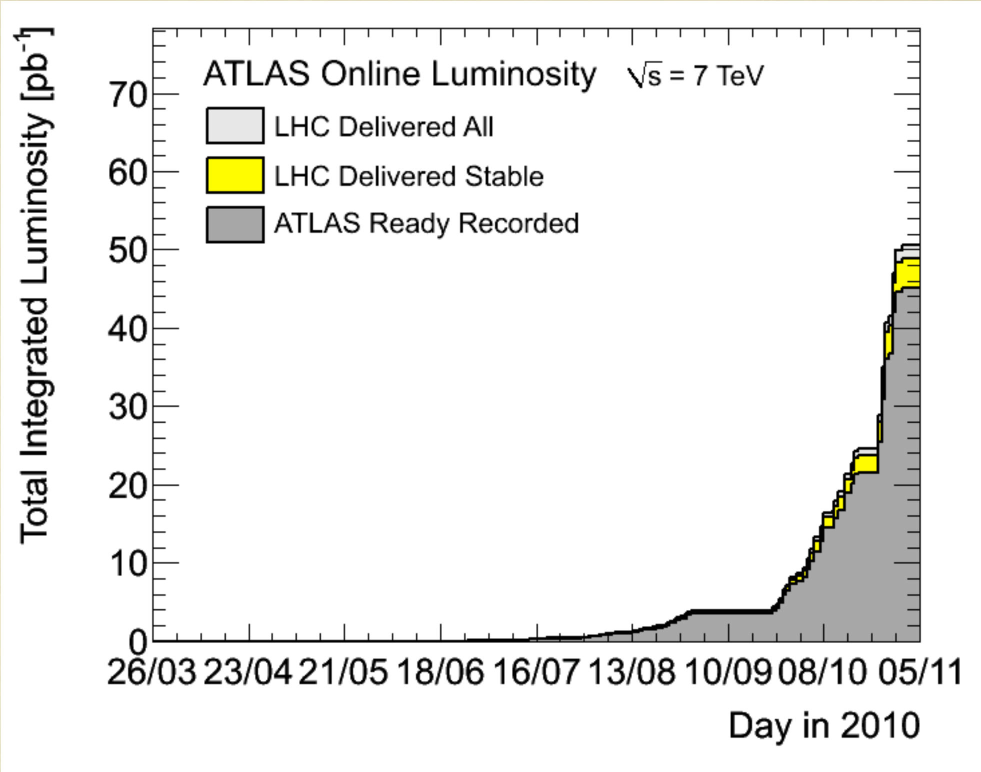
W/Z analysis with electrons

Elina Berglund
University of Geneva

Seminar at the Niels Bohr Institute, 18/11-2010

Introduction

- The first year of data taking for ATLAS has come to an end and 45 pb^{-1} of integrated luminosity has been successfully recorded

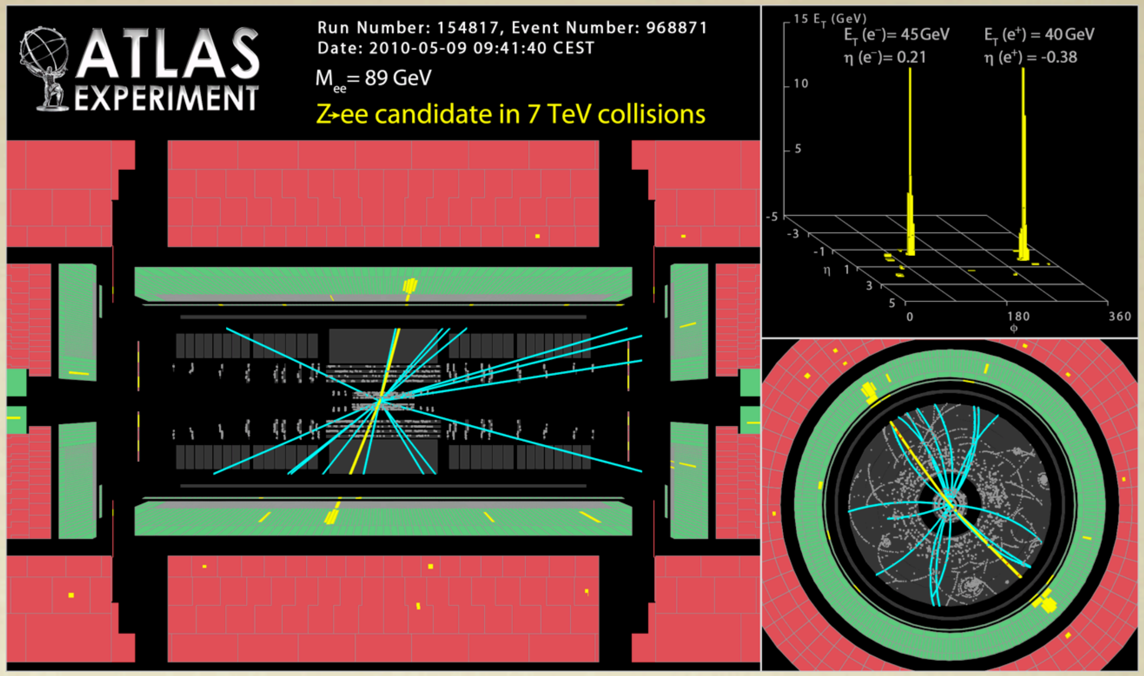


- It has been an intense year where all the preparations and studies done on MC have been put to the test

- For the SM and egamma group it has been a successful year resulting in, among other results, ATLAS' first W/Z cross section paper with 300 nb^{-1} - *arXiv:1010.2130*

- The W/Z work is however continuing, since a lot more data is now at hand. This will allow for more precise measurements of not only the W/Z inclusive cross section, but also in association with jets as well as interesting differential cross section measurements

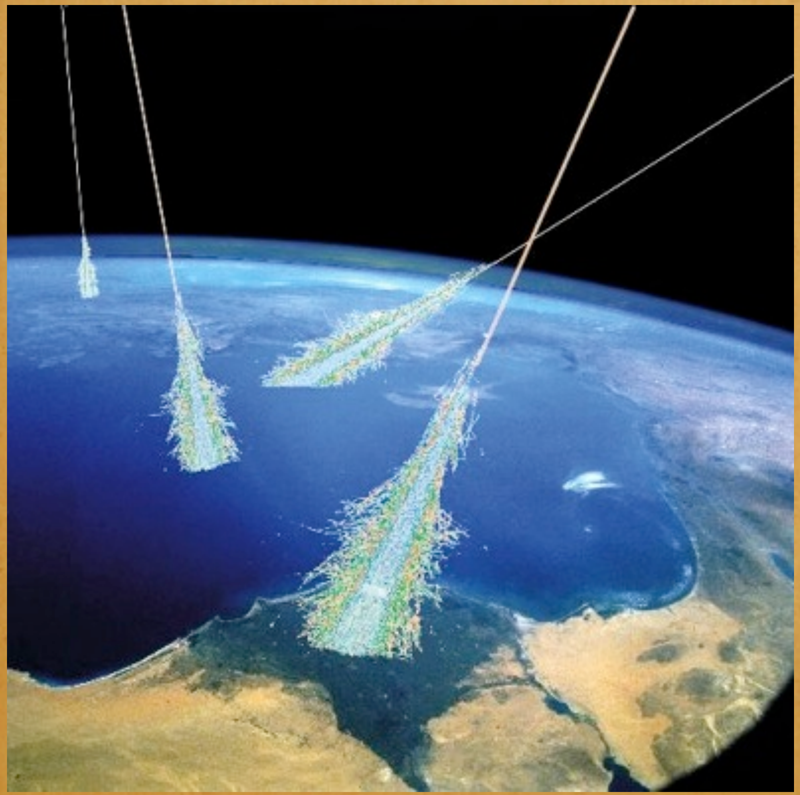
Outline



First Zee event seen in ATLAS

- Electrons in ATLAS
  - Reconstruction and identification of electrons
  - First electrons in ATLAS - cosmic ray data
- First W/Z cross section measurements; the electron channel
  - W/Z cross section paper with 300 nb^{-1}
  - W/Z inclusive analysis with 2010 data
- Ongoing W/Z analyses
  - Tag and probe electron efficiencies with the Z boson
  - The R_{jets} analysis

Electrons in ATLAS

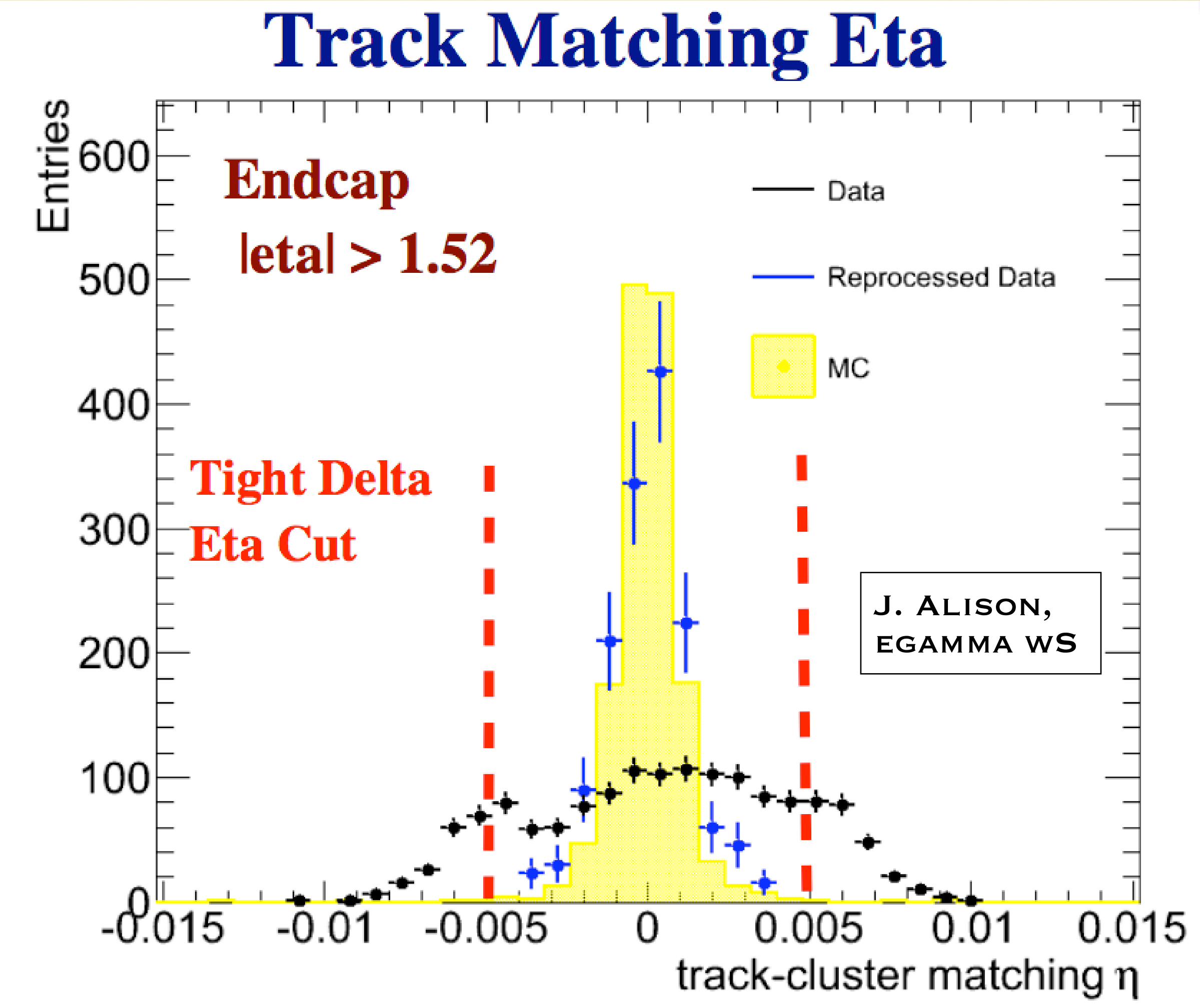


Electron reconstruction and Identification

- Reconstructing electrons
  - There are several electron-finding algorithms in the ATLAS reconstruction software
  - Standard algorithm ("egamma" electron): a seeding cluster in the 2^{nd} layer of the calorimeter with $E_T > 2.5$ GeV, which is matched to an ID track
- Identifying electrons
  - Calorimeter and track variable cuts have been optimized on MC in the E_T,η phase space of the electron.
  - The three set of cuts give different level of background rejections at the expense of electron identification efficiencies
  - **Loose**: shower shape variables in the 2^{nd} sampling and hadronic leakage
  - **Medium**: loose + shower shapes in the 1^{st} sampling, SCT and pixel hits, track impact parameter and track-cluster matching (20 GeV jet rejection factor: 7×10^3)
  - **Tight**: medium + B-layer hits, TRT high threshold hit ratio, conversion rejection and E/p matching (20 GeV jet rejection factor: 10^5)

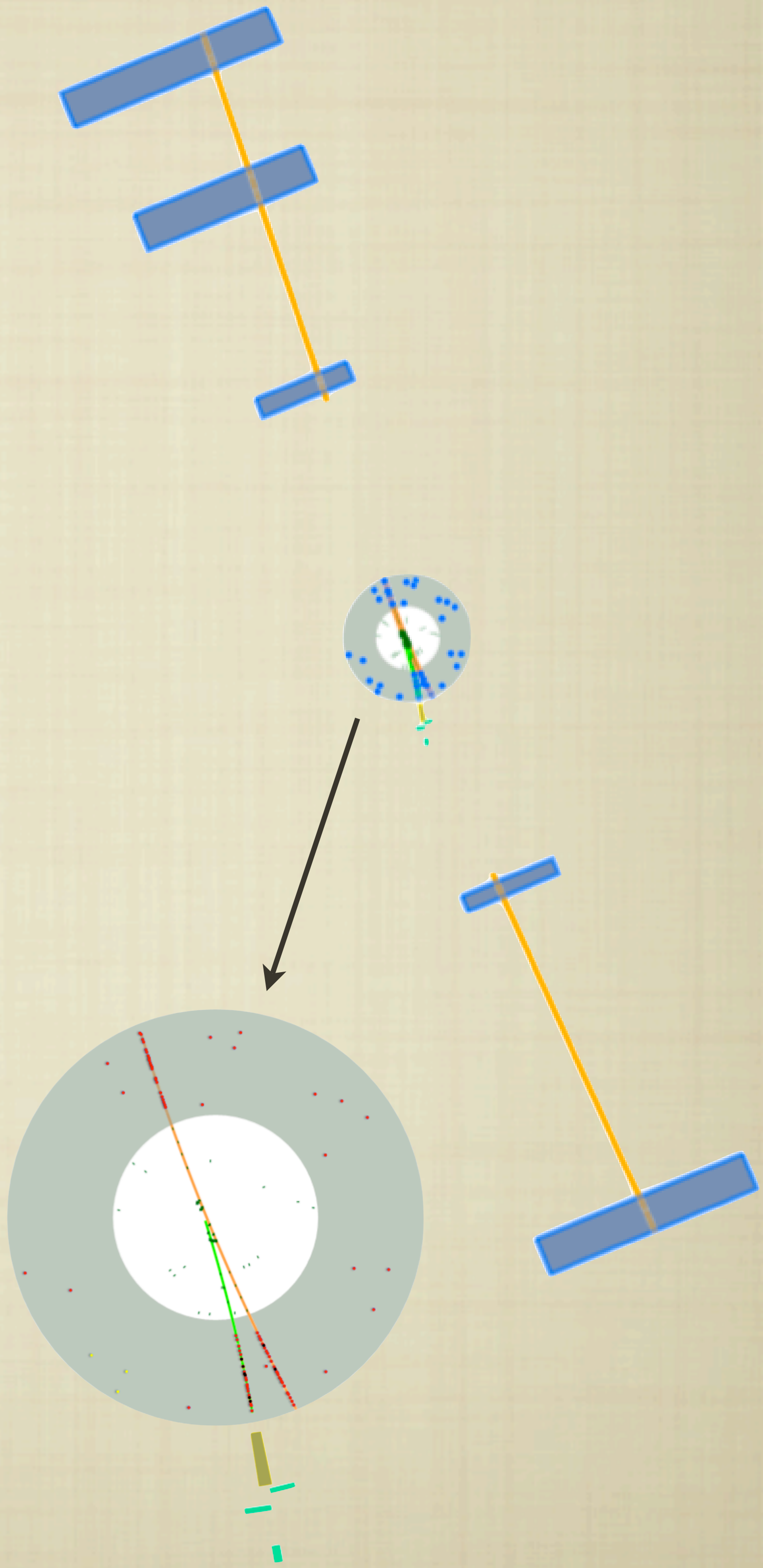
Robust, robuster, robustest...

- Due to differences found in data and MC, some ID cuts have been relaxed creating robuster identification; **robust loose, robust medium** and **robuster tight**
- The robust tight were first developed to relax the tight track-cluster matching, which was significantly worse in data, especially in the endcaps (see plot below).
- The robust tight script also checks if the electron crosses a disabled B-layer module and if so, the conversion cut is removed
- The shower variables Reta and weta2, applied at loose level, were found to be shifted in data wrt MC, especially for the endcaps.
- These cuts were therefore loosened as much as the trigger allowed and the robuster ID was born.
- These discrepancies will be much reduced with the reprocessed data which is well underway. Also the MC is altered to better describe the data.

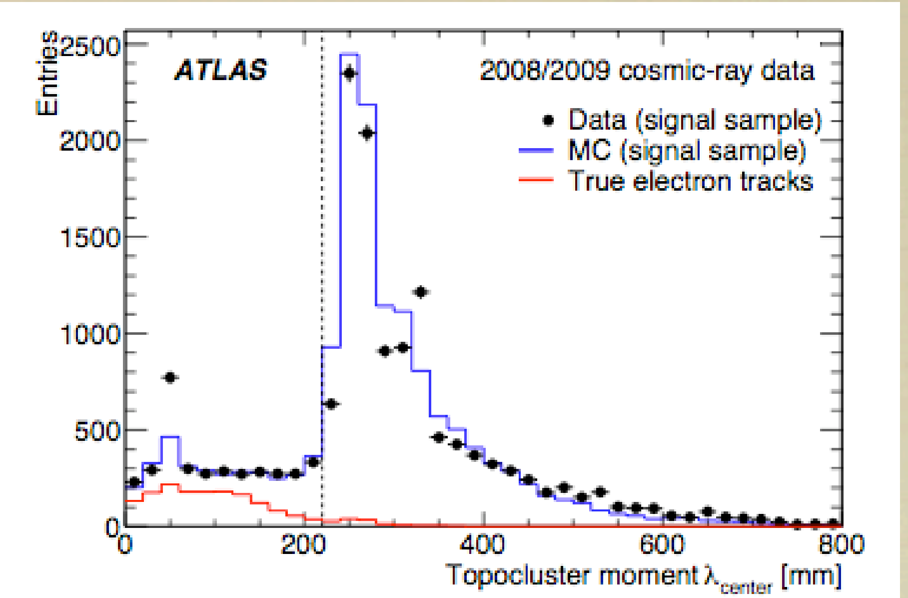


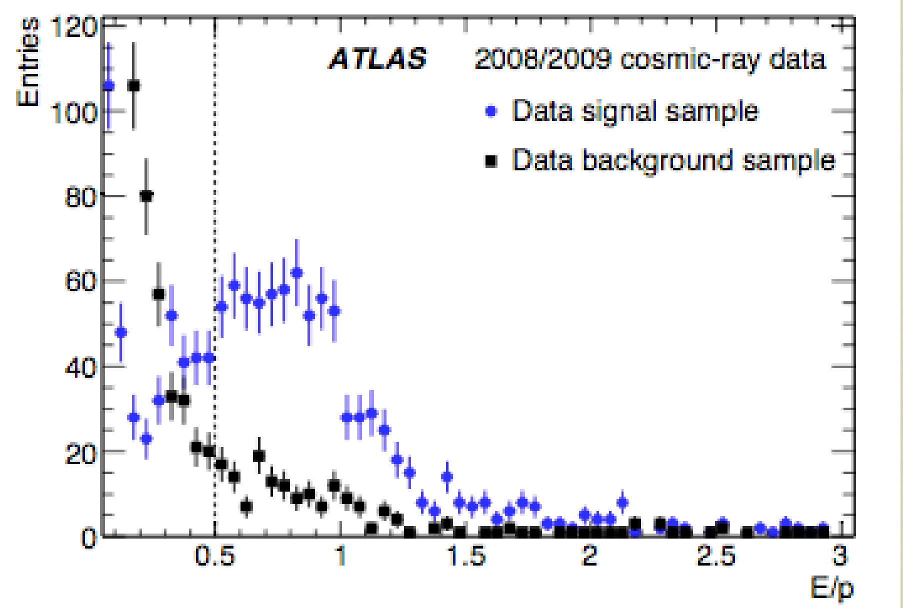
Electrons in cosmic-ray data

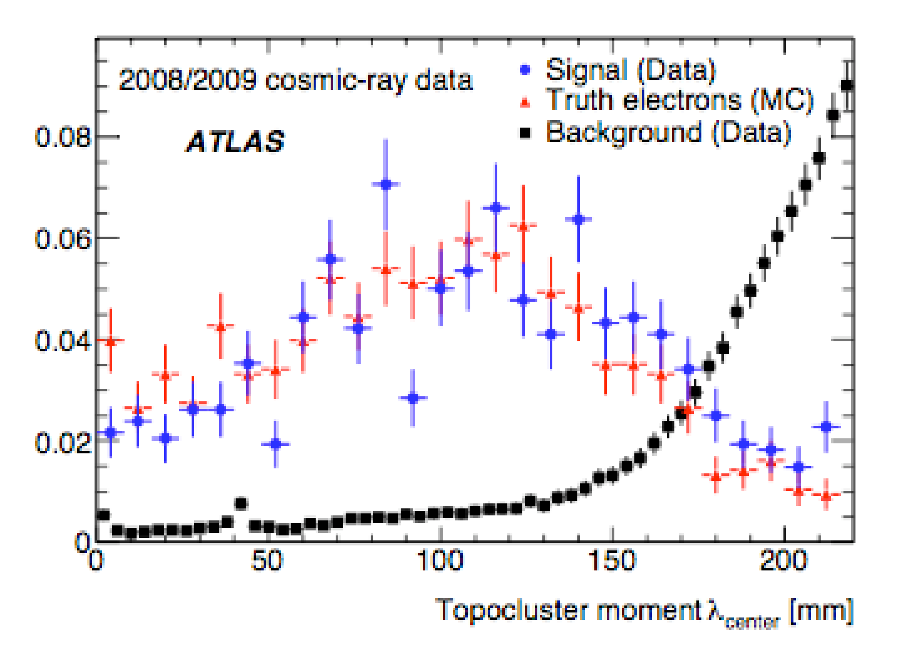
- Before we had the luxury of collision events, the first electrons in ATLAS were studied in cosmic-ray data.
- The electrons originate from a cosmic muon interacting with the material in the detector and emitting a delta-ray
- Two methods were used to identify cosmic-ray electrons. Both are relying heavily on the TRT, since the probability of having pixel and SCT hits is low due to the geometry of the cosmic event
- The results of both methods are summarized in the ATLAS-PERF-INT-2010-02 paper about to be published: “Studies of the performance of the ATLAS detector with cosmic-ray muons”
- The first method uses the standard “egamma” electrons applying tight ID, but removing the pixel and SCT requirements.
- This method identifies 34 electrons above 2.5 GeV in 2008 cosmic ray data

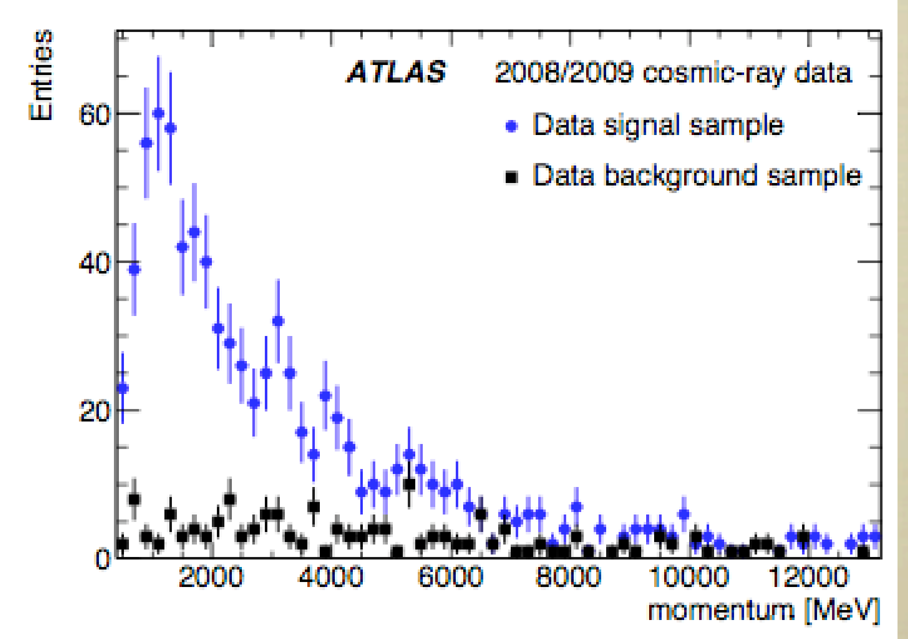


- The reason for the low yield from the first method is the low energy of the delta-rays.
- The second method therefore uses a track matched to a topological cluster, rather than a sliding window cluster, which allows for electron identification to be made down to 0.5 GeV
- The identifying variables here are based on the topological cluster moments as well as E/p and the TR ratio
- 882 electrons are identified in 2008 and 2009 data
- The muon background is estimated to be 5%, with the template method using the moment λ_{center}



