3-months meeting - 28/11/2023

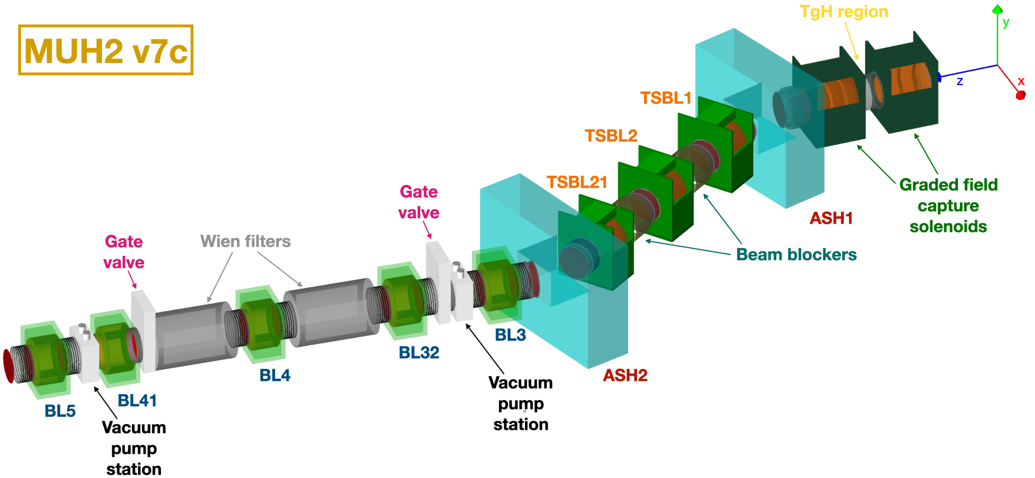
Giovanni Dal Maso

November 2023

MUH2 updates

MUH2 v7c

Optimization of MUH2 v7c ongoing: first max rate, than beam spot centering and contamination.



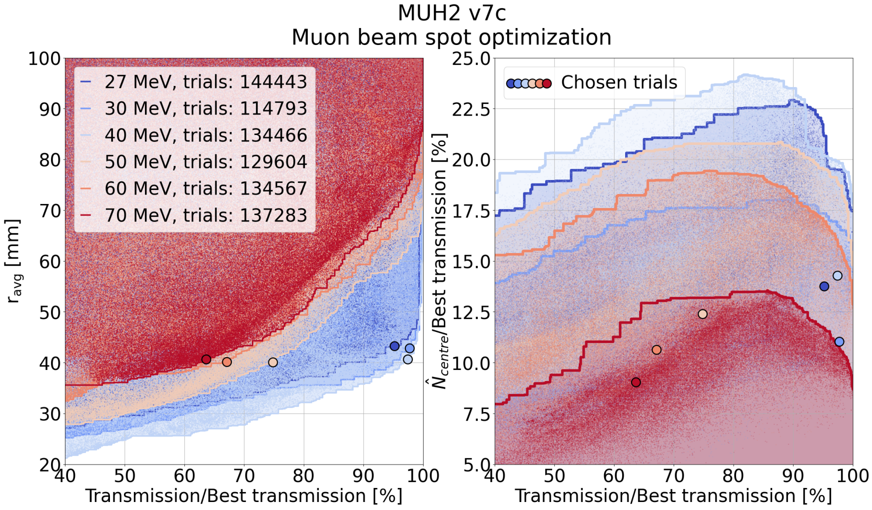
MUH2 v7c - Beam Spot optimization

Optimization of MUH2 v7c beam spots ongoing. The optimized parameters are:

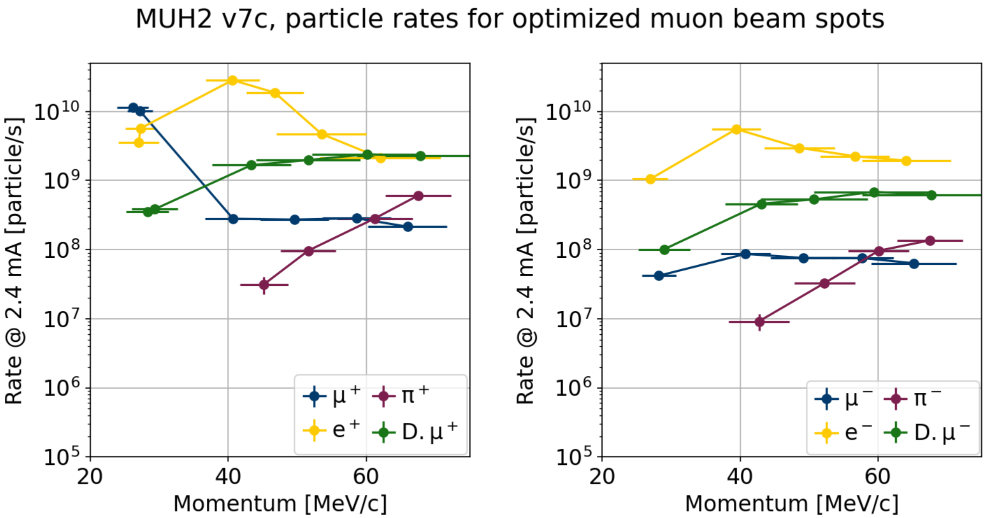
- number of transmitted muons
- average radius of the final beam spot: $\mathbb{E}[x^2 + y^2]$
- number of particles within 50 mm at the center of BL3, BL32, BL4, BL41 and BL5 ($\sim$ centering)

The fields of the radiation hard solenoids are frozen to maximum transmission. Only BL3, BL32, BL4, BL41, BL5, ASH1 and ASH2 are free to vary.
It was run for full muon momentum spectrum, 50 MeV/c positrons, 70 MeV/c negative pions.

