$Z \to 2l\gamma$ form factor at 8 TeV analysis validation

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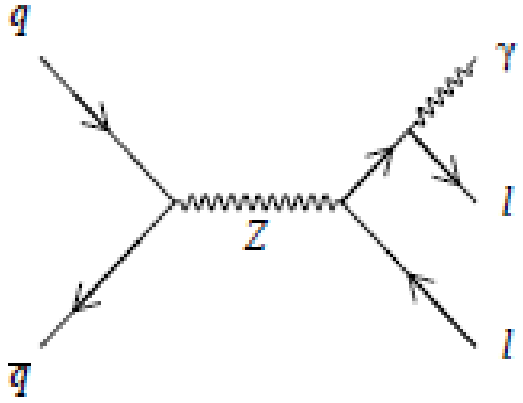
Novosibirsk State University
*THE REAL SCIENCE

CERN

ATLAS EXPERIMENT

Outline

- Motivation
- My goals
- Analysis
- Conclusion

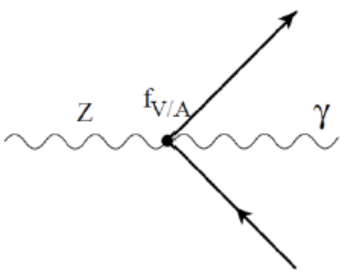


•Z decay to real lepton and virtual one
•Z→ll vertex depends on lepton virtuality
•This vertex function is called "form factor" V(Q)

$$\langle f\bar{f}|J_Z^\mu|0\rangle = V_f(q^2)\bar{u}_f\gamma_\mu\left[\frac{I_{3f}(1-\gamma_5)}{2} - \hat{k}_f(q^2)\hat{s}^2Q_f\right]v_f,$$

[A. Sirlin, A.Ferroglia. Rev.Mod.Phys., V85 (2013): eq. (59) p.273]

V(Q) is sensitive to interference effects from New Physics.



D. Bruss, O. Nachtmann, P. Overmann, Eur.Phys.J.C1:191-199,1998

$$\mathcal{L}_{SM} = \mathcal{L}_{SM}^{(4)} + \frac{1}{\Lambda}\sum_k C_k^{(5)}Q_k^{(5)} + \frac{1}{\Lambda^2}\sum_k C_k^{(6)}Q_k^{(6)} + \mathcal{O}\left(\frac{1}{\Lambda^3}\right)$$

B. Grzadkowski, M. Iskrzynski , M. Misiak, J. Rosiek arXiv:1008.4884v2

My goals

- 1 The selection criteria described in the note (ATL-COM-PHYS-839) application to the 2012 data and MC.
- 2. Analysis validation and comparison of results with the note. Cut flow tables.
- 3. Atlas style application to all pictures and automation of the drawing procedure.
- 4. Events selection variation to study the systematical uncertainties.

Events selection

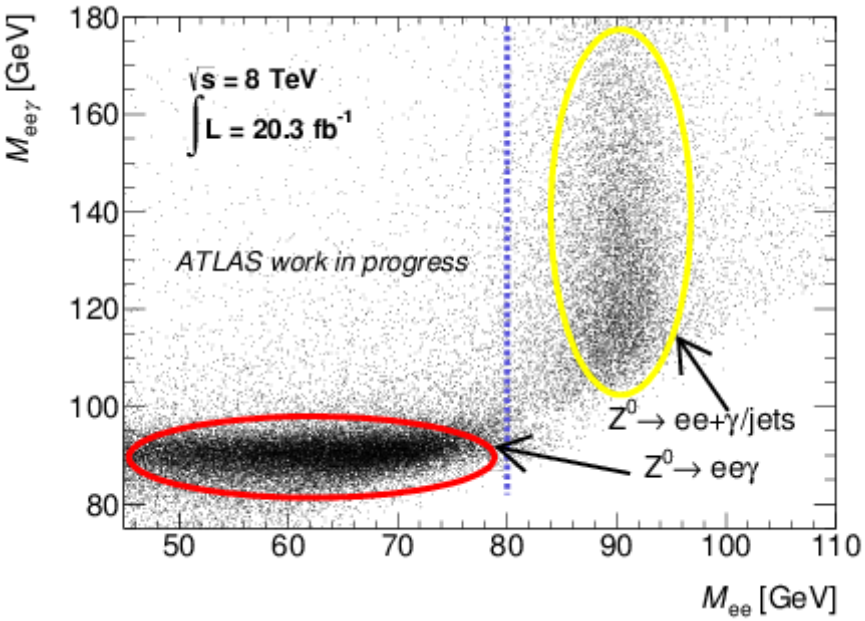
	$Z \rightarrow ee\gamma$	$Z \rightarrow \mu\mu\gamma$
Triggers	EF_2e12Tvh_loose EF_e24vh_medium EF_e60_medium	EF_mu18_mu8_EFFS EF_2mu13 EF_mu24i_tight EF_mu36_tight
Events Preselection	Apply All_Good GRL for all final states; Remove all events that have LAr EventInfo error flag (larError==2 in D3PD); Remove all events that have titleError==2 in D3PD; Remove all events that have coreFlags&0x40000!=0 in D3PD; Remove Tile corrupted events passing other quality criteria in periods G-J using; Primary vertex with at least three tracks coming from a beam spot $\lvert d_0 \rvert < 1\ mm; \lvert Z_0 \rvert < 10\ mm$	
Photon Selection	Photon with the highest P_t; $P_t(\gamma) > 15\ GeV$ $\lvert\eta(\gamma)\rvert < 2.37$ excluding $1.37 < \lvert\eta(\gamma)\rvert < 1.52$; pass tight ID $\delta R(\gamma, l) > 0.4$; topoEtcone40$(\gamma) < 4\ GeV$	
Lepton Selection	$P_t(e) > 10\ GeV$; loose e $\lvert\eta(e)\rvert < 2.47$ topoEtcone40(e)/$E_t < 0.3$	$P_t(\mu) > 10\ GeV$ $\lvert\eta(\mu)\rvert < 2.37$ topoEtcone40$(\mu)/E_t < 0.2$
Invariant Mass	At least 1 photon + 2e with opposite sign $\max(P_{t_1}, P_{t_2}) > 25\ GeV$ $45\ GeV < M(ee) < 80\ GeV$ $80\ GeV < M(ee\gamma) < 100\ GeV$	At least 1 photon + 2μ with opposite sign $\max(P_{t_1}, P_{t_2}) > 25\ GeV$ $45\ GeV < M(\mu\mu) < 80\ GeV$ $80\ GeV < M(\mu\mu\gamma) < 100\ GeV$

