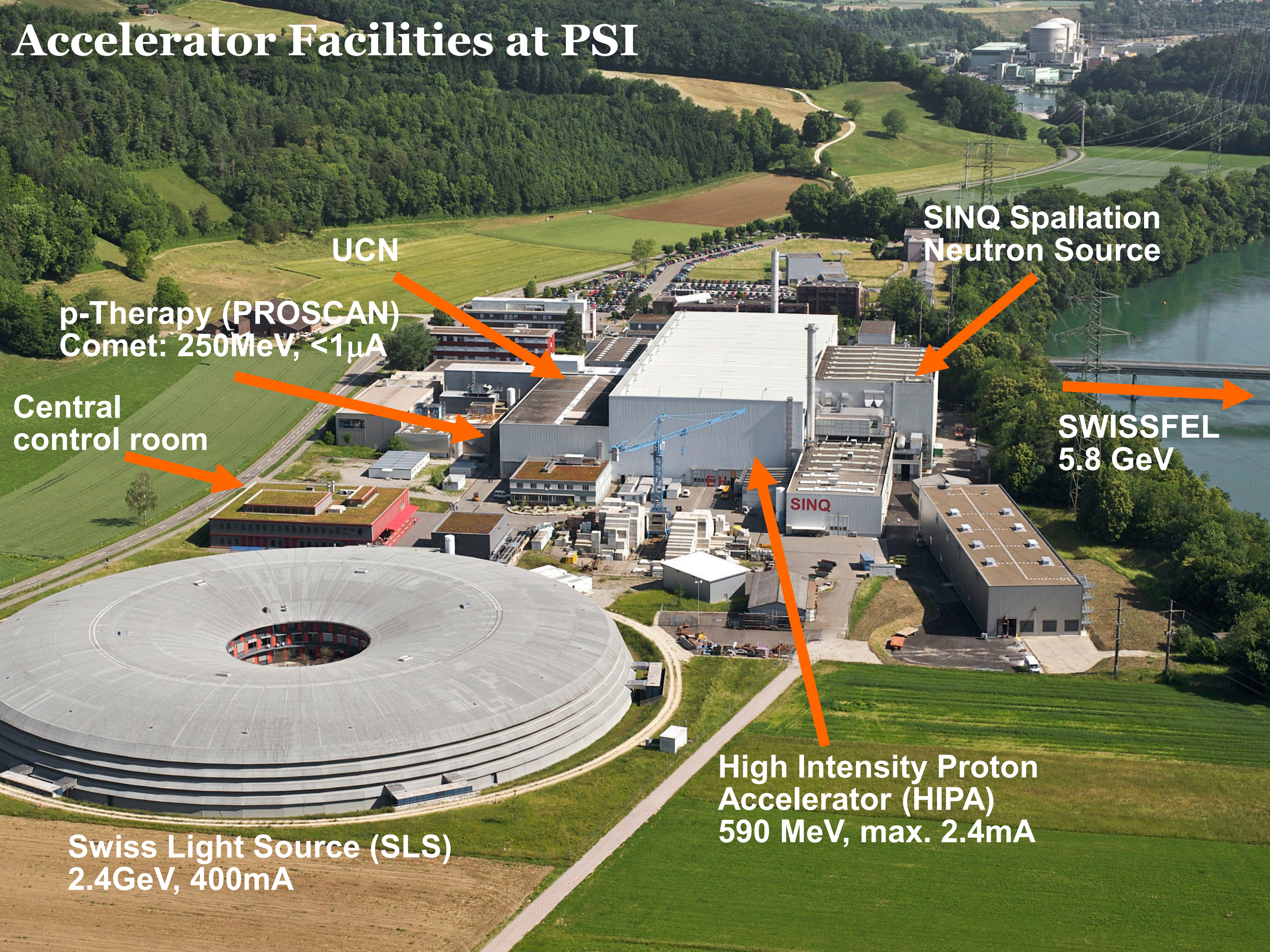
Daniela Kiselev :: ASA/GFA :: Paul Scherrer Institut
for the IMPACT collaboration

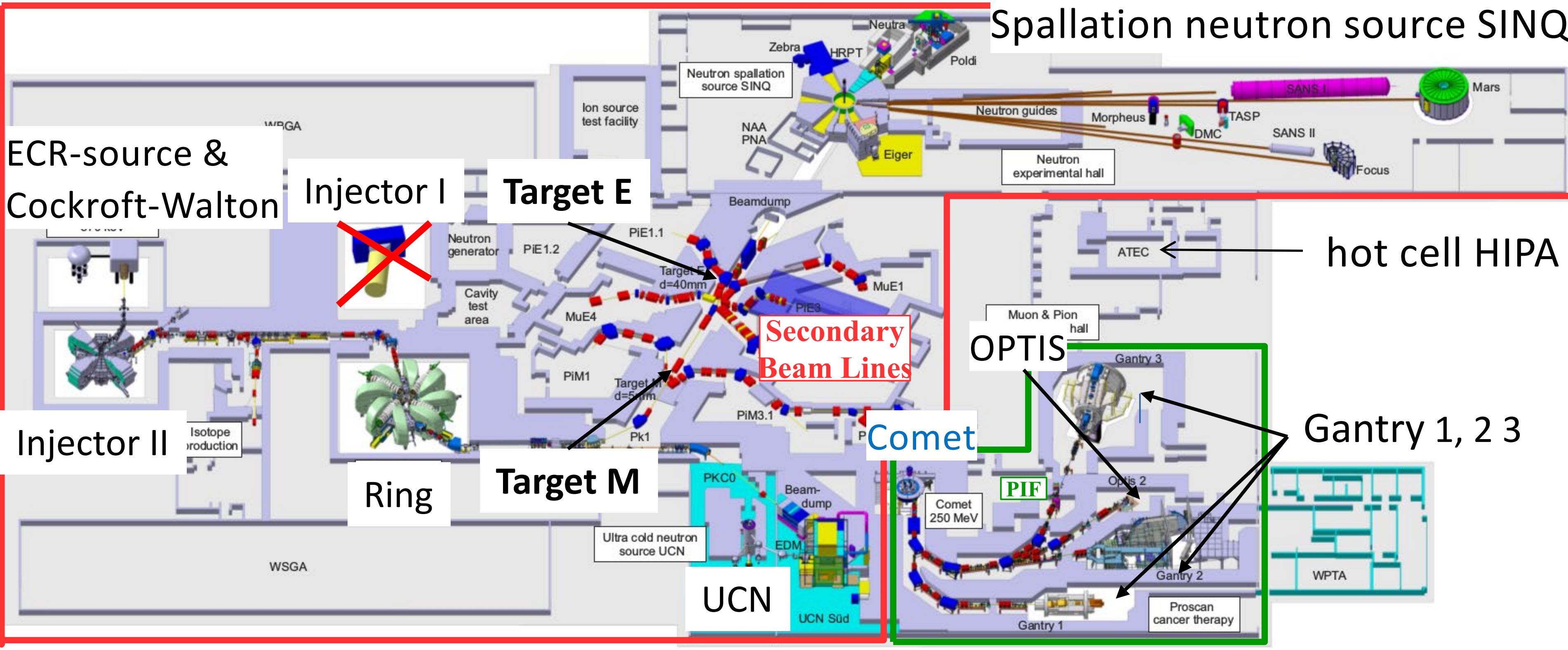
THE PSI MESON TARGET FACILITY AND ITS UPGRADE IMPACT-HIMB

INTDS 2022 - 30th World Conference of the International Nuclear Target Development Society

Accelerator Facilities at PSI



The PSI Proton Accelerator Facilities



HIPA (High Intensity Proton Accelerator)

- CW (50.63 MHz), 590 MeV,
- up to 2.4 mA(1.44 MW)
- **2 meson production targets**
- 7 secondary beam lines
- SINQ and UCN spallation source

