

# Jet energy studies with the ILD detector.

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DESY

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# Outline

- 1 Latest standard JER and JES
- 2 A different look at jet energy
- 3 New uds generator samples
  - 1 Validation of  $uu$ ,  $dd$ ,  $ss$
  - 2 New  $cc$  and  $bb$  dijet samples



# JER and JES with the ILD detector

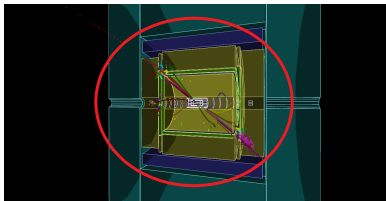
## Jet energy resolution and scale measurements

### Use well defined dijet events

- $e+e- \rightarrow uu, dd, ss$
- Off-shell Z boson at (0,0,0)
- $q\bar{q}$  with same momentum and opposite direction
- No background

### **No jet clustering.** Assume that:

- $E_{jet} = E_{tot}/2$  and  $E_{jet1} = E_{jet2}$
- $\sigma_{E_{jet}} = \sigma_{E_{tot}}/\sqrt{2}$
- $\sigma_{E_{jet}}/E_{jet} = \sqrt{2}(\sigma_{E_{tot}}/E_{tot})$

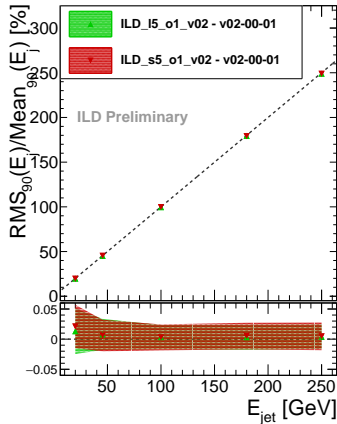
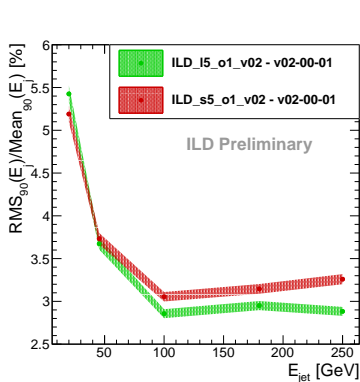


### Estimators for $E_{tot}$ and $\sigma_{E_{tot}}$ :

- Compute  $Mean_{90}$  for  $E_{tot}$
- Compute  $RMS_{90}$  using  $Mean_{90}$  for  $\sigma_{E_{tot}}$

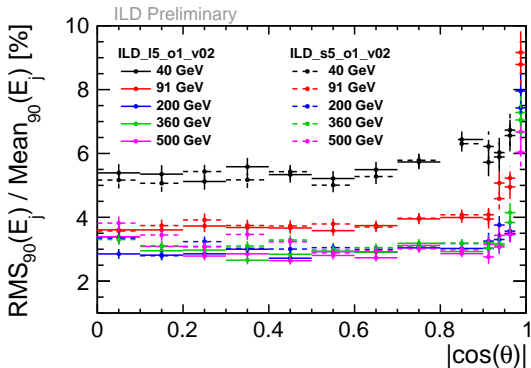
# JER and JES with the ILD detector

JER and JES - ILD large vs small (v02-00-01)



# JER and JES with the ILD detector

JER versus  $\cos(\theta)$



Limited statistics per bins ( $\sim 400$  to  $\sim 700$  events) causing fluctuations



# A different look at jet energy

## Alternative methods ?

Total energy method assumes jet energies are somehow equal.

→ Investigating new methods to quantify JER

- **MC clustering:** cluster jets using available MC information
- **Durham clustering:** jet clustering algorithm
  - forced to 2 jets
  - distance:  $d_{ij} = 2 \min(E_i^2, E_j^2)(1 - \cos\theta_{ij})$

Use the MC clustering result for comparison with Durham clustering

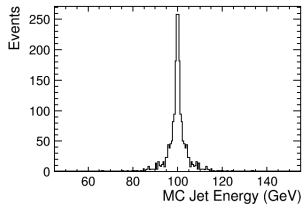
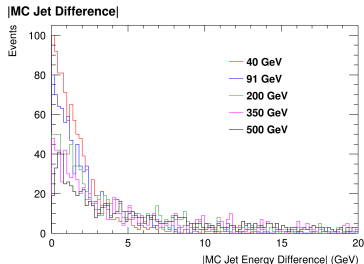
Niall MC Hugh



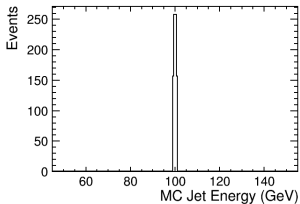
# A different look at jet energy

## MC clustering

- Energies of jets are not symmetric
- Apply cut on energy difference
  - Compromise between remaining asymmetry and statistics
  - $n\%$  of total energy?



No cut, CMS = 200 GeV



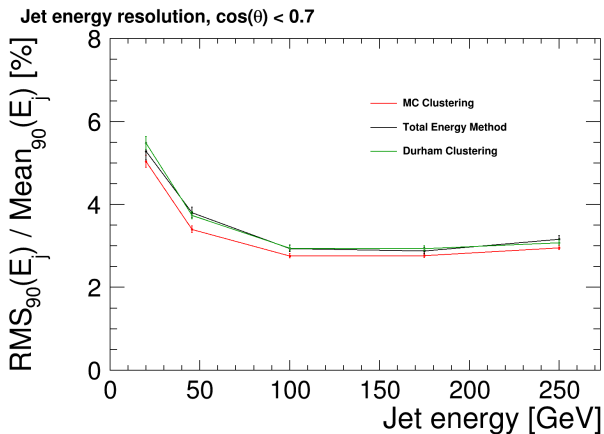
1% cut, CMS = 200 GeV

Niall MC Hugh



# A different look at jet energy

JER - 3 methods comparison



Niall MC Hugh





# A different look at jet energy

## JER - 3 methods comparison

- 3 methods are compatible by using uds di-jets
- No background + di-jet event topology  
→ too simple for Durham clustering
- Spotting performances using a physics channel ?
  - Background treatment: proper removal versus cheated removal
  - Effect of PFA: standard PFA versus perfect PFA
  - Jet clustering: FastJet versus perfect jet clustering
  - Example of channel:  $e^+e^- \rightarrow H\nu\nu$



# New uds(bc) generator samples

- Current uds di-jet calibration samples are  $\gtrsim$  15 years old
- Why new samples ?
  - MC particles history is different with Whizard 2
    - Must match our current analysis tools
  - Need more statistics and can't find out old settings
  - Currently no *bb* and *cc* samples
    - Need consistency between uds and bc samples

Produced new udsbc samples with Whizard 2

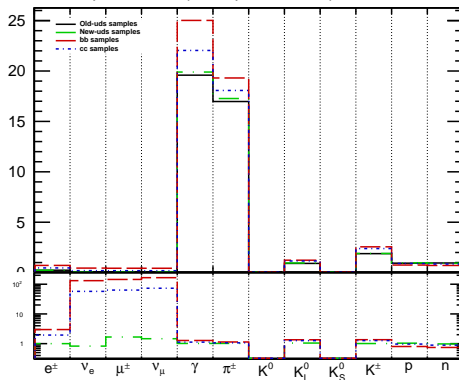
- No ISR
- No beam spectrum
- Pythia 6
- Whizard 2.6



