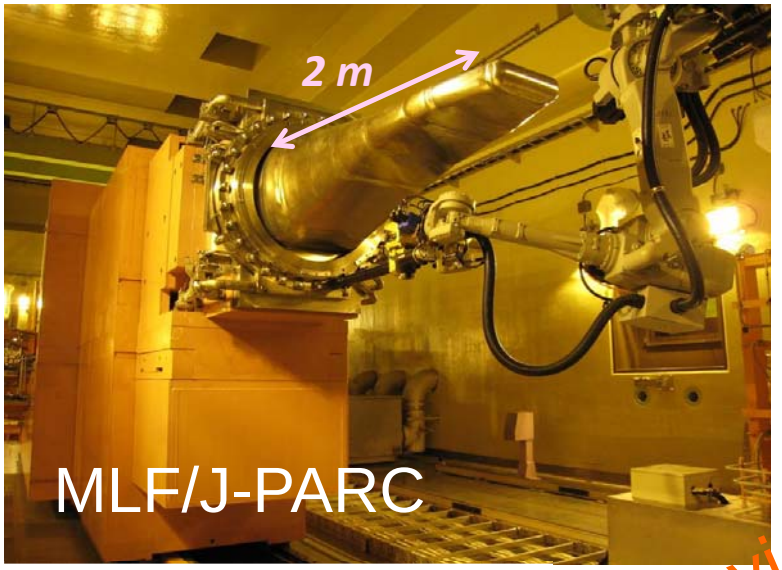
In-situ structural integrity evaluation for the high-power pulsed spallation neutron source

MLF/J-PARC

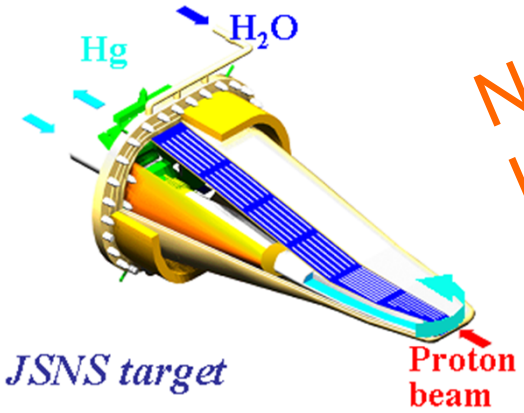
Tao WAN, Katsuhiro HAGA,
Takashi NAOE, Takashi WAKUI,
Hiroyuki KOGAWA, Masatoshi FUTAKAWA

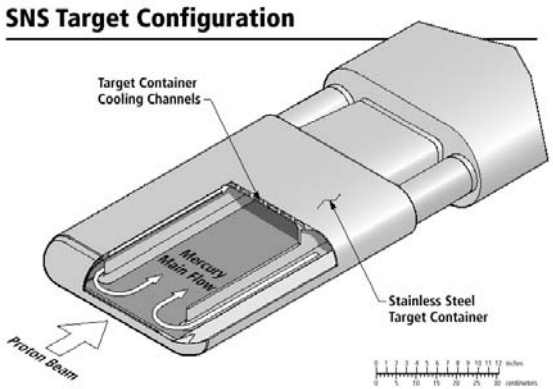
Mercury target

for high power spallation neutron source



Neutron yield performance
Liquid coolant efficiency

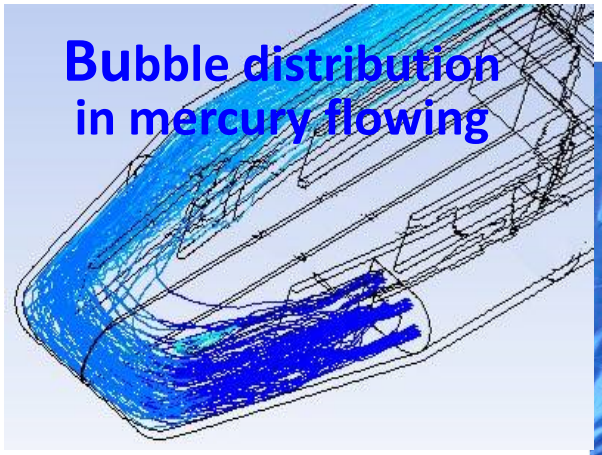


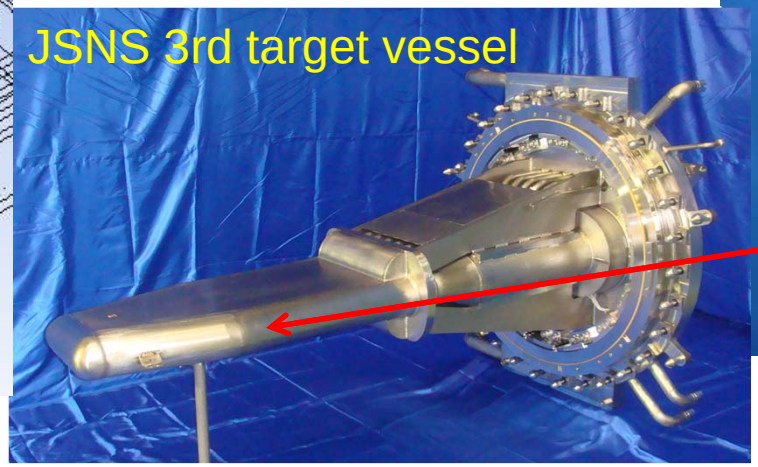


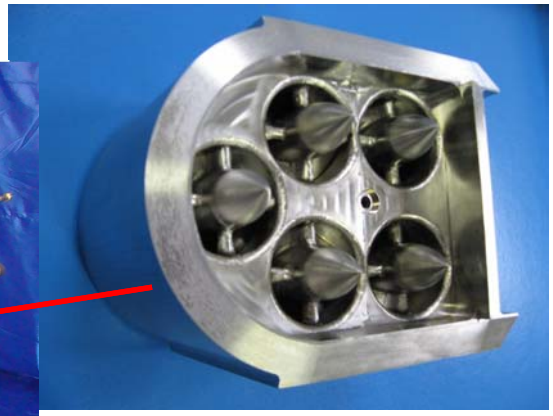
Both of the targets suffer with the proton beam- induced pressure wave due to thermal shock.

