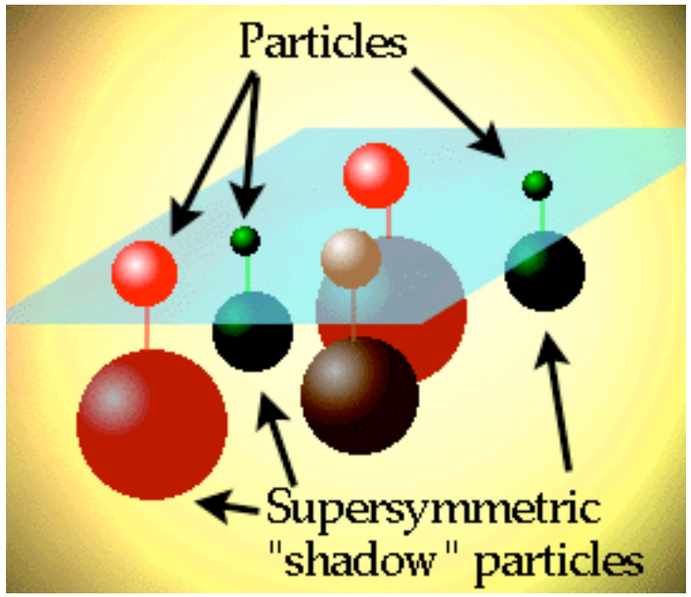
CDF Chargino-Neutralino Trilepton Search with 3.2 fb^{-1} of Data

DPF
Detroit, July 27, 2009

Rob Forrest, UC Davis
For the CDF collaboration

Supersymmetry

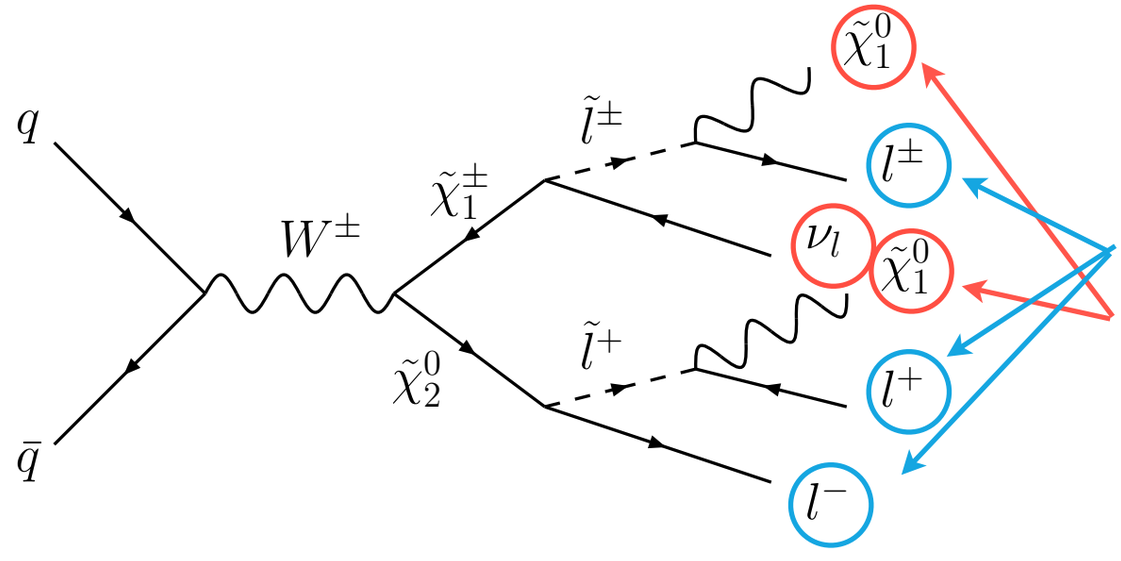
- Postulates a new symmetry that creates a superpartner for every known SM particle.



- Charginos $\tilde{\chi}^{\pm}_{1,2}$ and neutralinos $\tilde{\chi}^{0}_{1,2,3,4}$ emerge as mixtures of SUSY higgsinos and gauginos.

- Provides a dark matter candidate; protects ewk scale from divergences.

SUSY Trileptons

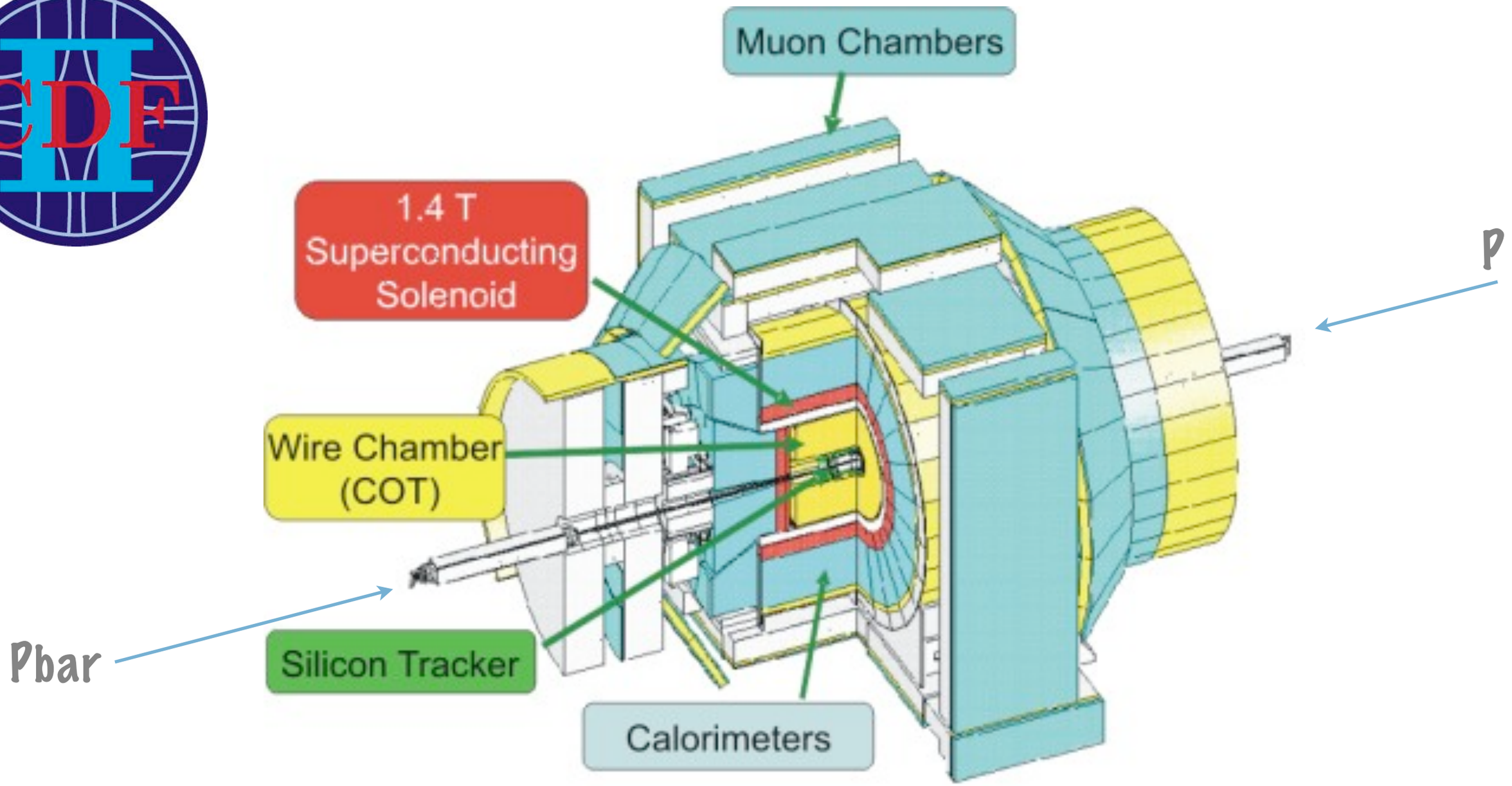


Signature:
3 Leptons + MET

$\tilde{\chi}_1^0$ is LSP - DM candidate

- Chargino $\tilde{\chi}_1^{\pm}$, Neutralino $\tilde{\chi}_2^0$ directly produced and subsequently decay to leptons and MET.
- Direct production allows avoidance of strong sector squarks and gluinos.
- Clean signature (3 Leptons) and low SM background.
- Neutralino/Chargino associated production can have appreciable cross sections.

Collider Detector at Fermilab (CDF)



~435 Publications in Run II

~ 40 PhDs granted/year

Trilepton analysis strategy:

- Select dilepton events, compare expected BG to data.
  - Dileptons stage well understood, useful for validation.
- Require third lepton, compare again.
  - Reduces statistics by factor ~1000
- Make SUSY optimized event level cuts.
  - Use mSugra as reference, don't tune to model.
- Open signal box and set limits (or discover!)

More Strategy:

- Leptons (e, μ) categorized as 'Tight' (t) or 'Loose' (l).
- Also define an isolated track (T) object. Recoups acceptance from detector gaps, leptons failing cuts, taus.
- This is a unified analysis, with predefined **exclusive** trilepton channels ordered by sensitivity.
- Final combination of trilepton channels is straightforward.

Exclusive Channels (ordered):

More Sensitive

Less Sensitive

(3 Tight Leptons) or (2 tight+Loose e)	(ttt)	Trilepton Channels
2 Tight + 1 Loose μ	(ttC)	
1 Tight + 2 Loose	(tll)	
2 Tight + Track	(ttT)	Dilepton+Track Channels
1 Tight + 1 Loose + Track	(tlT)	

An event can only qualify for **one** of these channels.

SM Backgrounds

Drell-Yan, WW } 2 real leptons + conversion

WZ, ZZ, ttbar } 3 real leptons

SM Dilepton + Fake Lepton } Lepton fakes

SM Dilepton + Fake Track } Track Fakes

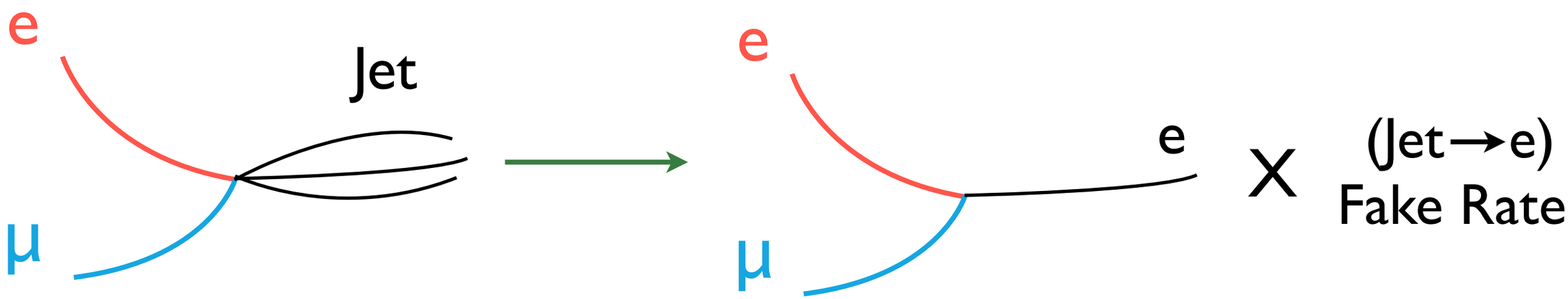
Lepton Fakes

Data-driven fake determination:

- Choose data events with 2 good leptons and fakeable object (tracks fake muons, jets fake electrons).

