A photon sample selection from $Z \to ll\gamma$ decay

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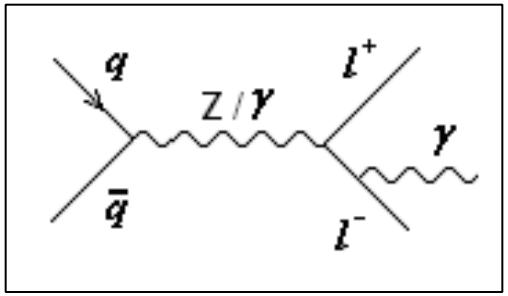
"Physics&Computing in ATLAS" – 22/09/2010

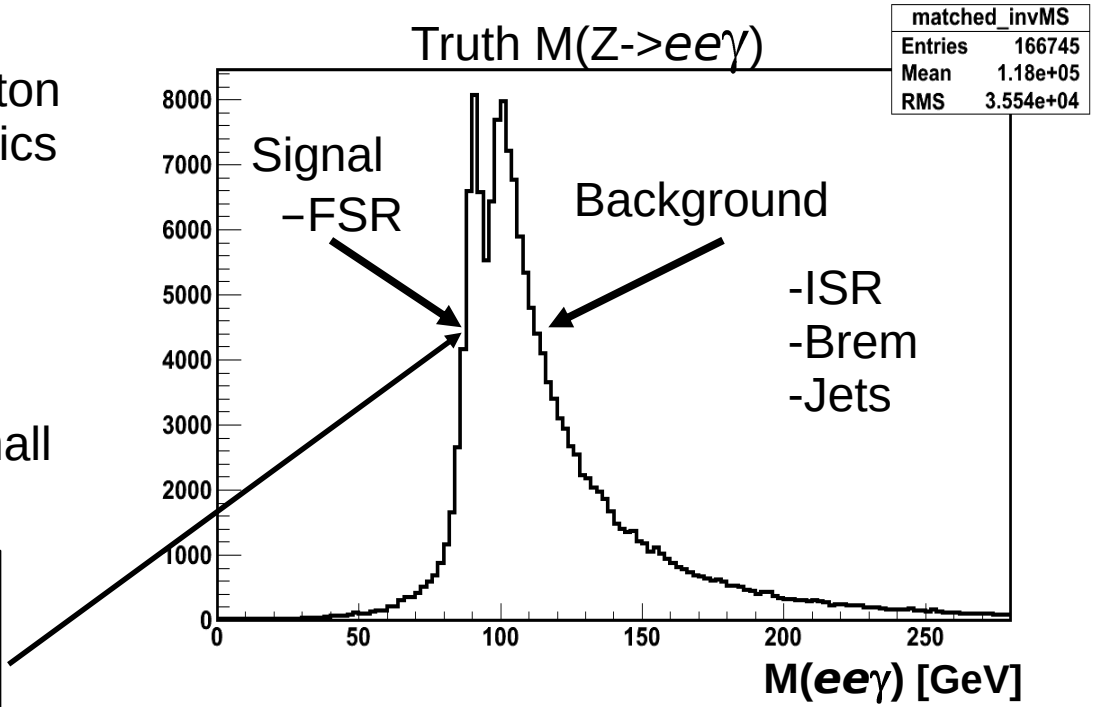
Outline:

- Motivation
- True level Signal Background
- Reconstruction level control plots
- Reconstruction Signal/Background optimization
- Results for Z -> $ee\gamma$
- Results for Z -> $\mu\mu\gamma$
- Conclusions

Photon sample selection using Z->//γ process

- Idea is to obtain pure photon sample from known physics process with distinctive kinematical feature -
  - -M(*ee*γ) and dR(*e*γ)
  - -M(μμγ) and dR(μγ)
- One of a problems is a small production cross section.





Main goal of the analysis is to find the signal selection method
- check Signal to Background ratio
- and statistical yield

MC sample and preselection

Public FullSim MC samples – 5M events ~4.5 fb^{-1}

$Z \rightarrow ee\gamma$

mc08.106050.PythiaZee_1Lepton.recon.AOD.e347_s462_r541_tid028253

$Z \rightarrow \mu\mu\gamma$

mc08.106051.PythiaZmumu_1Lepton.merge.AOD.e347_a84_t53_tid061356

$Et(\gamma) > 5$ GeV;

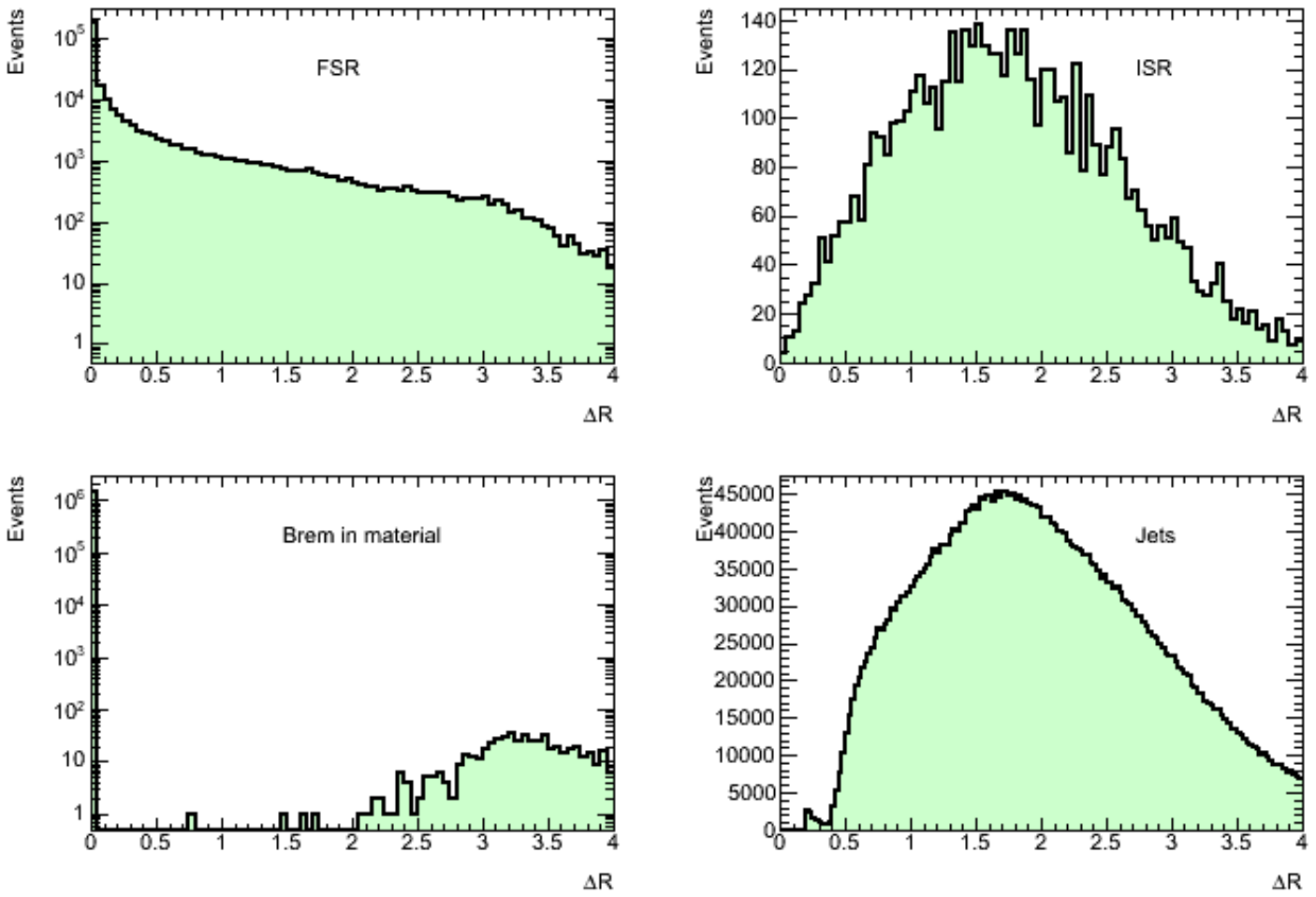
$Pt(e) > 15$ GeV; $Pt(\mu) > 15$ GeV;

$|\eta(e)| < 2.5$; $|\eta(\mu)| < 2.5$;

Public Analysis code rel. 15.6.1

Z -> *ee*γ signal and backgrounds (truth level)

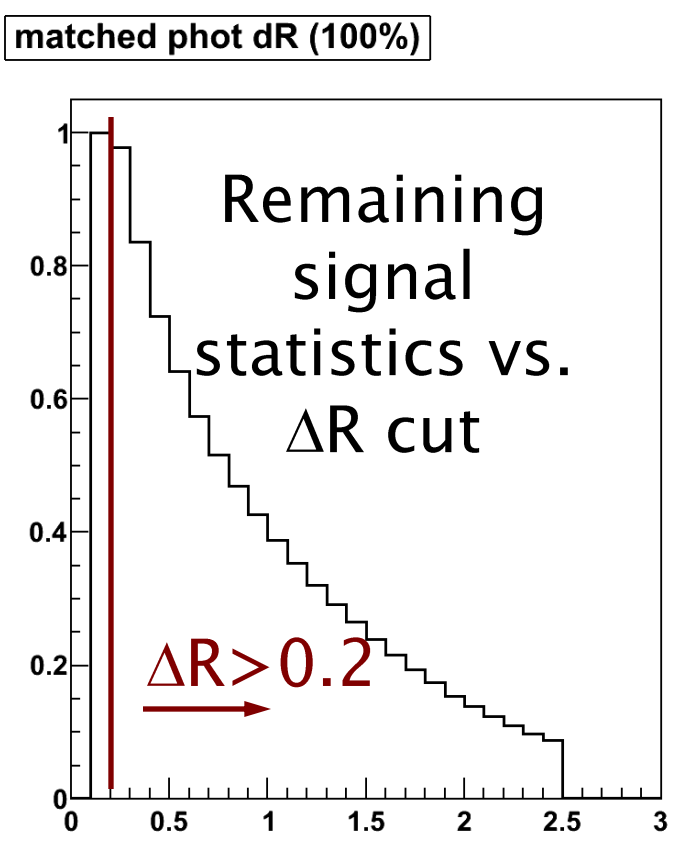
ΔR distribution for signal and all backgrounds (TRUTH)

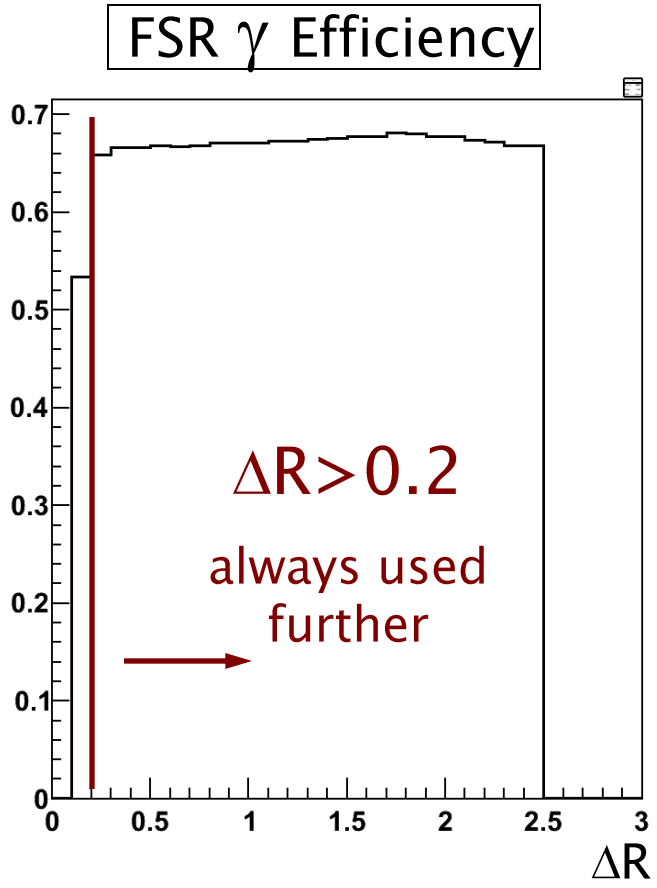


$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$ γ−to−closest lepton angle

ΔR cut selection

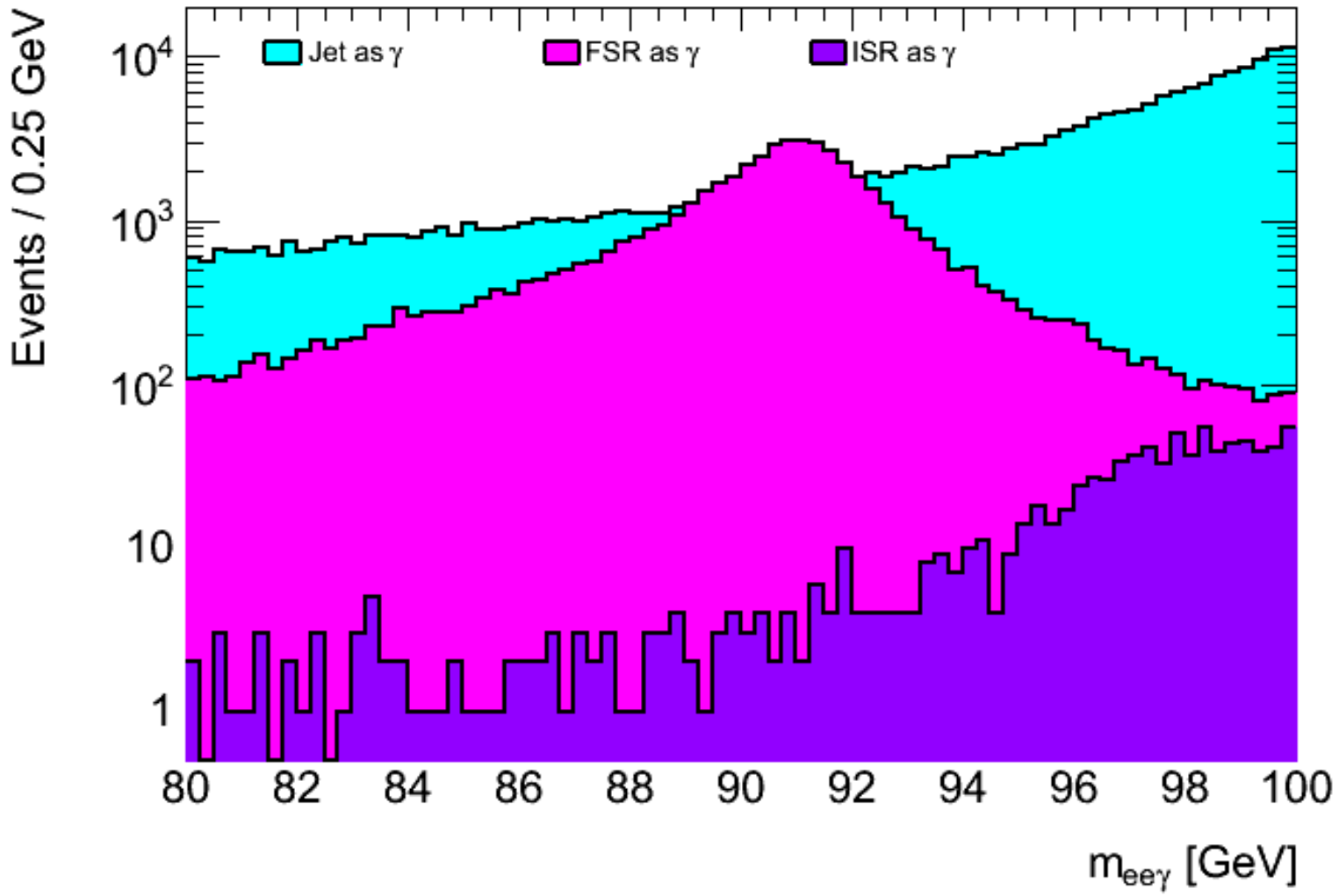
Remaining statistics & efficiency of photon reconstruction vs. ΔR cut.