Pressure wave and damage

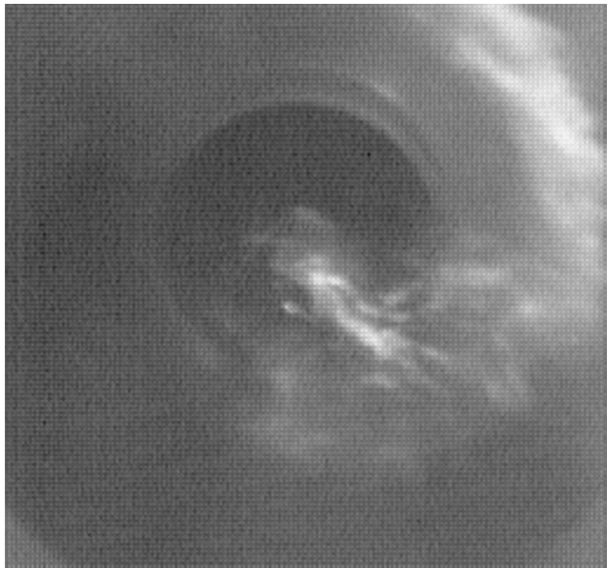
Microbubble generator for JSNS

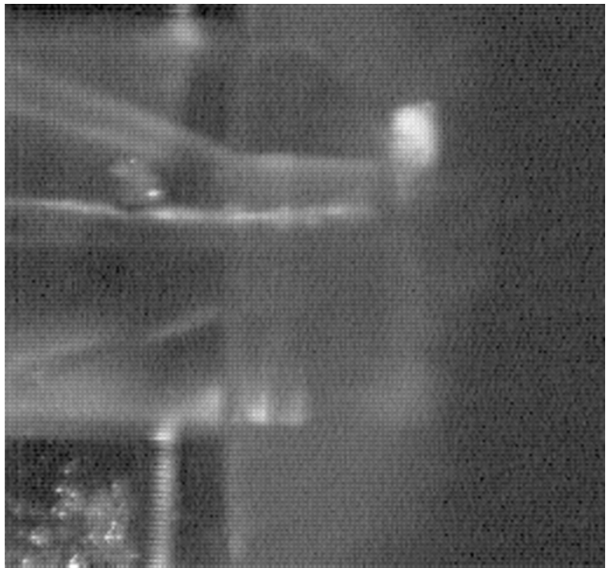






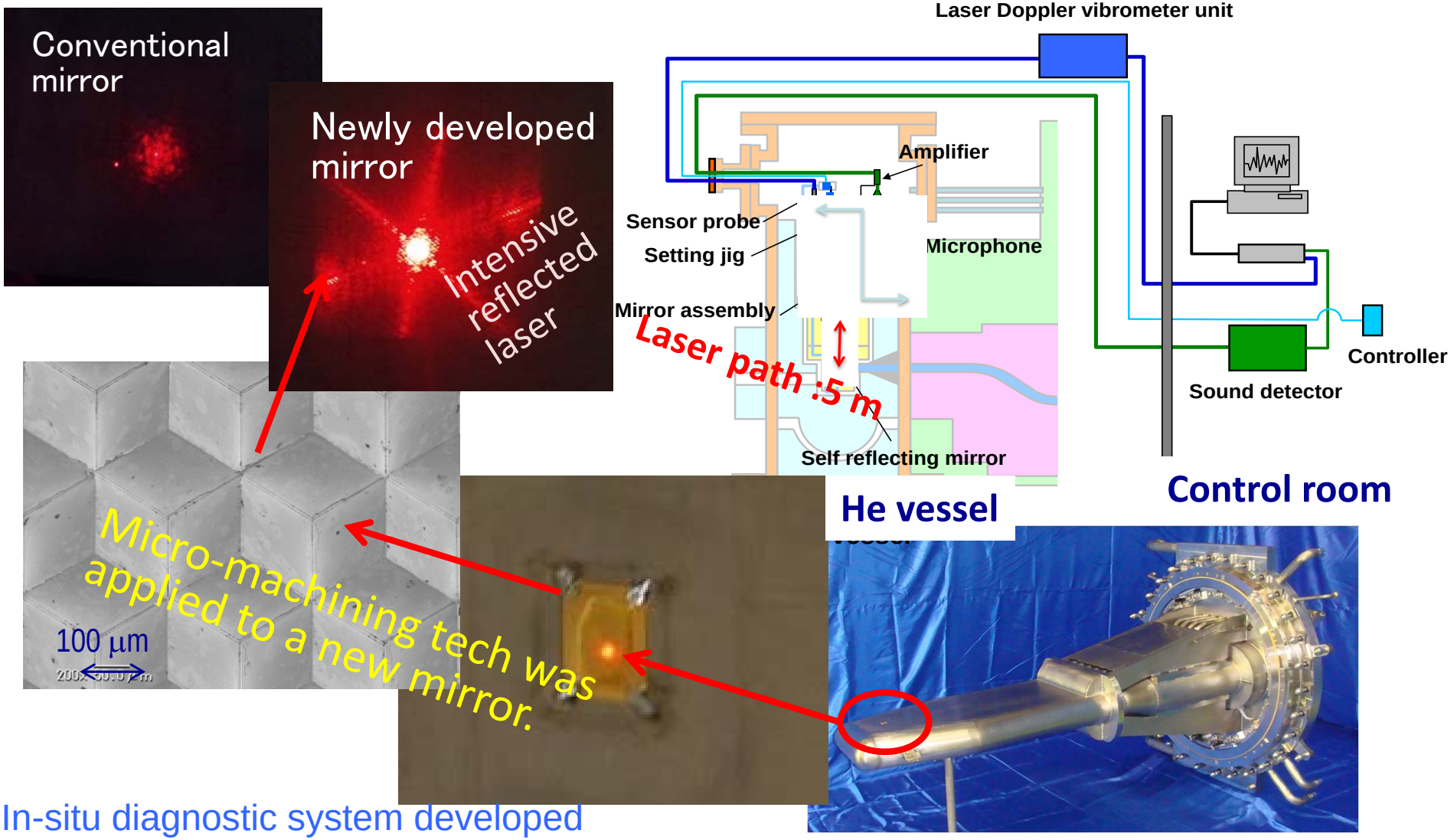
Swirl-type bubble generator



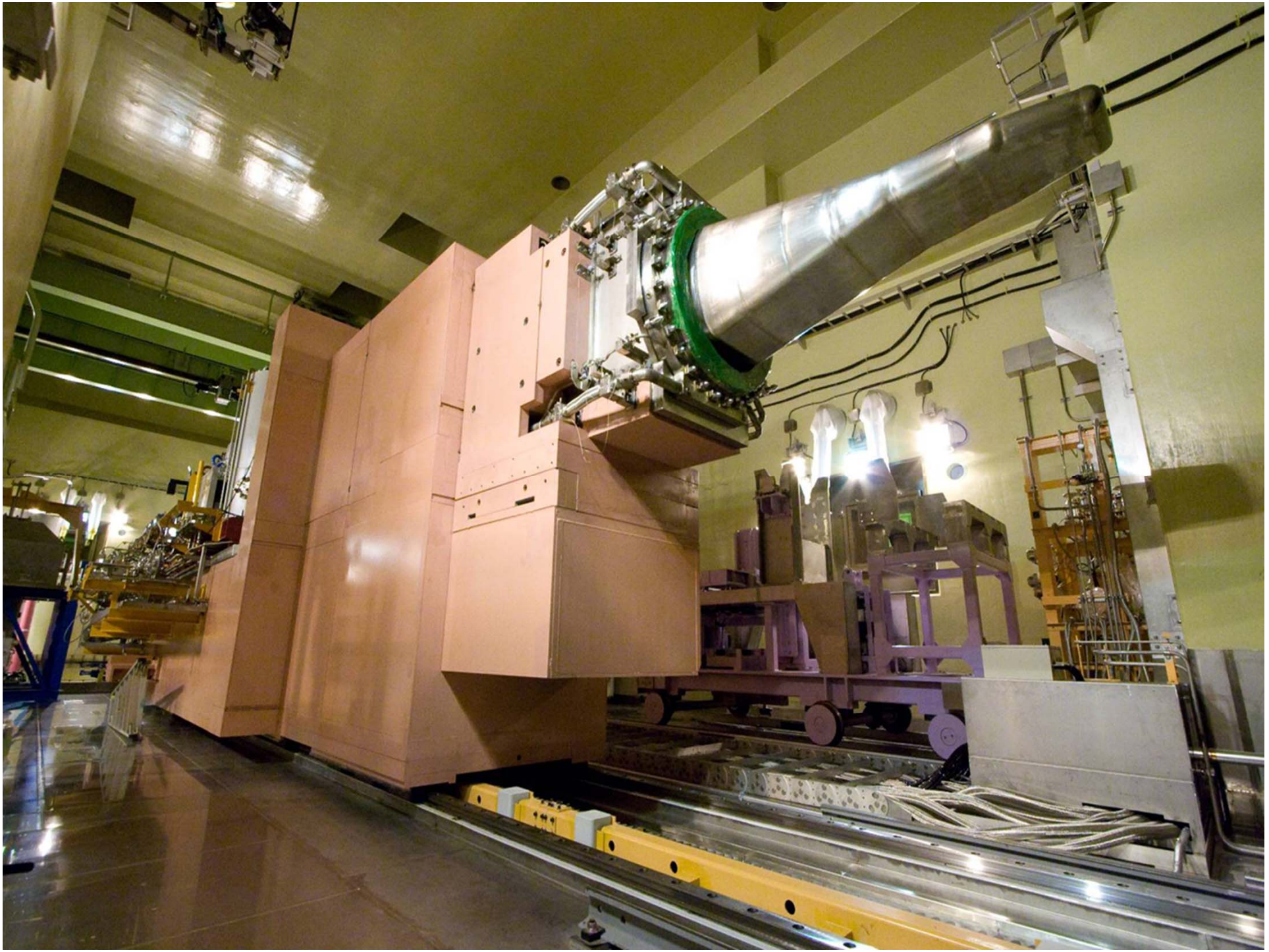


Swirl-type bubble generator which has the strong shear force to cut gas column into microbubbles

