ACOUSTIC MITIGATION TEAM
PROGRESS REPORT

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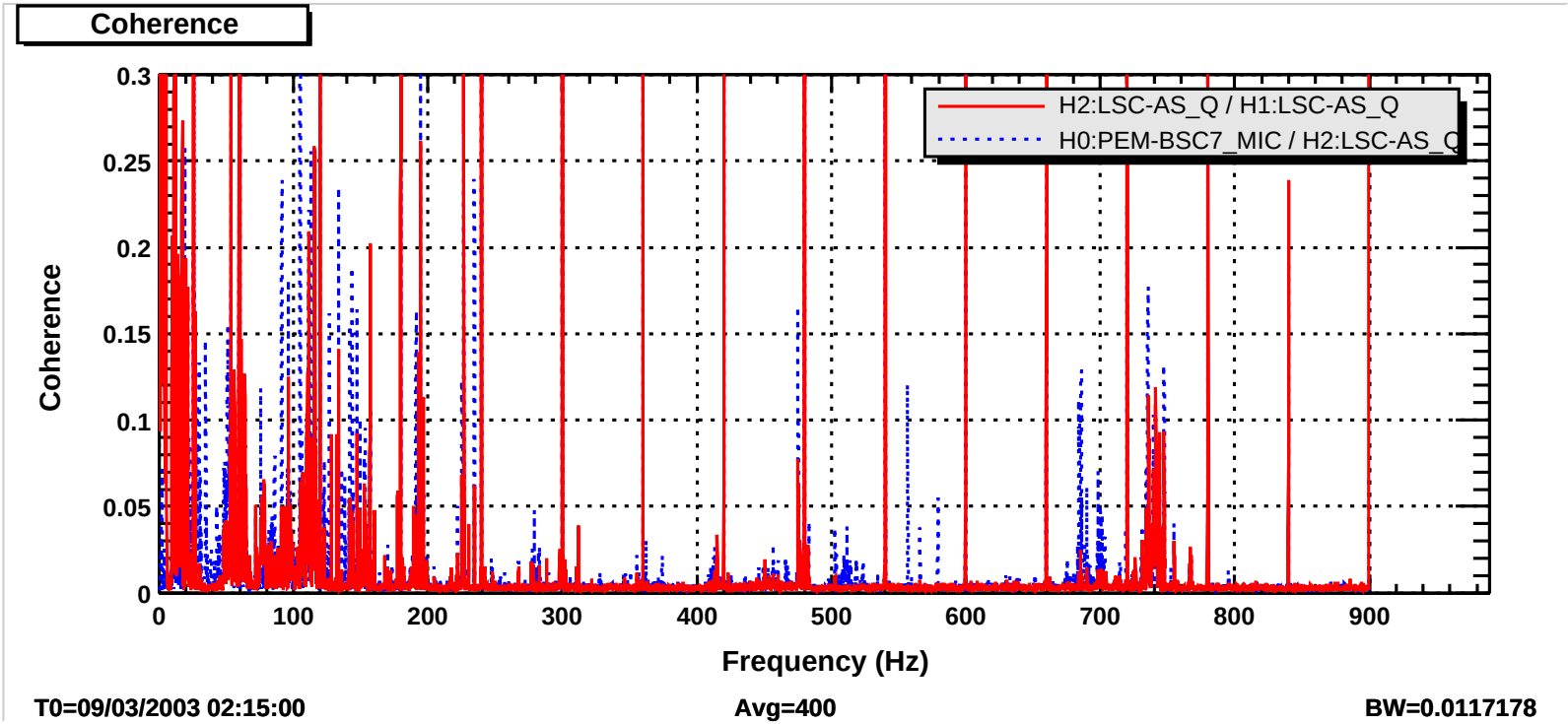
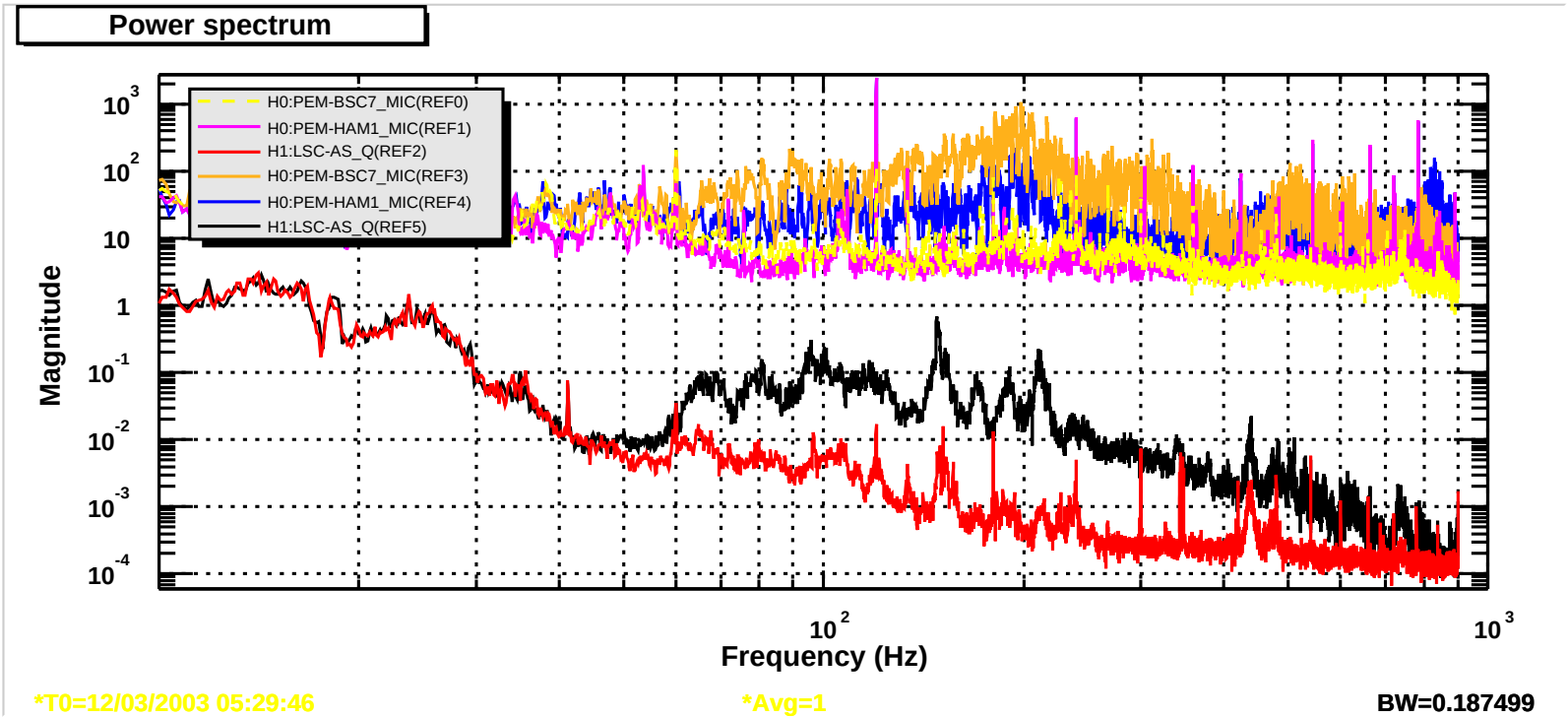
PROBLEM

