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W and Z Measurements with Initial CMS Data

IoP HEPP Meeting 2008

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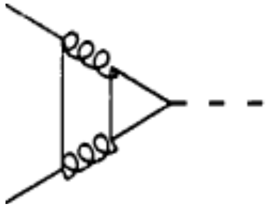
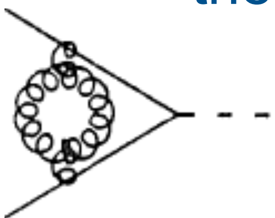
Overview

- Motivation for measurements of W and Z using leptons
- The CMS detector
- Electron reconstruction
- Selections of $W \rightarrow e\nu$ and $Z \rightarrow ee$
- Measuring efficiencies using Tag and Probe
- Estimating background from data
- The cross-section measurement
- Summary

W and Z : Motivation



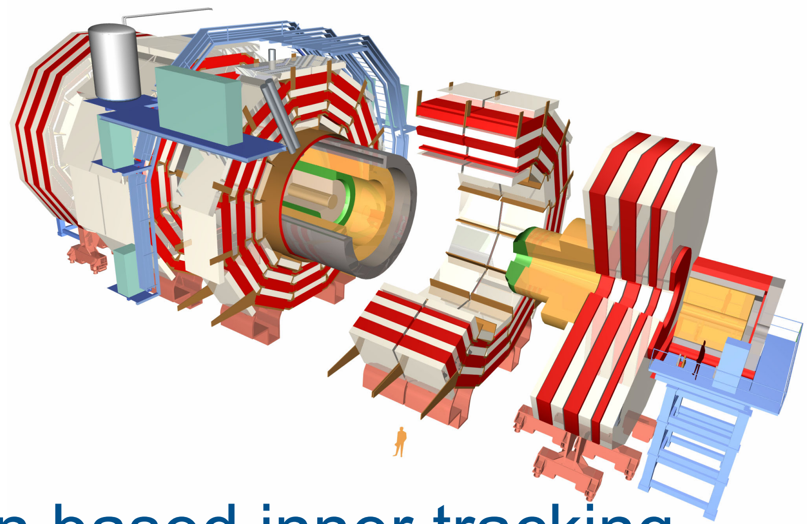
- W and Z production well-understood theoretically
  - Except for PDF uncertainties, radiative corrections
- Ratios of cross-sections can
  - Provide precision test of standard model
  - Provide information on PDF parameterisations
- Production of W and Z have large cross-sections at LHC : ~190 nb and ~60 nb respectively
  - $10pb^{-1}$ sufficient for a significant analysis
- Well isolated leptons with high transverse momenta
  - Distinctive in hadron collisions and readily triggered
- Measurements of W and Z production cross-sections and decays to leptons useful for our understanding of the CMS detector



Philosophy of Analyses

- Focus on early data-taking period ($\int L dt = 10 pb^{-1}$)
- W and Z measurements will be among the first results from CMS
- The detector will be imperfectly understood
  – The analyses are designed to be insensitive to this
  – Used events fully simulated to represent a misaligned and miscalibrated detector
- Data-driven methods used where possible, rather than relying on Monte Carlo

CMS Detector



- CMS is optimised for a wide range of physics at LHC
  - 4T large radius solenoid
- Large, fine-grained, silicon based inner tracking
- Hermetic, fully active, $PbWO_4$ crystal electromagnetic calorimeter (ECAL) within the solenoid
- Level 1 trigger system hardware based
- High Level Trigger (HLT) software on commodity PCs