# New uds(bc) generator samples

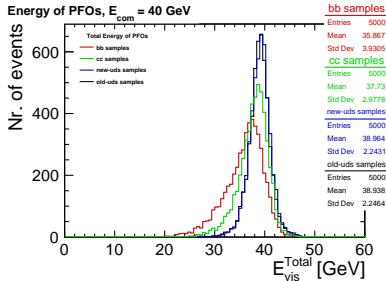
Validation of new uds samples - MC particle content at 91 GeV (Preliminary)

Nr. of Stable MCParticles per event 91GeV (ratio respect with old-uds)

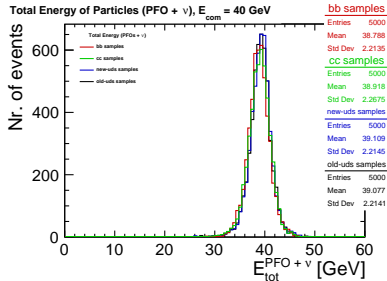


# New uds(bc) generator samples

Validation of new uds samples - Total energy 40 GeV (Preliminary)



Without neutrinos



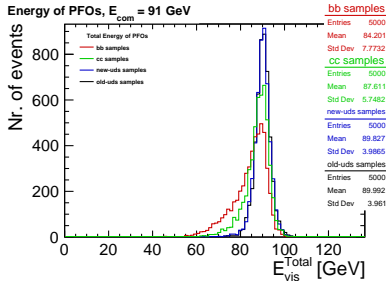
With neutrinos

Yasser Radkhorrami

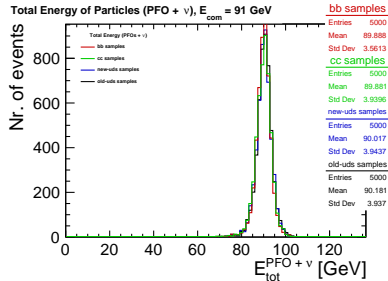


# New uds(bc) generator samples

Validation of new uds samples - Total energy 91 GeV (Preliminary)



Without neutrinos



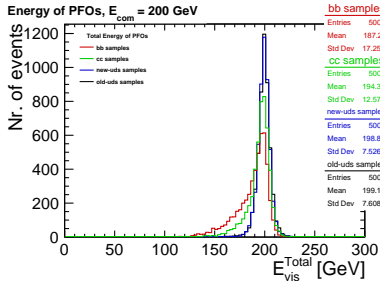
With neutrinos

Yasser Radkhorrami

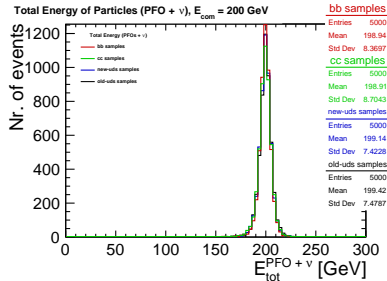


# New uds(bc) generator samples

Validation of new uds samples - Total energy 200 GeV (Preliminary)



Without neutrinos



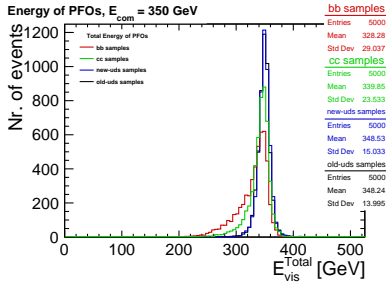
With neutrinos

Yasser Radkhorrami

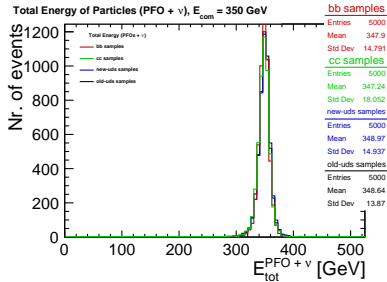


# New uds(bc) generator samples

Validation of new uds samples - Total energy 350 GeV (Preliminary)



Without neutrinos



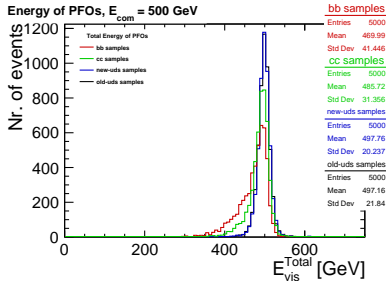
With neutrinos

Yasser Radkhorrami

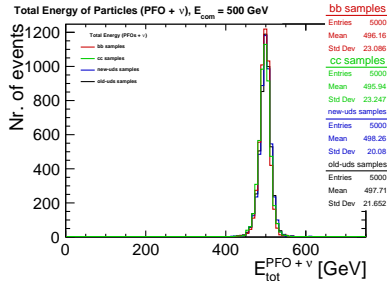


# New uds(bc) generator samples

Validation of new uds samples - Total energy 500 GeV (Preliminary)



Without neutrinos



With neutrinos

Yasser Radkhorrami





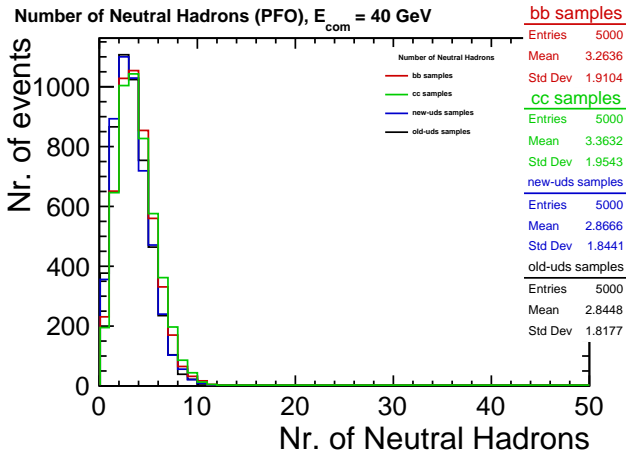
# Conclusion

- Standard JER/JES performances
  - Consistent results for large/small ILD model
  - ✓ Still in the race for 3-4% !
- Alternative JER/JES methods have been investigated
  - Total energy method vs MC clustering vs Jet clustering
  - 3 methods show similar results / performances
  - Jet clustering not really sensitive: simple jet topology, no bkg
  - **Requires a proper physics channel with various levels of cheating**
- New uds(cb) di-jet calibration samples with Whizard 2
  - ✓ New uds samples are validated
  - ✓ bc samples show consistent results in terms of particle content
  - Degradation of PFO energy distribution (low energy tail)



