Scattering Loss

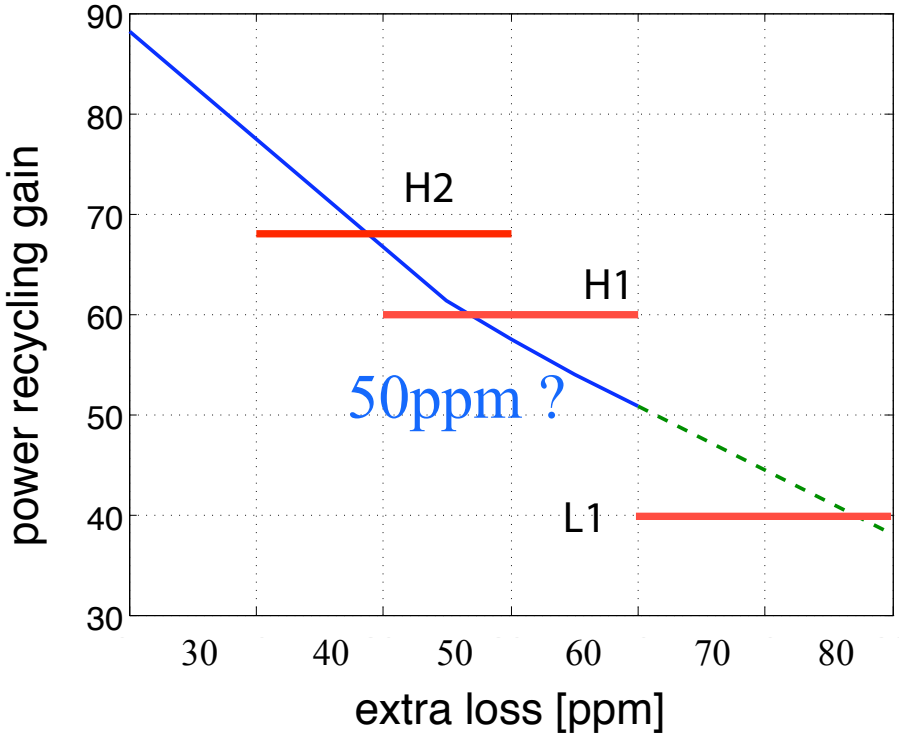
Hiro Yamamoto - Caltech LIGO

- LIGO I mirror loss estimation
  - » surface figure, micro roughness and larger angle scattering
- LIGO I mirror surface qualities
  - » polished surface data by CSIRO and coated surface data by LIGO
- Does not include new issues of LMA mirrors
  - » bubbles, AR coating, etc
- Advanced LIGO loss requirement
  - » implication of the LIGO I mirror quality
- Diffractive loss in stable Michelson cavity
  - » Loss due to the “effective long distance propagation” in the stable Michelson cavity

Crude estimation of loss budgets in a LIGO I arm

- Recycling gain, visibility, etc are consistent with 140 ppm loss per arm
- known loss per arm
  - » surface figure (λ>0.5cm) : 10 ppm / mirror x 2
  - » ETM transmission : 7 ppm
  - » absorption : 4ppm / mirror x 2
  - » diffractive loss : 2ppm
- 140ppm total loss - known loss = 100 ppm / arm or 50 ppm / mirror

Recycling gain as a function of extra loss per mirror in FFT simulation



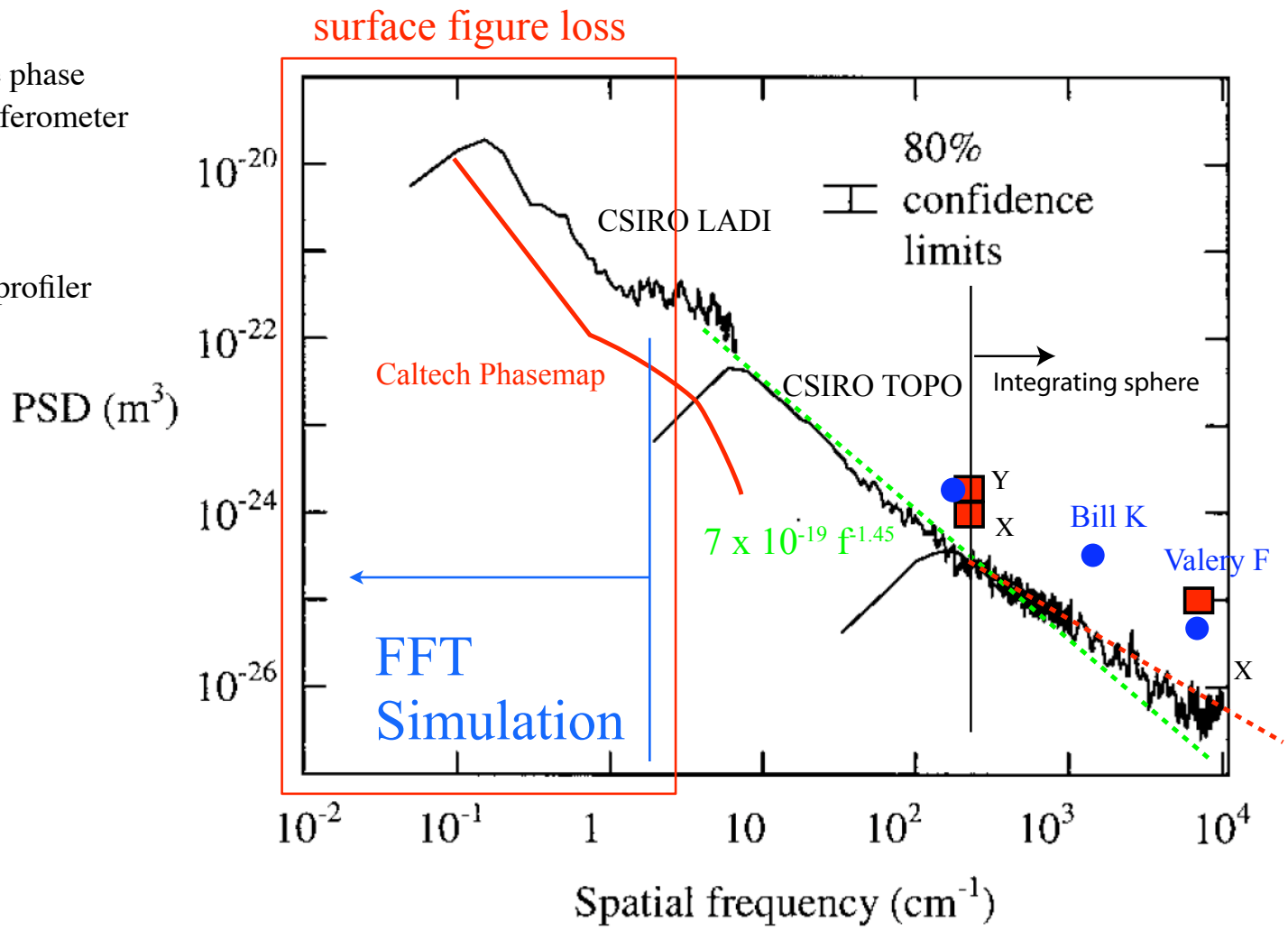
Polished (CSIRO) vs coated (LIGO) surface data

