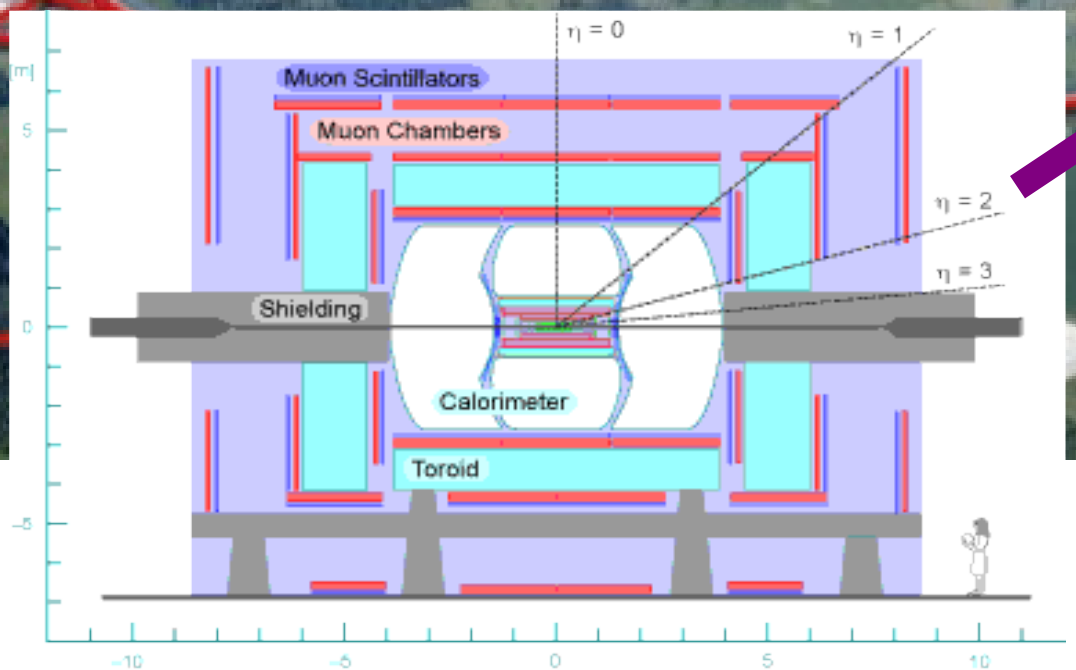


√S = 1.96 GeV

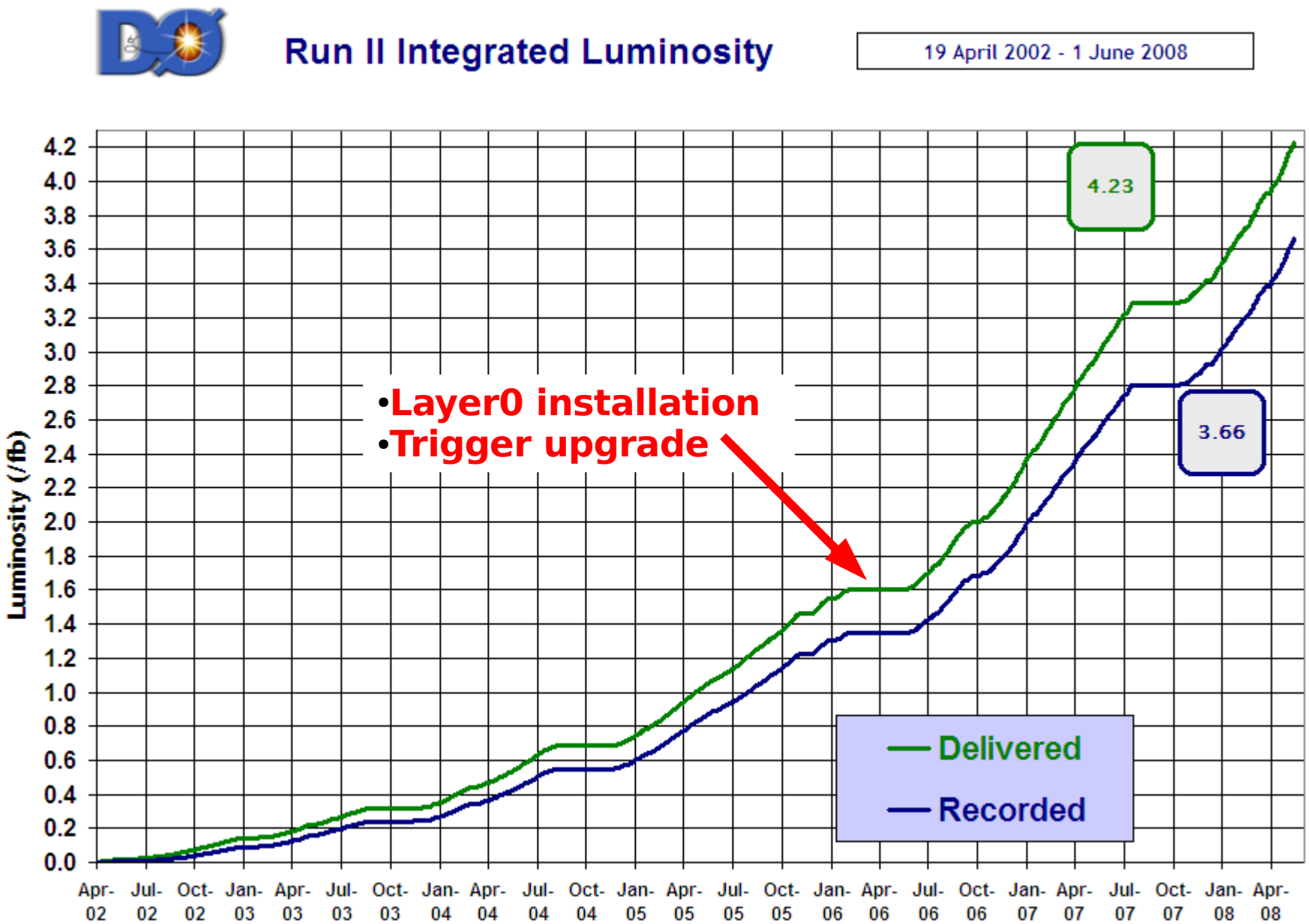
Peak luminosities ~ 3×10^{-32} $cm^{-1}s^{-2}$

The DØ Experiment



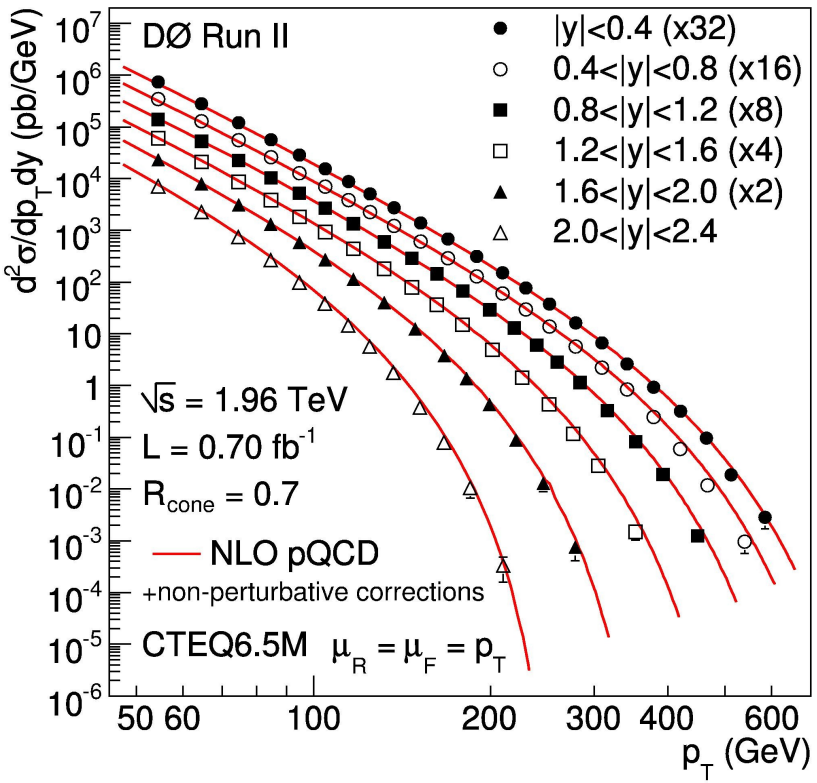


The DØ Experiment

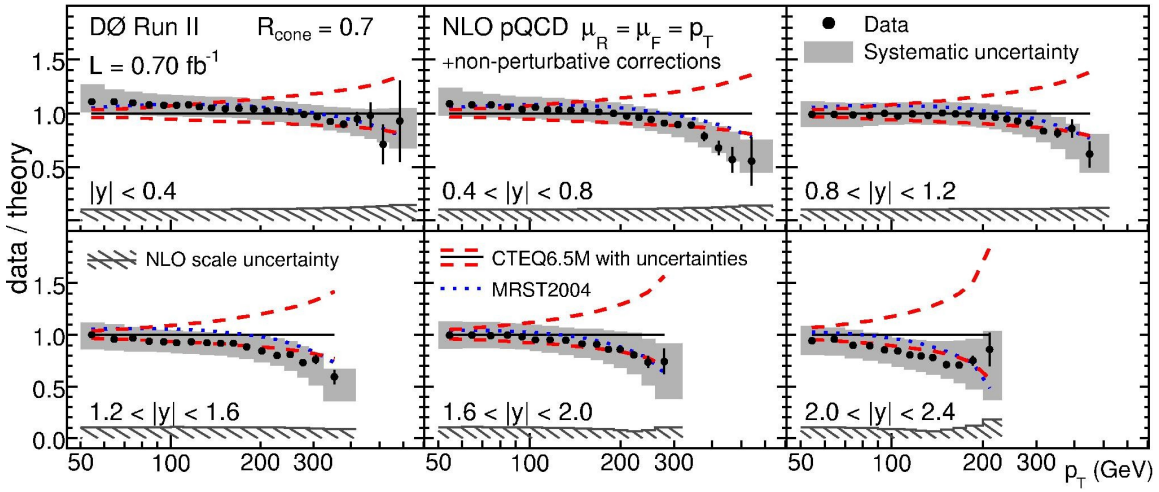


QCD

- Studies jet production and the structure of the proton
- **Inclusive jet production:**

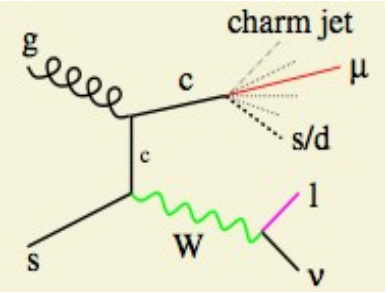


- Impressive agreement
- Comparison to modern PDFs



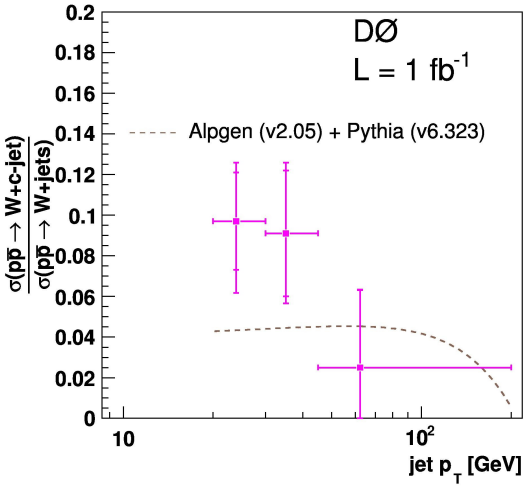
QCD

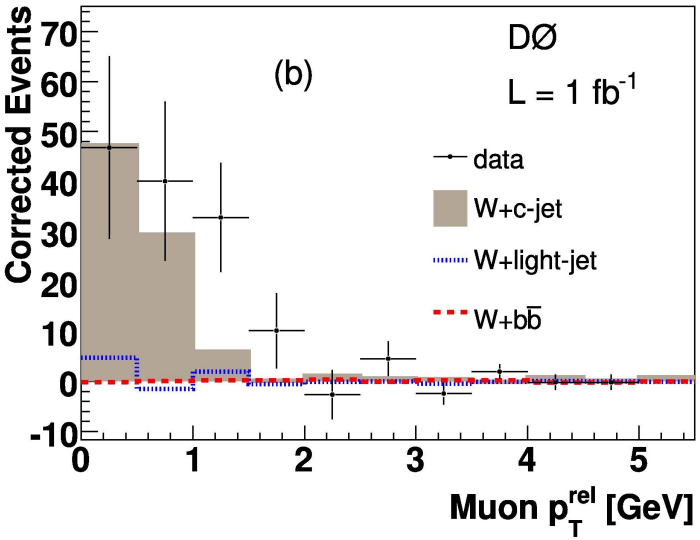
- Boson + jets are important backgrounds to top and Higgs Physics.
- **W+c-jet cross section:**
  - Selection based on muon-based tagger: opposite charge of muon in jet and lepton in W



  - 3.5 sigma

$$\frac{\sigma\,[W + c\text{-jet}]}{\sigma\,[W + \text{jets}]} = 0.074 \pm 0.019(\text{stat.})^{+0.012}_{-0.014}(\text{syst.})$$



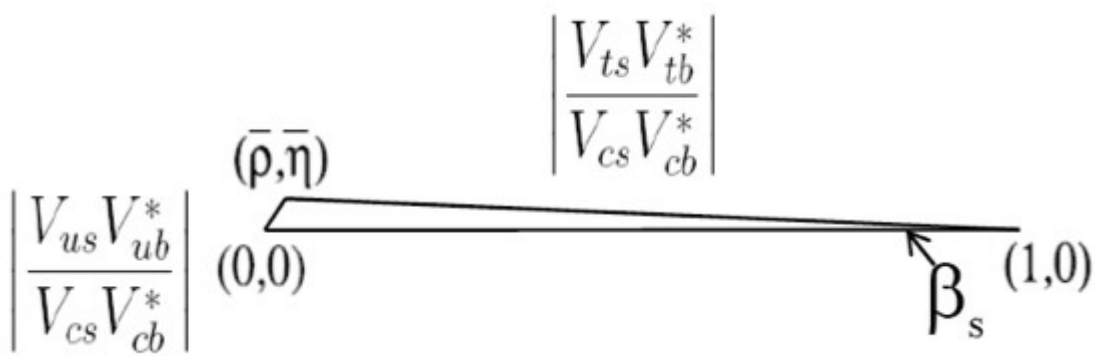


B Physics

- Study weak decays and mixing of B hadrons
- Many new results:
  - First direct observation of the strange b baryon Ξ_b^-
  - B_c mass and lifetime
  - CP violation in $B^+ \rightarrow J/\psi K^+$
  - $B^0_{(s)} \rightarrow \mu^+\mu^-$ rare mode
  - etc.

