The current status of the move to KHz Laser Ranging at Herstmonceux

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Completed

- Replacement of SR620 timer with an Epoch Timer (July 2006).
- Software/Hardware to read and control ET.
- Verification of Linearity and jitter of ET.
- Purchase and installation of a KHz Laser(2005).
- Software/Hardware to arm C-SPAD at KHz rate.
- Software to collect, plot and archive KHz data, detect track in real-time, control telescope and safety radar, interact with observer and control beam divergence, ND, Iris and beam steering.

Incomplete

- Control of Laser & safety systems for single manning of system.
- Implementation of software control of Laser & overlap control.
- Reduction software.
- Full Software package for KHz ranging.
- Ranging to Champ/Grace
- Daytime Glonass. GPS/Etalon day or night
- Full implementation of monitoring software for ET.
- Viewing laser in daytime – we can see the beam by moving our night-time camera
- Software to pre-arm C-SPAD for the calibration target inside the dome it works but not 100%

Herstmonceux Event Timer

- We have used the commercially available Modules from Thales Systems – 2 timing and 1 clock module
- Separate power supplies for each module.
- 8-Euro-Cards containing 15 power supply units, all optimised for their specific purpose.
- Forced air cooling to remove heat from these power supplies, and provide good air flow around modules
- ET can accept either NIM or TTL start pulses from laser and stop pulses from the C-SPAD
- It accepts a 1-pps pulse from GPS to enable epoch synchronisation of the timing modules.
- It has an on-board 1 KHz pulse on the PCB to determine the timing difference for the two modules.
- It outputs to the modules a standard ECL pulse into 50Ω @ -2Volts

Herstmonceux Event timer

- We get 5ps jitter for start and stop.
- Comparisons with our SR620s give the same results as identical tests carried out with PPET in 1998.
- Comparisons with SR620s have confirmed the non-linearities in the SR620s and have enabled us to quantify errors in our system calibration back to 1994

