W, Z measurements from early data with CMS

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Outline

- Introduction
- Inclusive cross section measurements (e, μ)
  - efficiency measurements
  - events selections and background estimation
  - acceptance studies
- Summary

Introduction

- **"early data"** $\rightarrow$ assume an integrated luminosity ~**10-100 pb^{-1}**
  - instantaneous luminosity~10^{32} cm^{-2} s^{-1}
- W, Z ($\rightarrow$ leptons) measurements with early data
  - large and high purity samples thanks to the high production cross section and clean experimental signature

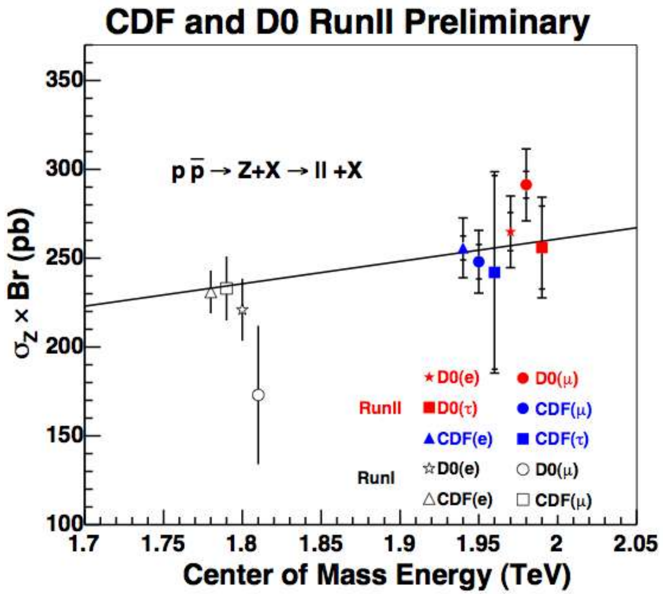
Process	σ x Br [pb]	$\varepsilon \times$ A (estimate)	Events 10 pb^{-1}
Z $\rightarrow$ ll	2000	25%	5000
W $\rightarrow$ lν	20000	35%	70000
ttbar $\rightarrow$ lν +X	370	1.5%	< 100
Jet E_T > 25 GeV	$3 \cdot 10^9$	100%	$3 \cdot 10^{10}$ x p.f.
Minimum bias	10^{11}	100%	10^{12} x p.f.

  - "Standard candles" for detector calibration/understanding and first physics measurements
    - <u>inclusive cross sections measurements</u>
    - monitor collider luminosity
    - constrain Parton Distribution Functions (looking at σ_{TOT}, W rapidity,...)

Inclusive cross section measurement

$$\sigma_{W(Z)} \times BR(W(Z) \rightarrow leptons) = \frac{N^{obs}_{W(Z)} - N^{bkg}_{W(Z)}}{\epsilon_{W(Z)} A_{W(Z)} \int \mathscr{L}\, dt}$$

- compare the measure to theory or reverse the relation for
  - luminosity measurement
  - constraining PDFs
- with large LHC datasets, main uncertainties are non-statistical
  - luminosity (5-7%), systematics (2-3%)
    [see also D0 Note 4750; arXiv:hep-ex/0508029]



- Efforts to define methods to measure most of the parameters from the data themselves and to minimize the dependence on MC
  - ε = trigger and offline lepton efficiencies ⇒ from data
  - N^{bkg} = expected background ⇒ from data and MC
  - A = acceptance ⇒ from MC

Efficiency measurement from data

The Tag&Probe method

- Use $Z \rightarrow ee(\mu\mu)$ events to provide an unbiased, high purity electron (muon) sample to measure the efficiency of a particular selection

TAG : electron (muon) selected with tight criteria

PROBE : electron(muon) candidate with loose selections depending on the efficiencies under study

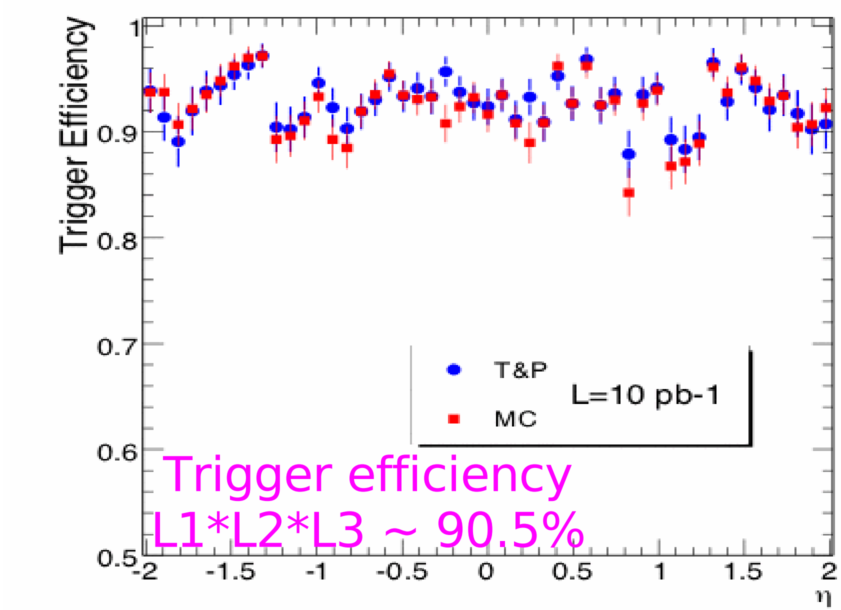
$$\epsilon = \frac{\#\, probes\; passing\; the\; selection}{\#\, all\; probes}$$

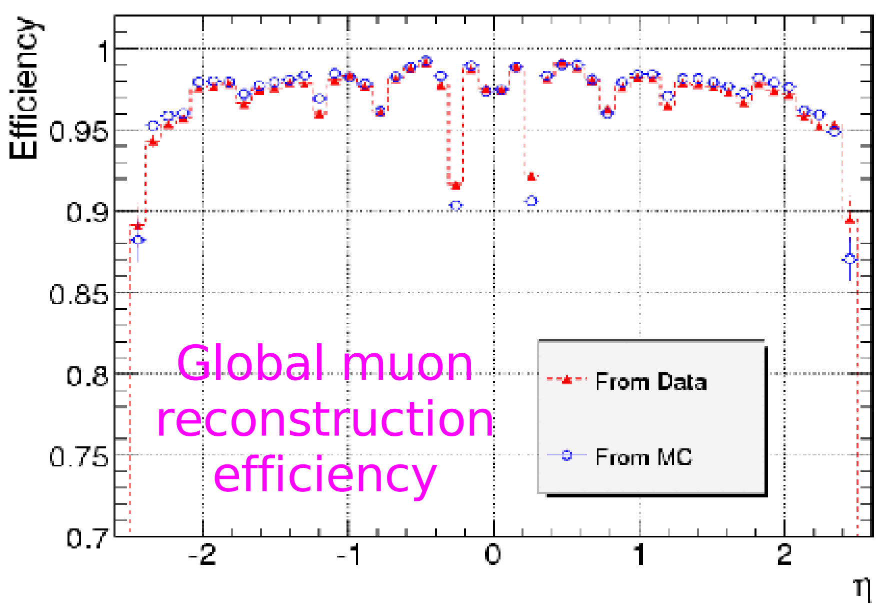
- tag-probe invariant mass within a narrow window around M(Z) + possible requirement on $\Delta\Phi$(tag-probe)
- tight tag selections + kinematic cuts to ensure a high purity sample
- map efficiencies as a function of p_T, η, Φ for phyisics analysis
- critical issues of the method
  - residual background contamination (QCD, W+jets) to be subtracted
  - check of correlations and dependencies on the selections applied

