LIGO

Status of the LIGO Detectors

7th EDOARDO AMALDI CONFERENCE,
Sydney, July 9, 2007

Daniel Sigg, LIGO Hanford Observatory

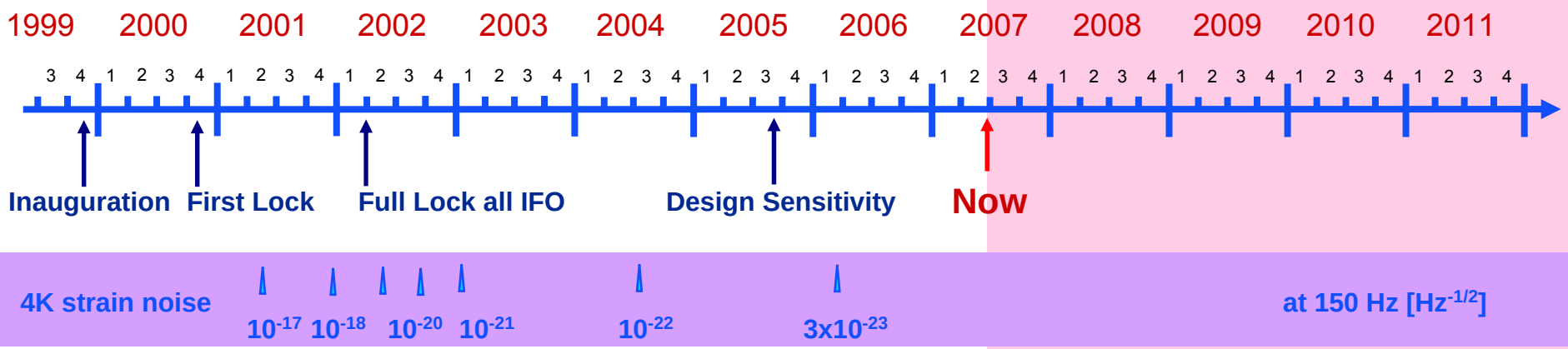
G070413-00-D

Arial View of the LIGO Sites

LIGO Hanford Observatory

LIGO Livingston Observatory

Time Line

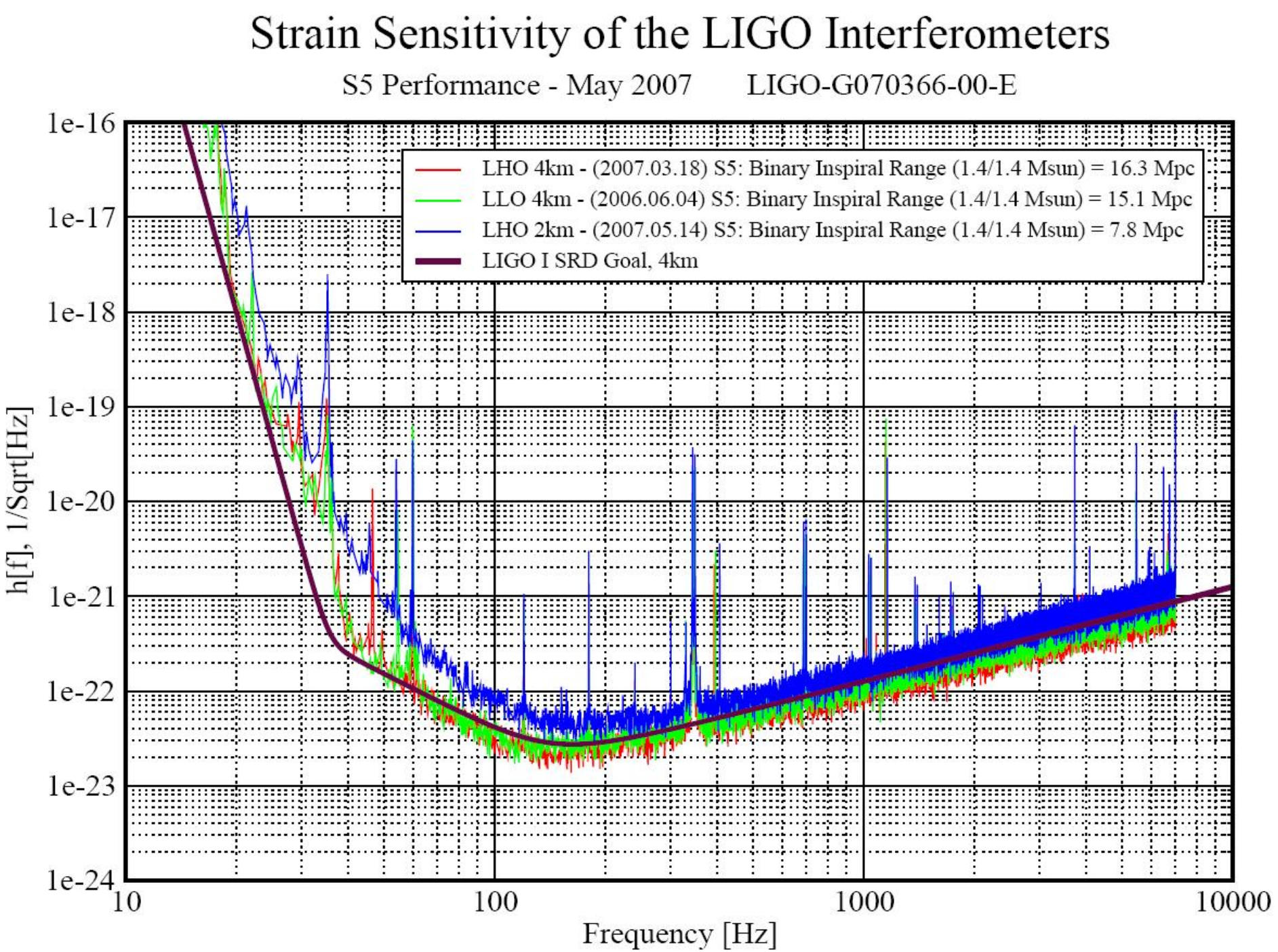

1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Inauguration
First Lock
Full Lock all IFO
Design Sensitivity
Now
4K strain noise
10-17 10-18 10-20 10-21 10-22 3x10-23
at 150 Hz [Hz-1/2]
Science
S1 S2 S3 S4 S5 S6
First Science Data
1 year of Coincidence Data
