Discrimination between converted photons and π^0s

Giorgos Anagnostou

I. Physikalisches Institut B, RWTH Aachen

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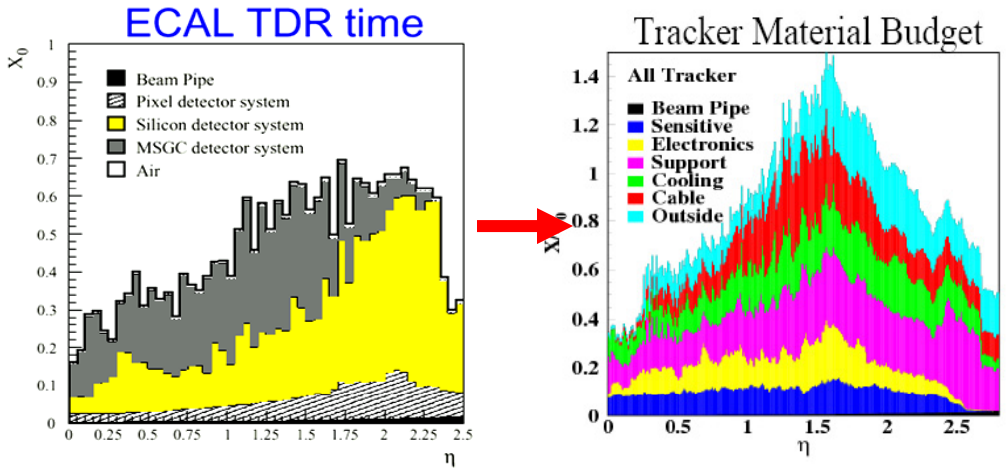
Background rejection for converted photons



- In final states with isolated photons (e.g $h \rightarrow \gamma\gamma$), it is important to reduce the **huge QCD bkg** from neutral pions to levels below the irreducible one.

- For unconverted photons the rejection of neutral pions is based on ECAL **cluster shape methods** (Barrel region) and the use of the preshower (endcaps).

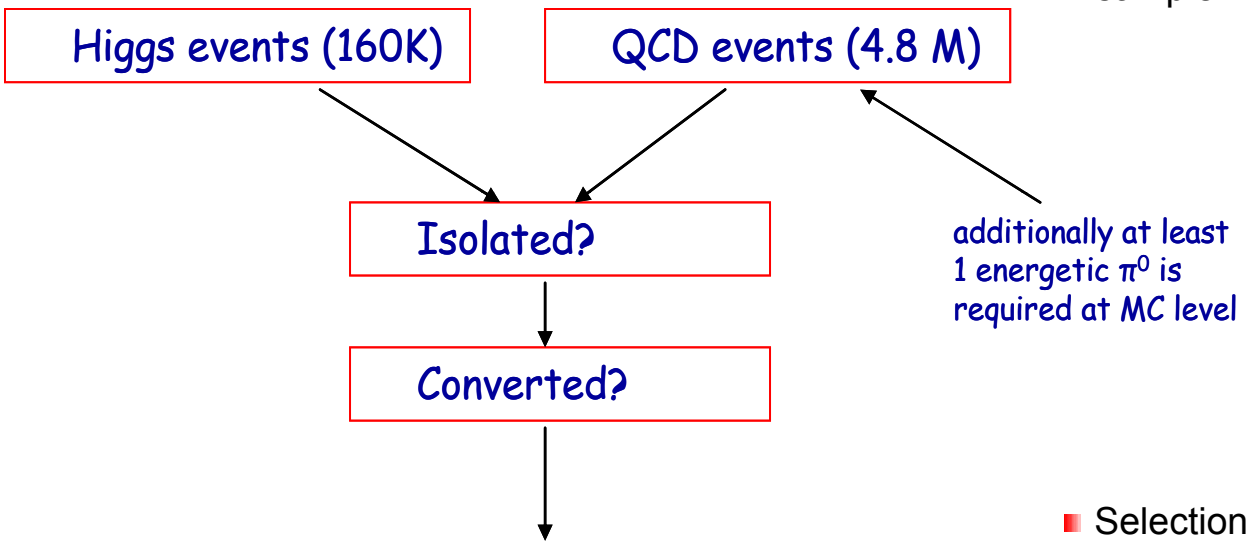
- But what about the **converted photons?**

- In more than half **of the $H \rightarrow \gamma\gamma$ events there is at least one** due to the increased material budget.

- The lateral shape cannot help- both converted signal photons and π^0 **have similar shape**.

Samples used for neutral pions & photons

- ORCA study, **CMS IN 2007/032**
- Using **realistic events**: for signal photons from H→γγ (gluon fusion με m_h=120 GeV) and for π^0 the γ-jet QCD sample with pile-up.

