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Search for The Standard Model Higgs Boson in the $\tau\tau\mu$ + X final state at DØ

IOP Joint HEPP and APP Meeting 2012

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For the DØ Collaboration

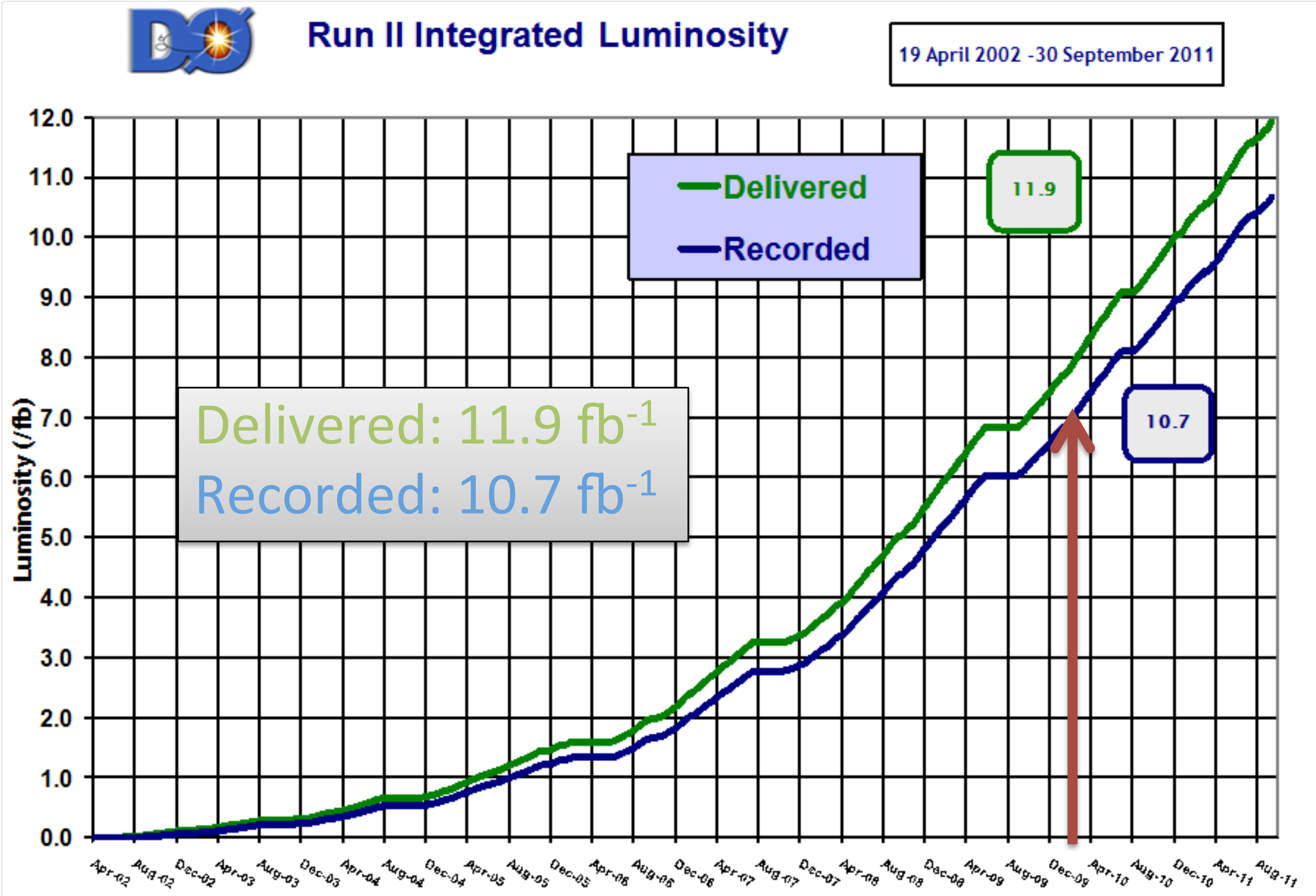
The Fermi National Accelerator Laboratory

