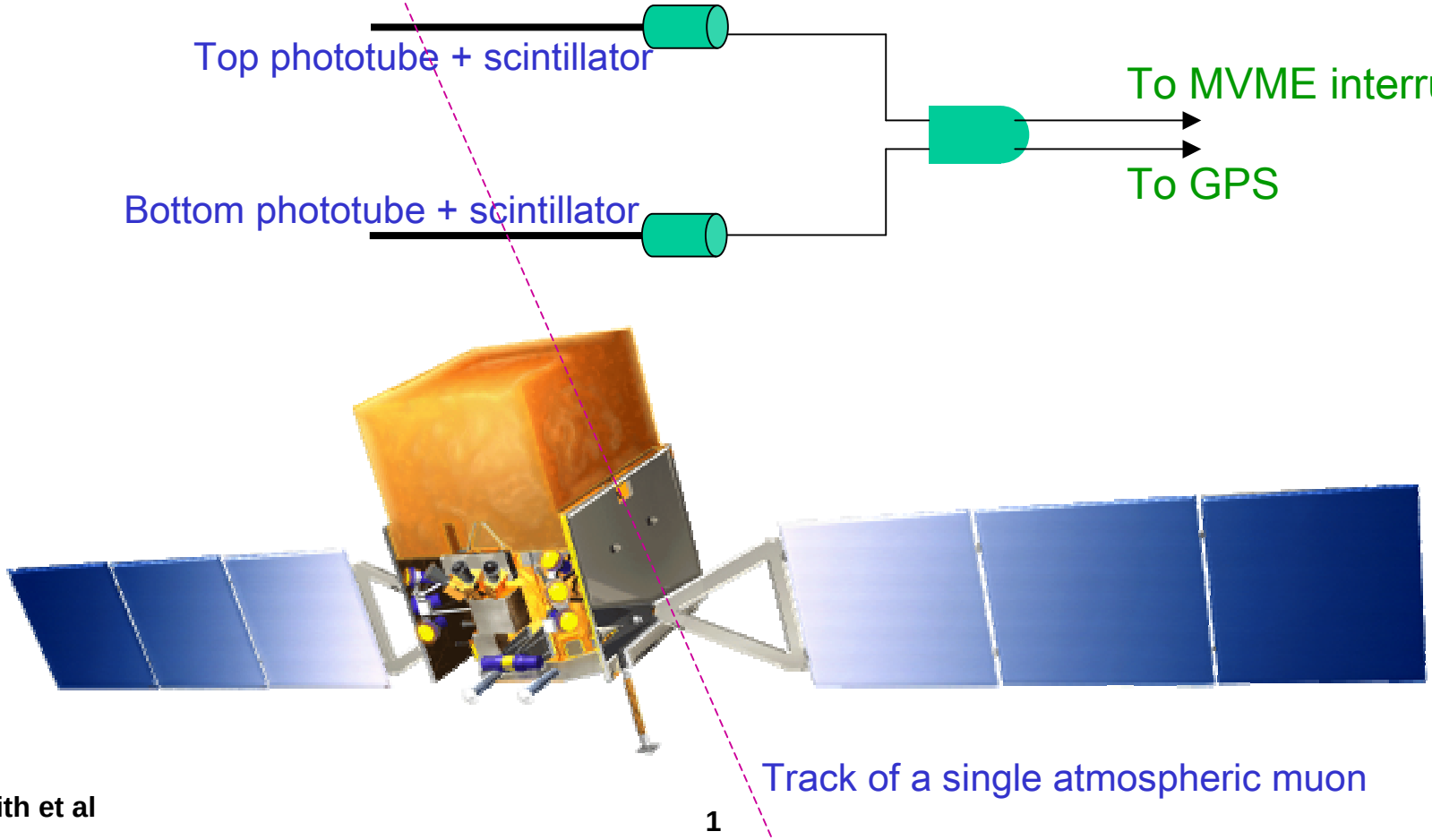
Update of GLAST LAT absolute timestamp end-to-end test

David Smith, Eric Grove, Denis Dumora, Patty Sandora, Eric Siskind
with invaluable support from Anders Borgland and Gregg Thayer.

Sci Ops VRVS, 16 March 2007



Reminder: why, and what

- Accurate measurement of gamma ray arrival times is *essential* for pulsar science.
- Example: PSR J0218+4232 has a rotation period of 2.3 ms.
- Time-stamping is non-trivial: significant problems on major missions.

- Muons allow a simple LAT end-to-end test.
- Bordeaux had the CELESTE VME GPS in the basement…
- …and NRL had a muon telescope from CAL integration.