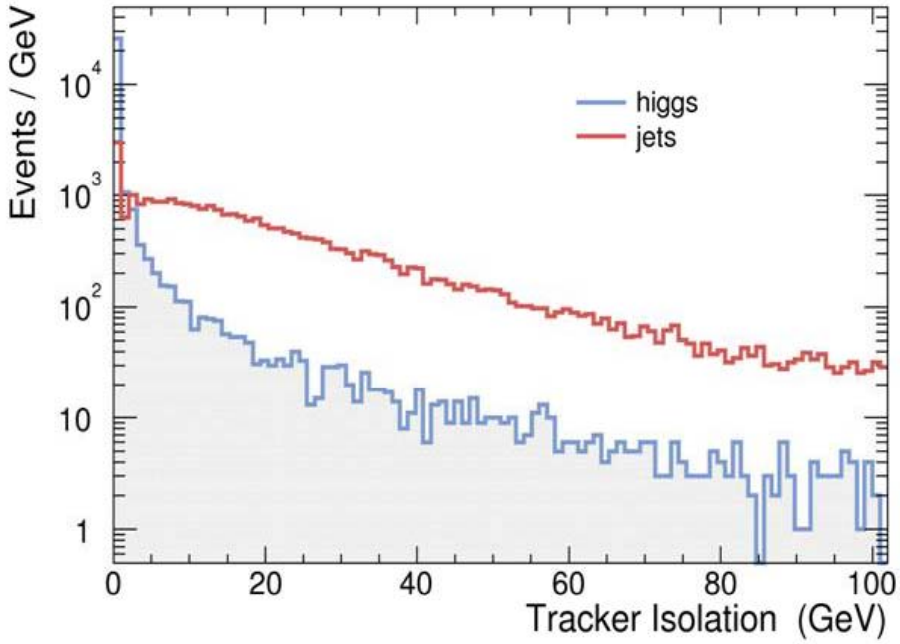


- Selection of **isolated photons** from all photon candidates
- **Conversion identification** as next step.

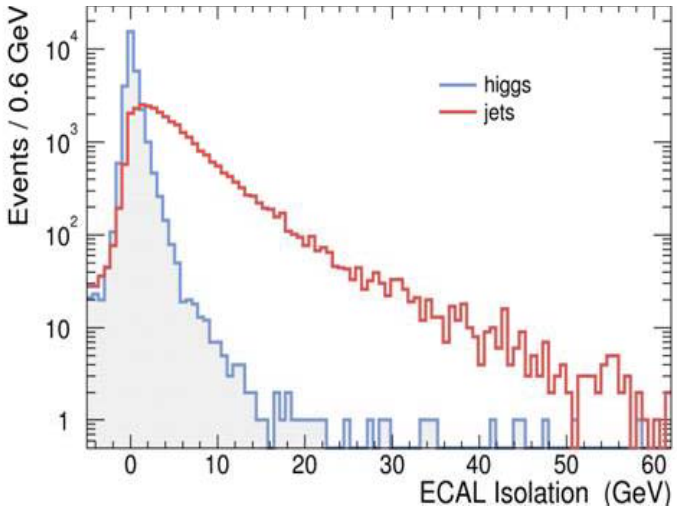
Isolation – tracker

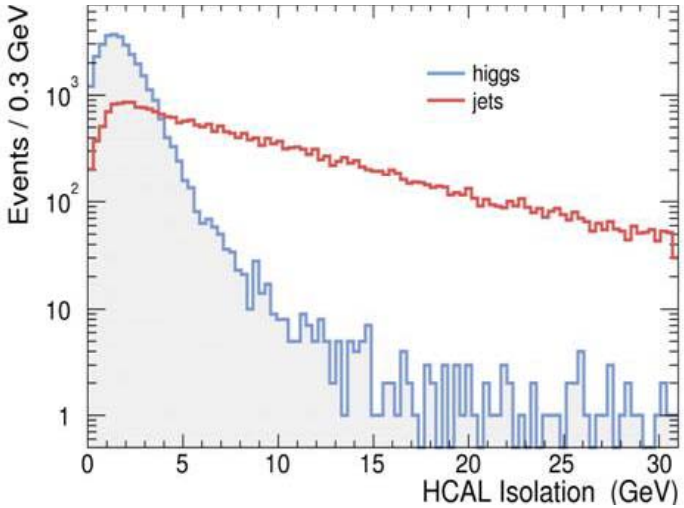
- Isolation must take place in **3 detectors**: Tracker, ECAL, HCAL.

- For the **tracker** all tracks with P_T>1.5 GeV in a cone ΔR=0.3 must have $\sum p_T$ < 3 GeV.



