High Intensity Muon Beams at PSI

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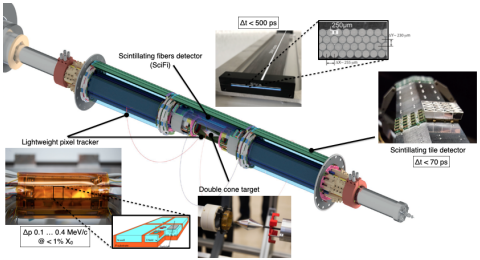
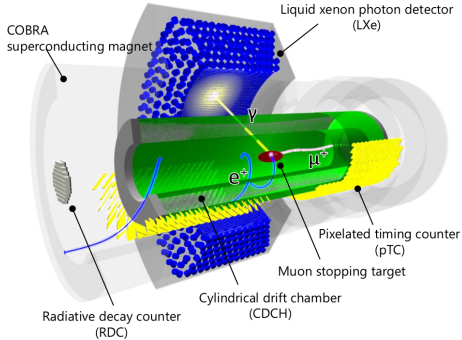
ΠE5 area

MEG II and Mu3e experiments

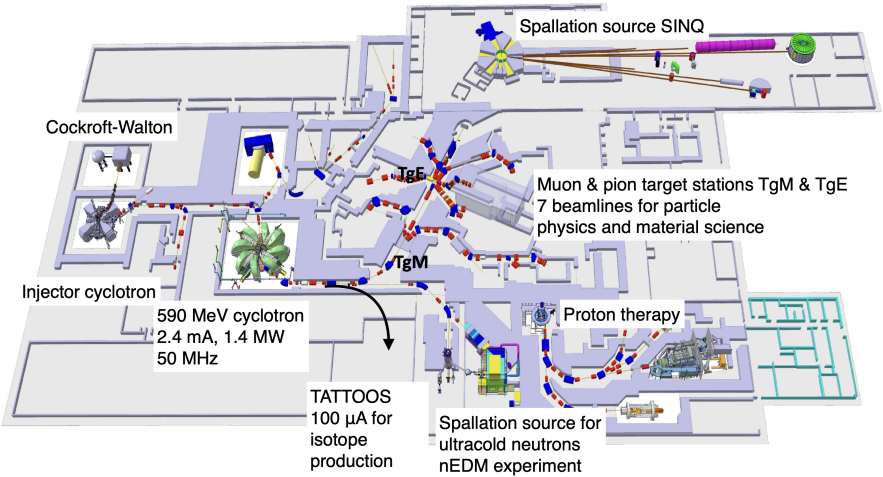
The goal of the MEG II experiment is to measure the decay $\mu^+ \to e^+ \gamma$. The current limit on this process - most stringent upper limit on any particle decay - was set by the MEG collaboration at PSI to $B(\mu^+ \to e^+ \gamma) < 4.2\ 10^{-13}$ (90 % CL). The upgrade aims at reaching a sensitivity of $6\ 10^{-14}$ (90 % CL).





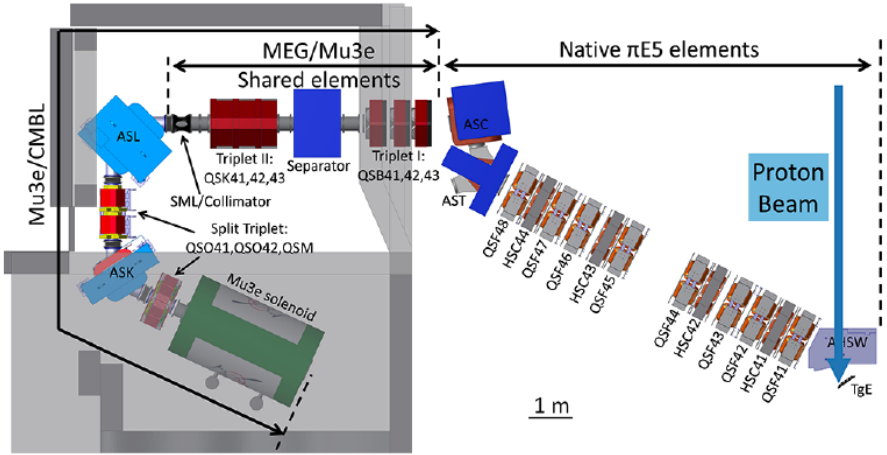
The goal of the Mu3e experiment is to measure the decay $\mu^+ \to e^+ e^- e^+$. The current limit on this process was set at $1.0\ 10^{-12}$ (90 % CL) by the SINDRUM II collaboration at PSI. The Mu3e collaboration aims at reaching a sensitivity of $2\ 10^{-15}$ (90 % CL) in its first phase, and 10^{-16} (90 % CL) in the second one.

