Uli and Signature-Based Searches With Gauge Bosons At the Tevatron

Henry Frisch

Enrico Fermi Institute,
University of Chicago

Uli Understood- test the SM

The identification of new phenomena is only possible if there are precise SM predictions- Uli's forte

Task: identify 1 in 10^{14} of these

We depended on Uli for guidance

Uli Understood- test the SM

The gauge sector- W's and Z's at a hadron collider are a filter

1 in 1,000,000

Earth::QCD Soccerball::W's and Z's

Uli focused on understanding rare events in the smaller sphere

The danger of exploring without a trusted guide who owns a SM topo

Rubbia and the 1984 Top Discovery

Volume 147B, number 6 PHYSICS LETTERS

Received 8 October 1984

A clear signal is observed for the production of an isolated large-transverse-momentum lepton in association with two or three centrally produced jets. The two-jet events cluster around the $W^{\pm}$ mass, indicating a novel decay of the Intermediate Vector Boson. The rate and features of these events are not consistent with expectations of known quark decays (charm, bottom). They are, however, in agreement with the process $W \to t\bar{b}$ followed by $t \to b\ell\nu$, where t is the sixth quark (top) of the weak Cabibbo current. If this is indeed so, the bounds on the mass of the top quark are $30\ \mathrm{GeV}/c^2 < m_t < 50\ \mathrm{GeV}/c^2$.

Table 10

	All		$\lvert\cos\theta^*\rvert < 0.8$		$\lvert\cos\theta^*\rvert < 0.8$ 60 GeV < m(4-body) < 100 GeV	
	Data	$b\bar{b}g$	Data	$b\bar{b}g$	Data	$b\bar{b}g$
Muon: $p_T > 12$ GeV	3	0.9	3	0.4	3	0.15
Electron: $E_T > 15$ GeV	9	1.3	7	0.5	7	0.25

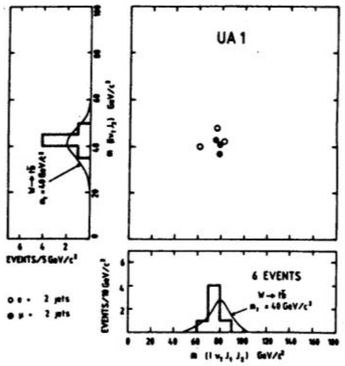


Fig. 10. Four-body versus three-body mass distribution for the six $W \to t\bar{b}$ candidate events. The effective mass of the lepton, the lower-E_T jet, and of the transverse component of the neutrino is plotted against the mass of the lepton, two-jet, transverse neutrino system. The four-body mass peaks at the W mass. The three-body mass clusters around a common value of $\sim 40\ \mathrm{GeV}/c^2$. The curves show the expected [14] distributions, taking into account the experimental resolution. Allowance should be made for a systematic error arising from uncertainties in the jet reconstruction ($\pm 10\ \mathrm{GeV}/c^2$).

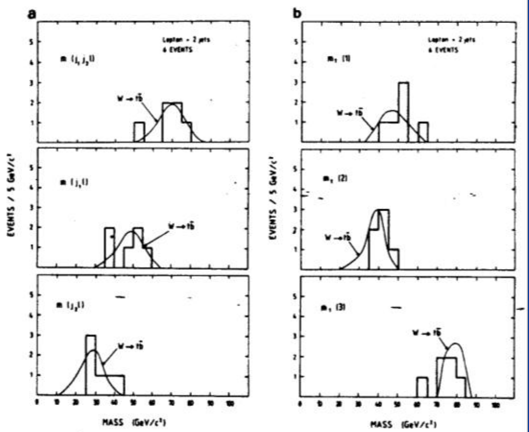


Fig. 12. Kinematic distributions for the six $W \to t\bar{b}$ candidates, compared with theoretical expectations [19] for a top mass $m_t = 40\ \mathrm{GeV}/c^2$. (a) Mass distributions for (i) the lepton two-jet system $m(j_1j_2\ell)$; (ii) the lepton highest-E_T jet system $m(j_1\ell)$; and (iii) the lepton lowest-E_T jet system $m(j_2\ell)$. (b) Transverse mass distributions defined in ref. [19]: (i) $m_T(1)$; $m_T^2(1) = m_W^2 + m_b^2 - 2m_W(m_b^2 + \hat{b}_T^2)^{1/2}$, where $\hat{b}_T$ is the transverse momentum of the highest-E_T jet. (ii) $m_T(2) = m_T(b\ell, \nu)$, where $m_T^2(c\nu) = (c_T^0 + \nu_T)^2 - (c_T + \nu_T)^2$ and $c_T^0 = (c_T^2 + m_c^2)^{1/2}$. (iii) $m_T(3) = m_T(\bar{b}b\ell; \nu)$.

Expected and so Found

Lederman and 1971 J/Psi

CHAIRMAN'S SUMMARY

L M Lederman

Columbia University

1. $\left(\frac{e}{\pi}\right)^+ \approx \left(\frac{e}{\pi}\right)^- \approx \left(\frac{\mu}{\pi}\right)^+ \approx \left(\frac{\mu}{\pi}\right)^- \cong 10^{-4}$
2. This is independent of P_T from 1.5 to 5 GeV/c.
3. This is independent of nucleon target size.
4. This is independent of CM viewing angle.
5. This is independent of s from $\sqrt{s} = 7$ to $\sqrt{s} = 53$. (See Fig. 1).

All of these statements may be true to within a factor of 2 or so.

(A BNL point is taken from a comment by R Adair). The implications are that leptons and pions have a common origin. Statement 5 implies the source mass must be less than 3-4 GeV (no threshold effects) for

$$p + p \to X + \text{anything}$$
$$\quad\quad\quad\ \ \llcorner\!\to \text{leptons}$$

or less than 1.5-2 GeV for pion production e.g. Charmed particles. Statement (1) in its lack of charge asymmetry is discouraging for charmed meson sources analogous to K-mesons. The agreement of the ISR with NAL rules out low masses (M_x > few hundred MeV) because narrow angle leptons are vetoed in the ISR measurements.

The ISR muons and NAL electrons set limits on the production of single leptons e.g. from $W^{\pm}$ up to the kinematic limit. However, it is out of fashion to convert these limits to mass limits because the necessary models are currently discredited.

The lack of $P_\perp$ "bumps" means there are no significant heavy objects (M from 3 → 10 GeV) decaying into two leptons.

History is Fickle. LL

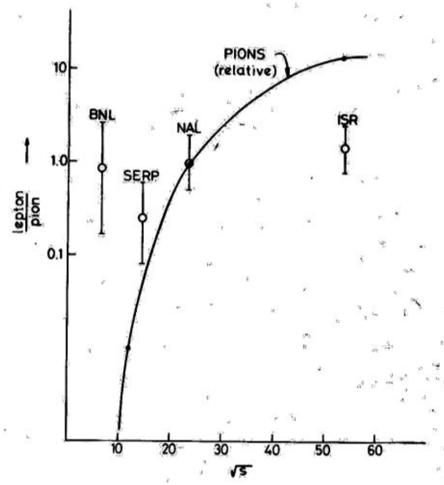
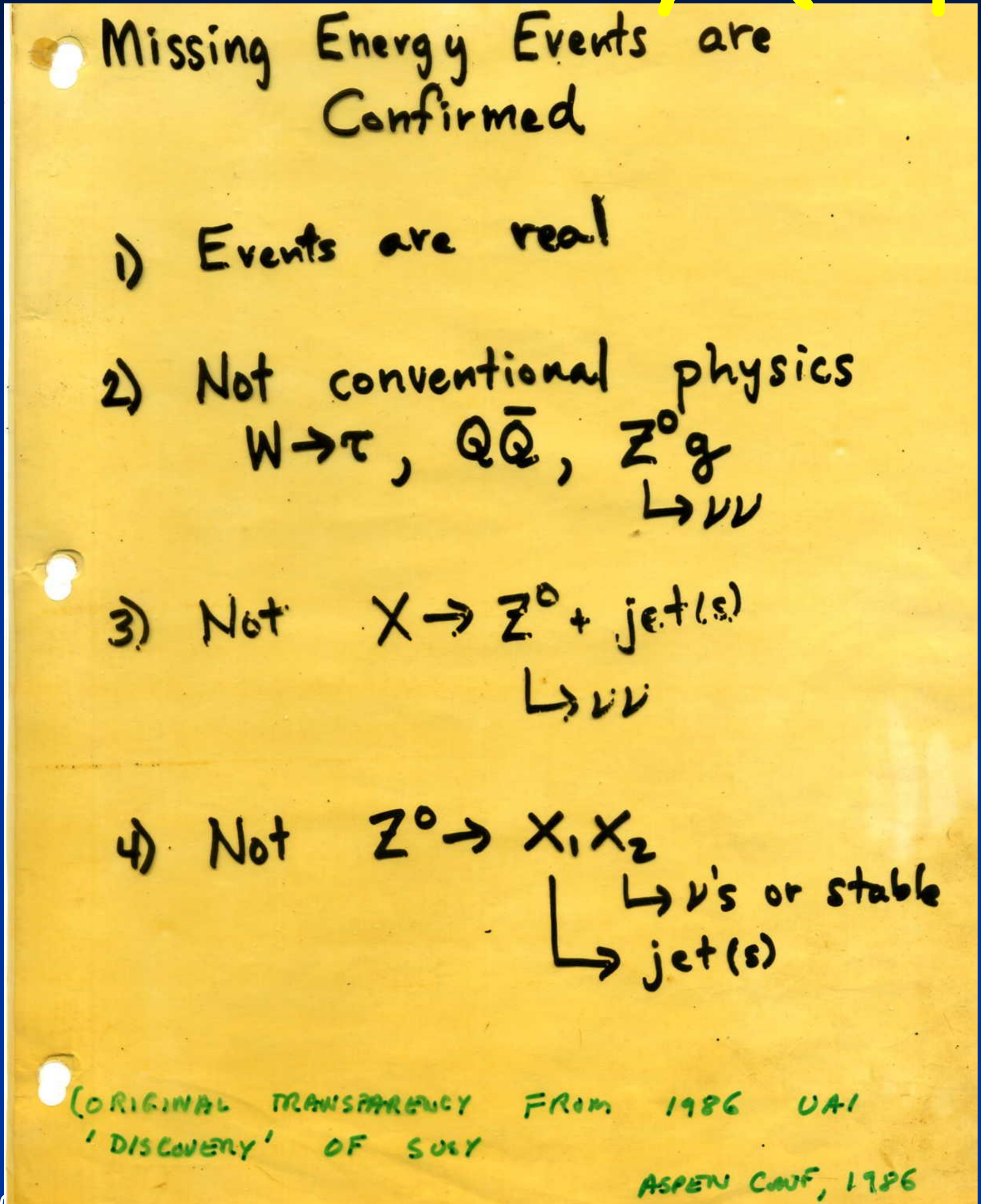


Fig. 1 lepton/pion ratio vs $\sqrt{s}$ compared to pion production ($P_\perp \sim 3$ GeV). Errors are estimated freely.