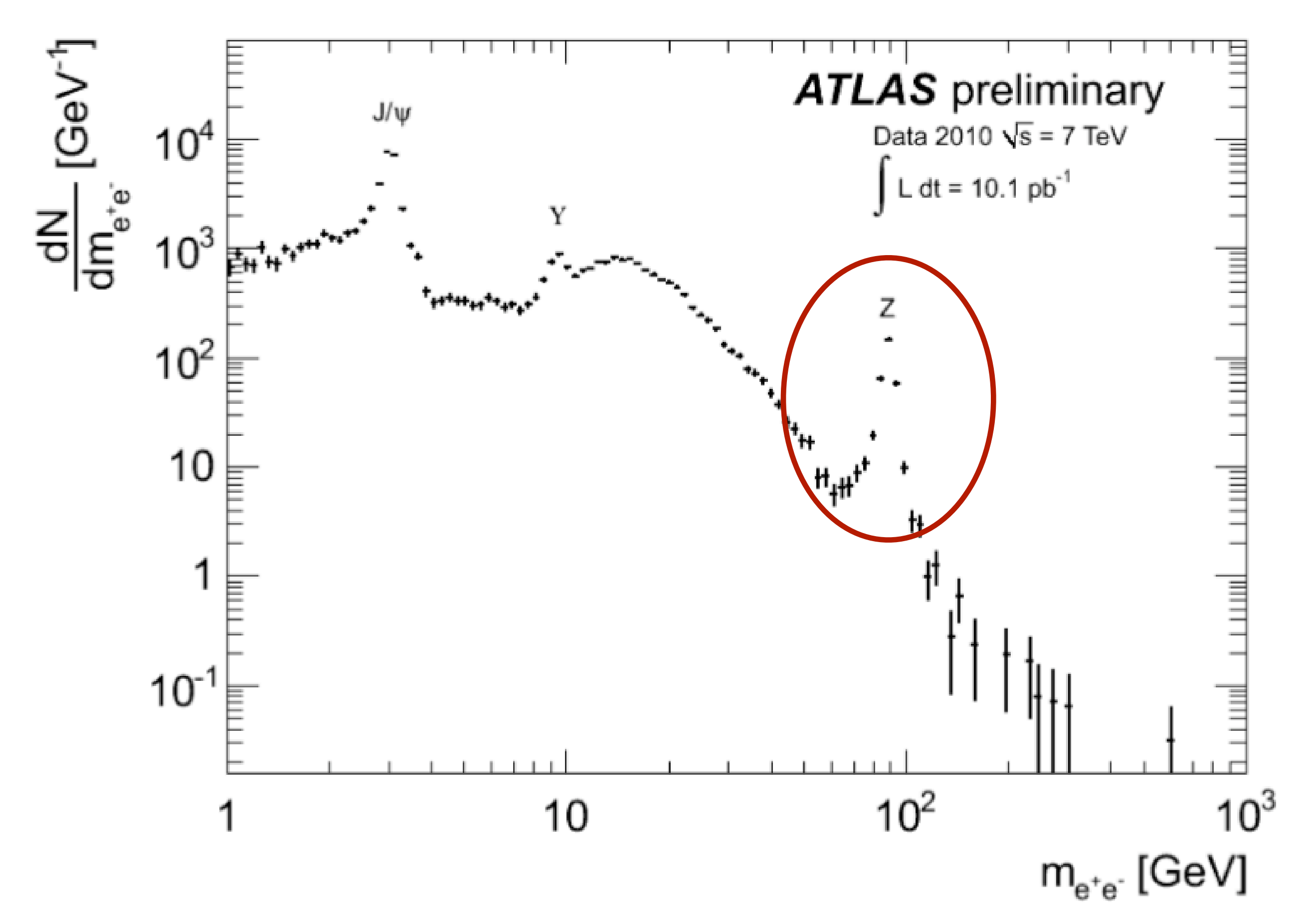






Electrons in collision data

- Now, with collision data at hand, we have more interesting physics analysis to perform with electrons

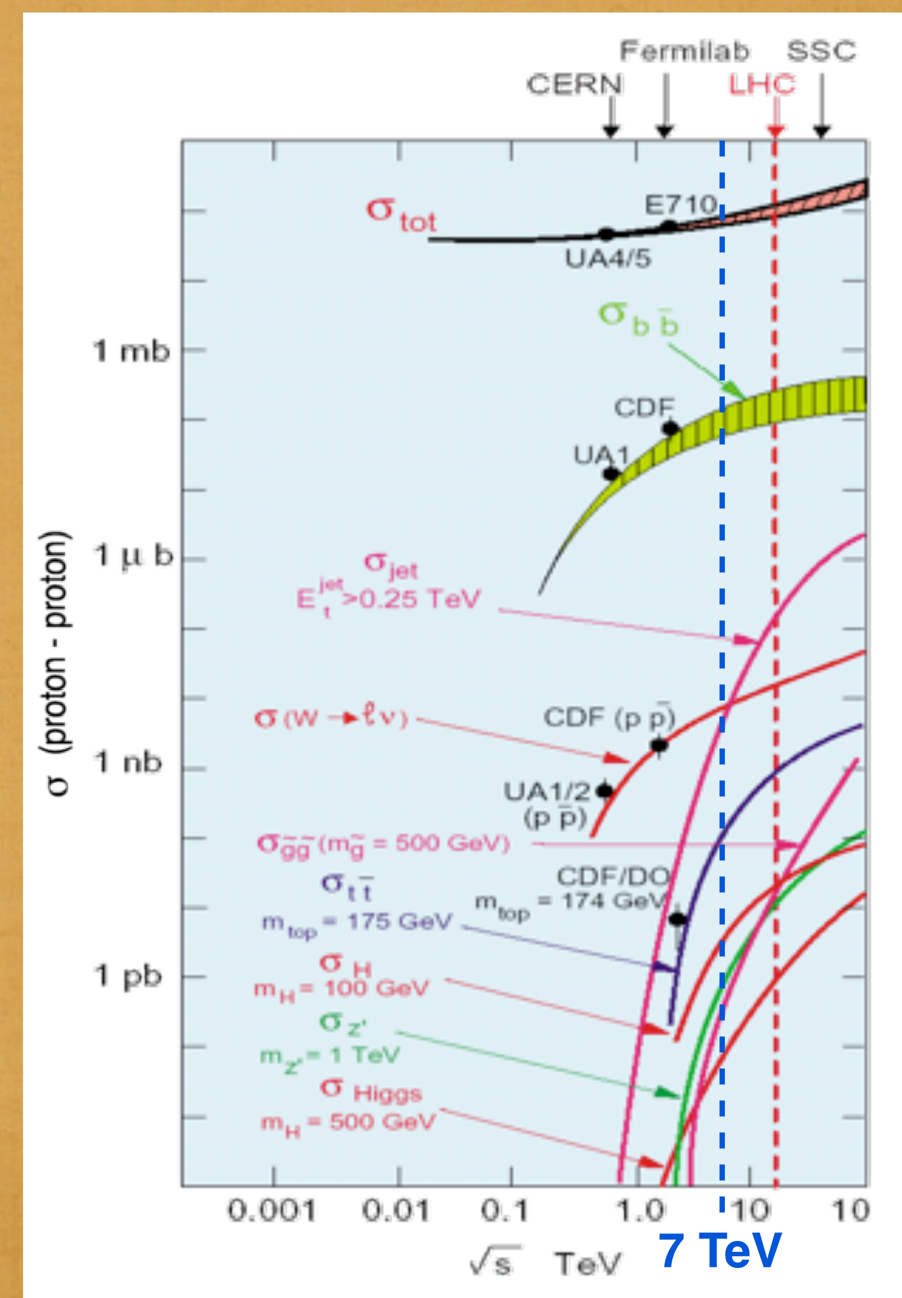


Taken from:
http://cdsweb.cern.ch/record/1303022

- The plot above show opposite sign di-electron invariant mass spectrum, measured using a 5 GeV di-electron trigger with 10.1 pb^{-1} of data

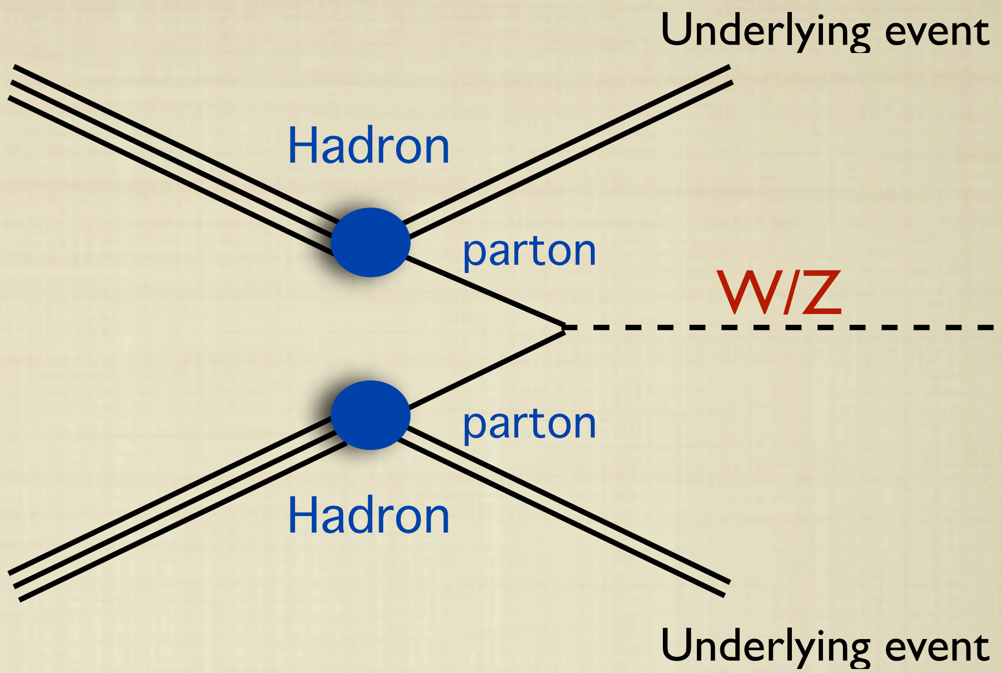
- The rest of the seminar will focus on W and Z bosons in the electron channel

First W/Z cross section measurement



Motivation for W and Z studies

- W/Z physics are well known processes with small background contamination and will therefore provide with:
    - Identification: data driven efficiencies can be obtained with a clean Z sample
    - Calibration: energy scale studies that can also be applied to other processes
    - Missing E_T studies



$\sigma^{NNLO}_{W\to l\nu} = 10.46$ nb, whereas

$\sigma^{NNLO}_{W^+\to l^+\nu} = 6.16$ nb and $\sigma^{NNLO}_{W^-\to l^-\nu} = 4.30$ nb

$\sigma^{NNLO}_{Z/\gamma^*\to ll} = 0.96$ nb for $[66-116]$ GeV mass window

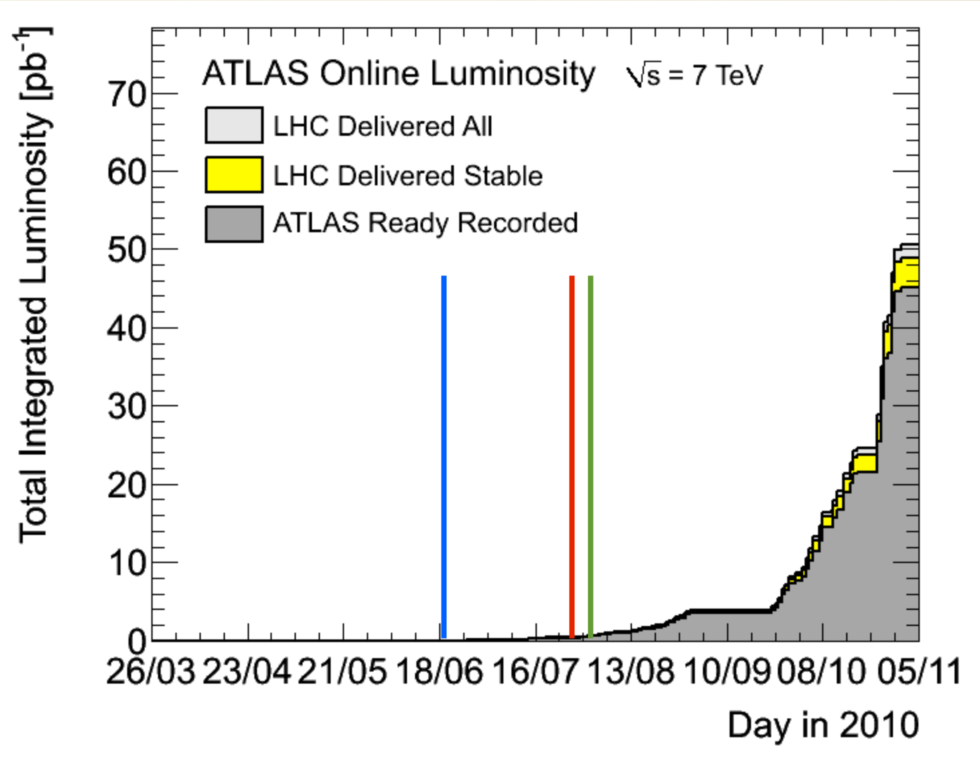
- With a better knowledge of the detector performance:
    - Precise W measurement: can use W's as luminometer
    - Provide tests on QCD, which will eventually constrain the PDFs
    - Understand W/Z as backgrounds for new physics searches

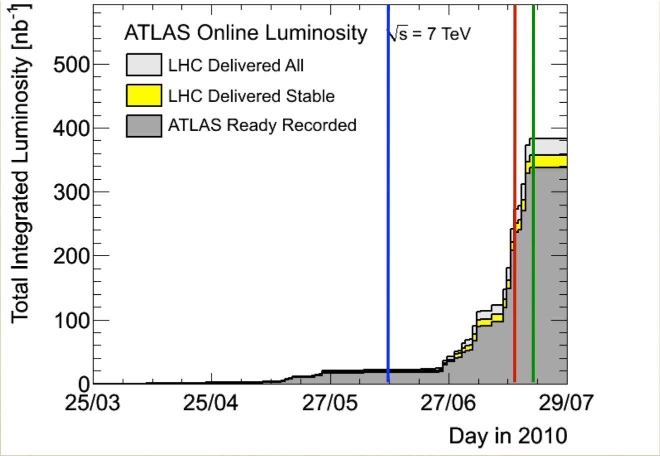
First W/Z measurements

- ATLAS recorded 2010: 45 pb^{-1}
- Sub-detectors used for the electron channel must be in nominal condition - applied through the "good run list" (GRL): 37 pb^{-1}
- The W/Z GRLs can be found at:

  https://svnweb.cern.ch/cern/wsvn/atlasgrp/Physics/StandardModel/WZPhysics/Common/GRL/

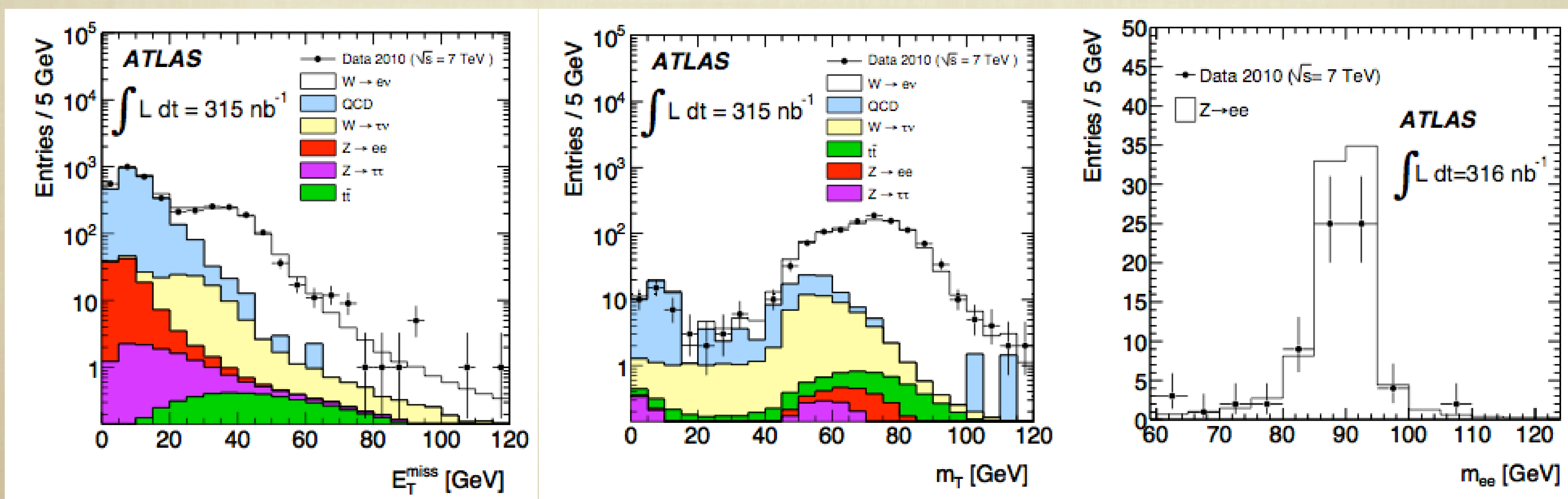
- ICHEP results:
  - W cross section with 17 nb^{-1}, data up to June
  - Z cross section with 225 nb^{-1}, data taken up to mid July
- W/Z cross section paper with 315 nb^{-1}, data taken up to end of July - CERN-PH-2010-037
- A more precise W/Z cross section measurement as well as differential measurements will be done with the full 2010 statistics





W→eν and Z→ee event selection

- For the W/Z cross section paper, using data period A-D (315 nb^{-1}), the event selection for the electron channel was as follows
  - Event preselection: GRL, L1_EM10 trigger, any primary vertex with > 2 tracks and missing E_T cleaning for the W
  - At least 1 (W) or 2 (Z) electrons passing: author Electron, $|\eta| < 2.47$ and outside crack region [1.37,1.52], $E_T > 20$ GeV and OTX fiducial cuts
  - W: robuster tight, Zee veto (medium), $E_T$miss > 25 GeV and $M_T > 40$ GeV → 1069 events
  - Z: robust medium, third electron veto (medium) and $66 < M_{ee} < 116$ GeV → 70 events

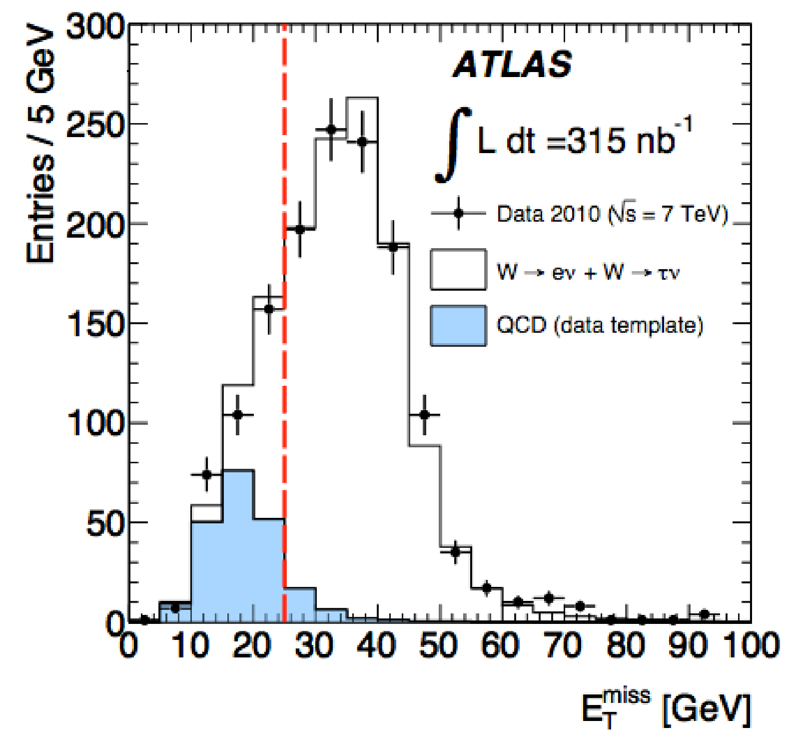


W/Z backgrounds

- The expected electroweak background for the W, from the $W \rightarrow \tau\nu$, $Z \rightarrow ee$ and $Z \rightarrow \tau\tau$ are 25.9, 1.9 and 1.6 events

- The QCD background in the electron channel was estimated with the template method, relaxing the missing E_T cut.

- The background template was obtained by not applying the electron ID requirements and reversing some of the tight ID cuts. The result of the fit: N_{QCD} = 28 ± 3.0(stat) events



ℓ	Observed candidates	Background (EW+$t\bar{t}$)	Background (QCD)	Background-subtracted signal N_W^{sig}
e^+	637	18.8 ± 0.2 ± 1.7	14.0 ± 2.1 ± 7.1	604.2 ± 25.2 ± 7.6
e^-	432	14.7 ± 0.2 ± 1.3	14.0 ± 2.1 ± 7.1	403.2 ± 20.8 ± 7.5
$e^\pm$	1069	33.5 ± 0.2 ± 3.0	28.0 ± 3.0 ± 10.0	1007.5 ± 32.7 ± 10.8

- For the Z, the electroweak background is estimated to be very small

- The QCD background is obtained from fitting the invariant mass and gives N_{QCD} = 0.91 ± 0.11(stat) ± 0.41(sys) events

ℓ	Observed candidates	Background (EW+$t\bar{t}$)	Background (QCD)	Background-subtracted signal N_Z^{sig}
$e^\pm$	70	0.27 ± 0.00 ± 0.03	0.91 ± 0.11 ± 0.41	68.8 ± 8.4 ± 0.4

W/Z cross section calculation

- Taking the W as example, the total cross section is obtained by:

$$\sigma_W \times BR(W \to l\nu) = \frac{N_W^{obs} - N^{bkg}}{A_W C_W L_{int}}$$

- $A_{W/Z}$ is the geometrical acceptance calculated at generator level; electrons from W/Z passing E_T and η cuts as well as M_{inv}/M_T cuts in truth over all events.

$$A_W = \left(\frac{N^{acc}}{N^{all}}\right)_{gen}$$

- The acceptance is calculated with different generators and 3% (4%) is taken as an overall systematic for the W (Z)

- $C_{W/Z}$ is a factor correcting for reconstruction, trigger and identification efficiencies for the electron

$$C_W = \varepsilon^W_{\text{event}} \cdot \alpha^W_{\text{reco}} \cdot \varepsilon^W_{\text{lep}} \cdot \varepsilon^W_{\text{trig}}$$

$$C_Z = \varepsilon^Z_{\text{event}} \cdot \alpha^Z_{\text{reco}} \cdot (\varepsilon^Z_{\text{lep}})^2 \cdot [1-(1-\varepsilon^Z_{\text{trig}})^2],$$

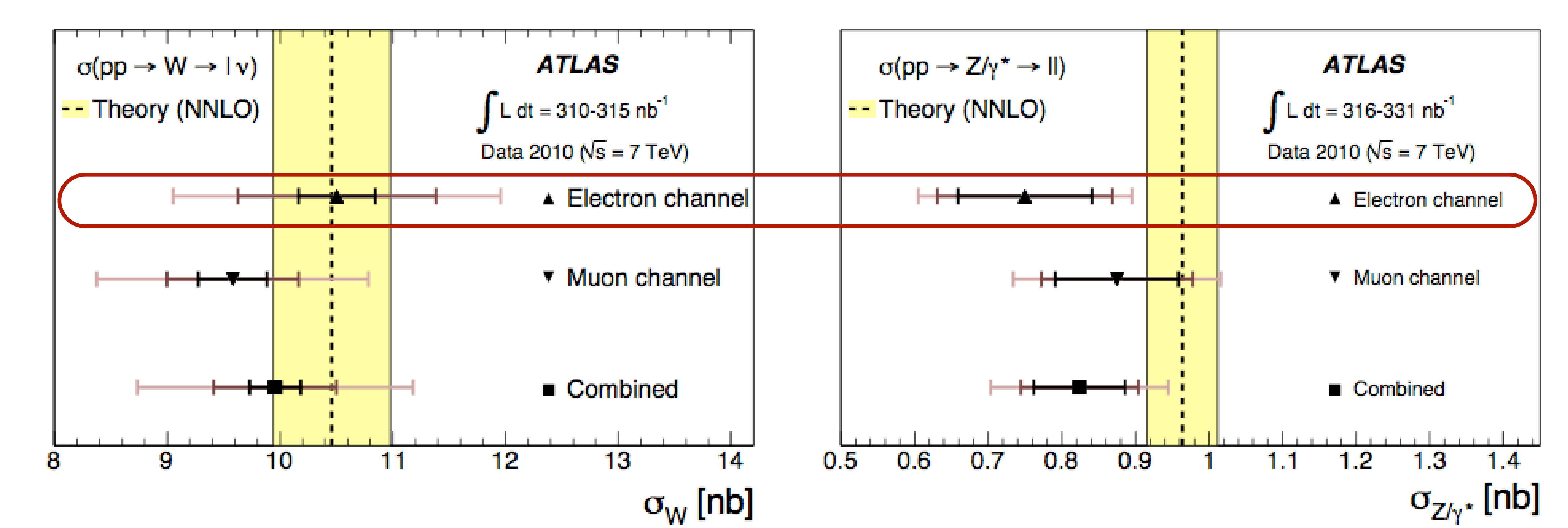
	$W \to e\nu$		$Z \to ee$	
	Central value	Relative uncertainty	Central value	Relative uncertainty
C_W, C_Z	0.659	7.0%	0.651	9.4%

Parameter	$\delta C_W/C_W(\%)$	$\delta C_Z/C_Z(\%)$
Trigger efficiency	<0.2	<0.2
Material effects, reconstruction and identification	5.6	8.8
Energy scale and resolution	3.3	1.9
E_T^{miss} scale and resolution	2.0	-
Problematic regions in the calorimeter	1.4	2.7
Pile-up	0.5	0.2
Charge misidentification	0.5	0.5
FSR modelling	0.3	0.3
Theoretical uncertainty (PDFs)	0.3	0.3
Total uncertainty	7.0	9.4

W/Z cross section results with 300 nb^{-1}

- The resulting cross section values
- The W cross section is compatible with theory, while there is a significant deficit of Z's in data, not incorporated in the large uncertainty
- This is something still seen with the current amount of data, but might be improved with the reprocessed data?

