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Progress report of SC 65 and SC 68

A μ^+ beam for μ^+ SR experiments

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A. The μ^+ beam for the μSR experiments.

Principles:

In a μSR (muon spin rotation) experiment polarized muons are stopped in the material to be studied. If a magnetic field is present the muons will precess. A measurement of the precession frequency gives information on the local magnetic field at the muon's position inside the sample.

The (positive) muon's precession is observed by means of the decay positrons. These are emitted in a direction dependent on the muon's spin direction at the time of decay. The precession frequency is seen as a modulation of the decay curve (τ = 2.2 μsec) obtained when the time elapsed between the arrival of a muon and the detection of a positron is measured. 10^5 - 10^7 such events are necessary for the determination of the precession frequency with good accuracy.

For μSR experiments the requirements on the beam are

i) A beam of good intensity containing mainly positive muons

ii) The muons must have a high degree of polarization

iii) The energy of the beam must be taken down to a low value (~ 50 MeV) in order to stop the muons in targets of a few g/cm^2.

iv) Only one muon at a time should be present in the sample. A DC-like time structure of the beam is therefore necessary if the muon intensity is high.

Beam development:

The beam is obtained from a positive pion beam in the C-pipe of the proton hall (Fig. 1). The beam calculations were performed by O. Hartmann during spring and summer 1975 by means of the CERN computer programs Beamop and Decay Turtle. It was decided to use the "forward" muons from the decay in flight of the pions. Therefore a rather long beam-line is employed, and the muons are separated from the pions by degrading. The degrading at the same time takes down the muon momentum to suitable values for stopping in the target.

The beam tests in September and December 1975 resulted in a beam line with current settings in close agreement with the calculated ones. The separation of muons from pions by degrading proved to be successful (Fig. 2), although the intensity losses in the degrader were found larger than estimates from multiple scattering formulas.

In the beam test in January 1976 the beam intensity and the number of muons stopped in a target were studied at different momenta from 150 to 300 MeV/c. The total flux in the beam was as expected highest at 250-300 MeV/c, while the smaller degrading losses at lower momenta results in a maximum number of stopped muons at a momentum around 200 MeV/c. (Table I and Fig. 4).

The polarization of the muons was found to be high at 275 and 300 MeV/c ; $\geq$ 80% (Fig. 3). The background radiation was disturbingly intense at low momentum and this made polarization measurements at 200 MeV/c unreliable. To some extent these difficulties are believed to be due to high intensities in combination with low detection efficiency for positrons (5% solid angle). A percentually larger β^+ contamination at low momenta might also be a cause of trouble.

The fourth run in February was not very successful. Several interrupts of the beam disturbed systematic measurements. In addition we could not reproduce the intensities found in December and January (Table I). A large part of the available machine time was used to seek for a reason for this discrepancy. No explanation was found during the run.

However, the time of flight method was tried to find out the beam composition (Table I and Fig.5). With an ordinary Be target for Π^+-production a fairly strong β^+ contamination was found at low momenta. With water as a production target the μ^+ content was high at low momenta. We were not able to resolve the time of flight spectra at higher momenta. It was also found that slight adjustments of the currents of different beam elements did not alter the beam composition markedly.

I was also found that the degrader is an intense source of secondary radiation, which reaches the target region. We did not get time to find a good compromise for the degrader geometry and material.

Polarization at 250 MeV/c was measured and was found to be high.

B. Other progress

Cryogenics:

A cryostate which allows cooling of large (3.5 x 3.5 cm) samples down to 50 mK has been installed at the C pipe in the proton hall. The February run was performed with samples inside the cryostate. Cooling was not tried.

Computer:

CERN has given us and other experimentalists at SC access to a HP2100. This computer was used during the January and February runs to Fourier analyse the recorded time histograms. The computer will be used in our on-line data-aquisition system and for this reason the EP data group have prepared a revised version of the ISOLDE data aquisition programs. These programs will be tested in March.

