Latif finds a coincidence time resolution of ~0.3-0.4ns (rms) (see next slide for longer story)

What is the expected resolution?

Why some experiments care: In (e,e'h) one would arguably like to have at least 6σ separation between beam bursts for the particle of interest. (Non-Gaussian tails typically make this less generous than it sounds.)

- For 499/2 MHz beam bunches in Hall C (4 nsec separation): the real coincidence peak cut at +-2nsec only needs a resolution of 0.67 nsec rms. That's easy. So no worries.
- For 499 MHz beam bunches in Hall C (2 nsec separation): the real coincidence peak cut at +-1 nsec needs a resolution of 0.33 nsec (rms). That's a little more challenge.

The ctime resolution for Hall C at 12 GeV was never specified, but in 20/20 hindsight the above 499 MHz beam bunch scenario could have motivated a requirement of 0.33 nsec (rms) or better.

From the previous slide, the 20/20 hindsight ctime spec would be 0.33 nsec (rms).

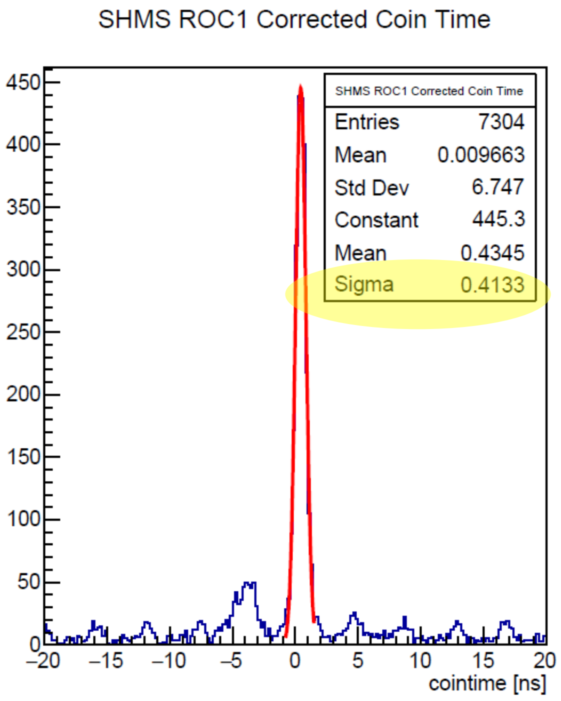
(left two plots) Here Latif apparently gets ~0.4 nsec (rms). Can we do better?

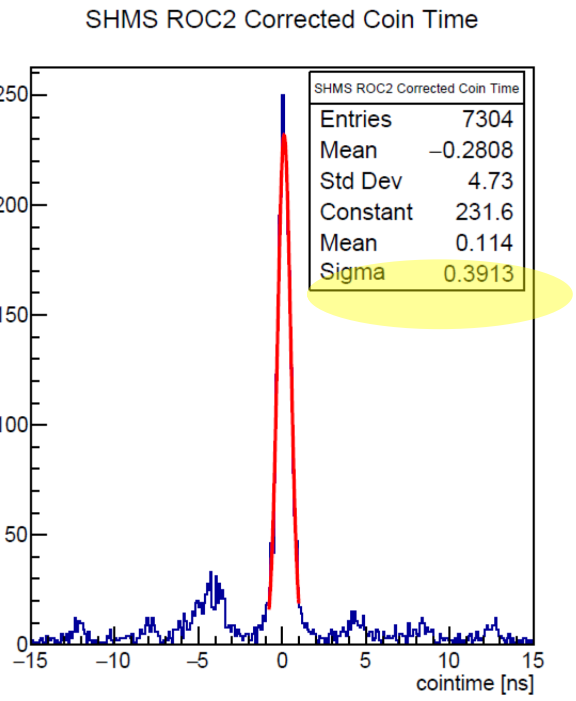
(right two plots) With production C(e,e'p) data, the resolution *is* significantly better, ~0.3nsec (rms), with small errors.