	$\sigma^{tot}_{W(\pm)} \cdot BR(W \to e\nu)$ [nb]
W^+	$6.27 \pm 0.26(stat) \pm 0.48(syst) \pm 0.69(lumi)$
W^-	$4.23 \pm 0.22(stat) \pm 0.33(syst) \pm 0.47(lumi)$
W	$10.51 \pm 0.34(stat) \pm 0.81(syst) \pm 1.16(lumi)$
	$\sigma^{tot}_{Z/\gamma^*} \cdot BR(Z/\gamma^* \to ee)$ [nb], $66 < m_{ee} < 116$ GeV
Z/γ^*	$0.75 \pm 0.09(stat) \pm 0.08(syst) \pm 0.08(lumi)$



A deeper look into the efficiency uncertainty

$$C_W = \varepsilon^W_{\text{event}} \cdot \alpha^W_{\text{reco}} \cdot \varepsilon^W_{\text{lep}} \cdot \varepsilon^W_{\text{trig}}$$

$$C_Z = \varepsilon^Z_{\text{event}} \cdot \alpha^Z_{\text{reco}} \cdot (\varepsilon^Z_{\text{lep}})^2 \cdot [1-(1-\varepsilon^Z_{\text{trig}})^2],$$

- The largest systematic uncertainties for the factors C_W and C_Z come from the electron ID efficiencies
- For the W/Z 300 nb⁻¹ paper, statistics did not permit using data-driven methods to assess the central values of the electron ID efficiencies
- The W/Z medium and tight efficiencies were therefore estimated with MC, applying a "loose" truth matching, which includes the shower from the W/Z primary electron
- The systematic uncertainty was taken from data driven efficiencies obtained with a tag and probe like study performed on the $W \to e\nu$ events with 1 pb⁻¹.

Contribution	Central value $W \to e\nu$	Relative uncertainty $W \to e\nu$	Central value $Z \to ee$	Relative uncertainty $Z \to ee$
ϵ_{event}	99.7%	< 0.2%	99.8%	< 0.2%
α_{reco} :				
- kinematic cuts	100.5%		95.4%	
- lepton energy scale and resolution		3.0%		3.0%
- E_T^{miss} scale, resolution and pile-up		2%		
- FSR	97.2%	< 0.5%	95.0%	< 0.5%
- reconstruction efficiency	90.0%	1.6%	80.7%	3.0%
ϵ_{id}	75.3%	5.2%	89.2%	8.4%
ϵ_{trig}	99.8%	< 0.2%	100%	< 0.1%
Theoretical uncertainty		0.3%		0.3%
Total C_W and C_Z	65.9%	7.0%	65.1%	9.9%

Table 10: Decomposition of the C_W and C_Z correction factors and related systematic uncertainties for the electron channel.

Taken from
ATL-COM-PHYS-2010-701
ATL-COM-PHYS-2010-703

	$\varepsilon(data)/\varepsilon(MC)$ Method 1	$\varepsilon(data)/\varepsilon(MC)$ Method 2
Loose	98.3±0.4±4.5%	99.7±0.4±4.5%
Medium	95.6±0.8±4.5%	98.4±0.5±4.5%
Tight	99.9±1.0±4.5%	102.0±1.0±4.5%

EFFICIENCY SYSTEMATICS - MATERIAL EFFECTS

- To assess how much of the efficiency systematic uncertainty come from material effects, 7 samples with different extra material were studied

- The largest effects:

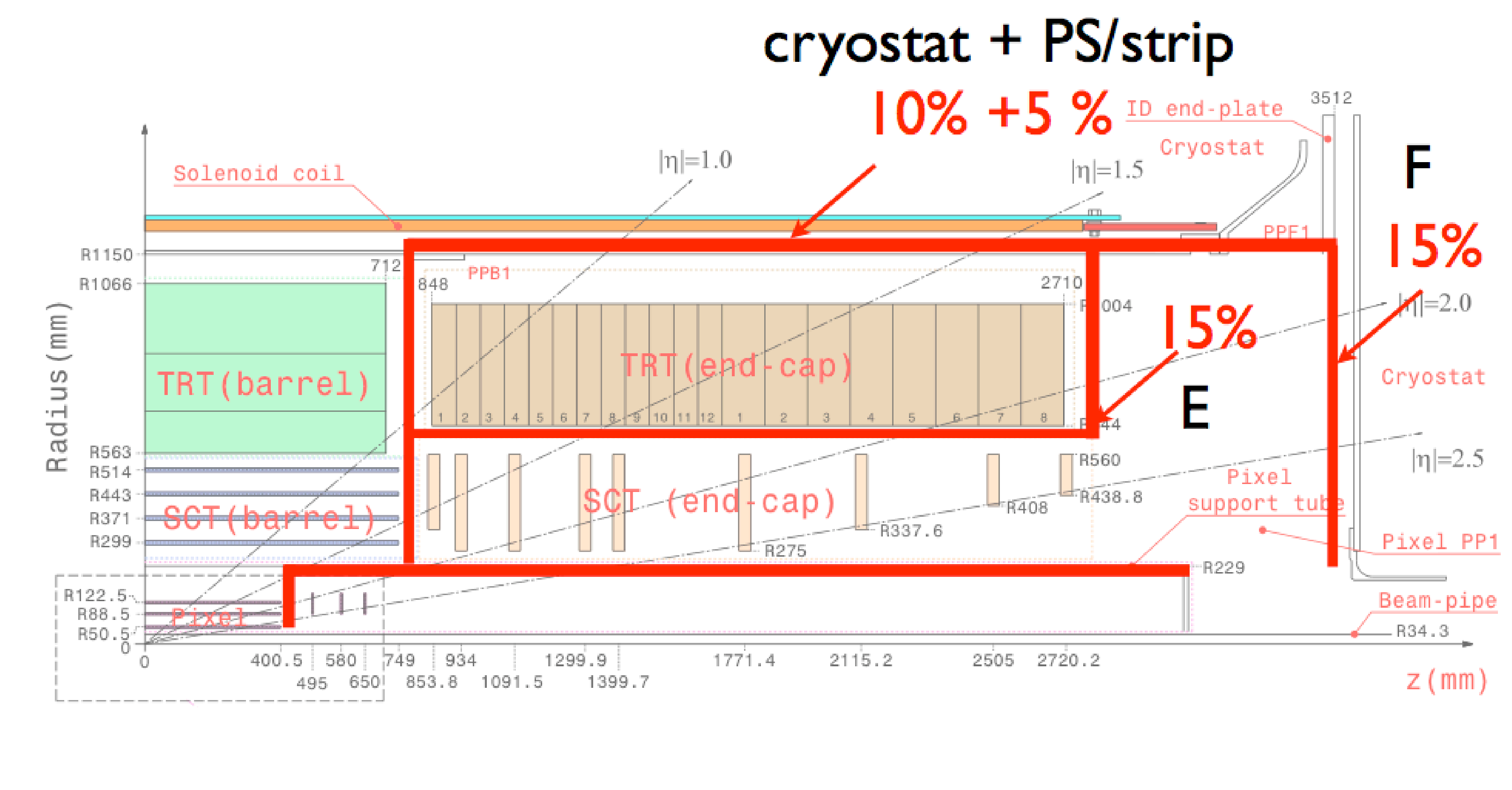
- Reconstruction and tight efficiencies - extra material in the whole ID

- Medium efficiency - extra material in the calorimeter

	$\Delta\varepsilon_{reco}$	$\Delta\varepsilon_{med}$	$\Delta\varepsilon_{tight}$
Systematic uncertainty	1.4%	0.4%	1.6%

- For more details see:

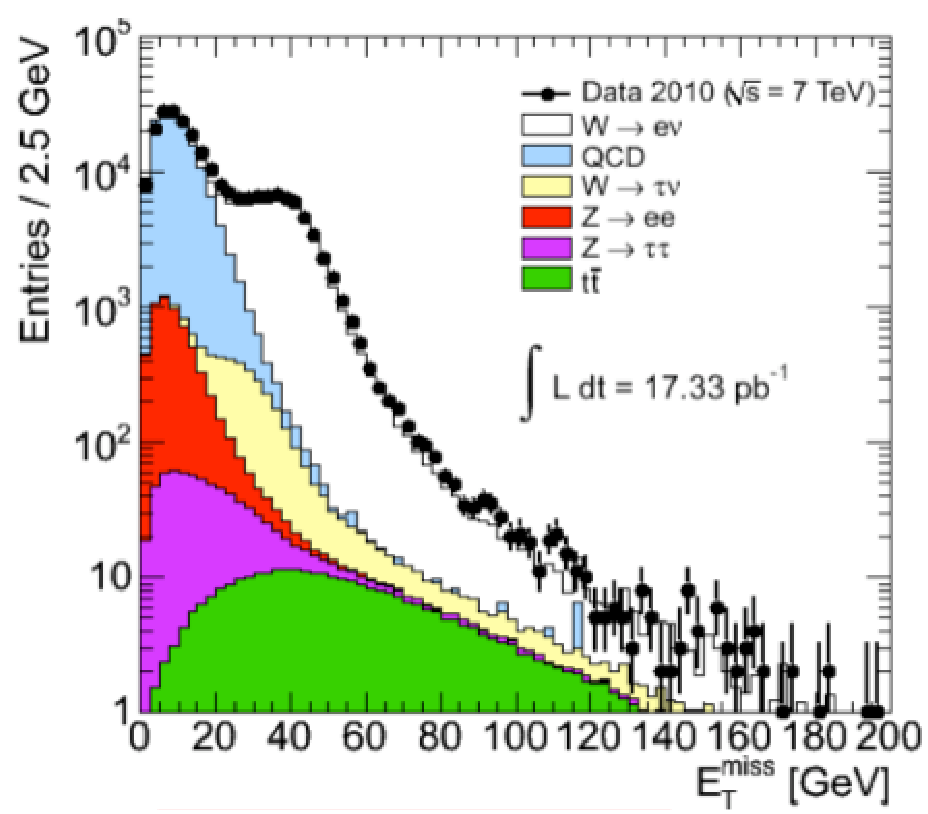
E. Berglund, egamma WS:
http://indico.cern.ch/getFile.py/access?contribId=13&sessionId=10&resId=0&materialId=slides&confId=99950

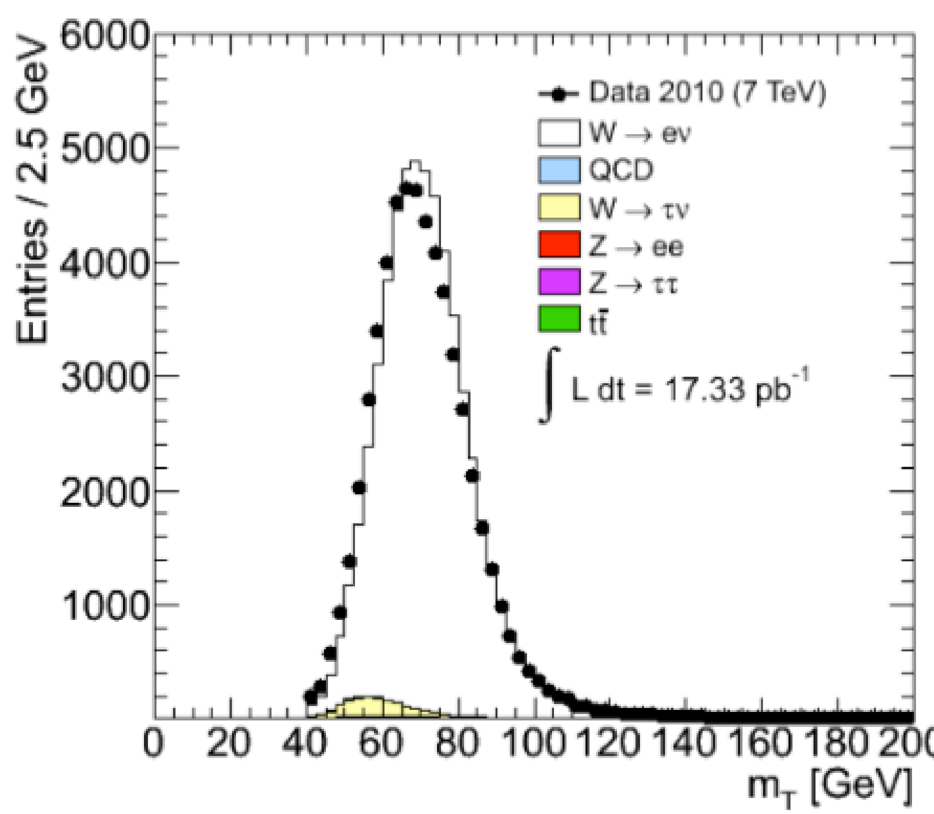


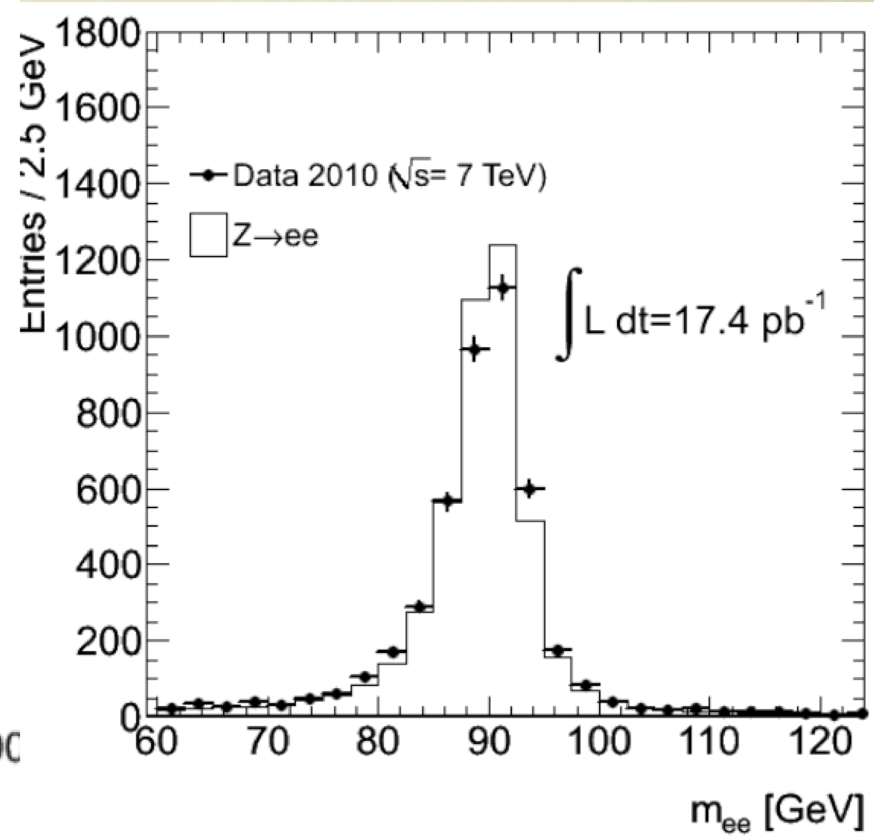
	$\Delta\epsilon^{W}_{reco}/\epsilon^{W}_{reco}$	$\Delta\epsilon^{W}_{medium/reco}/\epsilon^{W}_{medium/reco}$	$\Delta\epsilon^{W}_{tight/reco}/\epsilon^{W}_{tight/reco}$
Nominal + Calo	-0.6%	-0.3%	-0.3%
Nominal + 5% ID	-0.6%	-0.1%	-0.9%
Nominal + 10% ID	-1.3%	-0.2%	-1.6%
Nominal + 20% pixel services	-0.1%	<0.1%	-0.3%
Total (with 5% ID)	-1.3%	-0.4%	-1.5%
Total (with 10% ID)	-2.0%	-0.5%	-2.2%

W/Z inclusive analysis with 2010 data

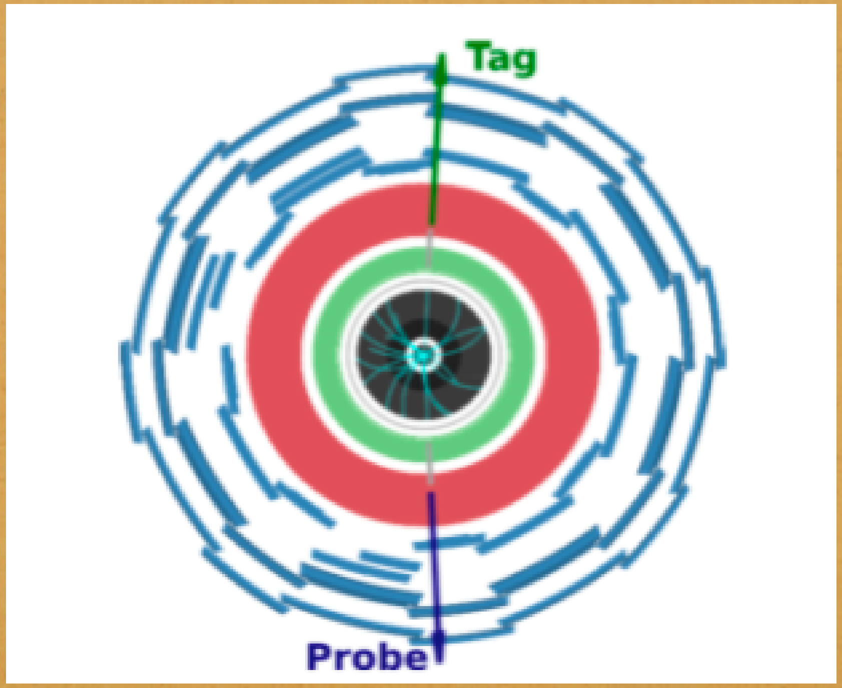
- The W/Z inclusive group is currently working on a cross section measurement with the full 2010 statistics, performed on the reprocessed data.
- The measurement will be much less statistically limited since now there is > 100 times the data used for the first cross section paper ⇒ important to reduce the systematic uncertainties
- The plan is to have public results ready in time for the winter conferences
- The plots below show more updated results for the W/Z analysis with 17 pb^{-1}







Ongoing analysis: Z→ee Tag and Probe



Z→ee tag and probe selection

- With the full 2010 data set available (A-I), adding up to 37 pb^{-1}, a more precise data driven electron efficiency study can be made with Z→ee tag and probe

- The event preselection follow the Z→ee inclusive analysis:

  - Event preselection: GRL, trigger L1_EM14 for A-E3 and e15_medium for E4-I, any primary vertex with > 2 tracks

  - At least 2 electrons passing: author Electron, η cuts, E_T > 20 GeV and OTX fiducial cuts

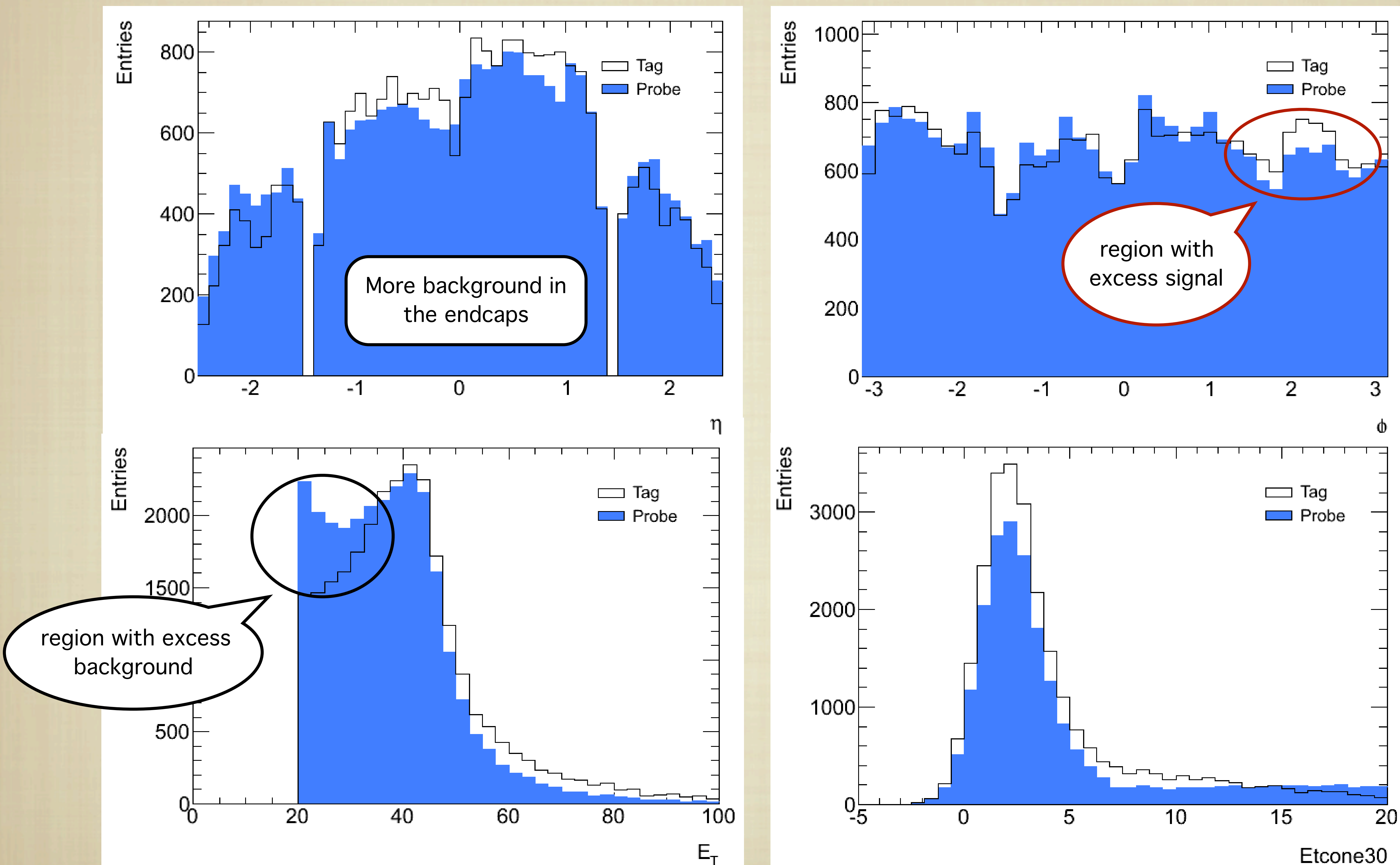
- Then, at "container level", all tags and probes in the event are chosen, but a comparison is made with choosing the pair with the best invariant mass

