The High-Intensity Muon Beams (HIMB) project at PSI

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for the HIMB Project

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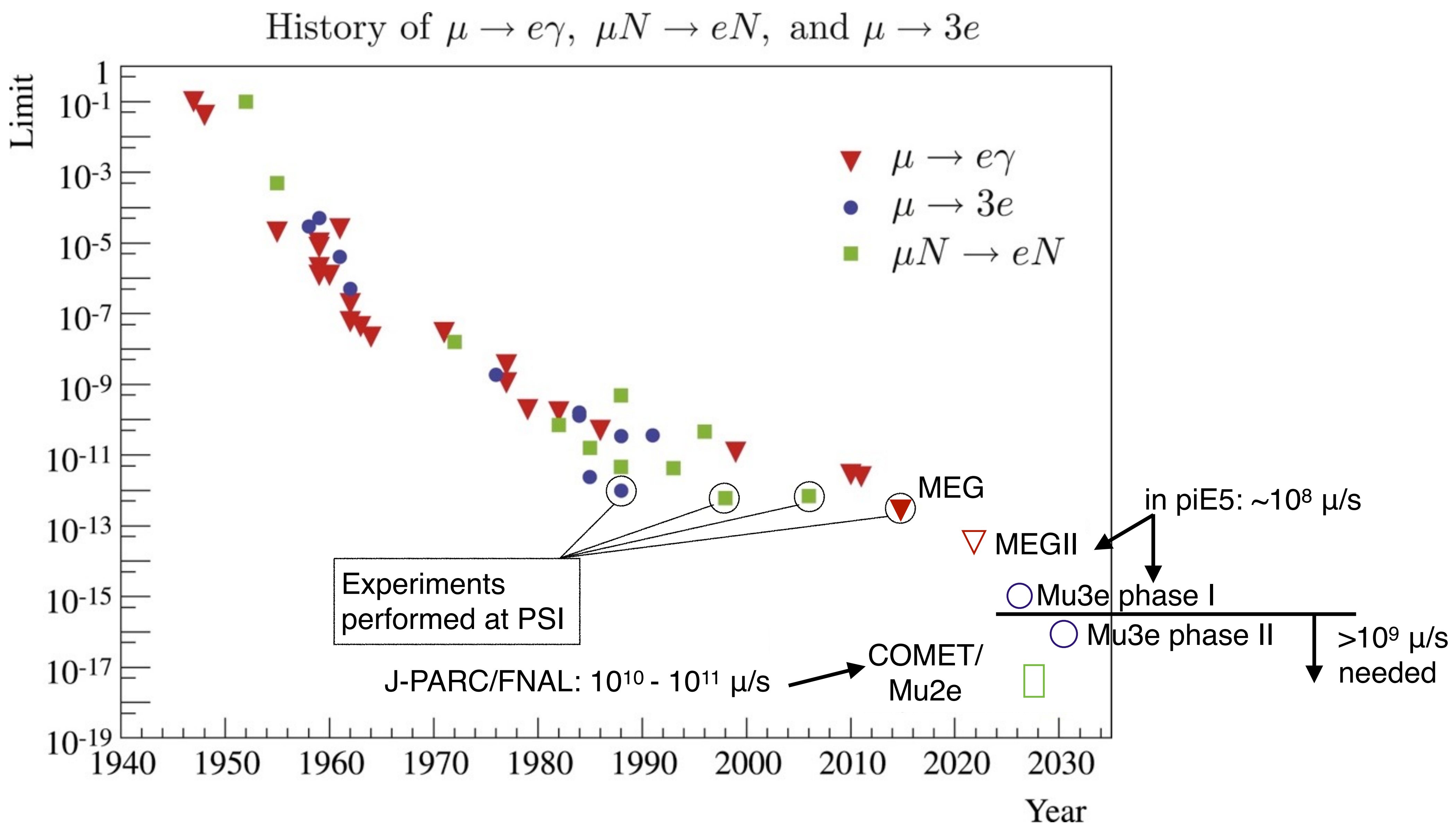
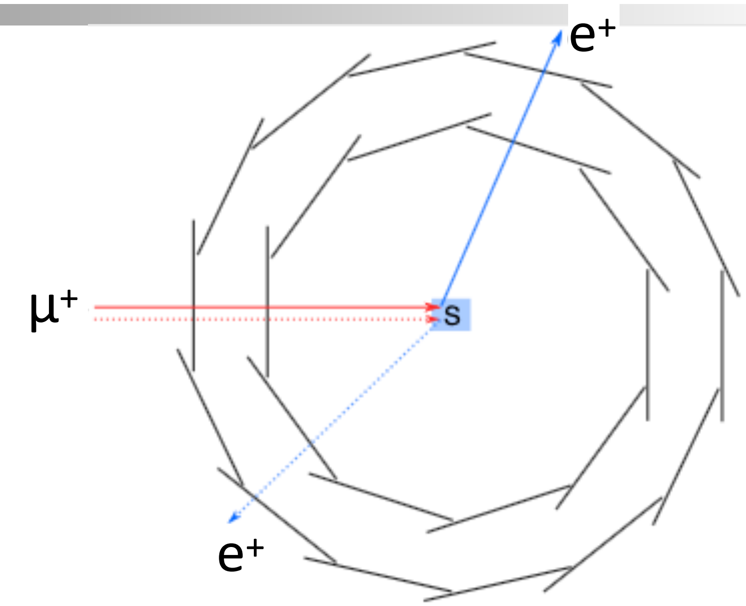
Motivation: cLFV



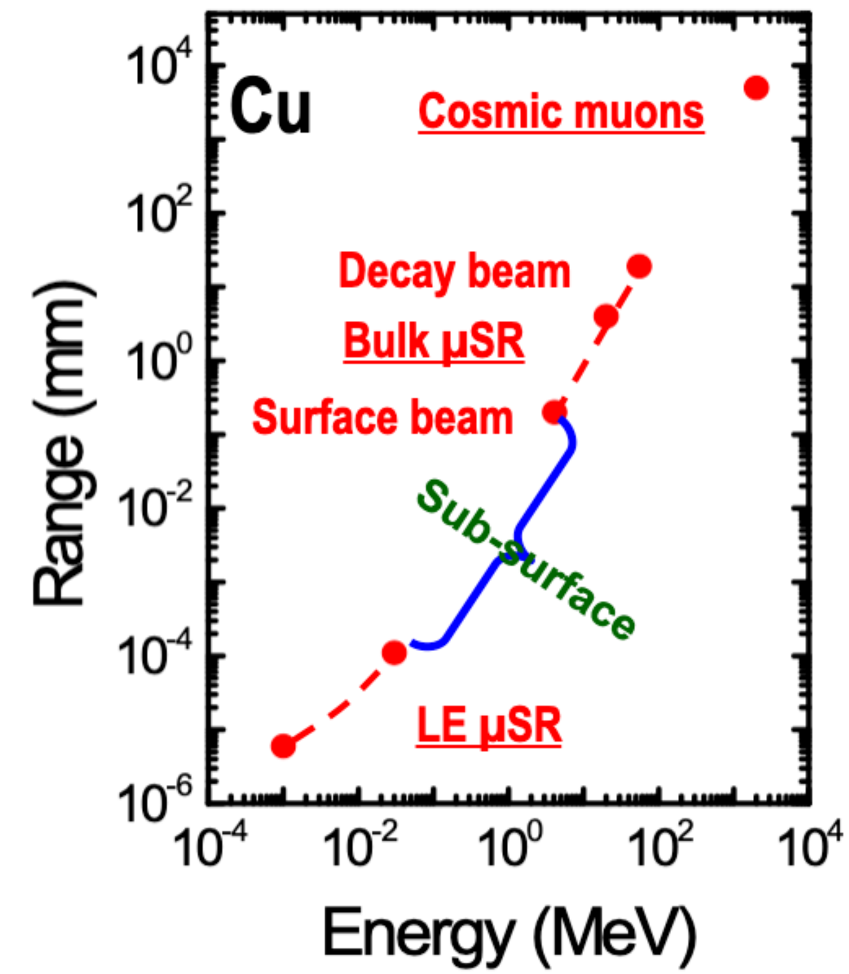
- Neutrinoless muon decays one of the most sensitive probes for new physics
- $\mu^+ \to e^+\gamma$ & $\mu^+ \to e^+e^-e^+$ only possible at DC & intensity-frontier machine such as PSI's HIPA accelerator
- Any future cLFV search at PSI will need higher beam intensities

Motivation: muSR

- Vertexing for muSR applications:
  - Pixel detector development together with particle physics
  - Enables 10-100x faster measurements.
  - Unprecedented small samples, 10-100x smaller (“μ-microscope”).
  - Allows putting samples in extreme conditions at unprecedented levels, e.g. 10x pressure



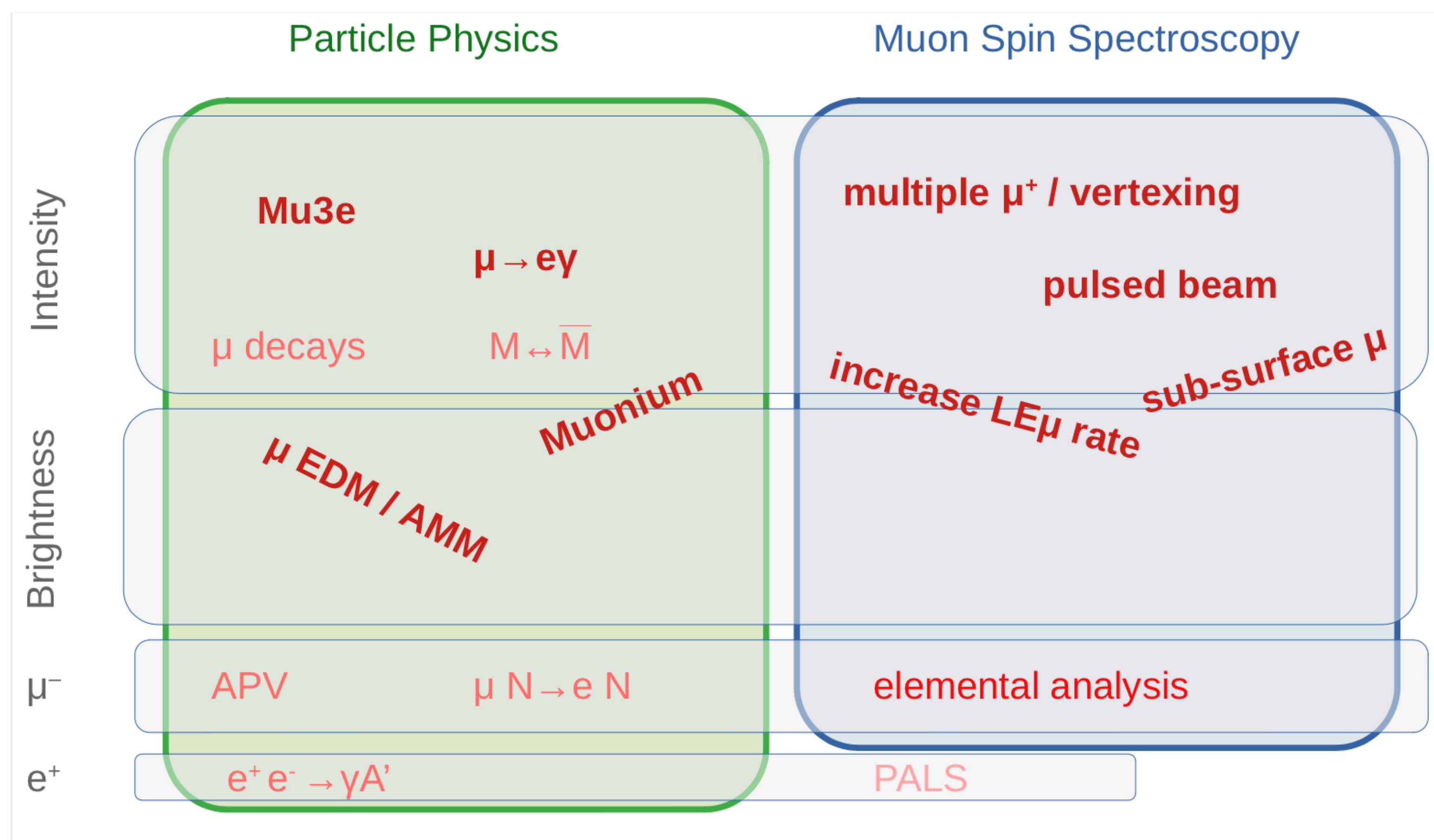
- Sub-surface muons at high rate:
  - They stop in thinner layers and cover a yet inaccessible depth range of 200 nm - 200 μm.
  - Perfectly suited for studies of energy materials and devices.



