Overlap-hits under the microscope

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Rationale

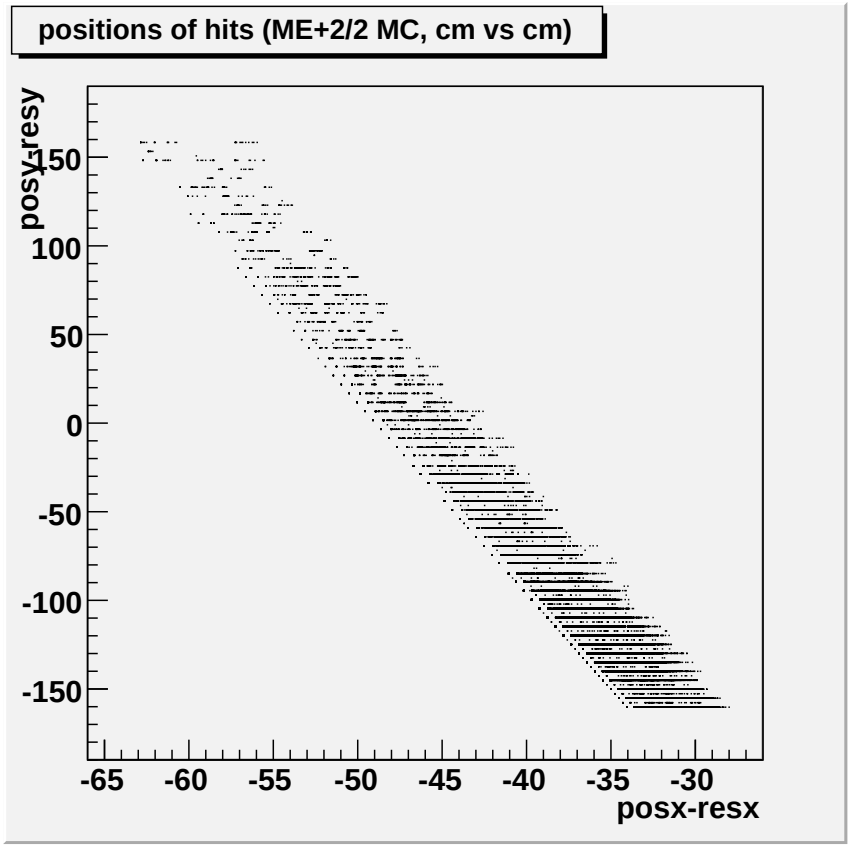
- HIPAlignmentAlgorithm properly treats the correlation between x and y, assuming that these are both continuous random variables with Gaussian errors.
- Both x and y distributions have structure: narrow Gaussian peak when the muon passes between strips/wire groups, flat distribution when the muon passes through strips/wire groups.
- Separation between y wire groups is much greater than our desired alignment precision (1.5 cm in ME+2/1, 5 cm in ME+2/2), so granularity in y could cause serious artifacts.
- These propagate into x because the strips are angled.

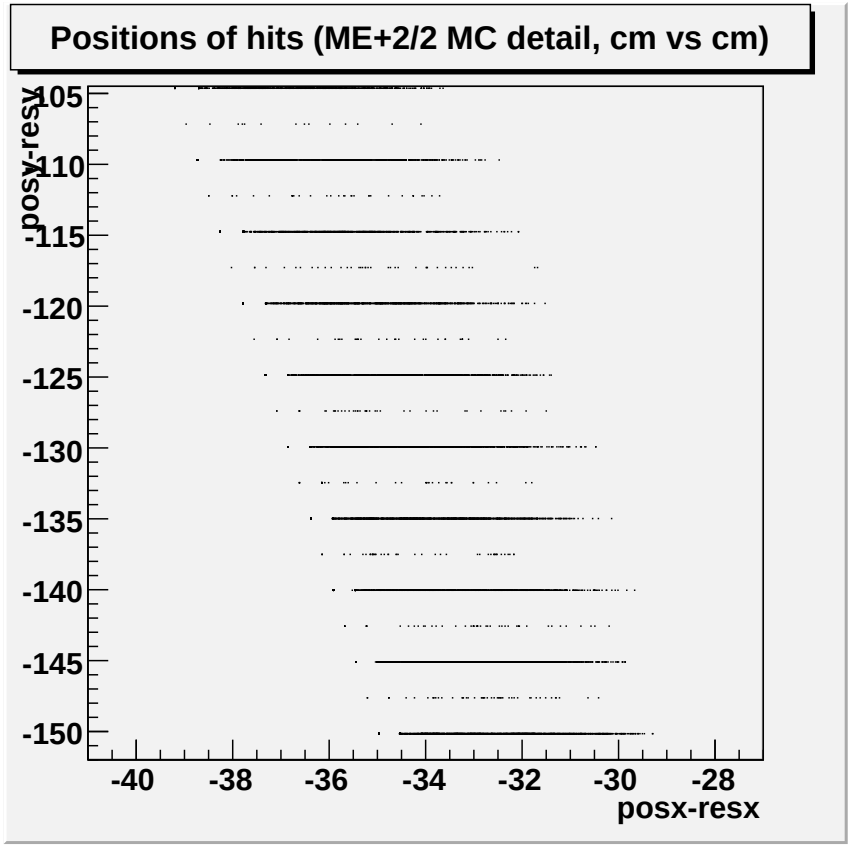
Exploratory study

- Made an ntuple of hit positions and residuals; looked at what we're starting with