Coherence between H1 and H2 AS_Q over 12h during S2 (red)



Blue is coherence between microphone near 4k dark port and 2k AS_Q

Noise played through speaker indicates that all three interferometers are close to being limited over a broad frequency range by acoustic coupling

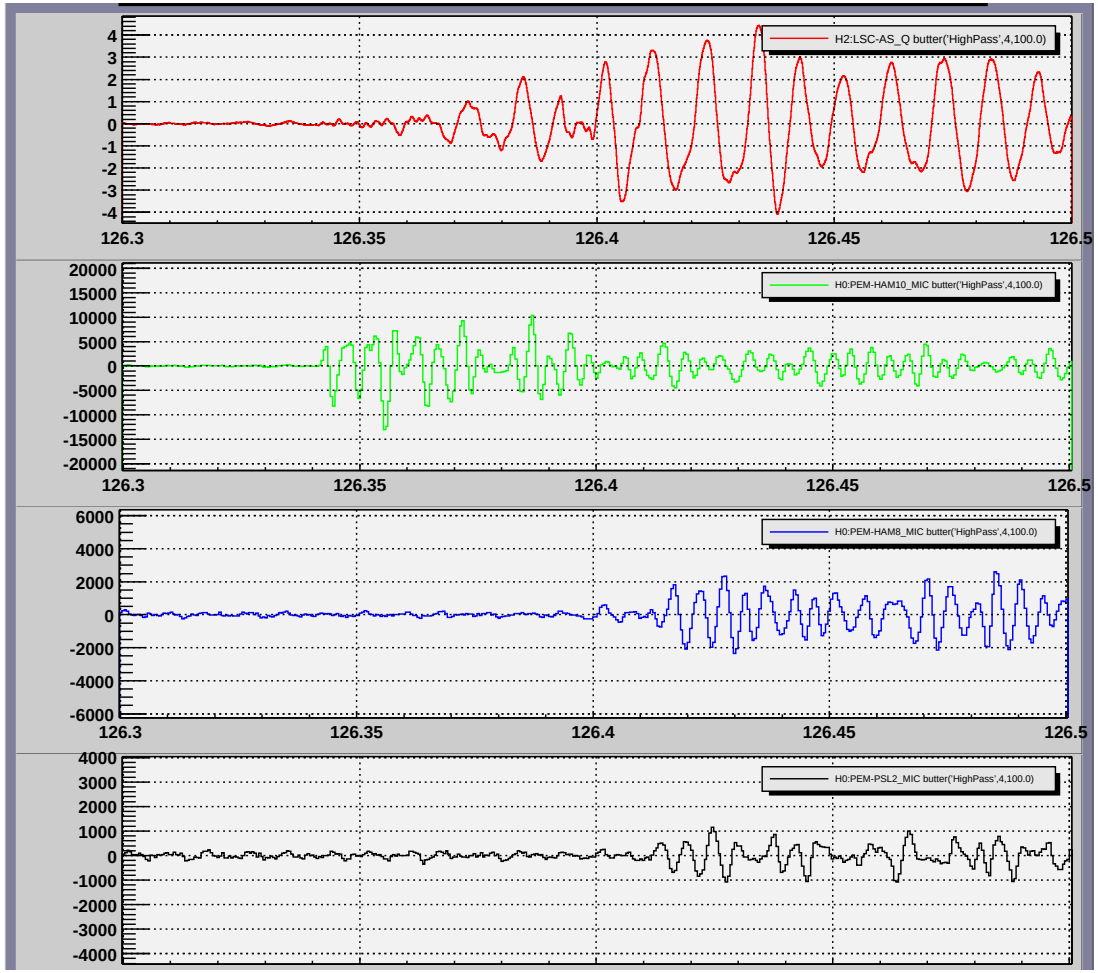


Black: AS_Q with noise; Red: normal

We would like to reduce acoustic-seismic contribution to noise by 100 to 1000

COUPLING SITES

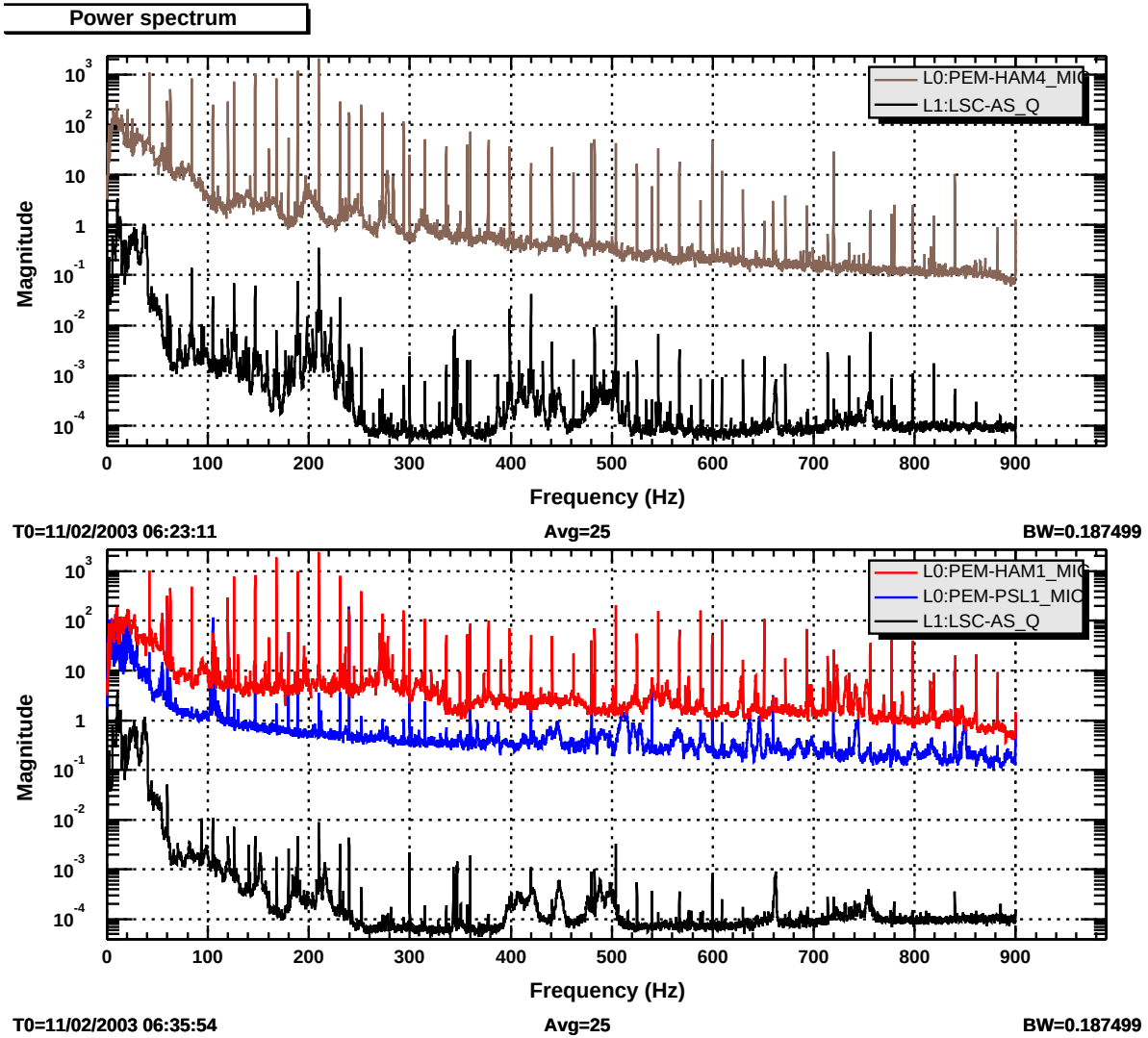
Burst propagation delays:



Predominant Coupling Sites : All 3 dark ports, LHO 4k PSL

How much lower is coupling at other tables?

21 Hz sawtooth played near LLO ISCT4 (top), ISCT1 (bottom)



For S2 coupling at other tables is at least a factor of 10 lower than at dark ports.

SOURCES

S2 LVEA sound levels are similar to those of an average residence

Location	dB
near LHO 2k dark port, outside of ISCT10	50
near LHO 4k dark port, outside of ISCT4	53
near LHO 2k reflected port, outside of ISCT7	56
1m from ajar electronics rack	59
1m from closed electronics rack	57
1m from vacuum pipe feed-through into mechanical room	56
mechanical room	65-70
bay between mechanical room and LVEA	52

Worst offenders seem to be equipment fans (especially electronics cabinets). Some lines in AS_Q have been traced to equipment such as ~135 Hz from laser chiller

HVAC: what is relative contribution, esp. at 100 Hz? Experiments after S2

Transients (e.g. building relaxation): these are hard to control

PROPAGATION FROM SOURCE TO COUPLING SITE

Speaker on floor outside LLO triple PSL enclosure: comparison of inside to outside sensors

Frequency Hz	Micropone: Outside/ Inside	Accelerometer: Outside/ Inside	Accel to Mic attenuation ratio
100	29	17	0.59
200	114	89	0.78
500	111	67	0.60
800	100	100	1.00

Enclosures appear to reduce table acceleration as well as sound pressure level.
Also, table accelerations are ~10x greater than floor

Signal seems to travel predominantly through the air.