Electron Objects

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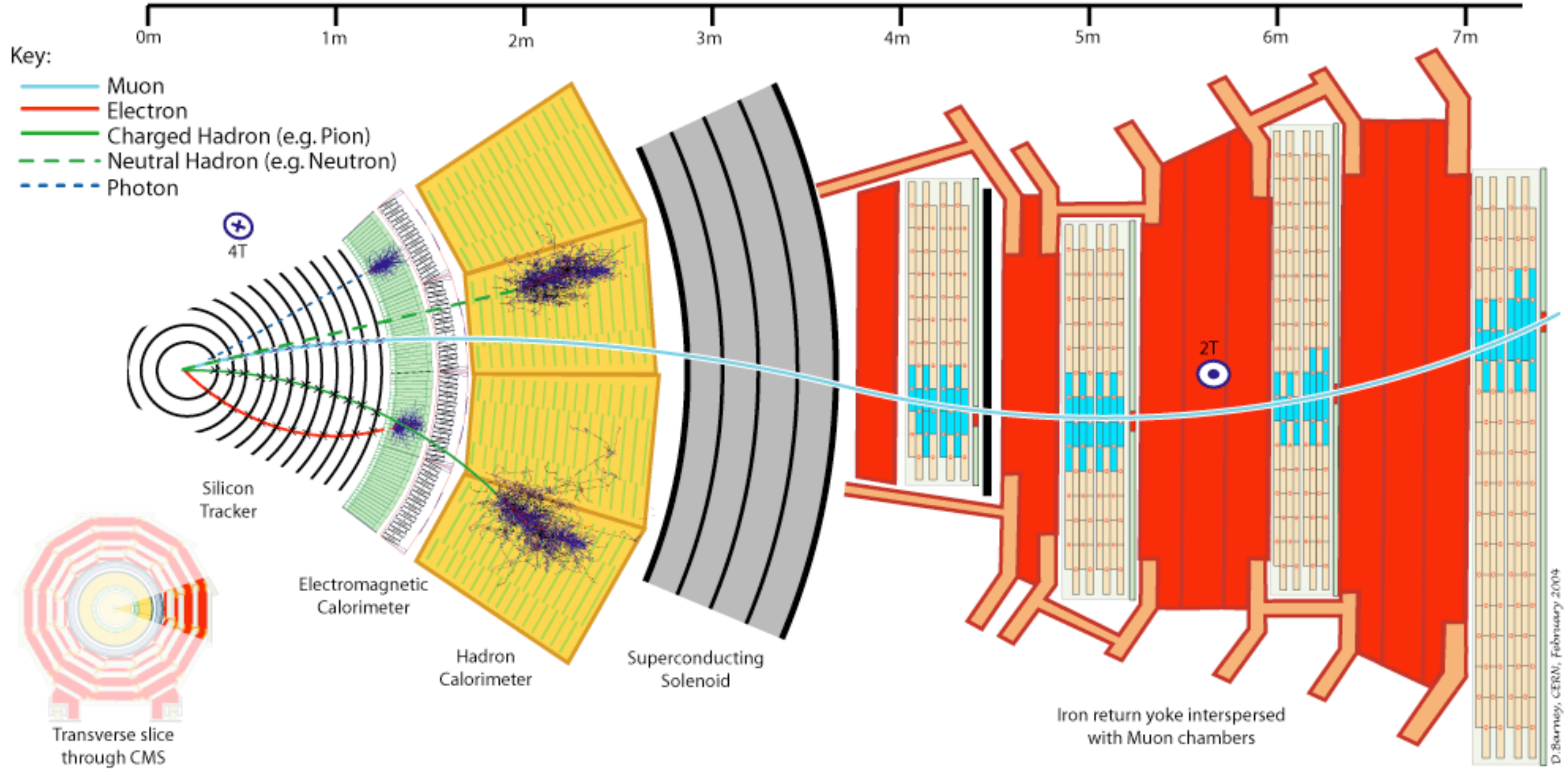
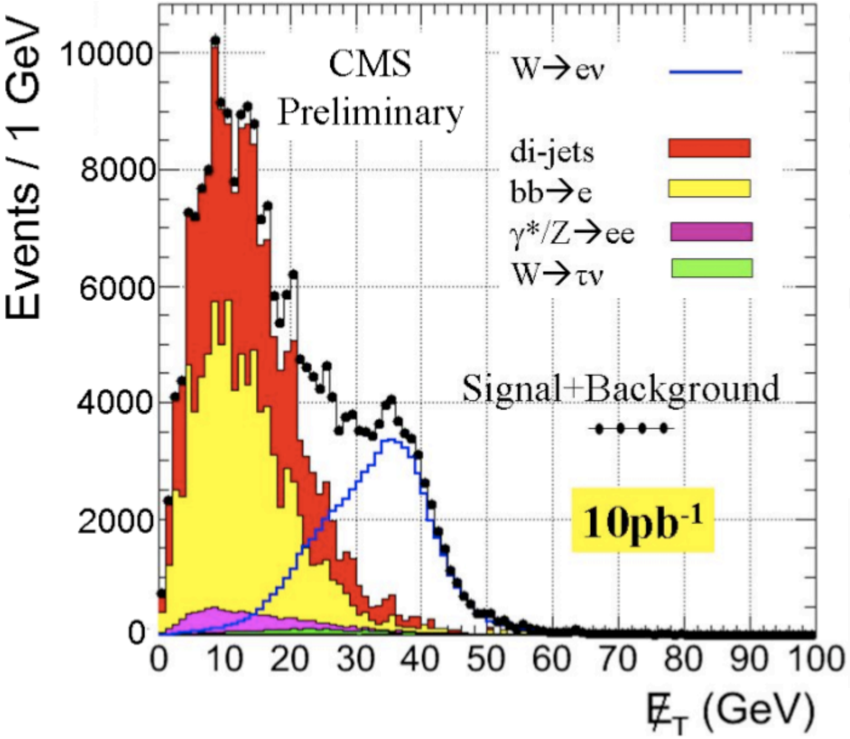


