TAU IDENTIFICATION AT FERMILAB D0 AND HIGGS SEARCHES USING TAUS

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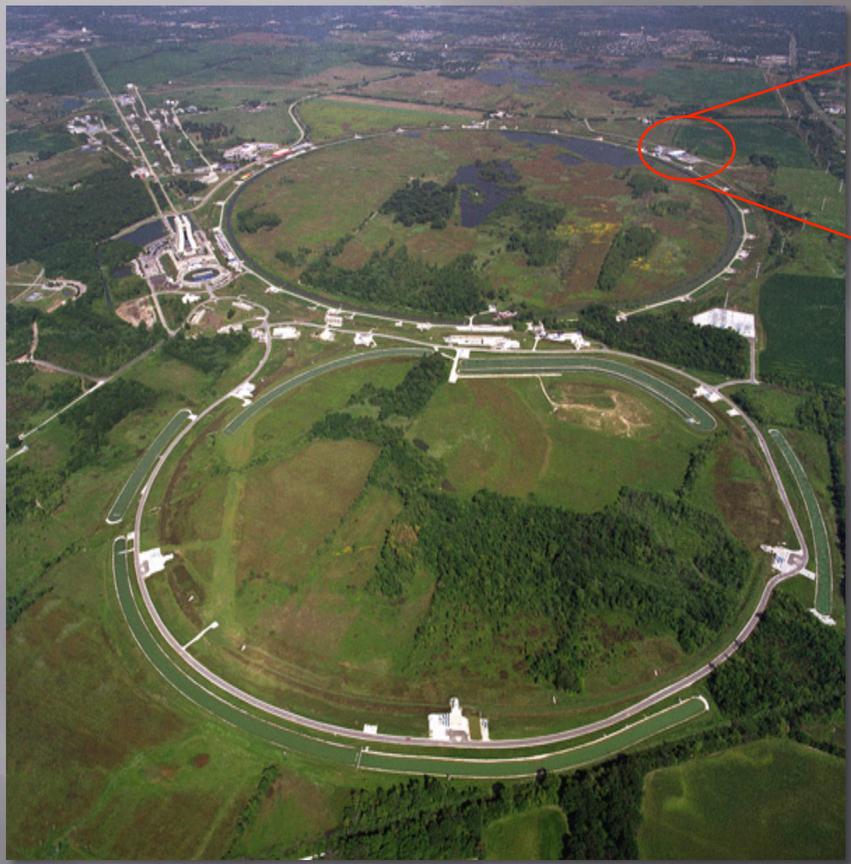
for the D0 Collaboration

