Search for Supersymmetry in Multi-tau Final States at CDF
- Challenging to Large tanβ -

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Outline

Why? How? Where?

Motivation

Supersymmetry

at large tanβ

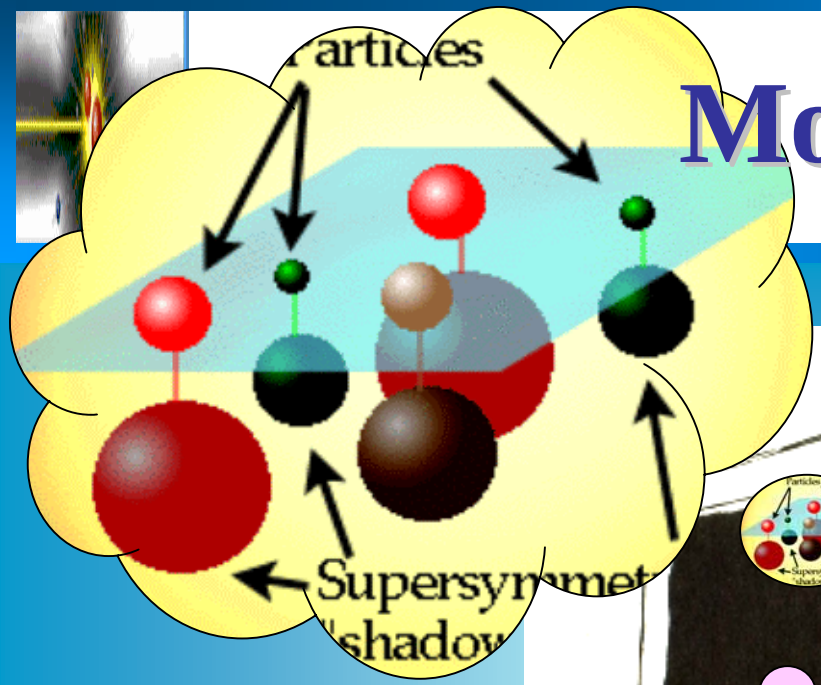
Lepton+Track Trigger and Physics Analysis Road Map

Analyses in progress

- ***Z***
- ***RPV stop (tau b)***
- ***GMSB 3 tau***
- **…**

Summary

Motivation



SUGRA
GMSB
…

Anomaly –
Signature-Based Search?

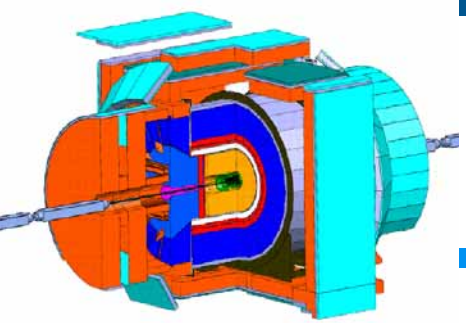
Where to Look for?

- **Large tanβ (5-55) by other experimental results**

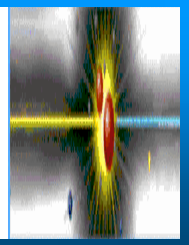
- **Unique situation in the 3rd generation SUSY particles (stau, stop) - They might be lighter than other SUSY particles.**

- **Experimentally difficult situation - The final state particles in its SUSY particle decay are also 3rd generation SM particles.**

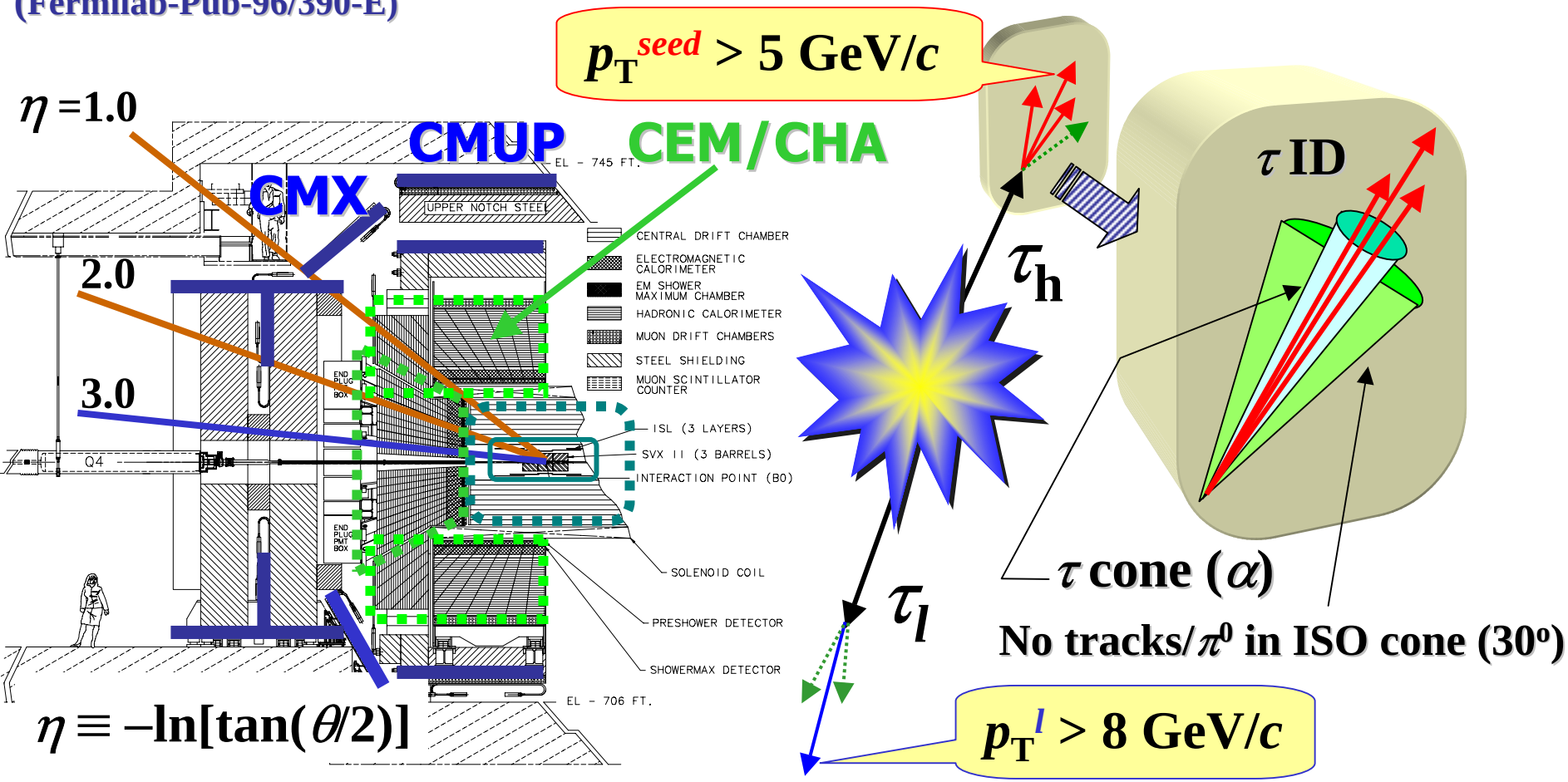
  "No Pain, No Gain" → "No trigger&ID, No discovery"