Runs
Enhanced LIGO
Advanced LIGO

Major Achievements Since Last Amaldi

- All 3 interferometers reached design sensitivity
  - Operation at high laser power
  - Many improvements in performance and robustness
- 24 observational papers published or submitted
- Almost done with S5 (1 year of coincidence data)
- LIGO enhancements well underway
  - Output mode cleaner
  - DC detection scheme
- Advanced LIGO is making its way through Congress
- Collaboration started with VIRGO

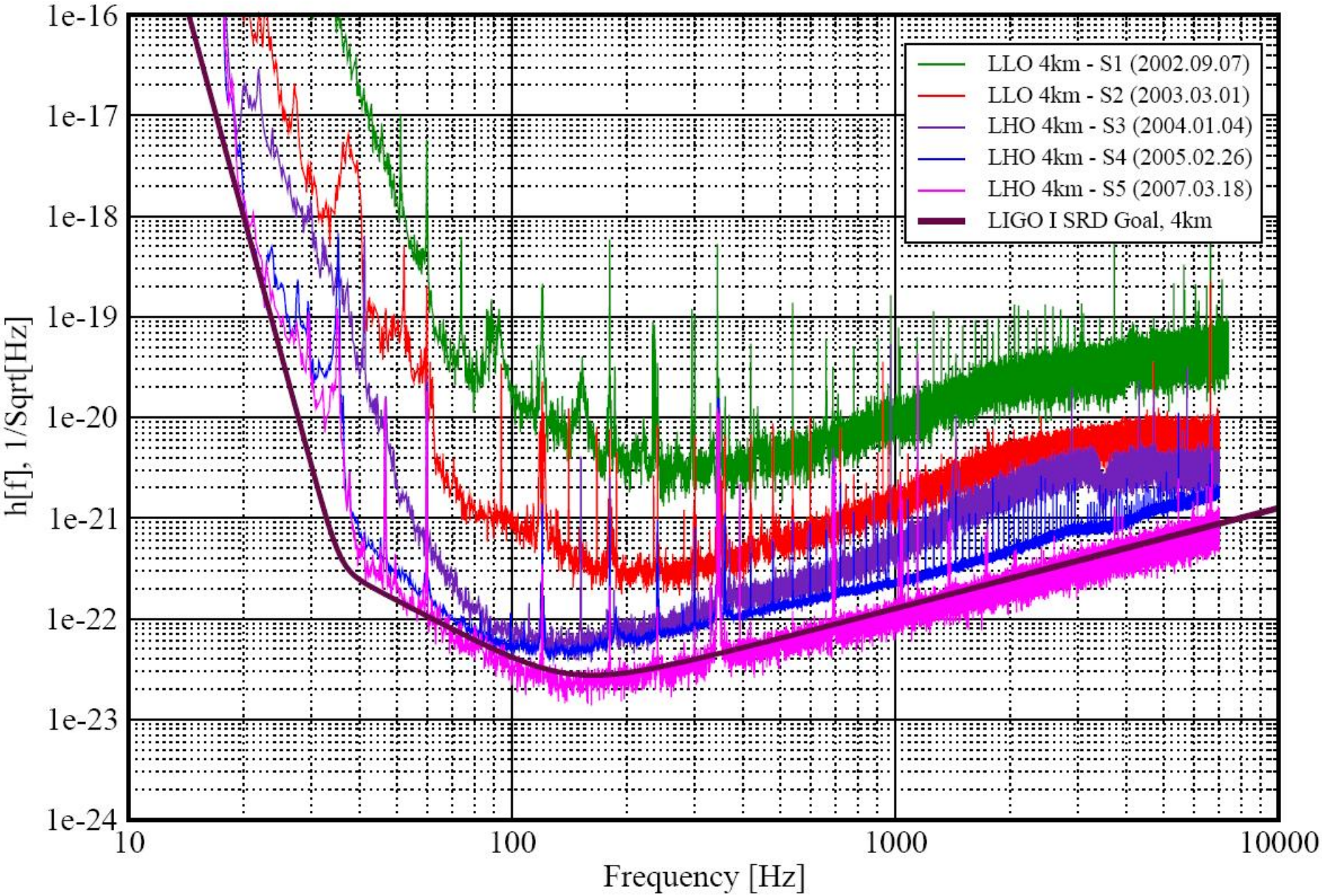
Most Recent Published Results up to the 4th Science Run