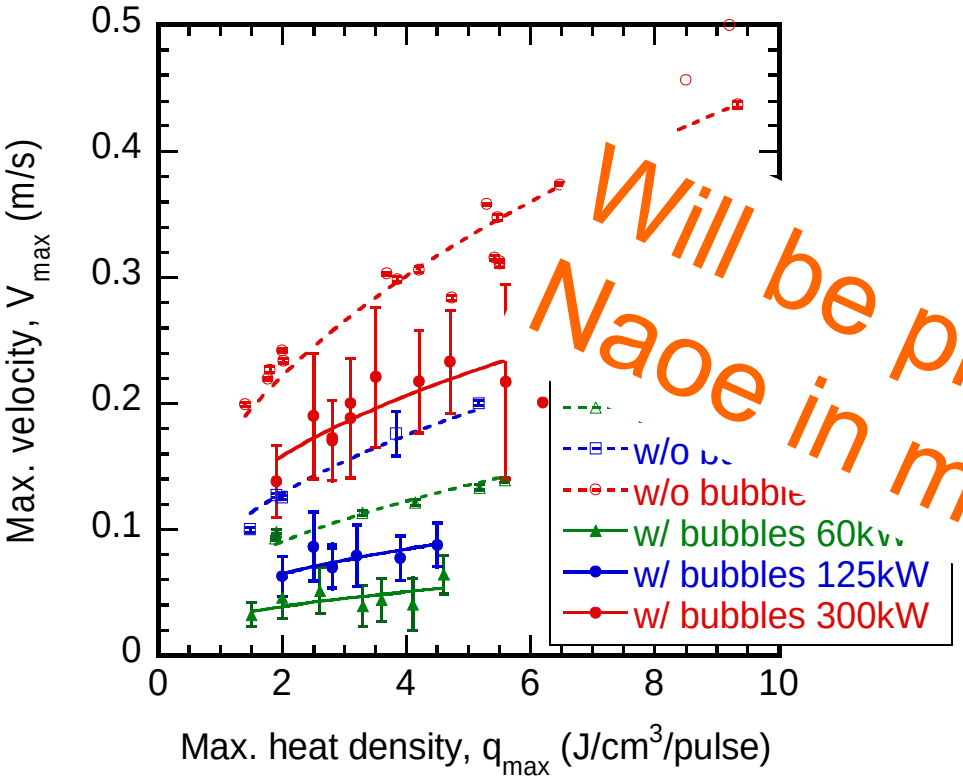
In-situ diagnostic system on pressure waves

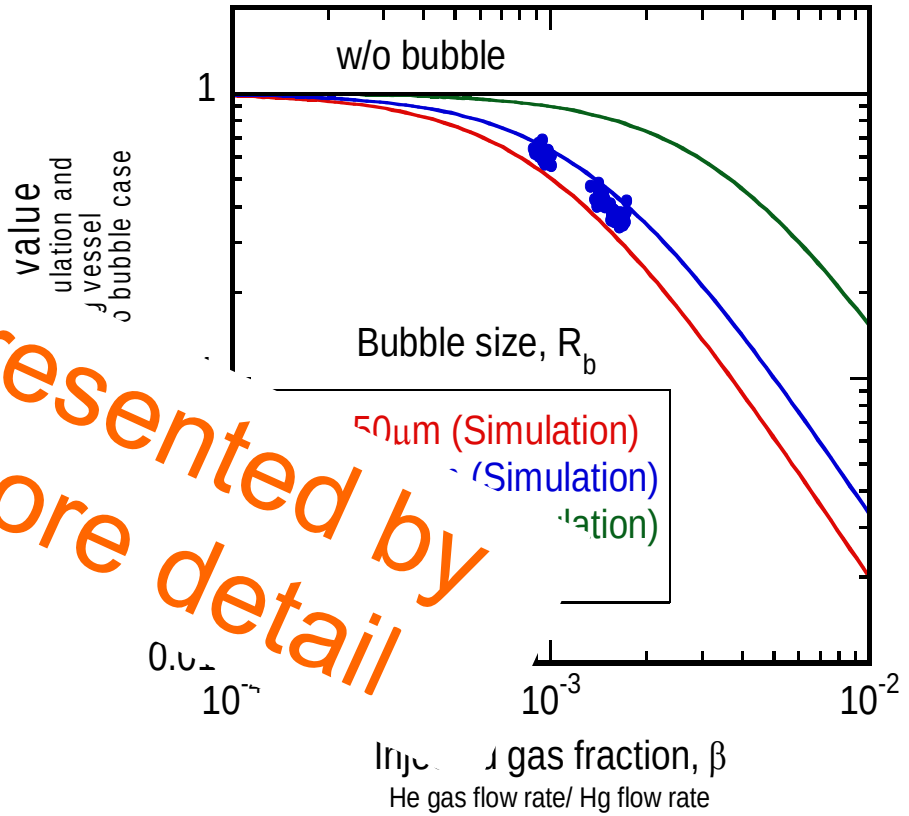


In-situ diagnostic system developed
to recognize the pressure wave mitigation effect



Bubbling effect on pressure wave in JSNS target



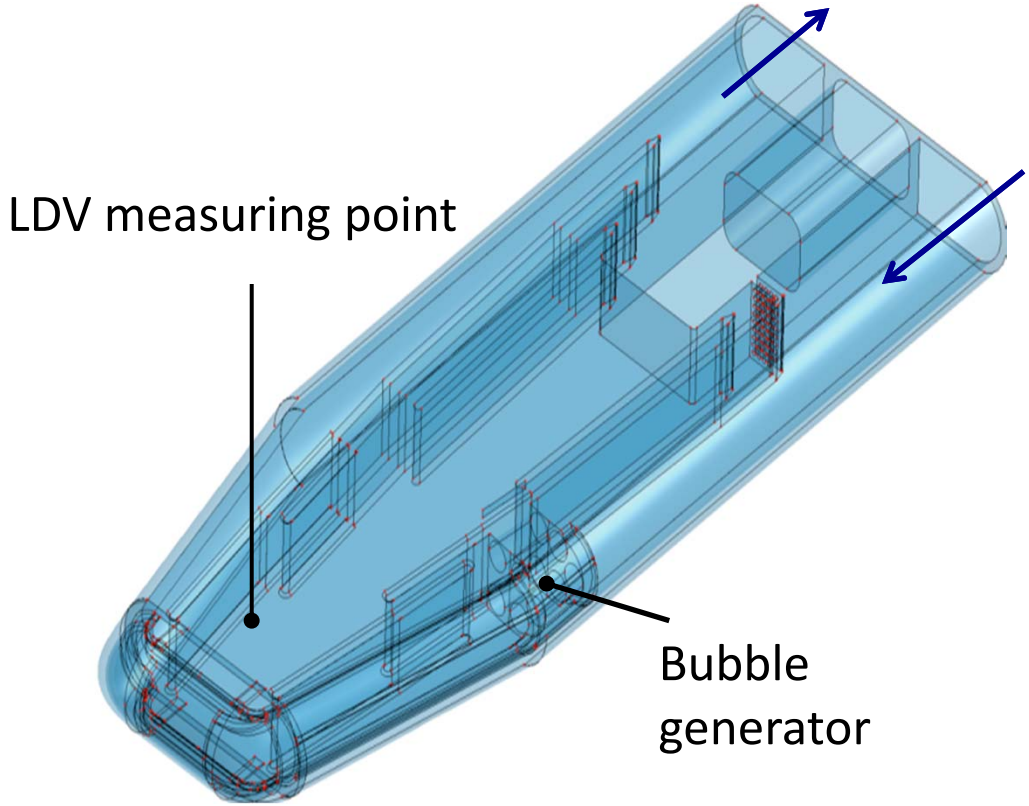


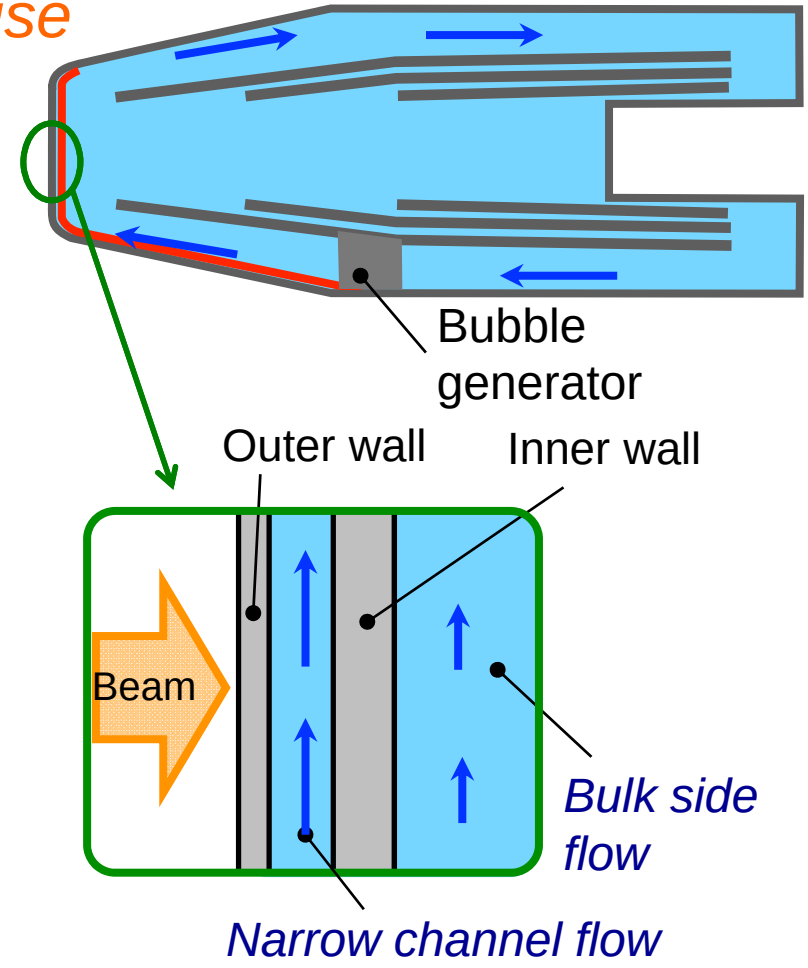
Bubbling effect on vessel-wall-displacement velocity due to the pressure waves affected by heat density at each beam power

