Scattering of the ITM and ETM mirrors and constraints for the Wide-Angle Baffles in bKAGRA

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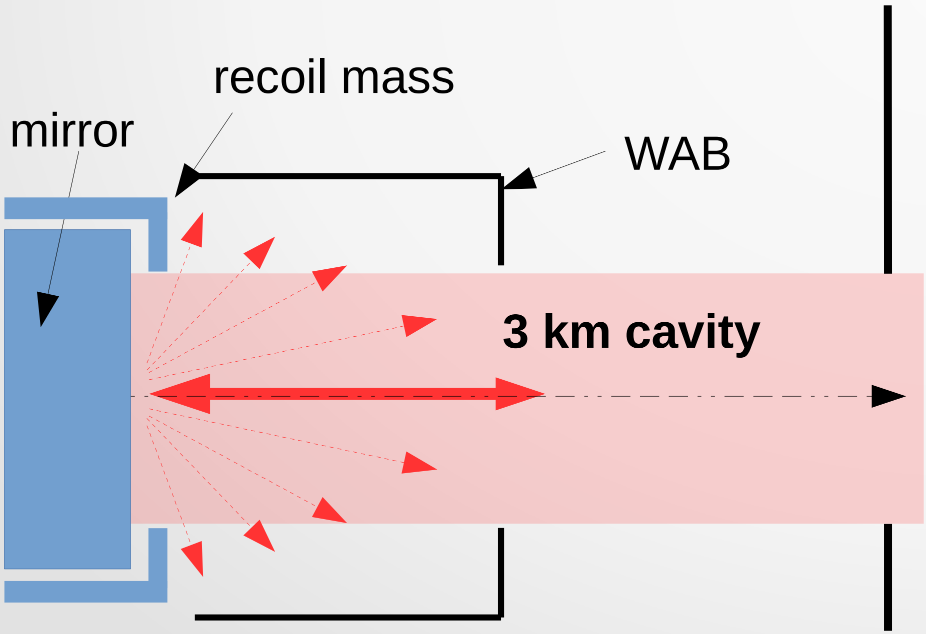
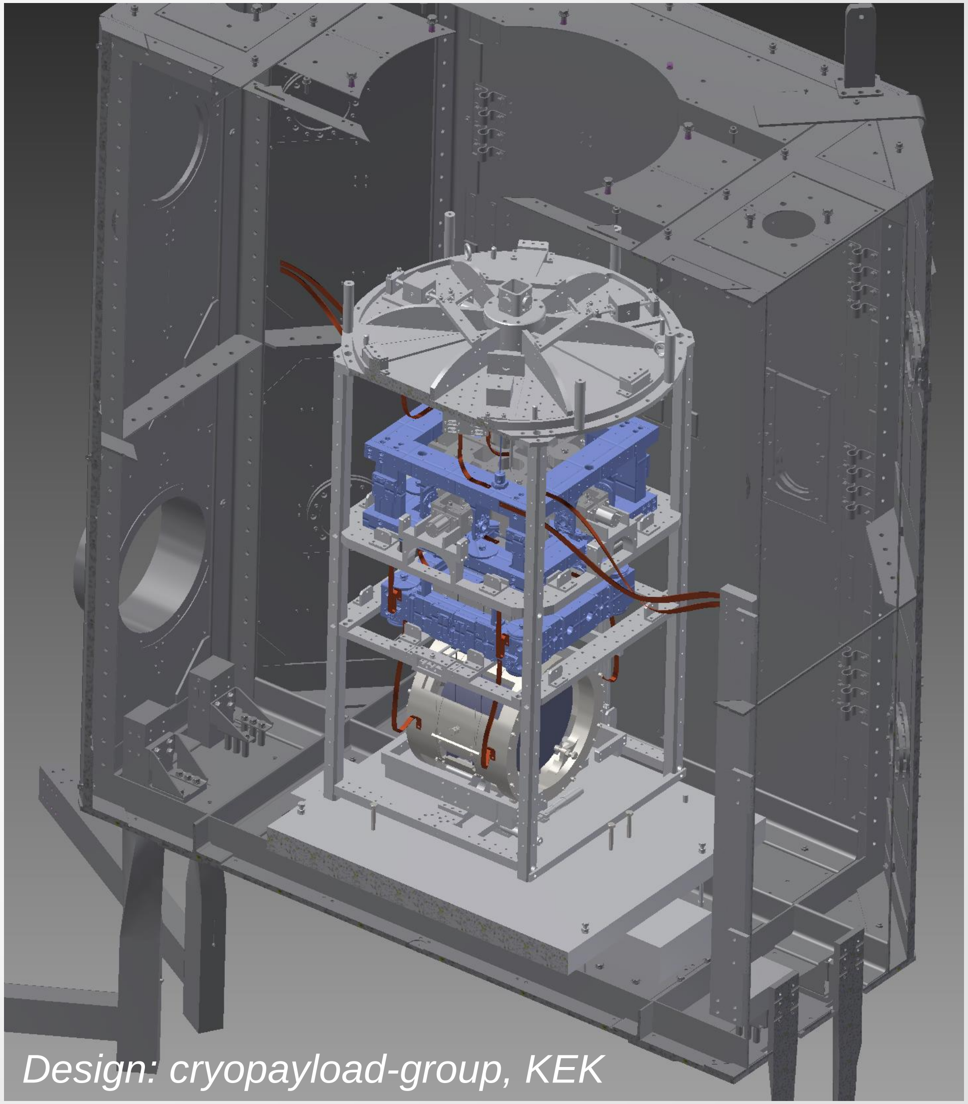
NAOJ, AOS

f2f KAGRA meeting at the University of Niigata, March 2017

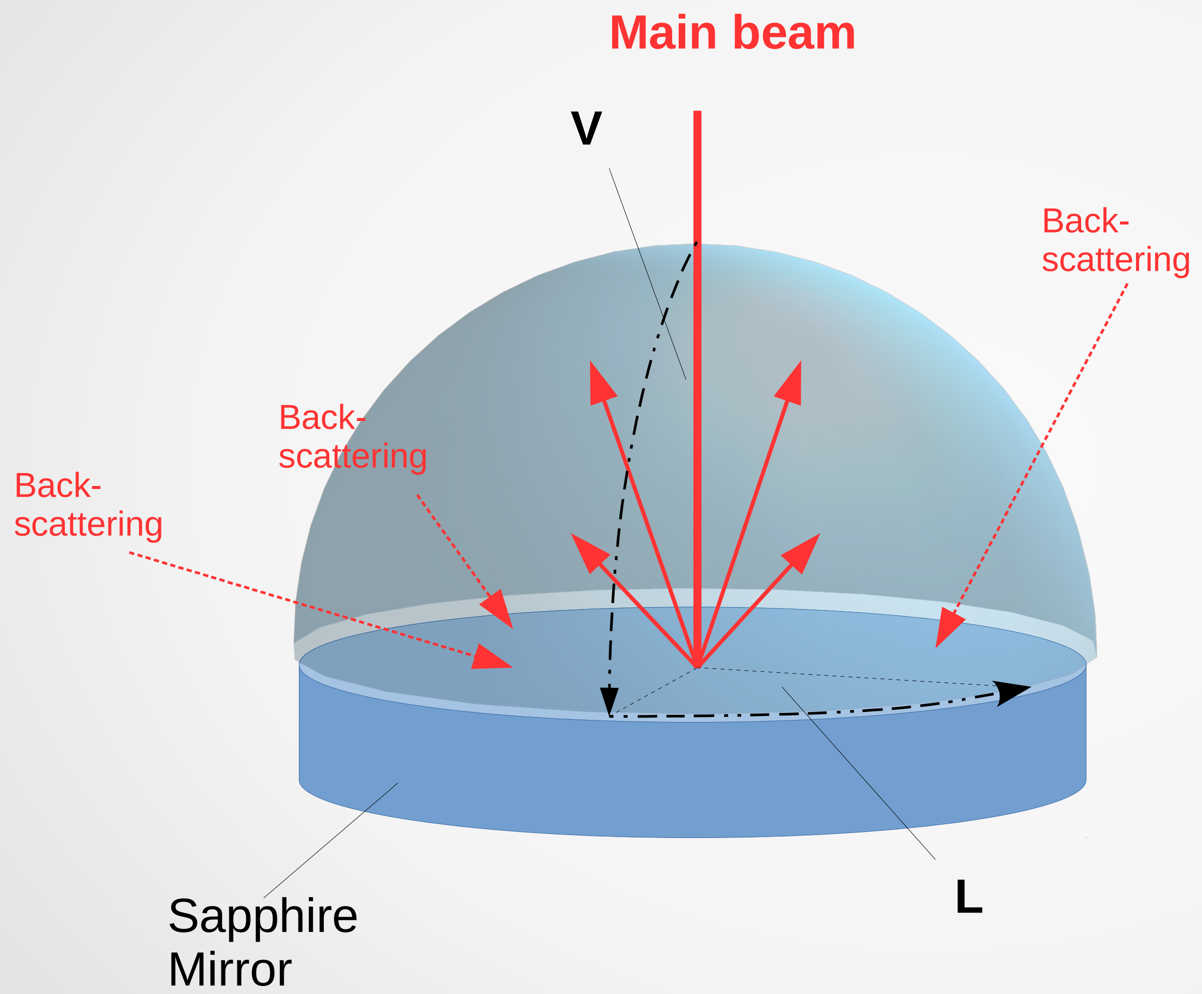
Wide-Angle Baffles (WAB)

- Baffles to be installed close to the **ITM** and **ETM** mirrors
- Inside the cryostats
- To block scattering at wide angles (~ 30° – 85°)
- Simulations to find most effective design