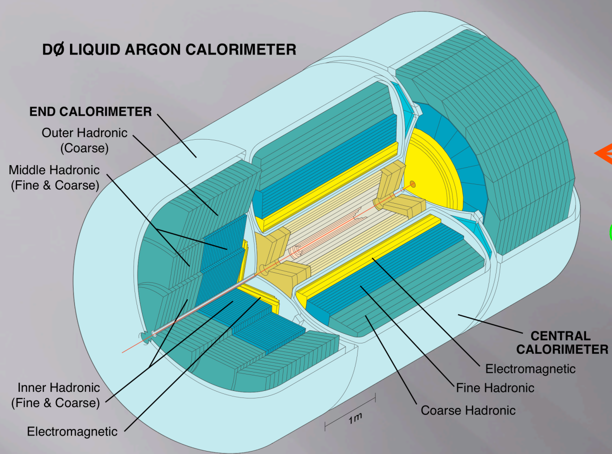
Tau 2008 Workshop, September 25th

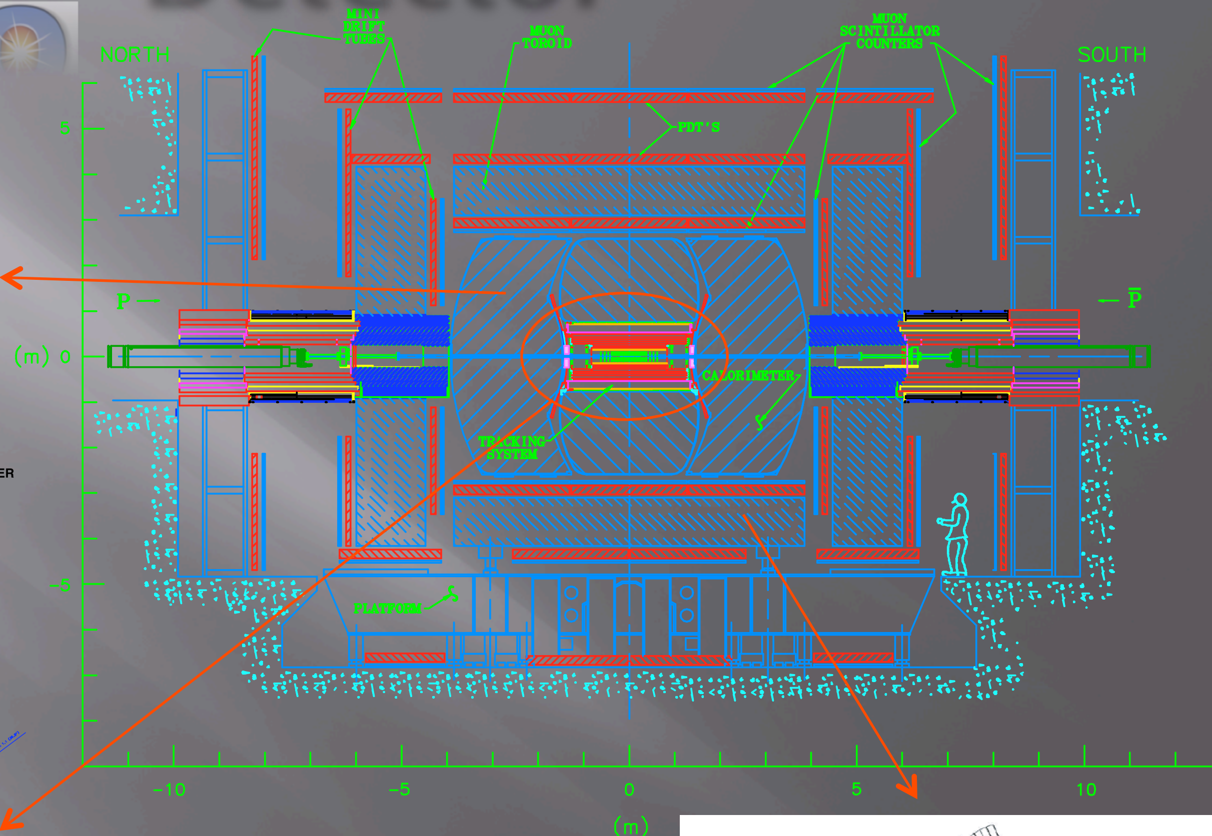
Fermilab



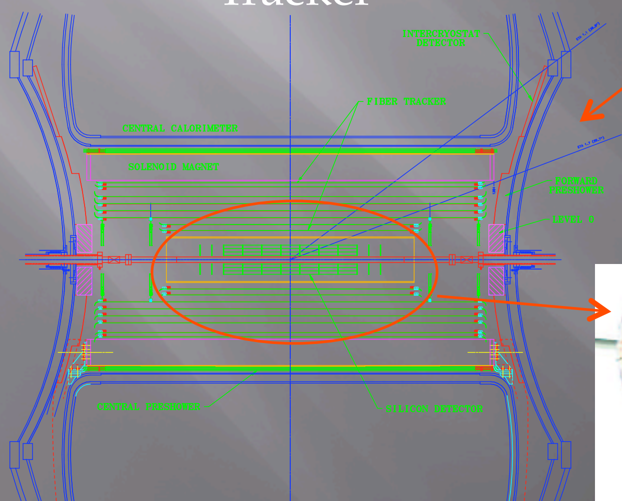
5 fb^{-1} delivered last week

DØ Detector

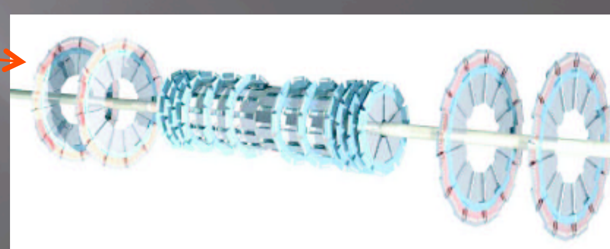


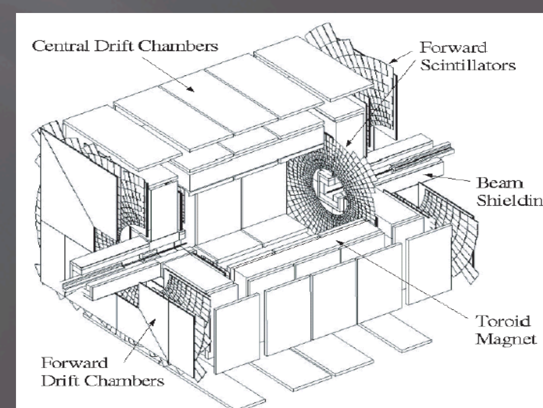


Tracker



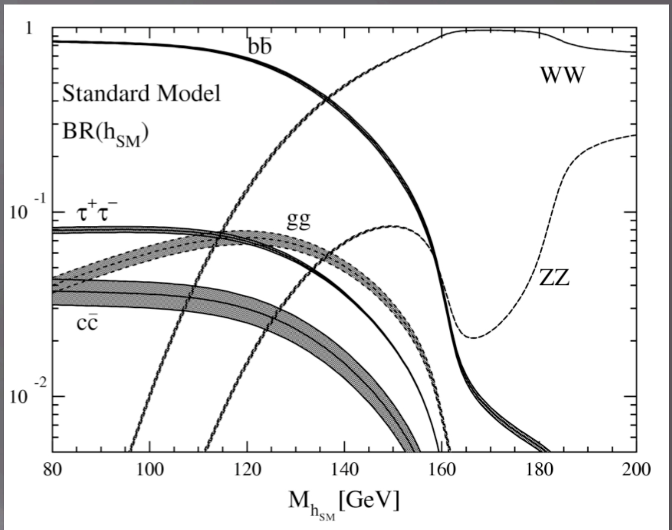
SMT

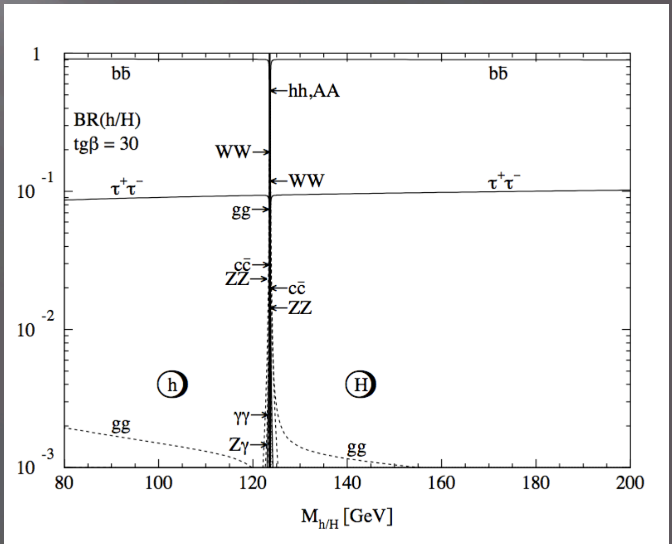




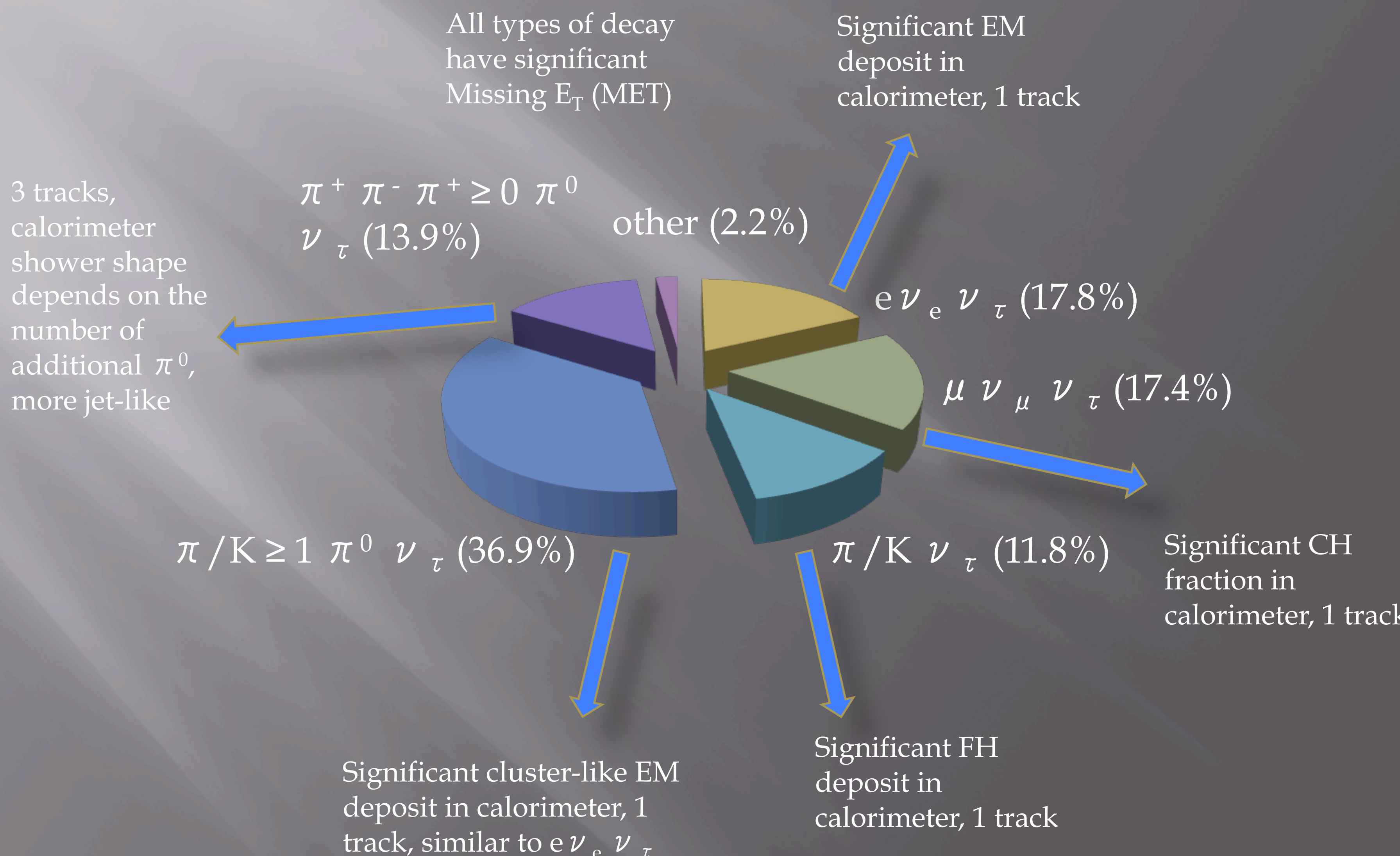
What are taus good for at TeV?

