Selection of FSR photons in $Z \rightarrow ll\gamma$ decay and tight ID cut efficiency definition from early data

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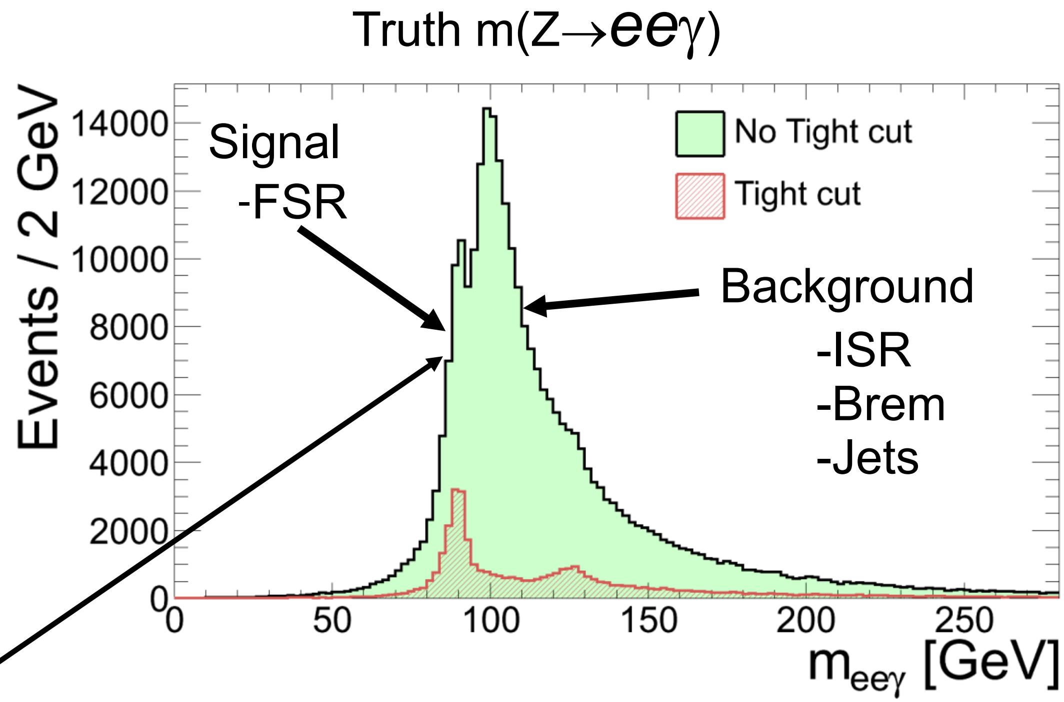
Outline:

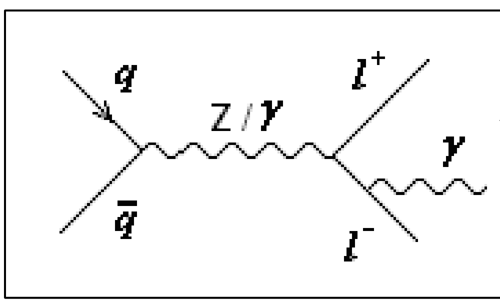
- Introduction
- Results of selection from data for $Z \rightarrow ee\gamma/\mu\mu\gamma$
- Tight photon ID efficiency definition
- Conclusions

Introduction: some results of preliminary MC studies

Photon sample selection using $Z \rightarrow ll\gamma$ process

- Idea is to obtain pure photon sample from known physics process with distinctive kinematical feature -
  - m($ee\gamma$) and $\Delta R(e\gamma)$
  - m($\mu\mu\gamma$) and $\Delta R(\mu\gamma)$
- One of a problems is a small production cross section.



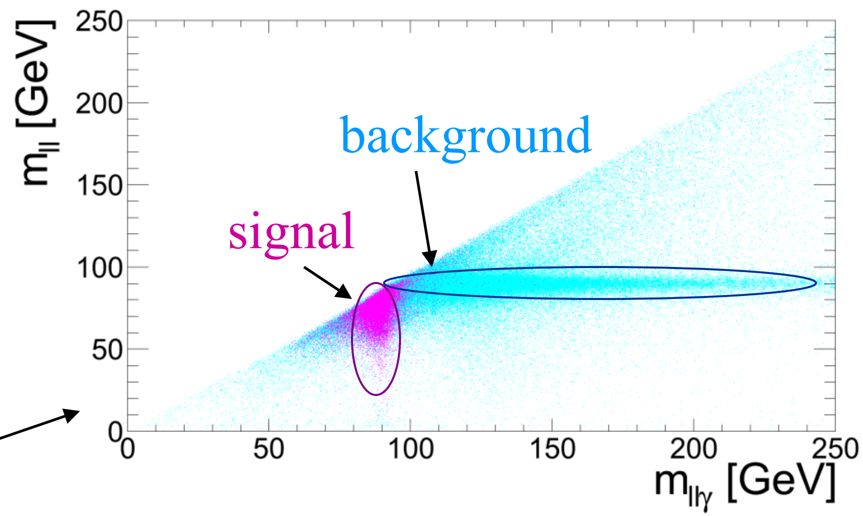


Earlier MC study of ~5M Z decays into each lepton channel has provided a selection set of requirements:
http://indico.cern.ch/getFile.py/access?contribId=3&resId=1&materialId=slides&confId=92681

$ll\gamma$ selection optimisation

Standard Approach

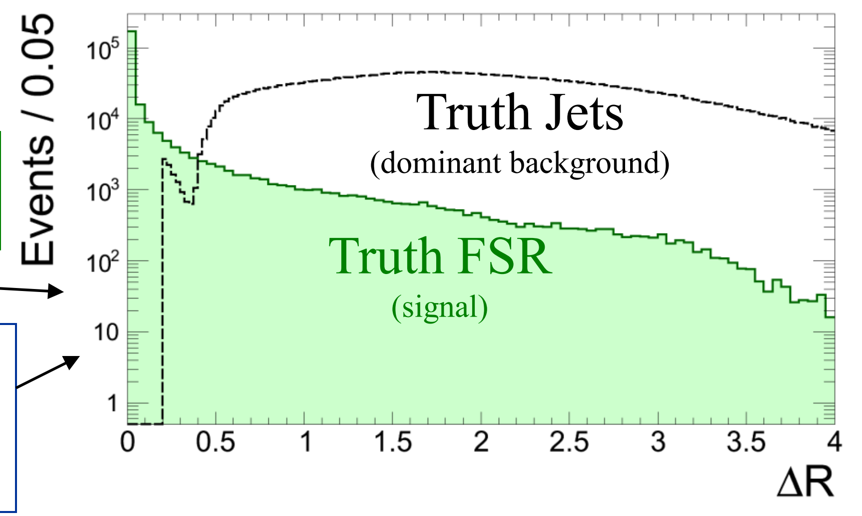
- $m_{ll\gamma}$ window; 80<m($ee\gamma$)<94 GeV, 81<m($\mu\mu\gamma$)<95 GeV
- $\Delta R(l\gamma)$ threshold; $\Delta R(e\gamma)>0.2$, $\Delta R(\mu\gamma)>0.2$
- Tight photon selection criteria.
- Collision $Z\to ee/\mu\mu$ event selection



