Estimation of electron-to-photon misidentification rate in Z(νν)γ measurements for conditions of ATLAS experiment during Run II

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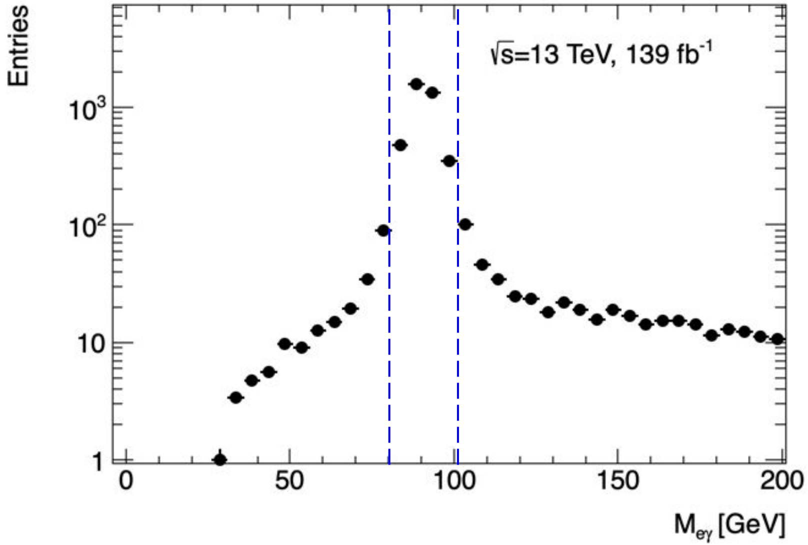
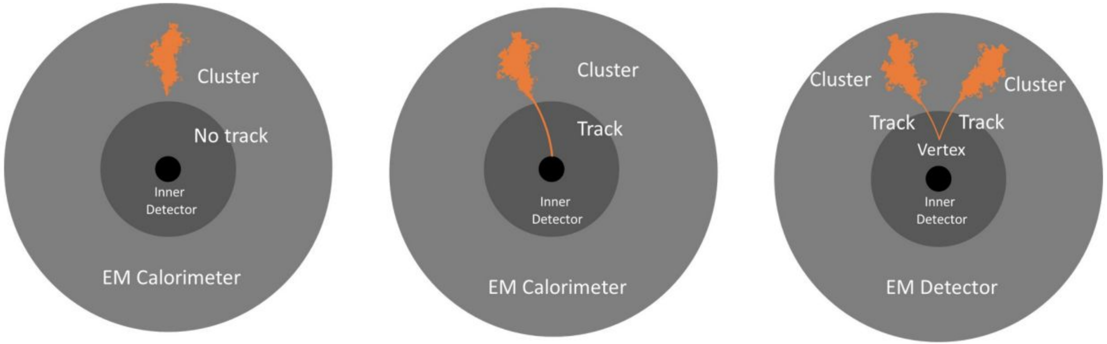
Introduction

- Z-peak tag-n-probe method was widely used for estimation of electron-to-photon misidentification rate for photon-oriented studies in Run I and in early Run II pp-collisions data at LHC.
- It is based on the assumption that reconstructed photons, those invariant mass together with reconstructed electron or positron lies in range of Z-boson mass peak, is in fact an electron/positron which was misidentified as photon.





source link Photon Electron Photon Conversion

Mostly an electron is mistaken as a converted photon if there are two matching electron tracks in the ATLAS Inner Detector. Also it may happen if the track of electron is not reconstructed in ID.

Estimation of e→γ misidentification

Background estimation method:

1. estimating e→γ fake-rate as $rate_{e\to\gamma} = \frac{(N_{e\gamma} - N_{bkg})}{(N_{ee} - N_{bkg})}$,

   where $N_{e\gamma}$, N_{ee} − number of ee and eγ events in Z-peak mass window (M_Z−10 GeV, M_Z+10 GeV)

