



# S5 Report to the LSC

Reported by Vern Sandberg

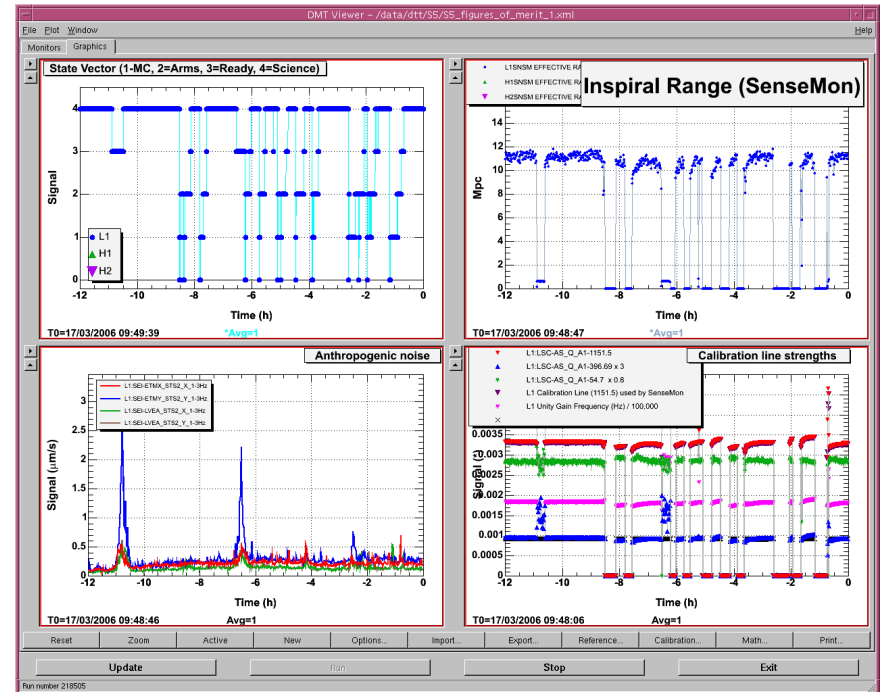
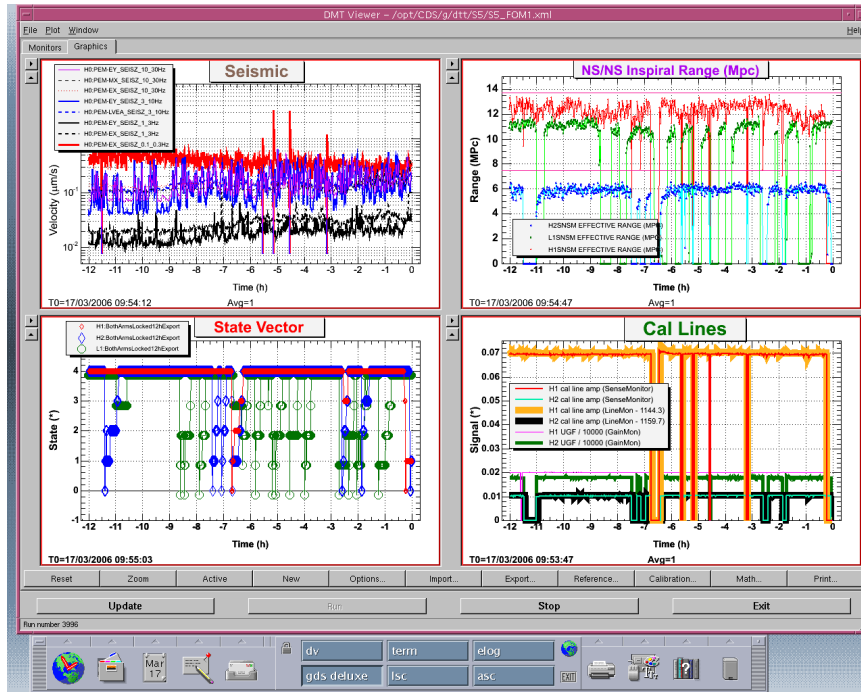
LIGO Scientific Collaboration Meeting  
19-22 March 2006, LHO

March 20, 2006



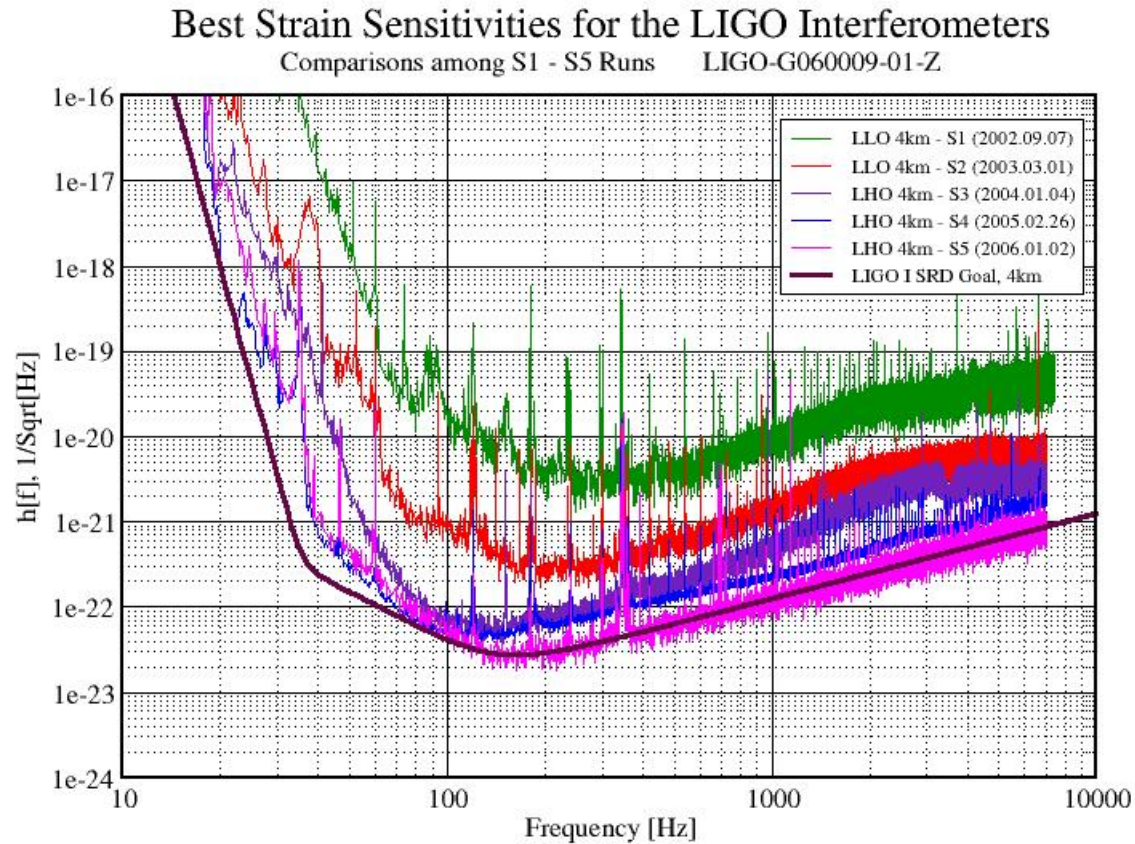
# LHO

# LLO





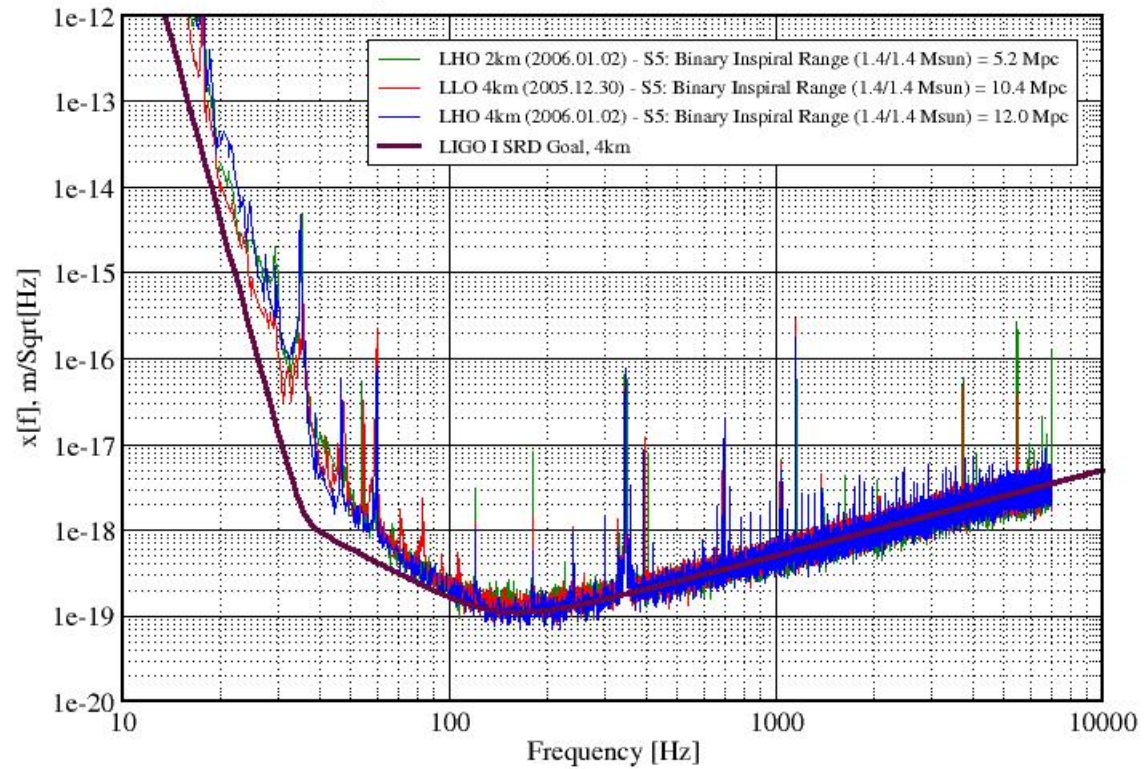
# Early S5 Run Sensitivity compared to S1, S2, S3, S4 (from Jan 2006)





