High Intensity Muon Beams at PSI: slits system

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Brief overview about beamlines used for cLFV searches at PSI in the present and in the future.

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The HIMB project: recap

The High Intensity Proton Accelerator (HIPA) facility

We produce the muons impinging a 590 MeV, 1.4 MW proton beam (world record) on two targets: Target M (TgM, 5 mm thick) and Target E (TgE, 40 mm thick). At the end, the beam is stopped in a spallation target to provide neutrons (SINQ).

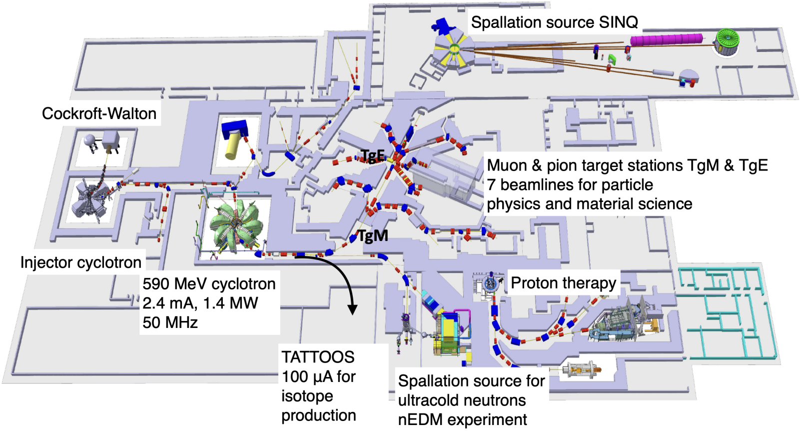
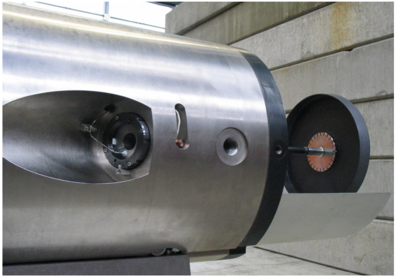


Figure: *The proton accelerator complex at PSI.*

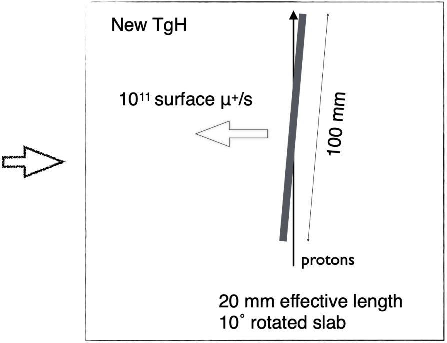
Target H

The plan is to substitute the existing Target M station with a High intensity one using a slanted target geometry:

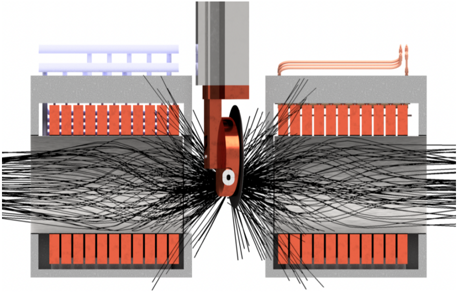
- 5 mm TgM $\rightarrow$ 20 mm TgH
- 10 deg rotation angle w.r.t. the proton beam, as efficient (surface μ) as a standard 40 mm TgE
- muon collection sideways
- Slanted geometry tested at TgE to significantly enhance the surface muon yield



Existing TgM

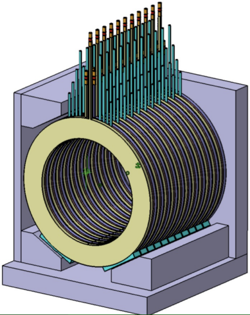


Split capture solenoids



We can't surround our target with a unique solenoid (SINQ) $\rightarrow$ let's split it:

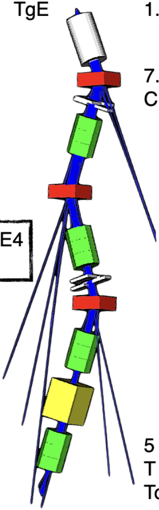
- Two normal conducting, radiation-hard solenoids close to the target for capture (very similar to the ones used in the existing μE4 beamline at PSI)
- Central field $\sim$ 0.4 T



Solenoid-based beamlines

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

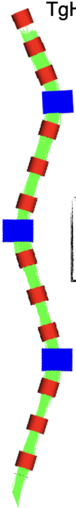
TgE



Existing μE4 beamline

⇨ Gain due to high capture and transmission efficiency

TgH



Solenoid-based beamline

MUH2 beams

Due to the high acceptance of the solenoids, the intensity is going to increase as well as the transmitted momentum bite: currently the maximum momentum bite in πE5 is ~ 5 %.