B Physics

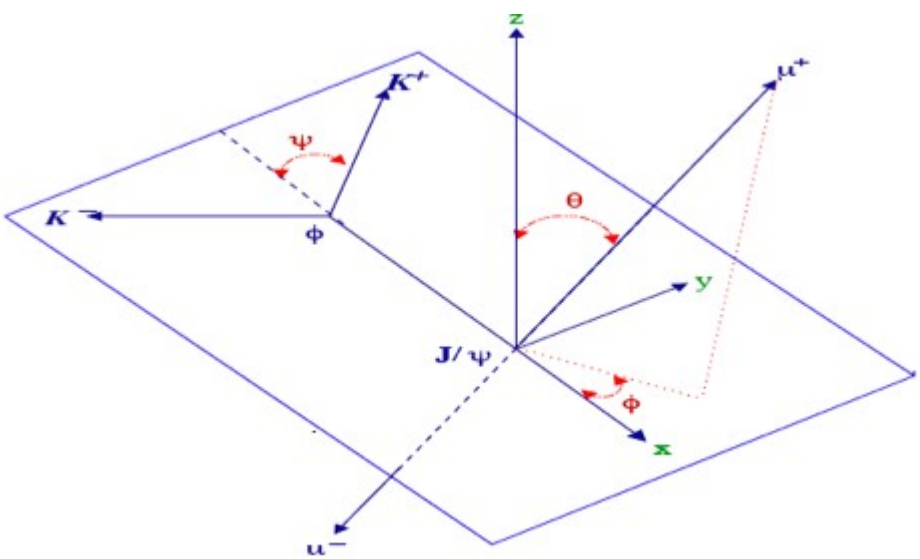
- **B_s mixing parameters $B_s \rightarrow J/\psi\phi$**
- CP violation in interference
- Δm_s, $\Delta\Gamma_s$, ϕ_s, polarization amplitudes,...
- Equivalent of $B_d \rightarrow J/\psi K_S$ but $\beta_s << \beta$

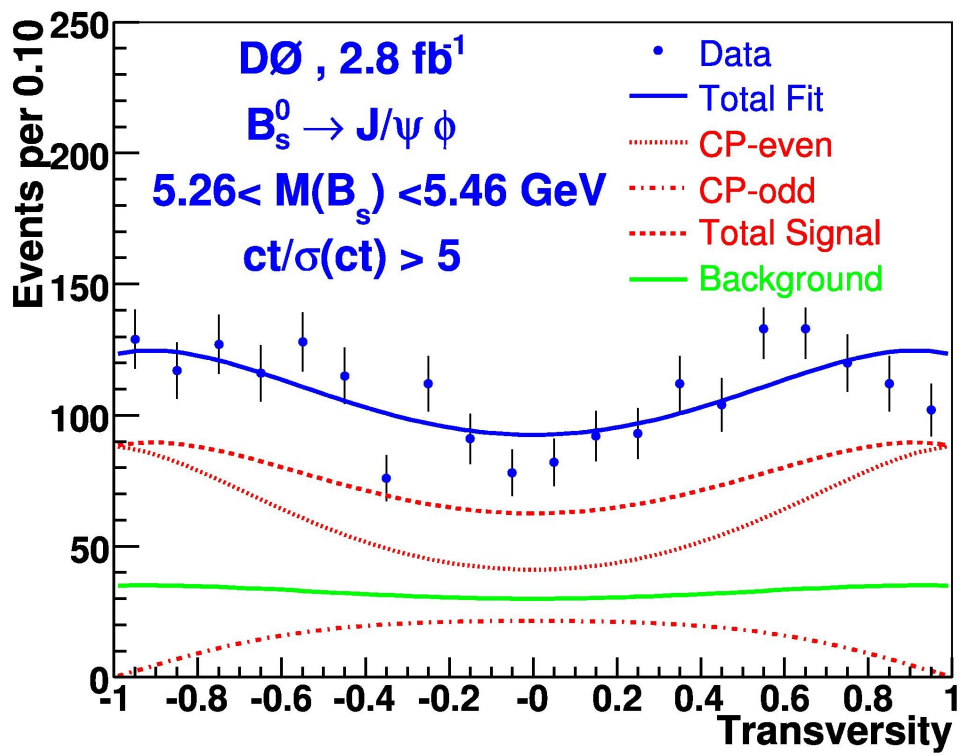


- CP violating mixing phase $\phi_s = -2\beta_s$, but new phenomena may do $\phi_s = -2\beta_s + \phi_s^{\Delta}$

B Physics

- VV final state → both CP eigenstates possible
- Disentangle by determining relative polarization of J/ψ and ϕ
- Express angular dependence in J/ψ rest frame in terms of polarization → extract CP eigenvalue





B Physics

- Use flavor tagging: opposite-side and same-side
  - Combined tagging power $\epsilon D^2 = 4.68\ \%$
- Use unbinned maximum likelihood fit:

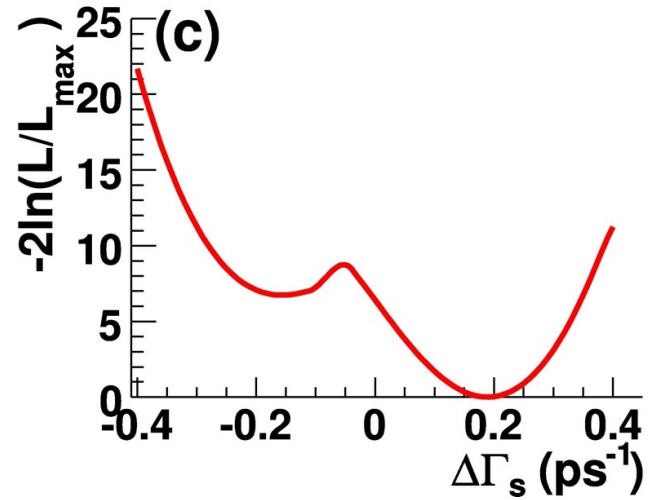
	free ϕ_s	$\phi_s \equiv \phi_s^{SM}$
$\overline{\tau}_s$ (ps)	1.52±0.05	1.51±0.06
$\Delta\Gamma_s$ (ps^{-1})	0.19±0.07	0.14±0.08
$A_\perp(0)$	0.42±0.04	0.44±0.04
$\lvert A_0(0)\rvert^2 - \lvert A_\parallel(0)\rvert^2$	0.34±0.04	0.34±0.04
δ_1	$\equiv -0.46$	$\equiv -0.46$
δ_2	$\equiv 2.92$	$\equiv 2.92$
ϕ_s	-0.35 ± 0.23	$\equiv -0.04$
ΔM_s (ps^{-1})	$\equiv 17.77$	$\equiv 17.77$

B Physics

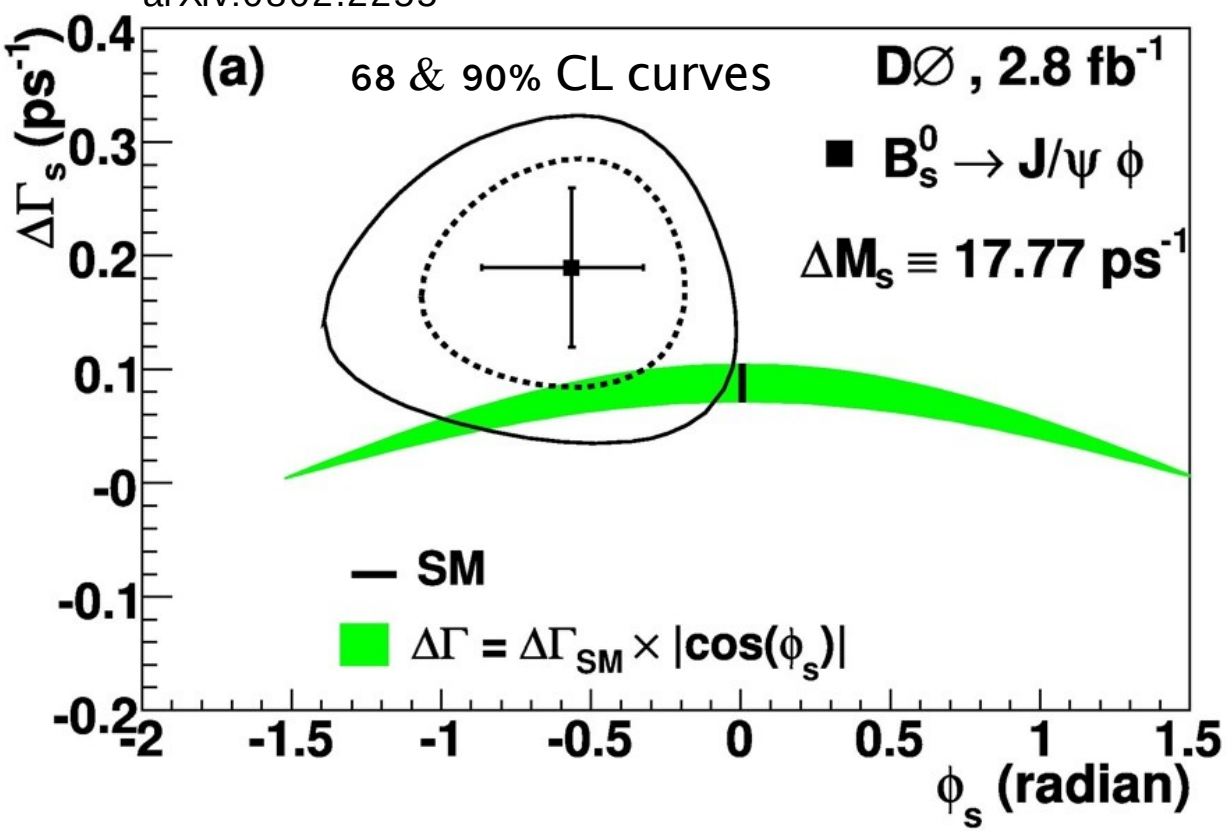
$$\overline{\tau}(B_s^0) = 1.52 \pm 0.05 \pm 0.01 \text{ ps}$$

