Electron Identification

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Overview

I. Physics motivation

II. Physics of electron detection

III. ID variables used by E/Gamma POG

IV. Rejecting fakes

V. CMS2

Physics motivation

- What are electrons useful for? What physics can they help us learn about?
  - Very clean – can be reco'd with high precision/resolution
  - Appear in decays of Zs, Ws
    - Useful in $H \to ZZ$ and $H \to WW$ searches
    - Precision measurements of standard model physics processes (e.g. our Z cross-section measurement)
    - Electrons from Ws from top decay are an important part of my signal in AFB analysis
  - Could appear in decays of new particles (Z', t', SUSY particles, ...)

Physics of electron detection

- Electrons lose energy exponentially as they pass through material
  - Radiation length X_0: distance to lose all but 1/e of initial energy.
- Transverse spread of energy governed by Molier radius R_M
  - 99% of energy deposited in 3 R_M
- Thick layers of material will absorb lots of energy from a moving electron, and slow it down.
- Thin layers of material will absorb small blips of energy without slowing particle down.
- ECAL made of lead-tungstate crystals ($PbWO_4$), crystals are ~25 X_0 long * $1R_M$ * $1R_M$ cross section.
  - Amount of scintillation light induced in crystals tells us energy of a particle
- Tracker made of thin layers of silicon
  - Read out small energy deposits in tracker to ascertain successive positions of particle.

Physics of electron detection

- How do electrons interact with our detector?
  - Deposit nearly 100% of energy in $PbWO_4$ crystals in ECAL
    - Should deposit little to no energy in HCAL
  - Due to brem and conversion, electron energy deposits in ECAL are smeared in phi. Create “superclusters” of energy deposits.
  - They're charged particles, so they leave hits in our silicon tracker, hits can be fit to make a track.
  - Bend in magnetic field, so tracks are curved
- Information we have to work with: ECAL position, ECAL energy, tracker position (trajectory), tracker momentum
  - These are the main measurements used in electron ID (can get some info from other detector subsystems too...)
  - Can arrange this information into a bunch of variables, whose values help us identify electrons and reject fakes.

ID variables

- Fiduciality: $|\eta|$
  - Need your electron to hit the detector in a place with good instrument coverage.
  - The gap between barrel and endcap has reduced efficiency and resolution, so one might wish to ignore electron candidates in that eta range.
- $\sigma_{i\eta i\eta}$
  - Definition is complicated. See: https://indico.cern.ch/event/27560/contribution/1
  - Cuts on the fact that electrons should deposit most of their energy in just 2 crystals in η.
  - Common alternative: E^{2x5} / E^{5x5}.
  - Related variable, $\sigma_{i\varphi i\varphi}$, exists – similar idea, but in φ-direction.
- $\Delta\eta_{in} / \Delta\varphi_{in}$
  - Defined as $|\eta_{SC} - \eta_{track}|$ and $|\varphi_{SC} - \varphi_{track}|$
  - Measurement of how well aligned a supercluster and its associated track are
- H/E
  - Hadronic energy in HCAL tower behind seed cluster, divided by energy of ECAL seed cluster
  - Helps tell us if there were hadronic objects in the vicinity of electron candidate.