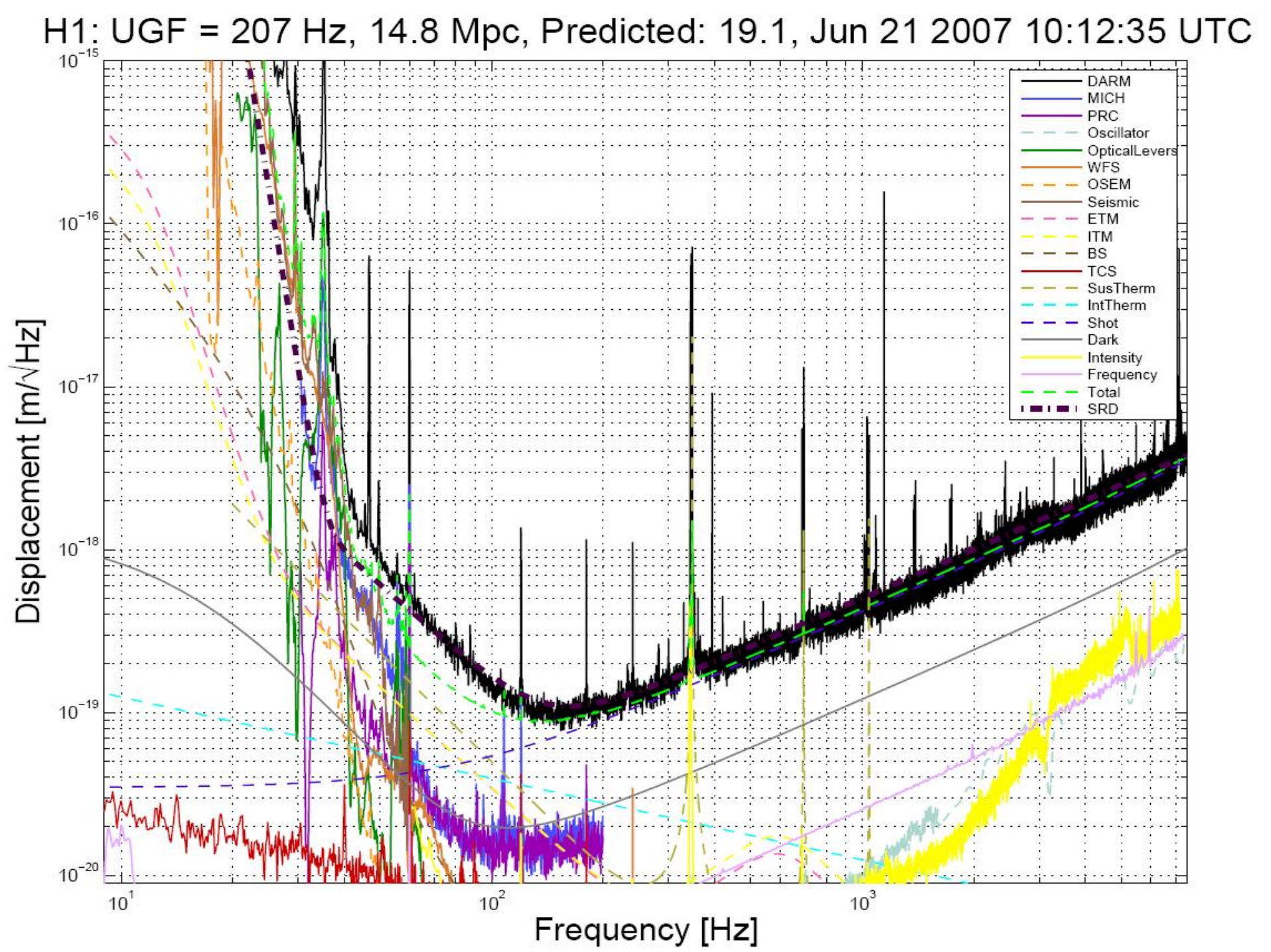
- Binary inspirals (S3/S4):
  - Neutron star binary (1-3 $M_\odot$): rate ≤ 1.2/y/L_{10} (90% CL, Milky Way ~ 1.6 L_{10})
  - Black hole binary (3-40/80 $M_\odot$): rate ≤ 0.5/y/L_{10} (90% CL)
  - Primordial black hole binary (0.35-1 $M_\odot$): rate ≤ 4.9/y/L_{10} (90% CL)
- Pulsars (S3/S4):
  - Limits on 78 pulsars
  - Upper limits on h as low as 3.2×10^{-25} (95% CL) and as low as 1×10^{-6} on the eccentricity
- Stochastic background (S4):
  - Energy limit as fraction of closure density: $\Omega_{GW} \leq 6.5\times10^{-5}$ (90% CL) for a frequency independent GW spectrum between 51 Hz and 150 Hz
- Burst (S4):
  - Sensitivity: h_{rss} ~ 10^{-21} - $10^{-20}/\sqrt{Hz}$, rate ≤ 0.15/day (90% CL) corresponds to ~ 8×10^{-8} $M_\odot$ at a distance of 10 kpc (150Hz/Q=9 SG)
  - SGR1806-20 hyperflare on 12/27/04: $h_{rss} \leq 4.5\times10^{-22}/\sqrt{Hz}$ and $<4.3\times10^{-8}$ $M_\odot$


