$Z \rightarrow \tau\tau$ and R-parity Violating SUSY Search with taus at CDF-II

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Outline

- **Motivation: Stop with R-parity violation**
- **Run II Analysis ($Z \rightarrow \tau\tau$)**
- **Run II Prospects (R-parity violating Stop)**
- **Summary**

Scalar Top (STOP) Quark

The Standard Model (SM)

is **a gauge theory of elementary particles.**

$R_p = +1$

Top quark is the heaviest fermion in the SM.

Spin = 1/2

Charge = 2/3

Mass = 175 GeV/c^2

Supersymmetry (SUSY)

is **a gauge theory with fermion-boson symmetry.**

$R_p = -1$

Stop is a SUSY partner of the top quark.

Spin = 0

Charge = 2/3

Mass = ? GeV/c^2

$$R_p = (-1)^{3B+L+2S}$$

R-parity (R_p) Violation

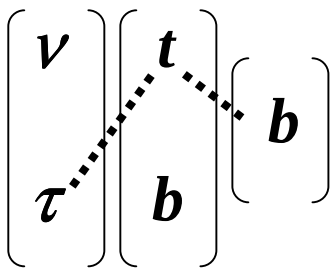
$$\mathbf{W} = \mathbf{W}_{\mathbf{SM}} + \mathbf{W}_{\mathbf{MSSM}} + \underbrace{\mathbf{W}_{\mathbf{TRPV}} + \mathbf{W}_{\mathbf{BRPV}}}_{\text{Superpotential for RPV}}$$

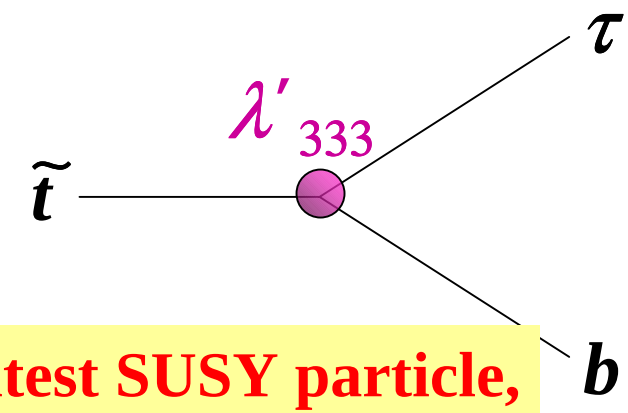
where

$$\mathbf{W}_{\mathbf{TRPV}} = \varepsilon_{\mathbf{ij}}[\lambda_{\mathbf{ijk}} L^{\mathbf{i}} L^{\mathbf{j}} E^{c\mathbf{k}} + \lambda'_{\mathbf{ijk}} L^{\mathbf{i}} Q^{\mathbf{j}} D^{c\mathbf{k}} + \lambda''_{\mathbf{ijk}} U^{c\mathbf{i}} D^{c\mathbf{j}} D^{c\mathbf{k}}]$$

$$\mathbf{W}_{\mathbf{BRPV}} = \varepsilon_{\mathbf{ij}}[\eta_{\mathbf{i}} L^{\mathbf{i}} H_d^{\ \mathbf{j}}]$$