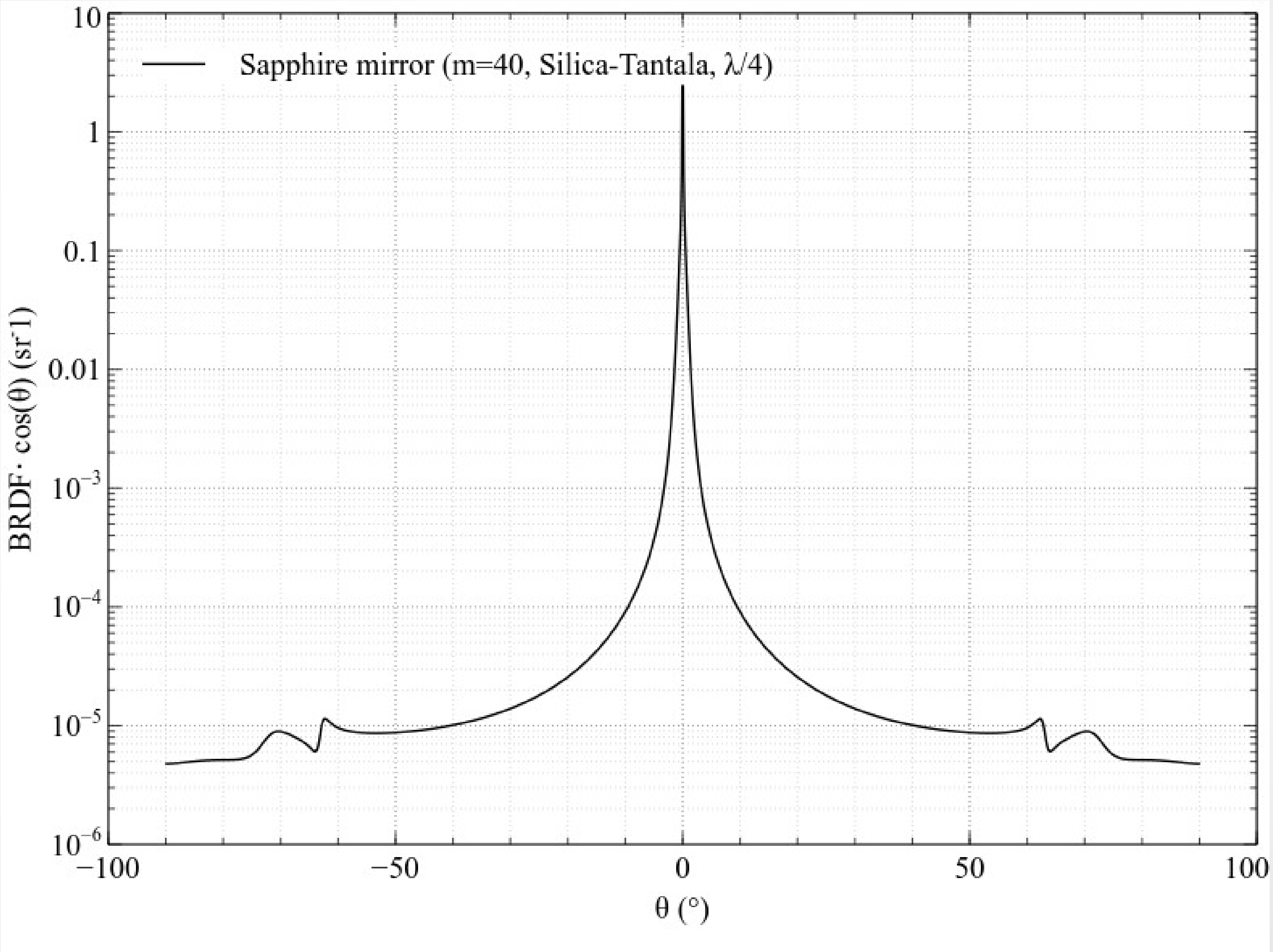


Simulating back-scattering from the interior of the cryostat



- Simulation tool: "LightTools"
- 10^8 rays per simulation run
- Mirror's scattering distribution calculated with multi-layer scattering theories
- Specular reflection not included
- Result: scattering map as a function of **L** (longitude) and **V** (latitude)

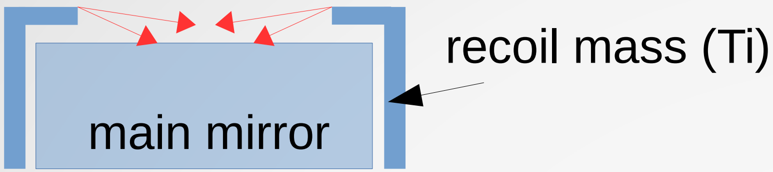
Scattering distribution on coated sapphire mirror



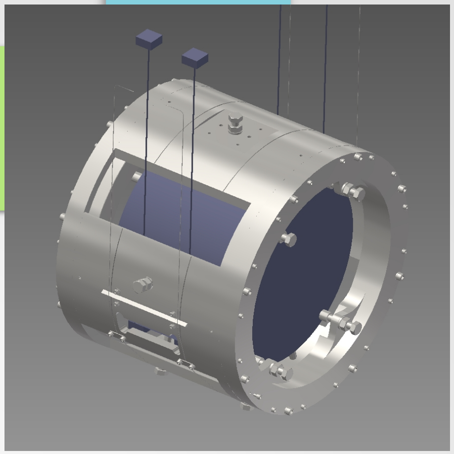
→ surface roughness (100ppm) + point defects (30ppm)