Strain Sensitivity of the LIGO Interferometers
S5 Performance - May 2007
LIGO-G070366-00-E
LHO 4km - (2007.03.18) S5: Binary Inspiral Range (1.4/1.4 Msun) = 16.3 Mpc
LLO 4km - (2006.06.04) S5: Binary Inspiral Range (1.4/1.4 Msun) = 15.1 Mpc
LHO 2km - (2007.05.14) S5: Binary Inspiral Range (1.4/1.4 Msun) = 7.8 Mpc
LIGO I SRD Goal, 4km
h[f], 1/Sqrt[Hz]
1e-16
1e-17
1e-18
1e-19
1e-20
1e-21
1e-22
1e-23
1e-24
10
100
1000
10000
Frequency [Hz]

Best Strain Sensitivities for the LIGO Interferometers

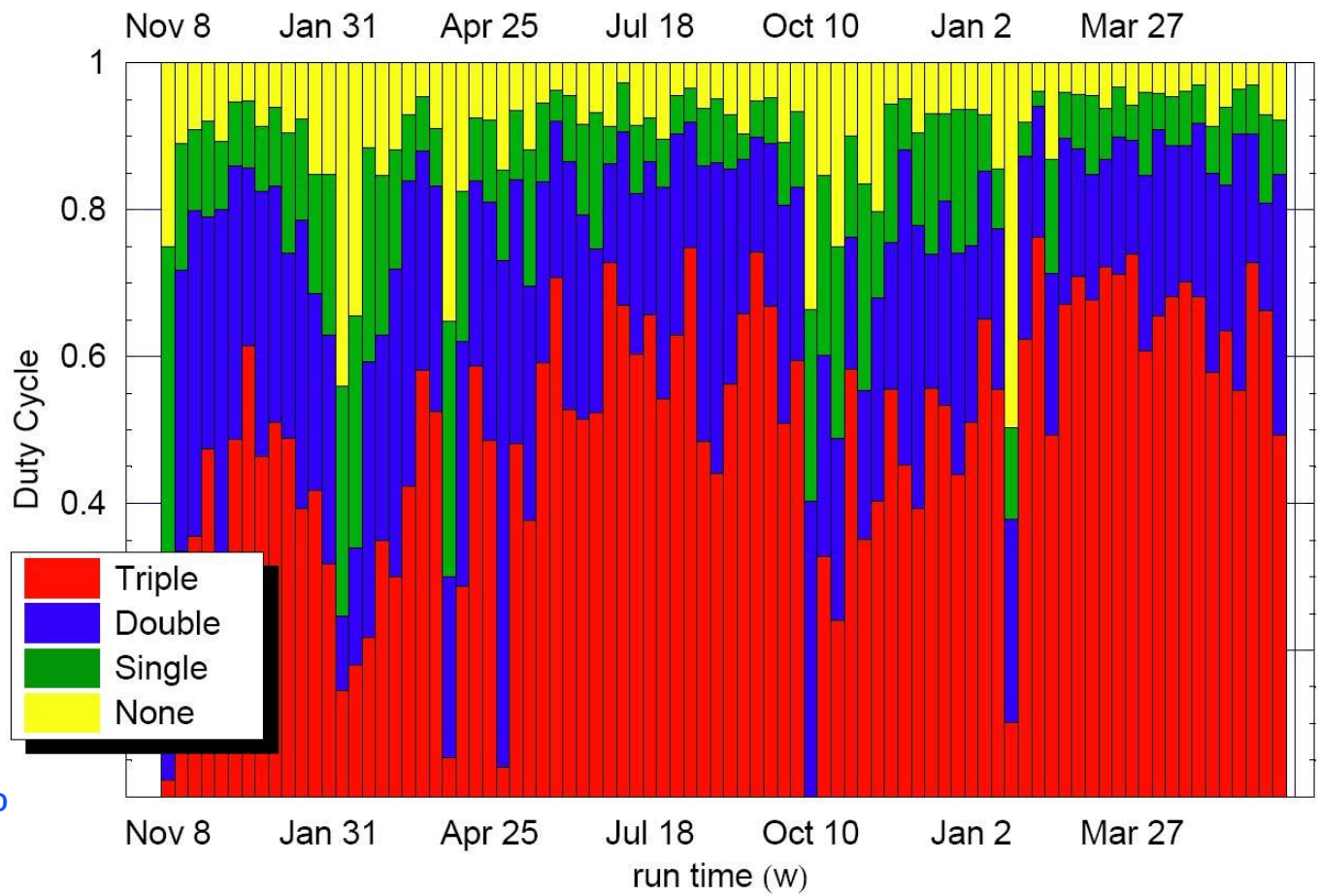
Comparisons among S1 - S5 Runs LIGO-G060009-03-Z



