Tau Leptons at CDF

Experimental HEP Seminar
University of Pennsylvania
April 15th, 2008

OUTLINE
- Why ?
- How ?
- Searches with taus at CDF
- Taus at ATLAS
- Conclusions

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Taus in the SM and beyond

Standard Model

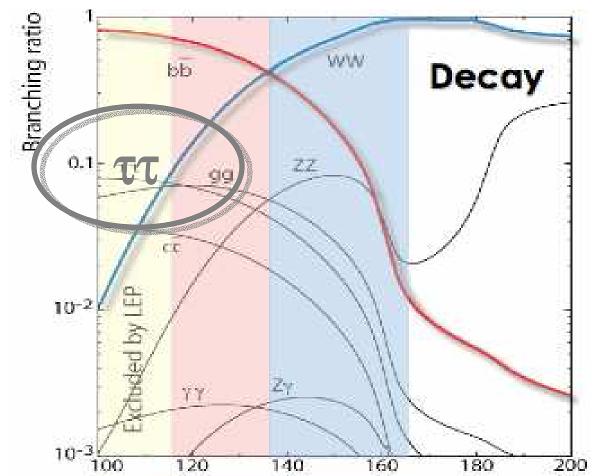
- $H \rightarrow \tau\tau$ ~ 10% in low mass region

Supersymmetry

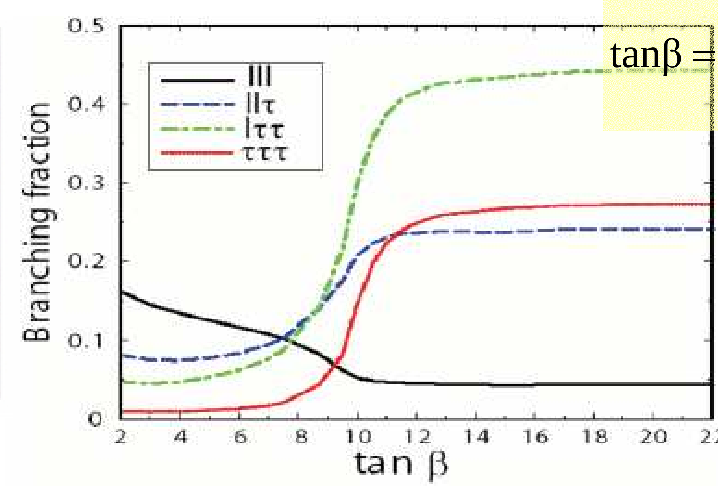
- Higgs sector
  - SM-like h, $H^{\pm}$, $H^{\pm\pm}$
- RPV, $t_1 \rightarrow b\tau$, $s\nu \rightarrow \tau\ell$
- At large $\tan\beta$,
  - mSUGRA $\chi_2^0 \rightarrow \tau\nu\chi_1^0$
  - GMSB $\tan\beta$, $\tau_1 \rightarrow \tau G$

New gauge bosons

- Sequential Z'
- LFV Z'
  - $Z' \rightarrow \tau\ell$



Higgs mass (GeV)



$$\tan\beta = \frac{\langle H^d \rangle}{\langle H^u \rangle}$$

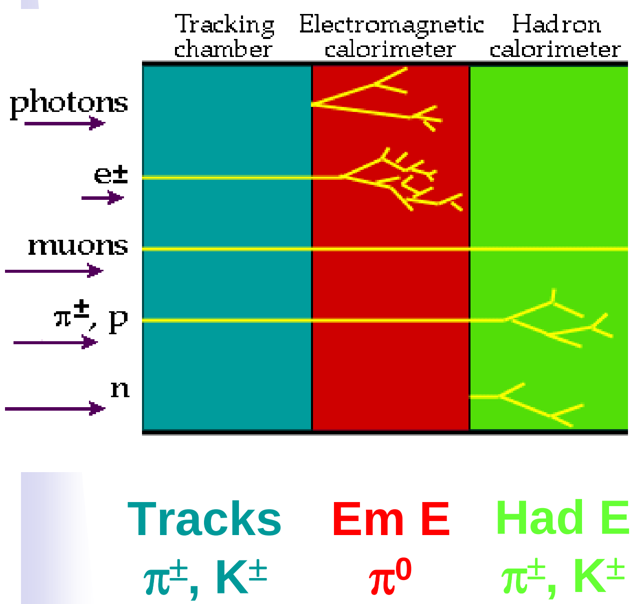
The tau lepton

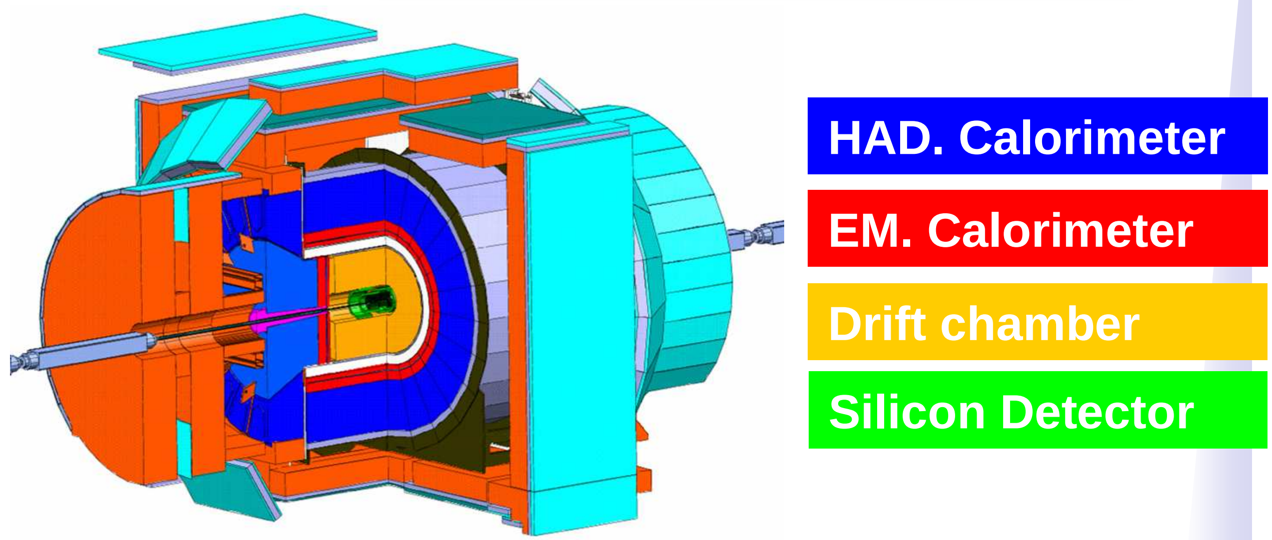
- Short lived
  - Mean lifetime 291 ps
  - Decay length 87 μm
- m = 1.8 GeV
  - Rich phenomenology!

Decay Mode	Final Particles	BR
Leptonic	$e^-\bar{\nu}_e\nu_\tau$	17.8%
	$\mu^-\bar{\nu}_\mu\nu_\tau$	17.4%
Hadronic 1-prong	$\pi^-\nu_\tau$	11.1%
	$\pi^-\pi^0\nu_\tau$	25.4%
	$\pi^-2\pi^0\nu_\tau$	9.2%
	$\pi^-3\pi^0\nu_\tau$	1.1%
	$K^-\nu_\tau$	0.7%
	$K^-\pi^0\nu_\tau$	0.5%
Hadronic 3-prong	$2\pi^-\pi^+\nu_\tau$	9.5%
	$2\pi^-\pi^+\pi^0\nu_\tau$	4.4%

35% τ_ℓ

65% τ_h





Tau reconstruction (I)

Reconstruction of visible products of hadronically decaying taus

STEP 1 *Calorimeter cluster*

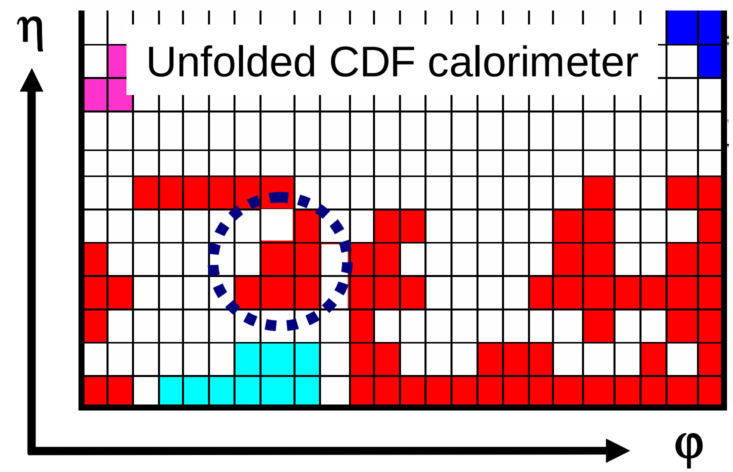
- "Clump" clustering
  - Seed (shoulder) tower E > 6 (1) GeV
  - N towers < 6

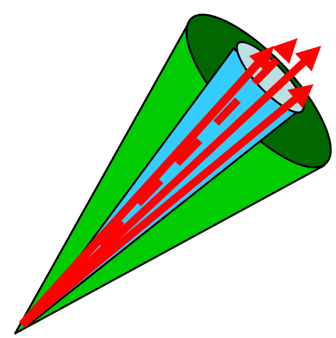
STEP 2 *Track matching*

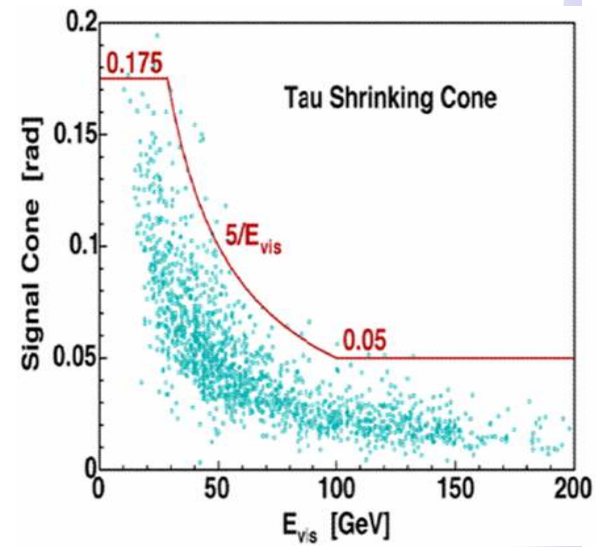
- Highest p_T track pointing to the cluster in cone $R \equiv R(\eta,\varphi) = 0.4$
- Seed track *becomes* tau direction

STEP 3 *Geometry*

- "Signal" and "Isolation" Tracks
- $\alpha^{sig} \equiv \alpha(\varphi,\theta) < \min(0.17, 5/E_\tau)$
- $0.17 < \alpha^{iso} < 0.52$
- $p_T > 1$ GeV



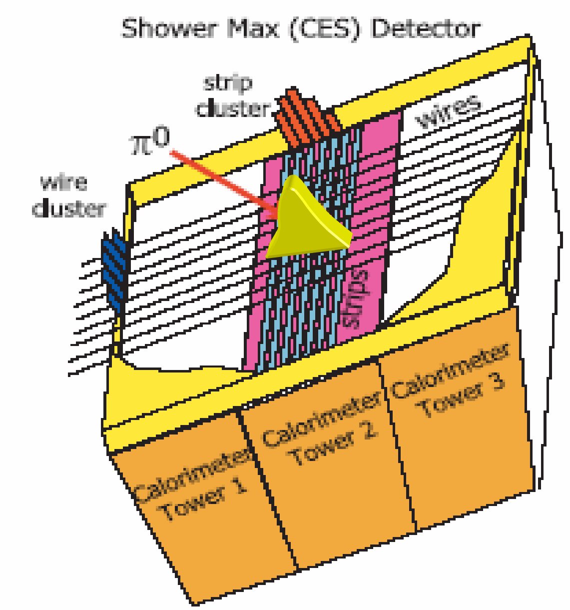




Tau Reconstruction (II)

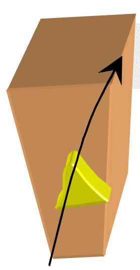
Reconstruction of neutral π^0 from showers in the CES detector

- CEM E assigned to π^0
- Reconstructed τ identified with
  - Visible momentum $p_{vis} = p^{tracks} + p^{\pi 0}$

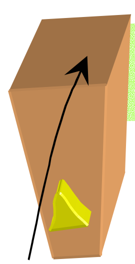


- Proportional strip/wire drift chamber
  - 2 coordinates
- Located at $6\chi_0$ in CEM
- Position resolution 2-3 mm
- Energy resolution ~ 30%
- Clustering:
  - seed strip
  - cluster ±5 strips the seed
  - calculates χ^2

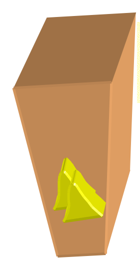
__Assumptions__



no π^0



$E(\pi^0)$ = CEM E – 0.32 GeV



$E_i(\pi^0)$ = CEM E$\cdot E^{CES}_i / E^{CES}$

Tau identification at EWK scale

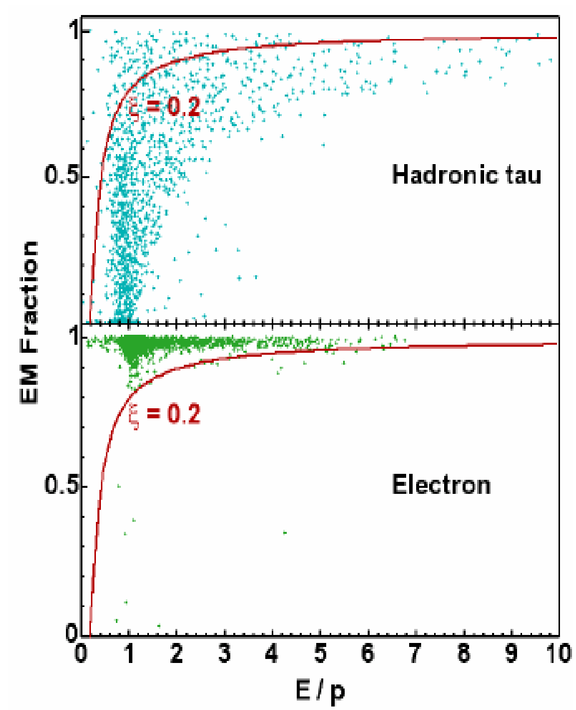
- Taus are reconstructed from
  - Narrow cluster in HAD calorimeter
  - Track pointing to it
  - Showers in the CES detector

~ 1/3 jets reconstructed as taus

electrons reconstructed as taus

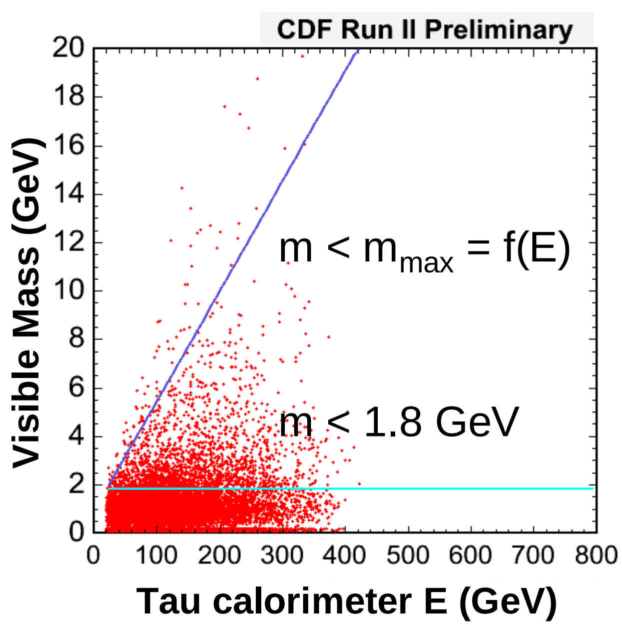
Identification criteria

- Vis. Mass < 1.8 GeV
- 1 or 3 signal tracks
- Isolation
  - track isolation
  - π^0 isolation
  - calorimeter isolation
- electron suppression
  - Energy based cut
  - Explicit ID electron removal



… at large E

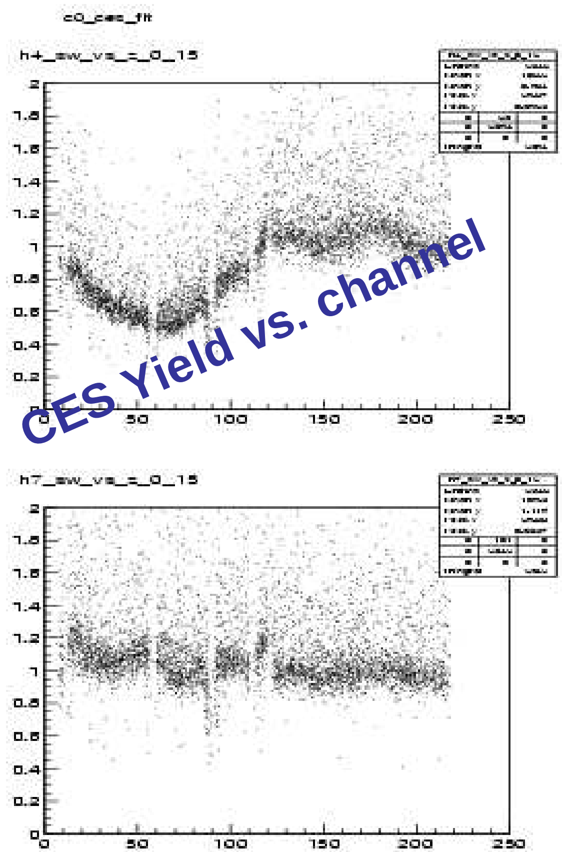
- Energetic taus
  - collimated decay products
  - track resolution $\sigma(p_T)/p_T^2=0.0015\ GeV^{-1}$
- Loosen up the requirements on tau candidate mass



- Calibration of CES detector
  - Position and energy device now!
  - Visible momentum resolution:

  1-prong τ from 66% to 82%

  3-prong τ from 82% to 85%



Efficiency measurement

$$\mathcal{E} = \frac{N^{ID}}{N^{real}}$$

- MC measurement
  - Select τ originating in $W \to \tau\nu$
- Data measurement
  - Taus are different from muons and electrons, no resonance!

