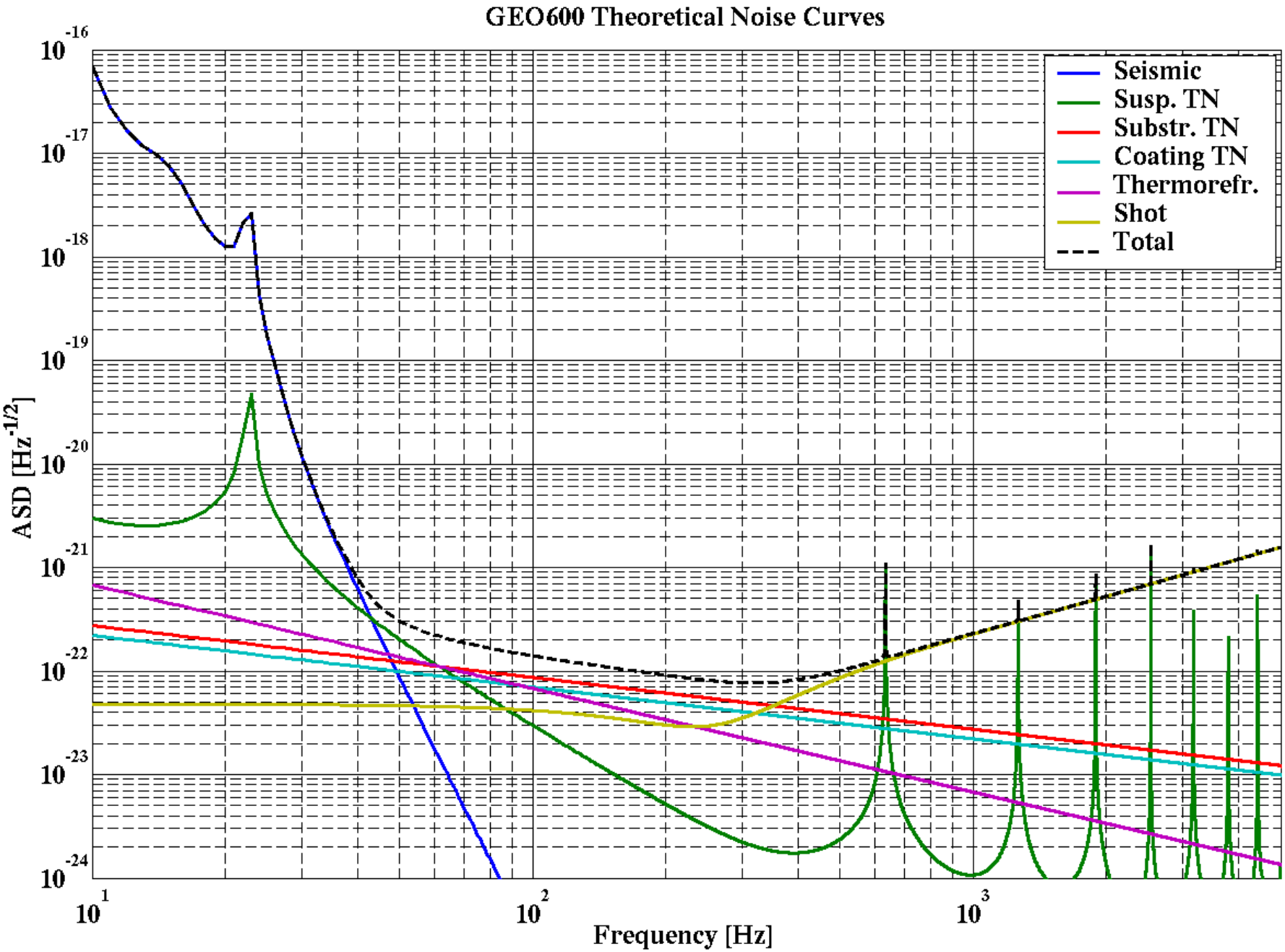
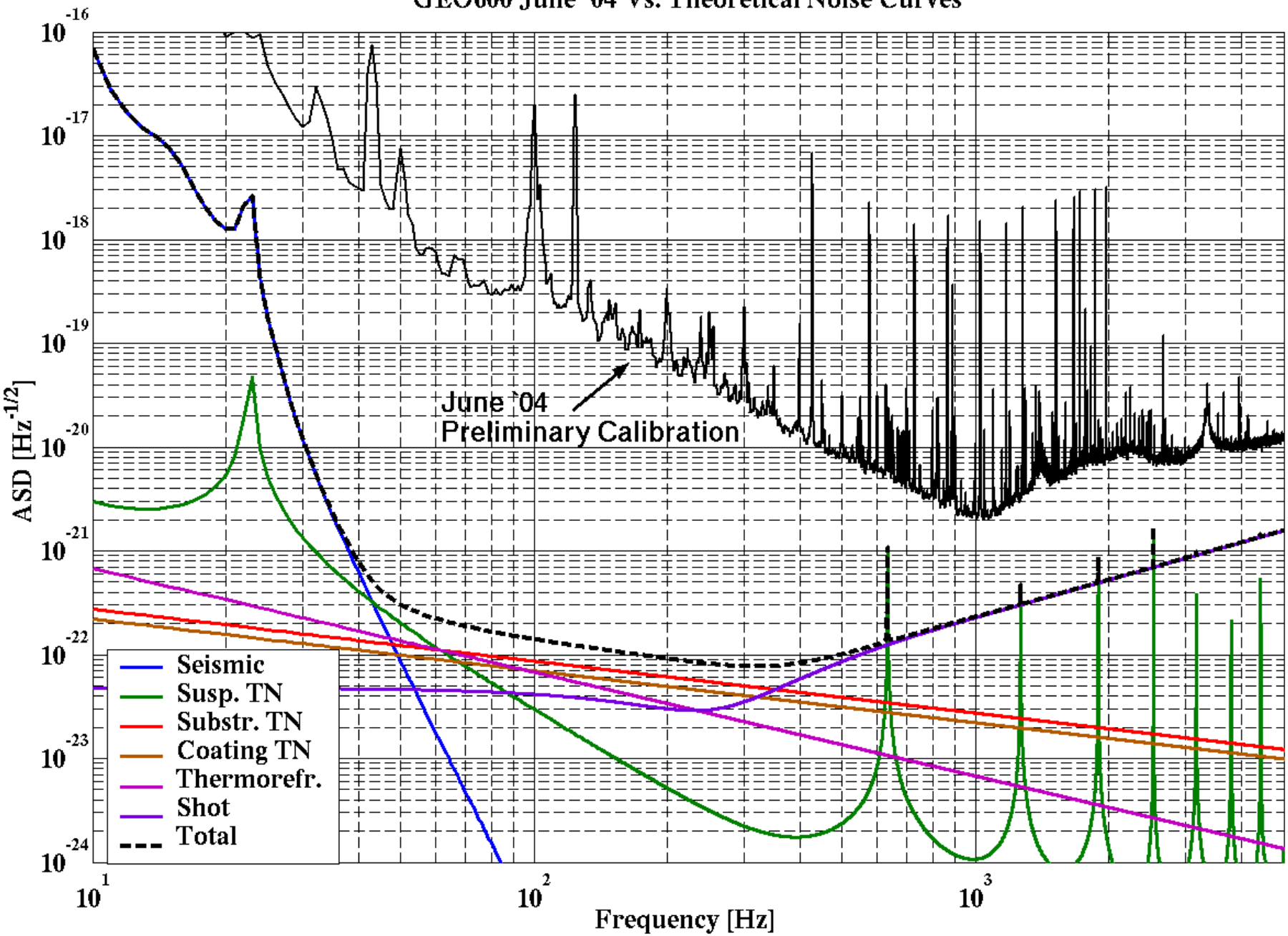
Identifying and eliminating limiting noise sources of GEO600

