Data based method for background subtraction: $Z \rightarrow \mu^+\mu^-$

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Outline

- Motivation.
- Example of application: bb Z $\rightarrow$ $\mu^+ \mu^-$
- Method proposed
- Software & Generators
  - Simulation, Reconstruction, Analysis.
- Sample
- Conclusion and future development

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MonteCarlo

Isajet

Ariadne

Cojest

Sherpa

- **Les Houches Guidebook hep-ph/040345**

Jetset

Herwig

Pythia

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Frascati, 27-28 Febbraio 2006

P. Nason

Shower MonteCarlo

Conclusions

SMC are amazing models for hard interactions

Include most useful background and signals for LHC

Reliable in leading order for

- Hard interaction
- Jet structure

Less reliable (but very realistic) for

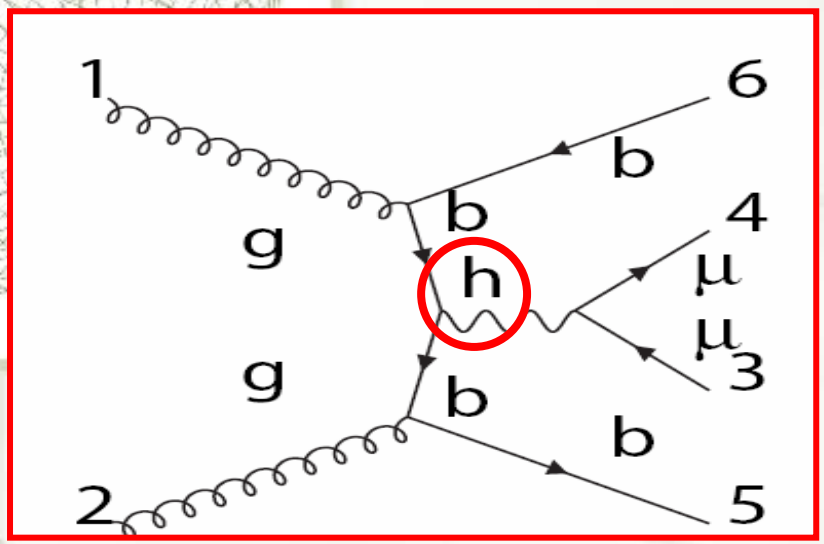
- Hadron formation
- Underlying event
- Multiple interactions

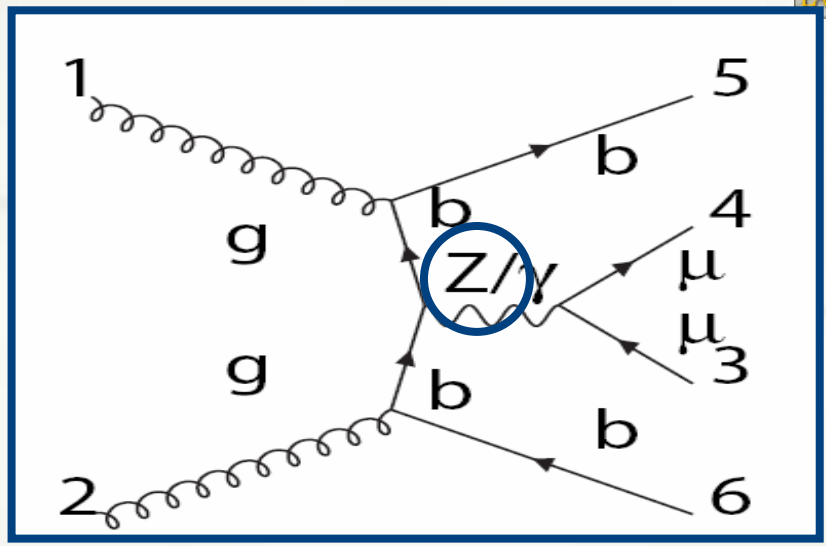
Motivation

- It is then extremely important to rely on alternative method to MonteCarlo, as much we can
- We propose a method based on a different data sample of experimental data
- Only hypothesis: lepton universality.
- Example of application: bb $Z \rightarrow \mu^+ \mu^-$

(most copious background of bb $h_0/A \rightarrow \mu^+ \mu^-$ studies (14/12/2005) S.G. presentation, ATLAS-PHYS-2003-015, June 2003.)

Signal & background





$\sigma \sim 0.2 - 0.01$ pb
(even lower)

$\sigma \sim 22.8$ pb

✦ **$h_0\ bb \rightarrow \mu^- \mu^+ bb$**

✦ **$Zbb \rightarrow \mu^-\mu^+\ bb$**

(Pythia 6.226)AcerMC (v.2.3) interfaced with Pythia 6.2 (hep/ph0405247).

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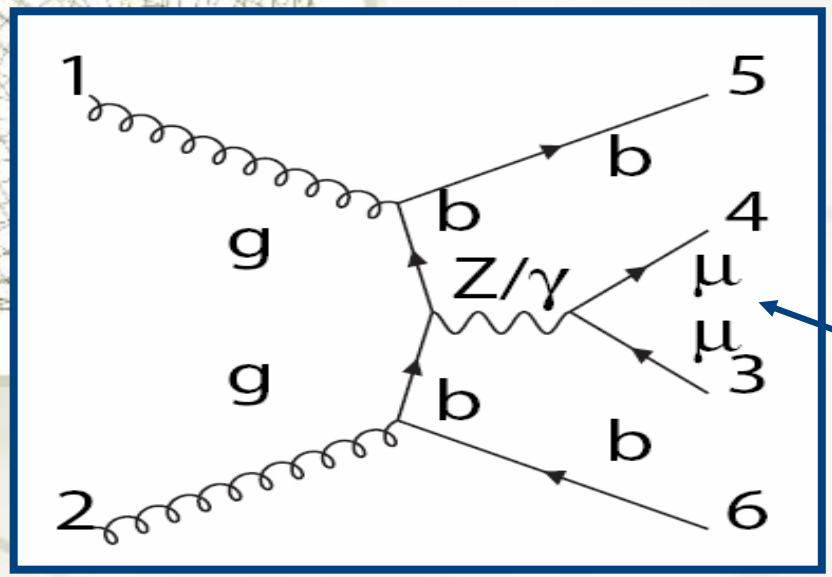
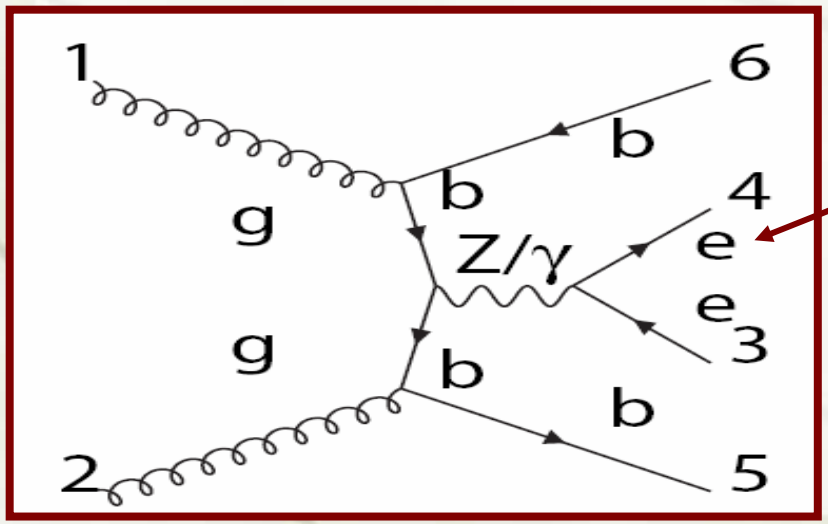
Background Subtraction Method





Precise Knowledge of background is crucial

- Experimental method proposed based on $Z \rightarrow \mu^+ \mu^-$ and $Z \rightarrow e^+ e^-$
- Relying on experimental data
- **Br($h_0 \rightarrow e^+ e^-$) neglegible**

$$\propto \left(\frac{m_{\mu}}{m_{e}} \right)^2$$

- **Different Inner Bremsstrahlung**

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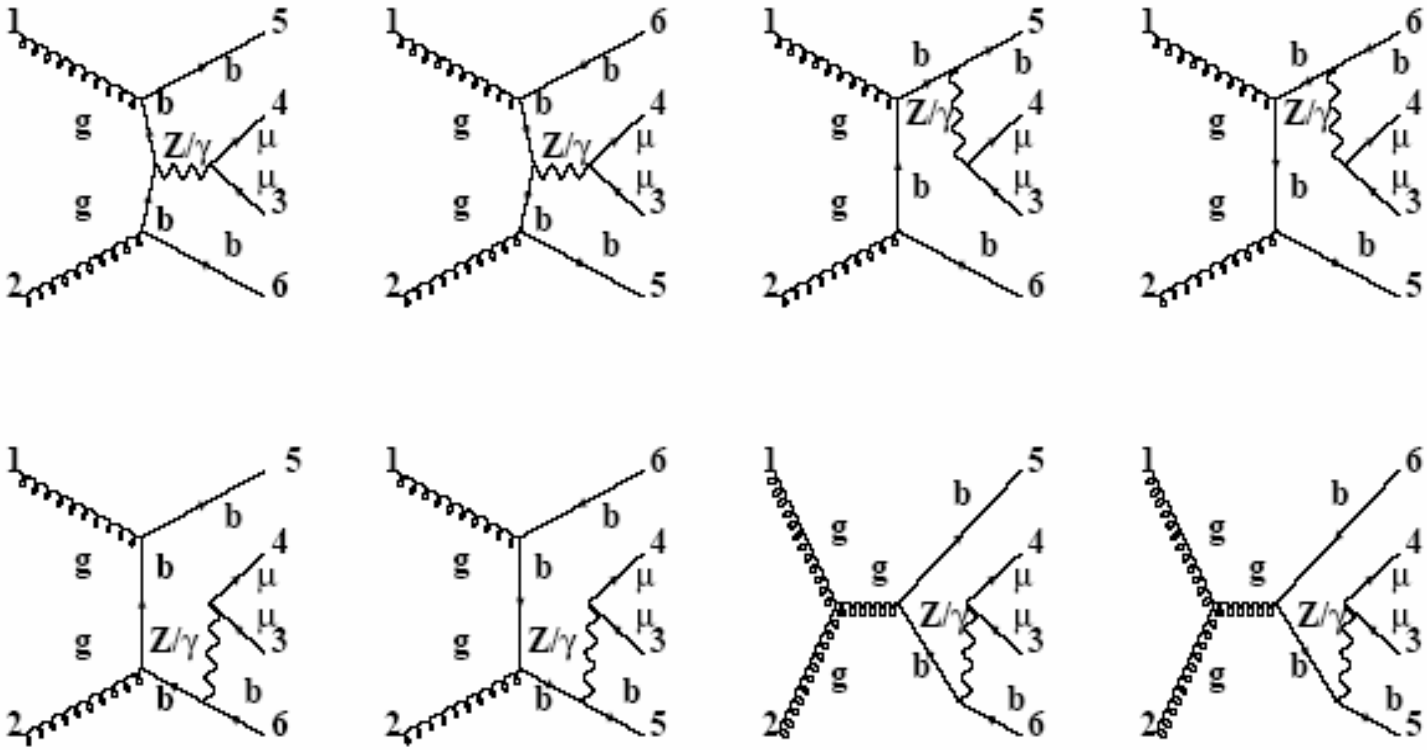
Z production



$$gg \to hb\bar{b} \to \mu^+ \mu^- b\bar{b}$$

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Software Release & Sample

- Generation Athena 9.0.4 - Pythia (v.6.226) - Acer (v. 2.3)
- Simulation, Digitalization, Reconstruction Athena 10.0.1
- Analysis based on CBNT (root –ntuples).

➢ **Final study in scenario** $\int L dt = 30\, fb^{-1}$

~ 600000 events

➢ **In this presentation $L_{int} \sim 20\ fb^{-1}$**

~ 400000 events

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Study performed

- **Different Inner Bremsstrahlung**

  $Zbb \rightarrow \mu^-\mu^+ bb\ (\gamma)$ $N_\gamma \sim 0.086$ $N_{ev}=464522$

  $Zbb \rightarrow e^-e^+ bb\ (\gamma)$ $N_\gamma \sim 0.157$ $N_{ev}=442828$

- **Different Detector Response**
- **The most significative variable of**

bb $h_0/A \rightarrow \mu^+ \mu^-$ analysis has be chosen M_{inv} as test .

- **NB. The combination of a same flavor lepton originating from b and one of Z are included inevitably in the plots**

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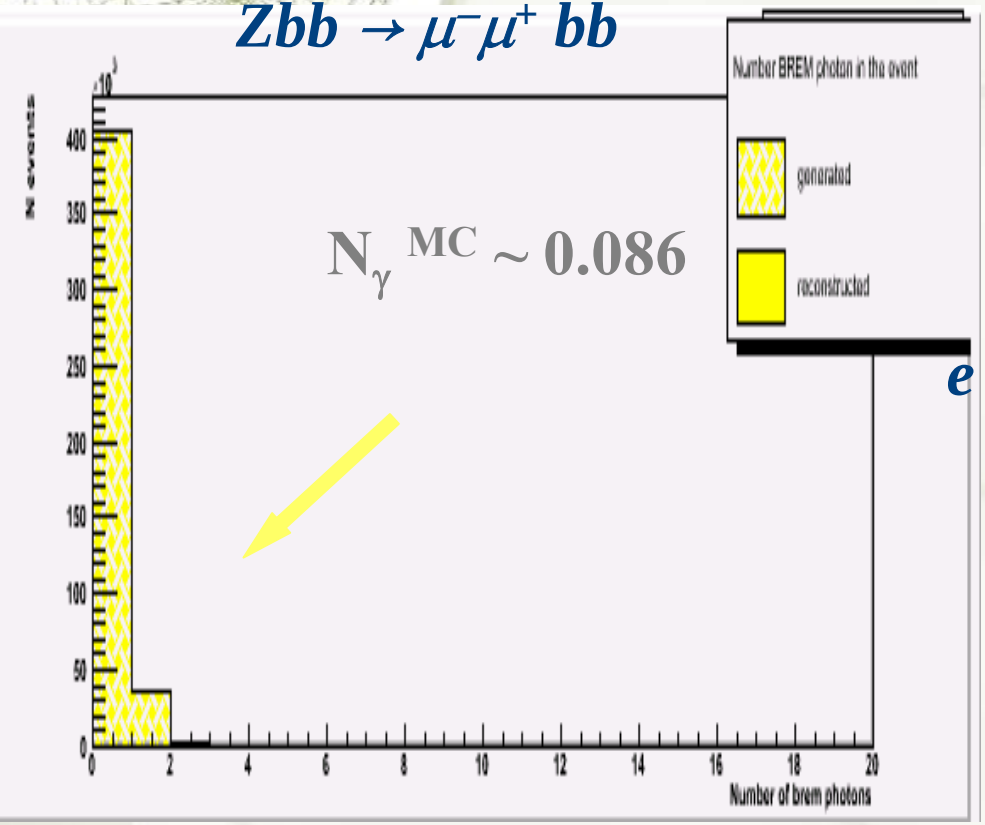
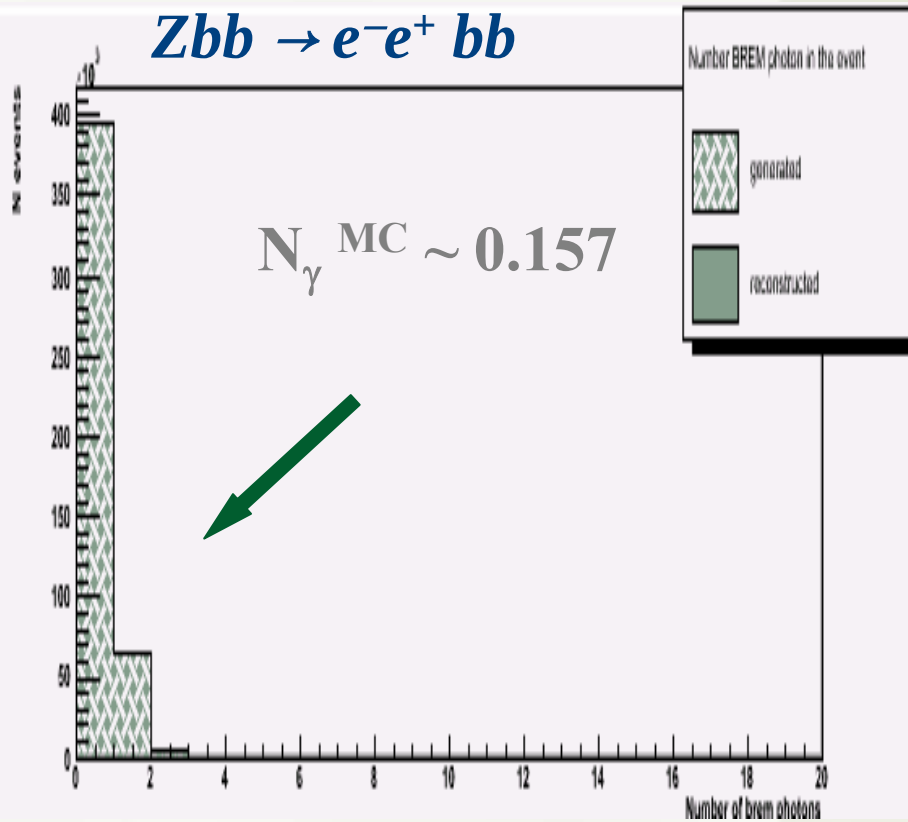
Bremsstrahlung Photons