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

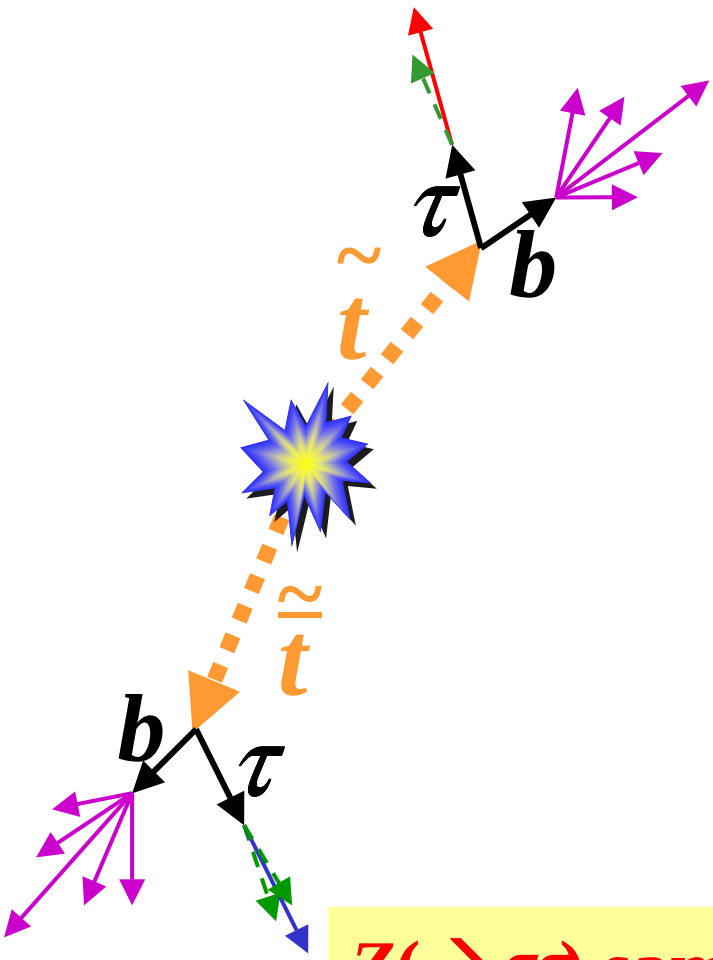




NOTE: $\lambda, \lambda', \lambda'', \eta$ couplings are assumed to smaller than the SM gauge couplings

If stop is the lightest SUSY particle, the branching ratio can be 100%.

Experimental Signature



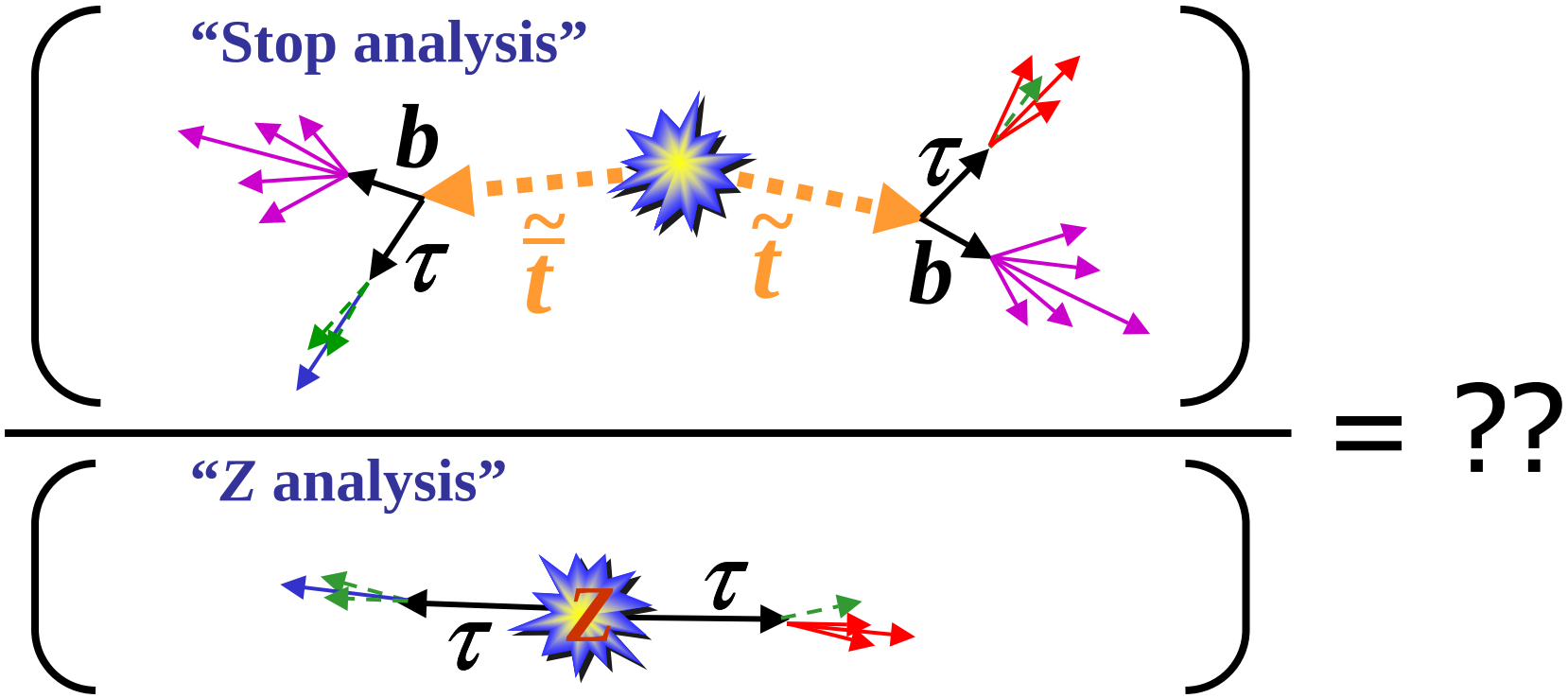
$$\underbrace{l + \tau_h}_{\text{Trigger}} + \underbrace{b + b}_{\text{No } b\text{-tag for Run I}}$$