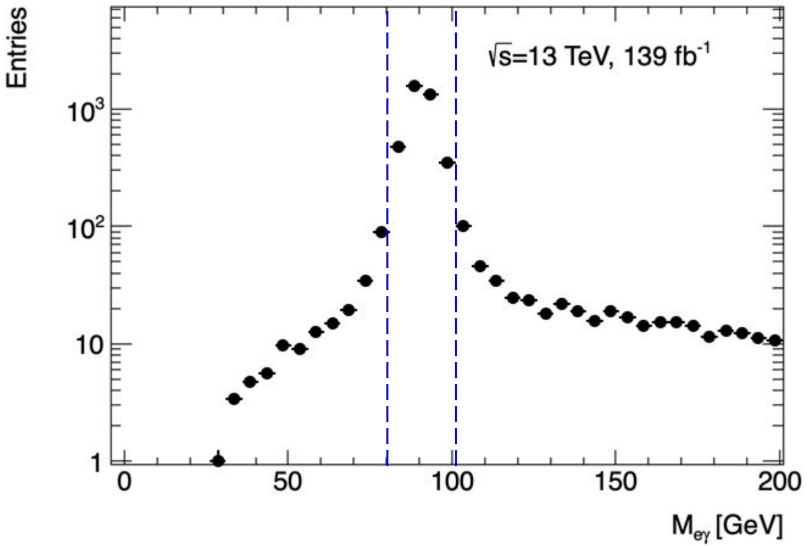
   eγ pair selection:
   signal region photon with p_T>150 GeV (probe),
   selected electron with p_T>25 GeV (tag)

   ee pair selection:
   selected electron with p_T>150 GeV (probe),
   selected opposite sign electron with p_T>25 GeV (tag)

2. building e-probe control region (CR) in data:
   signal region region with selected electron with p_T>150 GeV instead of photon

3. scaling data distributions from e-probe CR on fake rate

High-pT photons are used together with 140 GeV trigger in Z(νν)γ measurements in ATLAS

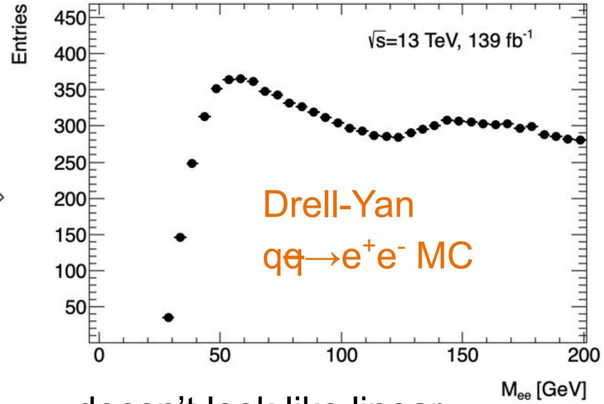


Under Z-peak background

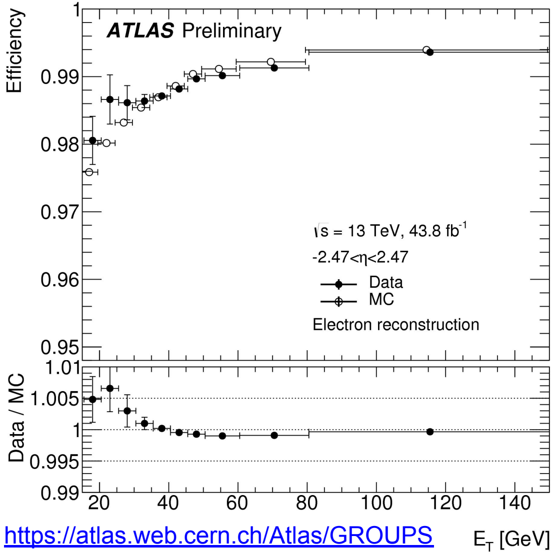
In Run I the background distribution under Z-peak was considered to be linear for simplicity.

