Searches for Like-Sign and Trilepton Signals at CDF

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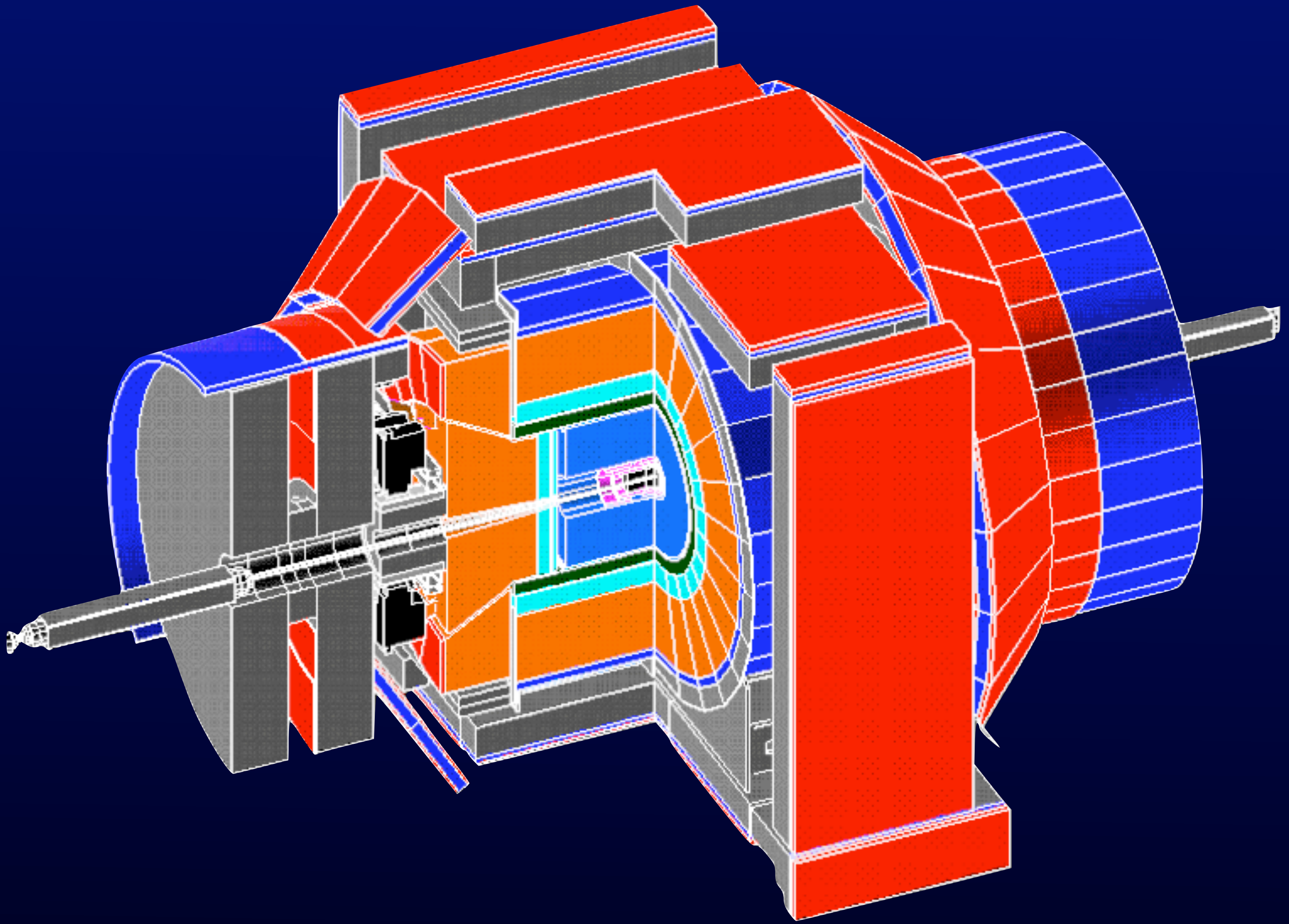
Outline

- Introduction
- Trileptons
  - **Chargino-Neutralino search**
  - **WZ and ZZ cross section measurements**
- LS Dileptons
  - **4th Gen. fermion search**
  - **MFV scalar search**
  - **Generic LS search**
- Conclusions

Why LS and Trileptons?

- Leptonic signatures of new physics critical at hadron colliders due to overwhelming backgrounds
- Multiple physics “object” signatures appealing:
  - Dileptons: OS and LS; Trileptons, etc.
  - These signatures dramatically decrease hadronic backgrounds
  - Must include tau leptons

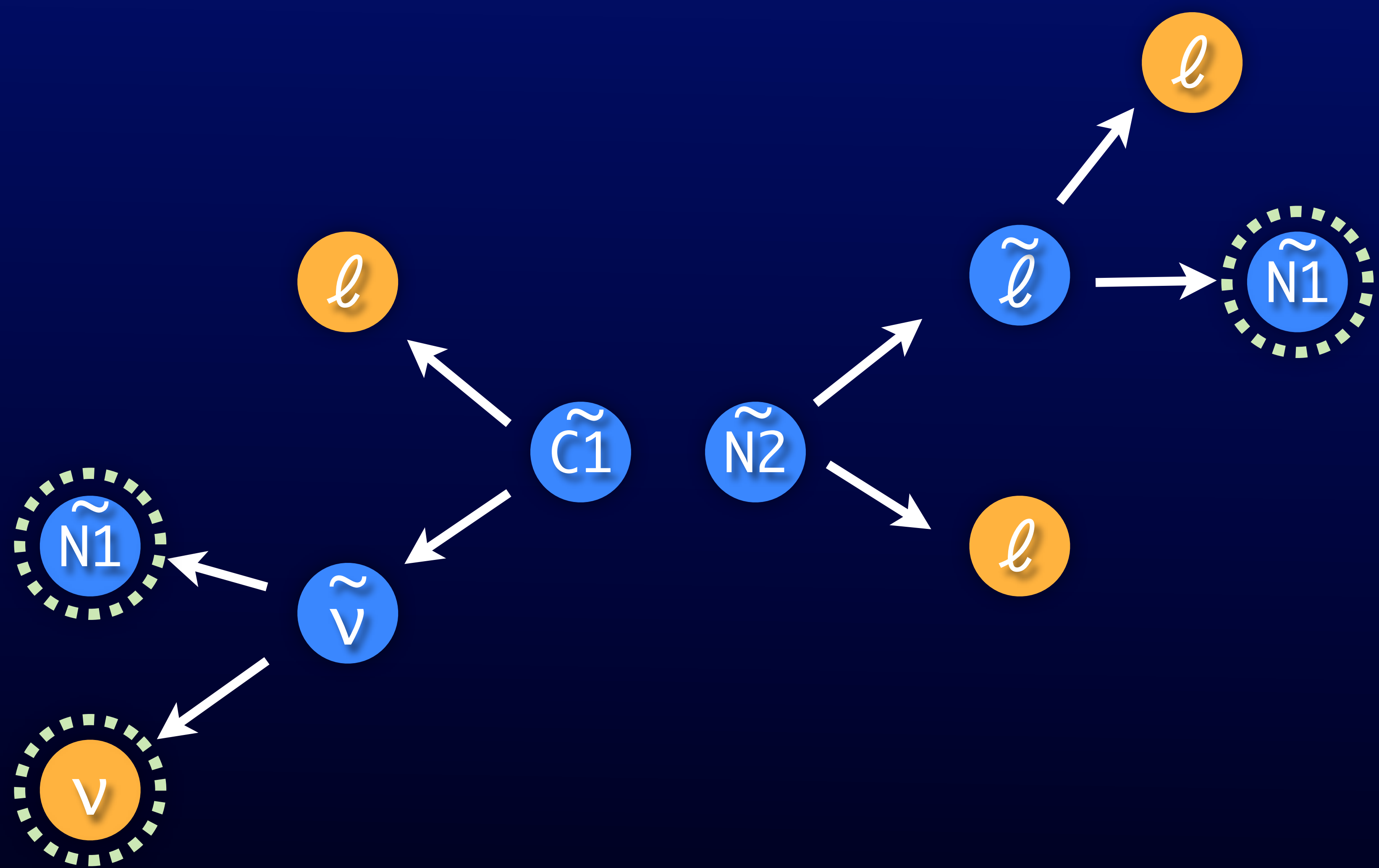
CDF Run II Detector



Vertexing & Tracking
TOF
Solenoid
EM Calorimetry
Hadron Calorimetry
Muon Chambers

➠ *e,μ,τ identified with excellent efficiency/purity*

Search for SUSY Trileptons



$$M_{\tilde{C}1} \approx M_{\tilde{N}2} \approx 2M_{\tilde{N}1}$$

N2C1 Search

- Direct (EWK) or from cascades (strong), imparts boost
  - **Cascades more relevant for LHC**
- Dilepton edge from N2 decay. challenging if stau involved
  - **slepton virtual: modifies edge**
- $|\Sigma Q_i|=1$, so 2 OS pairs
- MET cancellation not complete
  - **topology cuts to reduce WZ, ttbar**

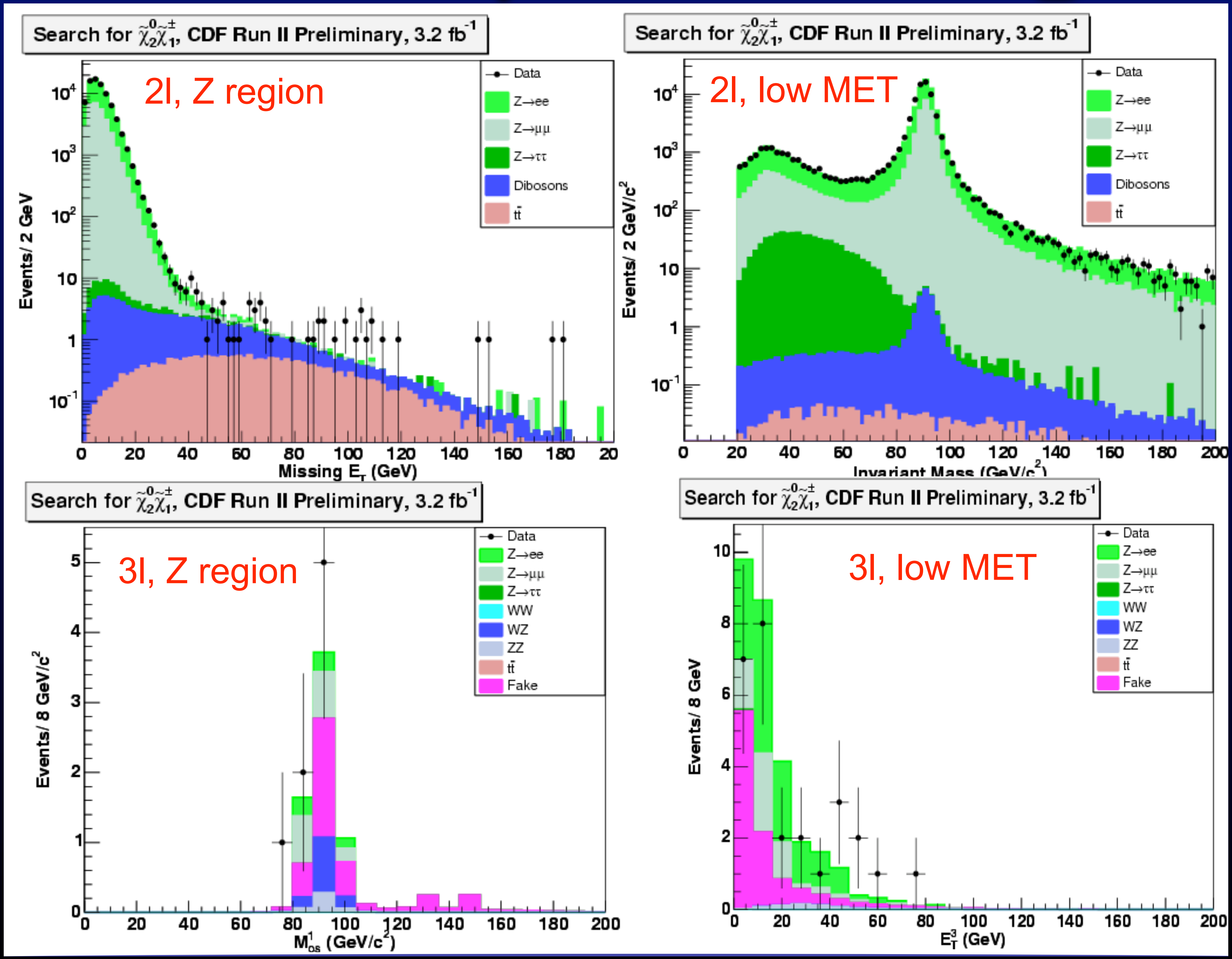
Trilepton Search with 3.2 fb^{-1}

- 5 exclusive channels

	CHANNEL	SELECTION	$(E_T$ or $P_T)_{123}$ [GeV]
trilepton	3 tight	3 tight l or 2 tight l + 1 loose e	15,5,5
	2 tight + 1 loose	2 tight l + 1 loose muon	15,5,10
	1 tight + 2 loose	1 tight lepton + 2 loose l	20,8,5 *
dilep+track	2 tight + 1 track	2 tight l + 1 iso track	15,5,5
	1 tight + 1 loose +1 track	1 tight l + 1 loose l + 1 iso track	20,8*,5