- Lepton analyses benefit from added sensitivity
  - (Theoretically) Single lepton by factor of 1.5, di-lepton by factor of 2, tri-lepton by factor of 2.5
  - (In practice) Not that simple
- Higgs couples to mass
  - SM Higgs exclusion M_H > 114 GeV limits τ usefulness (BR), but we have SM Higgs analyses using τ in SM combination
- Minimal SUSY enhances Higgs coupling to down-type leptons and quarks by about a factor of tan β
  - Associated production with b-quark is enhanced
  - Branching ratio to τ's is enhanced at higher Higgs masses
- τ signature is more advantageous in combination with a light lepton and b-jet for MSSM Higgs search





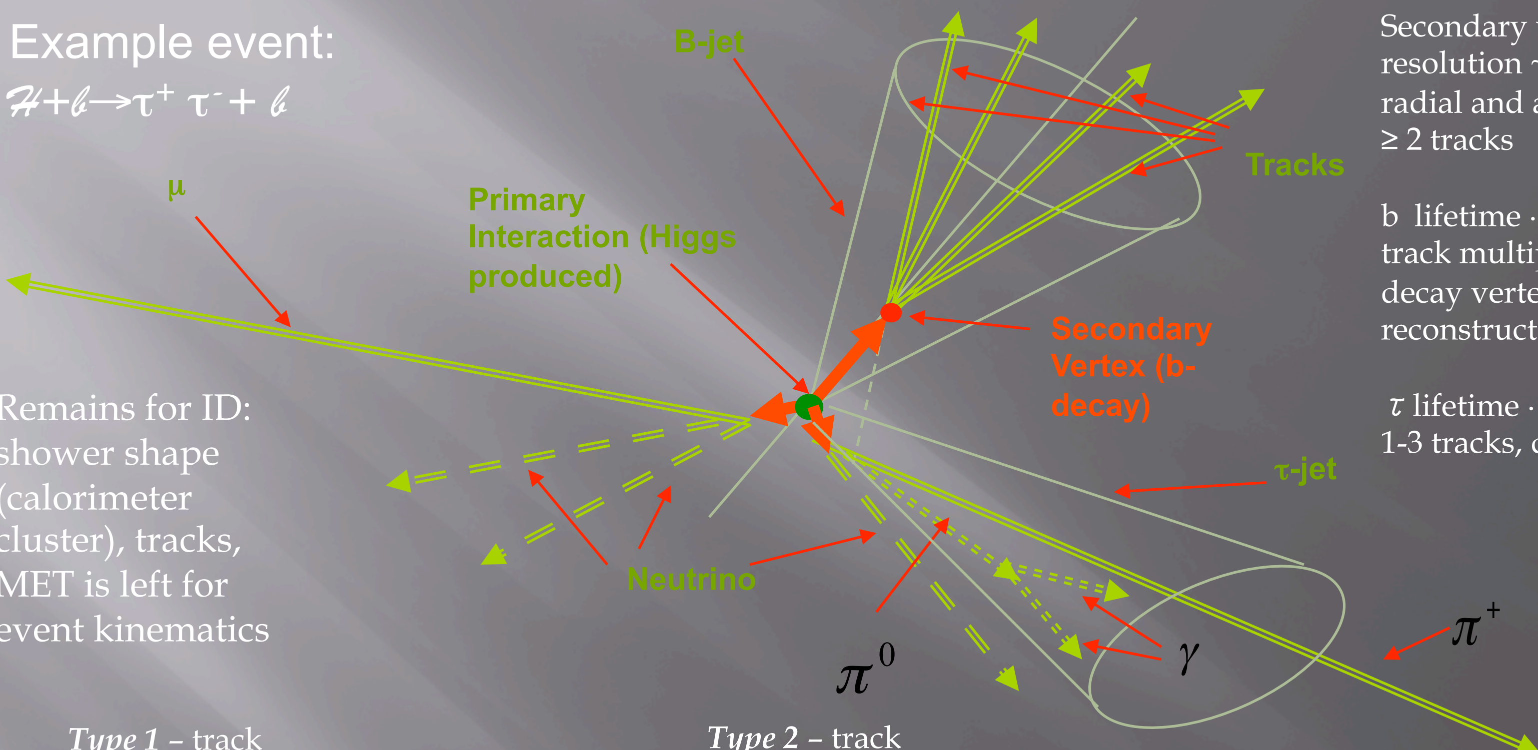
Tau properties



τ identification

Example event:

$H + b \rightarrow \tau^{+}\tau^{-} + b$



Secondary vertex resolution ~ 15 μm radial and asimuthal for ≥ 2 tracks

b lifetime · c ~ 450 μm, track multiplicity → decay vertex reconstruction

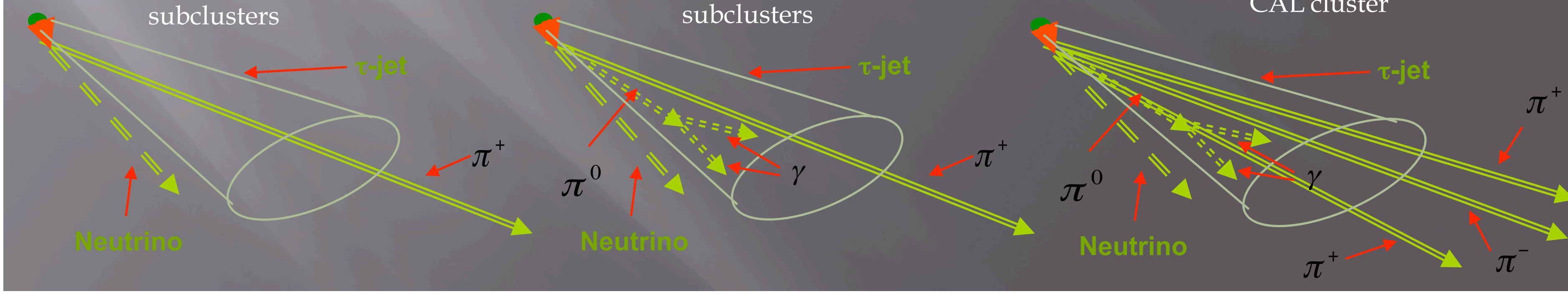
τ lifetime · c ~ 87 μm, 1-3 tracks, decay vertex?

Remains for ID: shower shape (calorimeter cluster), tracks, MET is left for event kinematics

Type 1 – track + CAL cluster + no EM subclusters

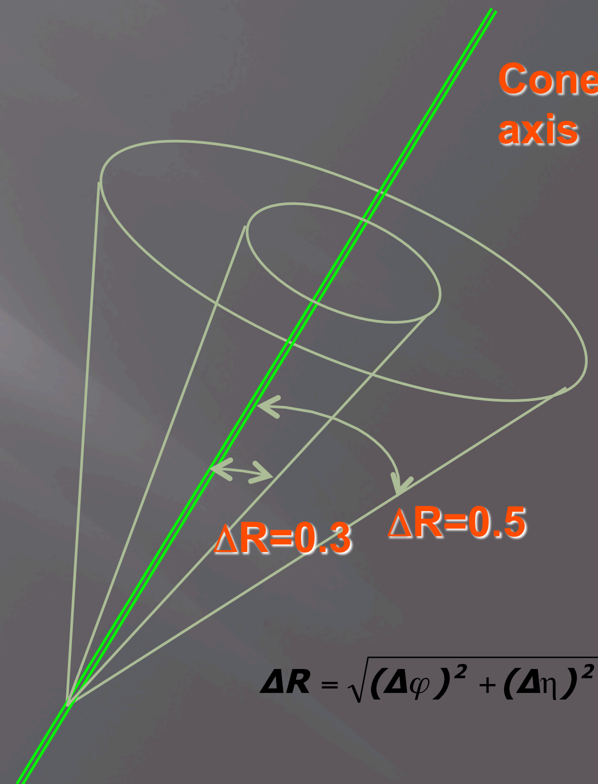
Type 2 – track + CAL cluster + some EM subclusters