Cut flow table

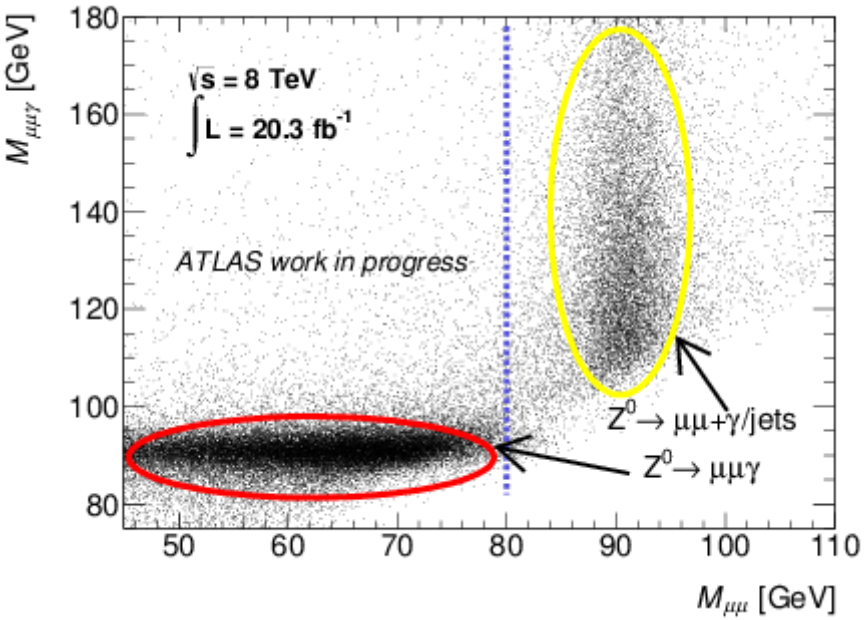
Z→ $ee\gamma$	
Cut	Events
Triggers GRL $\lvert d_0\rvert < 1mm$, $\lvert Z_0\rvert < 10mm$ $\lvert\eta(e)\rvert < 2.47$ $\lvert\eta(\gamma)\rvert < 2.37$ excluding $1.37 < \lvert\eta(\gamma)\rvert < 1.52$	6510969
recoclass=1	5888750
G_quality>2	1101215
$P_t(\gamma) > 15\ GeV$	149737
$\delta R(\gamma, l) > 0.4$	123488
$\min(P_{t_1}, P_{t_2}) > 10\ GeV$	73252
$\max(P_{t_1}, P_{t_2}) > 25\ GeV$	68779
topoEtcone40(γ) $< 4\ GeV$	58092
topoEtcone40(e)/$E_t < 0.3$	50919
$80\ GeV < M(ee\gamma) < 100\ GeV$	30843
$45\ GeV < M(ee) < 80\ GeV$	27331