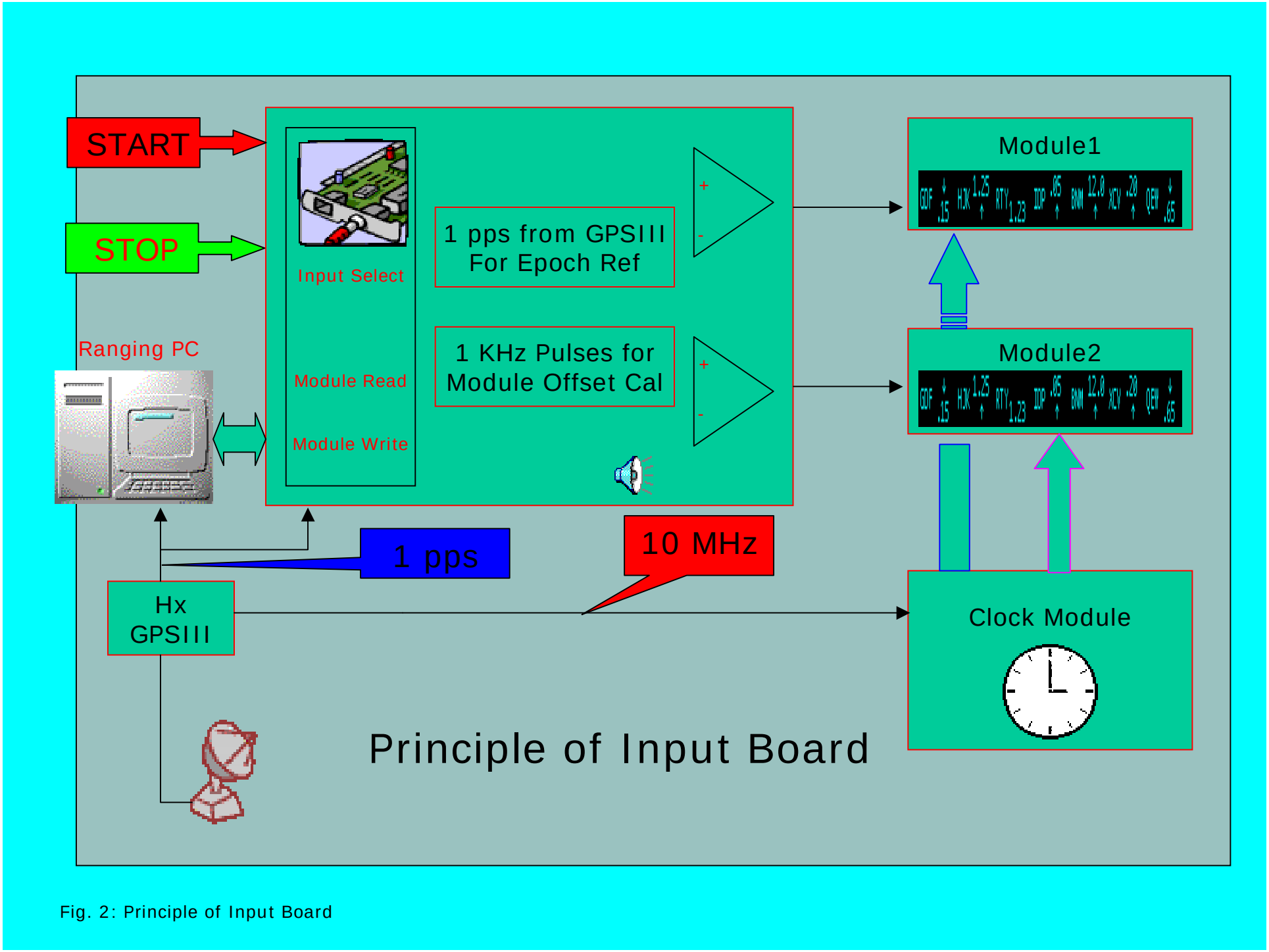


Fig. 2: Principle of Input Board

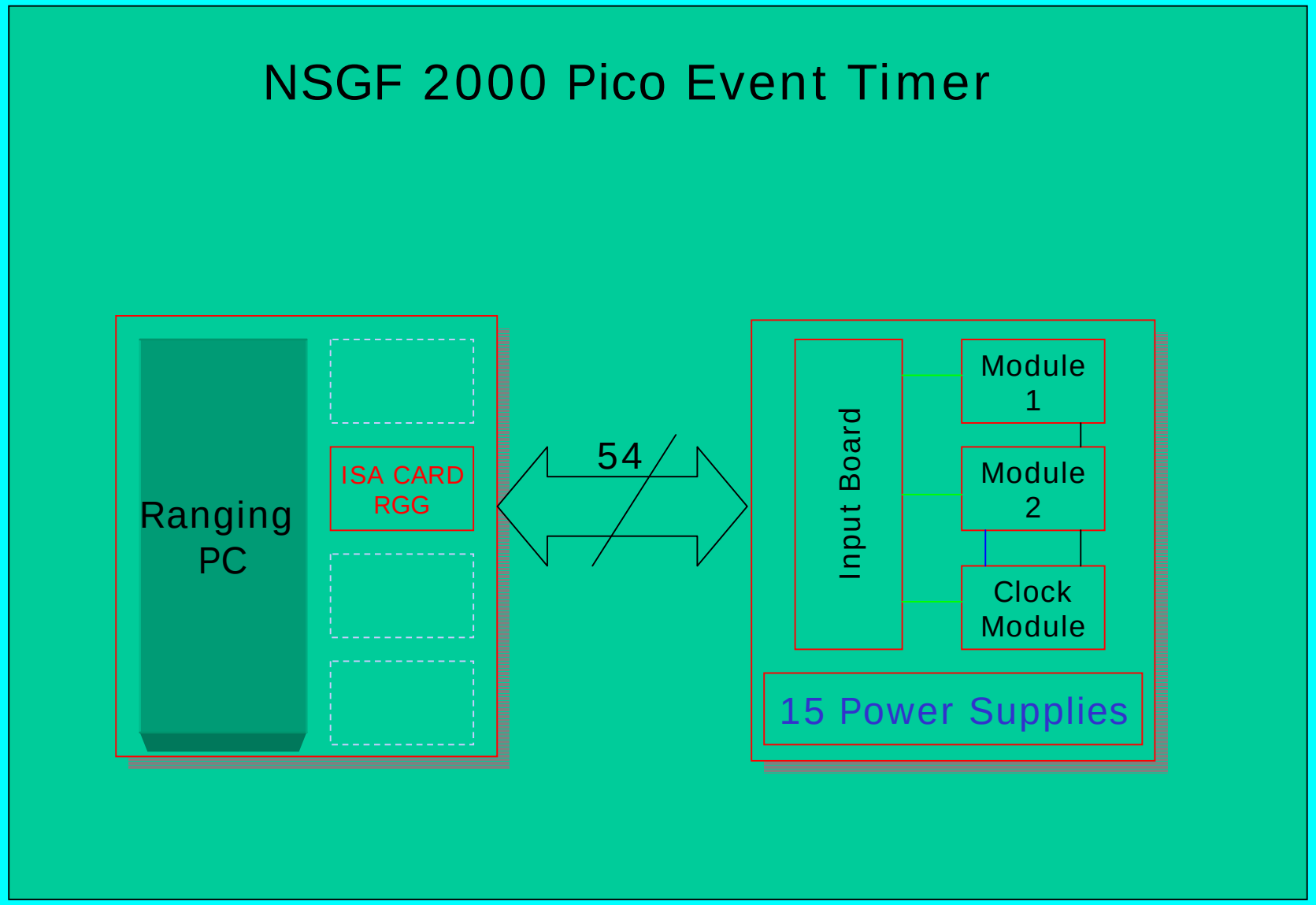


Fig.1: General Setup Block Diagram

Fully programmable ISA card

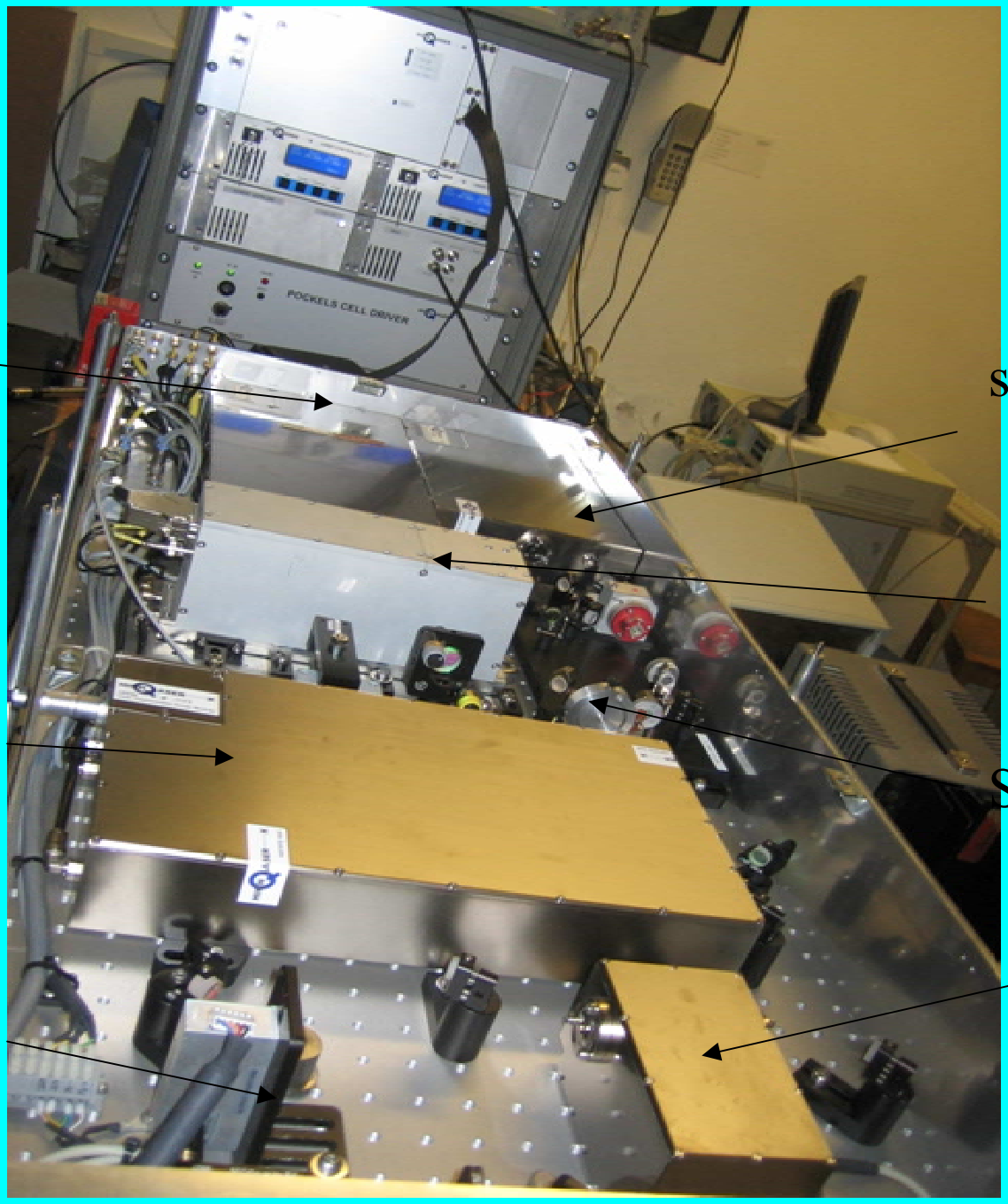
This was purchased from Graz along with demo Fortran code. It allows us to

- Read and control ET.
- Send range gate pulses to the C-SPAD.
- Control laser and laser rates and avoid overlap between incoming and outgoing pulses.
- Bring world peace – not yet implemented

KHz Laser

- Nd:Vanadate picoREGEN laser from High-Q
- Pulse energy 0.5mJ at 532nm at 1KHz

  0.4mJ at 532nm at 2KHz
- We have had repetition rates of between 100 and 2000 with no need for re-alignment
- Pulse width is 10ps FWHM at 532nm

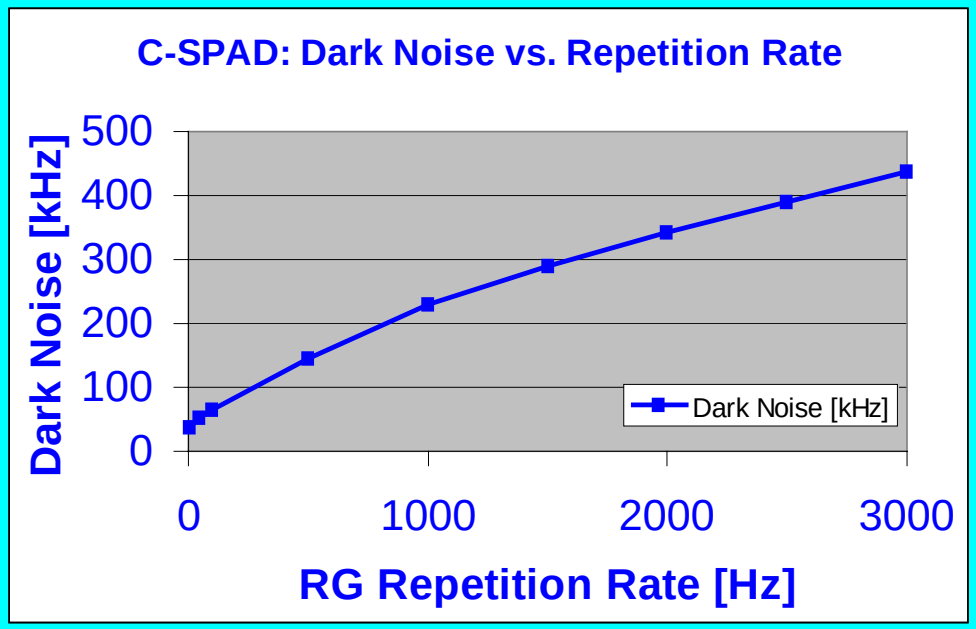

Regenerative amplifier
seed
pockels
Post amplifier
Start diode
Optical safety shutter
Frequency doubler

Tracking so far

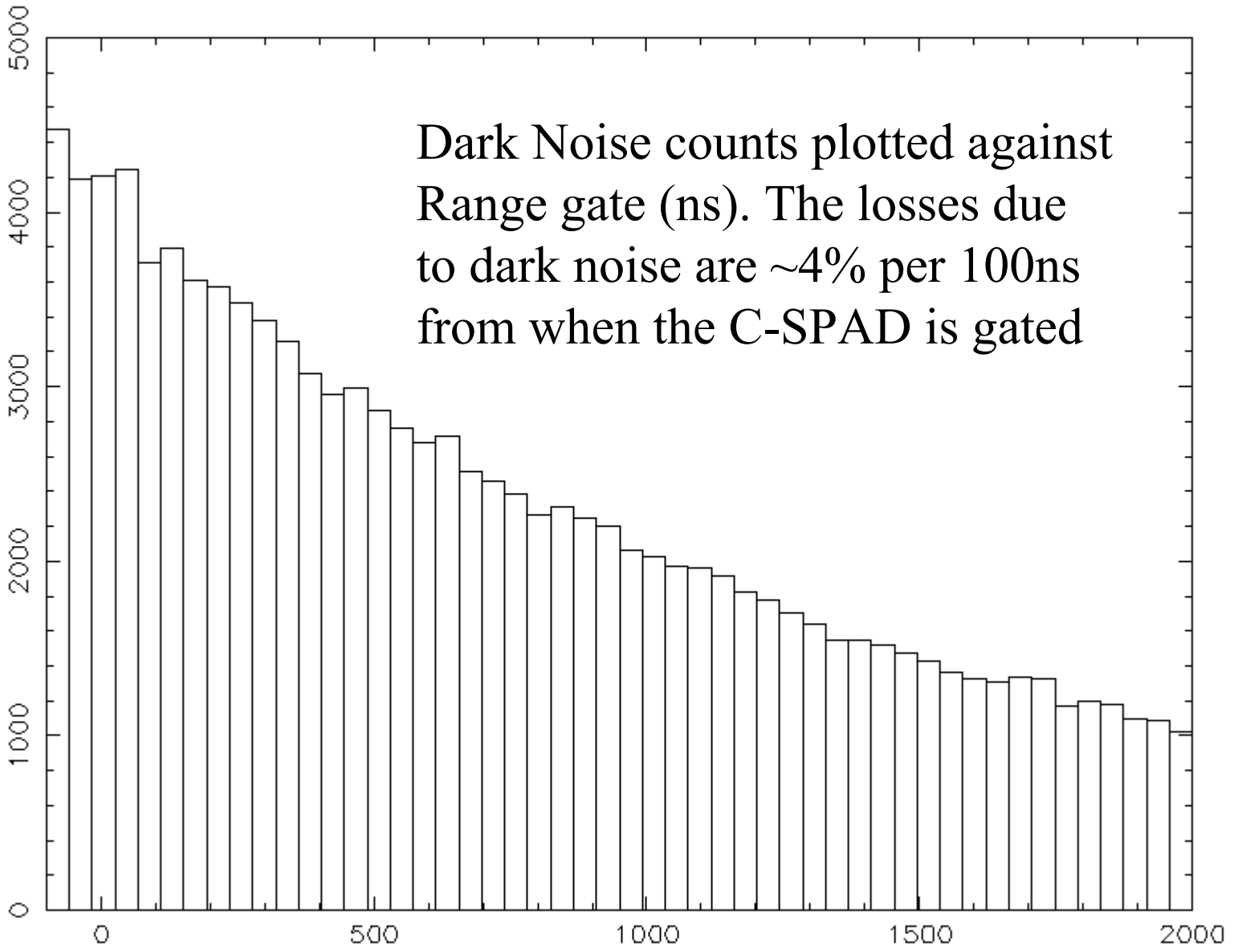
- We have successfully tracked
  - Day
    - Lageos and below except Grace & Champ
  - Night
    - All satellites except
      - GPS/Etalon – no opportunity
      - Champ/Grace – we have some software issues

Problems

- The extra dark noise generated by the C-SPAD has given us a few problems detecting faint tracks in real-time and at the reduction stage



Picture provided by Graz as a response to our enquiry about the increase in Dark Noise



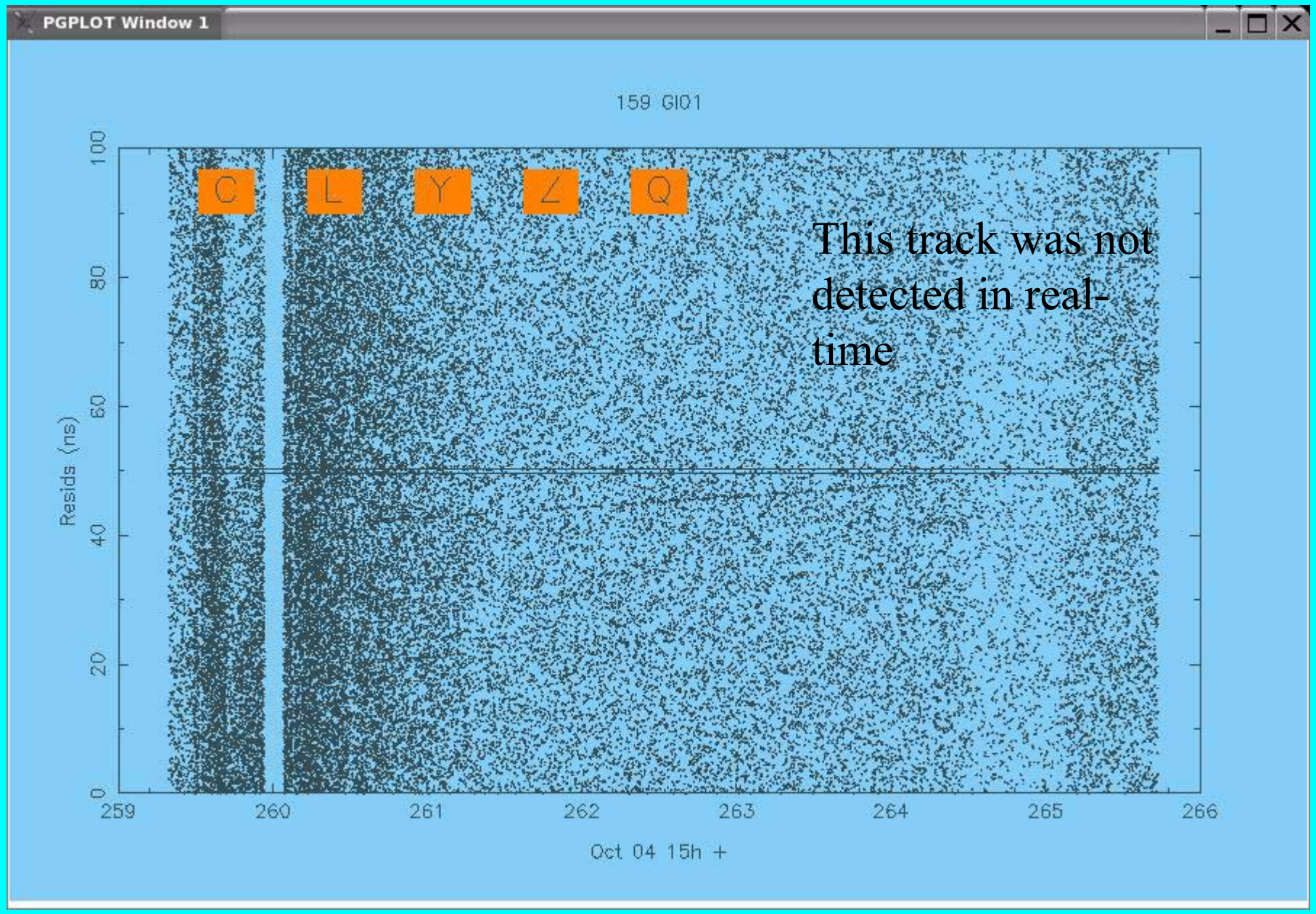
Dark Noise counts plotted against Range gate (ns). The losses due to dark noise are ~4% per 100ns from when the C-SPAD is gated