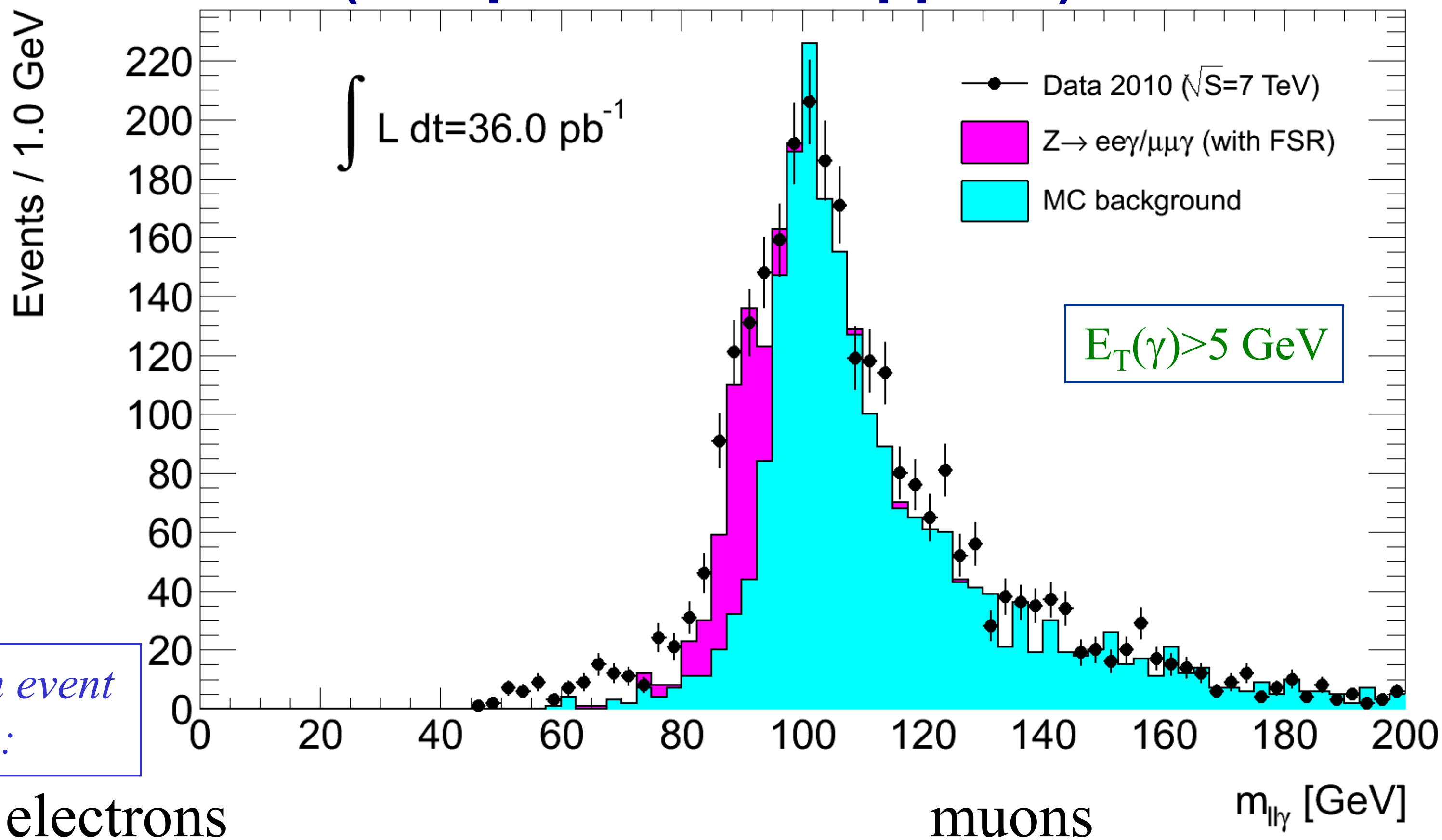
Kinematical Approach

- m_{ll} requirements; 60<m(ee)<83 GeV, 40<m($\mu\mu$)<82 GeV
- Photon E_T threshold; ($ee\gamma$): $E_T(\gamma)>5/15$ GeV, ($\mu\mu\gamma$): $E_T(\gamma)>5/15$ GeV
- Upper ΔR cut.

(Different truth distribution shapes give us an addition way to reject jets background)



$Z\rightarrow ll\gamma$ event selection from collision data (no specific cuts applied)



Collision event selection:

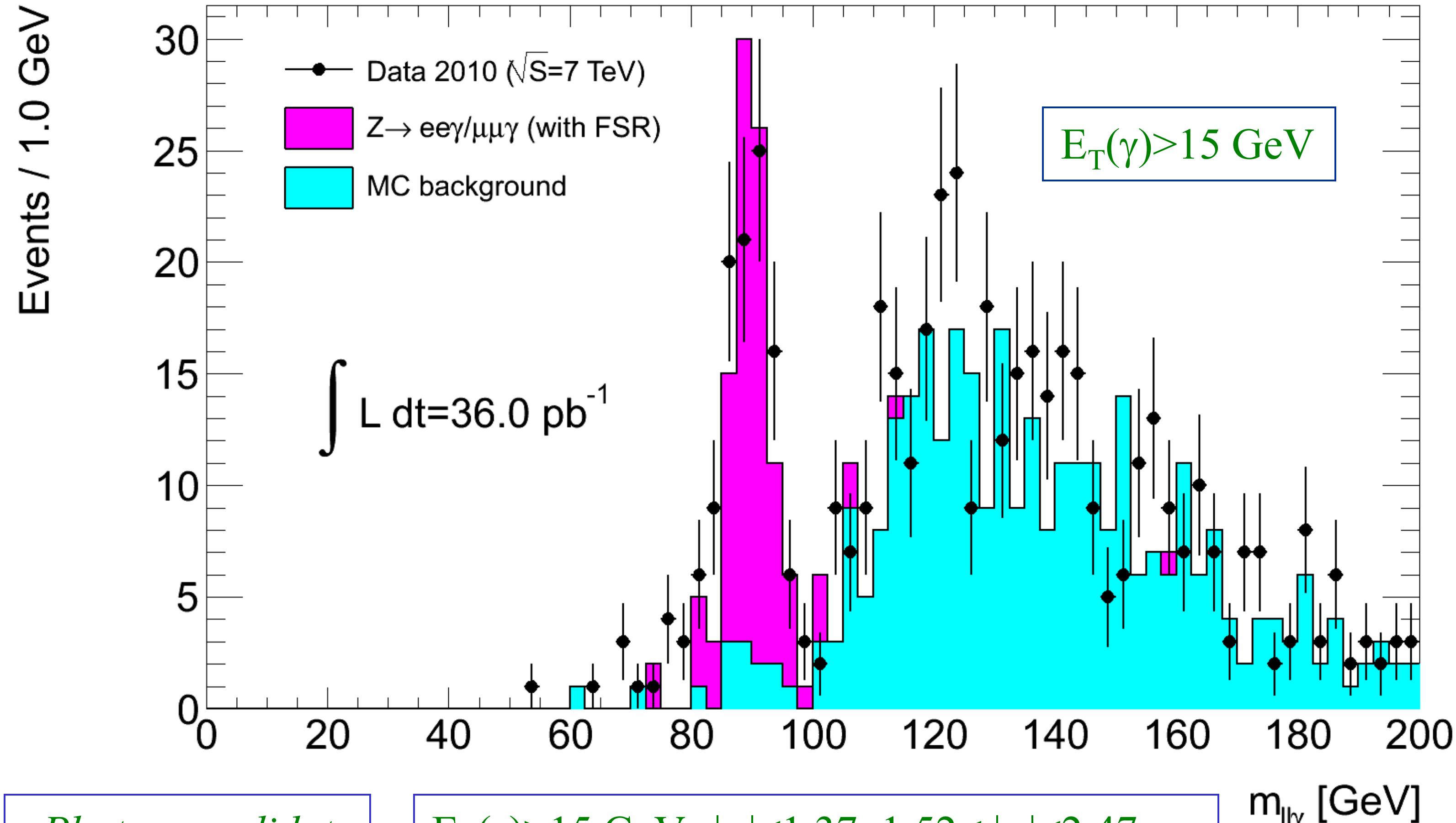
electrons

At least one primary vertex with $N_{tracks}\geq3$, $P_T(e)>20$ GeV, $|\eta|<1.37$, $1.52<|\eta|<2.47$, two medium electrons with opposite charge.

muons

At least one primary vertex with $N_{tracks}\geq3$, $|z_{vtx}|<150$ mm, Two combined muons with opposite charge, each has $P_T(\mu)>20$ GeV, $|\eta|<1.37$, $1.52<|\eta|<2.4$, $P_T^{MS}>10$ GeV, $|P_T^{MS}-P_T^{ID}|<15$ GeV, $|z_0-z_{vtx}|<10$ mm, $\Sigma P_T(\text{Cone40})/P_T<0.2$.