Dominant SM BGs

- $Z(\rightarrow \tau\tau)$ + $\geq$2 jets
- $W(\rightarrow l\nu)$ + $\geq$3 jets
- QCD
- $t\bar{t} \rightarrow Wb+Wb$
- $WW/WZ/ZZ$

$Z(\rightarrow \tau\tau)$ sample can be our calibration sample.

Stop and Z Analyses



= ??

- Cancellation : Luminosity, BR($\tau \rightarrow l \cdot \tau \rightarrow \tau_h$)
- Reduce Sys.Uncertainty: Lepton and τ_h ID, Iso cut

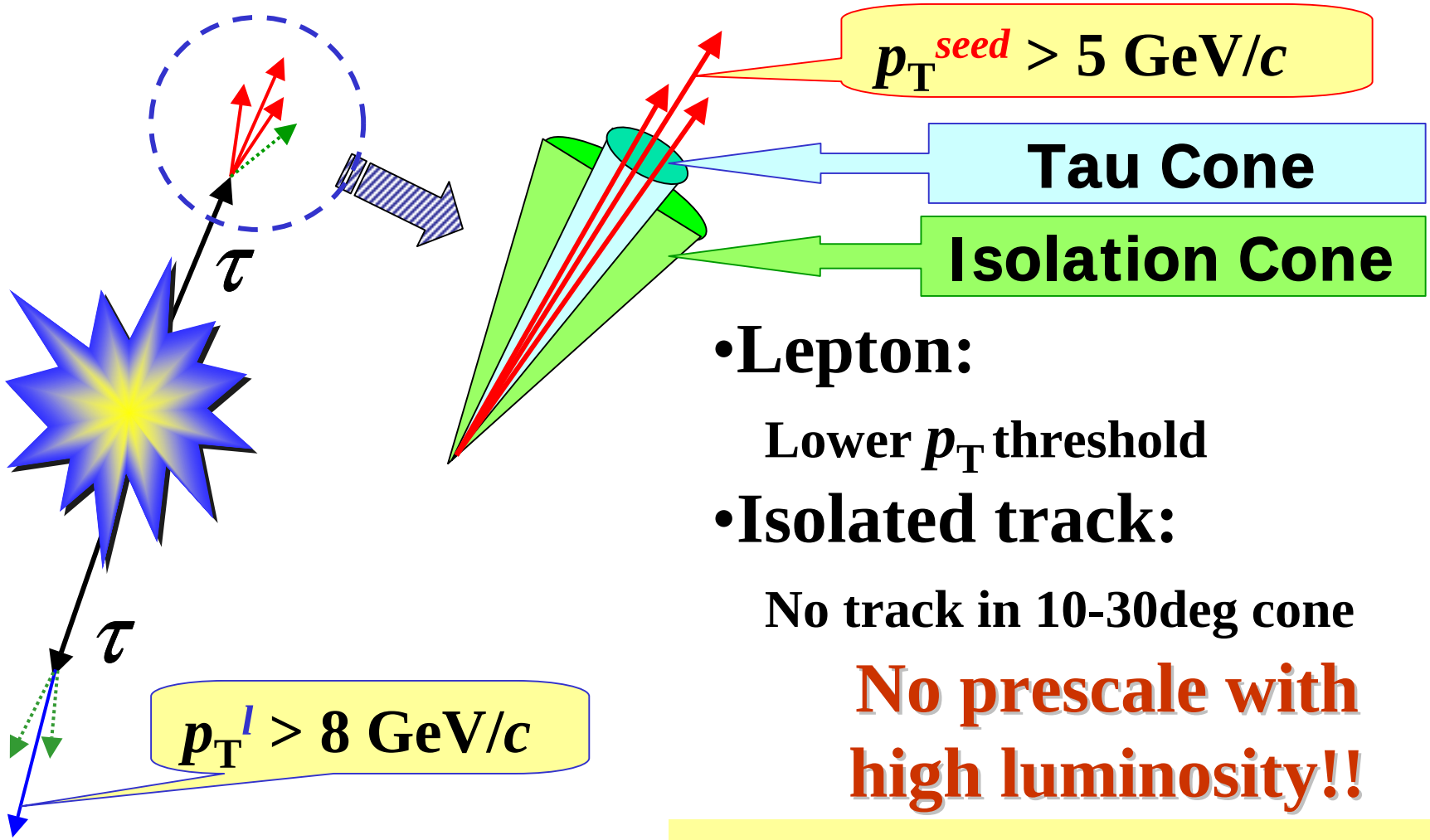
Run I vs. Run II

- $\int L dt$ (pb^{-1}) : 72 ⇔ 106
- $\sqrt{s}$ (TeV) : 1.96 ⇔ 1.8
- New Trigger : Generic dilepton trigger including two tau in the final state

  Lepton[8GeV]+Track[5GeV] *(w/o Prescale)*

  ⇔ Lepton[8GeV] *(w/ Prescale)*

Run II: Trigger



- **Lepton:**
  - Lower p_T threshold
- **Isolated track:**
  - No track in 10-30deg cone

No prescale with high luminosity!!

