Non Standard Model Higgs searches at DØ

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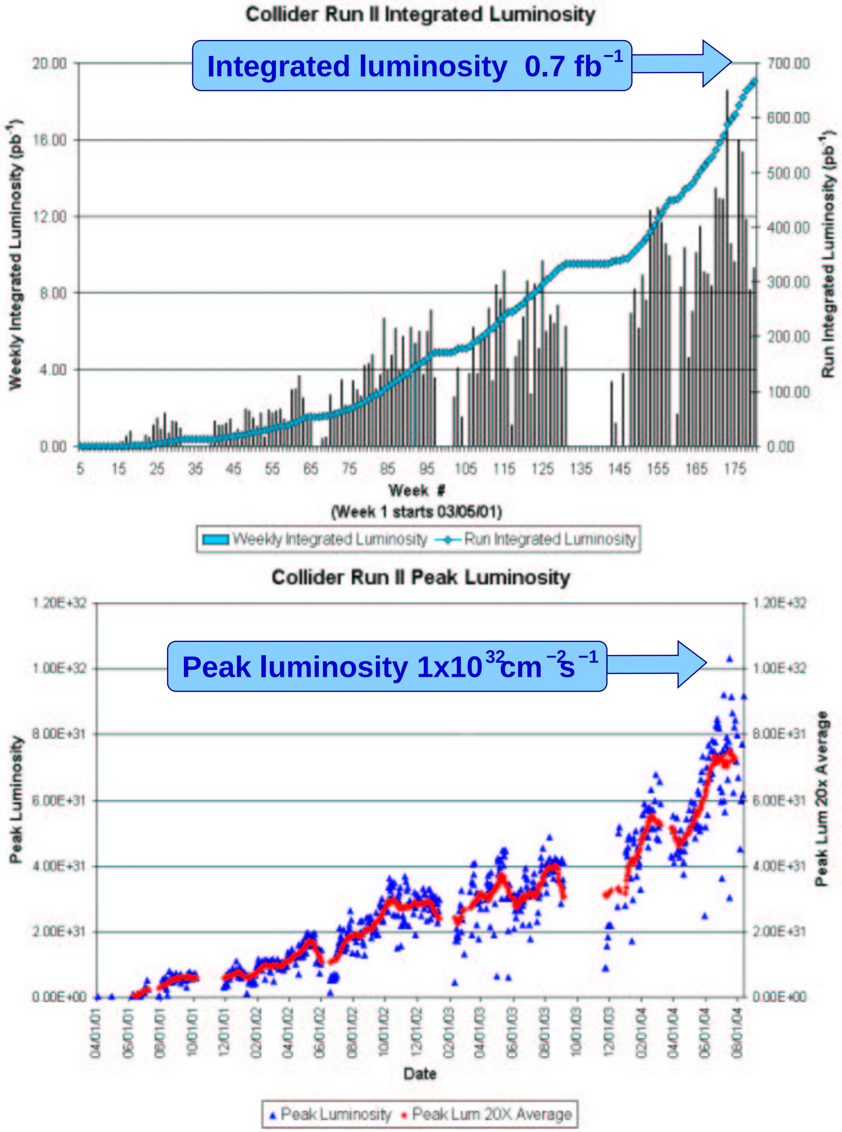
Outline

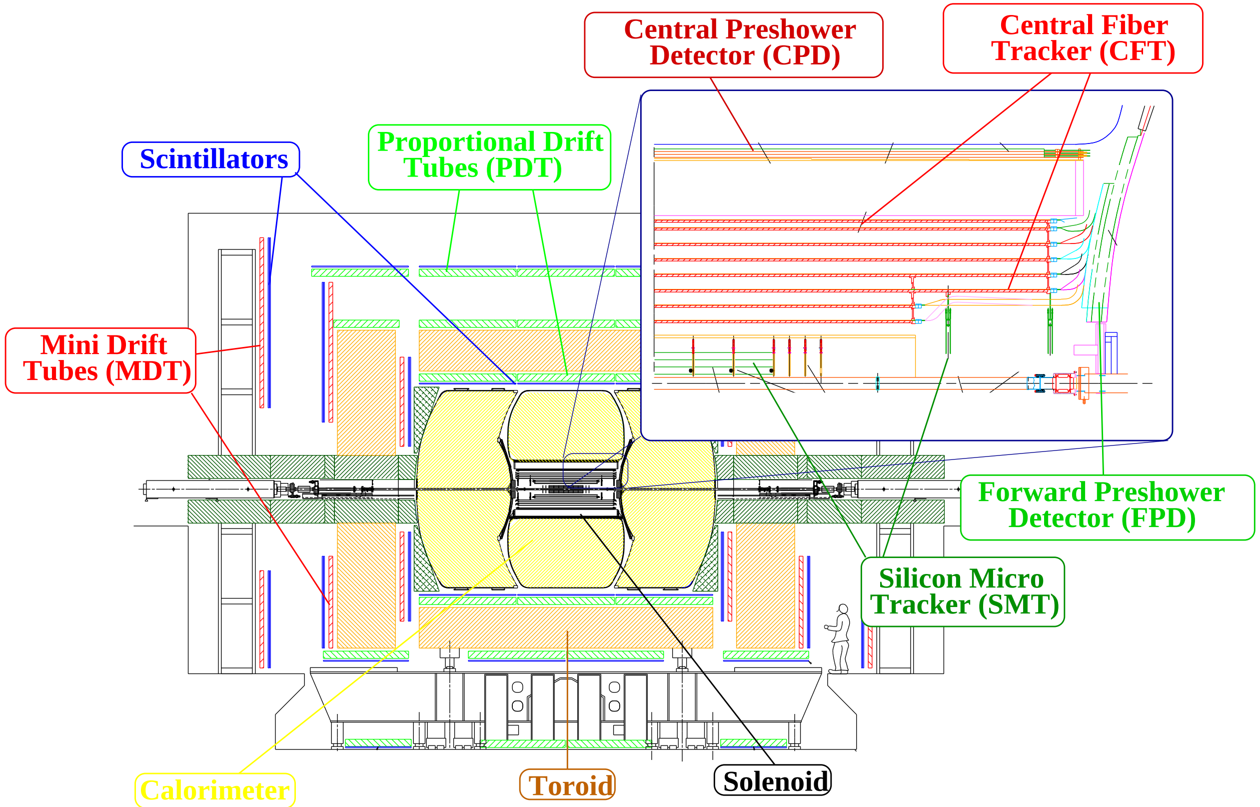
- Introduction
- Tevatron and the DØ detector
- Search for $\mathrm{H} \rightarrow \mathrm{WW}^{(*)}$
- Search for $\mathrm{H} \rightarrow \gamma\gamma$
- Doubly charged Higgs bosons
- Neutral Higgs bosons at high $\tan\beta$
- Summary and outlook