Unexpected and so Not Found

Announcement of the 1986 UA1 SUSY Discovery (Aspen 1986)



Missing Energy Events are Confirmed

1) Events are real

2) Not conventional physics
$W \to \tau$, $Q\bar{Q}$, $Z^0 g$
↳ $\nu\nu$

3) Not $X \to Z^0 +$ jet(s)
↳ $\nu\nu$

4) Not $Z^0 \to X_1 X_2$
↳ ν's or stable
↳ jet(s)

(ORIGINAL TRANSPARENCY FROM 1986 UA1 'DISCOVERY' OF SUSY
ASPEN CONF, 1986

(original transparency- don't ask)

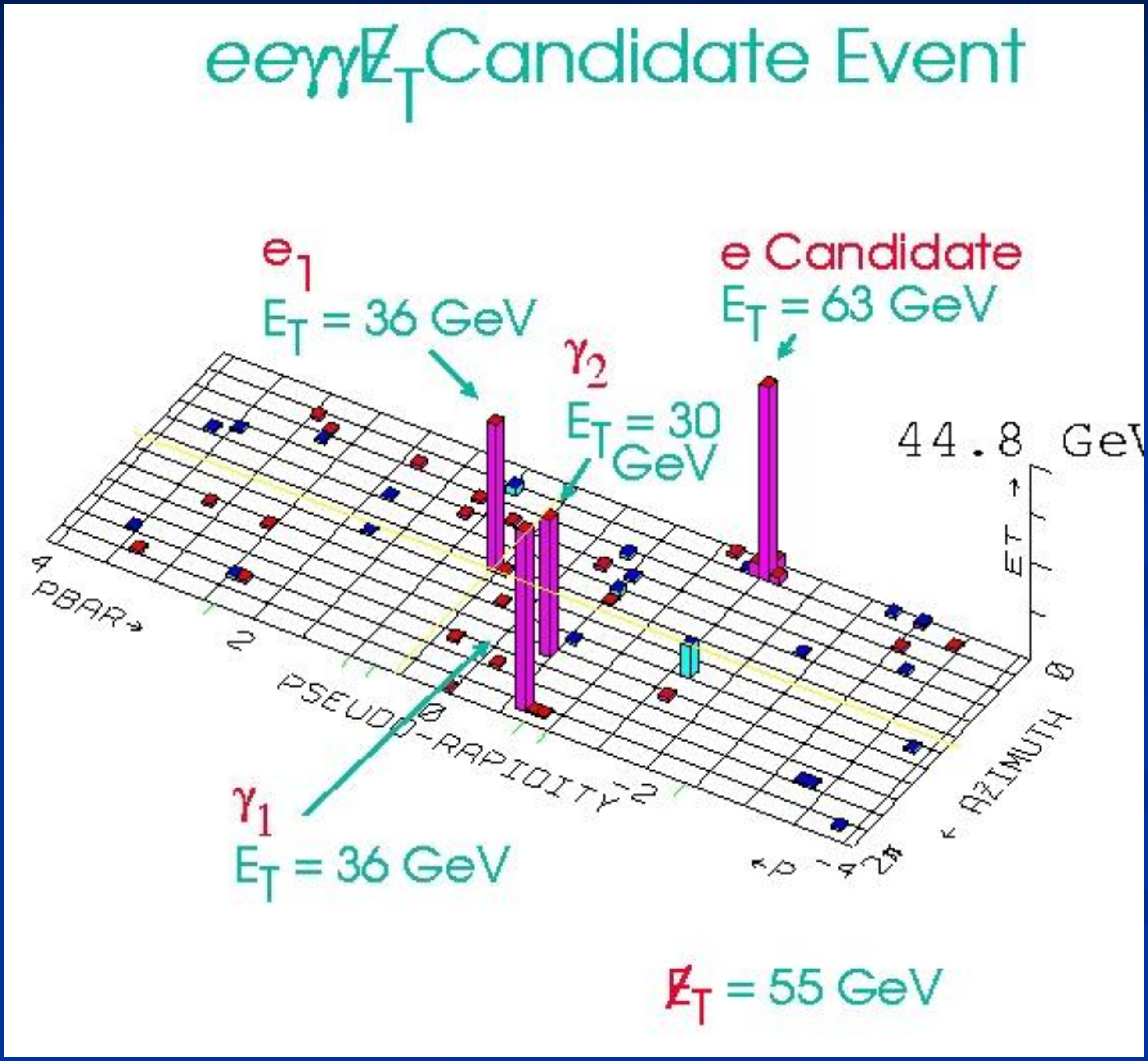
Shot down by Steve Ellis- it turned out to be explainable as a `cocktail' of SM processes – power of theory (theorists)

SelectedUli's papers related to our group's measurements

Radiative corrections to W gamma gamma production at the LHC	Precision calculations for future colliders
Weak Boson Emission in Hadron Collider Processes	Probing electroweak top quark couplings at hadron and lepton colliders
Electroweak physics at the Tevatron and LHC: Theoretical status and perspectives	Probing electroweak top quark couplings at hadron and lepton colliders.
Electroweak radiative corrections to $pp \to W^{\pm} \to \ell^{\pm}\nu$ beyond the pole approximation	Measuring the W boson mass at hadron colliders.
Electroweak radiative corrections to weak boson production at hadron colliders.	Theoretical and experimental status of the indirect Higgs boson mass determination in the standard model.
Status and prospects of theoretical predictions for weak gauge boson production processes at lepton and hadron colliders	Electroweak radiative corrections to neutral current Drell-Yan processes at hadron colliders.
Direct measurement of the top quark charge at hadron colliders	Theoretical challenges for a precision measurement of the W mass at hadron colliders.
QCD and weak boson physics in Run II	Electroweak radiative corrections to W and Z boson production at hadron colliders.
Two photon radiation in W and Z boson production at the Tevatron	Electroweak radiative corrections to W boson production in hadronic collisions.
QCD corrections and anomalous couplings in $Z\gamma$ production at hadron colliders	QED radiative corrections to Z boson production and the forward-backward asymmetry at hadron colliders.
$W\gamma\gamma$ production at the Fermilab Tevatron collider: Gauge invariance and radiation amplitude zero	Finite width effects and gauge invariance in radiative W productions and decay.
WZ production at hadron colliders: Effects of nonstandard WWZ couplings and QCD corrections	Rapidity correlations in $W\gamma$ production at hadron colliders.
The $t\bar{t}\gamma$ background to $pp \to W\gamma + X$ at the SSC	QCD corrections to hadronic $W\gamma$ production with nonstandard $WW\gamma$ couplings.
Ratios of $W\gamma$ and $Z\gamma$ cross-sections: New tools in probing the weak boson sector at the Tevatron n. b.	Probing the weak boson sector in $\bar{p}p \to Z\gamma$
Probing the weak boson sector in $Z\gamma$ production at hadron colliders	Electroweak Vector Bosons: Standard Model And Beyond.
Hadronic Production Of Electroweak Vector Boson Pairs At Large Transverse Momentum	Probing the W W gamma Vertex at Future Hadron Colliders.

Our Own Odyssey at CDF Run I

Trigmon found one event-the `eeggmet' event



Note the overlap with Uli's interests

Event looks like it has (at least) 4 gauge bosons- 2 W's and 2 gammas

Backgrounds are radiation + W and Z's- one of Uli's arenas

SM prediction is negligible- (2 very stiff gammas doesn't happen radiatively, + high pair mass, and very large met (>>MW/2))

But it's one event- what more can we do to explore beyond it?

KEY IDEA OF SIGNATURE-BASED SEARCHING

LOOK FOR SIGNATURES THAT ARE FORBIDDEN/SUPPRESSED IN THE SM-

ONE NEEDS AT LEAST SEVERAL EVENTS PER CHANNEL, AND IN (HOPEFULLY) MULTIPLE CHANNELS, BUT CAN LOOK FOR LOW CROSS-SECTION NEW PHYSICS BY LOOKING WHERE THE SM AIN'T.