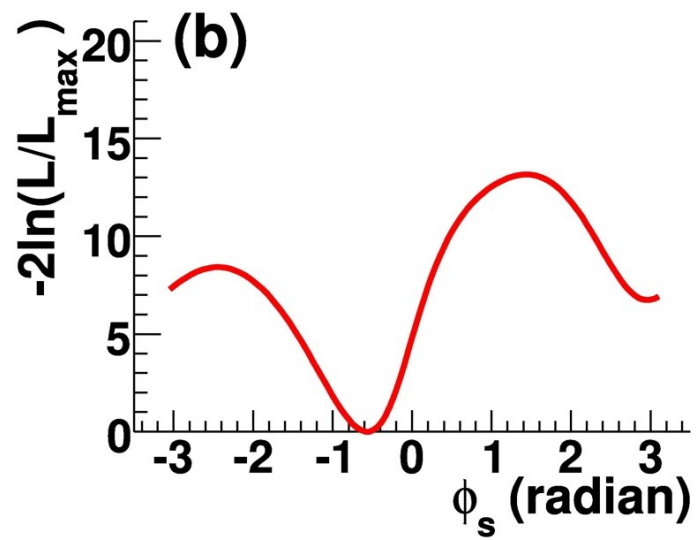
$$\Delta\Gamma_s = 0.19 \pm 0.07(\text{stat})^{+0.02}_{-0.01}(\text{syst}) \text{ ps}^{-1}$$

$$\phi_s = -0.57^{+0.24}_{-0.30}(\text{stat})^{+0.07}_{-0.02}(\text{syst})$$



arXiv:0802.2255





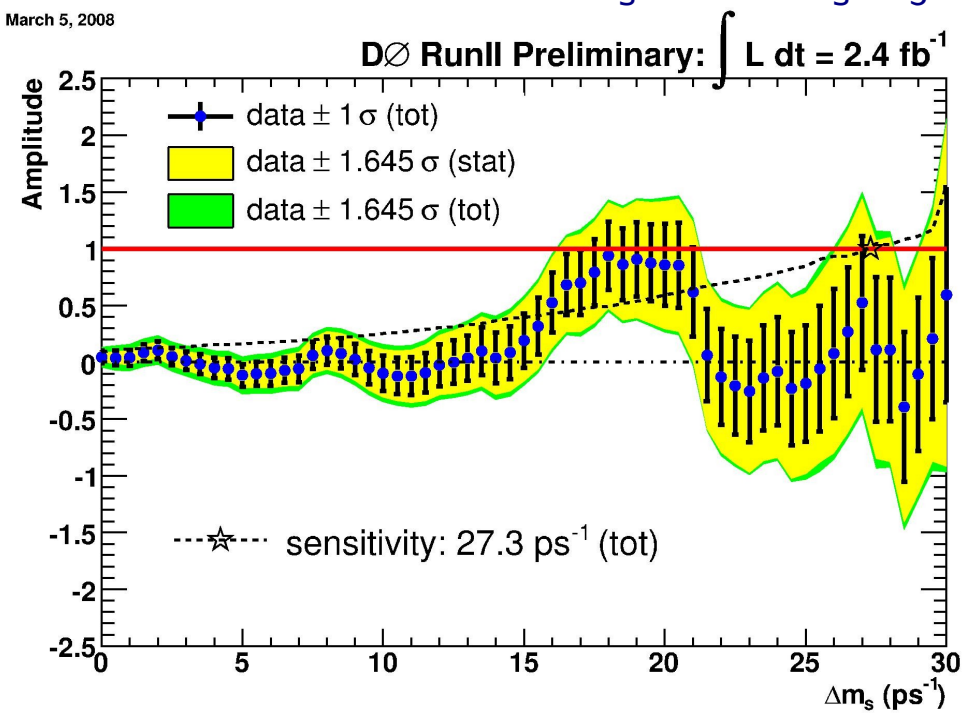
SM probability: ~ 7% ✓

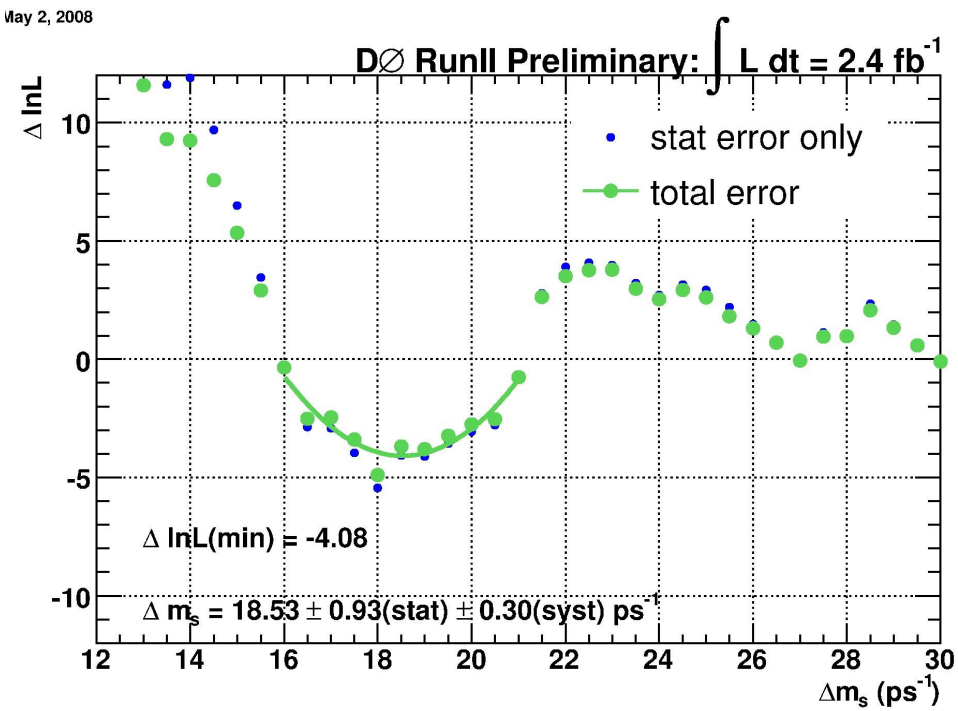
B Physics

- **B_s mixing combination**
- Major Canadian contribution from Wendy Taylor and Steve Beale (York U.).
- Combine: $B_s \rightarrow \mu\nu D_s(\phi\pi)X$, $B_s \rightarrow \mu\nu D_s(K^*K)X$,

  $B_s \rightarrow e\nu D_s(\phi\pi)X$, $B_s \rightarrow \pi D_s(\phi\pi)X$ (2.4 fb^{-1}),

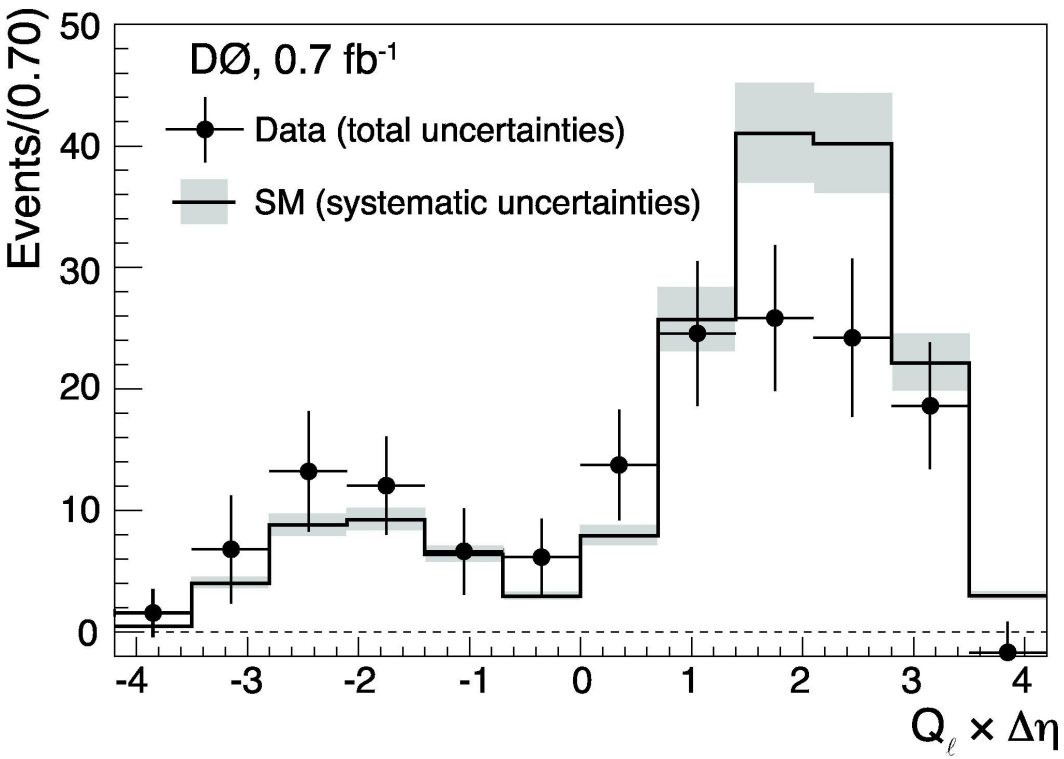
  $B_s \rightarrow \mu\nu D_s(K_sK)X$ (1.2 fb^{-1})



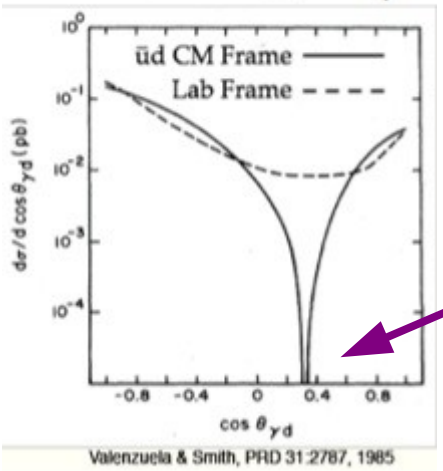


Electroweak Physics

- Study the structure of the Standard Model to the last corner
- **Radiation Amplitude Zero in Wγ:**
  - Property of gauge theory:



$d\bar{u} \to W^-\gamma$



$$\cos(\theta_{\gamma d}) = \frac{q_d + q_u}{q_d - q_u} = -\frac{1}{3}$$

Dip diluted by:
- Final state radiation off leptons
- NLO corrections
- Background
- Anomalous couplings

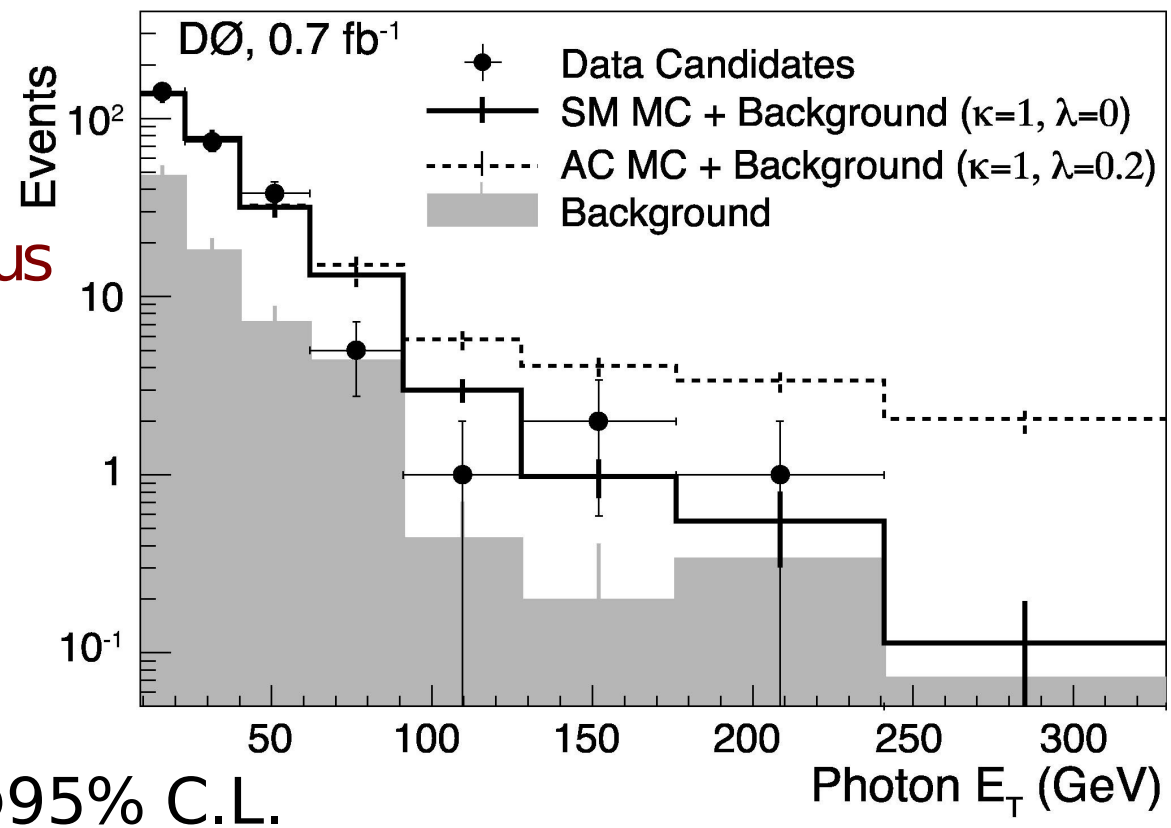
Electroweak Physics

- Study the structure of the Standard Model to the last corner
- **Radiation Amplitude Zero in Wγ:**

Tail in $d\sigma/dE_T^{\gamma}$ distribution used to set limits on anomalous WWγ vertex taking place in the s-channel diagram:

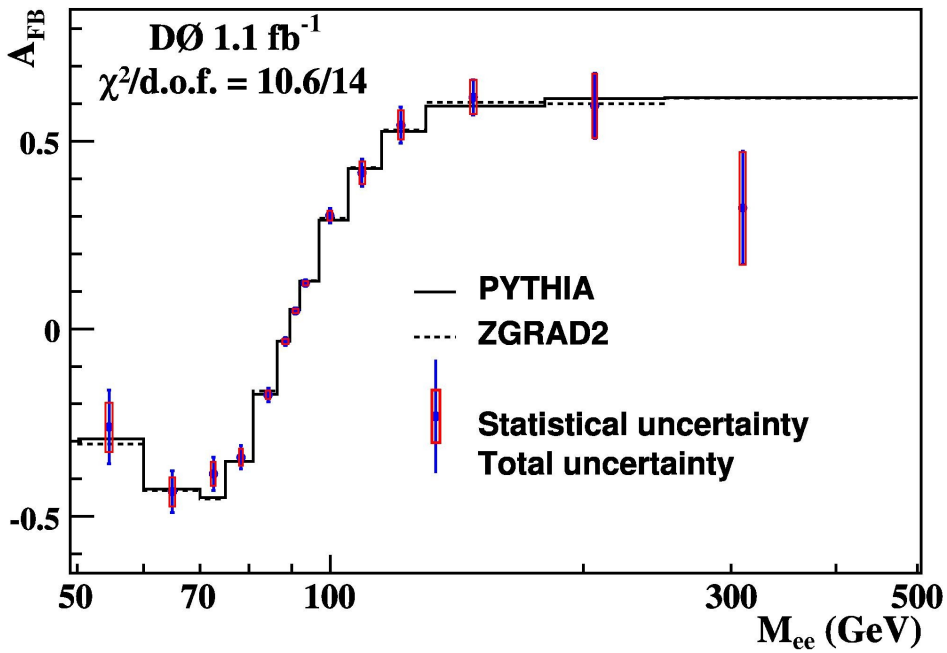
$0.49 < \kappa_{\gamma} < 1.51$

$-0.12 < \lambda_{\gamma} < 0.13$ @95% C.L.