Z→ $\mu\mu\gamma$	
Cut	Events
Triggers GRL $\lvert d_0\rvert < 1mm$, $\lvert Z_0\rvert < 10mm$ $\lvert\eta(\mu)\rvert < 2.37$ $\lvert\eta(\gamma)\rvert < 2.37$ excluding $1.37 < \lvert\eta(\gamma)\rvert < 1.52$	5936302
recoclass=2	5834814
G_quality>2	1104018
$P_t(\gamma) > 15\ GeV$	145167
$\delta R(\gamma, l) > 0.4$	95435
$\min(P_{t_1}, P_{t_2}) > 10\ GeV$	73049
$\max(P_{t_1}, P_{t_2}) > 25\ GeV$	66240
topoEtcone40(γ) $< 4\ GeV$	61226
topoEtcone40(μ)/$E_t < 0.2$	56677
$45\ GeV < M(\mu\mu) < 80\ GeV$	34084
$80\ GeV < M(\mu\mu\gamma) < 100\ GeV$	30687

Analysis



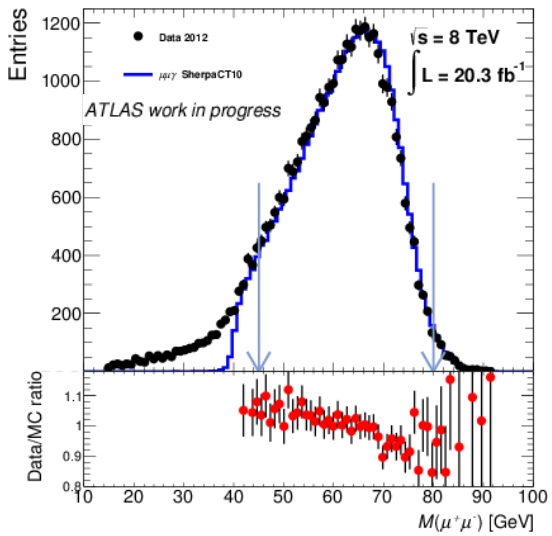
The eeγ invariant mass vs ee invariant mass



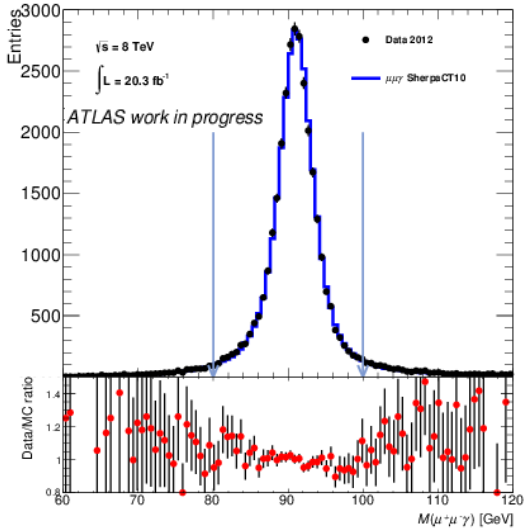
The μμγ invariant mass vs μμ invariant mass

Only Z→2lγ red regions of these plots were taken for the analysis.