$Zbb \rightarrow \mu^-\mu^+ bb$



$N_\gamma^{MC} \sim 0.086$

$Zbb \rightarrow e^-e^+ bb$



$N_\gamma^{MC} \sim 0.157$

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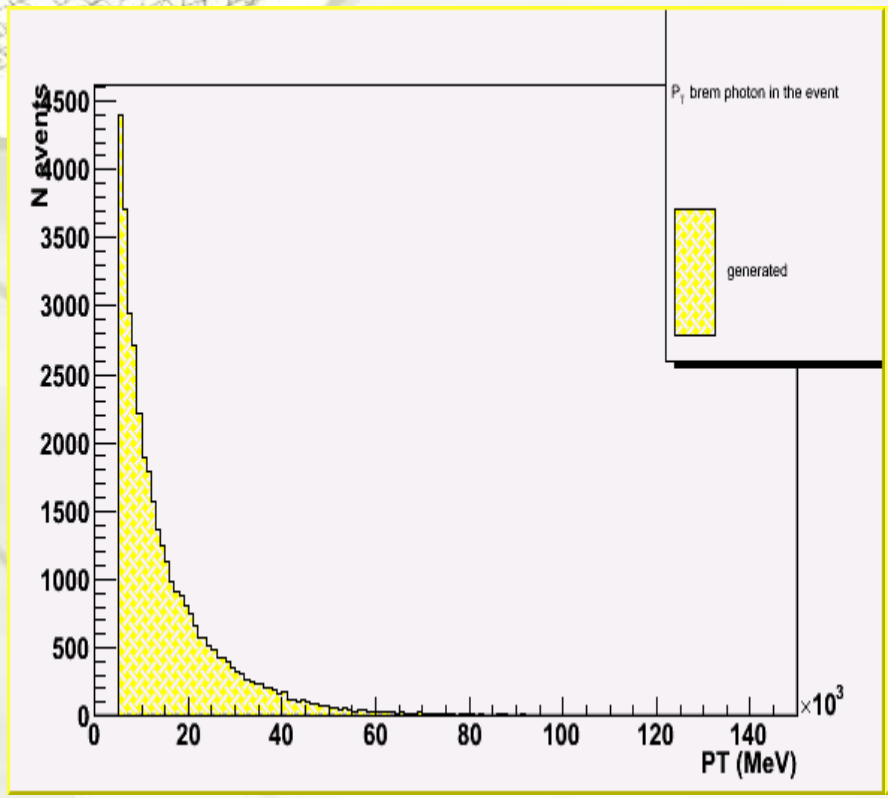
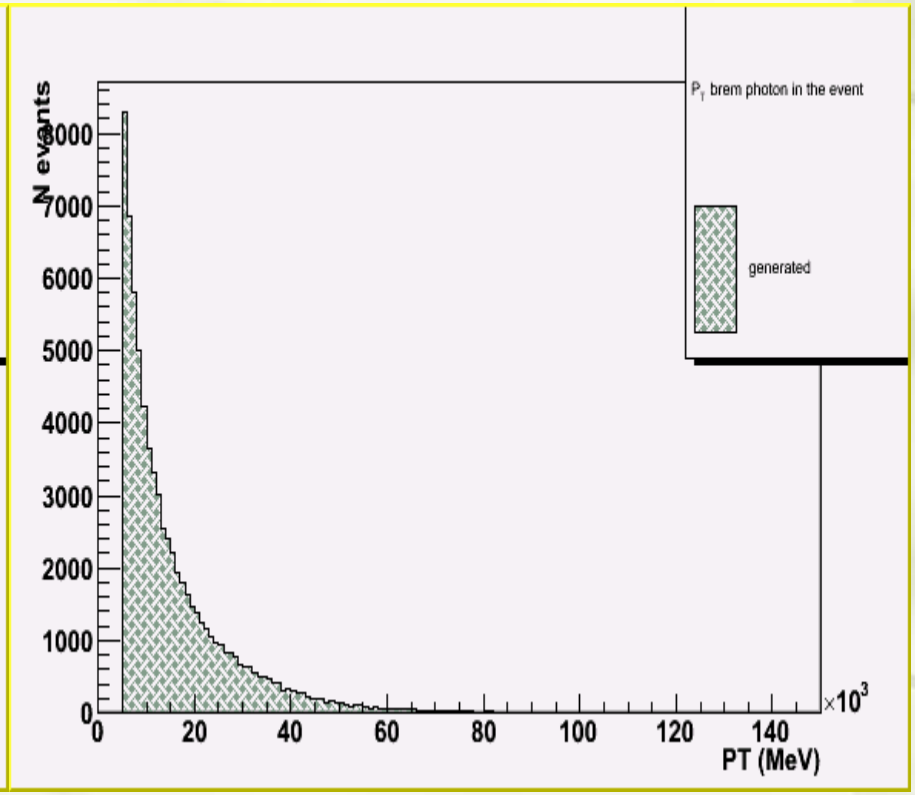
Bremsstrahlung Photons

$Zbb \rightarrow \mu^- \mu^+ bb$



$Zbb \rightarrow e^- e^+ bb$



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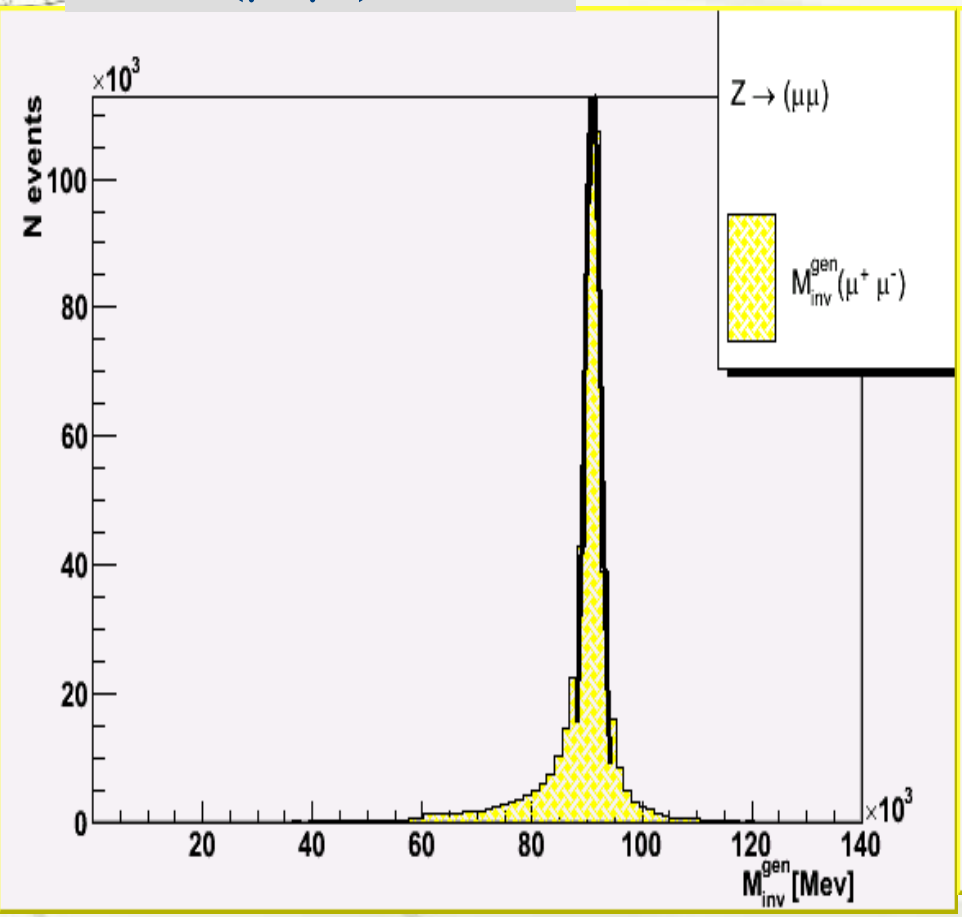
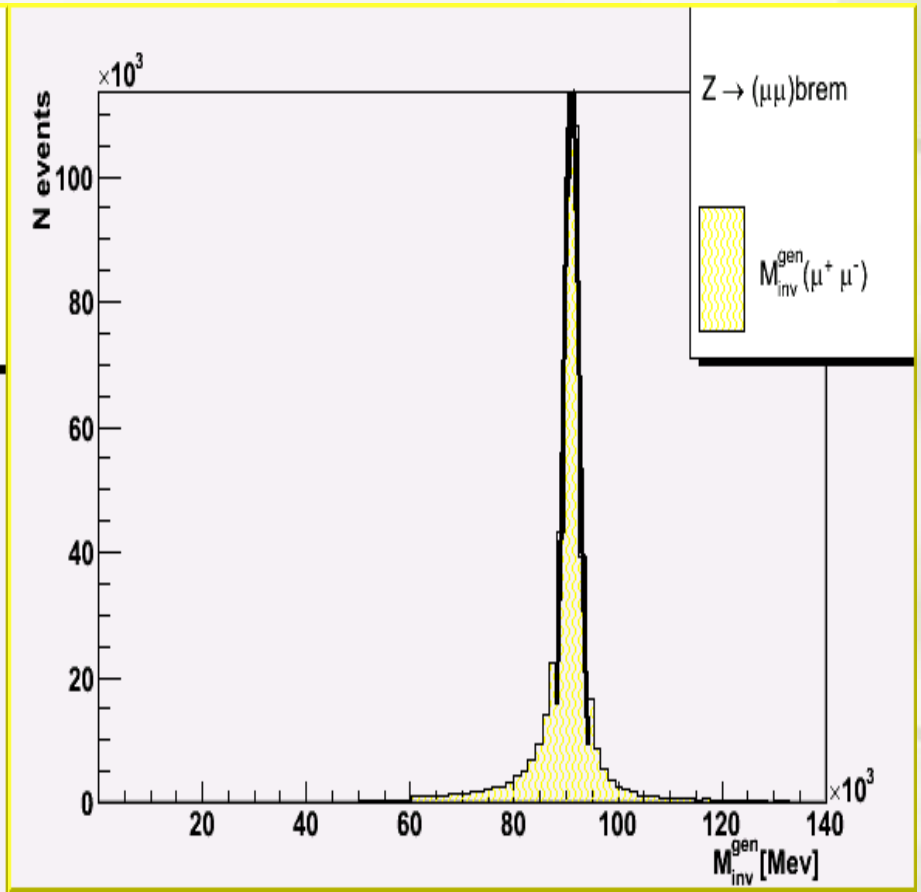
Generator level: $Zbb \rightarrow \mu^- \mu^+ bb$

Minv($\mu^+\mu^-$)



Minv($\mu^+\mu^-$)γ



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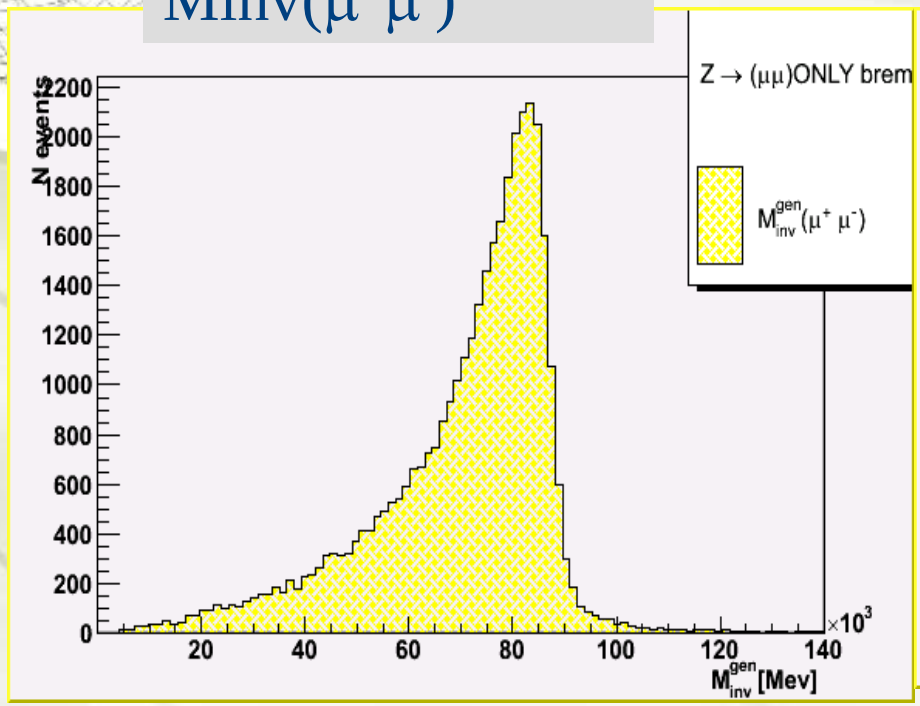
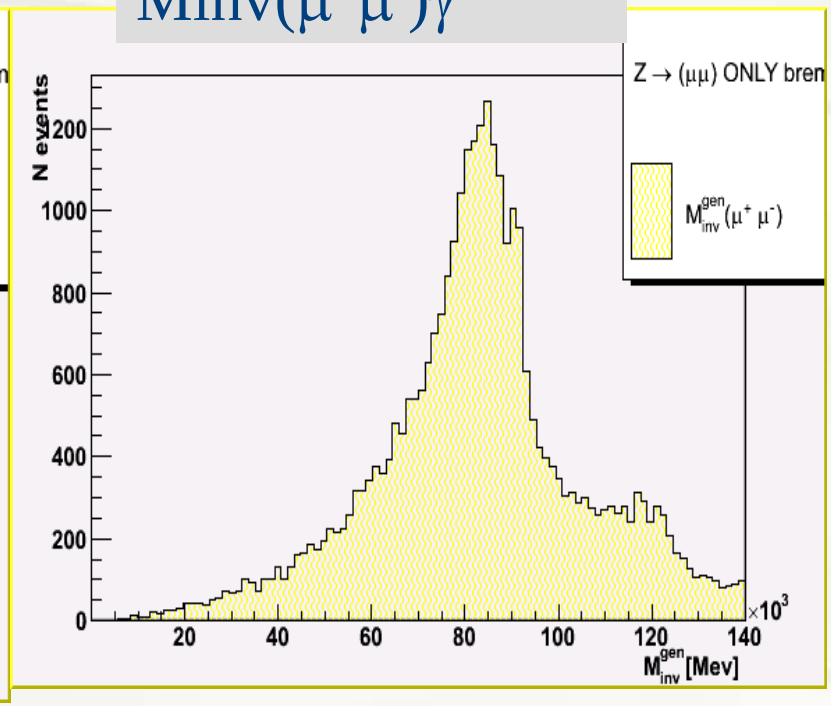
Generator level: $Zbb \rightarrow \mu^- \mu^+ bb$

Minv($\mu^+\mu^-$)