HIMB Science Case Workshop & Document

https://indico.psi.ch/e/himbws

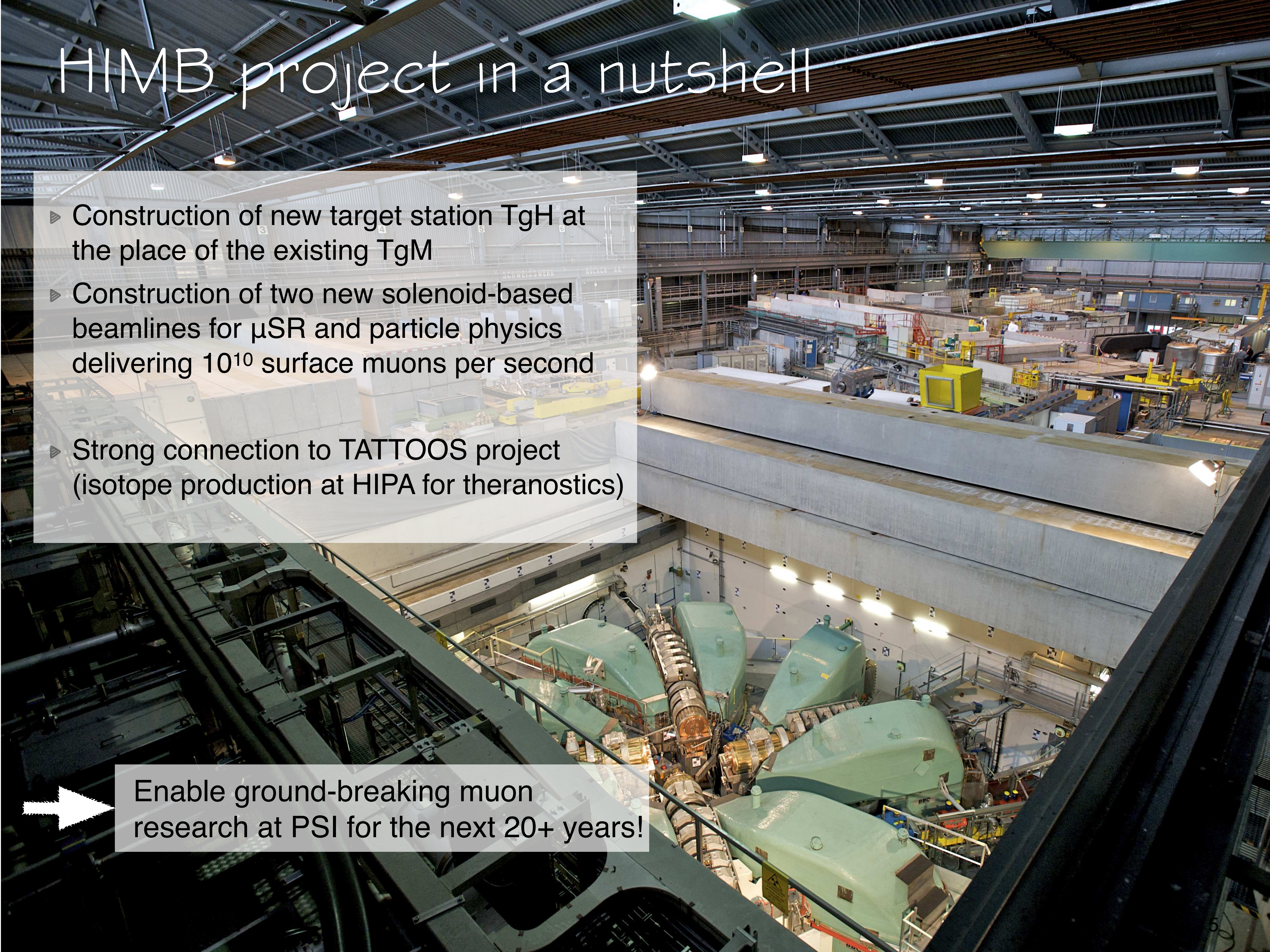
- Workshop held in April to gather and identify HIMB Science Case
- HIMB science case document in preparation and to be published on arXiv in a few months



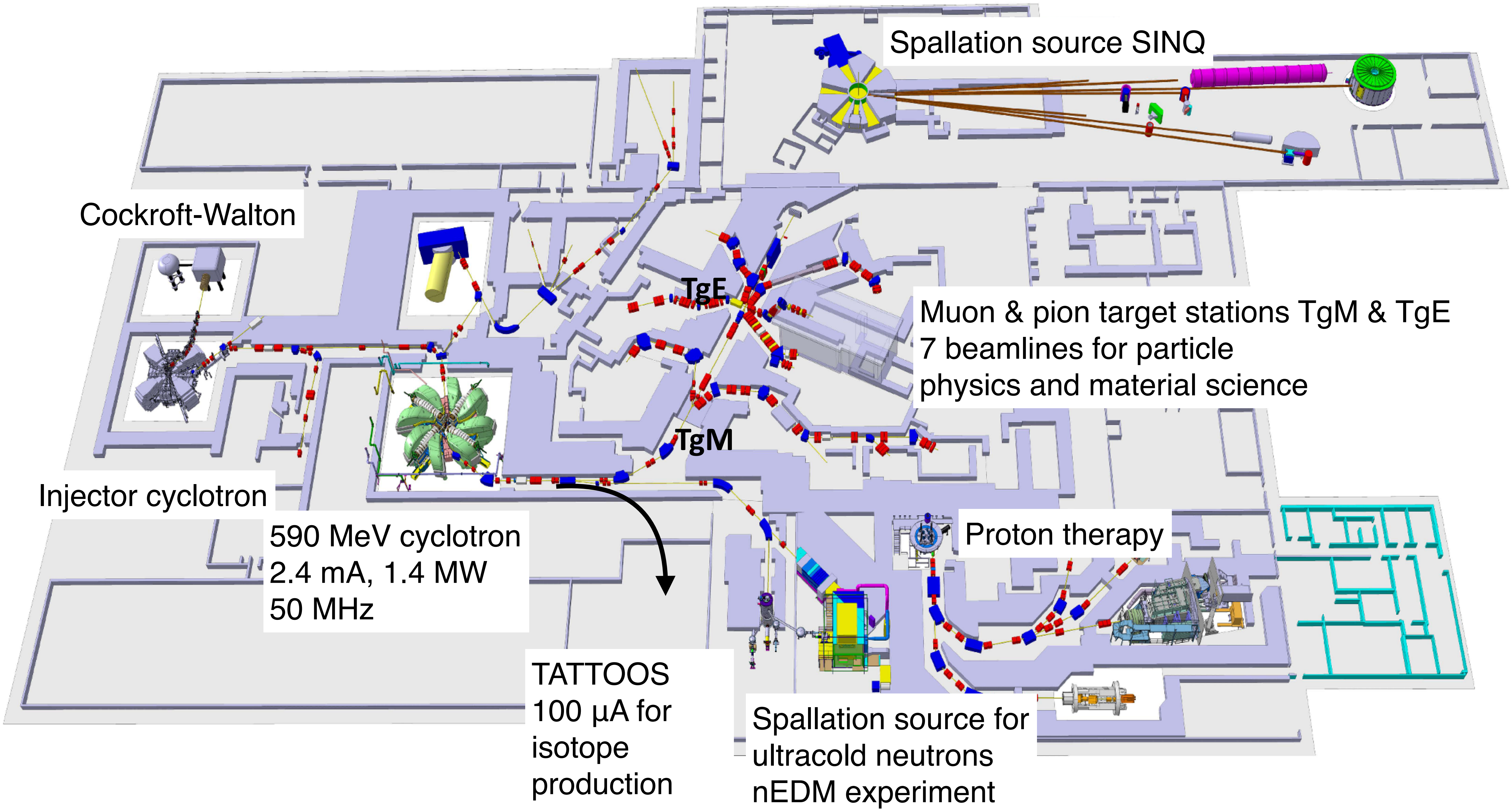
HIMB project in a nutshell

- Construction of new target station TgH at the place of the existing TgM
- Construction of two new solenoid-based beamlines for µSR and particle physics delivering 10^{10} surface muons per second
- Strong connection to TATTOOS project (isotope production at HIPA for theranostics)

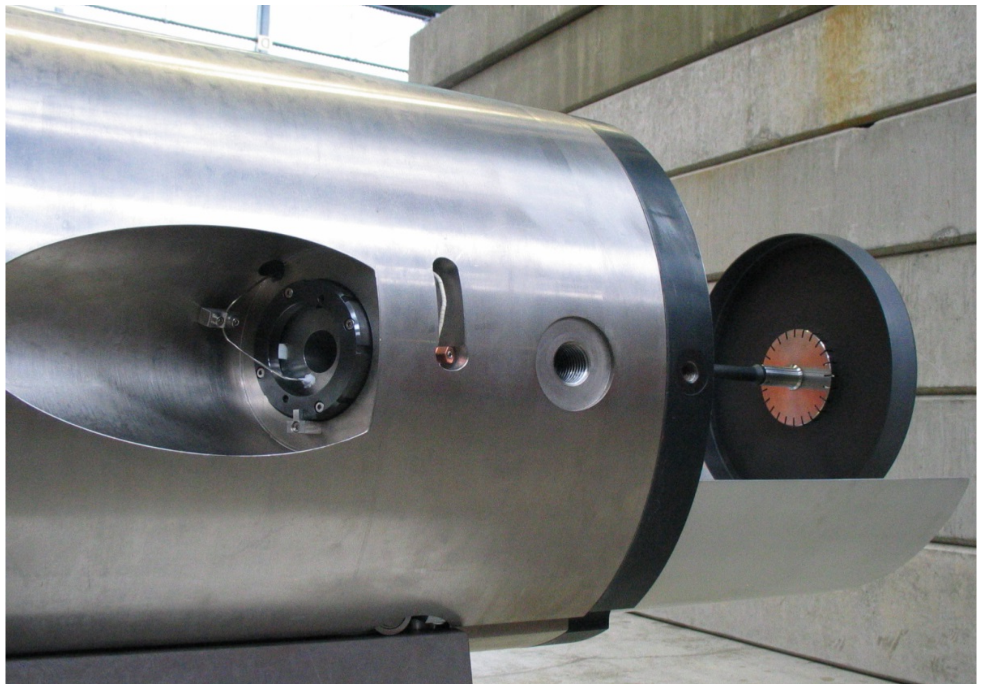
→ Enable ground-breaking muon research at PSI for the next 20+ years!



