On the Brink of Revelation and Revolution: Electroweak Symmetry Breaking in 2008

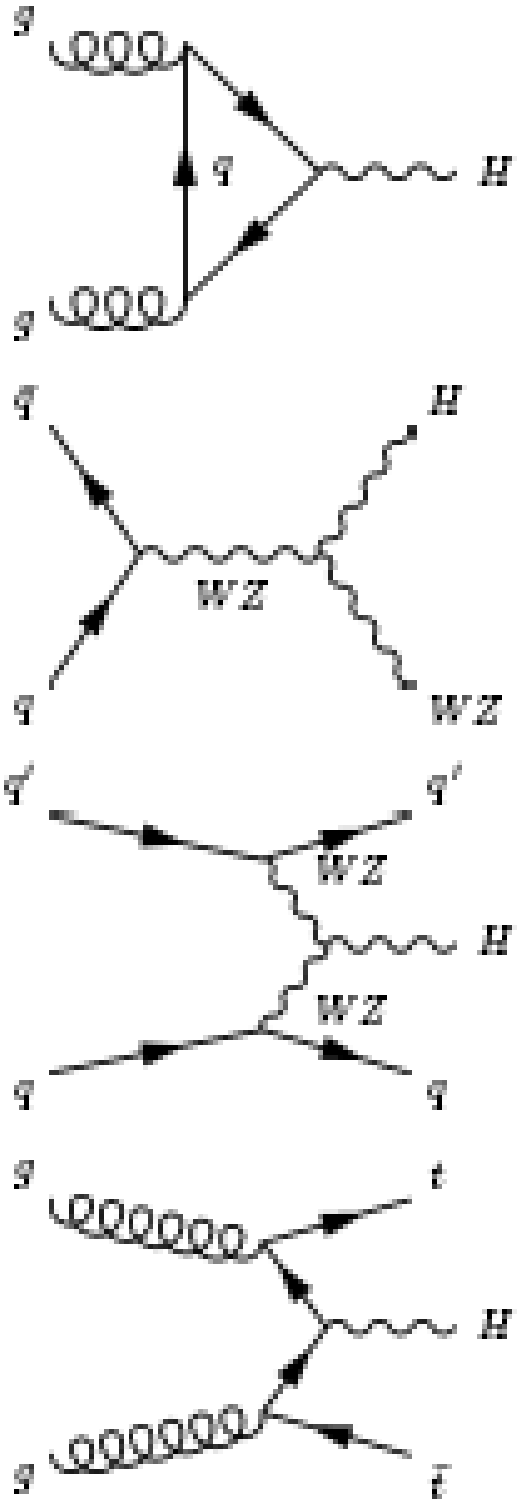
Rick St. Denis – Glasgow University

Outline

- Higgs Decay Modes at Tev and LHC
- The two paths
- The CDF sensitivity
- Scenario
- HWW, Vector Boson Fusion Production of Higgs at TeV and LHC
- Conclusions

Higgs Production

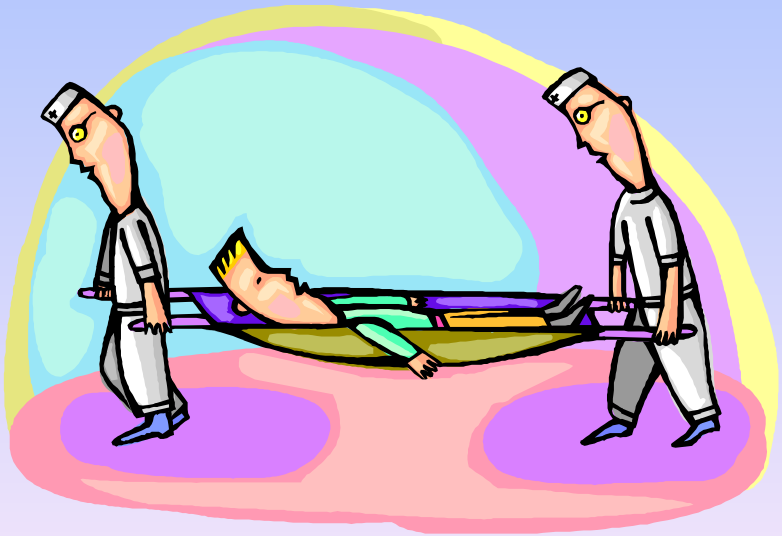
- 4 main mechanisms
- Gluon Fusion Dominates at Tevatron: HWW
- Associated Production: WH, ZH, WWH, TTH



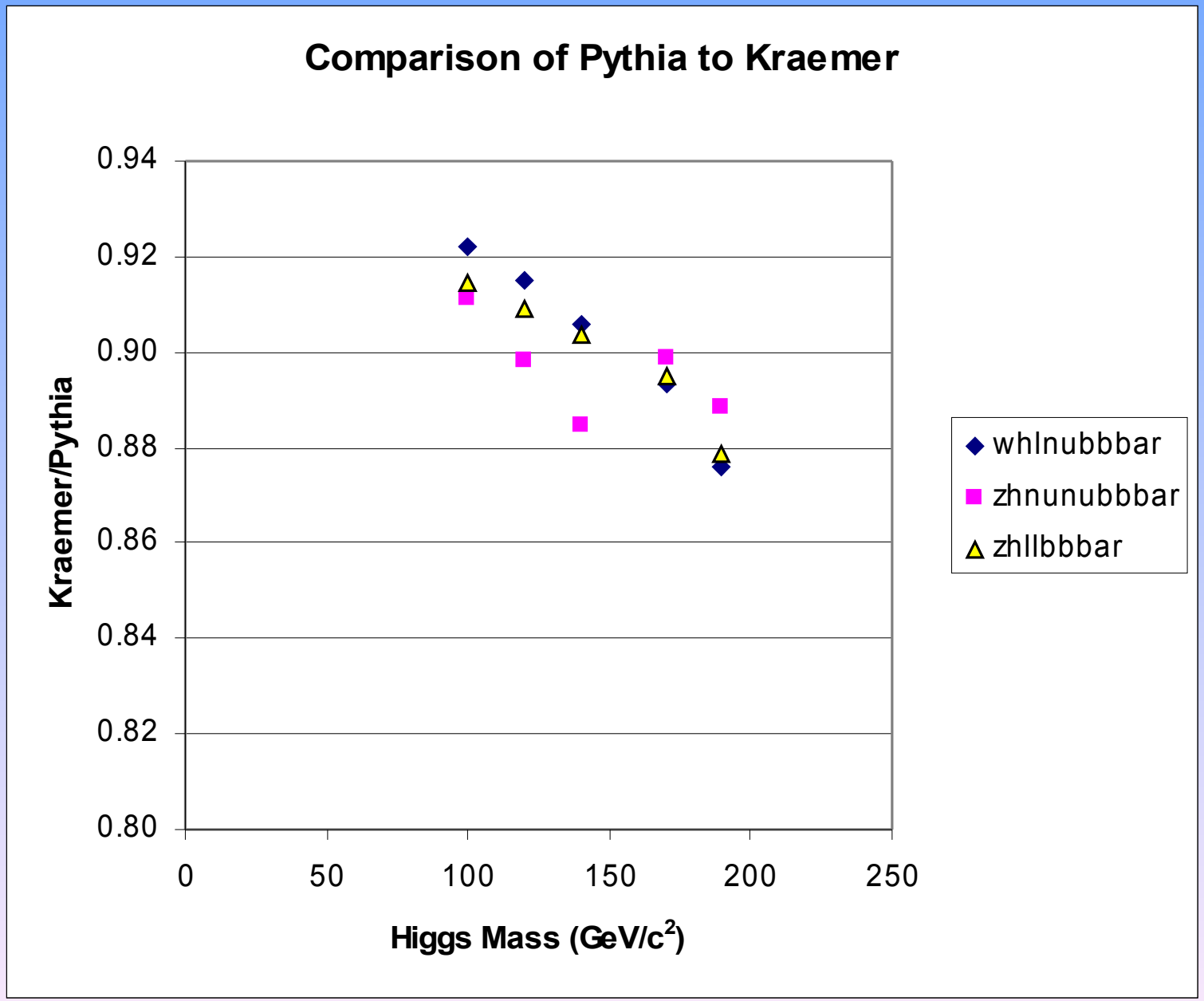
Hγγ,HZZ

Higgs DIY

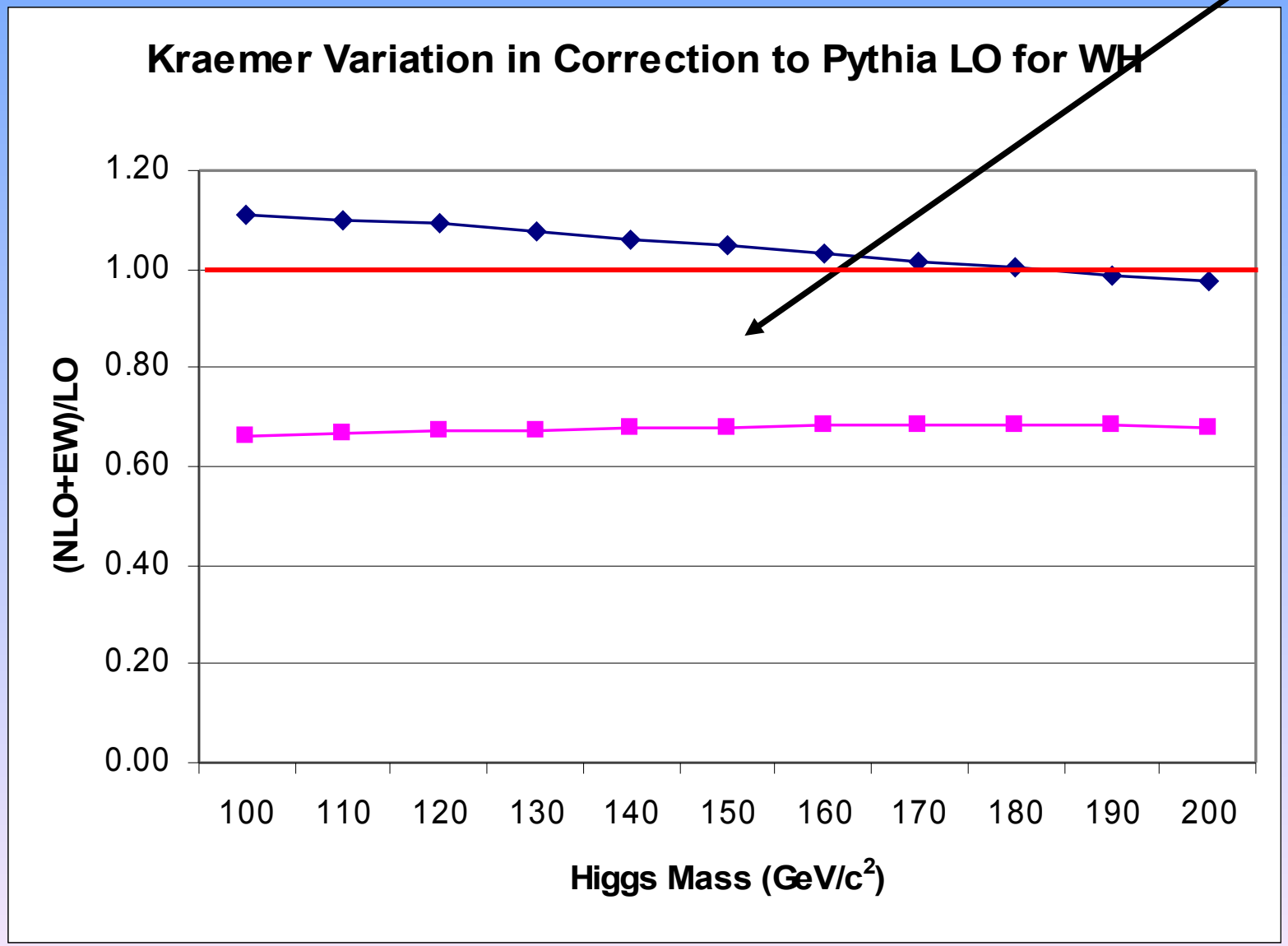
(DYI?)



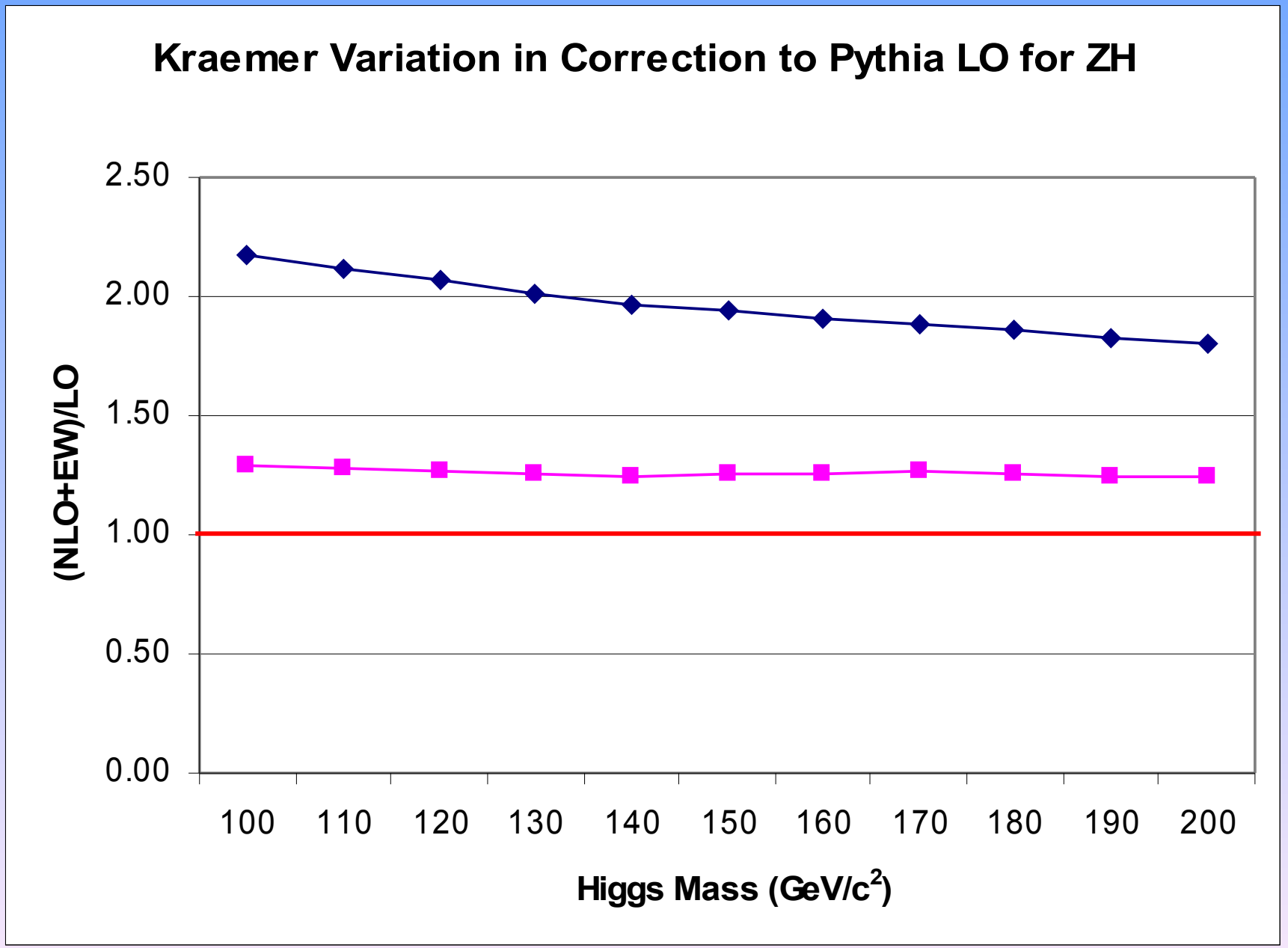
Kraemer vs. Pythia(6.2.2.2)



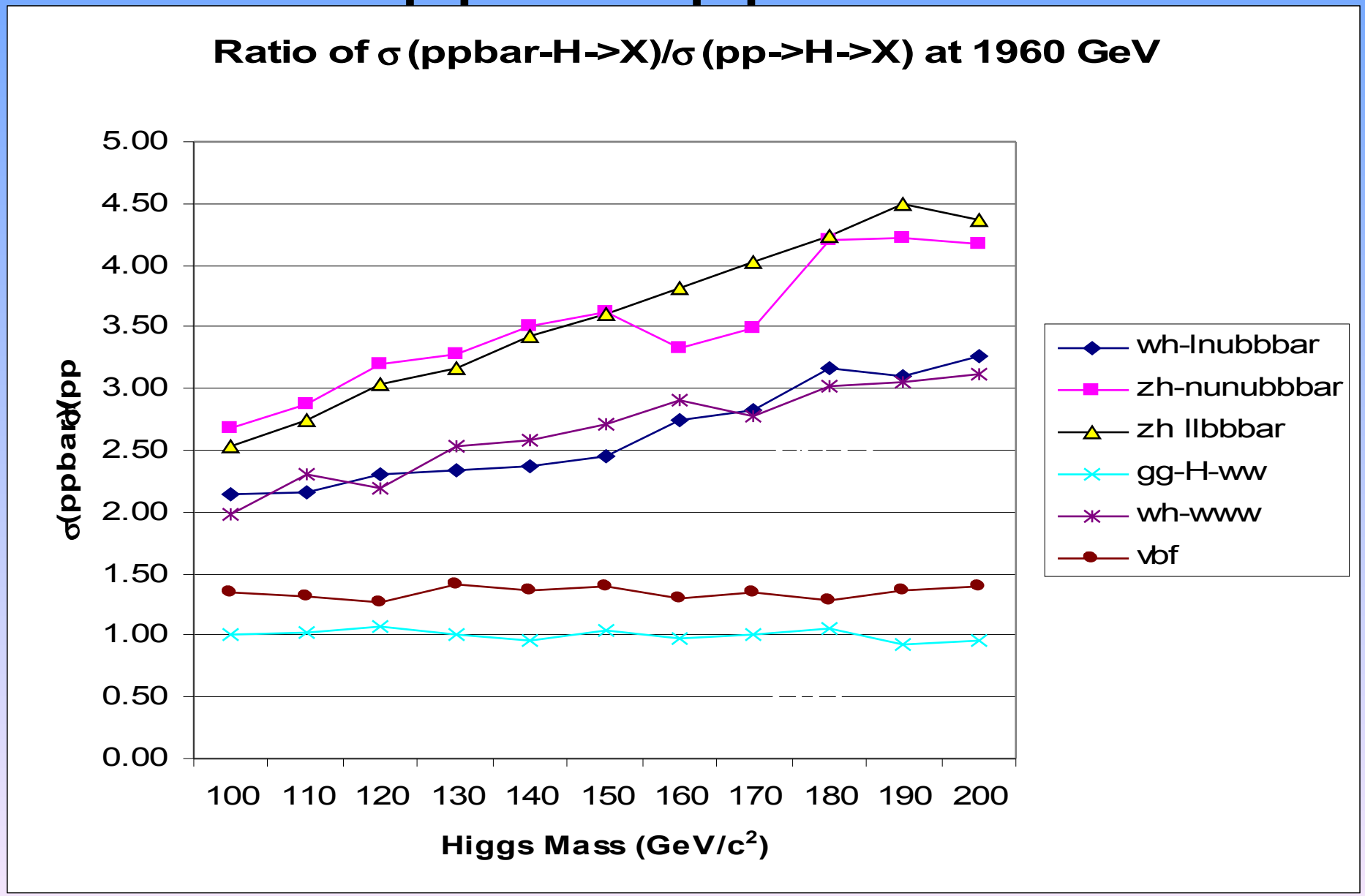
Production:Check Pythia, Kraemer, Spira



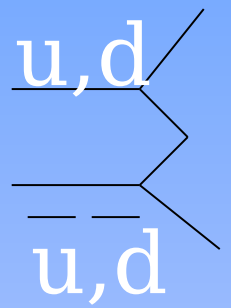
ZH corrections

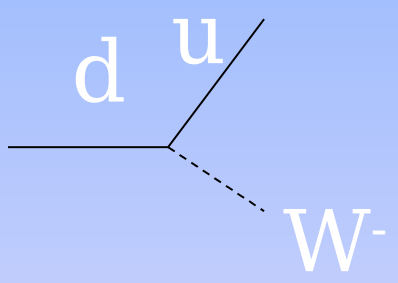


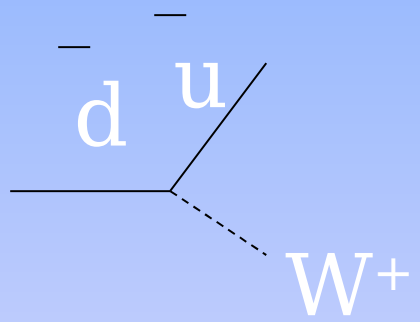
Interesting Diversion: pp vs. ppbar

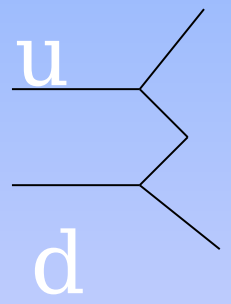


VBF 25% Better in PbarP

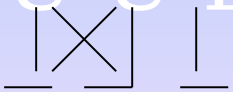








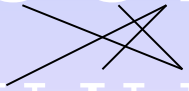
Hence: U U D



U U D

5 chances

U U D

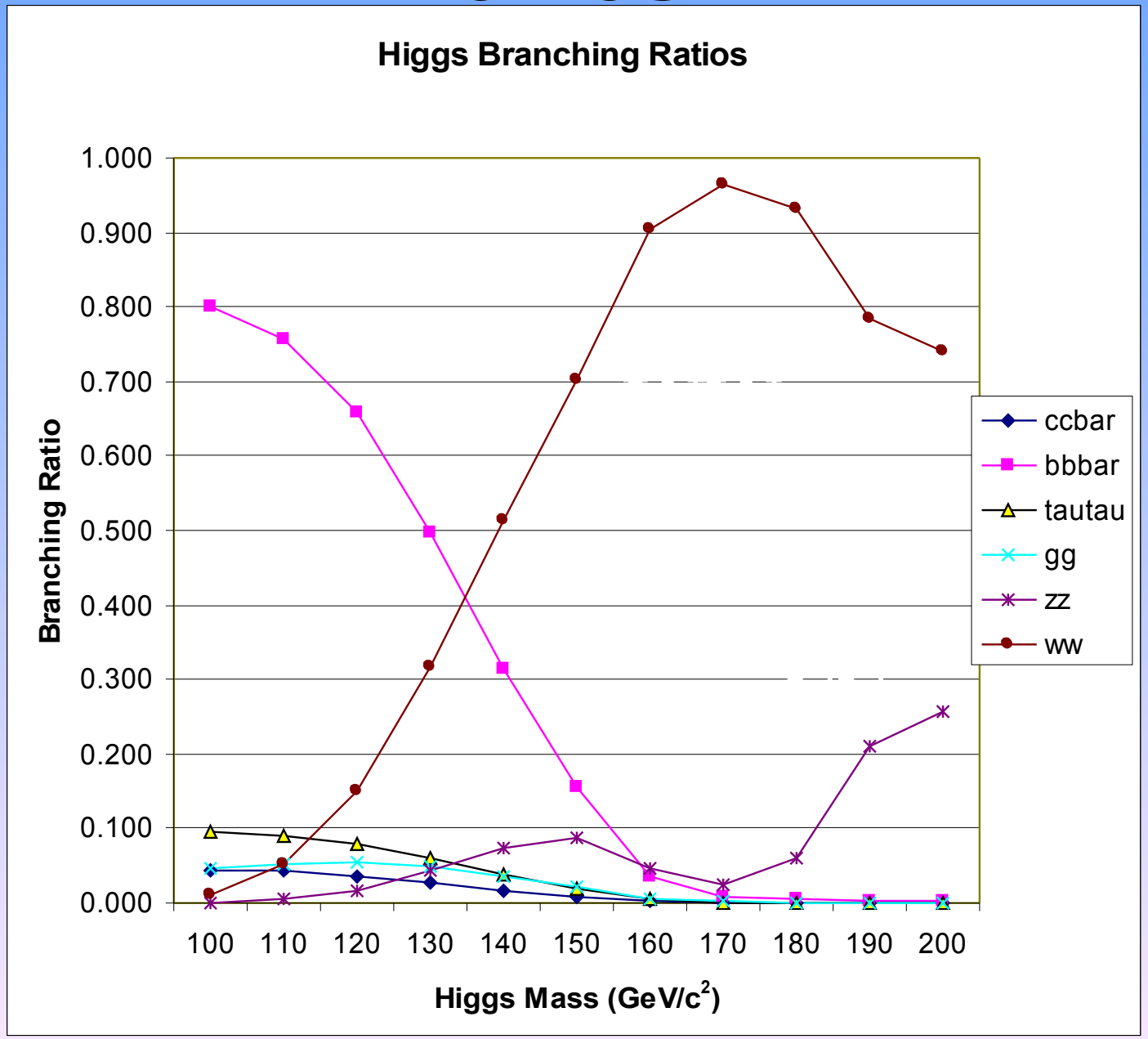


U U D

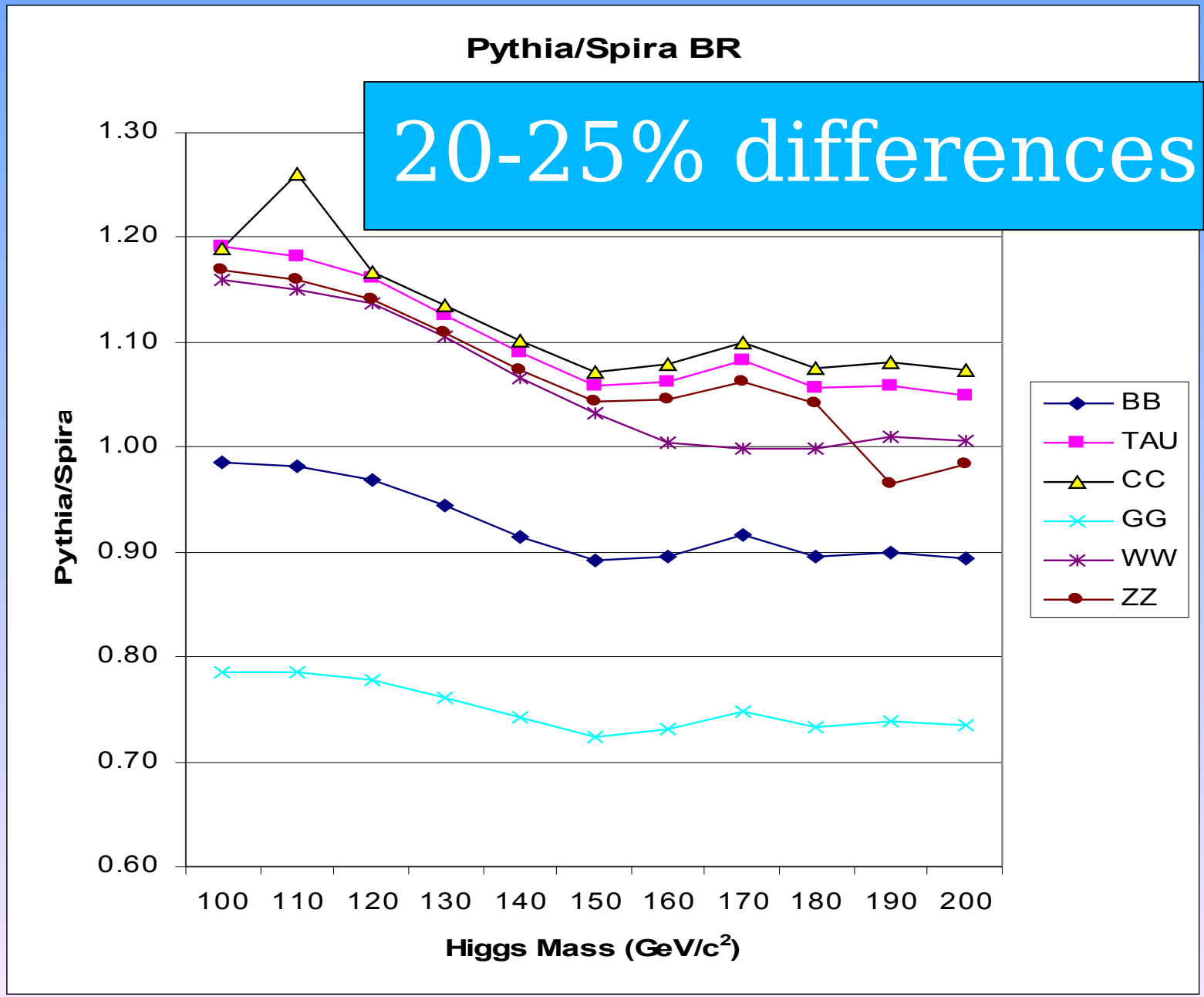
4 chances

Ratio is
5/4 = 1.25

Check of Higgs Branching Ratios



Check of Higgs BR: Pythia/Spira



CDF Channels NOW Ntupled 1fb^{-1}

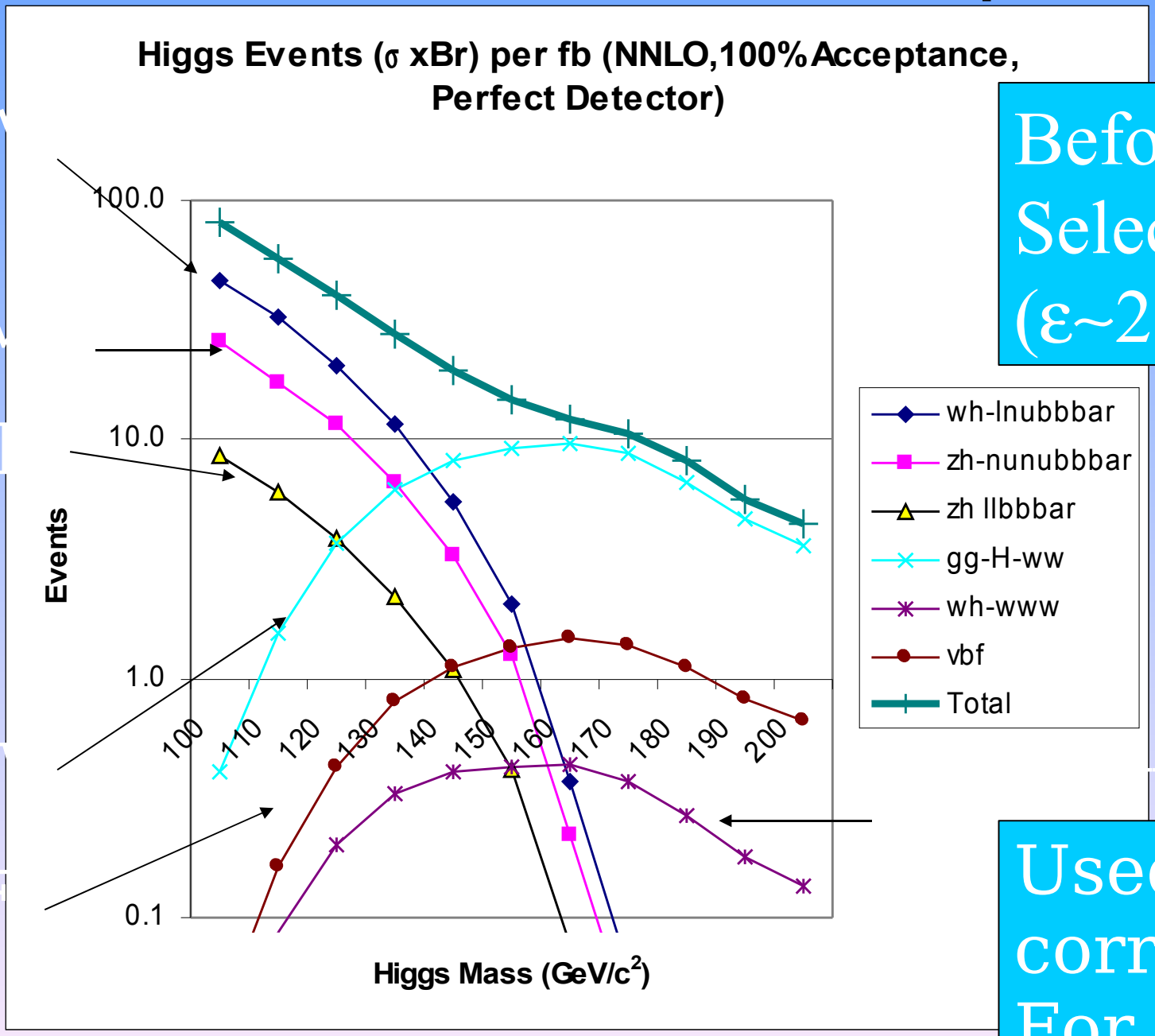
WH(l

ZH(vv

ZH(ll

gg-W

VBF

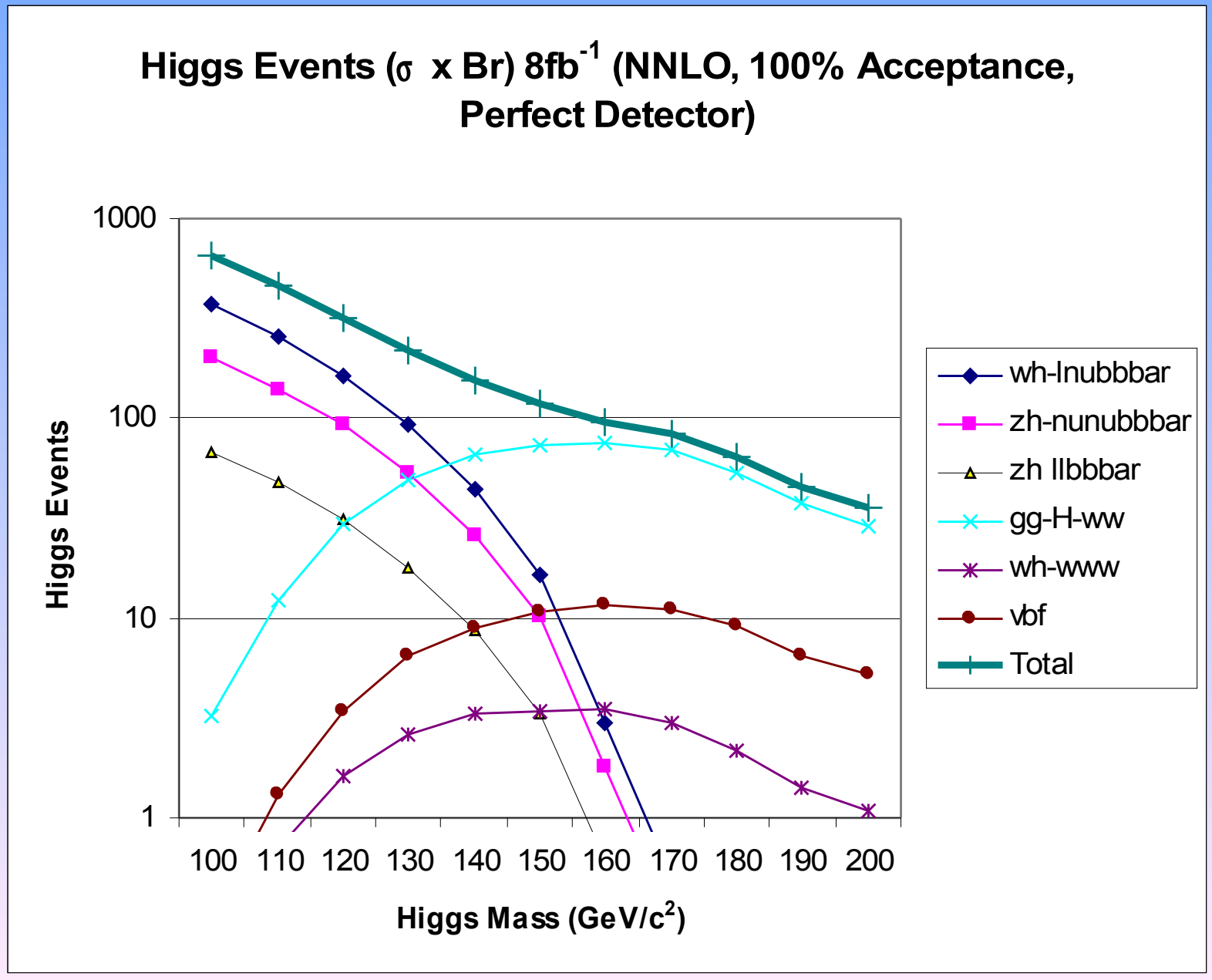


Before Selection! (ε~2-7%)