- For this analysis, electrons (ECAL ‘supercluster’ + track) must
  - Have supercluster, E_T > 20 GeV in ECAL fiducial region
  - Pass track isolation
  - Pass electron identification criteria : cluster shape properties and track-supercluster matching

Robust Selections

W→ev selection :

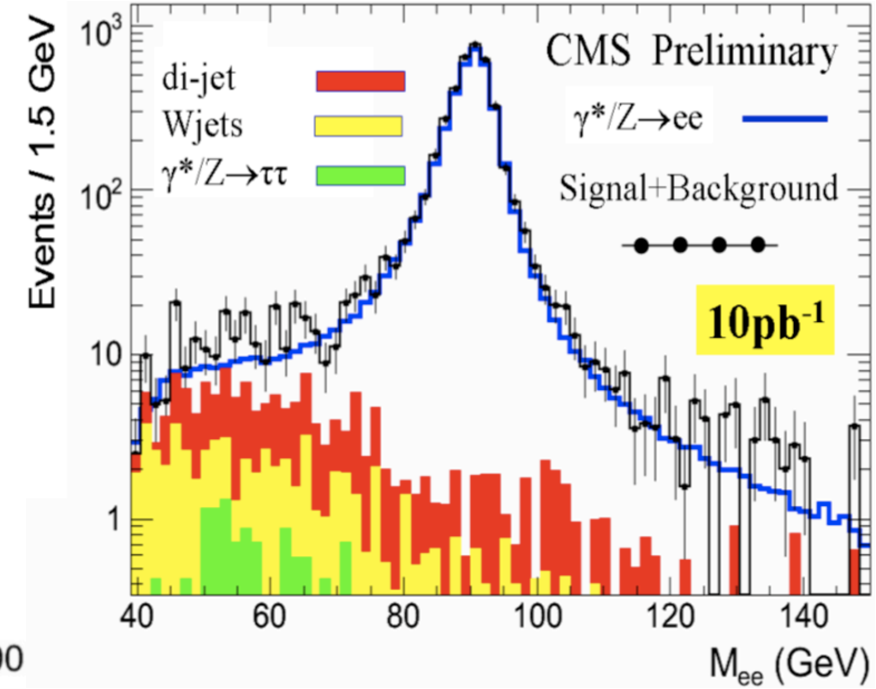
- **Pass single electron HLT path**
- **≥1 selected electron**



Missing transverse energy after selection

Z→ee selection :