** 10 GeV if loose muon*

Di- and Trilepton Ctrl regions

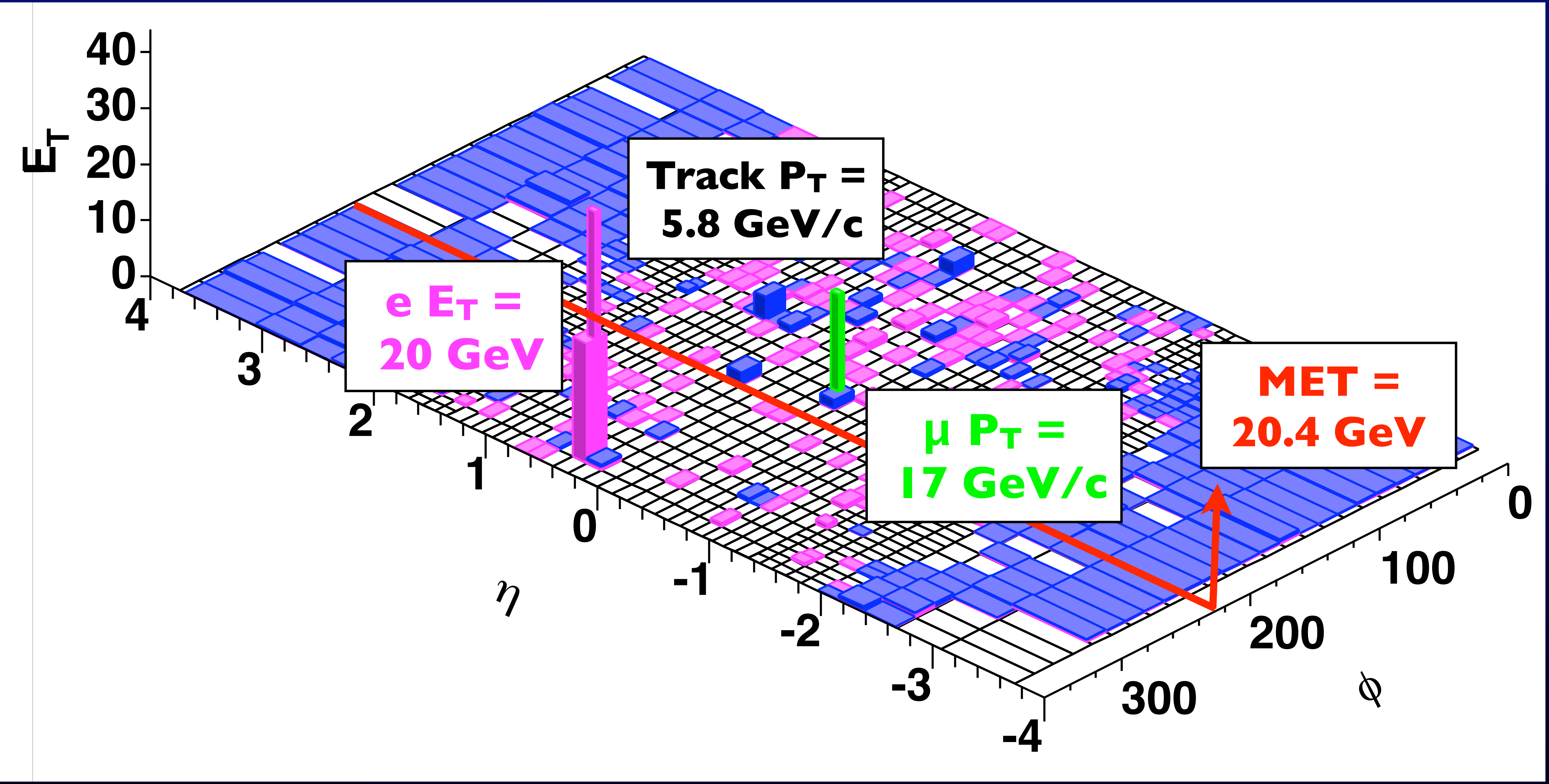


Trilepton Results in 3.2 fb^{-1}

CHANNEL	Total Background	Signal Point	Observed
3 tight	0.8 ± 0.2	3.6 ± 0.5	1
2 tight + 1 loose	0.4 ± 0.1	2.6 ± 0.4	0
1 tight + 2 loose	0.2 ± 0.1	1.1 ± 0.2	0
2 tight + 1 track	5.8 ± 1.2	7.2 ± 1.0	4
1 tight + 1 loose +1 track	3.5 ± 0.7	4.1 ± 0.6	2

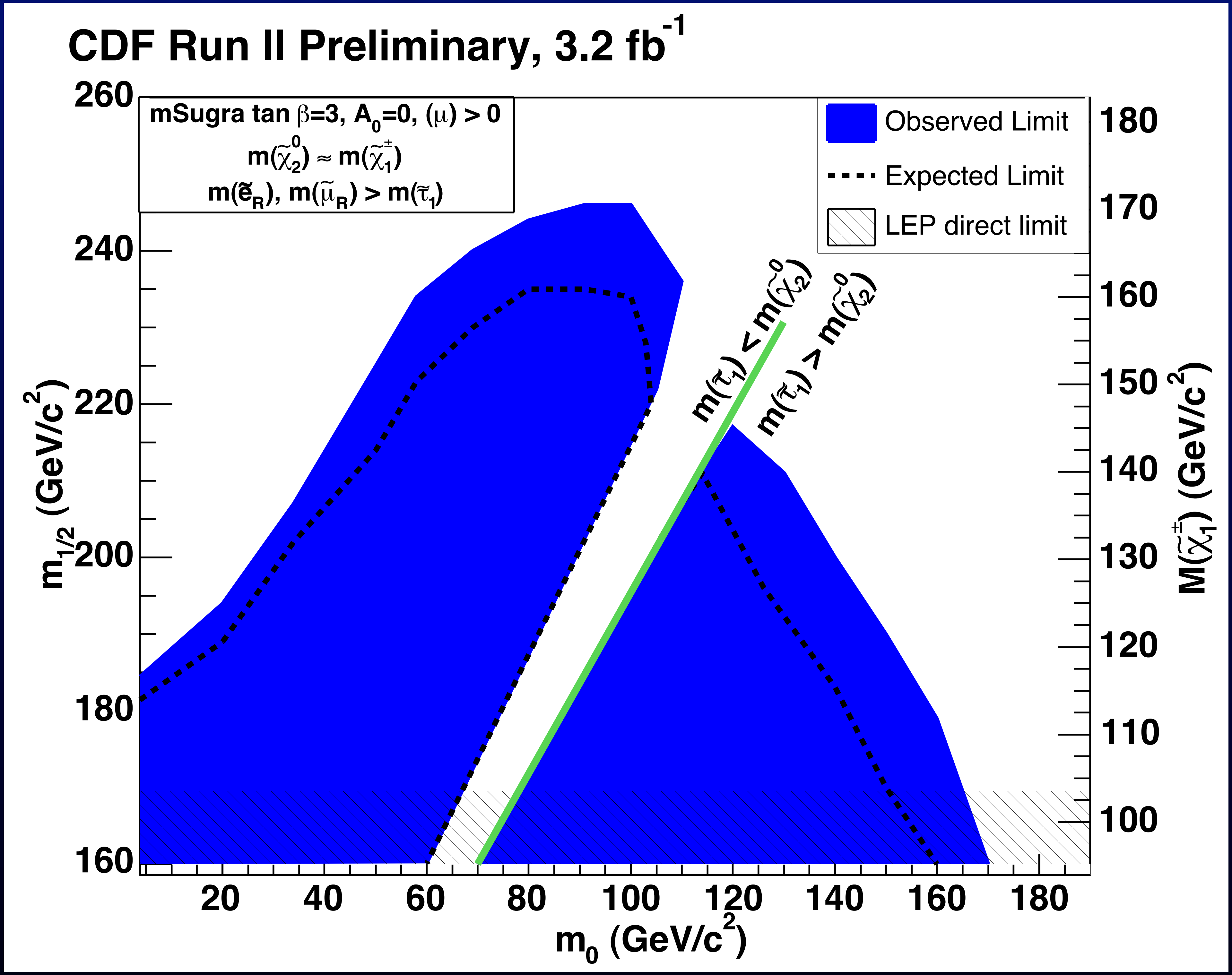
Signal point: $M_0 = 60$, $M_{1/2} = 190$, $\tan\beta=3$, $\mu>0$, $A_0=0$

