Search for pair production of scalar top quarks decaying to a τ lepton and a b quark in $p\overline{p}$ collisions at $\sqrt{s} = 1.96$ TeV

Dissertation Defense Presentation

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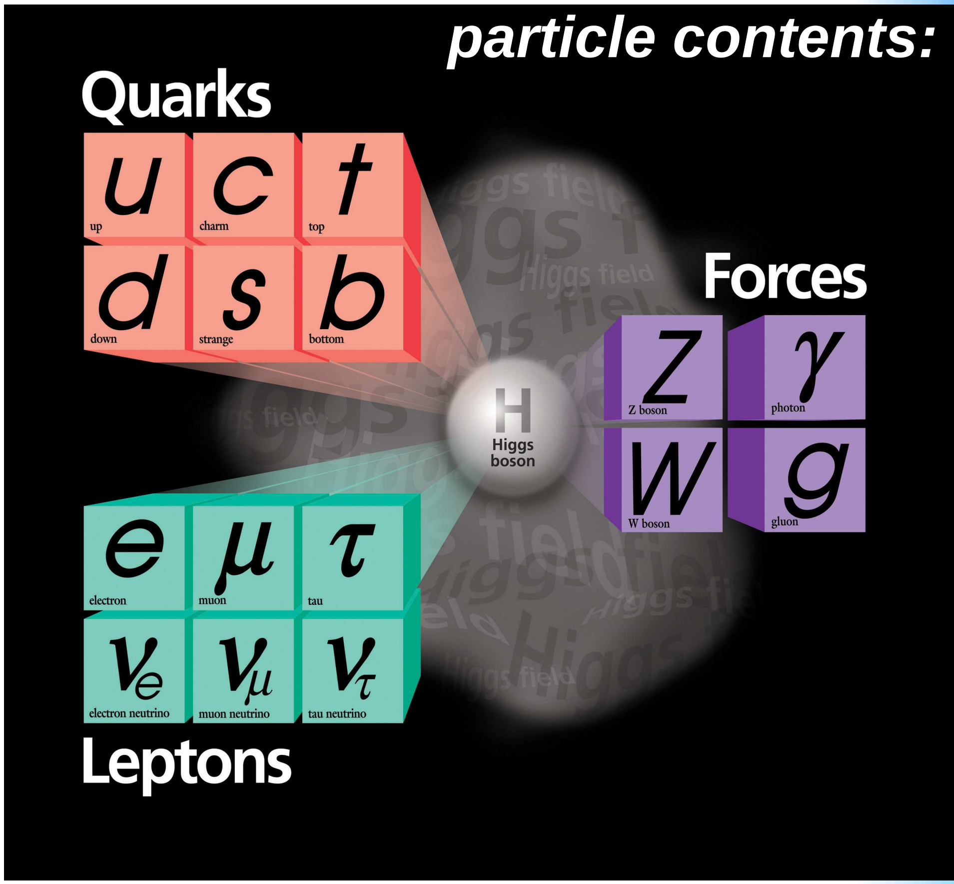
Outline

- Theoretical motivations and models
- Process and existing limits
- Tools
  - Tevatron and CDF detector
  - Lepton+Track triggers
  - Hadronic tau decay reconstruction
- Analysis
  - Event selection
  - Background estimation
  - Fitting procedure
- Cross-section and mass limits
- Summary and prospects

Standard Model (SM) and its Limitations

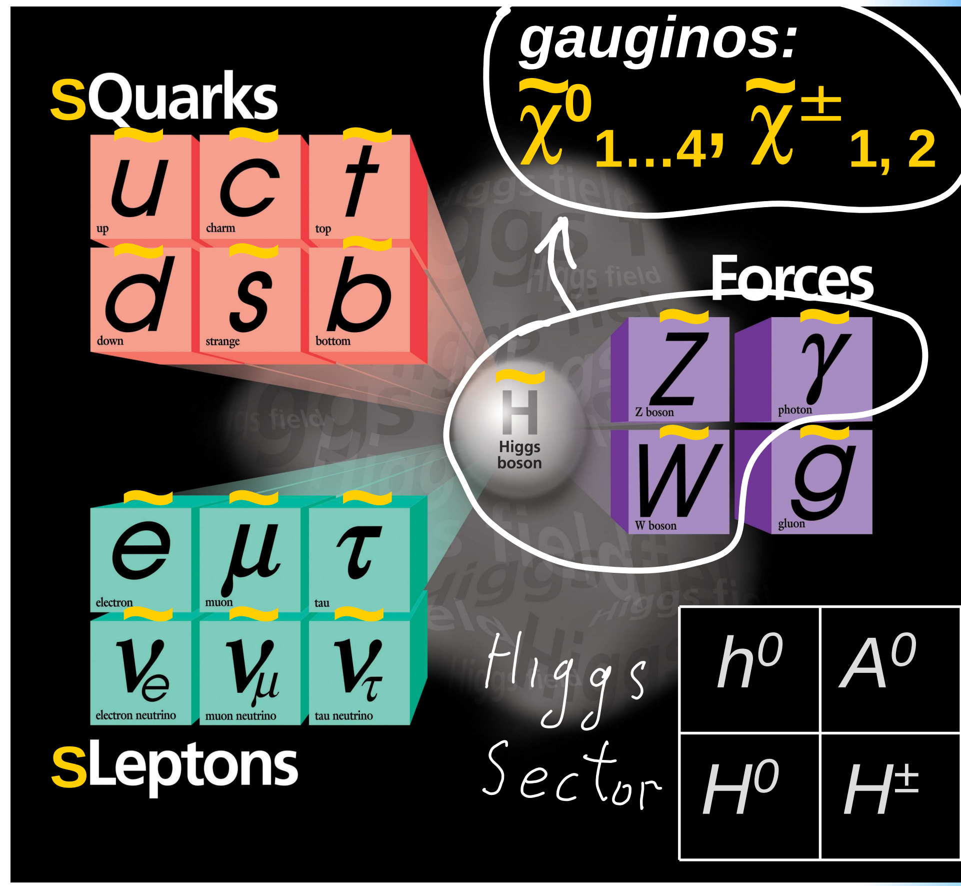
- $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauge theory
- Combines strong, weak and electromagnetic interactions
- Successfully describes vast majority of phenomena



- Limitations and problems:
  - Some theoretical limitations:
    - Higgs "naturalness" problem
    - Interactions are not unified at high energies
    - Need extensions to describe neutrino masses
  - Experimental disagreement:
    - Evidence of massive neutrinos
    - Cosmological problems: SM explains only visible matter, which is 4% of the Universe
    - $a_\mu=(g_\mu-2)/2$ measurement

Supersymmetric (SUSY) Theories

- Symmetry between bosons and fermions:
  - Fermions get spin 0 superpartners
  - Bosons get spin ½ superpartners



- Can solve all problems of the SM outlined in previous page!

- SUSY has to be broken at low energies
  - Many different theories for SUSY breaking mechanisms exist
  - This analysis doesn't explicitly depend on a specific mechanism

- R-parity quantum number:
  - $R_P=(-1)^{3B+L+2S}= \begin{cases} 1 \text{ for SM particles} \\ -1 \text{ for SUSY particles} \end{cases}$
  - If R-parity is conserved:
    - Superparticles: produced in pairs, decay products always have sparticles
    - Lightest SUSY particle (LSP) is stable: good Dark Matter candidate

R-parity Violating (RPV) SUSY Theories

- No direct evidence exists that R-parity must be conserved
- Consequences of RPV:
  - **SUSY particles can decay into SM only particles**
  - Instability of LSP makes it poor candidate for dark matter
  - RPV can provide a new mechanism for baryon asymmetry
- General RPV superpotential:

$$W_{RPV} = \underbrace{(\mu_i L_i H_u + \lambda_{ijk} L_i L_j E_k + \lambda'_{ijk} L_i Q_j D_k)}_{\text{lepton number violating terms}} + \underbrace{\lambda''_{ijk} U_i D_j D_k}_{\text{barion number violating}}$$

  - λ – trilinear, μ – bilinear RPV couplings
- Lepton and Barion number violating terms can't be non-zero at the same time (strong limits from proton lifetime)
- Typical experimental limits: $\lambda, \lambda', \lambda'' < (10^{-2}\text{-}10^{-1})\ \tilde{m} / (100\ \text{Gev}/c^2)$
- **RPV SUSY provides a natural mechanism for neutrino mass**

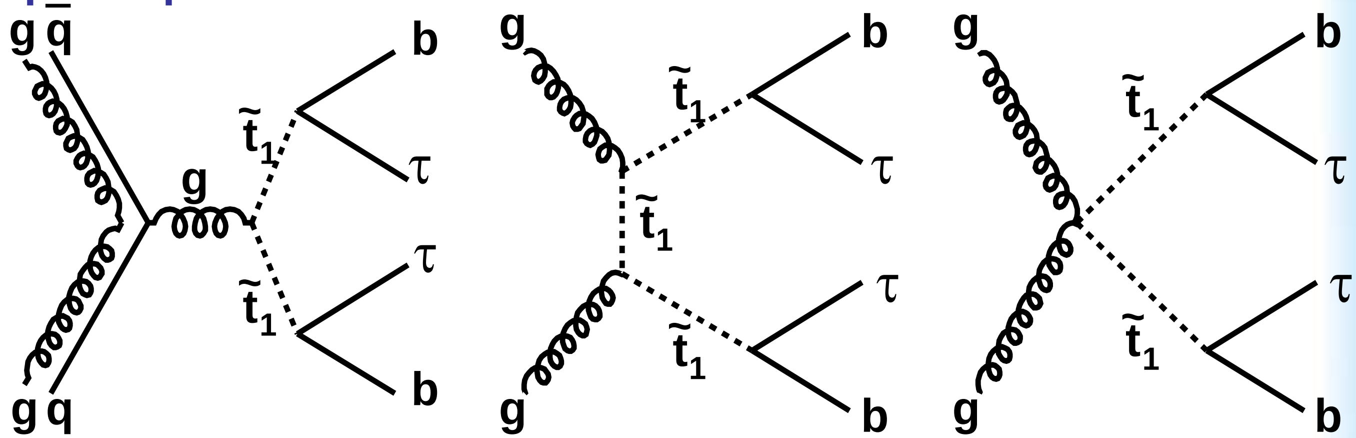
RPV Stop Decay

- Supersymmetric top quark $\tilde{t}_1$ might be even **lighter than top quark**
  - While experimental data suggest that superpartners of 1st and 2nd generation have masses higher than any SM particle
- We are interested in $\tilde{t}_1 \rightarrow \tau b$ decay
  - λ'_{333} is RPV coupling which is responsible in LO for this decay
  - Neutrino oscillation experiments suggest limits