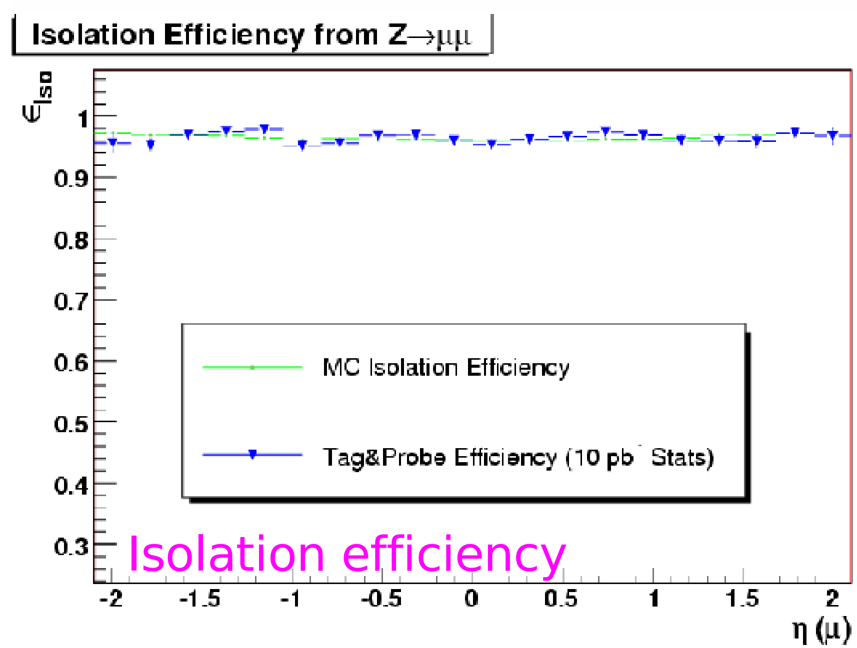
Muon efficiency with “Tag&Probe”

CMS AN 2007/031

- $\varepsilon = \varepsilon_{reco} \times \varepsilon_{isolation} \times \varepsilon_{trigger}$
  for muons: $\varepsilon_{reco} = \varepsilon_{tracking} \times \varepsilon_{standalone} \times \varepsilon_{matching}$
- Example: measuring trigger efficiency
  - TAG: isolated global reconstructed muon, p^T > 20 GeV, passing HLT
  - PROBE: isolated global reco. muon
  - 83.7 GeV < M($\mu\mu$) < 98.7 GeV
- overall precision on efficiency <1%



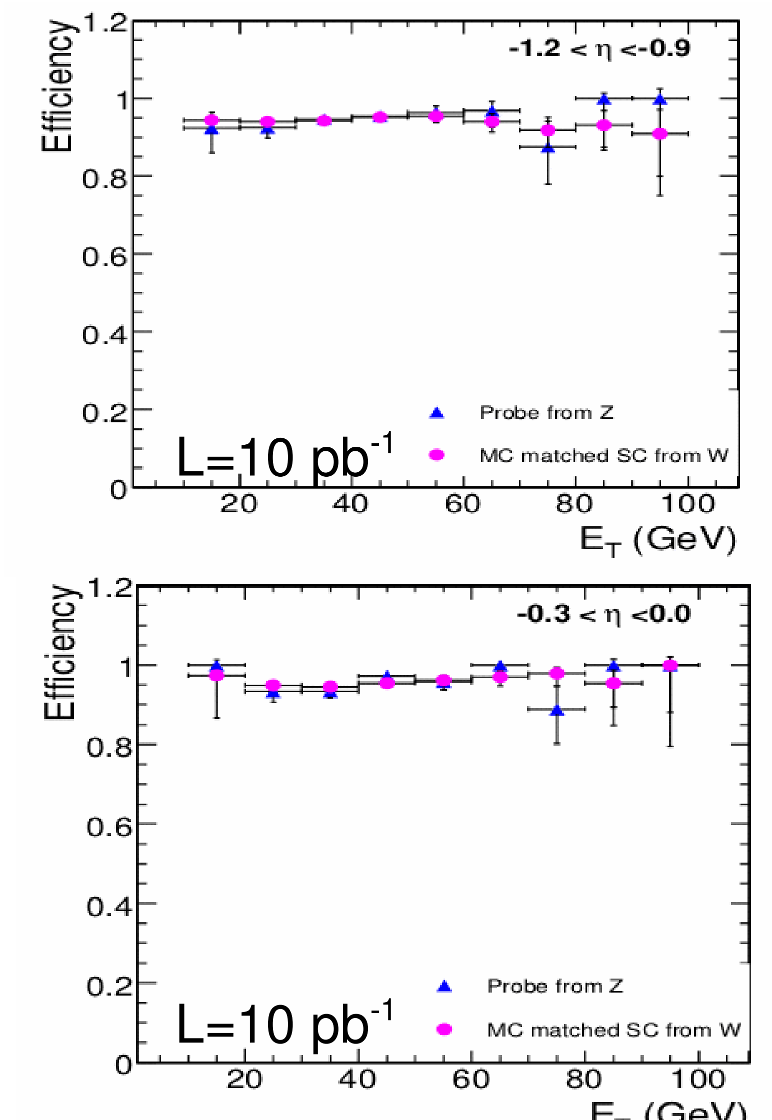




Efficiency:Tag&Probe vs W→lν

- apply efficiency measured with Z→ll to W→lν
- efficiency mapped in **p^T,η** bins to account for *different kinematic distributions* of leptons from Z and W
- good agreement between "Tag&Probe" efficiency and MC truth in W→lν
  - from comparison between "Tag&Probe" efficiency and MC efficiency in W→lν performed as a function of E^T and in η slices