- See my 10 November 2006 “SO VRVS” presentation.
- More details at my “blog” https://confluence.slac.stanford.edu/display/CAL/Event+Timestamps

November proof-of-principle (1 of 4)

Written up in LAT-TD-08777-03

- Week of November 16, 2006: Eric, Patty, and I at General Dynamics.
- LAT separate from Spacecraft.
- Use Virtual SpaceCraft (VSC), but without GPS antenna.

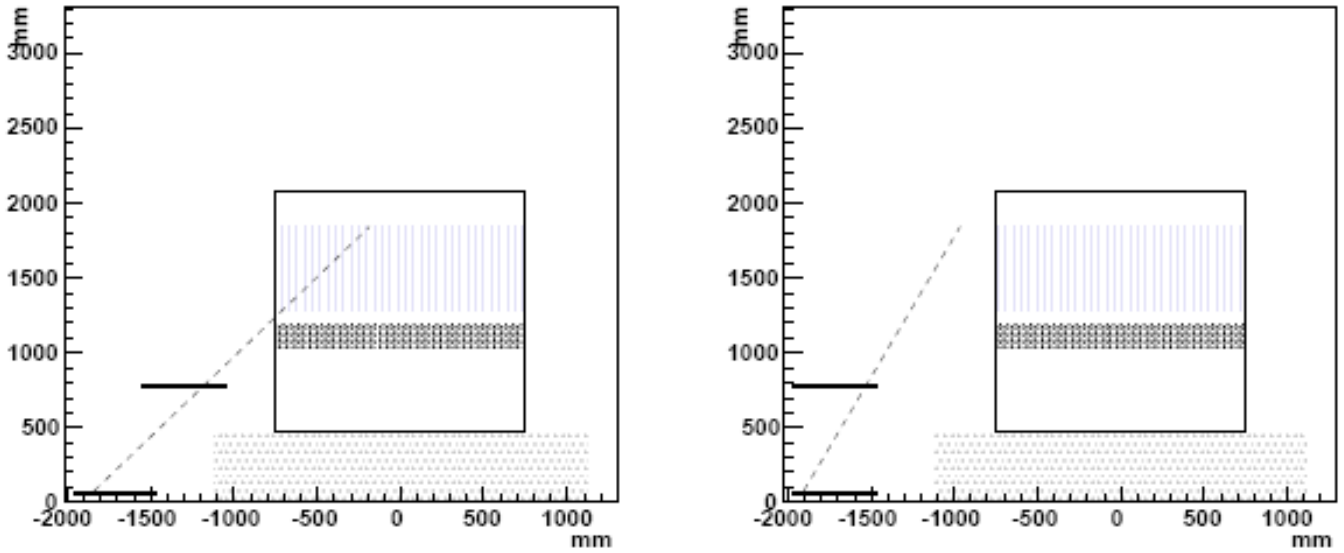


Figure 1: Muon telescope placement. Left: for run 77013003, with the top scintillator unbolted from the stand. Right: for runs '947, '948, '970. No coincidences were observed in data taken in this configuration.

November proof-of-principle (2 of 4)

- Aerial view of LAT and μ telescope.
- Extrapolate TKR tracks to scintillator heights:

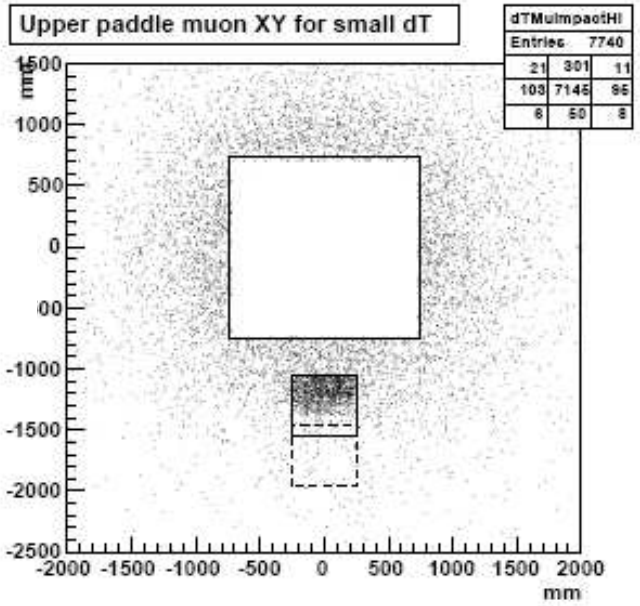
```
XhitHi = Tkr1EndPos[0] + (-Tkr1EndPos[2]+ZPaddleHi)*Tkr1EndDir[0]/Tkr1EndDir[2]
YhitHi = Tkr1EndPos[1] + (-Tkr1EndPos[2]+ZPaddleHi)*Tkr1EndDir[1]/Tkr1EndDir[2]
```