Clean candidate event



No jets with E_T > 15 GeV

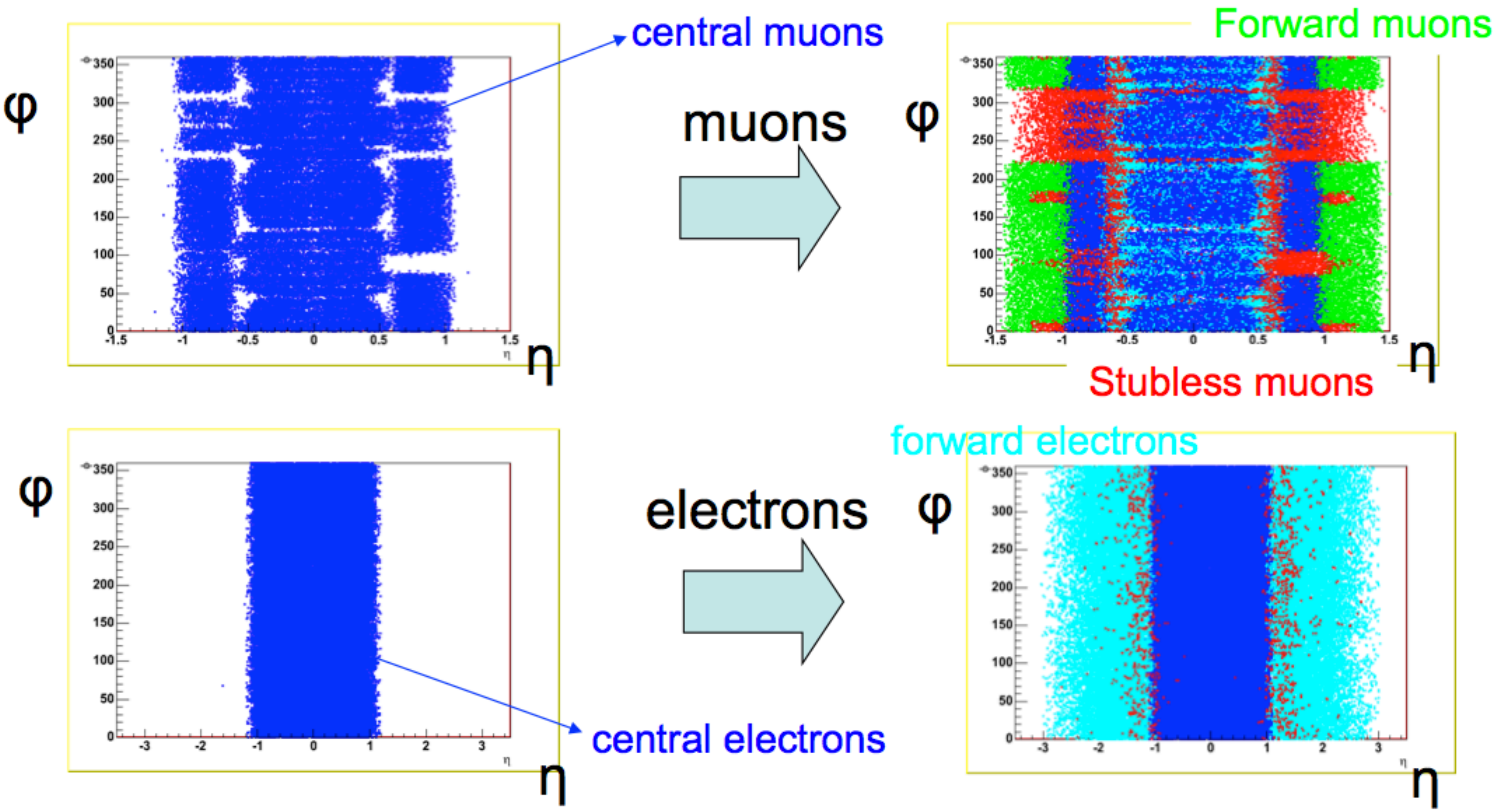
Scan in mSUGRA



$M(\chi^{\pm}) > 164$ GeV for $m_0 = 60$ GeV @ 95% CL

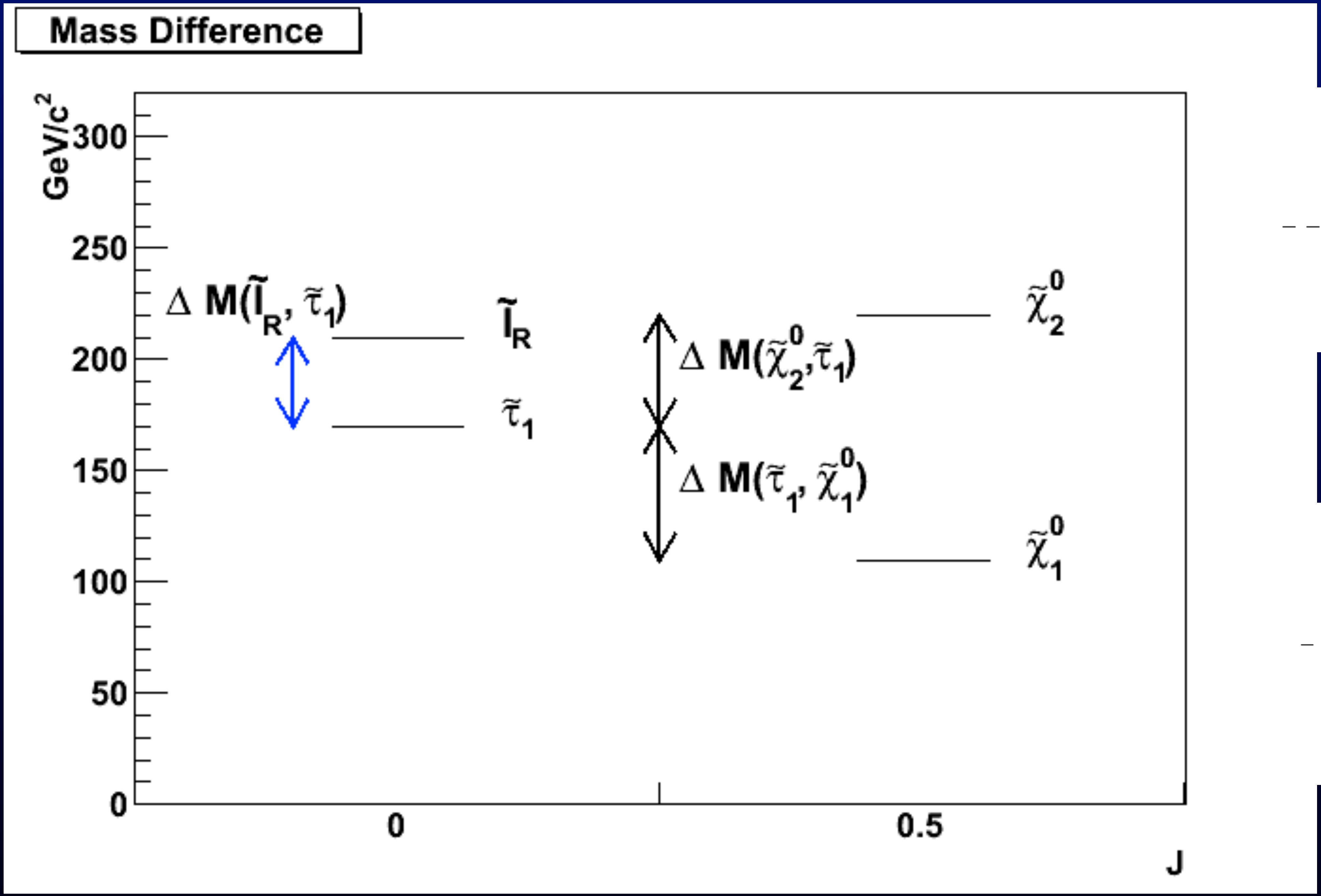
Extending lepton coverage

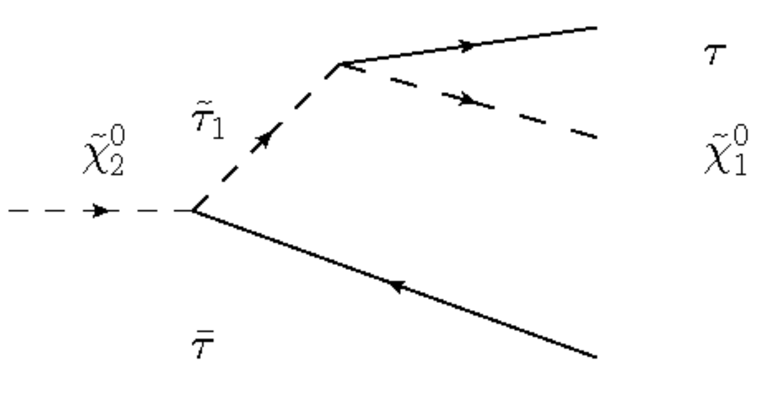
- forthcoming from CDF...

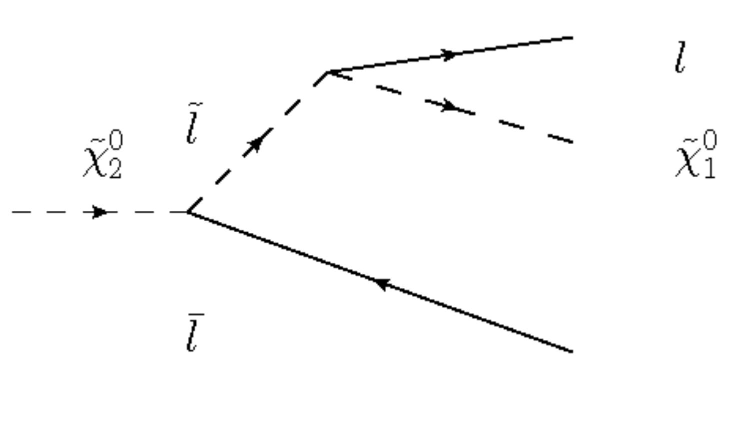


- We will use the full CDF detector, including the forward calorimeters and muon systems.
- The forward objects roughly double (triple) our dilepton (trilepton) acceptance

Extending to high tan β



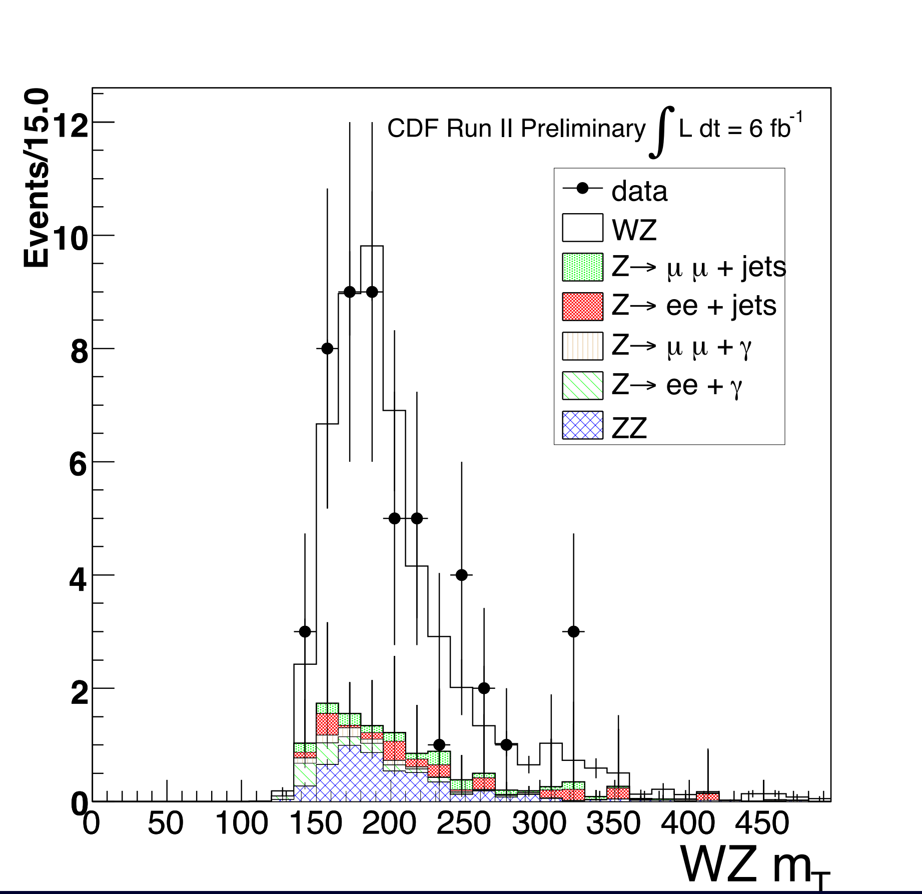




WZ and ZZ Cross Sections

CDF WZ and ZZ Analyses

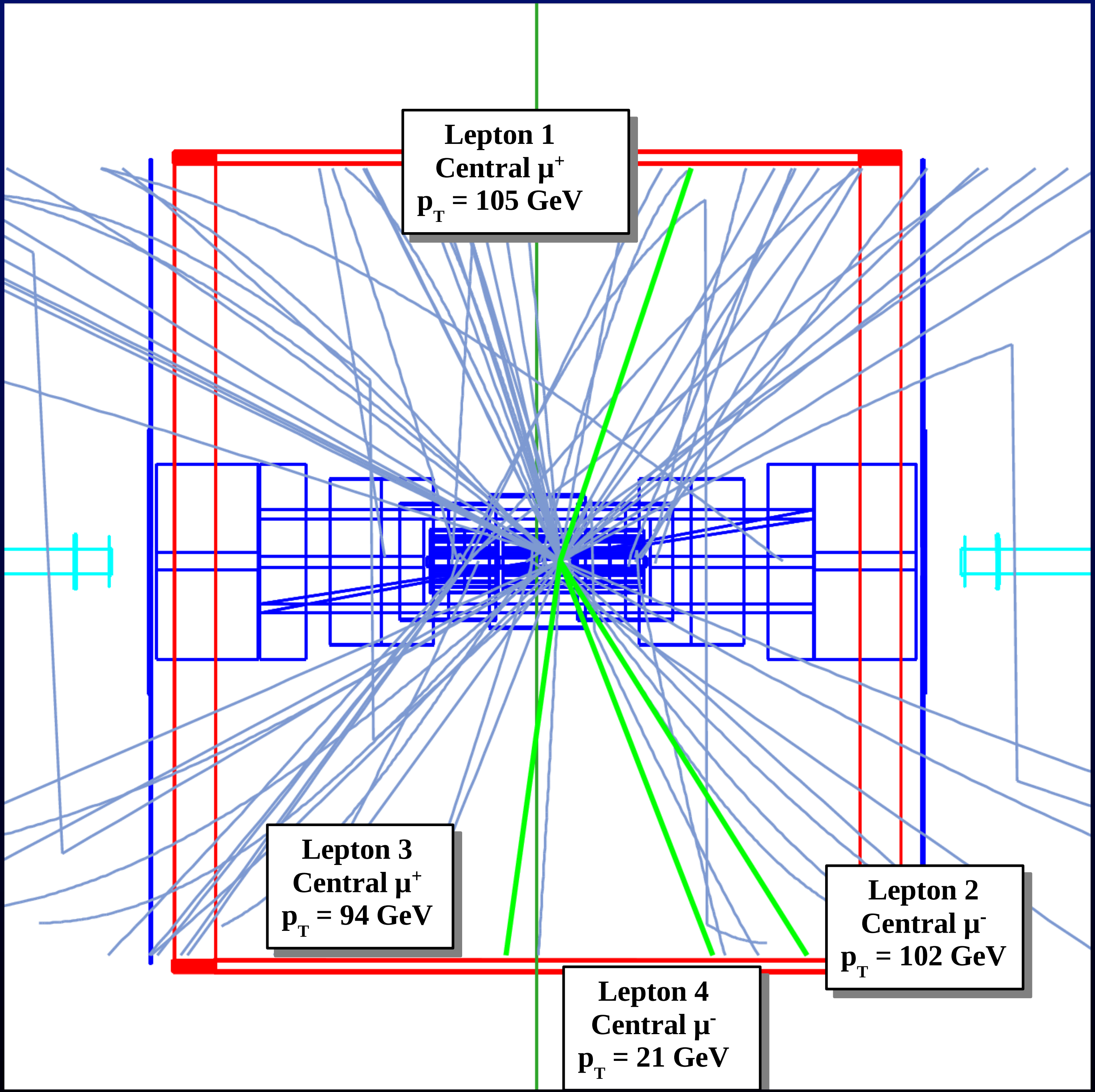
- Measurement of σ WZ and ZZ in 6 fb^{-1}
  - **50 Obs: 3*l* + MET events**
  - **4 Obs: 4*l* events**
  - **$\sigma(WZ)/\sigma(Z) = (5.5\pm0.9) \times 10^{-4}$**
  - **$\sigma(ZZ)/\sigma(Z) = (2.3\pm1.5) \times 10^{-4}$**