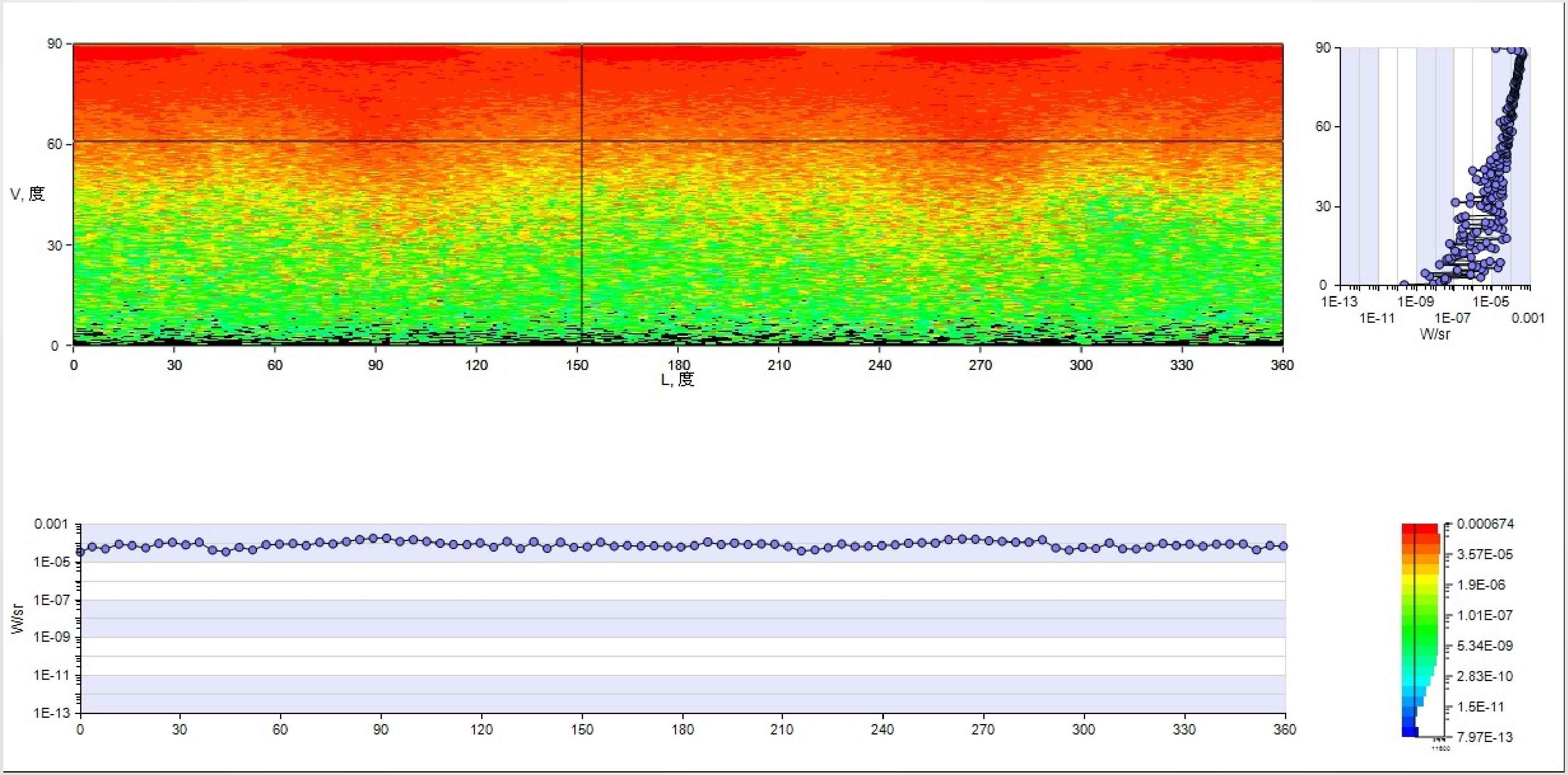
coating design: Hirose-san

Simulation results of recoil-mass scattering

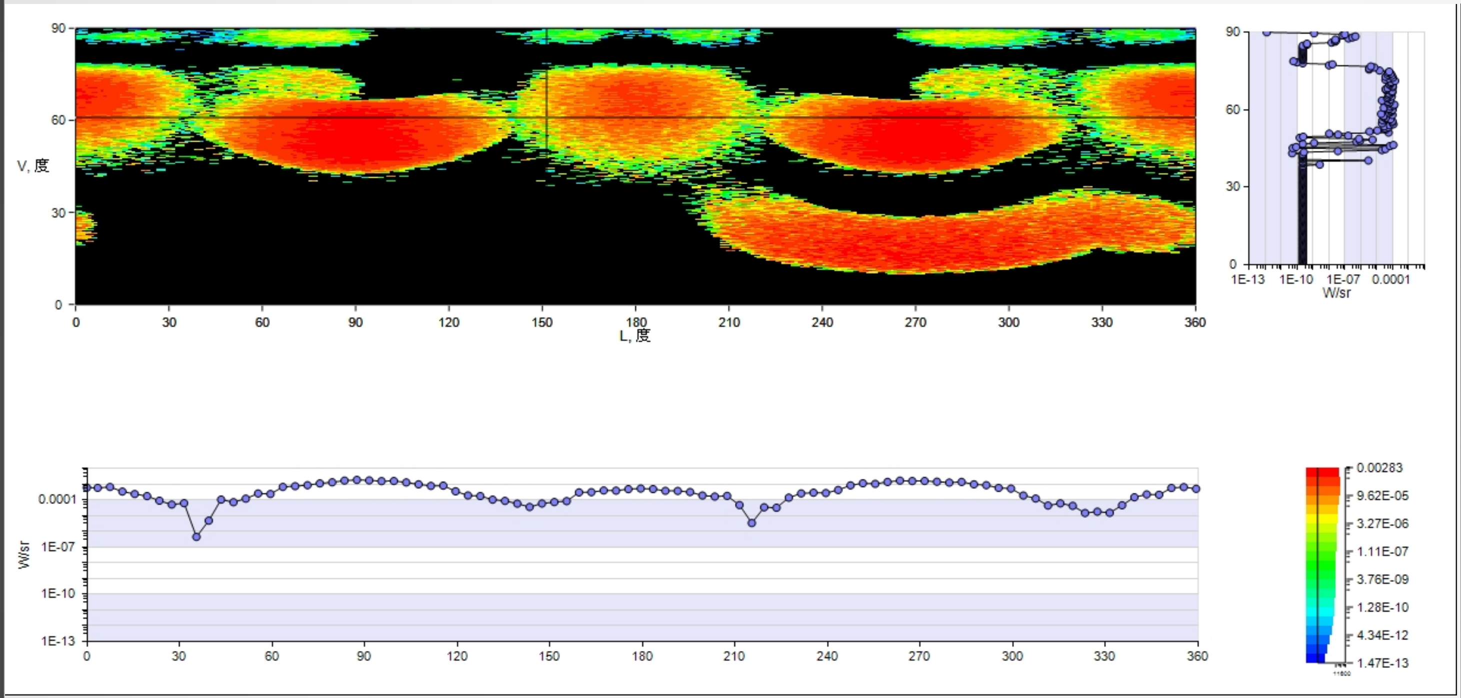


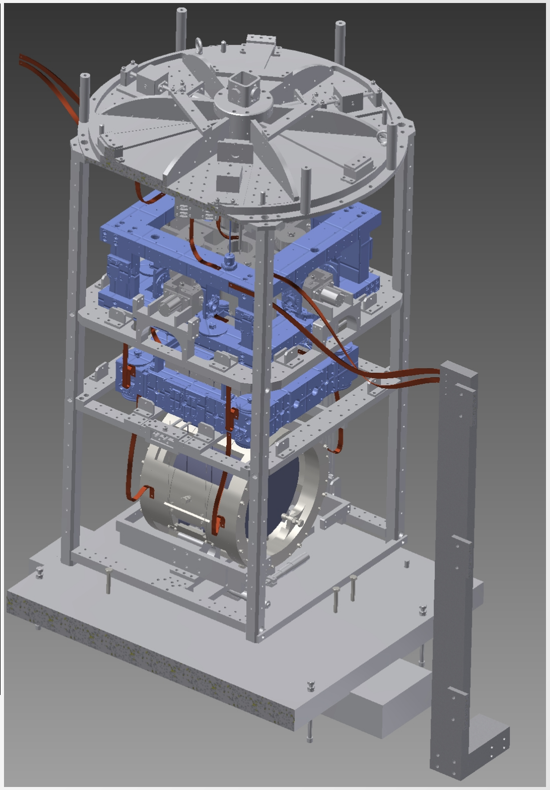
P_{bsc}/P_{scat} ~ 0.027 %





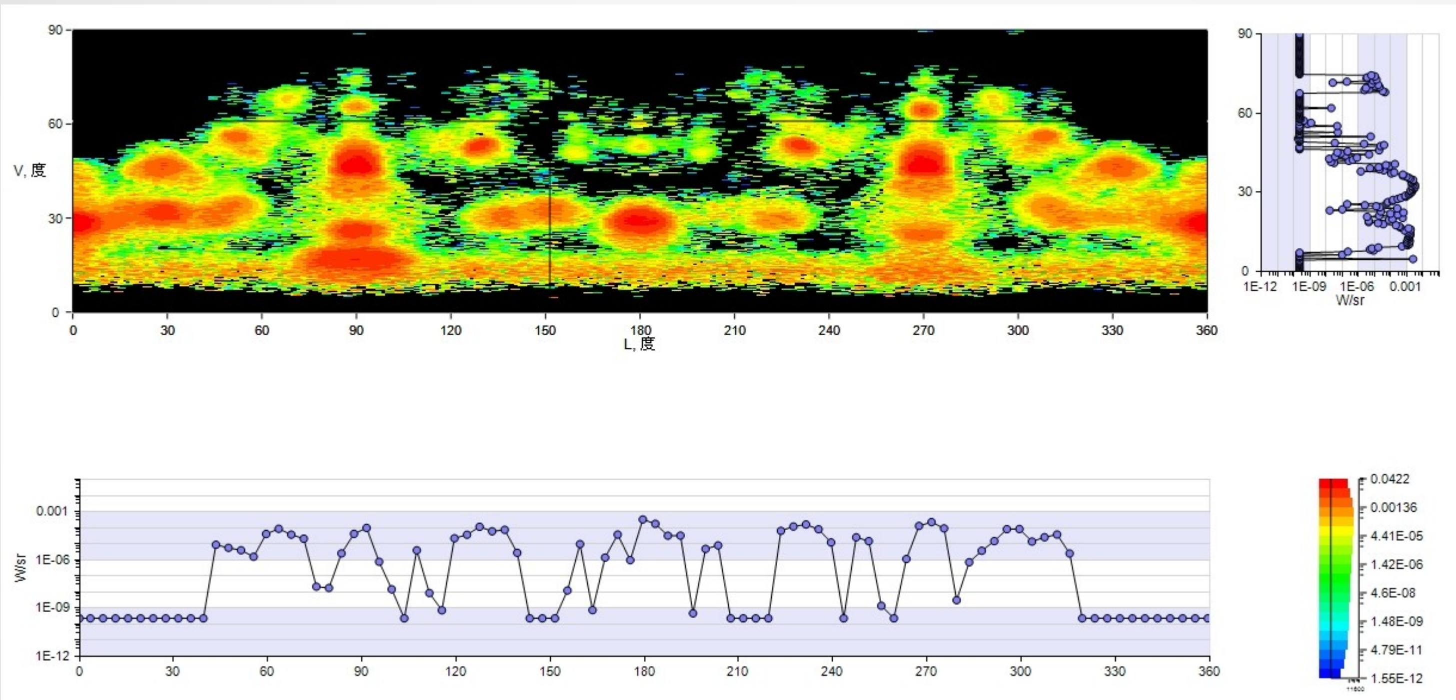
Simulation results of assembly-frame scattering

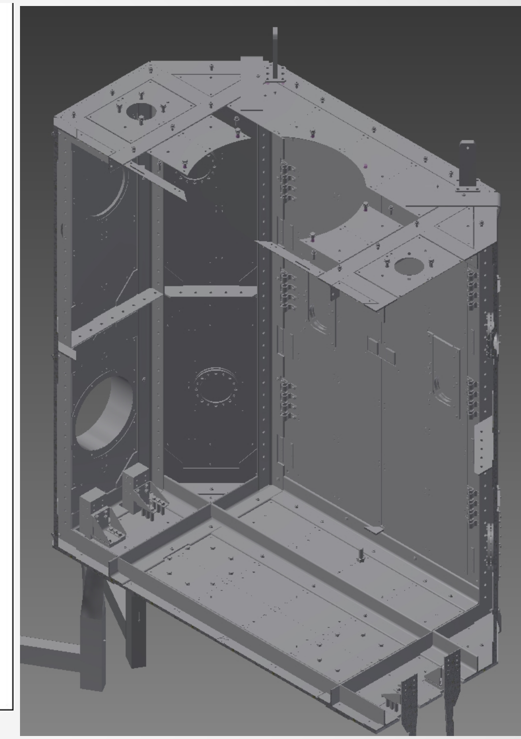




$P_{bsc}/P_{scat} \sim 0.043$ %

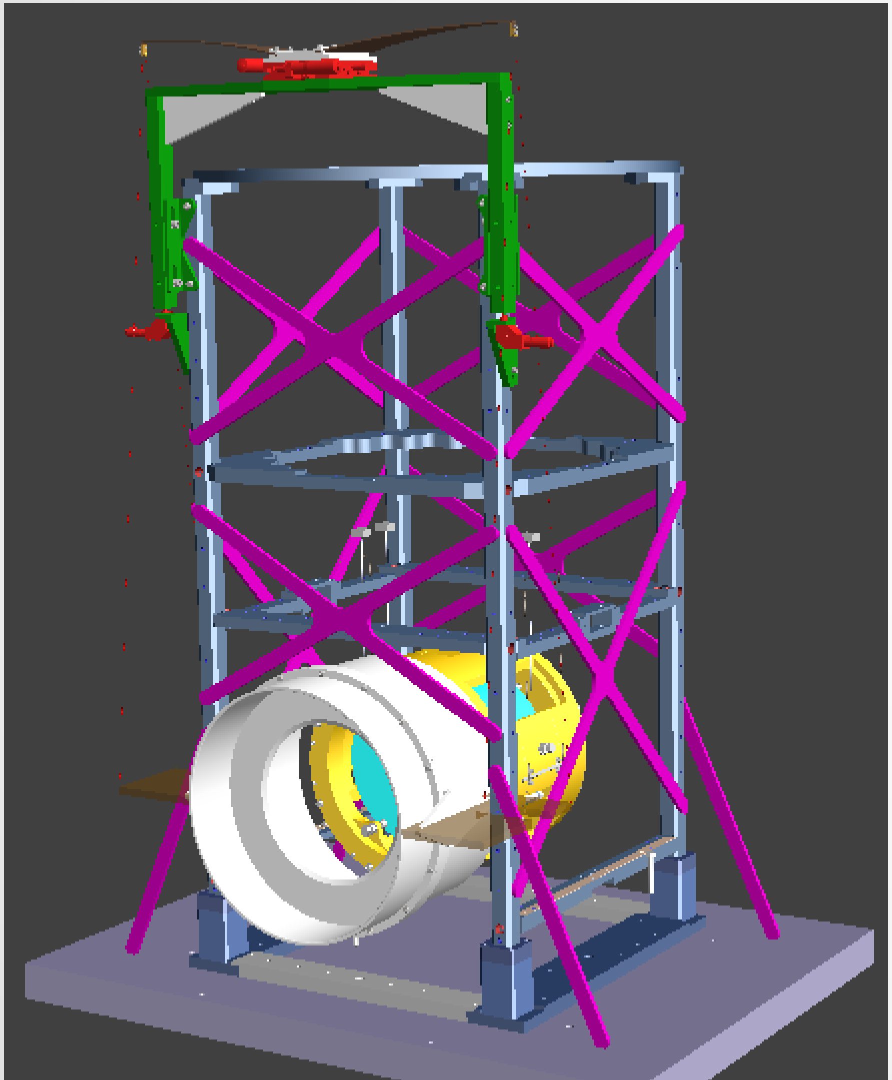
Simulation results of inner-shield scattering