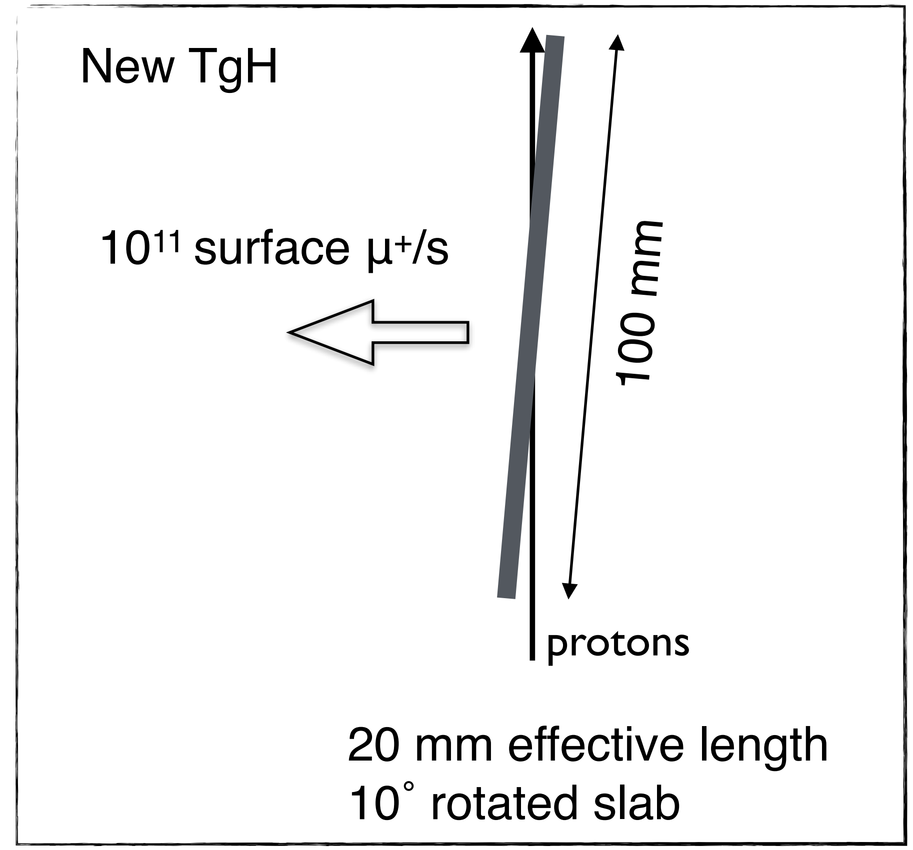
PSI Proton Accelerator HIPA



Target Geometry for new TgH



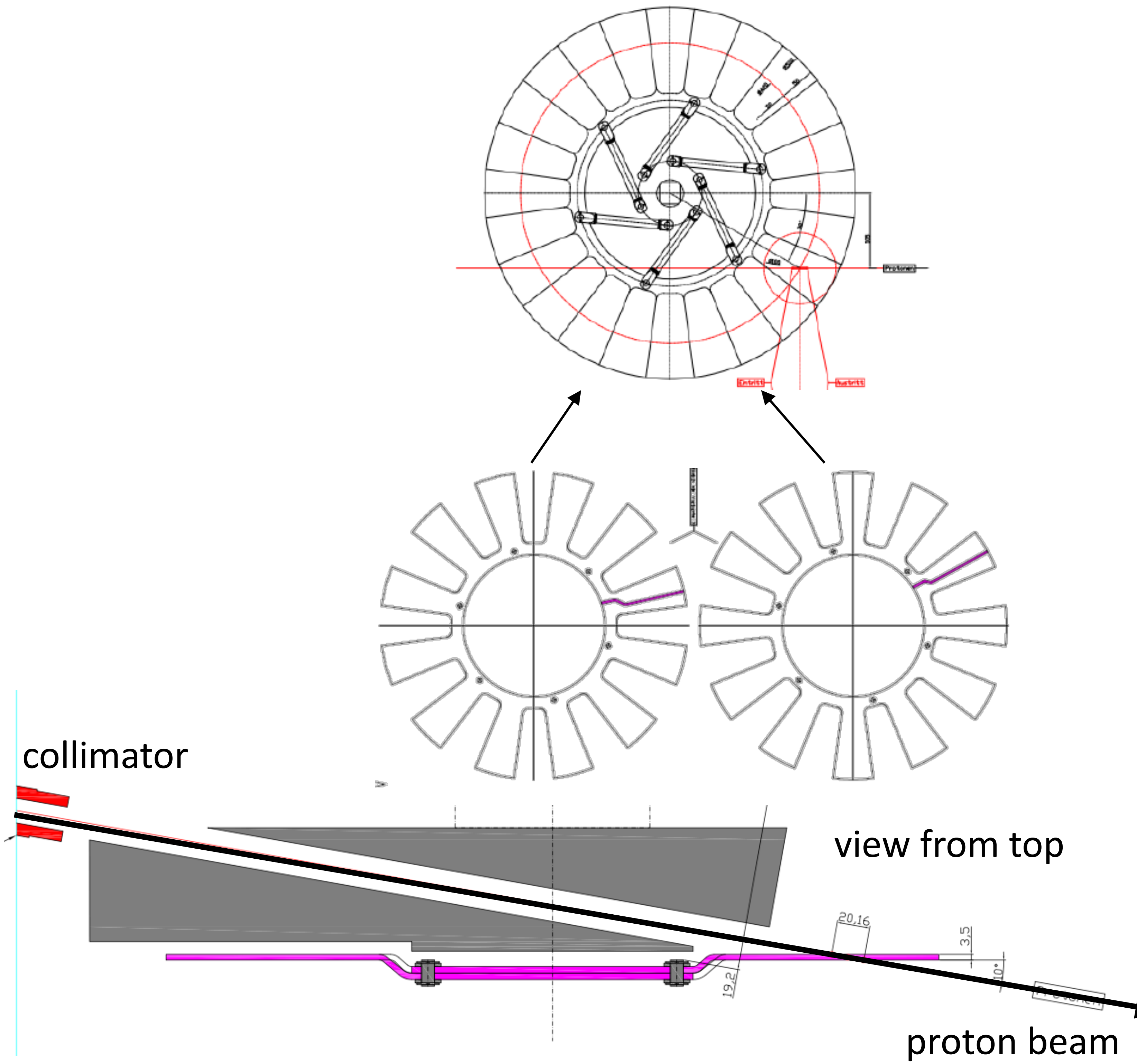
Existing TgM



- Change current 5 mm TgM for 20 mm TgH (known situation from 60 mm TgE)
- 20 mm rotated slab target as efficient as 40 mm standard Target E
- Slanted target geometry also implemented and tested for TgE → 40-50% gain in surface muon rate

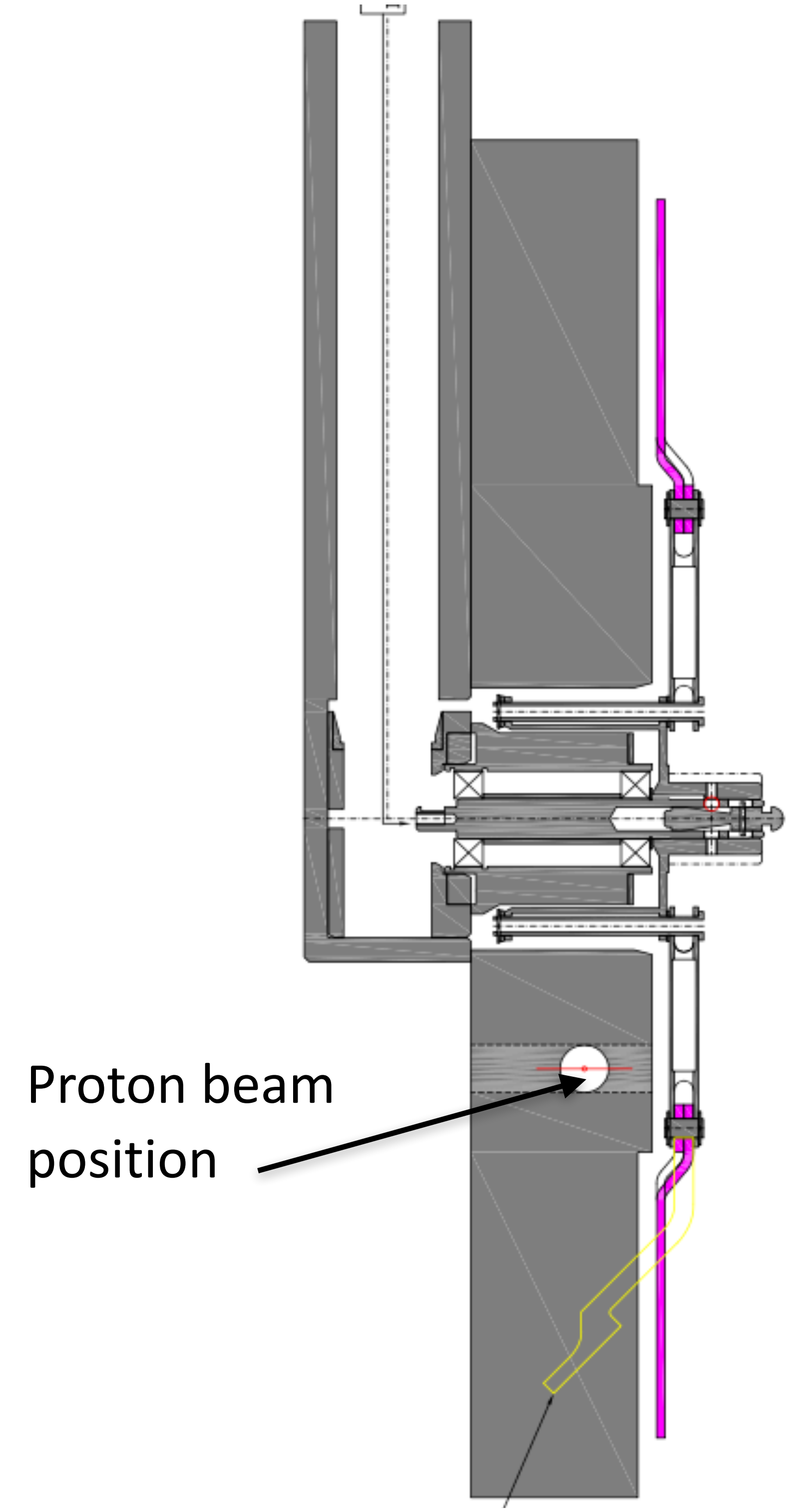
Target design

- Two discs with individual "leaves" that sit on top of each other -> well controllable slits
- Proton beam impinges target from the back
- Protection collimator upstream
- Fits into existing TgE exchange flask

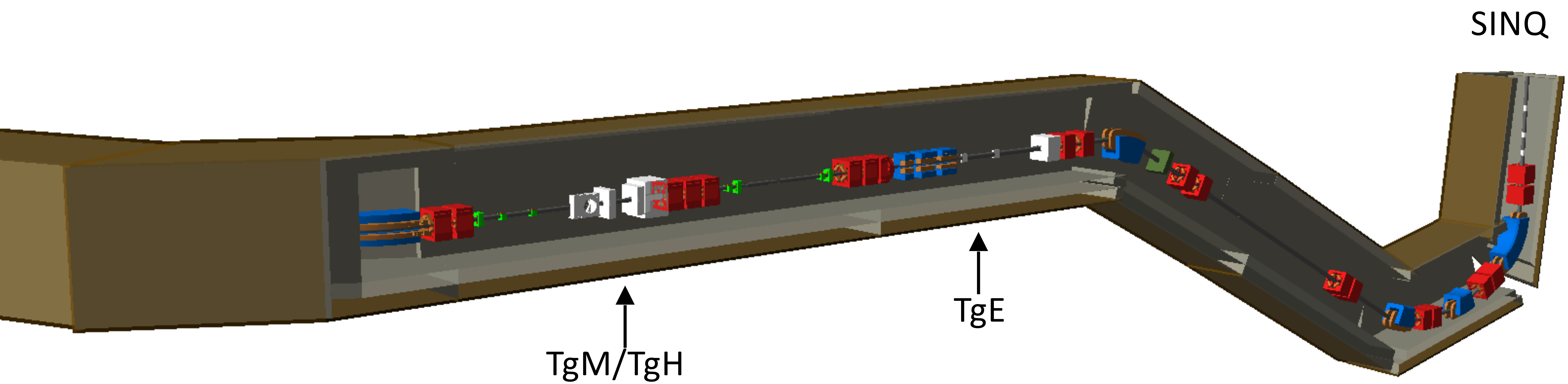


Target design

- Proton beam impinges on target wheel below the rotation axis
  -> allows “flat” target, gives a bit more usable space and moves the proton beam away from the shaft of the target wheel