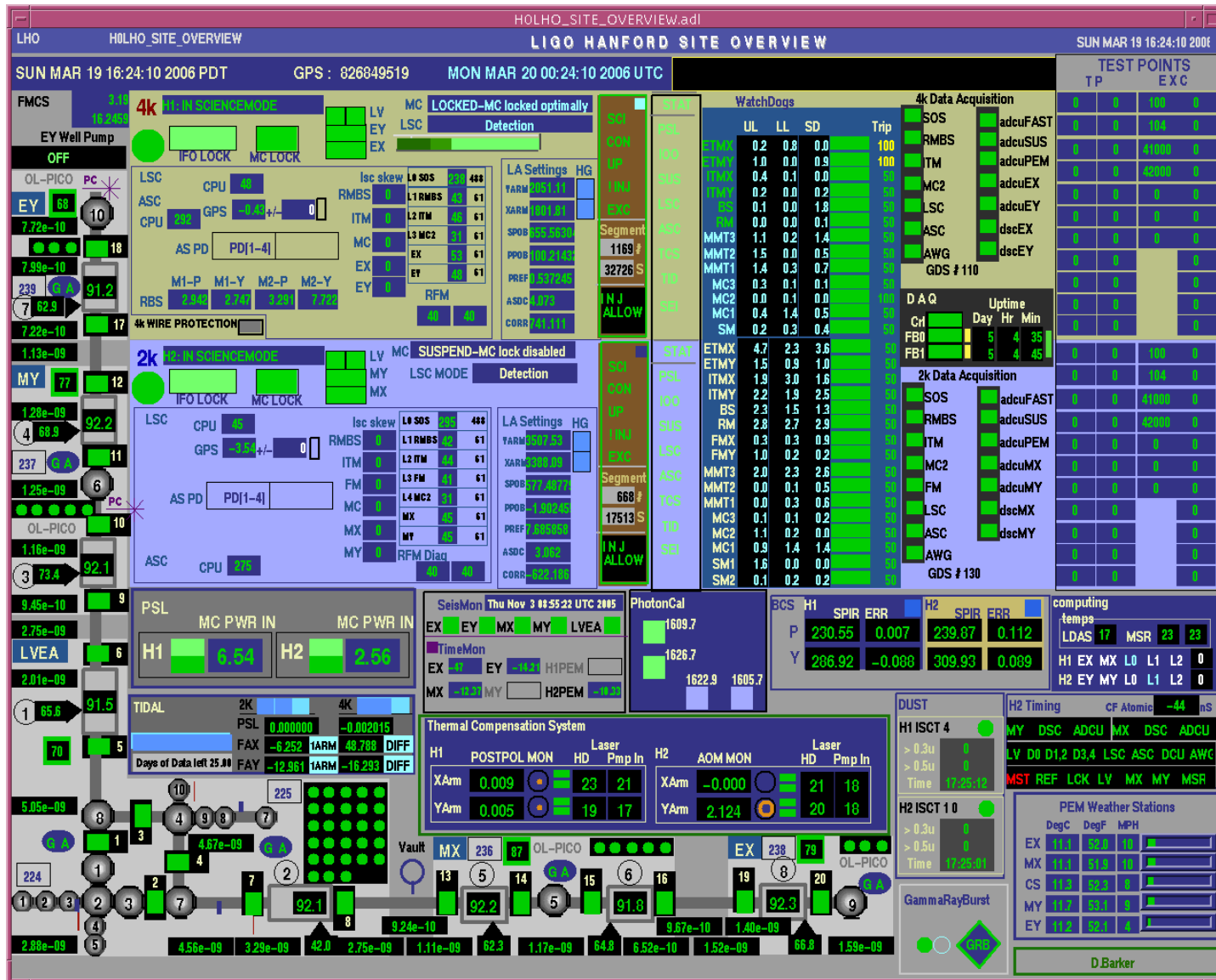
## Displacement Sensitivities for the LIGO Interferometers

Early Performance for S5 LIGO-G060011-00-E





Laser Power



Wind



## General Guidelines:

- Maximize Science Mode Time
- Maintain Optimal Range and FOMs

## Tuesday Maintenance Periods Coincident between sites

- LHO 08:00 - 12:00 PST
- LLO 10:00 - 14:00 CST



## The Start of S5: Hopes, Pleas, and Wishes

- o November 4, 2005 Begin the S5 run at LHO, with both H1 and H2 interferometers.
- o November 14, 2005 LLO joins with the L1 interferometer.
  
- o The target sensitivities (specified in NS-NS inspiral range) are 10Mpc for H1 and L1 and 5Mpc for H2.

The present states of the IFOs are close to these goals, but we will need some additional tuning. With that reality in mind, we will attempt to bring order out of chaos with the following goals and calendar:

- o Tuesdays will be the scheduled maintenance and repair days. In order to maximize coincident operations amongst the IFOs, LHO will schedule its maintenance from 08:00 to 12:01 PST and LLO will schedule its maintenance from 10:00 to 14:00 CST on Tuesdays. The local site managers will coordinate all maintenance, deliveries (LN<sub>2</sub>, water, canteen items, etc.), repairs, pickups (garbage, FedEx, etc.), and any other controllable disturbances during this time window. Unforeseen problems, such as ion pump failures, will need to be addressed as they occur and be resolved based on the judgment of the local site coordinators and their staffs. Keeping the IFOs up and at sensitivity will be the primary criteria.
  
- o CDS code freeze at LHO on Wednesday, 00:01 PST November 26, 2005. After this date software changes will be added on a "work permit" style basis.
  
- o DMT monitors running on CDS should follow the CDS code freeze date. There is a plan to check out monitors on the GC-side and to migrate "tested" monitors into the control rooms under carefully controlled approvals. This way new monitors can be added, but will not disrupt data taking.
  
- o LDAS at LHO code freeze November 2, 2005. Interpreted to mean that the systems in place to handle the data delivered from the IFOs to the recording and level 0 archives will be in place, stable, and ready to receive data. This does not effect the analysis work, but should be used as a guideline for best practice.



## The Start:

Science Run S5

LHO: Begins Fri Nov 4, 2005 at 8:00 PST

LLO: Begins Mon Nov 14, 2005 at noon CST

## On Tuesdays:

Maintenance

## On Wednesdays:

**S5 Run Coordination Meeting**

**Wednesday, February 32, 2006**

12:15 PST, 14:15 CST, 15:15 EST, and 21:15 CET

*Please note this meeting will start 15 minutes past the hour..*

### **Topics:**

- Status at the Observatory Sites, Maintenance Activities, Detector Characterization, and Monitors
- Calibrations and Injections
- Offline Monitors and FOMs Offline Analysis and Reports from Analysis Groups (In-Spiral, CW, Burst, Stochastic)



### Herding Cats



### Site Run Coordinators

- LHO - Fred Raab, Daniel Sigg, Rick Savage
- LLO - Mike Zucker, Valera Frolov, Ken Yoshiki Franzen, Brian O'Reilly, Igor Yakushin, and Joseph A. Giaime



## S5 Operations

- Run Coordinators and Observatories' Staff
- SciMons
- Operators
- Computer Handlers – CDS and LDAS
- Calibrators
- Injectors
- Monitor Keepers
- Analysists



# Performance Metrics

(Apologies to M. Zucker, G060022)

- Duty Factor (% “science mode” uptime)
  - » singles, doubles, triples relevant for different search targets
  - » “discovery phase” puts emphasis on doubles and triples, even for sources that don’t nominally require coincidence (e.g. long-term CW, GRB/SN coincidence with EM or  $\nu$ )
  - » Can always run longer as contingency
- Sensitivity
  - » complicated balance in principle due to different target sources, but detectors and environment make lots of decisions for us
  - » default to using “BNS inspiral range” as shorthand
  - » convenient scalar, but misleading for many science targets
- “Tradeoffs” between duty factor and sensitivity?
  - » for BNS/BBH (for which H1,H2,L1 see well into Virgo cluster) rate  $\sim$  range<sup>3</sup>...  
· so one can (sort of) equate inspiral range to cube of duty factor
  - » this is **wrong** for galactic sources and unknown source distributions
  - » However, it does help guide when/how long to interrupt running to try and boost sensitivity, if we also have a good idea what to do



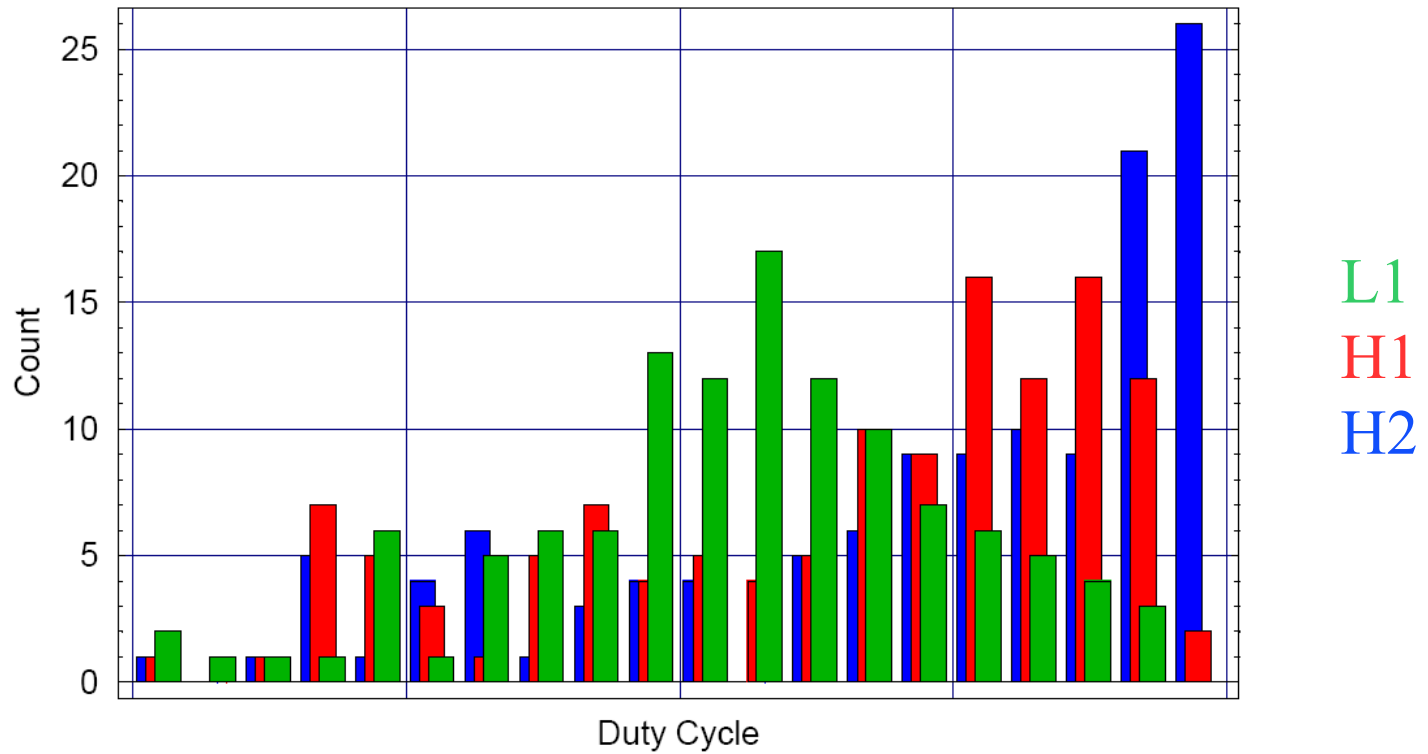
# Interferometer Duty Factor

From the PAC18 presentation

- HEPI works; L1 less vulnerable to logging,  $\mu$ seism
- What's the remaining background of downtime?
  - » H1, H2: high winds *uncorrelated with L1*, ~ 10% uptime loss
  - » L1: extreme weather *uncorrelated*, ~ 1-3% loss
  - » All 3: global earthquakes (magnitude > 5) *correlated*, ~ 1-3%
  - » All 3: equipment maintenance *correlated*, ~ 7-10%
    - e.g., liquid nitrogen deliveries, HVAC maintenance
    - current experience bottoms at about 1/2 day per week
  - » All 3: hardware & software failure *uncorrelated, high @ run start*
    - Latter 1/4 of S4 uptimes averaged 87% (L1), 86% (H1), 90% (H2)
- What are realistic goals?
  - » 3 x 85% @ 70% triple looks achievable without heroic investments
  - » Approaching 3 x 90% @ 75% triple goal may require a wind noise solution, near 100% equipment reliability, and *much more experience*



# Duty Factors





# Duty Factor Targets\* & Actuals

(\*from Nov. 2006 NSF review)

Run	S2	S3	S4	S5 Target (proposed)	S5 to 3/18/06 <sup>A</sup>
L1	37%	22%	75%	85%	52%
H1	74%	69%	81%	85%	64%
H2	58%	63%	81%	85%	72%
3-way	22%	16%	57%	70%	36%