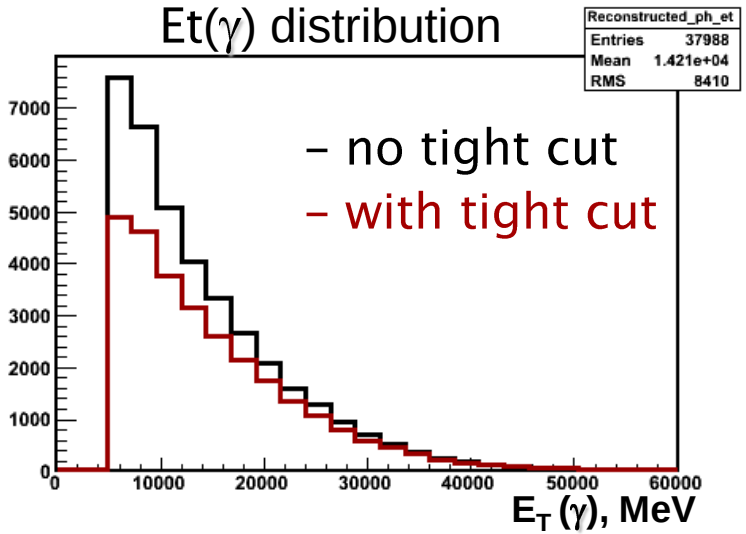
$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$$

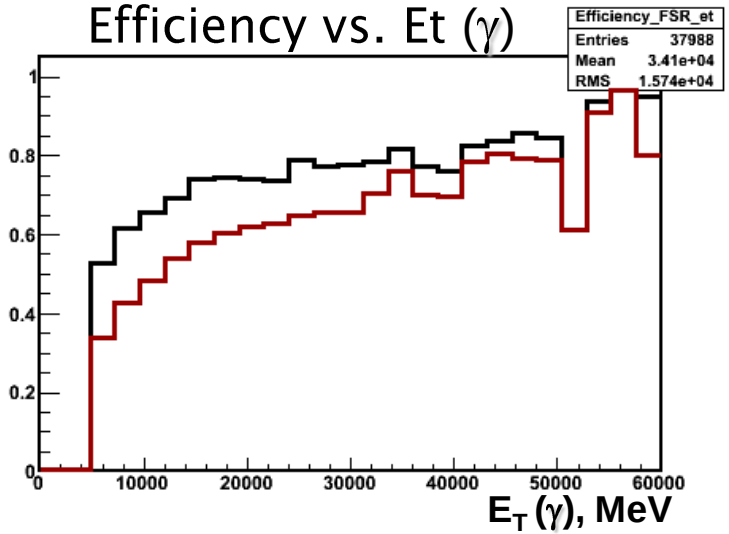
TRUTH invM(eeγ) for FSR, ISR and Jets (as photon)

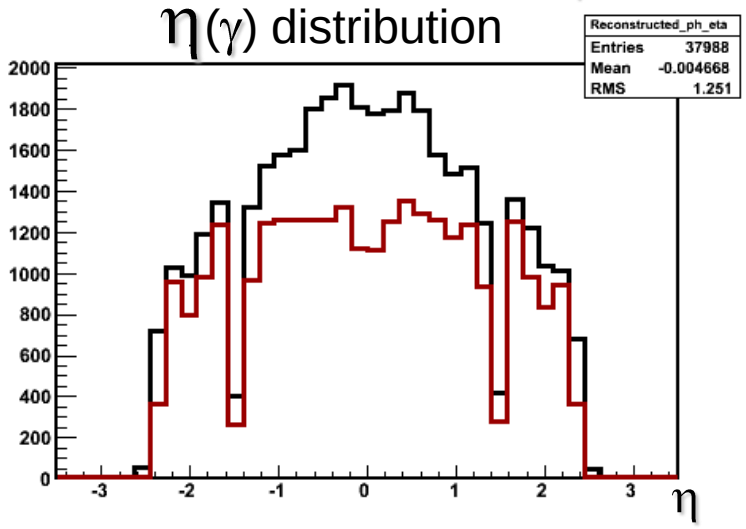


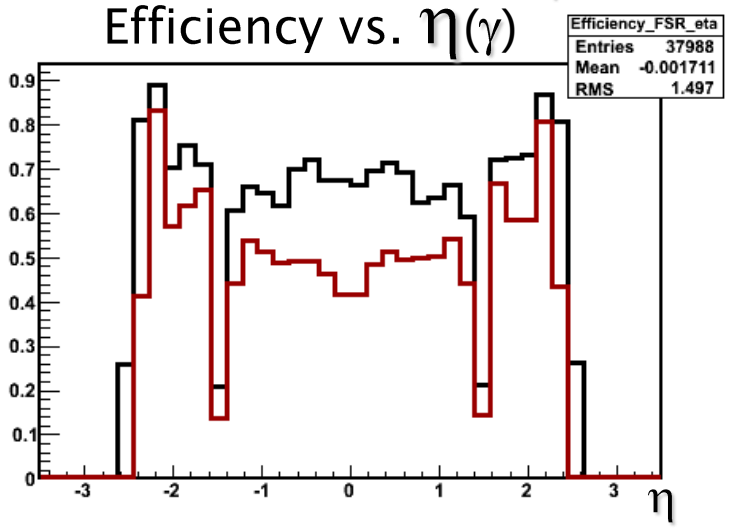
Z -> *ee*γ Reconstruction level

Control plots for reconstructed FSR photons (signal)



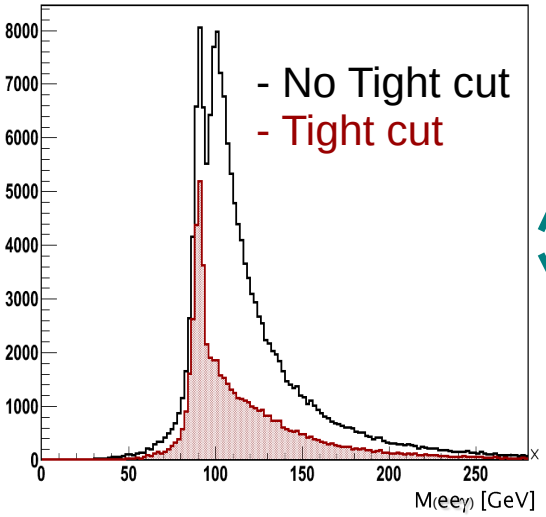


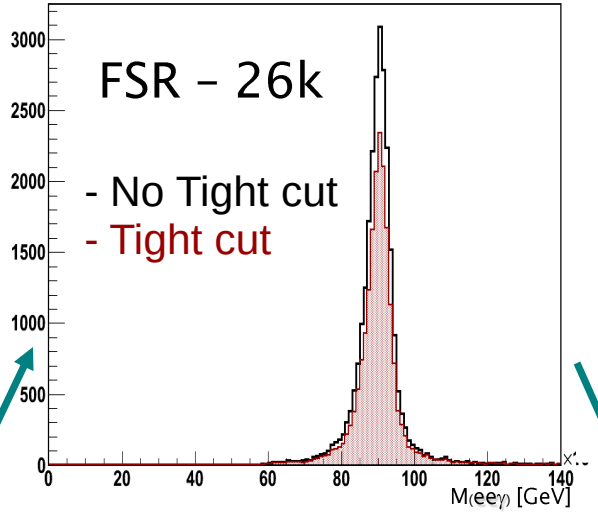


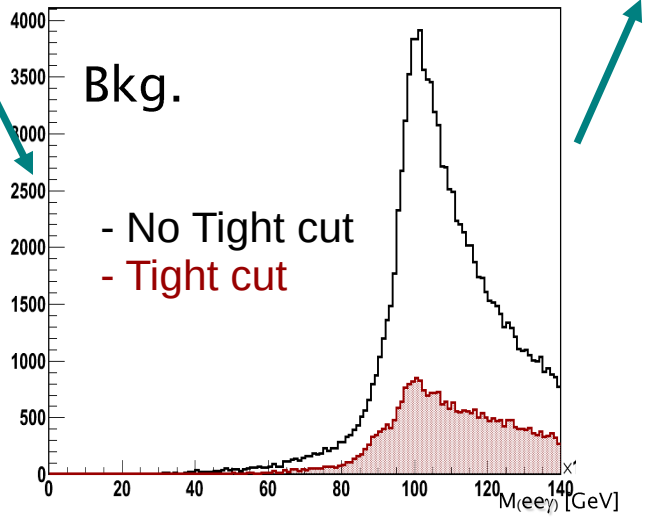


Reconstructed invM(eeγ)

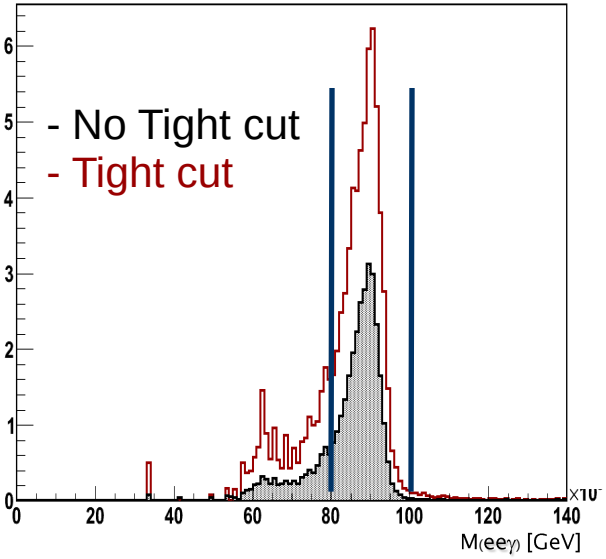
all Z-> eeγ events







Signal/Background



Optimal M((eeγ) window is 82<M(eeγ)<95 GeV (see backup slides)

$ee\gamma$ selection optimization

Usual selection:

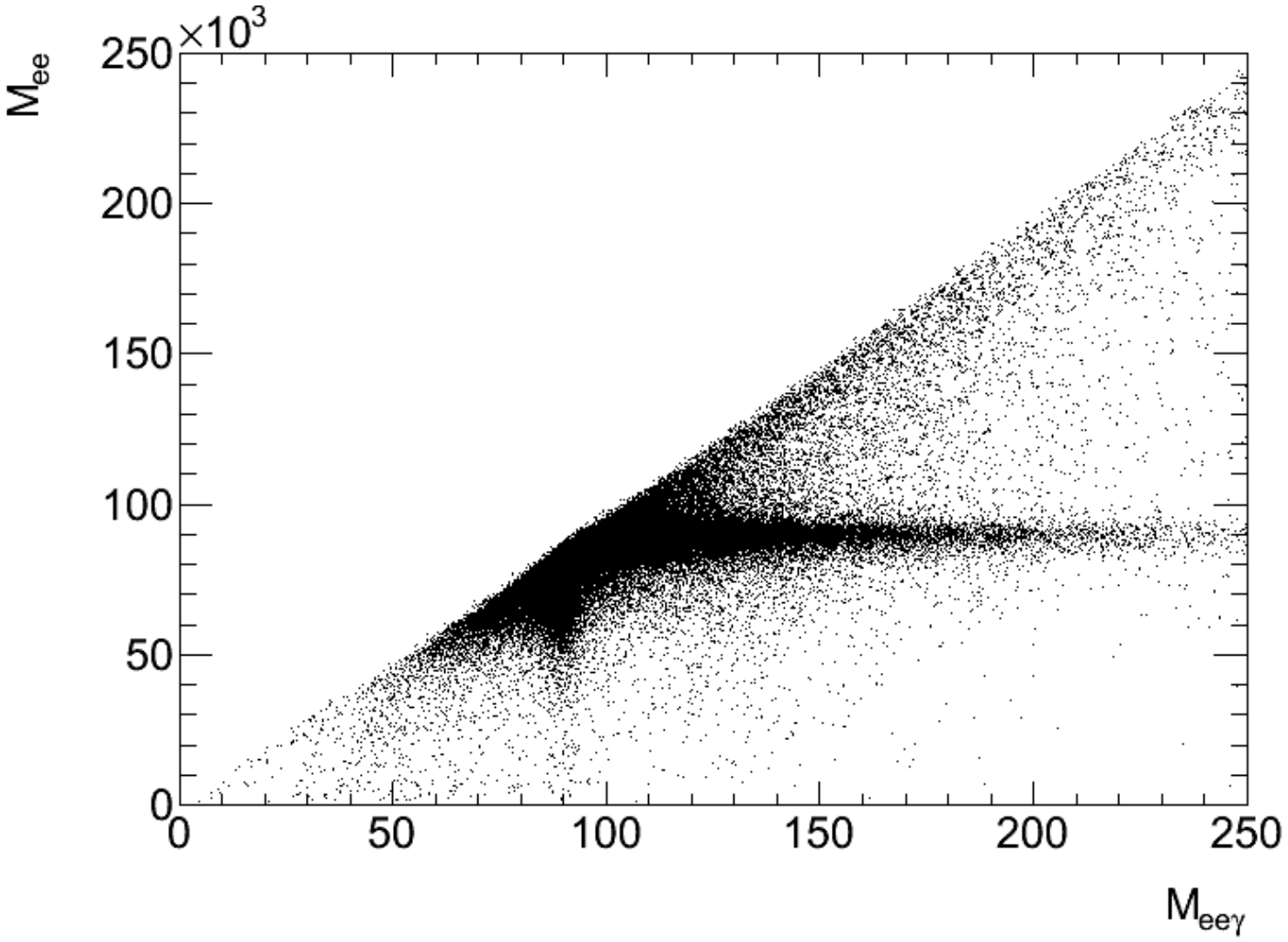
- Mass window 82<M($ee\gamma$)<95 GeV window
- Photon tight cut

Extra cuts:

- Mass window for invariant M(ee);
- Photon E_T cut;
- Upper ΔR cut.

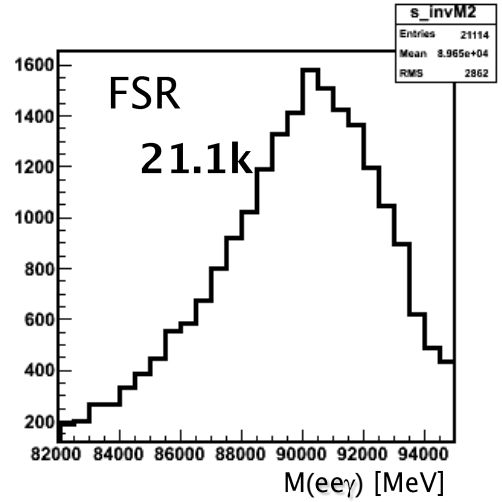
All these cuts will be applied sequentially to the signal with initial statistics **26139** events.

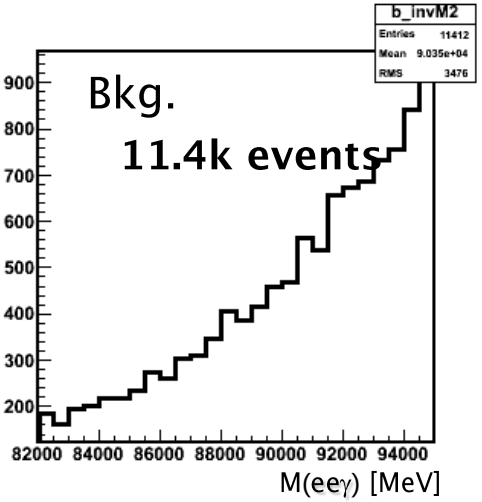
$ee\gamma$ mass selection optimization



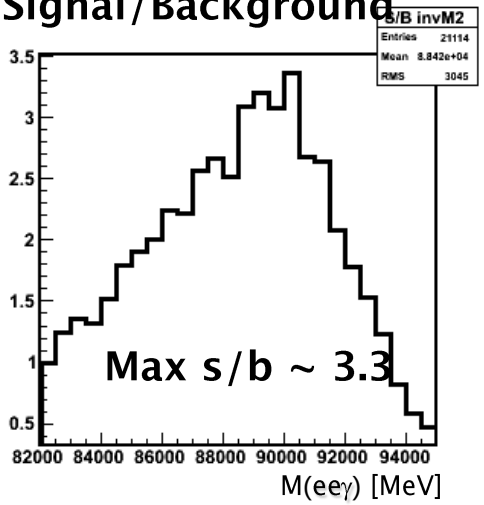
Reconstructed invM M(eeγ) - 82<M(eeγ)<95 GeV window