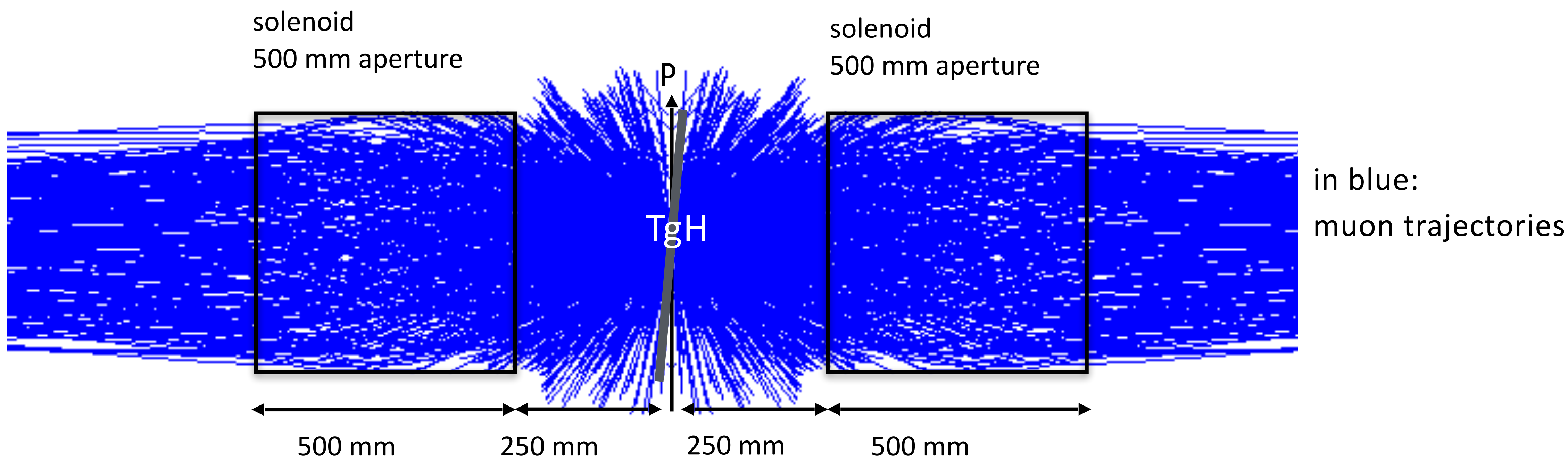


Impact on other facilities of HIPA



- Full simulation of high-energy proton beam line in BDSIM using either TgM or TgH to assess impact on the other HIPA target stations
- Optimizations still ongoing; current transmission to SINQ with TgH 60…63% compared to 70% with TgM
- Beam shape at TgE and SINQ preserved

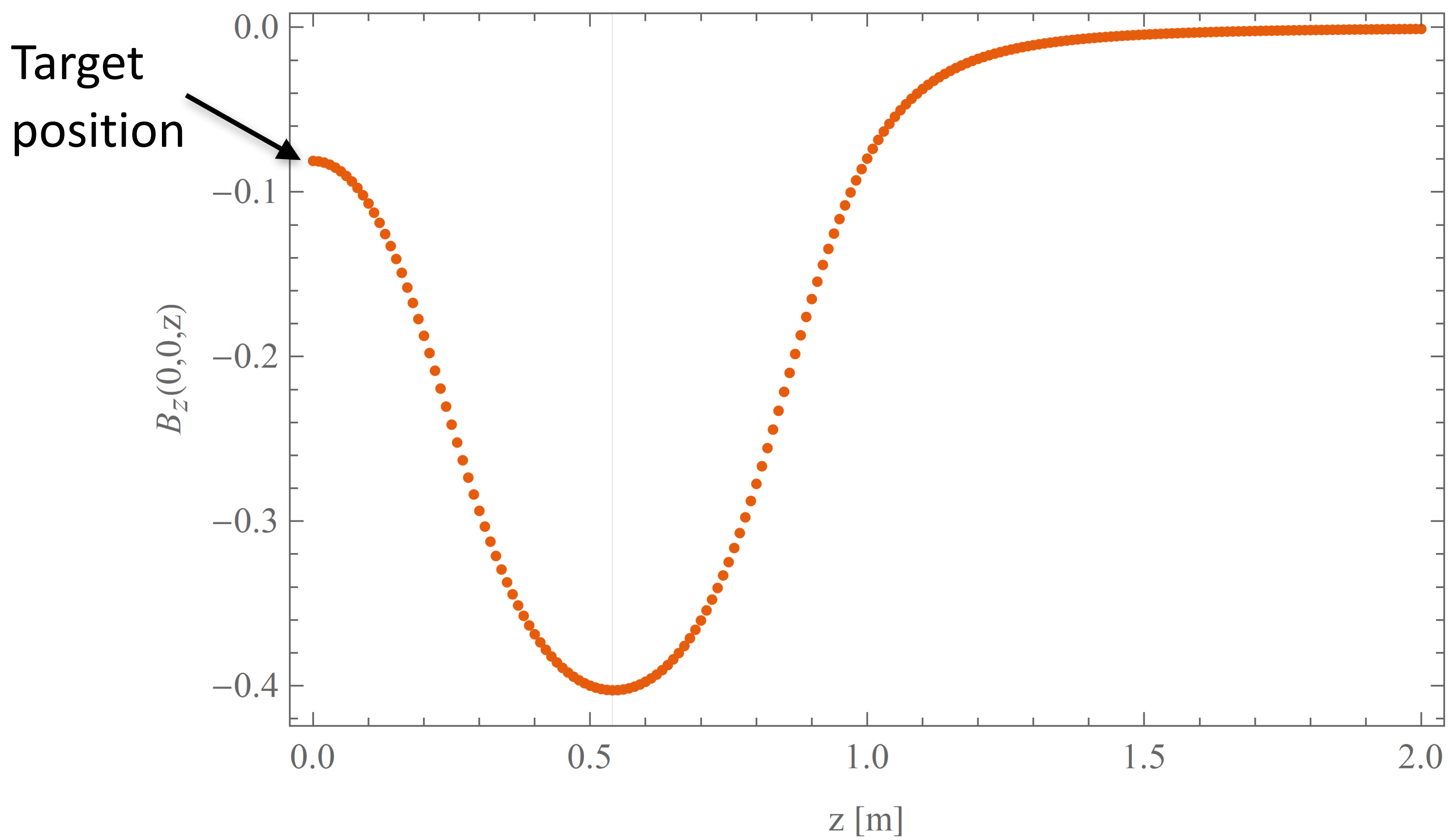
Split Capture Solenoids

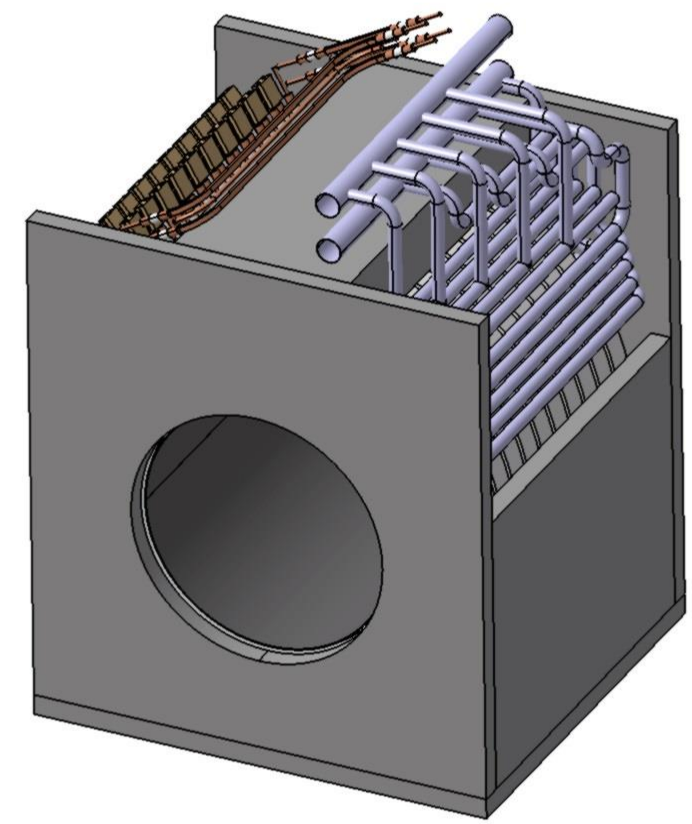


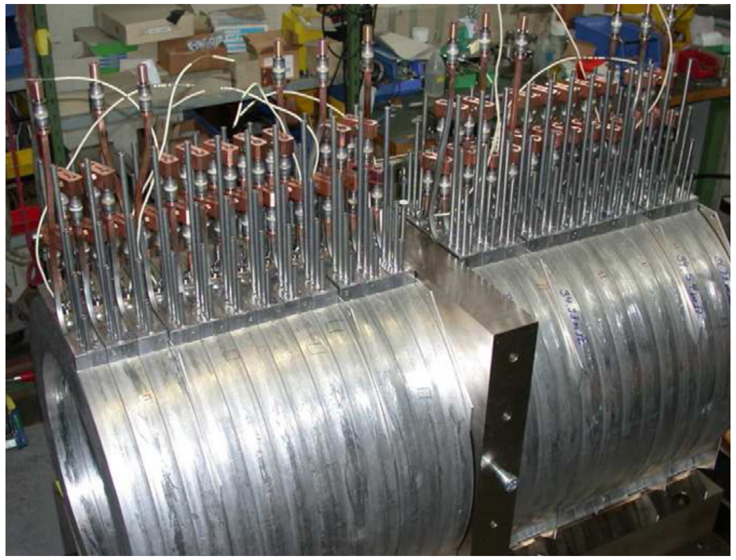
- Two normal-conducting, radiation-hard solenoids close to target to capture surface muons
- Central field of solenoids ~0.4 T

Capture solenoids

- Current design of capture solenoid with iron return yoke
- Modelled after existing radiation-hard µE4 solenoids
- The two capture solenoids will create a non-negligible field at the target