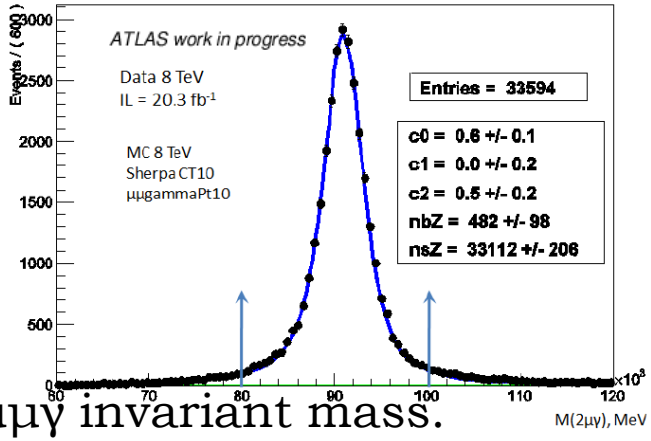
Analysis



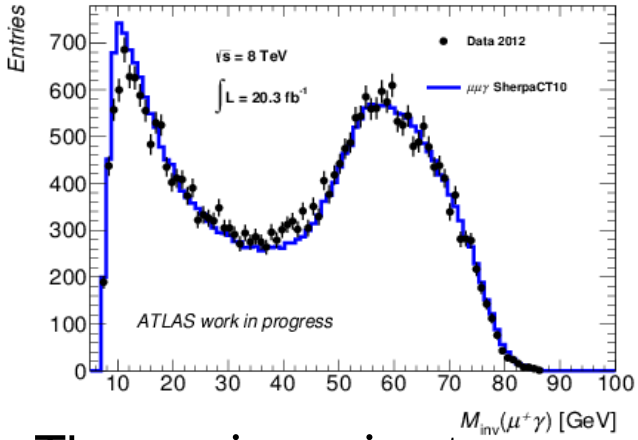
The μμ invariant mass



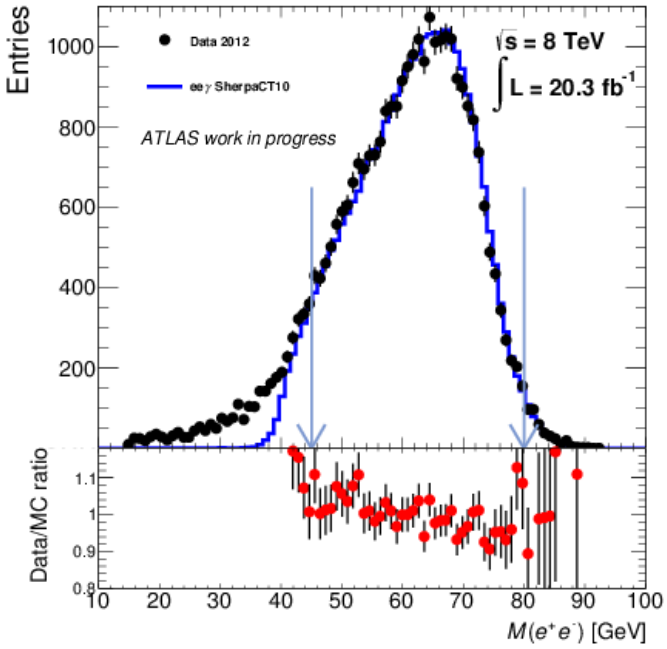
The μμγ invariant mass



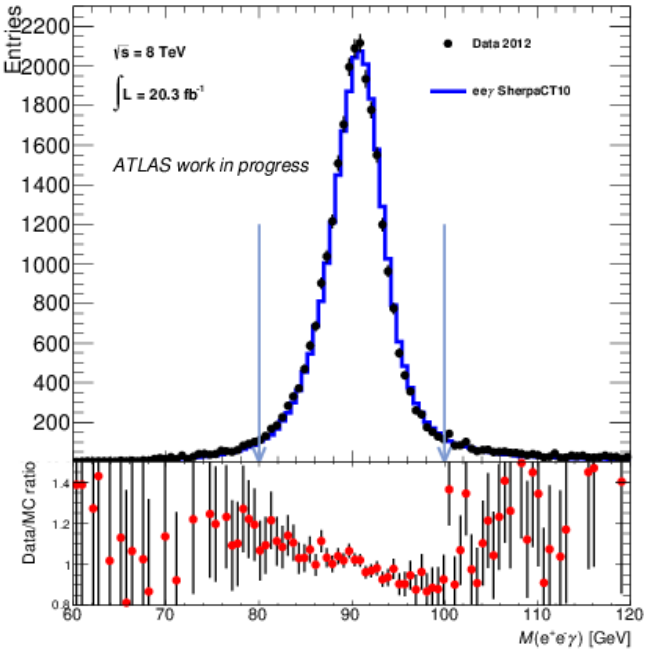
The μμγ invariant mass. Green histogram is the background contribution