Isolation – tracker, calorimeters

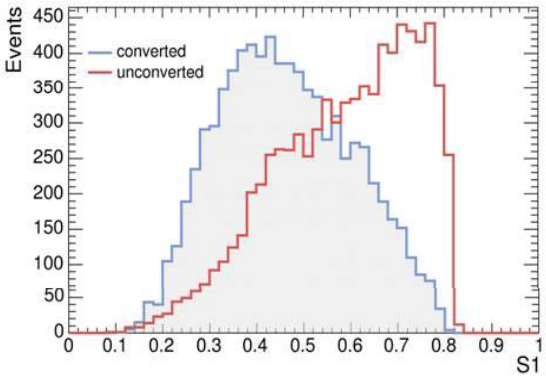


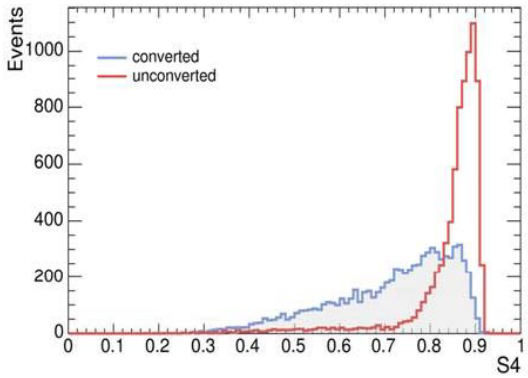


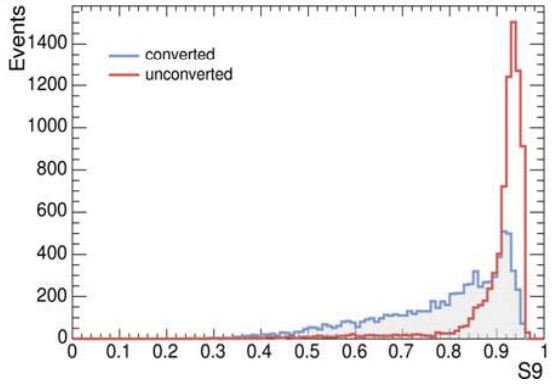
- For the **E/M calorimeter** the E_T of all clusters in a cone of 0.35 should be less 2 GeV.

- For the **Hadronic calorimeter** all towers with E>0.5 GeV in a cone (0.3) must have $\sum E_T$<4GeV.

Conversion identification– ECAL

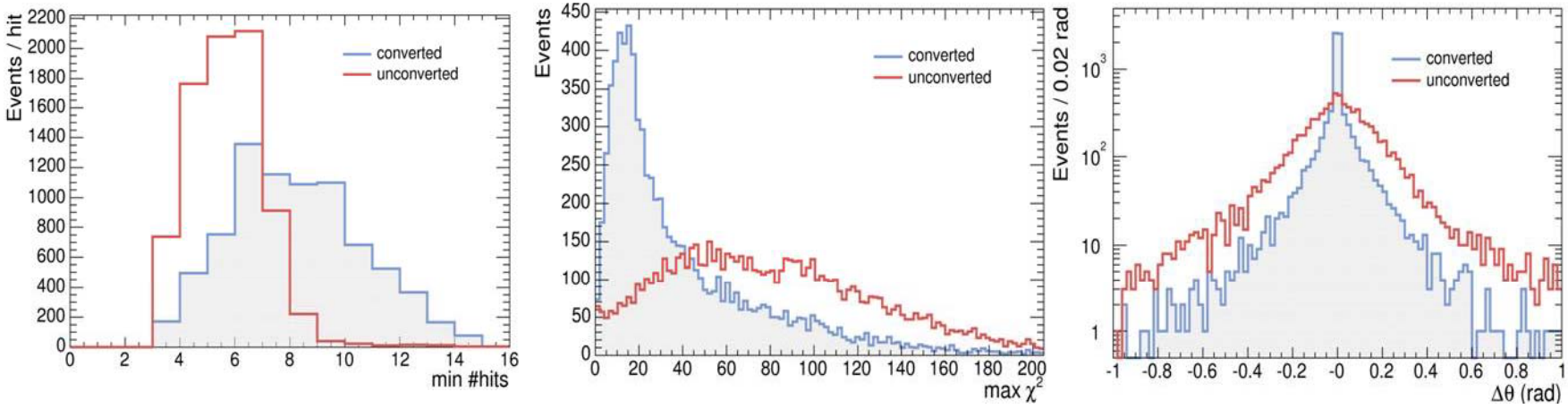






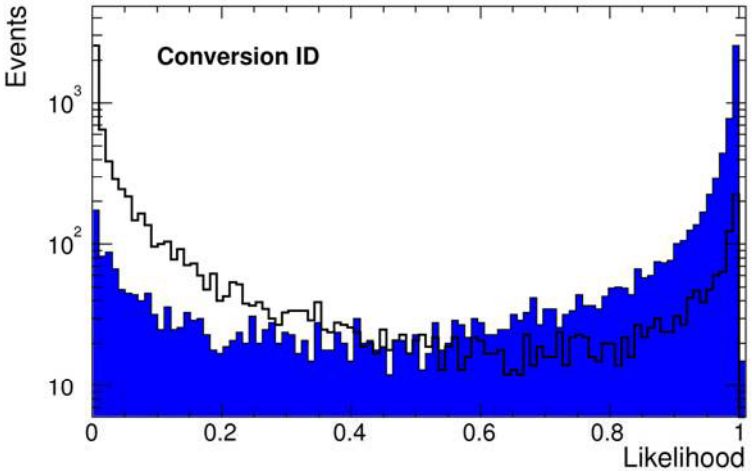
- For conversion identification with the Ecal the fraction of energy of the photon candidate in N crystals (S_N, N=1,4,9) can be used.

