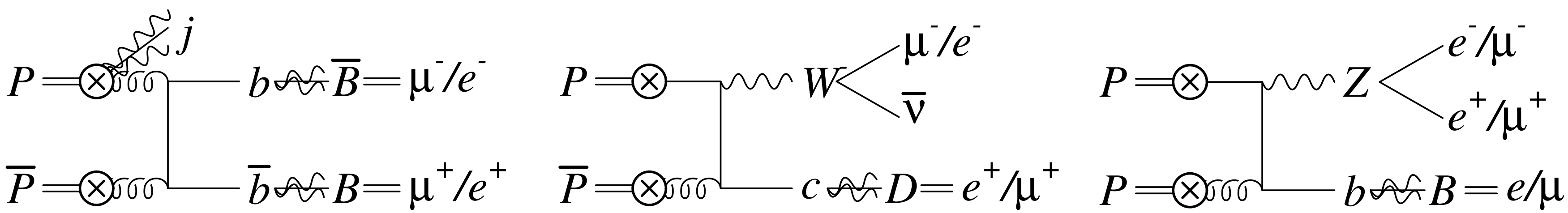
Isolated leptons from heavy flavor decays

Theory and Data



Zack Sullivan

Illinois Institute of Technology

Based on Z.S., E. Berger, hep-ph:1003.4997;
and PRD **74**, 033008 (06); PRD **78** 034030 (08).

Outline

1. The Motive
   - Dileptons: $H \to WW$ vs. leptons from heavy flavors at the LHC (ATLAS)
   - Trileptons: $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$ (The "Golden" SUSY channel) vs. leptons from heavy flavors at LHC (CMS)
2. The Physics
   - The underlying physics of isolated leptons from heavy flavors (b/c) $\Rightarrow$ isolation is a band pass filter
3. The Evidence
   - Measurement of $b\bar{b}$ to isolated muons (CDF)
4. The Verdict
   - A new rule-of-thumb: $1/200$ of all b/c look like μ or e

Dileptons and trileptons at LHC:

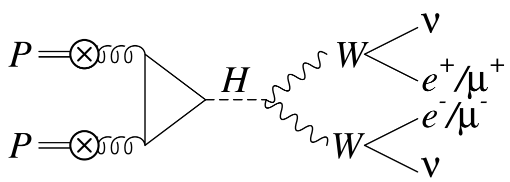
Foil: $H \to WW$

Foil: $\chi_1^{\pm} \chi_2^0$

Z.S., E. Berger, PRD 74, 033008 (2006); and PRD 78, 034030 (2008)

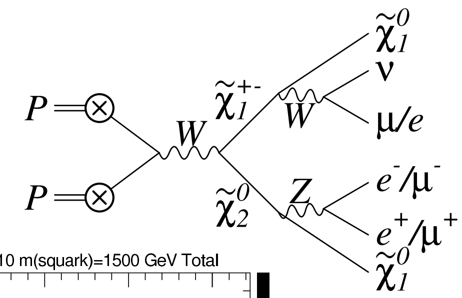
Higgs and SUSY — the main LHC searches!

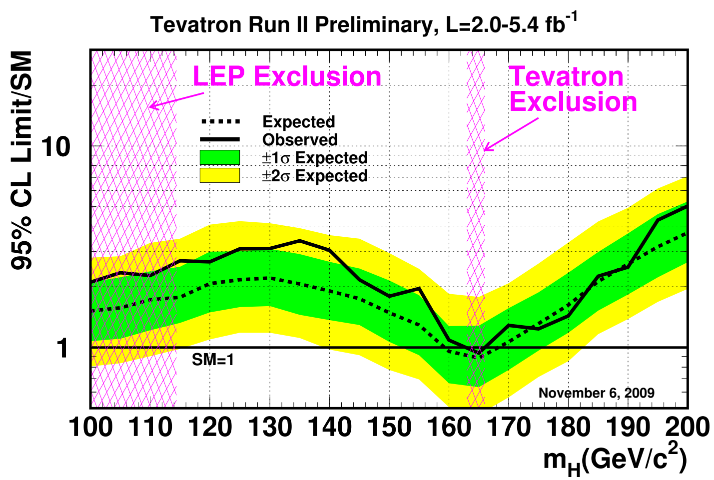
$H \rightarrow WW^* \rightarrow l^+ l^- \not{E}_T$