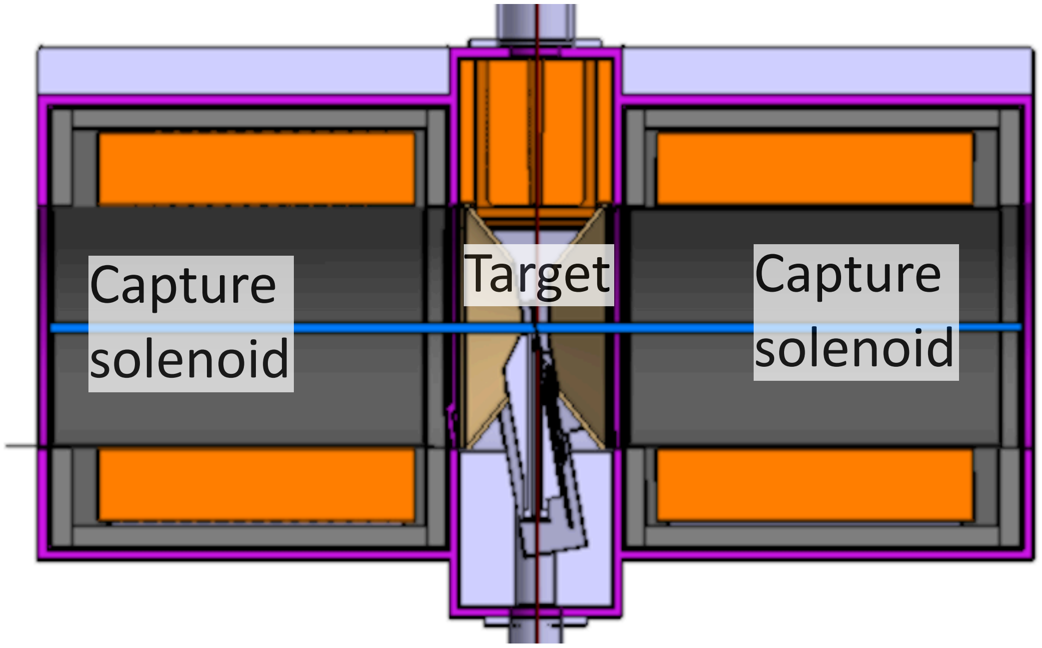


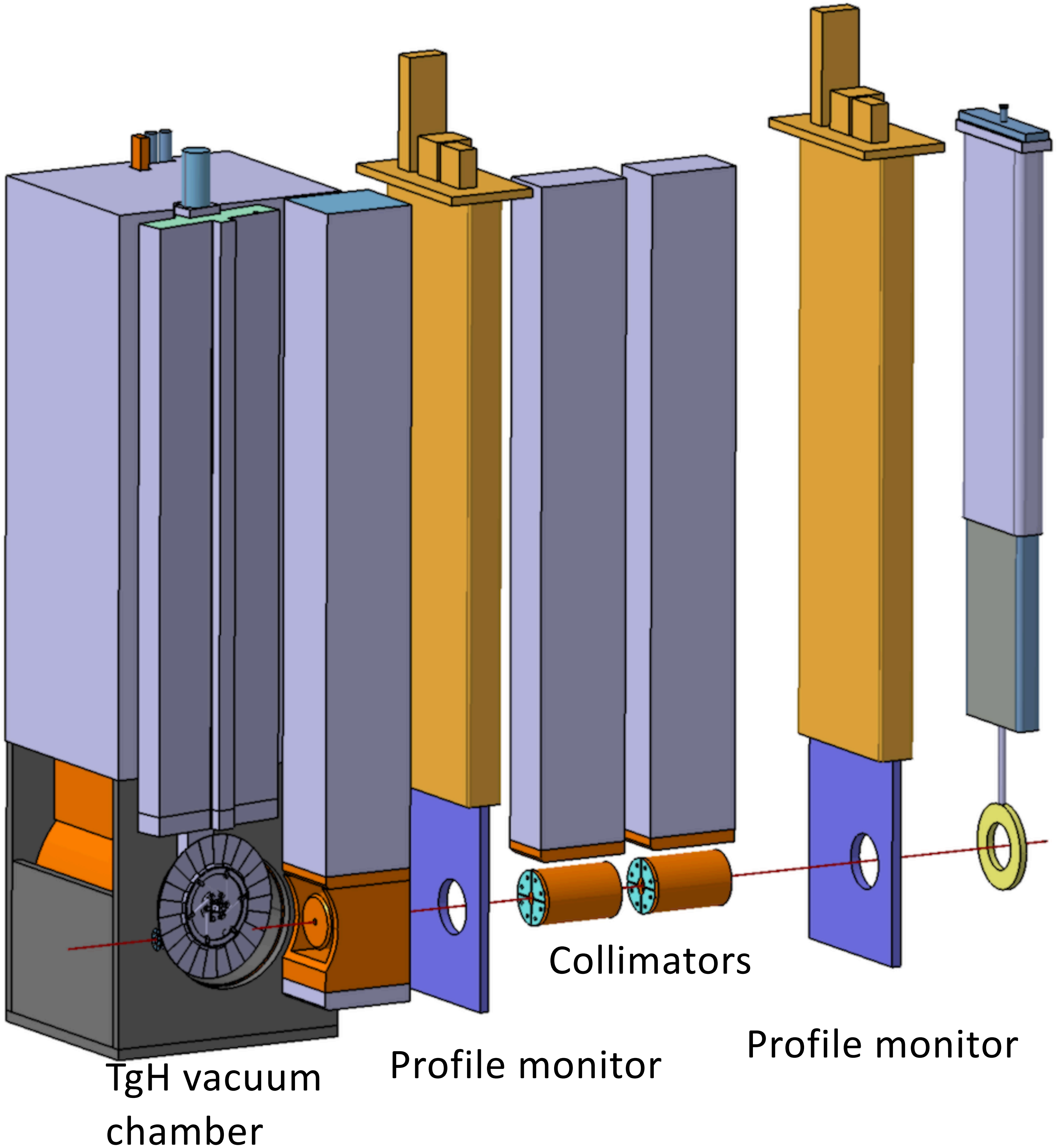


µE4 solenoids

Concept for new target station TgH

- Concept similar to existing TgE
  → allows to profit from existing tools and experience
- Separate exchange flask for capture solenoids
- In order to have capture elements for muons as close as possible, they are integrated into the target vacuum chamber





Solenoid Beamline

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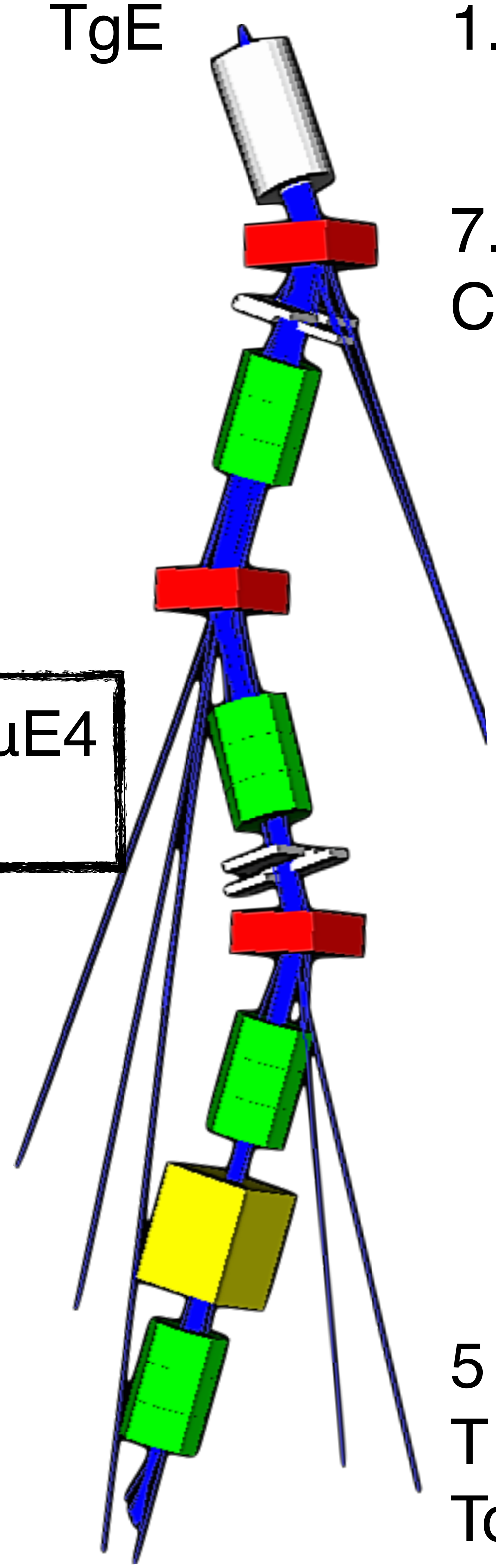
Existing μE4 beamline (TgE)		Solenoid-based beamline (TgH)
1.2×10^{11} μ+/s	Source	1.3×10^{11} μ+/s
7.2×10^{9} μ+/s C ~ 6%	Capture	3.4×10^{10} μ+/s C ~ 26%
5×10^{8} μ+/s T ~ 7% Total ~ 0.4%	Transmission	1.3×10^{10} μ+/s T ~ 40% Total ~ 10%