This background consists of Drell-Yan production of e^+e^- pairs

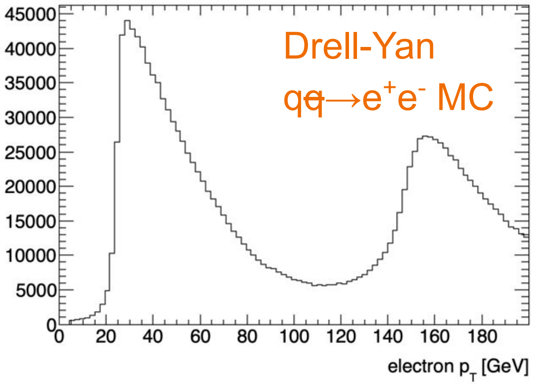
$\sqrt{s}\nearrow$ and $p_T\nearrow$



doesn't look like linear



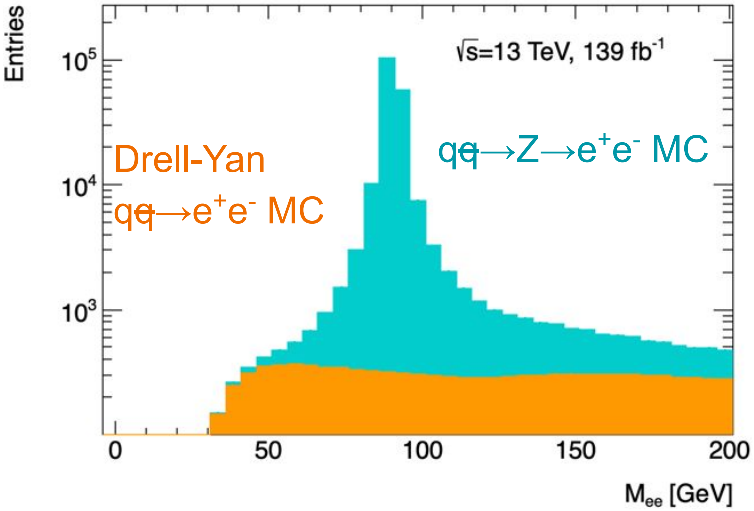
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/EGAM-2018-002/



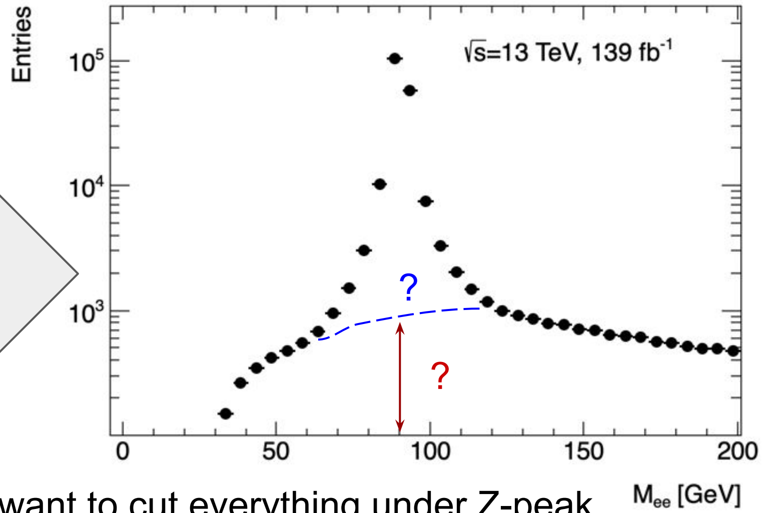
this shape is caused by combination of reconstruction and identification efficiency overlapped with kinematic distribution on electron pT

"threshold effect": leading e pT> 150 GeV, subleading e pT>25 GeV

Under Z-peak background



in data looks like



In data we want to cut everything under Z-peak, since we're sure that Z is in the peak for sure

In this work we consider two ways:

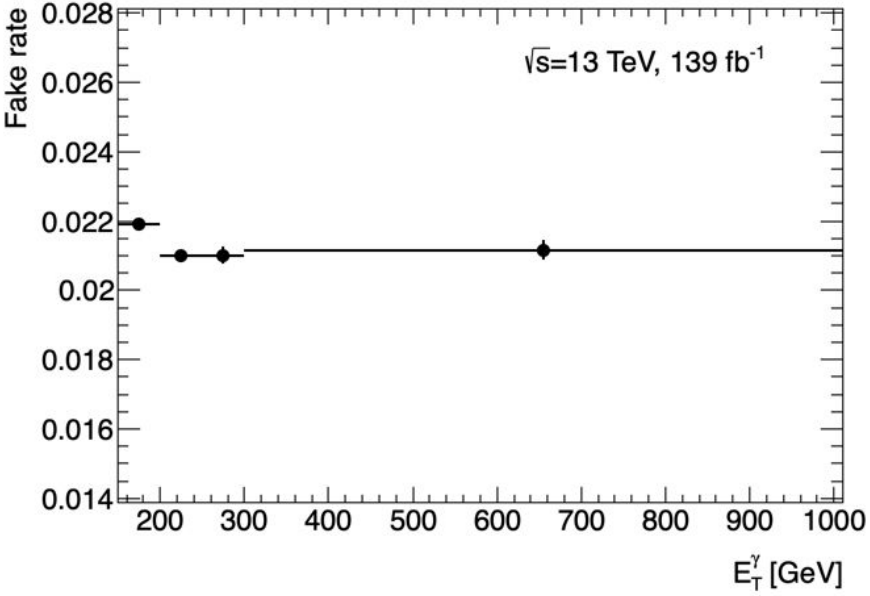
1) fit with exponential polynomial functions, does not include the Z peak
2) fit includes the Z peak, which is described by a Voigtian function