CSIRO LADI

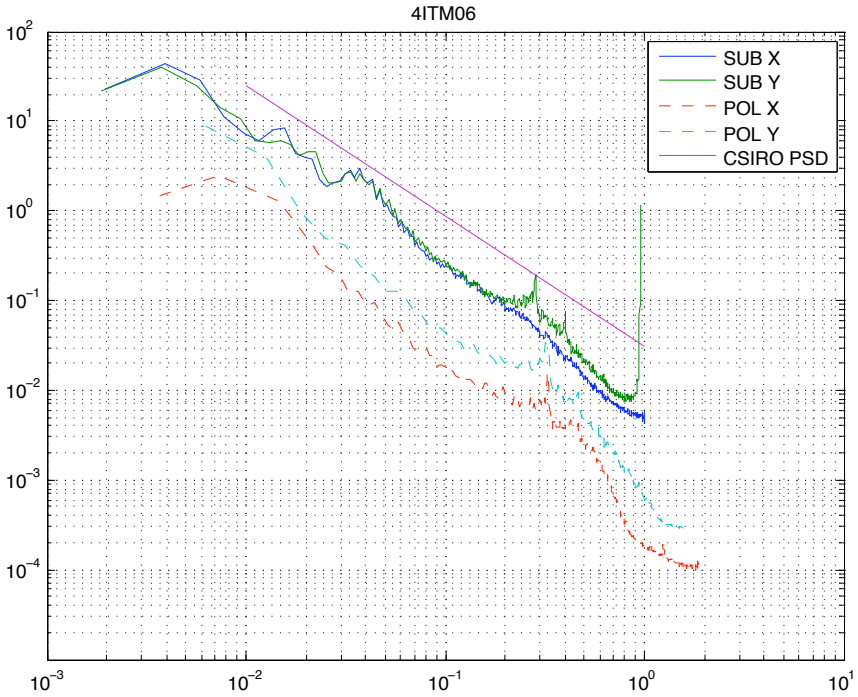
A 300-mm aperture phase shifting fizeau interferometer

CSIRO TOPO

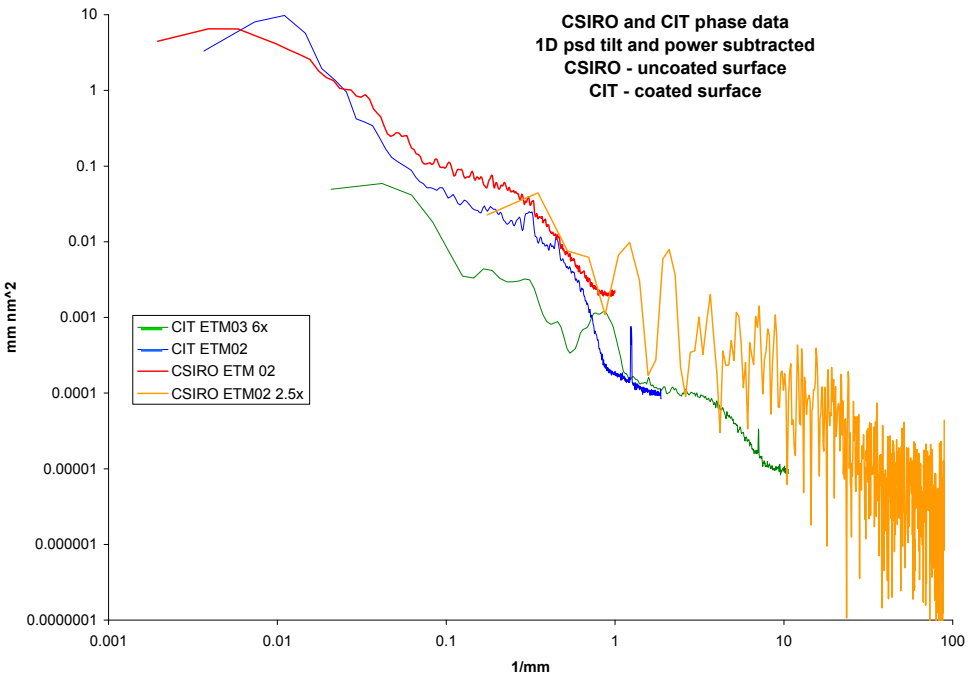
three dimensional noncontact optical profiler