Lepton+Track Trigger for Multi-τ Final States



(Fermilab-Pub-96/390-E)



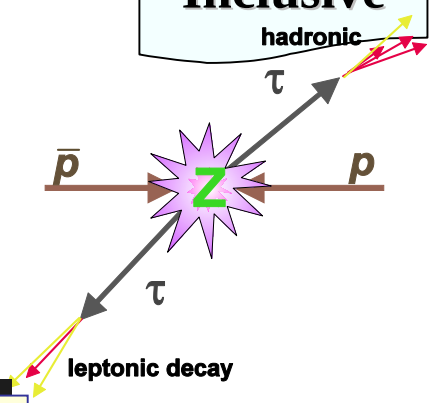
Physics Analysis Road Map using LT Trigger

LT

T=e,μ

$Z \to \ell\ell$

Inclusive



T=τ_h

N_j=1

$h(\to \tau\tau) + j$

$N_j \geq 2$

$\tilde{t}_1\bar{\tilde{t}}_1 \to \tau^+ b \tau^- \bar{b}$

$b\bar{b}h(\to \tau\tau)$

$W(\to jj)Z(\to \tau\tau)$

$\not{E}_T$ > 20 GeV

$N_j \geq 2$

$t\bar{t} \to WbWb$

3rd track

$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \to (\tilde{\tau}_1\nu)(\tilde{\tau}_1\tau)$

ALSO

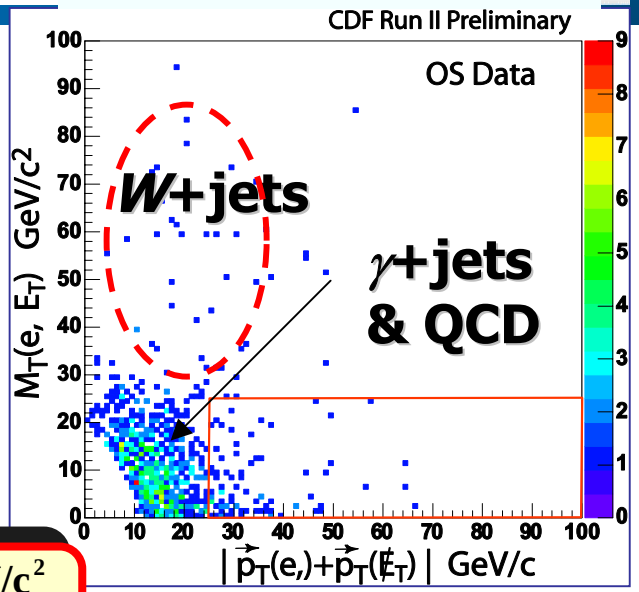
$A \to \tau_\ell \tau_h$, $Z' \to \tau_\ell \tau_h$

(See A. Anastassov's talk)

Z Selection

$M_T^{\ell \not{E}_T}$ vs. $p_T^{\ell \not{E}_T}$

Events passing e ID and τ(w/o π^0 isolation) ID



Electron $E_T > 10$ GeV + τ_h $p_T > 15$ GeV/c

$$\varepsilon(e\ \mathrm{ID}^*) = 72.1 \pm 1.0(\mathrm{stat}) \pm 3.1(\mathrm{syst})\%$$

