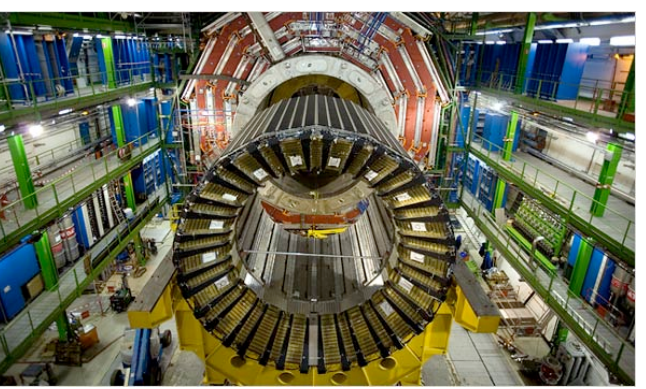


# Measurement of Electron Reconstruction Efficiency for CMS



Kalanand Mishra

Fermi National Accelerator Laboratory, CMS Collaboration

1

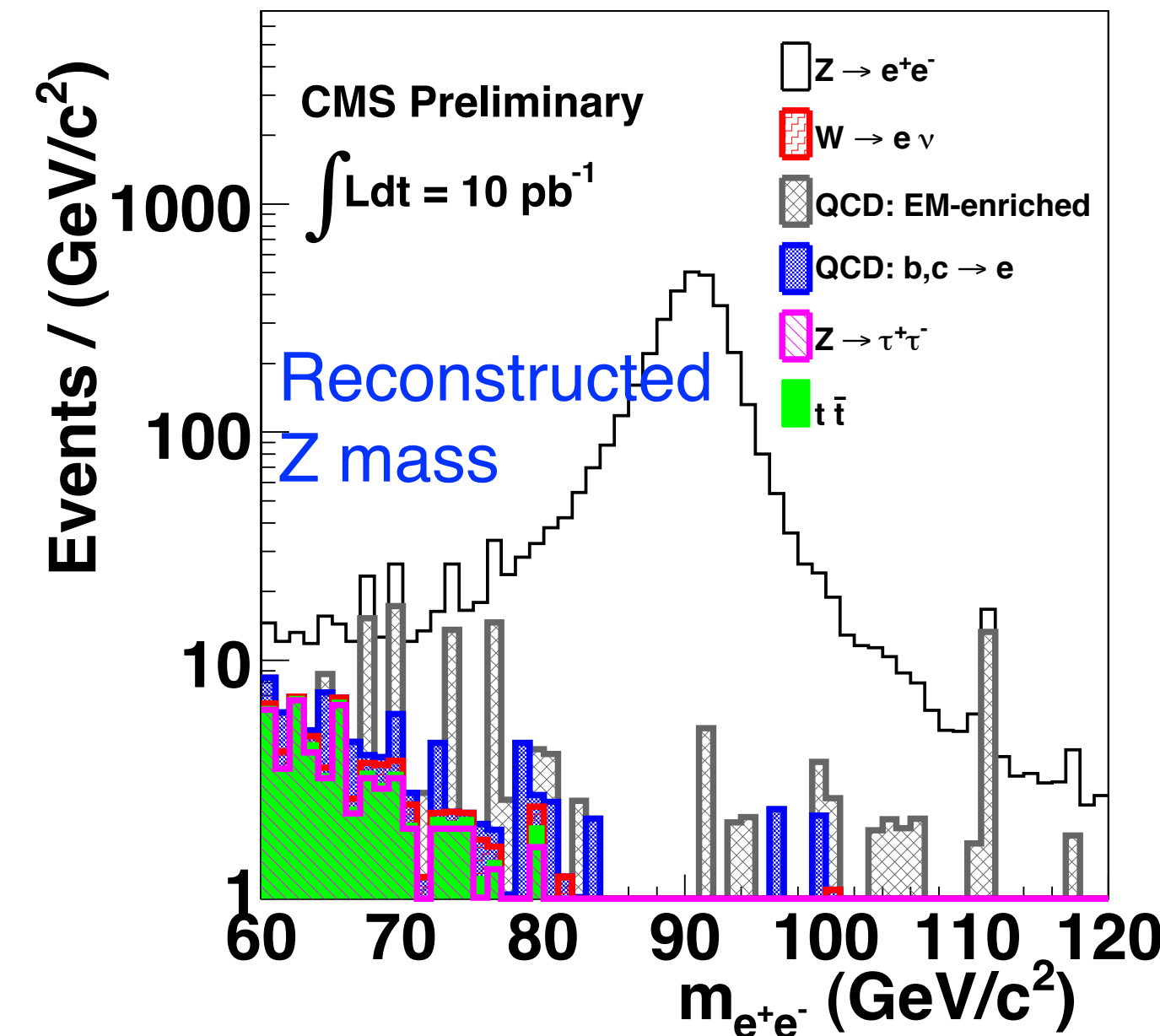
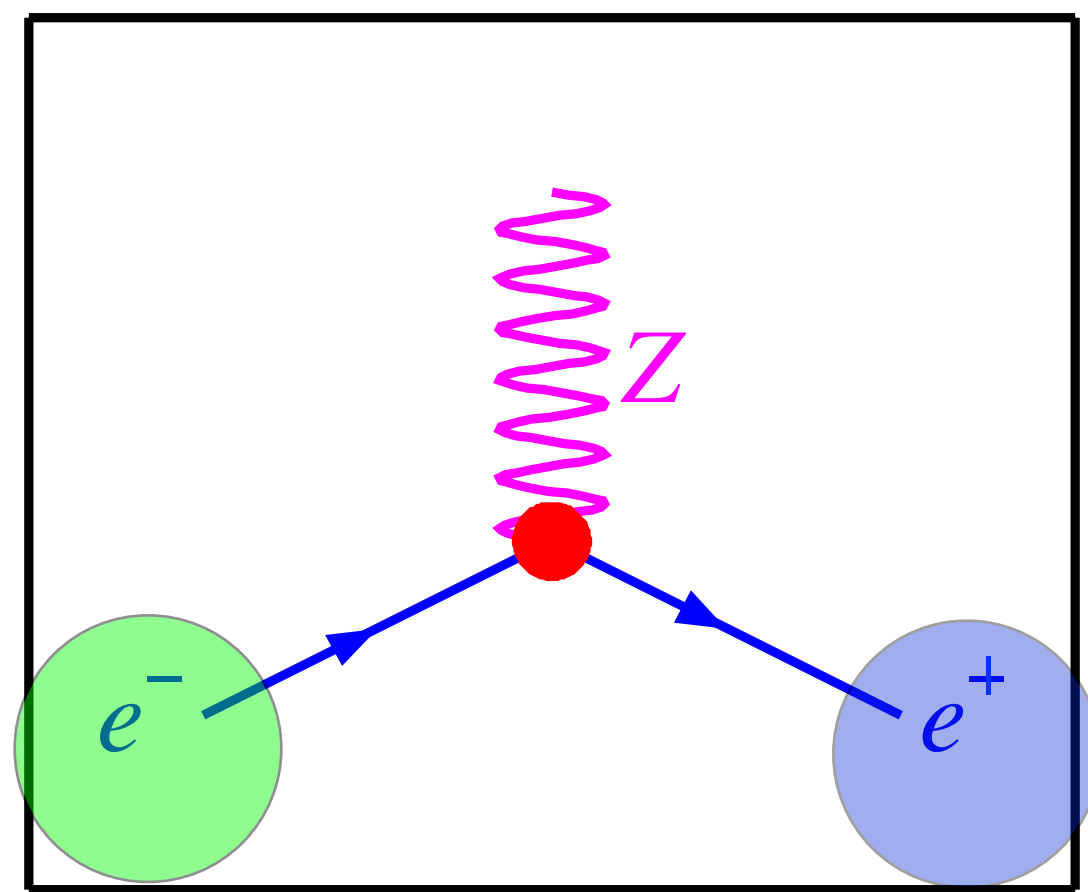
## Why do we need to measure electron efficiency ?

