Is *gamma coreness* a useful concept for gamma:CR separation (II)?

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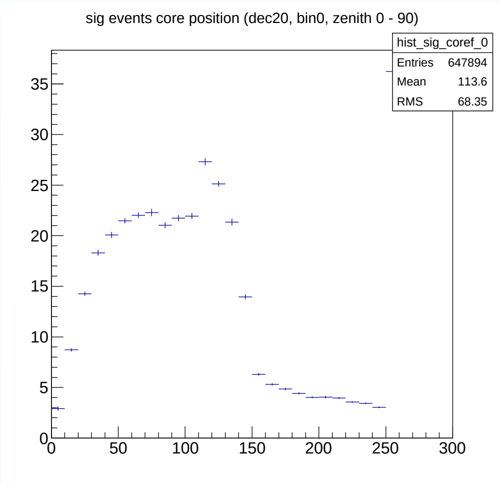
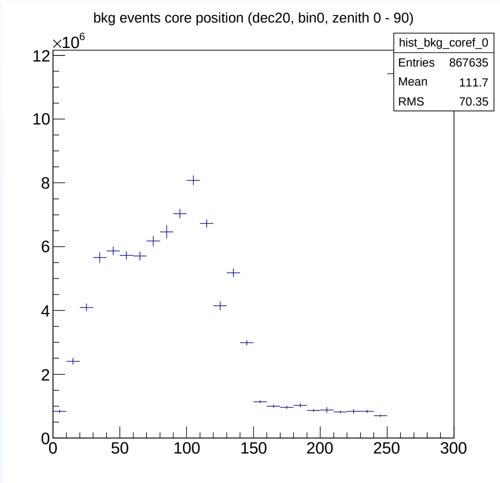
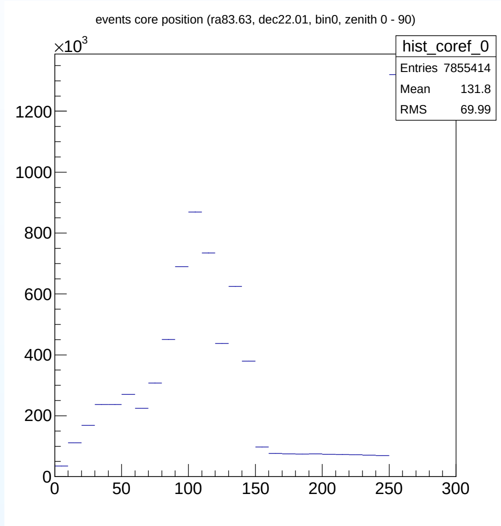
Where are HAWC *small* events (I)?







- HAWC *large* events typically have their cores on the array ...
- What about *small* events as in the *n0* analysis bin:
  1. Left: plot of gamma Monte Carlo events VS core fiducial scale (CFS)
  2. Middle: plot of background Monte Carlo events VS CFS
  3. Right: plot of data events VS CFS ... which blush do not look much like gamma or background Monte Carlo predictions!
- Naively restricting gamma events to CFS$\lesssim 100$ could reduce backgrounds.
- Should we use events in the SFCF *tails* with CFS$\gtrsim 150$?

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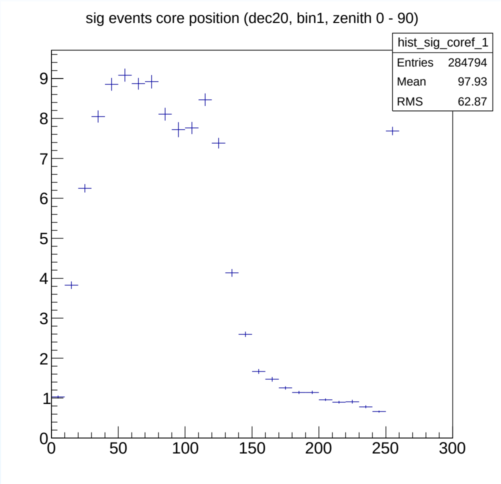
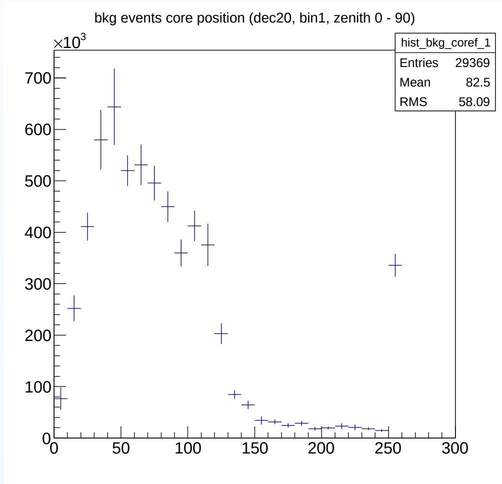
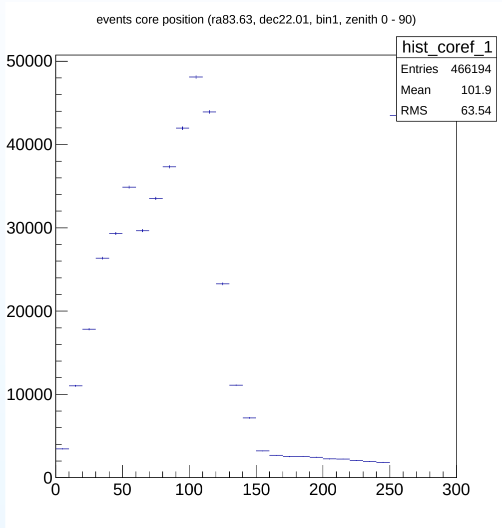
Where are HAWC *small* events (II)?