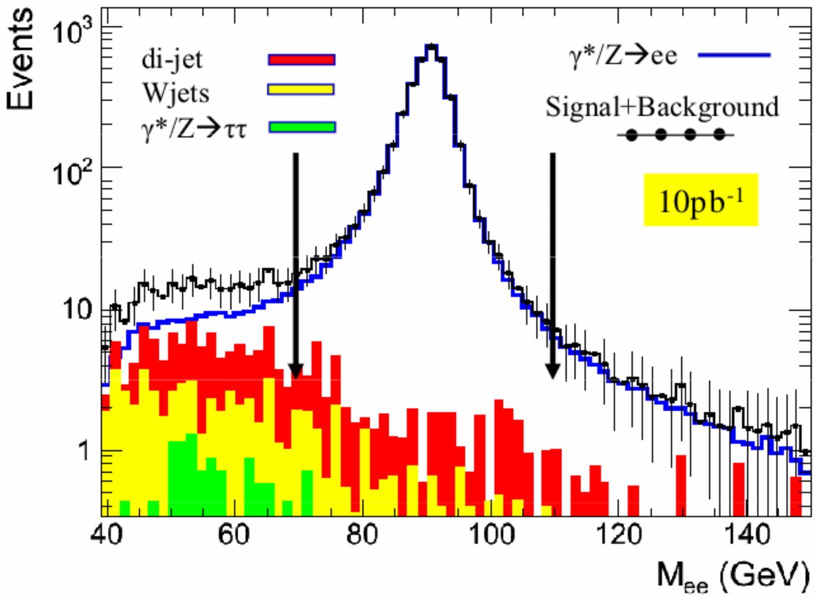
Electron tracking efficiency

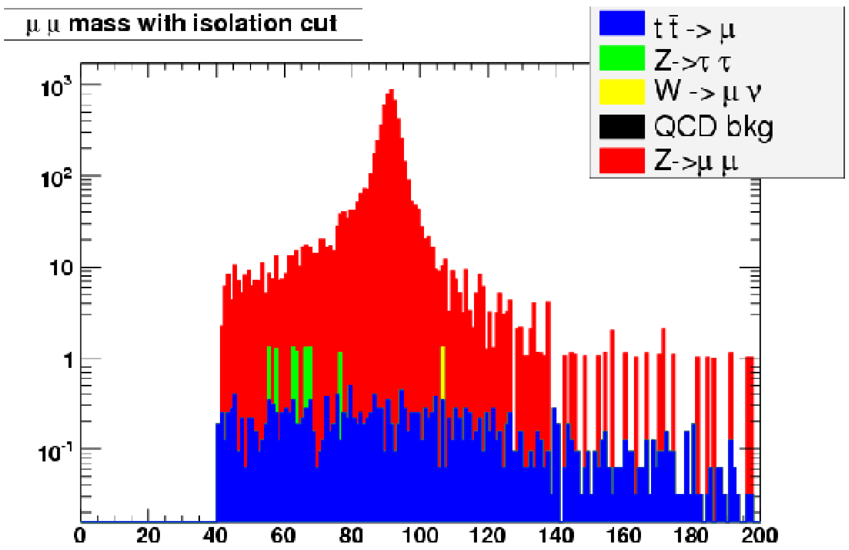


Tag: HLT electron, E^T>15GeV, track isolation
Probe: ECAL SC, E^T>20 GeV
85 GeV < M(tag-probe) < 95 GeV

Events selection and backgrounds Z→ll

- Selections:
  - two well reconstructed isolated leptons with opposite charge within detector acceptance (|η|<2.4)
    - lepton ID based on simple but robust cuts
  - hight pt (well above trigger thresholds)
  - invariant mass (70 GeV<M<110 GeV)
- Main Backgrounds
  - Z→ττ, ttbar, W+jets
  - true or misidentified leptons from di-jet events
- almost negligible background contamination (~ few ‰) after all selections





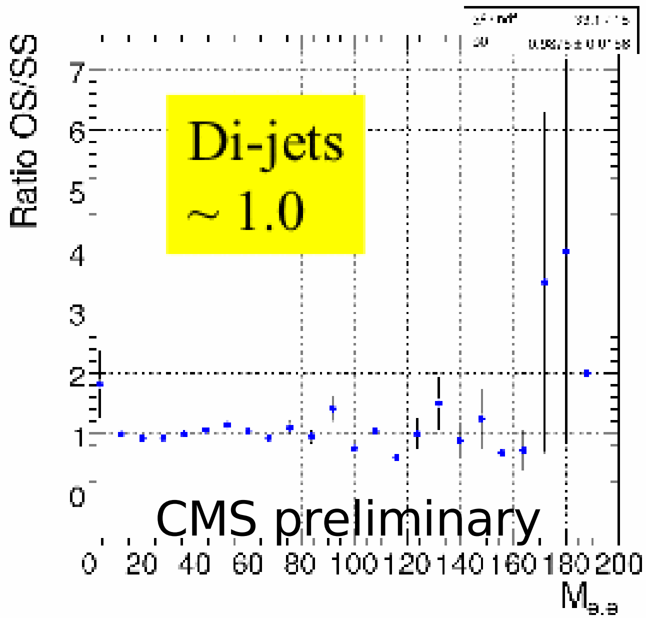
Backgrounds from data in Z→ll

- subtraction of residual background needed for a correct estimation of efficiencies with T&P and cross sections

Different techniques under investigation

(1) "Charge Correlation" Method

- look at "same-sign"(SS) and "opposite-sign"(OS) events
- **N(SS)=N(OS)** under the assumption of no charge correlation in lepton pairs from hadronic events
- need to take into account charge mismeasurement probability in signal and possible non-negligible charge correlations



(2) "Side Bands" Method

(3) fit with background (or signal+bkg.) templates of a discriminating variable

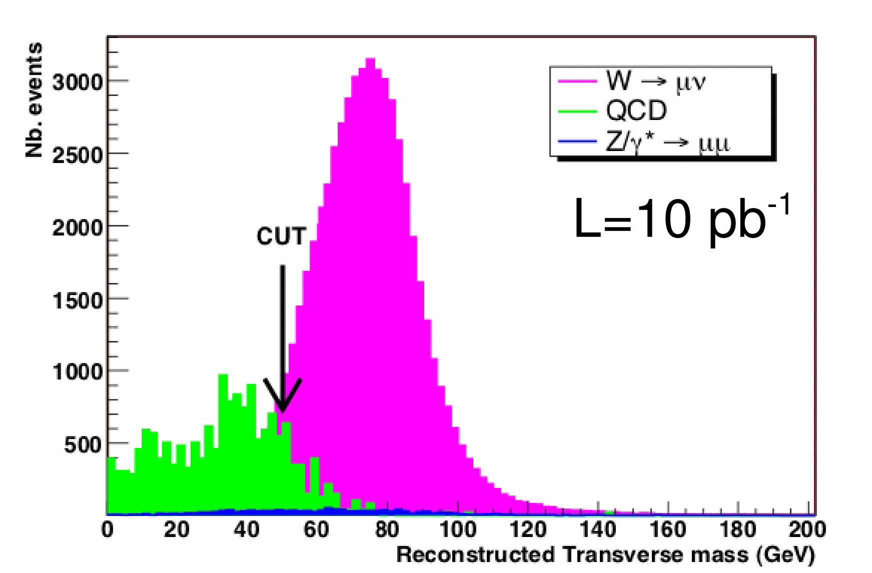
- more sophisticated, may require higher luminosities (i.e. with enough data to model background shapes)