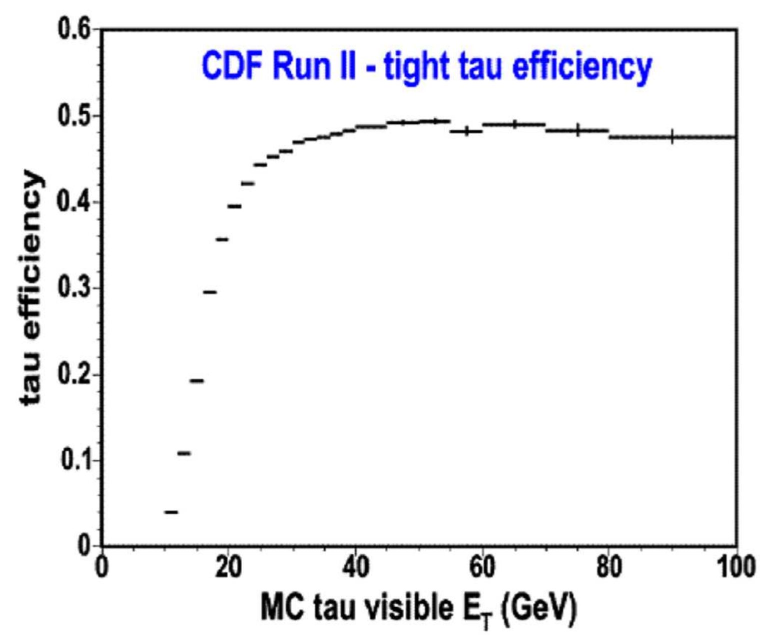
Three approaches

- Normalization to $W \to \tau\nu$

$$\sigma = \frac{N^{obs} - N^{bkg}}{A \cdot L \cdot \varepsilon} \equiv 2.7 \text{ nb}$$

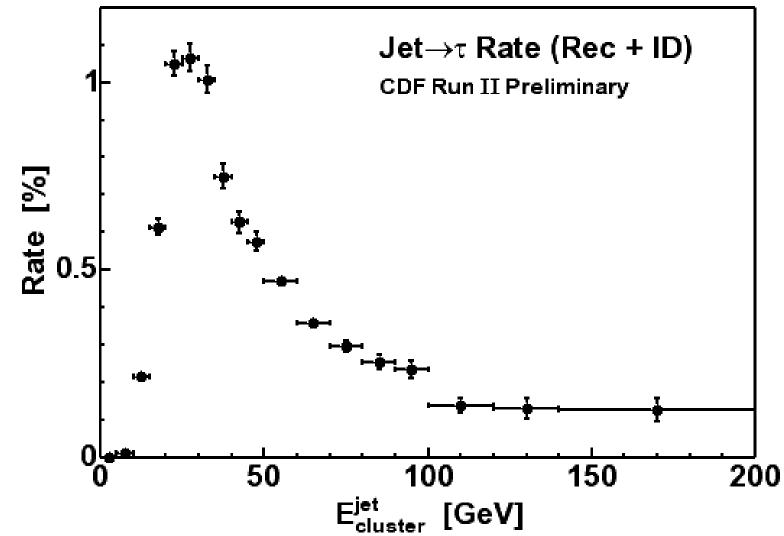
- Tau embedding
- Background from fit to data

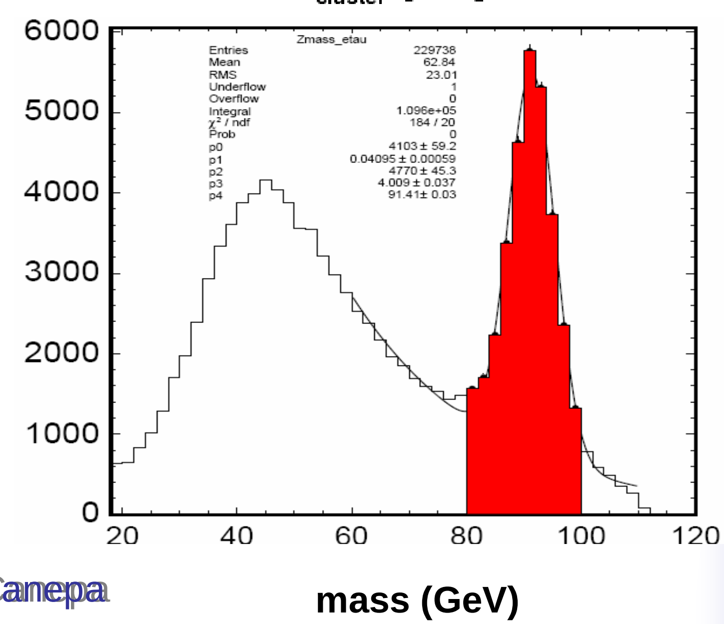
$$\varepsilon = \frac{N^{ID\,\tau} - N^{ID\,backg}}{N^{\tau} - N^{backg}}$$



Misidentification (fake) rates

- Jets faking taus
  - Fake rate FR = $N^{ID}\,\tau/N^{jet}$
  - Measured in data samples collected with jet triggers
    - If measured in MC samples, must tune the tau shape and hadronic response
- Electrons faking taus
  - Fake rate FR = $N^{ID}\,\tau/N^{ele}$
  - Measured in data
  - Select events in the Z mass window
    - One ID electron & One reconstructed tau
  - Subtract background from side-band
  - Fake rate ~ 10^{-3}



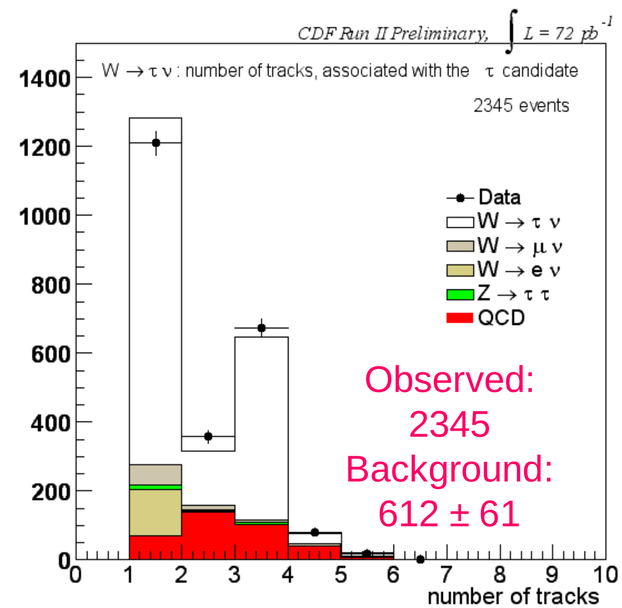


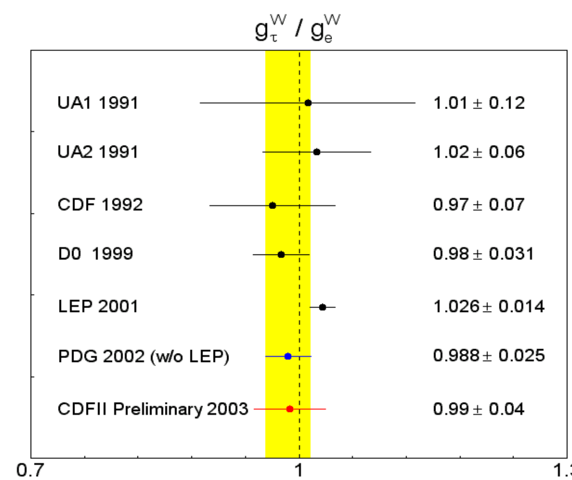
EWK Measurements

The W cross section

- W’s as the largest source of isolated taus
  - Best choice for understanding τs
  - Test of lepton universality !
- Events selected if
  - τ Vis E_T > 25 GeV & MET > 30 GeV
  - τ back-to-back w.r.t MET (no extra jets)
  - Acceptance ~ 1%
- Backgrounds
  - QCD measured in QCD enriched independent sample
  - W→eν from fit to data

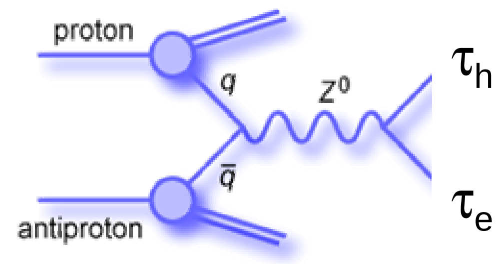
$\sigma(p\bar{p}\rightarrow W)\cdot BR(W\rightarrow \tau\nu)$ =
2.62 ± 0.07(stat) ± 0.21(syst) ± 0.16(lum) nb

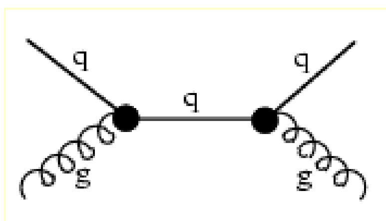




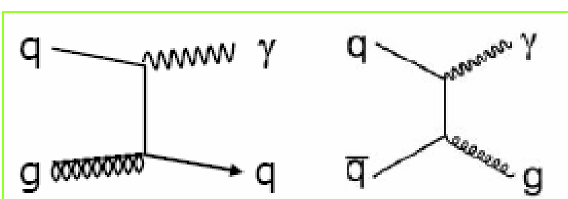
The Z cross section

- Z as a "calibration" for a number of searches!
- *Golden channel with one hadronic and one leptonic tau*
- Events selected if
  - τ Vis $E_T > 10$ GeV & electron $E_T > 10$ GeV
  - Electron and tau with different charge (OS events)
  - Acceptance ~ 5%
- Dominant backgrounds from QCD

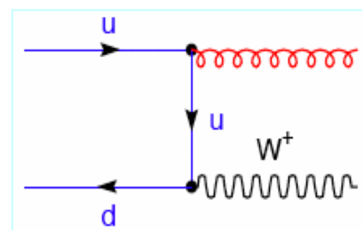


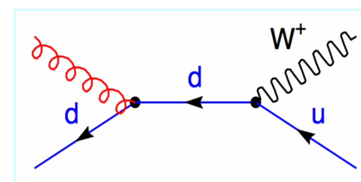


Jet $\rightarrow \tau$
Jet $\rightarrow$ e
Flat electron isolation
$Nev^{LS} = Nev^{OS}$



Jet $\rightarrow \tau$
$\gamma \rightarrow$ e
Isolated electrons
$Nev^{LS} = Nev^{OS}$





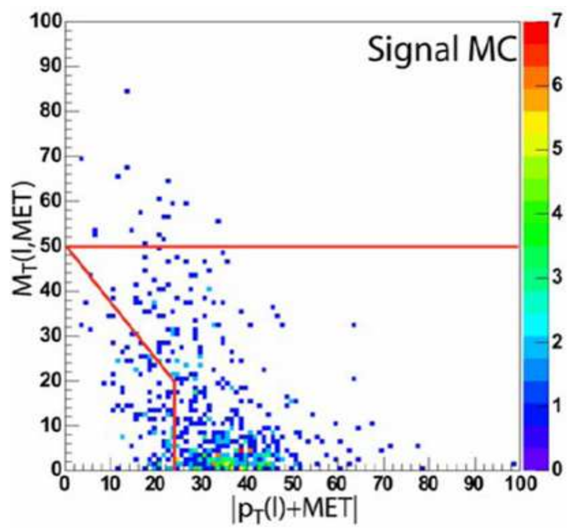
Jet $\rightarrow \tau$
W $\rightarrow$ eν
$Nev^{LS} << Nev^{OS}$

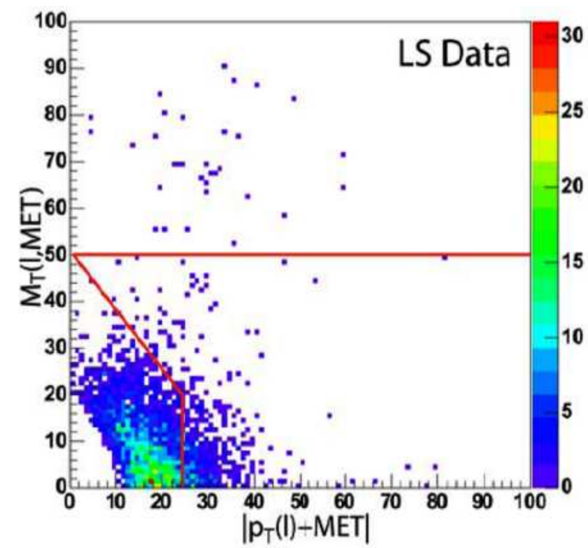
Backgrounds

- QCD background suppressed asking for large p_T and low m_T(e,MET)
- Background estimate
  - QCD dijet
    - LS data events with non isolated electrons
  - γ+jet
    - LS data events with isolated electrons
  - W+jets MC based estimate
  - Z/γ*→ee MC based estimate

$$m_T = \sqrt{2 \cdot p_T^{ele} \cdot MET \cdot (1 - \cos\Delta\varphi)}$$

$$p_T = \left| \overrightarrow{p_T^{ele}} + MET \right|$$



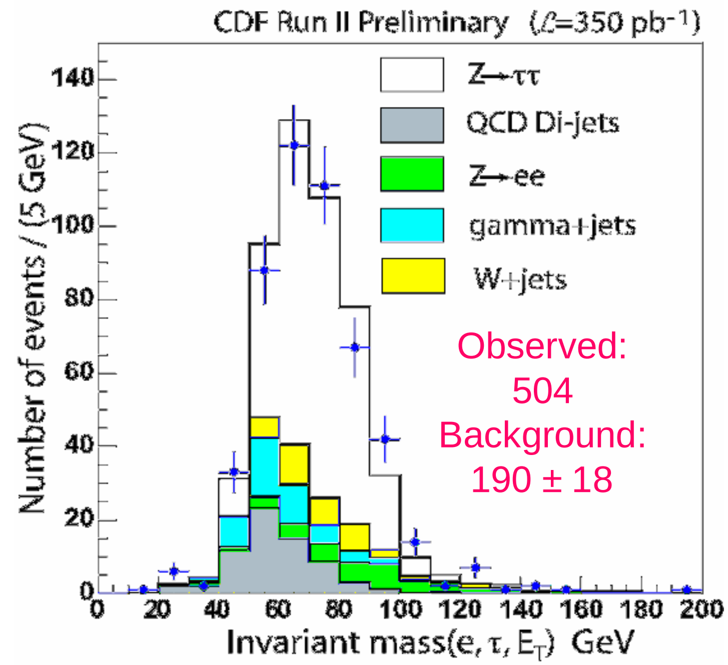


Results

- Signal extraction
  - 4 regions in m_T(e,MET) and electron isolation
  - split into OS and LS samples
  - Normalizations from fit to data