Electroweak Physics

- **Forward-Backward Z-Production Asymmetry:**
  - In qq → Z/γ* → e^+e^-: asymmetry between the forward and backward cross-section which depends on the dilepton mass (M_{ee})



  - Good agreement with SM prediction

$$\sin^2\theta_W^{\rm eff} = 0.2327 \pm 0.0018\ (\text{stat.}) \pm 0.0006\ (\text{syst.})$$ (World average: 0.23152 ± 0.00014)

  - Large M_{ee} sensitive to new Z' boson

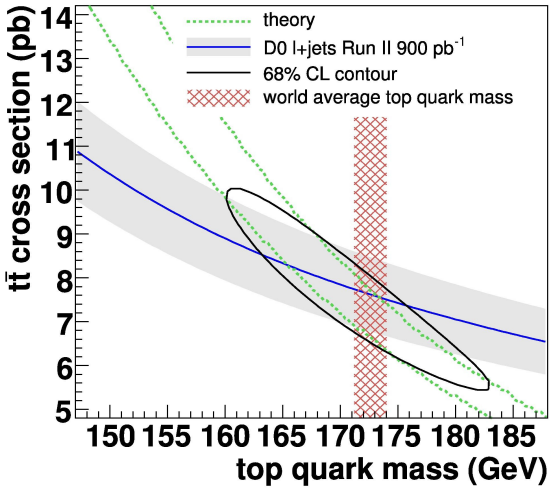
Top Physics

- Top quark discovered in Tevatron
- Top properties:
  - pair production cross section
  - mass
  - charge, width, lifetime,...
- Single top
- Other measurements:
  - resonances
  - forward-backward charge asymmetry
  - W helicity, W', ...

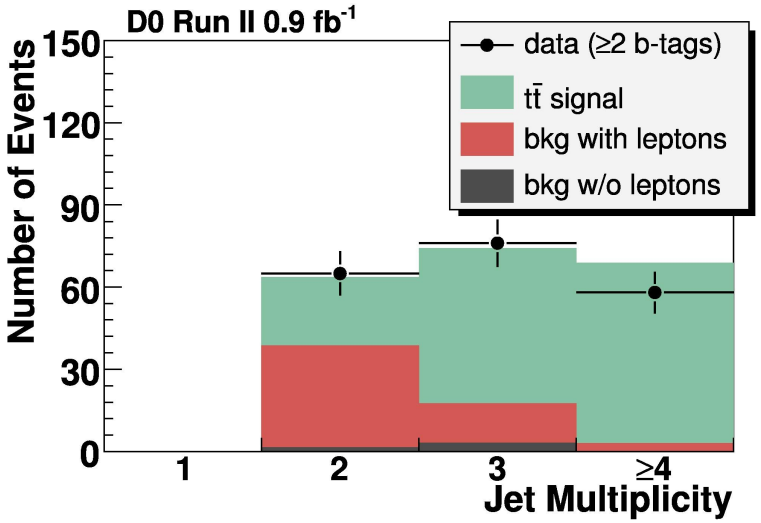
Top Physics

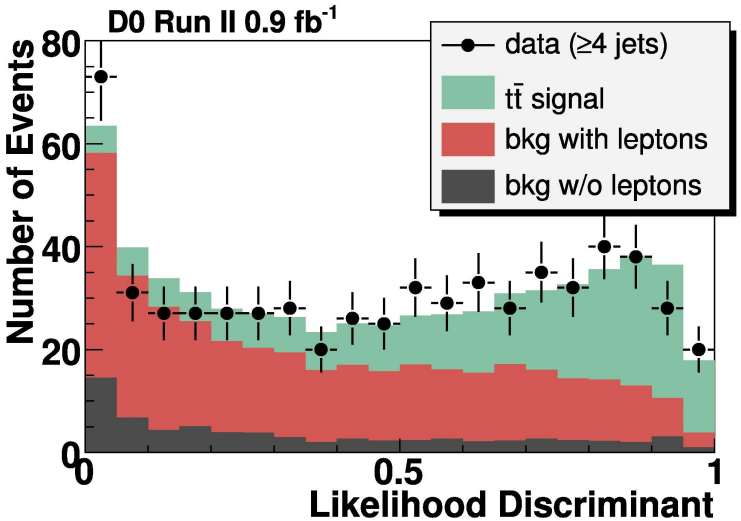
- **Pair cross-section** (lepton+jets)
  - Two analyses:
    - One uses b-tagging
    - Other likelihood discriminant

$$\sigma_{t\bar{t}} = 7.42 \pm 0.53(\text{stat}) \pm 0.46(\text{syst}) \pm 0.45(\text{lumi})\ \text{pb}$$



  - Extract mass too



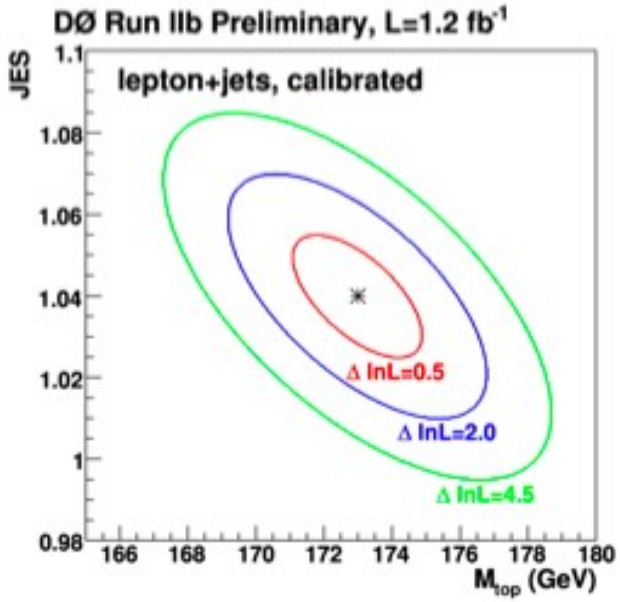


Top Physics

- **Top mass** (lepton+jets)

$$P_{sig}(x; m_{\rm top}, JES) = \frac{1}{\sigma_{\rm obs}(p\overline{p} \to t\overline{t}; m_{\rm top}, JES)} \times \sum_{\rm perm} w_i \int_{q_1,q_2,y} \sum_{\rm flavors} dq_1 dq_2 f(q_1) f(q_2) \frac{(2\pi)^4 \left|\mathcal{M}(q\overline{q} \to t\overline{t} \to y)\right|^2}{2q_1 q_2 s} d\Phi_6 W(x, y; JES).$$

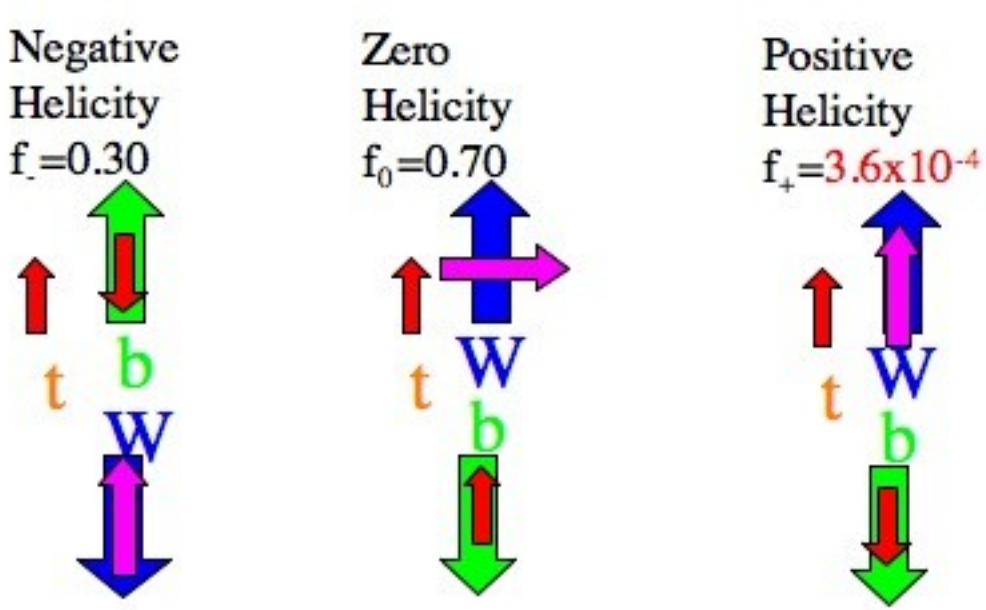
JES fitted in situ using m_W



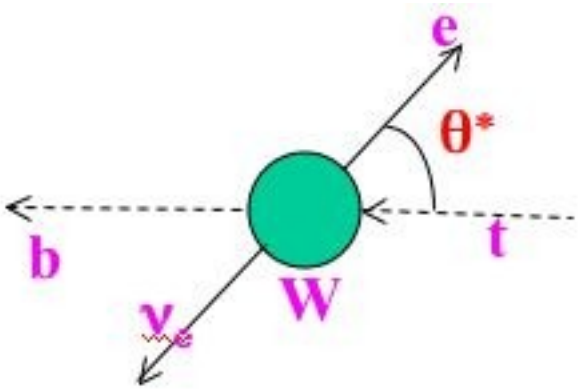
$$m_{\rm top} = 172.2 \pm 1.1({\rm stat}) \pm 1.6({\rm syst})\ {\rm GeV/c^2} \qquad L = 2.1\ {\rm fb}^{-1}$$

Top Physics

- **W helicity:**



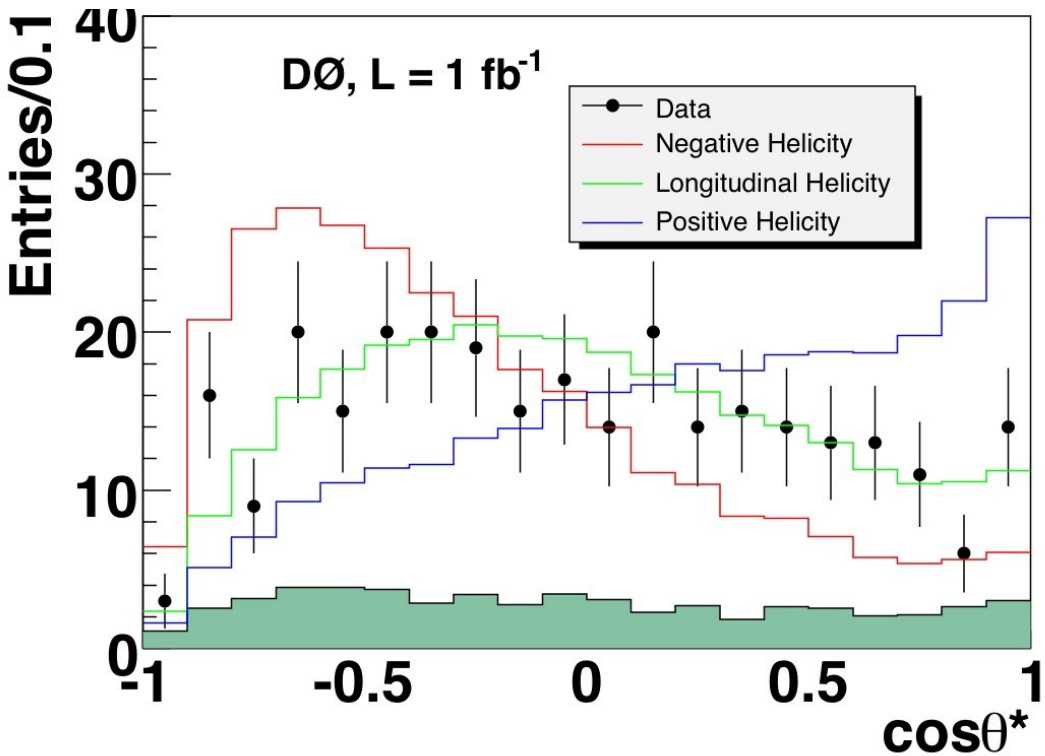
- Use θ^* in W rest frame:
  - small for negative
  - ~90° for zero
  - big for positive