WHOLE ENTERPRISE RESTS ON RELIABLE SOLID SM PREDICTIONS- IN OUR CASE PARTICULARLY EWK BOSONS…- THIS IS WHY WE WENT TO ULI SO OFTEN…

Search for signatures related by (non-SM) Branching ratios

(first signature-based search at the Tevatron, to my knowledge)

Called this looking for `cousins'-look for related BR's

ee$\gamma\gamma$-met

Example would be ttbar- look in l+jets, ll, and 6 jets…

2 decay chains each ending in a photon (e.g. GMSM)

2 decay chains ending in met, plus a decay into a photon in at least one chain (e.g. N2C1)

2 photons+X

Lepton+photon +X

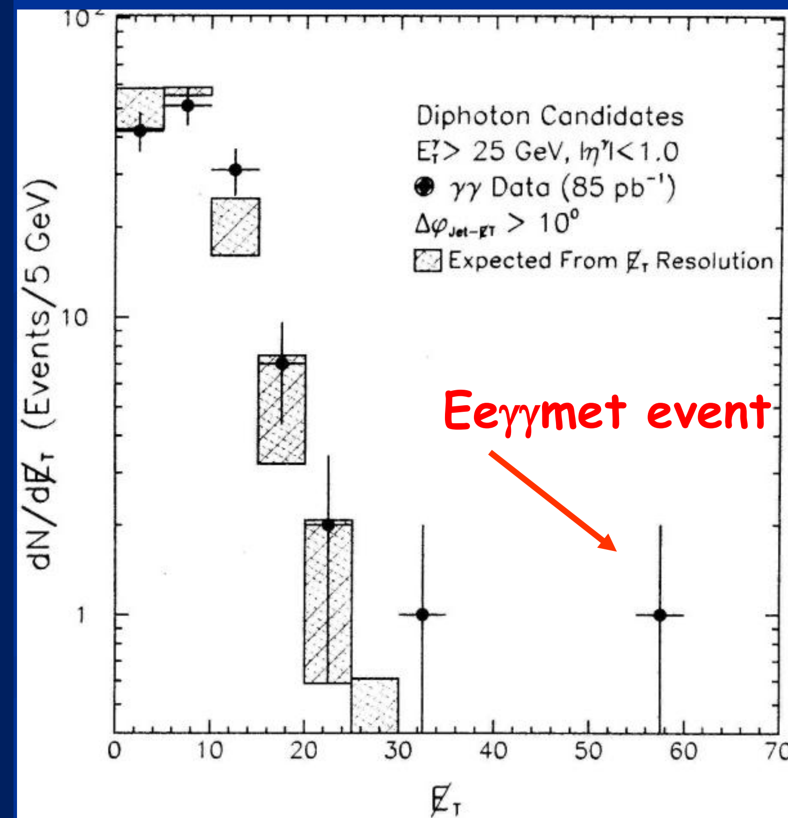
The γγmet +X signature

D. Toback Ph.D Thesis Dec. 1997 PRL 81, 1791 (1998) PRD D59,092002 (1999)

SM expectation

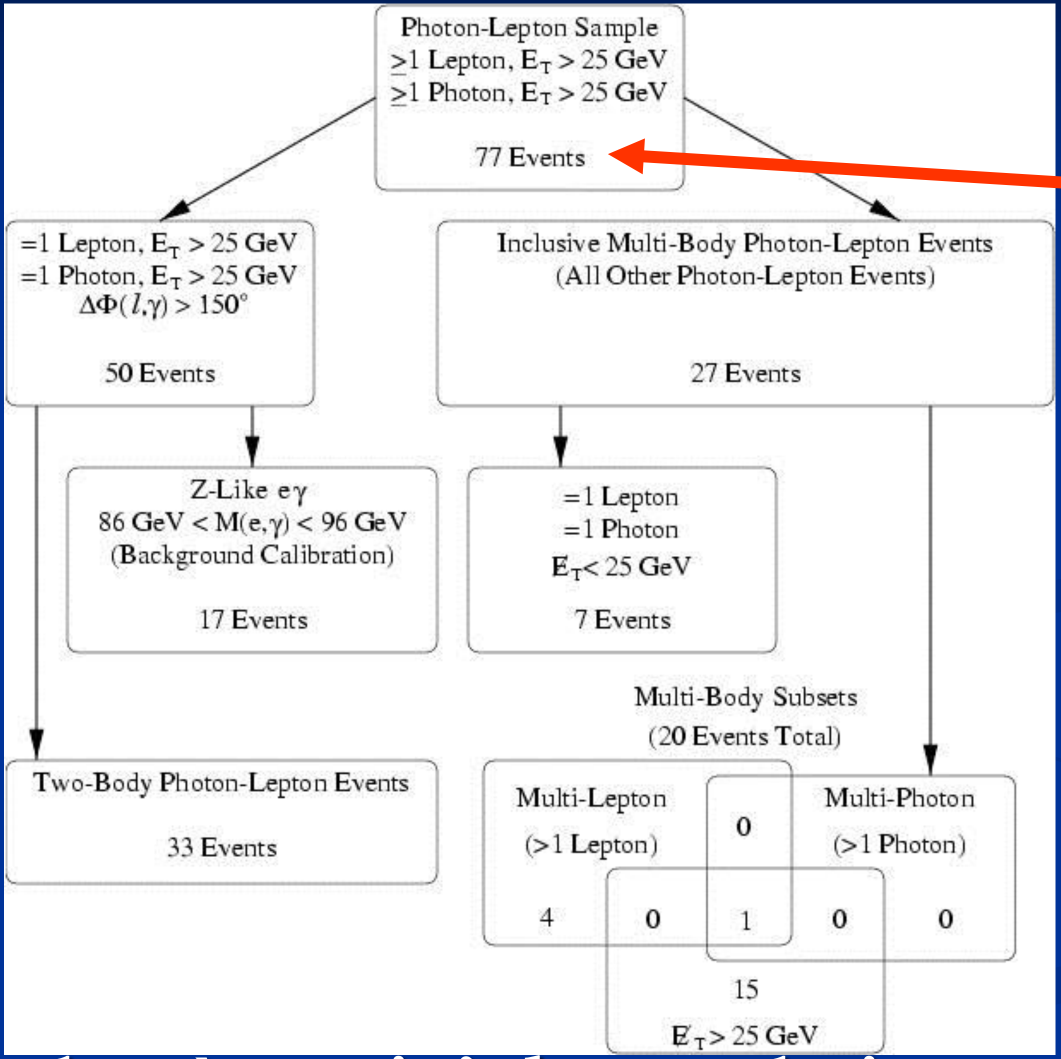
Observed

$E_T^\gamma > 12$ GeV Threshold		
Object	Obs.	Exp.
$\not{E}_T > 35$ GeV	1	0.5 ± 0.1
$N_{Jet} \geq 4$, $E_T^{Jet} > 10$ GeV, $\lvert\eta^{Jet}\rvert < 2.0$	2	1.6 ± 0.4
Central e or μ, $E_T^{e \text{ or } \mu} > 25$ GeV	3	0.3 ± 0.1
Central τ, $E_T^\tau > 25$ GeV	1	0.2 ± 0.1
b-tag, $E_T^b > 25$ GeV	2	1.3 ± 0.7
Central γ, $E_T^{\gamma_3} > 25$ GeV	0	0.1 ± 0.1
$E_T^\gamma > 25$ GeV Threshold		
Object	Obs.	Exp.
$\not{E}_T > 25$ GeV	2	0.5 ± 0.1
$N_{Jet} \geq 3$, $E_T^{Jet} > 10$ GeV, $\lvert\eta^{Jet}\rvert < 2.0$	0	1.7 ± 1.5
Central e or μ, $E_T^{e \text{ or } \mu} > 25$ GeV	1	0.1 ± 0.1
Central τ, $E_T^\tau > 25$ GeV	0	0.03 ± 0.03
b-tag, $E_T^b > 25$ GeV	0	0.1 ± 0.1
Central γ, $E_T^{\gamma_3} > 25$ GeV	0	0.01 ± 0.01



The lγmet signature

J. Berryhill Ph.D thesis, Dec. 2000 PRL 89,041802 (2002), Phys Rev D66, 12004 (2002)



Start with >4x10^12 events: this is the filter chain for rare SM signatures.

Note the dependence on precise Wγ and Zγ SM calculations- needed Uli

The other `cousin' decay chain- -one leg charged current, other neutral- e.g. C1-N2 in SUSY

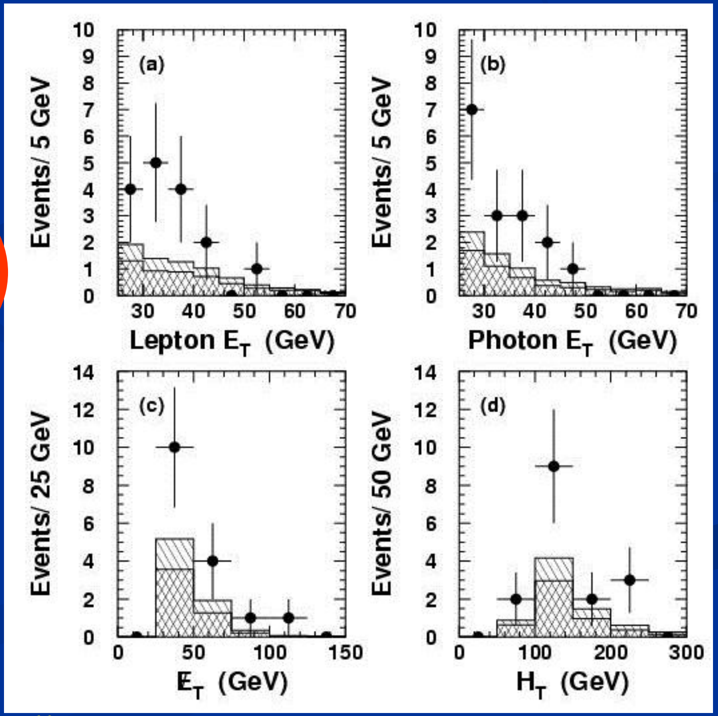
The lγmet signature-results

J. Berryhill Ph.D thesis, Dec. 2000 PRL 89,041802 (2002), Phys Rev D66, 12004 (2002)
(Run I- 86 inverse pb)

Process	$e\gamma$	$\mu\gamma$	$\ell\gamma$
W+γ	2.44 ± 0.32	2.53 ± 0.34	4.97 ± 0.59
Z+γ	5.01 ± 0.54	4.60 ± 0.54	9.61 ± 0.94
ℓ+jet, jet $\rightarrow \gamma$	1.73 ± 0.32	1.46 ± 0.27	3.19 ± 0.59
$Z \rightarrow ee, e \rightarrow \gamma$	1.68 ± 0.49	-	1.68 ± 0.49
Hadron+γ	-	0.45 ± 0.25	0.45 ± 0.25
π/K Decay+γ	-	0.28 ± 0.31	0.28 ± 0.31
b/c Decay+γ	< 0.01	< 0.01	< 0.01
Mean Rate μ_{SM}	10.87 ± 0.97	9.33 ± 1.00	20.19 ± 1.66
CDF Data N_0	11	16	27
$P(N \geq N_0 \mid \mu_{SM})$	0.52	0.037	0.10

SM expect.