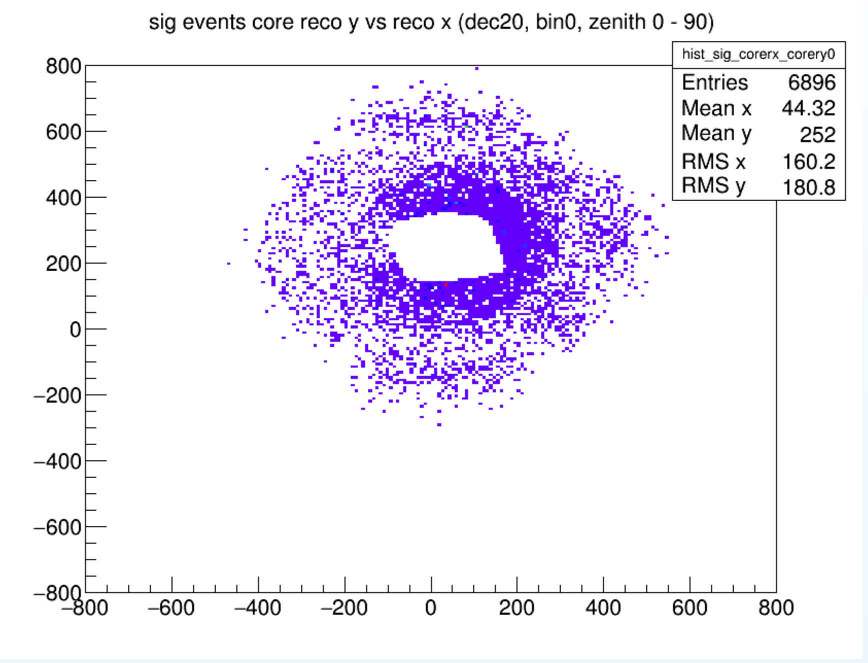


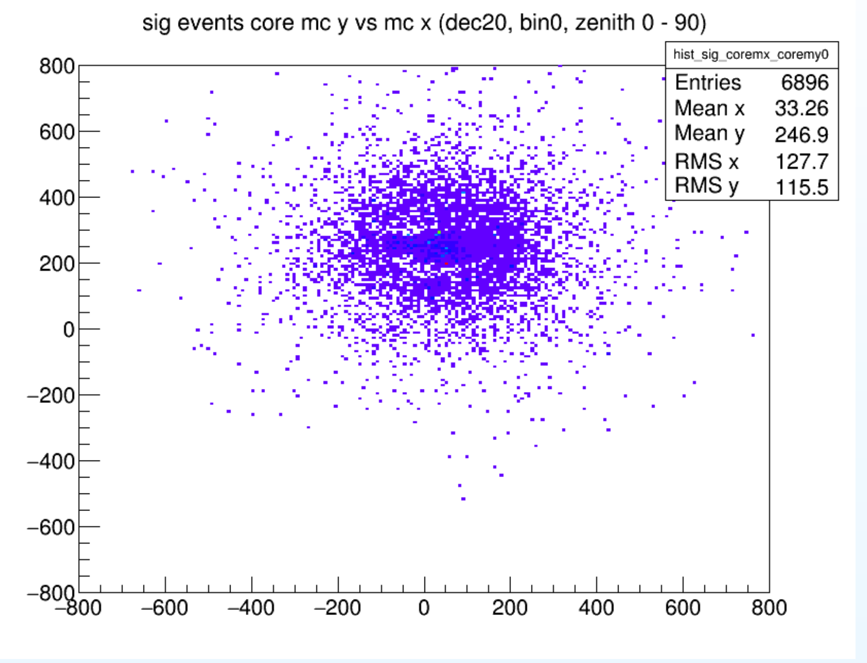




- What about *small* events as in the *n1* analysis bin: Left: plot of gamma Monte Carlo events VS CFS, Middle: plot of background Monte Carlo events, and Right: plot of data events.
- As with the *n0* analysis bin:
  1. data to not look like Monte Carlo simulations ...
  2. naively restricting gamma events to CFS$\lesssim 100$ could reduce backgrounds.
- If CFS $\lesssim 100$ then events are on the array accessible to *gamma coreness* tests!
- But first: the SFCF *tails* with CFS$\gtrsim 150$ persist! What is going on?

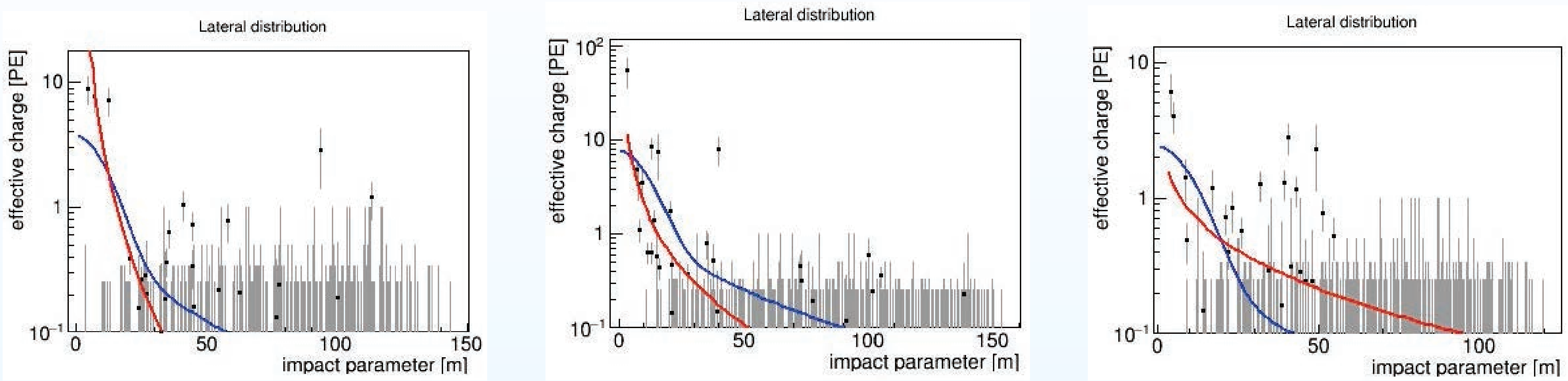
What to do with SFCF events with CFS$\gtrsim 150$?





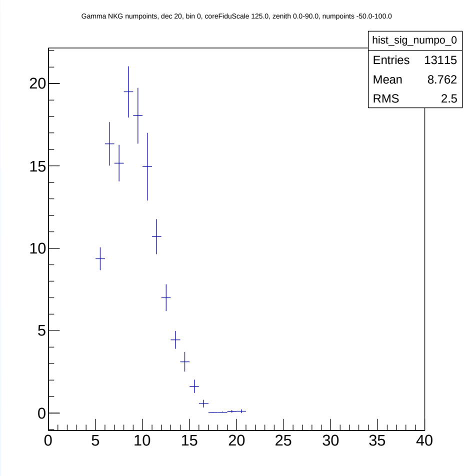
- What is going on with SFCF reconstructions with CFS$\gtrsim 150$?
  1. Left: plot of *n0* events' reconstructed core positions
  2. Right: plot of *n0* events' Monte Carlo core positions
- In comparing Left VS Right plots of CFS$\gtrsim 150$ events: is the SFCF providing any useful information on the core position? Should events with CFS$\gtrsim 150$ be classified as *bad* SFCF reconstructions?

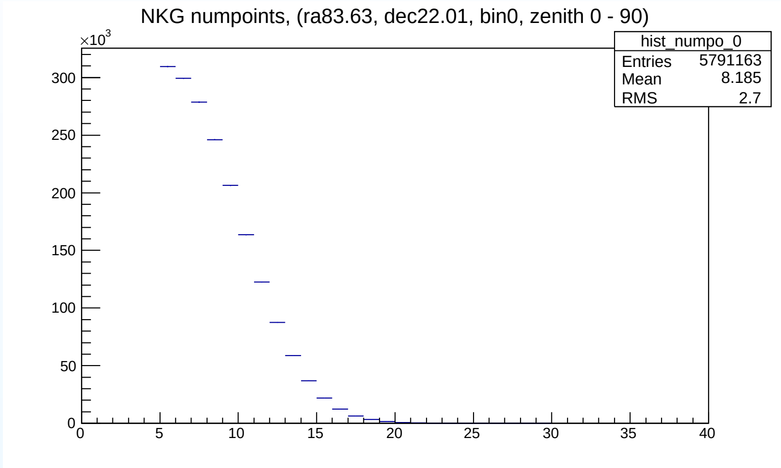
New *gamma coreness* module: GamCore.cc (I)



- Our analysis is based on the LatDist.cc NKG code by Kelly Malone ... but with several changes:
  1. restrict the minimum (5m) and maximum fit distance from the SFCF core: *e.g.* for *n0* $\sim$ *n2* events this is 25m (to avoid issues of tanks with no signals).
  2. require the closest tank to be near the SFCF core: default < 7.5m
  3. fit the same (refined) tank signals used in the second call to SFCF (these are the signals plotted in the HAWC event display).
  4. modify the signal uncertainty to include the core position uncertainty.
  5. include in the output two tank *counts*: *numpoints* and *num_sum*.
- Plots show *n0* events with: (Left) $s = 0.5$, (Middle) $s = 1.61$ and (Right) $s = 2.5$

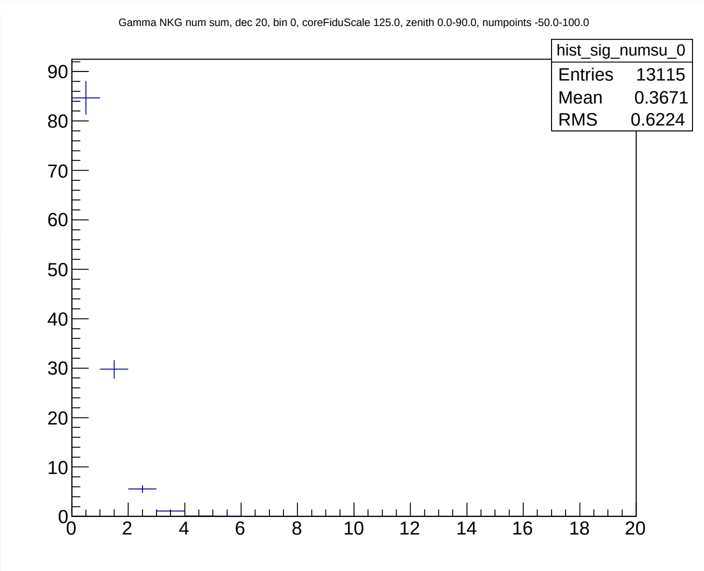
New *gamma coreness* module: GamCore.cc (II)

