Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE EXISTING MUON BEAMS AT LAMPF

AUTHOR(S) Chandra Pillai

SUBMITTED TO Philosophenweg 12
Heidelberg, Germany

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes.

The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Existing Muon Beams at LAMPF

Chandra Pillai *

Los Alamos National Laboratory, Los Alamos, NM 87545, USA

The Stopped Muon Channel (SMC) at LAMPF is heavily used for a variety of muon experiments: (1) Muon Catalyzed Fusion (μ CF), Muon Spin Rotation (μ SR), and Muonic X-rays using decay muon beams; (2) Muon Level-crossing Resonance (μ LCR), Rare Decays, and Muonium Hyperfine Structure & Muon Magnetic Moment using surface muon beams; (3) Laser Polarized Muonic Atoms using cloud beams.

There are two dedicated experimental caves for muon experiments. When one crew is taking the beam, the other one can set up and check out their equipment in the other cave. We also have crossed-field separators, beam profile monitors, and a fast high-voltage chopper, which can provide chopped muon beam at a rate of 60-70 kHz for experiments which are limited by pileup problems.

The SMC channel at LAMPF is of conventional design. It is a beam transport system designed to accept as large a fraction of pions from the primary production target as possible, to capture muons from pion decays, and finally to select from the resulting beams muons with the desired momenta and focus them onto the target. The details of the channel are described elsewhere[1]. In addition to the muons from pion decay in flight, the channel is also being used successfully for surface muons and cloud beams. For decays in flight, pions of a given momentum decaying into muons produce a muon momentum (laboratory) spectrum extending from about one-half the pion momentum (backward decays) to slightly greater than the pion momentum (forward decays). The decay section can capture muons with decay angles up to ± 5 degrees (lab); because the maximum laboratory decay angles

* Presented by M. Leon

are much larger than 5 degrees for practical range of pion momentum, only extreme forward and backward decays are accepted, and the muon momentum spectrum for a given pion momentum is narrow (less than 2% for pion momentum up to 230 MeV/c). Hence the muon polarization is high (80-90 %) and the muon momentum spectrum is determined mainly by the pion momentum spectrum. Table I gives the calculated rates for μ^- and pions at the end of the SMC channel.

A. Backward Decay beam

Because of the large difference between the pion and muon momentum for the backward decay beam, it is easy to generate a very high-purity beam in this mode of operation. For this reason, many experiments which require good quality muon beams for stopped muons in the momentum range of 40-150 MeV/c use the channel in this mode. Table II gives some measured rates for μ^- for the backward decay beam; the rates for μ^+ are approximately four times higher.

B. Forward decay beam

Due to the kinematics of the decay, the forward decay beam should be significantly more intense than the backward decay beam. The channel can deliver muons of momenta from 100 to 250 MeV/c in this mode of operation. The main drawback of this mode is the high pion and electron backgrounds - up to 5 times the muon flux depending on the momentum selected. The channel is very seldom used in this mode.

C. Surface Beam

Many experiments in muon physics require stopping many muons in small, thin targets. This requires a high flux of low-energy muons with small momentum spread. Surface muons are produced from pions stopped near the surface of the production target; the maximum momentum for these muons is 29.8 MeV/c. Because of the high current of the proton beam at LAMPF (1 mA), the yield for the surface muon beam is also high; one can get a rate of $5 \times 10^7 \mu^+/\text{s}$. Crossed-

field separators in the channel reduce the high positron background (10 times μ^+ flux) to less than 5%. The beam size at the end of the channel is rather large, about $8 \times cm^2$; experiments normally use collimators to make the beam size fit their requirements. Furthermore, large superconducting solenoids are available for experiments which require large solid angle. At the same time, the solenoidal field focuses the beam to a smaller area. We have obtained beams of $3 \times 3cm^2$ (FWHM) by using this technique. Table III gives some measured surface muon rates for a tune which is used to get small beam size at the expense of rate.

D. Cloud Muon Beam

Experiments which require low-energy negative muons for higher stopping densities in thin targets can use the cloud beam. These are muons from pion decay near the production target. Since both the backward and forward decay beams are accepted in this mode, the polarization of the beam is very low (about 10%). A crossed-field separator is used to reduce the electron background in the cloud beam below 5%.

The SMC channel was originally designed for decay muons and has a long decay section having alternating quadrupole magnets. Therefore the channel is not very efficient in transporting mono-energetic beams like the surface and cloud beams because of the strong focusing in the decay section. We found theoretically as well as experimentally that one can transport monochromatic muons efficiently with most of the quads in the decay section turned off. This narrows the momentum spread and the chromatic aberration is also reduced, resulting in a cleanly dispersed beam. This technique has been successfully used in stopping a large fraction of negative muons in gas targets[2]. But in this mode of operation, the intensity of the beam is reduced by a factor of approximately two compared to the tune designed to obtain the maximum flux. One can use the same technique to get a good quality surface beam at the expense of rate.

E. Pion Beam

The channel can also deliver a good quality pion beam. Normally, π^- beam is used for calibration purposes. One can tune the channel for the pion beam of momenta 40 to 250 MeV/c. The typical rate for π^- beam at 150 MeV/c is 2×10^7 /s with 1 mA proton on a 4-cm-long carbon target.

Figure Caption: Fig.1. Measured rates of Surface beam, Cloud and Backward decay μ^+ and μ^- beams as a function of momentum for the SMC at LAMPF.

References:

1. P.A. Thomson *et al.*, Nucl. Instruments and Methode. **161** (1979) 391.
2. R. Holmes *et al.*, Nucl. Instruments. and Methode., **A303** (1991) 226.

Table I. Calculated rates for pions and decay muons				
Particle	Momentum (MeV/c)	Rate (/s/mA)	Contamination(%)	
			π	e
Backward(μ^-)	40-150	$1-30 \times 10^6$	0.2	10
Forward(μ^-)	100-250	$30-60 \times 10^6$	10	10-100
π^-	100-250	$30-300 \times 10^6$	—	50-100

Table II. Backward Decay Rates	
Momentum(MeV/c)	Rate(μ^- /s/mA)
50	3×10^5
60	1.3×10^6
70	2.0×10^6
85	8.0×10^6
105	2.0×10^7
115	2.2×10^7
130	2.5×10^7
140	2.5×10^7

Table III. Surface muon rates		
Momentum(MeV/c)	Rate(μ^+ /s/mA)	e^+/μ^+
3.0	2.5×10^3	1000
5.0	7.5×10^4	
7.5	5.0×10^5	
10.0	7.0×10^5	
15.0	3.2×10^6	
20.0	1.0×10^7	10
28.5	3.0×10^7	

Table IV. Measured cloud μ^- rates		
Momentum(MeV/c)	Rate(μ^+ /s/mA)	e^-
20.0	0.7×10^6	2.0×10^6
28.0	2.0×10^6	2.5×10^6
45.0	6.0×10^6	3.2×10^6
60.0	1.5×10^7	3.5×10^6

Fig. 1