Type 3 - >1 track + CAL cluster



τ reconstruction

- Tau Calorimeter clusters are found using Simple Cone Algorithm in $\Delta R<0.5$ cone (stitching together calorimeter towers)
- EM subclusters are seeded in EM3 calorimeter layer (double granularity, shower maximum) and reconstructed using Nearest Neighbor Algorithm (picks neighboring cells), other layers attached (including preshower hits)
  - EM3 transverse energy deposit of a subcluster > 800 MeV
- All tracks within $\Delta R<0.5$ cone compatible with τ decay (invariant mass cut).
  - Highest track $p_T > 1.5$ GeV
- Tau variables are calculated using $\Delta R<0.3$ cone, $\Delta R<0.5$ cone, and track variables

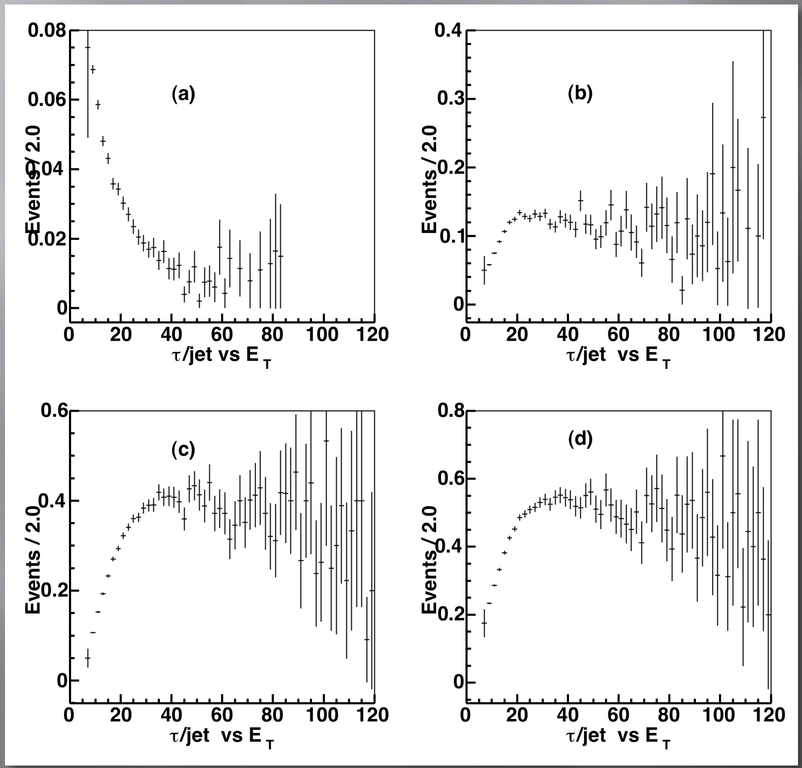


$$\Delta R = \sqrt{(\Delta\varphi)^2 + (\Delta\eta)^2}$$

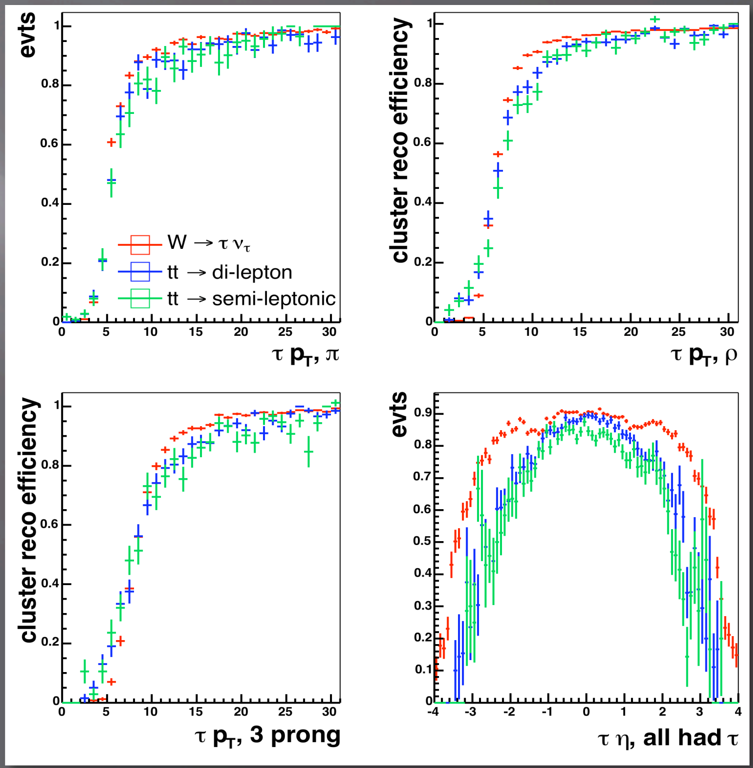
τ reconstruction efficiencies

- Jet fake rates after basic reconstruction are high, more discrimination needed

Jets faking taus (data)



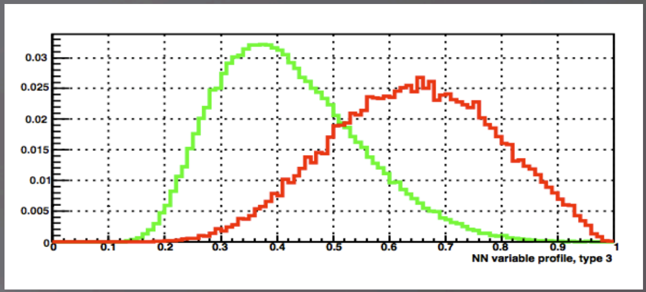
Taus from MC

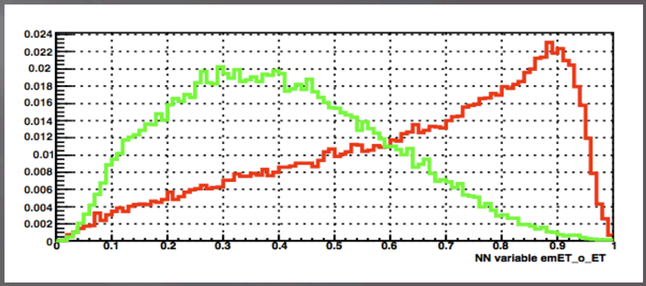


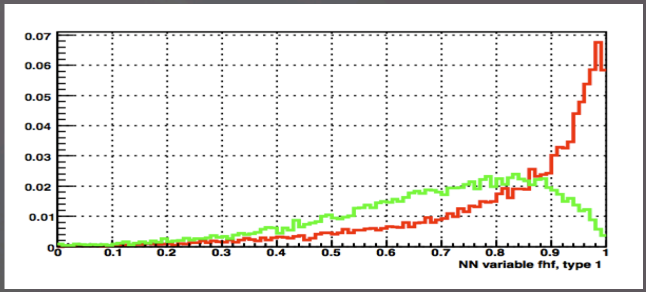
Neural Network

- 3 NNs, 1 for each τ type
- Some τ variables (energies are transverse):
  - Profile – fraction of τ cluster energy in two highest towers, $(E^{tower1}_{\tau} + E^{tower2}_{\tau})/E_{\tau}$, type 3
  - Emf – fraction of τ cluster energy in electromagnetic calorimeter, E^{EM}_{τ}/E_{τ}, type 2
  - Fhf – fraction of τ cluster energy in fine hadronic calorimeter, E^{FH}_{τ}/E_{τ}, type 1