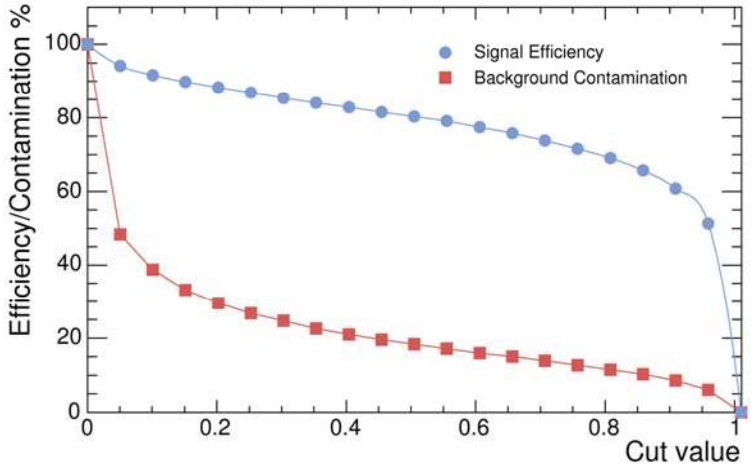
Conversion identification – Tracker



- Track quality recontruction observables can suppress the fakes (min#hits,maxChi2 & the angle between the 2 tracks in the r,z plane.

Conversion ID - likelihood





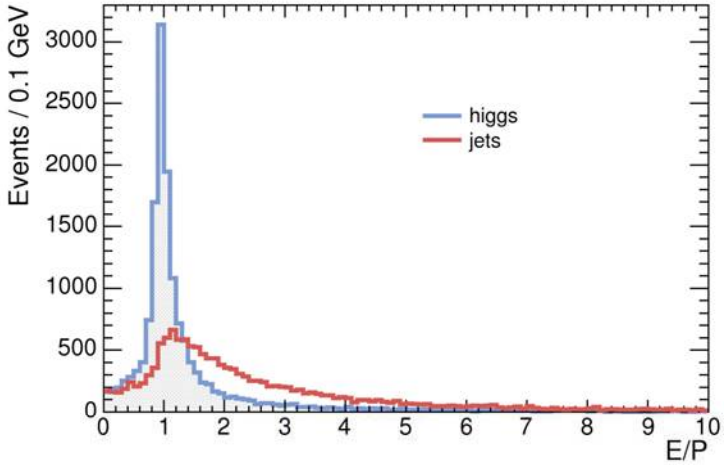
$$\mathcal{L} = \frac{\mathrm{P_i(signal)}}{\mathrm{P_i(signal) + P_i(background)}}$$

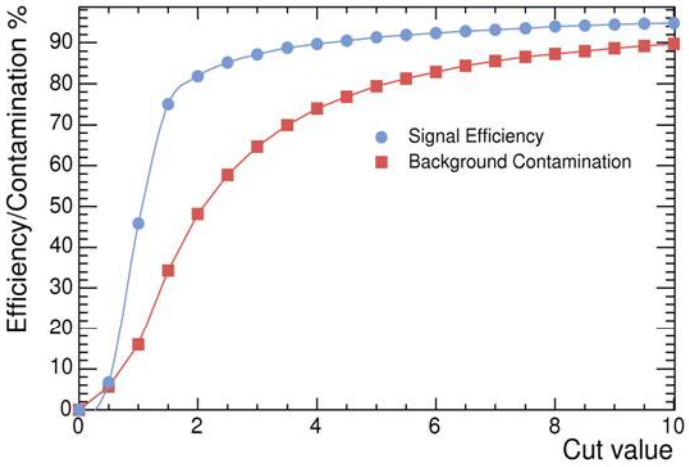
- fake tracks are ~5% - set the cut to supress them to ~1% keeping high signal efficiency (~90%).
- Combination of info from 2 detectors increase performance of the identification.

The problem with E/P

- Now we have a sample **of isolated converted photon candidates**. How can we distinguish the signal photons from isolated π^0 inside jets?

- π^0 do have an **extra photon**.- Energy in ECAL is usually larger the tracker momentum (E/P).





