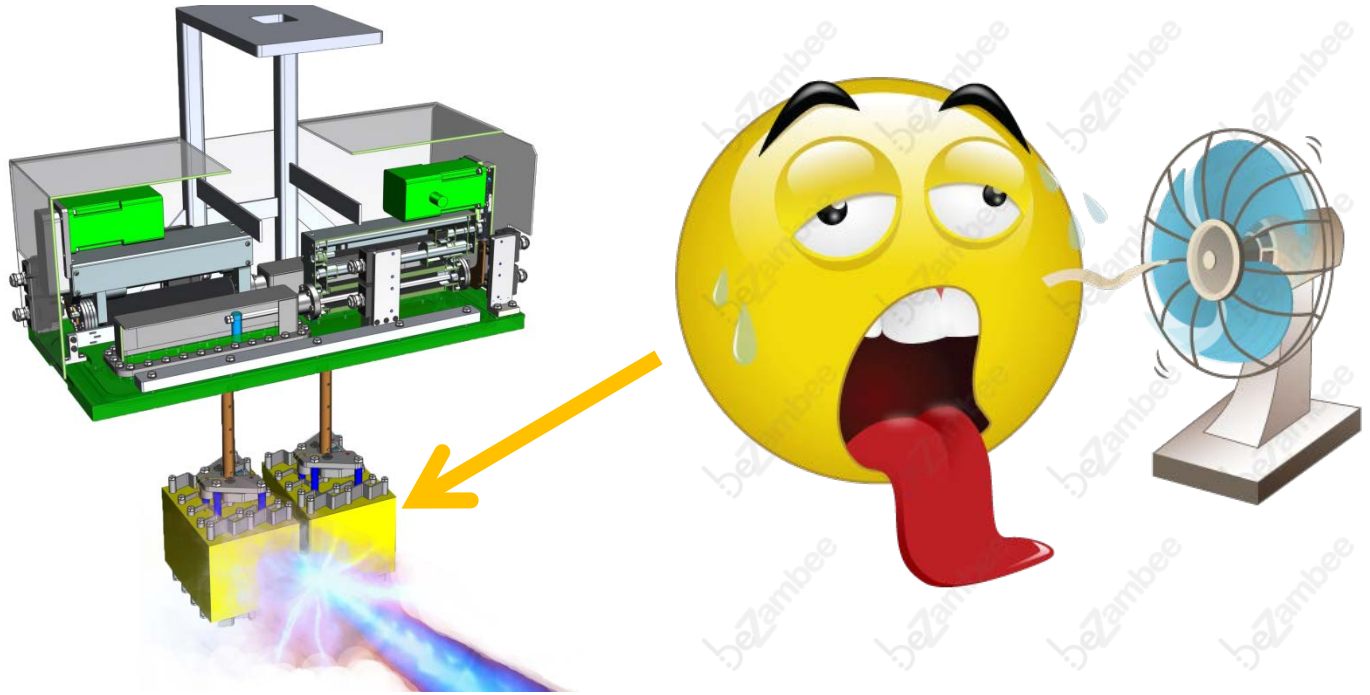
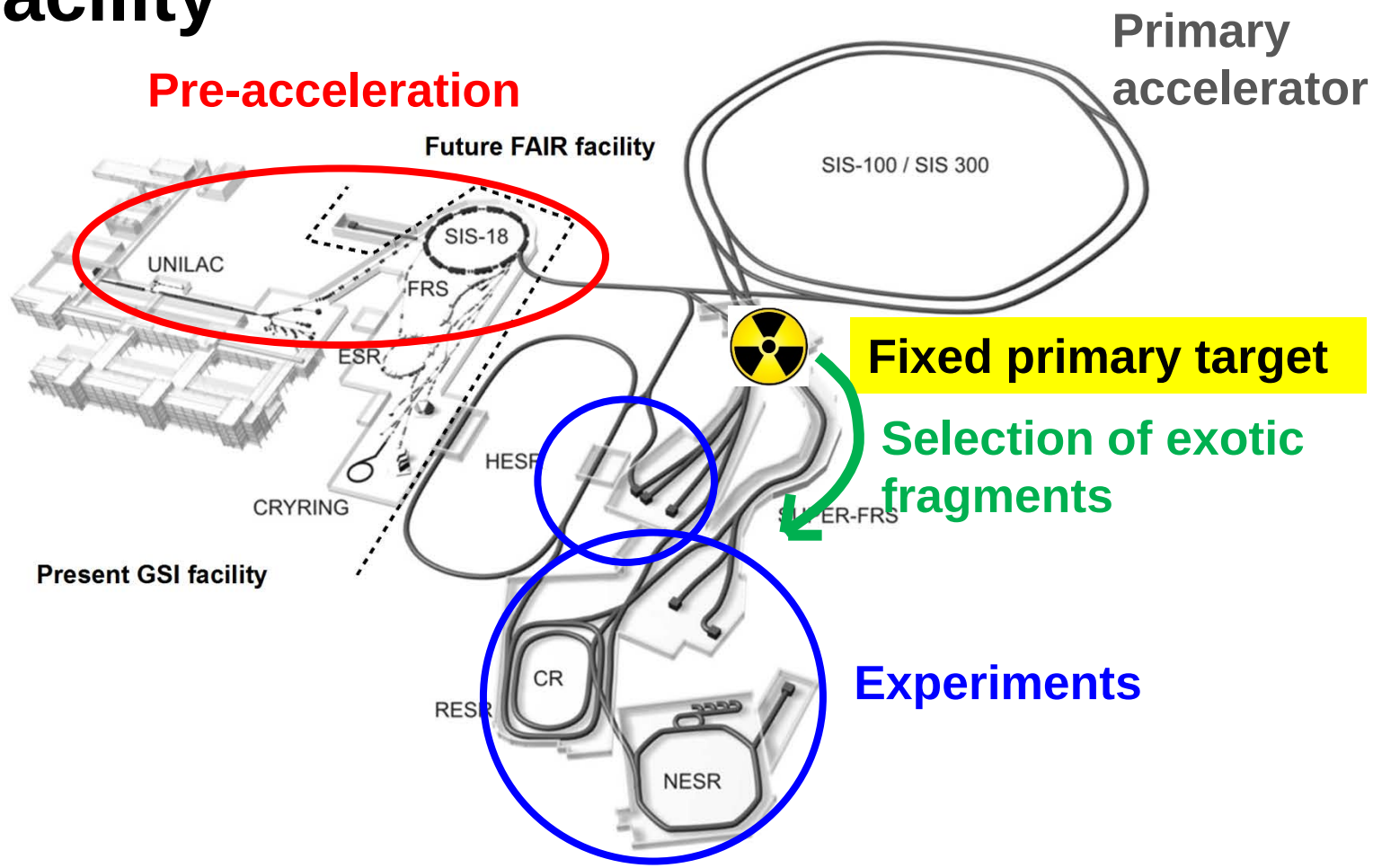
Verification of passive cooling techniques in the Super-FRS beam collimators