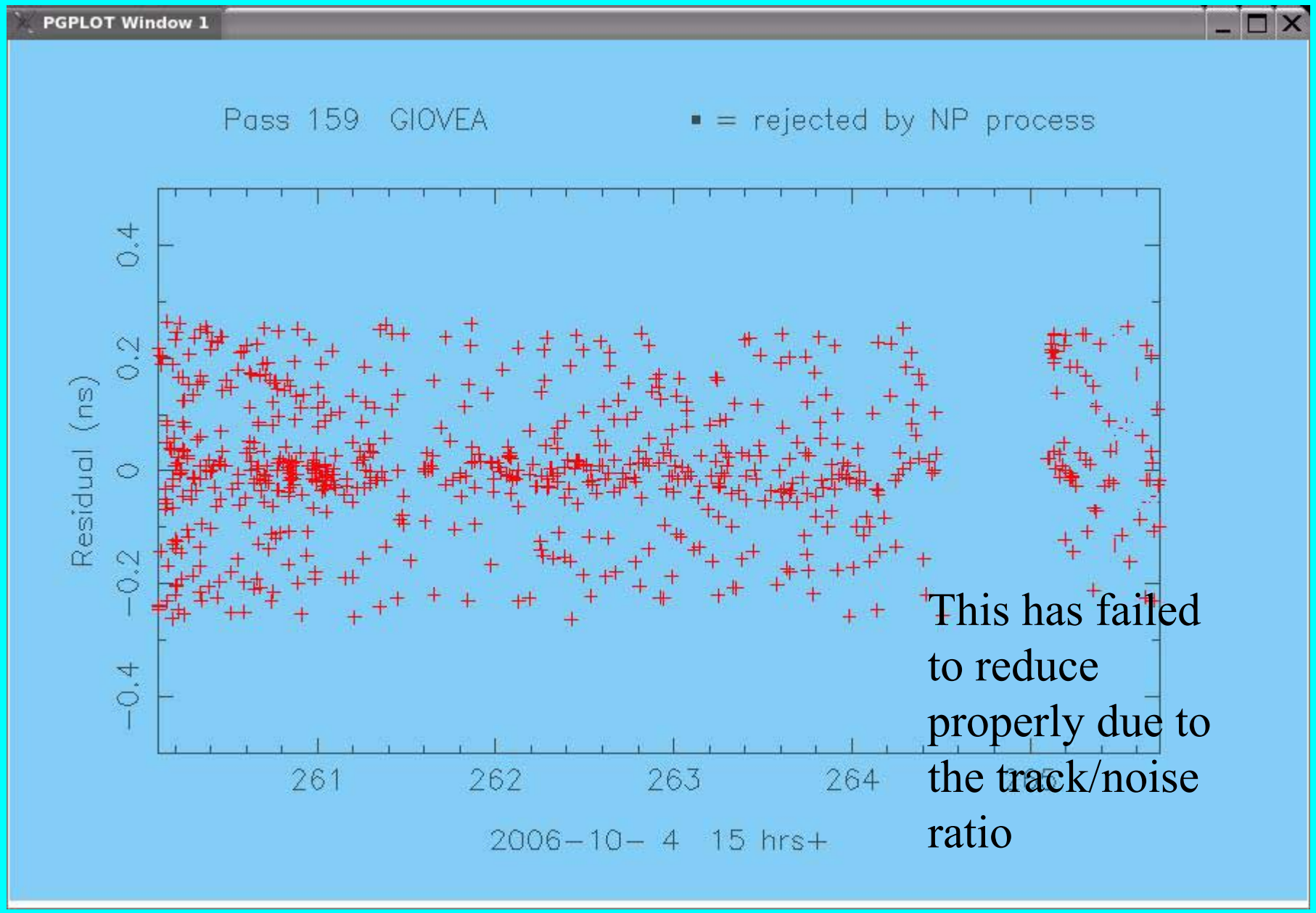
Problems

- We have had some communication problems with the Linux machine we are archiving the data on.
- We have not yet managed to track Champ/Grace.
- Faint tracks have failed to reduce to our satisfaction using our current software because of the high background noise.
- Different return energies give us different looking data sets.
- When we try to get return energies above 20% for calibrations (and satellites??) the system appears to get swamped and the return rate drops off.