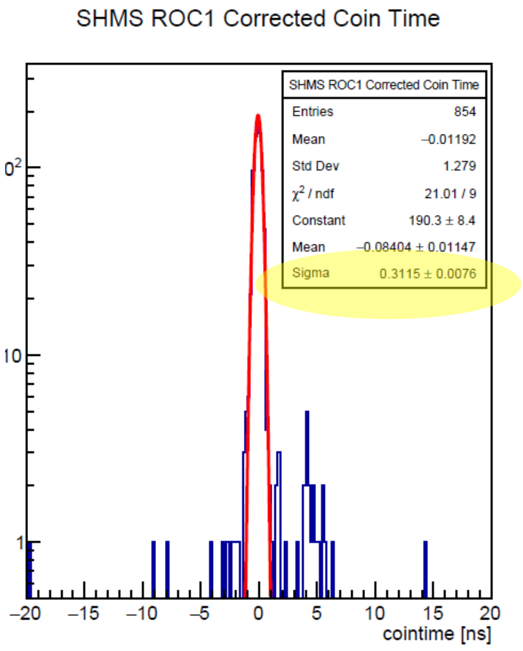
These ctime rms values are inconsistent. In the backup slides, it looks like the SHMS pathlength corrections need a little tweak at large negative delta, impacting C(e,e'p) data less. So the ctime resolution of ~0.3 nsec (rms) seems real.

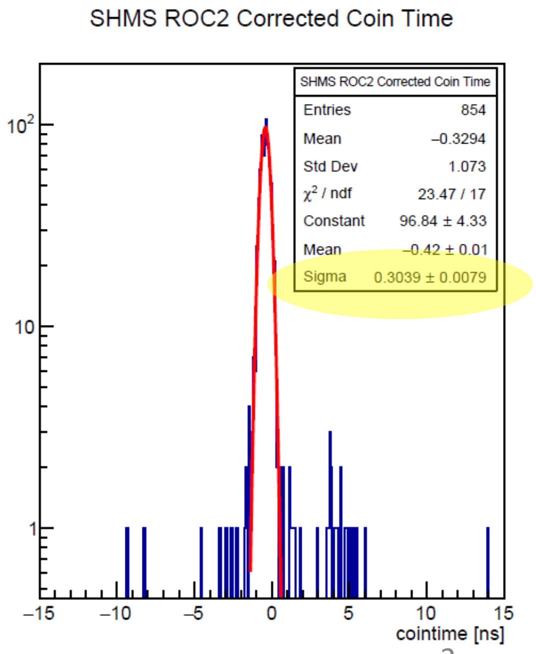
Latif, run 1889 https://logbooks.jlab.org/entry/3519840

Latif, production C(e,e'p) https://logbooks.jlab.org/entry/3521769









Let's check what ctime resolution we expect in the best-case scenario. Unfortunately, there's no timing information in the JMU slides from their cosmic studies. But beta resolutions from beam data are available, so let's write formulae to use σ_β as the fundamental input.

Single arm definitions and formulae

Mean-time resolution of a bar: σ_{bar}

Mean-time resolution of S1 or S2 = $\mathrm{sqrt}(\ \sigma_{bar}^2 + \sigma_{bar}^2\ )\ /\ 2 = \sigma_{bar}/\sqrt{2}$

Mean-time resolution of S1 and S2 ("focal plane time"):

$$\sigma_{FP} = \mathrm{sqrt}(\ (\sigma_{bar}/\sqrt{2})^2 + (\sigma_{bar}/\sqrt{2})^2\ )\ /\ 2 = \sigma_{bar}/2$$

Resolution of TOF between S1 and S2:

$$\sigma_{TOF} = \mathrm{sqrt}(\ (\sigma_{bar}/\sqrt{2})^2 + (\sigma_{bar}/\sqrt{2})^2\ ) = \sigma_{bar}$$