Tevatron collided protons and antiprotons from 1985 to 2011

2 general purpose detectors DØ and CDF

Over 10 fb^{-1} recorded

DØ luminosity



Delivered: 11.9 fb^{-1}

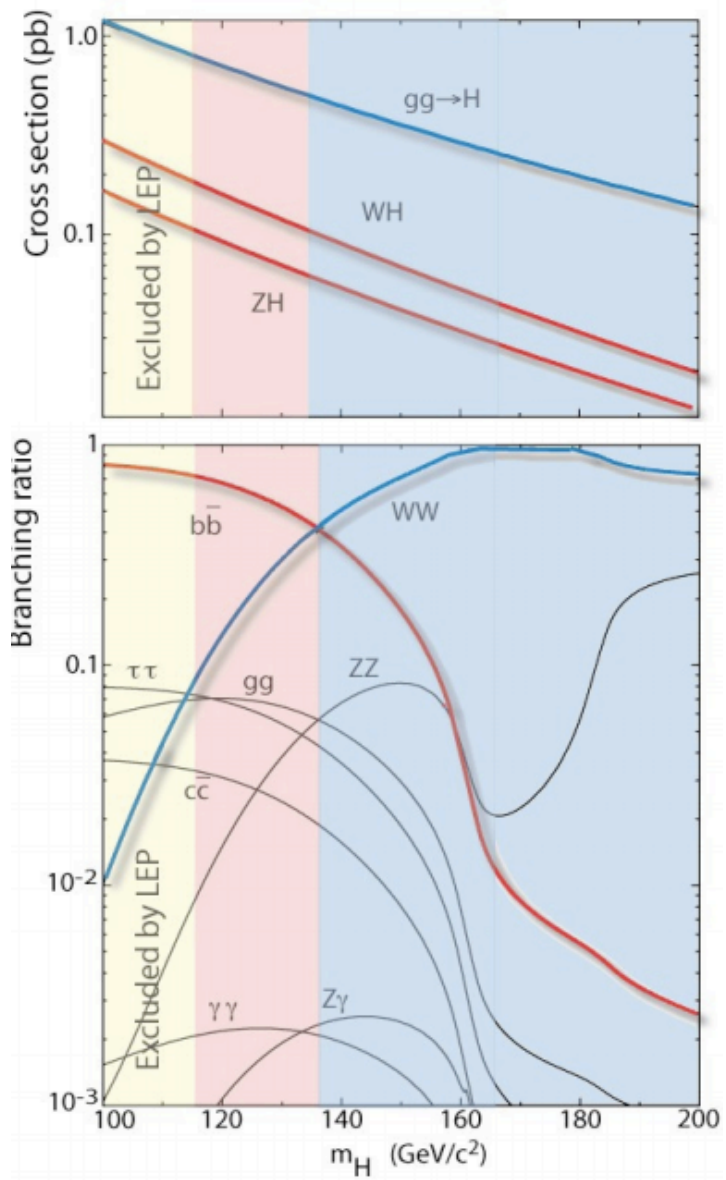
Recorded: 10.7 fb^{-1}

Showing results with up to 7.0 fb^{-1}

SM Higgs with tau leptons

- No single channel has sufficient sensitivity
  - Explore as many final states as possible
  - Separate these into sub-channels
    - different signal purity
    - different background composition
- Two main channels;

  H->WW, H->bb
- Next dominant channel at low mass is H->ττ



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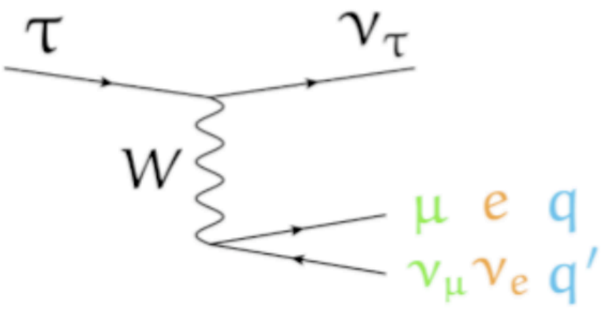
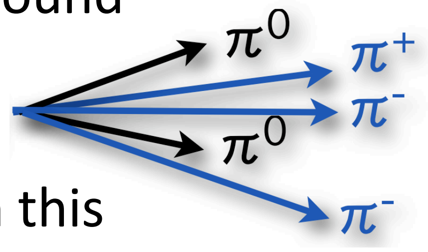
Tau identification

- Heaviest lepton with M = 1777 MeV and lifetime of just 2.9 x 10^{-13} s, so we only observe its decay products.
- We use different tools for leptonic and hadronic tau decays



- For e, μ use standard leptonic identification tools
- Hadronic tau decay suffers from large jet background

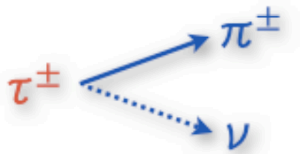


- Specific identification tools created to deal with this

Tau identification

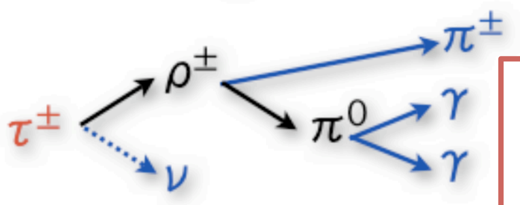
Define 3 types of hadronic τ decays:

Type 1



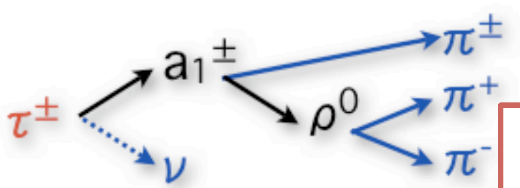
1 Track
Calorimeter cluster

Type 2



1 Track
Calorimeter cluster
> 0 EM sub-cluster

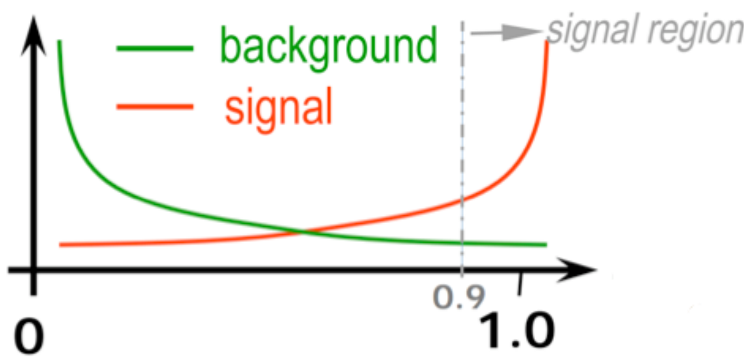
Type 3



> 1 Track
Calorimeter cluster
> 0 EM sub-cluster

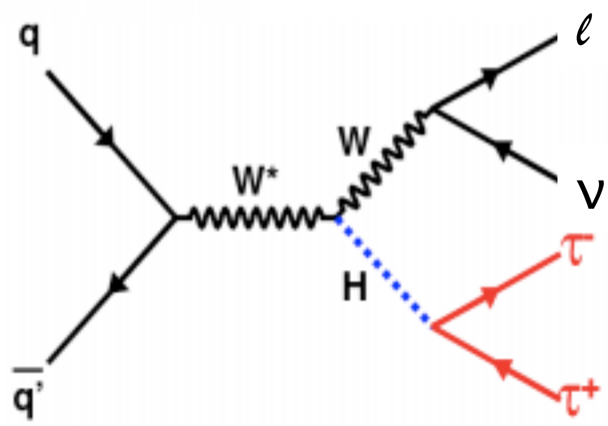
Efficiency = 65% Fake rate = 2.5%

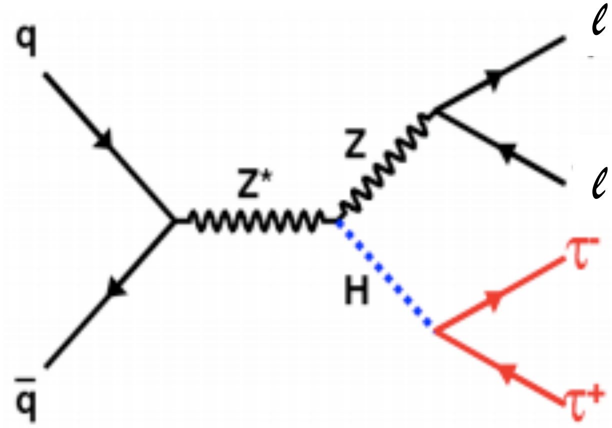
- Neural Network trained for each type
- Trained on Z → ττ to differentiate real taus from jets



ττμ + X channel

- Built from previous PRL arXiv:1106.450
- Look for two hadronic tau decays and a muon
- Channel sensitive to:
  - associated production modes, WH and ZH
  - H -> ττ decay modes





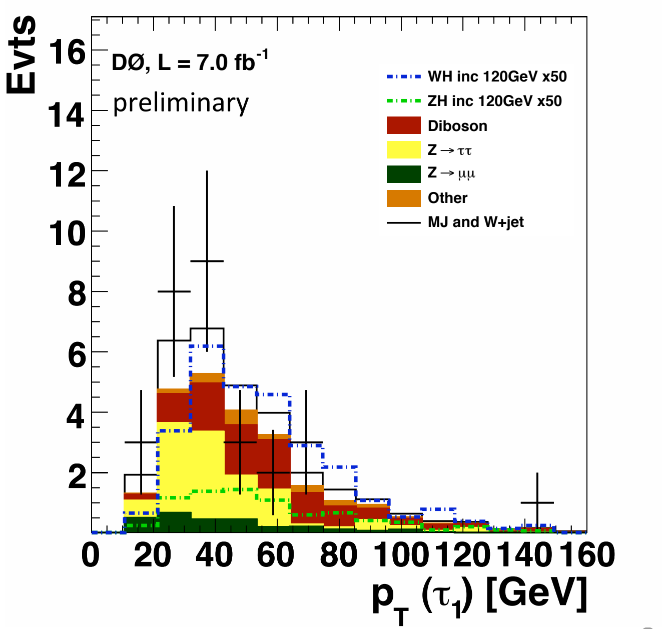
Analysis selection

Selection

- Select the two taus with highest p_T and the highest p_T muon.
- Neural Net output NN_τ is used to discriminate τ from jets.
- Sum of charges of final state objects must be ±1.

Main Backgrounds

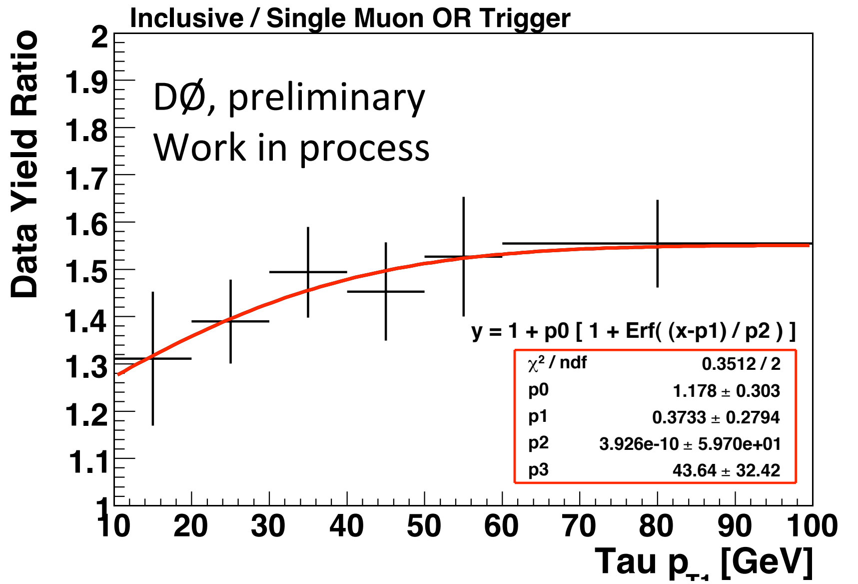
- Z(➔ ττ) + jets
- Z (➔μμ) + jets
- Diboson (WZ, WW, ZZ)
- Multijets and W + jets
  - – predicted from data