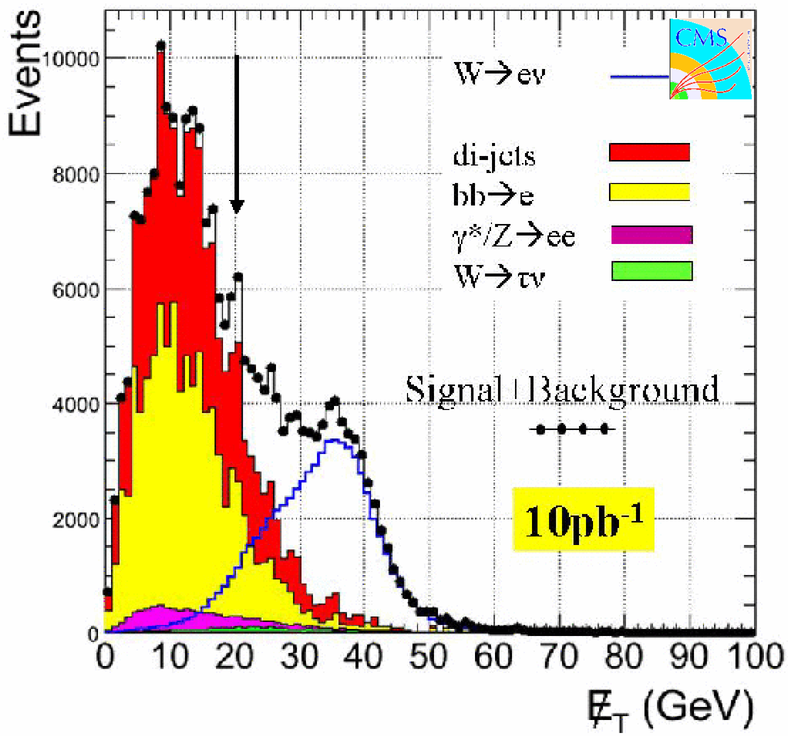
(1) and **(2)** are simple but robust methods:

- desirable for a start-up scenario
- adequate for the level of background expected in ~10 pb^{-1}

Events selection and backgrounds W→lν

- Selections
  - one well reconstructed lepton within detector acceptance and passing HLT requirements
  - lepton isolation
  - lepton p^T > 20 GeV
  - transverse mass and/or MET cut + possible jet vetoes to reduce hadronic backgrounds
- Electroweak backgrounds
  - W→τν, Z/γ*→ll, Z→ττ, ttbar (~few %)
  - WW, WZ, ZZ (~negligible)
  - can be reliably estimated from MC simulation
- Hadronic backgrounds
  - highest uncertainty
  - can be estimated **from data**

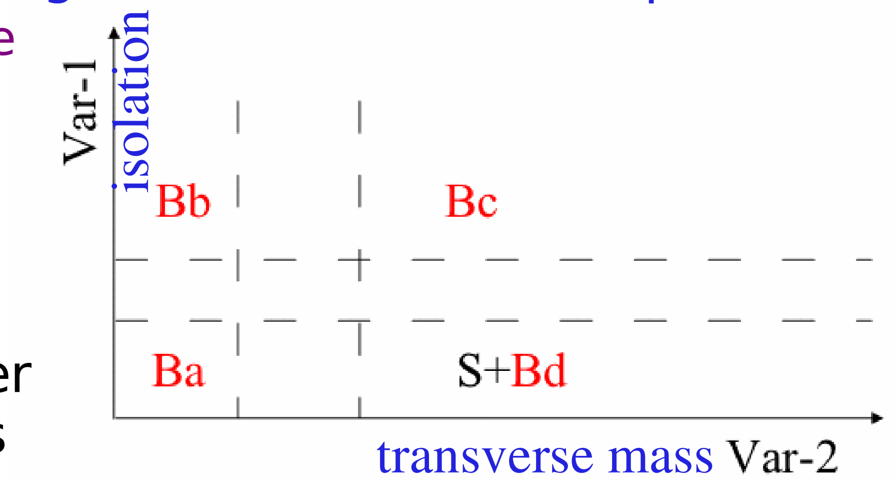




Background estimation: “Matrix method”

General technique used by CDF and D0

- consider two variables with signal/background discrimination power
  - main assumption: the two variables are largely uncorrelated
  - e.g.: lepton isolation and MET(M^T)
  - look at Var1%Var2

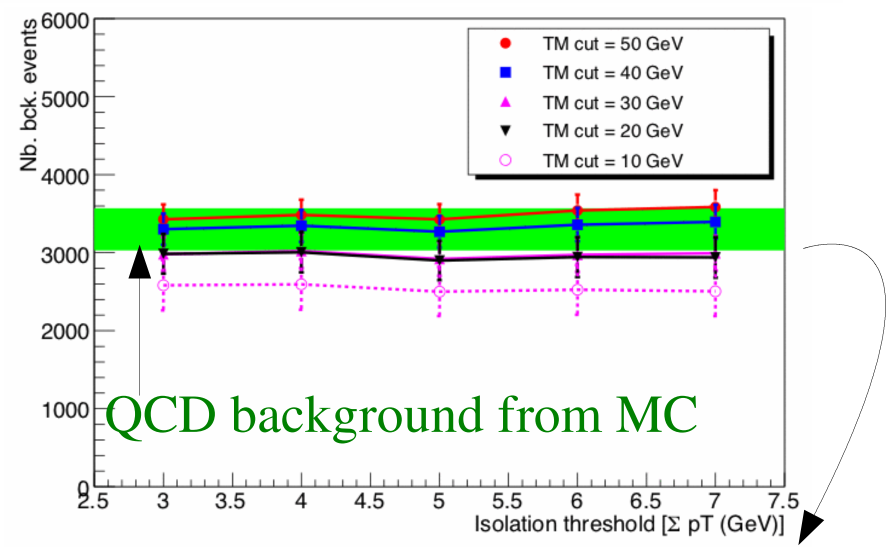


- Simplest approach: assuming that Ba, Bb, Bc are *only QCD* events, the number of bkg. events Bd in the signal region is deduced by the ratio R

$$R = \frac{Bb}{Ba} = \frac{Bc}{Bd} \rightarrow Bd = \frac{Bc}{R}$$

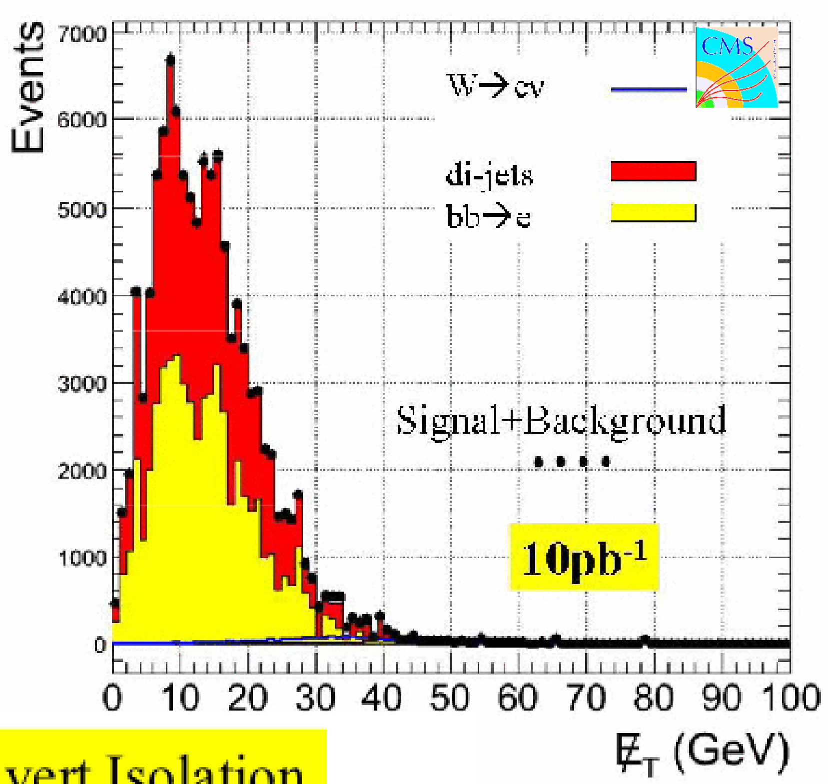
- “non-QCD” contamination correction in regions a, b, c may be required