Tevatron

- $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
- Peak luminosity $4-8\cdot10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Weekly delivered 8–16 pb^{-1}



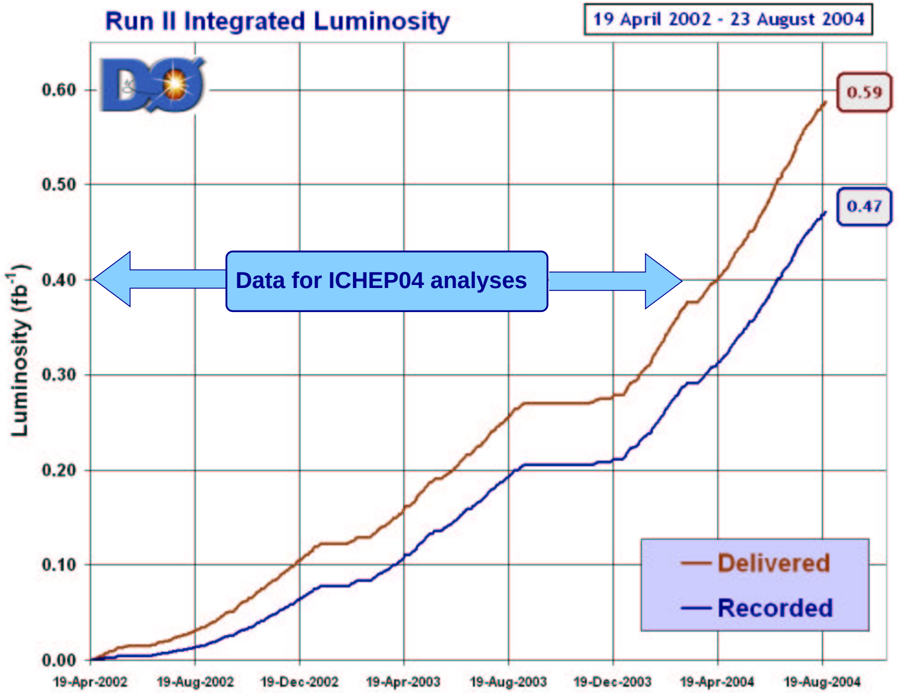
DØ detector

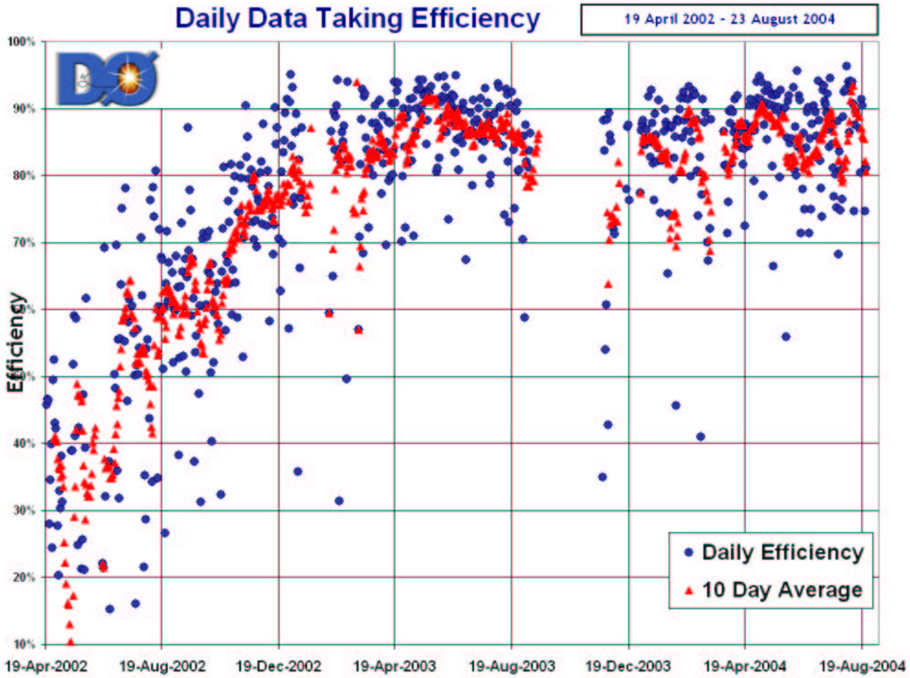


- 4 layer silicon detector and 8 layer fiber tracker inside solenoid (2T)
- 3 layer muon system up to $|\eta| = 2$
- Liquid argon calorimeter with new electronics
- Preshowers in front of calorimeter
- New trigger and DAQ

DØ performance

- Recorded luminosity $\sim 500\ \mathrm{pb}^{-1}$
- Data used for the analyses
  $\int \mathcal{L}dt$ = 100 – 200 pb^{-1}