- ◆ One of the first measurements at LHC will be that of the W and Z boson production rate. To perform this measurement in the electron channel we need to determine the electron reconstruction efficiency with good precision.
- ◆ Other early analyses using electrons, including new physics searches, need electron efficiency as input.

## Tag & probe technique for efficiency measurement

- ◆ Tag & probe (TP) is a powerful data-driven technique to measure reconstruction efficiencies from standard candle physics processes
  - $Z \rightarrow e^+e^-$  decay can be used to compute electron reconstruction efficiency with good statistics in the  $p_T$  range 20 to 60 GeV/c
  - Similarly,  $J/\psi$  or  $\Upsilon$  decay for low  $p_T$  electrons
  - Goal: efficiency table as a function of  $\eta$  and  $p_T$
- ◆ Choose a reference process:  $Z \rightarrow e^+e^-$ 
  - Choose a tag electron: "high quality" reconstructed electron
  - Choose a probe electron: probable electron based on criteria to study
- ◆ Requiring the tag-probe invariant mass to be consistent with Z boson mass yields a high-purity and almost unbiased sample of probe electrons
- Several different strategies for handling background
  - Sideband subtraction, signal+background likelihood fit, etc.

## How does TP work for electrons from Z decay ?



Probe efficiency for passing some selection criteria can be computed as

$$\epsilon(Probe) = \frac{N_{\text{passing probes}}}{N_{\text{all probes}}} \quad (\text{Ideal: Monte Carlo truth})$$

$$\epsilon(Probe) = \frac{N_P}{N_P + N_F} \quad (\text{in data: from tag \& probe}) \quad \begin{matrix} N_P : \#TP \text{ pairs with passing probes} \\ N_F : \#TP \text{ pairs with failing probes} \end{matrix}$$

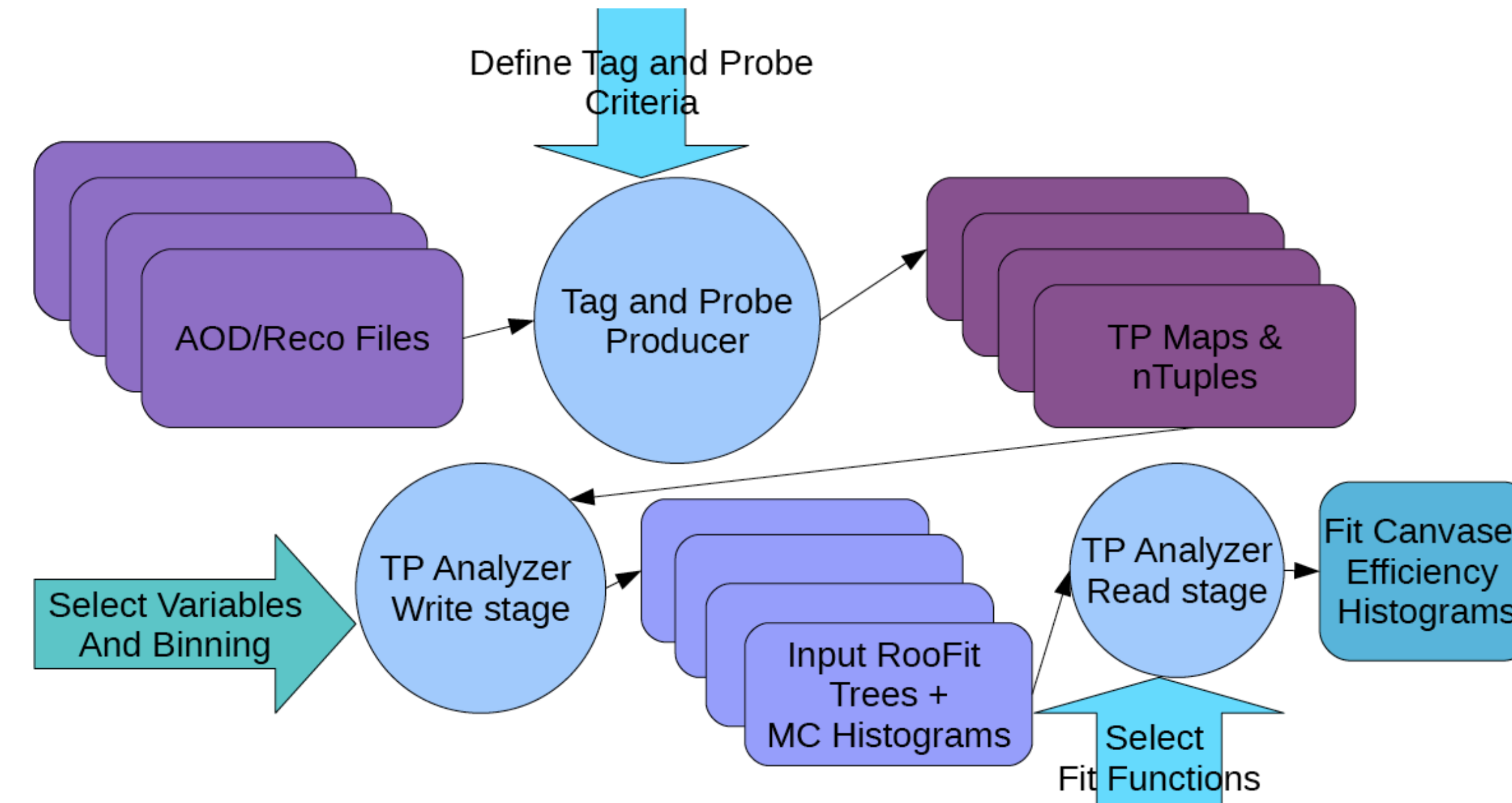
Perform a maximum likelihood fit of the TP invariant mass to simultaneously compute  $N_P$ ,  $N_F$ , and efficiency in each  $\eta$ ,  $E_T$  bin of the probe. The Z mass signal is modeled by the Breit-Wigner lineshape with Gaussian resolution. Background is modeled by a polynomial or exponential function or some empirical shape.

## CMS implementation of tag & probe

- ◆ A unified software package to compute electron and muon efficiencies: from Z decay for high  $p_T$   $e/\mu$  and from  $J/\psi$  or  $\Upsilon$  decay for low  $p_T$   $e/\mu$
- ◆ Efficiencies can be easily recalculated for different selections, in a configurable way
- ◆ Developed entirely by LPC/ USCMS people

2

## Organization of tag & probe machinery in CMS



## Basic electron reconstruction monitoring

### Tag selection:

- *GsfElectron*: super cluster seed matched to a track
- Within the acceptance of the tracking system and electromagnetic calorimeter
- $E_T > 20$  GeV/c.
- Track isolation, "Loose" electron ID
- Trigger-matched