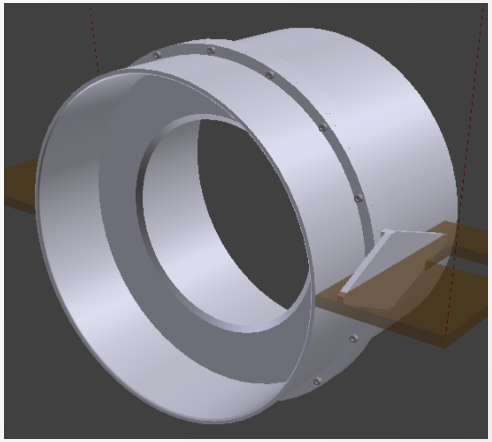
$P_{bsc}/P_{scat} \sim 0.1$ %

Change of back-scattered power with WAB



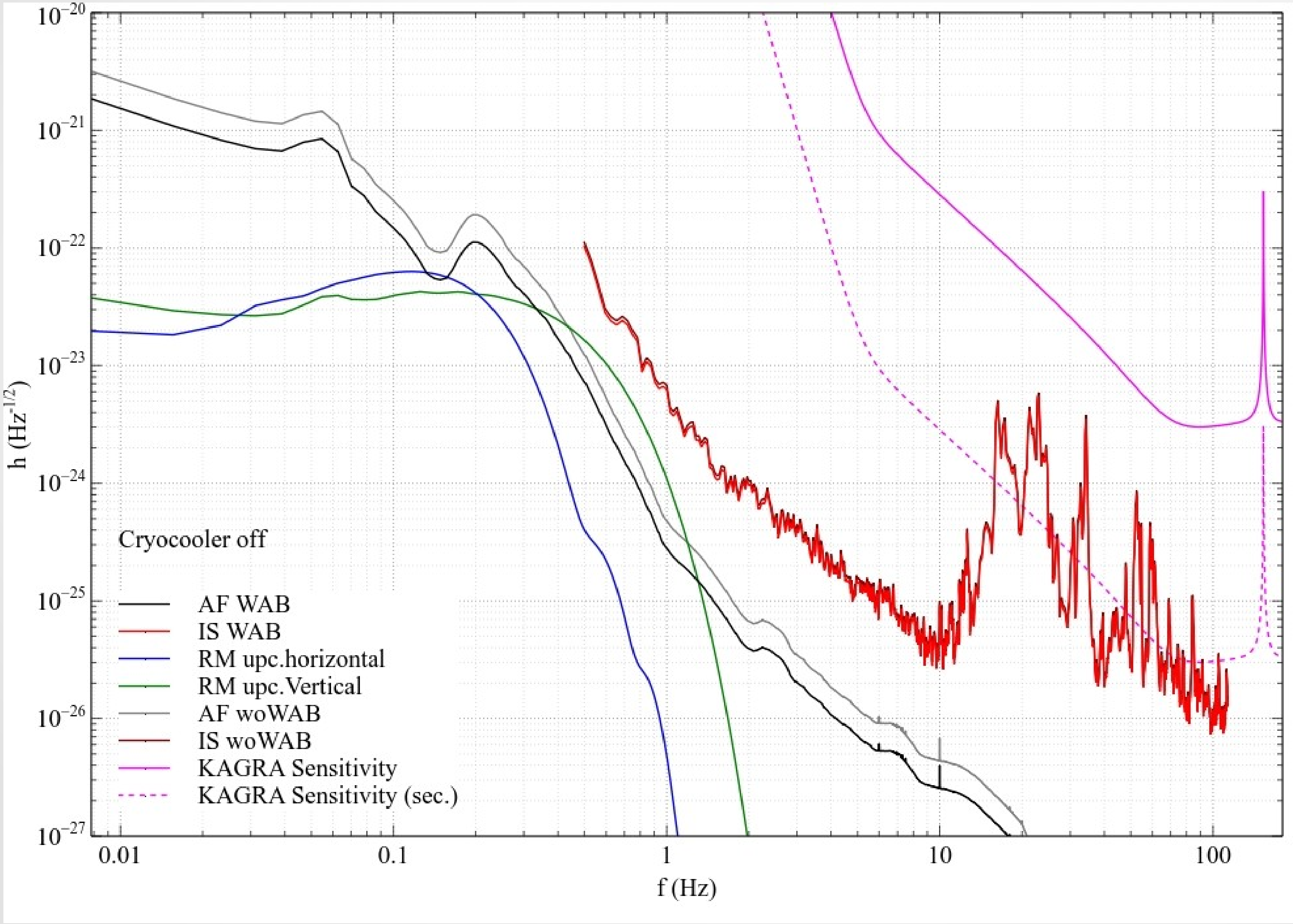
Design: Obuchi-san
(ATC, NAOJ)