Distribution of hits

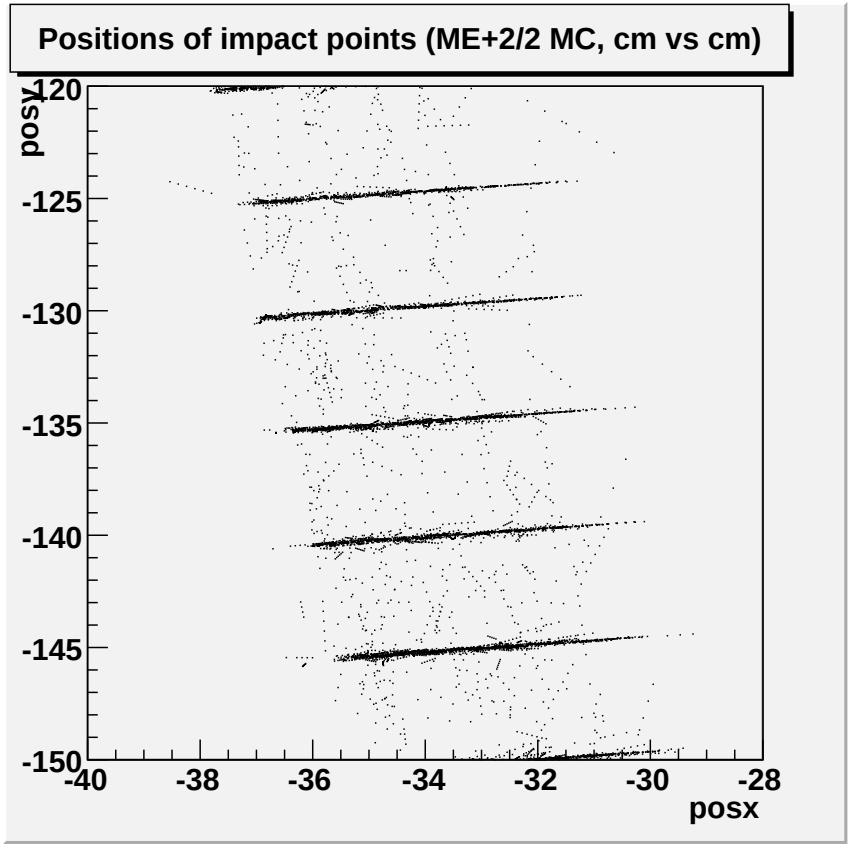
- Edge of trapezoid is clearly visible
- As are the wire groups in y
- I don't understand the gap on the far left edge or the small half-integer peaks
- This isn't discovery: CSCRecHits are constructed to have this distribution
- ME+2/2 has 5 cm between wire group centers

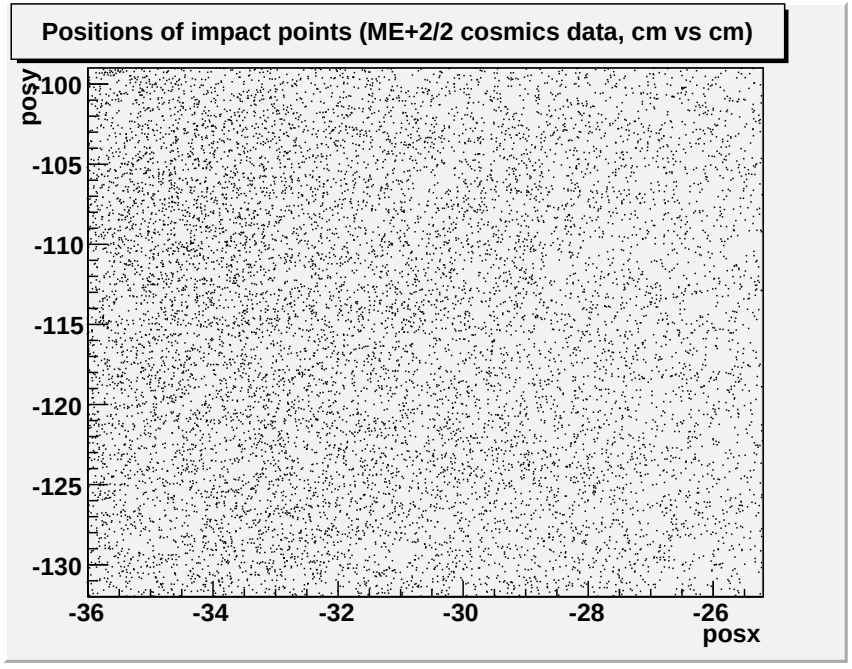




Distribution of impact points

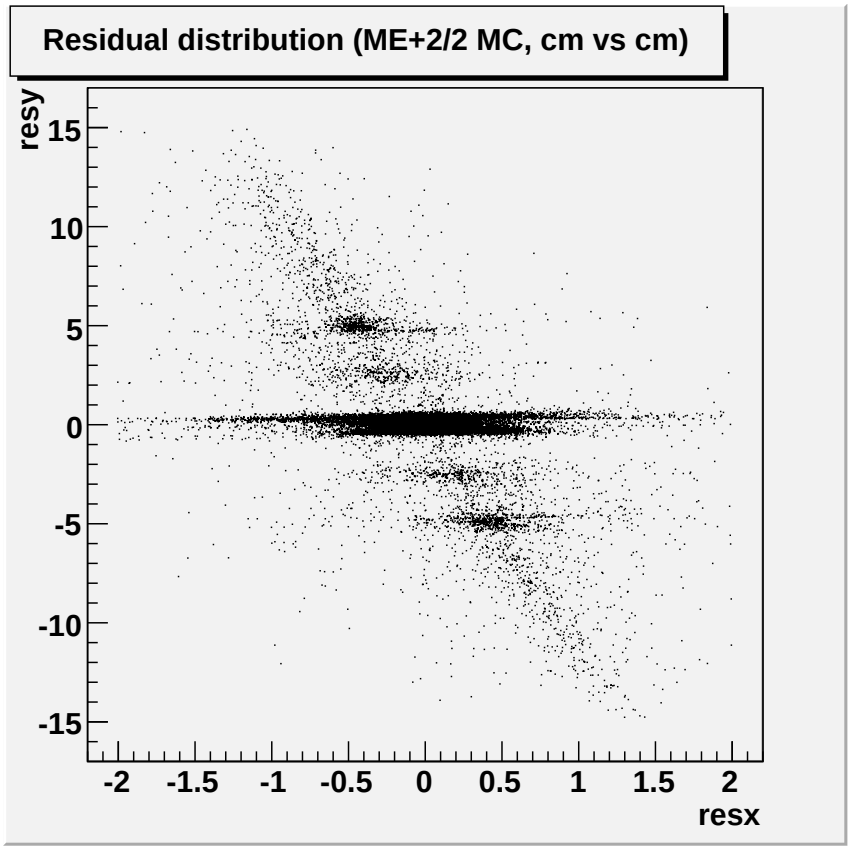
- Propagate tracks from reference chamber, plot them in local coordinates of target chamber
- Clearly see the angle between the two chambers
- Some broadening because tracks are not perfectly parallel
- In *cosmics* data, complete smearing because tracks are nowhere near parallel