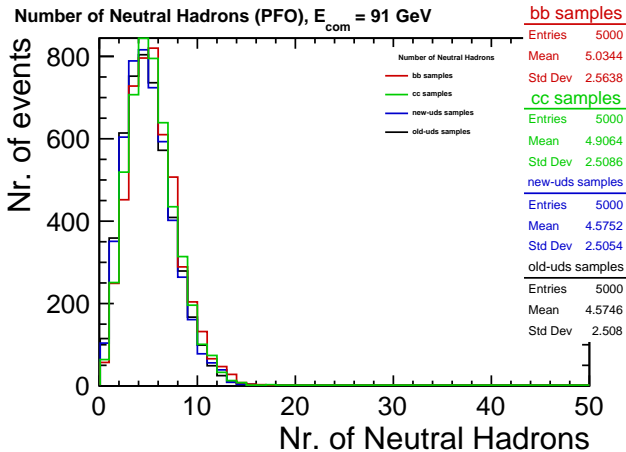
# Backup

## Validation of new uds samples - Check plots



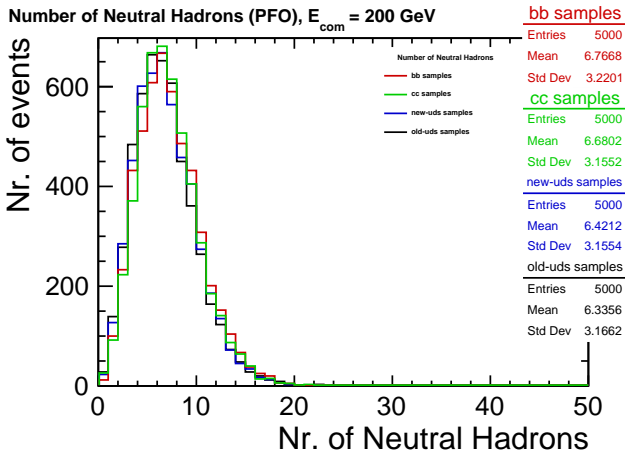
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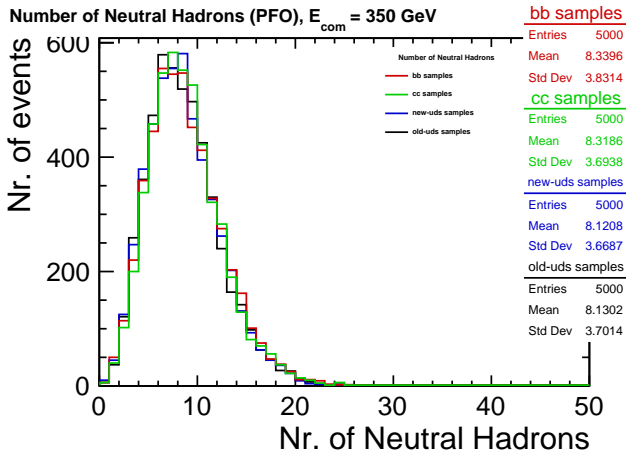
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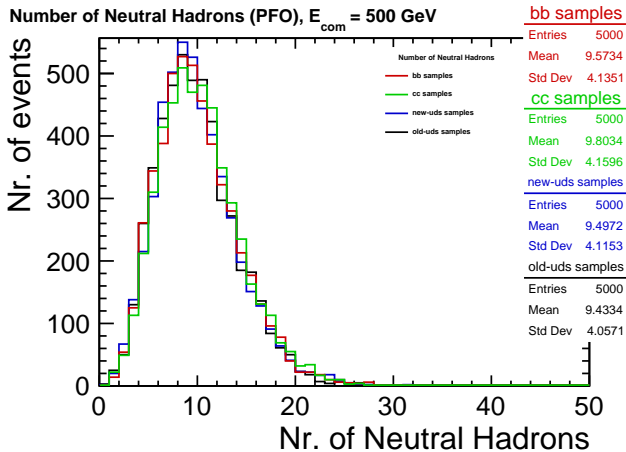
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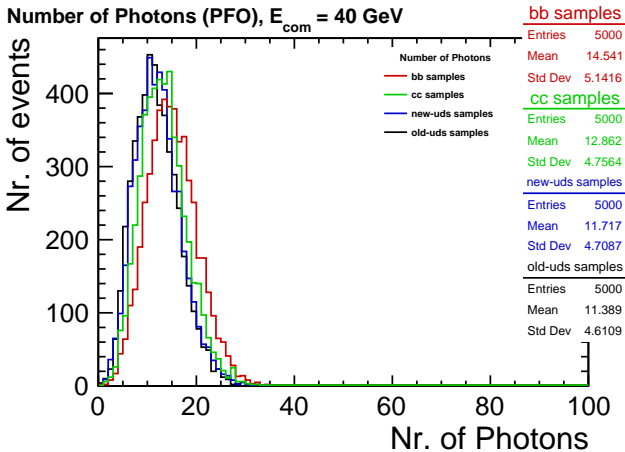
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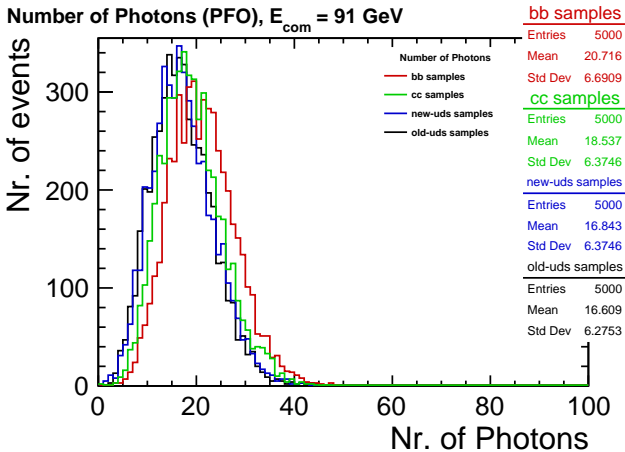
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Validation of new uds samples - Check plots



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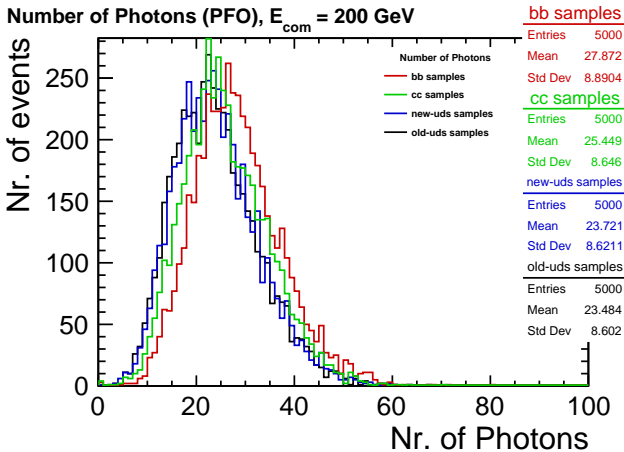
Validation of new uds samples - Check plots