MUH2 v7c - Beam Spot optimization results - muons

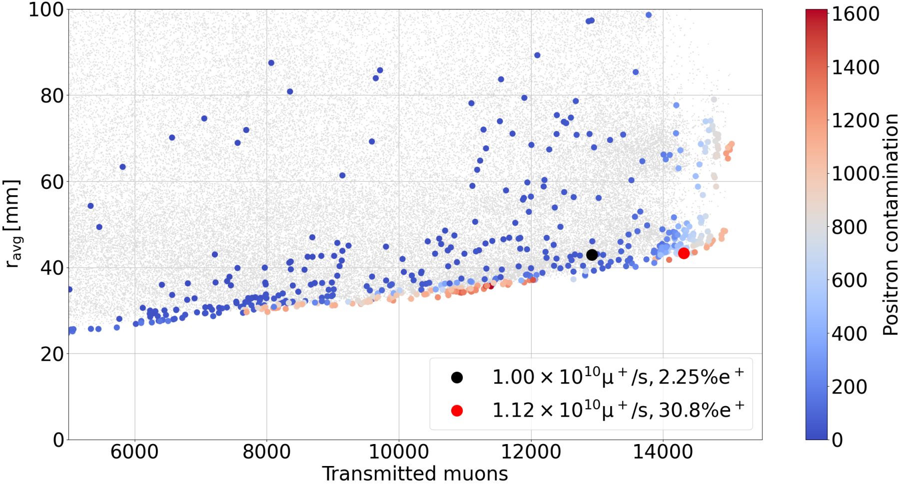


MUH2 v7c - Beam Spot optimization rates



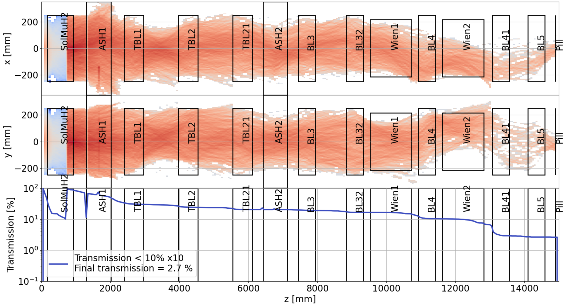
MUH2 v7c - Low contamination surface muons

Positron contamination was added as a figure of merit to surface muons.

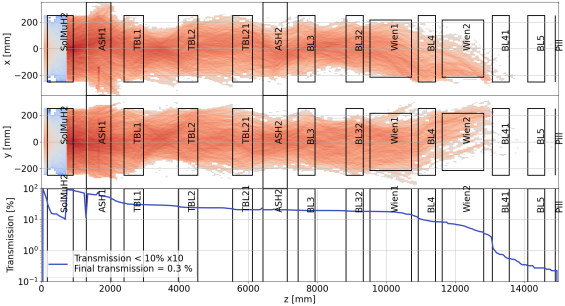


MUH2 v7c - Low contamination surface muons

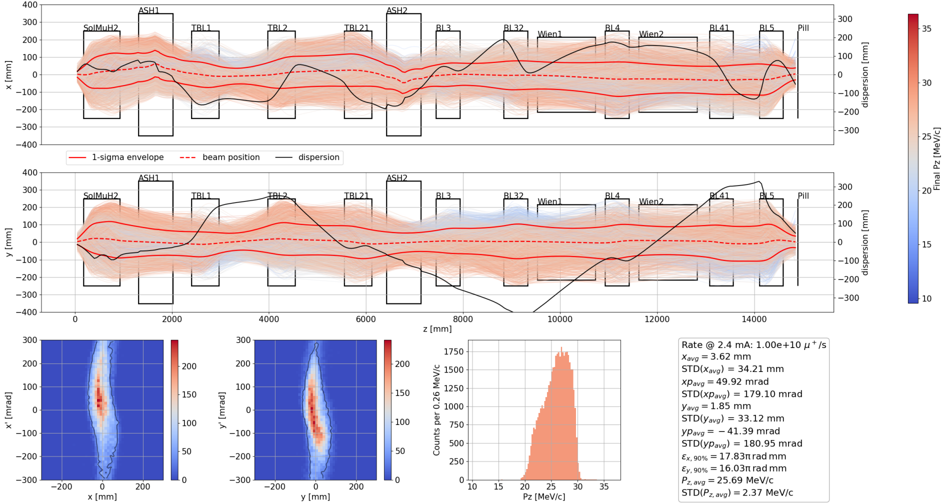
Beams spot trade-off only.