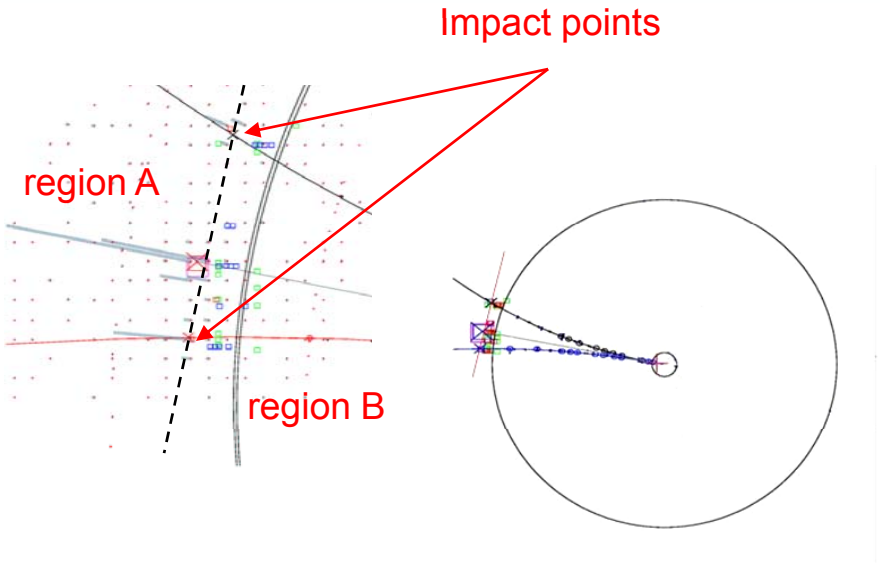
- The E/P ratio can be used to distinguish the $\gamma/\pi^0\varsigma$. Rejection ~28% for a signal efficiency 90%.

- Conversions in large tracker radius have small number of hits $\rightarrow$ **bad momentum measurement**.

finding the e^+,e^-,γ in the ECAL surface

- How a π^0 with conversion looks like? Can we find **the physics objects in the ECAL surface**?

- Extrapolating the e^+,e^- tracks to find the impact points in the ECAL surface.

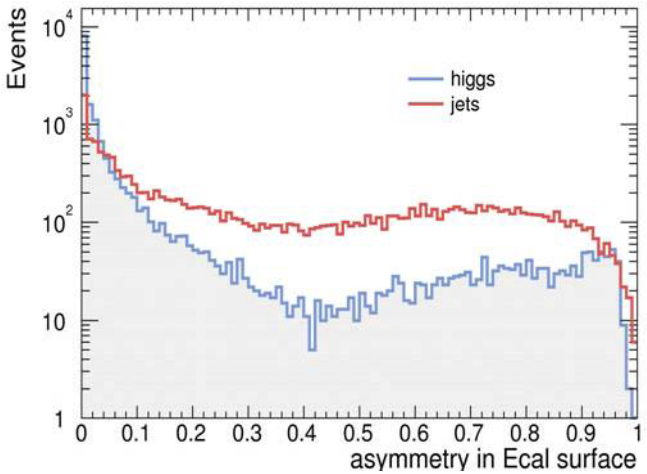


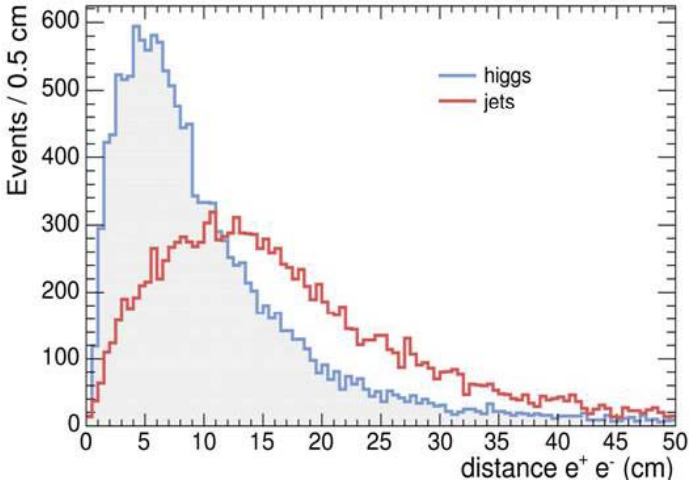
$$\text{Asymmetry} = \sum_{\text{regionA}} E_{\text{clusters}} - \sum_{\text{regionB}} E_{\text{clusters}}) / E_{\gamma}$$

- The impact points defines a **line in the η,φ plane**.

- The line divides the surface into two **regions**. For an event originating from a π^0 only one of these two regions contains an **extra** photon.

