PAUL SCHERRER INSTITUT PSI

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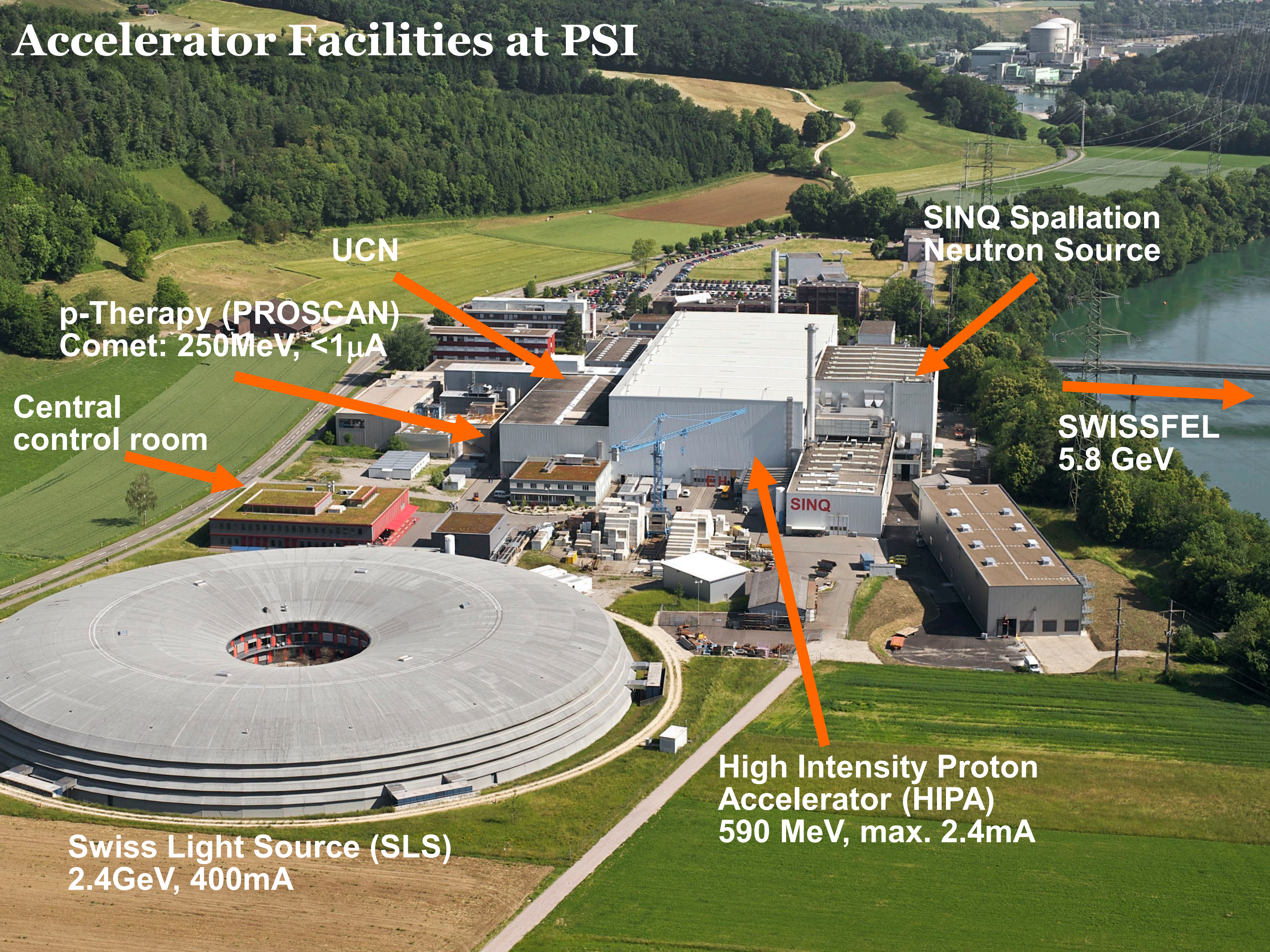