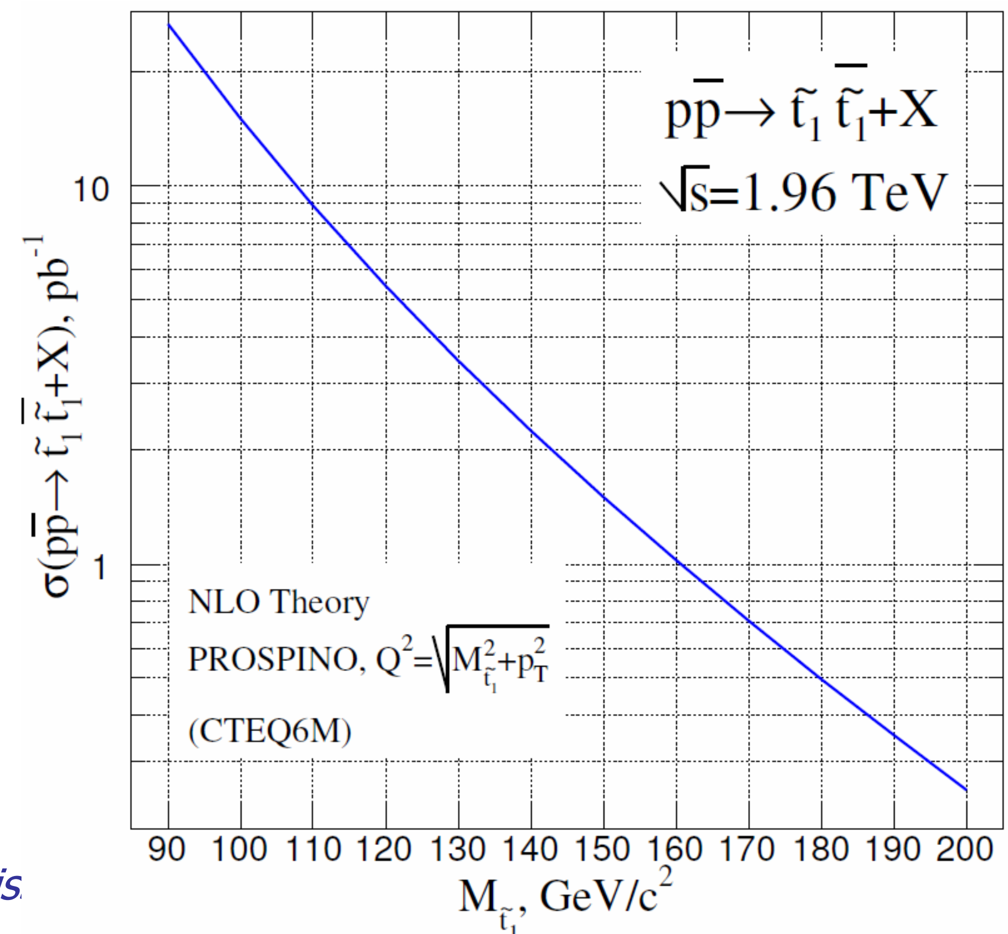
    $\lambda'_{i33} < 10^{-5} - 10^{-3}$
  - Stop RPC decays are naturally suppressed and may compete with RPV ones even for small values of λ'_{333}
  - It was shown that $Br(\tilde{t}_1 \rightarrow \tau b)$ may be dominant for wide range of parameters

Stop Pair Production

- Stop quark can be pair-produced at the Tevatron
- Set of leading order Feynman diagrams:



- Stop pair production cross section as function of $m(\tilde{t}_1)$:
  - NLO calculation with PROSPINO v2 (CTEQ6M PDF)
  - **~35% higher than for Run I**



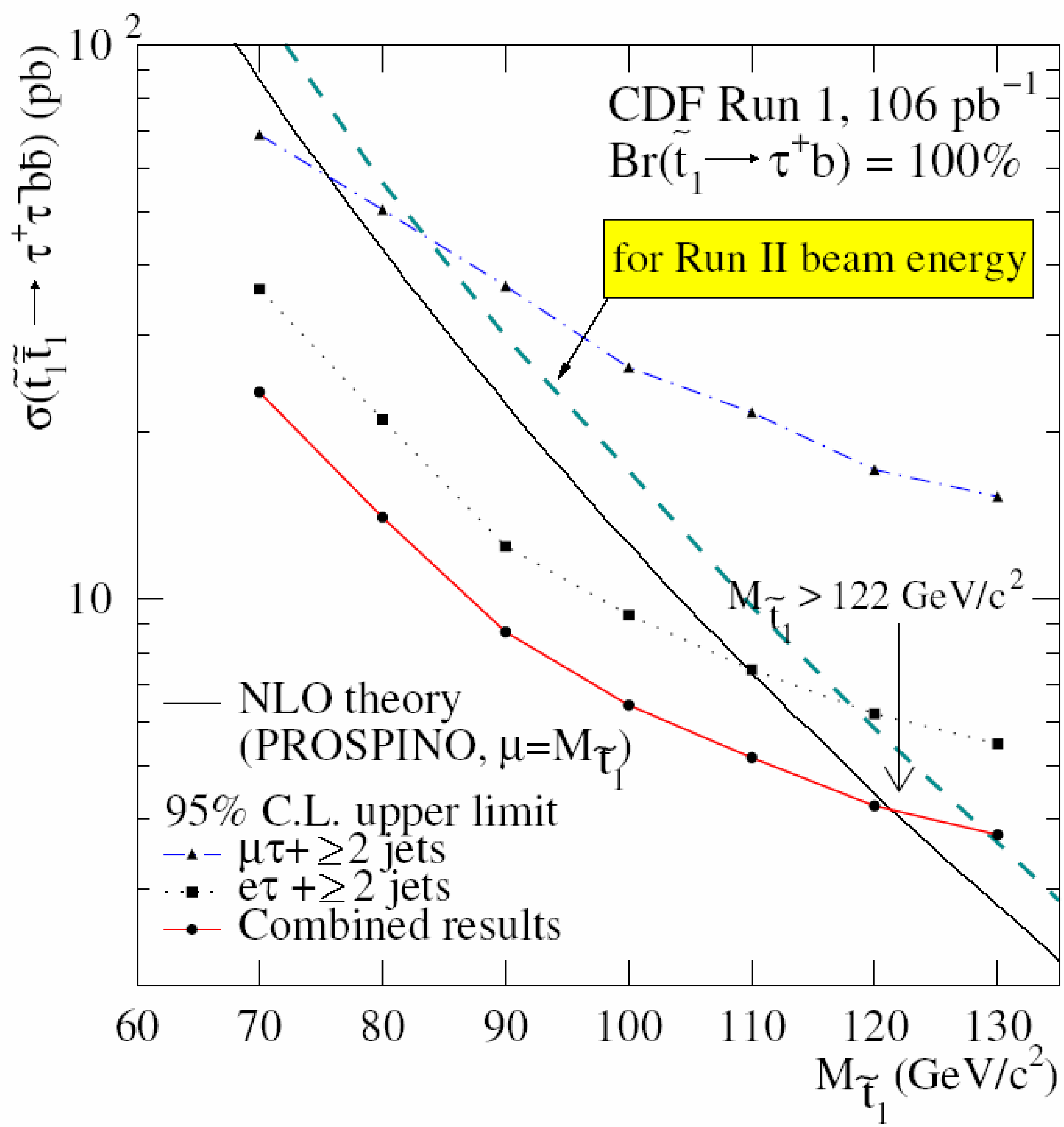
3^{rd} Generation Scalar Leptoquark Interpretation

- SM: remarkable symmetry between quarks and leptons
  - Could there be interaction between them?
- Interaction mediated by **Leptoquark** particle
  - Color-triplet boson, spin 0 or 1, has lepton and barion numbers
  - Appears in SU(5) GUT, Superstrings, SU(4) Pati-Salam, Composite, Technicolor models
  - Third generation scalar leptoquark decay: **Br($LQ_3 \rightarrow \tau b$)=1** if $m(LQ_3)<m(t)$
- Scalar LQ_3 pair production is identical to the case of stop pair production in the limit of high gluino mass
- RPV stop models can be interpreted as LQ models if **Br($\tilde{t}_1 \rightarrow \tau b$)=1**
- **The results which we'll get for RPV stop will apply for LQ_3 too**

Existing Limits on RPV Stop

- LQ3: m > 99 GeV/c2 (LEP / CDF Run I)
- RPV stop: m >122 GeV/c2 (CDF Run I)

CDF Run I:



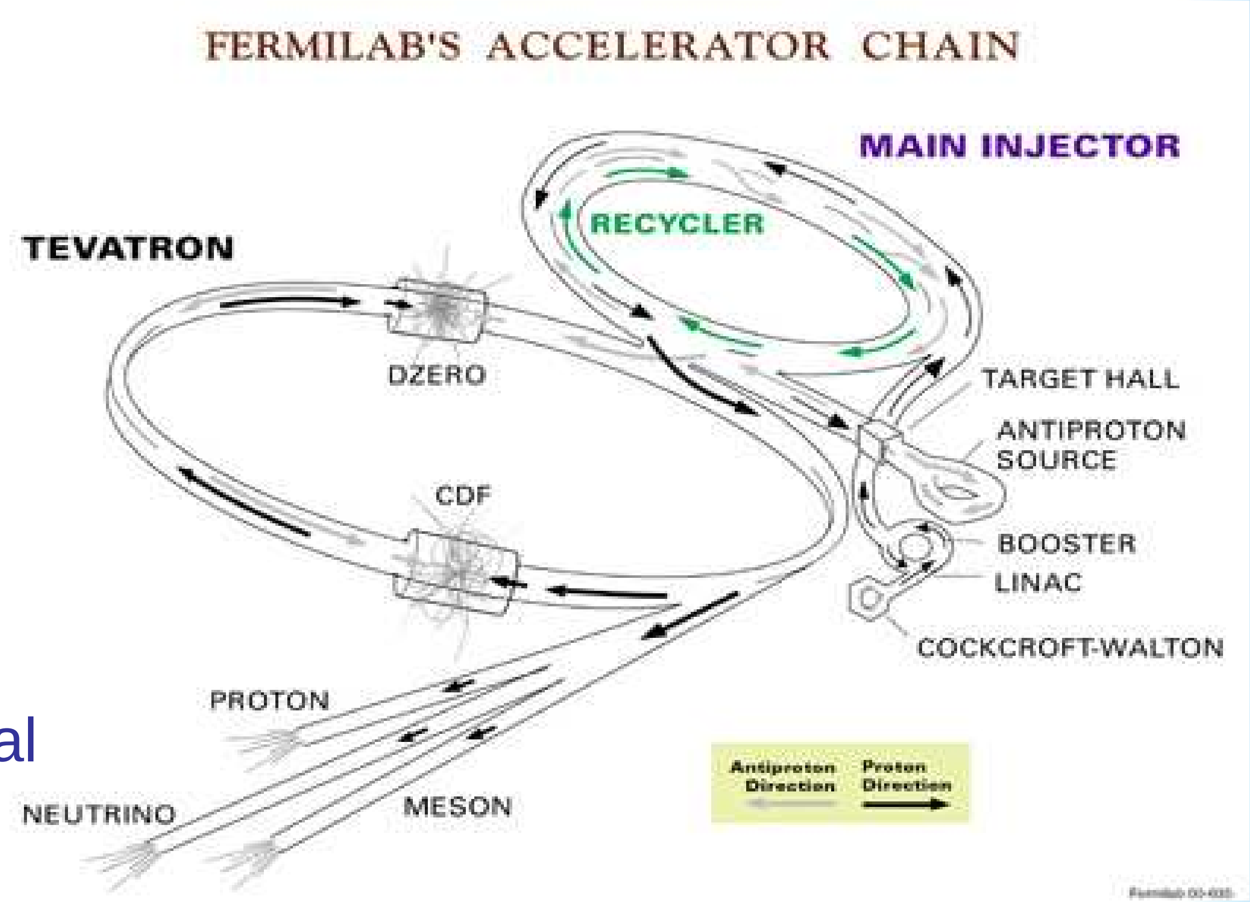
Experimental Tools

- Tevatron and CDF II
- Lepton + Track triggers at CDF
- Hadronic tau identification