π^0 rejection - observables

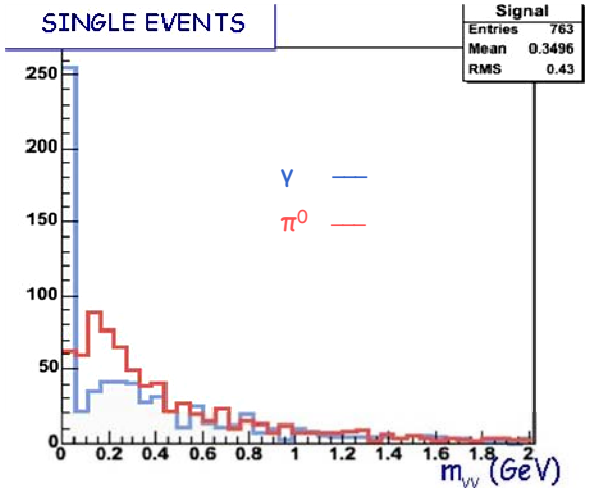


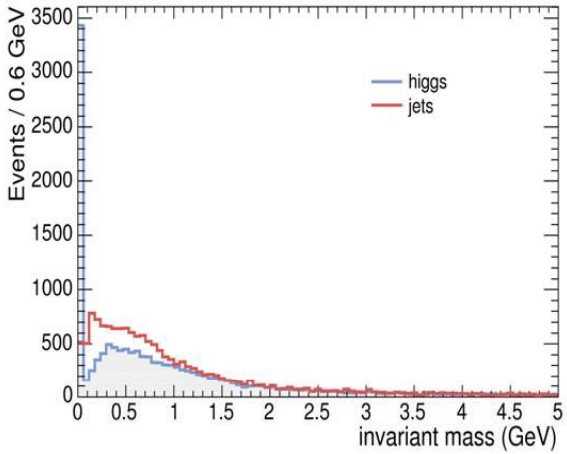


- The asymmetry in the Ecal surface is a powerful variable which is not depending on the quality of the momentum measurement.
- Even for conversions with few hits remains strong – the only requirement is to find the impact points in the Ecal.

π^0 mass reconstruction

- **Recontstruction** of the 2 photons: converted and unconverted.
- The converted photon vector already known from the **tracks**.
- For the unconverted we can search **for the most energetic cluster** in a cone around the photon candidate.

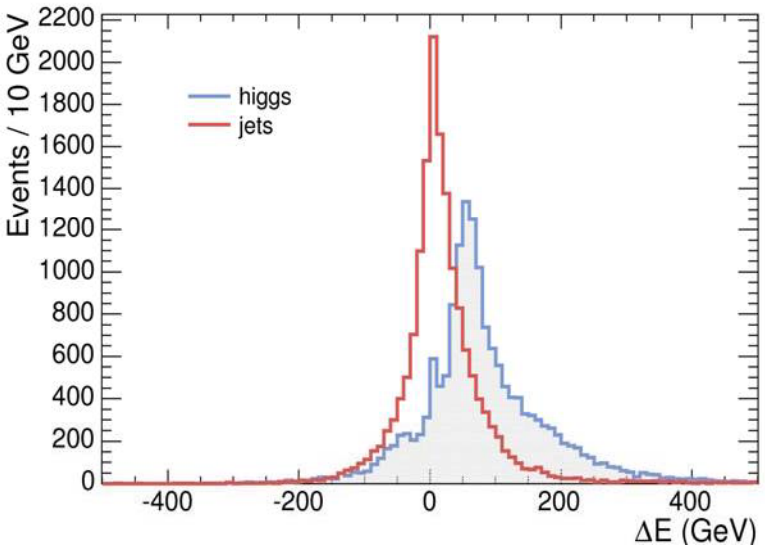


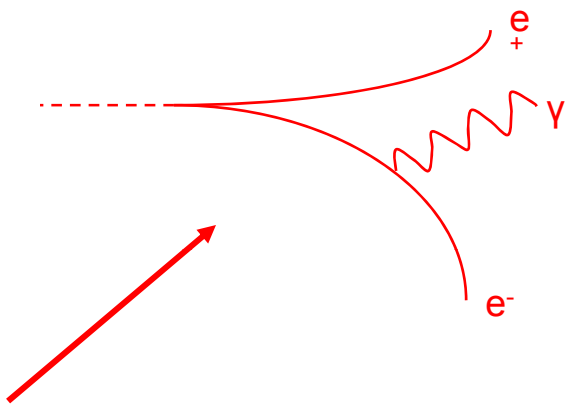


If there is no other cluster in the cone but those of electron- positron then:

- **Subtract** from the vector sum of the 2 photons (cluster in Ecal) the vector of the converted one (known from tracks).