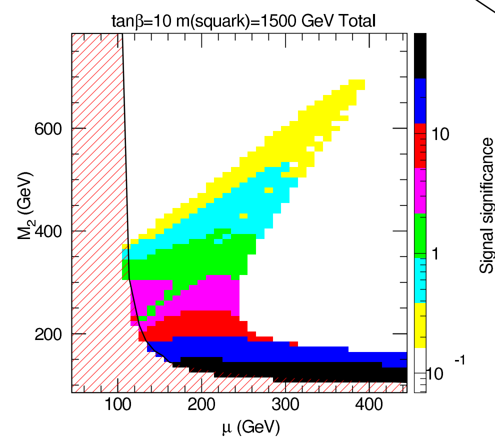
Common thread: multi-leptons$+\not{E}_T$

Trilepton SUSY





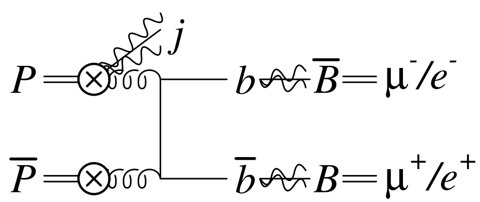
CDF & DØ, hep-ex/0911.3930, 1001.4162

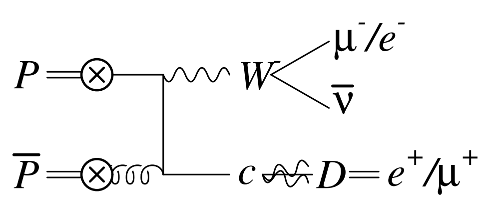


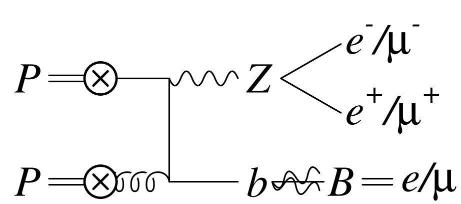
W. Vandelli, thesis

Experimentalist RULE of THUMB: All jet signals fake leptons at 10^{-4}.

Is this really true? The real physical processes below do not matter?

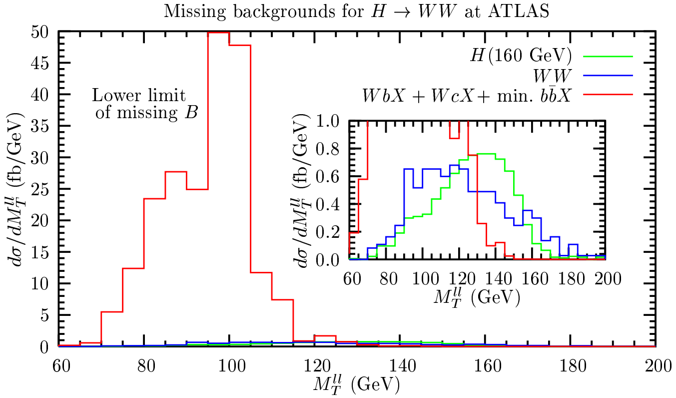




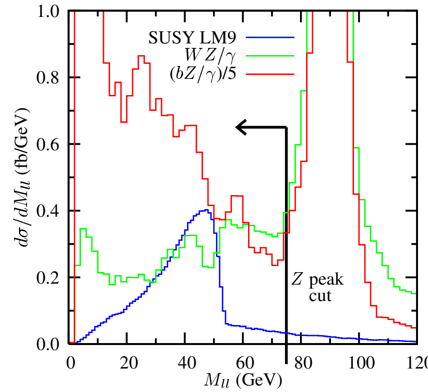


Isolated leptons from heavy flavors (b/c) in Higgs and SUSY at LHC

$H \to WW^* \to l^+ l^- \not{E}_T$



Trilepton SUSY



Isolated leptons from b/c decay 10–50$\times$ other backgrounds.

