Update on $Z \rightarrow e^+e^-$ analysis

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Fermilab

*on behalf of **Z Signal Extraction** team*:

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VBTF meeting

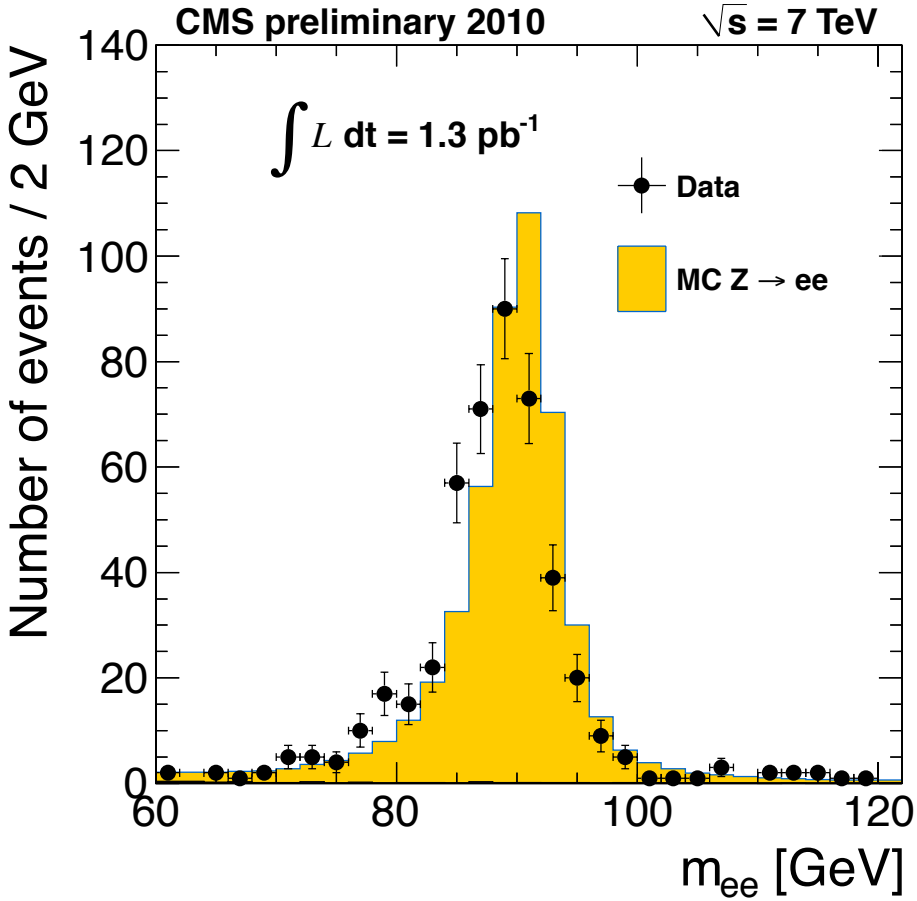
(August 27, 2010)

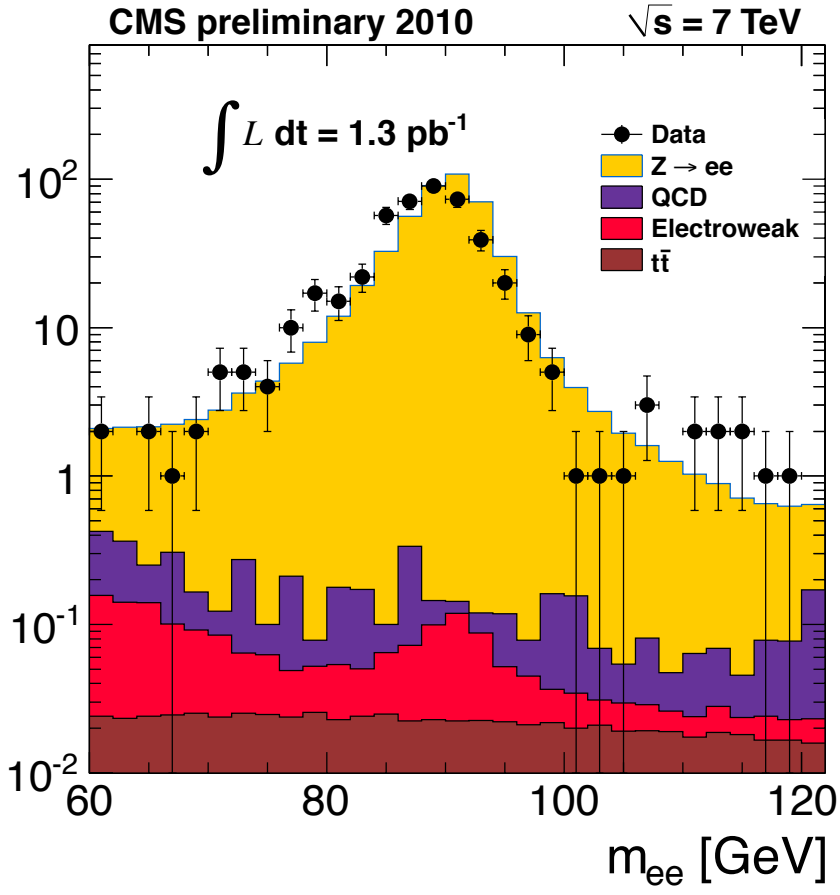
Overview

- PR plots with 1.34 pb^{-1} integrated luminosity (*i.e.*, last JSON)
- Cross section measurement update
- Status on specific topics:
  - More on simultaneous fit to estimate cross section and eff
  - Data-driven background subtraction and systematics
  - Electron efficiency systematics due to energy scale
  - Systematics in Z acceptance due to electron energy scale
  - Improvements in CMSSW_3.8.1

PR plots with 1.34 pb^{-1} data

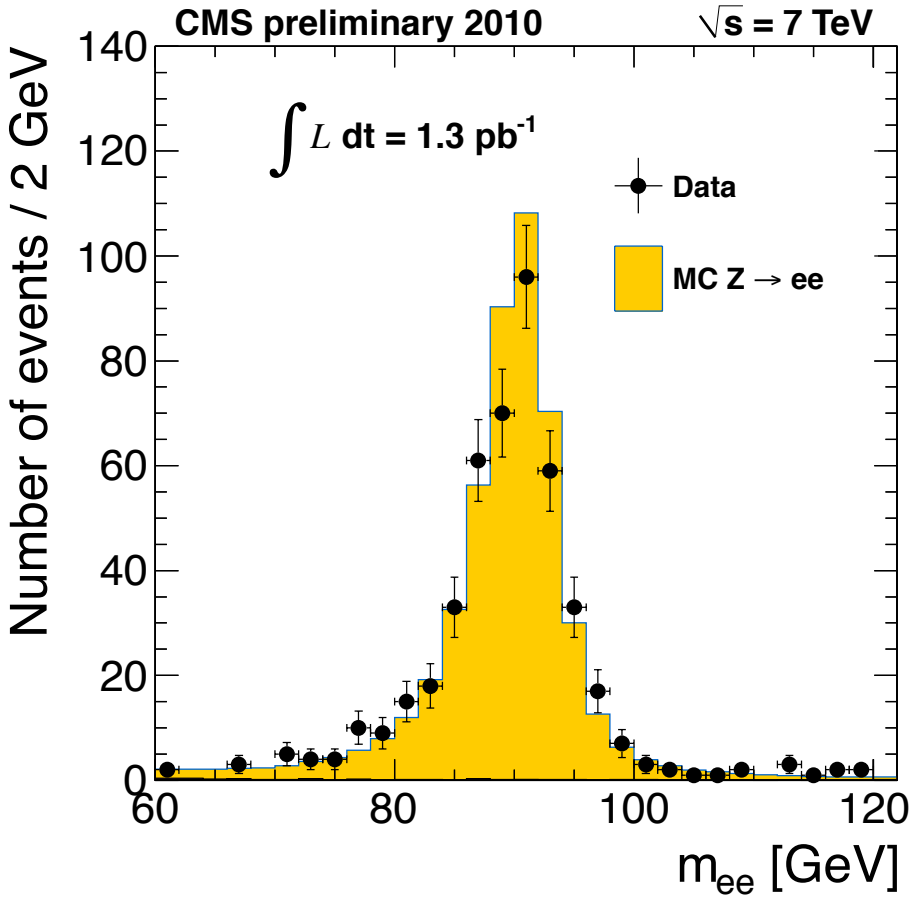
✦Have 463 golden Z→ee candidates.