  - Tag: must pass robuster tight and be matched to the trigger object

  - Probe: used for the efficiency calculation by checking if it passes loose, medium, tight and if it fired the trigger

  - All electrons in the event are checked if they pass the tag requirement such that an event can be used several times: ~ 27000 probes

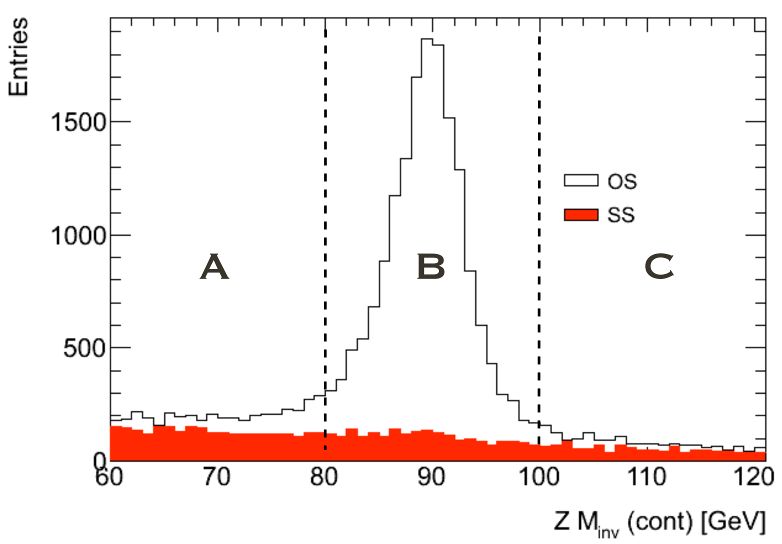
Cross check plots for the tag and the probe



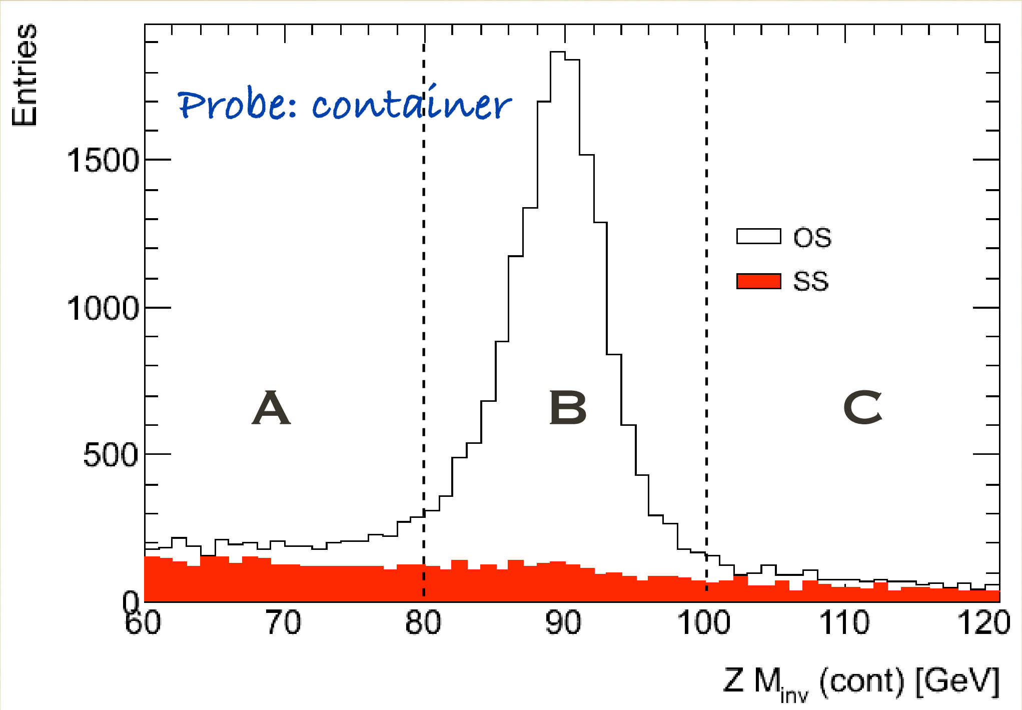
Background subtraction methods
- simple methods

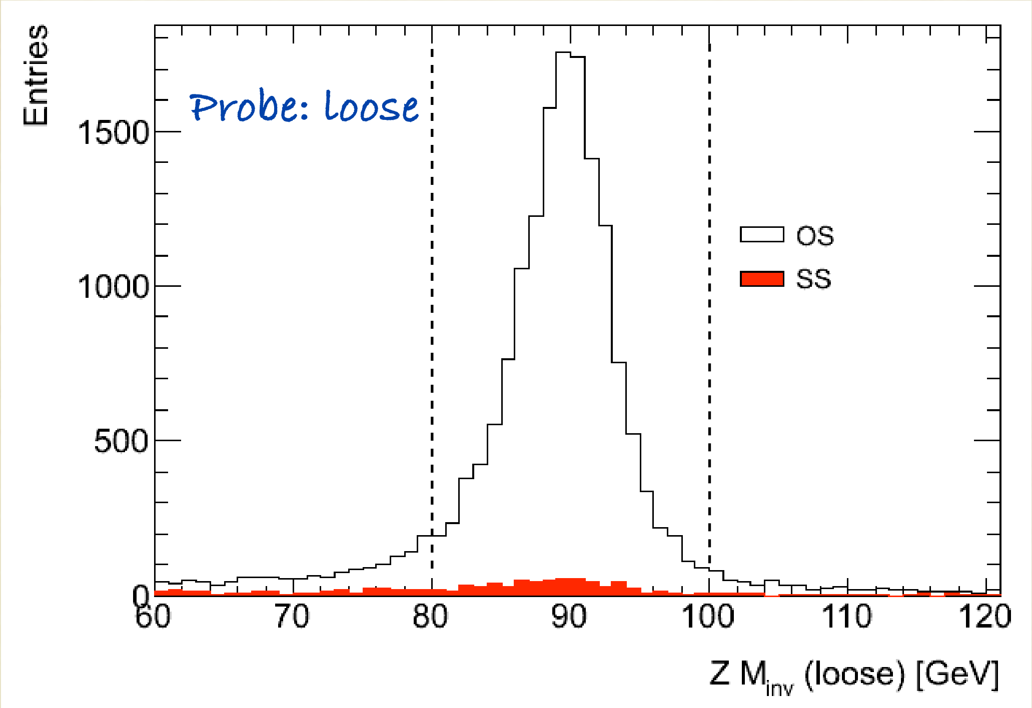
- The amount of background in both the numerator and denominator must be subtracted in order to get a proper efficiency estimate
- This should ideally be performed in E_T,η space
- Different background subtraction methods are being attempted due to the low statistics at hand
- Simple methods using same sign events and M_{inv} sidebands: A [60,80] GeV, B [80,100] and C [100,120]

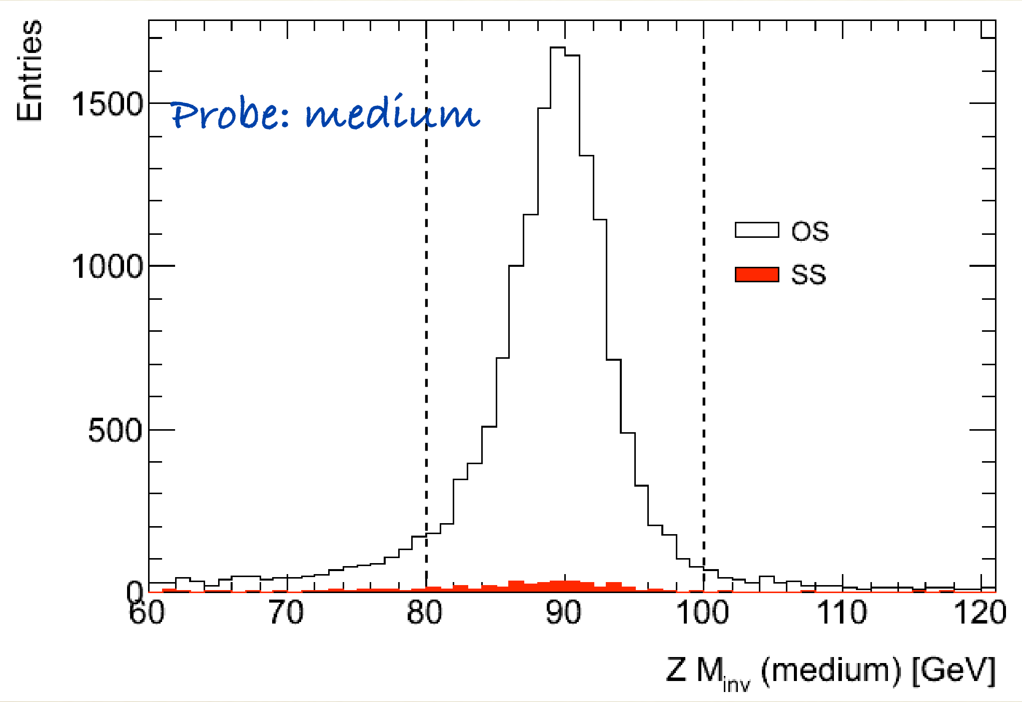
1. Only look at OS events and assume $N_{bkg(OS)} = N_{SS} - N_{misID}$ (66 - 116 GeV).
   Downside: N_{misID} is taken from MC and $N_{bkg(OS)}$ might be different from $N_{bkg(SS)}$
2. Divide the M_{inv} range into sidebands:
   Assume signal in region B is : $S_B = B - (A+C)/2$
   Can be done with a) OS+SS, b) only OS and c) OS for B and SS for A and C.
   Downside: 2a) and b) includes some signal in the background subtraction from the tails of the mass distribution: 2c) more accurate!

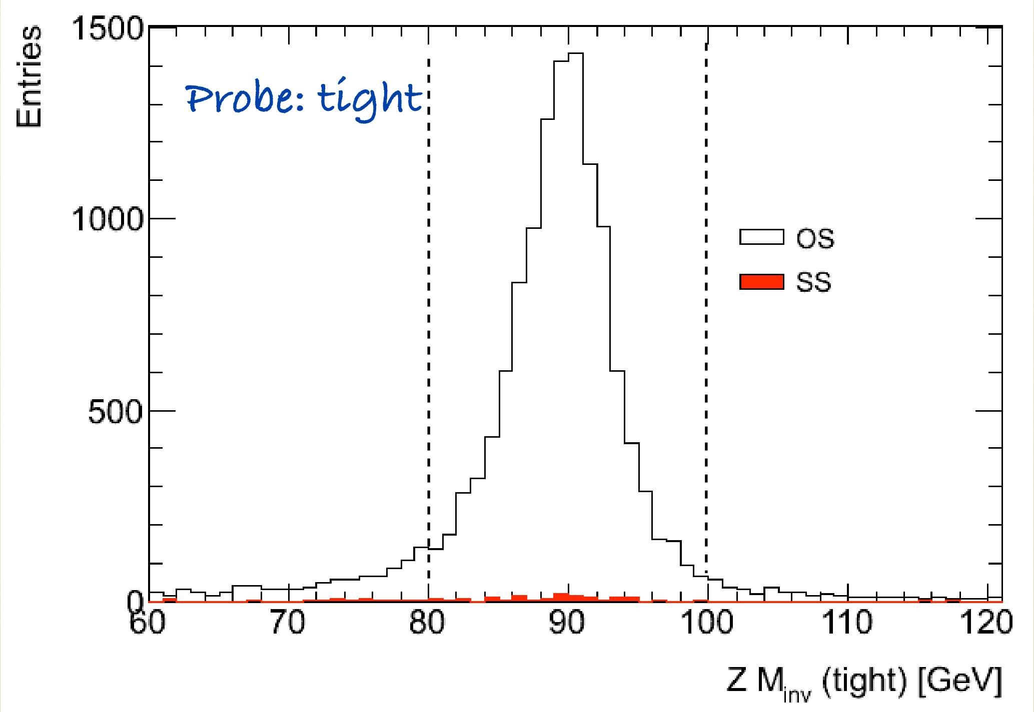


Background subtraction methods
- simple methods



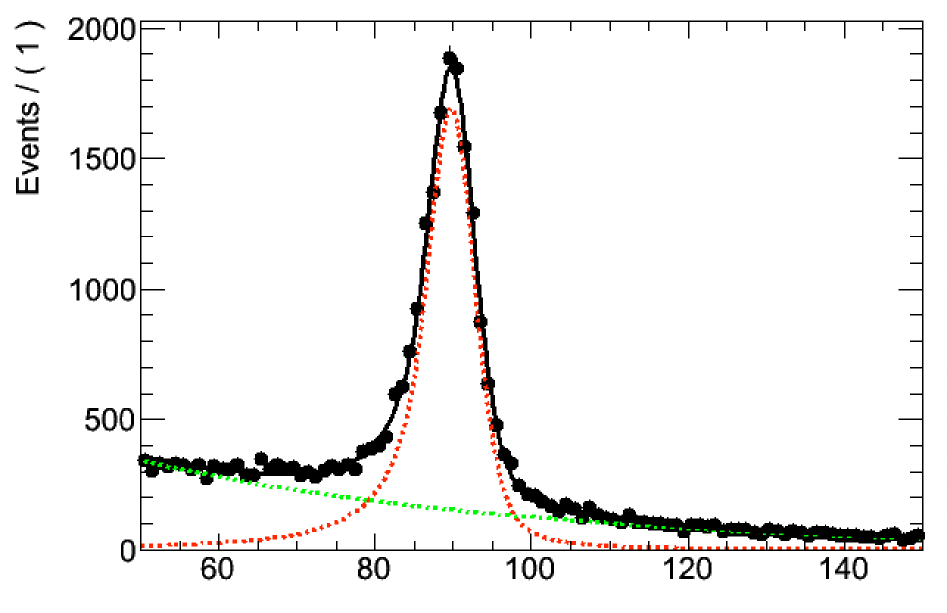






Background subtraction
- fitting method

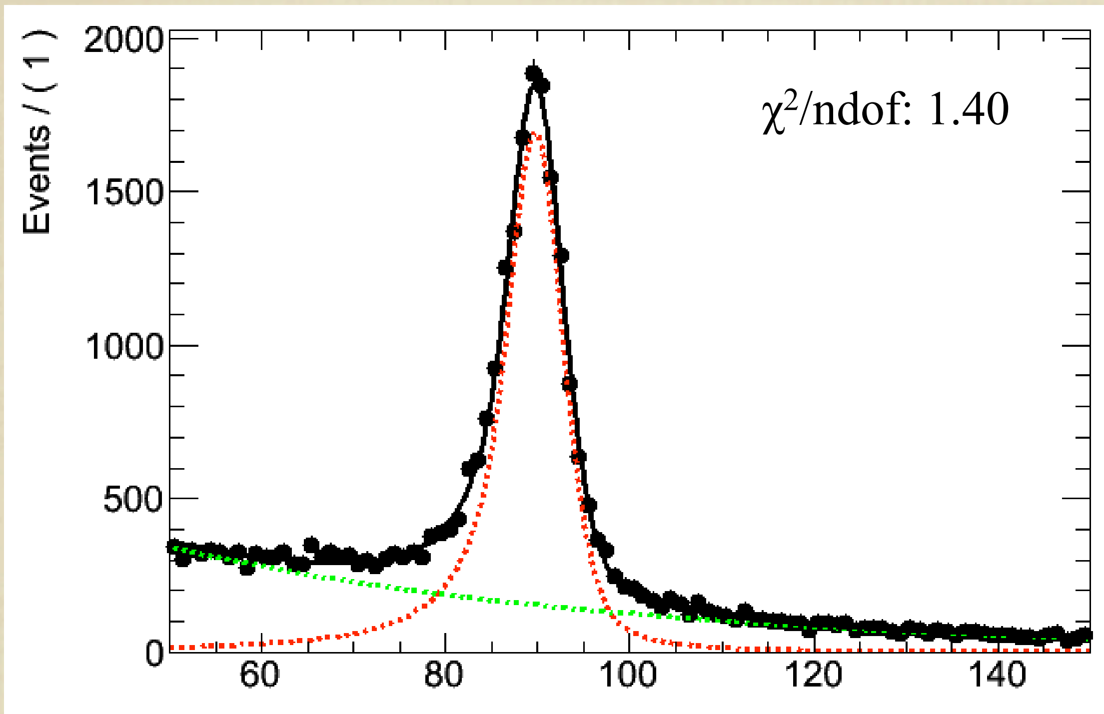
- The invariant mass of the Z can be fitted to extract the background at the different identification levels
- Difficult for medium and tight - use loose fit and apply medium/tight jet rejection factor with respect to loose
  - loose to medium jet rejection: 0.126 ± 0.001
  - loose to tight jet rejection: 0.022 ± 0.004
- The signal is fitted with a convolution of a Crystal ball and a Breit Wigner distribution
- The background is fitted with an exponential distribution

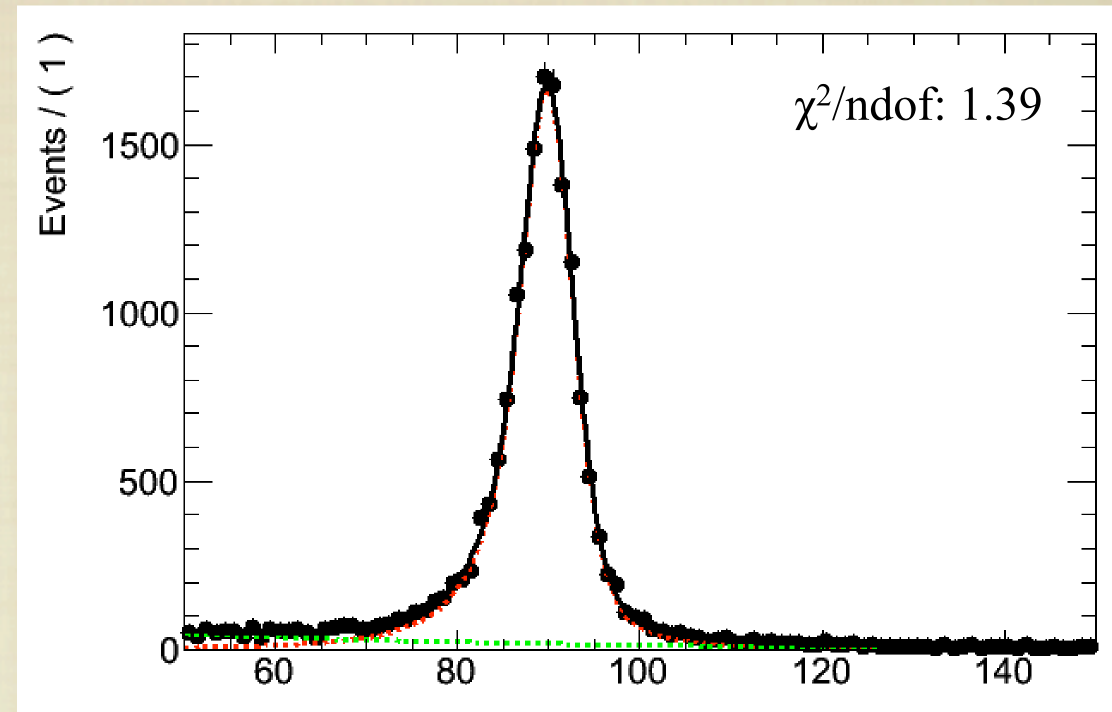


Background subtraction
- fitting method

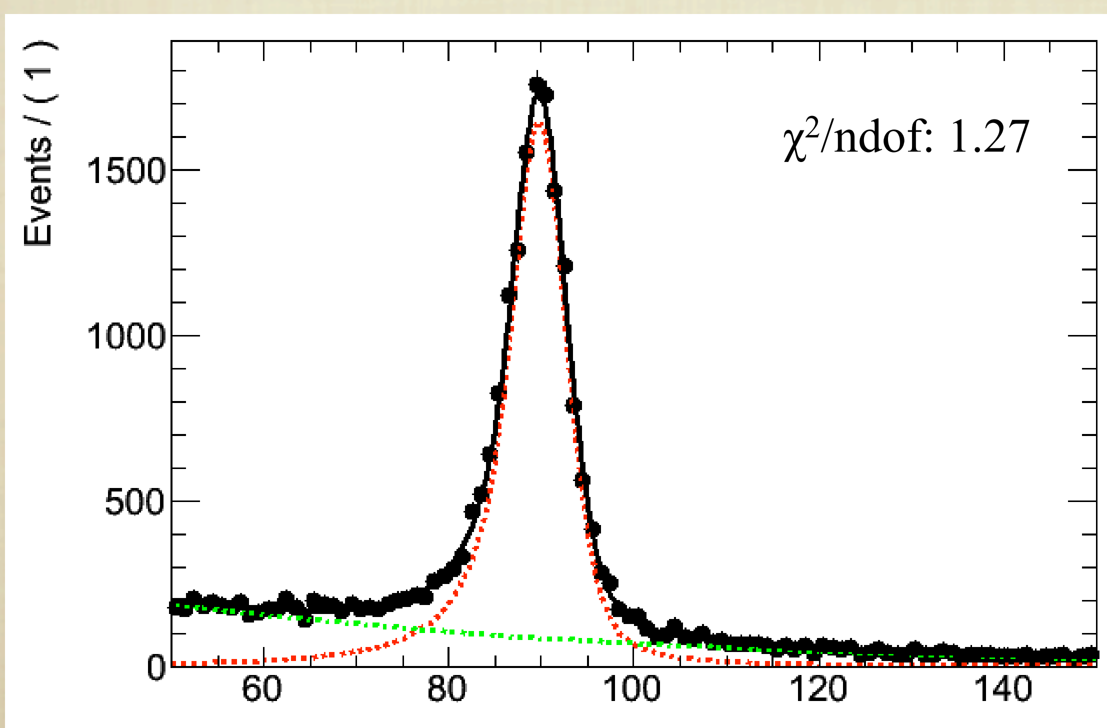
Probe: container | Probe: loose

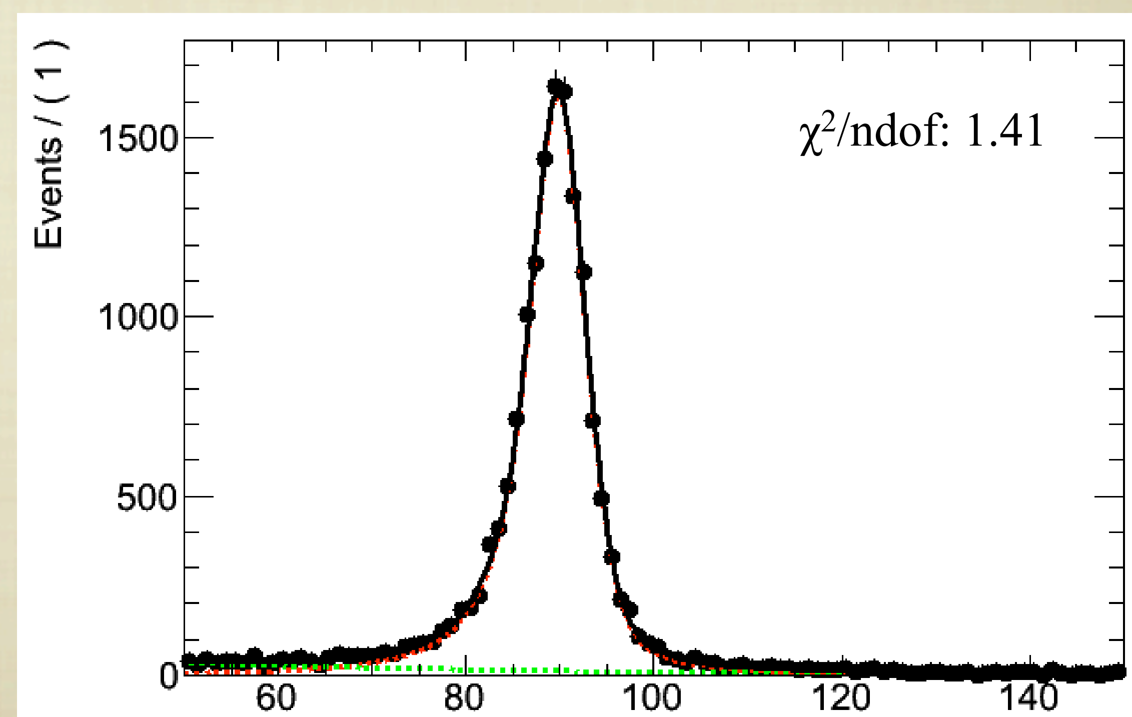
OS+SS





OS





Electron ID efficiencies

- The fitting method and the 2c) OS-SS sideband method behave well, while the other methods tend to overestimate the background
- The efficiencies are then estimated by taking the binomial mean of the numerator and denominator after background subtraction.
- The errors are taking the background subtraction and correlation between numerator and denominator into account according to