### Probe selection:

- Super cluster
- Within the acceptance of the tracking system and the electromagnetic calorimeter
- $E_T > 20$  GeV/c.
- Tag-probe invariant mass must be consistent with Z mass

Obtain factorized efficiencies for passing probes:

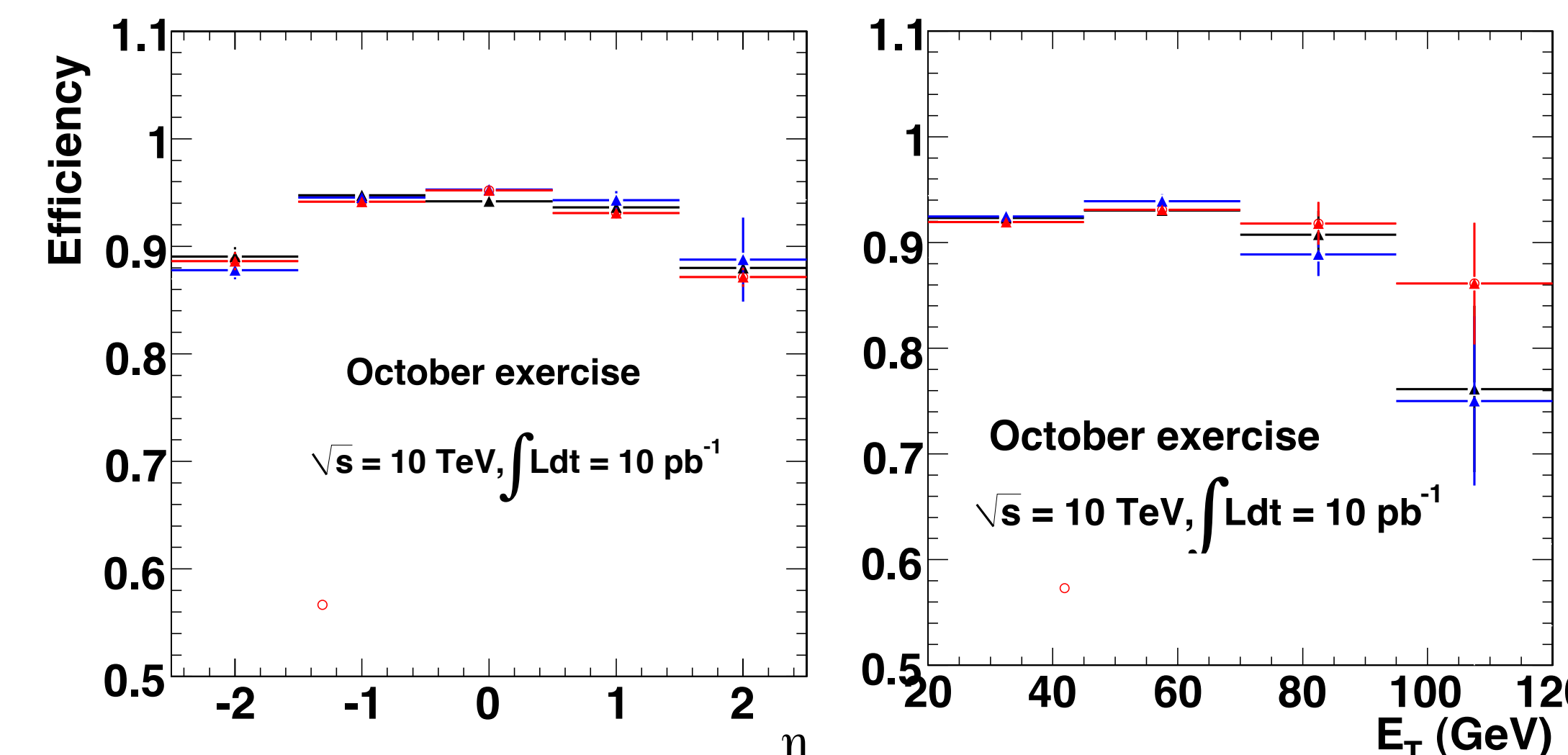
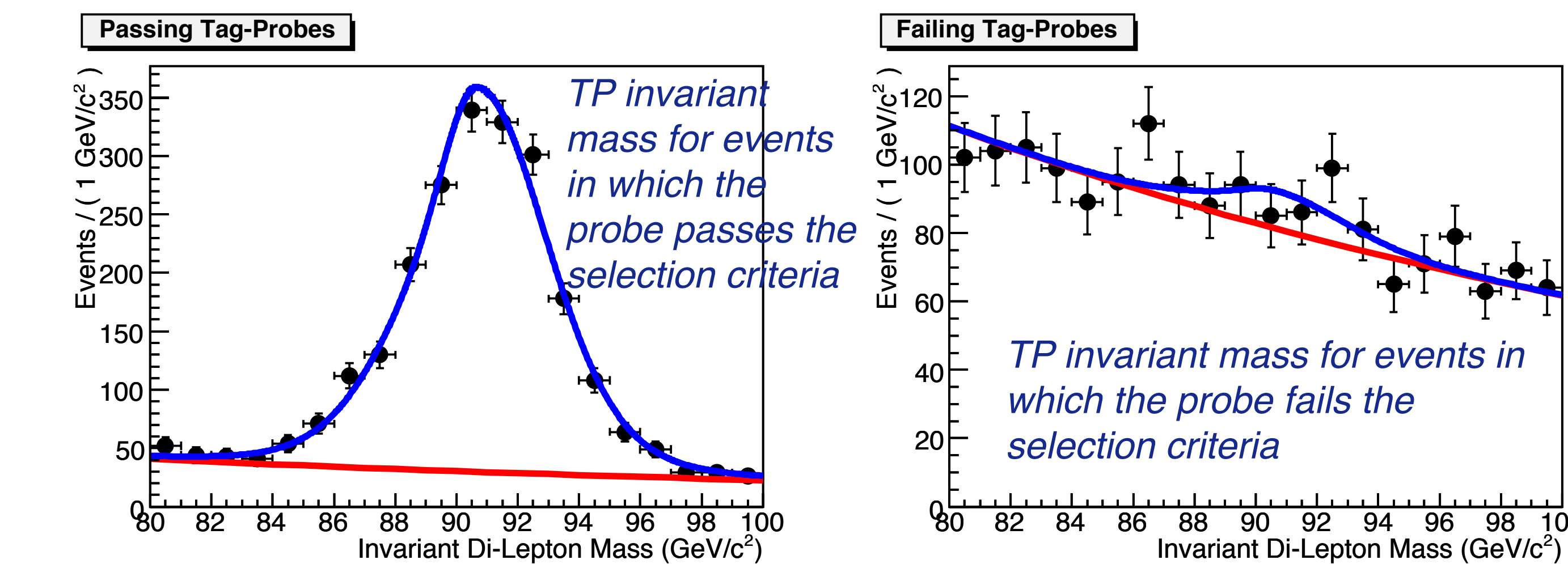
SuperCluster → *GsfElectron* → Isolation → ID → HLT