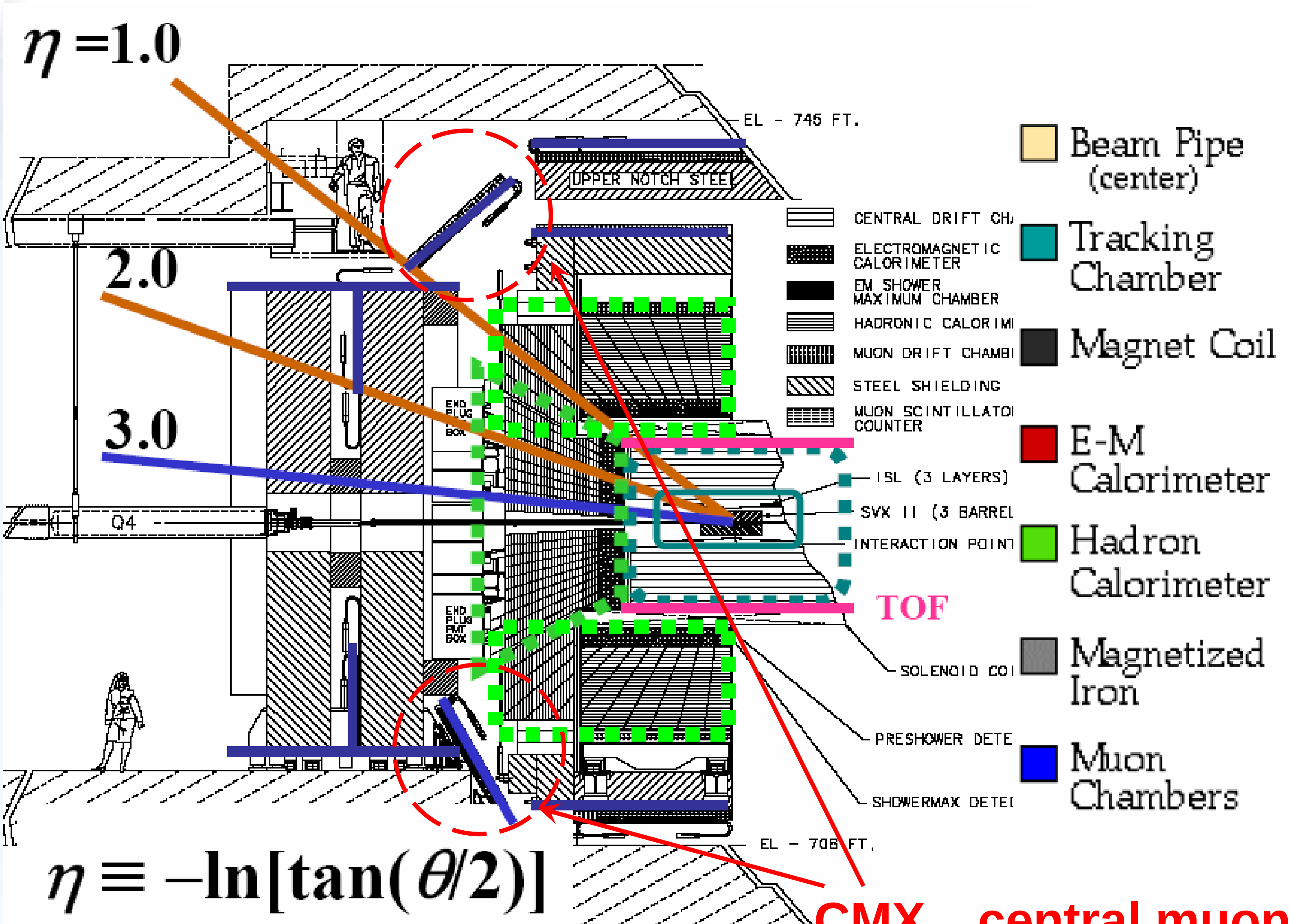
Tevatron Accelerator

- 1.96 GeV comparing to 1.8 GeV in Run I
  - **Increases stop cross-section by ~30% !**
- 36*p* x 36*pbar* 396ns separated bunches.
- ~60mb inelastic cross-section: 6 trillion collisions per 100/pb.

- Total Integrated Luminosity ~3 /fb delivered up to date
- This analysis uses 322 /pb
  - **Almost 3 times more than in Run I**
- Plan: ~6/fb in Run II total



Collider Detector at Fermilab in Run II

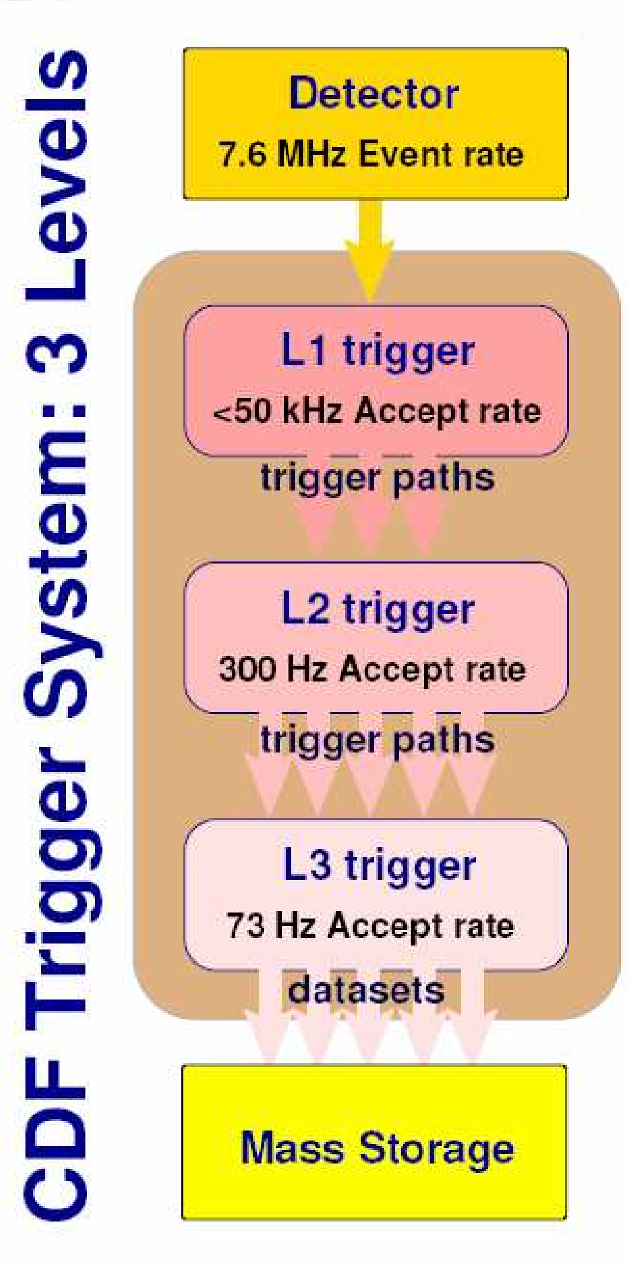


$$\eta \equiv -\ln[\tan(\theta/2)]$$

CMX – central muon extension

Increased muon coverage!

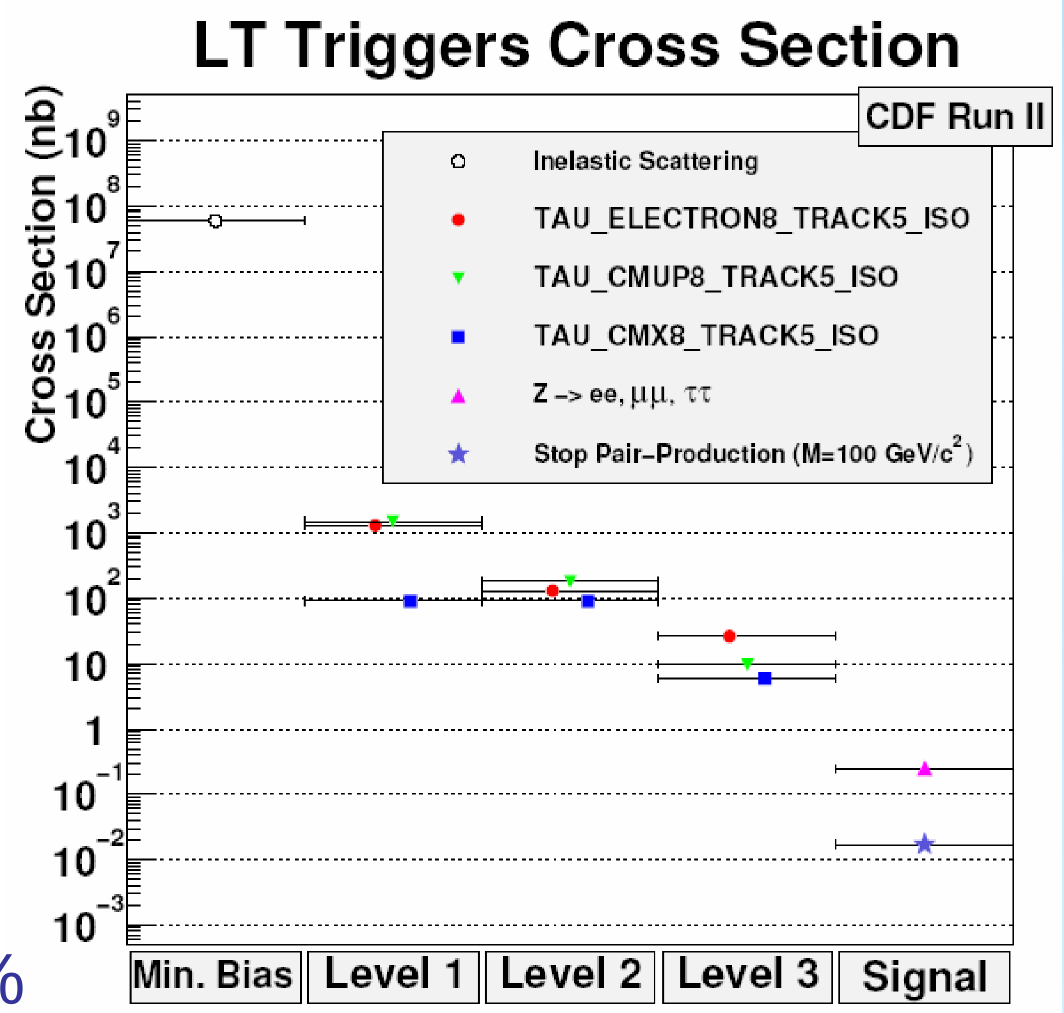
CDF Triggering System and Lepton+Track Triggers



- Lepton+Track Triggers
  - 3 pathes:
    - TAU_ELECTRON8_TRACK5_ISO
    - TAU_CMUP8_TRACK5_ISO
    - TAU_CMX8_TRACK5_ISO
  - Require:
    - L1&L2 (hardware levels):
      - Central trigger electron or muon with P_T>8 GeV/c
      - XFT track with P_T>5 GeV/c
    - L3 (software level):
      - More refined reconstruction
      - Additional req. of isolation of 2nd track in 10º -30º annulus

LT Triggers Cross Section

- LT triggers help a lot to filter signal events with taus!
- Comparing to Run I: considerably increased tau preselection efficiency
- Trigger Efficiency: ~92%

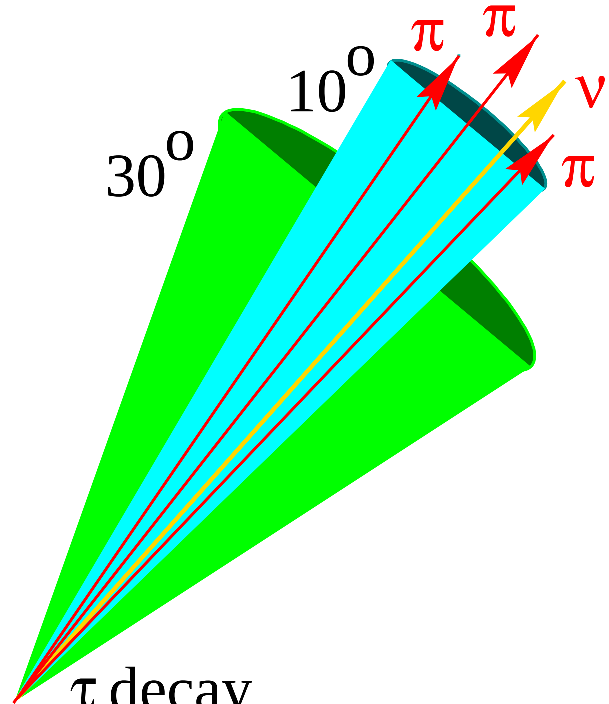


Tau Decay and Identification

- τ_h pattern:
  - Tracks, π^0s & narrow calorimeter jet in 10º cone,
  - isolation in 10º -30º annulus
- Taus are hard to detect at Tevatron
  - Jets and Leptons can be misidentified as tau
  - ID efiiciency:

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

- Tau signal sone for tracks is dependent on tau energy
- Tau visible momentum:
  - $p^{vis}(\tau)=\Sigma p(\mathrm{tracks}) + \Sigma\ p(\pi^0)$
  - Correction Procedure exists to compensate for effects of poor π^0 reconstruction



decay type	decay prod.	Br
electronic	e+nu+nu	17.4%
muonic	mu+nu+nu	17.8%
hadronic	mesons+nu	64.8%

Analysis

- We use unbiased analysis strategy:
  - Define a signal region
    - Contains most of signal and not much of backgrounds
    - Do not look at data in it until all selection criteria are finalized
  - Define control and sideband regions
    - Used for validation and background estimation

- Flow:
  - Define and optimize event selection cuts, determine acceptances for signal and backgrounds
  - Validate looking at data in control regions
  - Determine systematic uncertainties
  - Look at data in signal region
  - If no excess → set 95% CL limits on stop cross-section & mass

Signal Signature and MC

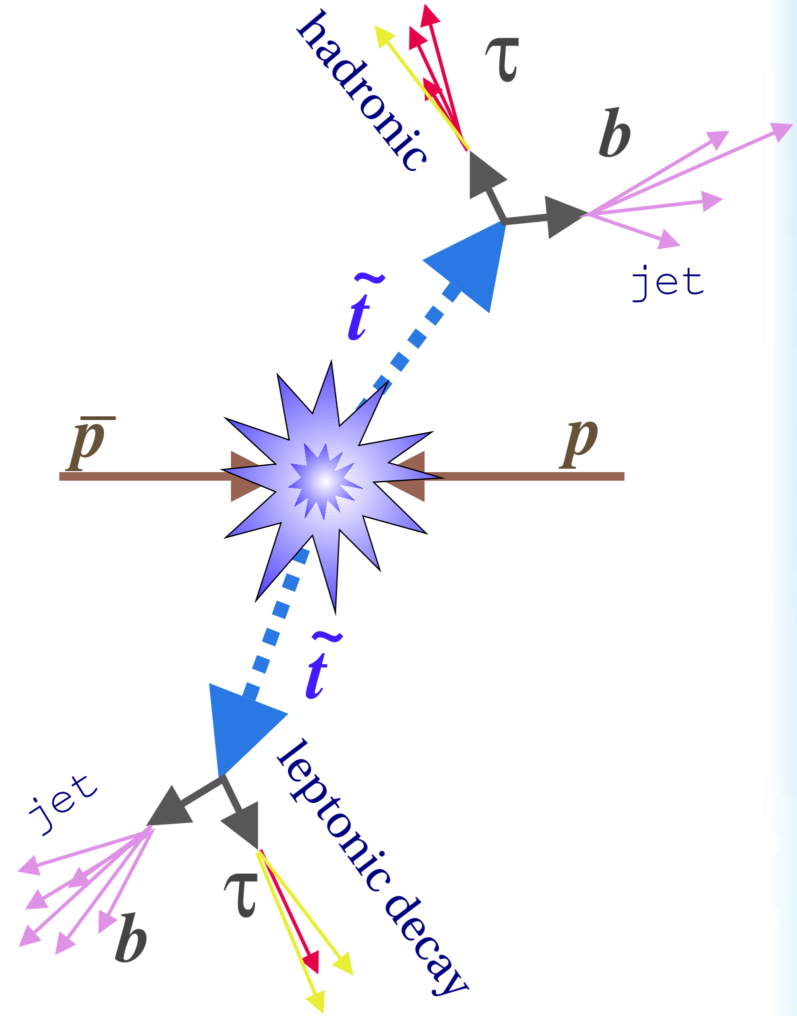
Detector signature to look for:

- **e or μ**: from leptonically decaying tau
- τ_h : hadronic tau
- **2 jets**: from b-quarks

To model:

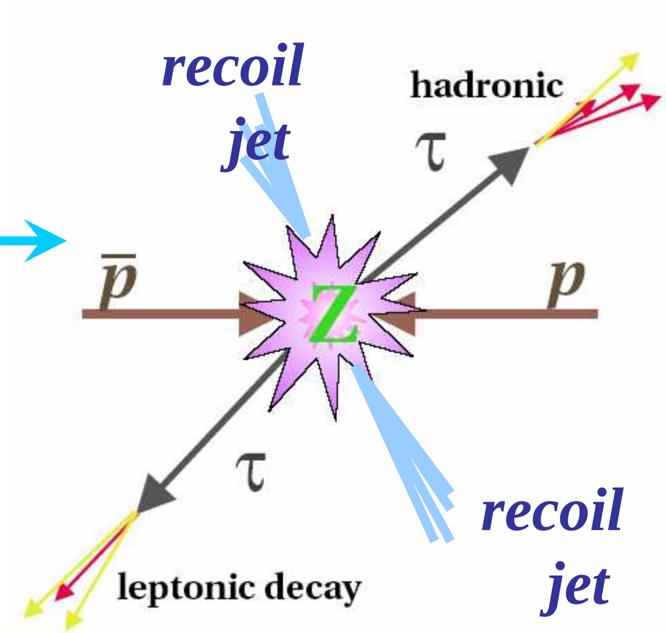
- PYTHIA using CTEQ5L PDF
- GEANT-based CDF full detector simulation
- samples for different stop masses:

  m(stop) = 100 - 170 GeV/c^2



Backgrounds

- **Physics BG:**
  - *Z* (→ $\tau_l \tau_h$) + ≥ 2jets *(**dominant**; use MC corrected with Data)*
  - *$t\bar{t}$, WW/WZ/ZZ (small; use MC)*

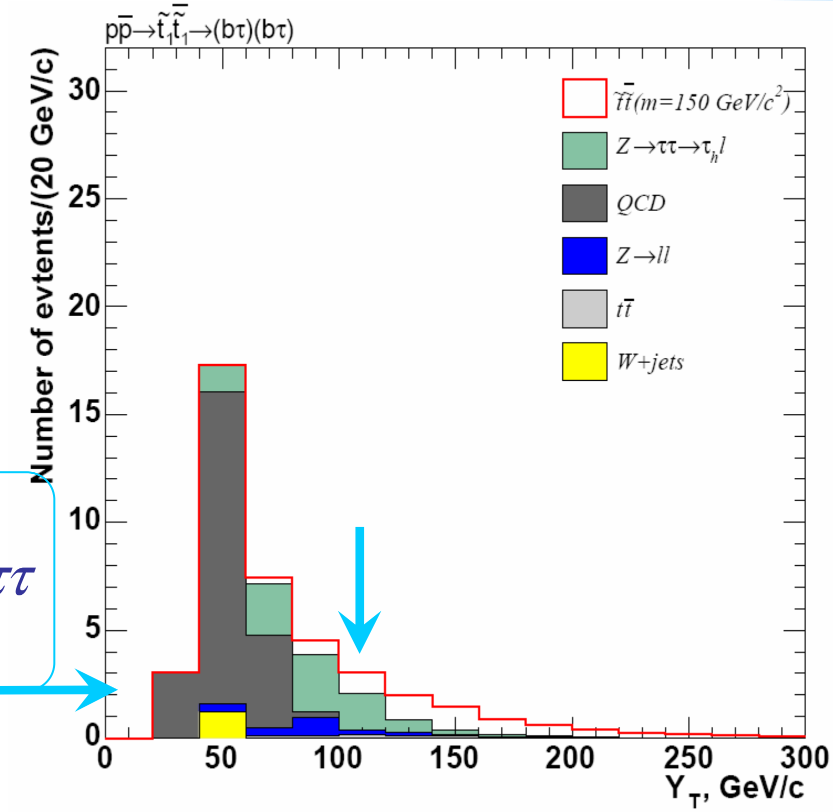


- **BG from misidentification** (usually jet or *l* fakes tau)**:**
  - *Z* (→*ee*/$\mu\mu$) + ≥ 2jets *(**Z→ee is rather sizeable**; use MC corrected with Data)*
  - QCD (≥ 4jets) *(use Data)*
  - W (→***l*** / → τ → ***l***) + ≥ 3jets *(small, but hard to estimate; use Data)*

- ***MC estimated BG:***
  - *Use Pythia or Alpgen+Herwig for acceptance*
  - *Normalize with NLO cross-sections*

Event Selection

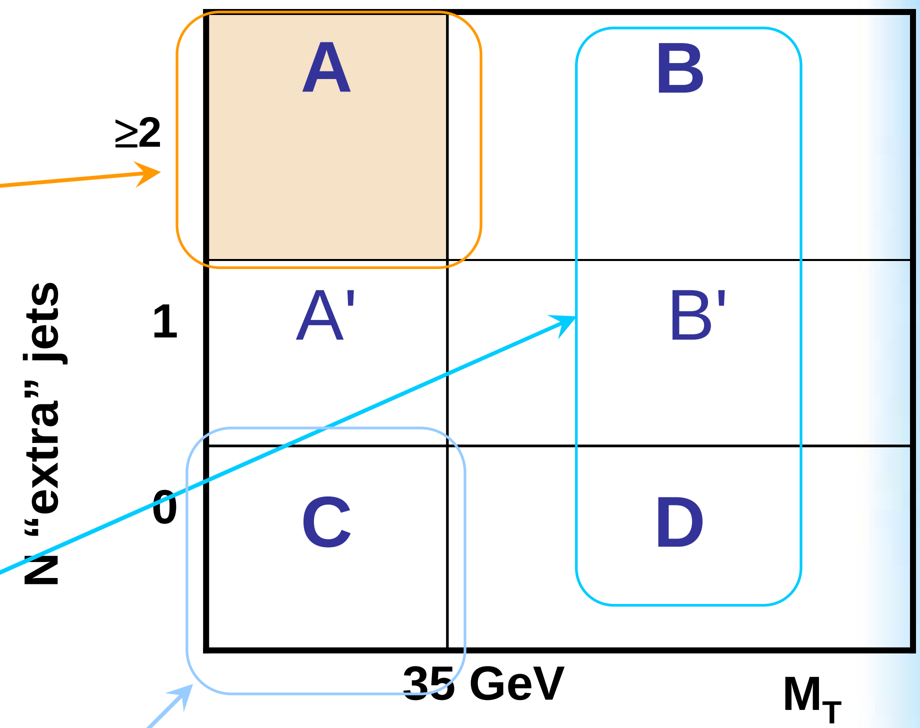
- **Central e or μ :** $p_T(l)$>10 GeV/c
- **Hadronic tau :** $p_T(\tau)$>15 GeV/c
- **Series of standard ID cuts**
- **Background removal:**
  - DY, cosmics rays, conversions
  - **$S_T = p_T(l) + p_T(\tau)$ + MET > 110 GeV**
    - strong suppression of QCD and $Z\rightarrow\tau\tau$
    - cut value is optimized



- **Two more discriminating variables:**
  - **m_T(l, MET)**
    - Transverse mass of lepton and MET
  - **N_{jet}**
    - Number of extra jets:
      - other than lepton or tau and with E_T >20 GeV
      - Threshold value is optimized