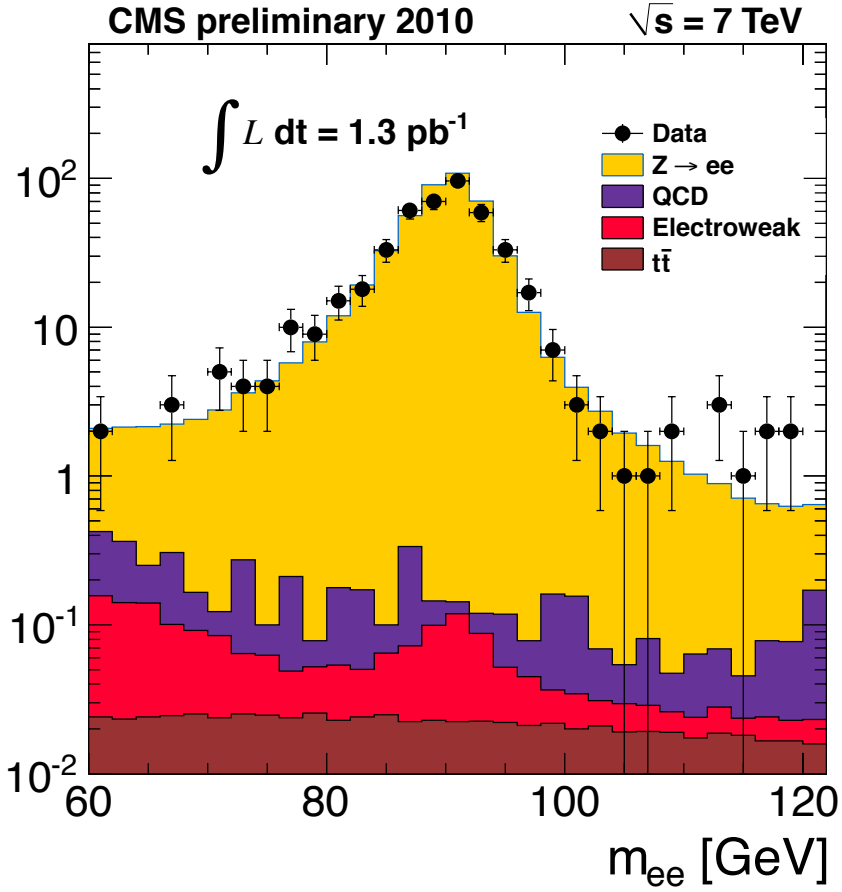




Z→ee mass after energy scale correction

Z mass shift = -0.8% for EBEB and -2.4% for EBEE for WP95 ele (after adc2GeV corr.)



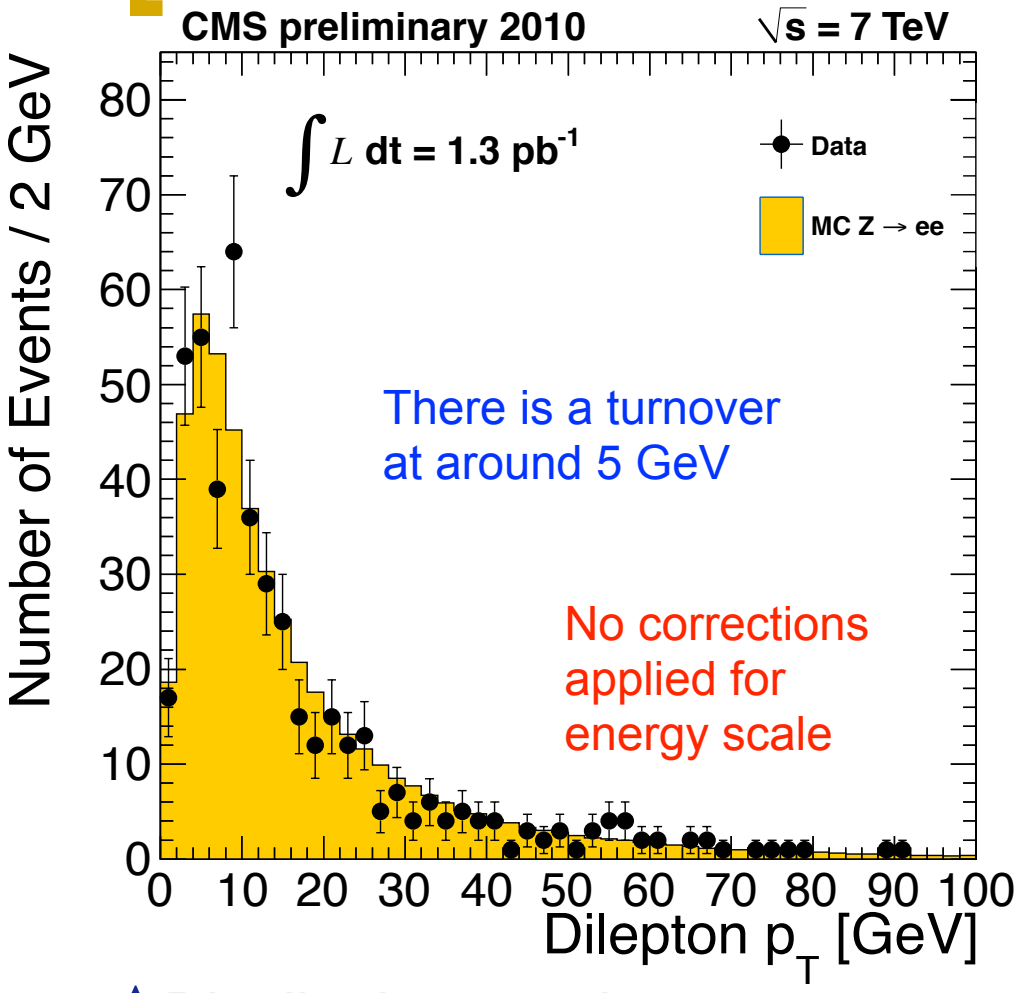


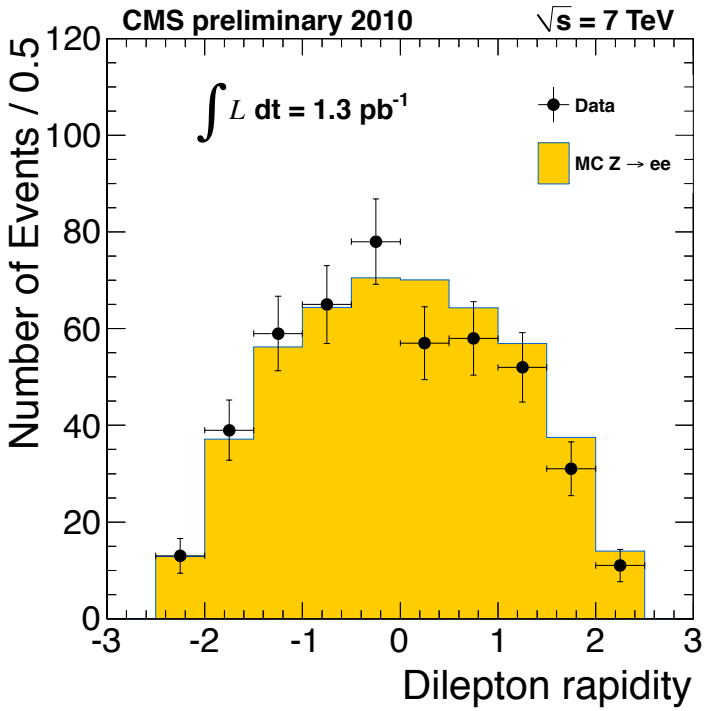
Mass shift in π^0, η:

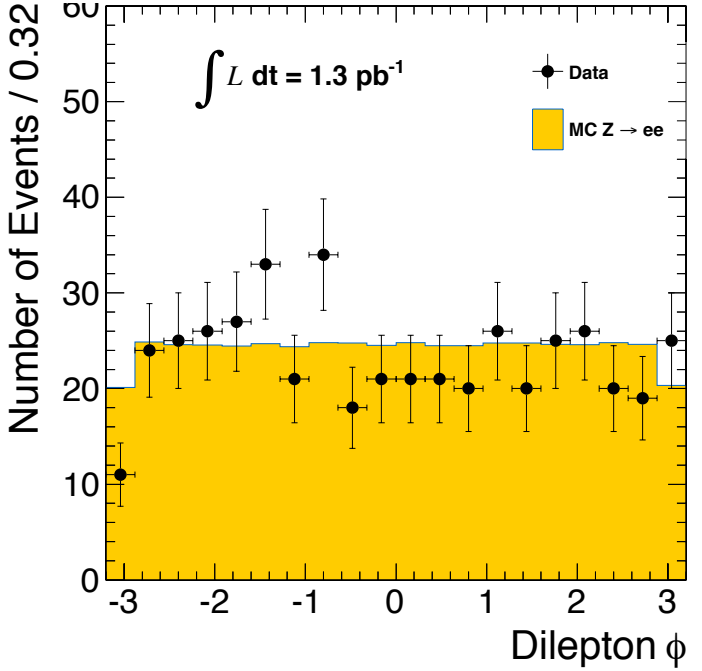
EB+EB	−0.7% ± 0.02% (stat.) ± 0.9% (syst.)
EE+EE	+2.5% ± 0.2% (stat.) ± 2.2% (syst.)