Inclusive trigger method

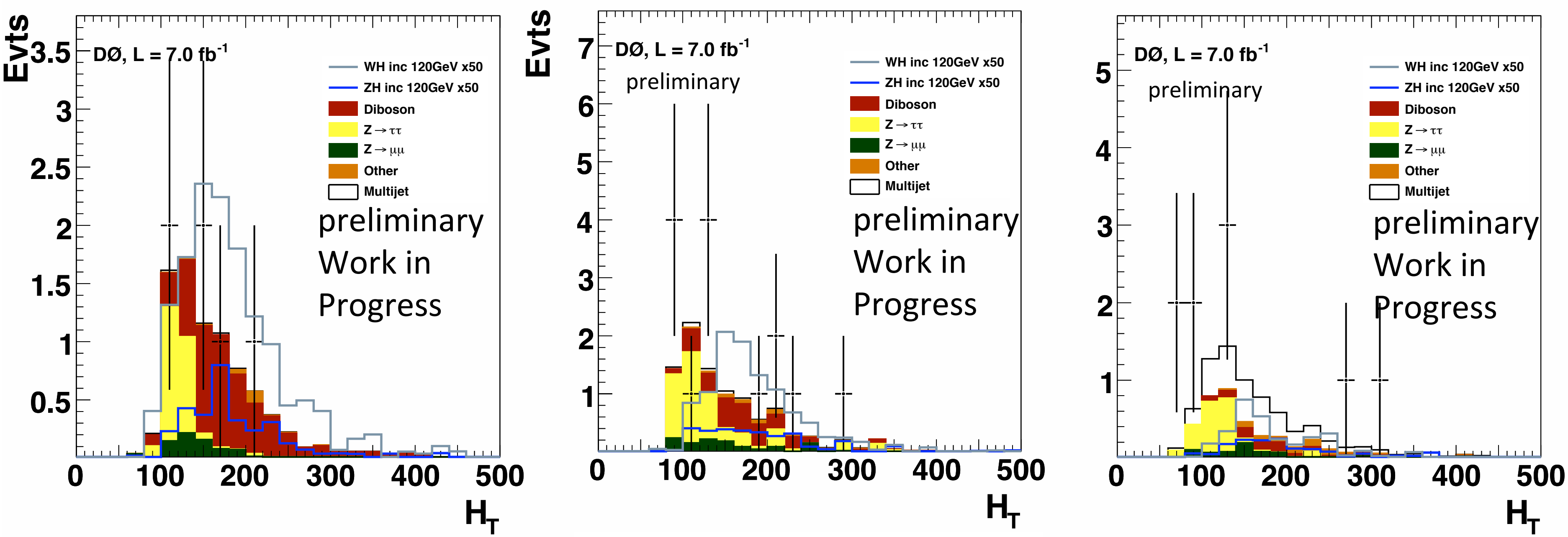
- Analysis uses an inclusive trigger method, where events are not selected by any specific trigger.
- Enables us to increase signal acceptance.
- Efficiency of method determined using a well-understood Muon Trigger.
- Important technique for this low statistics search.

Correction parameterized in the transverse momentum of the leading τ.