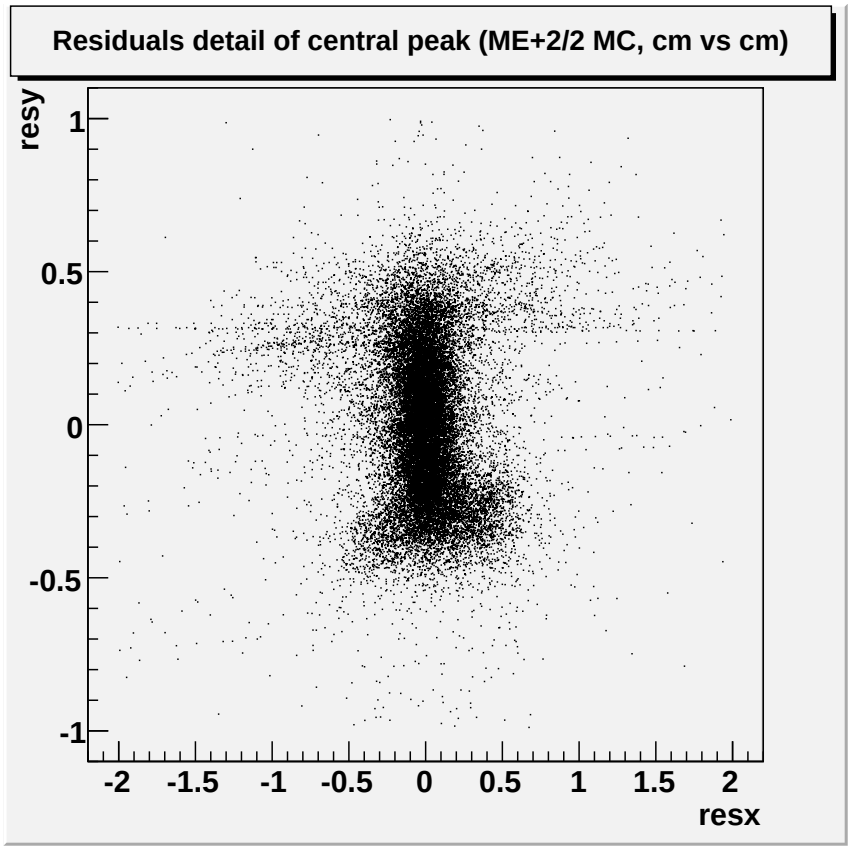




Residuals

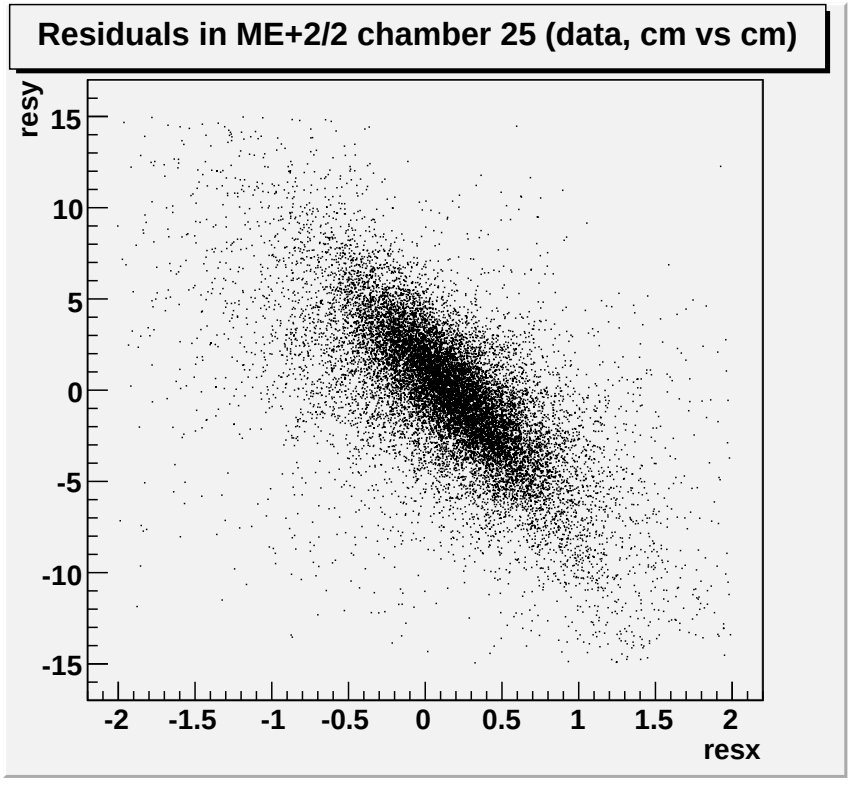
- 2-D residual distribution: expect
  - correlation between x and y because x can only be determined from strip if y is known
  - peaks in y corresponding to ± 0, ± 1, $\pm 2 \ldots$ differences in wire groups from reference to target
- Observed both features: slope is 0.1, central peak has vast majority of the events
- Inner $|r_y| < 2$ mm is featureless