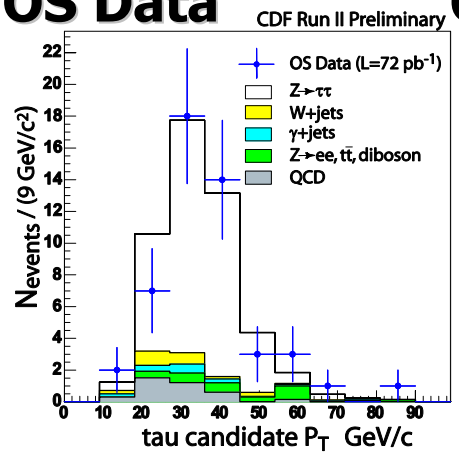
*) Including tight isolation requirement

$$\varepsilon(\tau_h\ \mathrm{ID}) = 55.6 \pm 1.6(\mathrm{stat}) \pm 2.2(\mathrm{syst})\%$$

$M_T^{\ell \not{E}_T} < 25\ \mathrm{GeV/c^2}$

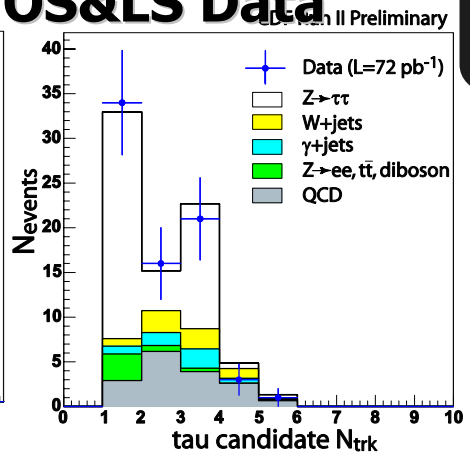
$p_T^{\ell \not{E}_T} > 25\ \mathrm{GeV/c}$

OS Data

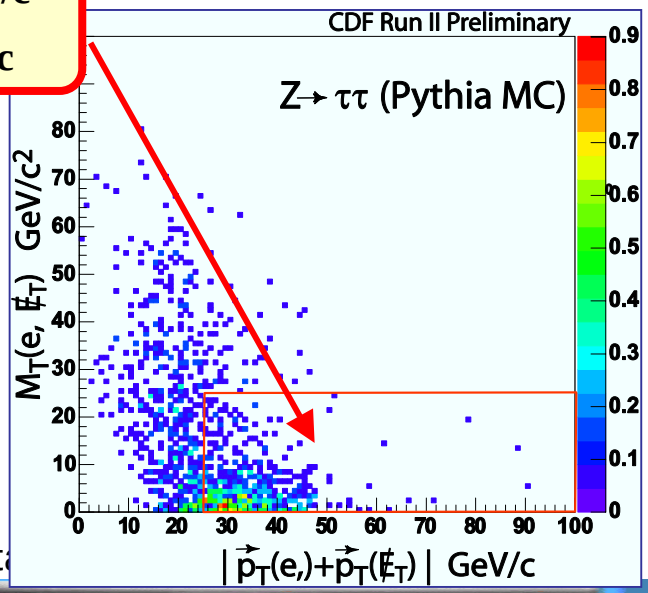


$p_T(\tau_h)$

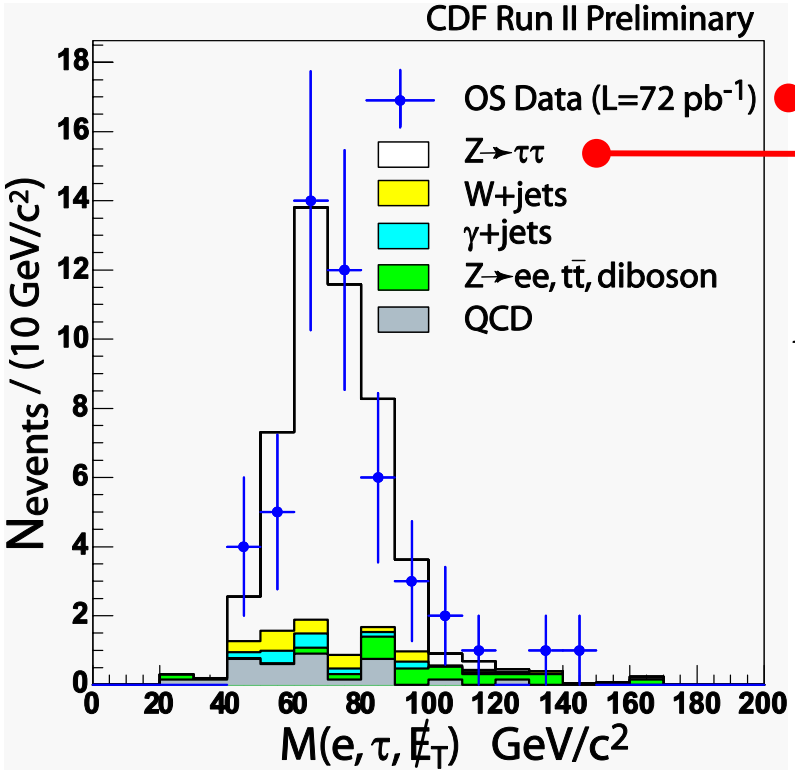
OS&LS Data



$N_{track}(\tau_h)$



First Cross-Section Measurement on $Z \rightarrow \tau\tau$



$N_{\text{data}} = 50\ \tau_e \tau_h$ events (after topology cuts)

$$N(Z \rightarrow \tau_e \tau_h) = 38.9 \pm 7.7(\text{stat}) \pm 1.6(\text{syst})$$

$$\sigma(Z \rightarrow \tau_e \tau_h) = 242 \pm 48(\text{stat}) \pm 26(\text{syst}) \pm 15(\text{lumi})\ \text{pb}$$