Relation between TOF and β and bar resolutions:

$$\beta = v/c = (d/TOF)/c$$

$$\sigma_\beta = [(d/c)/TOF^2]\ \sigma_{TOF} = [(d/c)/TOF^2]\ \sigma_{TOF} \sim [c/d]\ \sigma_{TOF} = [c/d]\ \sigma_{bar}$$

Double arm coincidence time formula

$$\sigma_{ctime} = \mathrm{sqrt}(\ (\sigma_{FP}^{HMS})^2 + (\sigma_{FP}^{SHMS})^2\ ) = \mathrm{sqrt}(\ (\sigma_{bar}^{HMS}/2)^2 + (\sigma_{bar}^{SHMS}/2)^2\ ) = 0.5 * \mathrm{sqrt}(\ (\sigma_{bar}^{HMS})^2 + (\sigma_{bar}^{SHMS})^2\ )$$

where $\sigma_{bar} = (d/c)\ \sigma_\beta$

The ctime resolution is then

$$\sigma_{ctime} = sqrt((\sigma_{FP}^{HMS})^2 + (\sigma_{FP}^{SHMS})^2) = 0.5* sqrt((\sigma_{bar}^{HMS})^2 + (\sigma_{bar}^{SHMS})^2)$$

We need the following inputs (summarized in the table below):

$\sigma_{bar}^{HMS} = (d^{HMS}/c)\ \sigma_\beta^{HMS} = 0.166$ nsec and $\sigma_{bar}^{SHMS} = (d^{SHMS}/c)\ \sigma_\beta^{SHMS} = 0.304$ nsec

Plugging in the numbers, **we should be able to achieve $\sigma_{ctime} = 0.173$ nsec !**

	σ_β (measured)	d	$\sigma_{bar} = (d/c)\ \sigma_\beta = \sigma_{TOF}$	$\sigma_{FP} = \sigma_{bar}/2$
HMS	0.025 Simona https://hallcweb.jlab.org/doc-private/ShowDocument?docid=853	2m(?)	0.166 nsec	0.083 nsec
SHMS	0.0414 Simona https://logbooks.jlab.org/entry/3519628	2.2m https://hallcweb.jlab.org/doc-private/ShowDocument?docid=669 slide 14	0.304 nsec	0.152 nsec

The ctime resolution is the quadrature sum of these two.

Summary

1. The beta resolutions of the HMS and SHMS hodoscopes indicate a best-case ctime resolution of ~0.17 nsec.

So the like-to-have goal of ~0.33 nsec rms ctime resolution for 499 MHz beam burst running is not crazy.

2. Latif's ctime resolution for the C(e,e'p) data demonstrates that the ~0.33 nsec like-to-have goal is actually met.

The inconsistency between his 0.3nsec rms and 0.4 nsec rms fits may be due to greater focal plane coverage in the latter dataset. It looks like the path-length corrections need a tweak at large –delta. (see backup slides)

