HyCal and GEM matching

- Default values for the matching radii in the PRadEvent viewer are:
  - 15 mm for PWO
  - 35 mm for transition
  - 50 mm for LG

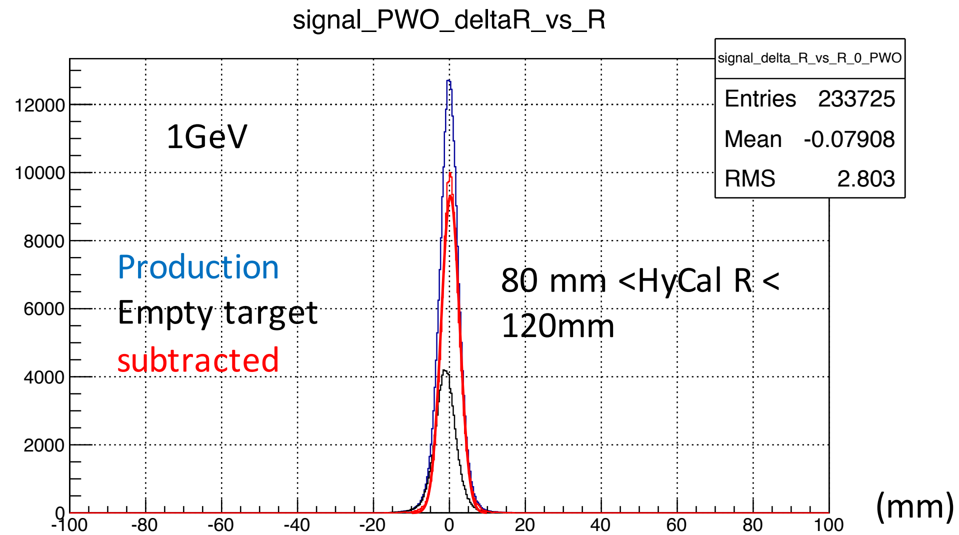
- Might be too tight for the low energy Mollers

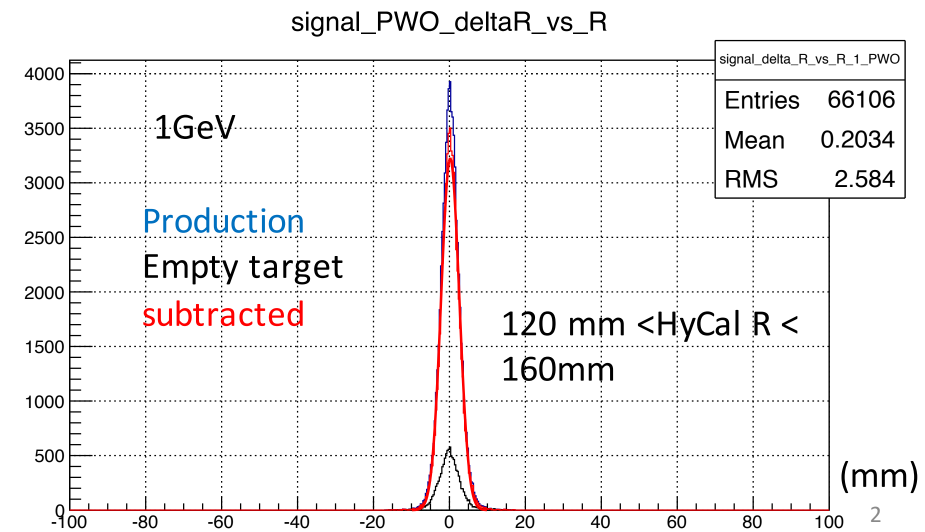
- Want to find a better cut by looking at HyCal position resolution, sensitivity of yield on the matching cut (in particular, no angular dependence should be introduced)

- Procedure for matching:
  - Apply the Primex shower depth correction to all HyCal hits, and project them to HyCal PWO surface
  - Project the GEM hits onto the HyCal PWO surface
  - Calculate the distance between the HyCal hit and projected GEM hit
  - Require the distance to be less than certain cut, based on the HyCal resolution

HyCal Position Resolution

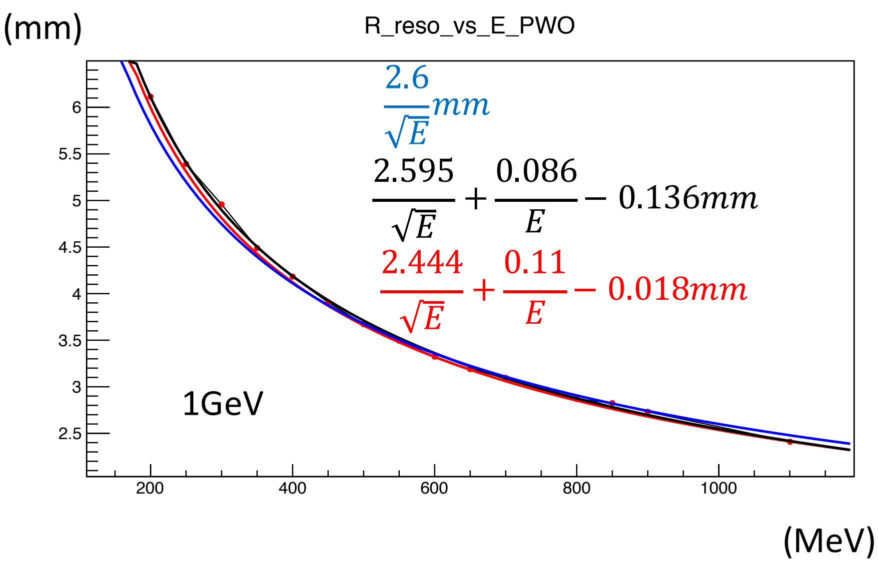
- To measure the HyCal position resolution (and so as the relative z distance between GEMs and HyCal), Use **Δ**R (HyCal R – GEM R)
    - The R coordinate difference between HyCal hit and projected GEM hit (HyCal R – GEM R)
- If **Δ**R is not centered at 0, it could means:
    - The distance between target, GEM, and HyCal is not right (or the particle is not coming from the target)
    - Reconstructed hit position is biased (HyCal transition region)

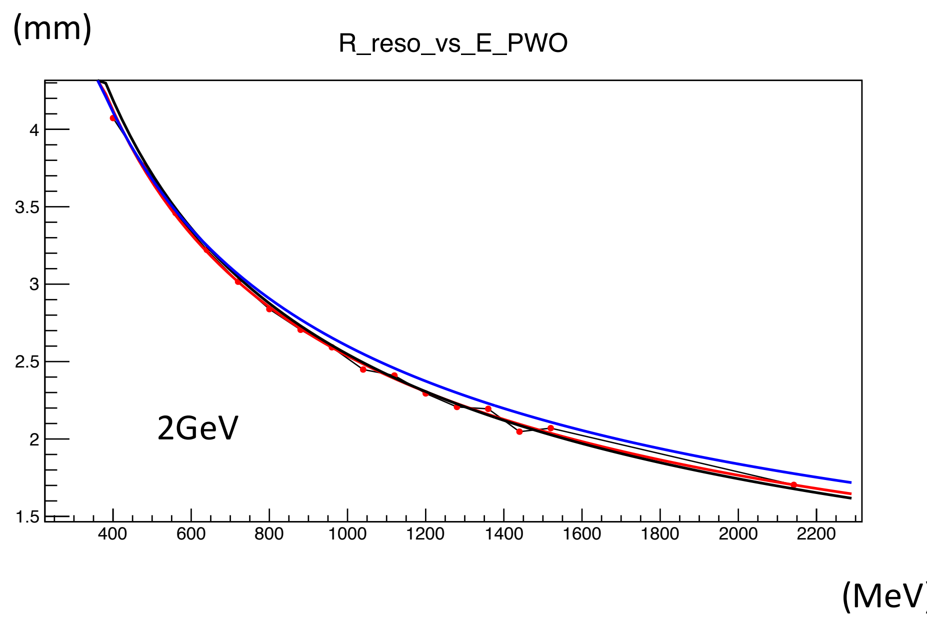




Energy dependence of the HyCal Position resolution

- Using ep + ee2 to determine the energy dependence of the HyCal position resolution
- Black curve over the data point is 2.6mm/sqrt(E)
- Data points can be fitted reasonably well by function A/sqrt(E) + B/E + C, but 1.1 and 2.2 GeV give slightly different parameters