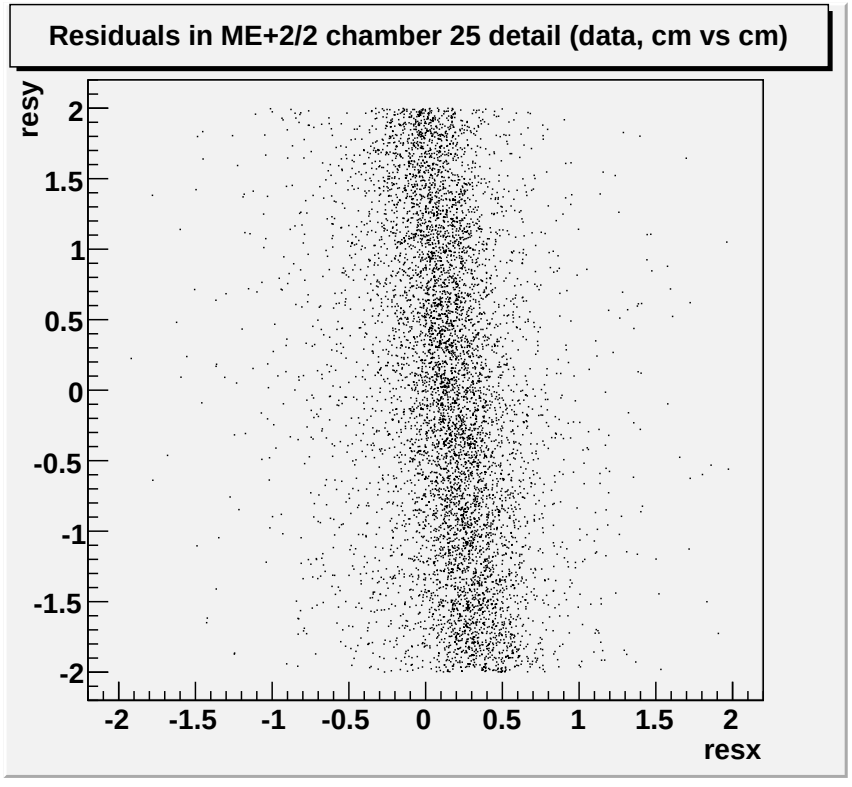




Residuals in data

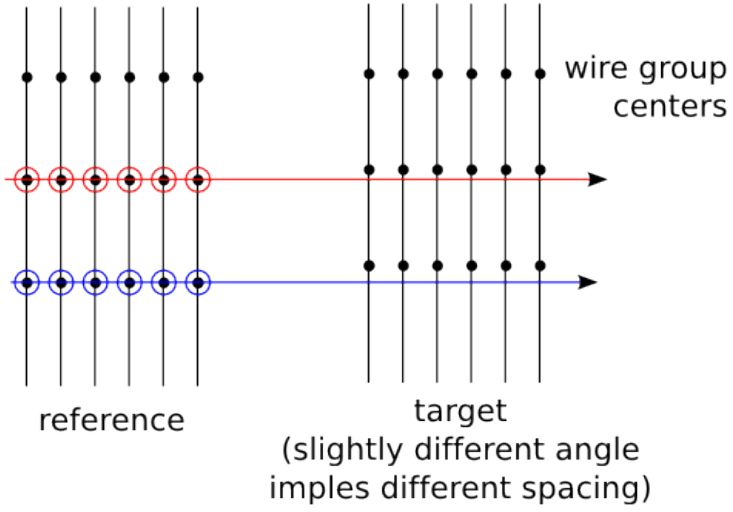
- Look at the same distributions in CRUZET data
- Same correlation, but structure is entirely washed out
- More to do with the fact that these are cosmics than the fact that these are data
- (Yes, we only look at one chamber at a time in data. This one has the most hits.)



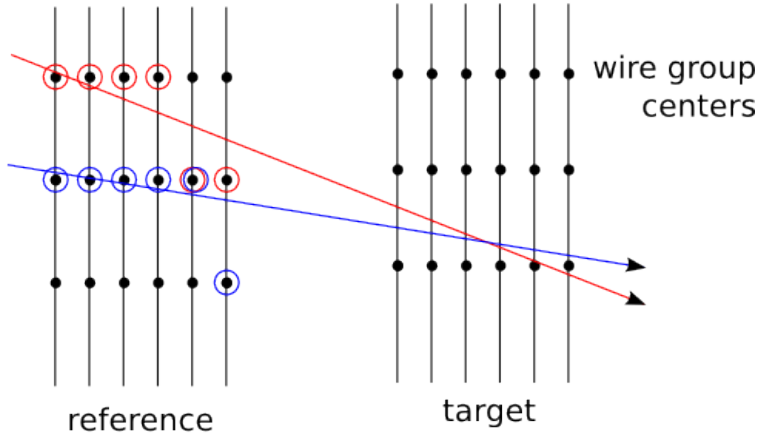


Why are cosmics smeared?

Side view (beam-halo):



Side view (cosmics):



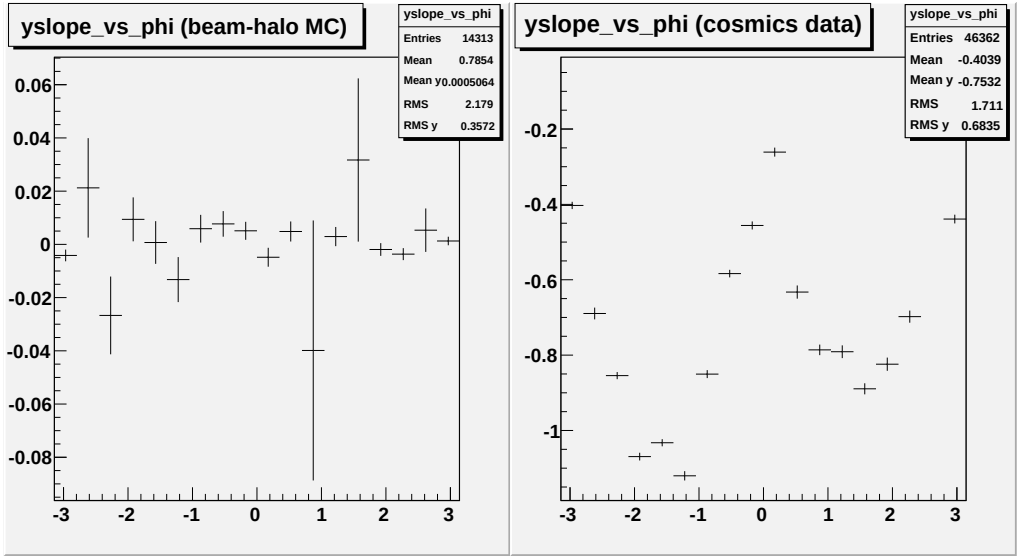
More continuous distribution of extrapolated tracks