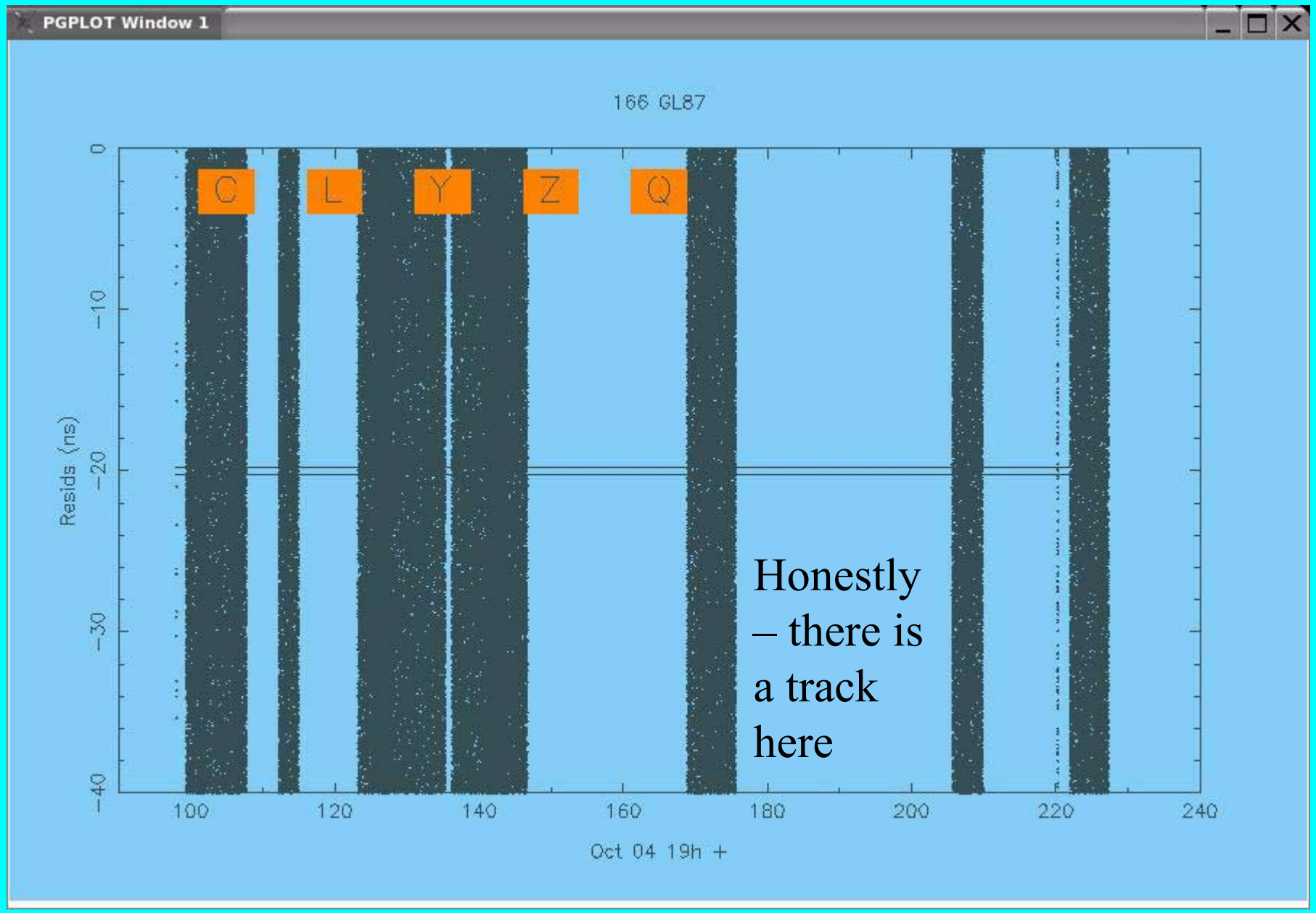
Successes

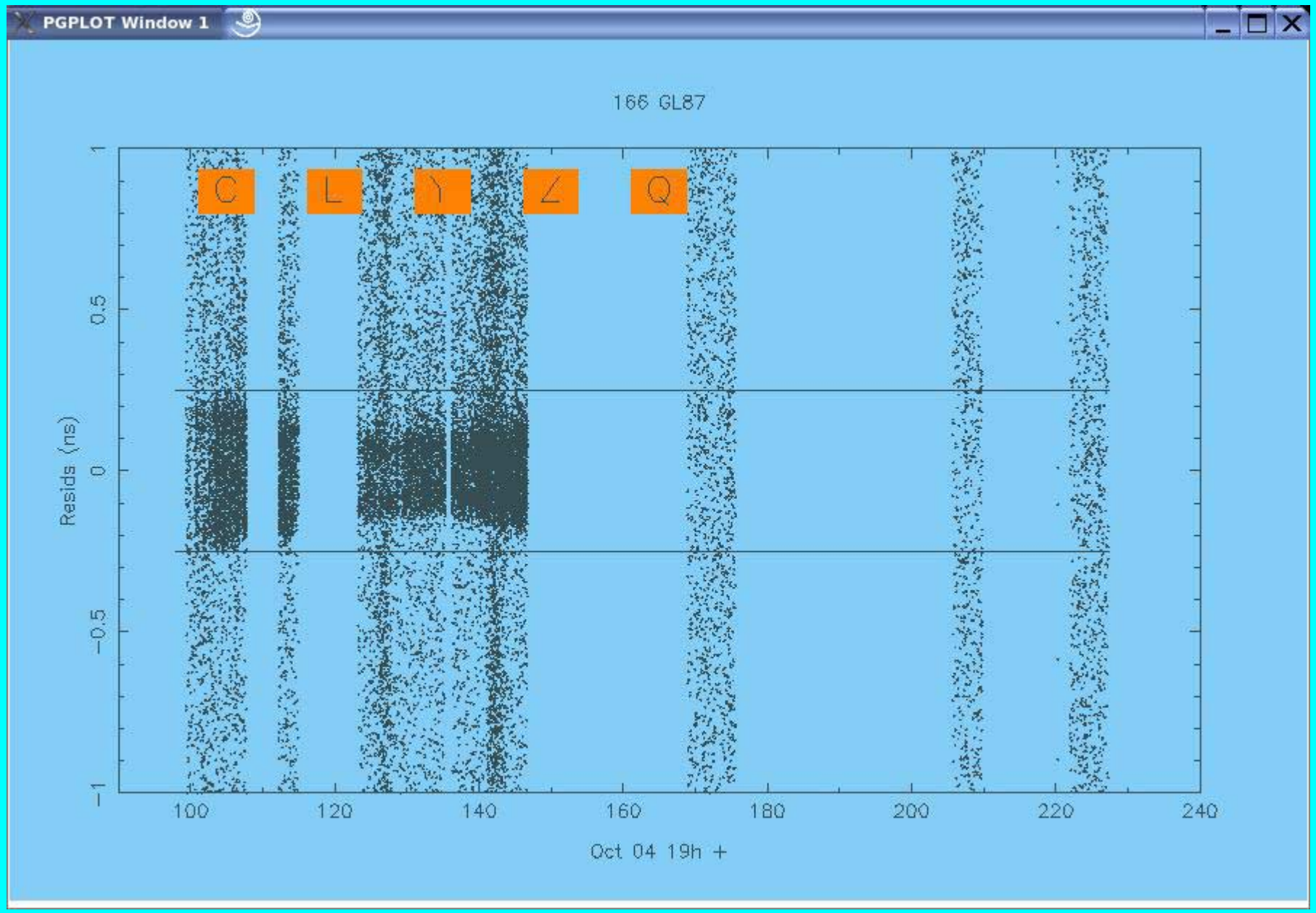
- The Laser had had no work done on it for 2 months when we turned it on to use it and none during the test period and it worked well for any fire rate we threw at it (100Hz – 2KHz).
- The software to do the initial tracking was cobbled together in a few days and worked almost immediately.
- Tracking Giove to Larets .
- Calibrating to our target inside the dome.

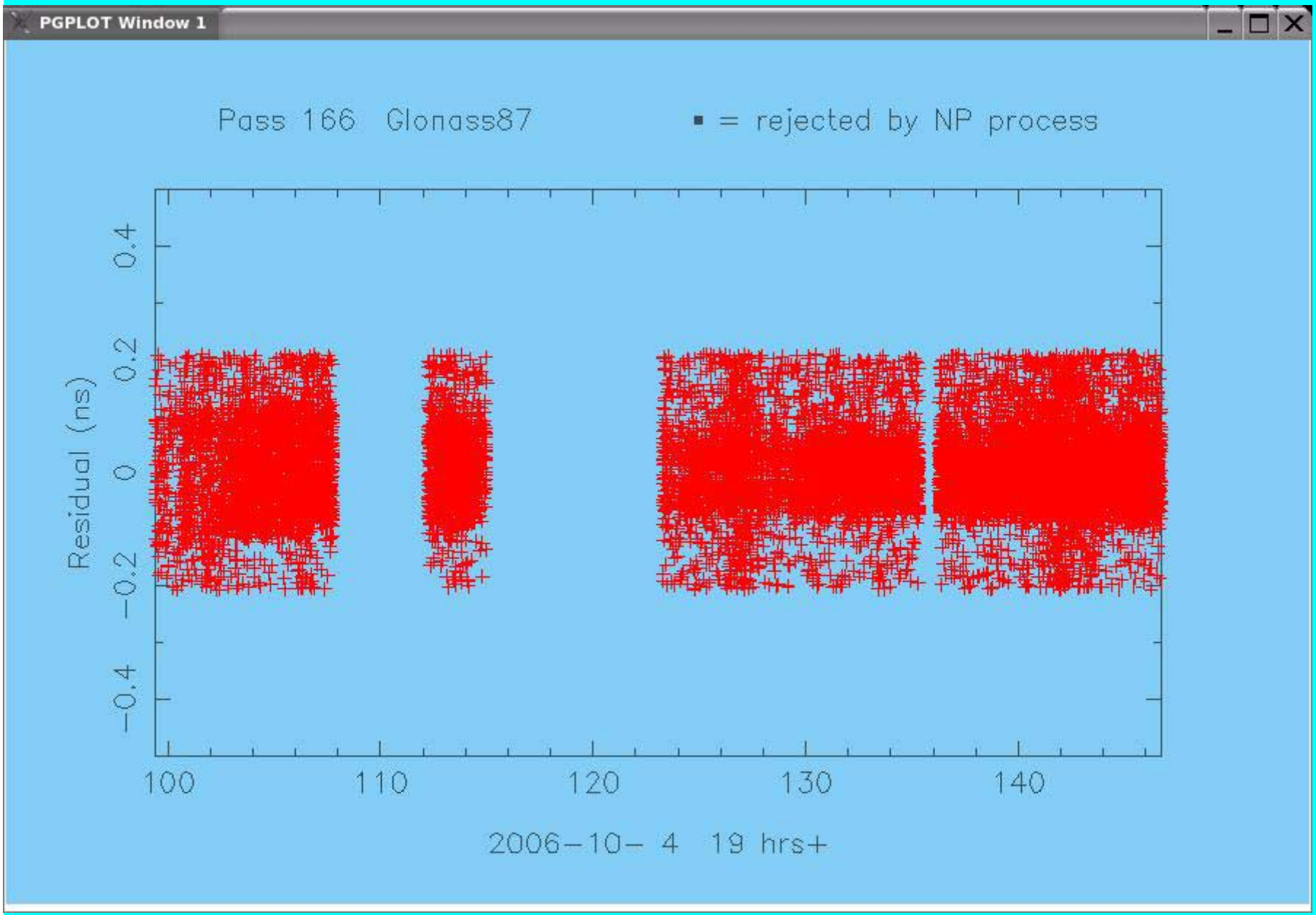

PGPLOT Window 1
159 GI01
C
L
Y
Q
This track was not detected in real-time
Resids (ns)
0
20
40
60
80
100
259
260
261
262
263
264
265
266
Oct 04 15h +

