High Intensity Muon Beams at PSI

Giovanni Dal Maso

ESR meeting

Bachelor and Master degrees

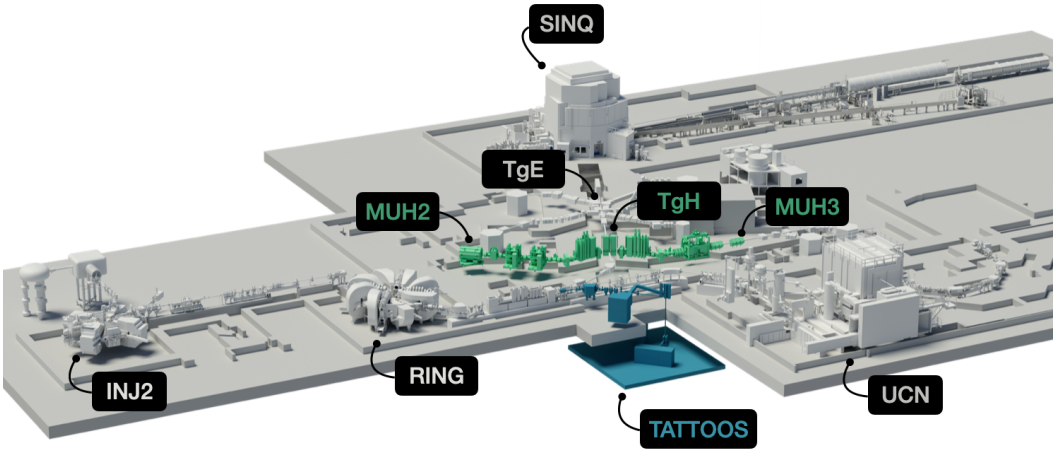
- Born in Cuneo and grown up in Siena, Italy
- Bachelor in Physics at University of Pisa, 2015-2018
- Master in Fundamental Interactions at University of Pisa, 2018-2020. Thesis title: "Beam diagnostic and calibration tools for the MEGII experiment".
- Started Ph.D. at PSI - ETH Zürich on March 2021

giovanni.dal-maso@psi.ch

The HIMB project

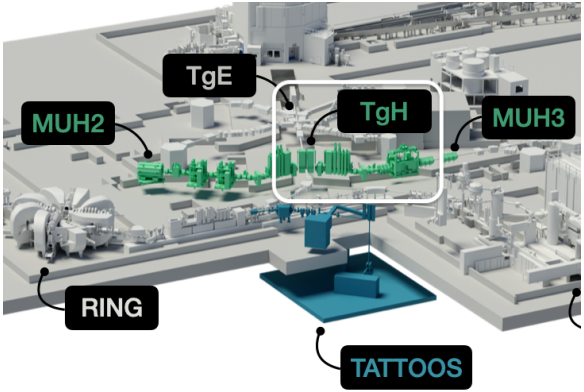
The High-Intensity Muon Beams project (HIMB)

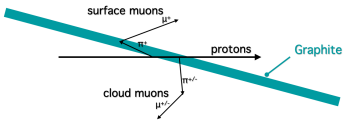
The HIMB project aims at further pushing the current muon rates at PSI by two orders of magnitude, from $10^8\ \mu^+/\mathrm{s}$ to $10^{10}\ \mu^+/\mathrm{s}$, with a new target station and high transmission beamlines.



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.