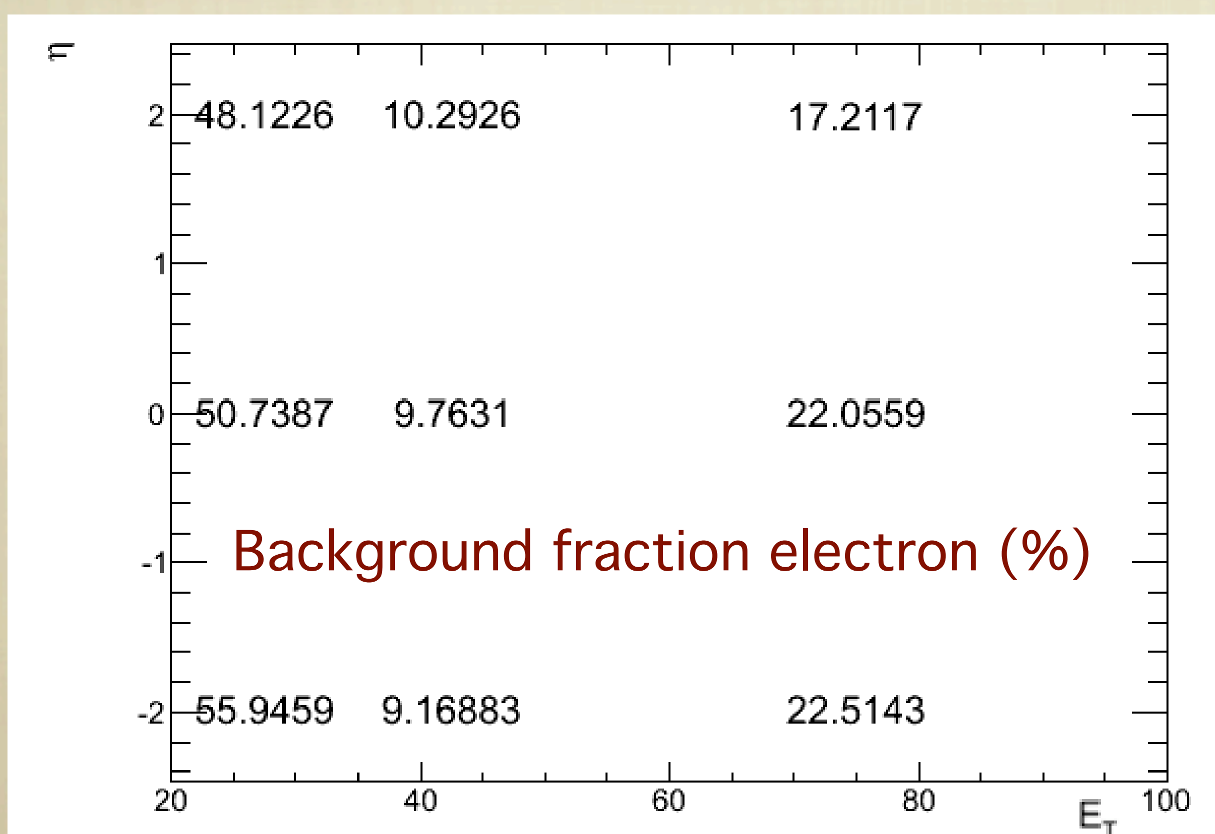
http://www-cdf.fnal.gov/publications/cdf7168_eff_uncertainties.ps

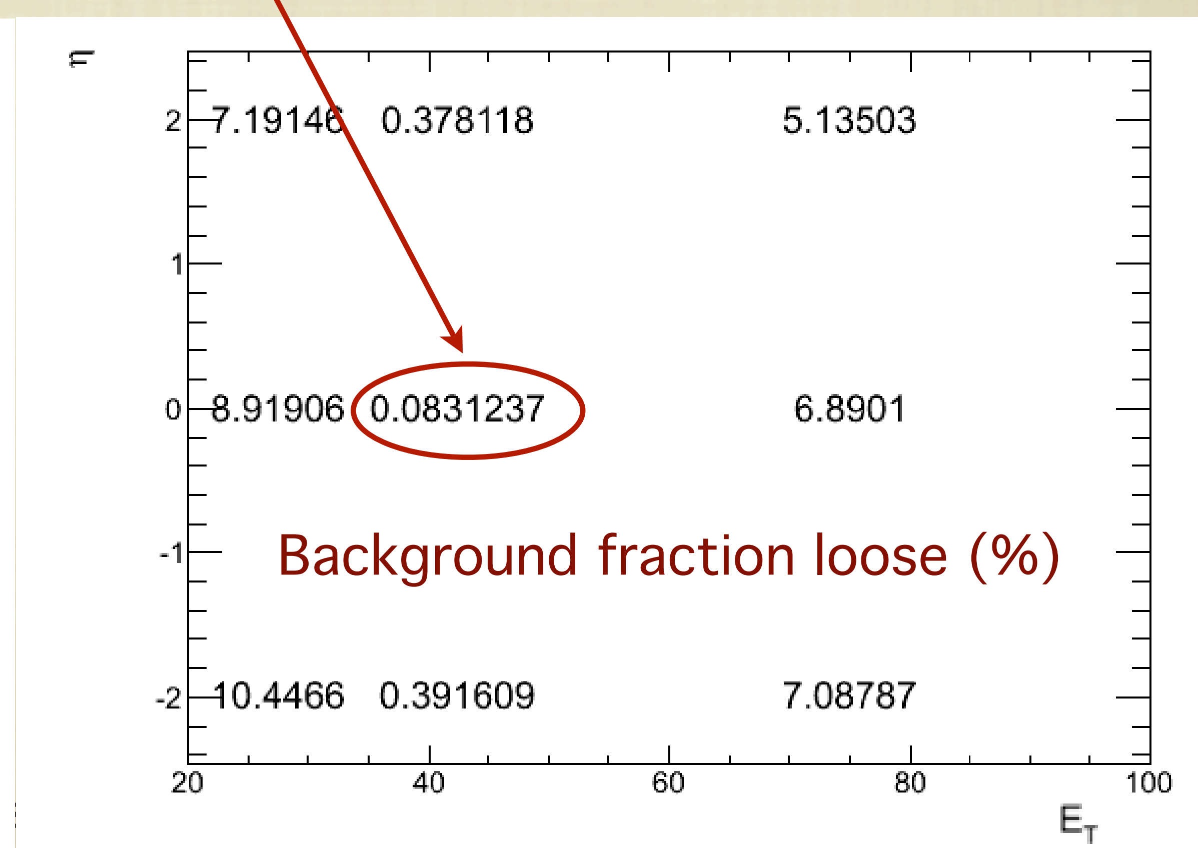
Efficiencies (truth) (%)	**1) OS - SS [66-116]**	**3a) OS Fit [66-116]**	**2a) sideband [80-100] ***	**3b) Fit [80-100]**	**2b) OS sideband [80-100]**	**2c) OS w SS in sidebands [80-100]**	**3c) OS Fit [80-100]**
robust medium	88.7 ± 0.6 (94.5 ± 0.03)	90.5 ± 1.1 (94.5 ± 0.03)	94.1 ± 0.6 (94.1 ± 0.03)	90.9 ± 1.0 (94.1 ± 0.03)	94.0 ± 0.4 (94.7 ± 0.03)	92.7 ± 0.4 (94.7 ± 0.03)	92.8 ± 1.2 (94.7 ± 0.03)
robuster tight	76.1 ± 0.6 (78.4 ± 0.06)	77.0 ± 0.9 (78.4 ± 0.06)	79.1 ± 0.6 (77.5 ± 0.06)	76.4 ± 0.9 (77.5 ± 0.06)	79.9 ± 0.5 (78.8 ± 0.06)	78.7 ± 0.4 (78.8 ± 0.06)	78.8 ± 1.0 (78.8 ± 0.06)

- The tight efficiency is compatible with MC, while the medium efficiencies are lower in data than in MC - explains part of the Z deficit seen in data?

Binned efficiency

- Since the ID efficiency varies throughout the E_T,η electron phase space, it is desirable to bin the efficiency to be able to, for example, apply the result to the W
- This is attempted with the two well behaving methods; 2c) OS-SS sidebands and 3) fitting
- Fitting method - some bins only contain little statistics, which imposes constraints on the fit
  - Can lead to some bins with efficiencies > 100%
  - No background is found for certain bins at loose level





Binned efficiency

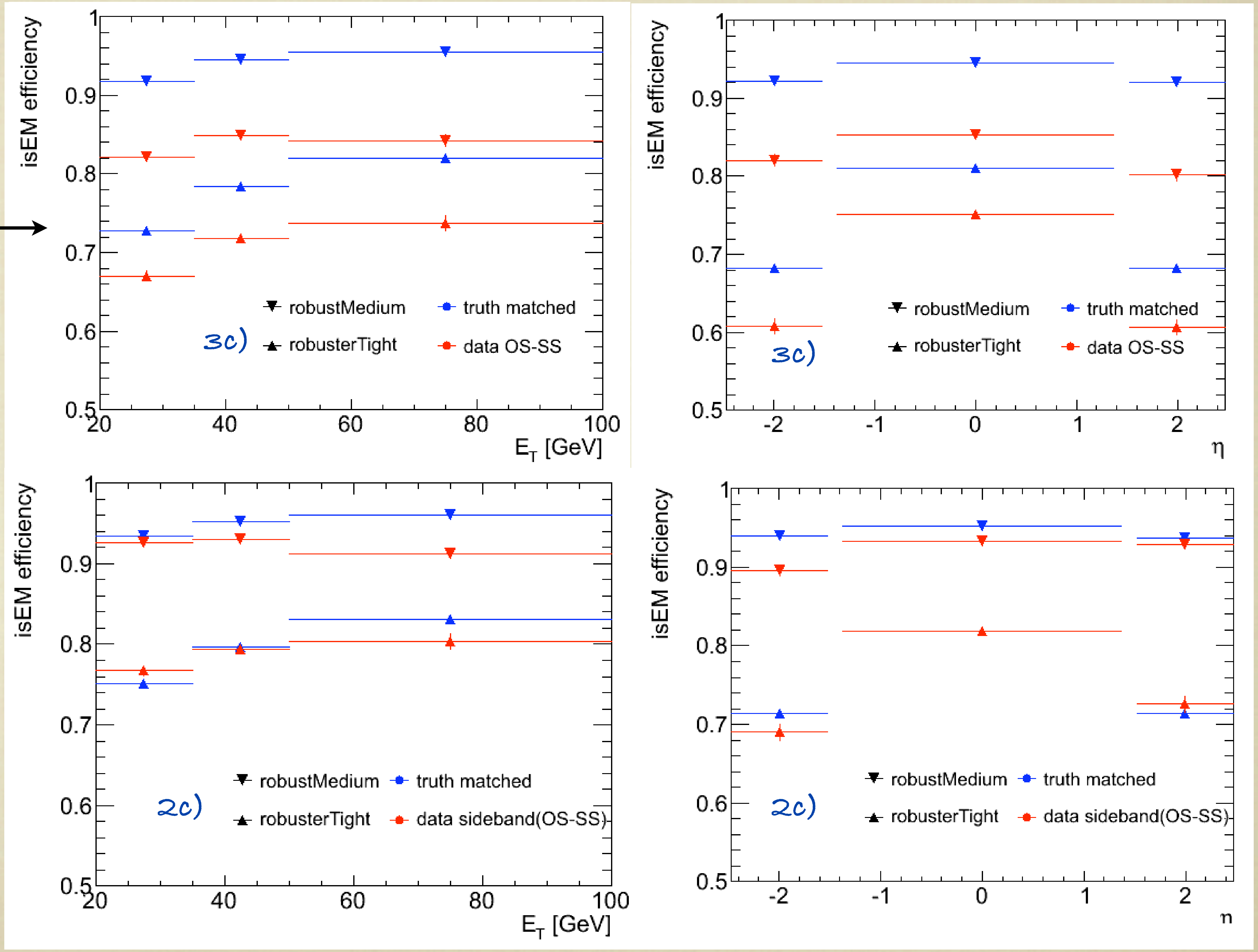
Two compatible methods: 3c and 2c

3c) Fit OS +SS
66-116 GeV

Background subtraction bin-by-bin unreliable →

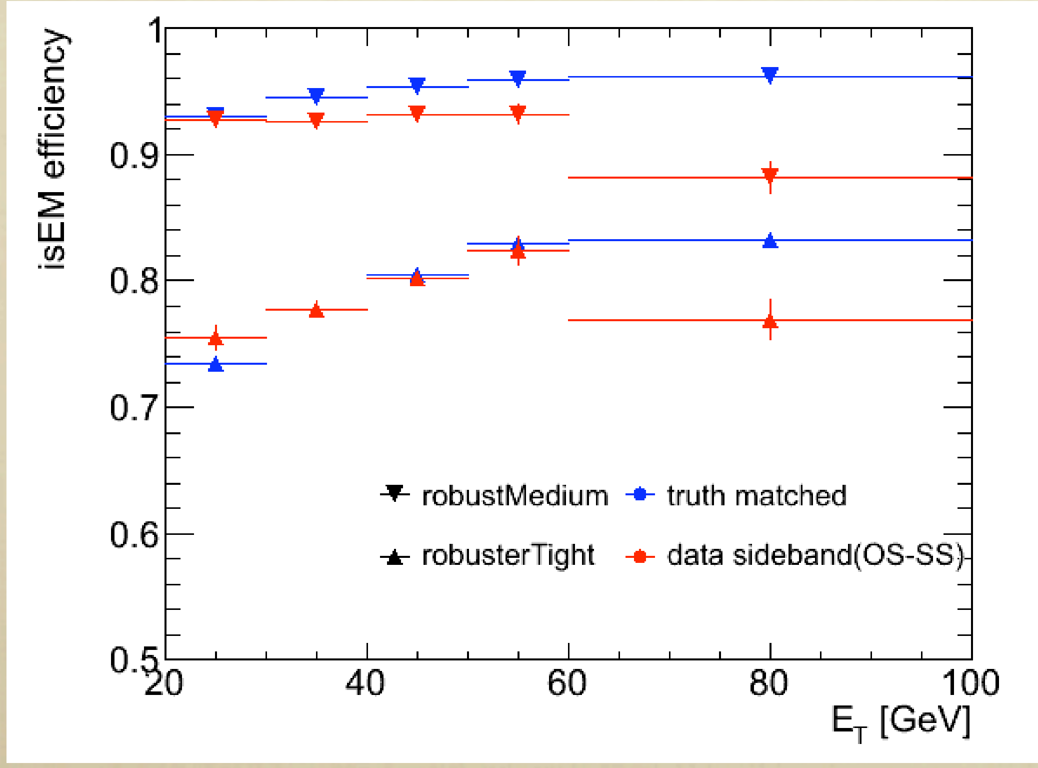
The error bars do not include background subtraction!

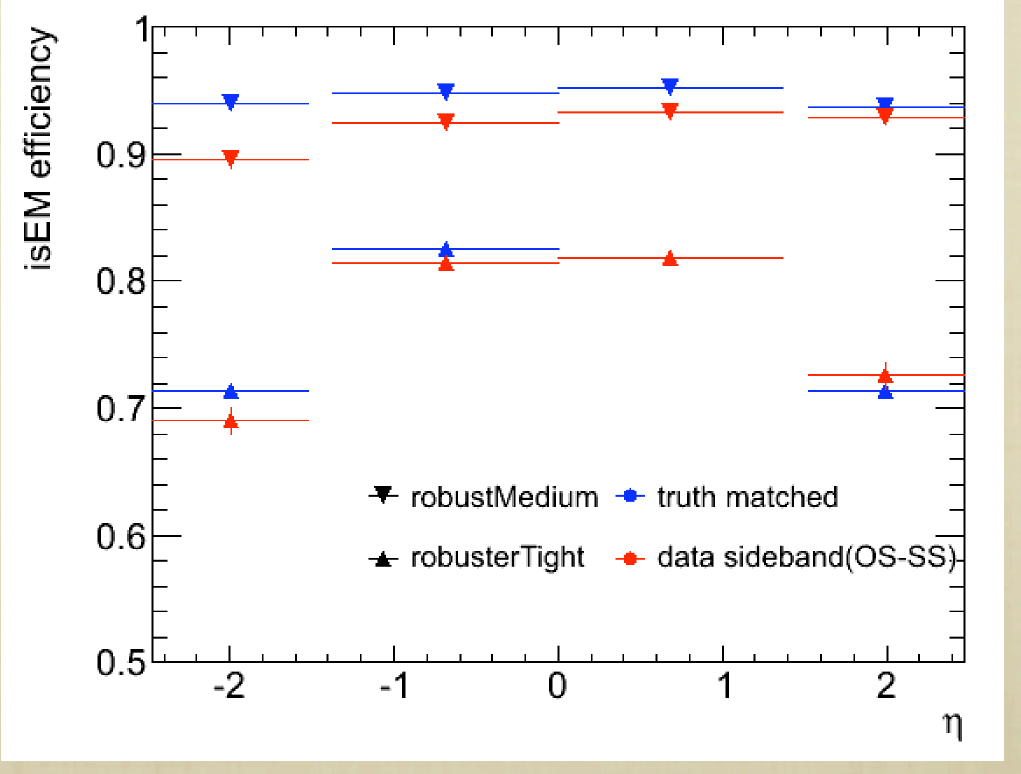
2c) Sideband
with OS as signal
and SS in sidebands



Binned efficiency
- method 2c) OS-SS sidebands

- Even with the full 2010 statistics (37 pb^{-1}), the fitting method is unstable when the fit is performed in each E_T,η bin
- The OS-SS sideband method is less limited by statistics, but might still not show reliable results for different bins, since the assumption $B_{bkg} = (A+C)/2$ breaks down
- At higher E_T, where the QCD background peaks in the signal region instead of decaying exponential throughout the mass window, the method will underestimate the background
- This might explain why the efficiency decreases with E_T for medium, rather than increases as expected. Let's have a look in finer binning:





Systematic uncertainty

- A comparison between the two best performing methods, OS-SS sideband and fitting, is made for the same scenario (OS pairs within 80-100 GeV)
- Other sources of systematics:
  - Switching to choosing the best mass pair at container level rather than all pairs
  - Fitting method: Re-bin the mass plots with 2
  - Fitting method: change the fitting range from [50,150] to [55,150] GeV

Efficiencies (truth) (%)	2c) OS-SS sideband	with best mass	3a) OS Fit	Rebin(2)	fitting range [55,150]	with best mass
robust loose	97.4 ± 0.4 (98.6 ± 0.02)	97.2 ± 0.3 $\Delta\varepsilon$ = -0.2%	97.0 ± 1.5 $\Delta\varepsilon$ = -0.4%	96.9 ± 1.5 $\Delta\varepsilon$ = -0.5%	97.3 ± 1.5 $\Delta\varepsilon$ = -0.1%	96.1 ± 1.4 $\Delta\varepsilon$ = -0.2%
robust medium	92.7 ± 0.4 (94.8 ± 0.03)	92.5 ± 0.4 $\Delta\varepsilon$ = -0.2%	92.8 ± 1.2 $\Delta\varepsilon$ = 0.1%	92.7 ± 1.2 $\Delta\varepsilon$ = 0.0%	93.1 ± 1.1 $\Delta\varepsilon$ = 0.4%	91.8 ± 1.1 $\Delta\varepsilon$ = -0.9%
robuster tight	78.7 ± 0.4 (78.8 ± 0.06)	78.6 ± 0.4 $\Delta\varepsilon$ = -0.1%	78.8 ± 1.0 $\Delta\varepsilon$ = 0.1%	78.8 ± 1.0 $\Delta\varepsilon$ = 0.1%	79.1 ± 0.9 $\Delta\varepsilon$ = 0.4%	78.0 ± 0.9 $\Delta\varepsilon$ = -0.7%

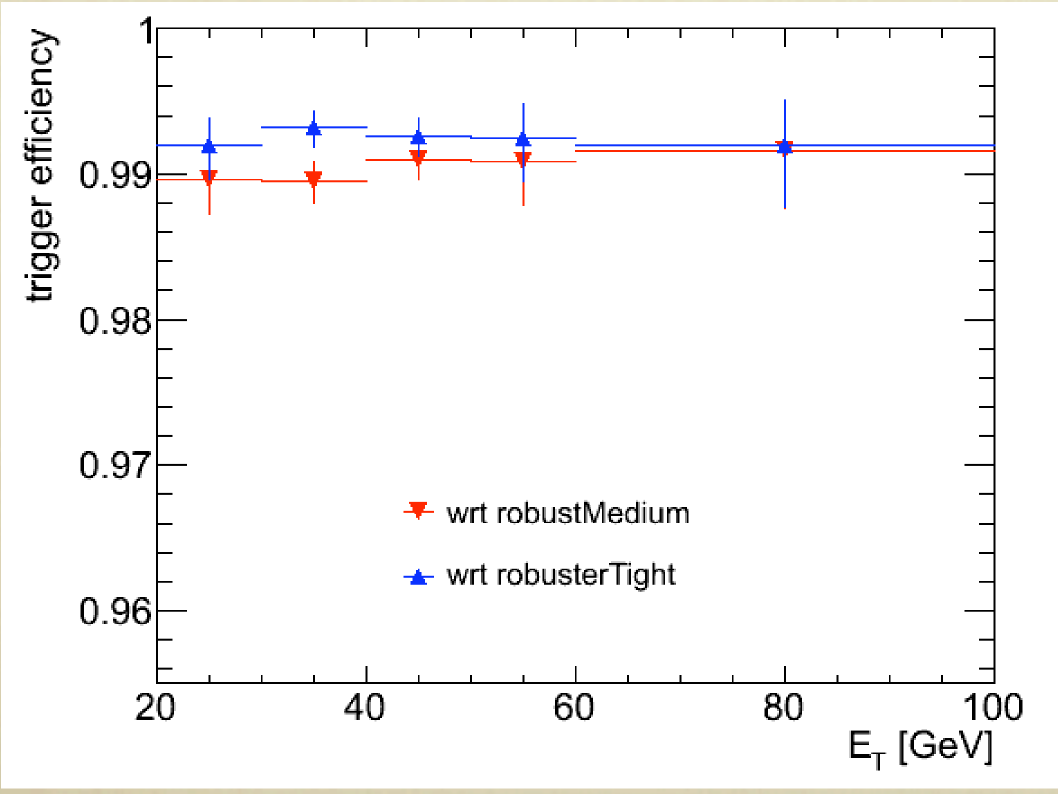
- Largest differences found for: loose 0.5%, medium 1.3% and tight 1.1%

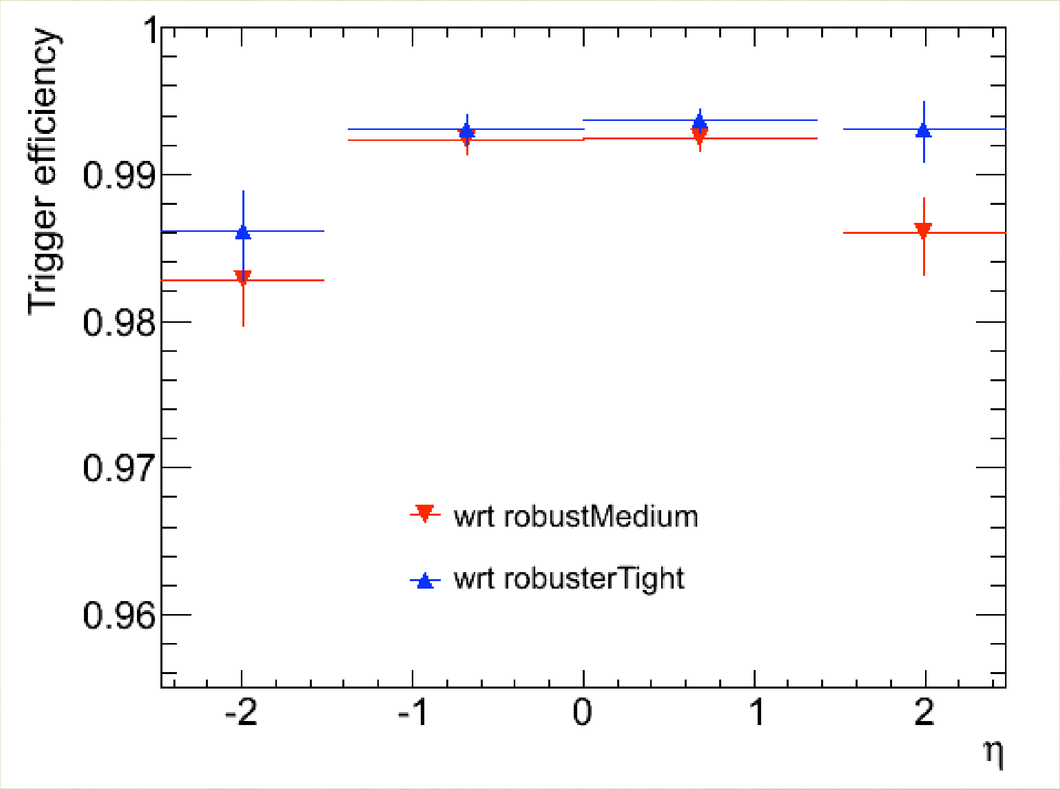
Trigger efficiency wrt offline ID

- Trigger efficiency wrt medium/tight probe for OS pairs within 66-116 GeV
- The probe is matched to L1_EM14 for period A-E3 and e15_medium for period E4-I (e15_medium applied for > 98% of the luminosity)
- Here, no background subtraction is performed due to the negligible and compatible background in the numerator and denominator

wrt medium (%)	99.02 ± 0.08
wrt tight (%)	99.26 ± 0.08

- Since no background subtraction is carried out, Bayesian mean and errors are quoted





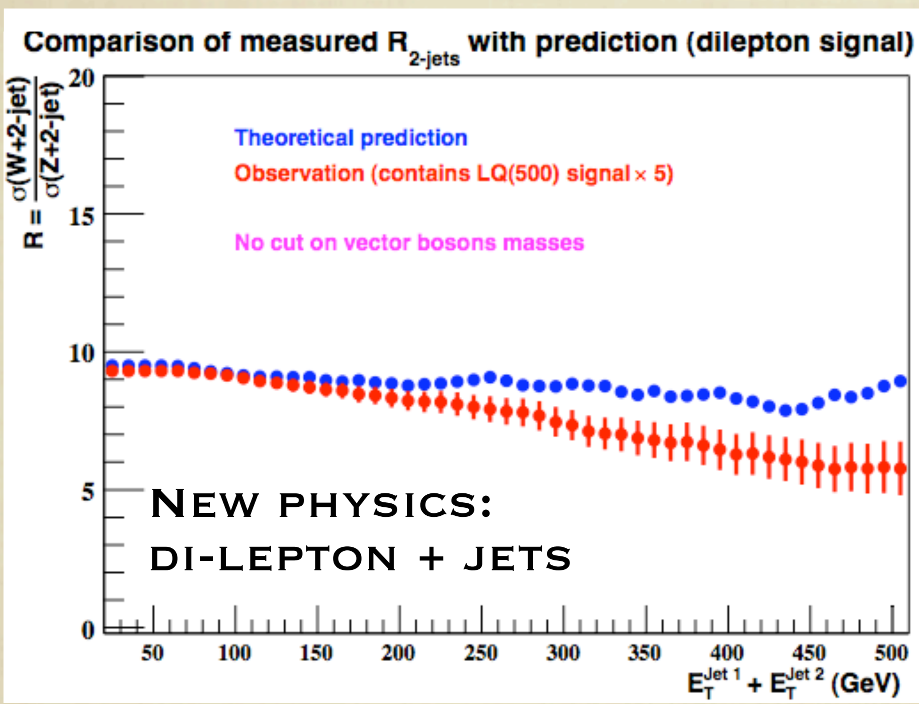
Summary and future plans
- tag and probe

- With the full 2010 statistics, 37 pb^{-1}, electron ID (and trigger) efficiencies can be estimated on data using tag and probe on $Z \rightarrow ee$ events
- The main source of error in the analysis come from the background subtraction
- Several background subtraction methods have been attempted. The most successful methods are found to be the fitting method and the sideband method taking OS pairs in the signal band and SS pairs in the background bands
- Binning in E_T,η space is still a challenge with the statistics at hand
- The resulting efficiencies are lower in data than in MC at loose and medium level, while compatible at tight level
    - The TRT has been found more efficient in data, which compensates the tight efficiency
- Current work is ongoing within a few people in egamma to converge on T&P results, with a common selection and method. Similar efforts are also made on the W and J/ψ events. The results will then be used as a benchmark for different physics groups.