Relationship between bubbling effect on pressure waves and injected gas fraction

Double flow target

Double flow is useful:
for enhancement of damage mitigation with
combination of the microbubble effect
for in-situ diagnostic of failure, like a fuse





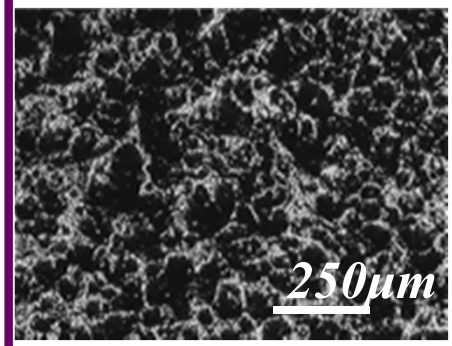
Double flow target is now installing

Flow effect on cavitation damage

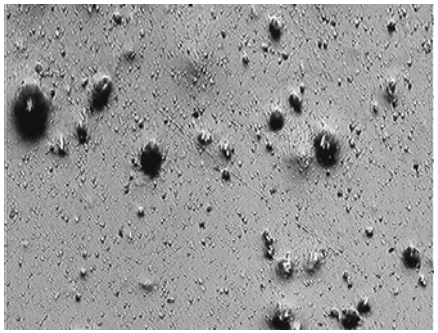
Laboratory experiment

Mechanically-induced pressure pulse

Stagnant



Flow 1m/s

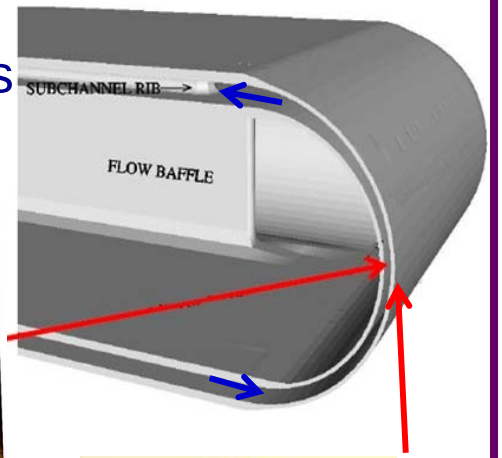


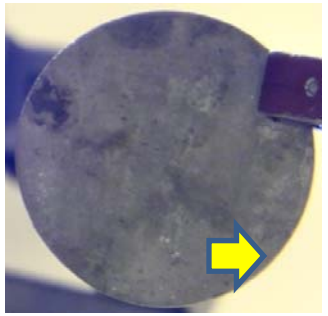
10^4 impacts damage tests

T.Naoe, et al., NIMA(2008)

SNS #1 target PIE

Flow at narrow channel : ~3 m/s





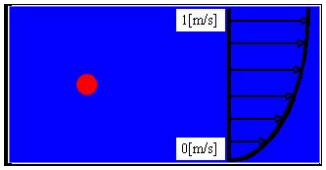
No obvious pitting damage

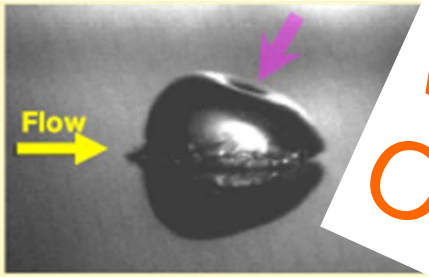
D. McClintock, et al., JNM 431(2012)

Fast flow might have the effect to mitigate the pitting damage.
Narrow channel may also have some effects.

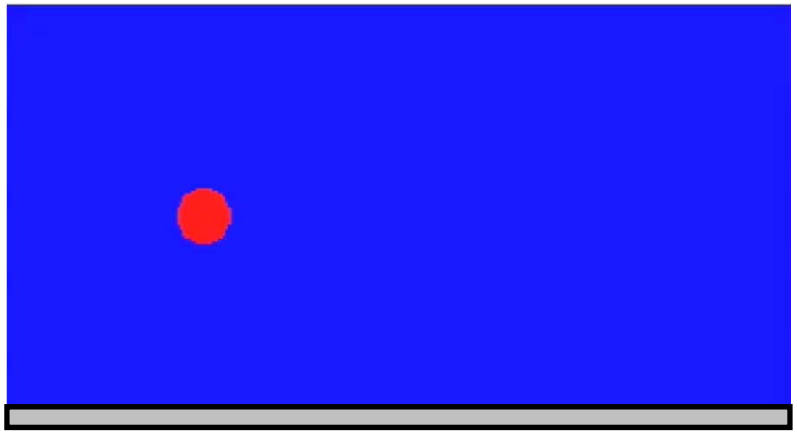
Effects of flow and boundary on bubble collapse behavior