POSSIBLE COUPLING MECHANISMS

- Backscattering (seen at ISCT9)
- Clipping (short focal length lens helped at ISCT10)
- Microphonics

Mechanisms considered unlikely:

- Doppler shift (seen at H2 PSL table)
- Index of refraction modulation (seen in H2 PMC)

Coupling does seem to be roughly linear in investigated range.

Much experimentation to be done after S2

POSSIBLE MITIGATION SCHEMES

I. Reduce at source

A. Acoustic:

1. HVAC: What is the relative importance, especially near 100 Hz? Experiment after S2
   a. Outlet mufflers. Could common wall be main source?
   b. Reduce air flow. Temperature fluctuation problems?

2. Electronics cabinets:
   a. Equipto: no experience or specs
   b. Knurr: Checking for specs

3. Crates: Ducting, liquid cooling, quiet fans etc.
   a. Elma: ducting 10% extra per unit + 1k engineering; also liquid cooling; little acoustic experience.
   b. Dawn: No experience or specs

4. Enclosure for electronics cabinets:
   a. Self supporting
      i. AEI: working on a bid

ii. ASC: 4 sided: 10db experience $2000 r&d, $3000 per unit, or 5 sided?
iii. AS: Not bid yet

b. Rack supported: ~3" thick acoustic insulation on outside of racks 2lb/ft2 $15k, about 22dB transmission attenuation at 100 Hz. Thermal, weight, or access problems?

B. Seismic:

1. Racks on isolation legs

C. Reverb:

1. AEI: 75% of walls covered: $300k (no labor); sprl down by 5 at low frequencies
2. AS: $190k to 450k.

II. Reduce level at coupling site:

A. Acoustic shielding:

1. Enclosures around ISCT tables:

a. AS: Delivery 1.5m; 9 enclosures 104k; 125Hz 31dB; doors at the back? How well did AS enclosure work? Factor of ~10 in SPL from outside AS enclosure to inside blue enclosure. Only 4 or 5 reduction in frequency noise.

ENTRY DOORS – ACCESS OPENINGS WITHOUT THEIR COVERS.