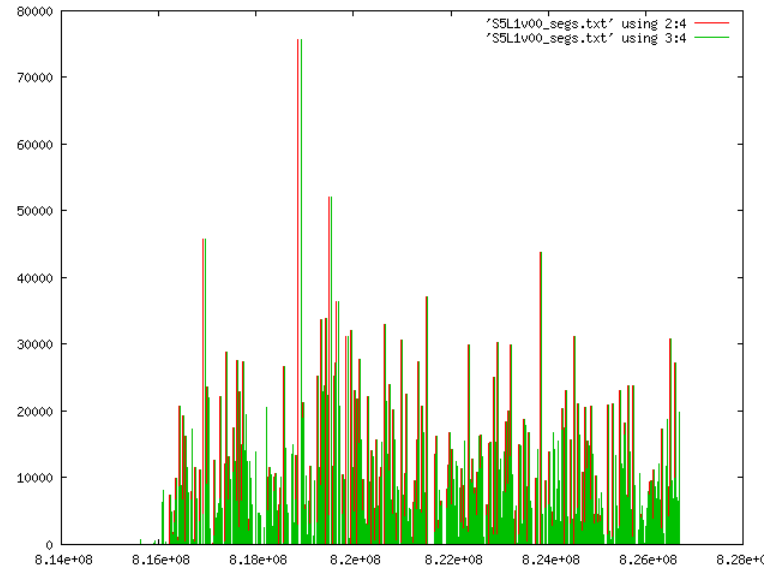
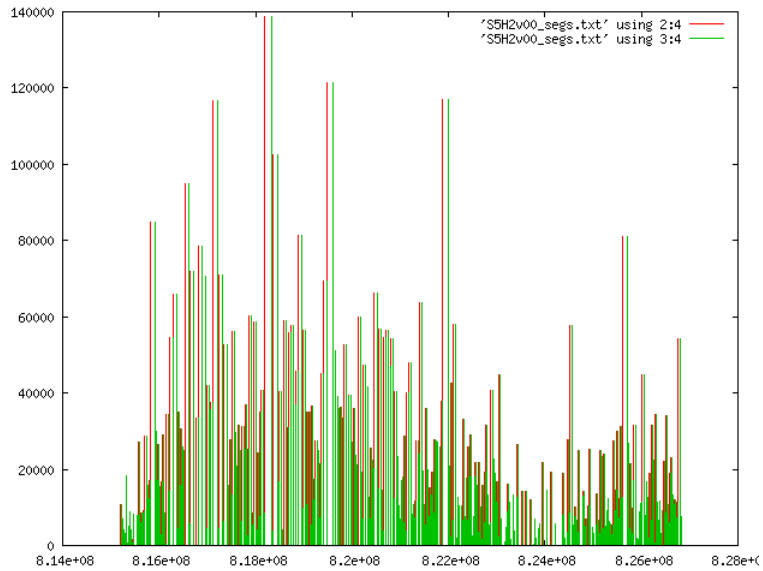
<sup>A</sup>Including run startup transient and current commissioning break



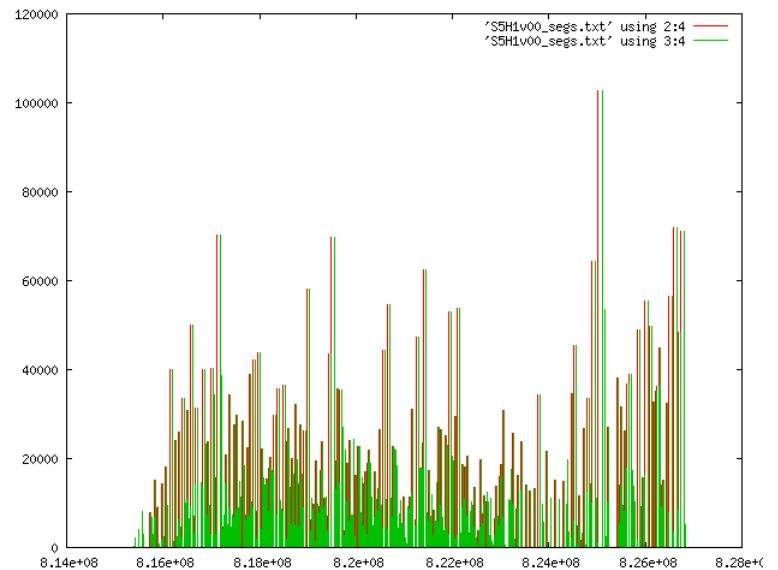
		Duration
Science Run #5	04Nov2005 – ongoing	> 3240 hrs
Science Run #4	22Feb2005 – 23Mar2005	708 hrs
Science Run #3	31Oct2003 – 9Jan2004	1680 hrs
Science Run #2	14Feb2003 – 14Apr2003	1415 hrs
Science Run #1	23Aug2002 – 9Sep2002	408 hrs



# S5 Science Mode Intervals



Height ~ duration  
Red Start   Green Stop







## S4 Lock Statistics

science data from 793130413 (2005 02/22 18:00:00) to 795679213 (2005 03/24 06:00:00 utc)

L1

duty cycle 74.5%

Total Locked time: 528 hrs

Longest segment was 18.7 hrs

L1 and H1

duty cycle 63.1%

Total coincident time: 447 hrs

Longest segment was 14.5 hrs

H1

duty cycle 80.5%

Total Locked time: 570 hrs

Longest segment was 23 hrs

L1 and H2

duty cycle 62.9%

Total coincident time: 445 hrs

Longest segment was 12.2 hrs

H2

duty cycle 81.4%

Total Locked time: 576 hrs

Longest segment was 22.8 hrs

H1 and H2

duty cycle 72.1%

Total coincident time: 510 hrs

Longest segment was 19.6 hrs

L1, H1, and H2

duty cycle 56.9%

Total coincident time: 403 hrs

Longest segment was 11.9 hrs



# S5 Lock Statistics Single Detector

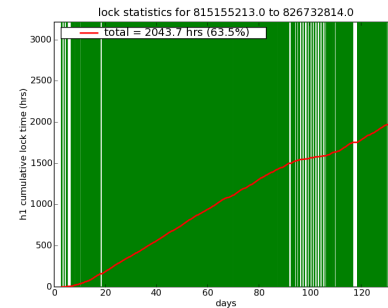
Statistics for science data from Nov 04 2005 16:00:00 UTC to Mar 18 2006 16:00:00 UTC

Plot color scheme:

- white indicates not locked;
- green indicates locked;
- red line is cumulative locked time

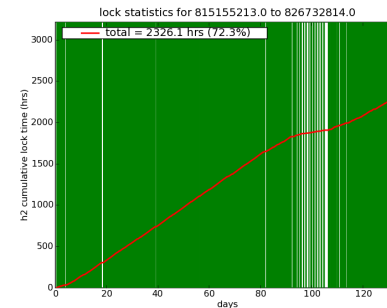
## H1

duty cycle between 815155213 and 826732814 is 63.5%  
total locked time: 2043.7 hrs (23.3% of 1 year)  
longest segment was 28.6 hrs starting at 824999081



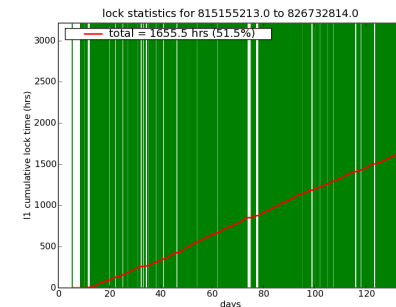
## H2

duty cycle between 815155213 and 826732814 is 72.3%  
total locked time: 2326.1 hrs (26.5% of 1 year)  
longest segment was 38.6 hrs starting at 818185336



## L1

duty cycle between 815155213 and 826732814 is 51.5%  
total locked time: 1655.5 hrs (18.9% of 1 year)  
longest segment was 21.0 hrs starting at 818844607



(1 year = 8765.8 hours)

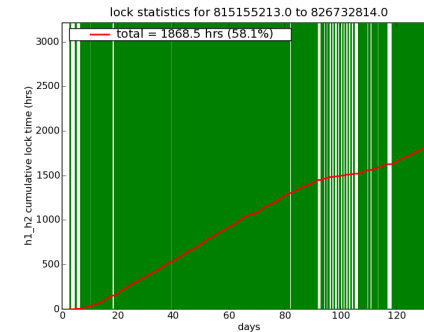


# S5 Lock Statistics Two-fold Coincidence

H1 H2

duty cycle between 815155213 and 826732814 is **58.1%**

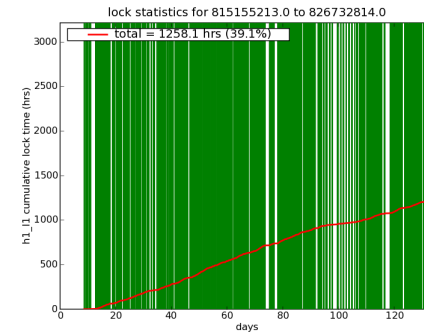
total locked time: 1868.5 hrs (21.3% of 1 year)  
longest segment was 19.5 hrs starting at 817108111



H1 L1

duty cycle between 815155213 and 826732814 is **39.1%**

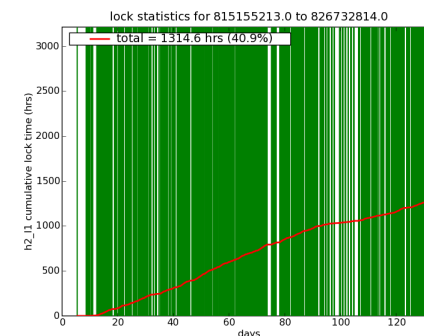
total locked time: 1258.1 hrs (14.4% of 1 year)  
longest segment was 14.5 hrs starting at 819490204



H2 L1

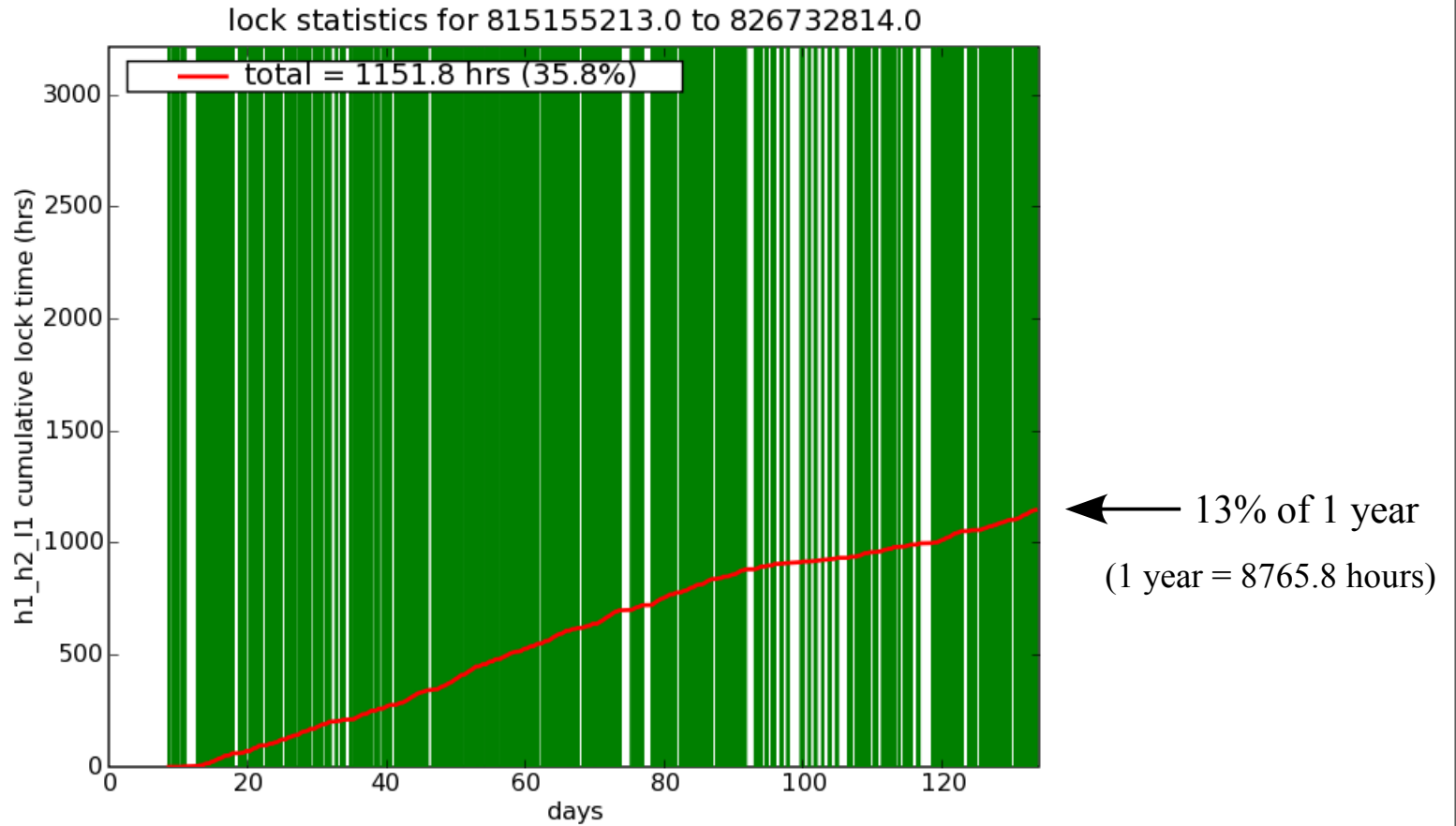
duty cycle between 815155213 and 826732814 is **40.9%**

