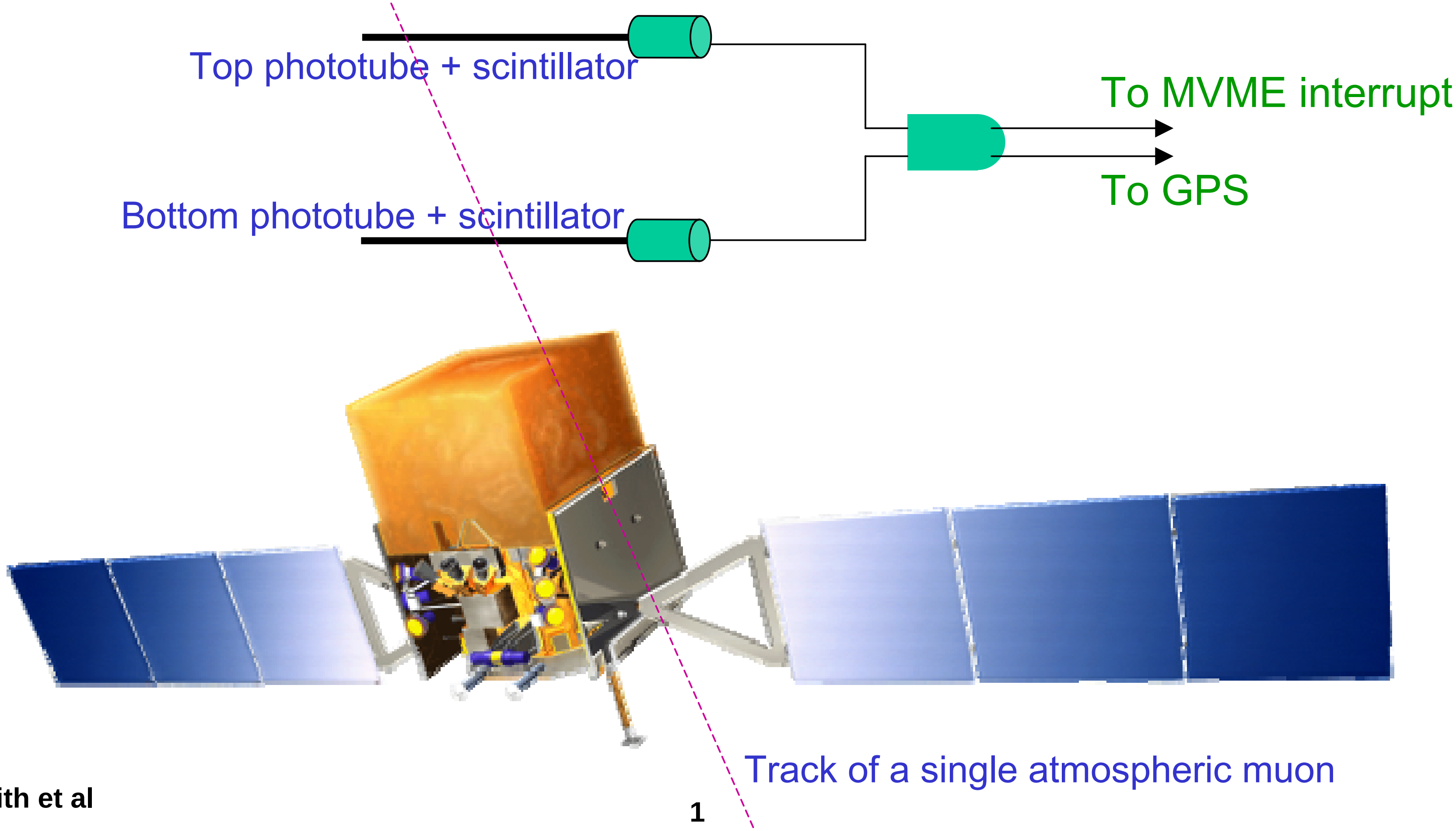
An end-to-end test of GLAST LAT absolute event times

David Smith, Denis Dumora, and Eric Grove. SO meet, 10 November 2006

With vital moral & material support from Neil Johnson & Dave Thompson.



What timing precision for pulsar science?