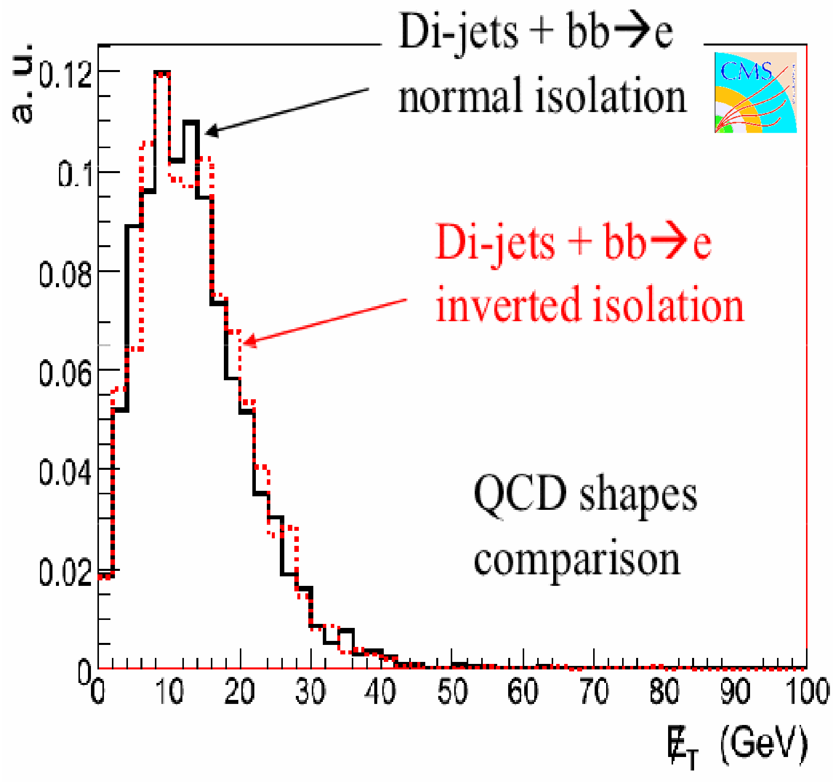
- systematics dominated by the validity of the assumption Bb/Ba=Bc/Bd



Results for QCD bkg estimation in $W\rightarrow\mu\nu$ shown for different control regions using 0.5 pb^{-1}

Background estimation from data (I)



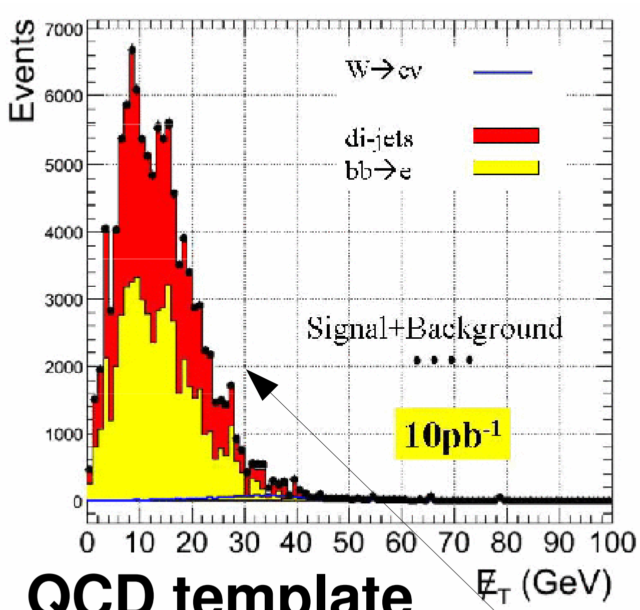


Invert Isolation

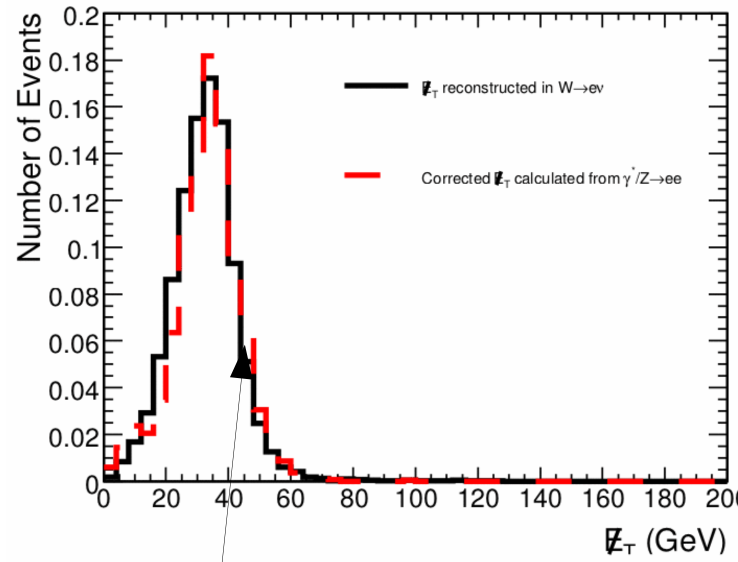
$$\sum_{track}\left(\frac{p_T^{track}}{p_T^{ele}}\right)^2 > 0.02$$

- MET distribution in QCD events is almost independent of whether the candidates pass or fail the isolation requirement
- it can then be modeled on ANTI-ISOLATED leptons

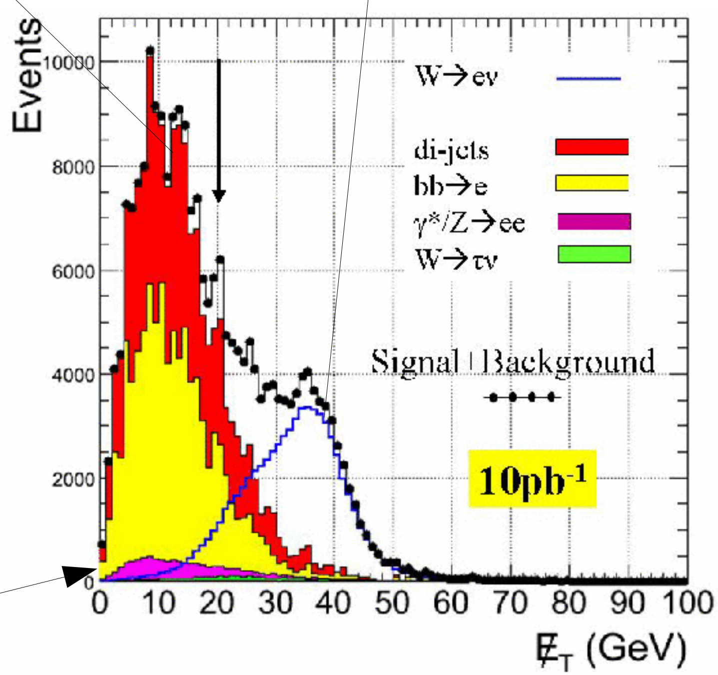
Background estimation from data (II)



