MANCHESTER 1824

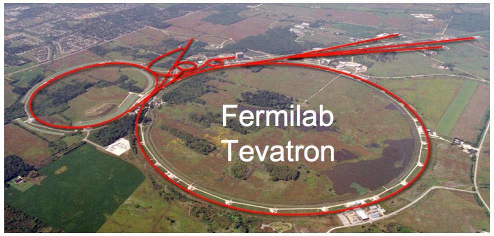
Using Tri-lepton + Missing Energy Final States to Probe Standard Model Production and Beyond

Fermilab Postdoc Interview

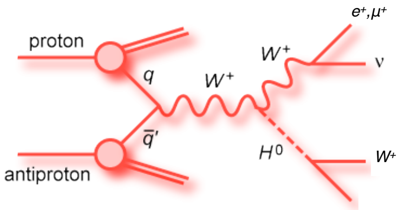
Carrie McGivern, Ph.D.

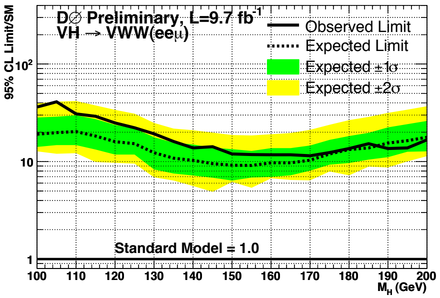
Outline

- Motivation
- DZero Experiment
  - Central Track Trigger



- Tri-lepton Analyses
  - WZ Cross Section Measurement
  - Flavor Changing Neutral Currents in Top Quark Decays
  - Search for the Higgs Boson

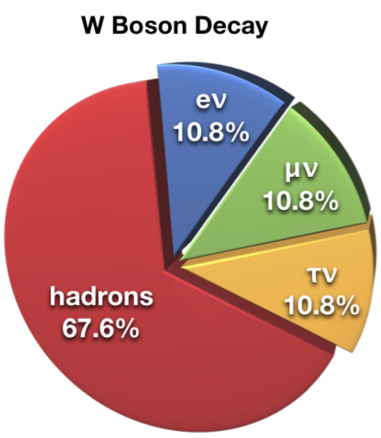


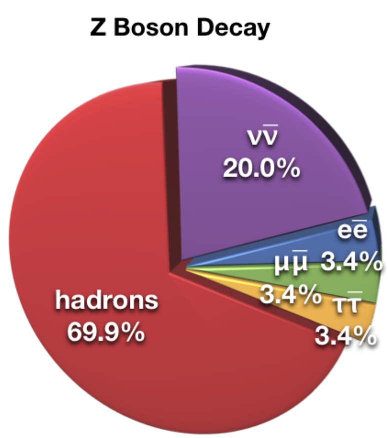


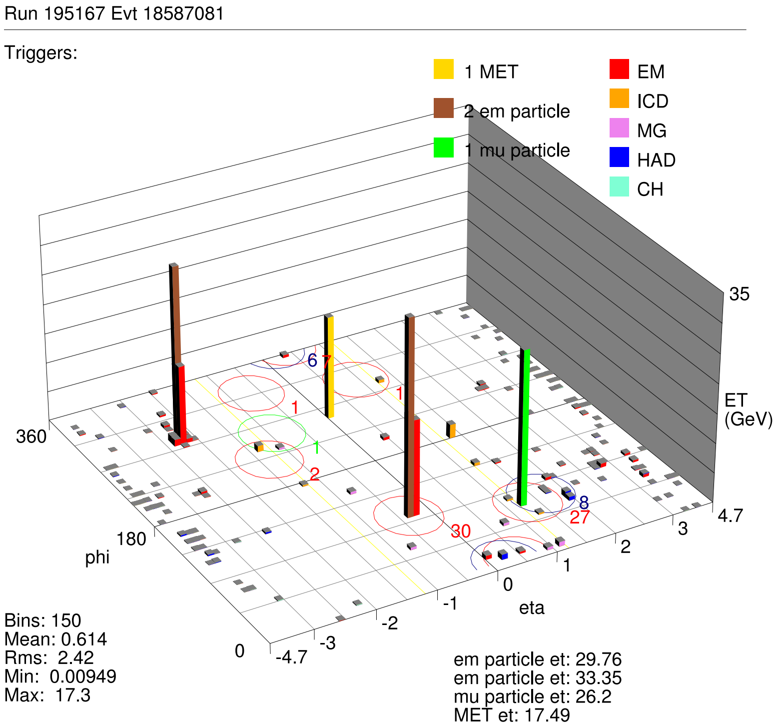
- Conclusion

Motivation

- The standard model (SM) has been found to be in excellent agreement with experimental results
- Why tri-lepton final states? With such a low signal acceptance...
  - clean signal with low backgrounds...

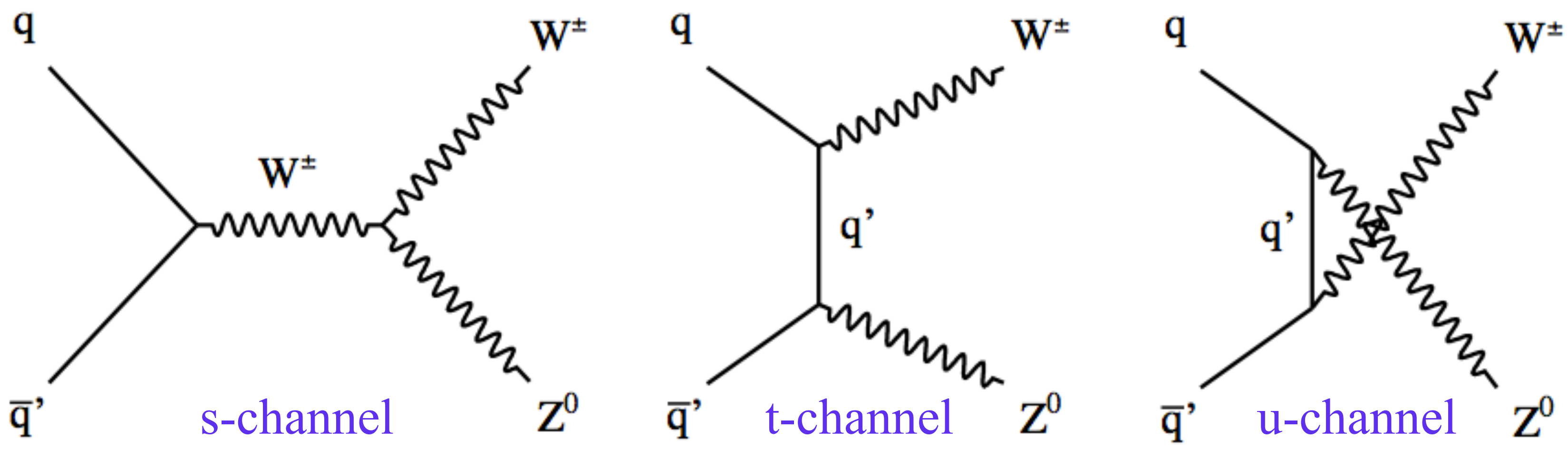






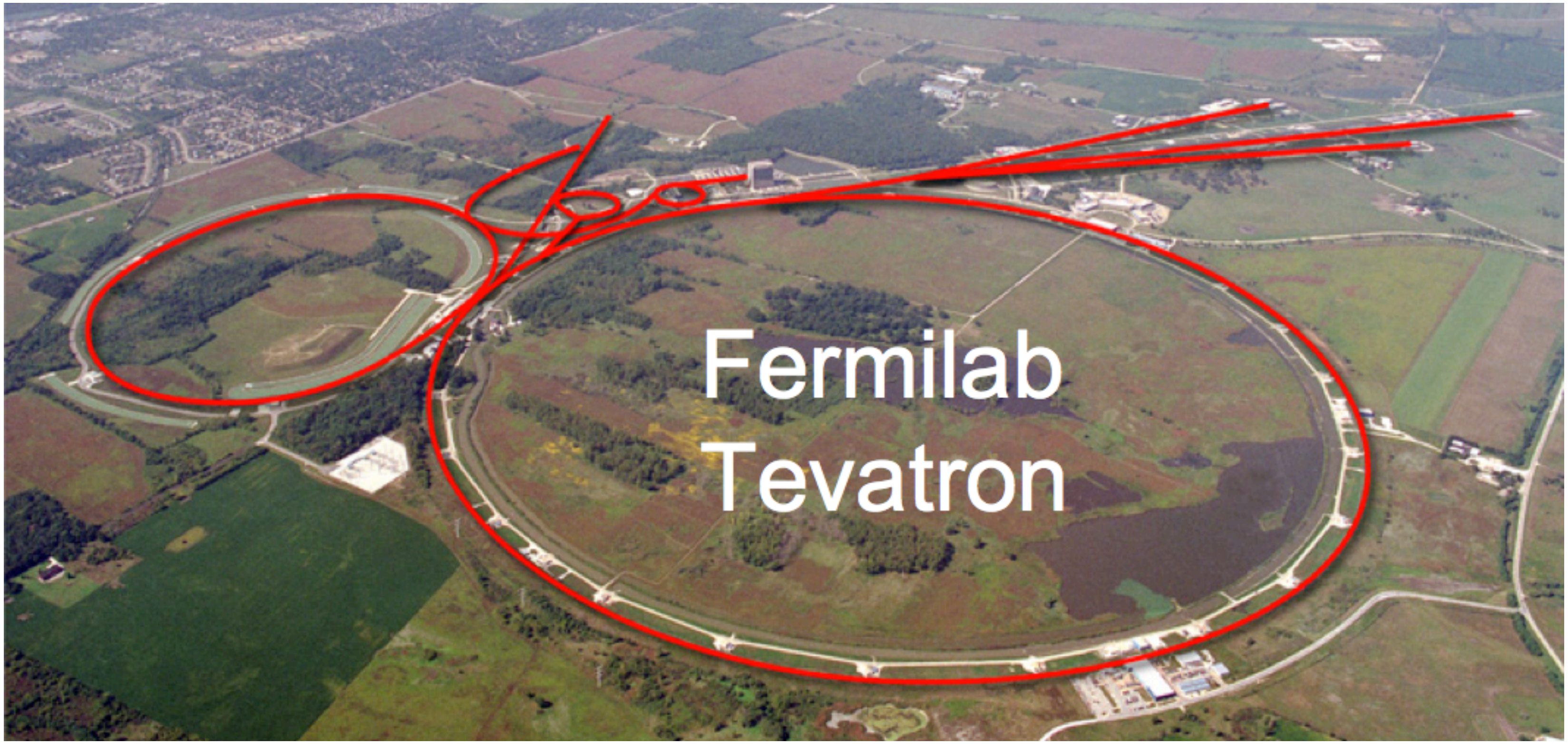
Motivation

- The standard model (SM) has been found to be in excellent agreement with experimental results
- Want to measure the WZ cross section and search for excesses
  - Search for physics beyond the SM : anomalous couplings, flavor changing neutral currents, W′ boson, technicolor, etc.
  - WZ production is a background for other searches : Higgs, SUSY, etc.



Fermilab

- Fermi National Accelerator Laboratory outside Chicago, IL



DZero Experiment

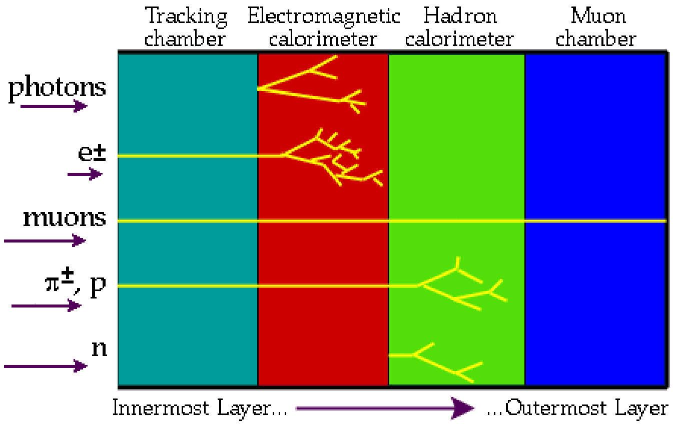
~450 Collaborators

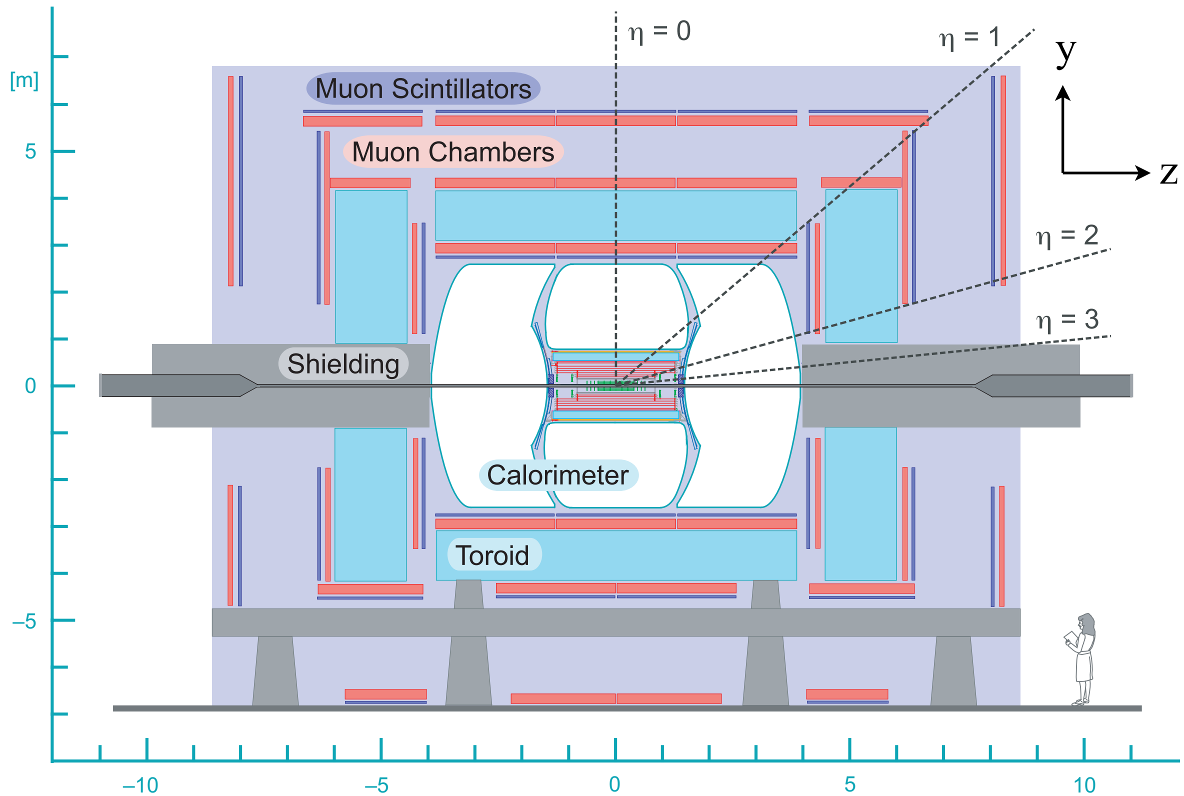
82 Institutions

18 countries

DZero Experiment

- Multi-purpose detector
- Consist of tracking, calorimetry, and muon sub-detectors





pseudorapidity

$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$

transverse momentum

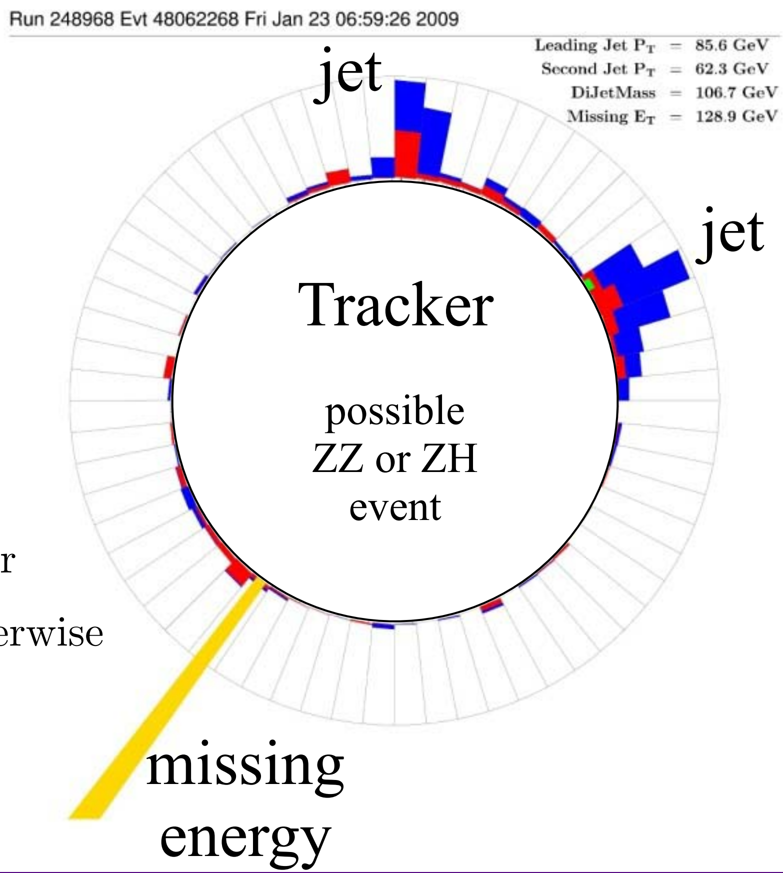
$$p_T = \sqrt{p_x^2 + p_y^2}$$

DZero Experiment - Missing Energy

- Missing Transverse Energy - imbalance of transverse momentum

$$\not{E}_{\mathbf{T}} = -\sum_i (\mathbf{p_T})_i$$

  - Missing energy from neutrinos, but also from instrumentation



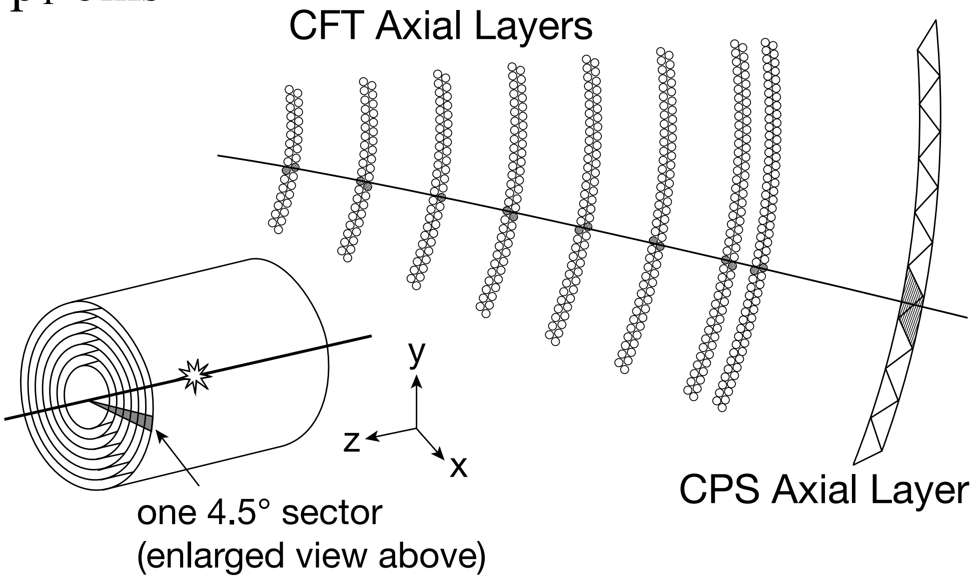
– special missing energy :

$$\not{E}_T^{special} = \not{E}_T \text{ if } \Delta\phi(\not{E}_{\rm T}, \text{nearest lepton/jet}) > \pi/2, \text{ or}$$
$$\not{E}_T^{special} = \not{E}_T \times sin(\Delta\phi(\not{E}_T, \text{nearest lepton/jet})) \text{ otherwise}$$

– missing energy significance : discriminate against fake missing energy

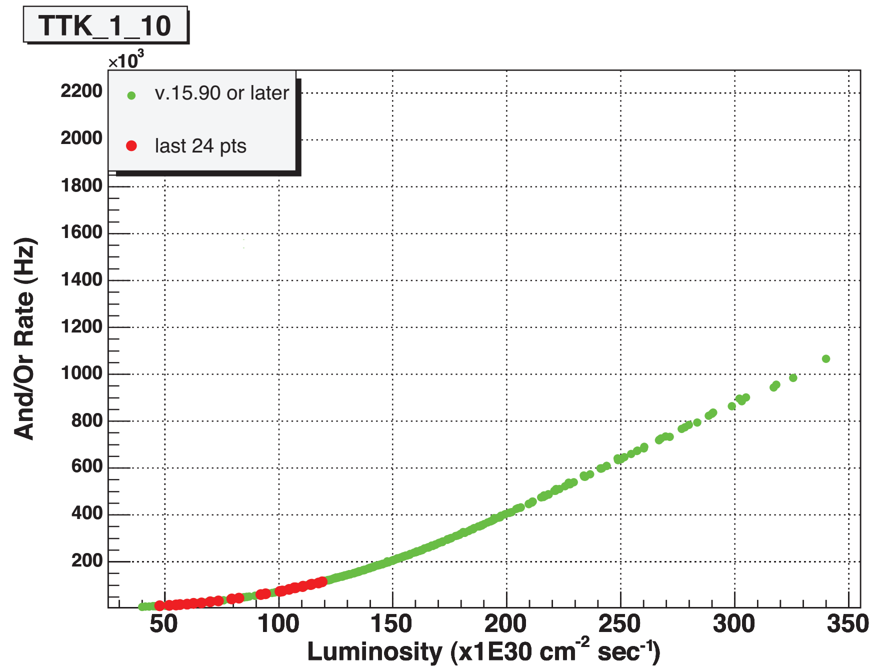
DZero Experiment

- Central Track Trigger (CTT)
  - triggers on central fiber tracker (CFT) discriminator hits
  - 8 concentric double layers
  - track reconstruction in p_T bins



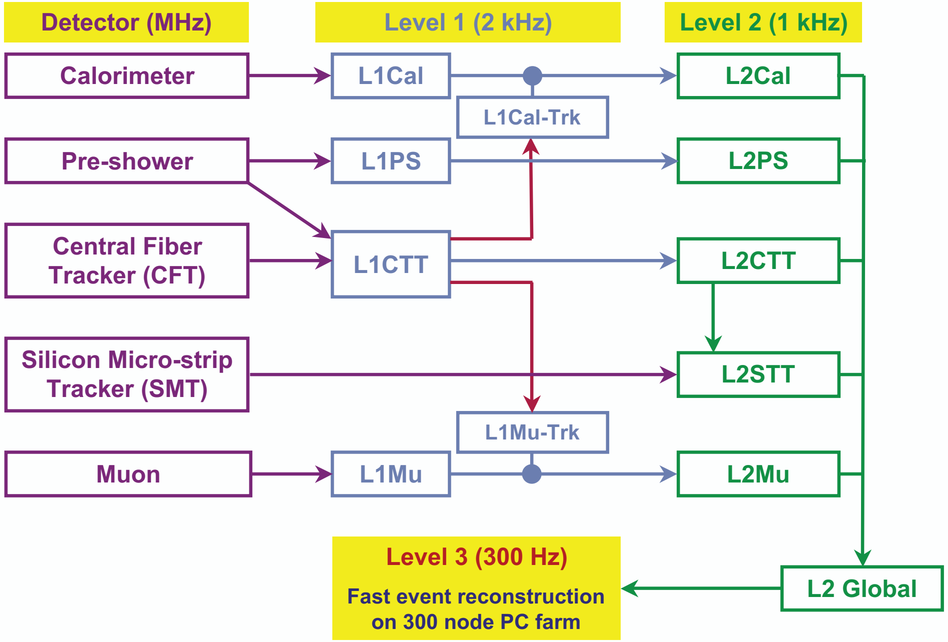
DZero Experiment

- Central Track Trigger (CTT)
  - triggers on central fiber tracker (CFT) discriminator hits
- AND/OR logic terms at Level 1 Triggering
  - TTK(1,10) - at least one track with $p_T > 10$ GeV

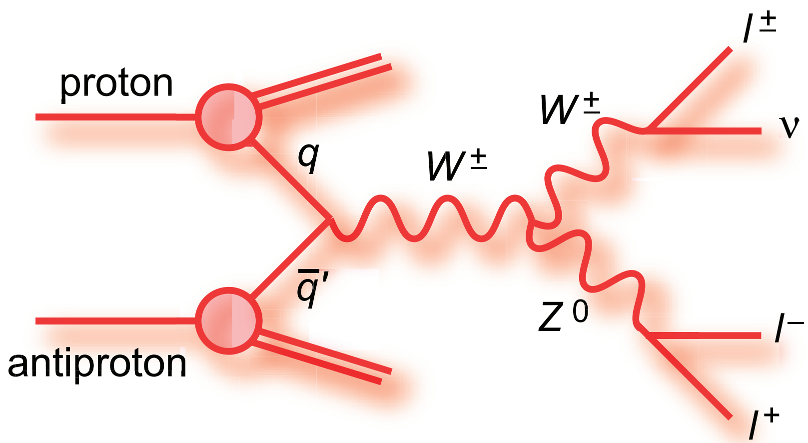


DZero Experiment

- Central Track Trigger (CTT)
  - triggers on central fiber tracker (CFT) discriminator hits
- AND/OR logic terms at Level 1 Triggering
  - TTK(1,10) - at least one track with $p_T > 10$ GeV
- Track information sent to Level 1 Calorimetry or Level 1 Muon for track matching



WZ General Event Selection



3 Isolated leptons, with high p_T, separated in $\Delta R = \sqrt{(\Delta\eta^2 + \Delta\phi^2)}$

Imbalance of transverse momentum

Jet inclusive

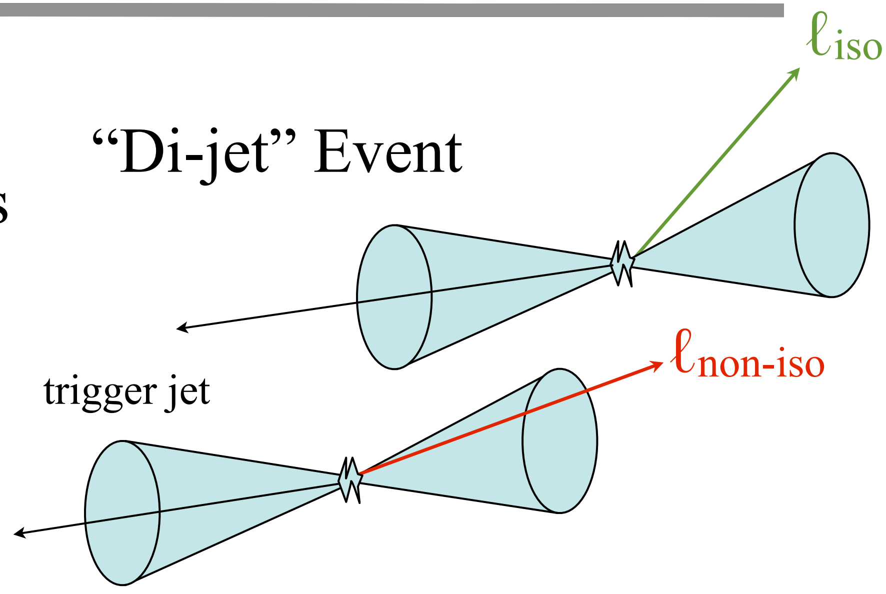
Δz (between any two lepton tracks)

