Compton Telescope

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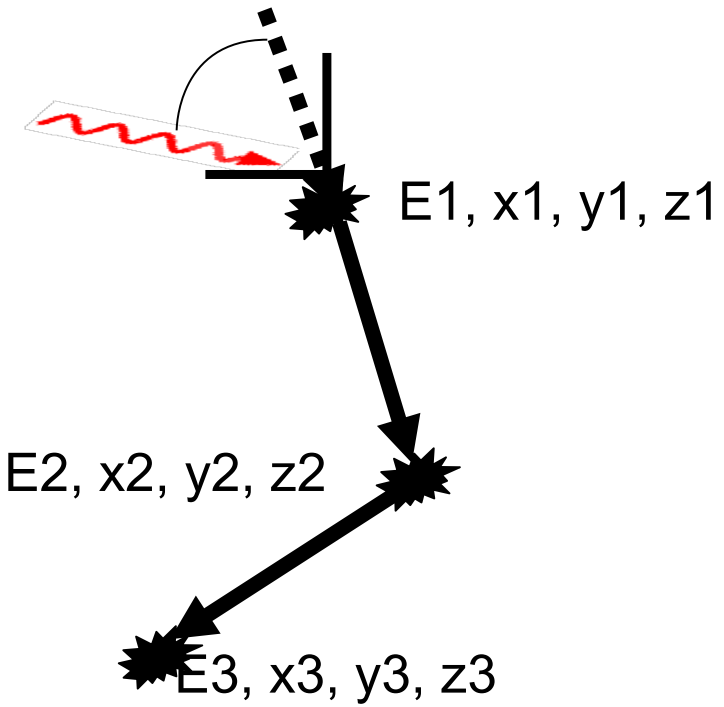
Compton Telescope

- Detector measures E, x, y, z for each sites
- Compton telescope determines source location given cluster locations and Compton scattering formula

$$\phi = \arccos[1 - m_e c^2 (\frac{1}{E_\gamma - E_1} - \frac{1}{E_\gamma})]$$

- Now we have two separate Compton Telescope methods



Why New Telescope?

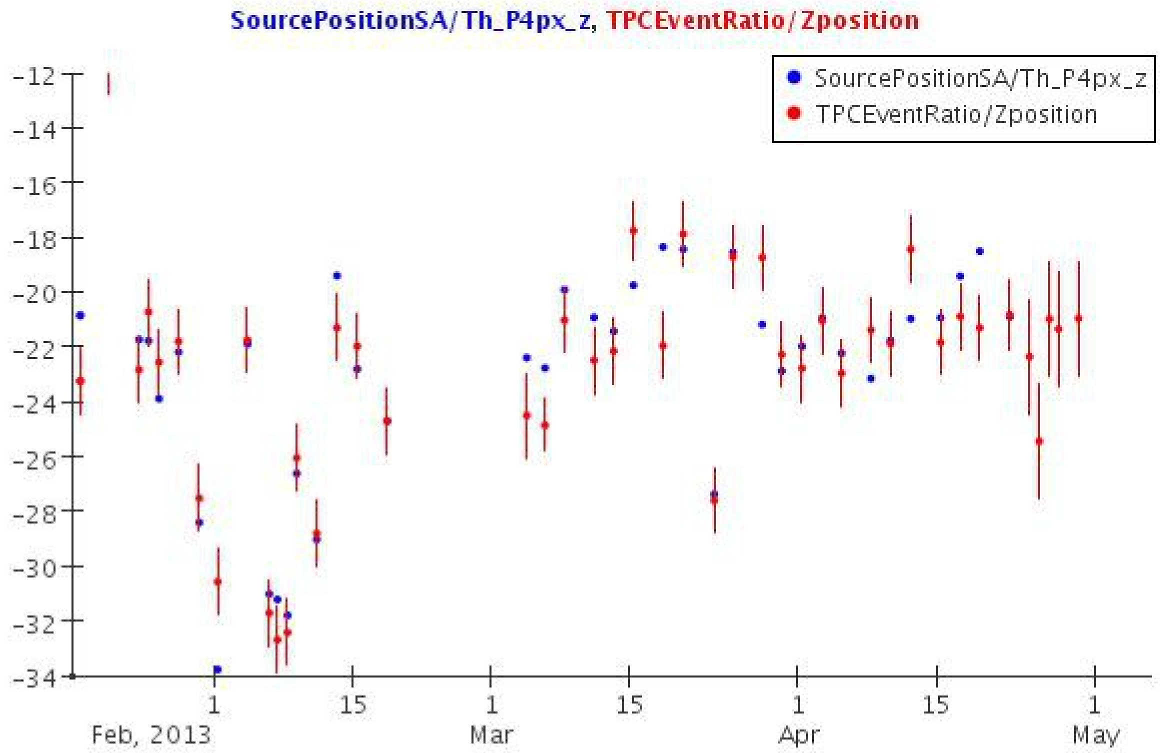
- Questionable physics results, for wk Th S5:
  - z position ~2cm more negative than other methods
  - Radial position closer to 20 than 25 cm
- Code architecture sub-optimal
  - Compton Imager without access to utilities common to other analysis scripts.
  - Code inefficiencies force cap on pipeline statistics.
  - Opaque error propagation.
  - 2,000+ lines of 3 tiered structure: Compton Module, Imager and root scripts, nearly impossible to debug
- Now: ~250 lines of nicely commented python script. Plus a third party “uncertainties” package which transparently handles error propagation.