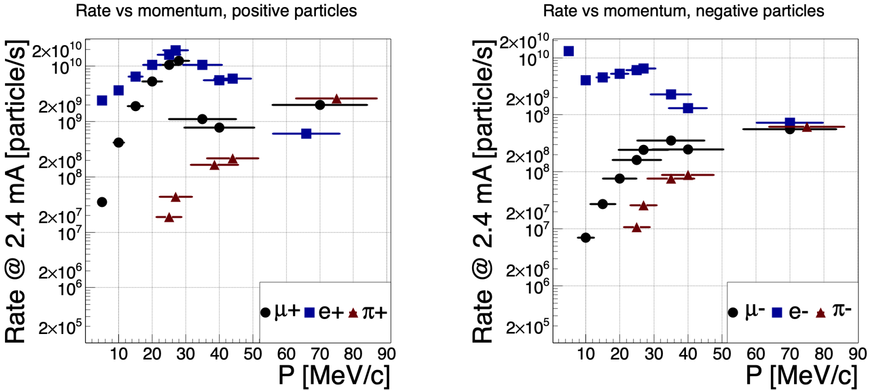
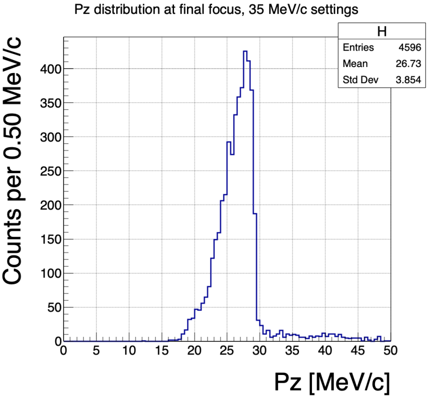


Figure: Here the momentum bite is obtained by filtering the surface muons for higher momenta muno beams

Surface muons contamination

For the same reasons, surface muons can dominate the rates for higher momenta beamline settings.



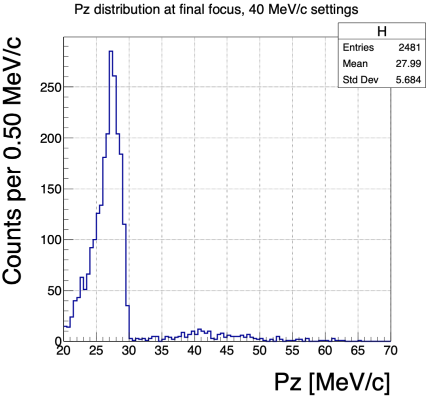
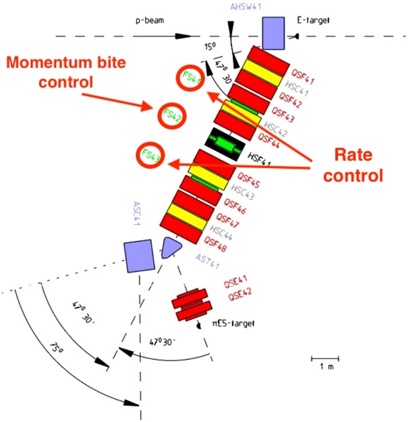


Figure: For the 35 MeV/c settings, the surface muons content is 93.5 %. For the 40 MeV/c case it is 90.8 %

In order to obtained the needed beam properties a possible solution is the combination of a Wien filter (not covered here) and a slits system.

Slits systems: πE5 example

Slits systems are usually used along accelerators and transfer lines for different purposes: rate control, momentum cite control, momentum spread reduction after degraders or interaction points, emittance measurements. In πE5 we have three slits systems: 2 for rate and 1 for momentum bite.