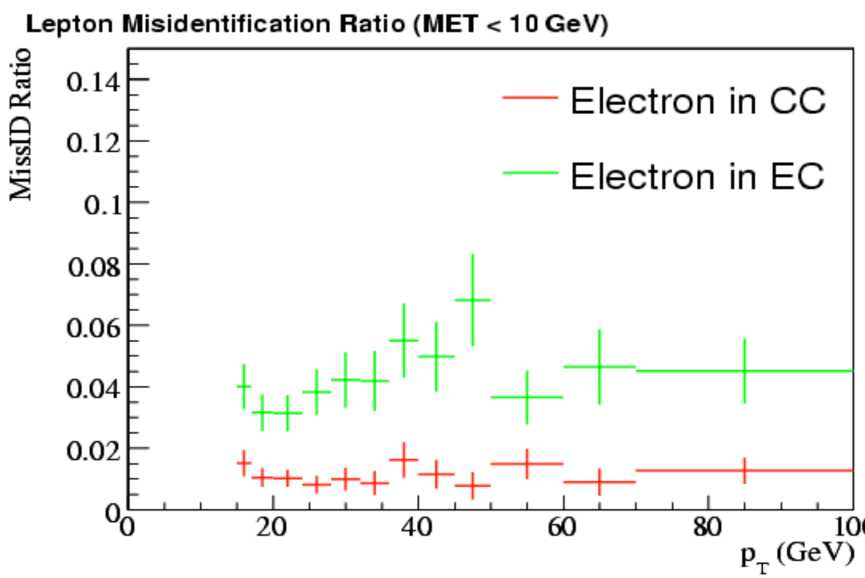
Invariant dilepton mass within Z window

- Use 4.1 fb^{-1} of integrated luminosity collected from the Tevatron Run II, selection criteria optimized with $s/\sqrt{(s+b)}$.
- Signal : WZ, Main Backgrounds: ZZ, V+Jets, Zγ, ttbar
  - Determined using Monte Carlo (MC) Simulations and Data

V+Jets Background (V = Z/W)

- MC simulation underestimates jet fake rate, use data
- Measure rate "jet → lepton"
- Measure the lepton mis-identification ratio using multi-jet (QCD) data events, $fr(QCD) = N_{iso}/N_{non\text{-}iso}$
- Apply *fr(QCD)* to a Z(→ℓℓ) + "non-isolated" lepton normalization sample
  - Small background, but very statistically limited



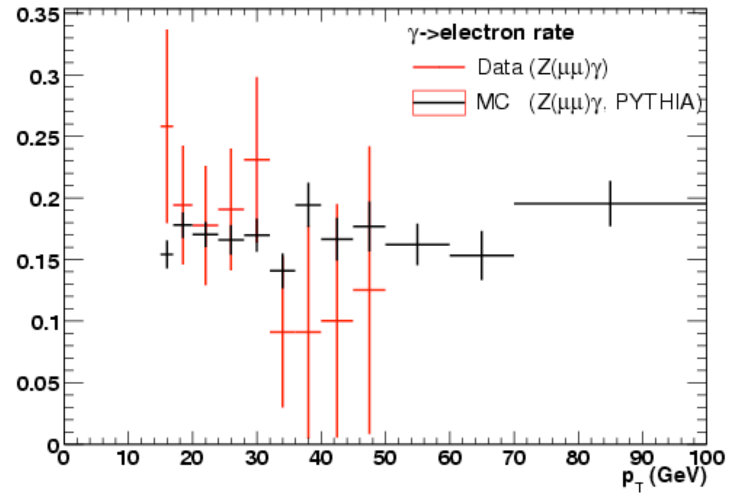


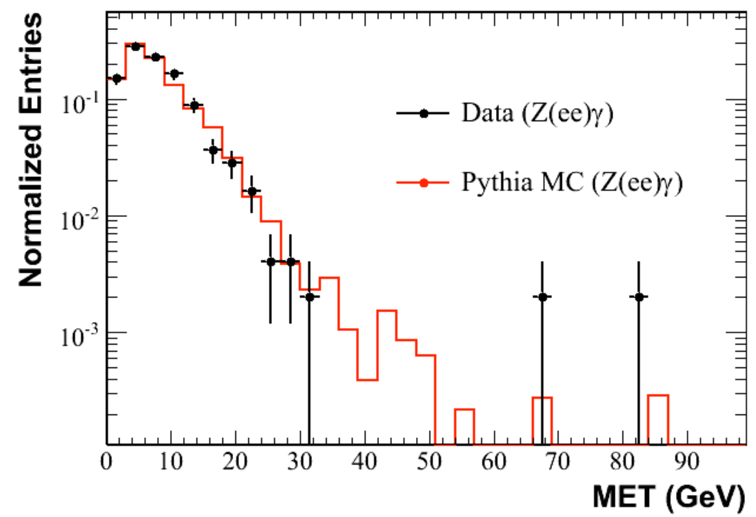
Zγ Background

- Measure rate "γ→e" (pair creation, track mismatched to photon)
- Compare $f_{\gamma\to e}$ rates obtained from data and PYTHIA MC simulation
  - Consistent with uncertainty
- Use Baur Zγ MC to determine the background estimate, combine with efficiencies from data and rates:

$$N_{Z\gamma} = \sigma_{\ell\ell\gamma} \times \mathscr{L}_{data} \times Acc \times \varepsilon_{selection} \times f_{\gamma\to e}$$

  - $\sigma(NLO) \times BR(Z\to\ell\ell) = 2.90$ pb ($p_T^{\gamma} > 15$ GeV)

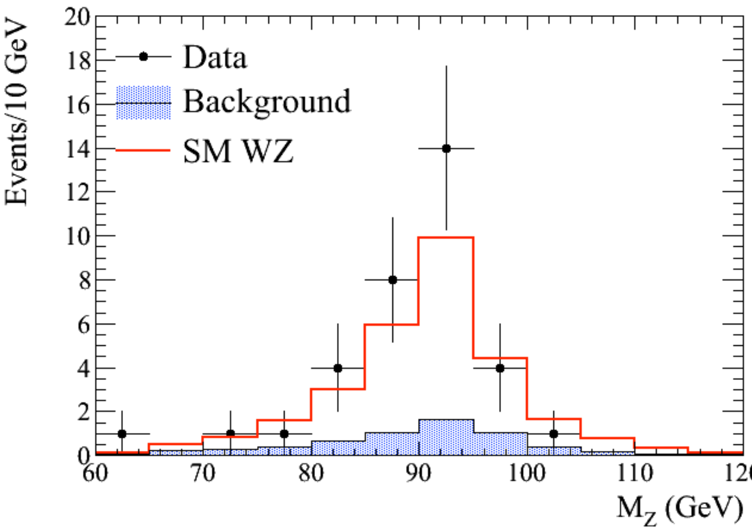




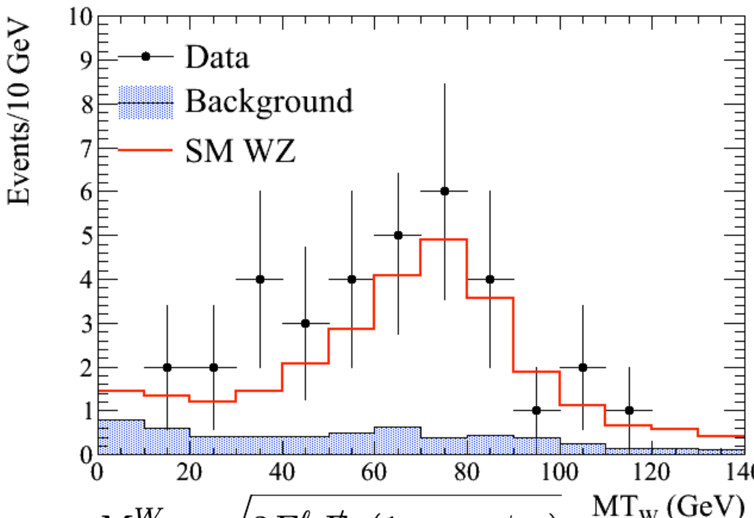
WZ Cross Section Measurement

- 34 candidate events — Phys. Lett. B **695**, 67 (2011)
  - WZ = 23.3 ± 0.2(stat+syst) events; Background = 6.0 ± 0.4 events
- Measured cross section : $3.90^{+1.06}_{-0.90}$ (stat+syst) pb
  - NLO Theoretical prediction : 3.25 ± 0.19 pb [http://mcfm.fnal.gov/]
- Dominant Systematic Uncertainties : Lepton ID and Theoretical Cross Sections

Dilepton Mass



Transverse Mass



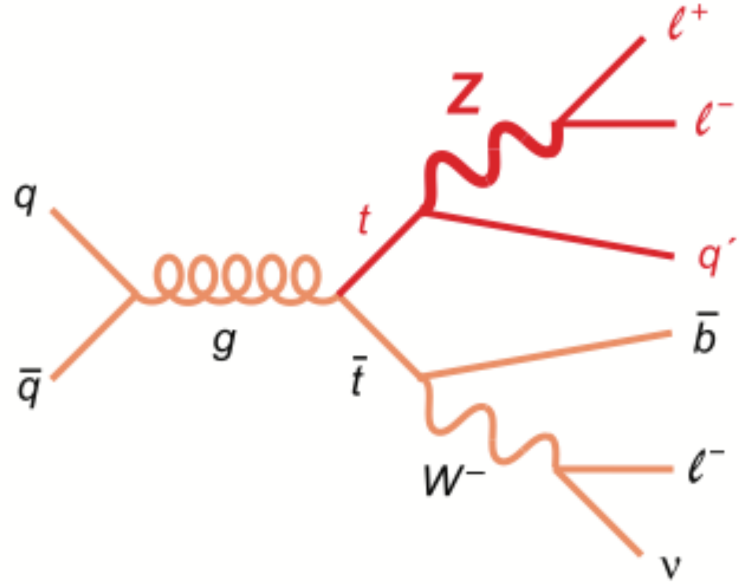
$$M_T^W = \sqrt{2E_T^\ell \not{E}_T(1-\cos\phi_{\ell\nu})}$$

Flavor Changing Neutral Currents

- Search for FCNC decays in the top quark sector
- New final state : X is any number of jets

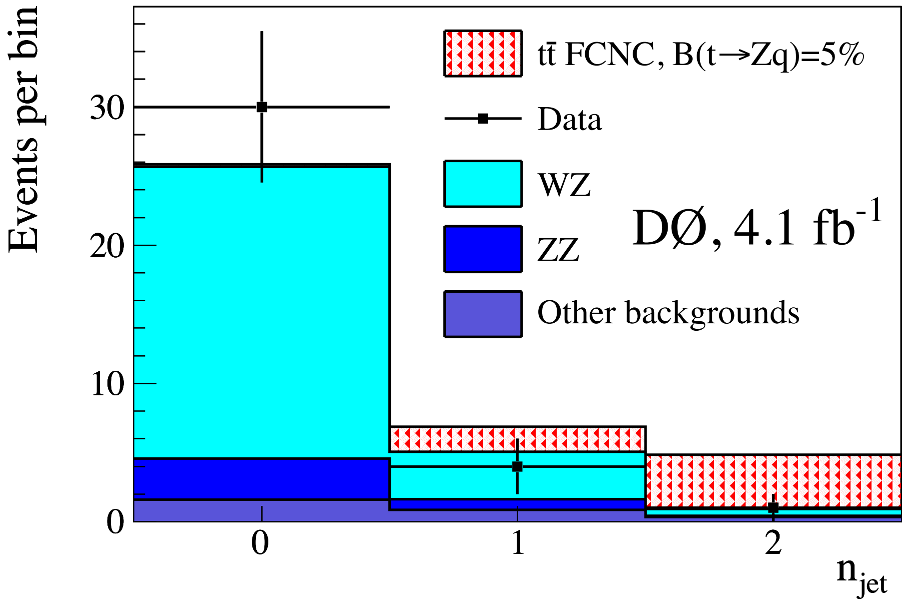
$$p\bar{p} \to t\bar{t} \to WbZq \to \ell\nu\ell\ell + X$$

- Set limits on branching ratio of t→Zq (q = u, c)



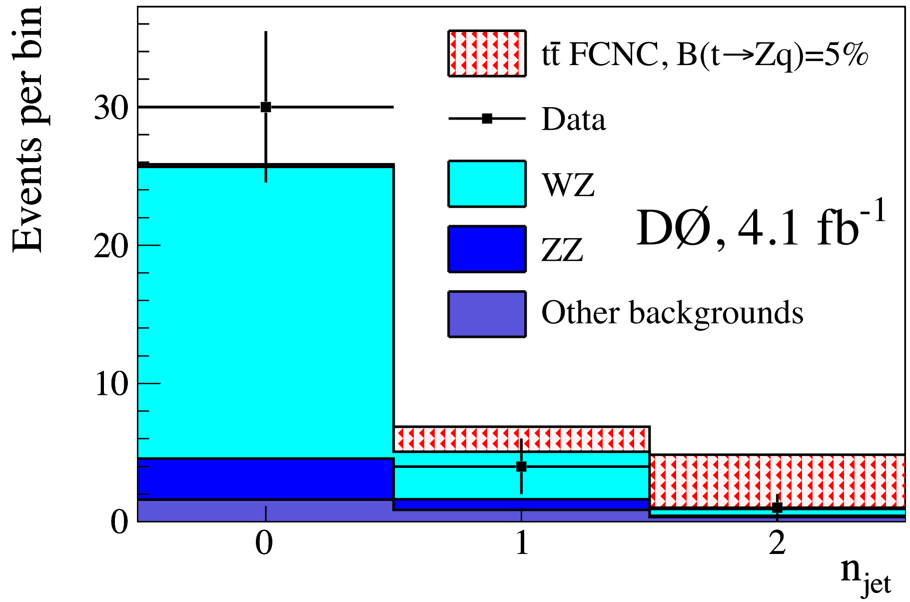
Flavor Changing Neutral Currents

- Use the same object and event selection as in WZ cross section analysis
- Break sample into three jet multiplicity bins; $n_{jet} = 0, 1, \geq 2$
  - require jets to have $E_T > 20$ GeV
  - ΔR(leptons, jets) ≥ 0.4 (0.5) for muons (electrons)
- We ensure that angular distributions are modeled correctly



Flavor Changing Neutral Currents

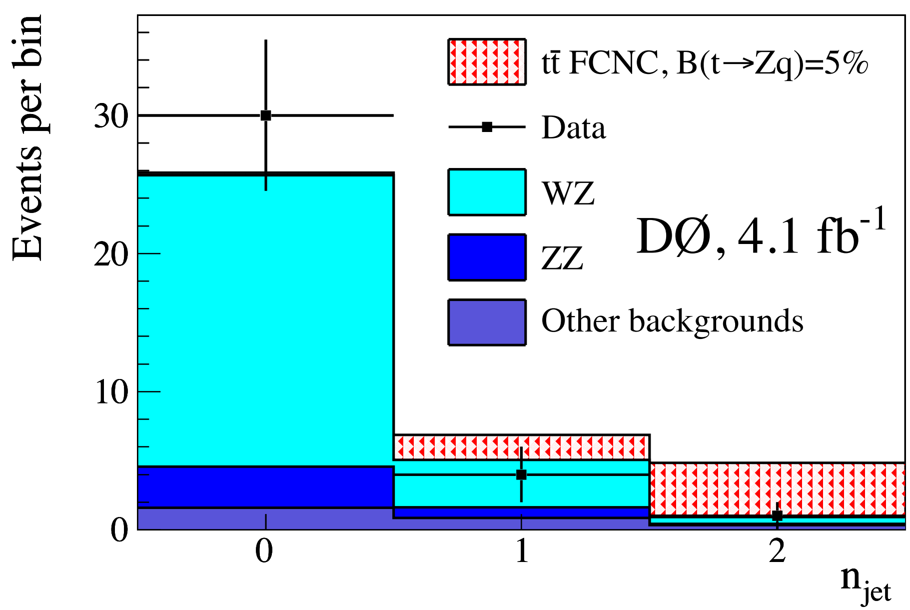
- Use the same object and event selection as in WZ cross section analysis
- Break sample into three jet multiplicity bins; $n_{jet} = 0, 1, \geq 2$
  - require jets to have $E_T > 20$ GeV
  - ΔR(leptons, jets) ≥ 0.4 (0.5) for muons (electrons)
- We ensure that angular distributions are modeled correctly



- Discrepancies found in eeX channels...
  - Incorrect run range used
  - Uncorrected Δz btw track and PV
  - Older MET recomputation used
  - Added one candidate event

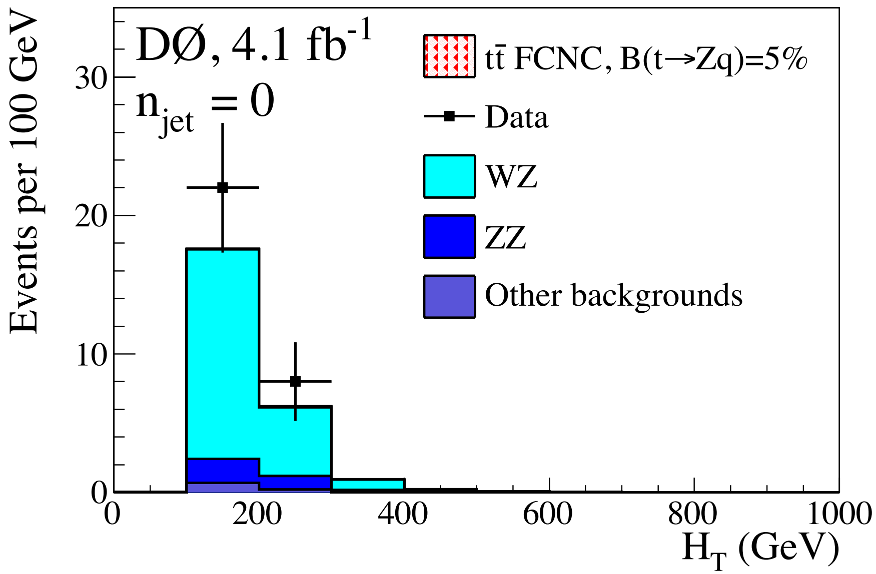
Flavor Changing Neutral Currents

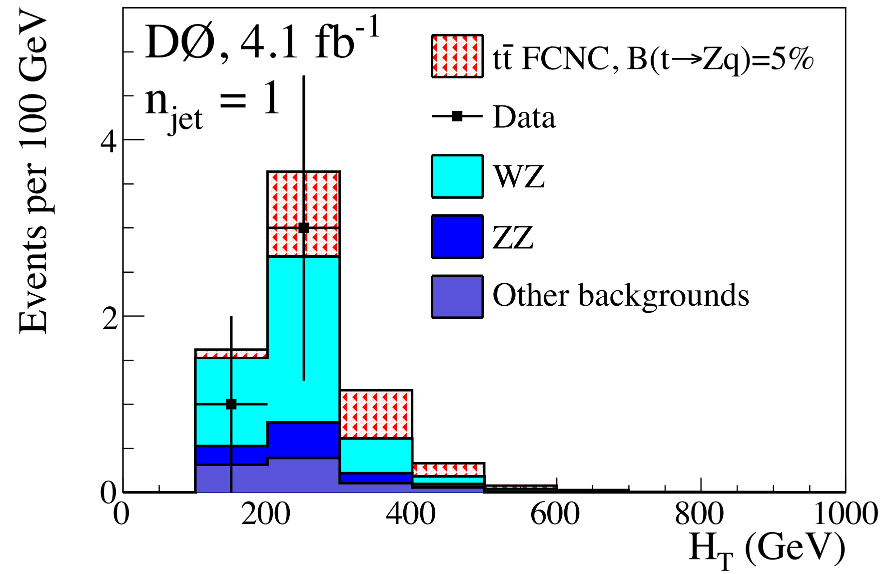
- Use the same object and event selection as in WZ cross section analysis
- Break sample into three jet multiplicity bins; $n_{jet} = 0, 1, \geq 2$
  - require jets to have $E_T > 20$ GeV
  - ΔR(leptons, jets) ≥ 0.4 (0.5) for muons (electrons)
- We ensure that angular distributions are modeled correctly

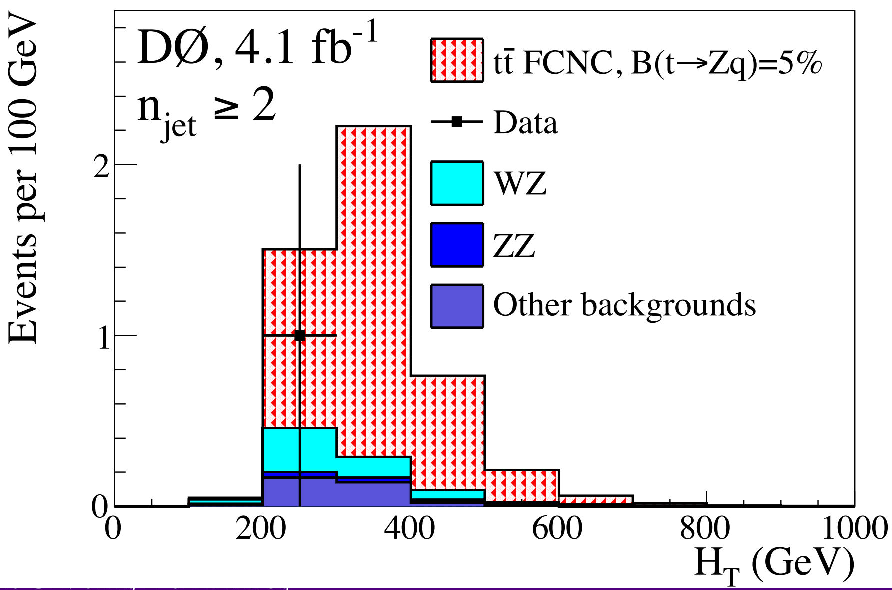


- 35 candidate events
  - Expected background events = 31.8 ± 0.3(stat) $\pm$ 3.9(syst)
- Dominant Systematic Uncertainties : Signal ttbar Cross Section, Jet Energy Scale, Jet Energy Resolution

H_T Distributions





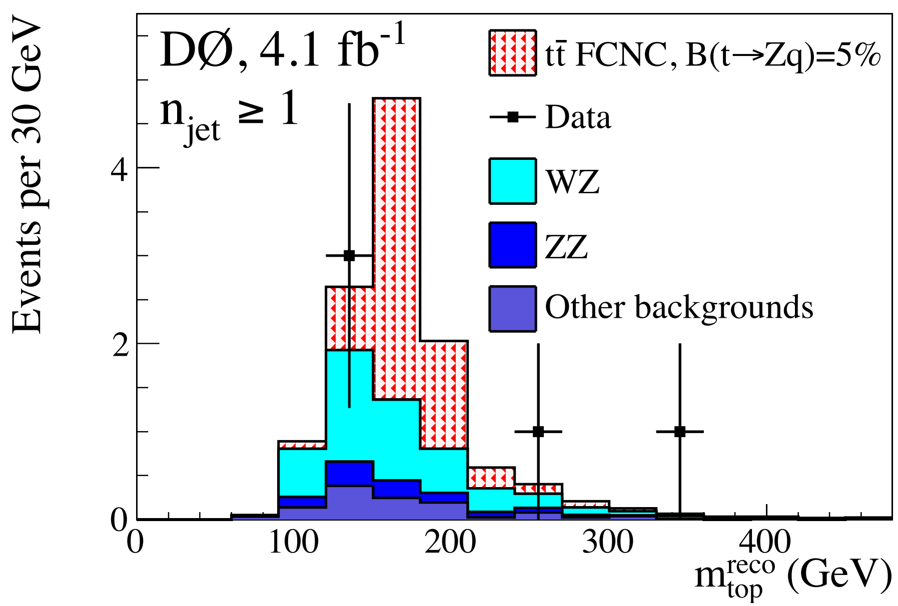


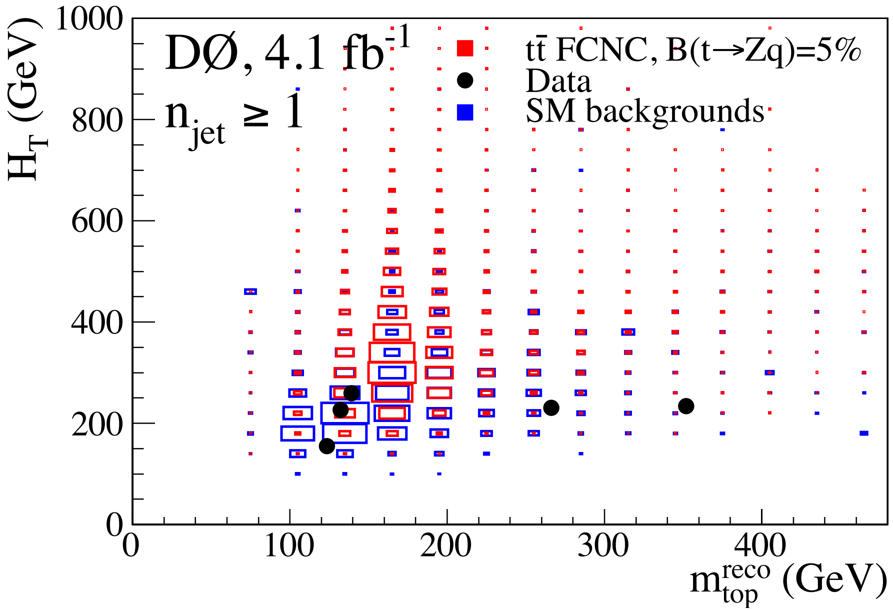
H_T (Σp_T(leptons)+MET+ Σp_T(jets))

H_T peak increases with jet multiplicity

B(t→Zq) Limits

- Use n_{jet}, H_T (Σp_T(leptons)+MET+ Σp_T(jets)), and reconstructed top quark mass (m_t^{reco}) (from the Z leptons and jets) to separate signal from background
- Good separation is observed between signal and background using these variables