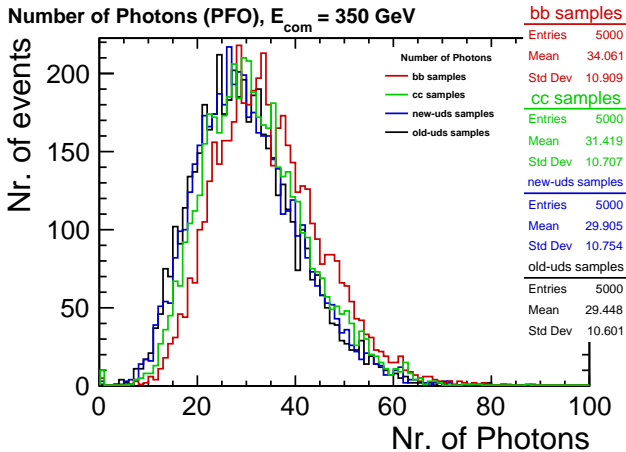
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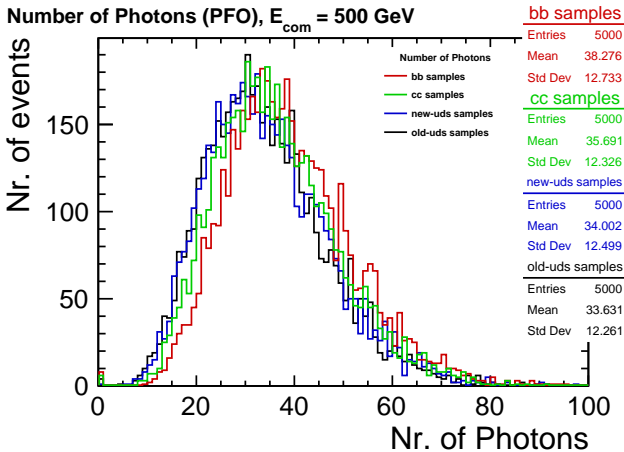
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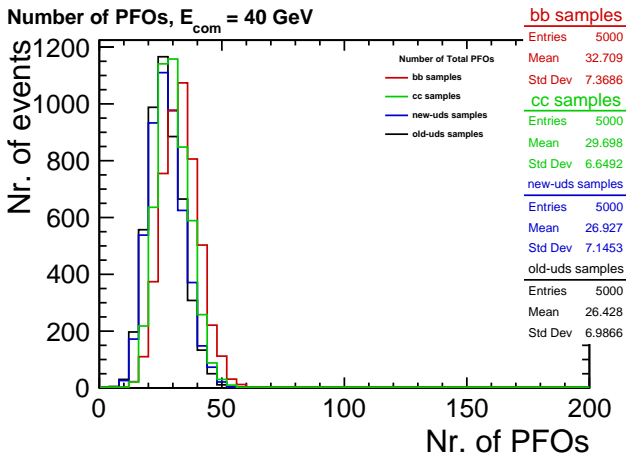
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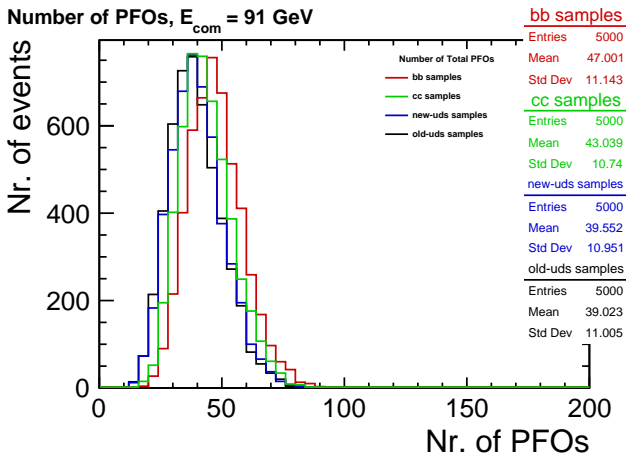
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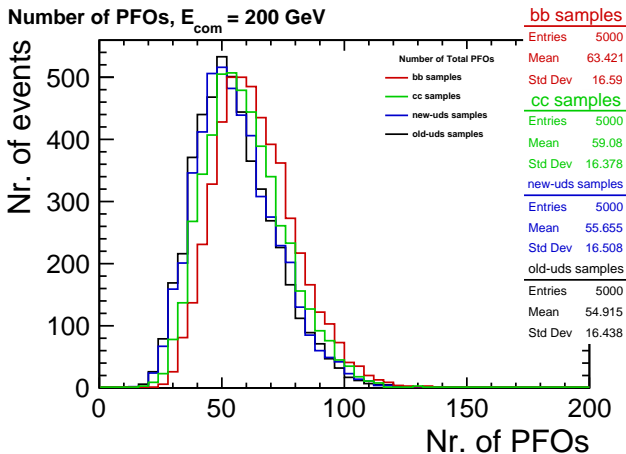
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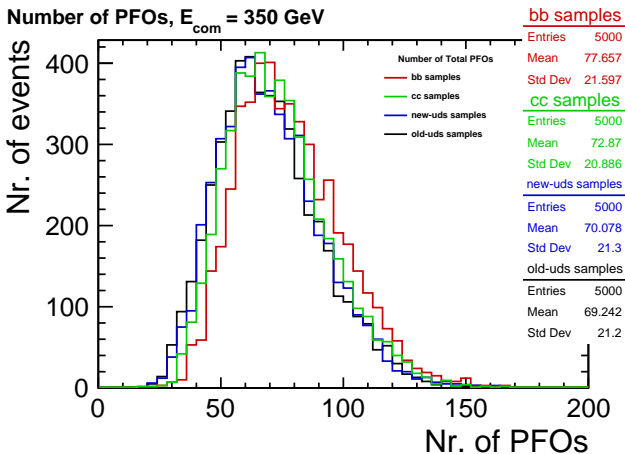
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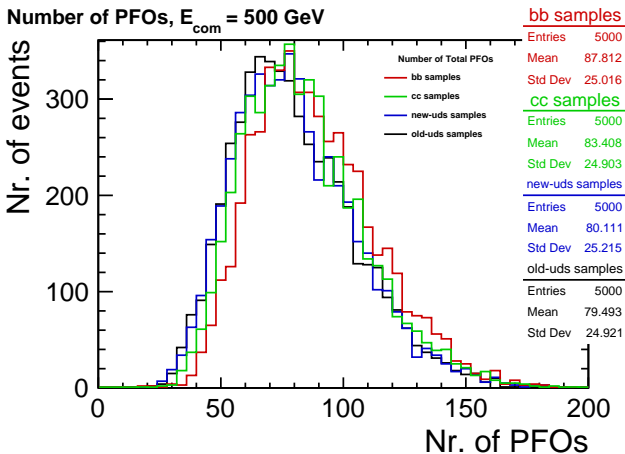
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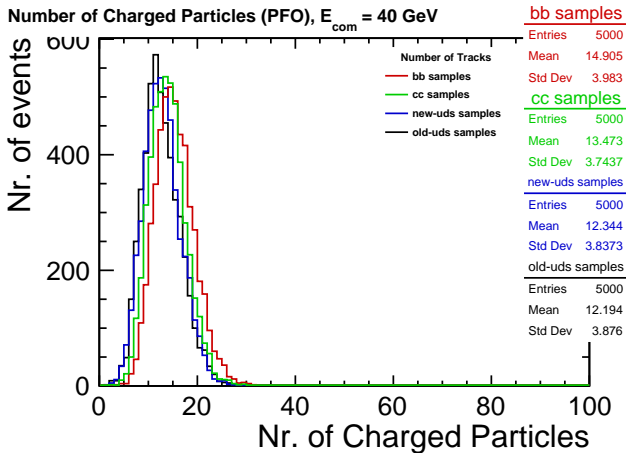
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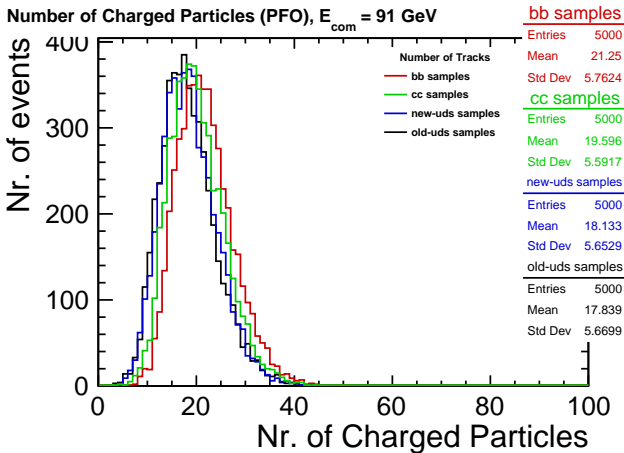
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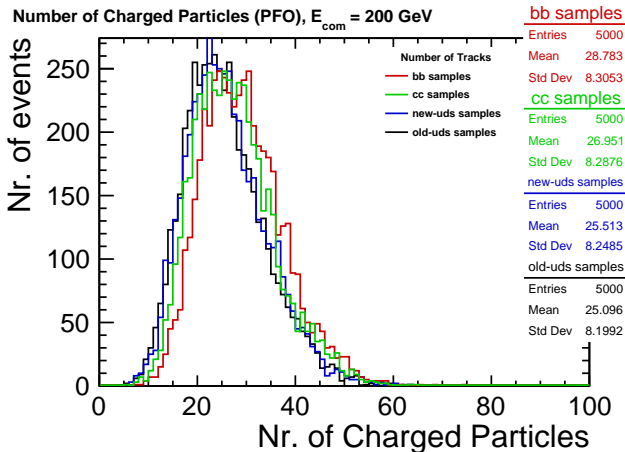
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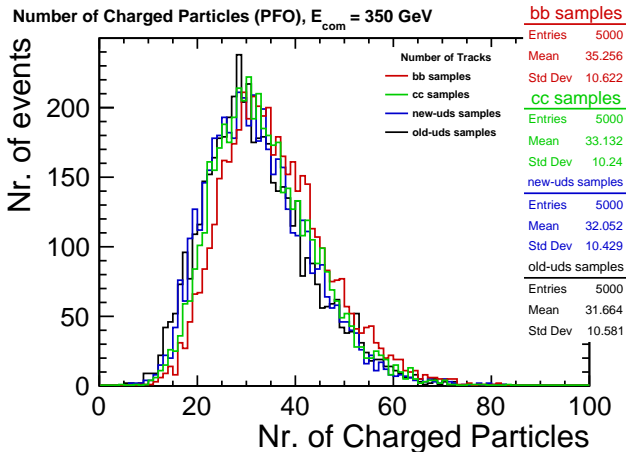
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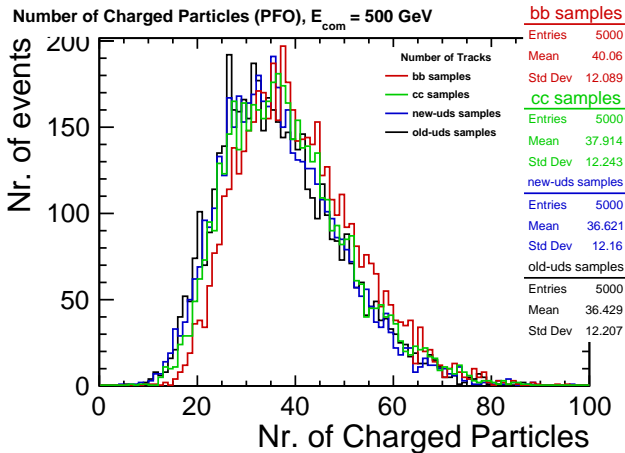
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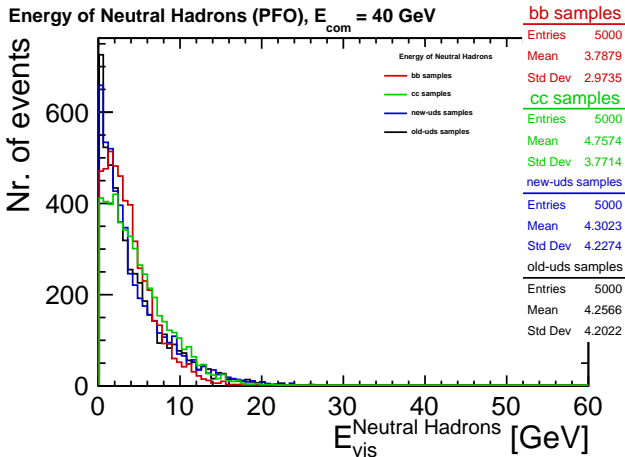
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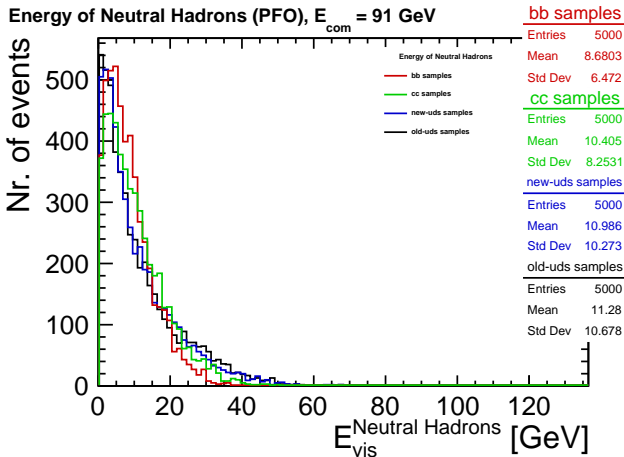
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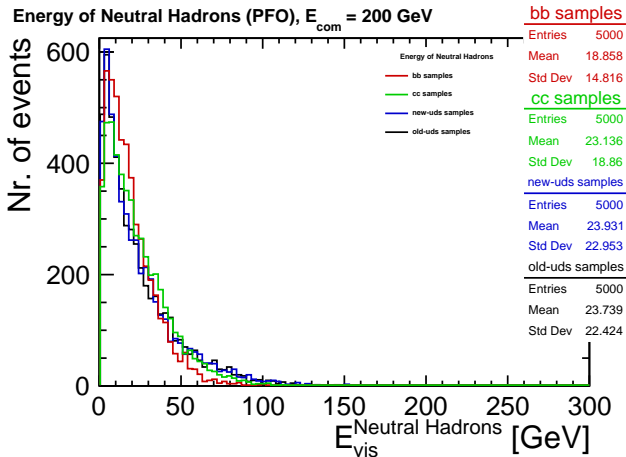
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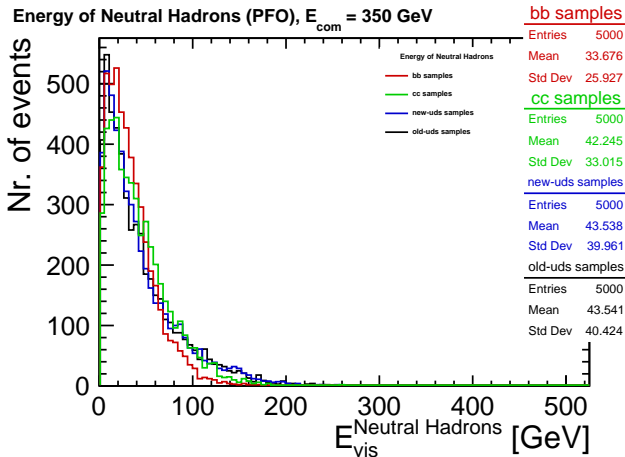
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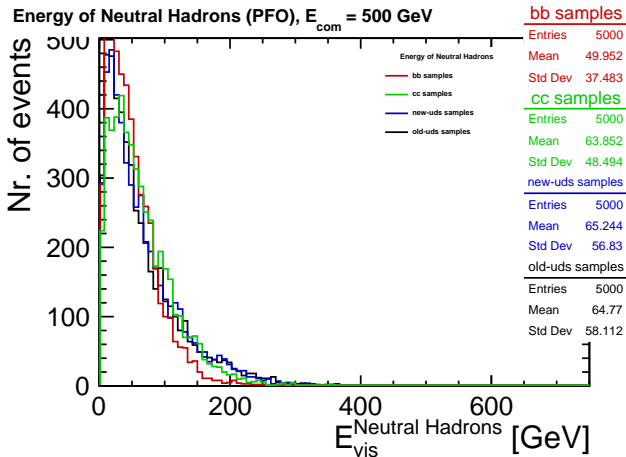
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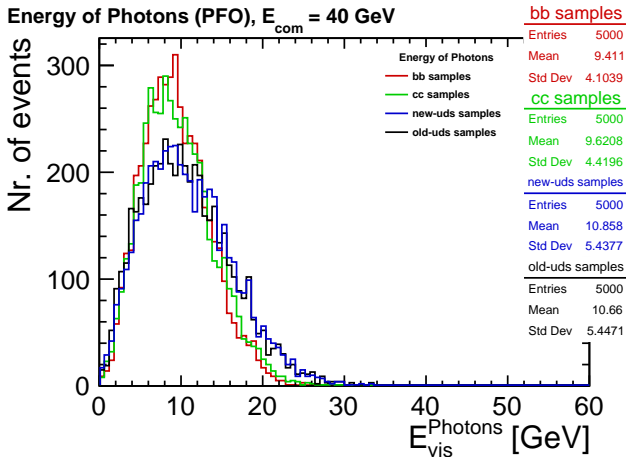
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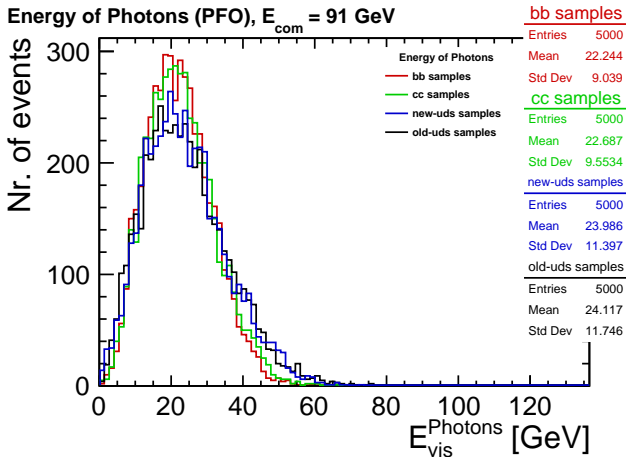
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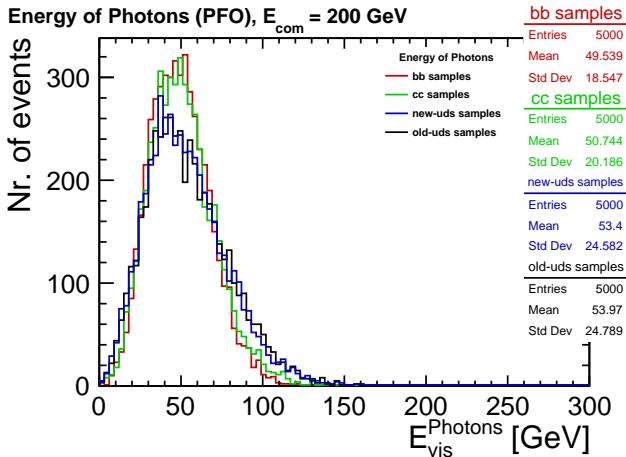
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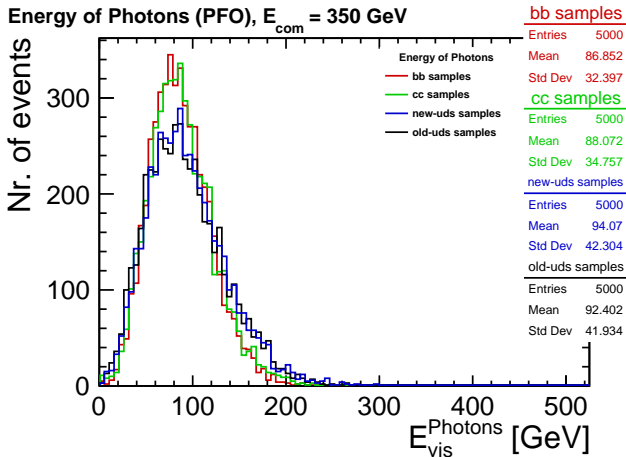
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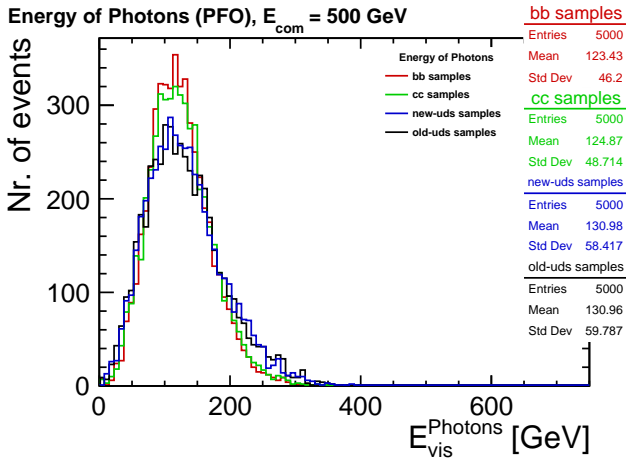
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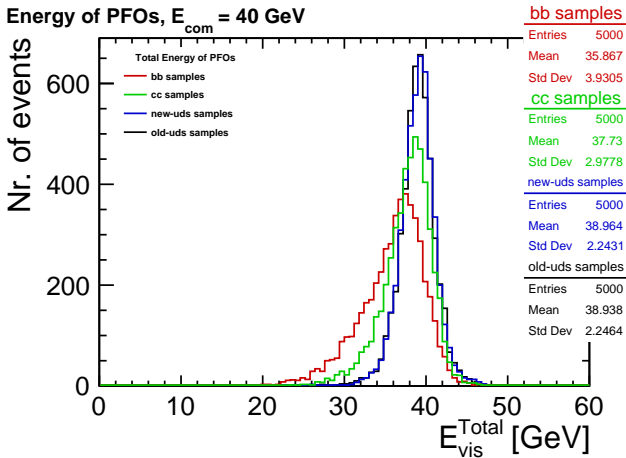
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Validation of new uds samples - Check plots