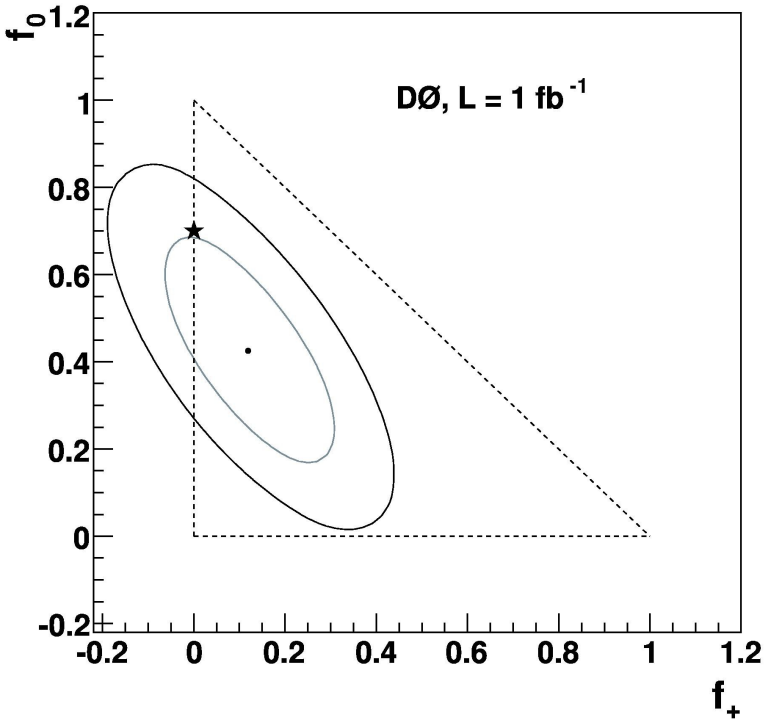


Top Physics

$f_0 = 0.425 \pm 0.195$

$f_+ = 0.119 \pm 0.104$





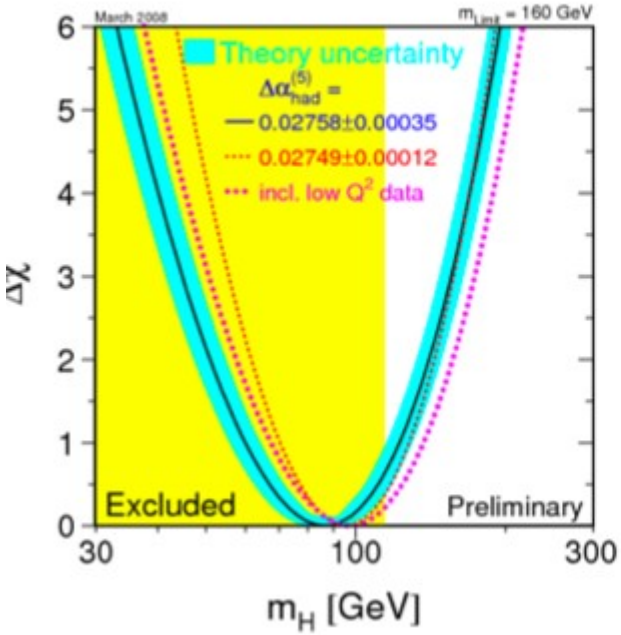
Top Physics

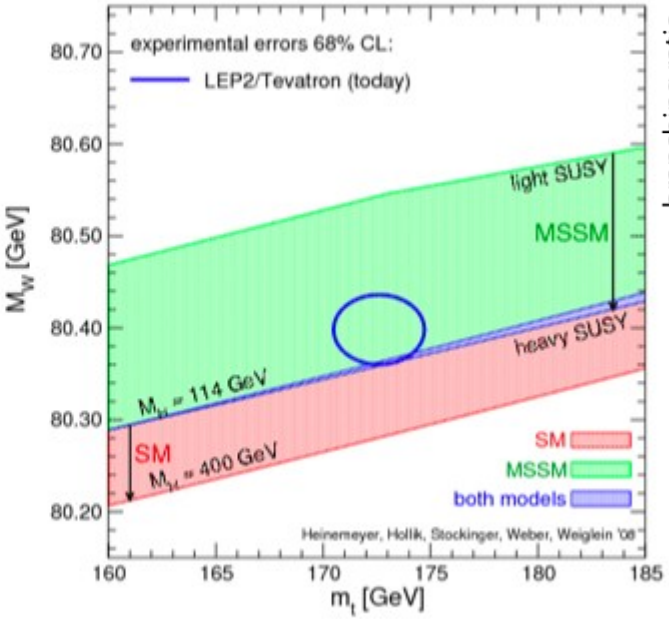
- **Single top**
- Major Canada contributions:
  - e+jets & μ+jets channels main analyses: 2006 evidence and ongoing effort: Dag Gillberg, Dugan O'Neil, Yann Coadou, Zhiyi Liu (SFU), Brigitte Vachon (McGill), Roger Moore, Kevin Chan (UofA), Ernest Aguiló.
  - Charged higgs: Brigitte Vachon, Chris Potter, Gustavo Kertzscher (McGill)
  - Hadronic τ+jets: Zhiyi Liu, Dugan O'Neil, Dag Gillberg, Ernest Aguiló

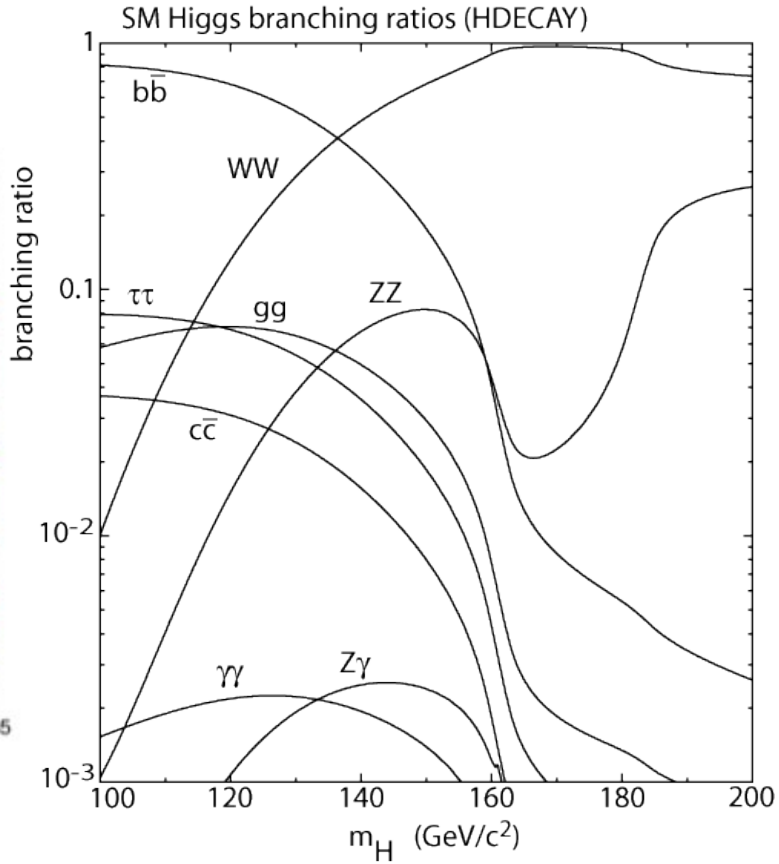
Higgs Searches

- **Strategies:**
  - searches at low mass: coupled with W or Z (less bkg.)
  - searches at high mass

$$m_H = 87 \pm {}^{36}_{27}\ \text{GeV}$$

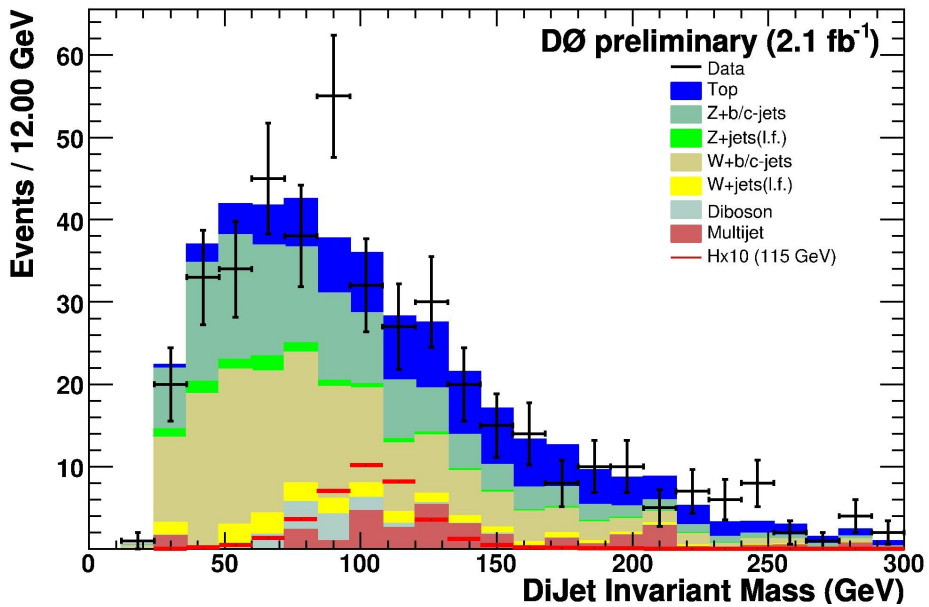


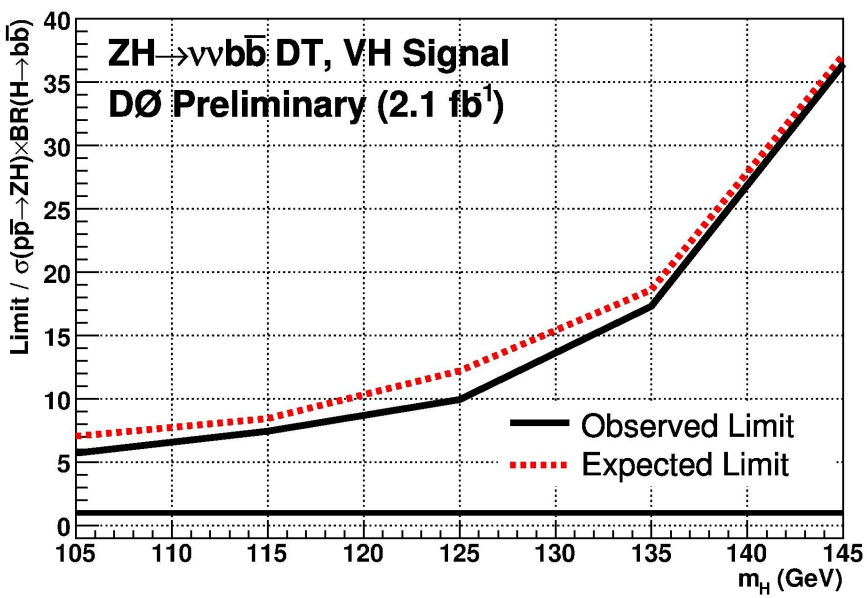


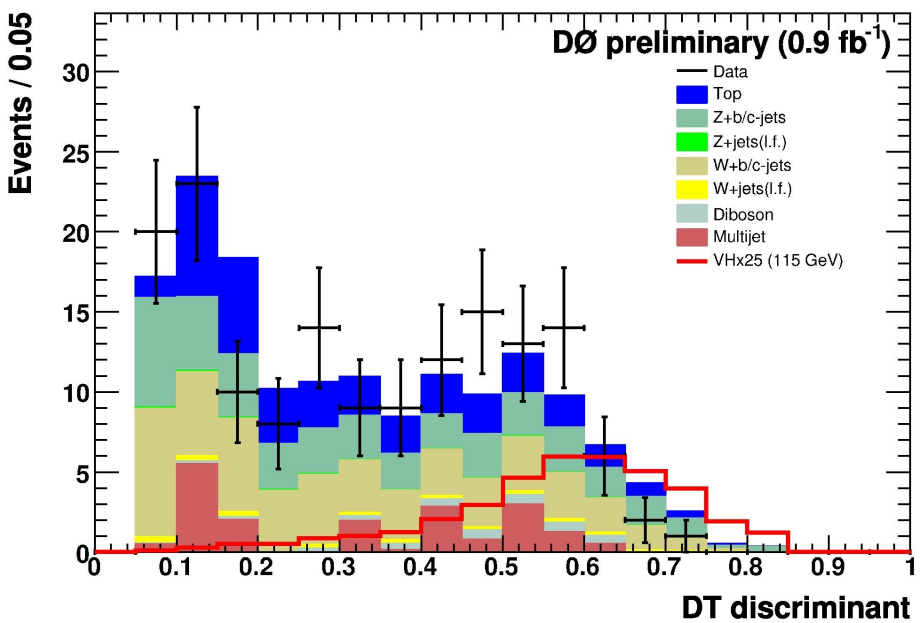


Higgs Searches

- **ZH → $\nu\nu$bb with decision trees**
- Selection:
  - 2 acoplanar jets
  - MET > 50 GeV
  - b-tagging