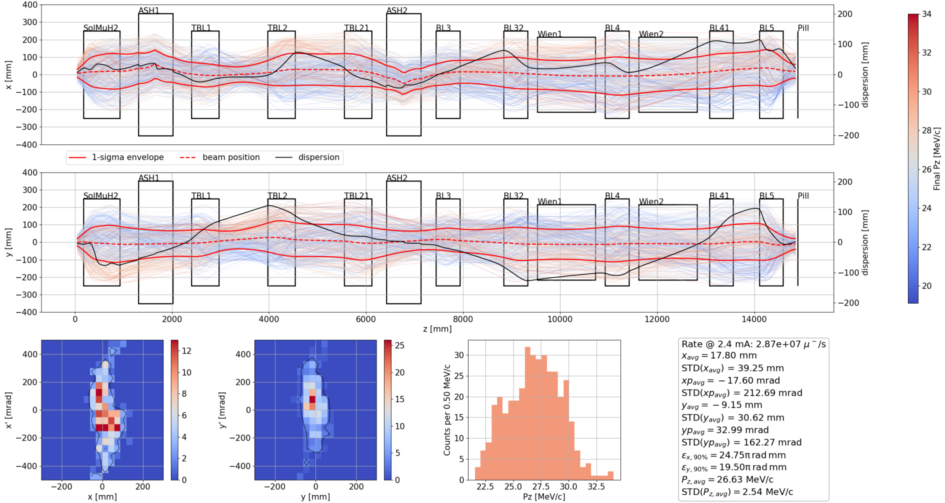
Beams spot trade-off + contamination cut.