ΔE between converted & unconverted photon

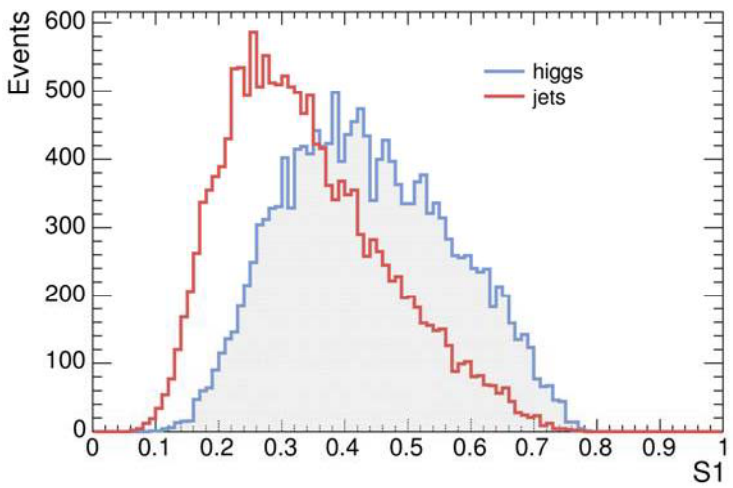


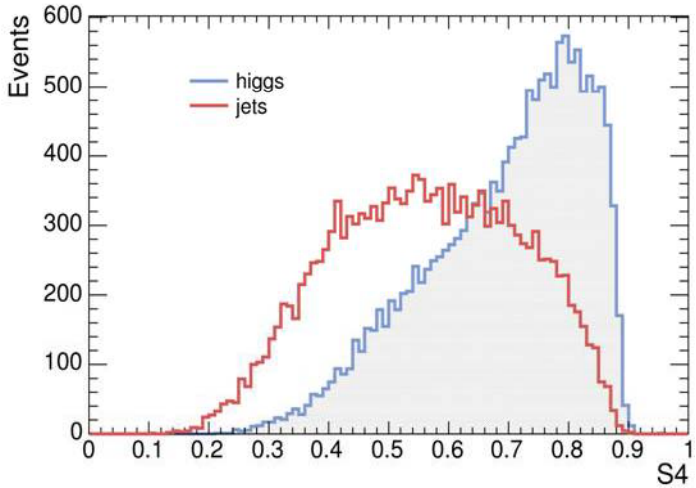


- For signal photons an extra non converted photon originates from **brem**. In this case, the unconverted photon can have energy only a **fraction of the energy of the converted**.

- The diff erence Econv-Eunconv must be positive. For neutral pions there is no such constraint. Difference **symmetrically distributed**.

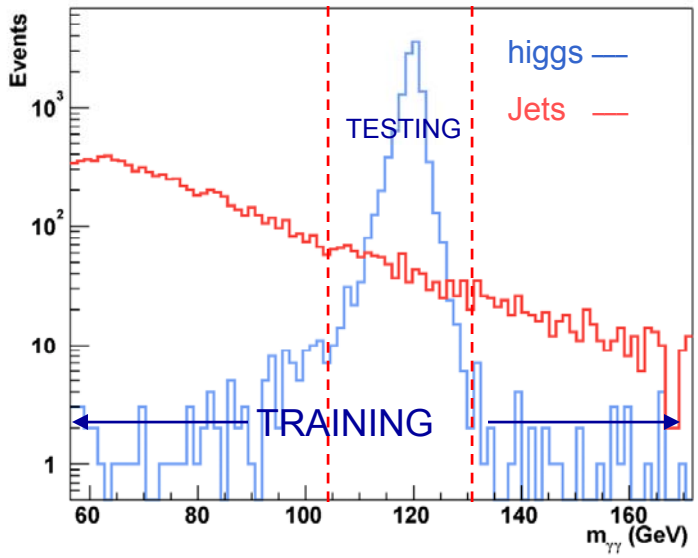
Shower shape – Can it help;





- S1, S4 can be used but have reduced discriminating power. Their impact on the final result small.

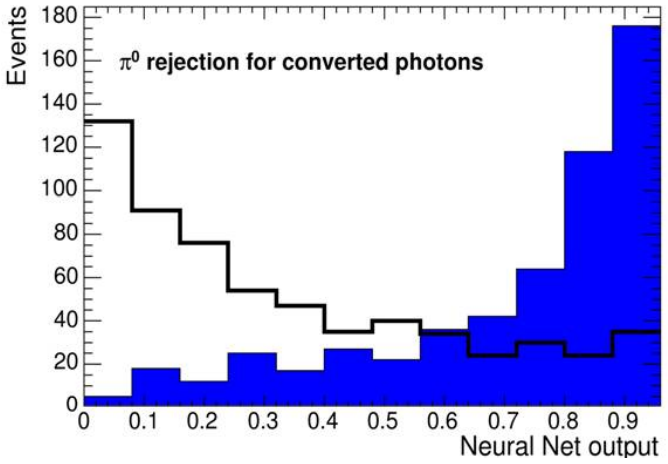
Combination of the variables with a neural net.