Minv($\mu^+\mu^-$)γ



Only events with a γ of Bremsstrahlung

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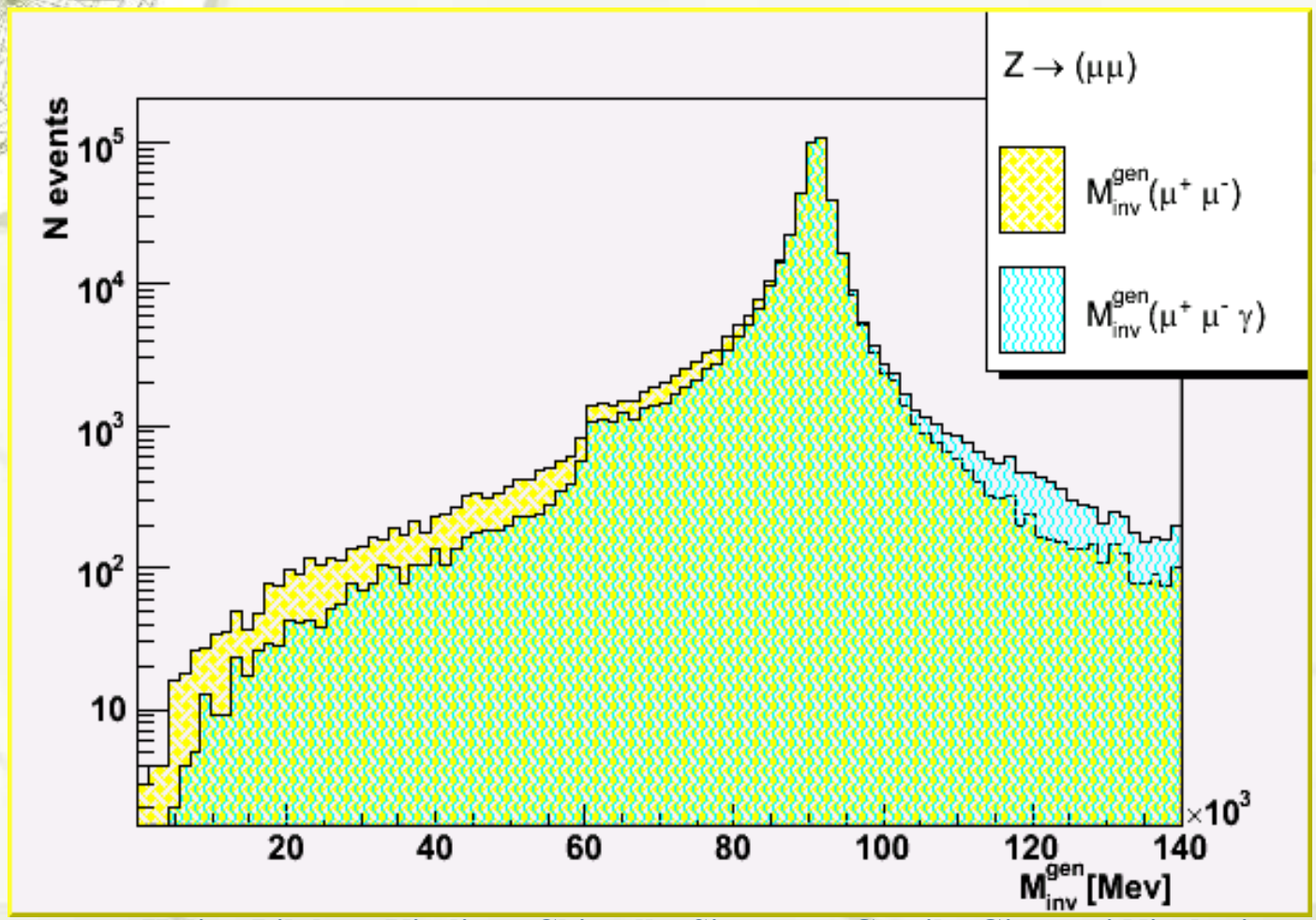
Generator level: $Zbb \rightarrow \mu^- \mu^+ bb$



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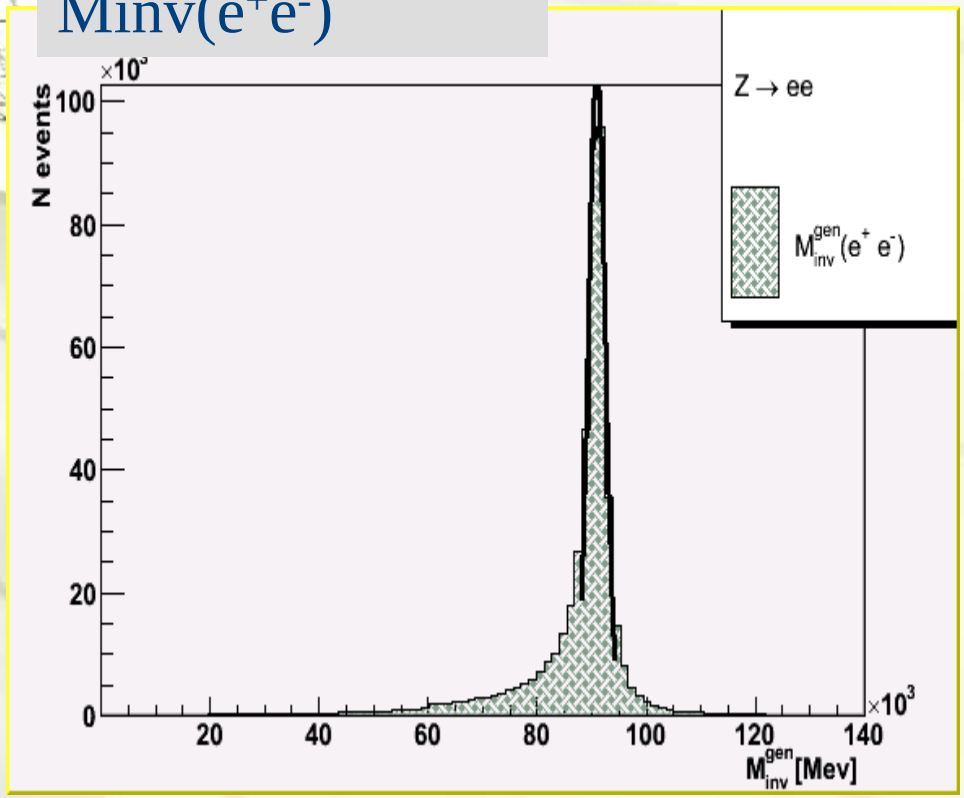
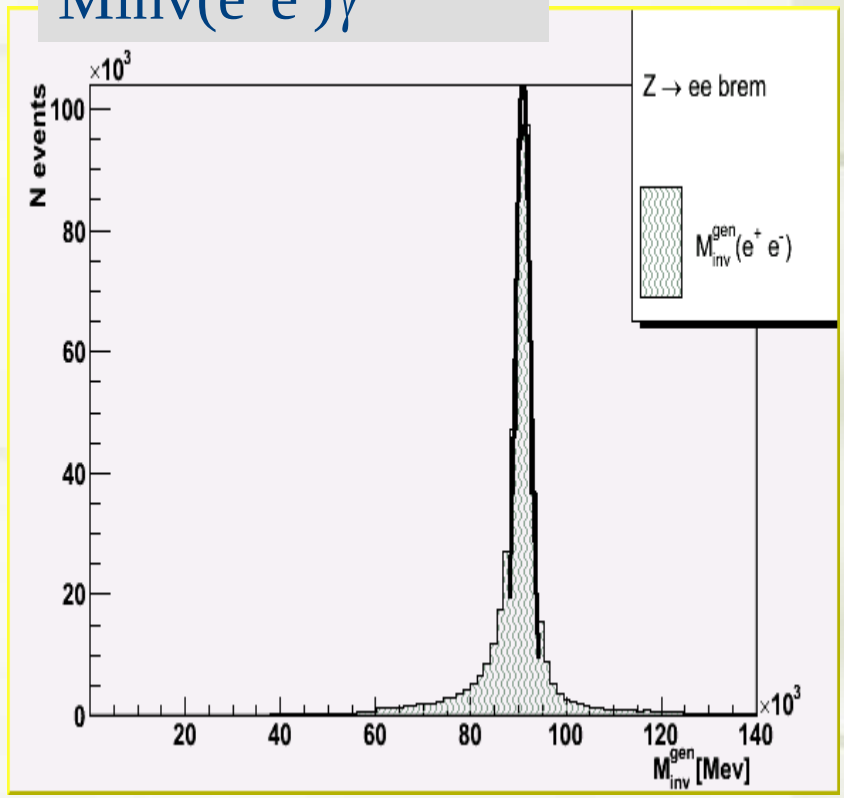
Generator level: $Zbb \rightarrow e^{-}e^{+}\,bb$

Minv(e^+e^-)



Minv(e^+e^-)γ



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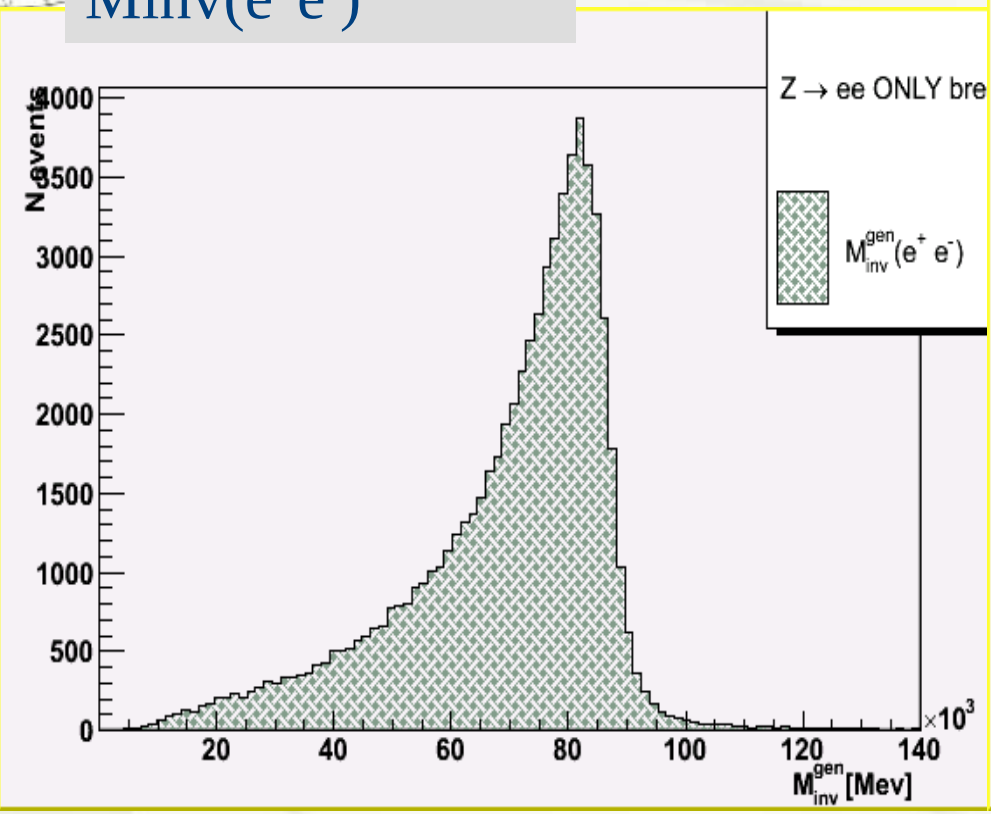
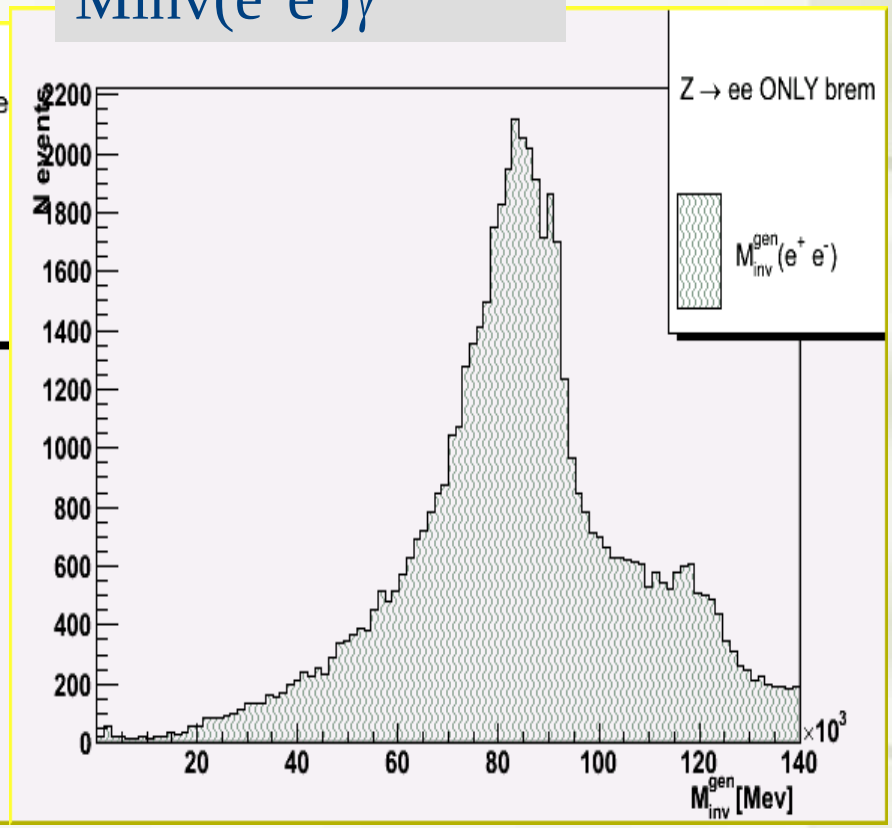
Generator level: $Zbb \rightarrow e^{-}e^{+}\,bb$

Minv(e^+e^-)



Minv(e^+e^-)γ



Only events with a γ of Bremsstrahlung

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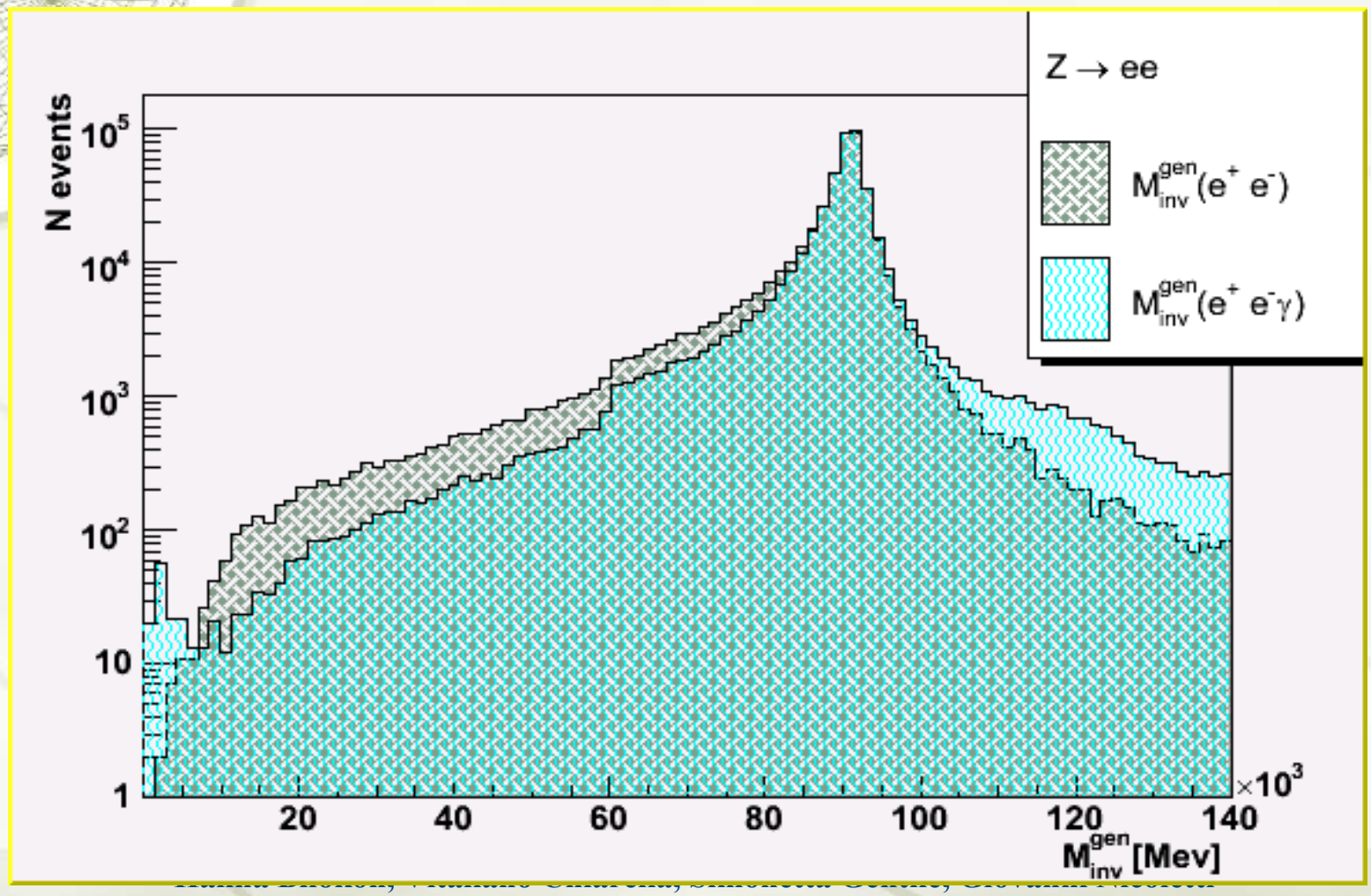
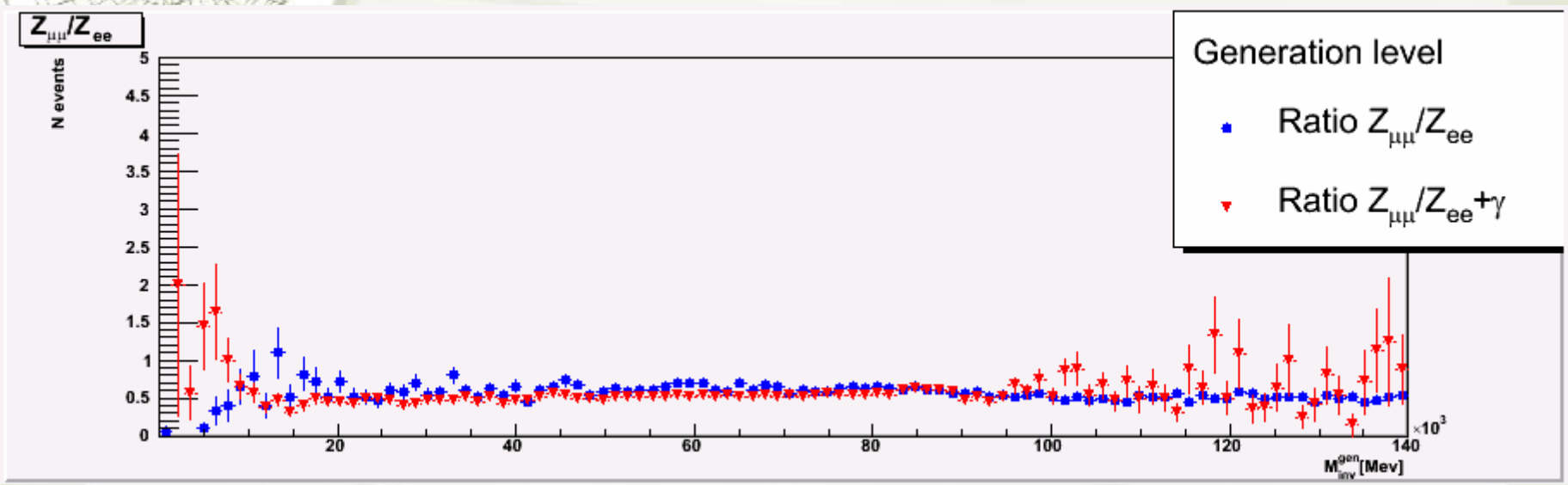
Generator level: $Zbb \rightarrow e^{-}e^{+}\ bb$