Definition of Control ans Sideband regions

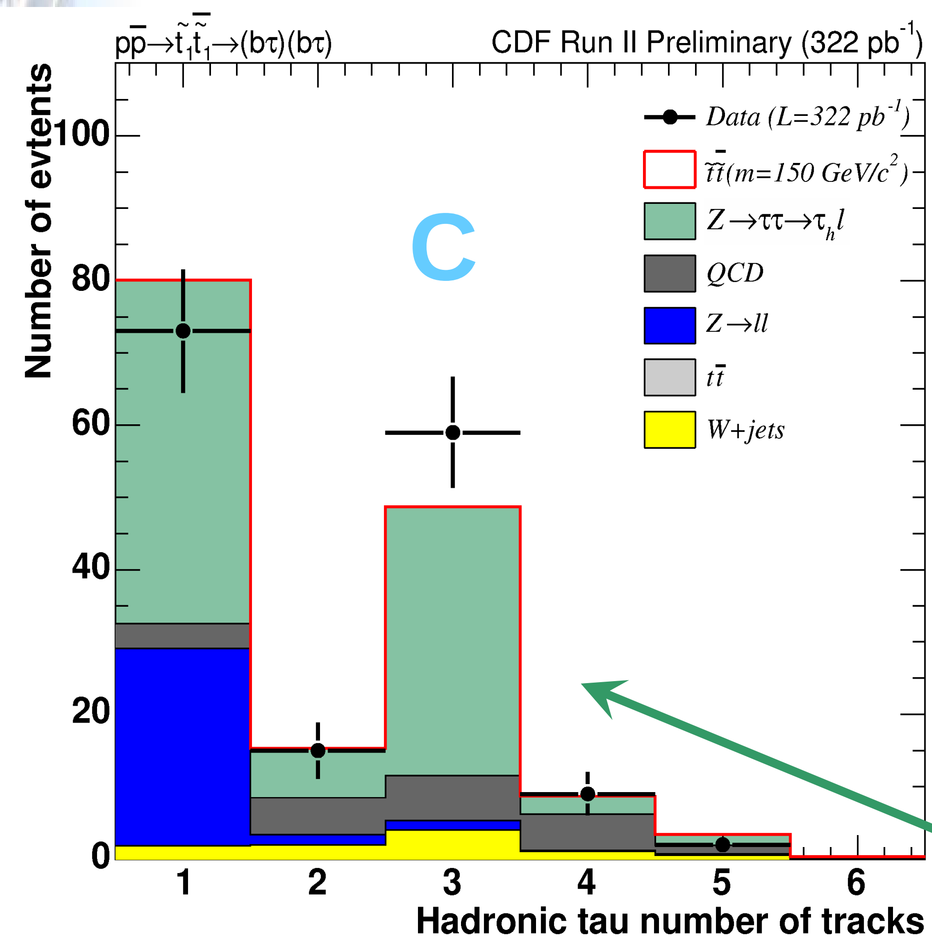
- After $S_T > 110$ GeV requirement:
  - Sort remaining events by N_{jet} & $m_T(l,\text{MET})$
- Signal dominates in *Region A* (“the blind box”)
  - $\boldsymbol{m_T(l, MET) < 35}$ **GeV/c^2** separates signal and W, top and di-boson backgrounds
  - $\boldsymbol{N_{jet} \geq 2}$ **($\boldsymbol{E_T > 20}$ GeV)** separates signal and most of BG (including $Z \rightarrow \tau\tau$)

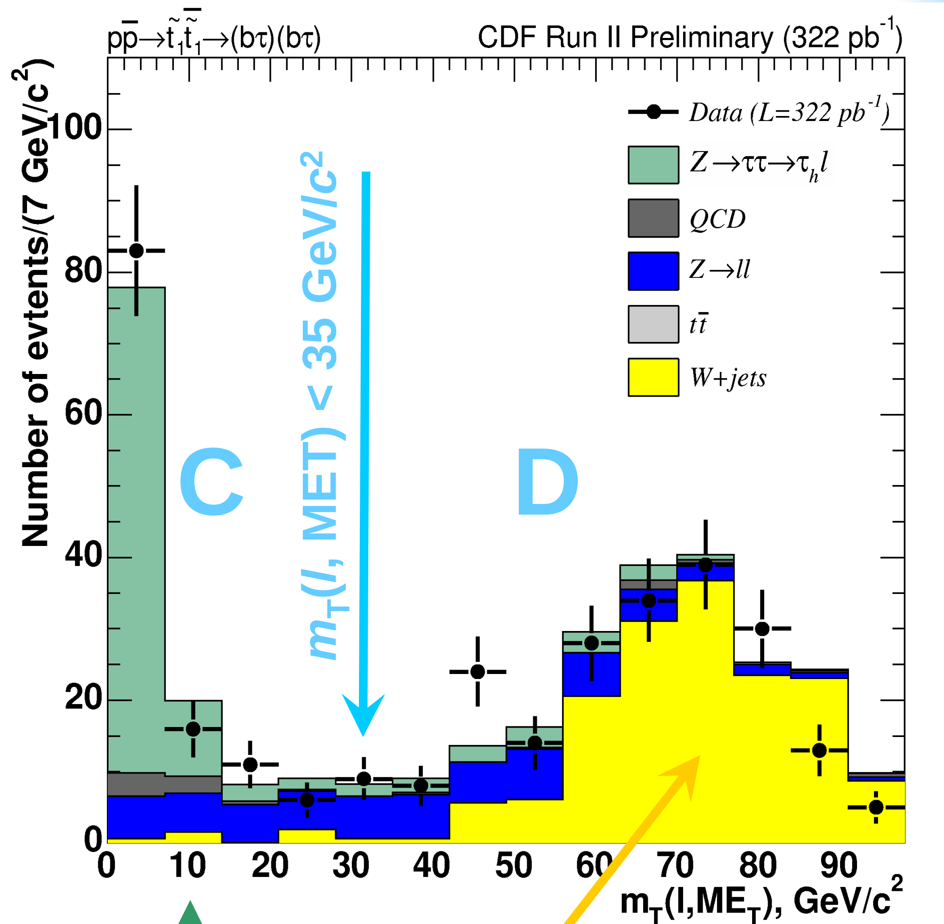


Validation: N_{jet}=0 Regions C and D

- Use S_T >80 GeV

(better statistics for validation)



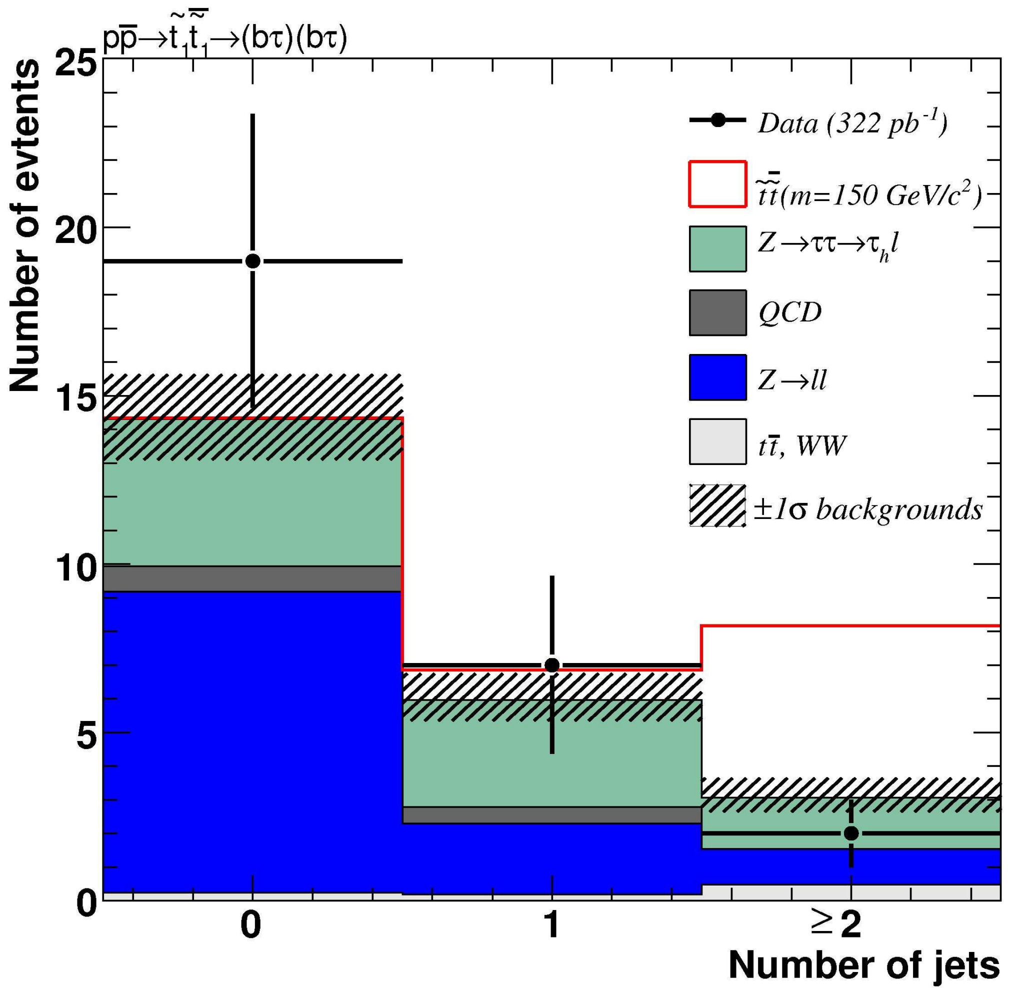


D is mostly W+jets

- C is dominated by $Z\rightarrow\tau\tau$
- clear tau signal

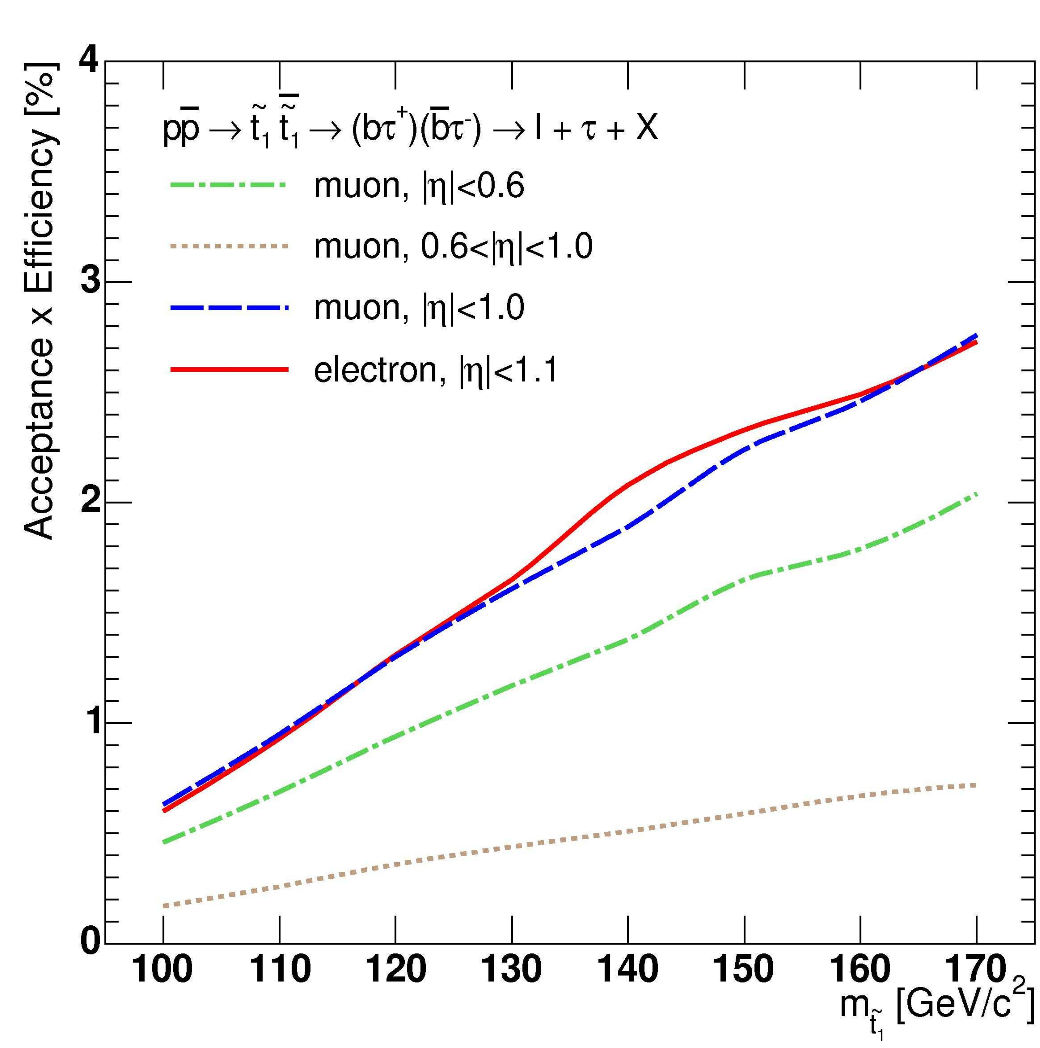
N_{jet} Distribution for m_T<35 GeV/c^2

- Signal region ($N_{jet} \geq 2$):
  - was looked after the validation in control regions was completed
  - N_{obs} = 2 (1e+1μ)
  - N_{BG} = $3.0^{+0.5}_{-0.4}$