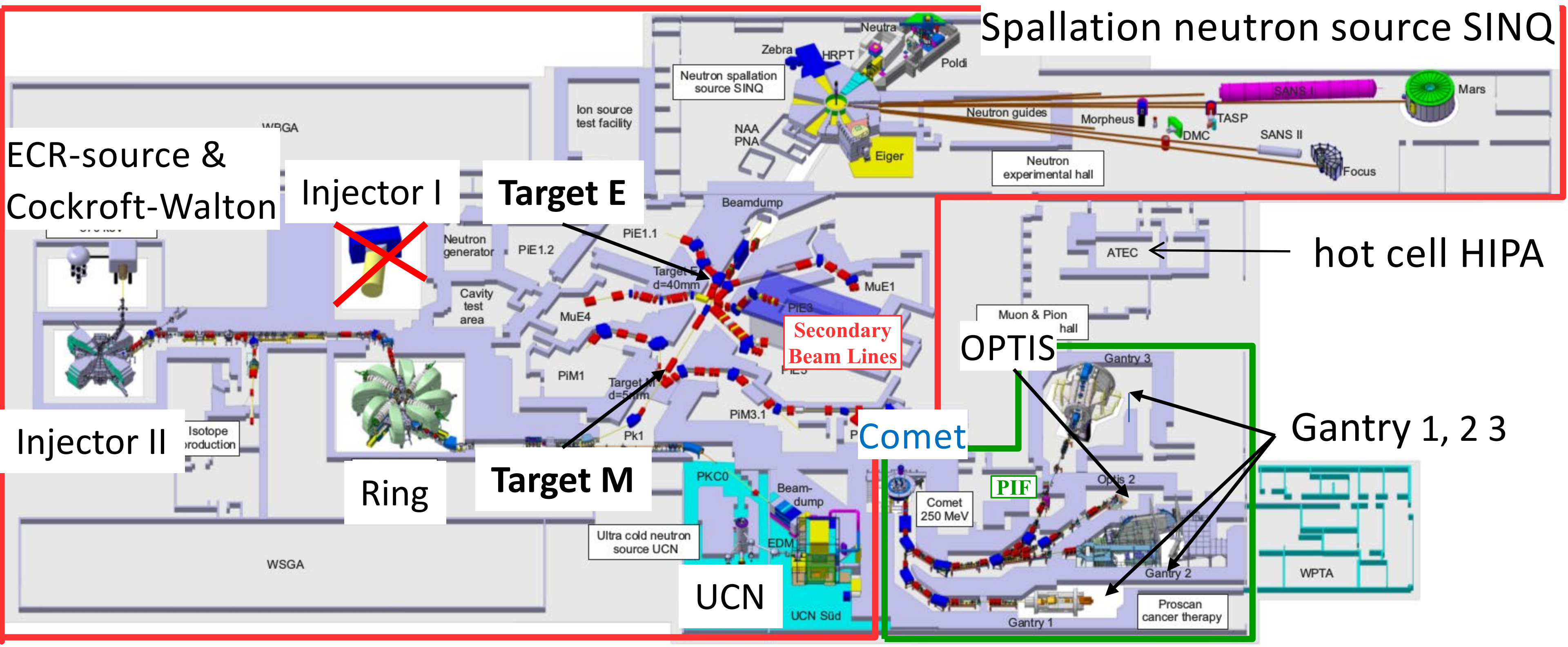
Muon Production Target Developments for PSI's High Intensity Proton Accelerator