surface figure
CSIRO vs Phasemap PSD

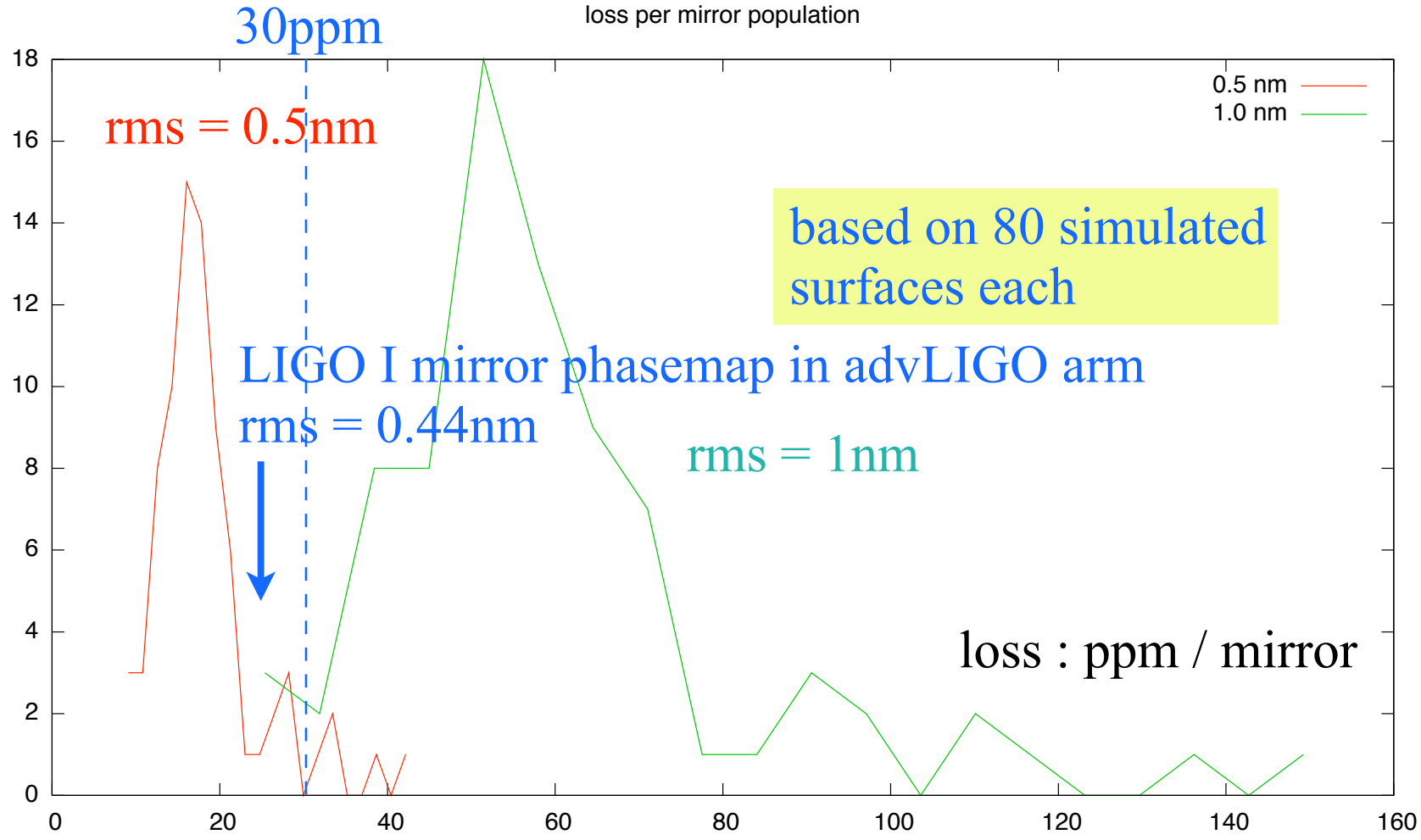


1 / mm



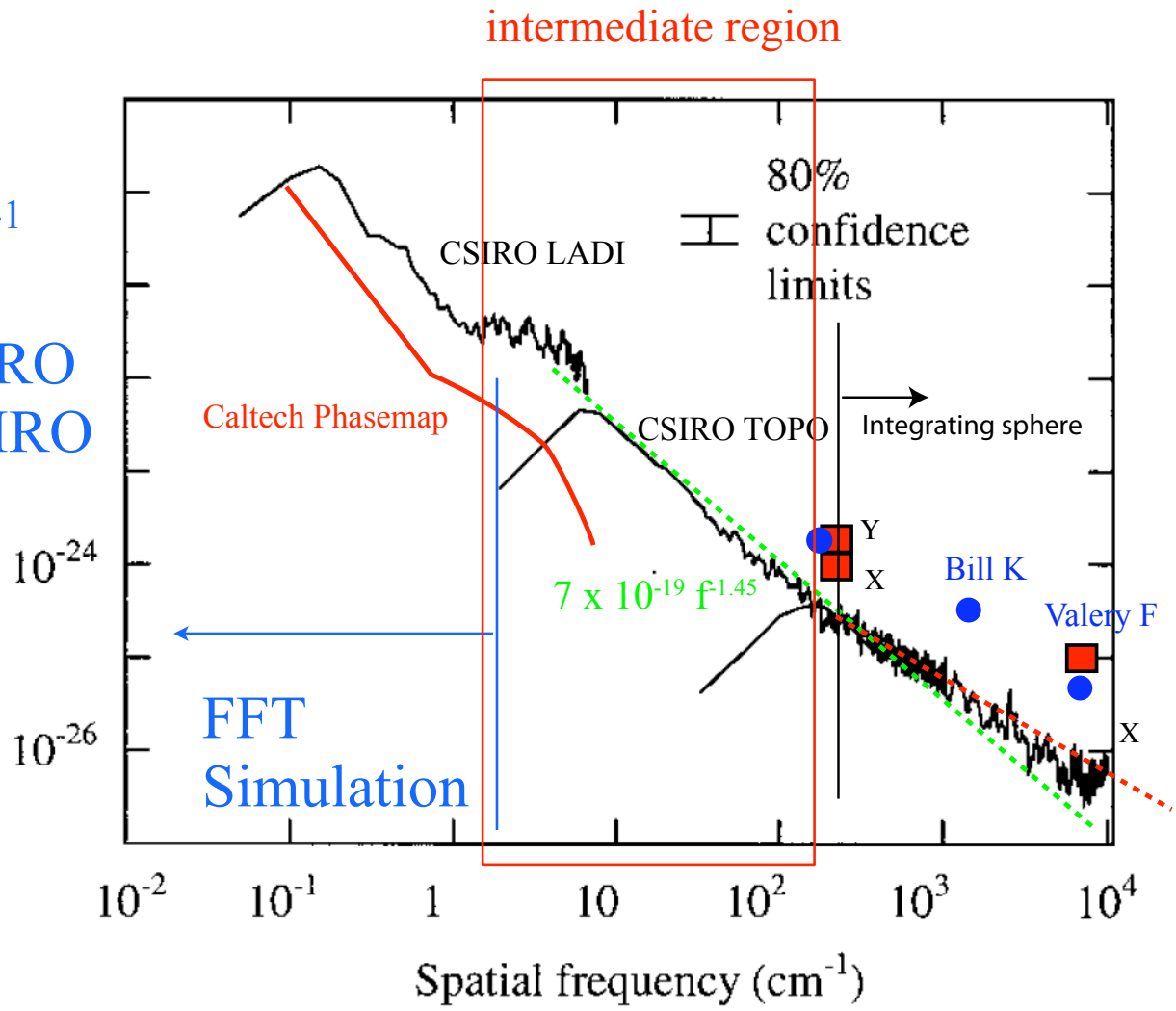
Surface figure loss of AdvLIGO

loss per arm : rms = 1nm vs 0.5nm



Loss in the least investigated region : $\lambda \sim 1$mm

- loss by integral of CSIRO fit in 2~100 cm^{-1} = 26ppm