offline electron reconstruction efficiency with respect to acceptance

electron trigger efficiency w.r.t. offline selection

Example:

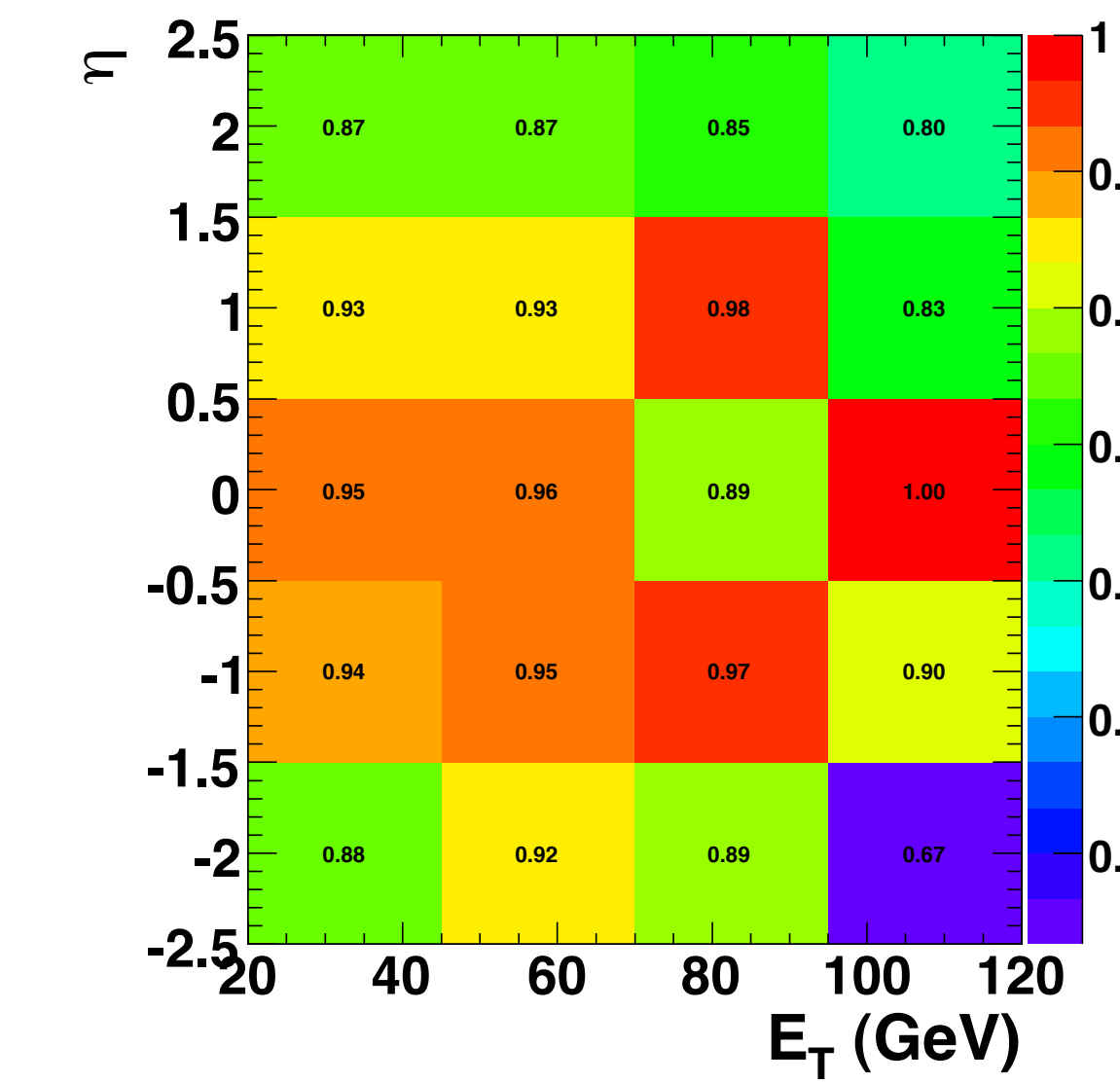
## Super cluster → *GsfElectron* reconstruction efficiency



