MACHINE PROTECTION SYSTEM FOR THE PROPOSED TATTOOS BEAMLINE AT HIPA

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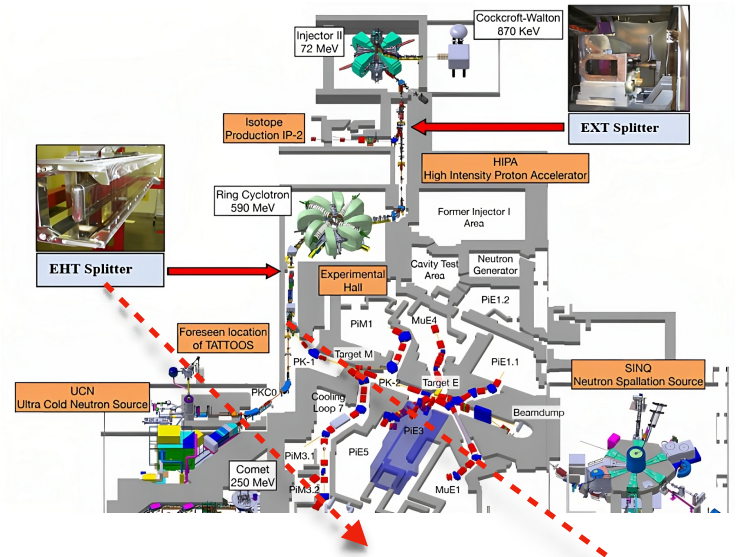


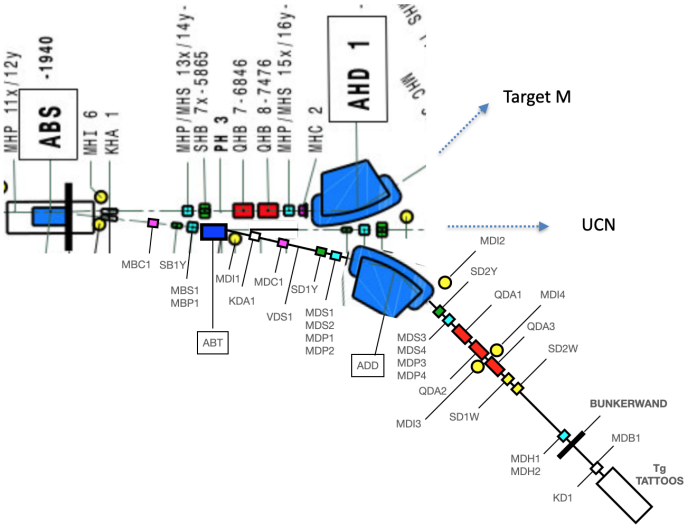
The TATTOOS beamline starts with the **EHT splitter** peeling off a small portion (up to 100 μA) from the main beam. Downstream a septum magnet (**ABS**) separates the HIPA and TATTOOS beam into individual beamlines. The first section of the TATTOOS beamline is common with the UCN beamline. At the next dipole magnet (**ABT**) the UCN and TATTOOS beamline are separated. Another dipole magnet (**ADD**) will bend for a total of 45 degrees. A quadrupole triplet shapes the beam on target and to distribute the beam more uniformly **2 fast dipoles will wobble the beam in two dimensions**. The spallation target operates in a high but narrow temperature range, high enough to achieve good radionuclide release efficiencies, but below the material melting point. This puts **strong constraints on the machine protection system to protect the target from overheating**.

HIPA (High Intensity Proton Accelerator) at PSI delivers 590 MeV proton beam with up to 1.4 MW beam power (2.4 mA) to spallation and meson production targets serving particle physics experiments and material research.

IMPACT (Isotope and Muon Production using Advanced Cyclotron and Target technologies) is a proposed upgrade project for HIPA with 2 new target stations:

1. HIMB (High Intensity Muon Beamline) replaces Target M to increase the surface muon rate.

2. TATTOOS (Targeted Alpha Tumour Therapy and Other Oncological Solutions), an online isotope separation facility, will produce radionuclides for diagnosis and cancer therapy for clinical studies. TATTOOS has a dedicated beamline intended to operate at a beam intensity of **100 µA** (60 kW beam power), requiring continuous **splitting of the high-power main beam** via an electrostatic splitter.



Risk	Cause	Protection diagnostics
Beam off-center or asymmetric on target	• wobbler system not working correctly • missteered beam • power supply (PS) failing	• 4-segment aperture foil • protection collimator • multi-wire profile monitors (harps) • PS surveillance
Beam overfocussed on target	• optics wrong • wobbler failing	• multi-wire profile monitors (harps) • 4-segment aperture foil (cf. w expected signal) • PS surveillance
Too much beam current	• beam on splitter unstable	• fast and precise beam current monitor system
Beamline activation by beam losses	• off-axis beam • misalignment • broad beam	• BPM feedback system • beam loss monitors

The well established HIPA machine protection system guarantees safe operation protecting from severe instantaneous beam losses and from prohibitive activation by large integrated losses. Handling a beam power of over 1 MW requires:

- Reliable protection mechanisms that evaluate and switch off the beam **within milliseconds**
- **High dynamic range** for currents between less than 1 and up to 2400 µA (a challenge for the beam diagnostics)

UCN / TATTOOS operation: Since the first part of the beamline is shared with UCN, **TATTOOS cannot be operated whenever a beam pulse is delivered to UCN**. To switch operation, the splitter is retracted, and the ABT changes its polarity. Then the kicker will be activated for the usual UCN operation. After that the ABT's polarity is changed back and the splitter is moved into the beam. **To ensure correct operation:**

- when ABT ramping: kicker disabled and splitter in park position
- no kick to TATTOOS: kicker disabled when ABT to TATTOOS
- no splitting to UCN: splitter in park position when ABT to UCN
- correct ABT polarity: short UCN test pulses & slow EHT ramp