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MAGNETIC FIELD VALUES IN SELEX (E781) CHARM BARYON PRODUCTION EXPERIMENT

by

Erdoğan Özel

A thesis submitted in partial fulfillment of the
requirements for the Master of Science
degree in Physics in the
Graduate College of The
University of Iowa

December 1998

Thesis supervisor: Professor Yasar Onel

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Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Erdoğan Özel

has been approved by the Examining Committee
for the thesis requirement for the Master of
Science degree in Physics at
the December 1998 graduation.

Thesis committee: _____
Thesis supervisor

_____
Member

_____
Member

To my Family...

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CHAPTER 1

INTRODUCTION

The SELEX (SEgmented LargeE-X) spectrometer is designed to observe charm baryons and their decay products. The main goal of the experiment is to improve the statistics in the previously measured quantities over a broad range of x values. There are also some additional studies like Primakoff physics, exotic mesons, and hyperon mass.

SELEX is located in the Proton Center (PC4) facility in Fermilab. There are four magnetic spectrometers: hyperon, M1, M2, and M3. Each magnetic spectrometer is designed to analyze and track particles in a specific momentum range.

The hyperon magnet is placed upstream of all these magnets. It selects the $\Sigma^-$and π^- particles that form the hyperon beam used in the experiment. Beam particles are produced by the interaction of the primary proton beam and the beryllium target.

The M1 magnet is set up to deflect low energy particles, mostly pions out of the beam direction. The M1 spectrometer mainly detects and tracks the low energy particles produced in the charm target or in the decays thereafter.

The M2 spectrometer is used to track the high energy particles produced in the charm target. On the other hand, the M3 magnet is used to separate the trajectories of the particles produced in the decay of energetic charm particles. The trajectories of these particles are then reconstructed by the chambers that are located downstream from the vertex region and just after the M1, M2 and M3 magnets.

In all these spectrometers and systems, the value of the magnetic field has to be known very accurately. Since the field values are used to determine the momenta of the particles, any error in the field values will mess up the mass resolution of the reconstructed particles.

In this thesis, the problems encountered in determining the magnetic field average values accompanying the data are explained and an algorithm to obtain an accurate field value in a spill by spill basis for a specific data set is developed. The physics goals of the experiment and the details of the setup are given briefly in the next two chapters.

CHAPTER 2

SELEX EXPERIMENT

SELEX is a Fermilab fixed target experiment designed for the purpose of studying charmed baryons at large x.

2.1 Physics Goals

SELEX is designed to make a survey of charm baryons, more specifically to study the baryons with one charm quark and their production and decay systematics. Most of these charmed baryons have been observed in previous experiments. SELEX aims to improve the statistics in these measurements. The experiment will try to determine the lifetimes of charmed baryons and their masses with higher precision[1].

On the other hand, some of the charm baryons have been observed with very low statistics: such as Σ_c^+, Ξ_c^+, Ω_c^0. SELEX experiment will try to determine their properties more accurately and with higher statistics.

The SELEX setup is also suitable to look for exotic states, do Primakoff physics measurements, and study the beam polarization. The Primakoff formalism relates processes involving real photon interactions to production cross sections involving the exchange of virtual photons [2]. This is an experiment which is very complex but rich in physics topics to study [3].

2.2 Experimental Setup

The main components of the SELEX setup are three magnetic spectrometers, beam spectrometer, and photon calorimeters (Figure 1).

The beam particles used in the experiment are a combination of Σ and π particles produced by the primary proton beam. The primary photon beam consists of 800 GeV protons delivered to the Fermilab Proton Center Hyperon facility.

The FWHM of the primary beam is about 1 mm^2. The targets used in the production of the hyperon beam are copper (Cu) and beryllium (Be). These targets have a cross sectional area of 1 mm^2 and approximately 15 cm long (one interaction length) for copper and 40.7 cm long (one interaction length) for beryllium. The primary beam has an angular divergence of 0.33 mrad (at half maximum). Mostly the beryllium target is used.

The hyperon magnet in the field region (Figure 2). The beam particles having a momentum value in a specific range pass through this curved channel with a radius of curvature of 700 m. The curvature of the channel is designed to accommodate the bending of the beam in the magnetic field of the hyperon magnet. This channel is constructed by using tungsten blocks. The aperture of the channel varies along its length and is 0.6 x 0.2 cm^2 at its terminus. This way all the other particles are filtered out. The channel acts like a collimator [4].