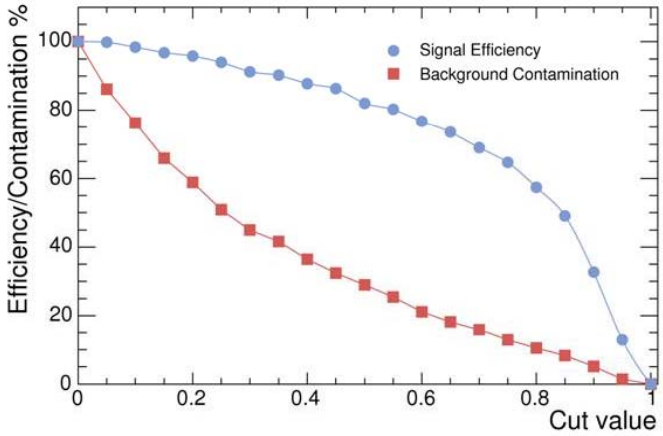


- The observables combined with a **neural net**.
- Used E/P, asymmetry in ECAL, distance between e^+e, $m_{\gamma\gamma}$ & S4.
- training with 2/3 of the events **in the whole diphoton invariant mass range**.

From the rest only those with $105 < m_{\gamma\gamma} < 135$ GeV used for testing so that it is **a realistic comparison** and the selection of photon candidates **is identical** with the CMS Physics TDR analysis.

Rejection of π^0 bkg - Results



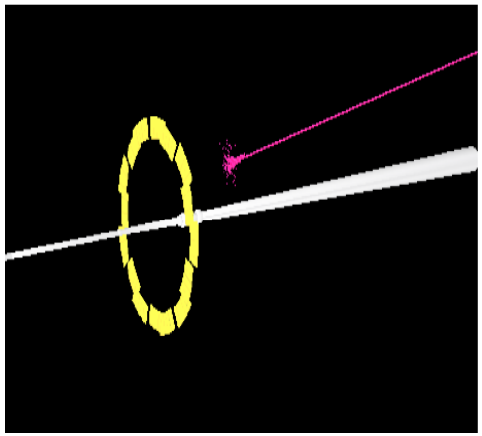


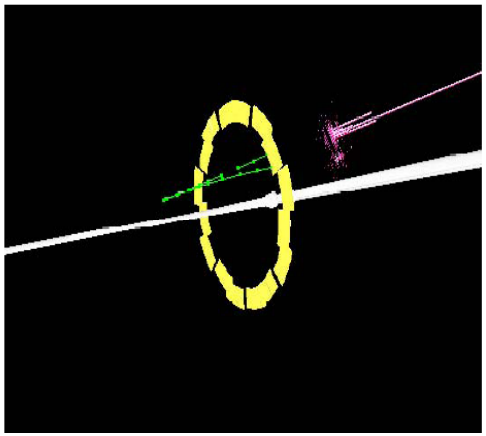
Rejection ~57% for efficiency 90%.

- Method based on finding the **physics objects** (e^+,e^-,γ) and **geometric characteristics** of the converted π^0.
- Initially **conversion identification** with variables from the tracker & Ecal using likelihood.
- rejection of π^0 with: asymmetry Ecal surface, distance e^-e^+, $m_{\gamma\gamma}$, E/P & shower shape.
- training with events in the whole $m_{\gamma\gamma}$ range, testing around Higgs peak.

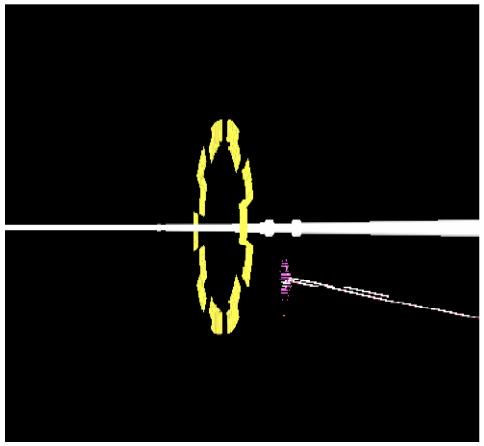
Back-up slides

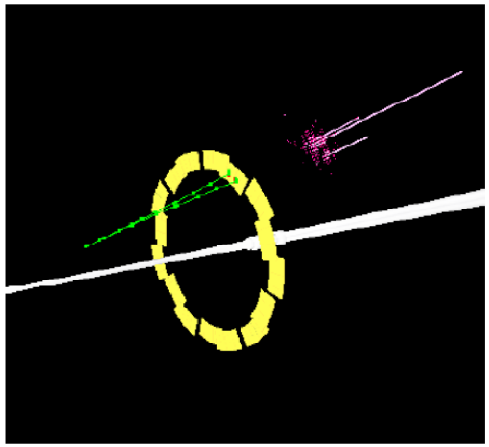
Pions & photon events





Photons with E_T=20 GeV





π^0 with E_T=20 GeV