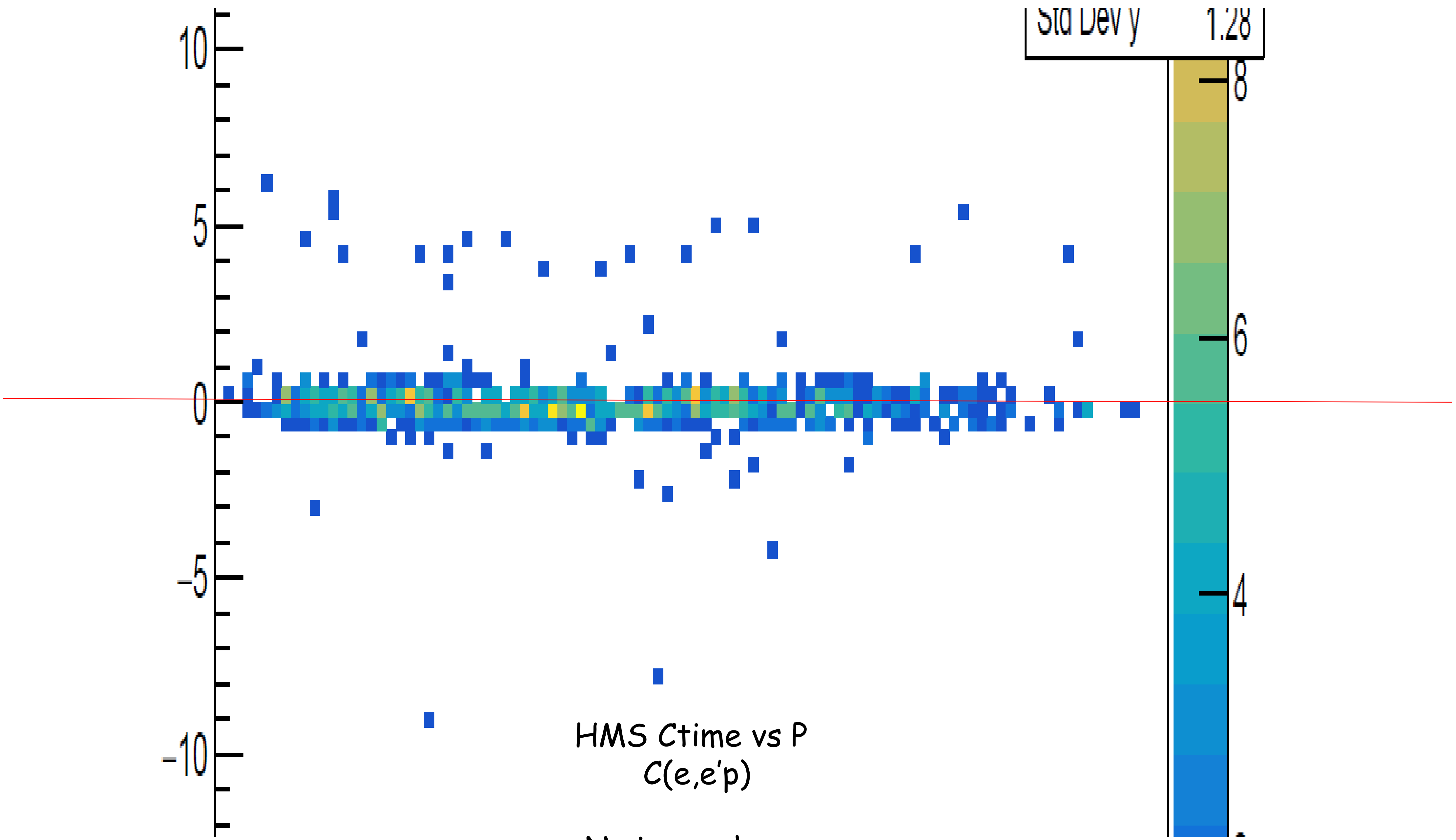
3. Latif's determination of the ctime resolution, 0.3 nsec rms, is only x1.8 larger than ideal.

The source of the 0.25 nsec rms "excess noise" is zero priority; we don't need a ctime resolution better than ~0.33 nsec (rms). But as an intellectual matter, it is puzzling. According to the CAEN 1190 TDC manual, this is larger than we'd expect from LSB, cross-talk, etc.

4. The main *calculated* contribution to the ctime resolution is the SHMS focal plane time resolution of ~0.15 nsec . The HMS focal plane resolution achieves ~0.08 nsec presumably because the scintillators are thicker.