P_{bsc}/P_{scat} ~ 0.1 %	→	~ 0.013 %
P_{bsc}/P_{scat} ~ 0.043 %	→	~ 0.003 %

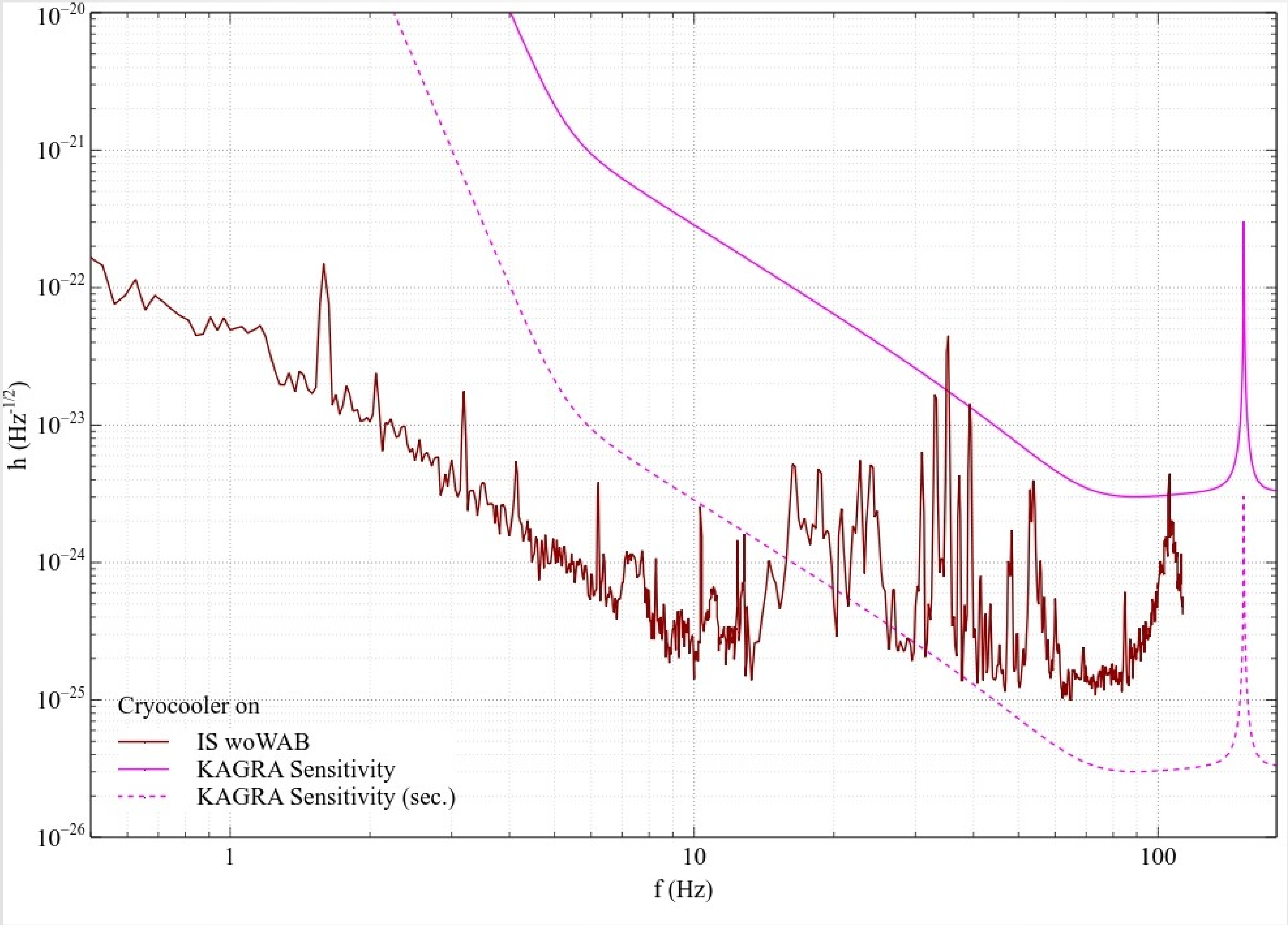


WAB: length – 300 mm
diameter – 280 mm
radiation disk – 210 mm from mirror

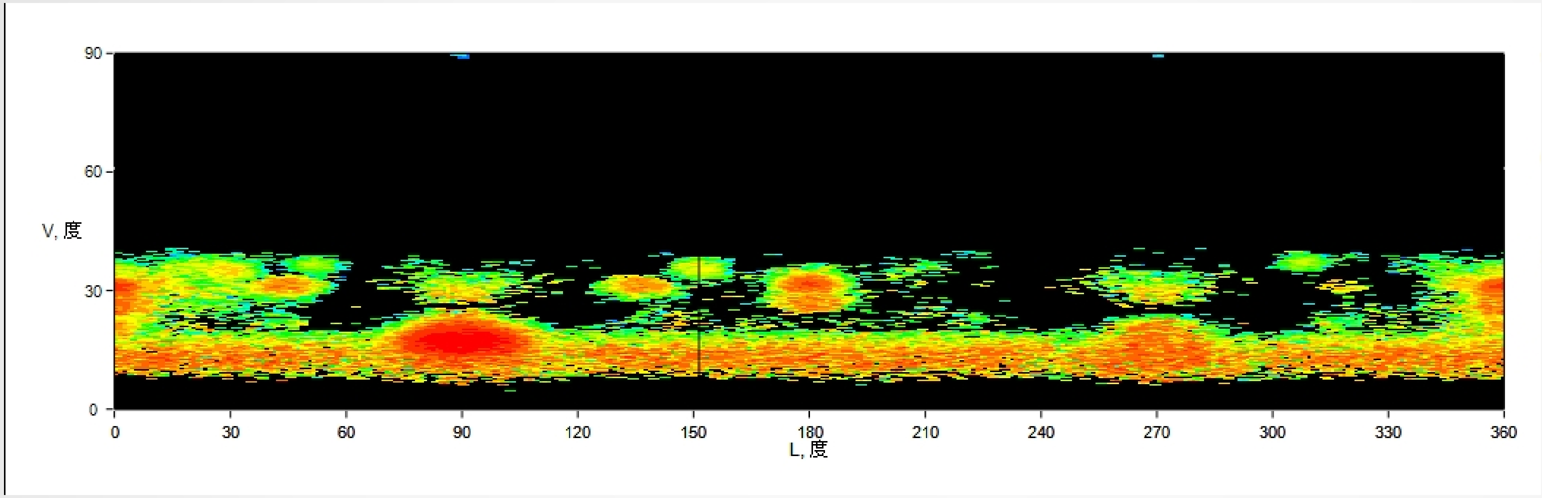
Impact on strain-noise of KAGRA

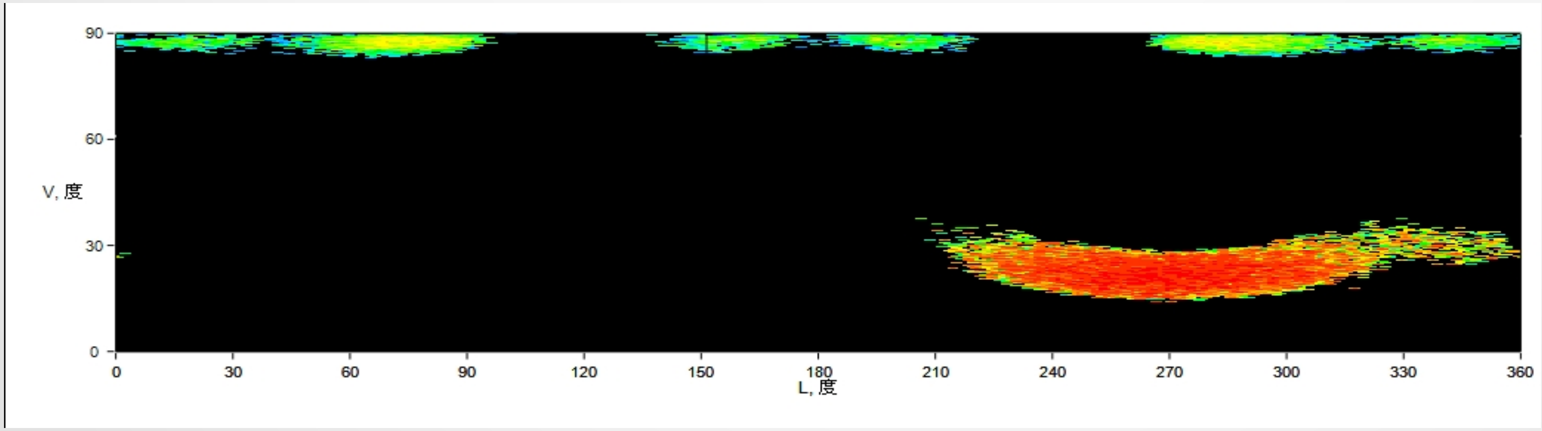


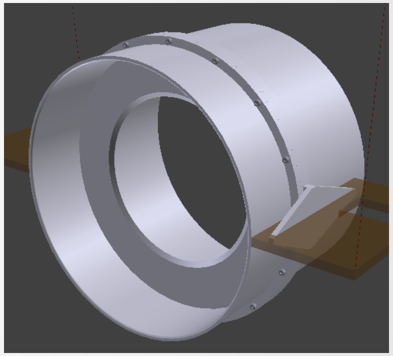
Impact on strain-noise of KAGRA



Simulation results with WAB

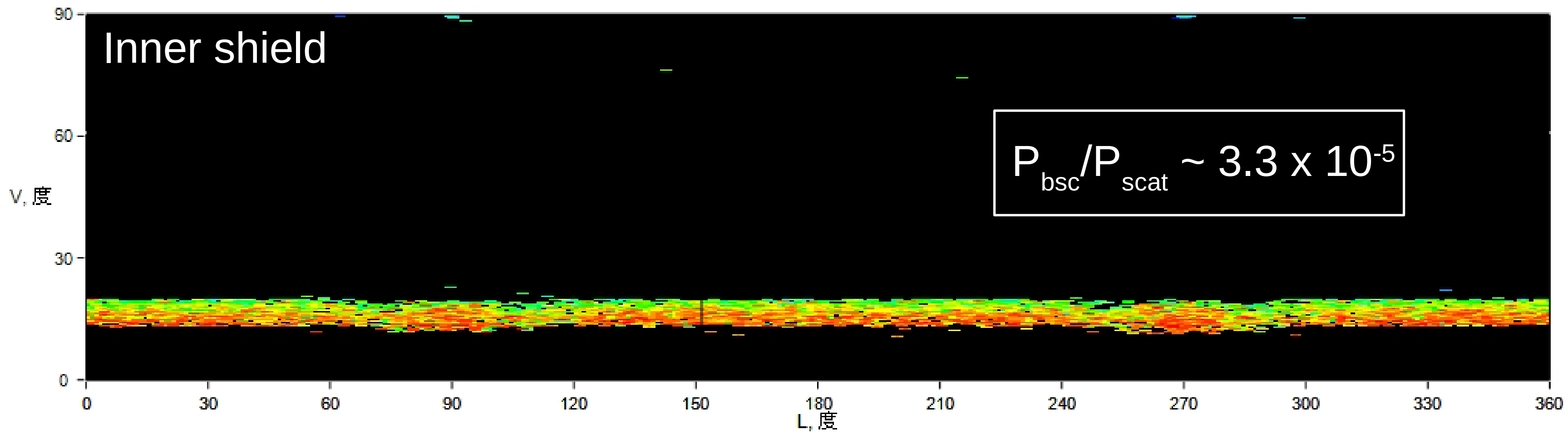


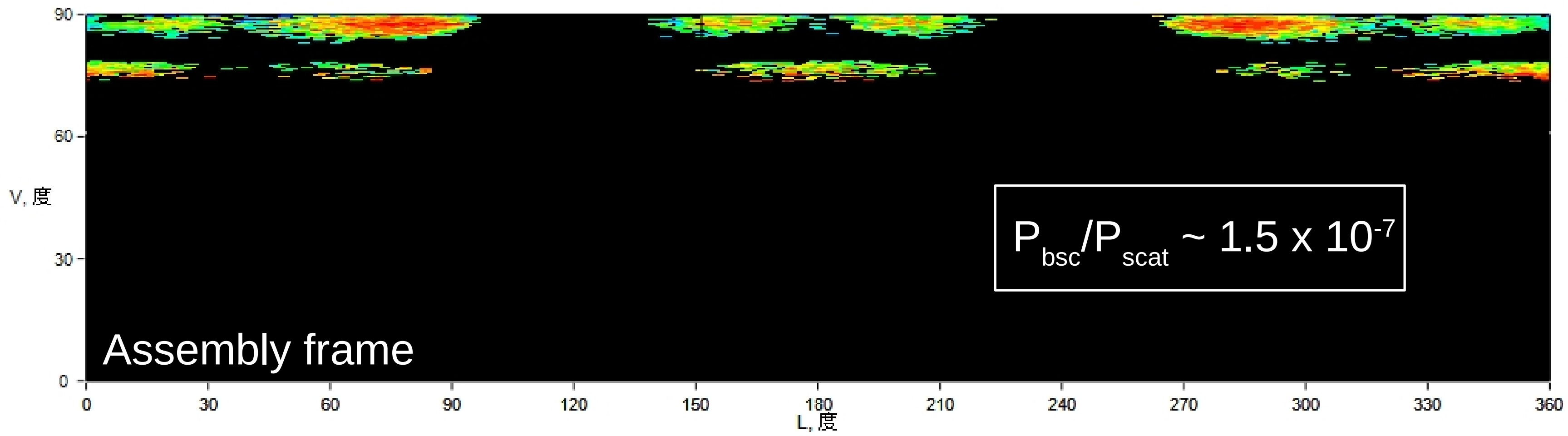




Elongation of WAB brings better results