Electronics:

CERN standard electronic modules have been used during the tests. For the moment we are relying on continued CERN support in this respect while we are devellopping crucial parts of the electronics ourselves.
We are building (Parma) a time to digital converter, which will be extremely linear and have a short dead time (1 μs + measured time). The time resolution will be ~1 ns.

It is directly compatible with the ISOLDE data aquisition system and will be tested and put into operation during March 1976.

For discrimination of relativistic particle (β^+) from slower ones (μ,Π) we have modified a fast window discriminator (constructed in Uppsala) to work with fast plastic scintillator pulses. These discriminators have shown to be very useful.

Targets:

High purity Ni targets have been prepared at the Institute of Chemistry, Uppsala. Single crystal targets of Cu, Al, Bi, Pb have been obtained from the neutron diffraction group at the research reactor at Studsvik, Sweden. High quality Fe single crystals are in preparation.

C. Conclusions

Times of measurement

For the moment a beam momentum of about 250 MeV/c gives the best combination of muon intensity, polarization and low background radiation. With the present counting rates (January) the time of measurement for a typical metal sample would be about 3-4 hours.

The following improvements of intensity are foreseen:

Solid angle of β^+ detection	x(4-5)
Extracted current, duty cycle	x(2-3)
Improved degrading and background suppression	x 2
Totally	~ x 20

With these improvements at least partially carried out the time of measurement for a metal target would be ~ 1 hour for each spectrum, including time for change of magnetic field intensity, sample temperature etc.

Remaining tests

The reason for the intensity loss in the February run should be found. An improved degrader should be tested together with a larger solid angle β^+ detection system, including pile up rejection and more efficient anti coincidence demands. (March).

The polarization at low momenta should be checked again.

Finally the on line data-aquisation should be tested with a real μ^+ beam. (March-April).

TABLE: I SC 65 & SC 68 Beam tests for μ^+SR-experiments.

	Dec-75 200 MeV/c	Jan-76 momentum in MeV/c							Feb-76 momentum in MeV/c			
		150	175	200	225	250	275	300	150	200	250	300
Total flux ($\pi^+ + \mu^+ + \beta^+$) on $10 \times 10\,cm^2$ at focus 30 m from p-target (sec^{-1})	10^6	$5 \cdot 10^5$	$6 \cdot 10^5$	10^6	$1.3 \cdot 10^6$	$1.7 \cdot 10^6$	$1.7 \cdot 10^6$	$1.6 \cdot 10^6$	$2.4 \cdot 10^5$	$3.6 \cdot 10^5$	$7 \cdot 10^5$	$4 \cdot 10^5$
Number of particles hitting a $5 \times 5\,cm^2$ sample after degrading (sec^{-1})	$3.3 \cdot 10^4$	$2.4 \cdot 10^4$	$3{,}4 \cdot 10^4$	$5{,}3 \cdot 10^4$	$4.6 \cdot 10^4$	$3{,}1 \cdot 10^4$	$1.3 \cdot 10^4$	$6 \cdot 10^3$		$\sim 10^4$	$\sim 10^4$	
Number of detected decay β^+ (sec^{-1}) (5% solid angle)		~90		~150			~120	~90		~40	~15	
Beam composition	μ^+/β^+ 3/2 after degrading			$\pi/\mu \sim 1/1$					$\beta^+ \sim 77\%$ $\mu^+ \sim 10\%$ $\pi^+ \sim 13\%$	$\beta^+ \sim 45\%$ $\mu^+ \sim 30\%$ $\pi^+ \sim 25\%$		

Intensities normalized to 1 μA extracted current.