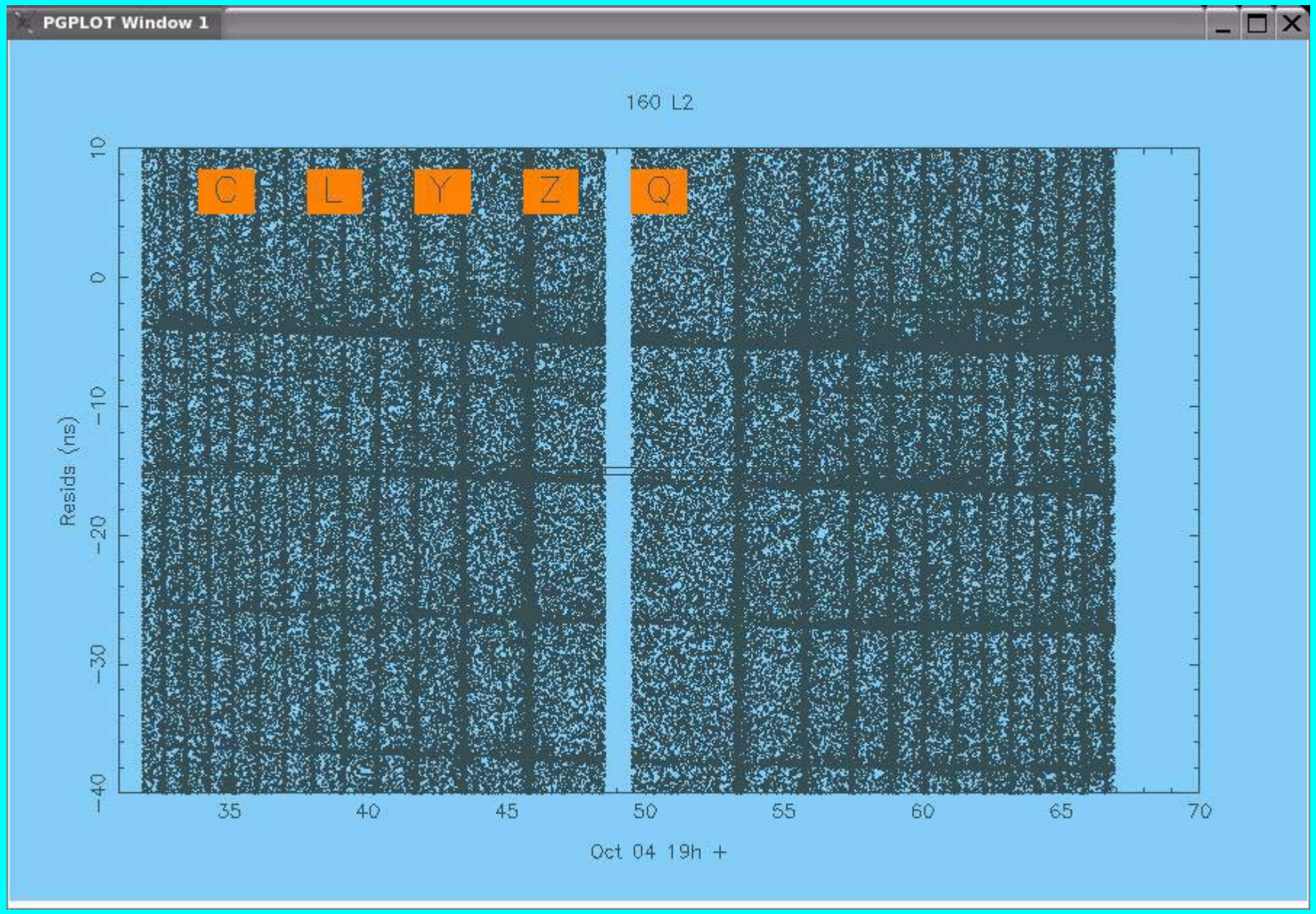


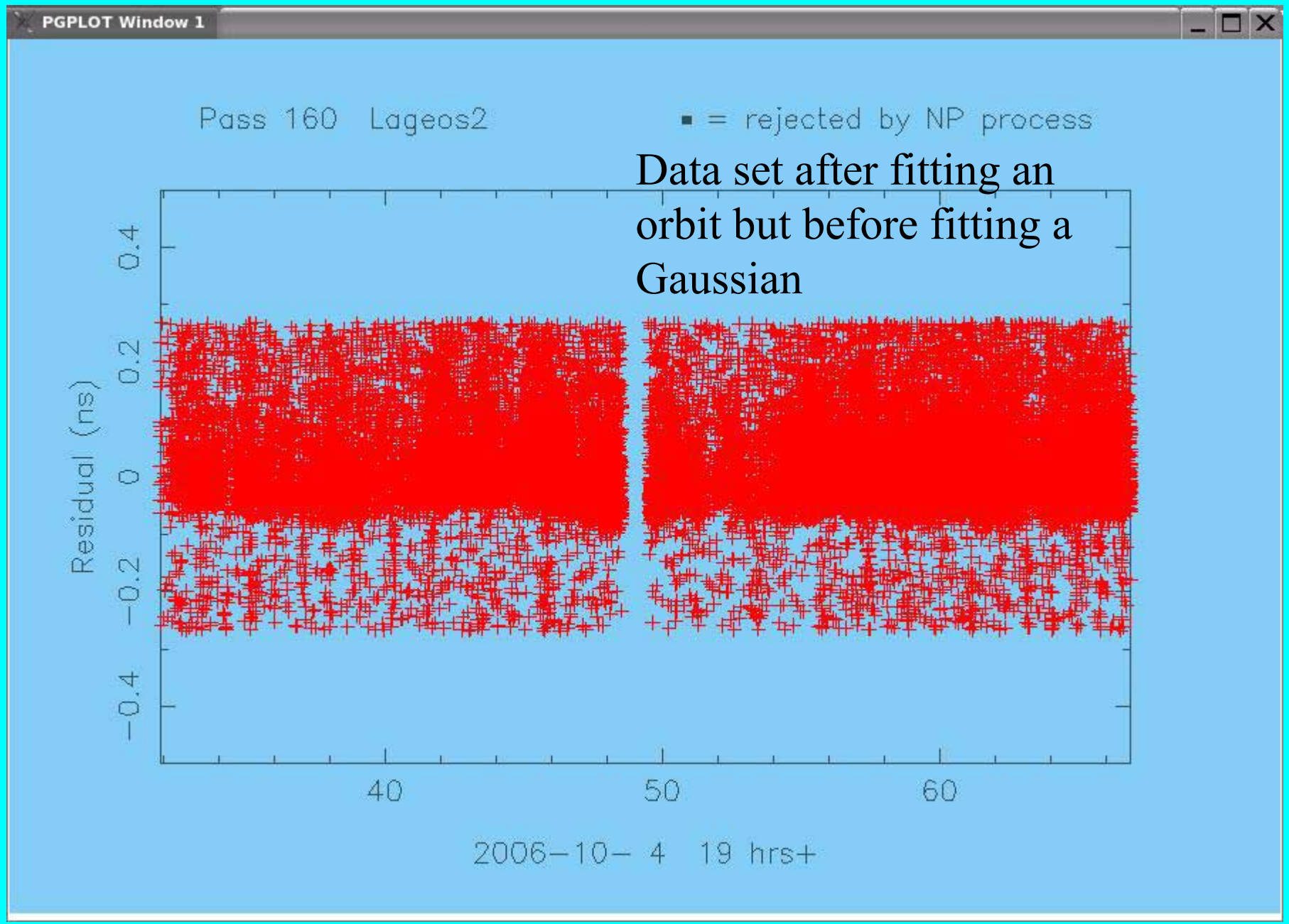
This has failed to reduce properly due to the track/noise ratio

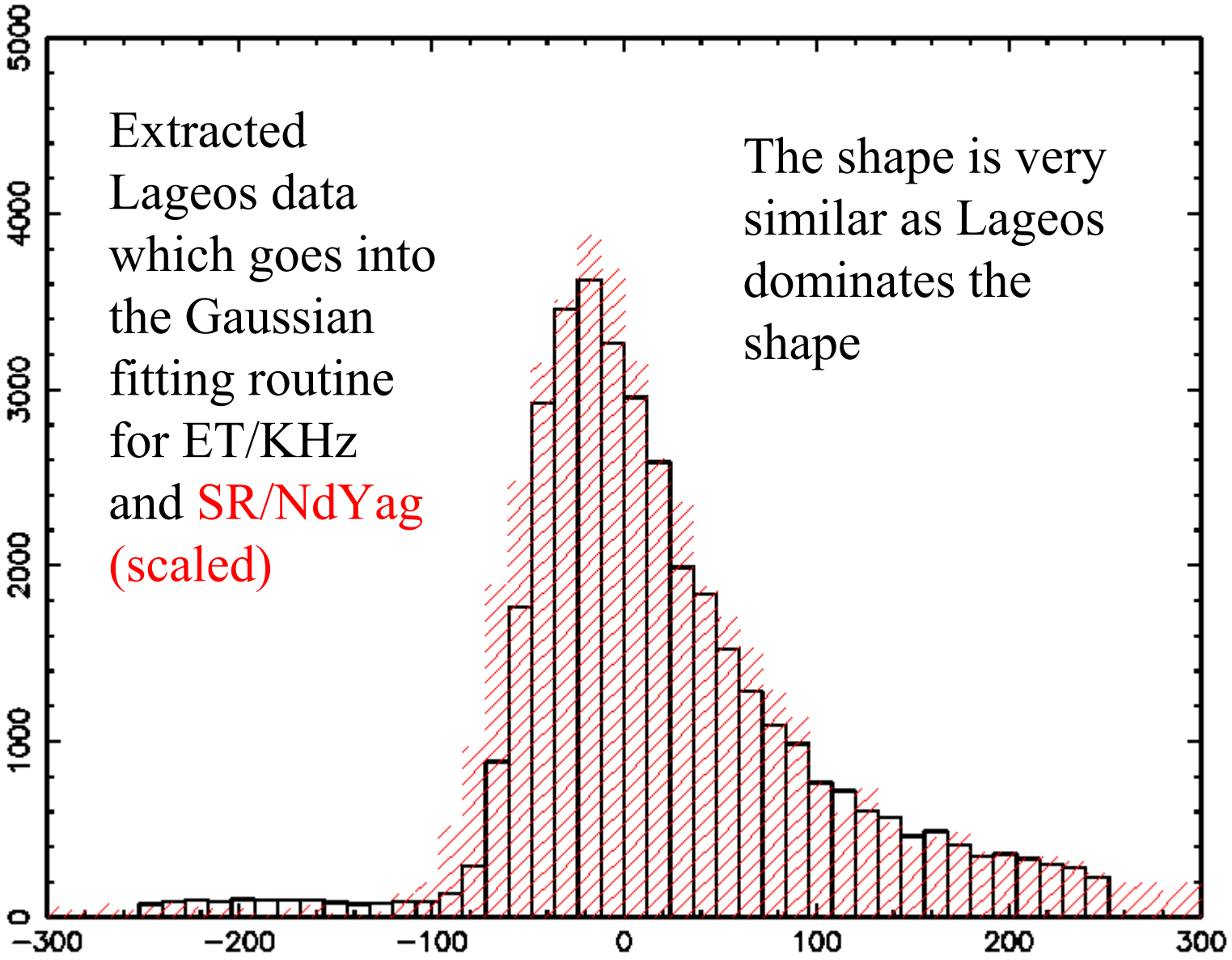

PGPLOT Window 1
166 GL87
C
L
Y
Z
Q
Resids (ns)
0
-10
-20
-30
-40
100
120
140
160
180
200
220
240
Oct 04 19h +
Honestly – there is a track here

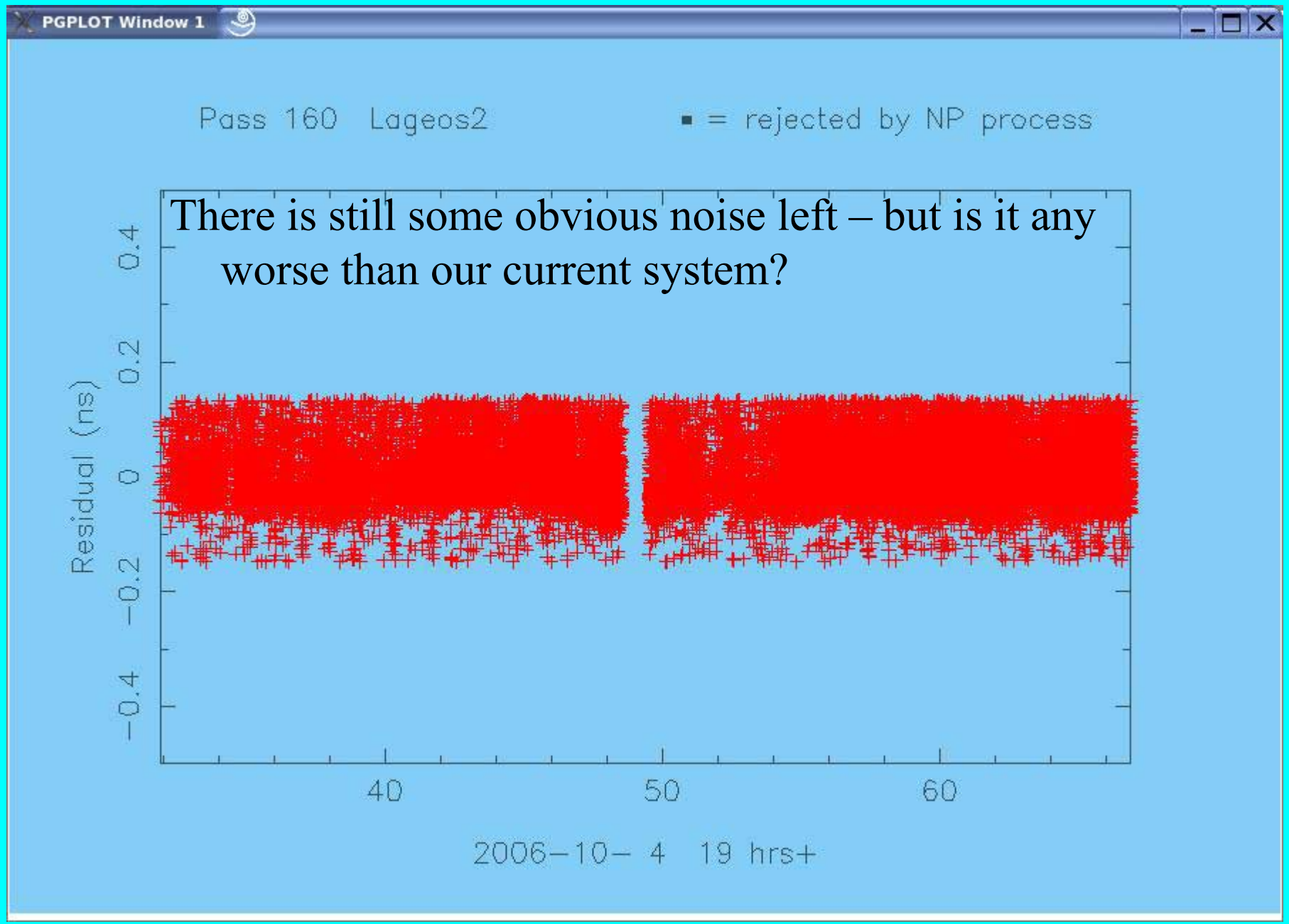

PGPLOT Window 1
166 GL87
C
L
Y
Z
Q
Resids (ns)
1
0.5
0
−0.5
−1
100
120
140
160
180
200
220
240
Oct 04 19h +