- Carry fake through analysis level cuts as real object.

- Fake contribution is fake rate of object:



Extra track (T) rate - Use MC for kinematics and normalize tracks to what we see in Z events.

Data

Gathered through July '08

- 3.23 fb^{-1}

Triggers Used:

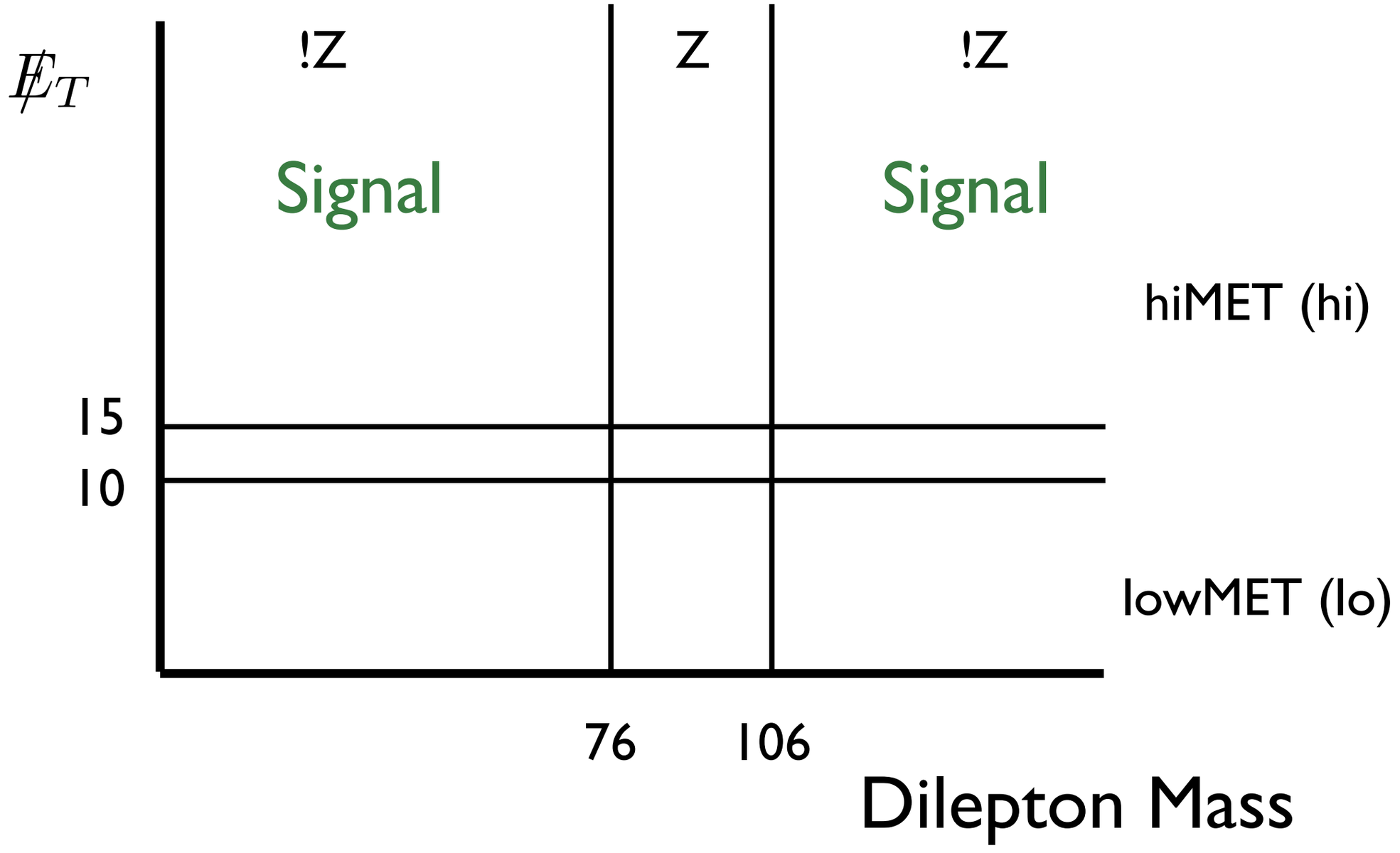
- High Pt inclusive lepton triggers. (Pt > 18 GeV/c)
- Lower Pt dilepton triggers. (Pt > 4, 4 GeV/c)

Dilepton Selection

Category	Lepton Pt Cuts (GeV/c)
tight-tight (tt)	15, 5
tight-loose (tl)	20, 8

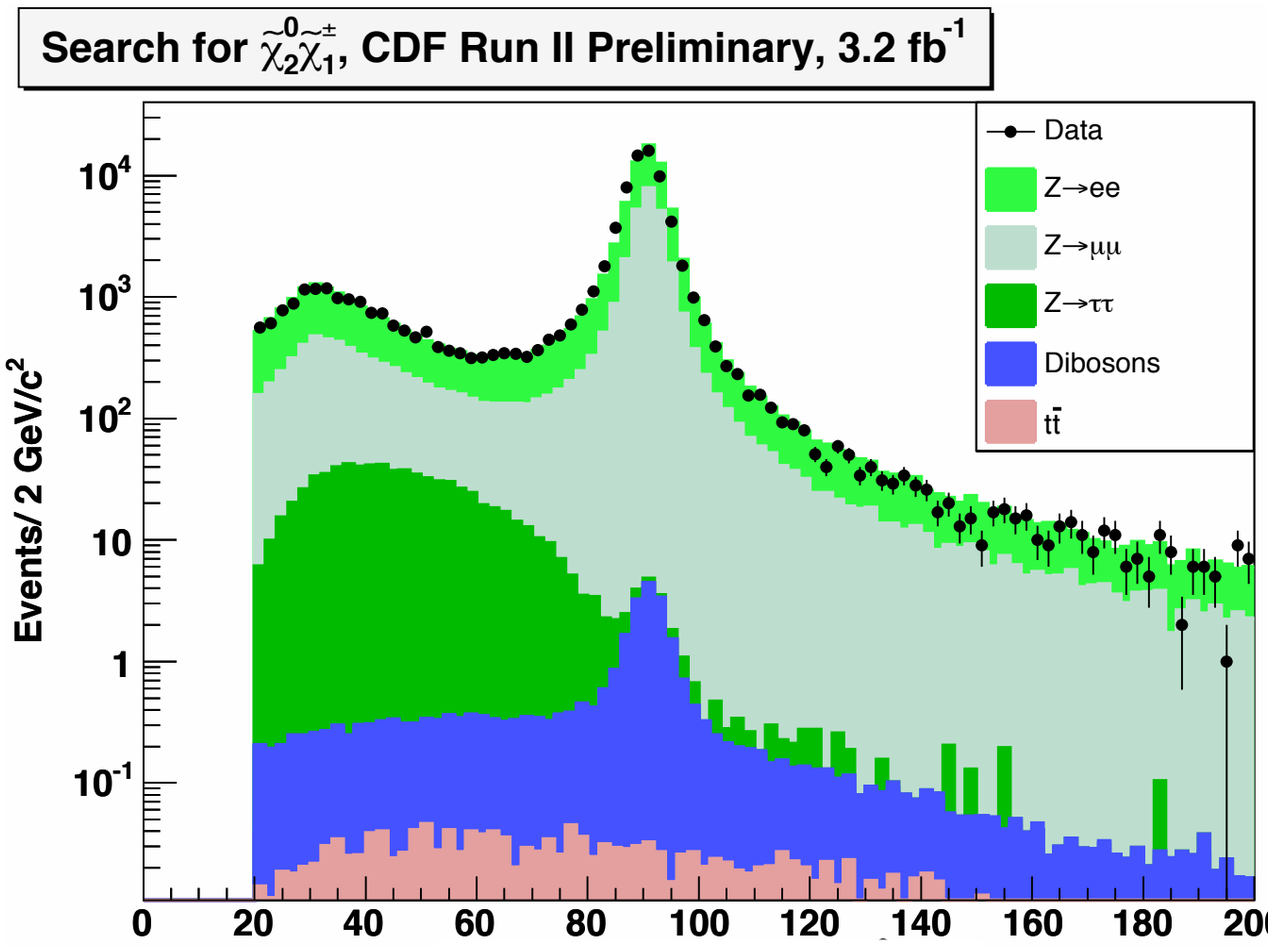
Require separation between leptons.