Super cluster → *GsfElectron* efficiency as a function of  $\eta$ ,  $E_T$ :

- likelihood fit
- sideband sub.
- MC truth

3



Super cluster → *GsfElectron* reconstruction efficiency in two dimensions as a function of  $E_T$  and  $\eta$

## Efficiency for electron selection in W/Z analysis

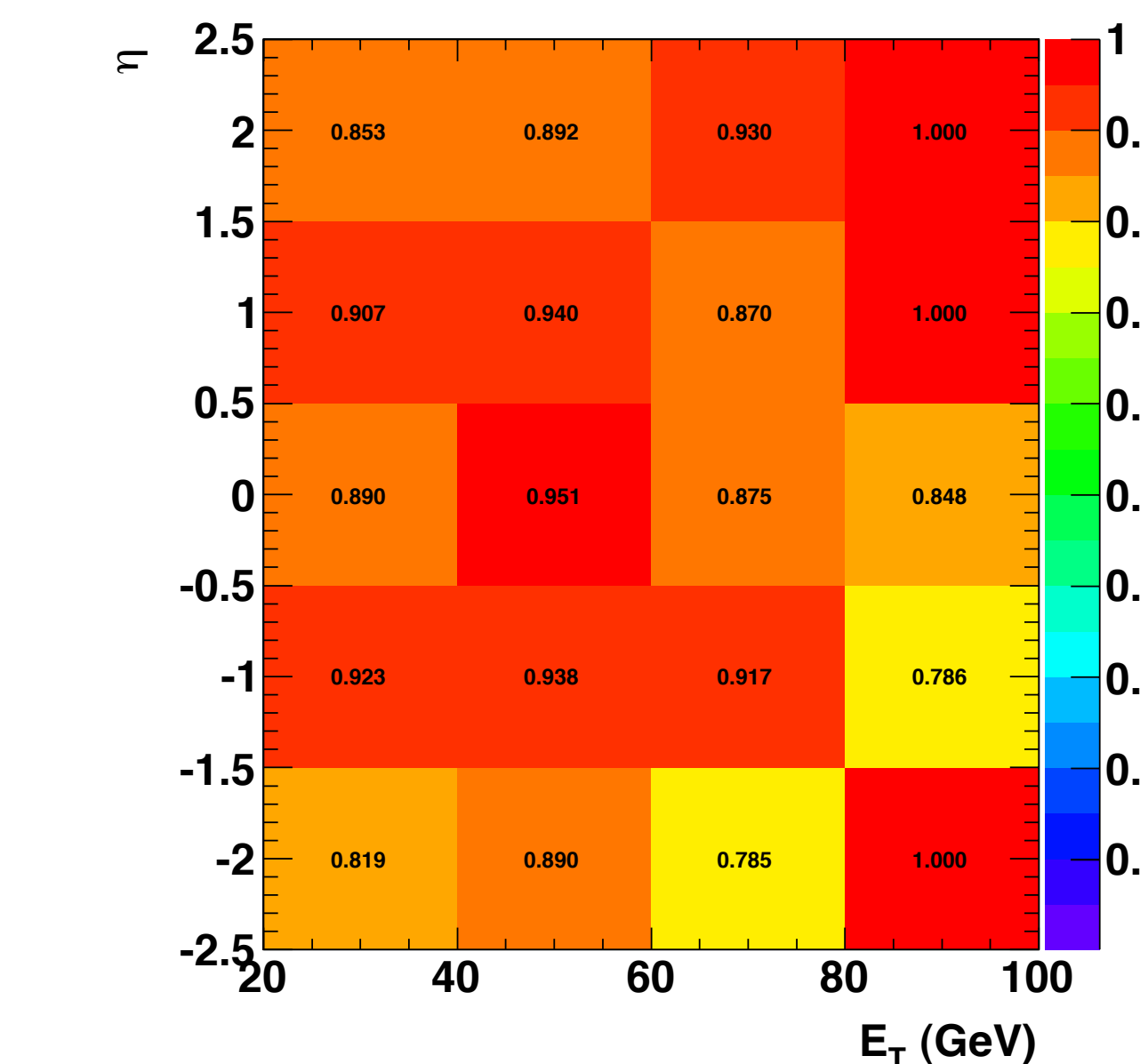
W/Z cross-section:

$$\sigma = \frac{N_{\text{signal}}}{A \cdot \epsilon \cdot \int \mathcal{L}}$$

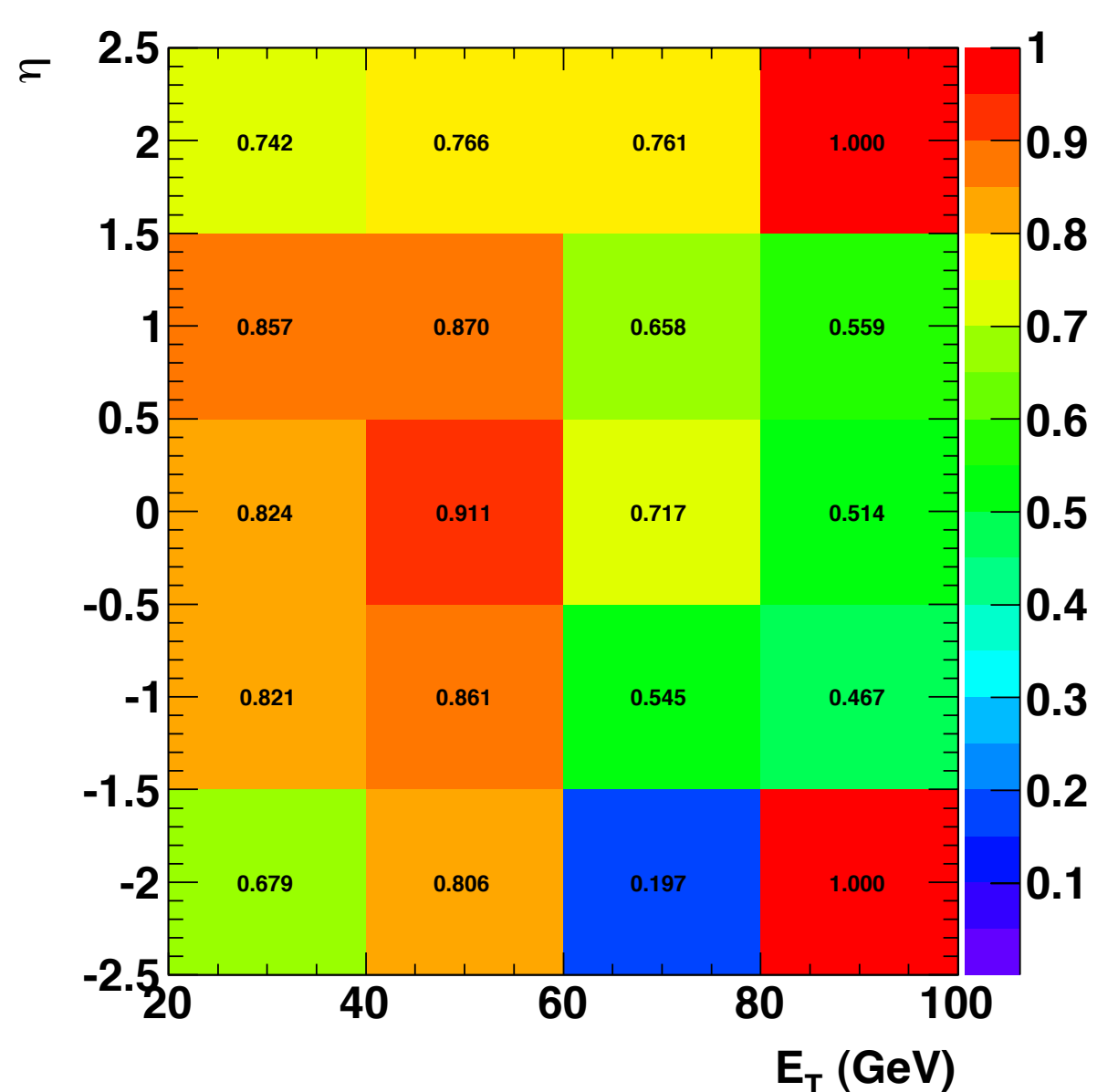
$A$  = Acceptance  
 $\epsilon$  = Efficiency  
 $\int \mathcal{L}$  = Int. luminosity