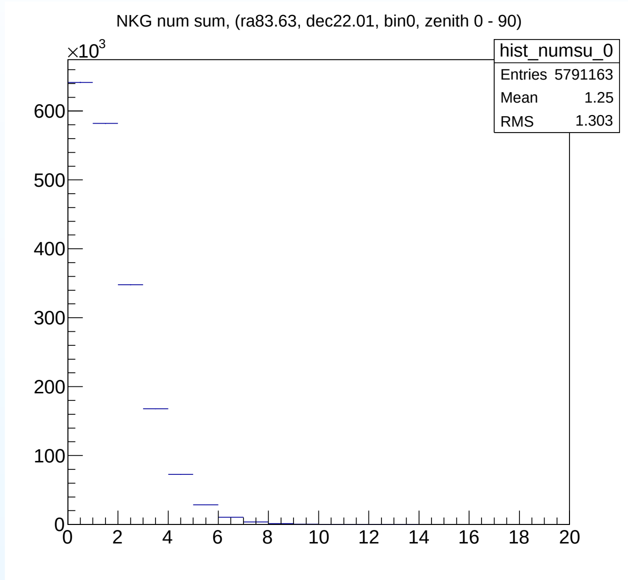




- The analysis output includes 4 outputs:
  1. GamCoreAge = NKG shower *age* parameter, s.
  2. GamCoreAmp = *log10-amplitude* of the NKG fit
  3. GamCoreChi2 = fit chisq / (number of tanks in NKG fit $\equiv$ *numpoints*)
  4. GamCorePackInt = compound of 3 integers: *numpoints*, *r_test* and *num_sum*
- Quantity *numpoints* is the number of tanks (with signals ≥ 0.1 PE) used in the GamCore fit. This is shown for (Left) gamma Monte Carlo *n0* events and (Right) data *n0* events. Note: *n0* event backgrounds peak at low values of *numpoints* and a larger fraction fail the minimum number of tanks requirement: numpoints ≥ 5.

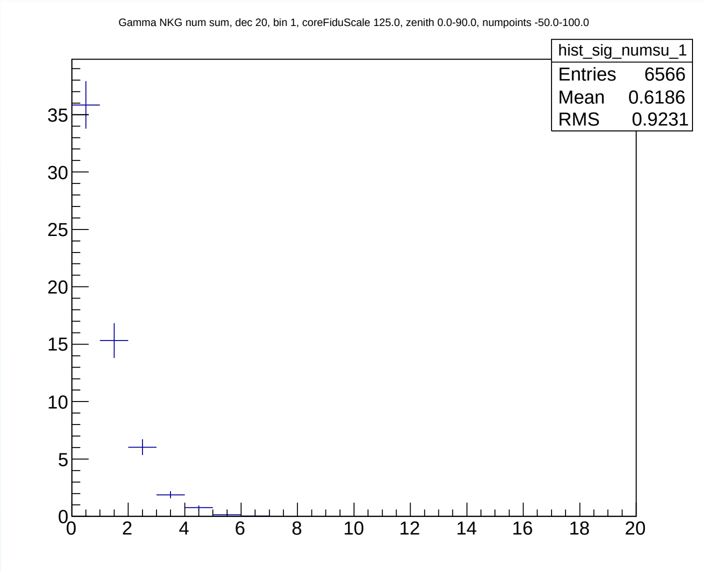
New *gamma coreness* module: GamCore.cc (III)

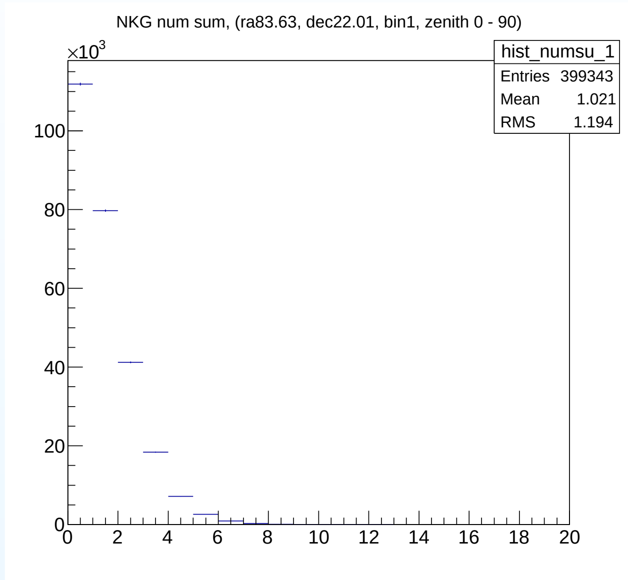




- The analysis output includes 4 outputs:
  1. the first 3 are the "same" as in the LatDist.cc output ...
  2. GamCorePackInt = compound of 3 integers: *numpoints*, *r_test* and *num_sum*
- Quantity *num_sum* is the number of tanks with signals above some threshold, *e.g.* 2.5 PEs, outside a radius with expected signals $< \frac{1}{3}$PE from the GamCore NKG fit. This is shown for (Left) gamma Monte Carlo *n0* events and (Right) data *n0* events. Note: *n0* backgrounds extend to larger values of *num_sum*.

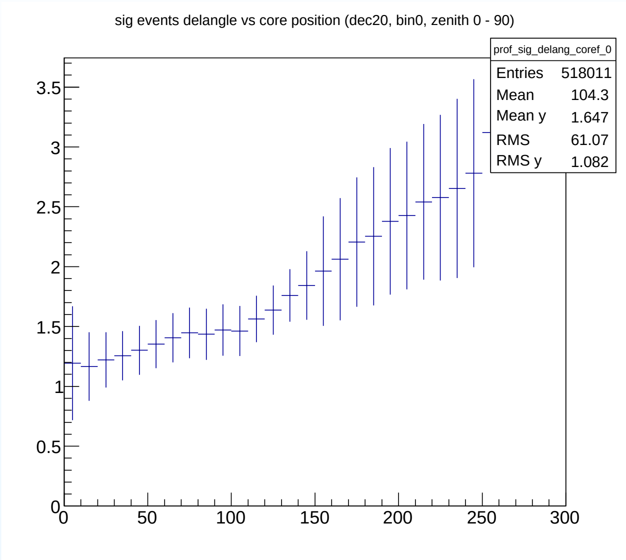
New *gamma coreness* module: GamCore.cc (IV)

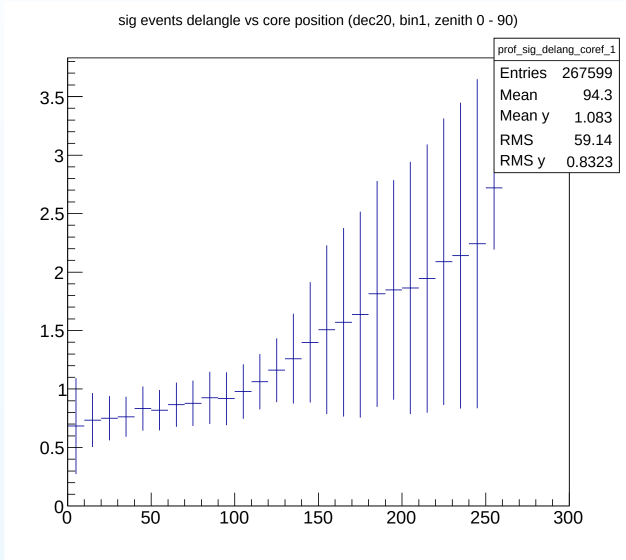




- The analysis output includes 4 outputs:
  1. the first 3 are the "same" as in LatDist.cc output ...
  2. GamCorePackInt = compound of 3 integers: *numpoints*, *r_test* and *num_sum*
- Quantity *num_sum* is the number of tanks with signals above some threshold, *e.g.* 2.5 PEs, outside a radius with expected signals $< \frac{1}{3}$PE from the GamCore NKG fit. This is shown for (Left) gamma Monte Carlo *n1* events and (Right) data *n1* events. Note: *n1* backgrounds extend to somewhat larger values of *num_sum*.