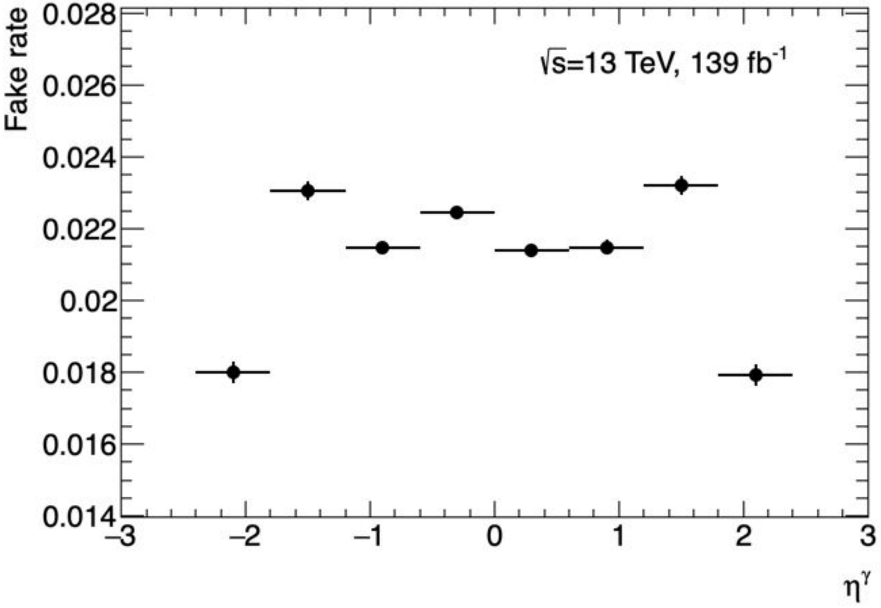
Goal: test both ways and compare

Tools:

➔ `MadGraph5_aMC@NLO` for process generation at $\sqrt{s}$=13 TeV
➔ `Pythia-PGS` for hadronization, simulation and reconstruction in ATLAS

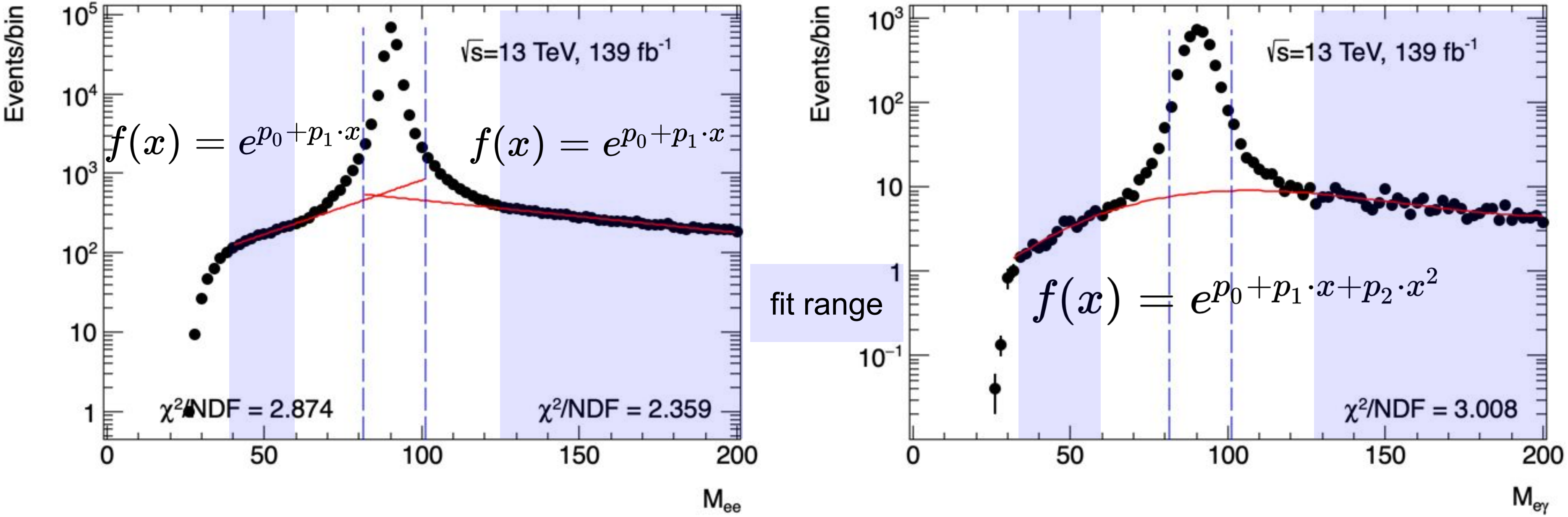
Fake-rate dependence from η and p_T





Fake-rate dependencies are obtained from Zee MC, no background.
They are smother in MC than ordinary observed in data, reason: imperfect detector simulation in pythia-pgs.
Since these dependencies are the same for both methods the calculation is made without division on η and p_T regions for simplicity of comparison.