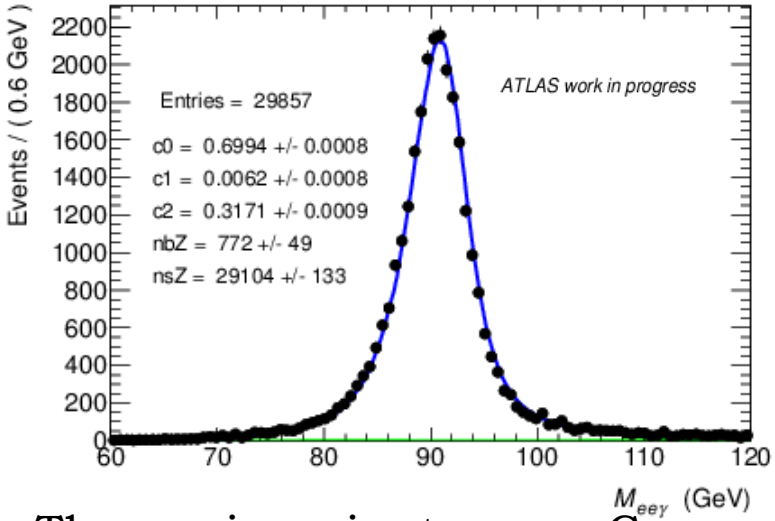
The μγ invariant mass



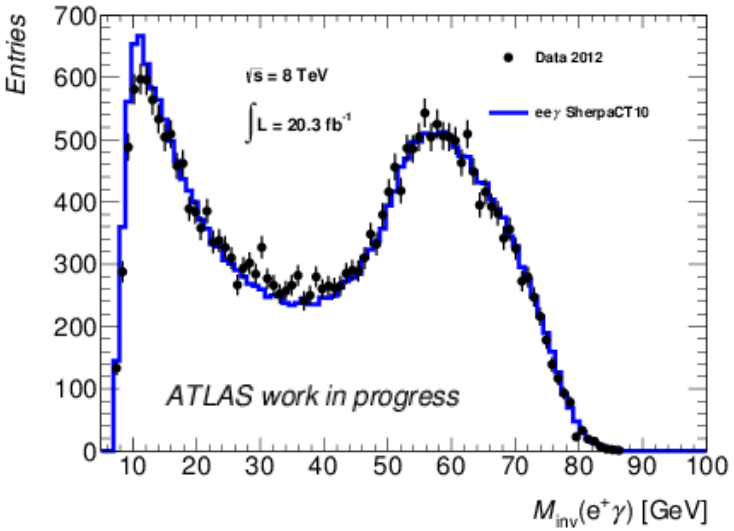
The ee invariant mass



The eeγ invariant mass

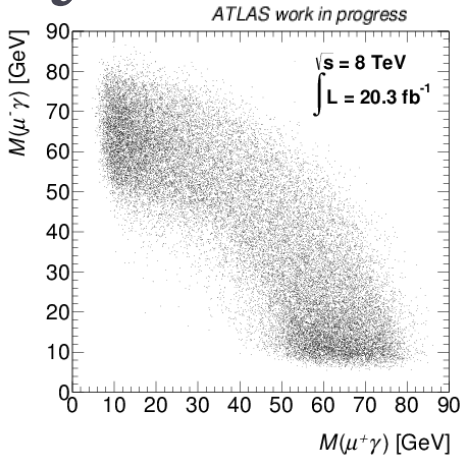


The eeγ invariant mass. Green histogram is the background contribution.

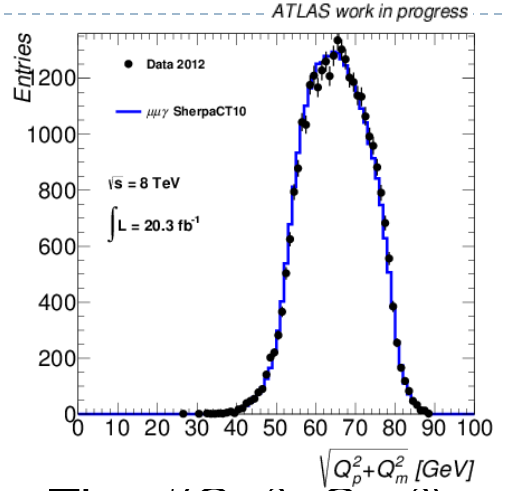


The eγ invariant mass

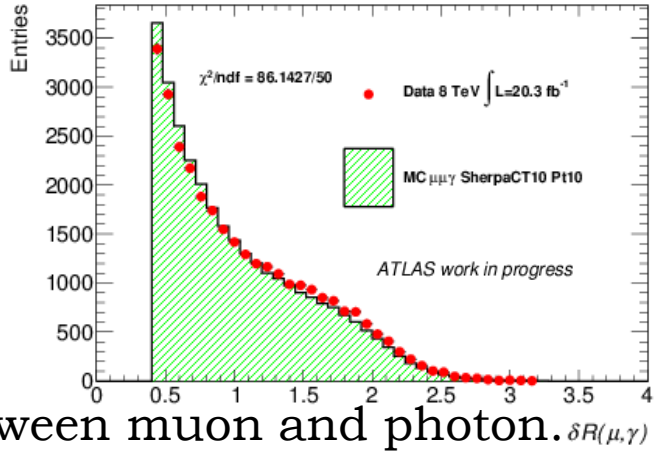
Analysis



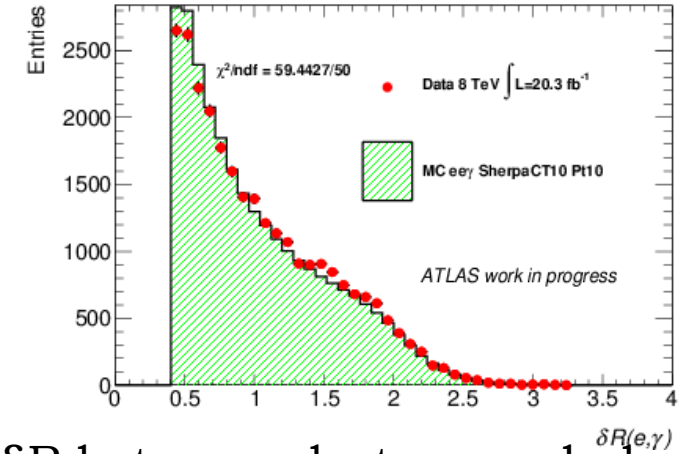
Negative muon and photon invariant mass vs positive muon and photon invariant mass



The $\sqrt{(Qp^2+Qm^2)}$ quantity.