Flow effect



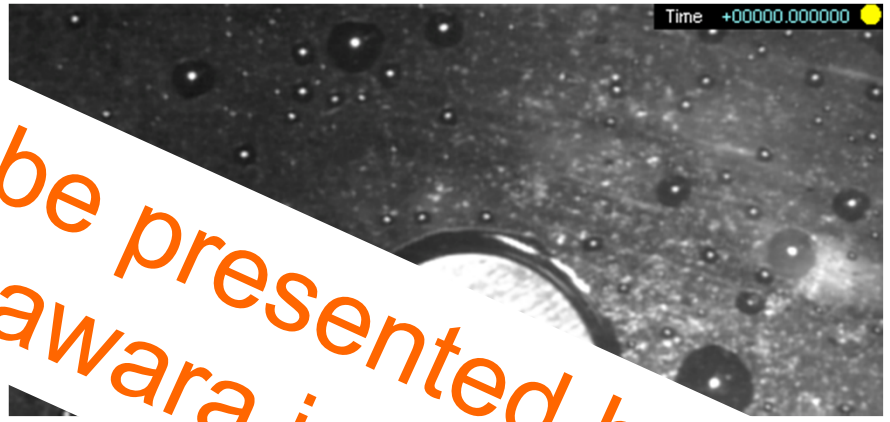


F. Guennoun, CAV2003

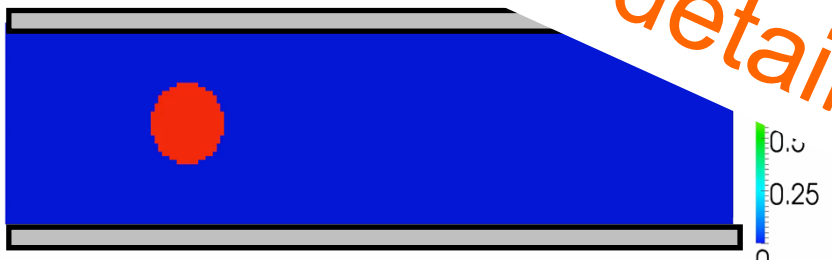


Shape of bubble is distorted and asymmetrically collapsing make weak on impact

Boundary effect



Time: 0.000000

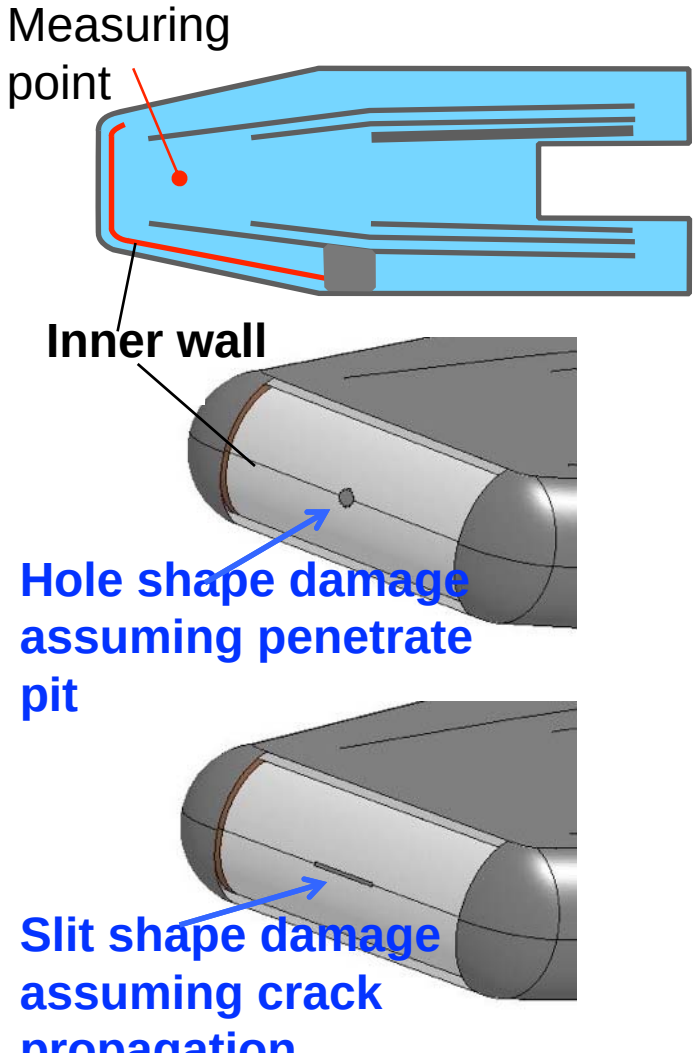


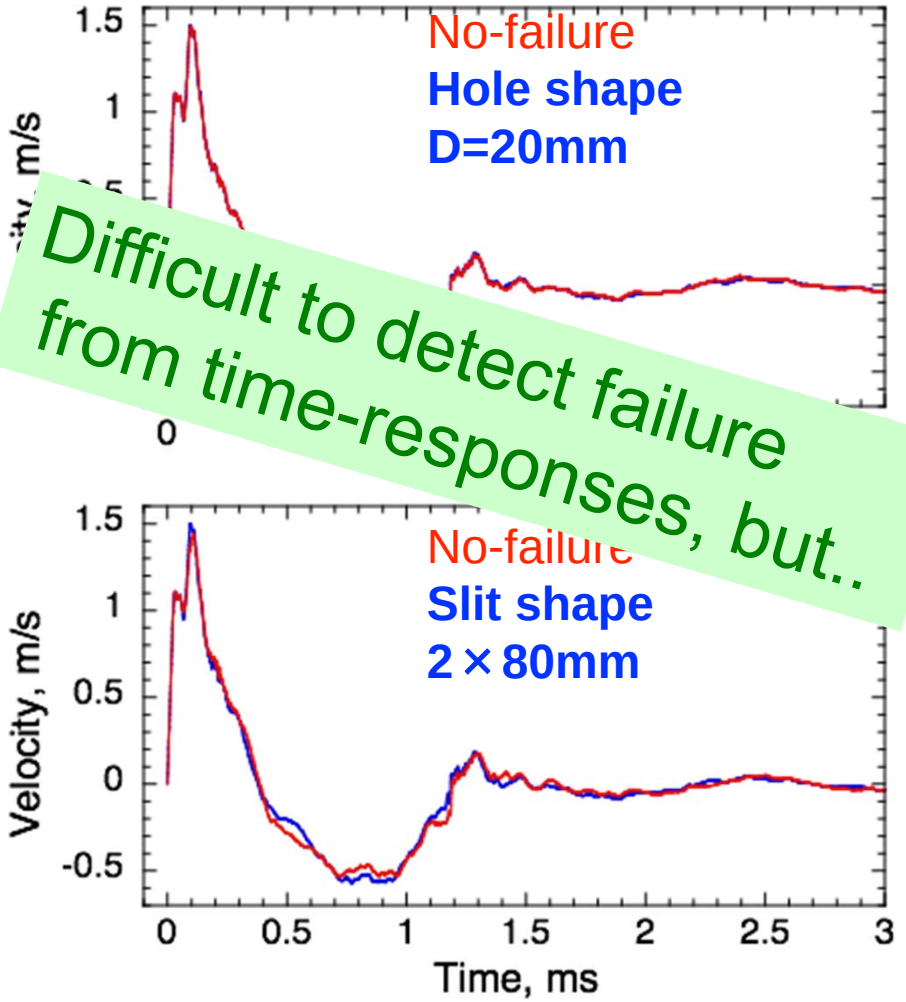
Direction of bubble collapsing is change due to the boundary effect

Will be presented by Ogasawara in more detail

Detection technique of inner wall failure

Numerical simulation on inner wall failure



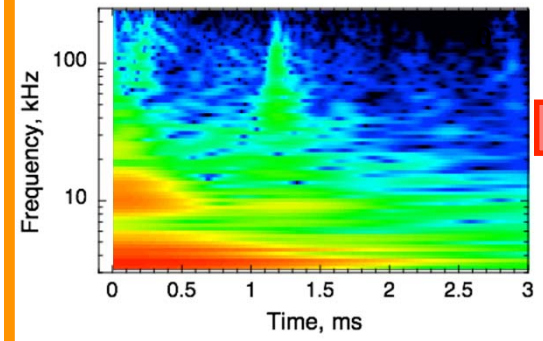


Difficult to detect failure from time-responses, but..

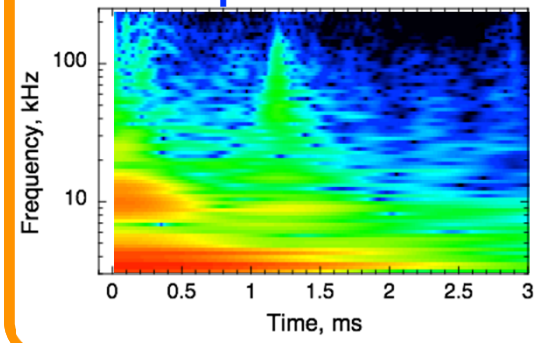
Wavelet differential analysis (WDA)

Wavelet analyses result

No-failure W

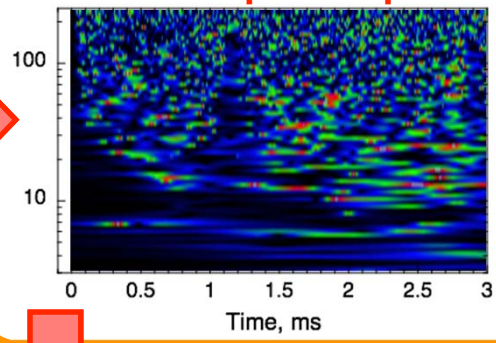


Hole shape D=20mm W



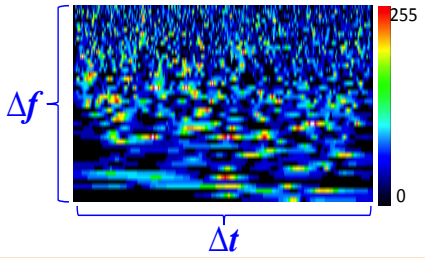
Differential frequency amplitude of wavelet

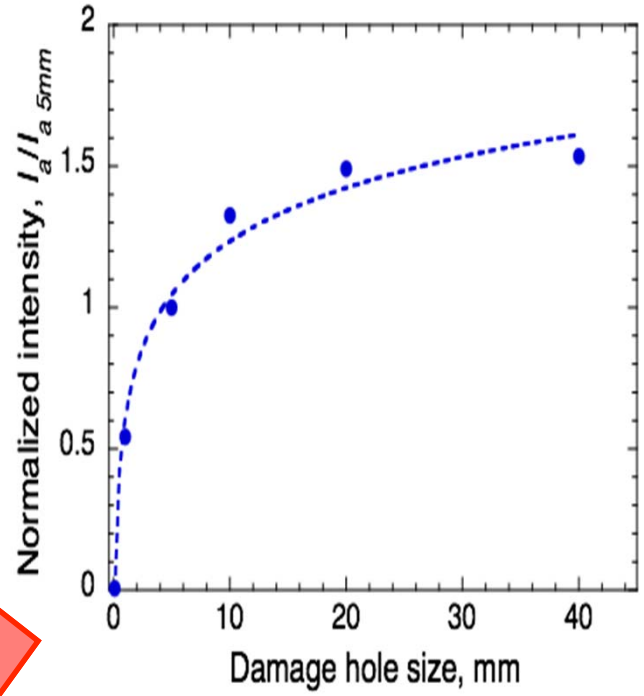
$W_D=|W_0-W_1|$



Change in average intensity of integral W

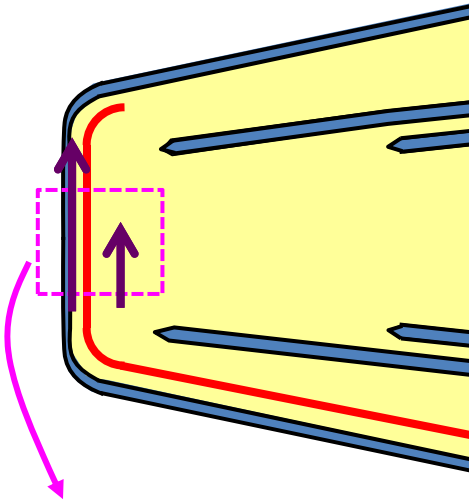
$$I_a = \int^{\Delta f}\int^{\Delta t} A(t,f)dtdf$$



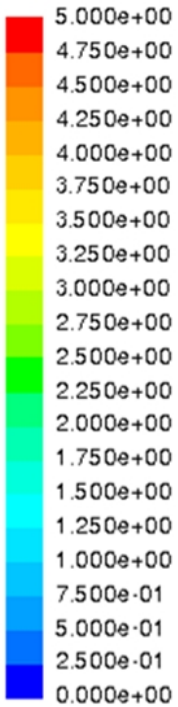


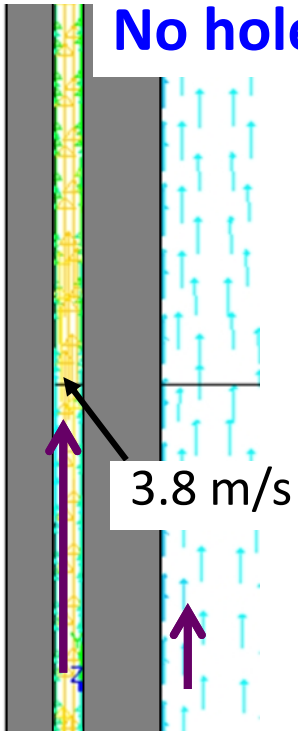
Small difference of vibration signal caused by inner wall can be detected by WDA technique.