Quantify angles of tracks with local $\partial y/\partial z$

Close to zero in beam-halo MC

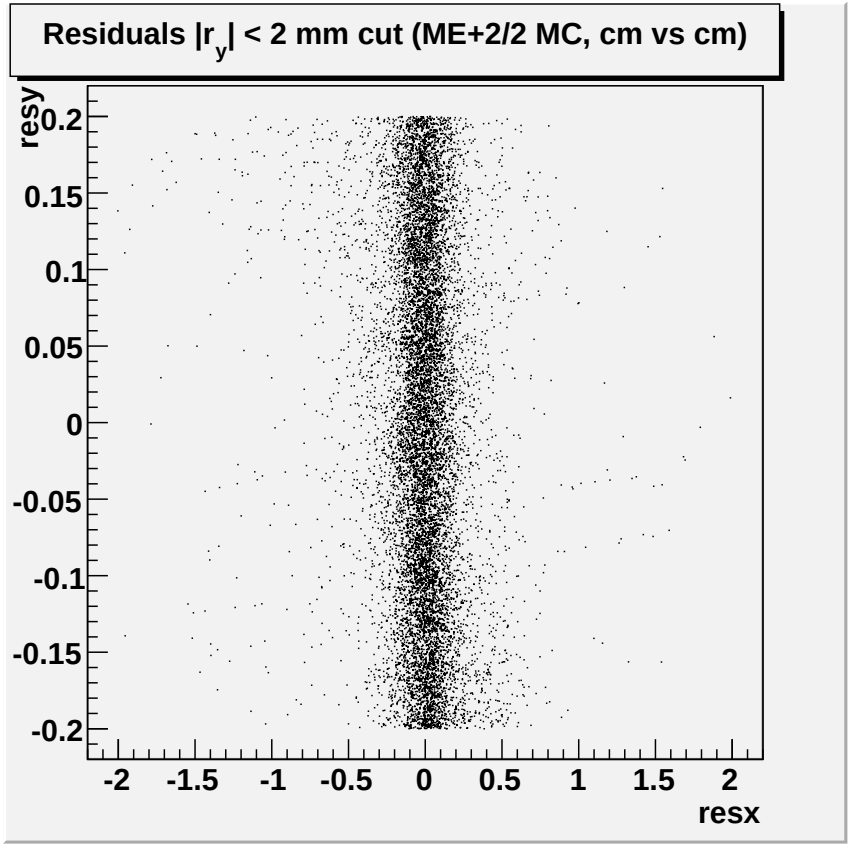
Clear shape in cosmic ray data

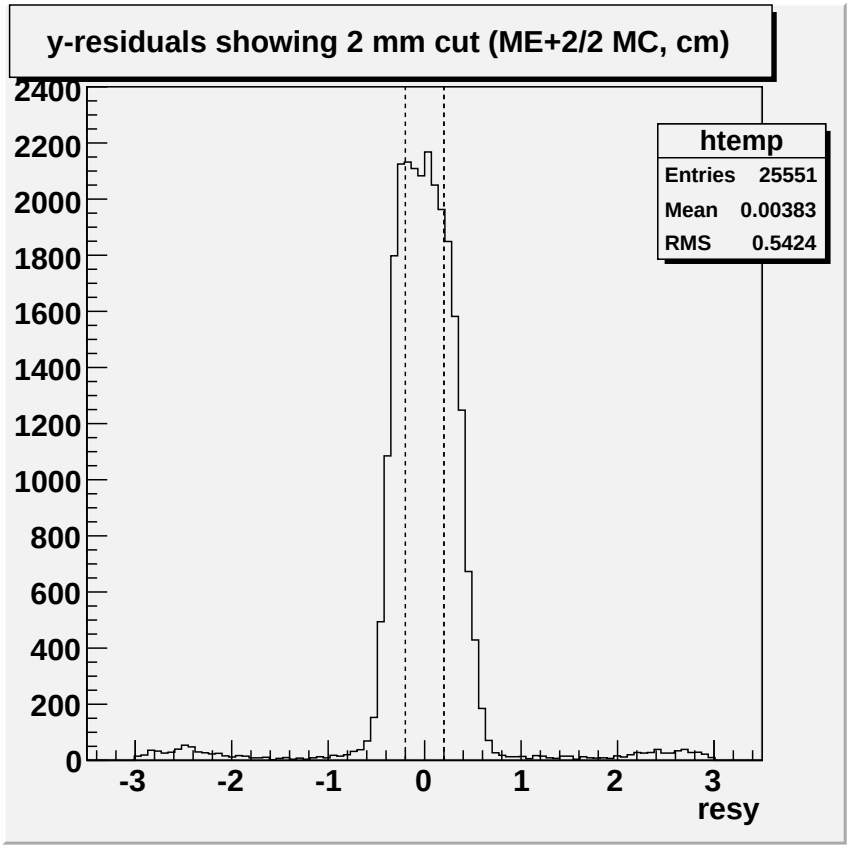
- cosmic rays steeply angled relative to beamline
- preference for negative $\partial y/\partial z$, points to interaction point (ALCT patterns)
- slope of 1 means a new wire group every two layers



Granularity in beam-halo (1/2)

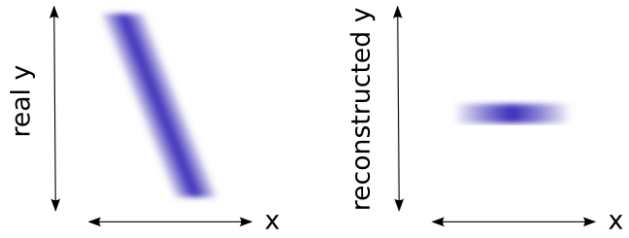
- Can deal with granularity in the beam-halo ME+2/2 case (biggest separation between peaks) by selecting events in good region of the $\Delta y = 0$ peak
- In this region, we have a flat probability distribution in y
- (Not as important right now as the cosmic-ray case)

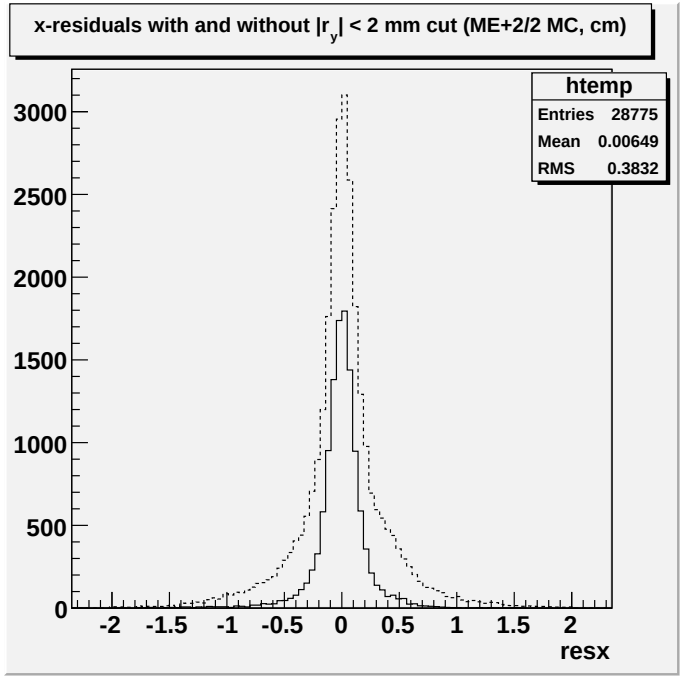


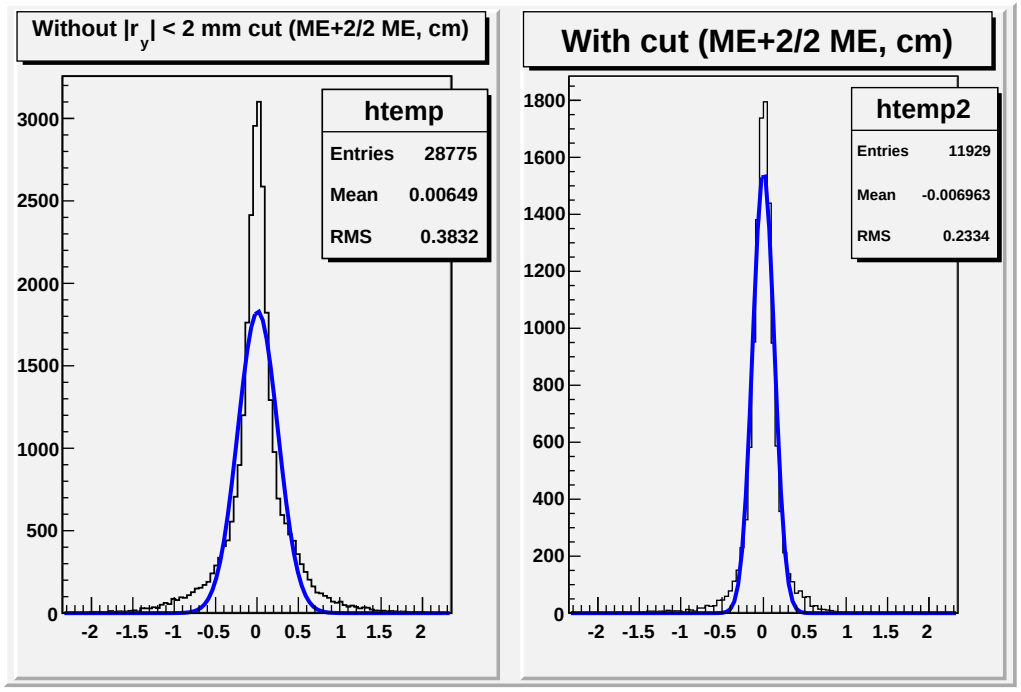


Granularity in beam-halo (2/2)