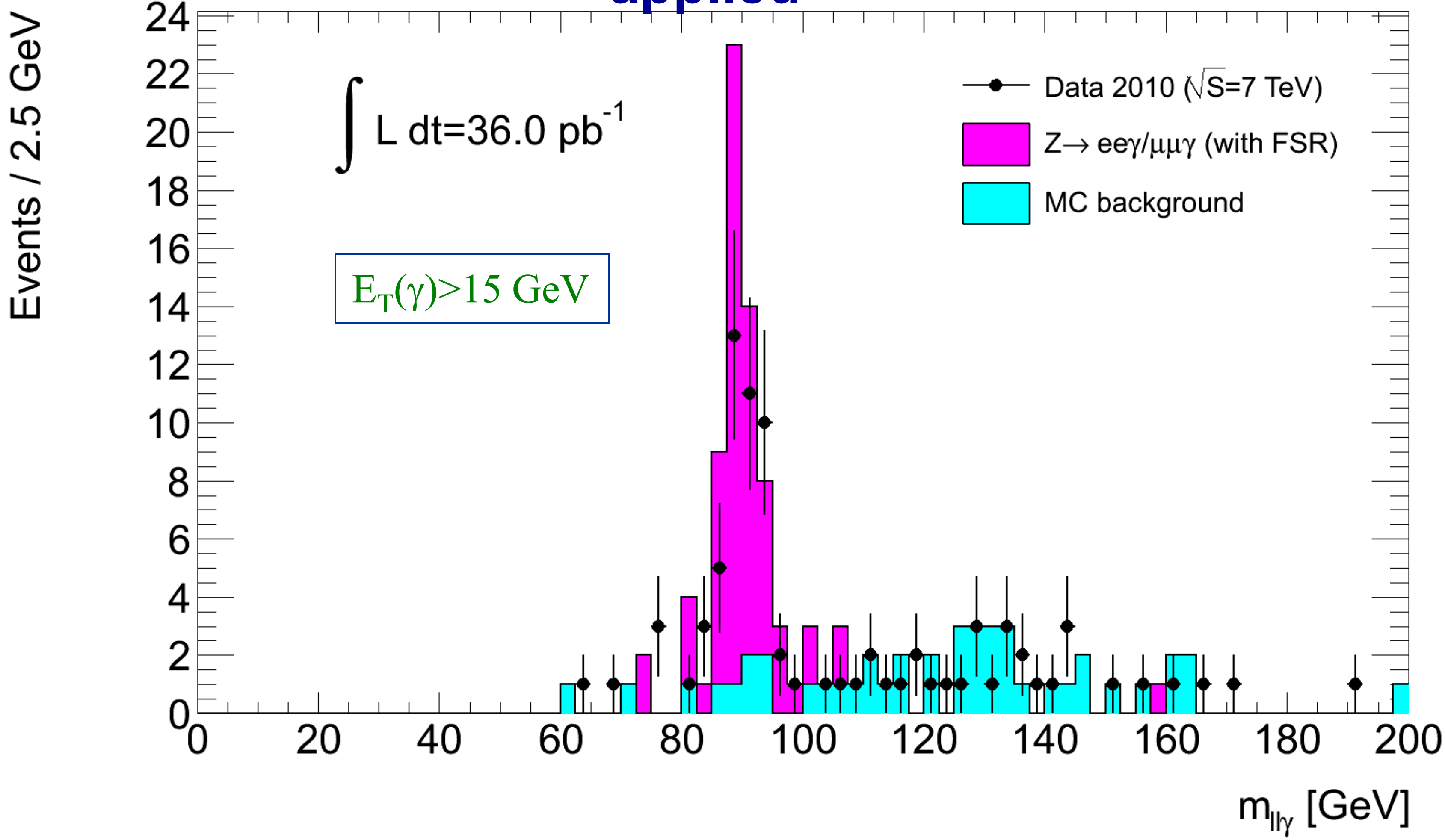
$Z \rightarrow ll\gamma$ event selection from collision data (no specific cuts applied)



Photon candidate preselection:	$E_T(\gamma)>15$ GeV, $\|\eta\|<1.37$, $1.52<\|\eta\|<2.47$, Isolation cut: $\Delta R(l\gamma)>0.2$

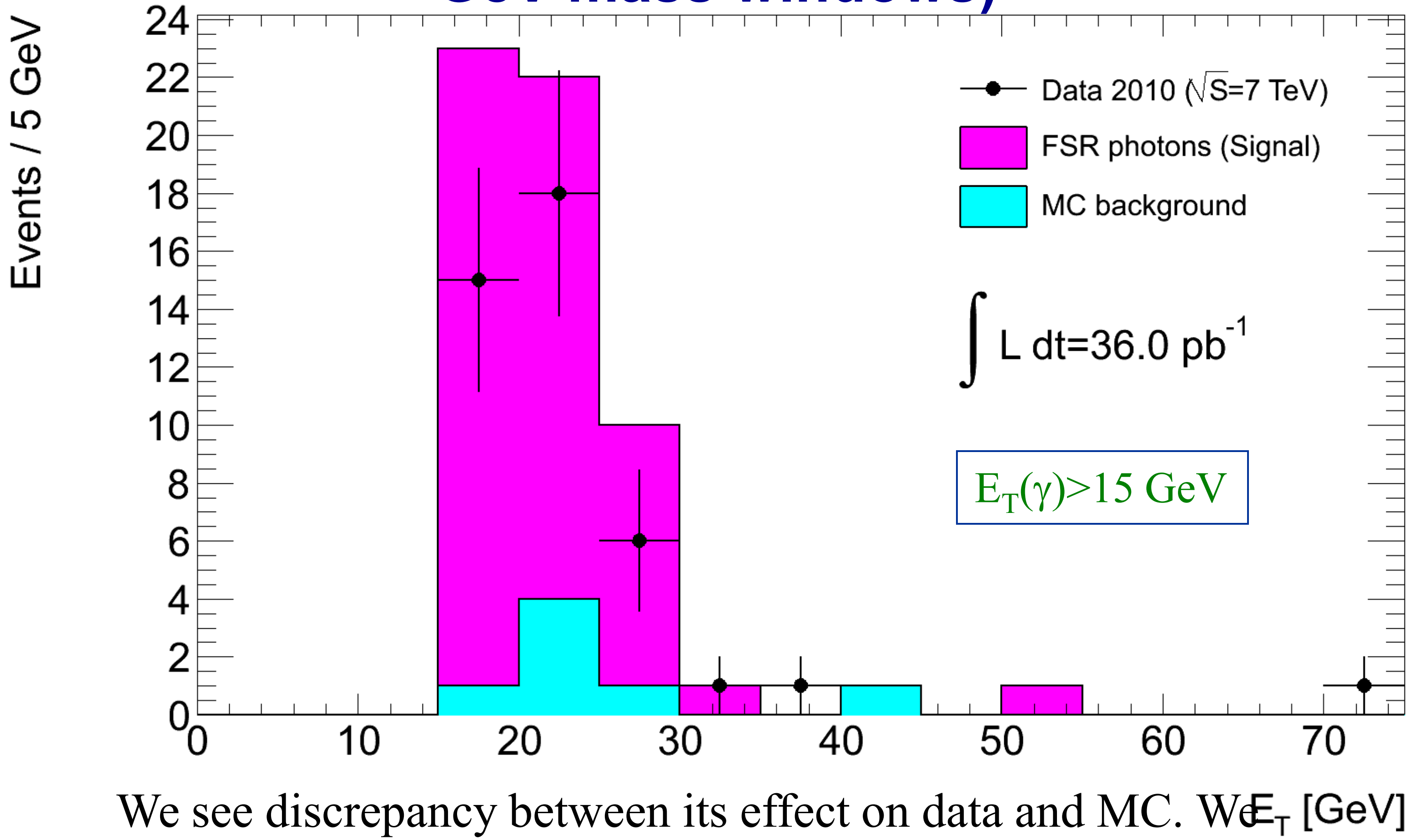
Increase of E_T threshold give a possibility for better separation of signal from main background. However, in the same time it decrease signal statistics a lot.