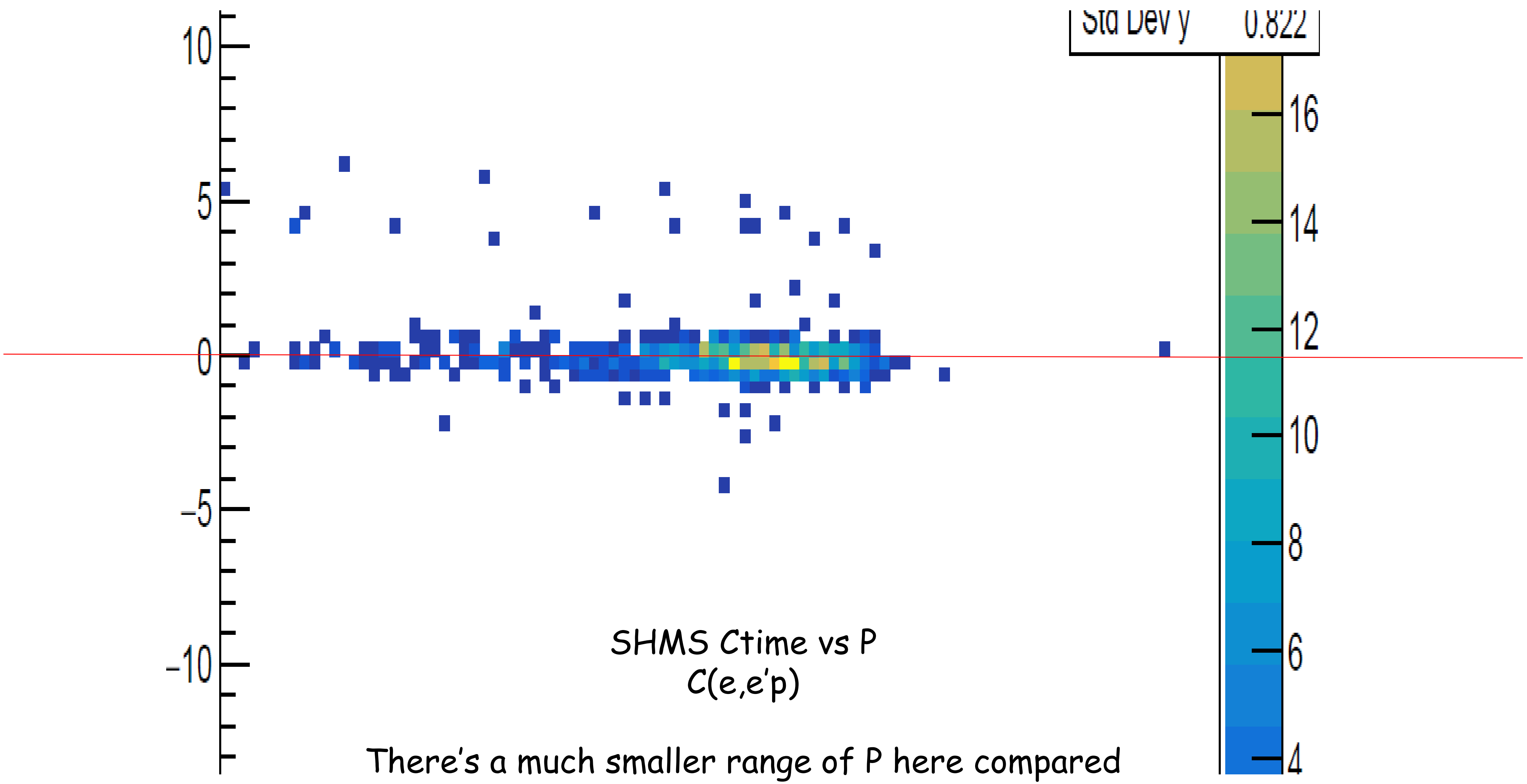
Still, the SHMS focal plane time resolution is great! Two SHMS's in coincidence could even do ~ 0.21 nsec (rms).

Backups



HMS Ctime vs P
C(e,e'p)

No issues here.