Control Regions

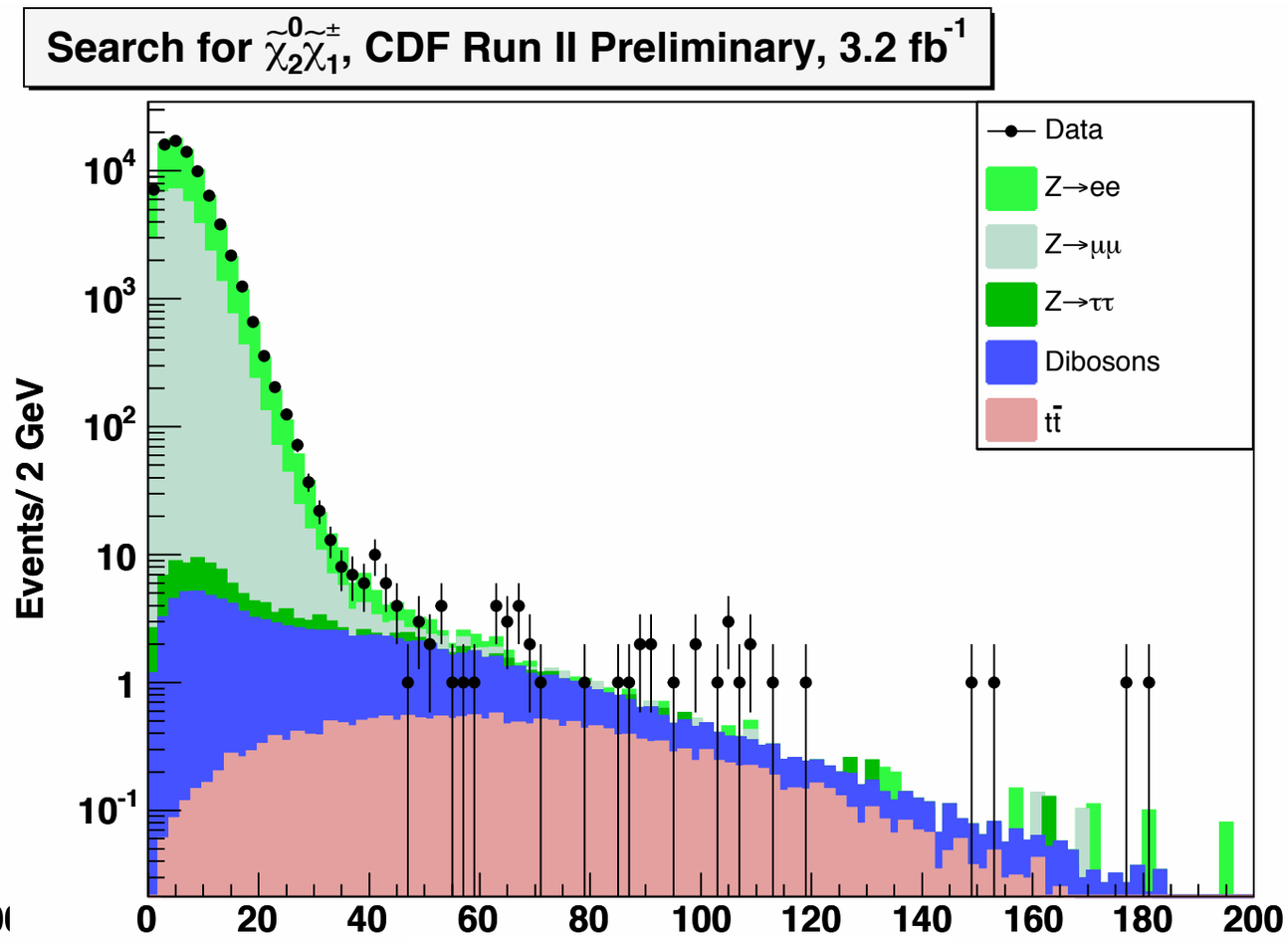


Dilepton Plots: 2 Tight Leptons

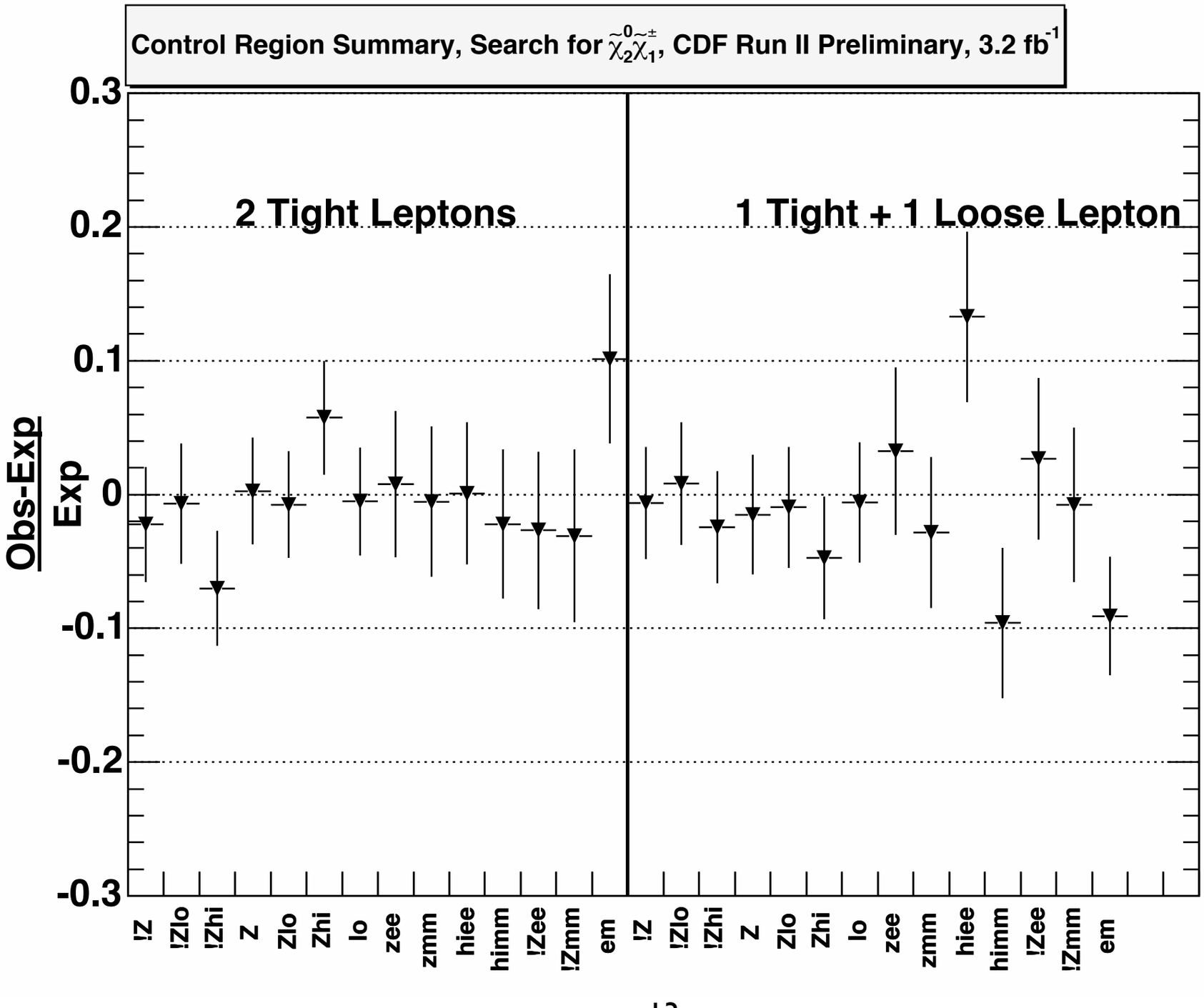
Low MET



Z Window



Dilepton Control Region Summary



Trilepton Selection

Kinematic requirements

Category	Object Pt Cuts (GeV/c)
ttt	15, 5, 5
ttμ_l	15, 5, 10
tll	20, 8, 5
ttT	15, 5, 5
tlT	20, 8, 5