DCC No. G040417-00-Z

LSC Meeting, Hanford WA, August `04

Joshua Smith for the GEO team


GEO600 Theoretical Noise Curves
Seismic
Susp. TN
Substr. TN
Coating TN
Thermorefr.
Shot
Total
ASD [Hz^-1/2]
Frequency [Hz]
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
10^-23
10^-24
10^1
10^2
10^3


GEO600 June `04 Vs. Theoretical Noise Curves
ASD [Hz^-1/2]
Frequency [Hz]
June `04
Preliminary Calibration
Seismic
Susp. TN
Substr. TN
Coating TN
Thermorefr.
Shot
Total

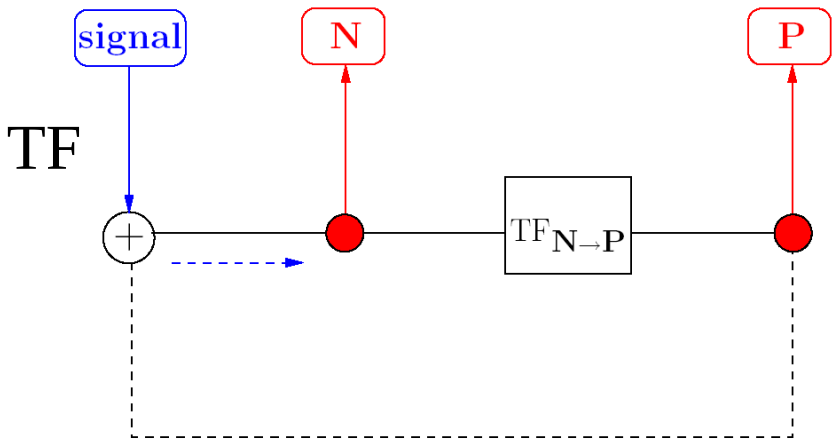
Noise hunting techniques

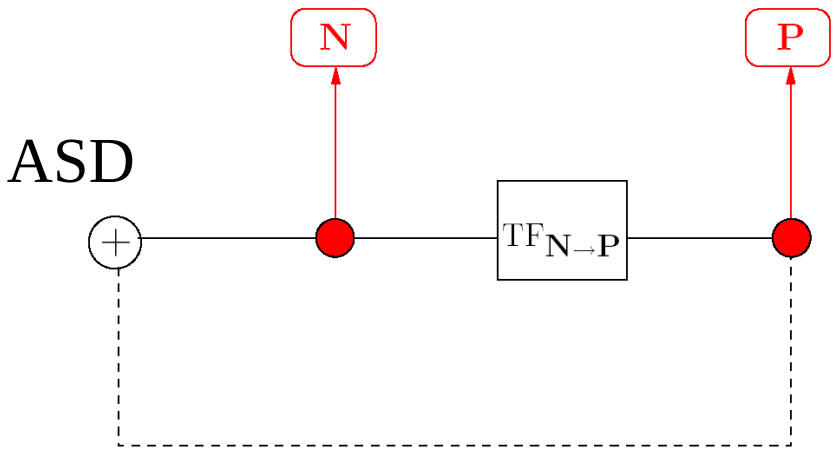
Easy

Nasty

- Open loops & freq's with loop gain << 1
  - Analytical
  - Coherence with care
  - Noise Projections (Assumes linearity)
- In-loop, freq's with loop gain
  - Coherence with more care
  - Analytical/Modeling, open loop measurements
- Nonlinear couplings
  - Nonlinear coherence, saturations, etc.
  - Under investigation by the GEO DC group

Noise Projections





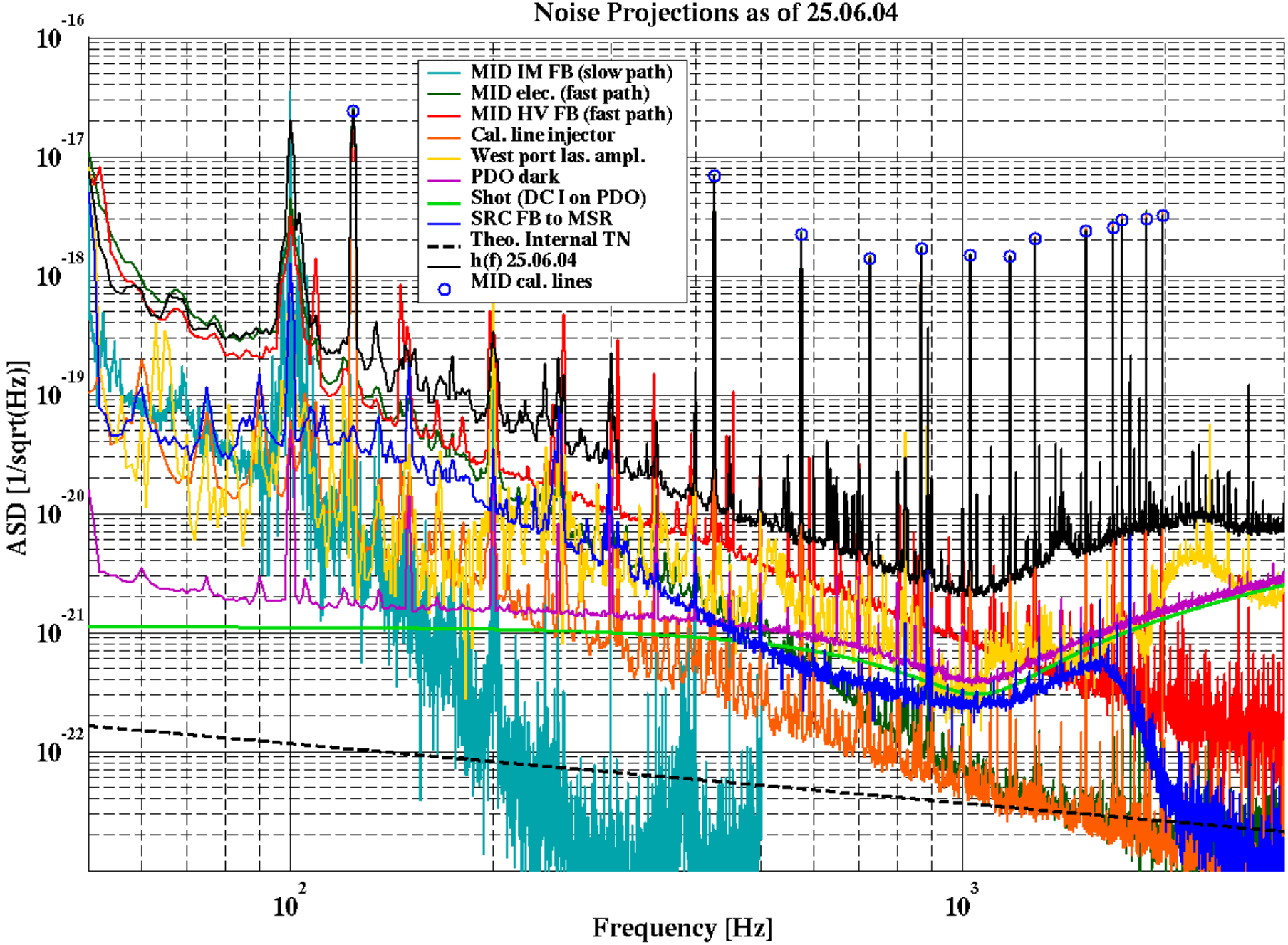
$$PROJ_{N \to P} = ASD_N \left| TF_{N \to P} \right|$$

