The highest-intensity surface muon beam μE4 at PSI

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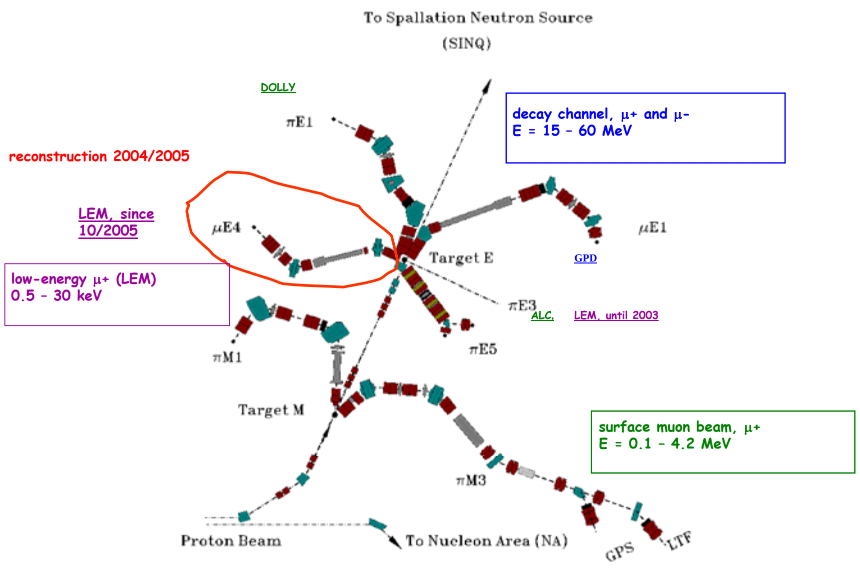
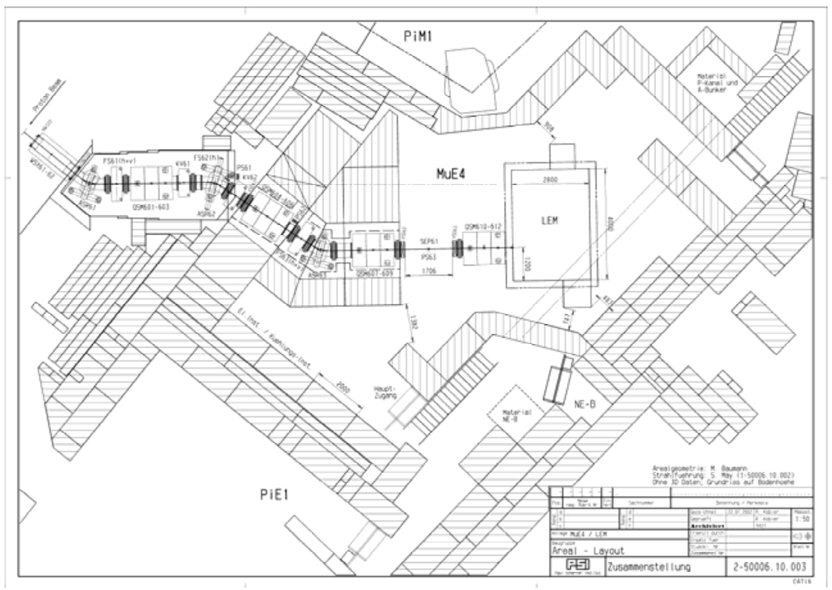
Motivation:

At PSI, low-energy positive muons (E<30keV, LE-μ^+, LEM) [1,2] are used as a new, unique depth selective spin microprobe for thin film and near-surface (d <300nm) μSR investigations. In order to fully exploit this new technique the old μE4 muon channel has been redesigned for the needs of the LE-μ^+ apparatus. The new μE4 beam line is a dedicated high-intensity surface muon beam (4.1 MeV) that produces low-energy muons at a rate comparable to standard μSR facilities since Dec. 2005. The present work demonstrates, how an existing muon beam can be modified to achieve an order of magnitude larger phase space acceptance which allows the generation of highest-intensity muon beams.





Beam parameter (for 4.2-cm target E):

Maximum beam momentum is 36 MeV/c (limited by solenoid WSX61). Rates are given at a proton beam current of 1 mA, i.e. 1/mAs. Present proton beam current (2006): 2.0 mA. Without electrostatic separator, the ratio e^+/μ^+ is about 5. μ^- can be extracted as well at a maximum rate of 2.9×10^6/mAs at 28 MeV/c. Rates increase proportionally with target E length up to 6 cm.

	new μE4, WSXoff	new μE4, WSXon
Horizontal emittance (TRACK)	**60 π cm mr**	**300 π cm mr**
Vertical emittance (TRACK)	**15 π cm mr**	**600 π cm mr**
accepted solid angle $\Delta\Omega$	**6 msr**	**125 msr**
$\Delta p/p$ (FWHM) **max. μ+ intensity** **on LEM moderator (3x3 cm^2)** **max. low-energy muon rate (at moderator)**	**1.5 - 10 %** **$10.3 \cdot 10^6$ / mAs** **$7.4 \cdot 10^6$ / mAs** **740 / mAs**	**4.5 - 9.5 %** **$210 \cdot 10^6$ / mAs** **$85 \cdot 10^6$ / mAs** **8500 / mAs**
Δx (FWHM) **Δy (FWHM)** **Δx' (FWHM)** **Δy' (FWHM)**	**2.5 cm** **3.5 cm** **115 mr** **70 mr**	**7.0 cm** **3.5 cm** **120 mr** **300 mr**
Channel length (up to LEM Moderator)	**19.3 m**	**19.3 m**
e+ contamination	**< 1%**	**< 1%**

Financial contributions:

The construction of the beam line has been supported financially by PSI, the German BMBF (TU Braunschweig and U Konstanz), the UK EPSRC (U Birmingham), and by the Universities of Zurich and Leiden.