Final Discriminant

$N_{jet} = 0$ $N_{jet} = 1$ $N_{jet} > 1$

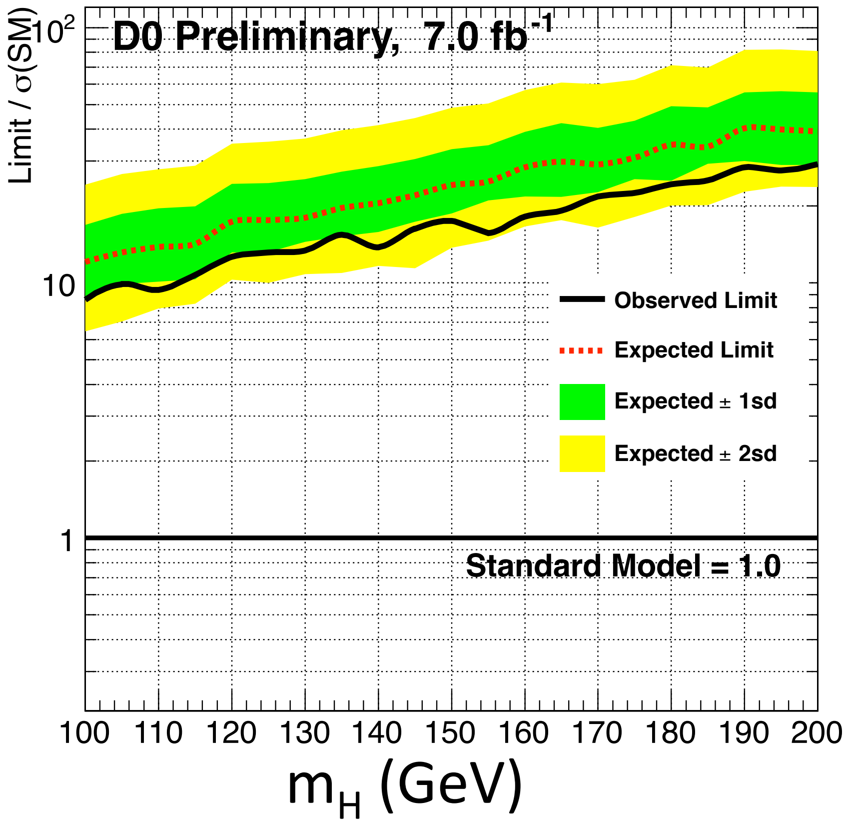


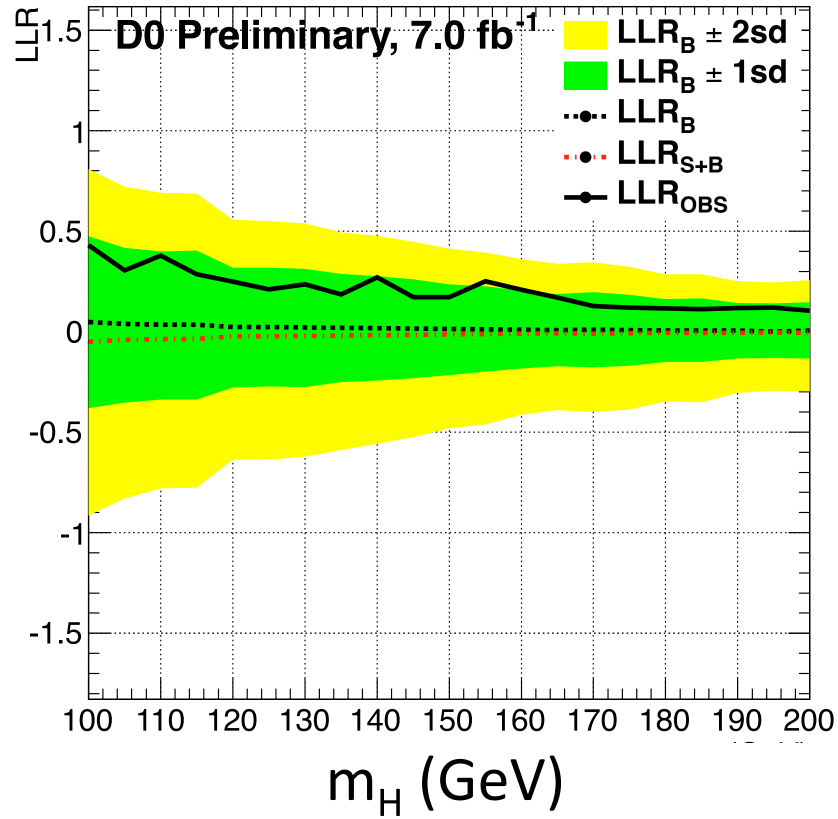
Events separated into jet multiplicity to further discriminate between signal and background.

$$H_T = \sum_{i=0}^{m} p_T(i) + \not{p}_T + \sum_{j=0}^{n} p_T(j)$$

jets missing ET leptons

Limits





Upper limit on cross section at 95% confidence level

Summary

- New DØ search for Higgs produced through associated production decaying to three lepton final state.
- Tau decays have additional sensitivity for lepton channels.
- This analysis shown for the first time at La Thuile
- Exciting results at the winter conferences from the Tevatron.

Updates expected in this channel for summer!

» Full data set

» increased signal acceptance

» use of multivariate techniques

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Back up

Systematics

Contribution	Dibosons	Z/γ^*	$t\bar{t}$	Instrumental	$gg \to H$	$qq \to qqH$	VH
Luminosity/Normalization	6	6	6	24	6	6	6
Trigger	3	3	3	–	3	3	3
Cross Section (Scale/PDF)	7	6	10	–	13-33/7.6-30	4.9	6.2
PDF	–	–	–	–	2.5	2.5	2.5
Tau Id per τ (Type 1/2/3)	7/3.5/5	7/3.5/5	7/3.5/5	–	7/3.5/5	7/3.5/5	7/3.5/5
Tau Energy Scale	1	1	1	–	1	1	1
Tau Track Match per τ	1.4	1.4	1.4	–	1.4	1.4	1.4
Muon Identification	2.9	2.9	2.9	–	2.9	2.9	2.9

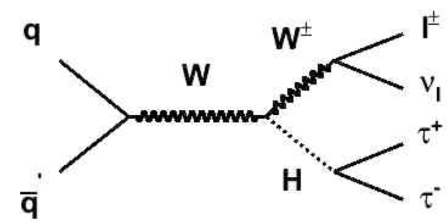
Breakdown of Limits

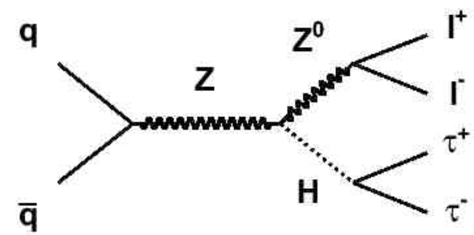
Mass (GeV)	100	105	110	115	120	125	130	135	140	145	150
$\sigma_{exp}/\sigma_{exp}^{SM}$	12.1	13.2	13.8	14.2	17.4	17.6	18.0	19.7	20.5	22.1	24.2
$\sigma_{obs}/\sigma_{obs}^{SM}$	8.6	9.9	9.4	10.7	12.6	13.1	13.4	15.4	13.8	16.3	17.5
Mass (GeV)	155	160	165	170	175	180	185	190	195	200	
$\sigma_{exp}/\sigma_{exp}^{SM}$	24.9	28.4	29.8	29.1	30.9	34.8	34.2	40.3	39.9	39.2	
$\sigma_{obs}/\sigma_{obs}^{SM}$	15.6	18.2	19.2	21.8	22.5	24.4	25.2	28.3	27.6	29.2	