MUH2 v7c - Low contamination surface muons

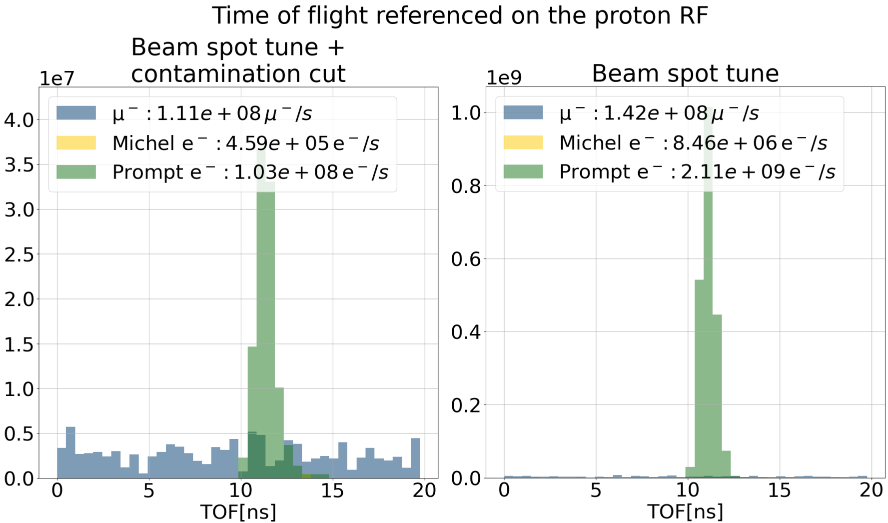


MUH2 v7c - Low contamination negative muons

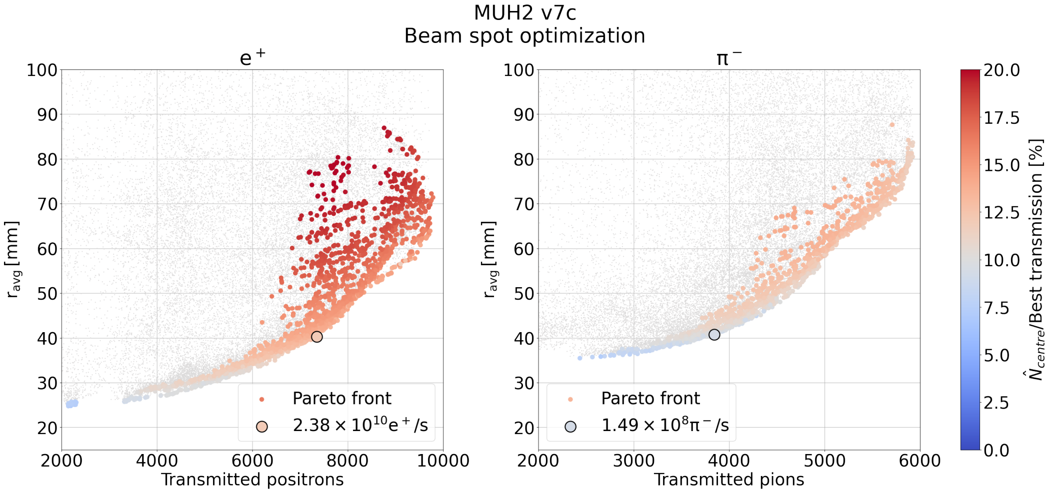


MUH2 v7c - Low contamination negative muons

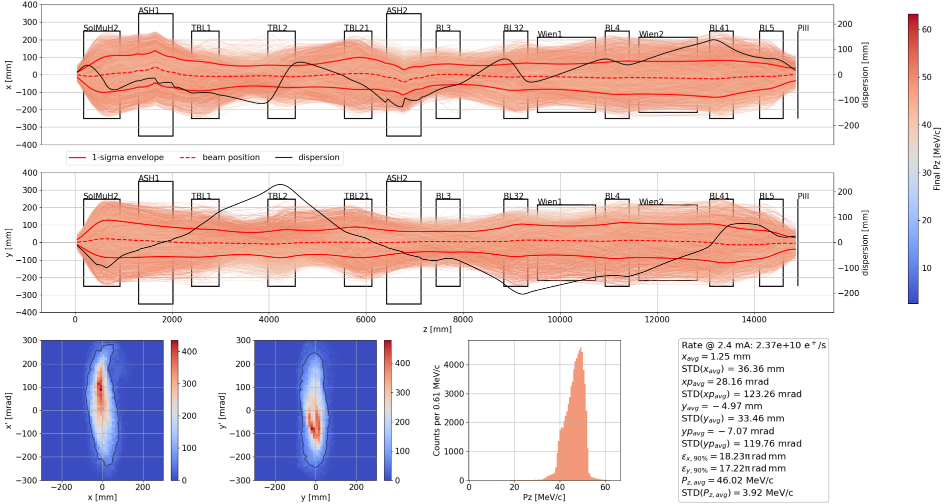
Hopefully the new separator will improve contamination here leading to manageable electron contamination. In alternative the time structure is promising.



MUH2 v7c - Mott positrons and CEX pions

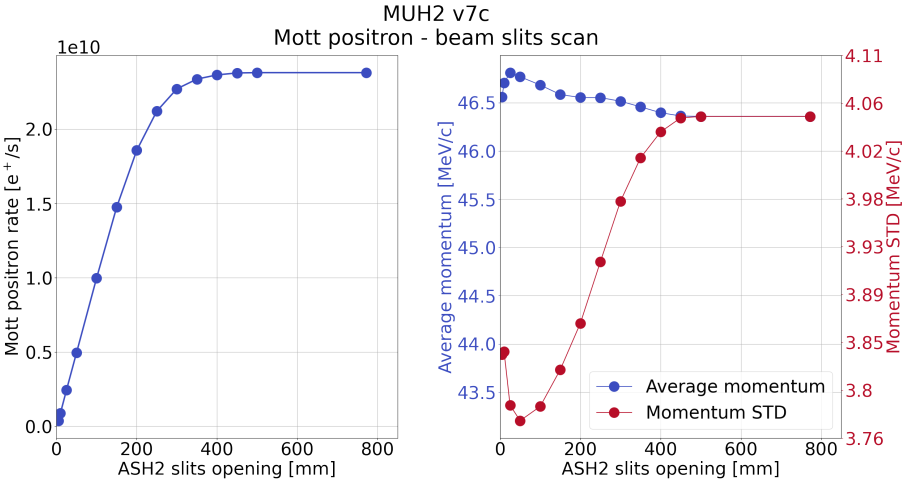


MUH2 v7c - Mott positrons

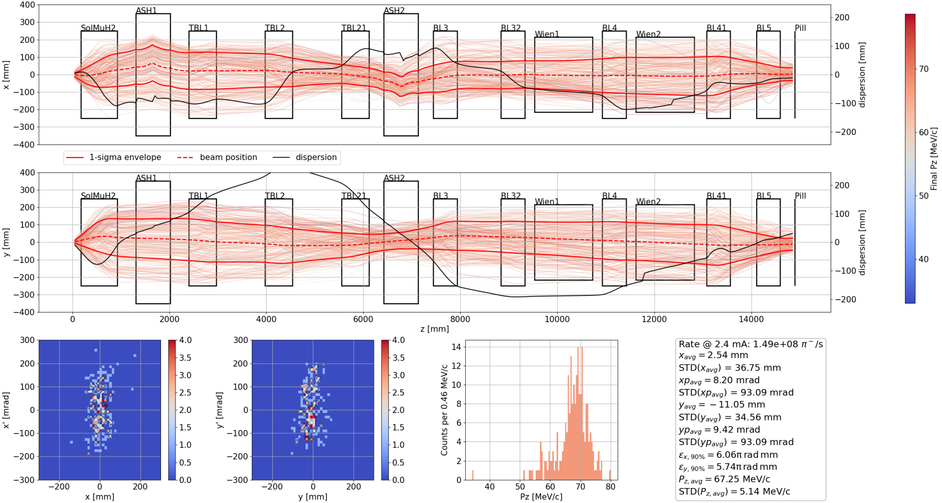


MUH2 v7c - Mott positrons - slits scan

As one would expect, not possible to go much lower in momentum spread.