- low end : LIGO < CSIRO
- high end : LIGO > CSIRO

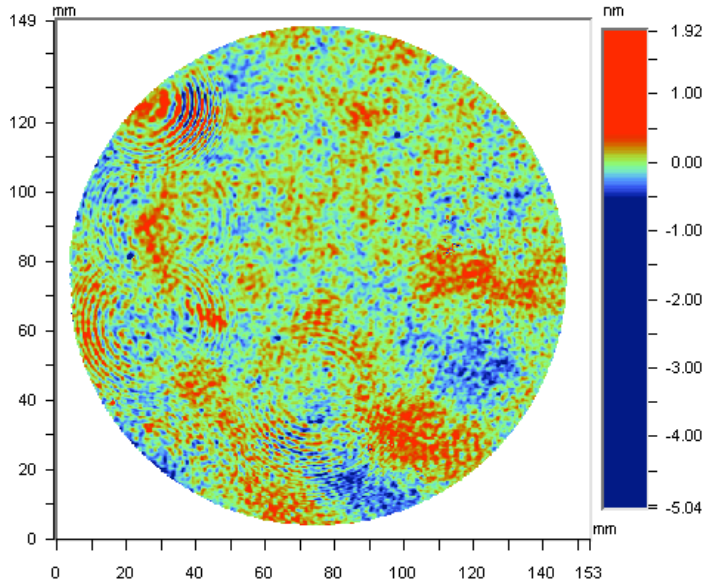


Orange peel
- psd shows bumps at ~0.3 cm -

Caltech phasemap

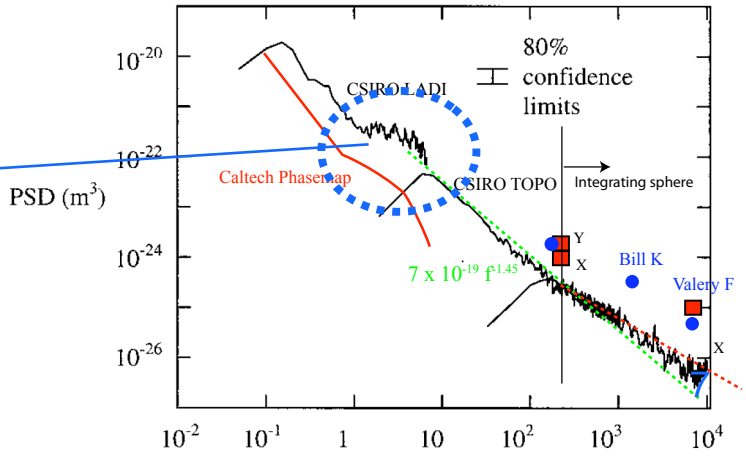
loss ~ 2.4 ppm
new FFT grid size
= 0.14 ~ 0.28cm

loss ~ 1.3 ppm x 2
old FFT :
loss(35cm/256) -
loss(35cm/128)