PAS: EGM-10-003

Z p_T, rapidity, azimuth

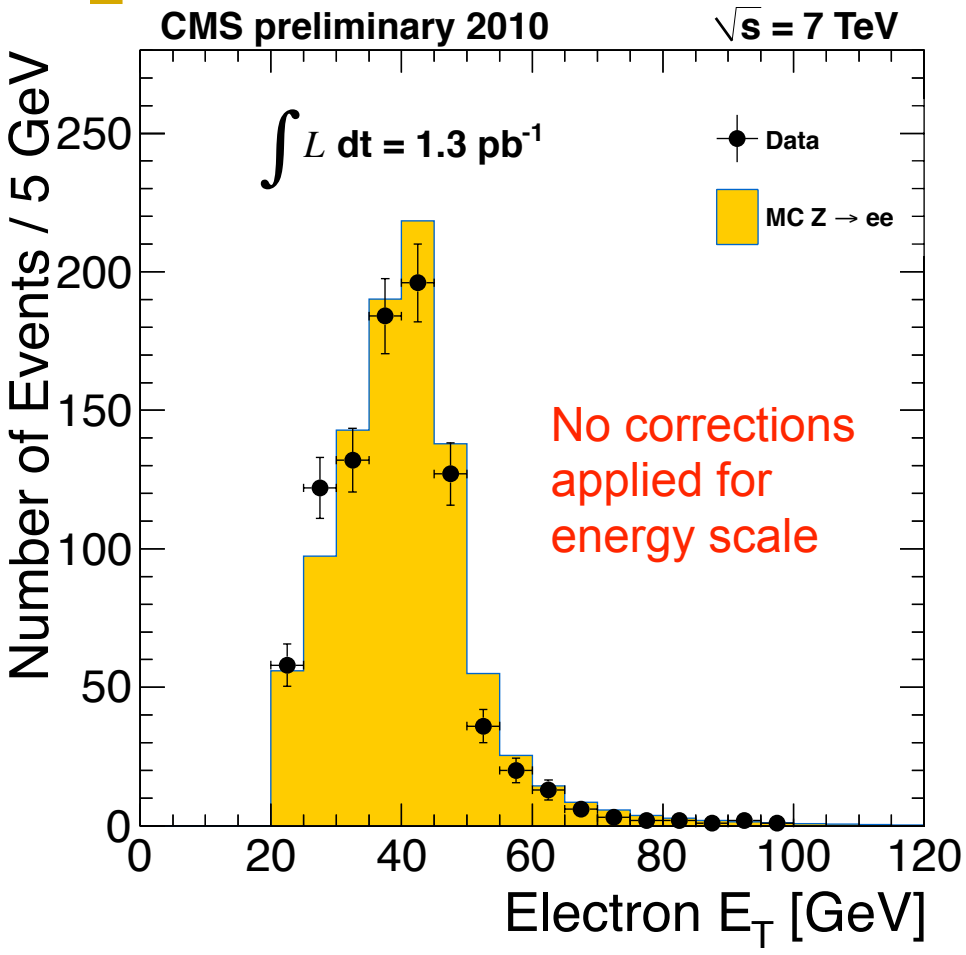


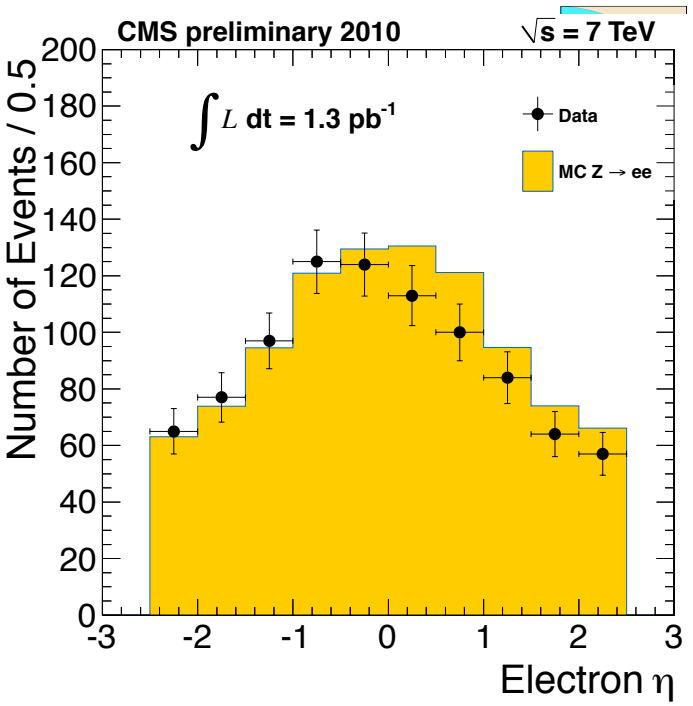


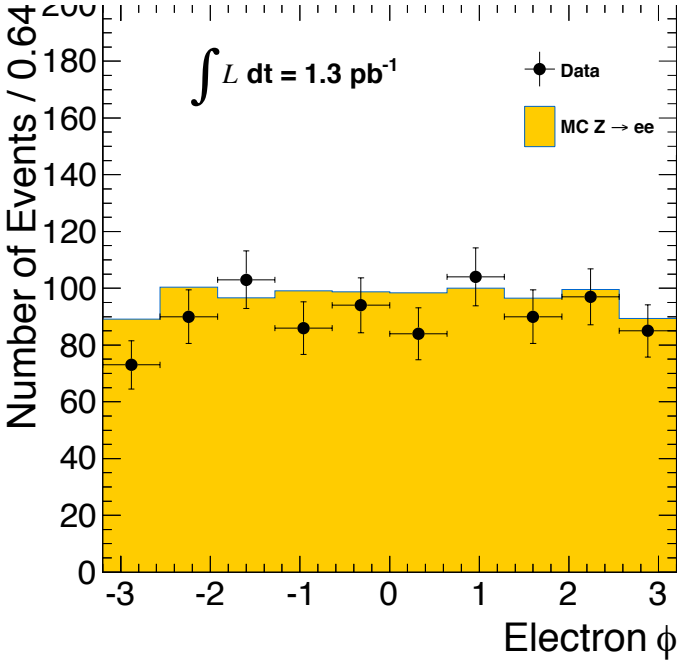


✦Distributions are in agreement with NLO predictions.

Electron P_T, rapidity, azimuth

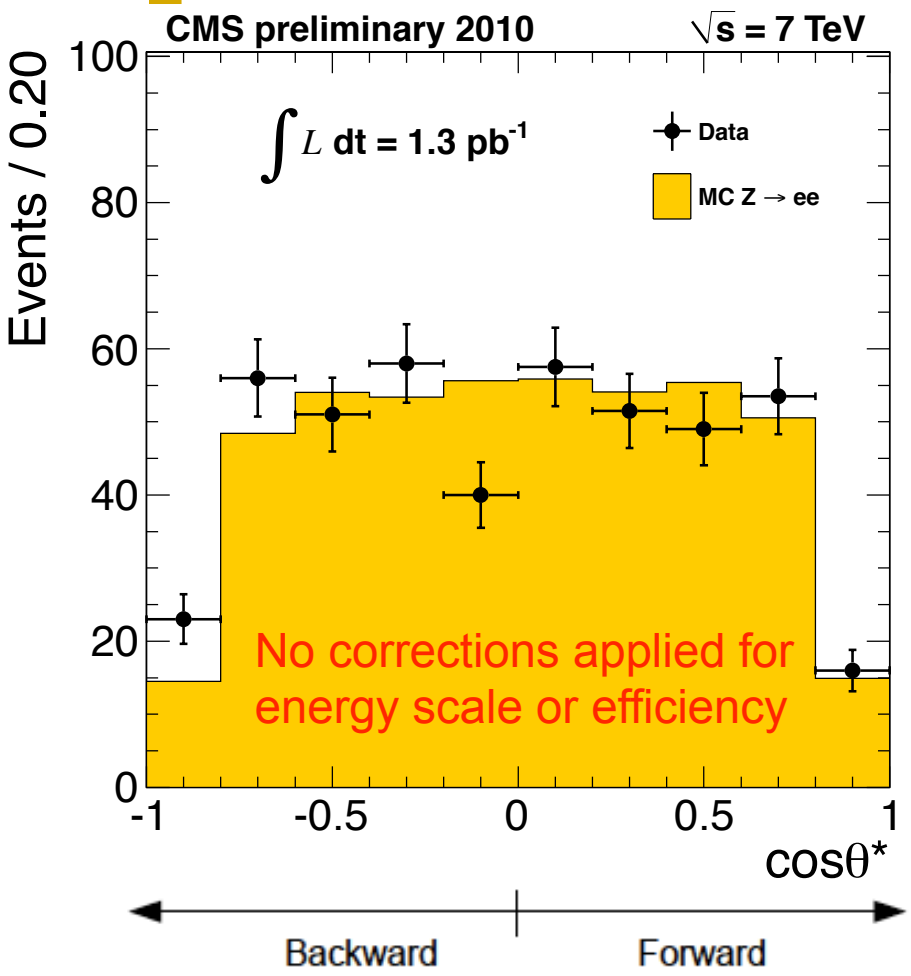




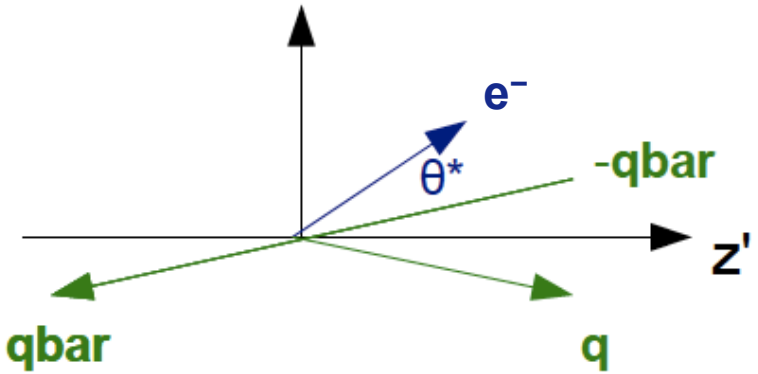


✦Rapidity distribution is somewhat shifted to the left !