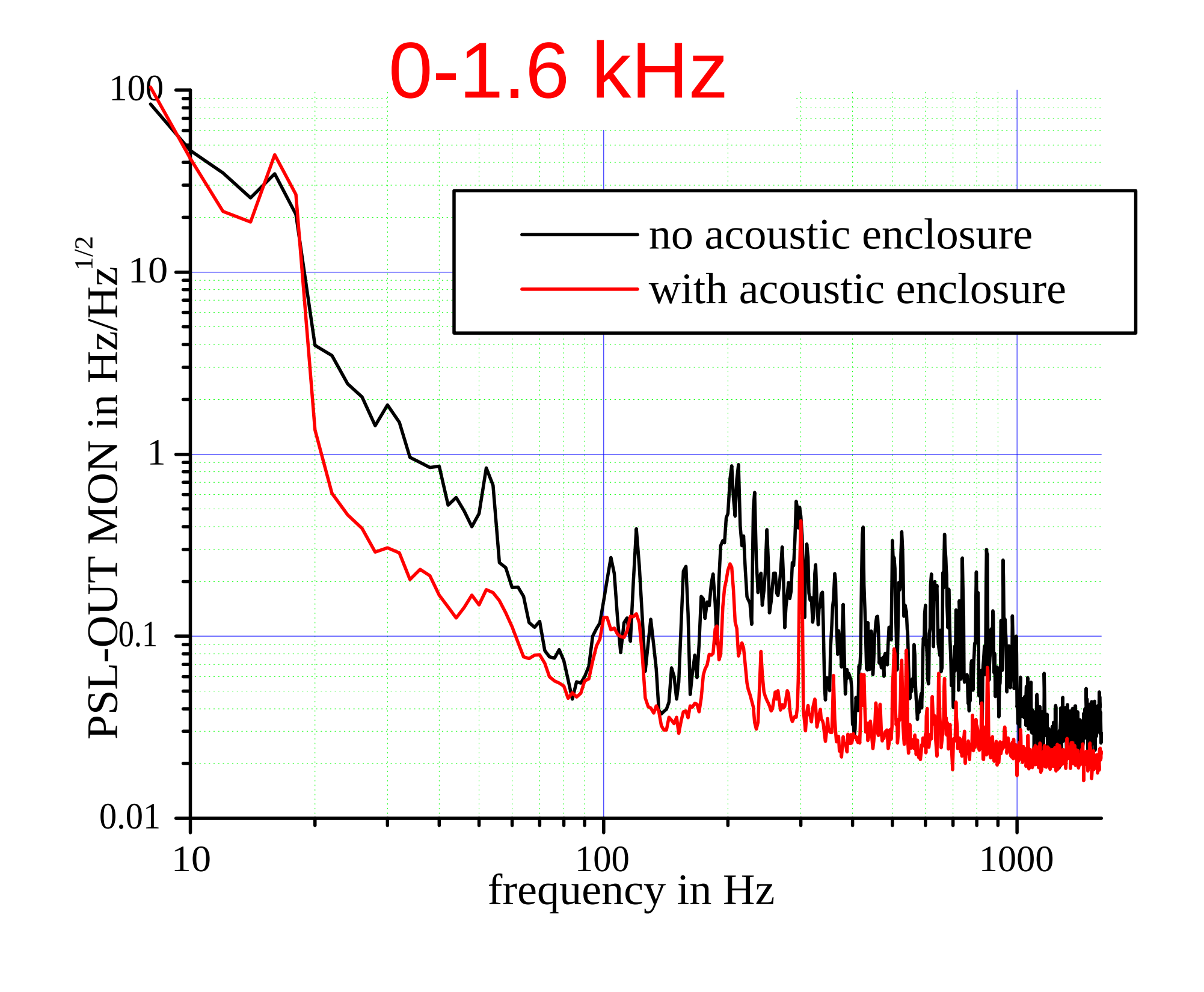
WALL CROSS SECTION DETAIL

LOOKING TOWARD DOORS FROM INSIDE OF 'MEAT LOCKER'