- Measurement of σ WZ in 5.9 fb^{-1} with neural net:
  - **$\sigma(WZ)=3.7 \pm 0.6 \pm 0.6$ pb**

CDF σ(ZZ) with 4.8 fb^{-1}

- σ(ZZ) =
  - 1.56 ± 0.8 ± 0.3 pb
- σ(ZZ)$_{NLO}$ =
  - 1.4 ± 0.1 pb



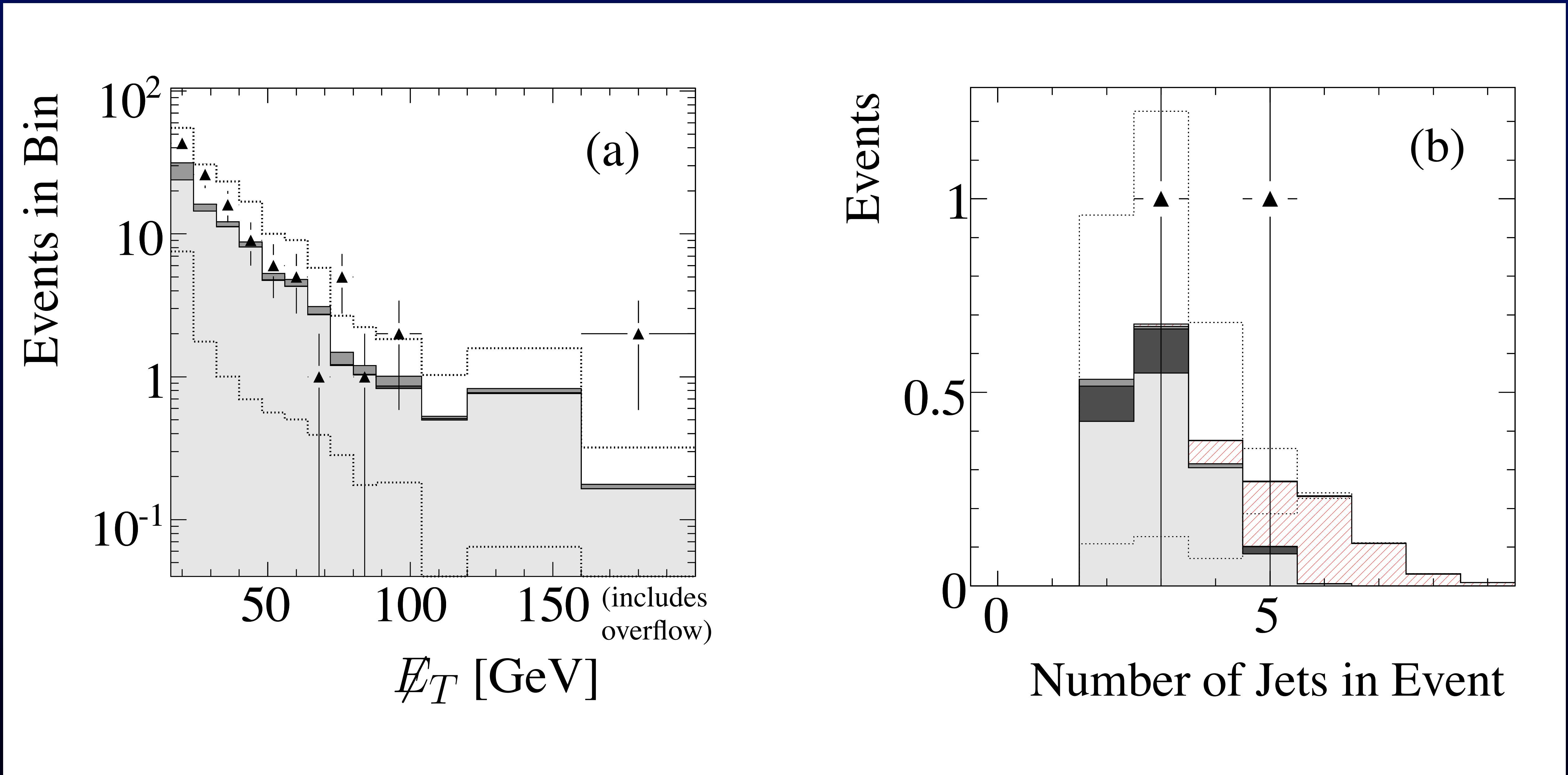
Like-Sign Dileptons

Search for 4th gen. fermions

$$Q\bar{Q} \rightarrow (tW^{\mp})(\bar{t}W^{\pm})$$

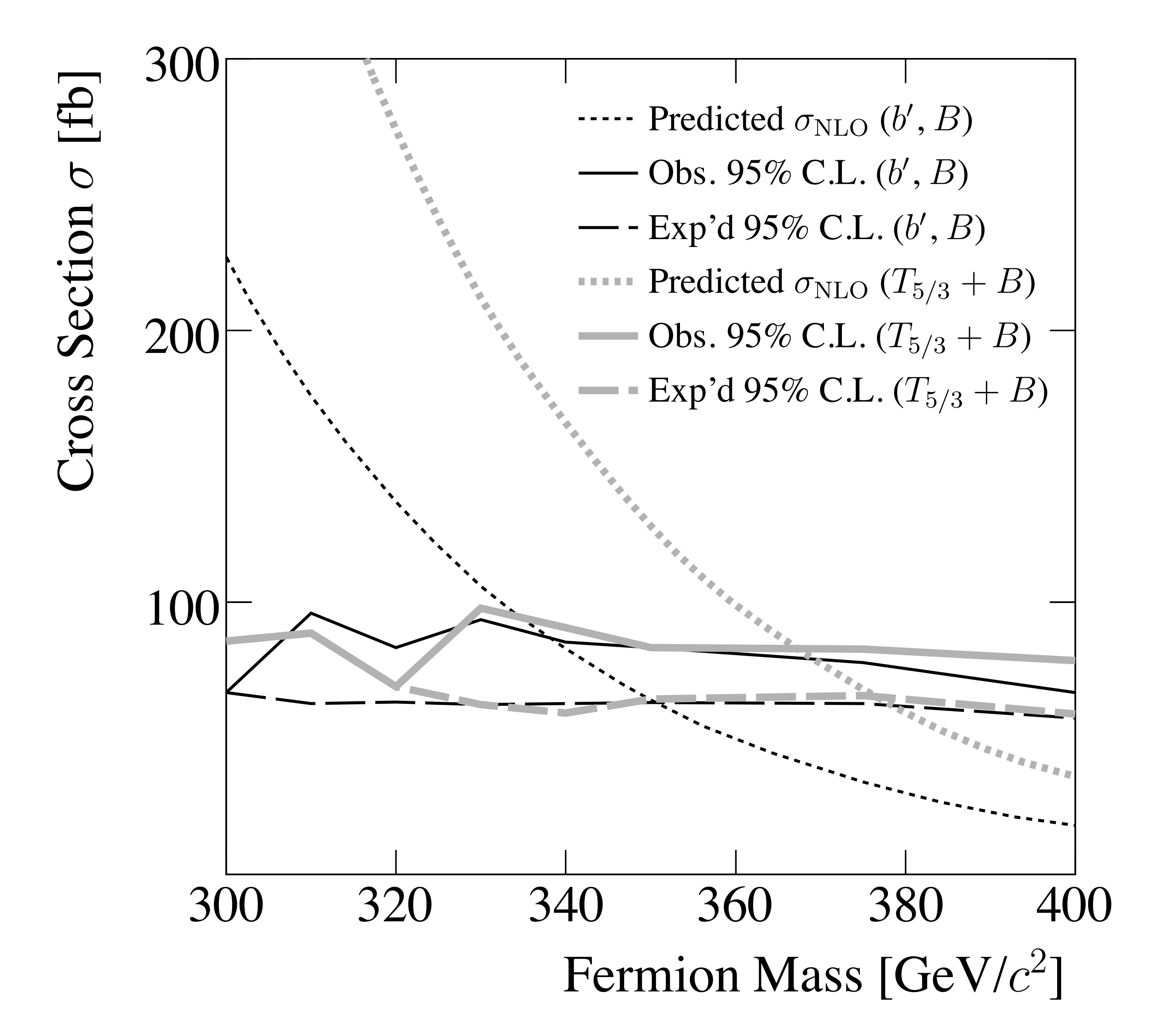
- Consider Q=
  - b′ (4th generation down-type quark)
  - B, $T_{5/3}$ (exotic top partners)
  - assume BR(t→bW) = 100%
- Require:
  - LS electrons and/or muons
  - MET > 20 GeV
  - Njet ≥ 2
  - 1 b: secondary vertex tag

Search for 4th gen. fermions



2.7 fb^{-1}

Search for 4th gen. fermions



Result in 2.7 fb^{-1}:
observe 2 events
(1 μμ + 1 eμ)
BG prediction 1.9 ± 1.4
(W→lν + fake: 1.4 ± 1.4)

$m_{b'}$, m_B > 338 GeV
$m_{T5/3}$ > 365 GeV

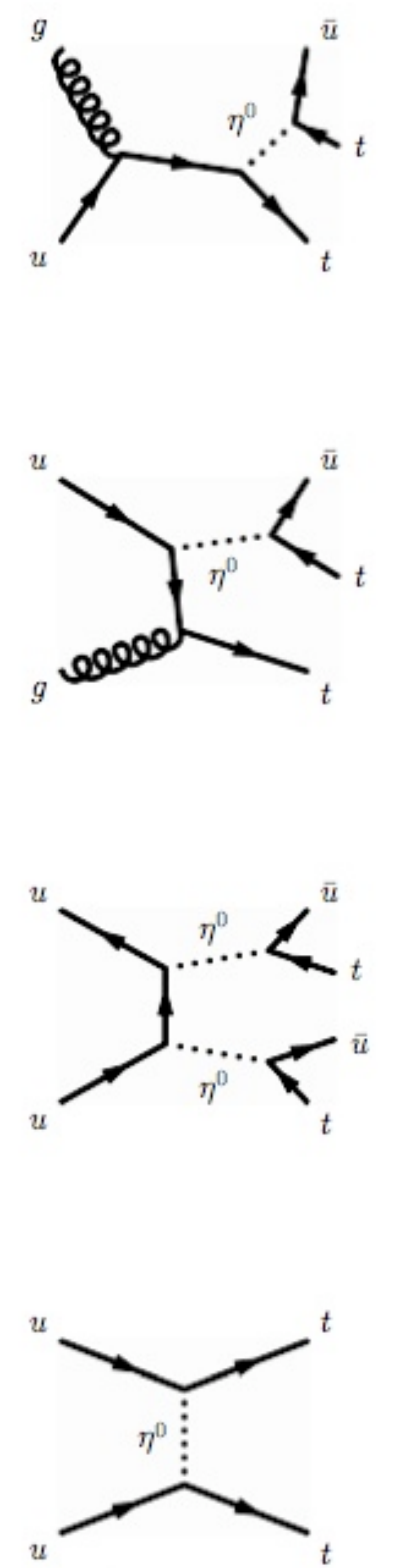
PRL 104, 091801 (2010)

Search for MFV scalars

- Consider new scalar field Φ_{FV}
  - couples to quarks via $\Phi_{FV}\, q_i\, q_j \;\propto\; \xi_{ij}$
    - $\xi_{i3}, \xi_{3i} \sim V_{tb}$ for i =1,2, and $\xi_{33} \sim V_{td}$
  - scalar doublet $\Phi_{FV} = (\eta^+, \eta^0)$
  - assume η^+ too heavy for observable effects
  - η^0 is lighter, yields signature: LS top quarks