C
A'
A
Signal Region

Signal Event Selection: Summary



Total signal event selection acceptance (in region A_2 as a function of *m*(stop) for:

- Electron channel
- Muon channel:
  CMUP ($|\eta|<0.6$)
  CMX ($0.6<|\eta|<1.0$)
  separately and combined

- Muons (combined) and Electrons give similar acceptance

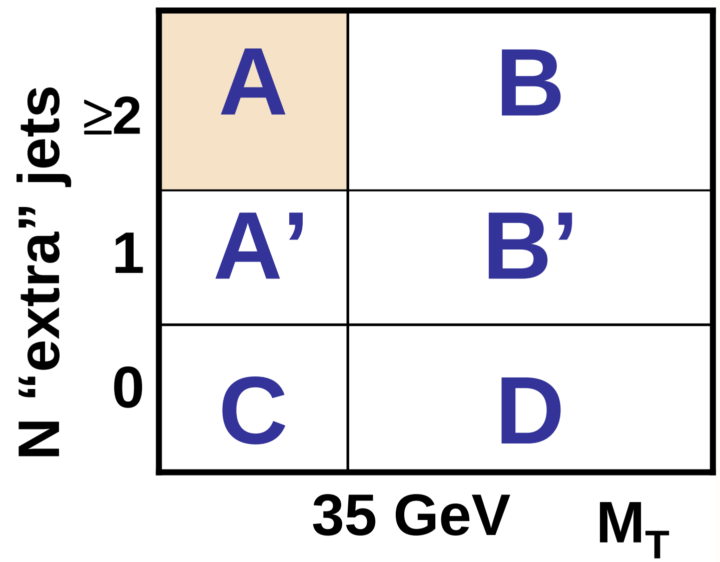
Systematic Uncertainties

- **Contributions:**
  - PDF: 3.8 – 5.0 %
  - ISR/FSR: 1.5 - 2.0 %
  - Jet energy scale: 1.2 - 8.7 %
  - MET: 0.3 – 2.1 %
  - Acceptance: 1.5 – 1.7 %
  - lepton/tau ID: 1.0 – 3.0 %
  - Trigger efficiency: ~1%
- **Total systematics [%] vs Stop mass [GeV/c^2]:**

m(stop),		100	110	120	130	140	150	160	170
Channel	$e+\tau$	10.8	11.1	10.3	8.5	7.8	7.3	7.2	6.9
	$\mu+\tau$	10.9	10.7	10.0	9.2	8.3	7.5	7.5	7.3

Fit Strategy

- Use fitting to the Data to find:
  - Probability Density Function as a function of signal cross-section
  - **estimate *W+jets* background



- **"4-region"** method:
  - Assume for W+jets

    $r \equiv [N(A)/N(B)]\ /\ [N(C)/N(D)] \sim 1$
    - unreliable rates but reliable ratios
    - verified with MC
  - Estimate all non-*W+jets* BG
  - Estimate N_B/N_A, N_C/N_A, N_D/N_A for signal events
  - Include systematic uncertainties (are in range of 7.0%~11.2%)
  - Fit to Data in all 4 regions

Building the Fit Likelihod

- Define Likelihood as a function of σ using Poisson Statistics $P(n_i,N_i)$:

$$LL(\sigma)=\int da\times\exp\left[-\frac{a-\alpha_0}{2\sigma_\alpha^2}\right]\times L\times Br\times a\times\frac{1}{V^W}\iiint dv_A^W\,dv_C^W\,dv_D^W\times$$

$$\times\int_{0.5}^{1}dr\times\prod_{i=A,B,C,D}\int_{\nu_i^b=0}^{\infty}d\nu_i^b\exp\left[-\frac{\nu_i^b-\nu_{i0}^b}{2(\sigma_i^b)^2}\right]\times P(\nu_i,N_i)\times J(r)$$

  - N_i is number of observed events in region i
  - $\nu_i=\sigma\,Br(\tau\tau\to\tau_l\tau_h)\,L\,\alpha_i+\nu_i^b+\nu_i^W$ is number of expected events in region i
  - ν_i^W and ν_i^b are numbers of W+jets and other background events
  - α_0 is signal acceptance
  - L is luminosity
  - $J(r)$ is Jacobian of transformation $(\nu_A,\nu_B,\nu_C,\nu_D)\to(\nu_A^W,\nu_B^W,\nu_C^W,\nu_A^S)$

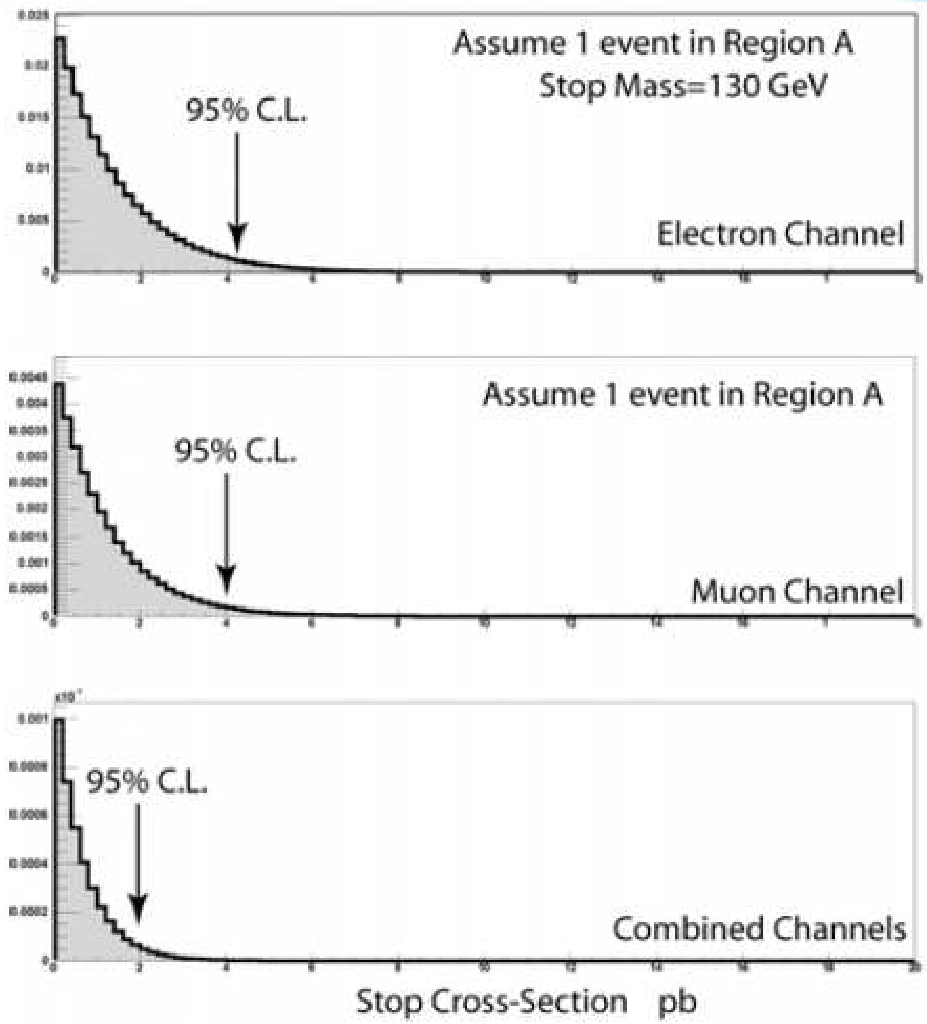
- **Likelihood for combined channels:** $LL(\sigma)=LL^{e+\tau}(\sigma)\,LL^{\mu+\tau}(\sigma)$

- Perform multidimensional numerical MC integration

- During integration:
  - Take into account correlations between channels and systematics
  - Migration effects between regions

4-regoins Fit

- Fully Bayessian
- Handles *W+jets* backgrounds
- Effectively allows to use signal from region B
  - B contains ~40% of signal
- The result:
  - **Probability Density Function as a function of signal cross-section**
  - Can set 95% C.L. limit or discover stop
  - Example



Number of events in Different Regions

Reg	N_{obs} ($e+\tau_h$ Channel)	SM Backgrounds Other ($e+\tau_h$ Channel)	SM Backgrounds W+jet ($e+\tau_h$ Channel)	N_{obs} ($\mu+\tau_h$ Channel)	SM Backgrounds Other ($\mu+\tau_h$ Channel)	SM Backgrounds W+jet ($\mu+\tau_h$ Channel)
A_2	**1**	$2.0^{+0.5}_{-0.4}$	$0^{+0.4}_{-0}$	**1**	$1.0^{+0.4}_{-0.2}$	$0^{+0.5}_{-0}$
B_2	4	$2.8^{+0.5}_{-0.3}$	$1.0^{+2.0}_{-1.0}$	4	$2.3^{+0.4}_{-0.3}$	$1.7^{+2.0}_{-1.5}$
A_1	4	$3.3^{+0.5}_{-0.5}$	$0.2^{+1.2}_{-0.2}$	3	$2.6^{+0.6}_{-0.4}$	$0.1^{+0.8}_{-0.1}$
B_1	9	$2.3^{+0.4}_{-0.3}$	$6.7^{+3.2}_{-2.7}$	6	$2.3^{+0.5}_{-0.3}$	$3.8^{+2.7}_{-2.1}$
A_0	11	$9.1^{+1.2}_{-1.1}$	$1.6^{+2.7}_{-1.6}$	8	$5.2^{+0.7}_{-0.5}$	$2.5^{+2.4}_{-2.1}$
B_0	25	$4.5^{+0.7}_{-0.6}$	$21.1^{+5.6}_{-4.3}$	28	$5.4^{+0.8}_{-0.6}$	$23.6^{+4.9}_{-5.7}$