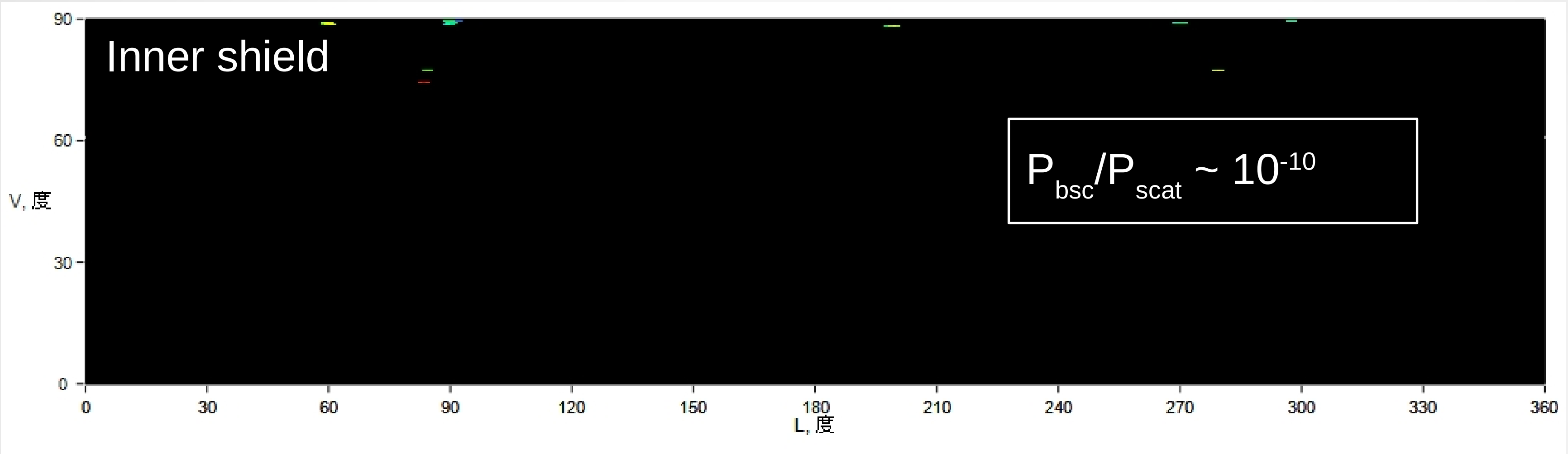
300 mm → 400 mm

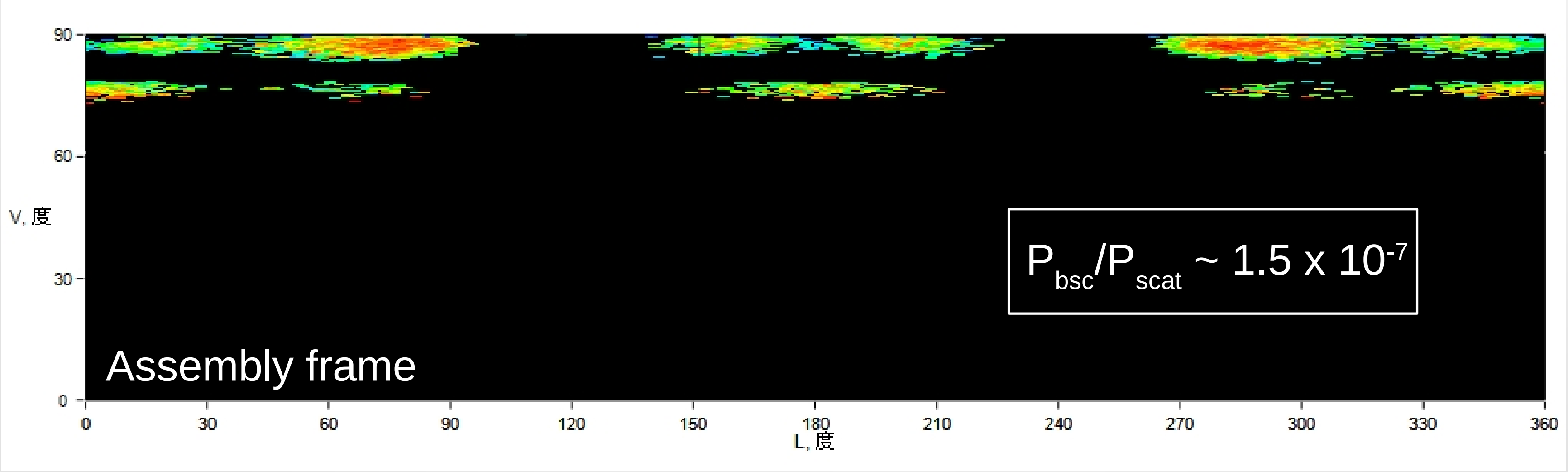




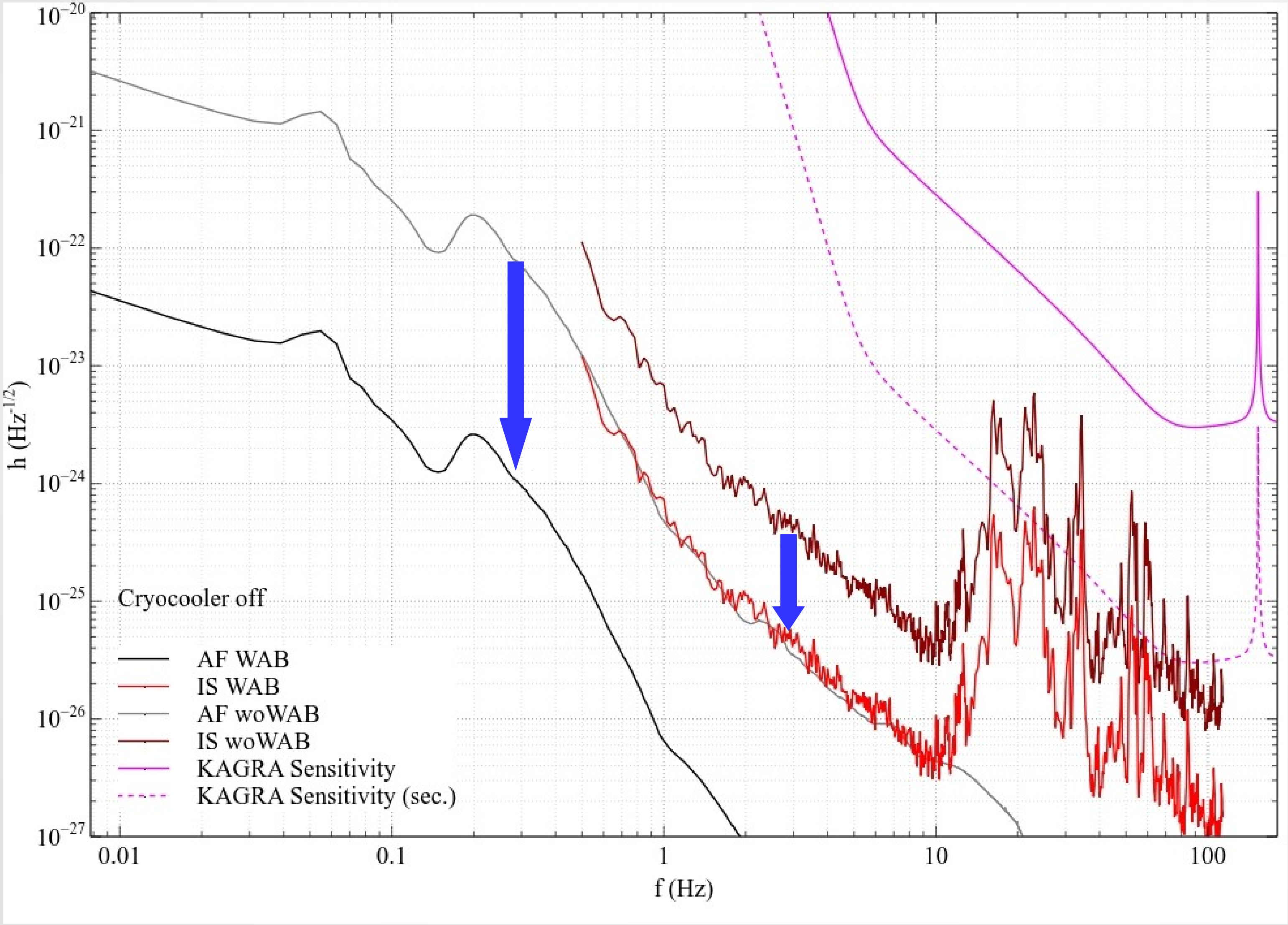
Elongation of WAB brings better results

400 mm → 546 mm (maximum elongation)

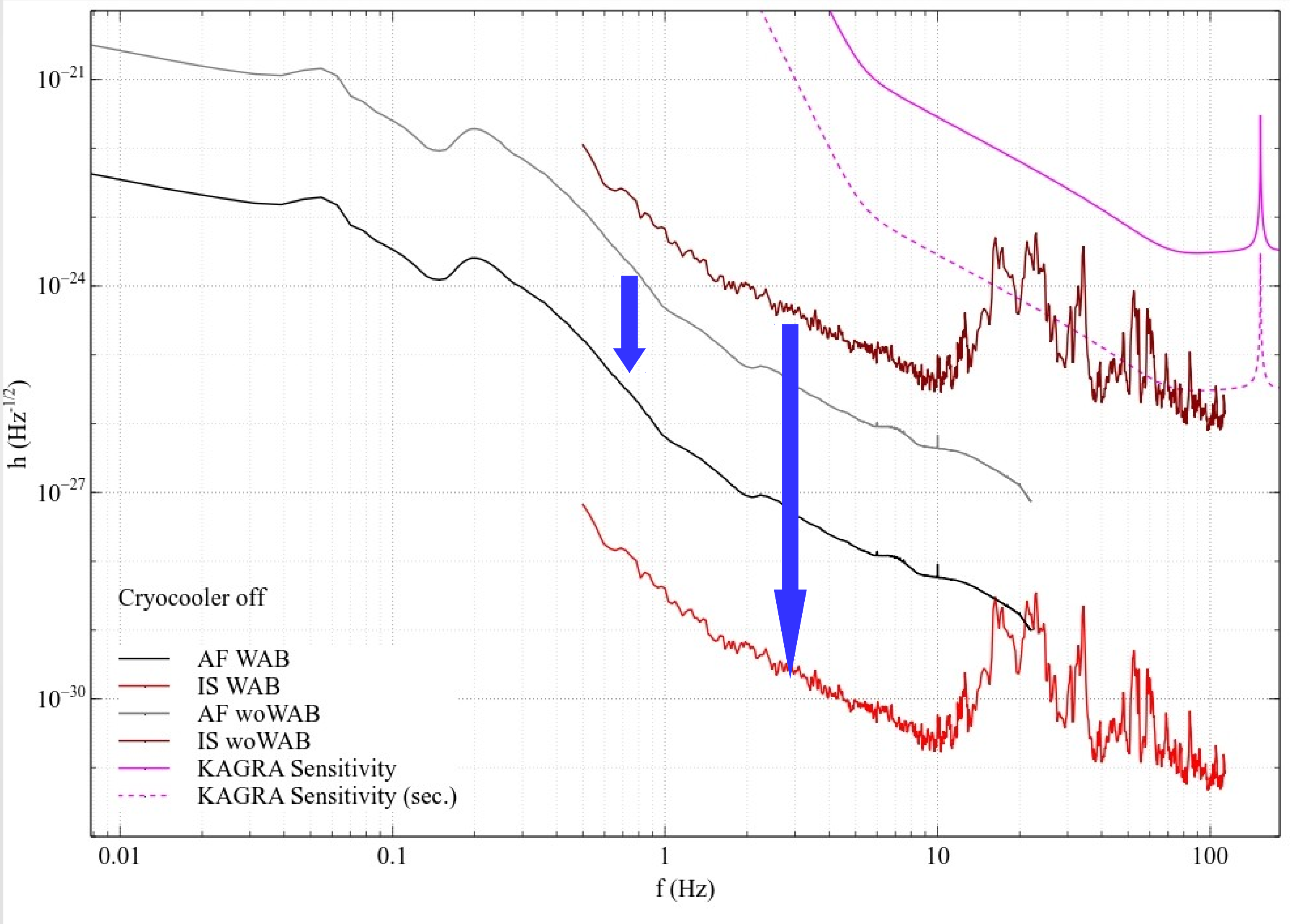




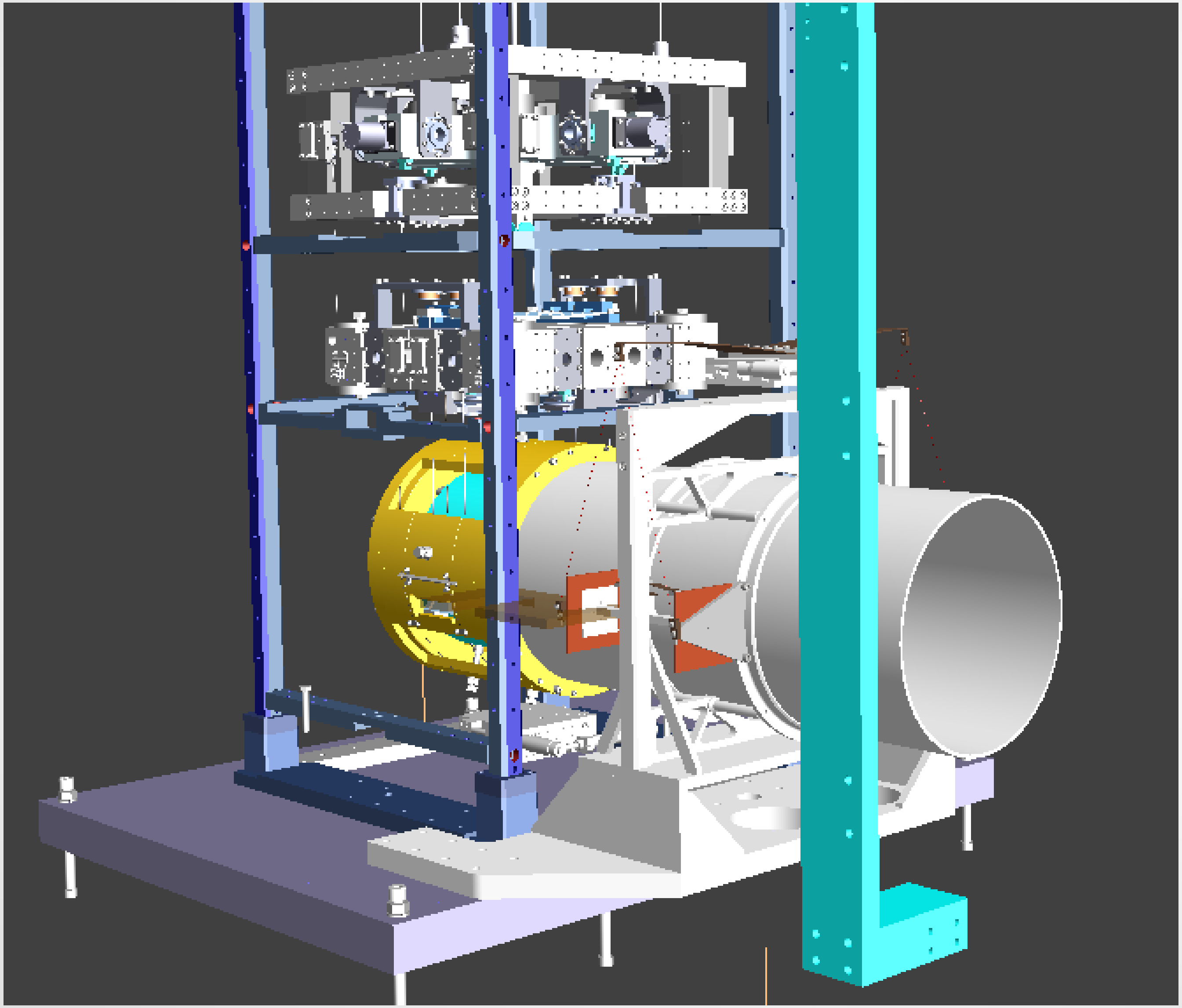
Strain-noise change for 400 mm WAB



Strain-noise change for 546 mm WAB



Elongated WAB in the cryostat



- Separated assembly frame for baffle suspension
- Issue: installation alongside the payload installation