- **Pass single electron HLT path**
- **≥2 selected electrons**

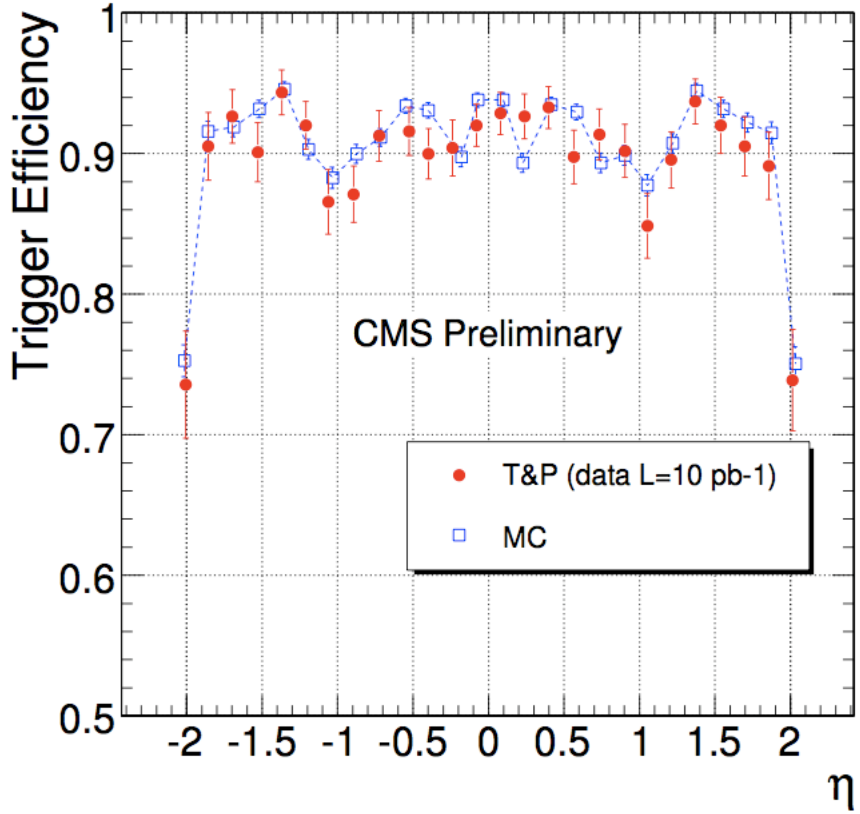


Invariant mass after selection

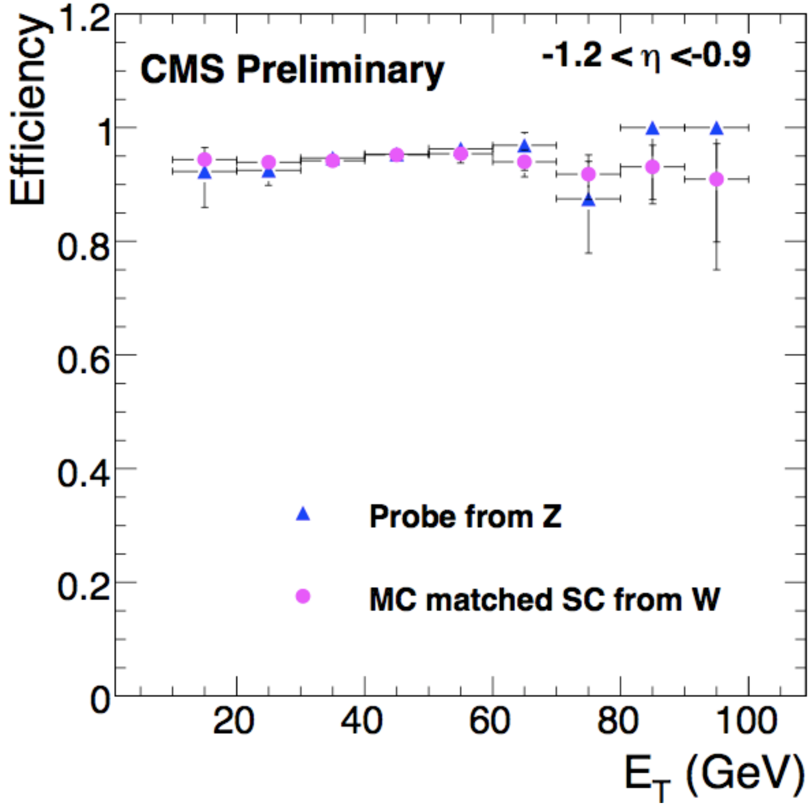
Efficiencies – Tag and Probe

- Trigger, reconstruction and selection measured from data by the "Tag and Probe" method
- An unbiased and pure sample of leptons is selected from $Z \rightarrow ll$ events (single lepton trigger used)
  - One lepton has tight criteria imposed on it, "tagging" the event – it must be able to pass the trigger
  - The probe need satisfy only very loose criteria, ensuring an unbiased sample
  - An invariant mass cut on the tag-probe pair ensures the purity of the probe sample