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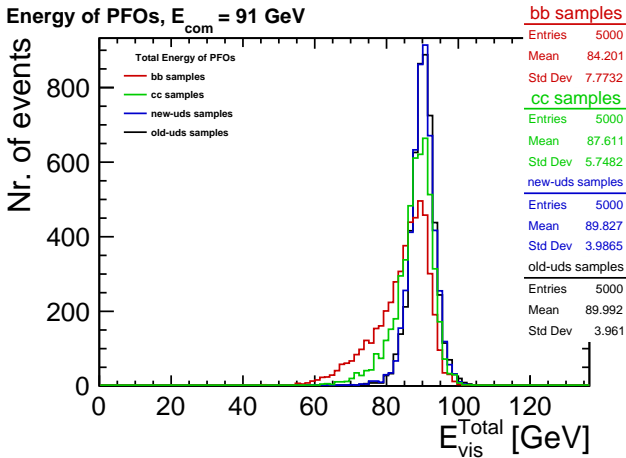
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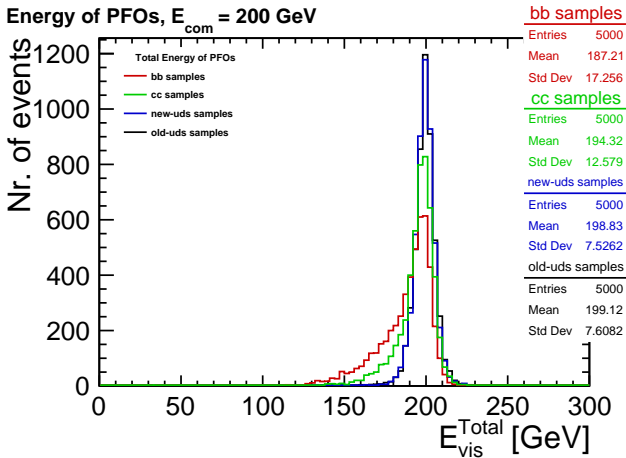
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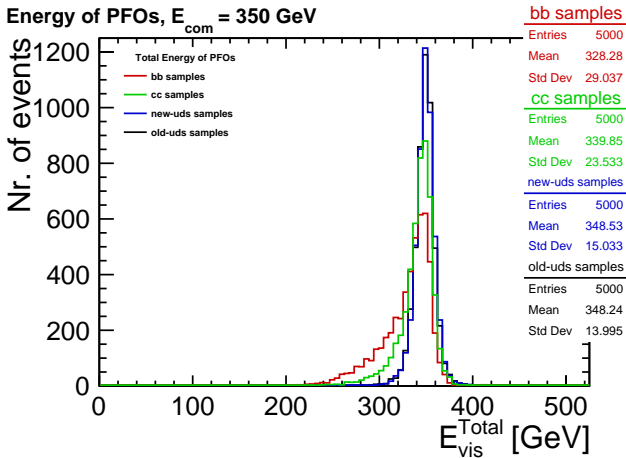
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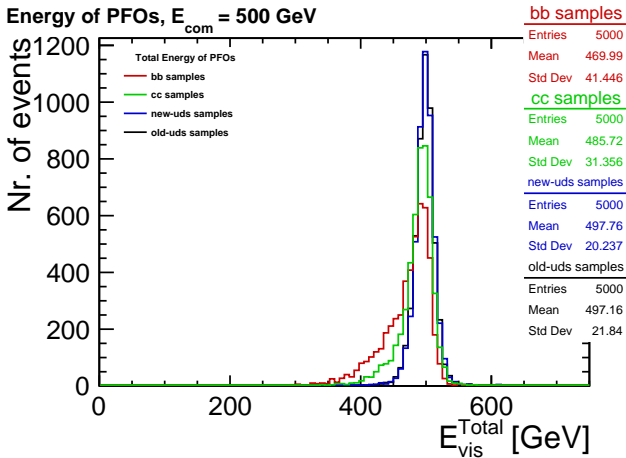
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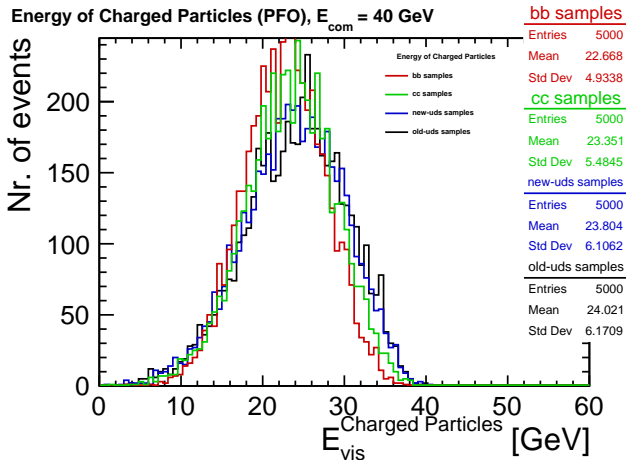
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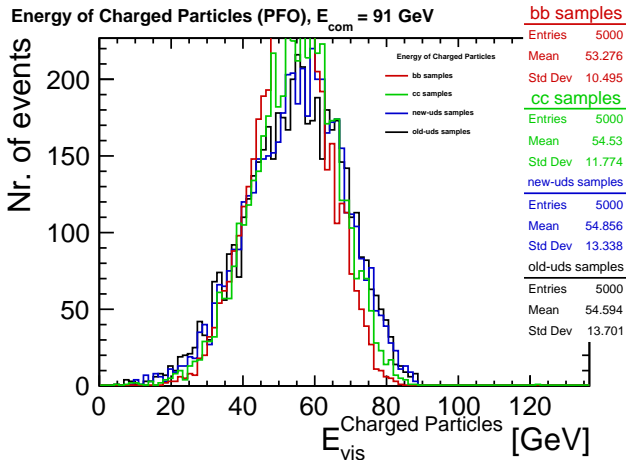
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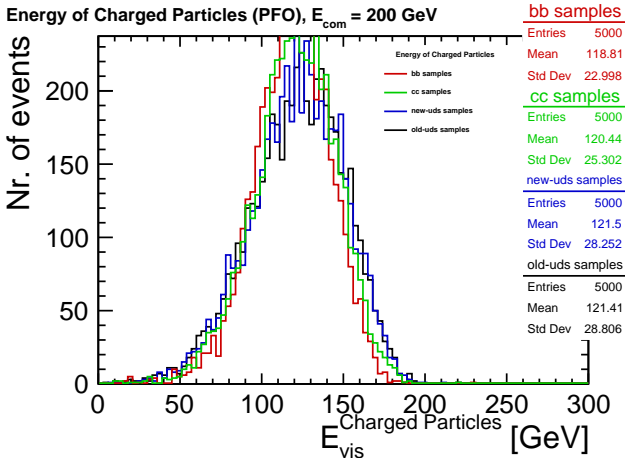
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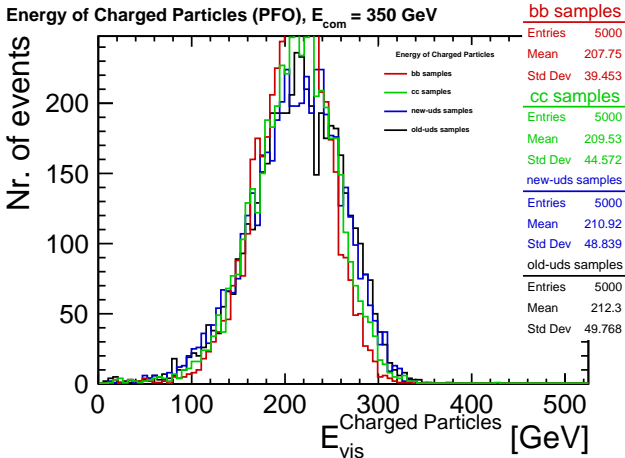
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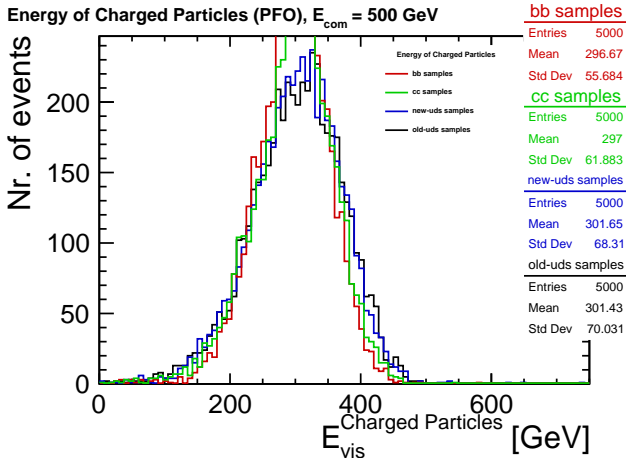
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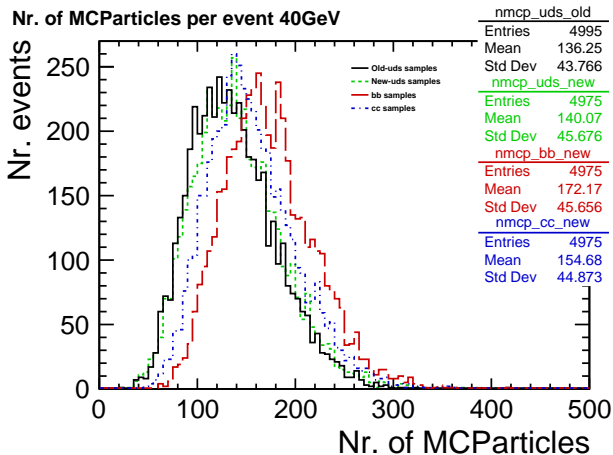
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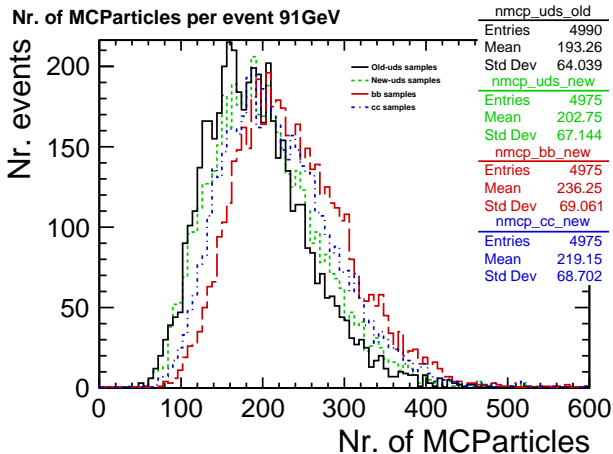
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Validation of new uds samples - Check plots