Signal – Z→ττ MC
Background – jets recoiling against non-isolated μ (QCD)



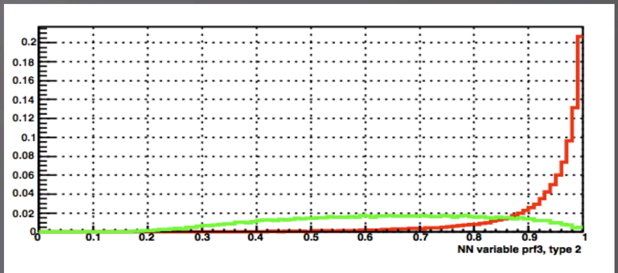


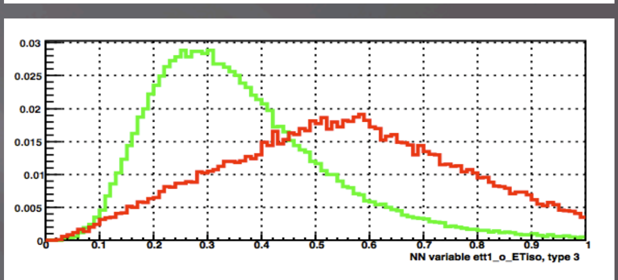


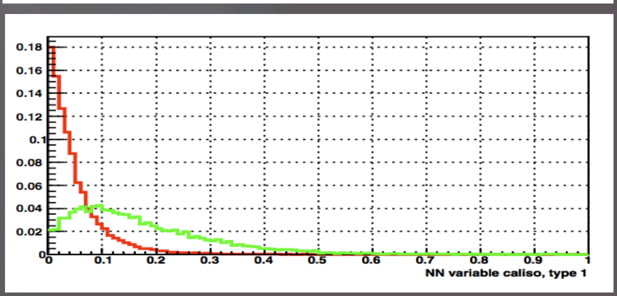
Neural Network

- More τ variables (energies and momenta are transverse):
  - Prf3 – energy of the leading τ EM subcluster in the EM3 layer over total EM3 layer energy, $E^{subclus.EM3}_{\tau} / E^{EM3}_{\tau}$, type 2
  - Ett1 – momentum of the leading τ track divided by the energy of the τ cluster, p^{T}_{τ} / E_{τ}, type 3
  - Caliso – energy in the hollow cone $0.3<\Delta R<0.5$ over τ energy in the $\Delta R<0.3$ cone, $(E^{\Delta R<0.5}_{\tau} - E^{\Delta R<0.3}_{\tau}) / E^{\Delta R<0.3}_{\tau}$, type 1

Signal – Z→ττ MC
Background – jets recoiling against non-isolated μ (QCD)

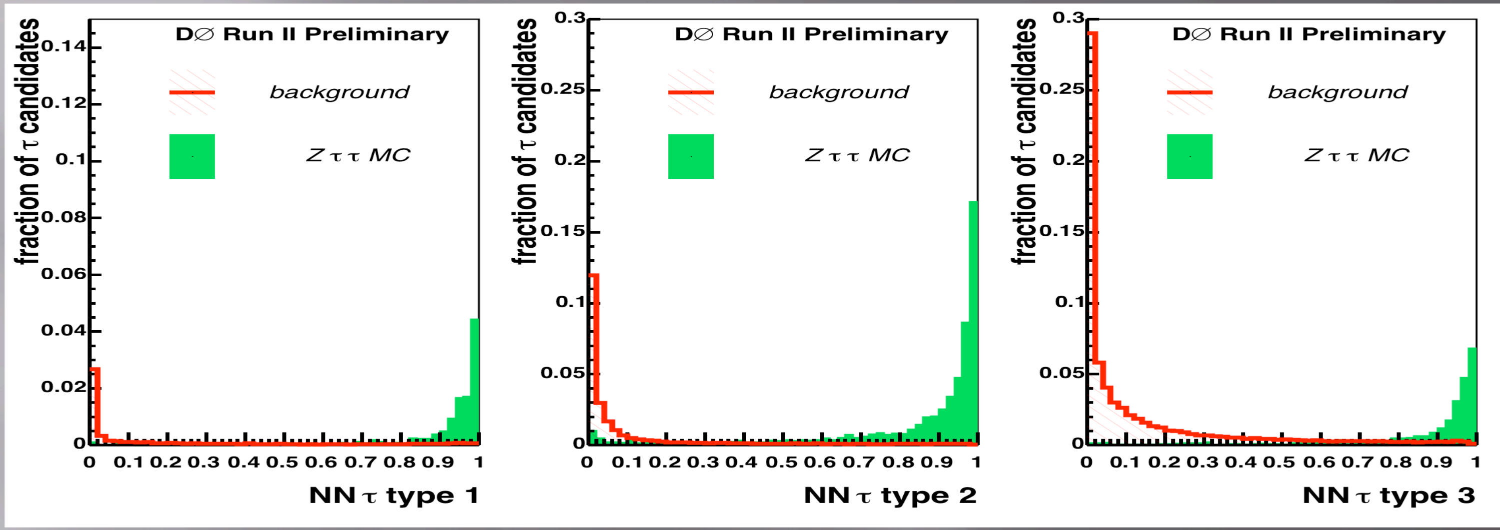






Neural Network

Outputs

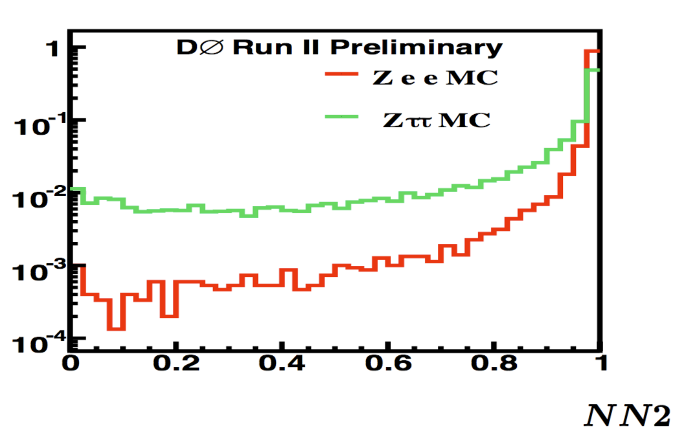


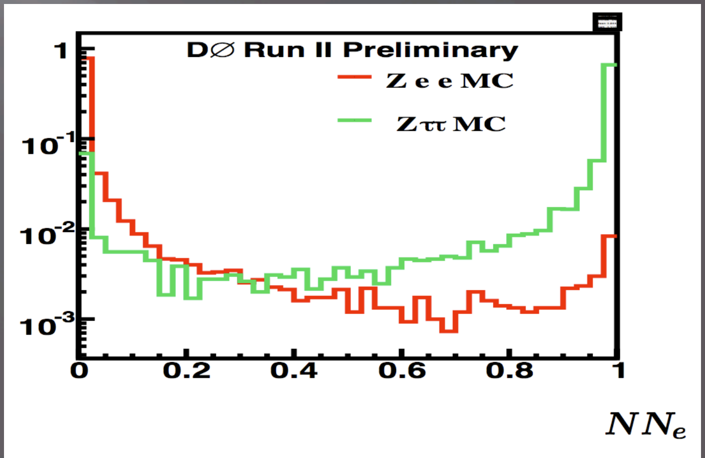
Efficiencies (%)				
$20<E^{\tau}_{T}<40$ GeV, $\mid \eta \mid <2.5$				
τ type	1	2	3	all
jets	2	12	35	52
τ	11	60	24	95
NN>0.9				
jets	0.06	0.24	0.8	1.1
τ	7	44	16	67

e- τ discrimination

- Electrons make nice type 2 τ's
- Another Neural Network trained on data electrons as a background