No tight CUT

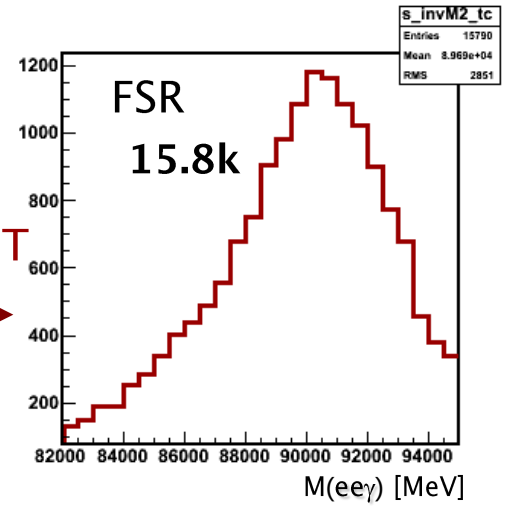


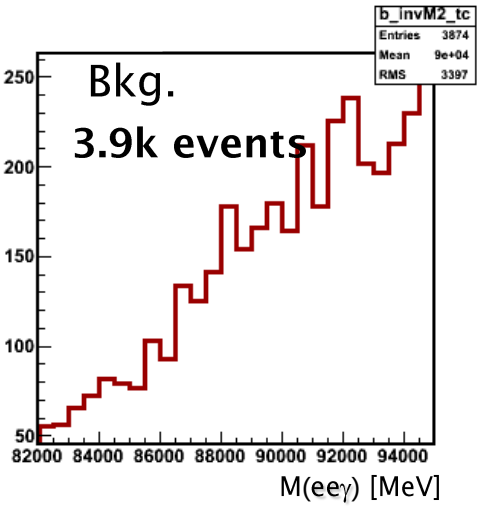


Signal/Background

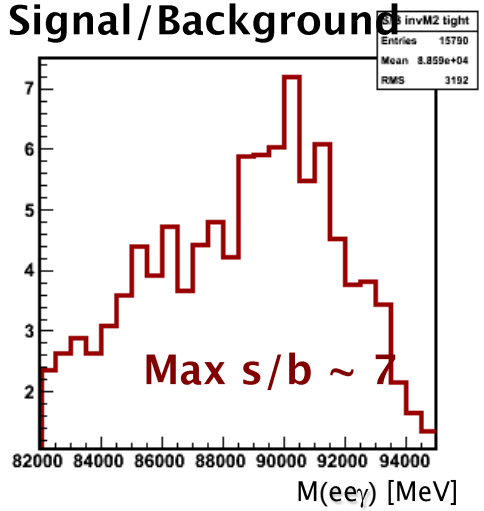


Tight CUT



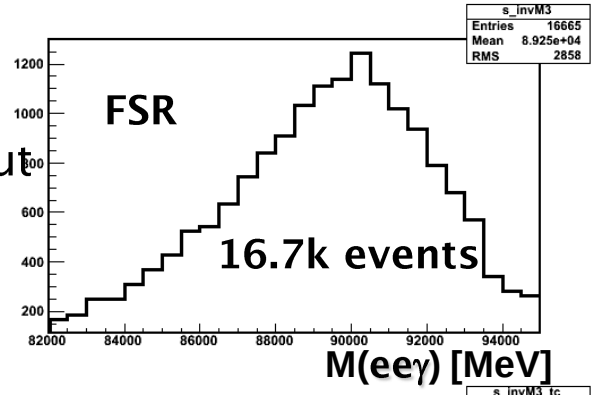


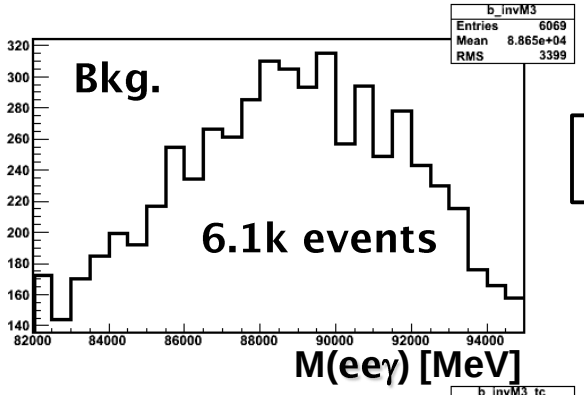
Signal/Background



Reconstructed invM(eeγ) @ 82<M(eeγ)<95 GeV & 50<M(ee)<82 GeV

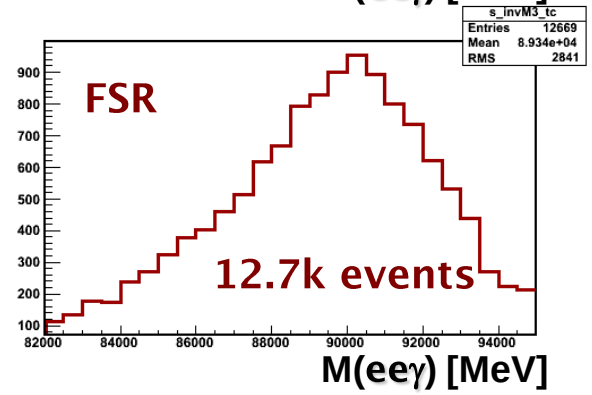
NO Tight cut →

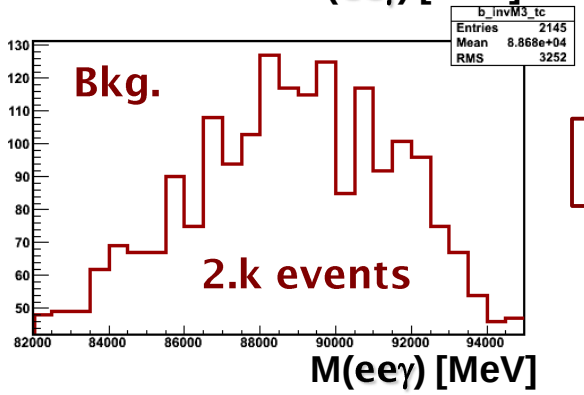




<S/B>~2.75

Tight cut →



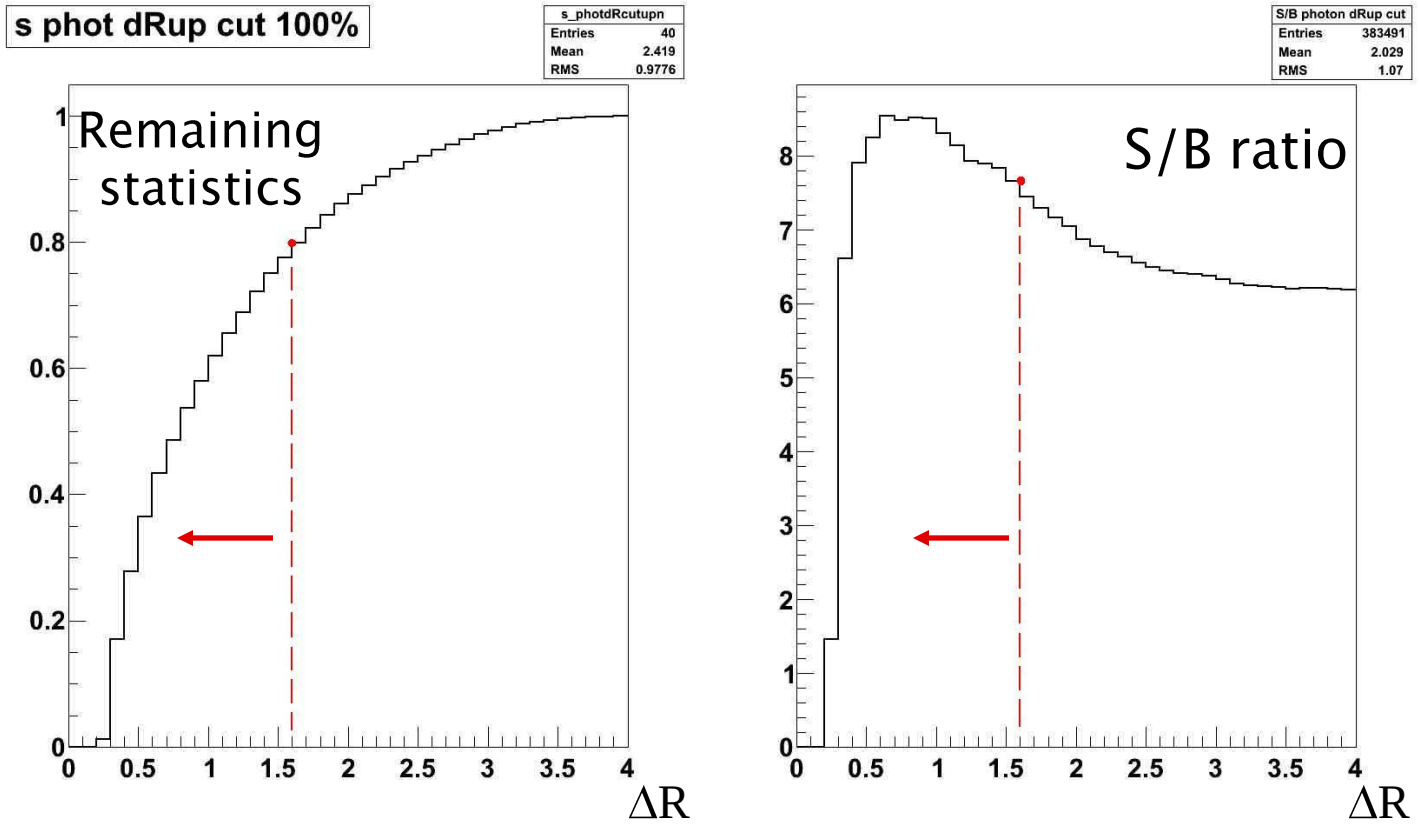


<S/B>~6.2

- 96% of background rejected if M(eeγ) and M(ee) window cuts applied
- 50% signal reduction (with tight cut)

Upper ΔR cut (Tight and M_{ee} cuts applied)

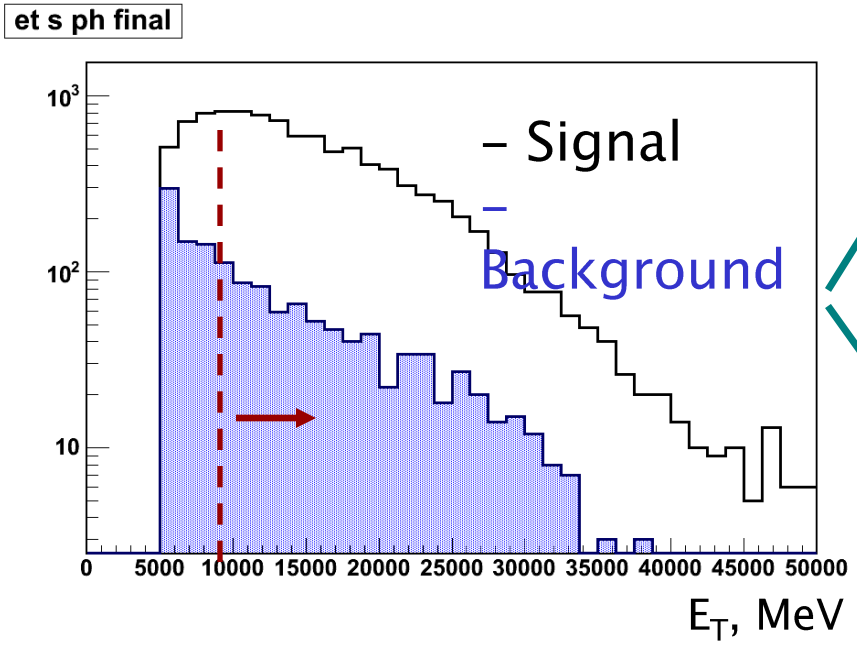
Remaining signal statistics and averaged s/b ratio (integral from 0.2 to upper ΔR cut) as a function of the upper ΔR cut with M_{ee} and tight cut.

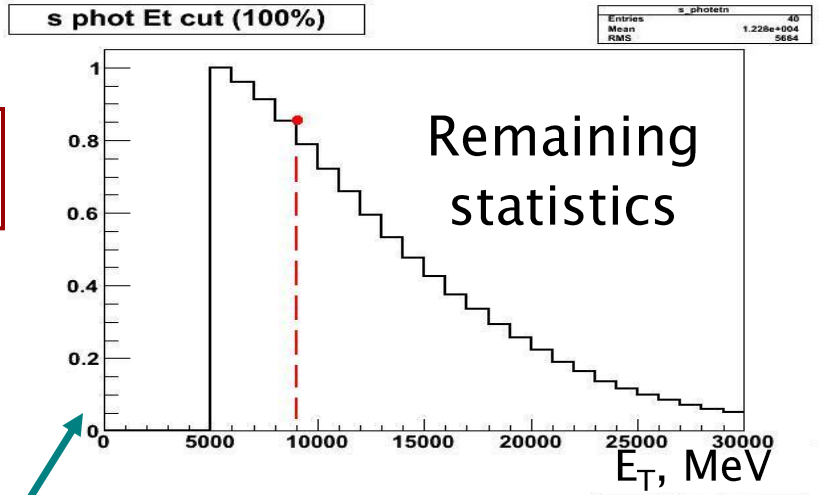


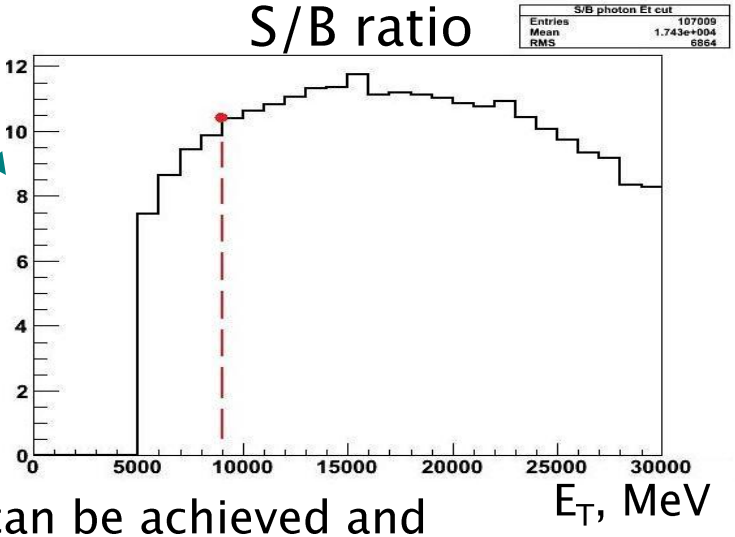
With the cut ΔR<1.6 the S/B ratio reaches level of **7.47** with remaining statistics **39%** of the initial one.

Effect of the low Et cut for photons (all previous cuts applied)

From E_T distribution, it is clear, that low E_T cut can give an effect



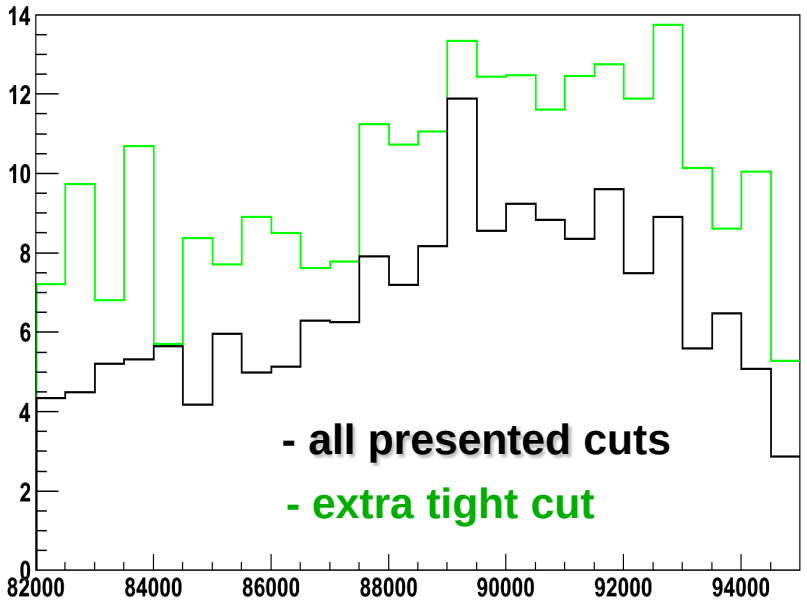




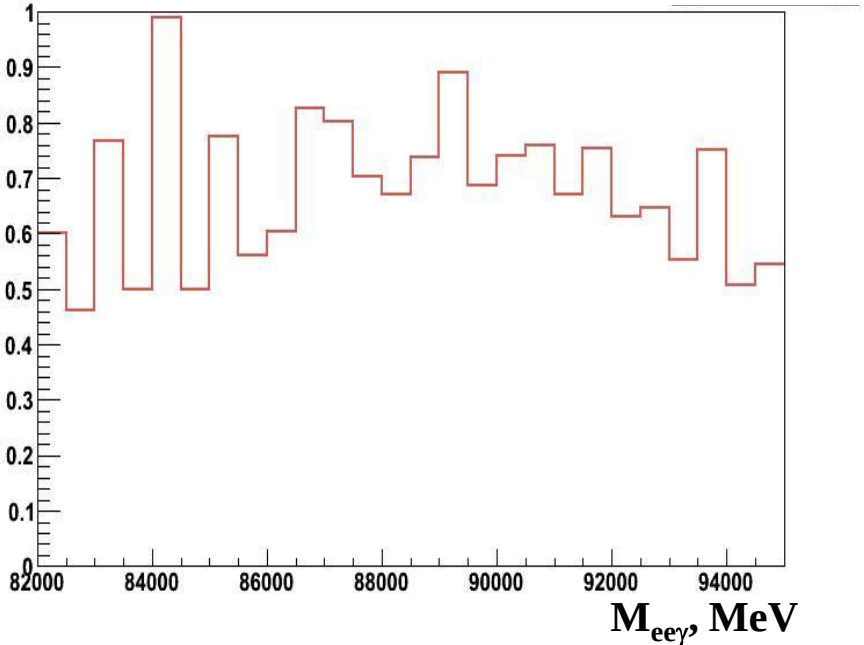
For E_T>9 GeV averaged S/B=**10.45** can be achieved and statistics is **31%** from the initial one.

Differential distributions of s/b ratio as a function of $InvM_{ee\gamma}$ for all previously presented cuts and with addition of the tight cut

S/B ratio



Ratio of S/B for selection w/o TightCut to selection with TightCut



For black line averaged S/B=**7.18** and remaining statistics is **39%** from the initial one. For green – it was given on the previous slide (**10.45** and **31%** accordingly).