The High Intensity Proton Accelerator (HIPA) facility



Mu3e: Compact Muon BeamLine (CMBL) commissioning

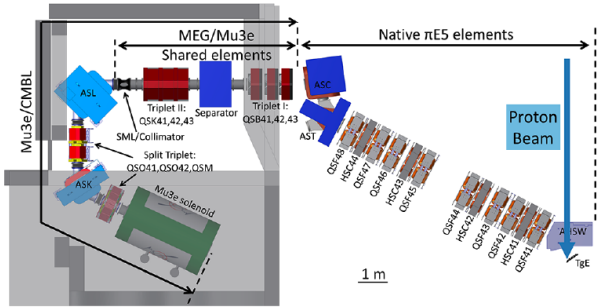
Within the Mu3e experiment I contribute to the commissioning of the beamline: the Compact Muon BeamLine (CMBL).



Mu3e: Compact Muon BeamLine (CMBL) commissioning

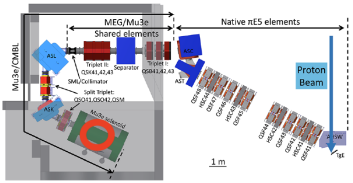
Within the Mu3e experiment I contribute to the commissioning of the beamline: the Compact Muon BeamLine (CMBL). Due to the lack of space the triplet wich couples the beam inside the Mu3e solenoid is "split" in two parts.

The first complete installation and commissioning was performed in 2021. The aim was to provide a first beam tune for the Pre-Ingeneering run of Mu3e in 2021.
In 2022 we focused on improving the transmission through the beamline. The main difficulty is coupling straight after the first bend due to the limited aperture of the QSO doublet.



Mu3e: Compact Muon BeamLine (CMBL) commissioning - 2022

Transmission to the solenoid center is limited by the 60 mm beam pipe (-44 %) and by the 40 mm window (-27 % w.r.t. 60 mm beam pipe configuration) at the end, leading to an overall 59 % loss in transmission. w.r.t. QSM41.



Beam Commissioning Comparison @ 2.2 mA			
Rates	Collimator	QSM41	Mu3e
2021	1.93 10^8 μ^+/s	1.1 10^8 μ^+/s	4.36 10^7 μ^+/s
2022	2.26 10^8 μ^+/s	1.65 10^8 μ^+/s	6.83 10^7 μ^+/s