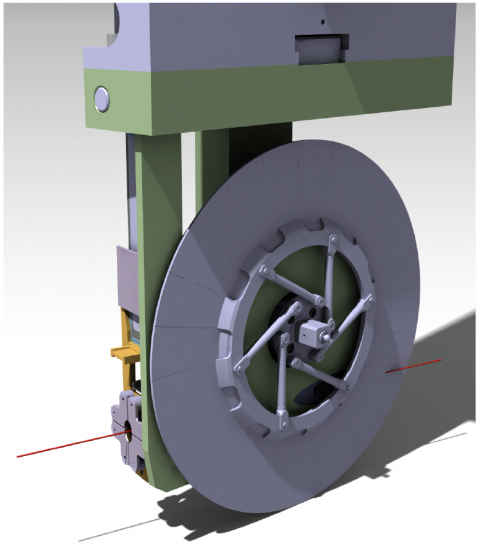


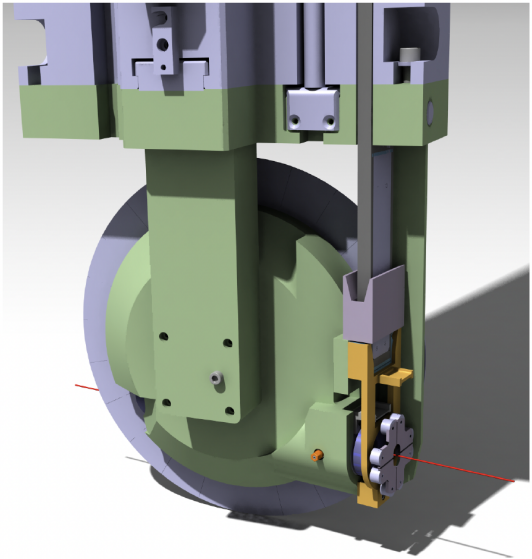


TgM (the thin meson production target) will be substituted by TgH, designed to boost surface muons production:

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

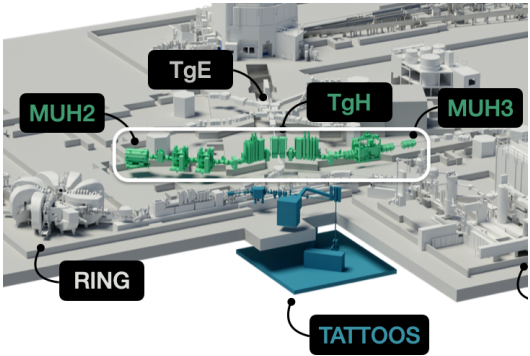
The High-Intensity Muon Beams project (HIMB): target



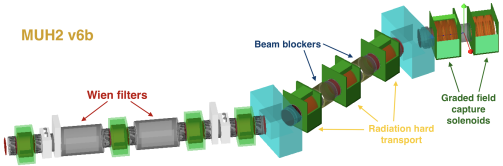


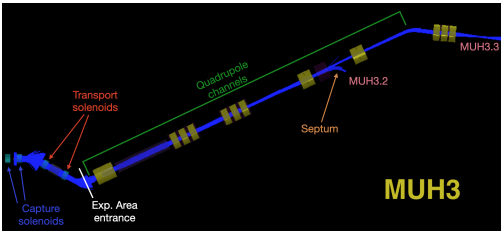
The High-Intensity Muon Beams project (HIMB): beamlines

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.





MUH2 beamline update

The MUH2 beamline is designed to transmit the highest muon beam rates thanks to a big acceptance, which comes with a few drawbacks:

- high positron contamination
- high neutron dose

Last time I showed you alternative designs of MUH2 based on adding bends. We evaluated the possibility of keeping two bends but adding a vertical component to them.

Rates

	Optimisation at			
Model	# parameters	Pill	Exp.	
Normal	11 + 4	1.32	1.02	$10^{10}\,\mu^+/s$
VerticalAsym	21 + 4	1.31	0.937	$10^{10}\,\mu^+/s$
VerticalFullAsym	21 + 4	1.03	0.789	$10^{10}\,\mu^+/s$
VerticalSym	21 + 4	1.32	0.975	$10^{10}\,\mu^+/s$
VerticalOnly	21 + 4	1.34	0.982	$10^{10}\,\mu^+/s$

Table: All rates are normalised to 2.4 mA.

Models

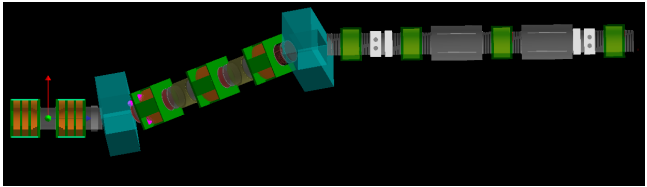
I ran the optimisation for 5 geometries:

- Normal: this is fully horizontal but the positioning of the corners is coherent with the following ones $\rightarrow$ **used as a reference to compare with the current MUH2 v6b achievement**
- VerticalAsym: the oblique angles are 36° and 40°, the vertical bends are 30°
- VerticalFullAsym: the horizontal angles are 36° and 40°, the vertical bends are 30°. The oblique angles are 45.5° and 48.4°
- VerticalSym: the oblique angles are both 36°, the vertical bends are 30°
- VerticalOnly: both bends are 36° vertical only

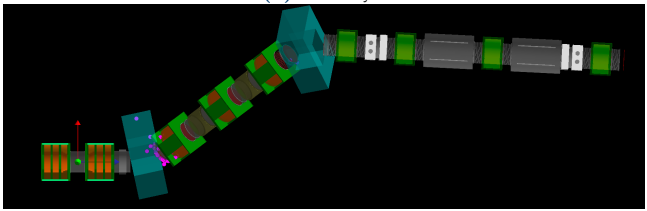
I optimised both the position and orientation of both dipoles.