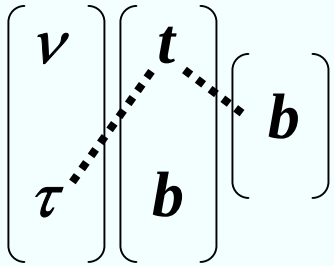
c.f.) $\sigma(Z \rightarrow \ell\ell)_{\text{NNLO}} = 251\ \text{pb}\,;\ \sigma(Z \rightarrow \ell\ell)_{\text{CDF}} = 254.9 \pm 3.3(\text{stat}) \pm 4.6(\text{syst}) \pm 15.2(\text{lumi})\ \text{pb}$

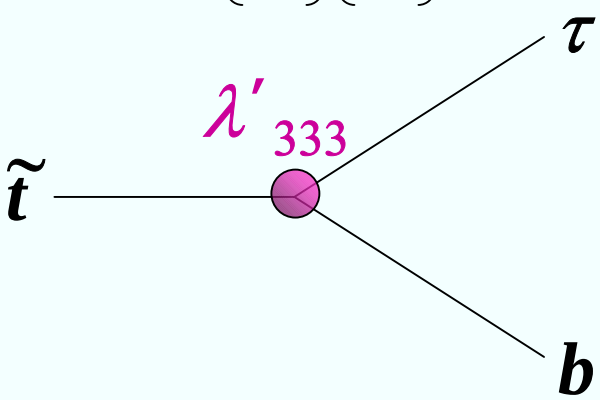
Next step: Full analysis with 200 pb^{-1} including muon channel

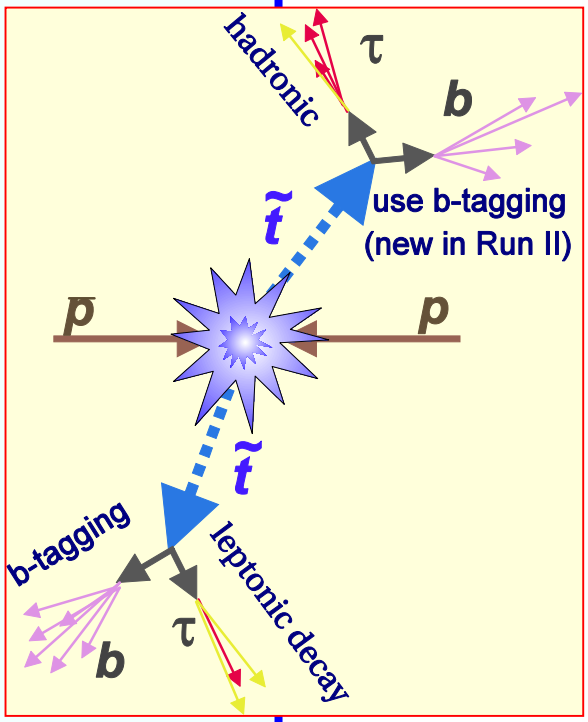
R_p Violation (RPV) Stop

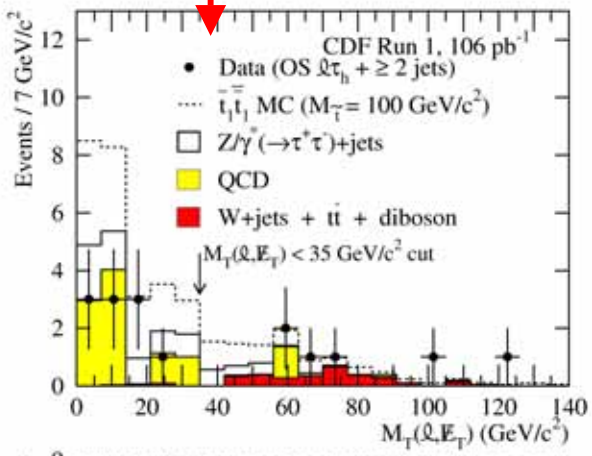
$E_T(l) > 10$ GeV + $p_T(\tau_h) > 15$ GeV/c + ≥ 2 jets + $M_T(l, \not{E}_T) + \Sigma p_T(l, \tau_h, \not{E}_T)$