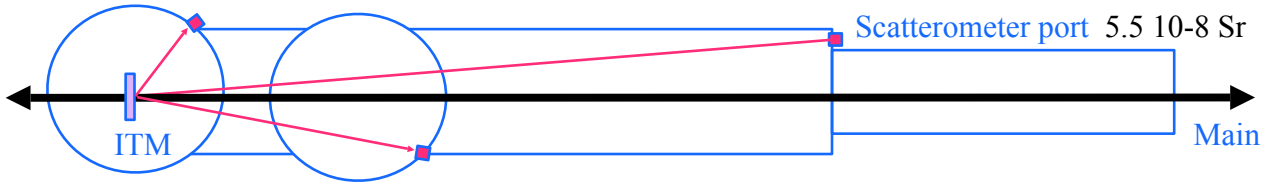


CSIRO PSD

Bill K estimated
~10ppm



Large angle scattering loss



large angle scattering loss

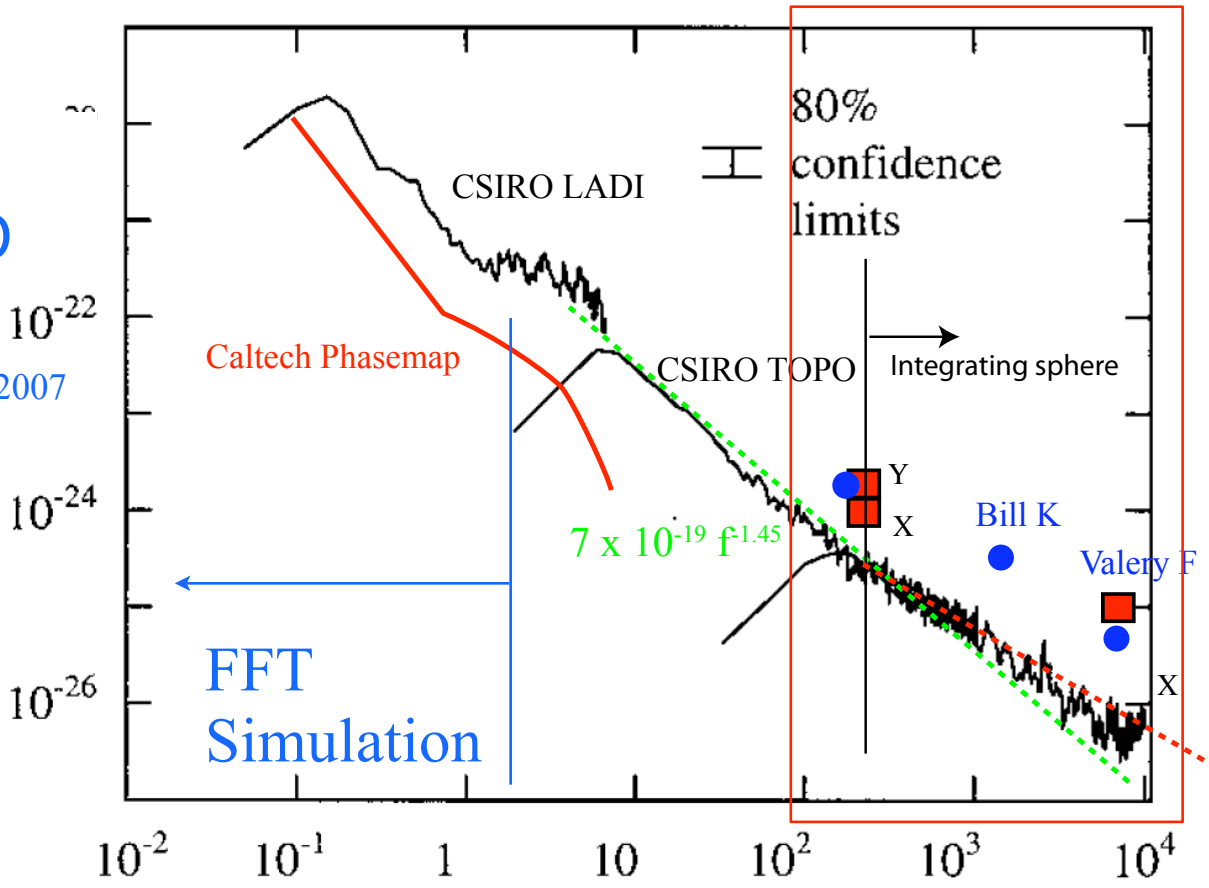
- In situ, large angle measurement : PD

  Bill Kells H1 ITMy June 2003

  Valera L1 ITMxy&ETMxy October 2007

- Caltech OTF : integrating sphere

  Liyuan



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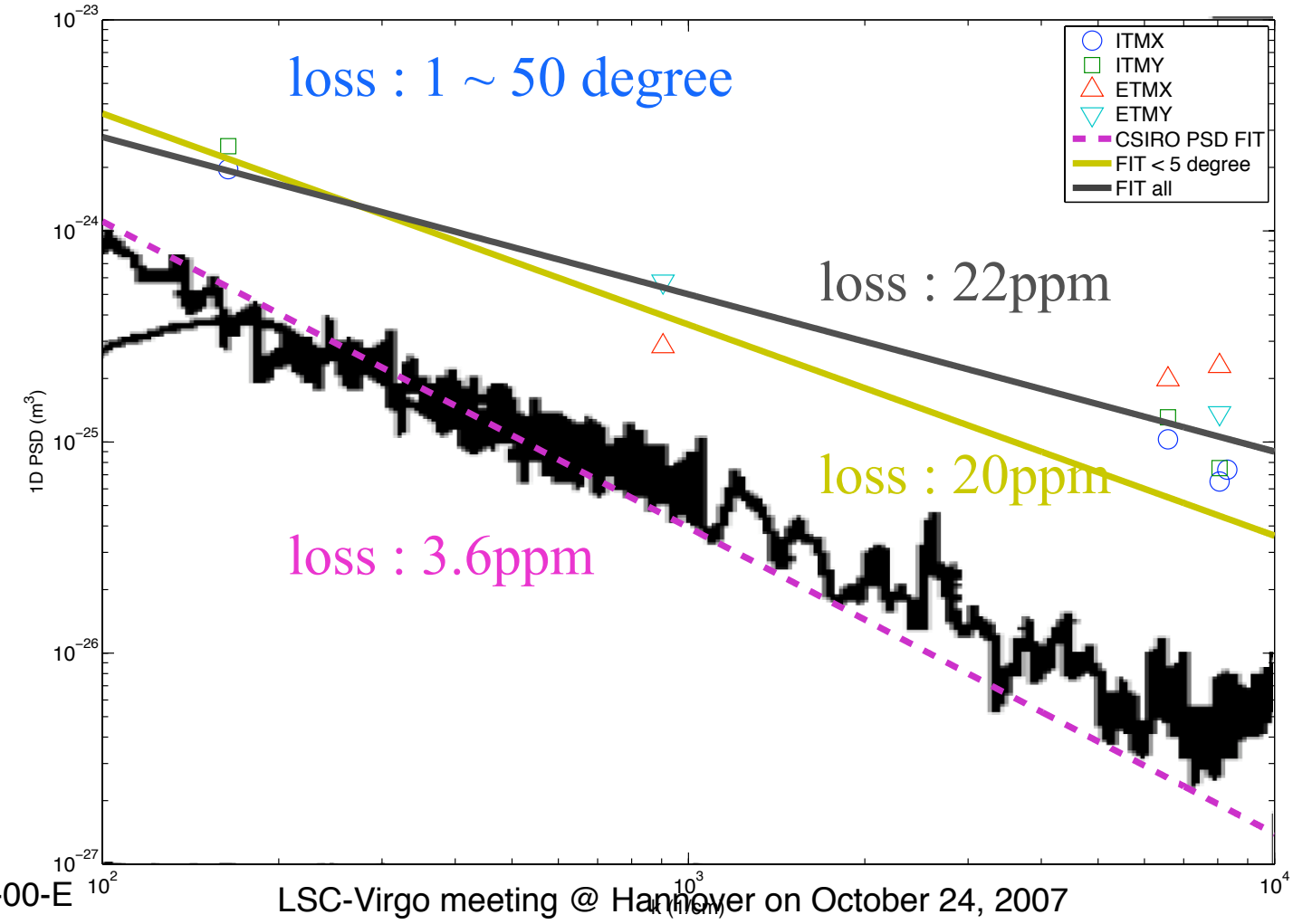
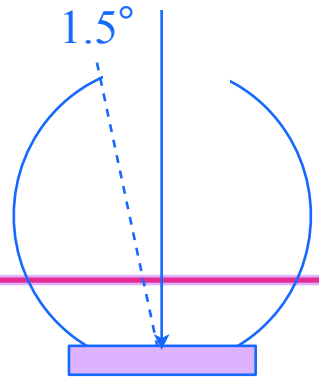
Large angle scattering
LLO ITM/ETM by Valery Frolov