Other event objects: Jets with $E_T > 15$ GeV

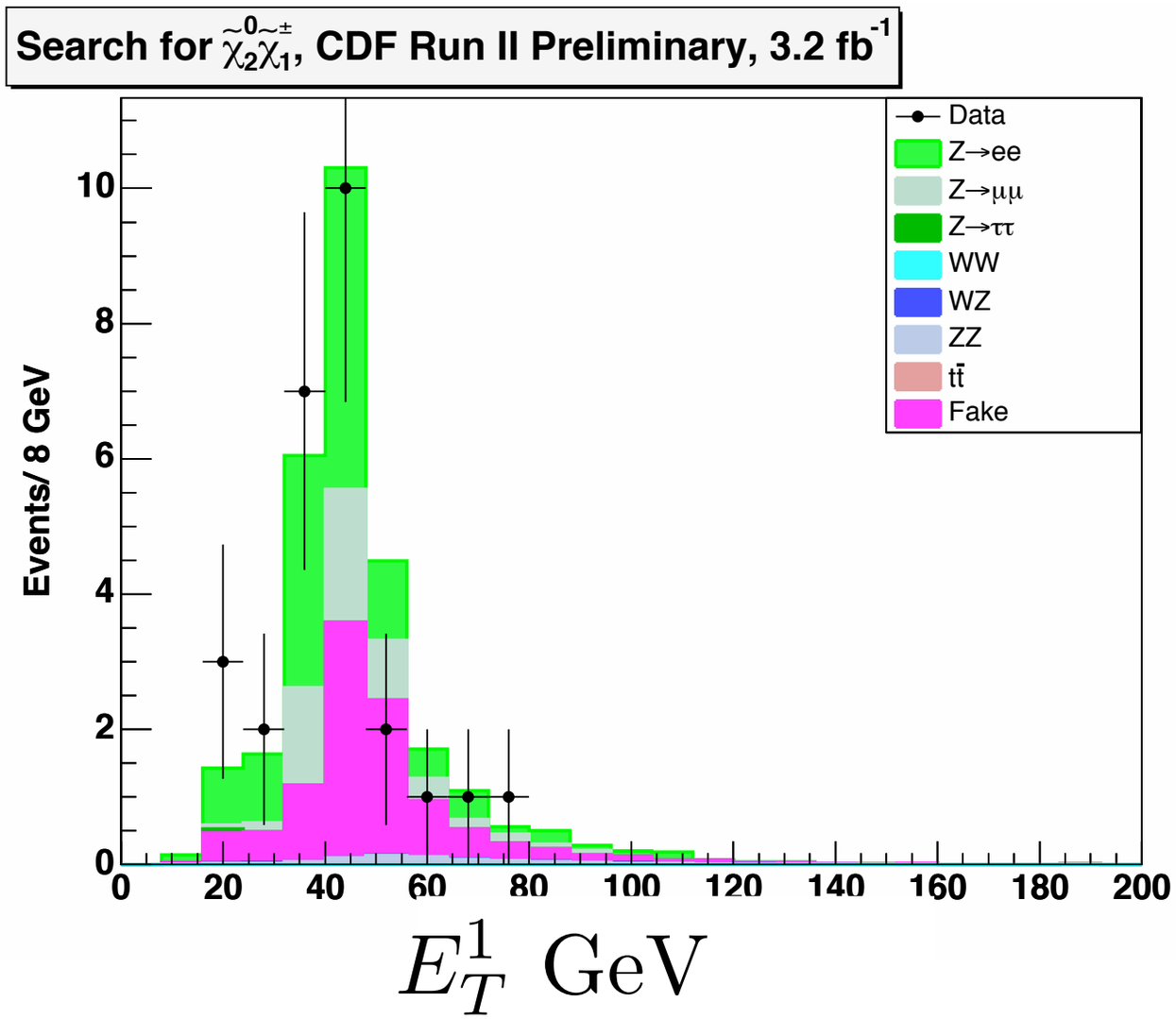
Missing energy, $\not\!\!E_T$

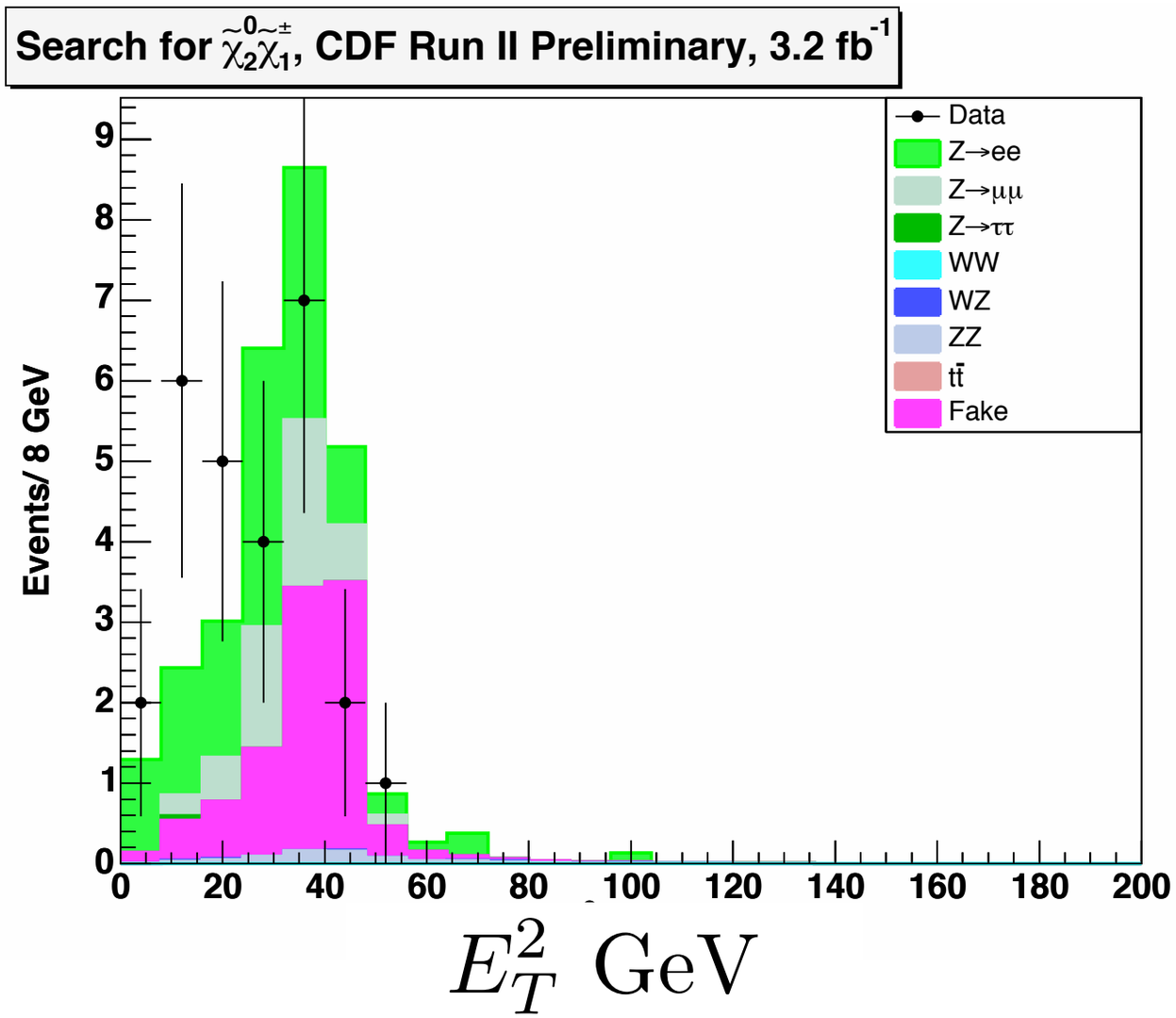
Requirements: Object angular separation.

Invariant mass cut.

Trilepton Plots - 3 Tight

Low MET region.
$\not\!\!E_T$ < 10 GeV





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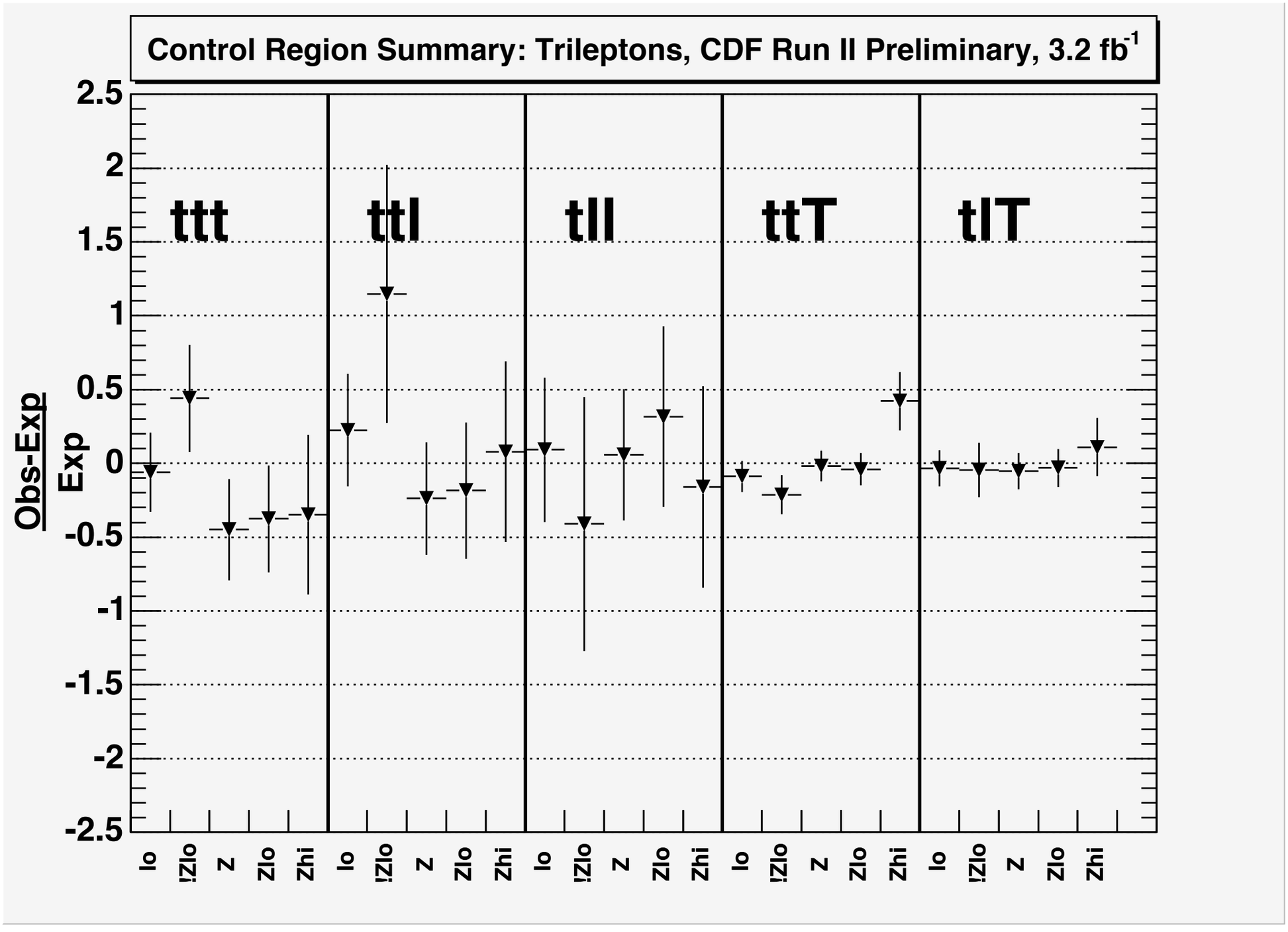
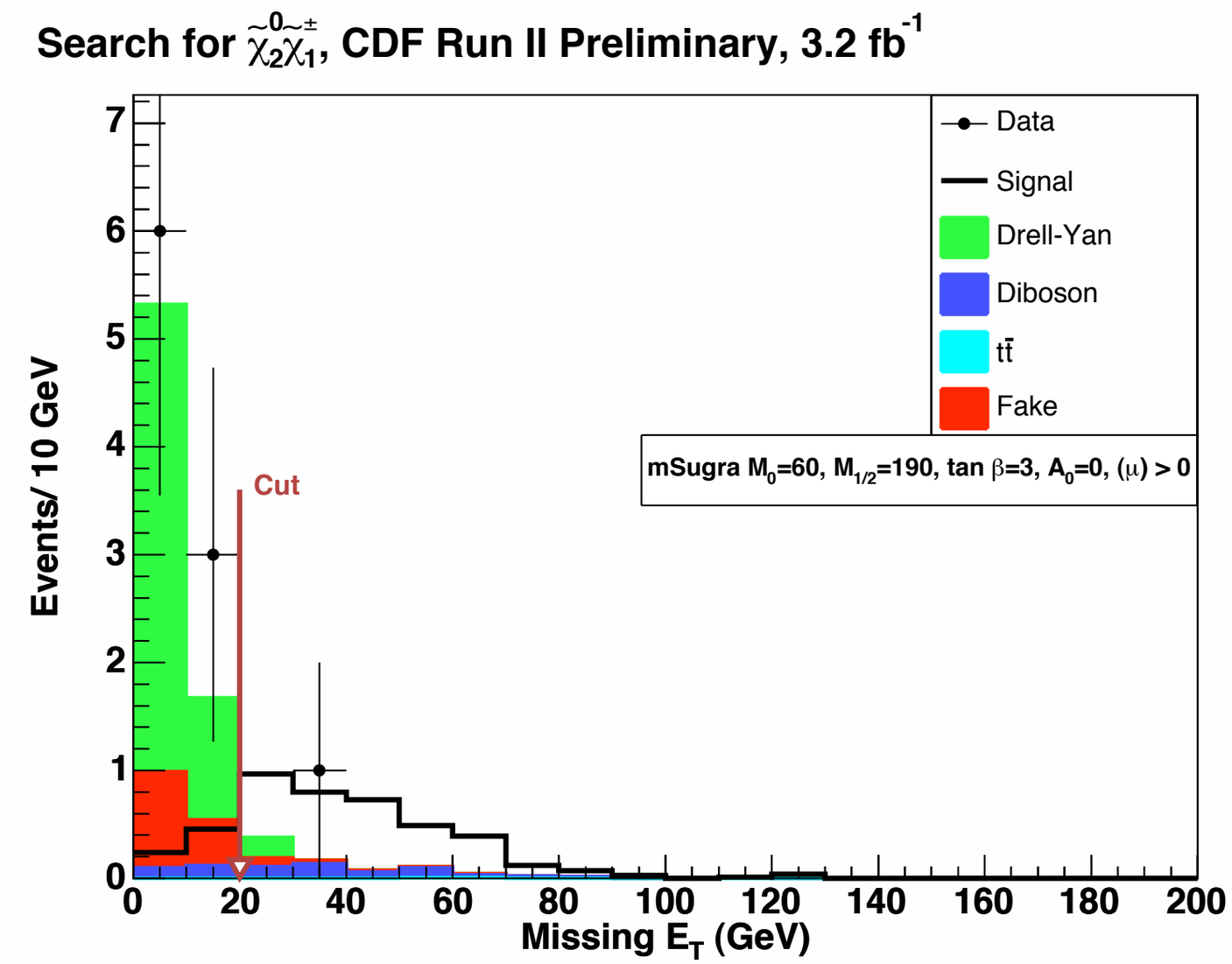


Event Selection - SUSY Cuts

Reduce DY:

$$\not\!\!E_T \geq 20\mathrm{GeV}$$



ttt Category N-1 Plot

Additional cuts applied to reduce Drell-Yan and $t\bar{t}$
Limit jet activity.