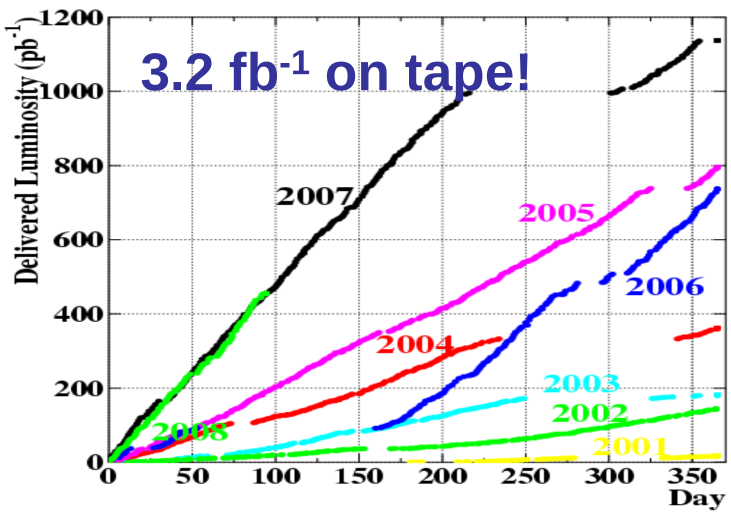
OS events

M_T 50:100 GeV	W+jets	QCD
M_T 0:50 GeV	$Z \to \tau\tau$	QCD
	Iso 0:1	**Iso 2:8**

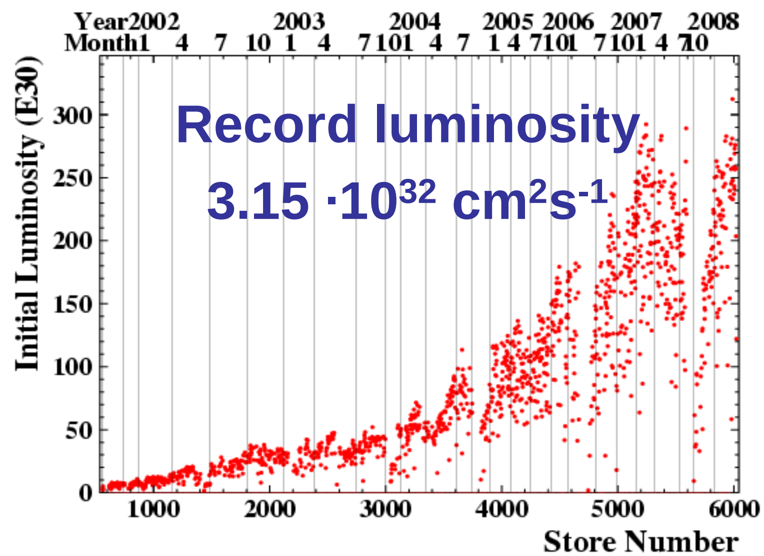


$\sigma(p\bar{p} \to Z) \cdot BR(Z \to \tau\tau) =$
$264 \pm 23\ (stat) \pm 13\ (syst) \pm 15\ (lum)$ pb

Searches



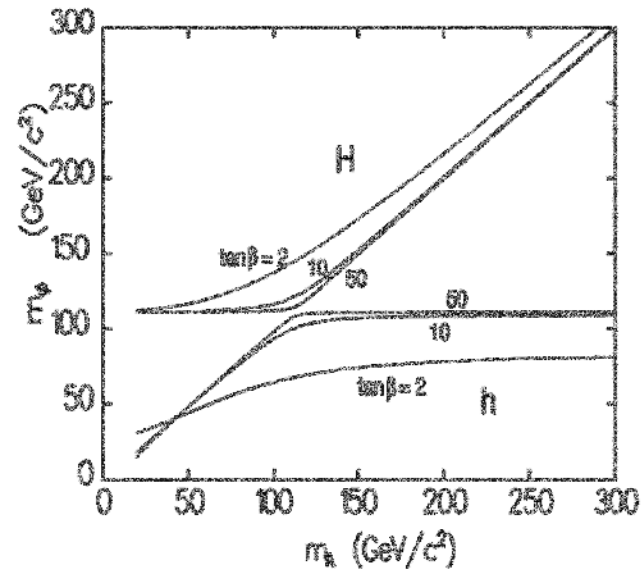
3.2 fb^{-1} on tape!
Delivered Luminosity (pb^{-1})
Day
2007
2005
2006
2004
2003
2002
2001
2008

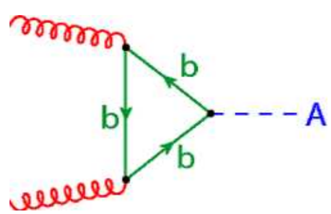


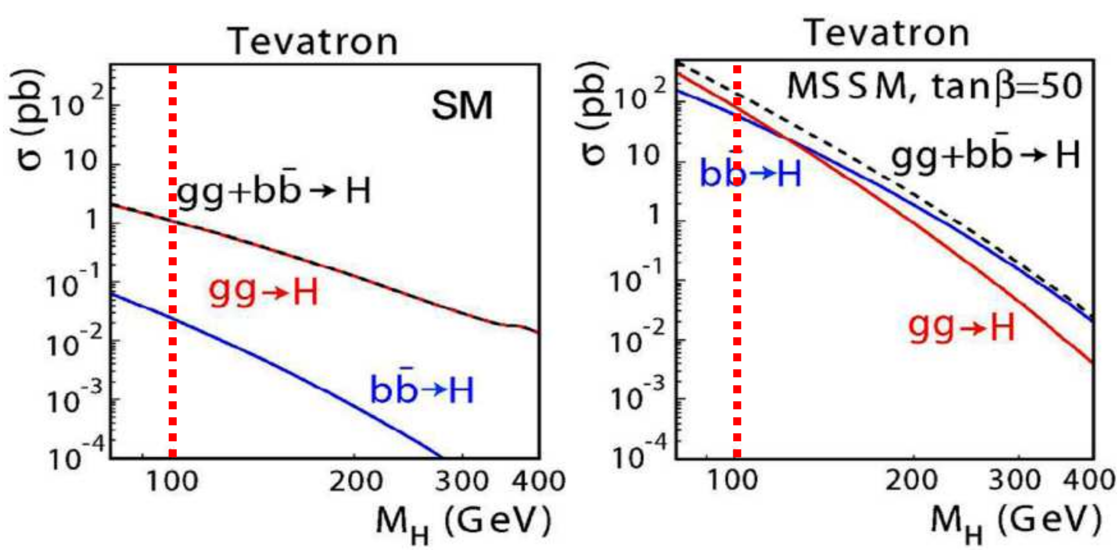
Record luminosity
3.15 ·10^{32} cm^{2}s^{-1}
Initial Luminosity (E30)
Store Number
Year 2002 2003 2004 2005 2006 2007 2008

Light mass SUSY Higgs

- MSSM Higgs sector with 2 doublets
  - *h*,*H* (CP-even), A (CP-odd), $H^{\pm}$
    - h expected to be low mass
    - tanβ relevant parameter
  - In the low mass region, *h* degenerate with *A*, at large tanβ
  - *A* cross section enhanced by $\tan^2\beta$!



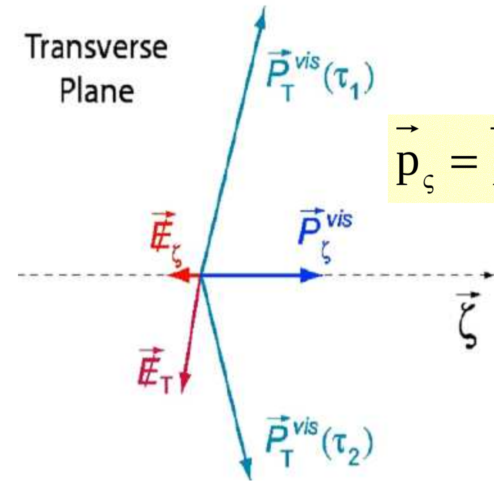




- Higgs decays
  - bb ~90%
  - ττ ~10%

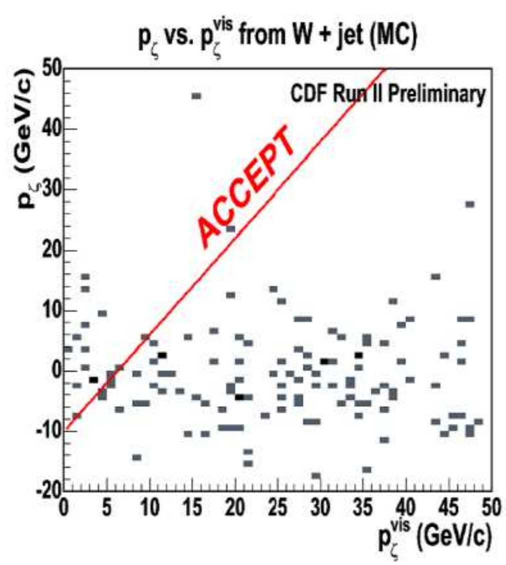
Event selection

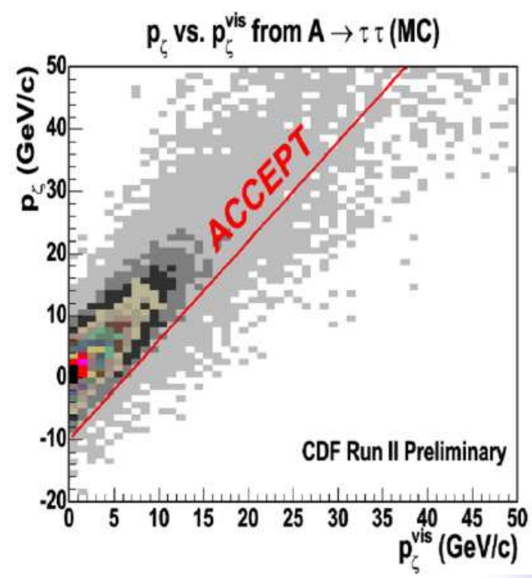
- Events selected in the sample used for the $Z \rightarrow \tau\tau$ cross section measurement
  - τ Vis $E_T > 15(20)$ GeV & lepton $E_T > 10$ GeV
  - new channel, $\tau_e\tau_\mu$



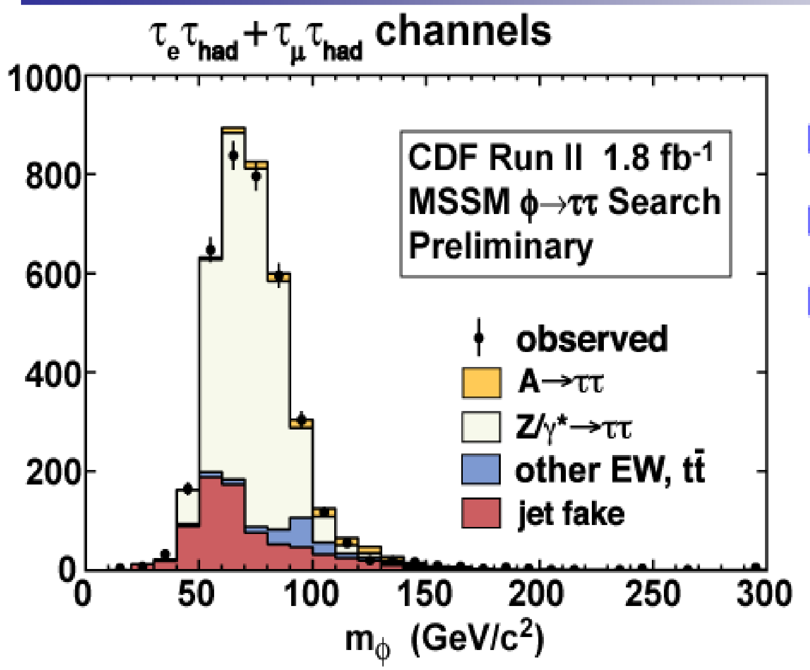
$$\vec{p}_\varsigma = \vec{p}_\xi^{\,vis} + \overrightarrow{MET}$$

- Backgrounds
  - W+jets
    - Suppressed with **ζ cut**
  - Soft QCD
    - Suppressed with **H_T cut**
  - Remaining QCD background
    - $\tau_e\tau_\mu$ channel, from events with non-isolated leptons
    - τ_h channels, computed from fake rate parameterization
  - $Z \rightarrow ll$ estimated from MC



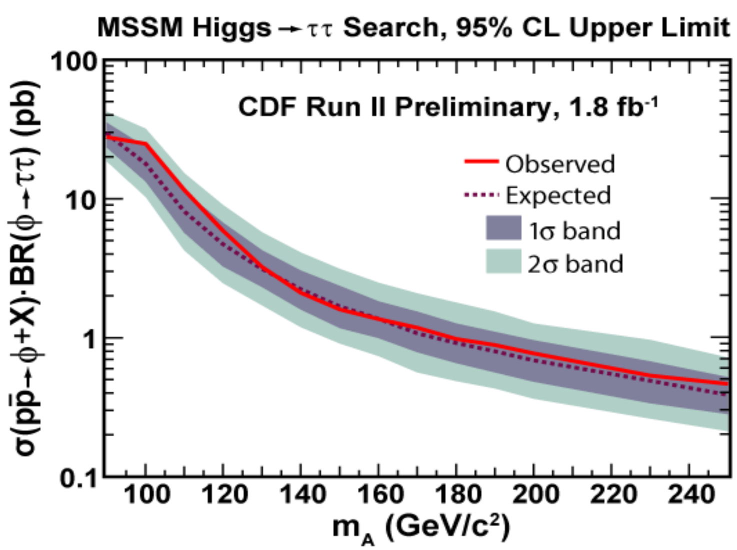


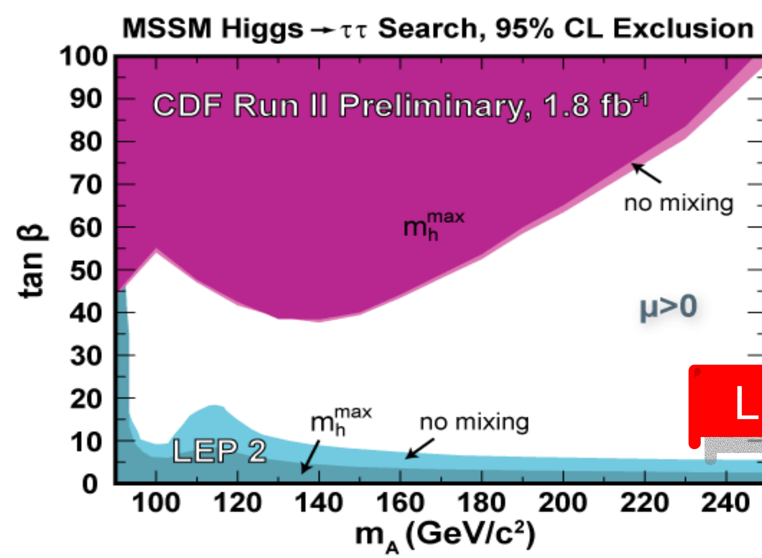
Results



- Search acceptance $A(m_h=100 \text{ GeV}) \sim 1\%$
- No excess w.r.t SM predictions
- Likelihood fit to the vis. mass to set limits
  - three final states as separate channels
  - backgrounds subject to gaussian constraints