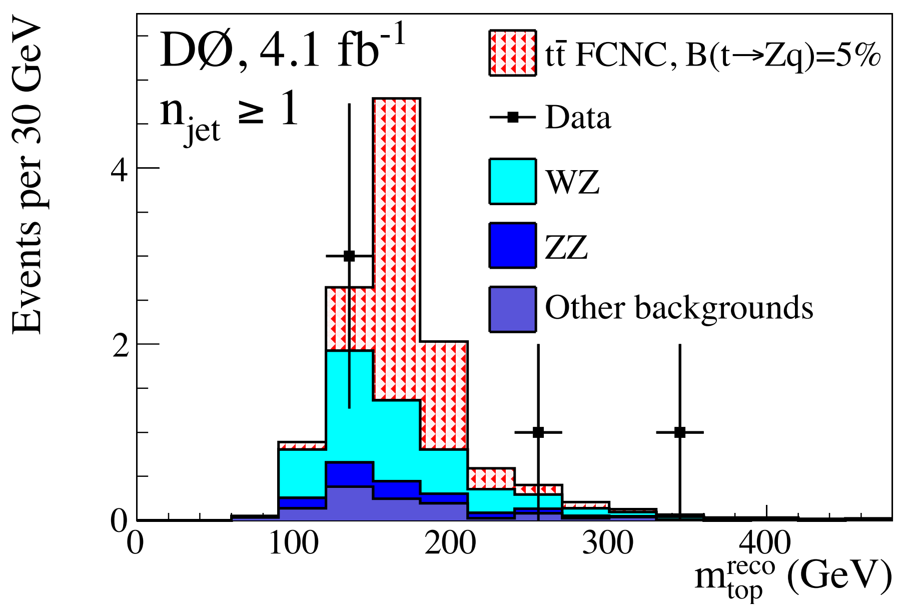


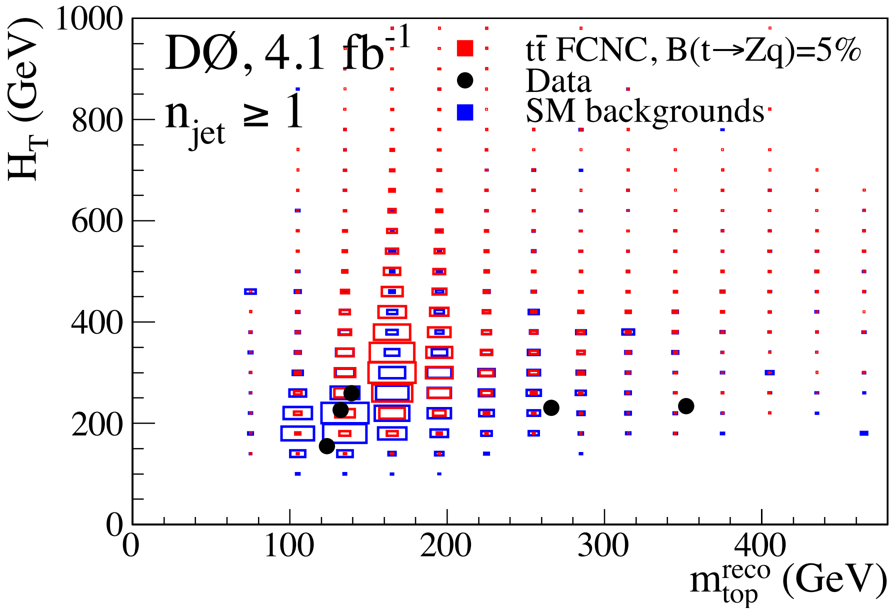


B(t→Zq) Limits

Phys. Lett. B **701**, 313 (2011)

- Use Poisson probabilities with systematic uncertainty gaussian smearing to extract the limits
- B(t→Zq) < 3.2% (observed), < 3.8% ± 1.9% (expected) at 95% CL





Search of the SM Higgs Boson

- VH → VWW* (V = W, Z) new analysis at DZero
  - use ggH → WW* → ℓνℓν framework - add third lepton information
- Expect low signal acceptance but also very clean background signature

Signal Acceptance

$$(\sigma_{ggH} = 383.7 \text{ fb},\ \sigma_{WH} = 43.60 \text{ fb at } m_H = 165 \text{ GeV})$$

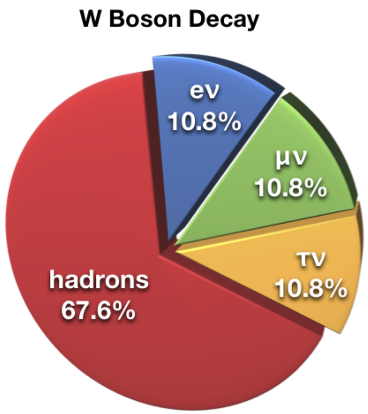
$$\sigma_{ggH} \times BR(H \to WW^*) \times BR(W \to e\nu, \mu\nu, \tau\nu)^2 = 40.28 \text{ fb}$$

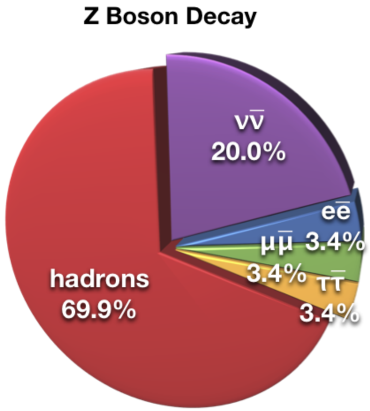
$$\sigma_{WH} \times BR(H \to WW^*) \times BR(W \to e\nu, \mu\nu, \tau\nu)^3 = 1.48 \text{ fb}$$

Sensitivity to $H \to WW^* \to e\nu e\nu$

$$\text{Dilepton}: s/\sqrt{s+b} = 0.024$$

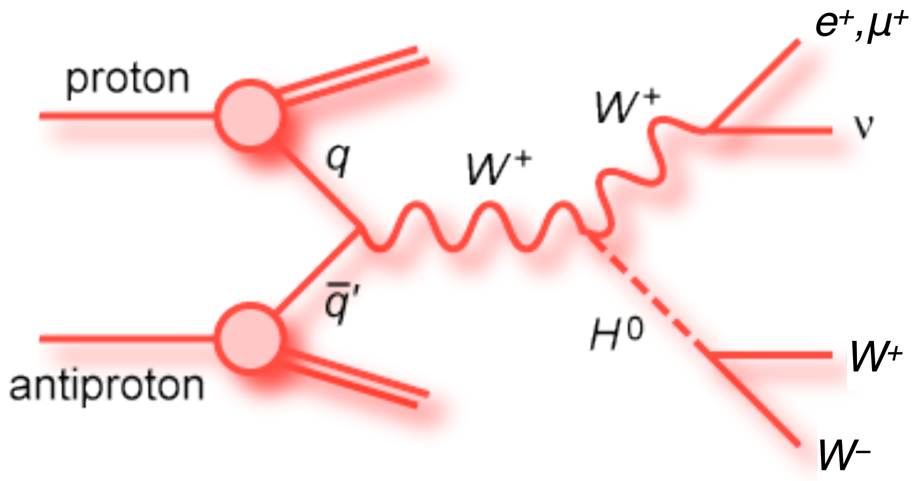
$$\text{Trilepton}: s/\sqrt{s+b} = 0.101$$





- Focus initially on the most sensitive channels, cleanest backgrounds - eeμ (and μμe)

VH General Event Selection



3 isolated leptons, with high p_T, separated in $\Delta R = \sqrt{(\Delta\eta^2 + \Delta\phi^2)}$

Δz requirement to ensure from same vertex

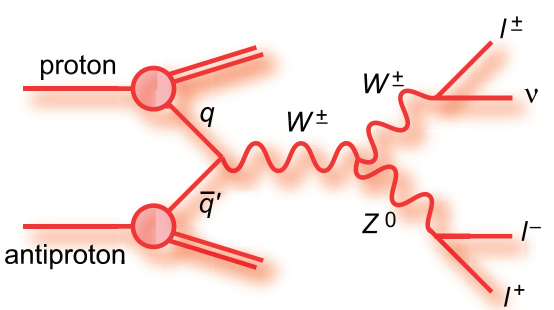
expect large amount of missing transverse energy

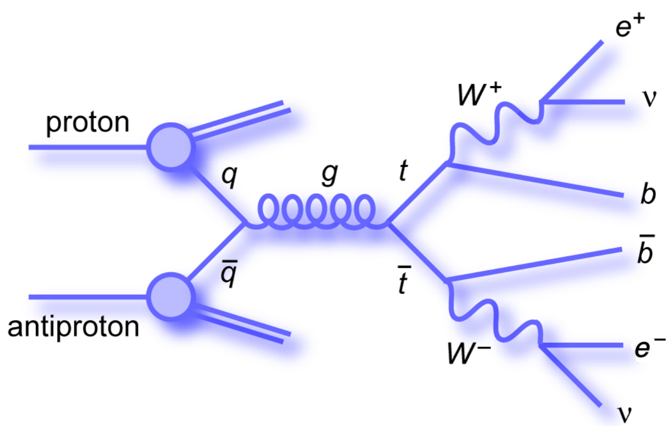
- Selection Criteria for eeμ channel:
  - minimum of two electrons
  - at least one muon
  - $M_{ee} > 15$ GeV
  - $p_T^{e1} > 15$ GeV, $p_T^{e2} > 10$ GeV, $p_T^{\mu} > 10$ GeV
  - $dR(\ell_i,\ell_j) > 0.3$, $dz(e_1,e_2) < 3$ cm, $\min[dz(e_i,\mu)] < 1$cm
  - allow for extra leptons in the event

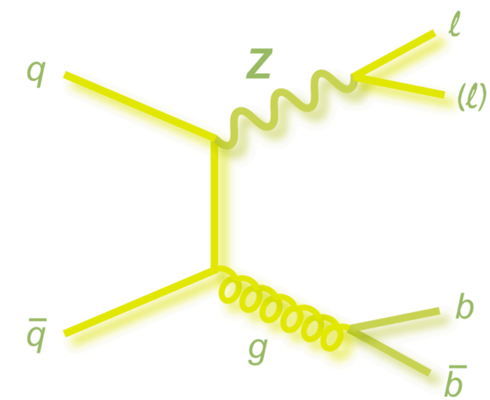
Signal and Backgrounds

The University of Manchester

- Main Signal : WH and ZH (and ggH → ZZ) determined using MC simulations
- Main Backgrounds: determined with MC simulation
  - diboson - WZ, ZZ, and WW
  - ttbar - quarks - b quark fakes an isolated muon
  - Z+jets - a jet fakes an isolated muon

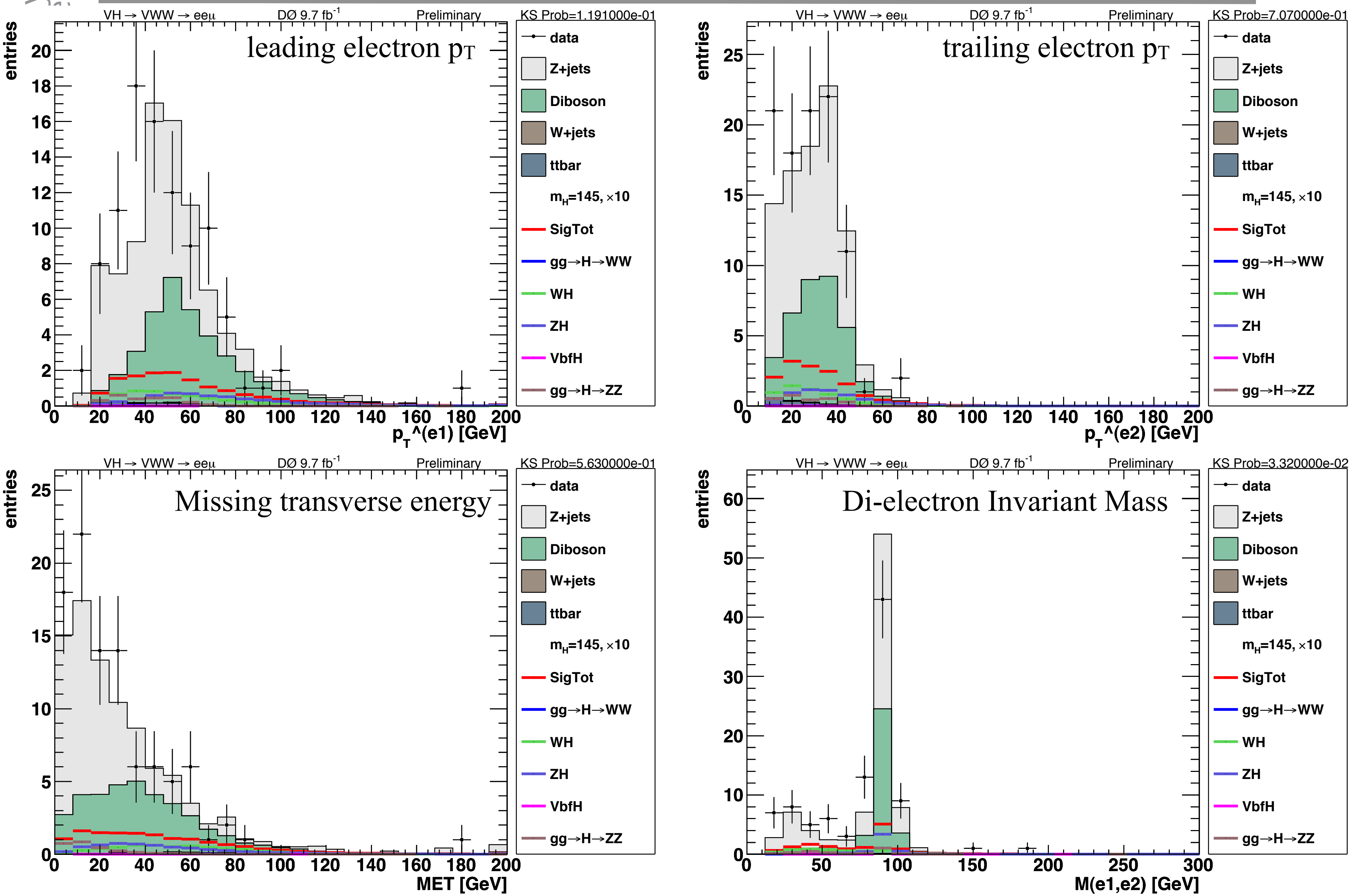




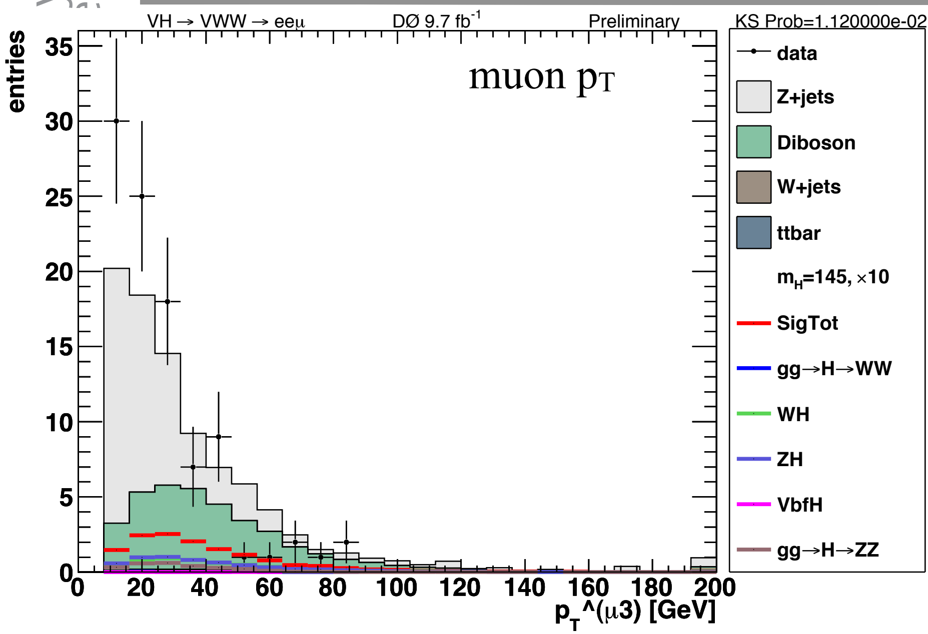


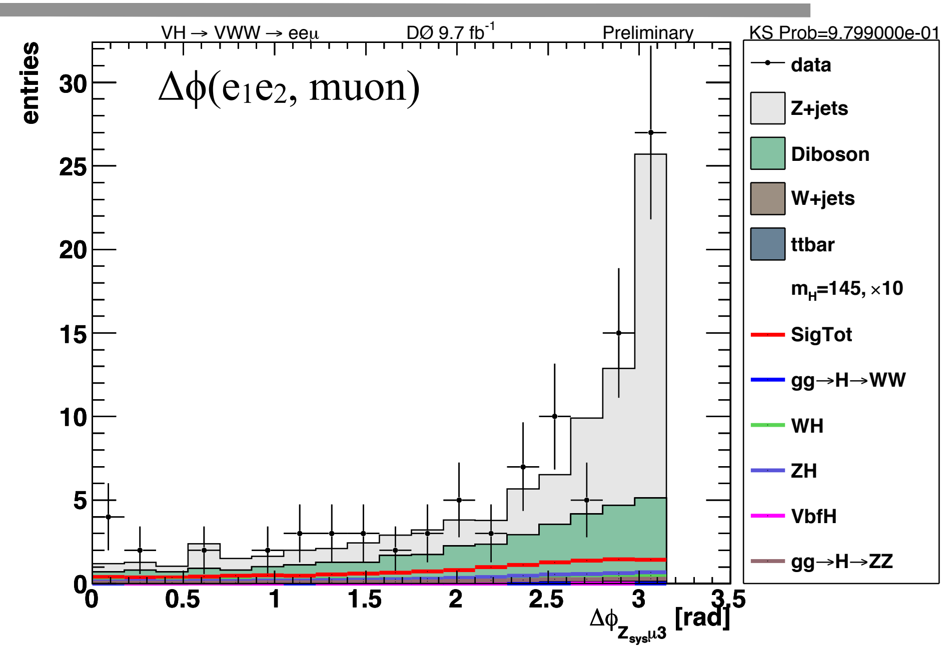
MANCHESTER 1824

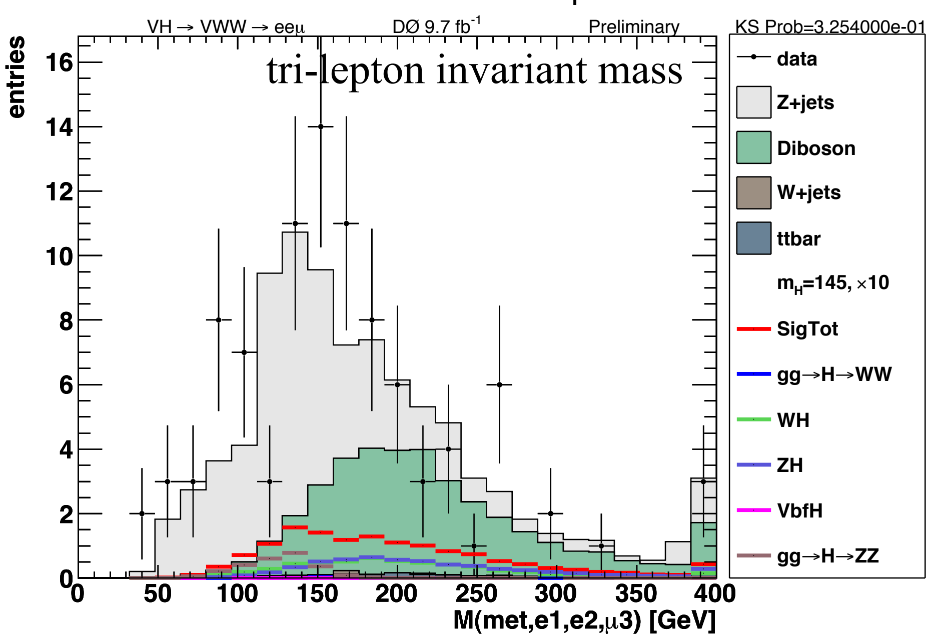
Kinematic Distributions @ m_H = 145 GeV

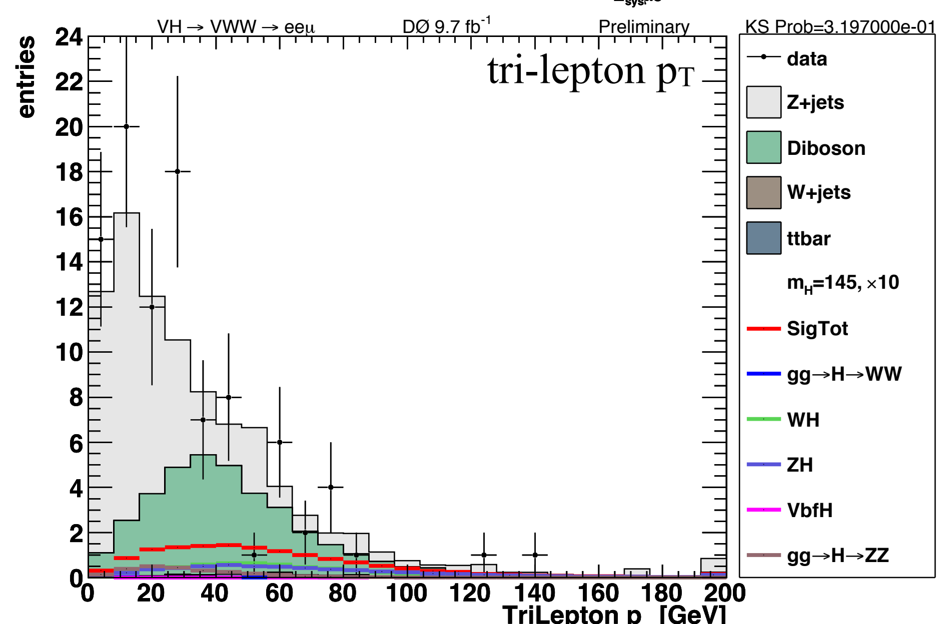


Kinematic Distributions @ m_H = 145 GeV

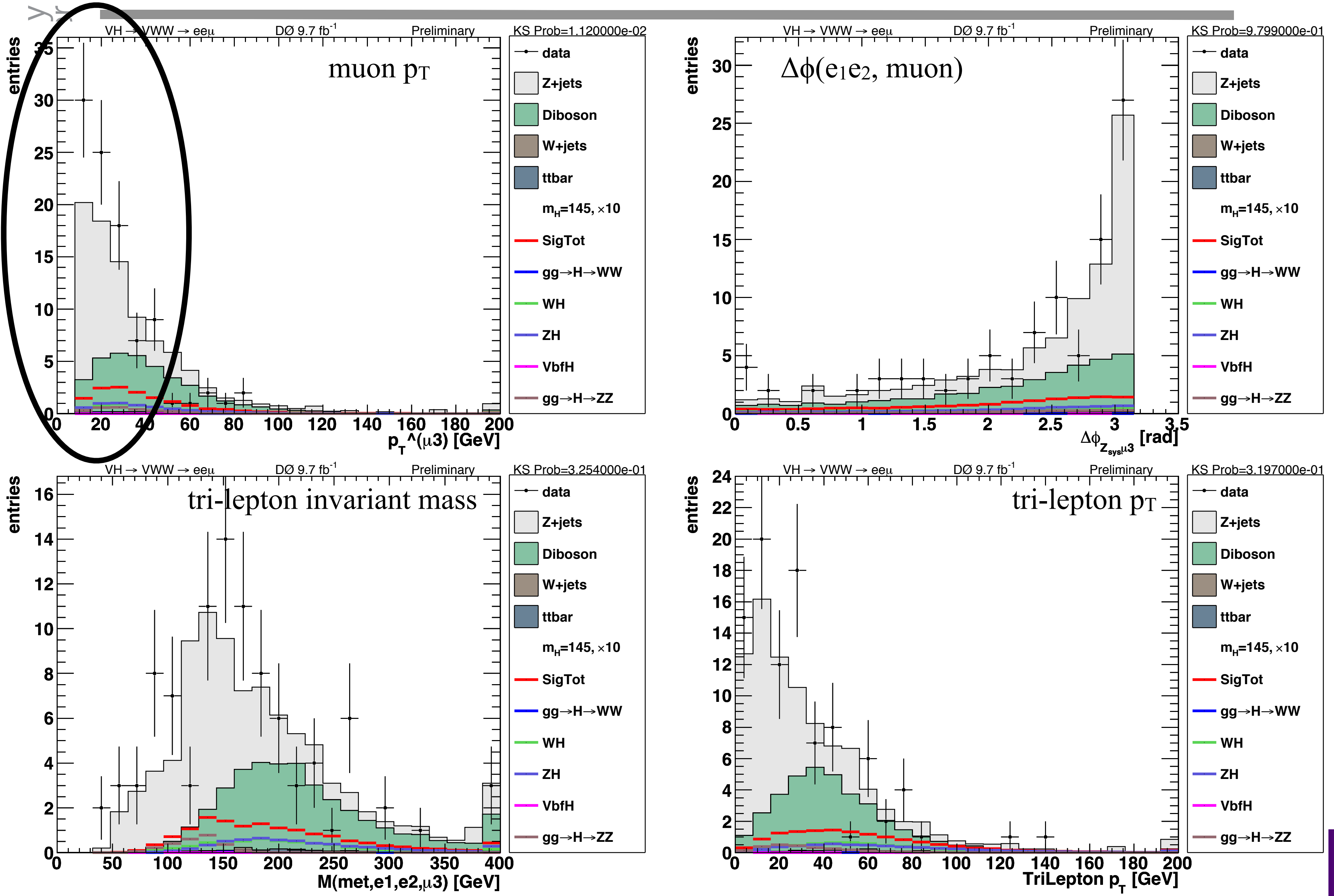






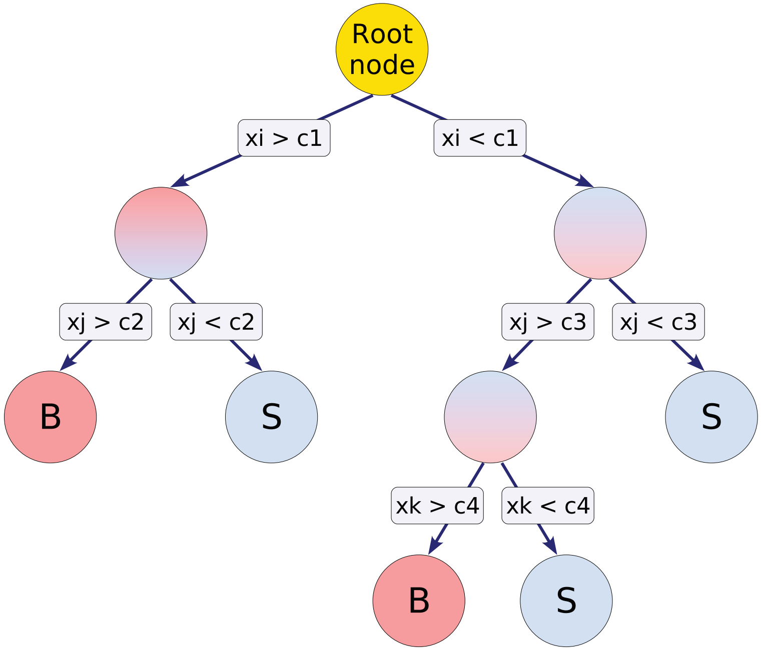


Kinematic Distributions @ $m_H = 145$ GeV



Multivariate Analysis Approach

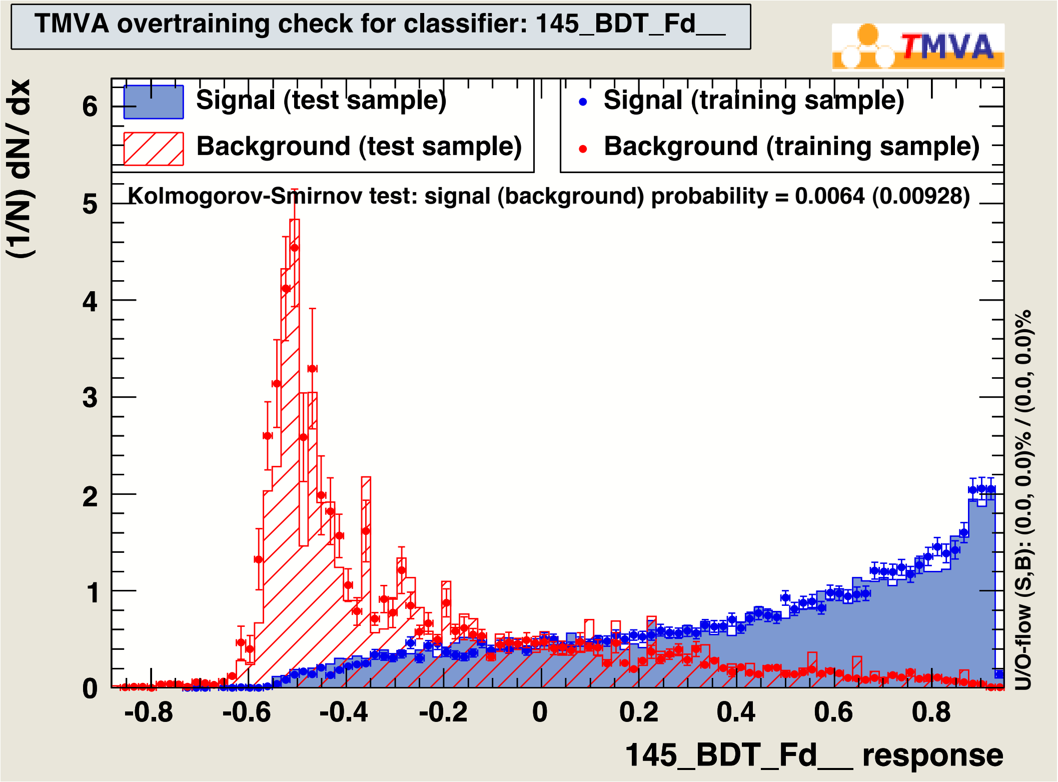
- Use multivariate analysis (MVA) boosted decision trees (BDT) to further separate signal from background
- Learning algorithm that uses training samples to classify an event as either signal or background
  - pass or fail cuts are applied at each splitting
- Each split uses variables that which maximizes the difference
- Algorithm is applied until certain stop criteria are fulfilled
- "Boosting" applies an average re-weighted final discriminant
  - acts to smear over the statistical fluctuations



