Early Pulsar Observations and GLAST LAT Performance

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Abstract

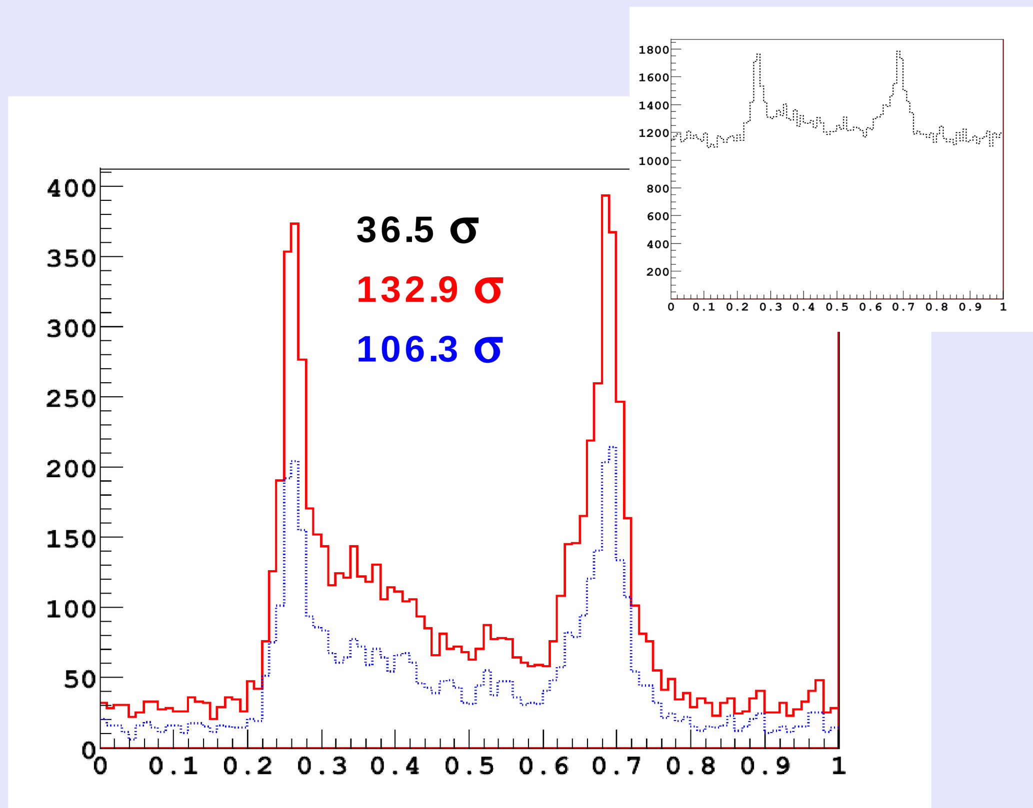
Vela is the brightest pulsar known in the GeV gamma ray range, yielding a clear signal in less than a day of observations with the Large Area Telescope (LAT). The striking pulsed signature provides a rich opportunity to compare the real gamma ray response of the GLAST LAT to expectations from the highly- detailed Monte Carlo detector simulations. This is critical because all flux and spectral measurements with the LAT rely on the acceptances parametrized by the Instrument Response Functions (IRF), extracted from the simulations. We use the off- pulse signal to estimate the background level in the data, and hence deduce the number of gamma rays in the peaks. We then successively apply the analysis cuts used to identify gamma rays and to reject background, comparing at each step the observed and predicted yields. This procedure is repeated for gamma rays incident on different parts of the LAT and at different angles. Incidence angles will vary widely during normal observations in sky survey mode, and a 2- week pointed mode observation during the Launch & Early Operations phase (L&EO) favors yet a different part of phase space. This method is expected to yield Monte Carlo validations complementary to those already obtained at CERN and at other particle accelerators. Finally, ground tests of the GLAST LAT absolute time stamps will be discussed in the context of Vela observations.

Event selection

We will observe the Vela pulsar during the Launch & Early Operations phase. The raw LAT data includes a charged particle background and event selection is necessary to clean up the data as shown in the figure where the expected time profile is plotted for a few different data selections. The present work is based on the DC2 data. The event selection and analysis performances are still under study.

- "class A" cuts allow a very clean selection keeping only gamma- rays (~99.7 %).
- "Loose" cuts allow a larger number of photons but keeps more charged particle background. In the case of pulsars, the time profile gives further information and the significance of the signal is increased by a factor $1/\sqrt{\Delta\Phi}$ where $\Delta\Phi$ is the pulsed fraction in the time profile. This cut is particularly well suited for faint sources (see D. Parent's poster, same symp.)
- Note that the pulsed signal is visible even when using the raw L1 data.