δR between muon and photon. Shaded histogram is the SM contribution



δR between electron and photon. Shaded histogram is the SM contribution

Conclusion

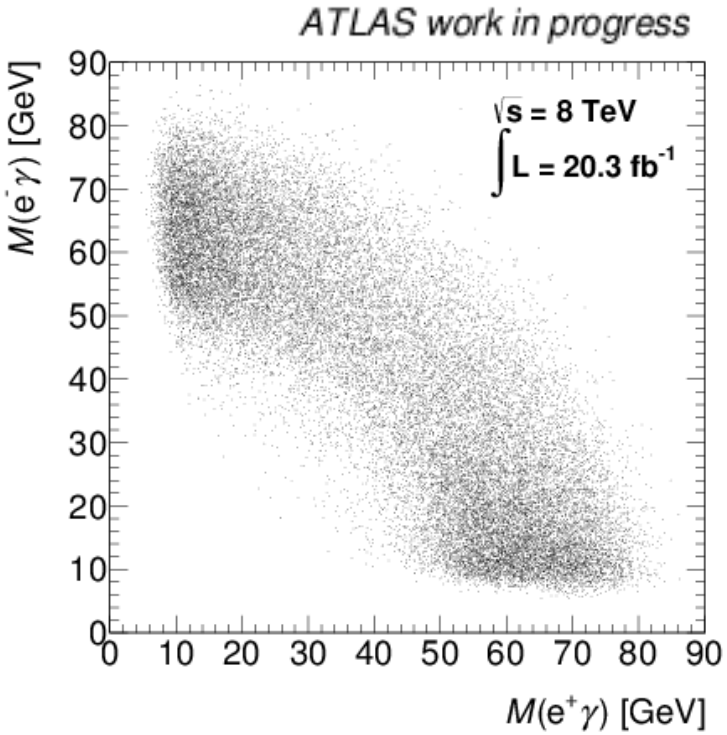
- 1. I have applied the selection criteria described in the note (ATL-COM-PHYS-839) to the 2012 data collected with ATLAS detector at 8 TeV pp collisions. The selection criteria were also applied to the SM MC of the $pp \rightarrow Z+X \rightarrow 2l\gamma+X$ process (mc12_8TeV_ZeegPt10, mc12_8TeV_ZmumugPt10).
- 2. I have checked the cut flow tables.
- 3. I have validated all pictures from the note. I have applied ATLAS Style to all the pictures. I have automated the procedure.
- 4. I have varied the selection criteria to study the systematical uncertainty.

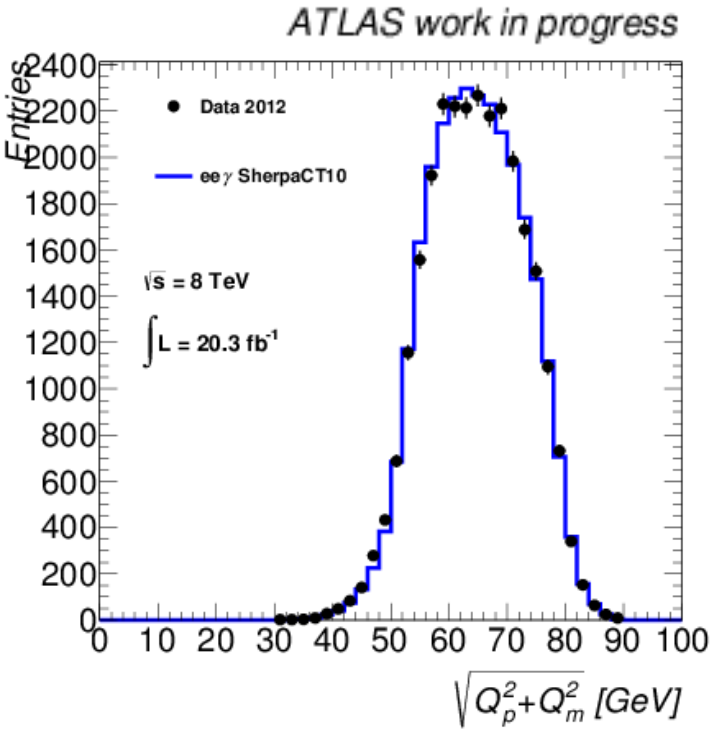
  My pictures were shown at SM Electroweak group meeting (22 Jul 2016). Also these pictures will be included in the note update.