- Consider PSR J0218+4232: a millisecond pulsar (and therefore, a binary…) with a rotation period of 2.3 ms.
- Seen by EGRET (3EG J0222+4253 confuses the pulsar with the blazar 3C66A). The light curve had ~100 photons Kuiper et al A&A 359, 615-626 (2000).
- With LAT, aim for >25x more: a 50 bin phasogram is possible.
    - 2.3 ms/50 ➔ 50 μS per bin.
- *The LAT goal is 10 μS absolute precision.*

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- Timing *offsets* gives phase offsets. A little *jitter* smears peak widths, and a lot of jitter renders a pulsed signal *undetectable*.
- Light curve shape versus energy is *rich* in information about beam geometry, and thus, acceleration zone and mechanism. (Crab 2nd peak creeps 3 ms towards 1st peak above 1 GeV, see Kuiper et al A&A 378, 918-935 (2001))
- Jitter to be smaller than pulse width (in radio, often <5% of a rotation period).

Why worry?

- The experienced and competent authorities are unanimous: getting absolute event times *right* is really hard.

- CGRO, USA, CHANDRA, and XMM all had problems, at instrument level (hardware & software) or at the spacecraft level (gps reception, telemetry packets).

- For details on this (and the rest of the talk) see
  https://confluence.slac.stanford.edu/display/CAL/Event+Timestamps

  (hereafter referred to as the "timing web page")

What, me worry?

How does LAT tell time?

- The spacecraft interprets signals from GPS satellites to obtain absolute time and position (XMM and CGRO got time from ground stations, and position from orbital elements).
- The spacecraft delivers a TimeToneMessage to LAT, using CCSDS* standard protocol.
- The spacecraft also delivers a Pulse Per Second ("PPS") signal for synchronization, precisely, at second-to-second rollovers.
- .LAT latches 20 MHz (50 ns) GEM scaler ticks when PPS received.
- .LAT event triggers also latch the GEM scaler ticks. Read out with event.
- Scalers count to 2^{25} = 33,554,432 = 1.68 seconds, more on rollovers later.
- The CCSDS and GEM data wind up in our digi.root files.
- The "timing web page" cites talks by Anders, Warren, and me on this.

* See ccsds.org

What's already been tested?

- Gregg Thayer demonstrated that the offset between PPS and a synchronous periodic external trigger is stable & constant. The LAT 13x tests to meet Level 3 req't 5.2.11 are described in LAT-MD-02730.

- Gregg's tests would not notice if the i^{th} timestamp belonged to the $(i-1)^{th}$ event, as happened for the CHANDRA HRC.