Summary ...



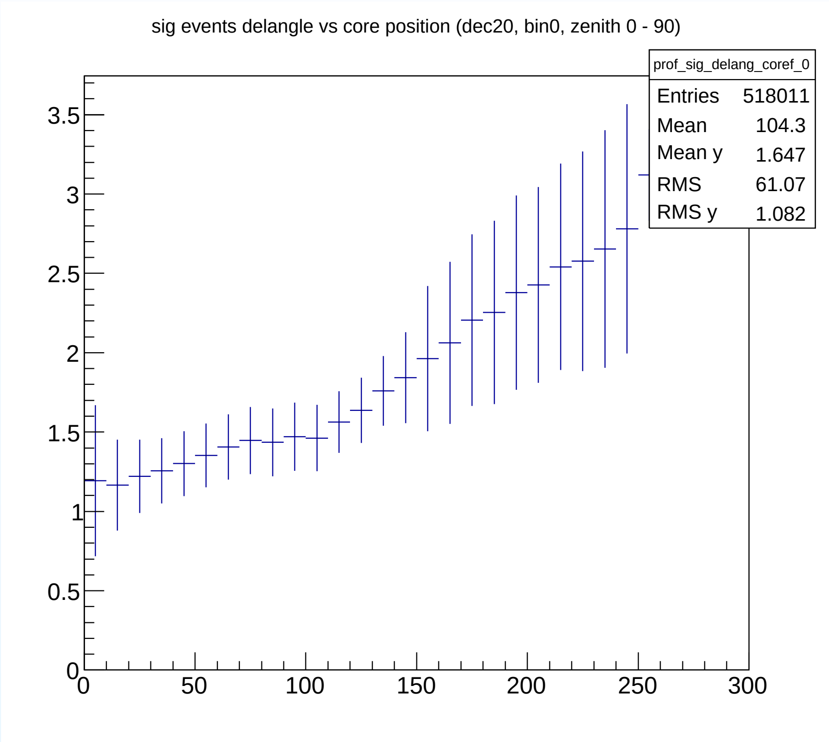


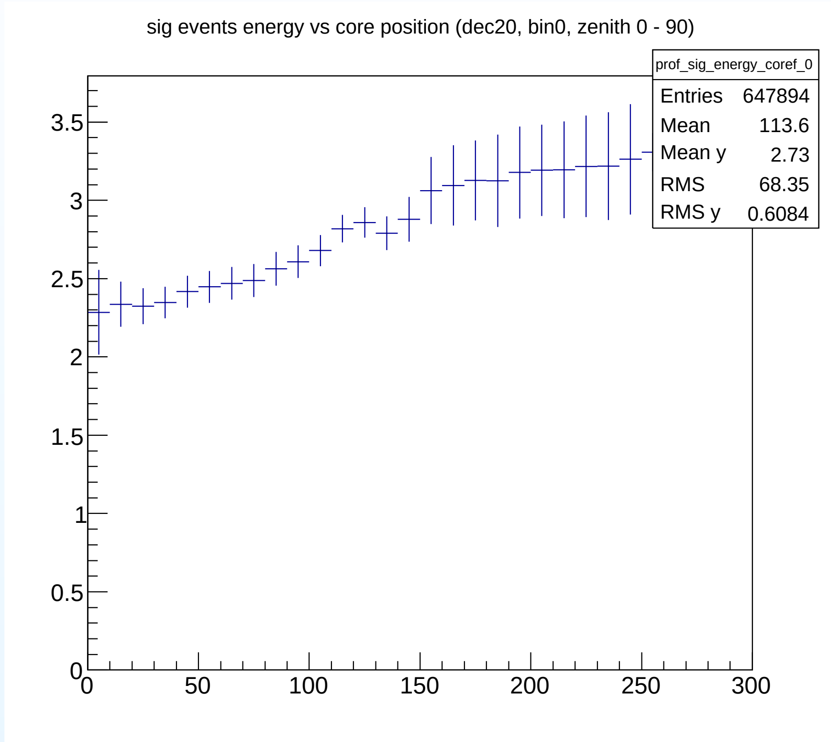
- *Small* events, *n0* and *n1* analysis bins, would probably have reduced backgrounds if we restrict CFS$\lesssim 100$.
- Then cores will be on the array and the new GamCore module provides additional quantities, *numpoints* and *num_sum* to enhance gamma signals.
- And gamma Monte Carlo events on the array are predicted to have better angular pointing: Left average (MC-reconstructed) direction (degrees) VS CFS for *n0* and Right *n1* events. See "Additional slides" for more details ...
- Aside: should events with CFS$\gtrsim 150$ be classified as *bad* SFCF reconstructions?

Additional/backup slides

Additional slides

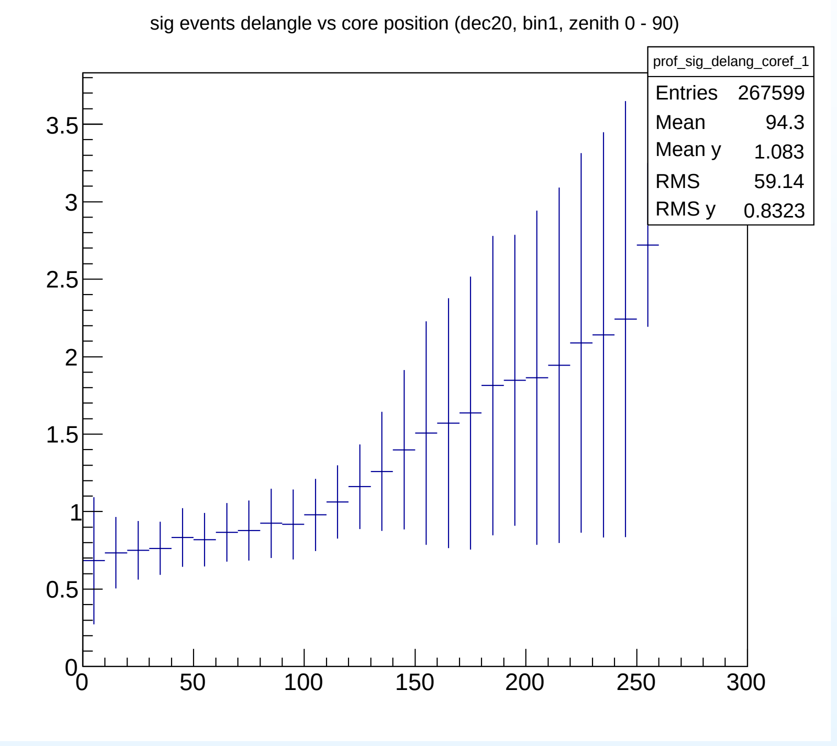
Core Fiducial Scale matters: *n0* analysis bin