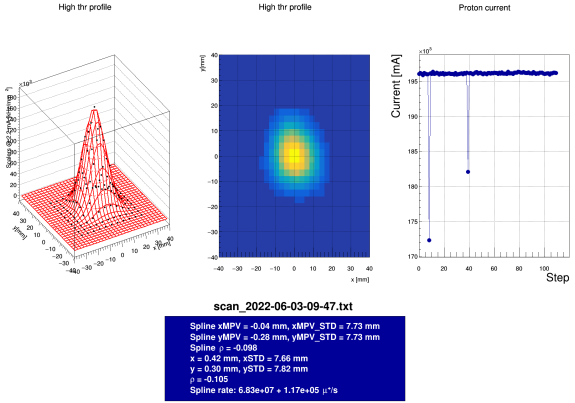
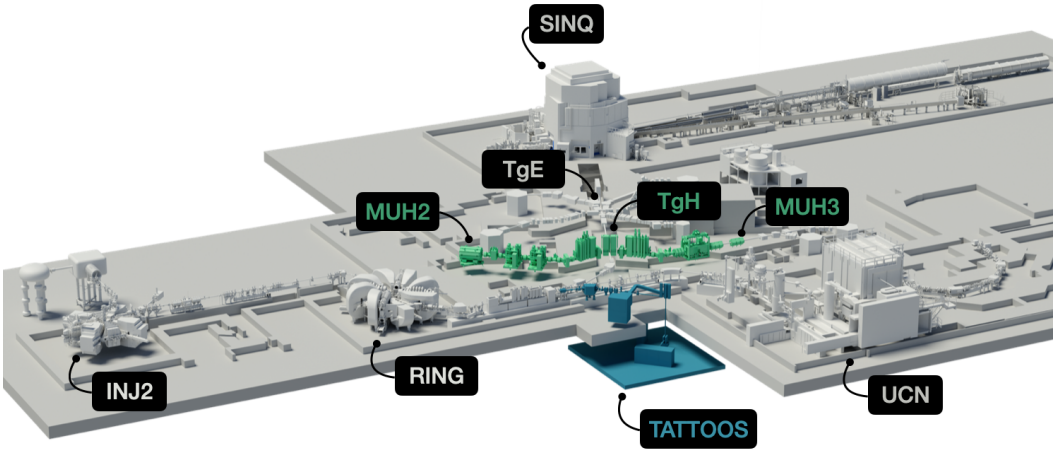


Figure: *Beam profile at Mu3e center*

The HIMB project

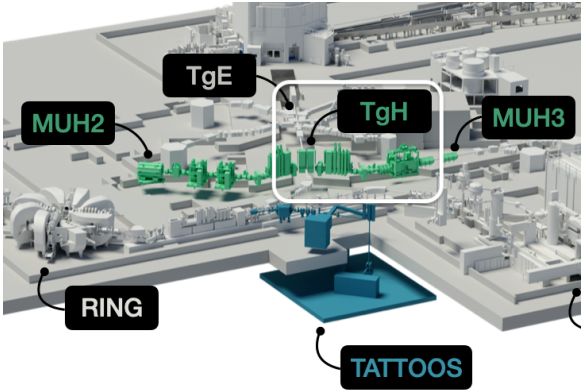
The High-Intensity Muon Beams project (HIMB)

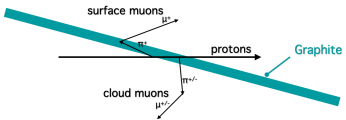
The HIMB project aims at further pushing the current muon rates at PSI by two orders of magnitude, from $10^8\ \mu^+/s$ to $10^{10}\ \mu^+/s$, with a new target station and high transmission beamlines.



The High-Intensity Muon Beams project (HIMB): target

The HIMB project aims at further pushing the current muon rates at PSI by two orders of magnitude, from $10^8\ \mu^+/\text{s}$ to $10^{10}\ \mu^+/\text{s}$, with a new target station and high transmission beamlines.



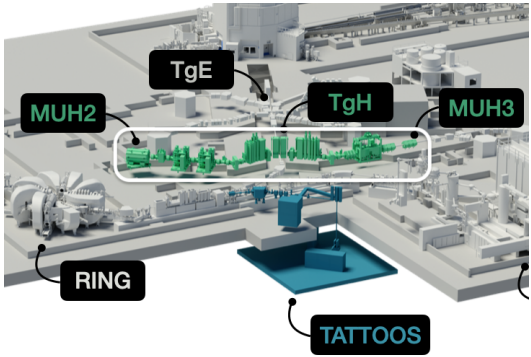


TgM (the thin meson production target) will be substituted by TgH, designed to boost surface muons production:

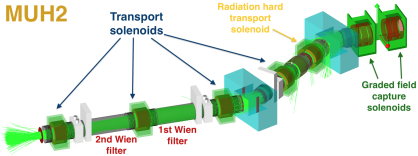
- thicker target: $5.2\,\text{mm} \rightarrow 20\,\text{mm}$
- target tilted w.r.t. to the proton beamline

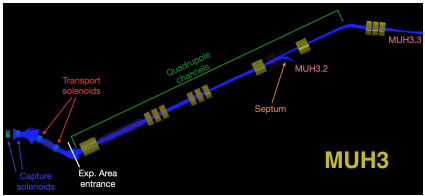
The High-Intensity Muon Beams project (HIMB): beamlines

The HIMB project aims at further pushing the current muon rates at PSI by two orders of magnitude, from 10^8 μ^+/s to 10^{10} μ^+/s, with a new target station and high transmission beamlines.



To increase the capture and the transmission of surface muons, the two HIMB beamlines will be based on solenoidal elements.

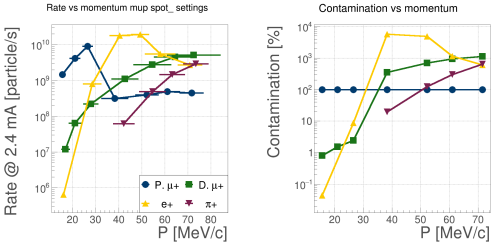




The High-Intensity Muon Beams project (HIMB): optimization

My contribution to the project consists of the optimization of the MUH2 beamline in the full momentum spectrum for the different particle beams.

To do so I'm employing both Bayesian optimization to find the highest transmissions, and Genetic Algorithms to optimize at once the figures of merit we are interested into, like the beam spot size and the average momentum.



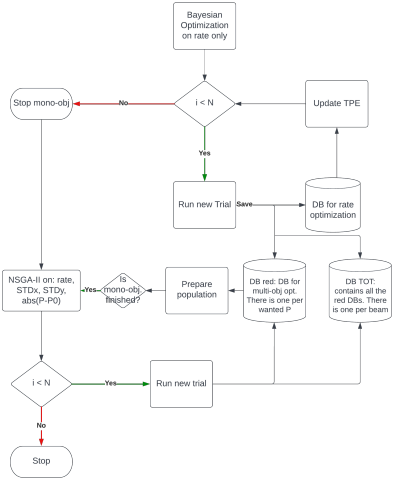


Figure: Hybrid optimization algorithm.

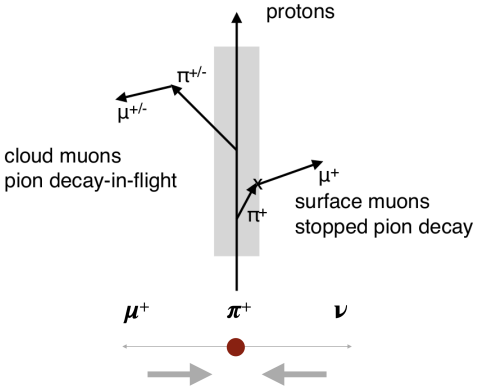
Thank you for your attention!

Backup

Muon production

The protons impinge on TgM and TgE, producing pions that decay in muons. Depending on where they are created, we classify:

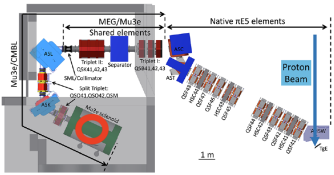
- Surface and sub-surface muons (5-30 MeV/c): they are created inside the target from pions at rest as a monochromatic line of 29.8 MeV/c of momentum. Therefore their energy depends only on their path inside the target. Additionally, they are fully polarized.
- Cloud muons: they come from pion decay in flight.