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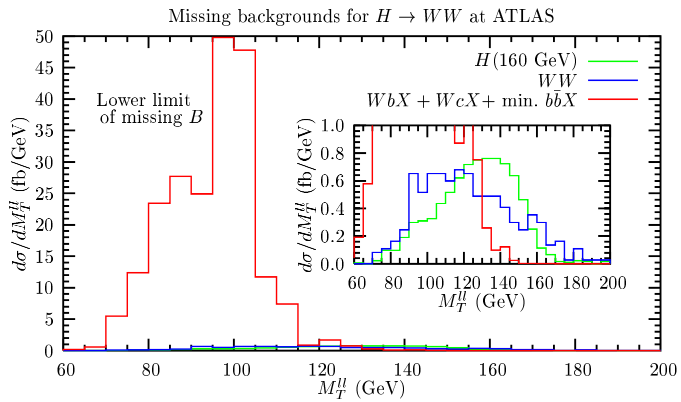

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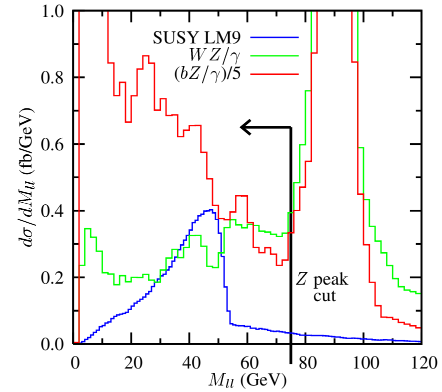

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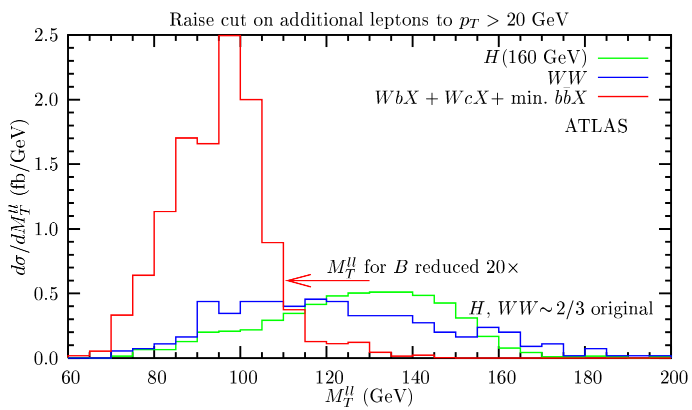
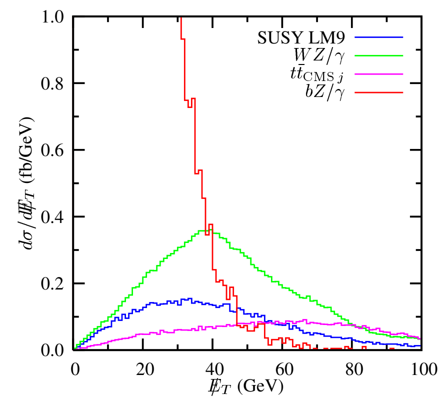
Solutions





$p_{Tl_2} > 10$ GeV $\Rightarrow p_{Tl_2} > 20$ GeV

$b\bar{b} \to b\bar{b}/30$; $S/B \sim 1$!