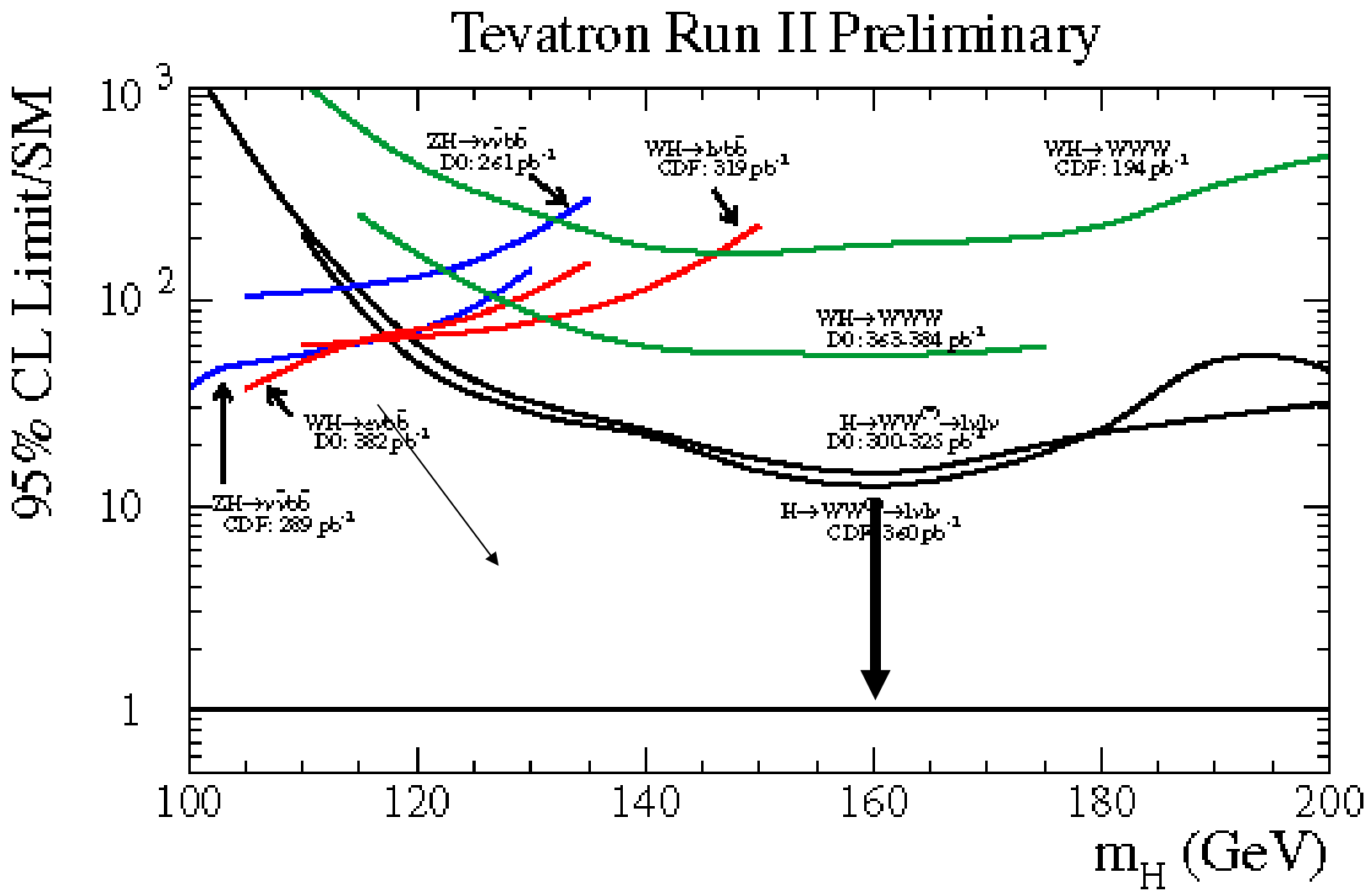
W

Used WW correction For VBF

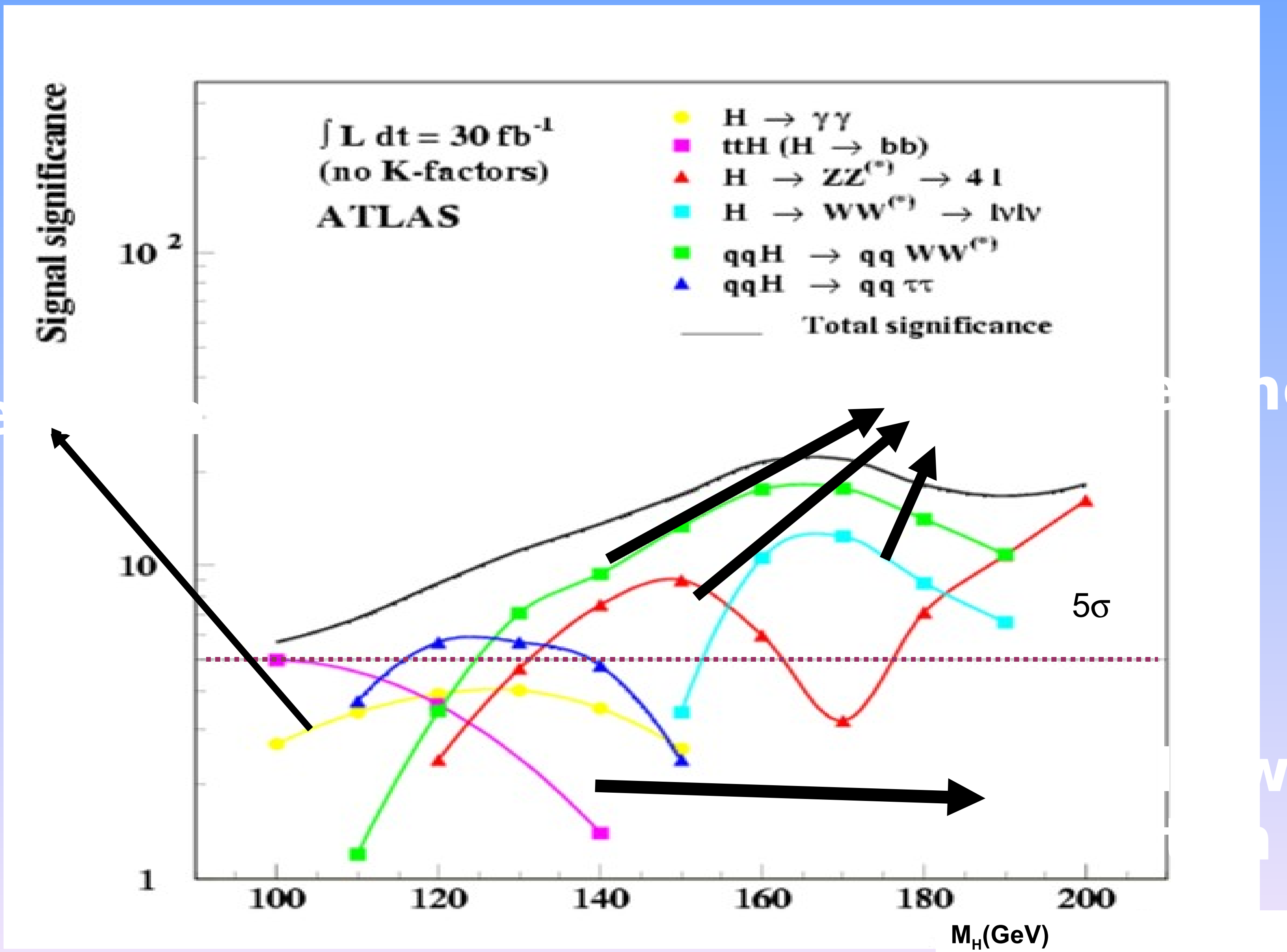
CDF (2009?) For 8fb^{-1}



CDF Limits: (WW:360 pb^{-1})



ATLAS Channels



De

now!

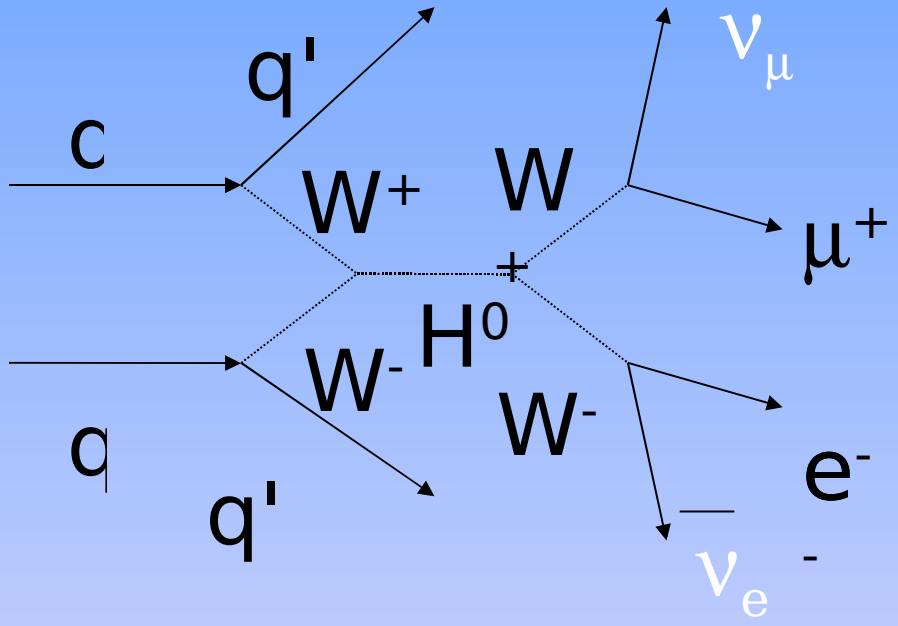
we

this?

The Two Paths

- H to WW depends on jets, leptons (VBF too). Same at LHC, CDF. Have studied VBF and fascinating match of detectors to machines!
- ttH depends on jets, b-jets: tagging and mass resolution. WH,ZH depends on same: Huge synergy. Very different path.
- There are two natural divisions of effort: those that need silicon and those that don’t.

HWW/VBF Production Features



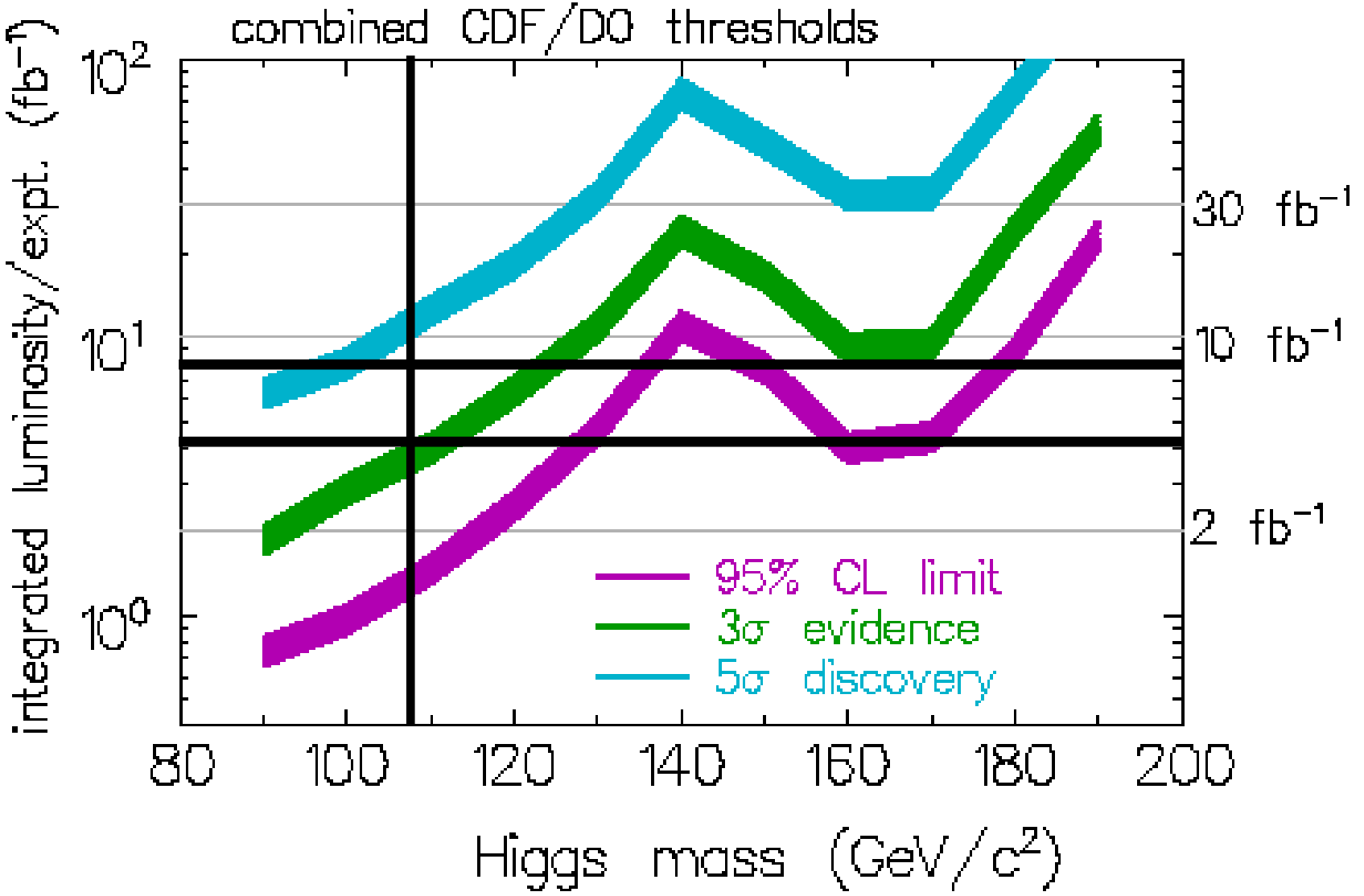
- Missing Et
- High Pt Leptons
- 2 forward jets, opposite in rapidity, high mass
- Spin 0 Higgs correlates spins of leptons: e,μ parallel and neutrinos also
- VBF: $\Delta\eta_{\text{e-jet}}$ about 1-1.5

VBF same as WW, but with forward jets. Do analyses together. Very unique events.

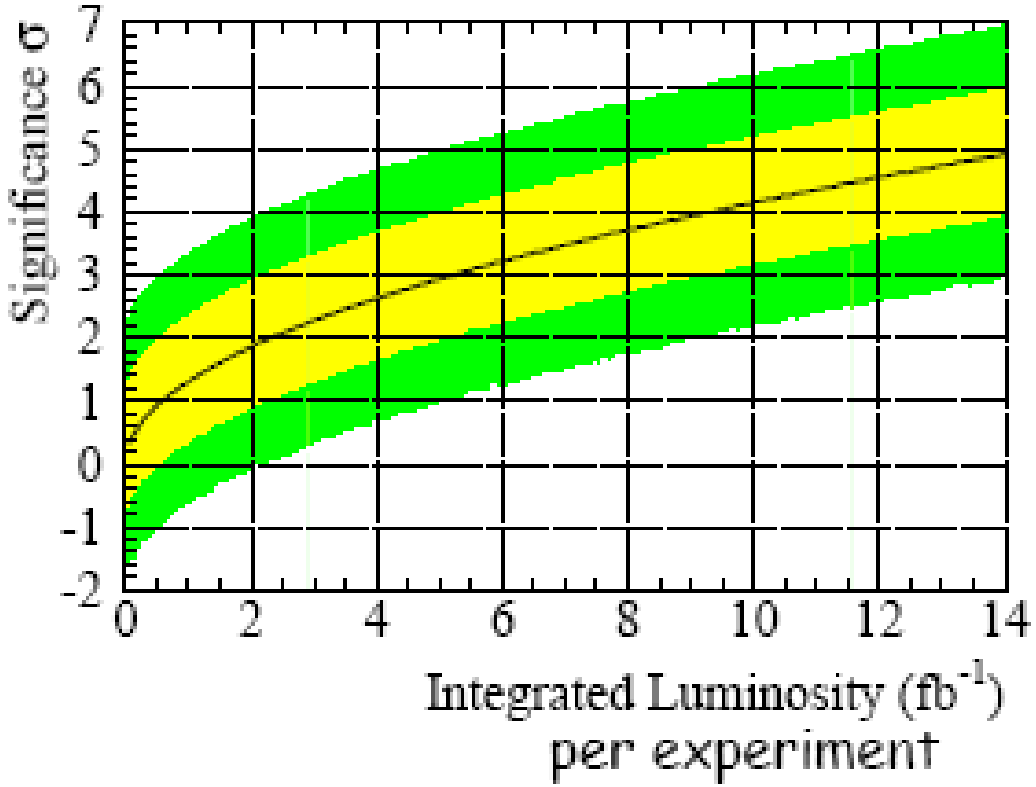
Studies

- Backgrounds: top, fakes, WW
- WW *is* the right laboratory in any case, even if no Higgs. Something has to keep the cross section under control
- Need to get detector understood using Z's to get e,μ. W's for Missing Energy
- Need to understand top, WW for backgrounds
- Do the Higgs detection at the same time

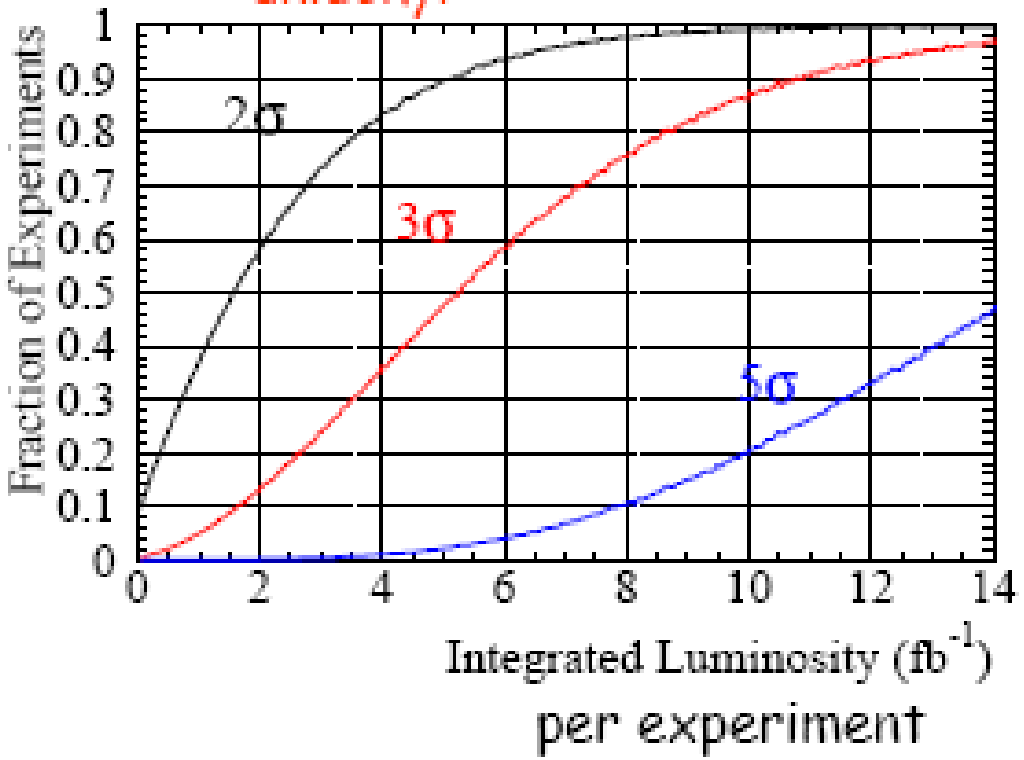
Tevatron Projections



Expected Signal Significance CDF+DØ vs Luminosity

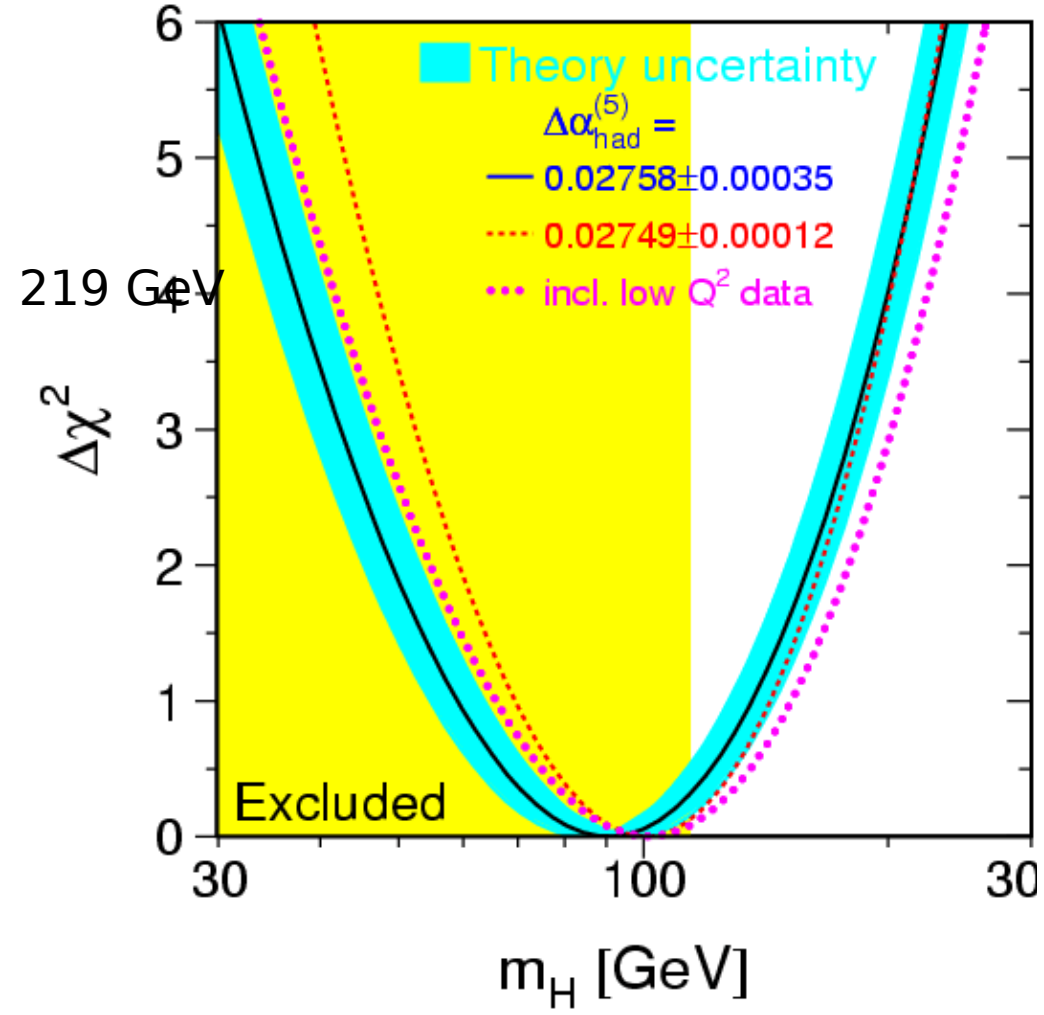


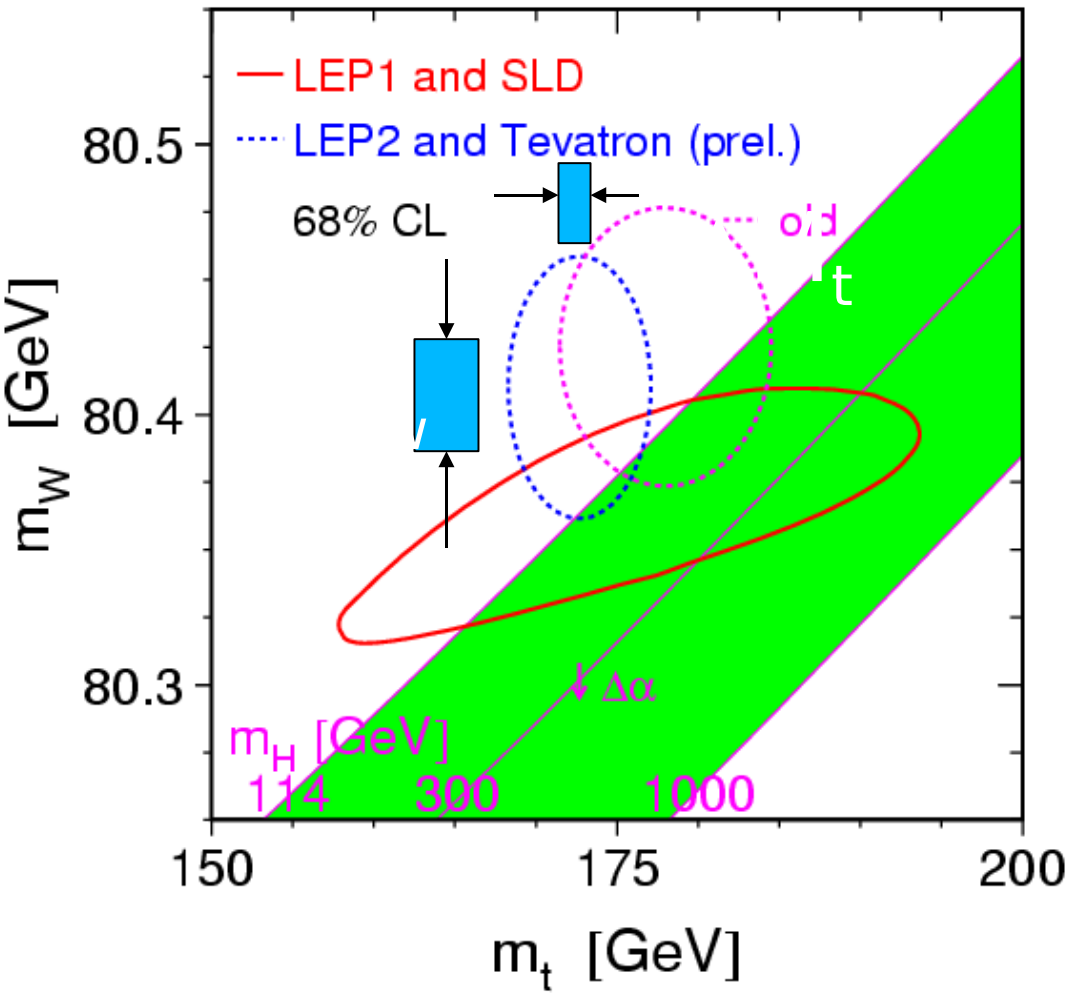
It's possible to be lucky or unlucky!



m_H=115 GeV assumed

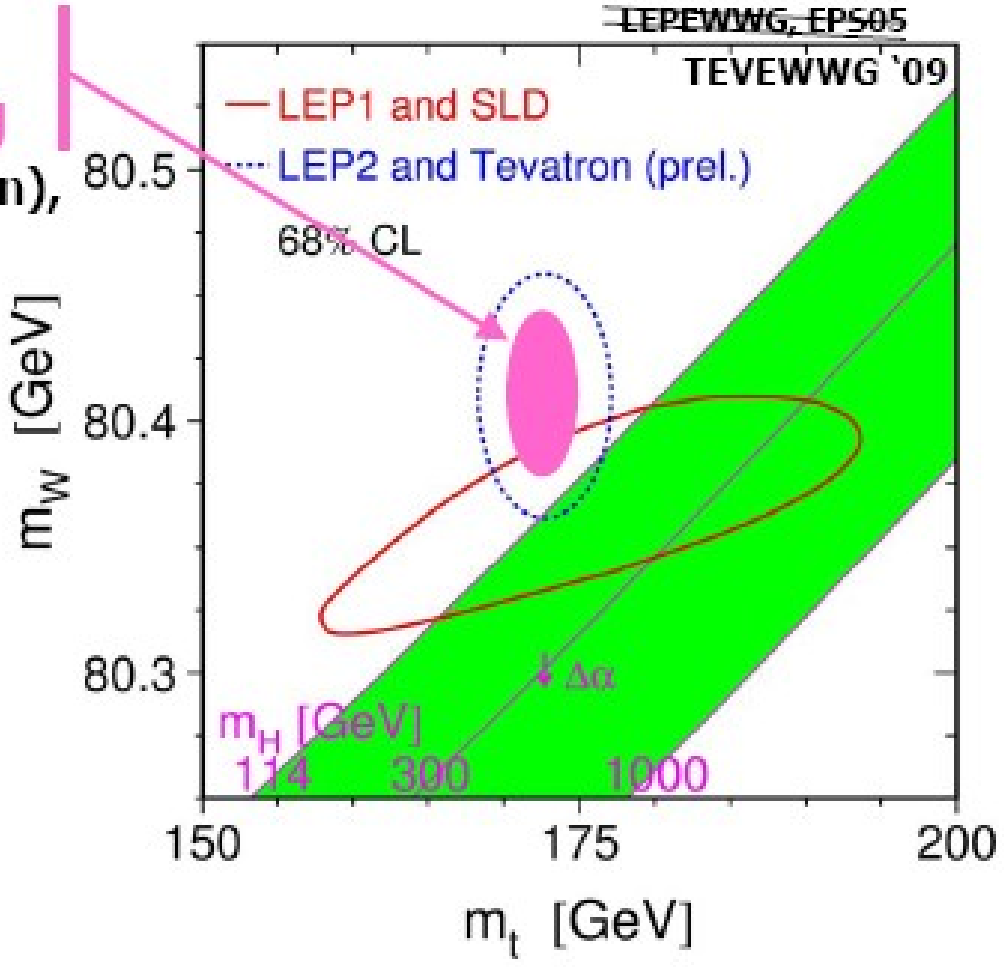
Virtual Measurement



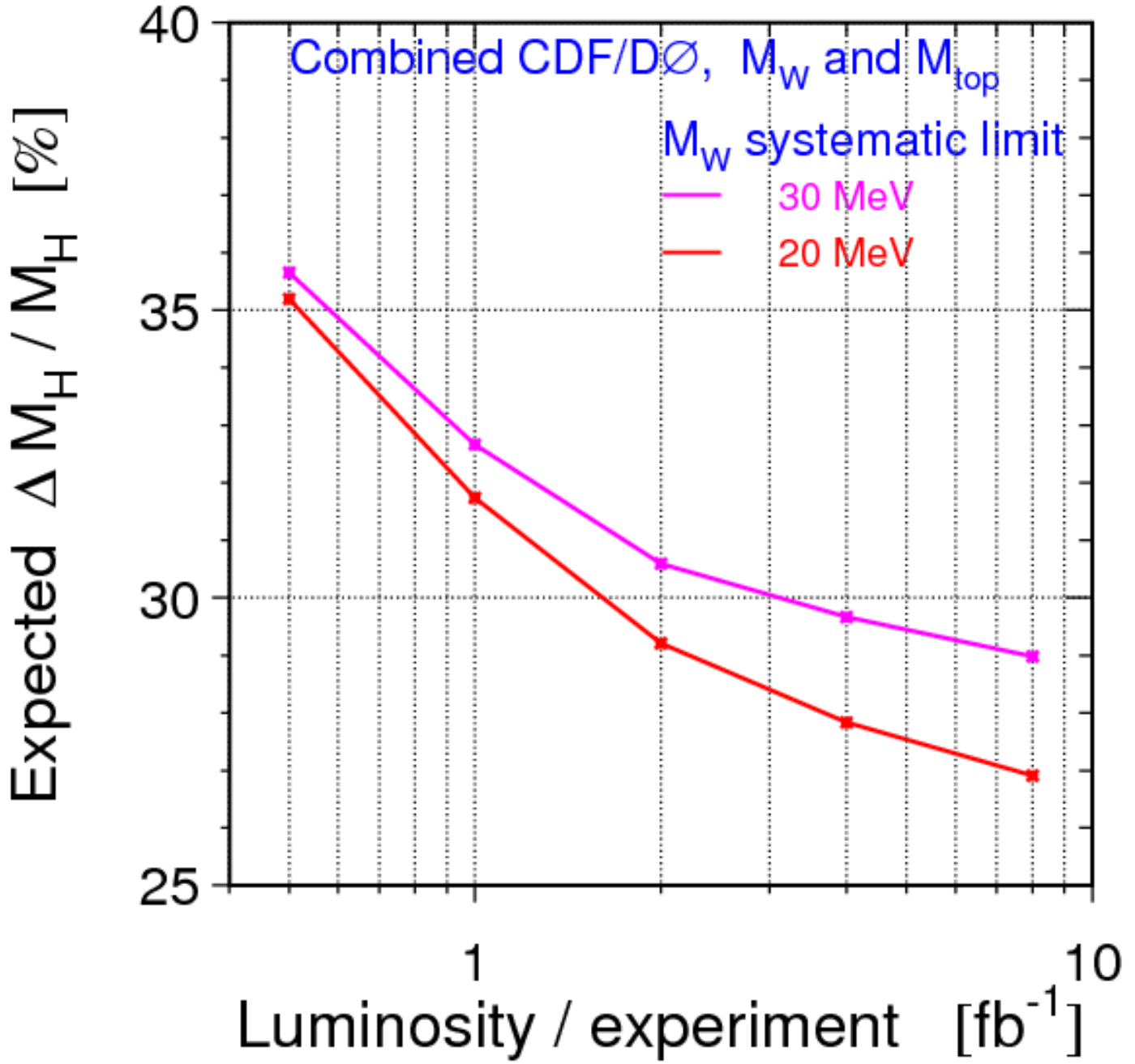


Projections on Virtual

δM_t = 1.2 GeV,
δM_W = 24 MeV, world avg
(LEP2 + δM_W = 30 MeV(Tevatron),
no LEP/TeV correlations)