Generator level



Bremsstrahlung events

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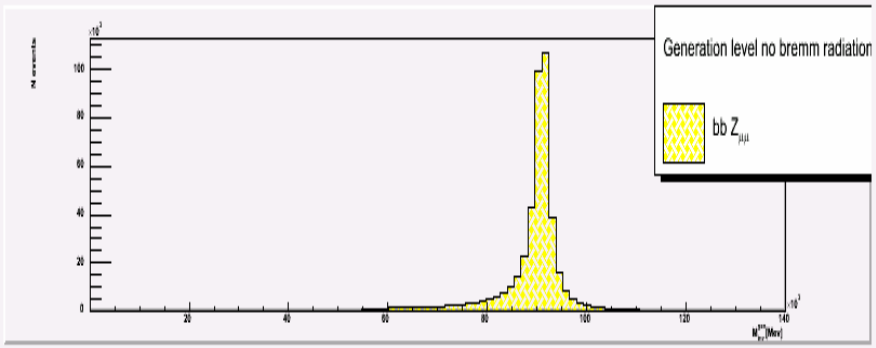
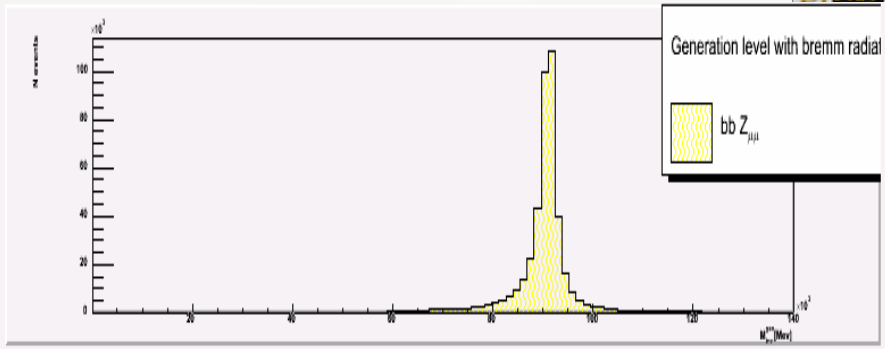
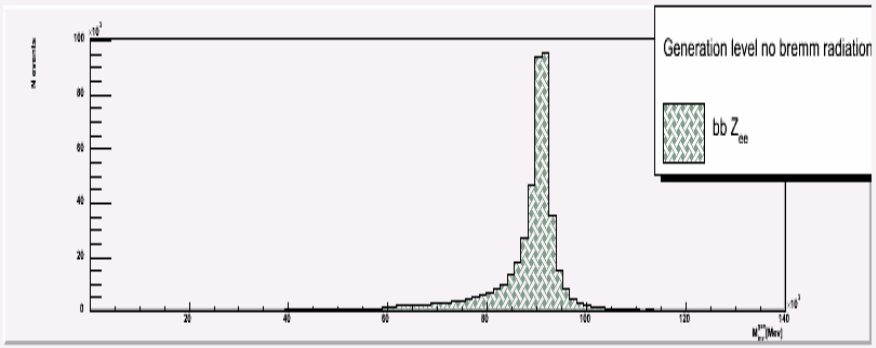
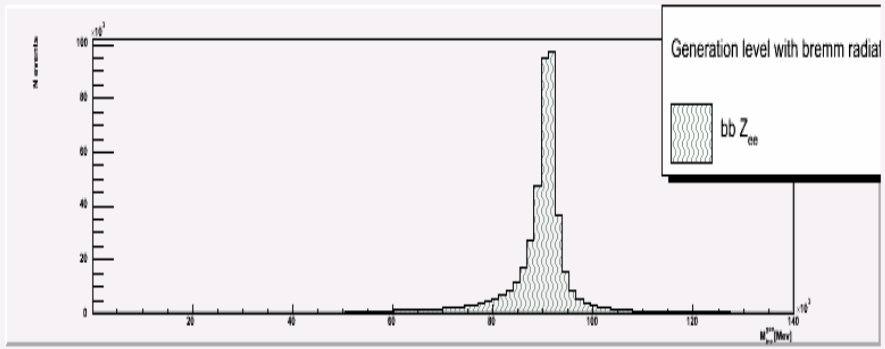
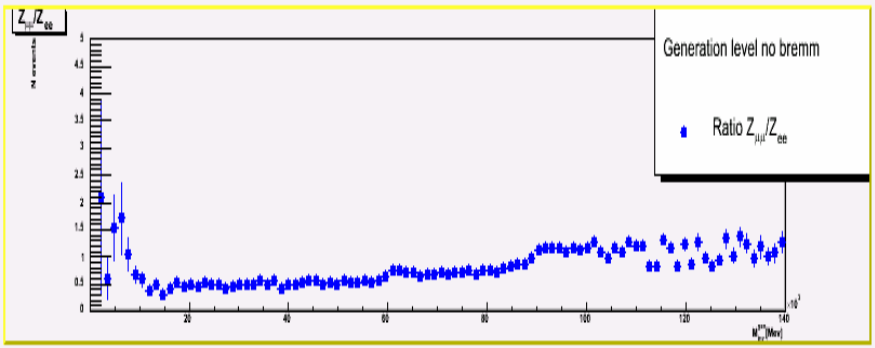
Generator level

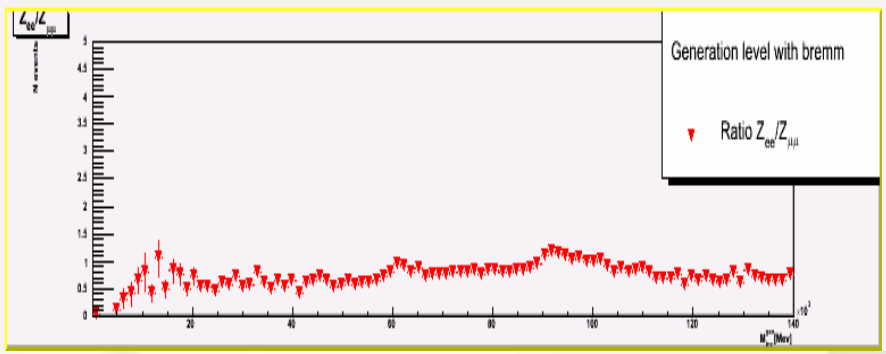












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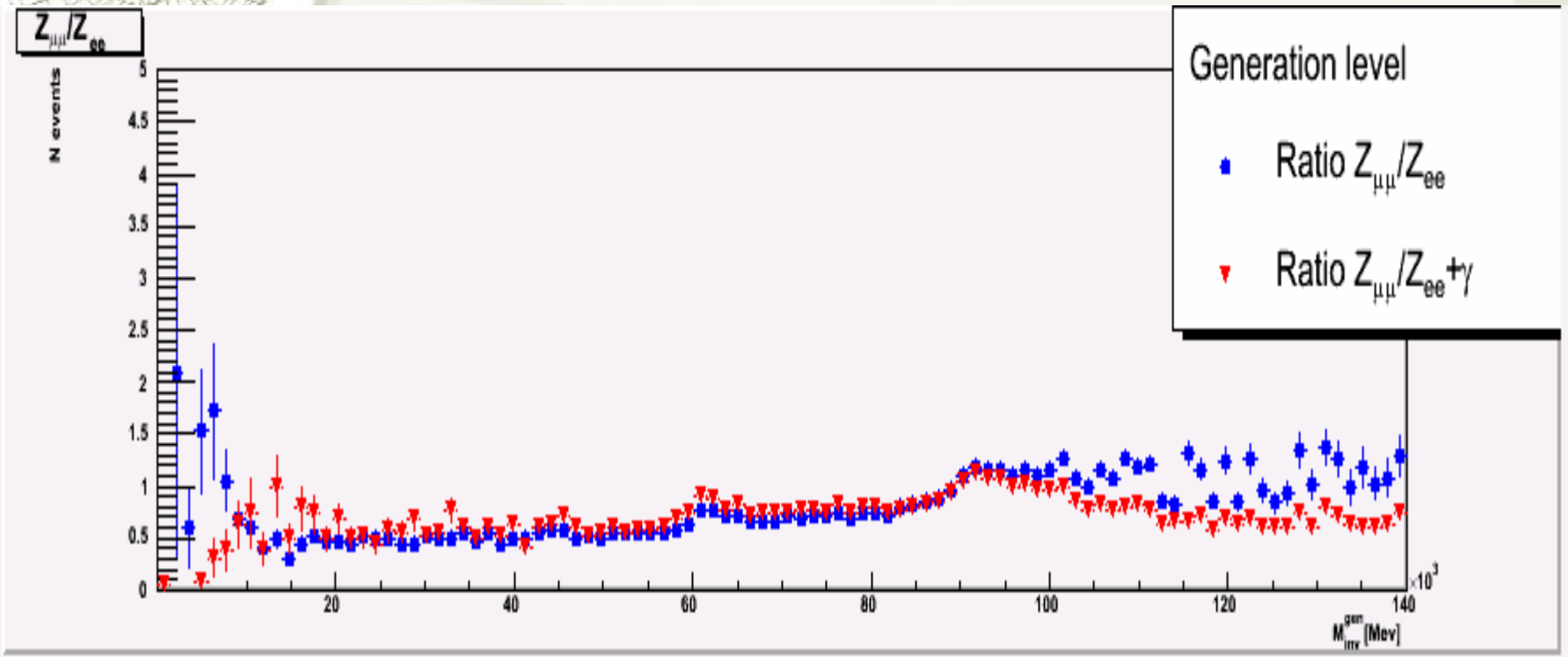
Generator level



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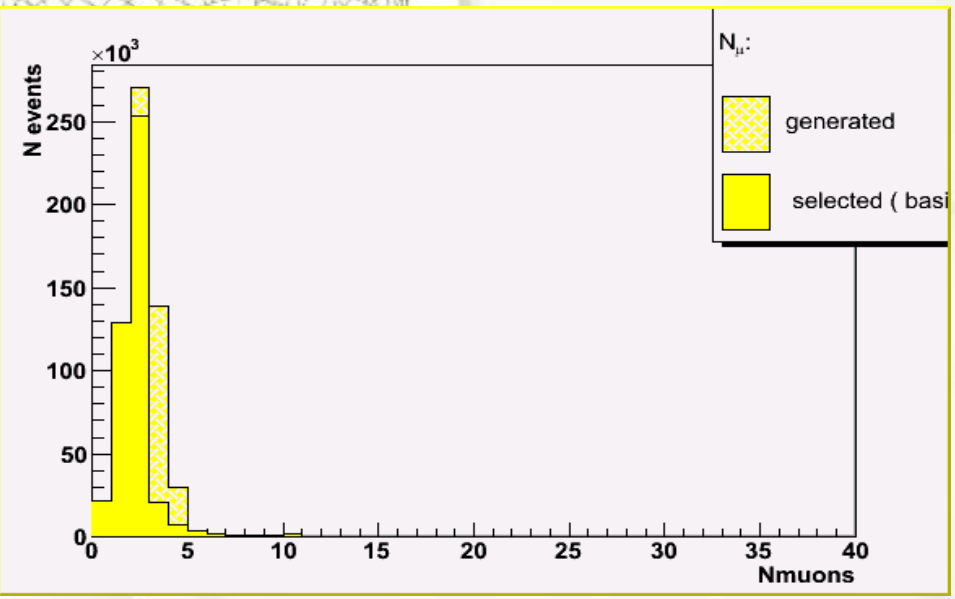
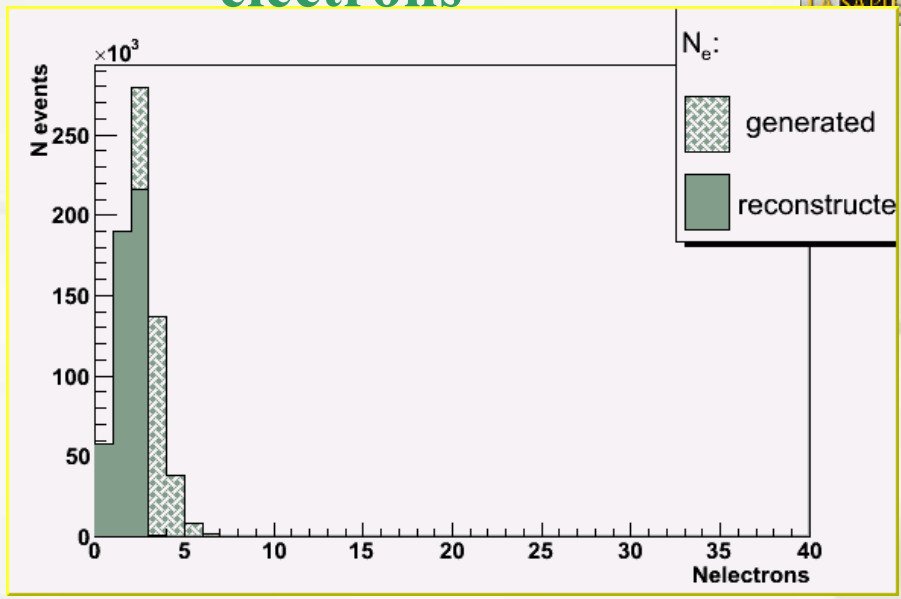
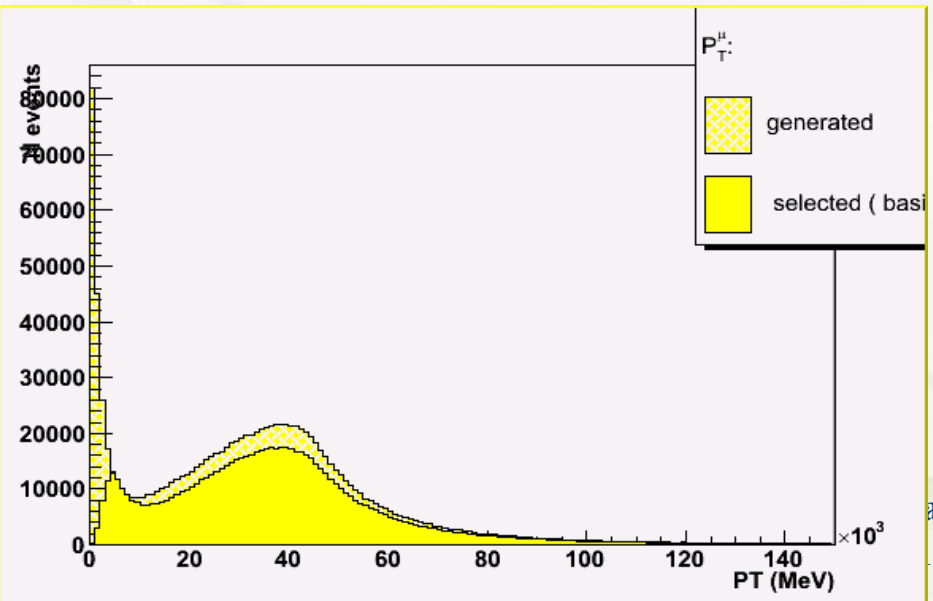
Leptons