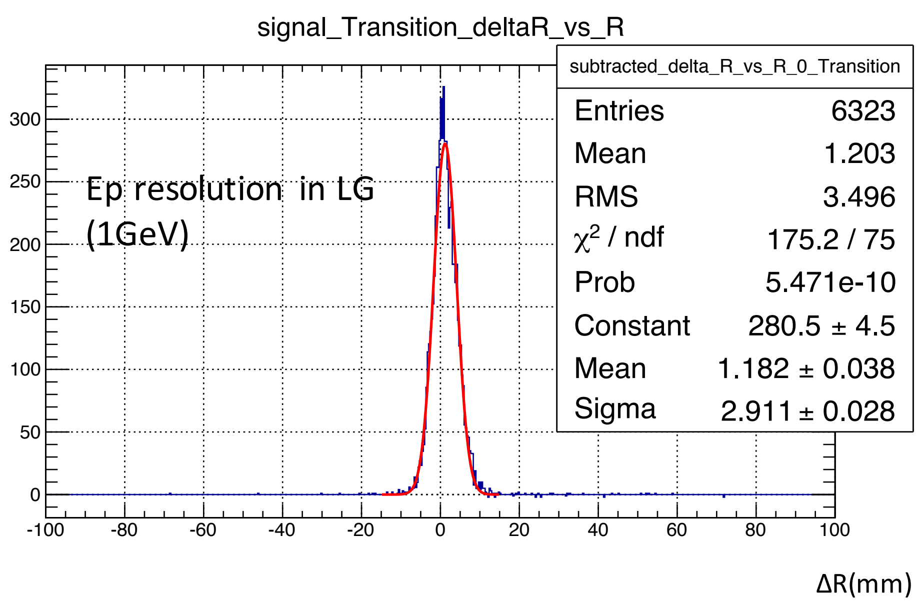


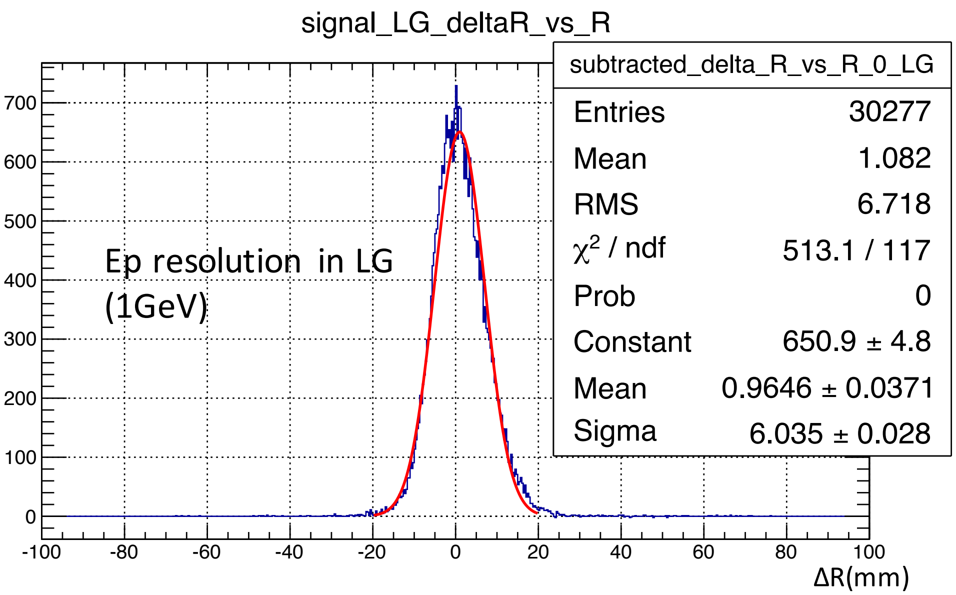


Suggesting for the PWO part, use the fitted result from 2 GeVwhere E is the measured energy on HyCal

Energy dependence of the HyCal Position resolution

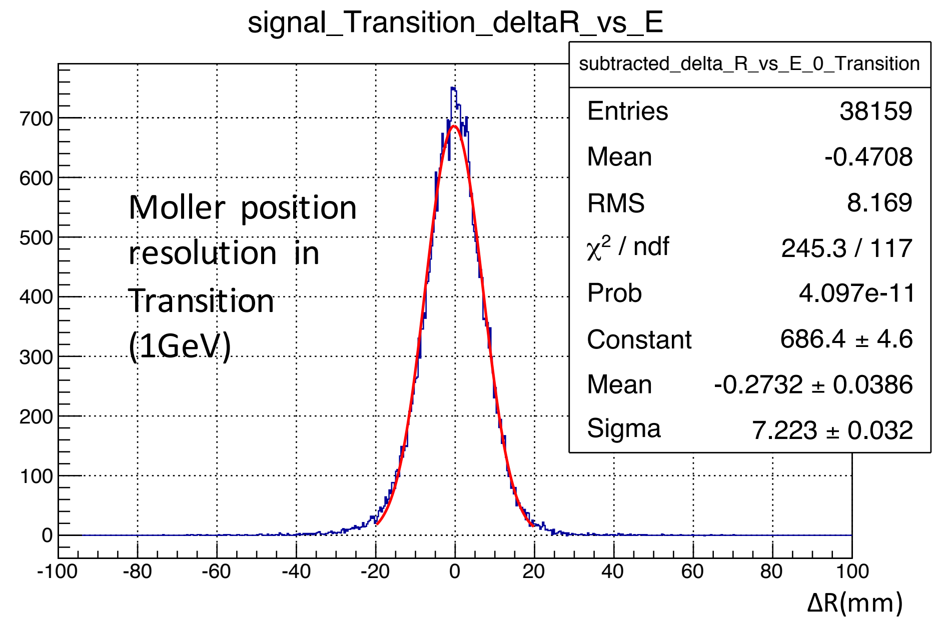
- 1 GeV ep in LG and transition region
- 6.33 mm = 6.035 x sqrt(1.1) for LG
- For transition, even though the average resolution is a lot better than LG, due to highly non-uniformity and bias in reconstruction, suggesting to keep it the same as LG

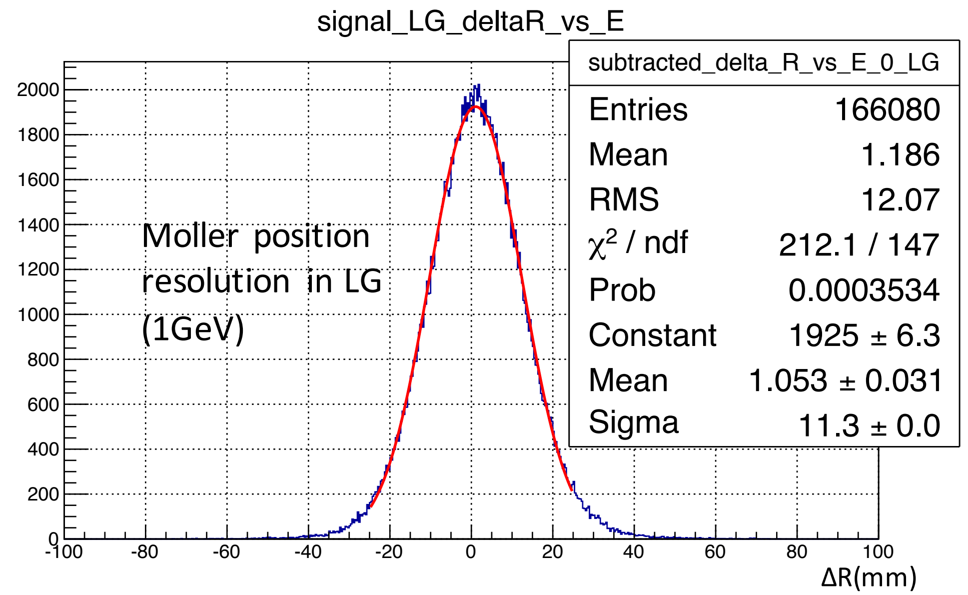




Energy dependence of the HyCal Position resolution

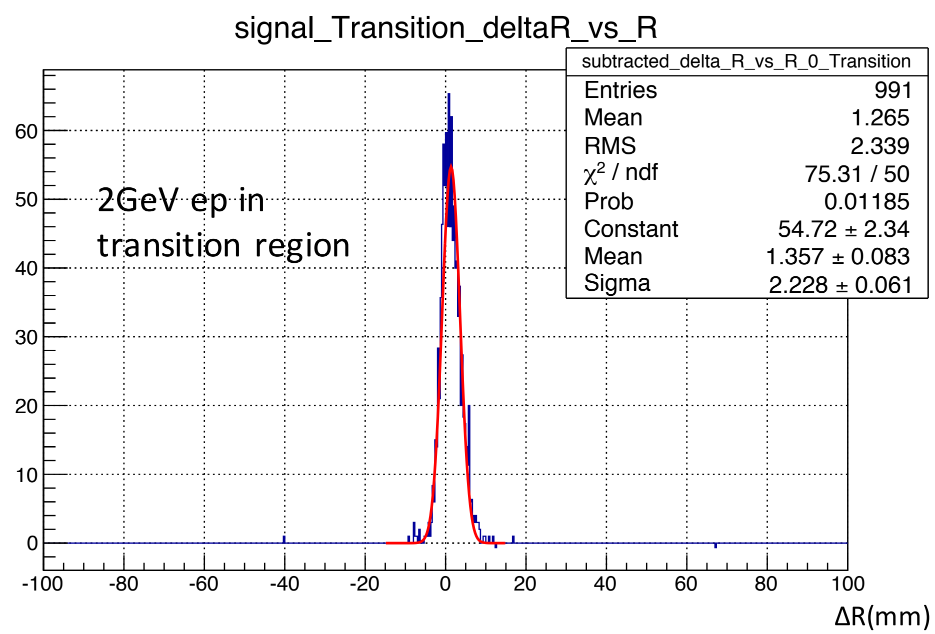
- For LG and transition, the maximum expected energy is around 250 MeV
- 6.3/sqrt(0.25) = 12.6 mm
- The resolution of Moller is better than expected so it is safe to keep the rule