$Z \to ll\gamma$ invariant mass spectrum. Photon tight cut applied



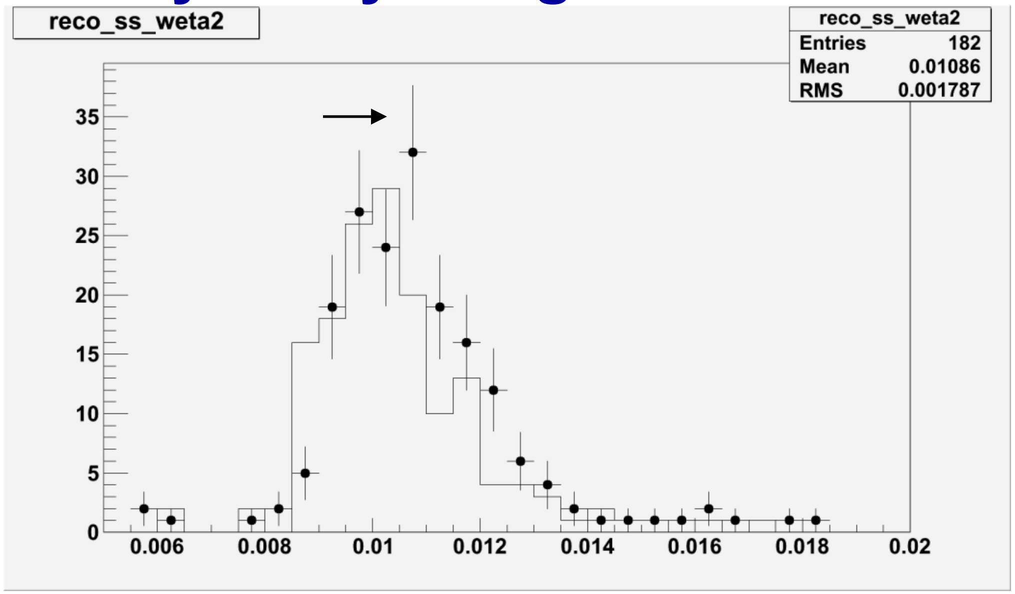
Tight photon cut – “standard” cut for photon separation from jets.

FSR Photon candidates obtained after a tight photon cut (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows)



We see discrepancy between its effect on data and MC. We should correct MC shower shapes!

ID efficiency study: fudge factor for MC correction

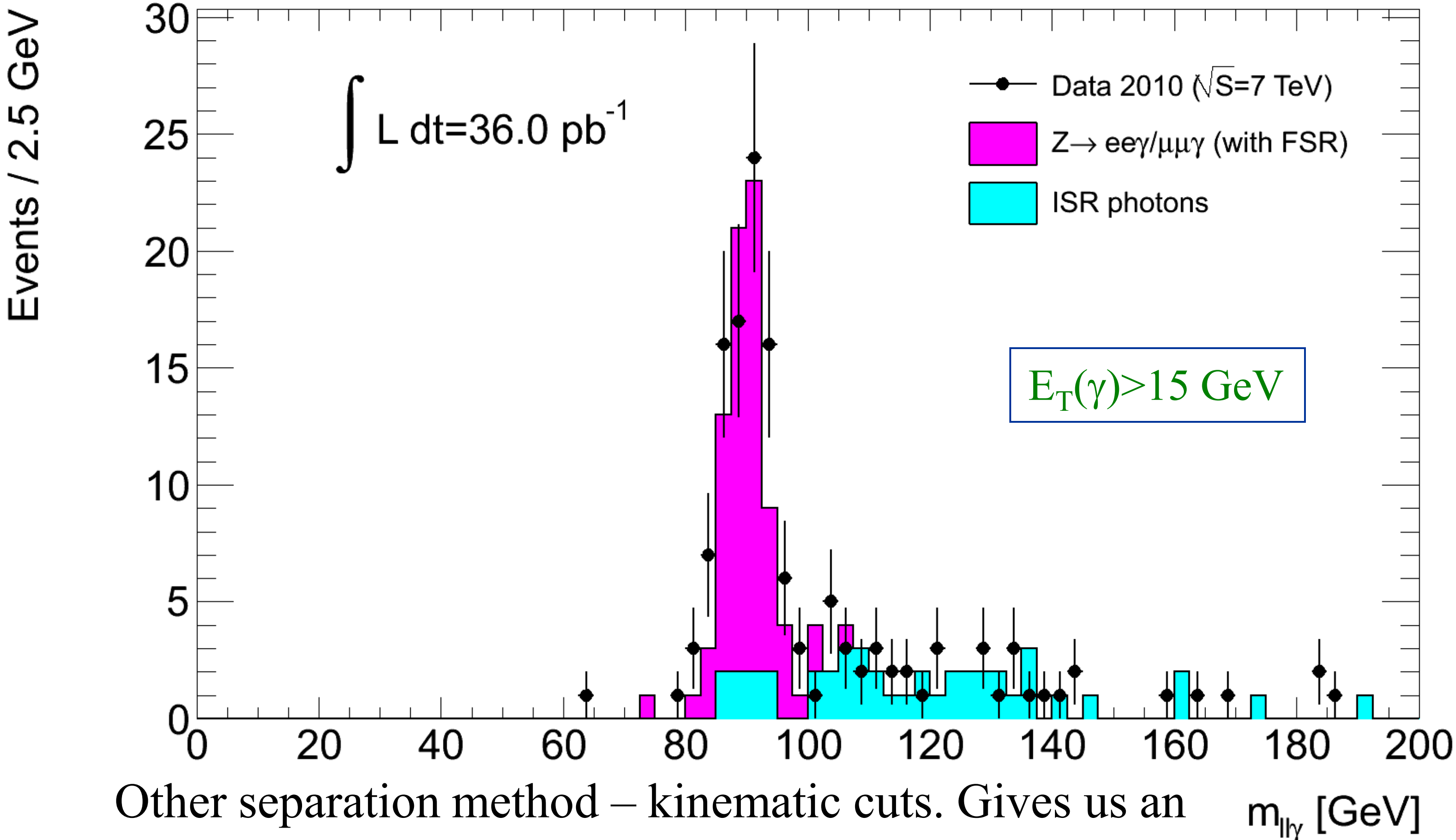


Some mean values of shower distributions (for all preselected photons)

	Data	MC
weta2	0.01198	0.01132
frac_s1	0.3724	0.3339
ethad	1245	867.2
ethad1	525	372.7
…	…	…