PROSCAN (Proton therapy): since 2007

Comet: superconducting cyclotron

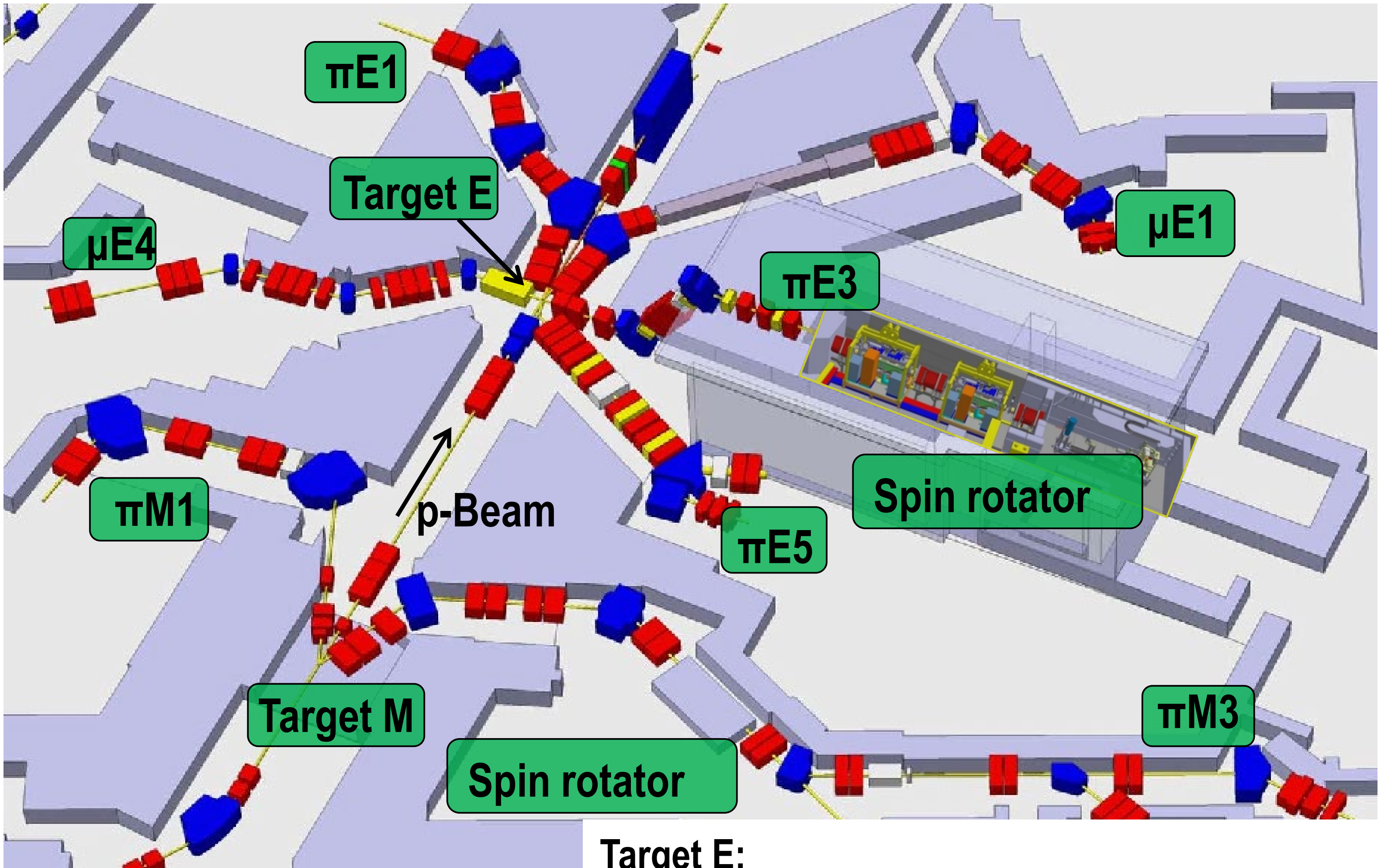
CW, 250 MeV, up to 1 μA protons

medical treatment:

3 Gantries, 1 Eye Cancer Treatment Station

Irradiation Station: PIF

μ/π Secondary Beam Lines



Target E:

πE1: 10 - 500 MeV/c High Intensity Pions und Muons

μE1: Polarized Muon Beam

πE3: 28MeV/c Surface polarized Muons

μE4: 30 - 100 MeV/c High Intensity Polarized Muons

πE5: 10 - 120 MeV/c High Intensity Muons

Target M:

πM1: 100-500 MeV/c Pions

πM3: 28 MeV/c Surface Muons

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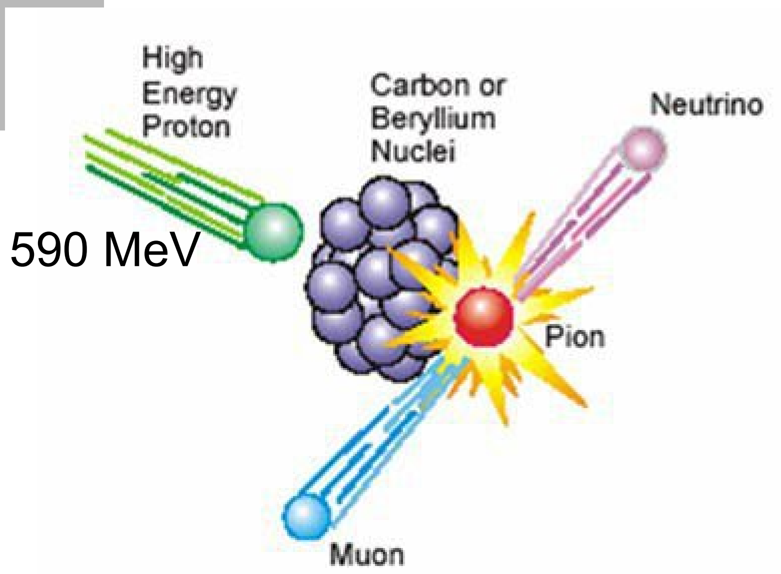
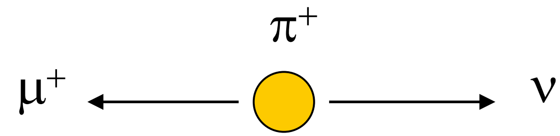
Meson production targets: Target E and Target M

Production of muons:



- Surface muons:

produced from pion decay at rest at the ***surface*** of the target (d < 1 mm)



- almost monochromatic:
  max. at 28 MeV/c (= 3.7 MeV)

- 100% polarized
  (spin in opposite direction to momentum)
  in reality: 90 – 95 % polarization due to pion decays in flight

World's highest intensity surface muon beams > 10^8 μ/s

- Low energy muons (LEM): 0.5 -30 keV
moderated by a cryogenic target in one of the beamlines (μE4)

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Challenges for meson production target E

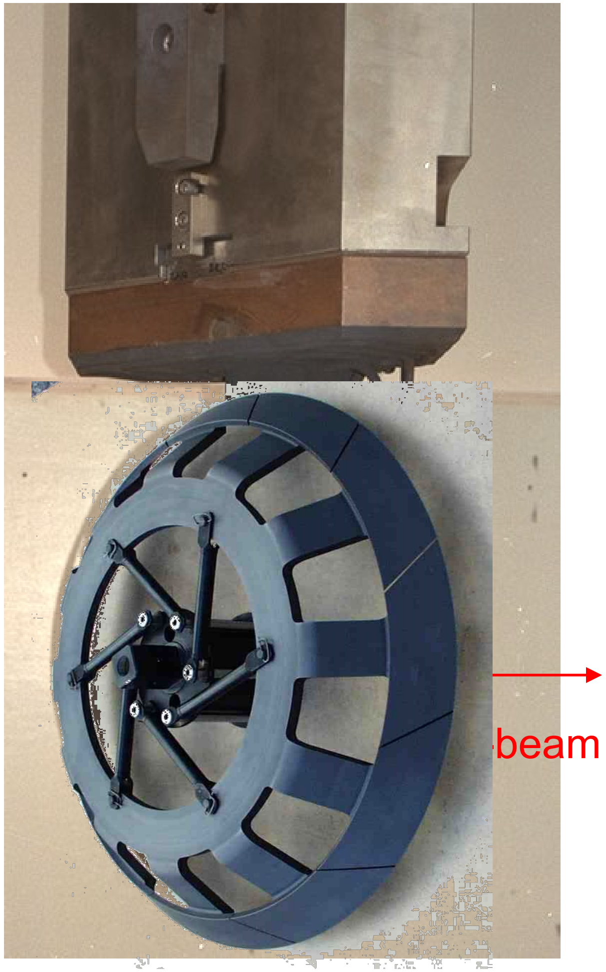
- Power deposition:

at 2.4 mA, 590 MeV protons ~ 50 kW on Target E
→ cooling
→ high temperature resistant material
→ thermal stress → deformation

Approach:

- polycrystalline graphite → isotropic properties
- spokes: allows thermal expansion of target cone
  hollow to avoid high temperature at bearing
- slits in wheel rim für thermal expansion
- cooling by radiation:
  - independent of conductivity (radiation damage!)
  - local shielding (Cu) is cooled by water
- distribute power:
  rotating wheel with 1 Hz → needs bearings