Purpose:

- consider measurement points (chans), N and P (detector output)
- determine how noise at N will appear at P based on properties of system

Procedure:

1. Identify noise that could couple to P
2. Find/create channel (N) that represents this noise
3. Quantify coupling from this channel to P (TF)
4. Quantify noise in N and P with simultaneous spectra (ASDs)
5. Project the noise in N to how it will appear in P

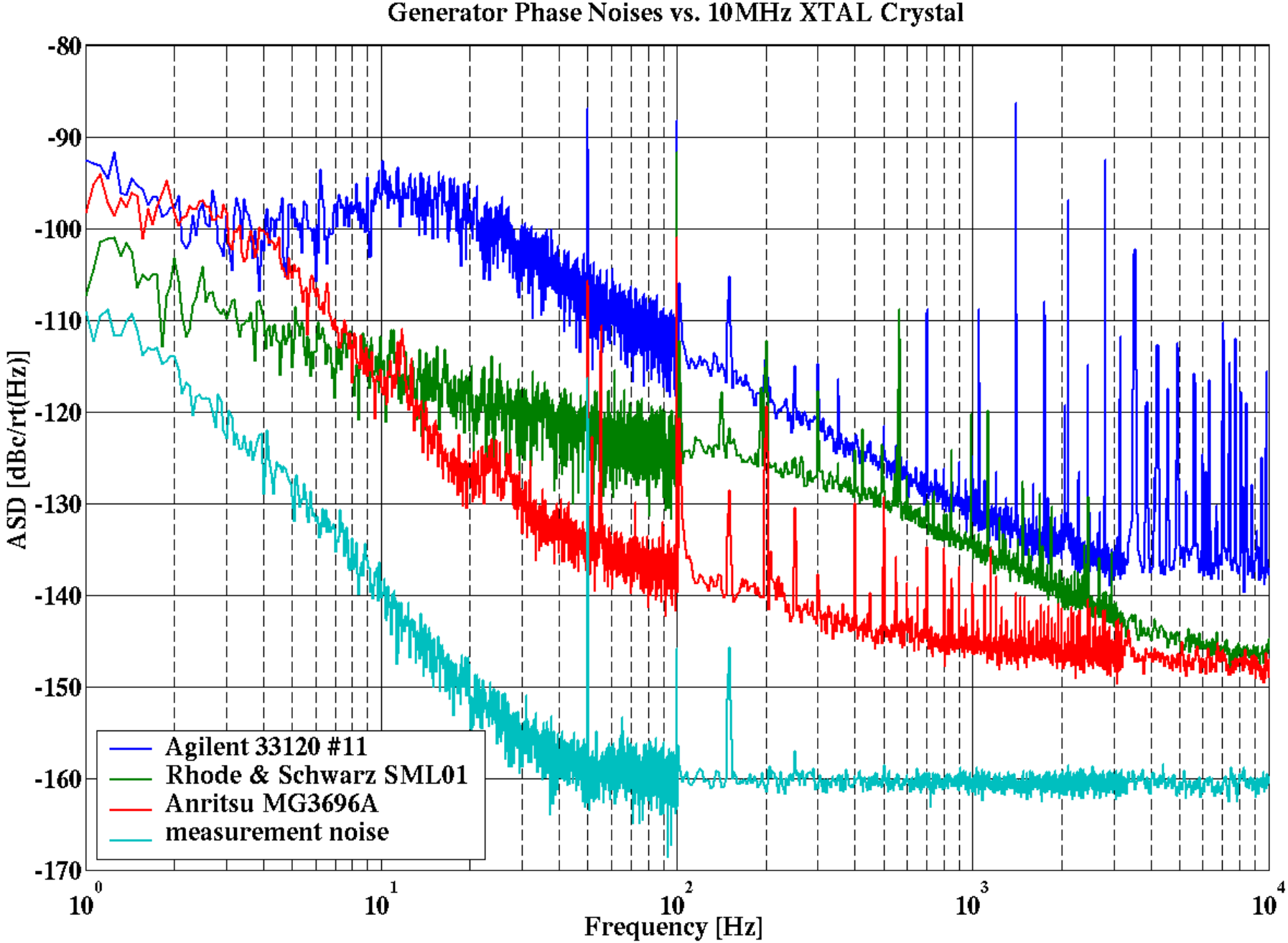

Noise Projections as of 25.06.04
MID IM FB (slow path)
MID elec. (fast path)
MID HV FB (fast path)
Cal. line injector
West port las. ampl.
PDO dark
Shot (DC I on PDO)
SRC FB to MSR
Theo. Internal TN
h(f) 25.06.04
MID cal. lines
ASD [1/sqrt(Hz)]
Frequency [Hz]