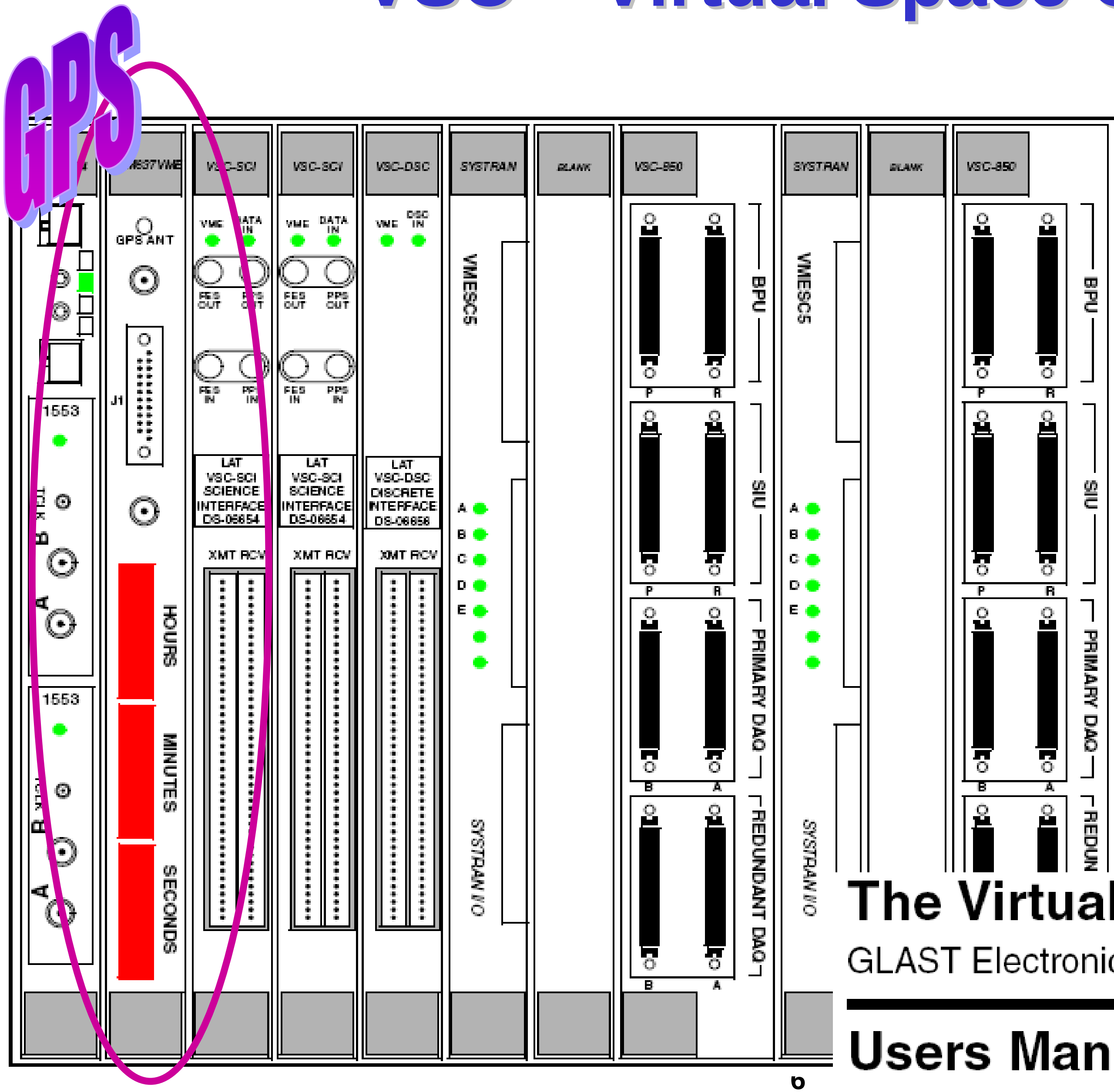
- Gary Godfrey used Van de Graaf data to further demonstrate LAT timestamp stability (e.g., no drifts).

  (some details on the timing web page.)

- The GPS in the VSC (see next slide) gave accurate absolute times after reset, then the time left to drift (GPS antenna unused).

- GLAST + LAT is virgin territory.

VSC = Virtual Space Craft



VSC is a VME crate with some ordinary and some special modules.

CELESTE VME GPS (Datum bc637) is very similar to the revised TTM637 used in the VSC.

