

Triggering on Taus at the Tevatron

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on behalf of

CDF and D0 collaborations



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Outline

- physics with taus
- how can we trigger them?
 - CDF/D0 trigger system
 - CDF tau triggers
 - ✓ e/mu + track
 - ✓ tau+met
 - ✓ di-tau
 - D0 tau triggers
 - ✓ exclusive e/mu
 - ✓ single muon
 - ✓ L1 calorimetric tau trigger
- recent results

Why study tau leptons?

tau leptons -> important role in

- electroweak measurements
- study of top quark properties
- **search for new phenomena**

MSSM higgs

high mass tau pairs

Charged/Doubly charged higgs

stop -> b τ

3rd generation leptoquarks

chargino-neutralino production

strong physics motivations!

tau reconstruction and **triggering**
is a difficult task due to huge backgrounds
dominated by multijet production

CDF and D0 trigger systems

L1

hardware

- calorimetric energy in towers
- raw tracks
- raw muons

L2

hardware
software

- jets
 - electrons
 - photons
 - tracks (refined -> isolation)
 - muons (refined)
 - met
- } clustering algorithm

L3

software fully
reconstructed
event

Accept rates

	L1	L2	L3
CDF	30 kHz	1 kHz	100 Hz
D0	1.6 kHz	850-900 Hz	55 Hz

tau ID at CDF

$$\tau \rightarrow \pi^- \nu_\tau,$$

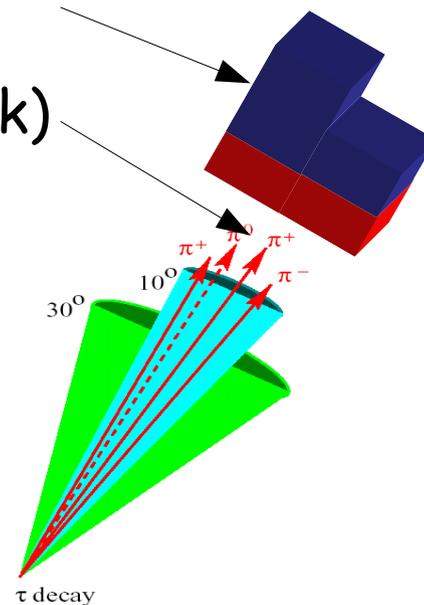
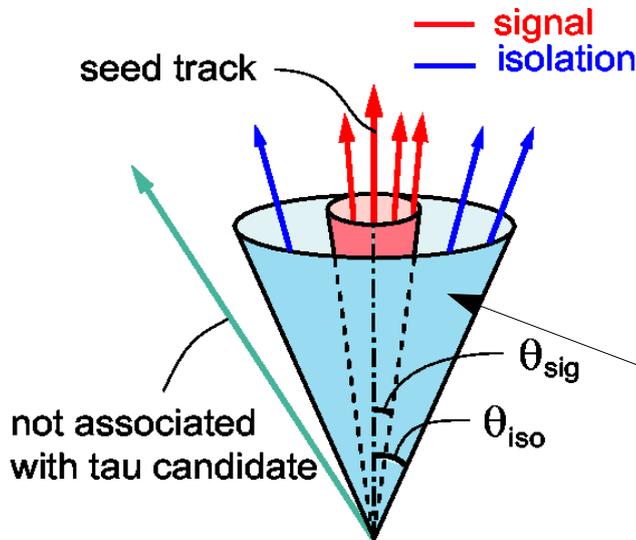
$$\tau \rightarrow \pi^- \nu_\tau \geq 1\pi_0$$

$$\tau \rightarrow \pi^- \pi^- \pi^+ \nu_\tau,$$

$$\tau \rightarrow \pi^- \pi^- \pi^+ \nu_\tau \geq 1\pi_0$$

1 - find a narrow cluster in the calorimeters

2 - find a track pointing to it (seed track)



3 - define signal and isolation cones

4 - match π_0 s

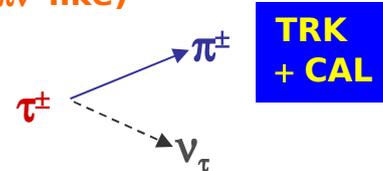
Tau ID at D0

1 - narrow calorimeter energy clusters matched to tracks

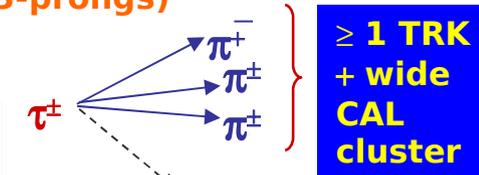
2 - separate τ s into 3 categories, defined by their decay mode

- * π -like (τ -type 1)
- * ρ -like (τ -type 2)
- * 3-prongs (τ -type 3)

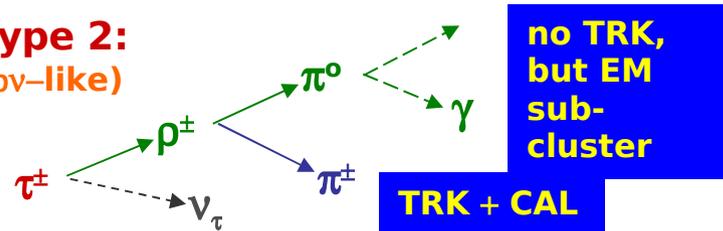
Type 1:
($\pi\nu$ -like)



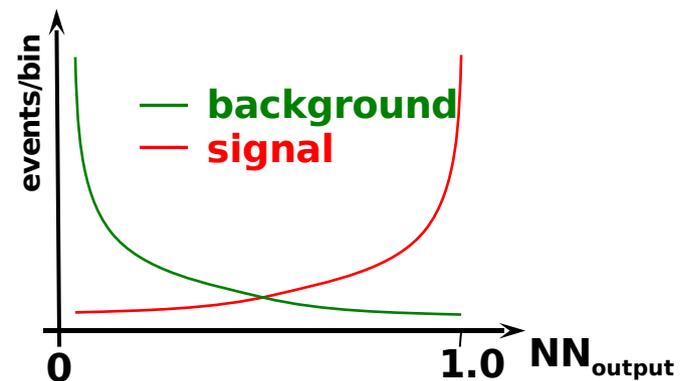
Type 3:
(3-prongs)



Type 2:
($\rho\nu$ -like)



3 - implement neural nets (NN) for each τ -type to discriminate τ signal from QCD jets



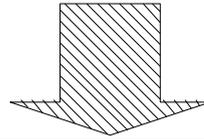
Tau triggers at CDF

e/μ^+ track

primarily designed
to detect $e/\mu^- \tau_{\text{had}}$
events

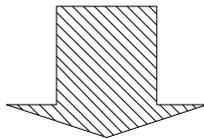
L1

- a single calorimetric trigger tower with $E_t > 8 \text{ GeV}$ OR muon hits in muon chambers
- a matching track



L2

- electron cluster $E_t > 8 \text{ GeV}$ / muon $P_t > 8 \text{ GeV}$
- a second track of $P_t > 5 \text{ GeV}$ 10 degrees in ϕ apart from the electron/muon track