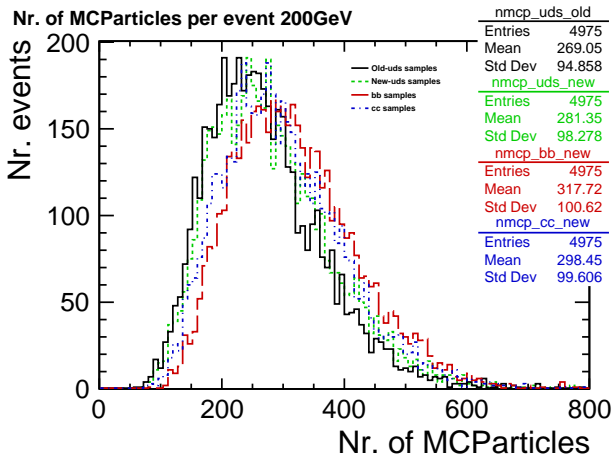
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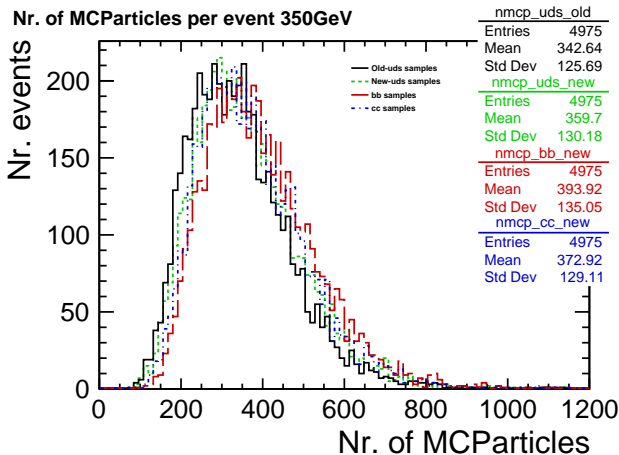
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Validation of new uds samples - Check plots