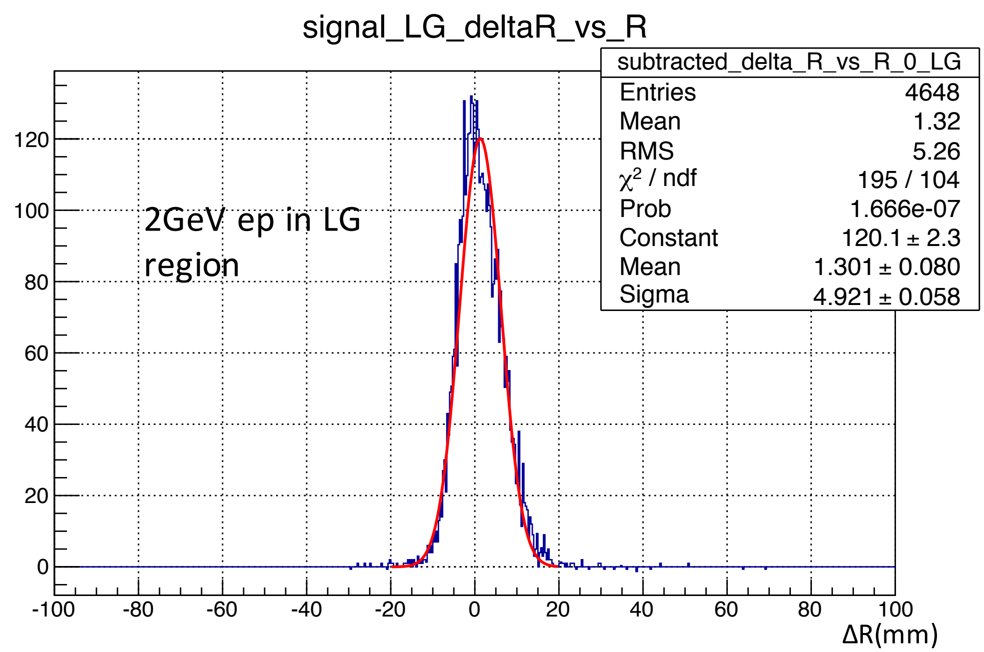




HyCal Position Resolution

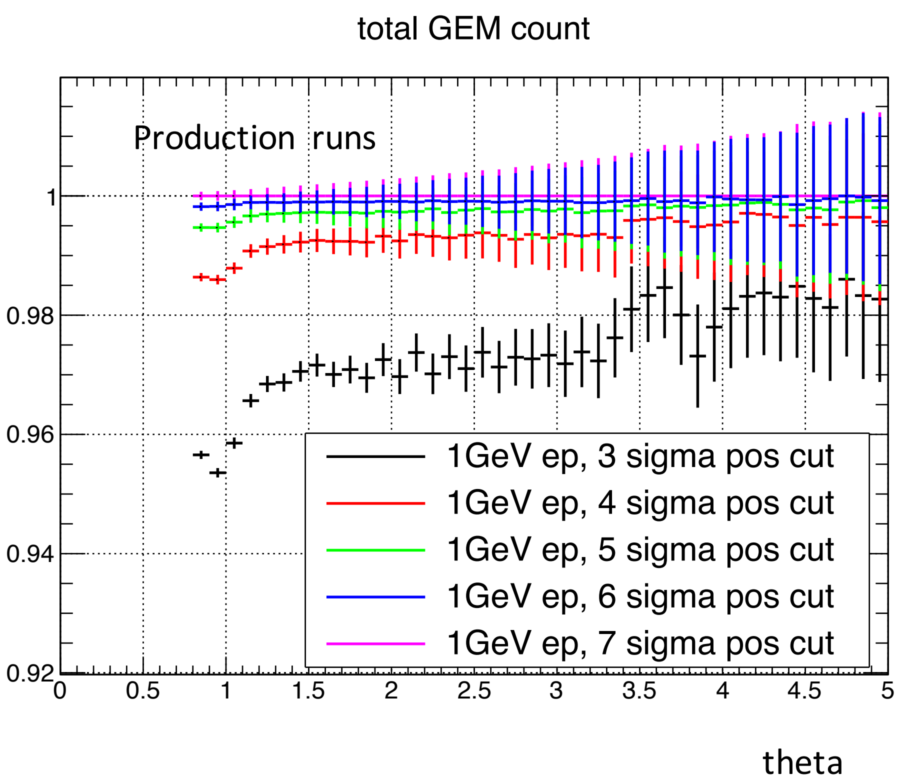
- At 2 GeV, Moller is not useful in LG and transition (due to fact that the higher energy one pass through the central hole and thus has much lower trigger efficiency)
- We can either choose the cut based on the ep resolution along and 4.921 x sqrt(2.142) = 7.2 mm

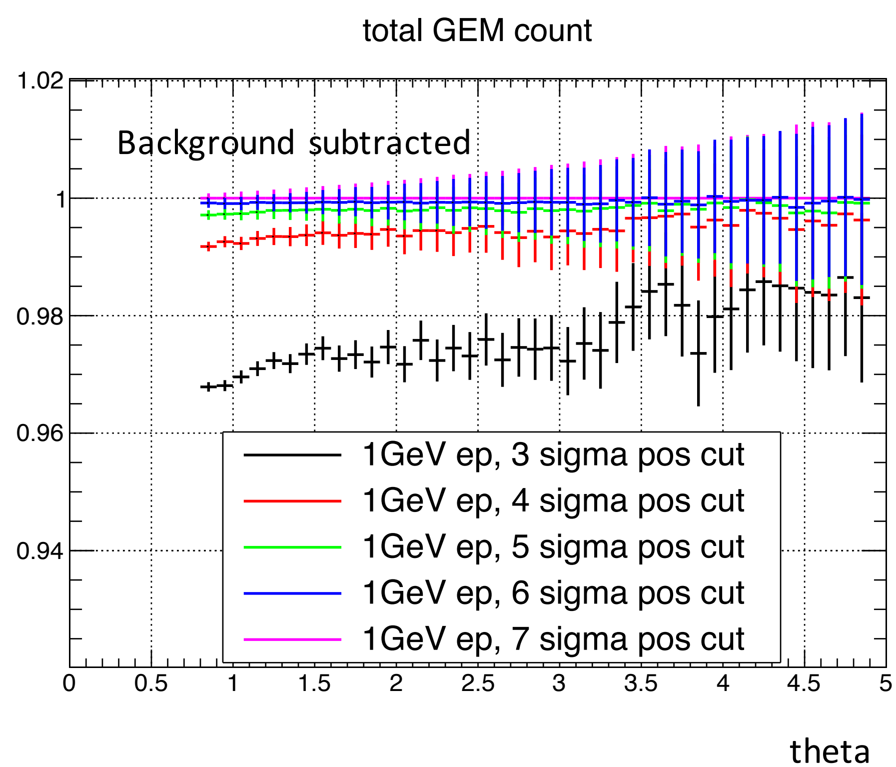




Sensitivity of ep yield (with GEM matched) on position cuts

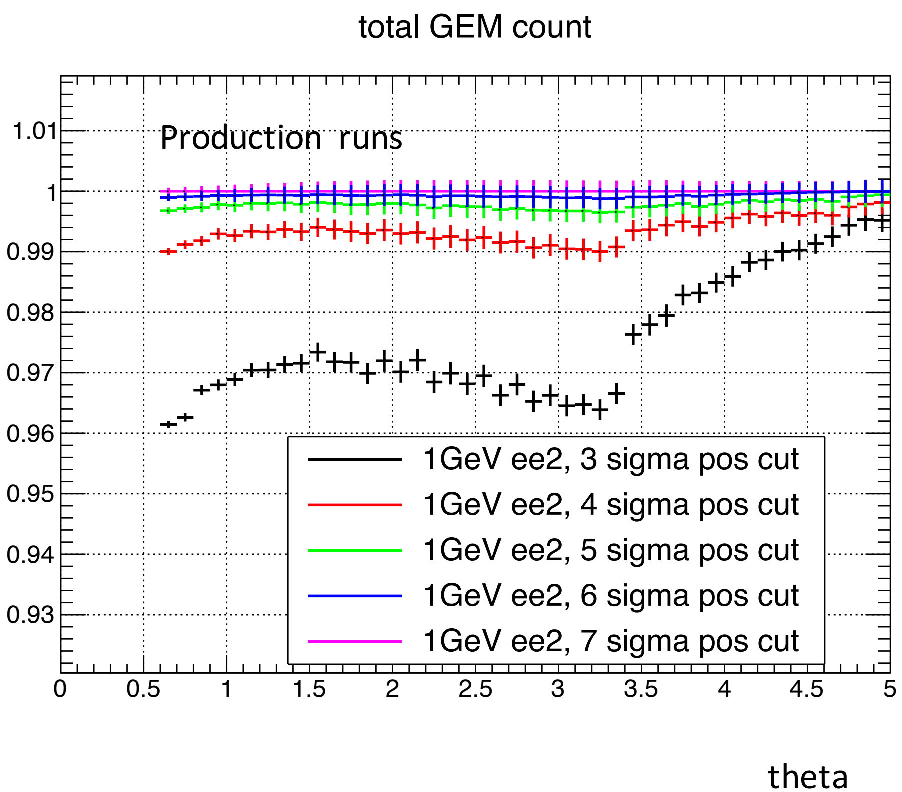
For the background subtracted yield, difference between 6 and 7 sigma cut is only ~0.1% level for all angular bins