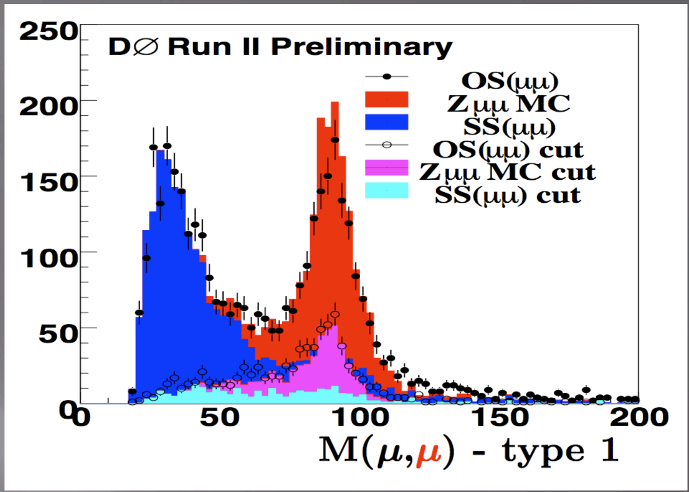
Efficiencies (%)		
$20<E^{\tau}_T<40$ GeV, $\|\eta\|<2.5$		
	$NN_2 > 0.9$	$NN_e>0.5$
e	98	3.4
τ	44	38



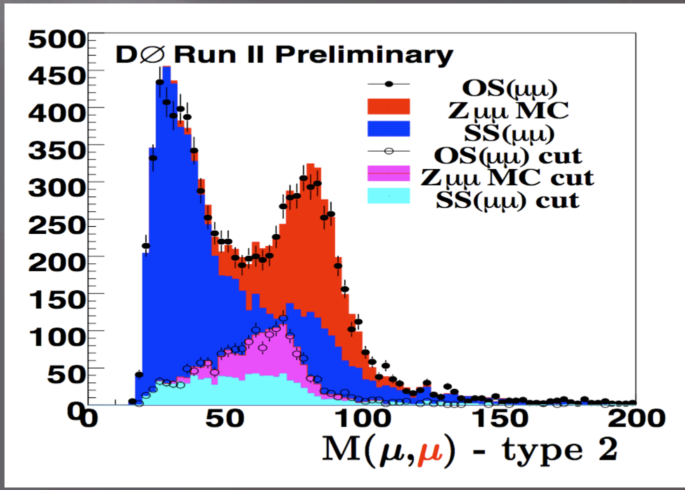


μ - τ discrimination

- μ misidentified as hadronically decaying τ is removed
- $E^{\tau}_T/P^{trk}_T\cdot(1\text{-}CHF)$ variable used to further reduce μ contribution

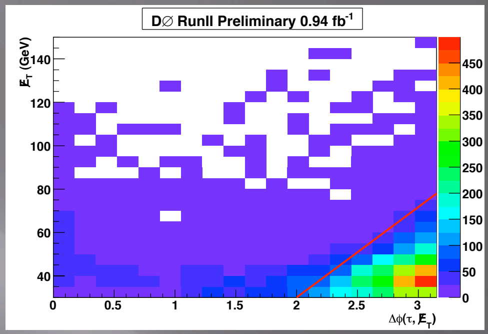


Efficiencies (%)		
$p^{\tau\, trk}_T$ >10 GeV, $\lvert\eta\rvert$<2.5		
	NN>0.9	
τ type	1	2
mis μ	2.5	3.1
elim μ id	0.4	0.8
$E^{\tau}_T/P^{trk}_T\cdot(1\text{-}CHF)>0.4$	0.2	0.4
τ	5.5	35

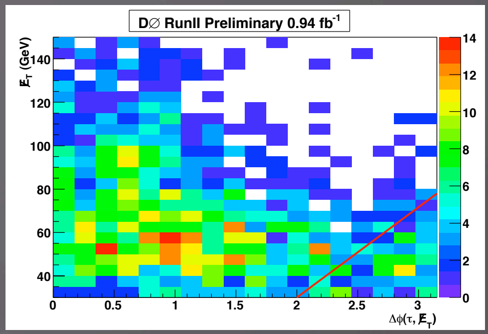


WH→ $\tau\ \nu_\tau$ bb search at D0

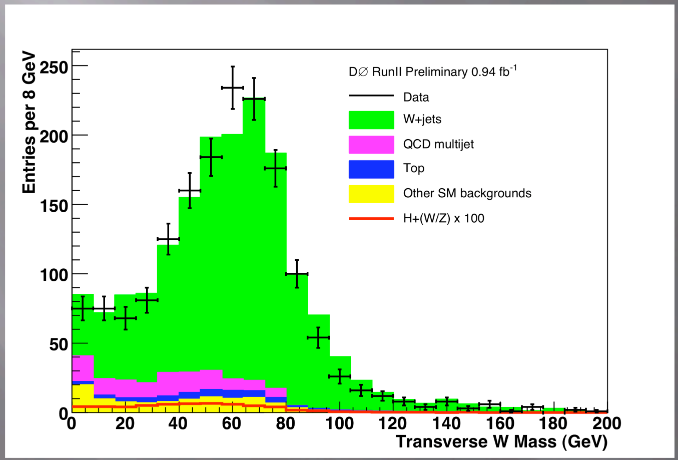
- Result uses 1.0 fb^{-1} 2002-2006 dataset (RunIIa)
  - Cuts on high MET > 30 GeV
  - 2D cuts on MET vs $\Delta\phi(\tau, MET)$
  - 2 b-tags (NN tagger)
- No significant excess in data over background
- 95% CL limits on $\sigma \cdot BR$
- Dijet mass is used as a limit calculation final variable