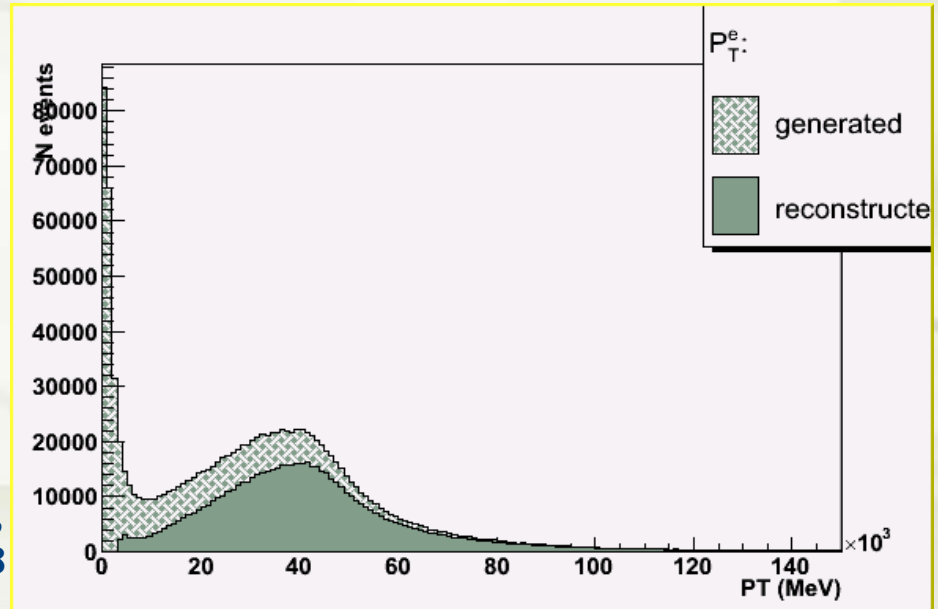
muons



electrons



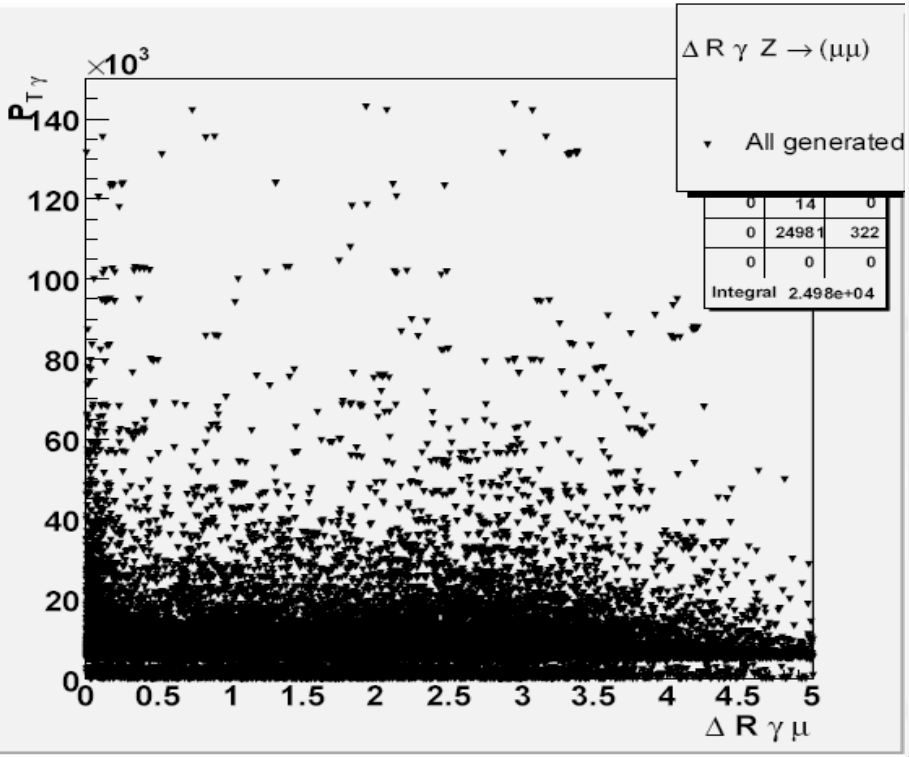




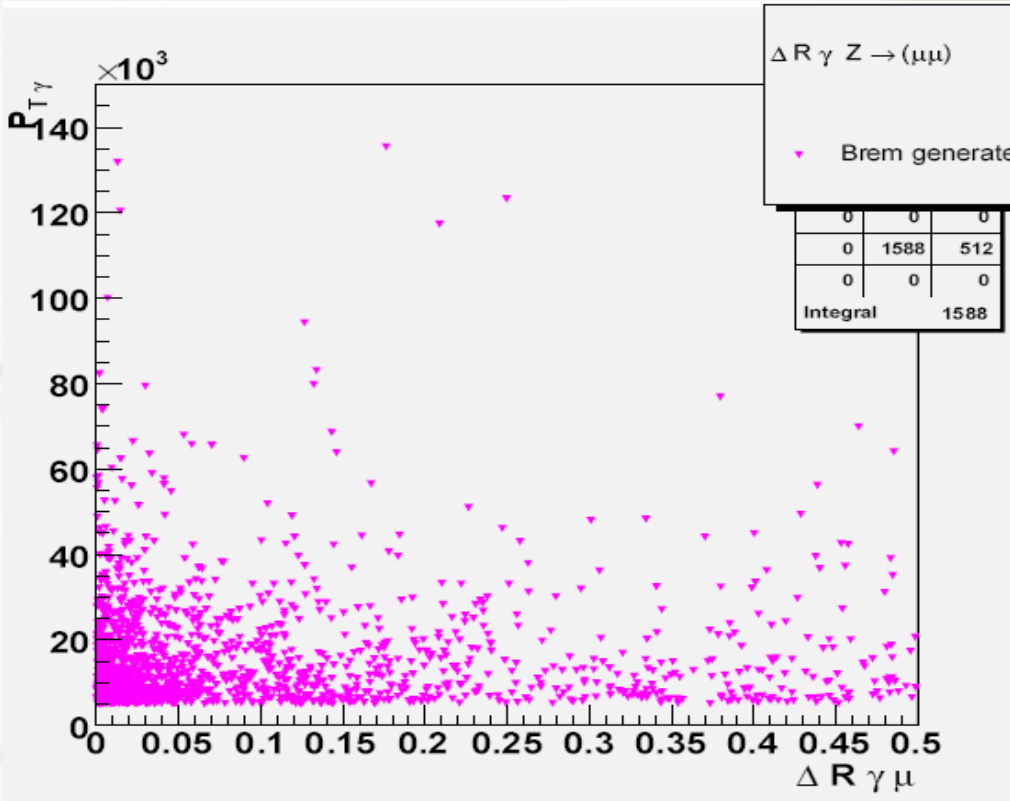
Photons: $Zbb \rightarrow \mu^- \mu^+ bb$

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

All photons



Bremsstrahlung photons



P_T vs. Distance between γ and μ

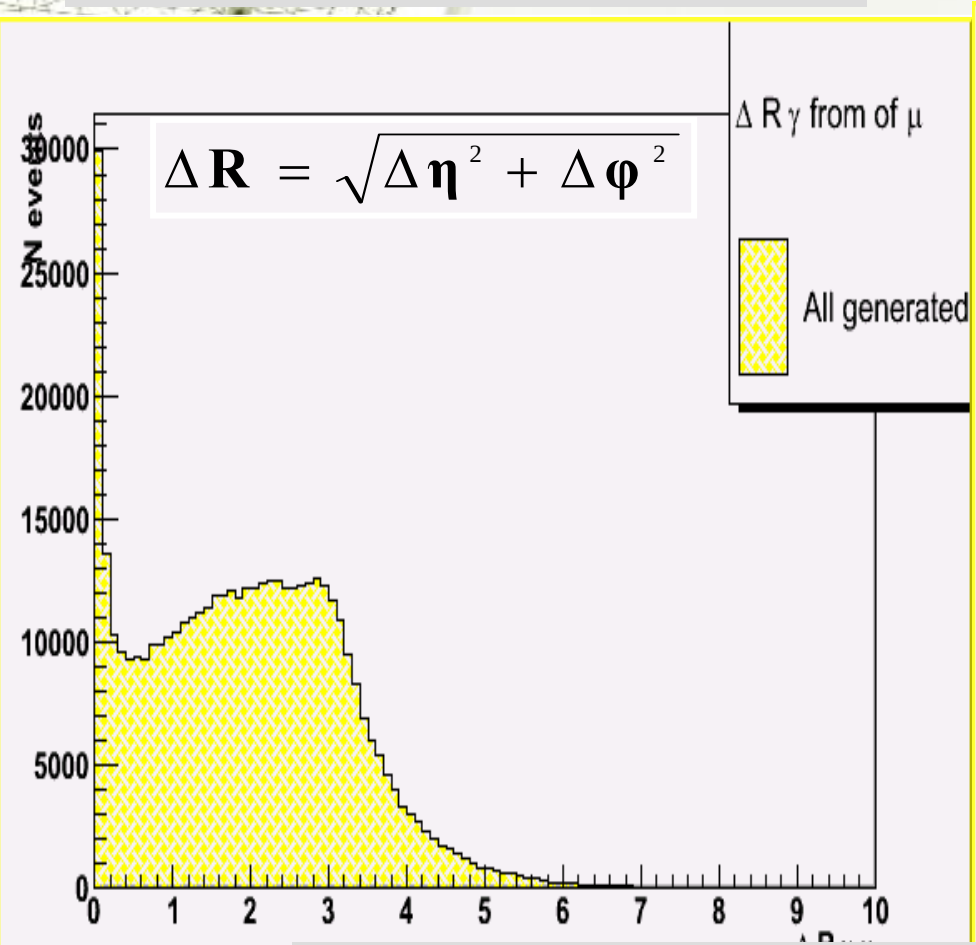
watch the different scale!

Subsample(~25000 ev)

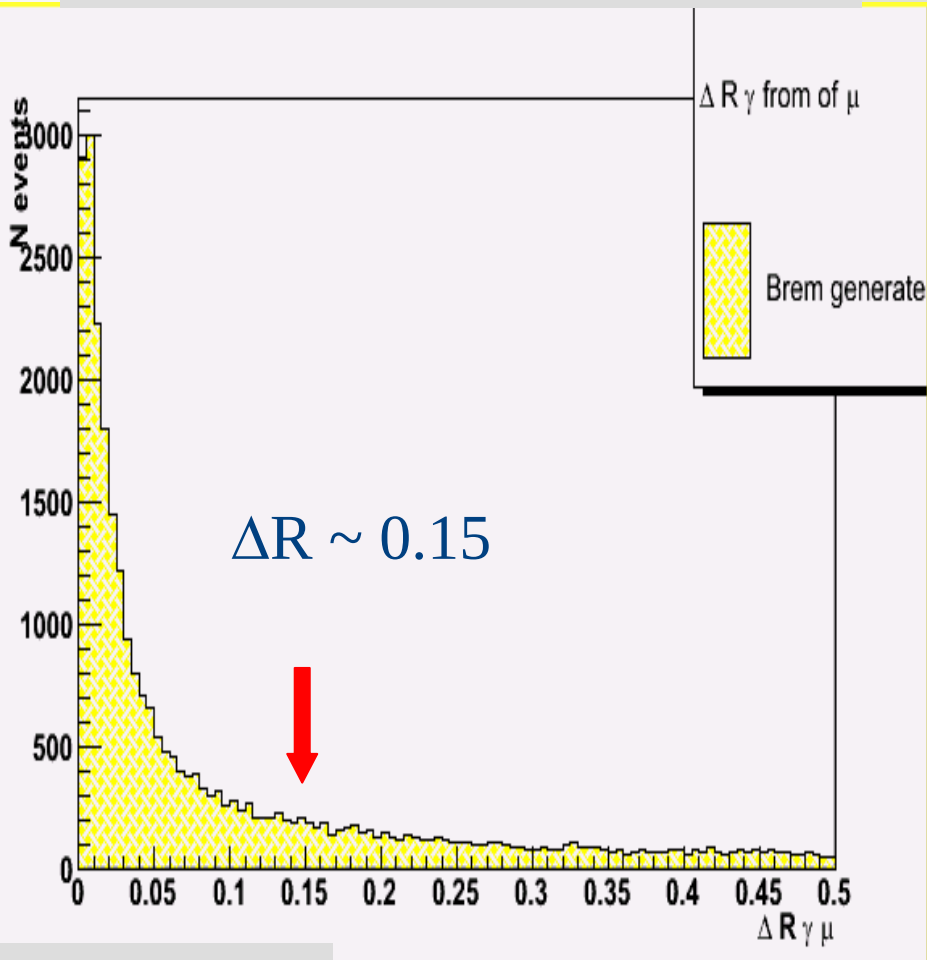
Gentile
CERN

Photons: $Zbb \rightarrow \mu^- \mu^+ bb$

All photons



Bremsstrahlung photons



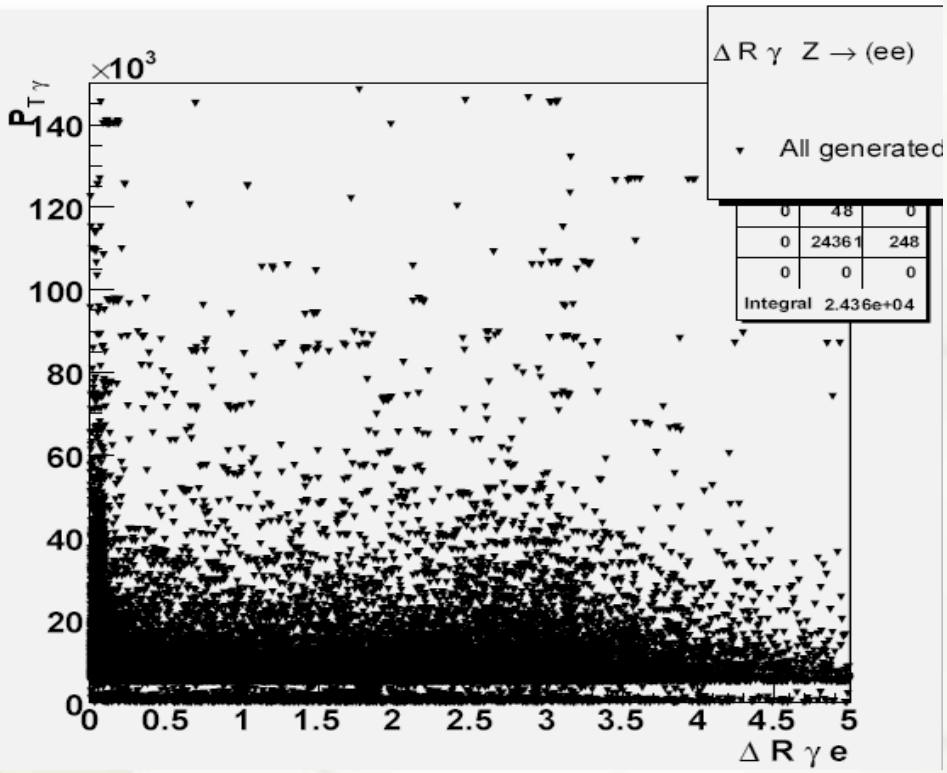
Distance between γ and μ

watch the different scale!

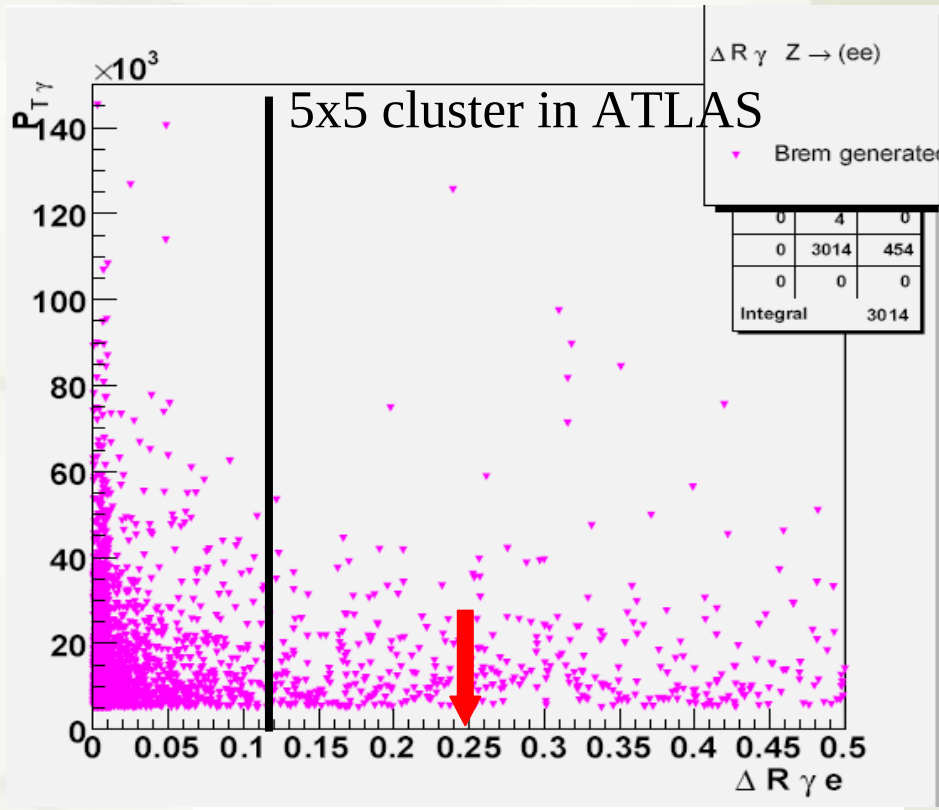
Photons: $Zbb \rightarrow e^{-}e^{+}\,bb$

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

All photons



Bremsstrahlung photons



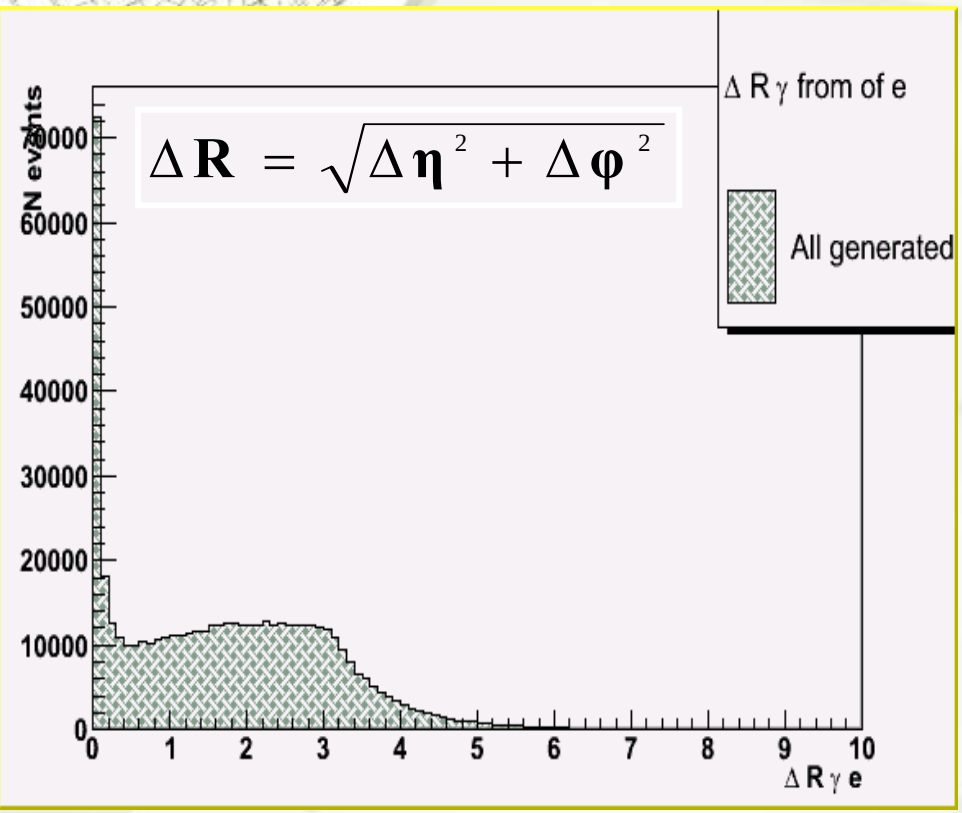
P_T vs. Distance between γ and e

watch the different scale!