total locked time: 1314.6 hrs (15.0% of 1 year)  
longest segment was 14.5 hrs starting at 819490204





# S5 Lock Statistics H1 H2 L1 Three-fold Coincidence



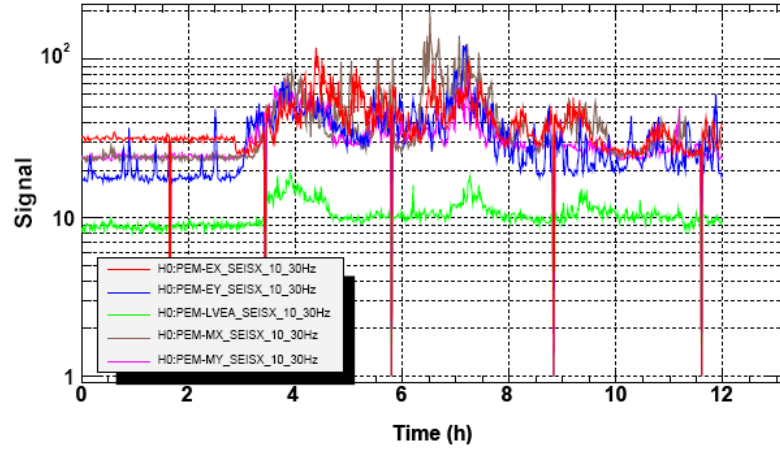
duty cycle between 815155213 and 826732814 is **35.8%**

total locked time: 1151.8 hrs (13.1% of 1 year)  
longest segment was 14.5 hrs starting at 819490204