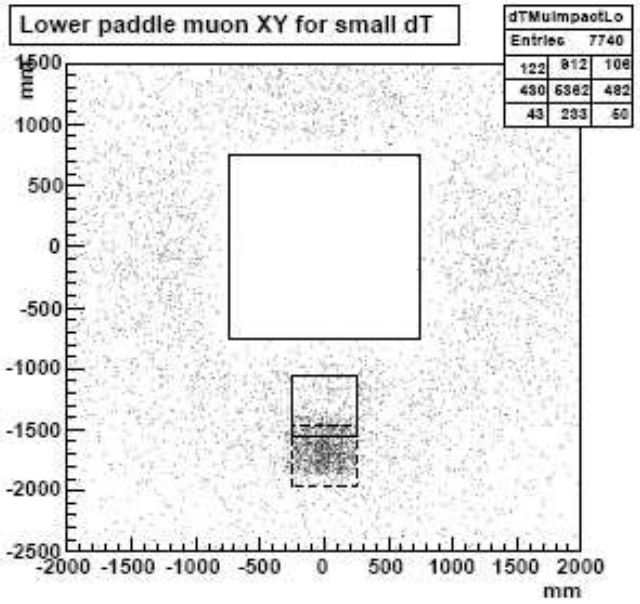
- .dT is time difference:

Then, to calculate dT, the time difference between the LAT and standalone GPS times, we

```
Double_t dT =
(double)(SecsBdx[iBdx]-TTCTSecs[iLAT]) + FracBdx[iBdx]-fraction[iLAT] ;
```

- Look for peak in dT distribution when you select tracks passing through Hi and Lo scintillators (next page).
- Here: Spatial coincidences when selecting small dT's.



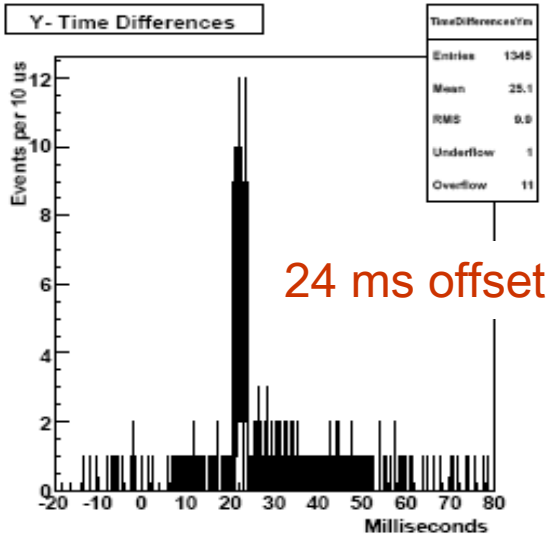


November proof-of-principle (3 of 4)

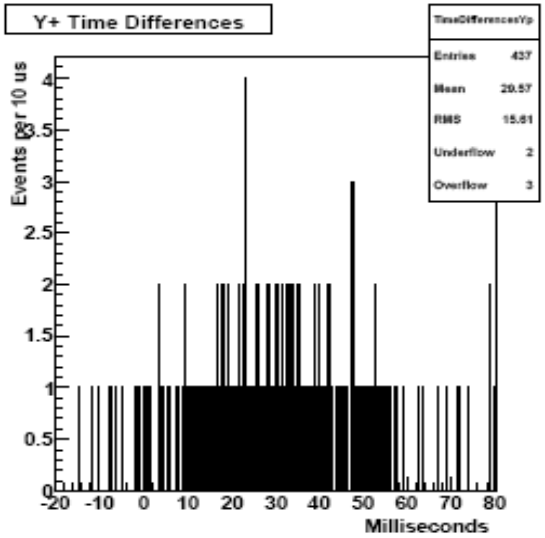
Side with telescope: signal!