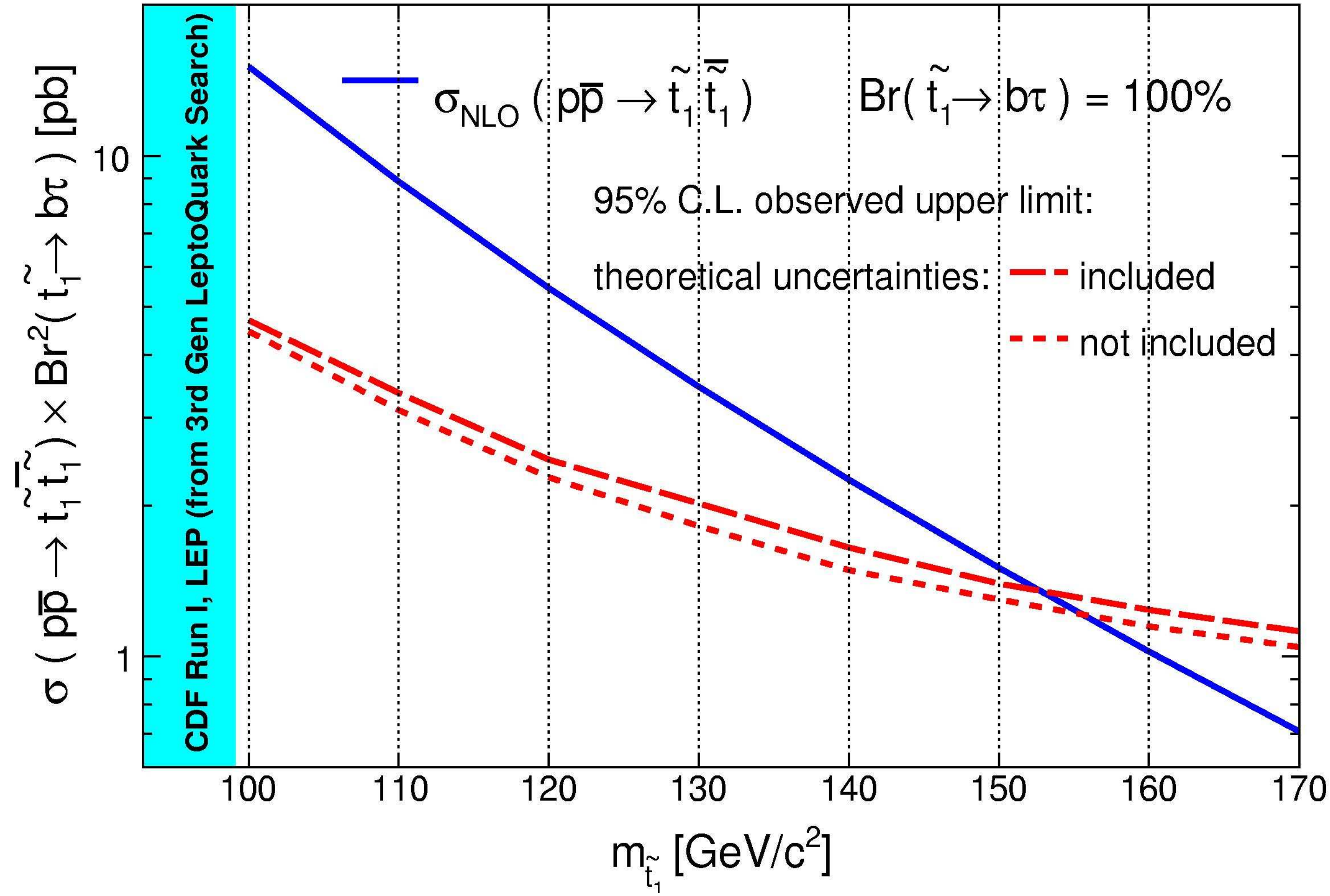
- Note:
  - W+jets and other BG's are not combined
  - ***W+jets are*** *estimated in the fit and* ***not independent*** *from number of data evt., other BG's and expected signal fractions*

Stop Cross-Section Upper Limits

- No excess observed → set limits
- Theoretical uncertainties on cross-section:
  - CTEQ6.1M special PDF sets for uncertainty estimation
  - ± ½ of QCD renorm./factor. scale
- 95% C.L. upper limit on $\sigma(\tilde{t}_1\bar{\tilde{t}}_1)\times\beta^2$ where $\beta = Br(\tilde{t}_1 \to \tau b)$ as function of stop mass, calculated for the cases when theoretical uncertainties on CS were or were not considered:

$m(\tilde{t}_1)$ (GeV/c^2)	100	110	120	130	140	150	160	170
$\sigma^{95\%}_{with\ uncert} \times \beta^2$ (pb)	4.73	3.37	2.50	1.99	1.61	1.38	1.26	1.14
$\sigma^{95\%}_{no\ uncert} \times \beta^2$ (pb)	4.48	3.11	2.27	1.81	1.47	1.26	1.16	1.04

Stop Mass Limits



- Stop mass 95% C.L. limits for the case $Br(\tilde{t}_1 \rightarrow \tau b) = 1$:
  - ***m* > 153 GeV/*c*^{2} (theoretical uncertainties considered)**
  - *m* > 156 GeV/*c*^{2} (not considering theor. uncertainties)

Summary and Prospects

- **No RPV stop discovery with *L*=322 pb^{-1}**
  - Expected $3.0^{+0.5}_{-0.4}$ BG events in primary signal region
  - Observed 2 events
  - Set 95% C.L. upper limit on $\sigma(\tilde{t}_1\bar{\tilde{t}}_1)\times Br(\tilde{t}_1 \to \tau b)^2$ as function of stop mass
  - Stop mass 95% C.L. limit for $Br(\tilde{t}_1 \to \tau b) = 1$ case:
    - m > 153 GeV/c^2 (theoretical CS uncertainties considered)
  - Results are fully applicable to Scalar LQ_3
- **Possible Prospects:**
  - Bigger dataset will need completely new analysis with *b*-tagging
  - Combined search of modes $\tilde{t}_1 \to eb \,\&\, \tilde{t}_1 \to \mu b \,\&\, \tilde{t}_1 \to \tau b$ has more potential
  - Procedures developed in this analysis could be applied to $pp \to (H \to \tau\tau)bb$ search
    - Feasibility needs more study
    - Needs improvement of tau and jet energy resolutions

Backup

Acceptance Definition

	Electron +Tau	CMUP/CMX Muon +Tau
Lepton:	***CEM Cluster:***	***Stub:***
	E_T > 10 GeV	CMUP / CMX
	Excl. wedges I=16 and 35	
	Matching Track:	***Matching Track:***
	P_T > 8 GeV/c	P_T > 10 GeV/c
	$\lvert z_0 \rvert$ < 60 cm	$\lvert z_0 \rvert$ < 60 cm
	$\lvert$z(R=COT)$\rvert$ < 150 cm	$\lvert$z(R=COT)$\rvert$ < 150 cm
	9<$\lvert$z(R=CES)$\rvert$ < 230 cm	Fiducial in CMUP / CMX
	$\lvert$x(R=CES)$\rvert$ < 21.5 cm	
Tau Candidate:	P_T(trk+π0) > 15 GeV/c; $\lvert \eta^{det} \rvert$ < 1.0	
	Seed track P_T > 6 GeV/c; $\lvert$z(R=COT)$\rvert$ < 150 cm	
	Seed Track 9<$\lvert$z(R=CES)$\rvert$ < 230 cm	
***l*-τ Separation:**	ΔR>0.7	

Lepton & Tau ID and Isolation

Electron:	*Muon:*	*Tau:*
Track Quality	Track Quality	Seed Track Quality
$E^{had}/E^{em} < 0.05+0.00045 \times E$	$E^{em}<2$, $E^{had}<6$	$\|z_0(seed) - z_0(ele)\|<5$ cm
E/P < 2.0 or ET>50	Ehad+Eem>0.1	$\|d_0\|<0.2$ cm
$-1.5 < Q \times \Delta X_{CES} < 3.0$ cm	$\|d_0\| < 0.2$ cm	$\xi > 0.1$ (electron removal)
$\|\Delta Z_{CES}\| < 3.0$ cm	$\Delta X^{CMU}<4$ $\Delta X^{CMP}<7$	M(trks) <1.8 GeV/c^2
CES $\chi^2_{strip} < 10.0$	Or $\Delta X^{CMX}<6$	$M(trks+\pi^0) < 2.5$ GeV/c^2
$L_{shr} < 0.2$		$N_{trk}=1, 3$
$\|d_0\| < 0.2$ cm		
Isolation:		
Jet Separation: $0.3 > \Delta R(e/\mu/\tau, jet) > 0.8$		
I_{trk} ($\Delta R=0.4$) < 2.0 GeV/c	I_{trk}($\Delta R=0.4$) < 2.0GeV/c	$N_{trk}(0.17<\Delta\theta<0.52)=0$
		$N_{trk}(0.17<\Delta R<0.52)=0$
		$I(\pi^0, \alpha<\Delta\theta<0.52)<0.6$ GeV/c

Event Selection: Summary

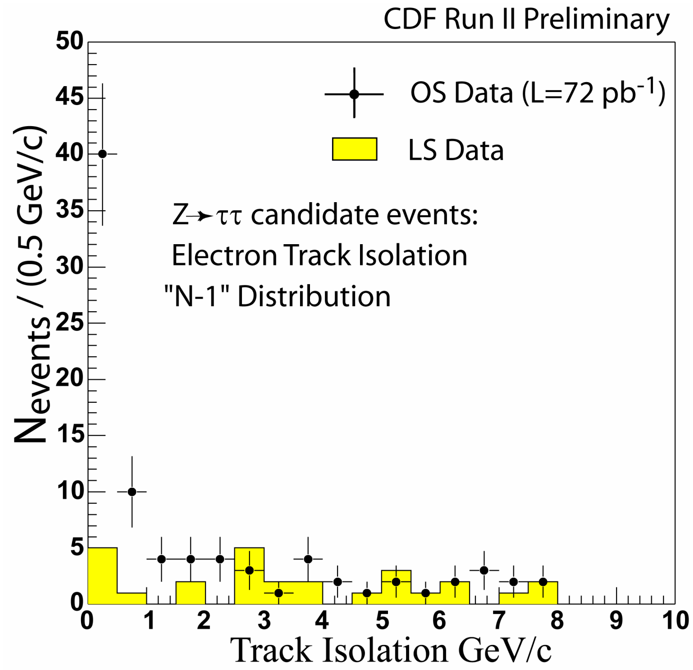
	$e+\tau$ [%]	CMUP+τ	CMX+τ
Acceptance	17.6 ± 0.3	10.4 ± 0.2	3.6 ± 0.1
Lepton ID Lepton ISO	83.8 ± 1.0 78.4 ± 2.4	84.9 ± 3.7 81.4 ± 2.5	91.0 ± 0.7 71.8 ± 2.5
Tau ID Tau ISO	75.2 ± 2.3 70.0 ± 2.2	74.0 ± 2.3 70.9 ± 2.2	71.8 ± 2.5 70.4 ± 2.5
Trigger Eff.: Lepton Tau XFT Track	97.6 ± 1.0	95.8 ± 1.0 96.4 ± 1.0	94.6 ± 1.1
Event Level Cuts	40.7 ± 0.8	47.7 ± 1.0	41.1 ± 1.7
Total	**2.33 ± 0.06**	**1.65 ± 0.05**	**0.59 ± 0.03**

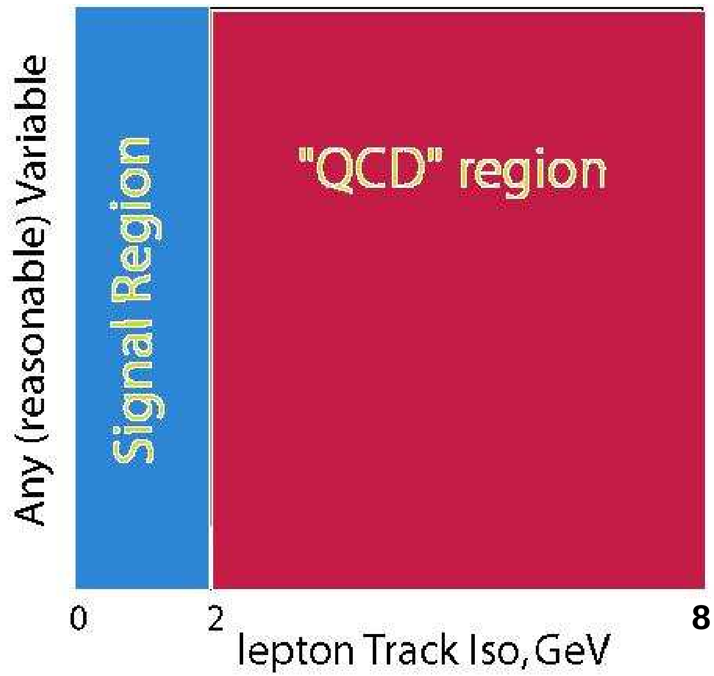
- Efficiencies quoted for Region A and m(stop)=150
- Consistent efficiencies across channels