# The Wind

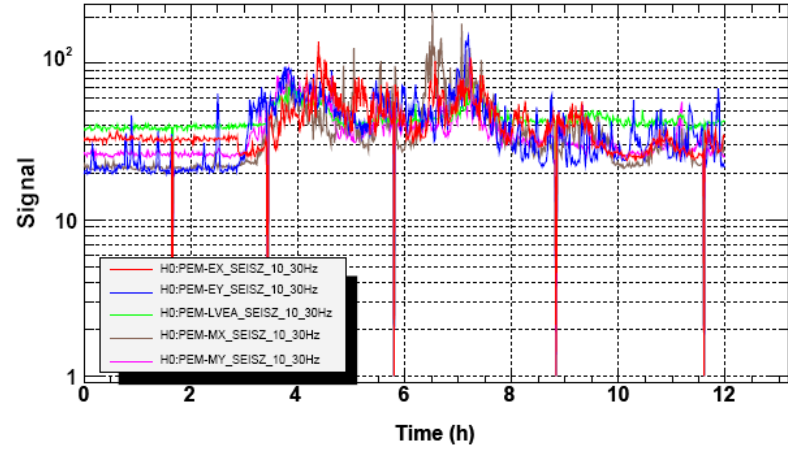
Time series



T0=11/01/2006 04:07:28

Avg=1

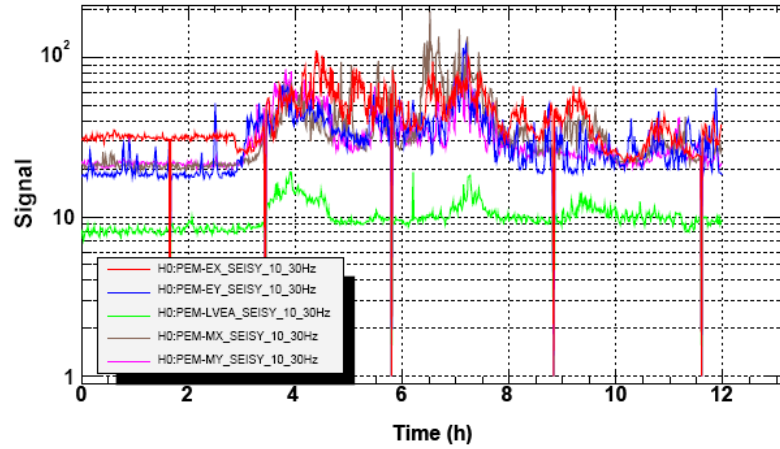
Time series



T0=11/01/2006 04:07:28

Avg=1

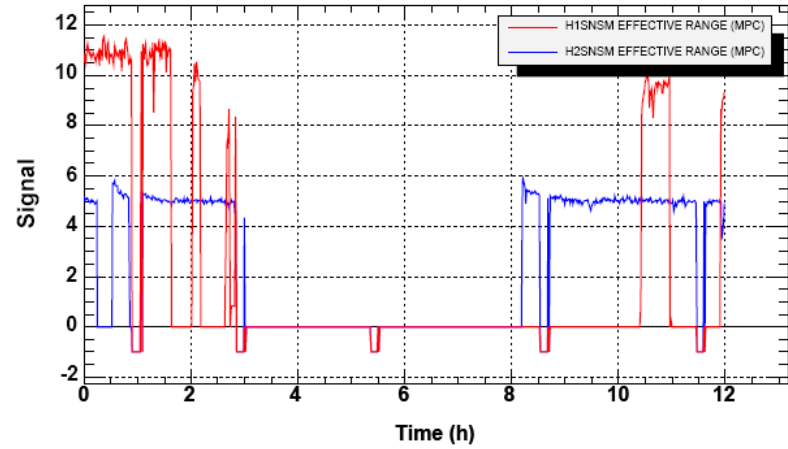
Time series



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Avg=1

Time series

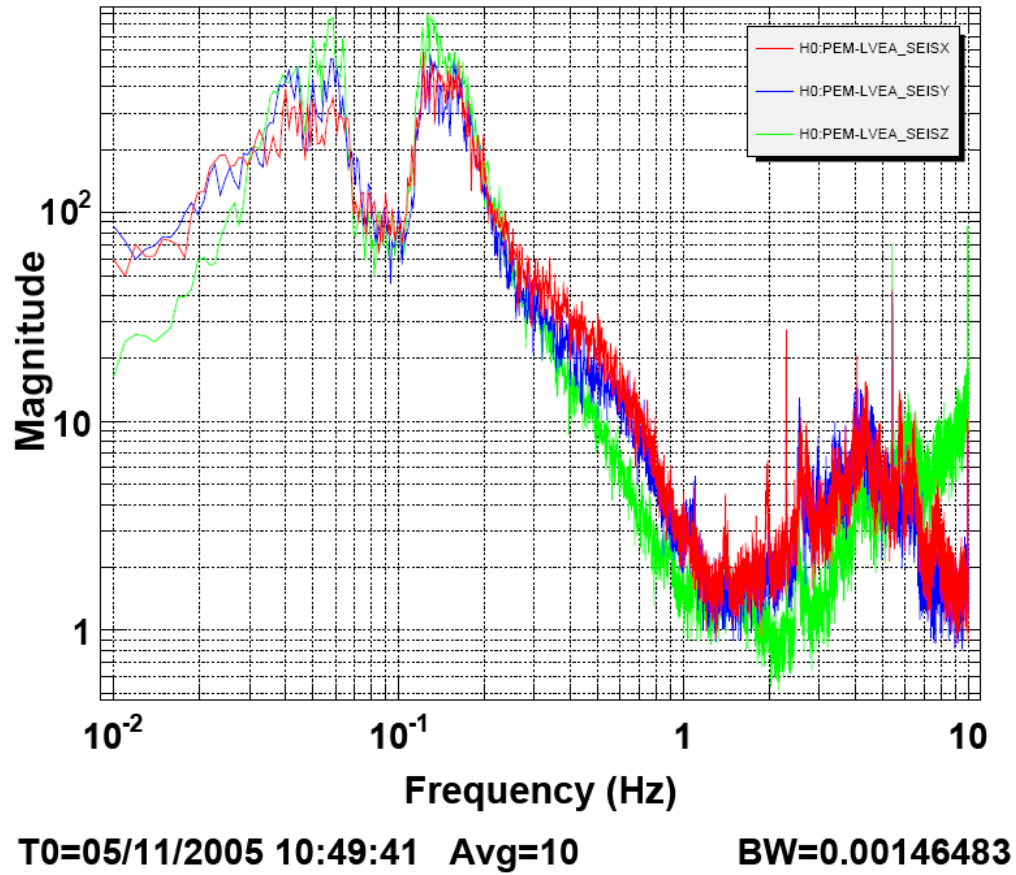


T0=11/01/2006 04:07:47

Avg=1



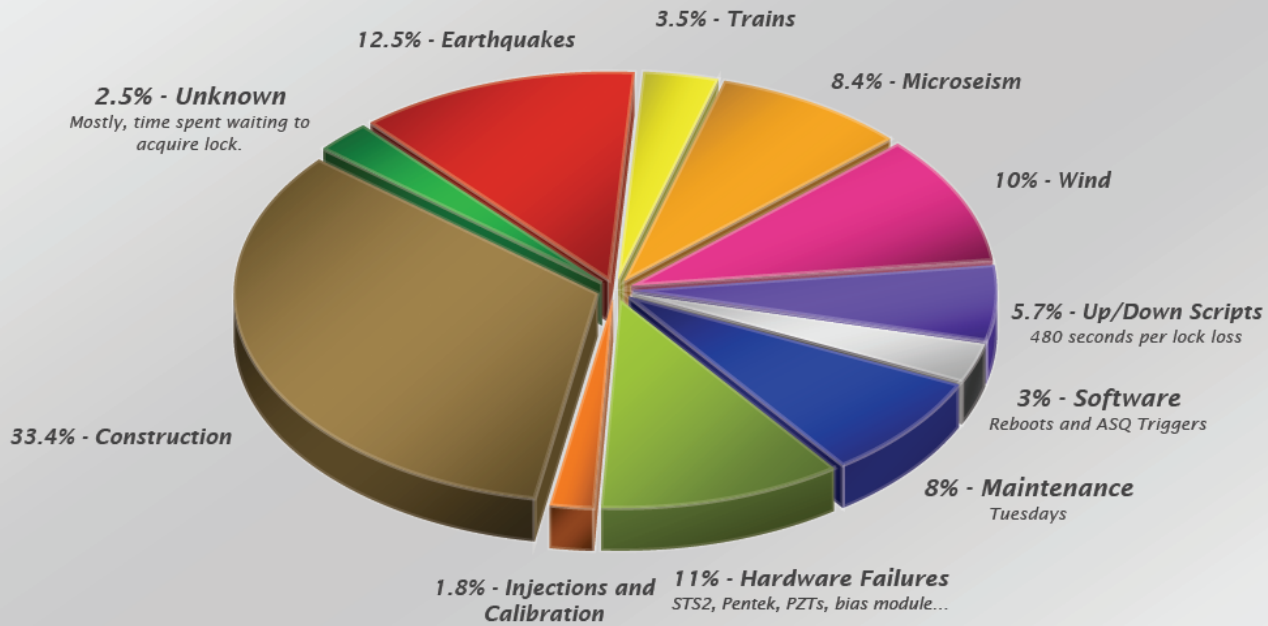
# Micro-seismics



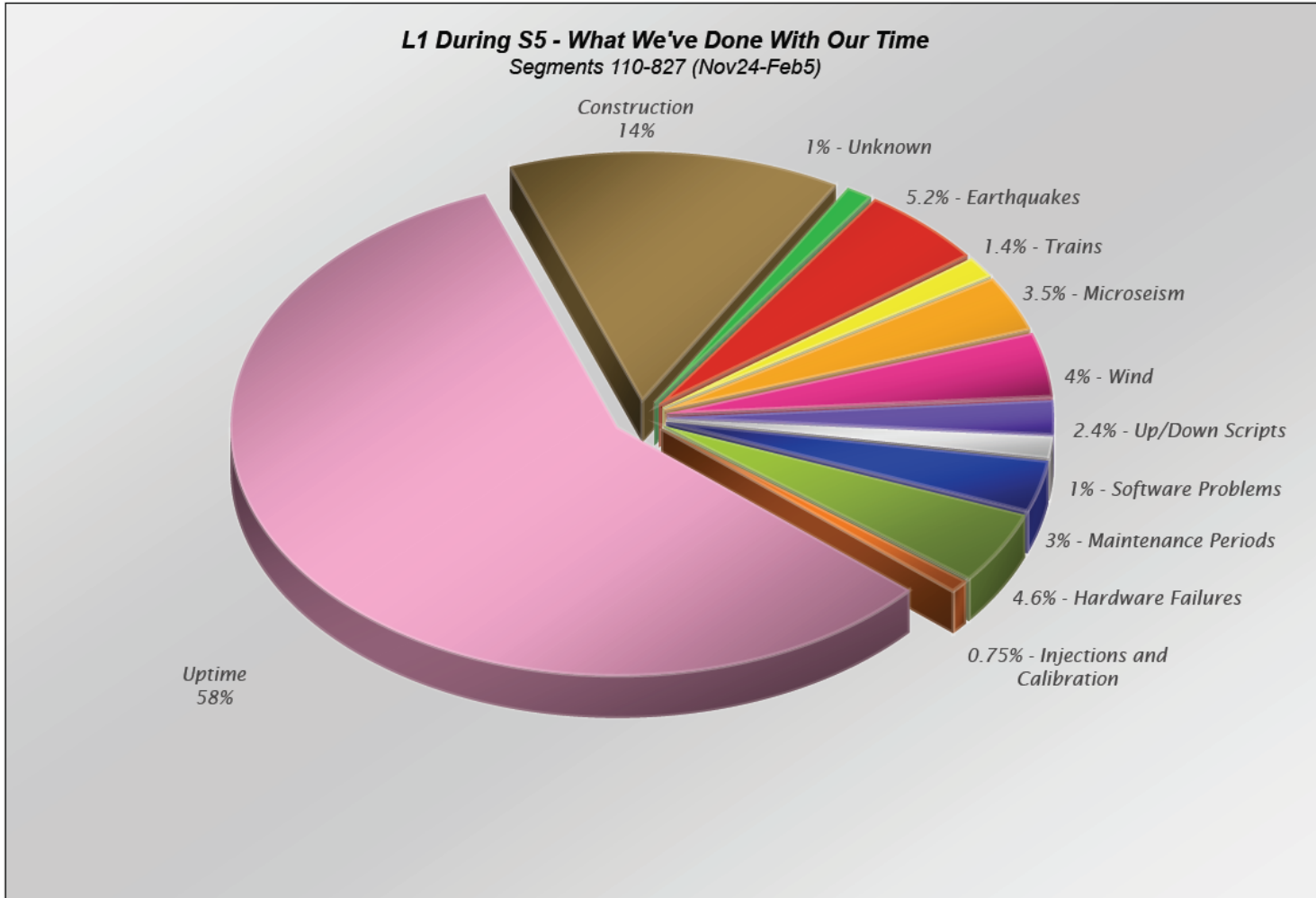
- SEC construction on site
  - » has taken ~18% off the top since run start (< 25% due to some credit for contractor holidays and “light activity” days)
  - » expected to improve in March as heavy work ends, BUT
  - » we have used as cover to get in extra maintenance & repairs (above nominal 2.4% allocated every week)
- High microseism
  - » Longest hurricane season on record, particularly intense in Gulf
- Wind sensitivity & winter weather
  - » Adverse side effect of HEPI inertial loops; unlike true seismicity, wind tilts the buildings
  - » Wind threshold (about 12 kt) is much lower than at LHO (about 20 kt)
  - » Moderate increase in # of windy days --> larger than expected downtime
- Still a significant rate of unexplained lock losses

**L1 Downtime in S5 Segments 110-827 (Nov24-Feb5)**

The data were primarily taken from the elog. Data prior to Nov24 2005 were omitted due to significant commissioning downtime.









## From the LLO Det-elog:

20:29:07  
Sun Jan 15  
2006  
(Local)

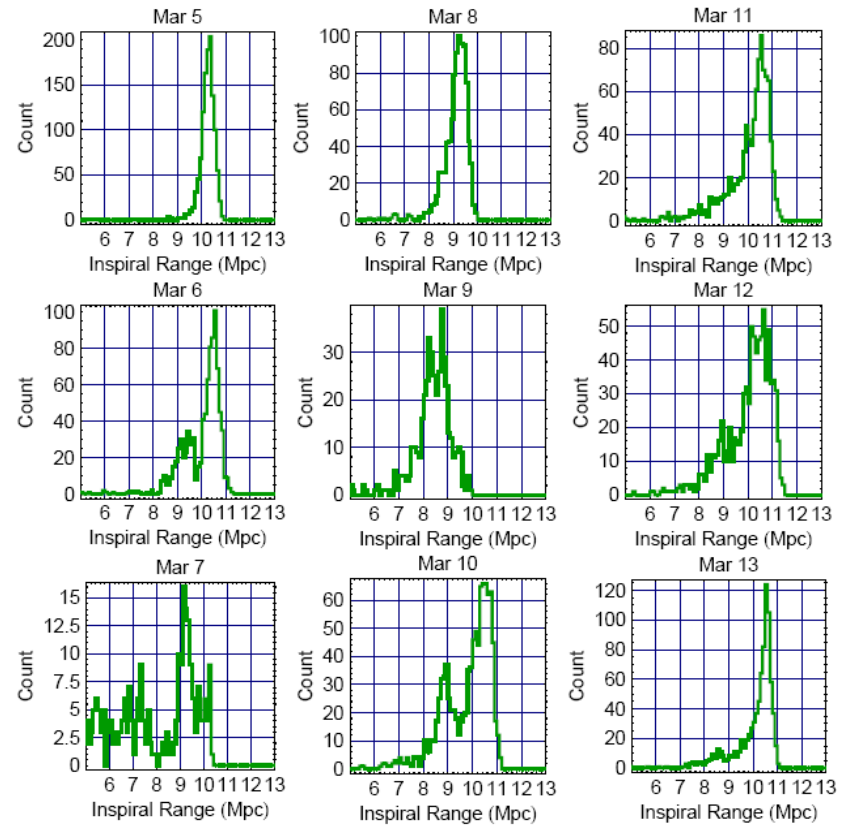
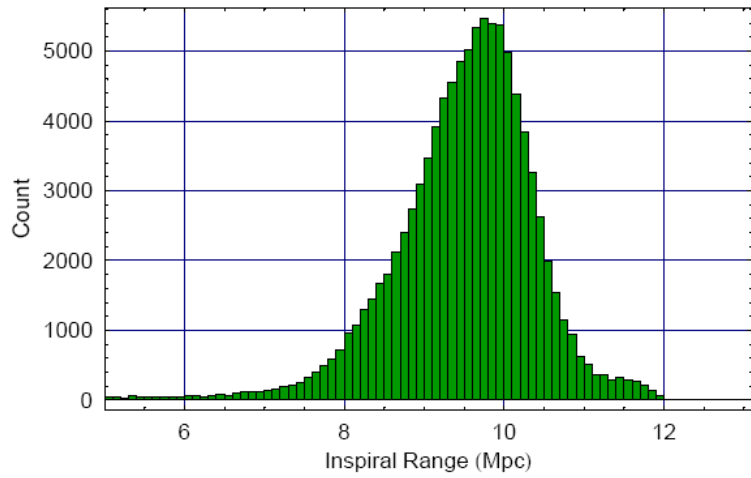
### L1 duty cycle, accounting for construction

The question of L1's duty cycle not during construction hours came up in the run meeting last week.

Currently, L1 has a total S5 duty cycle of 55%. The H1 IFO is at 67%.

Heavy equipment is typically active on site between 8am and 5pm every weekday. To see how L1 has measured up outside of these times, I examined the L1 locked statistics for S5 up to 14Jan. Of the 45 weekdays during that time, eight were holidays that experienced no construction (list below). This leaves 37 workdays where locking was impossible due to earthmoving. I subtracted  $37 \times 9 = 333$  hours from the total S5 time period, and ignored science segments during those hours (about 137,000 seconds, or 38hrs, of lunchtime locking).

This returns an **L1 not-during-construction duty cycle of 67%**.