L3

- Tighter electron/muon id
- charged track isolation (for tau)

cross sections at L3

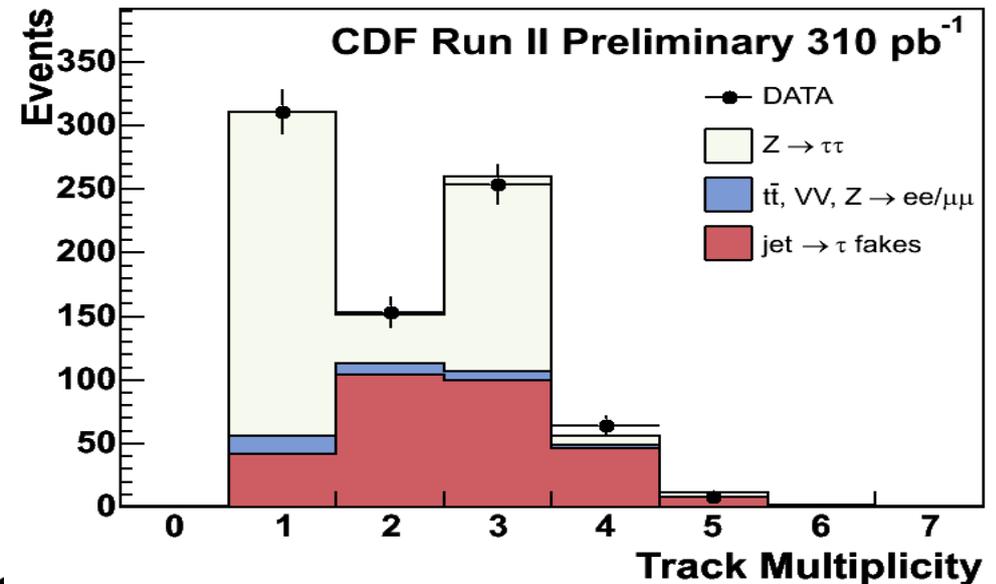
$$L = 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$$

- e^+ track $\sim 18 \text{ nb}$
- μ^+ track $\sim 12 \text{ nb}$

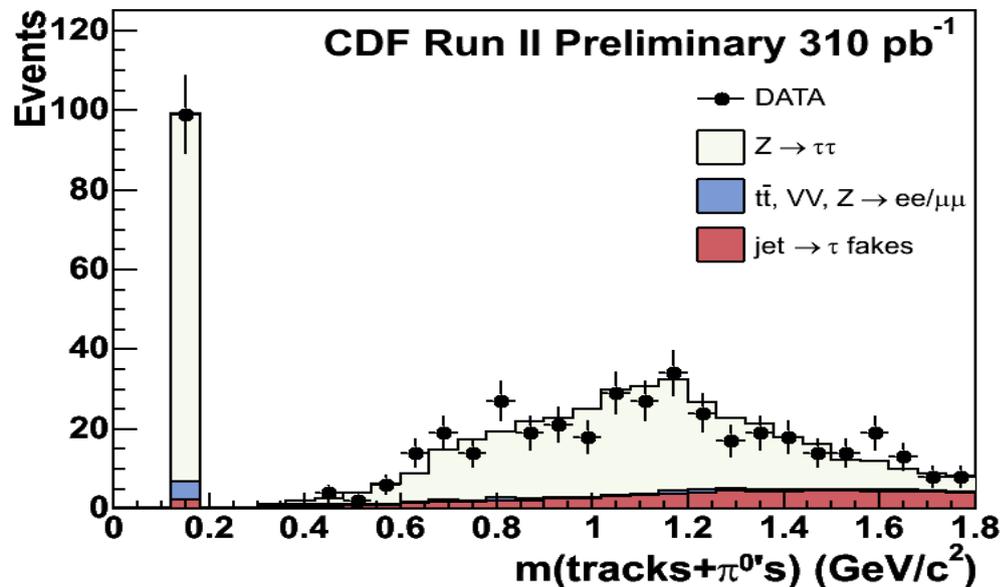
MSSM higgs $\rightarrow \tau\tau$

higgs $\rightarrow \tau_{e/\mu} \tau_{\text{had}}$

MSSM Higgs $\rightarrow \tau\tau$ Search, Track Multiplicity



MSSM Higgs $\rightarrow \tau\tau$ Search, Mass(track+...)



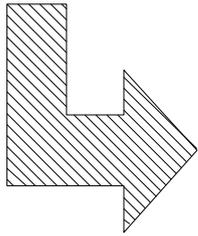
311 pb⁻¹ luminosity

hep-ex/0508051

L1

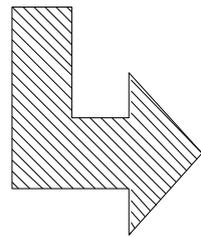
Calorimetric trigger tower with $E_t > 10 \text{ GeV}$

L3 cross section at
 $L = 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
 $\sim 8 \text{ nb}$



L2

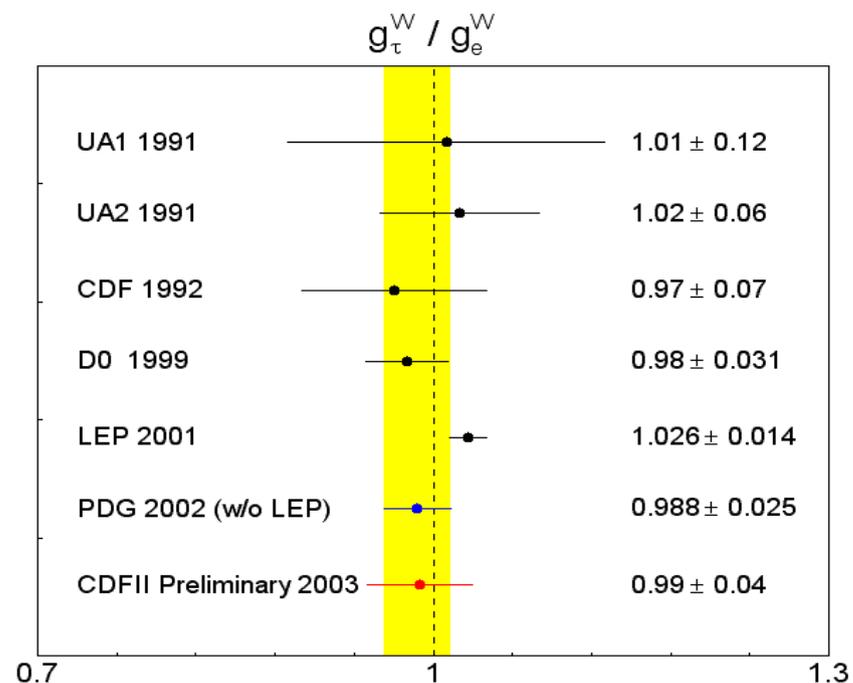
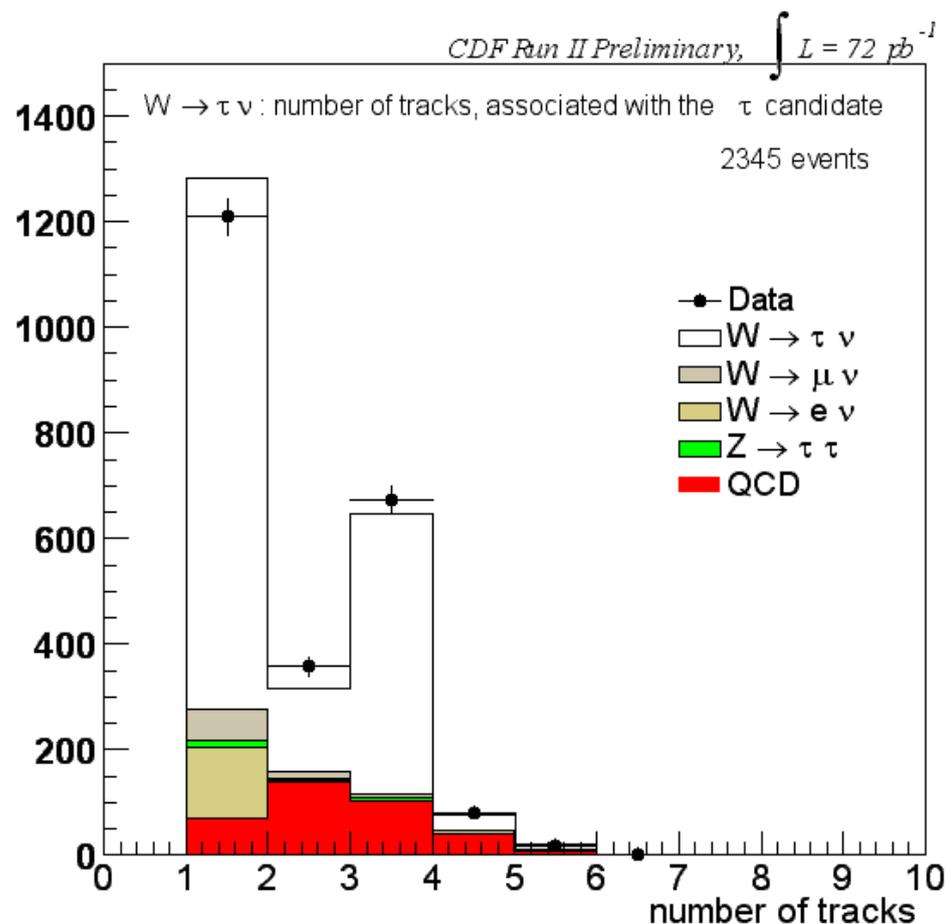
- missing $E_t > 20 \text{ GeV}$
- calorimeter cluster with isolated track