Reach extends below tanβ ~ 50
for m_A in [120;160] GeV

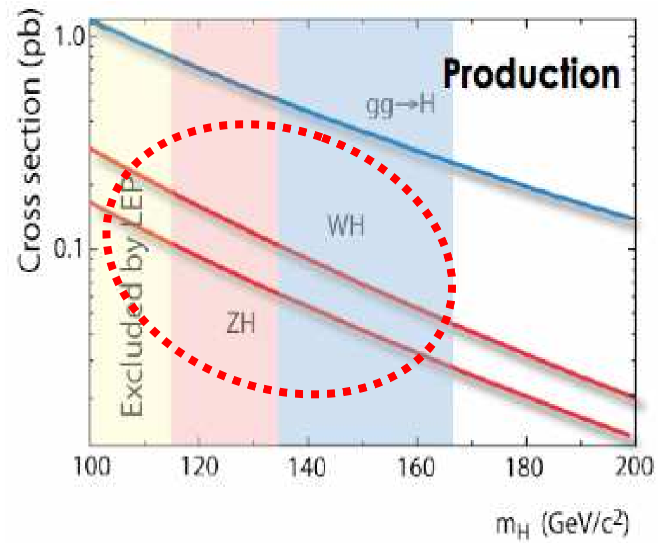




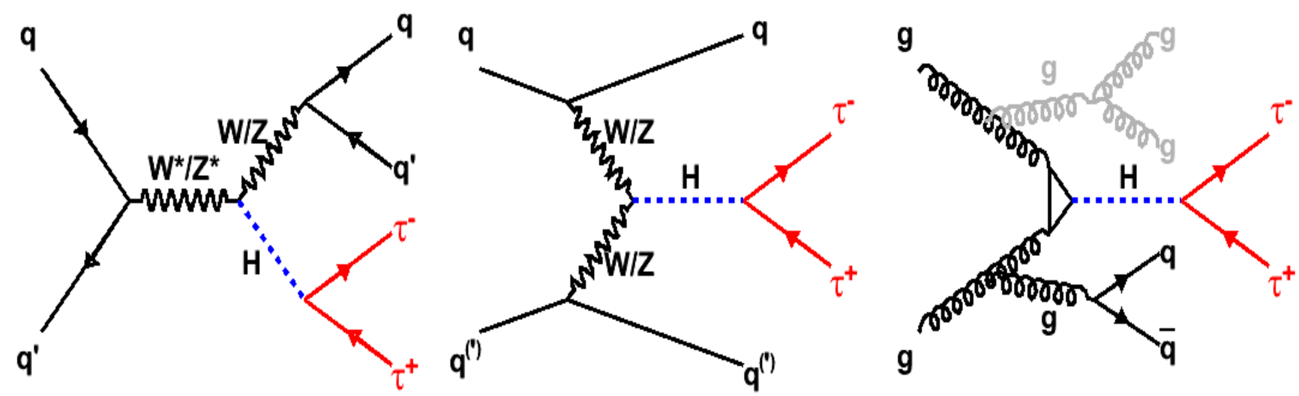
L = 1.8 fb^{-1}

Standard Model Higgs

- The Higgs boson is crucial for confirming the SM!
  - expected to be low mass (< 180 GeV)
  - in the low mass region, BR ($H \rightarrow \tau\tau$) ~ 10%
  - recover acceptance letting W and Z to decay hadronically
    - $W \rightarrow l\nu$ (22%), $Z \rightarrow ll$ (6%), $Z \rightarrow \nu\nu$ (20%)
    - $W \rightarrow jj$ (67%), $Z \rightarrow jj$(70%)



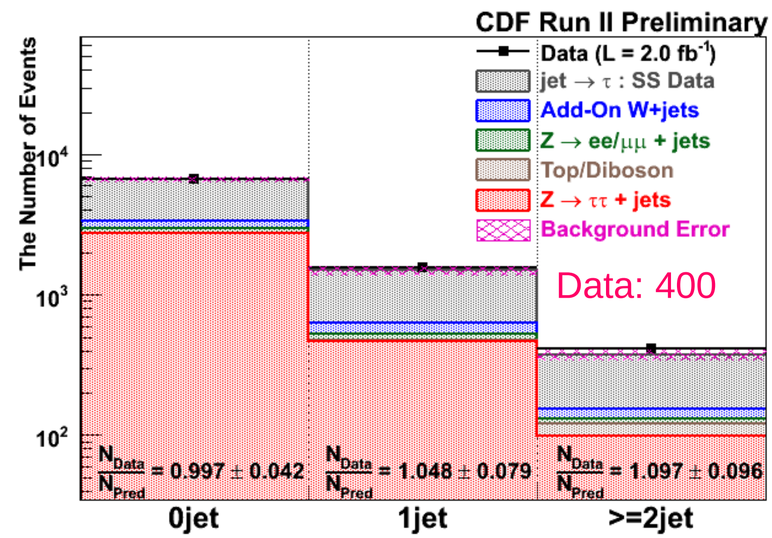
Search for WH, ZH, VBF $H \rightarrow \tau\tau$, and gg fusion in events with two taus and two jets



One hadronic and one leptonic tau !

Event selection

- Events selected if
  - τ Vis E_T > 15 GeV & lepton E_T > 10 GeV
  - Two jets with corrected E_T > 15 GeV
  - Veto Z and accept events with OS leptons
  - Acceptance A(m=110 GeV) ~ 5%
- Backgrounds
  - Diboson, t-tbar, Drell-Yan from MC
  - QCD (dijet,γ+jet,W+jet) from LS data
    - Correcting for DY contribution and W+jet charge correlation
  - $Z \rightarrow \tau\tau$ cross section measurement for validation of background model



$2fb^{-1}$	M_H=110	M_H=115	M_H=120	M_H=130	M_H=140	M_H=150
WH	0.25(1.5%)	0.21(1.5%)	0.18(1.6%)	0.11(1.7%	[illegible]	[illegible]
ZH	0.16(1.5%)	0.14(1.6%)	0.11(1.6%)	0.07(1.8%	[illegible]	[illegible]
VBF	0.14(1.4%)	0.13(1.4%)	0.12(1.5%)	0.09(1.6%	[illegible]	[illegible]
ggH	0.28(0.18%)	0.28(0.21%)	0.26(0.24%)	0.18(0.26	[illegible]	[illegible]
Total	0.83±0.01	0.76±0.01	0.67±0.01	0.45±0.004	0.26±0.002	0.12±0.001

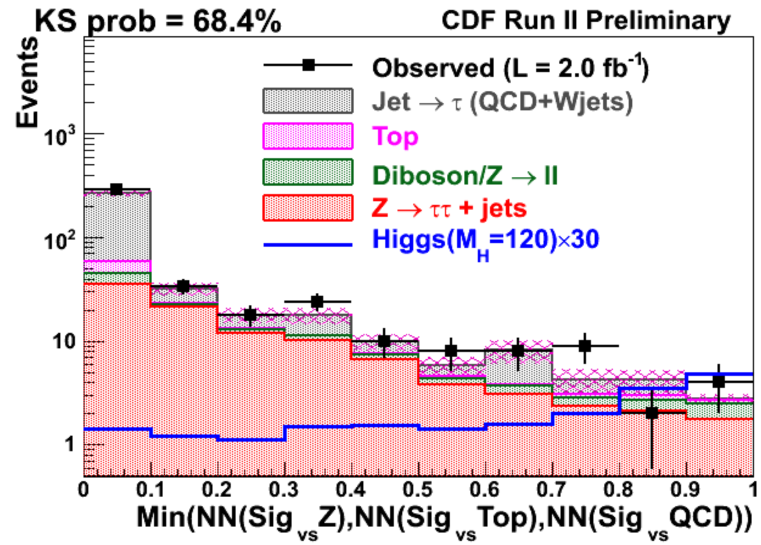
Background ~ 370 events

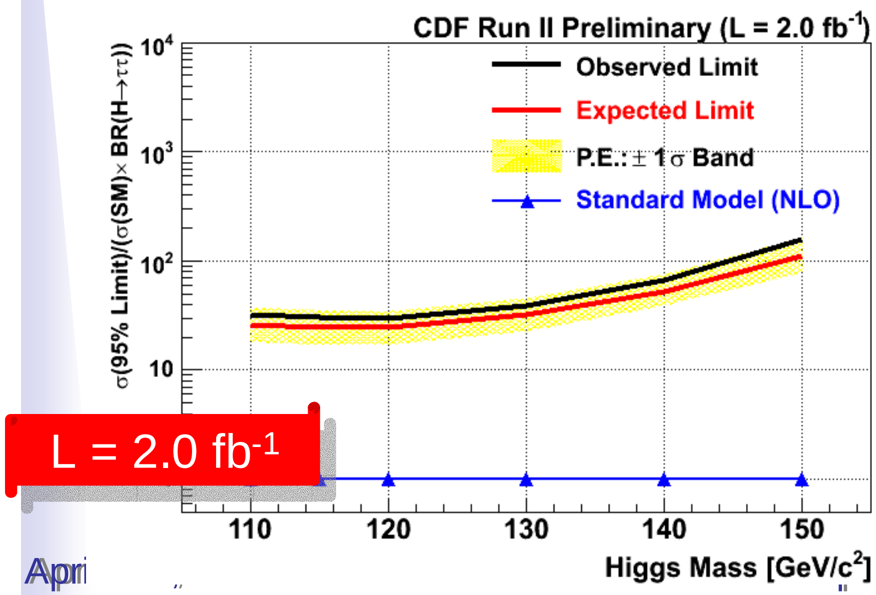
Very small signal !

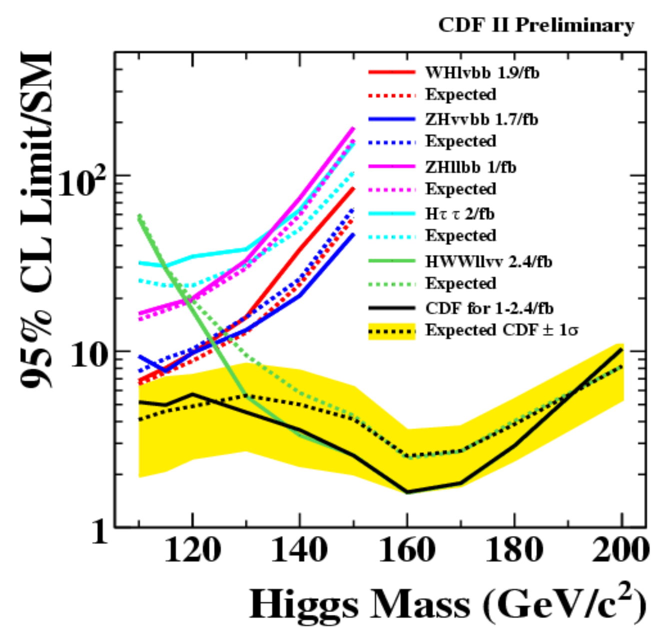
Results

Neural Network technique!

- Train NN for mixed Higgs signal vs
  - $Z \rightarrow \tau\tau$ (25% of background, $\tau\tau$ peak)
  - t-tbar (5% of background, Q^2)
  - QCD (60% of background, energy range)
  - Input 16 variables, rank with iterative method
  - 3 NN scores per event, choose the min. one
- No excess w.r.t SM background





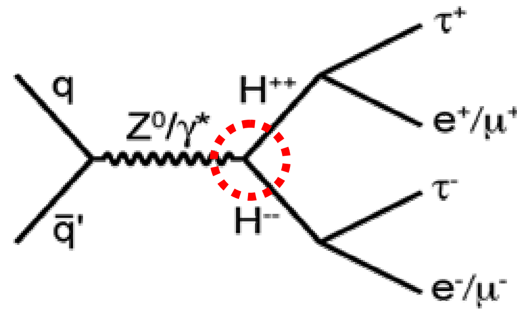


More exotic Higgs

Double charged SUSY Higgs

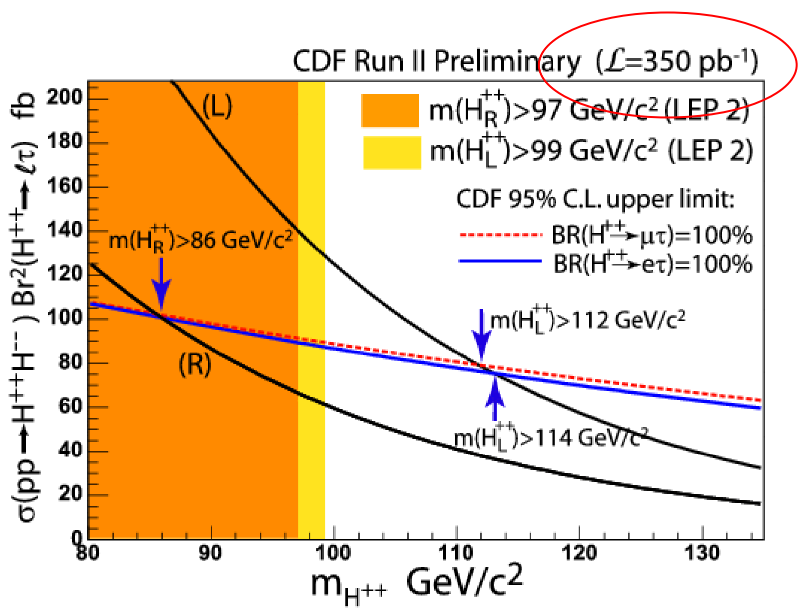
Higgs triplets, Little Higgs model

- Left-Right Symmetric Model (LRSM)
  - Right handed weak force
  - Mechanism for generating neutrino masses
- Higgs sector with 3 new triplets
  - 10 scalar bosons, among which $H_{R/L}^{++/--}$



Dominant production process

- $\Gamma_{ll'} \sim h^2_{ll'} \cdot m_H$
- Yukawa $h_{ll'}$ give mass to neutrinos
  - $h_{l\tau}$ expected to be large!

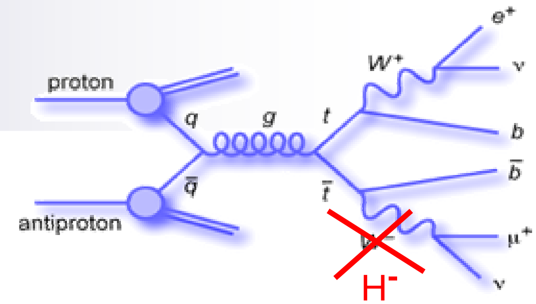


CDF Exclusion Limits:
$m(H_L^{++/--}) > 112\ (114)$ GeV

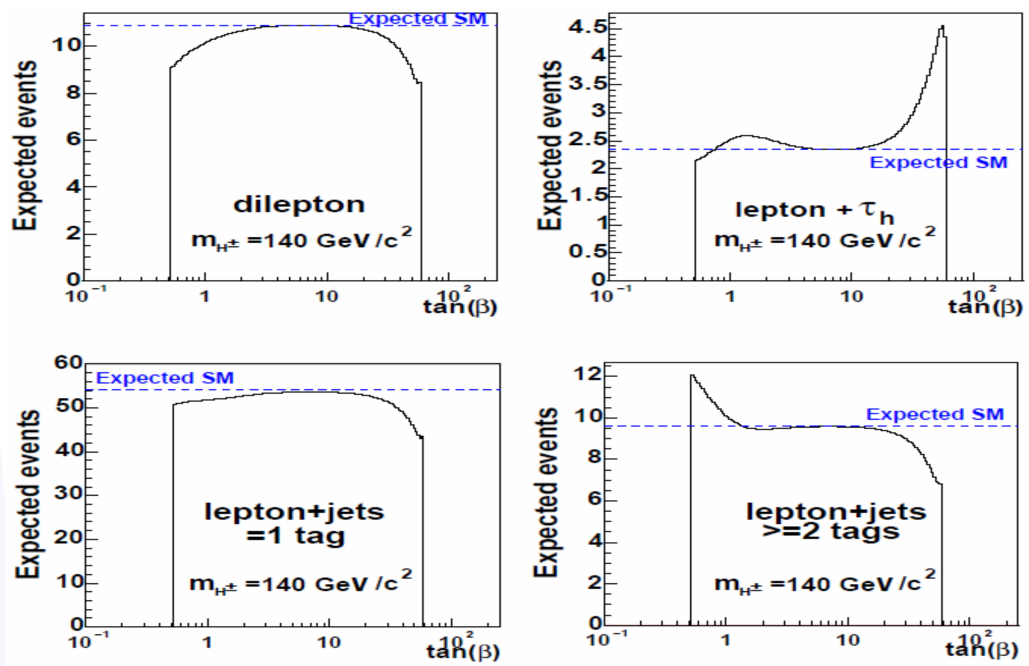
L = 1.1 fb^{-1}

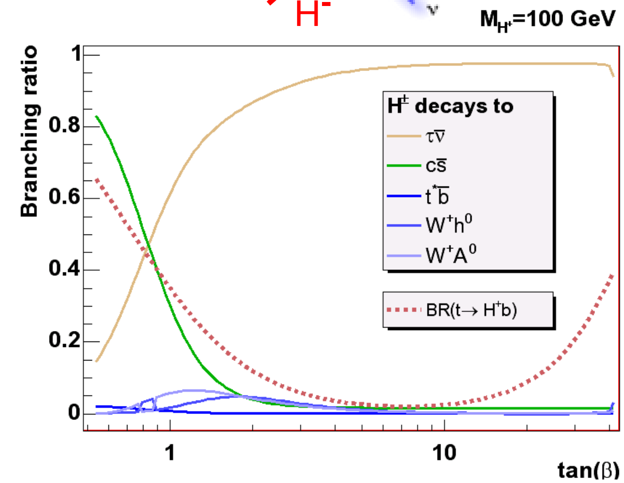
Exclusion Limits:
$m(H_L^{++/--}) > 150$ GeV
$m(H_R^{++/--}) > 127$ GeV