ID variables

Samples:
Z → ee
W → ev
QCD di-jet
photon+jets

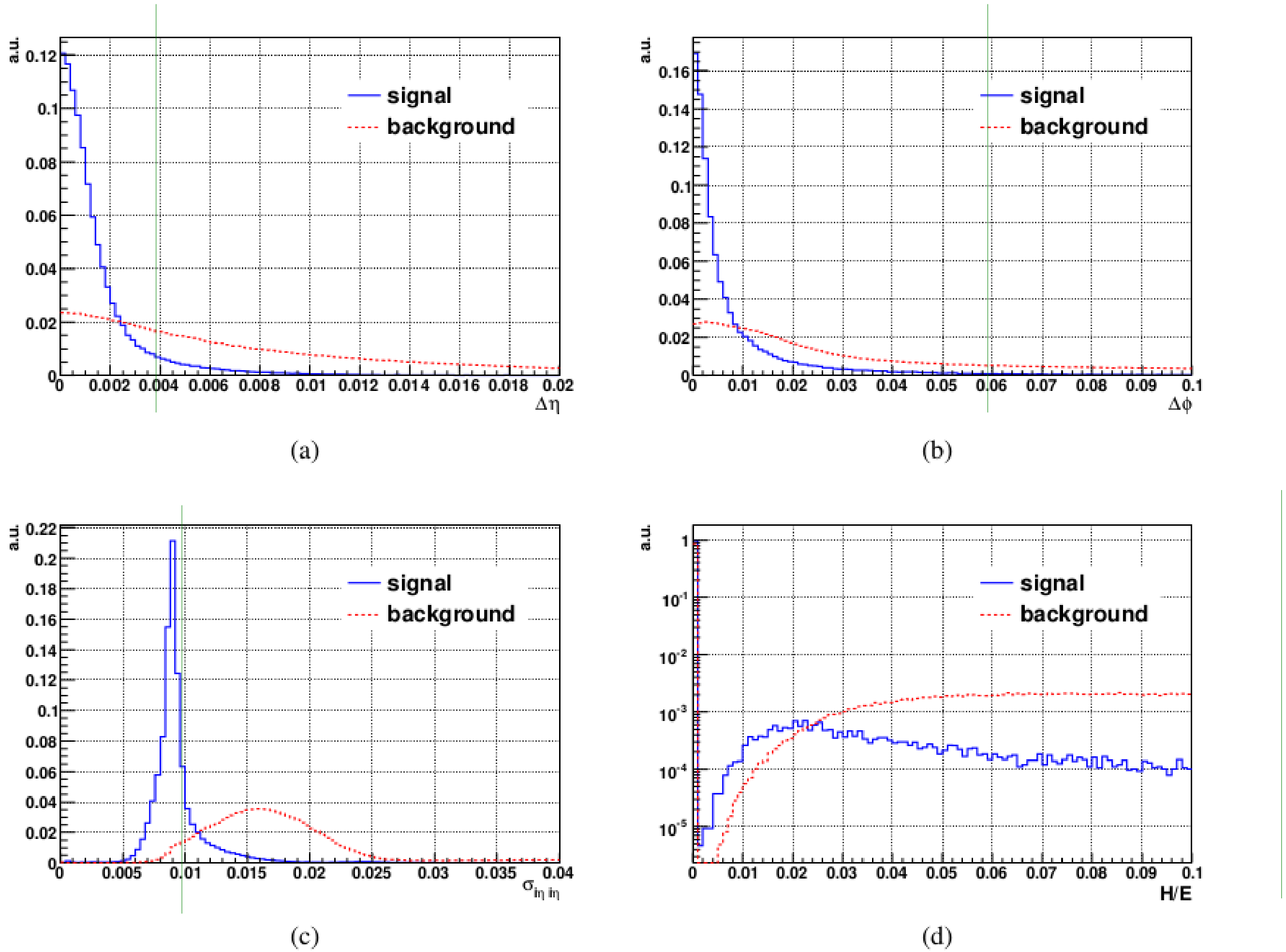

Figure 2: Distribution of the variables used in Fixed Threshold selection in the barrel: (a) $\Delta\eta_{\rm in}$, (b) $\Delta\phi_{\rm in}$, (c) $\sigma_{i\eta i\eta}$, (d) H/E. Signal and backgorund distributions are normalized to unity.

Source: AN 2009/178

ID variables

- 1/E – 1/p
  - What it sounds like: 1/energy (supercluster) – 1/momentum
  - Helps you tell whether ECAL energy and tracker momentum make sense together
- d0/dz
  - Transverse/longitudinal impact parameter from track to primary vertex
  - Prompt electrons should originate very close to the PV
- Missing hits
  - Count how many silicon layers in the track trajectory don't have hits
  - Prompt electrons should have few to no missing hits

How do we tell electrons apart from fakes?

- Photons
  - No tracks in tracker
  - ECAL deposits different shape ($\sigma_{i\eta i\eta}$)
- Electrons from jets
  - Will have nontrivial HCAL deposits lined up with ECAL cluster (H/E)
- Electrons from conversion
  - Have much larger D0, DZ values w/rt PV
  - Tend to have a few missing hits in the tracker
  - May be able to detect conversion partner
- Overlapping objects
  - Isolation... (not my topic)

Cut-based ID

Barrel Cuts (|eta supercluster| <= 1.479)

	Veto	Loose	Medium	Tight
fabs(dEtaIn) <	0.007	0.007	0.004	0.004
fabs(dPhiIn) <	0.8	0.15	0.06	0.03
sigmaIEtaIEta <	0.01	0.01	0.01	0.01
H/E <	0.15	0.12	0.12	0.12
fabs(d0) (vtx) <	0.04	0.02	0.02	0.02
fabs(dZ) (vtx) <	0.2	0.2	0.1	0.1
fabs(1/E - 1/p) <	N/A	0.05	0.05	0.05
PF isolation / pT (cone dR=0.3) <	0.15	0.15	0.15	0.10
Conversion rejection: vertex fit probability	N/A	1e-6	1e-6	1e-6
Conversion rejection: missing hits	N/A	1	1	0

Endcap Cuts (1.479 < |eta supercluster| < 2.5)

pT > 20 (pT < 20)	Veto	Loose	Medium	Tight
fabs(dEtaIn) <	0.01	0.009	0.007	0.005
fabs(dPhiIn) <	0.7	0.10	0.03	0.02
sigmaIEtaIEta <	0.03	0.03	0.03	0.03
H/E <	N/A	0.10	0.10	0.10
fabs(d0) (vtx) <	0.04	0.02	0.02	0.02
fabs(dZ) (vtx) <	0.2	0.2	0.1	0.1
fabs(1/E - 1/p) <	N/A	0.05	0.05	0.05
PF isolation / pT (cone dR=0.3) <	0.15	0.15(0.10)	0.15(0.10)	0.10(0.07)
Conversion rejection: vertex fit probability	N/A	1e-6	1e-6	1e-6
Conversion rejection: missing hits	N/A	1	1	0

Source: E/gamma POG TWiki

- Electron ID subgroup defines 4 standard working points (varying tightness of requirements)
  - Our Z cross-section AN uses medium working point
- Subgroup also has an MVA-based ID procedure (won't discuss here).
  - Let a computer optimize the selections for your particular needs

CMS2

- Most of the variables used in electron ID have their own branches in CMS2. Makes it easier to define your own ID criteria. E.g.:
  - els_dPhiIn
  - els_dPhiOut
  - els_d0
  - els_hOverE
  - els_sigmaIEtaIEta
  - els_lostHits

Summary

- Electrons are a clean, high-precision signal, useful in many analyses
- Deposit energy in ECAL, leave tracks in tracker
  - Can measure energy, momentum, ECAL position, tracker position
- We can make a series of cuts on certain variables to ensure electrons are well-reconstructed, and aren't fakes
  - η, $\sigma_{i\eta i\eta}$, $\Delta\eta_{in}$ / $\Delta\varphi_{in}$, H/E, 1/E – 1/p, d0/dz, missing hits