- The probe sample then used to determine efficiencies

Efficiencies - Example



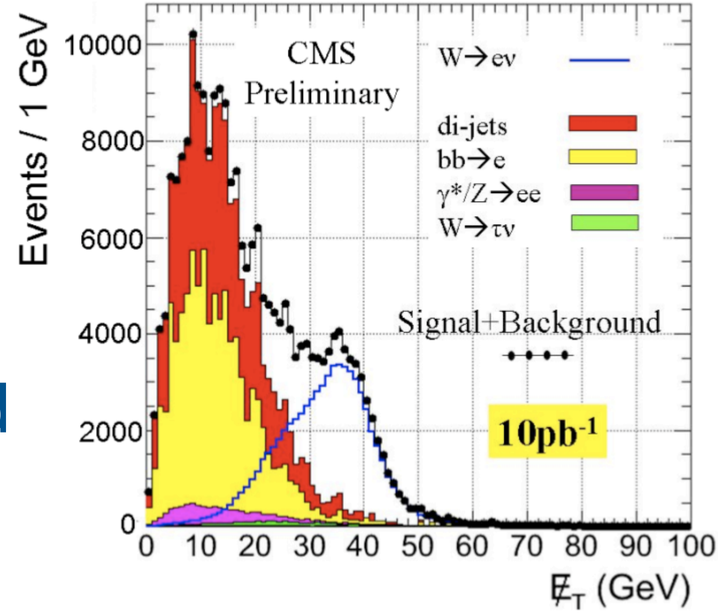
Single muon trigger efficiency for muons with p_T > 20 GeV, in selected $Z \rightarrow \mu\mu$ events



Supercluster-Track matching efficiency for superclusters in ECAL fiducial region and E_T > 20 GeV

W Background Estimation I

- Small electroweak backgrounds can be reliably estimated from simulation
- QCD backgrounds much larger and are difficult to simulate : must be determined from data
  - One jet may fake an electron; missing E_T arises from badly measured energy
  - b decays are source of real electrons
- Two data-driven techniques explored – “Template” and “Matrix”