MUH2 layouts

Here a comparison between the VerticalSym and VerticalFullAsym models (top view).



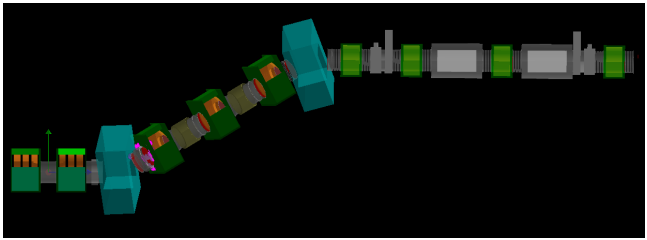
(n) VerticalSym



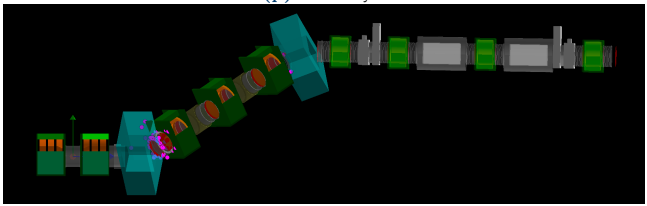
(o) VerticalFullAsym

MUH2 layouts

Here a comparison between the VerticalSym and VerticalFullAsym models (right view).



(p) VerticalSym



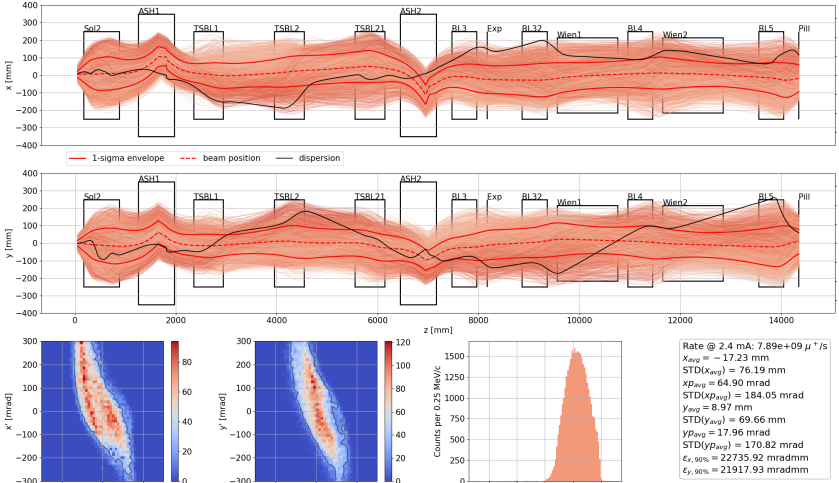
(q) VerticalFullAsym

Rates

	Optimisation at			
Model	# parameters	Pill	Exp.	
Normal	11 + 4	1.32	1.02	$10^{10}\,\mu^+/s$
VerticalAsym	21 + 4	1.31	0.937	$10^{10}\,\mu^+/s$
VerticalFullAsym	21 + 4	1.03	0.789	$10^{10}\,\mu^+/s$
VerticalSym	21 + 4	1.32	0.975	$10^{10}\,\mu^+/s$
VerticalOnly	21 + 4	1.34	0.982	$10^{10}\,\mu^+/s$

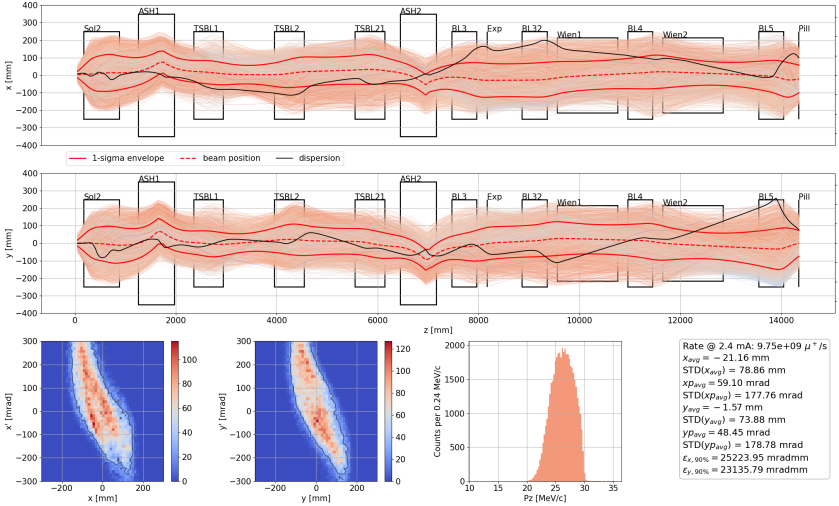
Table: All rates are normalised to 2.4 mA.