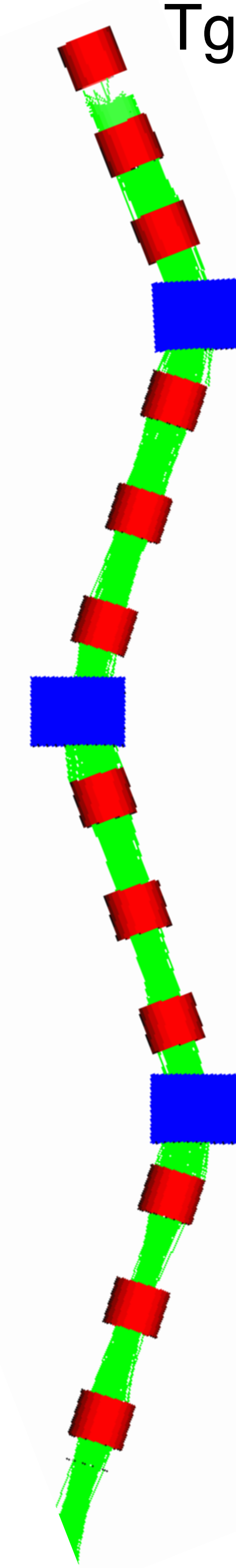
TgE



Existing μE4 beamline

⇒ Gain due to high capture and transmission efficiency

TgH

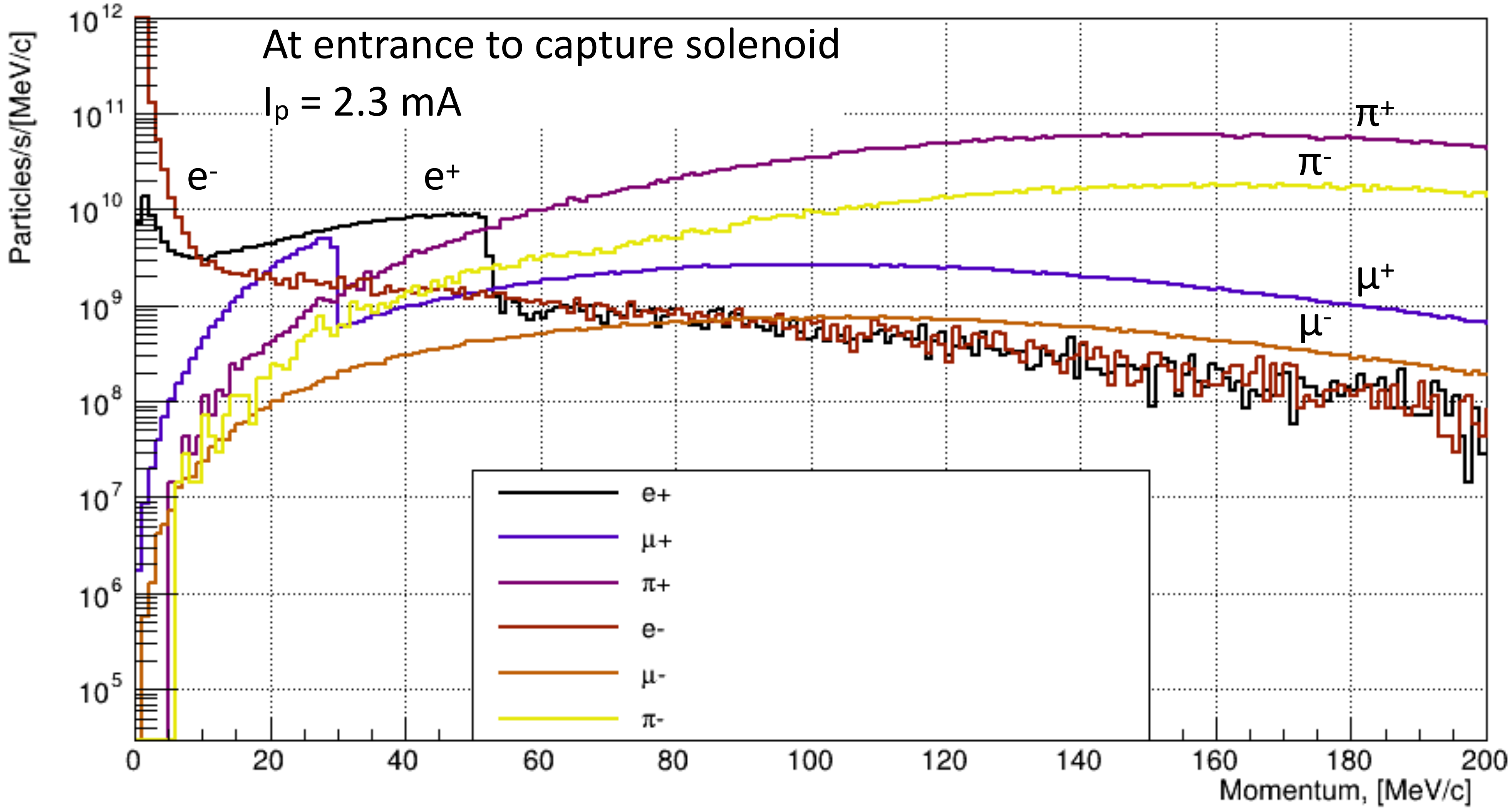


Solenoid-based beamline

Beamline layouts

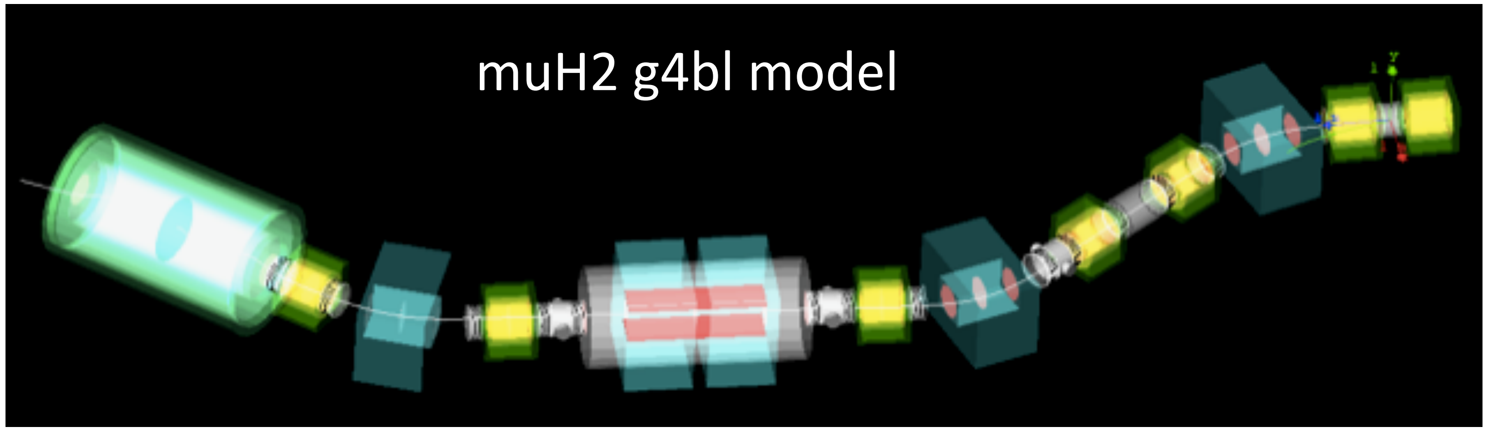
- Baseline scenario for target and beamline layouts:
  - New TgH at the same location as current TgM
  - 90 degree angle of muon beamlines with first bend in the upstream direction
- Technical layout, currently optimising positions of individual magnetic elements

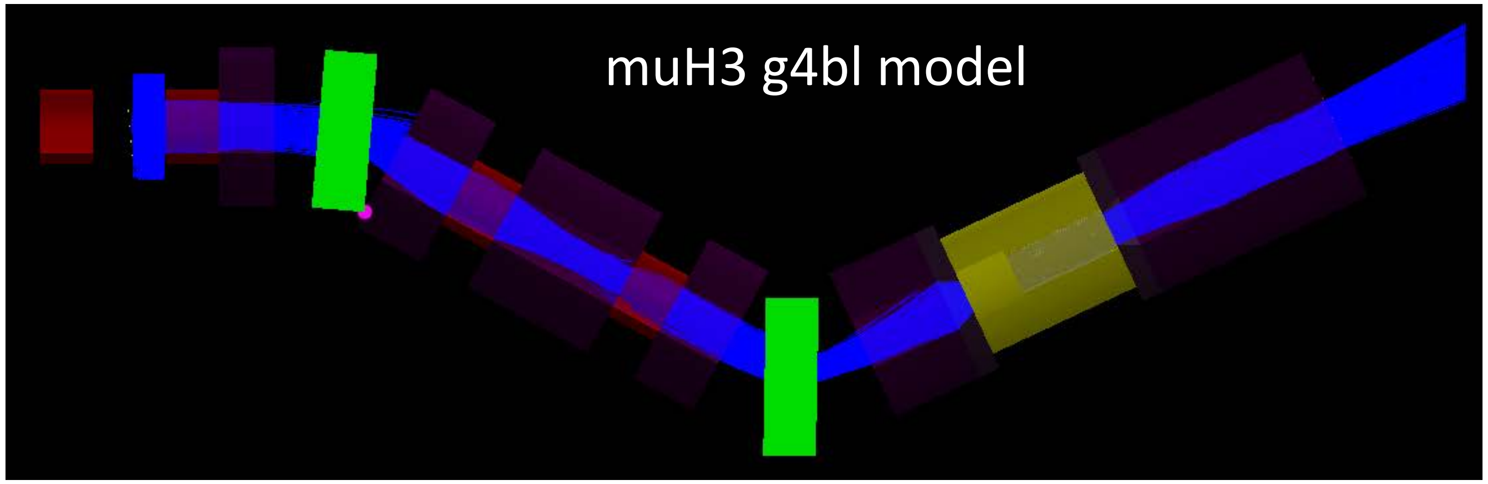
Particle production at TgH

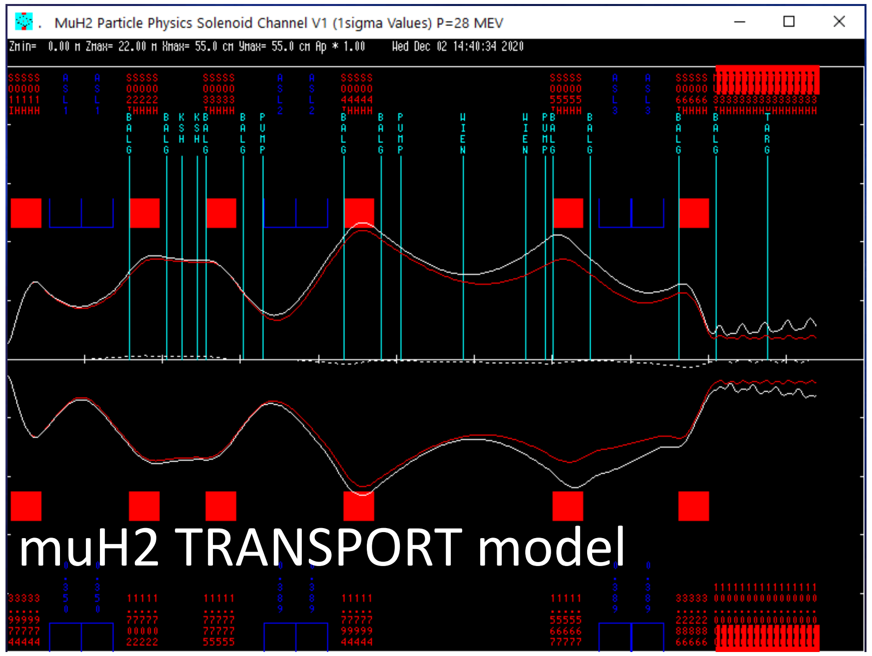


- Of course we are not only producing surface muons
- We will have good transport efficiency up to 40 MeV/c (given by capture solenoid)
- Plan is to design dipoles up to 80 MeV/c

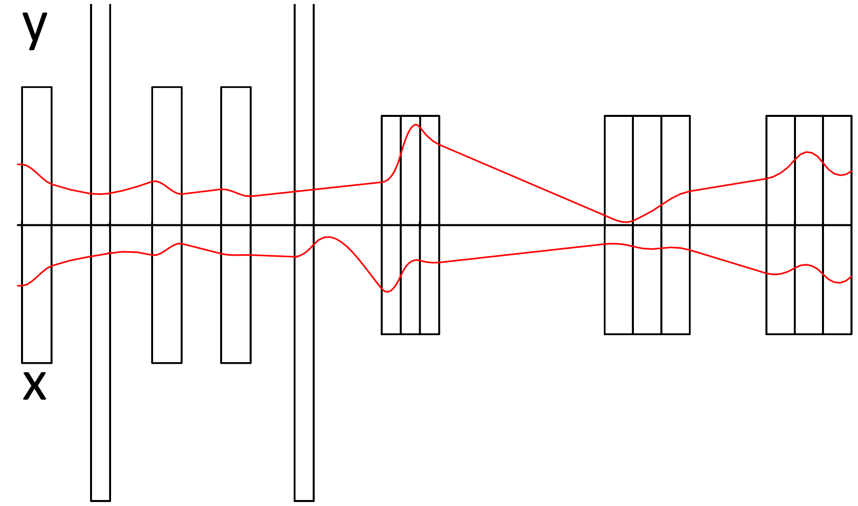
Simulation of beamlines







muH3 COSY INFINITY model

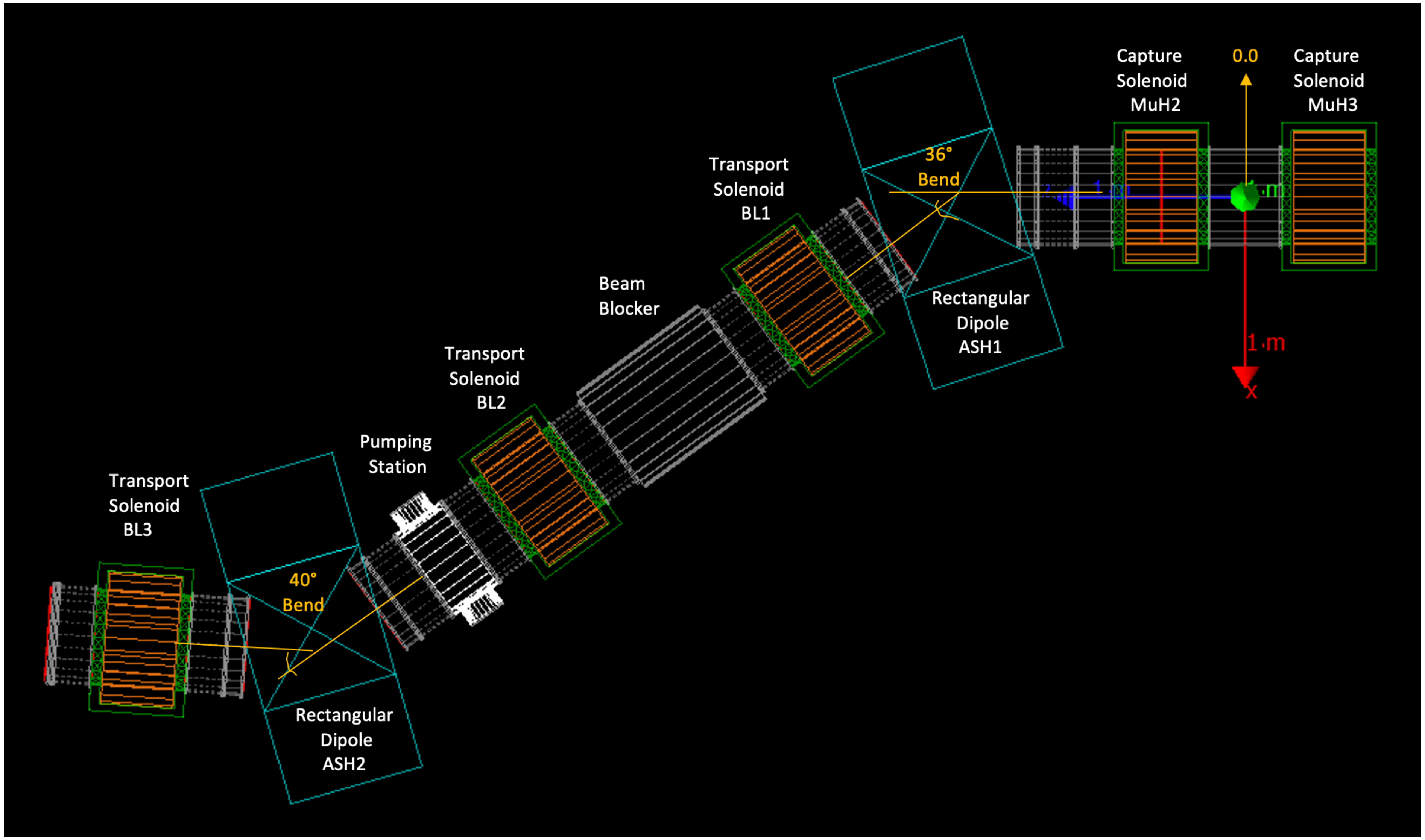


- Simulation tools: g4bl, TRANSPORT, TURTLE, COSY INFINITY
- Optimization tools: grid searches, hyperparameter searches