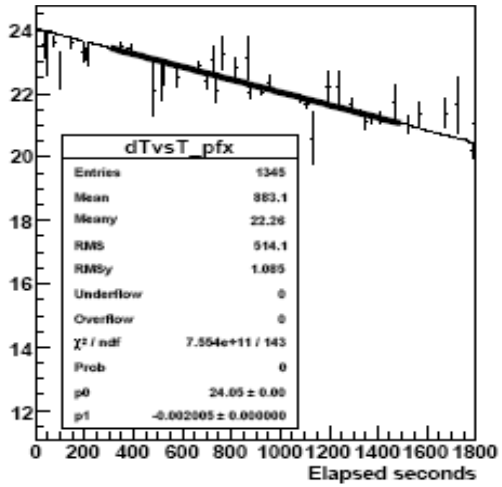
Other side : accidentals

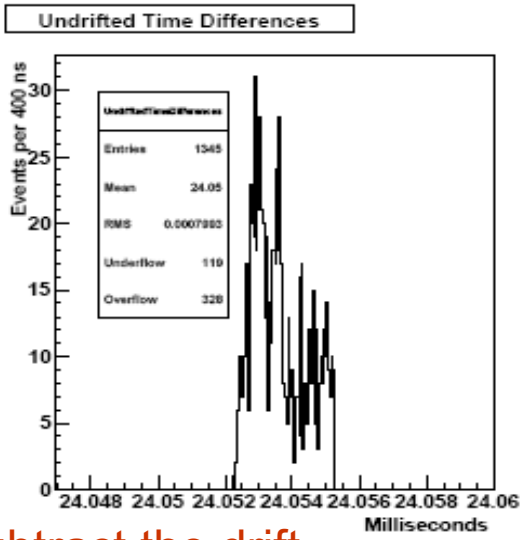
Signal vs time shows drift, 2.009 µs/s



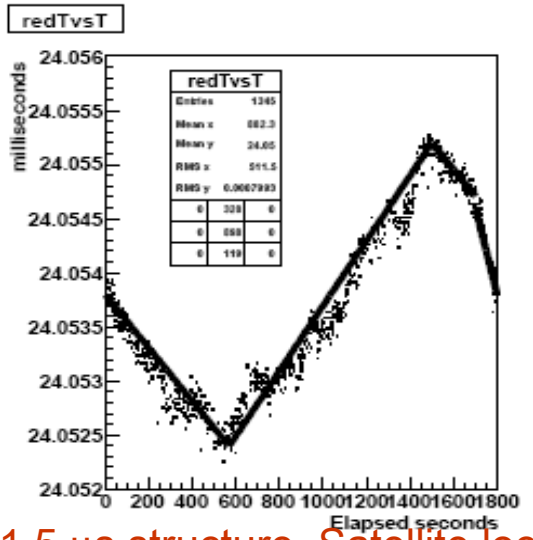
24 ms offset



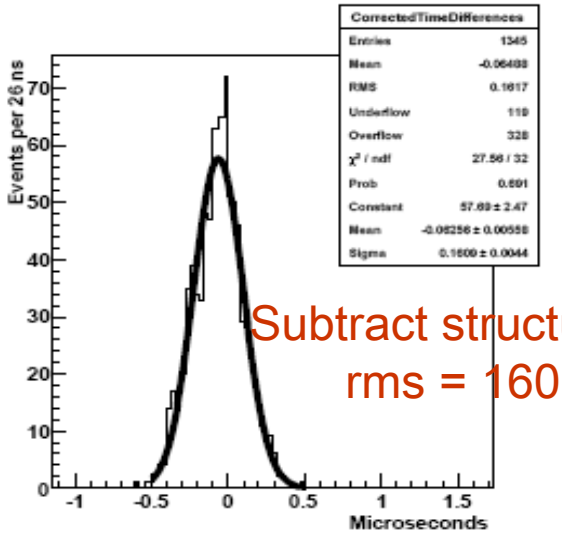




Subtract the drift.



±1.5 µs structure. Satellite lock?



Subtract structure, rms = 160 ns.

November proof-of-principle (4 of 4)

Written up in LAT-TD-08777-03

- Test scheme works – muons passing through both the LAT and the telescope provide sub-microsecond sensitivity.
- Observed drift and offset consistent with expectations for VSC without GPS satellite lock.
- 6 February 2006: project office at GSFC gives green light for “real” tests.

A First Look at GLAST LAT Absolute Times

Writeup on "blog" page, End2EndFeb07.pdf

- December: LAT integrated with observatory
- mid-February: Flight IEM installed, as well as GPS in C&DH package.

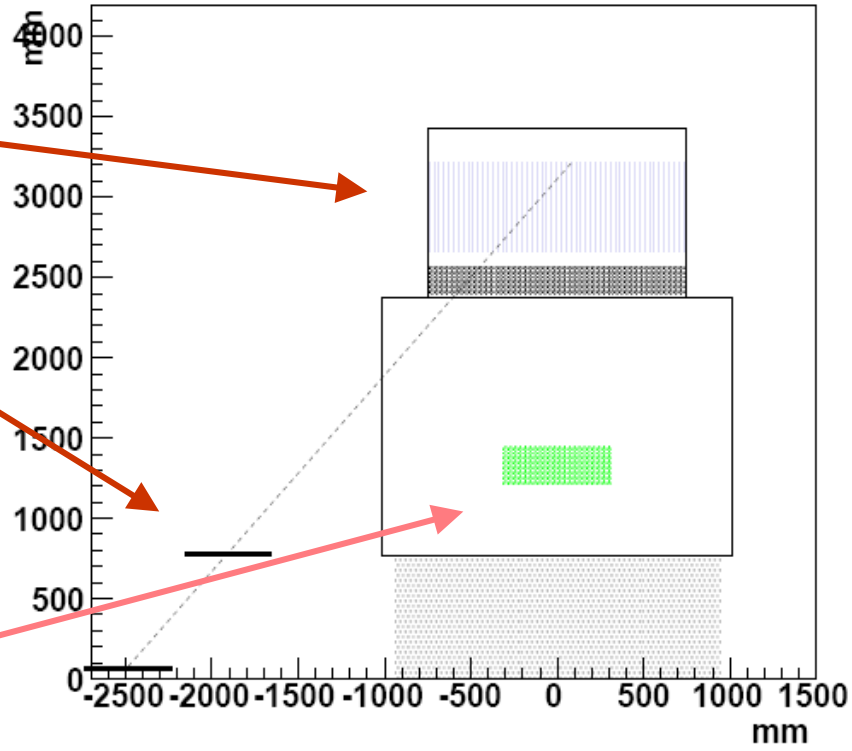
(C&DH = Control & Data Handling)