MUH2 v6b: VerticalFullAsym - envelope



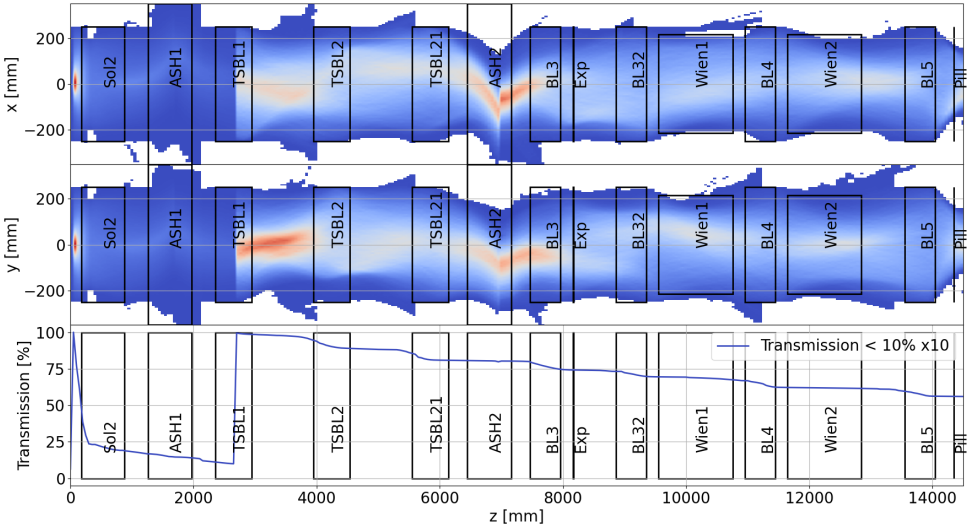
(a) VerticalSym

MUH2 v6b: VerticalSym - envelope

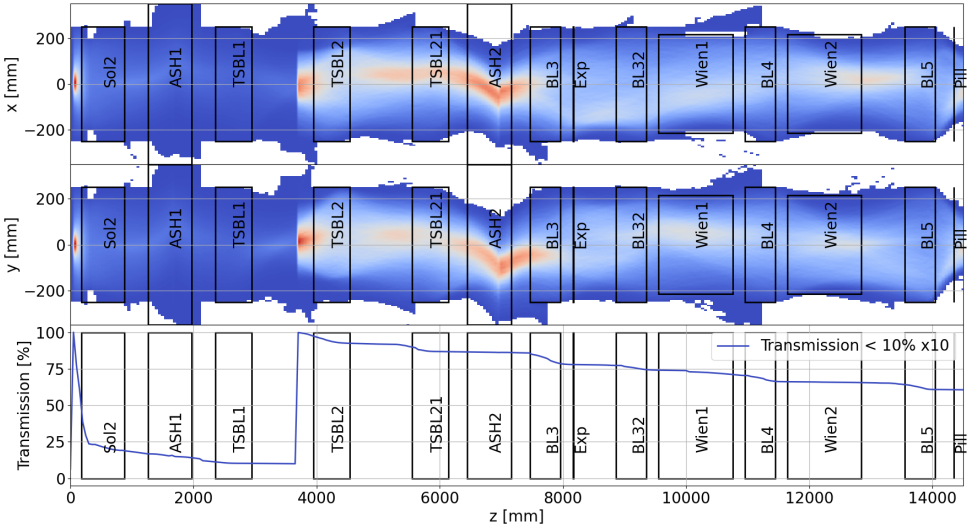


(a) VerticalSym

MUH2 v6b: VerticalFullAsym - transmission



MUH2 v6b: VerticalSym - transmission



Outlook

- MUH2 design fulfills requirements on muon rate
- including a vertical component to the bends leads to a loss in rate $\sim 5\,\%$

Lectures and teaching

Courses for PhD credits at ETH Zürich:

- autumn 2021:
  - "Learning to Teach": this course imparted a variety of teaching skills that help Doctoral Teaching Assistants with their teaching tasks
  - "Astronomical Observations and Instrumentations": course focused on the main and recent astronomical observations and description of the most relevant employed instrumentations
- spring 2022:
  - Joint Universities Accelerator School, COURSE 2: technology and applications of particle accelerators
- summer 2022:
  - Engaging Physics Tutoring Summer Camp
  - PSI Particle Physics Summer School - Vision and Precision
- autumn 2022:
  - Pluralist Philosophy of Mathematics: the goal is to introduce students to mainstream philosophies of mathematics.