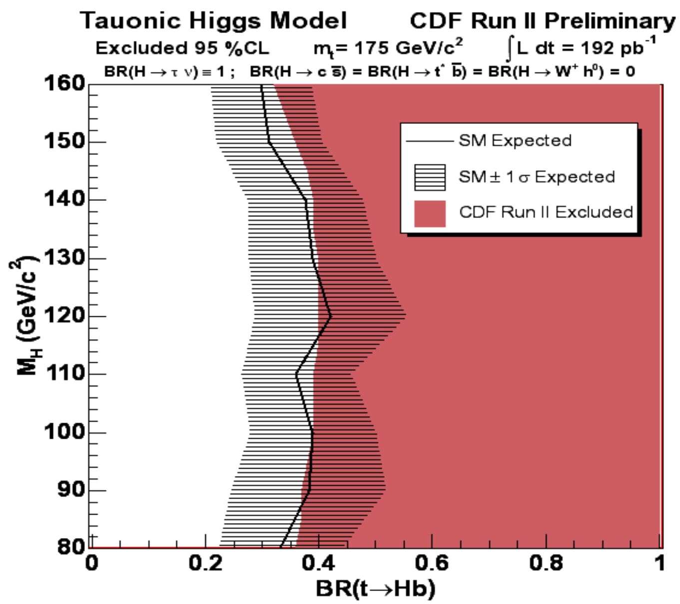
Charged Higgs



- In the MSSM, H± could be lighter than the top
- H± from t→bH+
  - accessible at Tevatron!
  - probing $m_H < m_t - m_b$
- Top BR's modified
- Different topologies in W± and H± decays

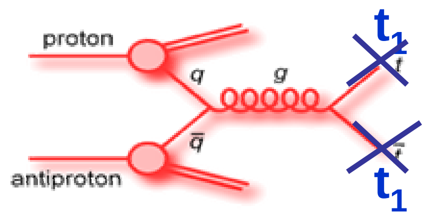


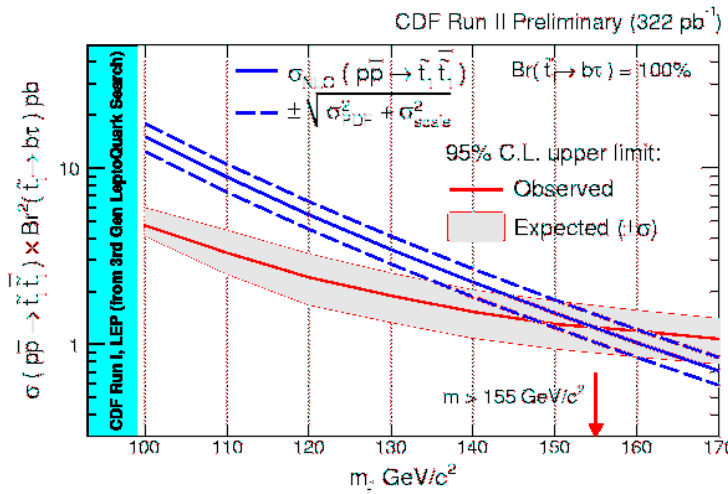




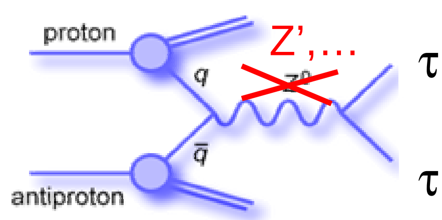
New particles

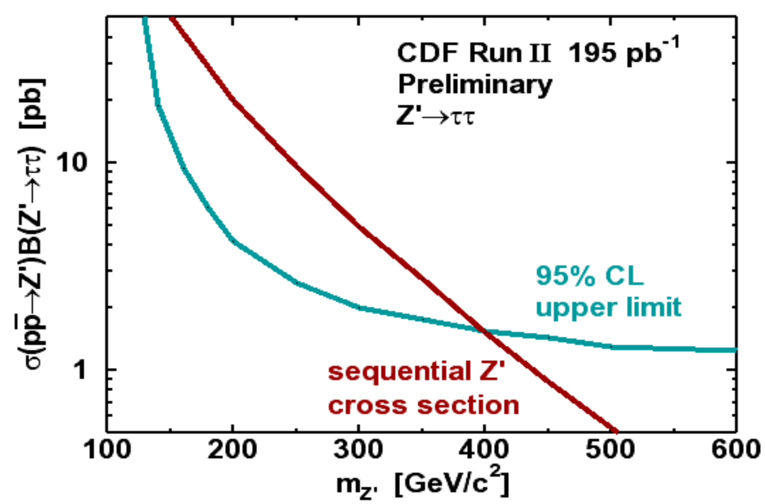
- In the MSSM, the lightest stop (t_1) can be very light (large tanβ scenarios)
- Lighter than SM top!
- Decay into τb





- New gauge bosons
  - Z', ED, …
- Is the third generation special ?

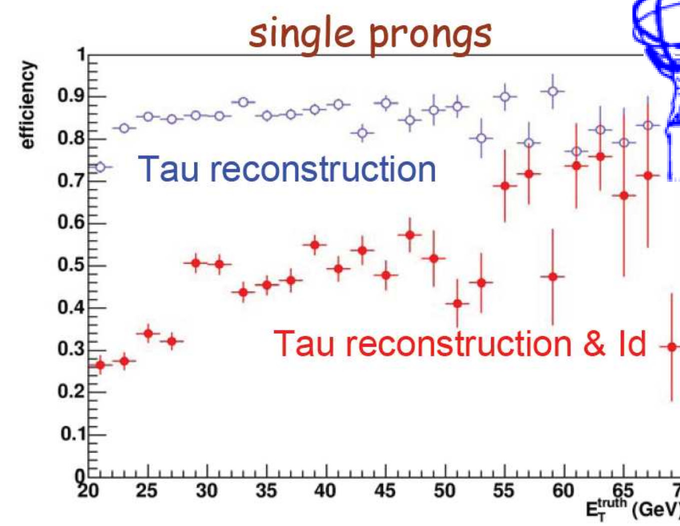


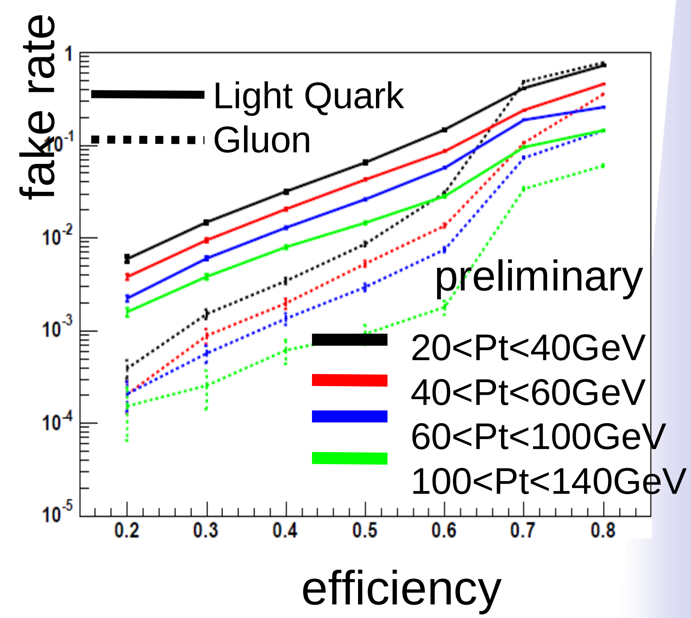


Taus at ATLAS

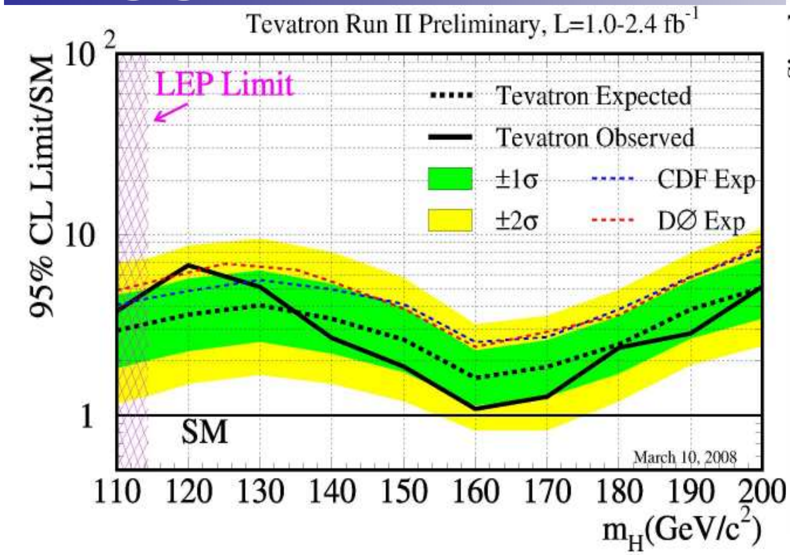
State of the art

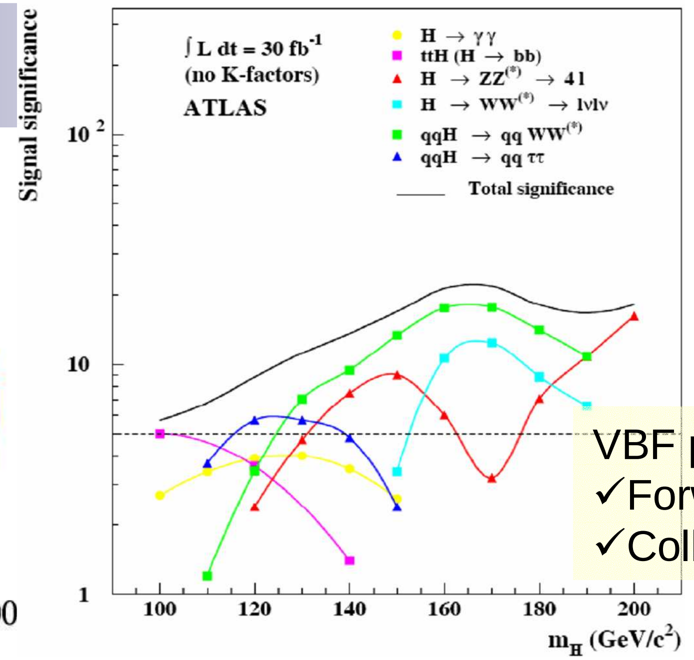
- Tau reconstruction seeded from calorimeter cell or charged track
  - *Energy flow for soft taus (from 20 to 70 GeV)*
- Calorimeter based isolation, cluster shape and track multiplicity
  - Radius of EM jet
  - Isolation E_T^{EM}/E^T_{HAD}
    - 0.1 < ΔR < 0.2 for E > 70 GeV
    - 0.2 < ΔR < 0.4 for soft taus
  - Impact parameter
  - Cut based or multivariate classification
- Misidentification rate as a function of
  - jet type (quark or gluon)
  - energy and η

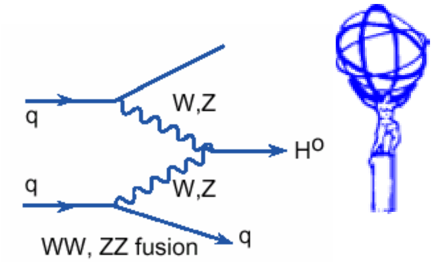




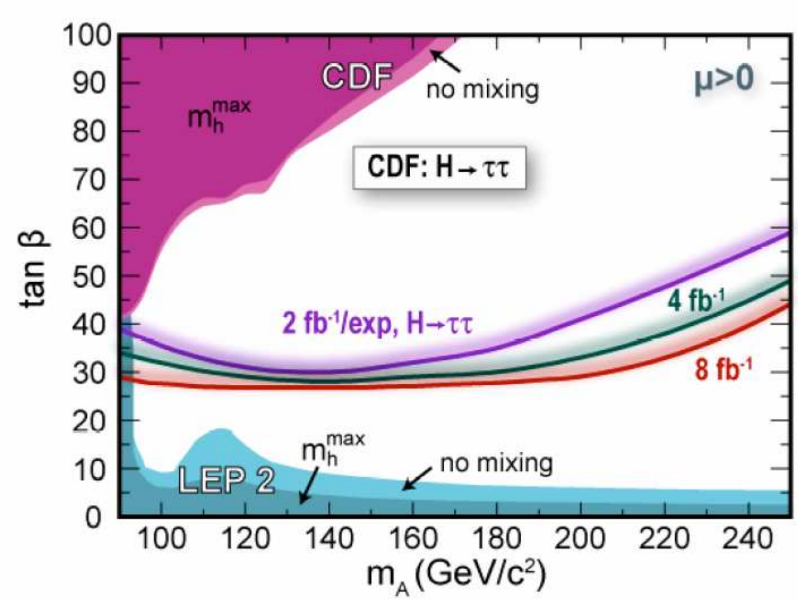
Higgs searches

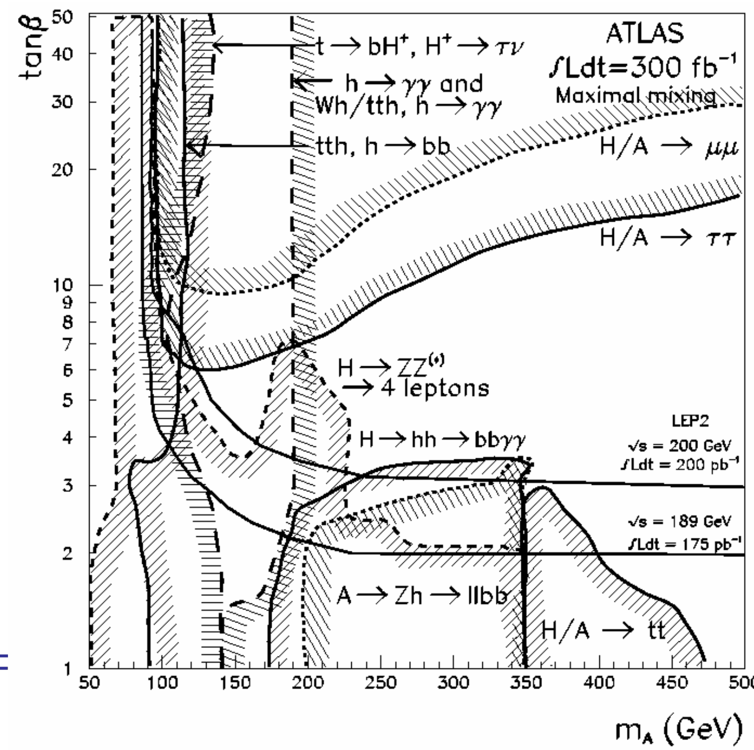






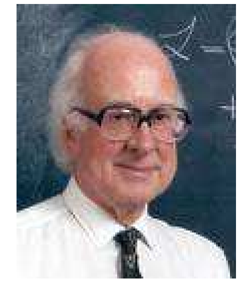
VBF production with H→ ττ
✓Forward jets
✓Collinear approximation





Conclusions

- The tau lepton was discovered in the late ‘70
- Electroweak processes involving taus are now measured precisely
  - *CDF (and D0) established robust tools for identifying hadronically decaying taus at hadron collider*
  - *Taus provide insights into EWK symmetry breaking*
- Taus are excellent probes for New Physics!
  - *Abundance of taus in SUSY, L-R symmetric models, theories with new gauge bosons, etc*
  - *Just limits, so far*
  - *But more data to come at Tevatron …*



Where is the Higgs boson?

And a new era at the LHC!