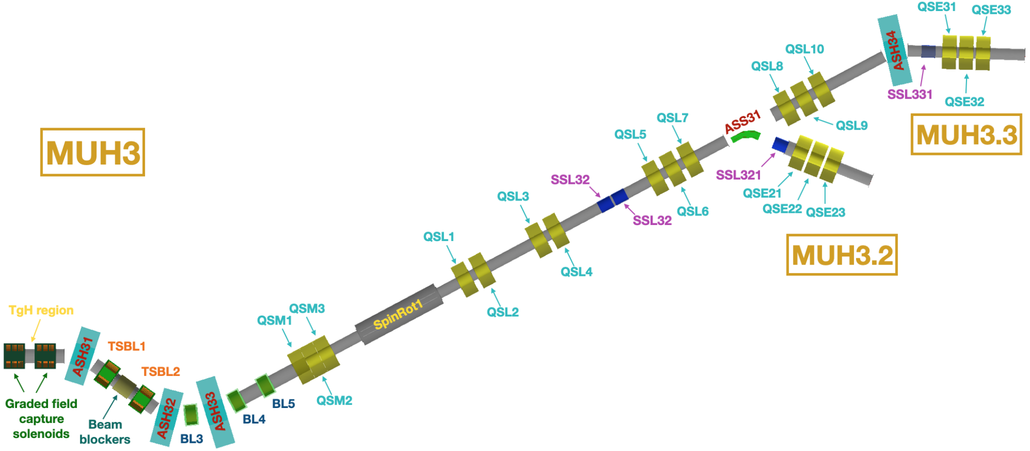
MUH2 v7c - CEX negative pions



MUH3 updates

MUH3 v6

MUH3 v6 is v5 from Eremey with additional bend on the US side.



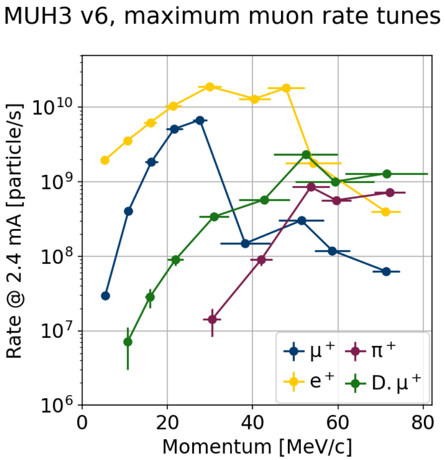
MUH3 v6

Muon rate is maximized at the end of the Spin Rotator. 14 free parameters:

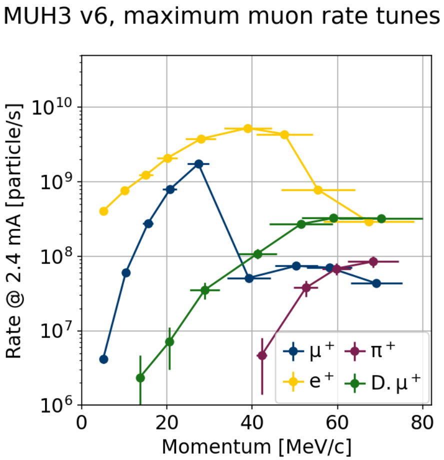
- 3 dipolar fields
- 8 solenoidal fields
- 3 quadrupolar fields

The optimization is done in the full momentum spectrum as for MUH2, analogously to what shown in CDR.