Z production topology: cosine θ*



Collins–Soper frame

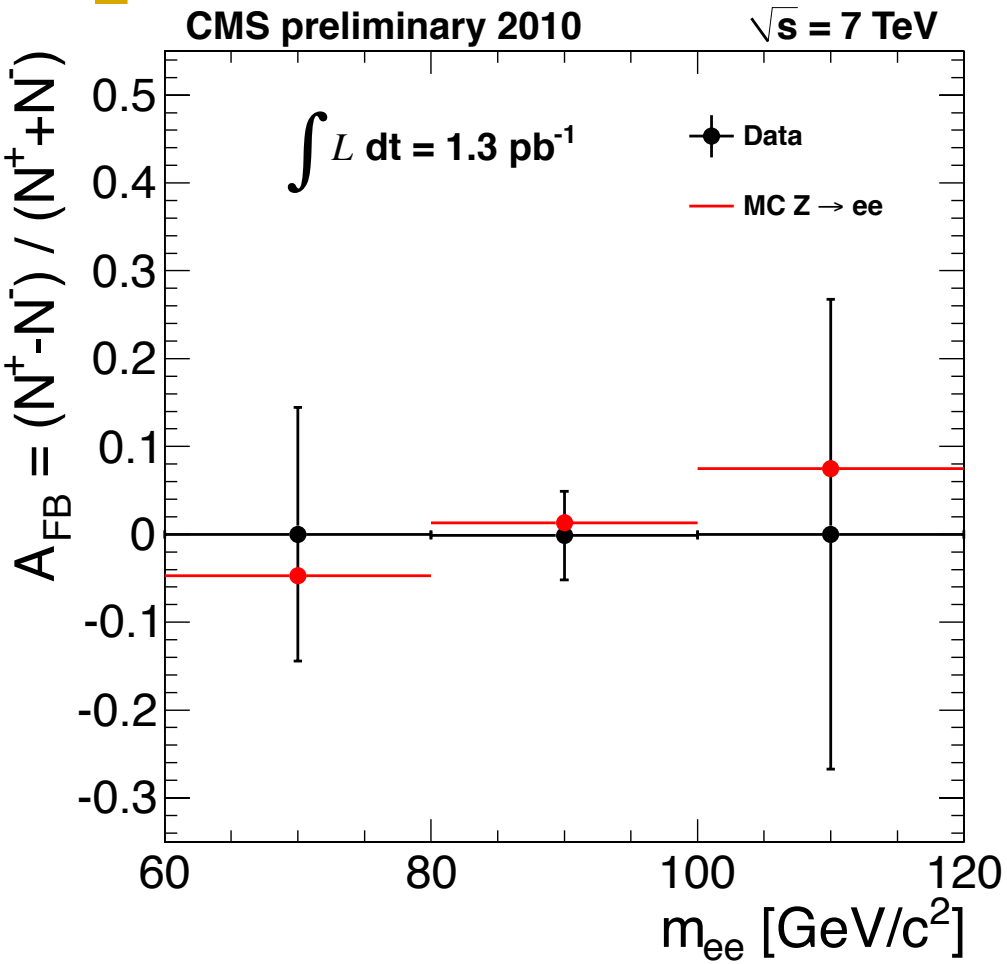


θ* is the angle between the electron momenta and the z' axis that bisects the angle between **q** and **−qbar**.

J.C. Collins and D.E. Soper, Phys. Rev. D 16, 2219 (1977)

✦Good agreement with NLO prediction.

Z forward–backward asymmetry



- **Forward** events (cosΘ*>0)
- **Backward** events (cosΘ*<0)

For each Z mass bin, we compute the asymmetry given by

$$A_{fb} = \frac{(N_f - N_b)}{(N_f + N_b)}$$

Observed asymmetry is consistent with NLO predictions.

Z→ee cross section using $\int L = 1.34\ pb^{-1}$

$N_{selected}$	463 ± 21.5
N_{bkgd}	4.9 ± 0.9 (from MC)
ε Acceptance Integrated Luminosity	0.8671 ± 0.0023 (MC stat.) ± 0.0867 (syst.) 0.4357 ± 0.0010 (MC stat.) ± 0.0131 (syst.) **1.34 ± 0.15** pb^{-1} (syst.)
$\sigma_{\gamma^*Z} \times BR(\gamma^*Z \to e^+e^-)$	904.9 ± 42.5 (stat.) + 69.5 (syst.) + 99.5 (lumi.)
Theoretical prediction	NLO prediction = 970 ± 20 pb (1607 pb for $m_Z > 20$ GeV)

dilepton efficiency

Acceptance = 43.6% ← from MC
Efficiency = 86.7 %
Cross section = 905 ± 42 pb ← our result
NLO prediction = 970 ± 20 pb

Breakdown of syst: 5⊕5% for efficiency ⊕ 3% for acceptance ⊕ 100% of bkg

Data-driven background estimation and efficiency available now. Close to MC.

Simultaneous fit for cross section & efficiency

Parameter	Value	HiError,	LoError
1 TF Bkg Expo	-0.009	+0.007,	-0.007
2 $e^{\pm}$ Efficiency	0.946	+0.018,	-0.021
3 TF nBkg	73.3	+12.1,	-11.3
4 TF resolution	0.87	+3.05,	-4.37
5 TT resolution	2.36	+0.29,	-0.29
6 Cross section	892.1	+51.7,	-49.4

Corr. matrix

NO.	GLOBAL	1	2	3	4	5	6
1	0.108	1.00	-0.10	-0.08	0.00	0.00	0.07
2	0.756	-0.10	1.00	0.63	-0.42	0.00	-0.63
3	0.644	-0.08	0.63	1.00	-0.35	0.00	-0.46
4	0.437	0.00	-0.42	-0.35	1.00	0.00	0.30
5	0.000	0.00	0.00	0.00	0.00	1.00	0.00
6	0.638	0.07	-0.63	-0.46	0.30	0.00	1.00

- Reconstructed Z line shape taken from NLO MC. Apply a resolution function
- The high purity sample assumed background-free,
  - we subtract the residual tiny background a posteriori.

eff = 89.5% in data Vs. 86.7 % in MC

cross section after bkg subtraction

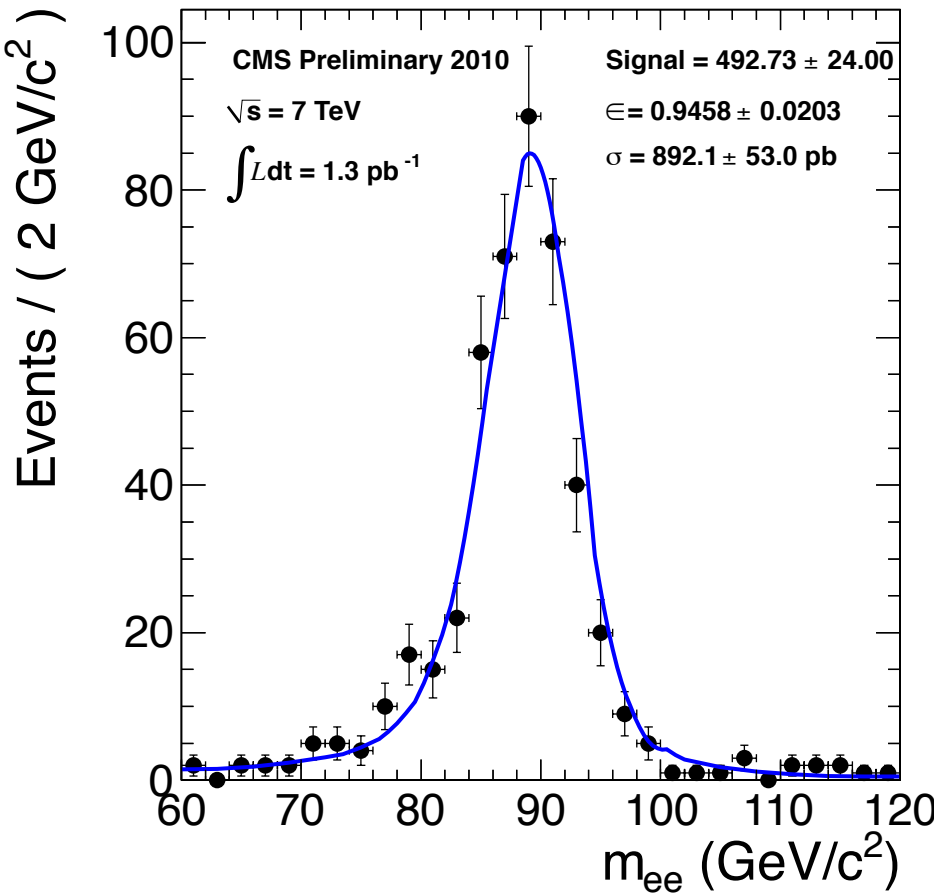
σ = 882.7 ± 51.7 (stat) ± 27.9 (syst) pb