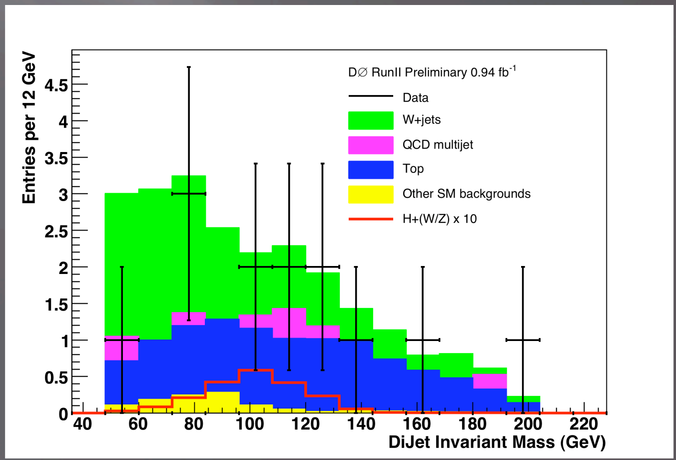
Signal



QCD background

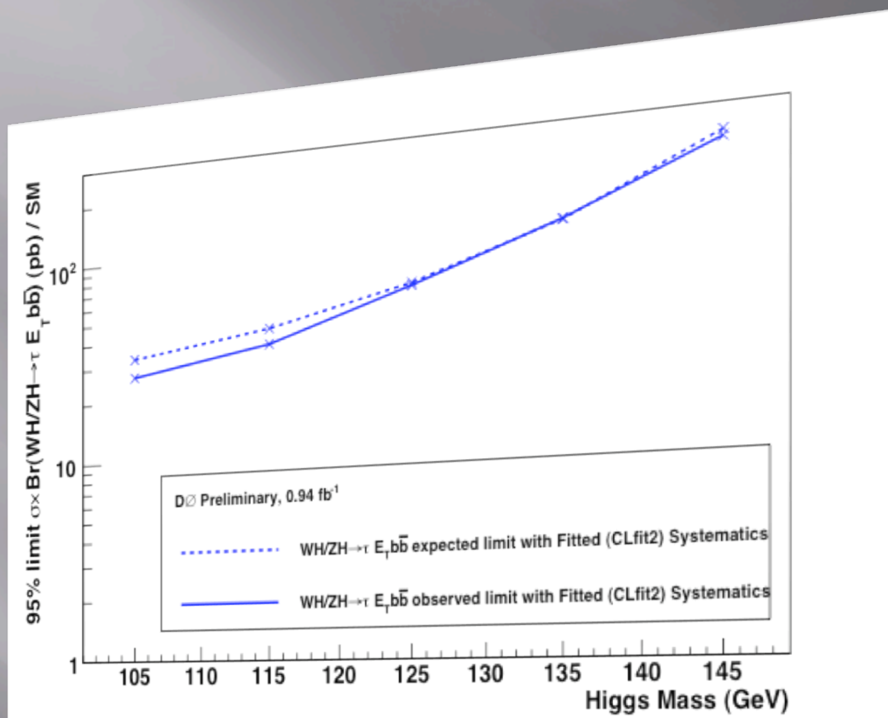


W mass, pretag



Dijet mass, b-tag

$WH \rightarrow \tau \nu_\tau$ bb limits



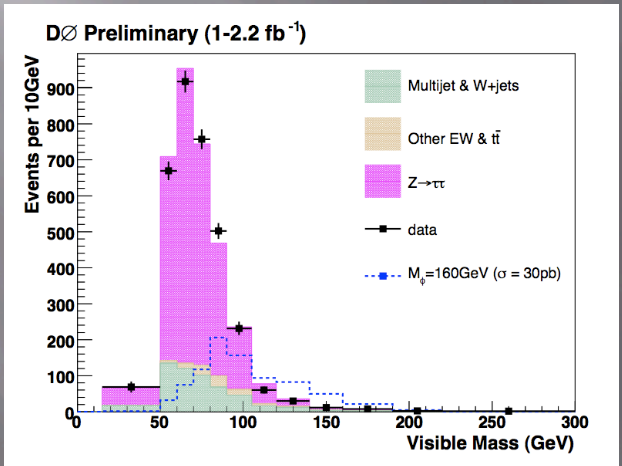
First time measurement at hadron colliders!

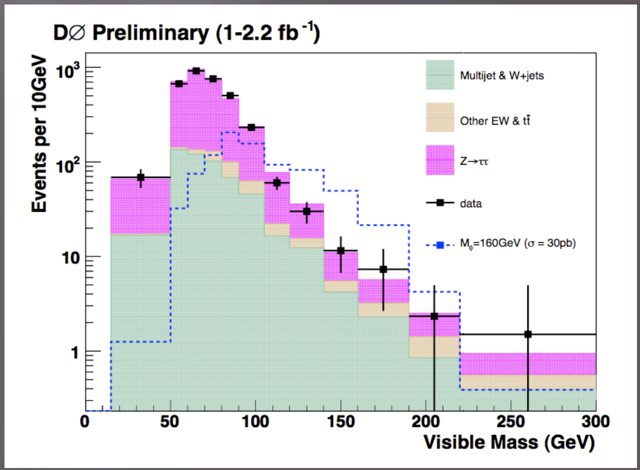
35 times the SM cross section

Limited by 30% systematic uncertainty in W+jets cross section, 10% uncertainty on the tt cross section

H→ $\tau\ \tau$ search at D0

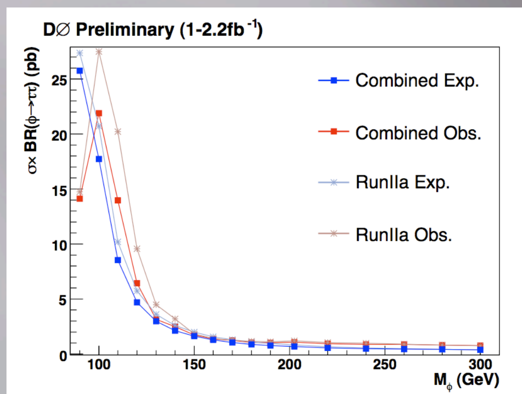
- Combined result of 1.0 fb^{-1} 2002-2006 dataset (RunIIa) and 1.2 fb^{-1} 2006-2007 dataset (RunIIb)
  - RunIIa result uses τ pair decays into $\mu\ \tau_{had}$, e τ_{had}, μ e (PRL, 101, 071804 (2008))
  - RunIIb requires $\mu\ \tau_{had}$ decay
- No significant excess in data over background
- 95% CL limits on $\sigma \cdot$ BR
- Constraints on the MSSM parameter space
- Visible mass (visible τ decay products and MET invariant mass) is used as a limit calculation final variable

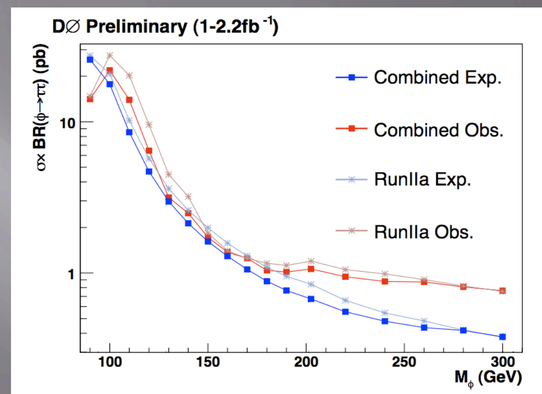




H→ τ τ limits

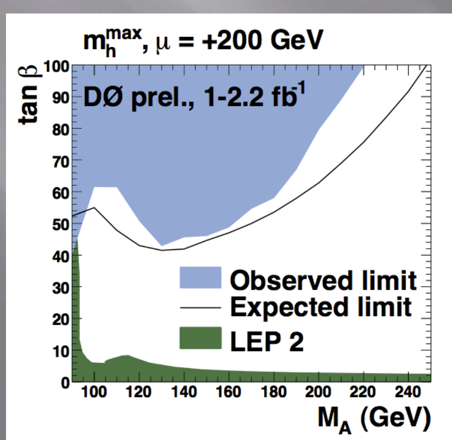
- $\sigma \cdot$ BR 95% CL limit (pb)



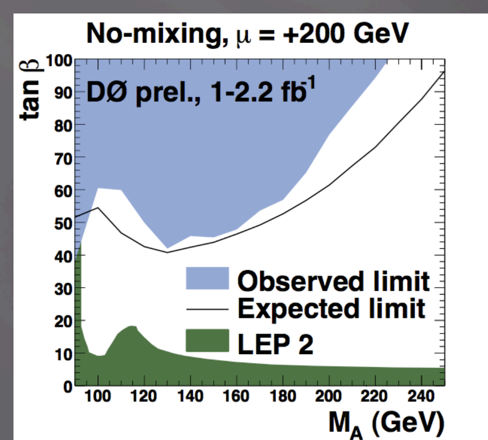


- Major sources of background are QCD, Z→ll, W→l ν
- Dominating systematics are on the Z→ll cross setion (5-13%), luminosity (6%), τ id (4-8%)

