Muon Final State Radiation

Meng Xiao
CEA-Saclay

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Outline

- **Past works**
  - MET muon term optimization
  - Muon-jet overlap issue
  - fake muon study

- **Study of Final State Radiation in the Z/Drell-Yan muon channel**
  - Data/MC comparisons
  - FSR tool efficiciency and purity
  - Impact on Z mass
  - Muon Isolation
  - Effect of the FSR on the calorimeter and track muon isolation

- **Effect of the FSR on H→4μ**

- **Summary**

Final State Radiation in Z/DY->μμ

- Final State Radiation (FSR) affects the shape of the di-muon mass spectrum, as well as the signal acceptance

- Motivation of the study :
  1. Check if the FSR are well modelled in MC using both pythia and Alpgen

  2. Verify how well the FSR tool is describing the data/MC
     (details about FSR tool can be found in https://indico.cern.ch/contributionDisplay.py?contribId=7&confId=155819)

  3. Check the effect of the FSR on the muon resolution and muon isolation calculation
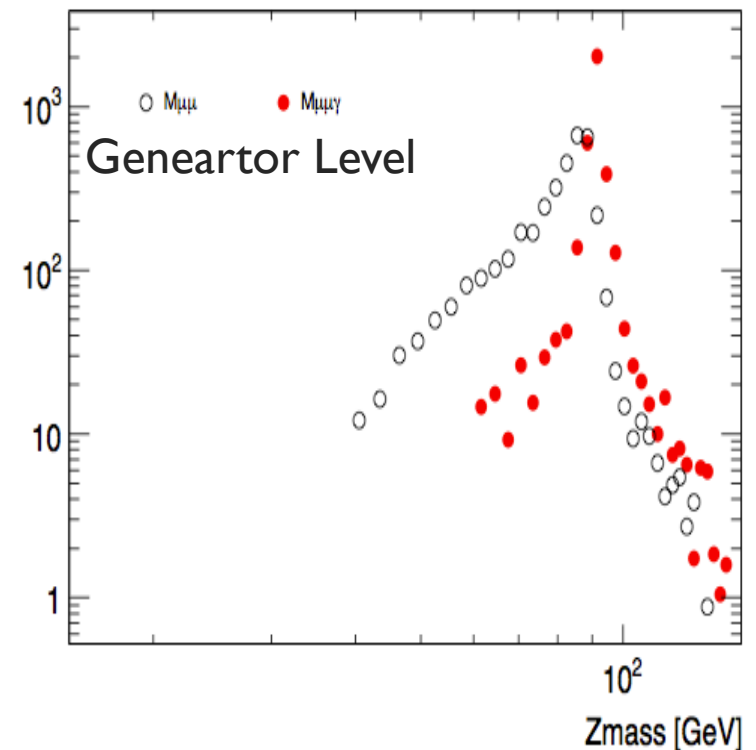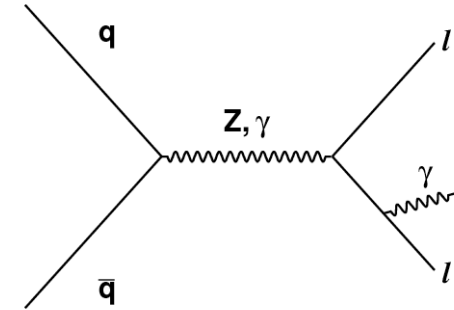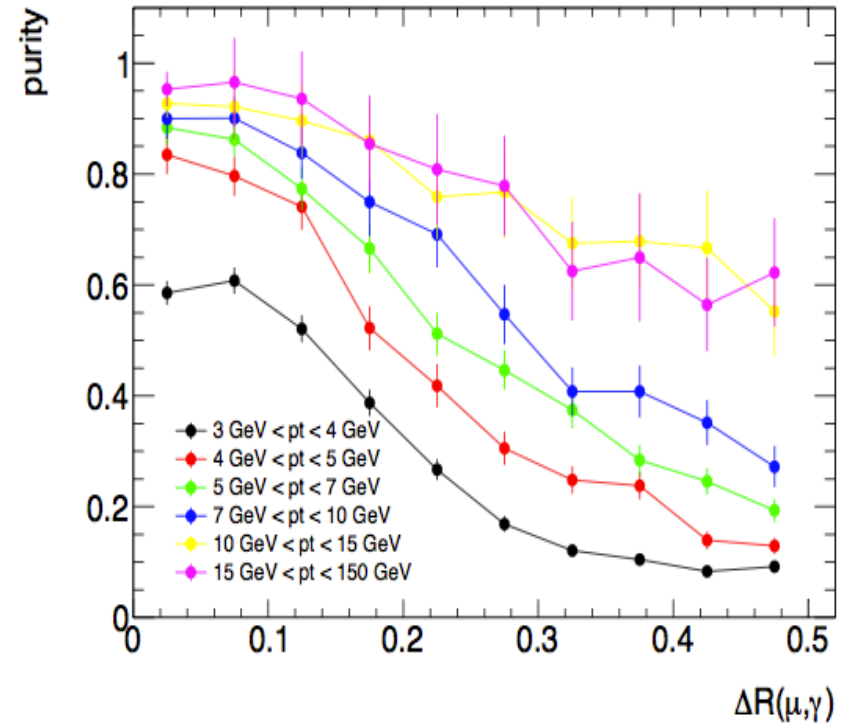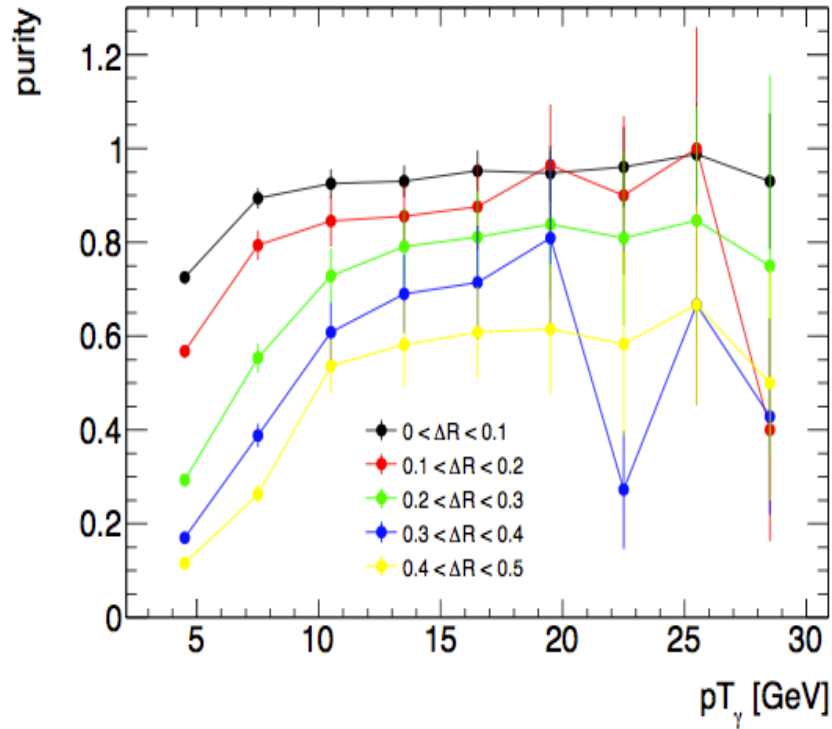
FSR tool

- It provides FSR photon candidates around a given muon. This algorithm is developed by S. Paganis, T.C. Donszelmann and D.Xu.

- The tool can be used at the AOD et D3PD level.

- More information can be found at https://twiki.cern.ch/twiki/bin/viewauth/Atlas/FSRStudy

- The candidates are required to be inside a ΔR cone around the muon, passing Et cut and f1 cut. (f1= fraction of energy in first calorimeter layer)

- The Fsr candidates can come from three categories:
    i) TopoSeededPhotons when Et<=10GeV;
    ii) Standard Egamma Photons when Et>10GeV;
    iii) Standard Egamma Electrons when Et>10GeV.