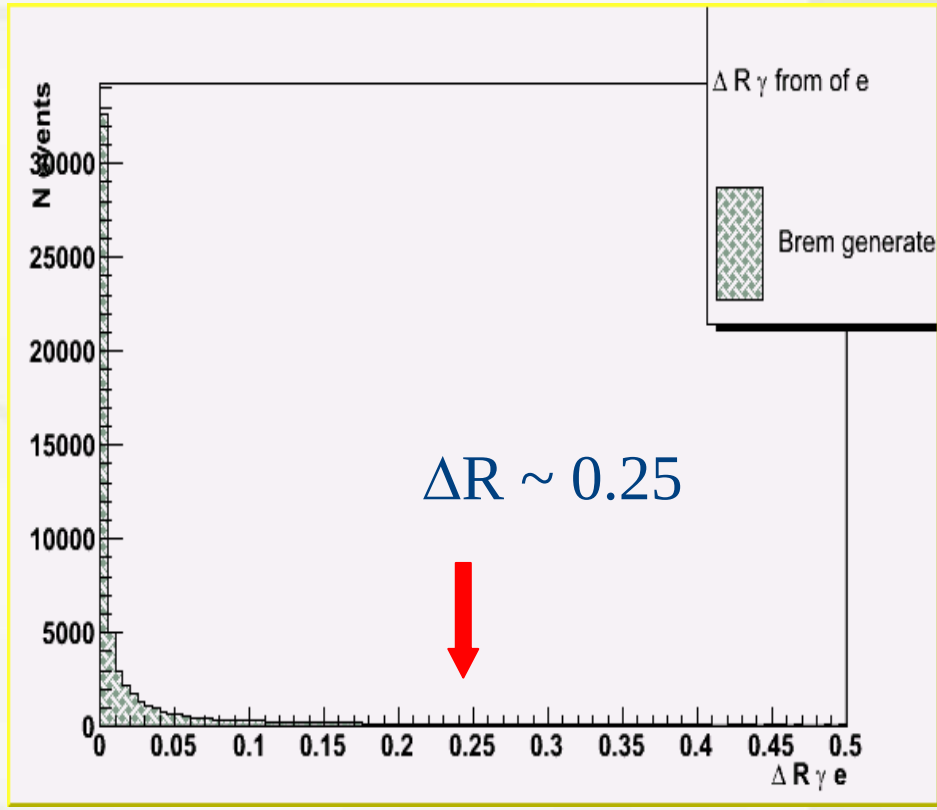
Subsample(~25000 ev)

Photons: $Zbb \rightarrow e^{-}e^{+}\,bb$

All photons



Bremsstrahlung photons



Distance between γ and e

watch the different scale!

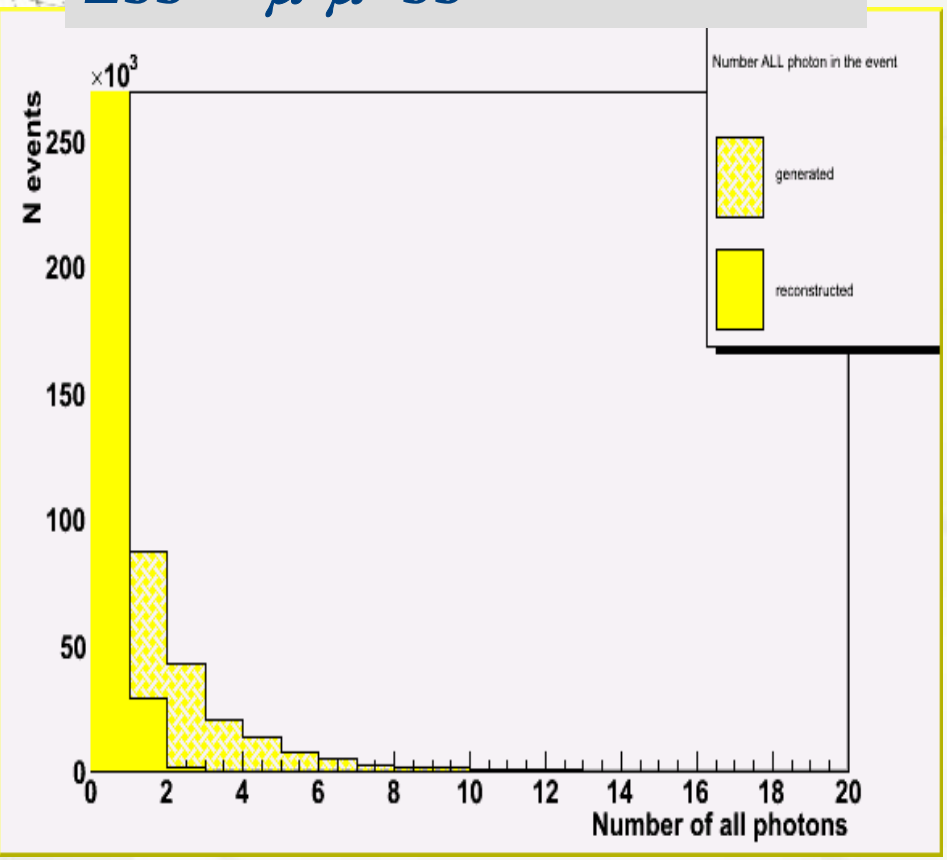
Photons

If the photon is emitted close to electron, only one cluster is reconstructed and the combined 4-momentum is measured. For $\sqrt{\Delta\eta^2 + \Delta\varphi^2} < \Delta R$ the γ is effectively absorbed in the same cluster of the electron.

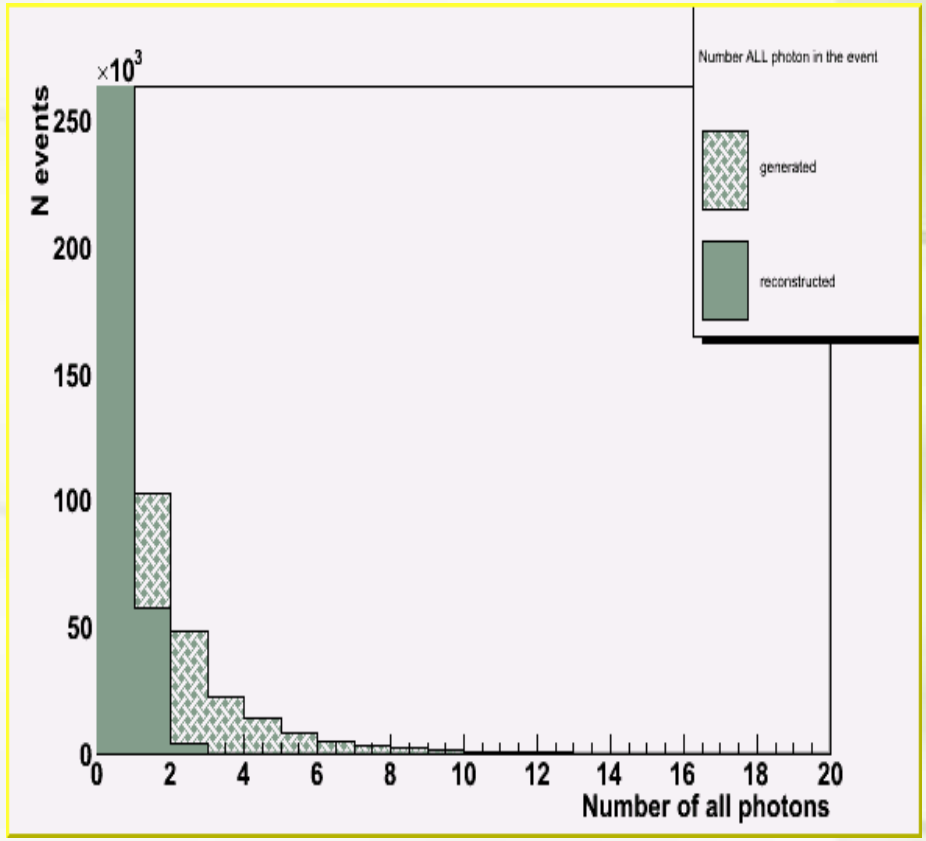
- $\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.125$ corresponds to a 5x5 cluster in ATLAS. The **energy** of electron is measured in **e.m. calorimeter**, **θ and ϕ are** measured in **tracker**.
- Photons, inside cone ΔR, are taken in account summing their 4-momentum to the 4-momentum of the nearest lepton.
- Photons reconstructed are e.m. clusters without track associated ($\Delta\eta = 0.025, \Delta\phi = 0.05$) and $P_T > 5$GeV, $|\eta| > 2.5$.

All Photons: $Zbb \rightarrow \mu^- \mu^+ bb$

$Zbb \rightarrow \mu^- \mu^+ bb$



$Zbb \rightarrow e^- e^+ bb$



$P_T^{\gamma} > 5$ GeV $|\eta| > 2.7$ recontructed γ

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Reconstruction

- **Muons**: combined reconstruction (inner detector + spectrometer), P_T >10 GeV, $|\eta|$ >2.5.
- **Electrons**: energy measured in calorimeter,(θ,ϕ) measured from tracker, P_T >10 GeV , $|\eta|$ >2.5.
- **Photons:** e.m. cluster **without track associated** :

$\Delta\eta$= 0.025, $\Delta\phi$ =0.05, P_T > 5 GeV, $|\eta|$ >2.5.

- **Brem photons**: >2 leptons reconstructed + γ reconstructed in a cone around lepton direction < ΔR.

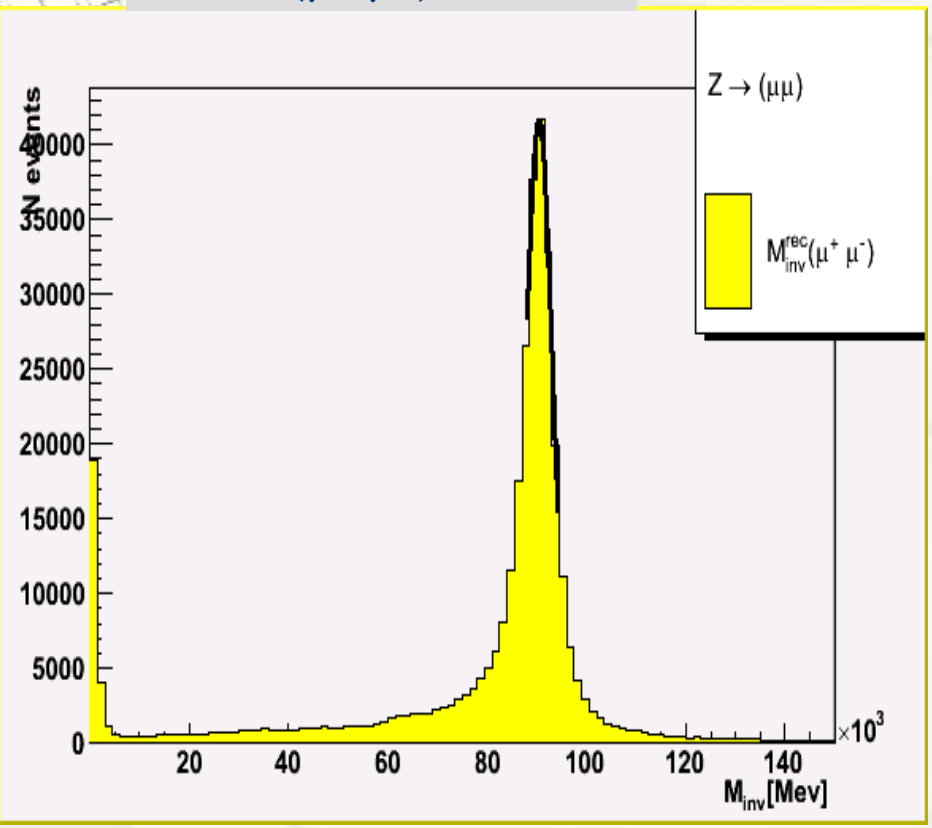
Electrons sample only one cluster is reconstructed.

Muon sample: μ track near photon cluster, misidentification.

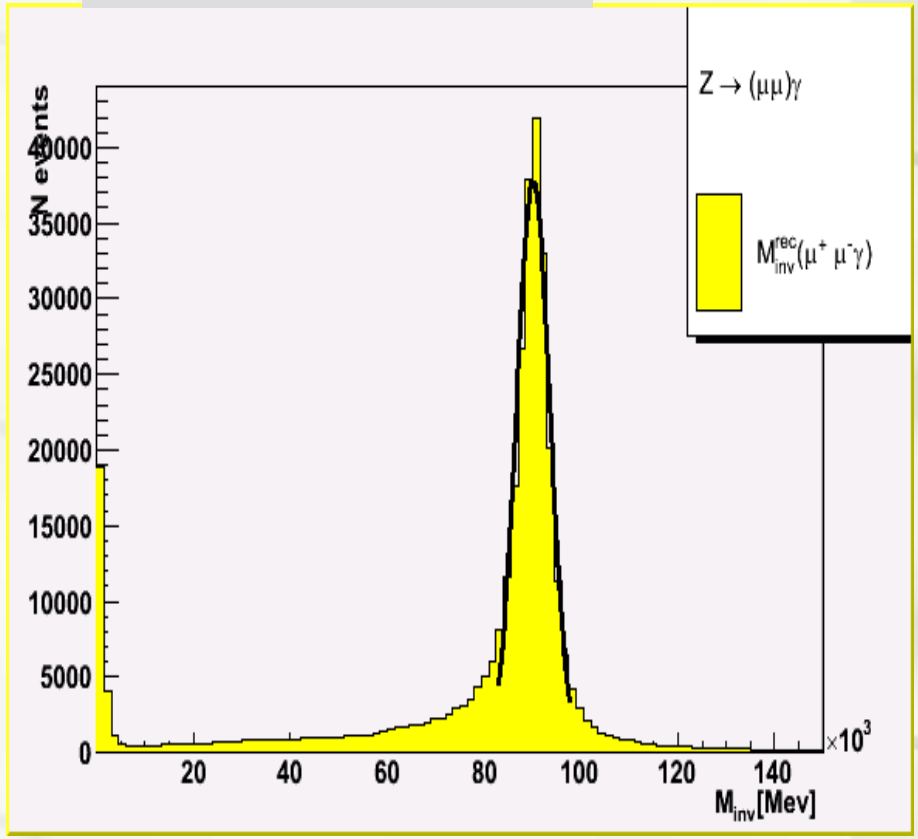
The number events reconstructed with γ **brem identified** is at percent level.