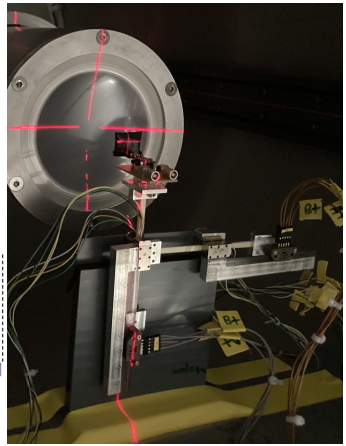


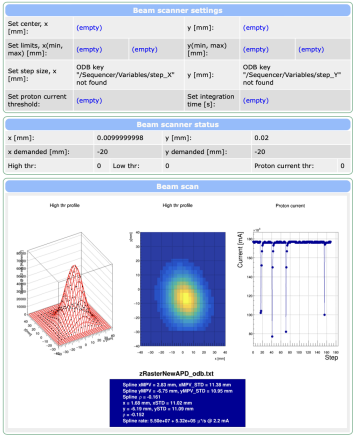
Due to the high intensity and low momentum, the most interesting muons for many experimental applications are surface muons: the HIMB project focuses on the transport of muons with a momentum around 28 MeV/c.

Mu3e: Compact Muon BeamLine (CMBL) commissioning - 2022

Measurements at solenoid center are performed using an Avalanche PhotoDiode (APD), moved by two piezoelectric motors with optical encoders. The whole scanner was built by Ioannis. This year we ran with a MIDAS front-end.

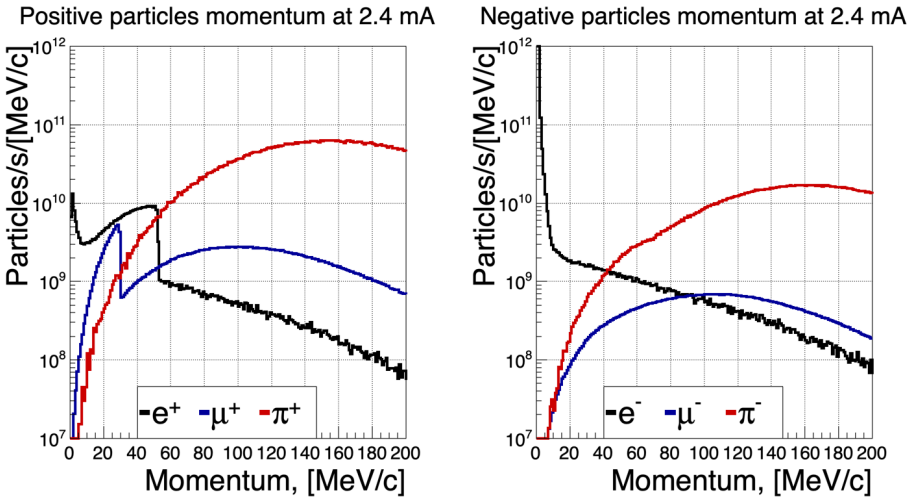






Particle production at TgH

We don't produce only muons of course!



Bayesian optimization

A Bayesian optimizer is a "black-box" global minimum finder.

At each iteration the parameters to be tested are randomly sampled from the domain to be explored, with a distribution which is weighted based on the previous results: at each iteration it is more probable to sample the parameters where the uncertainty on the "black-box" function is higher.

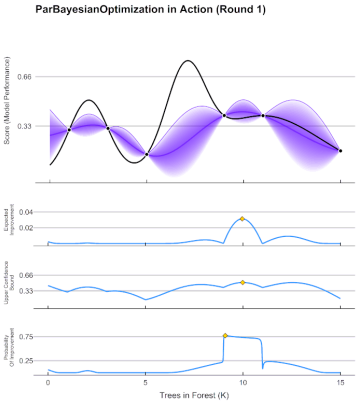


Figure: Wilson, Samuel (2019-11-22), ParBayesianOptimization R package, retrieved 2019-12-12

Non-dominated Sorting Genetic Algorithm-II

The basic idea is to define a population where each individual is characterized by his genes, namely the parameters of the problem.

At each epoch the individuals mix through breeding, crossover, mutation ...

The population is classified based on dominance and crowding distance