- Feb 22, 23: Eric & Patty take data in Arizona, Dave analyses in Bordeaux.

LAT on spacecraft, higher off the floor.

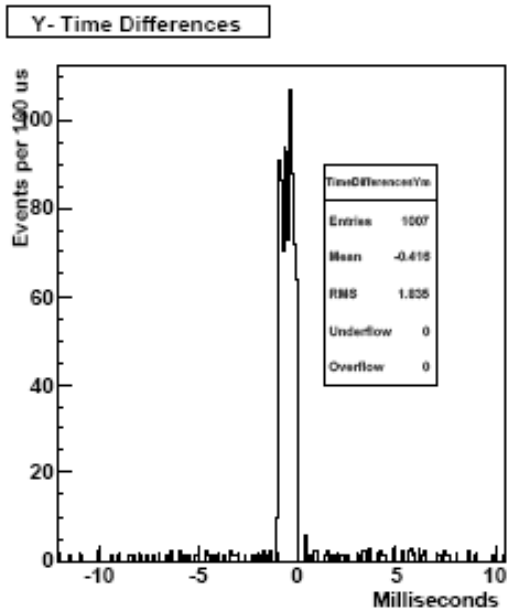
Top paddle cantilevered farther out.

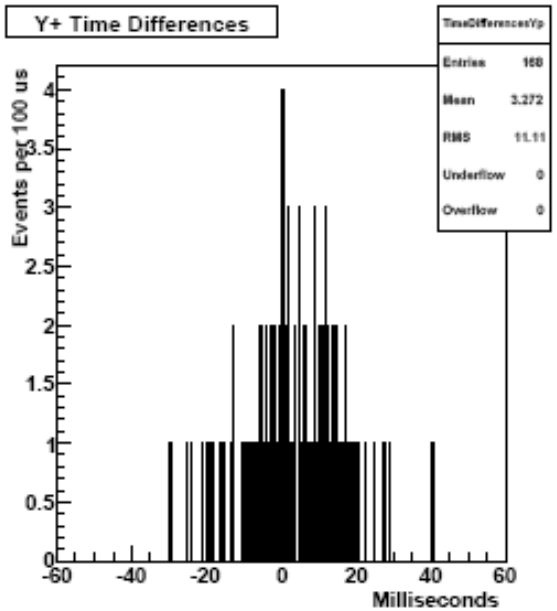
Add GBM geometry, for future use.