Crucial New CT Points

- Fully 3D location, rather than 2D
- We can locate each run independently
  - Plenty of statistics in one run
  - No methodological dependence on multiple source positions
    - Consider precision of deployment method
    - Possible lateral movements within tube
- Still promising avenues for further improvement
  - Cluster calibration not applied
  - MC independent of current method
    - Could be used to correct systematic effects

Compton Telescope vs Ratio Method

Jan 18 to May 6



S5 Wk Th Z position

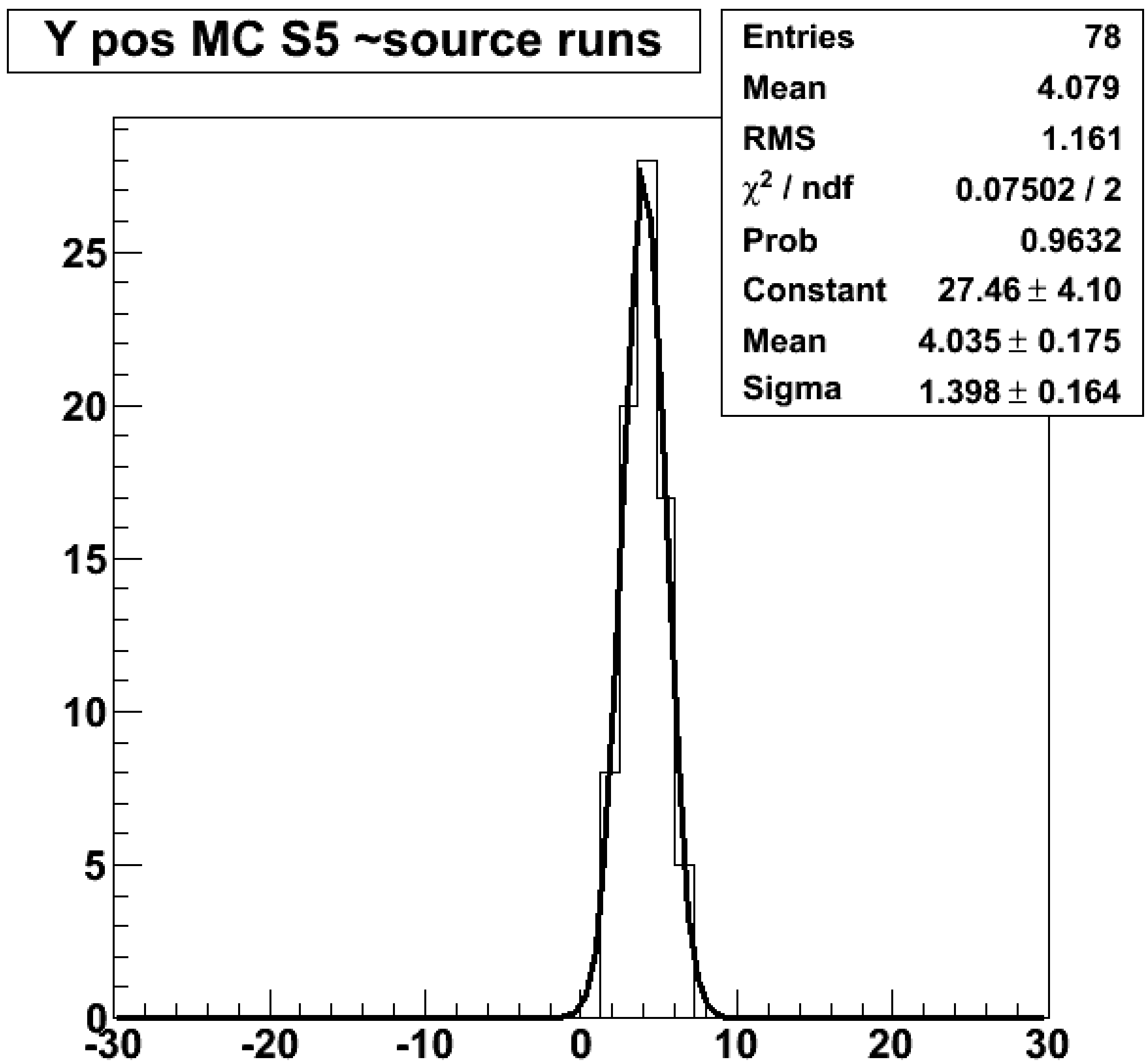
Compton Telescope Position
Mean -22.744 mm
RMS 4.3541 mm

Monte Carlo Test

- Brian simulated 1000 files of wk Th at S5
  - Each had 10,000 total events
  - ~200 pass cuts and used in Compton Telescope
  - I chained groups of 10 files together
    - Still less than half the events which are used from a typical source run
- Source Position
  - Y= 4 mm, Z= -20 mm, X= 250 mm,
- Summed PCD's smeared
  - Resolution taken from run over data