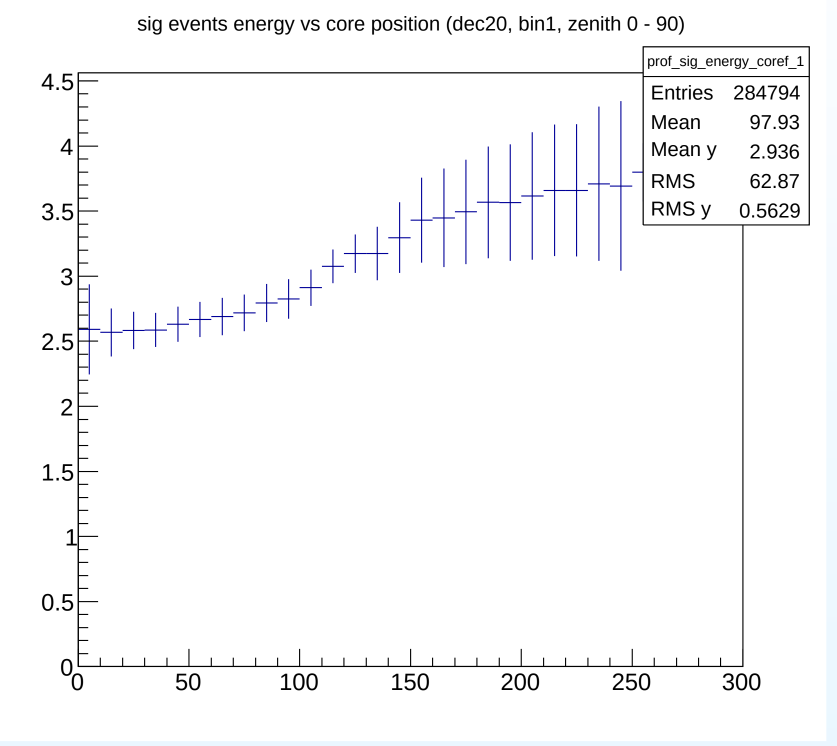




- Left plot: average gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS;
  thus $< 2.4 >= 250$ GeV.

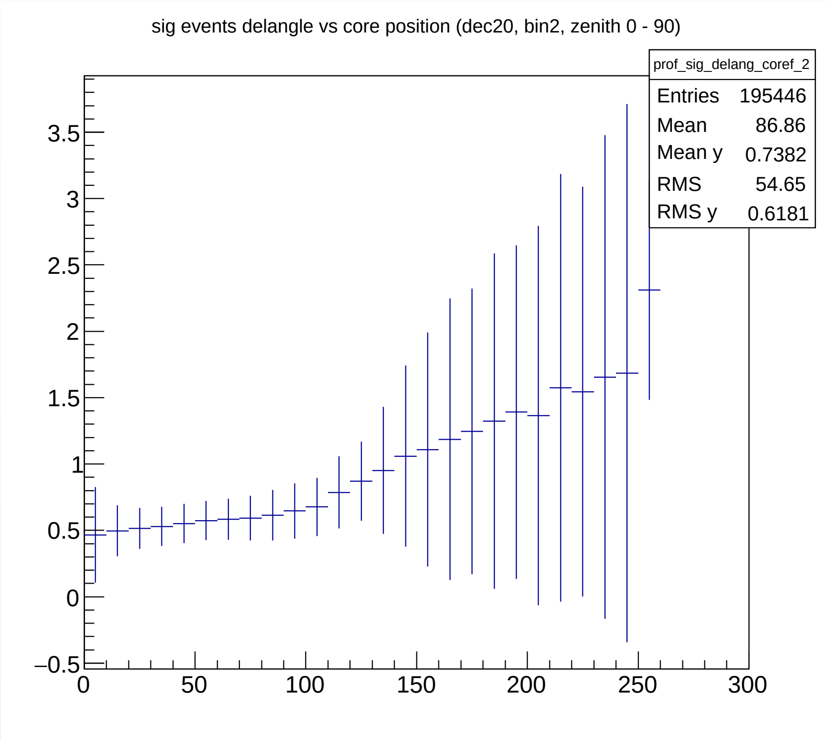
Core Fiducial Scale matters: *n1* analysis bin

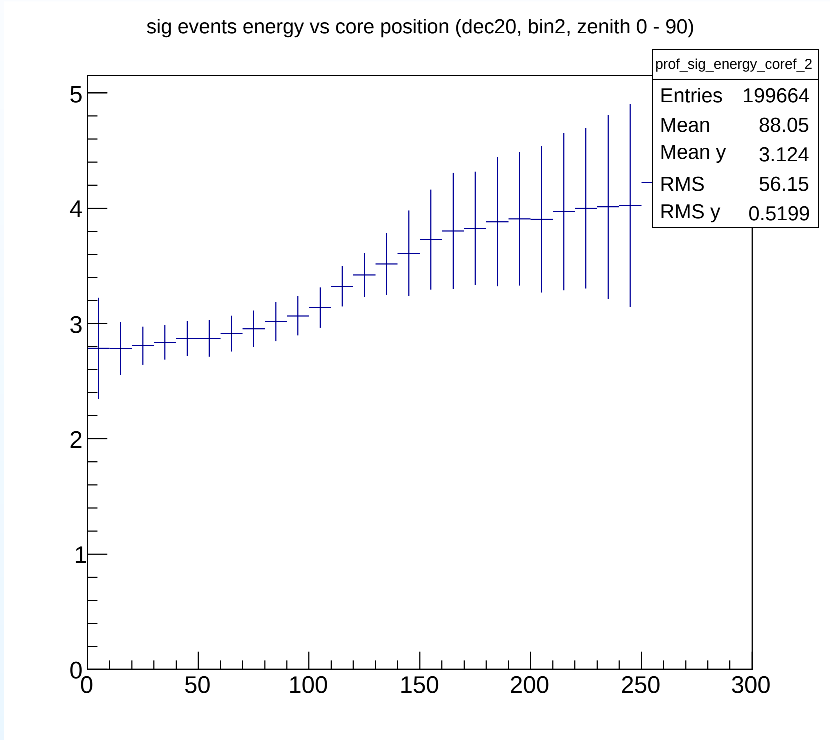




- Left plot: average gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS;
  thus $< 2.65 >= 450$ GeV.

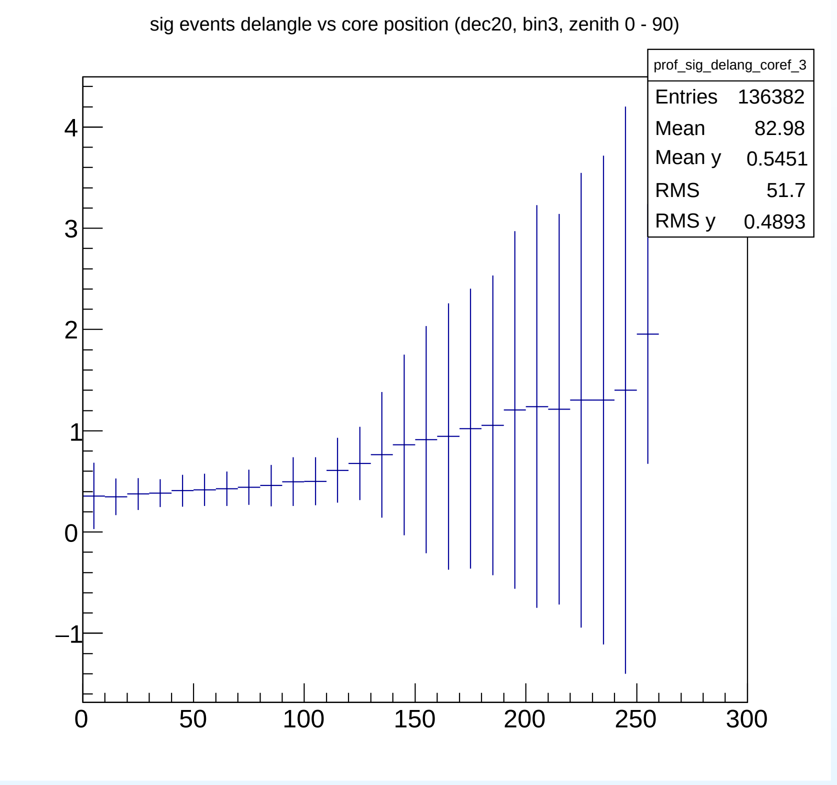
Core Fiducial Scale matters: *n2* analysis bin

