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Precision using electrons in CMS

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Outline

- $H \to ZZ^{(*)} \to 4e$
- $W/Z \to$ electron(s)
- W mass from $W \to$electron
- WZ/ZZ production
- tt dileptonic

- Summary

Not covered here: other Higgs channels, beyond SM, electrons in jets, top mass from J/Ψ etc.

Based on CMS Physics TDR Draft (June 3)

$H \rightarrow ZZ^{(*)} \rightarrow 4e$

- Theoretical uncertainties (PDF and QCD scale):
  - Uncertainties on background normalization:
    - ~6% for direct estimation of ZZ background
    - 2-8% for normalization to single $Z \rightarrow ee$
    - 0.5-4% for normalization to sidebands
  - 8% (in addition) for gluon fusion cross section uncertainty
  - 3% for pp luminosity (at $10fb^{-1}$)

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$H \to ZZ^{(*)} \to 4e$

- Experimental uncertainties:
  - Main uncertainties:
    - Knowledge of amount of material in front of ECAL
    - energy calibration
    - control of electron efficiencies
- Will rely on determining efficiencies from real data, using single $W \to e\nu$ and $Z \to ee$

$H \rightarrow ZZ^{(*)} \rightarrow 4e$

- Tracker material:
  - Methods proposed to determine it from the data:
    - use converted photon vertices
    - shape of E/p distribution
    - comparison of Z mass resolution to Monte Carlo
    - Compare track momentum at vertex and at outside of tracker $\rightarrow$ direct estimate of $\langle X \rangle / X_0$
  - demonstrated that the material could be estimated to an accuracy of about 10%
  - Claims that with $10 fb^{-1}$ and using single Z (i.e. improved statistics), 2% should be possible over the whole eta range
  - 2% material uncertainty has almost no effect on electron reconstruction efficiency in this channel

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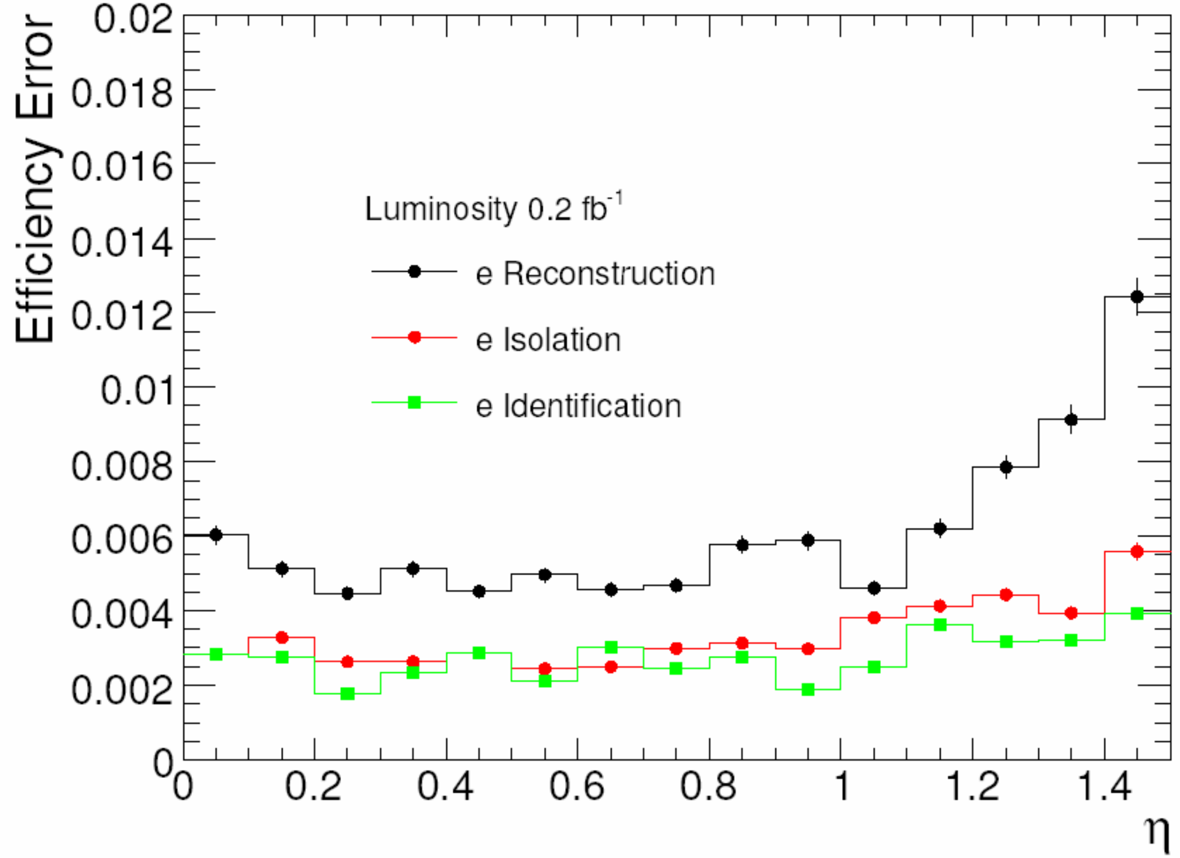
Electron reconstruction efficiency uncertainty as function of eta:



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$H \rightarrow ZZ^{(*)} \rightarrow 4e$

- Electron absolute energy scale uncertainty: 0.1% can be reached
  - for this study 0.5% for barrel, 1% for endcaps are considered (for $10fb^{-1}$)

- uncertainty on Higgs mass (for $30fb^{-1}$): < 0.4% for masses at which significance is at least 3σ

- uncertainty on cross section (for $30fb^{-1}$): 20-30% (15% for $60fb^{-1}$)

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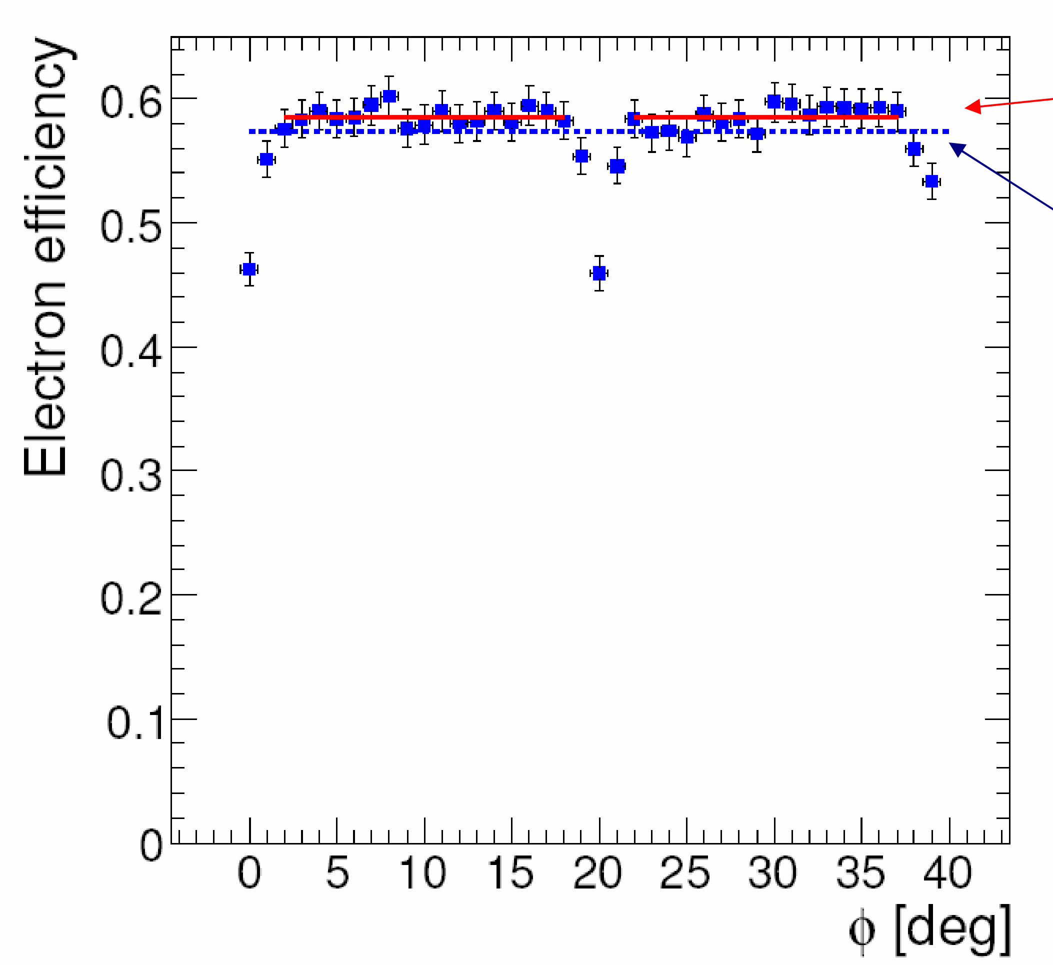
W/Z→electron(s)

- High cross section, several events per second
- Tight electron identification cuts
- Analysis focuses on gaps between supermodules ($1/36^{th}$ of CMS ECAL), which is considered to be the main source of uncertainties
- Selection efficiency uncertainties:
  - $Z \to ee$: ~ 1%
  - $W \to e\nu$: ~ 5 %

W/Z→electron(s)