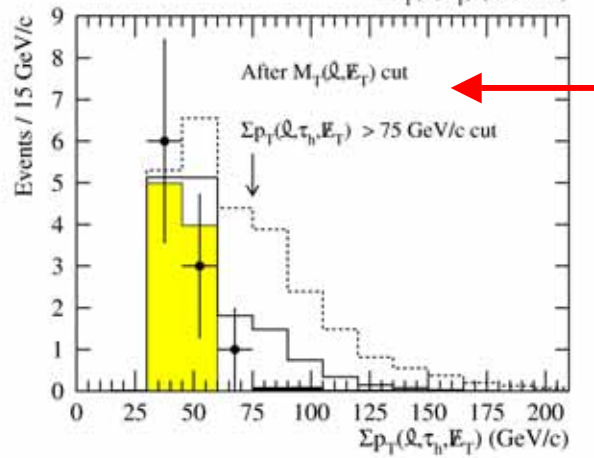
e.g., $\lambda'_{333} L_3 Q_3 D_3$









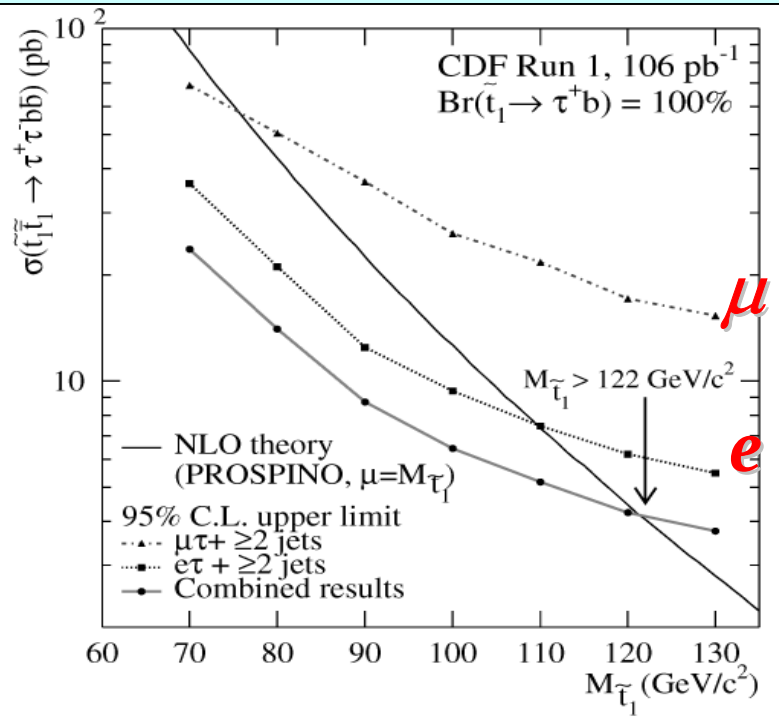


NOTE: $\lambda, \lambda', \lambda'', \eta$ **couplings are assumed to smaller than the SM gauge couplings**

Run 1 → Run 2

Improvement in Run 2

CDF Run 1 Result (PRL Vol.92, No.5)



Run 1

Incl. lepton[8 GeV] trigger:

Prescaled, $|\eta_e| < 1$, $|\eta_\mu| < 0.6$

vs.

Run 2

Lepton[8 GeV]+Track[5 GeV]:

w/o Prescale for both *e* and μ in $|\eta| < 1$

A(e) ~ A(μ)

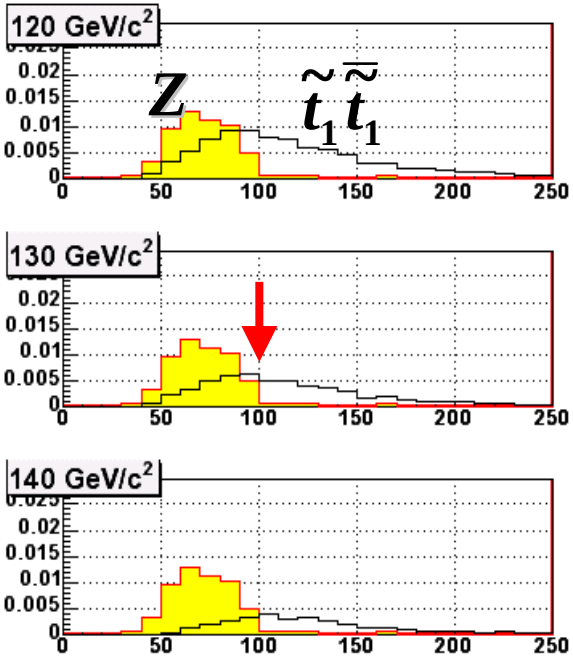
$S_T = \Sigma p_T(\ell, \tau_h, \not{E}_T)$

Optimization of S_T after $N_j \geq 2$ cut to reduce Z's and QCD (LS data)

$$M_T^{\ell \not{E}_T} < 35\ \mathrm{GeV/c^2}$$

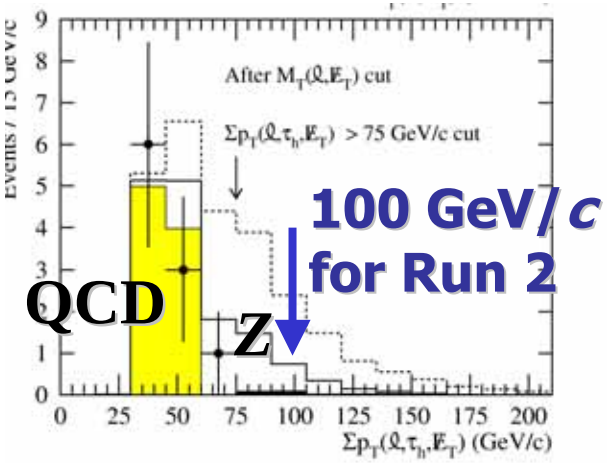
$$S_T^{\ell \tau_h \not{E}_T} > 100\ \mathrm{GeV/c}$$

Run 2 Simulation



S_T (GeV/c)

Run 1 Data



S_T (GeV/c)

Summary:

$A(e) \sim A(\mu)$

+

σ(stop): x1.2

L = 106 → 200 pb^{-1};

S_T = 75 → 100 GeV/c

→Scaling from Run 1

N_{signal}: x0.6(e), x0.8(μ)