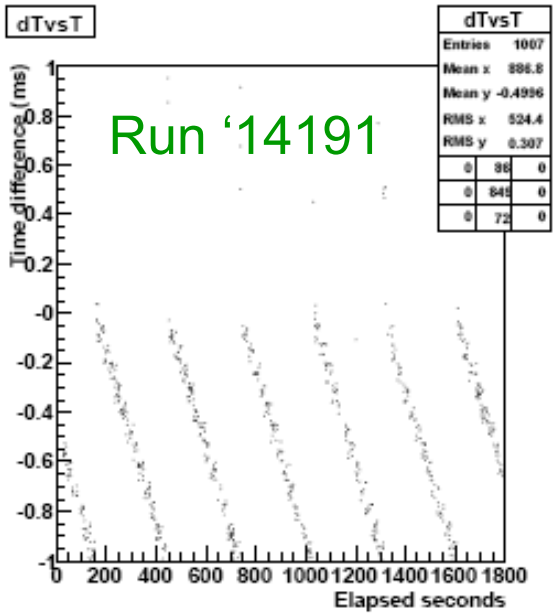


Something is wrong…

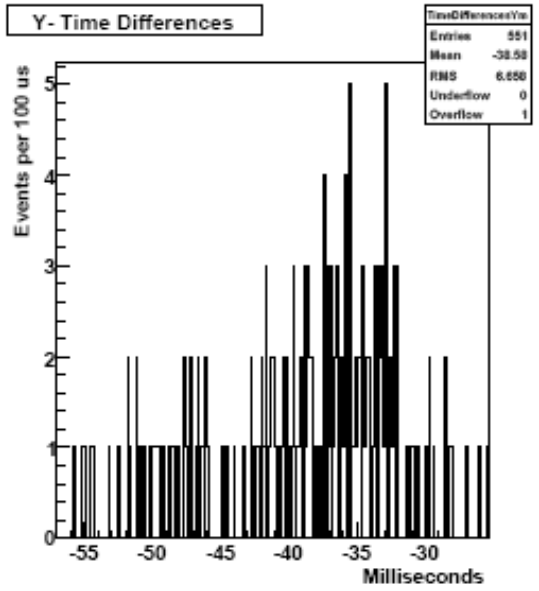
- 8 half-hour muon runs:
  - 4 for satellite side A, LAT config 1, and 4 for side/config B/2.
  - 4 with GPS lock, to test <10 μs absolute time requirement
  - 4 without GPS, to test <0.01 μs/s drift requirement.
- 0>dT>-1 ms sawtooth with ~290 s period during GPS lock runs.
- Need to add 1 second to Bordeaux times to match LAT