Influence of inner wall failure on flow distribution at window

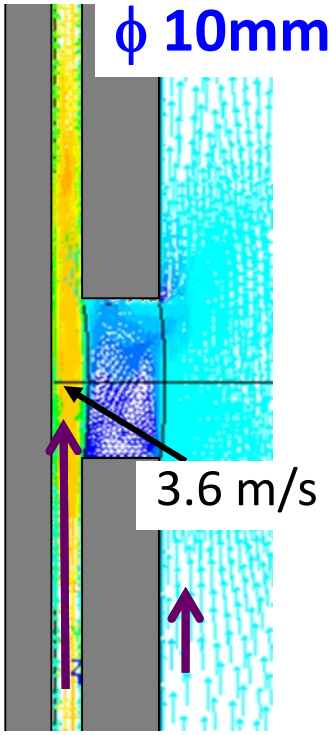


Inner wall failure was assumed as a circular hole at the center

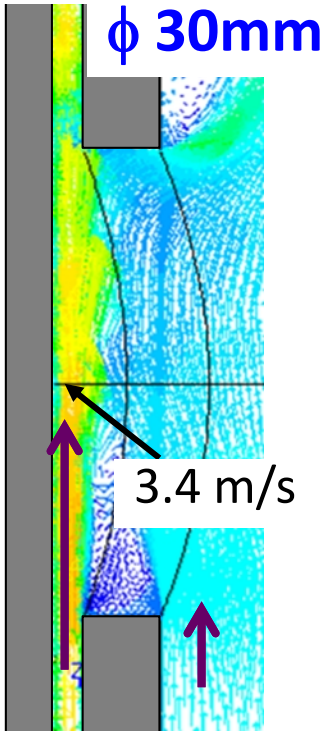




Q : Flow rate through the hole



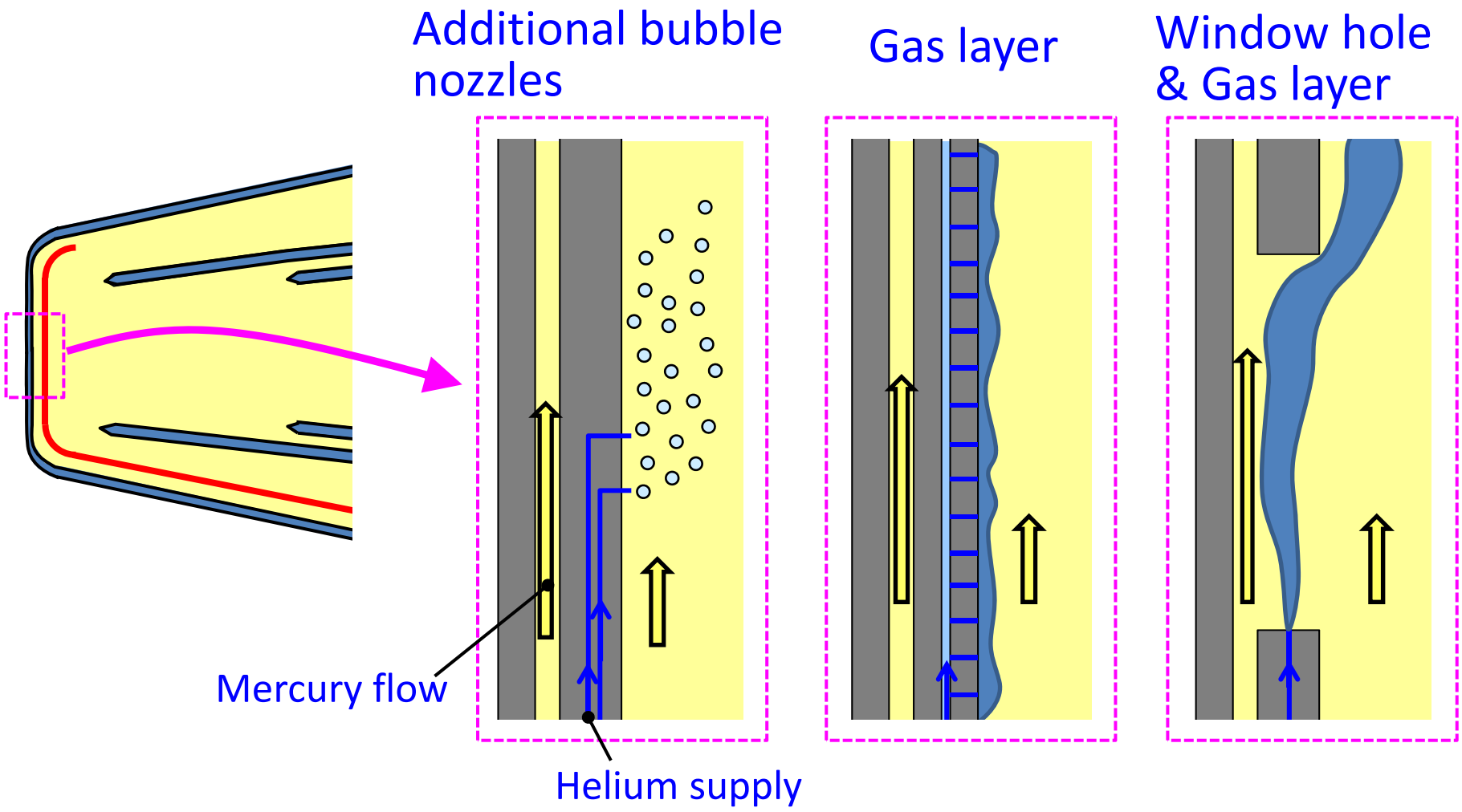
Q : 0.2 cc/s (0.03%)



Q : 27.3 cc/s (3.2%)

Pitting damage mitigation effect is still expected because the fast flow velocity in the narrow channel is maintained even after the inner wall is failed.

Advanced Bubbling Techniques



Inner wall is useful to improve bubbling techniques or apply gas-layer protection.