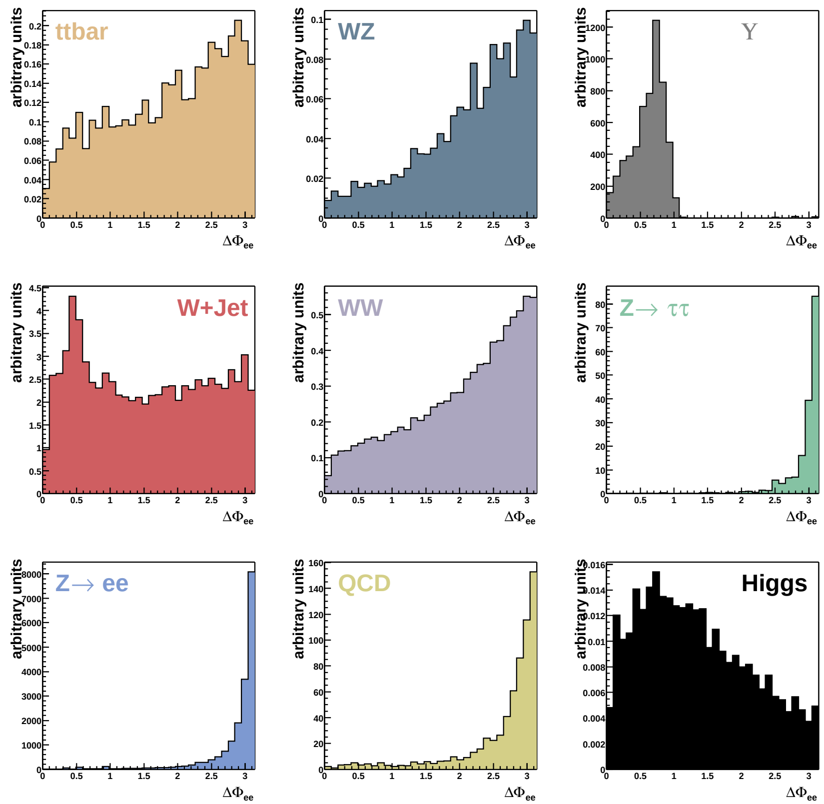




- Data taking efficiency
  80–90%

Selection strategy for $\mathrm{H} \rightarrow \mathrm{WW} \rightarrow \ell^+\nu\ell^-\bar{\nu}$

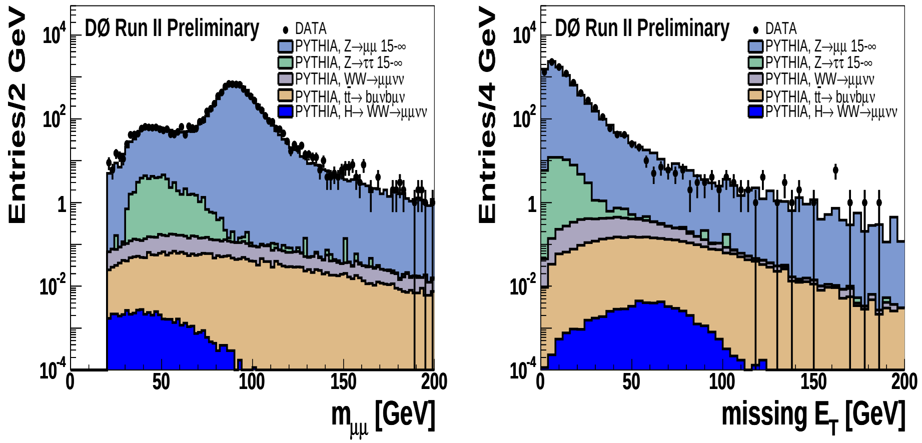
- Signal characterized by
  - Two leptons of opposite charge
  - Two neutrinos
    $\Rightarrow$ Large missing transverse energy
  - Small opening angle between two charged leptons in transverse plane
    $\Rightarrow$ Caused by spin correlations in decay
- Major backgrounds
  - Vector boson pair production
  - Single vector boson production
    - $\mathrm{Z}/\gamma^* \rightarrow ee$, $\mathrm{Z}/\gamma^* \rightarrow \mu\mu$, $\mathrm{Z}/\gamma^* \rightarrow \tau\tau$
    - W($\rightarrow e, \mu$)+jets/γ
- Other backgrounds
  - $\mathrm{t\bar{t}}$, QCD, $\Upsilon \rightarrow ee, \mu\mu$



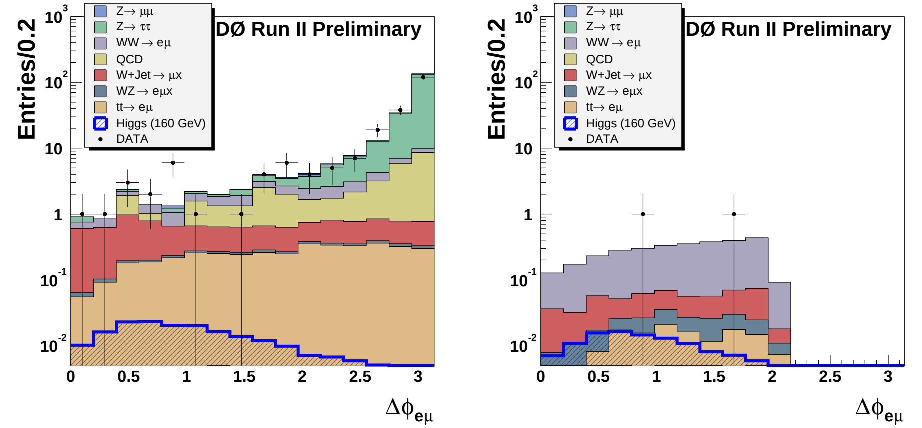
Signal selection for $\mathrm{H} \rightarrow \mathrm{WW} \rightarrow \ell^+\nu\ell^-\bar{\nu}$