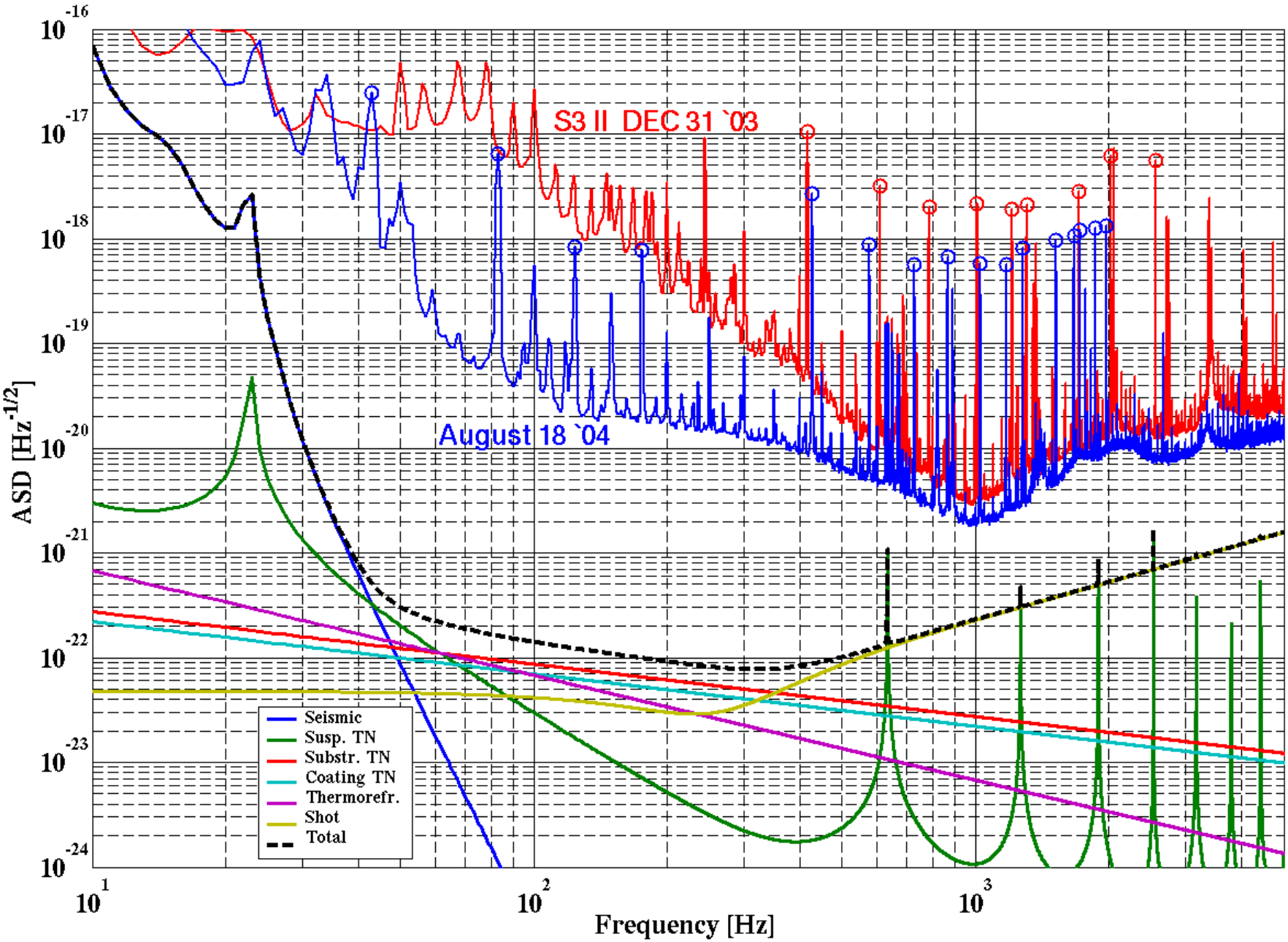
Eliminate them

- MID fast path noise [factors are for that noise source, not h(t)]
  - *bypass sqrt-circuit, factor 10 (this+gain distrib gives H(t) improvement)*
  - *build noise reduction loop around HVA, factor 10 possible*
  - *Reduce Vbias in lock (controlled by LabView)*
- dark & shot noise
  - *Increase laser power (2W to 10W into MC1) should give factor 2.2*
  - *Increase PR factor by replacing T=1.35% MPR with T~0.1% mirror, circulating ~ 10kW rather than 1.4kW (270 W now), factor 2.7*
- Laser amplitude noise
  - *second loop commissioned, noise seems to be added after sensor, perhaps sensing at later point is required*
  - *identify the cause*
- Front end (signal) limited loops (SRC, MID < 200Hz)
  - *Cross-projections : MID to SRC, etc.*
  - *coupled noise decrease with reduction of noise in other loops*

Other troublemakers

- MID oscillator noises
  - *amplitude:2-3 below from 400Hz to 1.1kHz (at least)!*
    - amplitude stab. loop (compare RF, stable DC ref, factor 50 possible)
  - *Phase: 8 below @ 1kHz*
    - new generator (Anritsu MG3696A)
    - other sol'ns: crystal oscillator or `2f' local oscillator
- acoustic & air current noises
  - *Couples at some level, output bench and MIC breadboard strongest*
    - Output telescope, HPD in vacuum now (some improvement@100Hz, cause?)
    - perhaps enclosure for MIC components
- scattered light
  - *visible problem, nonlinear, excited with e.g. stomps*
    - Removed some clipping by shifting MSRr suspension
- frequency noise ??
  - *complex frequency loop noise not yet evaluated*


Generator Phase Noises vs. 10MHz XTAL Crystal
ASD [dBc/rt(Hz)]
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
10^0
10^1
10^2
10^3
10^4
Frequency [Hz]
Agilent 33120 #11
Rhode & Schwarz SML01
Anritsu MG3696A
measurement noise

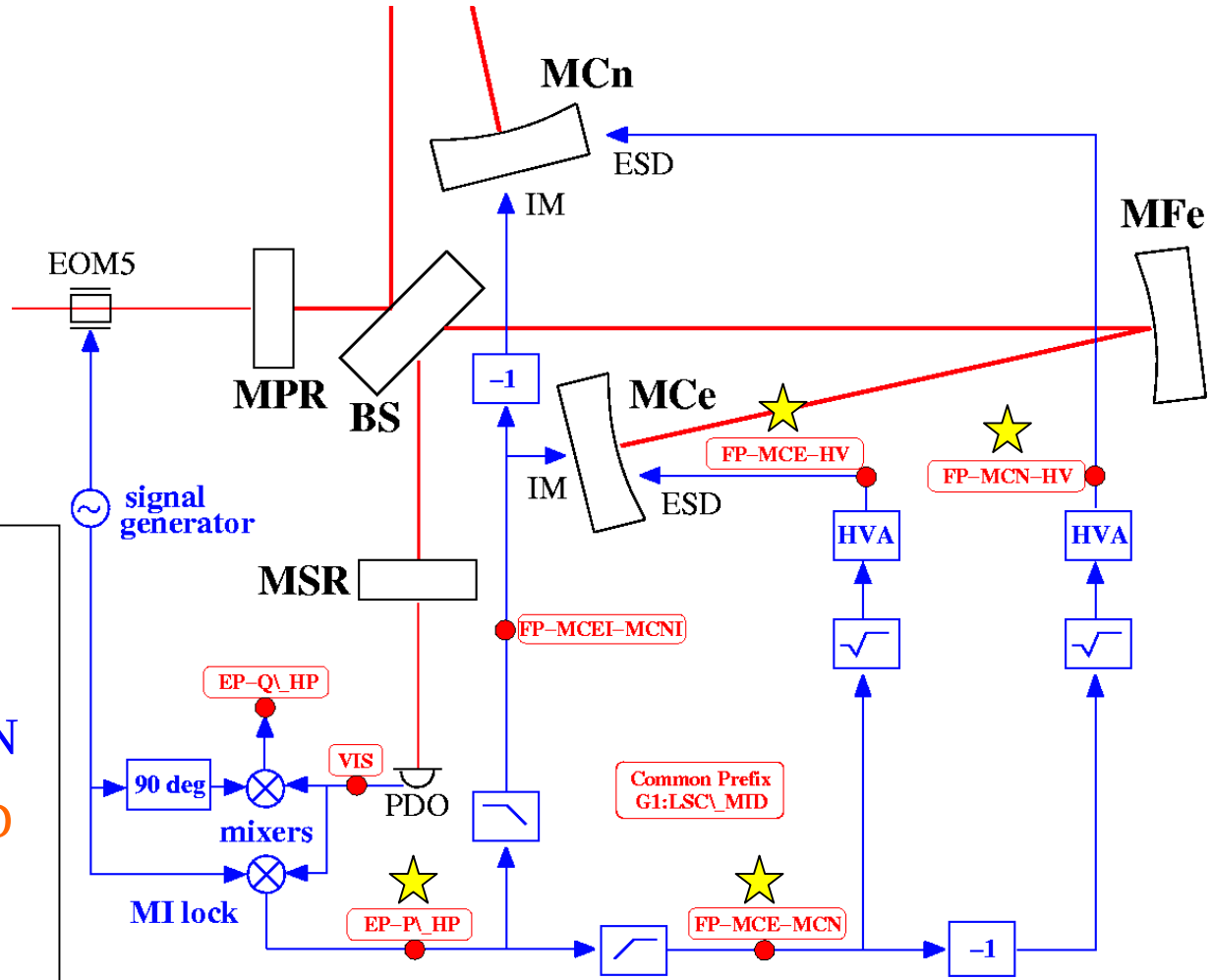

S3 II DEC 31 `03
August 18 `04
Seismic
Susp. TN
Substr. TN
Coating TN
Thermorefr.
Shot
Total
ASD [Hz^-1/2]
Frequency [Hz]
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
10^-23
10^-24
10^1
10^2
10^3