Multivariate Analysis Approach

- Overtraining - train on statistical fluctuations, not on real events
  – decreases the performance of an independent testing sample
- Independent test samples are used to determine overtraining

- Final discriminant output usually ranges from 1 to -1



BDT Training Variables

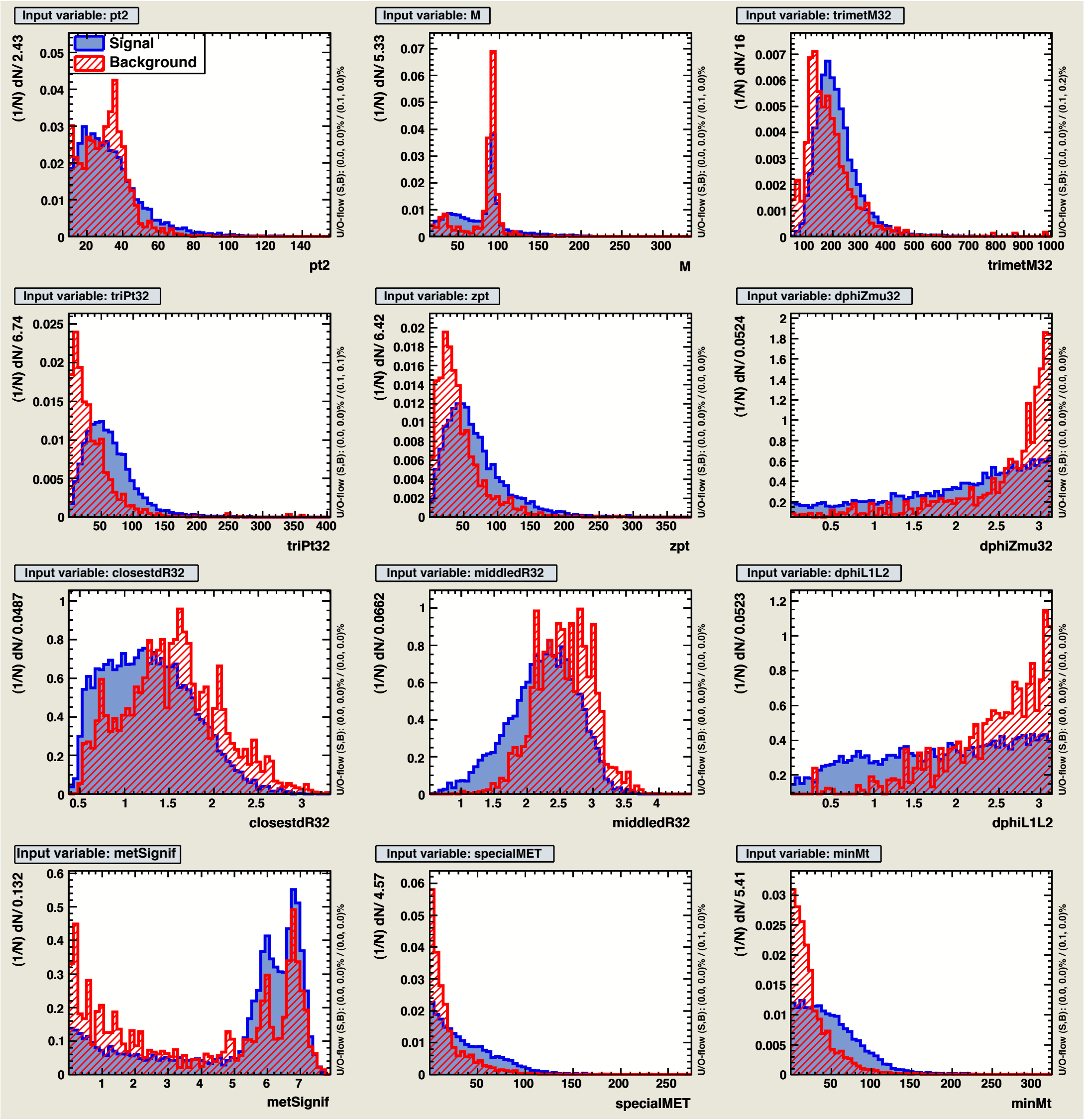
- Look for well-modeled or background discriminating variables
- Train 21 individual mass points, m_H = 100 - 200 with 5 GeV intervals
  - train with WH and ZH signals only

Training Variables :

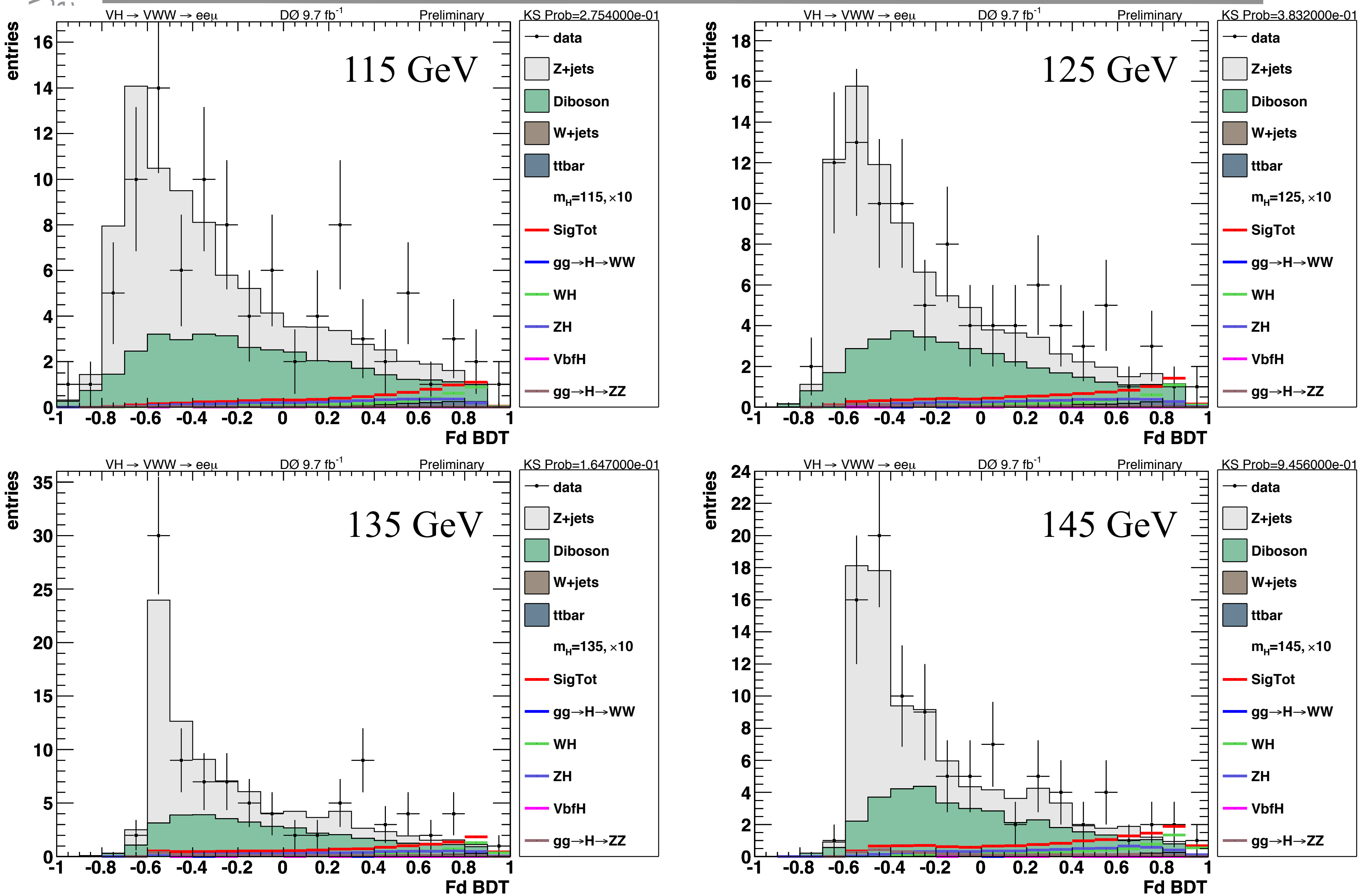
- p_T of trailing electron
- p_T of di-electron system
- p_T of tri-lepton system
- M of di-electron system
- M of tri-lepton system and MET
- minimum M_T of di-electron system
- missing energy - special
- missing energy - significance
- $\Delta\phi$ of di-electron system
- $\Delta\phi$ of di-electron system and muon
- $\min(\Delta R_{e1e2}, \Delta R_{e1\mu}, \Delta R_{e2\mu})$
- $\mathrm{med}(\Delta R_{e1e2}, \Delta R_{e1\mu}, \Delta R_{e2\mu})$

BDT Training Variables

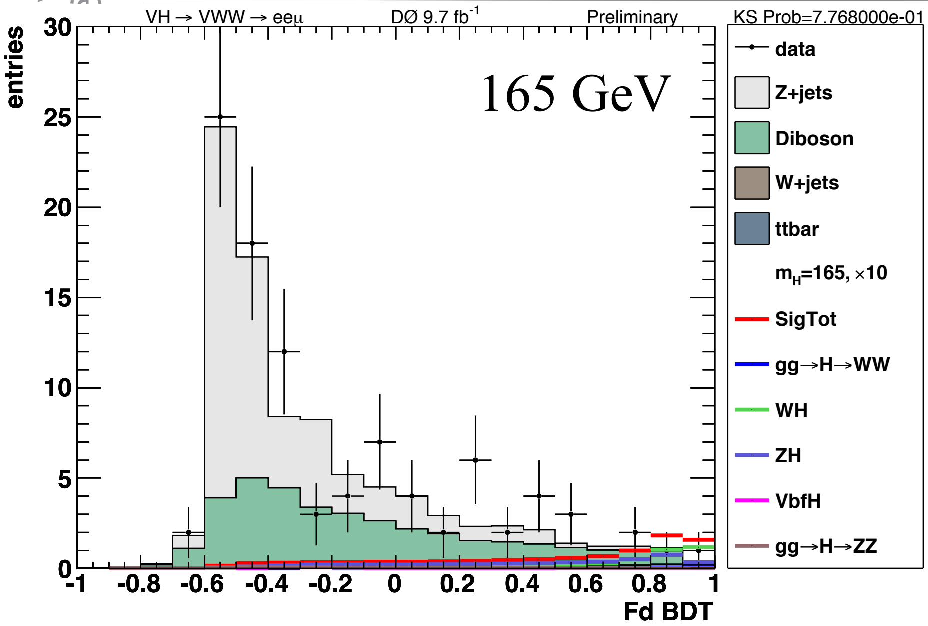
- 12 training variables

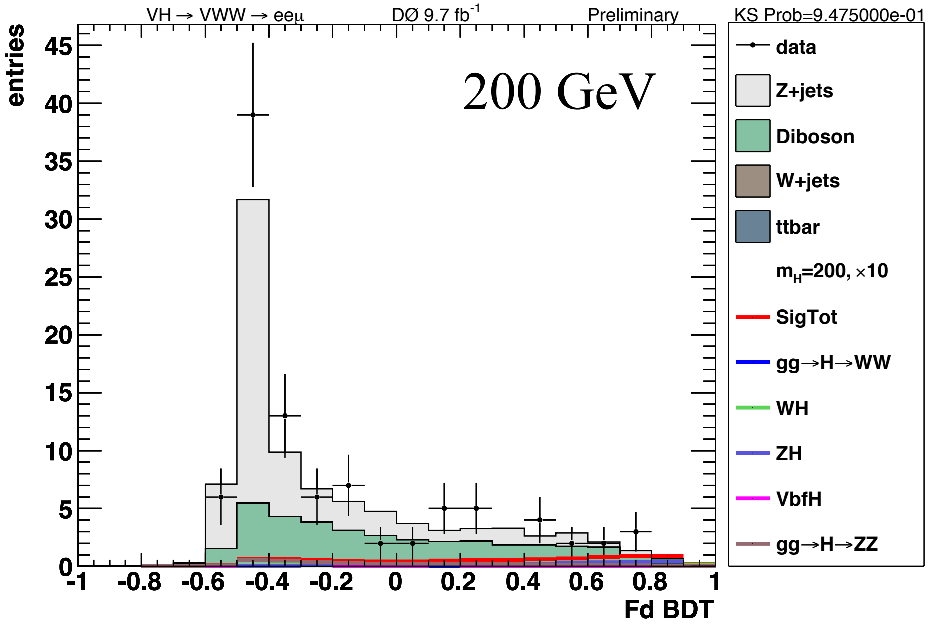


BDT Final Discriminant Distributions



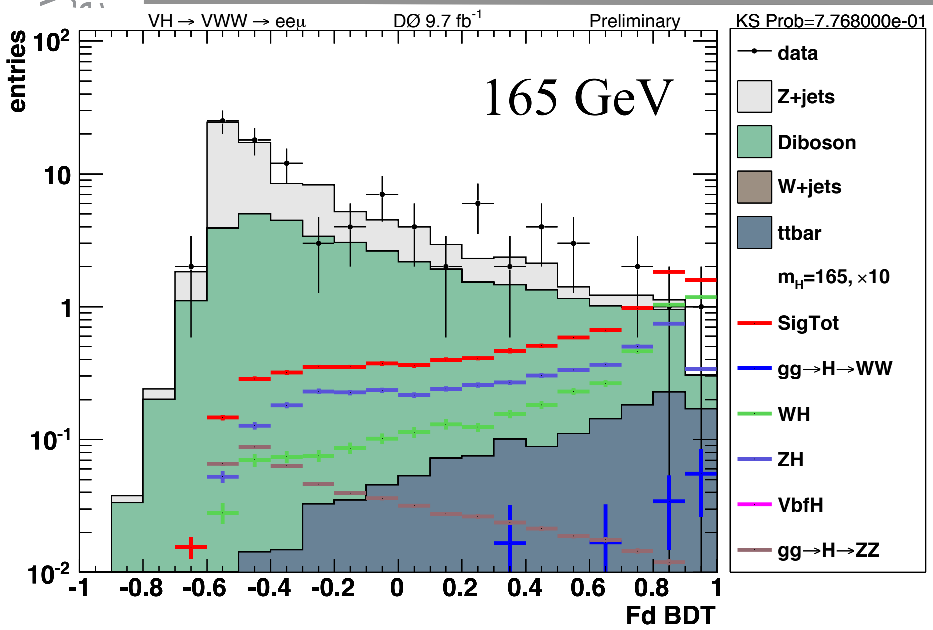
BDT Final Discriminant Distributions

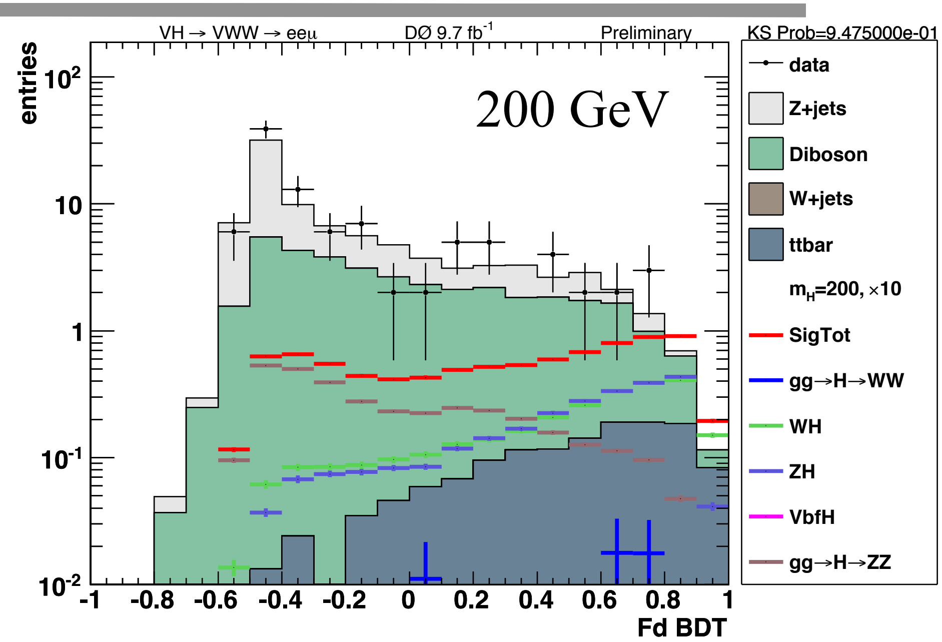




- Better separation with increasing mass due to increased sensitivity to $H \rightarrow WW^*$ at higher masses

BDT Final Discriminant Distributions





- ggH → ZZ trains as background due to the lack of real missing transverse energy

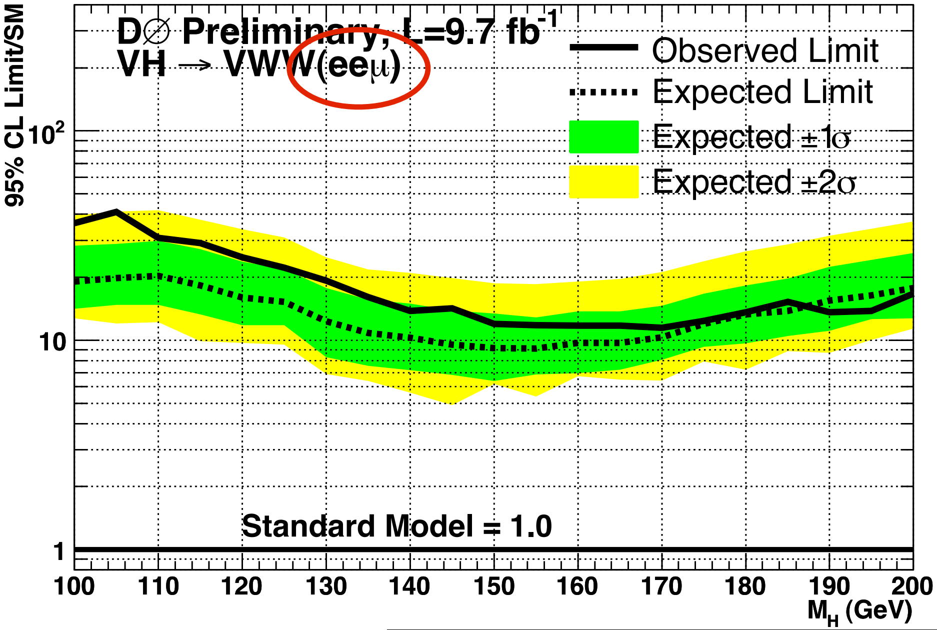
Systematic Uncertainties

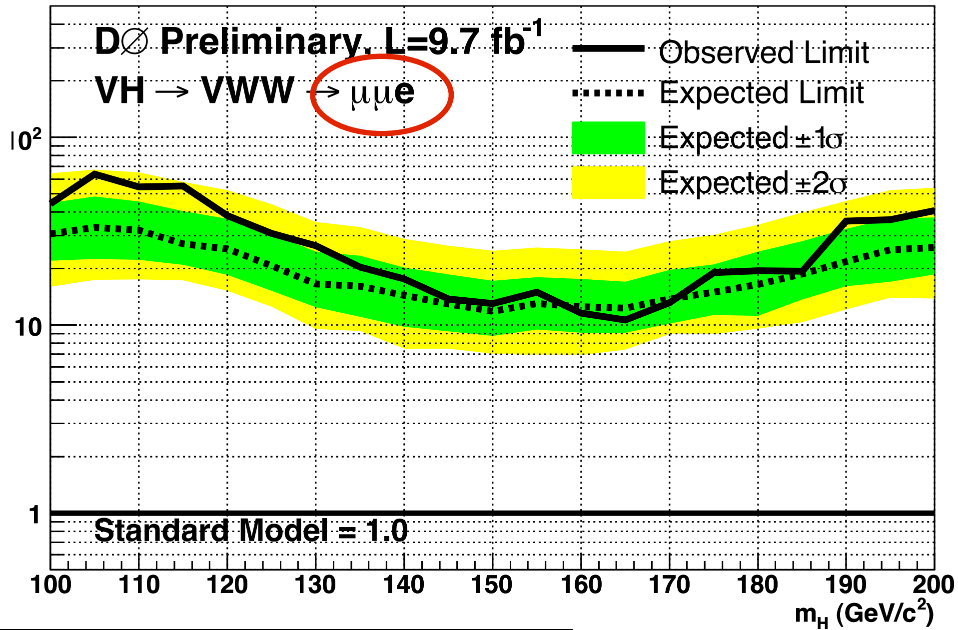
- Apply both flat (constant value) and shape systematics (nominal value shifted by ±1σ);

Systematic Uncertainties in percent	Signal	$\sum$ Bkgnd	Diboson	$t\bar{t}$	$Z+$jets	$W+$jets
Flat Systematics						
EM ID	2.5	2.5	–	–	–	–
MU ID	4	4	–	–	–	–
Luminosity	6.1	6.1	–	–	–	–
PDF	2.5	2.5	–	–	–	–
σ_{VH}	6.2	–	–	–	–	–
σ_{ggH}	7.0	–	–	–	–	–
σ_{VFB}	4.9	–	–	–	–	–
σ_{Bkgnd}	–	–	6	7	6	6
jet $\rightarrow \mu$ fake rate	–	–	–	–	30	30
Trigger	3.5	3.5	–	–	–	–
Shape Systematics						
Z-p_T rew.	–	–	–	–	$\pm 1\sigma$	–
Electron smearing	$\pm 1\sigma$	$\pm 1\sigma$	–	–	–	–
Muon smearing	$\pm 1\sigma$	$\pm 1\sigma$	–	–	–	–