Reconstruction: $Zbb \rightarrow \mu^- \mu^+ bb$

Minv($\mu^+\mu^-$)



Minv($\mu^+\mu^-$)γ



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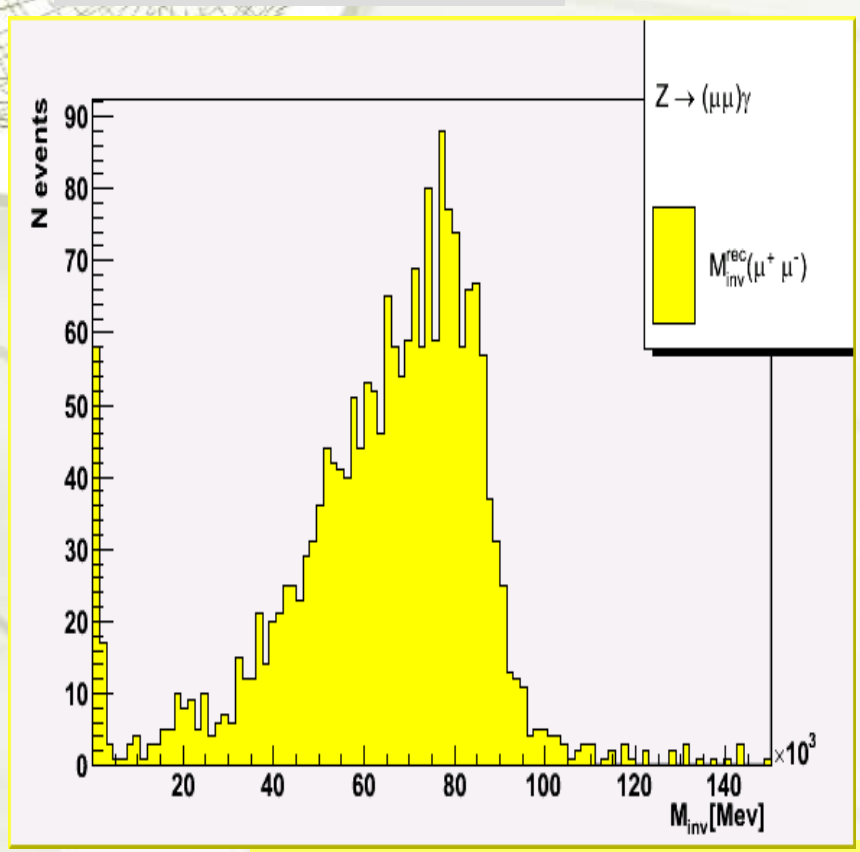
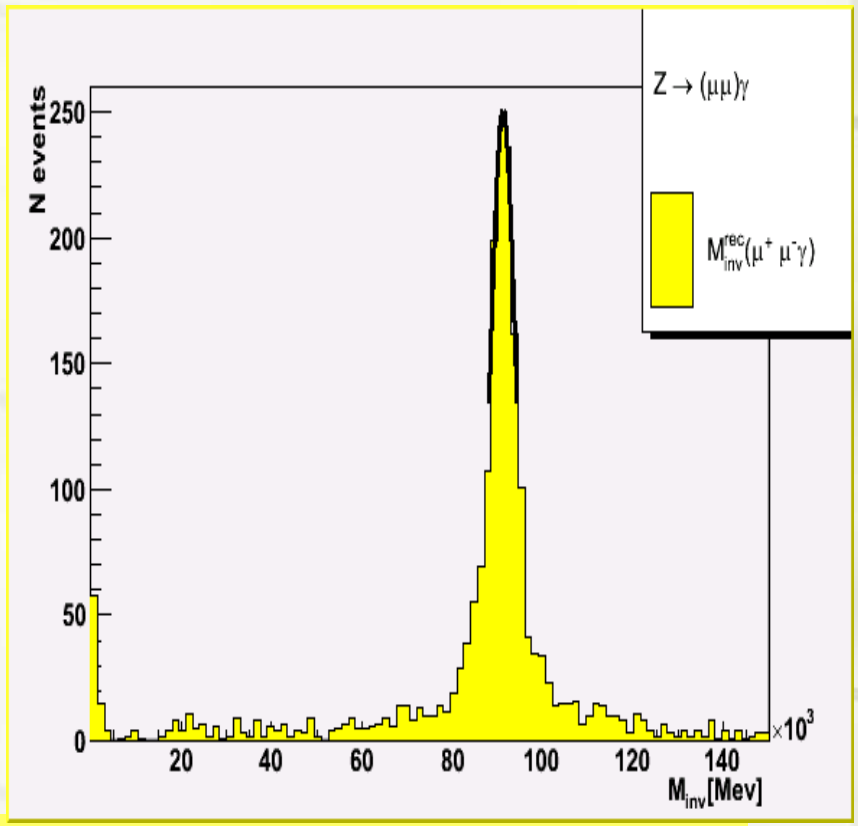
Reconstruction: $Zbb \rightarrow \mu^- \mu^+ bb$

Minv($\mu^+\mu^-$)



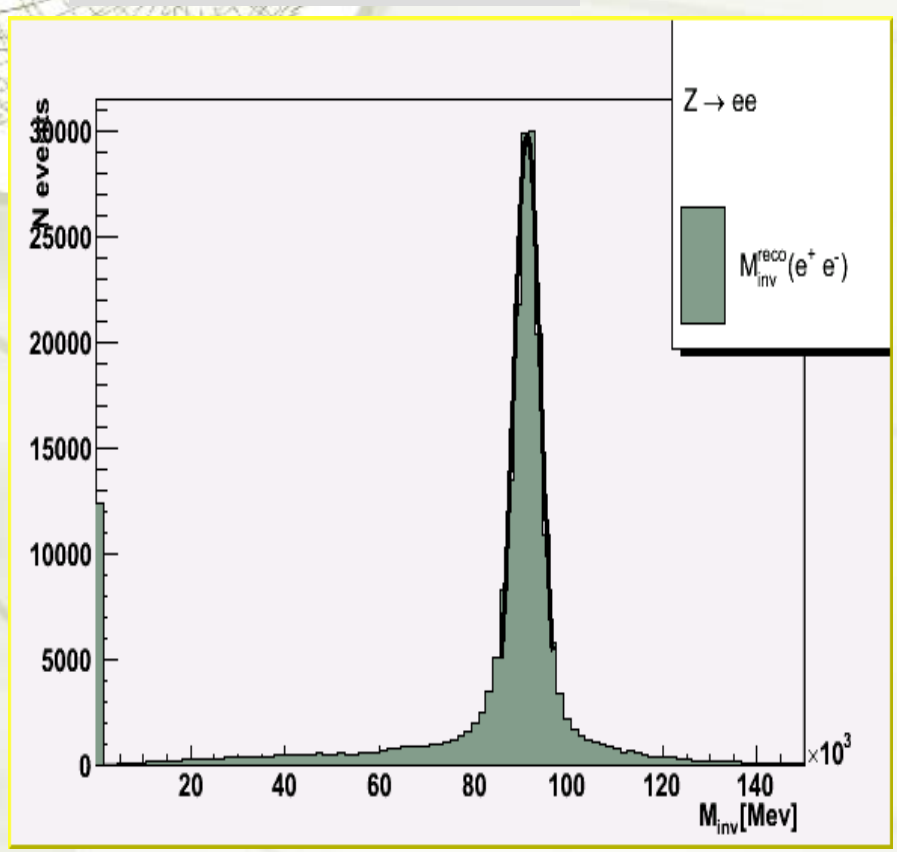
Minv($\mu^+\mu^-$)γ



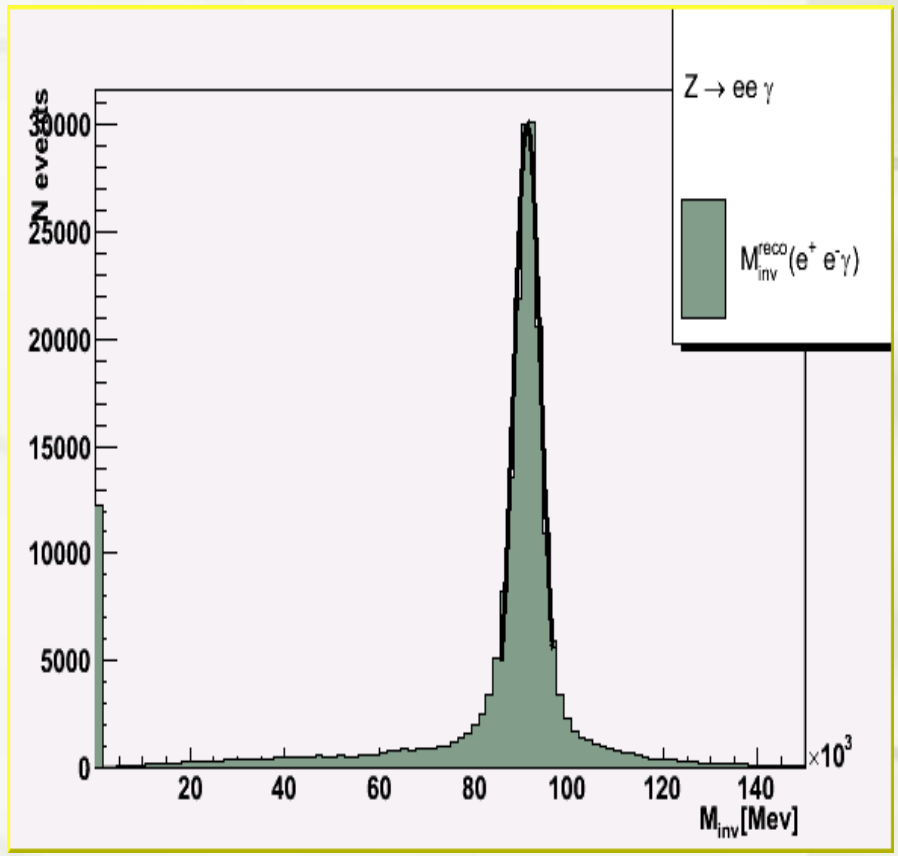
Only events with a γ of Bremsstrahlung

Reconstruction: $Zbb \rightarrow e^-e^+ bb$

Minv(e^+e^-)



Minv(e^+e^-)γ



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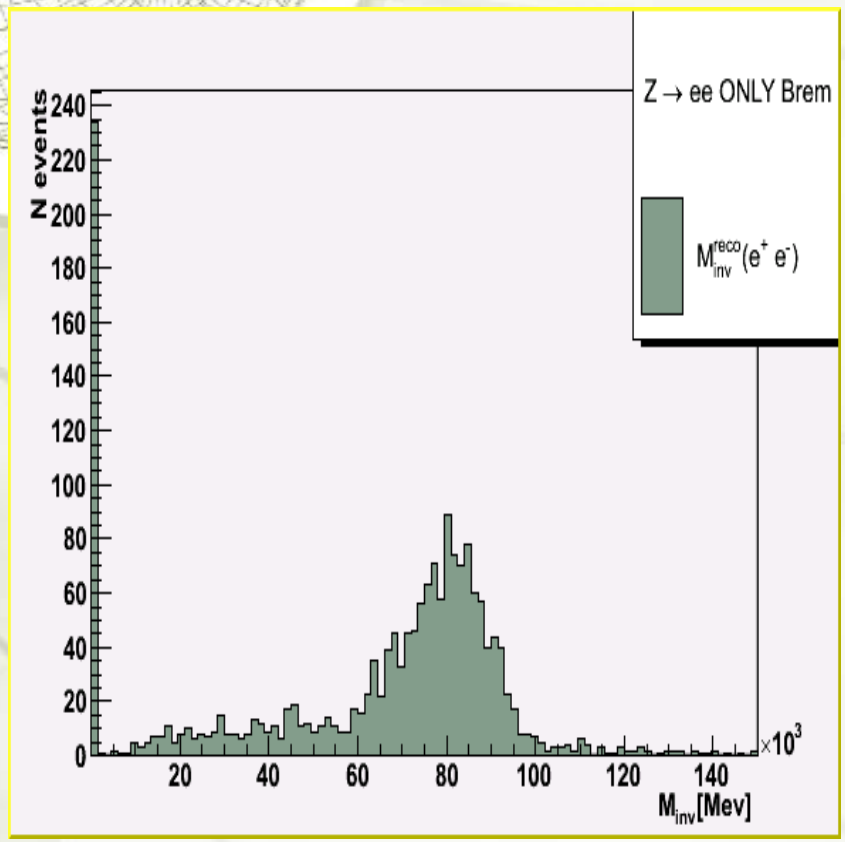
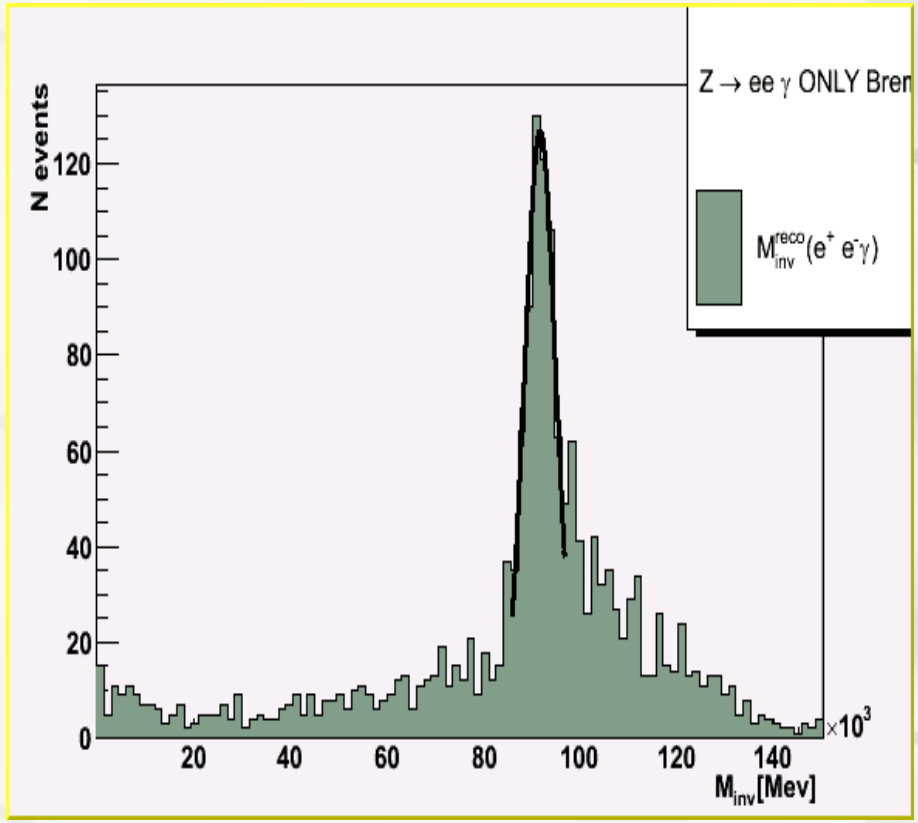
Reconstruction: $Zbb \rightarrow e^-e^+ bb$

Minv(e^+e^-)