- The three input variables are (ΔR, Et, f1>0.15)

FSR in data/MC : $\Delta R_{\gamma,\mu}$
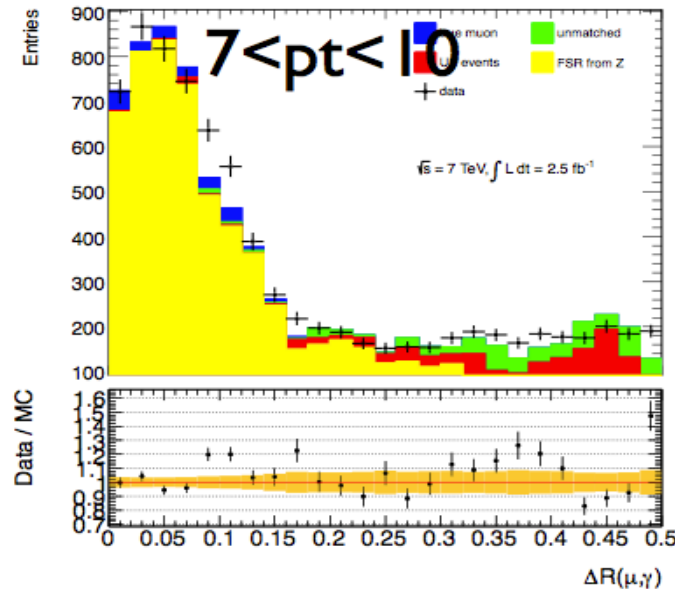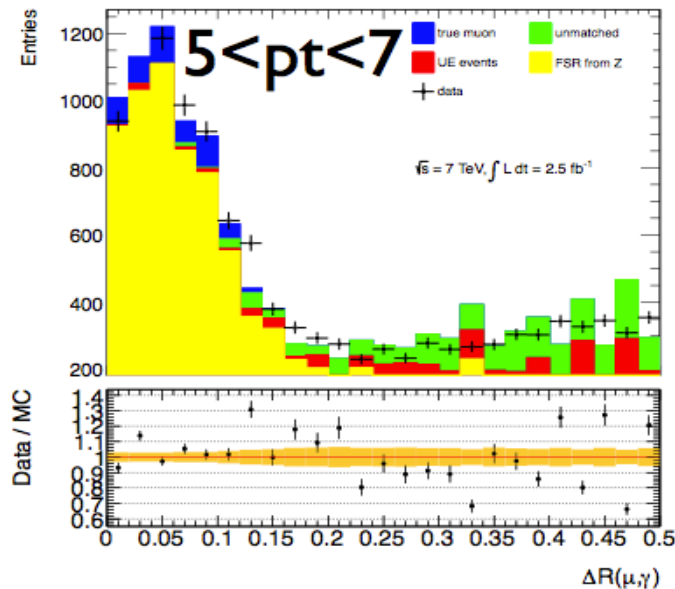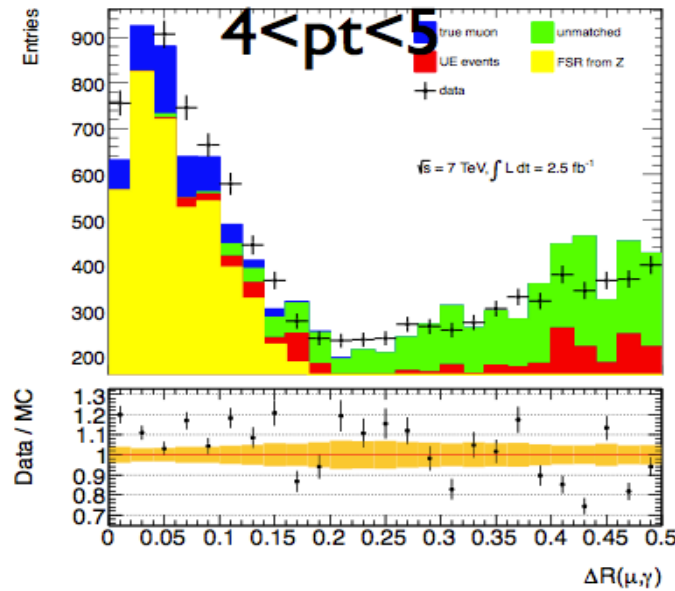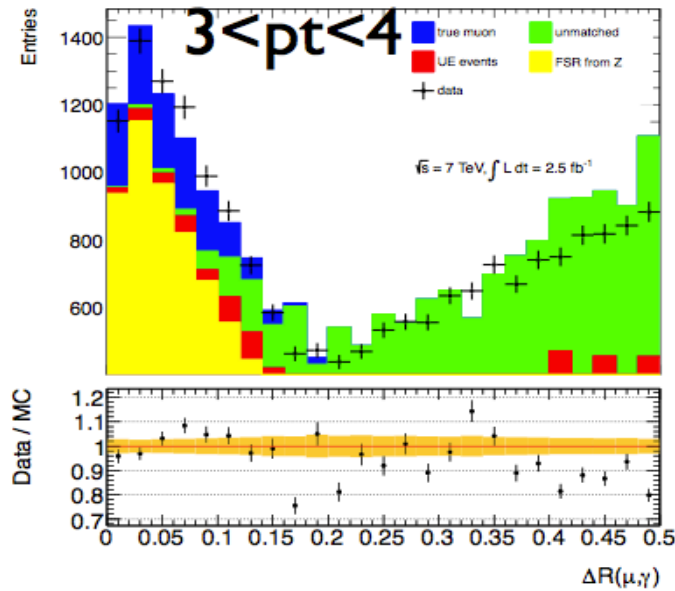
- Blue: photon is true muon (mainly photons reconstructed as electrons and linked to truth muon because sharing the same ID track)
- Yellow: photon from FSR (true photon, parent Z)
- Red: photon from underlying events(true photon, no parent or parent other than Z)
- Green: pile-up or misidentified object (no corresponding truth particle)

Purity of FSR candidates

- Purity definition = True FSR Photon/ All photons found by the tool

- High purity can be achieved for with $\Delta R_{\gamma,\mu} < 0.1$ and $E_{T_\gamma} > 3\,\text{GeV}$

FSR tool efficiency
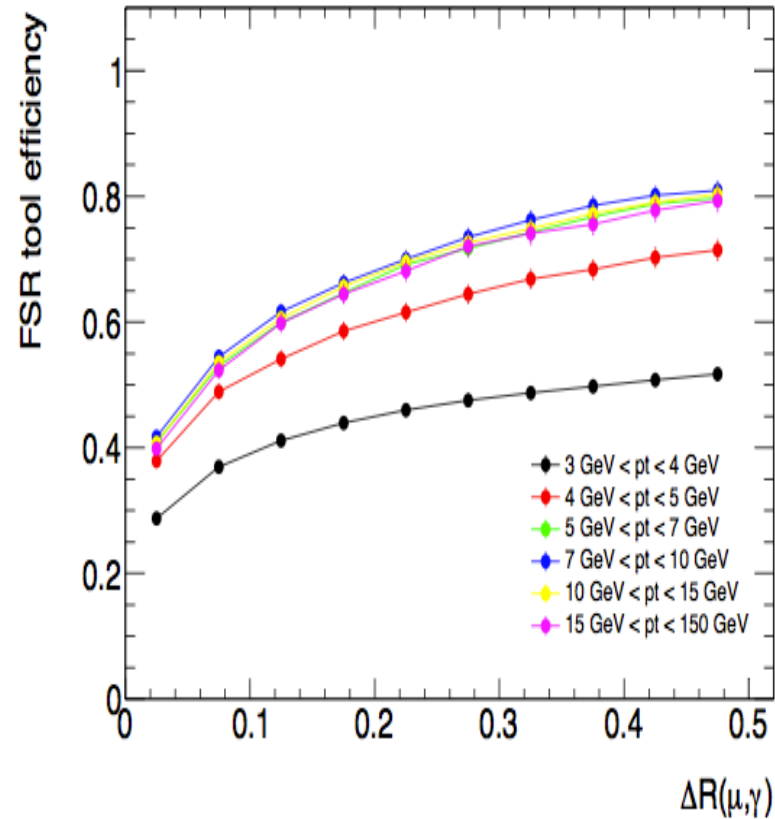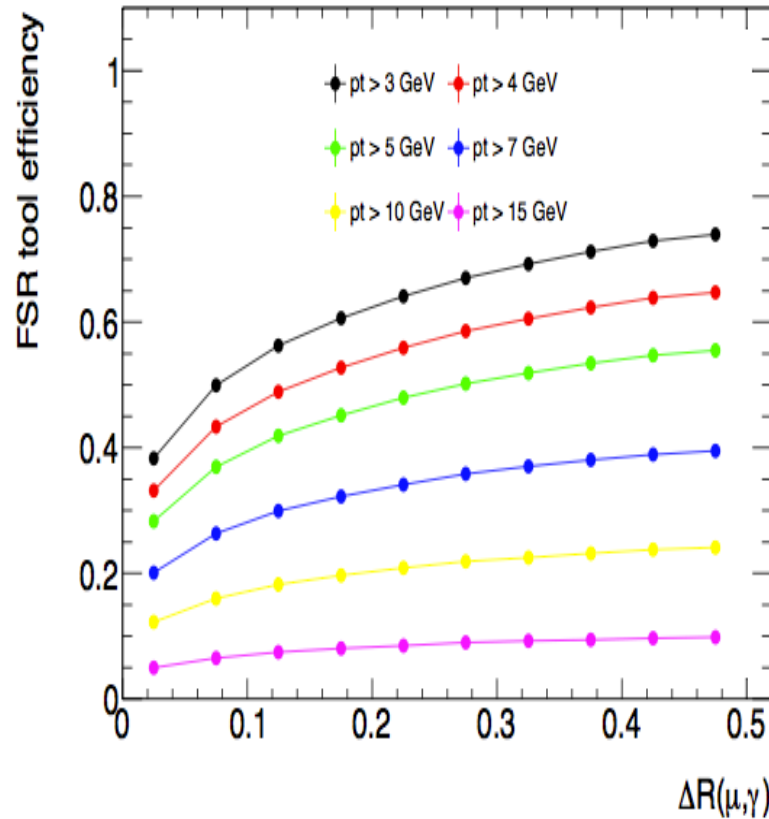
- (Left)Efficiency definition = FSR candidate (with a given pt, ΔR cuts) normalized to truth FSR photon with pt>3, without any truth ΔRcut.
- (Right)Efficiency definition = FSR candidate (within a given pt range, ΔR cut) normalized to truth FSR photon within the given pt range, without any truth ΔRcut.