- Search for the Higgs in three channels
  - ee channel: $\int \mathcal{L}dt$ = 177 pb^{-1}
  - $e\mu$ channel: $\int \mathcal{L}dt$ = 158 pb^{-1}
  - $\mu\mu$ channel: $\int \mathcal{L}dt$ = 147 pb^{-1}
- Selection criteria
  - Two leptons of opposite charge
  - Large missing transverse energy $\not{E}_T$
    $\Rightarrow$ Rejects Drell Yan, QCD
  - Dilepton mass or transverse mass
    $\Rightarrow$ Rejects Drell Yan, WW
  - Jet veto
    $\Rightarrow$ Rejects $\mathrm{t}\bar{\mathrm{t}}$
  - Opening angle $\Delta\phi_{\ell\ell}$
    $\Rightarrow$ Rejects Drell Yan, WW

$\mu\mu$ channel



$e\mu$ channel



Data and Monte Carlo comparison

$e^{\pm}\mu^{\mp}$ channel	$t\bar{t}$	WZ	W+jet/γ	WW	$Z/\gamma^{*} \to \tau\tau$
Cut 0	3.98±0.08	0.34±0.01	7.24±0.13	10.3±0.1	168±5
Cut 1	3.61±0.07	0.28±0.01	5.02±0.11	7.79±0.08	27.5±1.8
Cut 2	2.86±0.06	0.23±0.01	4.15±0.10	6.96±0.08	2.43±0.54
Cut 3	2.80±0.06	0.21±0.01	1.41±0.06	5.85±0.07	1.31±0.38
Cut 4	1.55±0.05	0.13±0.01	0.94±0.05	3.31±0.05	0.57±0.29
Cut 5	0.64±0.03	0.11±0.01	0.35±0.02	2.52±0.05	0.27±0.19
Cut 6	0.13±0.01	0.11±0.01	0.34±0.02	2.51±0.05	0.00±0.14

	$Z/\gamma^{*} \to \mu\mu$	QCD	SUM	DATA
Cut 0	5.21±0.79	25.2±2.4	221± 5 ±14	218
Cut 1	1.91±0.46	4.17±0.98	50.2± 2.1 ±3.3	54
Cut 2	0.49±0.22	2.32±0.73	19.4± 1.0 ±1.3	21
Cut 3	0.21±0.12	1.62±0.61	13.4± 0.8 ±0.9	12
Cut 4	0.05±0.05	0.92±0.46	7.46±0.55±0.49	6
Cut 5	0.0±0.05	0.0±0.23	3.89±0.31±0.25	4
Cut 6	0.0±0.05	0.0±0.23	3.10±0.28±0.20	2

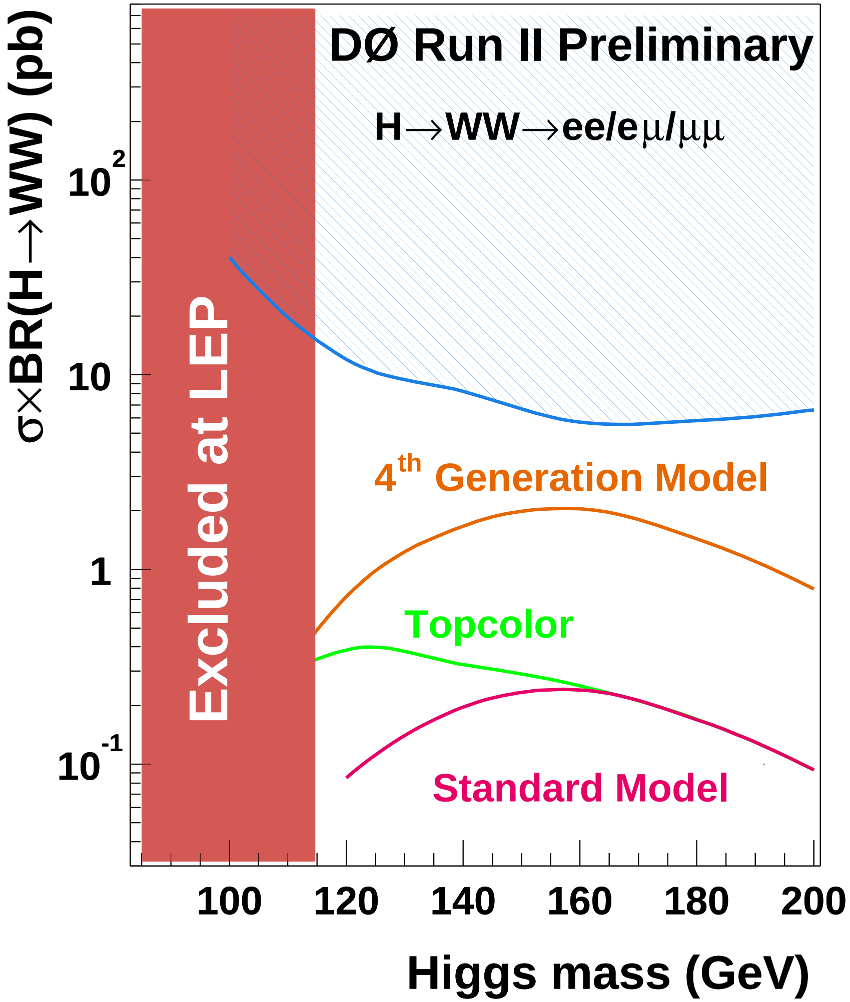
- Good agreement between data and Monte Carlo after every stage of the selection
- Similar agreement for $e^{+}e^{-}$ and $\mu^{+}\mu^{-}$ channels