Backup

W at CDF

- Electron rejection 90%
- Visible mass 85%

QCD

- Use events in L3_PS100_L1_MET25
- Select only events with taus 0.1<EMF<0.9 –> assume flat distribution of EMF for jets

W decaying into electron+neutrino

- Low fake rate, we cannot use only MC because of large uncert
- Background if real ele emitted photons and not ID as electron -> use the photon shower information
- Take W into tau candidates with EMF > 0.9 (likely ele), plot ΔZ(track,CES) in Wtau MC and Wele MC. Use as template, fit to data, find the background

SYSTEMATICS

- Tau ID 4.5% stat + 2.8 sys
- PDF 2%, monojet cut 2.6%

Z at CDF

Extract the signal:

- we now fit the expected number of events to the observations in all regions simultaneously and extract all the normalizations

LS events

M_T 50:100 GeV	W+jets	QCD
M_T 0:50 GeV	QCD Photon +jet	QCD
	Iso 0:1	**Iso 2:8**

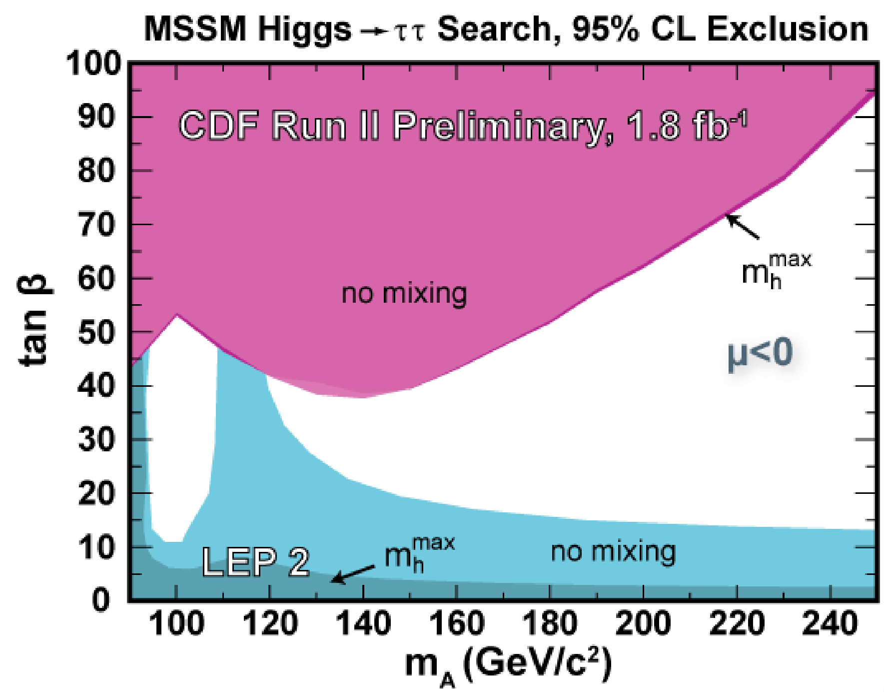
SYSTEMATICS (%)

Geometrical and kinematic acceptance (incl. PDFs) 3.0
Electron ID 1.9
Tau ID 3.0
Electron Trigger Efficiency 1.0
Tau Trigger Efficiency 1.0
Topology cuts 0.4
Background estimation 1.3
Total: 5.0

MSSM h at CDF

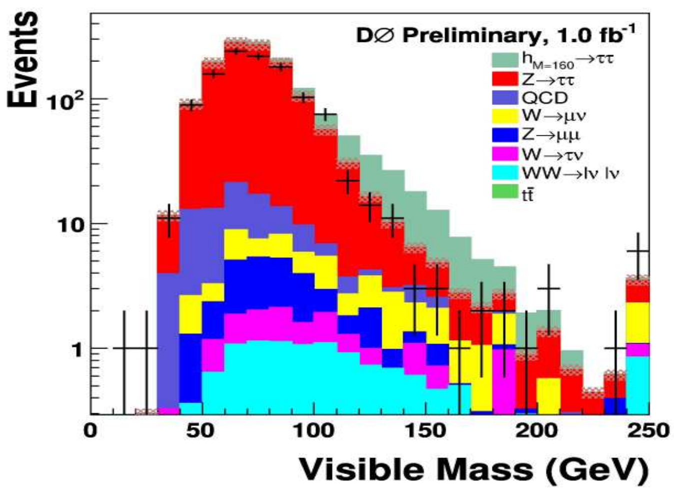
BACKGROUND
SYSTEMATIC UNCERTAINTIES (%)

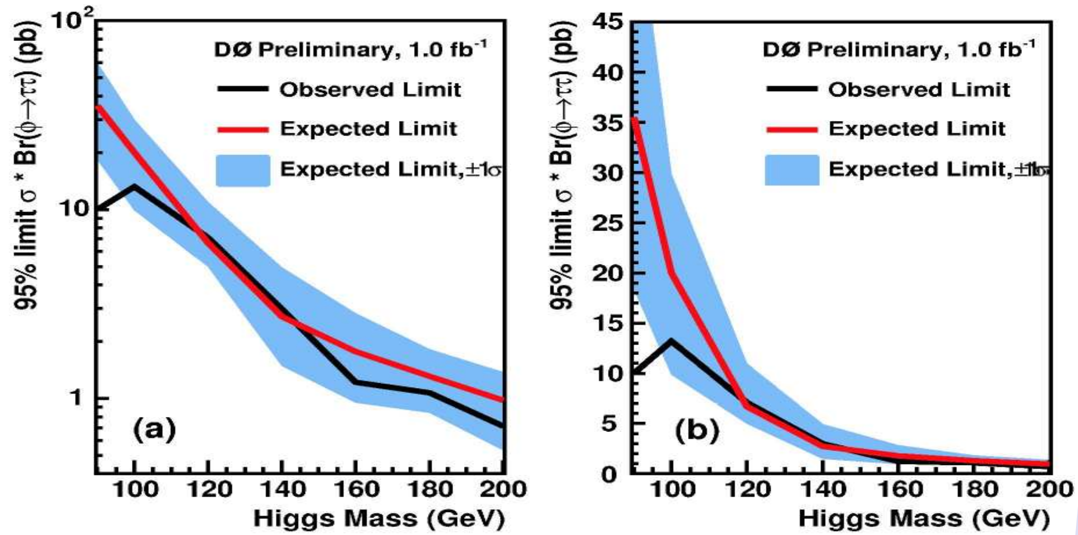
Ele ID 2
Muon ID 3
Tau ID 3
Trigger 0.3-1
Fake background in emu channel 32
Fake background in tau channels 6-9
Theory cross section 2-13
PDF 6

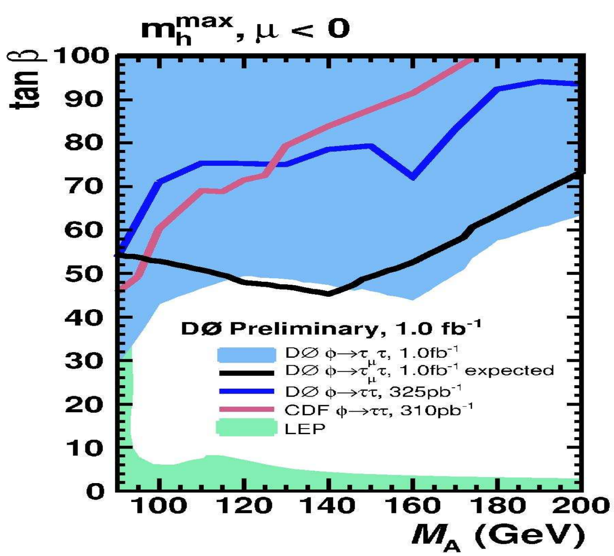


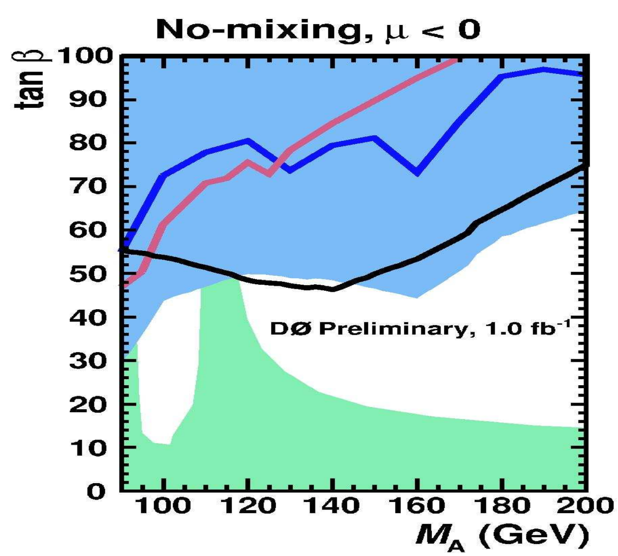
MSSM h at D0

NN selection





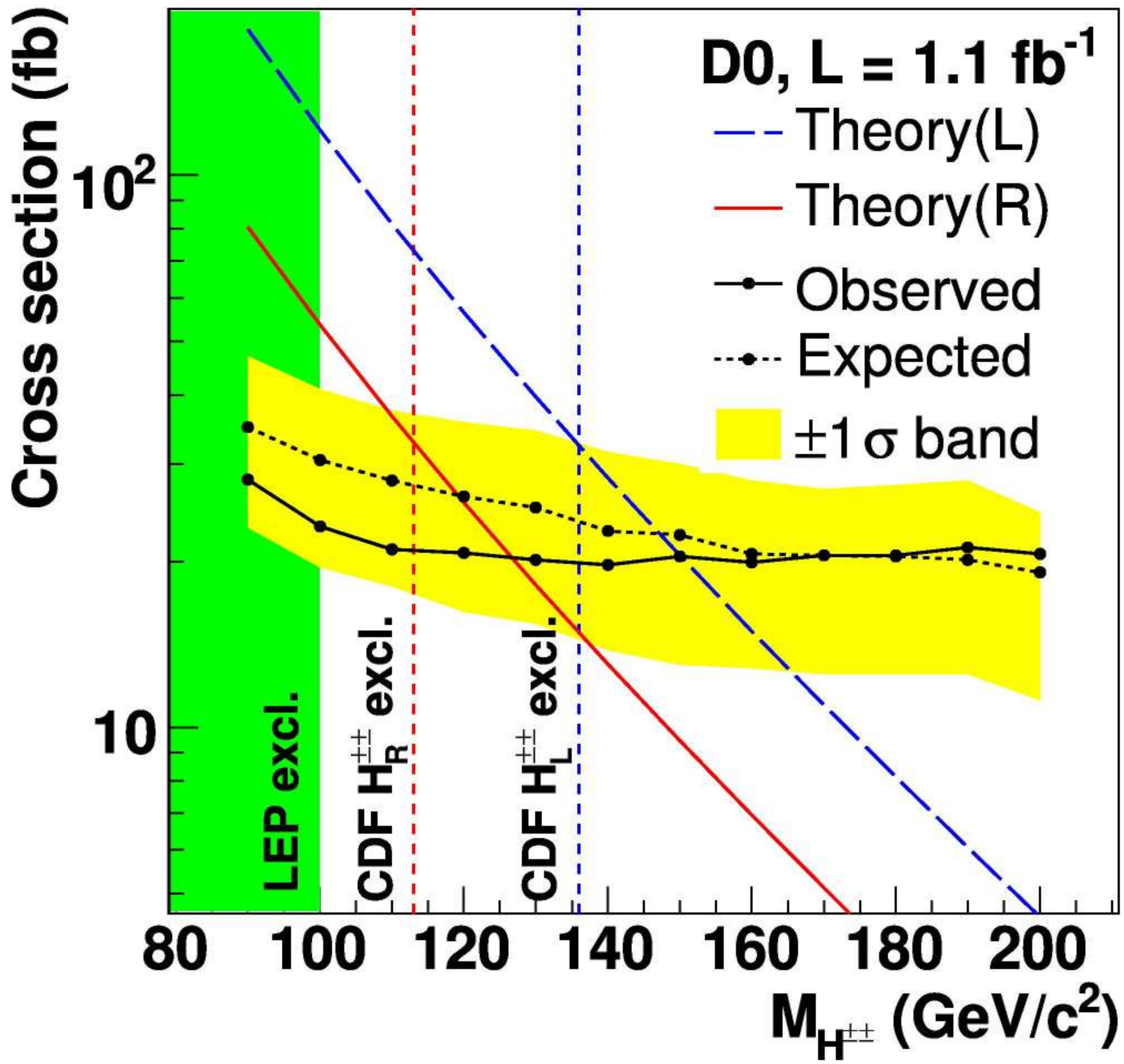




MSSM h at D0

In the MSSM, the masses and couplings of the Higgs bosons depend on tan and mA at tree level. Radiative
corrections introduce additional dependencies on SUSY parameters. In a constrained model, where unication of the
SU(2) and U(1) gaugino masses is assumed, the most relevant parameters are
the mixing parameter Xt;
The mass parameter ;
the gaugino mass term M2;
the gluino mass m~g;
the common scalar mass MSUSY.
In this analysis, the mmax
h and no-mixing scenarios are studied. The scenarios have the following parameters:
- **mmax**
h scenario:
Xt = 2 TeV;
M2 = 0:2 TeV;
m~g = 0:8 TeV;
MSUSY = 1 TeV.
- **No-mixing scenario:**
Xt = 0 TeV;
M2 = 0:2 TeV;
m~g = 1:6 TeV;
MSUSY = 2 TeV.

H++ at D0



Cross section (fb)
10^2
10
80
100
120
140
160
180
200
$M_{H^{\pm\pm}}$ (GeV/c^2)
D0, L = 1.1 fb^{-1}
Theory(L)
Theory(R)
Observed
Expected
±1 σ band
LEP excl.
CDF $H_R^{\pm\pm}$ excl.
CDF $H_L^{\pm\pm}$ excl.

SM Higgs

BACKGROUND
SYSTEMATIC UNCERTAINTIES (%)

Trigger 0.3-3
Ele ID 2
Muon ID 3
Tau ID 3
JES 16
MC stat 0.5
Normalization 2
MC model 20

Tau sneutrino (I)

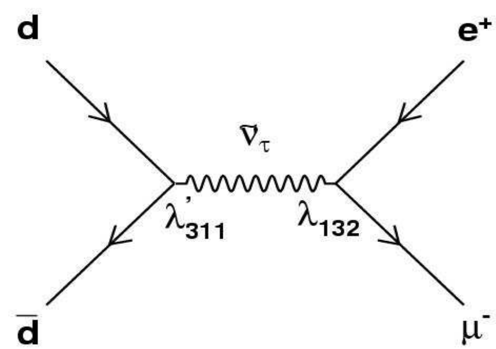
New!
L = 1.0 fb^{-1}

- Lepton number violation observed in the neutral sector
- RPV terms added to the theory

What if R_P is violated ?
What if R_P is violated ?

$$W_{RPV} = \frac{1}{2}\varepsilon_{ab}\lambda_{ijk} L_i^a L_j^b E_k + \varepsilon_{ab}\lambda'_{ijk} L_i^a Q_j^b D_k + \ldots$$

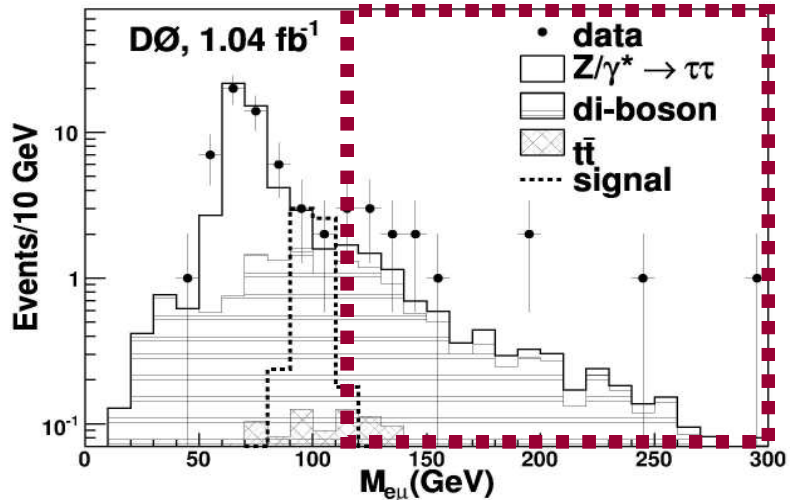
- **Search for τ-sneutrino**
  - "Single coupling dominance"
    - $\lambda'_{311} \neq 0$ and $\lambda_{132} \neq 0$
  - Look for "bump" in $M_{e\mu}$
    - Muon $p_T > 25$ GeV/c
    - Electron $E_T > 30$ GeV
  - SM Background
    - Drell-Yan, diboson, t-tbar



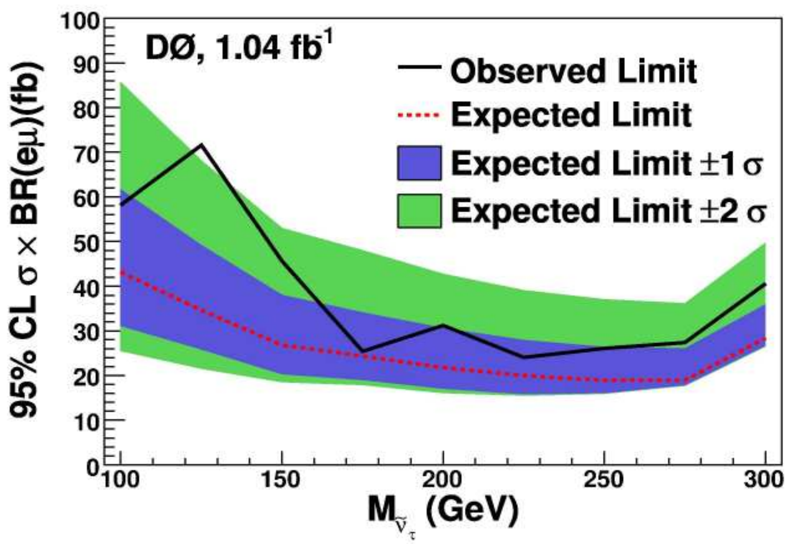
- SM suppressed vetoing
  - events with same flavor leptons
  - events with MET > 15 GeV not aligned with muons or with more than one jet $E_T > 30$ GeV