QCD template
from anti-isolated electrons



W→eν MET template
from Z→ee
- ignore one lepton
- corrections for different W/Z kinematics

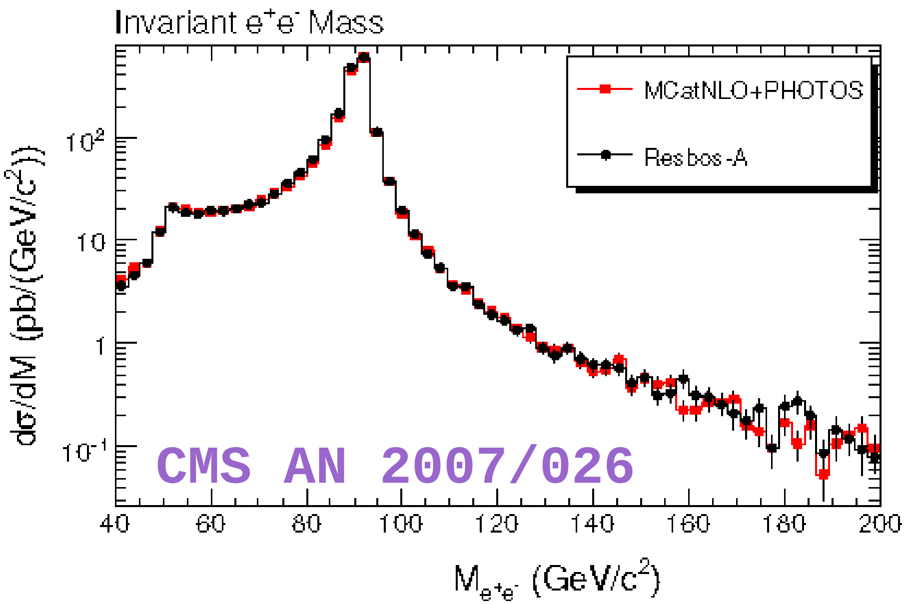


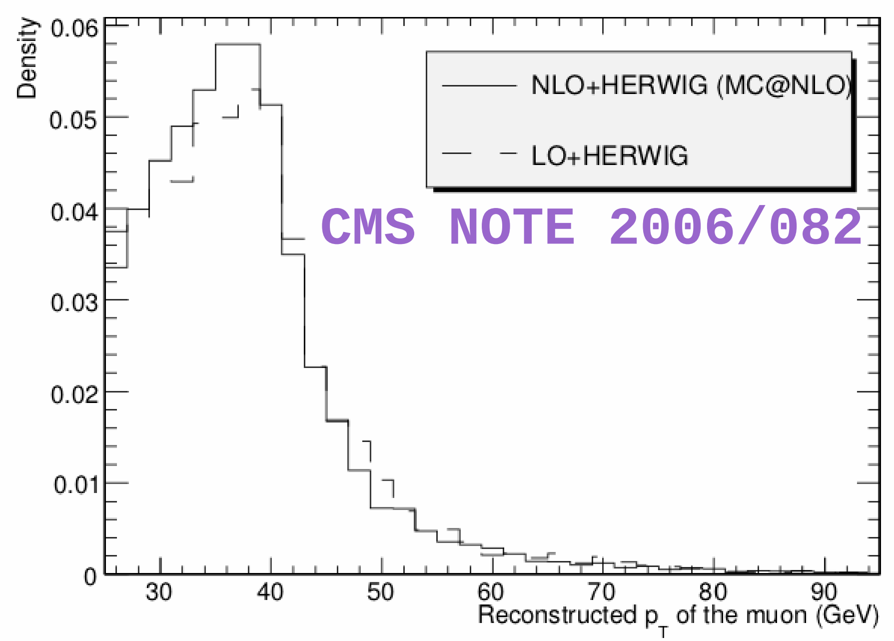
Other backgrounds: use full simulation

Possible systematic effects
- bias in modelling QCD and signal templates
- biases from W and EWK events in the non-isolated electron sample
- accuracy in the MC prediction of EWK backgrounds

Acceptance studies

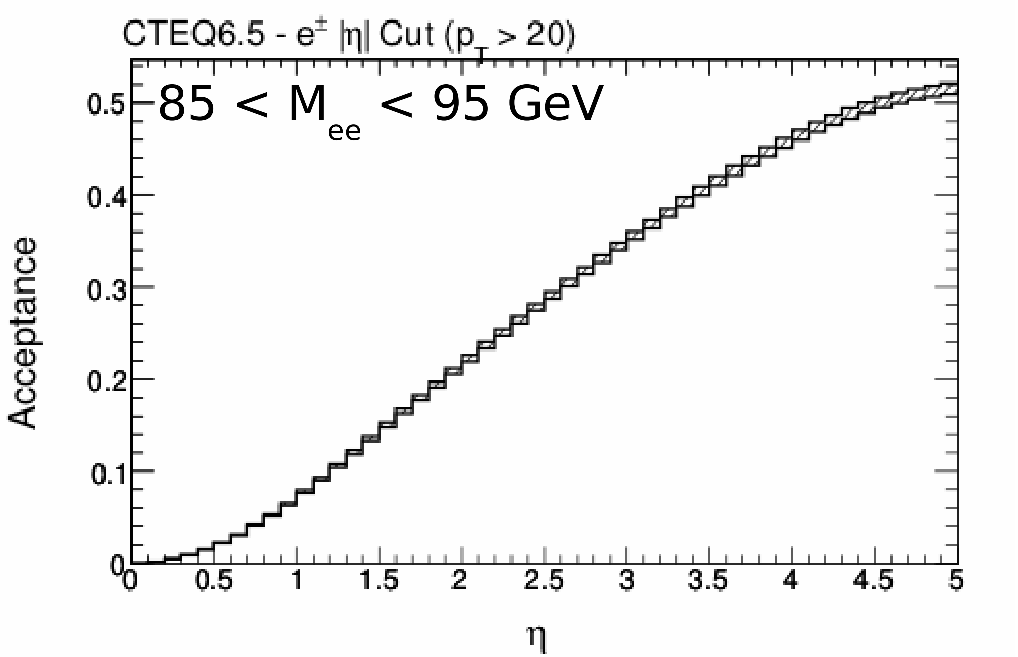
- Comparisons between different generators and predictions (LO vs NLO)
- NLO QCD and EWK corrections
  - MC@NLO+PHOTOS vs RESBOS-A
  - HORACE vs LO MC + PHOTOS
  - using MC@NLO+PHOTOS $\Rightarrow$ overall theoretical uncertainty on $Z \to ll$ acceptance at the percent level
- $W \to l\nu$
  - LO – NLO (MC@NLO) ~ 2 % uncertainty on acceptance