Exponential polynomial fit I



Background fit is extrapolated to Z peak mass window from both sides. Integrals under the fit function is this region give N_{min} and N_{max}

Background fit is extrapolated to Z peak mass window after the fit. Integral of extrapolated function in Z peak mass window is used as $N_{e\gamma}^{bkg}$

Average used as N_{ee}^{bkg} in fake-rate calculation: $N_{average}^{bkg} = \frac{N_{min}^{bkg} + N_{min}^{bkg}}{2}$

Exponential polynomial fit II

Systematics on bkg estimation under the Z peak is evaluated by variation of N^{bkg} values in ee and eγ pairs:

- N_{min} and N_{max} values are used as variations of N_{ee}^{bkg}.
- In eγ pairs extrapolation function parameters were varied by their statistical uncertainties one by one. Resulting integral of the function is used for variation of $N_{e\gamma}^{bkg}$.

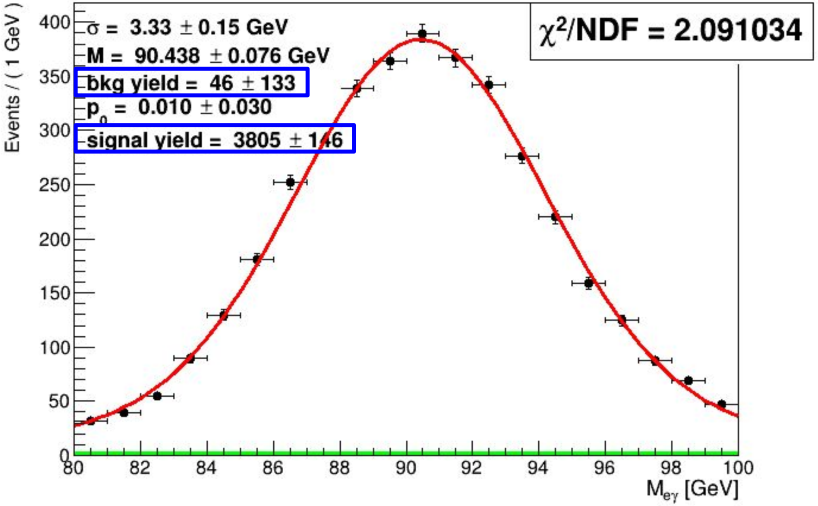
Sum in quadrature of the largest variations of $N^{bkg}_{e\gamma}$ and N^{bkg}_{ee} is taken as systematics.
It counts 1.2%.

Resulting value of $e \to \gamma$ fake-rate **0.0212±0.0004±0.0002**

Voigtian fit I

$$Voigtian(E, M, \Gamma, \sigma) = \int_{-\infty}^{+\infty} Gauss(x, M, \sigma) BreitWigner(E - x, M, \Gamma) dx$$

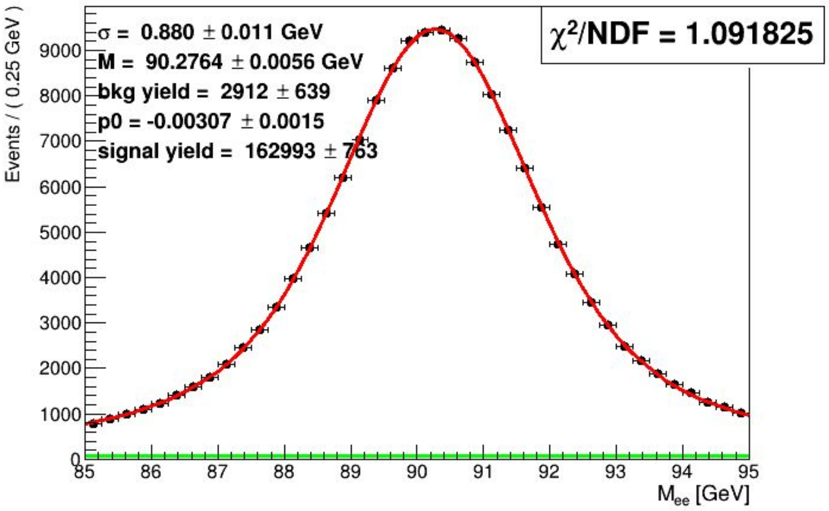
- **Breit Wigner** here describes Z boson decay and **Gauss** describes smearing in the detector.
- Γ - width of Z boson (fixed to 2.4952 GeV to achieve stability of the fit). M, E, σ are free parameters.
- Mass spectra are fitted with the sum of Voigtian, which describes the Z-peak, and linear function $f(x) = 1 + p_0 x$ for the under-Z-peak background.
- The background out of Z-peak range ($M_Z - 10$ GeV, $M_Z + 10$ GeV) is not considered in contrast with the previous method.