Status muH2

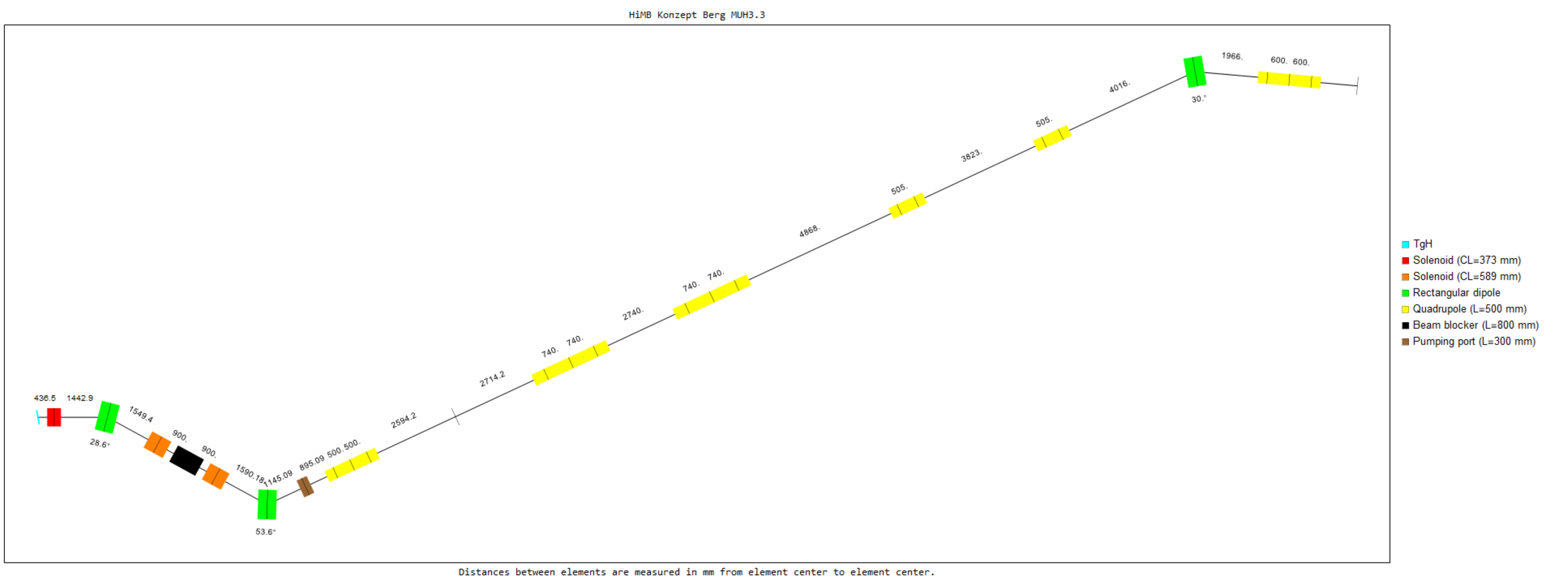
- We have in excess of 10^{10} mu^{+}/s at the final focus without the separator

- Working on getting the beam nicely through the separator, probably need two short separators in series for good transmission and sufficient separation power



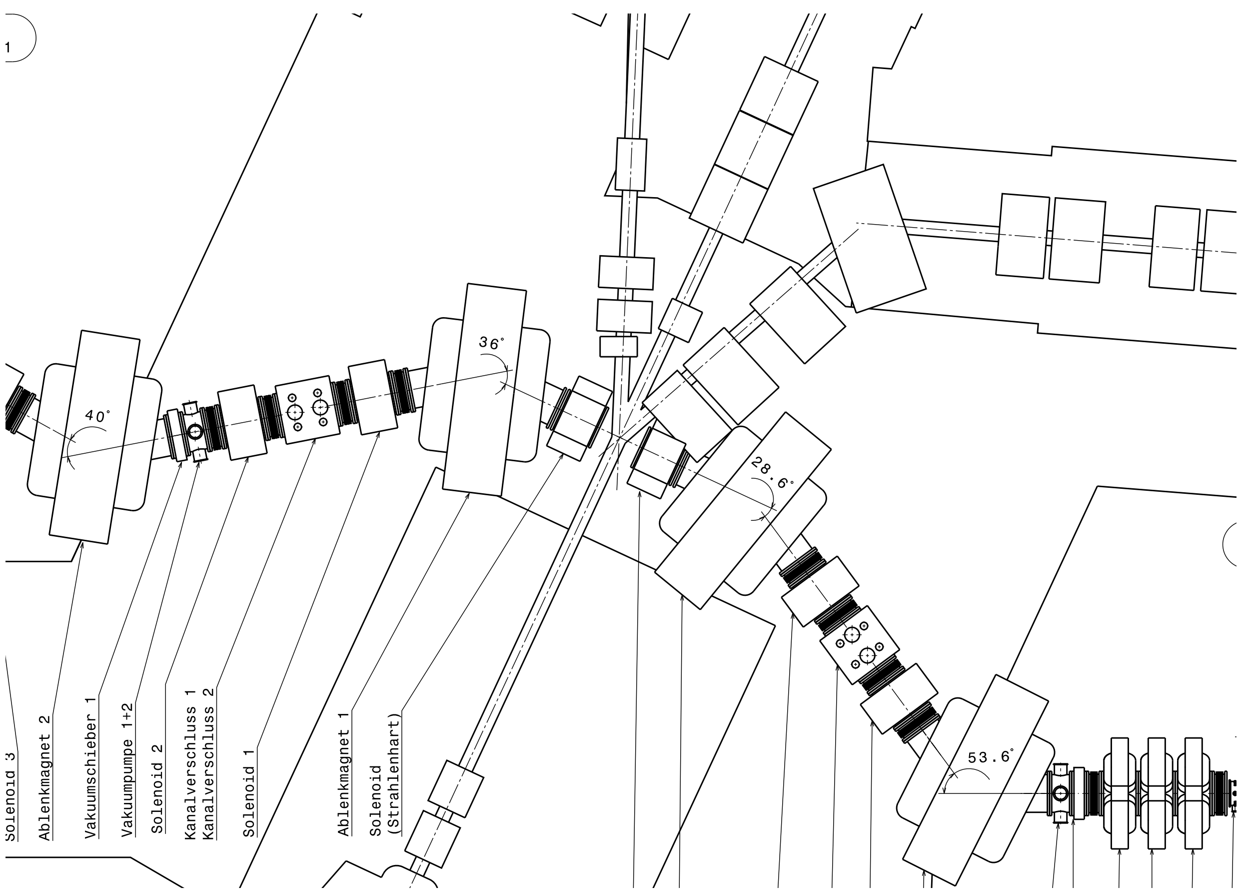
Status muH3

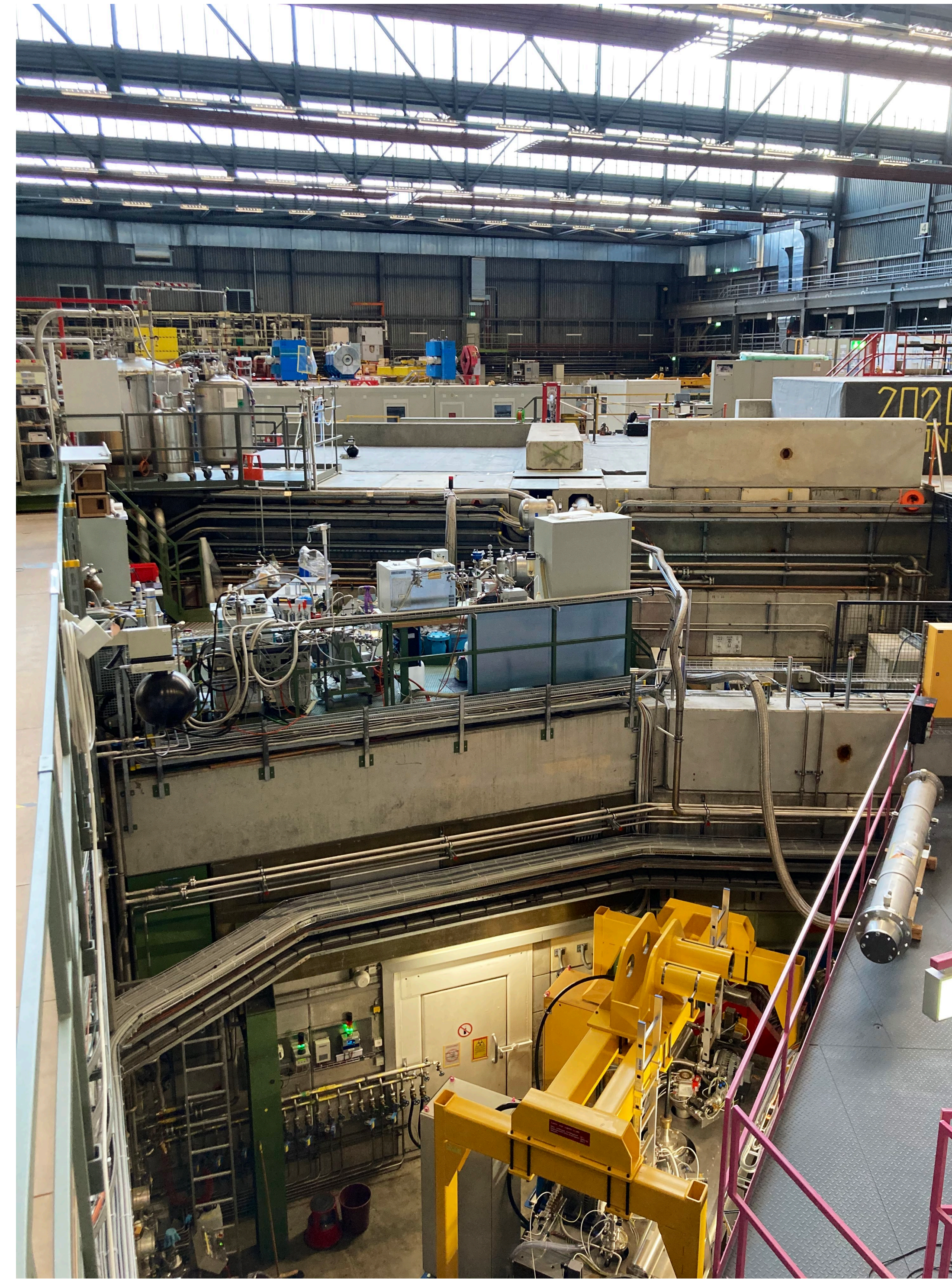
- We have ~10^{10} mu+/s at the end of the solenoidal channel, a few 10^9 mu+/s after the first triplet and ~10^8 mu+/s at the end of the 38-m long beamline
- Losses when coupling into the triplet and along the long quadrupole based beamline unavoidable