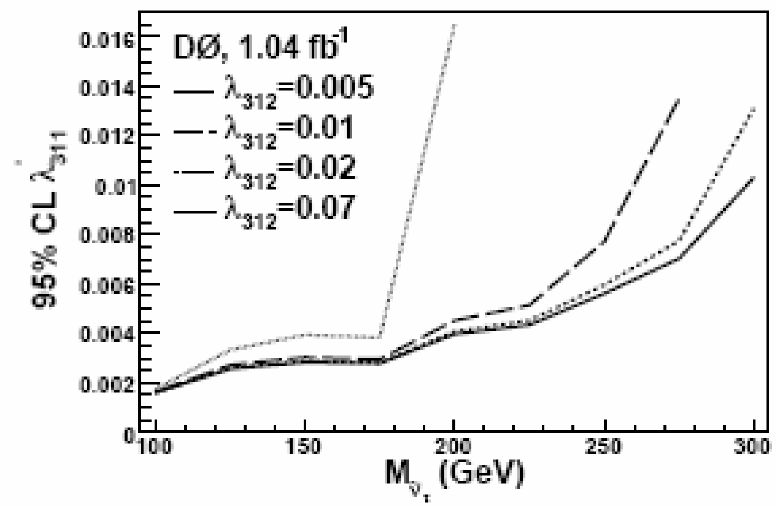
Tau sneutrino (II)

arXiv:0711.3207

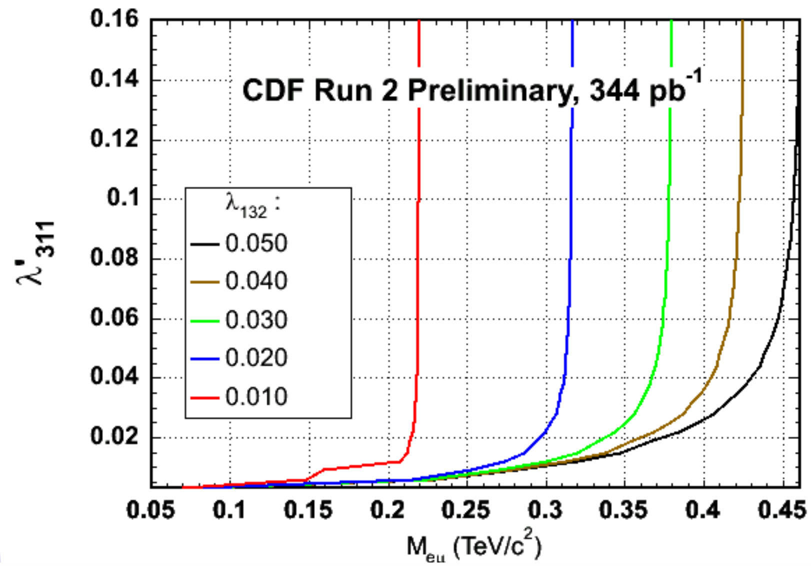


SM Backgr.	Data
$Z/\gamma^* \to \tau\tau$	42.9±4.2
WW	13.7±1.5
t-tbar	1.4±0.3
WZ	1.2±0.2
Total Backg.	59.2±5.3
Data	68

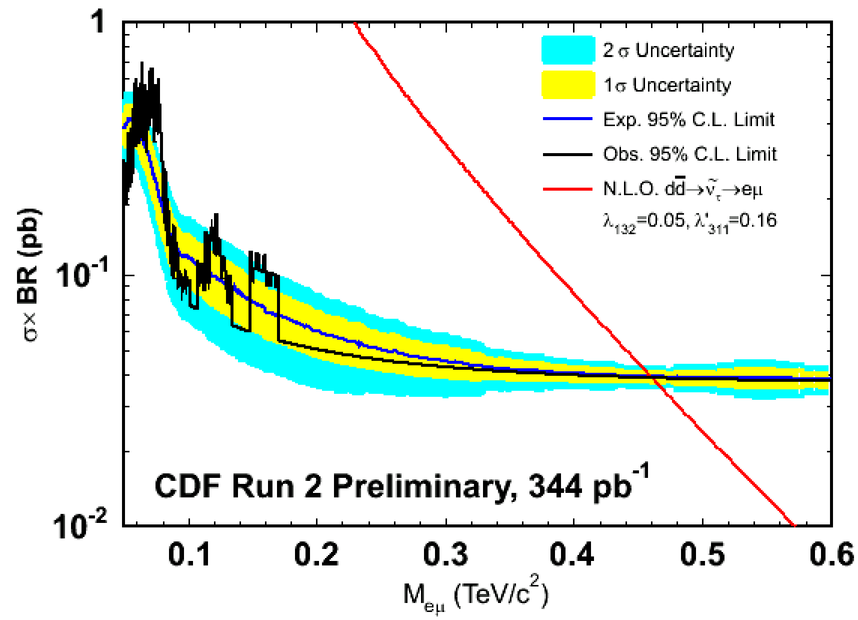




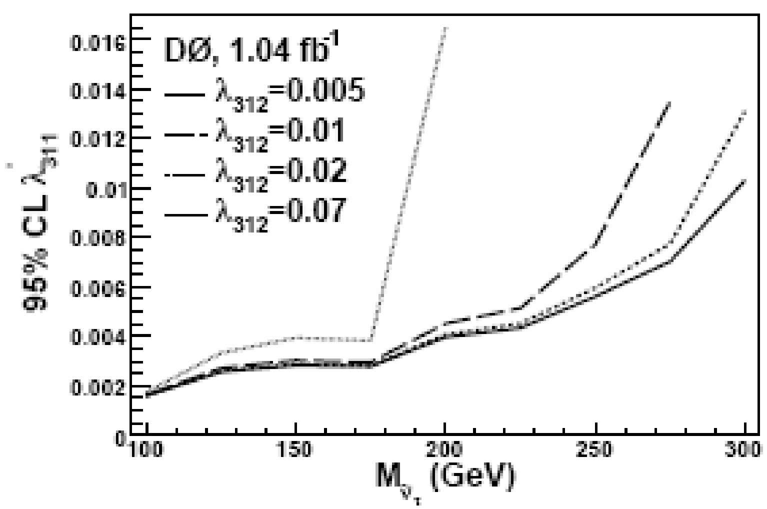
sν at CDF



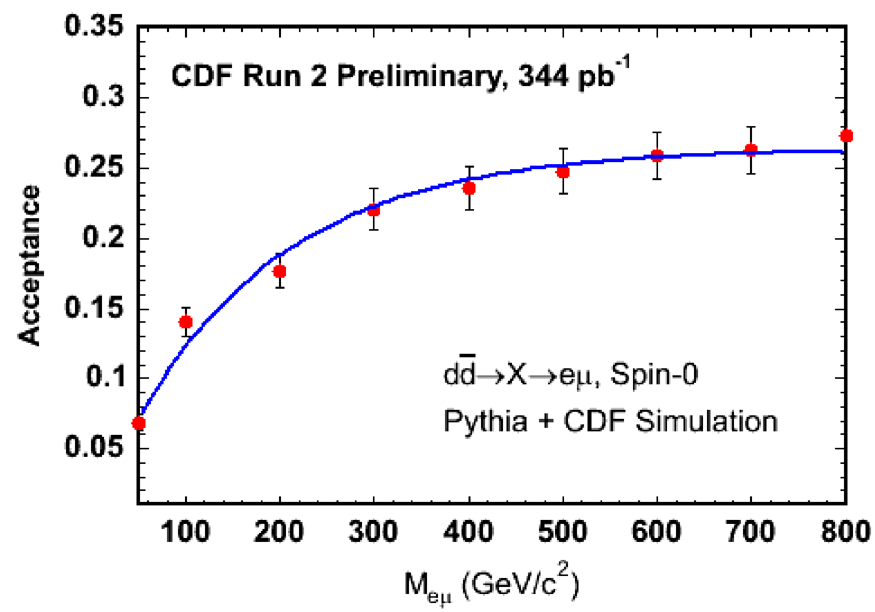
CDF Run 2 Preliminary, 344 pb^{-1}
λ_{132} :
0.050
0.040
0.030
0.020
0.010
λ'_{311}
$M_{e\mu}$ (TeV/c^2)



2 σ Uncertainty
1σ Uncertainty
Exp. 95% C.L. Limit
Obs. 95% C.L. Limit
N.L.O. $d\bar{d}\to\tilde{\nu}_\tau\to e\mu$
λ_{132}=0.05, λ'_{311}=0.16
CDF Run 2 Preliminary, 344 pb^{-1}
σ× BR (pb)
$M_{e\mu}$ (TeV/c^2)

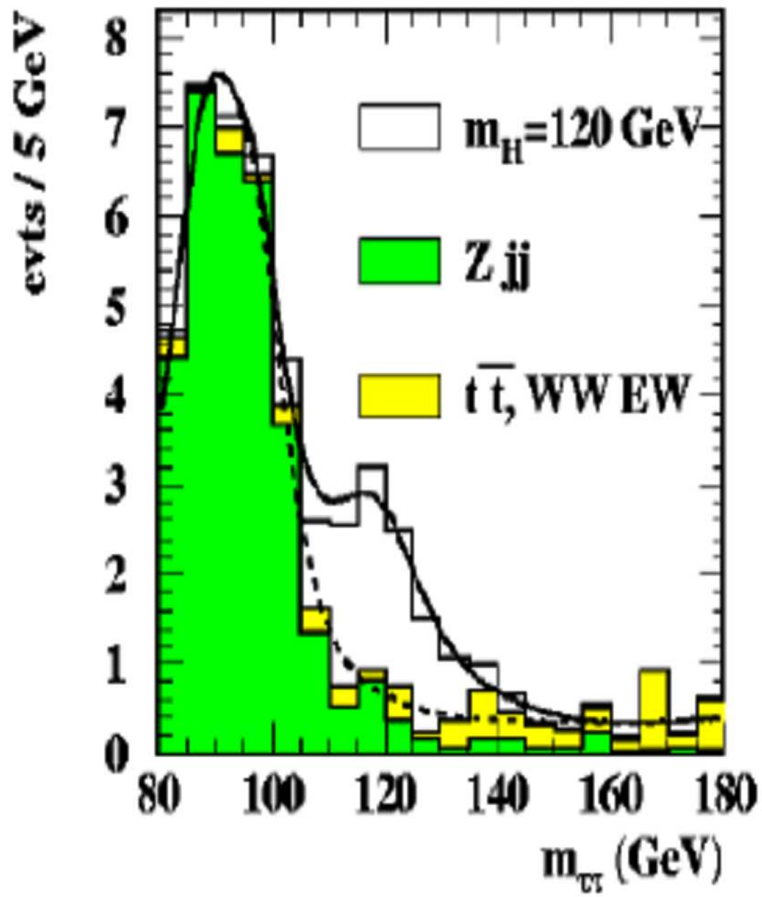


DØ, 1.04 fb^{-1}
λ_{312}=0.005
λ_{312}=0.01
λ_{312}=0.02
λ_{312}=0.07
95% CL λ'_{311}
$M_{\tilde{\nu}_\tau}$ (GeV)

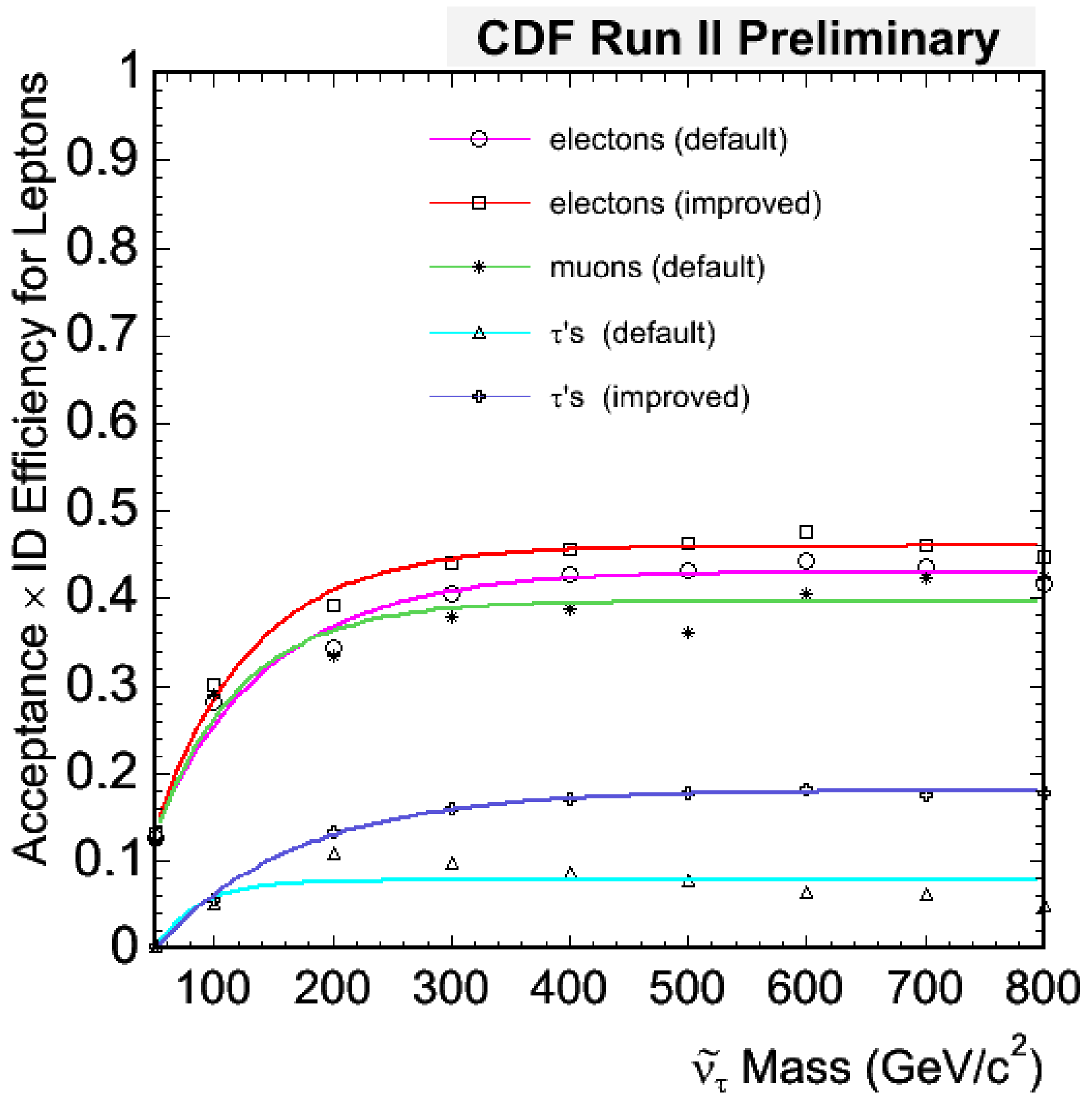


CDF Run 2 Preliminary, 344 pb^{-1}
$d\bar{d}\to X\to e\mu$, Spin-0
Pythia + CDF Simulation
Acceptance
$M_{e\mu}$ (GeV/c^2)