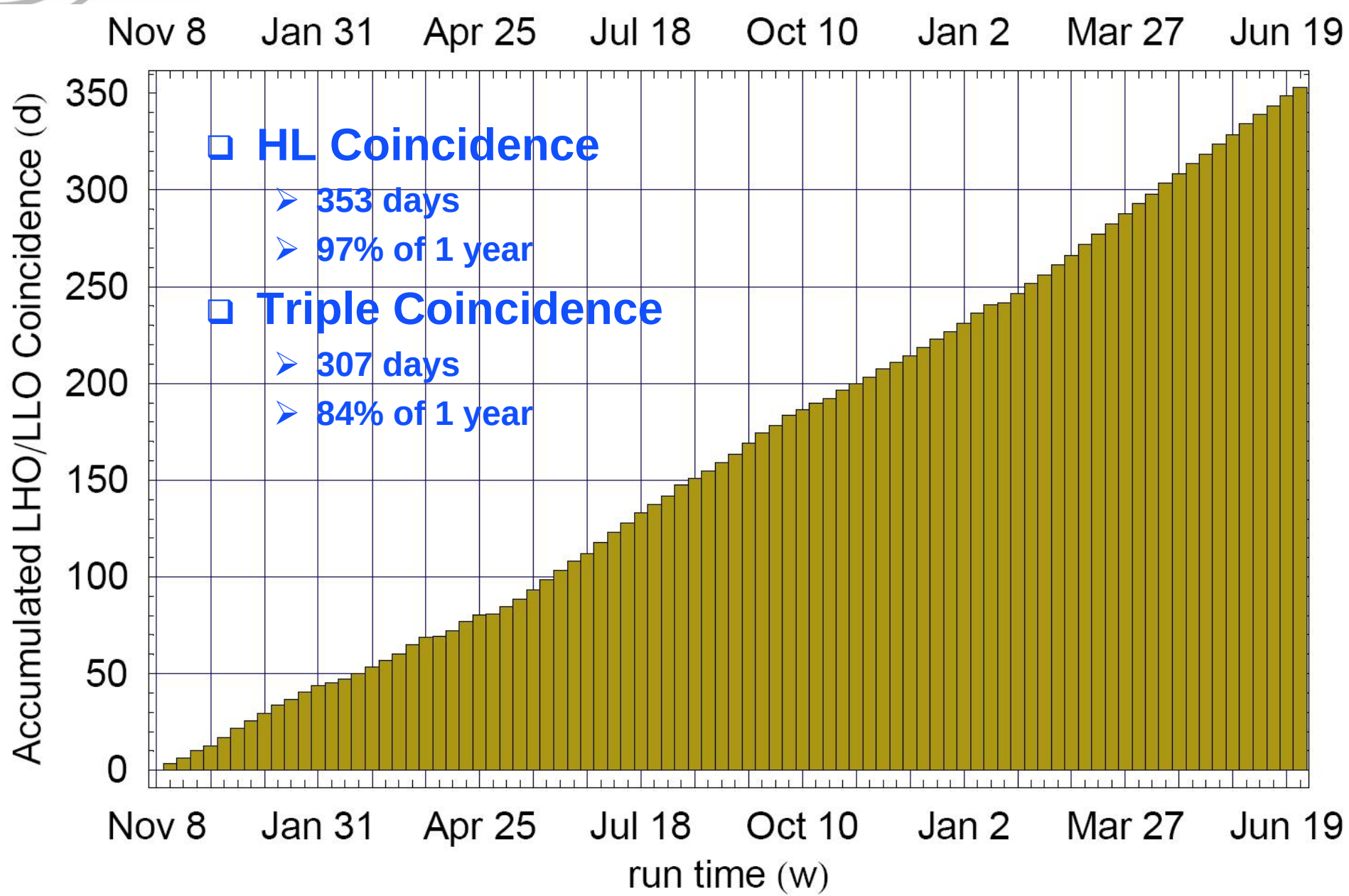

H1: UGF = 207 Hz, 14.8 Mpc, Predicted: 19.1, Jun 21 2007 10:12:35 UTC
Displacement [m/√Hz]
Frequency [Hz]
DARM
MICH
PRC
Oscillator
OpticalLevers
WFS
OSEM
Seismic
ETM
ITM
BS
TCS
SusTherm
IntTherm
Shot
Dark
Intensity
Frequency
Total
SRD