The "Template" Method

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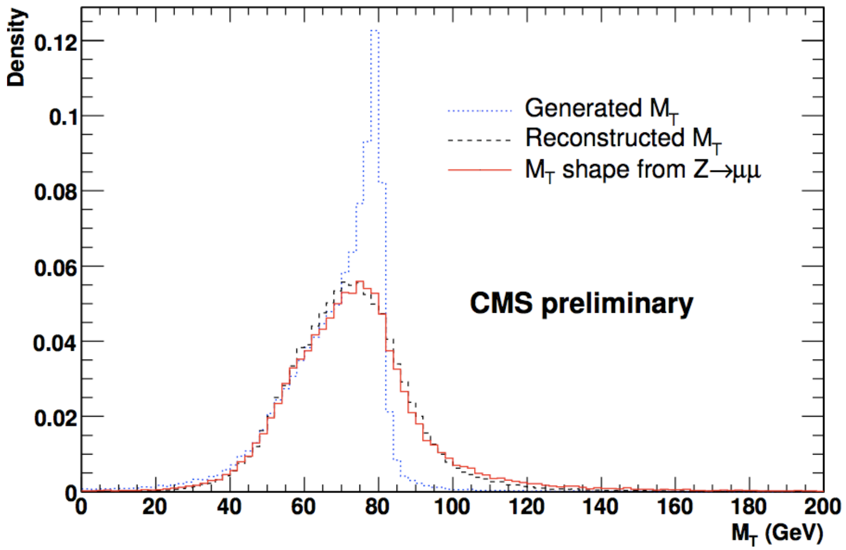
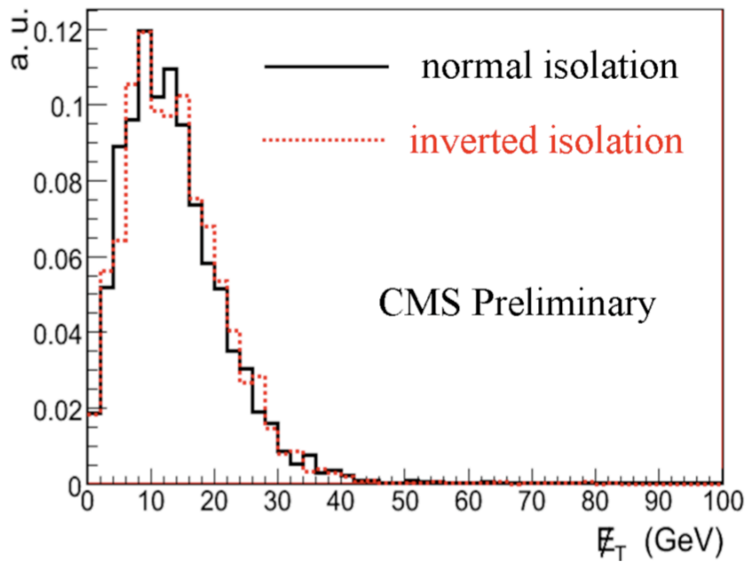
- Templates – predefined shapes of distribution of some background discriminating variable
- Determine from data for signal and background
- Simultaneously fit background and signal shapes to distribution observed in selected sample – estimates yields



W→lν shape estimated from Z→ll data



Shape of QCD di-jet background to W→eν

Measuring the Cross-Section

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$$\sigma(pp \to W) \times Br(W \to l\nu) = \frac{N_{observed} - N_{background}}{\varepsilon \times A \times \int Ldt}$$

(Similarly for pp→Z)

$N_{selected} - N_{bkgd}$	67954 ± 674
Tag&Probe ε_{total}	65.1 ± 0.5 %
Acceptance	52.3 ± 0.2 %
Int. Luminosity	$10\ pb^{-1}$
$\sigma_W \times BR(W \to e\nu)$	19.97 ± 0.25 nb
cross section used	19.78 nb

$N_{selected}$	3914 ± 63
N_{bkgd}	assumed 0.0
Tag&Probe ε_{total}	68.1 ± 0.6 %
Acceptance	32.39 ± 0.18 %
Int. Luminosity	$10\ pb^{-1}$
$\sigma_{Z/\gamma^*} \times BR(Z/\gamma^* \to e^+e^-)$	1775 ± 34 pb
cross section used	1787 pb

- Errors in table are purely statistical
- Systematic errors anticipated
  - Int lumi ~ 10%
  - Signal yield ~5% (for W→ev)
  - Acceptance ~1%

Summary

- In recent months, CMS has focused on preparing analyses for early data
  - (https://twiki.cern.ch/twiki/bin/view/CMS/PhysicsResults)
- Measurement of inclusive $pp \to W \to l\nu$ and $pp \to \gamma^*/Z \to ll$
  - Detector simulated with miscalibration and misalignment
  - Robust selections applied to account for these imperfections
  - Realistic, data-driven methods developed to determine efficiencies and signal and background yield
- Important to "rediscover" the Standard Model
  - For understanding CMS
  - Step toward potential discoveries
- These analyses will be further developed and LHC collision data is eagerly anticipated later in 2008