L3

at least one tau candidate

W -> tau nu cross section



72 pb⁻¹ luminosity

hep-ex/0405060

Nucl.Phys.Proc.Suppl. 144,323-332 (2005)

Tau triggers at CDF

di-tau trigger

L1

- two calorimeter trigger towers with $E_t > 5 \text{ GeV}$
- two matching tracks separated by an angle of $\varphi > 30^\circ$

L2

- Clusters $E_t > 10 \text{ GeV}$
- track isolation

L2

- $Met > 10 \text{ GeV}$
- NO track isolation

L3

- Two tau candidates originating from the same vertex

L2 acceptances

	LQ3	H ^{++/--}	A	Z'	Z
m (GeV)	130	120	120	120	91
E_t, iso	0.67	0.72	0.77	0.77	0.72
$Met, no iso$	0.87	0.94	0.66	0.63	0.51
overlap	0.60	0.72	0.51	0.48	0.35
Inclusive	0.95	0.95	0.93	0.93	0.88

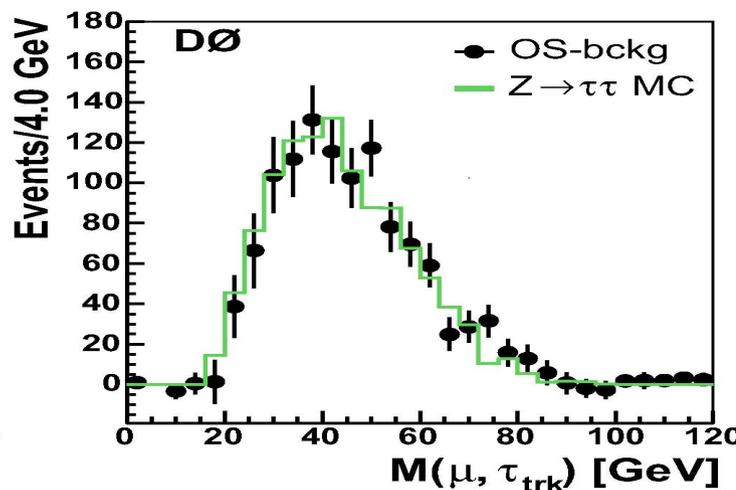
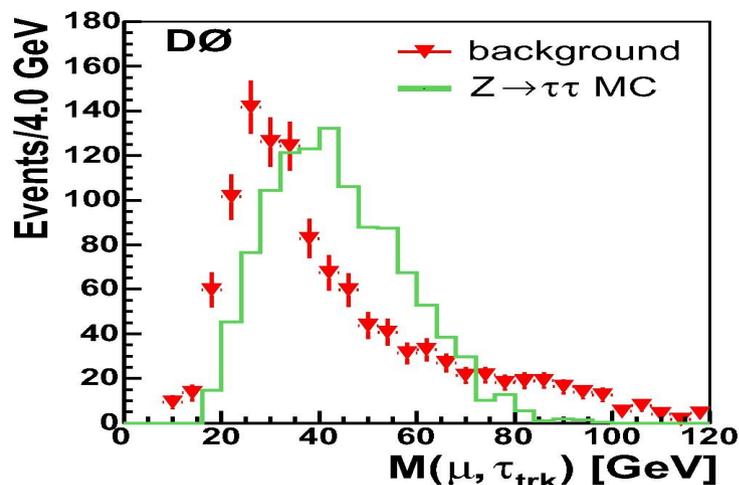
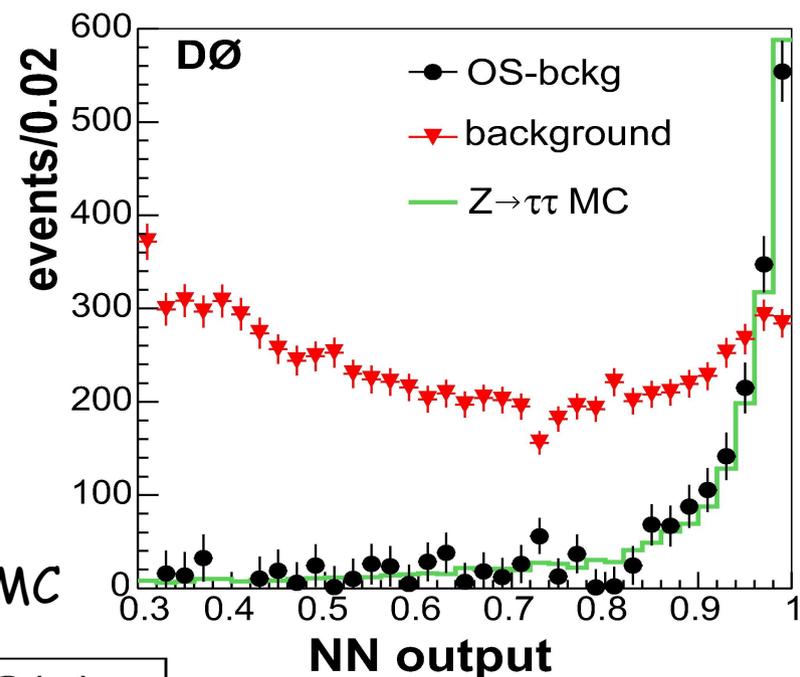
L3 cross section at
 $L = 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
 $\sim 12 \text{ nb}$

- 1 - focus tau \rightarrow muon ($P_t > 5 \text{ GeV}$)
- 2 - look for jet activity on the other side (tau \rightarrow hadrons) using NN tau id

$$Z \rightarrow \tau_\mu + \tau_{\text{had}}$$

226 pb⁻¹

● data
 ▲ bgnd
 — Z \rightarrow tau tau MC



exclusive electron trigger
 used in addition to muon for
 $H \rightarrow \tau\tau$ search

(FERMILAB-PUB-06/009-E-
 Submitted to PRL)

hep-ex/0412020

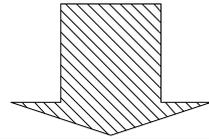
PRD 71, 072004 (2005)

Tau triggers at D0

Single tau trigger ($W^- \rightarrow \tau \nu$ analysis)

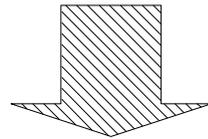
L1

- one central jet with $E_T > 7 \text{ GeV}$
- one isolated track with $P_T > 10 \text{ GeV}$