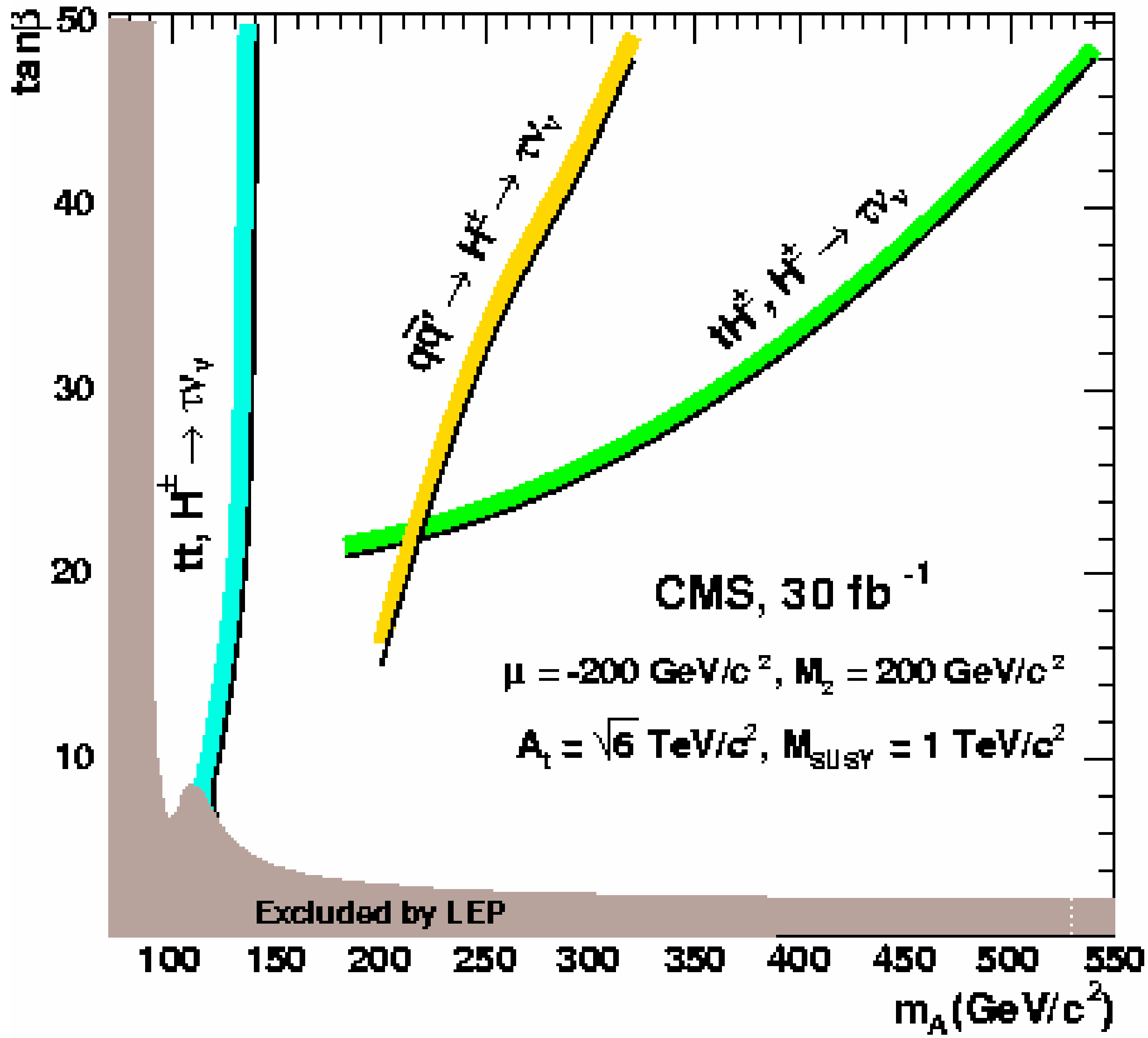
ATLAS SM H in VBF (10/fb)



Acceptance x Efficiency

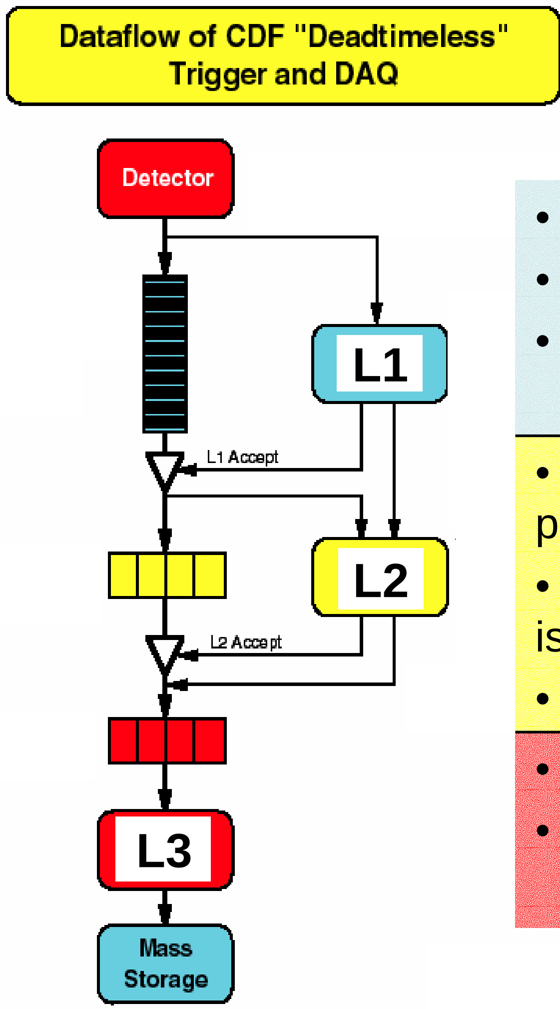


H+ at LHC



tanβ
50
40
30
20
10
tt, H± → τν
qq̄' → H± → τν
tH±, H± → τν
CMS, 30 fb⁻¹
μ = -200 GeV/c², M₂ = 200 GeV/c²
Aₜ = √6 TeV/c², M_SUSY = 1 TeV/c²
Excluded by LEP
100
150
200
250
300
350
400
450
500
550
m_A (GeV/c²)

Tau triggers

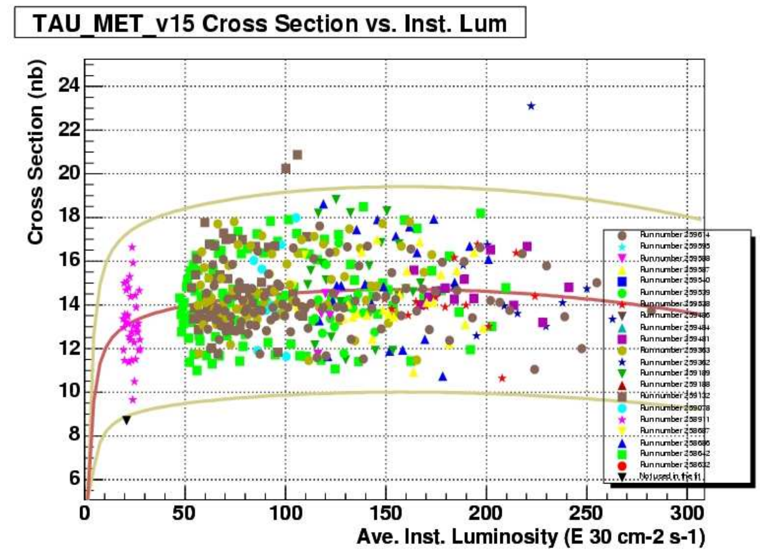


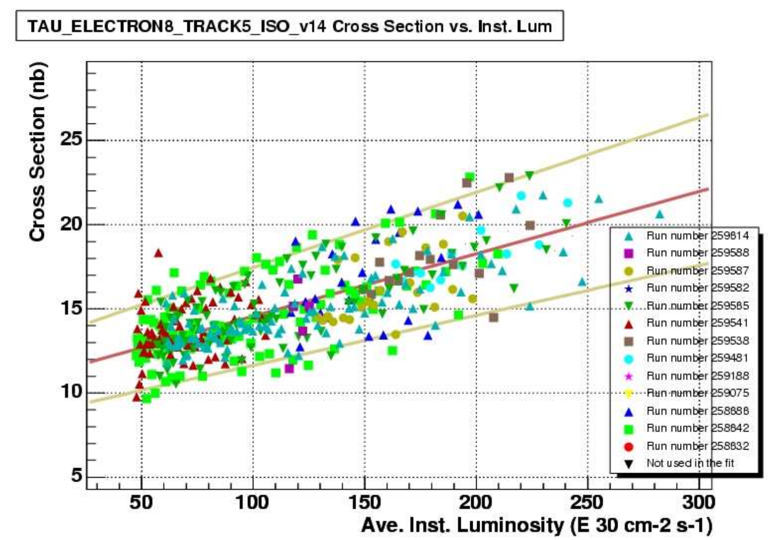
• Custom designed hardware • Tracking, calorimeter towers, MET • Primitives shared by other paths	L1 output < 30 kHz
• Custom hardware & commodity processor • Calorimeter clustering, track isolation, MET • Bandwidth limitations	L2 output < 1 kHz
• Processor farm • Full event reconstruction	L3 output < 150 Hz

L2 Tau triggers

- TAUMET
  - MET > 20
  - Narrow isolated jet E > 10 GeV
- DITAU
  - Two narrow isolated jets E > 10 GeV
- ELECTRON & TRACK
  - Central electron E > 8 GeV
  - Isolated track p_T > 5 GeV
- MUON & TRACK
  - Central muon p_T > 8 GeV
  - Isolated track p_T > 5 GeV

$R = \sigma \cdot L_{inst}$
$R\ (100 \cdot E30cm^{-2}s^{-1}) =$
$14 * 100 / 1000 = 1.4$ Hz



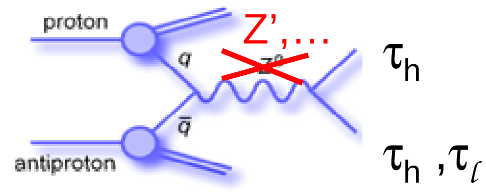


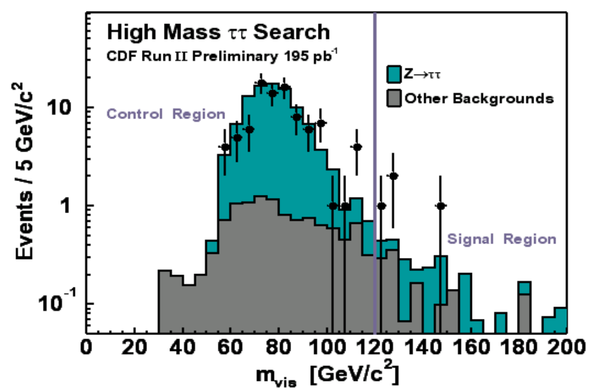
New bosons

- New physics predicts new gauge bosons

Z', RPV SUSY, ED, ….

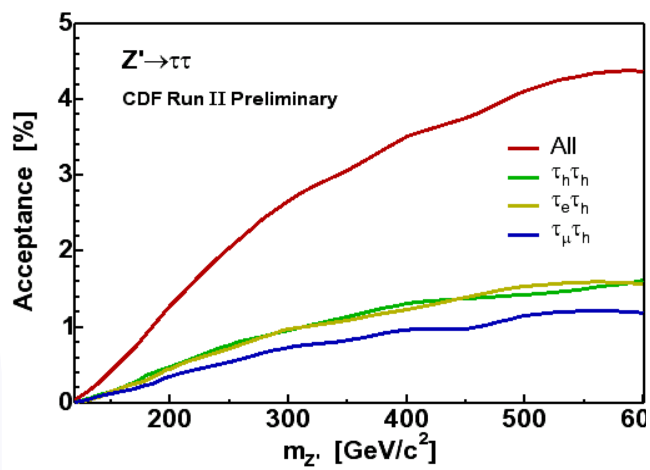
- Events with
  - τ Vis $E_T > 15$ GeV
  - lepton $E_T > 10$ GeV

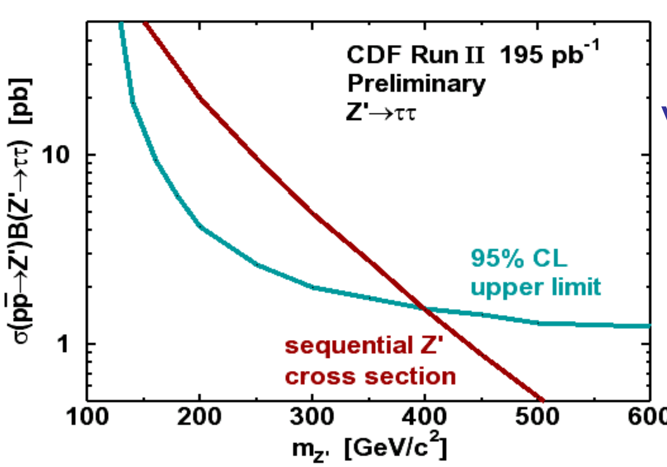




Background reduced with MET cut

Observed:4
Background:
2.8 ± 0.5





Vector Boson SM couplings
m(Z') > 399 GeV
Scalar Boson sν, λ'·B=0.01
m(sν) > 377 GeV

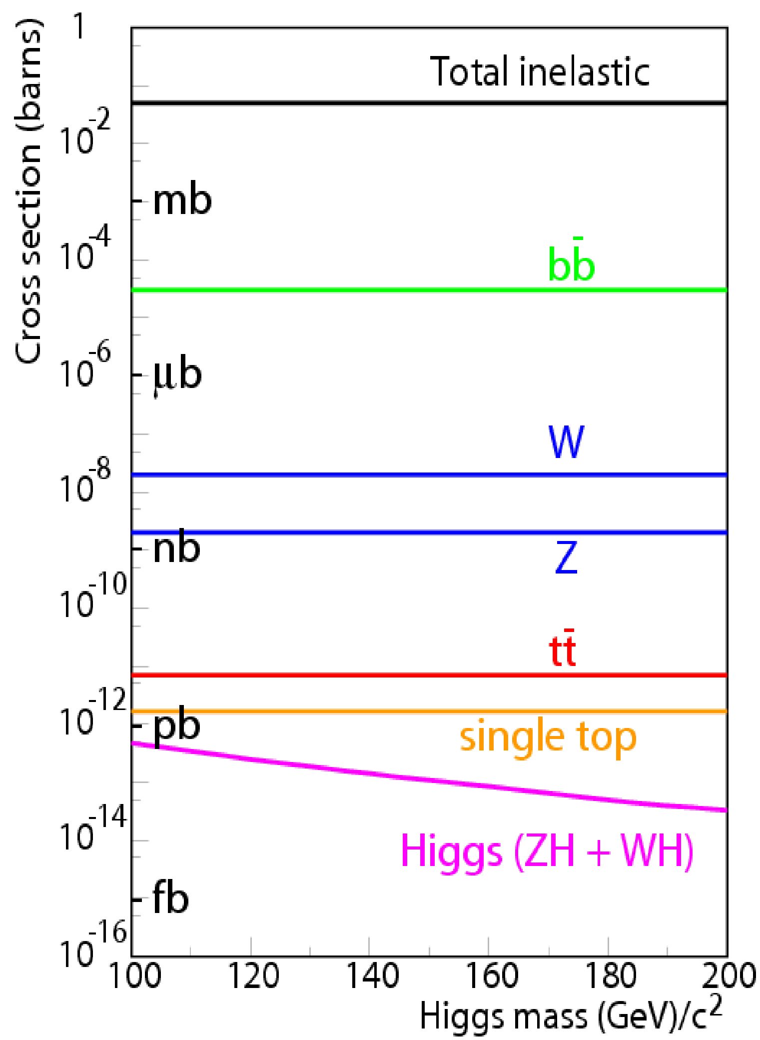
Double Charged H

- Events collected via LEPTON&TRACK trigger
  - τ Vis $E_T > 15$ GeV & lepton $E_T > 20$ GeV
  - Split into 2 exclusive channels
    - $+ \geq 1$ isolated lepton candidate with $E_T > 8$ GeV
  - Loose cuts yield large acceptance !
- Signal extraction
  - $30 < m$ (like sign pair) < 125 GeV
  - $H_T > 190$ GeV in thee lepton channel
  - $H_T > 120$ (150) GeV in four lepton channel
- Backgrounds
  - QCD, cosmics, W+jets, Drell-Yan+jets
    - Measured in data events with non-isolated leptons
  - Diboson and t-tbar from MC
  - validated in control regions with non-isolated leptons and in low H_T region

Isolated Track
mass < 1.8 GeV
track Isolation
π^0 isolation
1 or 3 signal tracks

Background from mis-measured tracks might contaminate signal region.
Highest pT track :
$\sigma(curv) \leq 3 \cdot 10^{-6}$ *(silicon tracks)*
$\sigma(curv) \leq 7 \cdot 10^{-6}$ *(COT tracks)*

3 lepton channel
ZZ : 0.02
WZ: 0.09
Drell-Yan: 0.10
tt-bar: 0.06
$H^{++/--}$(m=100GeV): 1.8


Cross section (barns)
1
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
10^-14
10^-16
mb
μb
nb
pb
fb
Total inelastic
bb̄
W
Z
tt̄
single top
Higgs (ZH + WH)
100
120
140
160
180
200
Higgs mass (GeV)/c2