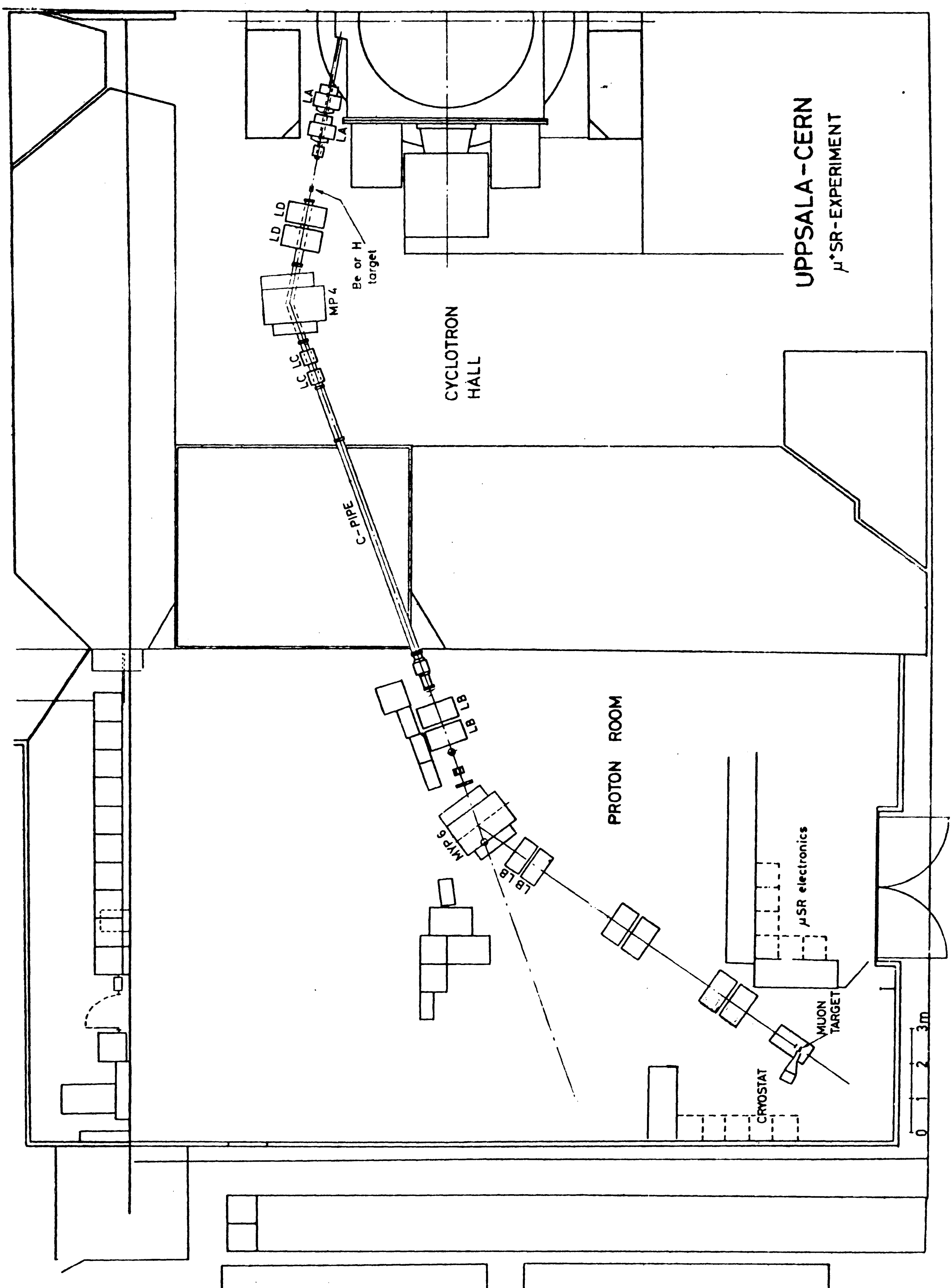

Fig. 1. Beamline for μSR in the proton hall.