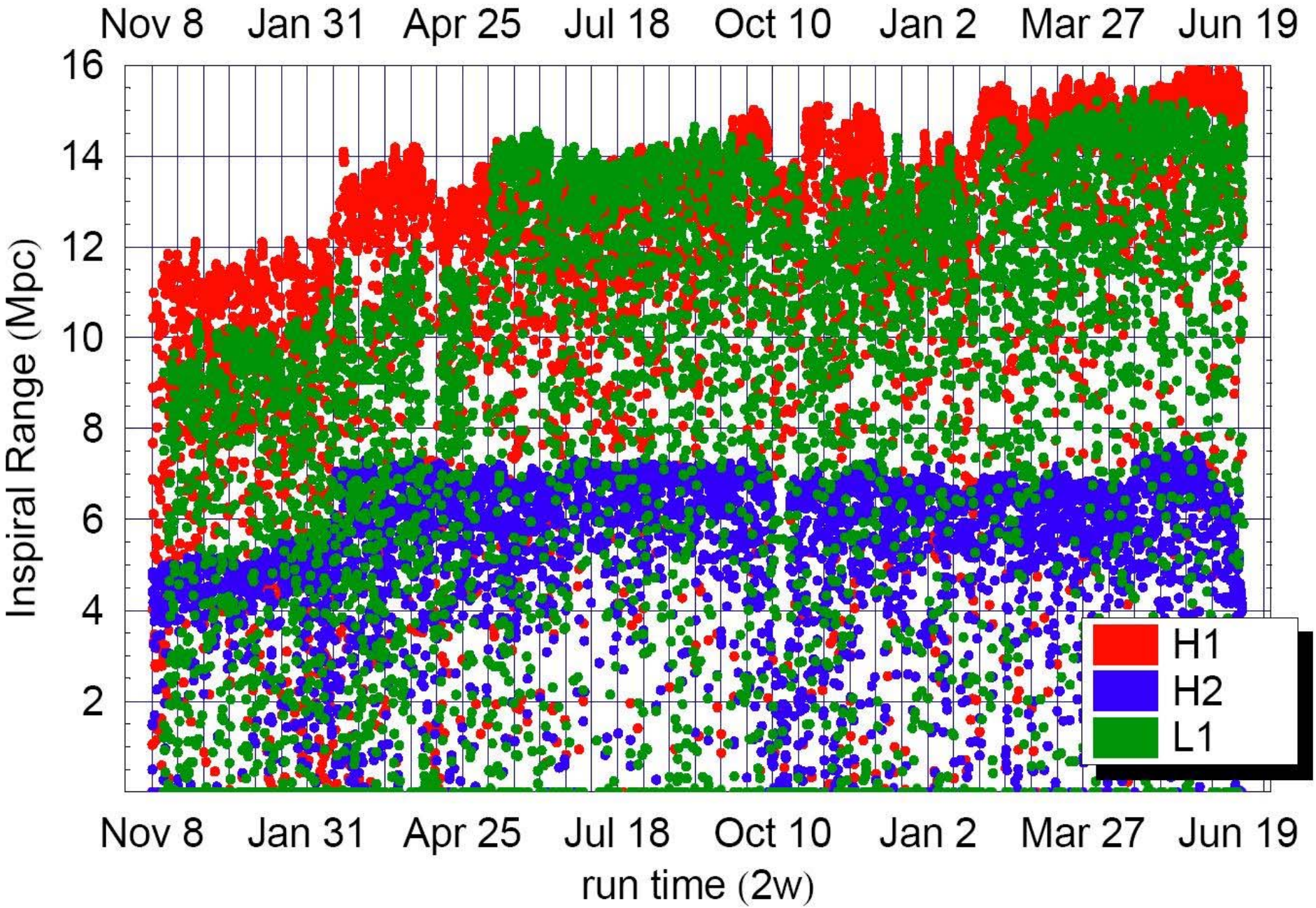
The 5th Science Run

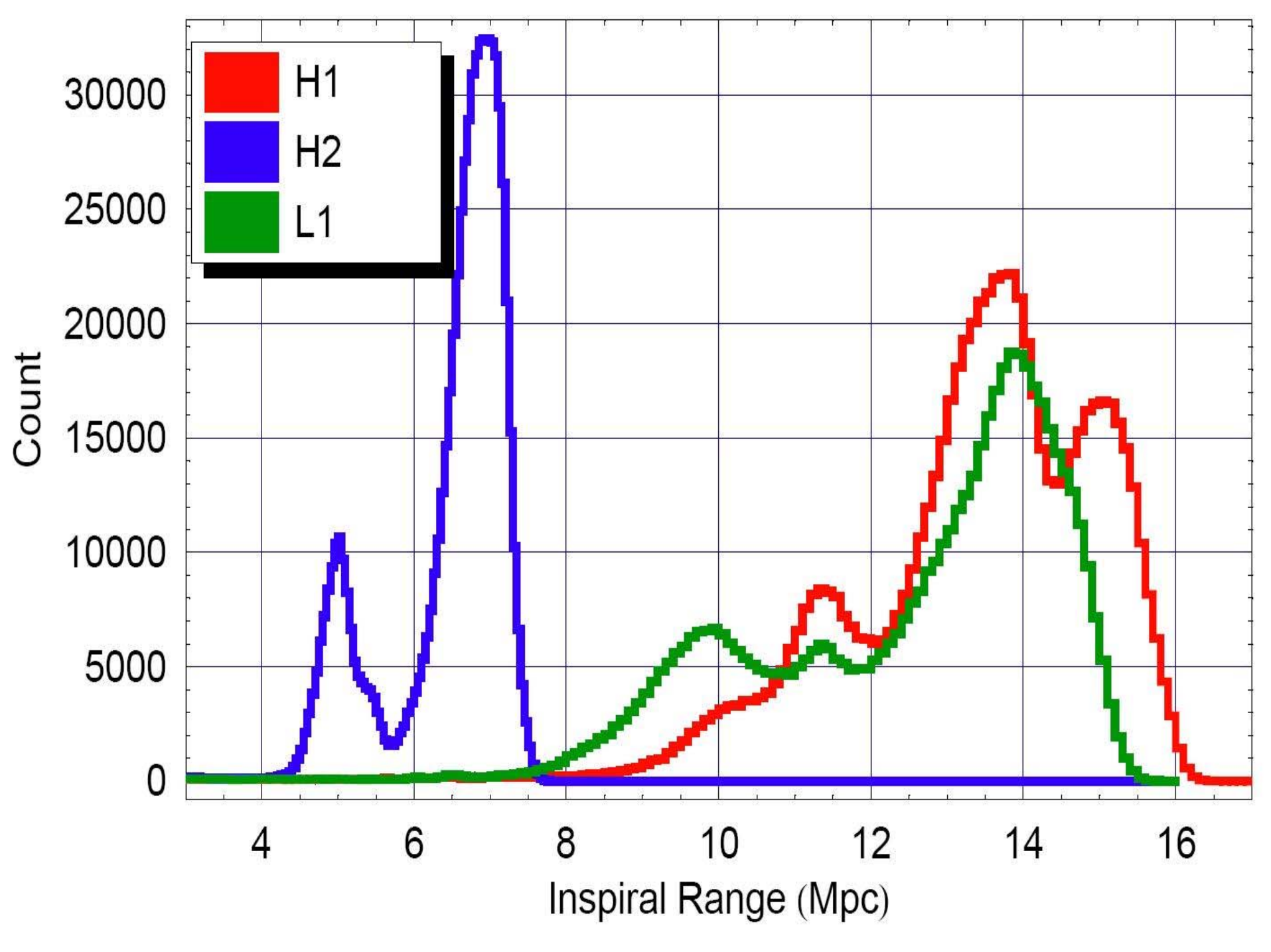
- Dates
  - Start: Nov '05
  - Stop: ~Oct '07
- Duty cycle:
  - H1: 76%
  - L1: 64%
  - H2: 78%
  - 3-coinc.: 51%
  - HL-coinc.: 59%