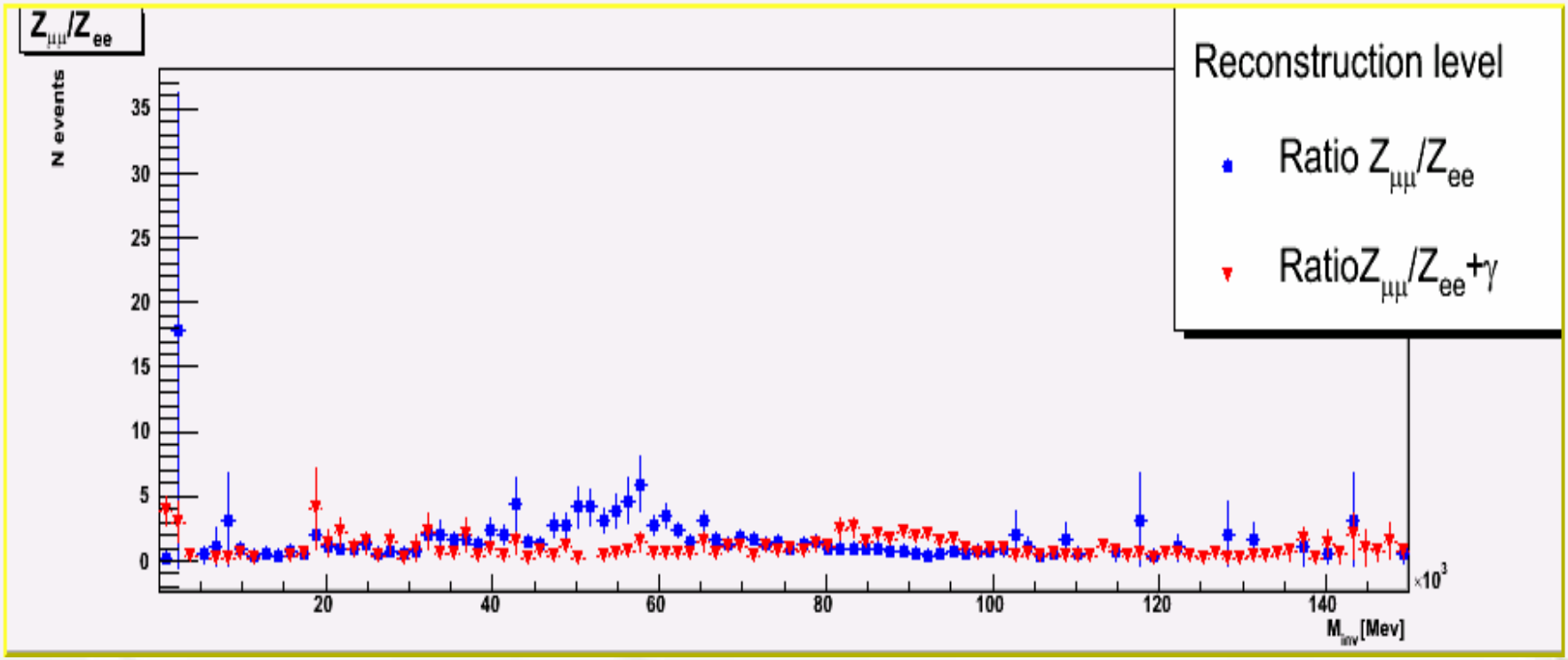


Minv(e^+e^-)γ



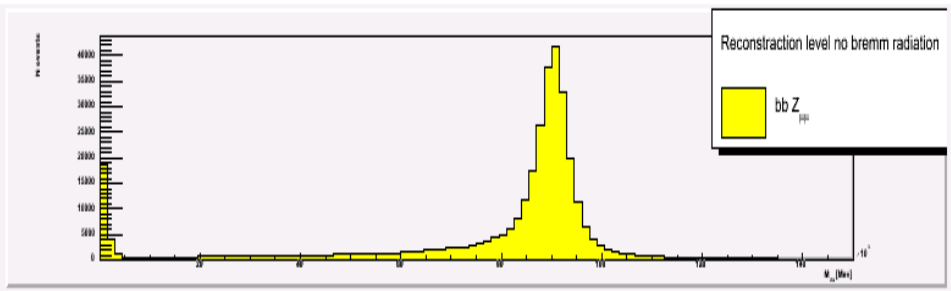
Only events with a γ of Bremsstrahlung

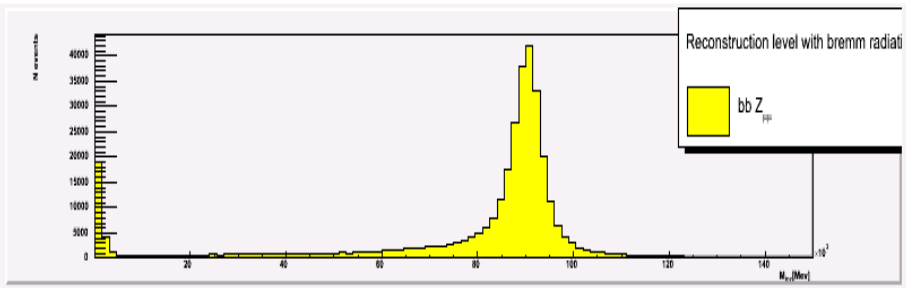
Reconstruction

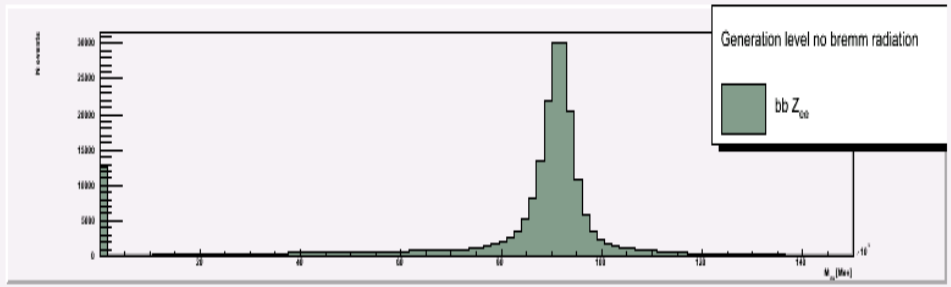


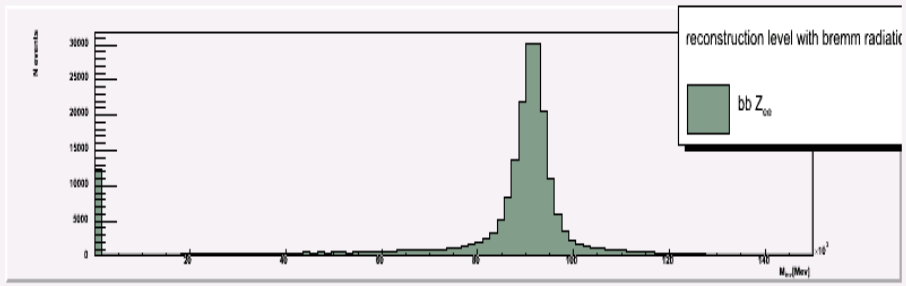
Only events with a γ of Bremsstrahlung

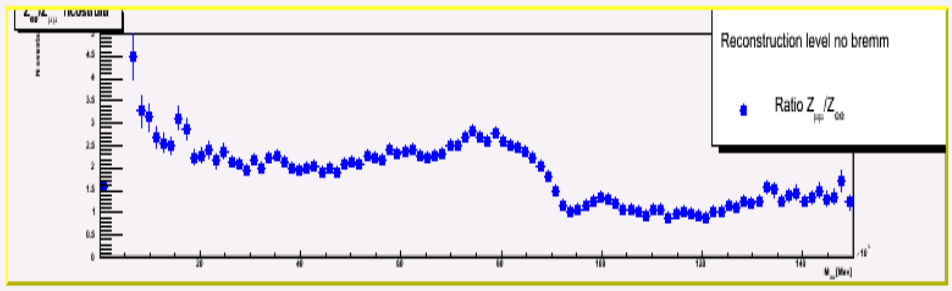
Reconstruction

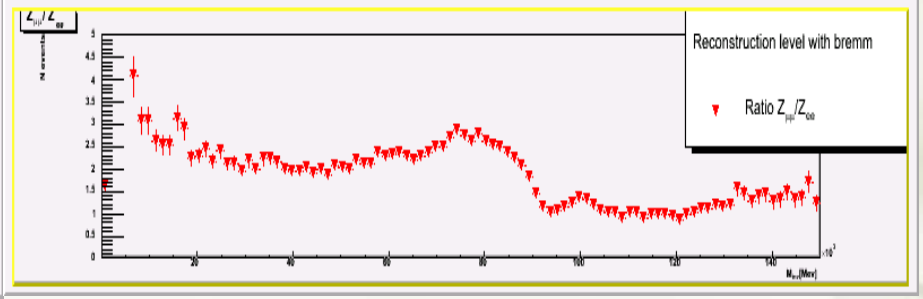






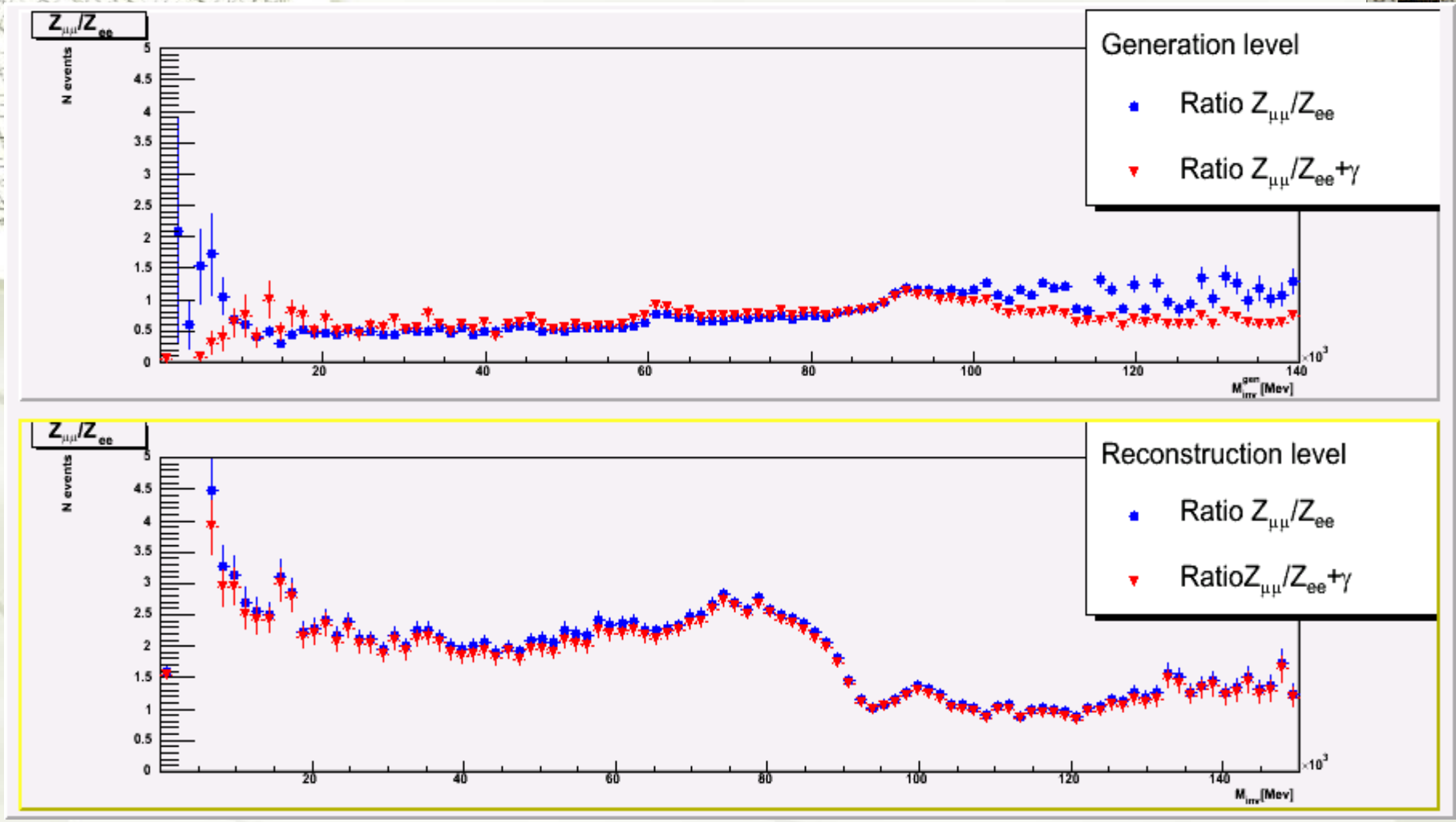






The number γ bremsstrahlung reconstructed separatly in muons events is higher than electron events, where are mostly absorbed in the electron cluster

Generation-reconstruction



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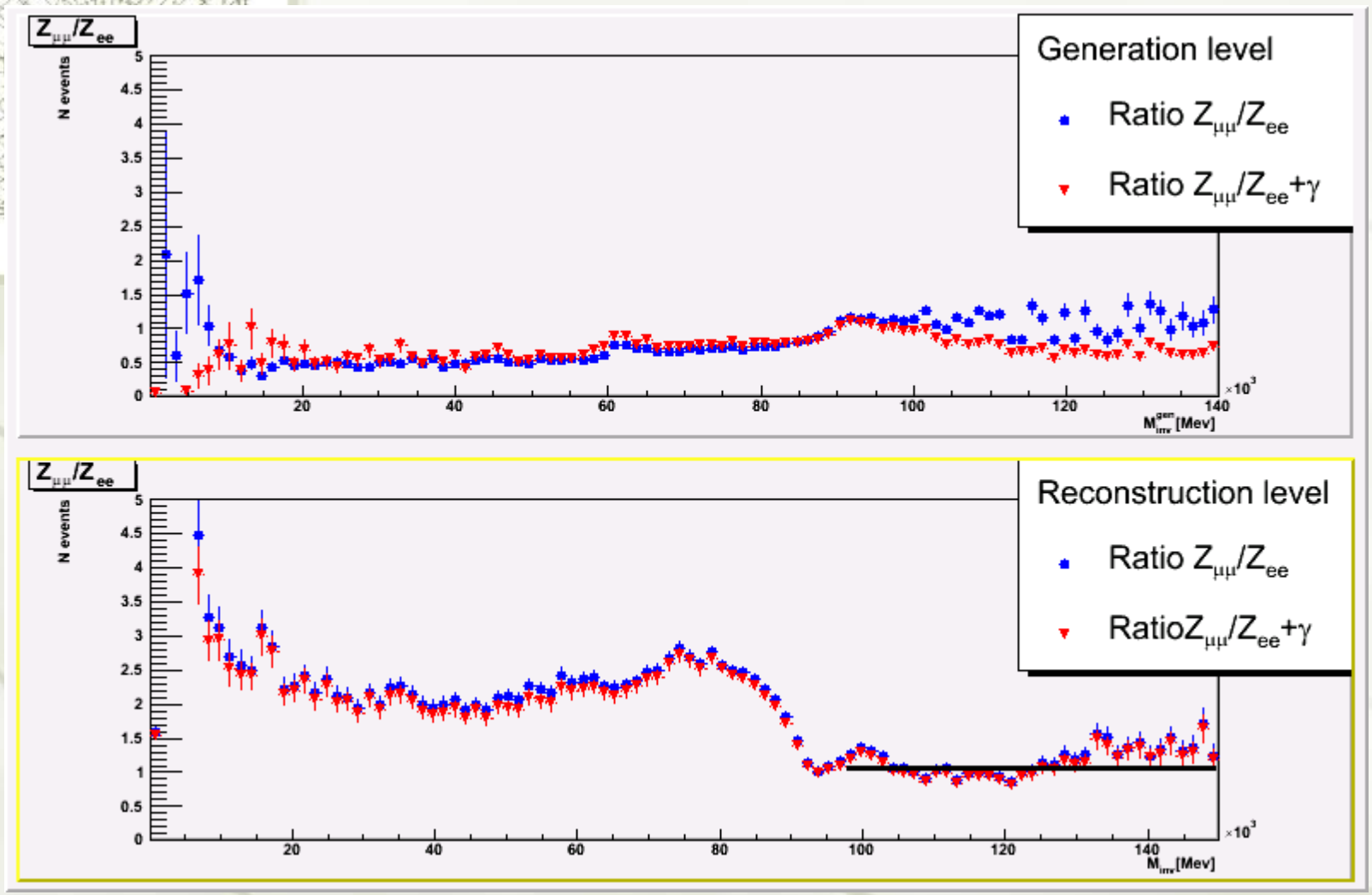
Generation-reconstruction



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Conclusions

- A study for an experimental method of background subtraction is developed based on fully simulated samples, $L_{int} \sim 20\ fb^{-1}$ of:

  $bb\ Z \rightarrow\ \mu+\ \mu^-$ and $bb\ Z \rightarrow\ e+\ e^-$

comparing:

- the **Bremsstrahlung of the two samples.**
- the **ATLAS detector response.**

- The study is preliminary and needs careful tuning on data collected.
- **ΔR is an extremely important parameter, that should be carefully tuned.**

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Conclusions

- In the region M_{inv} 98 -135 GeV the ratio is reasonably stable and the effect of Bremsstrahlung is negligible with respect to detector response
- The same method can be applied to $H \rightarrow \tau\tau$ and in general to all decays where the electron decay is negligible in the signal.
- The method relies on lepton universality and needs a good knowledge of detector response for different leptons
- The method doesn't need an implementation on MC of higher order corrections

Acknowledgements: Borut Kersevan, Dirk Zerwas,Donatella Cavalli

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- Riserve

- Matching track narrow

$\Delta\eta = 0.025$ $\Delta\phi = 0.05$

- Isolation broad

$\Delta\ \eta = 0.05$ $\Delta\phi = 0.10$

$\Delta R = 0.07$ size of cluster 5x 5 $\Delta\eta = 0.025$ $\Delta\phi = 0.05$

Implementations

- COJETS Odorico (1984)
- ISAJET Page+Protopopescu (1986)
- FIELDAJET Field (1986)
- JETSET Sjöstrand (1986)
- PYTHIA Bengtsson+Sjöstrand (1987), Sjöstrand (1994)
- ARIADNE Lönnblad (1991)
- HERWIG Marchesini+Webber (1988), Marchesini+Webber+Abbiendi+Knowles+Seymour+Stanco (1992)
- SHERPA Gleisberg+Hoche+Krauss+Schalicke+Schumann+Winter (2004)

See Les Houches Guidebook hep-ph/0403045 for a complete list.

- Collider Physics, K. Ellis, J. Stirling and B. Webber
- MONTE CARLO SIMULATION OF HARD HADRONIC PROCESSES. By B.R. Webber, Ann.Rev.Nucl.Part.Sci.36:253-286,1986
- PYTHIA homepage: http://www.thep.lu.se/~torbjorn/Pythia.html The PYTHIA manual (pythia6301.pdf): clear and instructive introduction. Tutorial, etc.
- HERWIG page: http://hepwww.rl.ac.uk/theory/seymour/herwig/
- LES HOUCHES GUIDEBOOK TO MONTE CARLO GENERATORS FOR HADRON COLLIDER PHYSICS, hep-ph/0403045