L2

- jet-track matching



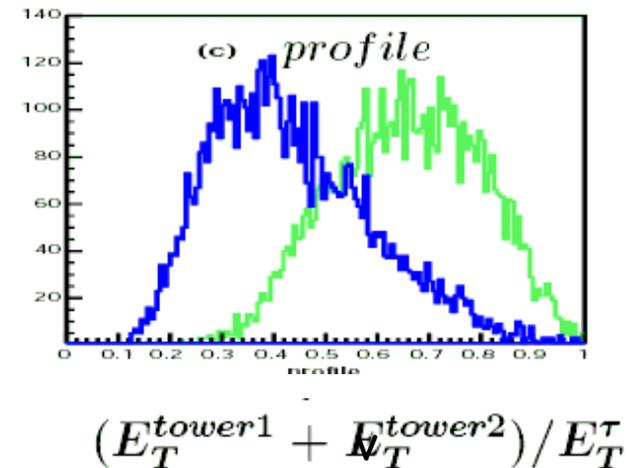
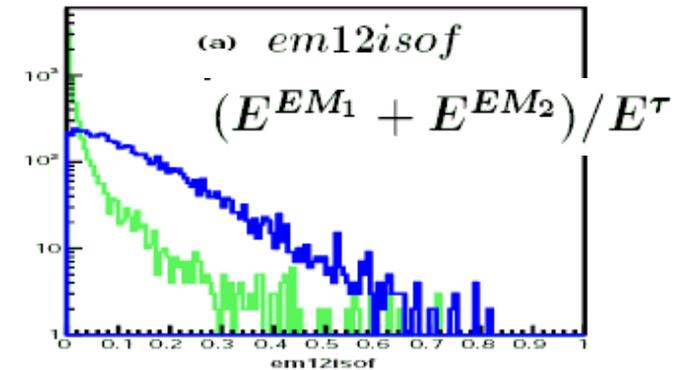
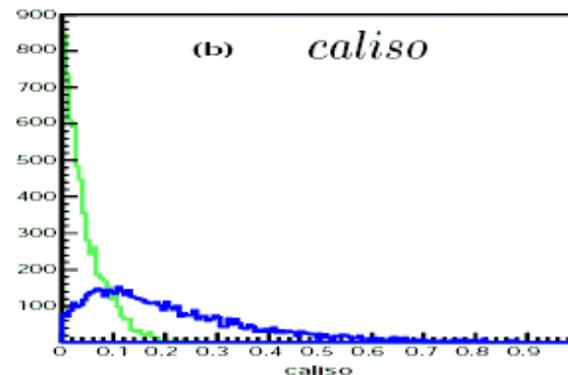
L3

- $Met > 10 \text{ GeV}$
- one tau candidate ($P_T > 10 \text{ GeV}$)
- NN algorithm based on cal clusters

Signal (MC)

Bgnd (jets from data)

τ -type 1



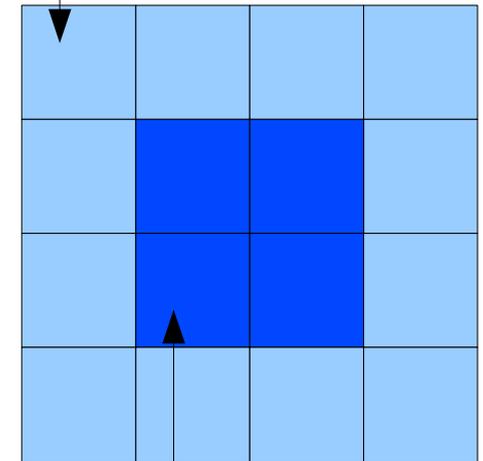
calorimeter cluster
isolation

$$(E_T^{\tau} - E_T^{core}) / E_T^{core}$$

L1 calorimetric tau trigger

- consider 2X2 and 4X4 clusters of calorimetric towers (region on interests - ROI)
- find local maxima (LM)
- isolation ring size is 1 trigger tower, define $\text{ratio} = E_t(2 \times 2) / E_t(4 \times 4)$
- if $\text{ratio} > \text{cut}$ (e.g. 0.5) LM is a tau candidate
- $E_t(2 \times 2) > 8 \text{ GeV} \rightarrow$ trigger fires

EM+H isolation



ROI/tau cluster

new proposal (part of the trigger upgrades for Run 2b)
tau jets are narrower than standard jets

Conclusions and future prospects

strong physics motivation

id algorithms and triggers at both CDF and D0:

- e/mu + track, tau + met (CDF)
- exclusive muon/electron, single tau (D0)

good results on SM analysis

application to new physics beyond SM

need for increased sensitivity:

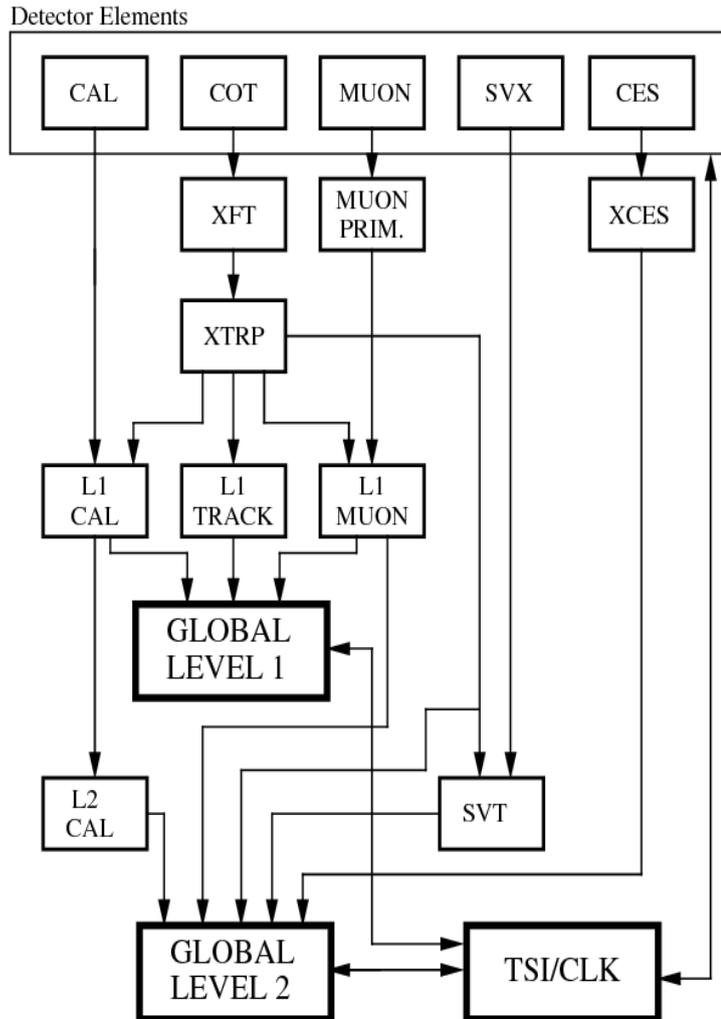
di-tau triggers (CDF, D0), L1 tau trigger (D0)