ADDITIONAL SLIDES

Selections – Electrons Additional

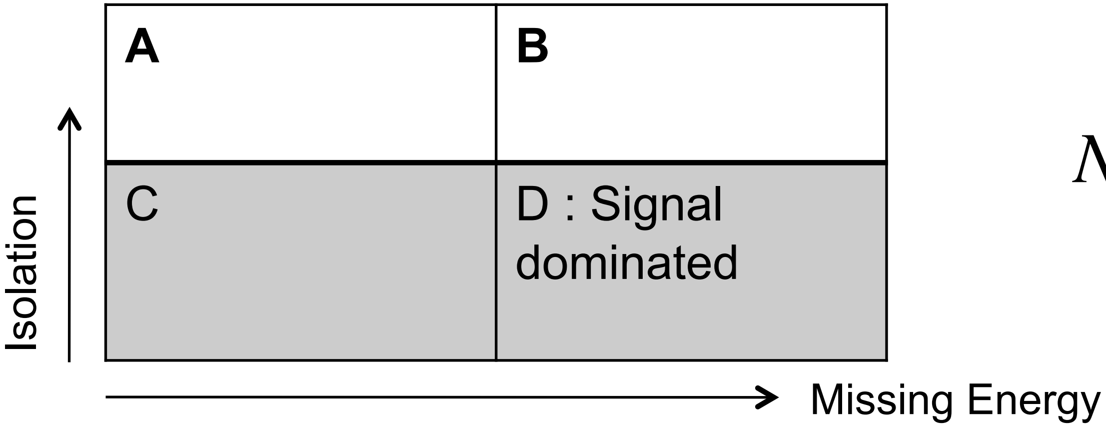
- ECAL fiducial region is |η|<1.4442 and 1.56<|η|<2.5 (excludes the barrel-endcap transition)
- Track Isolation :
  - sum over all tracks with p_T > 1.5 GeV, within an annular cone (limits 0.02 < ΔR < 0.6) centred on the electron :

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

- Electron Identification :
  - cuts on ratio of hadronic energy deposited behind supercluster to supercluster energy
  - Cluster shape in η
  - Matching between supercluster position and track direction at vertex in both η and φ

W Background Estimation IV

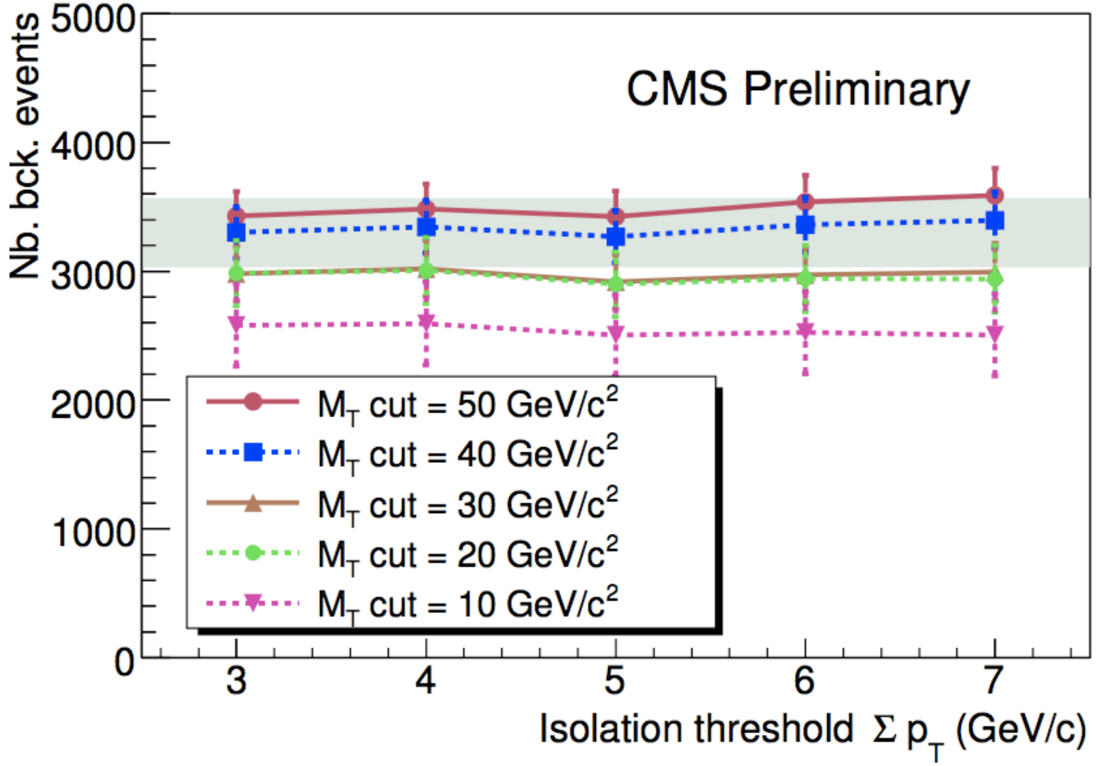
- "Matrix" method has been used to estimate background
  - Uses two uncorrelated background discriminating variables to form 4 regions – 1 signal dominated and the others ~ signal free
  - Number of QCD background events in signal region D = N_{QCD}