CDF: llττ, lνττ channels

- CDF look for 3 or 4 leptons including hadronic taus.
- Use 6.2fb^{-1} and multi variant technique Support Vector Machine

	3L				4L
	lll	$ll\tau$	$e\mu\tau$	$l\tau\tau$	$LLLL$
ZZ	6.55 ± 0.89	2.36 ± 0.41	0.22 ± 0.05	0.24 ± 0.05	0.92 ± 0.13
WZ	23.45 ± 3.10	3.78 ± 0.60	0.67 ± 0.11	0.53 ± 0.09	0.07 ± 0.02
WW	1.62 ± 0.35	1.77 ± 0.54	0.27 ± 0.10	0.50 ± 0.22	0.01 ± 0.01
$DY(ee)$	133.80 ± 20.26	84.50 ± 23.61	0.01 ± 0.01	0.96 ± 0.46	0.52 ± 0.12
$DY(\mu\mu)$	59.22 ± 9.24	55.58 ± 15.99	0.77 ± 0.33	1.09 ± 0.29	0.29 ± 0.07
$DY(\tau\tau)$	12.38 ± 1.49	22.95 ± 6.63	2.58 ± 1.06	7.69 ± 2.66	0.05 ± 0.02
$Z\gamma$	12.22 ± 1.98	4.95 ± 1.55	1.46 ± 0.63	0.60 ± 0.23	0.06 ± 0.02
$t\bar{t}$	19.01 ± 3.91	6.30 ± 1.73	0.55 ± 0.19	0.38 ± 0.15	0.24 ± 0.06
$W\gamma$	0.21 ± 0.06	0.27 ± 0.09	0.11 ± 0.05	0.03 ± 0.02	0.00 ± 0.00
$W + Jets$	11.22 ± 2.38	15.32 ± 4.65	0.38 ± 0.19	5.44 ± 2.03	0.00 ± 0.00
QCD	12.23 ± 9.19	27.43 ± 11.52	$0.00 + 1.32$	$4.83^{+5.35}_{-4.83}$	1.63 ± 1.04
total	291.91 ± 24.86	225.20 ± 31.90	$7.03^{+1.80}_{-1.32}$	$22.28^{+6.74}_{-5.91}$	3.80 ± 1.06
Data	284	203	8	16	6