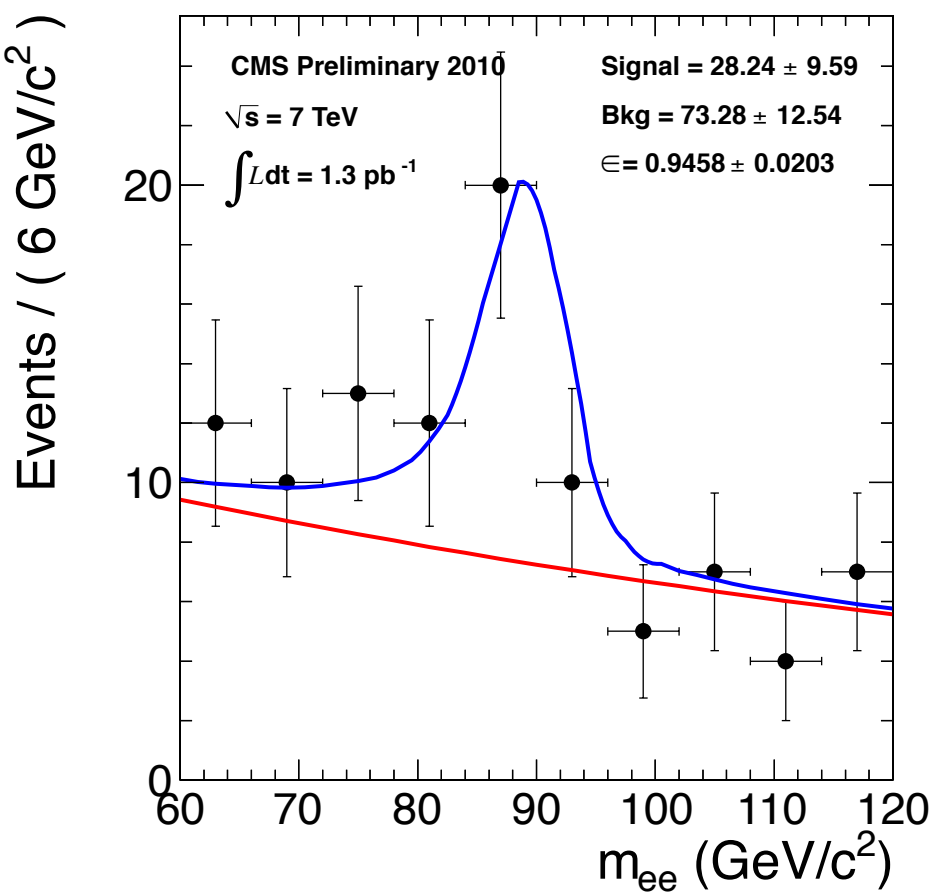
904.9 ± 42.5 ± 69.5 from simple counting

Small syst. uncertainty due to signal shape and $e^{\pm}$ energy scale yet to be included. Also, working on improving some qualitative features of the fit.

Simultaneous fit now gives more precise result on cross section than simple counting ! The measurement is now gradually becoming systematics limited.

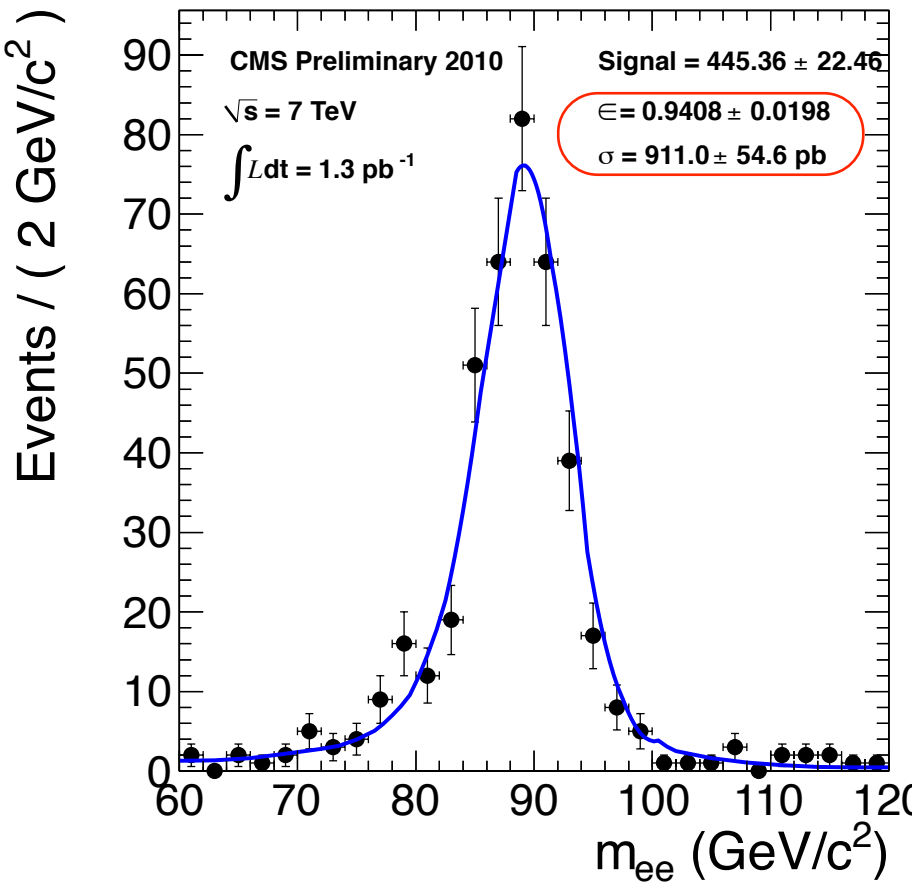
Simultaneous fit plots

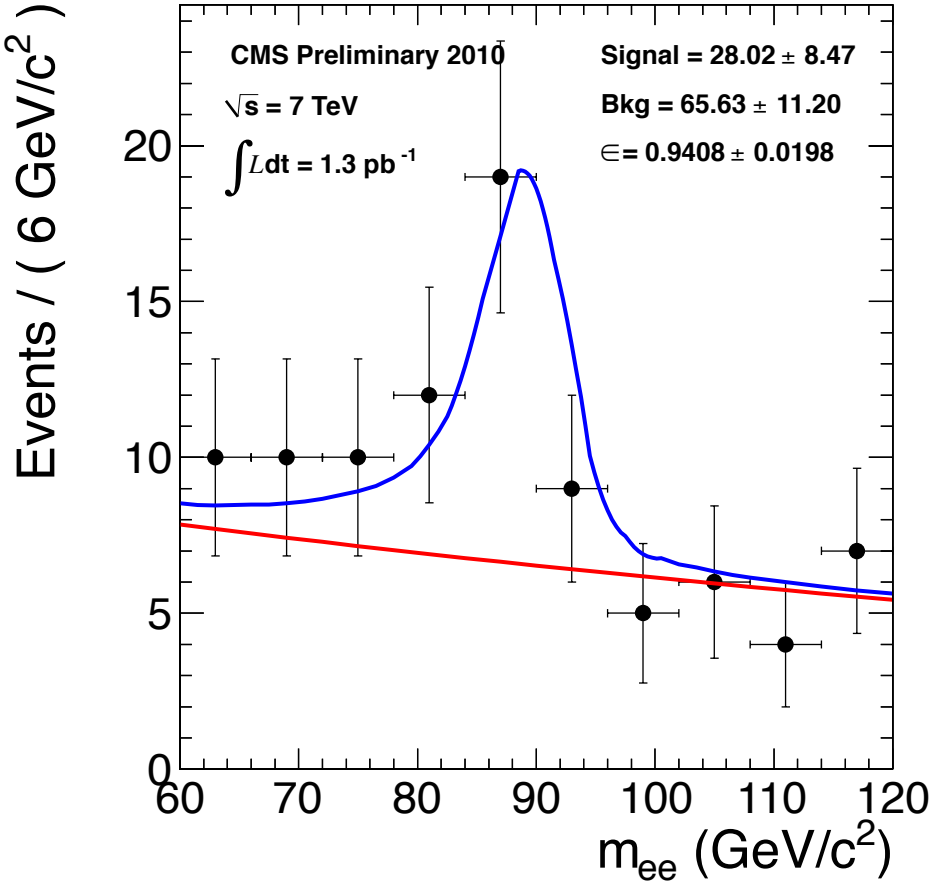




- Fit gives cross section and electron (reco⊗id) efficiency directly from data.
- Any shift is Z mass peak position gets absorbed in the resolution.