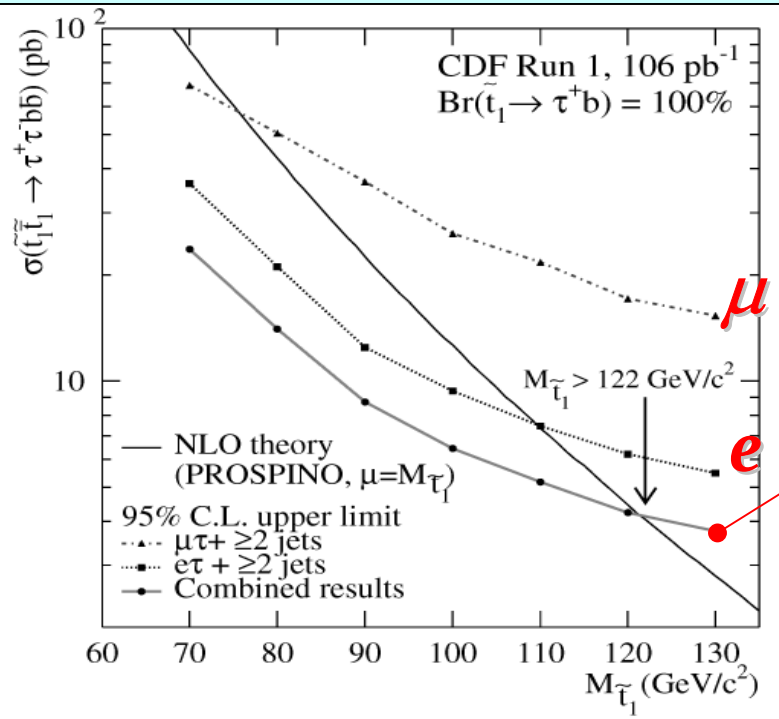
N_{BG} : x0.2(e), x0.4(μ)

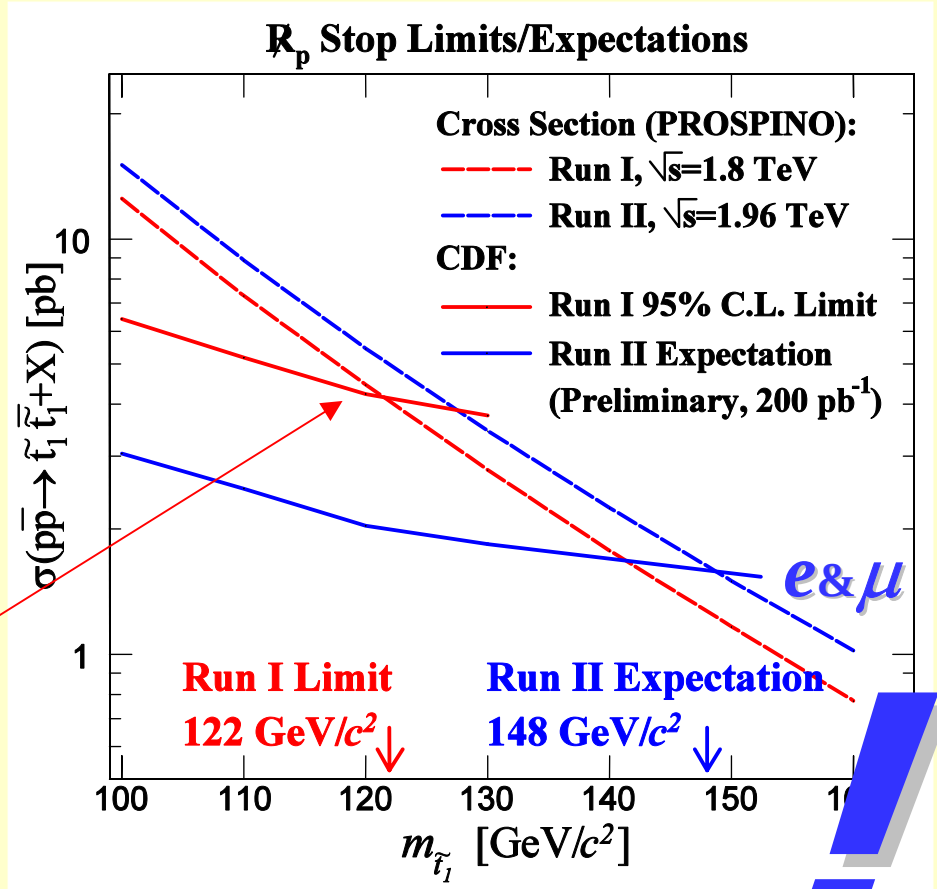
[N_{BG} < 1]

Run 1 → Run 2

Improvement in Run 2

CDF Run 1 Result (PRL Vol.92, No.5)