64th ICFA Advanced Beam Dynamics Workshop on High Intensity and High Brightness Hadron Beams (ICFA-HB2021), Fermilab, 3-8.10.2021

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

Challenges for meson production targets

- **Power deposition:**

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

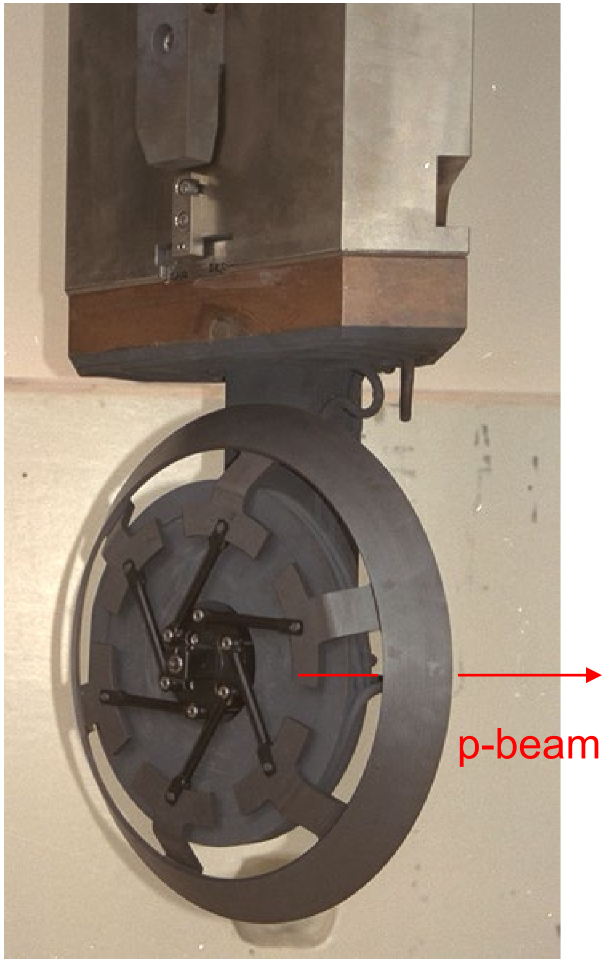
- **Radiation damage:**

→ embrittlement
→ deformation (also due to heating)
→ loss of conductivity

Approach:

- distribute power:
  rotating wheel with 1 Hz → needs bearings
- cooling by radiation:
  - independent of conductivity
  - local shielding (Cu) is cooled by water

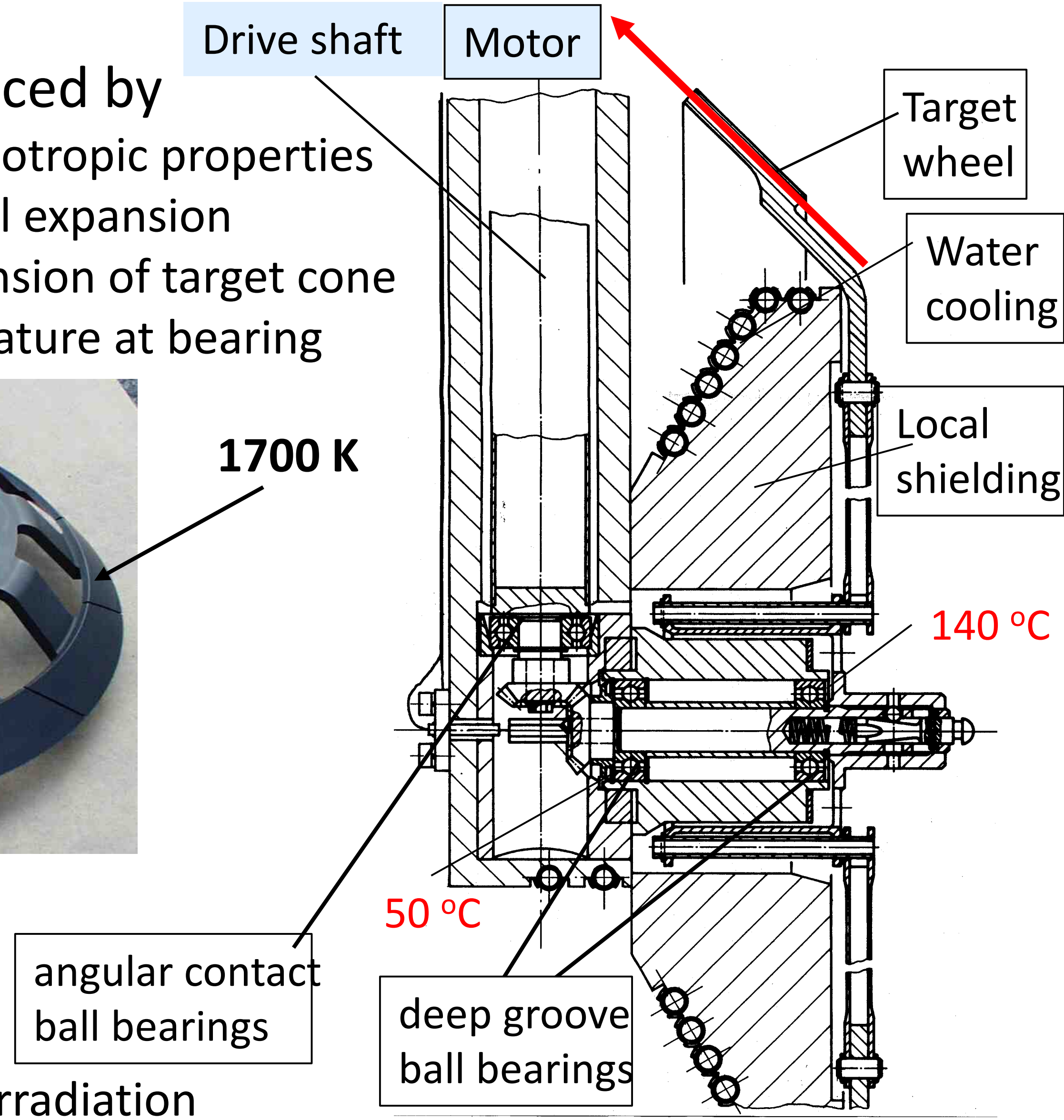
Target E



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

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

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 since April 2021!</u>

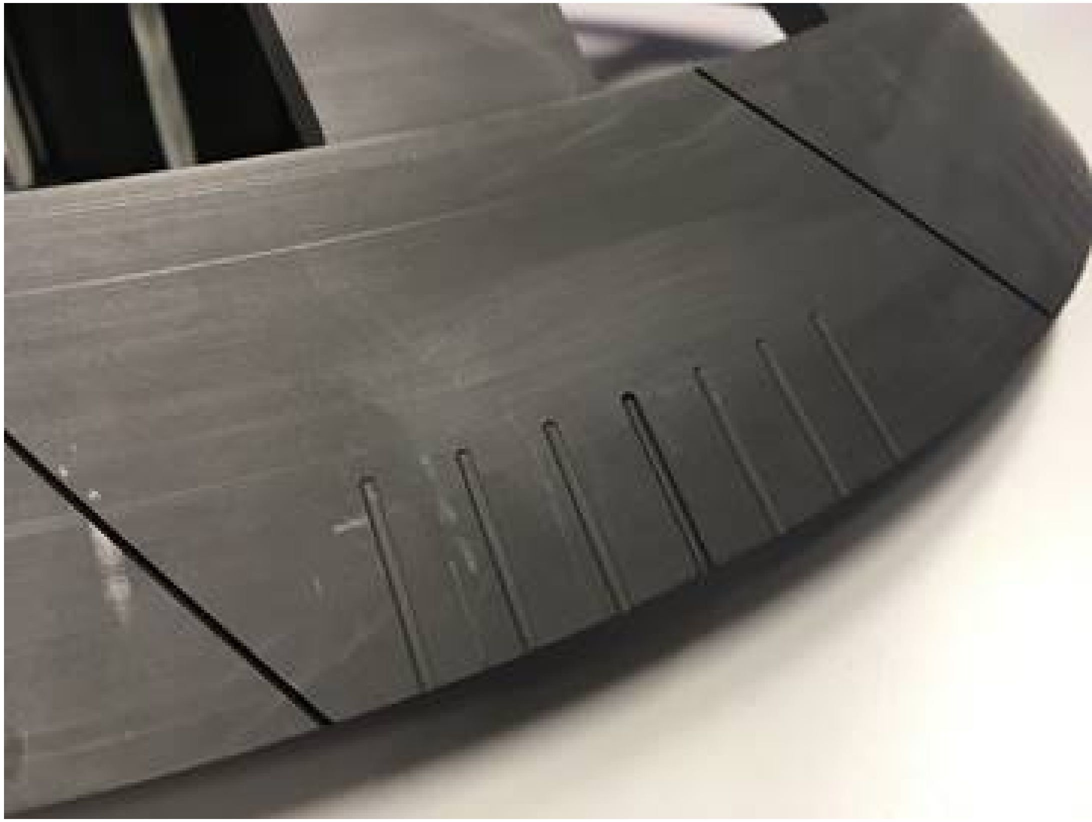
Target development I: Target E with grooves