→ See Sasha's talk for details.

Run II: Electron Selection

Electron Variables	Cuts
E_T	>10 GeV
p_T	>8 GeV/c
Had/Em	<0.055+0.00045·E
Lshr	<0.2
$Q_{trk} \cdot \lvert \Delta x \rvert$	>-3.0cm, <1.5cm
$\lvert \Delta z \rvert$	<3.0cm
$\lvert Z_0 \rvert$	<60.0cm
$\lvert d_0 \rvert$	<0.3cm
$Chi2_{stirp}$	<10
Cal Iso (R=0.4)	< 4.0 GeV
N_{SL}(axial, stereo)	>=3
Fidele	= 1

Central,
(Track Iso <0.2)
Conversion Removal,
Zee Removal

Run II: Tau Selection

Tau Variables	Cuts
$\lvert \eta_{det} \rvert$	<1.0
p_T(tracks+pi0)	>20 GeV/c
Seed Tower E_T	>6 GeV
Seed Track p_T	>6 GeV/c
Mass(tracks+pi0)	<1.8 GeV/c²
$\lvert Z_0 \rvert$	<60.0 cm
$\lvert d_0 \rvert$	<0.3 cm
N_{trk}, N_{pi0} in 10-30 deg	= 0
Cal Iso (R=0.4)	< 0.1
N_{SL}(axial, streo)	>=3
$E_{had}/\Sigma\lvert p \rvert$	>0.1