Z.S., E. Berger, PRD 74, 033008 (06)

Add $\not{E}_T > 30$–40 GeV, angular cuts

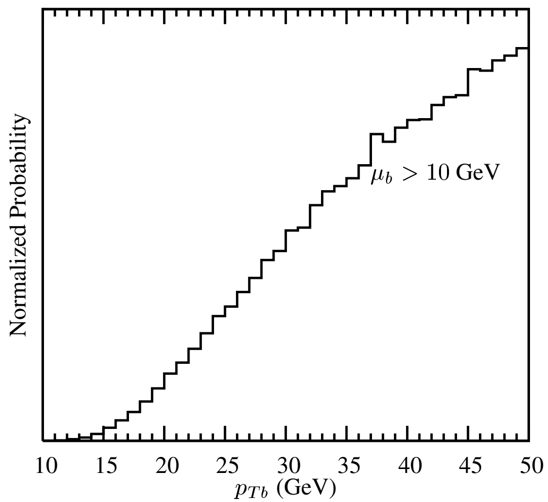
$bZ/\gamma \to bZ/\gamma/40$; $S/B \sim 1/2$!

Z.S., E. Berger, PRD 78, 034030 (08)

The physics of isolated leptons from heavy-flavor decays

Z.S., E. Berger, PRD 78, 034030 (2008); and now arXiv:1003.4997

Physics of isolated muons from b decay



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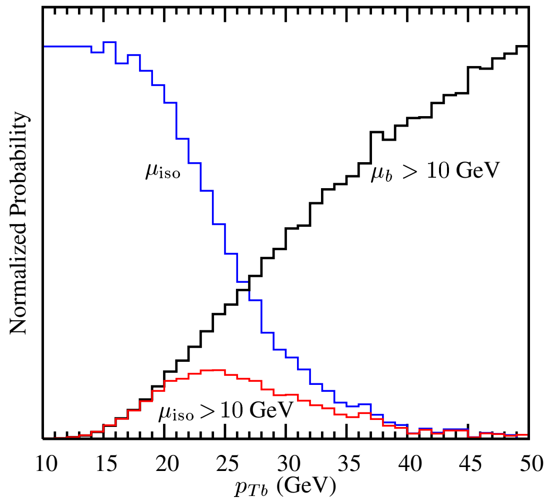


Prob. isolated muon

$= $ Prob. producing muon

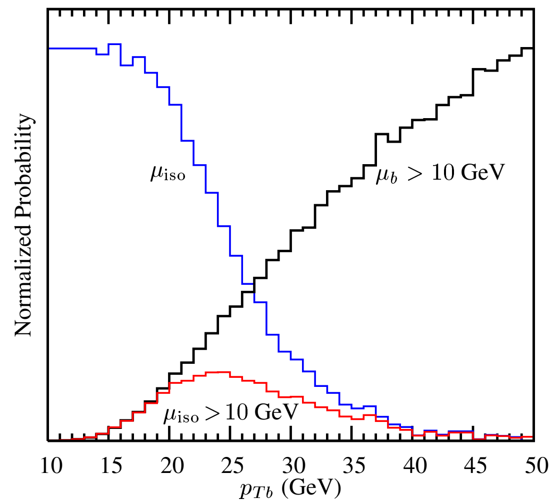
$\times$ Prob. B remnants missed

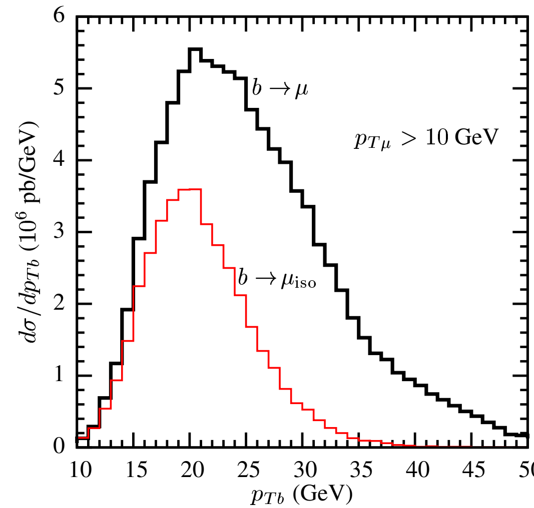
- Muons that pass isolation take large fraction of p_T
- Many isolated muons point back to primary vertex.

C. Wolfe, CDF internal

- Isolation leaves $\sim 7.5 \times 10^{-3}$ μ/b $\gg 10^{-4}$ per light jet

Physics of isolated muons from b decay





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Fold in $b\bar{b}$ production.