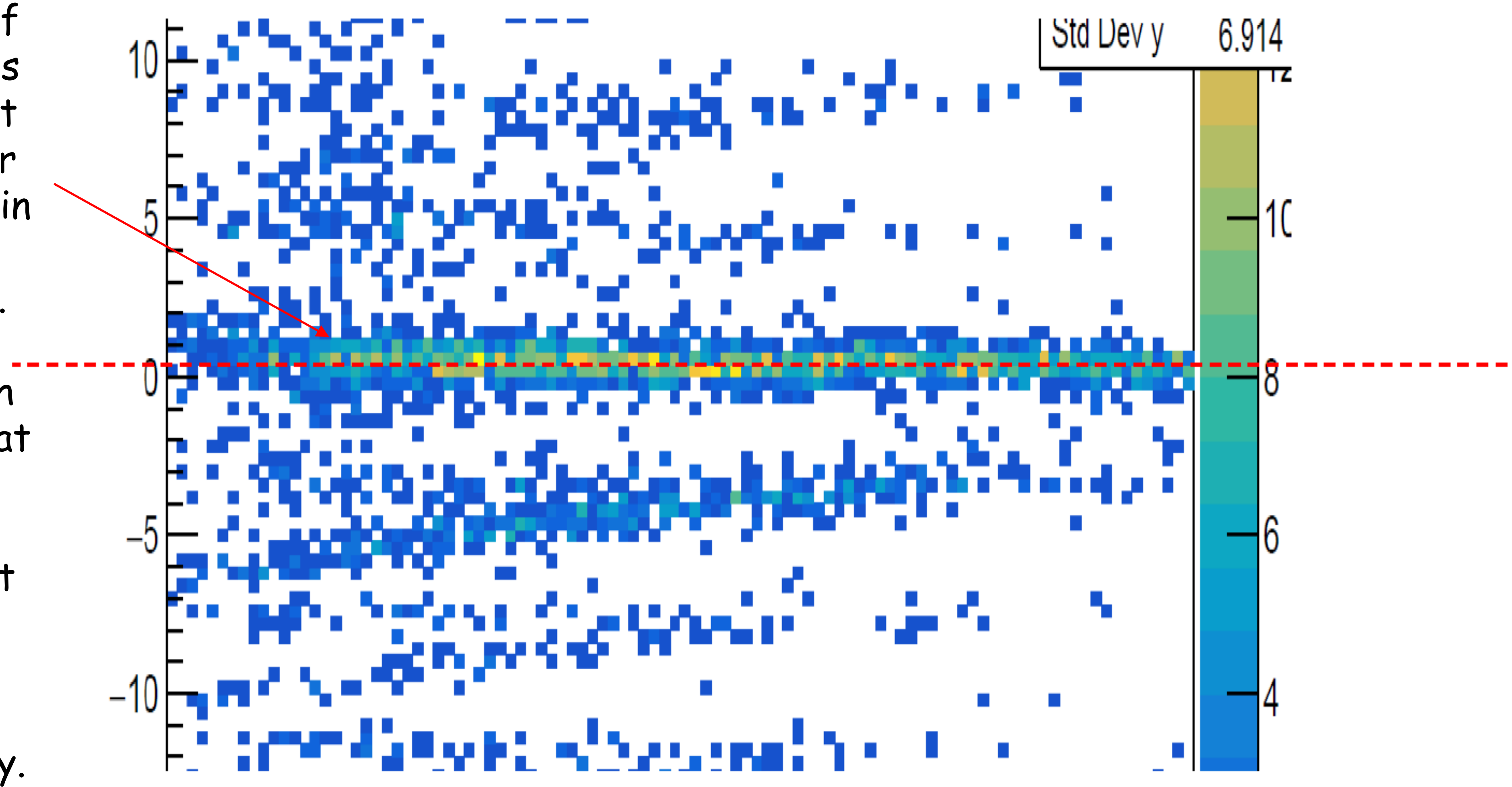
SHMS Ctime vs P
C(e,e'p)

There's a much smaller range of P here compared with the coincidence run that gave worse resolution (next slide).

Little bit of systematics here. Might account for difference in ctime resolution.

Path length correction at large negative delta might need a tweak?

Low priority. Need high statistics data to address.



SHMS ctime vs delta (zoomed)