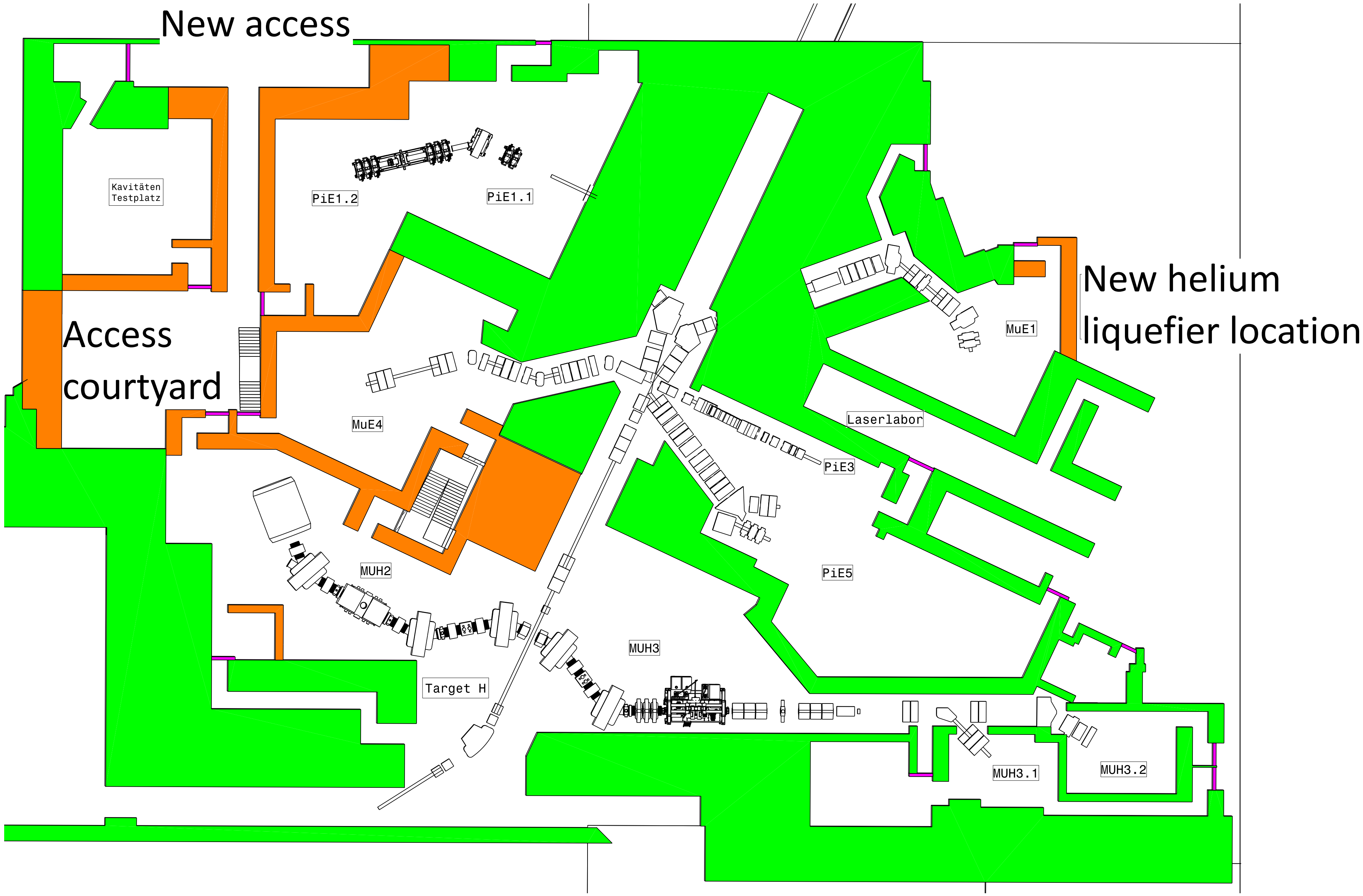
Building a new target station

- Challenging environment around TgM to change layout
- Helium liquefier, tertiary cooling loop 7, lots of pipes, cables and conduits, power supply platforms, …
- And of course in an environment with doses measured in Sv/h



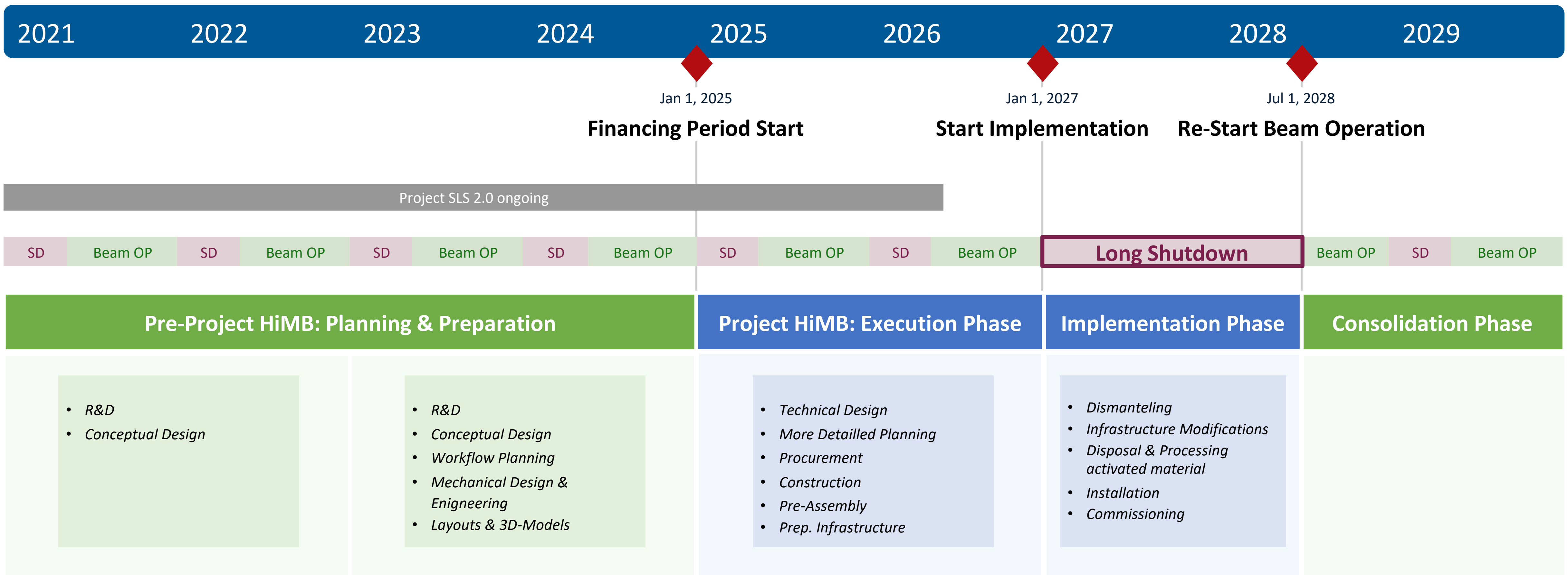


New beamlines and area layouts



- Together with the implementation of the beamlines will also need to adjust the experimental areas, access ways, infrastructure etc.
- At the same time will try to clean up legacy walls and structures as much as possible

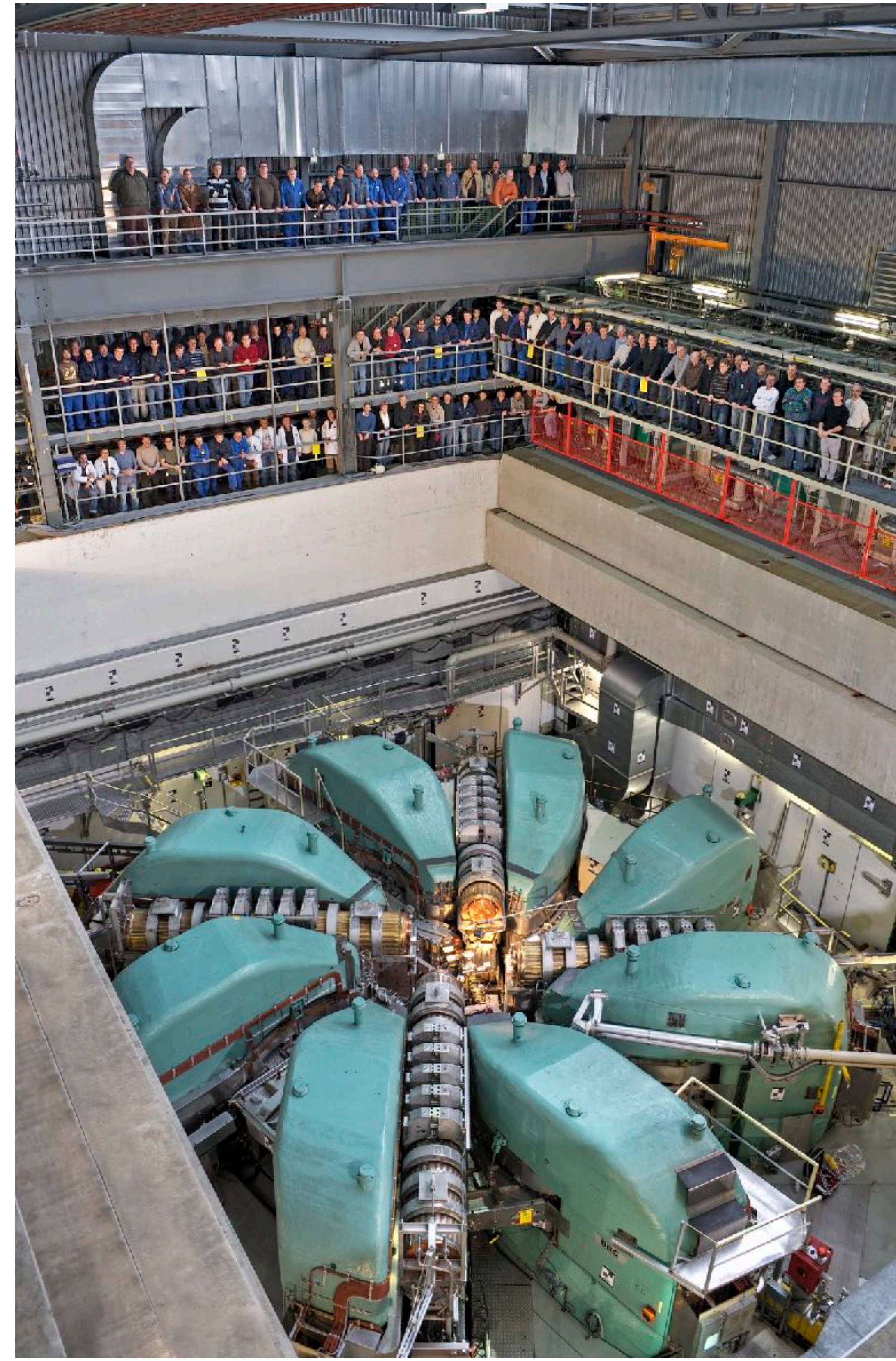
Timeline & next steps



Conclusions

- On track for achieving muon rates of 10^{10} mu^+/s at PSI, but many challenges ahead

- HIMB will enable forefront muon research at PSI for the next 20+ years



Many thanks to everyone from the HIMB project for providing slides and input for this presentation!