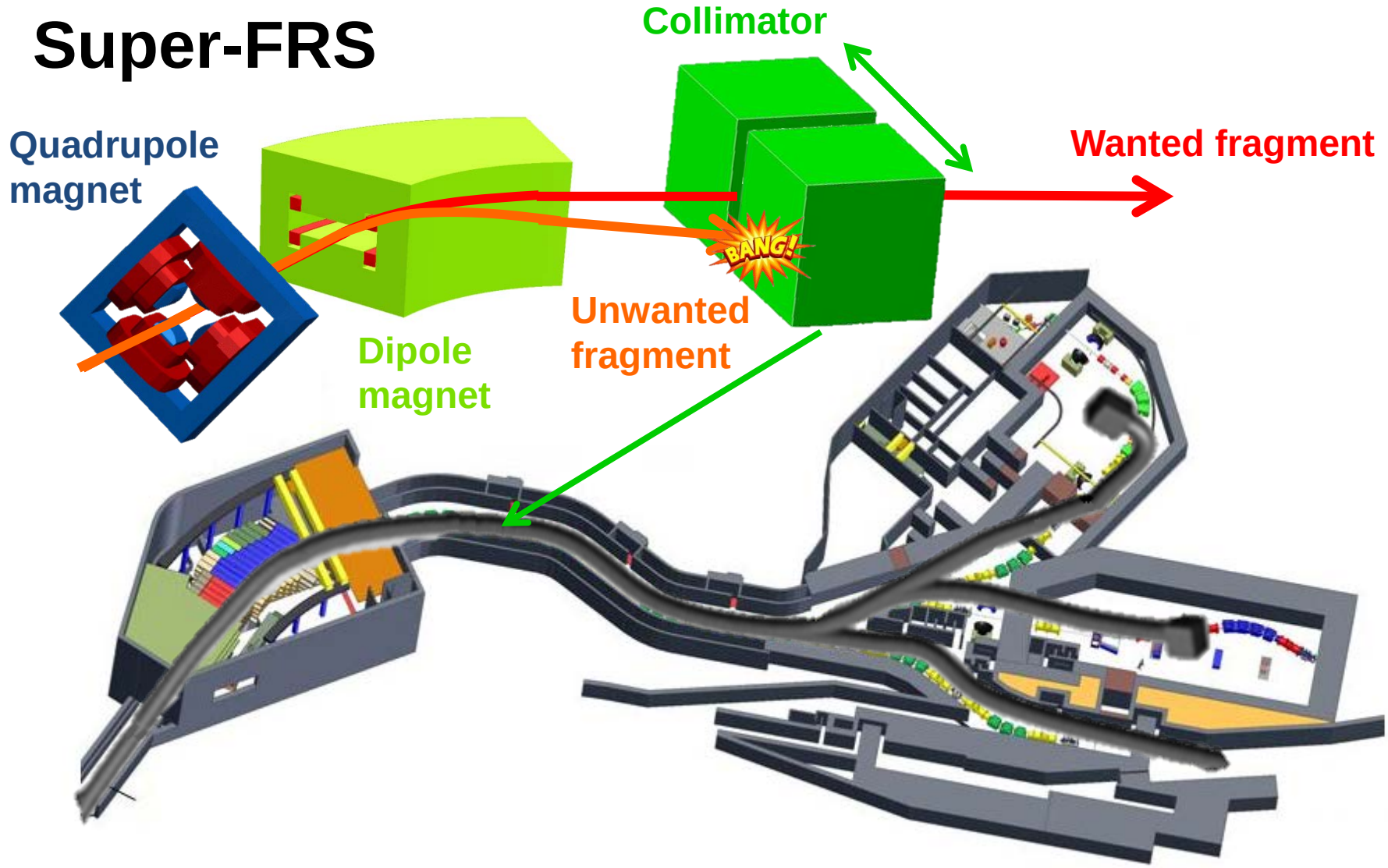


C.A. Douma, J. Gellanki, M. A. Najafi, H. Moeini, N. Kalantar-Nayestanaki, C. Rigollet, O.J. Kuiken, M.F. Lindemulder, H.A.J. Smit, H.J. Timersma
Presenter: C. A. Douma