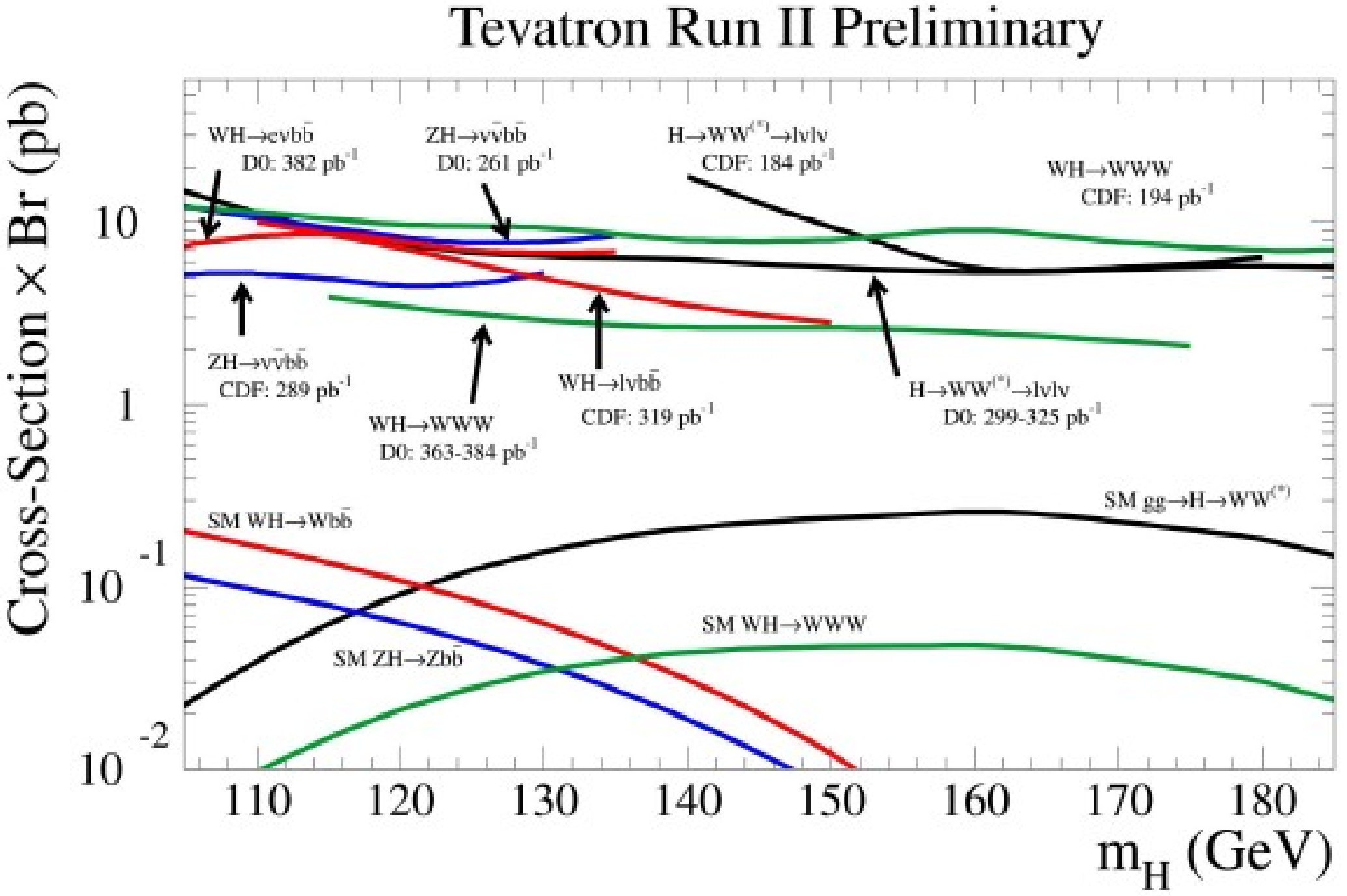


Higgs Mass Error: (Currently +45 –32= +49-35%) 95% CL at 60-90 GeV above M_H^{Fit}

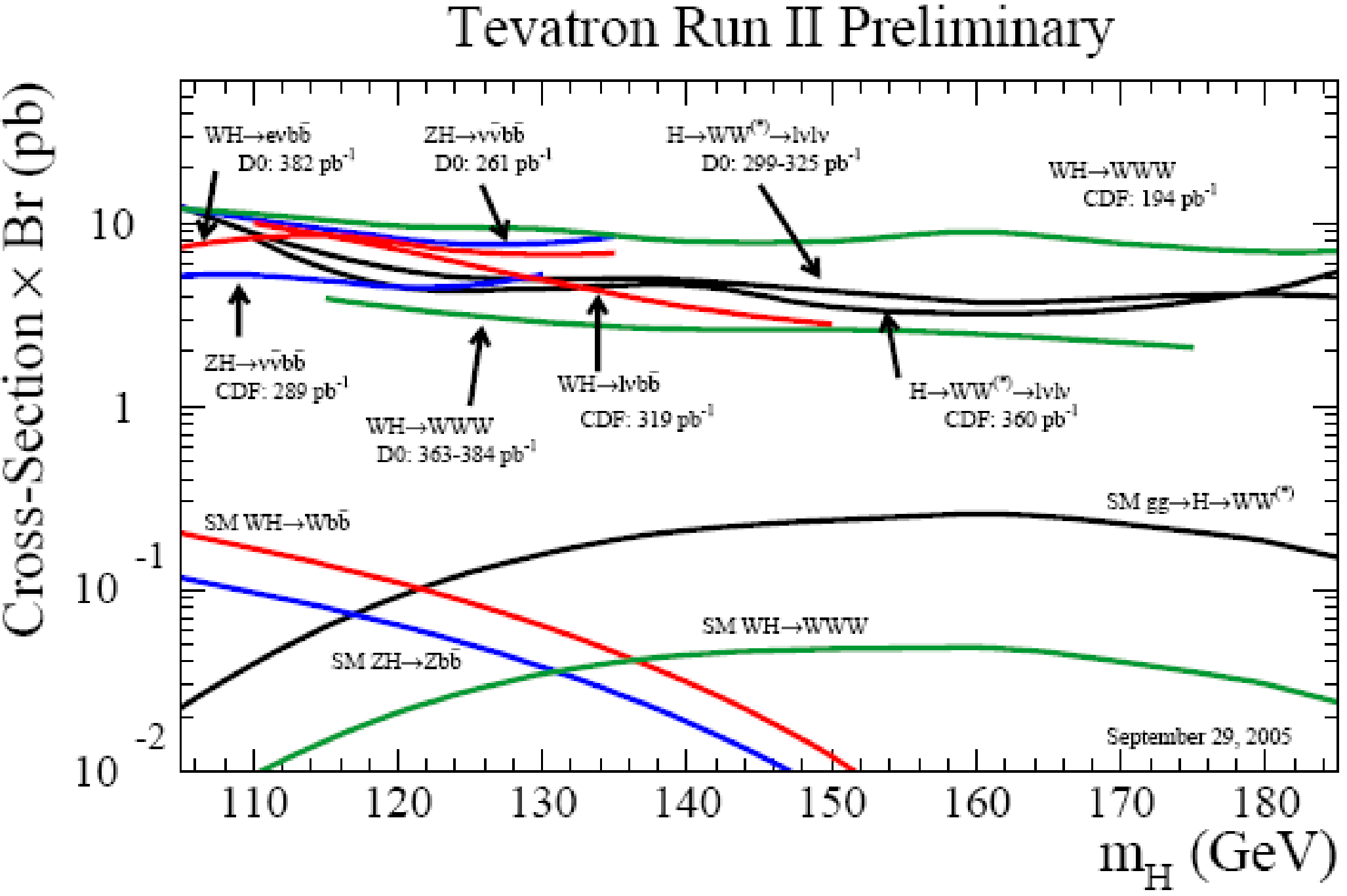


The Tevatron picture is changing rapidly!

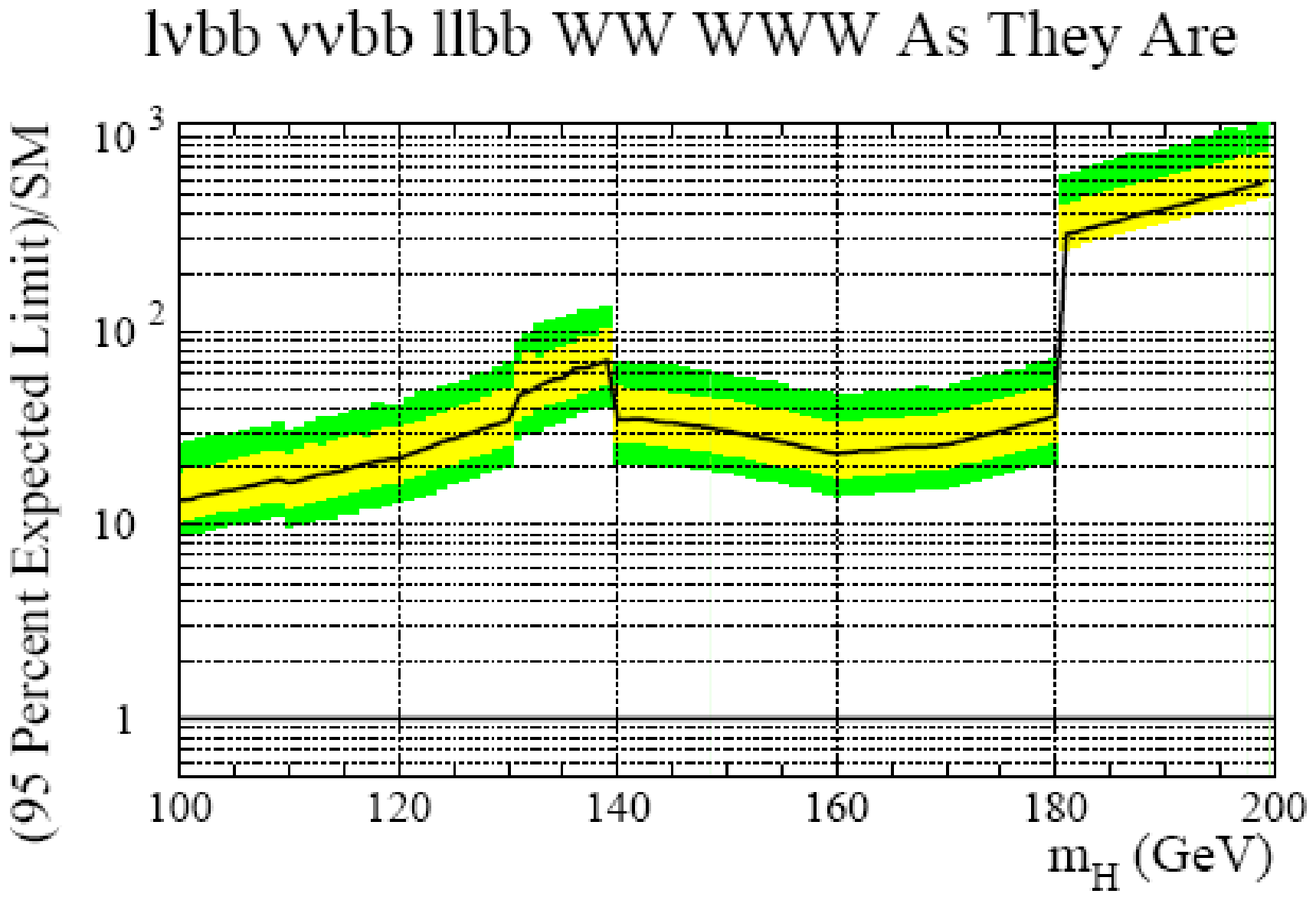
Collected CDF/D0 Plot for Summer 2005 Conferences



And in Late September 2005



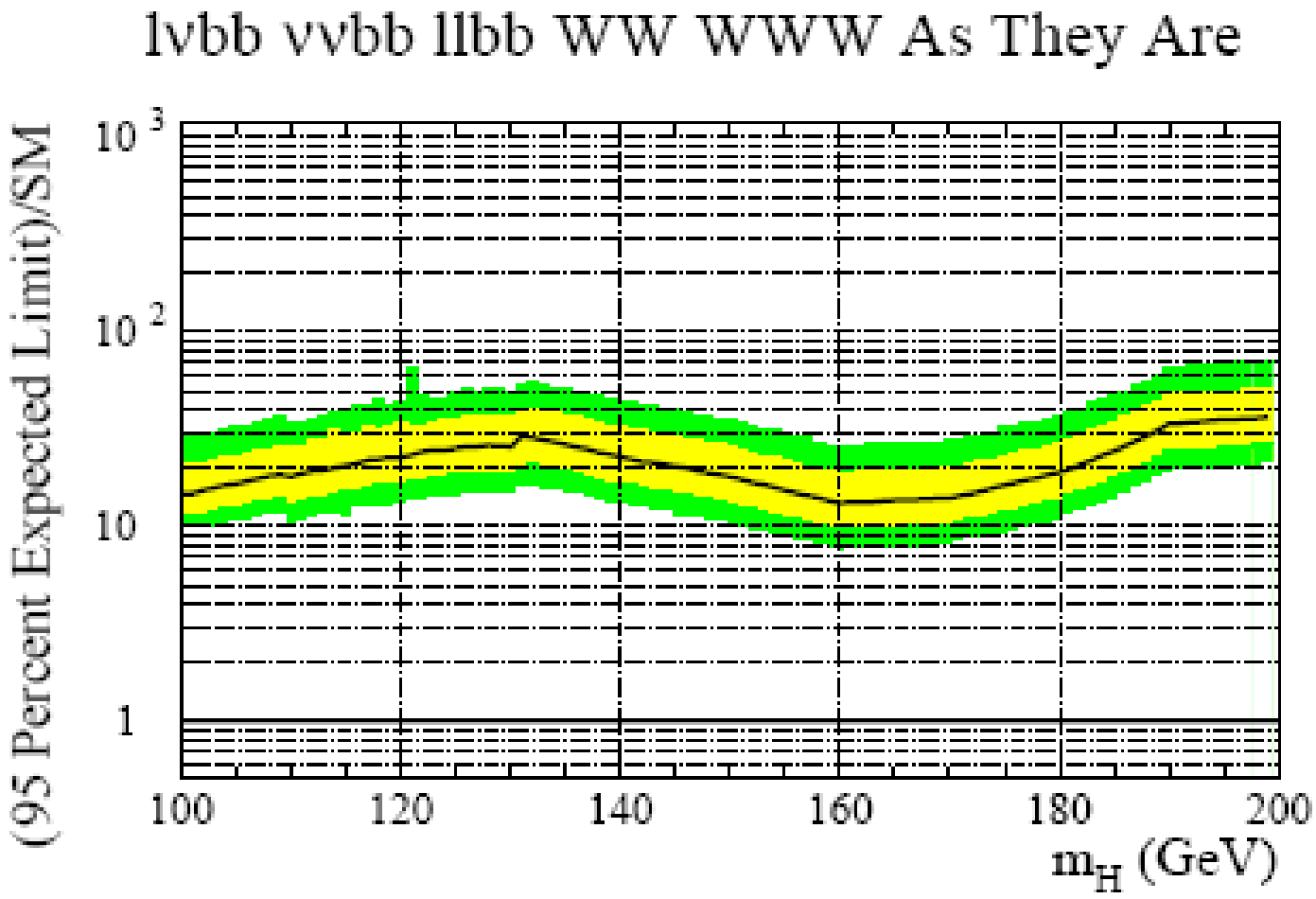
Old s95 limits (normalized to SM Cross-section – OSU Workshop)



Sensitivity with Current CDF Analyses

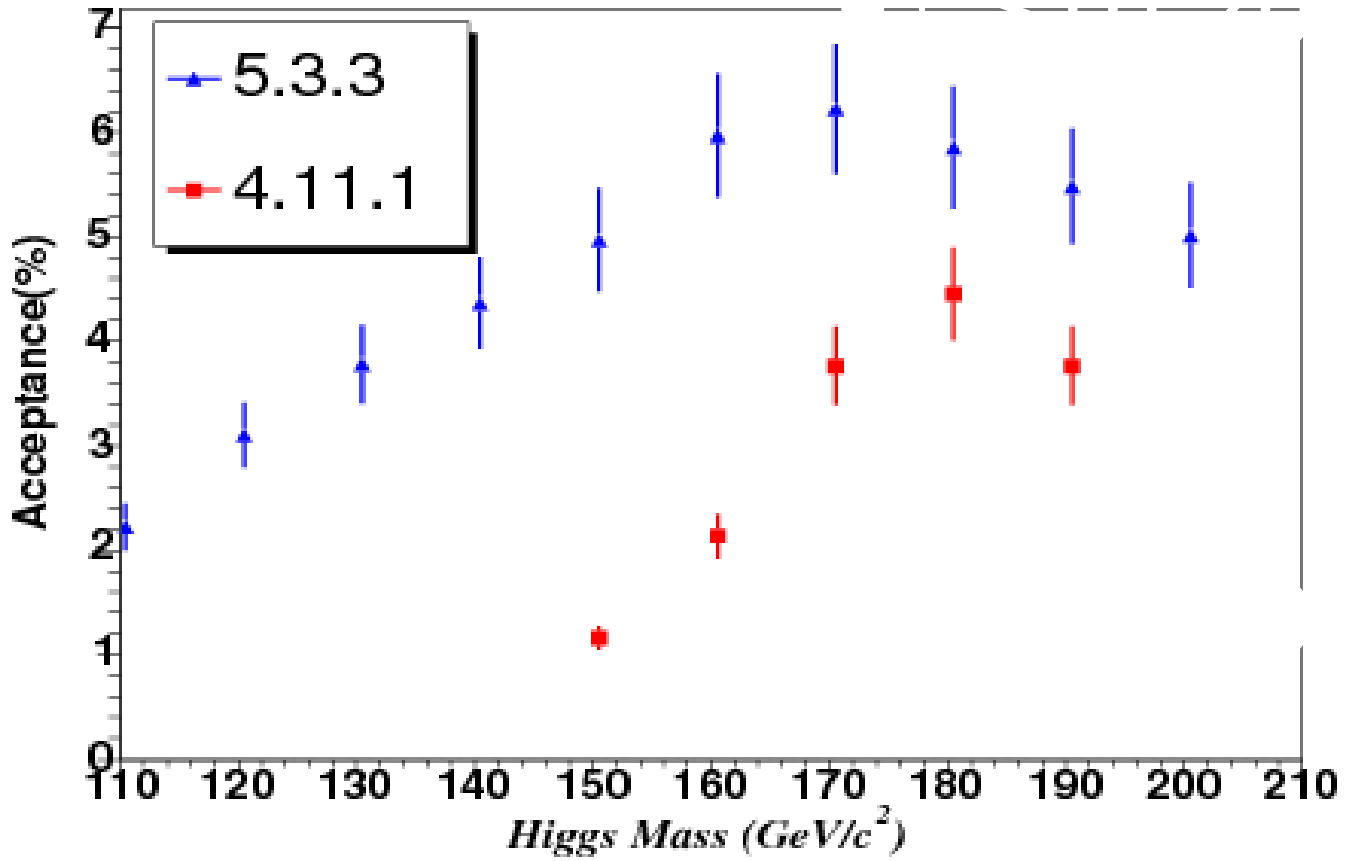
New 360 pb^{-1} $h \rightarrow WW$ analysis used

Cross-Section times branching fraction limit as a multiple of the SM rate



No Lumi Scale Factors: analyses "as is"

Improvements in Analysis: WW Acceptance

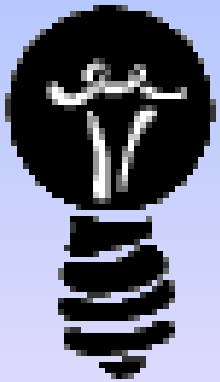


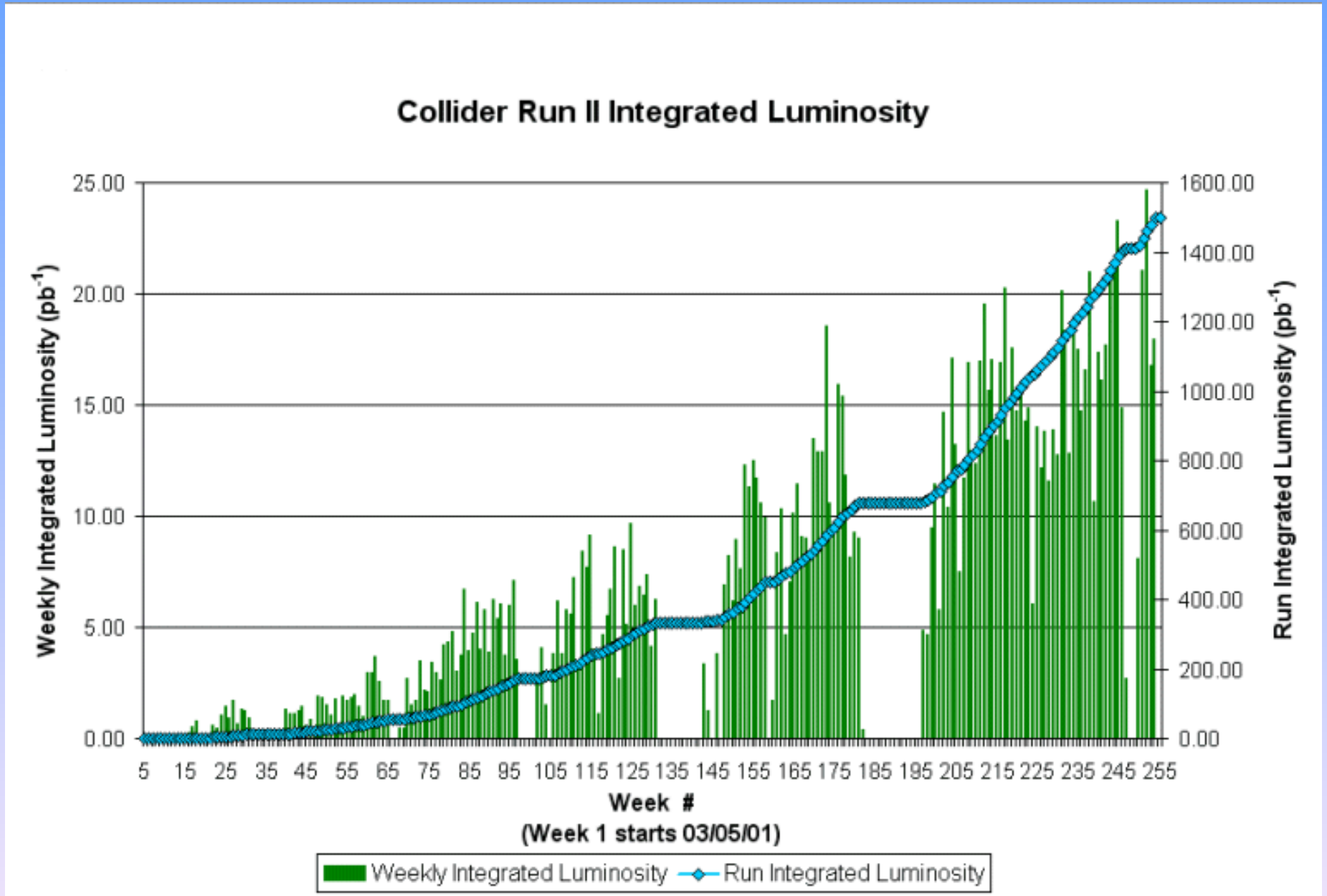
Improvements to Analysis: Associated Production Channels

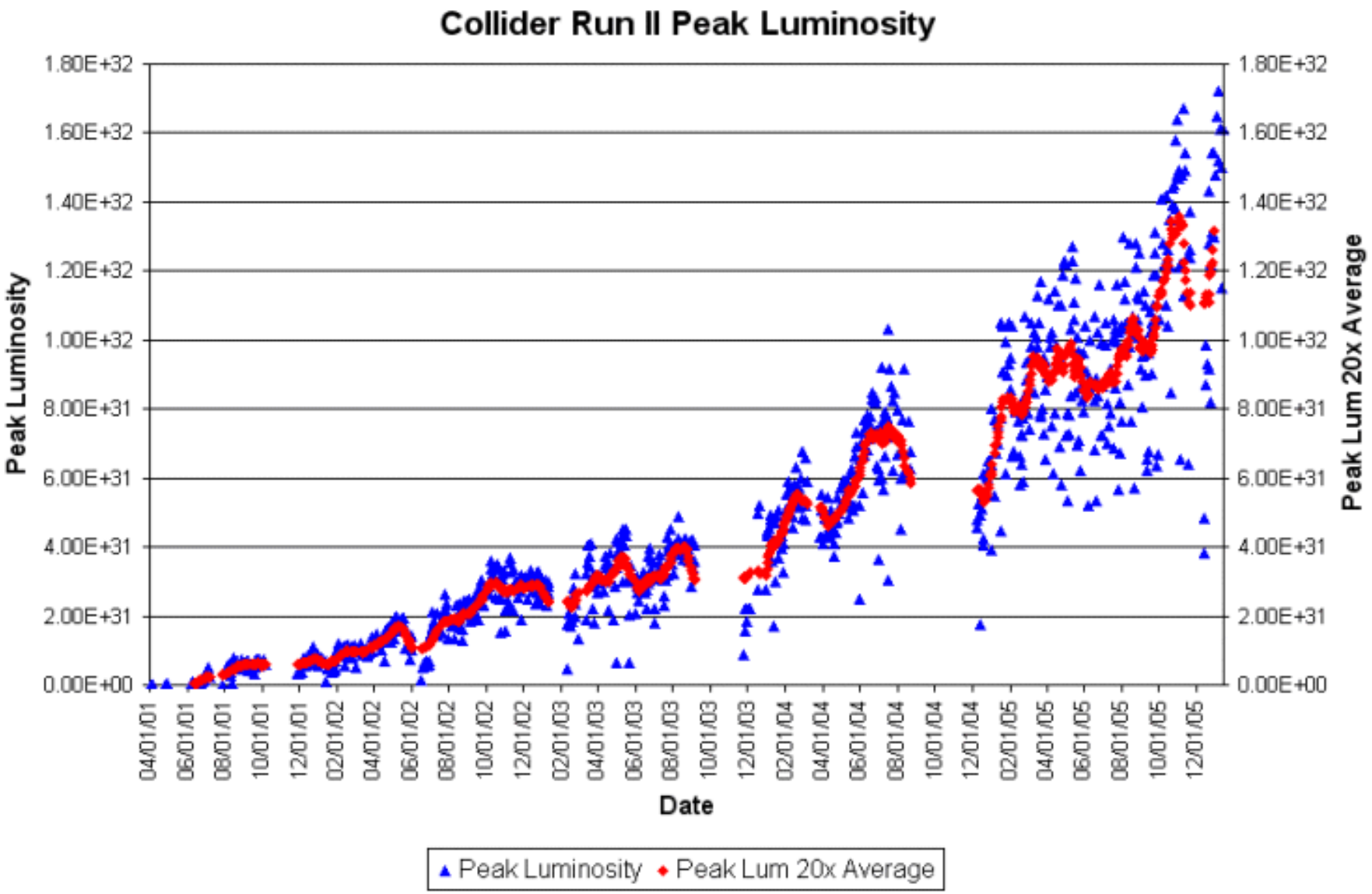
Luminosity Equivalent $(s/\sqrt{b})^2$

Improvement	WH→lνbb	ZH→ννbb	ZH→llbb
Mass resolution	**1.7**	**1.7**	**1.7**
Continuous b-tag (NN)	1.5	1.5	1.5
Forward b-tag	1.1	1.1	1.1
Forward leptons	1.3	1.0	1.6
Track-only leptons	1.4	1.0	1.6
NN Selection	**1.75**	**1.75**	**1.0**
WH signal in ZH	**1.0**	**2.7**	**1.0**
Product of above	8.9	13.3	7.2
CDF+DØ combination	2.0	2.0	2.0
All combined	17.8	26.6	14.4

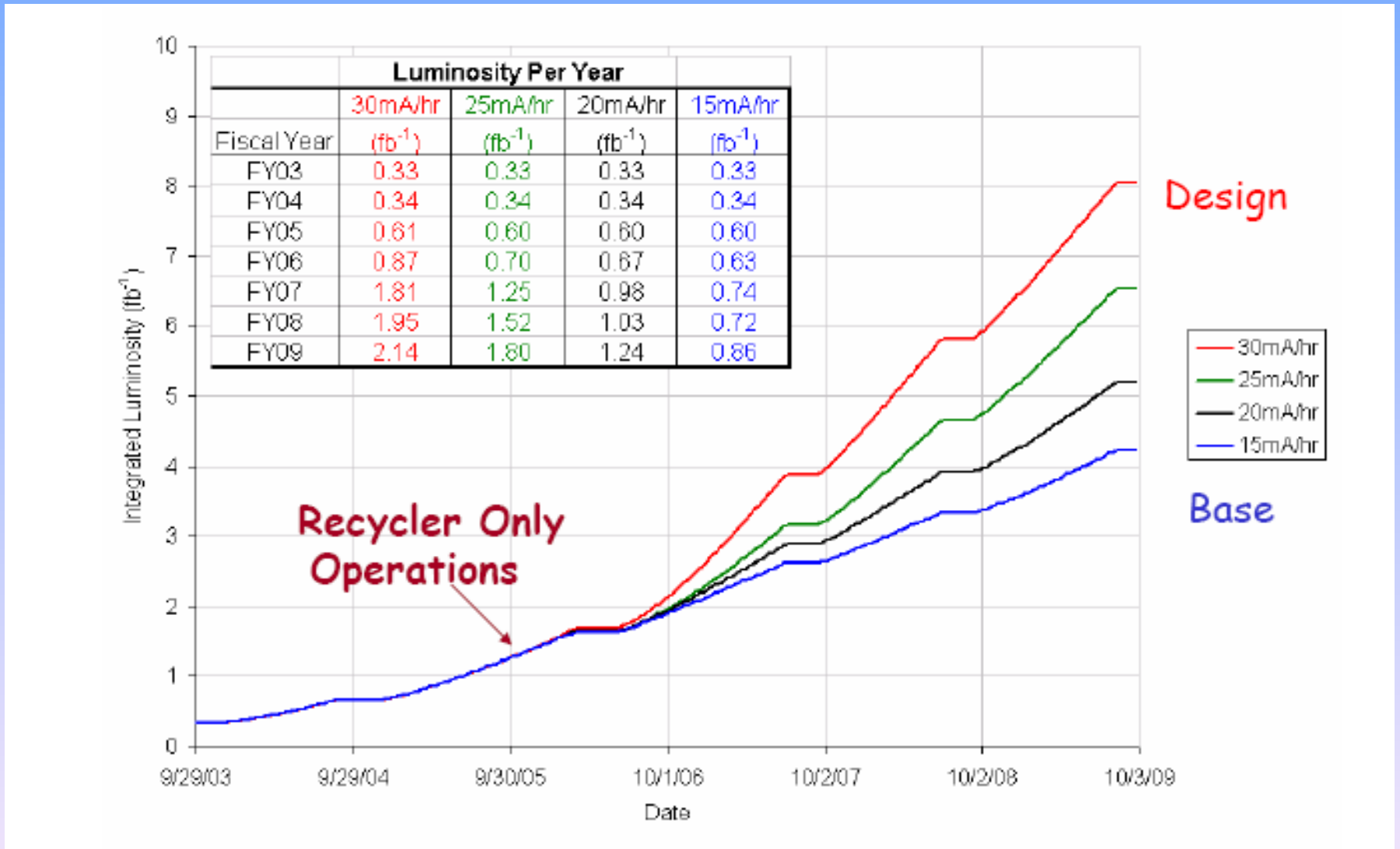
Tevatron Lumi



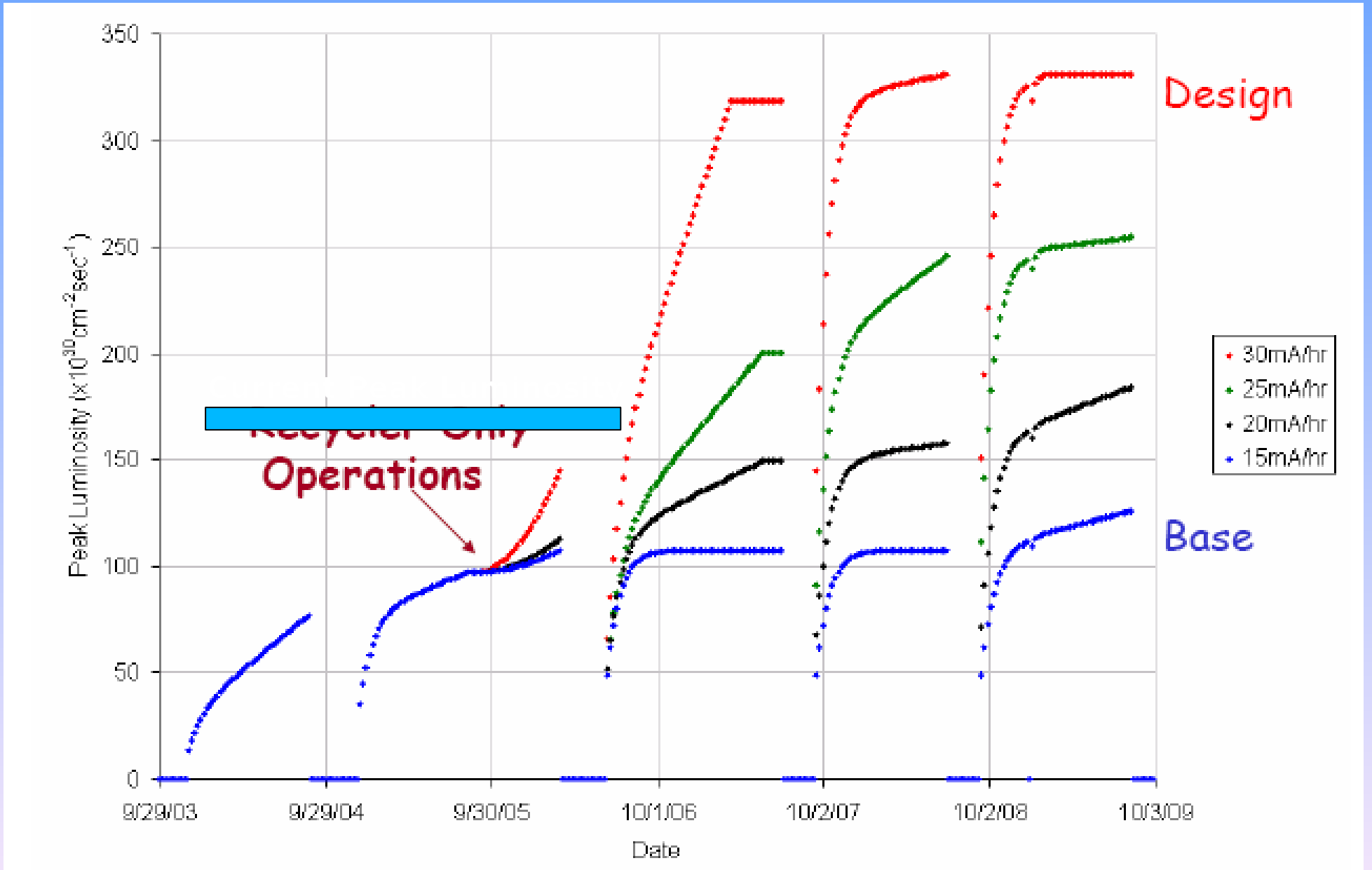

Collider Run II Integrated Luminosity
Weekly Integrated Luminosity (pb-1)
Run Integrated Luminosity (pb-1)
25.00
20.00
15.00
10.00
5.00
0.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195 205 215 225 235 245 255
Week #
(Week 1 starts 03/05/01)
Weekly Integrated Luminosity
Run Integrated Luminosity


Collider Run II Peak Luminosity
Peak Luminosity
Peak Lum 20x Average
1.80E+32
1.60E+32
1.40E+32
1.20E+32
1.00E+32
8.00E+31
6.00E+31
4.00E+31
2.00E+31
0.00E+00
04/01/01
06/01/01
08/01/01
10/01/01
12/01/01
02/01/02
04/01/02
06/01/02
08/01/02
10/01/02
12/01/02
02/01/03
04/01/03
06/01/03
08/01/03
10/01/03
12/01/03
02/01/04
04/01/04
06/01/04
08/01/04
10/01/04
12/01/04
02/01/05
04/01/05
06/01/05
08/01/05
10/01/05
12/01/05
Date
Peak Luminosity
Peak Lum 20x Average

Integrated Lumi Projections



Instantaneous Lumi Needed



To get the 2008 Picture,

Need LHC Projections

Rolandi: LP2005

Pilot: 300pb^{-1}

Objectives for the Pilot RUN

Reach a Luminosity of 10^{32}

Low Luminosity run at 25 ns separation

Difficult to speculate further on what the performance might be in the first year. As always, CERN accelerators departments will do their best !