Old focus: $1/2$ of all 10 GeV isolated μ come from threshold, b with $p_{Tb} < 20$ GeV.

It is common for analyses to start simulations with $p_{Tb} > 20$ GeV.

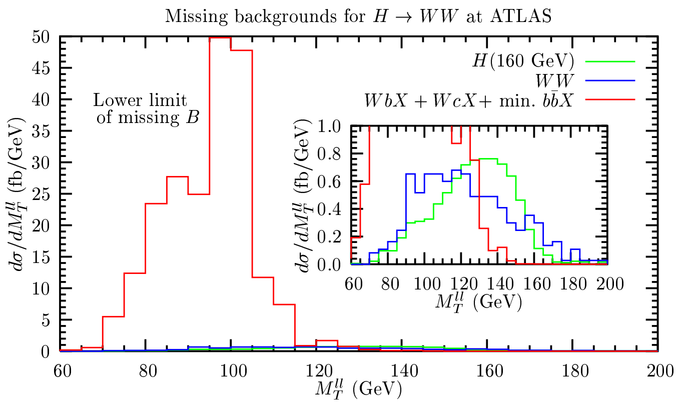
New focus: Isolation acts as a *narrow band-pass filter*!

Isolated muons of a given energy come from bs of barely more energy.

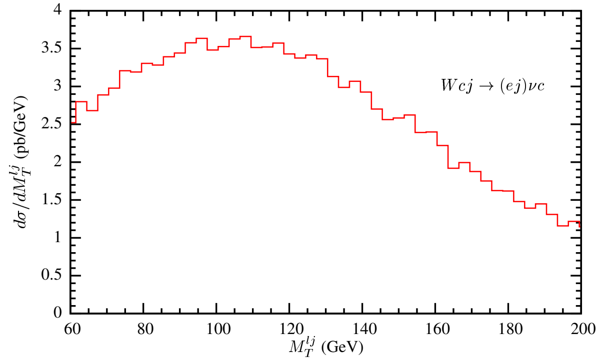
Effect of isolation on $H \to WW \to l^+l^-\not{E}_T$

Why does this new background have a hard right edge?

Why this?



Why NOT this?



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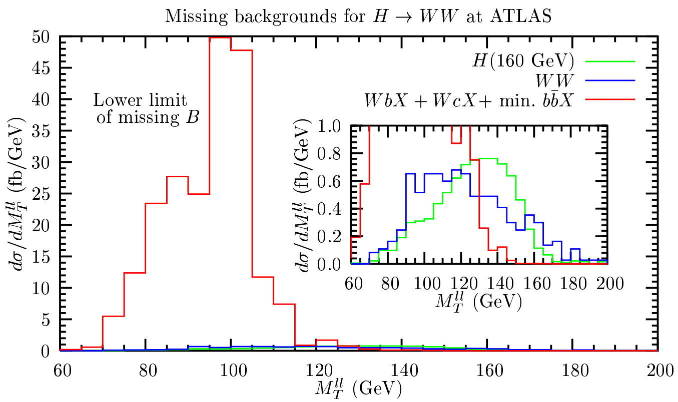

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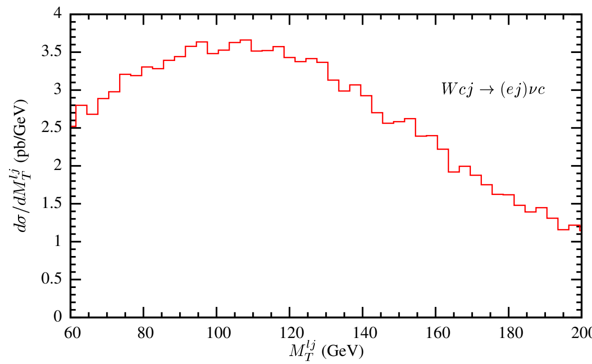
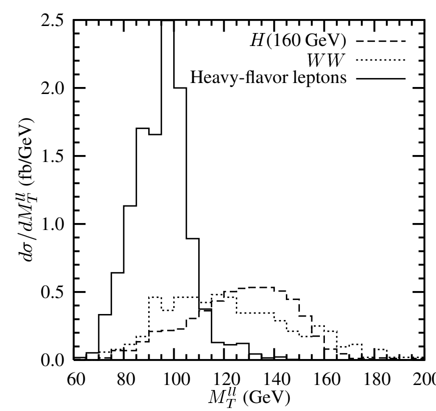