By applying cuts sequentially, and comparing the efficiencies obtained in the data with those predicted by the Monte Carlo, we will validate the Instrument Response Functions (IRFs), to decrease the systematic uncertainties on LAT flux measurements.



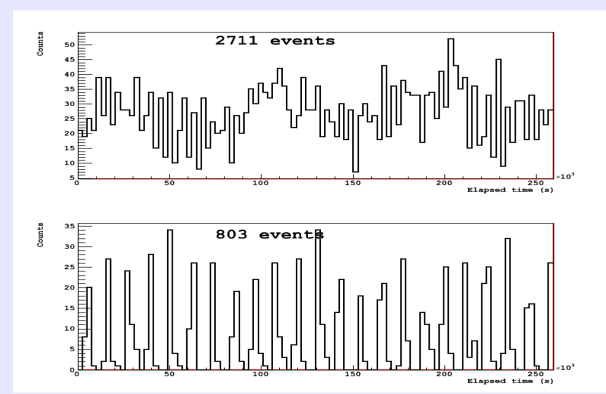
Vela time profiles from 2 weeks of DC2. Red is « loose » cuts, blue is « class A ». The black inset corresponds to "L1" data transmitted to ground, after selection by the On Board Filter, OBF.

Remaining events after selection for 2 weeks of DC2. ROI of 2 degrees around Vela.

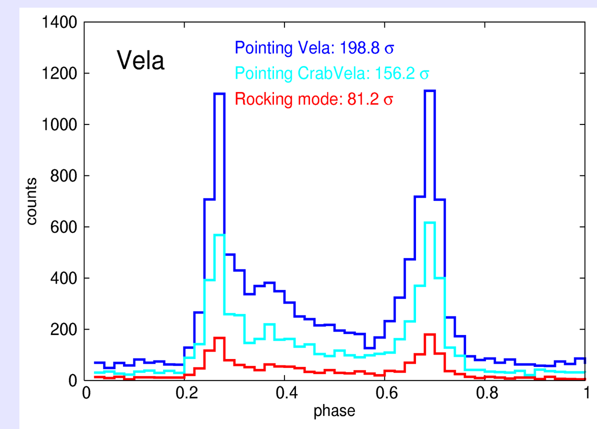
	#Charged particles	All gamma	Diffuse gamma	Vela
No cuts	**108512**	**16622**	**3034**	**12803**
Loose cuts	**147**	**8468**	**814**	**7569**
Class A cuts	**16**	**4716**	**390**	**4302**

Pointing versus Survey Mode

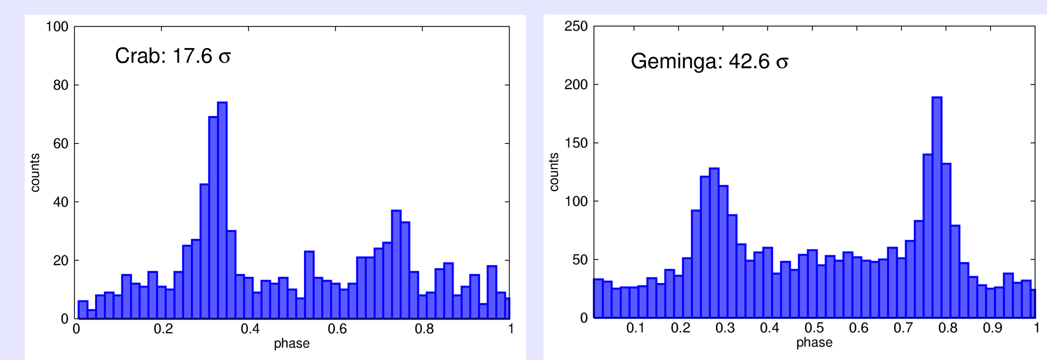
Here we explore bright pulsar rates expected during possible pointings. GLAST will mainly be in survey (scanning) mode during the first year, but during L&EO pointing is under discussion. We studied observations pointed midway between the Crab and the Vela pulsars ("CrabVela"), and directly at Vela. All data have been generated using the current version of the "Gleam" software for an observation time of 6.5 days. The best reconstructed events (class A) are kept in a Region Of Interest (ROI) of 1 degree.



Number of events as a function of the elapsed time for 1 day of Vela. Upper plot is for "CrabVela" pointing, lower plot corresponds to the survey mode.



Time profiles from Vela in several pointing configurations.



The significance is defined as

$$N_\sigma = Signal/\sqrt{Background}$$

Background is extracted from the off-pulse part.