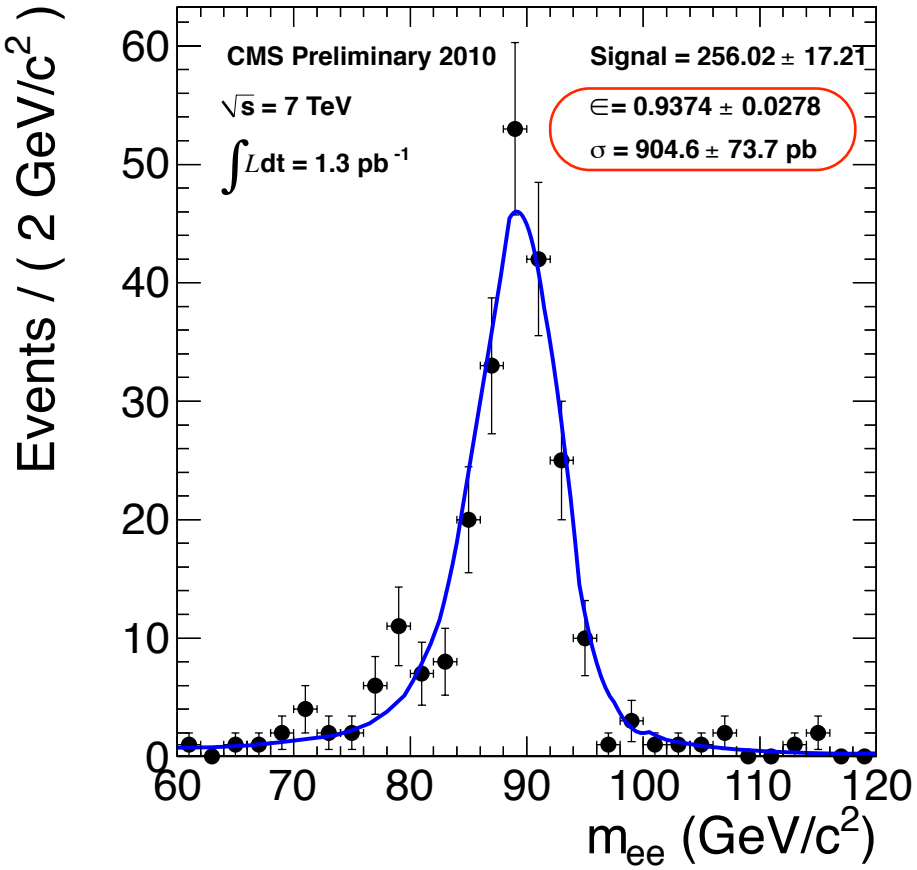
What if we remove EE-EE combination ?

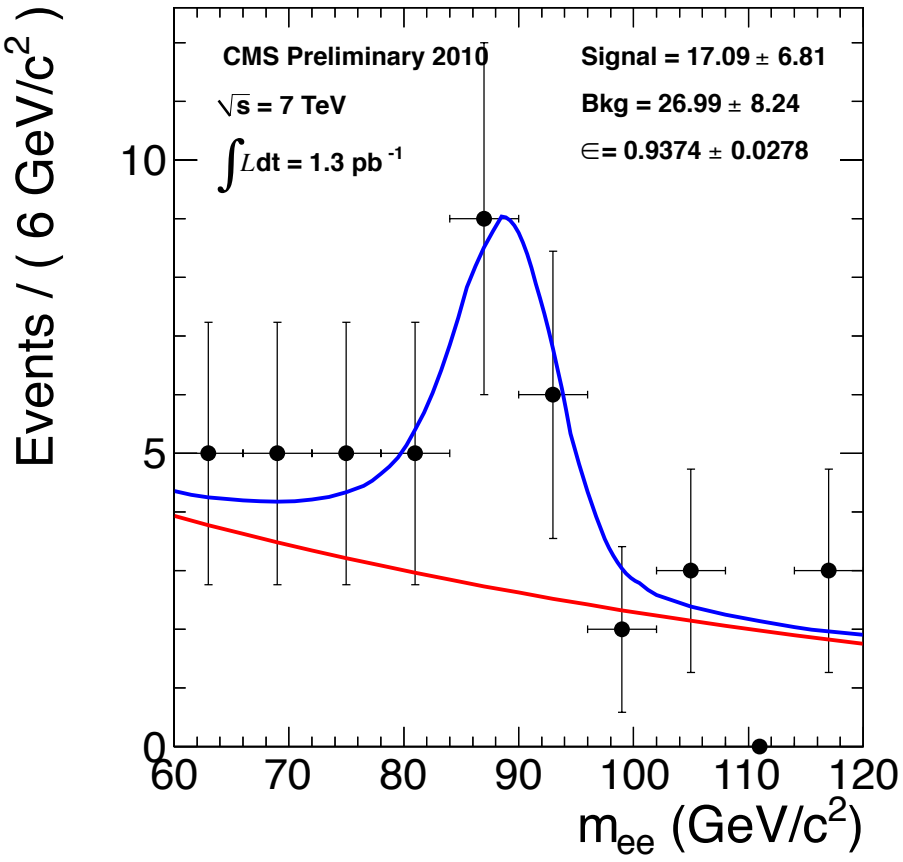




- Since EE-EE combination has smaller S/B ratio, removing it may help.
- Turns out that at this point this does not help by much.

Barrel-only measurement





✦Results look consistent

Data driven electron efficiency from Z

super cluster → gsfElectron

	Eff	σ_{stat}	N_{pass}	N_{fail}	MC
Total	99.8	0.4	552	1	98.6
Barrel	100.0	1.2	398	0	99.1
Endcap	98.6	1.3	154	2	97.4

gsfElectron → WP 95

Eff	σ_{stat}	N_{pass}	N_{fail}	MC
96.2	1.0	538	21	95.2
96.4	1.2	387	14	95.6
95.9	1.9	152	7	94.2

WP 95 → HLT

	Eff	σ_{stat}	N_{pass}	N_{fail}	MC
Total	97.2	0.7	518	15	98.6
Barrel	99.7	0.3	386	1	99.1
Endcap	90.4	2.5	132	14	97.4

gsfElectron → WP 80

Eff	σ_{stat}	N_{pass}	N_{fail}	MC
82.4	1.9	456	97	86.3
83.9	2.2	331	64	86.5
79.6	3.6	127	32	85.5

- Except for WP80 efficiency, all other efficiencies are very close to MC expectation.
- Statistical uncertainty in efficiency measurement ~ 2%.

Syst uncertainty in Eff due to energy scale

✦The impact of the energy scale on electron efficiency is marginal.
✦Here are the associated systematic errors we have computed:

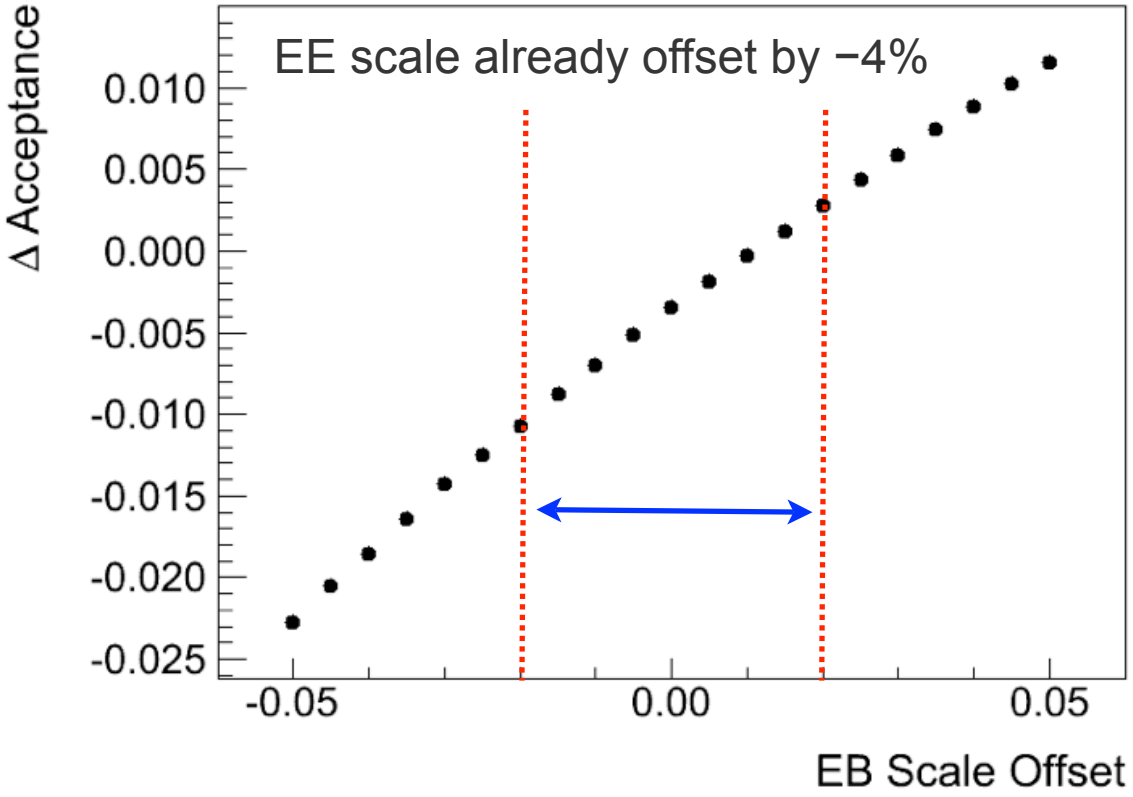
- super cluster → GsfElectron efficiency: 0.22%
- GsfElectron → WP95 efficiency: 0.10%
- GsfElectron → WP80 efficiency: 0.05%
- WP95 → HLT efficiency: 0.15%
- WP80 → HLT efficiency: 0.15%

✦The methodology to estimate this systematic is simple:
-We shifted the generator level energy scale by ± 3%.
-Compute MC tag & probe efficiency (and also truth-matched efficiency) for these two samples
- Then took the difference in the result between these 2 samples as the systematic uncertainty.