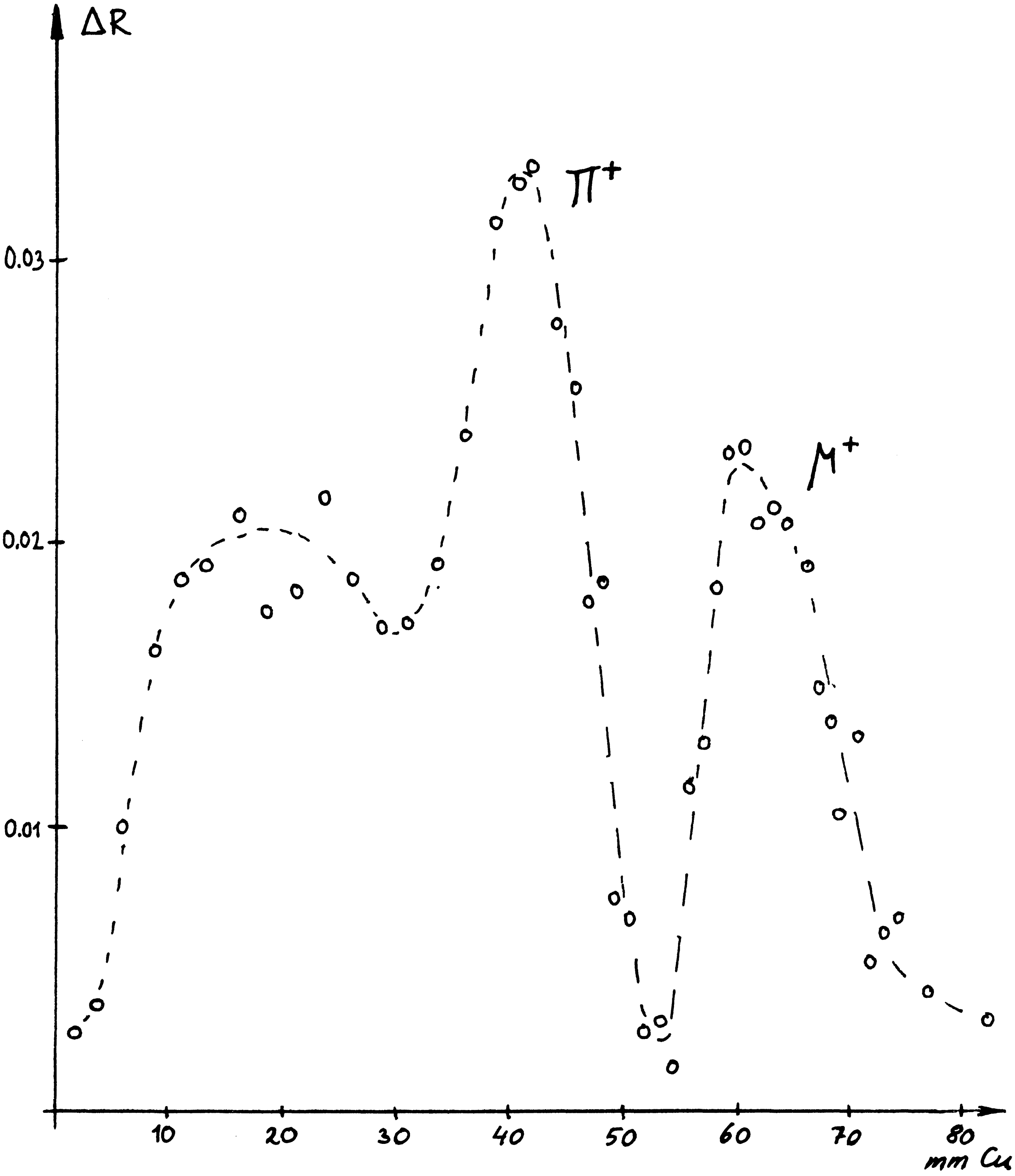

Fig. 2. Degrading exp. at 200 MeV/c . ΔR is differential of $23\overline{456}/23$. Detectors 2 and 3 are sitting in the beam before and after the degrader , 4 and 5 are sitting after the target and detector 6 beside the target.