$N_{e\gamma}$ - signal yield, $N^{bkg}_{e\gamma}$ - bkg yield

Voigtian fit II

- For ee-pairs the fit was made in range (85,95) GeV and the extrapolated to the full range (80,100) because of the peak asymmetry caused by the threshold effect.
- Systematic uncertainties on resulting N_{ee} and $N_{e\gamma}$ are calculated including fit parameter uncertainties and correlations between parameters as uncertainty on the integral of fit function.
- Resulting systematics on fake rate is estimated as uncertainty on a ratio of N_{ee} and $N_{e\gamma}$.
  it counts 3.9%



Resulting value of e→γ fake-rate

0.0212±0.0003±0.0008

Comparison and conclusion

- Electron to photon misidentification rates are obtained for photons with pT>150 GeV used in Z(νν)γ measurements for conditions of ATLAS experiment during Run II.
- Two methods of background-under-Z-peak subtraction are considered:
    - ➢ e→γ fake-rate with expo-pol. fit **0.0212±0.0004±0.0002, syst. unc. 1.7%**
    - ➢ e→γ fake-rate with Voigtian fit **0.0212±0.0003±0.0008, syst. unc. 3.9%**
- Systematic uncertainty for Voigtian method is at least twice larger, though results have good agreement within uncertainty.
- Looks like more sophisticated Voigtian method of the fit does not improve the result, so for the current pp-collision energy at LHC the exponential method gives satisfactory results for 150 GeV photons reconstructed in ATLAS.

Presumably expo-pol. fit can be used for studies with high-pT photons in ATLAS for Run III data.

Backup slides

Generation parameters

MadGraph5_aMC@NLO, version = 2.7.2

Pythia-PGS 2.4.5, Pythia version 6

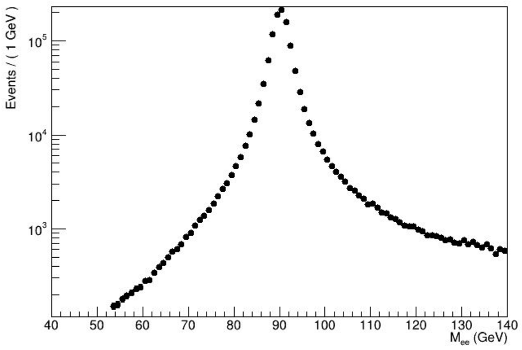
pp - collisions with $\sqrt{s}$=13 TeV

Drell Yan p p > e+ e- j $ z (no Z), N events = 2M, σ=0.07404 ± 0.00016 pb

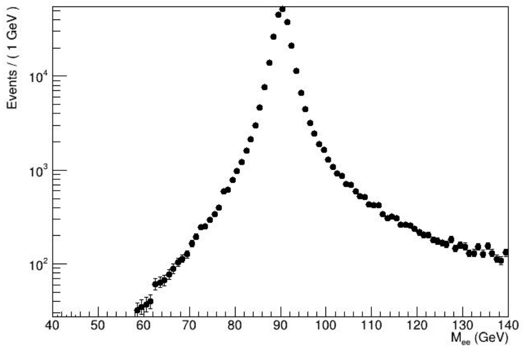
pp->Zj->eej N events = 2M, σ = 1.1920 ± 0.0006 pb

Demonstration of Z-peak asymmetry in dependence of p_T thresholds

p_T(lead) > 25 GeV,
p_T(sublead) > 150 GeV;



p_T(lead) > 50 GeV,
p_T(sublead) > 200 GeV;



p_T(lead) > 75 GeV,
p_T(sublead) > 250 GeV