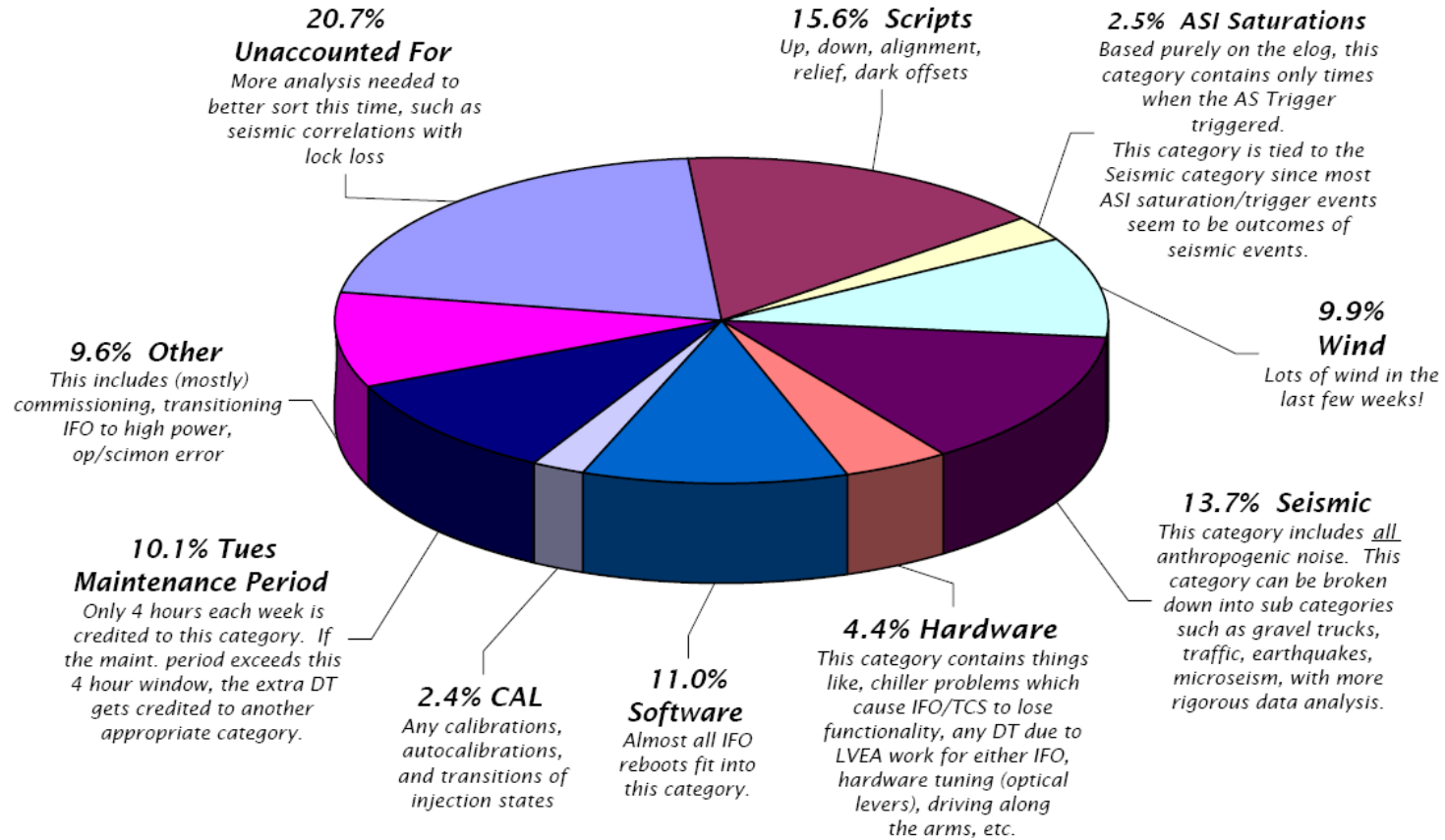


# H1

- Complicated picture; no single issue (?)
- Wind and microseism playing important roles at 10% level
- Clear relationship found early in run between robustness and operating power, leading to two-mode operation (best sensitivity at night, derated laser power during days)
- Under active investigation (next page)
- Last 2 weeks: commissioning “intervention” to improve both sensitivity and duty factor



**S5 H1 Downtime** Segments 100-695 (11/20/05-1/20/06)  
 This data was primarily taken from the elog. Data prior to 11/20/05 was omitted since there was a large amount of commissioning downtime.