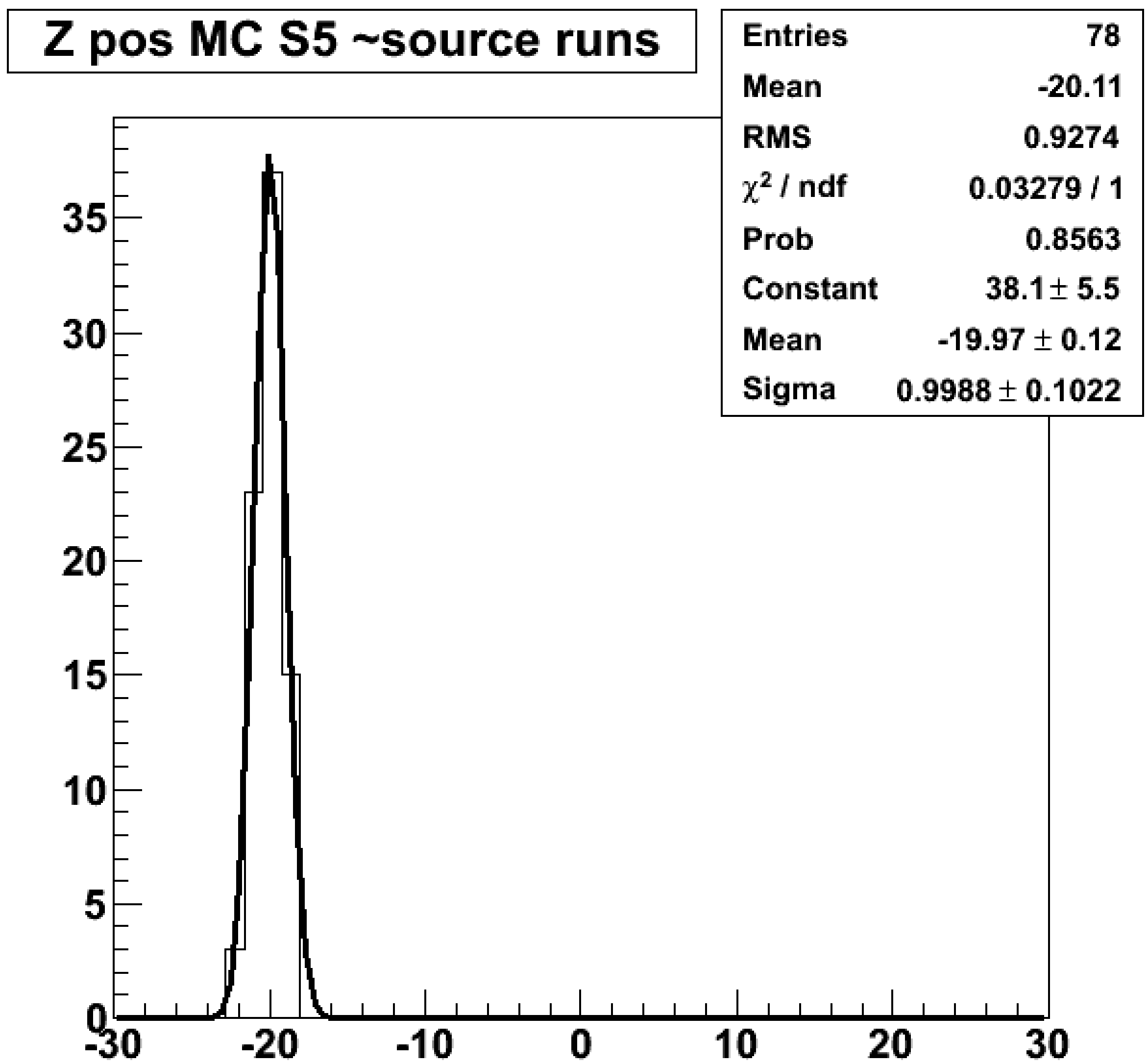
Fit = 4.035 (1.398) Sim = 4.0

Simulated bead size = .5 mm

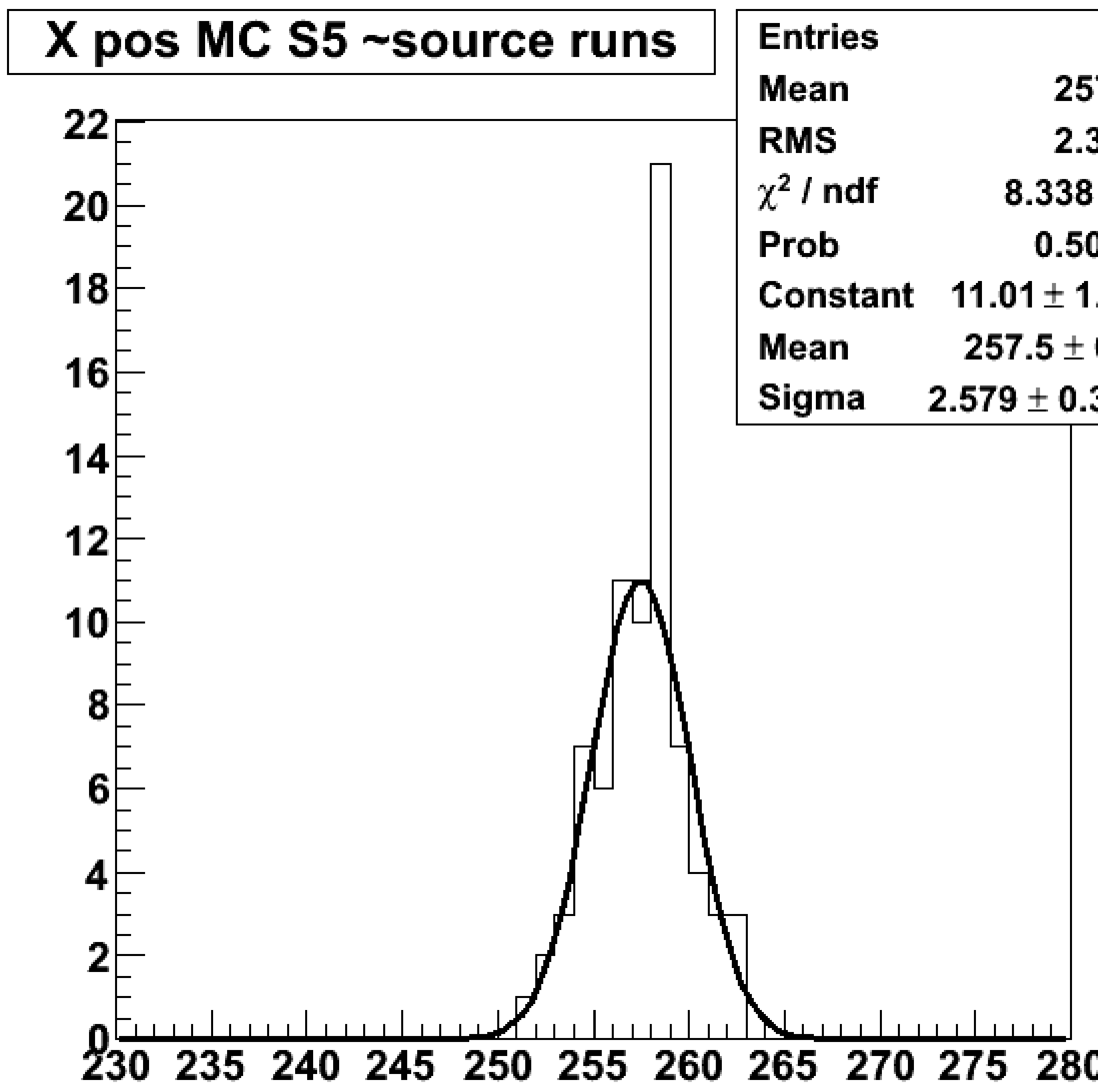


Fit = -19.97 (.9988) Sim = -20 mm

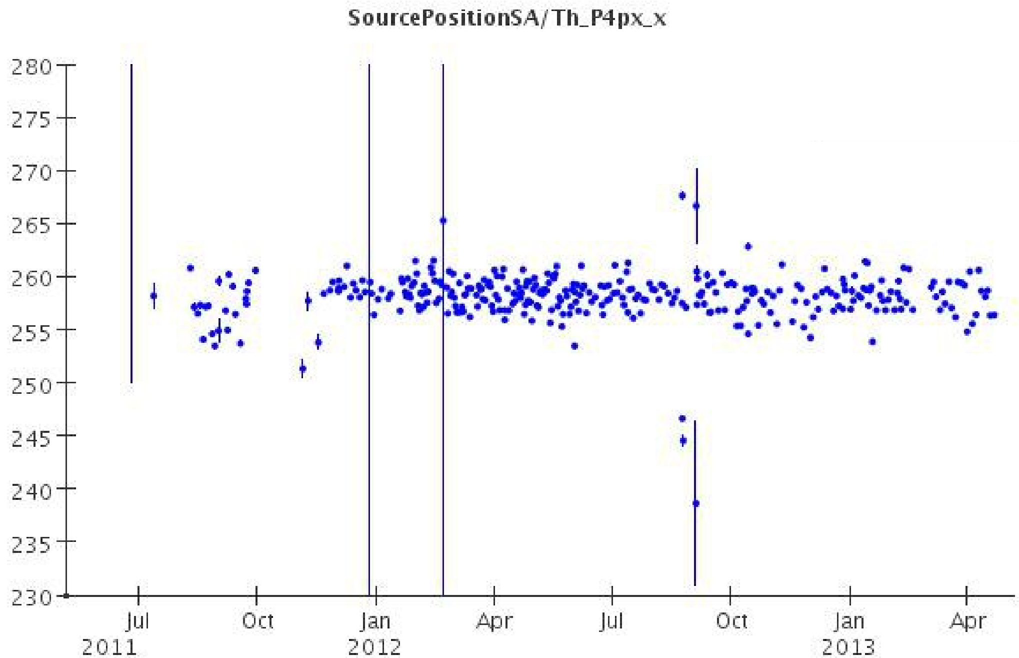
Simulated bead size = .5 mm

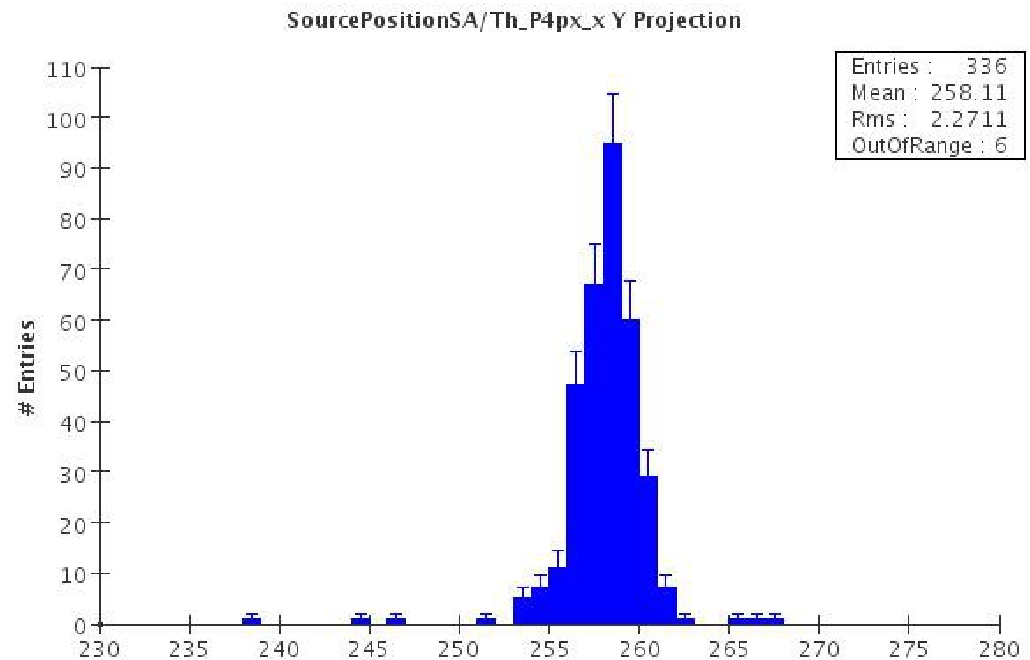