Cross section limits

- Expected and observed events

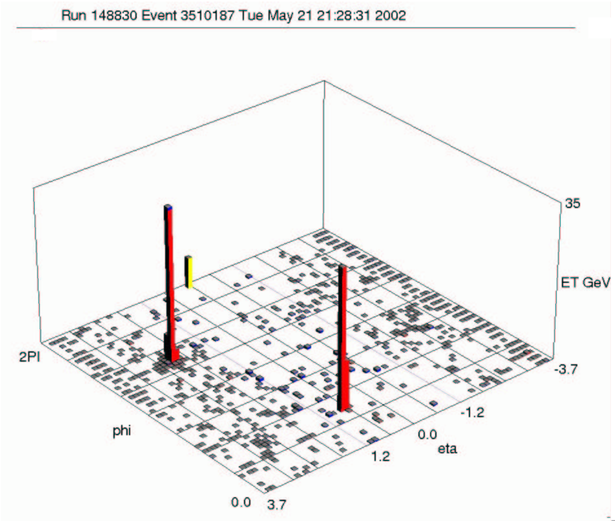
	Background	Data
ee	2.7±0.4	2
$e\mu$	3.1±0.3	2
$\mu\mu$	5.3±0.6	5

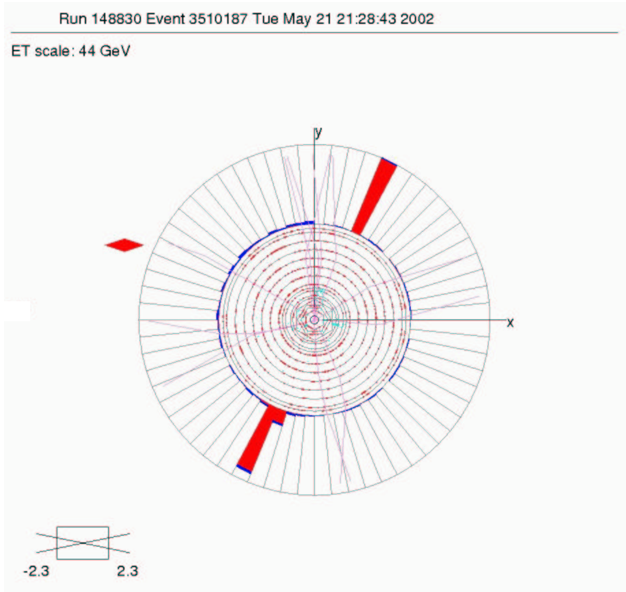
- Signal efficiencies
  - 13%–21% for $\mathrm{M_H}$ = 160 GeV
  - 6%–11% for $\mathrm{M_H}$ = 120 GeV
- Signal expectation
  - 0.27 events for $\mathrm{M_H}$ = 160 GeV
- Use Likelihood method to calculate limits
- Combine all three channels
  $\Rightarrow \sigma\times\mathrm{BR}(\mathrm{H} \rightarrow \mathrm{WW}^{(*)}) < 5.7$ pb
  for $\mathrm{M_H}$ = 160 GeV



Search for $\mathrm{H} \rightarrow \gamma\gamma$

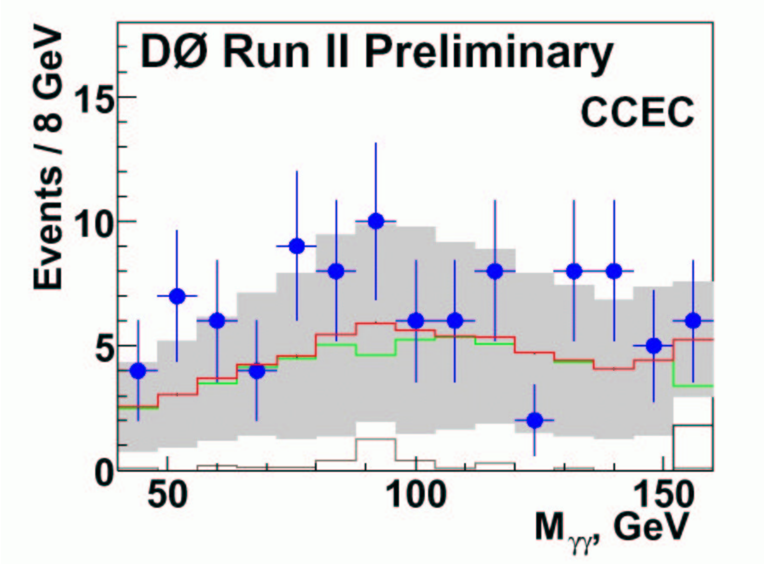
- Small branching fraction in Standard Model
- Enhanced branching fraction in non SM scenarios
  - Fermiophobic (no couplings to fermions)
  - Topcolor (Higgs couples to top quark)
- Two photons have clean signature in the detector
- Backgrounds
  - $\mathrm{Z}/\gamma^* \rightarrow ee$ with e misidentified as γ
  - Direct diphoton production
  - Multijet events with jets faking photons
- Integrated luminosity
  - $\int \mathcal{L}dt = 191\ \mathrm{pb}^{-1}$