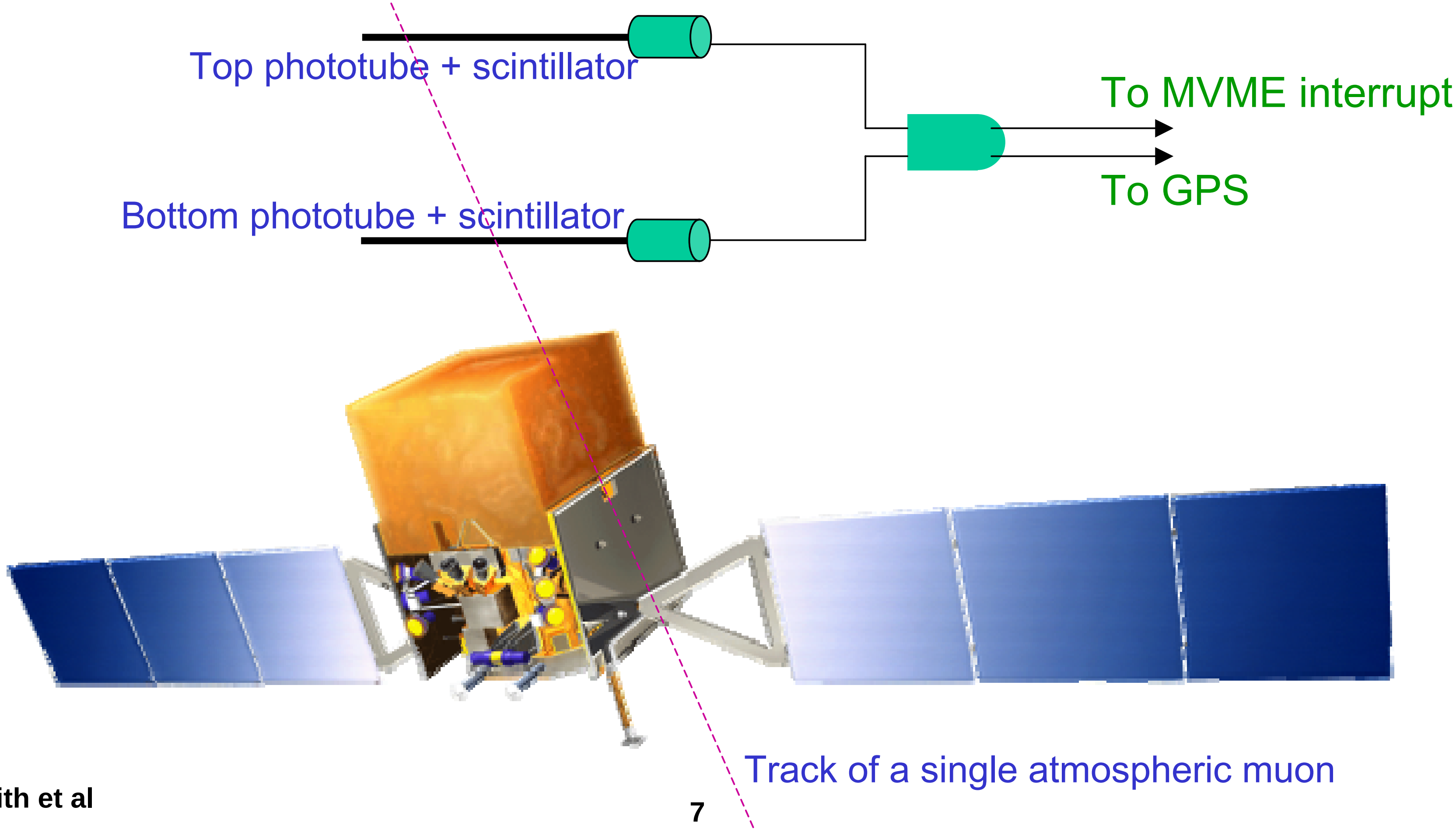
The Virtual Spacecraft (VSC)

GLAST Electronics group

Users Manual

Our end-to-end test

A muon telescope next to the LAT triggers an acquisition system with a GPS in it. For muons passing through both the LAT and the muon telescope, compare the dates from the two systems.



The muon telescope

- NRL muon telescope used during calorimeter fabrication.
- Each scintillator is $(50\ cm)^2$.
- Two photomultiplier tubes per scintillator (total of 4).
- High voltage supplies and settings, NIM discriminators and settings, and coincidences provided by NRL.
- The telescope will be on the floor, next to and slightly lower than the LAT. (Not above, or above & below like we once said).
- Rate at NRL was 10 Hz for a 1.5 CAL height scintillator separation. Perhaps half or a third for LAT+telescope coincidences.
- A small number of events suffices to test much.

(half hour @ 5 Hz ➔ ~10k events…)

VME and GPS

- D. Dumora and D. Smith saw the Crab optical pulsar with CELESTE. Correct absolute phase means we got the times right.
- Using e.g. http://nist.time.gov/timezone.cgi?UTC/s/0/java we know we're still right to better than a second (e.g. Leap second okay). Prove better than that? A couple of ideas, little done.
- CELESTE GPS obsolete – incompatible with Spectrum antennas. Use spare VSC module instead (on loan from SLAC – thanks to G. Thayer & G. Haller) .
- Motorola MVME 172 crate controller running Lynx (now "Lynux") OS.