Minor Backgrounds

- **Top and diboson (*ZZ*,*WZ*,*WW*)**
  - *WW* : negligible
  - Use Pythia(Alpgen+Herwig) for acceptance
  - Normalize to NLO cross-section
- γ (→***ee***) + ≥ **3jets : negligible in region A**
- ***Z* (→ee/**$\mu\mu$) **+ ≥ 2jets**
  - Pythia acceptance
  - Normalize to NLO cross-section

QCD Background Estimation

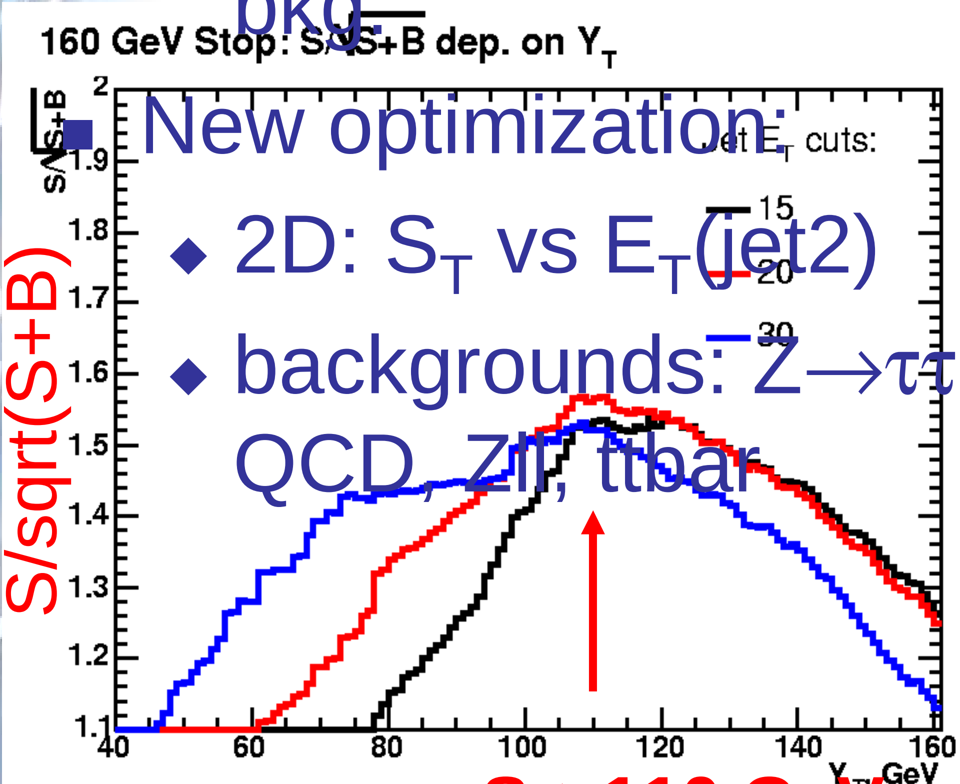




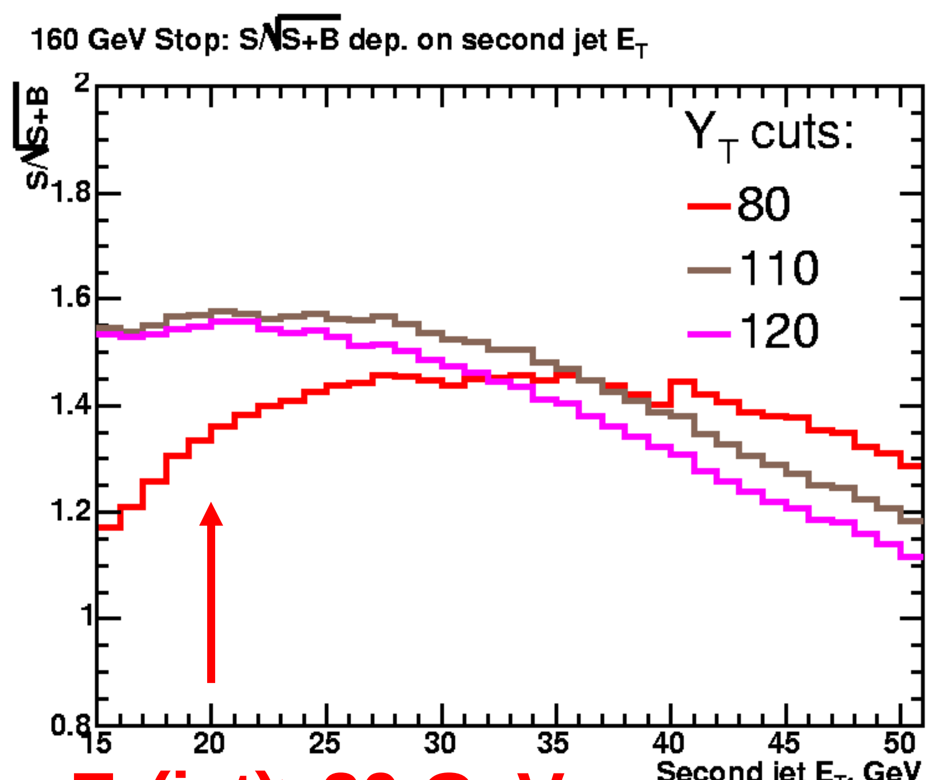
- **Prescription from *Z*→ττ analysis :**
  - Apply all desired cuts except lepton isolation
  - Measure the spectrum (or a number of events) in the “flat” region and rescale by (2-0)/(8-2)=1/4
  - This is the background in the signal region
  - *You can think of it as a variety of “sideband” subtraction*

S_T and jet E_T Cut Optimization

- Previously (Run I):
  - Used E_T(jet2)=15 Gev optimized at S_T >85
  - using S_T only and $Z \to tt$ as bkg.
- Target:
  - region A_2
  - m(stop)=160 GeV
- New optimization:
  - 2D: S_T vs E_T(jet2)
  - backgrounds: $Z \to \tau\tau$, QCD, Zll, ttbar



S_T>110 GeV

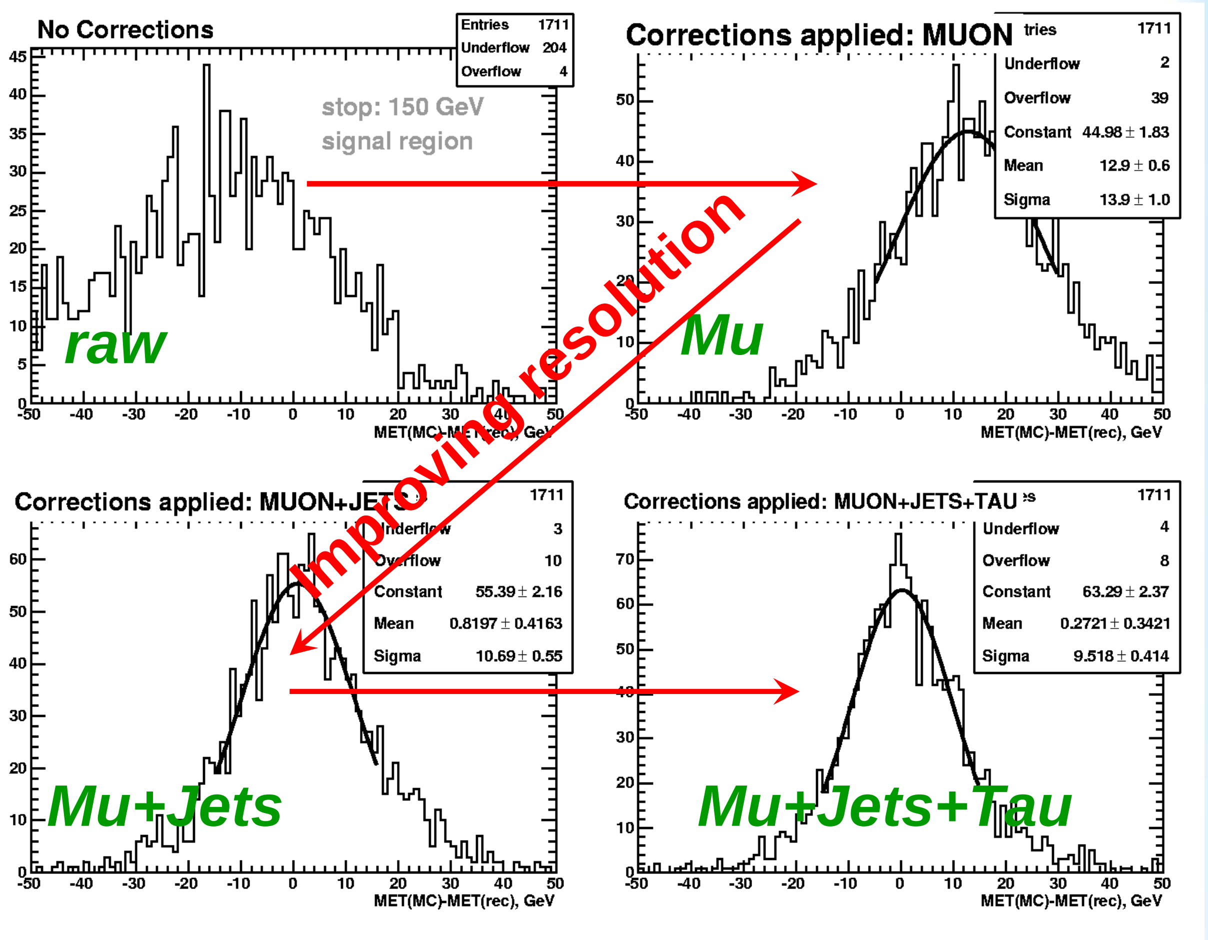


E_T(jet)>20 GeV

Missing Transverse Energy Correction

- Needs to be corrected due to energy corrections for:
  - Lepton
  - Tau
  - Jets
- Allows improved MET resolution
- Even more important for backgrounds

Signal in $\mu + \tau$ channel example:
MET(MC) – MET(Reconstructed)
at different levels of corrections:



Changes & Improvements Since Blessing

- ***Z→ee* MC sample updated**
  - Large statistsics zewk6d (5.3.3_ewk MC) instead of obsolete now zewkae (5.3.2)
    - Some changes in estimated *Z→ee* contribution
- **Correction procedure for known *Z→ττ* and *Z→ee* MC imperfectnesses**
  - Corrects for several effects, e.g.
    - Processes are treated as *2→1* LO in PYTHIA
      - Not adequate for **higher $p_T(Z)$ region**
    - MET in *Z→ee (5.3.3)* is known to disagree in data & MC:
      - not well modeled minbias and calorimeter response to jets
  - Our analysis rely on N_{jet}, Y_{T}, m_{T} that are sensitive to $p_T(Z)$ and MET

Scale Factors For Drell-Yan BGs

	Jet Bin		
	0	1	≥ 2
$Z \rightarrow ee$:			
$M_T < 35$	1.07 ± 0.13	0.99 ± 0.12	1.28 ± 0.27
$M_T > 35$	0.87 ± 0.13	0.91 ± 0.12	1.19 ± 0.28
$Z \rightarrow \tau\tau$:			
$M_T < 35$	$1.00 \pm 0.10(st) \pm 0.02(sys)$	$0.90 \pm 0.09(st) \pm 0.14(sys)$	$1.02 \pm 0.19(st) \pm 0.18(sys)$
$M_T > 35$	$0.99 \pm 0.18(st) \pm 0.02(sys)$	$0.94 \pm 0.23(st) \pm 0.11(sys)$	$1.03 \pm 0.23(st) \pm 0.19(sys)$