Fit = 257.5 (2.579)   Sim = 250 mm



Source Runs over 2 years





Mean: 258.11 mm

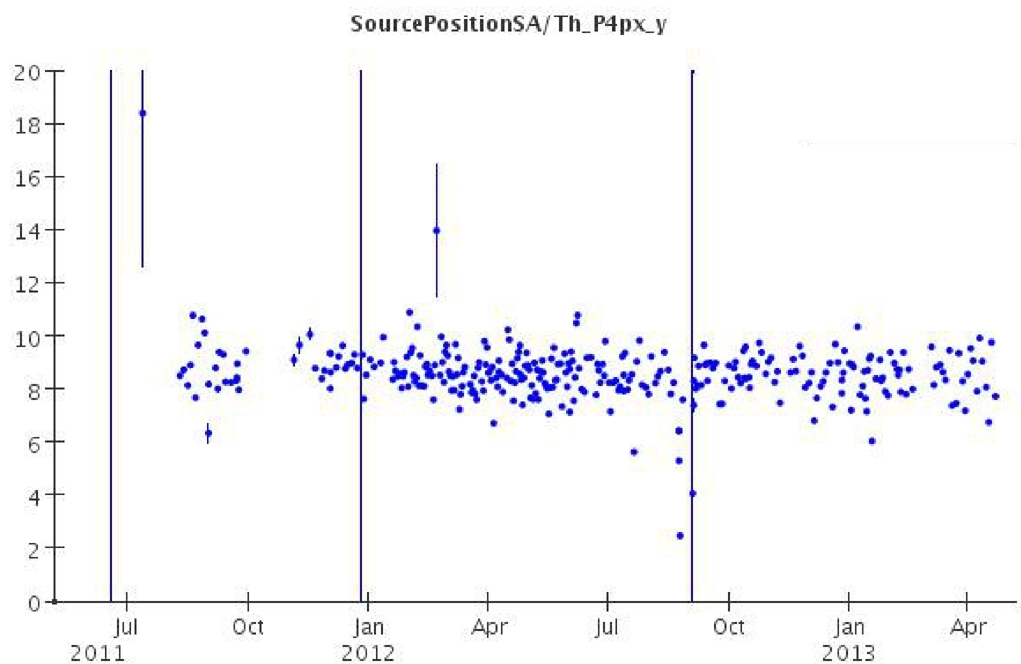
RMS: 2.2711 mm

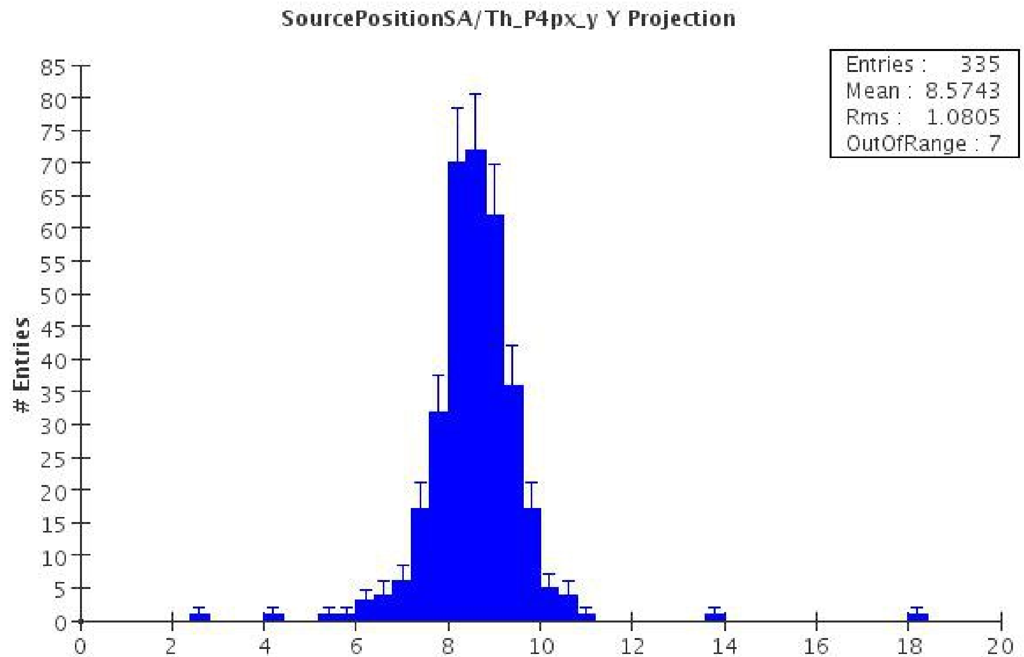
Weak Thorium

S5 X position

MC Comparison suggests the true position is 251-258 mm

Source Runs over 2 years



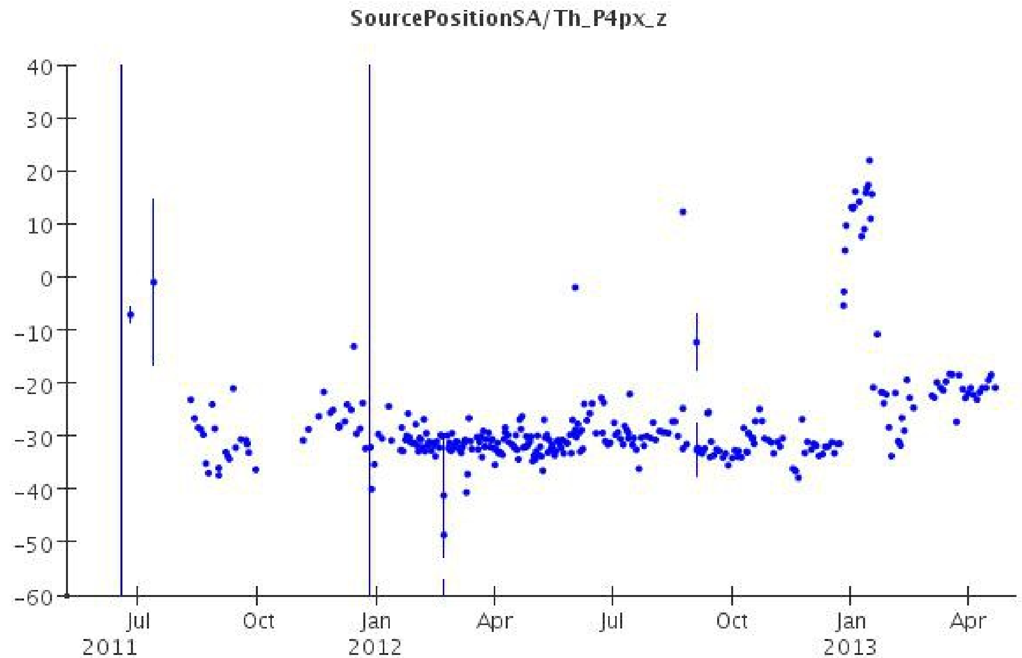