Event selection:
LS e/μ
1 b tag
MET > 20 GeV

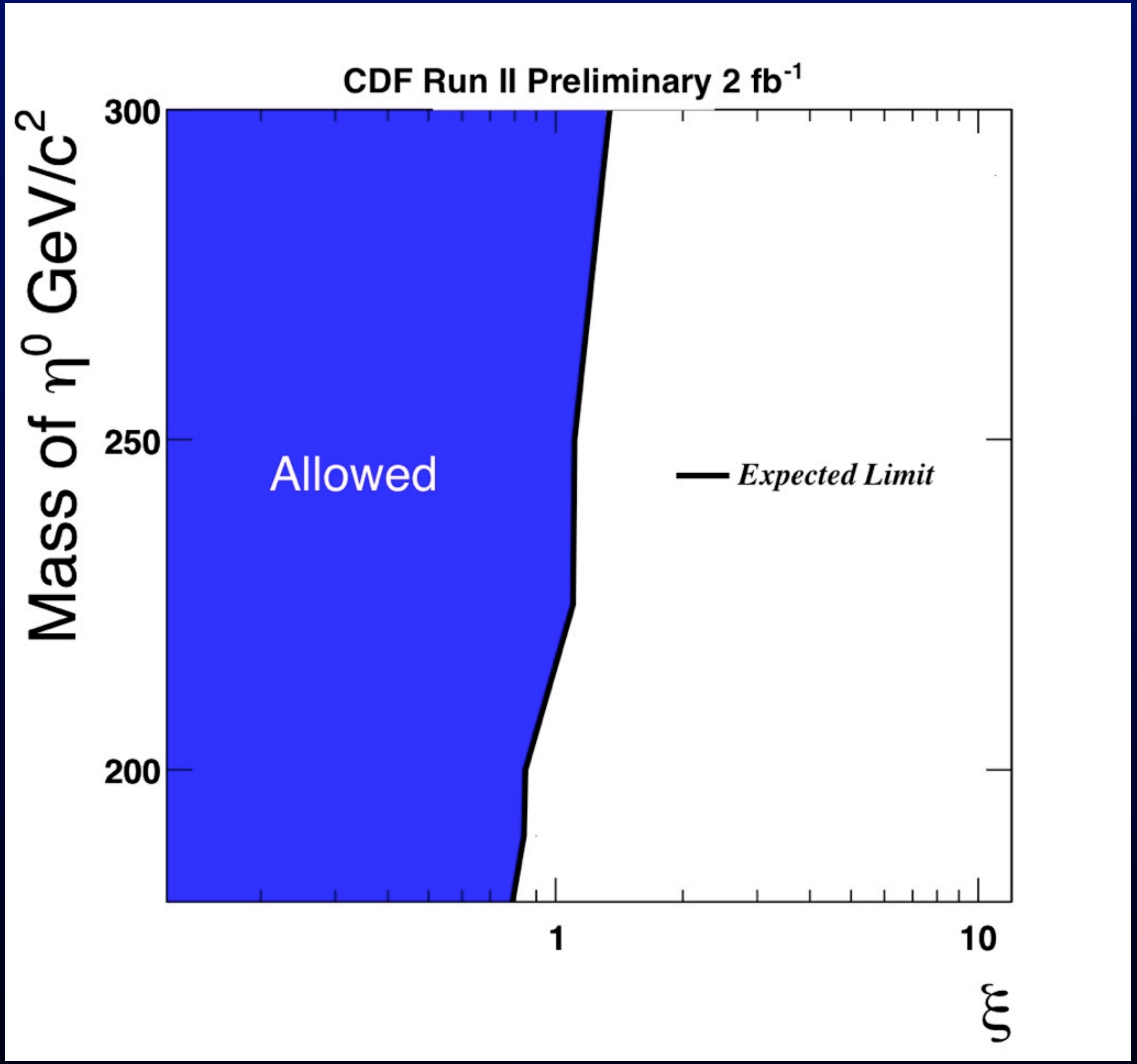
M. Chertok



Search for MFV scalars

Require: LS, 1 b tag, MET > 20 GeV

Result in 2.0 fb^{-1}:
observe 3 events
(1 $\mu\mu$ + 2 $e\mu$)
BG exp 2.9 ± 1.8
($W \rightarrow l\nu$ + fake: 1.8 ± 1.8)

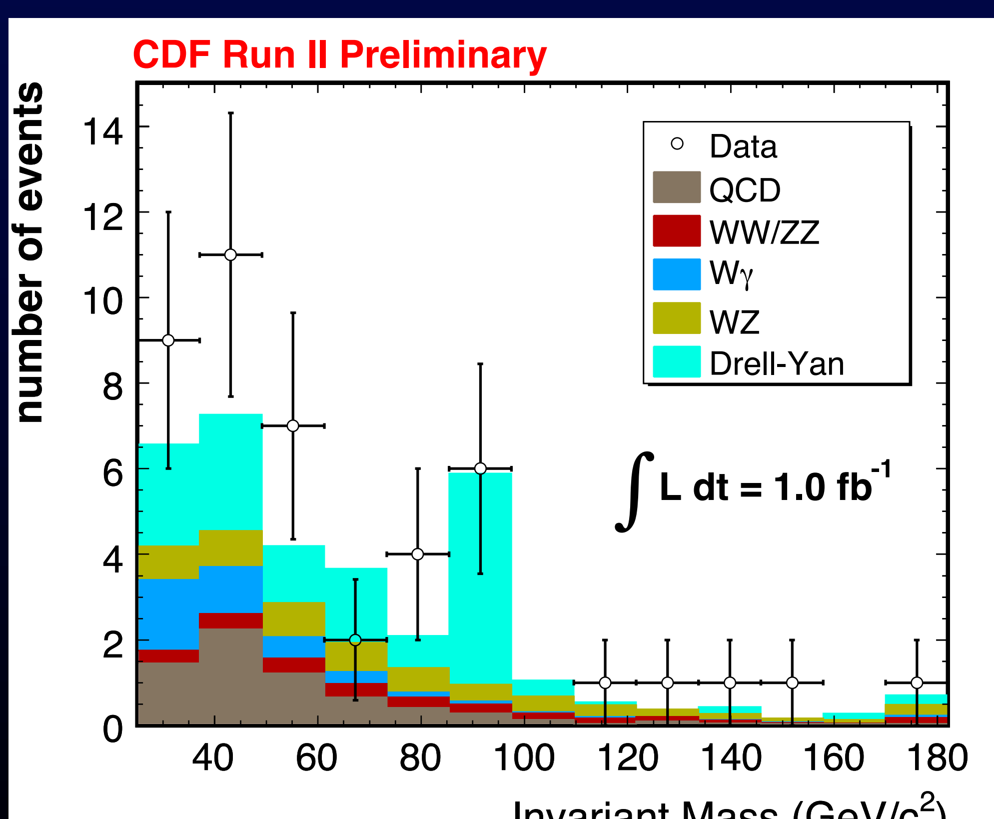


At $m_{\eta 0}$ = 200 GeV, ξ < 0.85

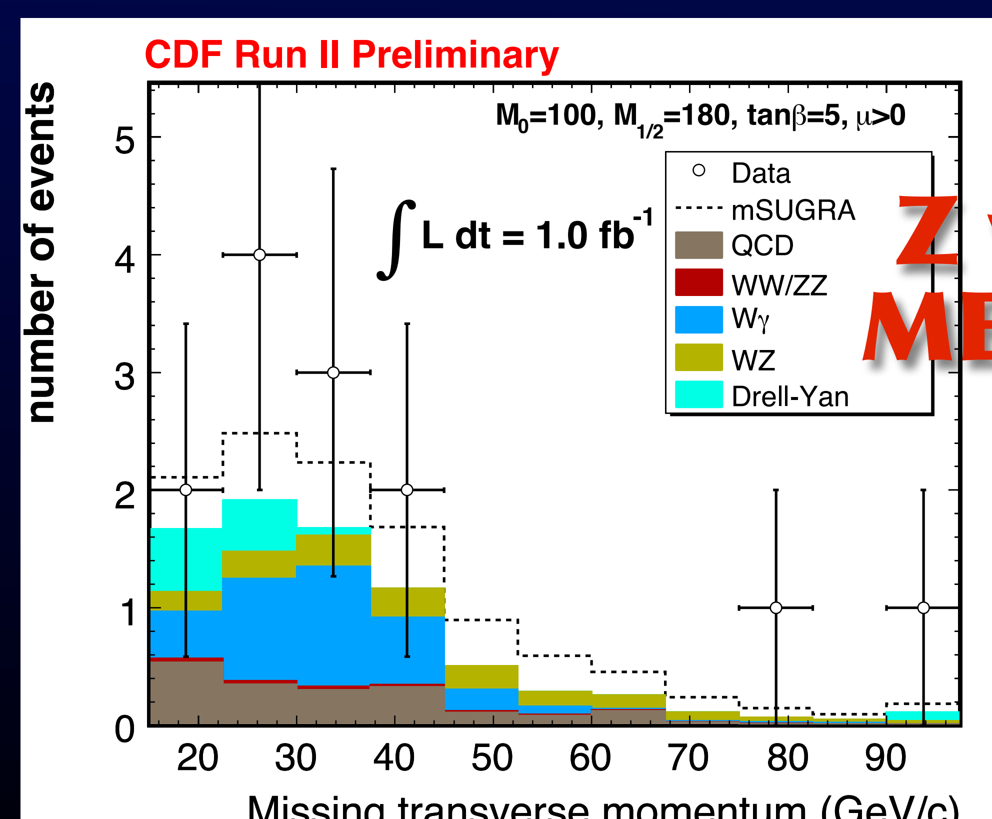
Generic LS search

PRL 98, 221803 (2007)

- Sensitive to SUSY trileptons, pair-produced Majorana particles
- LS e/μ with M_{ll} > 25 GeV
  - **BG: untagged γ conversions, VV, V+fake**



Exp: 33.7±3.5, Obs: 44



Z veto, MET>15

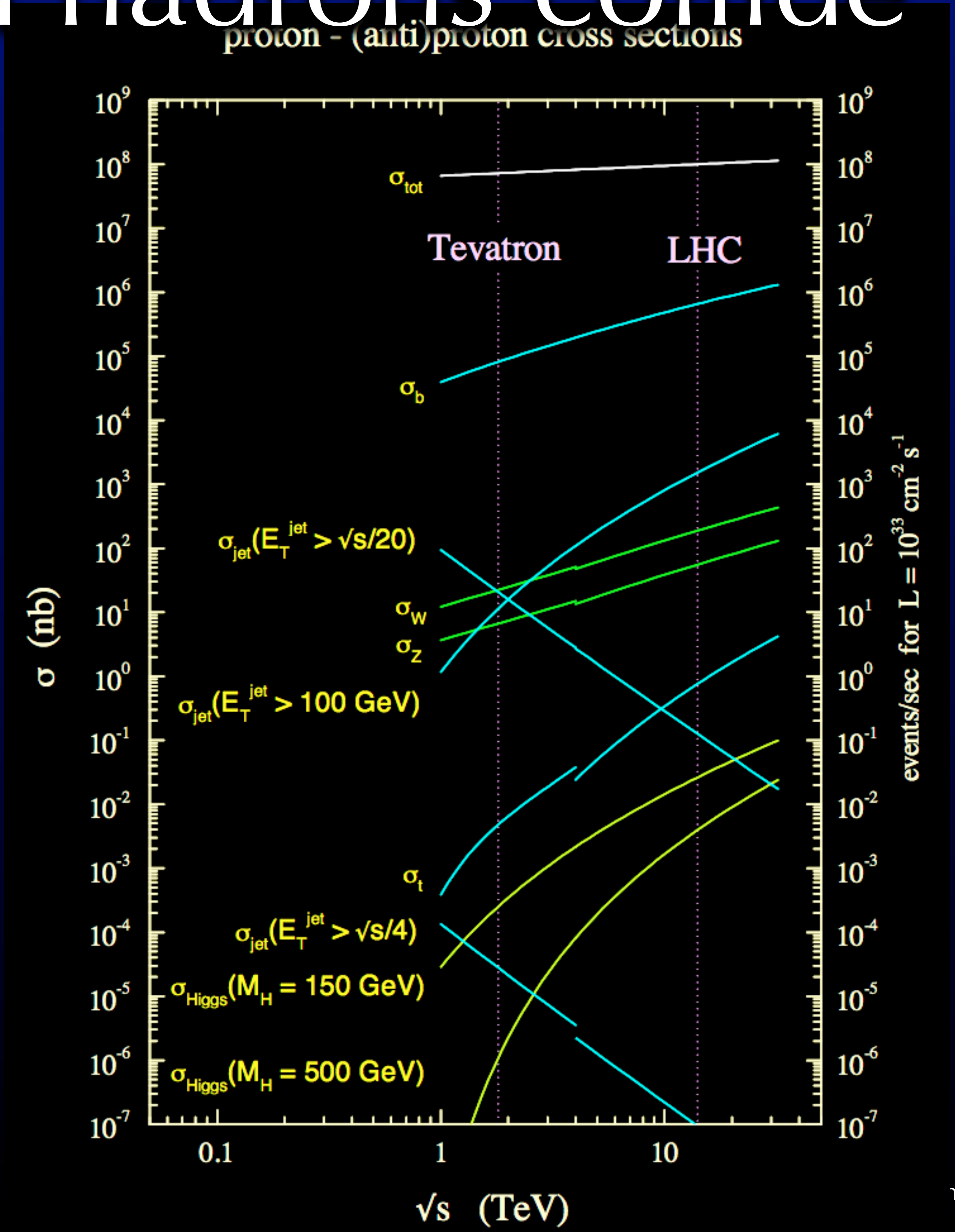
Exp: 7.9±0.3, Obs: 13

Conclusions

- Leptonic signatures key ingredient to exotics searches
- CDF preparing LS and trilepton searches with full data set ➠ new results this Fall/ Winter
  - **Extend e/μ coverage for trilepton search**
  - **LS search with e/μ: fill in gap**
  - **LS search with tau: extend to high tan β**
- LHC has started: the race is on!