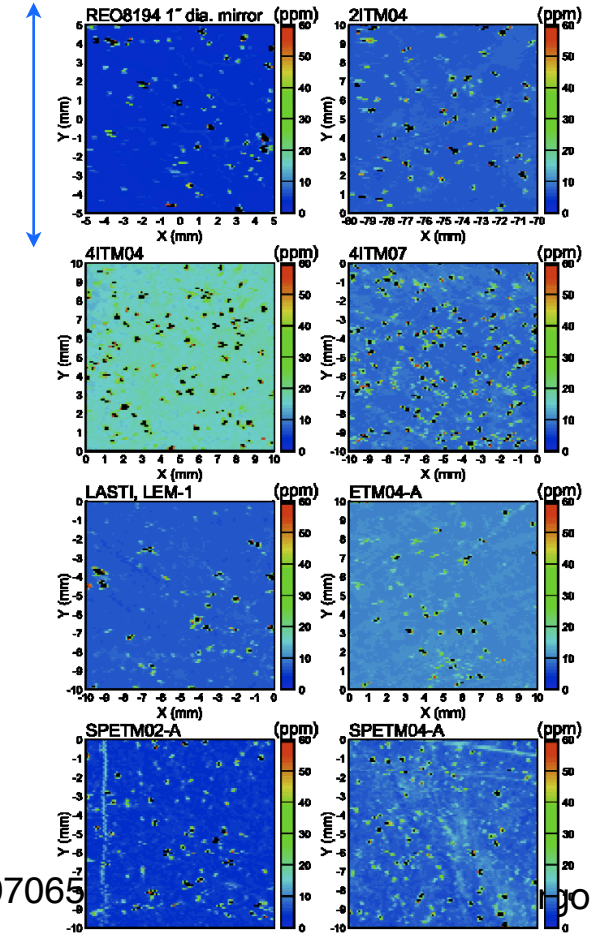
Integrating sphere data

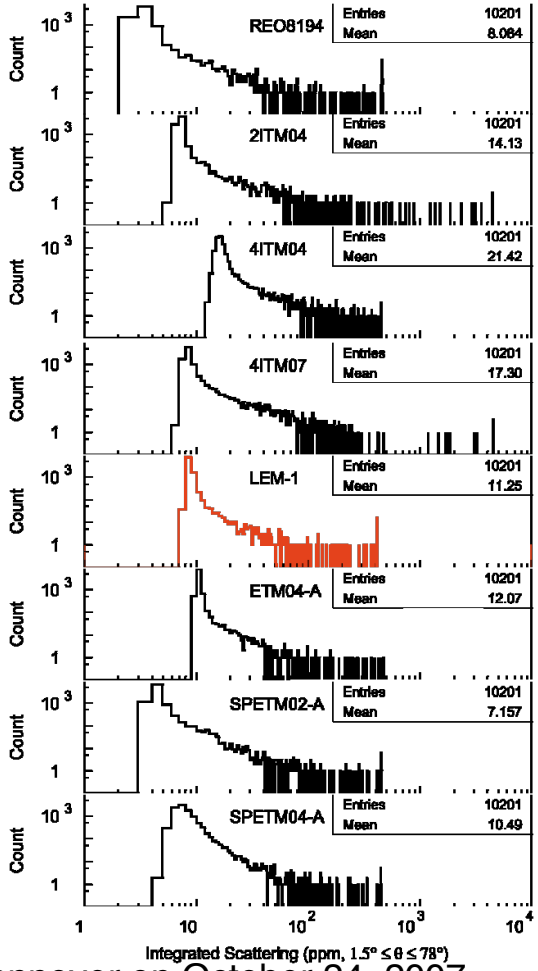
Liyuan, Herena (T070233)