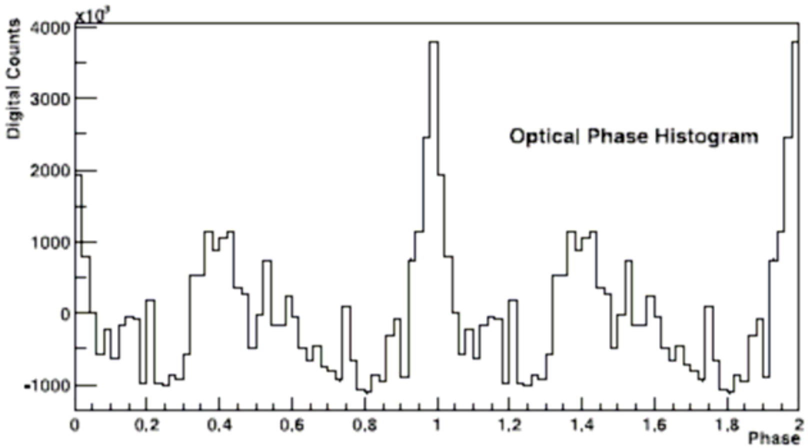


FIG. 16.—Phase histogram for the optical Crab data

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MEASUREMENT OF THE CRAB FLUX ABOVE 60 GeV WITH THE CELESTE CERENKOV TELESCOPE

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Received 2001 July 13; accepted 2001 October 10

VME GPS readout

Table 3-4

Bit #	15-12	11-8	7-4	3-0
EVENT0 Field	Not Defined	Not Defined	Status (Note 1)	Days Hundreds
EVENT1 Field	Days Tens	Days Units	Hours Tens	Hours Units
EVENT2 Field	Minutes Tens	Minutes Units	Seconds Tens	Seconds Units
EVENT3 Field	10E-1 Seconds	10E-2 Seconds	10E-3 Seconds	10E-4 Seconds
EVENT4 Field	10E-5 Seconds	10E-6 Seconds	10E-7 Seconds	Not Defined

Note 1:

bit 7	1 = RTC Battery failure	0 = RTC Battery OK
bit 6	1 = frequency offset > 5E7 in Mode 0	0 = frequency offset < 5E7 in Mode 0
	1 = frequency offset > 5E8	0 = frequency offset < 5E8
bit 5	1 = time offset > X microseconds	0 = time offset < X microseconds
	(X = 5 for mode 0, X = 2 more all other modes)	
bit 4	1 = flywheeling (not locked)	0 = locked to selected reference

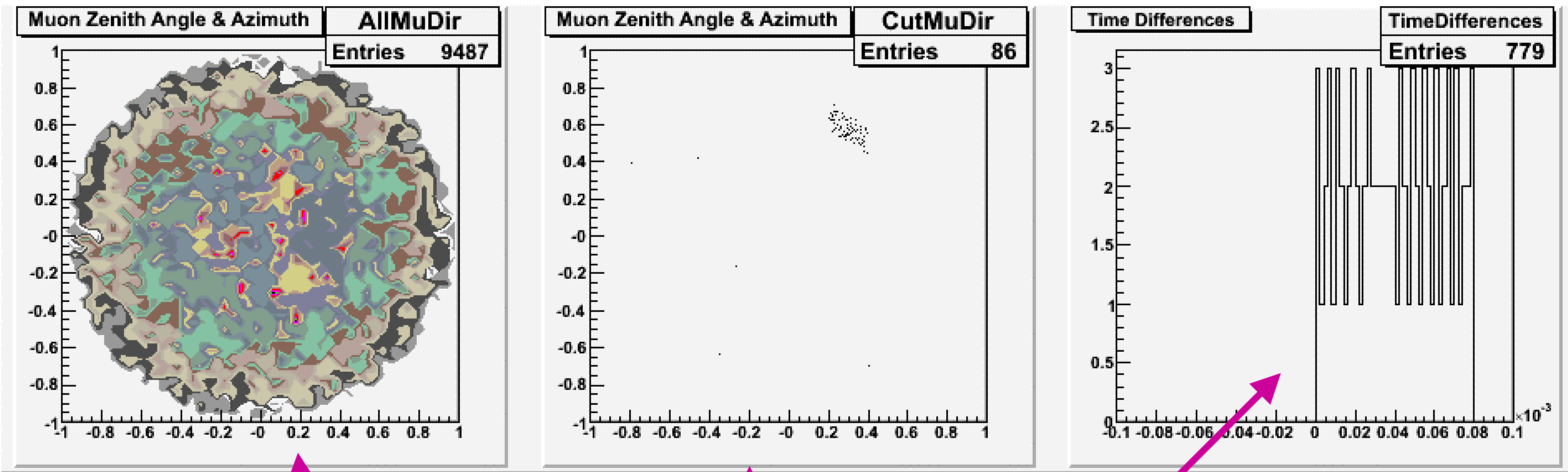
3-4 TTM635VME/TTM350VXI Time and Frequency Processor (Rev. B) Symmetricom, Inc.