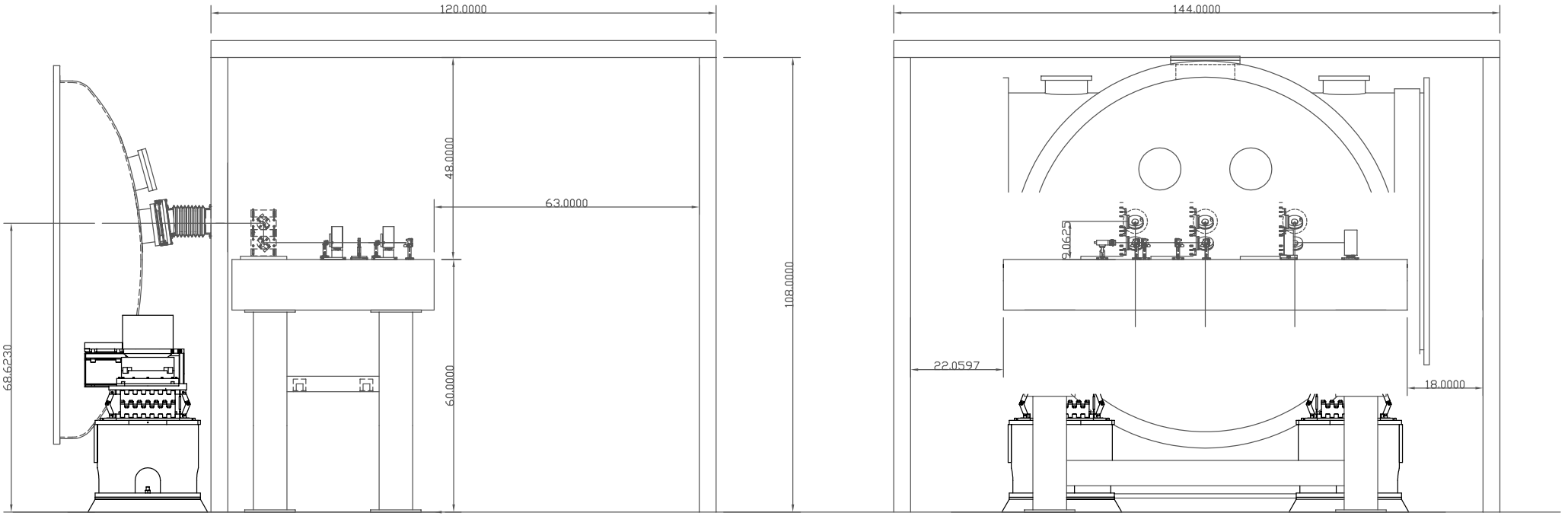
PSL ACCESS WINDOWS WITH THEIR COVERS INSTALLED

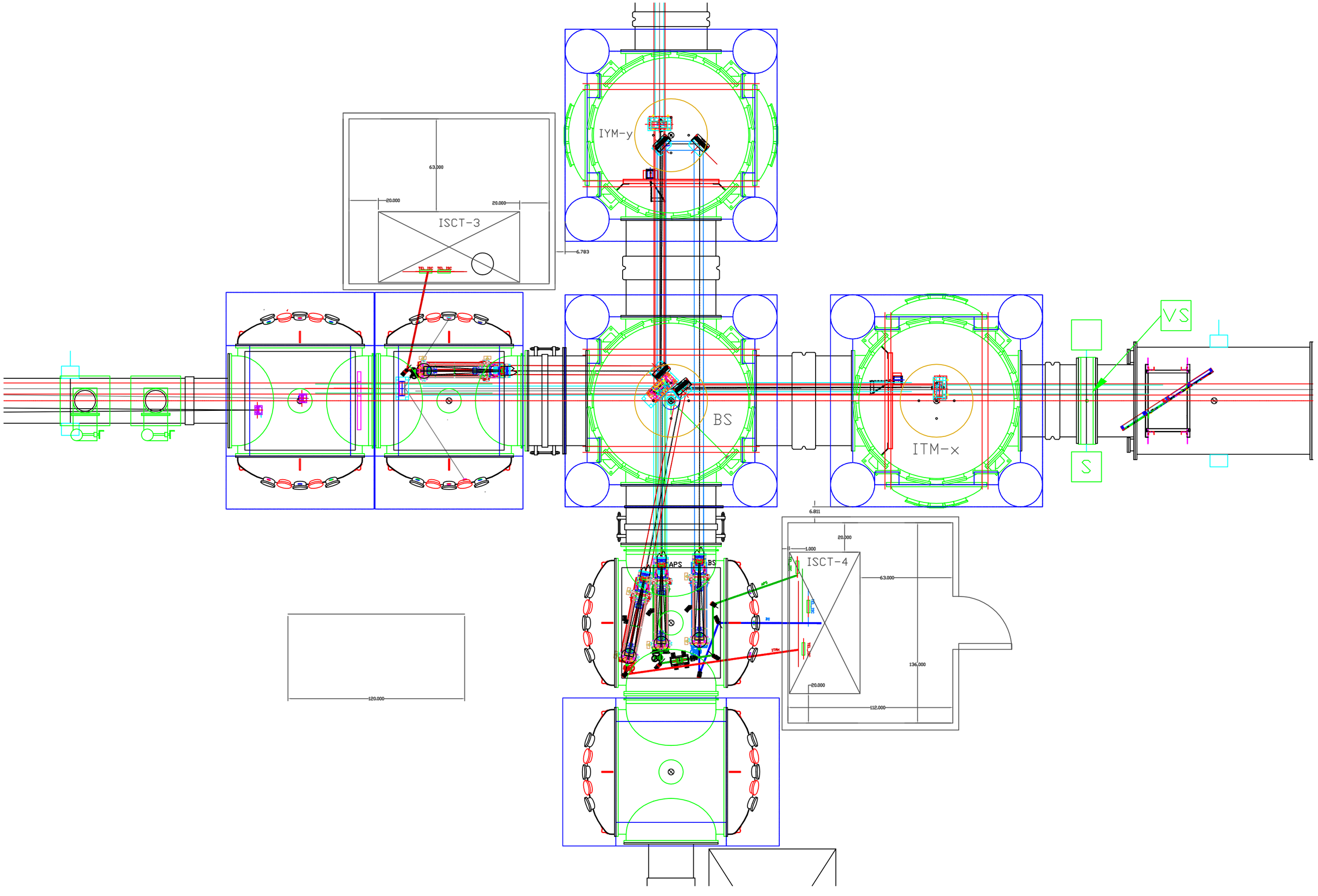
MEMBERS ONLY

FINISHED INSTALLATION…Beer :30


0-1.6 kHz
100
10
1
0.1
0.01
PSL-OUT MON in Hz/Hz^1/2
10
100
1000
frequency in Hz
no acoustic enclosure
with acoustic enclosure

Here is a sketch illustrating the general arrangement of ISCT4. I have drawn an enclosure with a 9' ceiling height, and 10 x 12' externally.
I raised the table arbitrarily to 60". The beam exits HAM4 ~69".




IYM-y
63.000
20.000
20.000
ISCT-3
6.783
TEL_ISC
TEL_ISC
BS
ITM-x
VS
S
6.811
20.000
1.000
APS
BS
ISCT-4
63.000
136.000
20.000
112.000
120.000

b. ASC: Delivery 2m; 9 enclosures 110k; 125Hz 27dB
c. EAI: Delivery 1.5m; 9 enclosures 180K; 125Hz 23dB

2. Absorption within table enclosure - AS enclosure not designed for absorption:
a. ASC low frequency absorption kit $3.5k per enclosure

3. Table-top vacuum system

B. Seismic shielding:
1. Table on damping polymer, above 50 Hz.
Doug estimates a few k$
2. Low frequency active isolation?

C. More rigid table: accelerations on table are ~10x that of floor underneath.
1. Thick optical table 4x8x6' $10.7k; finite element analysis desired
2. Cement or modified cement pedestal 5 k? finite element analysis desired

III. Reduce coupling (all of these require experimentation)

A. Reduce coupling at periscope
Relative coupling of periscope? Speaker experiment after S2

1. Eliminate Periscope by raising table:

2. Stiffer periscope with integral mirrors:
   Experiment after S2 with new periscope

B. Increase apertures (reduce clipping and backscattering):
1. Pool of larger optics: 2” 35 k total?