Target E



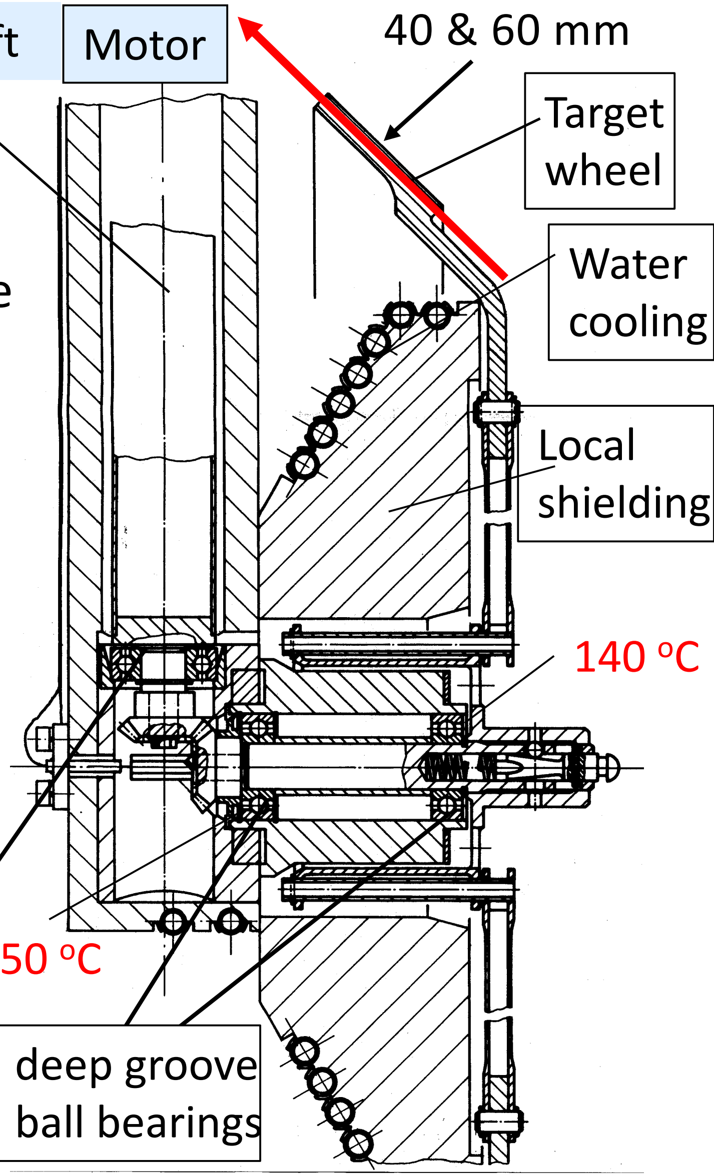
1700 K

Challenges for meson production targets

- Wheel deformation reduced by
  - polycrystalline graphite → isotropic properties
  - slits in wheel rim für thermal expansion
  - spokes: allows thermal expansion of target cone hollow to avoid high temperature at bearing

1700 K

12 segments with 1 mm slit



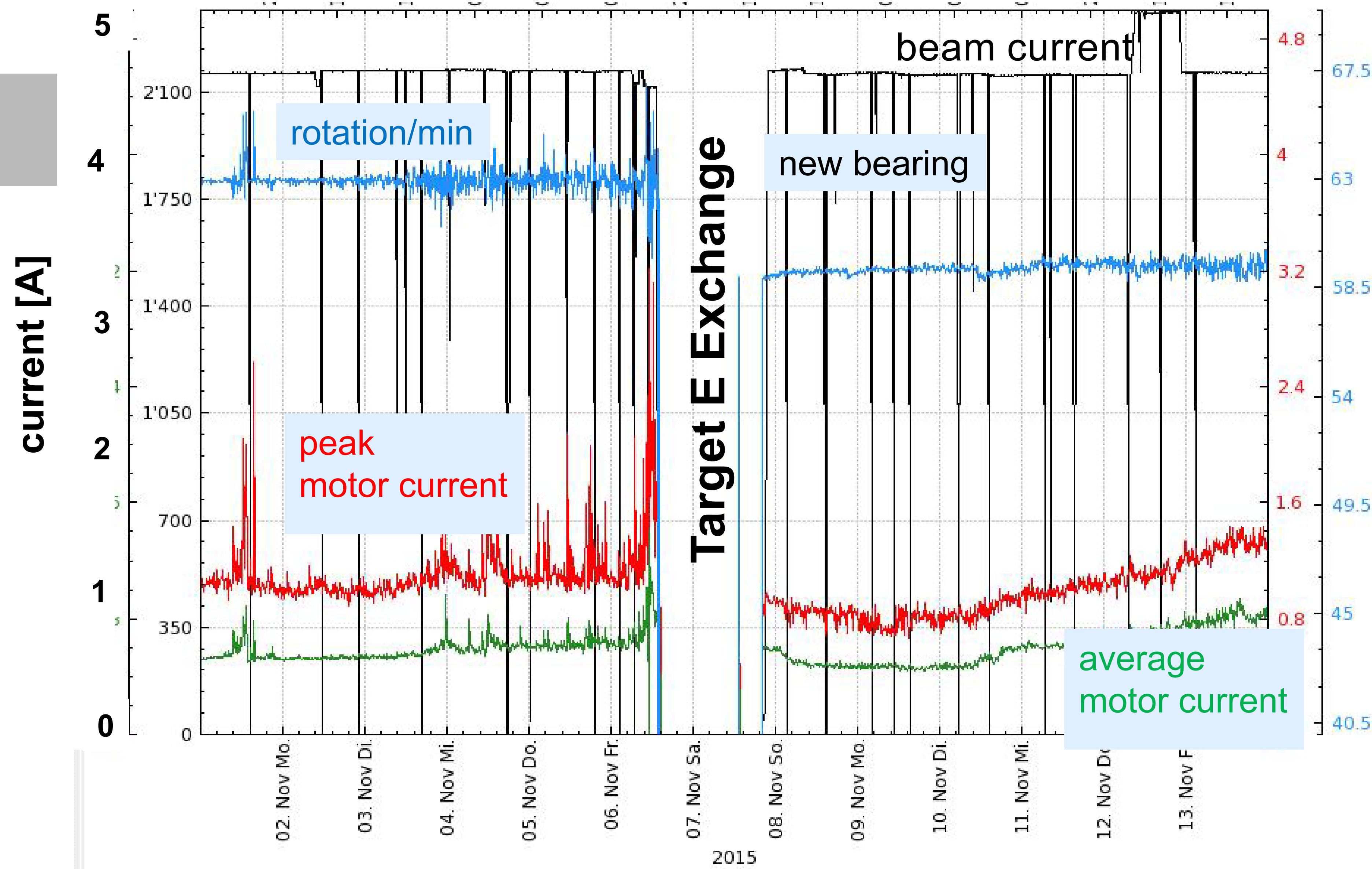
- Motor:

2.5 m above the beam line

→Functioning is not affected by irradiation

→ life time ~ 5 – 8 years

Monitoring of the motor current



Exchange of the high-activated components

Exchange flask:

- 45 t, shielded with 40 cm steel
- remotely operated
- used for > 15 components

Constraint for insert:
610mm x 480mm (inner cross section)

"Bridge":

- contains contamination protection
- door to close lifting hole
- sticks for positioning of the flask

Working platform:

- ~ 2m above beamline, shielded with steel
- Accessible after removing 3 – 4 m of concrete

For capture-solenoid:

Much simpler exchange flask planned
but with large cross section (1000mm x 800mm)

 Seite 9

Critical components: Bearings

- Ball bearings:

No grease as lubrication! → brittle due to hard irradiation
so called radiation hard grease does not help → proofed

in use since ~2002:

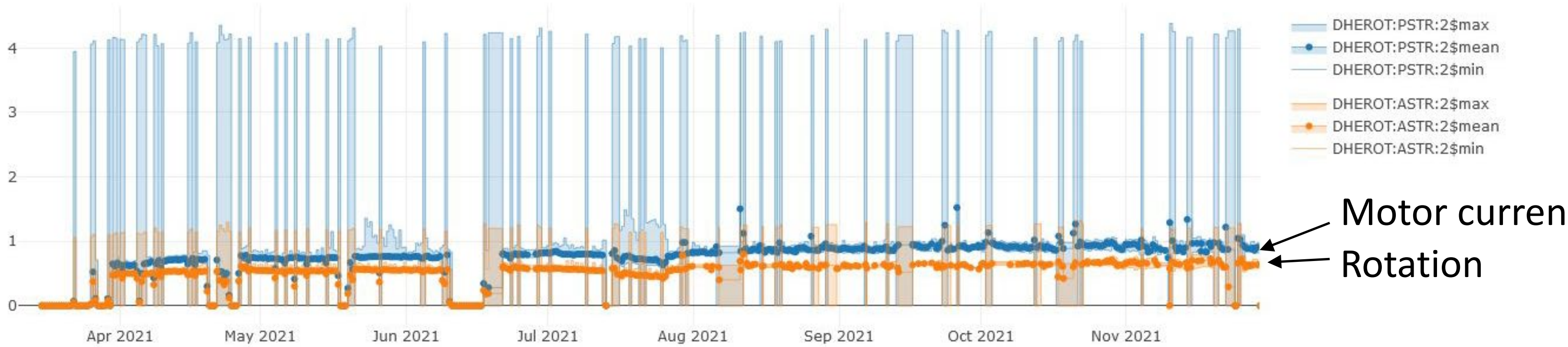
Balls Si_3N_4, GMN, Germany
Coating: MoS_2, Ag for ring & cage
1 -2 x exchange/year
←→ Graphite wheel lasts much longer: ~ 4Years
(39 Ah record)

in test this year:

Shun Makimura (JPARC)

Balls stainless steel + WS_2 blocks
Koyo, Japan
Test (without radiation): > 420 days
<u>In beam 2021, no change!</u>
(Motor current very smooth and stable)

Motor current with KOYO bearings 2021



- very smooth and flat motor current
- no degradation visible
- exchanged in April 2022 (before run period 2022)

  → could probably be in operation for much longer time

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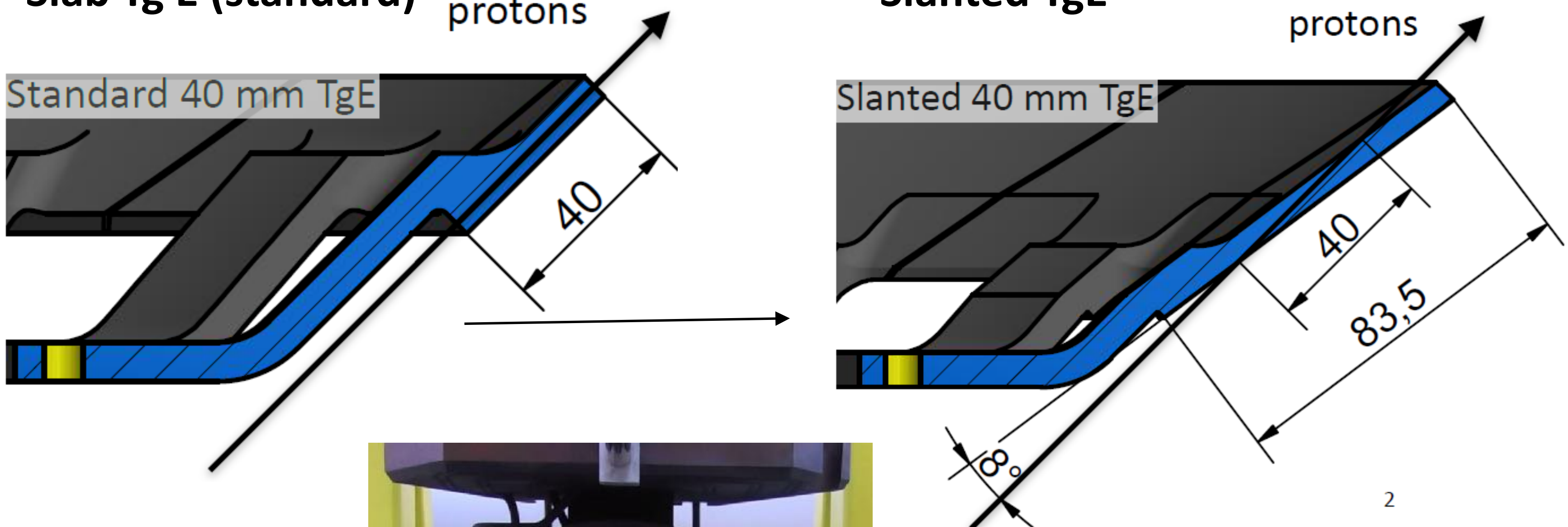
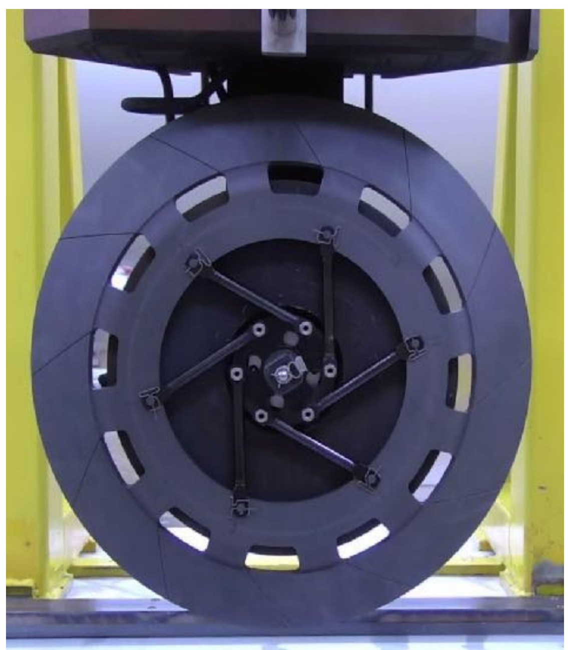
Target development II: Slanted Type

Slab Tg E (standard) **Slanted TgE**





- Significant increase of surface muon rate due to larger surface
- 30 – 50 % increase in surface muon rate measured (and simulated

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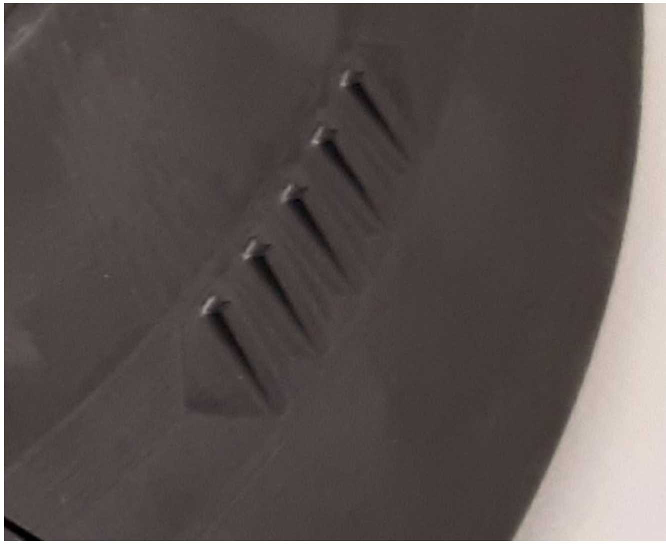
Slanted target type with grooves

Grooves:
left-right asymmetry in thickness



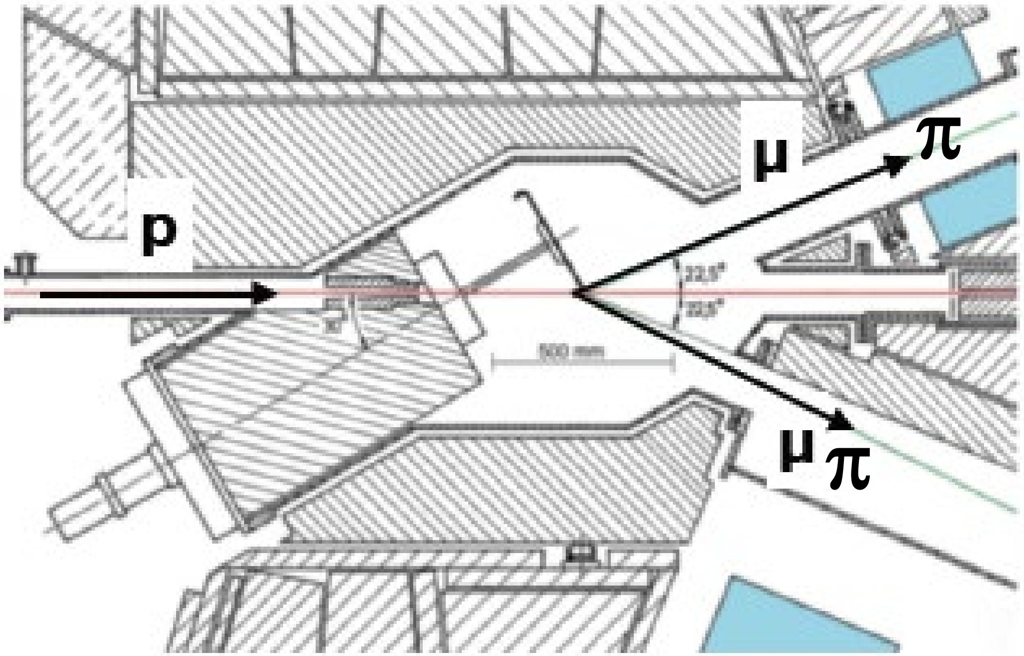
Idea:

Monitoring of the beam position according to the modulation in current transmission.