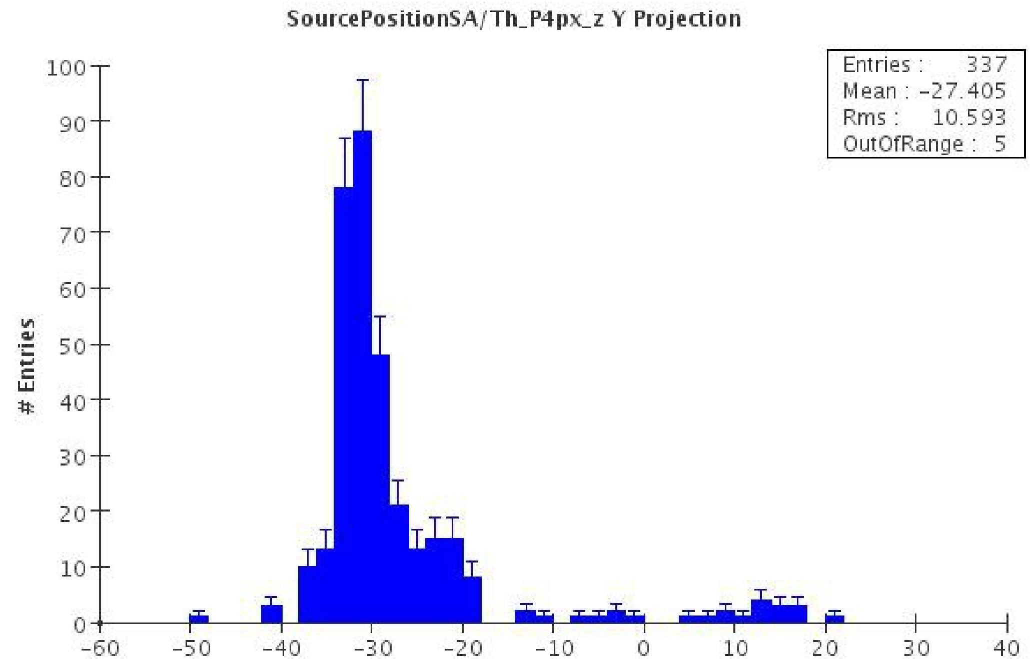
Mean: 8.57 mm
RMS: 1.08 mm

Weak Thorium
S5 Y position

MC Comparison suggests the true position is this position

Source Runs over 2 years





Mean: -27.41 mm

RMS: 10.6 mm

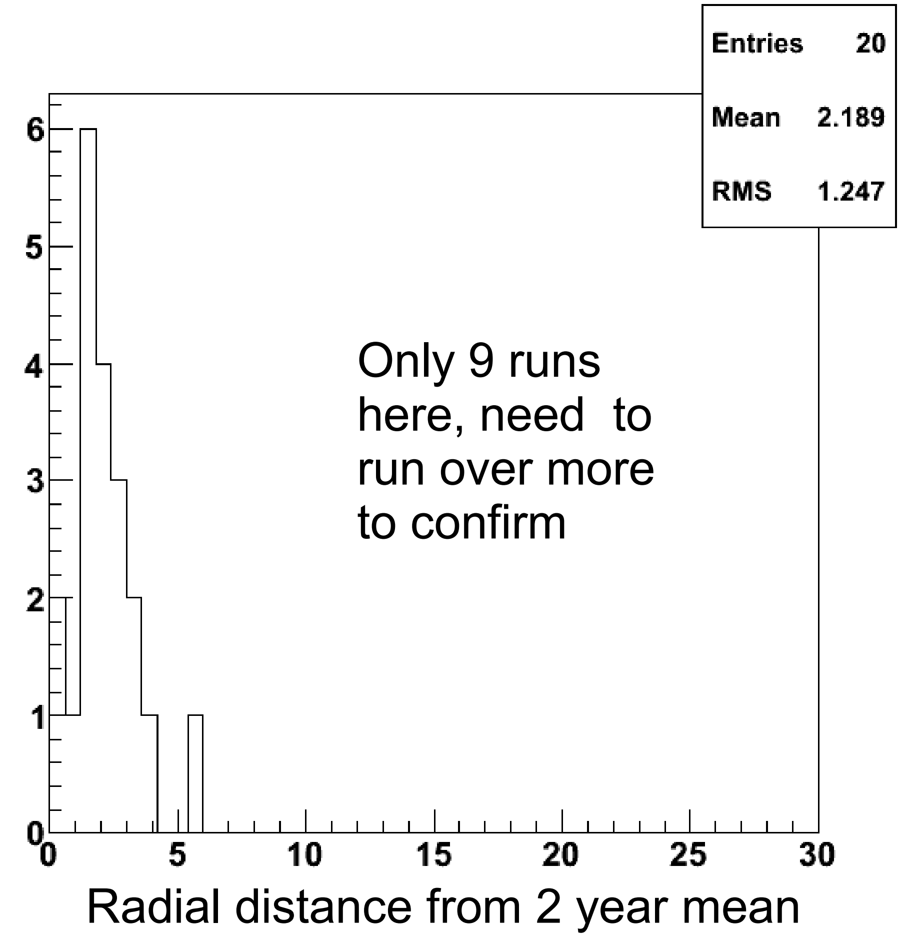
Weak Thorium

S5 Z position