Noise identification work ahead

- speed progress towards design sensitivity
- produce reliable information at f's with loop gain (frequency stab. loop next)
- develop well-characterized veto channels
- More automation & monitoring
  - track coupling (TFs) using callines
  - monitor potential veto channels before & during data runs

The End

MID loop (MI diff. arm-length)



- LSC_MID_EP-P_HP

→ main GW signal, inphase

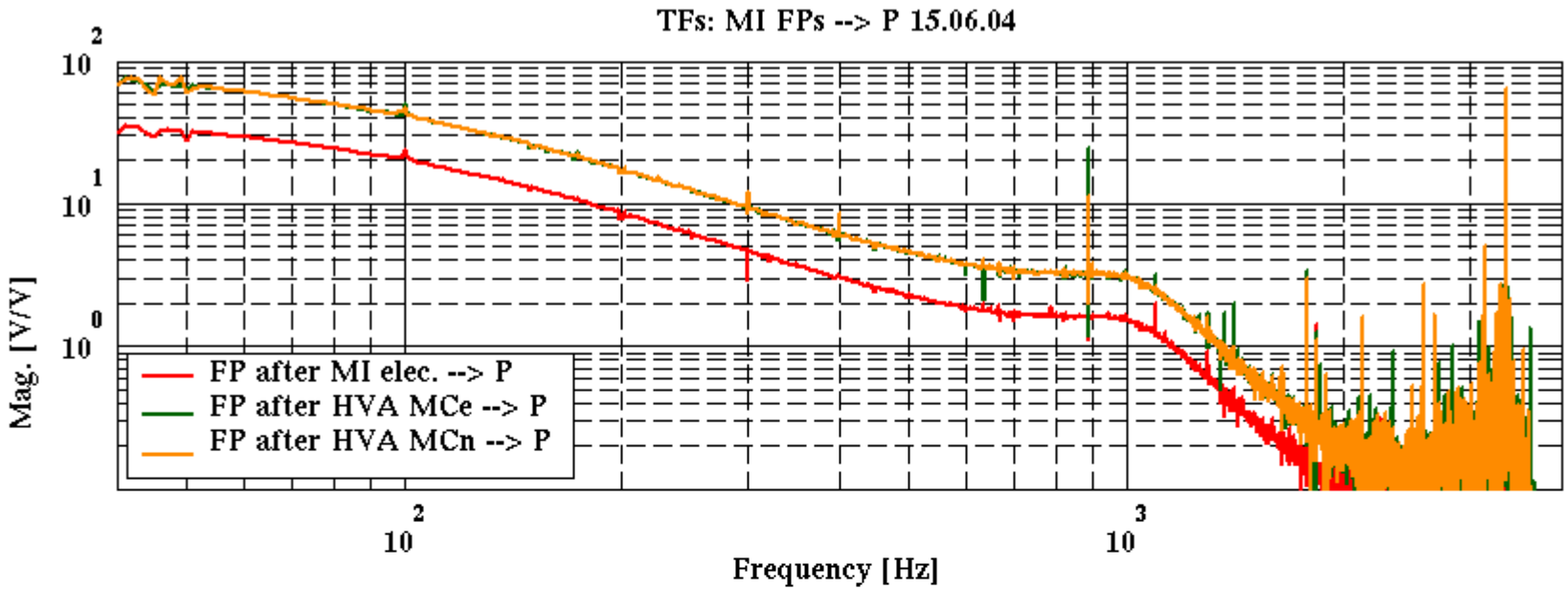
- LSC_MID_FP-MCE-MCN

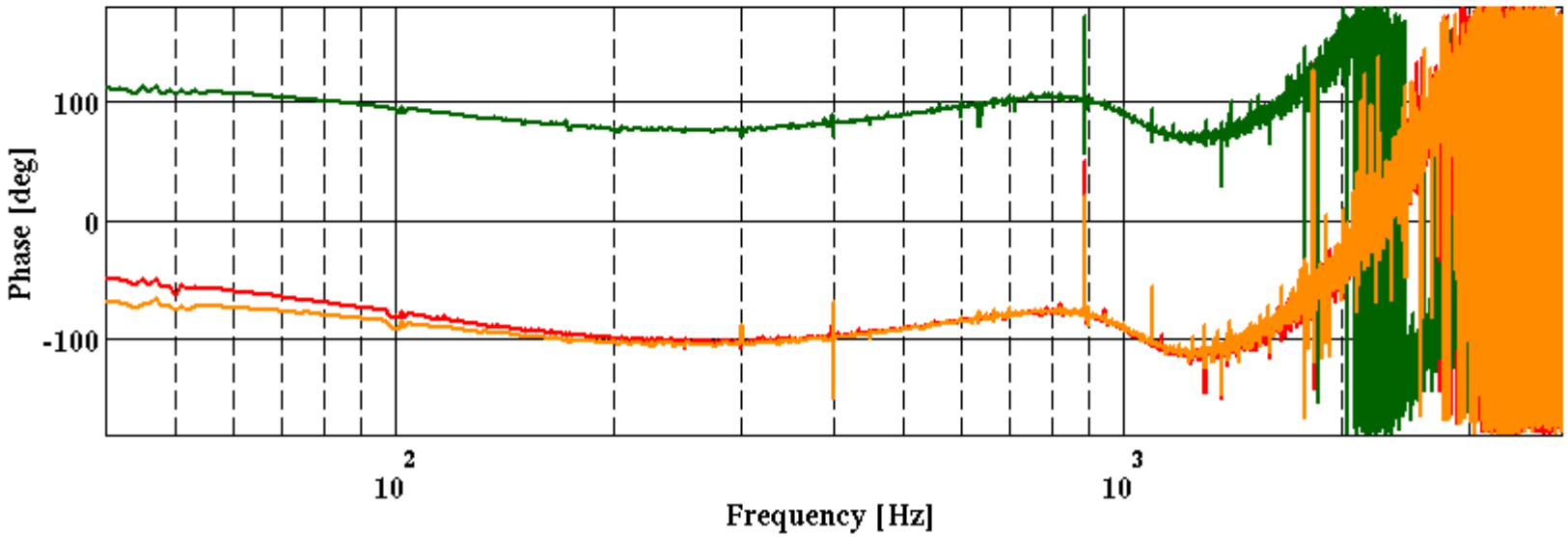
→ diff. FB sampled after MID electronics