Z->eeγ could be useful for the tight cut efficiency validation

Z -> $ee\gamma$ Selections Summary

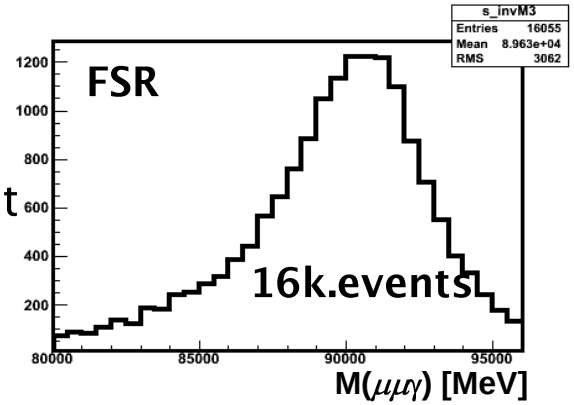
Selection	S/B ratio	Statistics from initial	Number of signal events
No cuts	0.18	100%	**26139**
Inv $M_{ee\gamma}$<95 GeV	1.40	89%	23221
+ Inv $M_{ee\gamma}$>82 GeV	1.87	82%	21499
+ Tight cut	4.22	62%	16112
+ Inv M_{ee}<82 GeV	5.58	53%	13770
+ Inv M_{ee}>50 GeV	6.19	50%	13004
+ ΔR<1.6	7.47	39%	10318
+ E_T>9 GeV	**10.45**	31%	8187

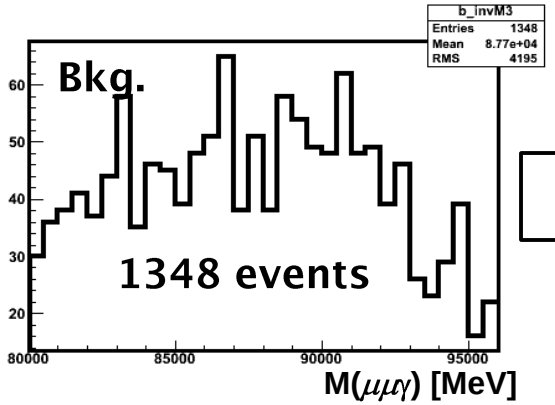
Z -> $\mu\mu\gamma$ Reconstruction level

Reconstructed invM($\mu\mu\gamma$) @ 80<M($\mu\mu\gamma$)<96 GeV & 15<M($\mu\mu$)<80 GeV

Same ΔR>0.2 used

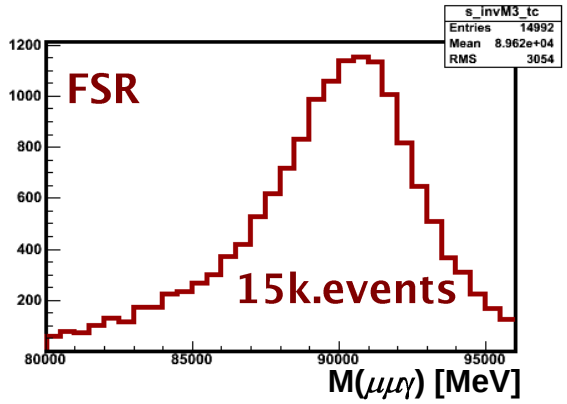
NO Tight cut →

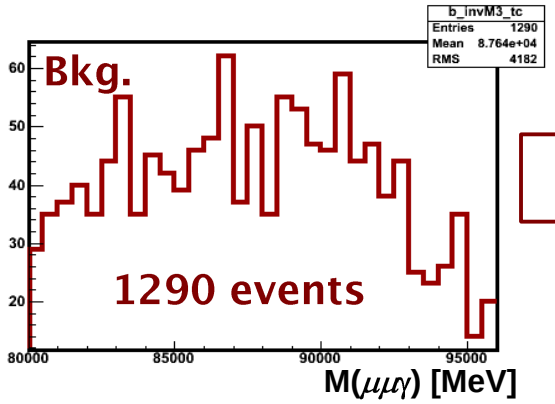




<S/B>~11.9

Tight cut →





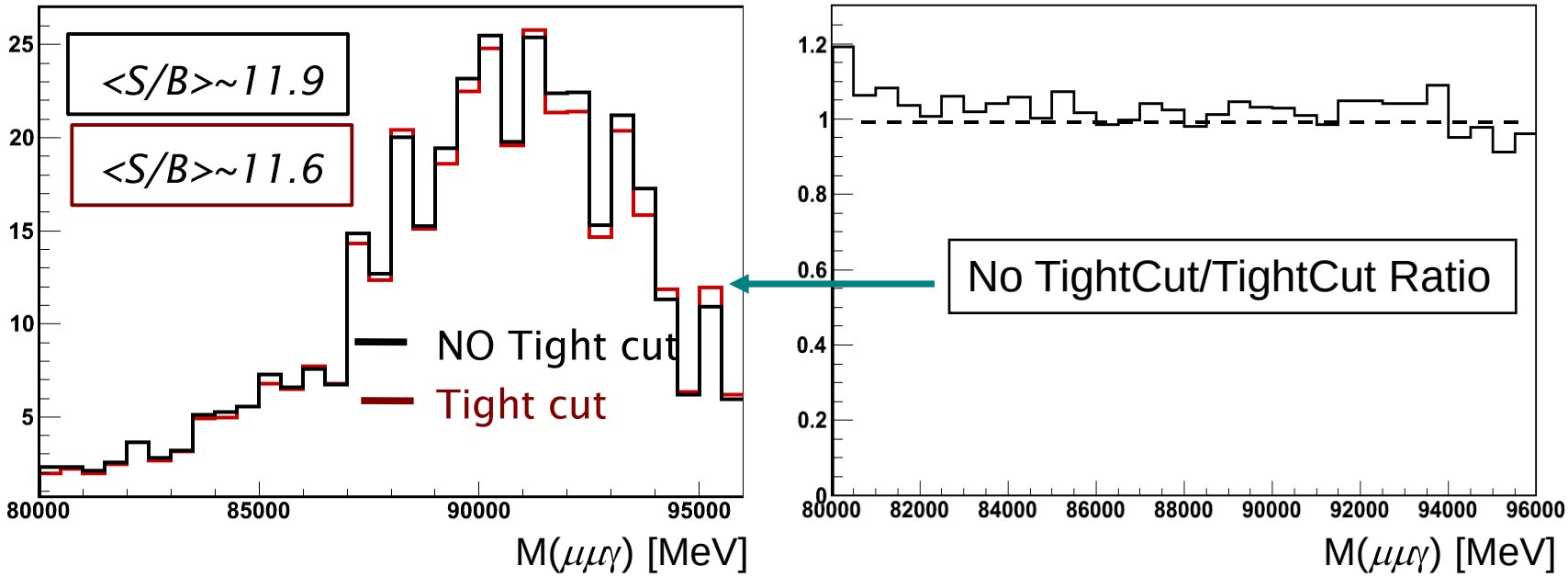
<S/B>~11.6

- 99% of background rejected if M($\mu\mu\gamma$) and M($\mu\mu$) cuts applied
- 30% signal reduction

- Tight cut has marginal effect on selection if M($\mu\mu\gamma$) and M($\mu\mu$) cuts applied

Differential Signal to Background Ratio as a function of invM($\mu\mu\gamma$)

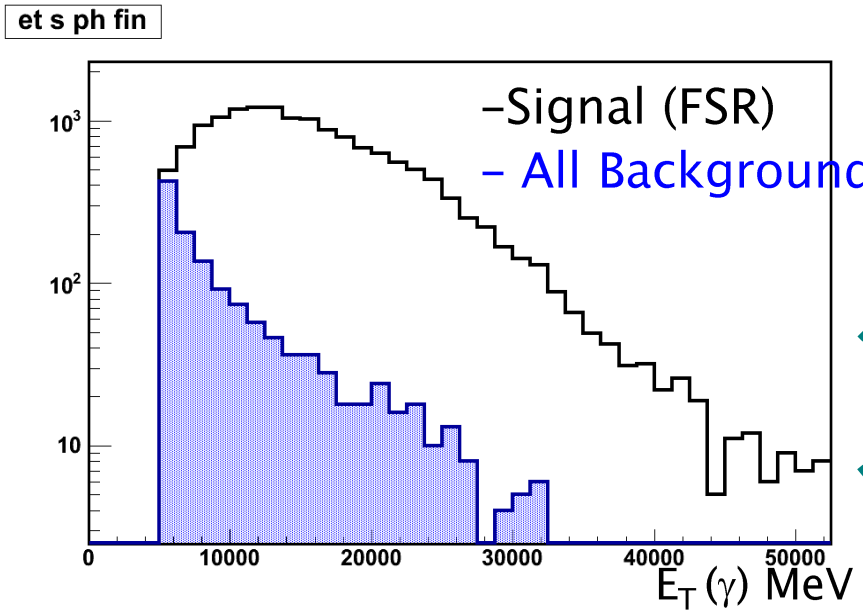
80<M($\mu\mu\gamma$)<96 GeV & 15<M($\mu\mu$)<80 GeV

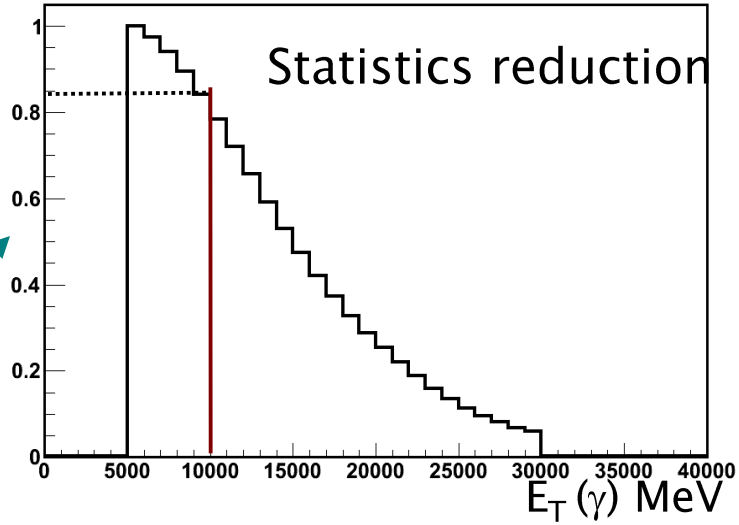


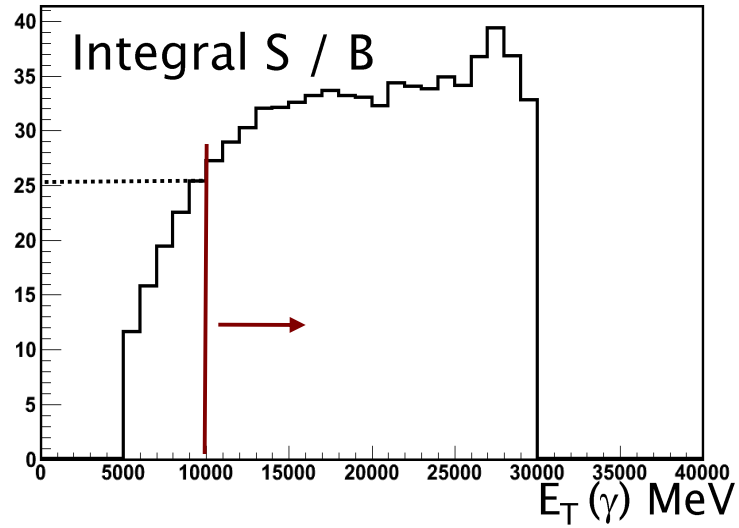
Tight cut has a marginal effect on selection if M($\mu\mu\gamma$) and M($\mu\mu$) cuts applied

Z->$\mu\mu\gamma$ could be useful for the tight cut efficiency validation.

Low Et(γ) selection @ 80<M($\mu\mu\gamma$)<96 GeV & 15<M($\mu\mu$)<80 GeV







For Et(γ) >10 GeV; => <S/B>~25;

Cost – 15% of signal events and Et(γ) range

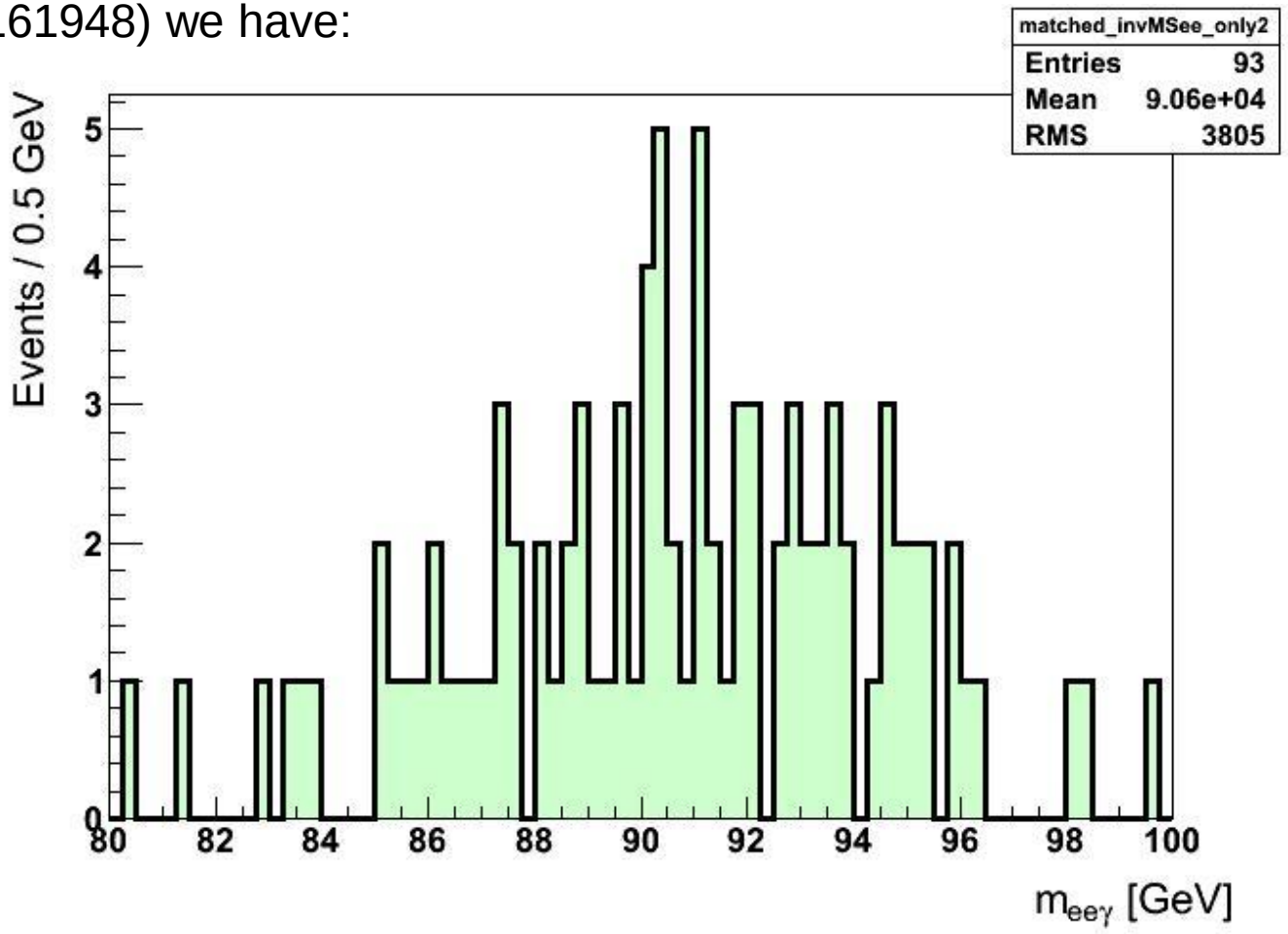
Z -> $\mu\mu\gamma$ selections Summary

Public FullSim MC sample of Z -> $\mu\mu\gamma$ – 5M events ~4.5 fb^{-1}

Selection	<S/B> ratio	Remaining events	Number of signal events
No Cuts	0.25	100%	33173
80<M($\mu\mu\gamma$)<96 GeV	2.4	86%	28523
+ Tight cut	6.7	65%	21516
15<M($\mu\mu$)<80 GeV No Tight cut	11.9	48%	16055
15<M($\mu\mu$)<80 GeV +Tight cut	11.6	45%	14992
+Et(γ) >10	25	41%	13600

About real data (I)

After all Z-boson note (ATL-COM-PHYS-2010-701) cuts for 310 nb^{-1} (runs 161520-161948) we have:



About real data (II)

Probability of considering process is ~0.5% of Z decays to two leptons. (For previous slide picture – 0 such events).

Expecting integral luminosity this year: ~60 pb^{-1} → ~20k of Z (~100 our photons);

Expecting luminosity next year: ~1 fb^{-1} → ~1M of Z (~5000 our photons).

So in the end of this year there will be necessary statistics for start of the analysis such process. But good analysis and good photon sample to obtain (there will be losses of statistics due to cuts) will be possible in the next year.

Conclusions

–Selection of a pure photons in the process Z -> $ee\gamma$ & Z -> $\mu\mu\gamma$ has been studied using 5M (~4.5 fb^{-1}) events MC samples.

– Tight cut allows to identify 62% of photons with the signal–to–background ratio of 4.2 ($ee\gamma$) and 6.7($\mu\mu\gamma$) in the invariant mass range 82–95 GeV.

- Z -> $ee\gamma$: set of cuts 82<M($ee\gamma$)<95 GeV & 50<M(ee)<82 GeV & Et(γ) >9 GeV & 0.2<ΔR<1.6 provides ~8200 photons with purity ~90%

- Z -> $\mu\mu\gamma$: set of cuts 80<M($ee\gamma$)<96 GeV & 15<M(ee)<82 GeV & Et(γ) >10 GeV & 0.2<ΔR provides ~13600 photons with purity ~96%

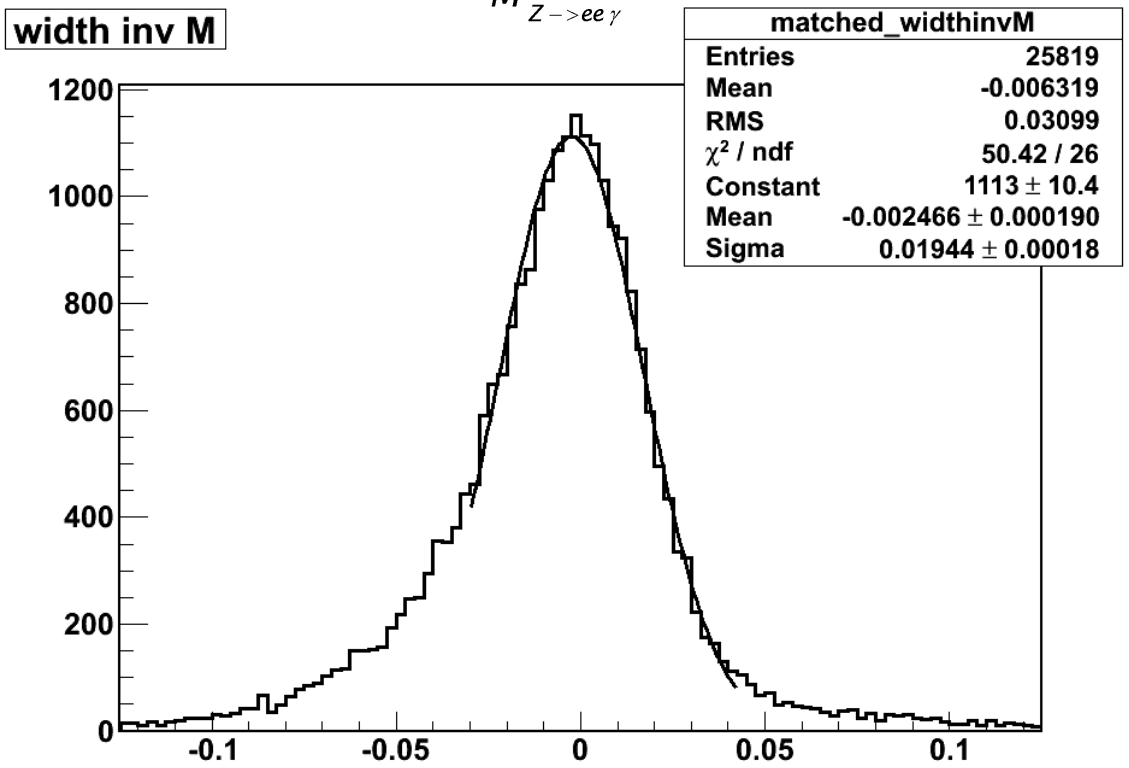
- Tight cut has a marginal effect on selection if M($\mu\mu\gamma$) and M($\mu\mu$) applied. Means that Tight cut can be studied using Z -> $\mu\mu\gamma$.