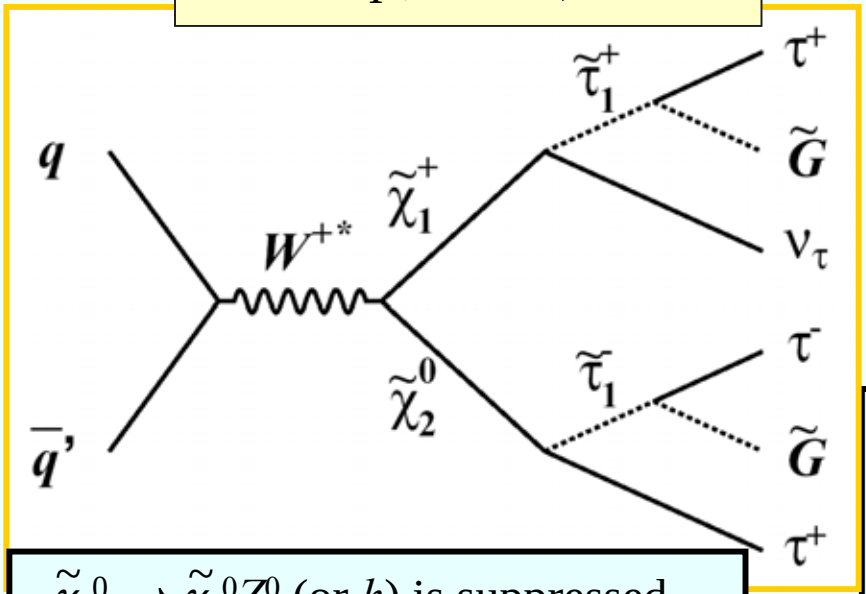


Next step: Finalize the BG estimate and then open the box …

GMSB at Large tanβ

LSP : $\tilde{G}$ ($M(\tilde{G}) \sim 1$ eV/c^2)

NLSP: $\tilde{\tau}_1 (\rightarrow \tau \tilde{G})$



- $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z^0$ (or h) is suppressed by $M(\tilde{\chi}_2^0) - M(\tilde{\chi}_1^0) < M(Z^0$ or $h)$
- $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \gamma$ is suppressed by $\tilde{\chi}_1^0$ is Photino-like and $\tilde{\chi}_2^0$ is Zino-like.
- $\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_1 \tau$ is dominant mode.

Experimental Signature

$3\tau + \not{E}_T$

Existing Limit (LEP2 slepton production):
$M(\tilde{\tau}_1) > 86.9$ GeV/c^2 (95% C.L.)

Final state:

e(10 GeV)+ τ_h(15 GeV)+track(5 GeV) +$\not{E}_T$(20 GeV)

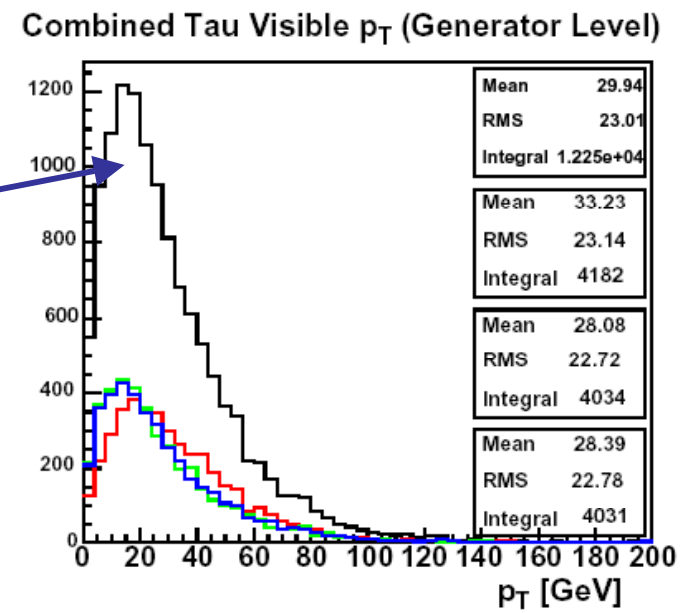
Or

μ(8 GeV)+ τ_h(15 GeV)+track(5 GeV) +$\not{E}_T$(20 GeV)

First Exercise: Total Event Acceptance

$$\varepsilon_{total} = A_{geom/kine}(\tau_l, \tau_h, 3^{rd}\,\text{track}) \cdot \varepsilon_{ID}(\tau_l, \tau_h, 3^{rd}\,\text{track}) \cdot \varepsilon_{\not{E}_T > 20\,\text{GeV}}$$

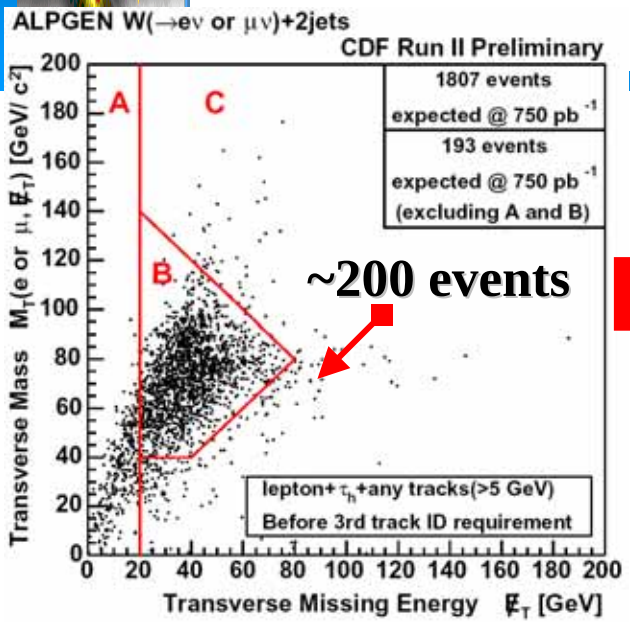
	Case I	Case II
Λ	32 TeV	68 TeV
M_{mess}	15Λ	2Λ
$\tan\beta$, n_m	20, 2	34, 1
$M(\tilde{\tau}_1)$ [GeV/c^2]	73.1	90.1
$M(\tilde{\chi}_1^+)$, $M(\tilde{\chi}_2^0)$ [GeV/c^2]	146, 146	170, 170
$BR(\tilde{\chi}_1^+ \to \tilde{\tau}_1 \nu)$	0.998	0.999
$BR(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau)$	0.843	0.960
NLO Cross Section [fb]	200	119
Total Event Acceptance	2.68±0.05%	3.70±0.06%
events @750 pb^{-1} (NLO)	3.4	3.2