PGPLOT Window 1
Pass 166 Glonass87
▪ = rejected by NP process
Residual (ns)
0.4
0.2
0
−0.2
−0.4
100
110
120
130
140
2006−10− 4 19 hrs+


PGPLOT Window 1
160 L2
C
L
Y
Z
Q
Resids (ns)
10
0
-10
-20
-30
-40
35
40
45
50
55
60
65
70
Oct 04 19h +

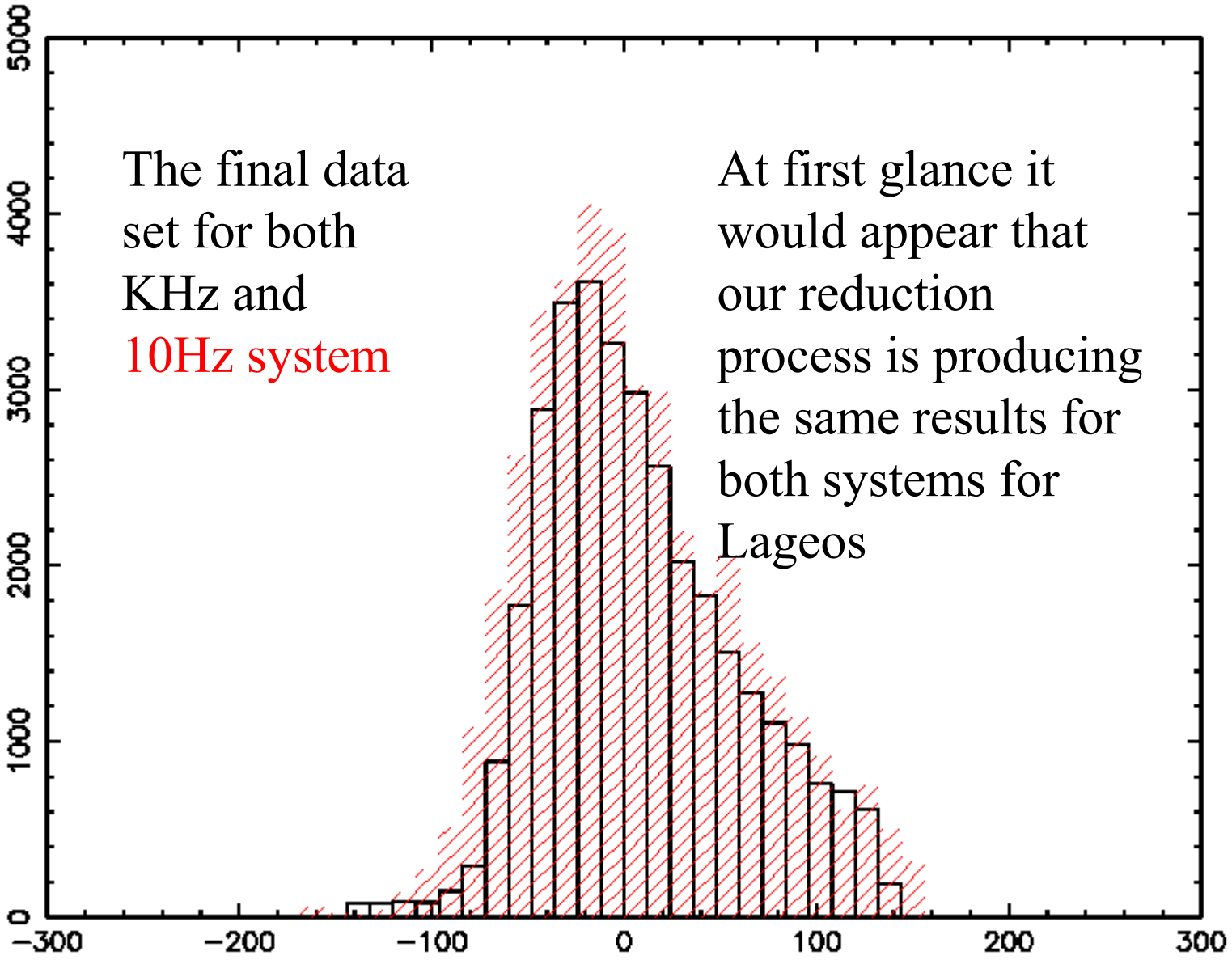

PGPLOT Window 1
Pass 160 Lageos2
▪ = rejected by NP process
Data set after fitting an orbit but before fitting a Gaussian
Residual (ns)
0.4
0.2
0
−0.2
−0.4
40
50
60
2006−10− 4 19 hrs+

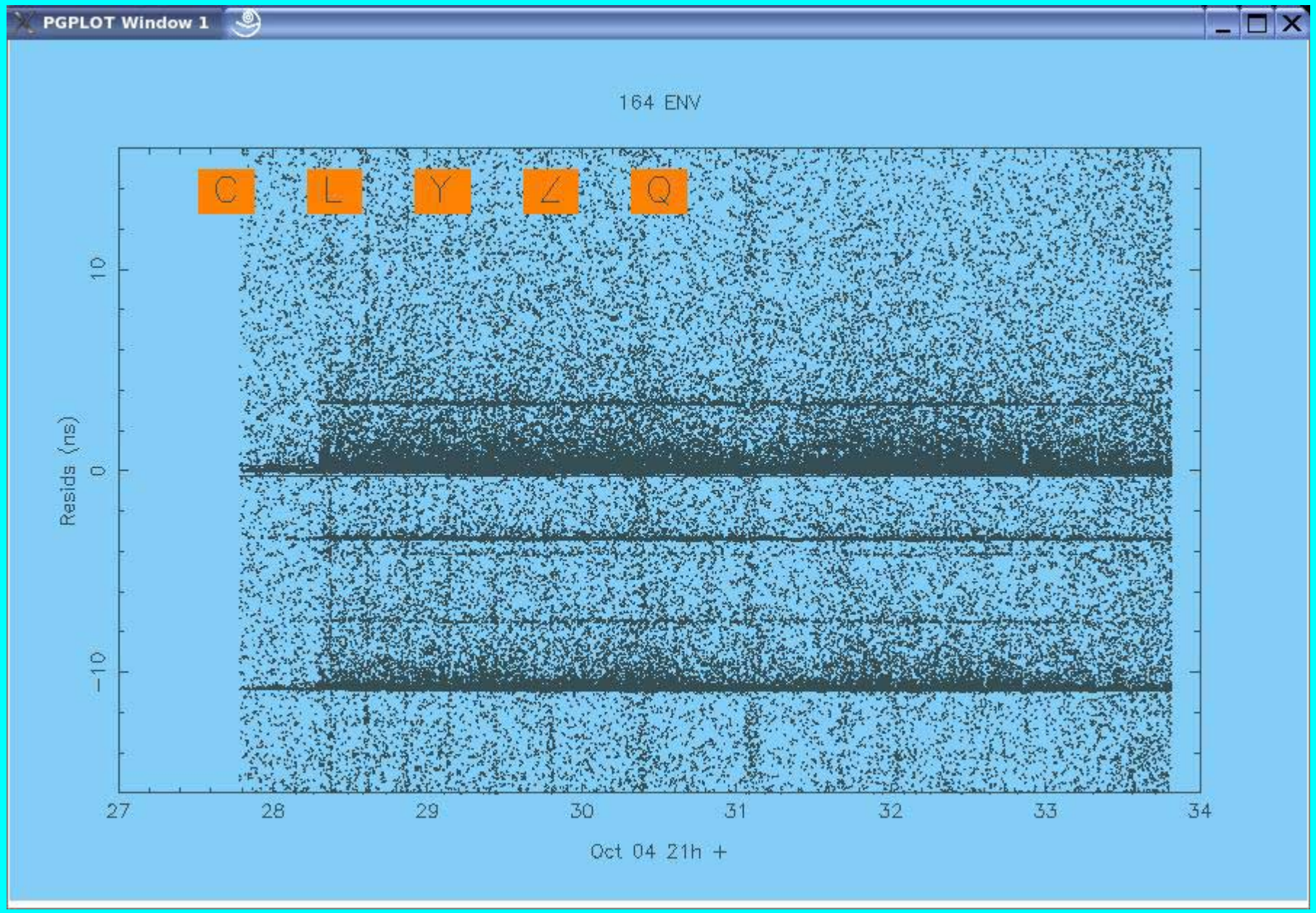

Extracted Lageos data which goes into the Gaussian fitting routine for ET/KHz and SR/NdYag (scaled)
The shape is very similar as Lageos dominates the shape
5000
4000
3000
2000
1000
0
−300
−200
−100
0
100
200
300

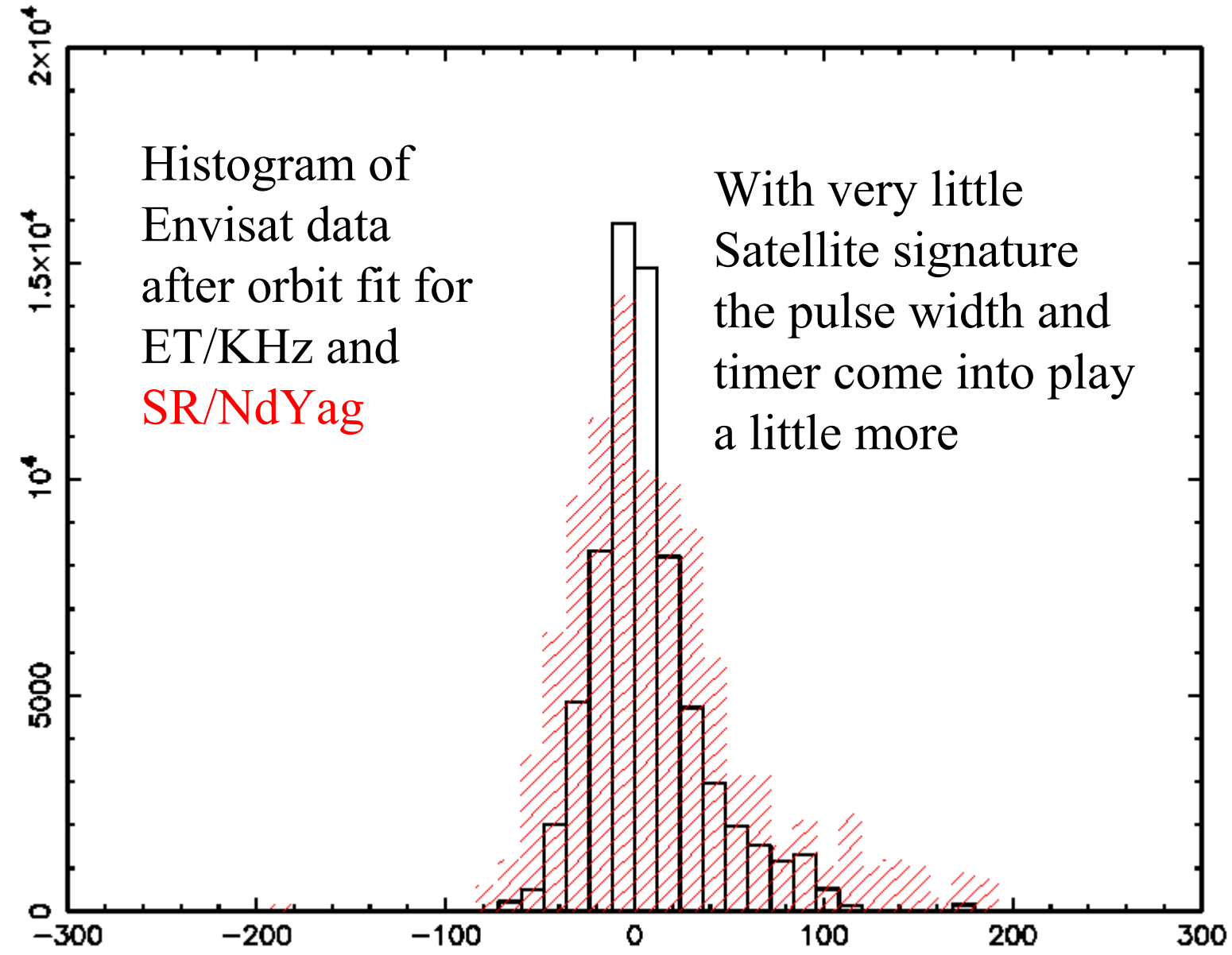

PGPLOT Window 1
Pass 160 Lageos2
▪ = rejected by NP process
There is still some obvious noise left – but is it any worse than our current system?
Residual (ns)
0.4
0.2
0
−0.2
−0.4
40
50
60
2006−10− 4 19 hrs+