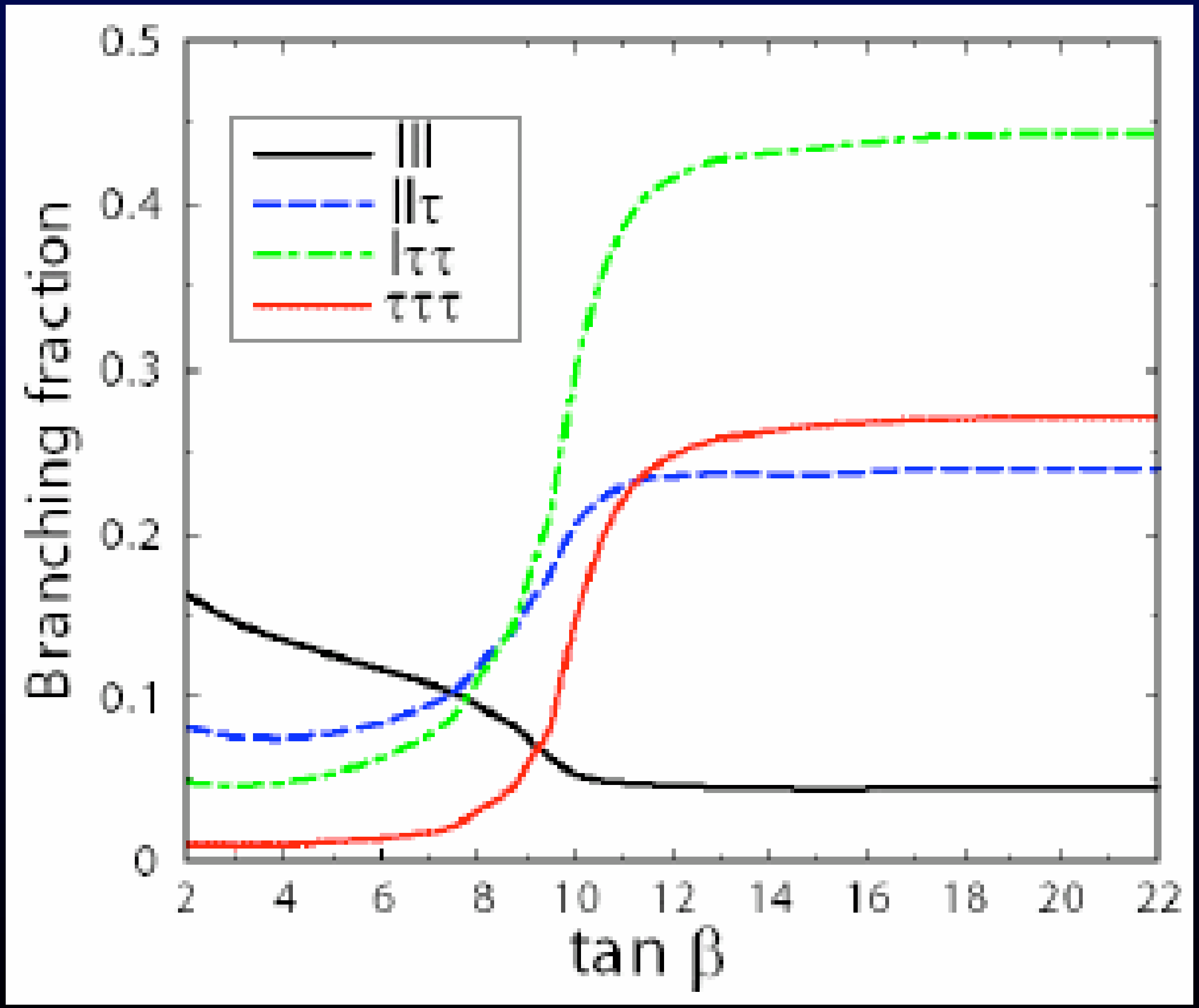
Backup Slides

When hadrons collide

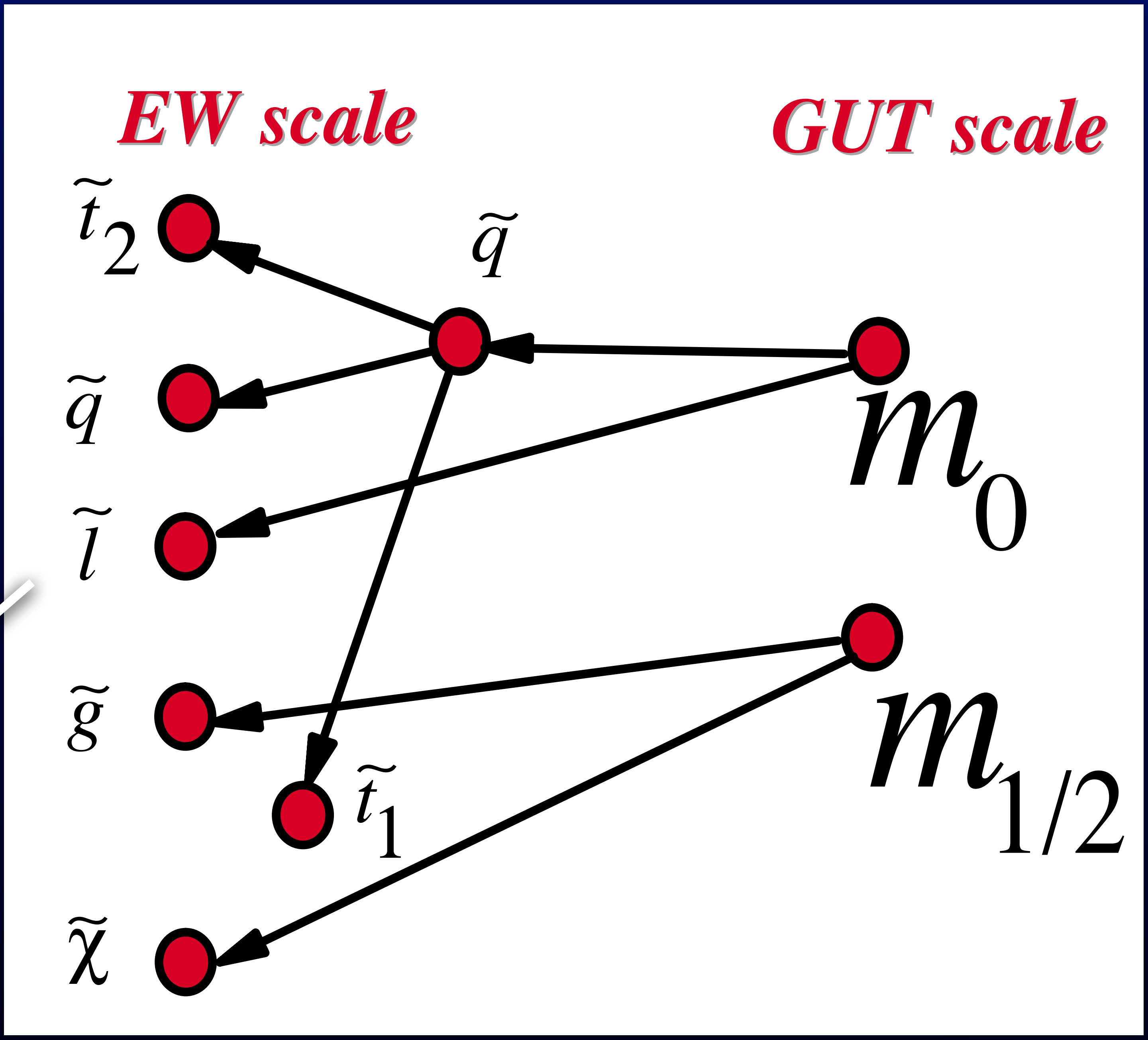


Why Study the Tau?

- Lepton universality may not hold in exotics decays (Higgs, SUSY)
  - **Must include the tau to maximize sensitivity**