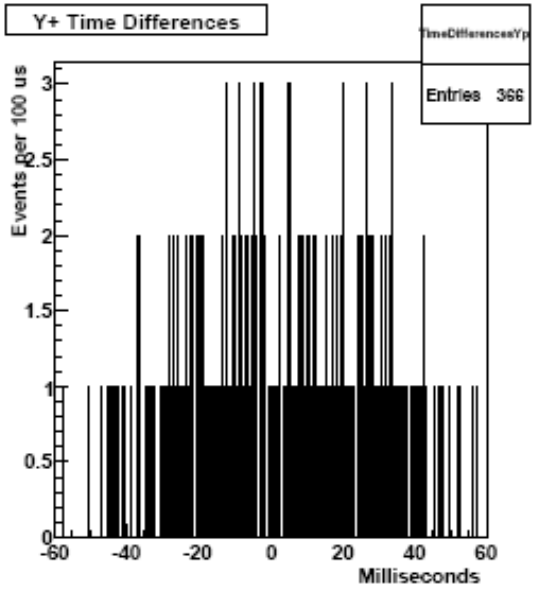


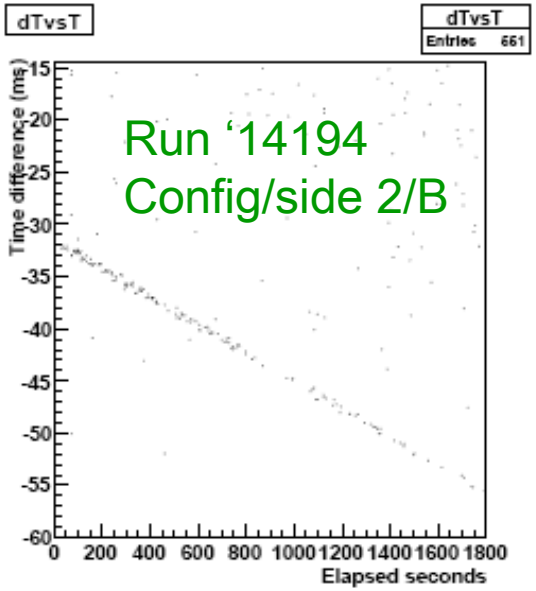


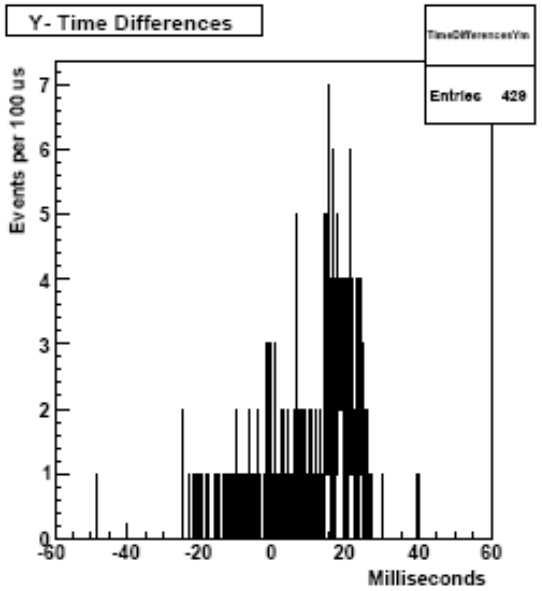


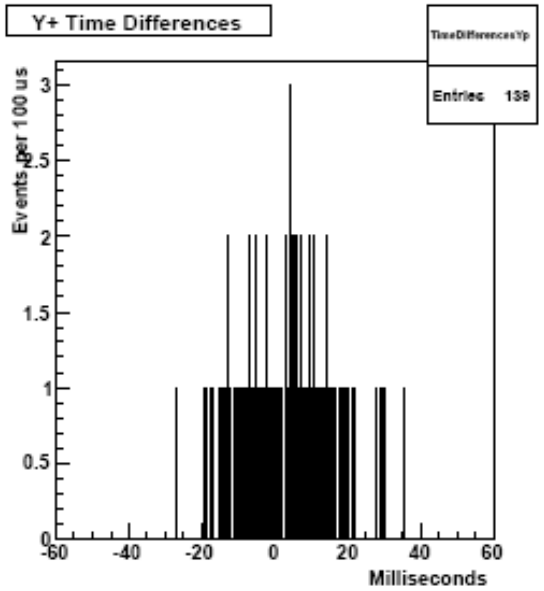
GPS unlock runs : no wrap-around

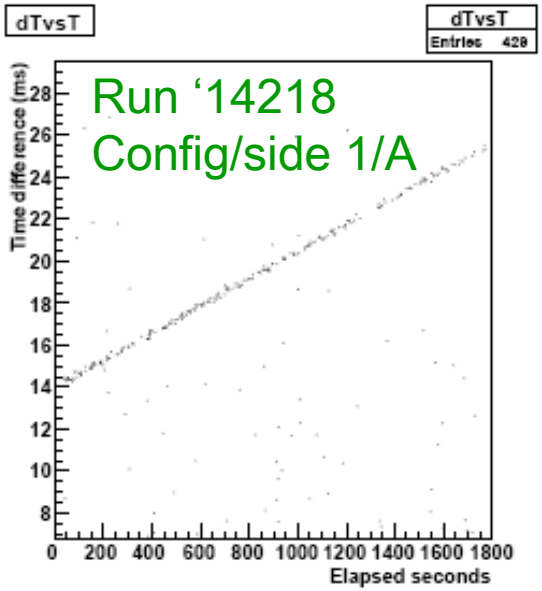












Details…

LAT run	GPS lock?	Config/Side	Diff. from 20 MHz ($\sim$ 50 ns ticks)	Observed dT drift	Wraparound?
77014191	Yes	2/B	110	$-3.4\,\mu s/s$	Yes
77014192	Yes	2/B	110	$-3.4\,\mu s/s$	Yes
77014193	No	2/B	306	$-13\,\mu s/s$	No
77014194	No	2/B	306	$-13\,\mu s/s$?	No
77014215	Yes	1/A		$-3.4\,\mu s/s$	Yes
77014216	Yes	1/A	115 to 125	$-3.4\,\mu s/s$	Yes
77014217	No	1/A	-70 to -60	$+7\,\mu s/s$	No
77014218	No	1/A	-60 to -50	$+7\,\mu s/s$	No

Table 1: The 8 data sets acquired February 22 and 23, 2007.

TicksPerSecond = scaler ticks between two successive PPS signals.