$9 < \lvert Z_{CES} \rvert < 230$cm
$\lvert Z_0(\tau) - Z_0(e) \rvert <$?cm

Z Event Selection

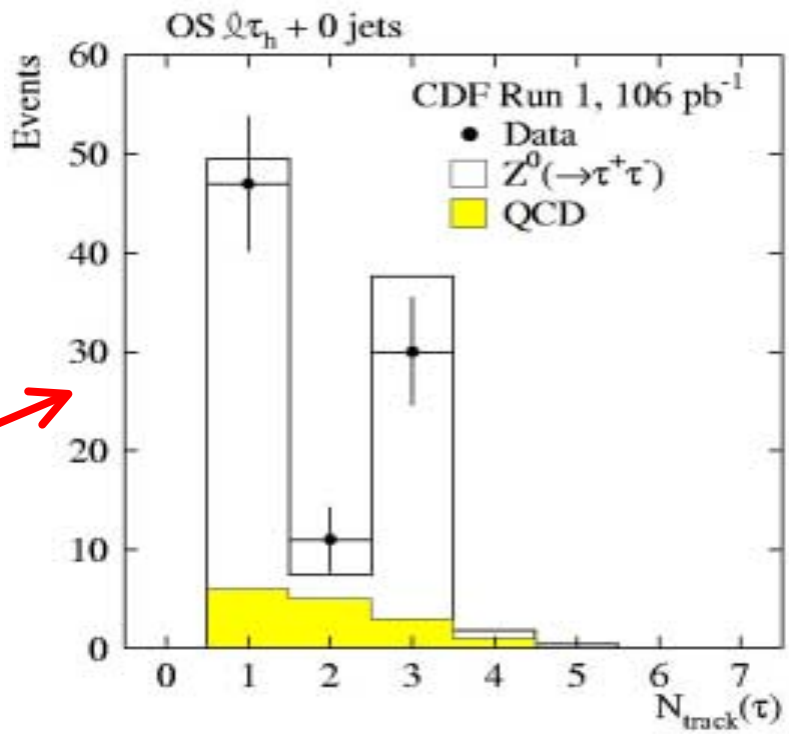
- Baseline selection: $e + \tau_h$
- Transverse mass cut to reduce W events:

  $+ M_T(l, \not{E}_T) < 25$ GeV/c^2
- Transverse p_T cut to reduce QCD events

  $+ p_T(l, \not{E}_T) > 25$ GeV/c
- Example: Run I

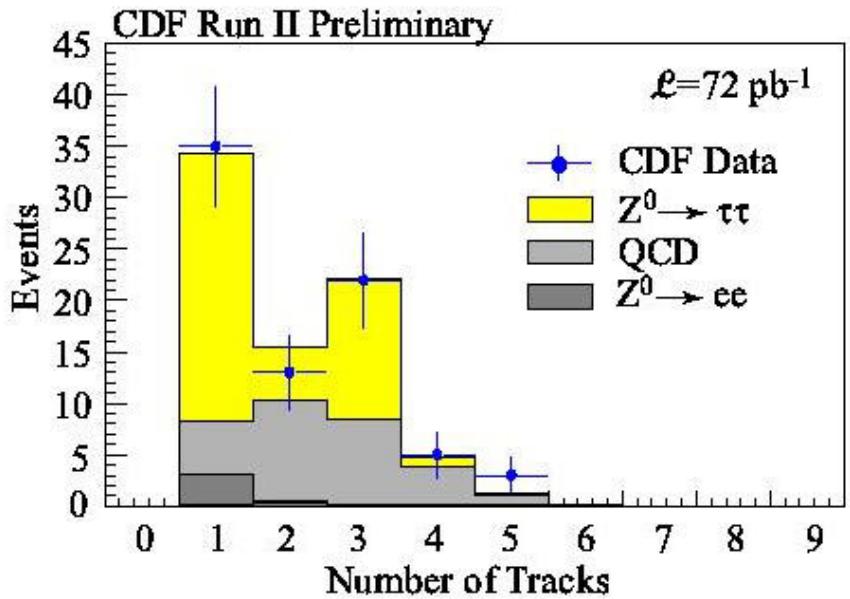
(OS l τ_h + 0 jets)