Observed



Note muons are P=4%- but I'm a firm believer in Trieman's theorem:
"You get (are allowed) only one miracle"

Run II eeγγmet Event Followup: lγ+X

In γ-l+X we found a 2.7s excess over SM. What to do?

Decided to repeat the analysis in Run II with the SAME (published) cuts-- forces it to be *a priori*. Only way to test.

Note- NOT optimized for GMSB, but is unchanged from Run I selection (we had to argue this with the CDF collab.).

CDF Run I PRL: ..***"an interesting result, but … not a compelling observation of new physics. We look forward to more data…"*** **(am proud of this- not so easy)**

Run II eeggmet Event Followup

Andrei Loginov repeated the lgmet analysis- same cuts (no optimization- kept it truly a priori.

Run II: 929 pb-1 at 1.96 TeV vs Run I: 86 pb-1 at 1.8 TeV

Analysis

- $\mathcal{L} \approx 1\ fb^{-1}$ (2002 - 2006)
- **DATA Samples** (High-P_T Lepton **OR** High-E_T Photon Trigger)
- **Signature-Based Search** ($\ell\gamma \not\!\!E_T$, $\ell\ell\gamma$, $e\mu\gamma$, $\ell\gamma\gamma$)
- *a priori* **defined cuts (same as in Run I):**
  - 25 GeV for "tight" central ($|\eta| \lesssim 1$) objects: e, μ, γ
  - 25 GeV for $\not\!\!E_T$
  - 20 GeV for "loose" central ($|\eta| \lesssim 1$) objects: e, μ
  - 15 GeV for electrons in end-plug calorimeter ($1 \lesssim |\eta| \lesssim 2$)
- **MadGraph, CompHep and Baur LO MC**
- **From LO to NLO:** $K_{factor} = \frac{\sigma_{NLO}}{\sigma_{LO}}$

  U.Baur, T.Han, J.Ohnemus PRD 48:5140, 1993

  U.Baur, T.Han, J.Ohnemus PRD 57:2823-2836, 1998

Run II eeggmet Event Followup

Run II: 929 pb-1 at 1.96 TeV

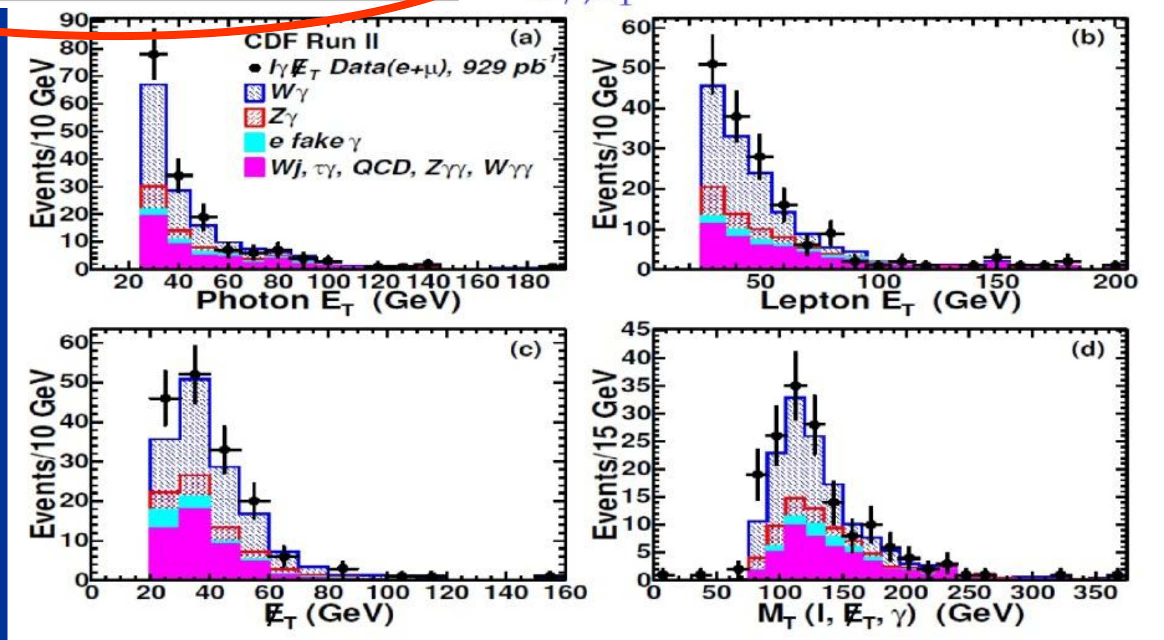
A. Loginov ITEP PhD thesis,
Phys Rev D75, 11201 (2007)

Lepton+Photon+$\not\!\!E_T$ Events, $\mathcal{L} = 929$ pb^{-1}

SM Source	$e\gamma\not\!\!E_T$	$\mu\gamma\not\!\!E_T$	$(e+\mu)\gamma\not\!\!E_T$
$W^{\pm}\gamma$	41.65 ± 4.84	29.85 ± 5.62	71.50 ± 10.01
$Z^0/\gamma^* + \gamma$	3.65 ± 1.31	14.10 ± 2.36	17.75 ± 3.65
$W^{\pm}\gamma\gamma$	0.32 ± 0.04	0.18 ± 0.03	0.50 ± 0.06
$Z^0/\gamma^* + \gamma\gamma$	0.09 ± 0.01	0.38 ± 0.05	0.47 ± 0.06
$t\bar{t}\gamma$	0.88 ± 0.12	0.54 ± 0.08	1.42 ± 0.19
$\ell e \not\!\!E_T$, $e \to \gamma$	9.59 ± 0.76	1.43 ± 0.23	11.02 ± 0.81
$W^{\pm}$+Jet faking γ	21.5 ± 4.8	6.2 ± 3.6	27.7 ± 6.0
$W^{\pm}\gamma$, $Z^0/\gamma^* + \gamma \to \tau\gamma$	2.15 ± 0.56	0.76 ± 0.24	2.91 ± 0.65
QCD (Jets faking $\ell + \not\!\!E_T$)	15.0 ± 4.1	$0.0^{+0.1}_{-0.0}$	15.0 ± 4.1
DIF (Decays-In-Flight)	–	2.3 ± 0.7	2.3 ± 0.7
Total SM Prediction	94.8 ± 8.1	55.7 ± 7.1	150.6 ± 13.0
Observed in Data	96	67	163

‘ Anomally’ went away- should have gotten stronger if real- key is SM expectation (Uli)

$\ell\gamma\not\!\!E_T$



ttbar+Gamma: Adding a b-quark, >=3 jets, and large Ht

Irina Shreyber and Andrei: start with lgamma-met:

add the requirement of a b-quark: e or μ, γ, b+X

(nice channel for BSM)

TABLE I: Summary for the $\ell\gamma \not{E}_T b$ search. Backgrounds from WW, ZZ, and single top quark with an additional radiated photon are found to be negligible.

CDF Run II, $1.9 fb^{-1}$			
Lepton + Photon + $\not{E}_T$ + b Events			
SM Source	$e\gamma b \not{E}_T$	$\mu\gamma b \not{E}_T$	$(e+\mu)\gamma b \not{E}_T$
$t\bar{t}\gamma$ semileptonic	2.06 ± 0.38	1.52 ± 0.28	3.58 ± 0.65
$t\bar{t}\gamma$ dileptonic	1.30 ± 0.23	1.02 ± 0.18	2.32 ± 0.41
$W^{\pm}c\gamma$	0.75 ± 0.16	0.72 ± 0.15	1.47 ± 0.26
$W^{\pm}cc\gamma$	0.08 ± 0.04	0.22 ± 0.06	0.30 ± 0.08
$W^{\pm}bb\gamma$	0.62 ± 0.11	0.42 ± 0.08	1.04 ± 0.17
$Z(\tau\tau)\gamma$	0.13 ± 0.09	0.11 ± 0.08	0.24 ± 0.12
WZ	0.08 ± 0.04	0.01 ± 0.01	0.09 ± 0.04
$\tau \to \gamma$ fake	0.12 ± 0.01	0.10 ± 0.01	0.22 ± 0.01
Jet faking γ	4.56 ± 1.92	3.02 ± 1.19	7.58 ± 3.11
Mistagged b-jets	4.11 ± 0.41	3.54 ± 0.37	7.65 ± 0.70
QCD	1.5 ± 0.8	$0.0^{+1.0}_{-0.0}$	$1.5^{+1.3}_{-0.8}$
$ee\not{E}_T b$, $e \to \gamma$	1.50 ± 0.28	–	1.50 ± 0.28
$\mu e \not{E}_T b$, $e \to \gamma$	–	0.45 ± 0.10	0.45 ± 0.10
Predicted	$16.8 \pm 2.2(tot)$	$11.1^{+1.7}_{-1.4}(tot)$	$27.9^{+3.6}_{-3.5}(tot)$
Observed	16	12	28

Irina Shreyber Ph.D thesis,
Phys Rev D80, 1 (2009)

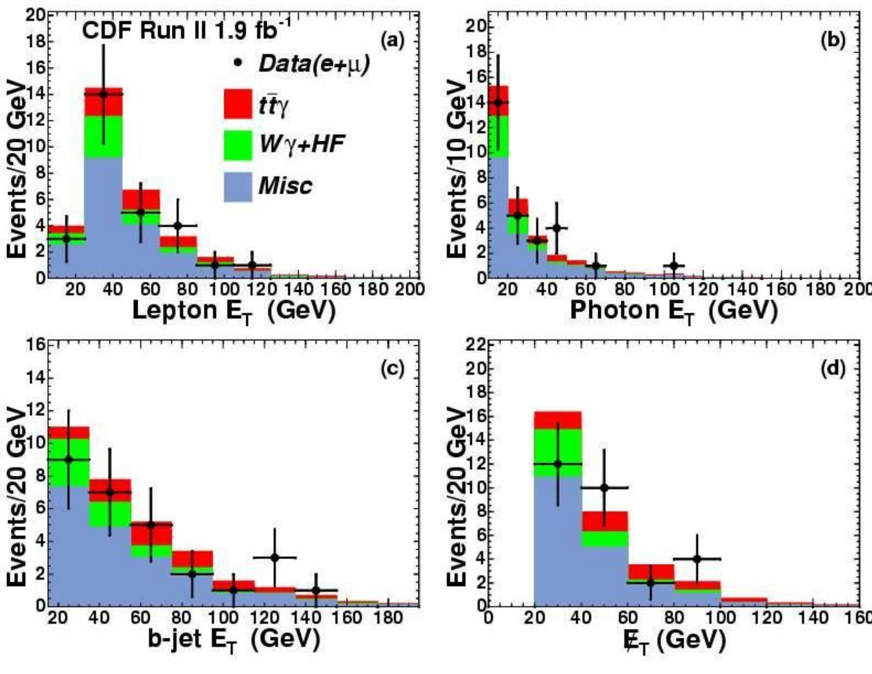
Then add requirement for >=3 jets+ large Ht to look for SM radiative top decays: ttbar+ γ