Ongoing analysis: the R_{jets} measurement

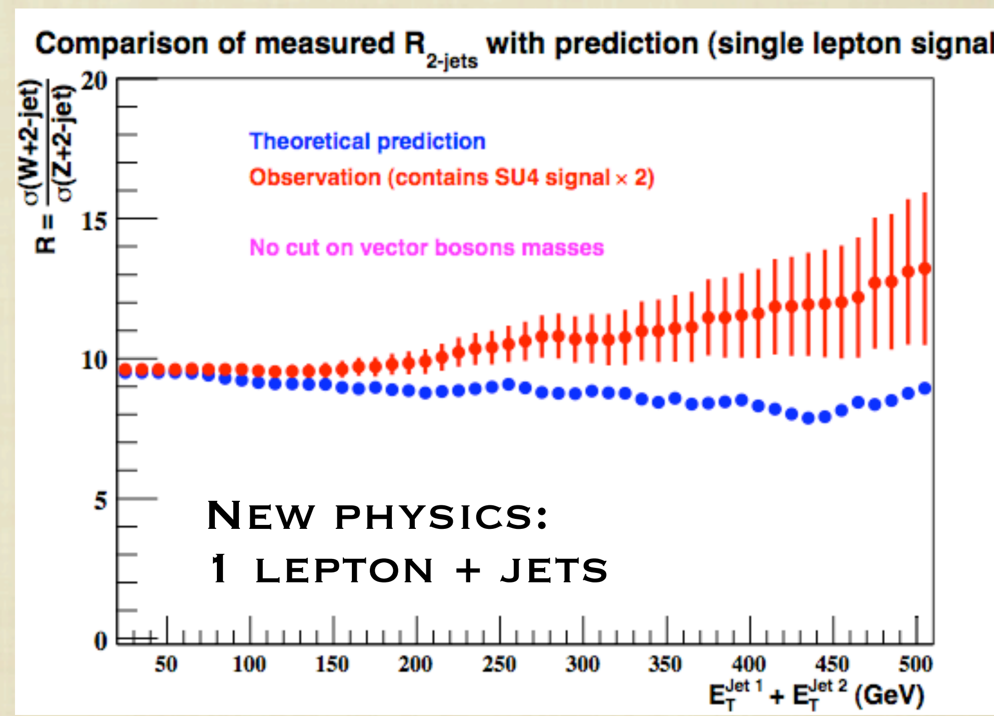
Introducing the R_{jets} measurement

- The R_{jets} measurement implies the cross section ratio: $R_{jets} = \frac{\sigma(W + \text{njets})}{\sigma(Z + \text{njets})}$
- Several theories beyond the SM predict final states with one or more leptons in association with jets
- Since the measurement is a ratio, many uncertainties cancel fully or partially, making it more sensitive to new physics



OR

Taken from H. Beauchemin

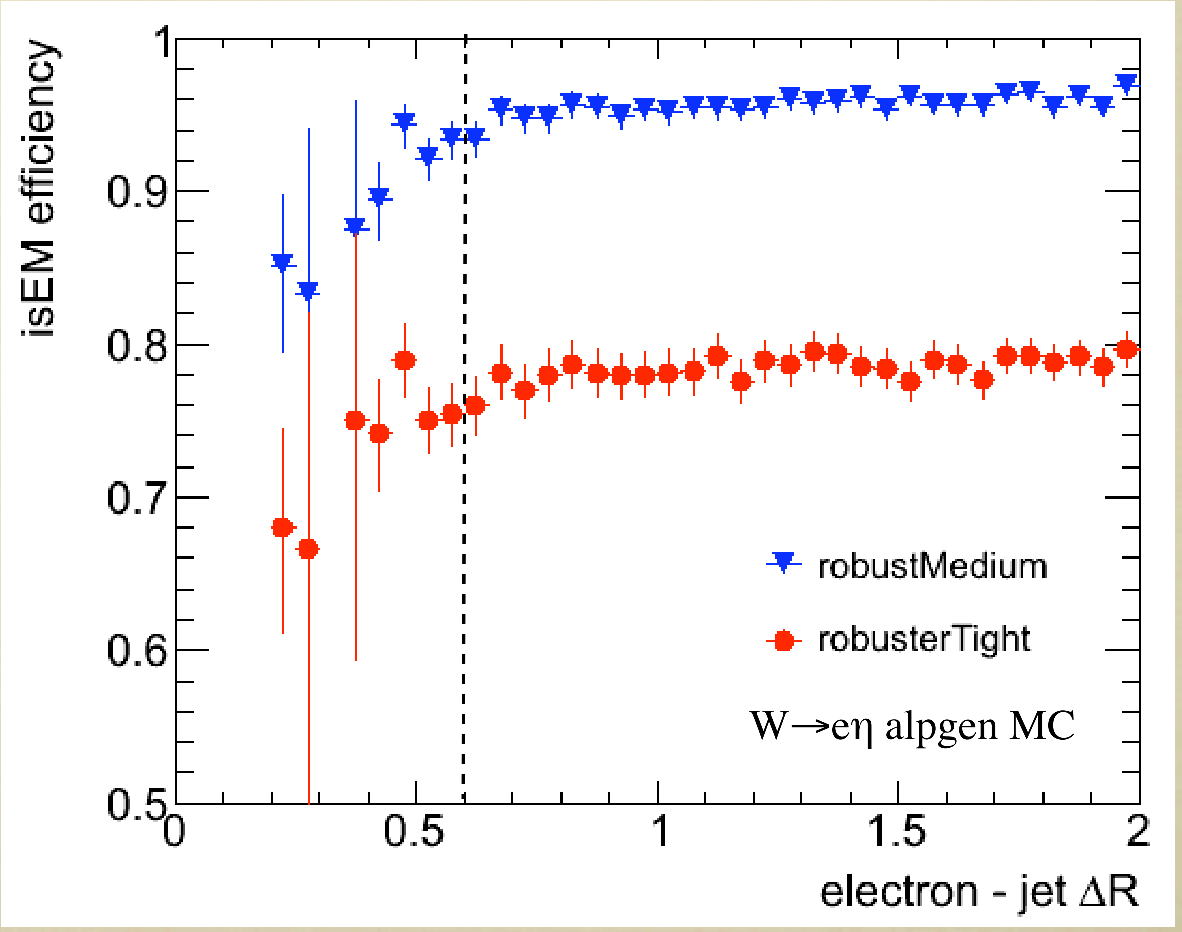


- The first measurement will be carried out in the 1 jet bin
- The statistically limiting factor is then the Z + 1 jet. The full 2010 data gives < 1000 such events after full selection

R_{JETS} SELECTION

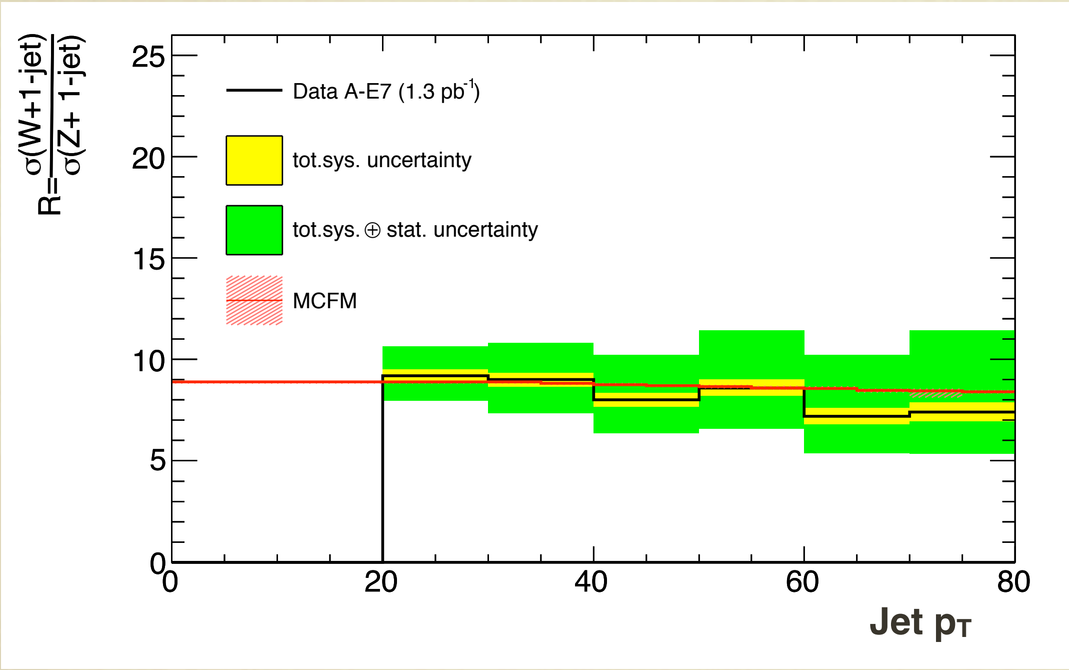
- The Rjets selection follows the W/Z inclusive selection with a few exceptions:
  - The primary vertex must be within $|z| < 150$ mm
  - The Z mass window is narrower: $71 < M_{ee} < 111$ GeV, due to higher background in the 1 jet bin
  - The electron selection for the Z is medium-tight, due to further cancellations in the ratio
  - Missing E_T cleaning and W GRL are applied to both the W and the Z

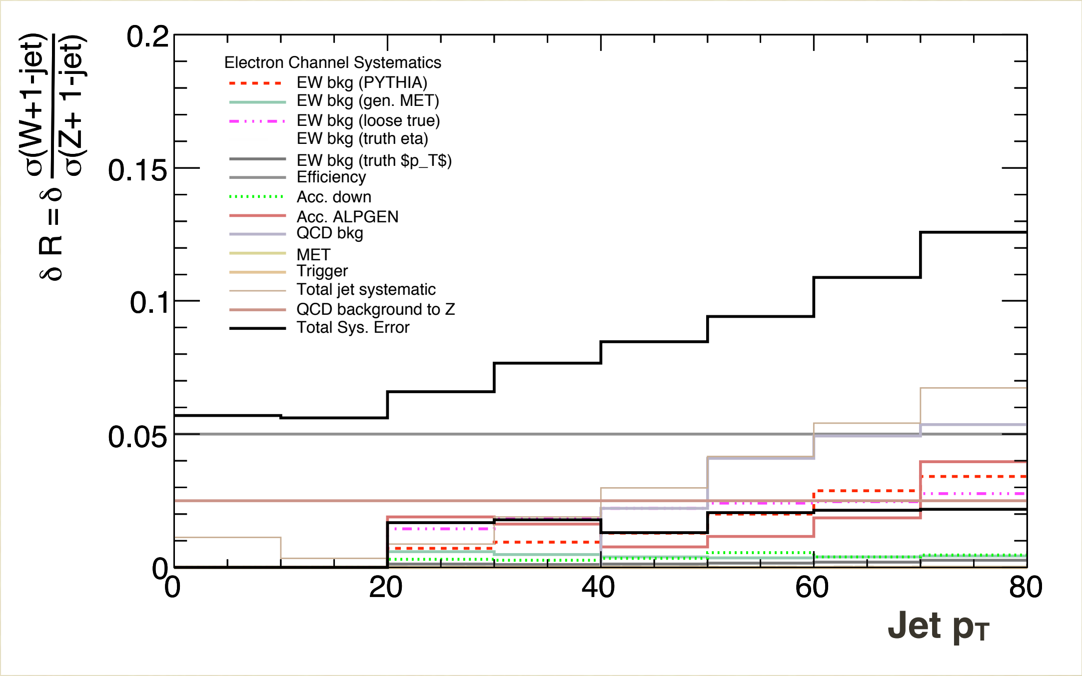
- For jet counting, AntiKt4H1Topo jets are chosen, which pass:
  - $p_T > 30$ GeV, $|\eta| < 2.8$ and passes electron overlap removal of $\Delta R < 0.2$
  - Events for with electron - good jet $\Delta R < 0.6$ are removed due to drop in efficiency (see plot on the right)



R_{jets} measurement; first try

- In September, the R_{jets} group tried to finalize the results into a note with 1 pb^{-1} (A-E)
- The following results were presented at the SM plenary for the electron channel, unfortunately the muon channel was missing...
- The resulting ratio is measured as a function of leading jet p_T in order to be able to spot new physics at higher energies

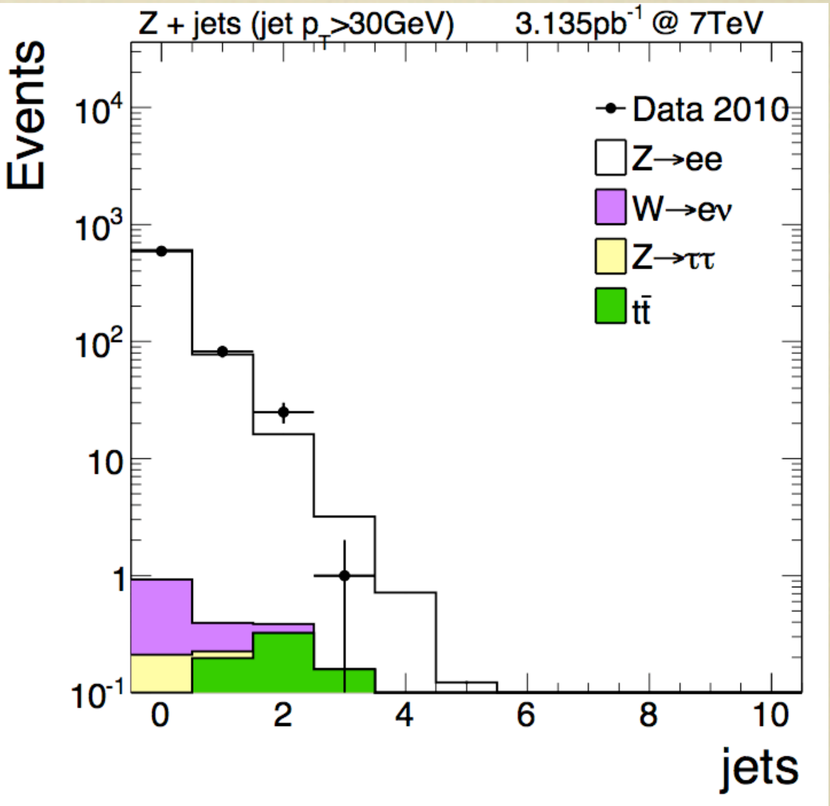


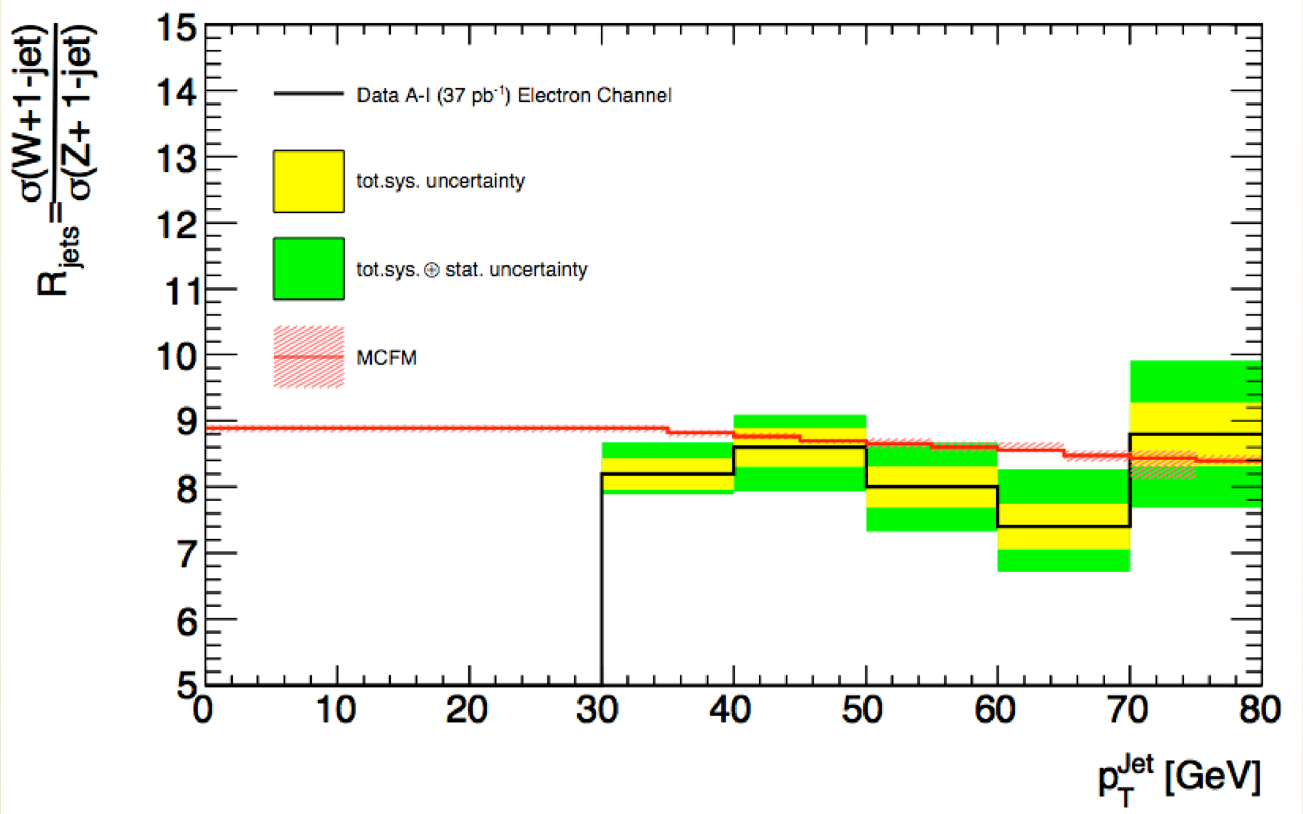


- Now, a note is being finalized with 3 pb^{-1} (A-F), at the same time as working on a more precise measurement with the full 2010 data set.