MC Comparison suggests the true position varies by run

Source Tube Diameter?

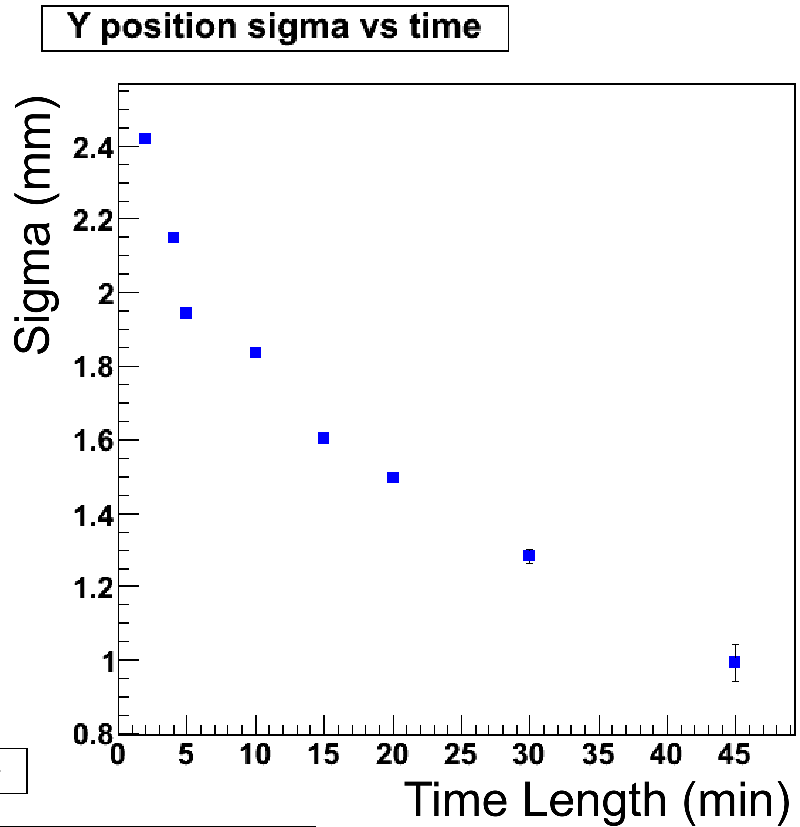
- Took 2 year mean for X and Y
  - 8.57 mm
  - 258.11 mm
- 9 runs, each run split into 45 mins
  - Distance in x/y plane between run pos and mean pos plotted
  - 2.413 mm Tube IR