For W:  $\epsilon = \epsilon_{\text{offline}} \times \epsilon_{\text{trigger}}$

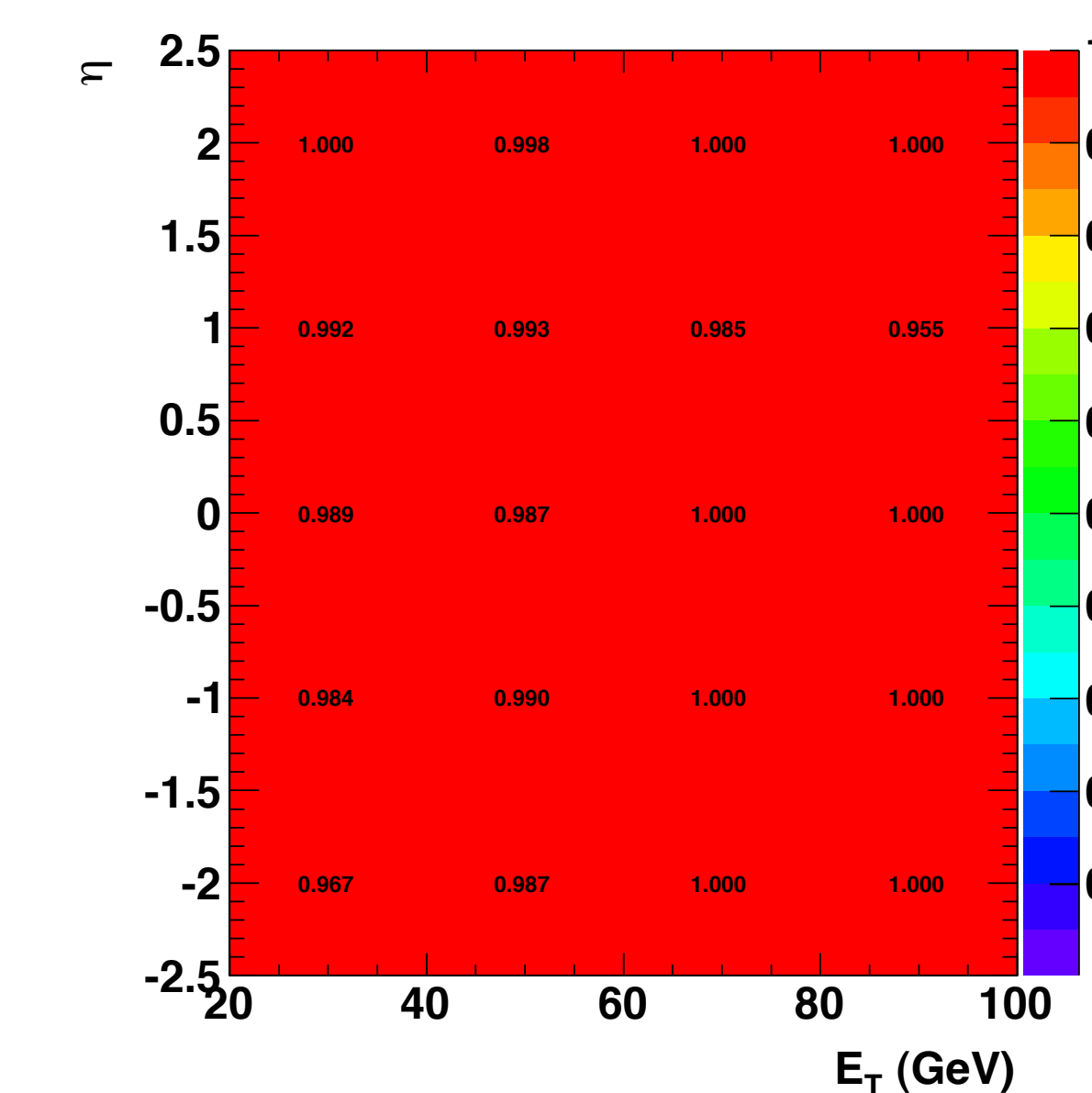
For Z:  $\epsilon = \epsilon_{\text{offline}}^- \cdot \epsilon_{\text{offline}}^+ \cdot [1 - (1 - \epsilon_{\text{trigger}}^-)(1 - \epsilon_{\text{trigger}}^+)]$   
 $= \epsilon_{\text{offline}}^2 \cdot [1 - (1 - \epsilon_{\text{trigger}})^2]$  (assuming same efficiency for  $e^+$ ,  $e^-$ )



Offline electron efficiency for  $Z \rightarrow e^+e^-$  events at 10 TeV (loose selection)



Offline electron efficiency for  $W \rightarrow e\nu$  events at 10 TeV (tight selection)



Efficiency for the reconstructed offline electron to pass the single electron trigger (non-isolated,  $E_T > 20$  GeV, large pixel-matching window) criteria for  $Z \rightarrow e^+e^-$  and  $W \rightarrow e\nu$  events at 10 TeV

## Summary

- ☑ We need to be calibrate electrons and compute their efficiency for important early physics measurements at CMS
  - Inclusive Z and W production cross section measurement
  - Integrated luminosity measurement using Z production cross section
  - Other electron analyses: Z/W+jets, top, new physics searches: W/Z', SUSY, ...
- ☑ Data driven techniques developed & demonstrated to work in Monte Carlo