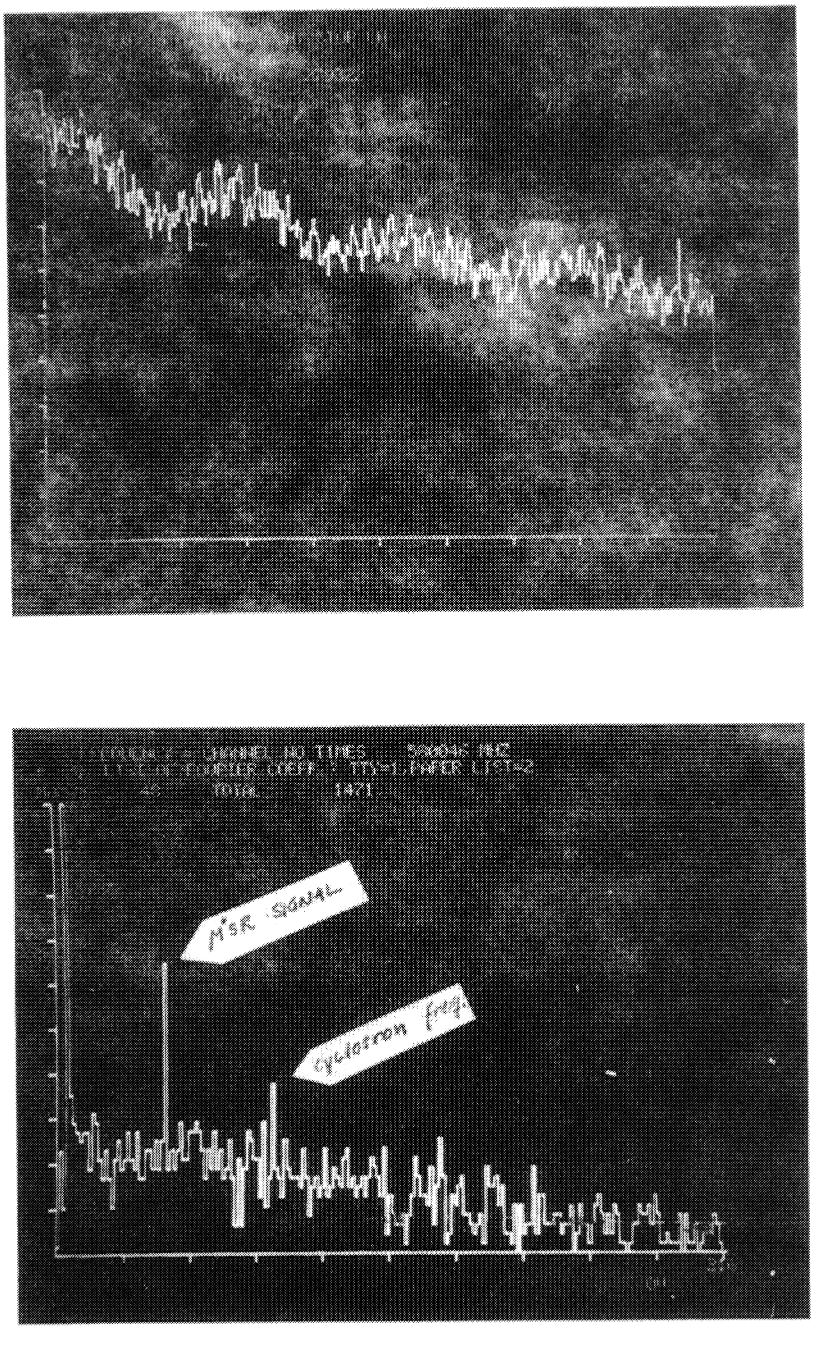

Fig. 3. Muonprecession in graphite at an applied magnetic field of 140 Gauss. Below is given the Fourier analysis of the experimental data.