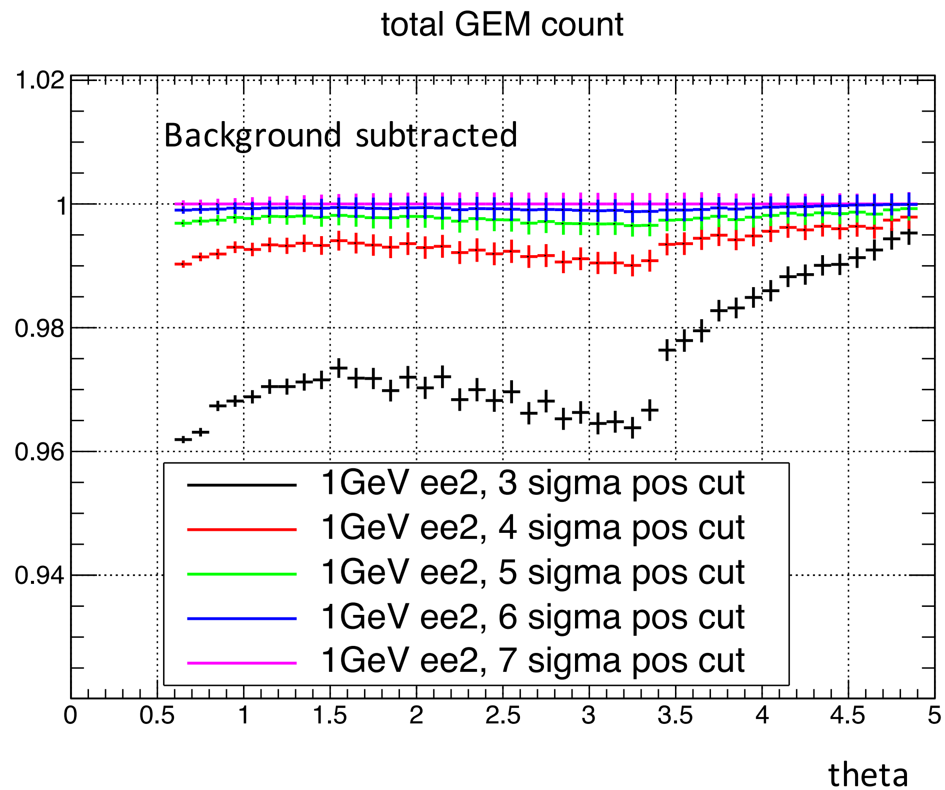




Sensitivity of 1.1 GeV ee2 yield (with GEM matched) on position cuts

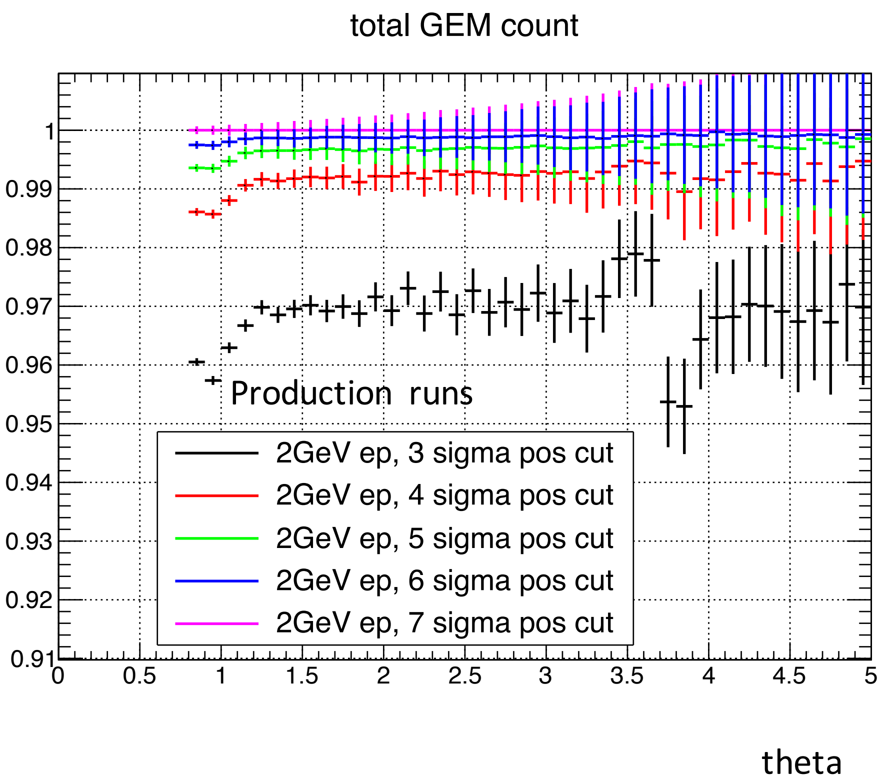
For the background subtracted yield, difference between 6 and 7 sigma cut is only ~0.1% level for all angular bins

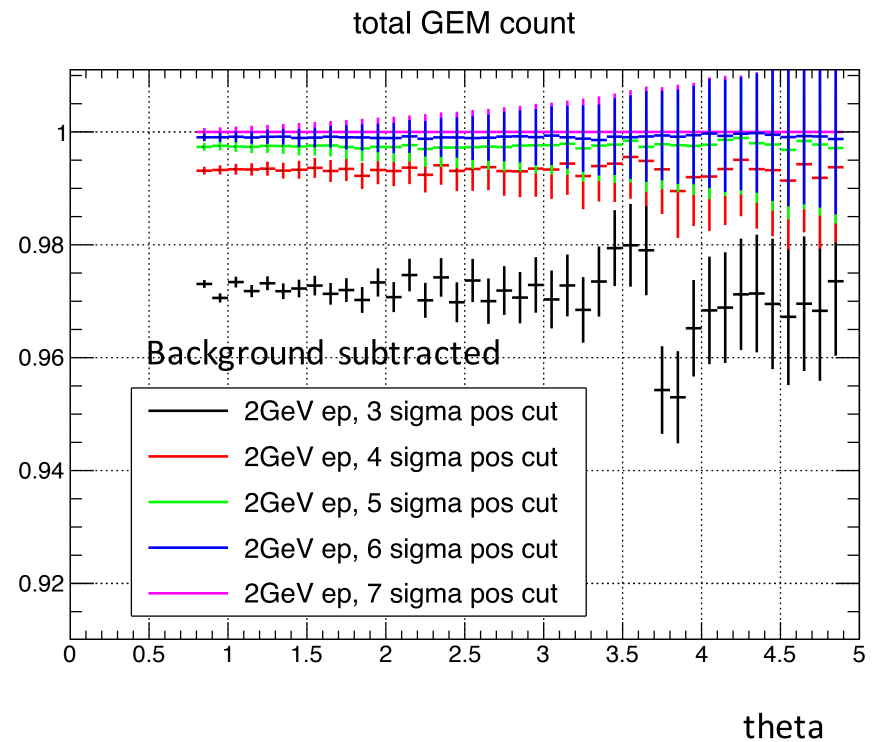




Sensitivity of 2.2 GeV ep yield (with GEM matched) on position cuts

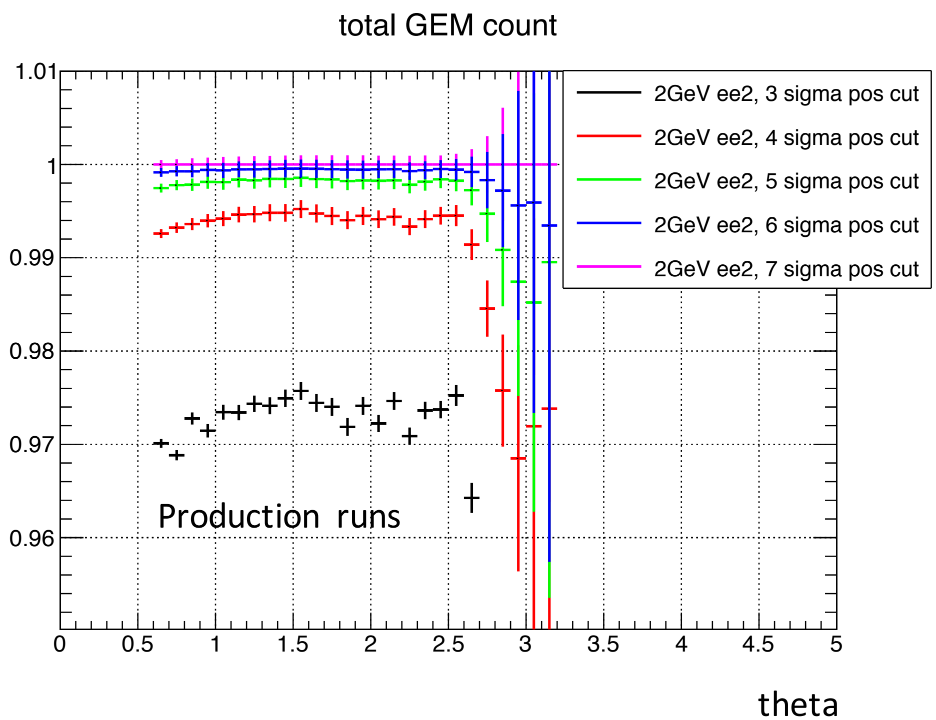
For the background subtracted yield, difference between 6 and 7 sigma cut is only ~0.1% level for all angular bins

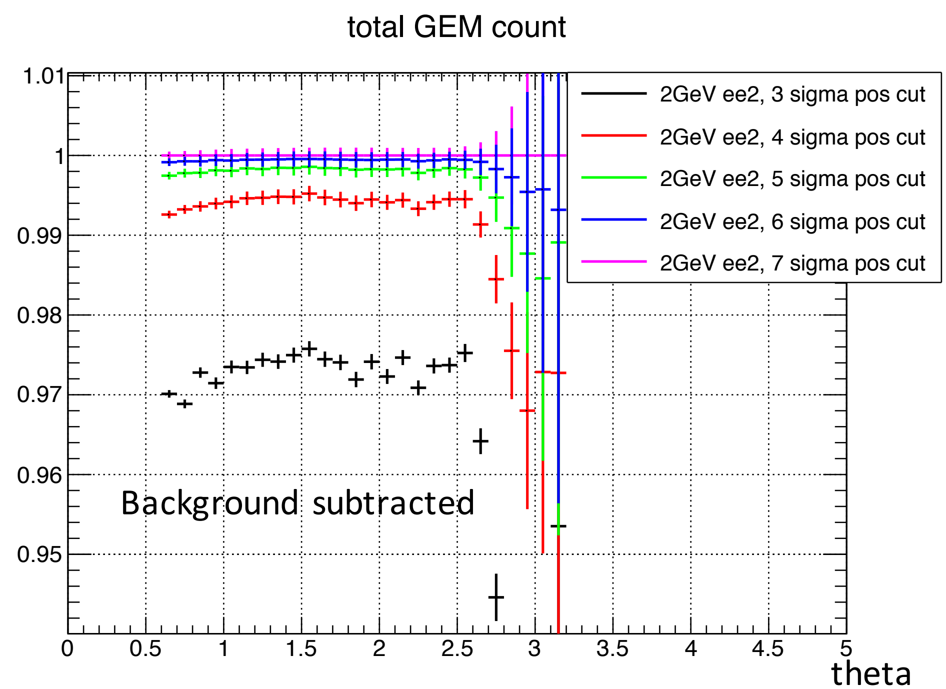




Sensitivity of 2.2 GeV ee2 yield (with GEM matched) on position cuts

For the background subtracted yield, difference between 6 and 7 sigma cut is only ~0.1% level for all angular bins