– All in all, about ~22k pure photons from ~4.5 fb^{-1} can be selected using Z boson decays to electrons and muons using proposed method. Analysis of the real data statistics has been done.

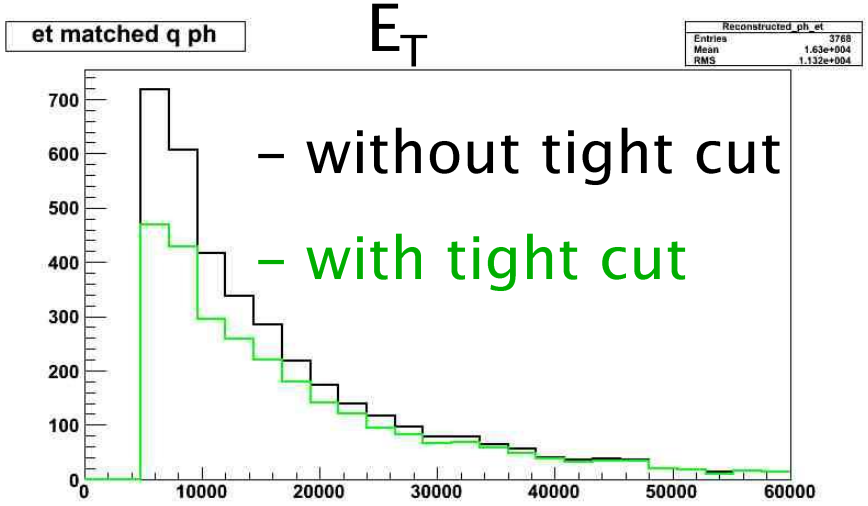
Backup slides

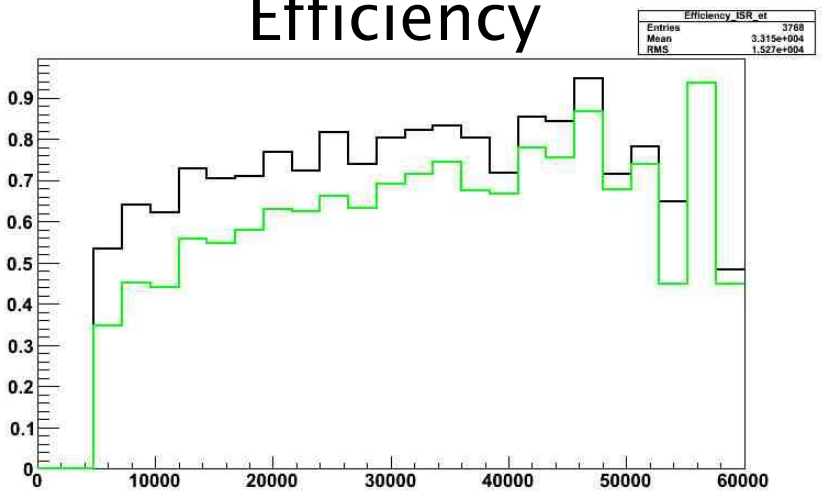
Resolution of reconstructed invM(eeγ), FSR only

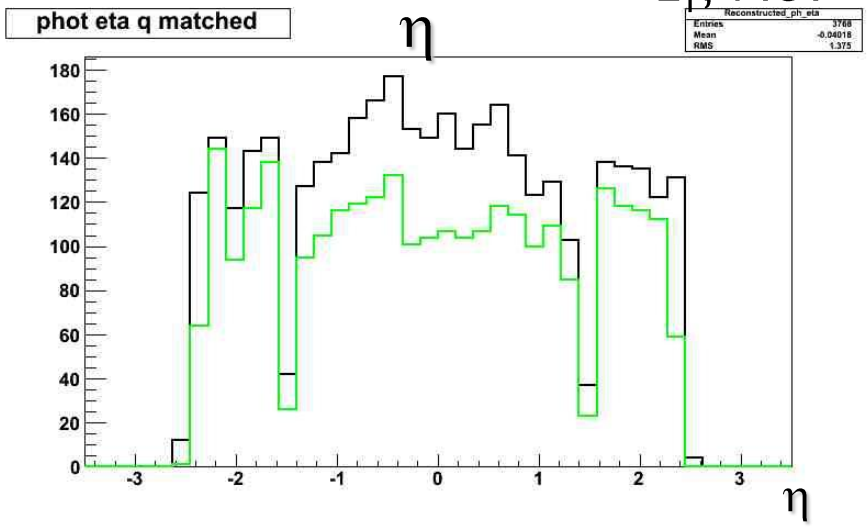
$$\frac{M^{reco}_{ee\gamma} - M^{truth}_{Z->ee\gamma}}{M^{truth}_{Z->ee\gamma}}$$

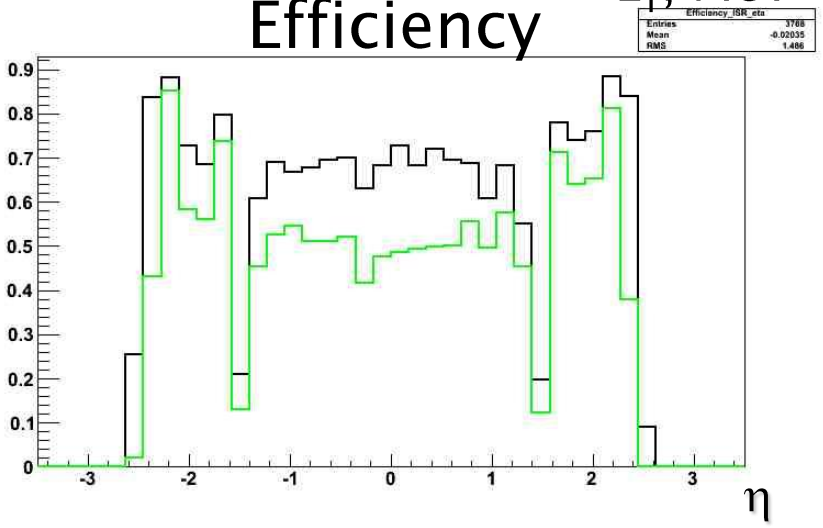


E_T and η distributions for reconstructed ISR photons (background) matched with truth and reconstruction efficiency



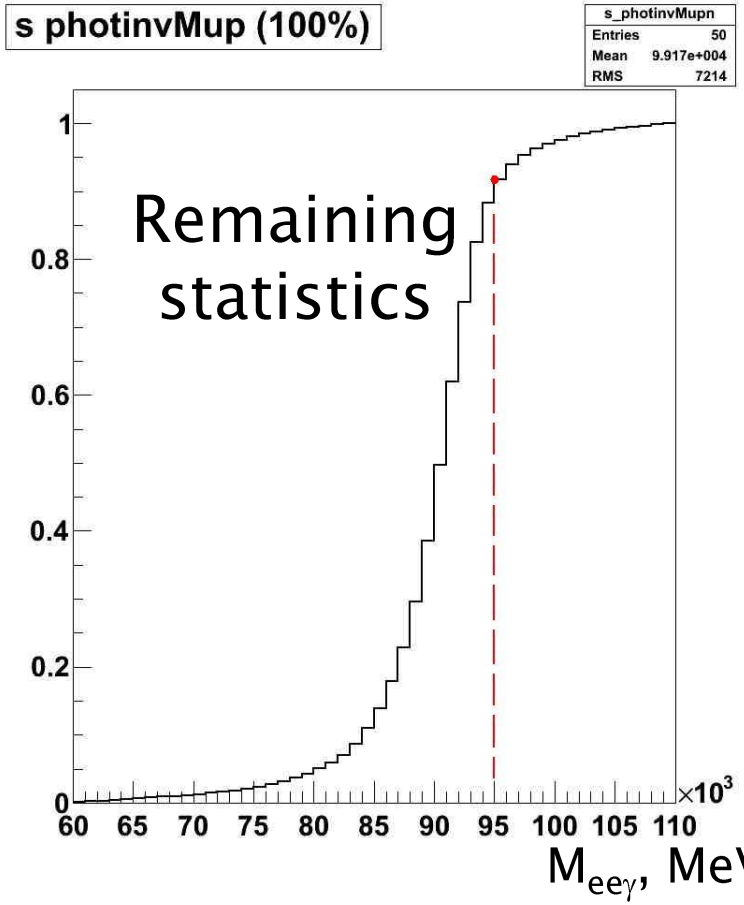


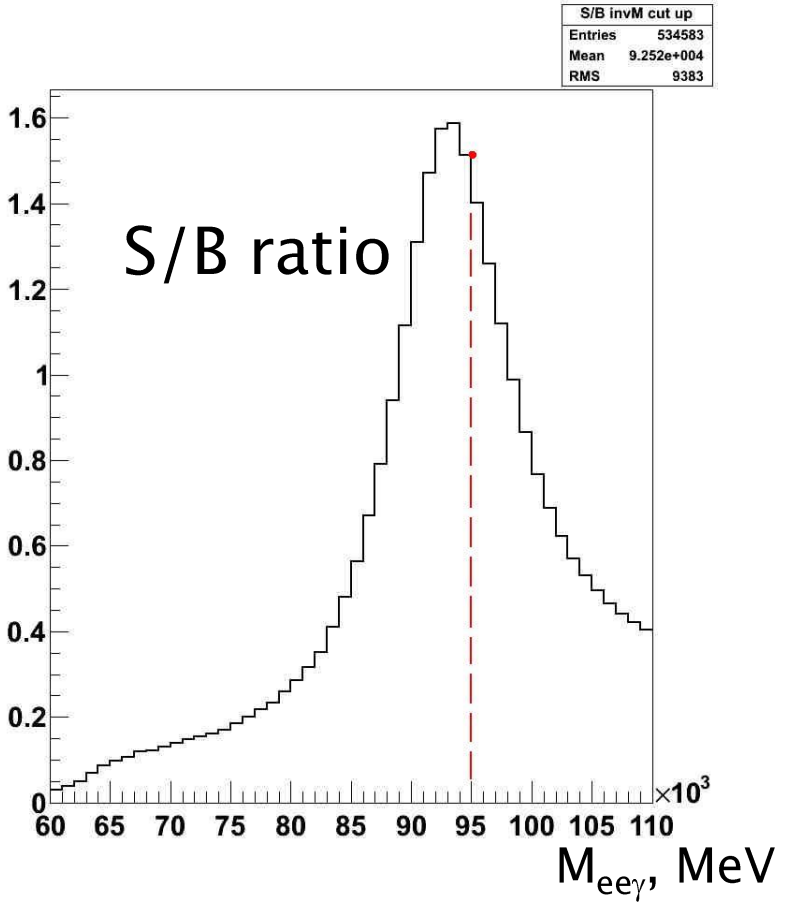




A choice of the mass window for Z→eeg – decay study (I)

Here presented the remaining signal statistics and averaged s/b ratio (integral from 0 to $M_{ee\gamma}$ limit) as a function of the upper $M_{ee\gamma}$ limit.

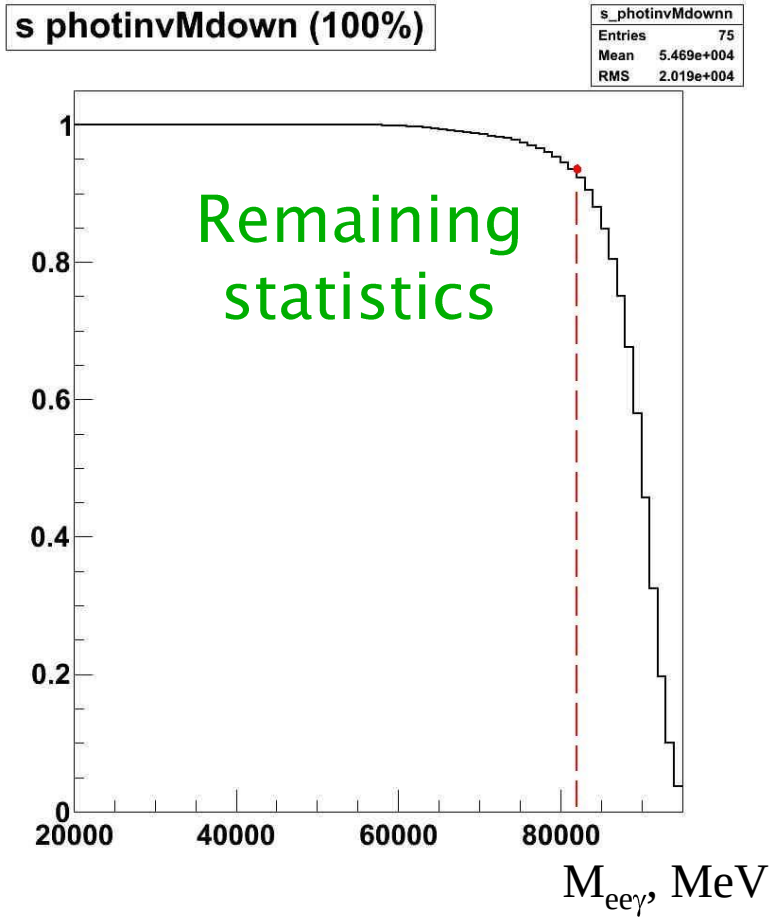


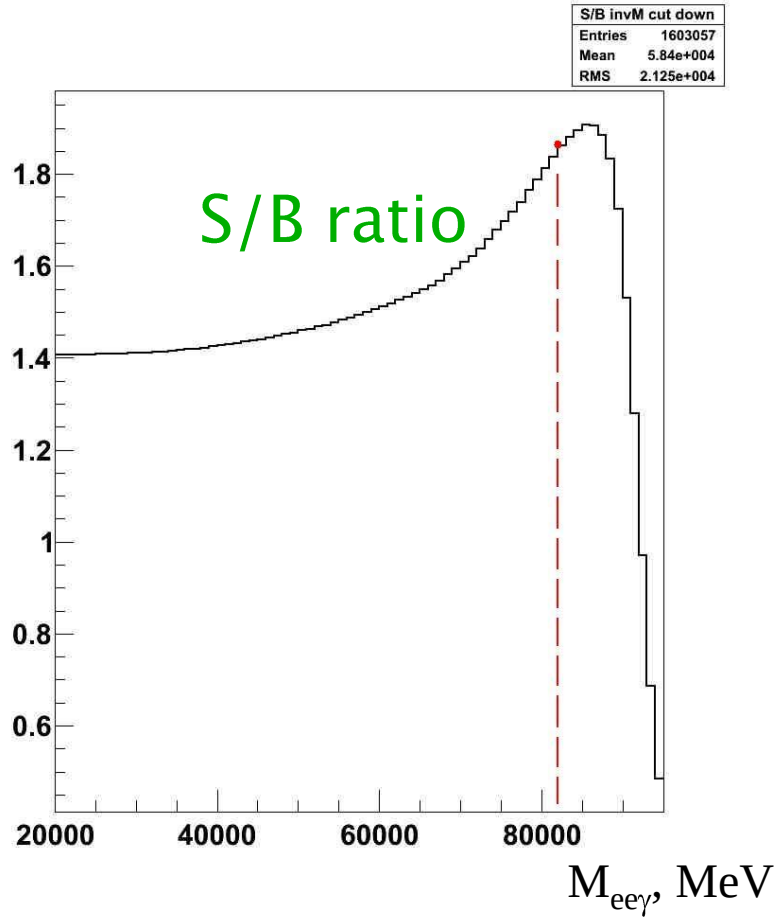


With the cut $M_{ee\gamma}$<95 GeV averaged S/B=**1.4** and statistics is **89%** of the initial one.