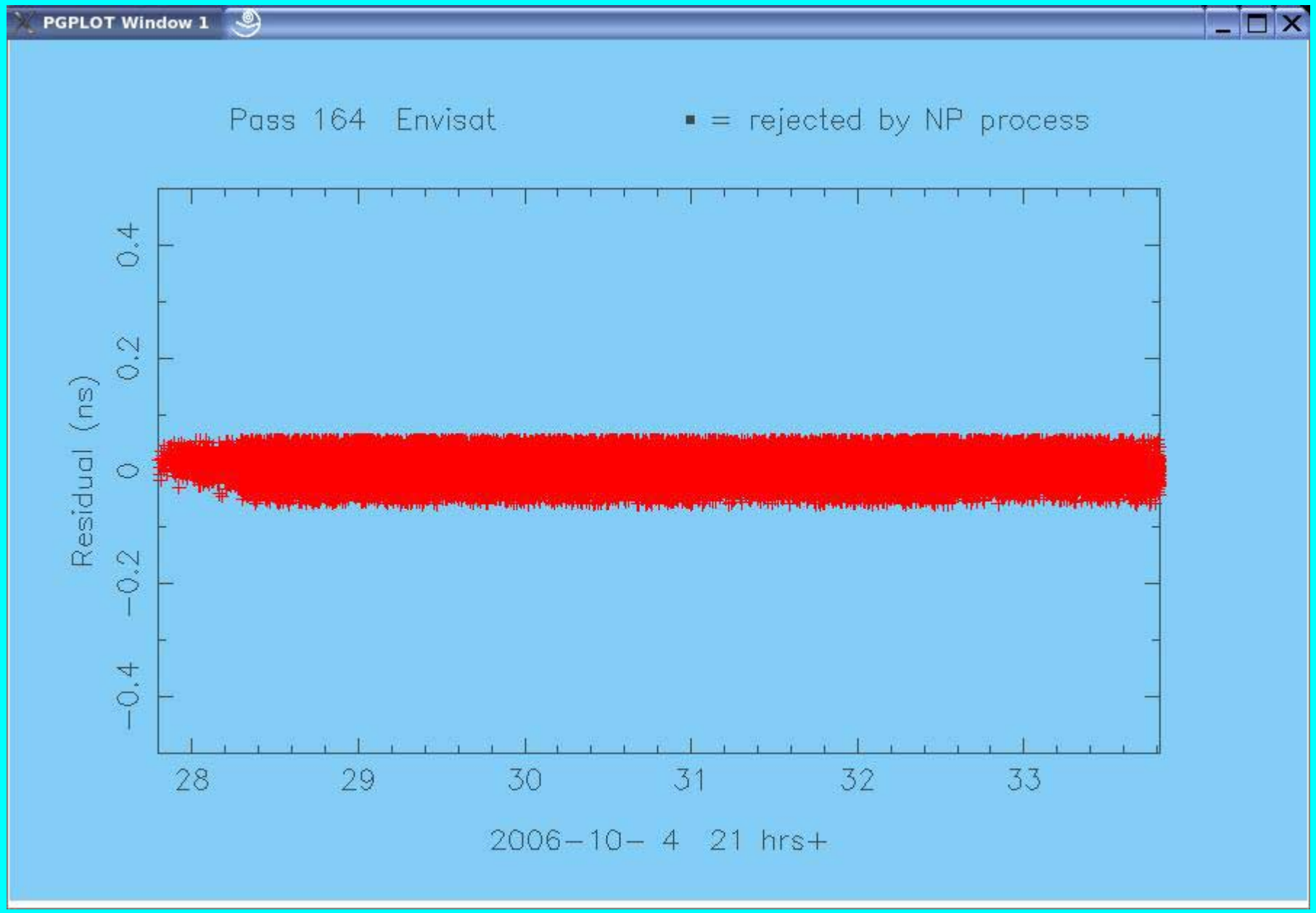
The final data set for both KHz and 10Hz system

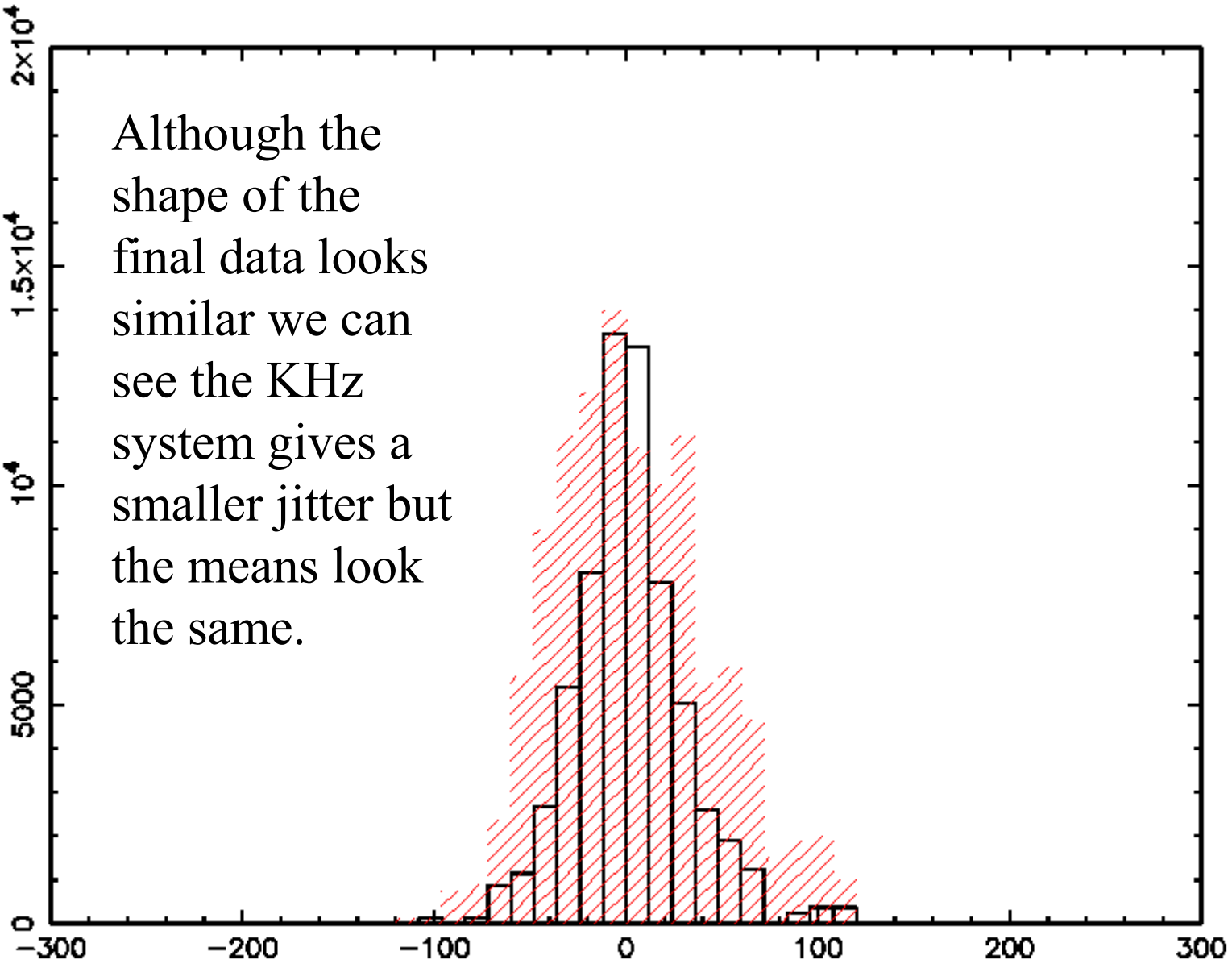
At first glance it would appear that our reduction process is producing the same results for both systems for Lageos