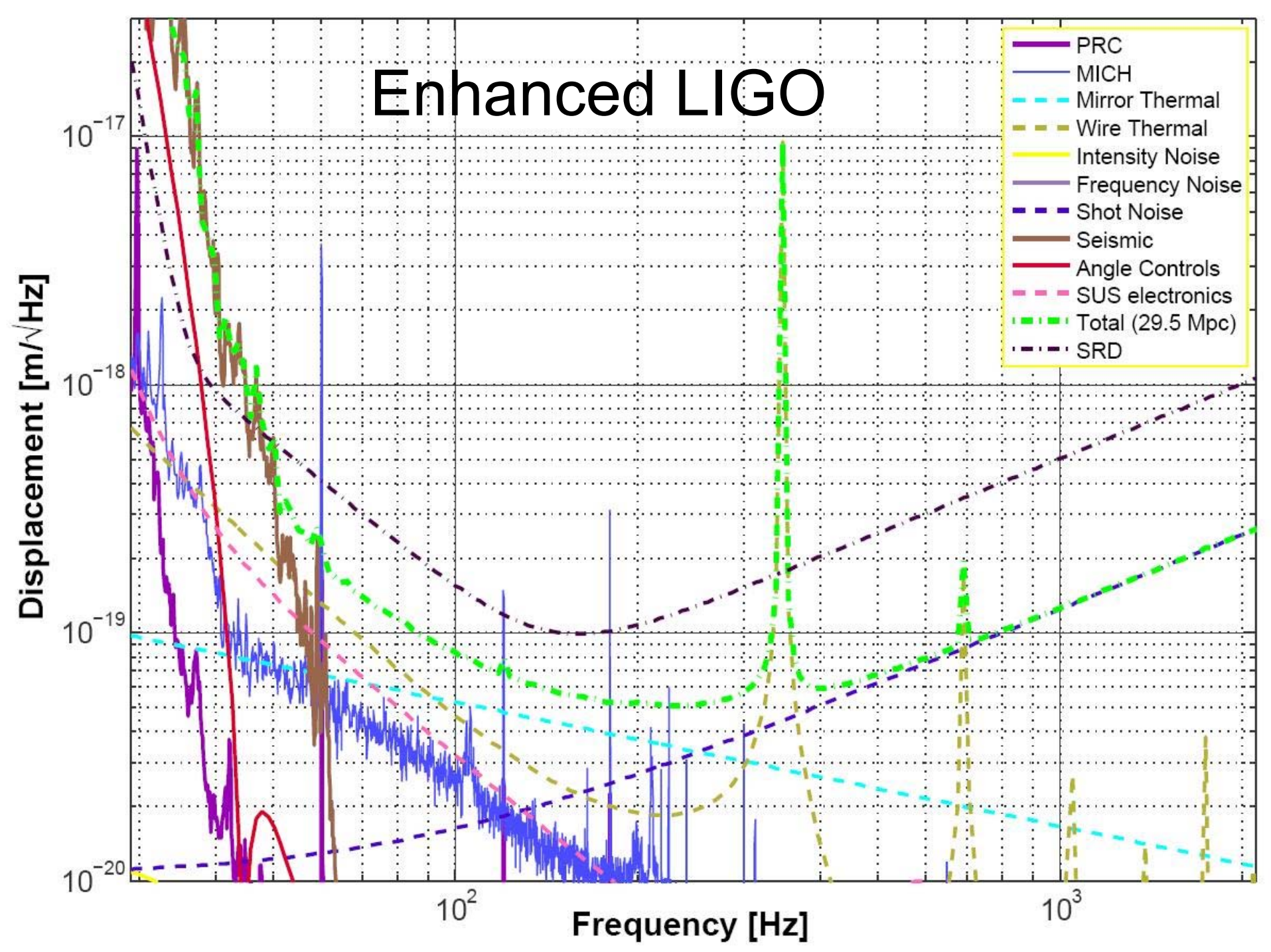


LIGO


Nov 8
Jan 31
Apr 25
Jul 18
Oct 10
Jan 2
Mar 27
Jun 19
Accumulated LHO/LLO Coincidence (d)
350
300
250
200
150
100
50
0
HL Coincidence
353 days
97% of 1 year
Triple Coincidence
307 days
84% of 1 year
run time (w)