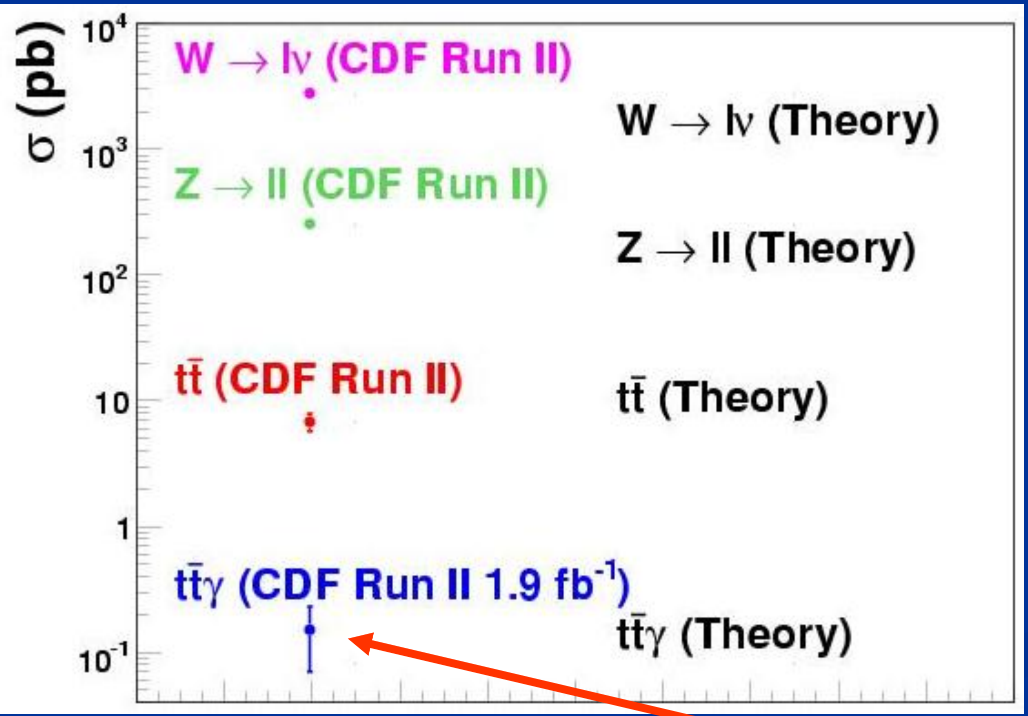
TABLE II: Summary of the expected SM contributions to the $t\bar{t}\gamma$ search. Backgrounds from WW, ZZ, single top quark with an additional radiated photon are found to be negligible.

CDF Run II, $1.9 fb^{-1}$			
$t\bar{t}\gamma$			
SM Source	$e\gamma b \not{E}_T$	$\mu\gamma b \not{E}_T$	$(e+\mu)\gamma b \not{E}_T$
$t\bar{t}\gamma(semileptonic)$	1.97 ± 0.36	1.47 ± 0.27	3.44 ± 0.62
$t\bar{t}\gamma(dileptonic)$	0.52 ± 0.10	0.43 ± 0.08	0.95 ± 0.17
$W^{\pm}c\gamma$	$0.0^{+0.02}_{-0}$	$0.0^{+0.02}_{-0}$	$0^{+0.03}_{-0}$
$W^{\pm}cc\gamma$	$0.0^{+0.02}_{-0}$	0.01 ± 0.01	$0.01^{+0.02}_{-0.01}$
$W^{\pm}bb\gamma$	0.06 ± 0.03	0.01 ± 0.01	0.07 ± 0.03
WZ	0.02 ± 0.02	$0.0^{+0.02}_{-0}$	0.02 ± 0.02
$\tau \to \gamma$ fake	0.08 ± 0.01	0.02 ± 0.01	0.10 ± 0.01
Jet faking γ	2.37 ± 1.22	1.42 ± 0.70	3.79 ± 1.92
Mistagged b-jets	0.78 ± 0.20	0.83 ± 0.22	1.61 ± 0.31
QCD	0.5 ± 0.5	$0.0^{+1.0}_{-0.0}$	$0.5^{+1.1}_{-0.5}$
$ee\not{E}_T b$, $e \to \gamma$	0.34 ± 0.11	–	0.34 ± 0.11
$\mu e \not{E}_T b$, $e \to \gamma$	–	0.20 ± 0.06	0.20 ± 0.06
Predicted	$6.7 \pm 1.4(tot)$	$4.4^{+1.3}_{-0.8}(tot)$	$11.1^{+2.3}_{-2.1}(tot)$
Observed	8	8	16

ttbar+Gamma

Irina Shreyber, ITEP Ph.D thesis,
Phys Rev D80, 1 (2009)
$1.9\ pb^{-1}$





No surprises- nothing really heavy, wild, or odd-

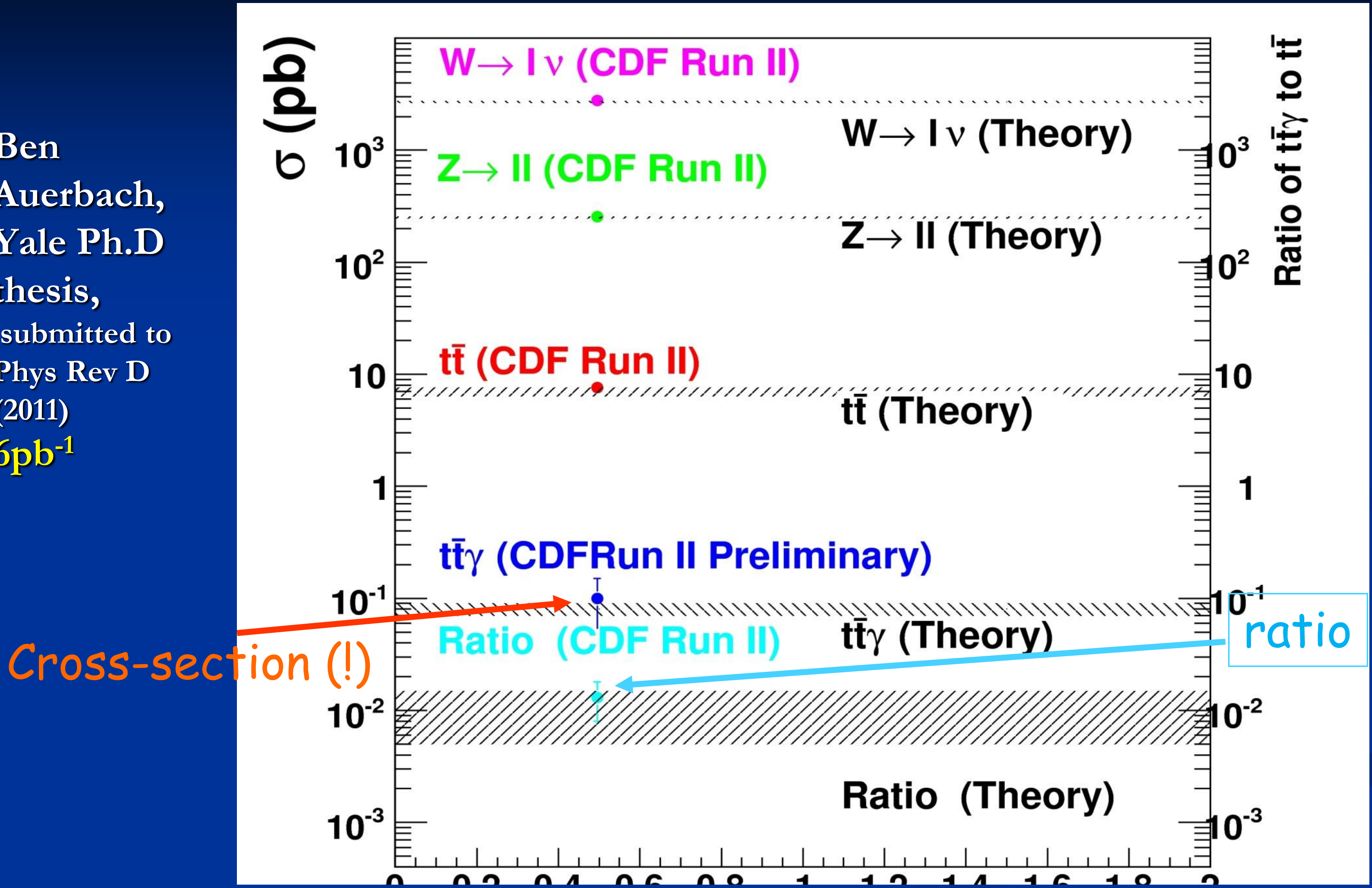
Consistent with ttbargamma =0.15+-0.08 pb (80 fb (!))

ttbar-gamma cross-section (?)

ttbar+Gamma:- next student…

Ben Auerbach, Yale Ph.D thesis, submitted to Phys Rev D (2011)