2.189 (1.247) mm

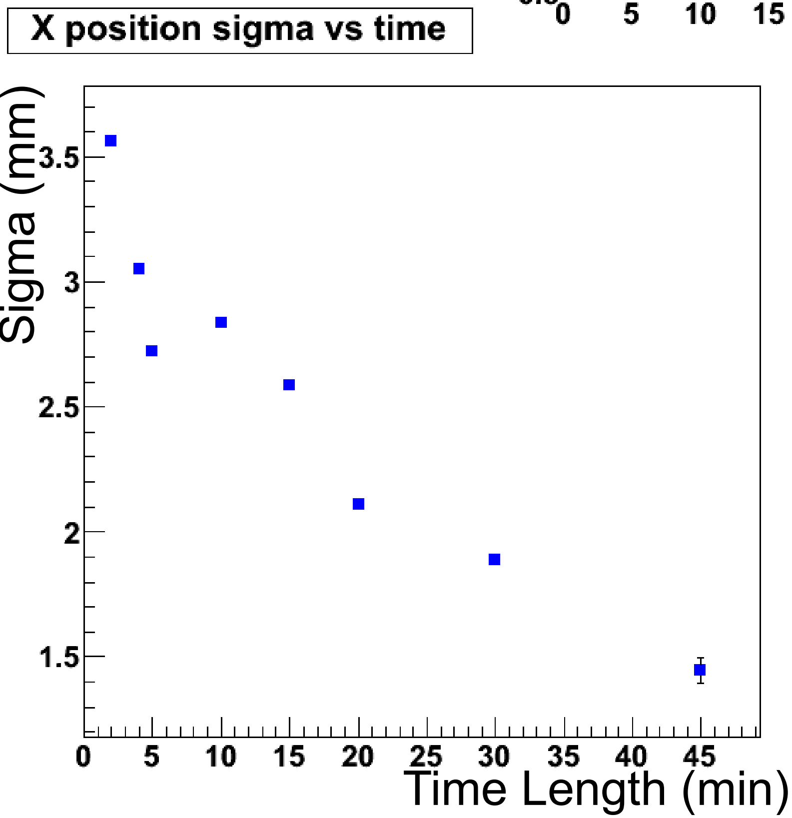
Precision Check

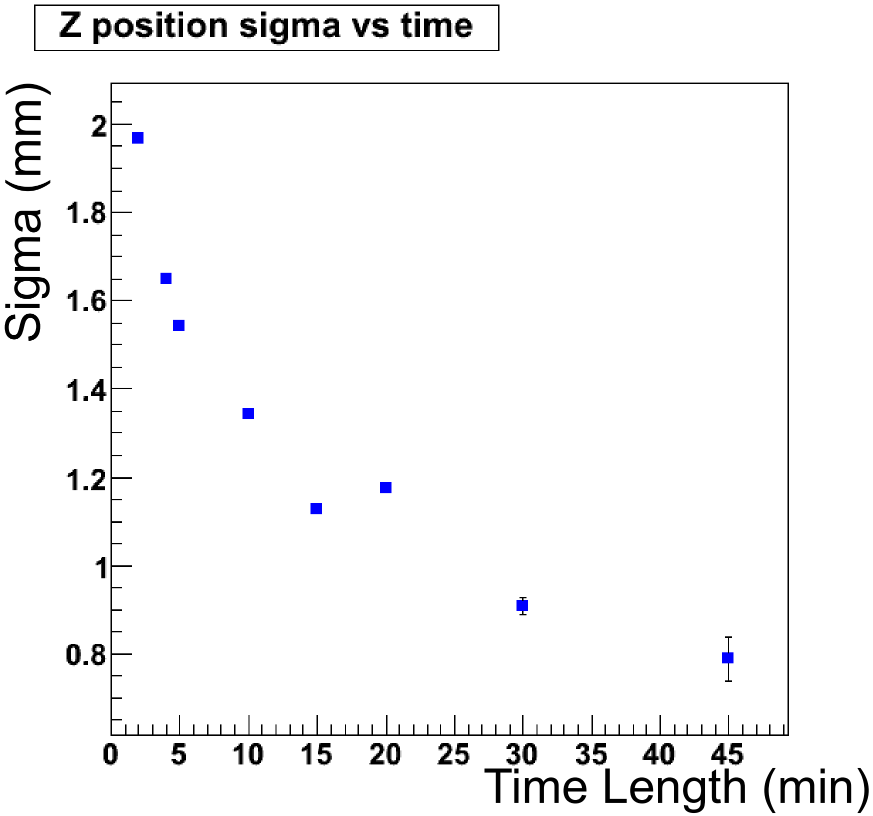
- run to run variation in true source position:
  - lateral or vertical movements within inner diameter of calibration tube
  - Shift-to-shift variations with z deployment
- I broke up each run into small “runs”
  - normalized by finding difference between CT position determination on small “run” and full run
    - I used 8 time lengths from 9 separate runs
    - Not every run has every time length



Separated Coordinates

Runs Still Combined





MC / Data Efficiency Check

- Measured by fraction CT accepts out of the entire number of entries / triggers in file
  - 2.05 % MC acceptance
  - 1.72 % Data acceptance
- Possibly from muon rate, noise, etc. being rejected by CT in data

Other Sources and Positions

S2	wTh	4449-4451		-26.632	3.1035	-286.01
	wCo	4442-4444		-27.03	2.4	-287.85
S5	wTh	4758, 4766, 482		258.49	8.689	-22.263
	wCo	4439		258.75	7.947	-23.072
	wCs	4777-4781		243.07	6.4781	-23.45

Systematic check / correction from MC not complete, errors not complete

Other Sources and Positions

S8	wTh	4769		27.609	1.2353	289.47
	wCo	4785-4786		24.103	1.8639	294
S11	wTh	4771-4772		1.8205	256.72	20.1
	wCo	4789-4790		1.5377	256.91	20.899

Systematic check / correction from MC not complete, errors not complete

Other Sources and Positions

Other:				x	y	z
S5+6	wTh	4828		262.58	6.1476	41.878
S5+4	wTh	4829		258.07	8.449	22.822
S5-2	wTh	4835		259.57	8.851	-41.348
S5-4	wTh	4836 and 4841		256.13	8.2947	-57.0765
S5+2	wTh	4839		254.86	8.3545	0.50538

Systematic check / correction from MC not complete, errors not complete

Further Work

- Get systematic and cross check from MC
  - Run on MC positions other than S5 wk Th
- Finish error assignment on positions

- Finish calibration, possibly need entirely new flavor, for clusters, if SS or MS does not work
- Correct z energy dependence
- Fine Tune cluster ordering, add 3 cluster event
- Check dependence on fiducial cut
  - We use larger cut than standard