R_{jets} measurement with 3 pb^{-1}

- With 3 pb^{-1} (A-F), full selection gives 1020 W's and 82 Z's in the 1 jet bin
- The statistics is low, but there is a lot more data at hand, which can be taken advantage of for some part of the analysis:
  - QCD background fraction
  - Tag and probe to assign scale factor and smaller systematic uncertainties for the MC efficiencies



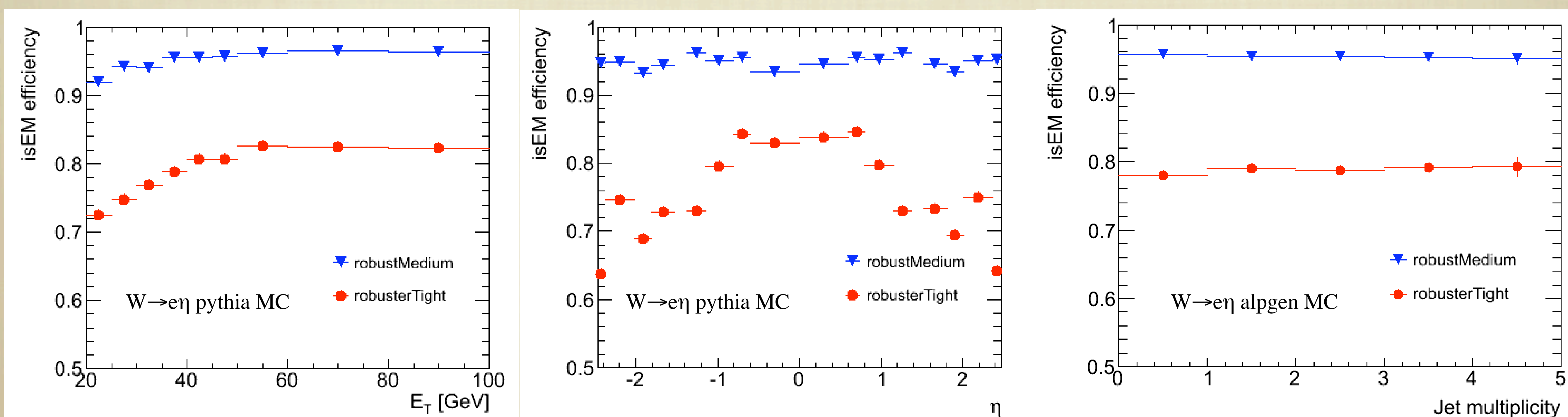


Preliminary!!!
results for 3 pb^{-1}

Electron efficiencies in the R_{jets} analysis

- The MC true efficiency E_T,η maps, produced for the inclusive analysis, are updated for the R_{jets} selection
- A study has been made to make sure that the number of jets in the event does not have any significant effect on the efficiencies. Binning in jet multiplicity is therefore not necessary
- Pile-up and OTX map weighting in the MC corresponds to A-F data

W	W+	W-	Z med	Z tight
75.0%	75.3%	74.6%	93.8%	77.2%



Electron efficiencies in the R_{jets} analysis

- The medium efficiency for the Z, is scaled down by 2% to better match the tag and probe results performed on data

- Then the average efficiencies are calculated taking the distribution of the data and background in E_T,η space into account:

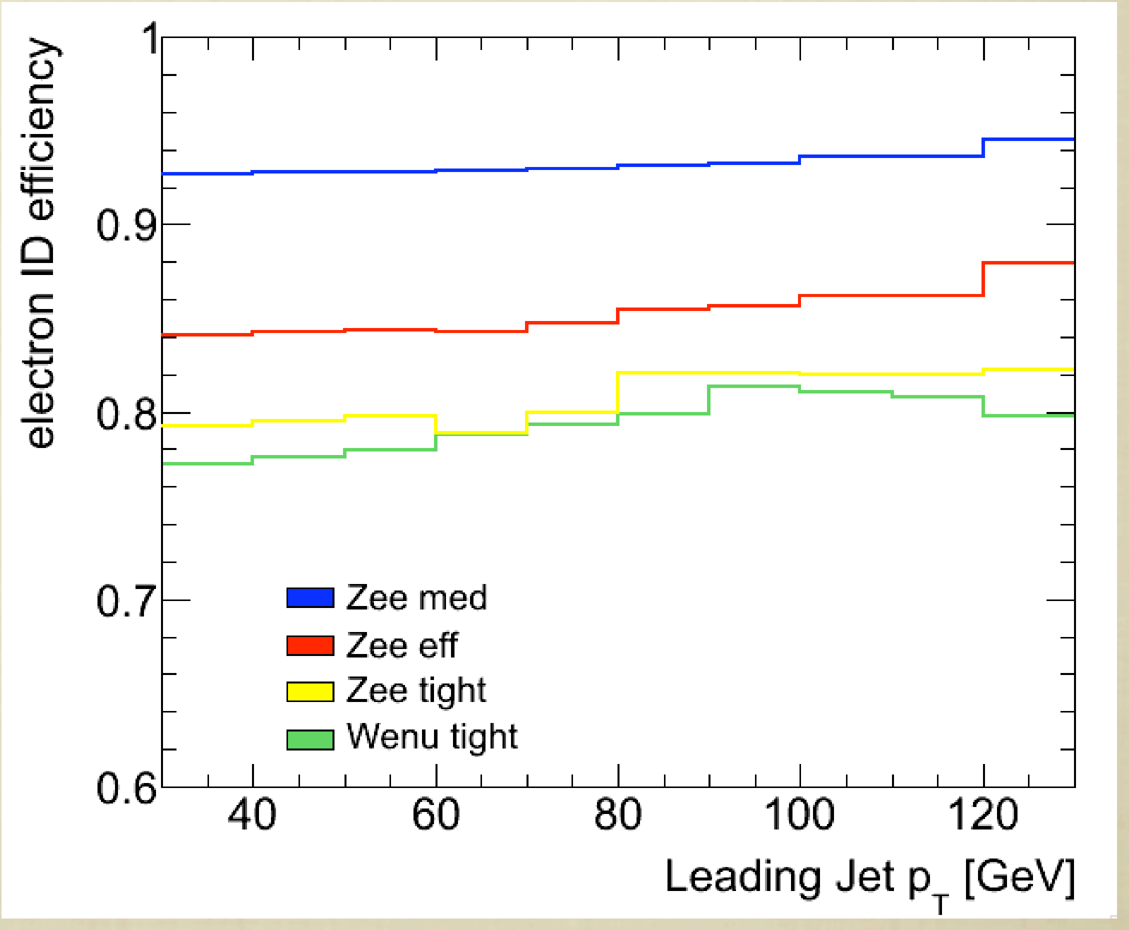
$$\epsilon_{med/tight} = \frac{\sum_{ij} \epsilon^{ij}_{med/tight} \cdot (N^{ij}_{data} - N^{ij}_{QCD})(1 - f^{ij}_{ewk})}{(N_{data} - N_{QCD})(1 - f_{ewk})}$$

, where ij are the η,E_T bins

$$\epsilon_Z = \epsilon_{tight}(2\epsilon_{med} - \epsilon_{tight})$$

$$\epsilon_W = \epsilon_{tight}$$

$$\epsilon_{Rjets} = \frac{\epsilon_Z}{\epsilon_W}$$



- This is performed for each jet p_T bin

- The resulting average efficiencies are presented in the plot on the right

Systematics for electron efficiencies

- For the W/Z inclusive paper, W tag and probe results performed on 1 pb^{-1} were used as systematic uncertainty

- 4% for medium and 5% for tight efficiencies were assigned. This results in ±4.1% systematic uncertainty on the efficiency ratio ε_{Rjets}.

- Now the Z→ee tag and probe results performed on 37 pb^{-1} can be used.

Old value

Taken from
ATL-COM-PHYS-2010-701

	$\varepsilon(data)/\varepsilon(MC)$ (300 nb^{-1})	$\varepsilon(data)/\varepsilon(MC)$ (900 nb^{-1})
Medium	0.94 ± 0.06	0.97 ± 0.03
Tight	0.94 ± 0.08	0.99 ± 0.05

→

New value (preliminary)

Zee (36.6 pb^{-1})	$\varepsilon_{data}/\varepsilon_{MC}$
Medium	0.98 ± 0.004 ± 0.02
Tight	1.00 ± 0.006 ± 0.03

- Data shows that medium efficiency is lower than what has been estimated by MC

- Scaling the medium efficiency to data therefore improves the accuracy of the ratio measurement and reduces the systematic uncertainty

- Applying the T&P uncertainty on the scaled efficiency ratio gives total systematic uncertainty of ± 1.5%, which is a large reduction from the former ± 4.1%

Summary and future plans
- R_{jets} measurement

$$R_{jets} = \frac{\sigma(W + \text{njets})}{\sigma(Z + \text{njets})}$$

- The R_{jets} is an interesting measurement, with high sensitivity to possible new physics
- The first results for the 1 jet bin with 3 pb^{-1} will hopefully soon be finalized. This is more of an exercise of putting together the many different pieces of the analysis, since the statistics is poor.
- A more precise measurement will be made with the full 2010 statistics, using the reprocessed data. Several components of the analysis with 3 pb^{-1} is already employing the full statistics, such as the electron efficiencies with tag and probe
- The central value for the electron efficiencies is taken from MC. The medium efficiency (for one leg from the Z) is scaled down by 2% to more accurately match the data. The systematic uncertainty for the efficiencies is also estimated with T&P
- The results obtained with the full 2010 statistics will be finalized for the winter conferences. This will be performed in the 1 jet bin, where the limiting statistics from Z + 1 jet still only gives < 1000 events.
- A first study will also be made for higher jet multiplicities

Time to summarize!

Conclusion

- Physics analysis with electrons is fun!

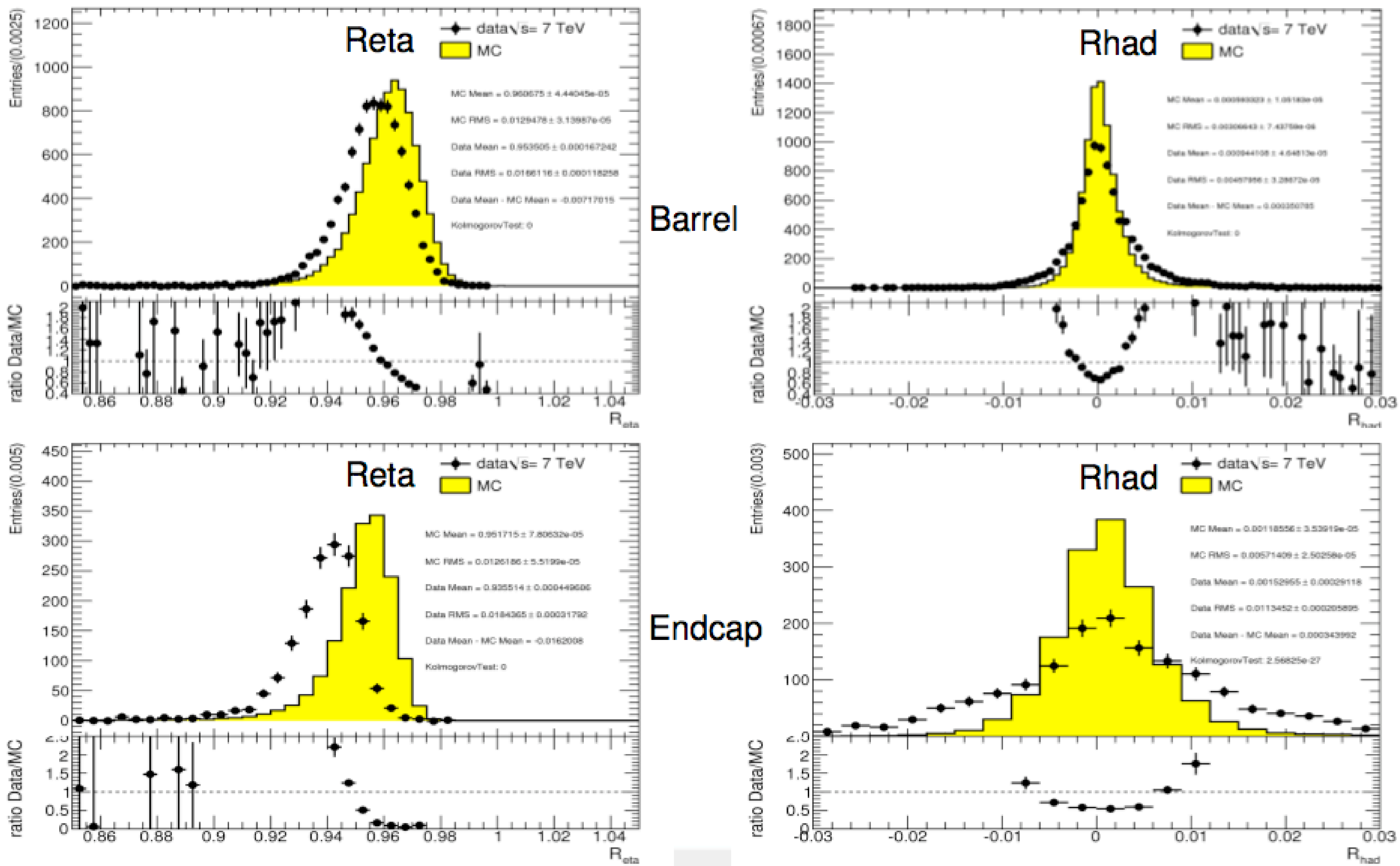
- This first year of data taking has taught us many important lessons when it comes to analysis on electrons in data
  - You have to stay on your toes, since the analysis can change rapidly and it is important to keep up with the details
  - We still have many things to learn about our detector and its impact on physics
- Finalizing the different electron measurements with the full 2010 statistics will bring us to a new level of understanding when it comes to physics with electrons in ATLAS
- Hopefully we'll get much more data starting from the beginning of next year, such that the productivity and interest will remain at top level!

Backup

Second layer: Reta, Rhad

Albert-Ludwigs-Universität Freiburg

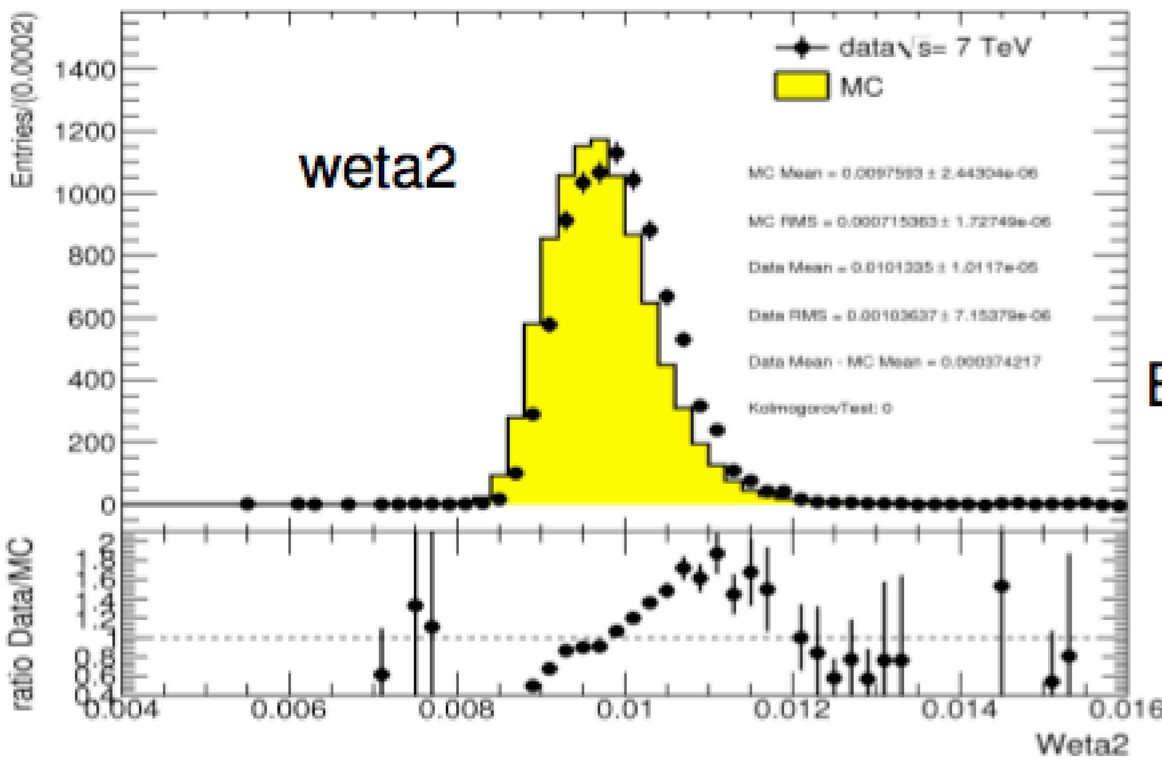
E. Schmidt
https://espace.cern.ch/atlas-sm-wz-observation/Observation/Shared%20Documents/Z_ee_shapes_PeriodA-I_Evelyn.pdf

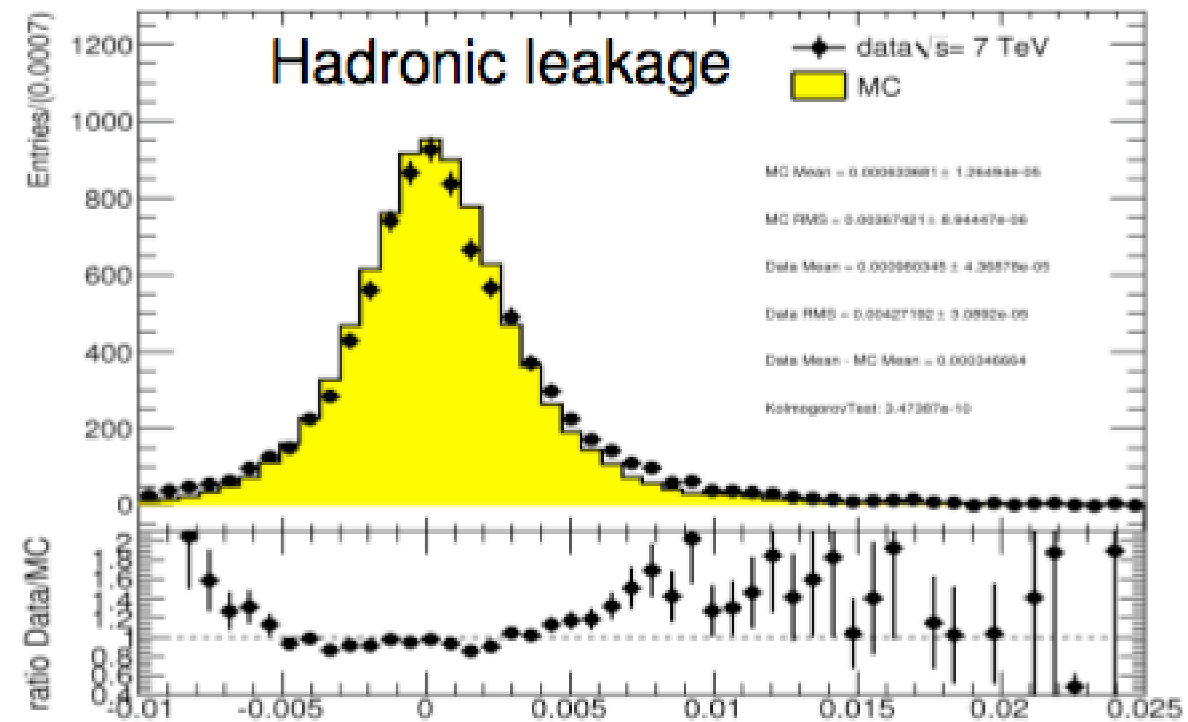


Second layer: weta2, hadronic leakage

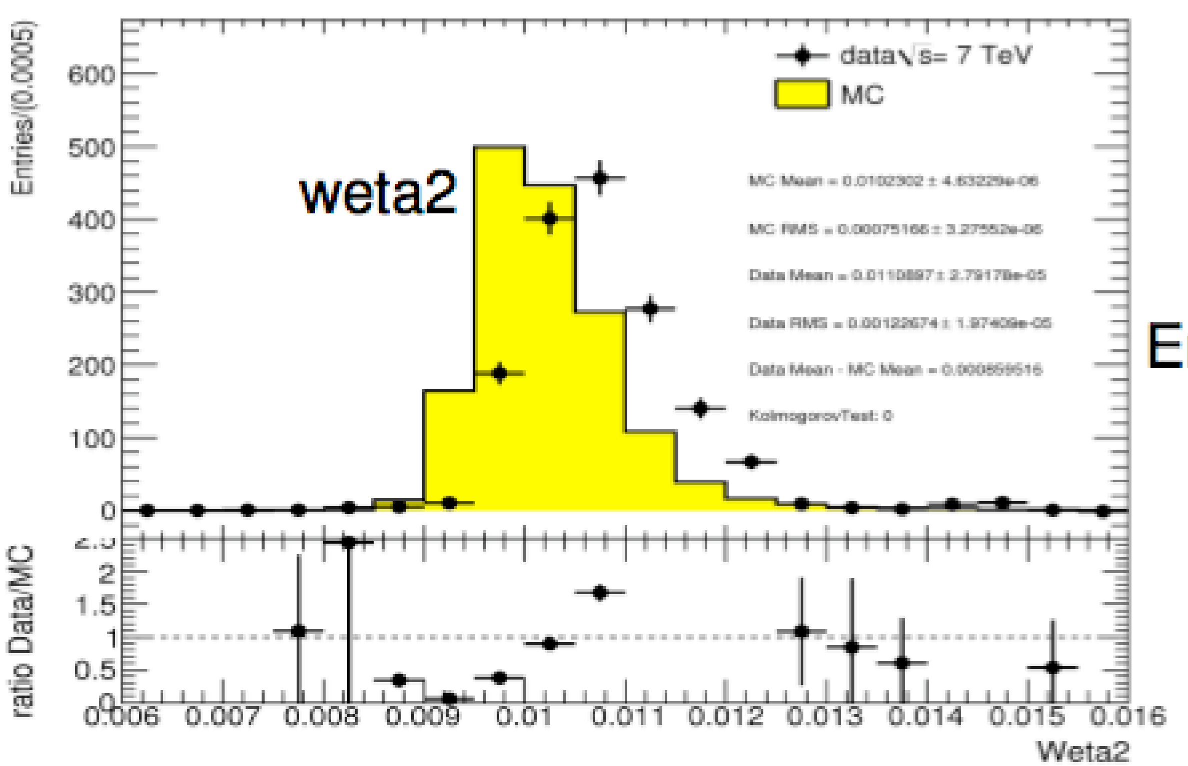
Albert-Ludwigs-Universität Freiburg

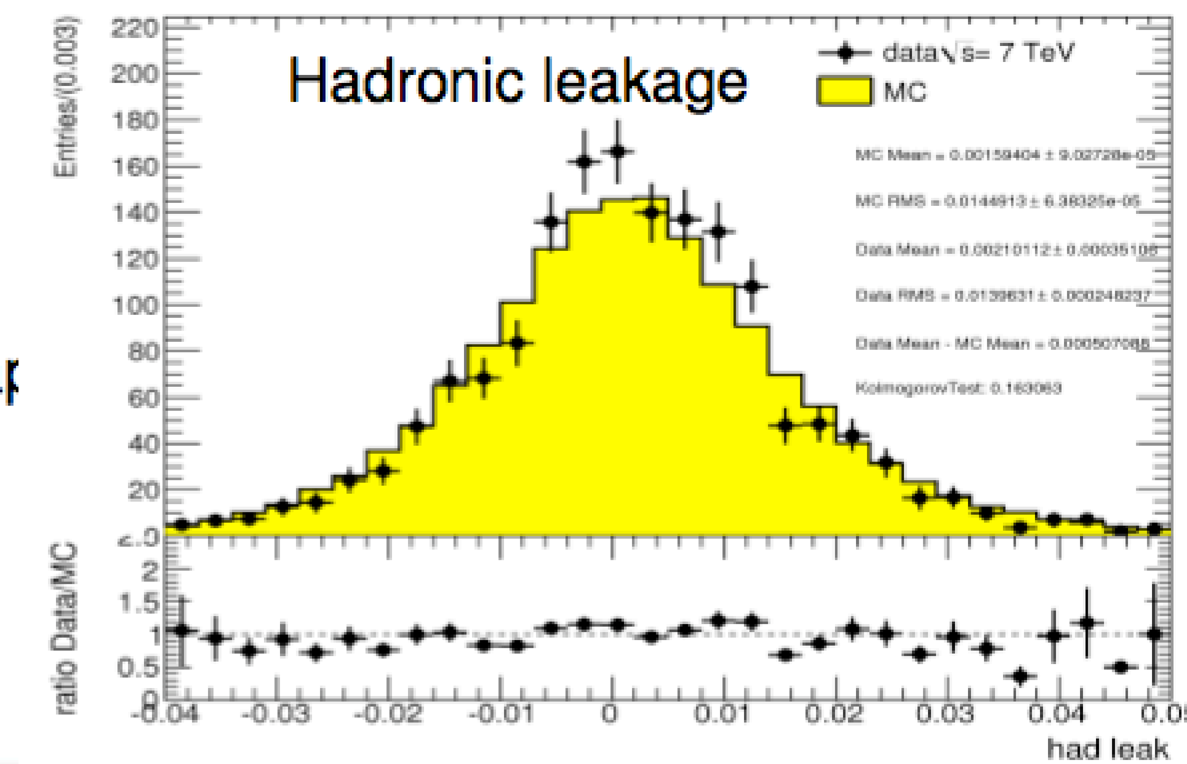
E. Schmidt
https://espace.cern.ch/atlas-sm-wz-observation/Observation/Shared%20Documents/Z_ee_shapes_PeriodA-I_Evelyn.pdf





Barrel





Endcap

Distorted material samples

- Samples with extra upstream material has been produced, but without pile-up; Needs to be compared with none pile-up sample with nominal geometry:

	ε^{W}_{reco} (W^+,W^-)	$\varepsilon^{W}_{tight/reco}$ (W^+,W^-)	ε^{Z}_{reco}	$\varepsilon^{Z}_{medium/reco}$	$\varepsilon_{loose/reco}$
no pile-up	85.8% (85.5%, 86.3%)	75.3% (75.5%, 75.0%)	85.6%	94.4%	98.7%
with pile-up	85.8%	74.9%	85.6%	94.3%	98.7%

(ATL-COM-PHYS-2010-701)

- GEO-10-00-00 (s765): Nominal geometry
- GEO-10-01-00 (s885): 5% X0 between barrel and strip; 20% X0 in the barrel cryostat before the presampler; 20% X0 in the cryostat after the LAr calorimeter (F)
- GEO-10-02-00 (s886): 5% increase of the whole Inner Detector
- GEO-10-03-00 (s887): 10% increase of the whole Inner Detector
- GEO-10-04-00 (s888): 20% relative increase of Pixel services
- GEO-10-05-00 (s889): 20% relative increase of SCT services
- GEO-10-06-00 (s890): Extra 15% X0 at the end of SCT/TRT endcaps (E)
- GEO-10-08-00 (s831): All the above together, with the 10% increase in the whole ID - older sample used for the first ICHEP W cross section measurement (G)

Impact on W electron efficiencies

- The impact from the 20% increase of SCT services and 15% X0 at the end of the SCT/TRT endcaps has been found to be negligible
- The total systematic uncertainty is then computed for the the different extra material together with the 5% and 10% increase of the ID material, separately

	$\Delta\epsilon^W_{reco}/\epsilon^W_{reco}$	$\Delta\epsilon^W_{medium/reco}/\epsilon^W_{medium/reco}$	$\Delta\epsilon^W_{tight/reco}/\epsilon^W_{tight/reco}$
Nominal + Calo	-0.6%	-0.3%	-0.3%
Nominal + 5% ID	-0.6%	-0.1%	-0.9%
Nominal + 10% ID	-1.3%	-0.2%	-1.6%
Nominal + 20% pixel services	-0.1%	<0.1%	-0.3%
Total (with 5% ID)	-1.3%	-0.4%	-1.5%
Total (with 10% ID)	-2.0%	-0.5%	-2.2%