A choice of the mass window for Z→eeg – decay study (II)

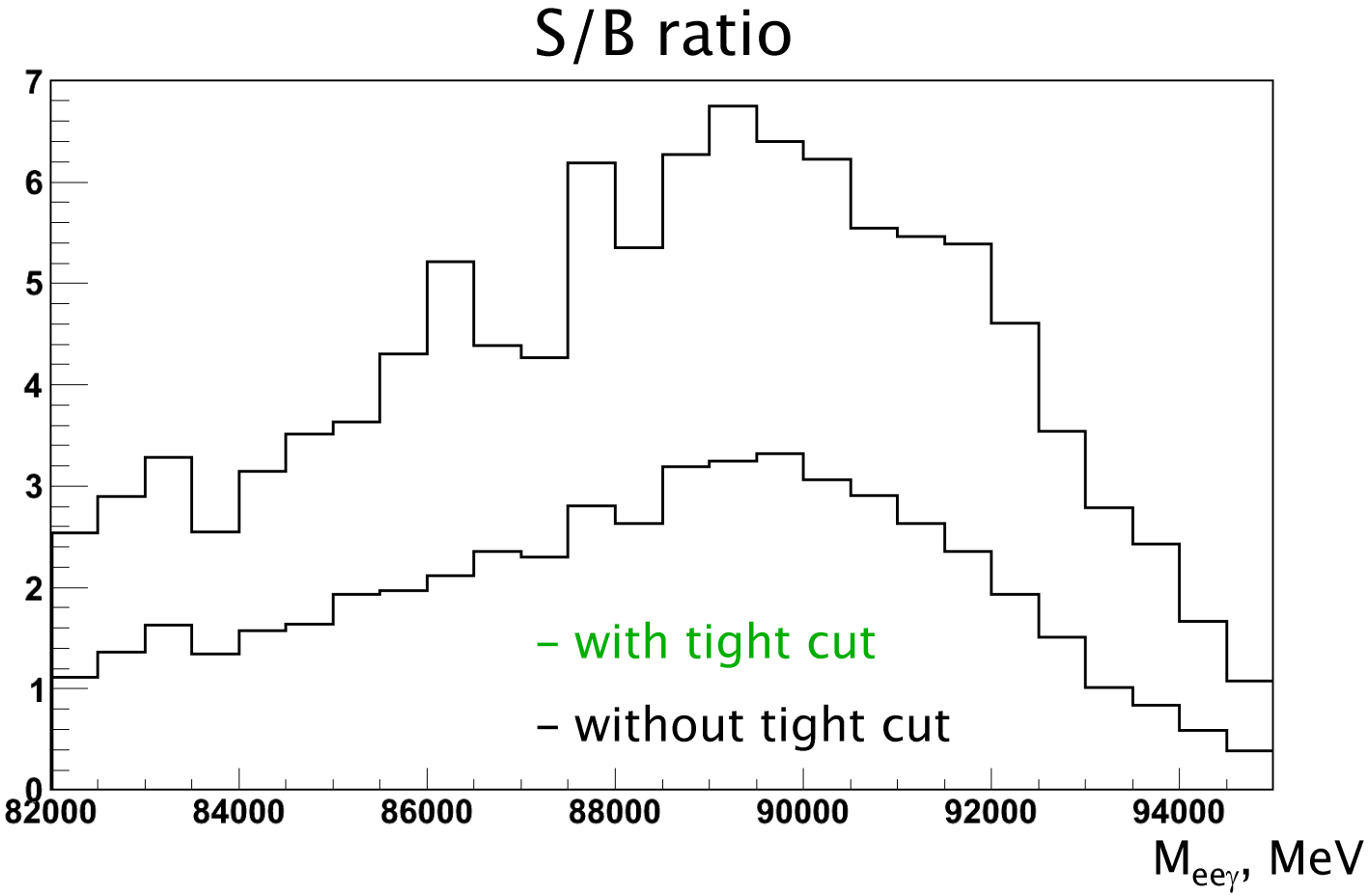
Here presented the remaining signal statistics and averaged s/b ratio (integral from bottom $M_{ee\gamma}$ limit to 95 GeV) as a function of bottom $M_{ee\gamma}$ limit.





Further interval mass 82< $M_{ee\gamma}$<95 GeV, with averaged S/B=**1.87** will be used for analysis (statistics is **82%** of the initial one).

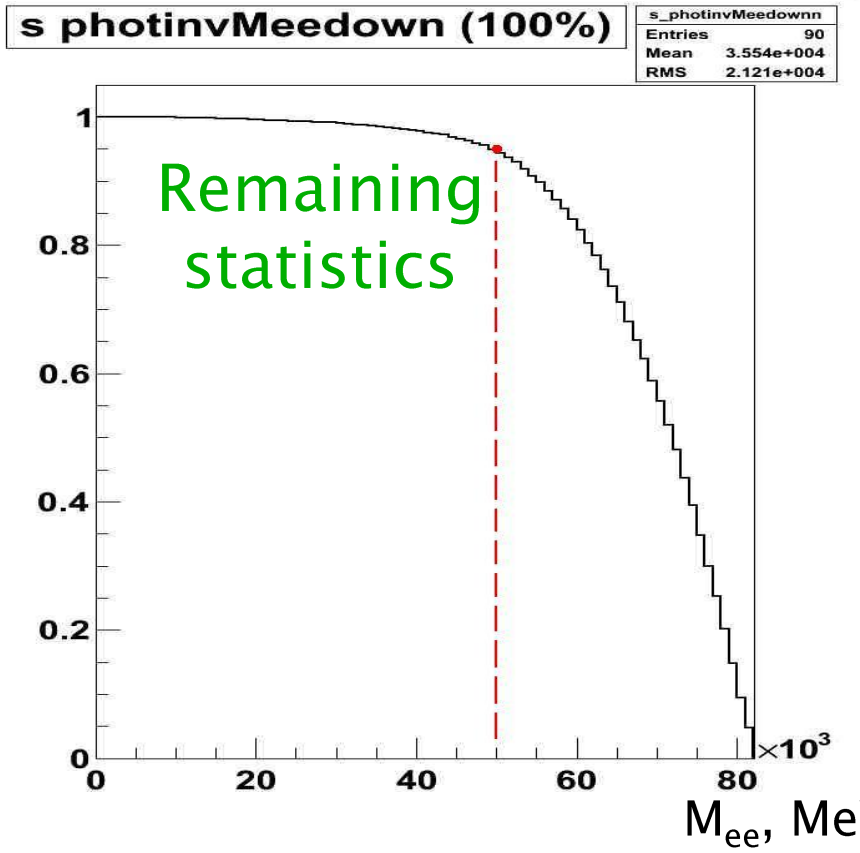
Differential distributions of s/b ratio as a function of $InvM_{ee\gamma}$ for $InvM_{ee\gamma}$

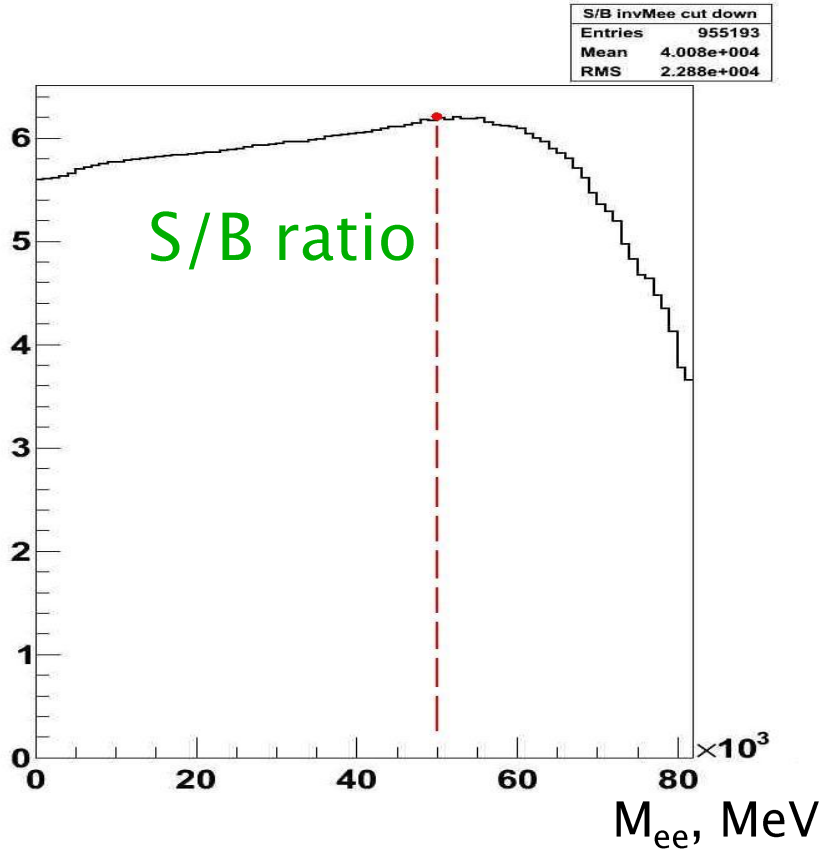


With the tight cut averaged S/B ratio in the chosen mass window is **4.22**. Remaining statistics is **62%** of initial.

Bottom cut for the Invariant Mass of **two** electrons. Upper cut is 82 GeV *(additional to the tight cut)*

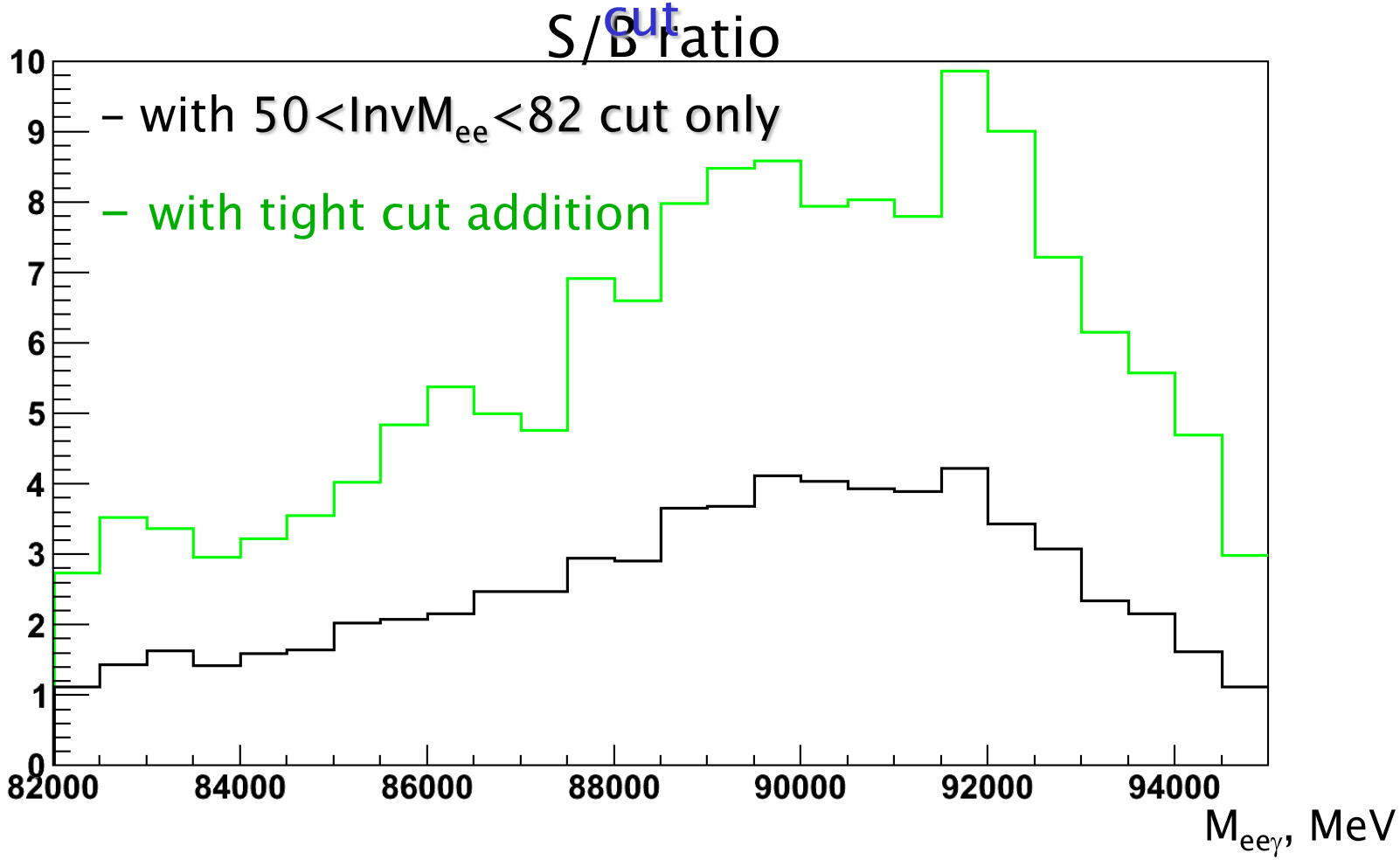
Here presented the remaining signal statistics and averaged s/b ratio (integral from bottom M_{ee} limit to 82 GeV) as a function of bottom M_{ee} limit.





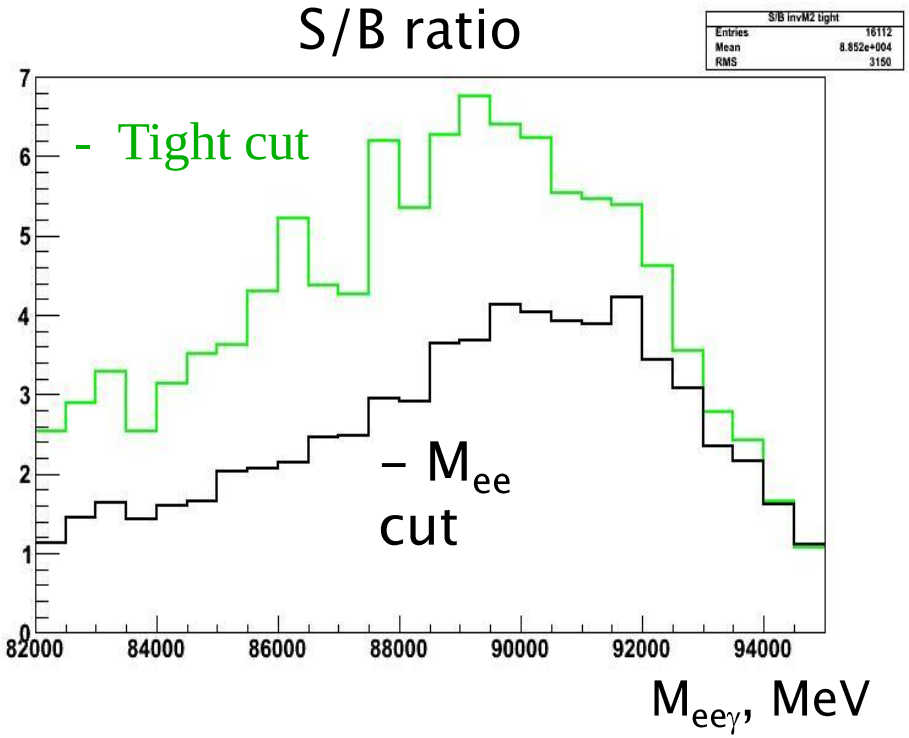
For the cut M_{ee}>50 GeV averaged S/B=**6.19** and remaining statistics is **50%** from the initial one.

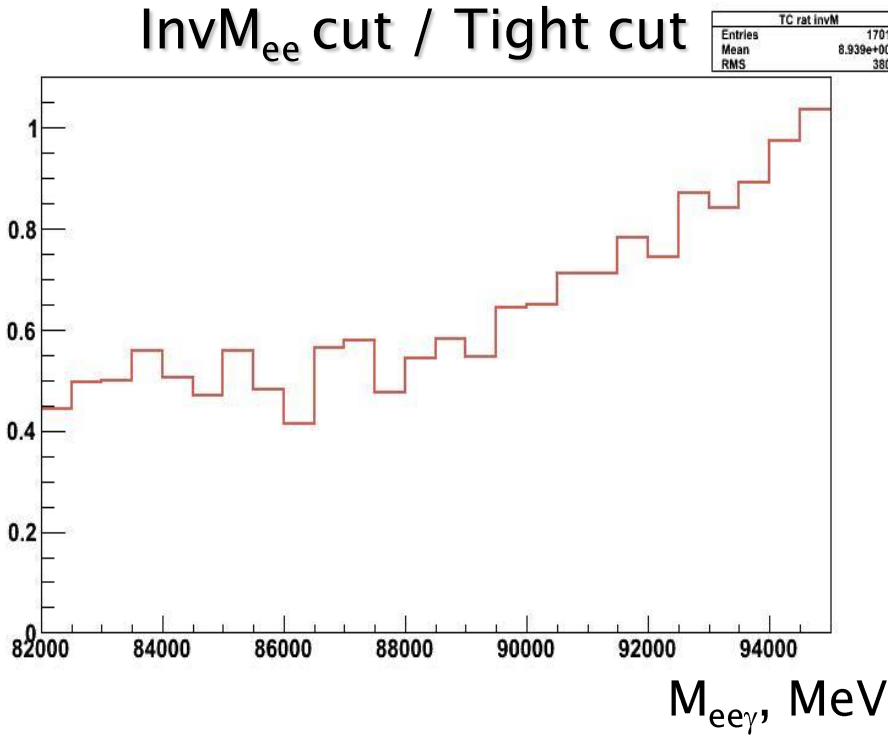
Differential distributions of s/b ratio as a function of $InvM_{ee\gamma}$ for $50<InvM_{ee}<82$ cut only and with addition of the tight cut



For black line averaged S/B=**2.75** and remaining statistics is **65%** from the initial one. For green – it was given on the previous slide (**6.19** and **50%** accordingly).