6pb^{-1}

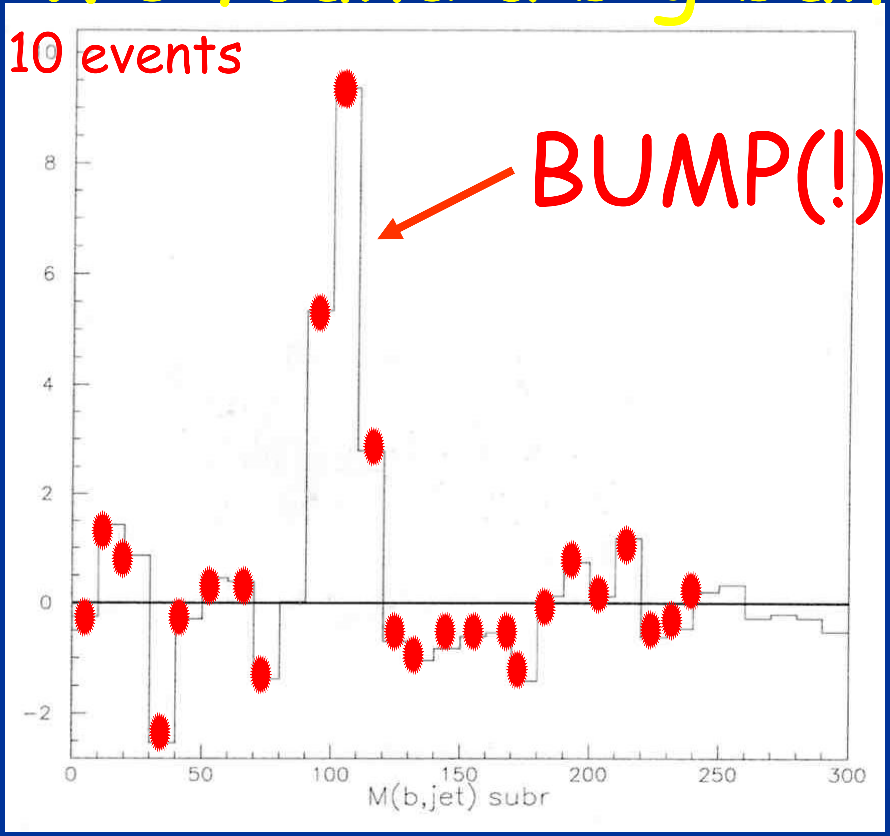


Note Uli ttγ paper- also control for ttbarH

Now for something wild and alas: Run I: the Eeggmet event and the gbjmet signature

Gordy Kane suggested looking for
C2N2-> stopbγN1->bcγmet

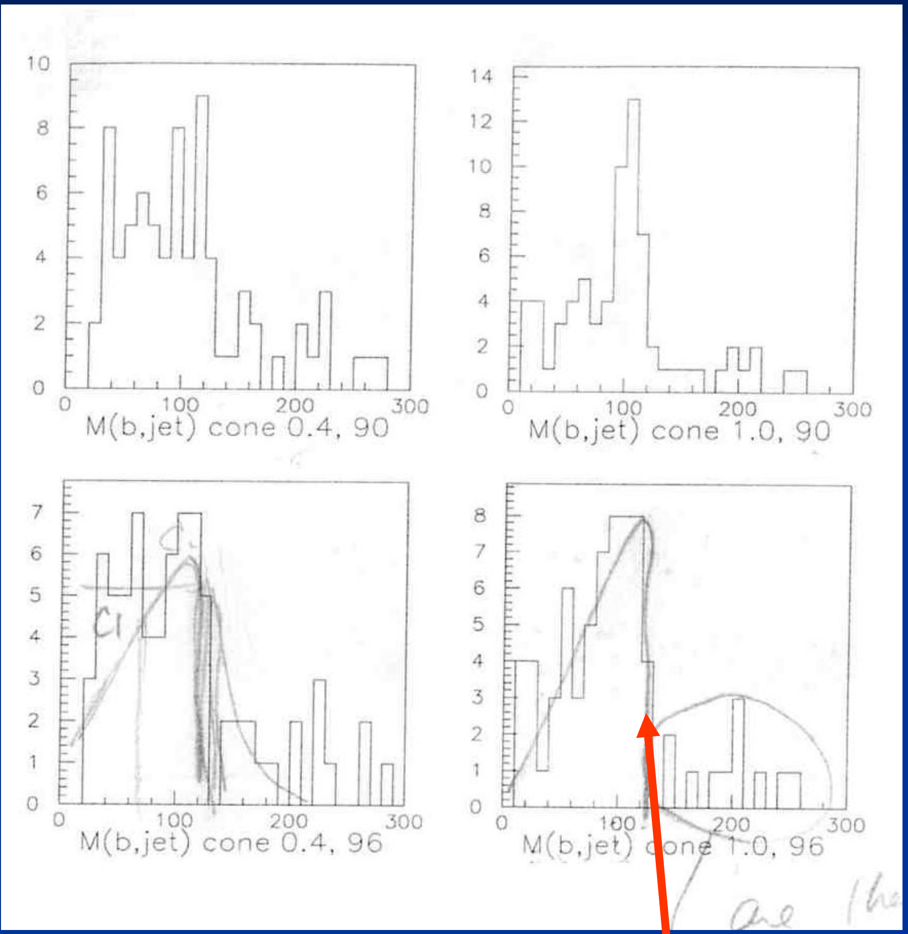
We found a big bump(!)

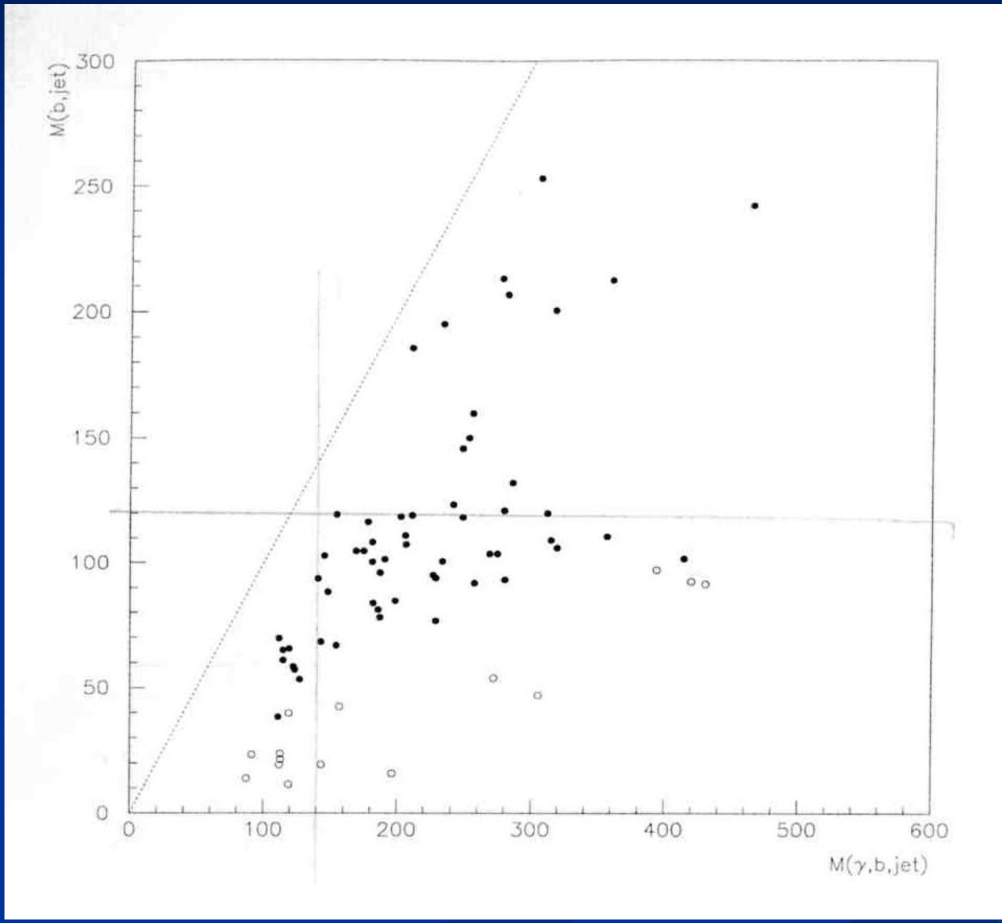


M(b,jet)

- **This was a priori-selected cone=1.0 for dijet mass from UA2 W ->jj detection**
- **We got excited (even Gordy)- but data not robust to changing cuts, and too little statistics to be sure…**

Run I: gbjmet signature cont.