Expected Signal

CDF II Preliminary, 3.2 fb^{-1}		
Channel	Total Background $\pm$ (stat) $\pm$ (sys)	Signal Point $\pm$ (stat) $\pm$ (sys)
ttt	$0.83 \pm 0.14 \pm 0.11$	$3.64 \pm 0.22 \pm 0.49$
ttC	$0.39 \pm 0.07 \pm 0.04$	$2.62 \pm 0.18 \pm 0.35$
tll	$0.25 \pm 0.08 \pm 0.03$	$1.12 \pm 0.12 \pm 0.15$
ttT	$5.85 \pm 0.57 \pm 1.11$	$7.15 \pm 0.31 \pm 0.91$
tlT	$3.53 \pm 0.52 \pm 0.5$	$4.06 \pm 0.23 \pm 0.53$

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

Totals:

	Background	Signal
Trilepton	1.5 ± 0.2	7.4 ± 0.7
Dilepton+Track	9.4 ± 1.4	11.2 ± 1.1

Observed

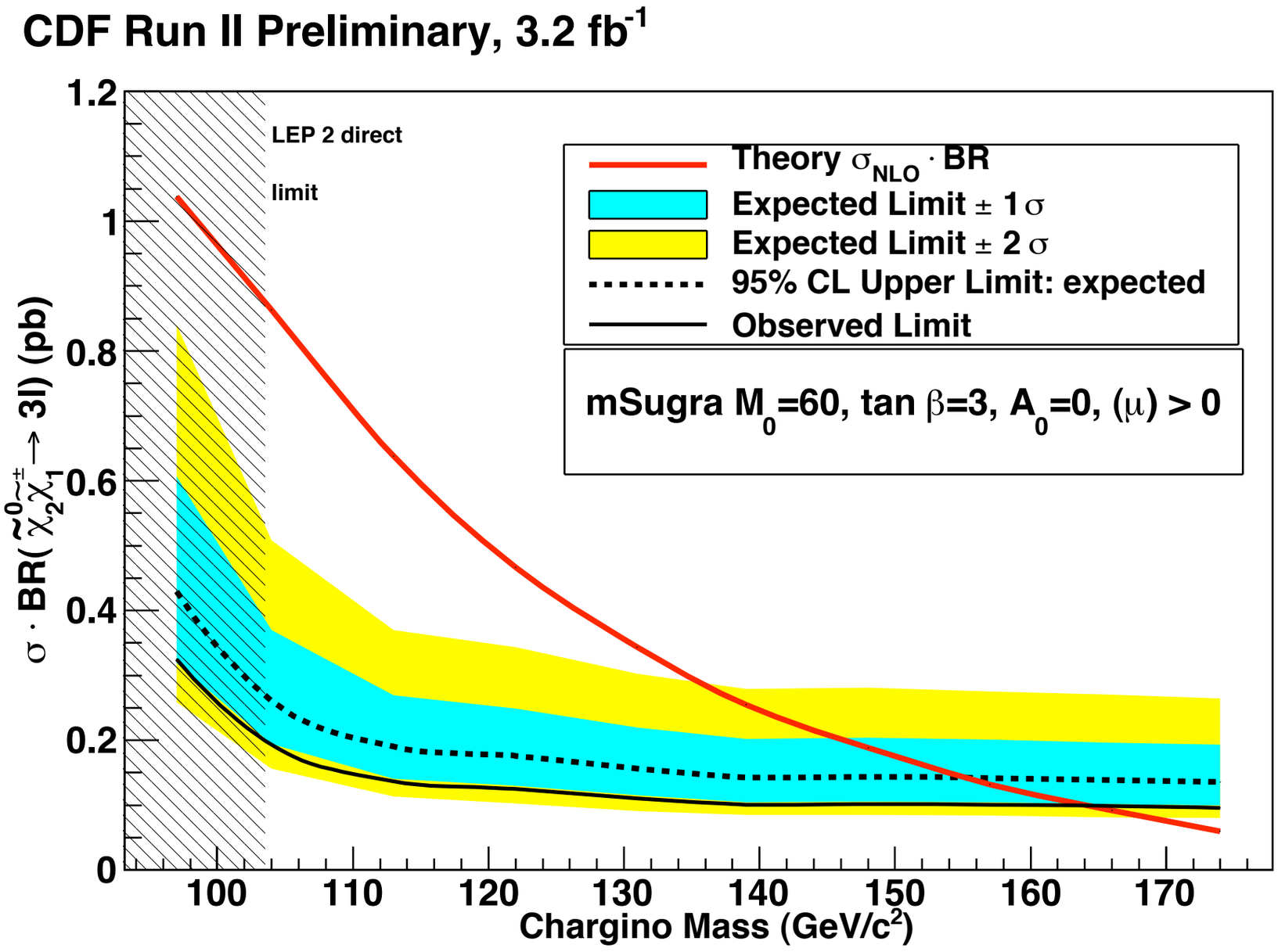
Totals:

	Background	Signal	Observed
Trilepton	1.5 ± 0.2	7.4 ± 0.7	1
Dilepton+Track	9.4 ± 1.4	11.2 ± 1.1	6

Data consistent with background, moderate deficit in dilepton+track channels.

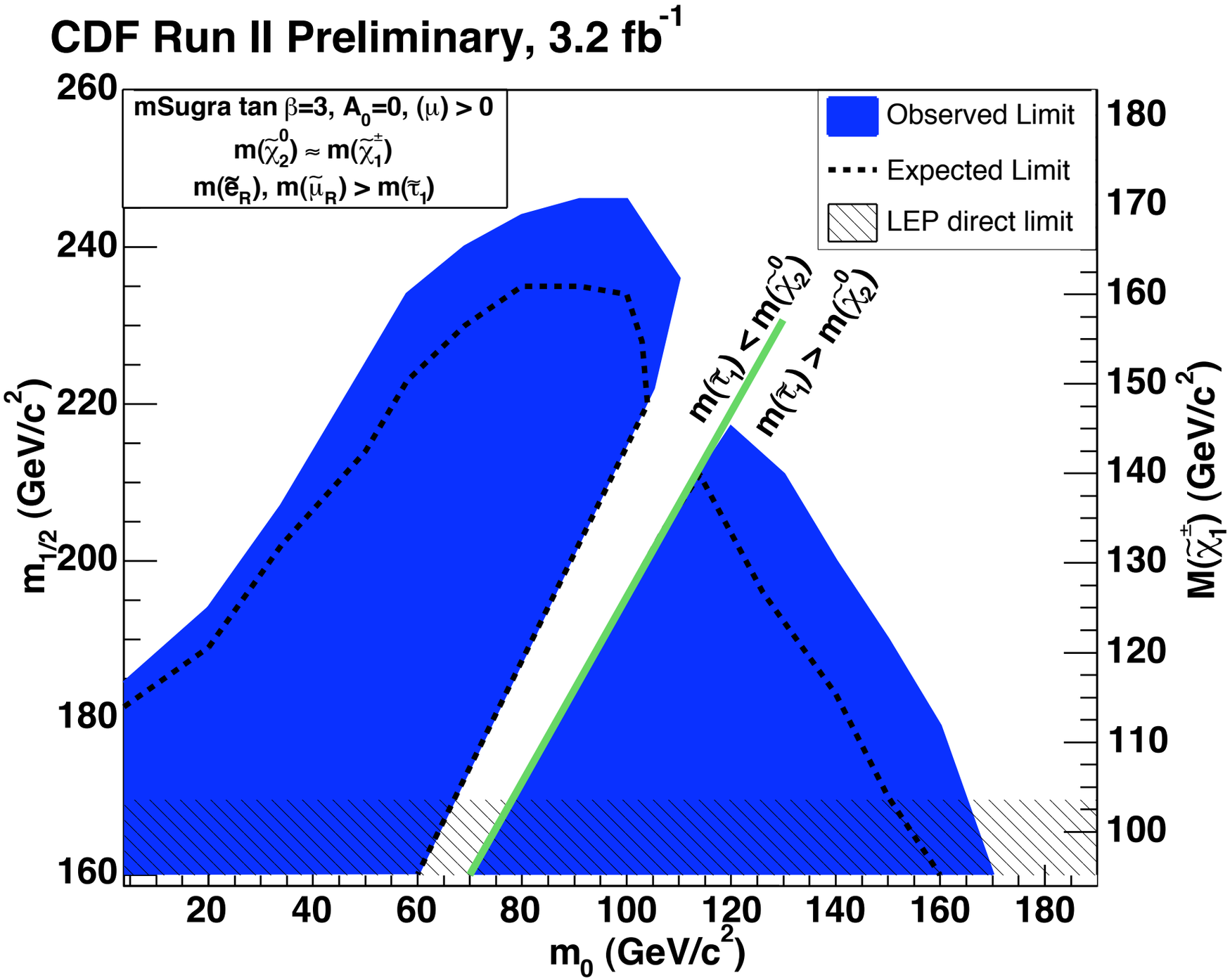
No evidence of SUSY.