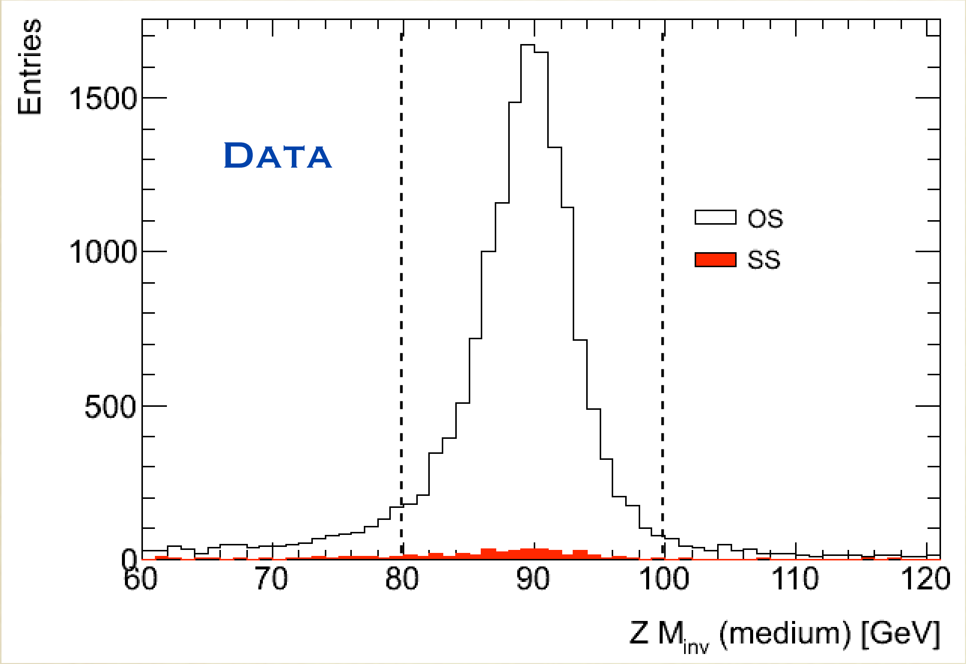
(ATL-COM-PHYS-2010-701)

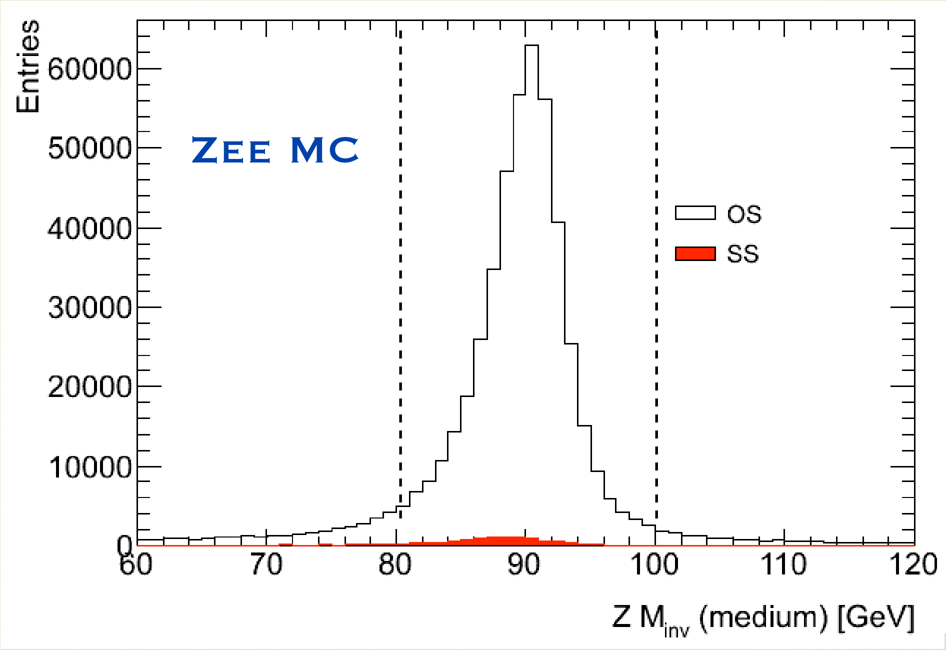
- The 5% corresponds to what has been estimated as an upper limit by min bias events in the region $|\eta| < 2$. For $2 < |\eta| < 2.5$, the uncertainty is larger and the 10% is therefore used.
- The two total values are hence added with the weights 0.8 and 0.2, which roughly corresponding to the equivalent acceptance in η.
- A comparison with the older sample containing all distortions (larger differences):

	$\Delta C^W/C^W$	$\Delta\epsilon^W_{medium/reco}/\epsilon^W_{medium/reco}$	$\Delta\epsilon^W_{tight/reco}/\epsilon^W_{tight/reco}$
Config G (10% ID)	-4.3%	-0.9%	-3.0%

2a) Sideband background subtraction method

- Is it safe to assume no signal in the sideband 60-80 and 100-120 GeV?





- Data finds 10.8% of OS the medium probe events in the sideband regions while Zee MC finds 9.2%, so while the sideband method would estimate 5.9% background for the data, maybe something < 1% is more accurate
- The difference in the fraction of SS and OS events in the sidebands could also give an idea of the signal in the sideband:
- There is ~10% more OS events in the sideband at levels with low background ⇒ signal?

%	container	loose	medium	tight
OS	20.5	11.8	10.8	10.6
SS	12.9	2.2	0.60	0.32

Background subtraction

Estimated background fraction and statistical errors for the different methods

Observation: The sideband methods 2a) and b) overestimate the background in medium and tight by a factor of > 10!

Well working methods: fitting and 2c) OS w SS in sidebands

Background (%)	**66-116 GeV OS**	**Sideband 80-100 GeV OS+SS**	**Sideband 80-100 GeV OS**
Probe: container	1) OS-SS: 22.2 ± 0.78 3a) Fit: 22.0 ± 1.0	2a) sideband: 25.2 ± 0.8 3b) Fit: 17.5 ± 2.6	2b) sideband: 17.4 ± 0.8 c) SS in sidebands: 11.0 ± 0.8 3c) Fit: 11.0 ± 1.1
Probe: loose	1) OS-SS: 5.5 ± 0.8 3a) Fit: 4.1 ± 0.9	2a) sideband: 8.2 ± 0.8 3b) Fit: 2.5 ± 0.9	2b) sideband: 7.2 ± 0.86 c) SS in sidebands: 1.4 ± 0.9 3c) Fit: 1.8 ± 0.9
Probe: medium	1) OS-SS: 2.7 ± 0.8 3a) Fit: 0.55 ± 0.04	2a) sideband: 6.4 ± 0.8 3b) Fit: 0.34 ± 0.02	2b) sideband: 6.2 ± 0.9 c) SS in sidebands: 0.34 ± 0.88 3c) Fit: 0.24 ± 0.02
Probe: tight	1) OS-SS: 1.4 ± 0.9 3a) Fit: 0.12 ± 0.02	2a) sideband: 6.4 ± 0.9 3b) Fit: 0.07 ± 0.01	2b) sideband: 6.0 ± 1.0 c) SS in sidebands: 0.18 ± 0.95 3c) Fit: 0.05 ± 0.01

Electron ID efficiencies

- The efficiencies can then be estimated by taking the Binomial mean of the numerator and denominator after background subtraction.
- The errors are taking the background subtraction and correlation between numerator and denominator into account according to

http://www-cdf.fnal.gov/publications/cdf7168_eff_uncertainties.ps

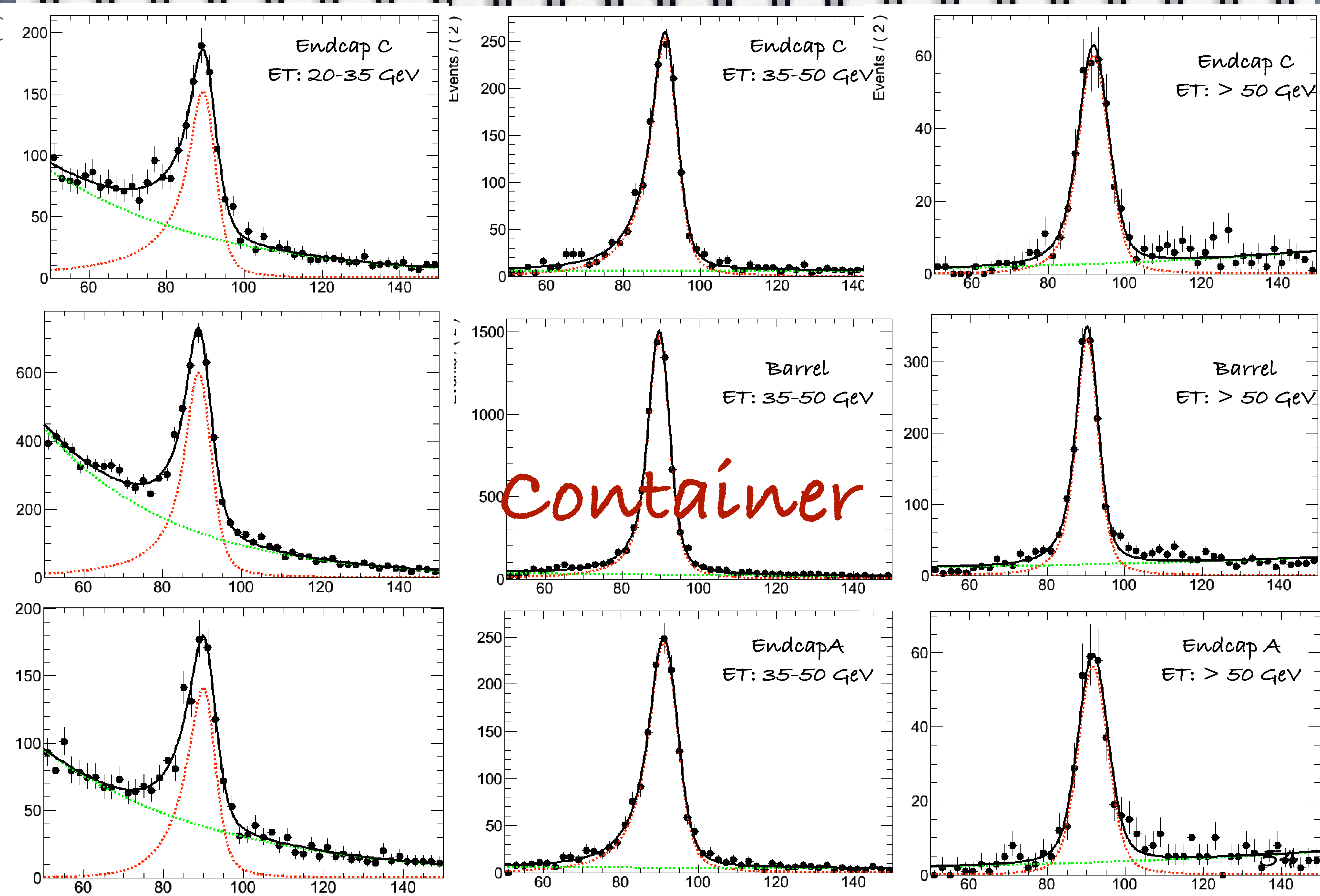
- The efficiencies are then compared to those obtained with loose truth matching in MC
- Tight efficiency is compatible with MC, while the loose and medium efficiencies are still lower in data than in MC - explains part of the Z deficit seen in data?

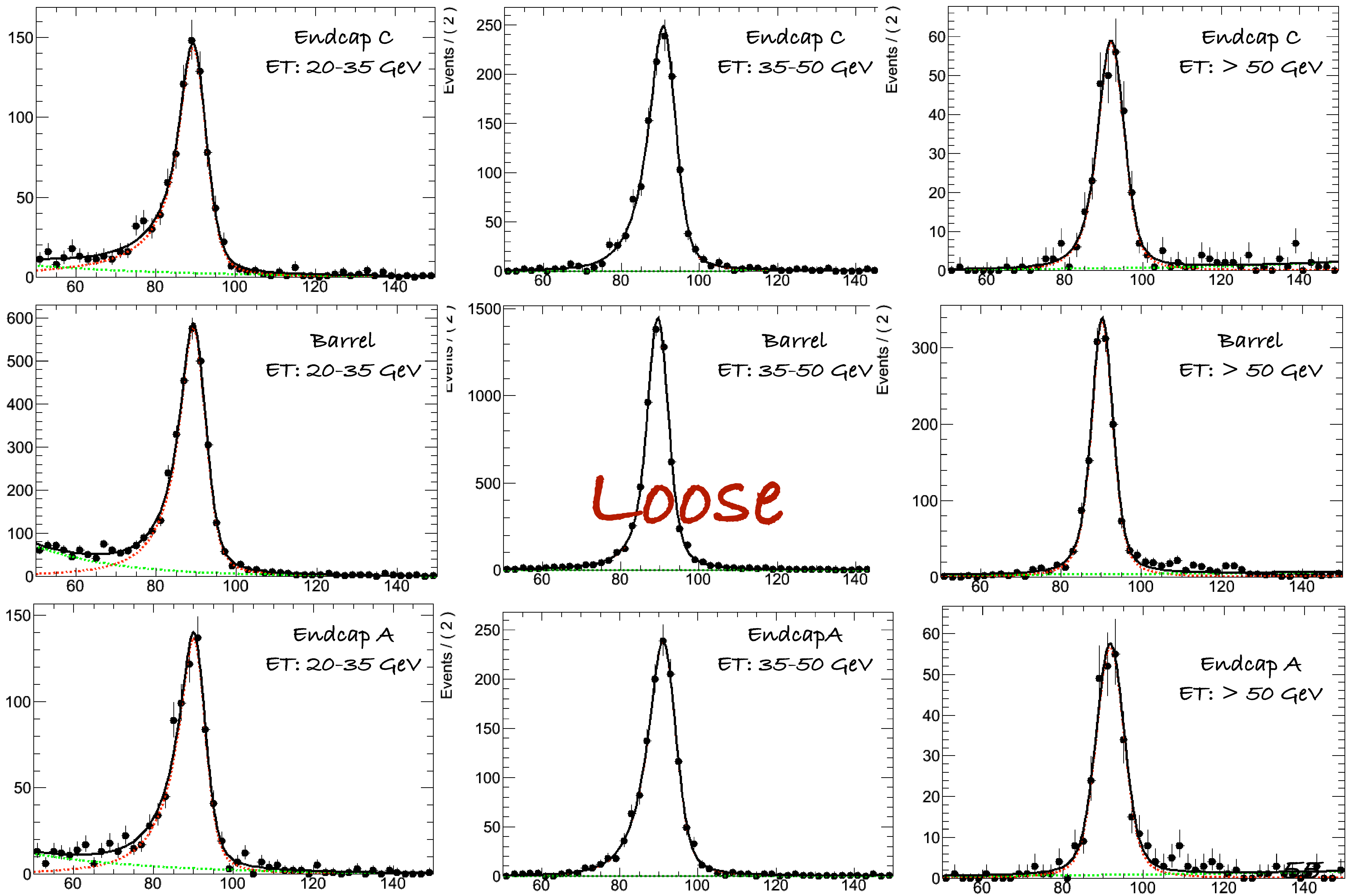
Efficiencies (truth) (%)	1) OS - SS [66-116]	3a) OS Fit [66-116]	2a) sideband [80-100] *	3b) Fit [80-100]	2b) OS sideband [80-100]	2c) OS w SS in sidebands [80-100]	3c) OS Fit [80-100]
robust loose	92.8 ± 0.5 (98.4 ± 0.02)	94.0 ± 1.4 (98.4 ± 0.02)	99.7 ± 0.5 (98.6 ± 0.02)	96.1 ± 1.3 (98.6 ± 0.02)	98.8 ± 0.4 (98.6 ± 0.02)	97.4 ± 0.4 (98.6 ± 0.02)	97.0 ± 1.5 (98.6 ± 0.02)
robust medium	88.7 ± 0.6 (94.5 ± 0.03)	90.5 ± 1.1 (94.5 ± 0.03)	94.1 ± 0.6 (94.1 ± 0.03)	90.9 ± 1.0 (94.1 ± 0.03)	94.0 ± 0.4 (94.7 ± 0.03)	92.7 ± 0.4 (94.7 ± 0.03)	92.8 ± 1.2 (94.7 ± 0.03)
robuster tight	76.1 ± 0.6 (78.4 ± 0.06)	77.0 ± 0.9 (78.4 ± 0.06)	79.1 ± 0.6 (77.5 ± 0.06)	76.4 ± 0.9 (77.5 ± 0.06)	79.9 ± 0.5 (78.8 ± 0.06)	78.7 ± 0.4 (78.8 ± 0.06)	78.8 ± 1.0 (78.8 ± 0.06)

All T&P pairs vs best mass pair

- For period A-H data, the results from taking all T&P pairs in the event, give significantly higher efficiency than choosing the two electrons with the best mass
- This difference is reduced using all 2010 data, A-I

Efficiencies (truth) (%)	All pairs 3a) OS Fit [66-116]	Best mass 3a) OS Fit [66-116]	All pairs 3b) Fit [80-100]	Best mass 3b) Fit [80-100]	All pairs 3c) OS Fit [80-100]	Best mass 3c) OS Fit [80-100]
robust loose	94.0 ± 1.4 (98.4 ± 0.02)	94.7 ± 1.4 (98.4 ± 0.02)	96.1 ± 1.3 (98.6 ± 0.02)	94.6 ± 1.6 (98.6 ± 0.02)	97.0 ± 1.5 (98.6 ± 0.02)	96.1 ± 1.4 (98.6 ± 0.02)
robust medium	90.5 ± 1.1 (94.5 ± 0.03)	91.2 ± 1.1 (94.5 ± 0.03)	90.9 ± 1.0 (94.1 ± 0.03)	89.4 ± 1.3 (94.1 ± 0.03)	92.8 ± 1.2 (94.8 ± 0.03)	91.8 ± 1.1 (94.8 ± 0.03)
robuster tight	77.0 ± 0.9 (78.4 ± 0.06)	77.5 ± 0.9 (78.4 ± 0.06)	76.4 ± 0.9 (77.5 ± 0.06)	75.1 ± 1.1 (77.5 ± 0.06)	78.8 ± 1.0 (78.8 ± 0.06)	78.0 ± 0.9 (78.8 ± 0.06)


Endcap C
ET: 20-35 GeV
Endcap C
ET: 35-50 GeV
Endcap C
ET: > 50 GeV
Barrel
ET: 35-50 GeV
Barrel
ET: > 50 GeV
Container
EndcapA
ET: 35-50 GeV
Endcap A
ET: > 50 GeV


Endcap C
ET: 20-35 GeV
Endcap C
ET: 35-50 GeV
Endcap C
ET: > 50 GeV
Barrel
ET: 20-35 GeV
Barrel
ET: 35-50 GeV
Barrel
ET: > 50 GeV
Endcap A
ET: 20-35 GeV
EndcapA
ET: 35-50 GeV
Endcap A
ET: > 50 GeV
Events / (2)
Loose

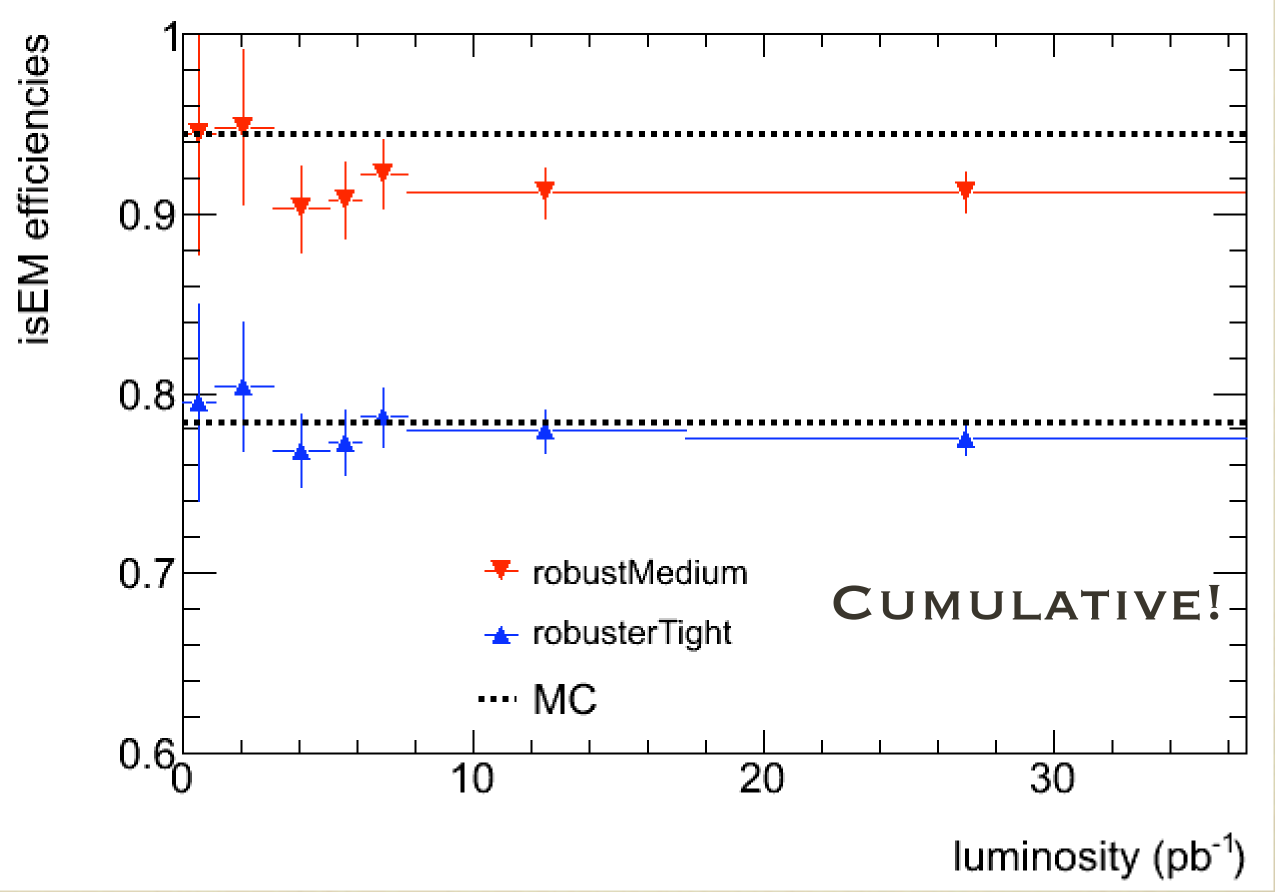
Timeline back to WZ paper times

	$\varepsilon(data)/\varepsilon(MC)$ (300 nb^{-1})	$\varepsilon(data)/\varepsilon(MC)$ (900 nb^{-1})
Medium	0.94 ± 0.06	0.97 ± 0.03
Tight	0.94 ± 0.08	0.99 ± 0.05

Taken from
ATL-COM-PHYS-2010-701

- Fitting best mass OS pairs for 66-166 GeV for the different time periods:
  - A-E (1.1 pb^{-1})
  - A-F (3.1 pb^{-1})
  - A-G2 (5.0 pb^{-1})
  - A-G4 (6.1 pb^{-1})
  - A-G5 (7.7 pb^{-1})
  - A-H (17.3 pb^{-1})
  - A-I (36.6 pb^{-1})

Results for WZ cross section paper obtained with sideband method 2 a). The results were assigned a 4% systematics uncertainty



Rjets: Unfolding Zee ID efficiencies with medium-tight

- To correct back to hadron level:

$$N_Z = \frac{(N_{data} - N_{QCD})(1 - f_{ewk})}{A \cdot \epsilon_Z \cdot L}$$

- The scenarios we can have with the med-tight selection: MT + TM = TT + M'T + TM' = T(T + 2M') = T(T + 2(M-T)) = T(2M -T), where M' is medium electrons NOT passing tight

- The efficiency ε_Z, then becomes:

$$\epsilon_Z = \epsilon_{tight}(2\epsilon_{med} - \epsilon_{tight})$$

- To calculate the average medium or tight efficiency for the electrons in data:

$$\epsilon_{med/tight} = \frac{\sum_{ij} \epsilon^{ij}_{med/tight} \cdot (N^{ij}_{data} - N^{ij}_{QCD})(1 - f^{ij}_{ewk})}{(N_{data} - N_{QCD})(1 - f_{ewk})}$$

, where ij are the η,E_T bins

$$\epsilon_W = \epsilon_{tight} \qquad \epsilon_{Rjets} = \frac{\epsilon_Z}{\epsilon_W}$$

- What's then needed?
  - medium and tight efficiency maps
  - maps of electrons after final selections in data for medium (all electrons) and those which pass tight (can be both electrons in the event!)
  - equivalent maps of the electroweak and QCD background (for the W, for the Z it can be neglected)