Supergravity Masses



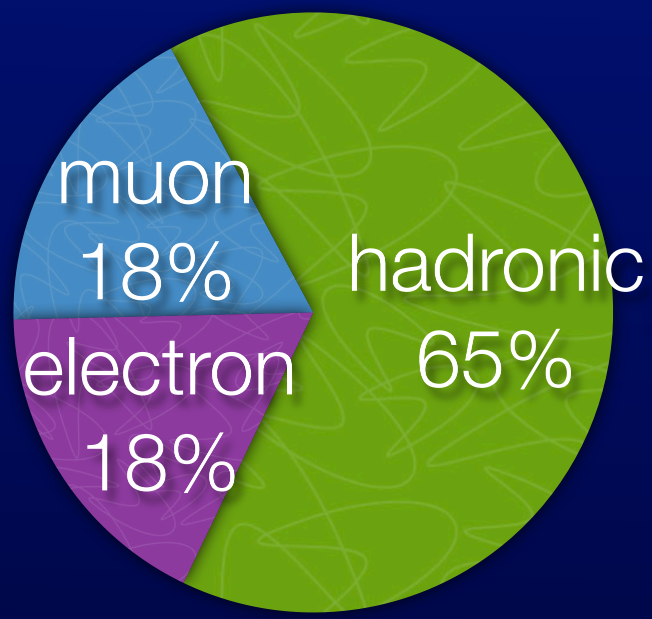
$\tilde{\tau}_1$

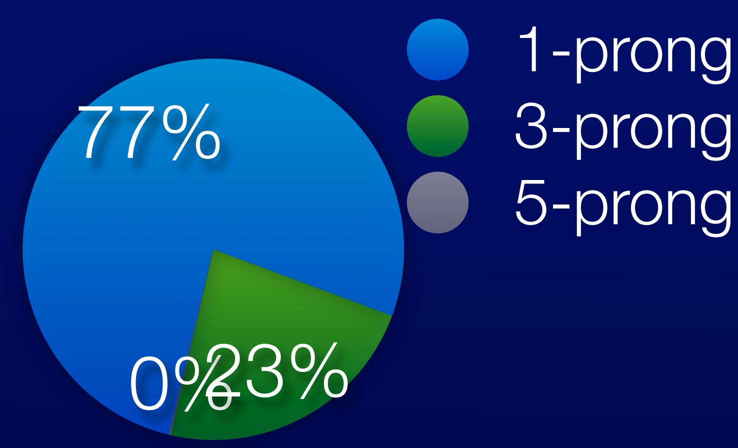
stau light if appreciable mixing

Tau Lepton Decays

τ_τ = 290.6 fs

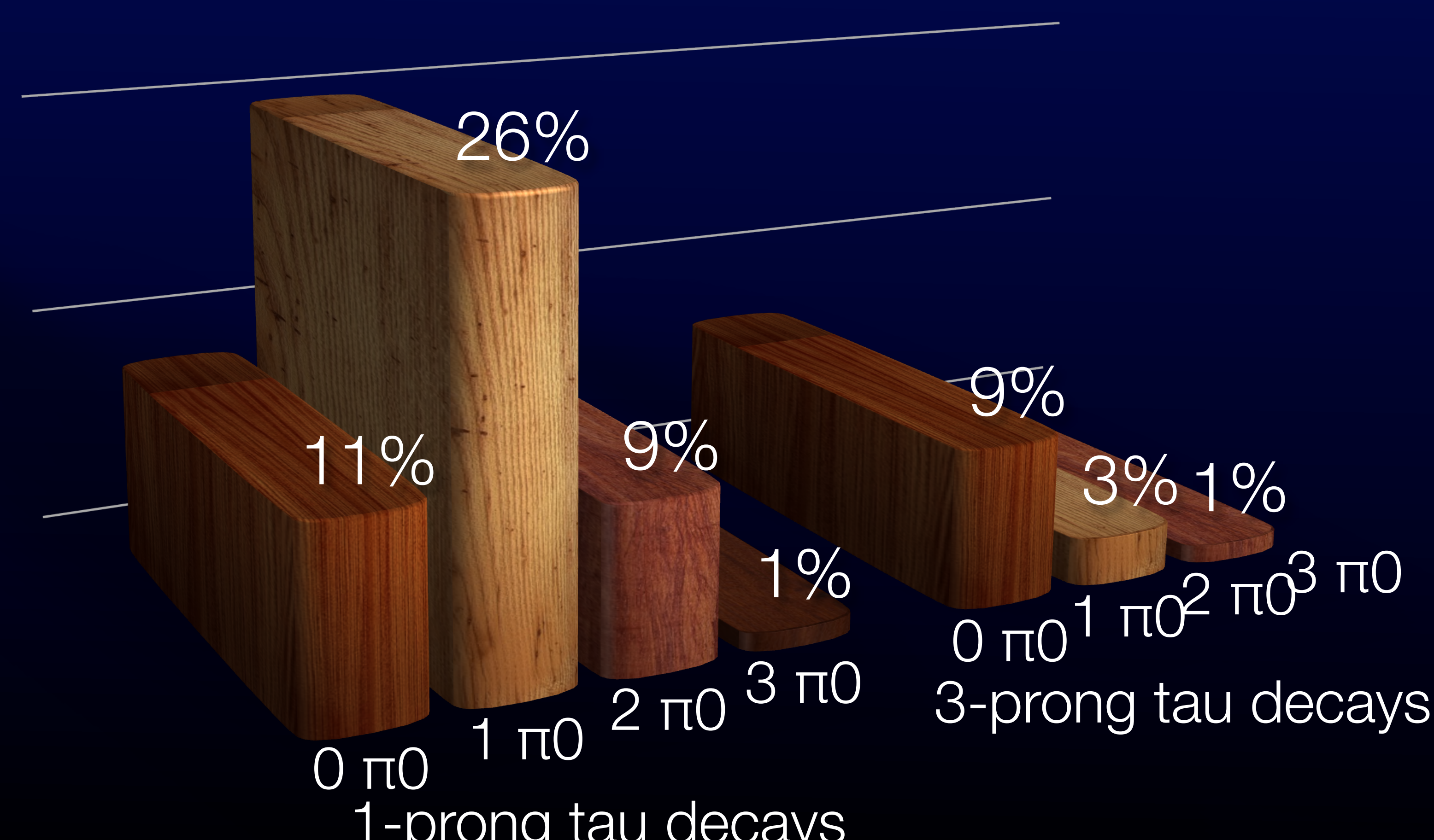
$c\tau_\tau$ = 87.11 μm





Hadronic

neutral pions:



Tau decays: hadronic modes

- For two taus produced

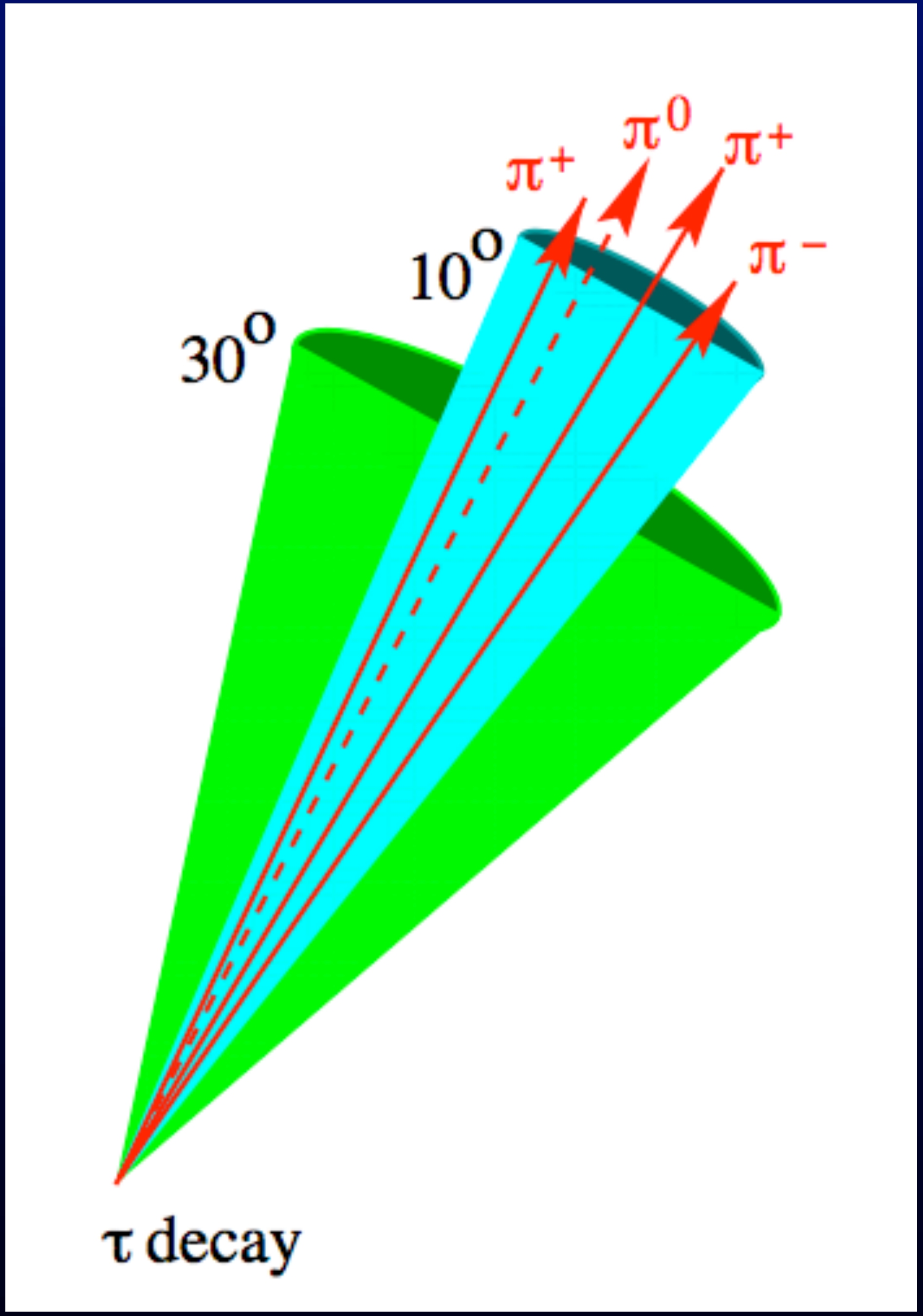
$\tau_h : \tau \rightarrow nh + \nu$
$\tau_l : \tau \rightarrow e\nu\nu, \mu\nu\nu$

mode	%
$\tau_h\tau_h$	44
$\tau_h\tau_l$	44
$\tau_l\tau_l$	12

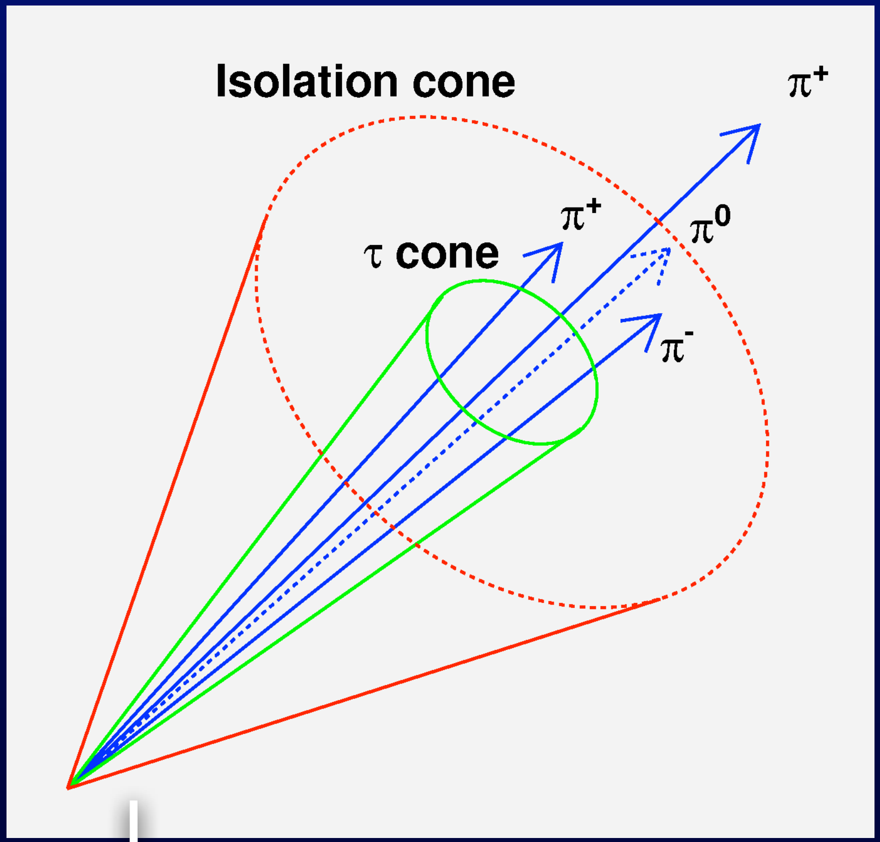
Must trade-off: BR ↔ efficiency

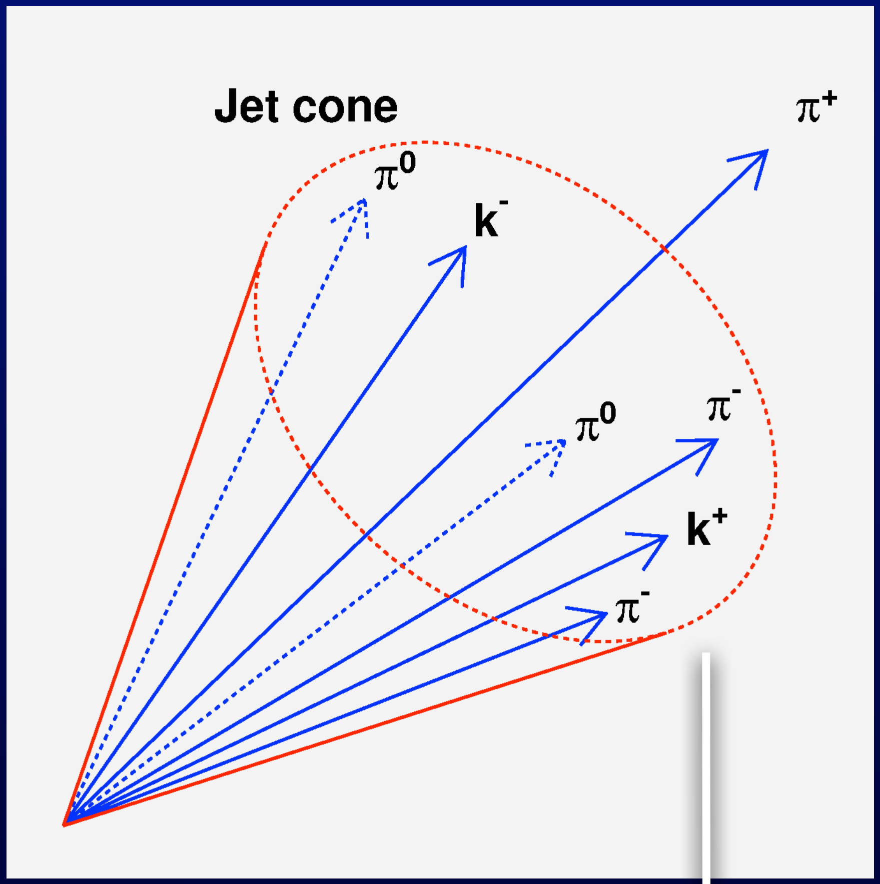
Tau decay product isolation

- Not an intrinsic quality, but result of EWK signal
- Critically important for background rejection
  - **Compare: hadronic jets**