Lyn Evans

STAGE 1
INITIAL COMMISSIONING
43 x 43 -> 156 x 156 $3x10^{10}$ per bunch
Zero to Partial squeeze

STAGE 2
75 ns OPERATION
3-4 x 10^{10} per bunch
Partial squeeze

STAGE 3
25 ns OPERATION
3-4 x 10^{10} per bunch
Partial to near full squeeze

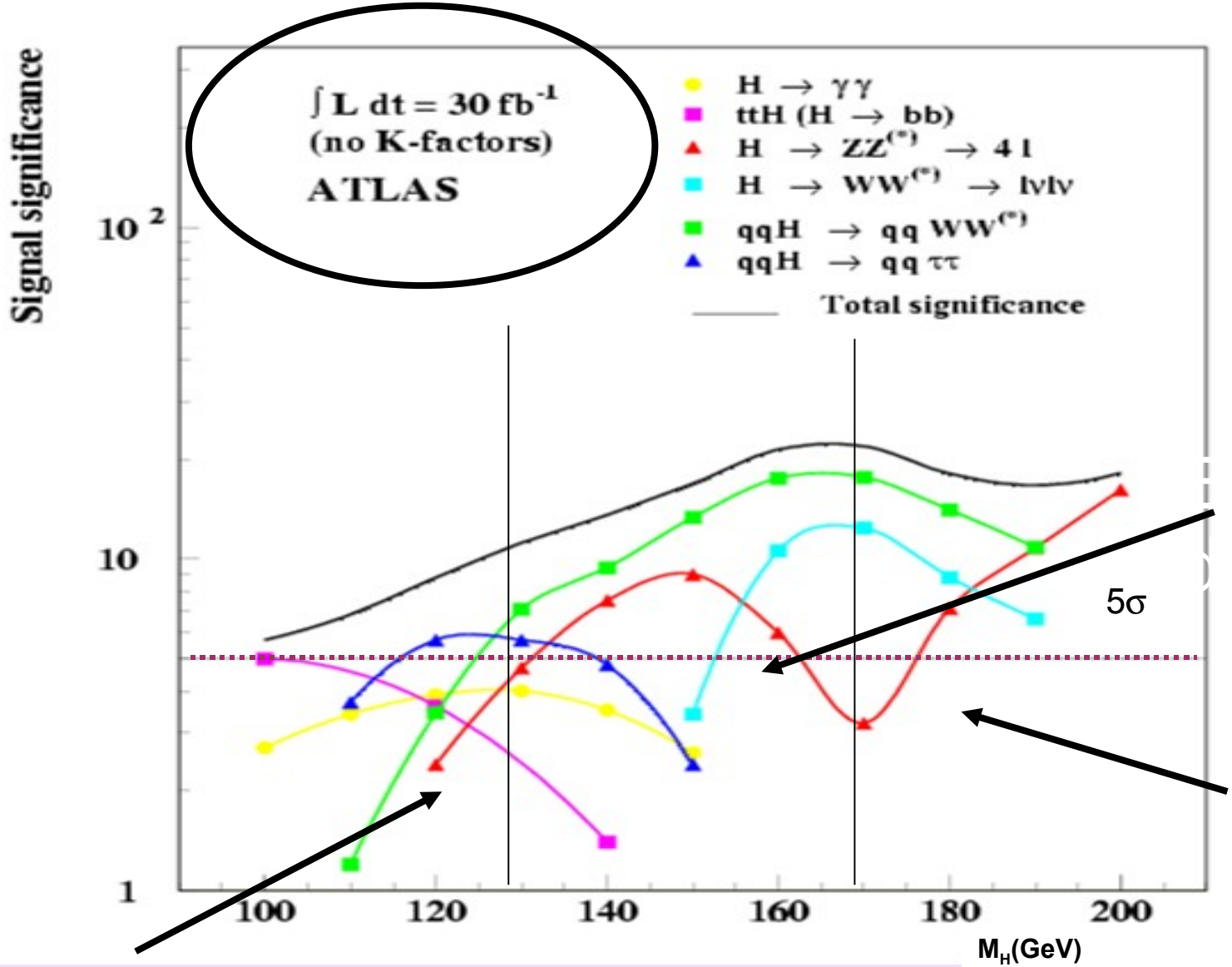
STAGE 4
25 ns OPERATION
push to nominal per bunch
Partial to full squeeze

14 vs 1.860 TeV

Channels (examples ...)	Events to tape for 1 fb^{-1} (per expt: ATLAS, CMS)	Total statistics from previous Colliders
$W \rightarrow \mu \nu$	7×10^6	$\sim 10^4$ LEP, $\sim 10^6$ Tevatron
$Z \rightarrow \mu \mu$	$\sim 10^6$	$\sim 10^6$ LEP, $\sim 10^5$ Tevatron
$t\bar{t} \rightarrow W\,b\,W\,b \rightarrow \mu \nu + X$	$\sim 10^5$	$\sim 10^4$ Tevatron
$\tilde{g}\tilde{g}$ m = 1 TeV	$10^2 - 10^3$	———

- $1fb^{-1}$ LHC >= 8fb-1 Tevatron (Table from Fabioa Gionatti, LP2005)

ATLAS Channels



lude/
iation

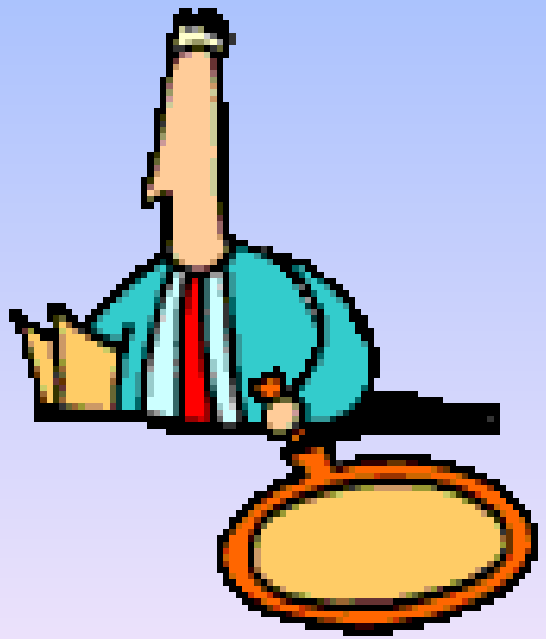
Mtop,
Mw

Exclude/Evidence for from CDF (if b jet resolution)

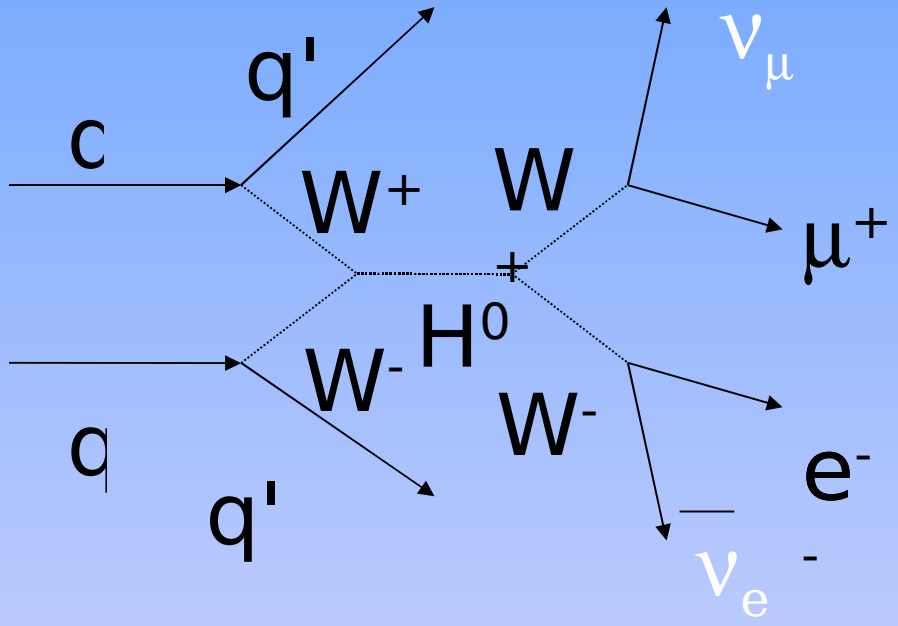
Scenario

- ATLAS 2007: Pilot Run, Z,W calib? 200pb^{-1}
- ATLAS 2008: Physics, 1fb^{-1}
- CDF 2007: 4fb^{-1} : HWW 4x3: at SM limit in the 140-170 range. TOP and W Mass improved as well, so SM fit limits narrower.
  - Deviations building from expected limit: we focus on this range for ATLAS 2008. Perhaps SM fit narrowing on this range.
  - Higgs is 130-150 OR 170-185. Perhaps SM Fit excludes upper range.
- CDF 2009: 3σ at 120: ATLAS 2011? For discovery. CDF Keeps running!?
- ATLAS 2010: 10fb^{-1} : Discover it for > 130.

Look at HWW



HWW/VBF Production Features



- Missing Et
- High Pt Leptons
- 2 forward jets, opposite in rapidity, high mass
- Spin 0 Higgs correlates spins of leptons: e,μ parallel and neutrinos also
- VBF: $\Delta\eta_{\text{e-jet}}$ about 1-1.5

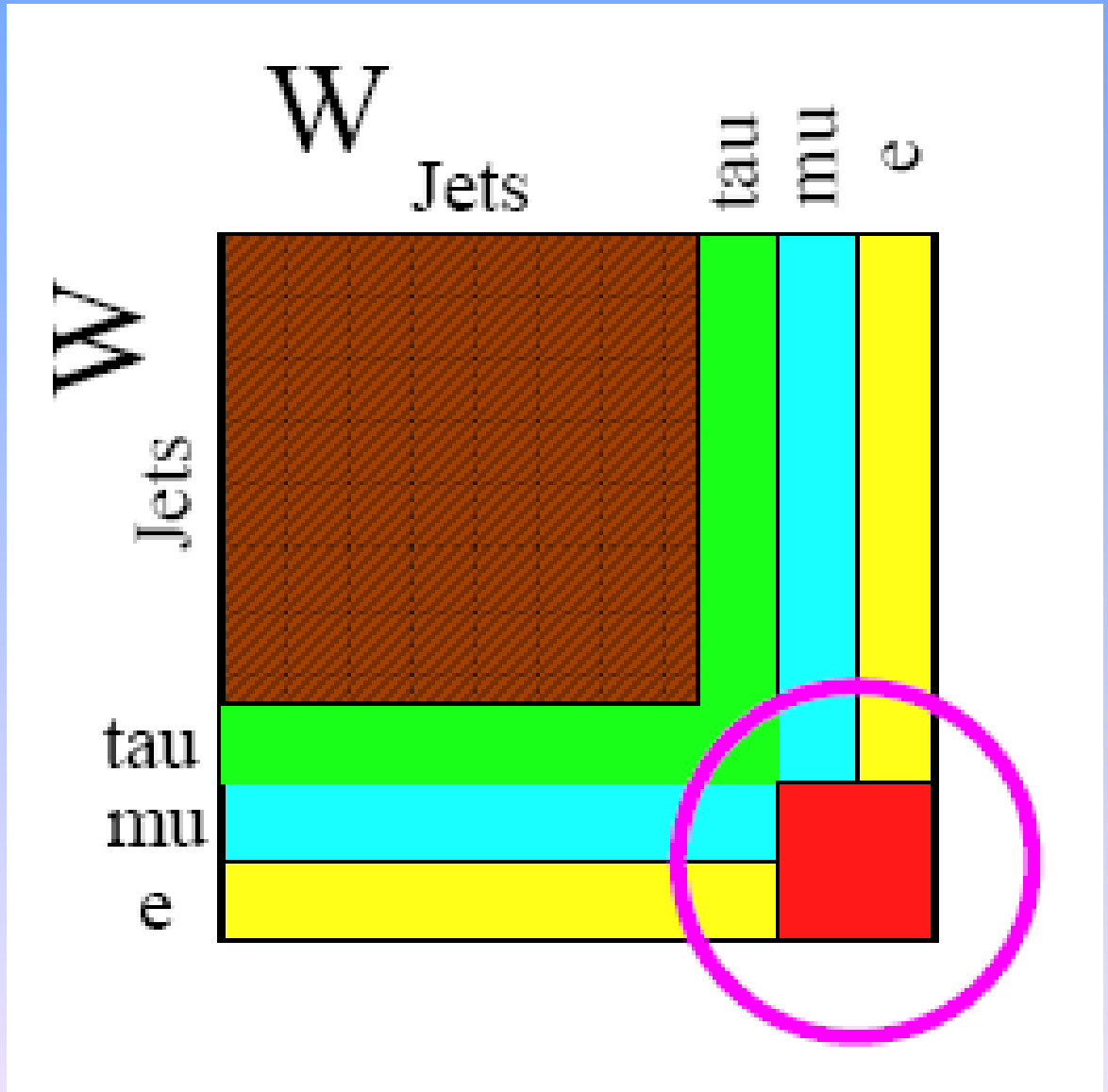
VBF same as WW, but with forward jets. Do analyses together. Very unique events.

HWW/VBF

- W Decay: 33% e,μ,τ
- Dilepton: 5%

Backgrounds

- W^+W^-
- Drell-Yan: Z/γ^*
- W + Jets (jet fakes e,μ)
- W+ γ



Acceptance(m_H = 160 GeV)

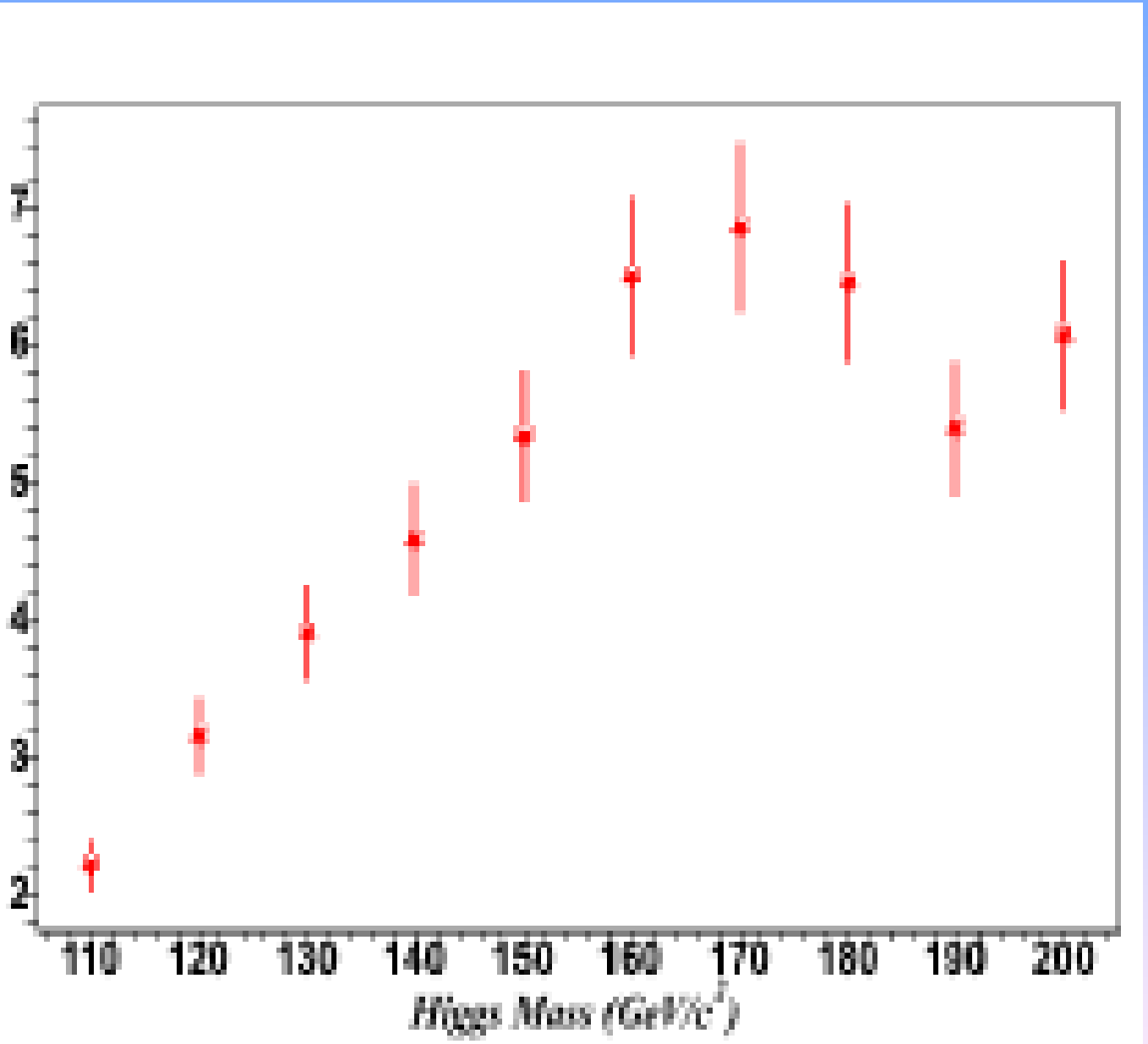
Cut	Efficiency %
2 leptons (20, 10 GeV)	9.14 ± 0.04
M_{ll} > 16 GeV	96.1 ± 0.06
Jet Veto	88.2 ± 0.11
$E_T^{miss} > m_H/4$	80.5 ± 0.14
E_T^{miss} > 50 GeV or $\Delta\phi_T 1/j > 20^o$	96.4 ± 0.07
Opposite Sign	98.7 ± 0.04
M_{ll} (1/2 x m_H - 5) GeV	98.9 ± 0.07
$P_T^1 + P_T^2 + E_T^{miss} < m_H$	97.2 ± 0.07

Jet $|\eta| < 2.5$, 0-Jet or $15 < E_T^{Jet1} < 55$ GeV

or $15 < E_T^{Jet2} < 40$ GeV

Muons $|\eta| < 1.0$, Electrons $|\eta| < 2.0$

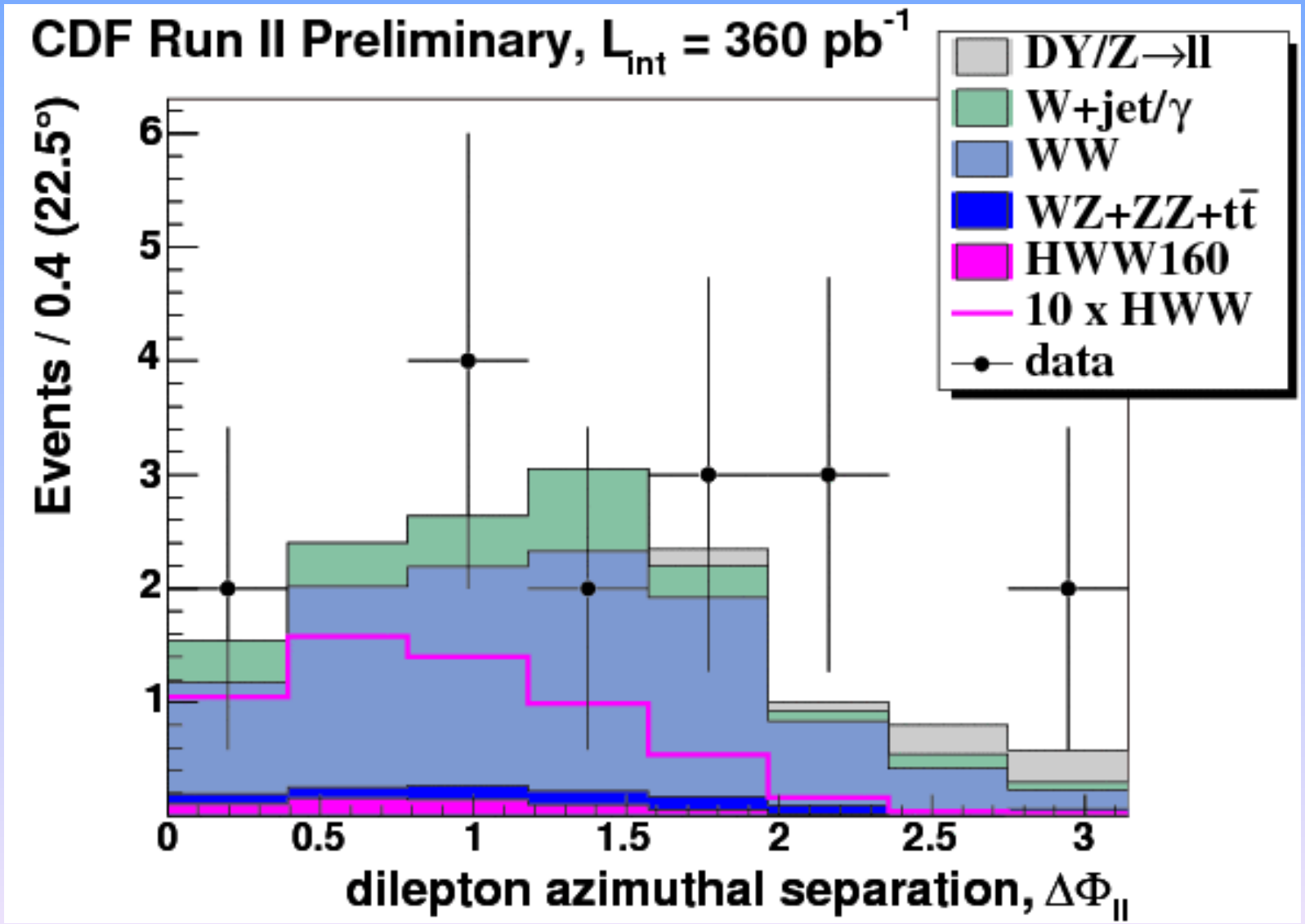
Acceptance


2
3
4
5
6
7
110
120
130
140
150
160
170
180
190
200
Higgs Mass (GeV/c²)

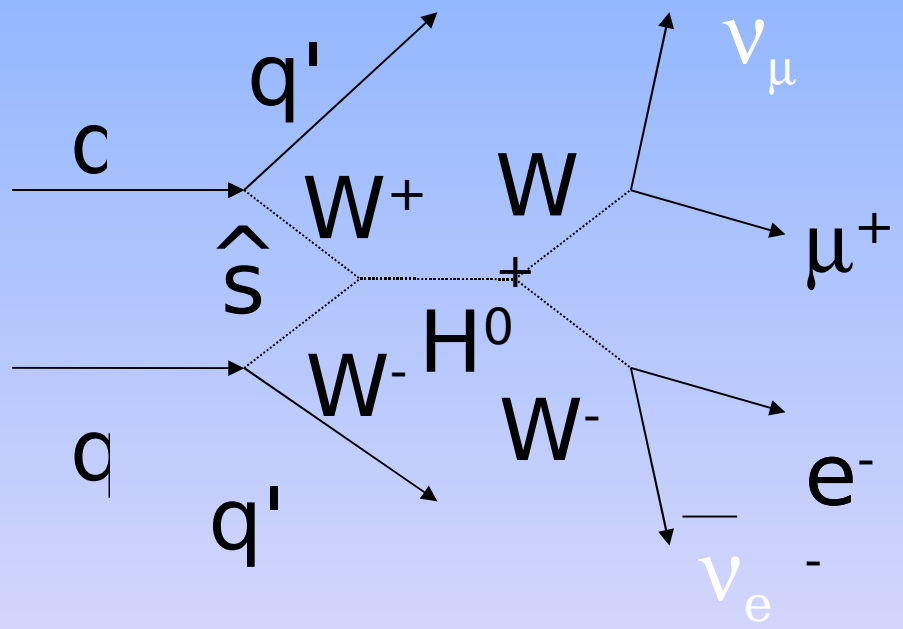
Background and Signal $M_H = 160$

WW	9.8	±	1.0
WZ	0.37	±	0.05
ZZ	0.04	±	0.01
tt	0.35	±	0.04
Wγ	1.1	±	0.1
Drell-Yan	0.76	±	0.19
fakes	1.3	±	0.7
Total BG	13	±	1.2
HWW	0.58	±	0.04
Data	16		

Results

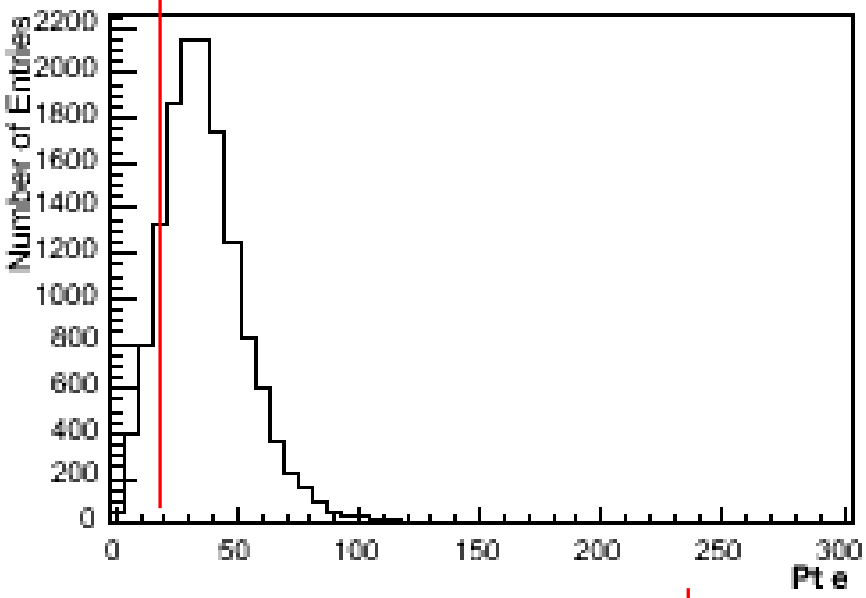

CDF Run II Preliminary, L_{int} = 360 pb^{-1}
DY/Z→ll
W+jet/γ
WW
WZ+ZZ+tt̄
HWW160
10 x HWW
data
Events / 0.4 (22.5°)
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5
3
dilepton azimuthal separation, $\Delta\Phi_{ll}$

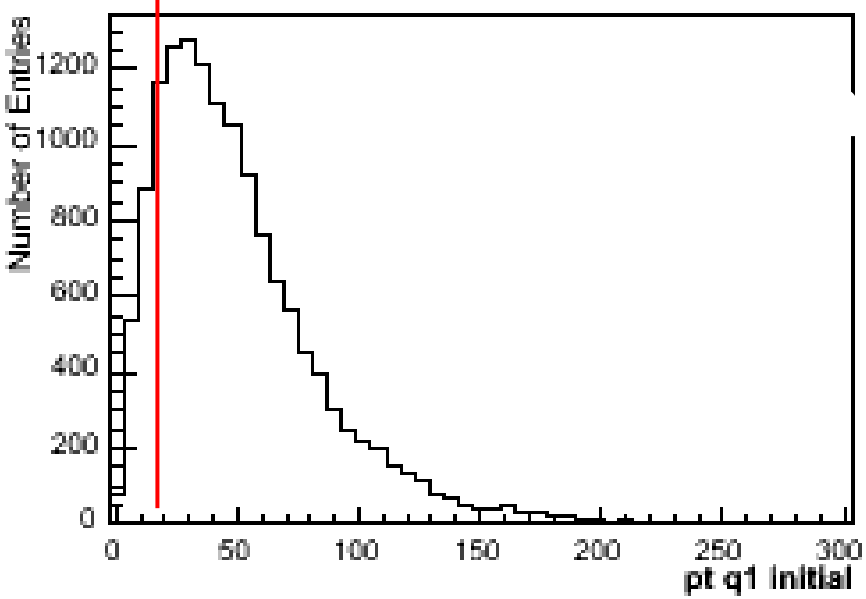
Study Characteristics at Tev and LHC for 160