backup slides

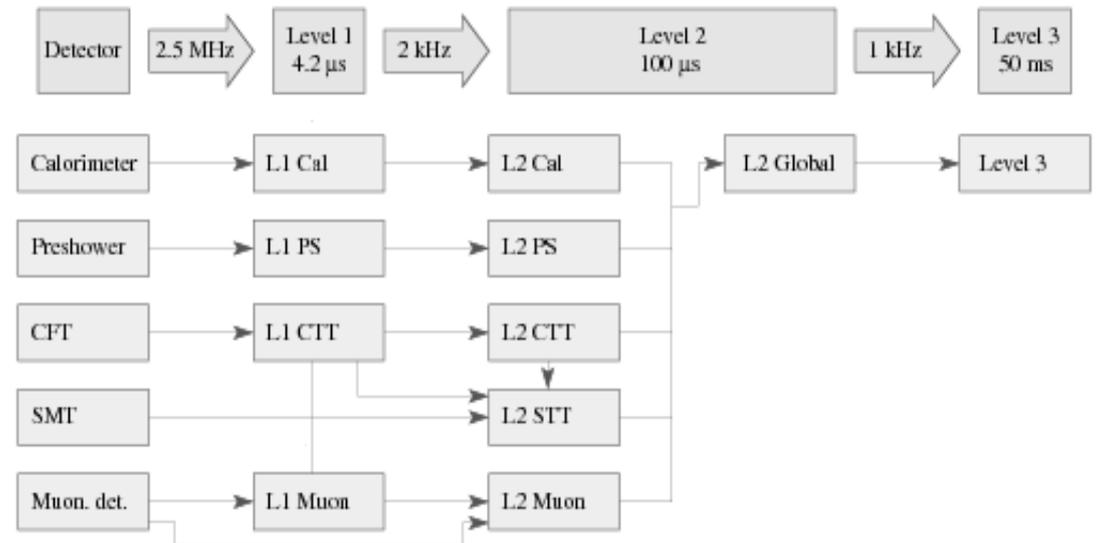
CDF/DO Trigger systems

RUN II TRIGGER SYSTEM

CDF



DO

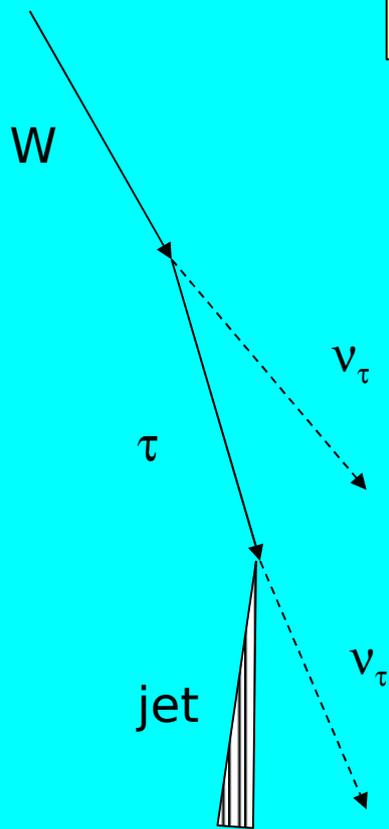


Tau decay modes

$$\tau \rightarrow e \bar{\nu}_e \nu_\tau$$

$$\tau \rightarrow \mu \bar{\nu}_\mu \nu_\tau$$

BR \cong 36%



$$\tau \rightarrow \pi^- \nu_\tau$$

$$\tau \rightarrow \pi^- \nu_\tau \geq 1\pi_0$$

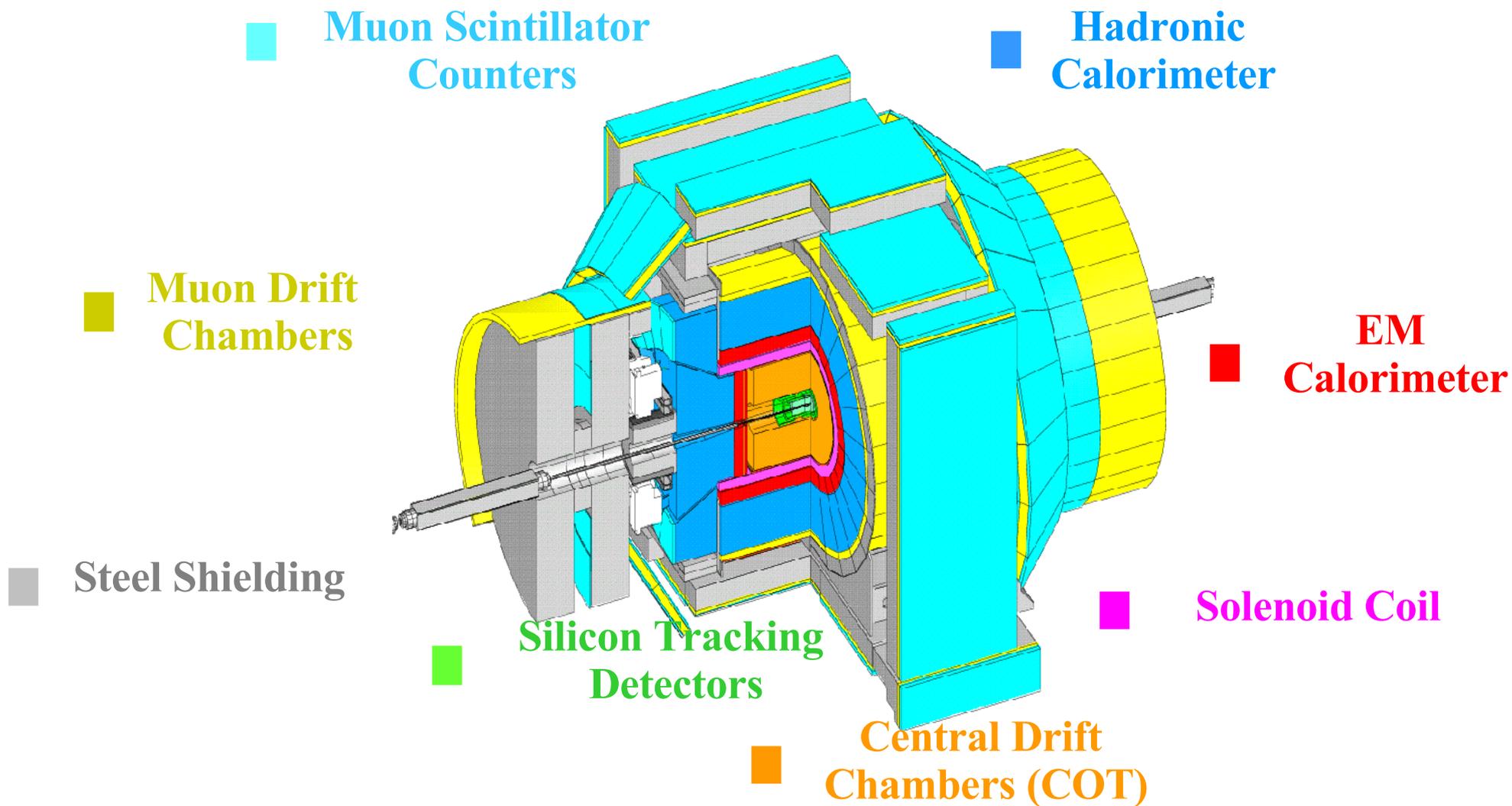
$$\tau \rightarrow \pi^- \pi^- \pi^+ \nu_\tau$$