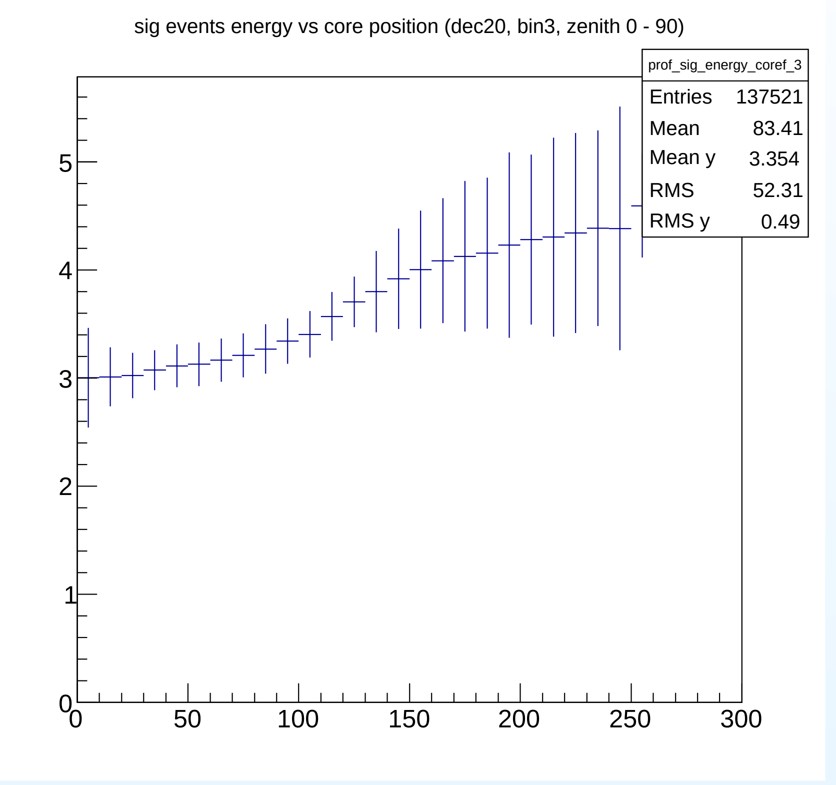




- Left plot: average gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS;
  thus $< 2.9 >= 800$ GeV.

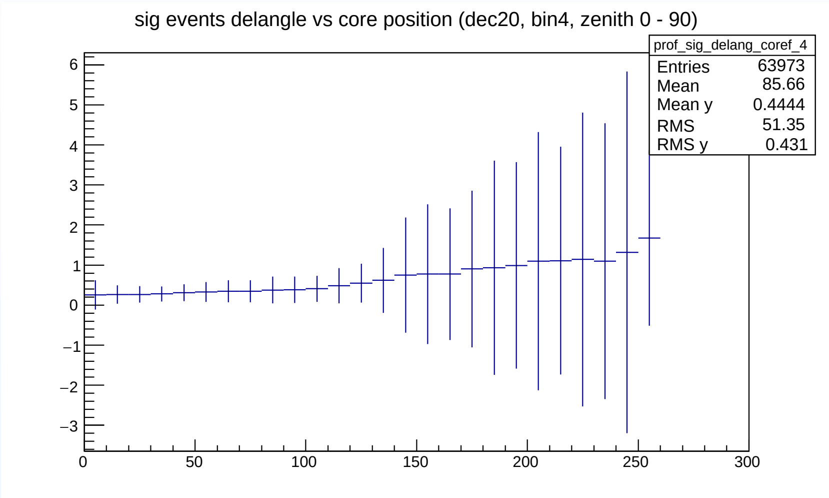
Core Fiducial Scale matters: *n3* analysis bin

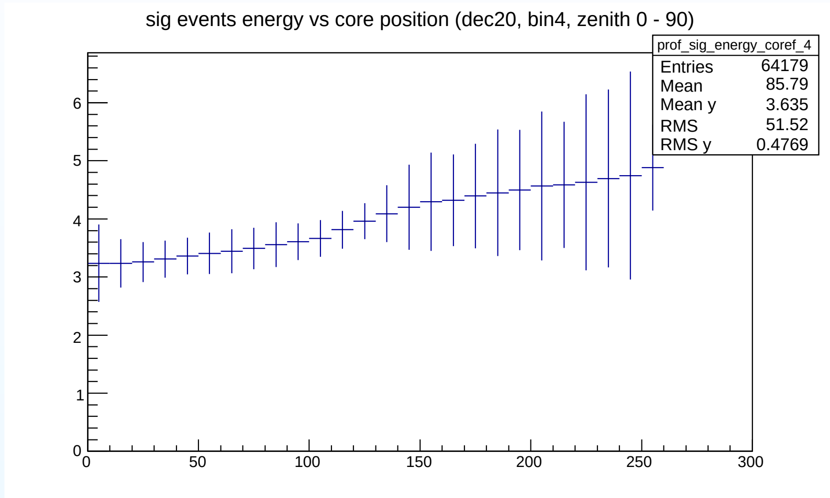




- Left plot: average gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS; thus $< 3.1 >= 1.25$ TeV.

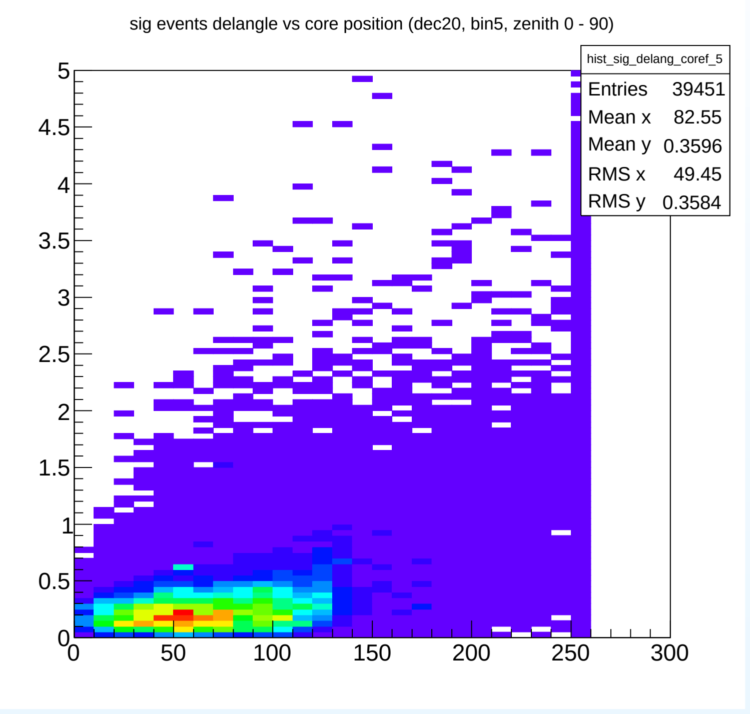
Core Fiducial Scale matters: *n4* analysis bin

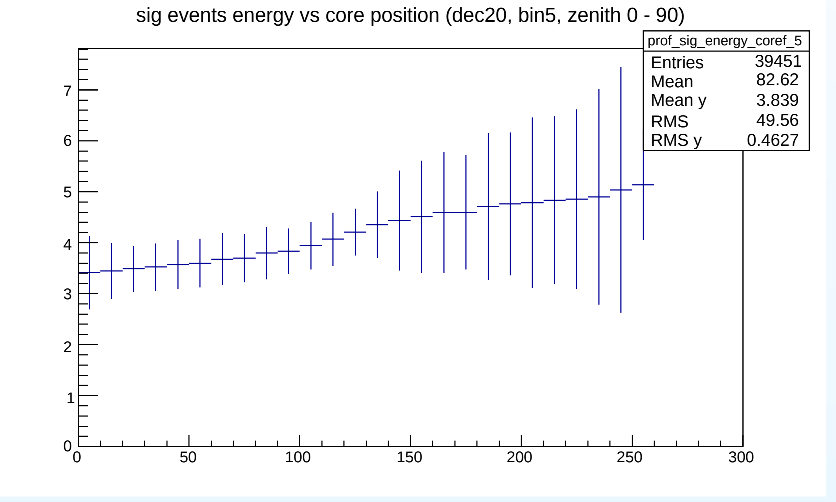




- Left plot: average gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS;
  thus $< 3.4 >= 2.5$ TeV.