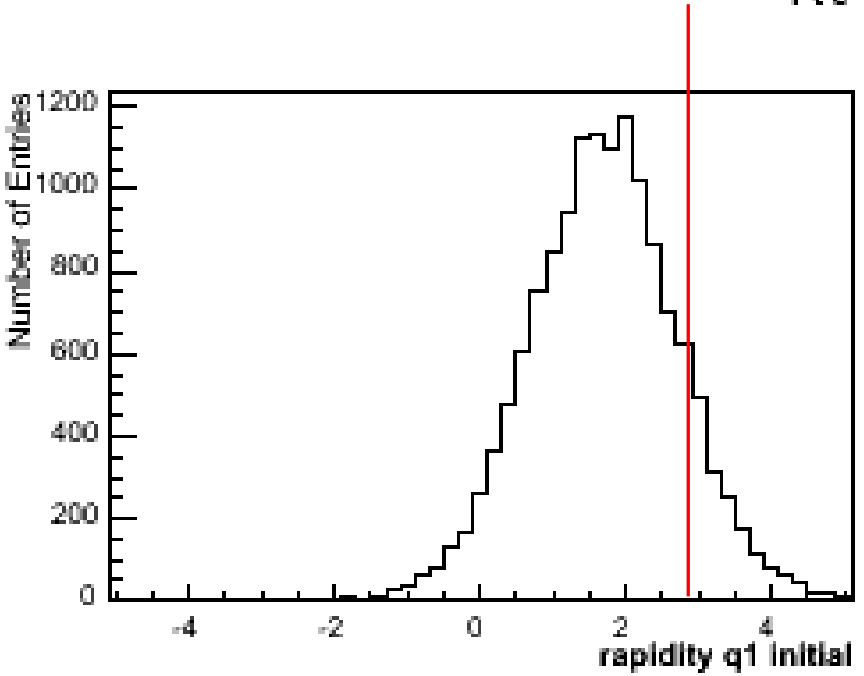


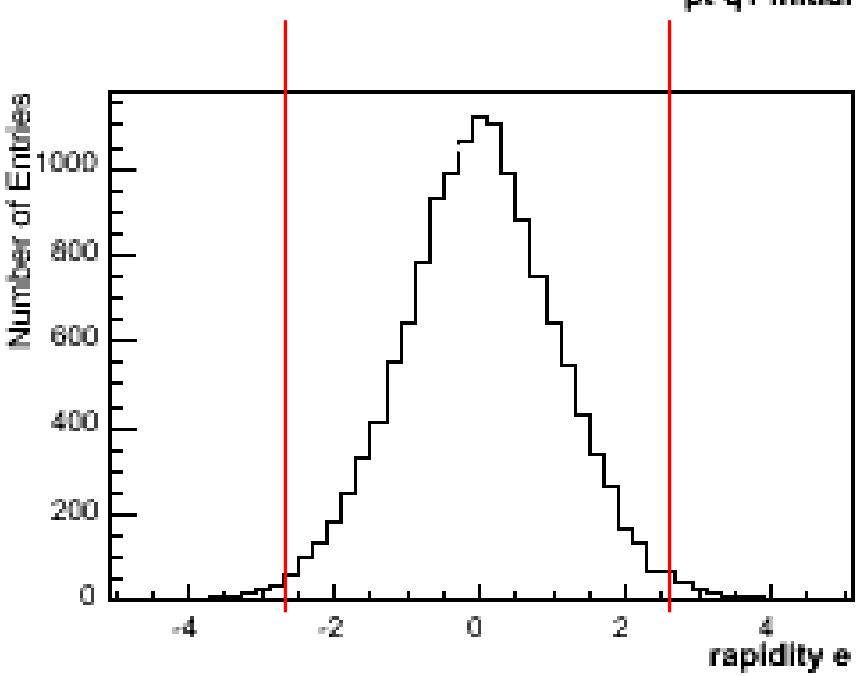
Tev, M_H=160

Pt, Rapidity of Leptons, Jets



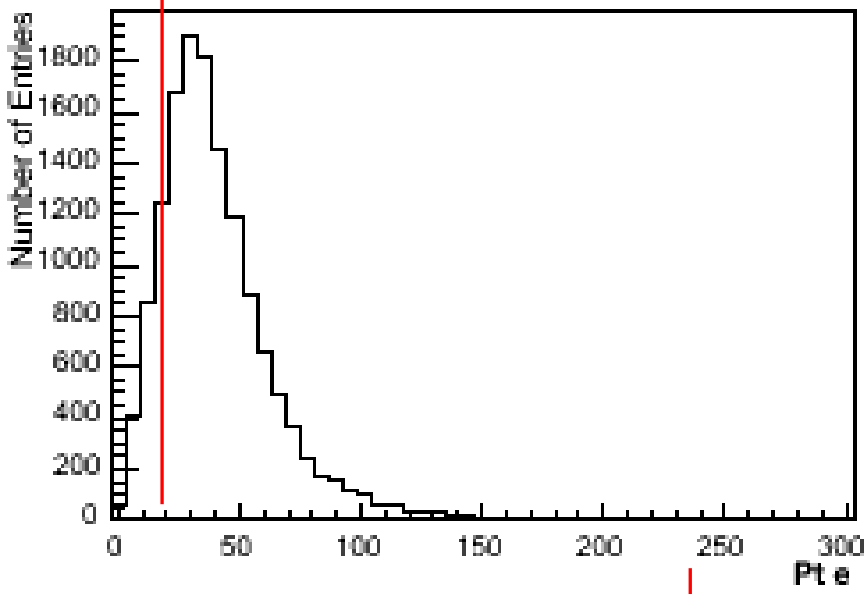


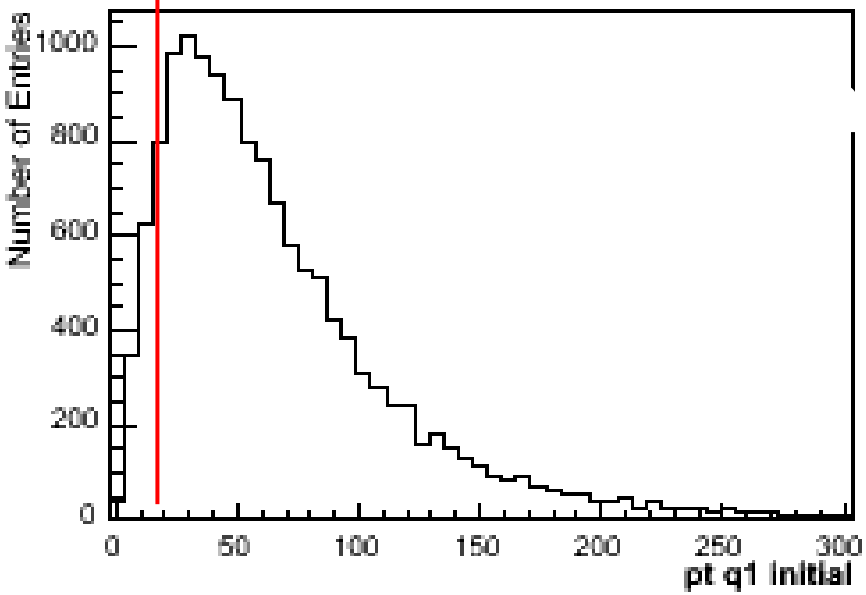


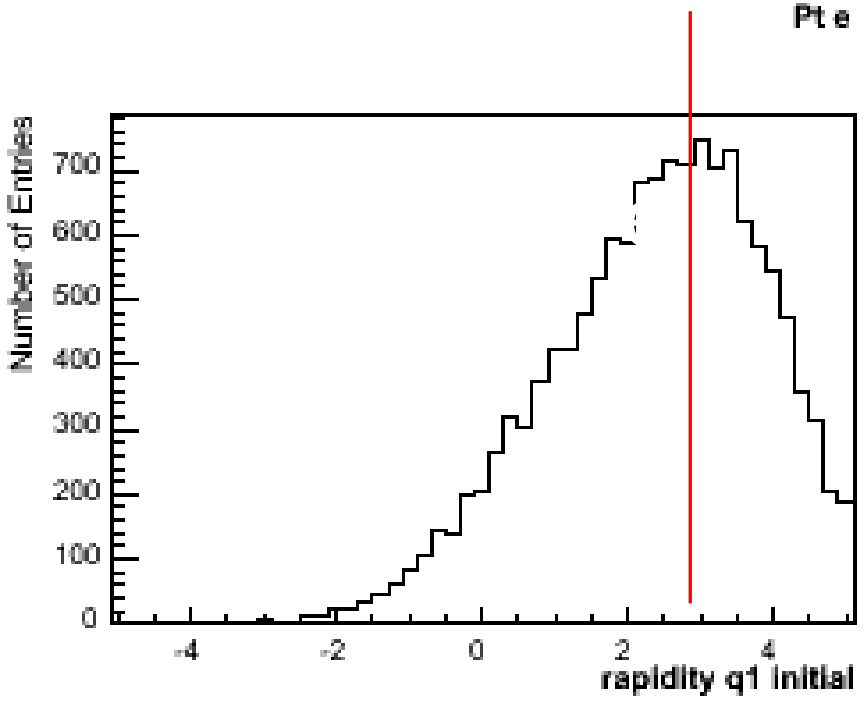


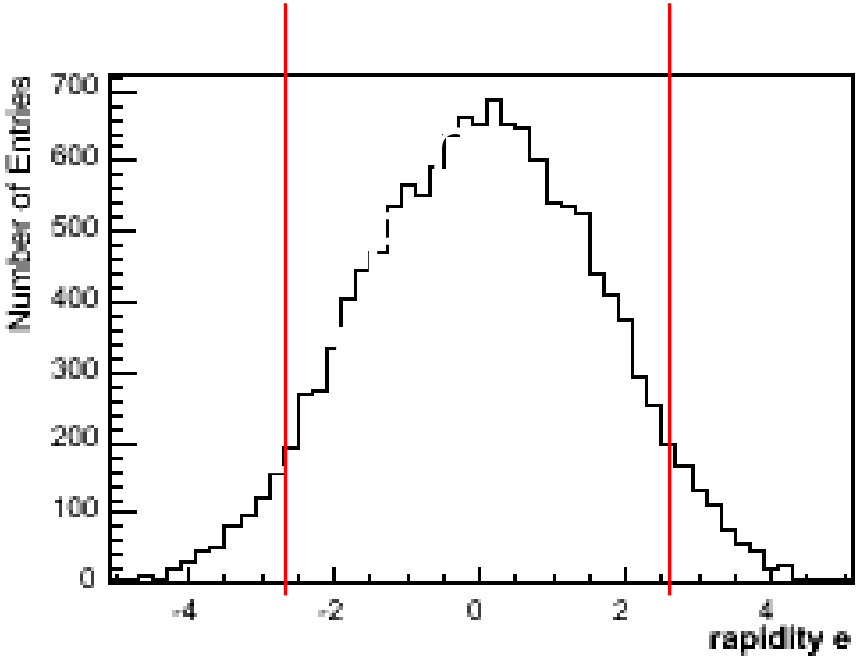
LHC, M_H=160

Pt, Rapidity of Leptons, Jets



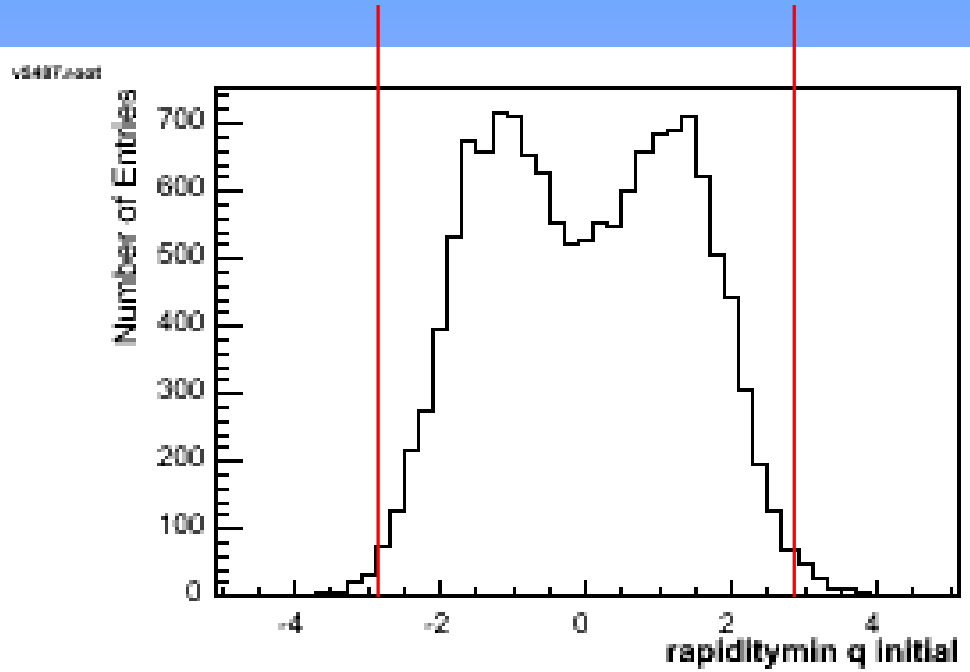


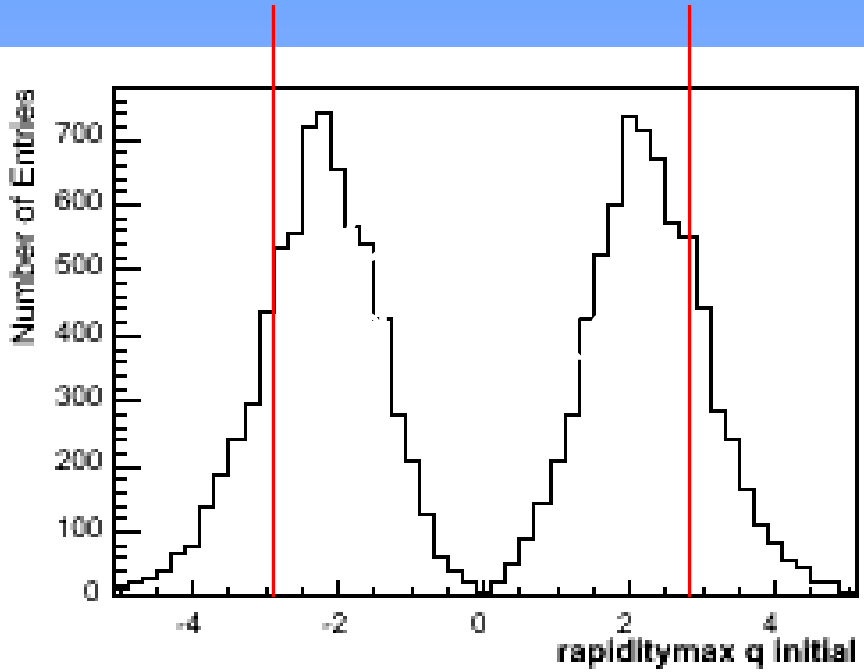


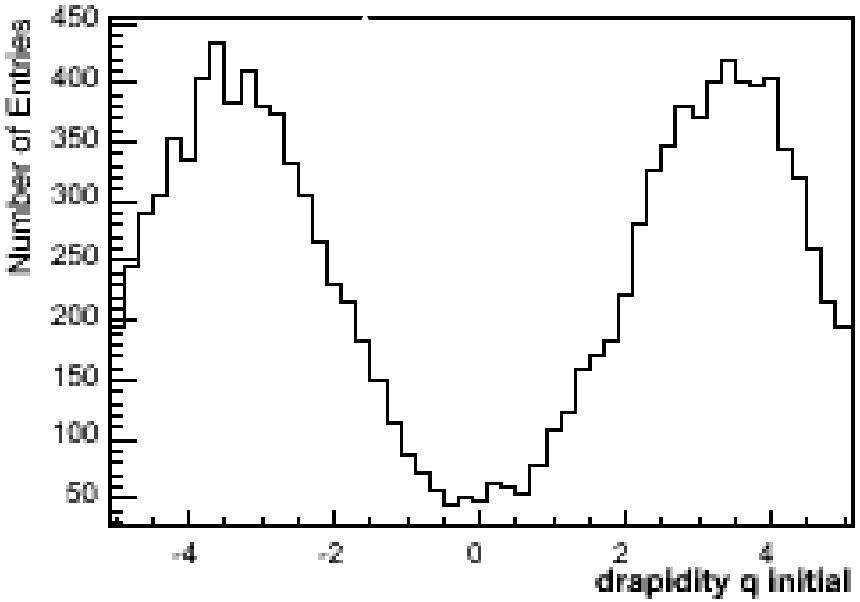


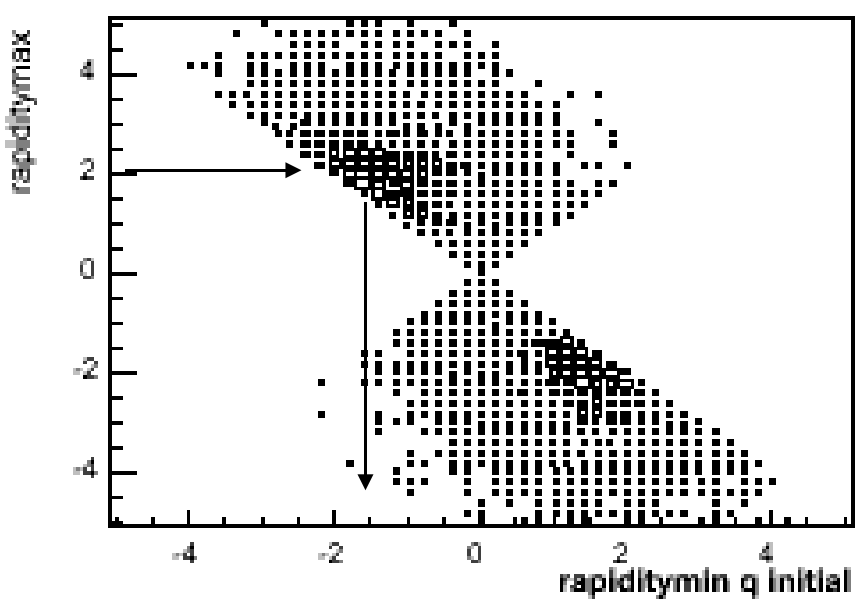
Tev, M_H=160

Rapidity of two quarks



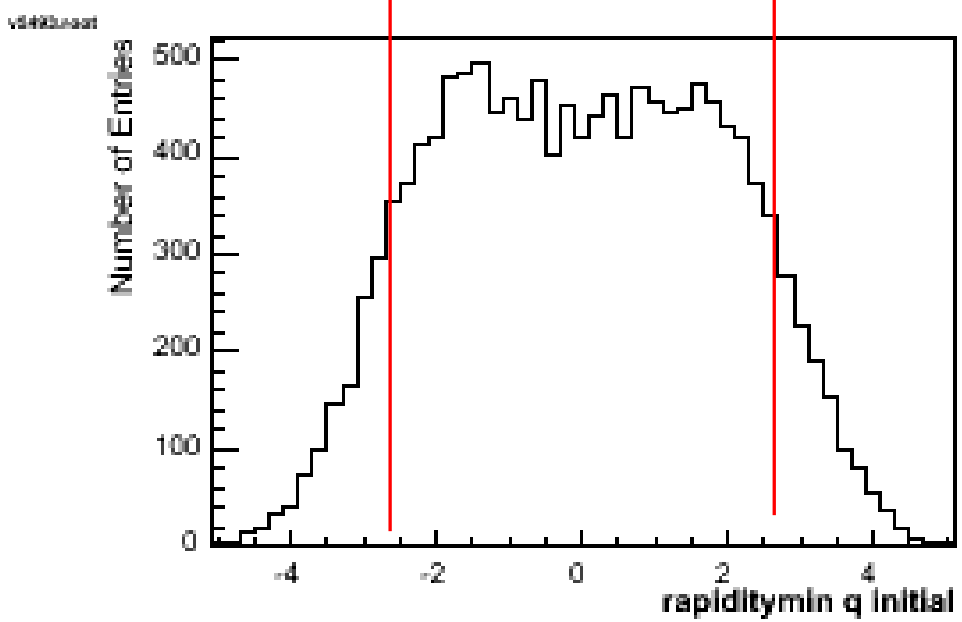


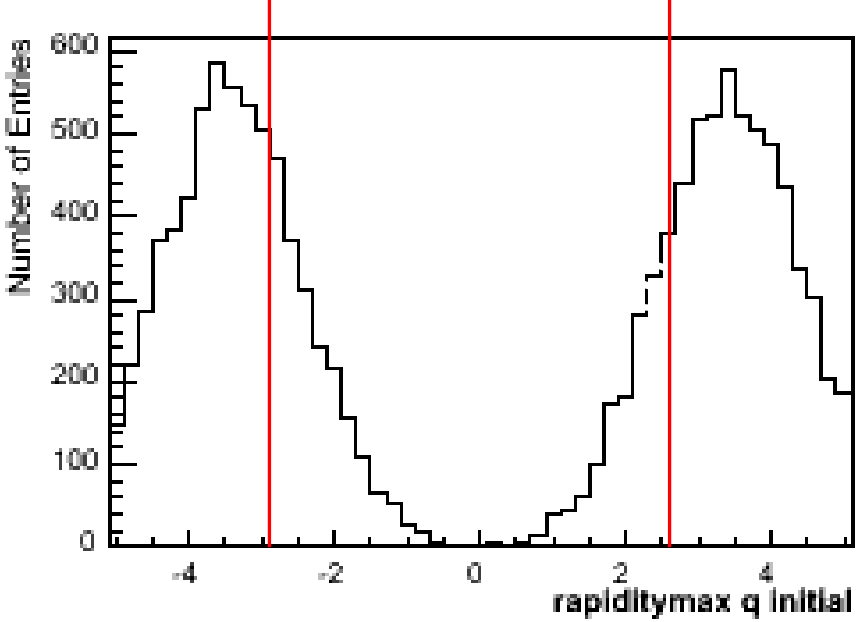


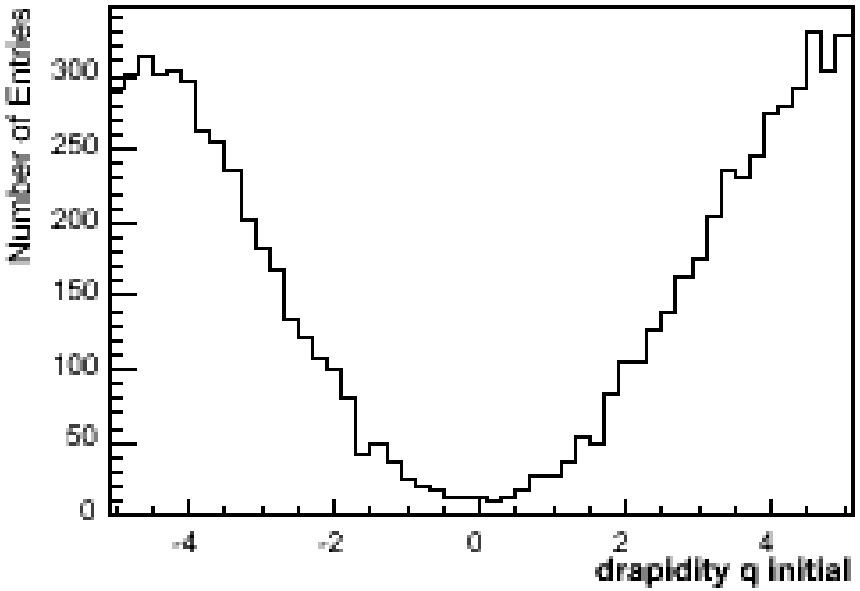


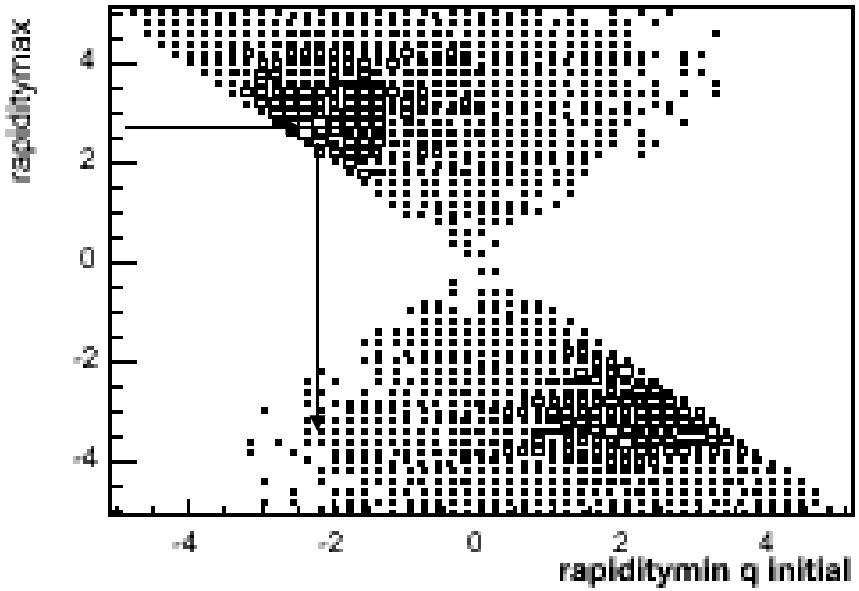
LHC, M_H=160

Rapidity of two quarks

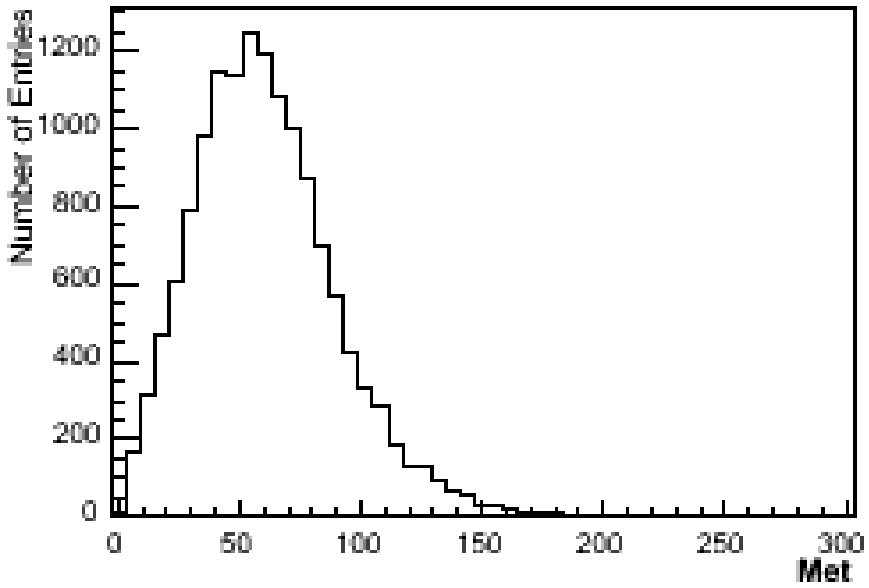


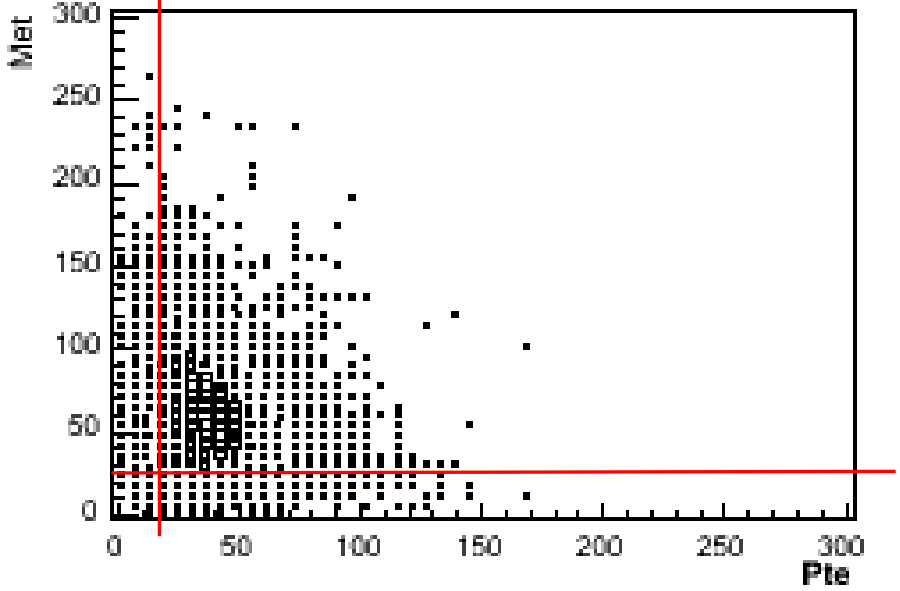


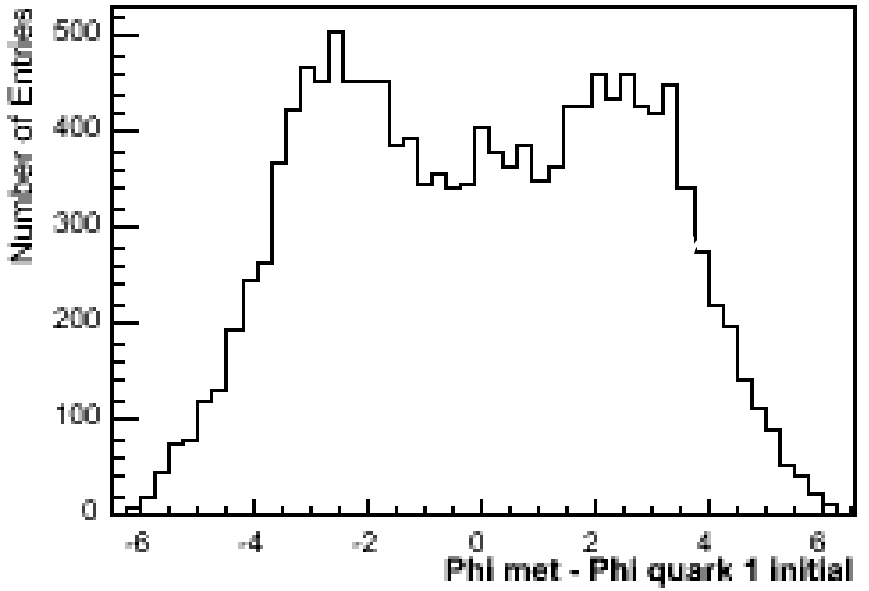


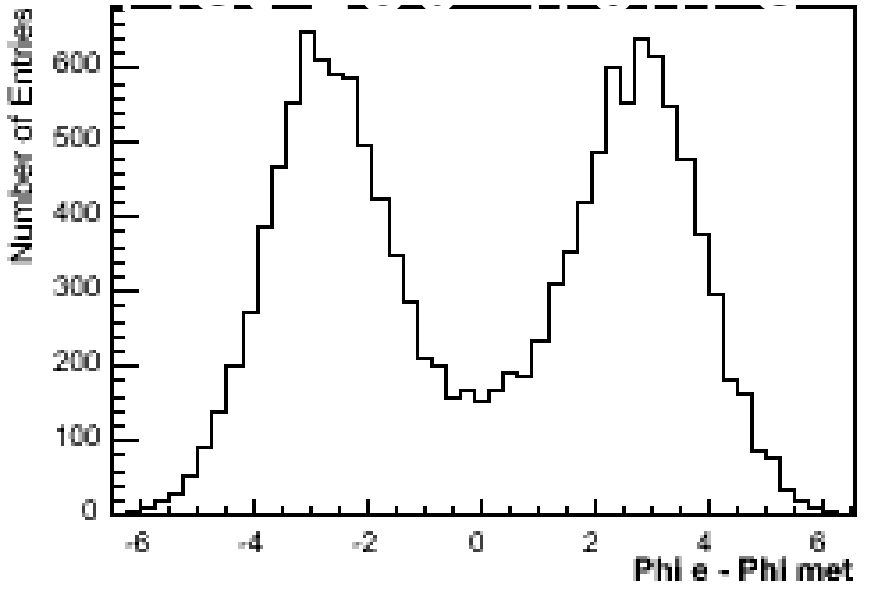


Missing Energy

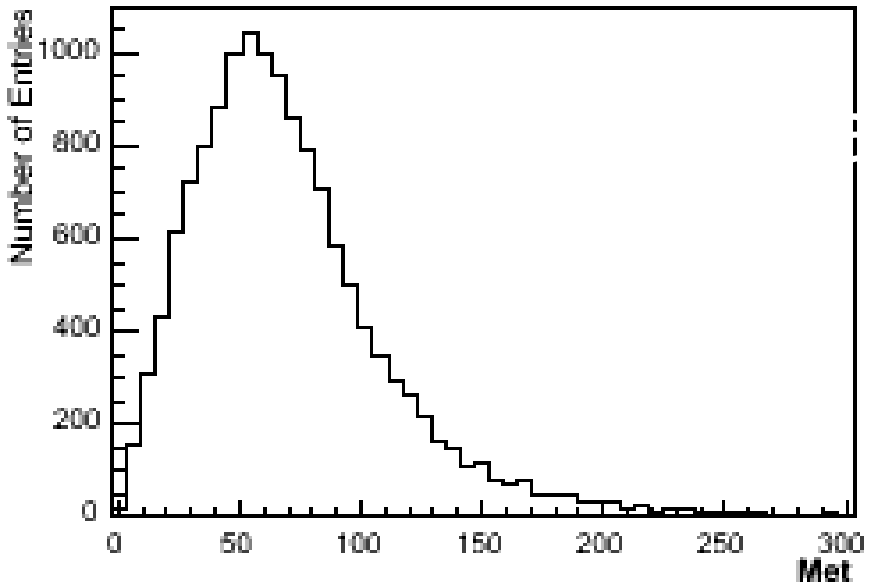


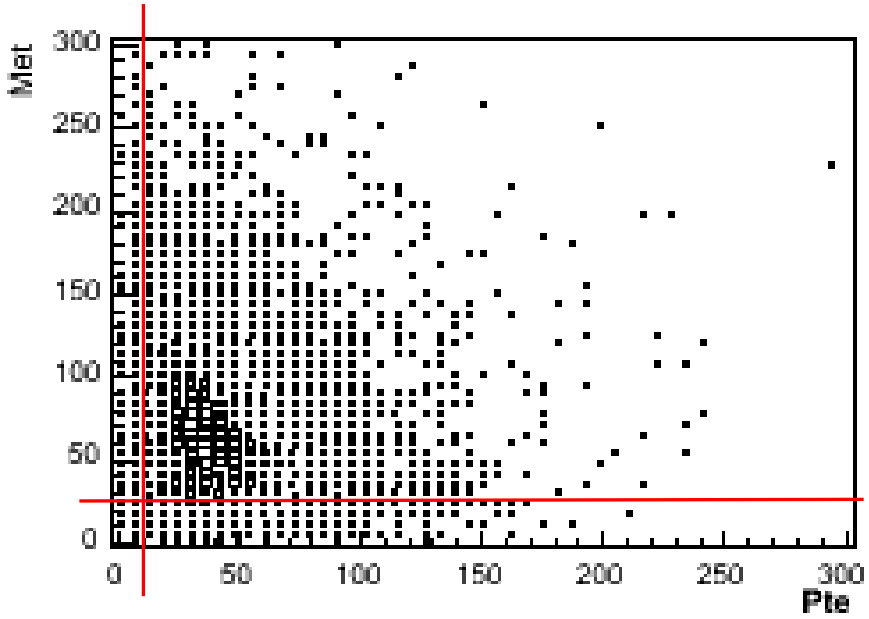


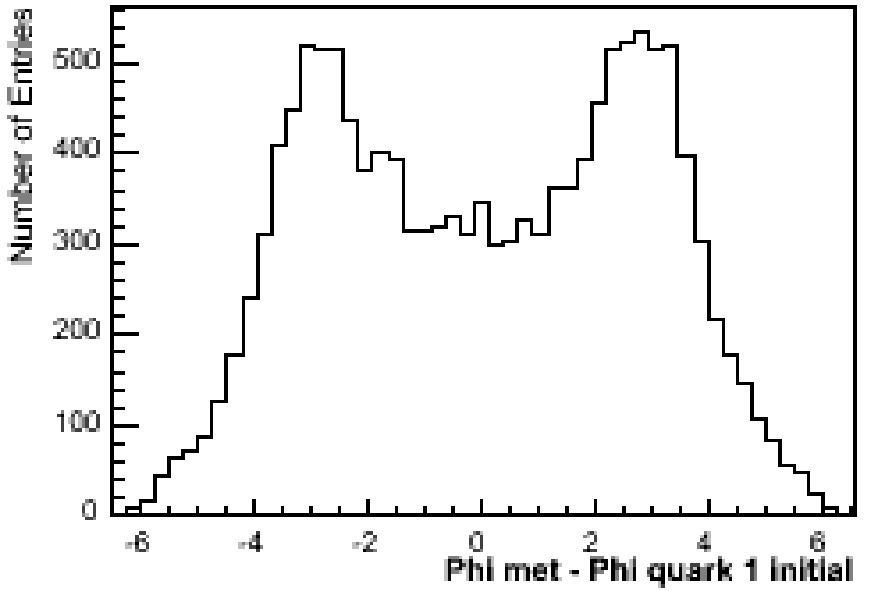


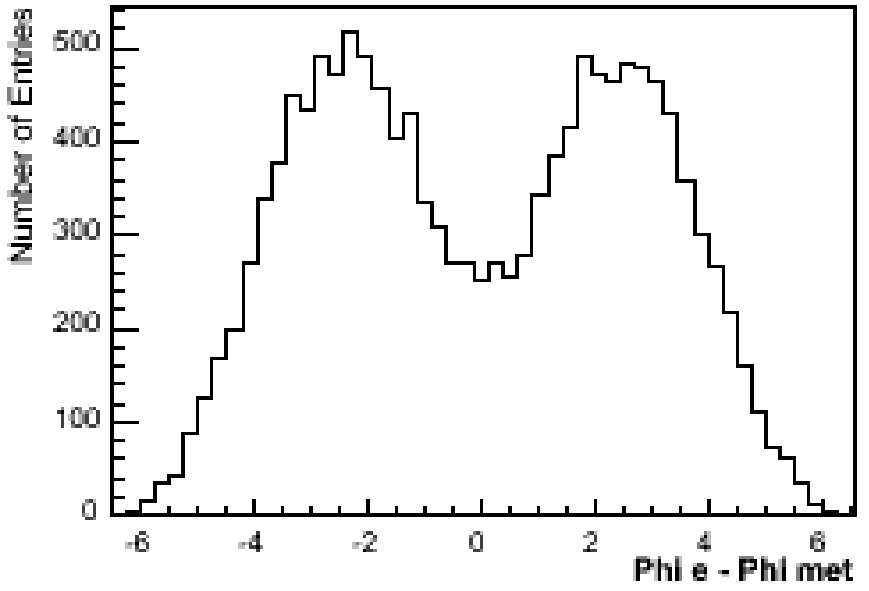


Missing Energy



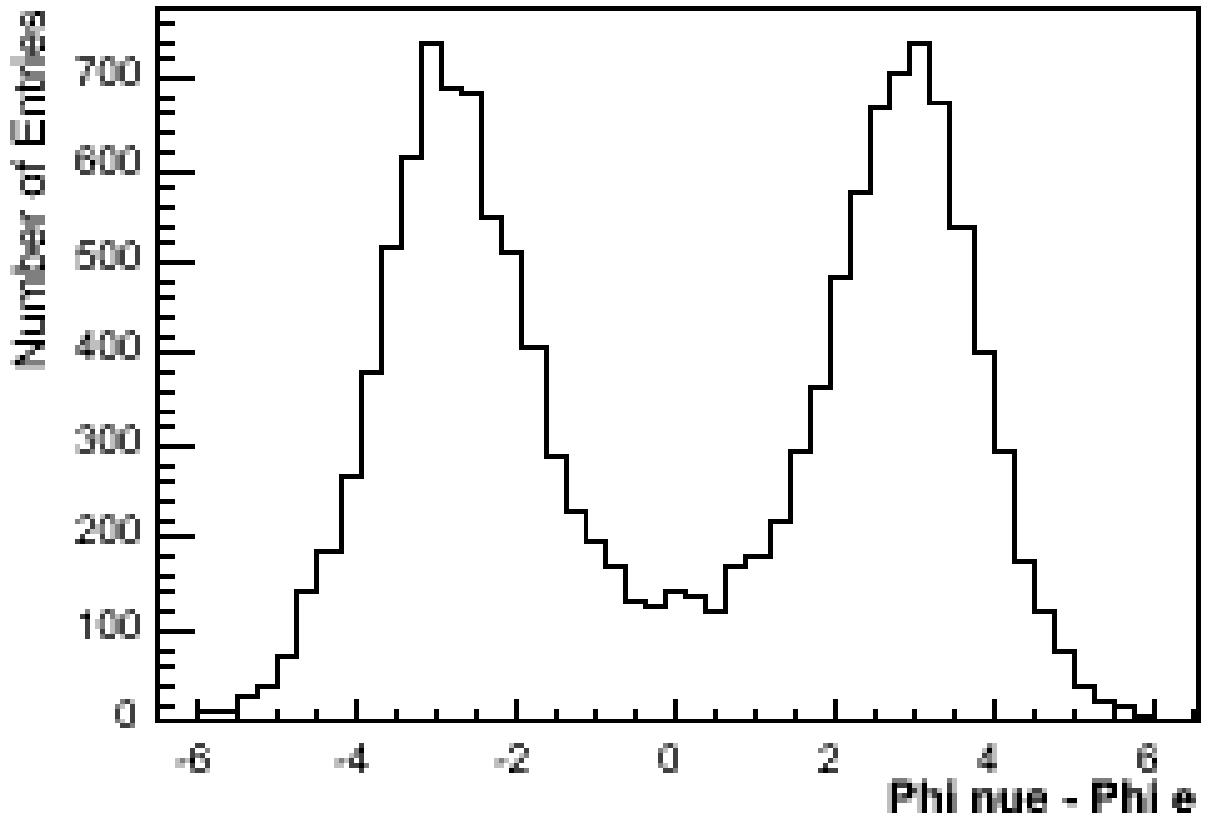






Tev, M_H=160

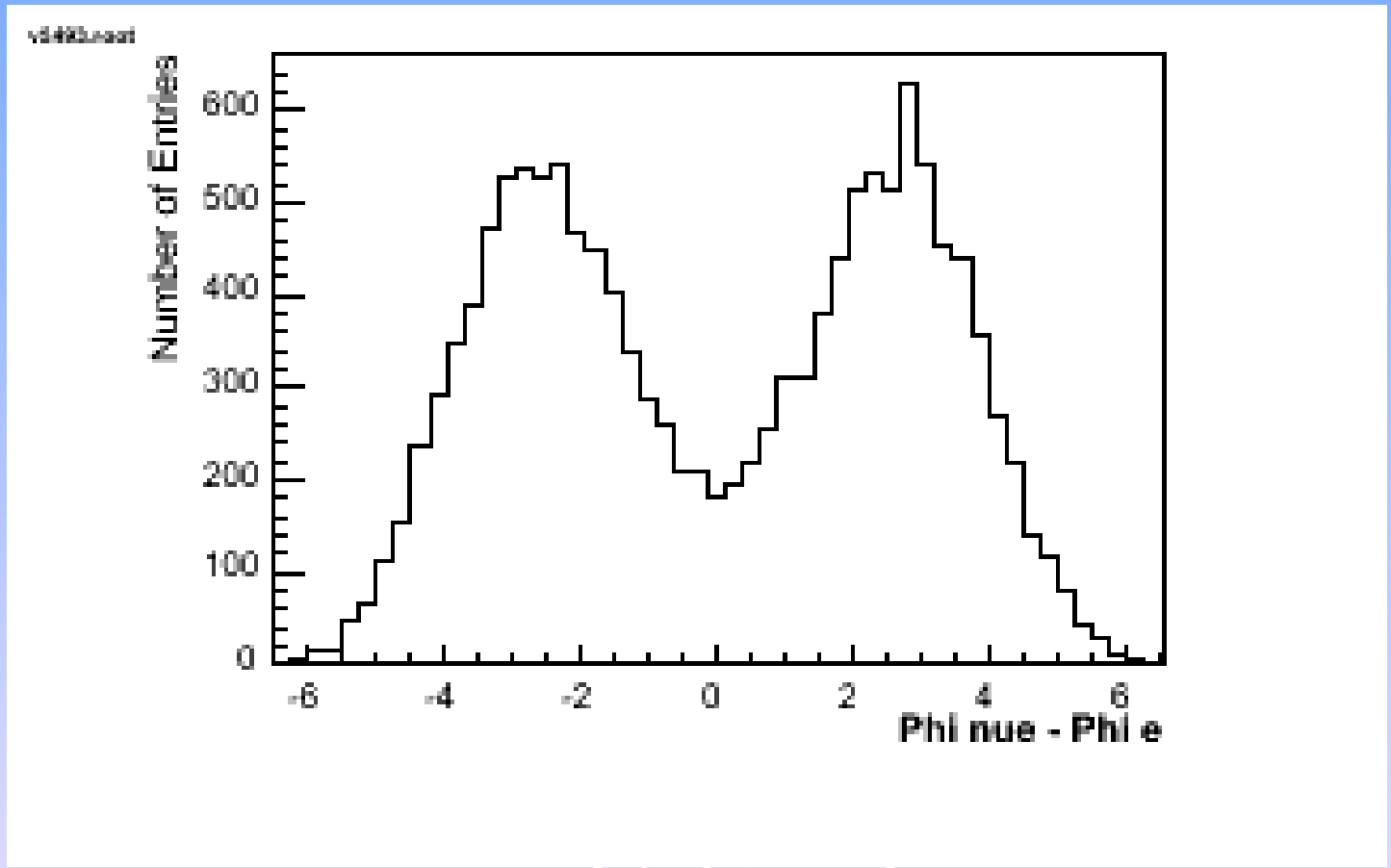
Lepton Correlations:e-ν_e



$\Delta\phi$ (e,ν_e)