Answer: This is a direct consequence of the band-pass filter of isolation cutting off the high-p_T leptons.

Without the filter of isolation, the critical transverse mass distribution would be swamped by QCD background!

With isolation, the background to isolated μ (and e) from heavy flavor (b and c) decays is much softer.

The less well-modeled high-M_T tail of the background is suppressed.



Dimuons from $b\bar{b}$ decays in the CDF data

The foil:

A Trilepton search at CDF, PRD 79, 052004 (09)

Z.S., E. Berger, arXiv:1003.4997

Searching the data — is this real?

- In our dilepton study (PRD **74**, 033008 (06)) we recommended measuring the production of isolated muons from $b\bar{b}$ production by varying isolation cuts to extract the $\mu_{\rm iso}$ fraction.

Searching the data — is this real?

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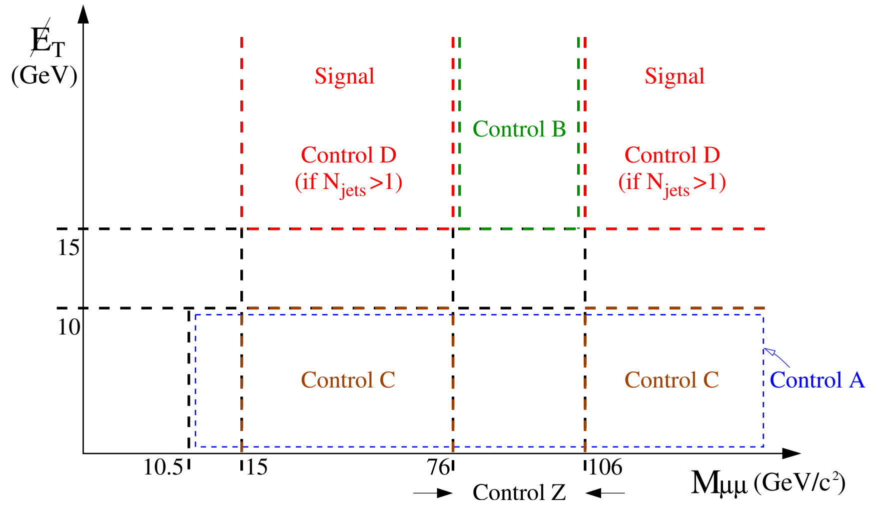
That is exactly what CDF has now done!



Region	DY	HF	Fakes	Diboson	$t\bar{t}$	**Total SM expected**	**SUSY expected**	**Observed**
Control Z	6419 ± 709	-	10 ± 11	2.4 ± 0.2	1.18 ± 0.14	6433 ± 712	0.30 ± 0.07	6347
Control A	14820 ± 2242	9344 ± 1612	2294 ± 1148	1.03 ± 0.09	0.12 ± 0.03	26459 ± 1429	0.9 ± 0.2	26295
Control B	217 ± 25	-	9 ± 7	1.7 ± 0.2	0.27 ± 0.05	227 ± 26	0.5 ± 0.1	253
Control C	5770 ± 1043	2238 ± 384	466 ± 234	0.49 ± 0.07	0.02 ± 0.01	8474 ± 857	0.7 ± 0.2	8205
Control D	7.8 ± 1.5	9 ± 4	0.3 ± 0.3	0.21 ± 0.07	4.1 ± 0.4	22 ± 5	1.8 ± 0.4	23
Signal Reg.	169 ± 30	90 ± 20	49 ± 25	6.5 ± 0.4	0.96 ± 0.11	315 ± 37	17 ± 3	297

Conclusion: Leptons from heavy-flavor decays are comparable to Drell-Yan at low M_{ll} and low $\not\!\!E_T$. CDF, PRD 79, 052004 (2009)

Comparing to CDF

Z.S., E. Berger, arXiv:1003.4997

We feed MadEvent events through PYTHIA and into the same detector simulation we used before to predict a signal for each control region. Our results are normalized to the Z peak. Our DY and $b\bar{b}$ include NLO K-factors.