$M_{\mu\mu\gamma}$ vs $M_{\mu\mu}$

$\Delta R<0.5$

$\Delta R<0.2$
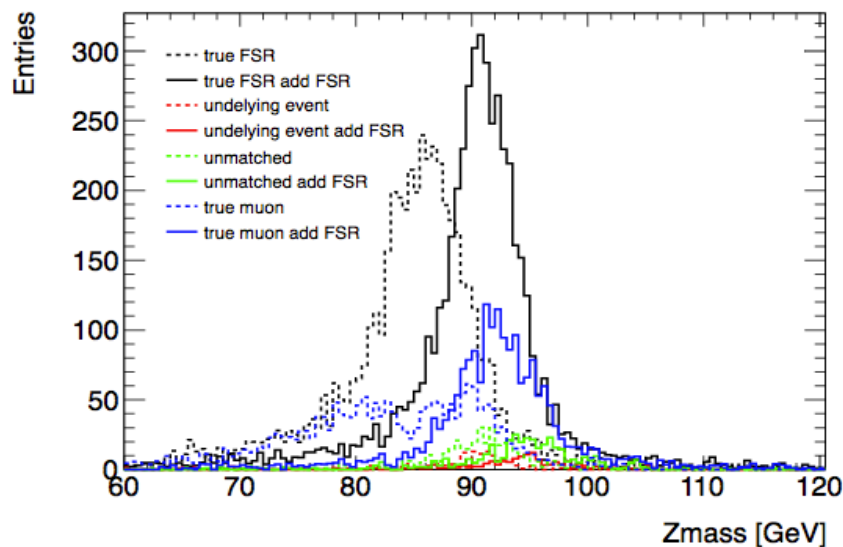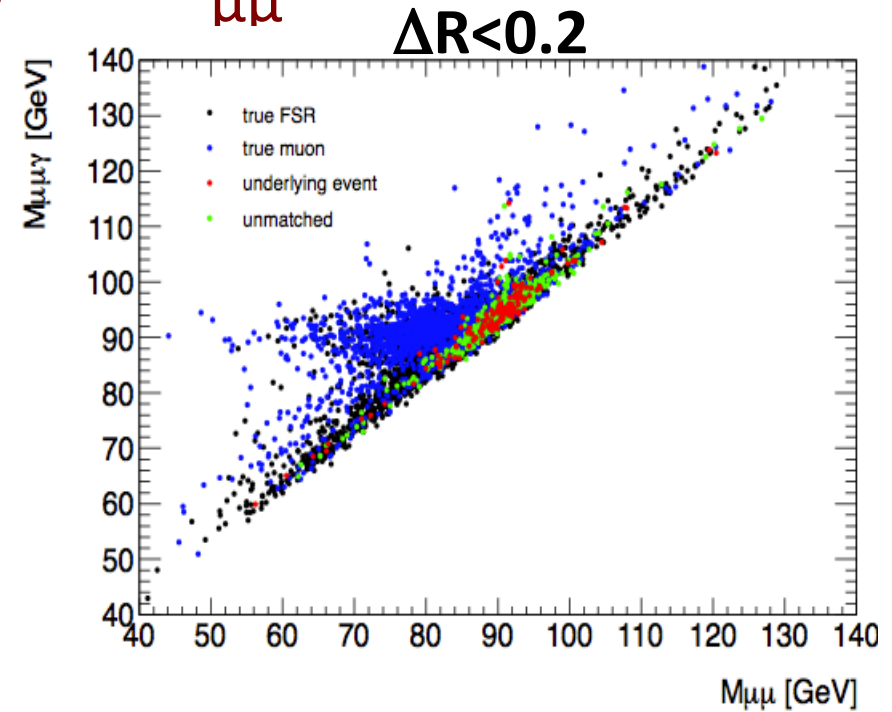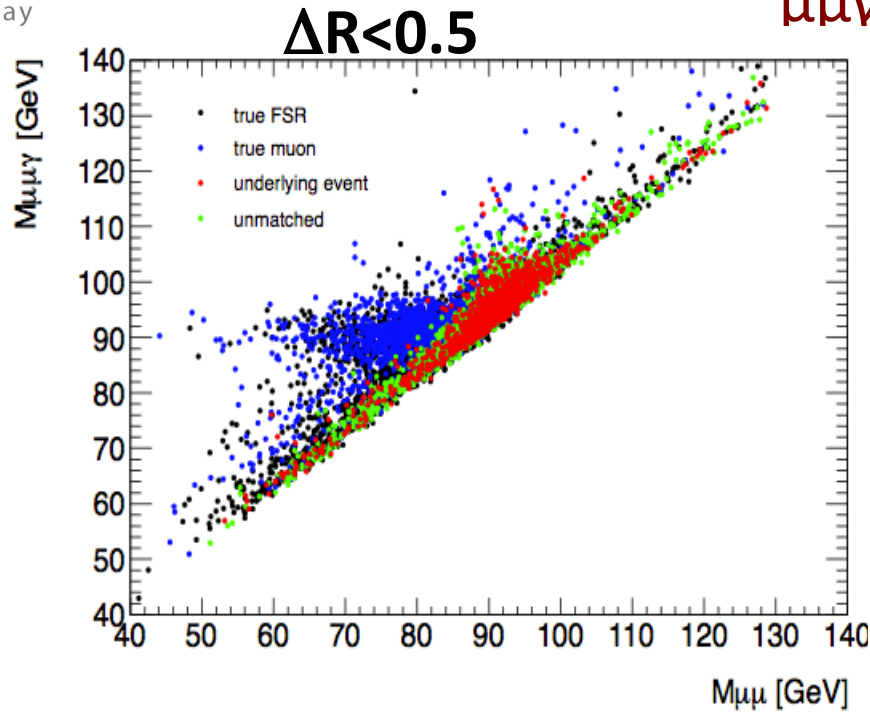
- Select event with FSR tool and look at the truth matching at generator level
  - Blue: photon is truth muon
  - Black: photon from FSR (true photon, parent Z)
  - Red: photon from underlying events (true photon, no parent or parent other than Z)
  - Green: pile-up or misidentified object (no corresponding truth particle)