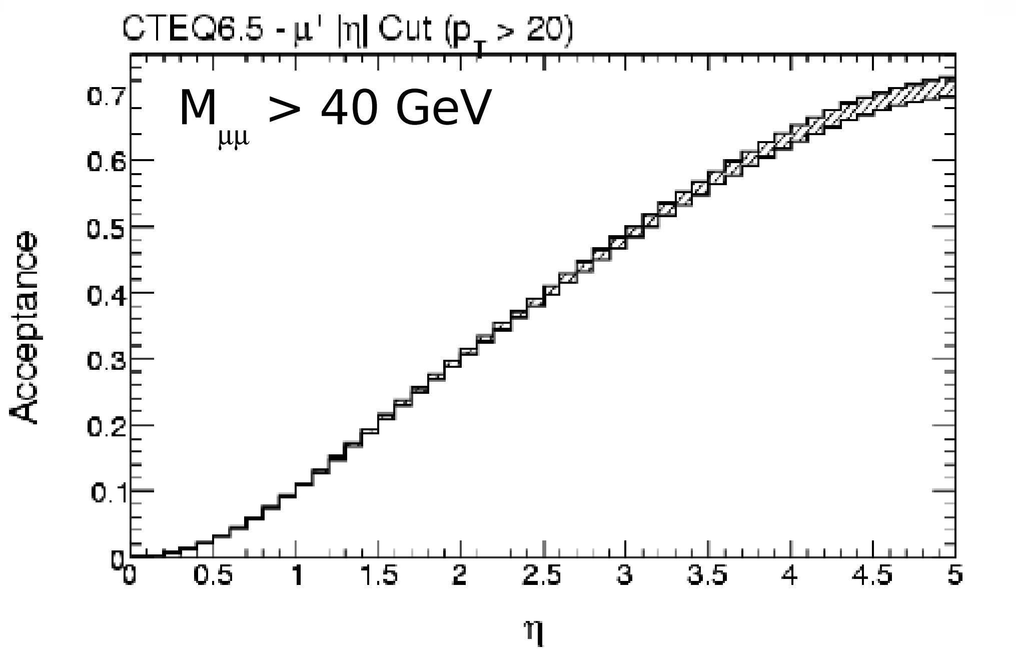




Acceptance uncertainty from PDFs

- uncertainty on acceptance in $Z \rightarrow ll$ events from PDFs at the 1% level
  - evaluated with CTEQ6.5
  - ~1% difference between CTEQ6.5 central value and other MRST PDF sets





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Summary

- W,Z inclusive cross section measurements will be one of the first measurements with early data
- Efforts to investigate strategies to measure most of the parameters from data and to minimize the dependence on Monte Carlo
- Trigger and offline efficiencies can be measured from data exploiting $Z \rightarrow ll$ events
- QCD background estimation (shape and normalization) from data using different methods
- Residual dependences on MC: acceptance determination, electroweak backgrounds

Backup slides

Trigger efficiency - electrons

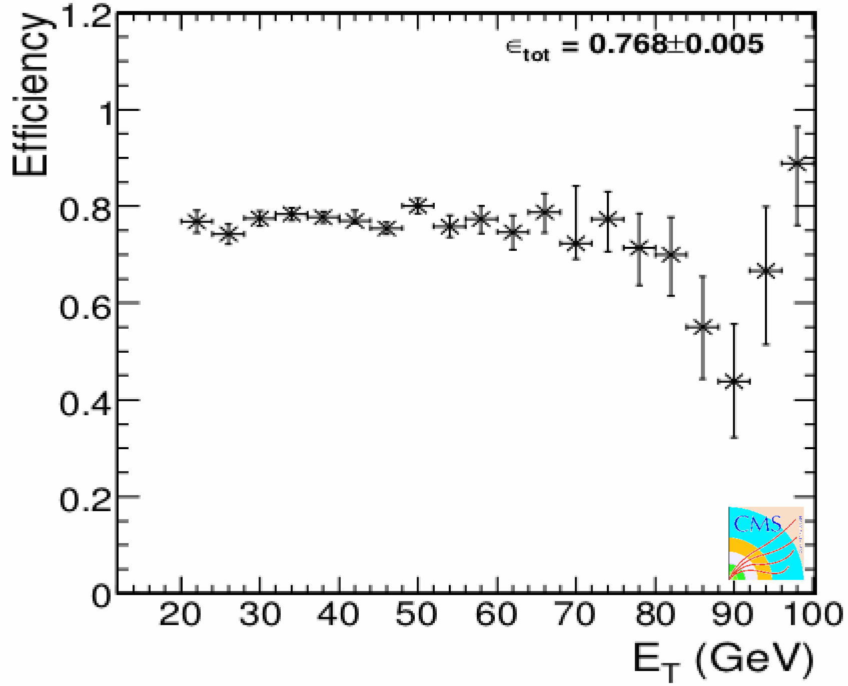


Figure 3: L1+HLT efficiency versus supercluster E_T.