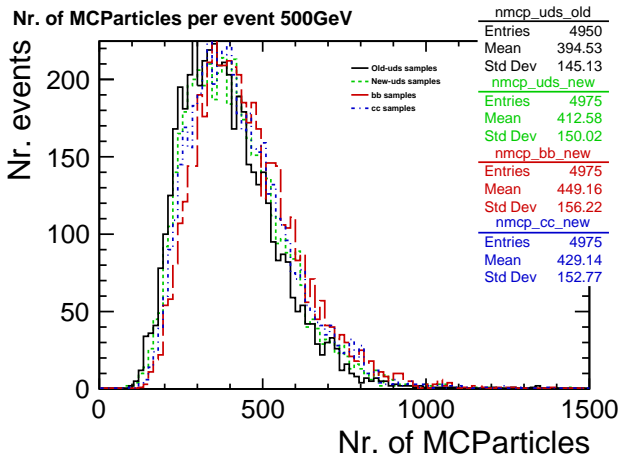
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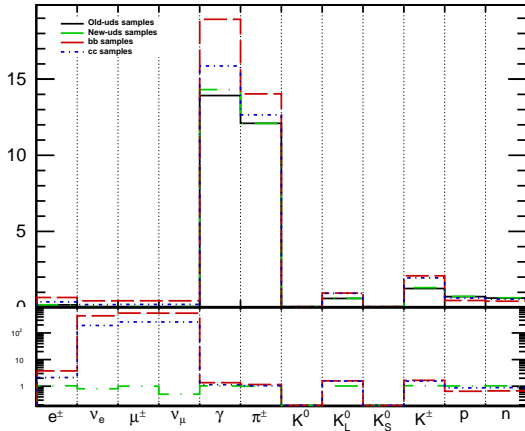
## Validation of new uds samples - Check plots