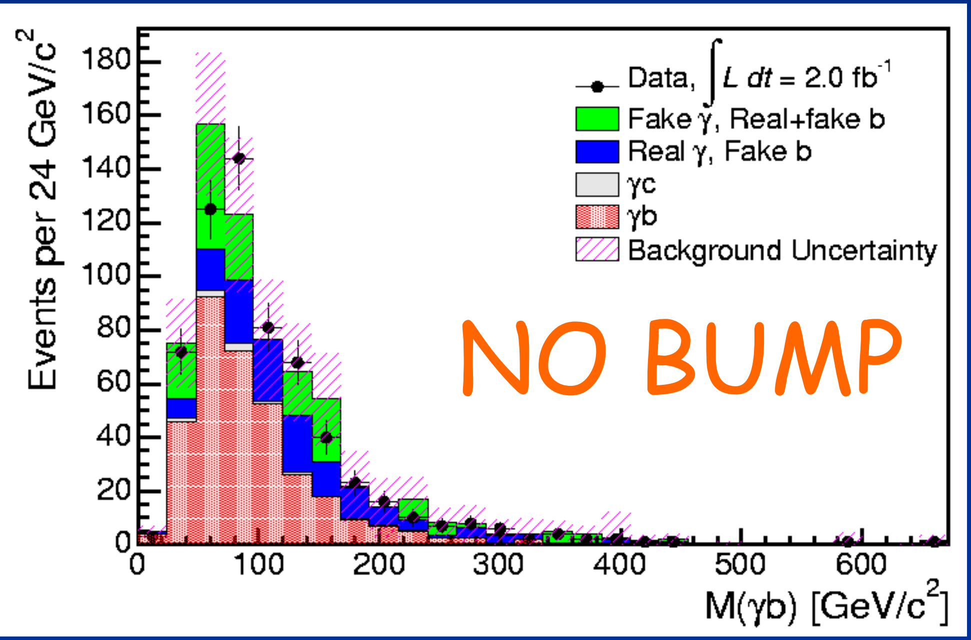


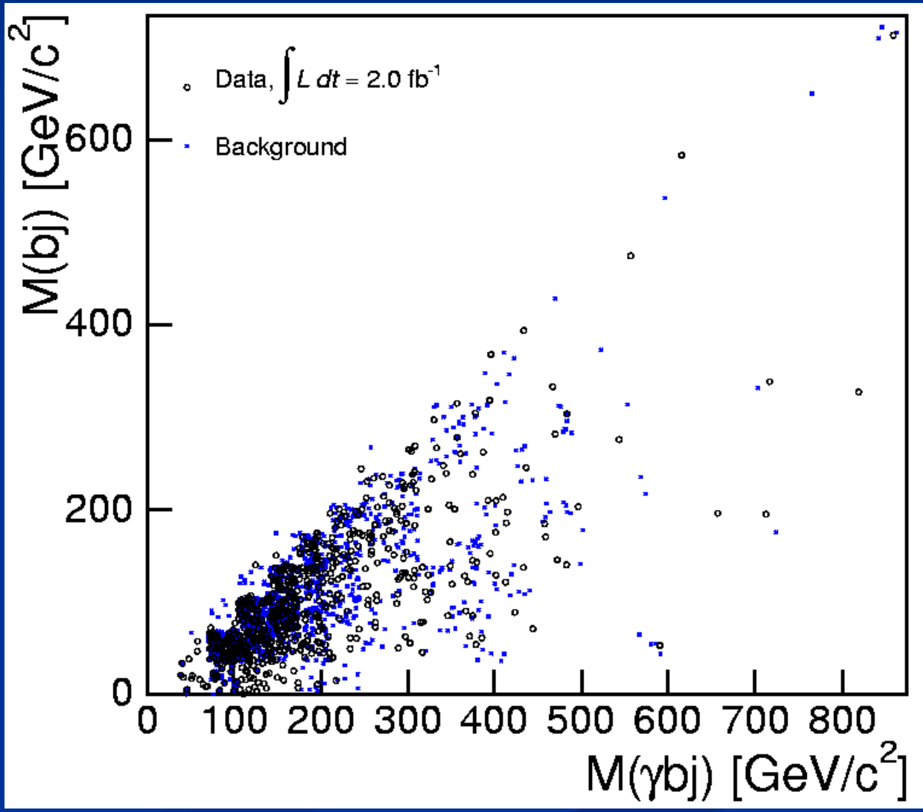
Different cone sizes: a) not robust; b) kinematic edge?

D3-body vs 2-body mass- bump and outliers- odd? (or not)

Run II- the gbjmet signature

- Dan Krop, Shin-Shan Yu, Carla Pilcher, Scott Wilbur, Ray Culbertson, HJF
- Look at the same 2 plots with >20 times the data





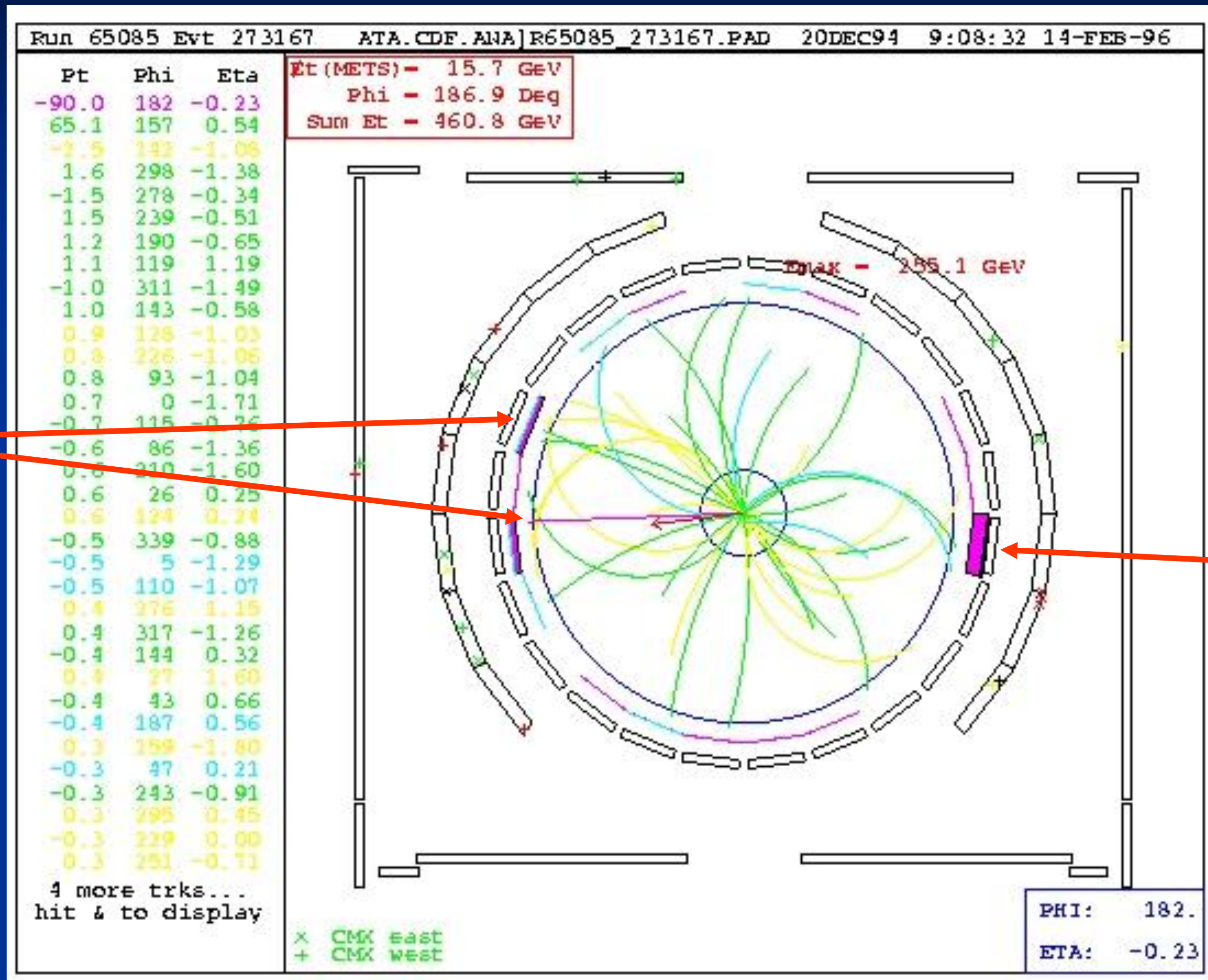
As Sasha Paramonov would say, \`Alas' (\`worse than losing a girl-friend')

PRD D80, 52003 (2009)

Run I: Other Odd Events with Photons and Leptons (another Uli interest)

Just one example

2 legs of the Z (!)



200 Gev Photon

- Z-boson to mu-mu balanced by a 200 GeV-Pt photon (presumably)

Run II: Search High Pt Z+X

Look at a central Z +X, for Pt > 0, 60, 120 GeV, and at distributions…
Need SM predictions even for something as `simple' as this

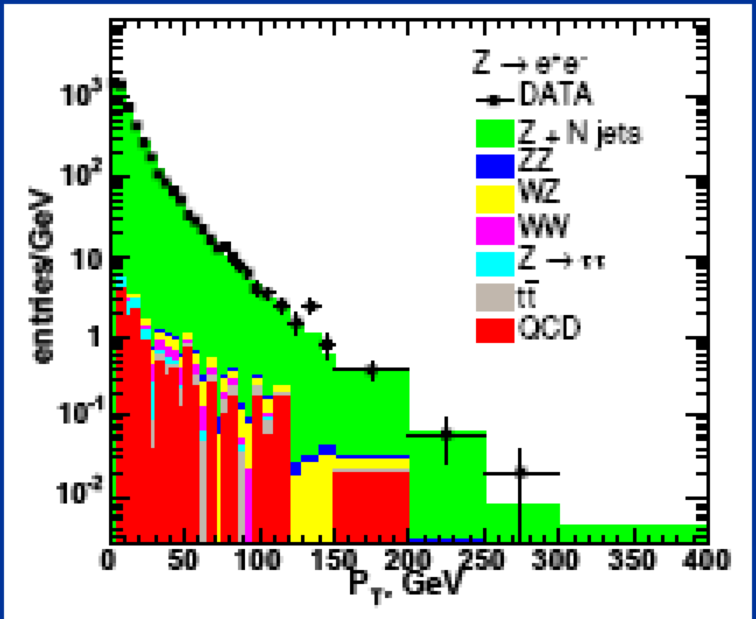
5 Observed and Expected events in each P_T-category

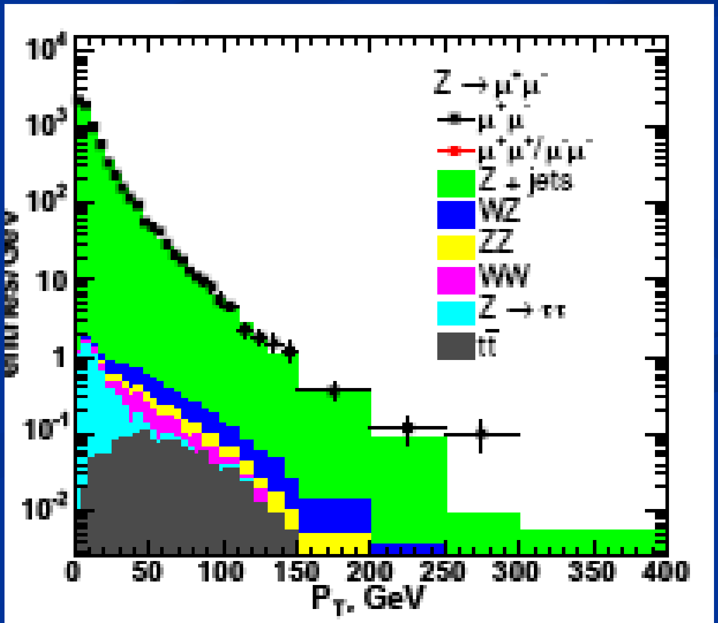
Z + X	Inclusive	$P_T(Z) > 60$ GeV	$P_T(Z) > 120$ GeV
$Z \to e^+e^-$	25079	587	70
$Z \to \mu^+\mu^-$	34222	721	74

Table 1: Number of Z + X events observed in each category.