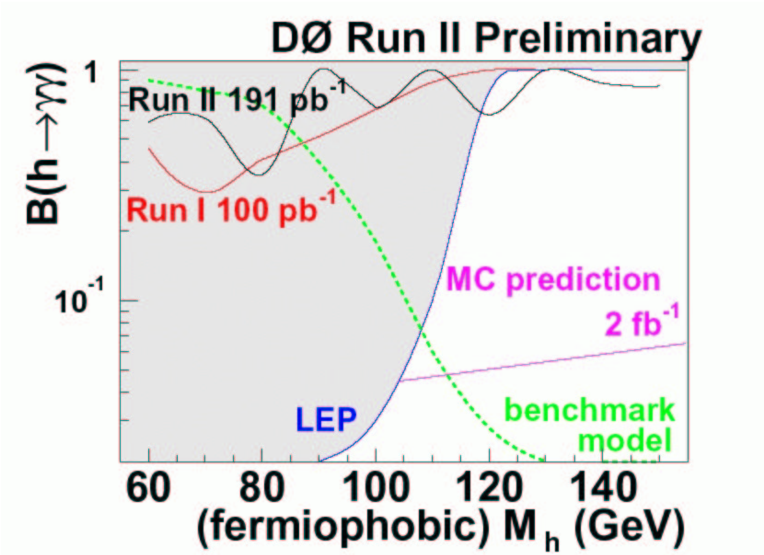




Event selection

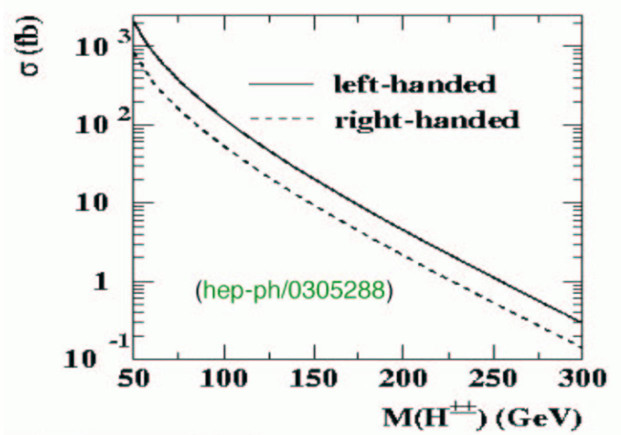
- Selection strategy
  - Two high p_T photons
  - Photon identification
    - Shower shape consistent with electromagnetic cluster
    - Track veto
- Cross section limits
  - Counting experiment in mass window
  - Window optimized for different Higgs masses
  - Width 5–10 GeV for M_H = 60–150 GeV
- Main systematics
  - Photon misidentification rate, luminosity

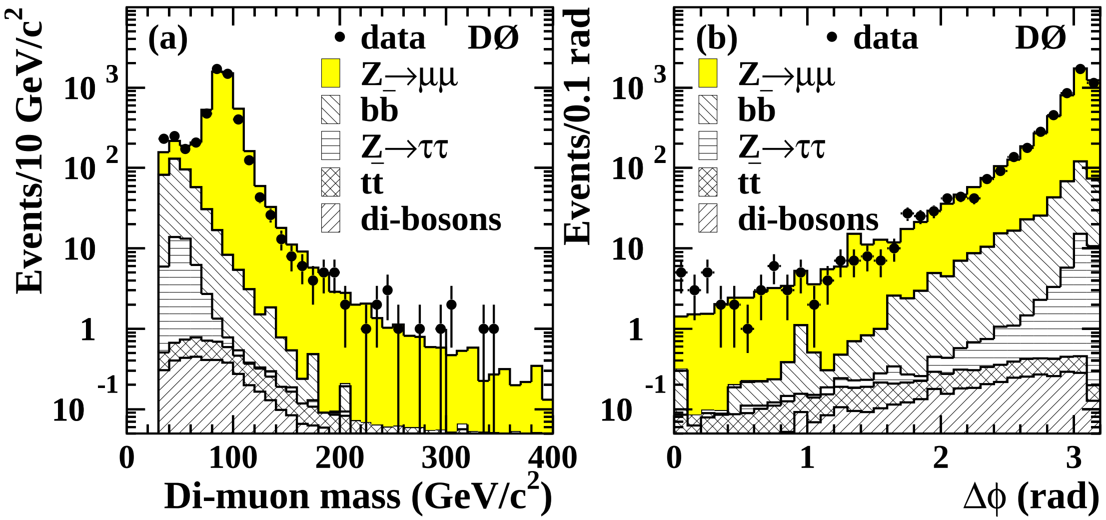




Doubly charged Higgs boson

- Many models beyond SM predict doubly charged Higgs bosons
- Some models predict large decay rates into leptons
- Clean signature