Cross Section times BR upper limit



- We exclude Chargino masses of up to $164\ \mathrm{GeV}/c^2$ at this reference SUSY point.
- Previous CDF limit was $145\ \mathrm{GeV}/c^2$ with 2.0 fb^{-1}: Phys.Rev.Lett. 101, 251801 (2008)

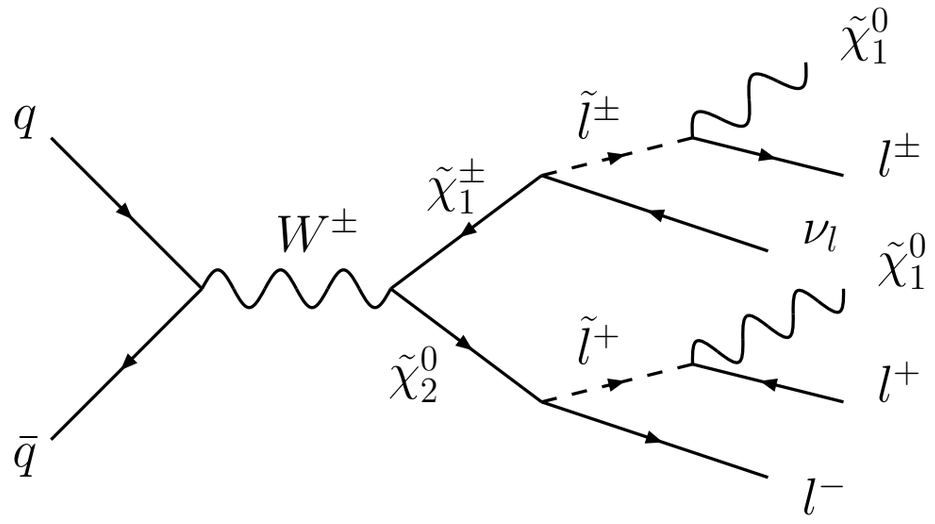
2-D Limit



- Generate ~50 million signal events at almost 100 points, get limit at each point.

Conclusions

- With no excess, we achieve limits of $164\ \mathrm{GeV}/c^2$ from previous limits* of $145\ \mathrm{GeV}/c^2$, and derive limits in the M12-M0 mass plane.
- Plan to update with more data and increase geometrical acceptance.
- Stay tuned for updated results soon!

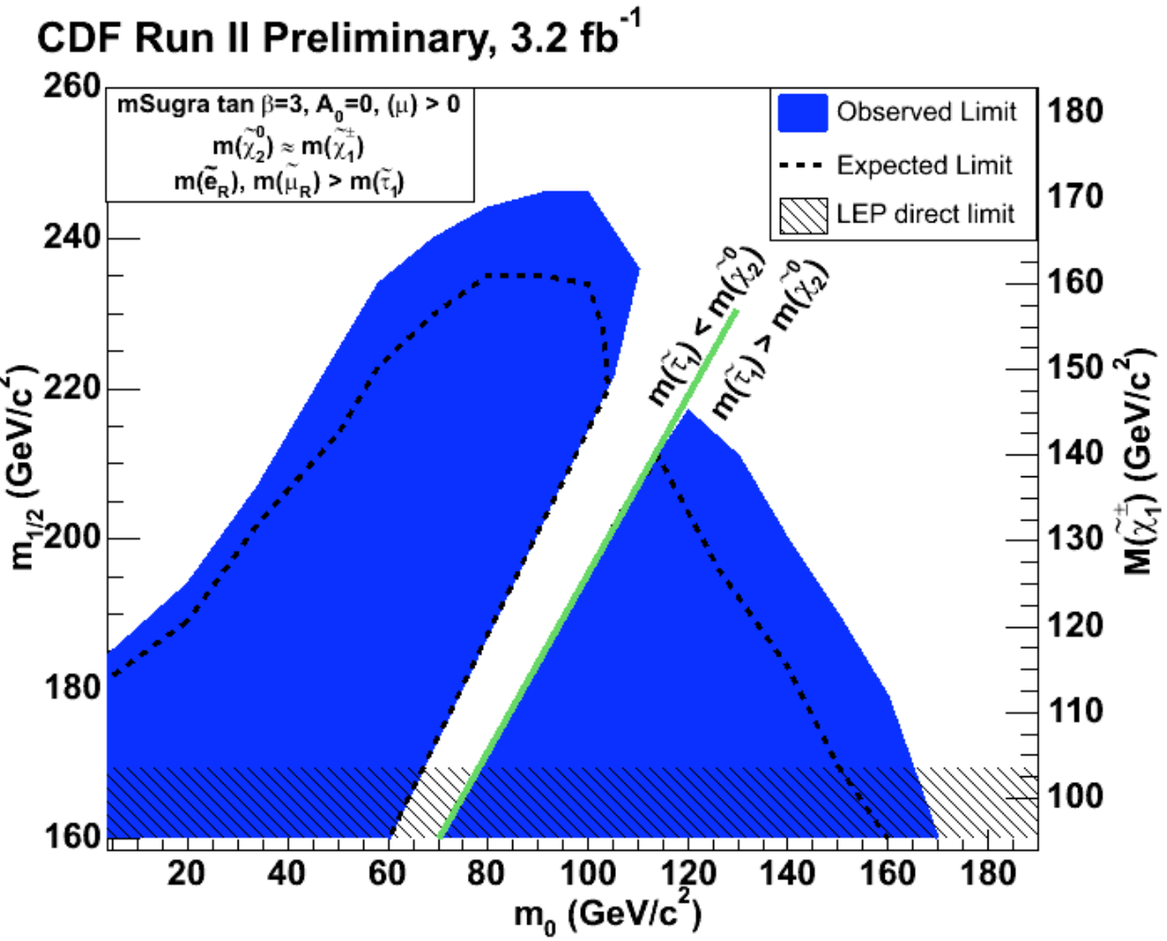


*Phys.Rev.Lett. 101, 251801 (2008)