- MSSM parameter space constraint (M_A, tan β) uses the no-mixing and m_h^{max} scenarios: (X_t is the mixing parameter, μ is the Higgsino mass parameter, M_2 is the gaugino mass term, m_g is the gluino mass, M_{SUSY} is the common scalar mass)
- μ <0 is presently theoretically disfavored



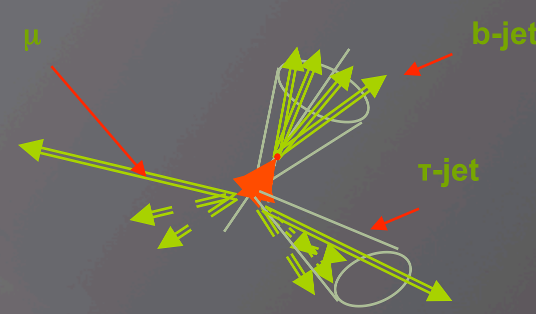
X_t=2 TeV
μ =+0.2 TeV
M_2=0.2 TeV
m_g=0.8 TeV
M_{SUSY}=1 TeV

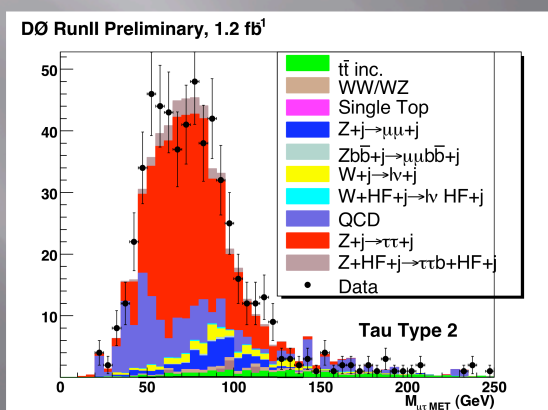


X_t=0 TeV
μ =+0.2 TeV
M_2=0.2 TeV
M_g=1.6 TeV
M_{SUSY}=1 TeV

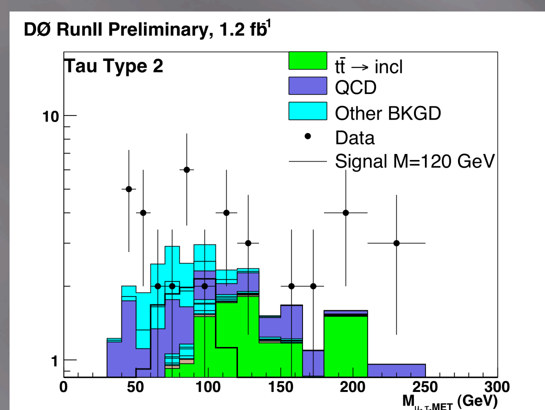
H+b→ $\tau\tau$ +b search at D0

- Uses 1.2 fb^{-1} preshutdown 2007 dataset (RunIIb)
  - RunIIb requires $\mu\tau_{had}$ decay
  - Looks for an additional b-jet (NN b-tagger)
  - Uses additional anti-QCD likelihood
  - Uses additional anti-top KNN
- No significant excess in data over background
- 95% CL limits on $\sigma \cdot$ BR
- Constraints on the MSSM parameter space
- 2D distribution of KNN vs anti-QCD likelihood is used as a limit calculation final variable

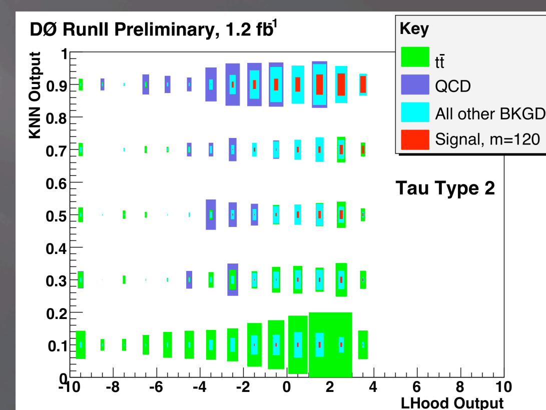




Visible mass, type 2 (leading for the limit calculation), pretag



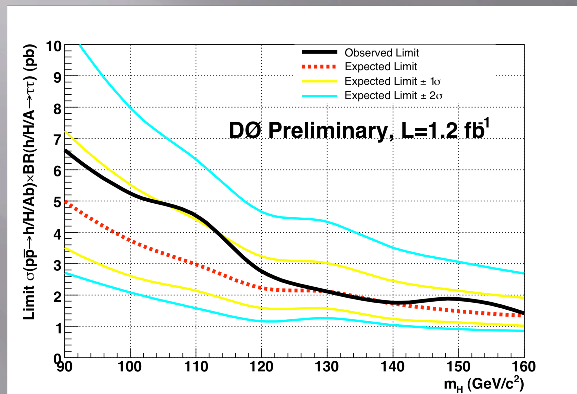
Visible mass, type 2 (leading for the limit calculation), b-tag



KNN vs QCD likelihood, type 2 (used for limit calculation), b-tag

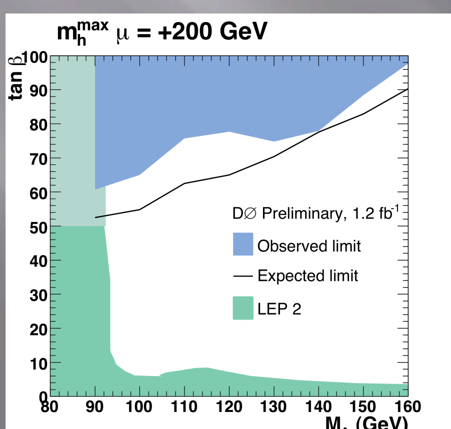
H+b→ τ τ +b limits

- $\sigma \cdot$ BR 95% CL limit (pb)



- Major sources of background are tt, QCD, Z+b(c)→ τ τ +b(c)
- Presently limited by large (50%) systematic on the Z+b(c)→ τ τ +b(c) NLO/LO scale factor, 20% systematic on the QCD estimate, 11% error on the tt cross section

- MSSM parameter space constraint (M_A, tan β) uses the no-mixing and m_h^{max} scenarios: (X_t is the mixing parameter, μ is the Higgsino mass parameter, M_2 is the gaugino mass term, m_g is the gluino mass, M_{SUSY} is the common scalar mass)
- μ <0 is presently theoretically disfavored



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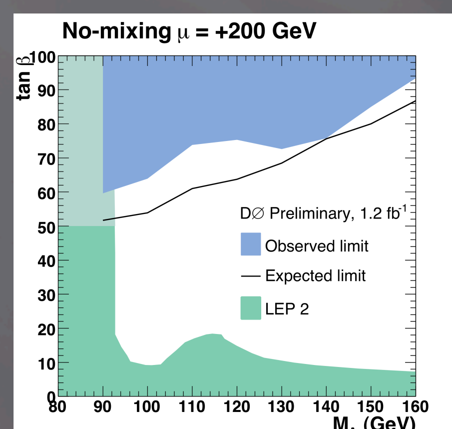
M_2=0.2 TeV
m_g=0.8 TeV
M_{SUSY}=1 TeV



X_t=0 TeV
μ =+0.2 TeV
M_2=0.2 TeV
M_g=1.6 TeV
M_{SUSY}=1 TeV

Summary

- τ signature in the detector allows reduction of jet fake rates to less than 1% level at τ efficiencies of around 65%
- e, μ misidentification can be reduced to low levels if pure hadronic τ decay is wanted
- Optimal τ purity in current Higgs searches is around 90%
- τ channels significantly increase sensitivity of MSSM Higgs searches