MUH3 - Max Rates

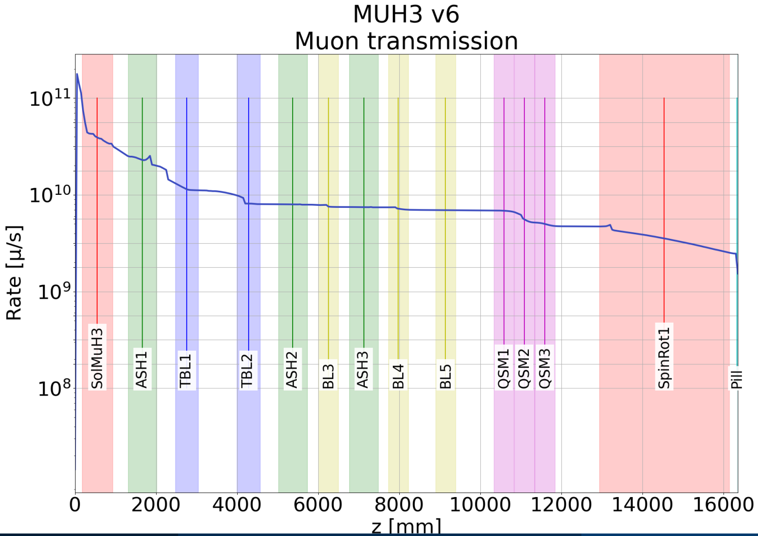


(a) BL5



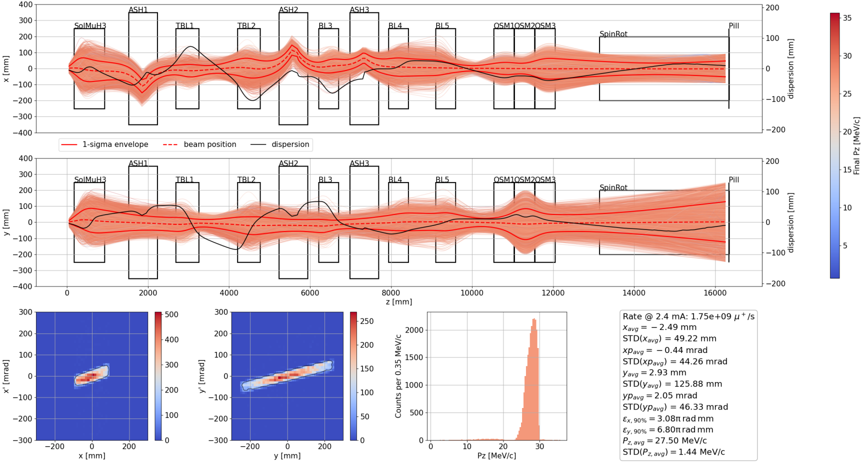
(b) SpinRot1

MUH3 - Surface muons transmission



MUH3 - Surface muons envelope

The idea is that SpinRot1 is cutting enough the phase space so that it doesn't change downstream to it for maximum transmission independentlì on momentum byte. Then, one can do the matching only downstream.
→ this is actually the case



MUH3 - Maximum transmission phase spaces

Nominal momentum	27 MeV/c	40 MeV/c	50 MeV/c	60 MeV/c	70 MeV/c
Prompt muon Rate [μ^+/s]	1.75×10^9	5.43×10^7	7.92×10^7	7.56×10^7	4.41×10^7
Deep muon Rate [μ^+/s]	4.01×10^7	1.32×10^8	3.00×10^8	4.15×10^8	3.68×10^8
$\hat{x}$ [mm]	-4.39	8.47	-0.33	-7.24	4.63
STD(x) [mm]	62.21	62.06	60.52	62.25	50.64
$\hat{x'}$ [mrad]	-0.49	3.74	4.12	-0.43	-0.52
STD(x') [mrad]	43.25	55.81	52.50	47.33	48.96
$\hat{y}$ [mm]	2.37	-19.27	-19.18	8.62	-31.92
STD(y) [mm]	125.24	122.72	120.29	128.71	117.47
$\hat{y'}$ [mrad]	1.87	-3.04	-7.69	-6.63	-11.31
STD(y') [mrad]	45.01	54.72	50.55	57.90	36.58
$\hat{P}z$ [MeV/c]	27.37	39.26	50.16	58.14	69.05
STD(Pz) [MeV/c]	2.61	5.23	5.09	5.48	6.17
$\epsilon_x(90\,\%)[\pi\,\mathrm{rad\,mm}]$	5.61	8.32	7.69	7.36	5.75
$\epsilon_y(90\,\%)[\pi\,\mathrm{rad\,mm}]$	9.83	11.14	12.35	12.65	9.57
Prompt muon polarization $\hat{P}$	-0.99	-0.09	-0.06	-0.09	-0.07
Prompt muon STD(P)	0.12	0.58	0.55	0.57	0.55
Deep muon $\hat{P}$	0.67	0.38	0.19	0.08	-0.01
Deep muon STD(P)	0.36	0.60	0.67	0.70	0.72

MUH3 - Maximum transmission phase spaces

Nominal momentum	27 MeV/c	40 MeV/c	50 MeV/c	60 MeV/c	70 MeV/c
Prompt muon Rate [μ^+/s]	1.75×10^9	5.43×10^7	7.92×10^7	7.56×10^7	4.41×10^7
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Deep muon $\hat{P}$	0.67	0.38	0.19	0.08	-0.01
Deep muon STD(P)	0.36	0.60	0.67	0.70	0.72

MUH3 - Maximum transmission polarization

Nominal momentum	27 MeV/c	40 MeV/c	50 MeV/c	60 MeV/c	70 MeV/c
Prompt muon Rate [μ^+/s]	1.75×10^9	5.43×10^7	7.92×10^7	7.56×10^7	4.41×10^7
Deep muon Rate [μ^+/s]	4.01×10^7	1.32×10^8	3.00×10^8	4.15×10^8	3.68×10^8
$\hat{x}$ [mm]	-4.39	8.47	-0.33	-7.24	4.63
STD(x) [mm]	62.21	62.06	60.52	62.25	50.64
$\hat{x'}$ [mrad]	-0.49	3.74	4.12	-0.43	-0.52
STD(x') [mrad]	43.25	55.81	52.50	47.33	48.96
$\hat{y}$ [mm]	2.37	-19.27	-19.18	8.62	-31.92
STD(y) [mm]	125.24	122.72	120.29	128.71	117.47
$\hat{y'}$ [mrad]	1.87	-3.04	-7.69	-6.63	-11.31
STD(y') [mrad]	45.01	54.72	50.55	57.90	36.58
$\hat{P}z$ [MeV/c]	27.37	39.26	50.16	58.14	69.05
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$\epsilon_x(90\,\%)[\pi\,\mathrm{rad\,mm}]$	5.61	8.32	7.69	7.36	5.75
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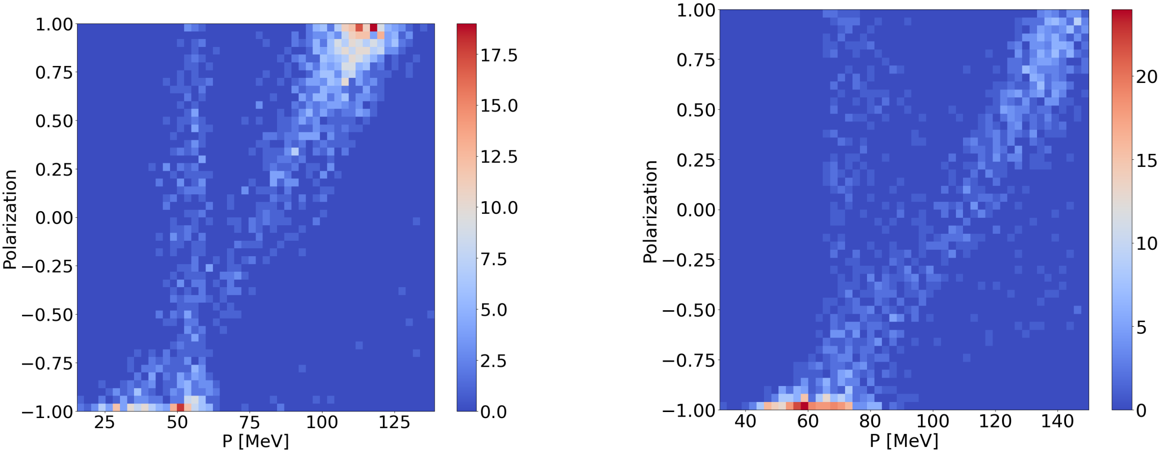
Prompt muon polarization $\hat{P}$	-0.99	-0.09	-0.06	-0.09	-0.07
Prompt muon STD(P)	0.12	0.58	0.55	0.57	0.55
Deep muon $\hat{P}$	0.67	0.38	0.19	0.08	-0.01
Deep muon STD(P)	0.36	0.60	0.67	0.70	0.72