Fudge Factor=<Data>-<MC>

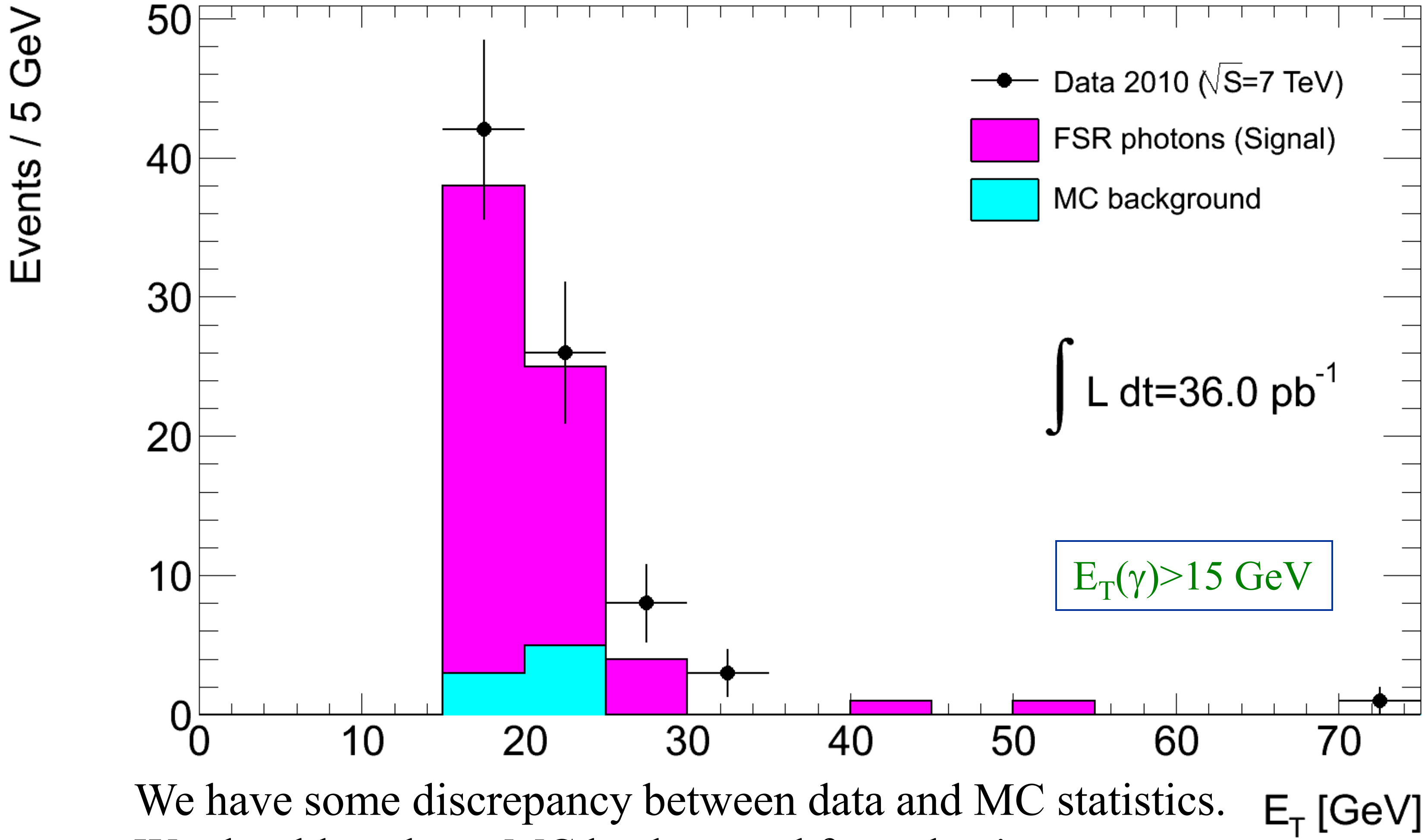
$Z \rightarrow ll\gamma$ invariant mass obtained after $60 < m_{ee} < 83$ GeV & $40 < m_{\mu\mu} < 82$ GeV windows requirement (no tight cut)



Other separation method – kinematic cuts. Gives us an independent way to separate the signal.

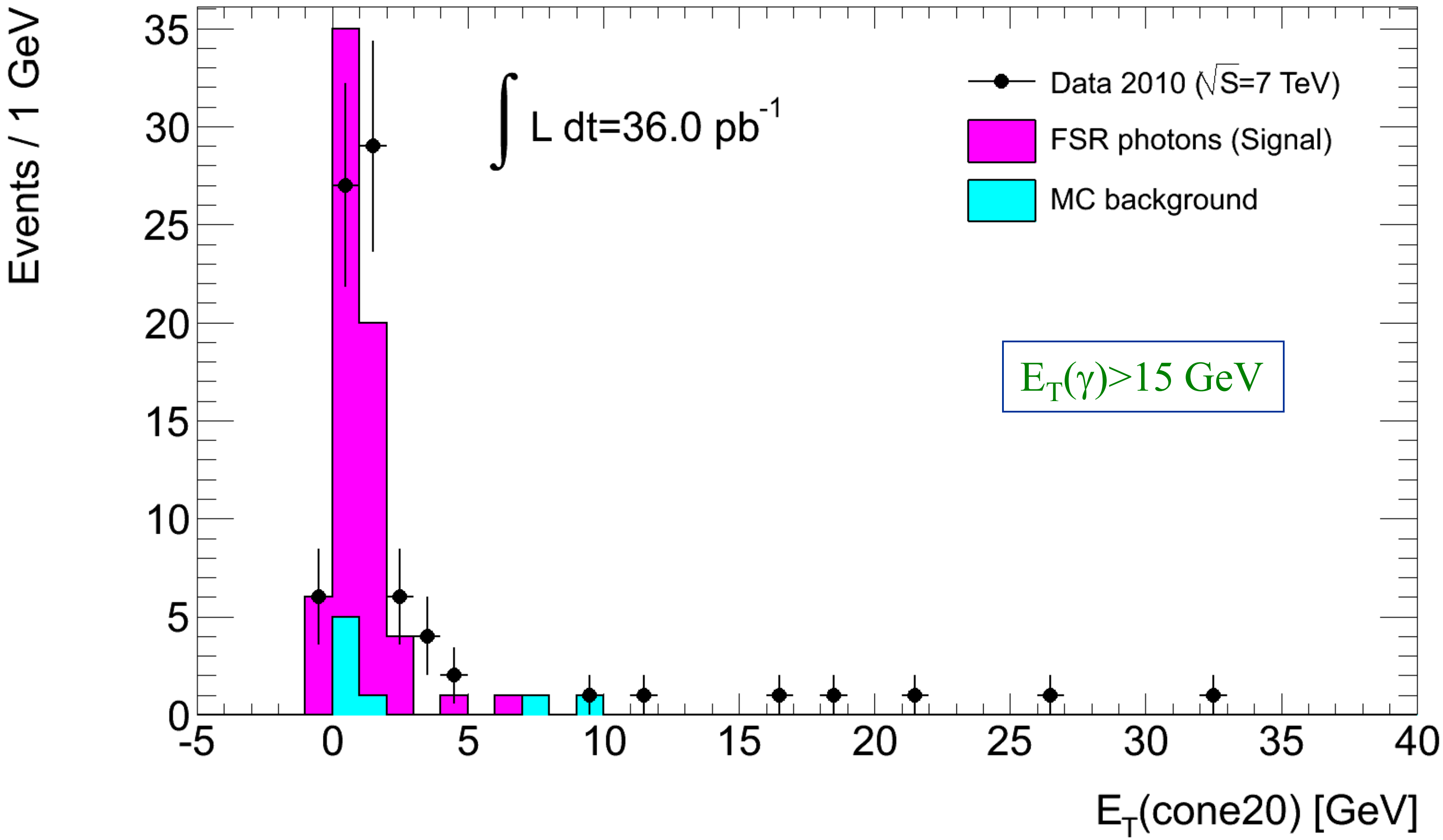
We can also study tight cut.