Purpose: **Beam centering** on the 6 mm rim of Target E

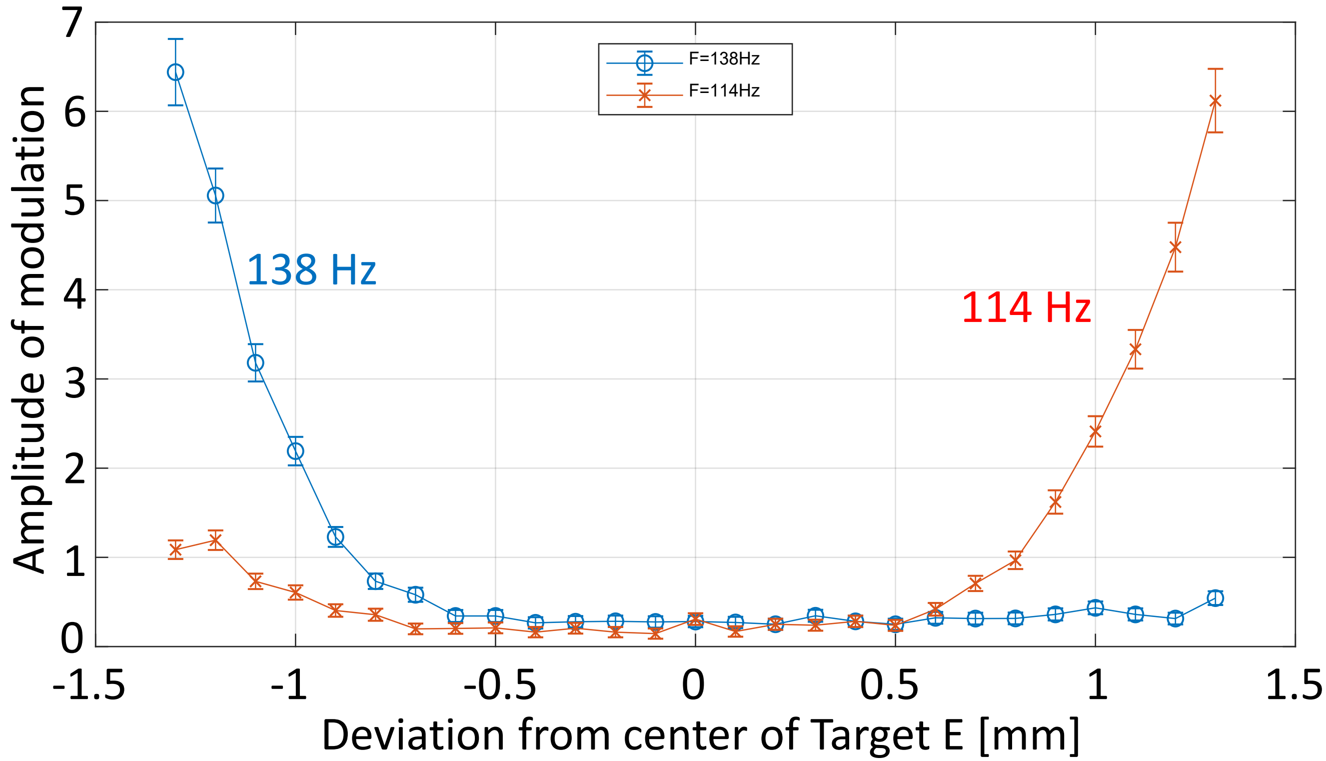
Idea:
Modulation of the beam current measurement (MHC5) after Target E
→ Strength of the signal is a measure for the deviation of the beam from center

Grooves inside and outside

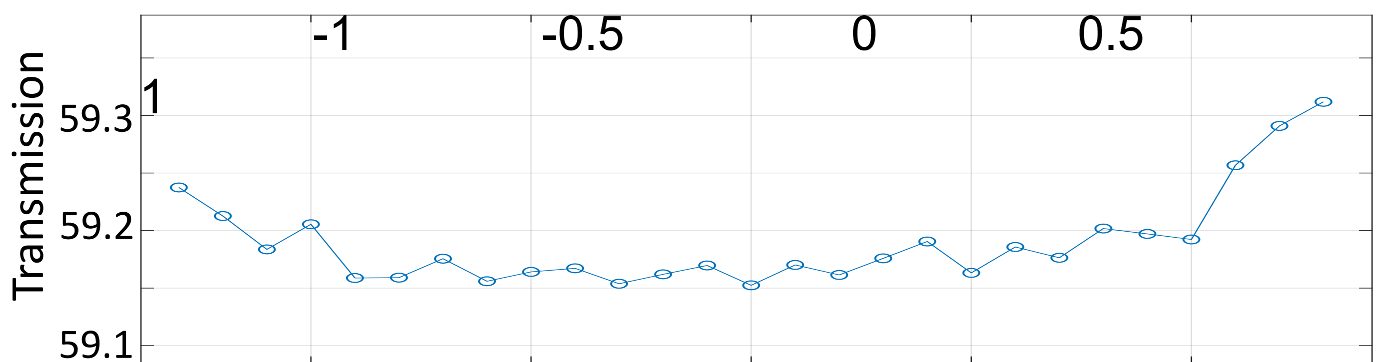
- with different frequencies: 114 Hz and 138 Hz
- to distinguish beam left and right from center
- different depths: 0.3mm, 0.5mm, 0.7mm, 0.9mm
- to find compromise between losses and signal