Higgs Boson Cross Section Limits

http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H119/



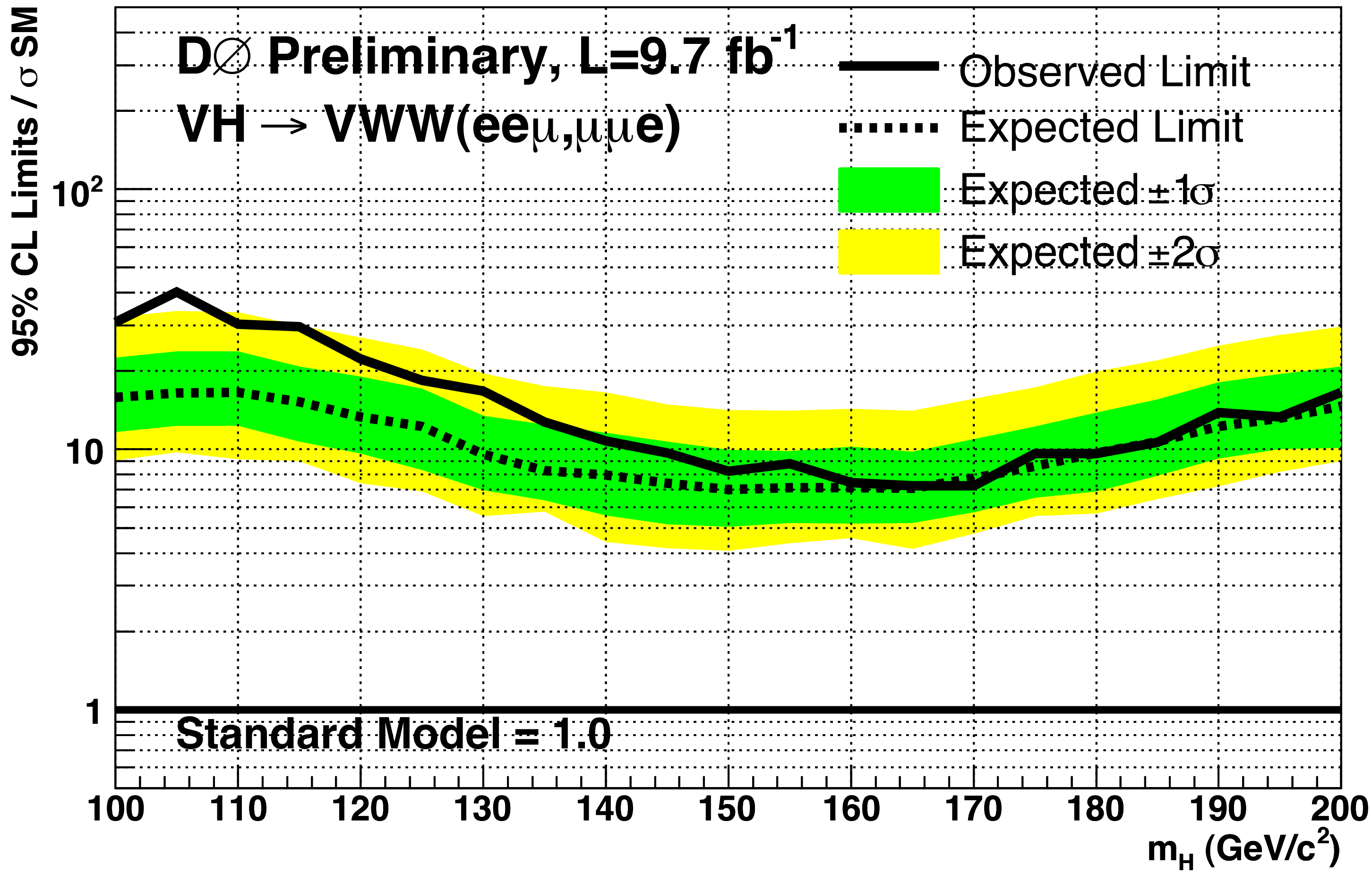


m_H (GeV/c^2)	100	105	110	115	120	125	130	135	140	145	150
Exp. all	15.82	16.46	16.54	15.25	13.34	12.25	9.57	8.29	7.99	7.41	7.01
Obs. all	30.78	40.39	30.30	29.68	22.30	18.42	16.75	12.72	10.78	9.69	8.24
Exp. $ee\mu$	19.09	19.84	20.29	18.30	16.03	15.28	12.29	10.81	10.27	9.54	9.16
Obs. $ee\mu$	36.22	40.97	30.83	29.11	24.94	22.24	19.23	16.06	13.82	14.17	11.97
Exp. $\mu\mu e$	30.73	33.18	32.04	27.11	25.55	20.74	16.58	16.08	14.46	12.97	11.84
Obs. $\mu\mu e$	44.41	63.71	54.39	55.16	38.32	30.74	26.48	20.37	17.65	13.80	13.03

m_H (GeV/c^2)	155	160	165	170	175	180	185	190	195	200
Exp. all	7.14	7.13	7.07	7.74	8.64	9.72	10.74	12.29	13.20	14.67
Obs. all	8.82	7.46	7.24	7.27	9.63	9.65	10.66	13.89	13.30	16.54
Exp. $ee\mu$	9.13	9.70	9.73	10.35	11.98	13.31	13.83	15.45	16.35	17.80
Obs. $ee\mu$	11.79	11.73	11.75	11.46	12.36	13.59	15.29	13.64	13.79	16.69
Exp. $\mu\mu e$	13.01	12.53	12.36	13.75	14.97	16.46	18.74	21.80	25.19	25.87
Obs. $\mu\mu e$	15.00	11.59	10.66	13.20	19.11	19.53	19.41	35.76	36.34	40.64

Higgs Boson Cross Section Limits

http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H119/



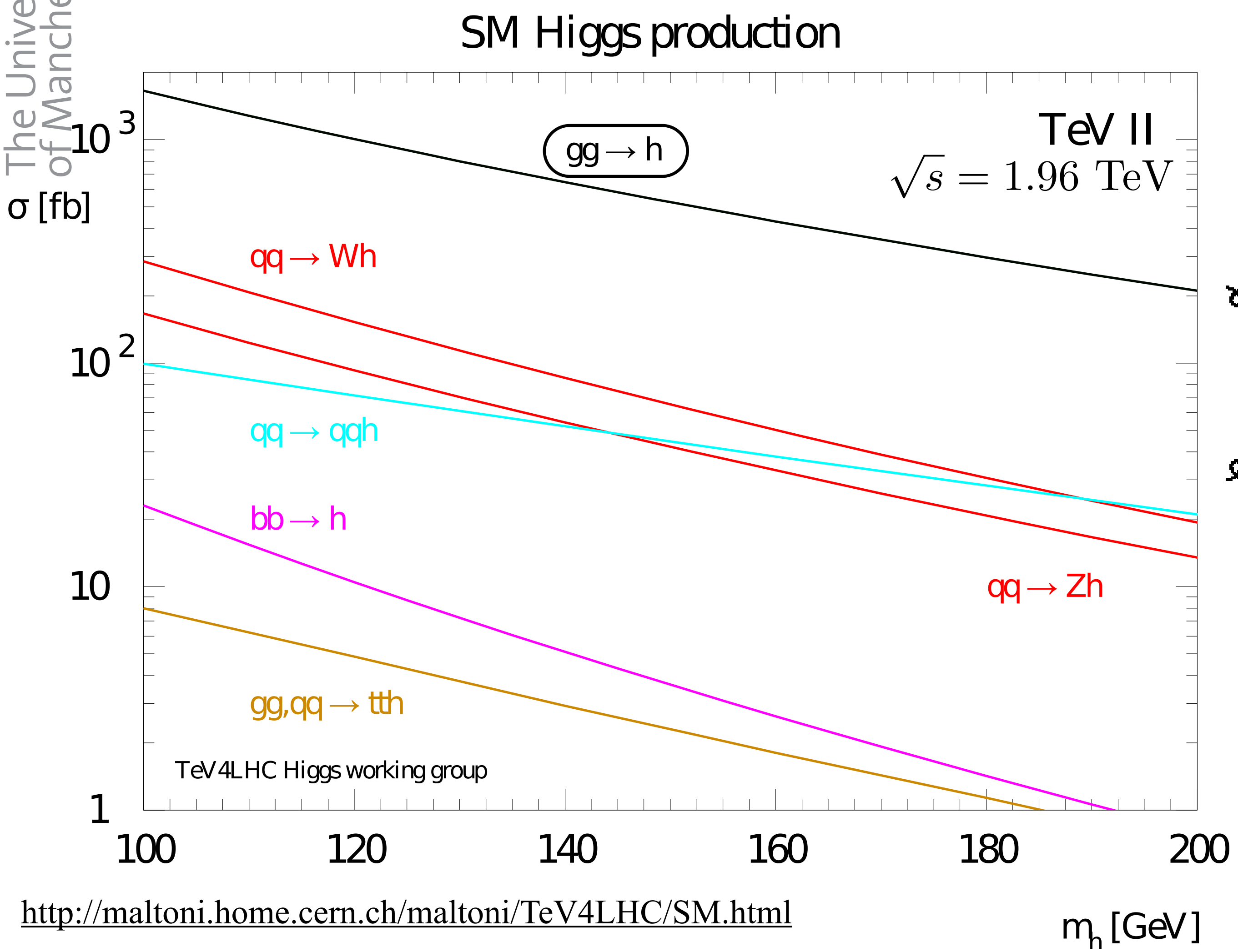
Conclusion

- Cross section for $\sigma_{WZ} = 3.90^{+1.06}_{-0.90}$ (stat+syst) pb with 4.1 fb^{-1} of integrated luminosity, in good agreement with the SM - no indication of physics beyond the SM
  - V. Abazov *et al.* [D0 Collaboration], Phys. Lett. B **695**, 67 (2011)
- FCNC search -- $B(t \rightarrow Zq) < 3.2\%$ ($< 3.8\%$) obs (exp), no indication of new physics as of yet, but lacking in statistics
  - V. Abazov *et al.* [D0 Collaboration], Phys. Lett. B **701**, 313 (2011)
- In our search for the SM Higgs boson we see no excess above the SM background prediction and extract limits at the 95% CL
  - We are most sensitive to a Higgs boson mass of $m_H = 150$ GeV where we set an expected cross section limit of $7.0\sigma_{SM}$ and observed of $8.2\sigma_{SM}$
  - Increase the overall sensitivity when added with rest of channels
  - DZero Conference Note 6276-CONF, 2012

Backup Material

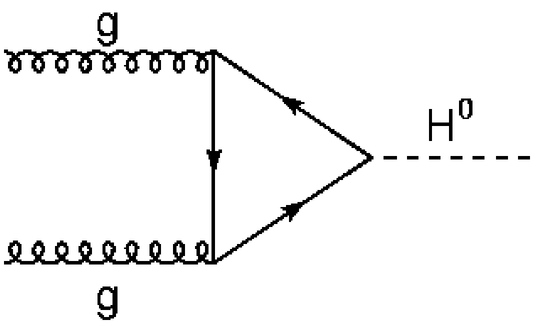
Higgs Boson Motivation Backup Slides

Higgs Production at the Tevatron



http://maltoni.home.cern.ch/maltoni/TeV4LHC/SM.html

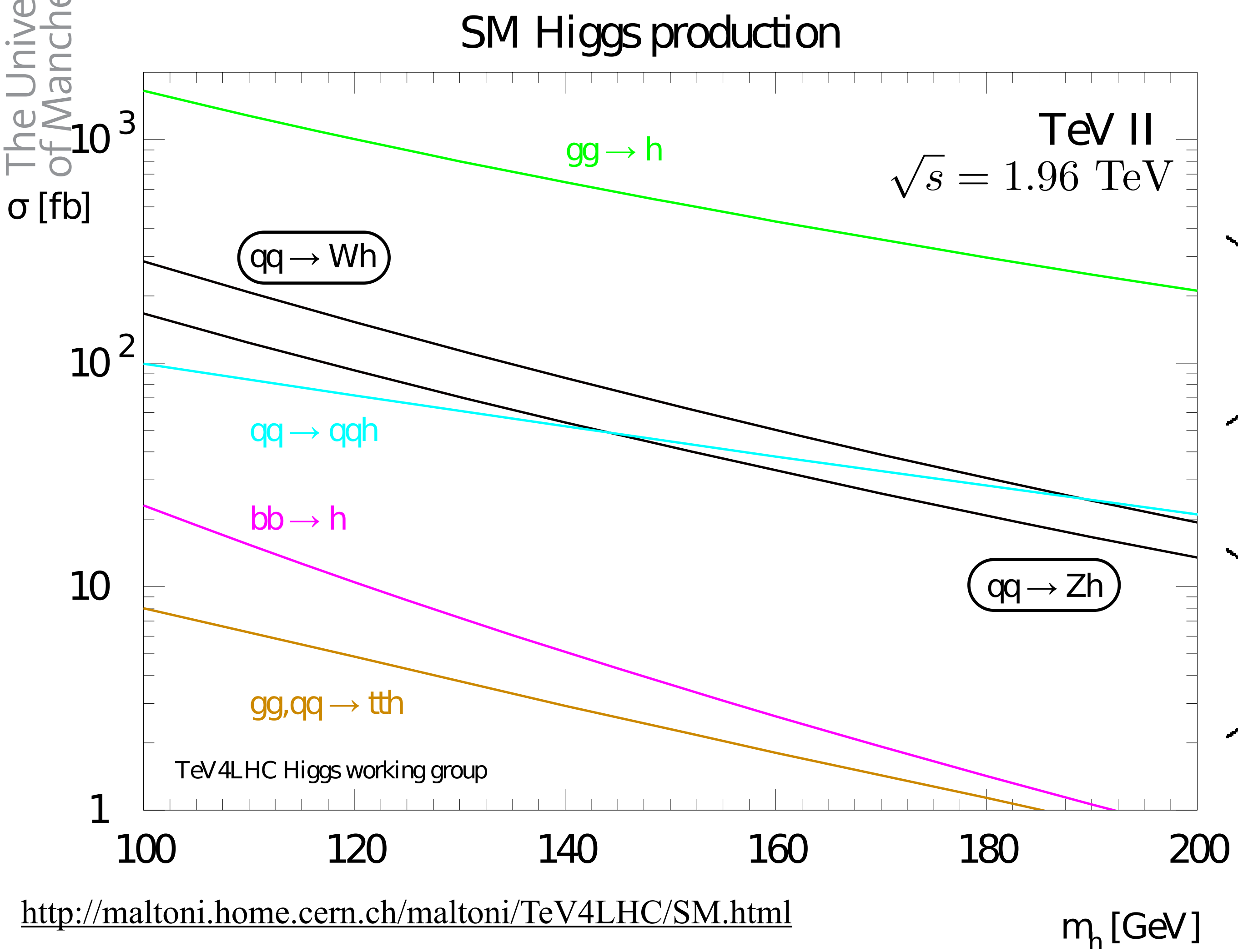
Gluon - Gluon Fusion



Time →

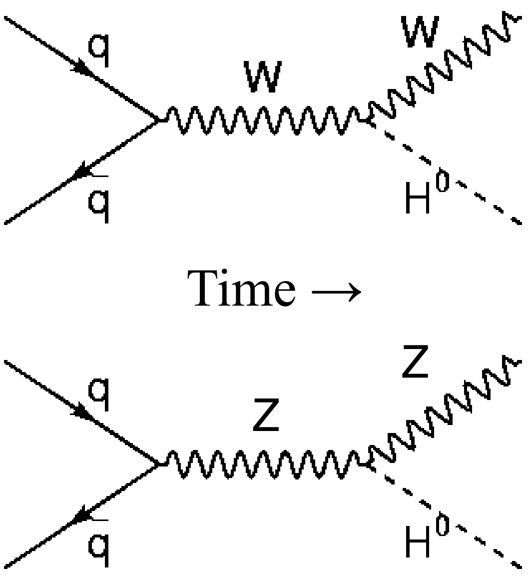
$1\ \text{fb} = 10^{-15}$ barn
$1\ \text{barn} = 10^{-24}\ \text{cm}^2$

Higgs Production at the Tevatron



http://maltoni.home.cern.ch/maltoni/TeV4LHC/SM.html

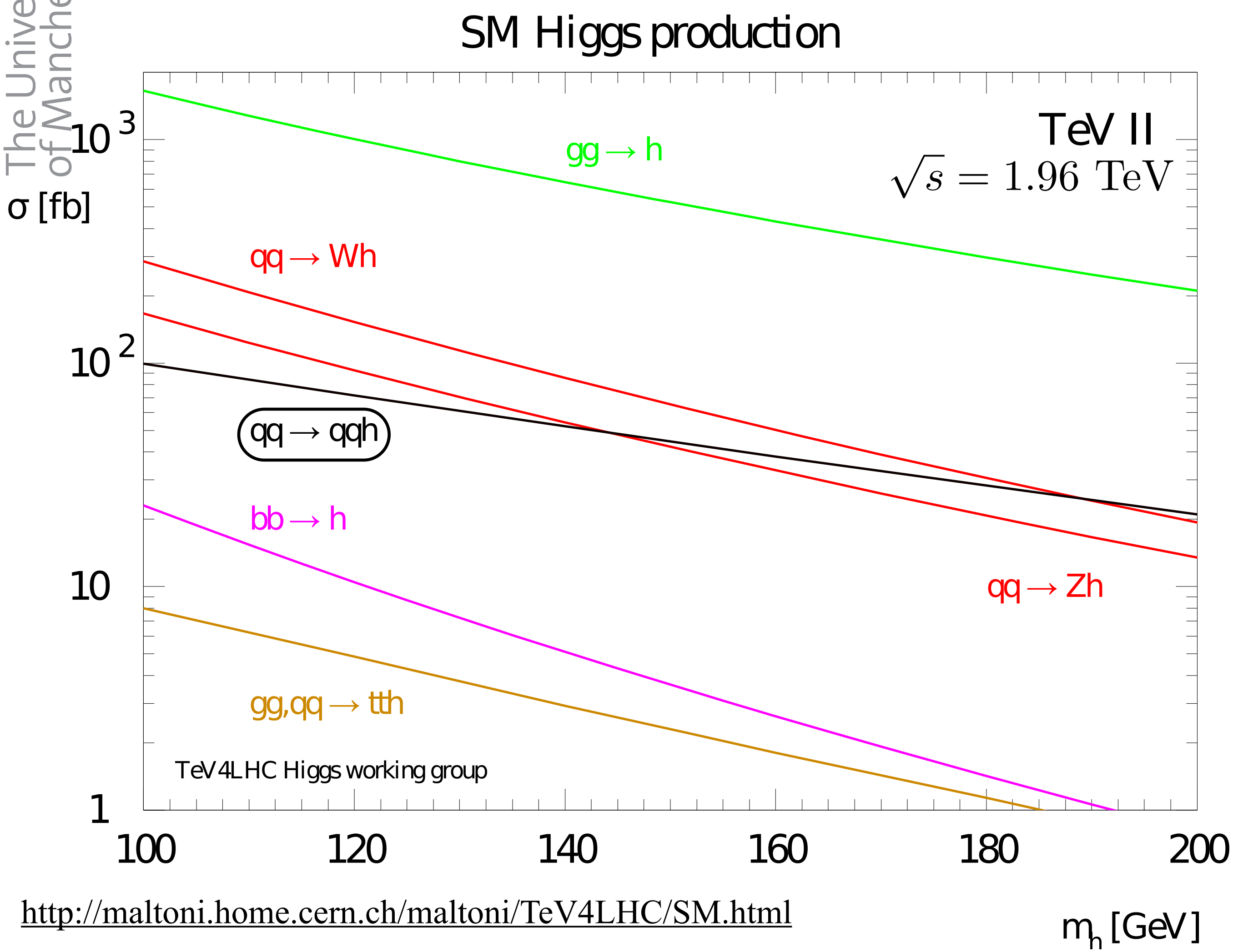
Associated Production



$1\ \mathrm{fb} = 10^{-15}\ \mathrm{barn}$

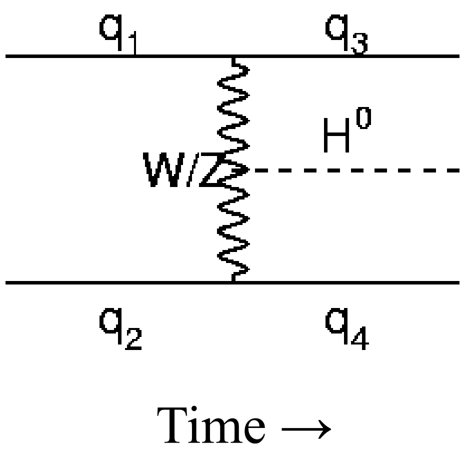
$1\ \mathrm{barn} = 10^{-24}\ \mathrm{cm}^2$

Higgs Production at the Tevatron



http://maltoni.home.cern.ch/maltoni/TeV4LHC/SM.html

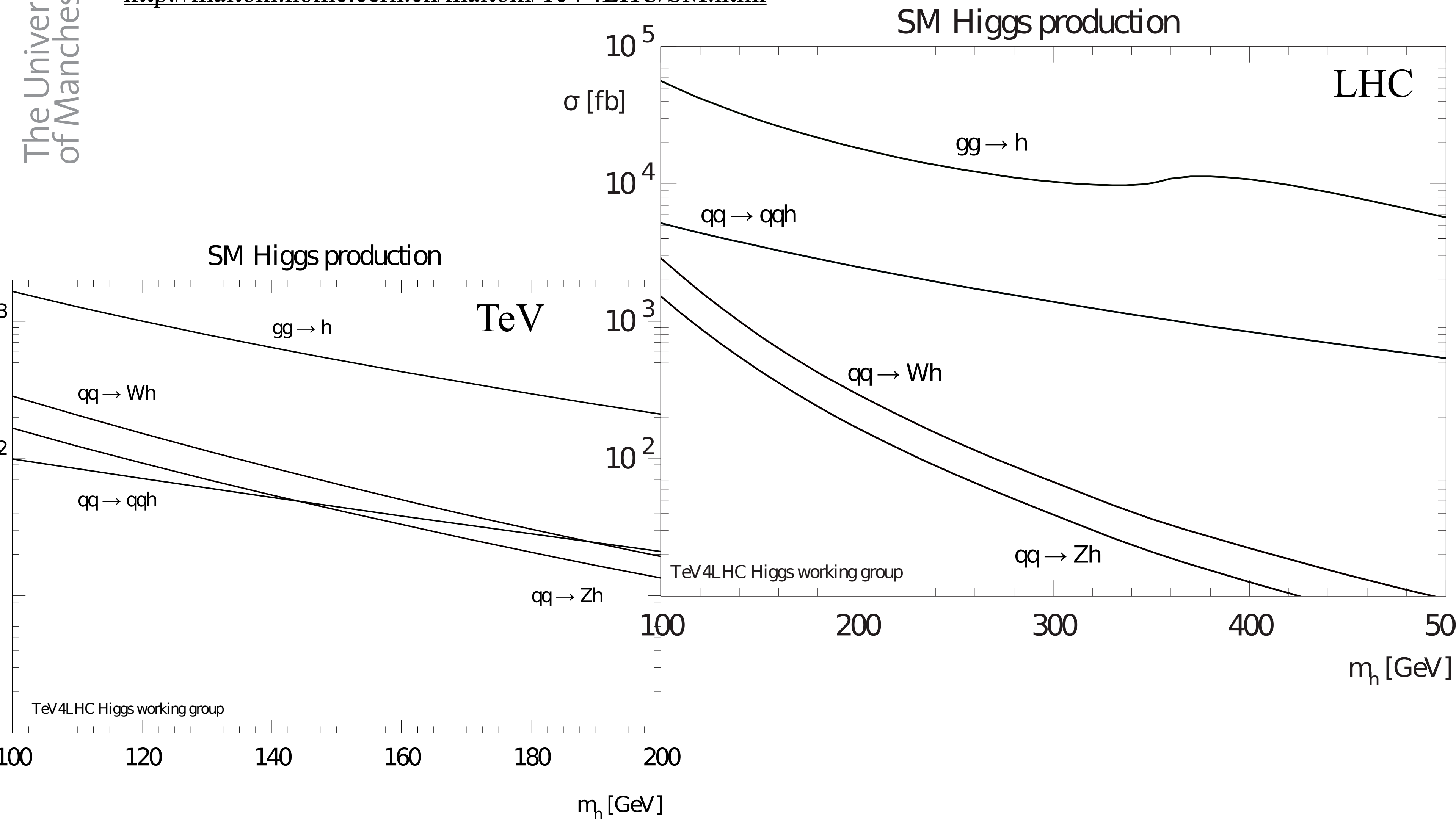
Vector Boson Fusion



$$1 \text{ fb} = 10^{-15} \text{ barn}$$
$$1 \text{ barn} = 10^{-24} \text{ cm}^2$$