FSR Photon candidates obtained after 60< m_{ee}<83 GeV & 40< $m_{\mu\mu}$<82 GeV windows requirement (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows, no tight cut) vs E_T

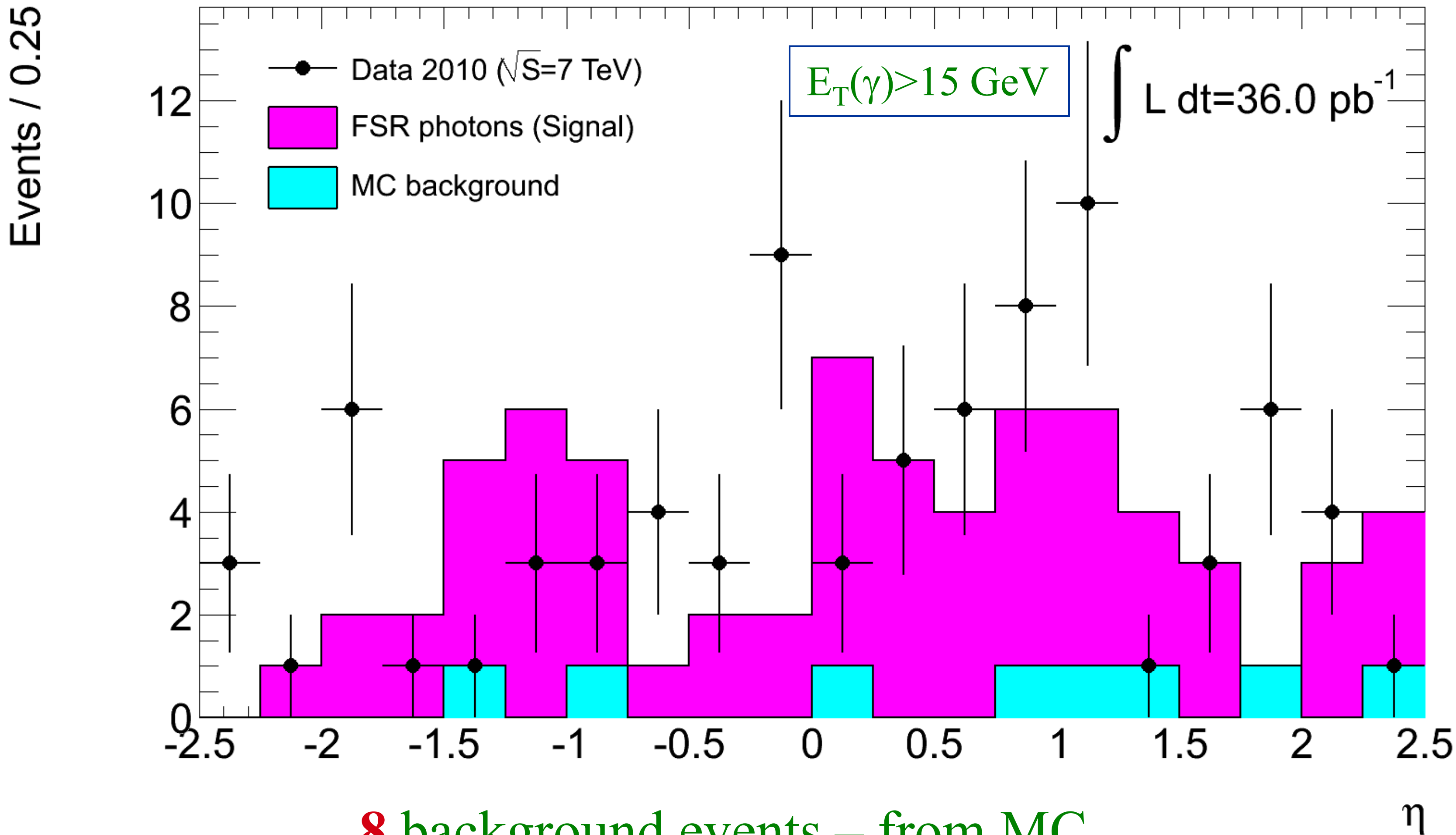


We have some discrepancy between data and MC statistics.
We should evaluate MC background from data!

FSR Photon candidates obtained after 60< m_{ee}<83 GeV & 40< $m_{\mu\mu}$<82 GeV windows requirement (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows, no tight cut) vs $E_T$cone(0.2)



FSR Photon candidates obtained after 60< m_{ee}<83 GeV & 40< $m_{\mu\mu}$<82 GeV windows requirement (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows, no tight cut) vs η



8 background events – from MC.

ID efficiency study: robust tight cut efficiency

Data events: **81**

	Number of events before robust tight cut	Number of events after robust tight cut	Background events	Efficiency (with background substruction)
No isolation cut on E_T(in cone 0.2)	81	41	8	(56±7)%
With isolation cut E_T(in cone 0.2)<5 GeV	74	40	6	(59±7)%

Expected efficiency for MC: ~ **(74±2)%**

Possible reason for difference: difference of <u>background predicted from MC and real data</u>, <u>low statistics</u> and <u>different shower shapes</u> for Data and MC.

Need to estimate background from data!

Data driven background estimation

1) We take the photon candidates, which associated with the lepton pairs from narrow two-body invariant mass window around Z boson mass (91-92 GeV - area 1). We can confidently say, that these photon candidates are mostly background and do not contain FSR photons.

2) We assume that all photon distributions of such kind of candidates is the same as for another two-body invariant mass window (which we use in kinematic approach – $60<m(ee)<83$ GeV, $40<m(\mu\mu)<82$ GeV - area 2) and number of background photons is proportional to the number of the lepton pairs.

3) After application of the 3 body invariant mass cut for signal selection, the background photon spectrum may change. For the moment the best way to estimate this change for the data is to use a similar information from MC. Correction coefficient from MC is found using the following method:

   a) obtain MC background spectrum using all cuts above;

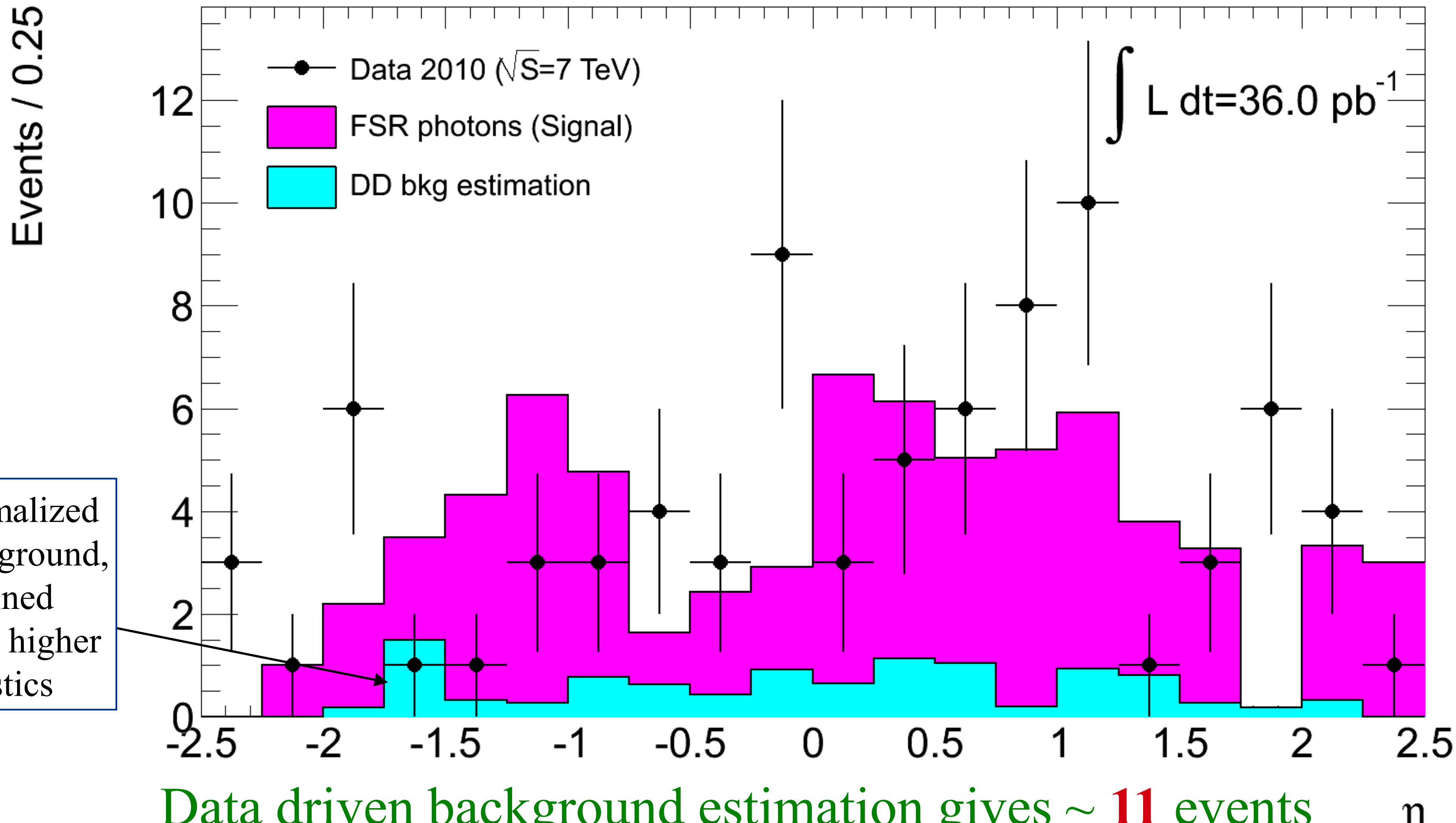
   b) obtain MC background spectrum after application three-body invariant mass cut;