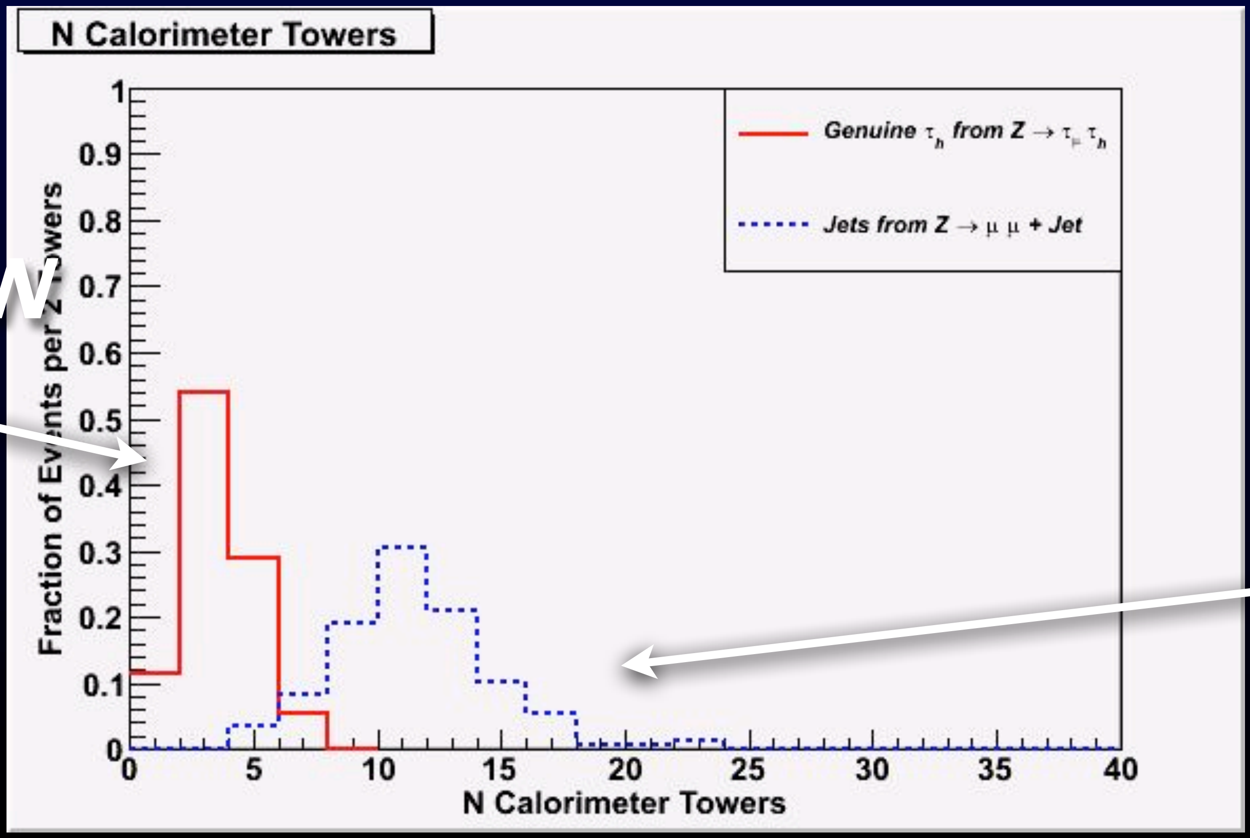
Taus versus Jets





τs are narrow

Jets are wide



Kinematic endpoints

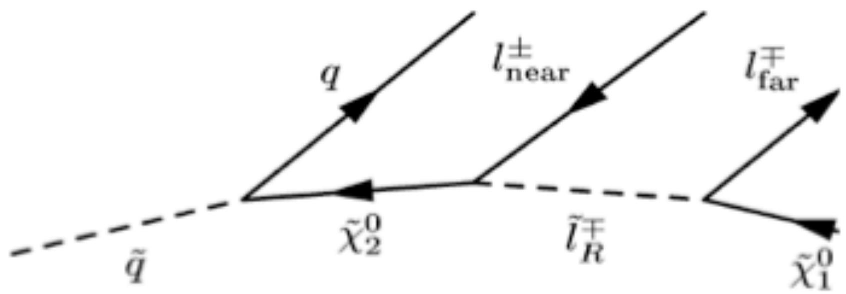
Di-lepton mass edge reconstruction

CMS PAS SUS-09-002 [13]

2-body decay

If $M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_1^0} > M_{\tilde{l}}$ (LM1) :

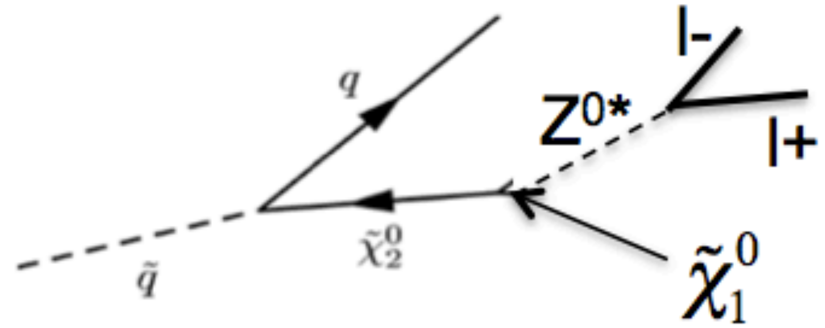
$$(m_{ll}^{max})^2 = \frac{\left(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{l}}\right)\left(m^2_{\tilde{l}} - m^2_{\tilde{\chi}_1^0}\right)}{m^2_{\tilde{l}}},$$



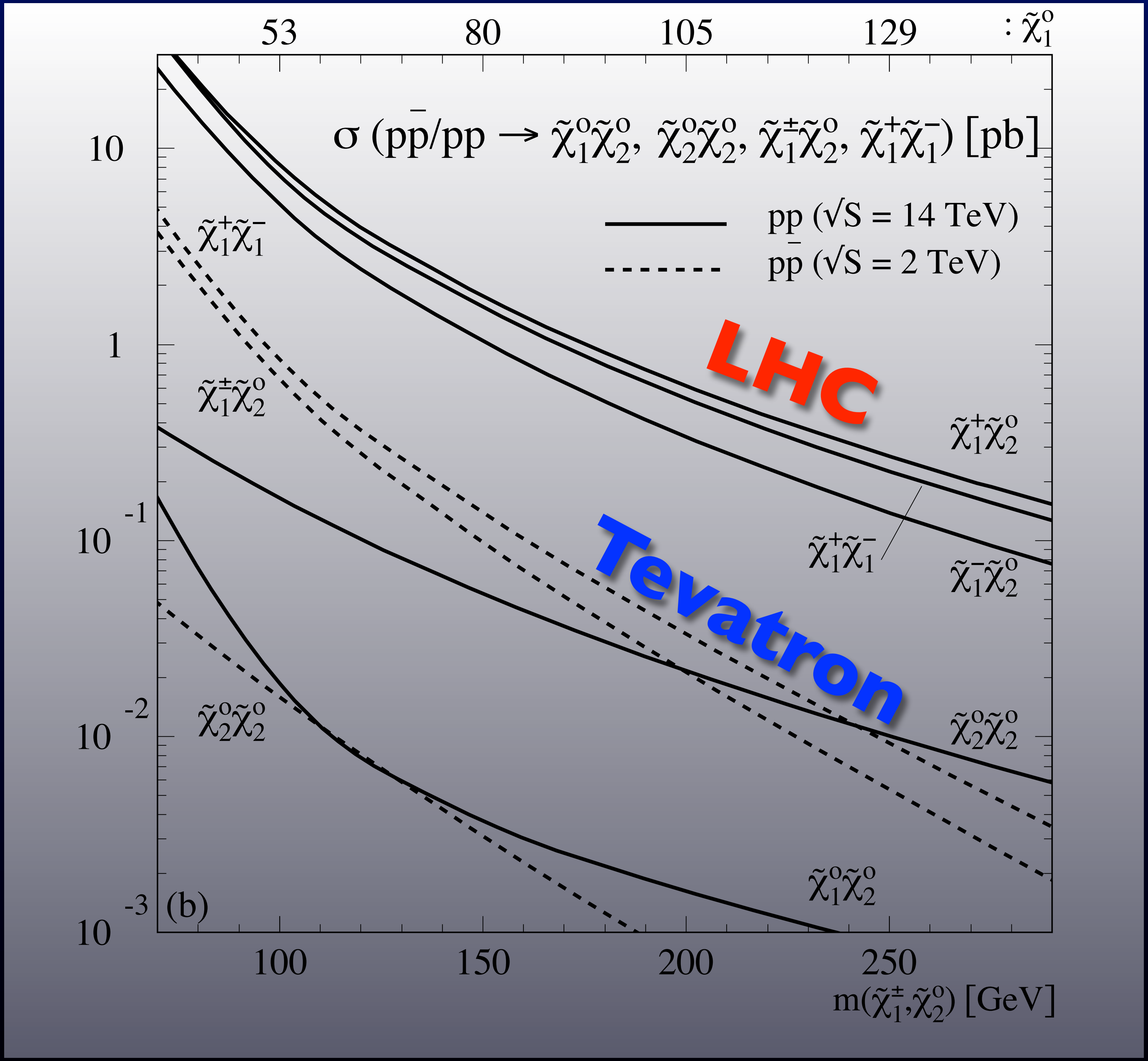
3-body decay

If $M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_1^0} < M_Z$ or $M_{\tilde{l}}$ (LM0) :

$$m_{ll,max} = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}.$$

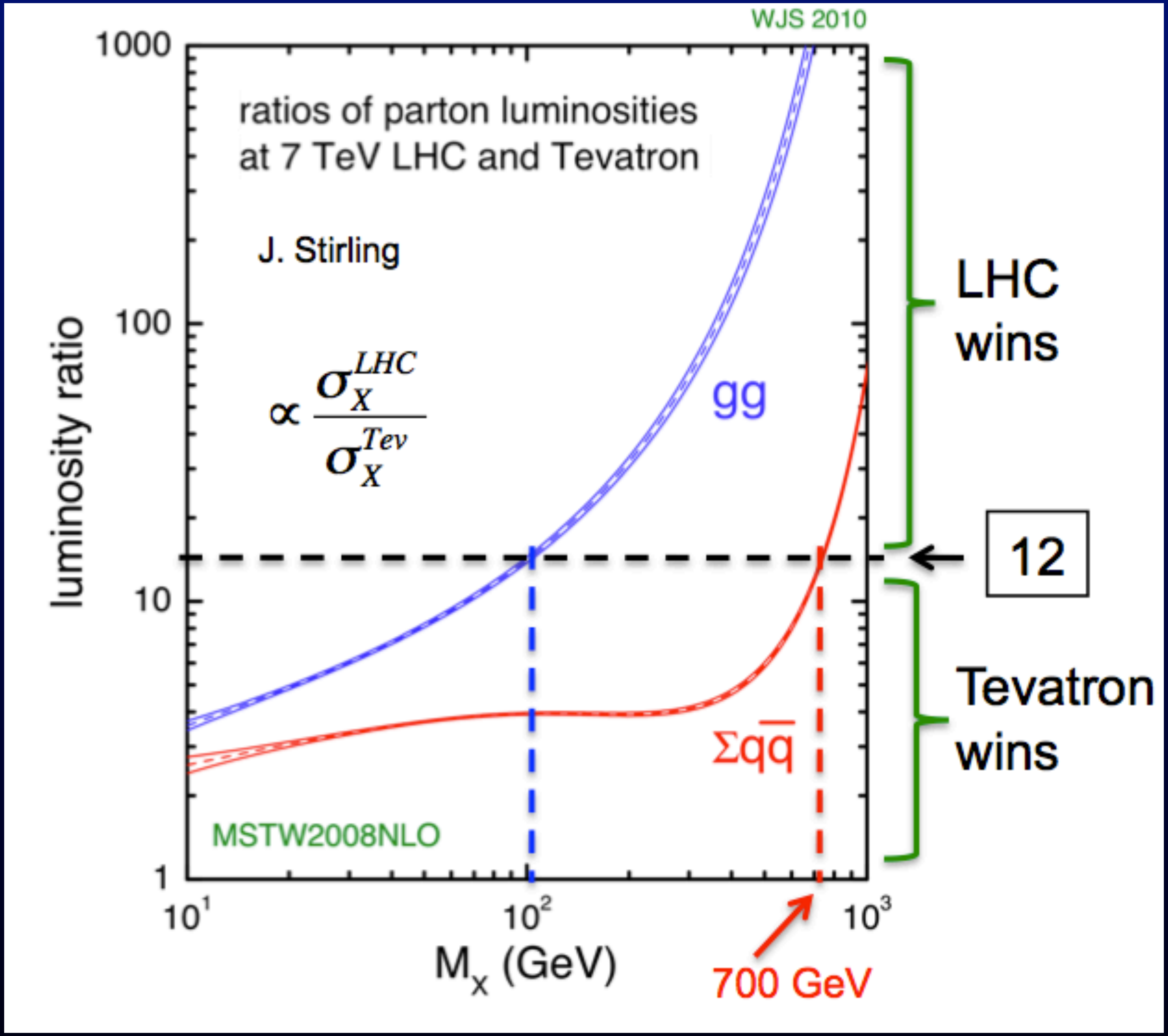


LHC versus Tevatron



Beenakker et al
PRL 83, 19 (1999)

Parton Luminosities



W.J. Stirling, 2010