1cm x 1cm

0.3mm beam size
0.1mm step





14.13 ppm

21.42 ppm

17.30 ppm

11.25 ppm

12.07 ppm

7.157 ppm

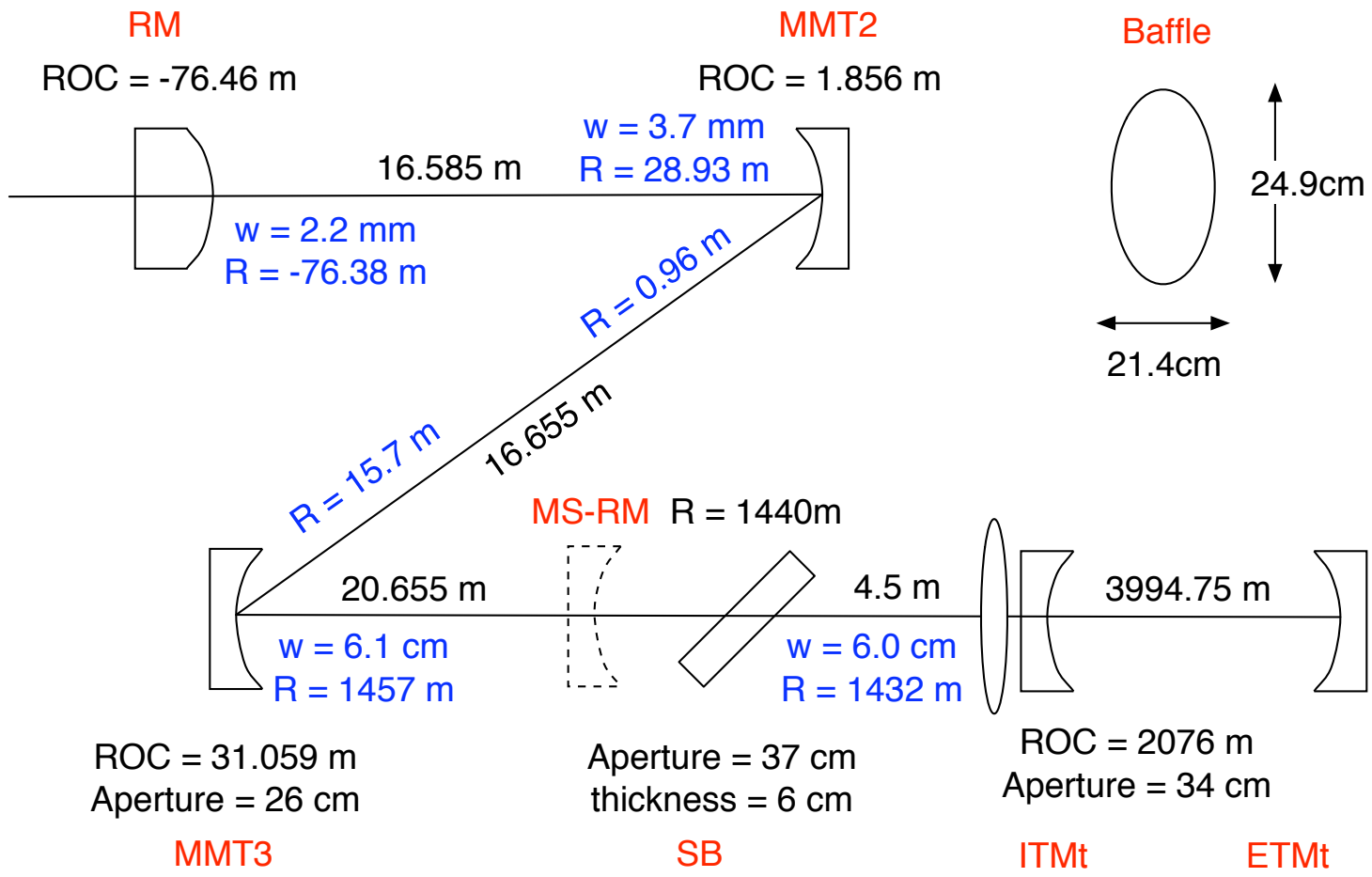
10.49 ppm

LIGO

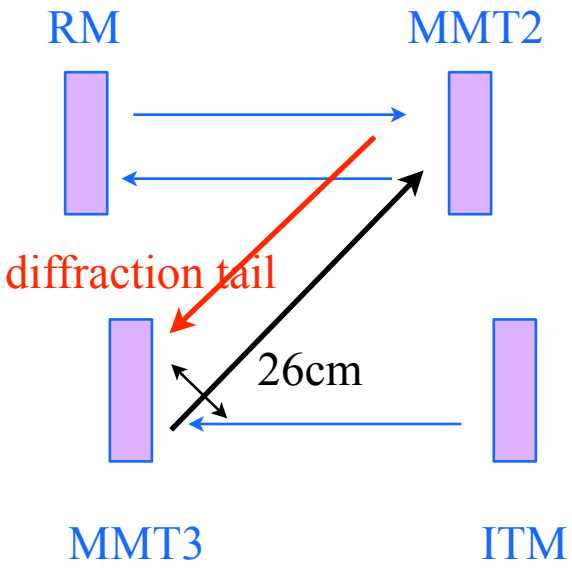
Advanced LIGO

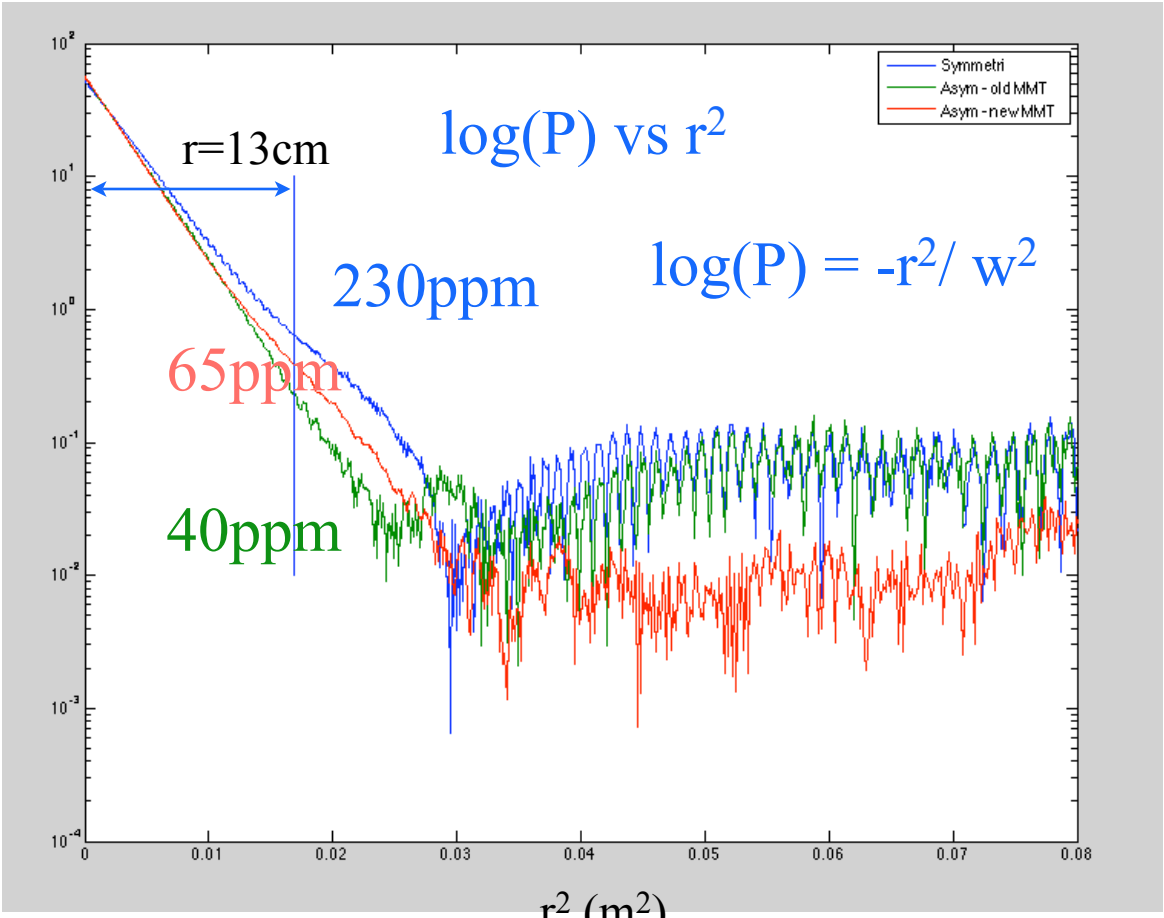
- total arm loss budget = 70ppm
- known loss : ~ 50 ppm / arm
  - » diffraction : 0.4 ppm
  - » absorption : 0.5 ppm x 2
  - » surface figure : 20ppm x 2
  - » ETM transmission : 7 ppm
- 11 ppm / mirror for micro roughness, large angle and all other losses
- LIGO I mirror : 50 ppm

Diffraction effect in Stable Michelson cavity



Beam profile on MMT3 coming from MMT2





LIGO

Summary

- LIGO I mirror loss estimation
  - » Scattering loss per mirror in LIGO I arm (Power Recycling gain, etc) : 50ppm
  - » Loss(λ>5mm) ~ 10 ppm/mirror
  - » Loss(λ~1mm) ~ not well understood (3 ~ 30ppm/mirror??)
  - » Loss(λ<0.1mm) ~ 10 ~ 30ppm
- LIGO I mirror surface quality - some inconsistencies
  - » λ>5mm : PSD(coated surface) ~0.1 PSD(polished surface)
  - » λ~1mm : not well understood
  - » λ<0.1mm : mesured loss ~ 10 x estimation by polished surface data
- Advanced LIGO loss requirement < 35ppm / mirror
  - » Loss(λ>5mm) ~ 20~25 ppm/mirror with RMS < 0.7nm
  - » Need to understand LIGO I mirror losses and to suppress losses or change the AdvLIGO specification to be more tolerant to extra loss
- Loss in stable Michelson cavity
  - » Due to far field propagation in the cavity, ~500 ppm loss by diffraction with w(ITM)=6cm.
  - » With asymmetric arm configuration (w(ITM)=5.5cm,w(ETM)=6.2cm), this is suppressed to ~50ppm.