   c) divide first spectrum to second;

   d) Normalize data photon spectrum found in step 2 to the correction coefficient.

4) Due to some methodology issues we use eta photon distribution for such evaluation.

FSR Photon candidates obtained after 60< m_{ee}<83 GeV & 40< $m_{\mu\mu}$<82 GeV windows requirement (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows, no tight cut) vs η (with data driven background estimation)



Normalized background, obtained from higher statistics

Data driven background estimation gives ~ **11** events

ID efficiency study: robust tight cut efficiency

Data events: **81**

Background events from data driven estimation: **11/6**

	Number of events before robust tight cut	Number of events after robust tight cut	Efficiency (with background substruction)
No isolation cut on $E_T$cone(0.2)	81	41	(59±7)%
With isolation cut $E_T$cone(0.2)<5 GeV	74	40	(59±7)%

Efficiency from MC: ~ **(74 ±2)%**

Agreement become a bit better!

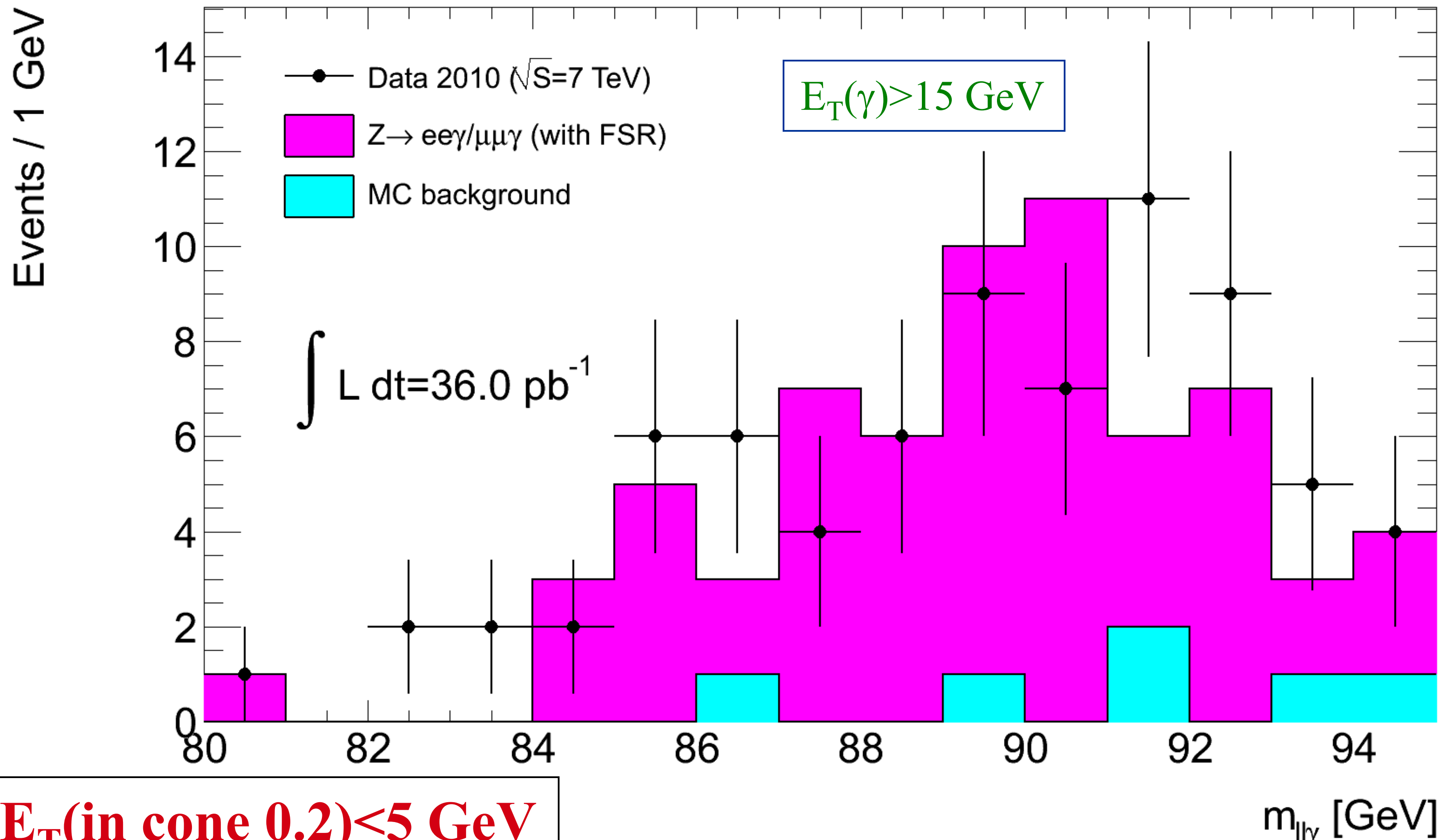
Discrepancy due to: low statistics and different shower shapes for Data and MC.
Need to improve MC shower shapes, using fudge factor from comparison with data.

Conclusions

1. Preliminary results for the studies of a photon selection in the processes $Z \rightarrow ee\gamma$ and $Z \rightarrow \mu\mu\gamma$ has been presented based on statistics of ~36.0 pb^{-1}.
2. Comparison with MC shows in general a good agreement.
3. A mass peak $Z \rightarrow ll\gamma$ peak is clearly seen after applying different type of cuts.
4. MC shower shapes correction and background estimation from data are necessary for tight cut efficiency evaluation.
5. More statistics is required for detailed studies and comparison between data and MC yet.