Even and odd numbered SuperModules are folded on top of each other

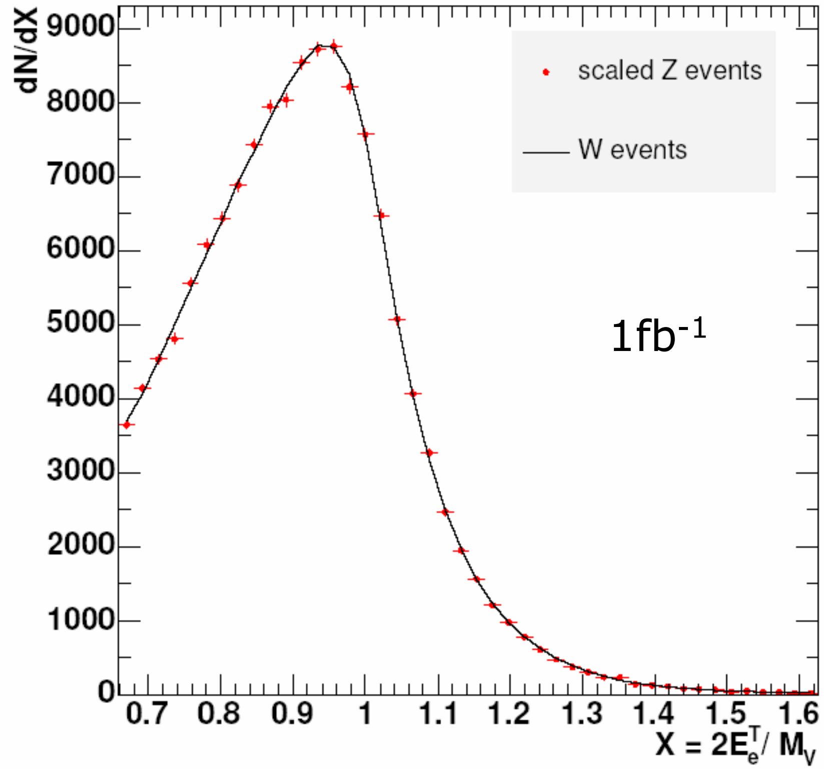
Gaps of SuperModules excluded: ε ~ 58%

Gaps of SuperModules included: ε ~ 57%

- **Relative efficiency correction $\Delta\varepsilon_{corr.}$ ~ 2%**
- **→ systematic error can be controlled by cutting on fiducial volume**

W mass from W→electron

- Idea: Predict $\frac{d\sigma_W}{dp_T}$ from $\frac{d\sigma_Z}{dp_T}$ using theoretical calculations and the W mass (which is fitted)
- Dominant error for 10fb^{-1}: QCD scale uncertainties (30 MeV)
- Can be improved by more precise theoretical calculations



W mass from W→electron

Source of uncertainty	Contribution to Δm_W [MeV]
statistics	40
Background (10%)	10
Electron energy scale (0.25%)	10
Scale linearity	30
Energy resolution (8%)	5
Missing E_T scale (2%)	15
Missing E_T resolution (5%)	9
Recoil system	15
PDF uncertainties	20
Γ_W	15
p_T	30
Quadratic sum systematic	56
Quadratic sum all	69

numbers for $1fb^{-1}$

WZ/ZZ to electrons

numbers for $1fb^{-1}$

- WZ selection

Source of uncertainty	Contribution to $\Delta\sigma$ (%)
Luminosity (inkl. PDF)	10.0
Trigger efficiency	1.0
Electron identification	2.6
Muon identification	3.4
Jet energy scale	5.0
$Z^0 b\bar{b}$ subtraction	12.0
$Z^0Z^0 \rightarrow \ell\ell\ell\ell$ subtraction	4.0
Total uncertainty	17.4
PDF uncertainty only	+3.9/-3.5

- ZZ selection: total cross section uncertainty 12.9%

tt dileptonic

- low efficiency (5%), high purity (S/B=5.5) selection
- using a likelihood for electron identification
- total cross section uncertainty (electrons and muons channels) for $10fb^{-1}$:

11% (syst)±0.9% (stat) ±3% (lumi)

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tt dileptonic

Source of uncertainty	Contribution to $\Delta\sigma$ (%)
Statistics	0.9
Jet energy scale	3.6
B-tag efficiency	3.8
Lepton reconstruction	1.6
Missing E_T	1.1
ISR and FSR	2.5
Pileup	3.6
Underlying event	4.1
Heavy quark fragmentation	5.1
PDF uncertainties	5.2
Total systematic	11
Luminosity	3

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Top mass from tt dileptonic

- Uses the following kinematic constraints:
  - W mass (2 equations)
  - transverse momentum conservation (2 equations)
  - top mass constraints (2 equations)
- six neutrino momenta and top mass unknown (7 unknowns in total)
- Can be combined into a fourth order polynomial in one of the neutrino components
- Scan over top masses between 100 and 300 GeV
  $\rightarrow$ for each top mass there are up to four solutions
- For each mass, count the number of events for which there is at least one real solution
- Caveat: Bias of 3.5 GeV, however seems to be constant as function of the generated top mass

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Top mass from tt dileptonic

- Main sources of systematic uncertainties on top mass:
  - approximations in the kinematic fit
  - detector effects
- Sources considered:

Source of uncertainty	Contribution uncertainty on m_{top} [GeV]
Initial/final state radiation (transverse momentum of tt system)	Shift of 0.3
Zero width approximations	Shift of 0.1
Jet energy scale after $10fb^{-1}$	1

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Summary

- Various analyses (using electrons) looked at various sources of systematic uncertainties

  Would be interesting if the analyses now include the 'other' sources...

- pp Luminosity uncertainty often taken as ~ 3% for $10fb^{-1}$
- effect of PDF uncertainties: 5-10%
- effect of electron efficiency uncertainty: < 3% in the examples presented here