e,$\nu_e$anticorrelated in ϕ

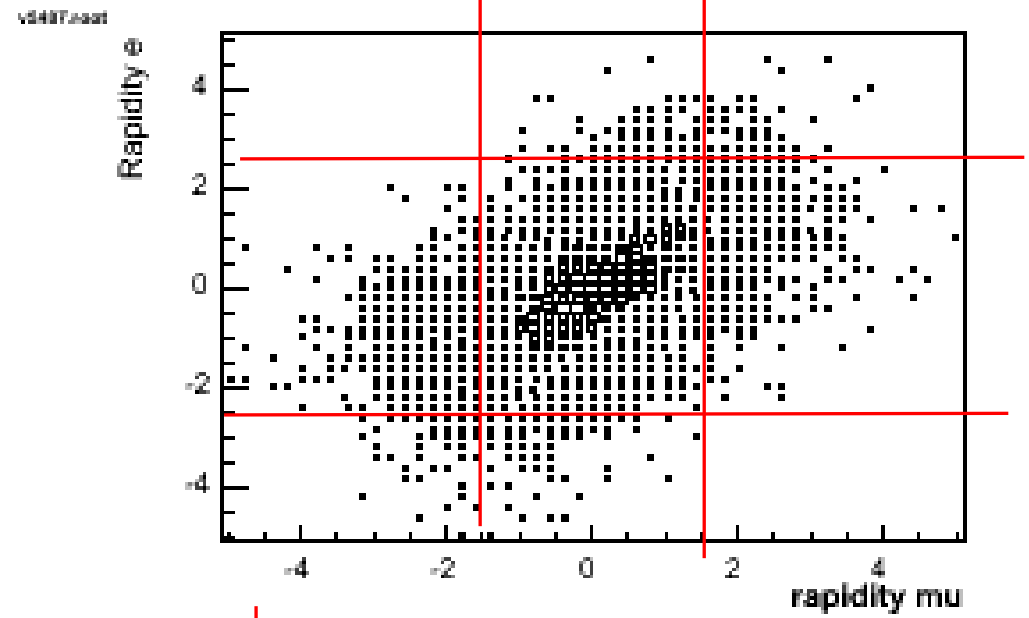
Lepton Correlations:e-ν_e

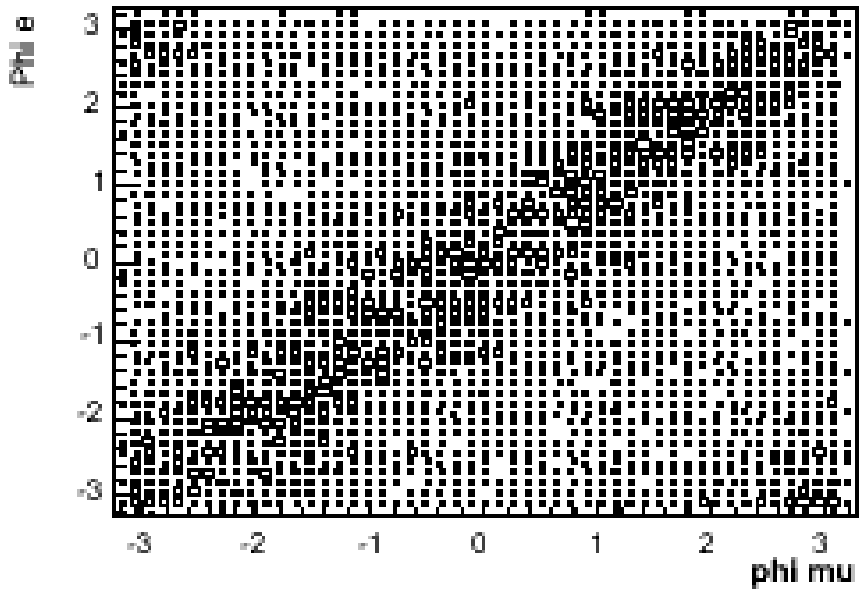


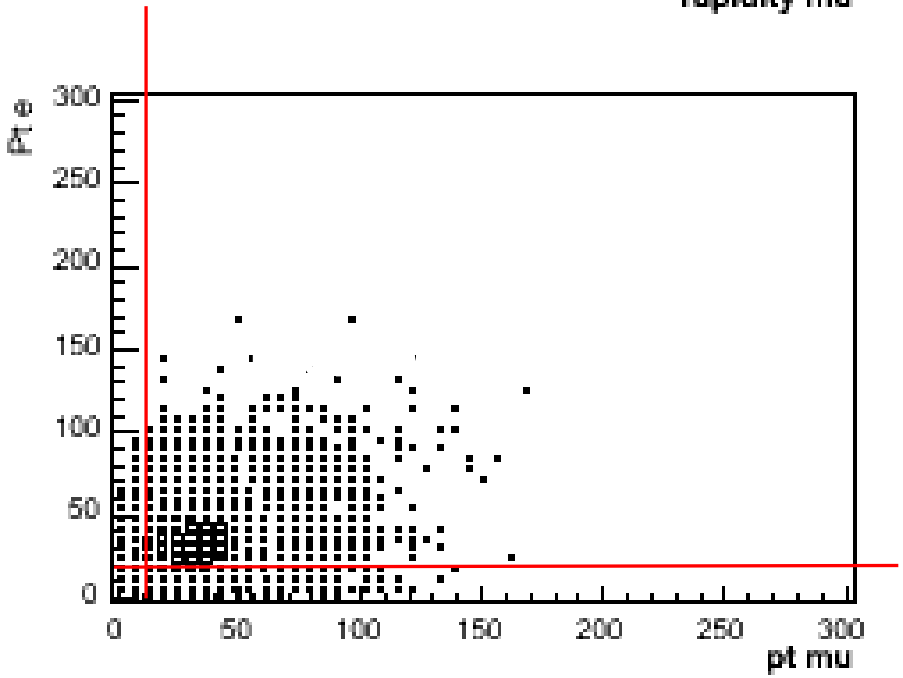
$\Delta\phi$ (e,ν_e)

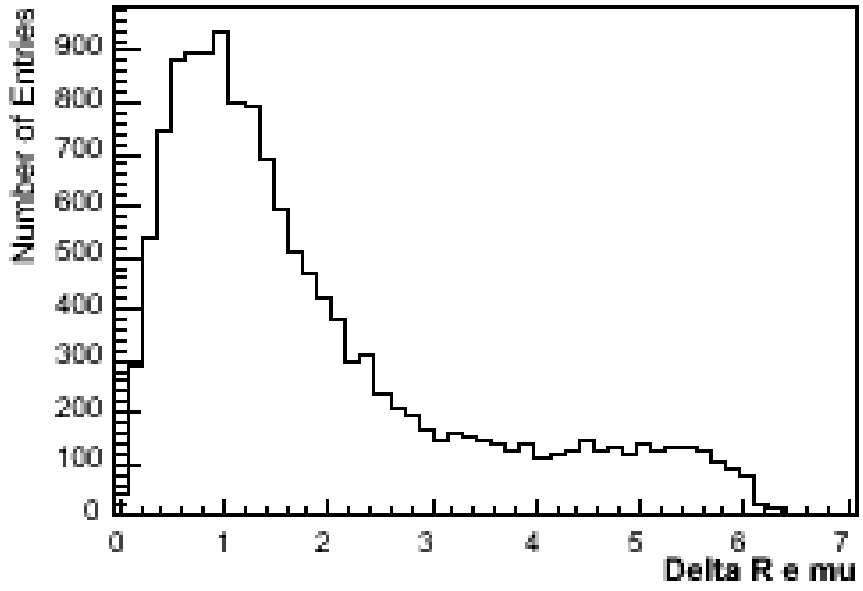
e,ν_e anticorrelated less sharply in ϕ

Lepton Correlations: e-μ

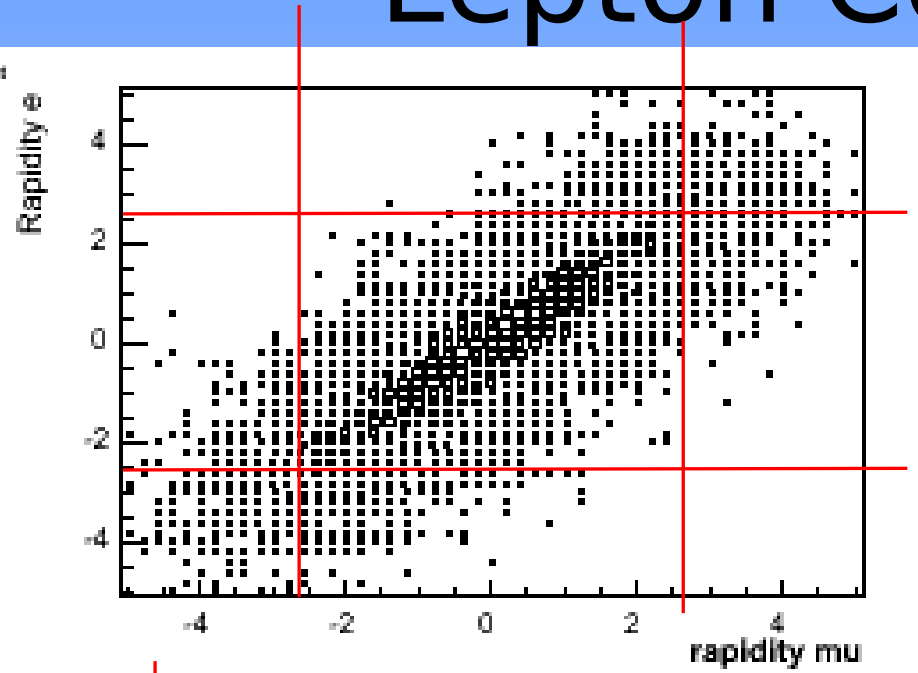


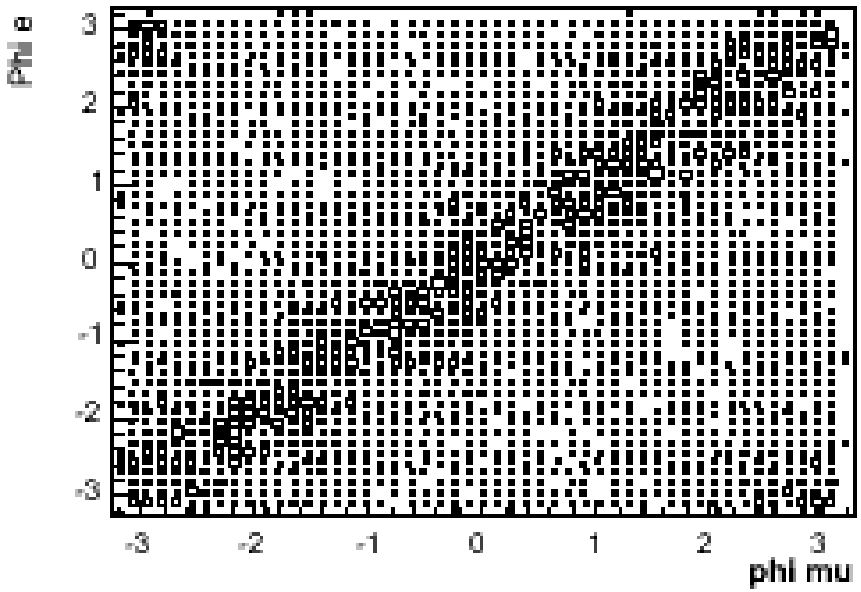


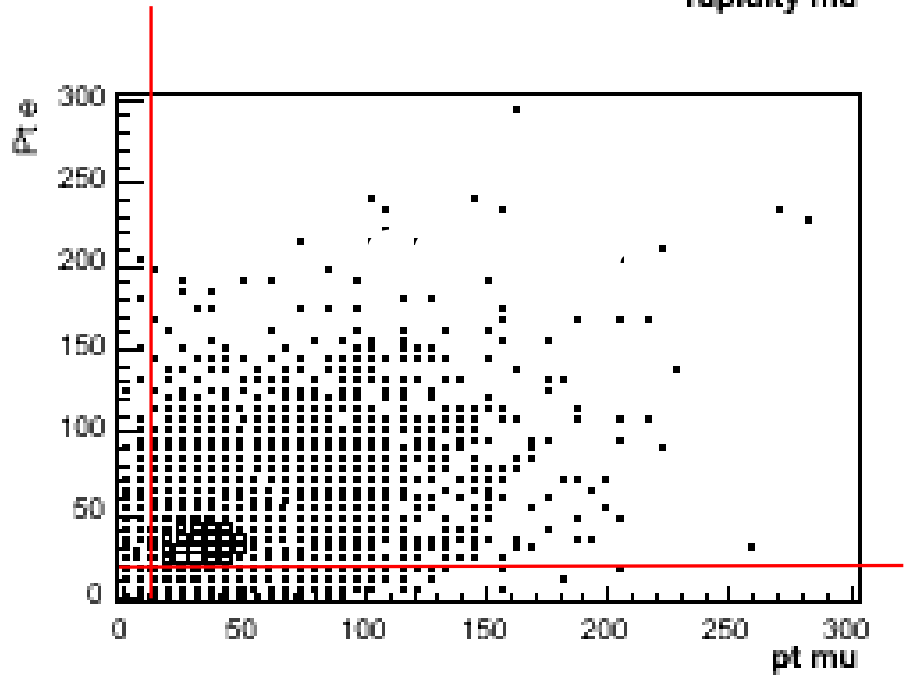


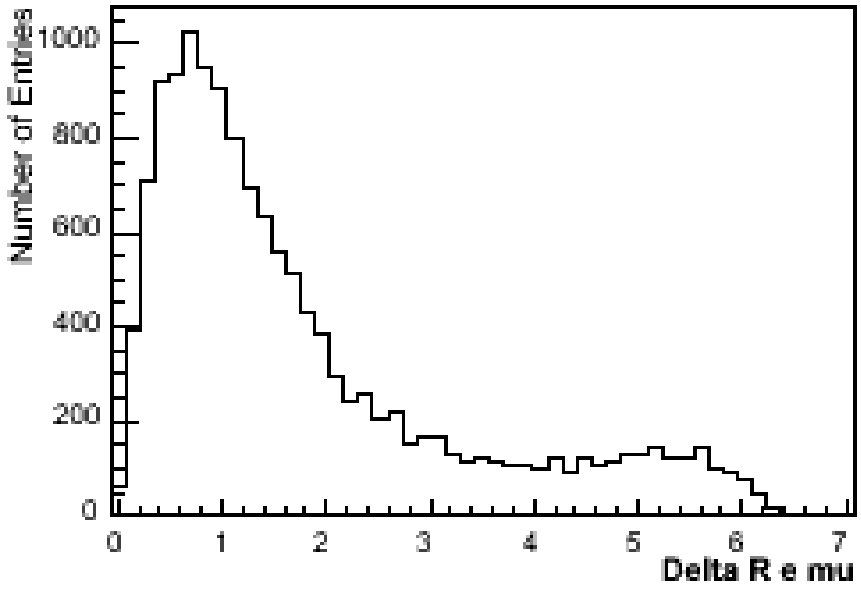


Lepton Correlations





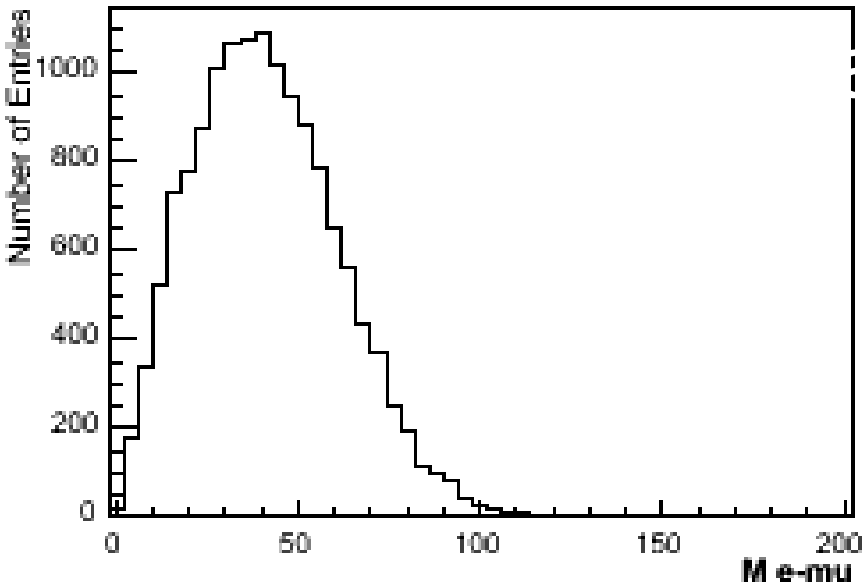


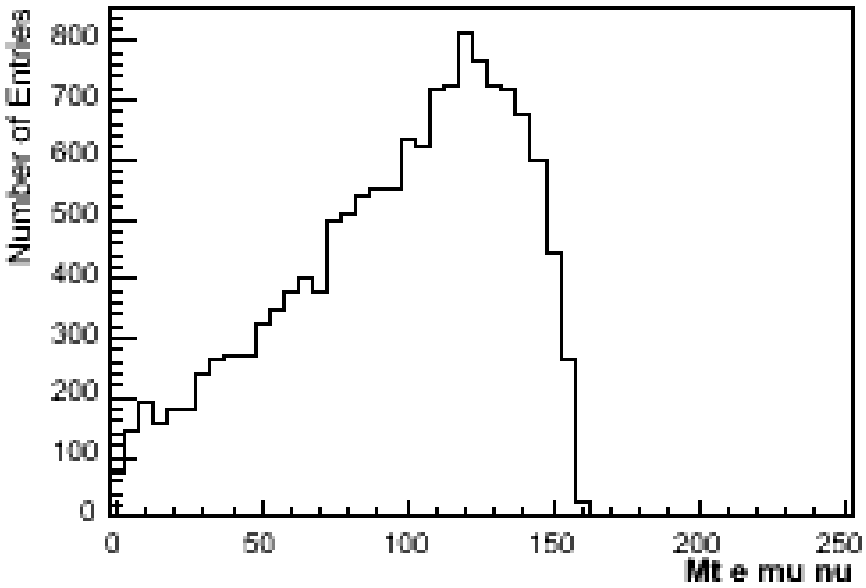


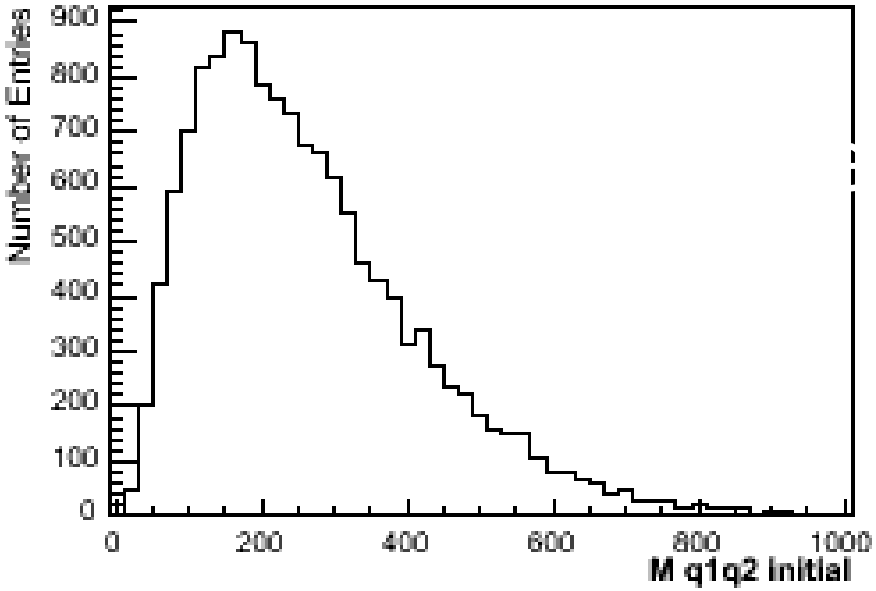
Tev, M_H=160

Masses

Mt for e μ ν



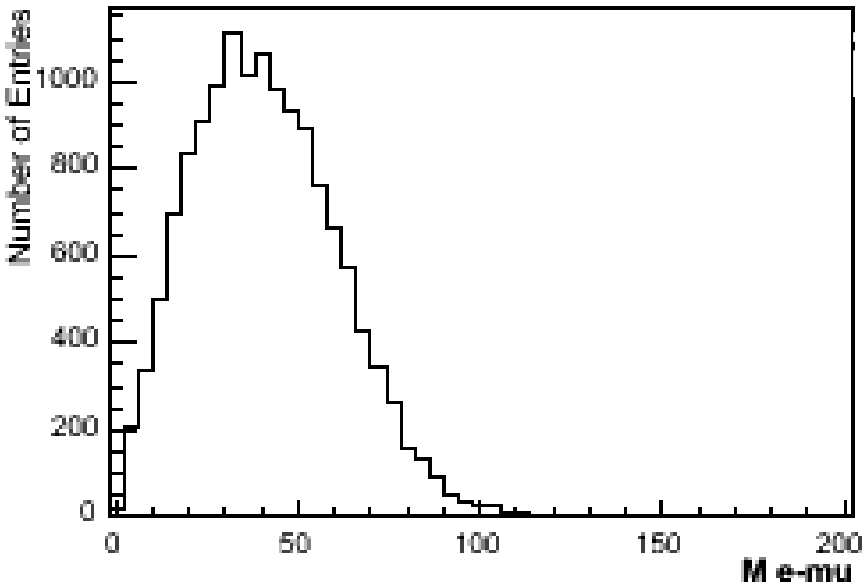


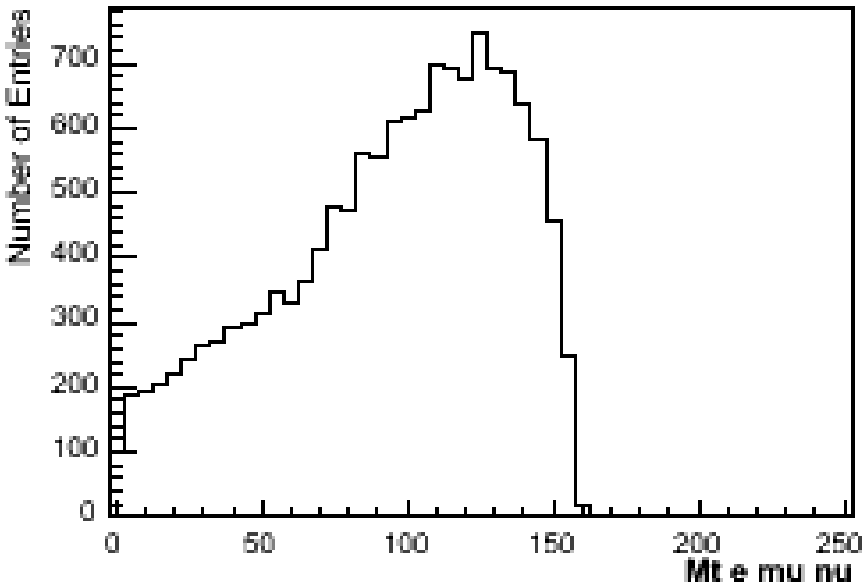


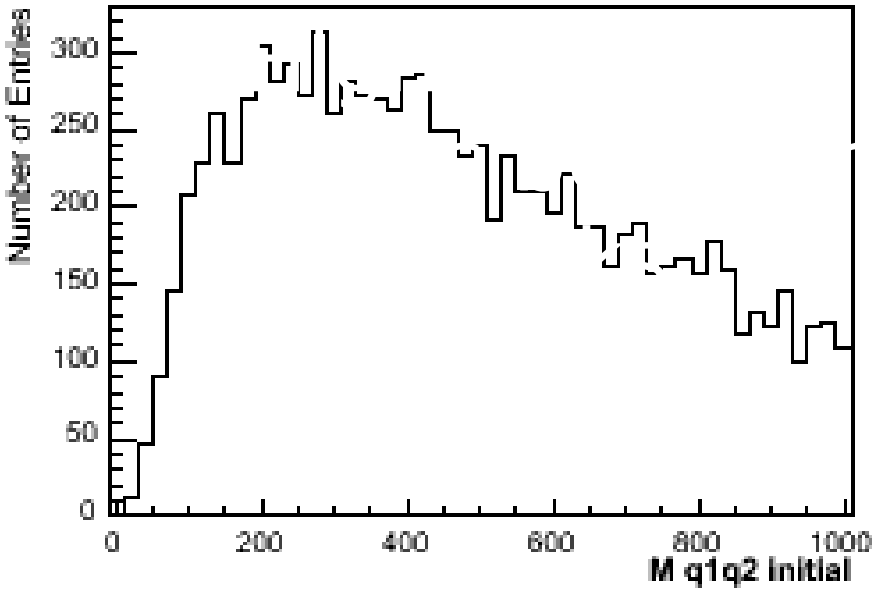
LHC, M_H=160

Masses

Mt for e μ ν

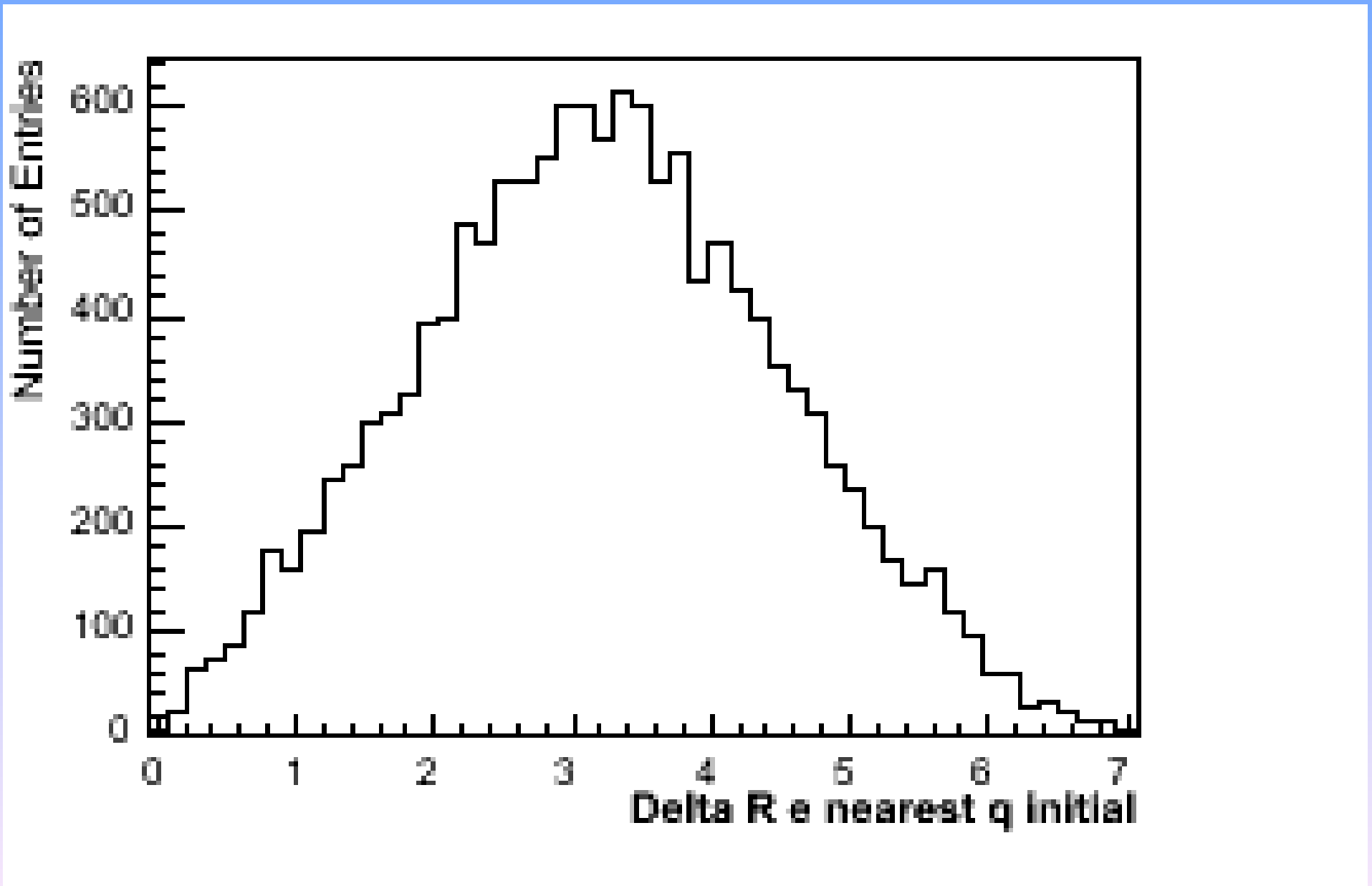






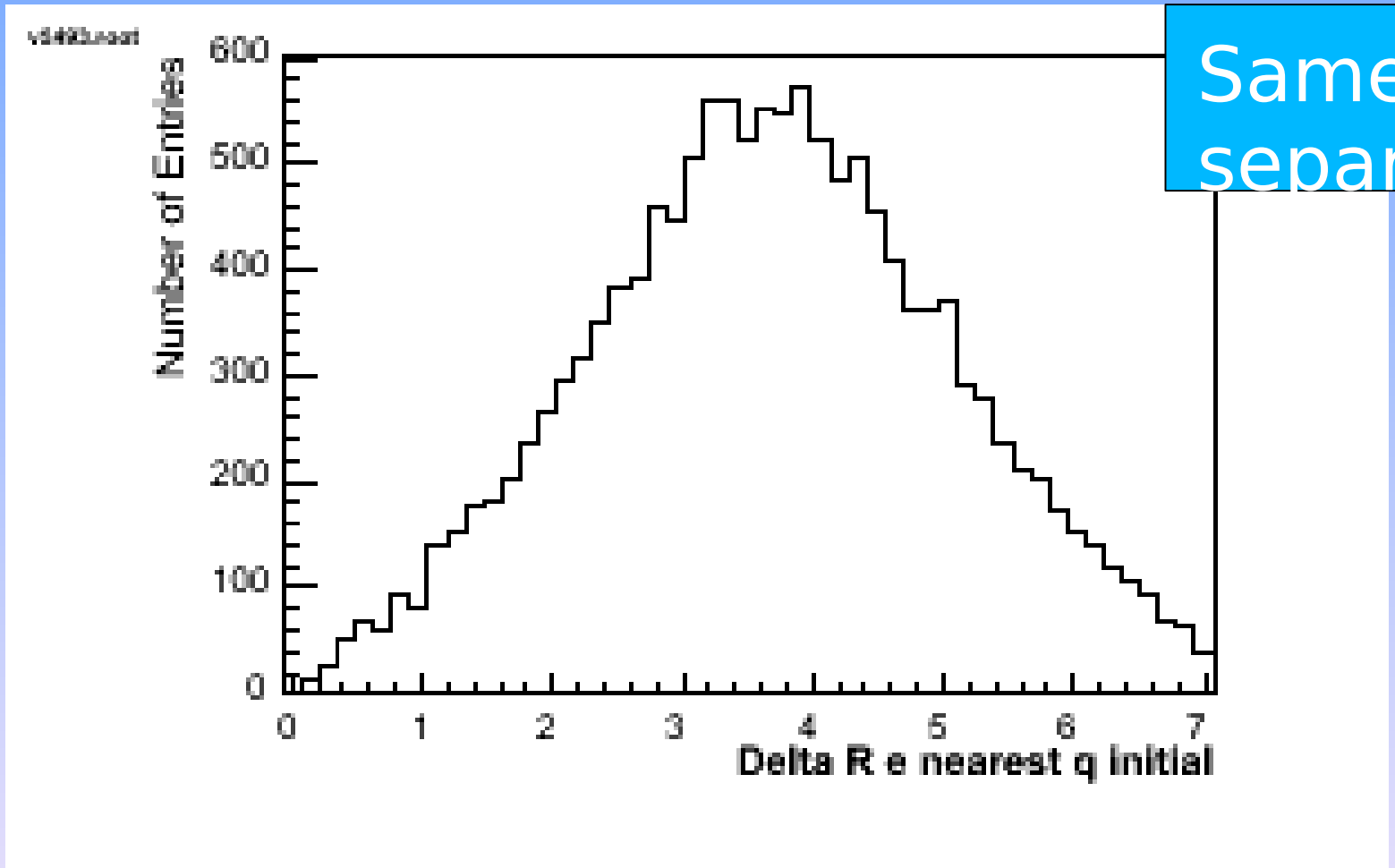
Tev, M_H=160

Electron-Jet Separation



LHC, M_H=160

Electron-Jet Separation



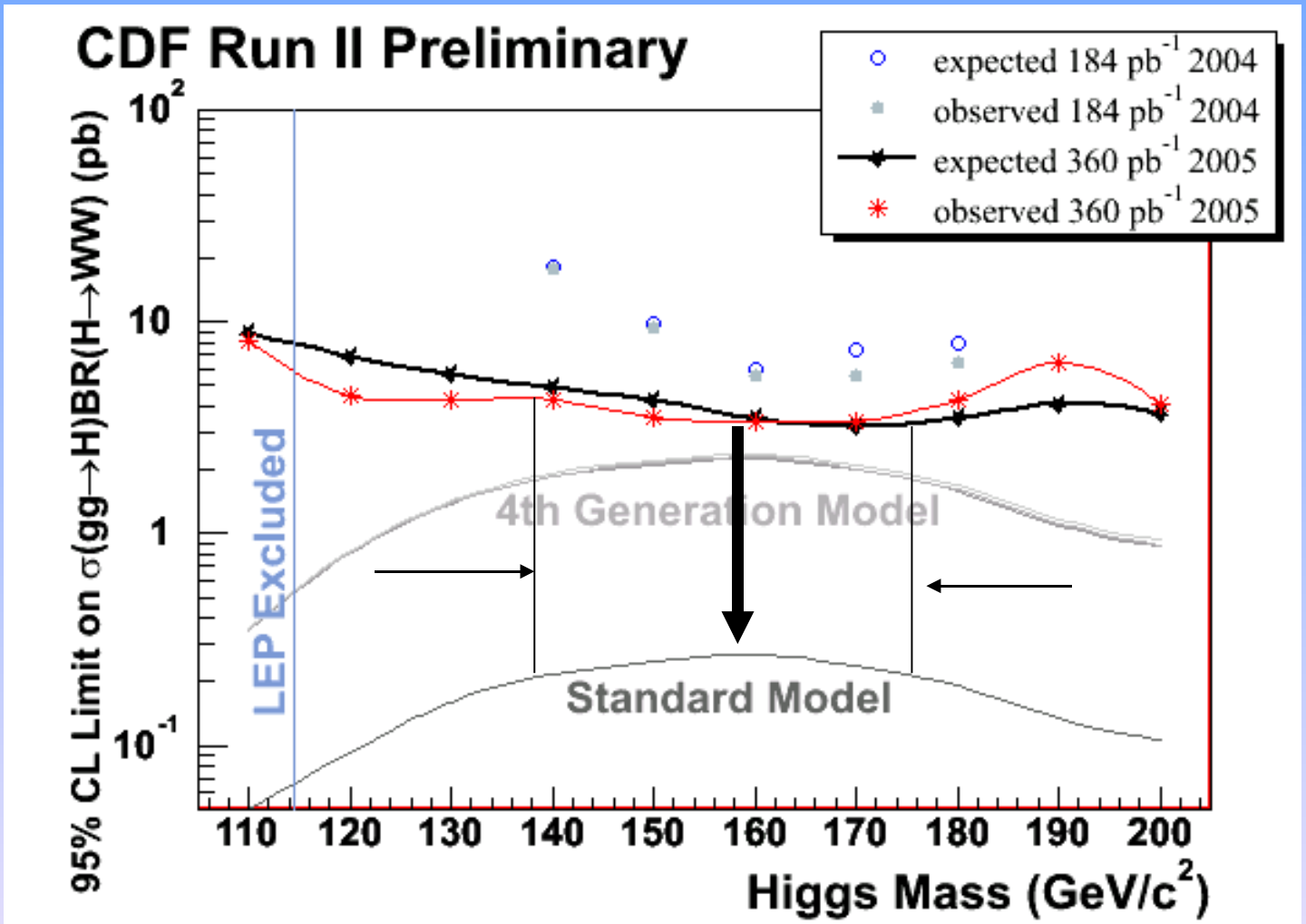
Same l-j separation

Summary/Conclusions

- CDF/ATLAS interest in W decay modes.
- Detector expertise/studies in Z,W to leptons: Where our efforts should be.
- Some jets interest, but not absolutely needed.
- WW is the right laboratory for studying EW Sym Breaking.
- Tevatron will have clear statements from Direct and Indirect searches when LHC searchs get serious.