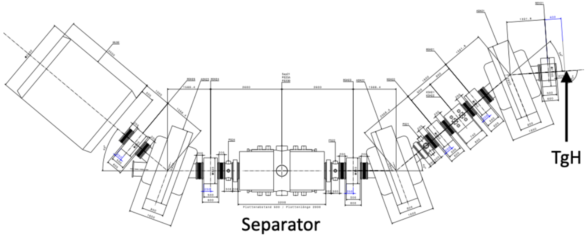


Dispersion

A slits system can be used to manipulate the momentum distribution of a beam by exploiting the correlation between particle's position and momentum: inside a dipole the bending radius depends on momentum, changing the envelope of the beam. This is characterized through a quantity called dispersion:

$$x(s) = x_0(s) + D \cdot \frac{\Delta p_z}{p_z}$$

This quantity depends only on the lattice of the beam line.



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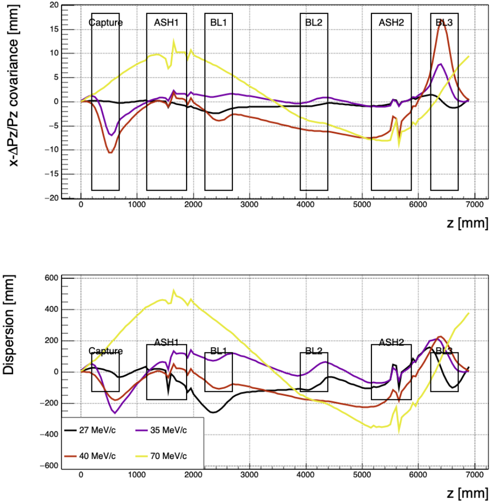
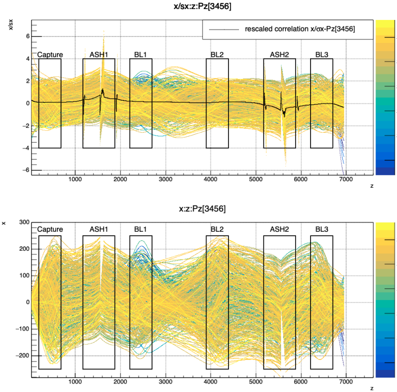


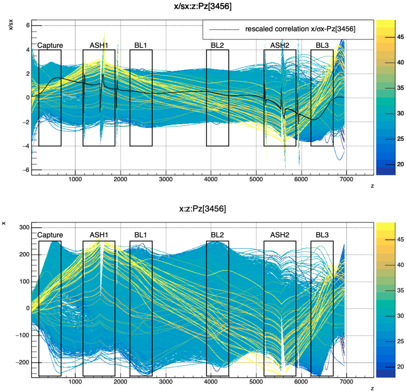
Figure: Dispersion plot for different momentum settings in MUH2

Slits position

As we are interested in the momentum distribution in the final focus, it is also interesting the correlation between the final momentum along z and the transverse position along the beamline:



(a) 27 MeV/c



(b) 35 MeV/c

The best positions are near the dipoles and near capture.

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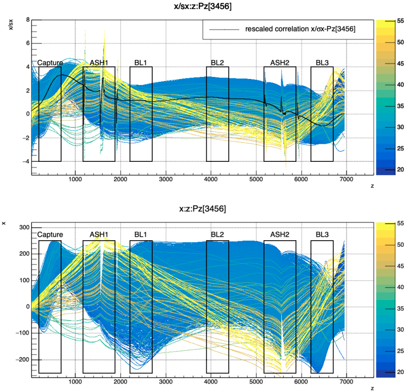
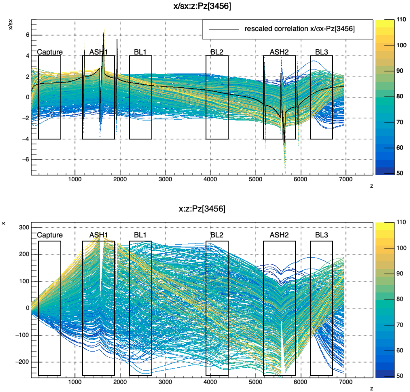


(c) 40 MeV/c



(d) 70 MeV/c

The best position are near the dipoles and near capture.

Slits position

I'm optimizing the slits systems settings in different combinations for the following positions: 180 mm, 720 mm, 900 mm, 2040 mm, 4774 mm, 6040 mm.