The "analysis" algorithm

- Bordeaux DAQ writes an ascii file with one date per muon trigger. Last digit is 0.1 µs.
- A root macro reads the ascii file and the SVAC tuple for that LAT run (so we need to wait for the pipeline. For internet access, probably have to leave SASS FoF – back to the hotel for data analysis?).
- 1st pass: find where the muon paddles are in TKR space by plotting events with $|T_{bdx} - T_{LAT}| < 100$ µs.
- 2nd pass: for TKR tracks from that direction, make histogram of $|T_{bdx} - T_{LAT}|$.
- If all is well, you'll see a spike at zero.

Practice Analysis

- Did a "pretend" data run and analysis, using FSW muons from NRL (run 77005390, 27 May, 2006, LAT is vertical)
- Faked Bordeaux dates by putting LAT dates into an ascii file. Pretended muon telescope was above and off to the side. Faked a problem by adding 1 μs per event.



AllMuDir->Fill(Tkr1EndDir[0], Tkr1EndDir[1])

Same, for $|T_{bdx} - T_{LAT}| < 100$ μs

$|T_{bdx} - T_{LAT}|$ for events in that piece of (Tkr1EndDir[0], Tkr1EndDir[1]) space.

A remark about LAT times

- In May & June, Anders Warren and Dave (me!) made IA presentations on how to calculate absolute time from GEM etc variables.
- The timing web page explains an "improvement" we discovered in October.
- Anders, Warren, Eric C, Eric S, and Gregg have, in the last 10 days, found some other algorithm improvements, concerning scaler rollovers, datagram creation timestamps, and the like.
- Soon, this "official, properly calculated absolute time" will be in the pipeline release and thus in the tuples.
- All this to say – work-in-progress. A few weird $|T_{bdx}–T_{LAT}|$'s won't necessarily mean that there is a real problem.

sample LAT times

- Anders kindly sent me checkDigi.C, their current state of the art.
- Run 077012543 from 1 Nov 09:06:45

checkDigi.tar is on the timing web page

borpc49% /bin/date -u -d "01 Nov 06 09:06:45" '+%s' ➔ 1162372005

Processing checkDigi.C...

Event index	GEM ID	CPU	Datagram Sec ID	CCSDS time	Event time
0	14780	1	0	1162372094.5722420	116 2372086.9203353
100	16676	1	0	1162372094.5722420	1162372090.7715082
200	18891	1	1	1162372101.8489671	1162372095.4053402
300	21057	1	1	1162372101.8489671	1162372100.0716181
400	22913	1	2	1162372108.6632769	1162372103.8877654
500	25399	1	3	1162372116.2267051	1162372108.9662673
600	27510	2	3	1162372115.3770850	1162372113.3687825
700	29420	2	4	1162372122.3734560	1162372117.3073518
800	31836	2	4	1162372122.3734560	1162372122.2417018
900	33974	2	5	1162372129.2213240	1162372126.6169515
1000	36141	1	5	1162372132.6089230	1162372131.2344065

Data packets with same sequence number but from different CPUs

Data packet times are *after* the many event times within a given packet.

Not shown: many GEM event id's missing, filtered on-board.

Calendar

- This week: SLAC VME module may arrive in Bordeaux (shipping snafu).
- Next week: Eric G and Dave S in Arizona – install muon telescope; setup VME; Dave training, badge etc. Denis not going because of issues for non-US citizen access to the Factory of the Future (=FoF).
- Goal: leave a working system in place on Friday 17th.
- The *real test* during muon runs during CPT after spacecraft installation of C&DH (=Command & Data Handling) hardware (="IEM", Instrument Electronics Module) & software. Mid-December? January? Not clear yet…