Analysis: via FFT in progress

First time in beam since May 2022 (equipped with KOYO bearings)

Present TgM station (built 1985)



PiM1

particle physics

PiM3

μSR (GPS, FLAME)

10^7 μ^+/s

nowadays surface muons needed

Beamlines under 22.5°

→ optimized for high-momentum π > 100 MeV/c,

@ 350 MeV/c: π+: 2x10^8 /(s mA)

Target: graphite

2 mm thick rim

→ effective 5 mm (due to angle),

cooled by thermal conduction

no problems with bearings, since well shielded!

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IMPACT = HIMB & TATTOOS

Isotope and Muon Production with advanced cyclotron and target technology

R, Eichler, D. Kiselev, A. Knecht, N. van der Meulen, A. Koschik

HIMB: High-Intensity Muon Beams is part of IMPACT

Surface muons (~ 28 MeV/c) rates of 10^{10}/s for particle physics and μSR (factor ~ 100 more than presently)

TATTOOS: Targeted Alpha Tumour Therapy and Other Oncological Solutions

Producing radioisotopes with 590 MeV protons (100 μA) for cancer treatment & diagnostics in quantities needed for clinical studies

Aim: Support by the Swiss Roadmap of Infrastructure by 60 MCHF

Jan. 2022 Conceptional Design Report (CDR)

July 2022 Triple-A rating in the scientific evaluation

Dec. 2022 Evaluation of feasibility & finances → Swiss Roadmap of Infrastructure 2023

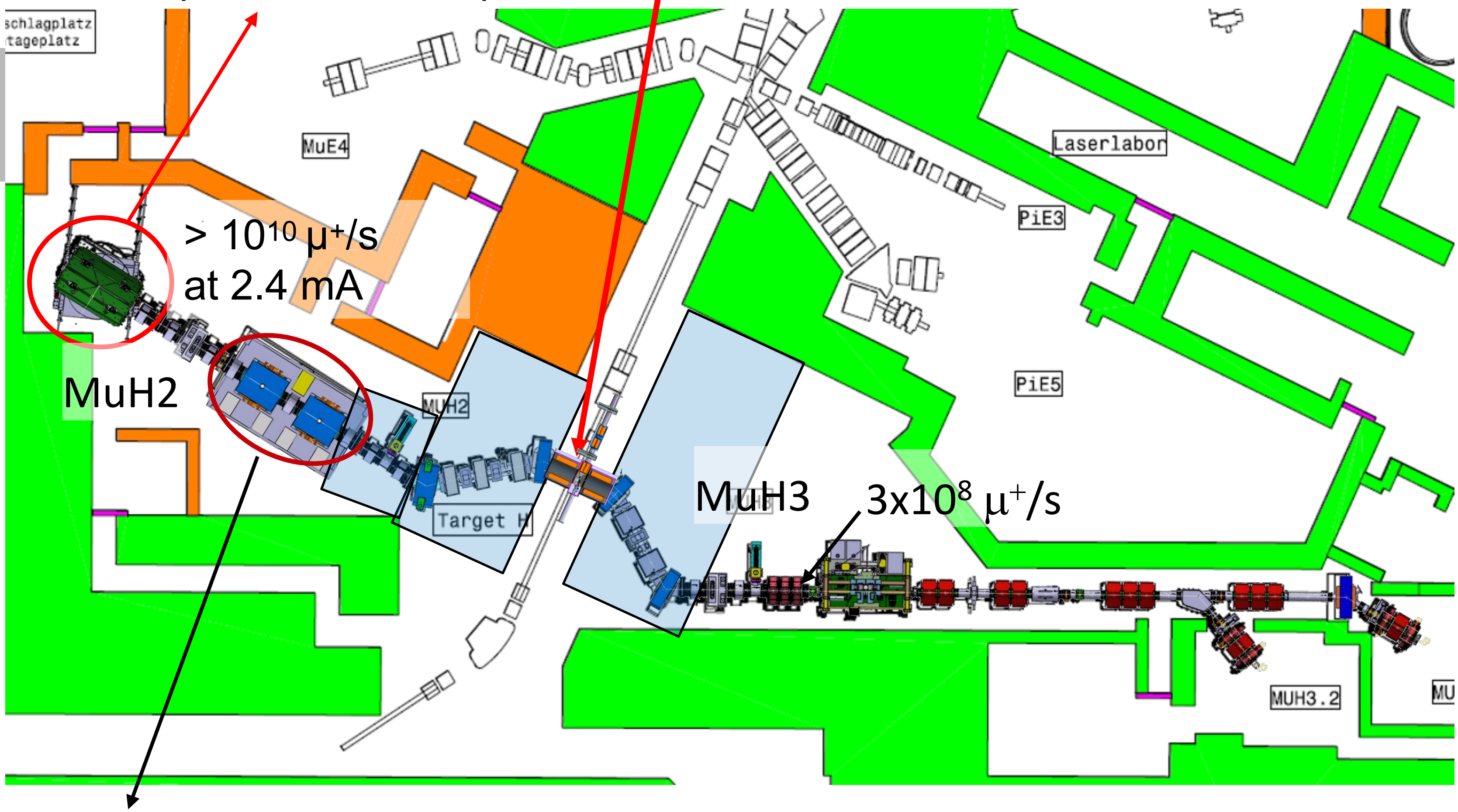
End 2024 Final decision→ Start Installation: 2027

Budget: 77 MCHF (10 MCHF PSI , 7 MCHF Third-Part money)

CDR https://www.dora.lib4ri.ch/psi/islandora/object/psi%3A41209

New Target H station and beamlines

exp. detector setup



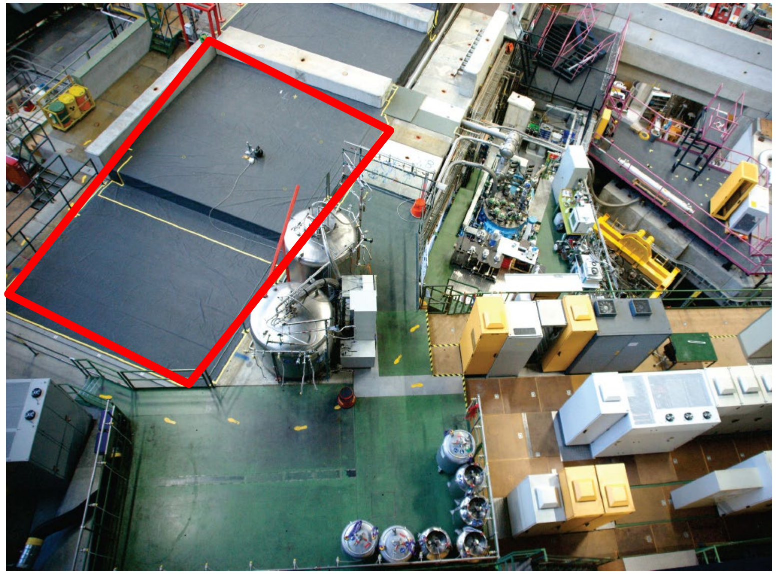
2 separators for momentum and particle selection