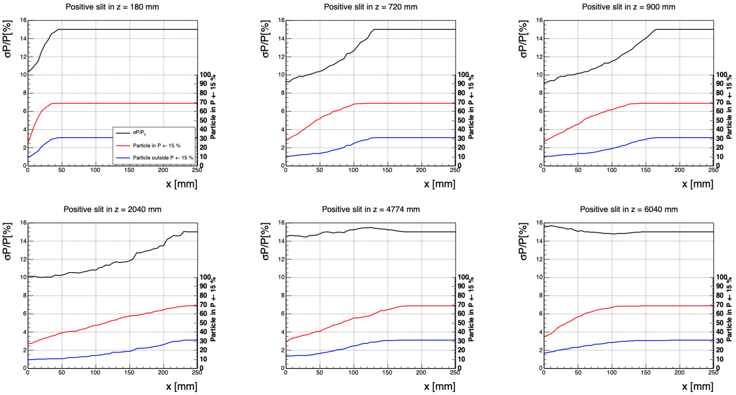
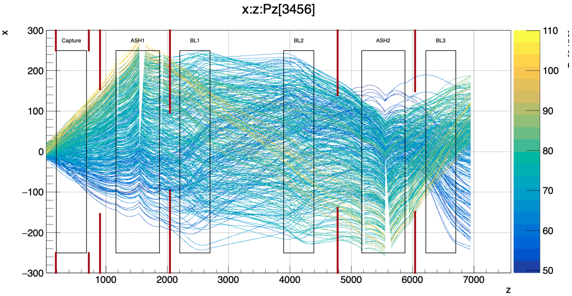


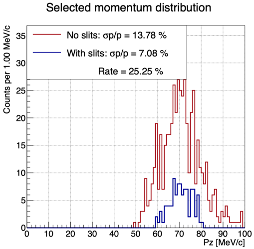
Figure: Pz standard deviation and rate dependence on slits position (positive x).

Slits studies

A single slits system is not very efficient on it's own, but their combinations improve drastically the beam quality (work in progress). Here as an example I show the effects on a 70 MeV/c μ^+ beam. Quantity minimized:

$$Q = N\Big(\frac{P_z - P_{z,0}}{P_{z,0}} > 15\%\Big)\Big/N\Big(\frac{P_z - P_{z,0}}{P_{z,0}} < 15\%\Big)$$

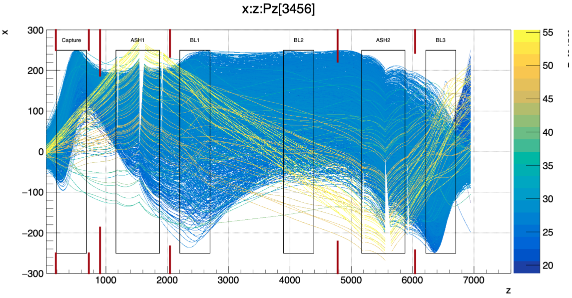


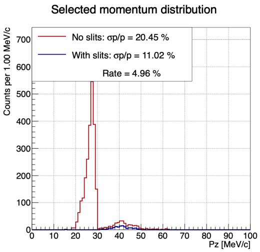


Slits studies

A single slits system is not very efficient on it's own, but their combinations improve drastically the beam quality (work in progress). Here as an example I show the effects on a 40 MeV/c μ^+ beam. Quantity minimized:

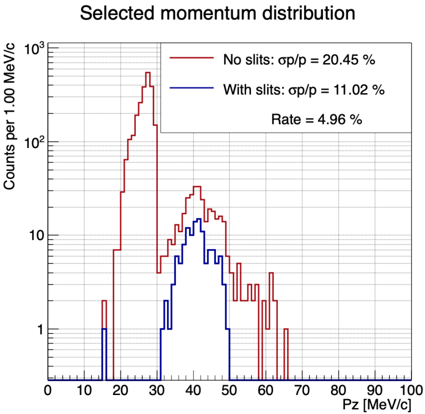
$$Q = N\Big(P_z < 30MeV/c\%\Big)\Big/N\Big(P_z > 30MeV/c\%\Big)$$





Slits studies

In this case the Rate drop must be compared to the fraction of particles above the surface muons threshold with no cuts: the rate drops by 50 %.



Next Steps

- finding good starting slits settings for the MUH2 μ^+ beams
- further optimization and beam tuning
- e^+/μ^+ separation studies with slits systems
- will be needed for the other particle beams as well