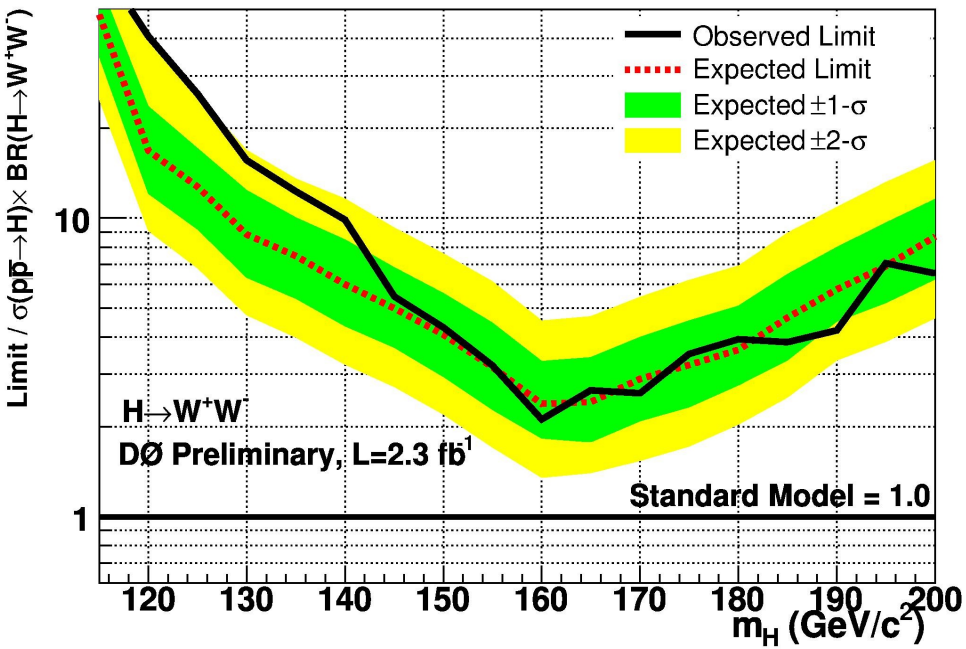


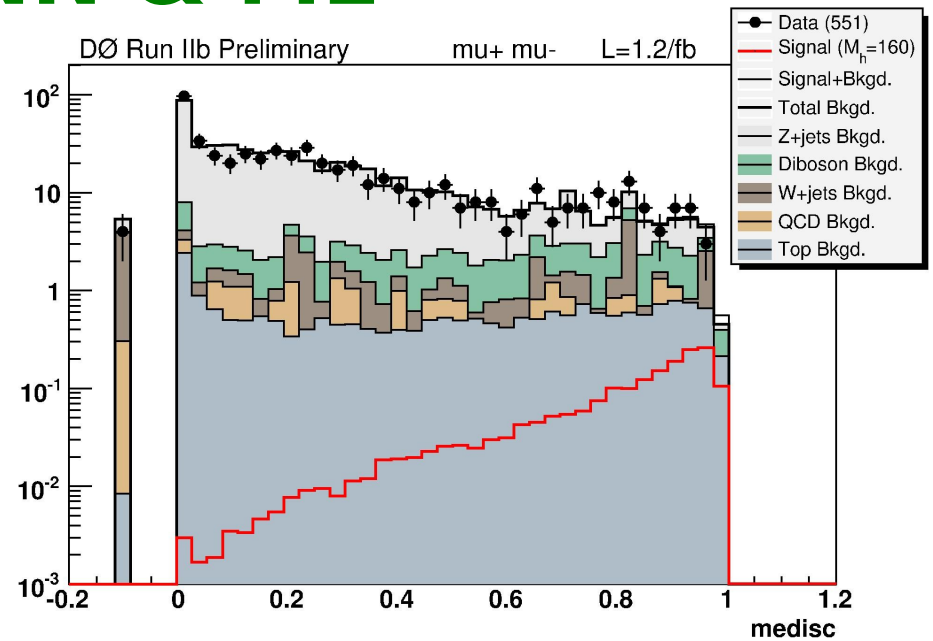


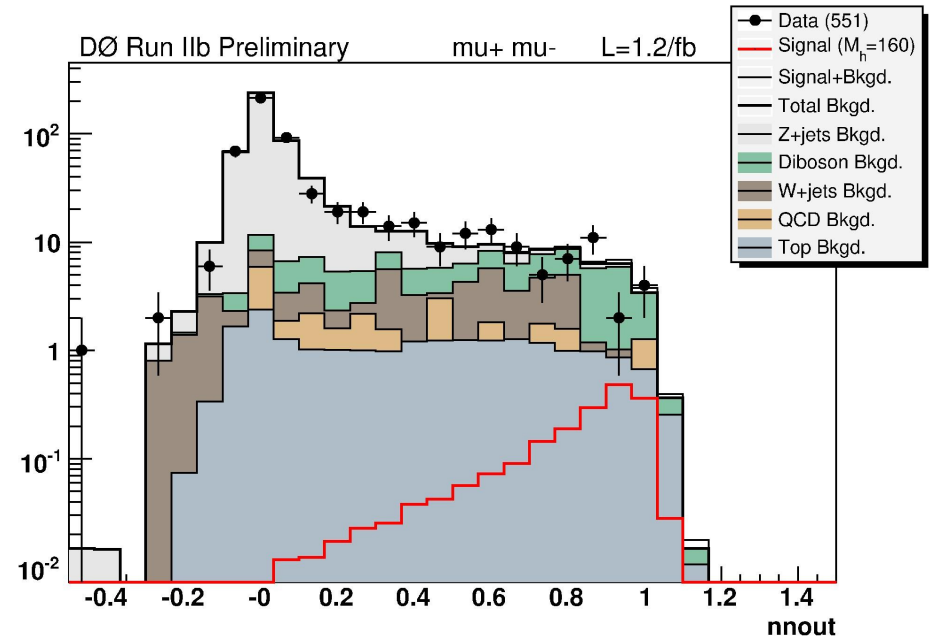


Higgs Searches

- **H → WW → lνlν with NN & ME**
- Use matrix element discriminant as one input to NN