MuH2: particle physics

MuH3: material science

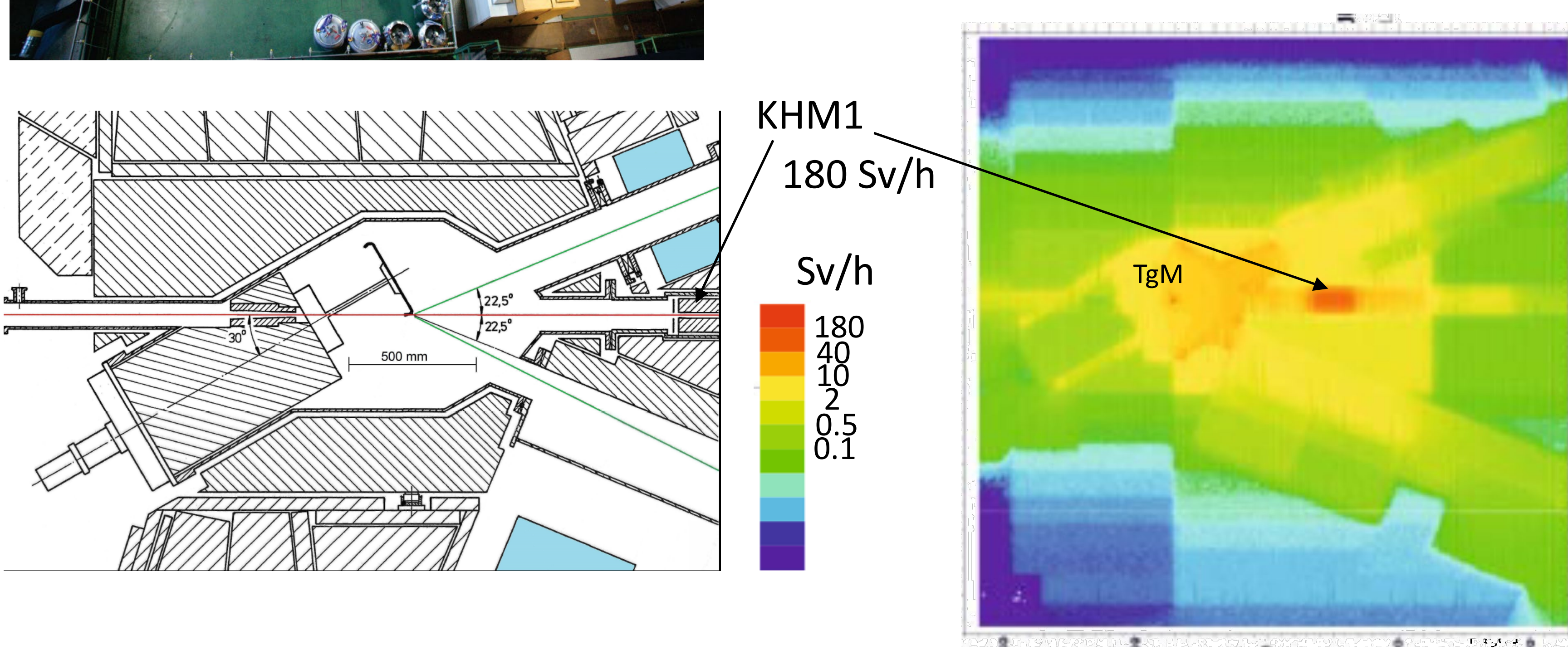
- Shielding is under calculation (MCNP simulation)

Target M Region in WEHA



Rückbaukosten: Fokus auf Targetblock

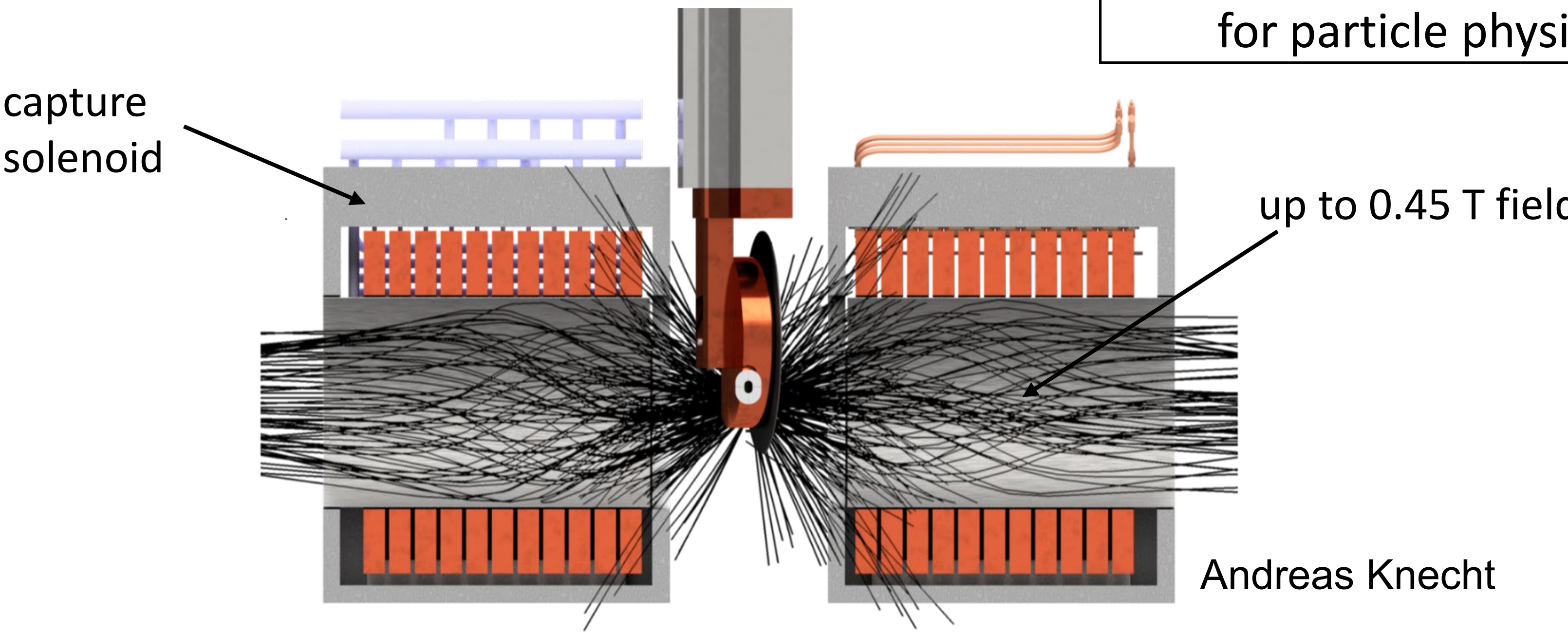
Abbau: 2027



Concept for new target station HIMB at TgM

HIMB = High-Intensity Muon Beams

goal: 10^{10} surface muons/s
for particle physics



- short wide solenoids with large fringing field in high radiation area
- close distance to the target +/- 250 mm
- thicker target (20 mm instead of 5 mm) → higher losses & activation
- slanted target type
  - large rim (> 100 mm)
  - large rotating wheel for cooling
  - small angle relative to beam
- beamline optimized for large transmission of surface muons & small losses of the proton beam

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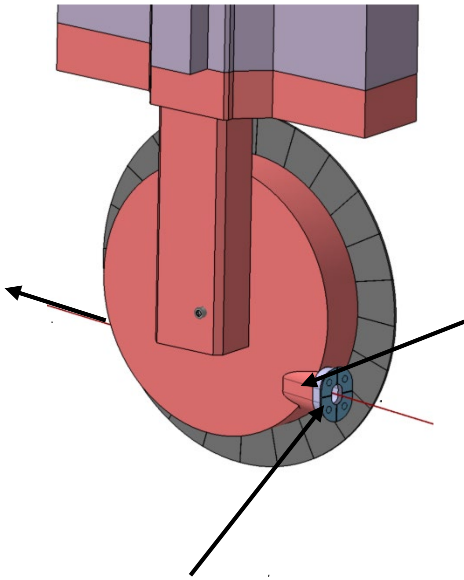
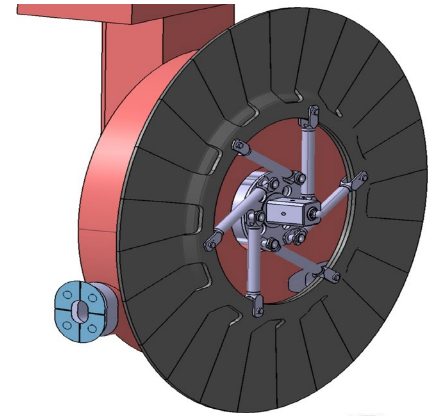
Target H insert