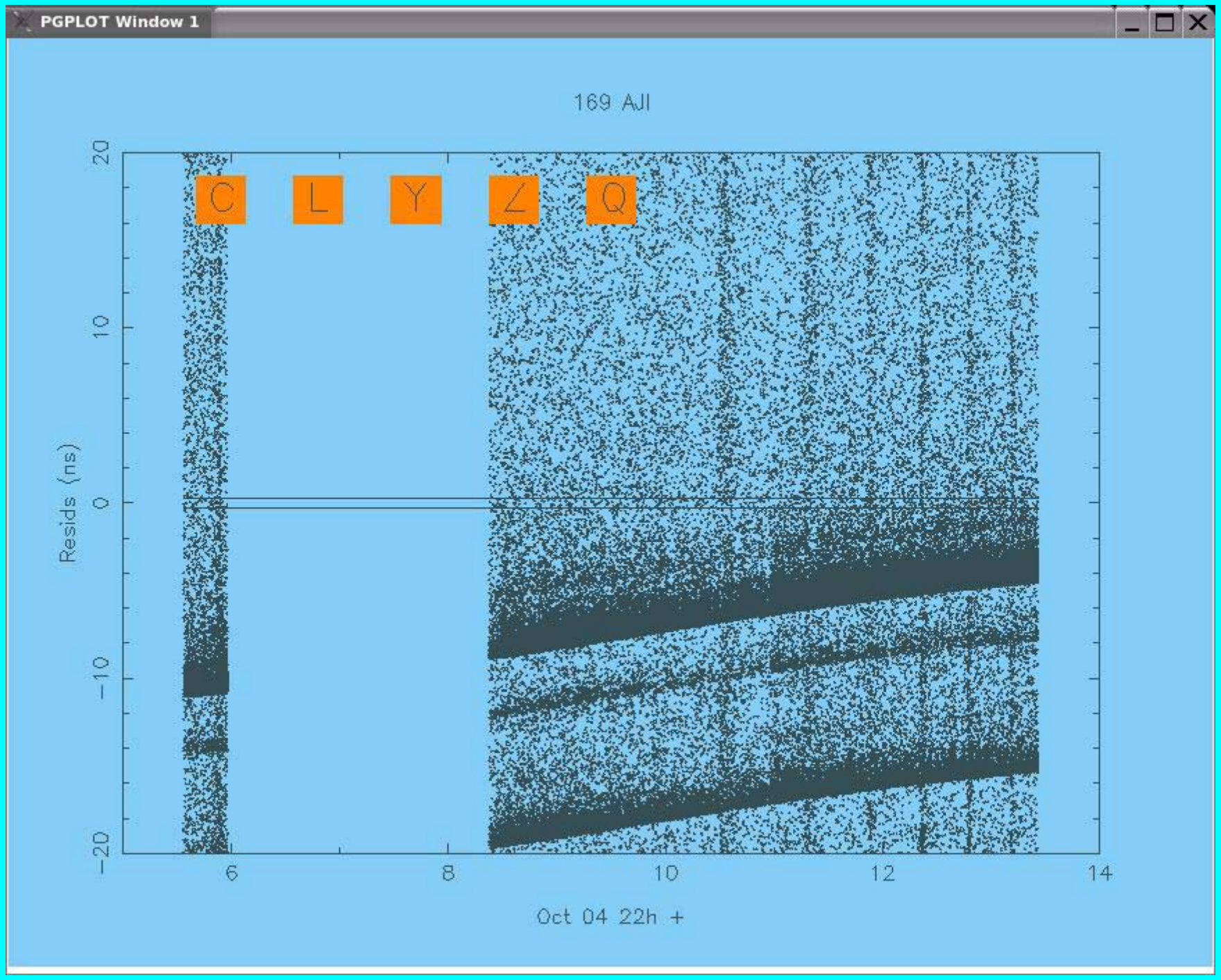


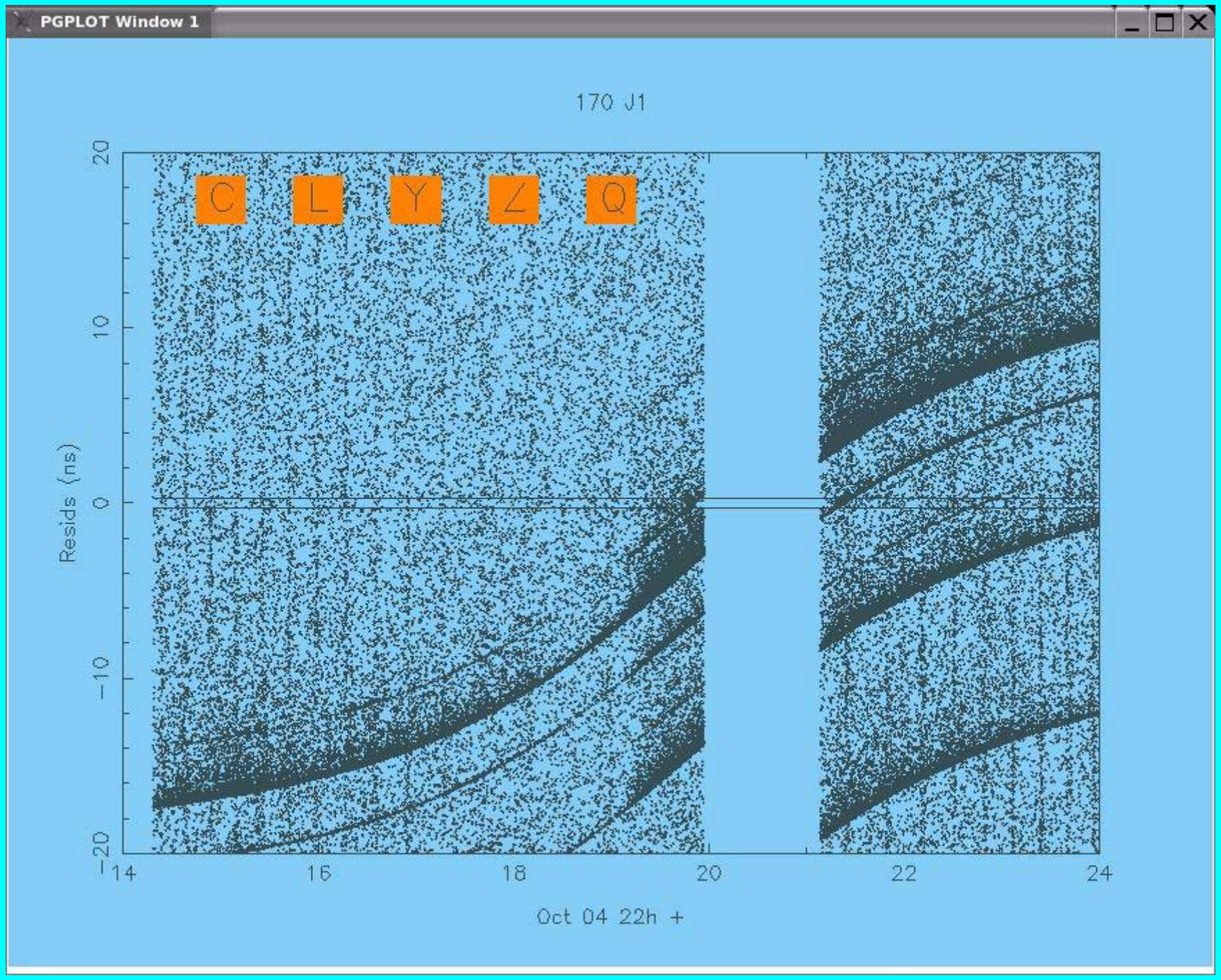

PGPLOT Window 1
164 ENV
C
L
Y
∠
Q
Resids (ns)
10
0
−10
27
28
29
30
31
32
33
34
Oct 04 21h +

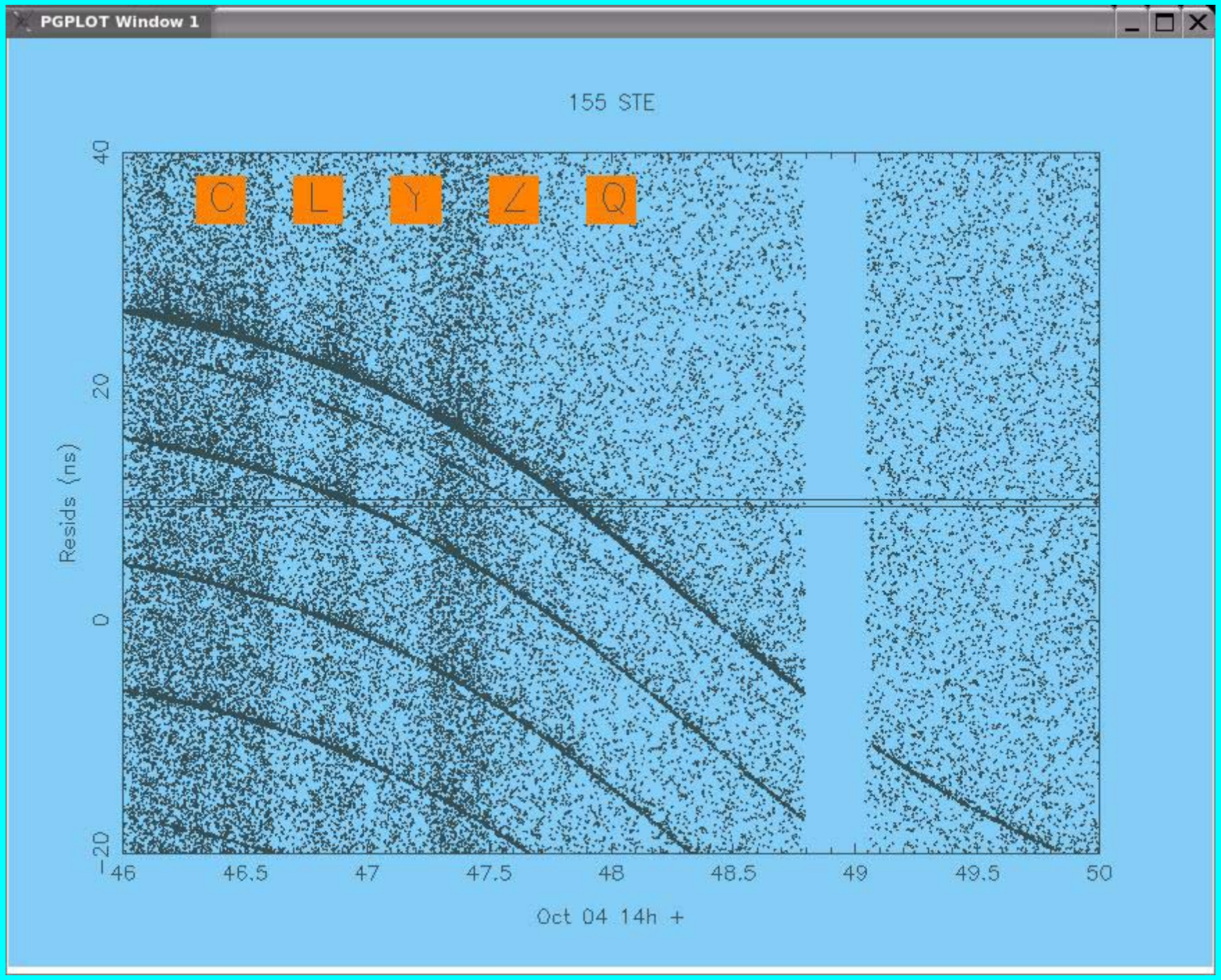

Histogram of
Envisat data
after orbit fit for
ET/KHz and
SR/NdYag
With very little
Satellite signature
the pulse width and
timer come into play
a little more
2×10⁴
1.5×10⁴
10⁴
5000
0
−300
−200
−100
0
100
200
300


PGPLOT Window 1
Pass 164 Envisat
▪ = rejected by NP process
Residual (ns)
0.4
0.2
0
−0.2
−0.4
28
29
30
31
32
33
2006−10− 4 21 hrs+


Although the shape of the final data looks similar we can see the KHz system gives a smaller jitter but the means look the same.
2×10⁴
1.5×10⁴
10⁴
5000
0
−300
−200
−100
0
100
200
300


PGPLOT Window 1
169 AJI
C
L
Y
∠
Q
Resids (ns)
20
10
0
−10
−20
6
8
10
12
14
Oct 04 22h +


PGPLOT Window 1
170 J1
C
L
Y
∠
Q
Resids (ns)
20
10
0
−10
−20
14
16
18
20
22
24
Oct 04 22h +


PGPLOT Window 1
155 STE
C
L
Y
Z
Q
Resids (ns)
40
20
0
-20
46
46.5
47
47.5
48
48.5
49
49.5
50
Oct 04 14h +

Satellite	RMS(mm) (10Hz)	RMS(mm) (KHz)	No.Pts
Calibration	8	4	
Lageos	16	14	33K
Icesat	10	6	12k
ERS2	10	6	70k
Envisat	10	6	65k
Gfo-1	11	8	10k
Larets	9	6	11k
Stella	14	10	10k
Jason	10	6	50k
Ajisai	40	42	57k

Future

- Control laser , add safety systems
- Remove all spurious tracks from laser
- Complete ranging software
  - Control data to single photon
  - Track Champ/Grace
  - Enable time biases
  - Real-time monitoring of ET
- See laser in daylight