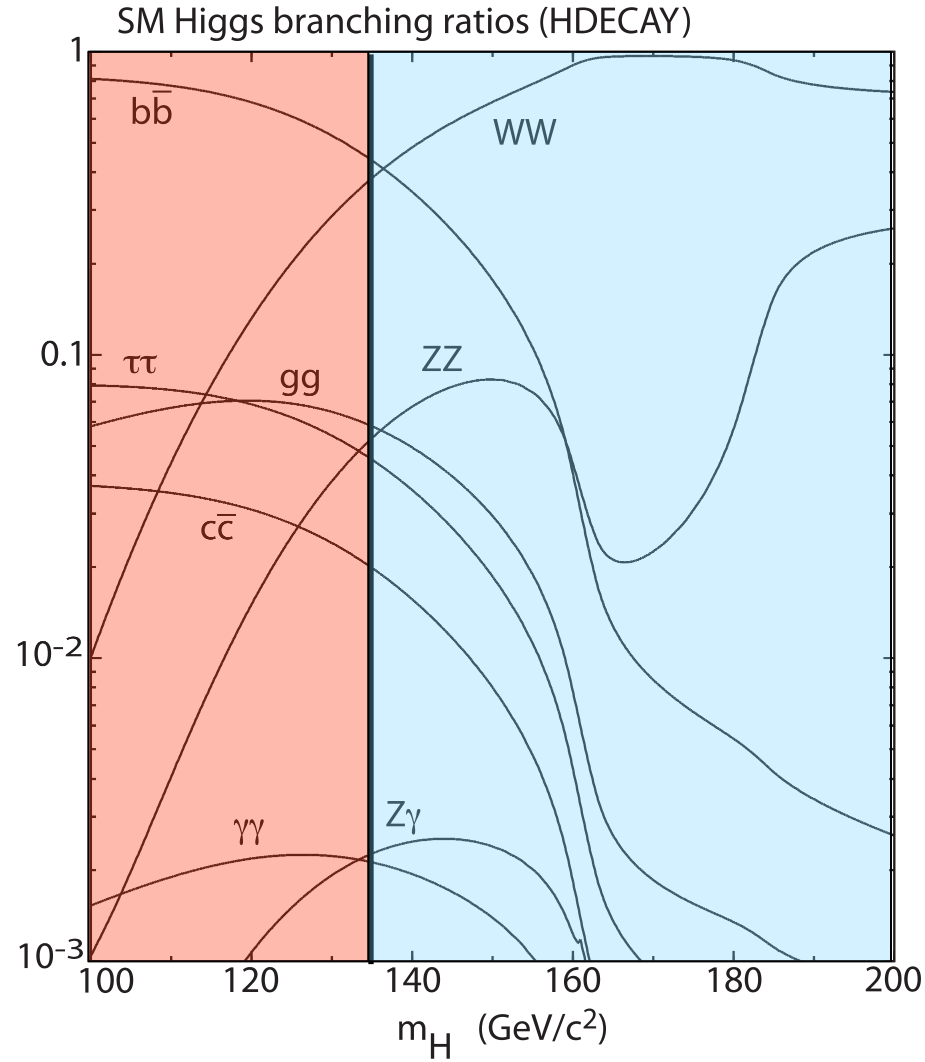
Higgs Production : TeV vs. LHC

http://maltoni.home.cern.ch/maltoni/TeV4LHC/SM.html



Higgs Production : TeV vs. LHC

- Considered "low mass" below $m_H = 135$ GeV

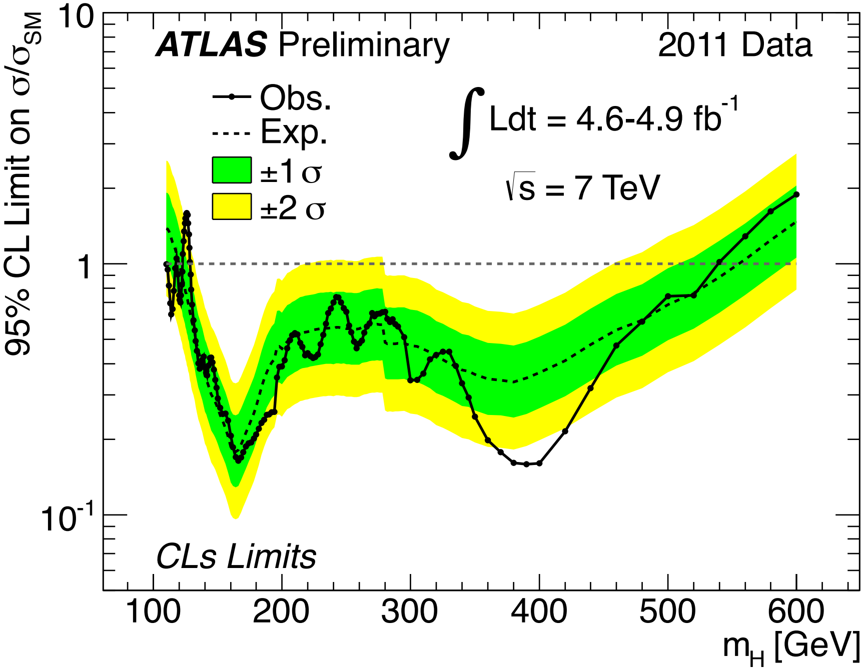


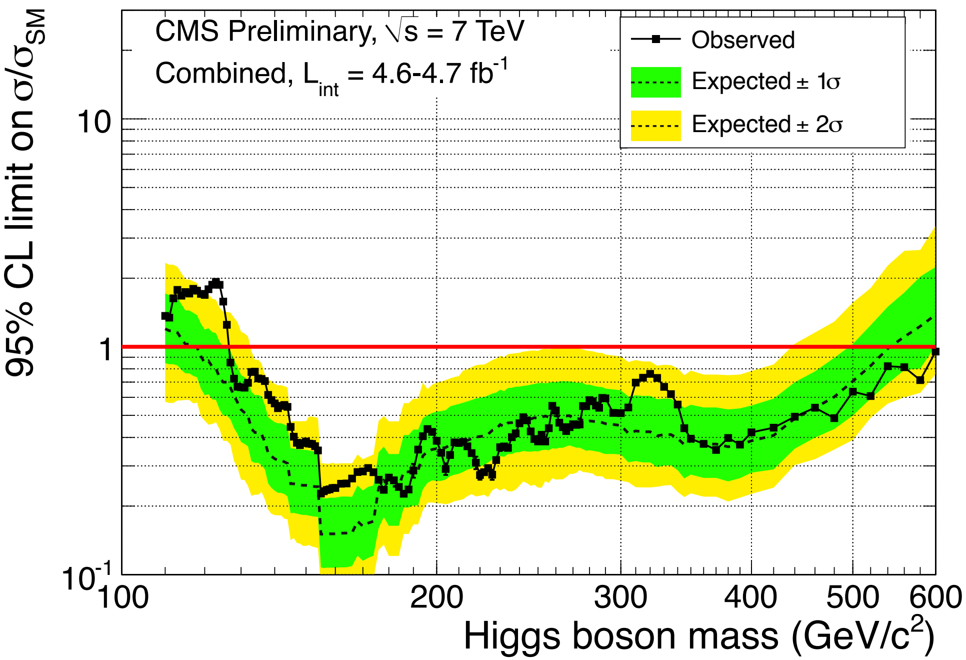
- $H \rightarrow$ b - anti-b quark production dominates at low mass
- $H \rightarrow WW^*$ production dominates at high mass

http://www.physics.ucdavis.edu/~conway/research/higgs/smhiggs-tev.html

Current Mass Exclusions @ 95% CL

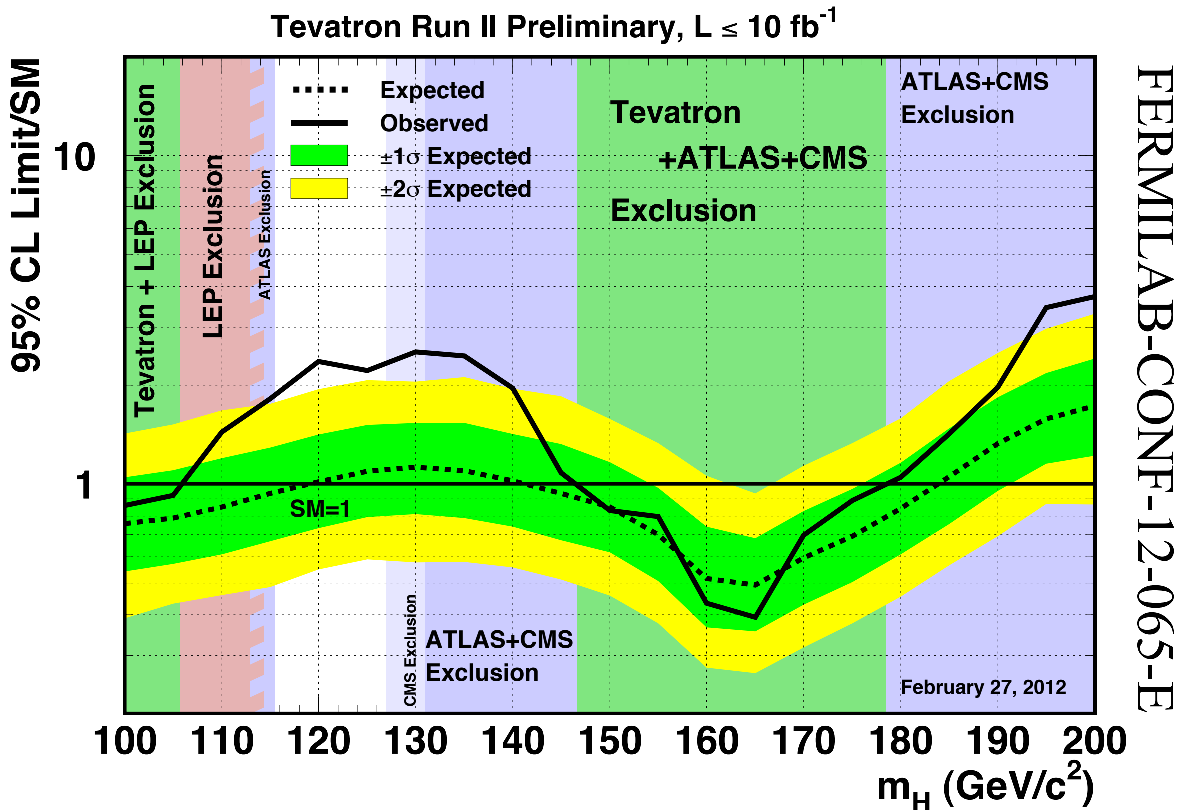
- LEP first excluded masses below 114.4 GeV [Phys. Lett B **565**, 61 (2003)]
- Combined LHC excludes the regions : 127 - 600 GeV
  - see excess around $m_H \sim 125$ GeV
  - ATLAS : ATLAS-CONF-2012-019, 2012 / CMS : HIG-11-032, 2011





Current Mass Exclusions @ 95% CL

- LEP first excluded masses below 114.4 GeV [Phys. Lett B **565**, 61 (2003)]
- Combined LHC excludes the regions : 127 - 600 GeV
  - see excess around $m_H \sim 125$ GeV
  - ATLAS : ATLAS-CONF-2012-019, 2012 / CMS : HIG-11-032, 2011
- Tevatron excludes : 147 - 179 GeV
  - See a broad excess in range of 115 - 135 GeV



Current Mass Exclusions @ 95% CL

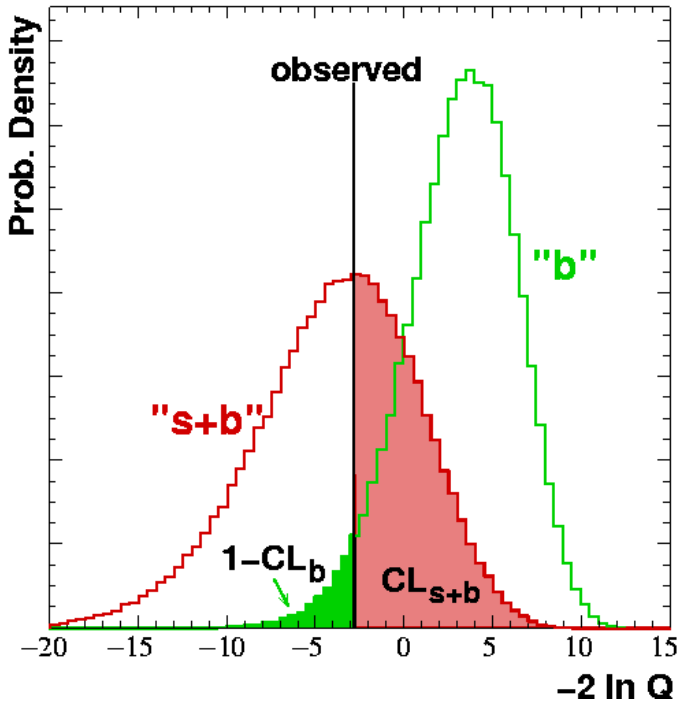
- Modified frequentist approach
- signal Confidence Level (CL) : $CL_s = CL_{s+b} / CL_b$
  - log-likelihood ratio (LLR) test statistic

$$-2\ln Q \equiv LLR \equiv -2\ln\left(\frac{p(data|H_1)}{p(data|H_0)}\right)$$

  - $H_1 = s+b$ (test) hypothesis
  - $H_0 = b$-only (null) hypothesis
  - Two p-values:

$$\begin{aligned} CL_{s+b} &= p(LLR \geq LLR_{obs}|s+b) \\ 1 - CL_b &= p(LLR \leq LLR_{obs}|b-\text{only}) \end{aligned}$$

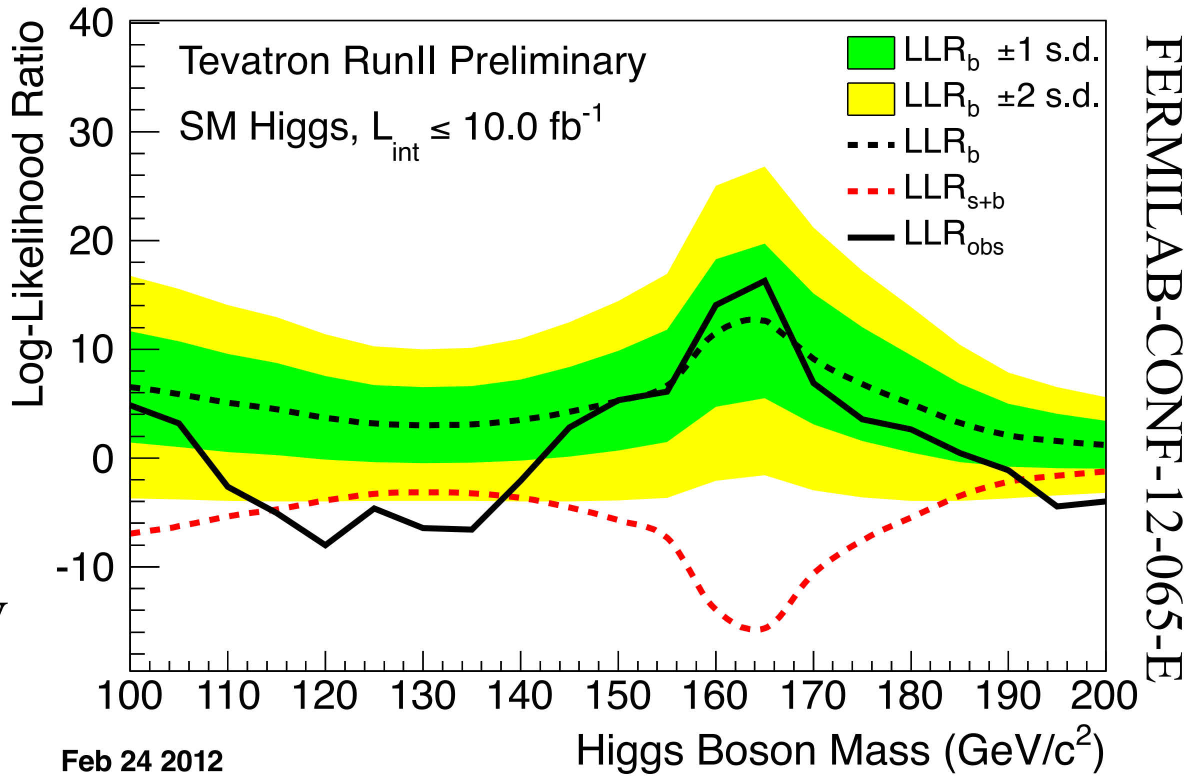
  - **Excluded** at 95% CL if $CL_s < 0.05$



Current Mass Exclusions @ 95% CL

- LEP first excluded masses below 114.4 GeV [Phys. Lett B **565**, 61 (2003)]
- Combined LHC excludes the regions : 127 - 600 GeV
  - see excess around $m_H \sim 125$ GeV
  - ATLAS : ATLAS-CONF-2012-019, 2012 / CMS : HIG-11-032, 2011

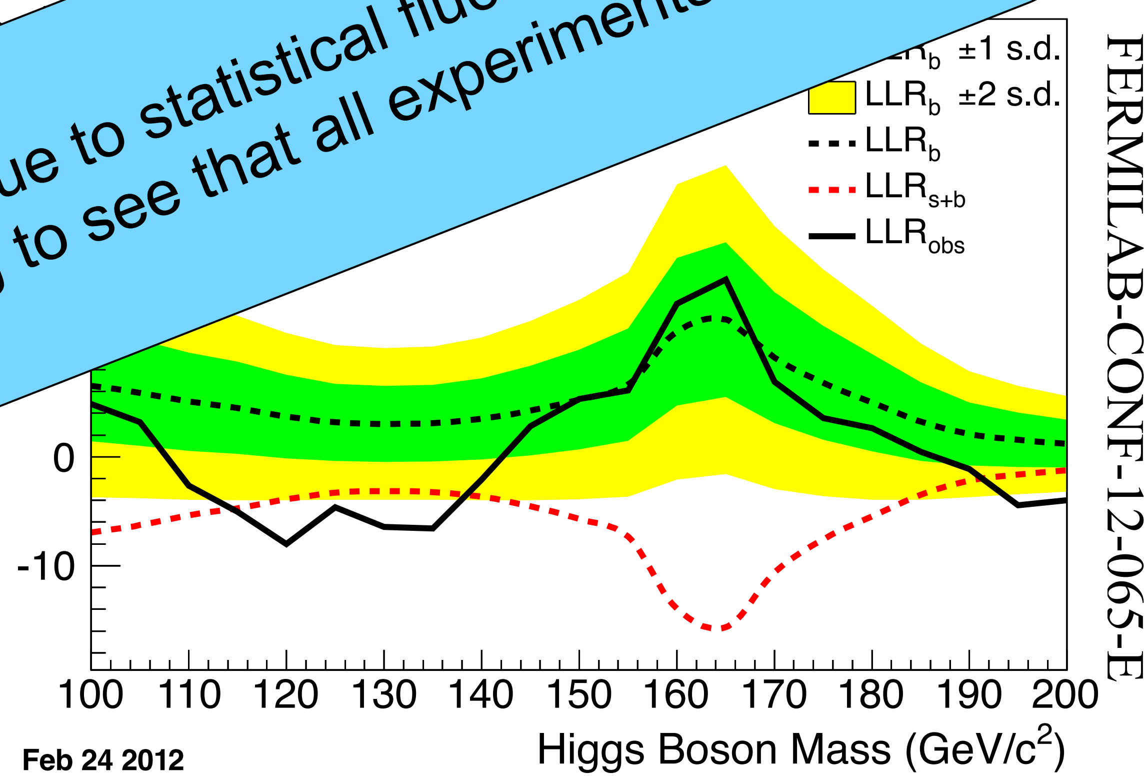
- Tevatron excludes : 147 - 179 GeV
  - See a broad excess in range of 115 - 135 GeV



Current Mass Exclusions @ 95% CL

- LEP first excluded masses below 114.4 GeV [Phys. Lett B **565**, 61 (2003)]
- Combined LHC excludes the regions : 127 - 600 GeV
  - see excess around $m_H \sim 125$ GeV
  - ATLAS : ATLAS-CONF-2012-019, 2012

Could be due to statistical fluctuations,
but still exciting to see that all experiments agree



- T
  14
  - broad excess in range of 115 - 135 GeV

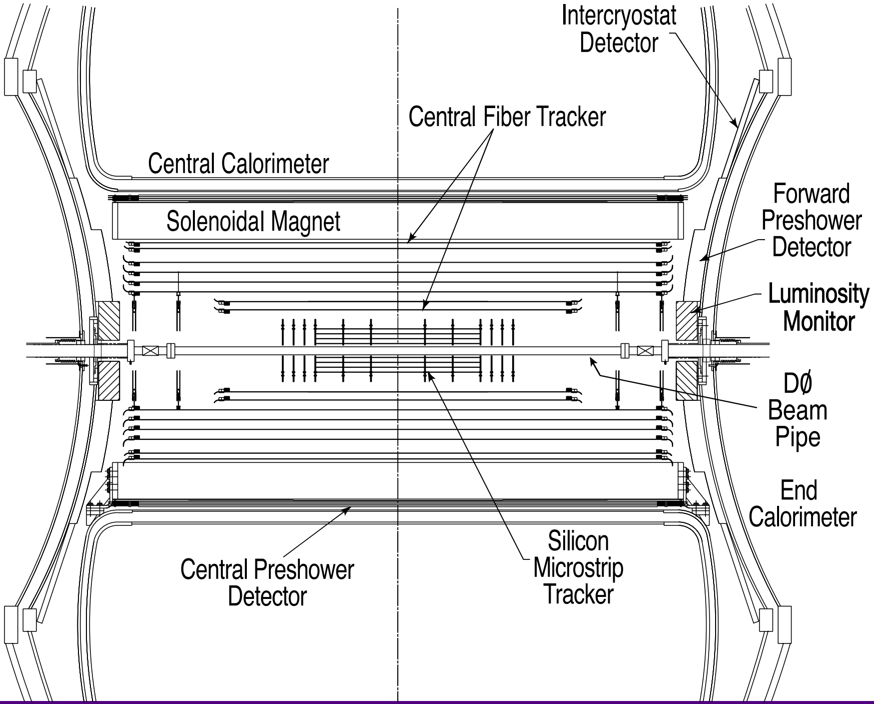
MANCHESTER 1824

The University of Manchester

DZero Detector Backup Slides

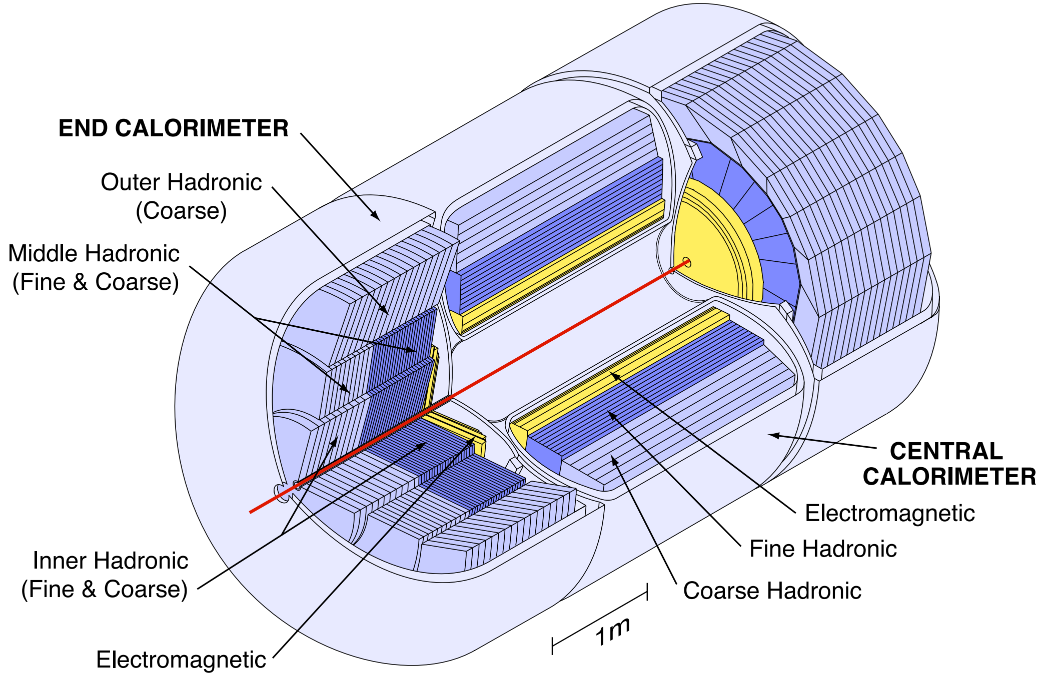
DZero Experiment - Tracking

- Tracking system consists of
  - silicon microstrip tracker (SMT), central fiber tracker (CFT), and central/forward preshower detectors (CPS/FPS)
- Enclosed in the 2T solenoid magnetic field
- Measures charged particle's vertex and momentum



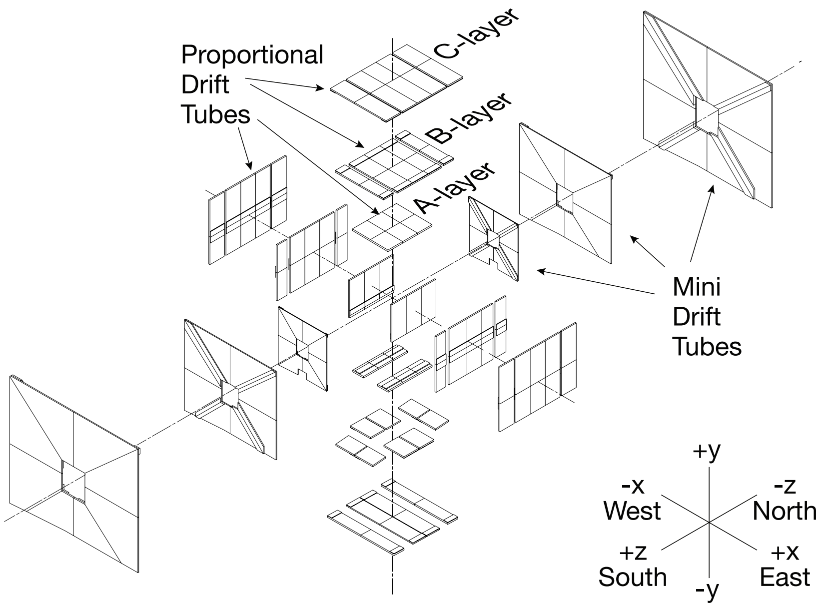
DZero Experiment - Calorimetry

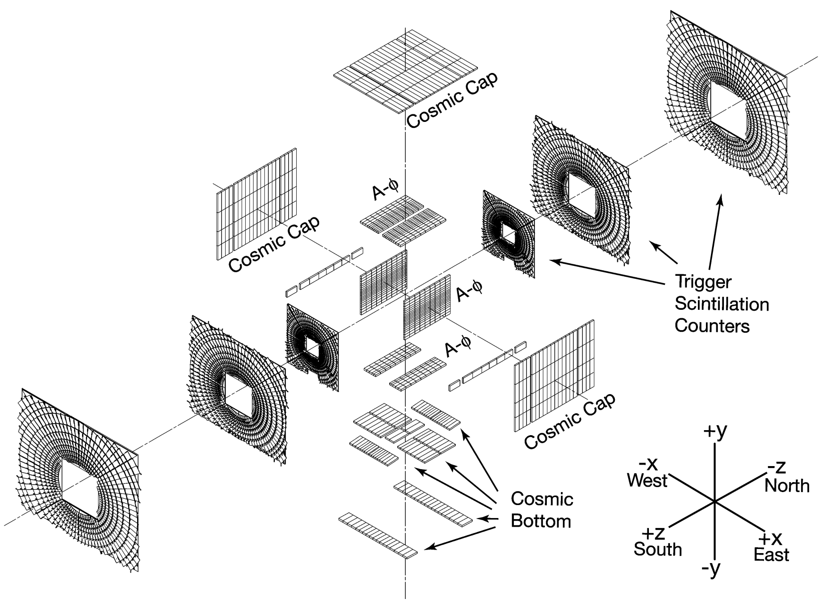
- Calorimetry system consists of
  - central (CC) and end cap (EC) electromagnetic (EM), fine (FH) and coarse (CH) hadronic
  - sampling liquid-argon/uranium (EM), liquid-argon/uranium-niobium alloy (FH) and liquid-argon/copper/steel (CH CC/EC)
- Measures particle's dE/dx (the energy deposited from showing particles)



DZero Experiment - Muon

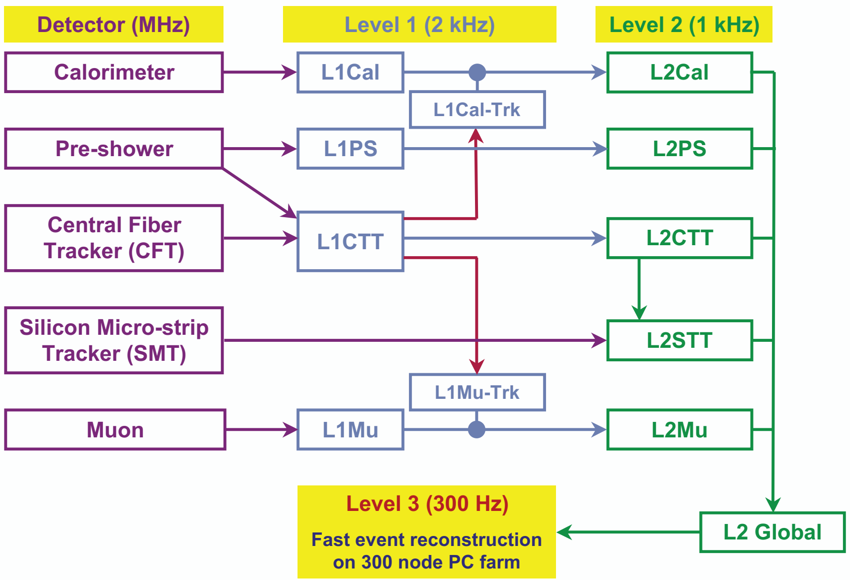
- Muon system consists of
  - central and forward wire drift tubes (positioning) and scintillation counters (timing)
- Layer A enclosed in a 1.8T toroid magnetic field
- Measures local muons and matches back to central tracker