- Lose a factor of 2, but x residuals become cleaner, better understood
- Resolution: (half y-gap) $\times$ slope $\oplus$ intrinsic $= \frac{5\text{ cm}}{2} \times 0.1 \oplus 300\ \mu\text{m} = 2.5$ mm
- Can't do better than this in x because
  - we have no knowledge about y except that it's closest to this wire-group center
  - determining x from the strip measurement is a linear function of y
  - hmmm... why isn't the x residual distribution a rounded box?



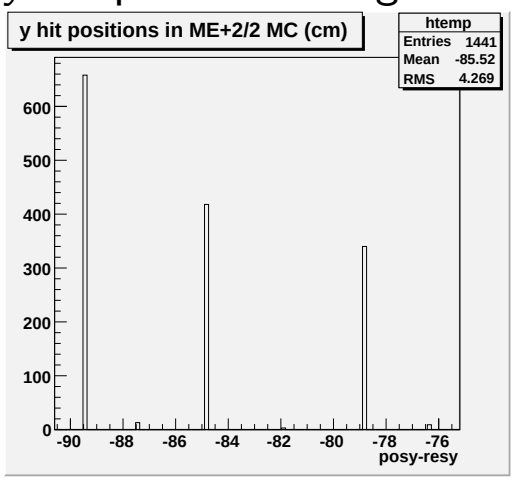




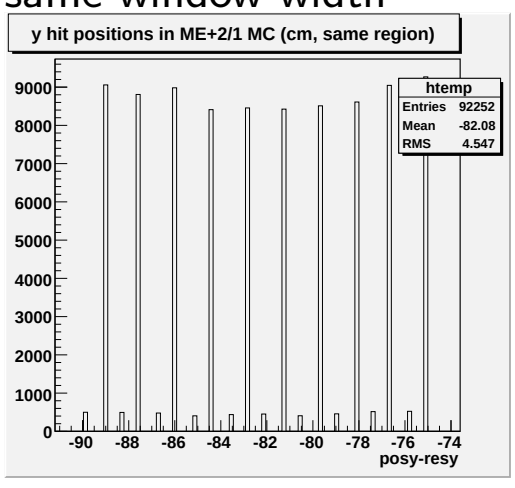
Inner ring vs. outer ring

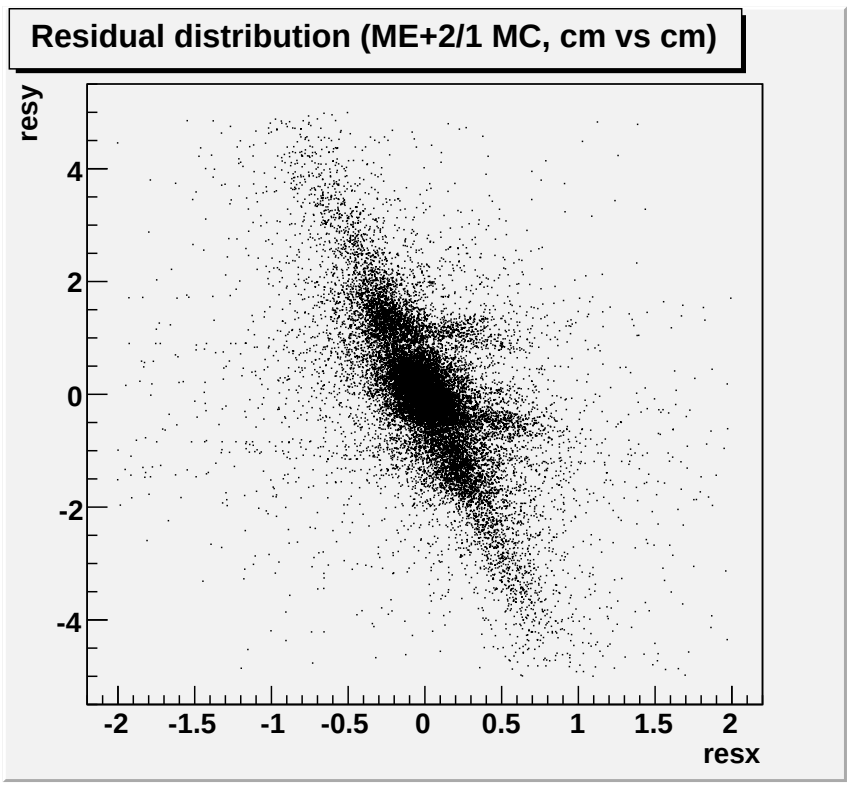
- Wire groups are 1.6 cm apart in ME+2/1, as opposed to 5 cm
- Smaller spacing washes out structure; harder to see ± 0, $\pm 1 \ldots$, peaks
- Slope in x-y correlation is 0.35, consistent with 20° trapezoidal chamber design