$$\tau \rightarrow \pi^- \pi^- \pi^+ \nu_\tau \geq 1\pi_0$$

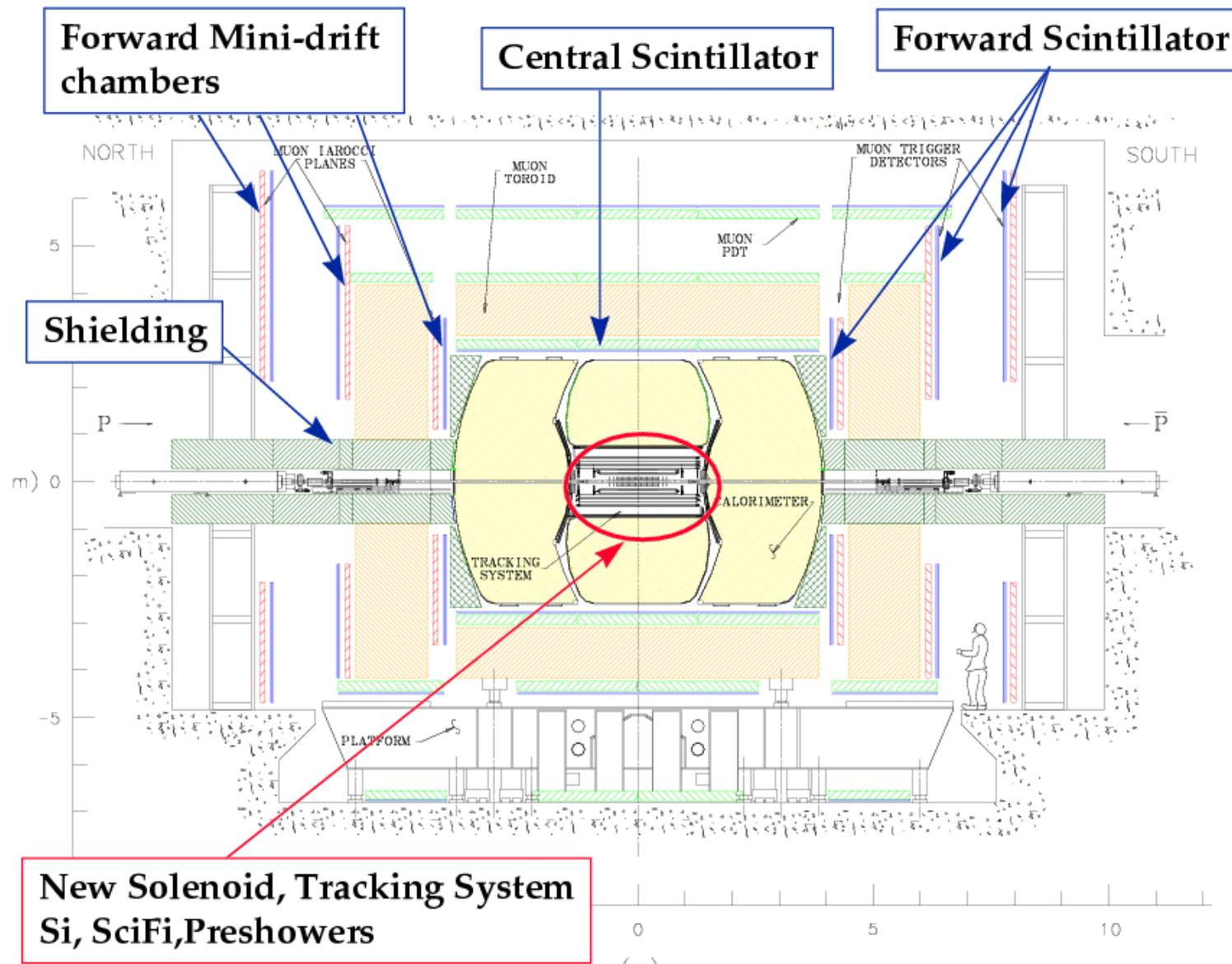
1-Prong (BR \cong 50%)

3-Prong (BR \cong 14%)

CDF detector



D0 detector

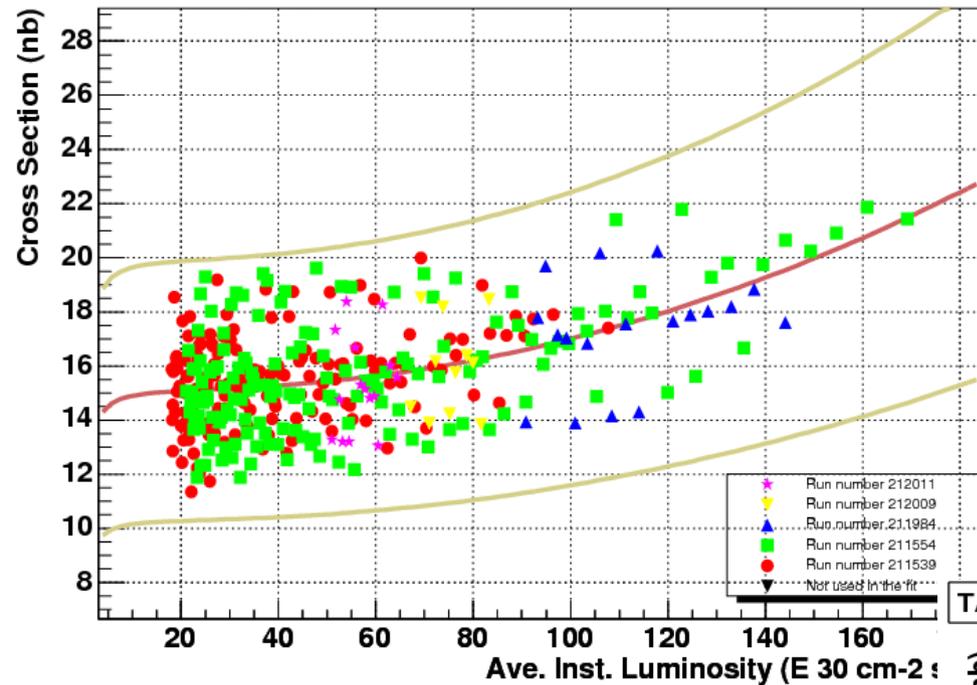


**New Solenoid, Tracking System
Si, SciFi, Preshowers**

+ New Electronics, Trig, DAQ

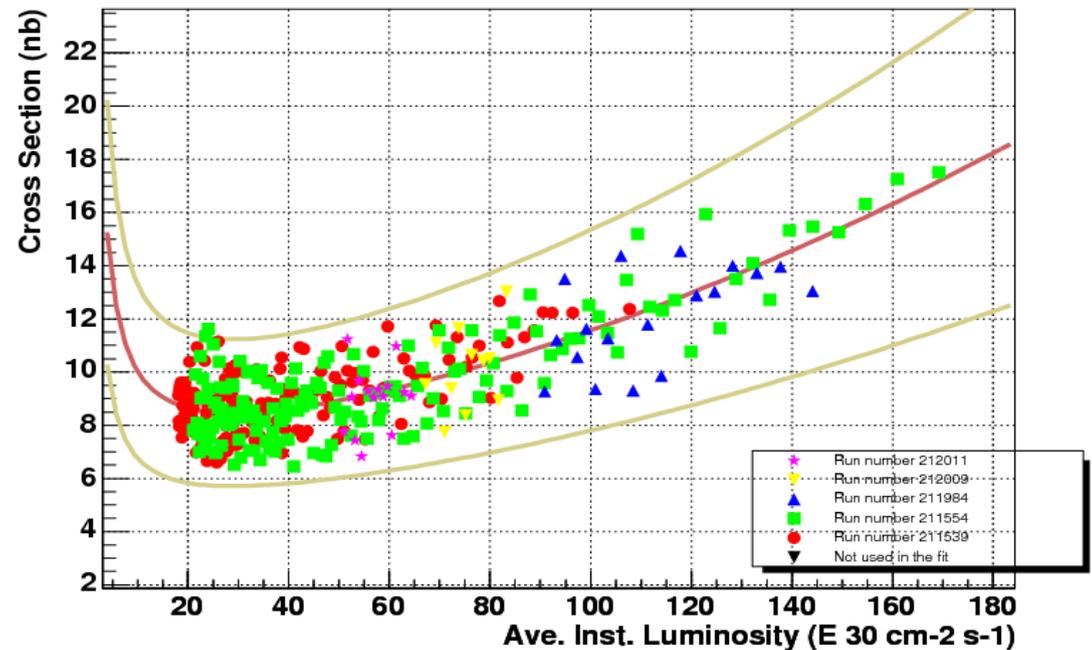
electron/muon + track trigger (CDF)