References:

[1] *Generation of very slow polarized positive muons*, E. Morenzoni et al., Phys. Rev. Lett. **72** (1994) 2793.

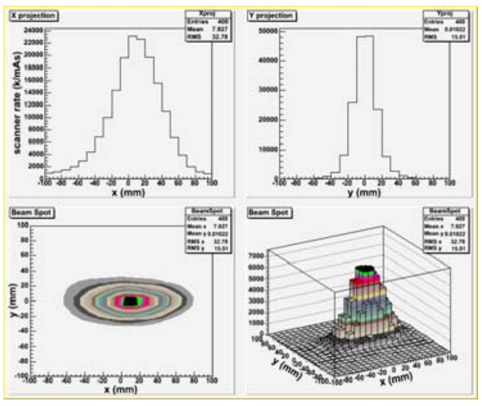
[2] *Generation and applications of slow polarized muons*, P. Bakule and E. Morenzoni, Cont. Phys. **45** (2004) 203.

[3] *The new high-intensity surface muon beam μE4 for the generation of low-energy muons at PSI*, T. Prokscha et al., Physica **B374-375** (2006) 460.

Realization:

A large acceptance is achieved by use of two normal-conducting solenoids (WSX61/62) close to the muon production target. Standard large aperture quadrupoles and bending magnets transport the beam to the experiment. Three slit systems and an electrostatic separator allow the control of beam shape, momentum spread, and to reduce background due to beam positrons or electrons.

WSXon beam spot, LEM moderator position, 4-cm target E, W I T H separator



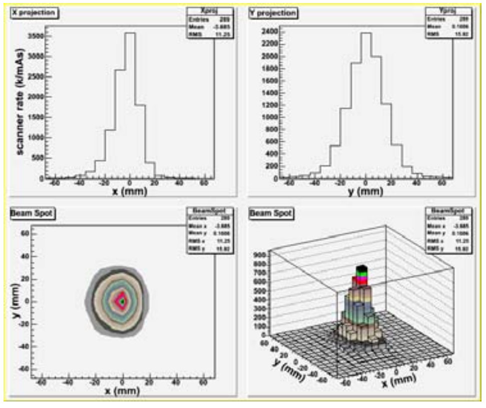
I_μ = 210 M/mAs
(I_μ = 85 M/mAs
on moderator)
On axis:
11 M/(mAs cm^2)

$\Delta p/p$ ~ 9.5% FWHM

FS61 = 500
FS62 = 555
FS63 = 500

Δx = 7.0 cm FWHM
Δy = 3.5 cm FWHM

WSXoff beam spot, LEM moderator position, 4-cm target E, W I T H separator



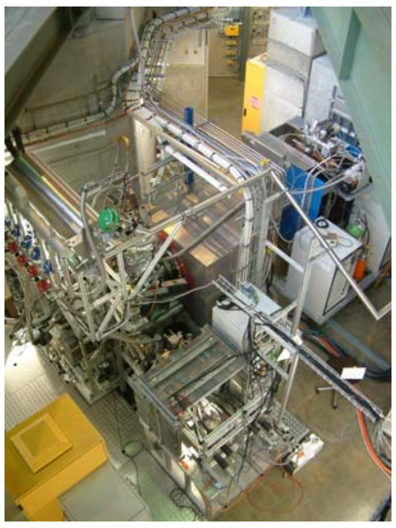
I_μ = 10.3 M/mAs
(I_μ = 7.4 M/mAs
on moderator)
On axis:
1.2 M/(mAs cm^2)

$\Delta p/p$ ~ 4.7% FWHM

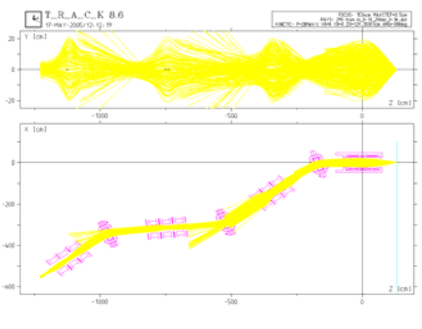
FS61 = 380-300
FS62 = 180
FS63 = 380-300

Δx = 2.5 cm FWHM
Δy = 3.5 cm FWHM

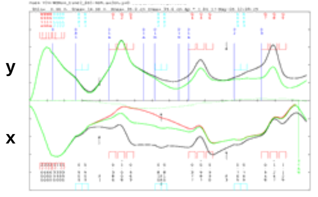
beam measurements



beam transport calculations



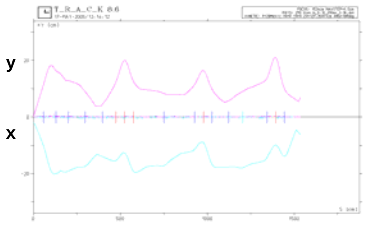
Transport and TRACK calculation for WSXon, at separator position



TRANSPORT: ***PSI Graphic Transport framework*** **by U. Rohrer, based on a CERN-SLAC-FermiLab version by K.L. Brown et al.**

0% $\Delta p/p$ 1st
3% $\Delta p/p$ 1st
3% $\Delta p/p$ 2nd

$\Delta p/p$ (FWHM):
4.5% - 9.5%
1.2×10^8/mAs μ^+ on LEM moderator (3x3cm^2)
(6cm target E)



TRACK: ***Three-dimensional Ray Tracing Analysis Computational Kit*****, developed by the PSI magnet section (V. Vrankovic, D. George)**

Transport calculation for WSXoff settings