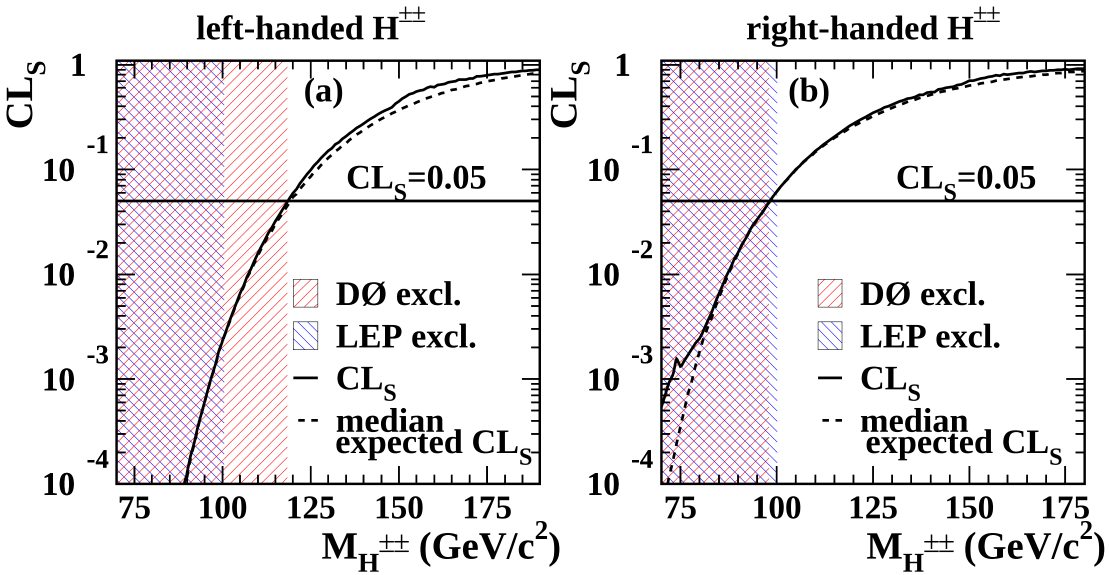




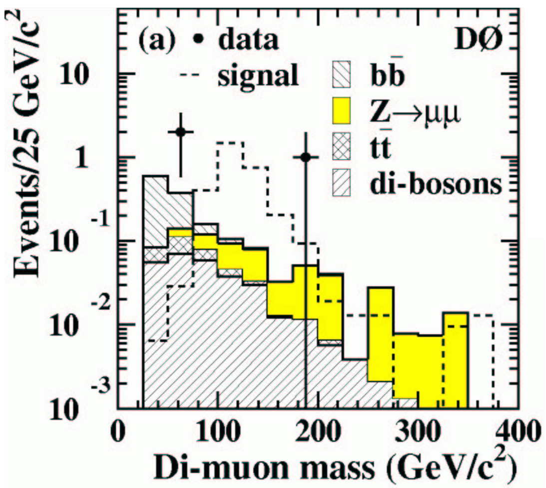
- Integrated luminosity
  - $\int \mathcal{L}dt = 113\ \mathrm{pb}^{-1}$
- Dominant background is $b\bar{b}$ production
- Event selection
  - Two or more muons
  - At least two same sign muons
  - Small opening angle

Limits for doubly charged Higgs bosons

- Background expectation 1.5 ± 0.4 events
- Three events observed in the data
- Signal efficiency $(47.5 \pm 2.5)\%$



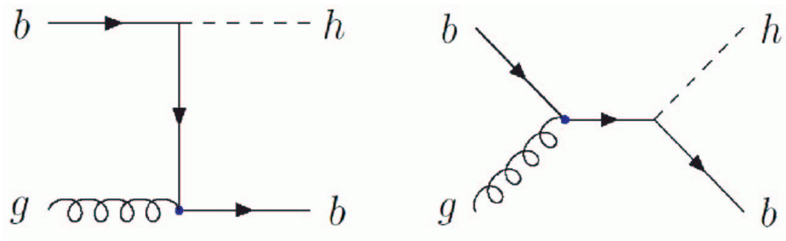
- Published in Phys. Rev. Lett. 93:141801, 2004



- Calculate limits using $\mathrm{CL_S}$ method
- Assume 100% BR into two muons
- 95% C.L. upper limits
  - $H_L^{\pm\pm}$: $M_H >$ 118.4 GeV
  - $H_R^{\pm\pm}$: $M_H >$ 98.2 GeV

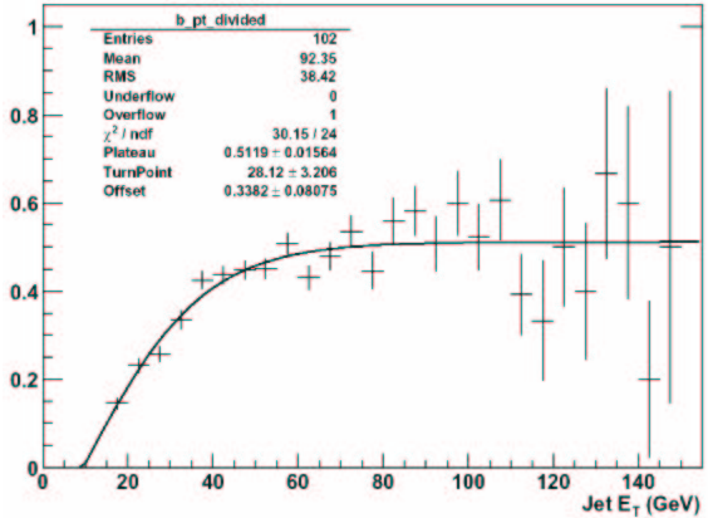
MSSM neutral Higgs bosons

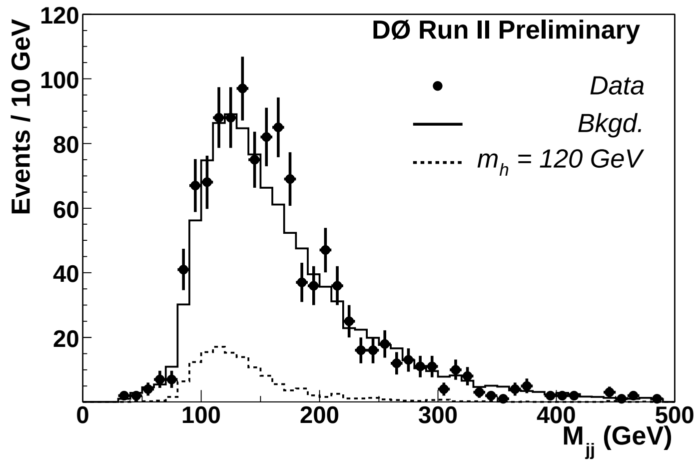
- Five Higgs bosons in MSSM, three of those Higgs bosons are neutral: h^0, H^0, A^0
- Physics at large $\tan\beta$
  - A^0 nearly degenerate with h^0 or H^0
  - Enhancement of coupling to down–type fermions
    - Production cross section scales as $\tan^2\beta$
    - Branching fractions: $\mathrm{b\bar{b}}$ ~90%, $\tau\tau$ ~10%
- Dominant Higgs signature at the Tevatron
  - $\mathrm{p\bar{p}} \to \mathrm{b(b)}\phi \to \mathrm{b(b)b\bar{b}}$
- Three or four b–quarks in final state
- b–tagging important for analysis
- Major backgrounds
  - 4j, 2b+2j, 4b, Z($\to \mathrm{b\bar{b}}$)+2j, $\mathrm{t\bar{t}}$