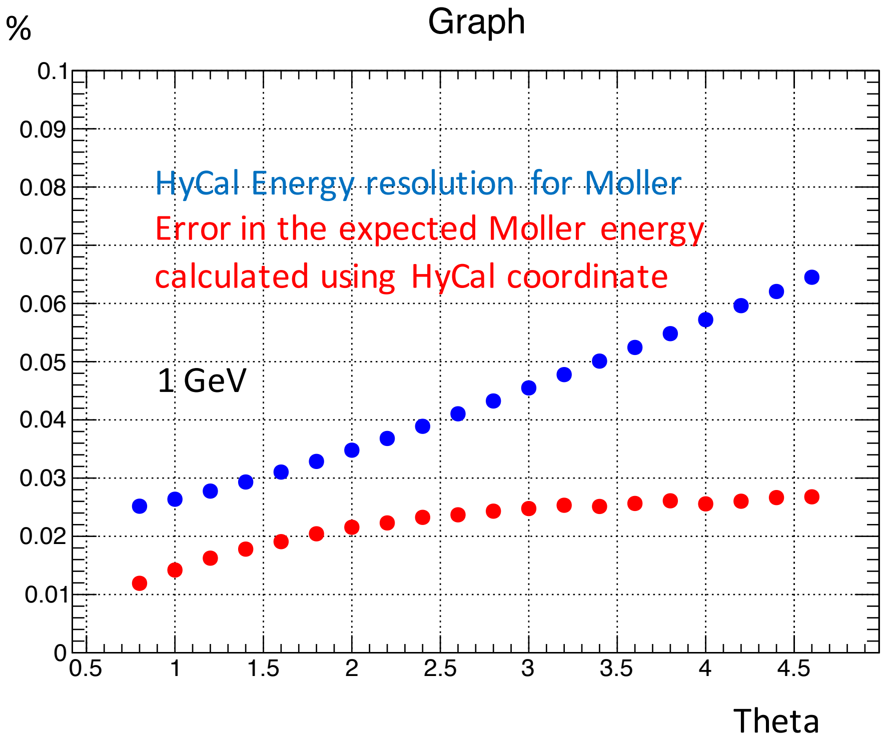
GEM Efficiency

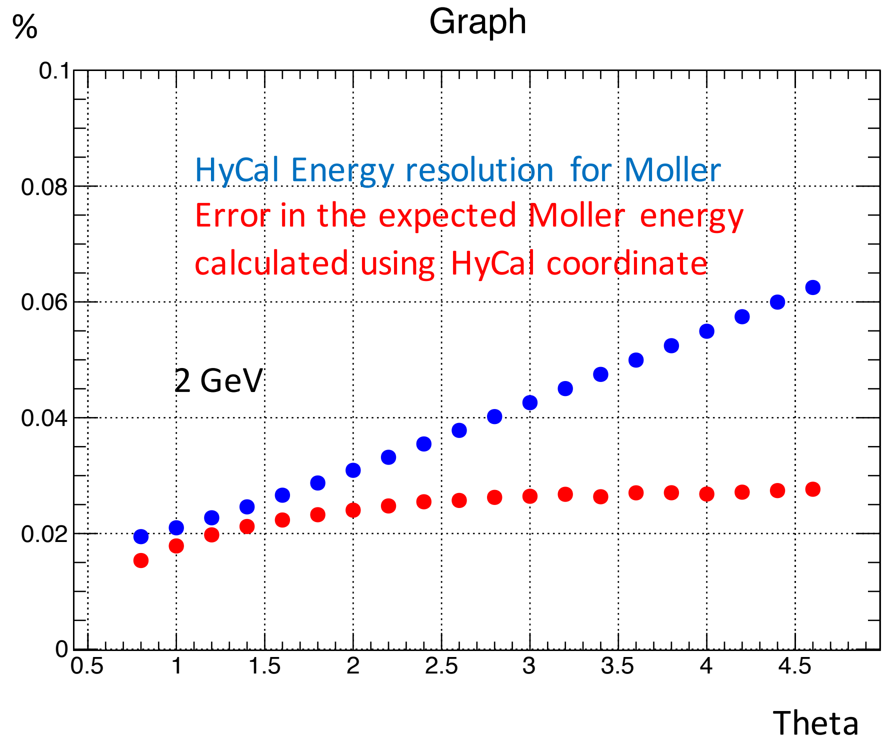
- Select data sample based on HyCal first, and see if there is a GEM hit fall in the matching radii (6 sigma)
- Selection for ep:
  - Cut on cluster energy (n x 2.4%/sqrt(E) for PWO, n x 6%/sqrt(E) otherwise)
  - Cut on Cluster size (for a good ep cluster on HyCal, typically have 19 modules for 1GeV ep and 24 module for 2GeV ep)

- Selection of ee2:
  - Each Moller must agree with the expected energy within n x 2.4%/sqrt(E) for PWO, 6%/sqrt(E) otherwise
  - Co-plane: < 10 deg
  - $|E1 + E2 - Ebeam| < n \times sqrt(\delta E1^2 + \delta E2^2)$
  - After chosen ee2 from HyCal, treat the two electron separately, like ee1, so that the efficiency will be convoluted

Uncertainty in the expected Moller Energy

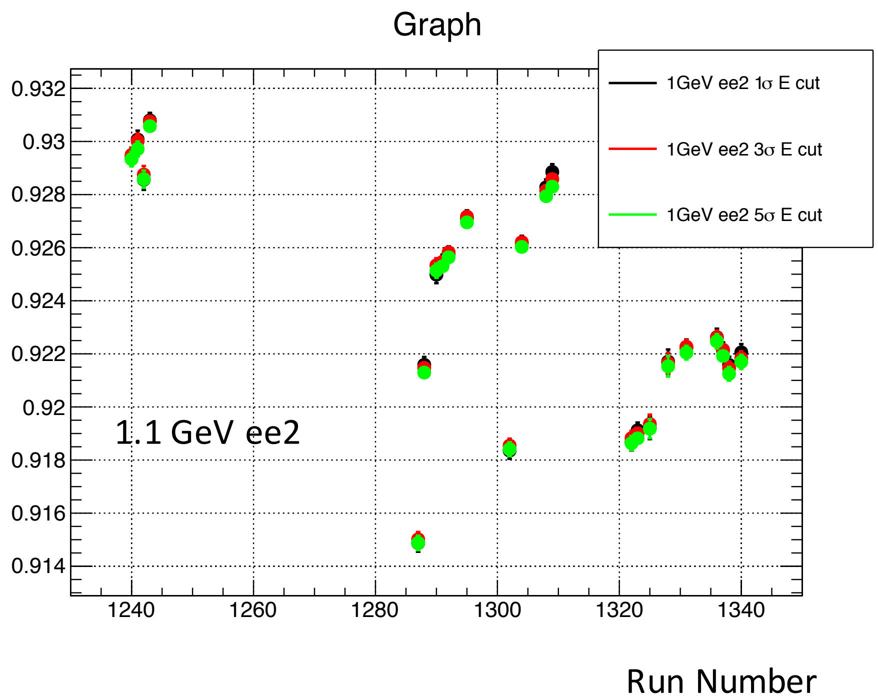
- The position resolution will introduce an error when calculating the expected energy
- If using the expected energy to select event, then the cut should be well above the error in the expected energy