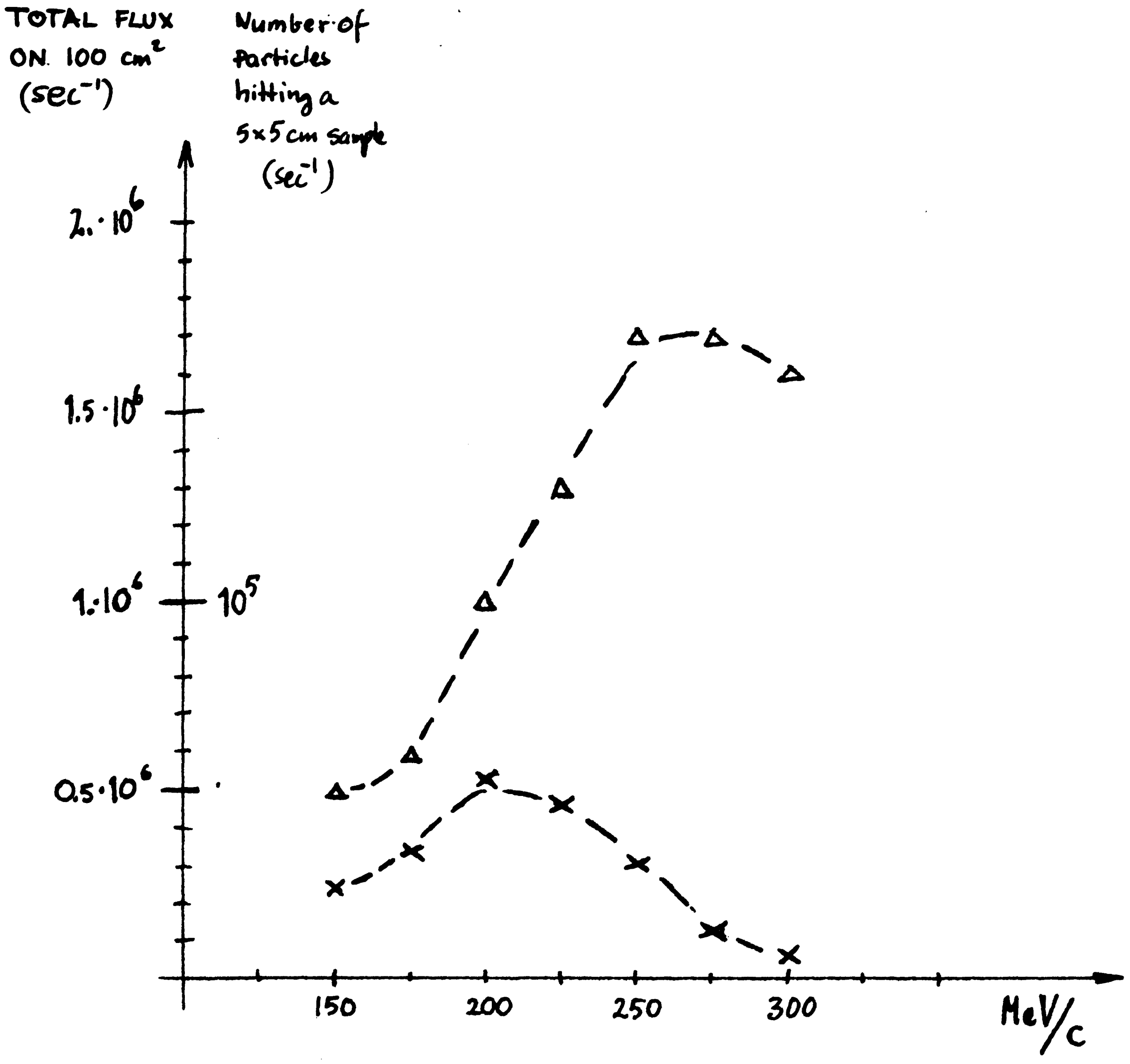

Fig. 4. Total intensity at different momenta (Δ). Number of particles hitting a 5 x 5 cm^2 sample per second after degrading to appropriate energy. (×).