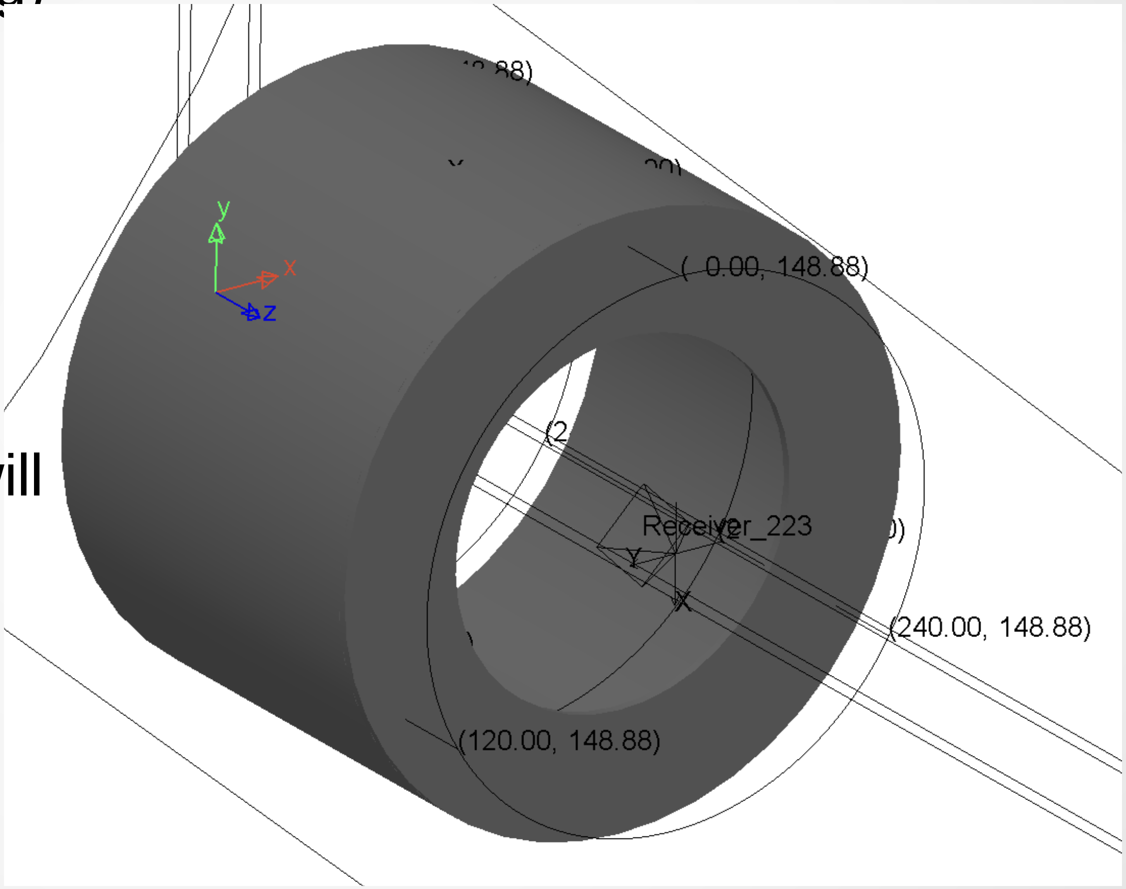
Design: Obuchi-san (ATC, NAOJ)

Summary

- Simulations on scattering inside the cryostats done under real conditions (scattering distribution, interior, etc.)
- Influence of back-scattering on the strain noise highest for “inner shield” and lowest for recoil mass
- Need motion-noise data for assembly frame (ongoing)
- Decreasing of strain noise possible but WAB needs to be longer than initial design
- Coating of baffle (Solblack) not included in simulations
- Influence from Solblack-coating: $P_{bsc}/P_{scat} \sim 1.7 \times 10^{-9}$

Installation

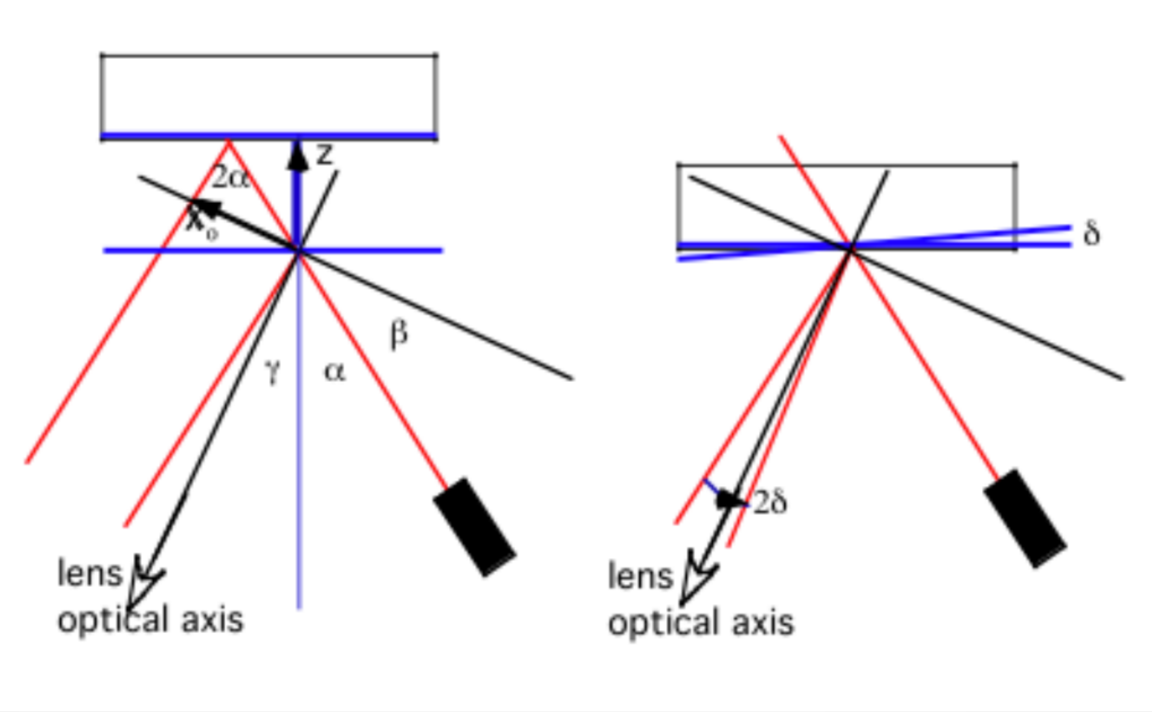
Solblack; ECB
(electro-chemical buffing)



- Installation alongside cryo-payload (AOS + CRY)
- Separated suspension will be installed
  - *Several issues to be solved (wires, blade springs, heat-link,…)*
  - *Ongoing discussion in “WAB meeting” (AOS + CRY)*

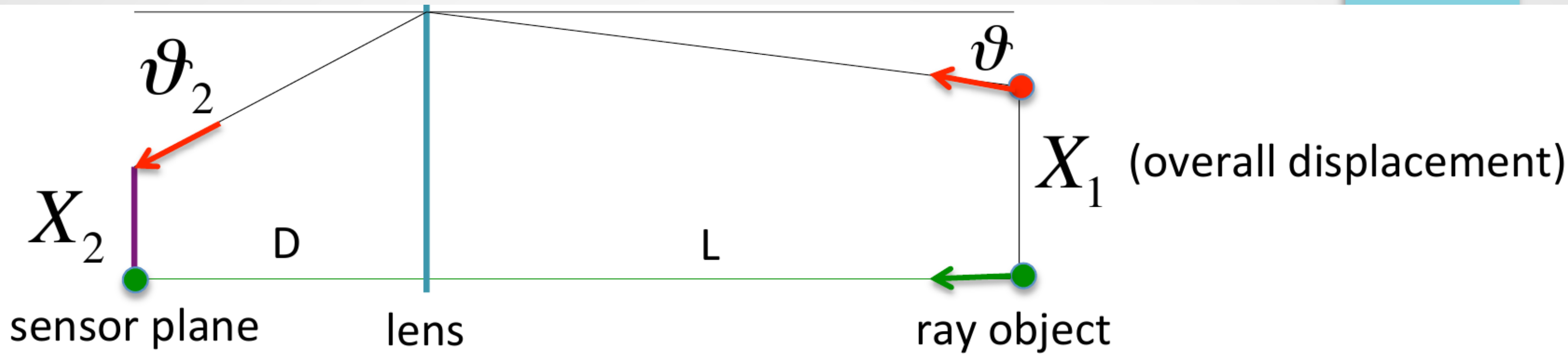
Length-Sensing OpLevs
(AOS – VIS Joint Venture)

- Right now OpLevs are used to measure the tilt of the mirrors
- For a measure of the shift along the mirror’s normal, we will use an “upgraded OpLev” system



(E. Majorana, 2015)

Basic Setup



$$\frac{\partial X_2}{\partial X_1} = 1 - \frac{\mathrm{D}}{\mathrm{f}} \qquad \frac{\partial X_2}{\partial \vartheta} = \mathrm{L}\left(1 - \frac{\mathrm{D}}{\mathrm{f}}\right) + \mathrm{D}$$

If $D = D_f = f$ (focal plane) ➔ the spot on the sensor moves only upon rotations

If $D = D_0 = \dfrac{Lf}{L-f}$ (image plane) $\qquad \dfrac{\partial X_2}{\partial X_1} = -\dfrac{\mathrm{D}}{\mathrm{L}} \qquad \dfrac{\partial X_2}{\partial \vartheta} = 0$