Event selection

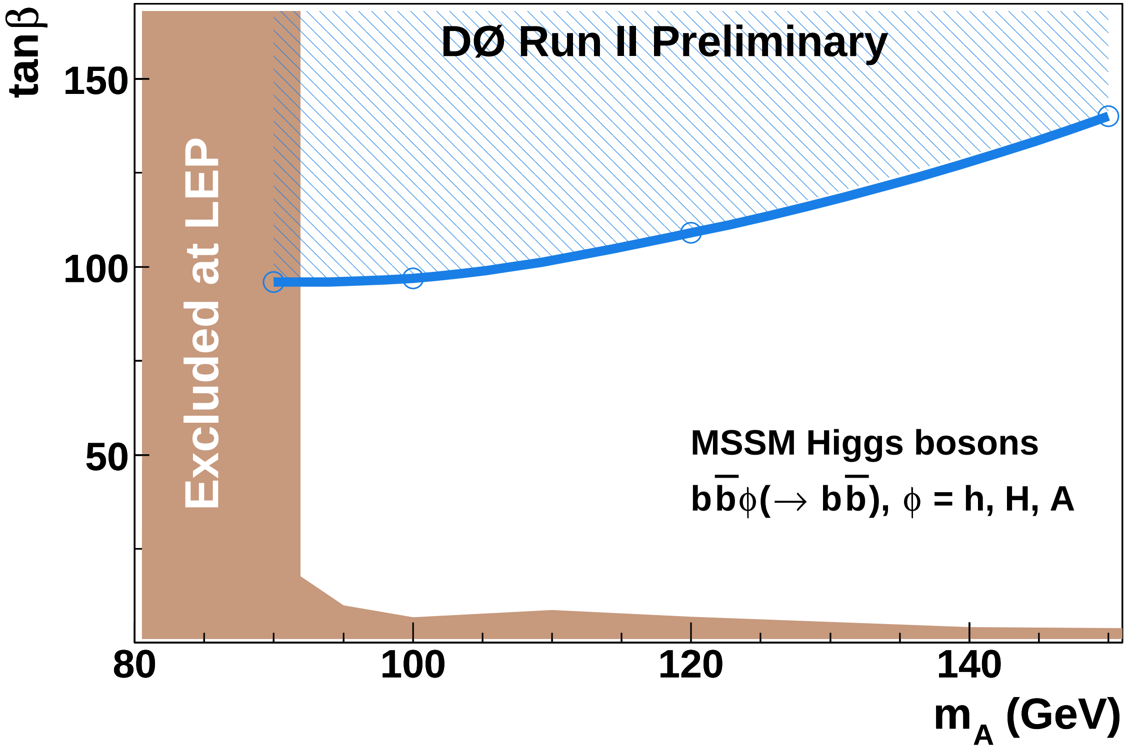
- Selection strategy
  - b–tagging: events with $\geq$ 3 b–tagged jets
  - Peak in invariant di–jet mass
- b–tagging efficiency
  - 50% efficiency with 2% mistag efficiency for light jets
- Event selection
  - Optimization for jet p_T cuts for various Higgs masses
  - $\geq$ 3 b–tagged jets (secondary vertex) $\Rightarrow$ typical acceptance 0.1–1.5%





Limits

- Integrated luminosity
  - $\int \mathcal{L}dt = 131\ \mathrm{pb}^{-1}$
- Use $\mathrm{CL_S}$ method to calculate limits
- Scan $\tan\beta$ for given $\mathrm{m_A}$



Summary

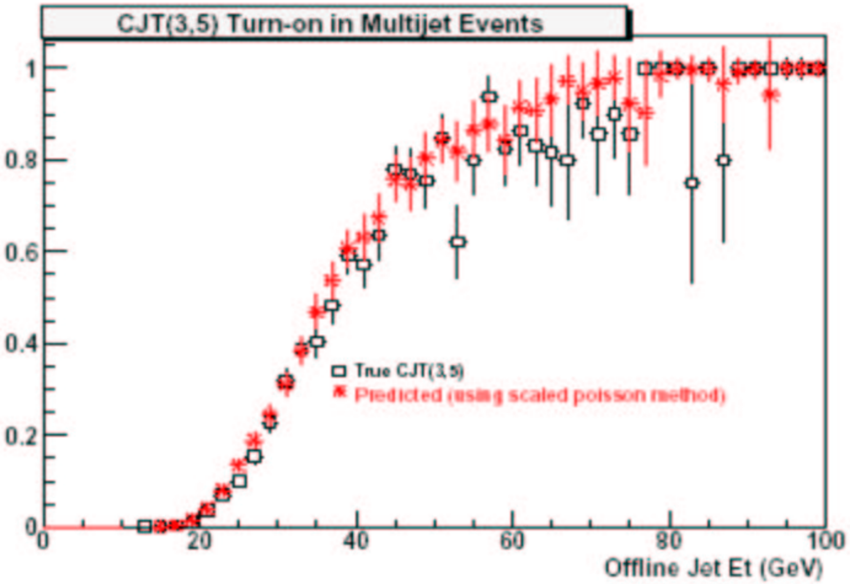
- Conclusion
  - DØ has performed several non SM Higgs searches
    - $\mathrm{H} \rightarrow \mathrm{WW}^{(*)}$ and $\mathrm{H} \rightarrow \gamma\gamma$ interpreted in non SM models
    - Doubly charged Higgs bosons
    - Neutral MSSM Higgs bosons
  - No new physics discovered yet
  - Limits are competitive with LEP
  - Analyses are statistically limited

- Outlook
  - Major improvements due to higher statistics
  - Factor 2–5 more data already on tape

Trigger for $b\bar{b}\phi$

- Trigger strategy (three Level trigger)

		Old version	New version
Level 1	Tower E_T	4×5 GeV	3×5 GeV
Level 2	Jet E_T	3×8 GeV	3×8 GeV
	$\sum E_T$	> 50 GeV	> 50 GeV
Level 3	Jet E_T	3×15 GeV	2×25 GeV, 1×15 GeV



- Trigger efficiency with respect to offline 68–80% (depending on M_H)