# Backup

## Validation of new uds samples - Check plots

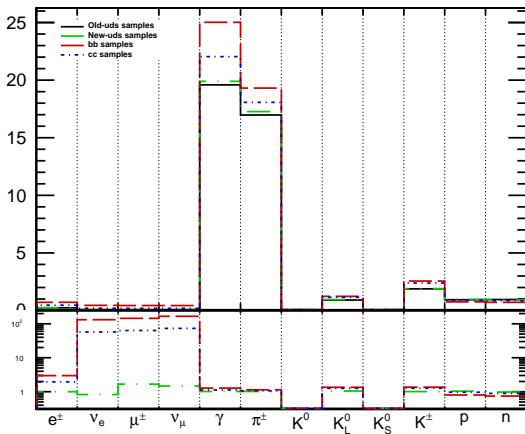
Nr. of Stable MCParticles per event 40GeV (ratio respect with old-uds)



# Backup

## Validation of new uds samples - Check plots

Nr. of Stable MCParticles per event 91GeV (ratio respect with old-uds)

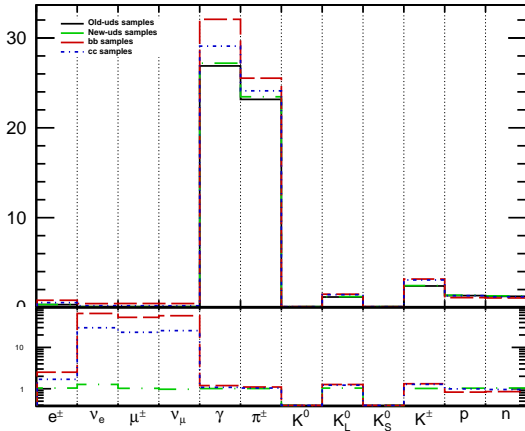




# Backup

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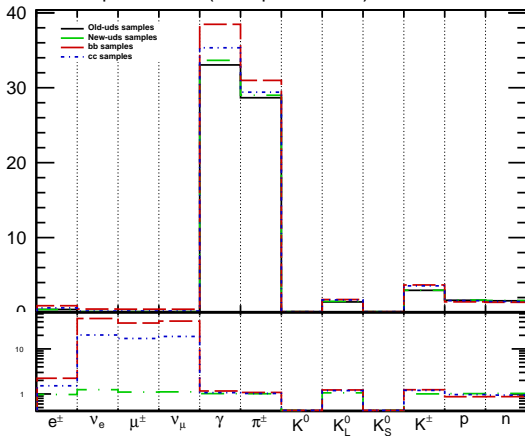
Nr. of Stable MCParticles per event 200GeV (ratio respect with old-uds)



# Backup

## Validation of new uds samples - Check plots

Nr. of Stable MCParticles per event 350GeV (ratio respect with old-uds)



# Backup

## Validation of new uds samples - Check plots

Nr. of Stable MCParticles per event 500GeV (ratio respect with old-uds)