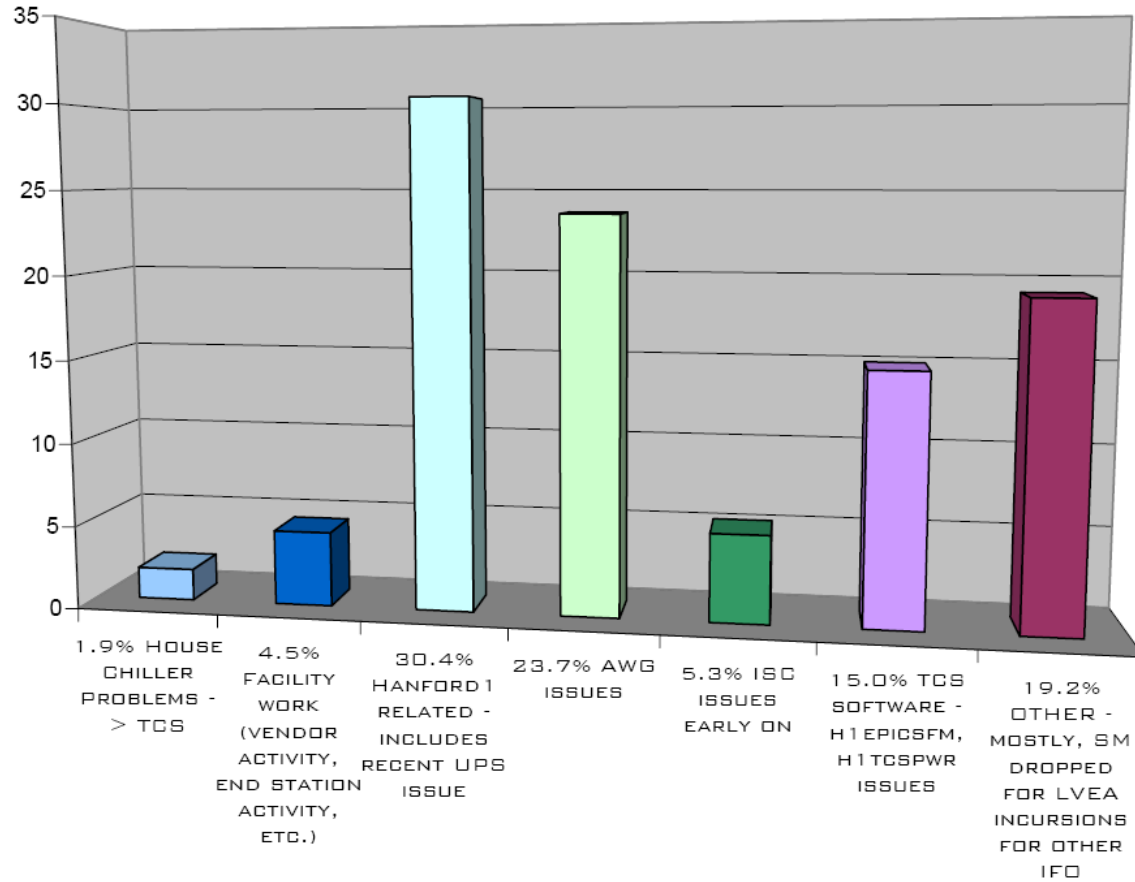


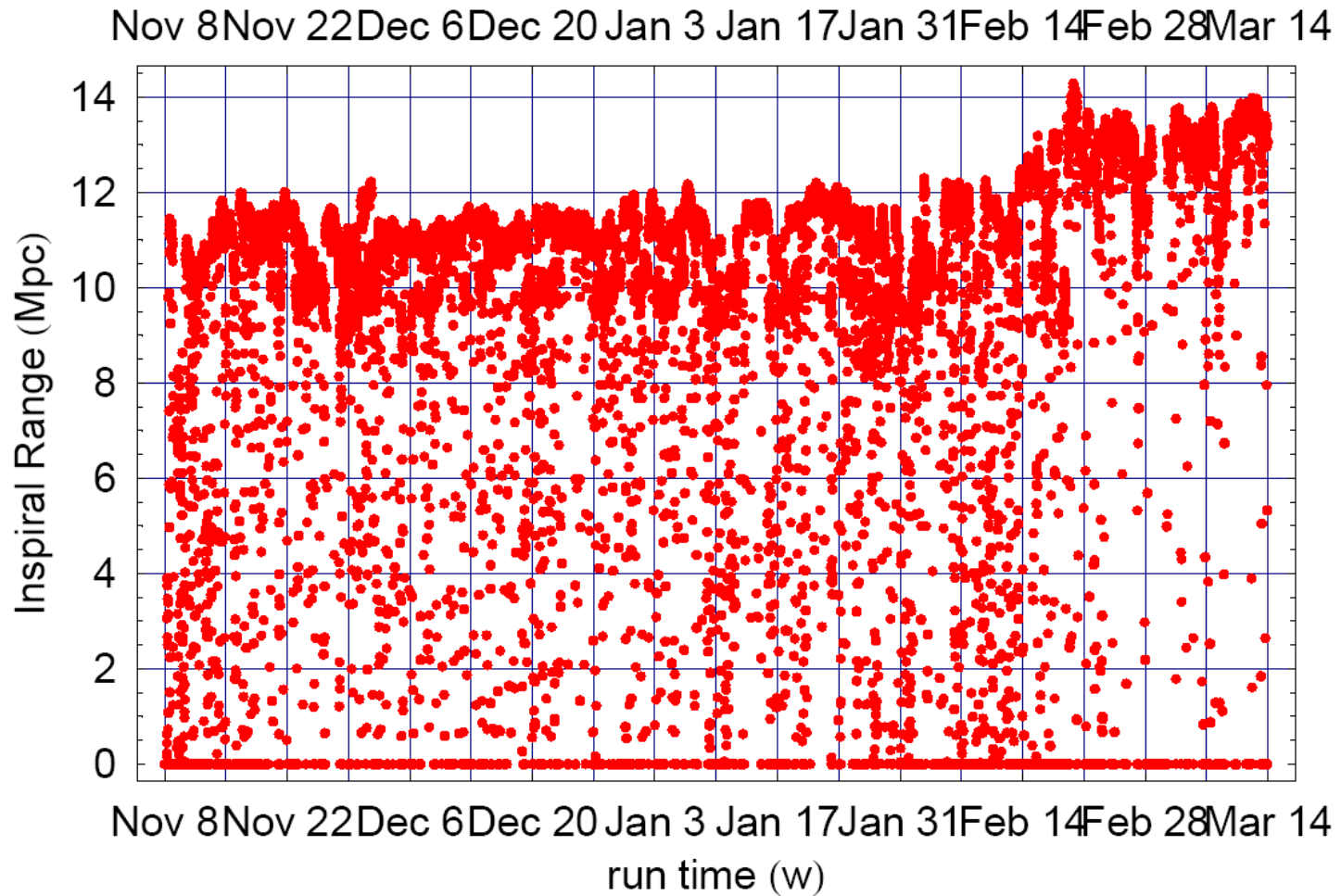


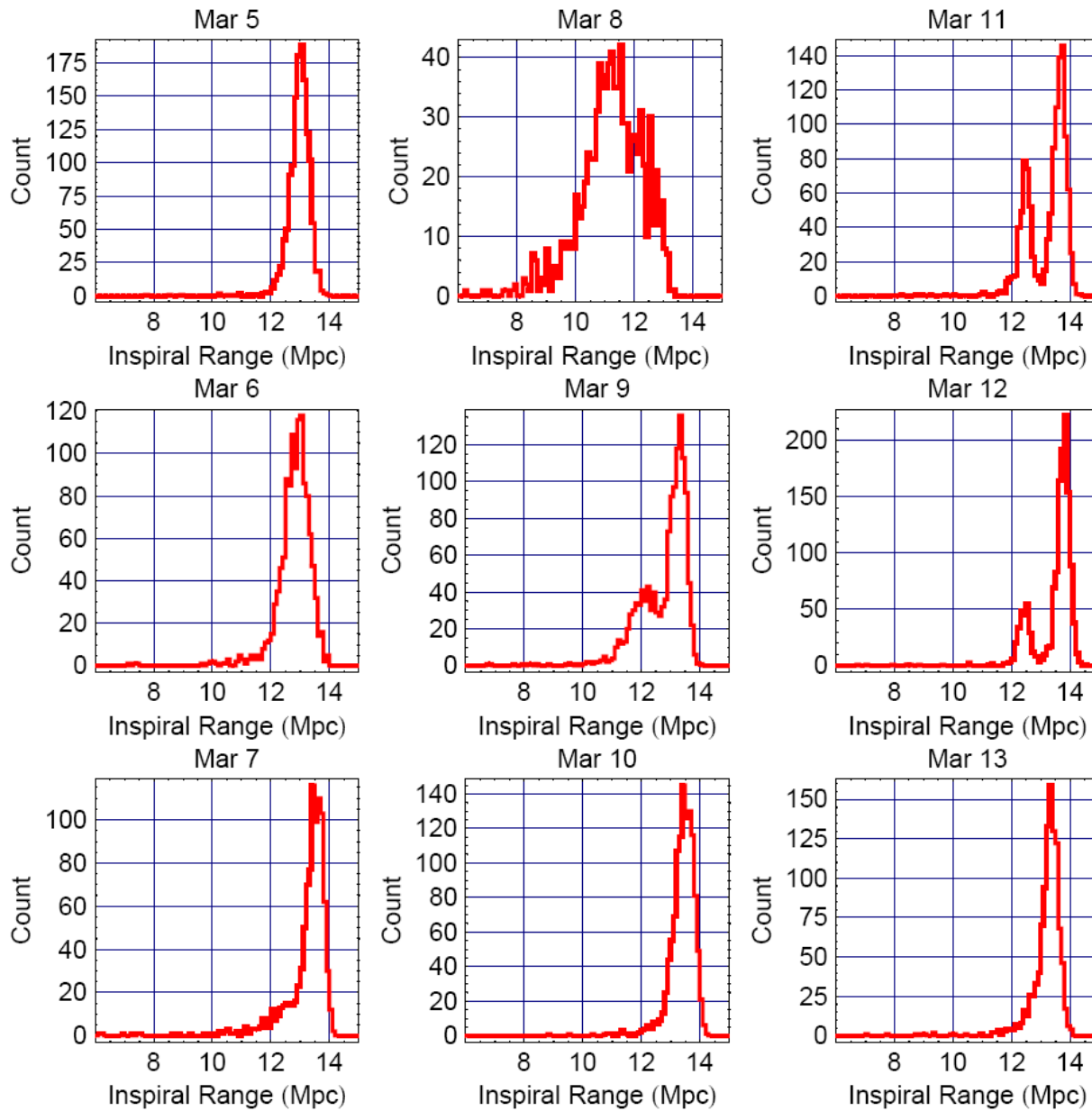
S5

**BREAKDOWN OF 15% SOFT/HARDWARE SLICE OF TOTAL DOWNTIME PIE** BBLAND 2/2/06

PERCENTAGE OF TOTAL S5 HARDWARE & SOFTWARE DT CATEGORY





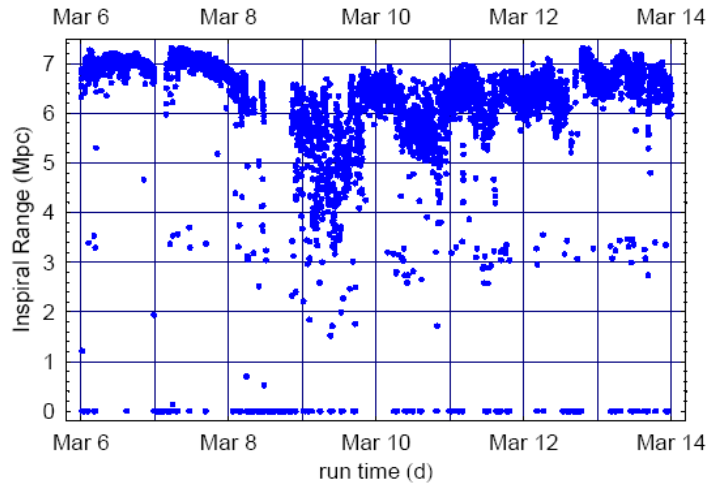
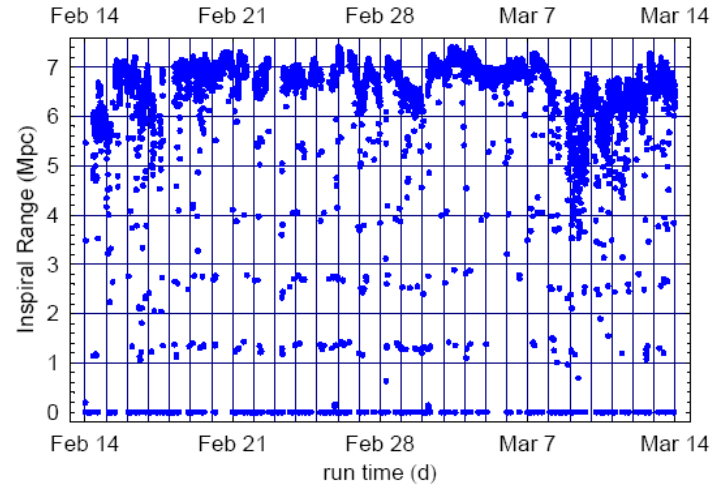
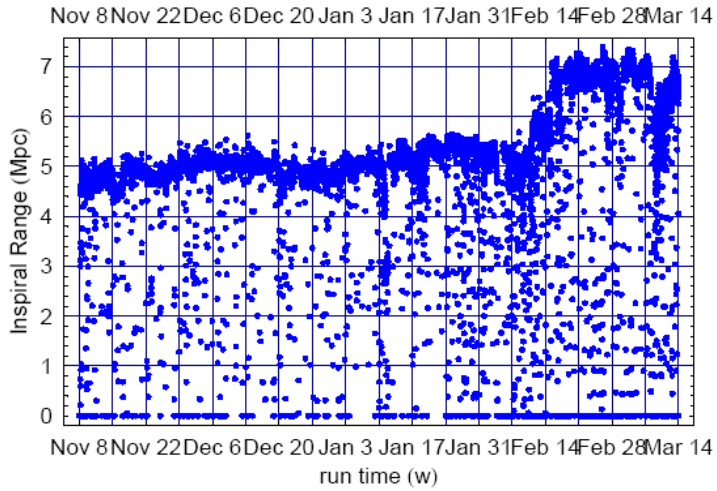