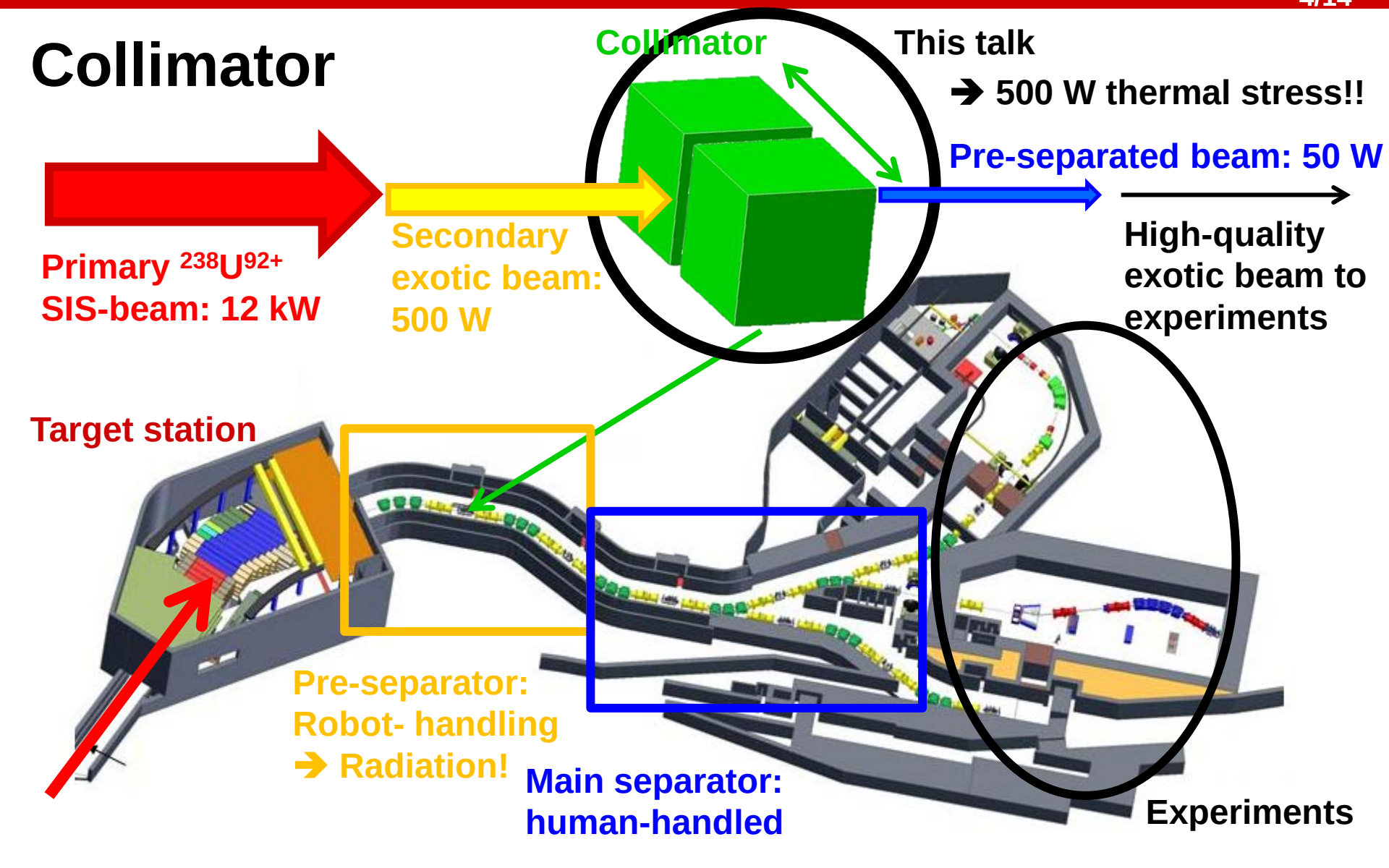
FAIR facility



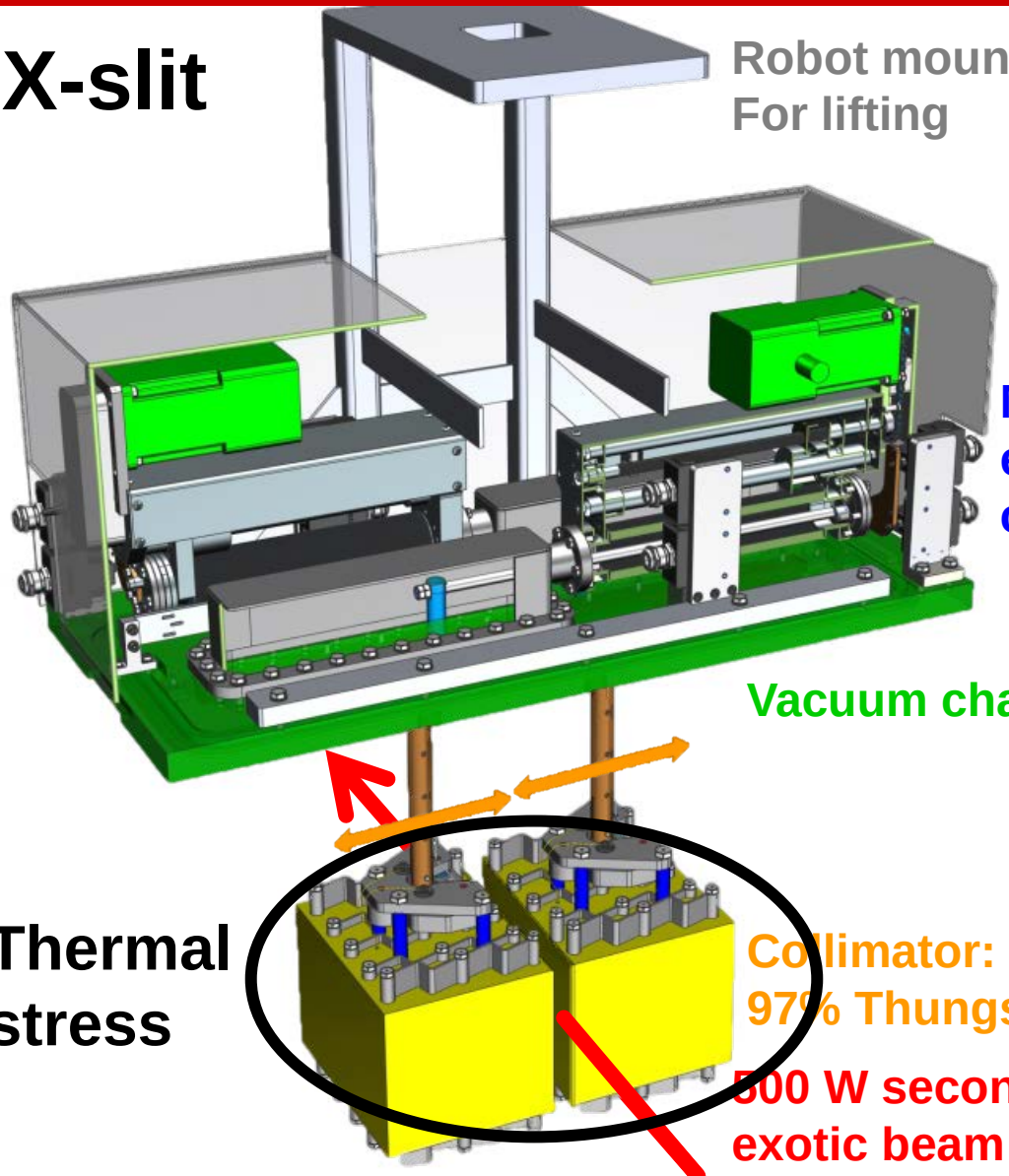
Super-FRS


Collimator
Quadrupole magnet
Wanted fragment
BANG!
Unwanted fragment
Dipole magnet

Collimator


Collimator
This talk
➔ 500 W thermal stress!!
Pre-separated beam: 50 W
High-quality exotic beam to experiments
Primary $^{238}U^{92+}$
SIS-beam: 12 kW
Secondary exotic beam: 500 W
Target station
Pre-separator:
Robot- handling
➔ Radiation!
Main separator:
human-handled
Experiments

X-slit



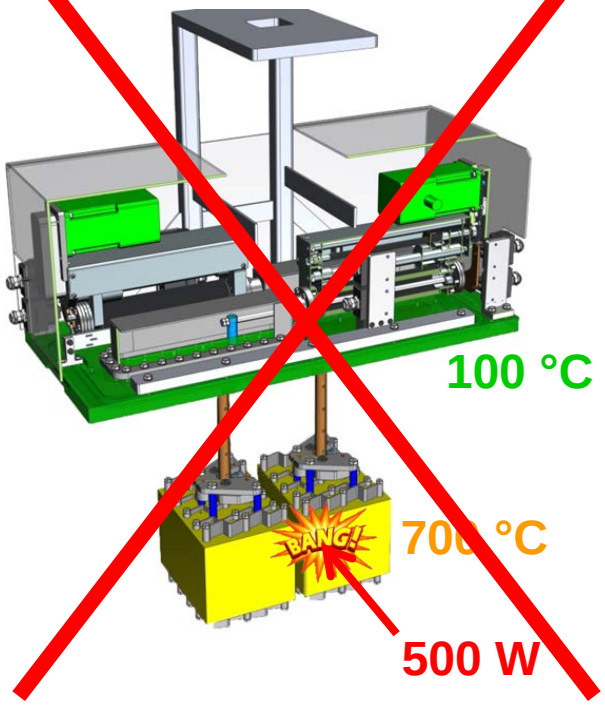
Options:

1. No cooling
2. Active cooling
3. Passive cooling

Thermal stress

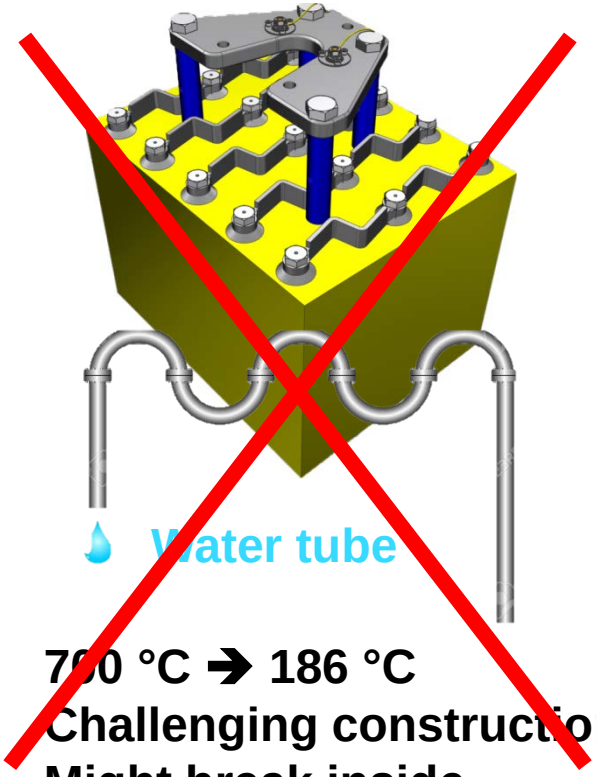
Cooling options

No cooling



Electronics might malfunction

Active cooling



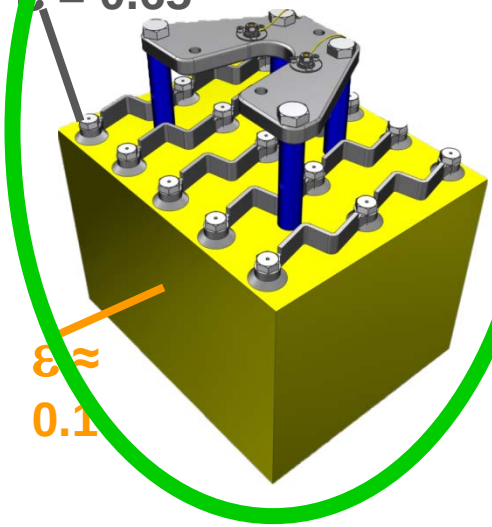
700 °C ➔ 186 °C
Challenging construction
Might break inside robot-handled area
Radioactive water

Passive cooling

➔ Increase infrared emission

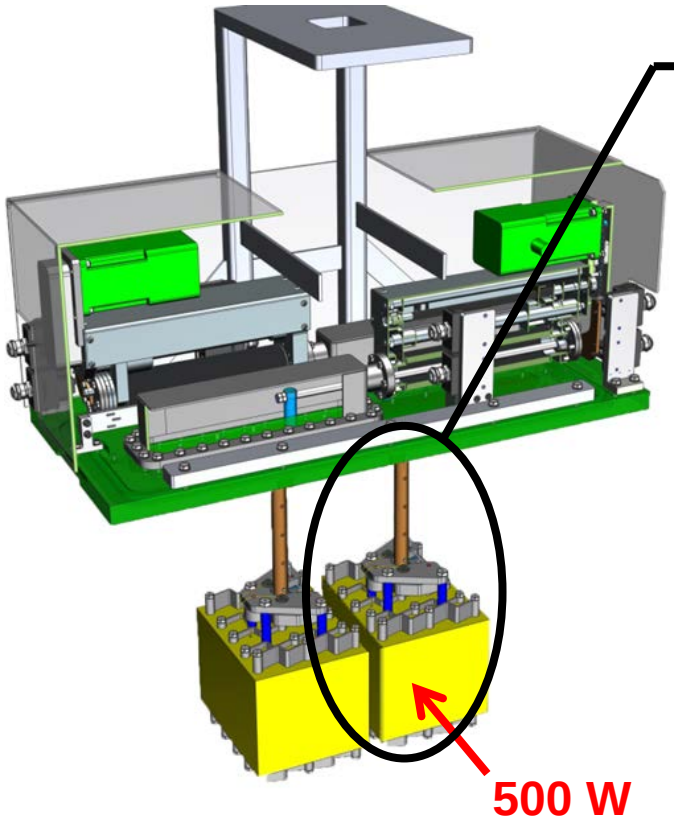
Stainless steel strips

ε = 0.65



Cooling while
Nothing can break!

Passive cooling

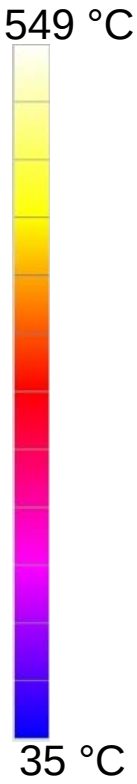


NX SIEMENS
Aula NX by Siemens PLM Software
Profesorado certificado por Siemens PLM Software

Thermal simulation with SS strips

T_{wall} = 100 °C ➔ 35 °C

T_{max} = 700 °C ➔ 549 °C

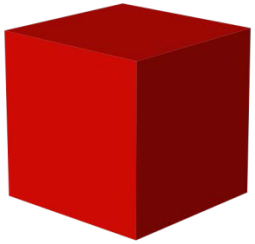


NX simulation: electronics are safe at 35 °C

Will the electronics be safe in the real world too?

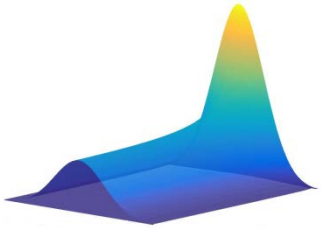
Simulation verification

Densimet block in vacuum



&

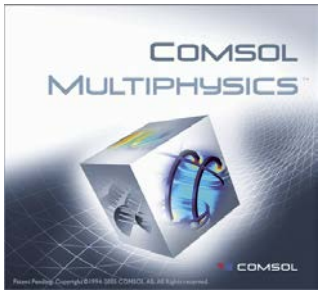
$^{238}U^{90+}$ beam
1.3 GeV/u & 500 W
Transverse Gaussian
Longitudinal Bragg

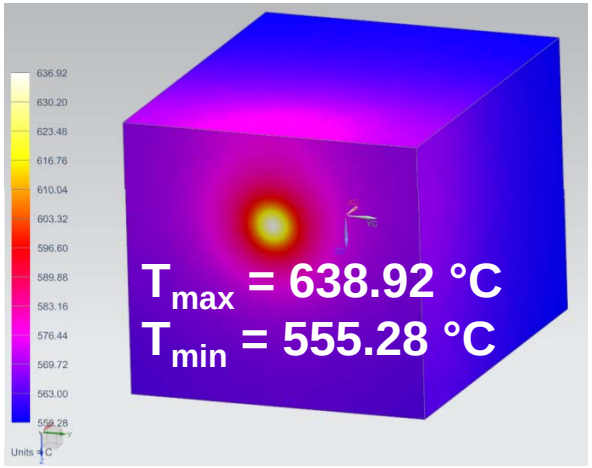


= **Precise**
0.3 mm mesh

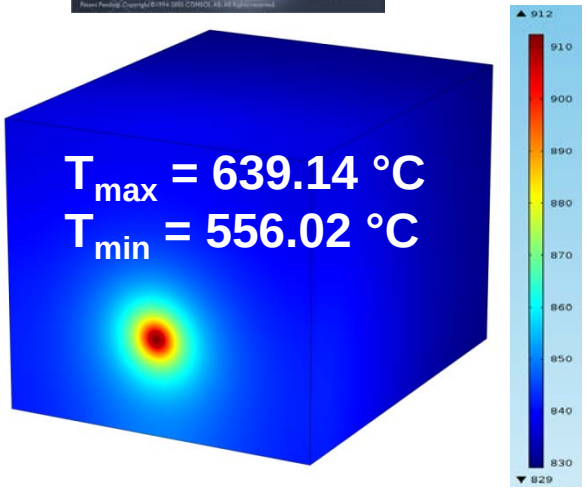
NX SIEMENS
Aula NX by Siemens PLM Software
Profesorado certificado por Siemens PLM Software