y hit position histograms



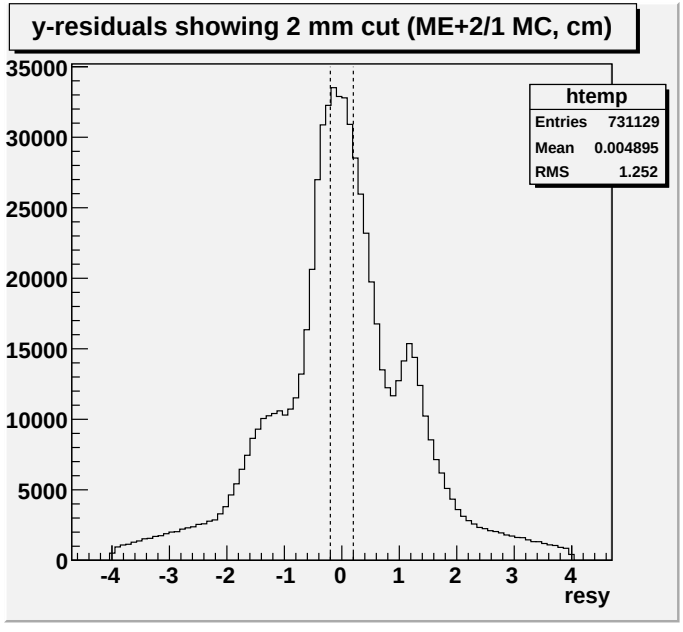
same window width

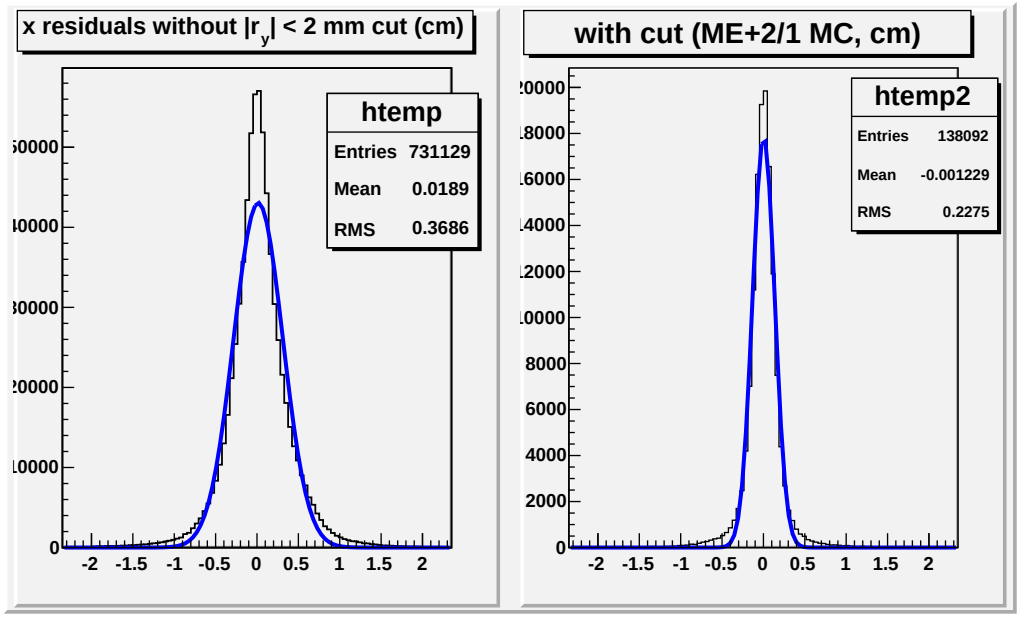




Same trick in inner ring

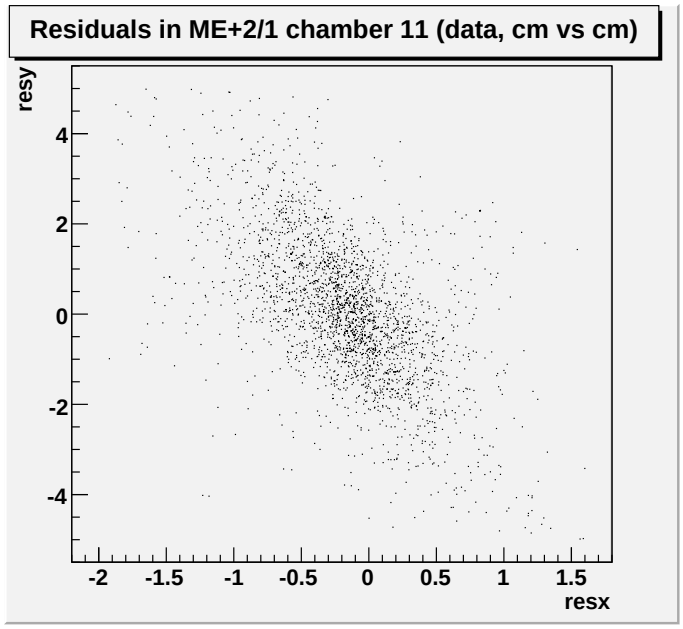
- Much greater loss in statistics due to greater probability of $\Delta y = 1$ or 2
- Only a marginal benefit, but final resolution is the same:
  (half y-gap) $\times$ slope $= \frac{1.6 \text{ cm}}{2}\ 0.35 = 2.5$ mm (by design?)
- When y is very granular, it pays to take advantage of this and select the clean central region, and if y were completely continuous, we wouldn't need to do anything special. But what about the middle case?