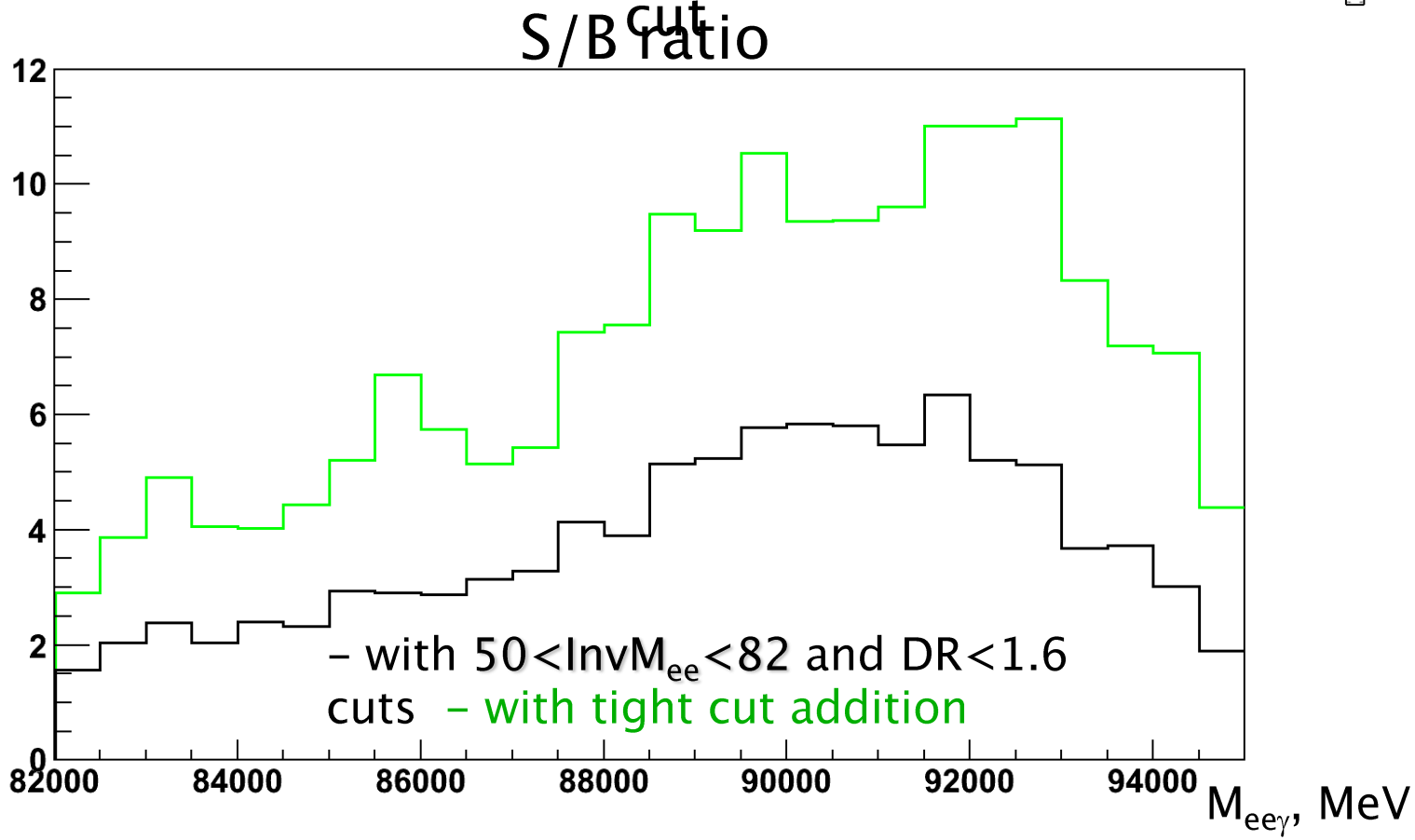
Comparison of the s/b ratio for **tight cut only** with the s/b ratio for **50<InvM$_{ee}$<82 cut only**





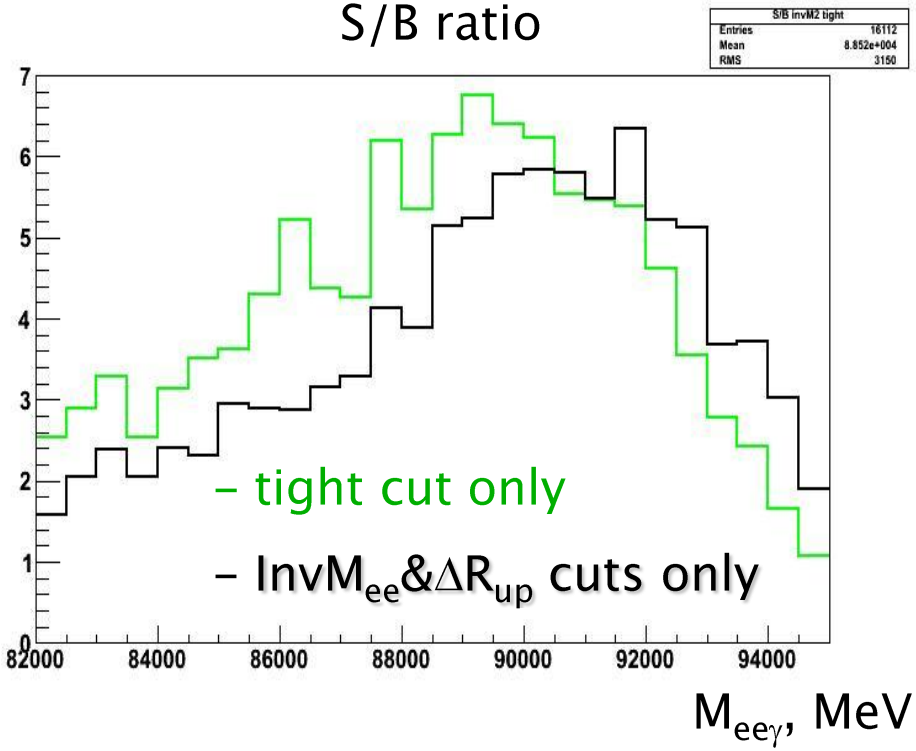
It could be useful for the tight cut efficiency validation.

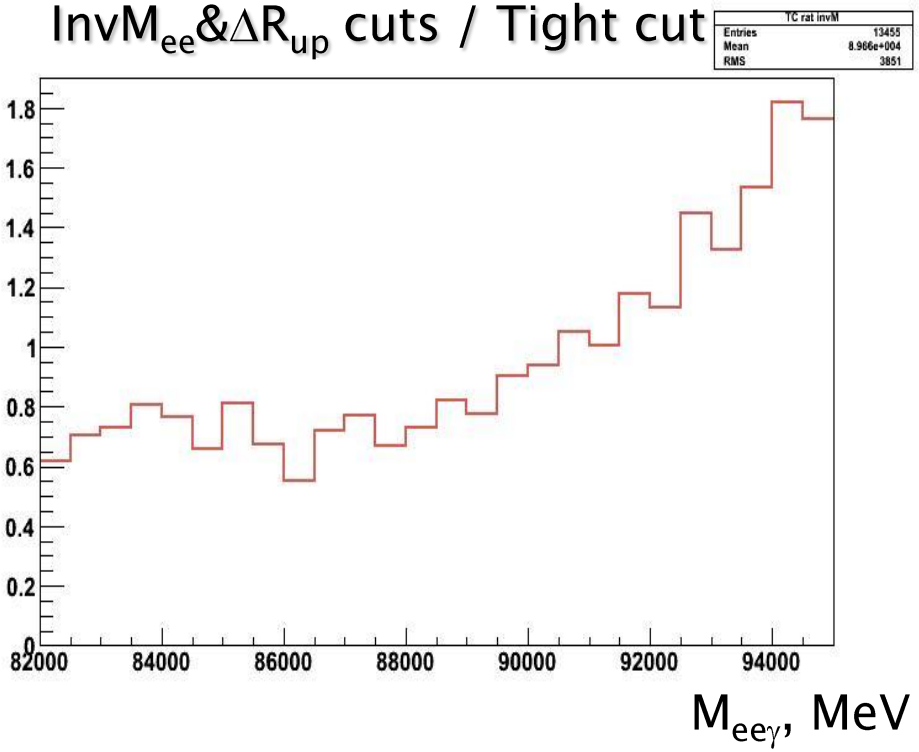
Differential distributions of s/b ratio as a function of $InvM_{ee\gamma}$ for $50<InvM_{ee}<82$ and DR<1.6 cuts and with addition of the tight cut



For black line averaged S/B=**3.98** and remaining statistics is **51%** from the initial one. For green – it was given on the previous slide (**7.47** and **39%** accordingly).

Comparison of the s/b ratio for **tight cut only** with the s/b ratio for **50<InvM$_{ee}$<82 and ΔR<1.6 cuts only**

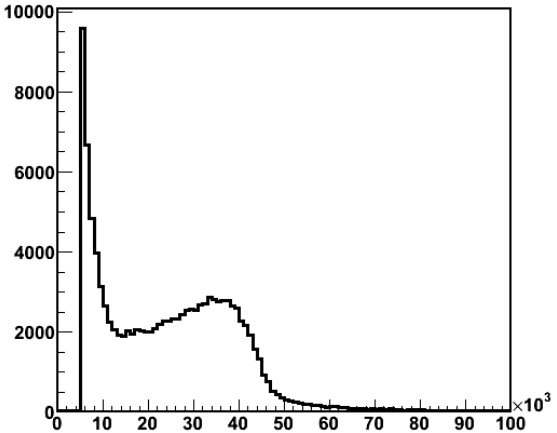




It could be useful for the tight cut efficiency validation.

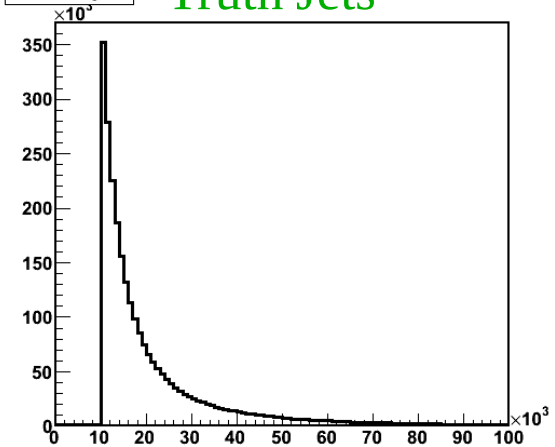
E_T and η distribution of the truth and reconstructed (in photon container) jets and efficiency of such reconstruction

et matched jet Reco Jets



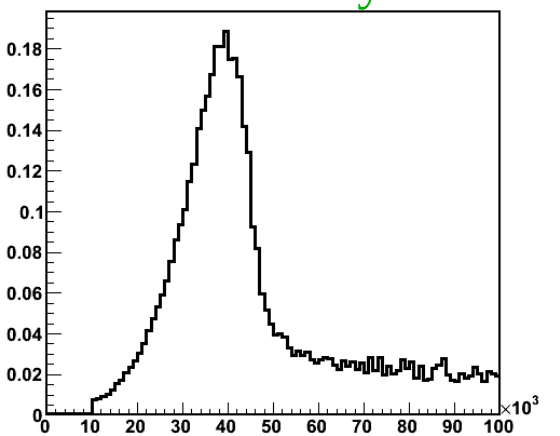
E_T, MeV

et true jet Truth Jets



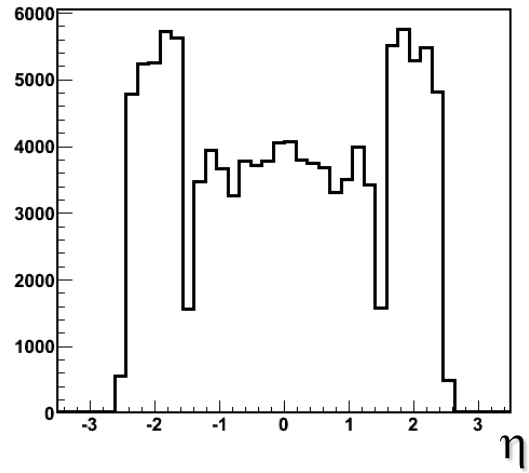
E_T, MeV

Efficiency



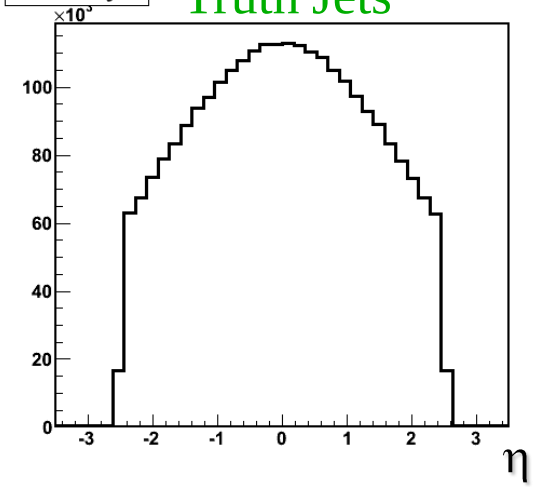
E_T, MeV

jet eta matched Reco Jets



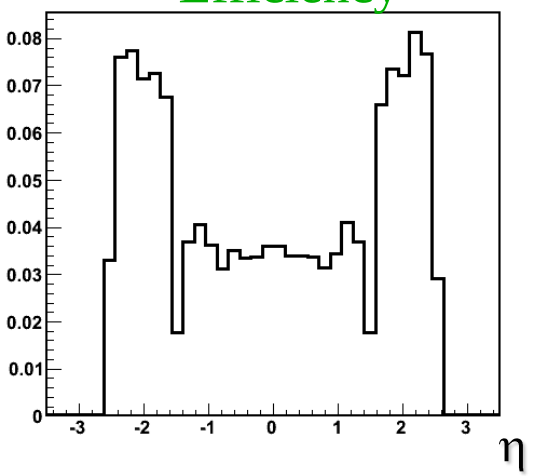
η

eta true jet Truth Jets



η

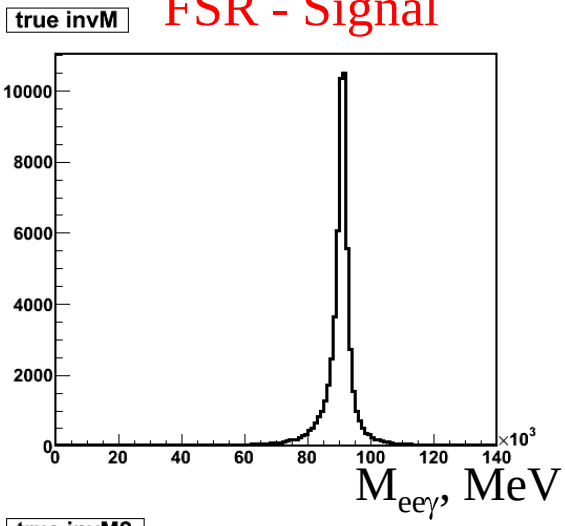
Efficiency



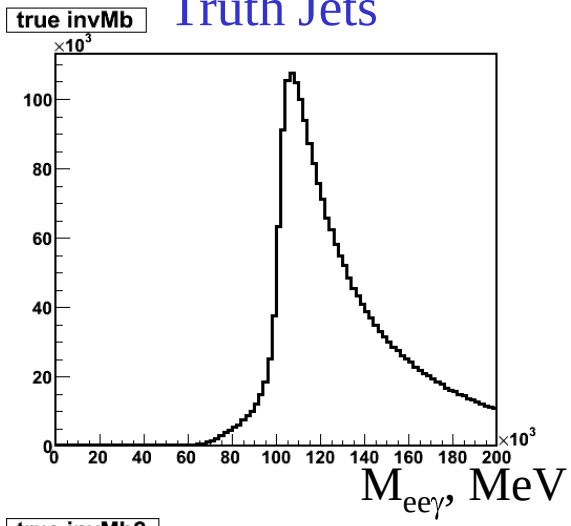
η

Truth signal, background and ratio of s/b ratio as a function of invariant mass eeγ in full area and in window