VS

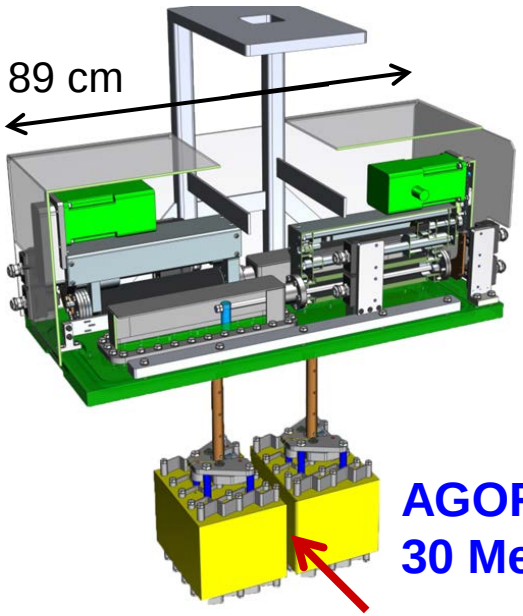




Δ<0.74 °C



Experimental verification

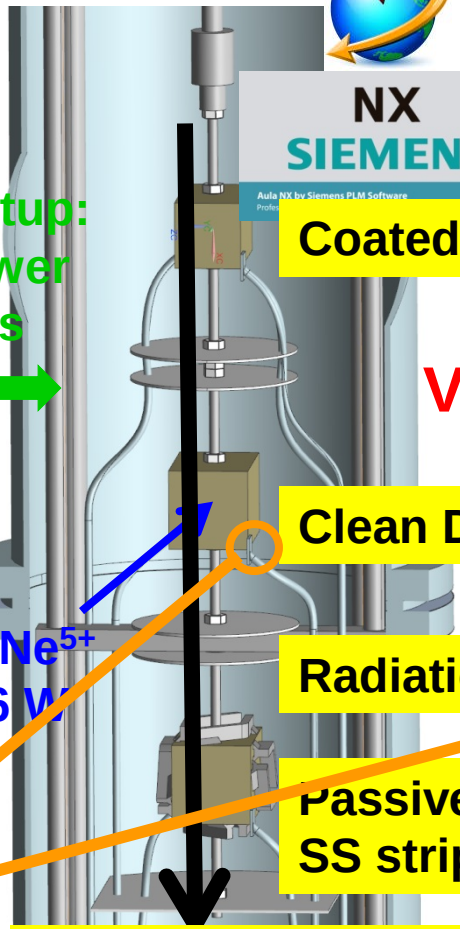


Shrink setup:
Beam power limitations

AGOR-beam: $^{20}Ne^{5+}$
30 MeV/u & 21.6 W

FAIR-beam: $^{238}U^{90+}$
1.3 GeV/u & 500 W

K-type thermocouples:
continuous readout



Coated: $\varepsilon > 0.9$

VS

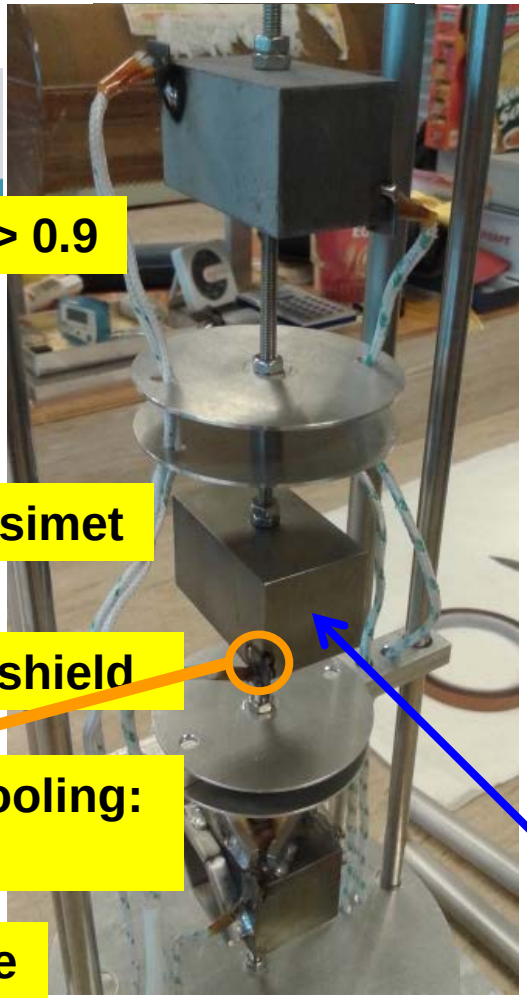
Clean Densimet

Radiation shield

Passive cooling:
SS strips

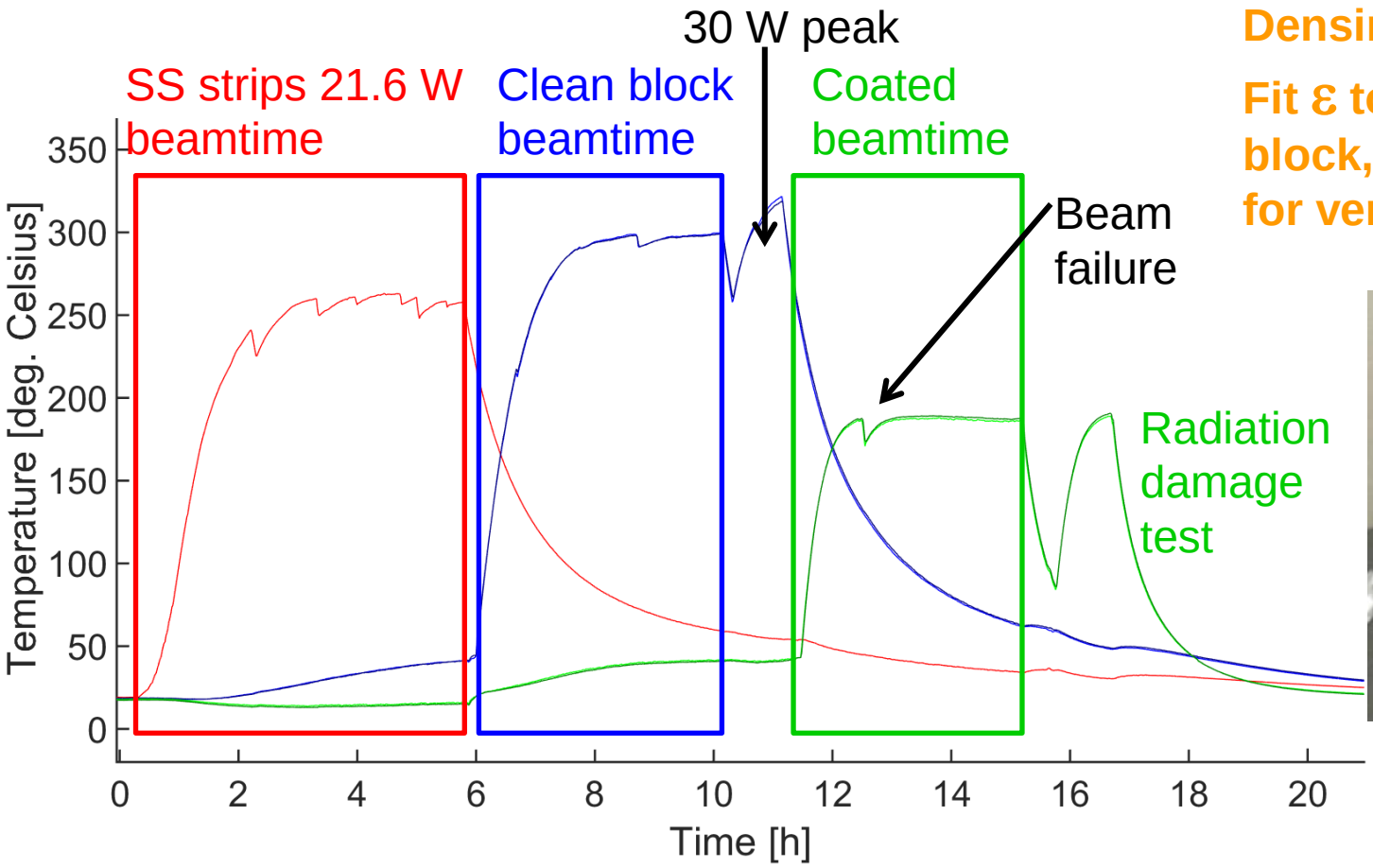
Move during beamtime

The real world: AGOR



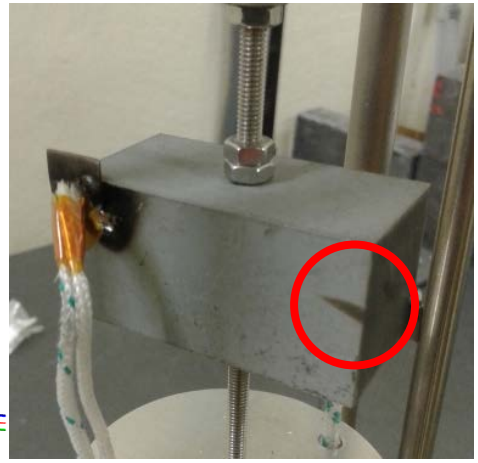
Experimental data

K-type thermocouples ➔ 2-point calibration ➔ ice and boiling water



Densimet ε = ?

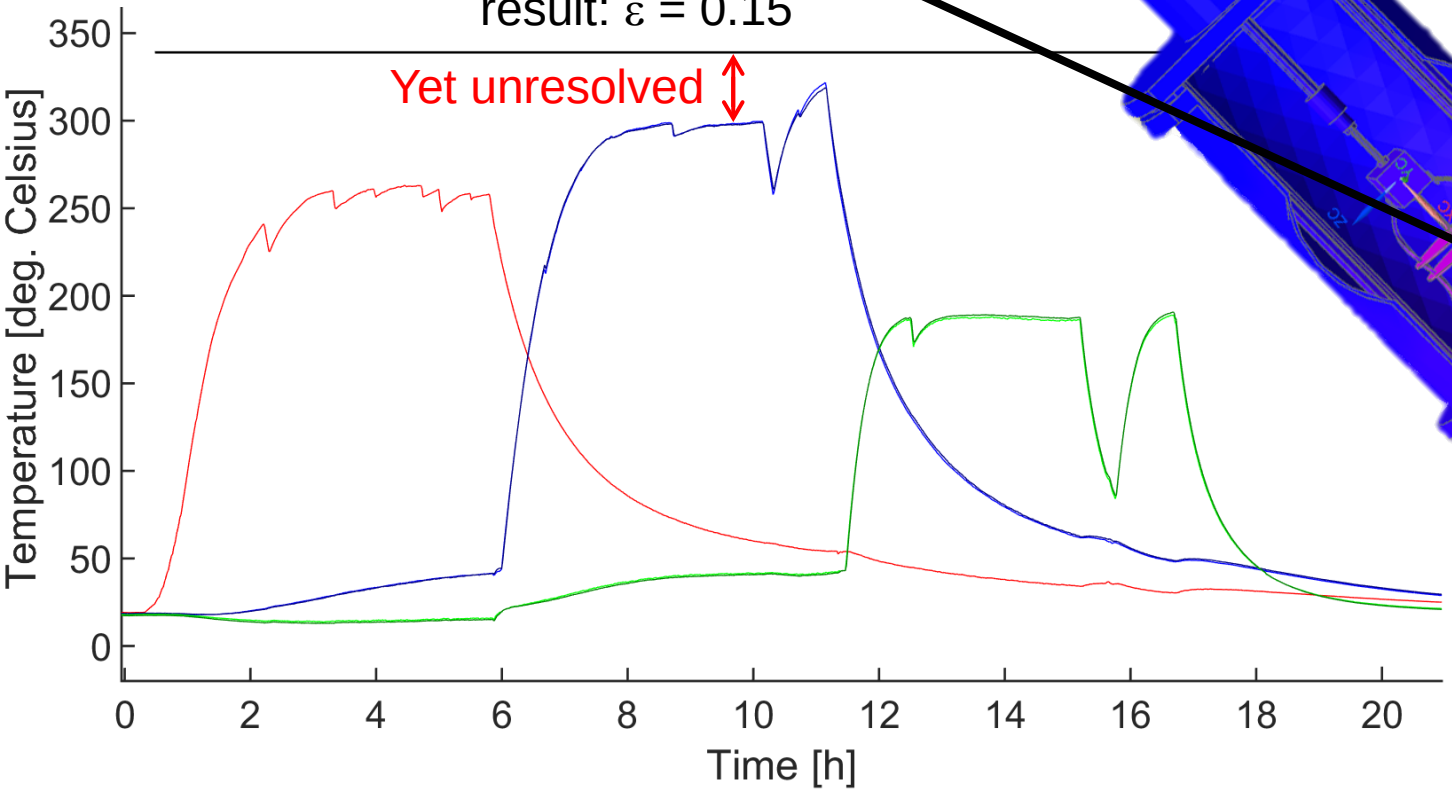
Fit ε to data for clean block, use other 2 blocks for verification

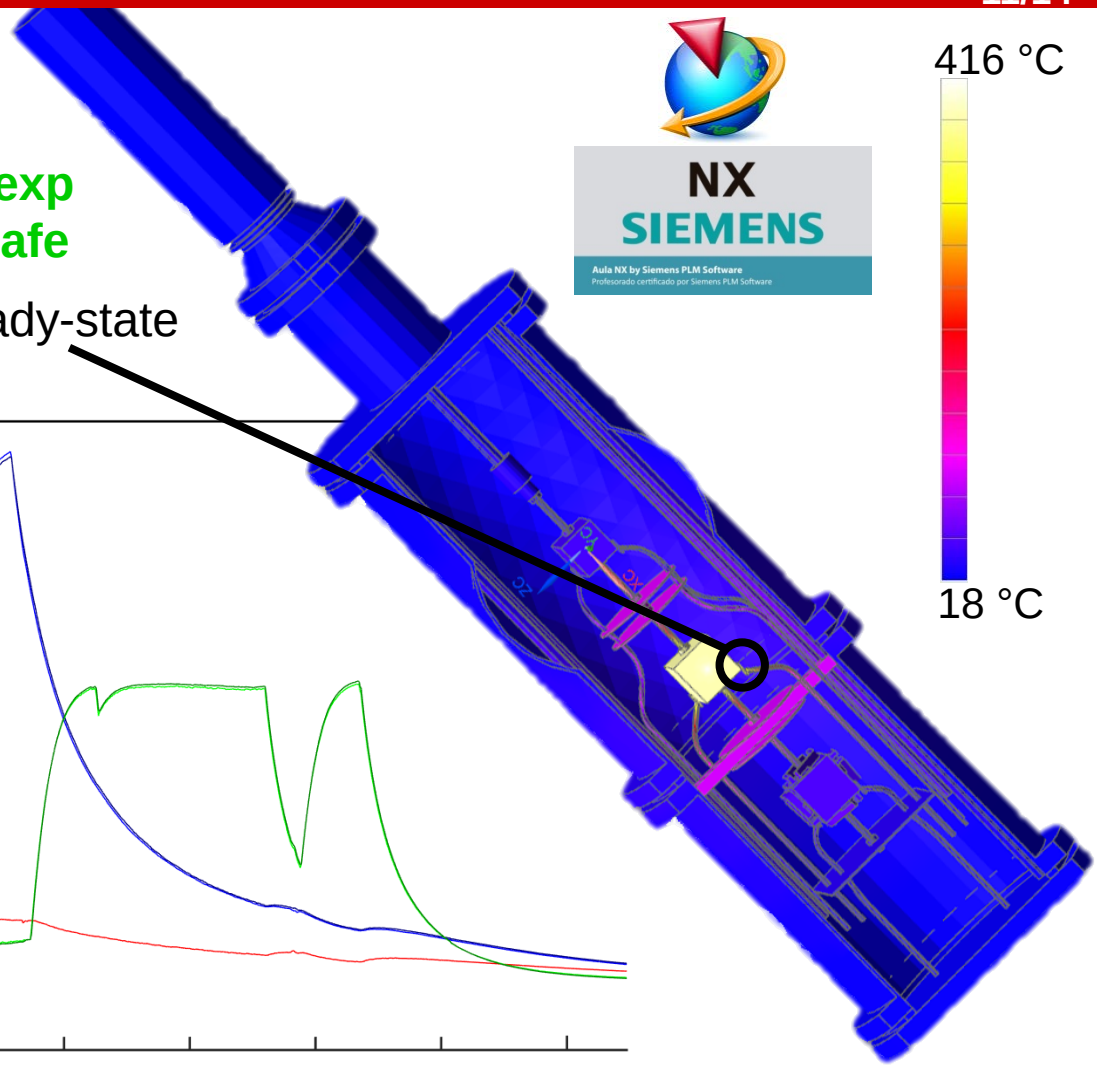


Coating not ideal for passive cooling

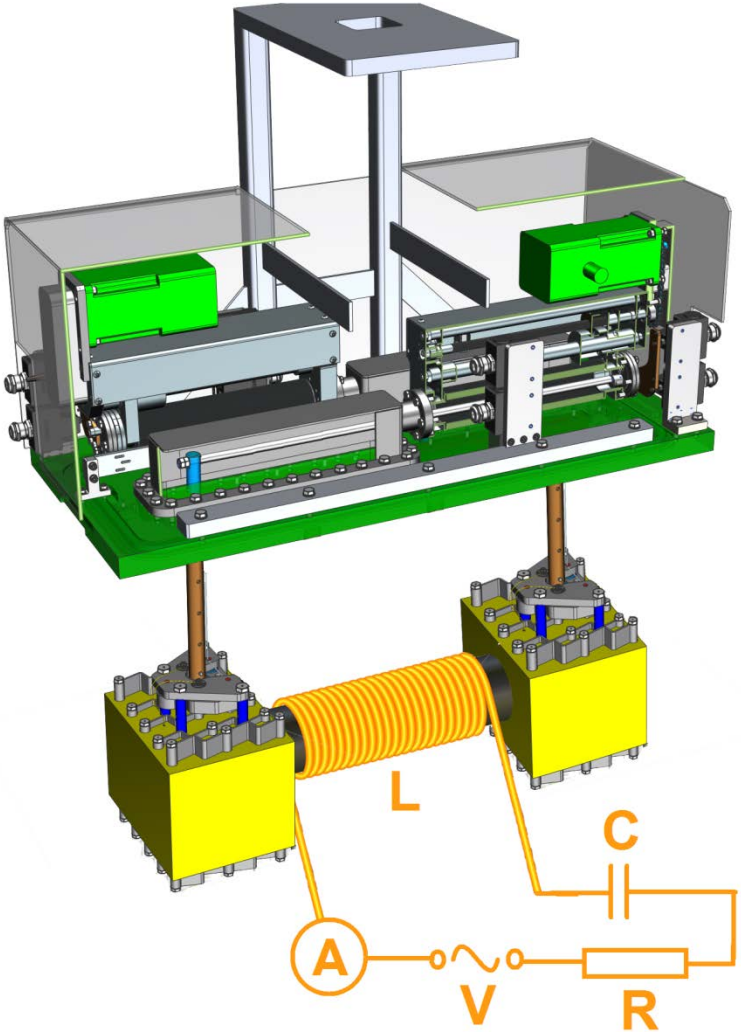
Experimental data

But each sim gives higher T then exp
➔ Suggests that electronics are safe



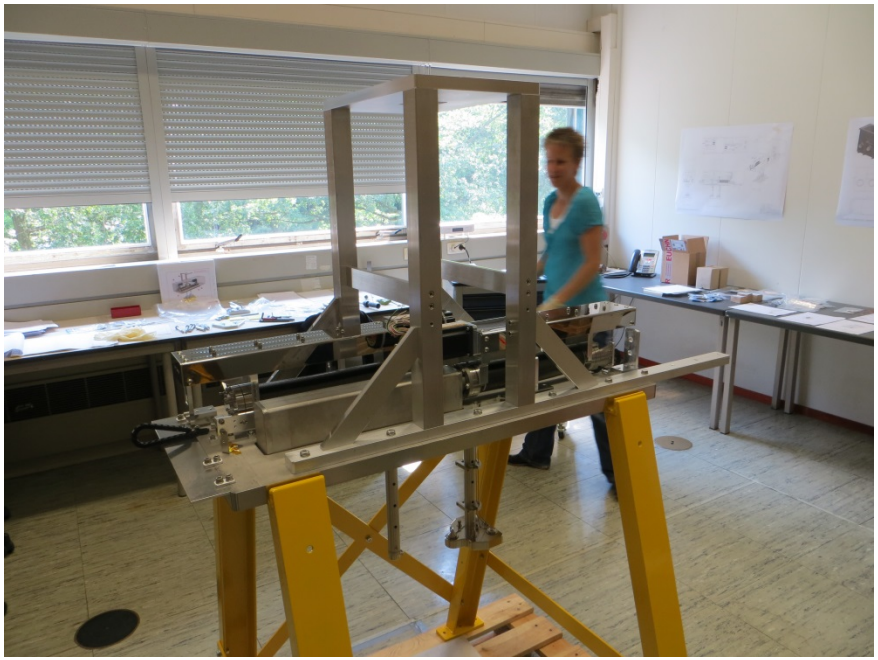


Design verification



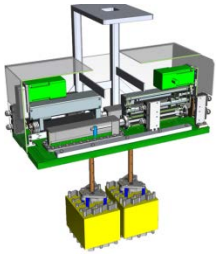
Test thermal stress with “induction boiling”

- 500 W energy deposition per block
- Test is performed on X-slit prototype
- A vacuum test-chamber is used
- Precise measurement of temperatures and energy deposition during runtime



➔ Performed when assembling is done!

Conclusion



➔ Passive cooling is required

➔ NX simulation shows that electronics are safe

NX SIEMENS

VS

COMSOL MULTIPHYSICS

2 independent setups:
➔ Δ<0.74°C on fine mesh
➔ NX simulation can be trusted

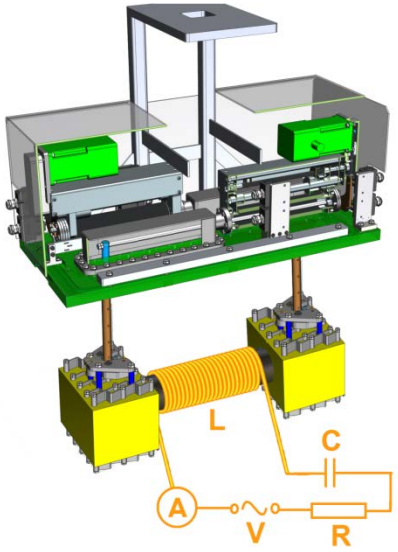
Δ≈40 °C preliminary

Each sim>exp

Since NX=safe, Real=prob. safe

Suggests that passive cooling is sufficient for X-slit system.

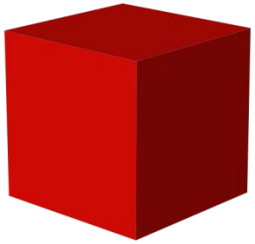
➔ Hopefully we are sure after final tests.



Questions?

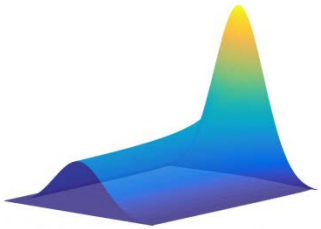
Simulation verification ➔ Coarse mesh

Densimet block in vacuum



&

$^{238}U^{90+}$ beam
1.3 GeV/u & 500 W
Transverse Gaussian
Longitudinal Bragg

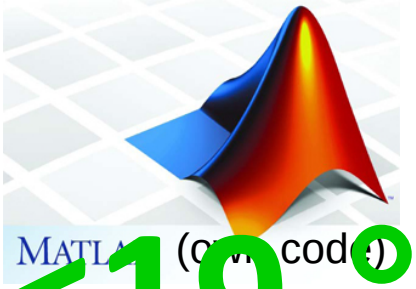


=

1 mesh: 14 mm
Same Volume!

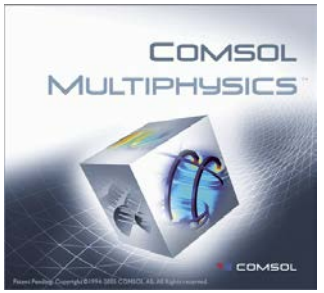
NX SIEMENS
Aula NX by Siemens PLM Software
Profesorado certificado por Siemens PLM Software

VS



MATLAB (own code)

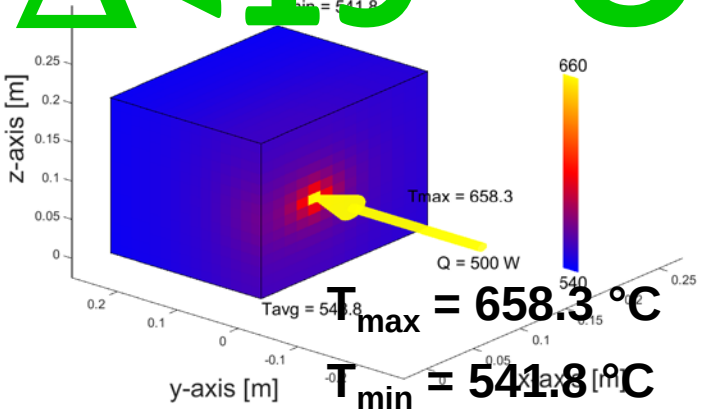
VS



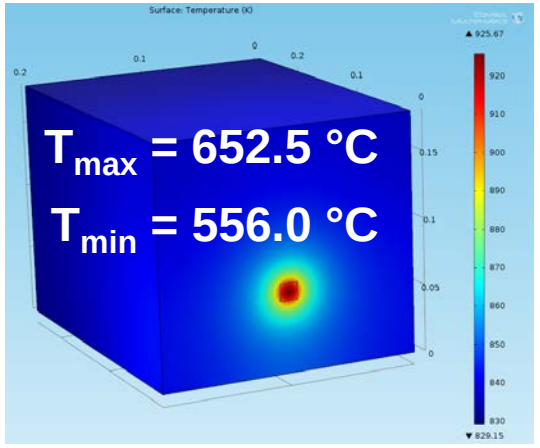
$\Delta < 19\,°C$

densimetonlyfinal_sim1 : Solution 1 Result
Load Case 1, Static Step 1
Temperature - Nodal, Scalar
Min : 555.51, Max : 671.13, Units = C

T_{max} = 671.1 °C
T_{min} = 555.5 °C

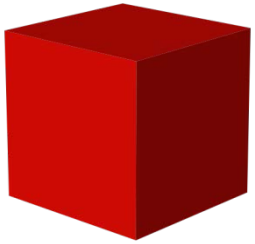


T_{max} = 658.3 °C
T_{min} = 541.8 °C



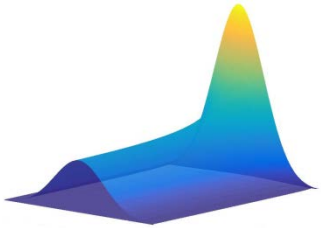
Simulation verification ➔ Fine mesh

Densimet block in vacuum



&

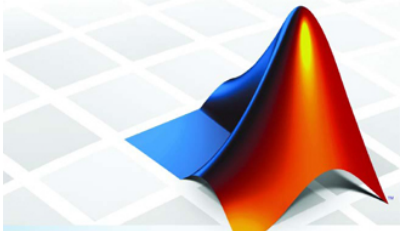
$^{238}U^{90+}$ beam
1.3 GeV/u & 500 W
Transverse Gaussian
Longitudinal Bragg



= Precise
0.3 mm mesh

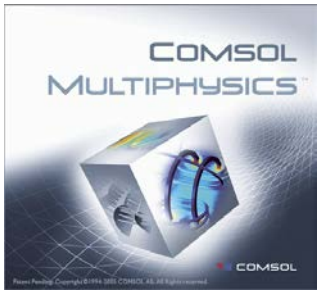
NX SIEMENS
Aula NX by Siemens PLM Software
Profesorado certificado por Siemens PLM Software

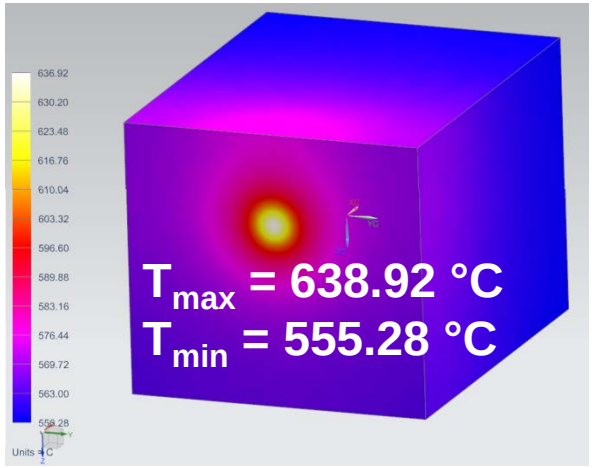
VS



(own code)

VS





Code = not advanced enough

Δ<0.74 °C