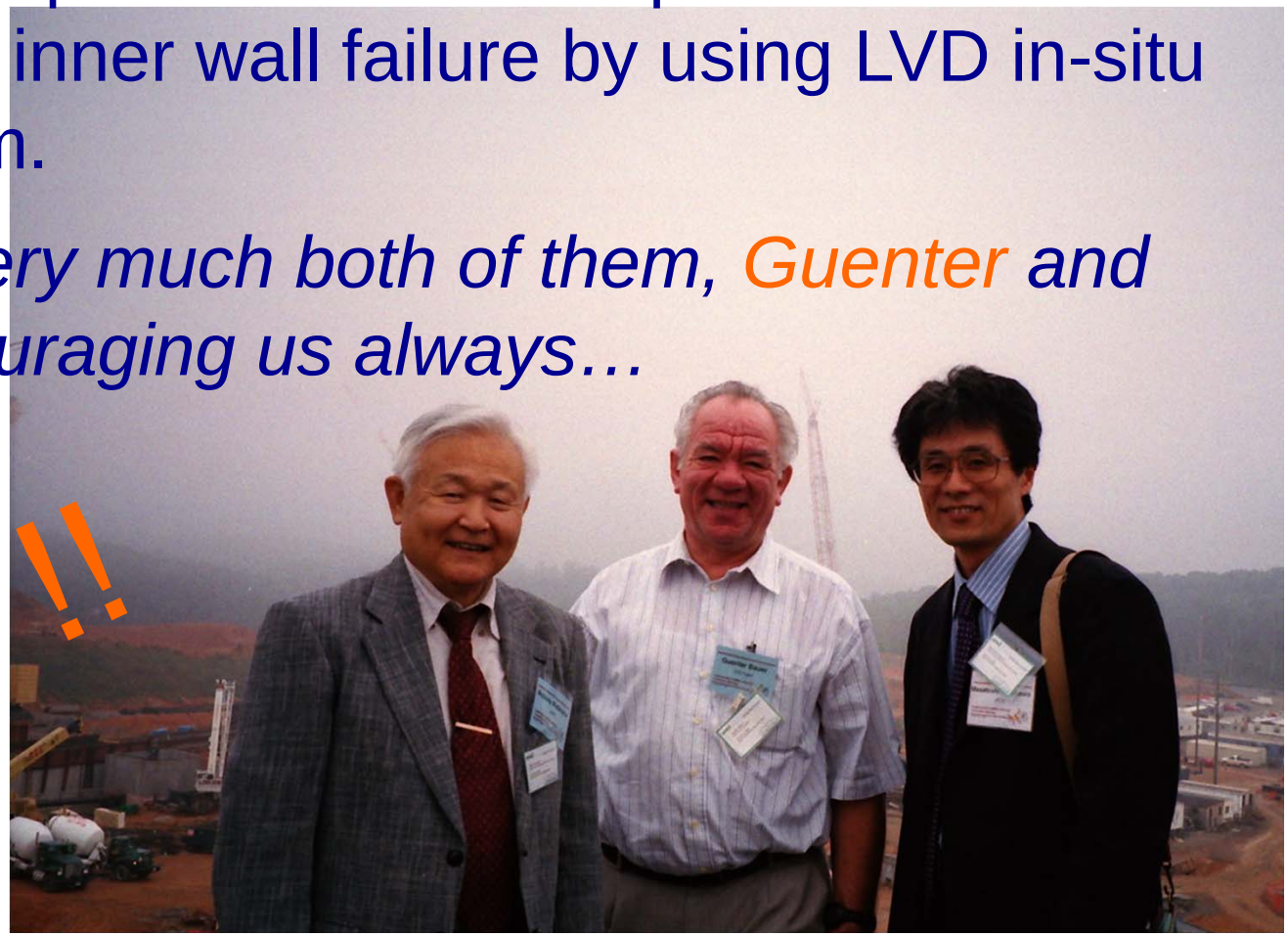
Summary

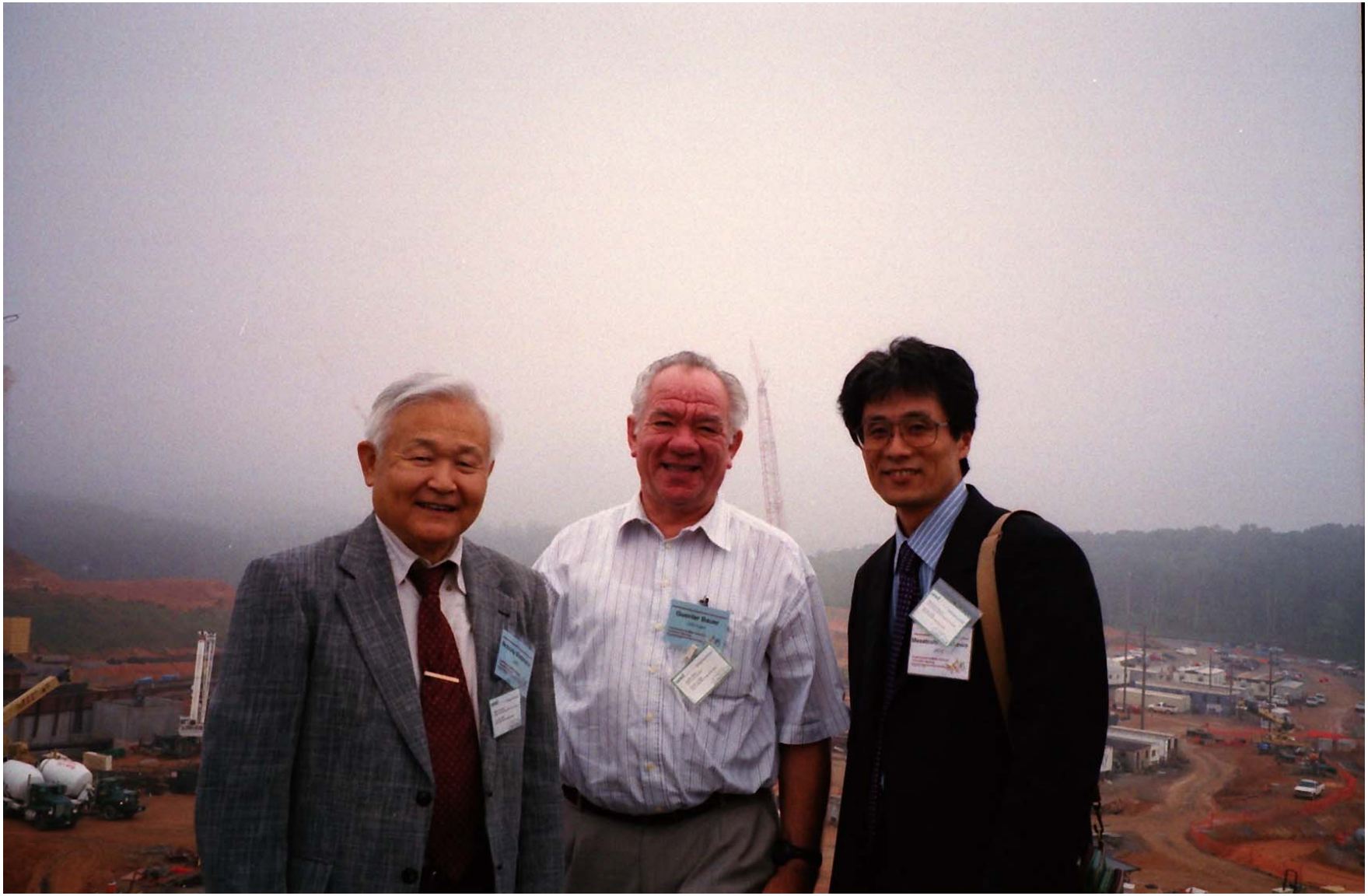
Bubbling effect on pressure wave mitigation was confirmed by using LVD in-situ diagnostic system.

Double flow concept is effective to expand the lifetime and to detect the inner wall failure by using LVD in-situ diagnostic system.

We appreciate very much both of them, Guenter and Noboru, for encouraging us always…

Thanks !!