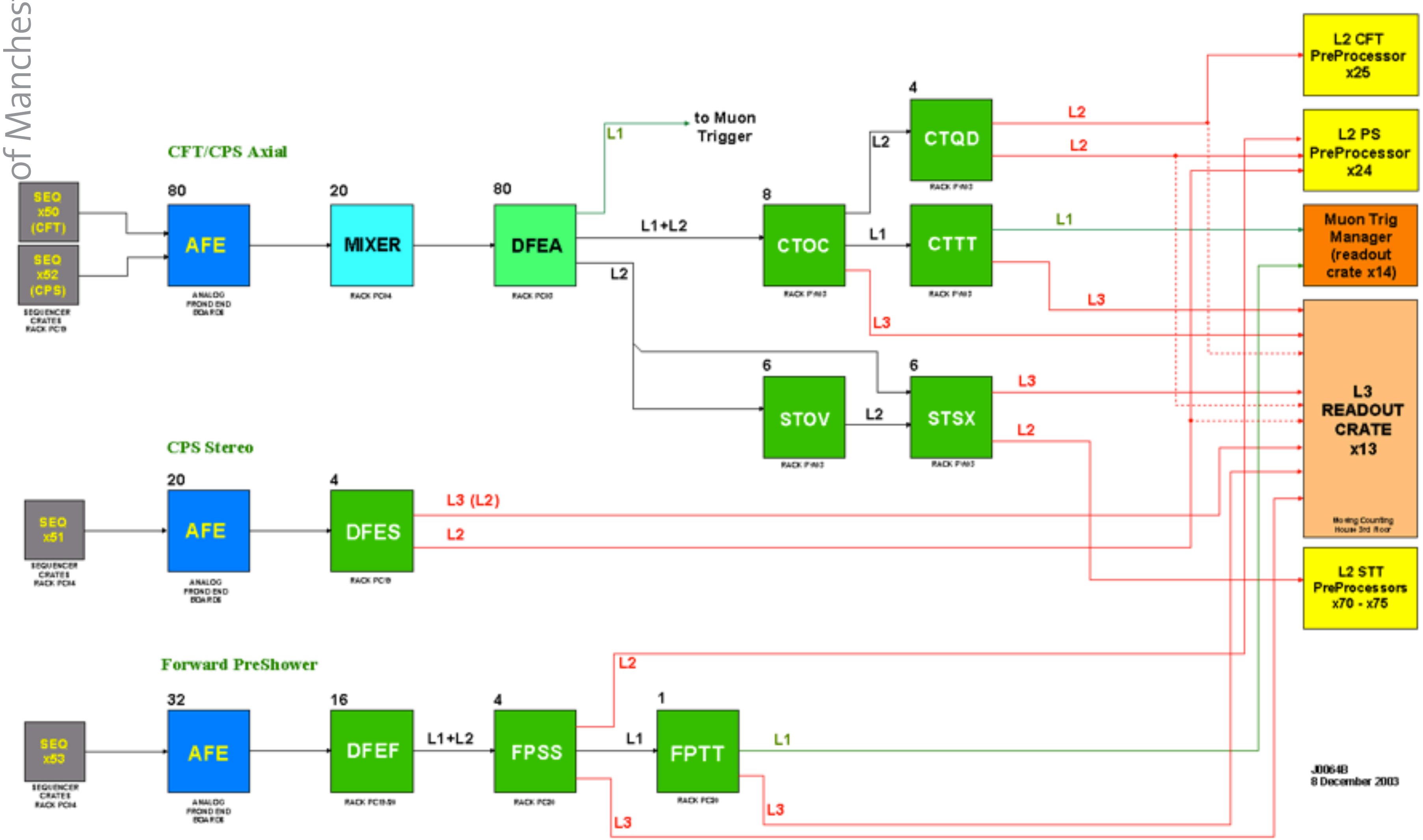


DZero Experiment - DAQ

- Three levels of triggering
  - Level 1 - fast trigger (1.7 MHz → 1.8 kHz at peak rate)
  - Level 2 - combination of hardware and programmable firmware (→ 900 Hz)
  - Level 3 - complex software algorithms (→ 200 Hz)
- Trigger suites used to collect



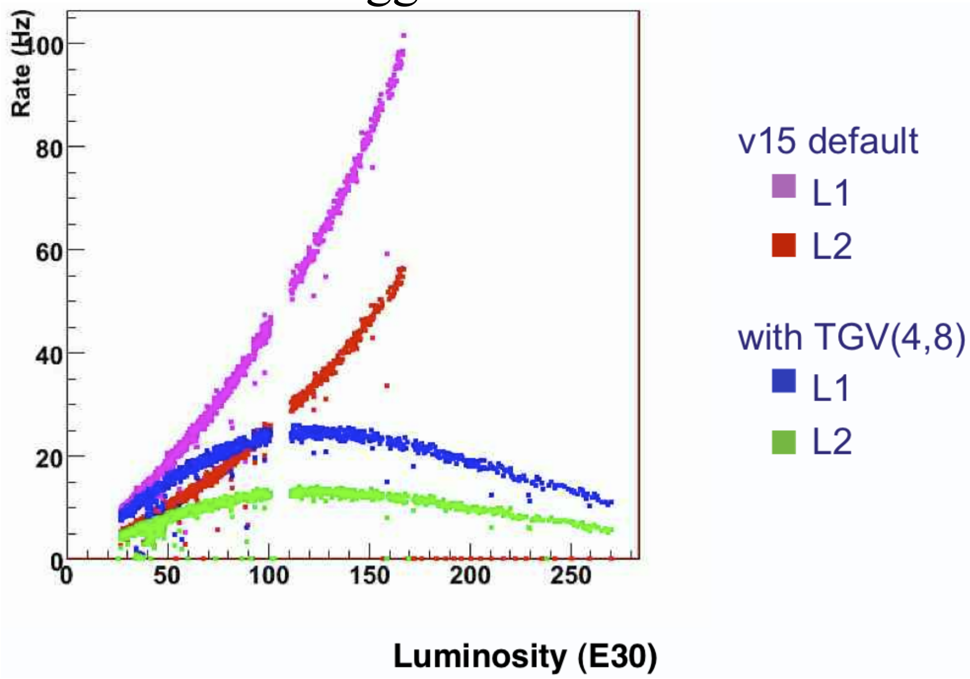
DZero Experiment - CTT



DZero Experiment - TGV Triggers

- Track Global Veto (TGV) terms
  - helps to reduce the amount of fakes at high luminosity
  - allows previously prescaled or turned off triggers to run at much higher instantaneous luminosity

MUHI 1 Trigger



DZero Experiment - TGV Triggers

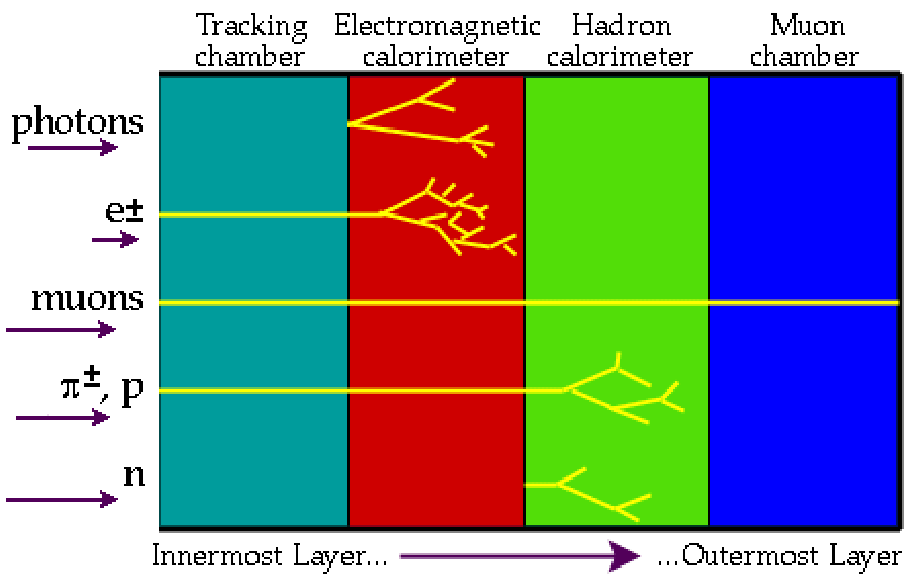
Table 2-3: TGV term threshold values. j represents the truncated octant sums, eg. j = 3 is the sum of the three lowest occupied octants. % Hit refers to the percentage of fibers hit for that TGV threshold i term with respect to the total number of singlets available in that truncated sum.

Term	$j = 1$	2	3	4	5	6	7	8	% Hit
TGV(0,j)	240	480	720	960	1200	1440	1680	1920	~ 5.0
TGV(1,j)	326	652	978	1304	1630	1956	2282	2608	~ 6.8
TGV(2,j)	412	824	1236	1648	2060	2472	2884	3296	~ 8.6
TGV(3,j)	498	996	1494	1992	2490	2988	3486	3984	~ 10.4
TGV(4,j)	584	1168	1752	2336	2920	3504	4088	4672	~ 12.2
TGV(5,j)	670	1340	2010	2680	3350	4020	4690	5360	~ 14.0
TGV(6,j)	756	1512	2268	3024	3780	4536	5292	6048	~ 15.8
TGV(7,j)	842	1684	2526	3368	4210	5052	5894	6736	~ 17.6
TGV(8,j)	928	1856	2784	3712	4640	5568	6496	7424	~ 19.4
TGV(9,j)	1014	2028	3042	4056	5070	6084	7098	8112	~ 21.2
TGV(10,j)	1100	2200	3300	4400	5500	6600	7700	8800	~ 23.0
TGV(11,j)	1186	2372	3558	4744	5930	7116	8302	9488	~ 24.8
TGV(12,j)	1272	2544	3816	5088	6360	7632	8904	10176	~ 26.6
TGV(13,j)	1358	2716	4074	5432	6790	8148	9506	10864	~ 28.4
Step Size	86	172	258	344	430	516	602	688	~ 1.792
Offset	240	480	720	960	1200	1440	1680	1920	
Total Singlet #	4800	9600	14400	19200	24000	28800	33600	38400	

– reject events with high occupancy

Particle Reconstruction

- Electrons : clusters in EM calorimeter are matched to central tracks
- Jets : clusters in FH/CH calorimeters are matched to central tracks
- Muons : local muons are matched to central tracks



WZ Cross Section Backup Slides

WZ General Event Selection

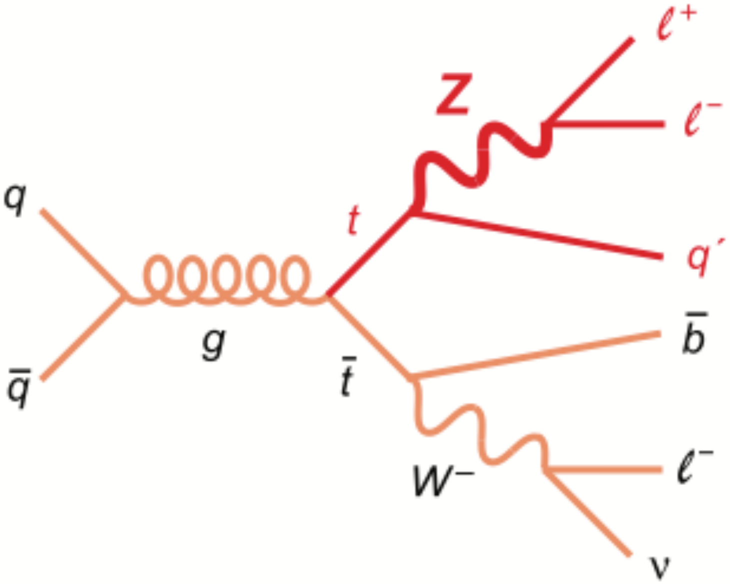
- Look for a signal with 3 or more isolated leptons and an imbalance in transverse momentum (MET)
- Use 4.1 fb^{-1} of integrated luminosity collected from the Tevatron Run II, selection criteria optimized with $s/\sqrt{(s+b)}$.
- Main Backgrounds: WZ, ZZ, Zγ, V+Jets, ttbar
  - Determined using MC Simulations and Data
- General selection criteria for all leptons :
  - Invariant dilepton mass (74 GeV < M_{ee} < 104 GeV, 65 GeV < $M_{\mu\mu}$ < 115 GeV, 60 GeV < M_{eeICR} < 120 GeV)
  - Missing Transverse Energy > (20 - 30) GeV
  - Lepton p_T > (15 - 30) GeV
  - Lepton ΔR ($=\sqrt{(\Delta\phi^2 + \Delta\eta^2)}$) > 0.5 - 0.6
  - Δz_{DCA} (between any two lepton tracks) < 3 cm
  - jet inclusive

FCNC Branching Ratio Limits Backup Slides

Flavor Changing Neutral Currents

- Standard Model (SM) Lagrangian contains no flavor changing neutral current (FCNC) terms
  - t→c,u quark transitions only possible through radiative corrections
  - very small branching ratio

- Branching ratio of t→Zc is $O(10^{-14})$, while t→Zu is $O(10^{-17})$
- Some theories beyond SM allow B ~ $O(10^{-4})$
- Observation would certainly point to physics beyond the SM



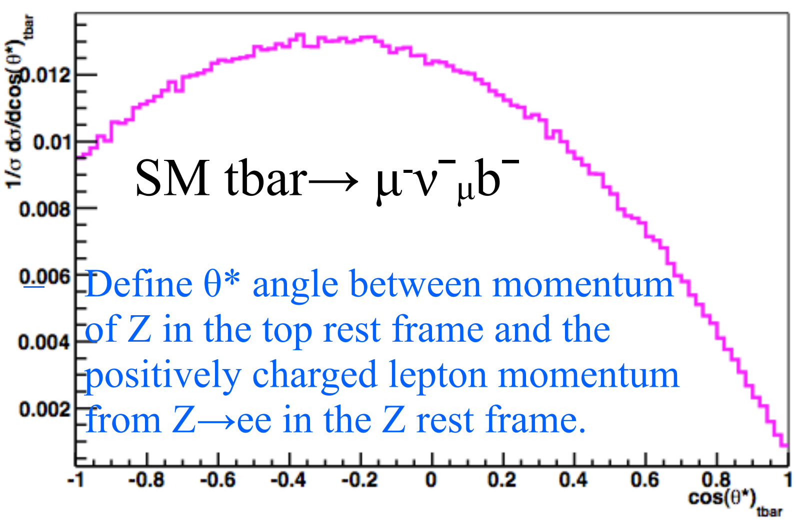
FCNC ttbar MC

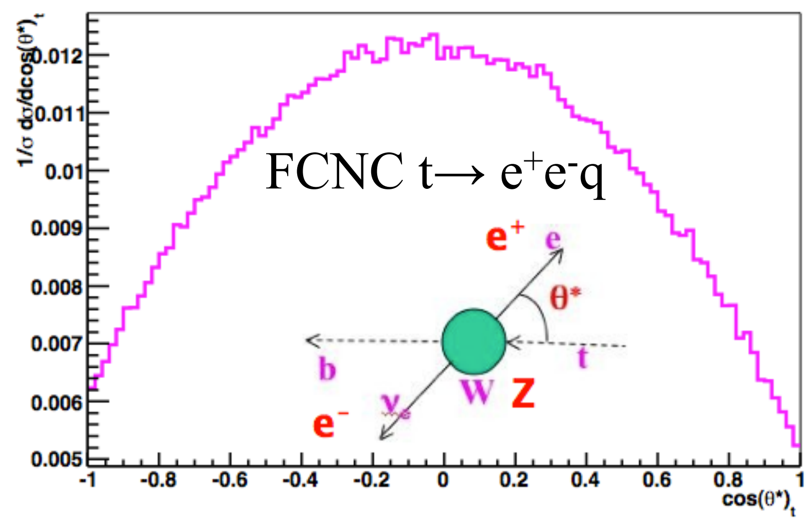
- Need to include the proper FCNC reweighting to PYTHIA
  - PYTHIA doesn't include the correct helicity structure for our signal
- Use COMPHEP to generate the signal at the parton level
  - Modified to include the following FCNC Lagrangian

$$\mathcal{L}_{FCNC} = \frac{e}{2\sin\theta_W \cos\theta_W}\, \bar{t}\gamma_\mu(v_Z - a_Z\gamma_5)cZ^\mu + h.c.$$

Assume SM neutral current couplings (Z→qqbar for up-type quarks) :

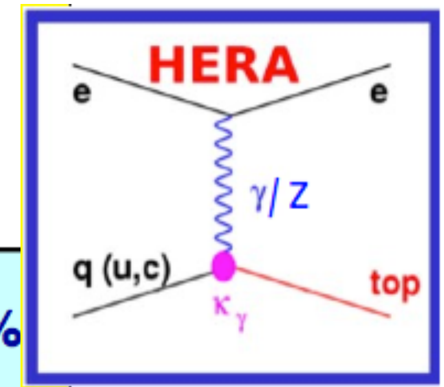
$$v_{tuZ} = 1/2 - 4/3\sin^2\theta_W = 0.192\,,\;\; a_{tuZ} = 1/2$$