- LSC_MID_FP-MCE-HV, LSC_MID_FP-MCN-HV

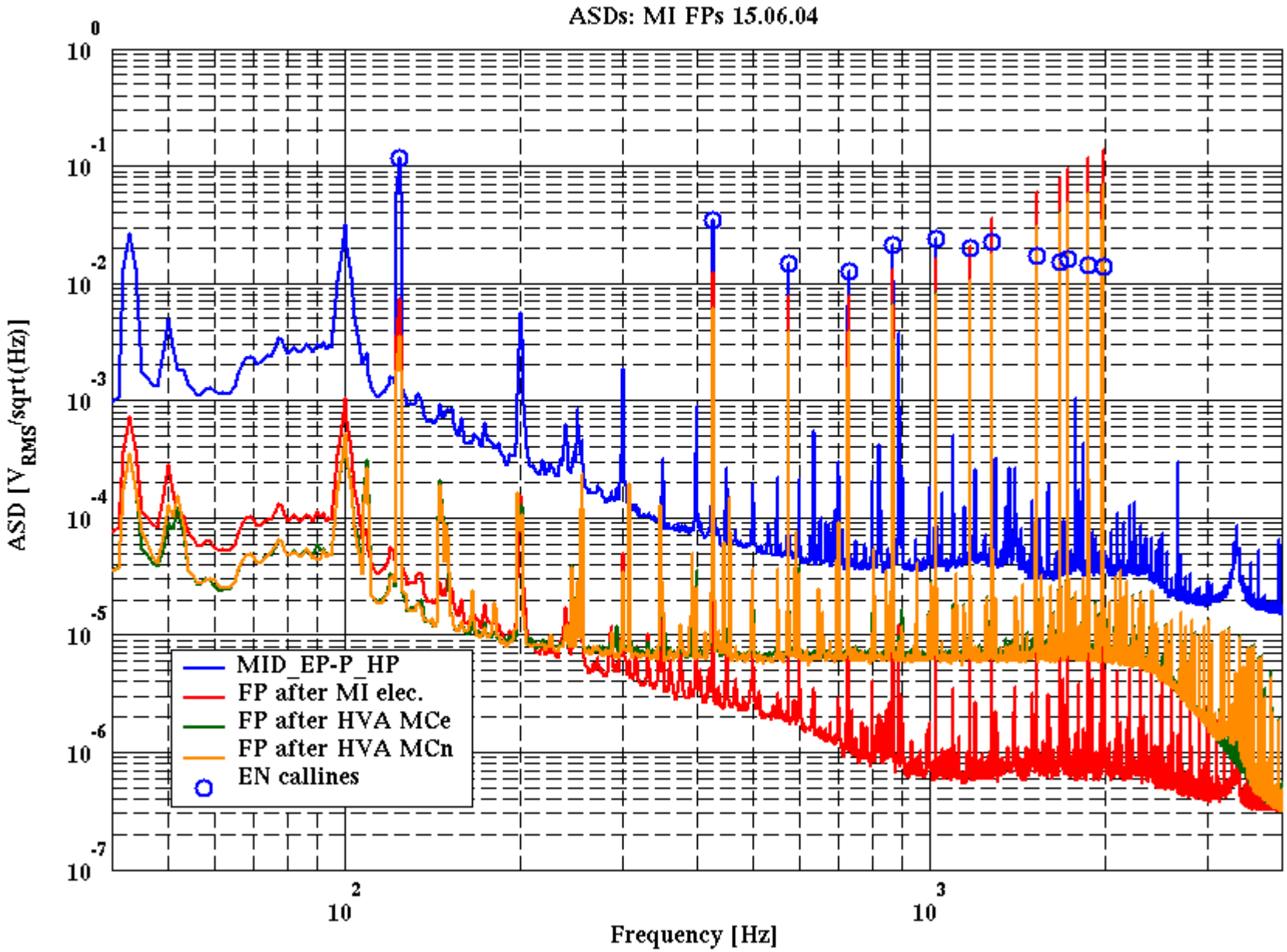
→ diff. FB sampled after HVA

MID Fast Path TFs

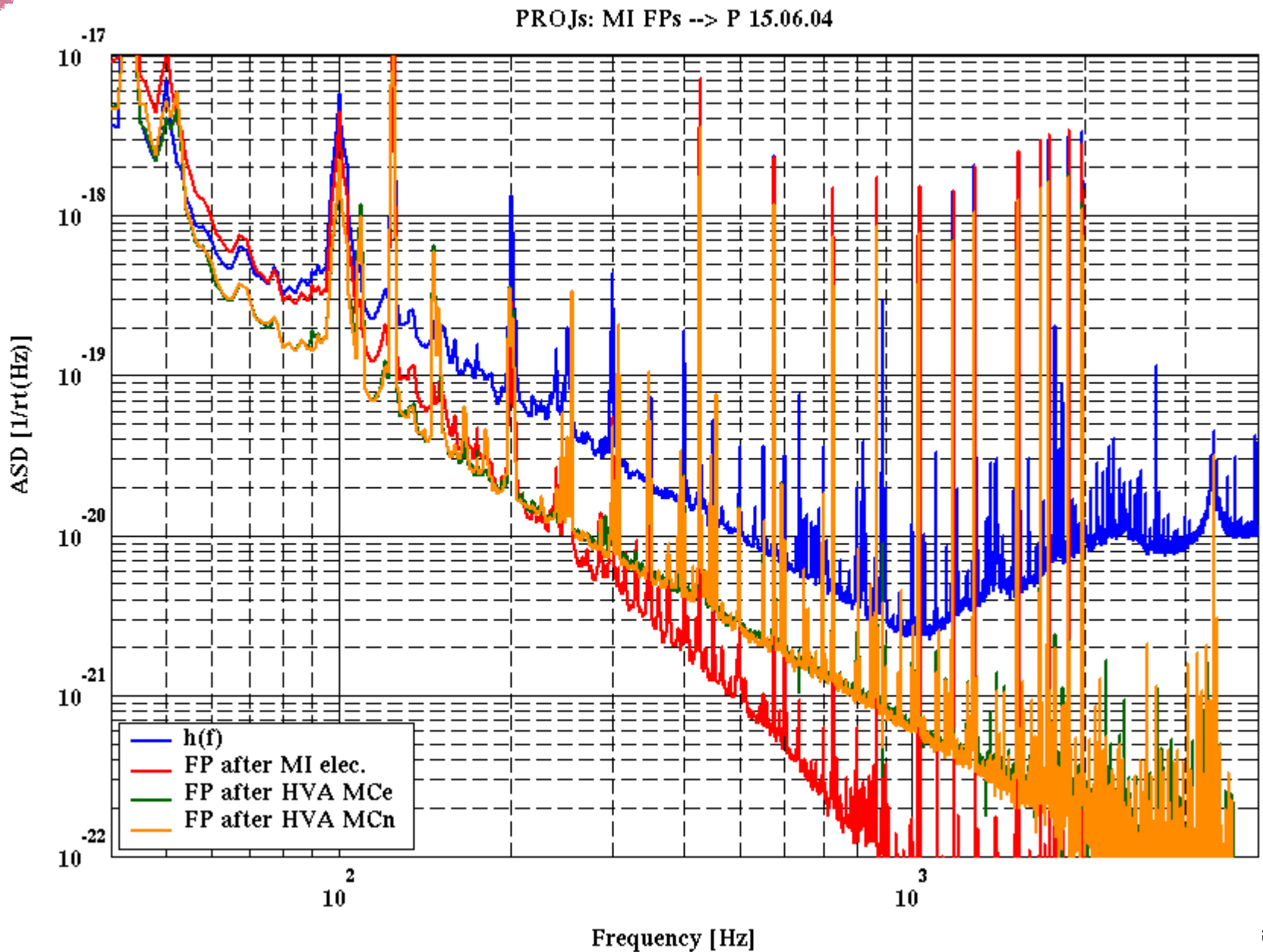