Z + X	Inclusive	$P_T(Z) > 60$ GeV	$P_T(Z) > 120$ GeV
$Z \to e^+e^-$	25079	500	53.7
$Z \to \mu^+\mu^-$	34222	650	61.8

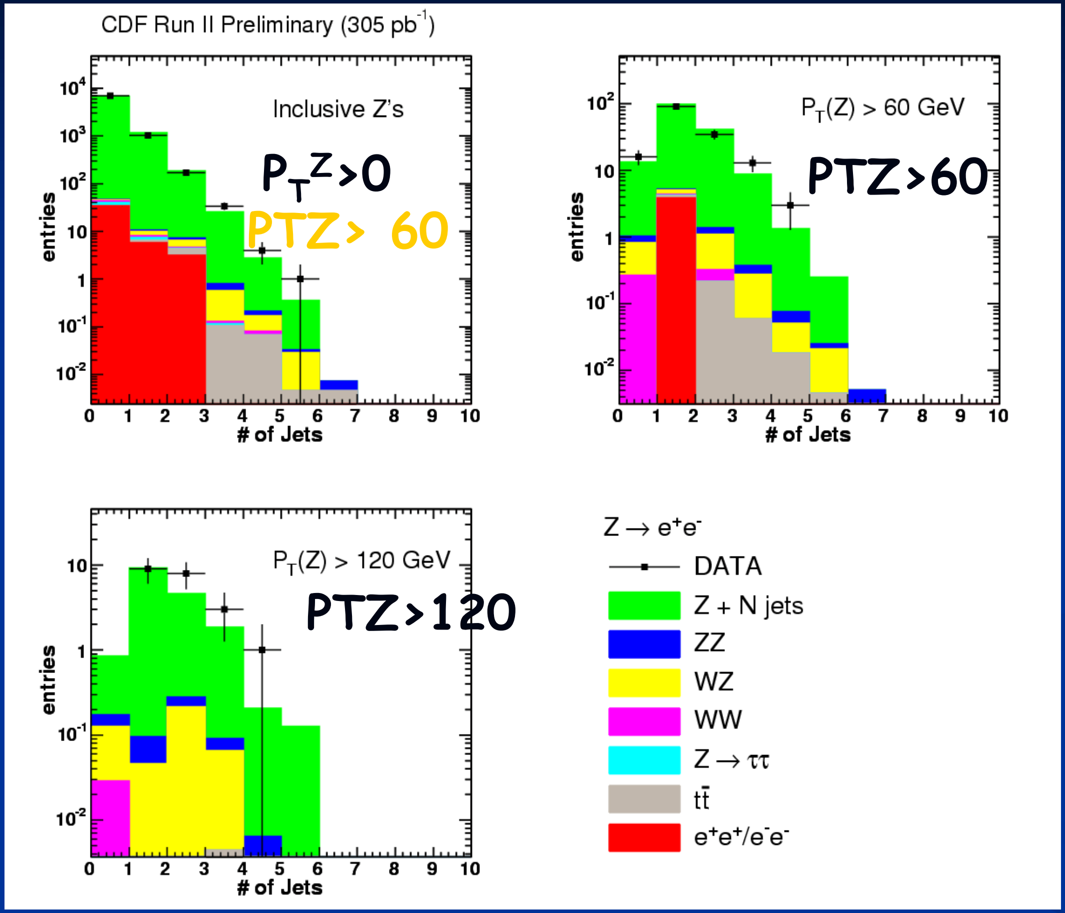
Table 2: Number of Z + X events expected in each category.





Signature-Based High Pt Z+X Searches

Sasha Paramonov (now Maria-Goeppert Mayer Fellow at ANL on Atlas



N_{jets} for $P_T^Z>0$, $P_T^Z>$ 60, and $P_T^Z>120$ GeV Z's vs Pythia (Tune AW)- this channel is the control for Met+Jets at the LHC (excise leptons - replace with neutrinos).

Signature-Based High Pt Z+X+Y

Simple Counting Expt- ask for a Z + one object, or Z+ 2objects

One Object

X	Observed	Expected
Lepton	3	1.6
Photon	14	12.4
Missing Energy	97	85.4
Ht	45	36

Z+X+anything

Two Objects

X+Y	Observed	Expected
Lepton+Photon	0	0.001
Lepton+Missing Energy	0	0.8
Lepton+Ht	0	0.14
Photon+Missing Energy	0	0.19
Photon+Ht	0	0.28
Missing Energy+Ht	6	3.5

Z+X+Y+anything

Sasha Paramonov (now Maria-Goeppert Mayer Fellow at ANL on Atlas

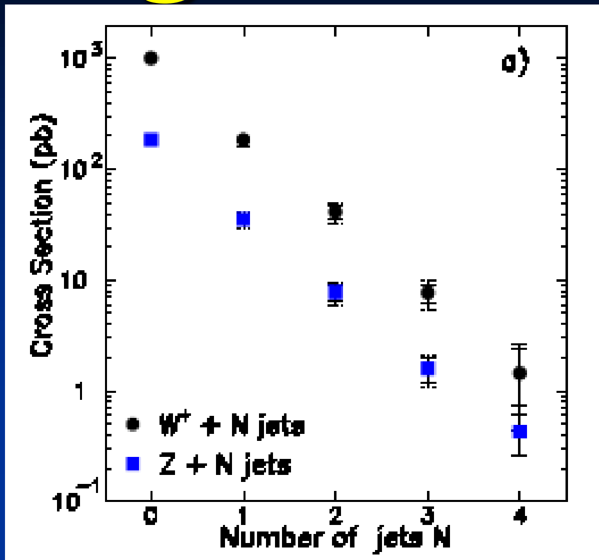
Last Topic- Using Ratios to minimize systematics at the Tevatron and (especially) the LHC

- Systematics rather than statistics limits the SM predictions for many W and Z channels- e.g. W or Z +jets.
- Uli recognized this early (me too at CDF)- use ratios to cancel out systematics- can be much more sensitive to non-SM contributions

Ratios of $W\gamma$ and $Z\gamma$ cross-sections: New tools in probing the weak boson sector at the Tevatron

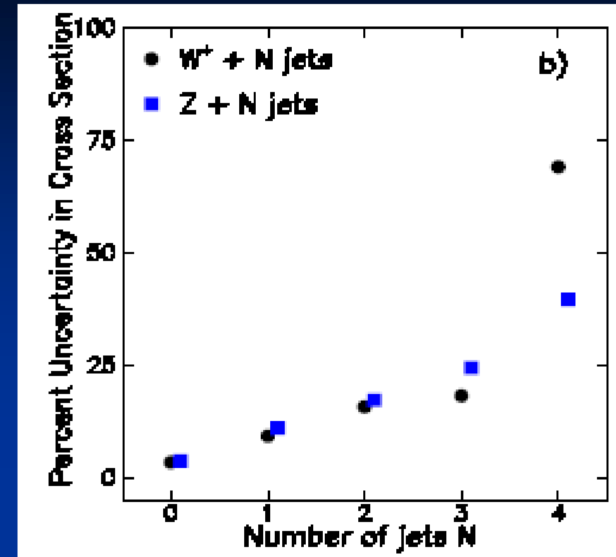
U. Baur (Florida State U.), S. Errede (Illinois U., Urbana),J.Ohnemus (Durham U.) 1993 Phys.Rev. D48 (1993)

Signature-based W/Z+Njets Search



Crossection vs number of jets in W and Z events

% uncertainty vs number of jets in W and Z events



So, switch to a measurable that is more robust: look for new physics by precise measurements of (W+Njets)/(Z+Njets). Systematics at few % level (Erin Abouzaid and HF, PRD68,033014;hep-ph/030388

Event and W Properties		W/Z Ratio Method Reach	
N(Jets)	σ_W	σ_{new} 2 fb^{-1}	σ_{new} 15 fb^{-1}
0	1896 pb	20 pb (1.0%)	20 pb (1.0%)
1	370 pb	4.4 pb (1.2%)	3.7 pb (1.0%)
2	83 pb	1.5 pb (1.8%)	0.9 pb (1.1%)
3	15 pb	0.5 pb (3.5%)	240 fb (1.6%)
4	3.1 pb	230 fb (7.5%)	95 fb (2.9%)
5	650 fb	100 fb (16%)	40 fb (6%)
6	140 fb	50 fb (36%)	18 fb (13%)
7	28 fb	20 fb (78%)	8 fb (29%)
8	6 fb	—	4 fb (63%)

Recent ATLAS ratio measurement basically Uli's 1993 strategy

Cornell University Library

arXiv.org > hep-ex > arXiv:1108.4908

Search or A

High Energy Physics - Experiment

A measurement of the ratio of the W and Z cross sections with exactly one associated jet in pp collisions at sqrt(s) = 7 TeV with ATLAS

ATLAS Collaboration

(Submitted on 24 Aug 2011)

The ratio of production cross sections of the W and Z bosons with exactly one associated jet is presented as a function of jet transverse momentum threshold. The measurement has been designed to maximise cancellation of experimental and theoretical uncertainties, and is reported both within a particle-level kinematic range corresponding to the detector acceptance and as a total cross-section ratio. Results are obtained with the ATLAS detector at the LHC in pp collisions at a centre-of-mass energy of 7 TeV using an integrated luminosity of 33 pb^-1. The results are compared with perturbative leading-order, leading-log, and next-to-leading-order QCD predictions, and are found to agree within experimental and theoretical uncertainties. The ratio is measured for events with a single jet with p_T > 30 GeV to be 8.73 +/- 0.30 (stat) +/- 0.40 (syst) in the electron channel, and $ 8.49 +/- 0.23 (stat) +/- 0.33 (syst) in the muon channel.

Thanks to Jason Nielsen, UCSC and Atlas

Uli at Fermilab 2001

Thank You, Uli, for everything