	CDF		Our study	
Region	DY	$b\bar{b}$	DY	$b\bar{b}$
Control Z	6419 ± 709	—	6419 ± 752	—
Control A	14820 ± 2242	9344 ± 1621	14222 ± 1615	5118 ± 584
Control C	5770 ± 1043	2238 ± 384	4898 ± 584	924 ± 117

Conclusions:

- We consistently *underestimate* the real background from $b\bar{b}$.
- We believe our results have been conservative.
- Isolated leptons from heavy flavor decays are a significant fraction of ALL low-p_T data samples.

The verdict

Z.S., E. Berger, arXiv:1003.4997

There is unambiguous evidence of dimuons from $b\bar{b}$ decay in the CDF data. CDF, PRD 79, 052004 (2009)

Isolated leptons (μ or e) from heavy flavor decays (b or c) will play an important role in the extraction of Higgs decays, trilepton SUSY, or any process with modest-p_T leptons.

The band-pass filter effect of isolation allows us to introduce:

A new "rule-of-thumb"

- Replace 1/200 of every produced b or c quark with a muon, and 1/200 with an electron having the same momentum as the b or c.

If the resulting background is more than 10% of the signal, it should simulated more carefully, and eventually measured *in situ*.

THANK YOU

BACKUPS

Comparing invariant mass distributions

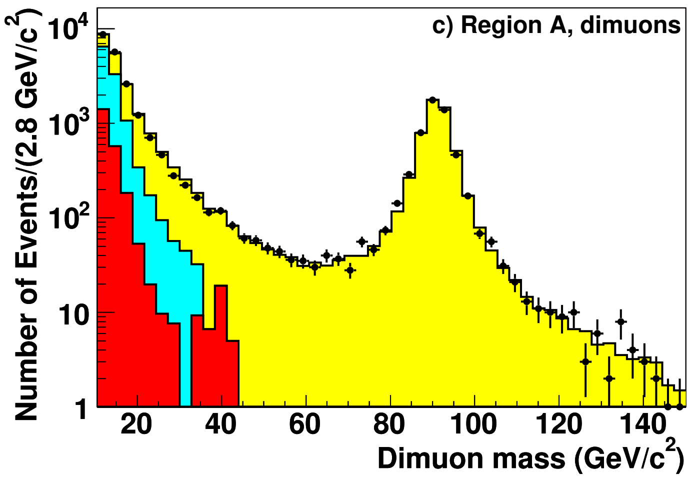
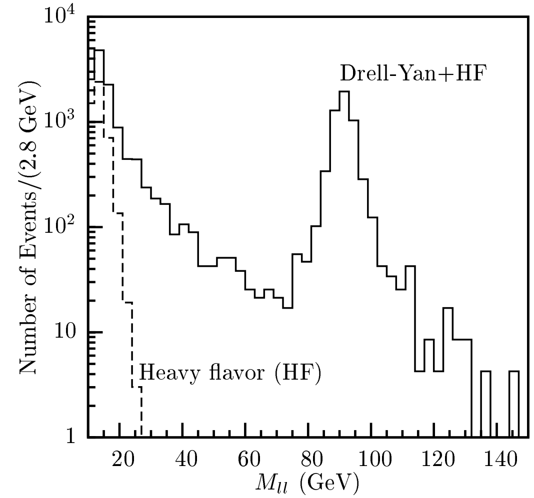


Fig. 6c, CDF, PRD 79, 052004 (2009)



Our distributions

Conclusion: Our shapes are very similar!