Signal as a function of position



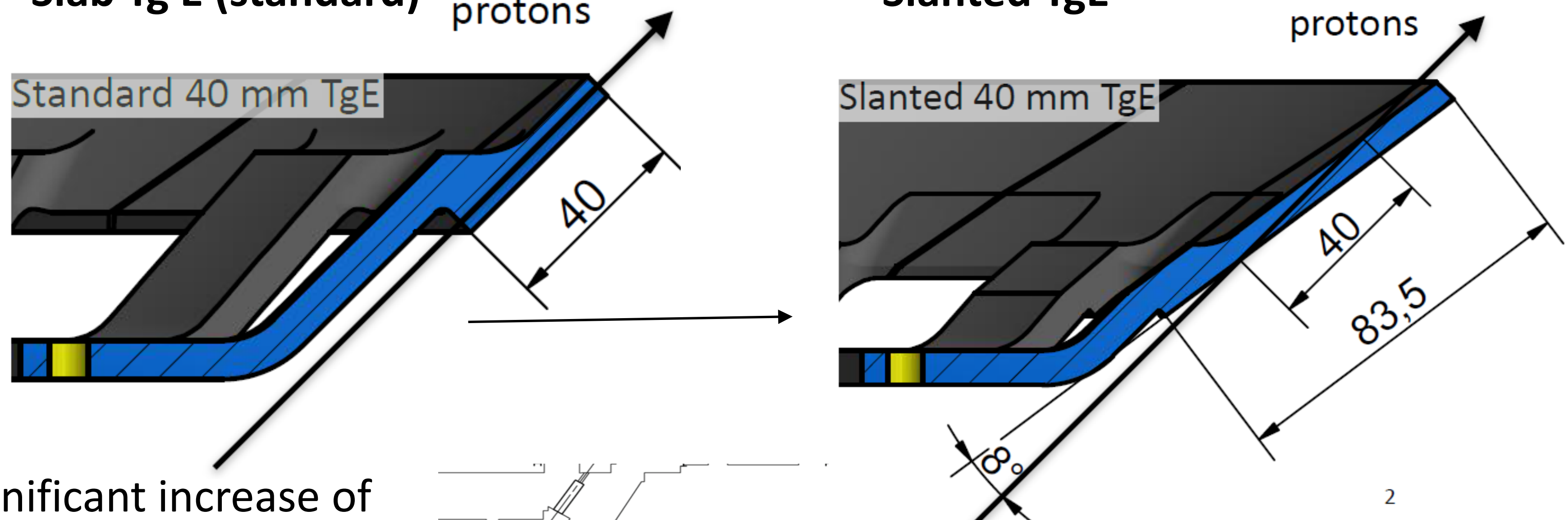
- Very sensitive method of ~factor 10 in signal change!
- Much more sensitive than transmission T = MHC5/MHC4



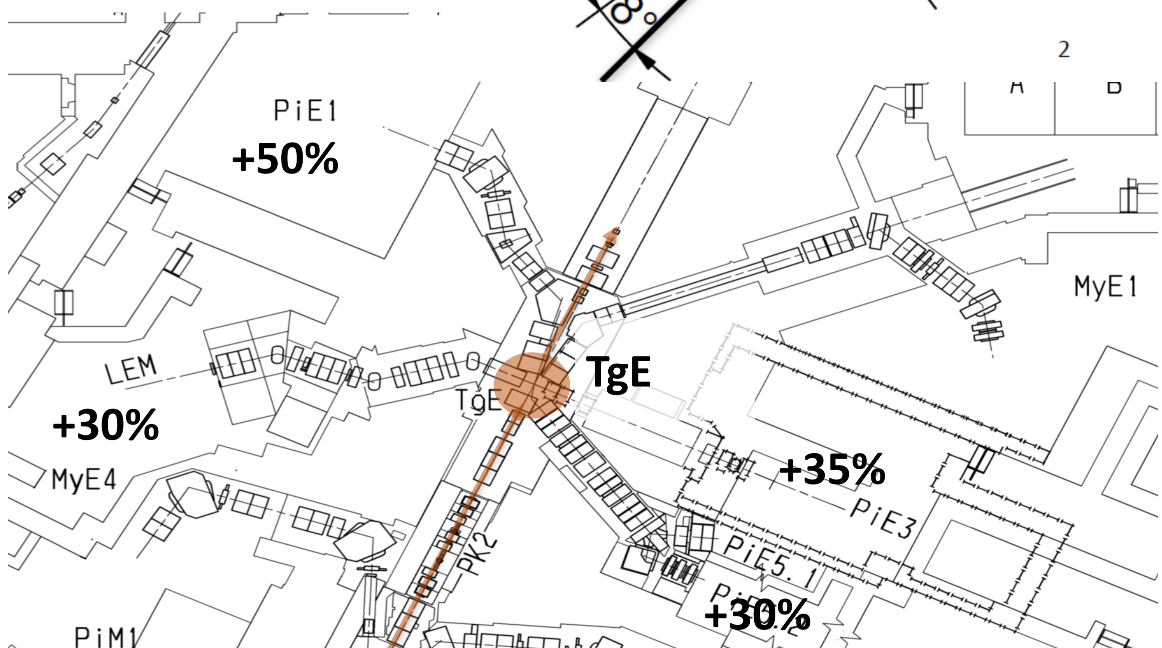
- Small change in Transmission
- Slower than modulation analysis