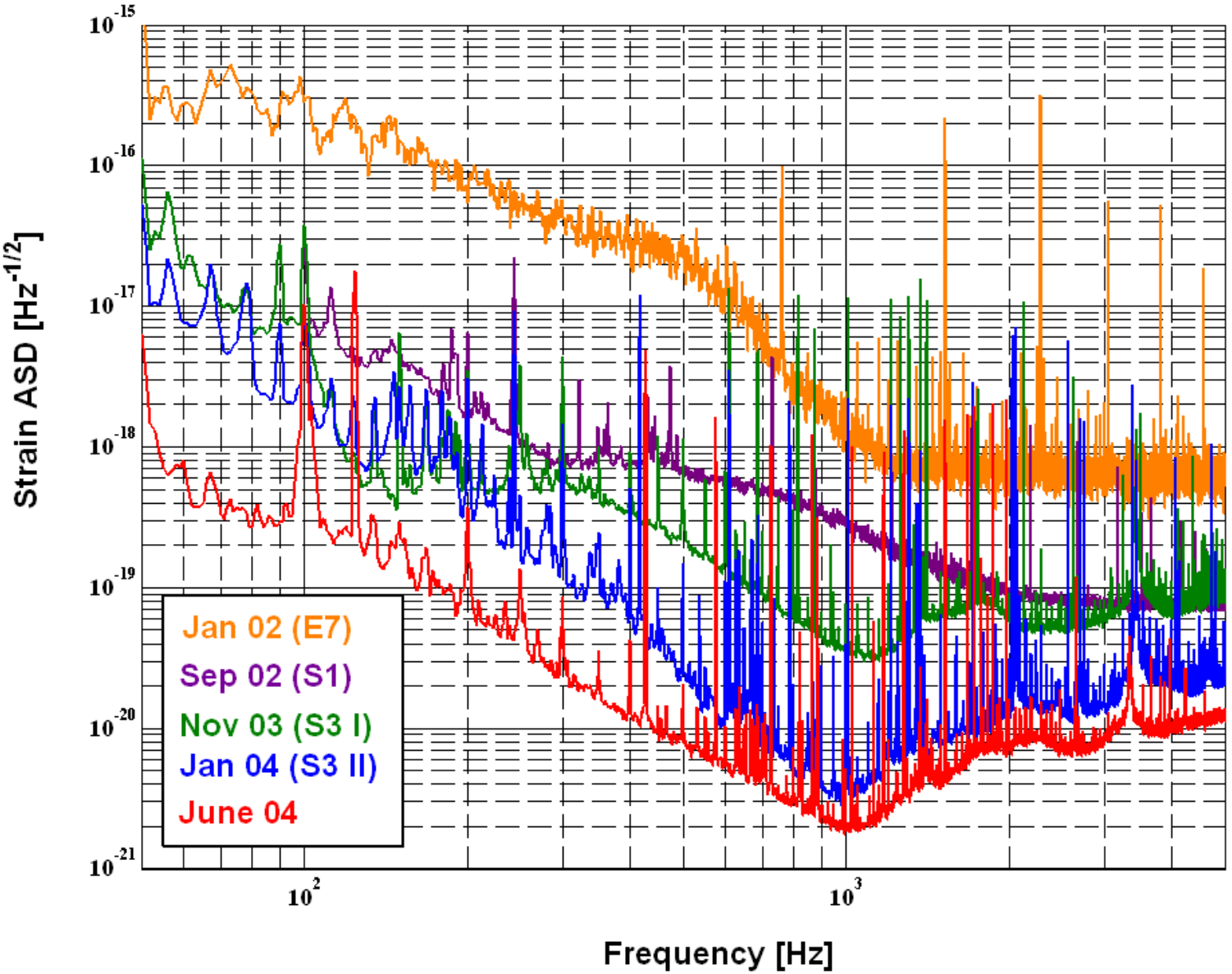
MID Fast Path ASDs



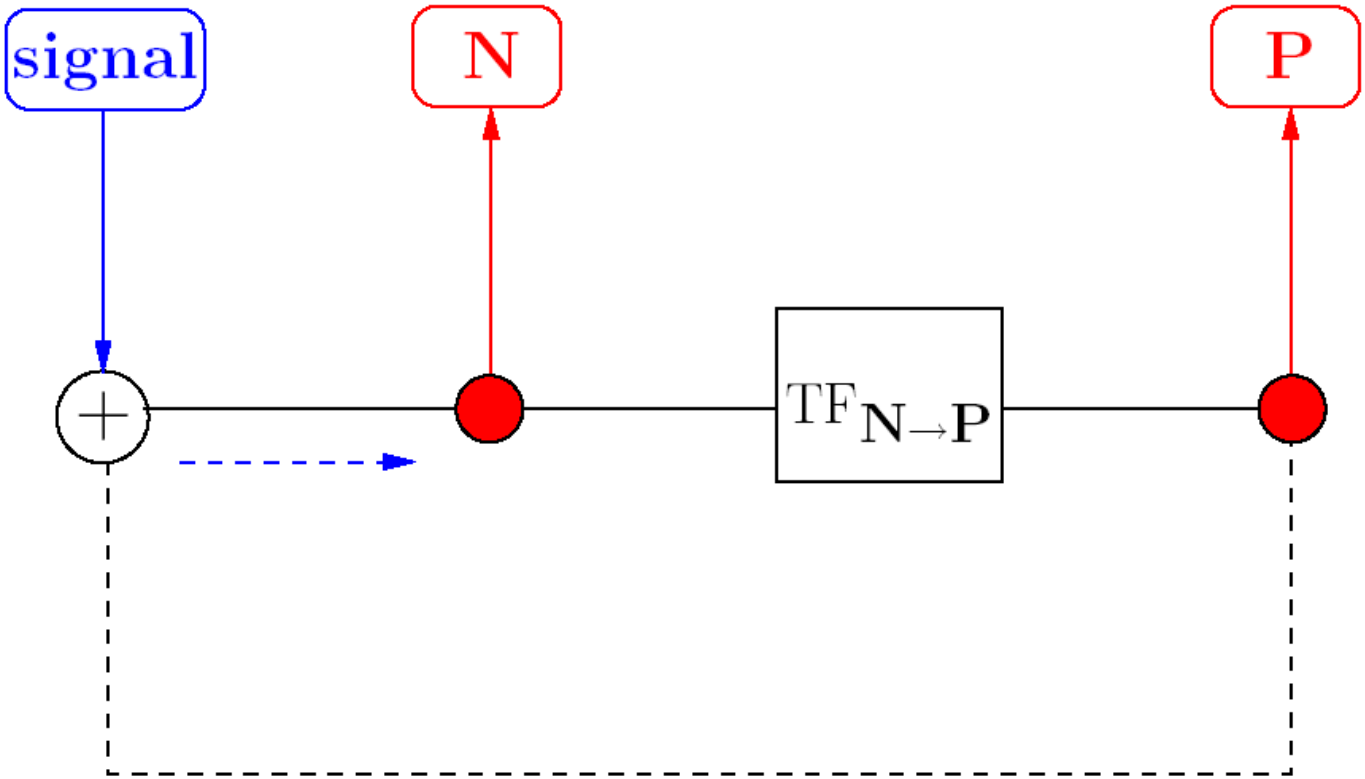
MID Fast Path Projections (to h)