What I have learned from the experience:

- A) How to analyze the data and select the events;
- B) How to compare the MC with the data;
- C) How to suppress the background;
- D) I have learned how Z-boson is born at pp collisions and how it decays. The radiative corrections are small but could reveal some physics;
- E) The ROOT skills were improved;

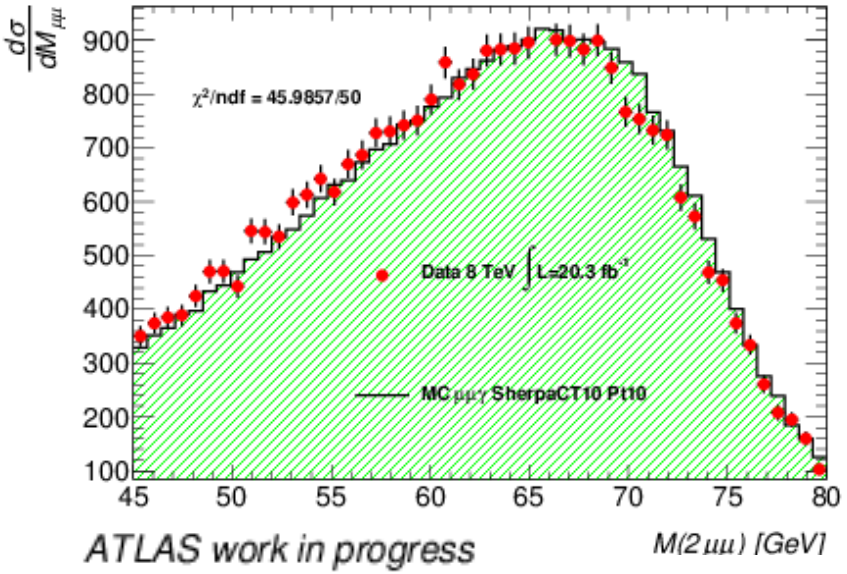
APPENDIX



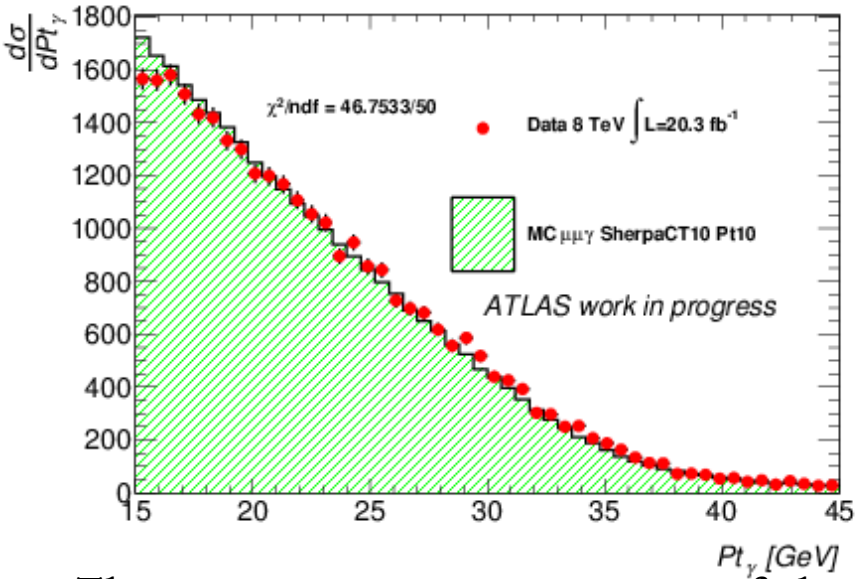


Negative electron and photon invariant mass vs positive electron and photon invariant mass

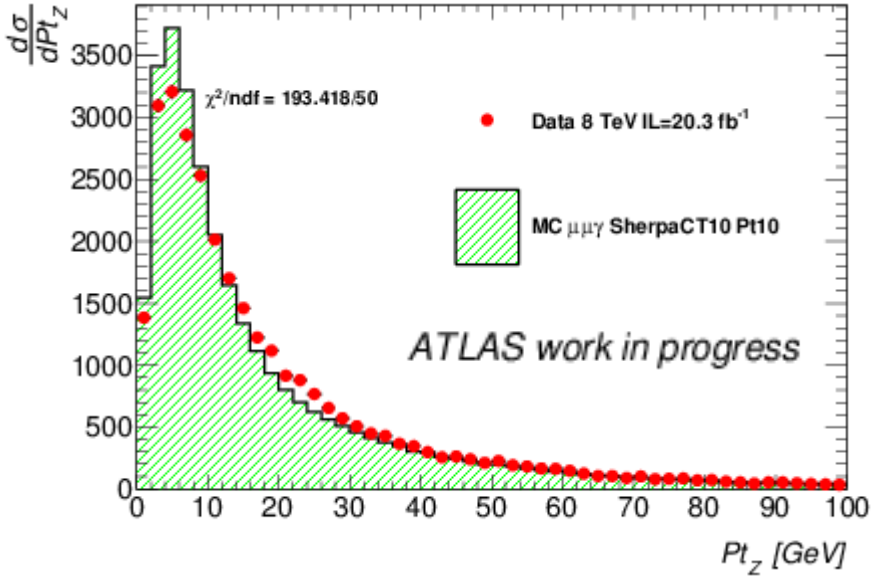
The $\sqrt{(Qp^2+Qm^2)}$ quantity.