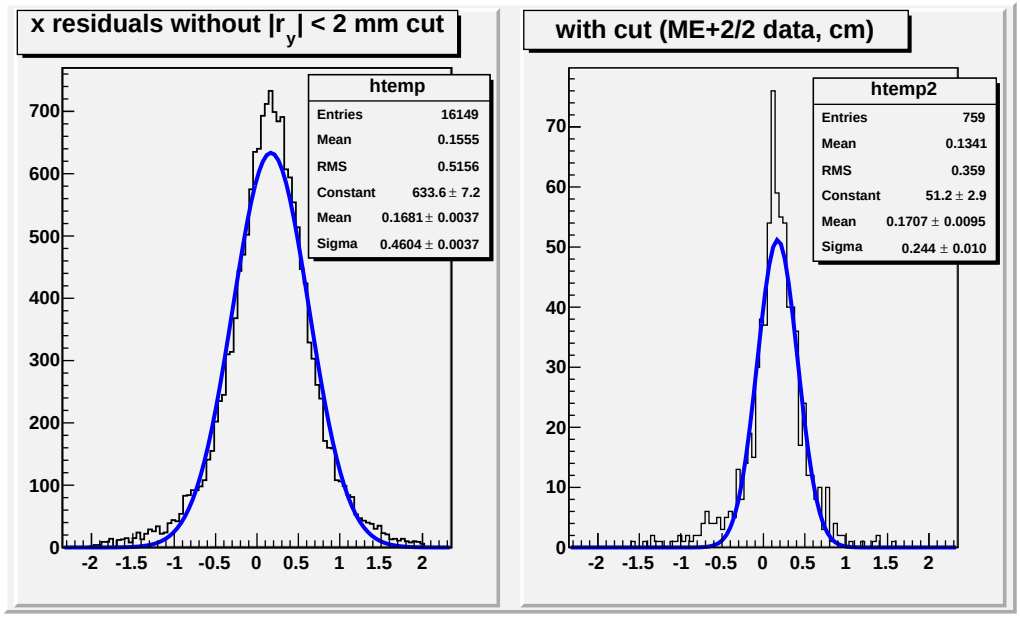




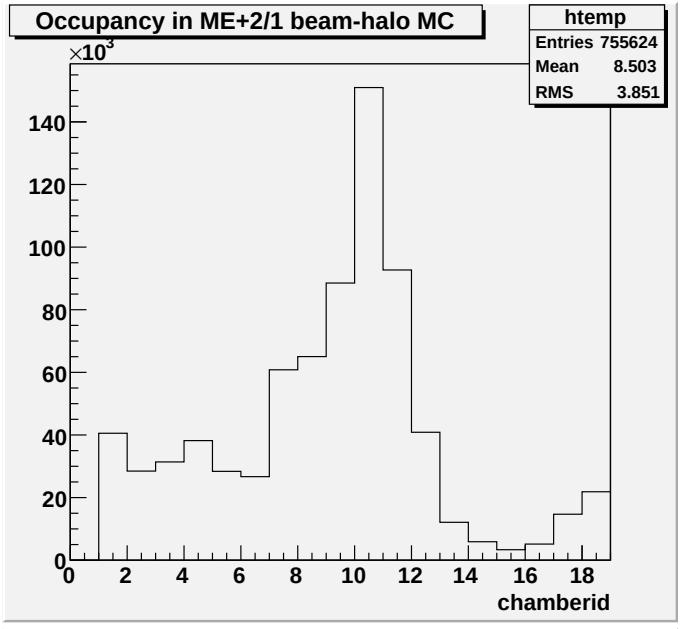
Data are smooth

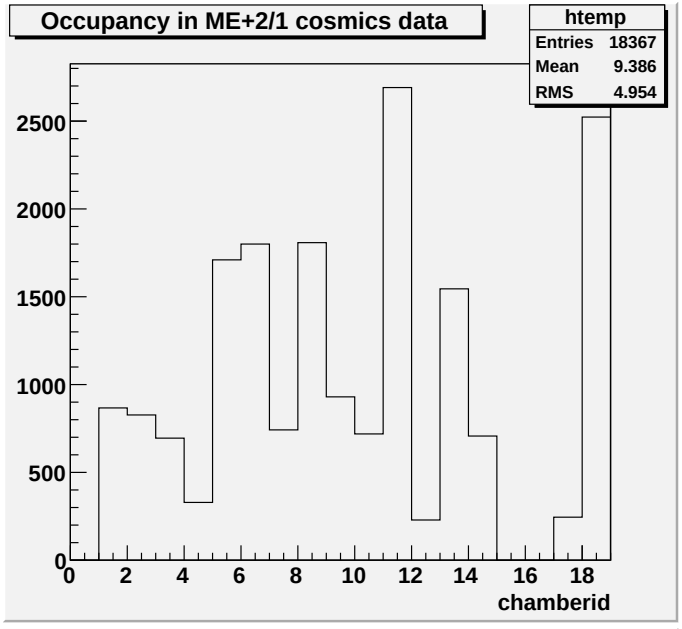
- Like I said, it's the fact that they're cosmic rays with non-horizontal impact angles (and the fact that there's a spread in impact angles can only help)
- Cutting central region trick does very little good here
- The distribution looks smooth: do you suppose it really is smooth? Can we just assume that the Gaussian correlations-handling in HIPAlignmentAlgorithm will take care of it?
- Layer misalignments can also smooth the *y* residuals, but 6 is a rather small number for such featurelessness
- Alignment artifacts we see in beam-halo MC will not necessarily affect cosmics data, so the MC is not a very helpful guide

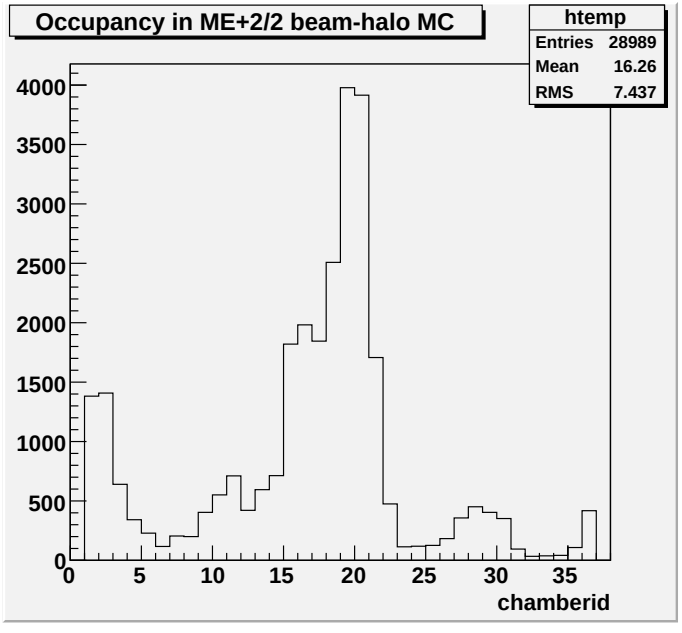


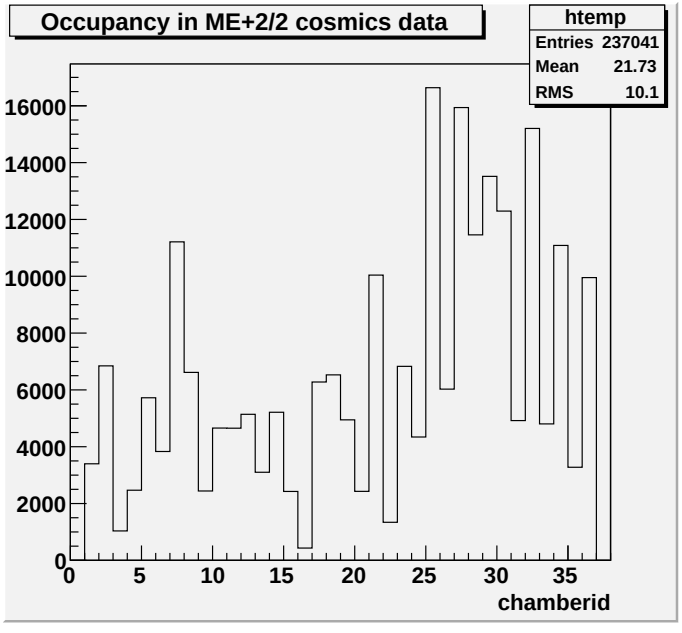


Occupancies: not very flat









What to do, what to do...

- No sign of structure in cosmic ray residuals: they're just broad, as would be expected from granularity plus large uncertainty as to which wire group you're on
- Maybe we can just call the cosmic ray case Gaussian and move on? (That is, interpret any failure to close as a *real* radial displacement of all chambers...)
- We'll need to specially handle granularity effects with beam-halo, but not yet
- Inner ring (ME+2/1), being intermediate between "large gaps" and "nearly continuous," could be a difficult case
- No need to modify the code now if we don't worry about granularity in cosmic rays
- We should not use beam-halo MC as a predictor of cosmic ray data!
- Running a one-step-at-a-time alignment from ME+2/2 chamber 34 in both directions to chamber 16 (which has the least statistics) to check closure in the simplest algorithm