Sensitivity Progress

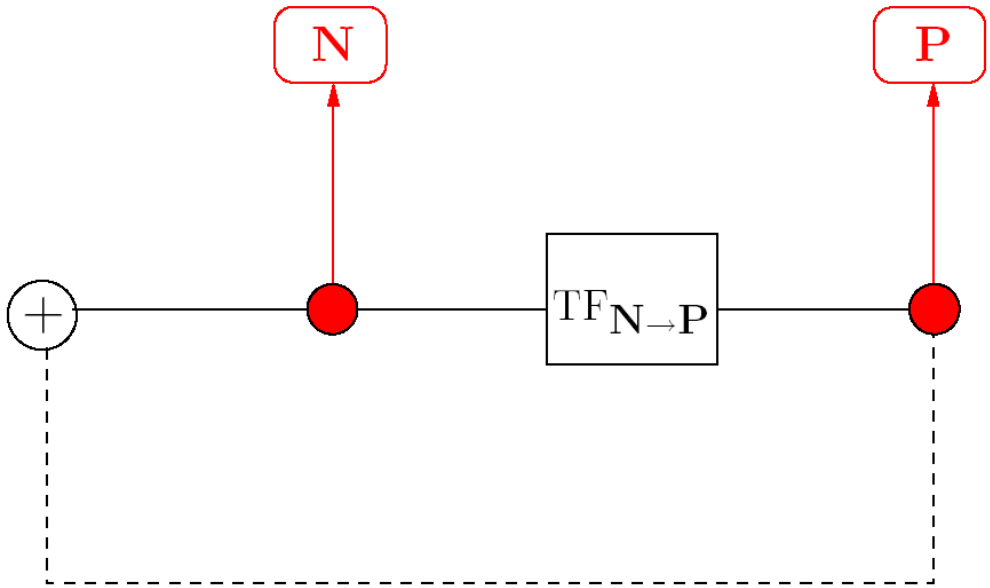


Transfer Function



- Dominate noise present in system with injected signal
- Measure TF

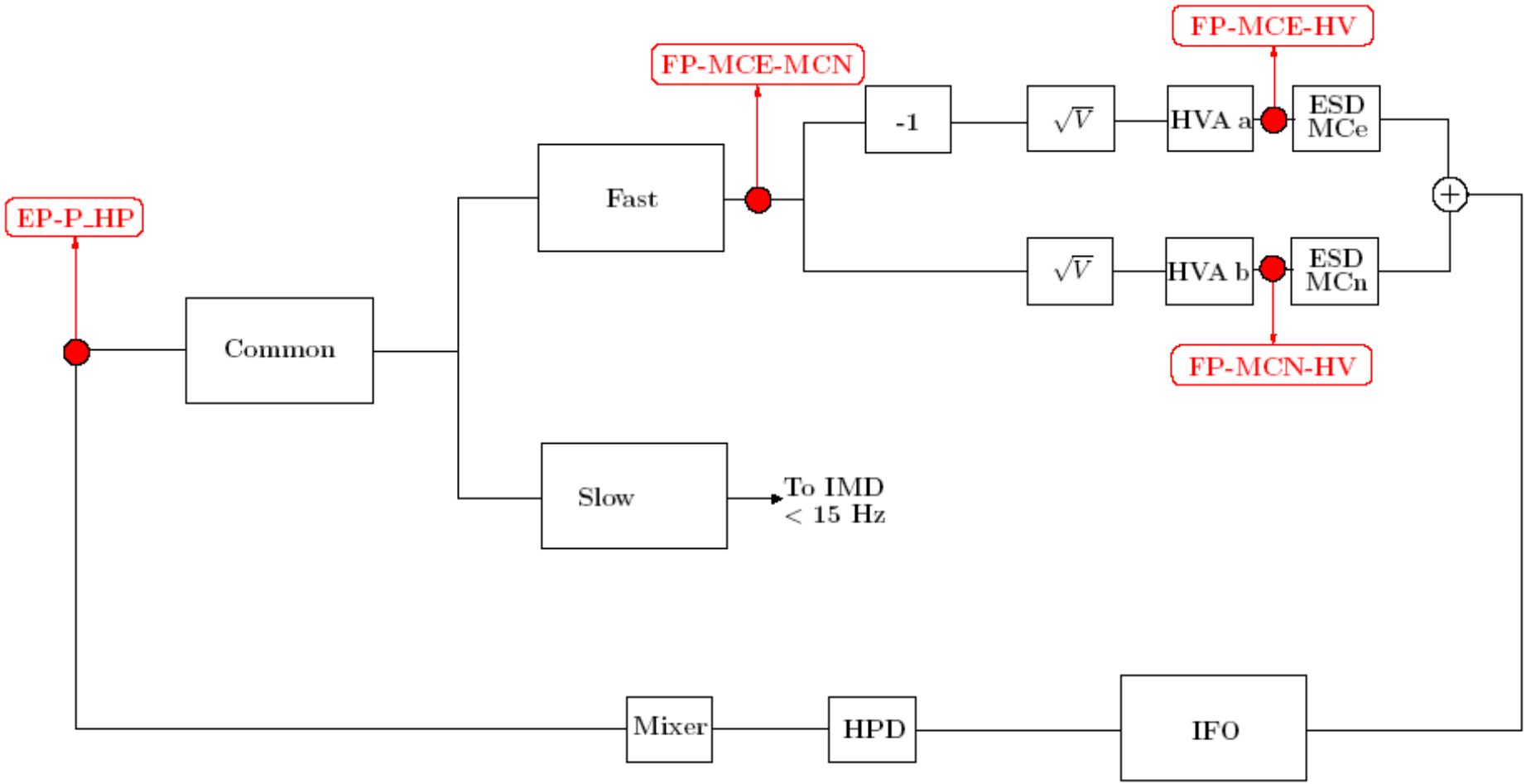
Projection



- Remove signal
- Measure ASDs *simultaneously* at N and P
- Multiply by TF to form projection

$$\mathrm{PROJ}_{\mathbf{N}\to\mathbf{P}} = \mathrm{ASD}_{\mathbf{N}} \left|\mathrm{TF}_{\mathbf{N}\to\mathbf{P}}\right|$$

MI Fast Path


FP-MCE-HV
FP-MCE-MCN
-1
$\sqrt{V}$
HVA a
ESD MCe
Fast
EP-P_HP
$\sqrt{V}$
HVA b
ESD MCn
Common
FP-MCN-HV
Slow
To IMD
< 15 Hz
Mixer
HPD
IFO

Outline

- Current vs. design sensitivity
- Outline noise hunting techniques
- Describe `noise projections' technique
- Current important noise sources & other known contributors
- Present plan for eliminating these