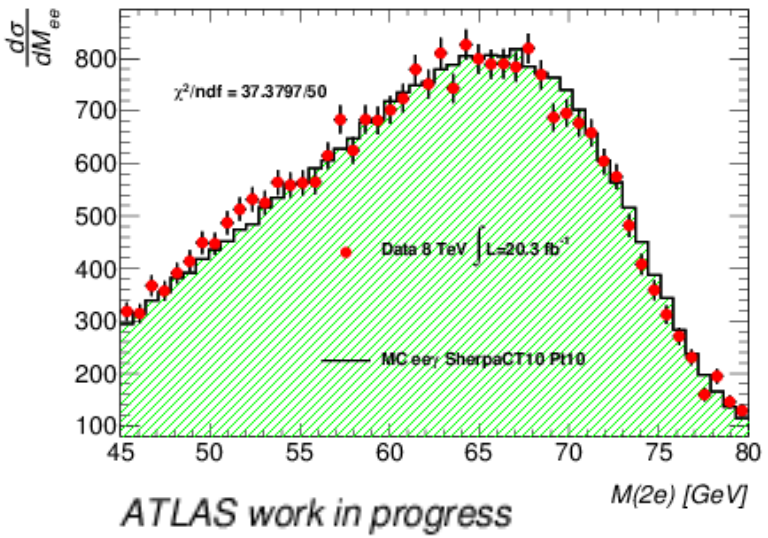
The invariant mass M(2μ).



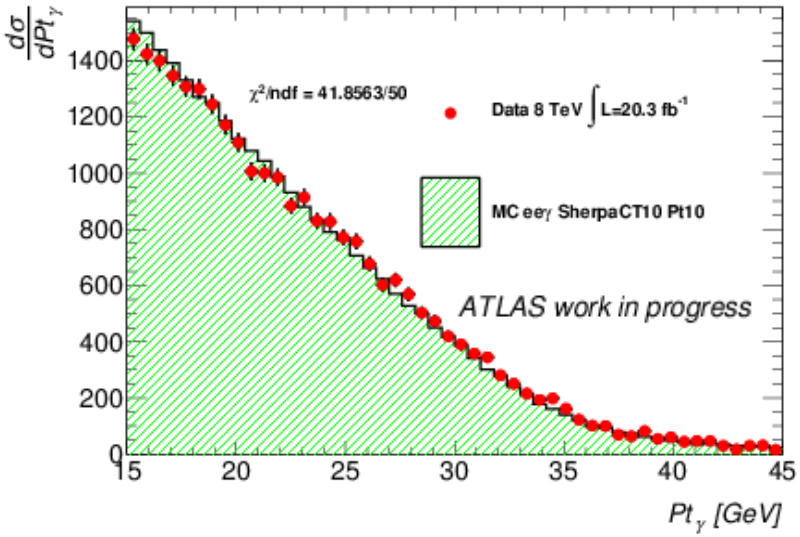
The transverse momentum of the photon for Z→2μγ.



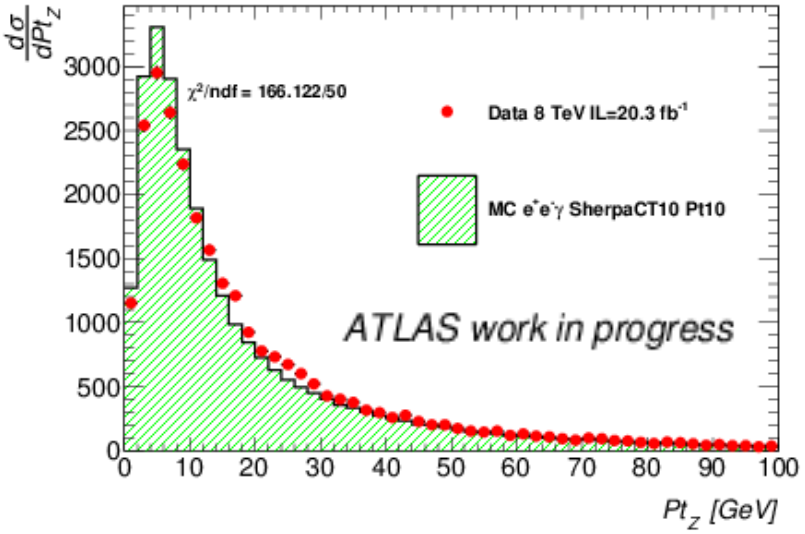
The transverse momentum of the reconstructed Z for Z→2μγ.



The invariant mass M(2e).



The transverse momentum of the photon for Z→2eγ.



The transverse momentum of the reconstructed Z for Z→2eγ.