✦See Jeremy Werner's talk for details.

Syst error in Z acceptance due to energy scale

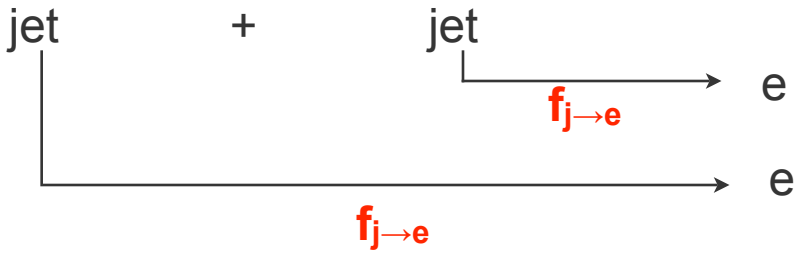
- The impact of the energy scale on Z acceptance is small.
- The plot below shows the % change in acceptance vs the change in the EB energy scale when EE energy scale has already been shifted by -4%.
- We can safely assign a maximum syst. uncertainty of 1%.



If you look at the point where EB scale is shifted -2% and EE scale is shifted -4%, you see that the acceptance changes by about 1%. So this is the maximum systematic effect we could have.

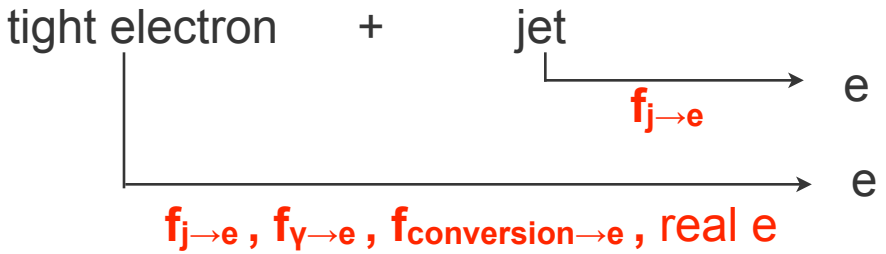
Data-driven bkg subtraction: via fake rate

1. From dijet sample in data (Jet30 trigger)



fake rate from QCD dijet to ee signature = $f^2_{j\to e}$

2. From electron + jet sample in data (Jet30 trigger)



fake rate from e+jet to ee =
$2.f^2_{j\to e} \oplus f_{j\to e} . f_{\gamma\to e} \oplus f_{j\to e} . f_{conversion\to e} \oplus f_{j\to e}$

Note the factor of 2 ! It comes from combinatorics !

[2] - [1] gives the fake rate for Z→ee events in data.

Jet→electron fake rate estimation from data

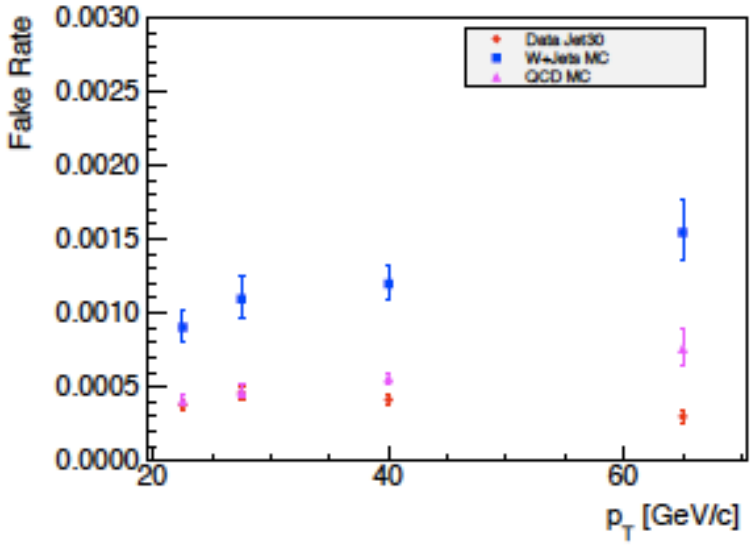
[from Si Xie]

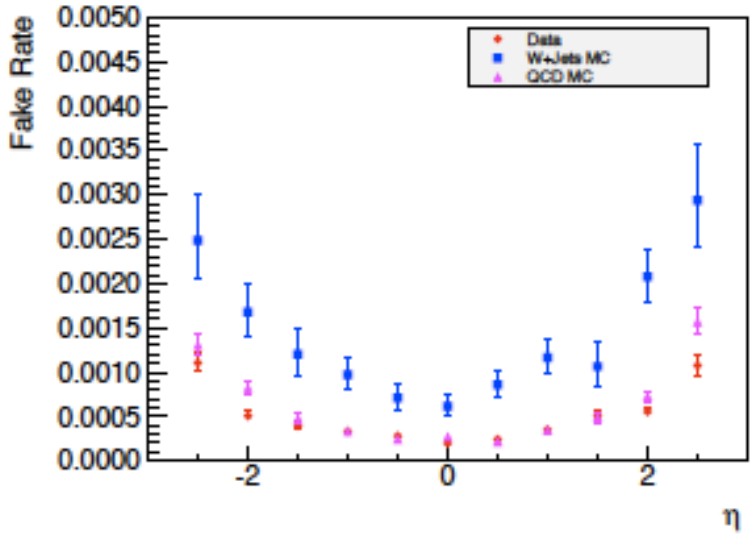
jet →WP95 fake rate

- Measurement is performed with HLT_Jet30U trigger sample
- Measure ε_{fake} as a function of p_T and η

•AntiKt 0.5 CaloJet -> VBTF95 fake rate :

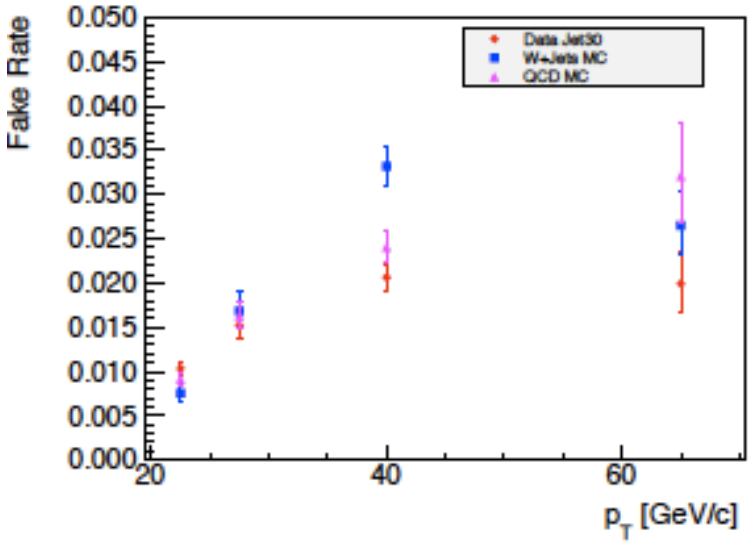
- Denominator Definition: AntiKt 0.5 CaloJet
- Numerator: VBTF 95% Working Point Electron ID+Isolation
- Veto the leading trigger jet (remove any bias due to trigger requirements)

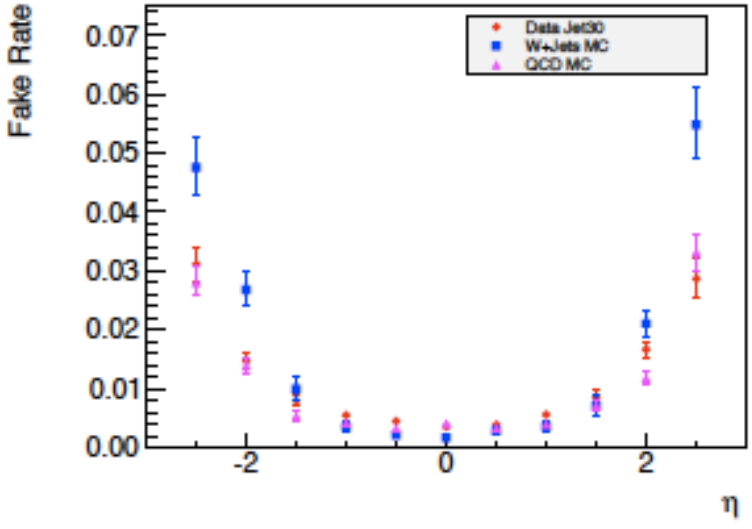




Reco electron→WP95 fake rate

- **Reco -> VBTF95 fake rate :**
  - Denominator Definition: ECAL Driven Reco Electrons
  - Numerator: VBTF 95% Working Point Electron ID+Isolation
  - Veto any electron candidates matching to the leading trigger jet (remove any bias due to trigger requirements)