IWSMT

In-situ diagnostic system at JSNS

Micromachining for mirro

Data acquisition

Statistical method: WEVLET、カルマンフィルター、ACOVA、
フラクタル、カオス、、、、

Just peak not clear but application of acova for making clear

Differencial Weblet reating to gas flowing rate

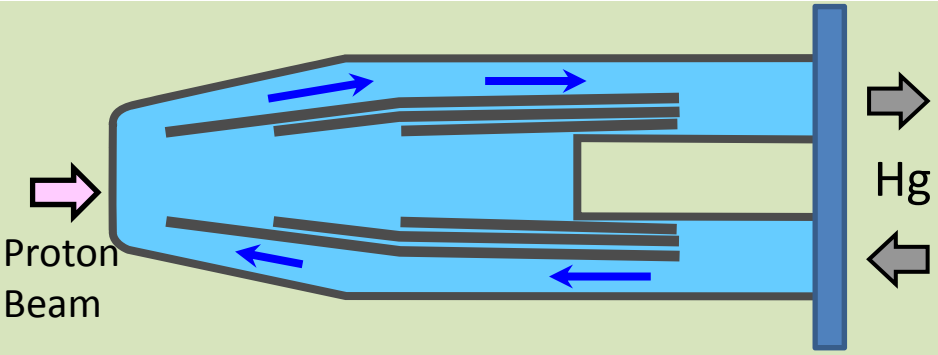
Simulation

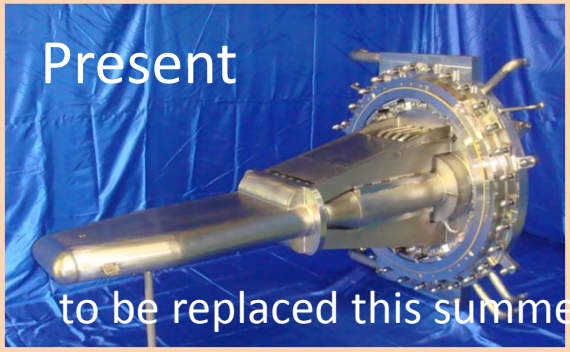
Double flowing target with double walls

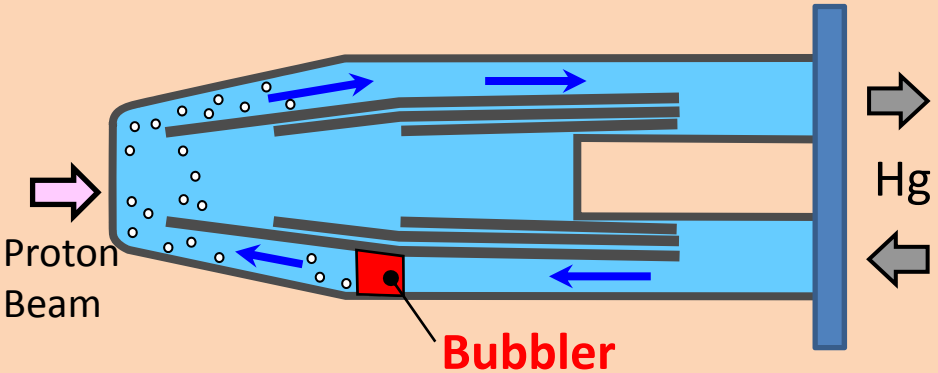
Inner wall damage & D.W.D in simulation

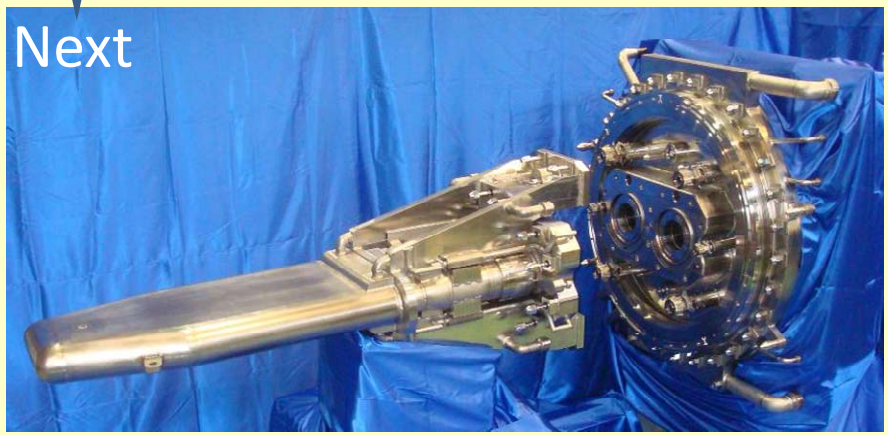
Inner wall damageless by Ogasawara…

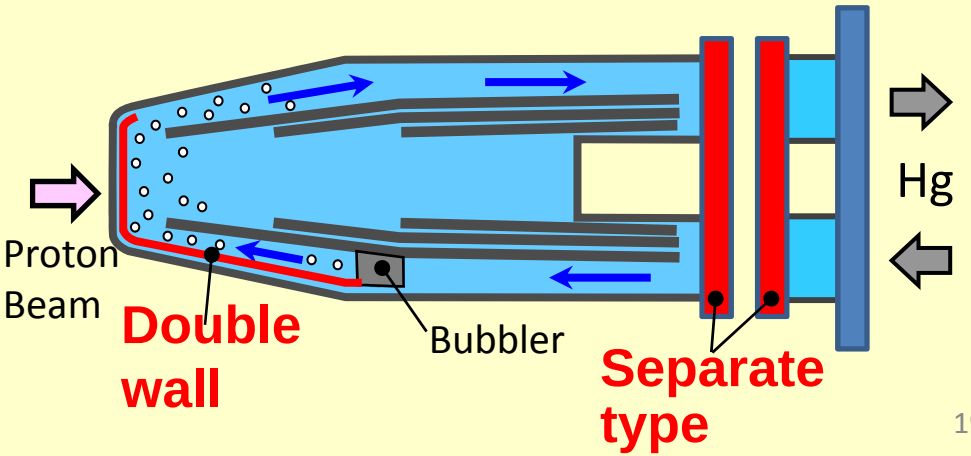
Evolution of Target Structure



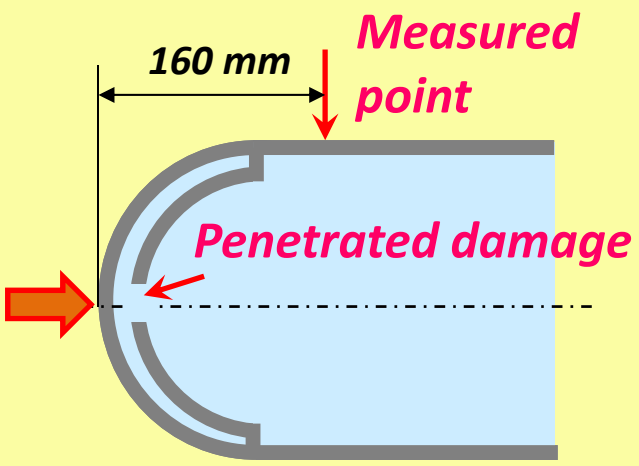




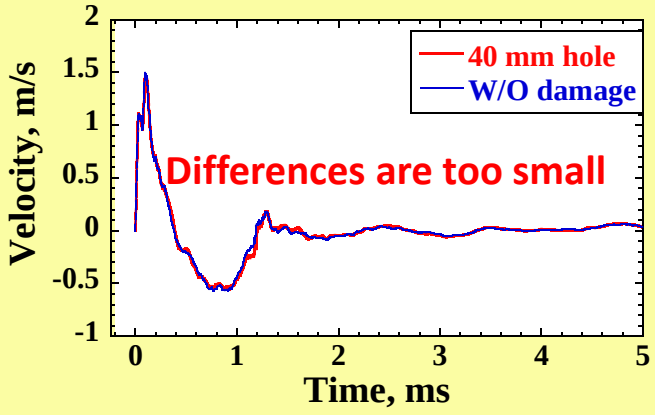


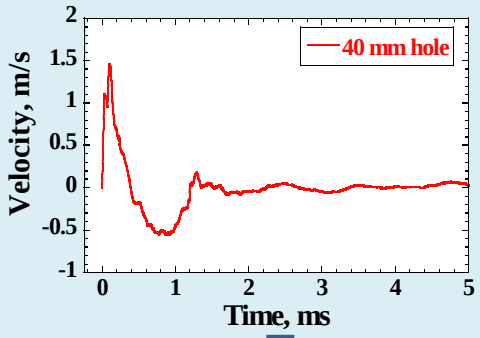


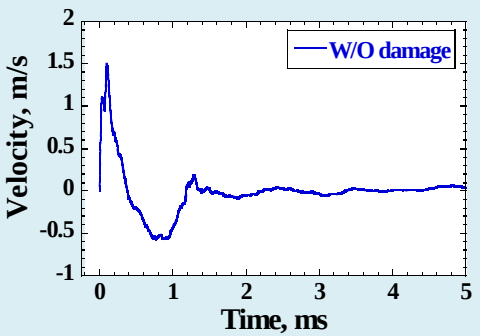
Wavelet Differential Analysis (*WDA*)



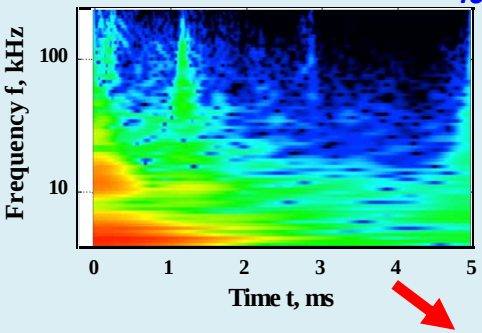
Time responses of vibration



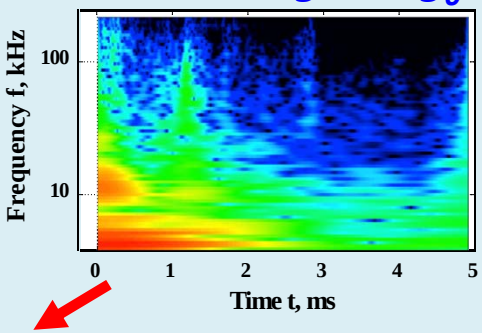




Wavelet image: Img_{40}

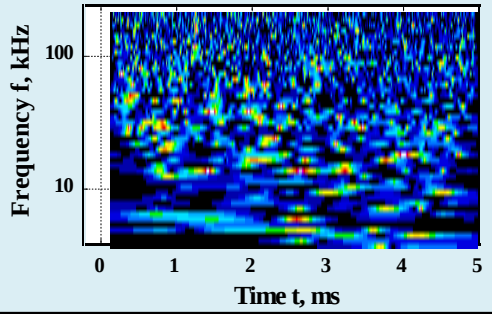


Wavelet image: Img_0



$$WDI_{45} = | Img_{40} - Img_0 | / | Img_0 |$$

Wavelet Differential Image (*WDI*)



- **WDA was used to enhance the differences between vibration waveforms**

Pressure waves propagation

Time: 67 μs