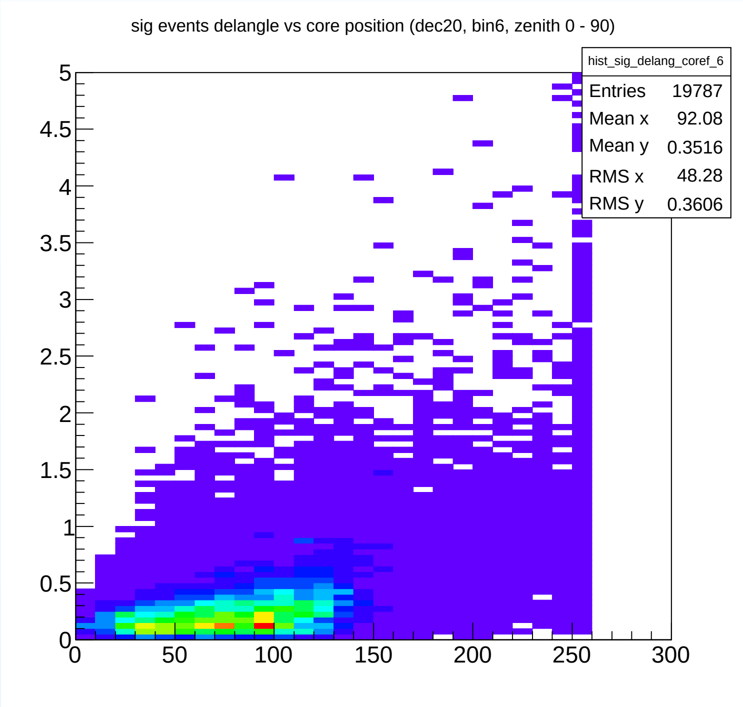
Core Fiducial Scale matters: *n5* analysis bin

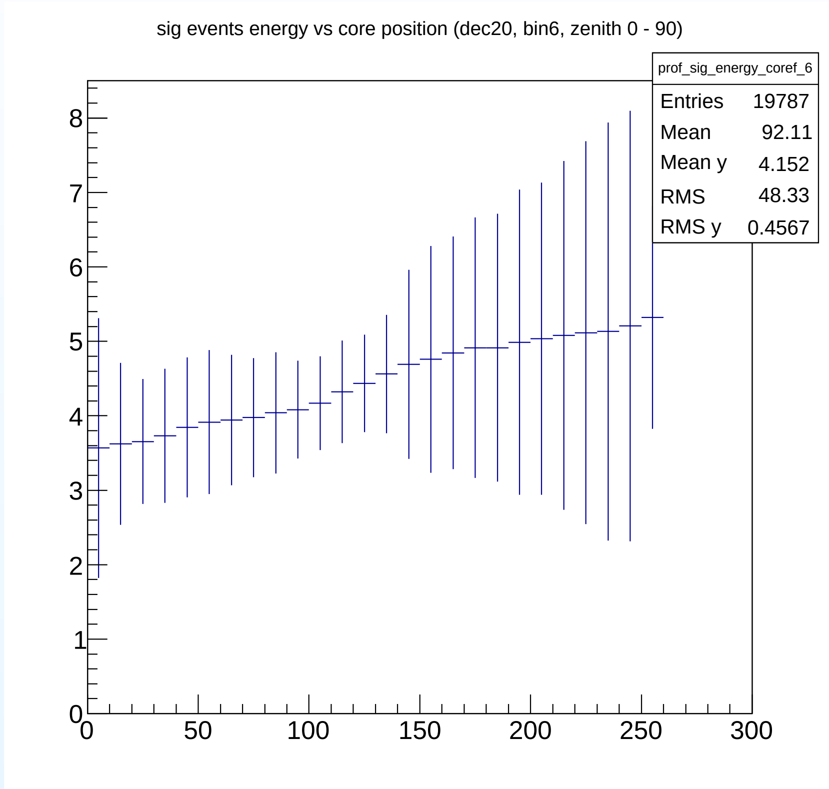




- Left plot: gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS; thus $< 3.6 >= 4.0$ TeV.

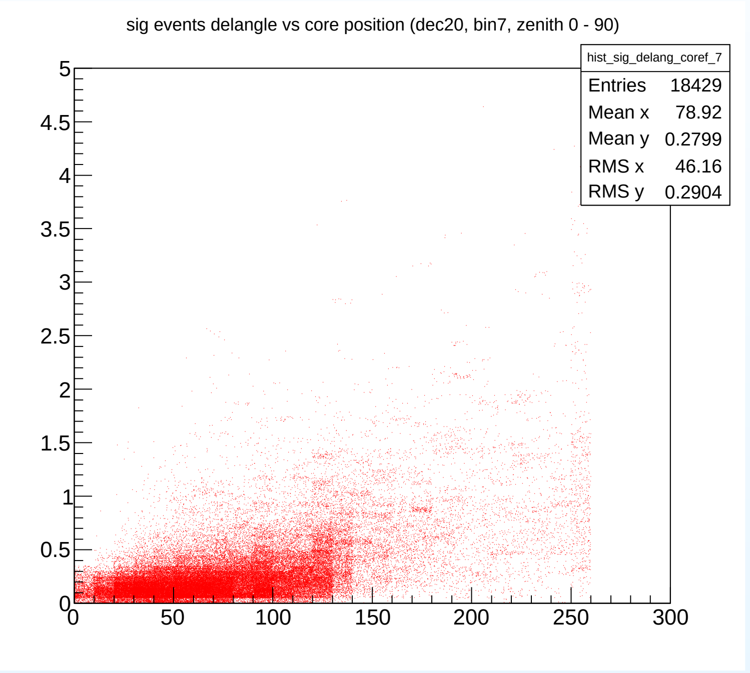
Core Fiducial Scale matters: *n6* analysis bin

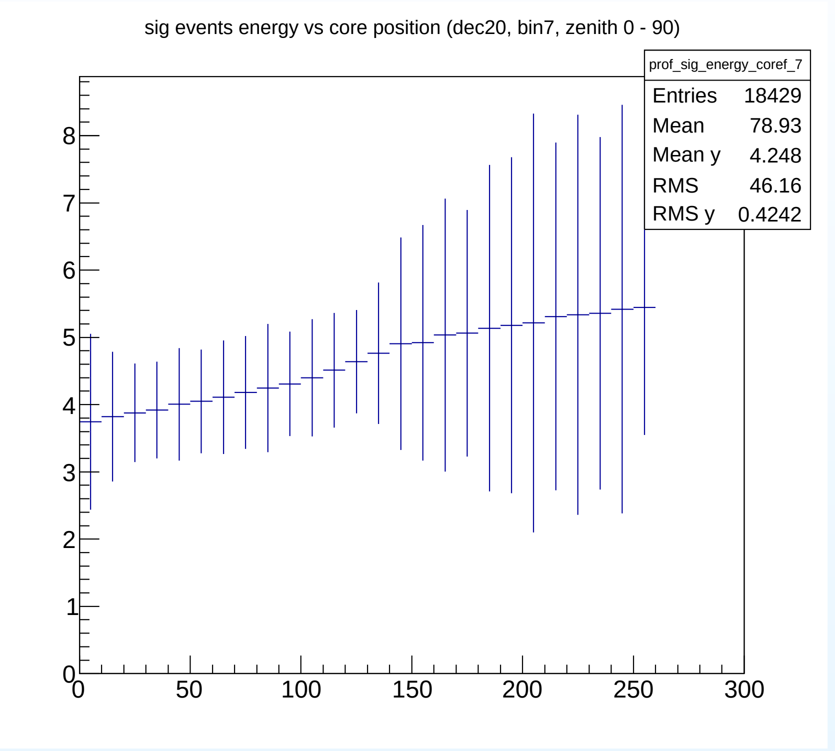




- Left plot: gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS; thus $< 3.8 >= 6.3$ TeV.