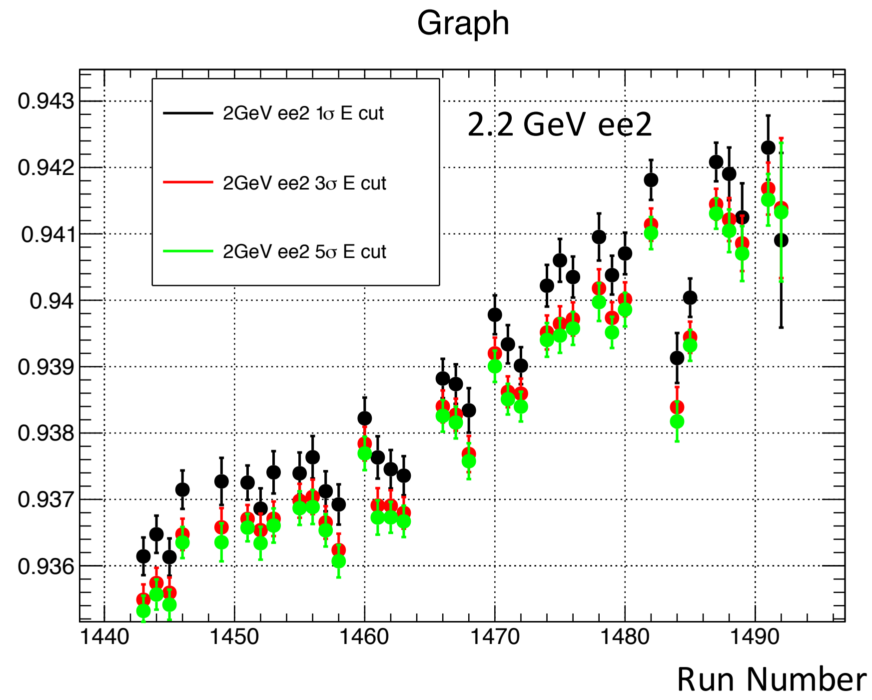




Time dependence of the GEM Efficiency

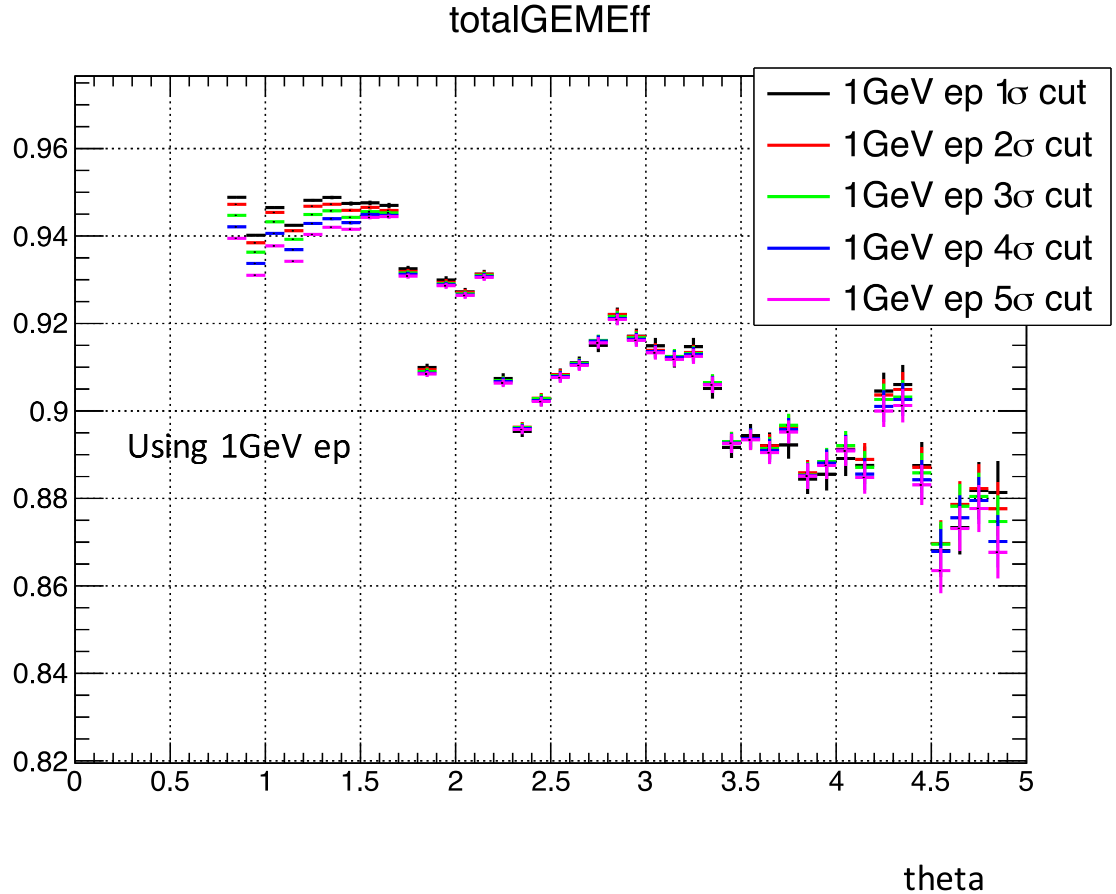
- Keeping the matching cut the same (6 sigma), varying energy cut, the dependence is still exist
- Integrated efficiency from 0.6 ~ 5 deg





Sensitivity of GEM efficiency on Cuts

- Keeping the matching cut the same by varying energy cut
- If the data sample is “clean”, then the efficiency should be independent on energy cut
- GEM efficiency from empty target run typically has worse efficiency, particular to ep



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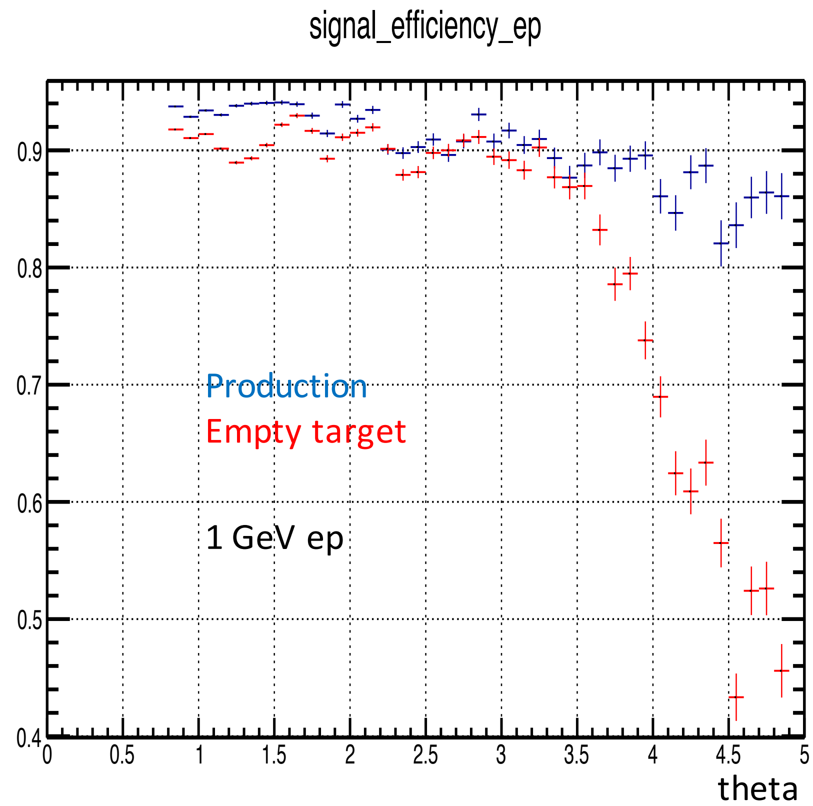

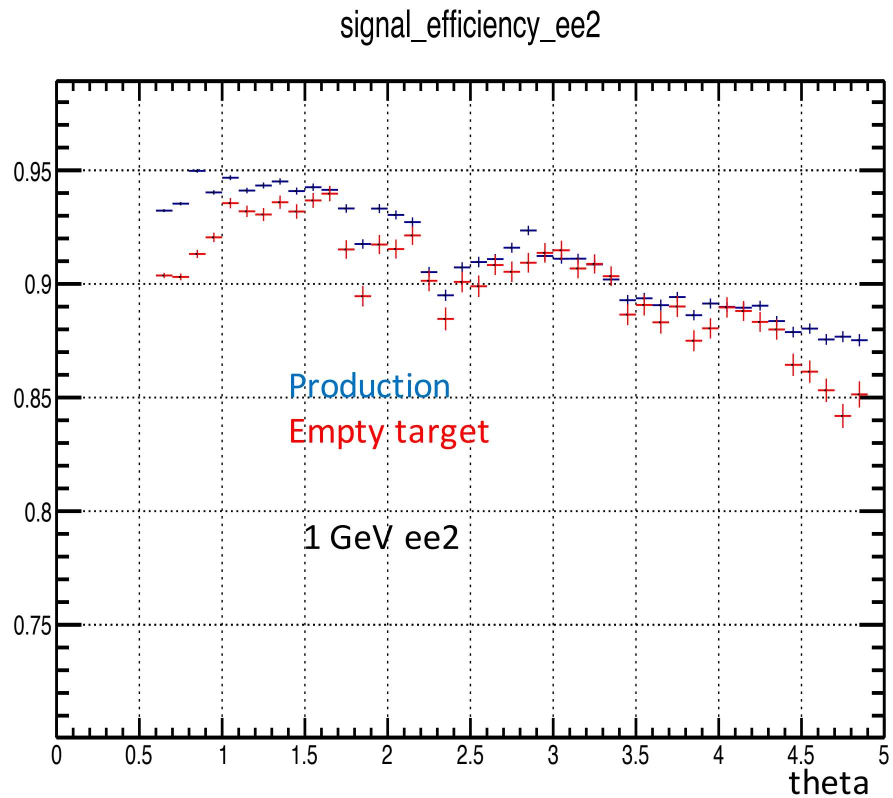

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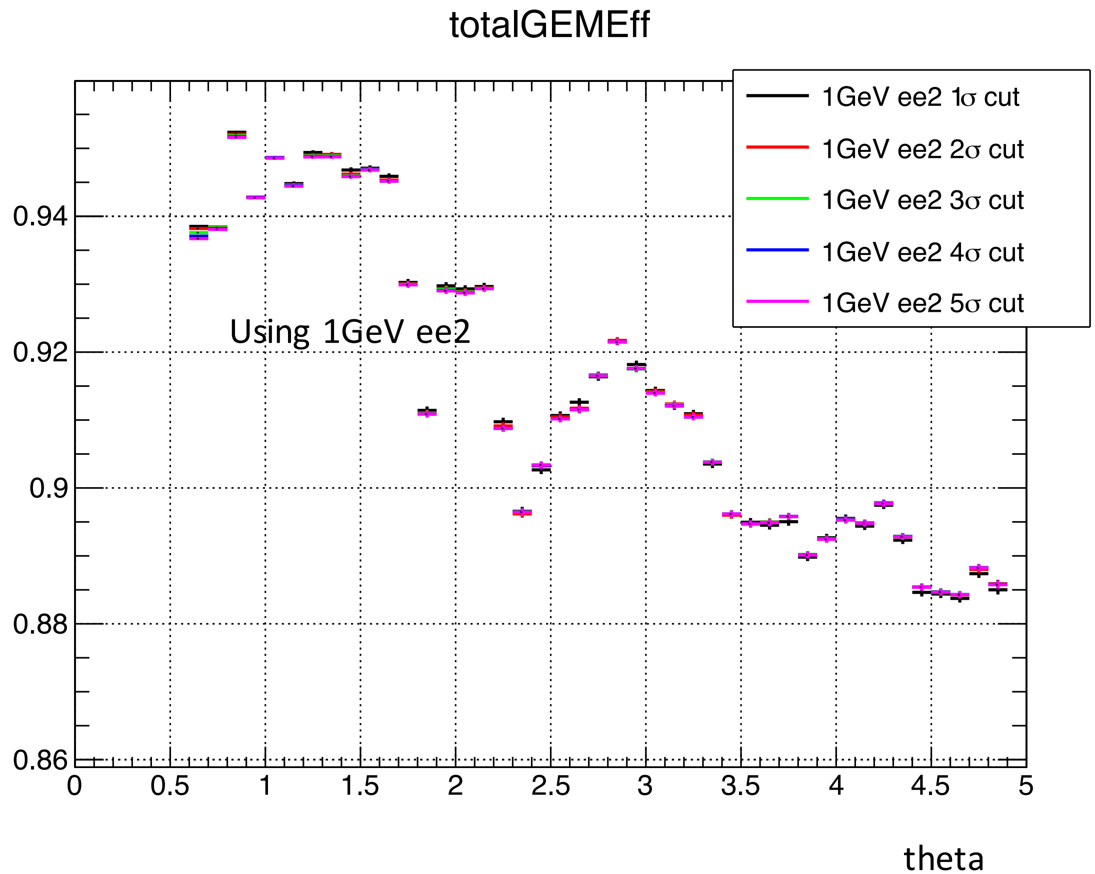

