Muon beams at PSI

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Abstract. The present upgrading of accelerators and beams at PSI will greatly improve the offered muon beams. A short description of the beam properties and a summary of the expected muon rates are presented.

all can be used as low energy - cloud, surface and sub-surface - muon beams.

1 Introduction

At PSI we almost finished a long improvement program. It started 6 years ago with the reconstruction of one of our two target stations (target M). In a long shutdown from the beginning of 1990 to June 1991 we rebuilt the second station (target E) together with the secondary beam lines and a proton beam transport system to the new spallation neutron source [1].

This long and expensive work was mainly done to be able to increase the current of the proton beam up to at least 1.5 mA [2,3]. This intense beam will carry almost one Megawatt and therefore calls for targets and a beam dump that can stand this power. In addition all elements, including dipoles and quadrupoles, all diagnostic devices and so on had to be prepared for remote handling because of the very high secondary activation.

In parallel we reconstructed all our pion and muon beams. There are only minor changes in the $\mu E4$ channel, but essential improvements in $\mu E1$, $\pi E1$ and $\pi E3$ and we built a completely new beam line, the $\pi E5$ (Fig. 1). The channels $\pi M1$ and $\pi M3$ were changed already 6 years ago and were not touched in the last shutdown, but there are plans to modify the $\pi M3$ such that it serves several μSR facilities by simple switching from one to the next with dipoles or even kickers.

All our beam lines with the exception of $\pi M1$, which is a high resolution pion beam and the μ -channels with superconducting solenoids, are now built without any windows between the vacuum system of the proton channel and the system of the secondary beams. By this they

2 Muon beam $\mu E1$

Up to now this beam line shared the first quadrupoles and a bending magnet with the $\pi E1$ channel and therefore the polarity and the momentum of the muons could only be changed in agreement with the users of the $\pi E1$. We decoupled these channels by installing half quadrupoles, focussing elements made of two poles - half of a quadrupole - and an iron mirror plate, which produce a perfect quadrupole field in half of the aperture [4] (Fig. 2).

We reinstalled the first coil of the superconducting solenoid, which tended to quench in earlier times because it was heated by the nearby beam dump, and built in new vacuum chambers and collimators. This will give higher muon rates and less contamination with pions and electrons. See Table 1 for rates and other beam properties. A flexible muon extraction system will allow to switch from SINDRUM II, which is permanently installed, to an other experiment within short time.

3 Pion beam $\pi E1$

As described in the previous section this channel became now independent from the $\mu E1$ beam line by a similar triplet of half quadrupoles for the first focussing. By greater bending angles in the dipoles, which forced us to introduce a third dipole in order to keep the geometry of the area, the momentum resolution of $\pi E1$ was improved. Since there is no more any window in the vacuum system between the production target and the experiment, this channel can now be used as a surface or low energy cloud muon beam, but the expected high contamination with electrons or positrons will always call for an electrostatic separator.

Fig. 1. Layout of the experimental hall

Table 1. Summary of expected muon fluxes and beam properties after the shut-down 1990-1991 from the various beam lines at 1 mA primary beam current

μ^+	mom. MeV/c	flux at 1 mA	$\delta p/p$ FWHM	spot size cm^2	pol.
$\mu E1$	40-125	2×10^8 at 125 MeV/c	3%	3×2	75 %
$\mu E4$	30-100	4×10^6 at 50 MeV/c	3%	6×4	75 %
$\pi E1$	5-30	2×10^6 at 28 MeV/c	0.8%	1.5×2	> 95 %
$\pi E3$	5-30	3×10^7 at 28 MeV/c	1 %	2×3	> 95 %
$\pi E5$	5-30	2×10^8 at 28 MeV/c	2 %	6×4	> 95 %
$\pi M3$	5-30	4×10^6 at 28 MeV/c	0.2 %	2×2	> 95 %
μ^-	mom. MeV/c	flux at 1 mA	$\delta p/p$ FWHM	spot size cm^2	pol.
$\mu E1$	40-125	6×10^7 at 125 MeV/c	3 %	3×2	75 %
$\mu E4$	30-100	1×10^6 at 50 MeV/c	3 %	6×4	75 %
$\pi E1$	5-280	4×10^7 at 100 MeV/c	0.8 %	1.5×2	(var.)
$\pi E3$	5-150	3×10^7 at 100 MeV/c	1 %	2×3	(var.)
$\pi E5$	5-120	2×10^8 at 100 MeV/c	2 %	6×4	(var.)
$\pi M3$	5-300	4×10^6 at 100 MeV/c	0.2 %	2×2	(var.)

4 Muon beam $\mu E4$

There is only one minor change in the $\mu E4$ channel: we installed a removable degrader made of 2.5cm Beryllium at the entrance of the superconducting solenoid. This, by reducing the pion decays in the injection system, will increase the rate of very low energy muons and makes the channel suitable for feeding the phase space compression device (PSC) proposed by D. Taqqu [5].

5 Pion Beam $\pi E3$

This channel was an excellent surface muon beam in the past and will be so in future. The rates are high because they are proportional to the projection of the production target seen by the channel and the $\pi E3$ looks to it under an angle of 90 degrees and images more than half of the 6 cm long target.

The main design criterium was a chromatic high resolution final beam spot matching the Low Energy Pion Spectrometer (LEPS), but an achromatic tune is possible for muon physics with bigger acceptance than in the high resolution mode [6].

6 Pion beam $\pi E5$

The $\pi E5$ is a new channel looking to the target from the back under an angle of 175 degree. The first focussing element of the $\pi E5$ is a bending magnet, which deflects the proton beam too. This limits the beam momentum to 120 MeV/c because at higher values it is no more possible to correct the proton deflections, but anyhow the pion production cross section at backward angles will fall steeply at higher momenta.

Fig. 2. Layout of the target E region

Fig. 3. Calculated particle fluxes from the new $\pi E5$ channel at 1 mA primary proton beam current.

This channel has an angular acceptance of 150 msr, which is five times bigger than in 'standard' beam lines, and transports a momentum band of 10% FWHM. To achieve this we had to develop special quadrupoles with an aperture radius of 20 cm and with built in octupole components for the correction of third order aberrations. Together with the short channel length of 11 meter the big acceptance will give outstanding high pion rates (Fig. 3) [7]. To give high flexibility the beam line can serve two experimental ports just by switching the polarity of the last bending magnet.

This beam will be most suitable

1. for stopped pion experiments at highest,
2. for adaption to the planned "pion-muon-converter", a special, 6.5 m long superconducting solenoid to produce a high purity μ -minus beam with a pion contamination

of 10^{-8} and with rates of the order 10^8 /sec in SINDRUM II, and
 3. for injection into a future "low energy muon facility" which will produce muons at keV energies [8,9].

7 Outlook

The reconstruction of the target station E and of the secondary beams, except the new $\pi E5$, was finished by summer 1991. At that time only part of the enlarged accelerating RF-power is available, allowing an average proton current of approx. $500 \mu A$ until the end of 1991. Two short shutdowns at the beginning and at the end of 1992 are planned for the installation of the last parts of the acceleration system.

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