Target development II: Slanted Type

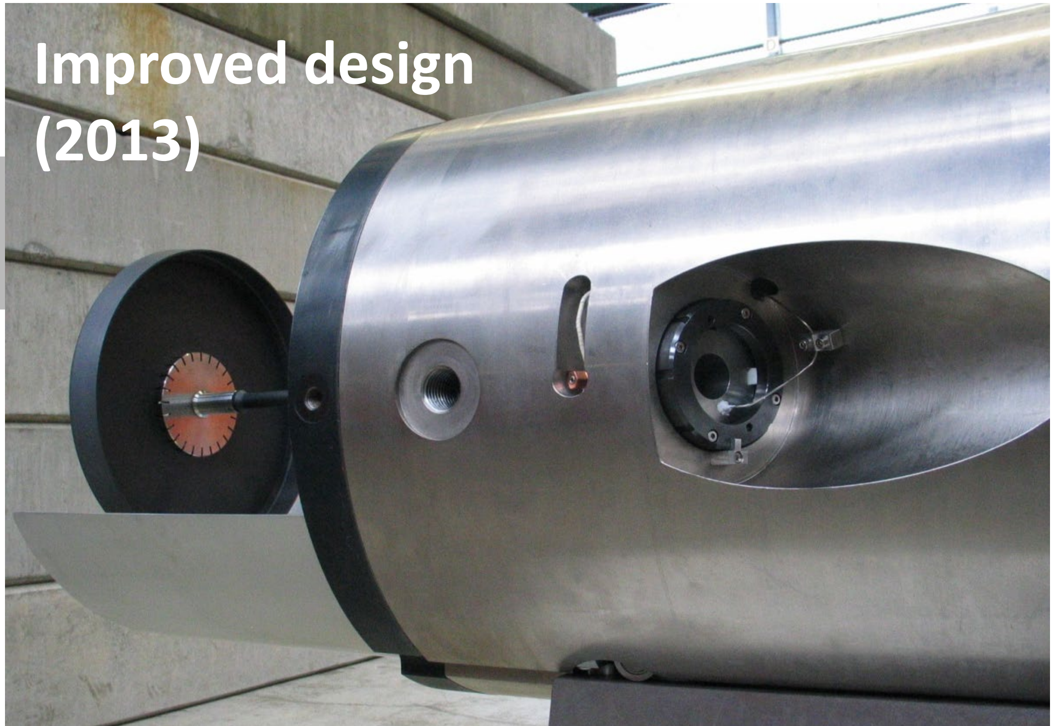
Slab Tg E (standard) | **Slanted TgE**



- Significant increase of surface muon rate
- Measurement (2019): 30 – 50 % increase
- Increased safety margin for “missing” TgE with the proton beam



Present Target-M



Target M:

- Mean diameter: 320 mm
- Target thickness: 5.2 mm
- Target width: 20 mm
- Graphite density: 1.8 g/cm^3
- Beam loss: 1.6 %
- Power deposition: 2.4 kW/mA
- Temperature: 1100 K
- Irradiation damage: 0.1 dpa/Ah
- Rotational Speed: 1 Hz
- Current limit: 5 mA
- Life time: up to several years

  up to ~ 60 Ah ~ 6 DPA

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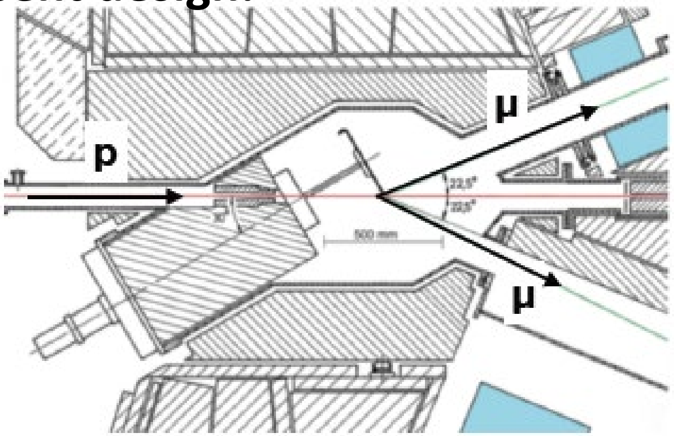
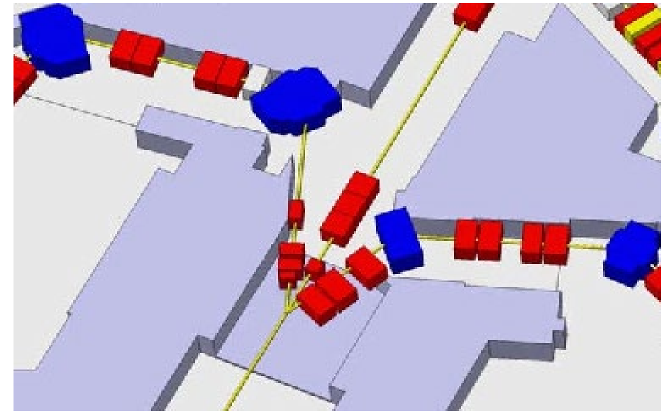
Future Project: High Intensity Muon Beam (HIMB)