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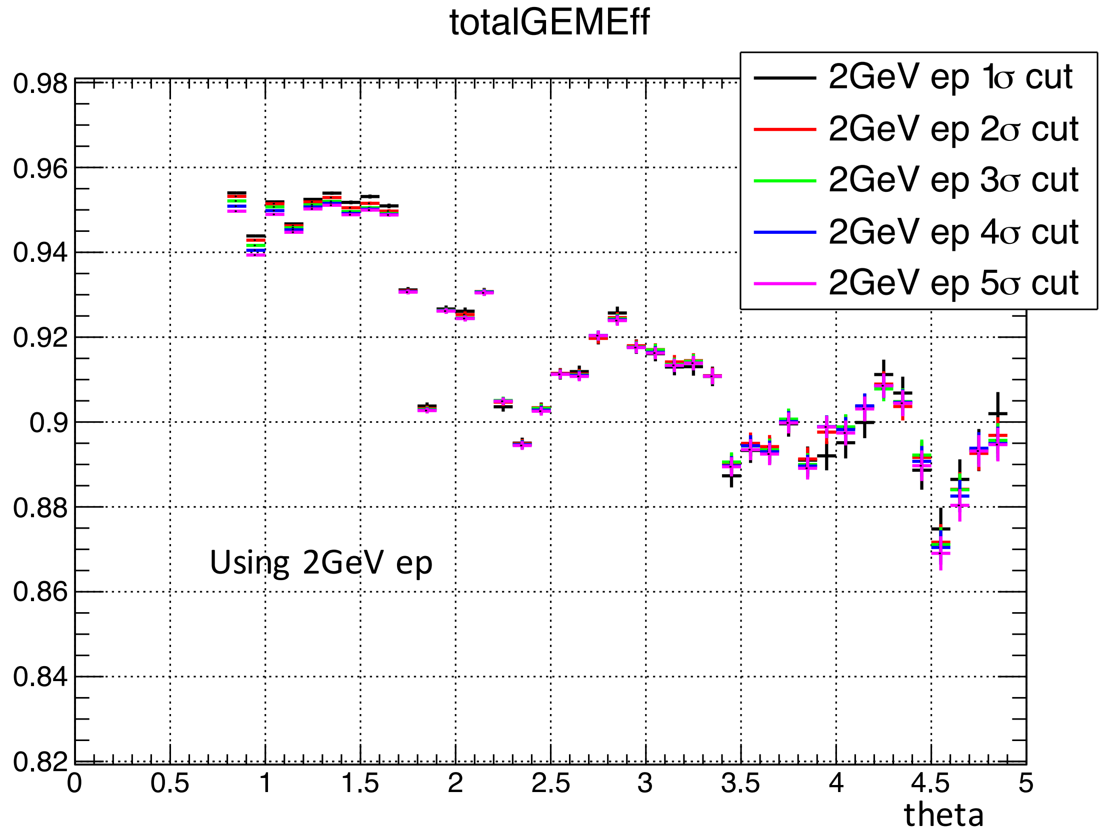
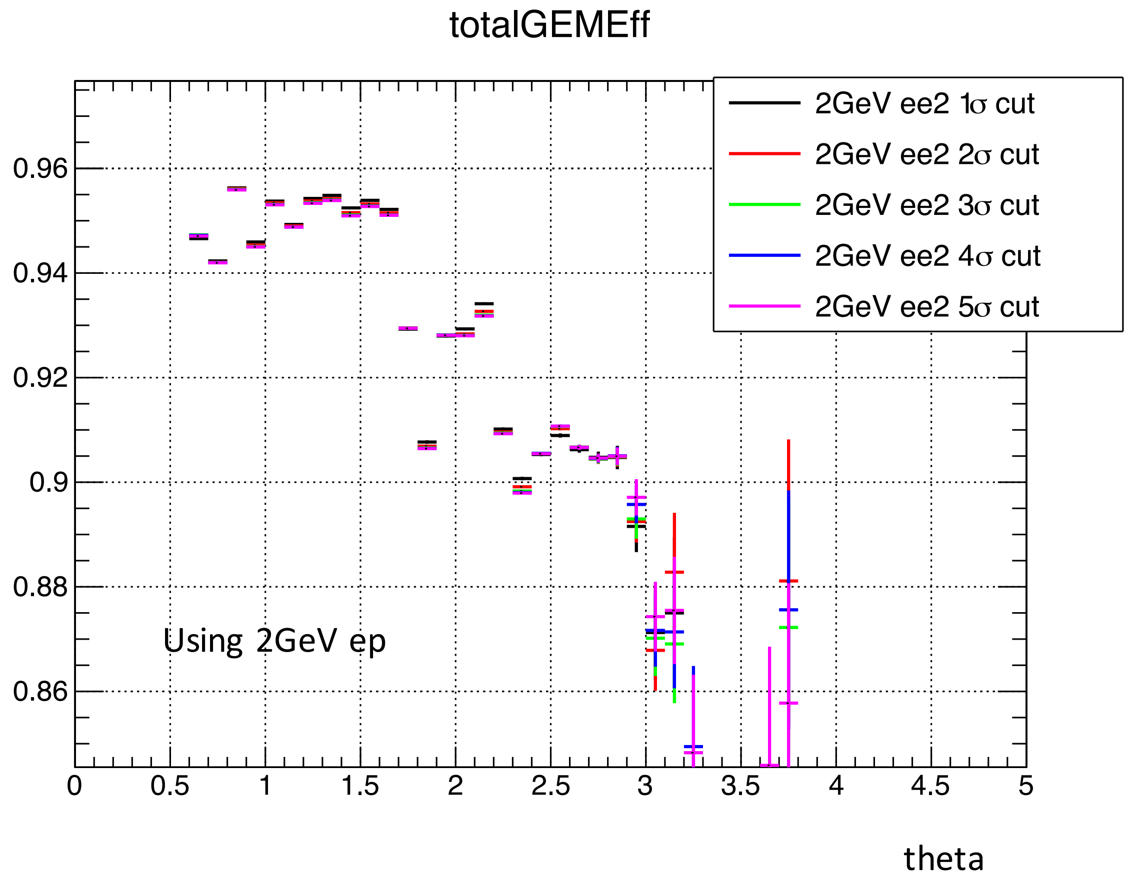


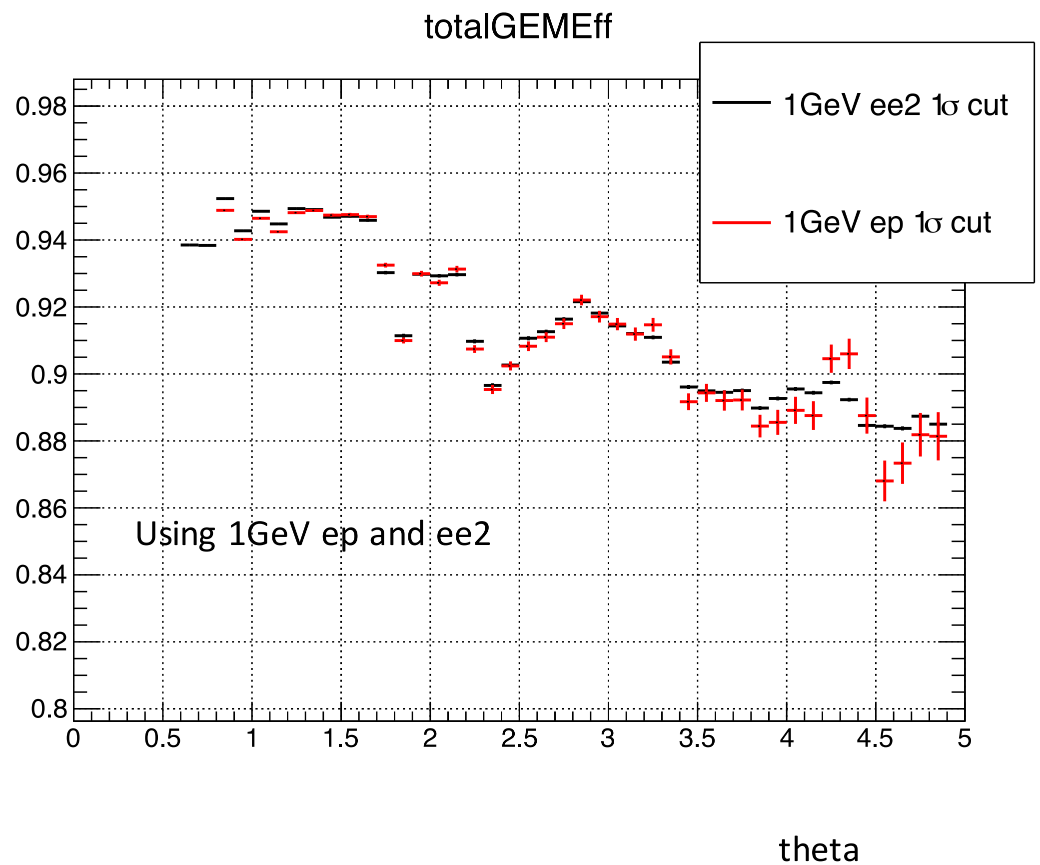
Sensitivity of GEM efficiency on Cuts

- Keeping the matching cut the same by varying energy cut
- If the data sample is "clean", then the efficiency should be independent on energy cut
- GEM efficiency from empty target run typically has worse efficiency, particular to ep
- 2GeV ee2 is probably the cleanest, unfortunately it doesn't cover much of HyCal