Extra Slides

Systematics Check

runs 4758, 4766, 4824, 4840, 4852, 4859

	TPC1		TPC2	
x	253.1	1.98	255.5	2.576
y	9.008	1.541	8.505	.4147
z	-17.49	1.877	-24.53	1.439

- All entries in mm
- Value, then RMS
- 7 mm disagreement in z position
- Further work needed to determine cause
- Saw similar effect with cut along Z

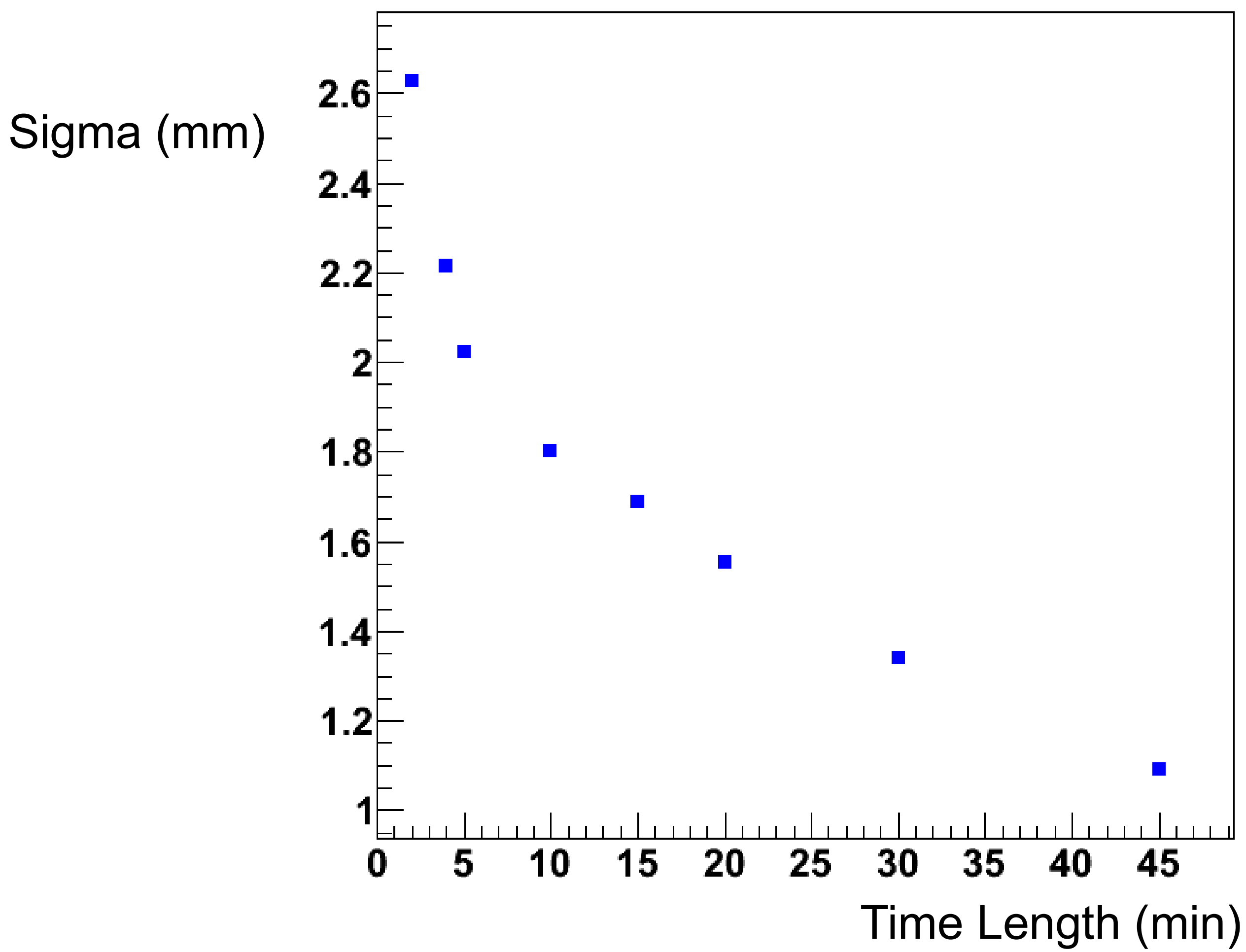
Statistics Check

runs 4758, 4766, 4824, 4840, 4852, 4859

	Even		Odd	
x	258.8	2.61	257.9	1.72
y	8.07	.767	9.358	.759
z	-22.42	1.82	-22.11	1.33

- All entries in mm
- Value, then RMS
- Script assigned error smaller than RMS in all cases

Sigma vs Time Length



Note: data from 9 runs is combined

Notable Differences

- Position determination
- Error Propagation
- Energy cut

- Ordering
- “Bad Events”
- Coord system
- Cluster Multiplicity

- Position determination
  - New CT chi squared optimization
    - Nominal source position used as initial guess
    - Each Event evaluated for discrepancy between the assumed position and the Compton scattering formula.
    - BFGS method used to optimize search along gradient.
  - Old CT is pixel based
    - created Compton cones and evaluated on a defined surface the number of overlaps in a bin.
    - This does not scale to 3d very well at all, however, for LB studies, the lack of an initial guess could be helpful.
- Error Propagation
  - New CT uses imported uncertainties package
    - Provides a python class dealing with numbers with associated errors, propagating correctly when these values are used in calculations.
    - See details: http://pythonhosted.org/uncertainties/user_guide.html
  - Old CT generated a variable, but high, number of cones for each event distributing the values for each from a Gaussian distribution around the central value given the error
    - Very slow, not transparent

- Energy cut
  - New CT uses calibrated, rotated energy space, Old CT used charge only, did not access calib DB or cut on combined energy
- Ordering
  - New CT tries both orderings of the two cluster events, Old CT orders two cluster events by energy, three cluster optimizes a figure of merit
- “Bad Events”
  - New CT weights events more dynamically, adding to chi-squared for an event with the weighting of how many sigma away from agreement
  - Old CT had hard cuts angle error, etc. to eliminate events which would be unlikely to improve resolution.
- Cluster Coord system
  - New CT uses UVZ, Old CT uses XYZ, also, the error applied to XYZ is archaic
- Cluster Multiplicity
  - New CT only uses two cluster events because the ordering problem is simpler to solve, Old CT trending uses 2 and 3 cluster events