Time profiles from the Crab (left) and Geminga (right) when pointing "CrabVela"

A hardware end- to- end test of event absolute times

Gamma ray pulsar searches require photon absolute times to be accurately recorded. GLAST requires < 10 µs precision. On- orbit dating is notoriously difficult [1,2]. Here we describe ground tests in progress [3].

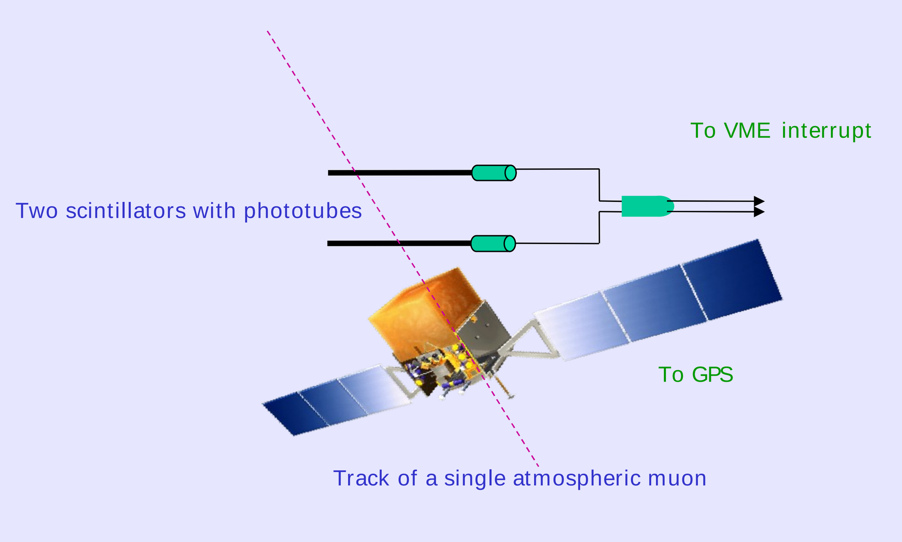
A GPS system on the GLAST satellite sends a timestamp and a Pulse Per Second (PPS) synchronization signal to the LAT and to the GBM. 20 MHz scalers in the LAT record the PPS and event arrival times. The satellite position and event times are included in the datastream to ground.

During satellite integration at General Dynamics C4 Systems in Arizona, scintillator paddles with photomultipliers have been placed next to GLAST (Figure 1). Cosmic ray muons trigger the readout of a GPS in an independent acquisition system, previously used to detect the optical Crab pulsar [4]. For muons passing through both the LAT and the muon telescope, we compare the dates recorded with the two systems.

Preliminary tests were run in November, 2006, before the LAT was mated to GLAST. Emulating the GLAST GPS was test equipment with known time drifts and offsets. Figure 2 shows the difference between muon event times recorded with the LAT and with the standalone equipment. After drift corrections, agreement at the < 3 µs level is obtained, demonstrating that the scheme will allow detailed verification of the timestamp system after the satellite GPS system is completed, in the weeks following the Symposium.

[1] S. Murray et al, ApJ 568, 226-231 (2002).
[2] M.G.F. Kirsch et al, Proc. SPIE 5165, 85-95 (2004).
[3] D.A. Smith, J.E. Grove, D. Dumora LAT-TD-08777-03 (2006).
[4] M. de Naurois, J. Holder et al., ApJ 566, 343-357 (2002).

Figure 1: Left, conceptual sketch. Right, scale drawing (mm) of LAT on support stand, showing scintillator paddles (dark horizontal lines), silicon tracker (light hatched), calorimeter (dark hatched), and a typical muon path (diagonal).



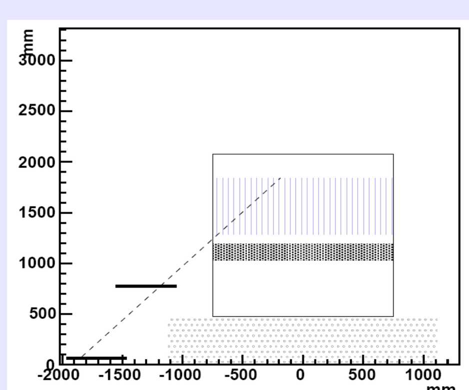
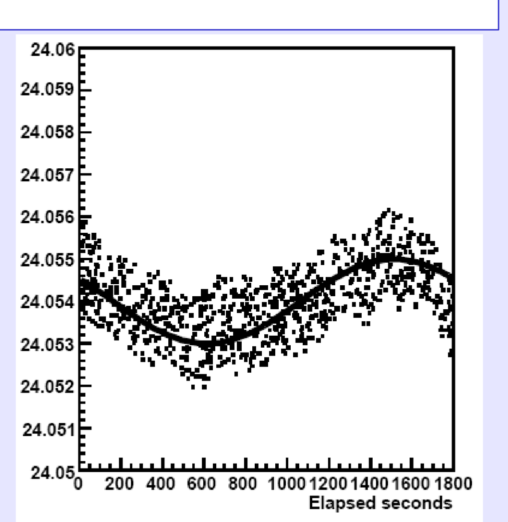


Figure 2: Difference in 1306 muon arrival times (ms) from the LAT and the standalone system, over a half-hour. The offset is an artifact of non- flight material used for proof- of- principle. The method is sensitive at the few microsecond level. The upcoming flight-hardware tests will provide a powerful end- to- end verification.