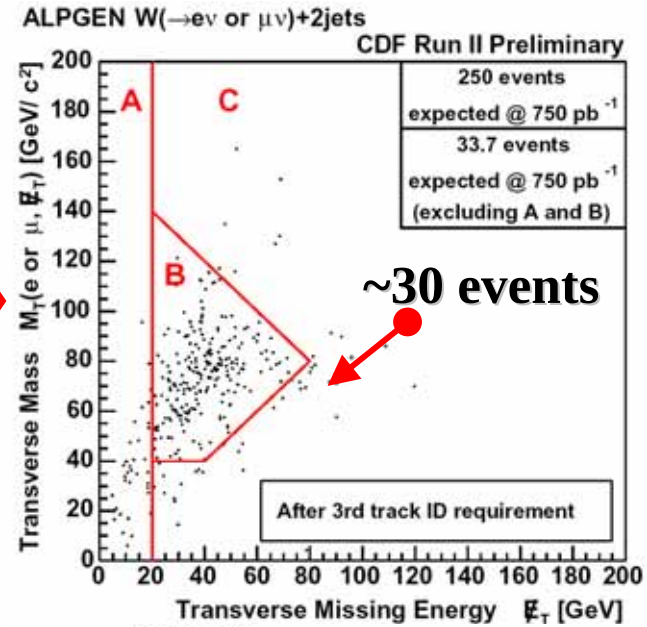


High tau reconstruction efficiency between 15 and 25 GeV is crucial …

Next step: Study tau reconstruction between 15 and 25 GeV; add *lll* mode

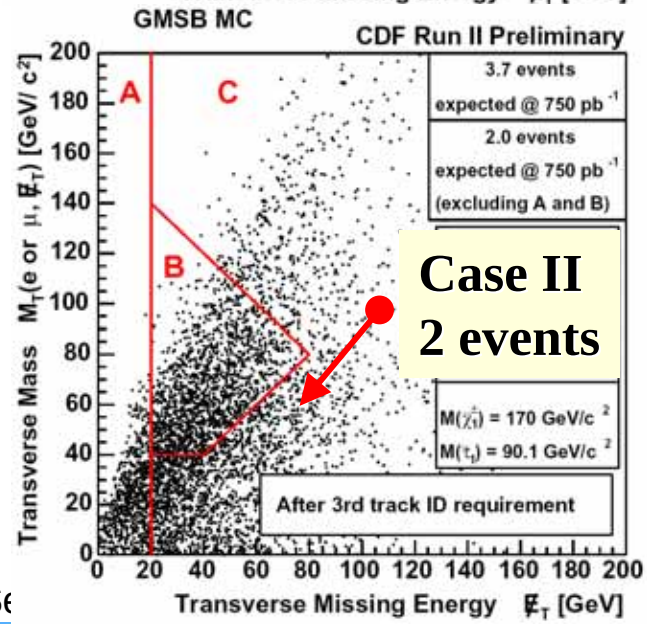
First Look at BG: *W*+2jets



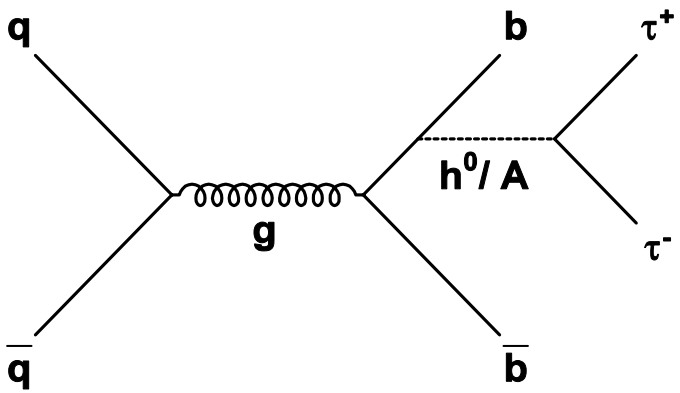


Excluding events in regions A and B, and requiring a 3rd track ID to reduce *W*+jets events.
(See the left plots.)

3rd track ID = consistent with tracks from τ decay



- **H_T-like cut?**
  Study in progress.
- **Studying Higgsino case where lighter chargino for a given stau mass.**

Summary

- **Lepton+Track (LT) trigger:** ***Effectively*** **accumulating multi-tau final state events**
- **$Z(\rightarrow \tau\tau)$:** ***First*** **cross-section measurement at hadron collider with 200 pb^{-1} for publication and calibration**
- **RPV stop (200 pb^{-1}):** **to understand $\tau\tau bb$ final state**
- **Signature-based searches as well as testing various models:**
  - **GMSB 3 tau's (750 pb^{-1})**
  - **SUGRA (> 1 fb^{-1})**
  - ***bb*+Higgs($\rightarrow \tau\tau$) (> 1 fb^{-1})**