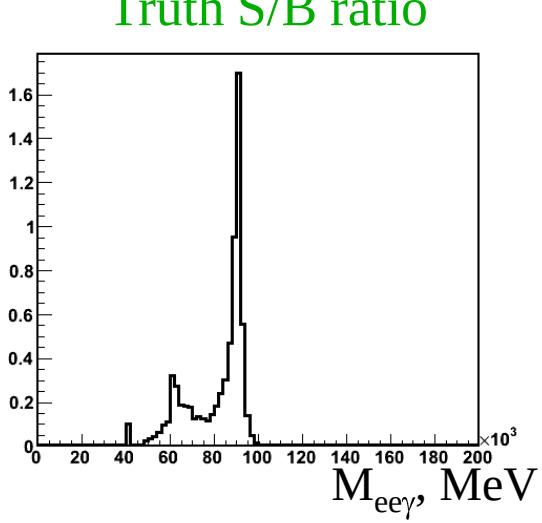
FSR - Signal

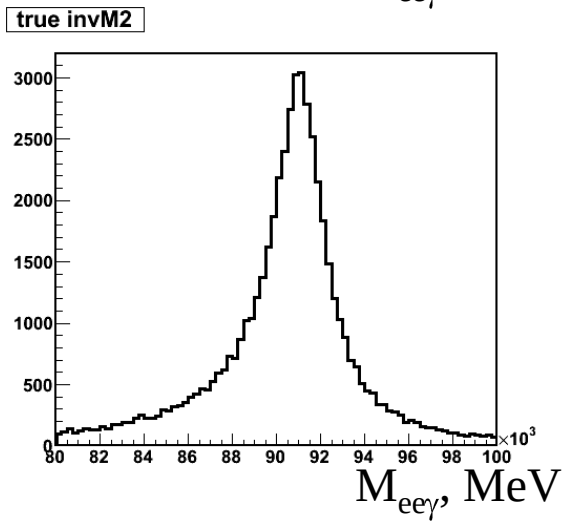


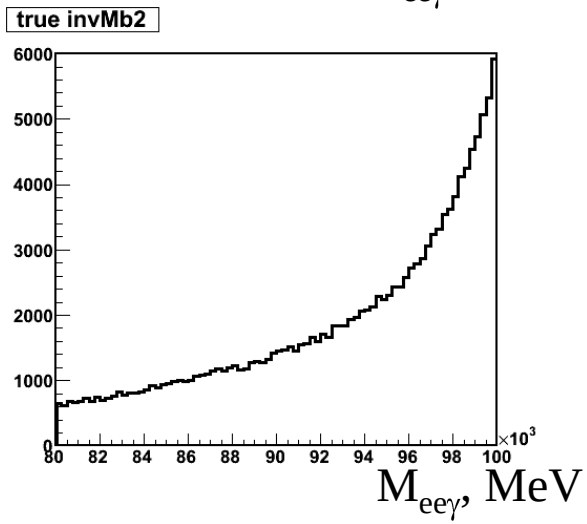
Truth Jets

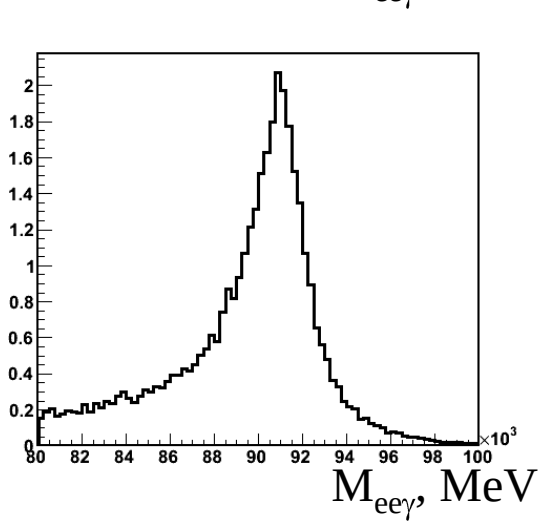


Truth S/B ratio

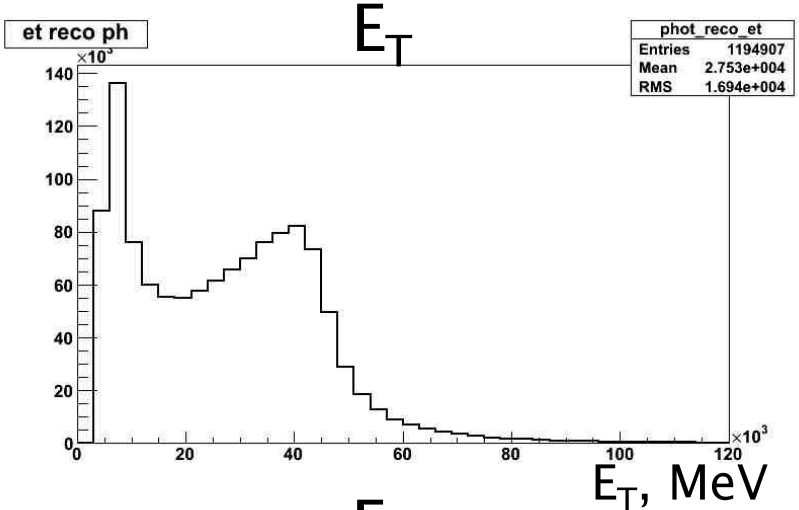


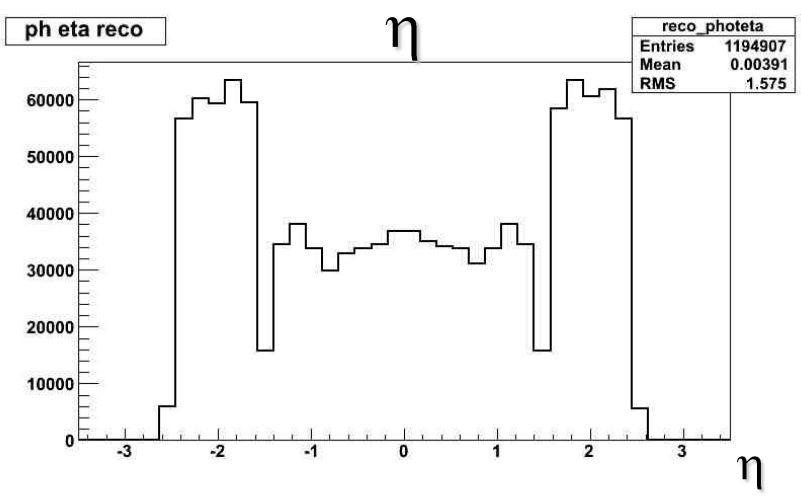


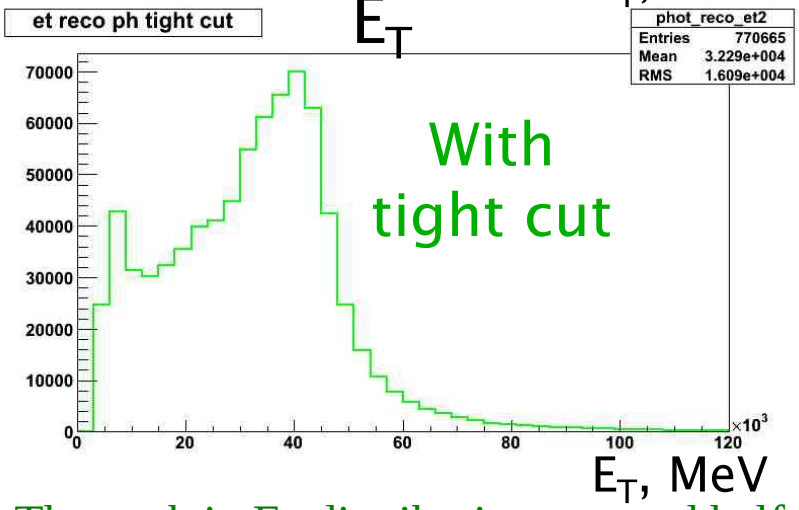


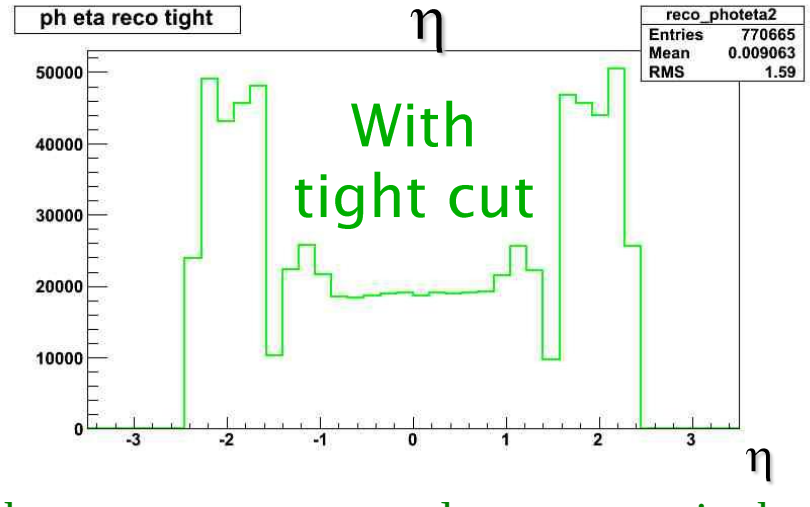


E_T and η distributions of all reconstructed photons (with and without tight cut)





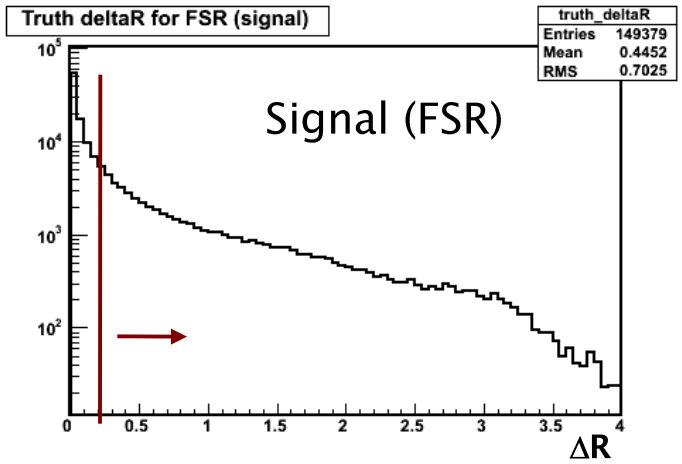


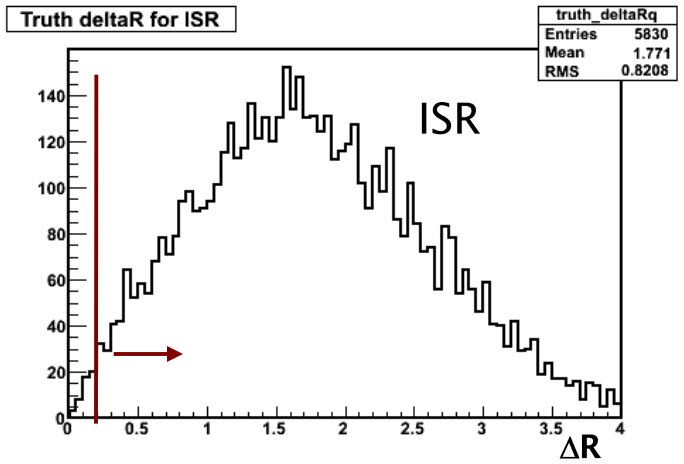


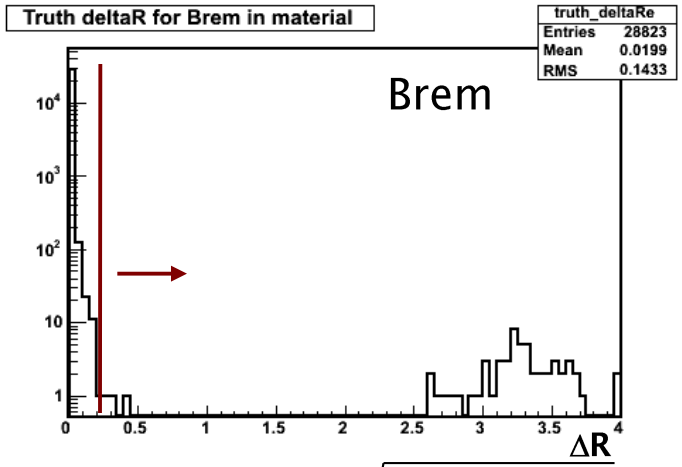
The peak in E_T distributions around half Z-boson mass corresponds to an error in the reconstruction of the conversion photon from one of the Z-boson's electron.

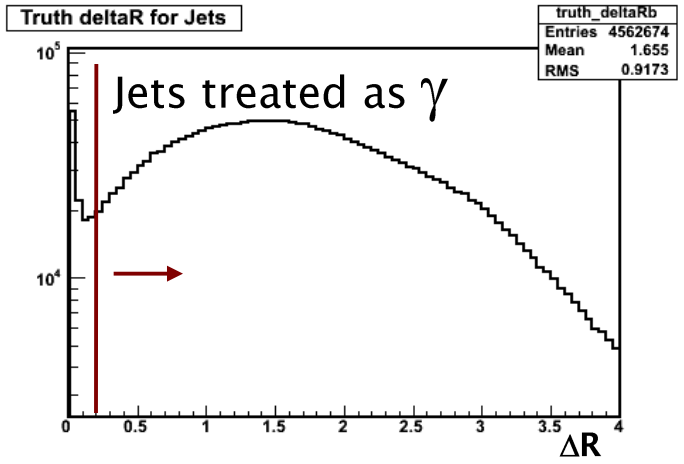
Backup slides Z -> $\mu\mu\gamma$

ΔR distributions for signal and background (TRUTH)





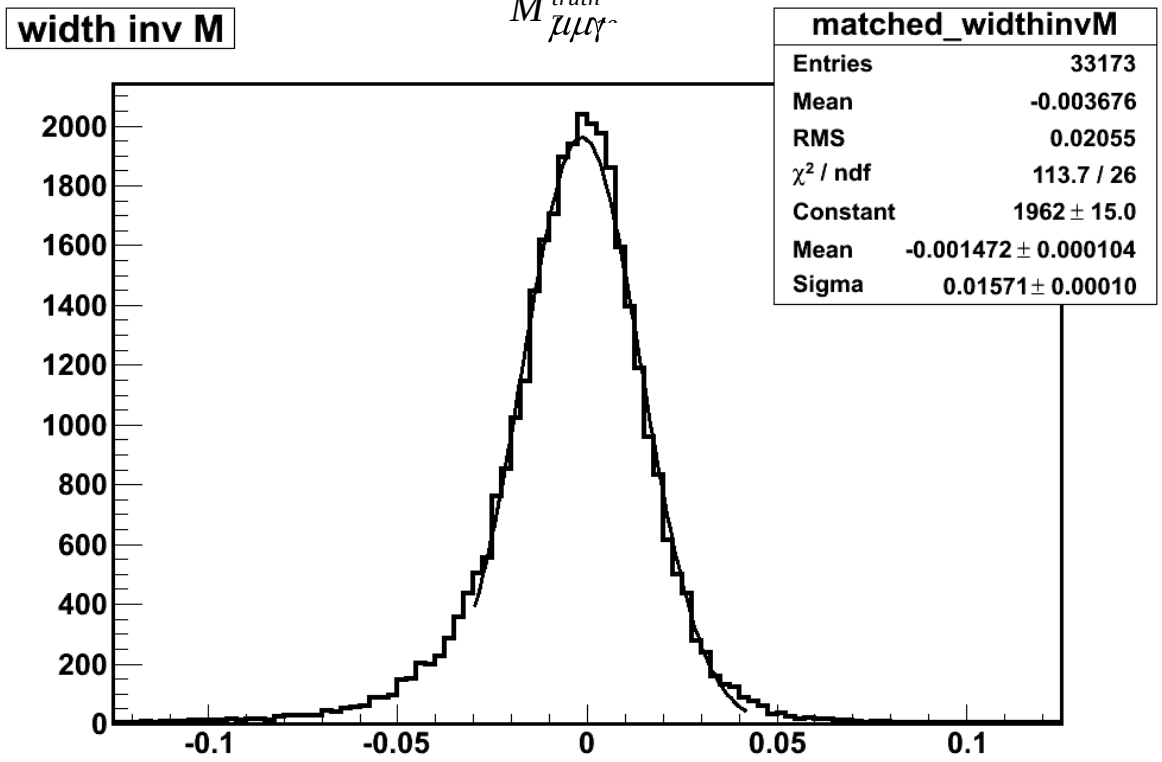




$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$$ γ−to−closest lepton angle

Resolution of reconstructed M($\mu\mu\gamma$)

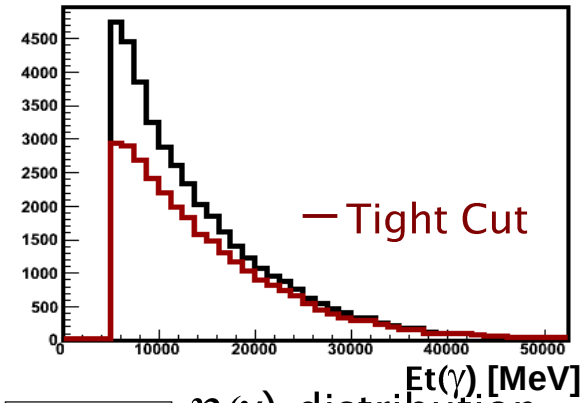
$$\frac{M^{reco}_{\mu\mu\gamma} - M^{truth}_{\mu\mu\gamma}}{M^{truth}_{\mu\mu\gamma}}$$



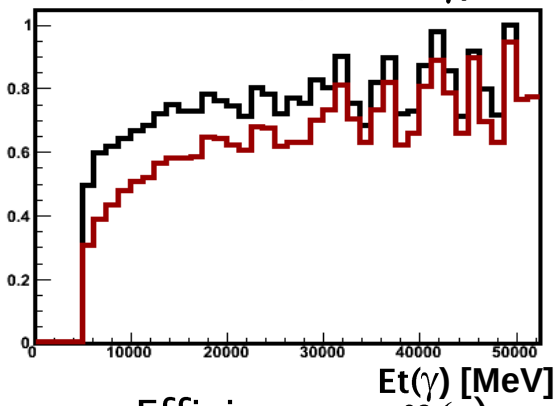
Control plots for γ reconstruction – Z -> $\mu\mu\gamma$

FSR photons reconstruction

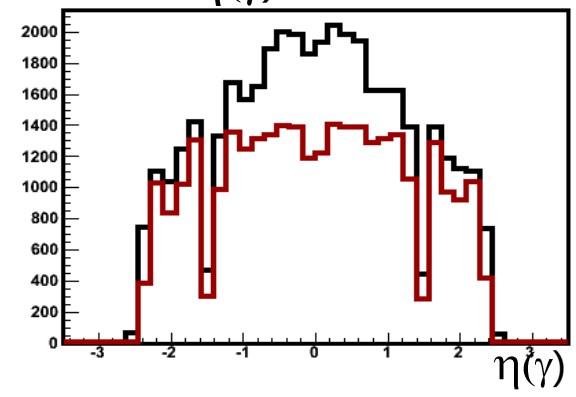
Et(γ) distribution



Efficiency vs Et(γ)



$\eta(\gamma)$ distribution



Efficiency vs $\eta(\gamma)$