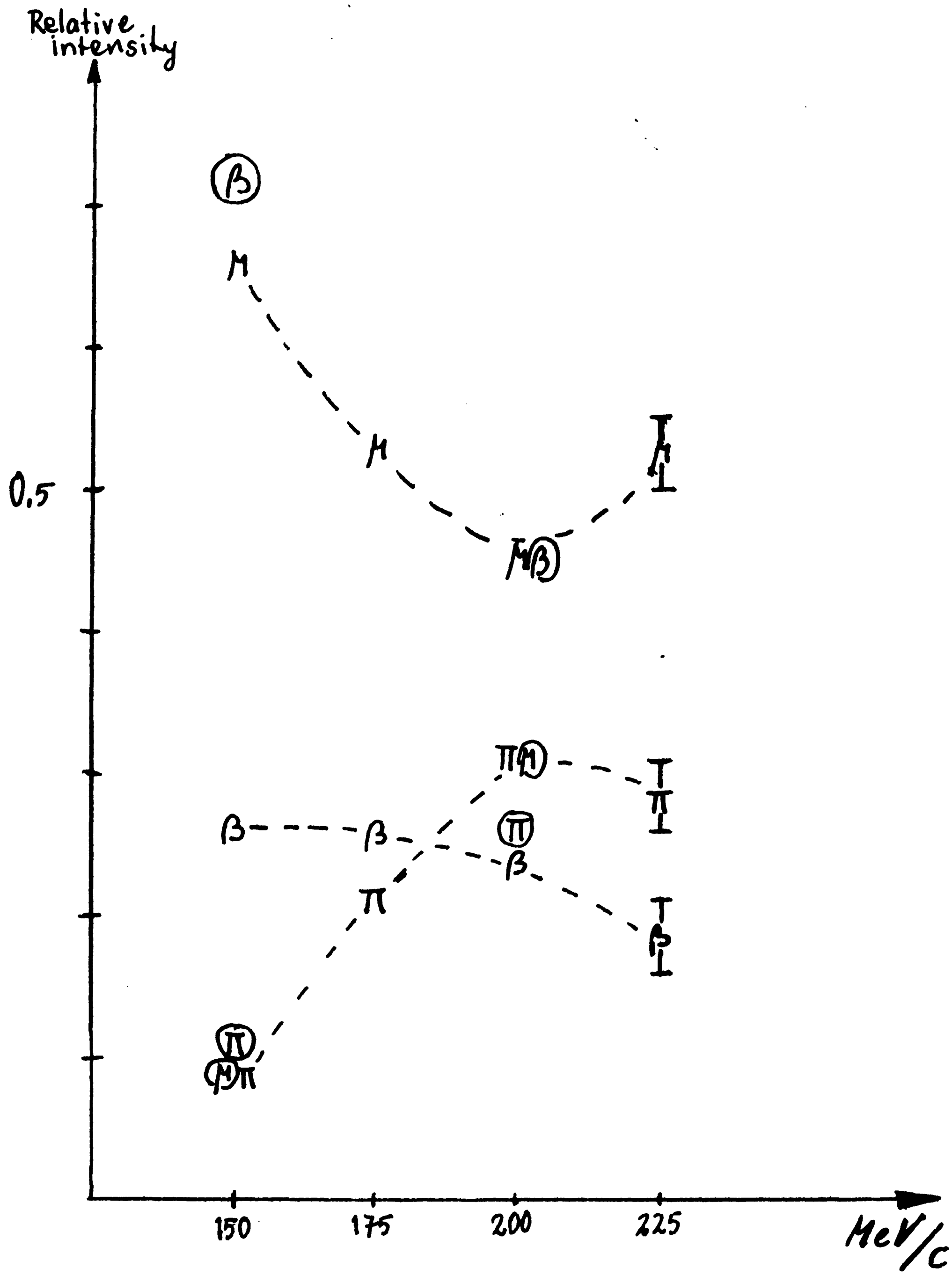

Fig. 5. Time of flight results of beam compositions at different momenta.

β; μ & π water as production target

(β)(μ)&(π) Be as production target.