Other pulsars to observe during the L&E0

Although Vela would be the main source to study during the L&EO phase, the wide field of view of GLAST gives the opportunity to observe other pulsars during these two weeks of special operating mode.

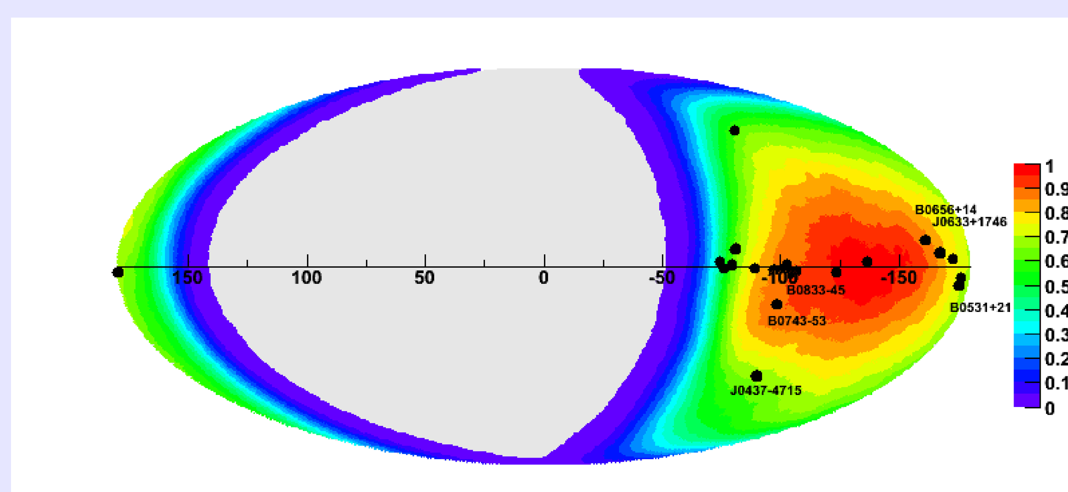
Assuming

- a 14 day pointing midway between Vela and Crab.
- an expected γ ray flux scaling as $\frac{\sqrt{\dot{E}}}{d^2}$
- and a "Class A" event selection

The expected number of photons detected from pulsars with $\dot{E} > 10^{34}$ erg/s in the observed area has been calculated with respect to the exposure of the source.

This rough flux hypothesis gives 22 sources with more than 10 photons and 6 with more than 100 photons. Among these 6 bright pulsar candidates, 3 are well- known and have already been detected by EGRET (Vela, Crab, Geminga) allowing a cross check for pulsar dating procedures.

Rank	Name	Normalized flux	Expected photons
1	B0833-45	1.000000	10293
2	J0633+1746	0.223700	2092
3	J0437-4715	0.179000	1355
4	B0531+21	0.171700	1384
5	B0656+14	0.074220	727
6	B0743-53	0.053730	542
11	B1055-52	0.010700	71
20	B1046-58	0.006076	41
22	J0940-5428	0.005072	46
23	J0538+2817	0.004762	37
25	J1124-5916	0.003804	18
27	J0834-4159	0.003656	37
29	B0906-49	0.003502	34
35	J1046+0304	0.003020	20
40	B0740-28	0.002796	30
48	J0855-4644	0.002231	22
53	J1105-6107	0.002041	11
57	B0611+22	0.001843	16
61	J0857-4424	0.001372	13
62	J0729-1448	0.001367	15
63	J0613-0200	0.001249	12
162	B0540+23	0.001528	12



Pulsars with more than 10 photons expected during the L&EO phase.
Labeled pulsars are those with more than 100 photons.
Background color gives the normalized exposure map scale during the two weeks of pointing.

Pulsars with more than 10 photons expected during the L&EO phase.
Left column gives the rank of the pulsar in a $\frac{\sqrt{\dot{E}}}{d^2}$ sorting
Third column gives the expected γ ray flux in Vela γ ray flux units.
Fourth column gives the expected number of photons detected by GLAST during the L&EO