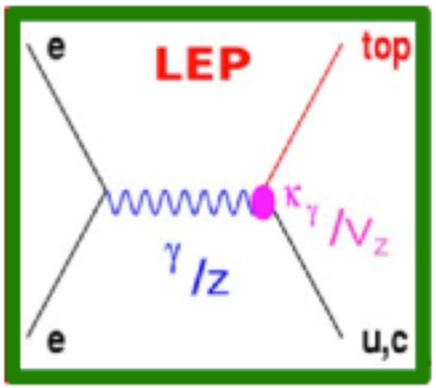


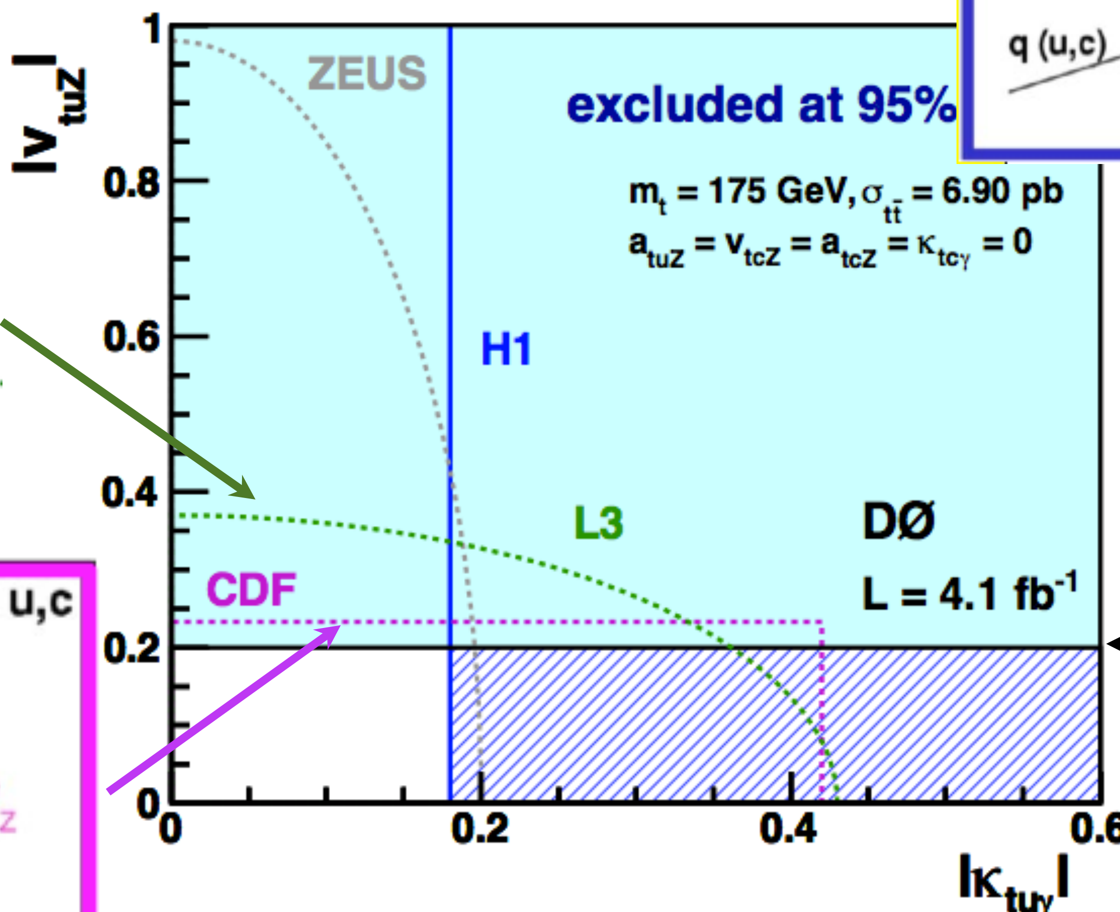


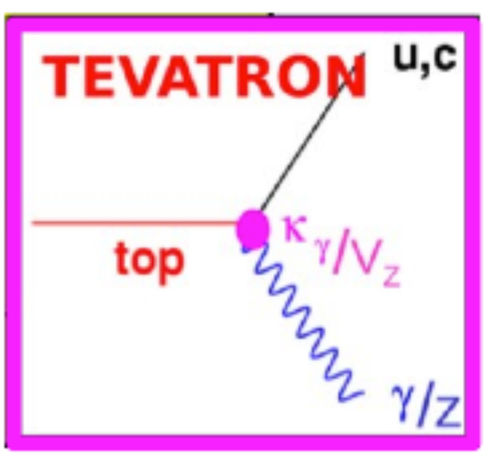
Limits on v_{tqZ} Coupling

- Coupling limits
  - $v_{tqZ} < 0.19$ (observed), < 0.21 (expected) at 95% CL



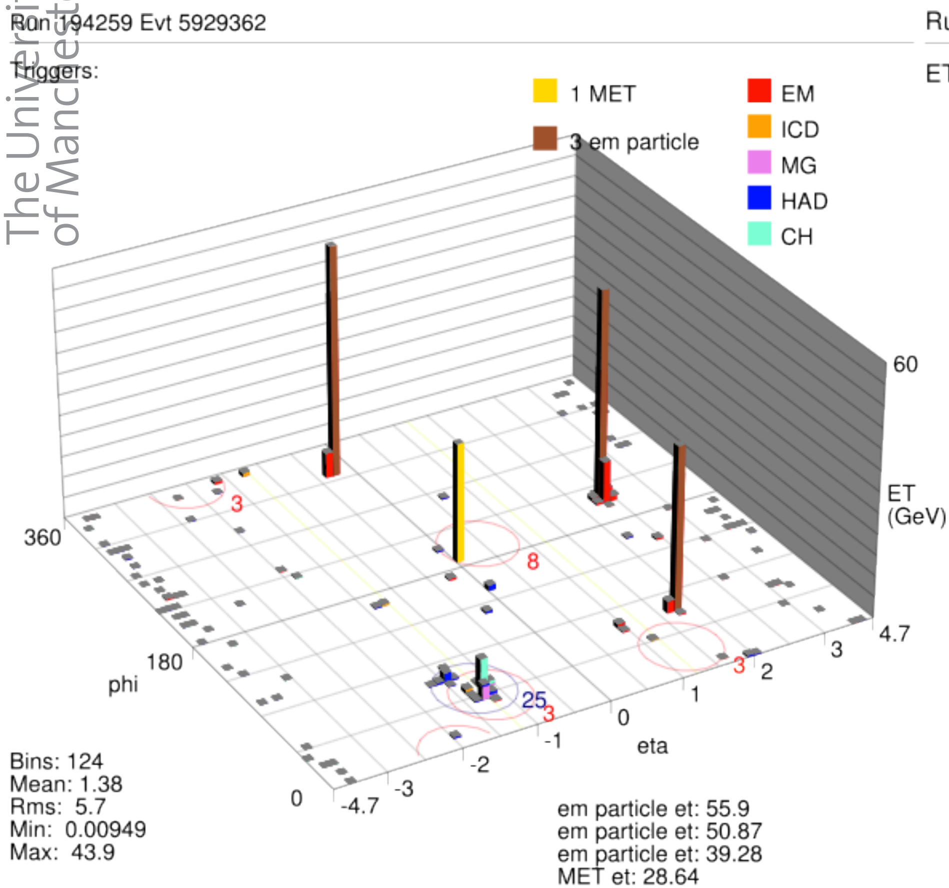


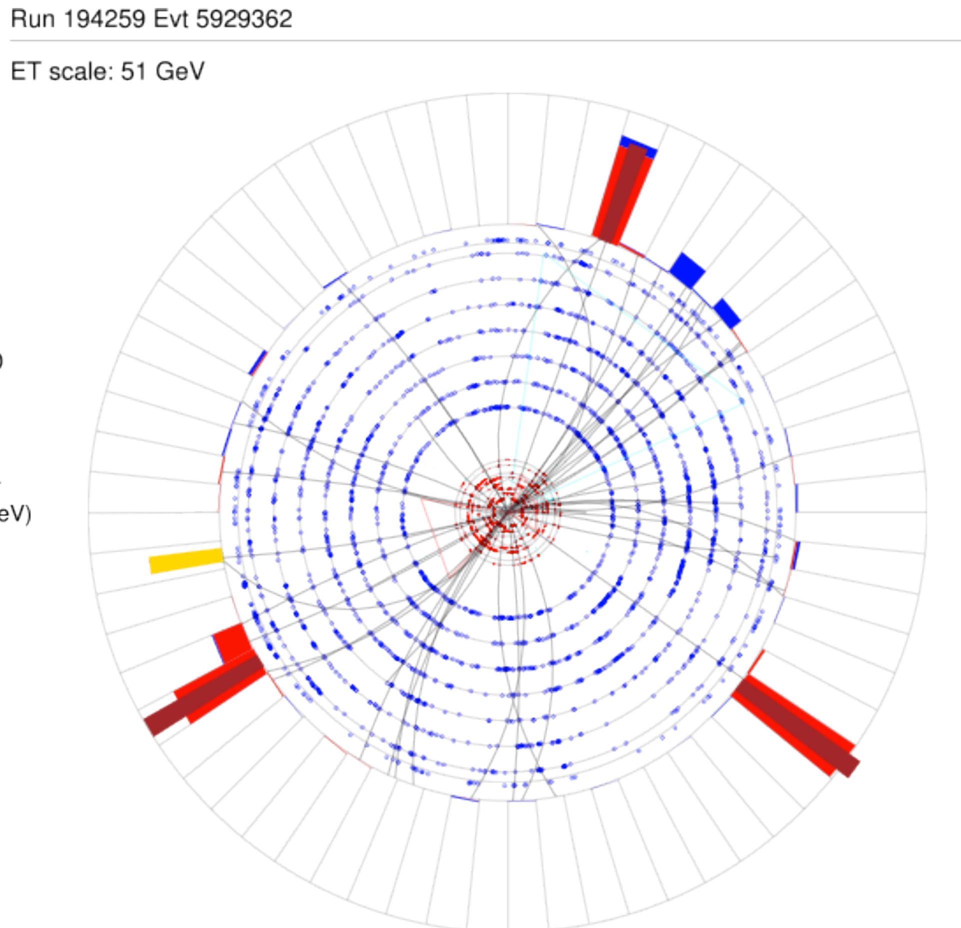




DZero new limits

Candidate eee + 1 jet Event





- eee + 1 jet candidate event, with m_t^{reco} = 350.8 GeV

Higgs Boson Cross Section Limits Backup Slides

MANCHESTER 1824

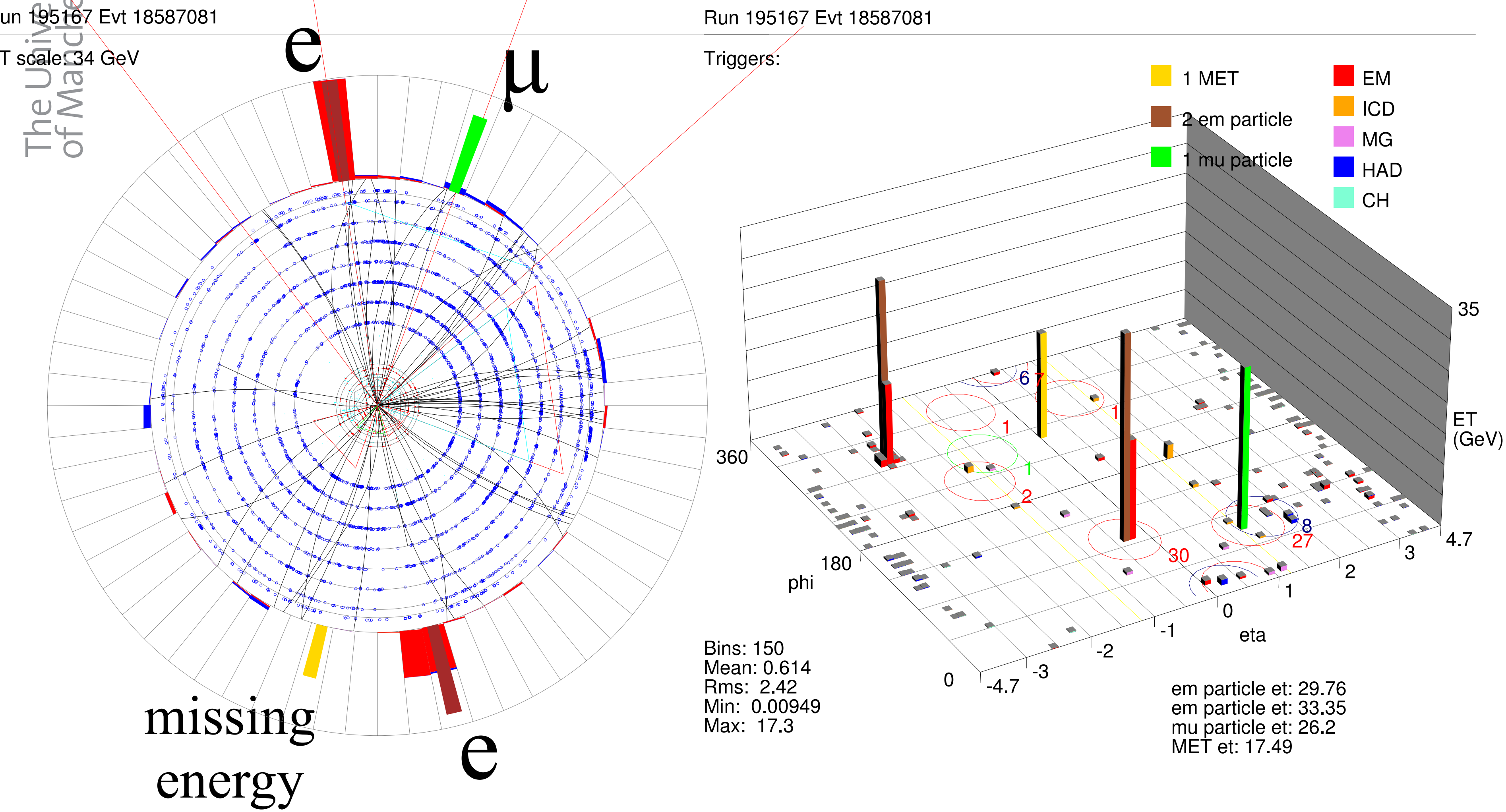
The University of Manchester

Event Yields

Errors reflect statistical uncertainties on the number of generated background events

Sample / m_H	115 GeV	125 GeV	135 GeV	145 GeV	165 GeV
Data	96				
Signal	0.716 ± 0.009	0.924 ± 0.010	1.233 ± 0.010	1.386 ± 0.011	0.964 ± 0.009
WH	0.329 ± 0.007	0.400 ± 0.007	0.512 ± 0.008	0.547 ± 0.008	0.431 ± 0.006
ZH	0.351 ± 0.006	0.418 ± 0.006	0.521 ± 0.006	0.574 ± 0.006	0.464 ± 0.005
HZZ	0.033 ± 0.000	0.099 ± 0.001	0.193 ± 0.002	0.258 ± 0.002	0.054 ± 0.000
HWW	0.002 ± 0.001	0.006 ± 0.003	0.005 ± 0.002	0.007 ± 0.003	0.013 ± 0.004
VBF	0.001 ± 0.000	0.001 ± 0.000	0.002 ± 0.001	0.001 ± 0.000	0.002 ± 0.001
Total Bkgnd	89.41 ± 2.36				
WZ	23.45 ± 0.35				
ZZ	11.09 ± 0.16				
WW	0.69 ± 0.13				
Z(→ee)+jets	48.26 ± 2.23				
Z(→ττ)+jets	4.33 ± 0.64				
ttbar	1.38 ± 0.07				
W+jets	0.21 ± 0.12				

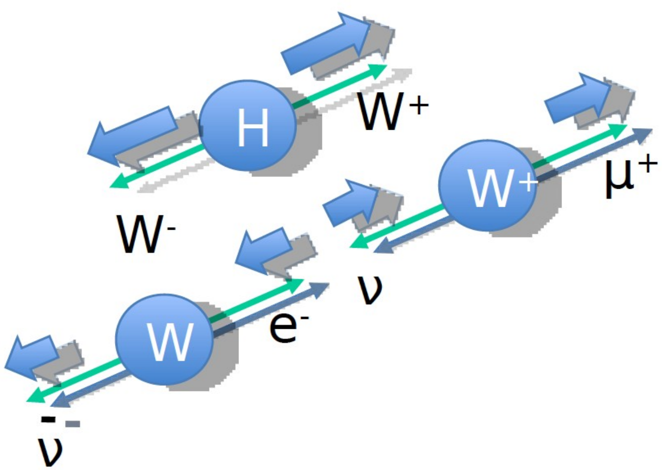
Candidate eeμ Event Display

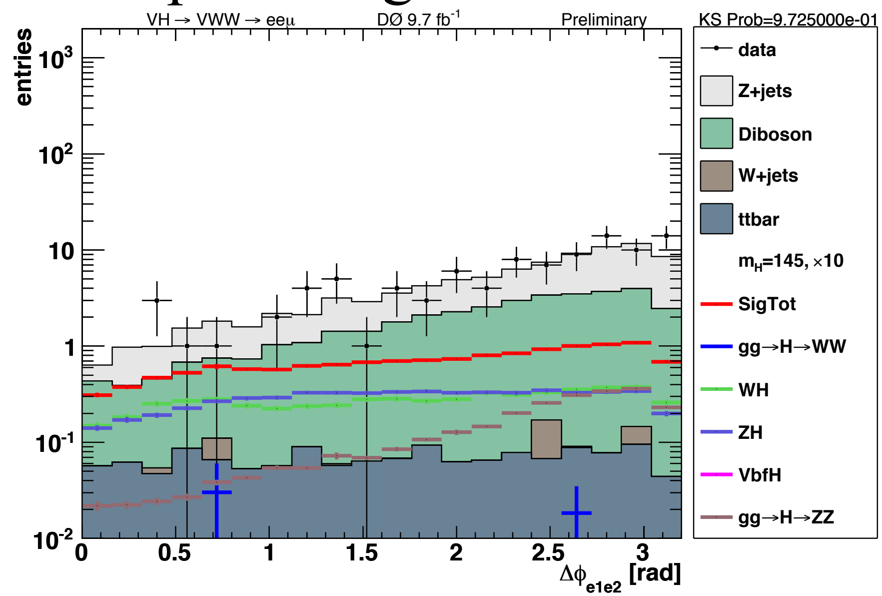


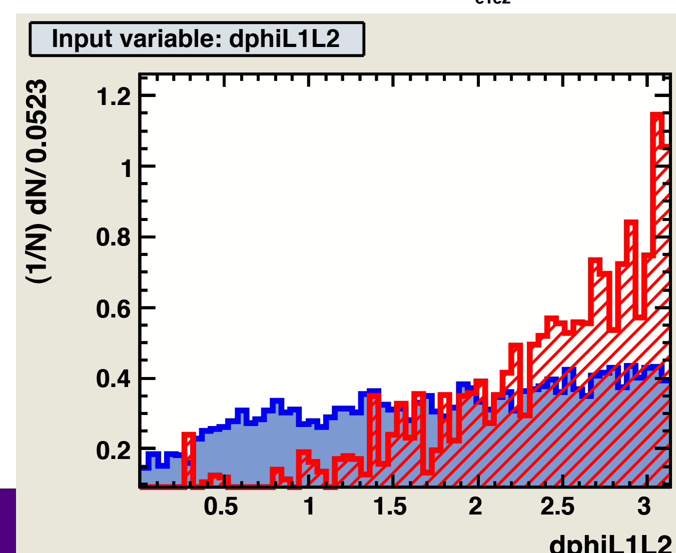
Multivariate Analysis Approach

The University of Manchester

- Take advantage of variables that separate signal from background... for example :

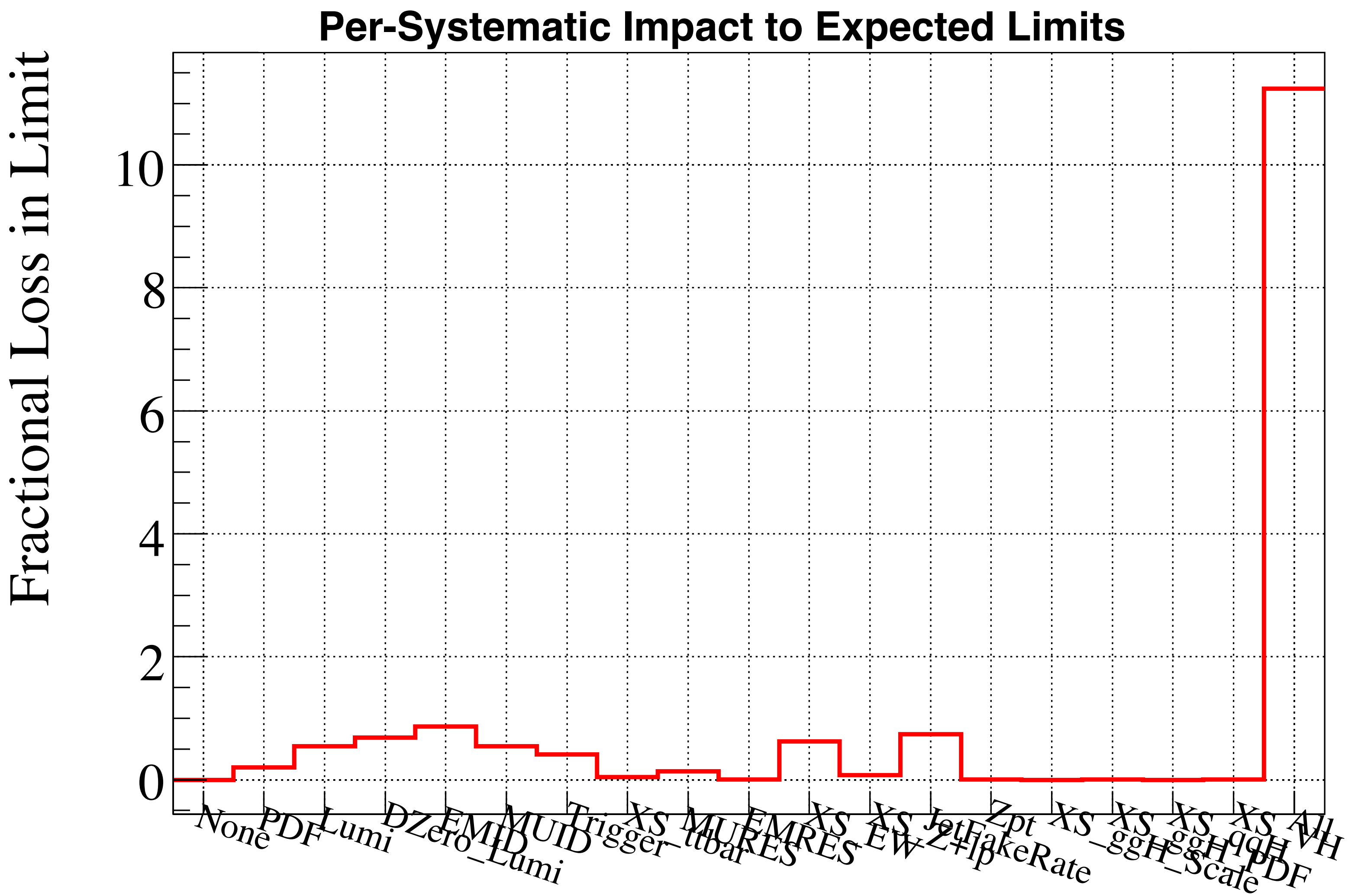






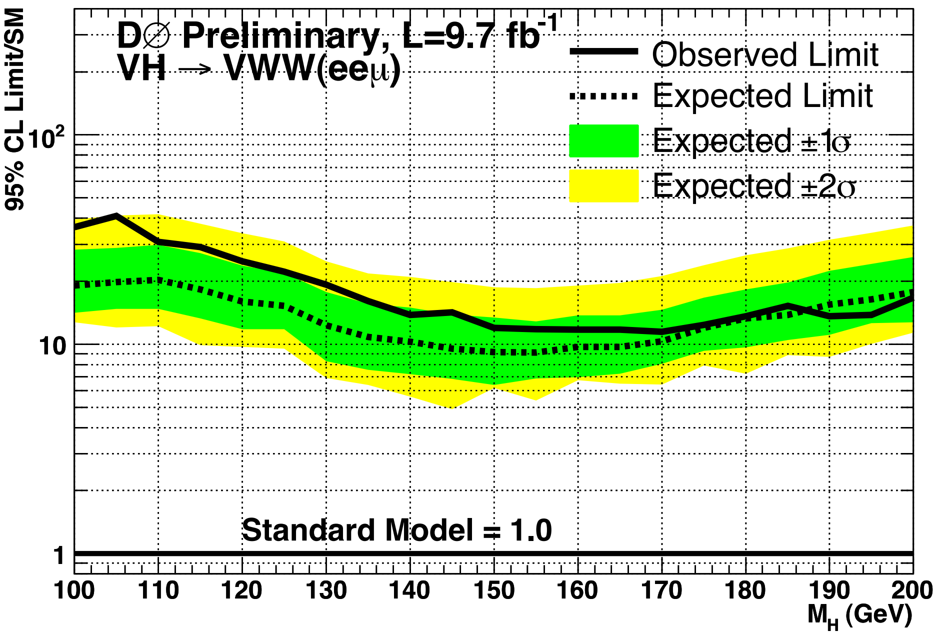
- Due to W spin correlations, expect a small Δϕ or ΔR opening between the two W leptons

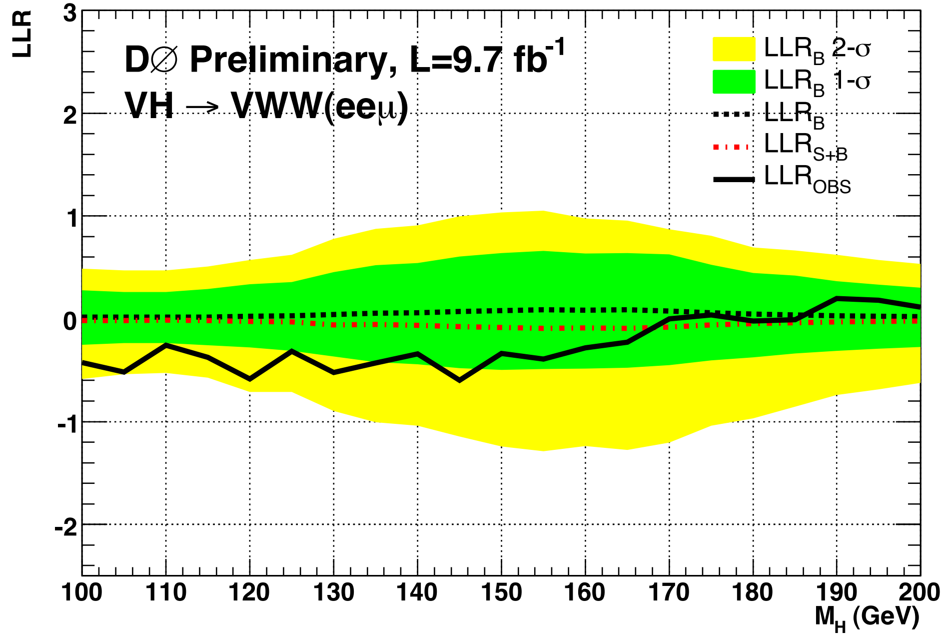
Sys. Uncertainty Impact on Limits



Higgs Boson Cross Section Limits

http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H119/

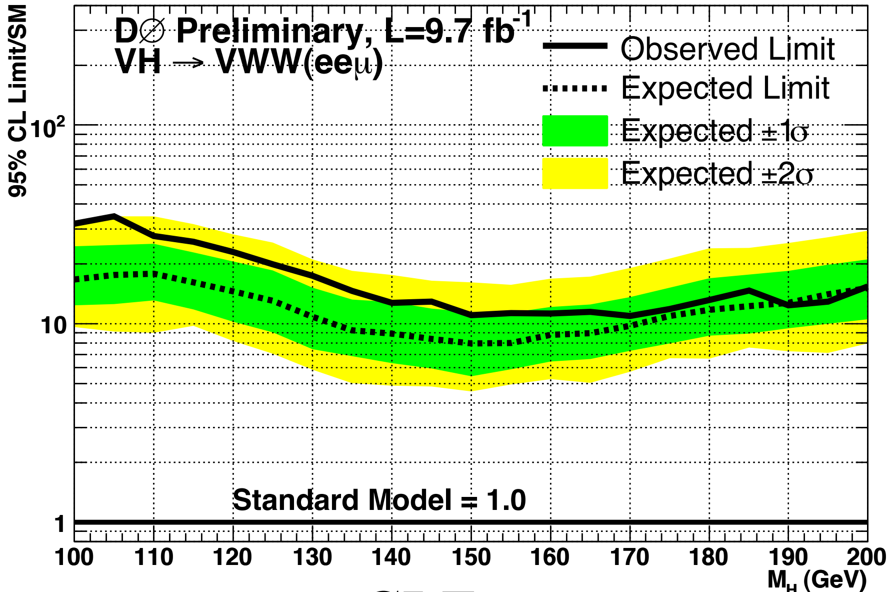


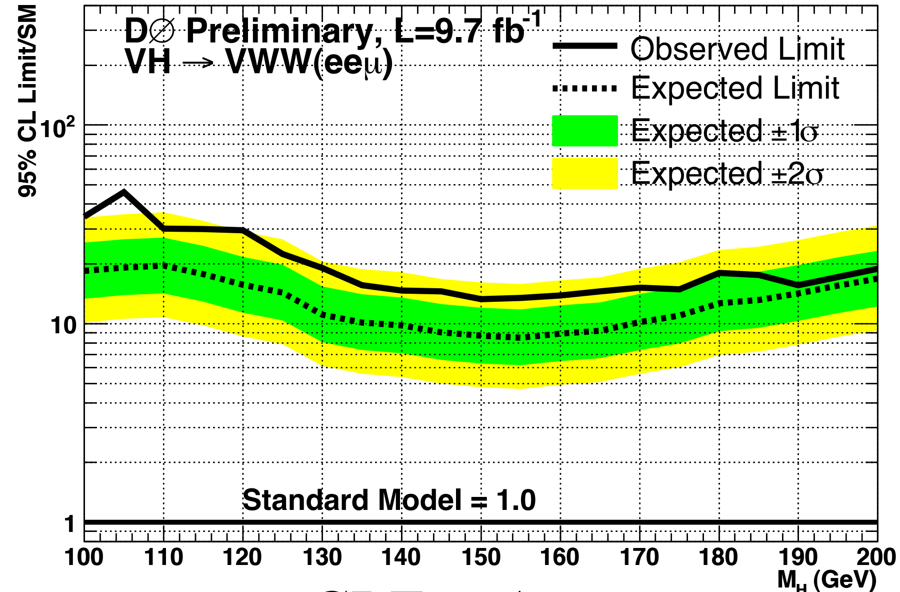


m_H (GeV)	100	105	110	115	120	125	130	135	140	145	150
CLFit2											
Expected	19.09	19.84	20.29	18.30	16.03	15.28	12.29	10.81	10.27	9.54	9.16
Observed	36.22	40.97	30.83	29.11	24.94	22.24	19.23	16.06	13.82	14.17	11.97

m_H (GeV)	155	160	165	170	175	180	185	190	195	200
CLFit2										
Expected	9.13	9.70	9.73	10.35	11.98	13.31	13.83	15.45	16.35	17.80
Observed	11.79	11.73	11.75	11.46	12.36	13.59	15.29	13.64	13.79	16.69

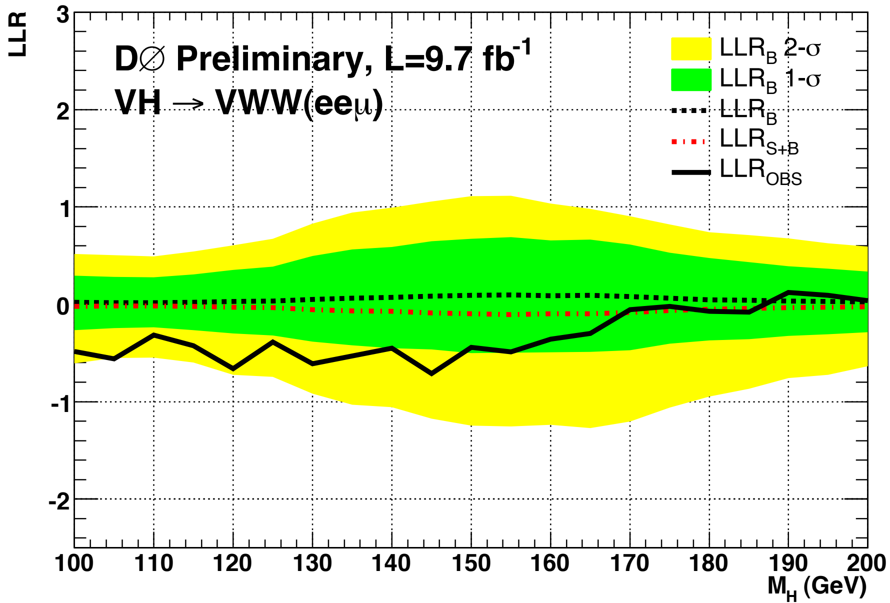
eeμ Cross Section Limits

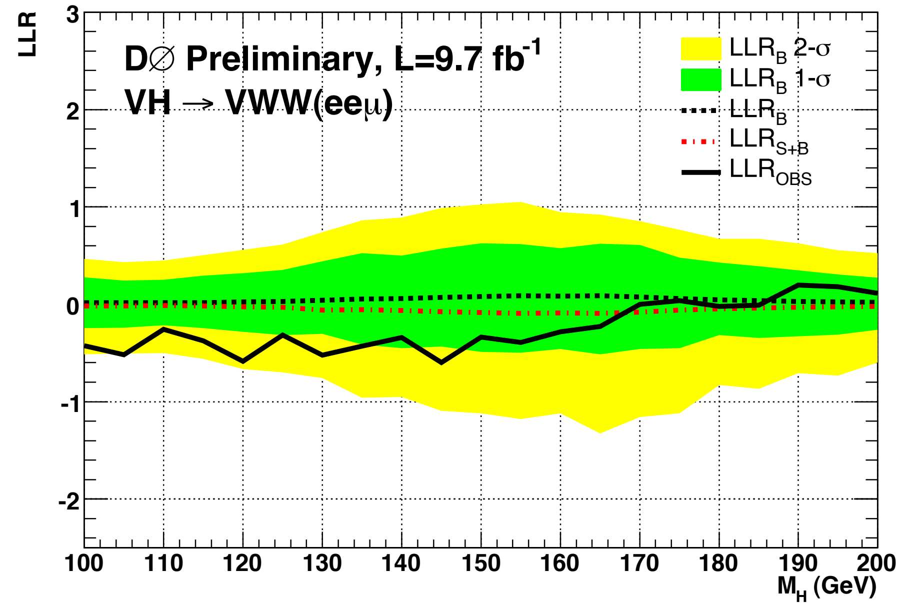




CLFast

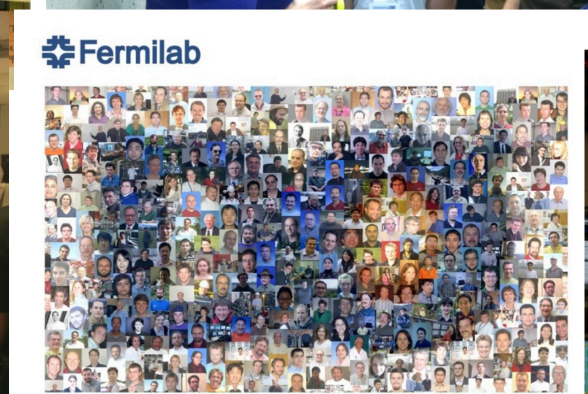
CLFastApprox

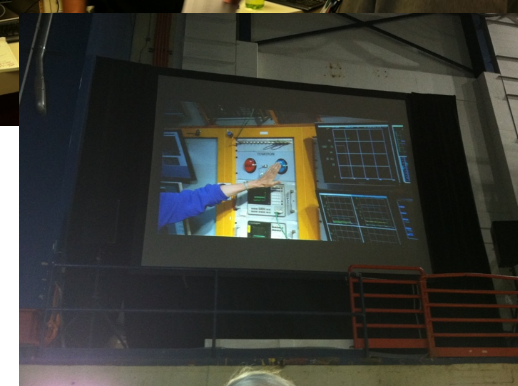




Early Morning Access...

Tevatron Shutdown Sept. 30, 2011





Shutting down the CTT

RIP - Jan 16, 2012