dTicks = 20,000,000 – TicksPerSecond

More details…

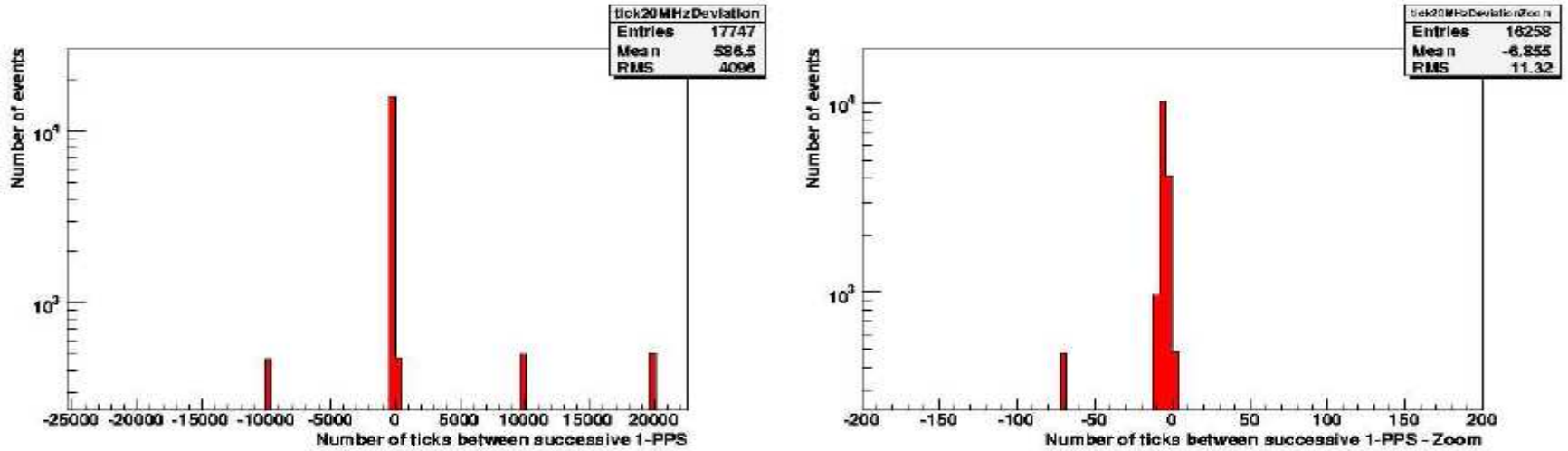


Figure 14: Run 77014210 (same S/C and LAT configuration as 14214, that is, GPS locked. `dTicks`, as in previous figure and text, plotted differently. Left: all events. Right: Zoom on central region. *Credit: A. Borgland*

- At wrap-around during GPS lock runs, dTicks acquires values of +/-10k and +20k ticks, i.e., +/-0.5 ms and +1 ms deviations from PPS.
- The wrap-around process lasts about 3 seconds.

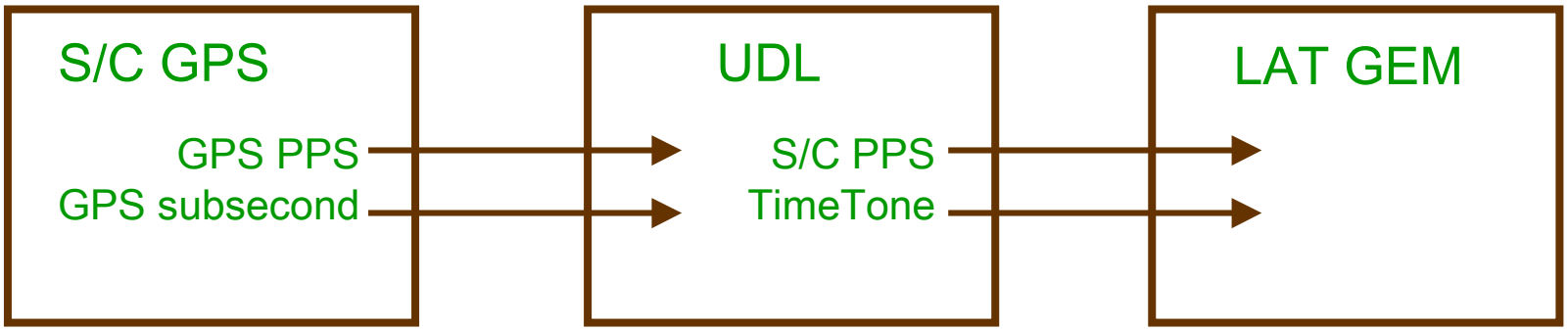
- Anders added the above plots to the pipeline digi report.

- We have several arguments to say that it is not the Bordeaux GPS system.

Diagnosis

- Once we were pretty sure of our result, we dumped it all on E. Siskind, who best knows LAT/GEM/Spacecraft circuitry (circuit diagrams hard to come by for the likes of me…)
- To make a long story short: the hypothesis that explains the observations the most easily is: *polarity inversion of the PPS signal between the spacecraft GPS and the UDL board?*

(UDL = Uplink DownLink, pronounced “oodle”, as in “oodles of noodles”.)



The UDL provides a reliable PPS to LAT & GBM even without GPS lock is lost, by “remembering” the “right” frequency from the previous 100 seconds.

Prognosis

- GSFC project office very supportive. We've discussed with GD engineers (GNC FSW, where GNC = Guidance and Navigation Control).
- As of yesterday: a S/C FSW modification has been identified ; it is undergoing internal review ; it would be included in the "next" build.
- S/C GNC has designed some tests & verifications at their end.
- They will request us to repeat the measurements.

Conclusions

- Will S/C GPS telemetry be available in ISOC "control room" ? In the MOC?
- Dave has a new GPS which he has used to re-verify the VME equipment (see End2EndFeb07.pdf) and its software gives lots of nifty diagnostics about GPS satellite configuration and resulting precision ("HDOP"=Horizontal Geometric Dilution of Precision, "PDOP" and that sort of thing) that it might be nice to have if we're ever scratching our heads about absolute pulsar phase.
- Oh by the way: Anders has added correct GEM-based times to the MeritTuple, if he hasn't already told you. From there to fits to Science Tools to Pulsars!

What, me worry?