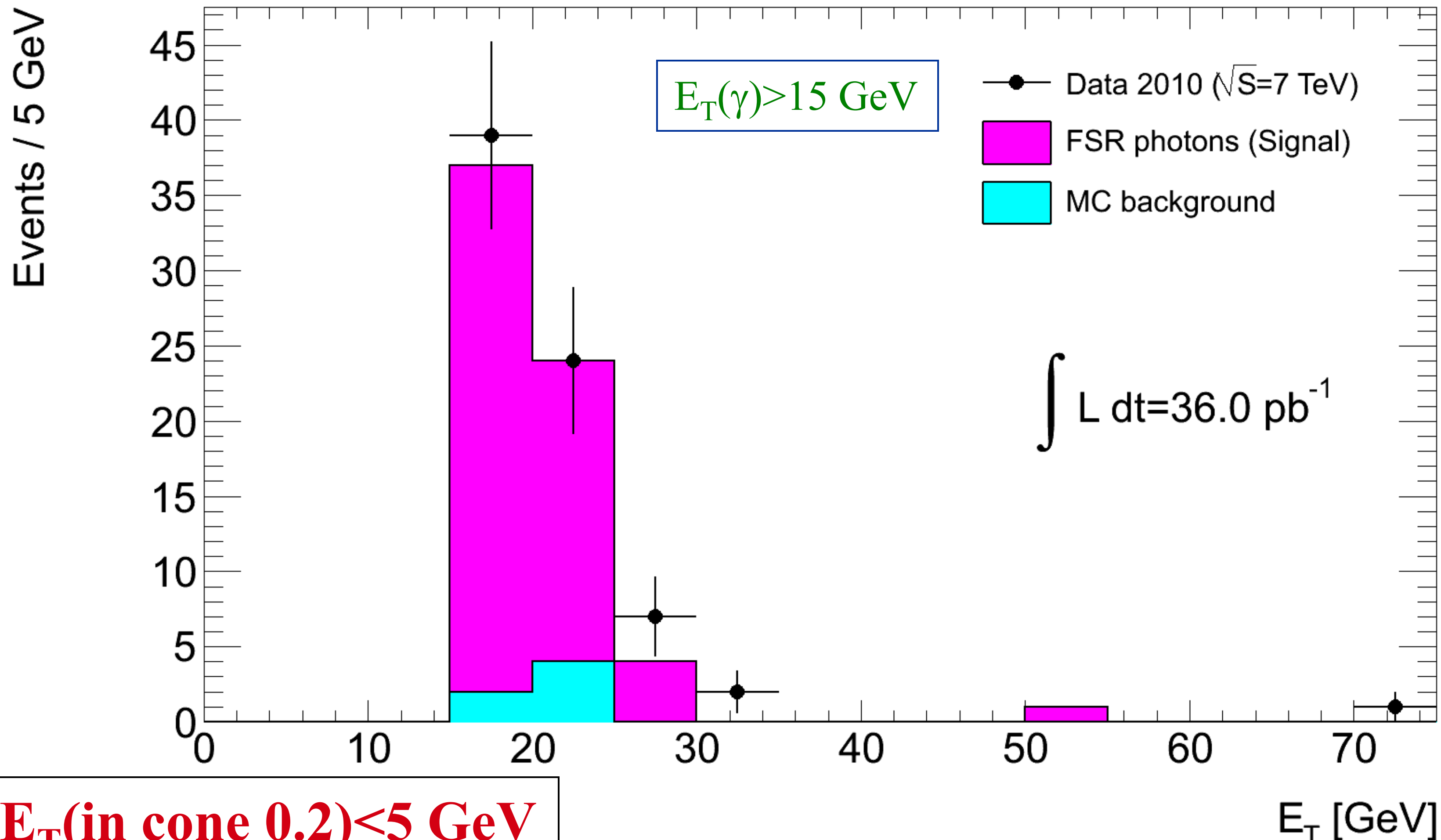
Backup slides

$Z \rightarrow ll\gamma$ invariant mass obtained after 60< m_{ee}<83 GeV & 40< $m_{\mu\mu}$<82 GeV windows requirement (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows, no tight cut)



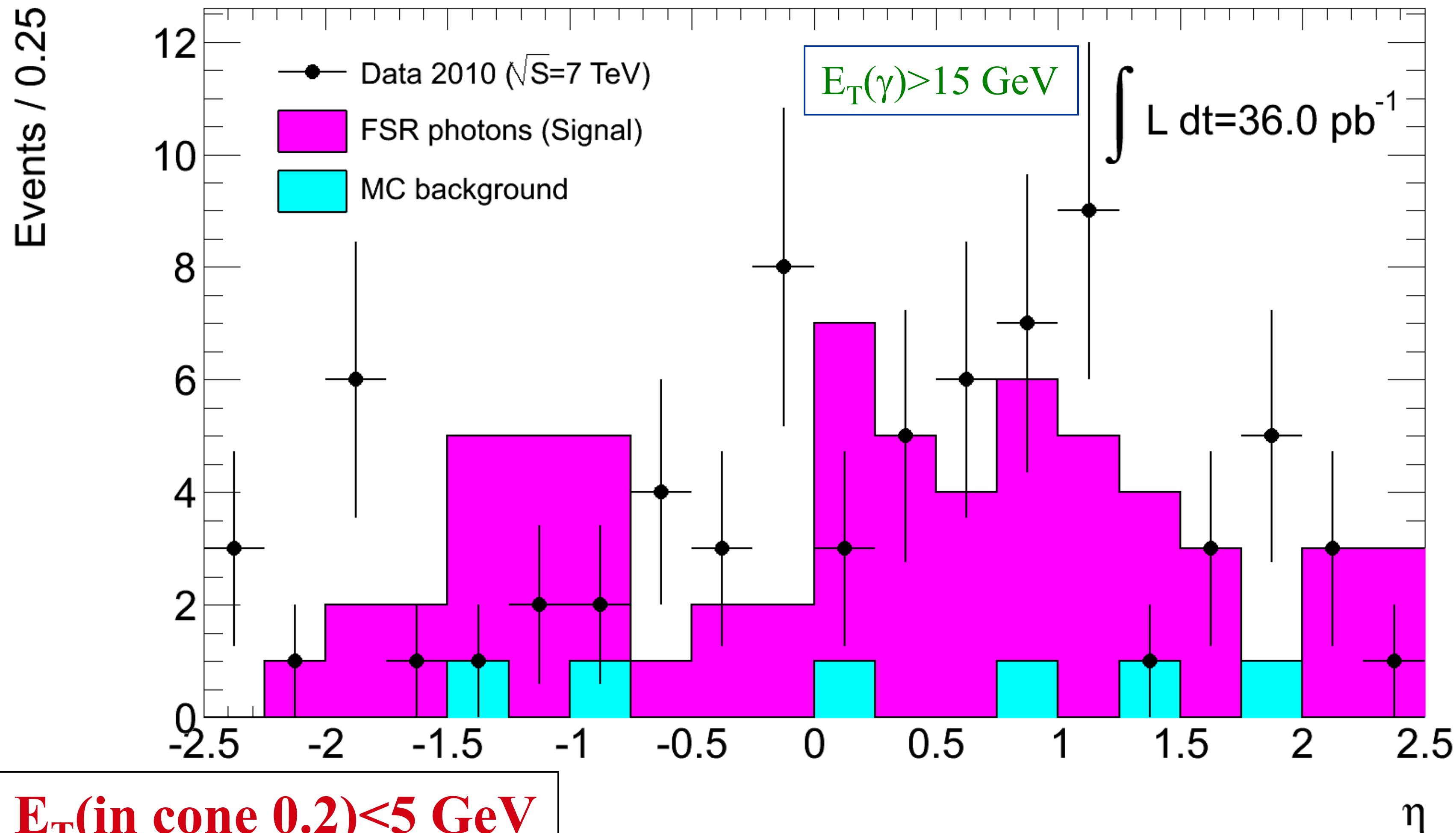
E_T(in cone 0.2)<5 GeV

FSR Photon candidates obtained after 60< m_{ee}<83 GeV & 40< $m_{\mu\mu}$<82 GeV windows requirement (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows, no tight cut) vs E_T



E_T(in cone 0.2)<5 GeV

FSR Photon candidates obtained after 60< m_{ee}<83 GeV & 40< $m_{\mu\mu}$<82 GeV windows requirement (in 80< $m_{ee\gamma}$<94 GeV & 81< $m_{\mu\mu\gamma}$<95 GeV mass windows, no tight cut) vs η



E_T(in cone 0.2)<5 GeV