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Effect of FSR on Calorimeter Isolation after applying Track Isolation
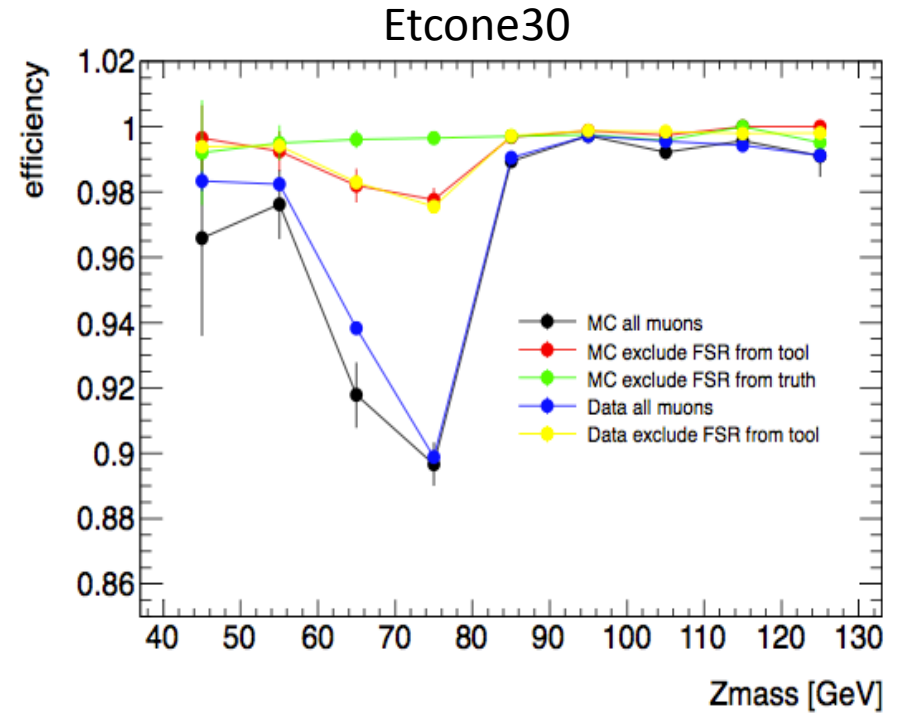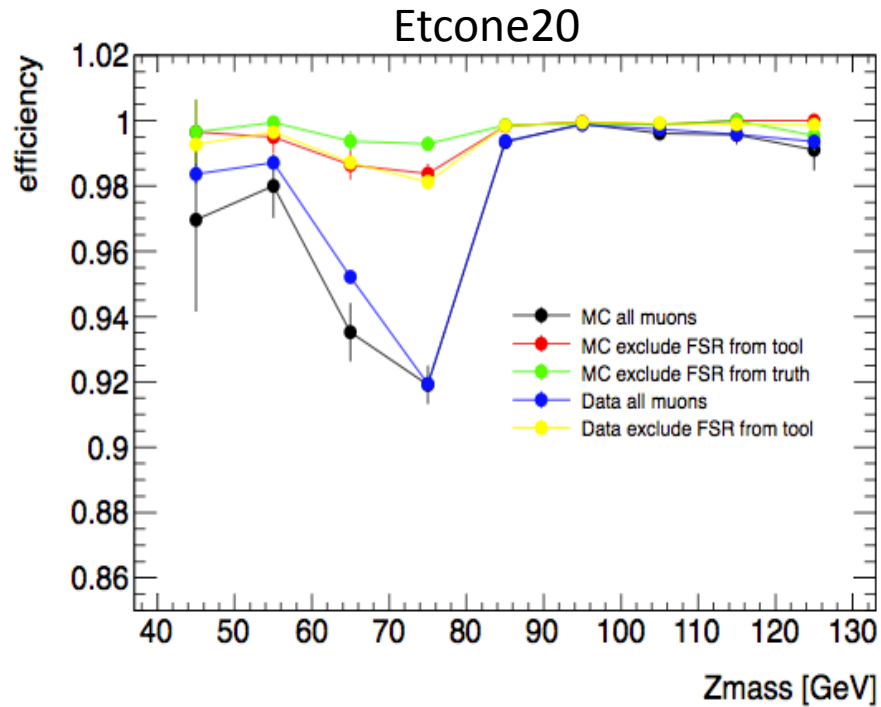
- The Calo isolation is shown after applying the track isolation (ptcone30/pt <0.14)

- The dip is well modelled by MC

- The loss in efficiency is reduced to (~10%) below Z peak caused by FSR

FSR effects on H->4l signal and background

	Signal (130)	ZZ	Zmumubb	Zmumujet	Ttbar	data
Z1_mass	1,00501	1,00054	0,998293	1	1,10629	1,155
Z2_mass	1,00312	1,00144	0,98777	1	1,16845	1,141
DeltaR	1,00314	1,00142	0,994245	1	1,11873	1,0588
track_iso	1,0032	1,00123	1,00162		1	1
calo_iso	1,0001	1,00011	1,00178		1	1
d0_sig	1,00011	1,00015	1,00419		1	1

	128-132 GeV	125-135 GeV	120-140 GeV
S/√B default	1,5255	1,3713	1,0101
S/√B adding FSR	1,5290	1,3744	1,0112

- The numbers in the first table are the ratio between results before and after adding FSR
- Small effect on the final significance

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Summary

- Good data/MC agreement is obtained using FSR tool

- Adding the FSR improves the Z mass

- The calorimeter isolation affects the Drell-Yan spectra

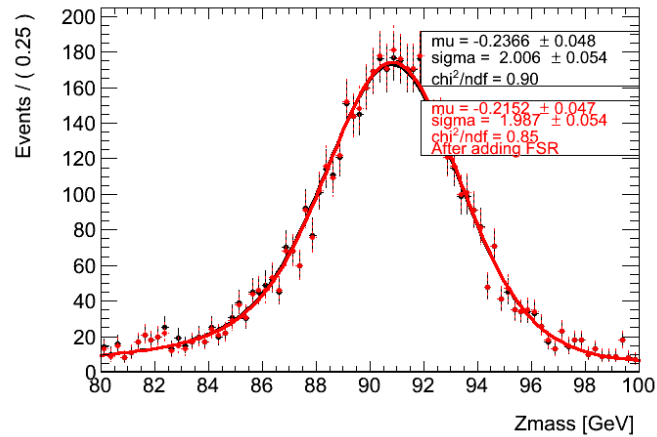- FSR has small impact on H->4mu result in low mass region
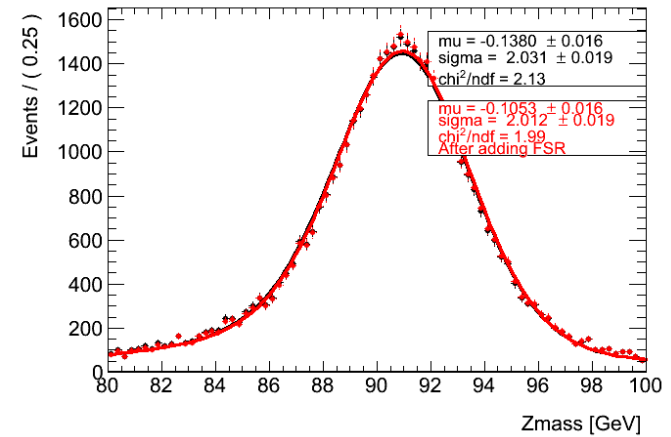
Backup

FSR spectra in data/MC : $E_T^{(\gamma)}$
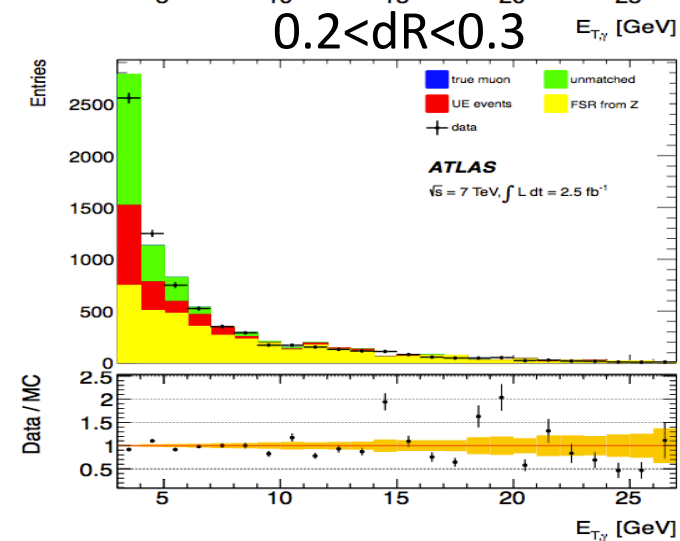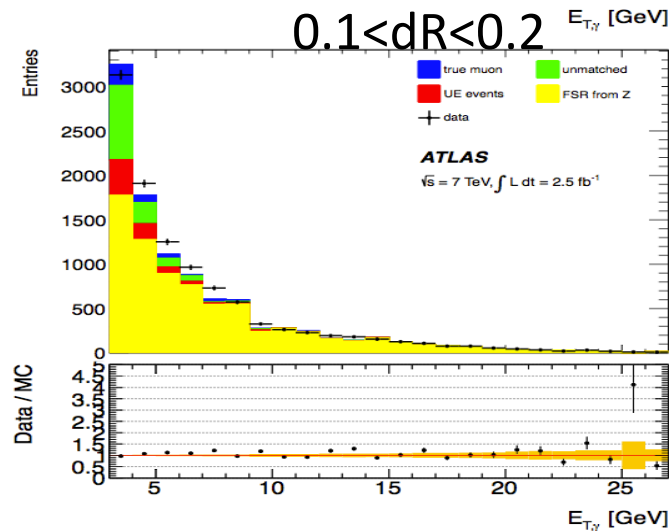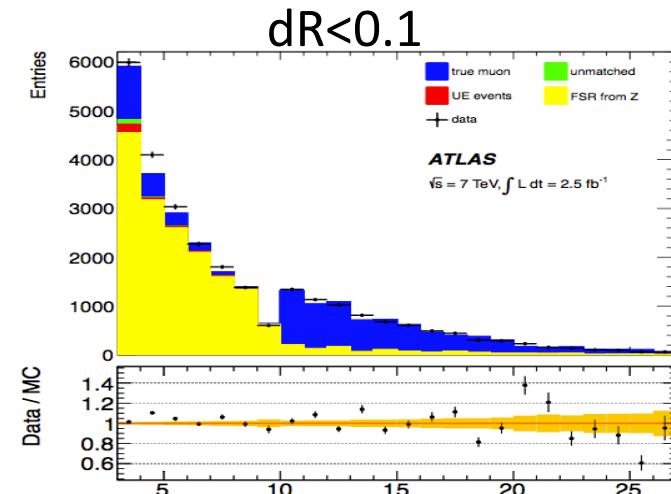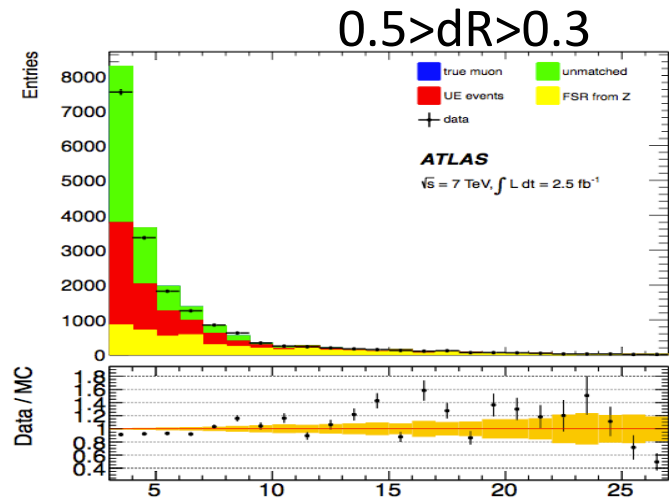
- The Fsr candidates can come from three categories:

i) TopoSeededPhotons when Et<=10GeV;

ii) Standard Egamma Photons when Et>10GeV;

iii) Standard Egamma Electrons when Et>10GeV.

data dR<0.2

BtoD

mu = -0.2366 ± 0.048
sigma = 2.006 ± 0.054
chi²/ndf = 0.90

mu = -0.2152 ± 0.047
sigma = 1.987 ± 0.054
chi²/ndf = 0.85
After adding FSR

EtoH

mu = -0.1380 ± 0.016
sigma = 2.031 ± 0.019
chi²/ndf = 2.13

mu = -0.1053 ± 0.016
sigma = 2.012 ± 0.019
chi²/ndf = 1.99
After adding FSR

ItoK

mu = -0.1581 ± 0.015
sigma = 2.028 ± 0.017
chi²/ndf = 2.66

mu = -0.1276 ± 0.015
sigma = 2.012 ± 0.017
chi²/ndf = 2.38
After adding FSR

M

mu = -0.1650 ± 0.012
sigma = 2.094 ± 0.013
chi²/ndf = 4.24

mu = -0.1344 ± 0.012
sigma = 2.078 ± 0.013
chi²/ndf = 3.93
After adding FSR

L

mu = -0.14006 ± 0.0096
sigma = 2.071 ± 0.011
chi²/ndf = 5.91

mu = -0.10953 ± 0.0095
sigma = 2.056 ± 0.011
chi²/ndf = 5.42
After adding FSR

MC, dR<0.2

MC,dR<0.5

data, dR<0.2

data,dR<0.5
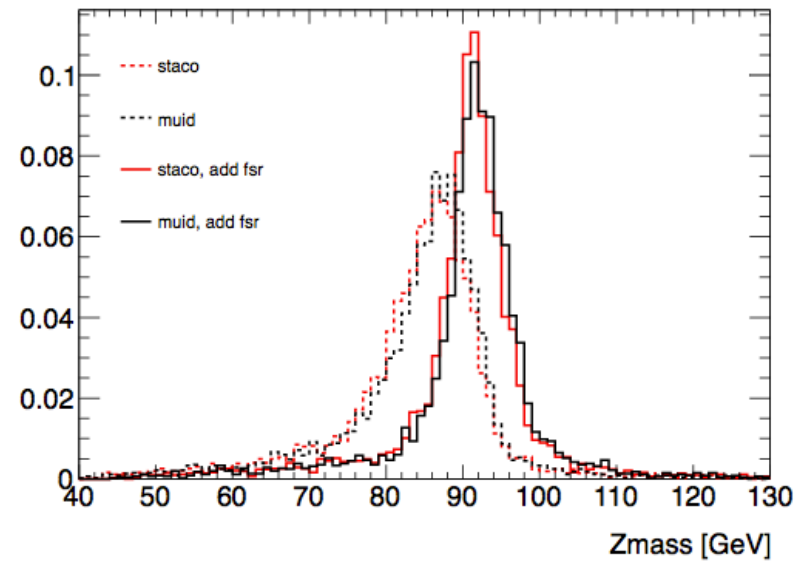
dR<0.2
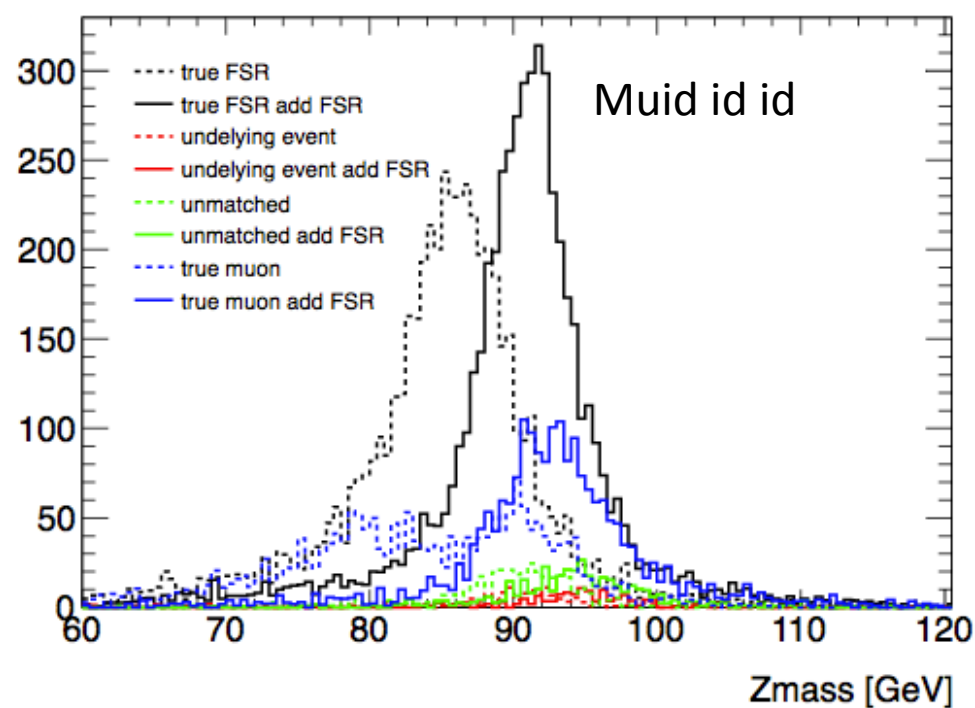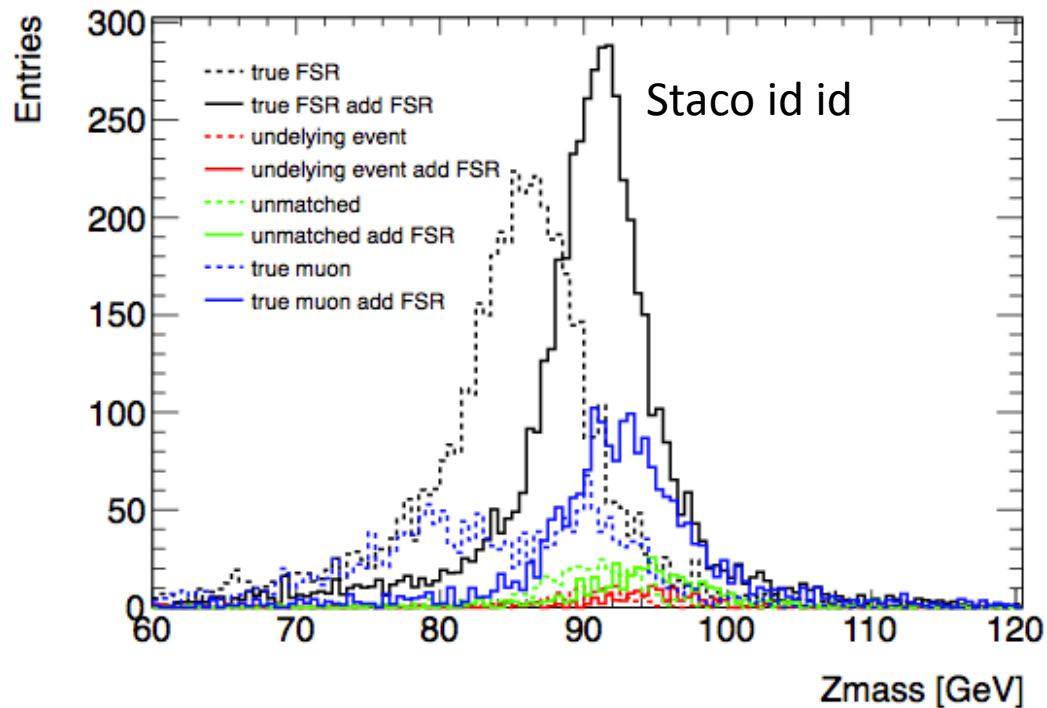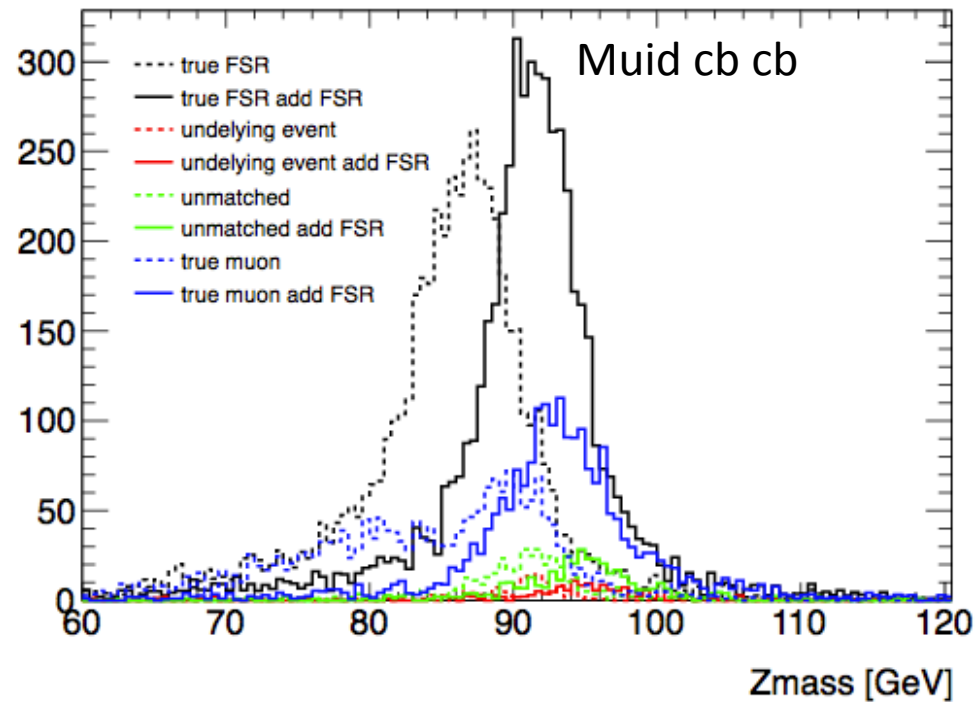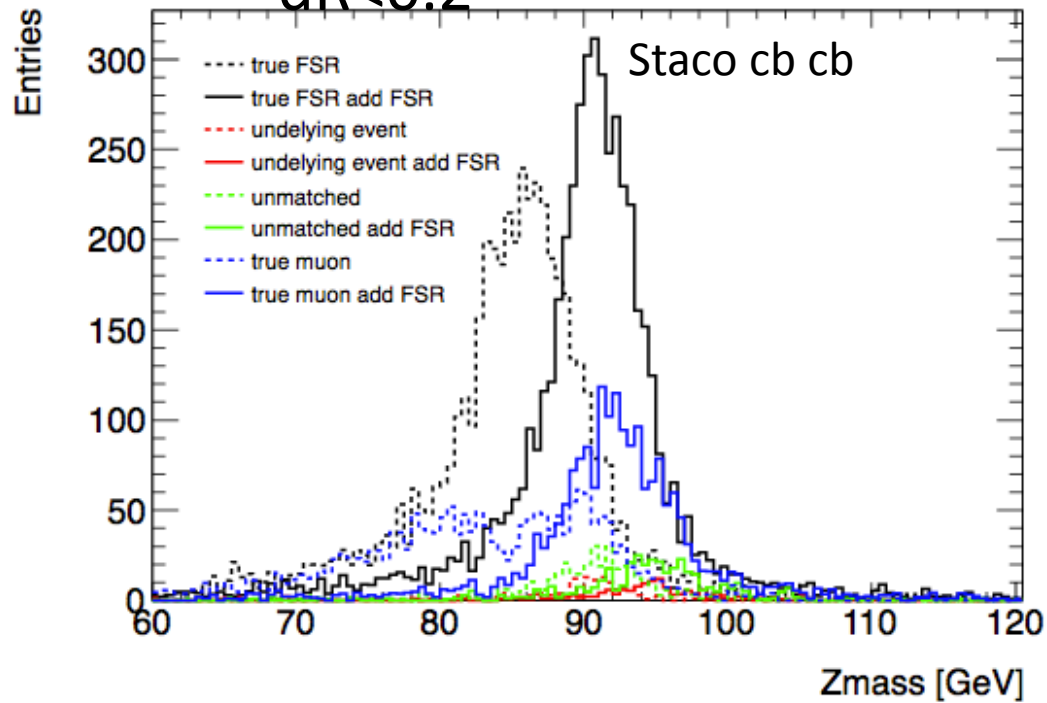
dR<0.5