Backup

HWW

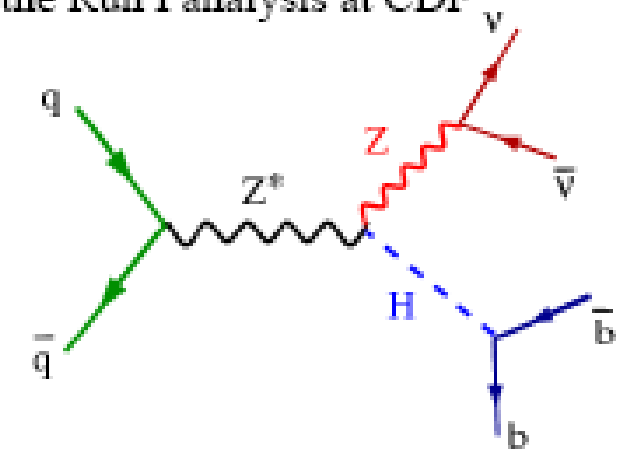

CDF Run II Preliminary
expected 184 pb-1 2004
observed 184 pb-1 2004
expected 360 pb-1 2005
observed 360 pb-1 2005
95% CL Limit on σ(gg→H)BR(H→WW) (pb)
10^2
10
1
10^-1
LEP Excluded
4th Generation Model
Standard Model
110
120
130
140
150
160
170
180
190
200
Higgs Mass (GeV/c^2)

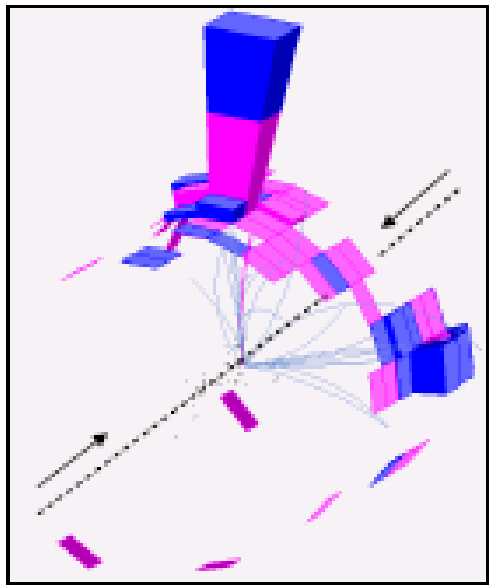
Z(νν)H(bb)

Selection

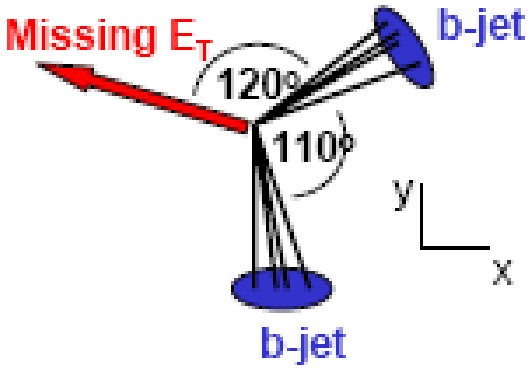
Select decay mode : $Z \rightarrow \nu\bar{\nu}$, $H \rightarrow b\bar{b}$

- This signature proved to be the most sensitive in the Run I analysis at CDF





- Signal has a distinctive topology
  - Large missing transverse energy
  - two jets (one is b-tagged)
- Trigger (MET35 + TWO JETS) on
  - Missing E_T > 35 GeV
  - Two jets E_T > 20 GeV



Acceptance

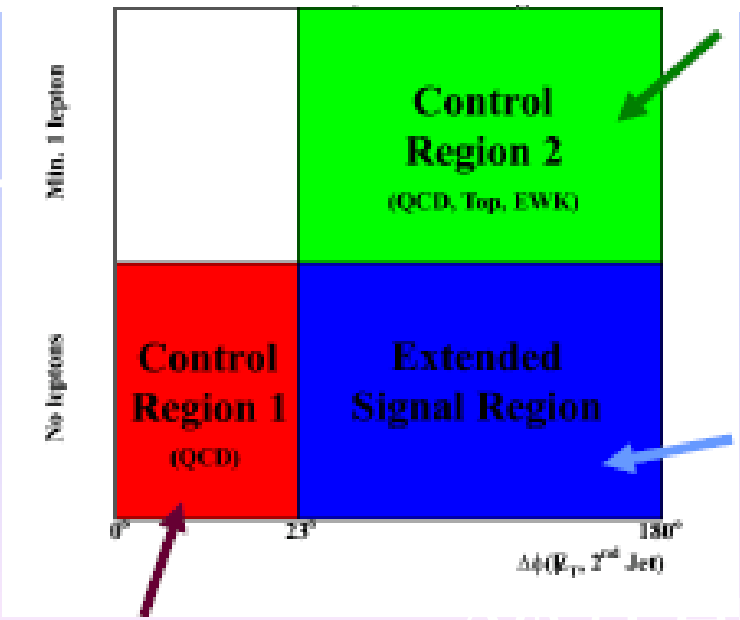
Mass (GeV)	Observed events	SM prediction	Higgs signal acceptance	Expected Limit (pb)	Observed Limit (pb)
90	6	7.18	0.45%	6.3 ± 1.2	5.4
100	7	7.07	0.55%	5.1 ± 1.0	5.0
110	7	5.9	0.64%	4.6 ± 1.4	5.2
115	7	5.9	0.67%	4.3 ± 1.4	4.8
120	6	4.36	0.73%	3.6 ± 1.4	4.5
130	8	4.11	0.77%	3.2 ± 1.0	5.2

Background

Process	Control Region 1	Control Region 2	Signal Region
QCD multi-jet	9.5 ± 4.3	5.2 ± 3	2.6 ± 1.7
TOP	0.01 ± 0.002	8.9 ± 2.3	2.1 ± 0.4
Di-boson	0 ± 1.2	1.5 ± 0.3	1.1 ± 0.2
W + h.f.	0 ± 1.2	9.7 ± 3.5	3.7 ± 2.6
Z + h.f.	0 ± 0.18	1.1 ± 0.3	3.2 ± 1.2
Mistag	2.9 ± 0.4	11.9 ± 2.3	7.0 ± 1.0
Total Expected BCK	12.4 ± 4.6	38.3 ± 5.7	19.7 ± 3.5
Observed	16	47	19

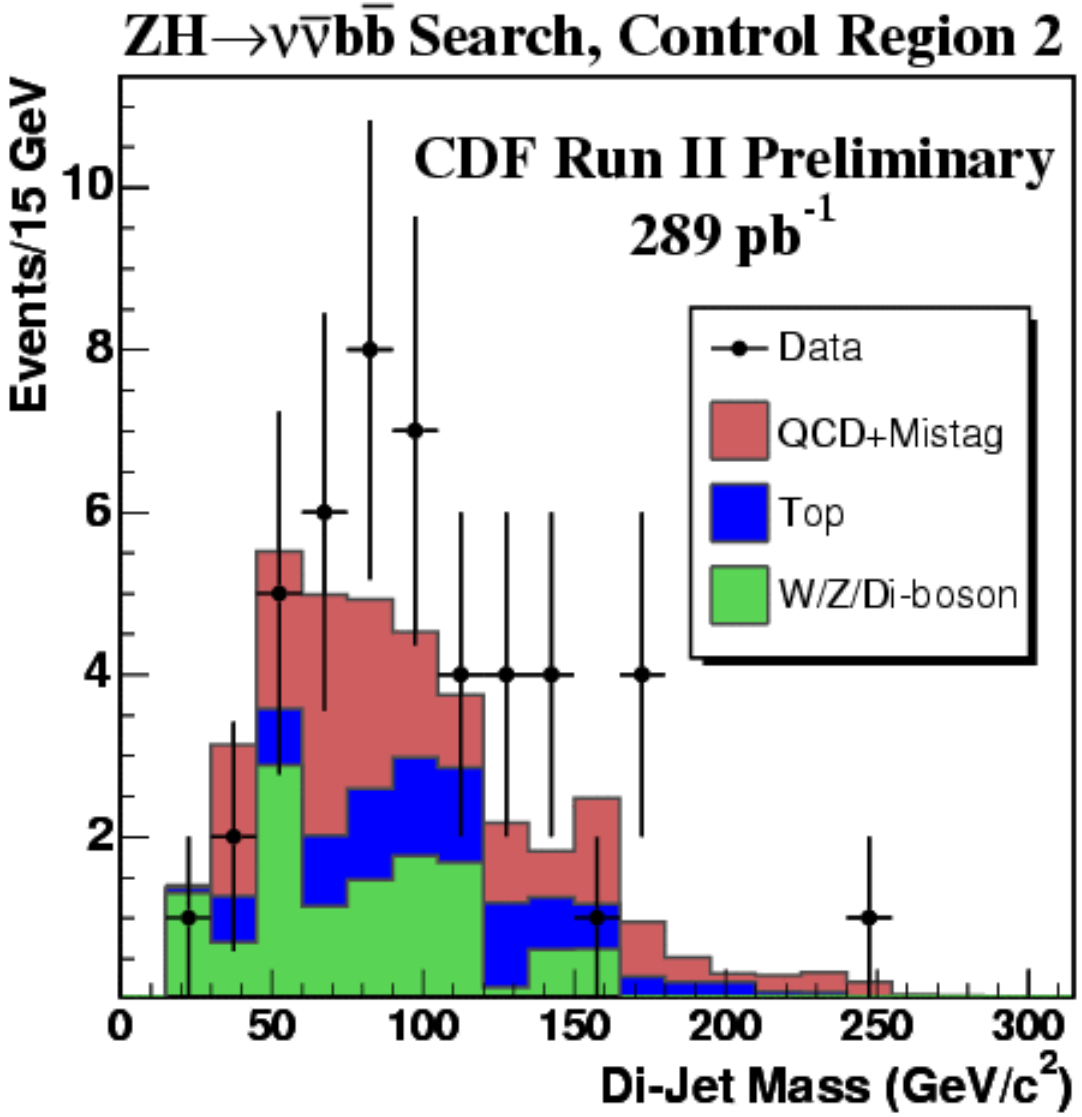
Lepton>=1

No Lepton

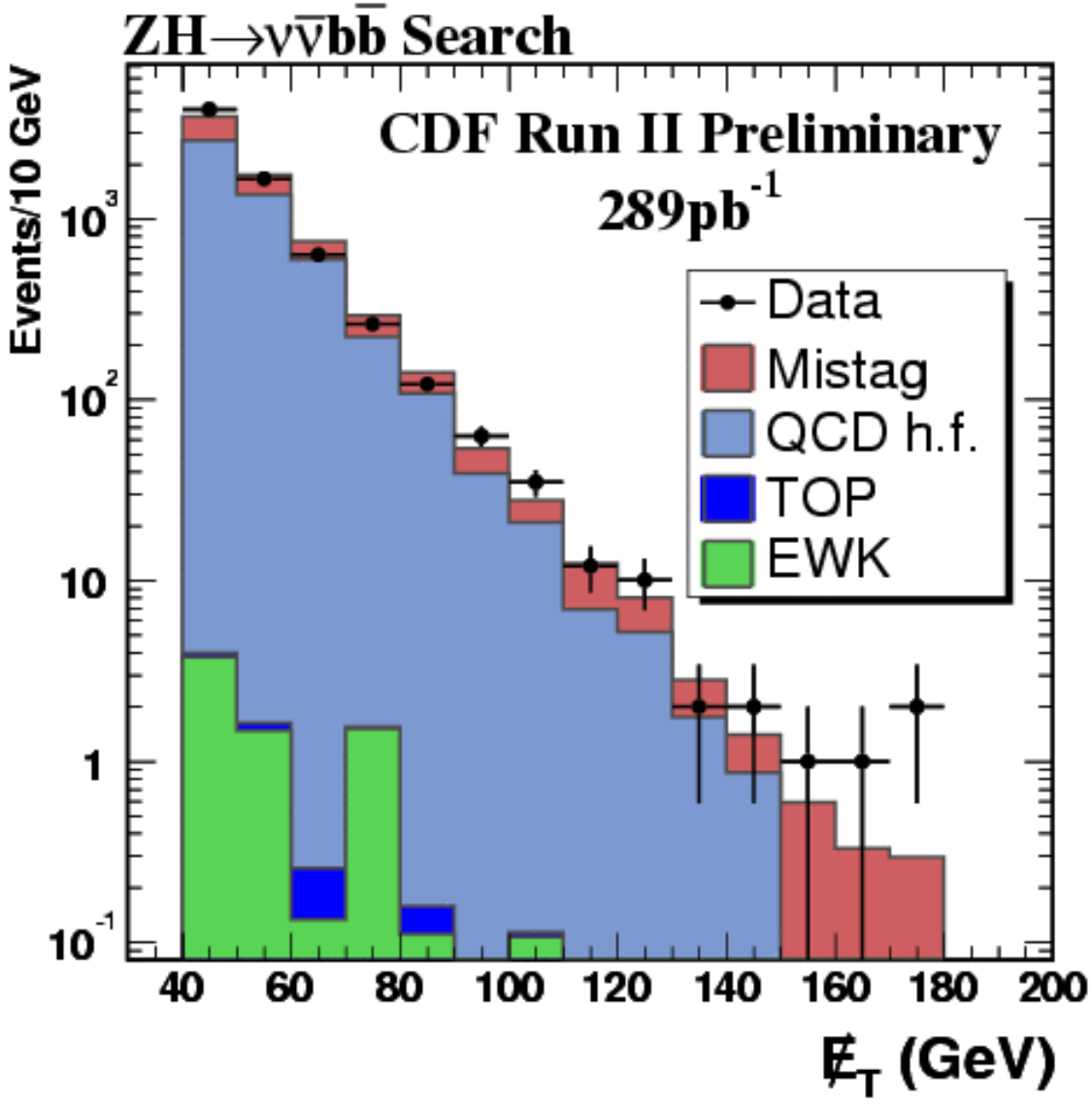


Δφ (Lepton-jet)

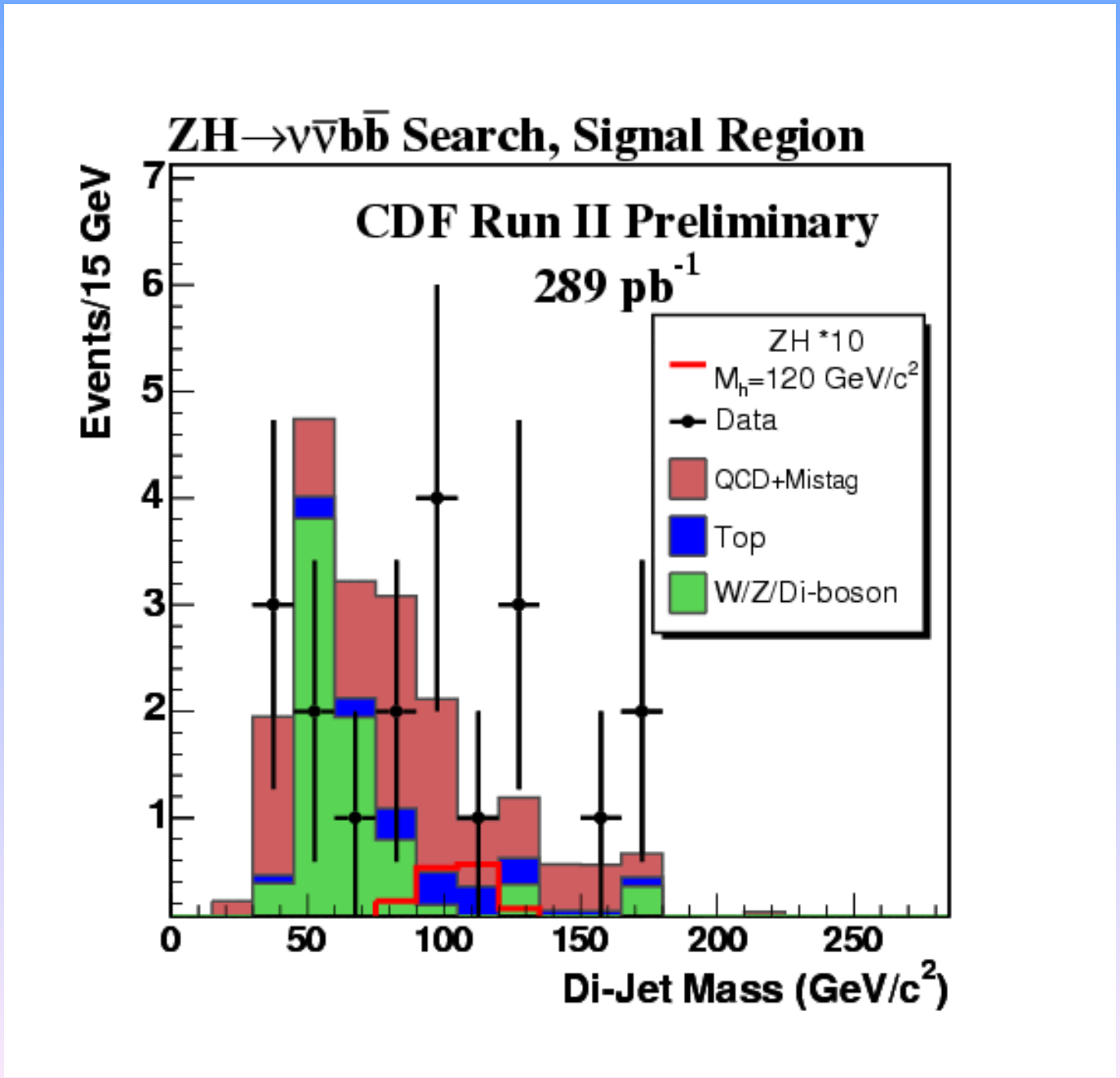
Control Region 2



Control Region 1

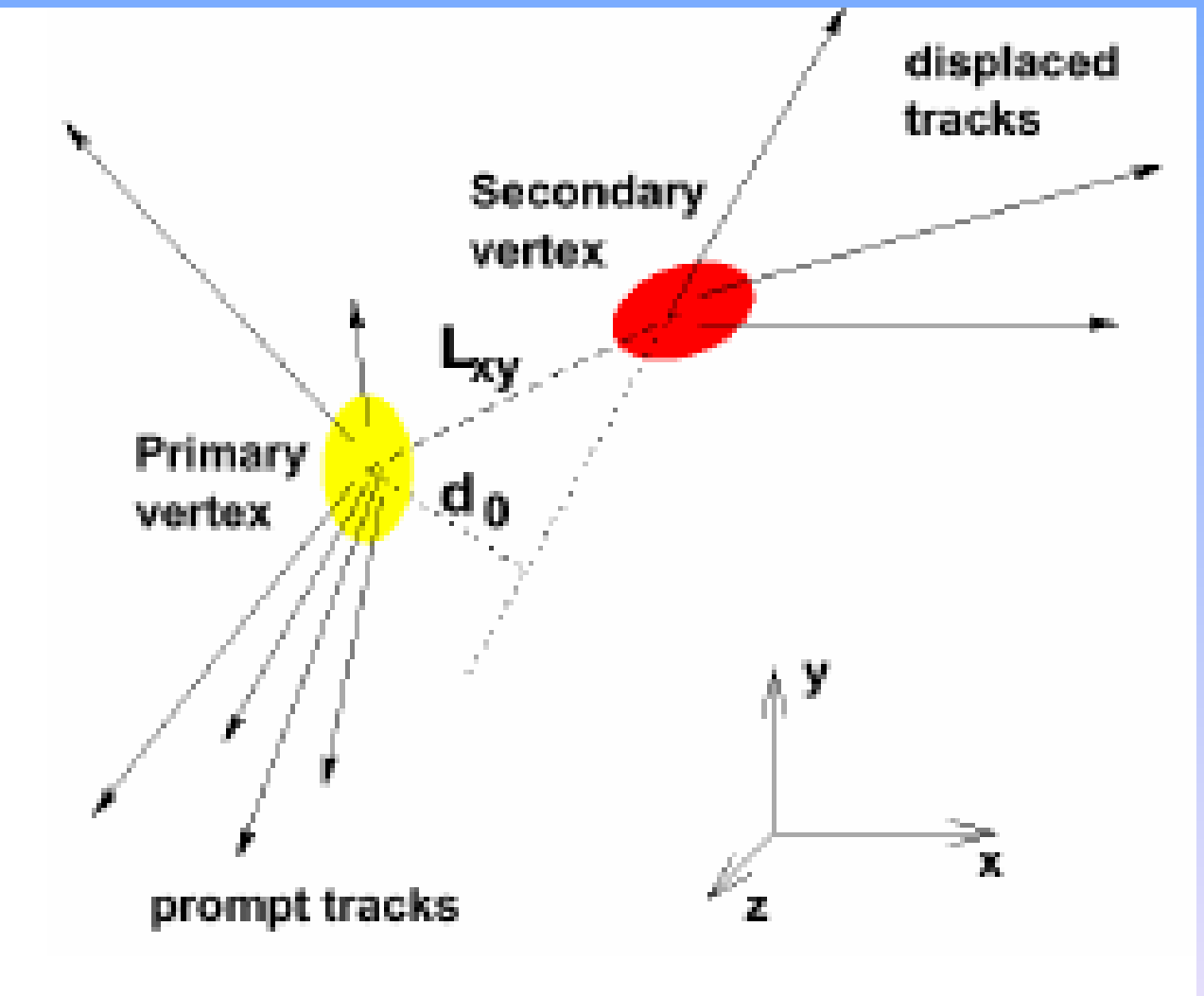


Result (Signal Region)



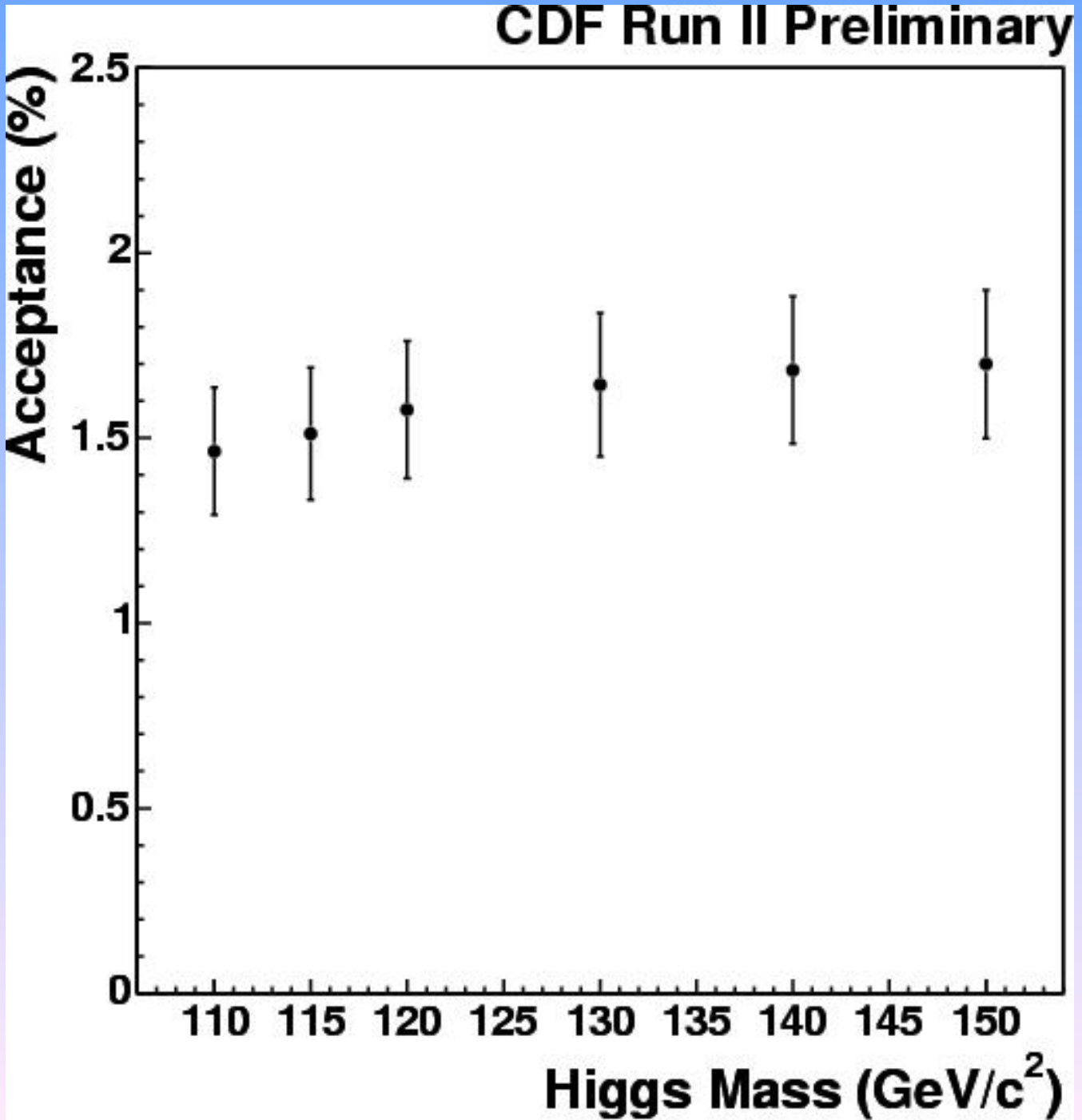
W(lν)H(bb)

Selection



- High Pt Lepton
- Missing Energy
- Displaced Vertex

Acceptance


CDF Run II Preliminary
Acceptance (%)
2.5
2
1.5
1
0.5
0
110
115
120
125
130
135
140
145
150
Higgs Mass (GeV/c^2)

Background(>=1 tag)

W + Jets

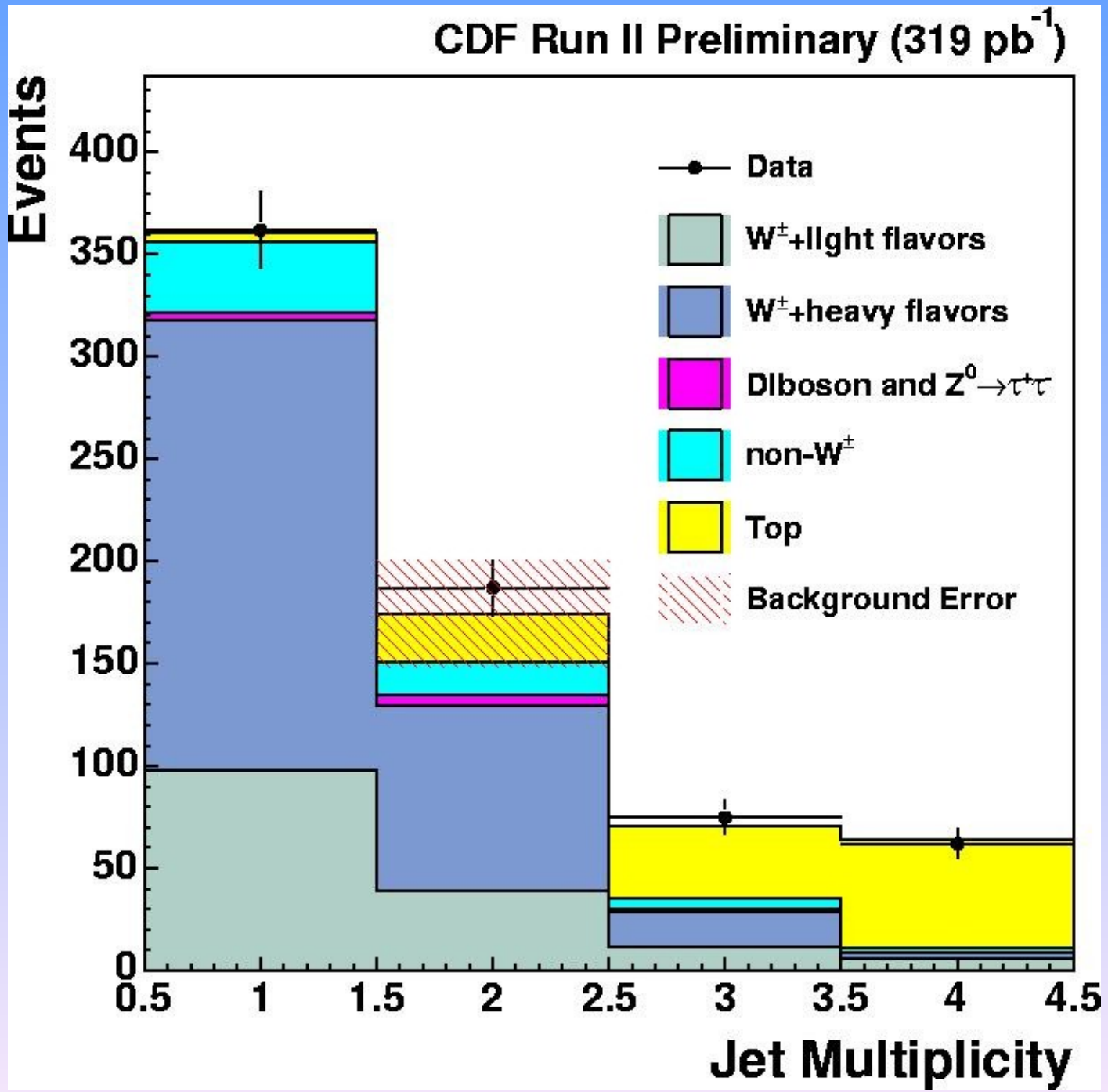
Background	$W^{\pm}+1$ jet	$W^{\pm}+2$ jets	$W^{\pm}+3$ jets	$W^{\pm}+\geq 4$ jets
Events before tagging	26218	3910	602	160
Mistags	98.0 ± 7.9	39.3 ± 3.1	12.1 ± 1.2	5.9 ± 0.8
$W^{\pm}+b\bar{b}$	99.3 ± 34.2	54.0 ± 18.4	10.5 ± 3.5	1.6 ± 0.7
$W^{\pm}+c\bar{c}$	37.6 ± 13.0	19.5 ± 6.6	4.2 ± 1.4	0.7 ± 0.3
$W^{\pm}+c$	83.2 ± 20.9	16.8 ± 4.3	2.2 ± 0.6	0.3 ± 0.1
Diboson ($Z^0 \rightarrow \tau^+\tau^-$)	3.7 ± 0.9	5.0 ± 1.1	1.5 ± 0.5	0.3 ± 0.1
non-$W^{\pm}$	34.3 ± 6.3	16.5 ± 3.2	4.8 ± 1.0	1.9 ± 0.4
single top	3.4 ± 0.7	9.6 ± 2.0	2.0 ± 0.5	0.4 ± 0.1
$t\bar{t}$	1.2 ± 0.2	14.1 ± 2.5	34.3 ± 6.0	54.2 ± 9.5
Total Background	360.6 ± 52.7	174.7 ± 26.3	71.6 ± 8.7	65.3 ± 9.9
Observed positive tags	362	187	75	62

Table 1: The number of observed positive tagged events and the background summary for an integrated luminosity of 318.5 pb^{-1} for CEM and CMUP and 305.2 pb^{-1} for CMX.