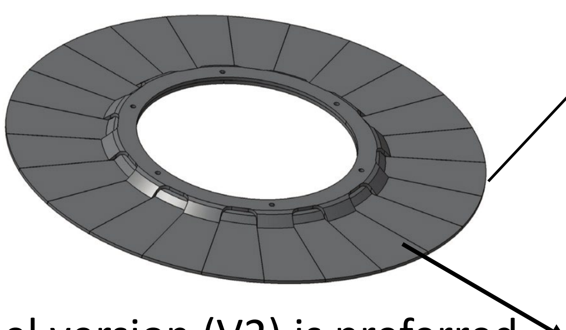
design & rotation mechanism similar to target E

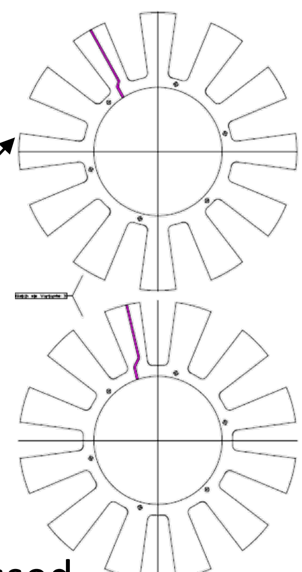


tungsten collimator inside

- isolated for current measurement
  → fast interlock
- 4-segment aperture for centring
  → fast interlock

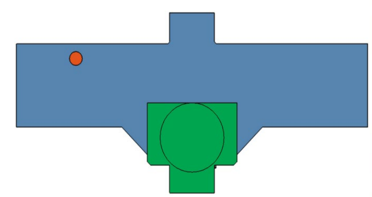
4-segment aperture

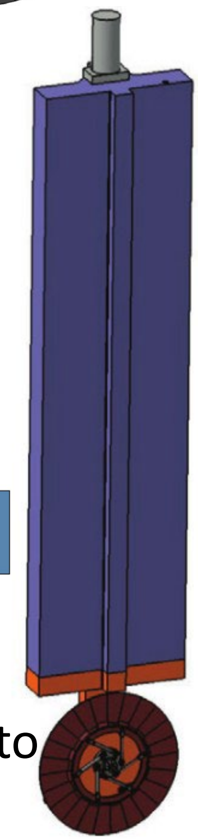




ANSYS simulation for temp. distr. & stress look promising

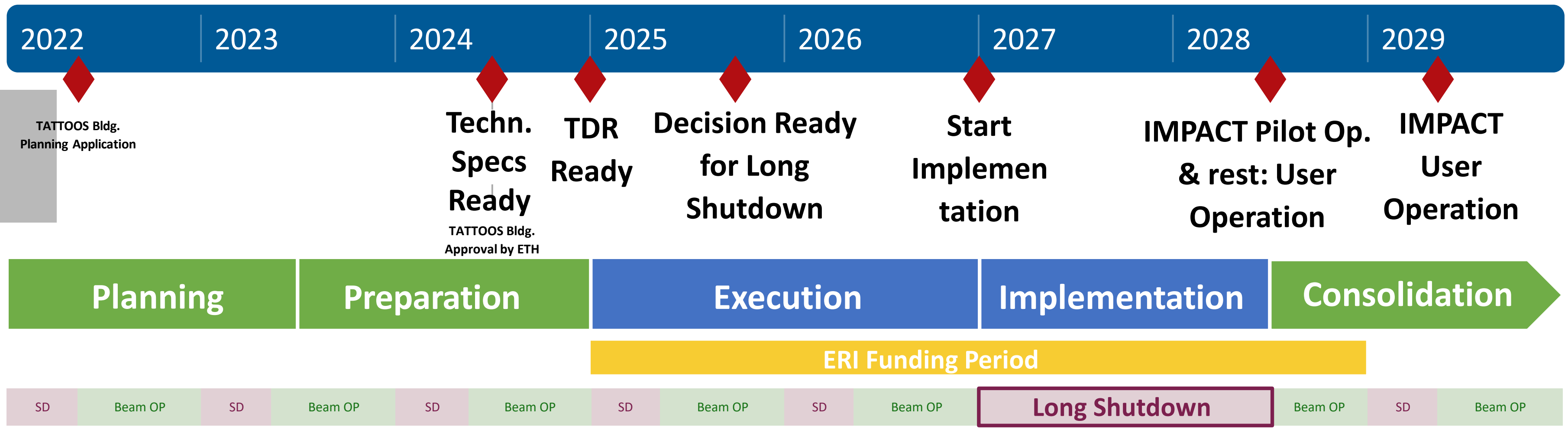
2 wheel version (V2) is preferred.
Reason: Wheels are flat and thin.
Graphite is more stable,
because not so many layers are crossed.





small insert due to space limitations

Time schedule



~ 100 people are involved

9 subprojects and 35 working groups

Conceptional Design Report

https://www.dora.lib4ri.ch/psi/islandora/object/psi%3A41209

Summary

- Challenges for the muon target at 50 kW:
  - Cooling, Deformation, Bearings suffer in the high irradiation area!
- KOYO bearings from JPARC worked very well for 2021 run period
- Slanted target type increases muon surface rate by up to 50 %
- Combined groove (for centering) and slanted target is ins use for the first time.
- Conceptual study HIMB for Swiss Roadmap aims for 10^{10} surface-μ/s in particle physics areal

  Good bearings are particularly important for HIMB to avoid doubling the downtime.