➔ the spot moves only upon translations

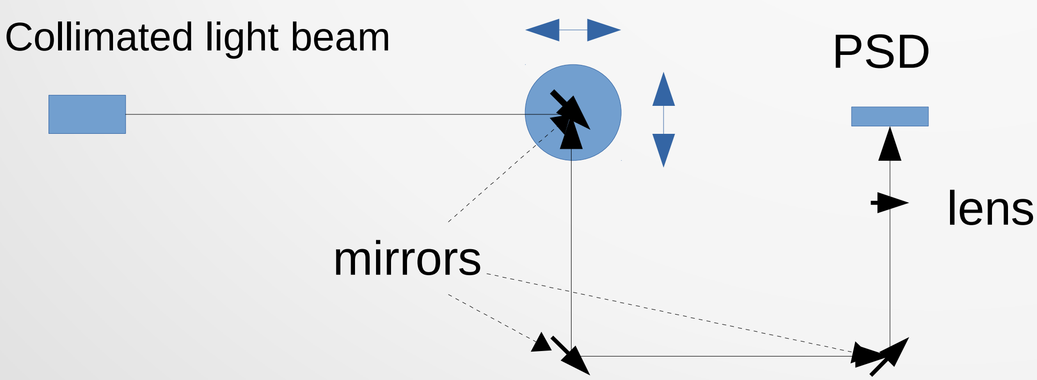
Testing for BS

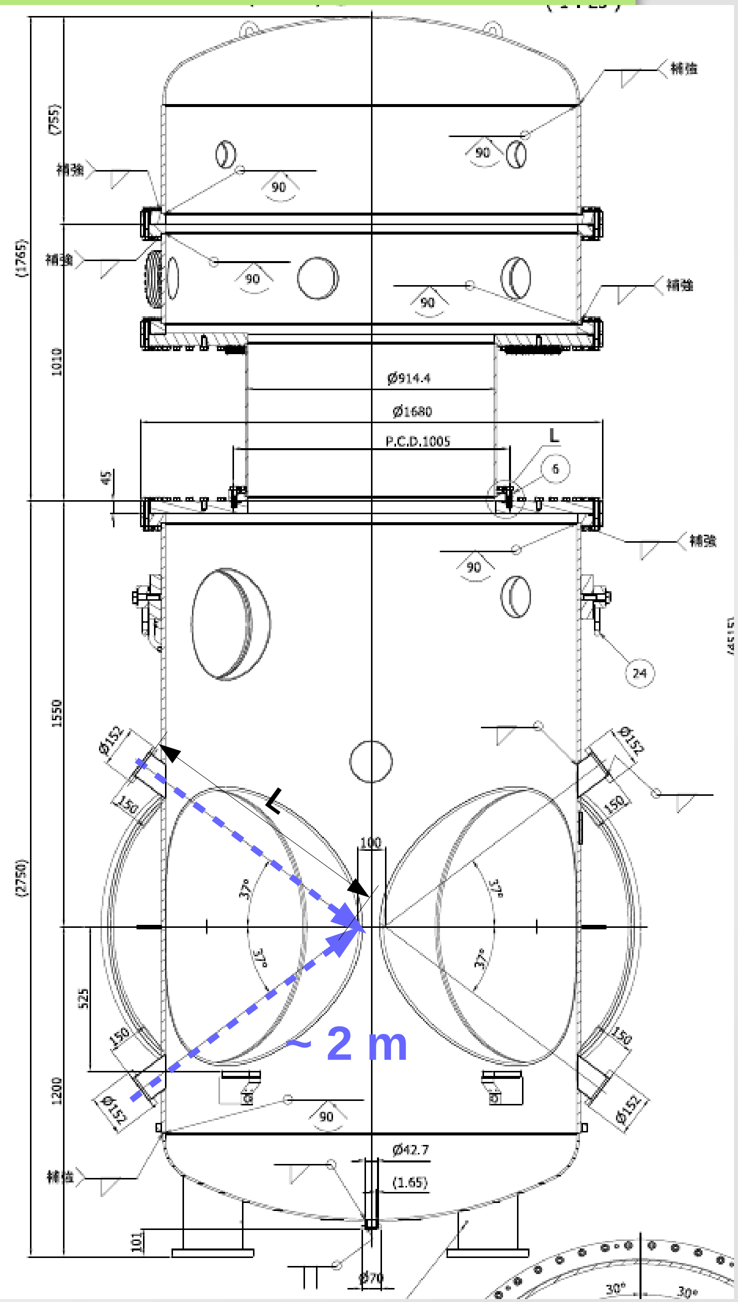
$$X_2 = 2d\cdot\sin(\alpha)\left[1-\frac{L}{L-f}-\frac{\delta D}{f}\right]+2\beta\cdot\delta D\left(1-\frac{L}{f}\right)$$

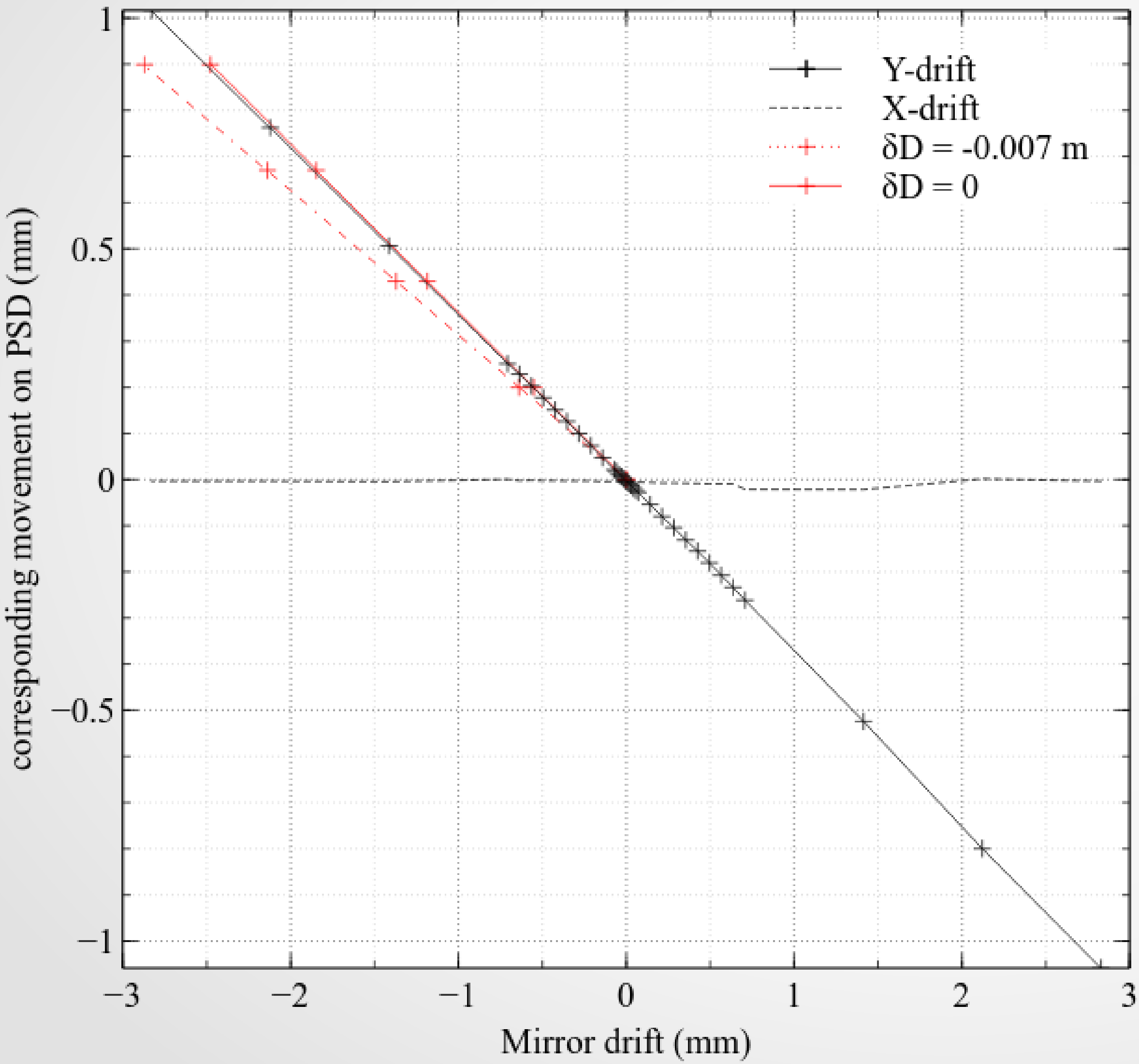
$$\begin{pmatrix} f=0.2\,m \\ \delta D=0 \end{pmatrix} \quad X_2 \approx -0.31\cdot d$$

δD is the misalignment from the theoretical, perfect position of the **position sensing detector** (PSD)

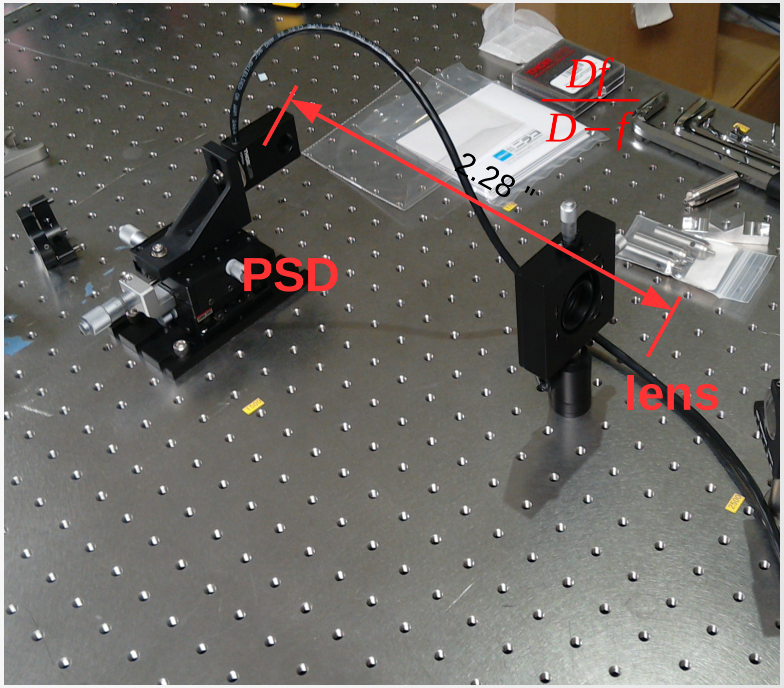
Setup for testing devices and calibration







Y-drift
X-drift
δD = -0.007 m
δD = 0
corresponding movement on PSD (mm)
Mirror drift (mm)
1
0.5
0
−0.5
−1
−3
−2
−1
0
1
2
3

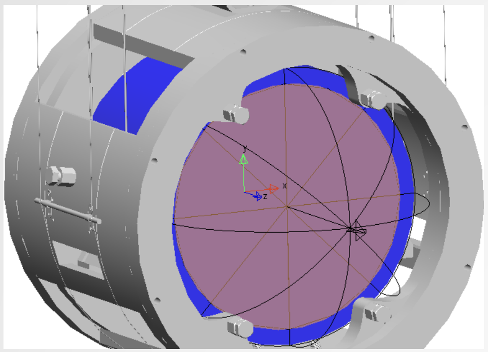


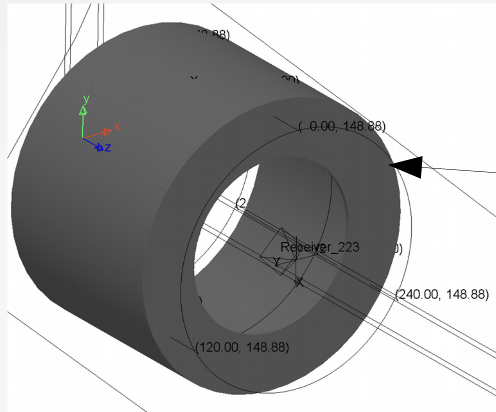
$\frac{Df}{D-f}$
2.28 "
PSD
lens

Outlook

- Starting production of WAB after discussing the design with ATC at NAOJ (September)
- Blade springs, wire, and how-to-install are still points of discussion
- Scheduled installation: summer 2017
- Length-sensing OpLev for BS is basically designed
- For other mirrors, we need more information on the requirements
- Most tricky part will be the actual installation due to limited space

Simulations using “LightTools”





Solblack coating

ECB

(electro-chemical buffing)