staco cb cb
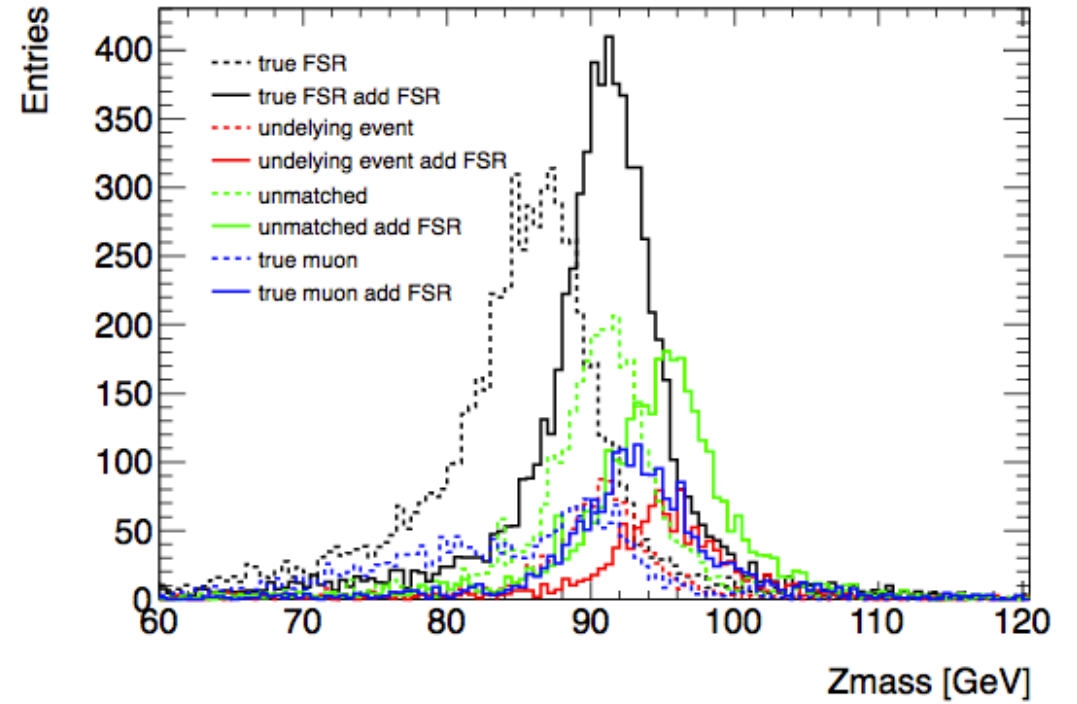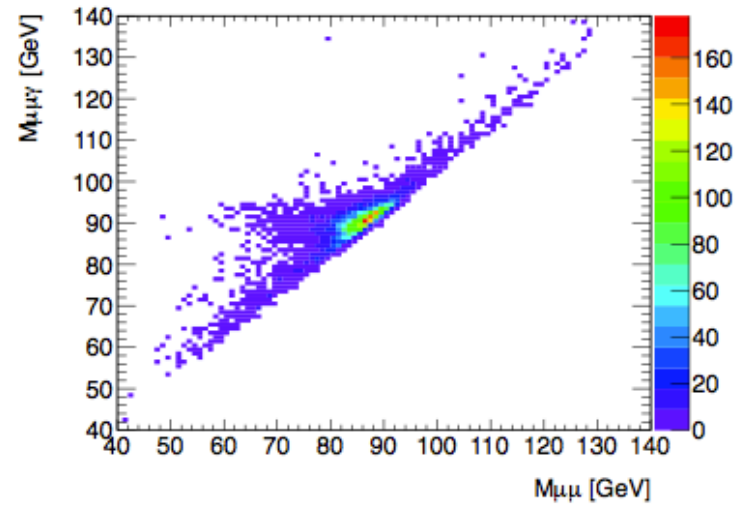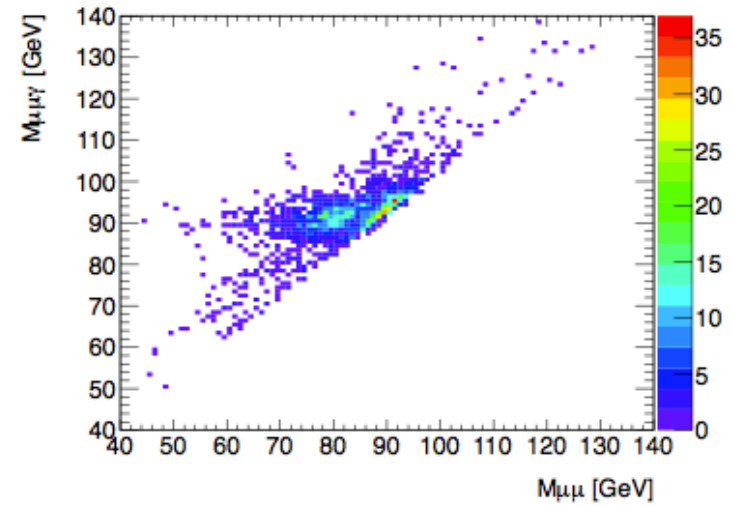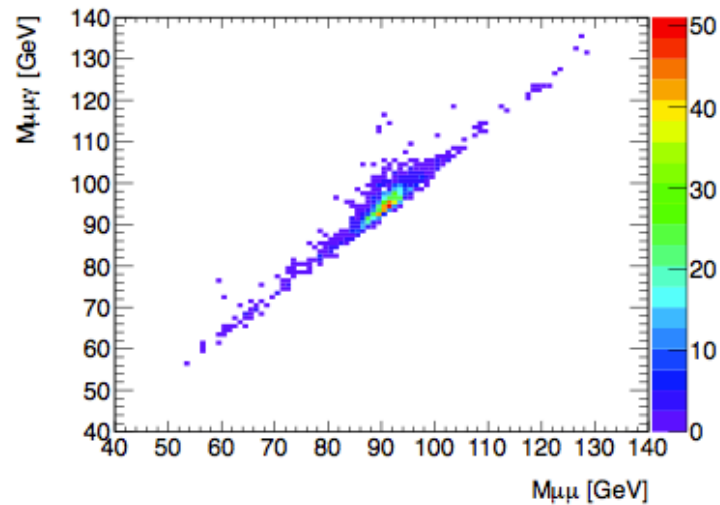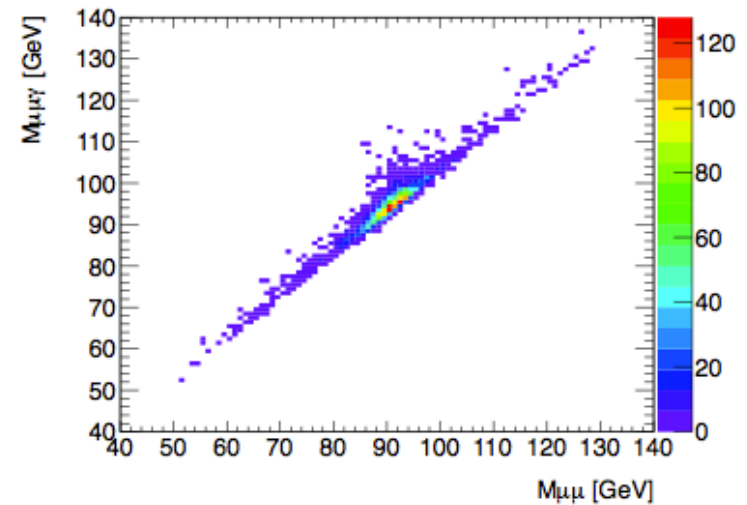
Muid cb cb
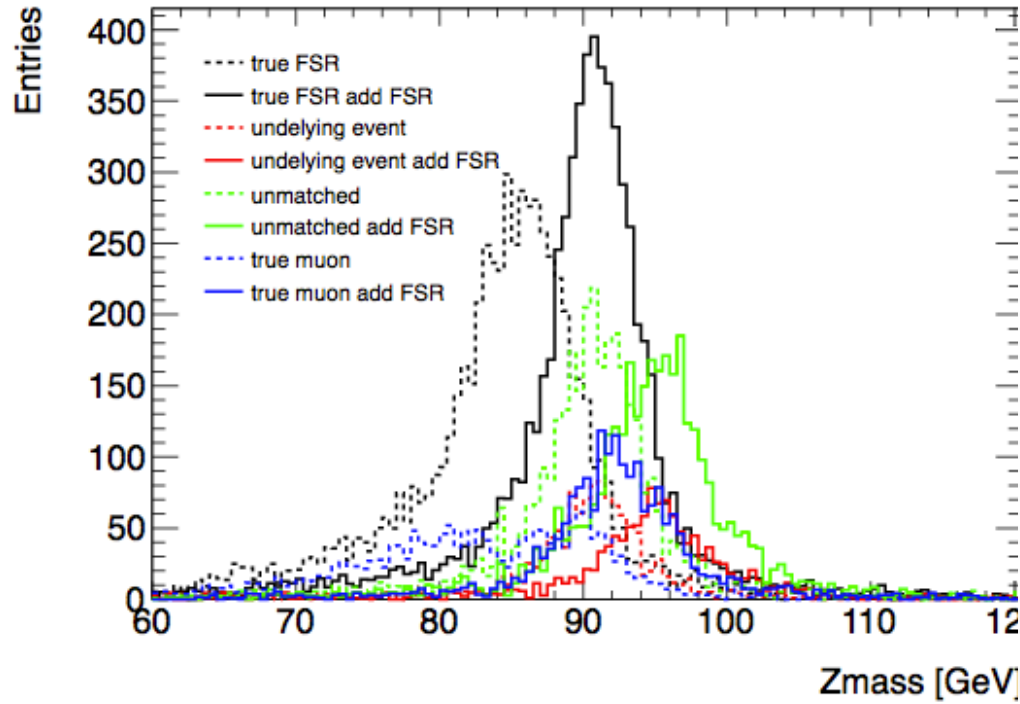
true photon from FSR