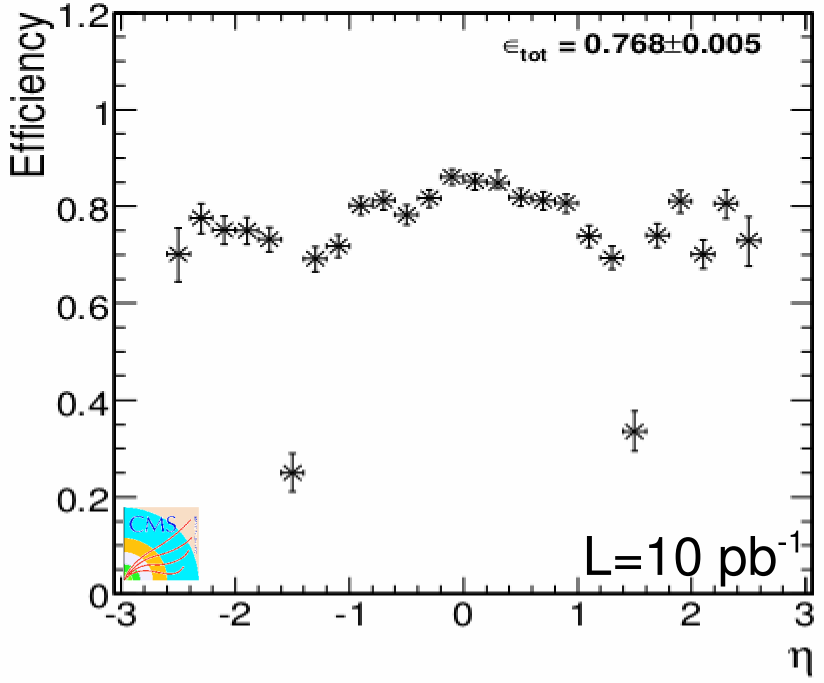
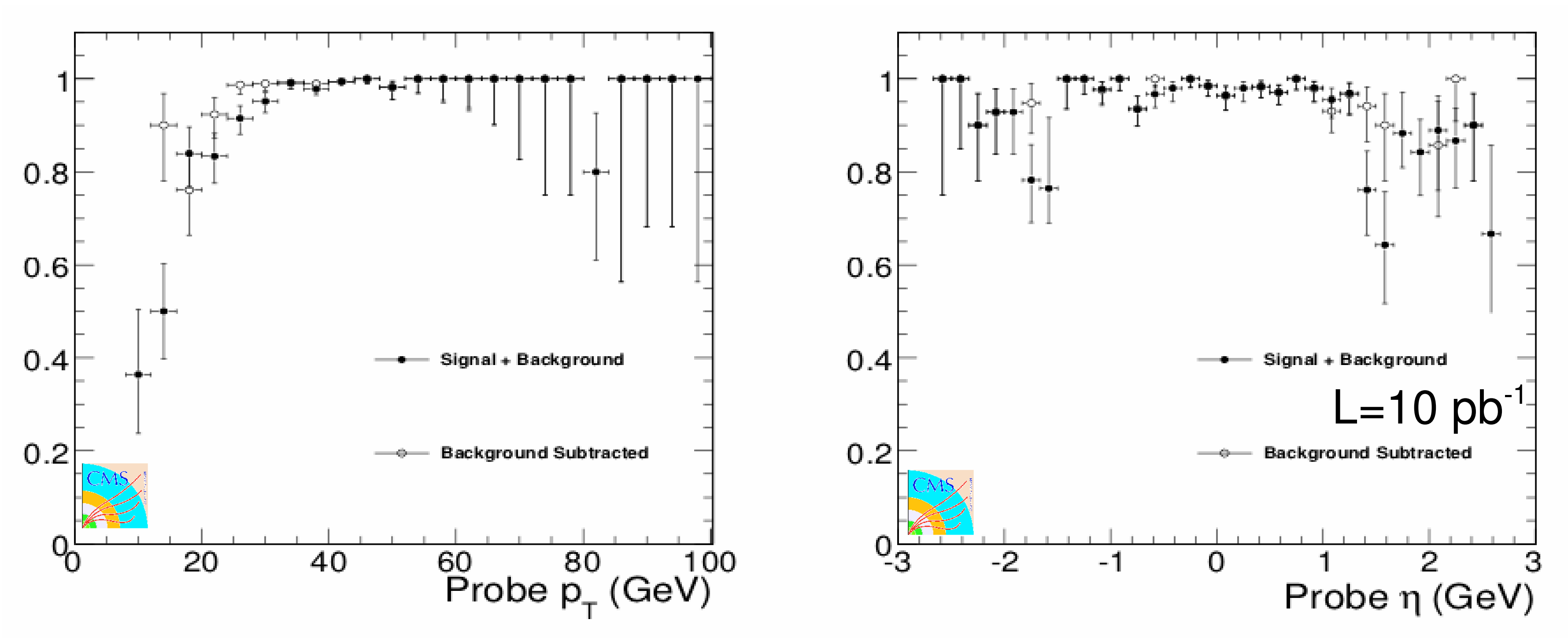


Figure 4: L1+HLT efficiency versus supercluster η.

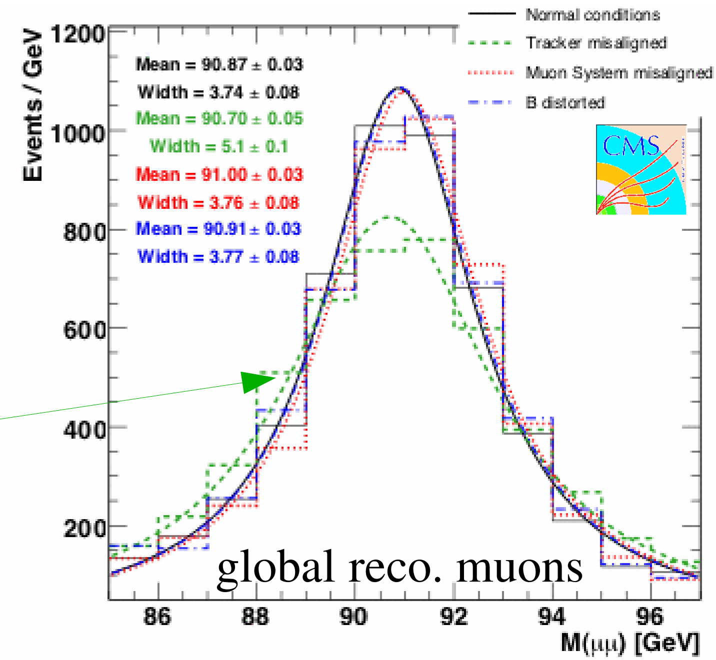
Efficiency - electrons

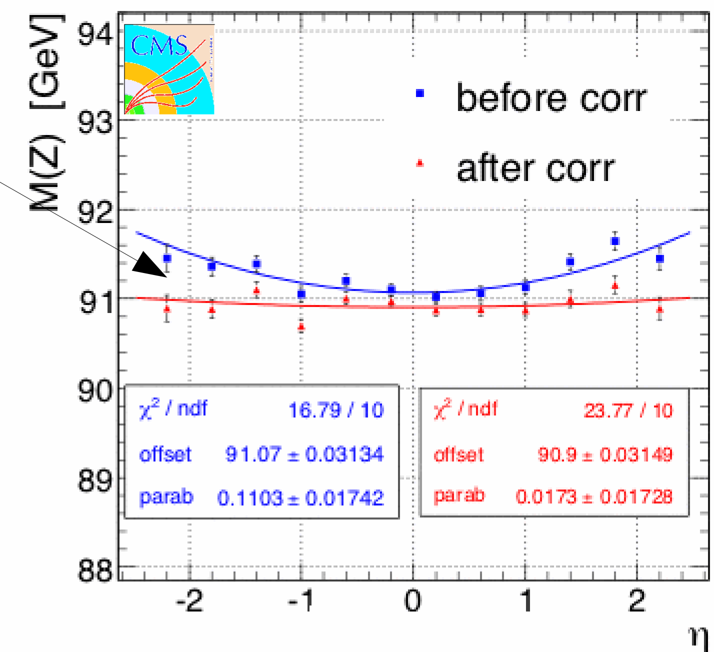
Electromagnetic calorimeter reconstruction efficiency as a function of probe track p^T: comparison between signal+background and after background subtraction



Muon momentum scale from Z

- use $Z \to \mu\mu$ events to correct muon scale biases due to
  - effectiveness of the muon reconstruction procedure
  - imperfect knowledge of the detector conditions
- studied for 10 pb^{-1} with different scenarios
  - normal detector conditions
  - tracker misalignment
  - muon system misalignment
  - modified B-field intensity
- correct μ scale as a function of muon kinematics: $p^T = k \times p^T$ with $k = F(p^T, \eta, \phi; \alpha\ldots)$
- scale corrections improve also systematics on cross section measurements (acceptance uncertainties)





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