TAU_ELECTRON8_TRACK5_ISO_v10 Cross Section vs. Inst. Lum

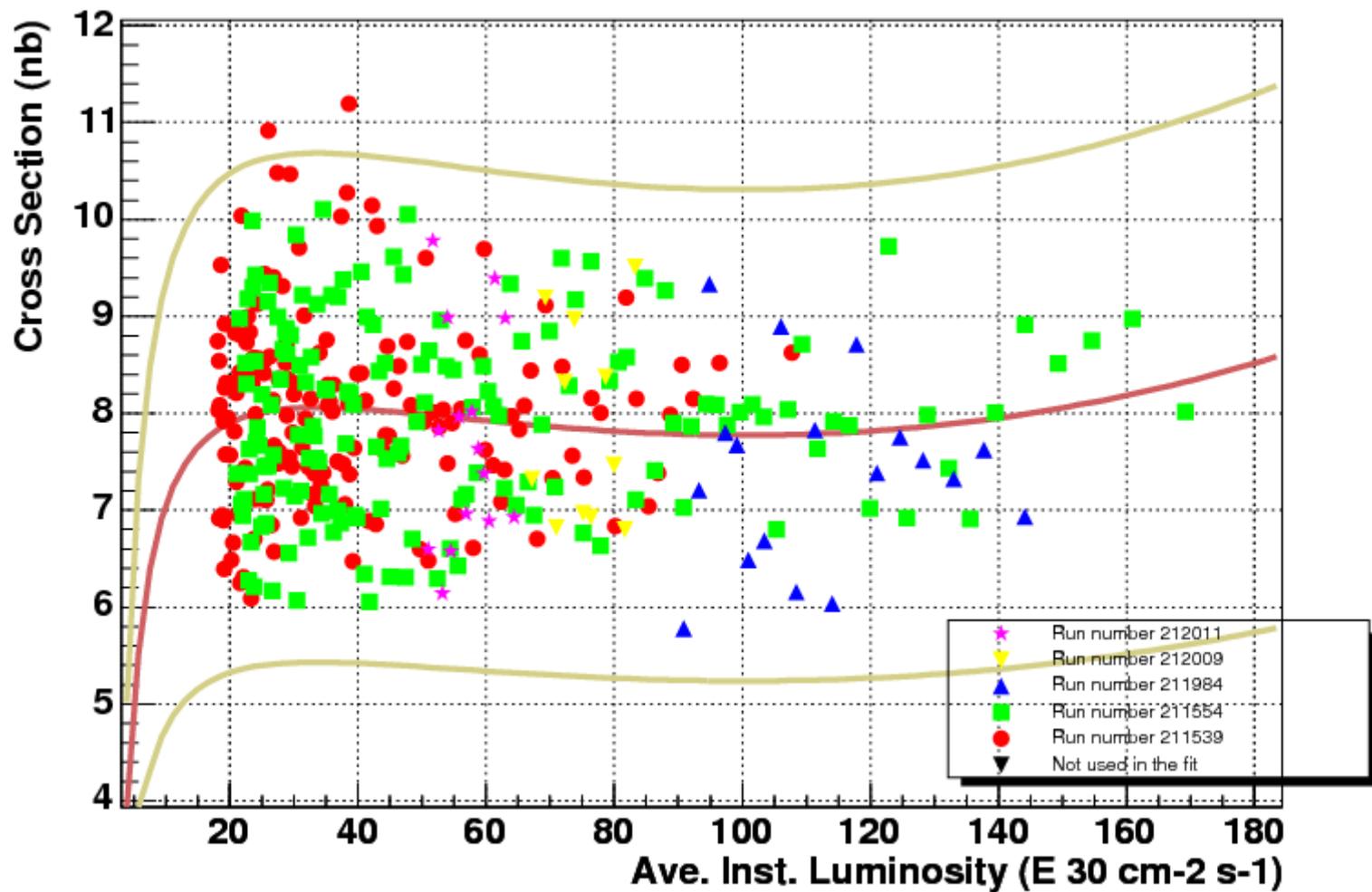


xsec VS luminosity

TAU_CMUP8_TRACK5_ISO_v9 Cross Section vs. Inst. Lum



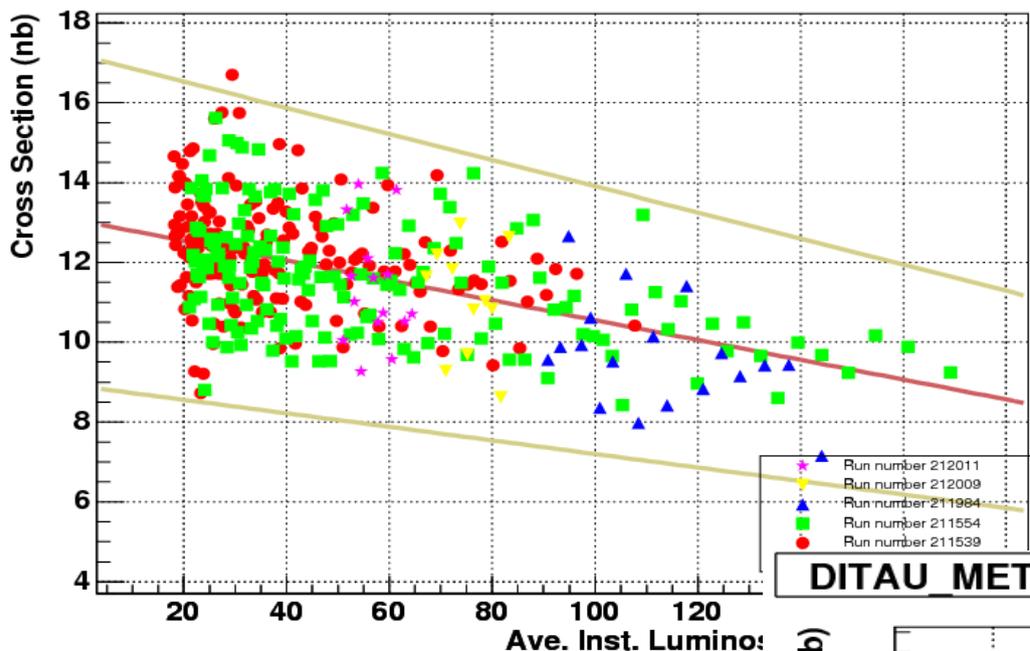
TAU_MET_v11 Cross Section vs. Inst. Lum



di-tau triggers (CDF)