Teaching at ETH Zürich:

- autumn 2021: Physics 1 exercise class for Medicine and Health Sciences students
- spring 2022: Physics 2 exercise class for Medicine and Health Sciences students
- autumn 2022: Physics 1 Übungschef for Medicine and Health Sciences students
- spring 2023: Physics 2 Übungschef for Medicine and Health Sciences students

Conferences

Training:

- 20-21 May 2021: *First Muon Community Meeting* (Muon Collider Workshop), Online
- 2-4 August 2021: *Fermilab 2021 Summer Student School at LNF*, Laboratori Nazionali di Frascati INFN Online
- 6-8 September 2021: *Shedding light on X17*, Centro Ricerche Enrico Fermi, Rome Online
- 24-26 November 2021: *International Workshop on Cosmic-Ray Muography (Muography2021)*, Ghent Online
- 4-6 July 2022: *LF(U)V Workshop*, Universität Zürich.

Conferences and workshops:

- 6-9 April 2021: *HIMB Physics Case Workshop*, PSI - Paul Scherrer Institut Online
- 10-11 June 2021: *CHIPP Plenary 2021*, Spiez Switzerland. Poster:"High Intensity Muon Beam project(HIMB): how to improve the most intense muon beam in the world"
- 30 August-3 September 2021: *Joint Annual Meeting of the APS SPS*, Universität Innsbruck. Talk: "High Intensity Muon Beam project (HIMB): how to improve the most intense muon beam in the world"
- 22-28 May 2022: *Pisa Meeting on Advanced Detectors - Edition 2022*, La Biodola - Isola d'Elba, Italy. Poster: "Beam monitoring detectors for High Intensity Muon Beams" + proceedings
- 27-30 June 2022: *Annual Meeting of the Swiss Physical Society*, Université de Fribourg. Talk: "High Intensity Muon Beam (HIMB): how to improve the most intense muon beam in the world"
- 29 August - 2 September 2022: *8th International Symposium on Symmetries in Subatomic Physics*, Universität Wien. Invited talk + proceedings: "Future facilities at PSI, the High-Intensity Muon Beams (HIMB) project".
- 16-21 October 2022: *Physics of fundamental Symmetries and Interactions - PSI2022*, Paul Scherrer Institut. Poster: "Multi-Objective Genetic Optimization for the High-Intensity Muon Beams at PSI".
- 15-17 February 2023: *New Physics Signals 2023 - NePsi 2023*, Department of Physics, Pisa University. Poster: "Multi-Objective Genetic Optimization for the High-Intensity Muon Beams at PSI".

Publications and secondments

Publications:

- A. Baldini et al., "The Search for $\mu^+ \to e^+\gamma$ with 10–14 Sensitivity: The Upgrade of the MEG Experiment", Symmetry 2021, 13(9), 1591 (https://doi.org/10.3390/sym13091591);
- M. Aiba et al., "Science Case for the new High-Intensity Muon Beams HIMB at PSI", arXiv:2111.05788.
- Eichler, R. et al. "IMPACT conceptual design report", (PSI Bericht, Report No.: 22-01). Paul Scherrer Institut.
- G. Dal Maso et al., "Beam monitoring detectors for High Intensity Muon Beams", Nucl. Instrum. Methods A (https://doi.org/10.1016/j.nima.2022.167739)
- G. Dal Maso et al., "Future facilities at PSI, the High-Intensity Muon Beams (HIMB) project", EPJ Web of conferences, (https://doi.org/10.1051/epjconf/202328201012)

Secondments:

- secondment at University of Tokyo for X17 analysis, 13th March - 5th April 2023
- secondment at University of Pisa for X17 analysis, 11th-28th April 2023

Backup

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.

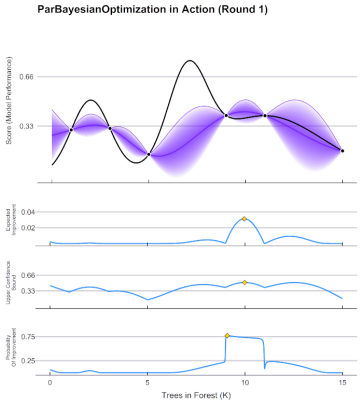


Figure: Wilson, Samuel (2019-11-22), ParBayesianOptimization R package, retrieved 2019-12-12

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