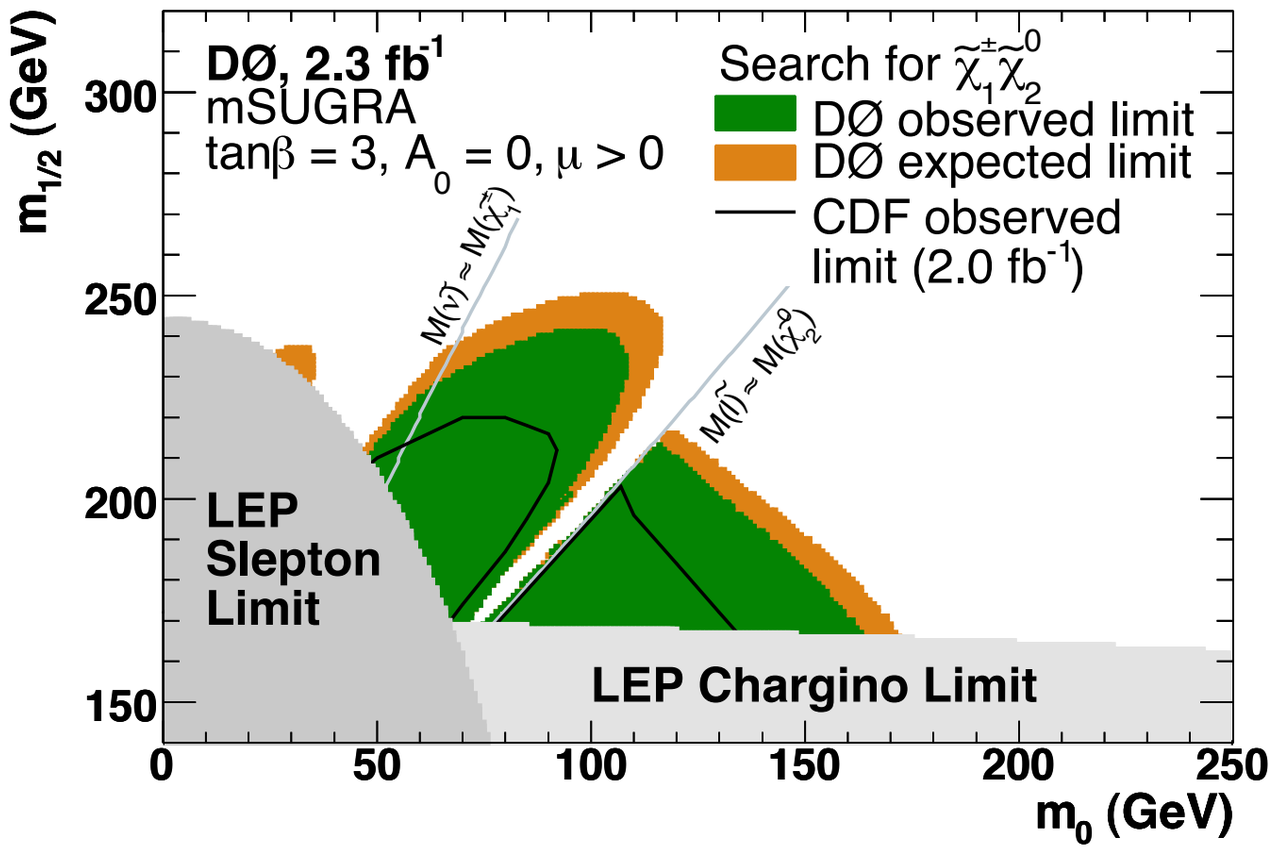
Backups

2-D Limit

This Analysis



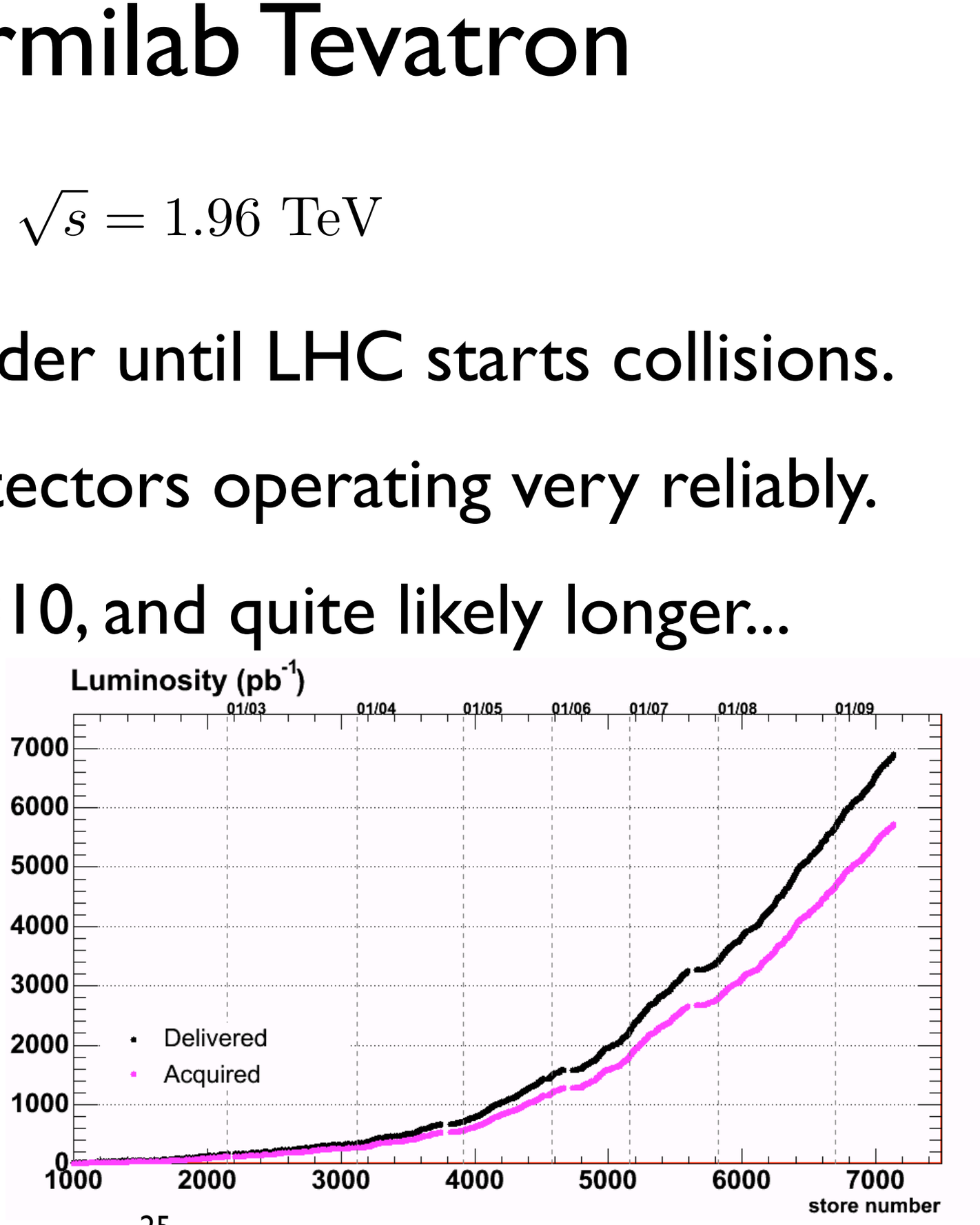
Recent D0 Result



- We observe a better than expected limit - the opposite of D0.
- Observed limits are comparable.

The Fermilab Tevatron

- P-Pbar collisions at: $\sqrt{s} = 1.96\ \mathrm{TeV}$
- Highest energy collider until LHC starts collisions.
- Accelerator and detectors operating very reliably.
- Will run through 2010, and quite likely longer...



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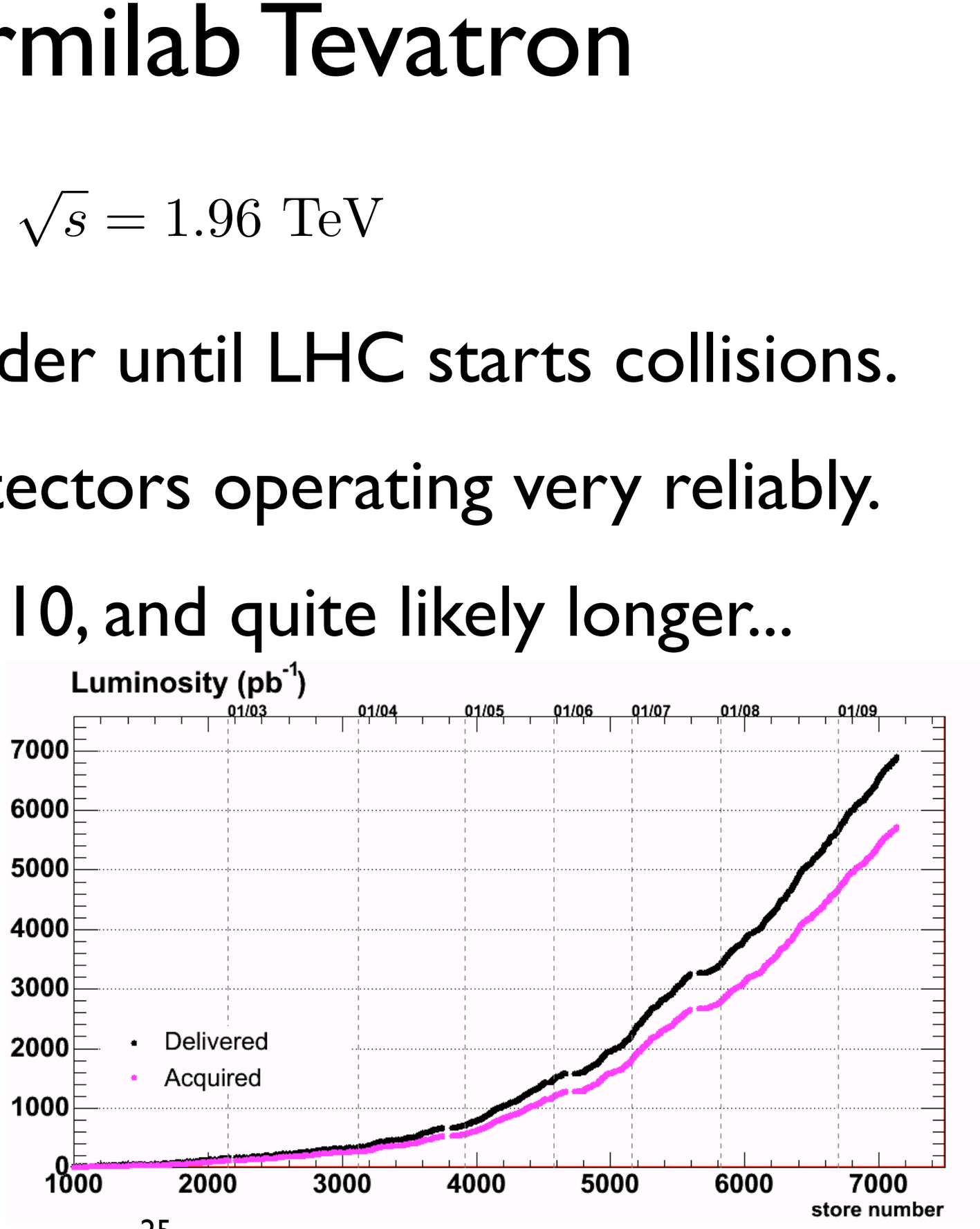
CDF Luminosity:

Delivered: ~6.9 fb^{-1}

Acquired: ~5.6 fb^{-1}

3.2 fb^{-1} (This Analysis)



Dilepton Control Regions

CR	Z→ ee	Z→ $\mu\mu$	Z→ $\tau\tau$	WW	WZ	ZZ	$t\bar{t}$	total	DATA
Tight-Tight									
!Z	15014.3	8031.6	1986.3	148.3	2.5	8.5	87.4	25279 ± 1090	24721
!Zlo	11562.2	6699.5	707.5	7.7	0.2	2.8	1.5	18981 ± 855	18859
!Zhi	1371.6	349.1	845.2	132.3	2.3	4.3	84.1	2789 ± 120	2594
Z	48268.6	31270.7	35.1	34.5	10.0	41.6	23.1	79684 ± 3175	79910
Zlo	39127.5	25963.4	16.9	2.6	0.3	15.6	0.4	65127 ± 2595	64653
Zhi	2211.2	1250.5	10.4	29.3	9.2	18.4	22.1	3551 ± 152	3756
lo	50492.9	32665.5	724.4	10.3	0.4	18.4	1.9	83914 ± 3390	83512
zee	48268.7	0.0	10.2	10.5	6.3	25.2	6.9	48328 ± 2642	48721
zmm	0.0	31267.5	6.7	6.8	3.7	16.4	4.7	31306 ± 1761	31149
hiee	3581.8	0.0	323.8	51.6	7.3	13.7	33.5	4012 ± 213	4016
himm	0.0	1569.5	146.9	30.9	3.9	8.5	21.0	1781 ± 99	1742
!Zee	15014.3	0.0	741.4	47.5	1.7	5.1	27.9	15838 ± 934	15418
!Zmm	0.0	7999.7	370.1	28.7	0.6	2.8	17.2	8419 ± 544	8162
em	0.0	35.0	893.0	89.3	0.1	0.6	53.9	1072 ± 68	1181
Tight-Loose									
!Z	2952.7	6687.9	1053.1	108.7	0.7	4.7	66.3	10874 ± 456	10807
!Zlo	1886.8	5395.6	444.3	5.8	0.0	1.5	1.1	7735 ± 354	7801
!Zhi	586.9	399.0	372.0	96.9	0.5	2.4	63.8	1522 ± 64	1485
Z	16832.9	48359.3	36.8	31.1	7.4	31.6	20.1	65319 ± 2928	64359
Zlo	13293.4	40307.0	19.6	2.3	0.3	11.8	0.4	53635 ± 2425	53136
Zhi	909.2	1941.6	10.5	26.5	6.8	13.9	19.3	2928 ± 134	2790
lo	15185.3	45601.7	463.9	8.1	0.3	13.3	1.5	61274 ± 2761	60937
zee	15781.1	0.0	7.9	3.9	1.9	8.0	2.6	15805 ± 993	16324
zmm	0.0	48297.4	10.4	10.5	5.3	23.1	6.7	48354 ± 2730	46994
hiee	1177.2	0.0	70.2	15.9	2.0	4.2	10.9	1280 ± 82	1451
himm	0.0	2247.2	108.6	41.4	5.4	11.4	27.7	2442 ± 137	2208
!Zee	2546.6	0.1	190.2	14.0	0.2	1.2	8.7	2761 ± 167	2836
!Zmm	0.0	6575.6	313.5	36.5	0.5	2.9	22.1	6951 ± 401	6901
em	1454.9	176.3	567.9	74.8	0.1	1.1	46.3	2321 ± 103	2111

Expected Signal (with sys)