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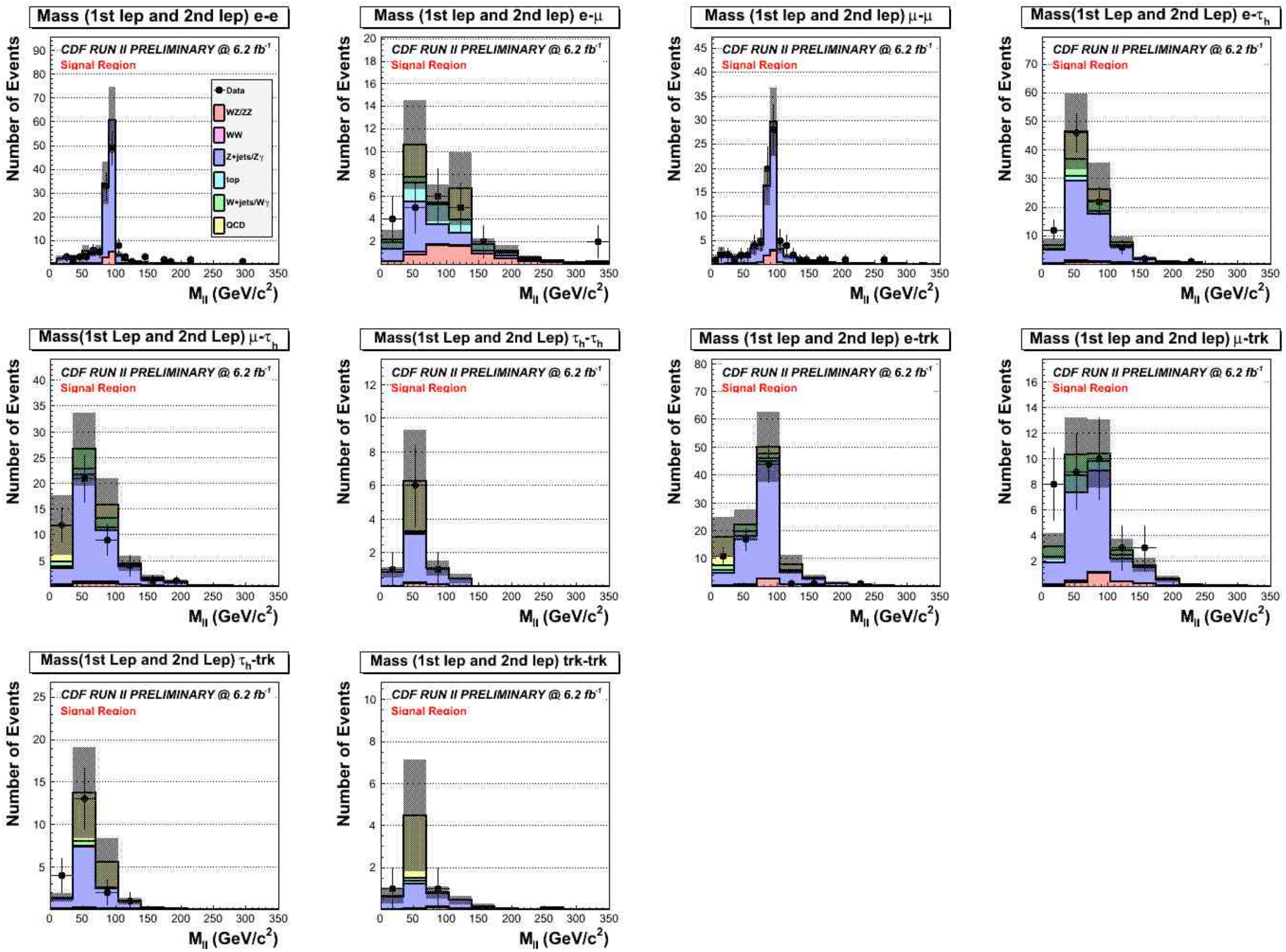
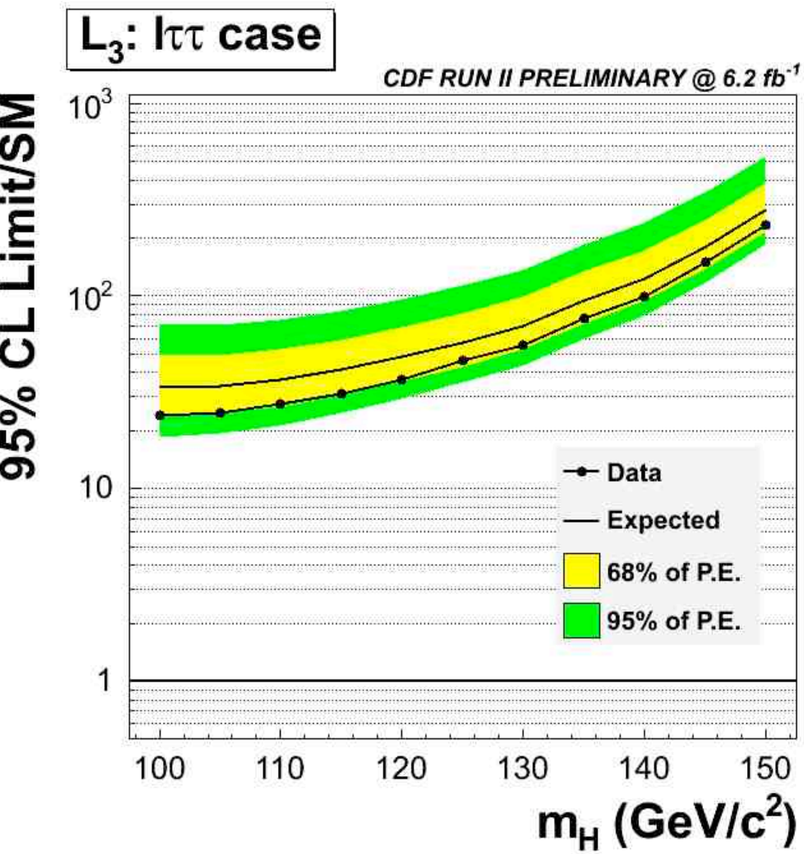
CDF: llττ, lνττ channels