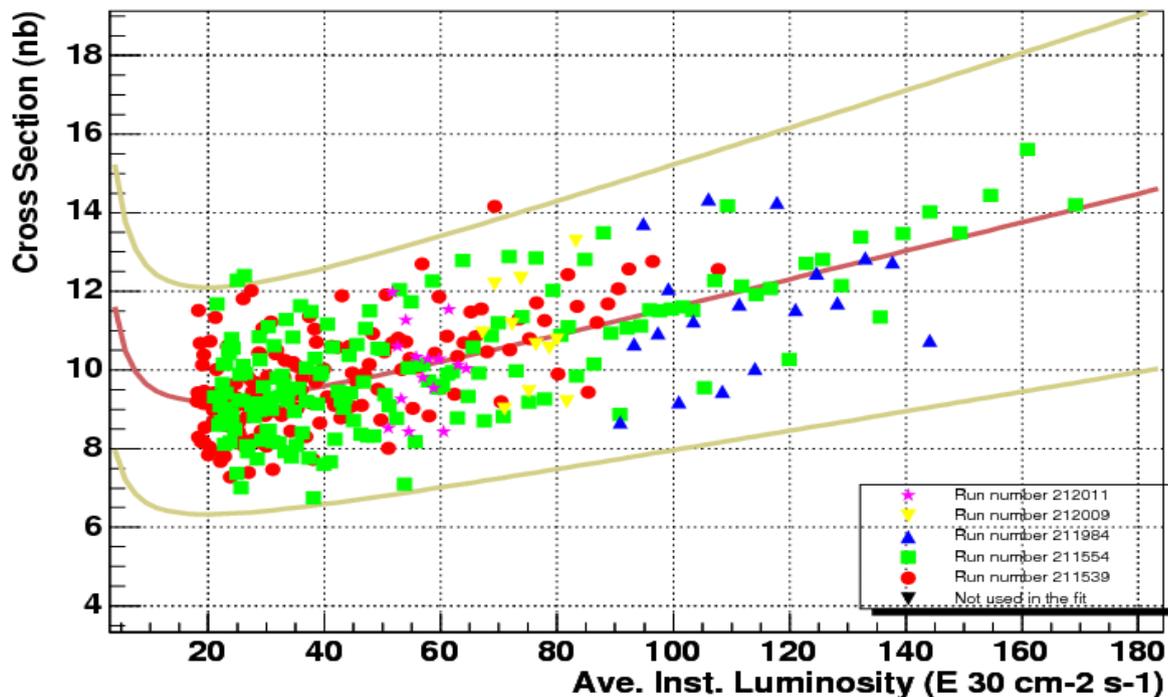
xsec VS luminosity

DITAU L2 PT10 v1 Cross Section vs. Inst. Lum



- Run number 212011
- Run number 212009
- Run number 211984
- Run number 211554
- Run number 211539

DITAU MET v1 Cross Section vs. Inst. Lum

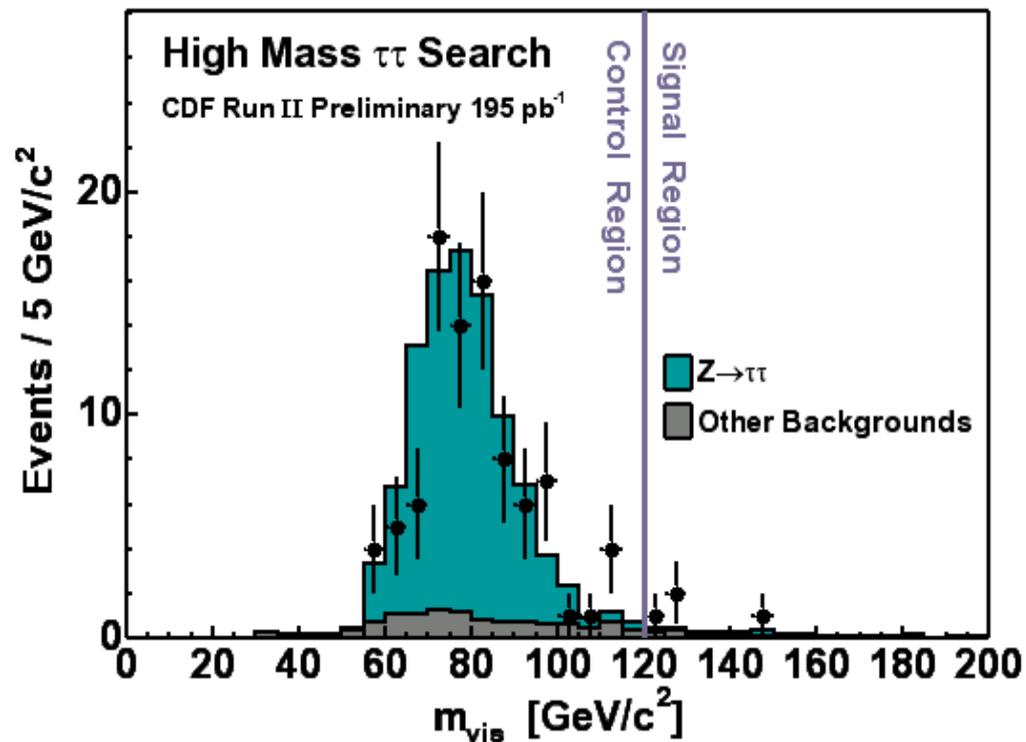
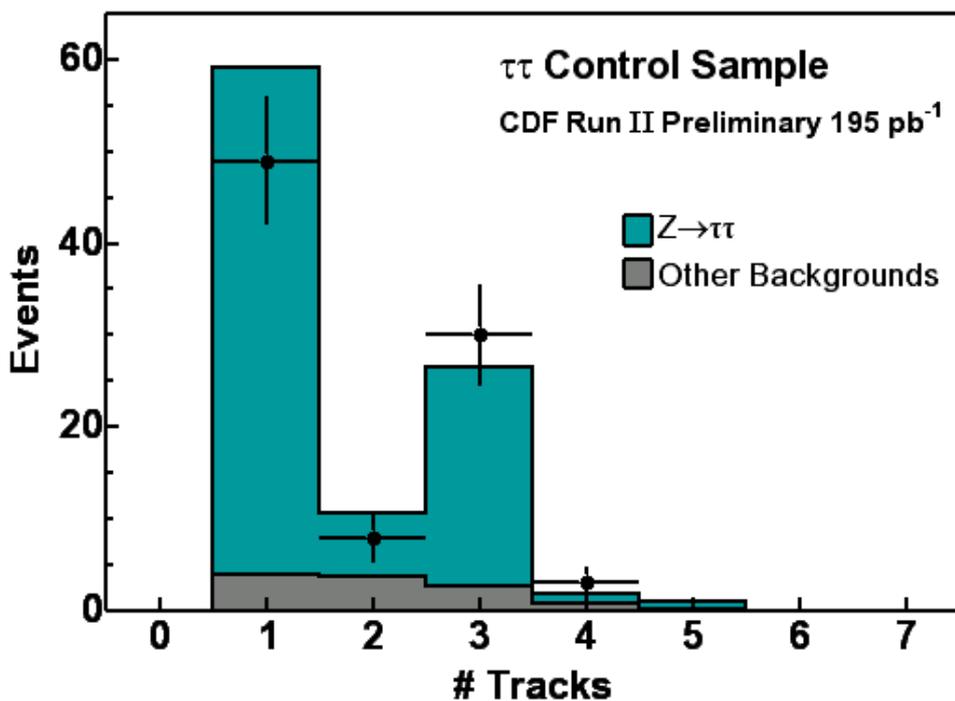


- Run number 212011
- Run number 212009
- Run number 211984
- Run number 211554
- Run number 211539
- Not used in the fit

high mass tau pairs search

3 final states

- $\tau_{\text{had}} \tau_{\text{had}} - \tau_e \tau_{\text{had}} - \tau_{\mu} \tau_{\text{had}}$



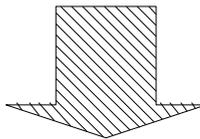
$$m_{\text{vis}} = m(\tau_{\text{vis}}^1 + \tau_{\text{vis}}^2 + \text{Met})$$

195 pb⁻¹ \rightarrow lepton+track

exclusive muon trigger - I (D0)

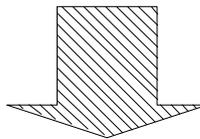
L1

- a single muon trigger inside the CFT (central) region based on a hit in the muon scintillator detector only



L2

- at least one muon found with $p_T > 5 \text{ GeV}$



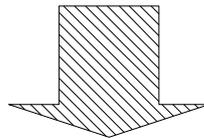
L3

- one track found via the L3 Global Tracker algorithm with $p_T > 10 \text{ GeV}$

exclusive muon trigger - II (D0)

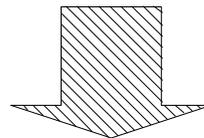
L1

- a wider region for the muon but based on a tight hit requirement with the muon scintillator and a loose requirement with the muon wire detectors



L2

- at least one muon with $p_T > 3 \text{ GeV}$



L3

- one track found via the L3 Global Tracker algorithm with $p_T > 10 \text{ GeV}$