Nov 8
Jan 31
Apr 25
Jul 18
Oct 10
Jan 2
Mar 27
Jun 19
16
14
12
10
8
6
4
2
Inspiral Range (Mpc)
H1
H2
L1
run time (2w)

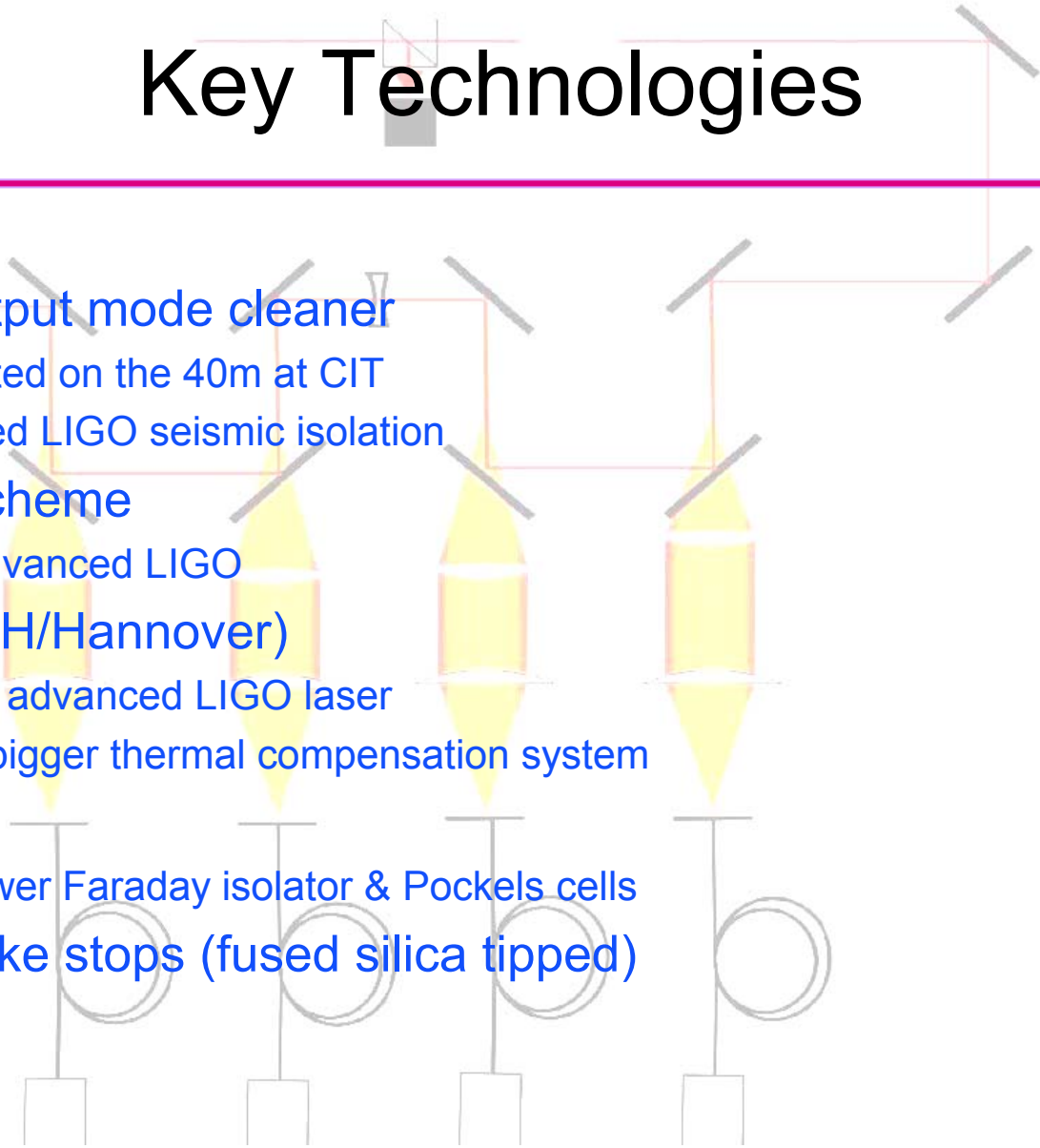

H1
H2
L1
30000
25000
20000
15000
10000
5000
0
Count
4
6
8
10
12
14
16
Inspiral Range (Mpc)


Enhanced LIGO
PRC
MICH
Mirror Thermal
Wire Thermal
Intensity Noise
Frequency Noise
Shot Noise
Seismic
Angle Controls
SUS electronics
Total (29.5 Mpc)
SRD
Displacement [m/√Hz]
Frequency [Hz]
10^-17
10^-18
10^-19
10^-20
10^2
10^3

LIGO

Key Technologies

- In-vacuum output mode cleaner
  - Currently tested on the 40m at CIT
  - New advanced LIGO seismic isolation
- DC readout scheme
  - Crucial for advanced LIGO
- 30W laser (LZH/Hannover)
  - First stage of advanced LIGO laser
  - May require bigger thermal compensation system
- Input optics
  - New high power Faraday isolator & Pockels cells
- New earthquake stops (fused silica tipped)



LIGO

Summary

- All LIGO interferometers are at design sensitivity over most of the frequency range
- For sources like binary neutron star and black hole coalescence we can see well into the Virgo cluster
- S5 almost done with 1 year of coincidence data
- Enhanced LIGO is around the corner
- Advanced LIGO will hopefully be funded next year