Present design:



5 mm graphite

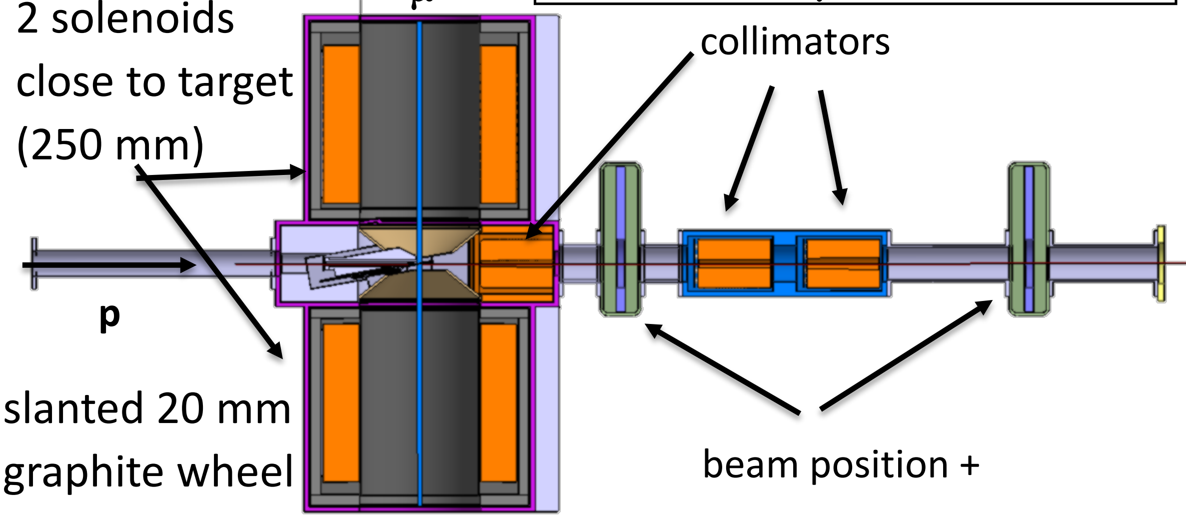


Future design:

10^{10} surface-μ/s in exp. areal

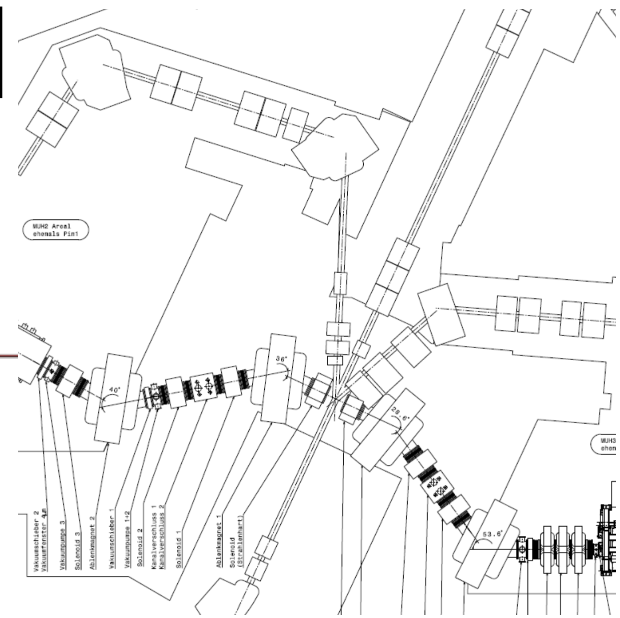
2 solenoids close to target (250 mm)

slanted 20 mm graphite wheel



collimators

beam position + profile monitors



Many constraints due to present beamline
→ CDR end of 2021

Summary

- Challenges for the muon target at 50 kW:
  - Cooling, Deformation, Bearings suffer in the high irradiation area!
- KOYO bearing from JPARC do a good job so far
- Slanted target type increases muon surface rate by up to 50 %
- Combined groove (for centering) and slanted target is built already
- Conceptual study HIMB for Swiss Roadmap aims for 10^{10} surface-μ/s in exp. areal
  Realization ~2028