Target R&D for the J-PARC neutrino experiment (II)

Yoshinari Hayato (KEK/IPNS)

for the J-PARC target R&D group

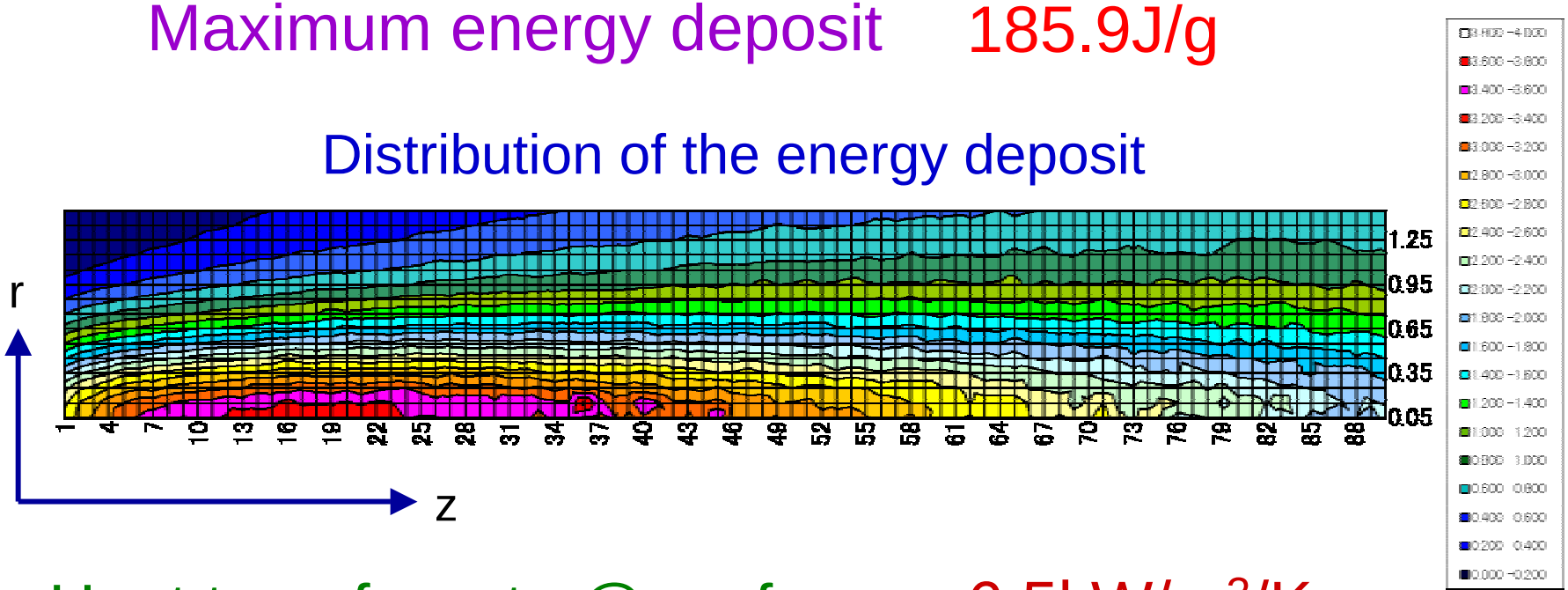
Temperature rise estimation (simulation input parameters)

Target size 30mm ϕ x 900mm L

Energy deposit 58kJ/spill

Maximum energy deposit 185.9J/g

Distribution of the energy deposit



Heat transfer rate @ surface 6.5kW/m^2/K

Temperature @ surface (environment) 25^{o}C

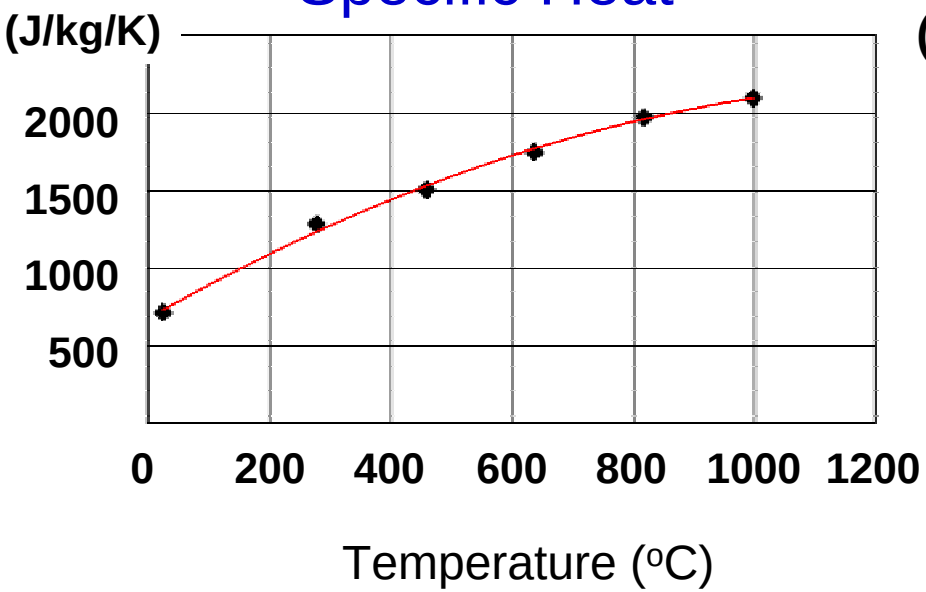
Temperature rise estimation (simulation input parameters)

Material IG-43 (Toyo Tanso)

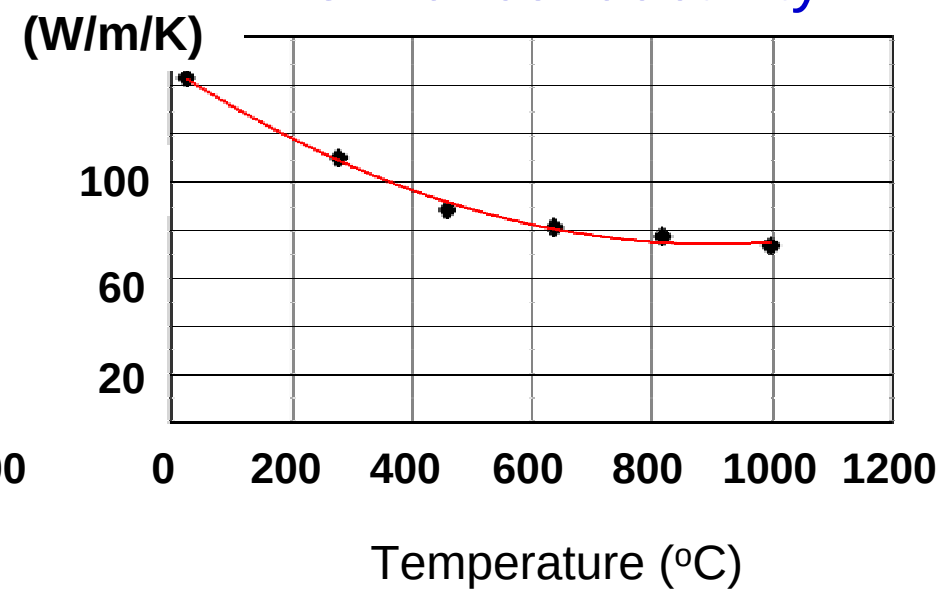
density 1850kg/m^3

Temperature dependent material parameters

Specific Heat

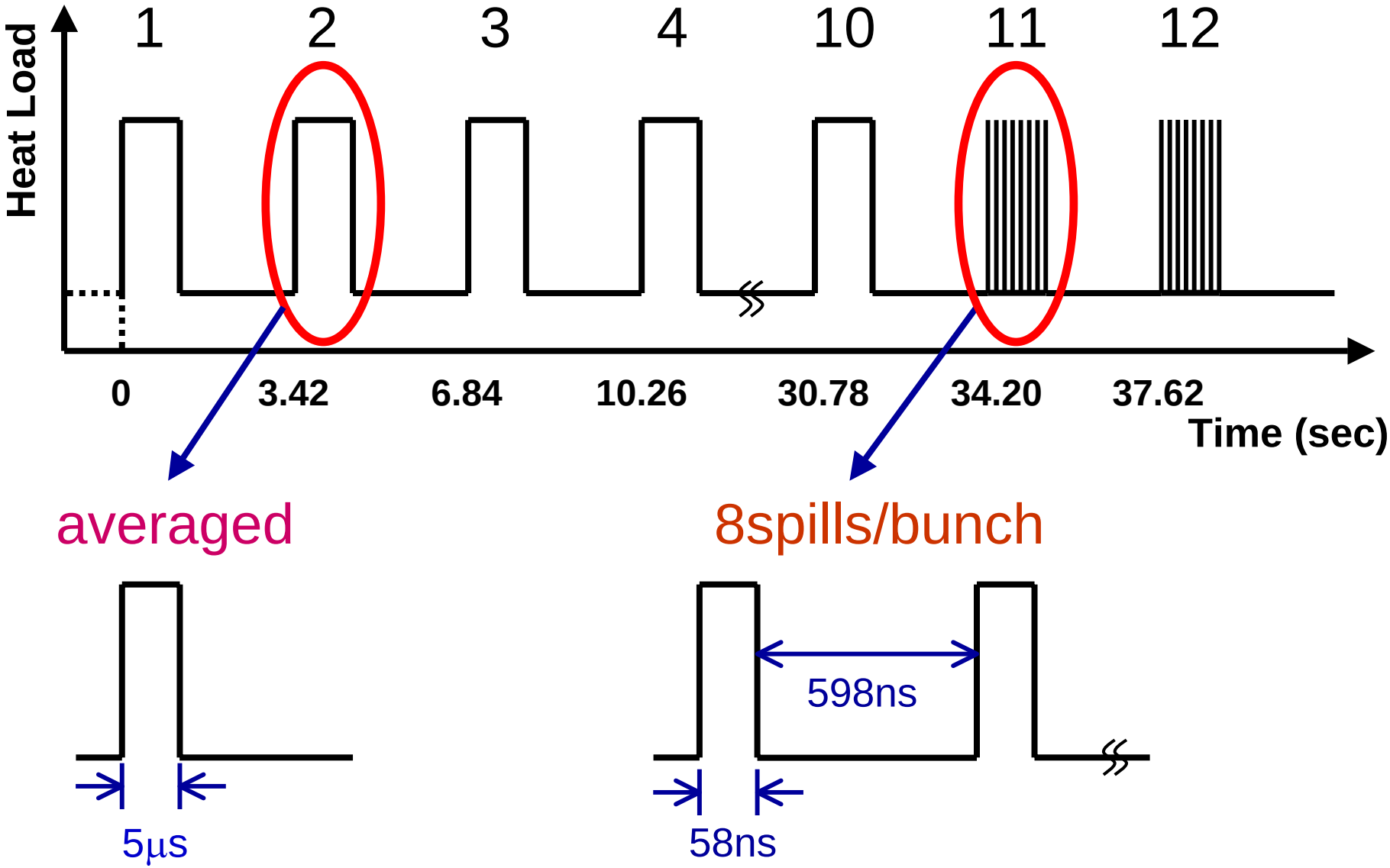


Thermal conductivity



Temperature rise estimation (simulation input parameters)

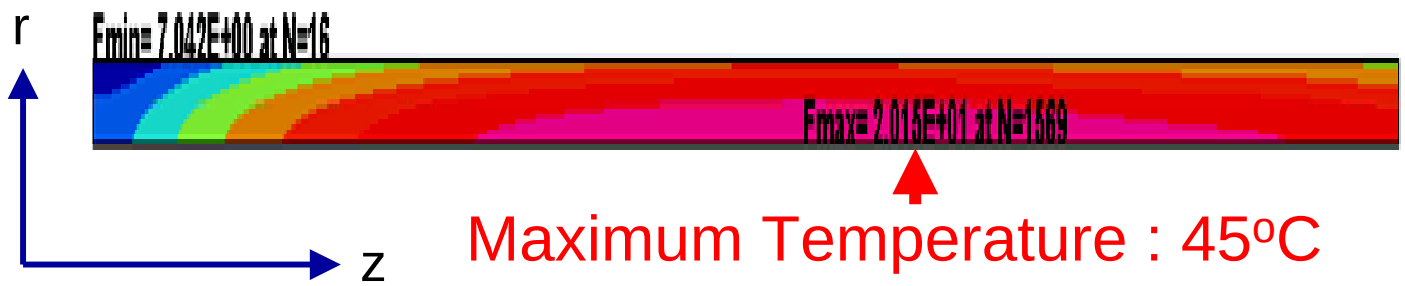
Time structure : for the detailed study, two patterns were simulated.



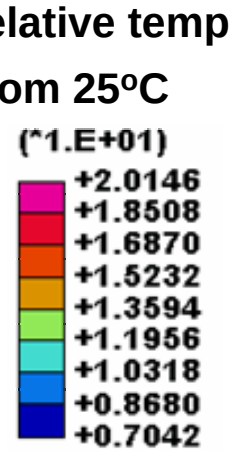
Temperature rise estimation

results : (I) distribution in the target

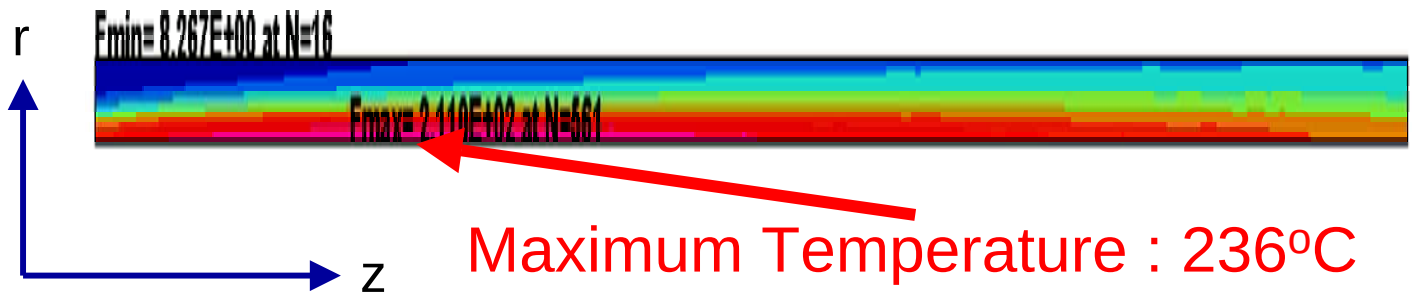
just before the 11th spill



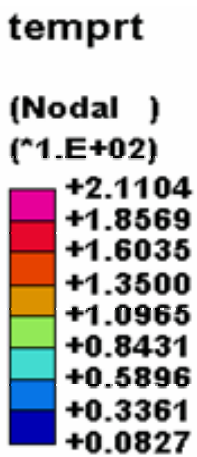
Maximum Temperature : 45°C



just after the 11th spill

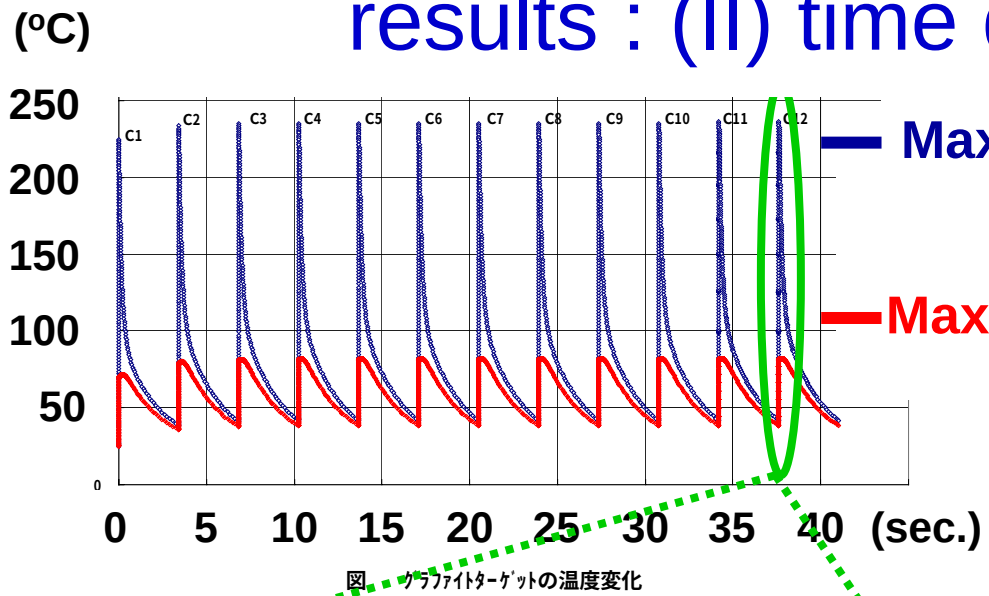


Maximum Temperature : 236°C



Temperature rise estimation

results : (II) time dependence



図．ｸﾞﾗﾌｧｲﾄﾀｰｹﾞｯﾄの温度変化

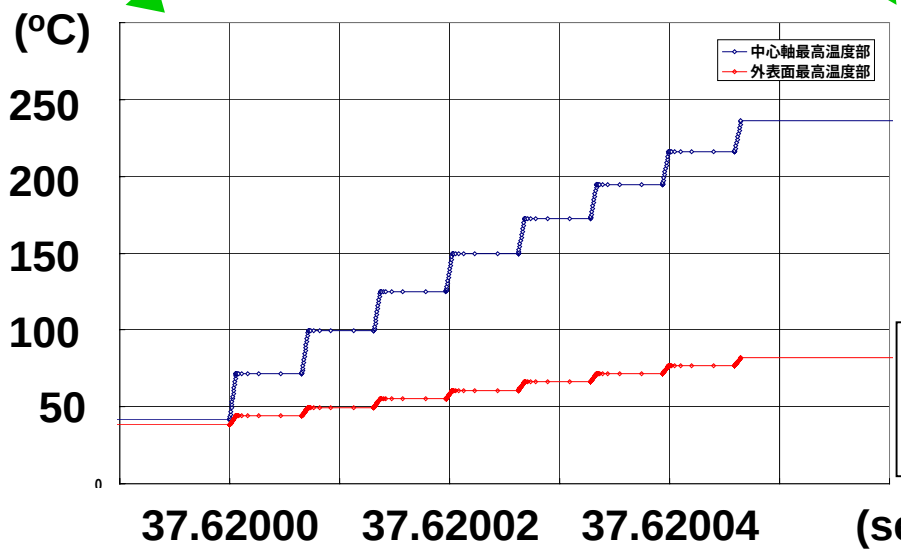
Maximum temperature at the center

236ºC @maximum

Maximum temperature on the surface

85ºC @maximum

(Initial temp. : 25 ºC)



Temperature is saturated in a few spills.

Temperature rise gradually decreased because of the temp. dependence of Cp.

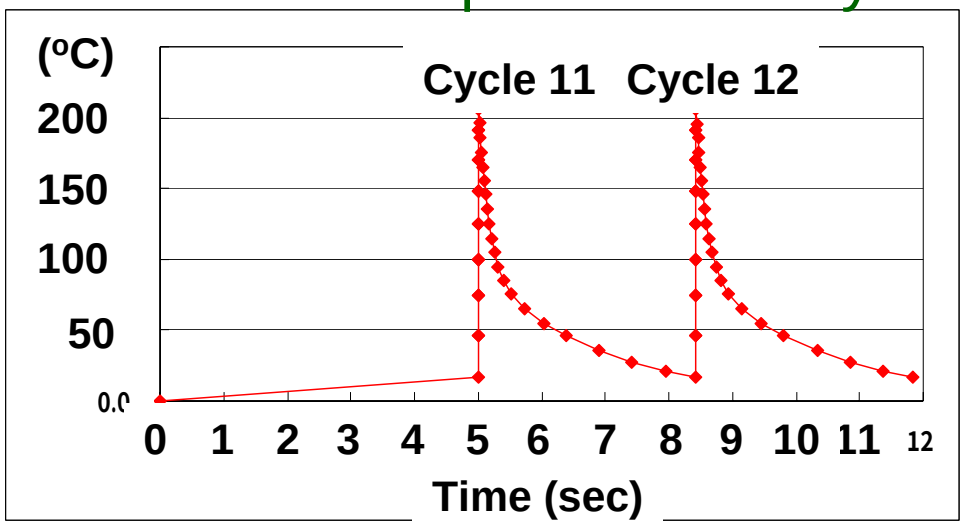
Thermal stress & displacements estimation

(simulation input parameters)

Temperature

Cycle 11 and 12

of the previous analysis



Material properties

Temperature (ºC)	Young's modulus (MPa)	Linear Expansion Coeff. ($x10^{-6}$)
0.0	10760	3.6814
20.0	10790	3.762063
100.0	10920	4.065344
200.0	11080	4.48612
400.0	11410	4.926584

Two types of the stress analysis (LS-DYNA)

For the radial displacements (fast components)

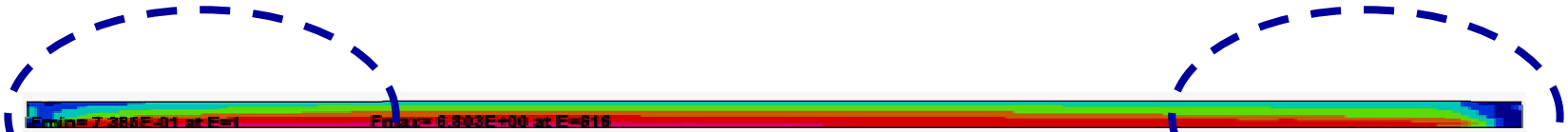
time step : 1μs (from 0 to 205μs)

For the longitudinal displacements (slower components)

time step : 10μs (from 0 to 2050μs)

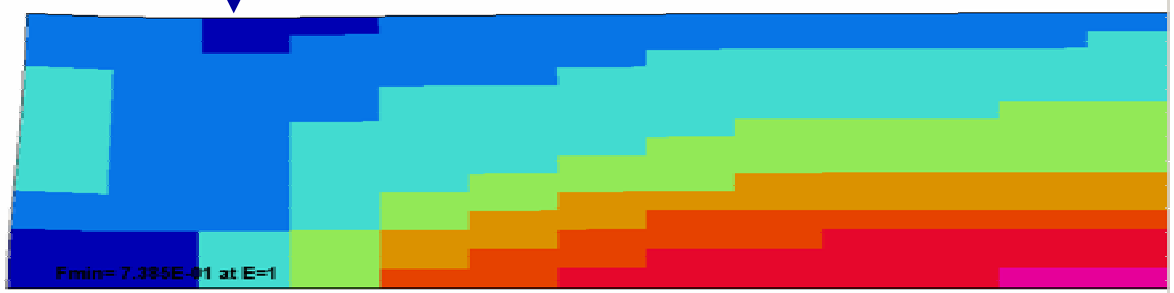
Thermal stress & displacements estimation results : (I) equivalent stress

Just after the 11th spill

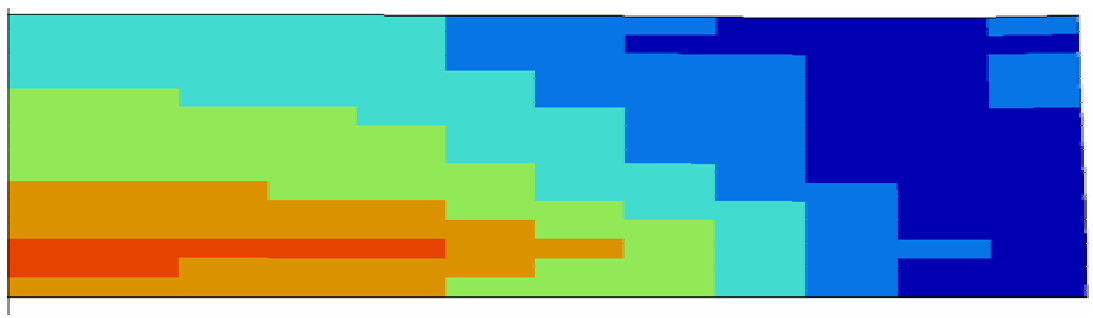


Maximum equivalent stress

6.8MPa

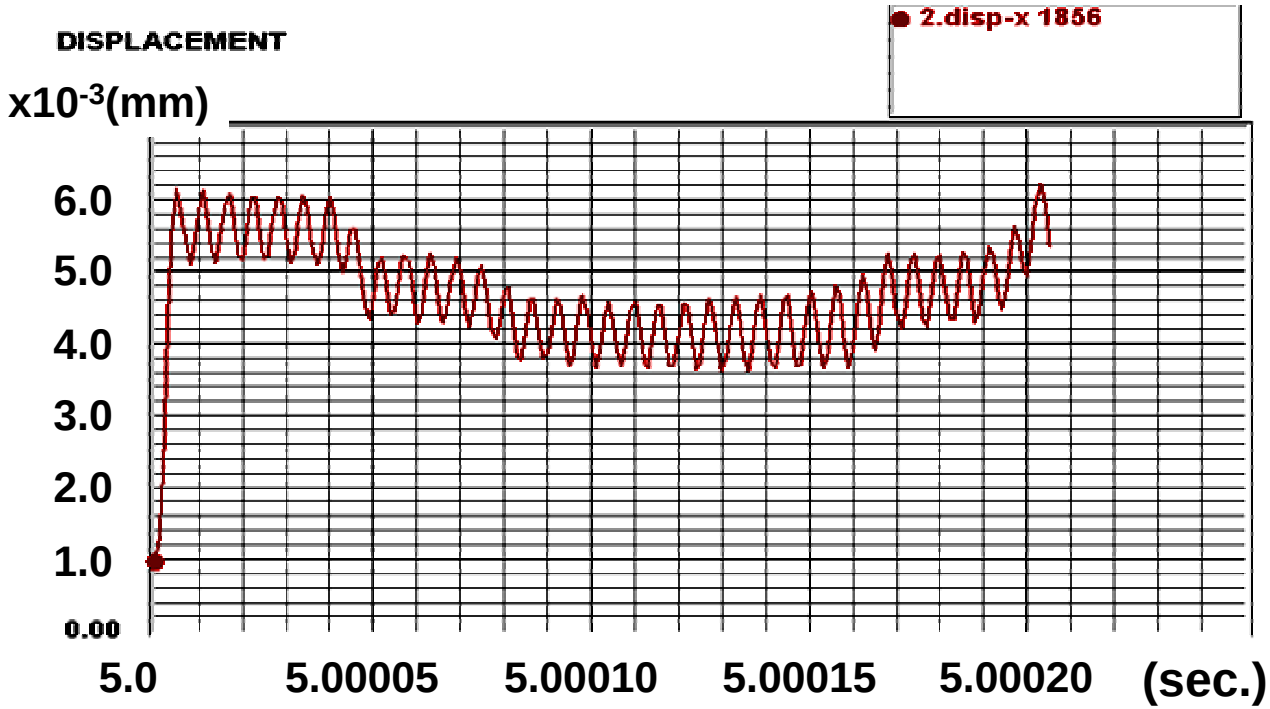


(x10 MPa)



Thermal stress & displacements

results : (II) displacements **(radial direction)**



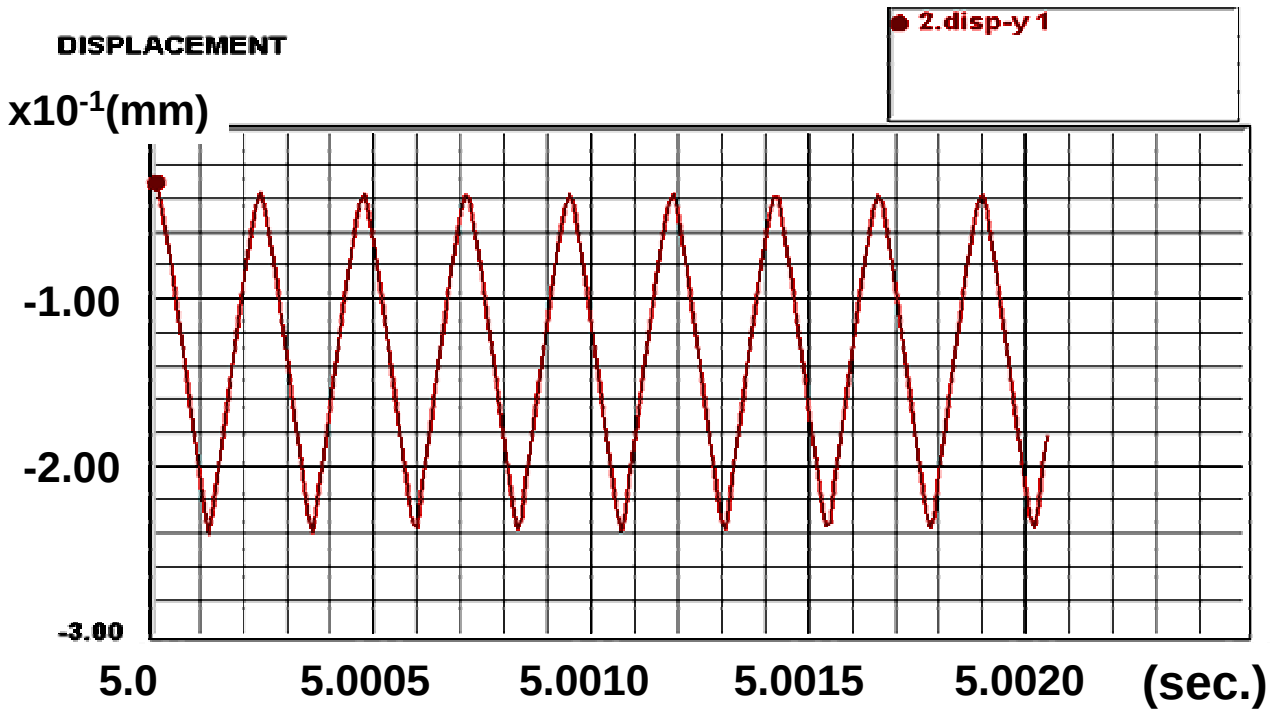
Displacement in the radial direction

Maximum displacement ~ 6×10^{-3}mm

Vibration cycle ~ 6μs

Thermal stress & displacements

results : (III) displacement **(longitudinal direction)**



Displacement in the longitudinal direction

Maximum displacement ~ 2.5×10^{-1}mm

Vibration cycle ~ 250μs

Summary & future prospects (I)

FEM simulation results

Maximum temperature @ center ~ 236^{o}C

(analytical : @ center ~ 250^{o}C)

@ surface ~ 85 ^{o}C

Maximum stress ~ 6.8MPa

(analytical ~ 7.5MPa)

→ Consistent with the analytical calculation.

Maximum displacement	radial	~ 6×10^{-3}mm
	longitudinal	~ 2.5×10^{-1}mm
Vibration cycle	radial	~ 6μs
	longitudinal	~ 250μs

Summary & future prospects (II)

Remaining questions / problems

1 piece or split the target into smaller pieces?

Off centered tolerance has to be estimated.

(Non-uniform heating may cause the problem.)

Can we put the graphite target in the water?

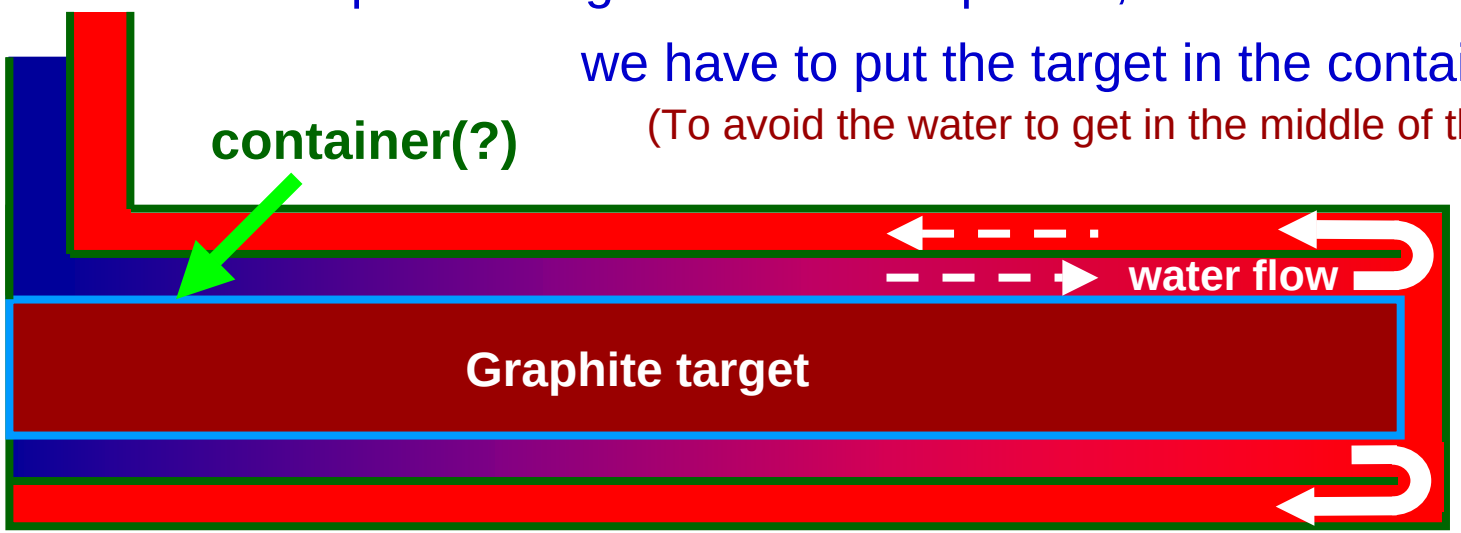
Is it necessary to put the target in the container

(to avoid graphite to touch the cooling water)?

If we split the target into smaller pieces,

we have to put the target in the container.

(To avoid the water to get in the middle of the beam.)



Schematic view of the possible target (cooling) system

Summary & future prospects (II)

Irradiation effects

Target may shrink by ~1(a few?)%

Large target (L=900mm) may not be possible.

If we put the target in the container, they will be separated.

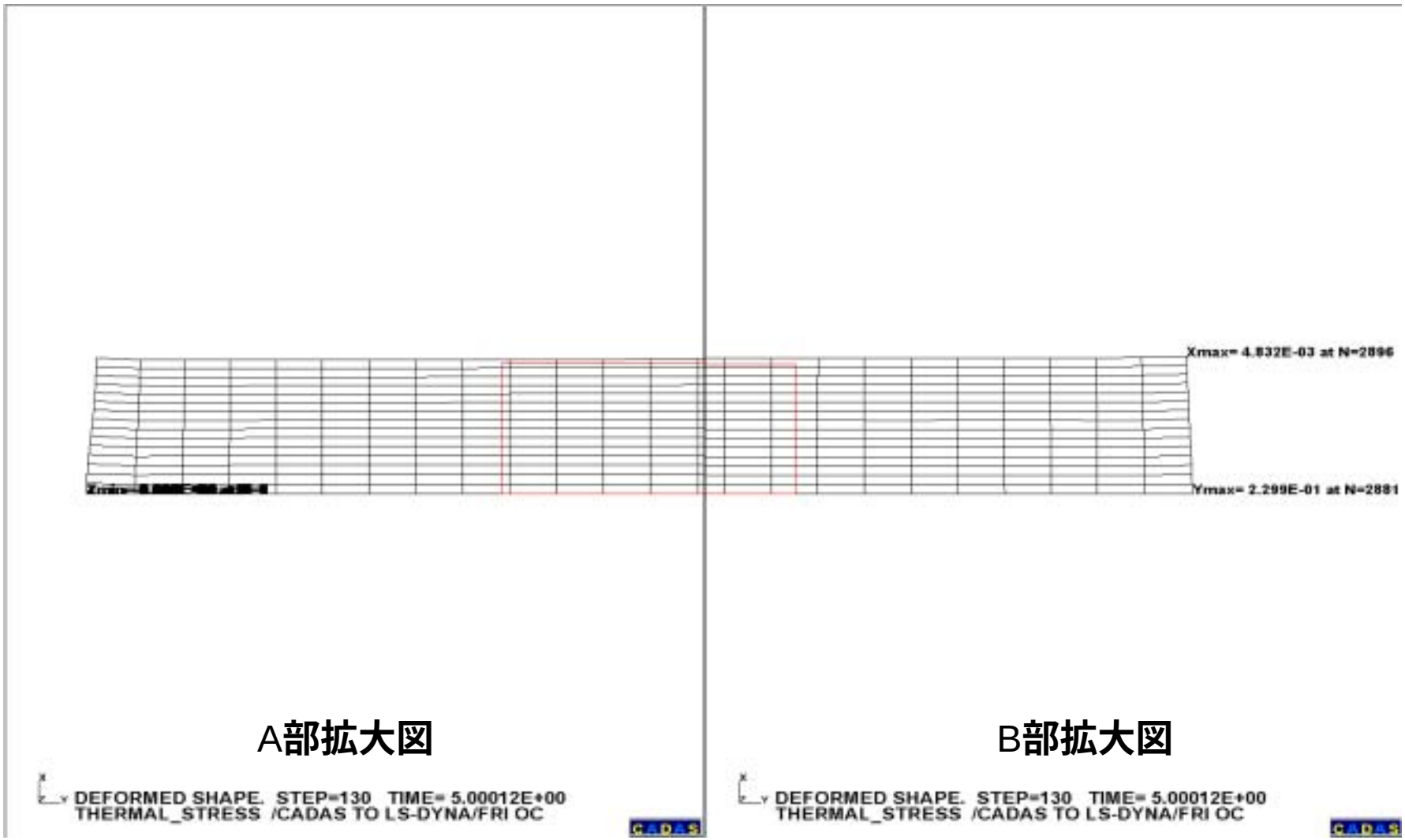
How to hold the target (in the container)?

→ Plan to measure the irradiation effects on the material properties

Very rough schedule

FY 2003	simulation studies & basic cooling tests. design the prototype (target holder, cooling system).
FY 2004	make the prototype and test. design the target support & handling system. measure the irradiation effects.
FY 2005	mockup tests (including supports & handling system). material determination.

変形倍率200倍にて表示
赤ライン=変形前
変形値単位=mm



A部拡大図

B部拡大図

グラファイトターゲット熱応力衝撃解析:変形図
(⑦ 軸変形最大=5.000125sec) 拡大図