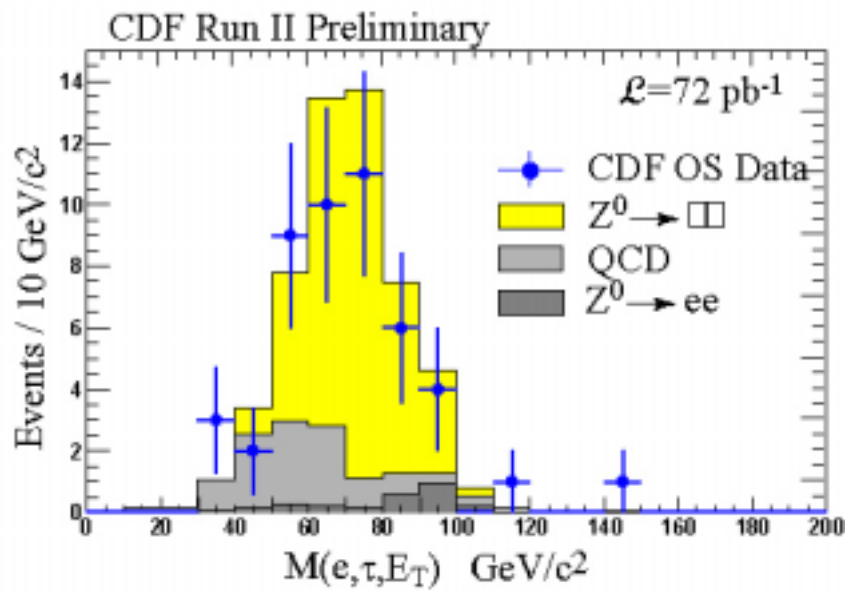
CDF Preliminary



Run II Results

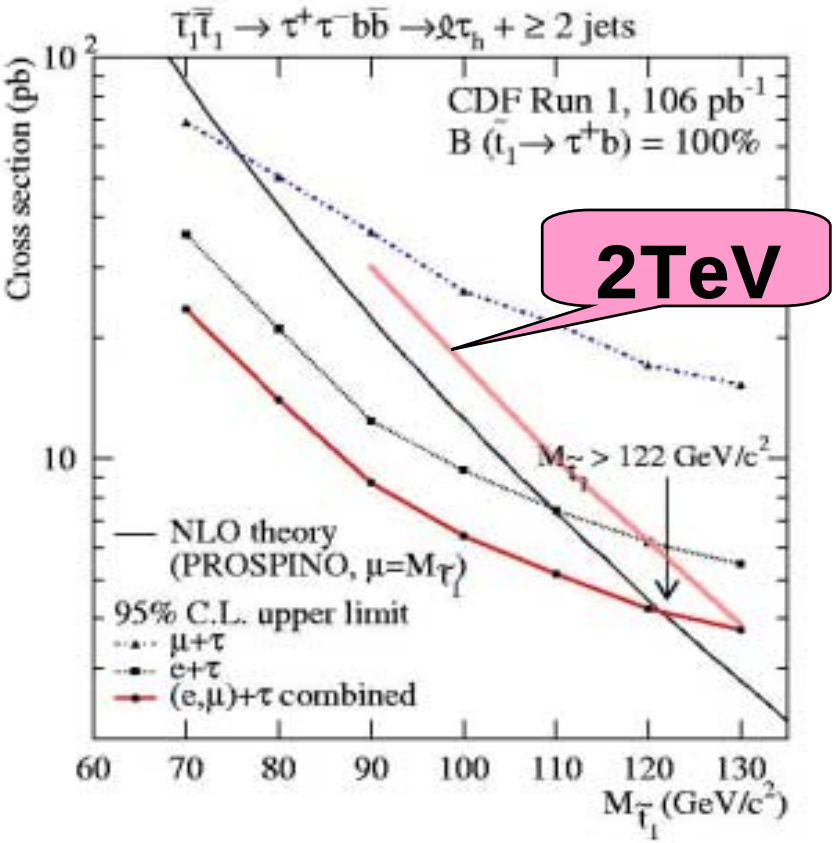
$e + \tau_h$ **(no cuts on jets)**





Run II Prospect

CDF (Run I) Preliminary



$$\sigma_{\text{limit1}} \times \varepsilon_1 \times L_1 = \sigma_{\text{limit2}} \times \varepsilon_2 \times L_2$$

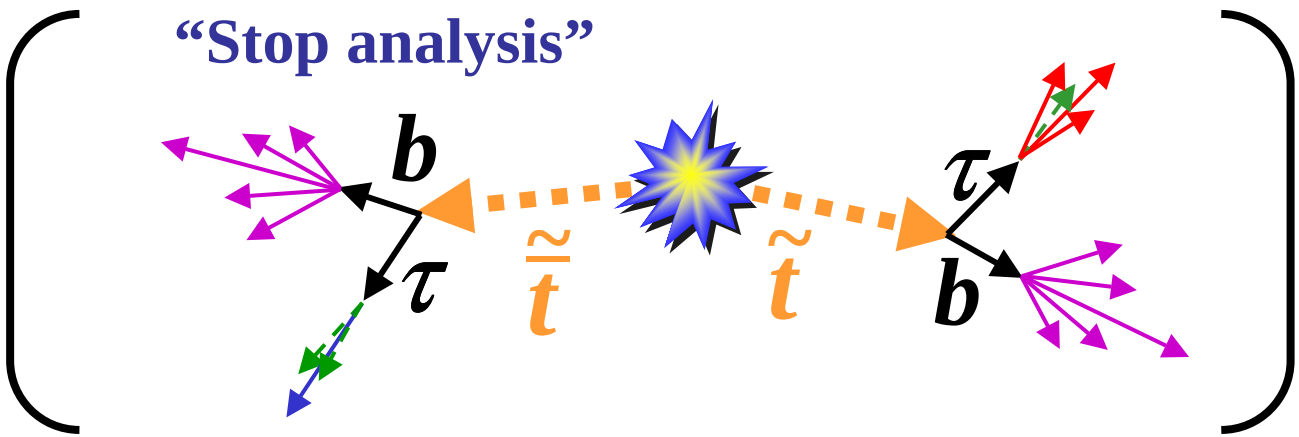
$$\Rightarrow \frac{\sigma_{\text{limit2}}}{\sigma_{\text{limit1}}} = \frac{\varepsilon_1 \times L_1}{\varepsilon_2 \times L_2}$$

$$\approx \frac{1.0}{1.0-(0.5\times 0.5)} \times \frac{110\,\text{pb}^{-1}}{2\,\text{fb}^{-1}}$$

$$\approx \frac{1}{14}$$

Mass Limit :
122 → ~180 GeV/c²

Assumption : No observation, same efficiency, same background level due to 1 b-tag ($\varepsilon_{\text{b-tag}}$=50%).

Summary

- New lepton+track trigger is working nicely in Run II. The trigger is designed to detect all dilepton final states (except $\tau_h \tau_h$).
- Status: a clear $Z \rightarrow \tau_e \tau_h$ signal
- Final goal: search for new physics with di-tau final state. One of them is: