ON-LINE TEMPERATURE MEASUREMENT IN A WATER COOLED SOLID-TARGET AT THE BC1710 CYCLOTRON

30th Conference of the International Nuclear Target Development Society INTDS 2022,
25. - 30. September 2022, Switzerland

I. SPAHN, R. RAYAPROLU, S. SPELLERBERG, S. MÖLLER, CH. LINSMEIER, B. NEUMAIER

INTRODUCTION

The generation of heat in using ion beams is a limiting factor for all accelerator facilities in the world.

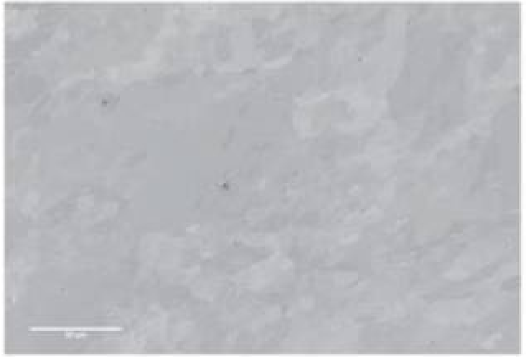
Limiting factors

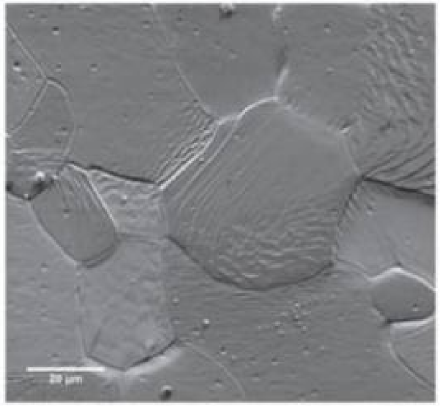
- Melting and evaporation
- Alloying issues, contamination
- Irradiation damage is heavily temperature dependent
- Change of material properties (change of density, cracking, re-crystallisation)
  - ➢ Yield reduction, change of chemical behaviour

Of particular importance for

- Development of new solid targets and novel production routes
- Optimisation and up-scaling for efficient radionuclide production
- Material science related technology and fusion reactor research (for which ion beams can be a valid model)
- Accelerator based material research experiments

INTRODUCTION





Generally accessible

Knowledge of thermal properties

Difficult to investigate

Effective temperature / irradiation temperature

Heat dissipation under irradiation conditions

Irradiation based change in thermal conductivity

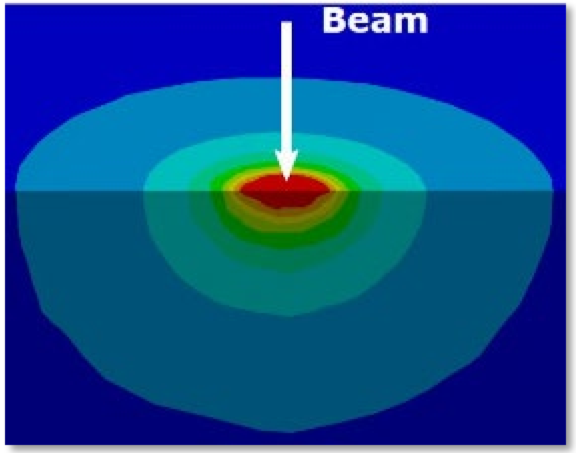
INTRODUCTION

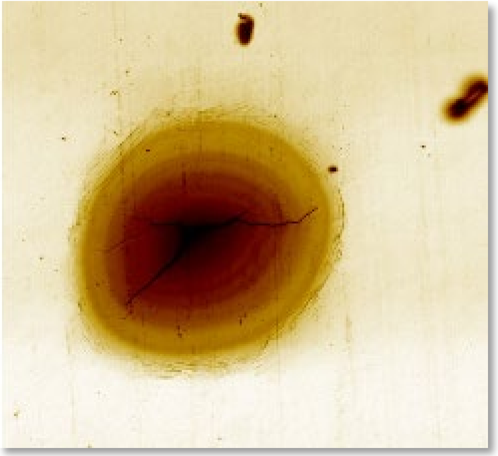
Computer Modelling of Heat Dissipation

Good theoretical models and computer codes exists for calculation of effective temperature in targets (e.g. ANSYS 14.1, COMSOL)

Potential problems under experimental conditions

- Bragg Peak problem (inhomogeneous heat generation within target)
- Different materials in target (holder)
- Contact surfaces, Geometry

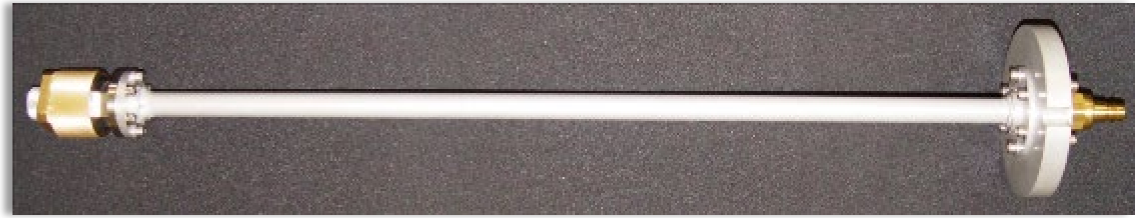




SET-UP OF EXPERIMENTAL MEASUREMENTS

Solid Target Station at Babycyclotron BC1710

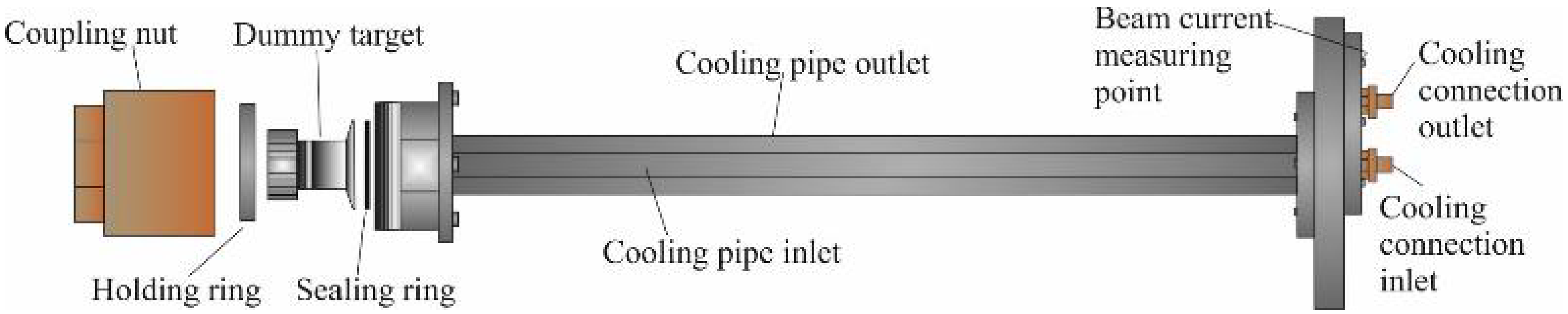
- “Medical” cyclotron (17 MeV protons) re-equipped with beam-line extension for solid target irradiation
- Water cooled lance for positioning of target close to adjustable collimator

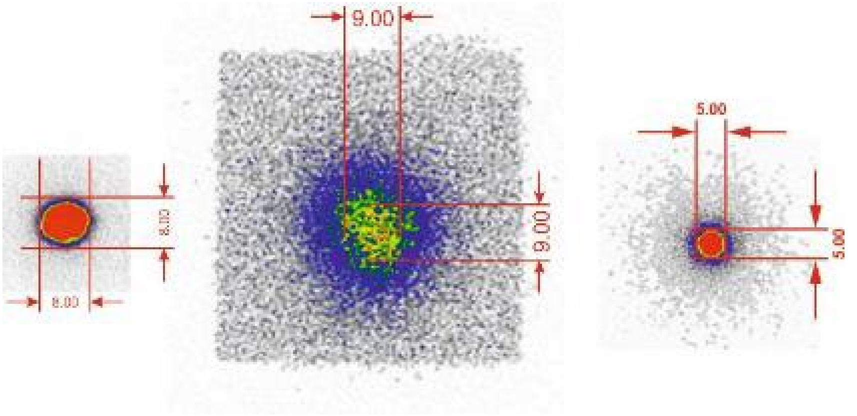


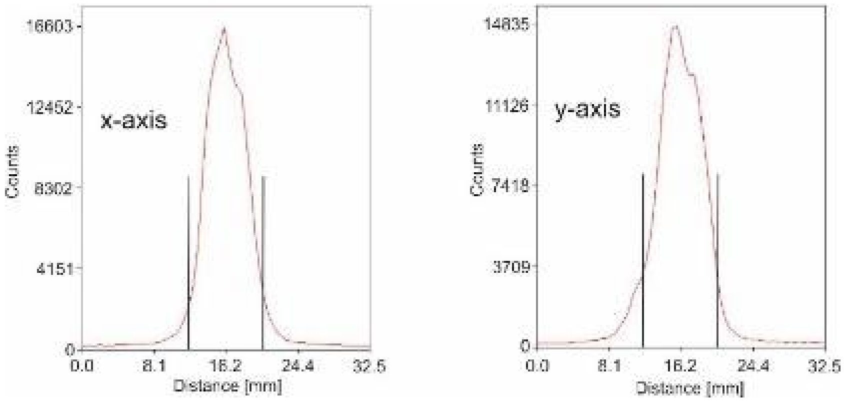
S. Spellerberg, B. Scholten, I. Spahn, W. Bolten, M. Holzgreve, H.H. Coenen, S.M. Qaim, Appl. Radiat. Isot. **104**, 104-112 (2015).

SET-UP OF EXPERIMENTAL MEASUREMENTS

Target Lance for Solid Target Irradiation







JÜLICH
Forschungszentrum

MEASUREMENT OF EFFECTIVE TEMPERATURE

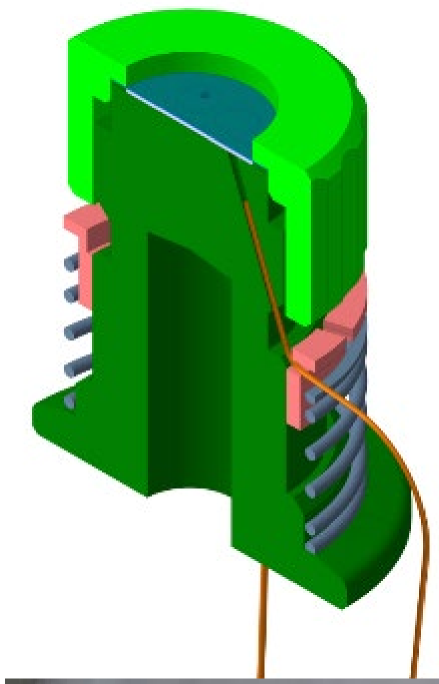
Temperature measurement at two positions and data compilation

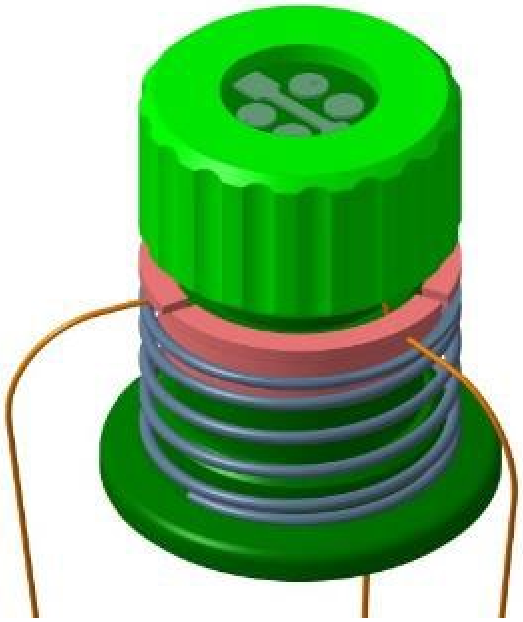
- Type N thermocouple (Pink)
  - Base - Nickel-Chrome-Silicon / Nickel-Silicon
  - Sheath – VXS
  - Temperature range – (-200°C to 1300°C)
  - Outer diameter – 0.5 mm
- Type K thermocouple (Green)
  - Base - Nickel-Chrome /Nickel
  - Sheath – Inconel600
  - Temperature range – (-200°C to 1200°C)
  - Outer diameter – 0.5 mm
- Data logger for temperature measurement and recording

Bild: Müller-IE, DLUI-HD

MEASUREMENT OF EFFECTIVE TEMPERATURE

Construction of Gauge Target

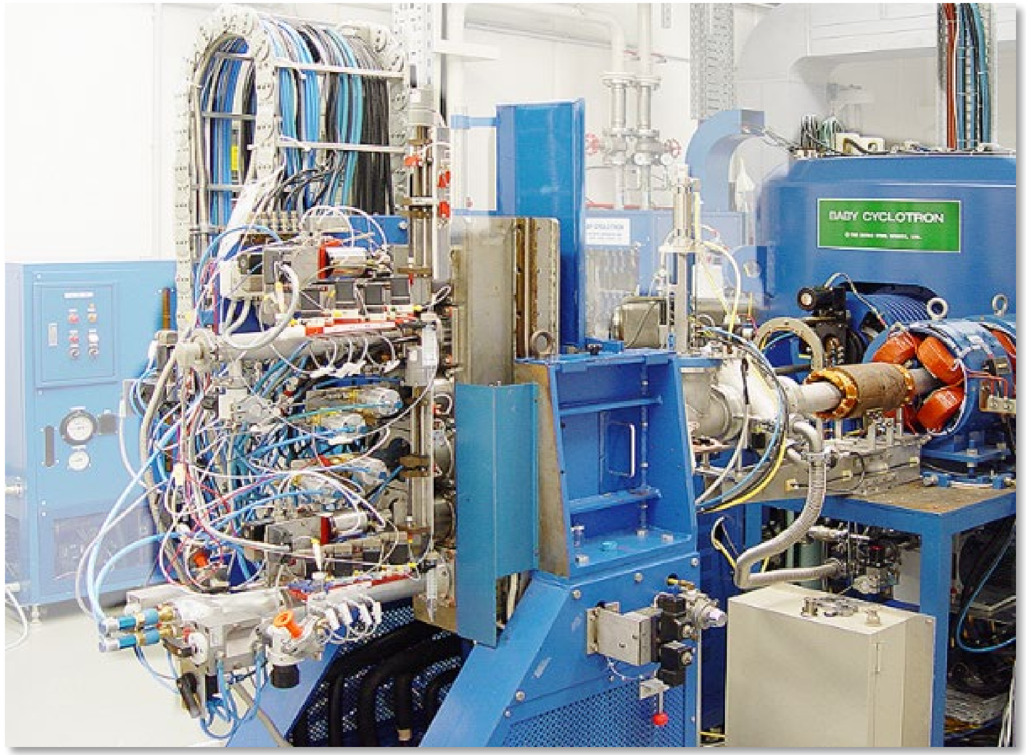




- 0.5 mm and 3 mm Tungsten targets
- Water cooled Copper holder

IRRADIATION EXPERIMENTS

- Irradiations with 16 MeV protons
- 1 to 3 hours with beam currents of 0.5 to 10 µA
- Data logger outside the cyclotron room at 10 m distance
- On-line temperature measurement with 8 °C water cooling active



THEORETICAL CALCULATION OF HEAT LOAD DURING PROTON IRRADIAION

ANSYS 14.1

- A finite element method based thermo-mechanical software
- Steady state thermal calculation (assuming constant ion current)

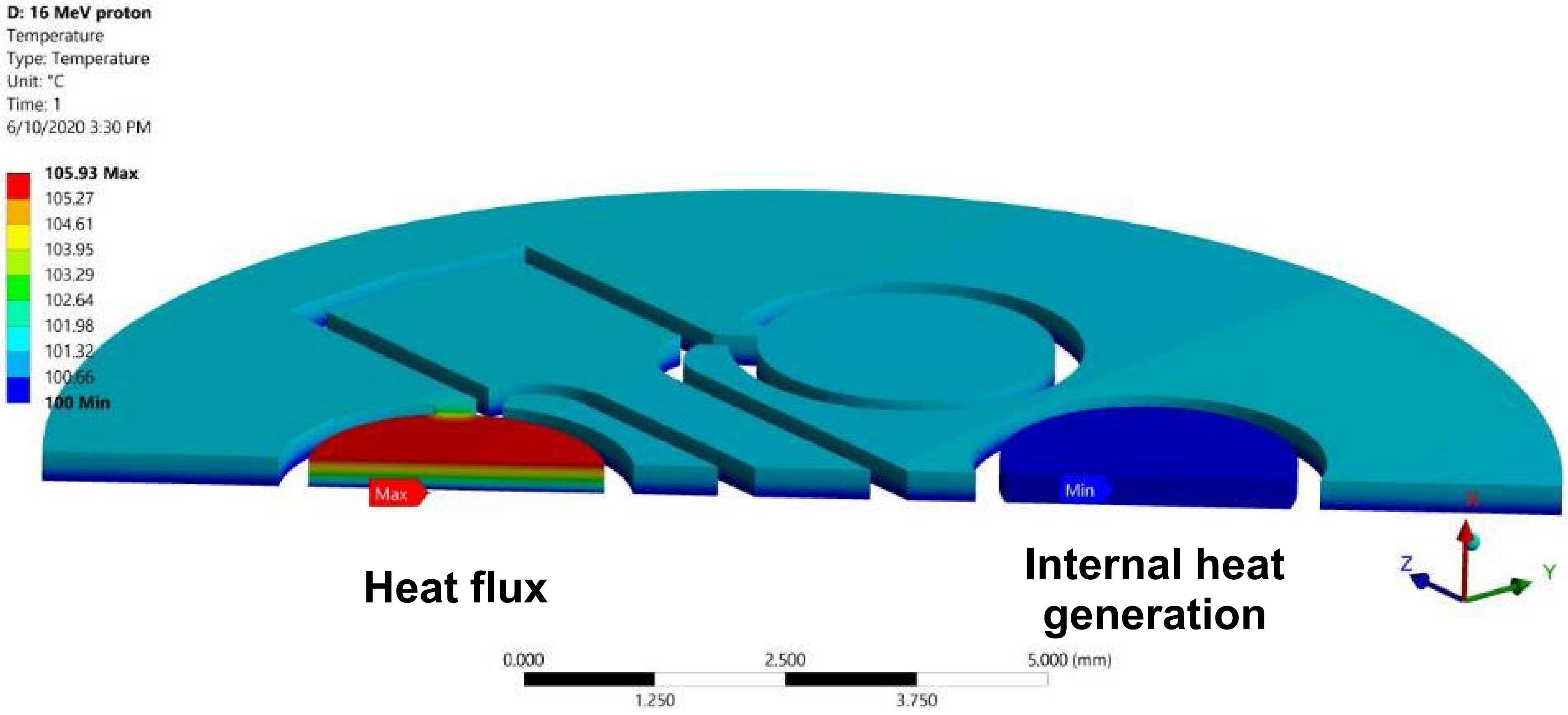
10 μA beam current
16 MeV proton energy
10 mm diameter

→

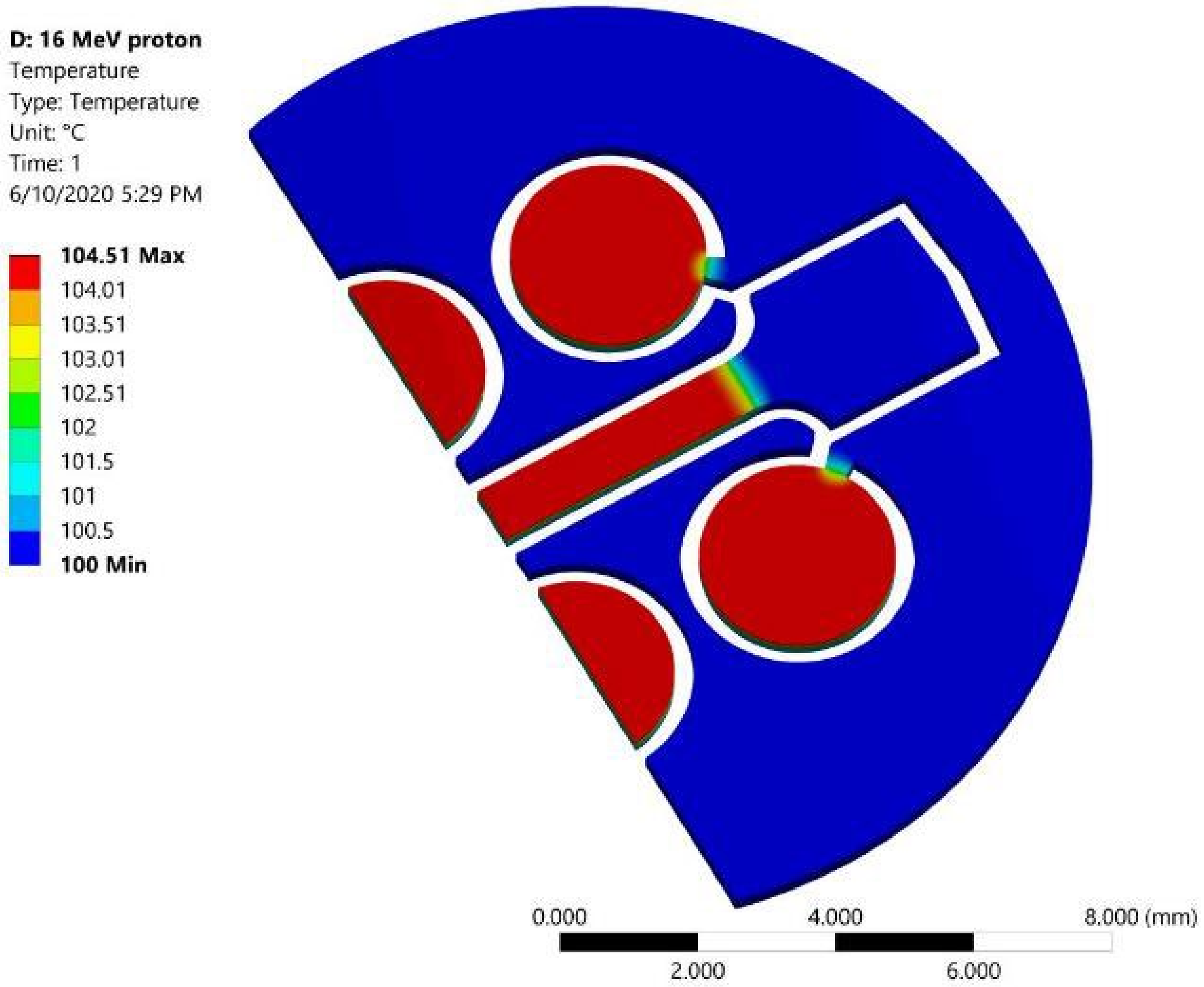
160 W heat load
(≈ 2 MW/m^2)

ANSYS CALCULATION OF HEAT LOAD IN W TARGET

Comparison of Different Methods of Heat Application



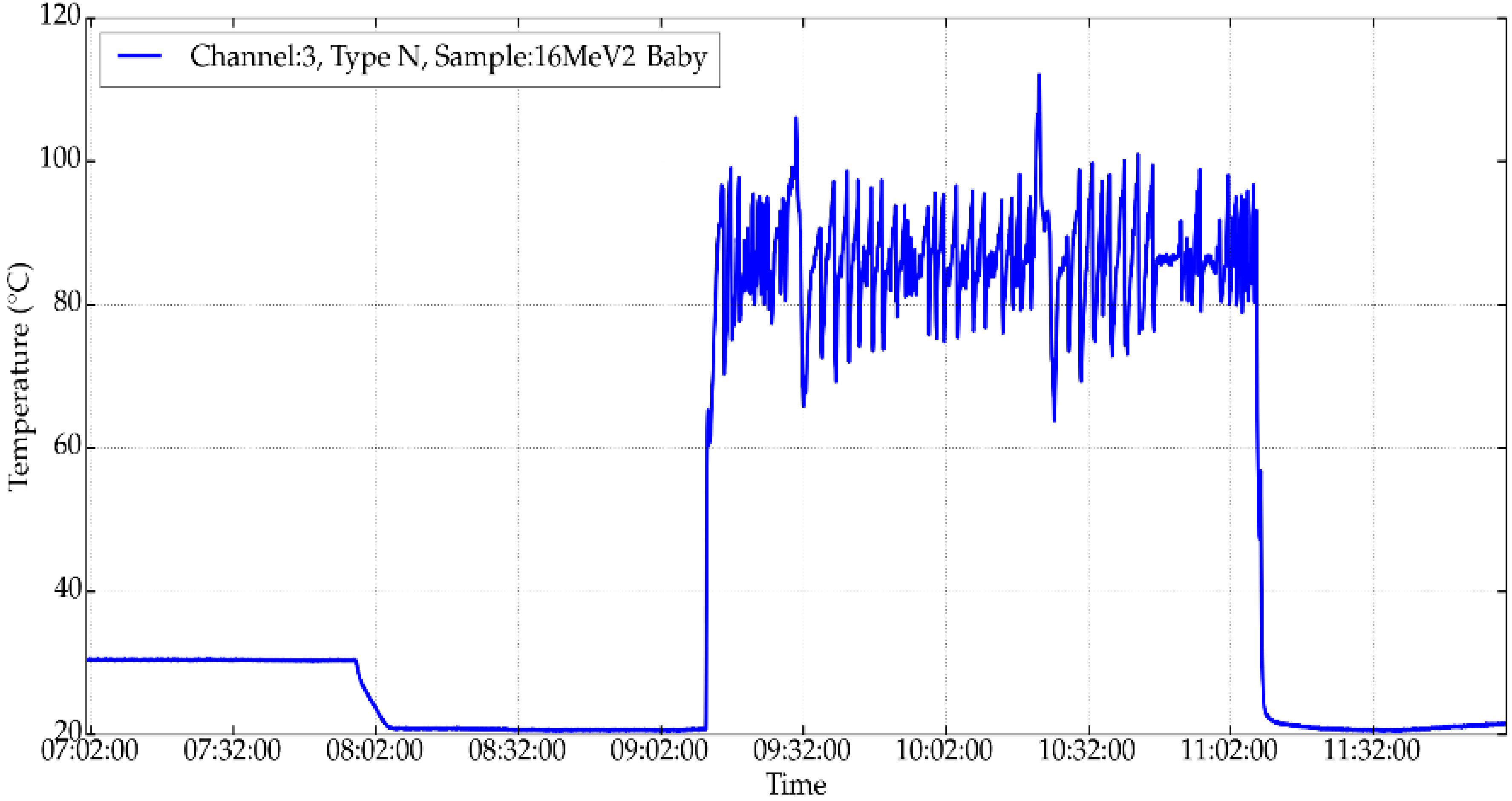
ANSYS CALCULATION OF HEAT LOAD IN W TARGET



- excellent thermal conductivity (thin sample) allow good dissipation (good thermal contact)

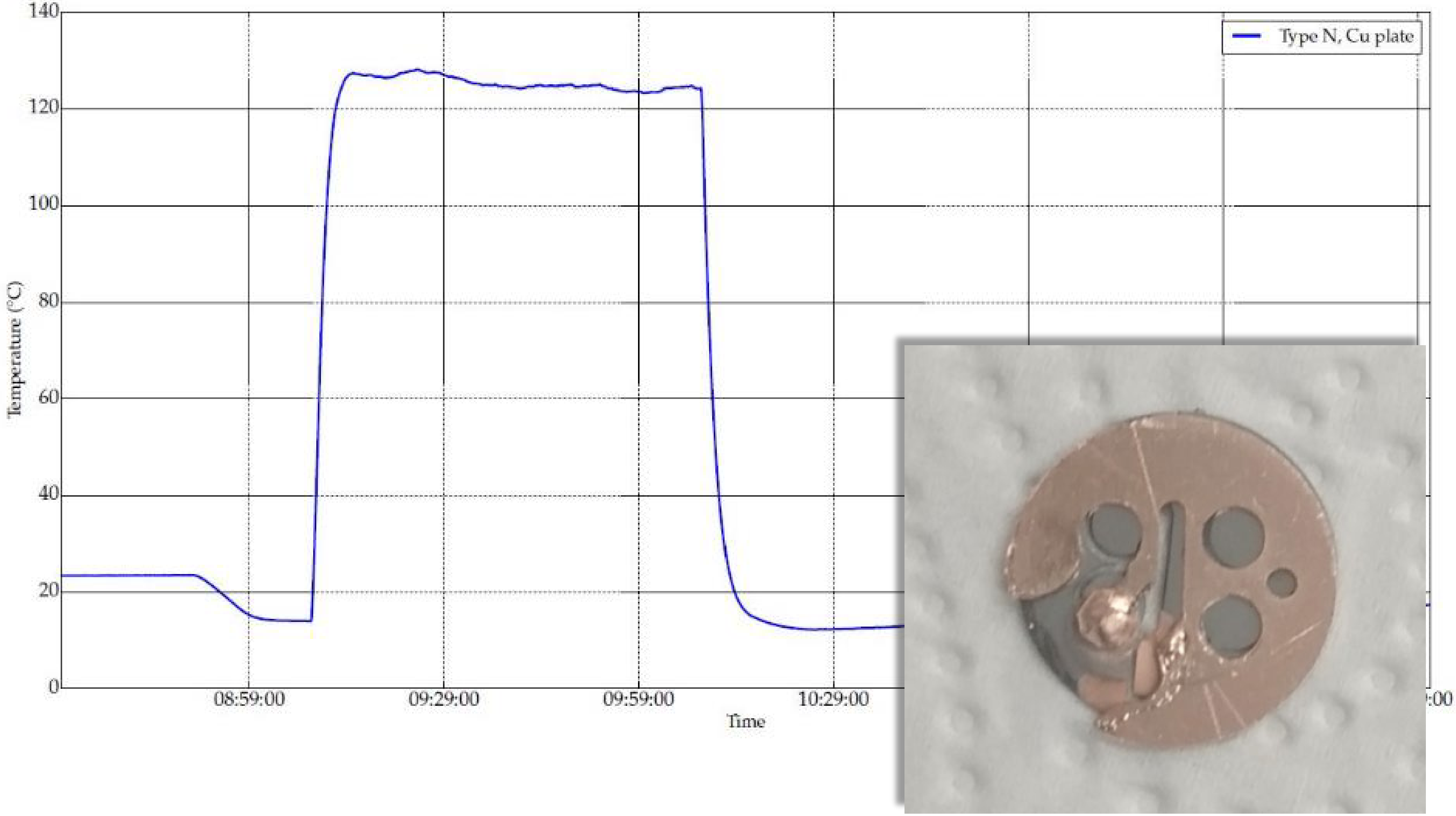
➢ 4°C difference between bottom and top of the sample

ON-LINE MEASUREMENT OF EFFECTIVE TEMPERATUR



1 hour irradiation with 3 µA beam current

ON-LINE MEASUREMENT OF EFFECTIVE TEMPERATUR



1 hour irradiation with 10 µA beam current

Loss of thermal contact.

SUMMARY

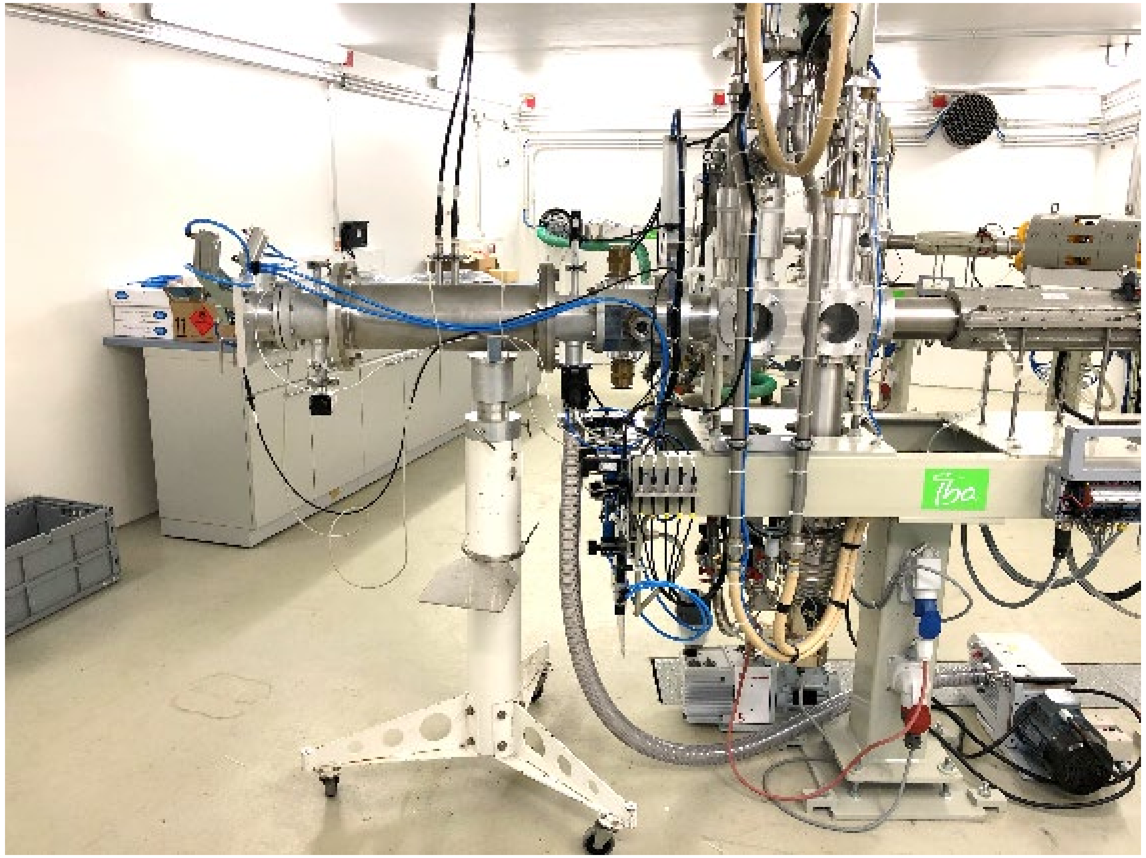
+ Implementing a two-point measurement system that allows on-line monitoring of effective temperature in a target stack
+ Thermocouple measurements agree with theoretical estimates
- Local hot spots cannot be captured by this method

□ Collection of experimental data in addition to theoretical for simulation of heat generation and dissipation

□ Way of optimising target set-ups and cooling systems

   ➢ Additional systematic measurements
   ➢ Adaption to new cyclotron and implementation of flexible reading point

OUTLOOK: ADAPTATION TO IBA CYCLONE 30XP



Beam current up to 350 μA

Protons: 15 – 30 MeV

Deuterons: 7 – 15 MeV

α-particles: 30 MeV

THANK YOU FOR YOUR ATTENTION !