MUH3 - Polarization vs pion momentum



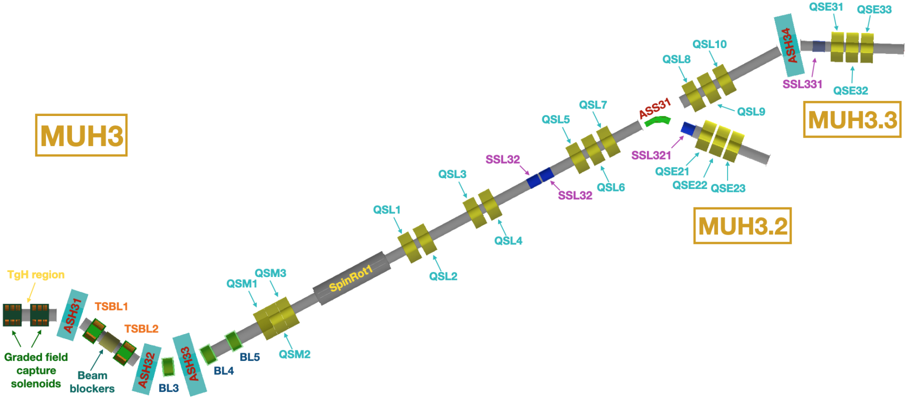
(a) 50 MeV/c tune

(b) 70 MeV/c tune

MUH3 - Surface muons beam spot

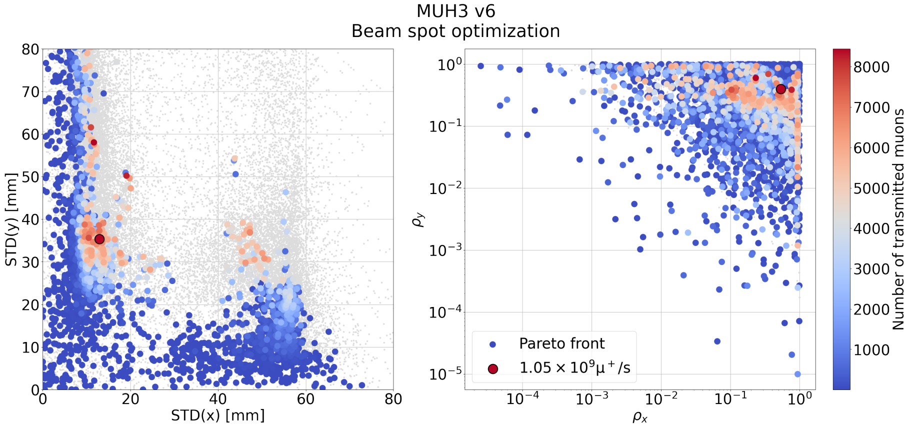
Beam spot optimized after SpinRot1. 2 additional quadrupole included. 6 figures of merit optimized:

- Rate
- STD(x)
- STD(y)
- ρ_x
- ρ_y
- $\sqrt{\hat{x}^2 + \hat{y}^2}$

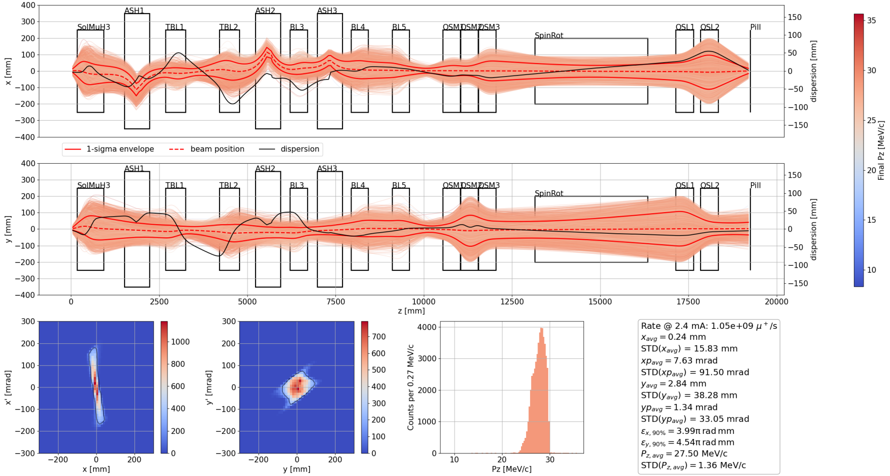


MUH3 - Surface muons pareto

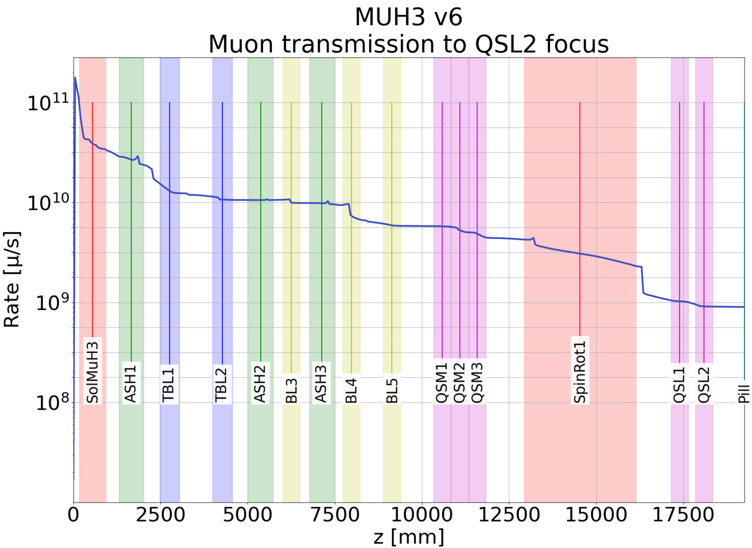
Optimization successful.



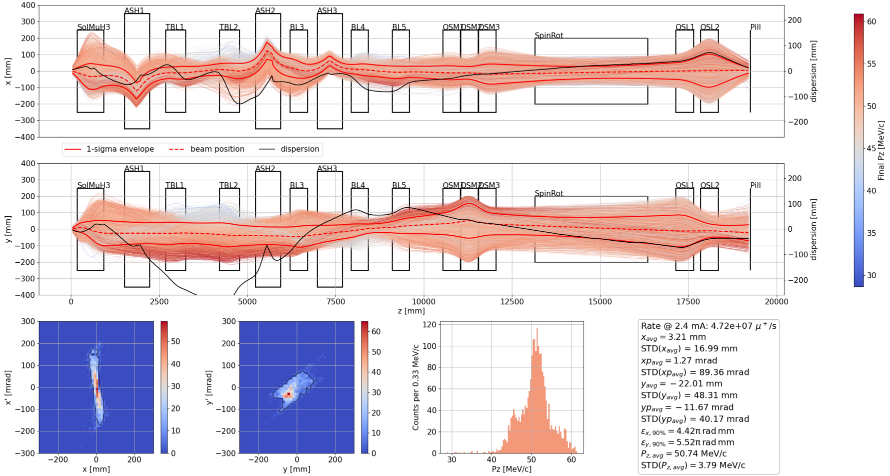
MUH3 - Surface muons envelope



MUH3 - Surface muons transmission



MUH3 - 50 MeV/c muons envelope



MUH3 - matched phase space phase spaces

Nominal momentum	27 MeV/c		50 MeV/c	
Muon Rate [μ^+/s]	1.05×10^9	1.89×10^7	4.73×10^7	1.38×10^8
$\hat{x}$ [mm]	0.24	-0.88	3.21	2.35
STD(x) [mm]	15.83	17.49	16.99	22.04
$\hat{x'}$ [mrad]	7.63	19.83	1.27	-0.33
STD(x') [mrad]	91.50	93.62	89.36	100.76
$\hat{y}$ [mm]	2.84	5.81	22.01	-3.46
STD(y) [mm]	38.28	47.99	48.31	55.50
$\hat{y'}$ [mrad]	1.34	3.07	-11.67	-3.71
STD(y') [mrad]	33.05	22.47	40.17	48.65
$\hat{P}z$ [MeV/c]	27.50	28.67	50.74	50.90
STD(Pz) [MeV/c]	1.36	3.06	3.79	7.25
$\epsilon_x(90\,\%)[\pi\,\mathrm{rad\,mm}]$	3.99	3.06	4.42	7.24
$\epsilon_y(90\,\%)[\pi\,\mathrm{rad\,mm}]$	4.54	3.05	5.52	6.94
Muon polarization $\hat{P}$	-0.98	0.80	-0.07	0.23
muon STD(P)	0.12	0.23	0.57	0.67

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