2. Remove EO shutter or replace with 1.6 cm shutter

C. Improve beam
1. Clean beam with small aperture? Experiment after S2
2. Is the beam bad when it comes out of vacuum? Why?

D. Reduce number of lenses on table

E. Improve beam dumping

F. Remove current enclosures (large size couples well)
experiment after S2

G. Shorter focal length lenses in front of photodiodes

H. Super-polished optics

I. Active beam stabilization

IV. Desirability of solutions:

A. Reduce coupling

B. Reduce sound level at coupling sites

C. Reduce continuous sources (electronics and HVAC)

V. Experiments planned after the S2 run:

A. Investigate coupling mechanism

1. Speaker excitation while listening to headphones
2. Neutral density filter for backscattering
3. Remove EO shutter
4. Accelerometer experiments
5. Super polished optics?

B.Investigate sources

1. Test new racks
2. Test HVAC contribution

RECOMMENDATIONS

I. For immediate purchase

1. Acoustic Systems dark-port enclosures (3); cost: ~$44k; improvement: 5 to 10
2. Acoustic Sciences Inc. low frequency damping kits for table enclosures (3) cost: ~10.4k; improvement 2-3
3. Seismic isolation for new racks; cost <2k; improvement?
4. Acoustic insulation of mechanical room - LVEA vacuum pipe feedthrough; <1k

TOTAL COST: ~$57k; EXPECTED IMPROVEMENT: 10 to 25

II. Possible purchase in next weeks

1. Low f acoustic insulation for exterior of racks, 3000 ft2, cost: $15k; improvement: 2-3, assuming new cabinets no worse.
2. More rigid tables (9) (awaits modeling and a few more accelerometer and periscope experiments to determine height). Cost: <$96K; improvement: ~5
3. Pool of larger optics; cost ~$35k; improvement?
4. Next weeks' discovery?