Comparison of efficiency obtained using ep and ee2

- ee2 usually has better efficiency compared to ep, probably due to cleaner data sample
- When calculate GEM efficiency we use HyCal position to determine which bin the event should go to?
- In that case due to finite resolution of HyCal, events could go to adjacent bins, if the bin size is too small



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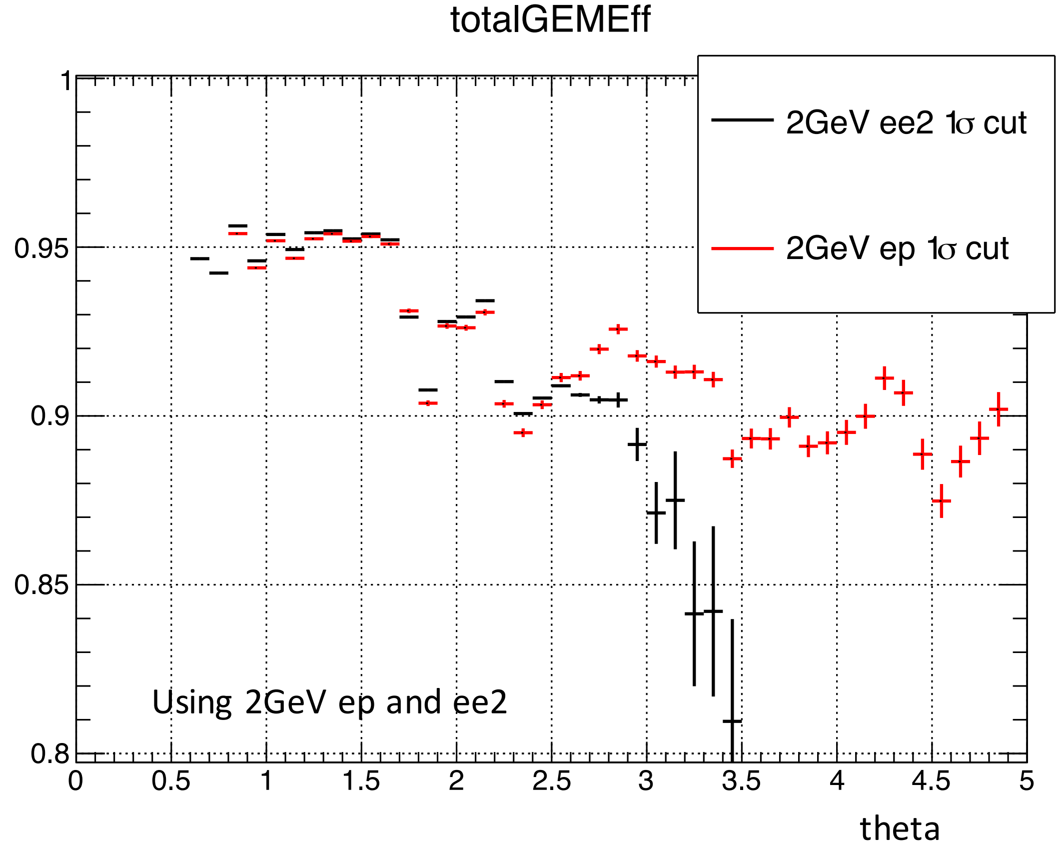
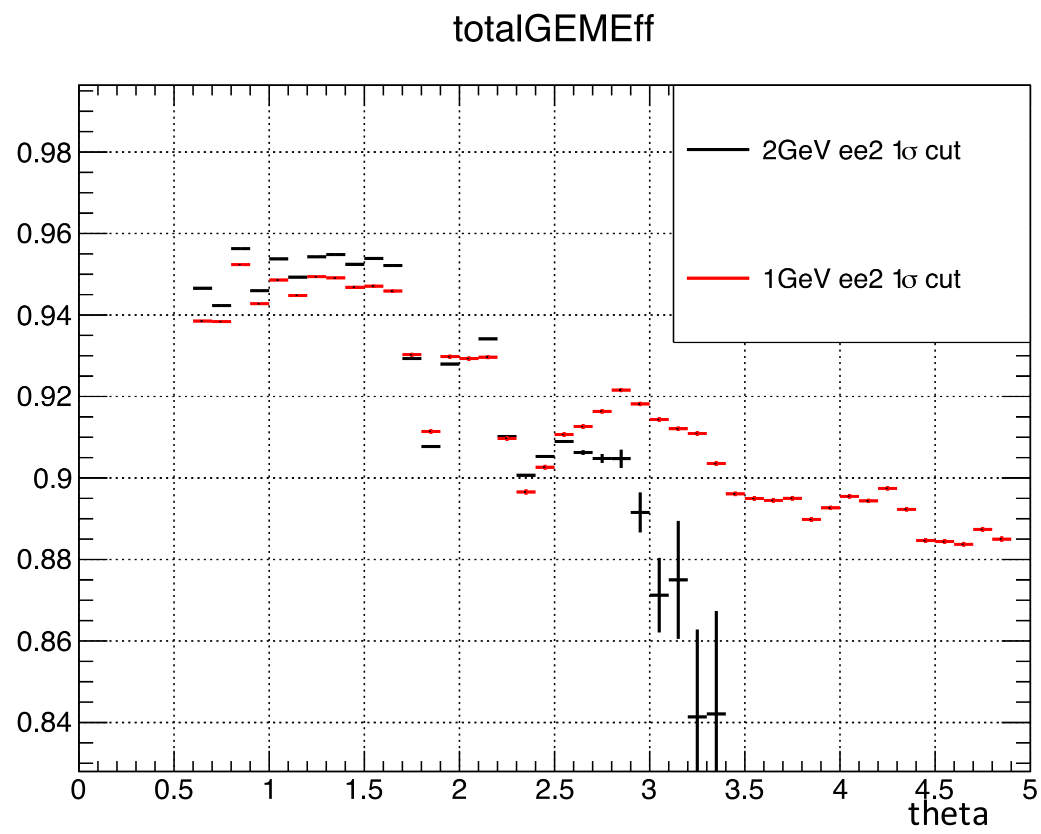


Comparison of efficiency obtained 1GeV ee2 and 2GeV ee2

- 2GeV ee2 seems to give consistently better efficiency compared to 1GeV ee2
- Could be due to different background level or time variation of the GEM efficiency?



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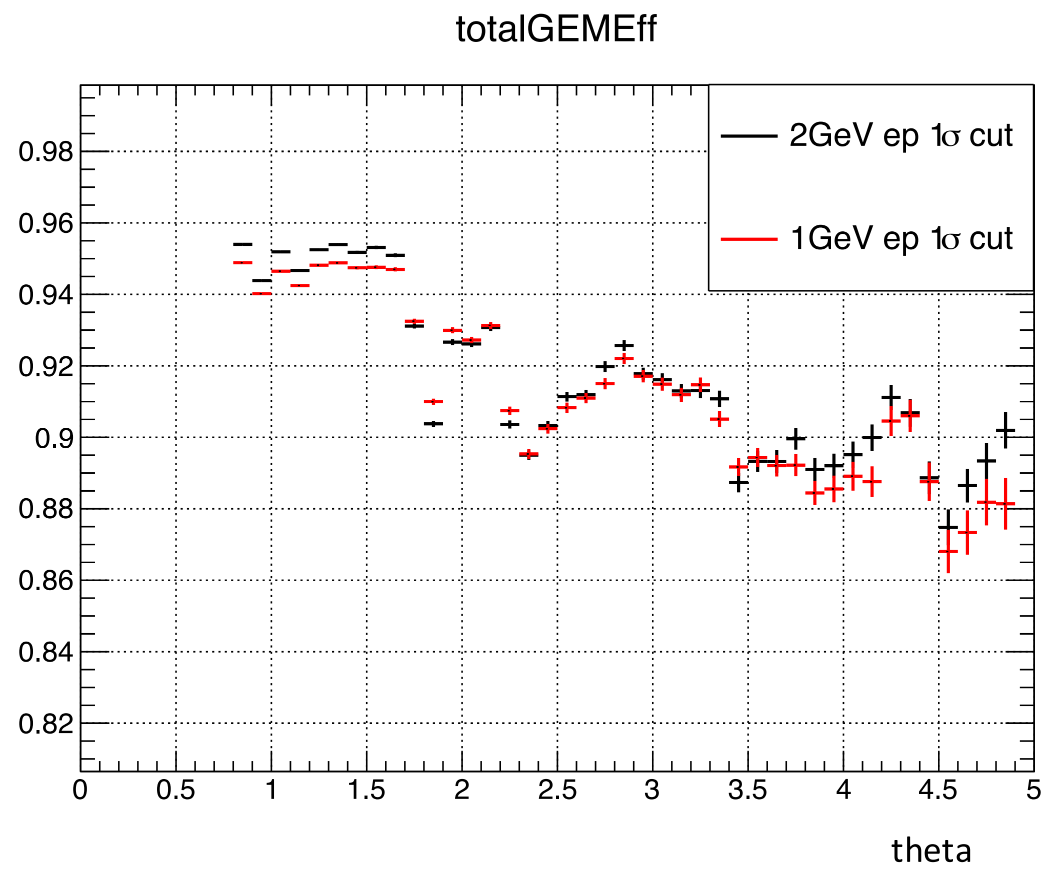

- 1GeV ee seems to be the best data sample for GEM efficiency study
- There are some systematic uncertainties in the calculation of GEM efficiency:
  - Effect of background
  - Time dependence
  - Finite resolution of HyCal (event goes to neighboring bins)
  - Energy dependence or R dependence of GEM efficiency?

- What's next:
  - Finalize the cuts for the 2.2 GeV runs
  - Finalize the theta or Q2 binning for the 2.2GeV runs
  - Extract the raw ratio for each bin
  - Estimate the systematic uncertainties for each bin