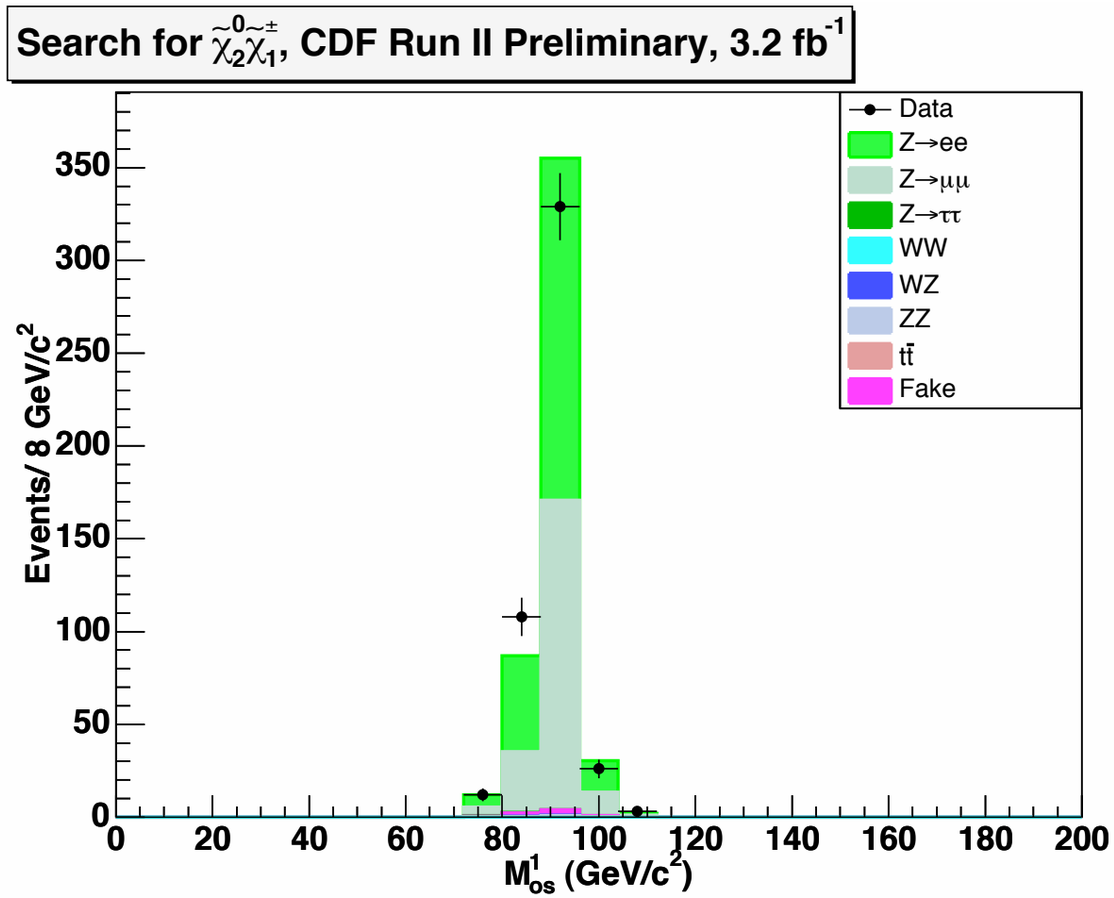
CDF II Preliminary, 3.2 fb^{-1}			
Channel	Total Background $\pm$ (stat) $\pm$ (sys)	Signal Point $\pm$ (stat) $\pm$ (sys)	Observed
ttt	$0.83 \pm 0.14 \pm 0.11$	$3.64 \pm 0.22 \pm 0.49$	1
ttC	$0.39 \pm 0.07 \pm 0.04$	$2.62 \pm 0.18 \pm 0.35$	0
tll	$0.25 \pm 0.08 \pm 0.03$	$1.12 \pm 0.12 \pm 0.15$	0
ttT	$5.85 \pm 0.57 \pm 1.11$	$7.15 \pm 0.31 \pm 0.91$	4
tlT	$3.53 \pm 0.52 \pm 0.5$	$4.06 \pm 0.23 \pm 0.53$	2

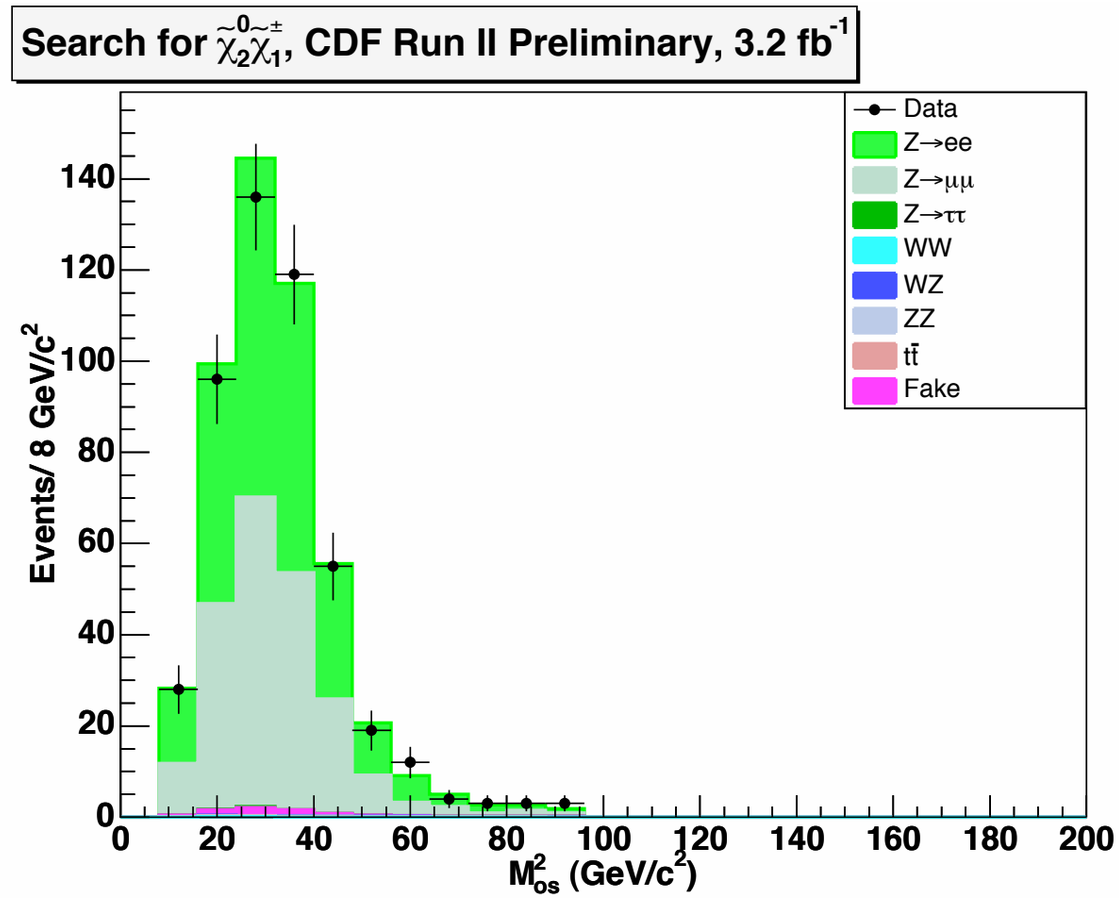
mSugra Signal point: $M_0 = 60, M_{1/2} = 190, \tan\beta = 3, A_0 = 0$

Additional event selection cuts

Cut	Description
$\Delta\phi_{OS} < 2.9(2.8)$ rad	Reduce back-to-back DY
$M_{ll} \leq 76$ GeV & $M_{ll} \geq 106$ GeV	Remove Z window for OS pairs.
$\Sigma E_t(\text{jets}) \leq 80$ GeV	Reduce $t\bar{t}$, QCD.
$N(\text{jets}) < 2$	Reduce $t\bar{t}$, QCD.

Dilepton + Track Plots - 2 Tight + Track





Z Window

Track Fakes

Measure track rate in data to get track component of **Dilepton + Track** backgrounds.

Cause:
2 Leptons from SM process
+
Random 3rd track

Measure:

Select Z events from data
Count events with $\geq$1 extra good tracks

And Apply:

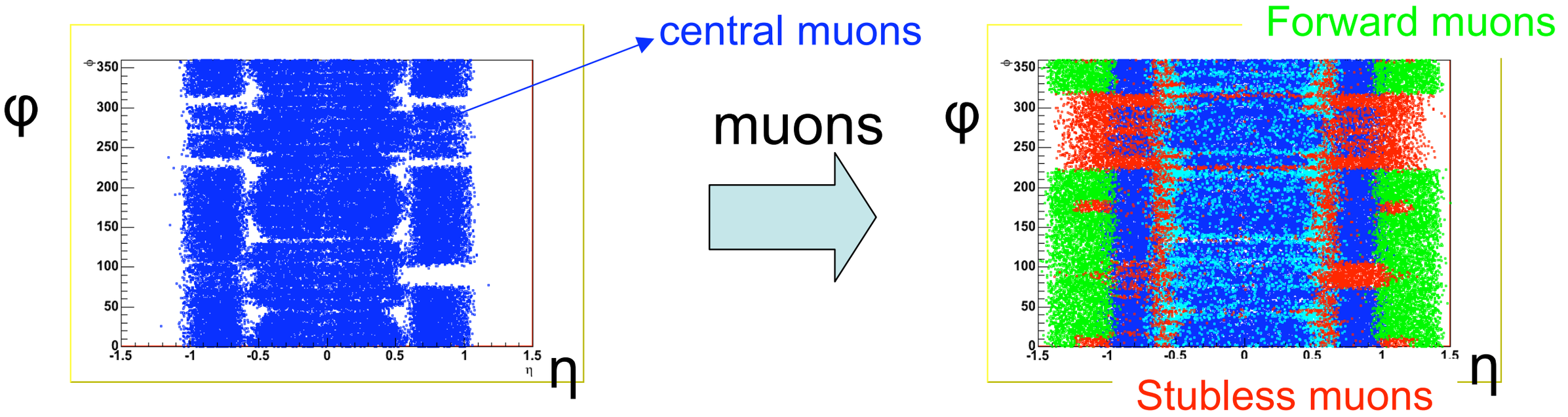
Add to MC as additional event weight.

Trilepton Stage Requirements

Cut	Description
$\Delta R > 0.4$	Cut between all leptons, tracks and jets.
$\Delta\phi > 0.35$	Between $\not\!\!E_T$ and jets.
$\Delta\phi > 0.17$	Between $\not\!\!E_T$ and leptons.
$\mathrm{M}_{OS1,2} > 20, 13\ \mathrm{GeV}/c^2$	Highest and second highest OS invariant mass.

3 Potential Acceptance Improvements:

1. Expand geometric acceptance. Including e's mu's with $|\eta| > 1$.
2. Lower P_t lepton and dilepton cuts.
3. Add hadronic Tau ID for a third object.



Increased acceptance with new muon types.