$$N_{QCD} = \frac{N_B N_C}{N_A}$$

- Can estimate signal contamination of regions A, B and C

W Background Estimation V



- Background events in W signal region evaluated by matrix method, for various definitions of background regions (signal region fixed)
- True number of background events with statistical uncertainties are shown as grey band

Theoretical Uncertainties I

- The theoretical uncertainties expected in the measurement of the $pp \rightarrow \gamma^{*}/Z \rightarrow ll$ inclusive cross section have been studied
  - Higher order terms & EWK corrections, PDF and renormalisation scales
- Using MC@NLO interfaced to PHOTOS, the overall theoretical uncertainty has been demonstrated to be ≈ 1%
- Comparisons were carried out between MC@NLO+PHOTOS and ResBos-A

Theoretical Uncertainties II

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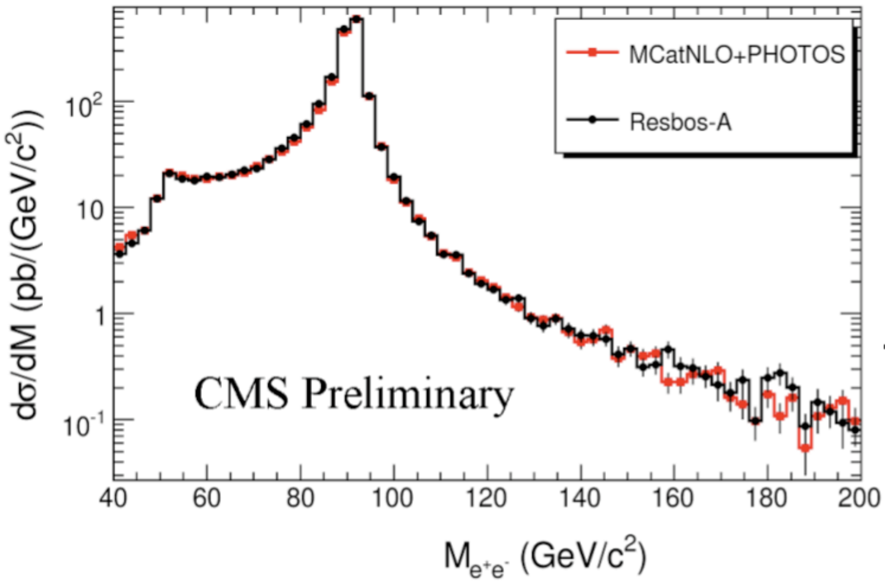
Comparison of $\gamma^*/Z \rightarrow ee$ invariant mass distributions between MC@NLO+PHOTOS and ResBos-A



Uncertainty on acceptance of $\gamma^*/Z \rightarrow ee$ due to PDFs, against electron $|\eta|$ cut