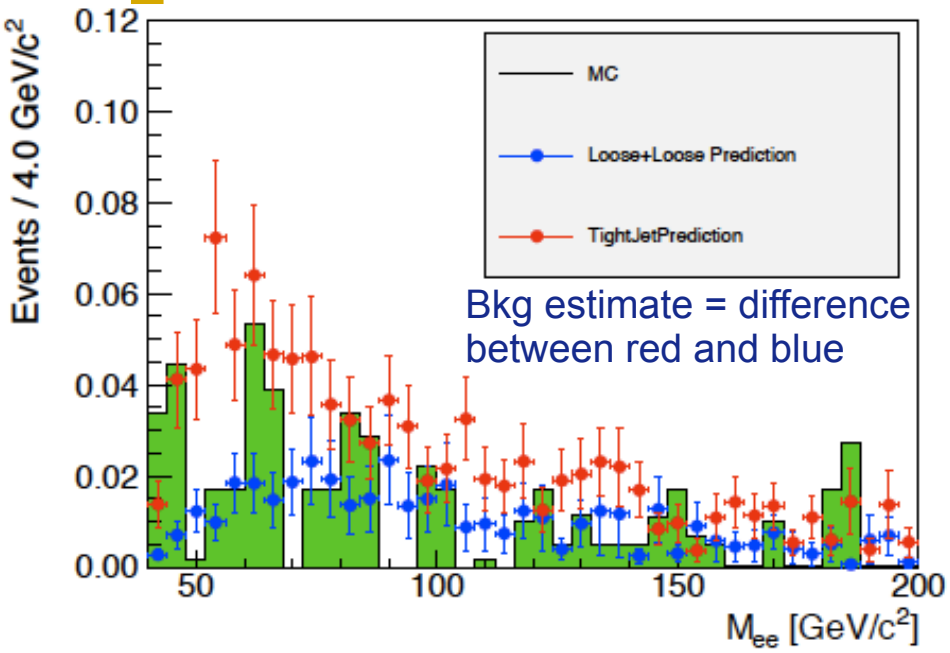




- Agreement between QCD MC and Jet data is excellent
- W+Jets fake rate is a factor of 2-3 higher. (b/c high fraction of quark jets)

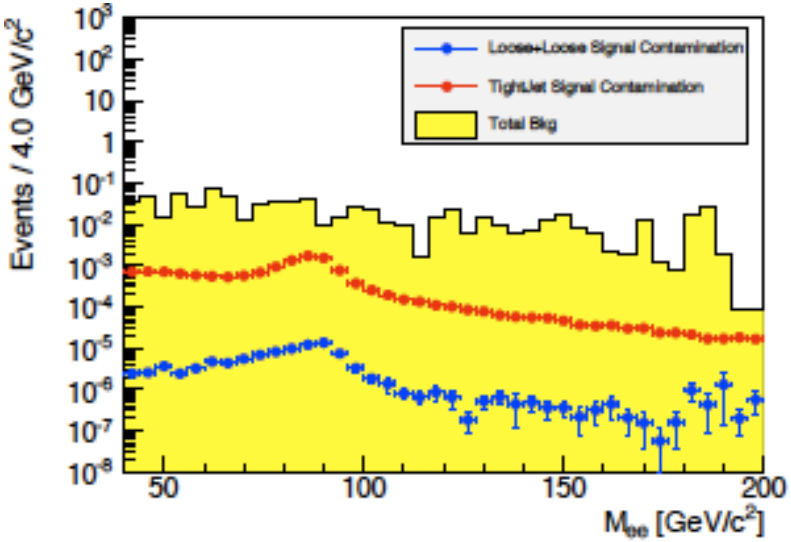
However, there are fewer W+jets & γ+jet background events.
Breakdown of our background sources: 60% dijet, 20% γ+jet, 20% W+jet.

Background prediction in data: 200 nb^{-1}



Signal contamination

Tight e + jet: ~1% signal contamination.
Loose+Loose: Negligible signal contamin.



Tight+Jet Prediction	0.93 +- 0.56 +- 0.58 (WJets Systematics)
Loose+Loose Prediction	0.25 +- 0.13
Final Prediction	0.68 +- 0.82
MC Simulation Prediction	0.42 +- 0.07

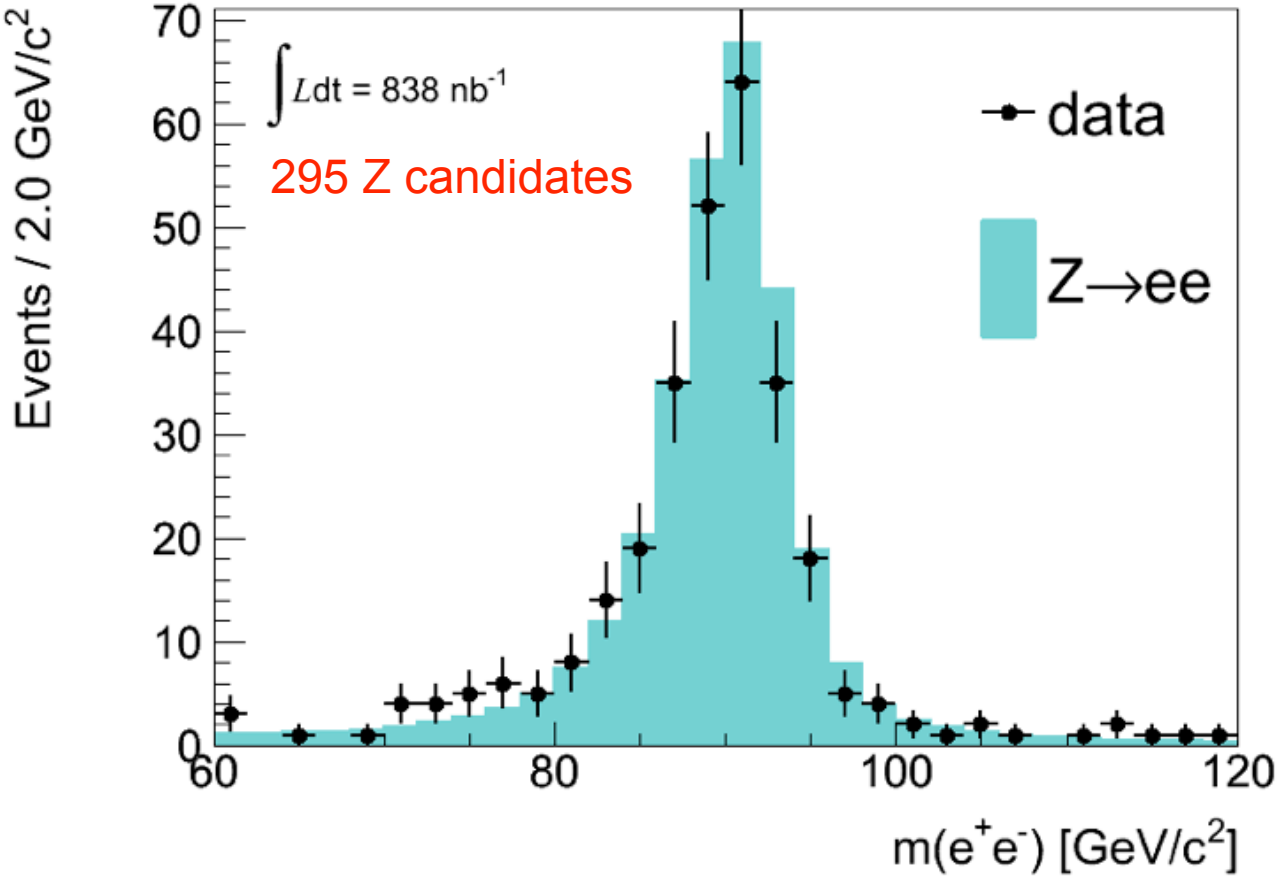
Take conservative estimates of systematic uncertainties: assign 100% of the difference between fake rates in data and in W+jets or γ+jets as syst.

See Si's talk for details

Improvements in electron calibration in 3.8.1

[from Kevin Sung]

We did a 3_8_1 private production on some of the data to get a look at improvements in the upcoming release. We note that there is a clear improvement in the Z peak position in the electron channel.



Summary

- PR plots: All look good
- Cross section measurement
  - Both simple counting and simultaneous fit performed
    - both give consistent results
    - somewhat below NLO predictions
- Status on specific topics
  - Electron energy scale: *ADC2GeV* scale come from π^0 and η. Need to apply additional correction to get Z peak right.
  - Background subtraction: Now becoming feasible for the first time. Able to estimate residual background from data-driven techniques within 200% syst. uncertainty.
  - Electron efficiency: Efficiency in data is close to MC expectation. Syst error due to electron energy scale is marginal.
  - Z acceptance: Syst effect due to electron energy scale is 1%.