CDF: llττ, lνττ channels

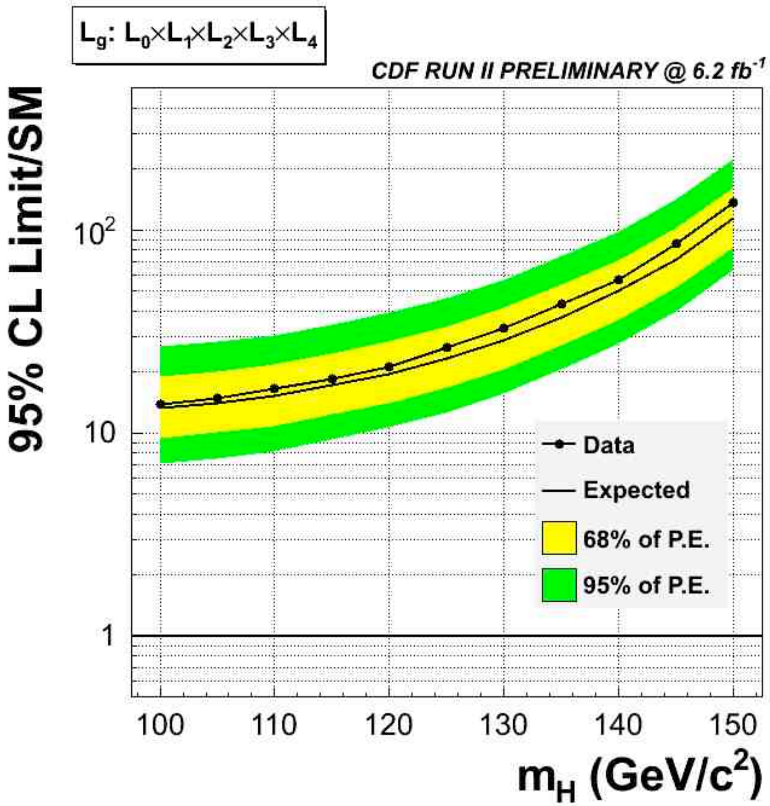
- Results for lττ channel



$l\tau\tau$ case	Expected limit/σ(SM)					Observed limit/σ(SM)
$M_H(GeV/c^2)$	-2σ	-1σ	median	$+1\sigma$	$+2\sigma$	
100	18.6	24.0	33.7	49.0	70.8	23.9
105	19.4	24.6	34.1	49.3	70.5	24.9
110	21.4	26.8	36.8	53.0	75.6	27.6
115	24.7	30.5	41.4	59.0	83.8	31.3
120	29.5	36.3	48.4	69.2	96.8	37.0
125	35.6	43.1	57.3	82.0	114.3	46.2
130	43.7	52.7	69.6	99.1	137.5	55.6
135	60.2	71.9	94.7	134.4	186.0	76.2
140	79.4	94.5	123.0	172.0	240.7	99.5
145	117.8	138.3	179.0	248.4	348.5	149.4
150	186.0	217.5	279.5	384.0	529.0	234.5

CDF: llττ, lvττ channels

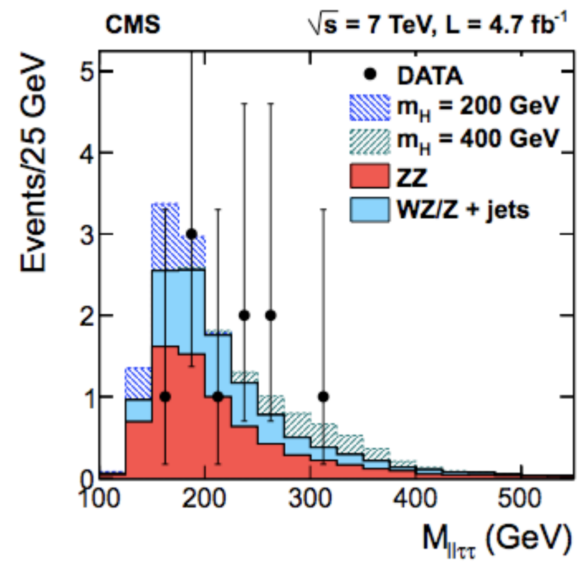
- Results all channels



M_H (GeV/c^2)	Expected limit/σ(SM)					Observed limit/σ(SM)
	-2σ	-1σ	median	$+1\sigma$	$+2\sigma$	
100	7.1	9.5	13.3	19.1	26.7	13.9
105	7.5	10.1	14.1	20.1	28.4	14.9
110	8.2	10.9	15.3	21.8	30.4	16.6
115	9.4	12.4	17.3	24.7	34.5	18.5
120	10.7	14.2	19.7	28.4	39.4	21.2
125	12.7	16.8	23.3	33.6	46.5	26.5
130	15.7	20.8	28.7	41.4	57.0	33.0
135	20.6	27.1	37.5	54.1	74.6	43.2
140	27.6	36.2	50.3	70.8	98.6	57.3
145	40.1	52.1	72.1	102	141.6	85.4
150	63.1	82.5	113.8	160.7	222.9	136.6

CMS: H -> ZZ -> llττ

- New 2012 result, 4.7fb-1
- where ll = ee, μμ, μe and ττ = $\tau_h\tau_h$, $\tau_h\tau_e$, $\tau_h\tau_\mu$, $\tau_e\tau_\mu$
- Final discriminant: invariant mass of four leptons



Decay channel	N_{ZZ}^{est}	Other backgrounds	Total backgr.	m_H 200 GeV	Observed
$\mu\mu\tau_h\tau_h$	0.79 ± 0.09	0.76 ± 0.31	1.55 ± 0.32	0.17	0
$ee\tau_h\tau_h$	0.75 ± 0.09	0.73 ± 0.32	1.48 ± 0.33	0.15	1
$ee\tau_e\tau_h$	1.12 ± 0.13	0.99 ± 0.34	2.11 ± 0.36	0.25	3
$\mu\mu\tau_e\tau_h$	1.20 ± 0.14	0.31 ± 0.29	1.51 ± 0.32	0.26	3
$\mu\mu\tau_\mu\tau_h$	1.08 ± 0.13	0.67 ± 0.36	1.75 ± 0.38	0.23	2
$ee\tau_\mu\tau_h$	0.94 ± 0.10	0.41 ± 0.16	1.35 ± 0.19	0.20	0
$ee\tau_e\tau_\mu$	0.51 ± 0.06	0.58 ± 0.42	1.09 ± 0.42	0.11	0
$\mu\mu\tau_e\tau_\mu$	0.58 ± 0.07	0.18 ± 0.18	0.76 ± 0.22	0.12	1
Total	6.97 ± 0.84	4.63 ± 1.49	11.60 ± 1.71	1.49	10