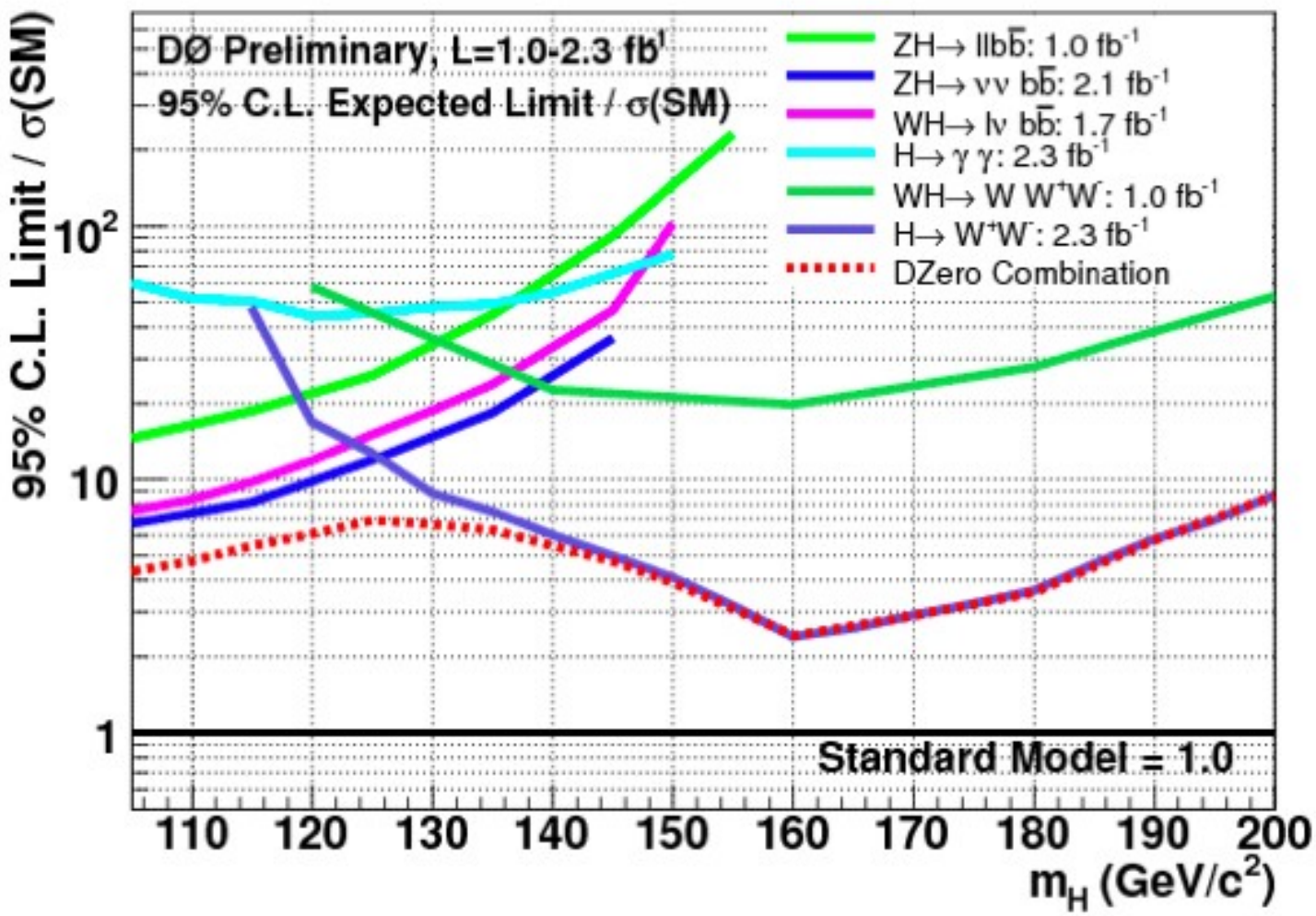






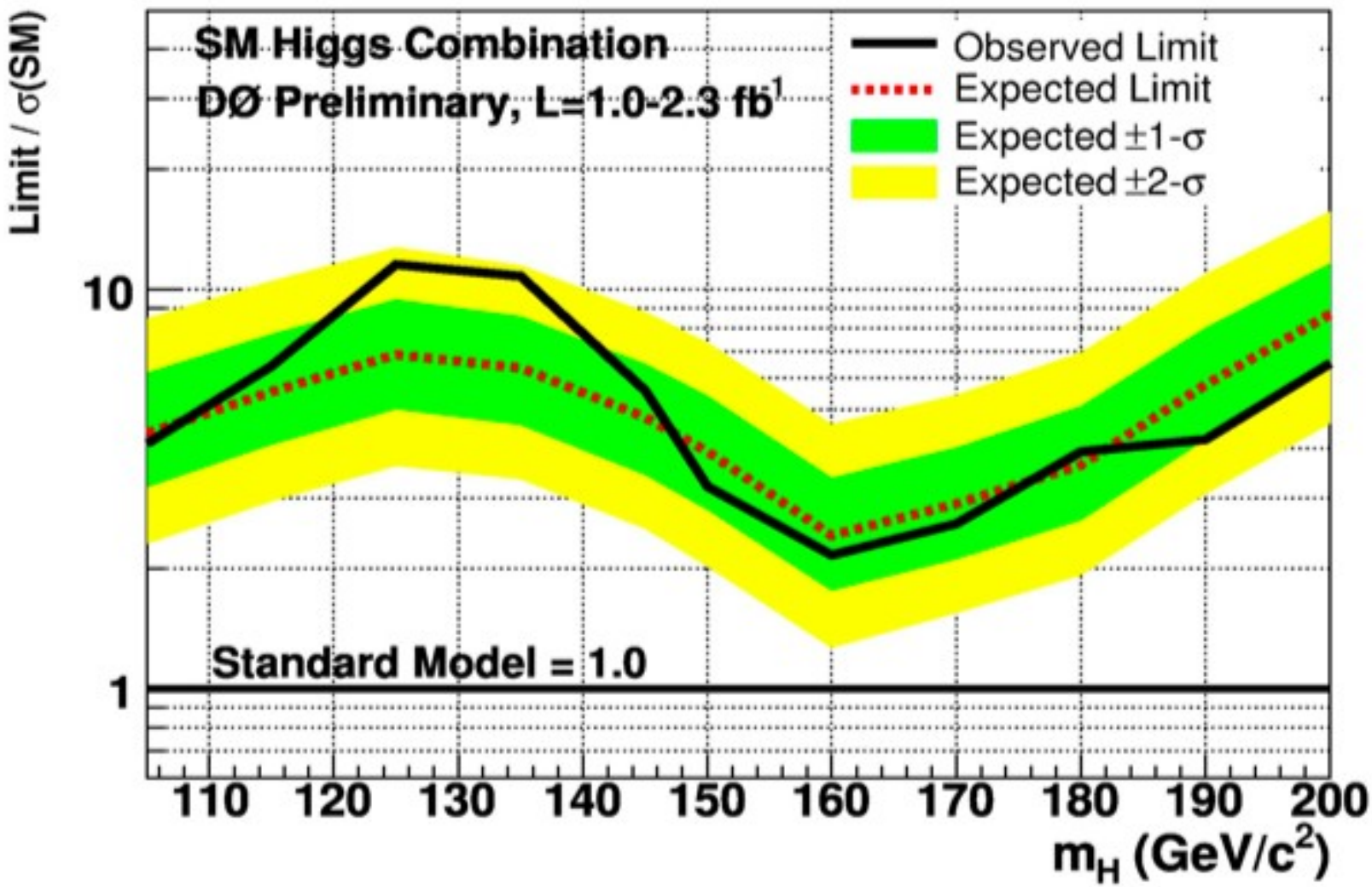
Higgs Searches

- **Higgs expected limits**



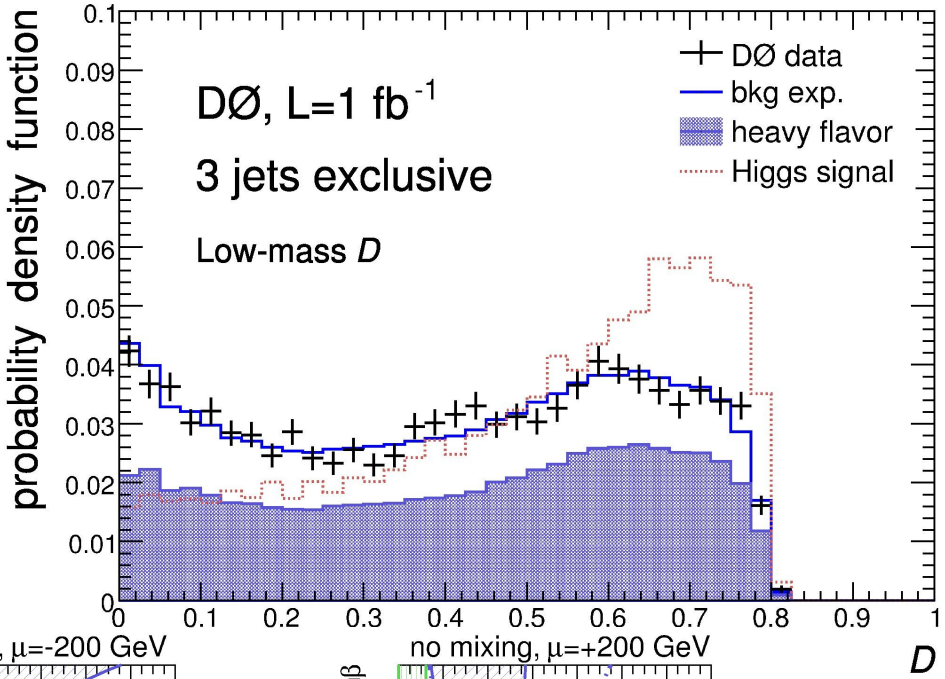
Higgs Searches

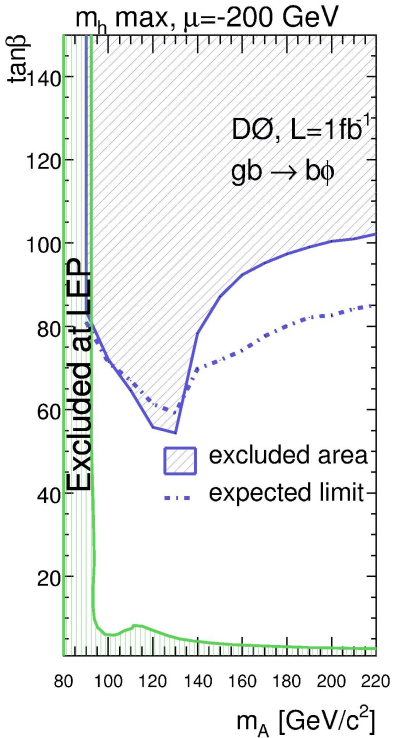
- **Higgs combination**

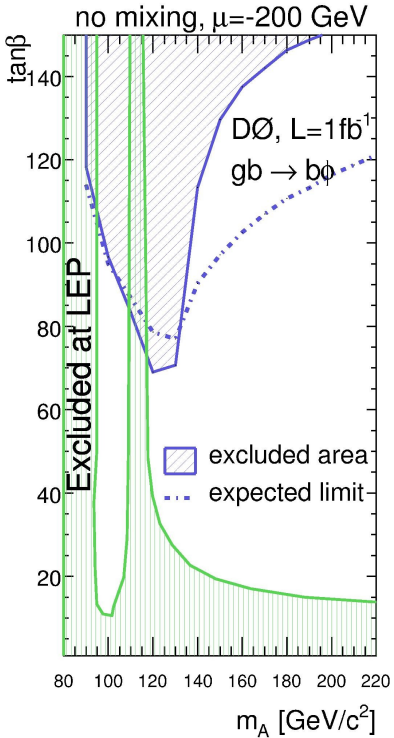


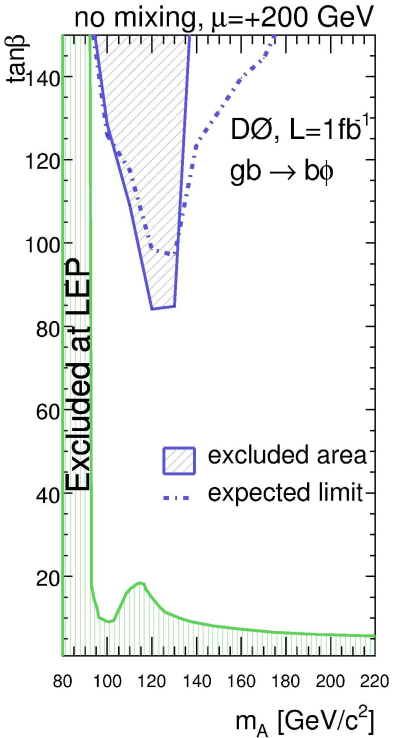
Higgs Searches

- **H → multi-b with likelihood**
- Enhanced in MSSM:
  - 2 Higgs doublets
  - New parameters



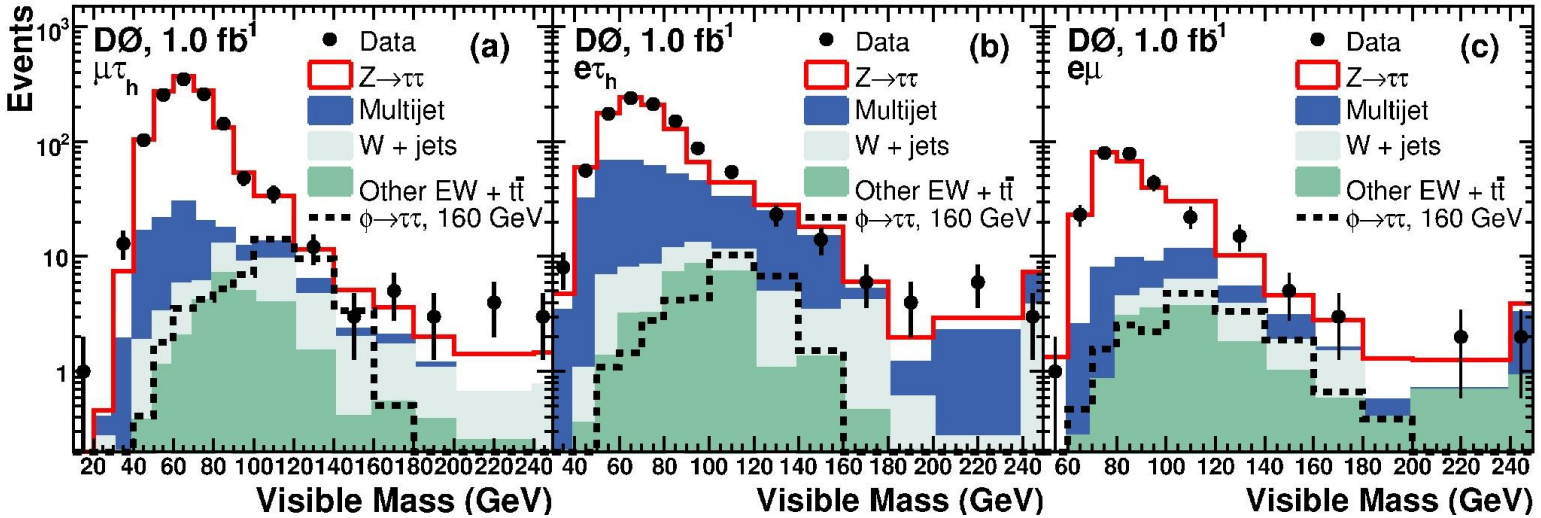


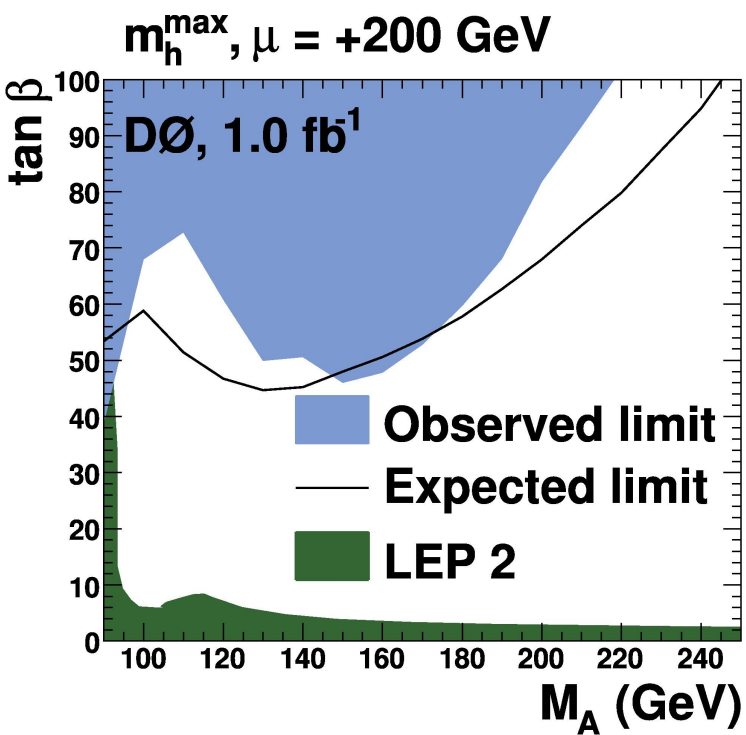


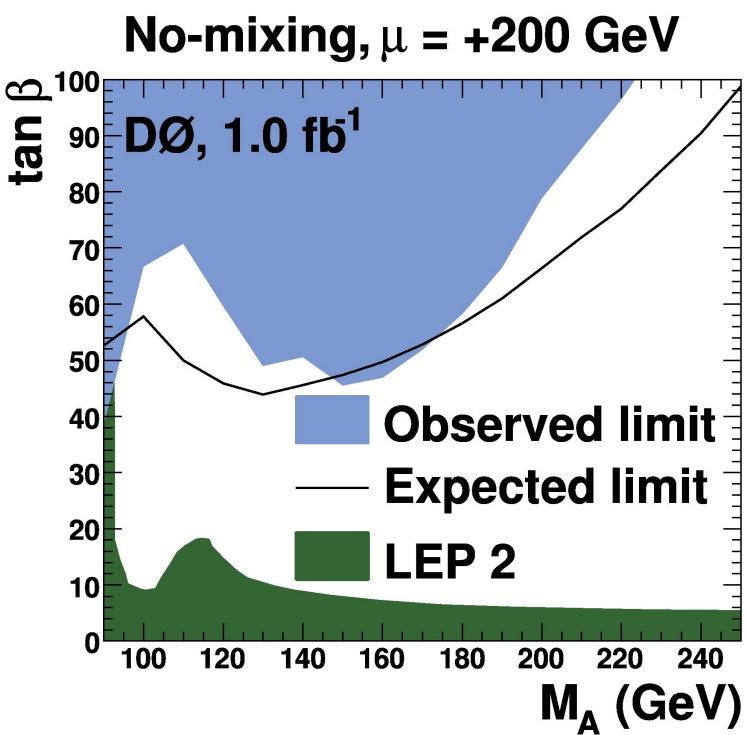


Higgs Searches

- **H → ττ**







New Phenomena

- **Many analyses:**
  - Search for SUSY paricles: chargino, neuralino, squarks, gluinos...
  - Gauge Mediated SUSY Breaking
  - Heavy gauge bosons
  - Large extra dimensions
  - Substructure of quarks and leptons
  - Excited electrons
  - 4th generation fermions
  - Long lived b'