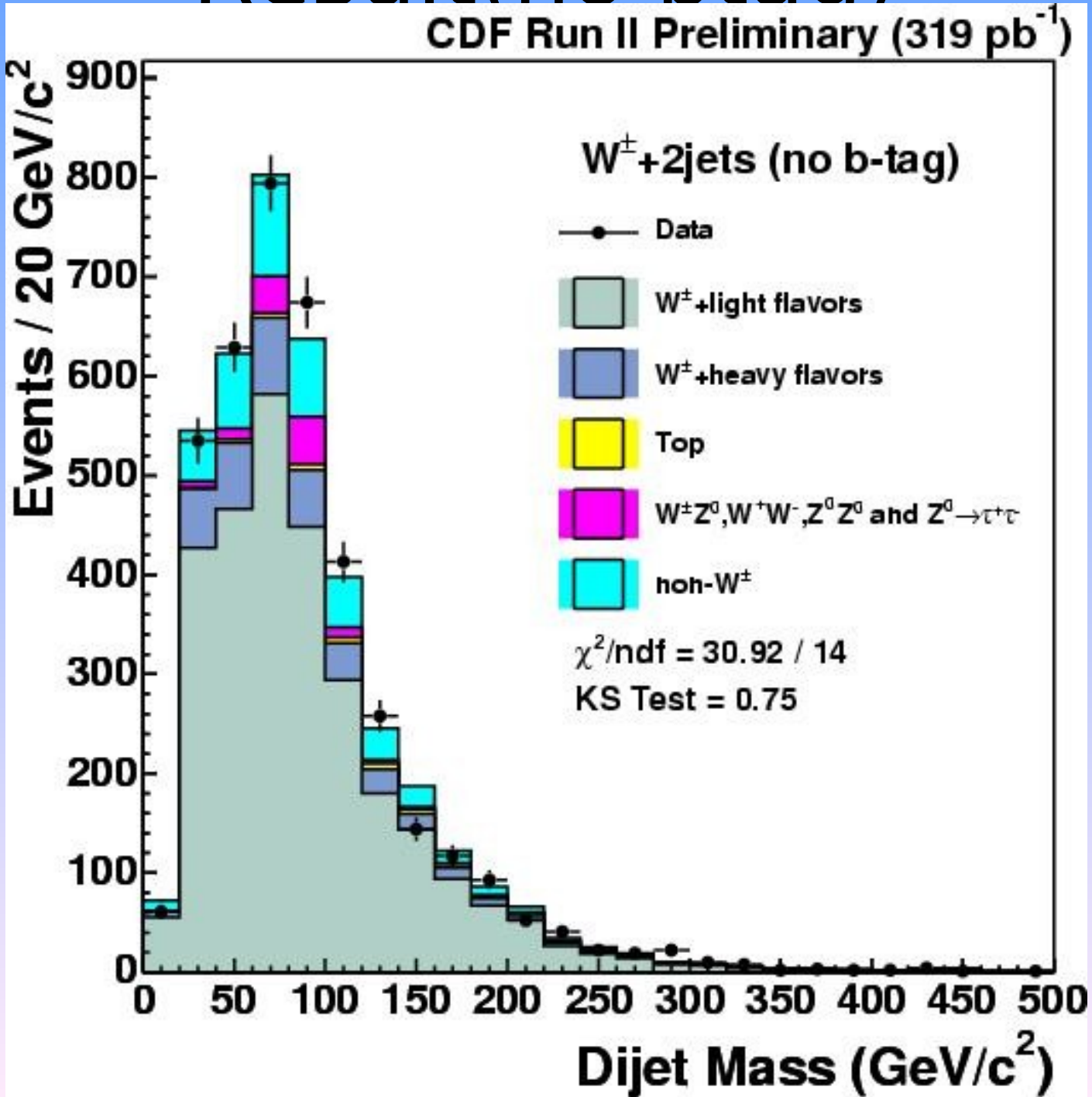
Background(2 tags)

Background	$W^{\pm}+2$ jets	$W^{\pm}+3$ jets	$W^{\pm}+\geq 4$ jets
Mistags	1.03 ± 0.11	0.41 ± 0.06	0.21 ± 0.03
$W^{\pm}+b\bar{b}$	8.04 ± 2.96	1.32 ± 0.47	0.25 ± 0.12
$W^{\pm}+c\bar{c}$	0.41 ± 0.15	0.08 ± 0.03	0.02 ± 0.01
non-$W^{\pm}$	0.38 ± 0.13	0.31 ± 0.11	0.12 ± 0.04
Diboson/$Z^0 \rightarrow \tau^+\tau^-$	0.34 ± 0.06	0.10 ± 0.03	0.02 ± 0.00
single top	1.30 ± 0.30	0.43 ± 0.12	0.09 ± 0.04
$t\bar{t}$	3.12 ± 0.54	8.31 ± 1.45	15.98 ± 2.78
Total Background	14.62 ± 2.25	10.96 ± 1.68	16.69 ± 2.84
Observed positive tags	14	12	19

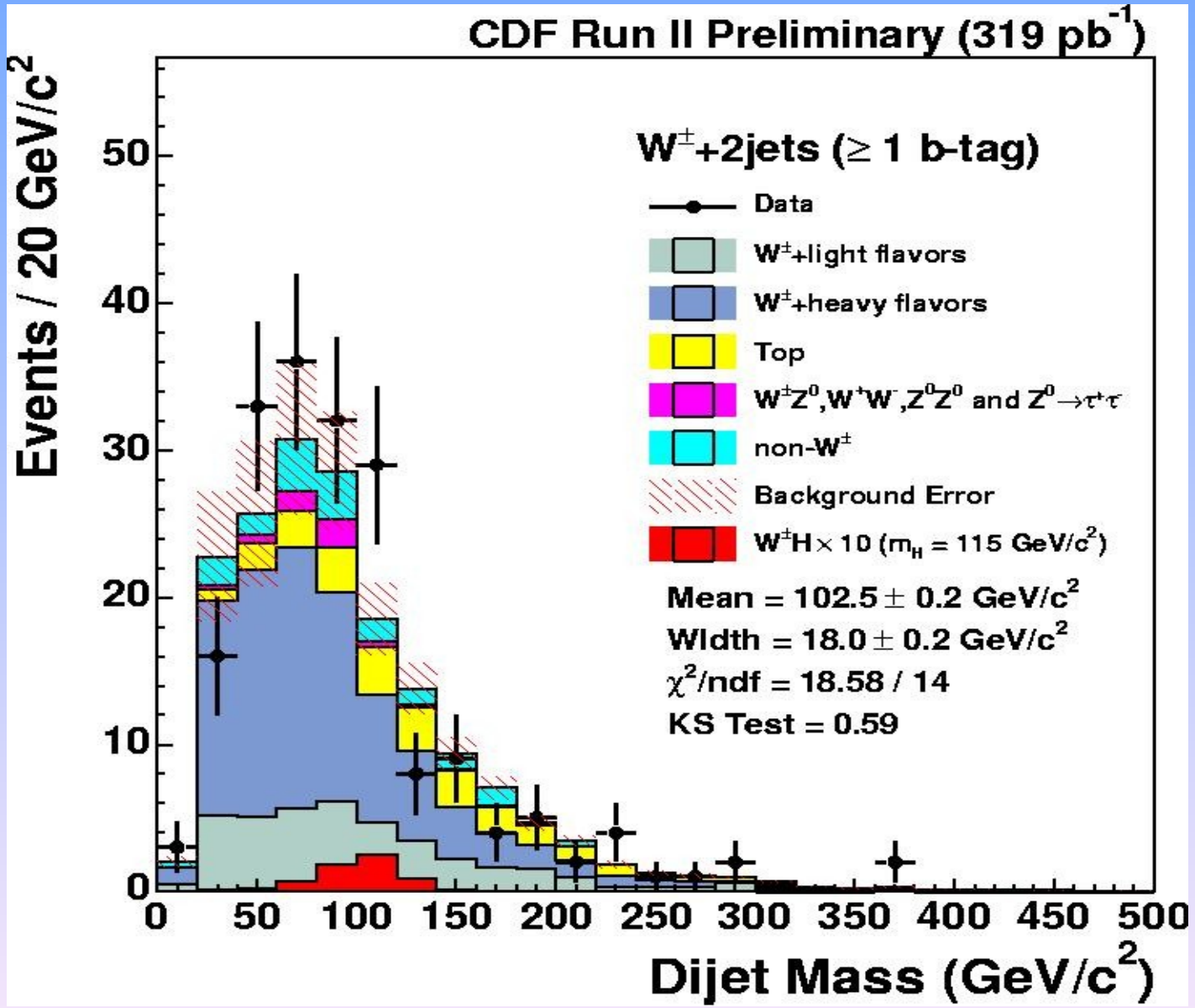
Table 2: The number of observed double positive tagged events and the background summary for an integrated luminosity of 318.5 pb^{-1} for CEM and CMUP and 305.2 pb^{-1} for CMX.


CDF Run II Preliminary (319 pb^{-1})
Events
400
350
300
250
200
150
100
50
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Jet Multiplicity
Data
W$^{\pm}$+llght flavors
W$^{\pm}$+heavy flavors
Dlboson and Z$^{0}\rightarrow\tau^{+}\tau^{-}$
non-W$^{\pm}$
Top
Background Error

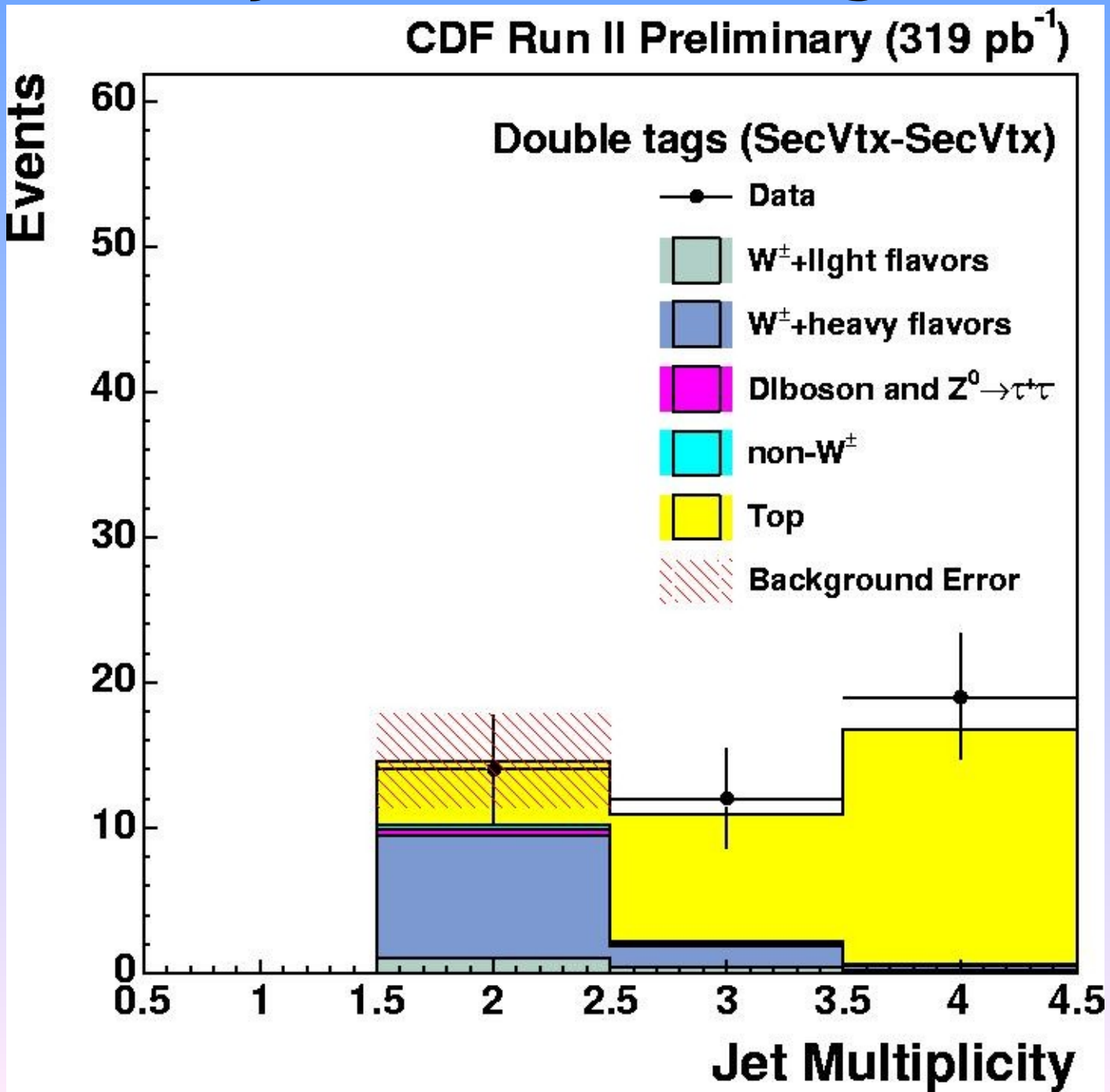
Result(no btag)



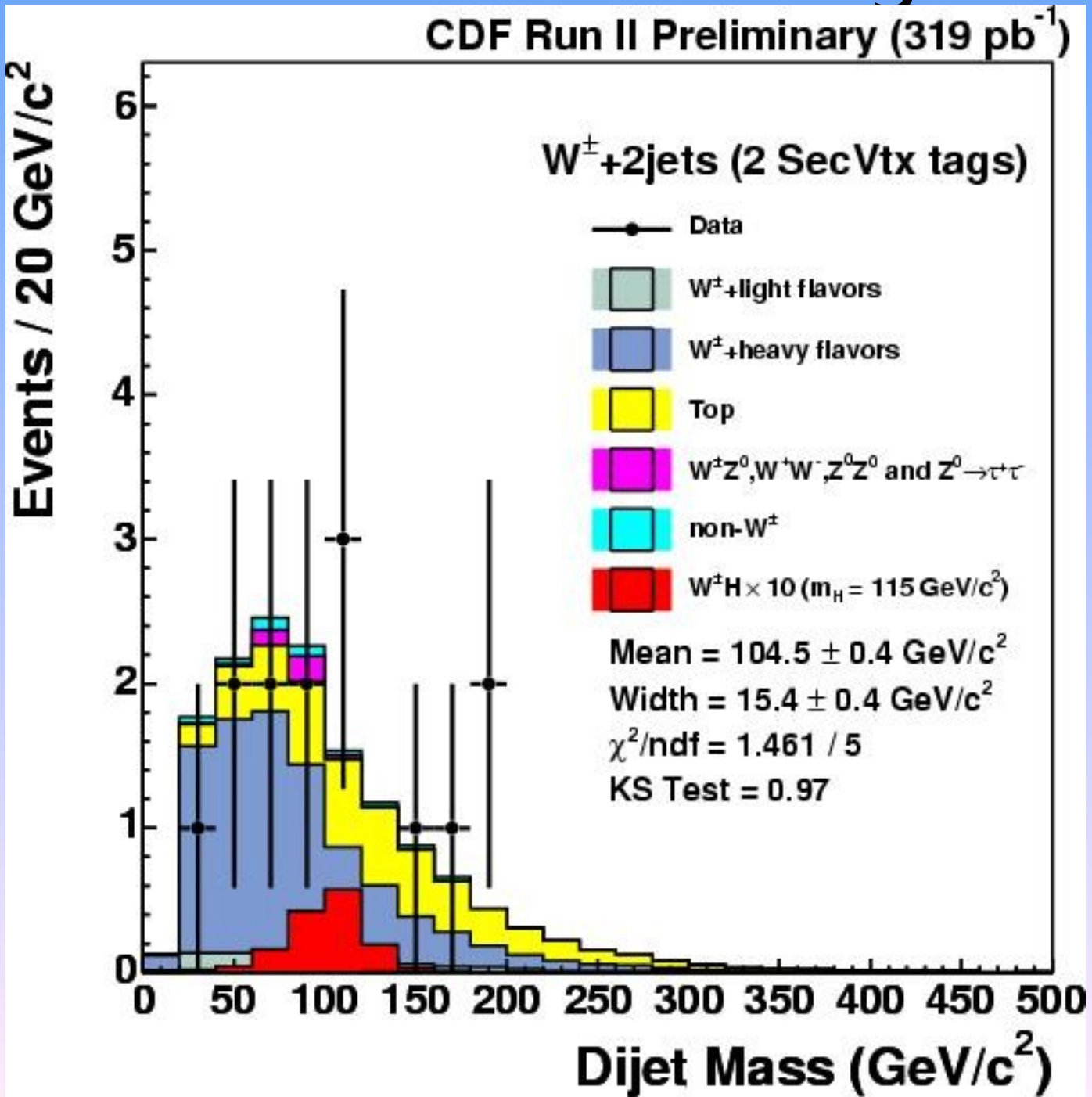
Result (>=1 btag)



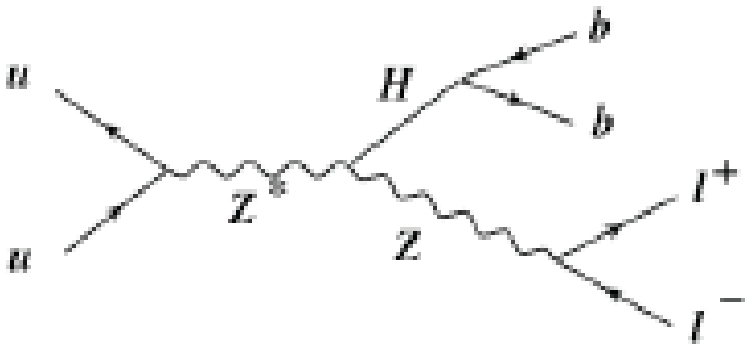
Njet (>=2 btag)

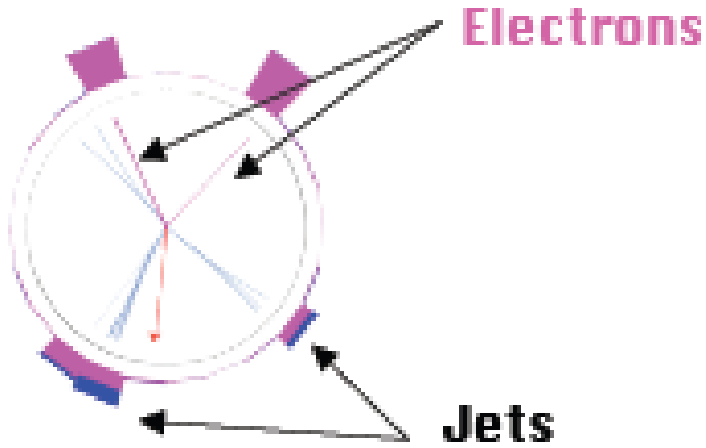

CDF Run II Preliminary (319 pb^{-1})
Double tags (SecVtx-SecVtx)
Data
W$^{\pm}$+llght flavors
W$^{\pm}$+heavy flavors
Dlboson and Z$^{0}\rightarrow\tau^{+}\tau$
non-W$^{\pm}$
Top
Background Error
Events
0
10
20
30
40
50
60
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Jet Multiplicity

Result >=2 btag



Z(ll)H(bb)
No RunII Results Yet





- **Basic Event Selection:**
  - 2 High Pt same-type leptons (*ee*, μμ)
    - in Z mass window
  - >= 2 High Et jets
  - >= 1 Tight SECVTX b-tag

- M_H = 110 GeV -> Acc 5.6 %
  - Acc*sigma*BR = 0.005 pb
- M_H = 115 GeV -> Acc 5.9 %
  - Acc*sigma*BR = 0.005 pb
- M_H = 130 GeV -> Acc 7.0 %
  - Acc*sigma*BR = 0.003 pb

denominator is ZH->l+l-bb (l = e,mu)

Sample	1 tight SECVTX	+1 loose jet prob	+ 2 NN Cuts
Z+l.f.	18 ± 6.0	0.7	0.5
Z+cc	24 ± 12	3.9	1.0
Z+bb	57 ± 19	18.0	4.3
Z+X	99 ± 35	22	5.9
ZZ	2.3 ± 0.4	1.0	0.5
ttbar	8.3 ± 1.6	4.8	0.57
Total	110	28	7.0
ZH (120)	0.69 ± 0.15	0.38	0.31

Signal & Backgrounds after event selection in 1 fb^{-1}

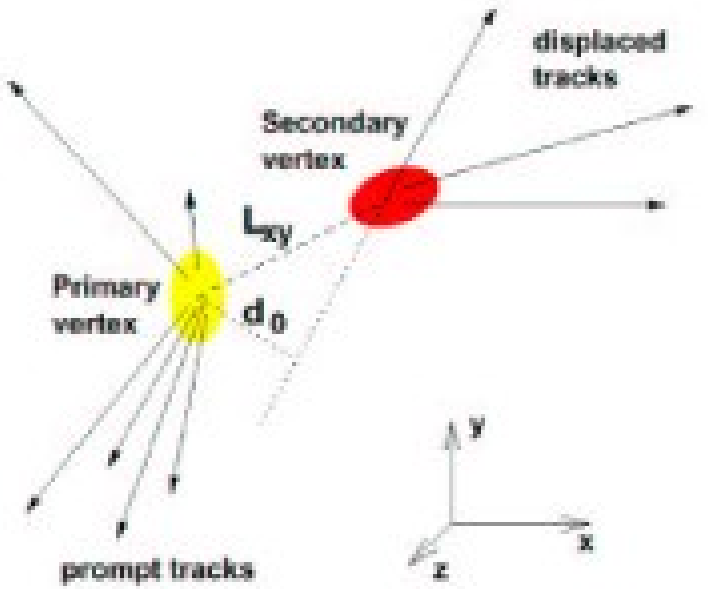
ttH
(No Run II result)

Event Selection for $t\bar{t}H$

For $m_H < 135$ GeV,
primary decay is $H \to b\bar{b}$

Look for signatures $W^+W^-b\bar{b}b\bar{b}$

Event identification relies heavily on b-tagging



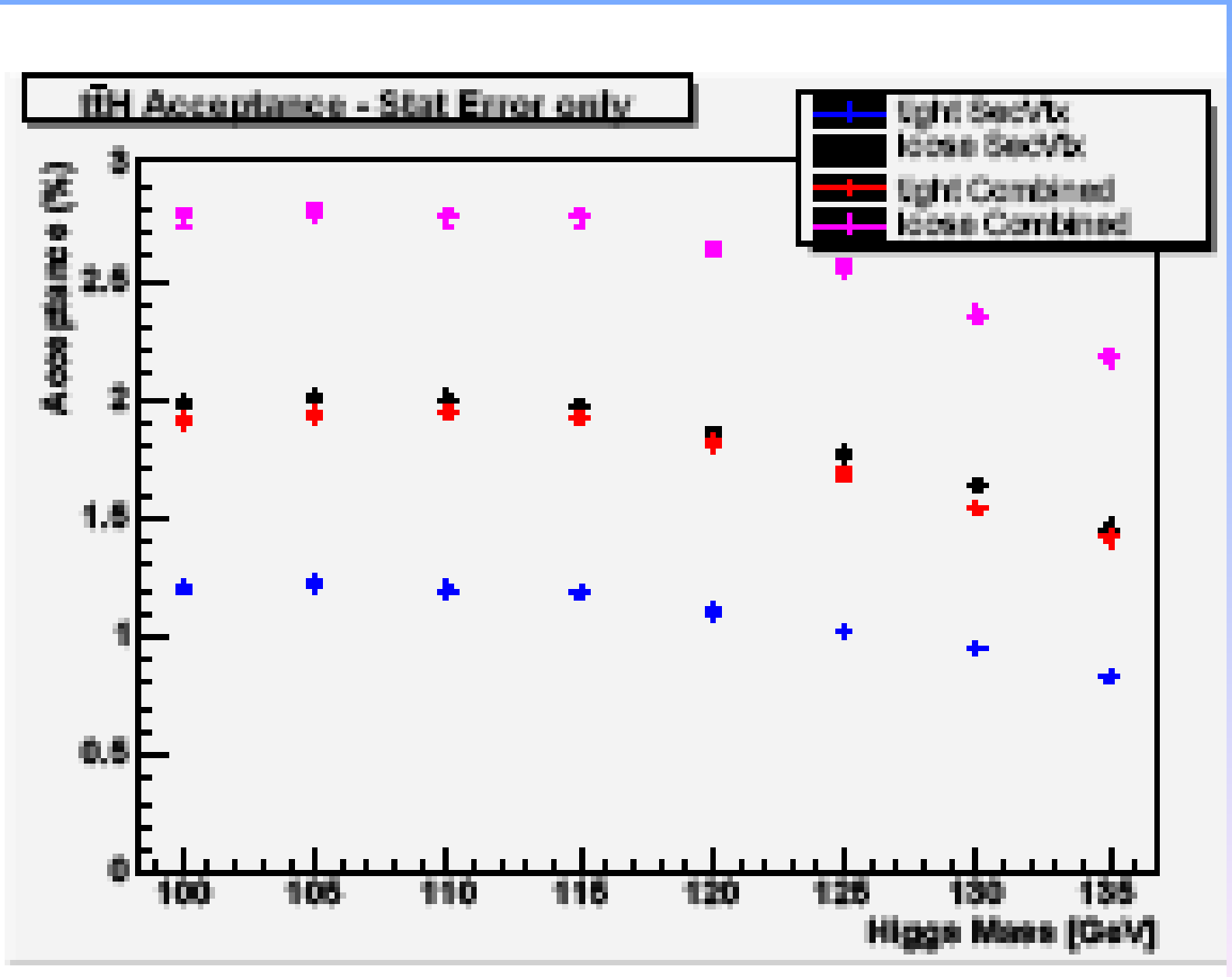
Event Selection:

- 1 identified electron or muon ($p_T > 20$ GeV)
- 4 or more jets ($E_T > 15$ GeV, $|\eta| < 2.0$)
- $\not\!\!E_T > 10$ GeV
- ≥ 3 jets that originate from Secondary Vertices

Background

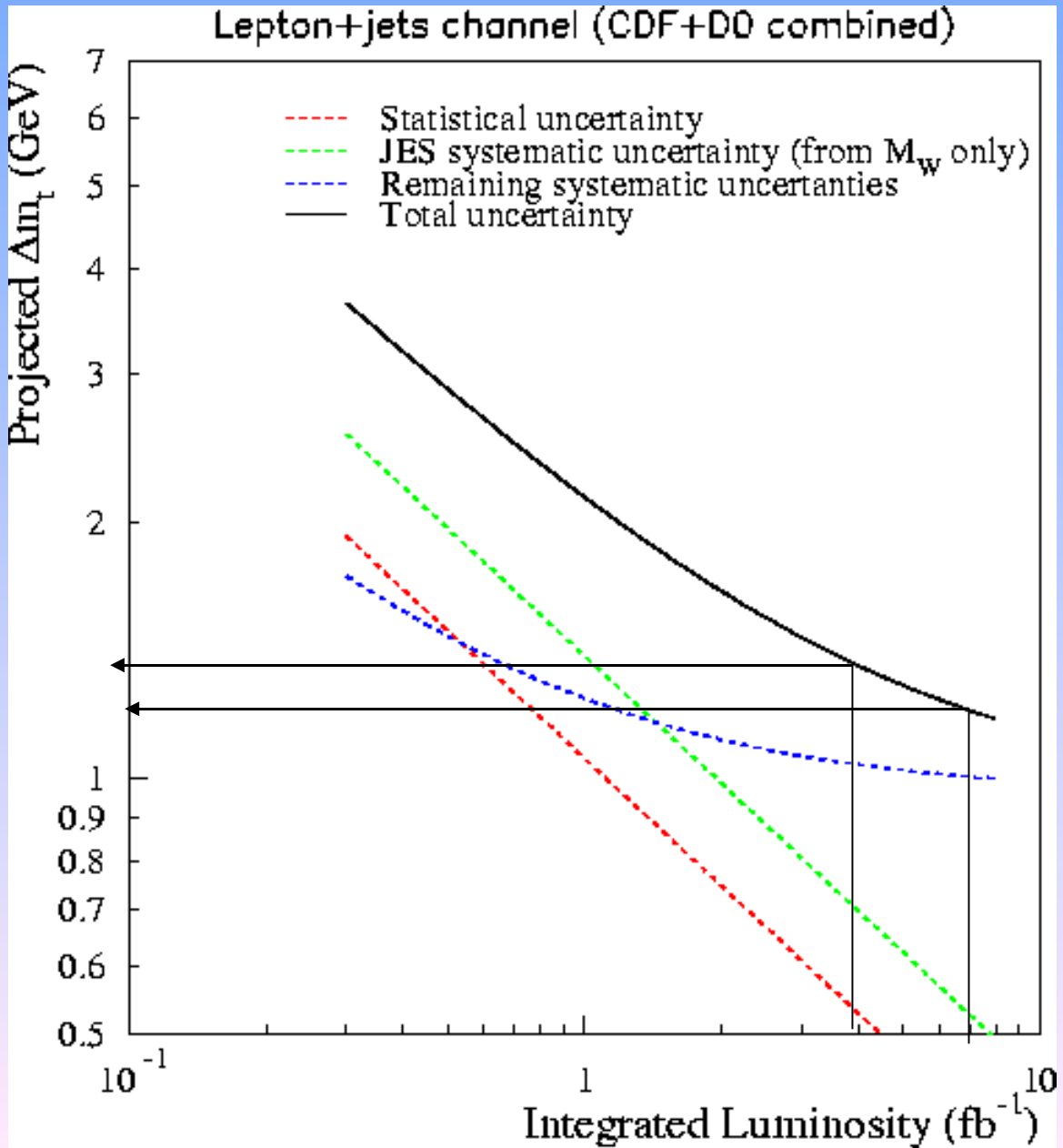
Process	σ (fb)	A (%)	$\sigma \times A$ (fb)	Events (320 pb^{-1})
$t\bar{t} + jj$	1003	0.21	2.1	0.7
$t\bar{t}b\bar{b}$	21.3	0.74	0.16	0.05
$t\bar{t}$	5700	0.114	6.50	2.08
$W \to e\nu + 4j$	10000	0.003	0.3	0.1
$W \to e\nu + b\bar{b} + jj$	220	0.035	0.077	0.02
$W \to \mu\nu + 4j$	10000	0.003	0.3	0.1
$W \to \mu\nu + b\bar{b} + jj$	220	0.018	0.040	0.01

Acceptance

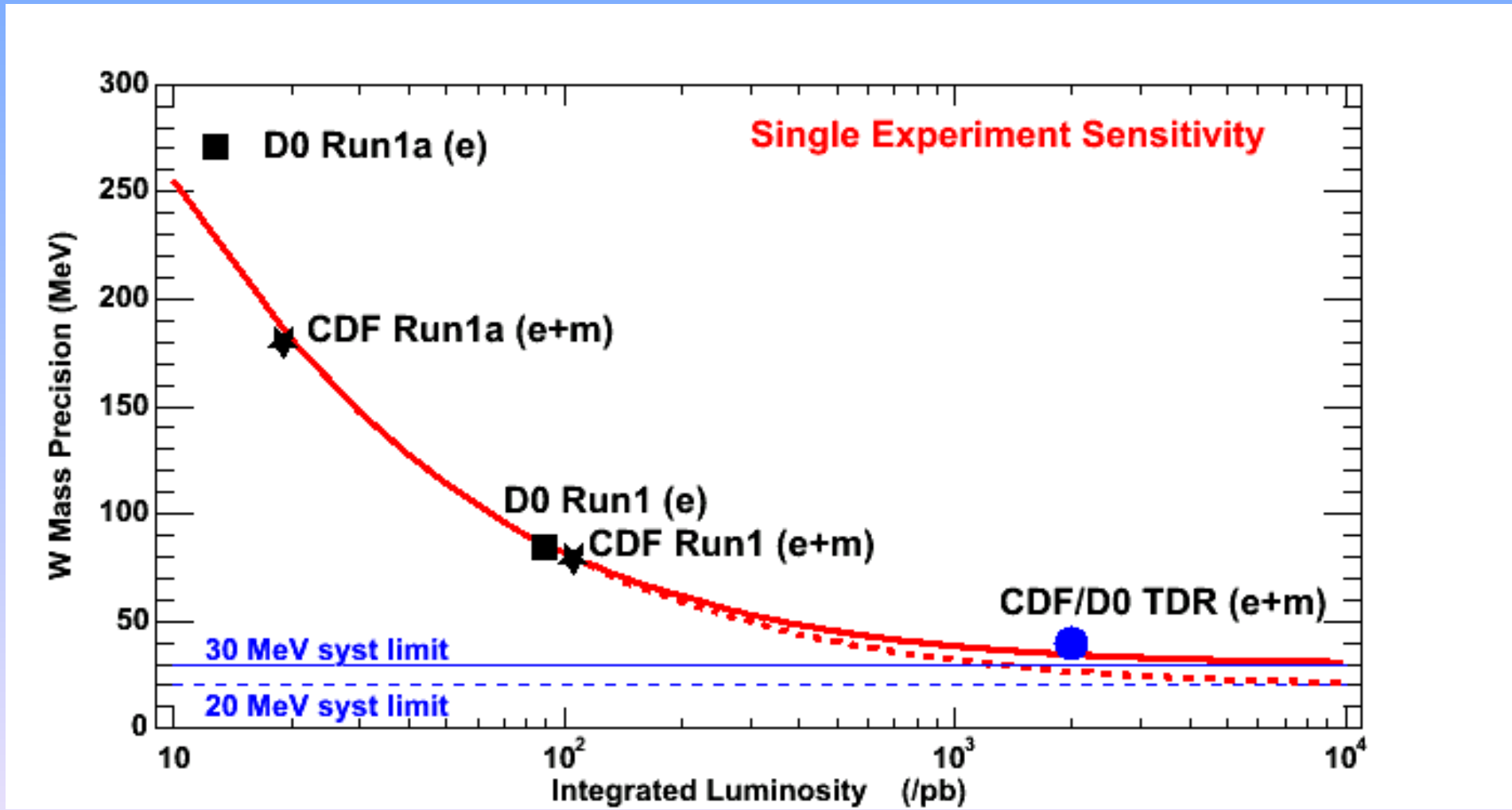


Mt, Mw projections

M_{top} Projection



Mw Projection



Background and Signal

CDF Run II Preliminary, $L_{int} = 360$ pb^{-1}

M_H	160	170	180	190	200
WW	9.794 ± 1.028	9.967 ± 1.046	9.892 ± 1.039	9.623 ± 1.010	9.193 ± 0.965
WZ	0.365 ± 0.047	0.379 ± 0.049	0.433 ± 0.056	0.577 ± 0.075	0.860 ± 0.112
ZZ	0.036 ± 0.007	0.044 ± 0.008	0.062 ± 0.012	0.139 ± 0.026	0.302 ± 0.057
$t\bar{t}$	0.349 ± 0.038	0.399 ± 0.044	0.459 ± 0.050	0.518 ± 0.057	0.576 ± 0.063
$W\gamma$	1.142 ± 0.084	0.969 ± 0.071	0.816 ± 0.060	0.654 ± 0.048	0.477 ± 0.035
DY$\ell\ell$	0.763 ± 0.191	0.827 ± 0.207	0.827 ± 0.207	0.843 ± 0.211	0.958 ± 0.239
fakes	1.334 ± 0.667	1.242 ± 0.621	0.884 ± 0.442	0.800 ± 0.400	0.722 ± 0.361
total BG	13.784 ± 1.245	13.826 ± 1.238	13.373 ± 1.152	13.154 ± 1.112	13.089 ± 1.068
HWW	0.577 ± 0.035	0.541 ± 0.032	0.409 ± 0.025	0.238 ± 0.014	0.214 ± 0.013
data	16	18	19	19	17

Background and Signal

CDF Run II Preliminary, $L_{int} = 360\ \mathrm{pb}^{-1}$

M_H	110	120	130	140	150
WW	3.838 ± 0.403	5.491 ± 0.576	6.826 ± 0.717	7.983 ± 0.838	9.132 ± 0.959
WZ	0.144 ± 0.019	0.230 ± 0.030	0.284 ± 0.037	0.338 ± 0.044	0.372 ± 0.048
ZZ	0.023 ± 0.004	0.025 ± 0.005	0.029 ± 0.005	0.032 ± 0.006	0.036 ± 0.007
$t\bar{t}$	0.080 ± 0.009	0.118 ± 0.013	0.152 ± 0.017	0.210 ± 0.023	0.281 ± 0.031
$W\gamma$	2.837 ± 0.209	2.895 ± 0.213	2.217 ± 0.163	1.967 ± 0.145	1.477 ± 0.109
DY$\ell\ell$	2.114 ± 0.529	1.635 ± 0.409	1.265 ± 0.316	1.014 ± 0.254	1.200 ± 0.300
fakes	1.595 ± 0.797	1.672 ± 0.836	1.780 ± 0.890	1.526 ± 0.763	1.507 ± 0.754
total BG	10.632 ± 1.059	12.066 ± 1.116	12.554 ± 1.198	13.071 ± 1.172	14.005 ± 1.262
HWW	0.028 ± 0.002	0.095 ± 0.006	0.205 ± 0.012	0.326 ± 0.020	0.436 ± 0.026
data	8	7	9	14	14