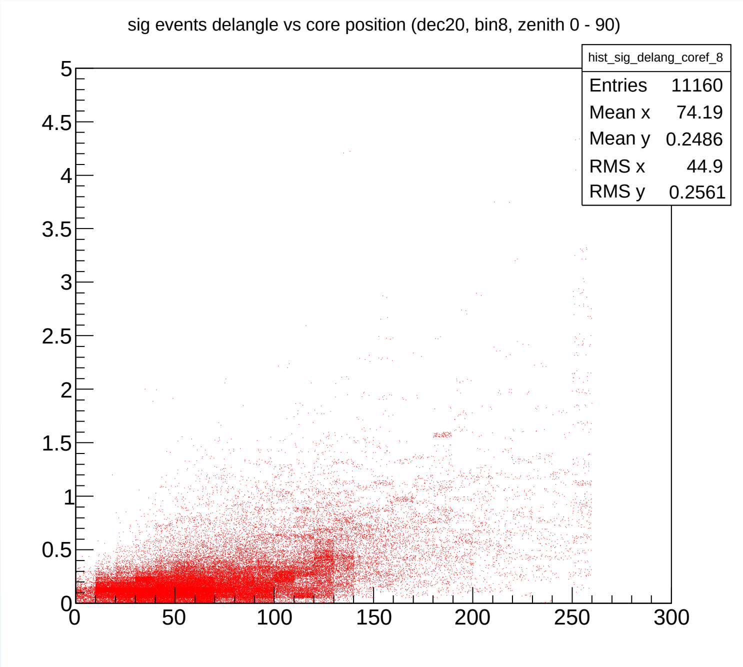
Core Fiducial Scale matters: *n7* analysis bin

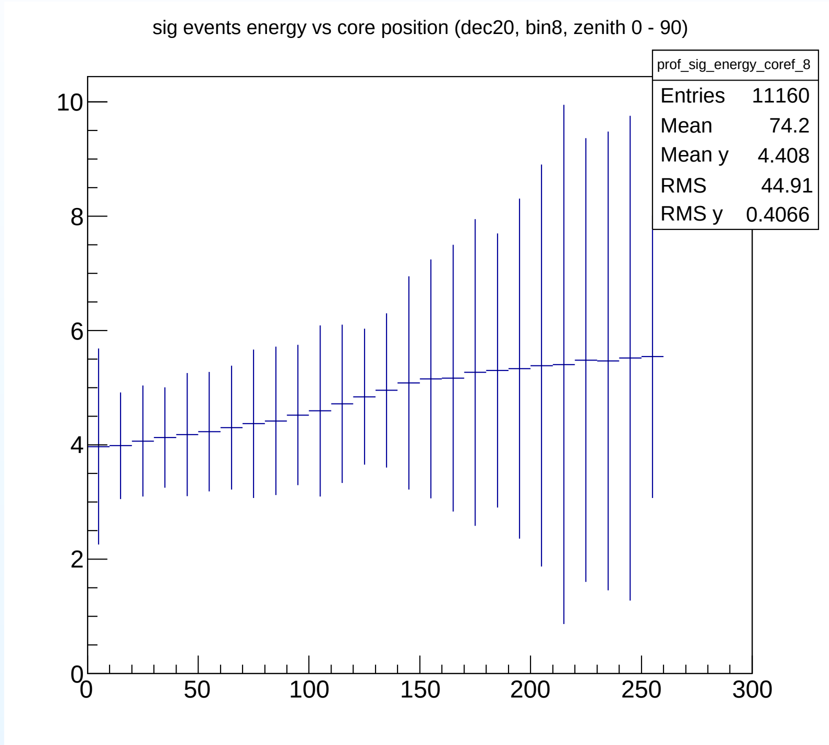




- Left plot: gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS; thus $< 4.0 >= 10.$ TeV.

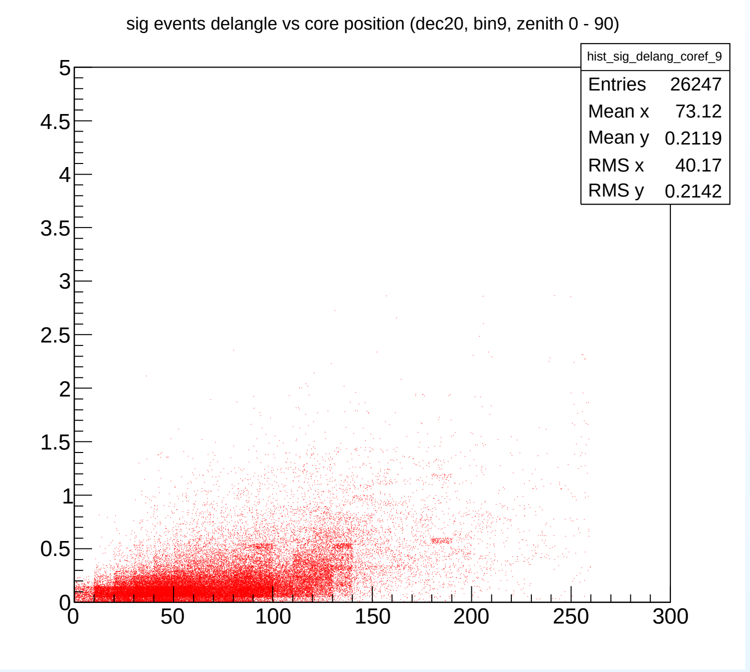
Core Fiducial Scale matters: *n8* analysis bin

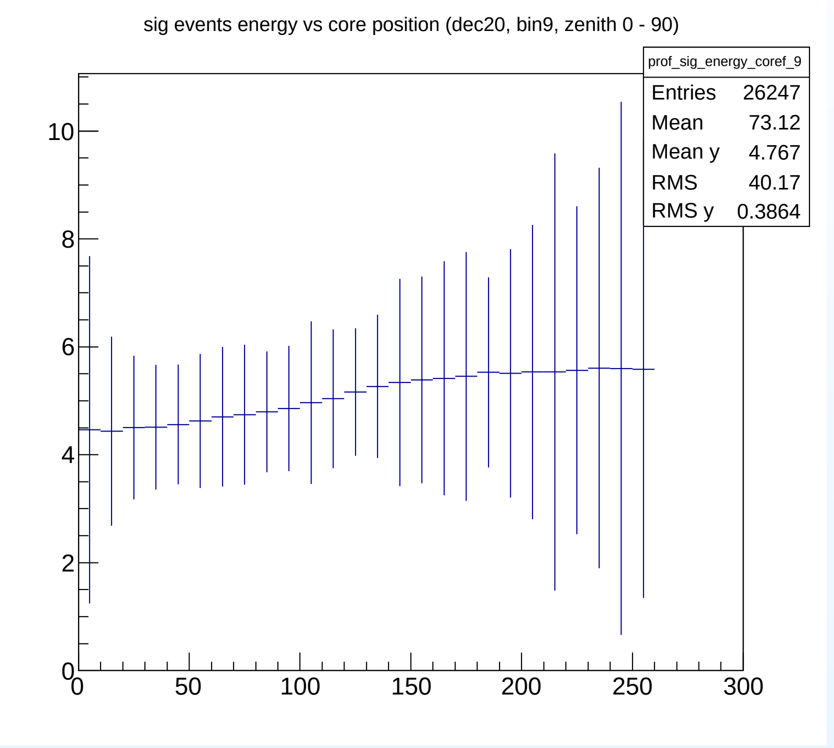




- Left plot: gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS; thus $< 4.25 >= 18.$ TeV.

Core Fiducial Scale matters: *n9* analysis bin





- Left plot: gamma (MC-reconstructed) direction (degrees) VS CFS
- Right plot: average gamma MC log10(energy(GeV)) VS CFS; thus $< 4.6 >= 40.$ TeV.