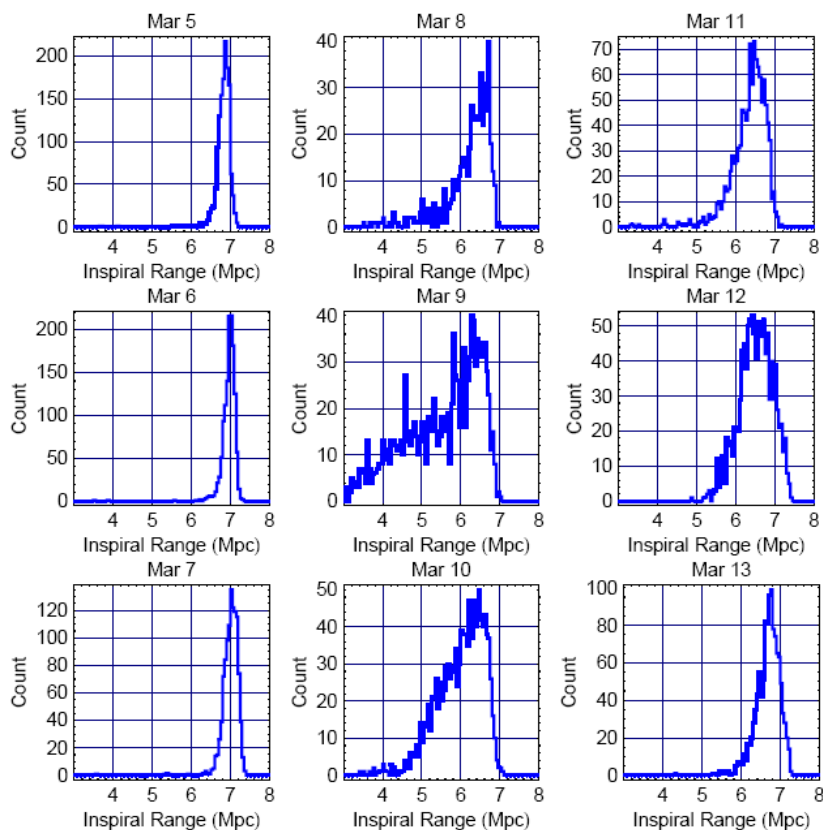


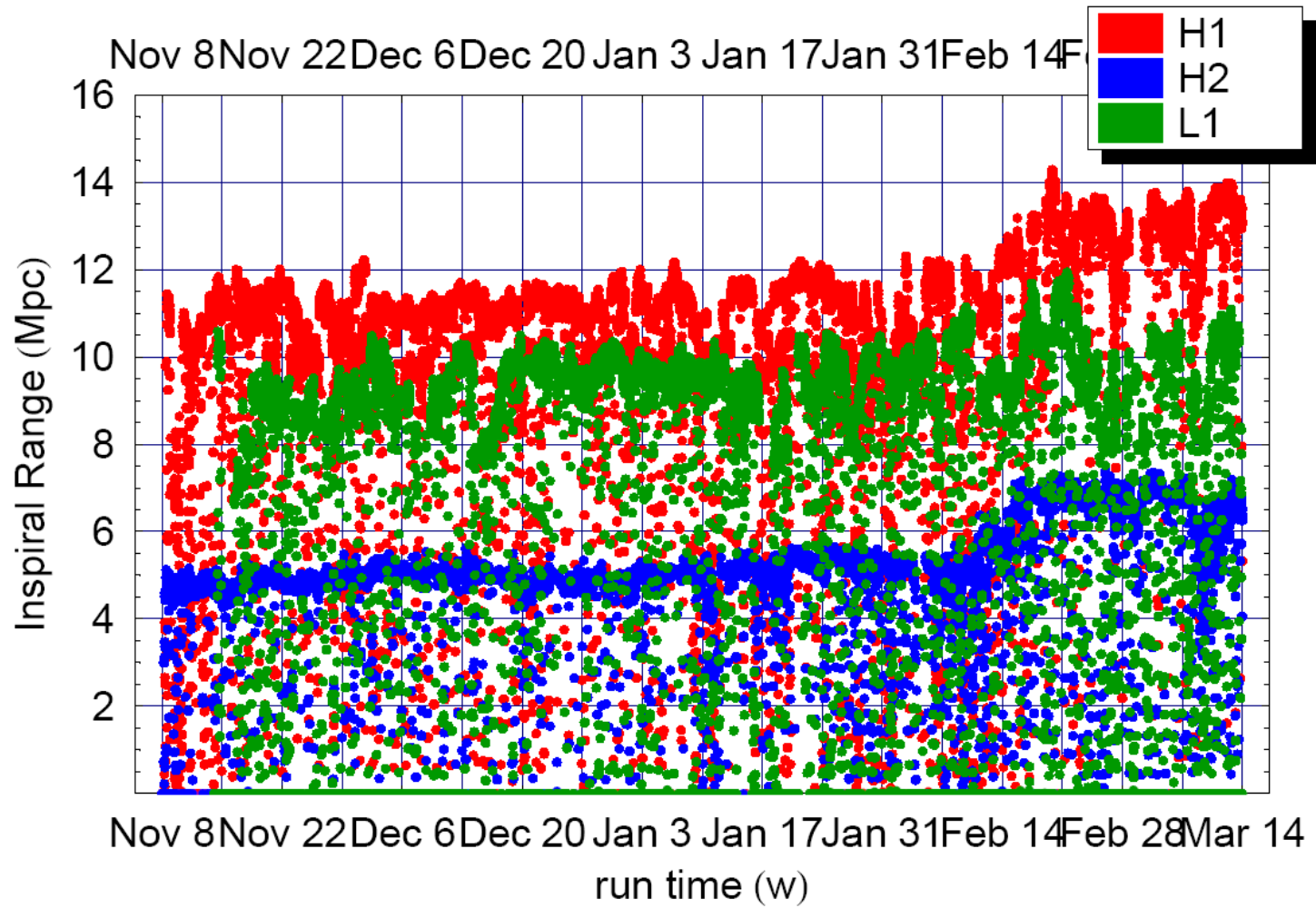


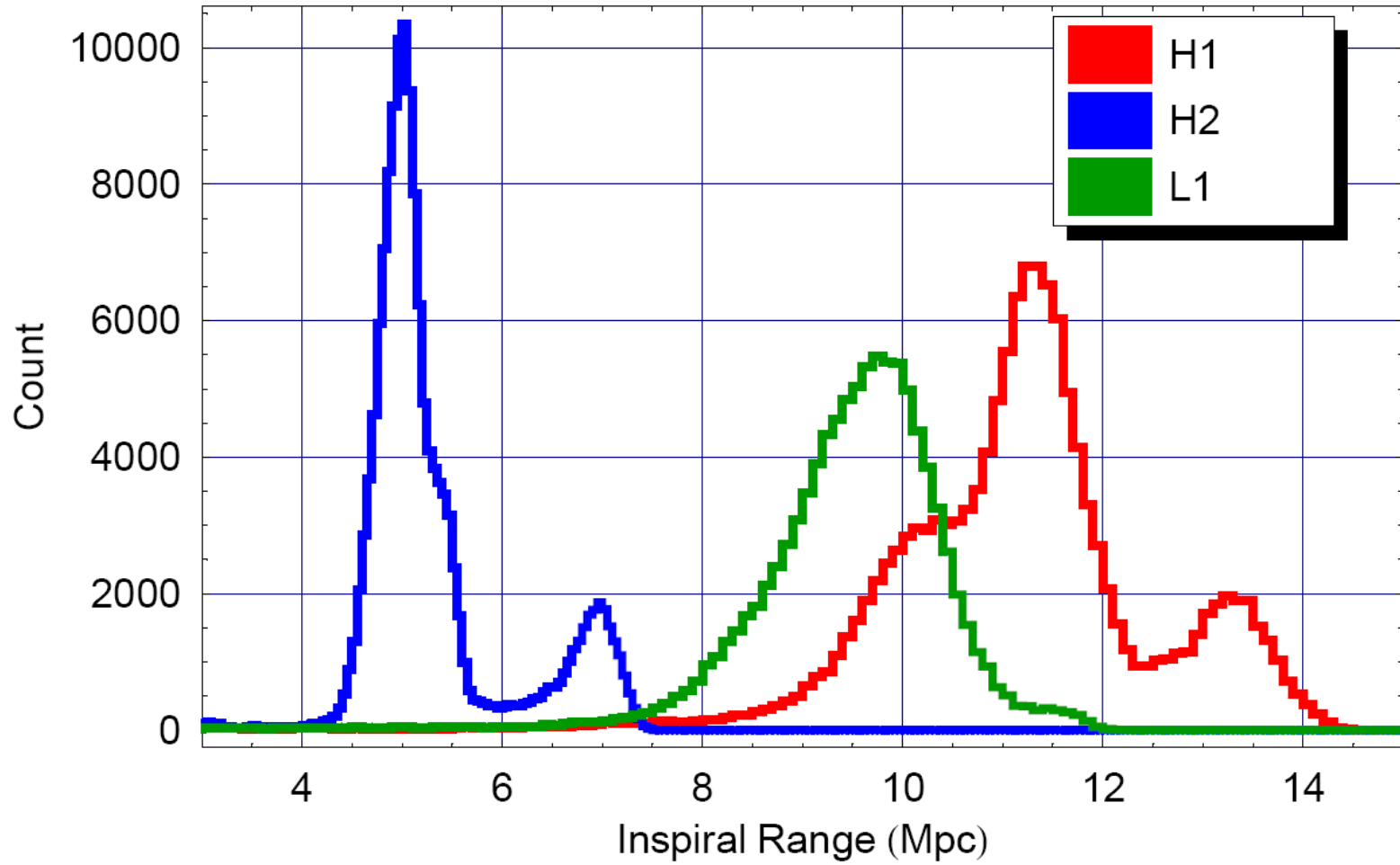
## H2

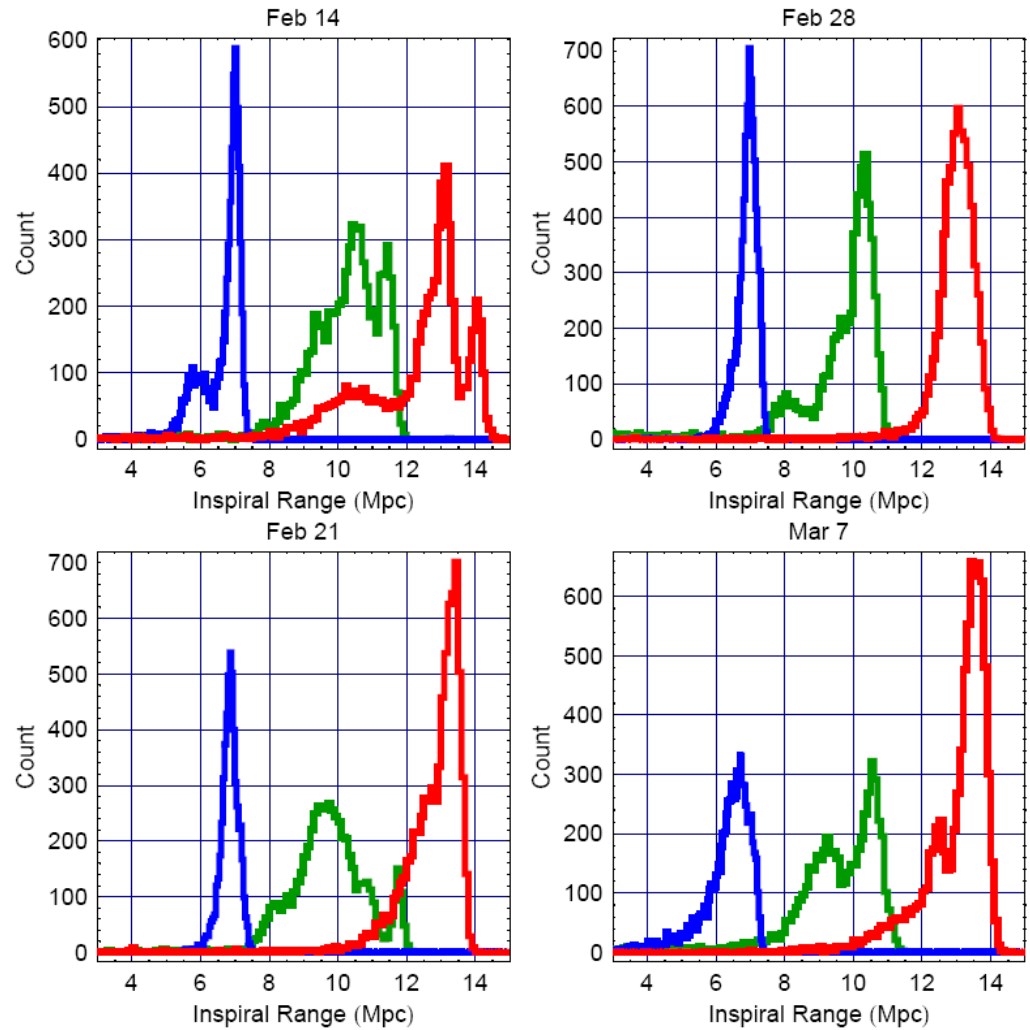
- Same environmental issues as H1 but somehow more robust
  - » 2km length makes a difference in degree of seismic correlation between the stations (more 'common mode') ?
  - » Some hardware differences ?
  - » Would like to bottle & sell it to L1 & H1, whatever it is
- Large fraction of H2 downtime is *due to* H1 downtime (unlocking H1 interferes with H2 directly, or, we do not trust H2 data with H1 off in the weeds)
- Note: worldwide earthquakes > Richter 5 or so (few per week) take out all three machines at once.

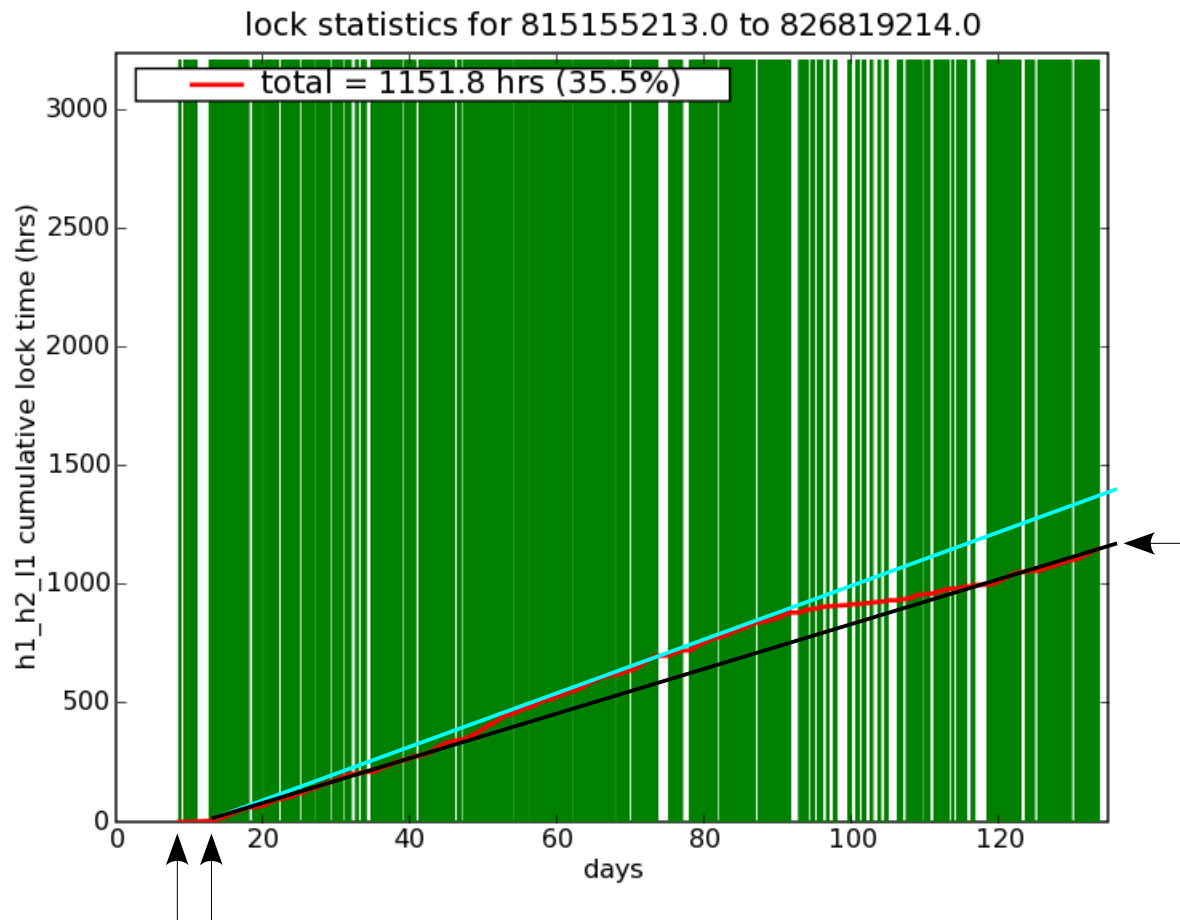














# Summary

- Duty factors are not up to targets yet
  - » LLO SEC construction activity is only one part of the equation
  - » Environmental sensitivities also appear to be worse
  - » Ongoing detector diagnostics, periodic interventions planned to address issues as they are understood
  - » SEC construction will enter a quieter phase in March
- Sensitivity is on target and improving
  - » Commissioning break at LHO produced significant returns
  - » Sensitivity issues (especially variability) and duty factor limits appear to be related in many cases (e.g., LLO  $\mu$ seism)
  - » LLO commissioning break starting April 3, 2006