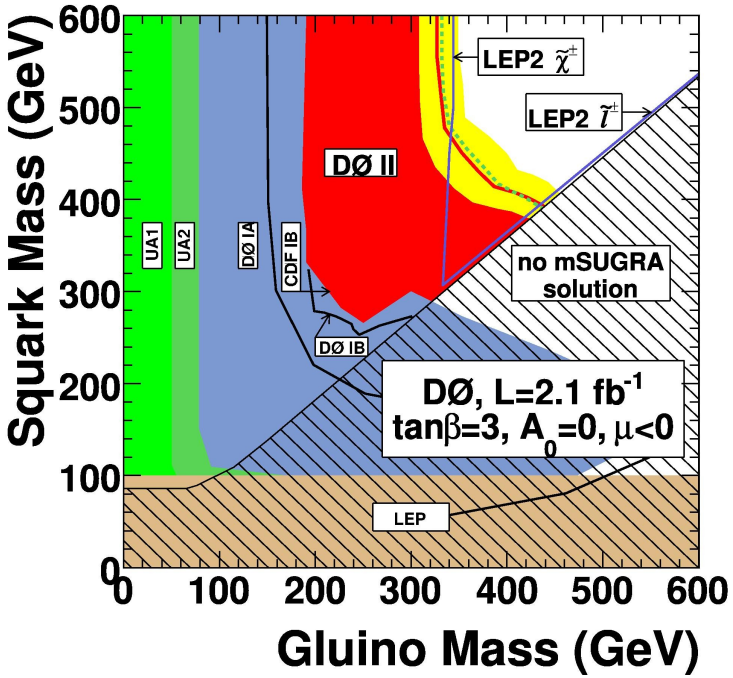
New Phenomena

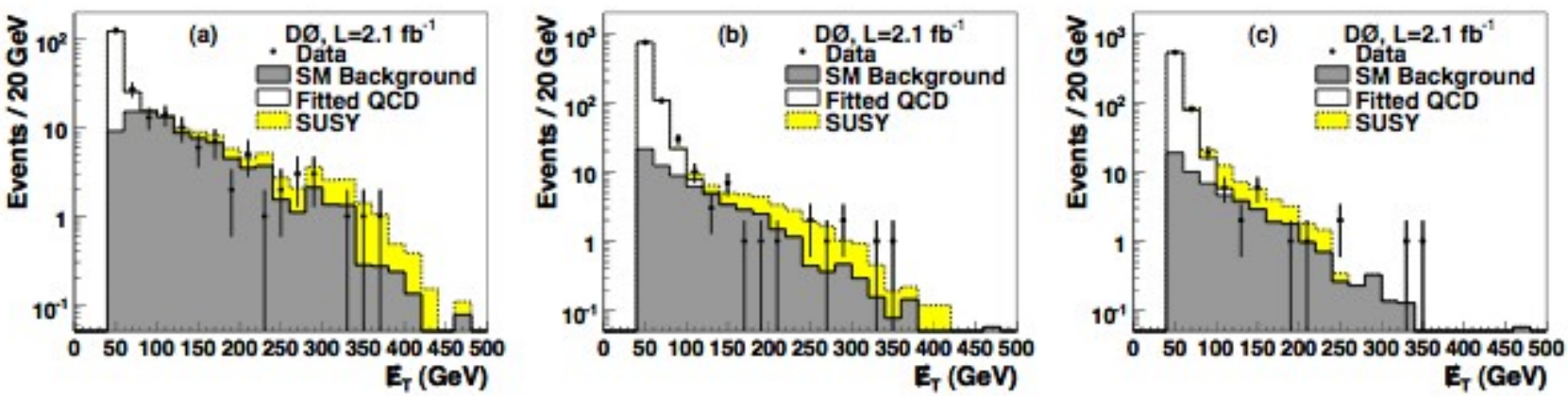
- **Squarks & gluinos:**
- Signal: jets + MET

$$m_{\tilde{q}} < m_{\tilde{g}} : p\bar{p} \to \tilde{q}\tilde{q} \to q\tilde{\chi}_1^0 q\tilde{\chi}_1^0$$

$$m_{\tilde{q}} \sim m_{\tilde{g}} : p\bar{p} \to \tilde{q}\tilde{g} \to q\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$$

$$m_{\tilde{q}} > m_{\tilde{g}} : p\bar{p} \to \tilde{g}\tilde{g} \to q\bar{q}\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$$



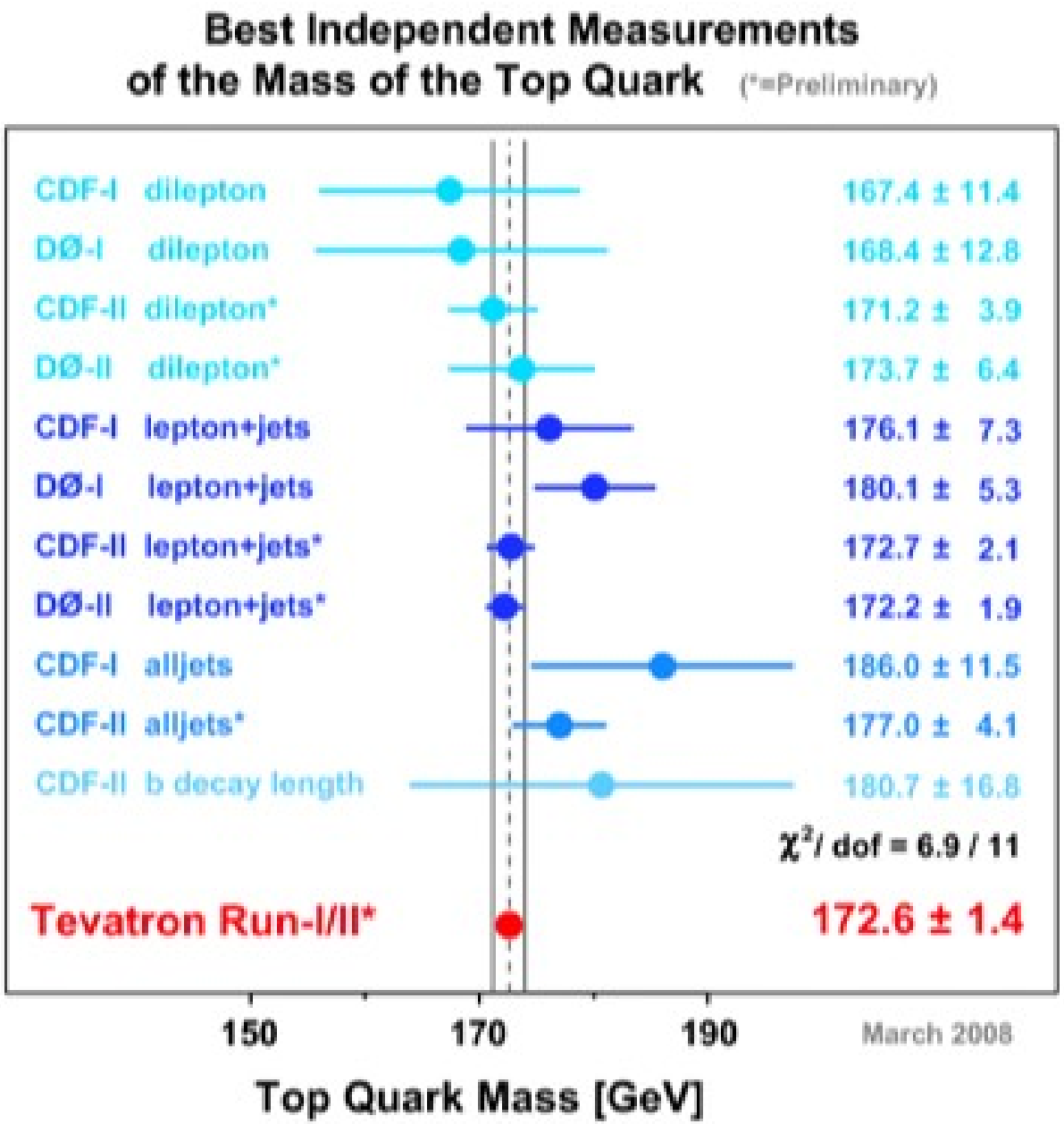


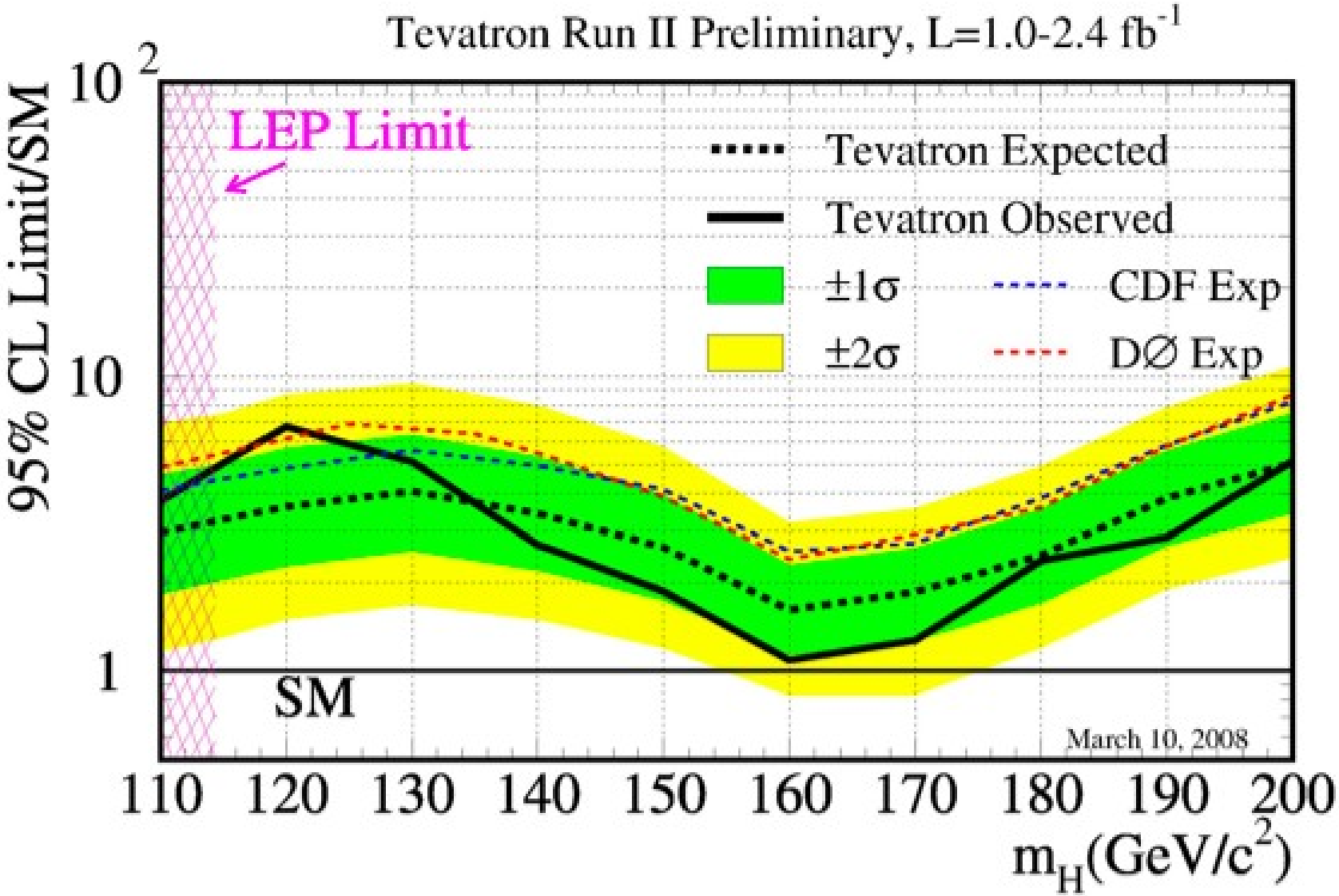
Summary

- DØ is producing a wide range of high quality results both testing the Standard Model and searching for new Physics.
- The challenges of the future are not just adding more data. We are improving analysis techniques and increasing our sensitivities faster than $\sqrt{L}$
- Lots of results I didn't mention:

http://www-d0.fnal.gov/Run2Physics/WWW/results.htm

Backup slides


Best Independent Measurements
of the Mass of the Top Quark (*=Preliminary)
CDF-I dilepton 167.4 ± 11.4
DØ-I dilepton 168.4 ± 12.8
CDF-II dilepton* 171.2 ± 3.9
DØ-II dilepton* 173.7 ± 6.4
CDF-I lepton+jets 176.1 ± 7.3
DØ-I lepton+jets 180.1 ± 5.3
CDF-II lepton+jets* 172.7 ± 2.1
DØ-II lepton+jets* 172.2 ± 1.9
CDF-I alljets 186.0 ± 11.5
CDF-II alljets* 177.0 ± 4.1
CDF-II b decay length 180.7 ± 16.8
χ²/ dof = 6.9 / 11
Tevatron Run-I/II* 172.6 ± 1.4
150
170
190
March 2008
Top Quark Mass [GeV]


Tevatron Run II Preliminary, L=1.0-2.4 fb^{-1}
95% CL Limit/SM
10^2
10
1
LEP Limit
Tevatron Expected
Tevatron Observed
±1σ
±2σ
CDF Exp
DØ Exp
SM
March 10, 2008
110 120 130 140 150 160 170 180 190 200
m_H(GeV/c^2)