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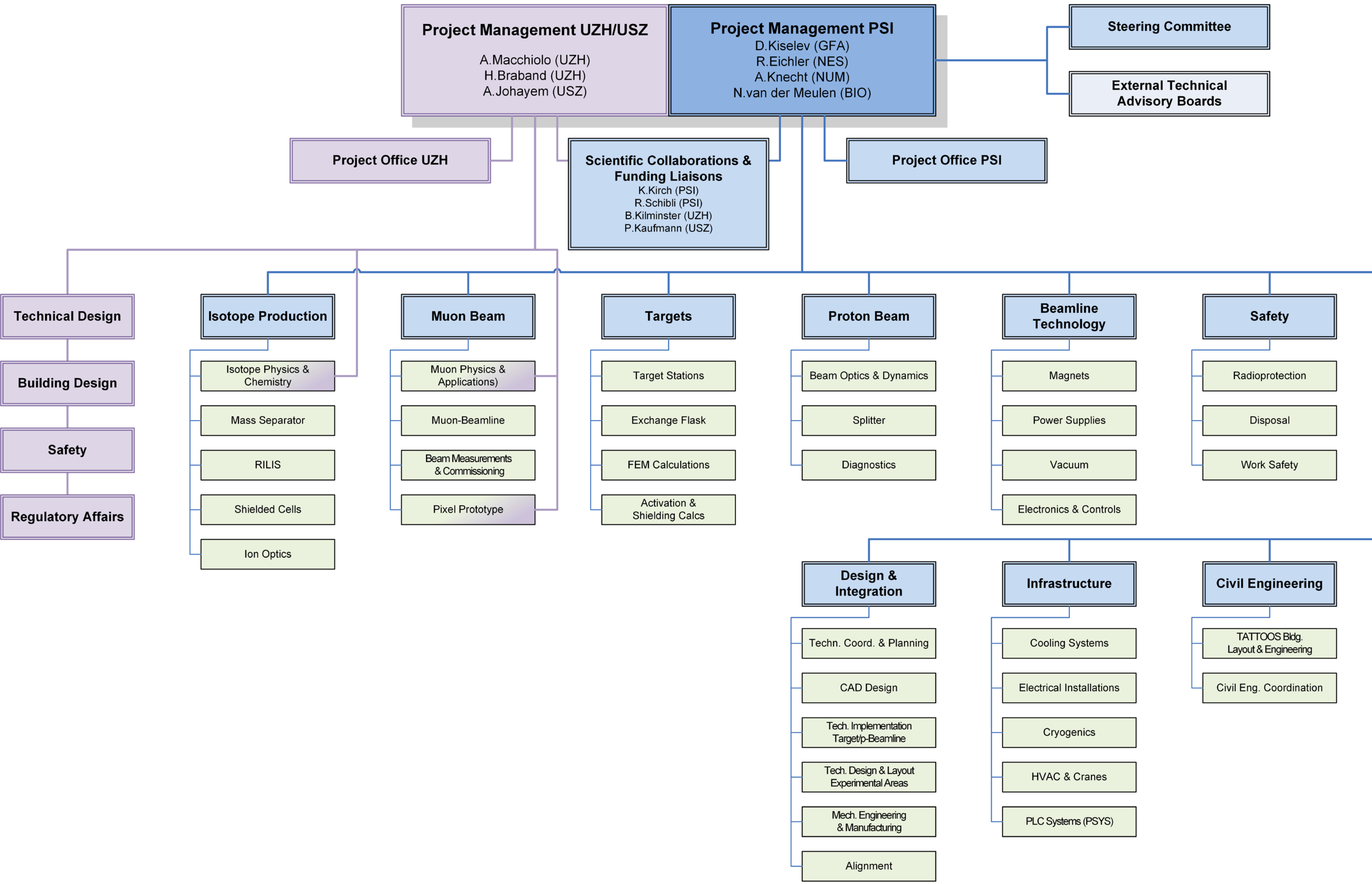
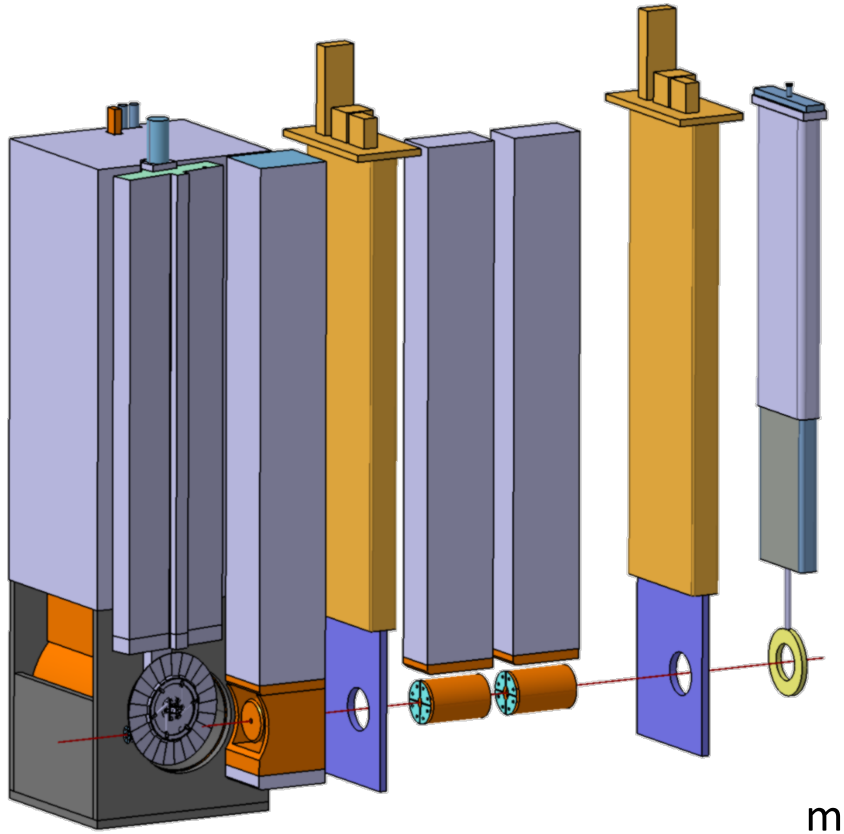
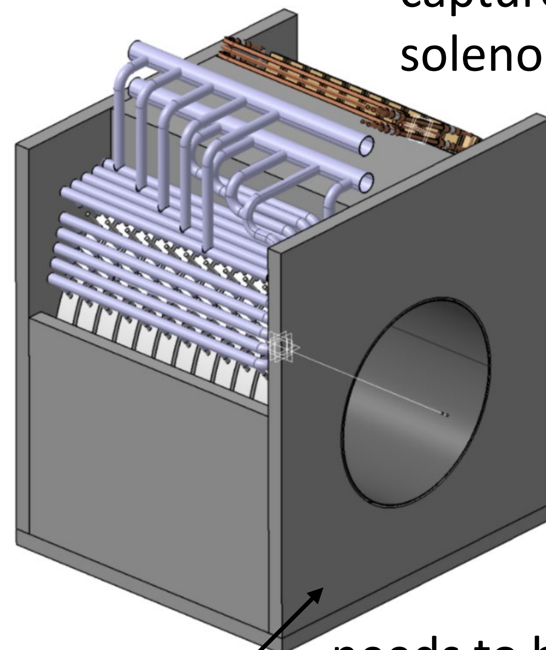
Organisation IMPACT



Side view of beamline components



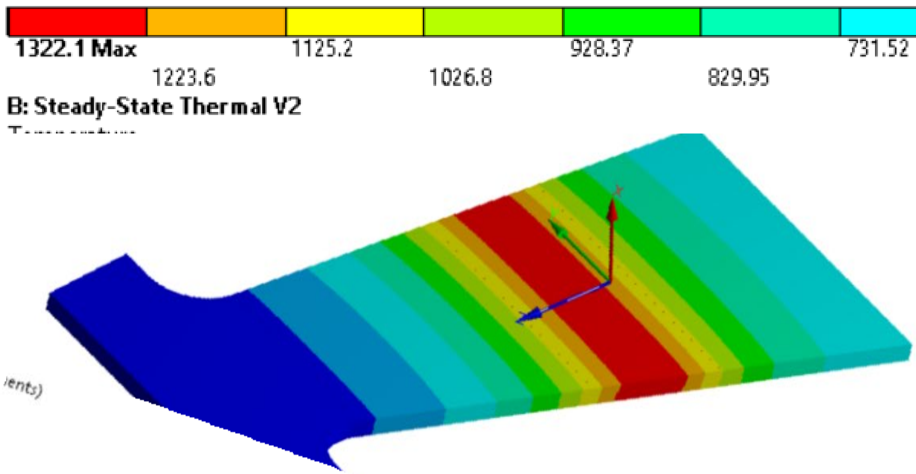


mirror plate (40 mm iron):
- to reduce magnetic field at beamline
- challenge for cooling

- Target and 2 capture solenoids in 1 vacuum chamber:
  no space for additional wall or pillow seal keeping +/- 250 mm from beamline
- all vacuum chambers are cooled by water
- exchange of solenoid in vertical direction with (new) exchange flask

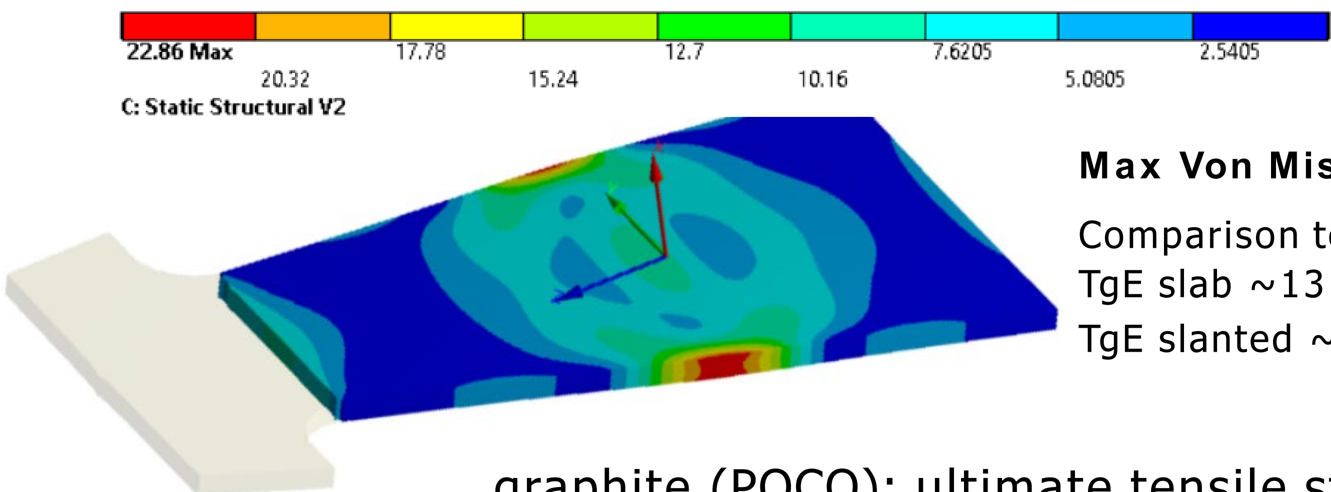
Rim Temperature and Stress Distribution

Simplified geometry of V2: 1 segment, straight movement through the beam



Max Temp: ~ 1322 °C @ 2.5 mA

Comparison to TgE (40 mm thick) :
TgE slab : 1536 °C
TgE (slanted): 1459 °C



Max Von Mises Stress: ~ 23 MPa

Comparison to TgE (40 mm thick) :
TgE slab ~13 MPa
TgE slanted ~26 MPa

graphite (POCO): ultimate tensile stress: 34- 69 MPa

Raffaello Sobbia