true muon from FSR

dR<0.5
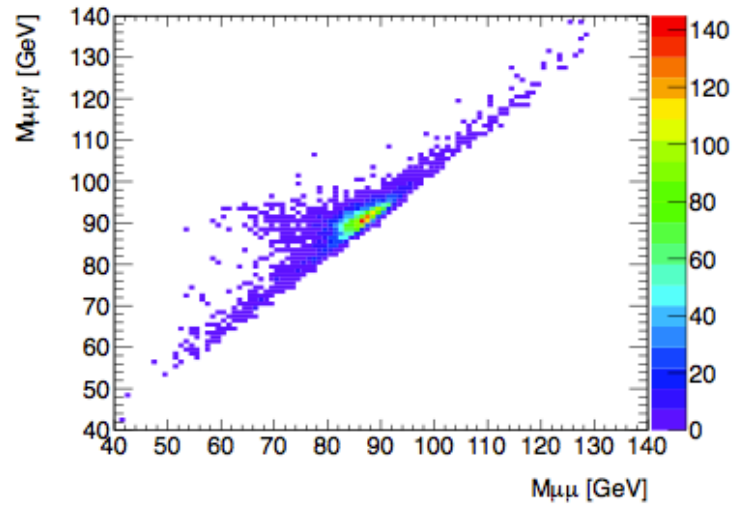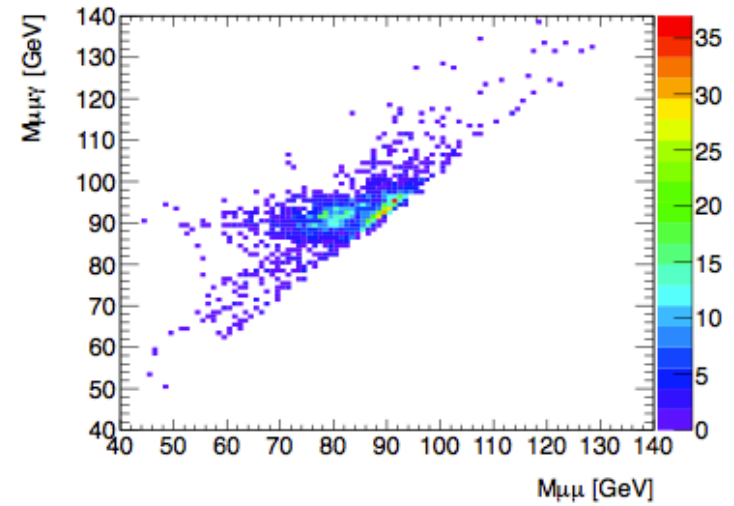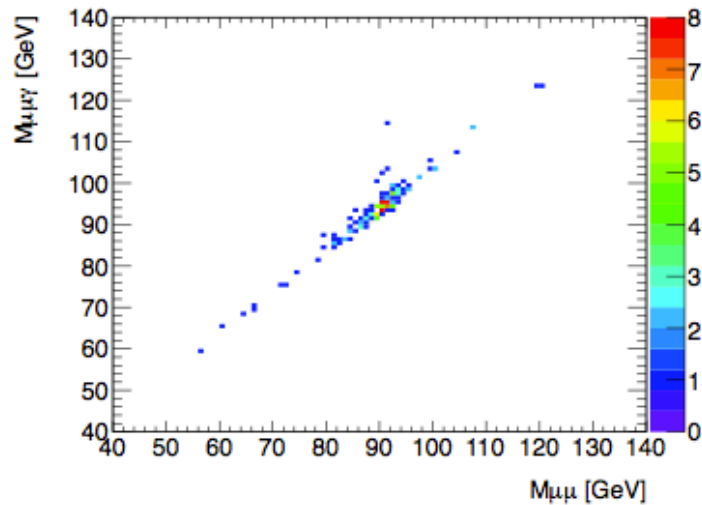
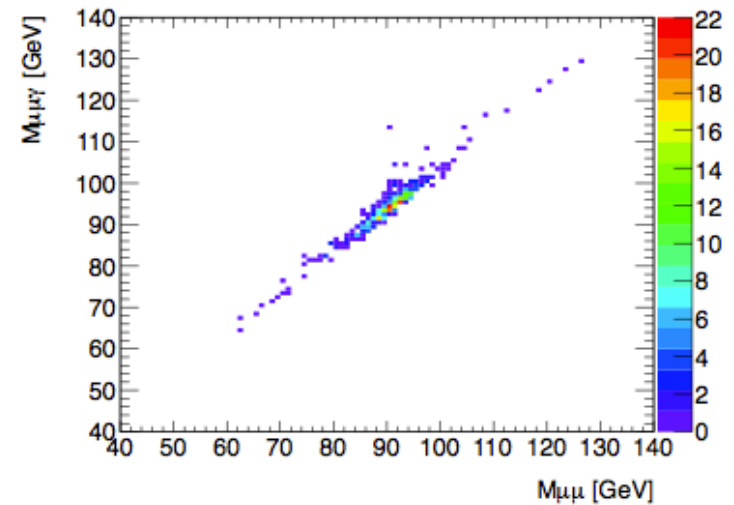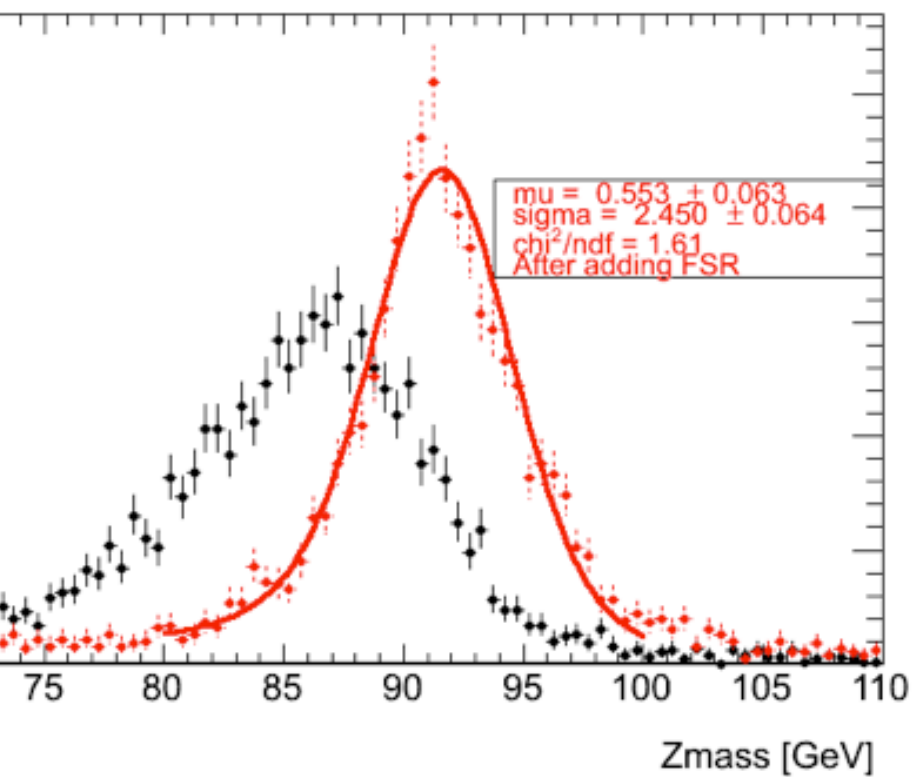underlying event

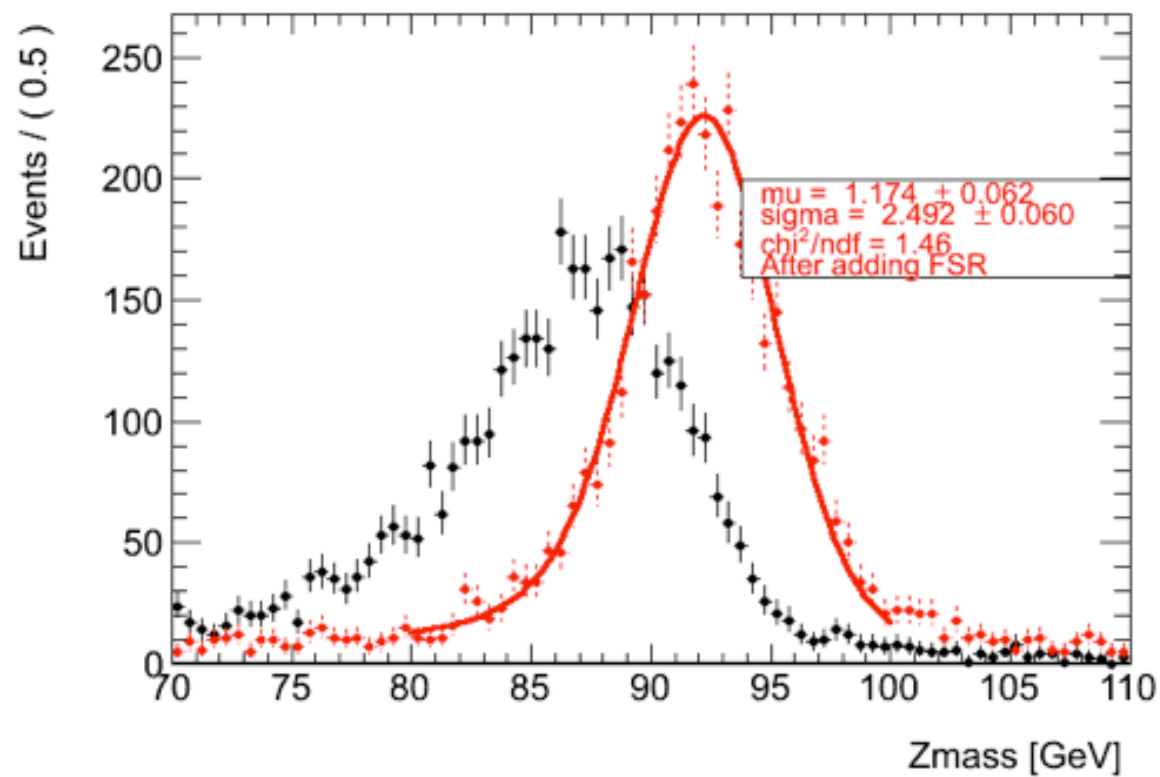unmatched

true photon from FSR

true muon from FSR

dR<0.2

underlying event

unmatched

mu = 0.553 ± 0.063
sigma = 2.450 ± 0.064
chi²/ndf = 1.61
After adding FSR

mu = 1.174 ± 0.062
sigma = 2.492 ± 0.060
chi²/ndf = 1.46
After adding FSR

Events / (0.5)

Zmass [GeV]

Zmass [GeV]

Data staco, cb

Data muid, cb