To obtain the necessary secondary beam flux, about 10^{12} protons per spill are needed. Each spill lasts for 20 seconds. Desired mixture of Σ and π and their momenta can be selected by a proper setting of the hyperon magnet.

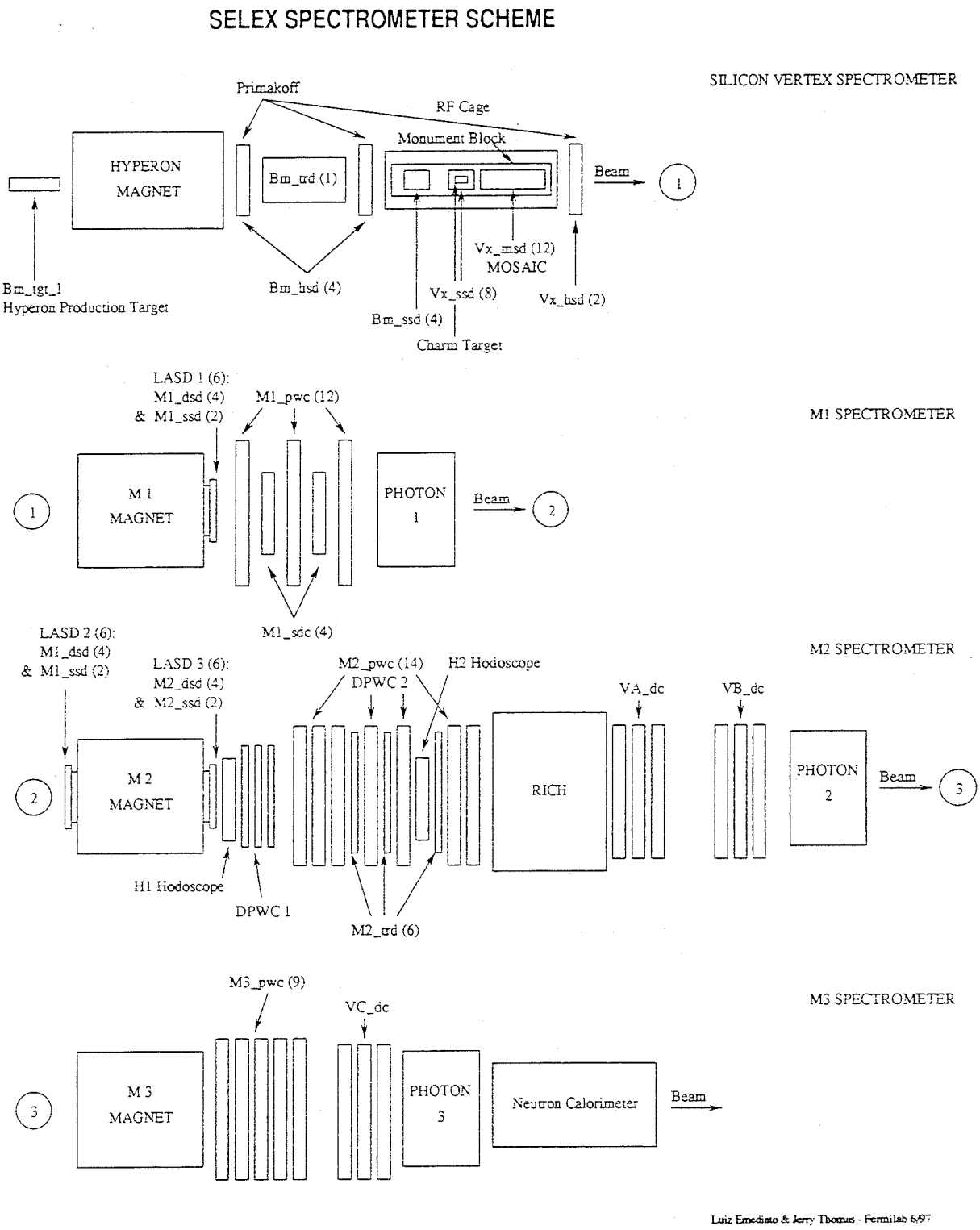


Figure 1: SELEX Experimental Setup In Fermilab Proton Center facility (PC4)

2.3 Beam Spectrometer

The beam spectrometer is placed downstream of the hyperon magnet. It has 10 planes of transition detectors (BTRD) to determine the type of the beam particle, 8 planes of silicon detectors (BSSD) to track the beam, and various scintillation counters for defining the beam and for timing purposes.

Each BTRD plane has three chambers of 3x3 cm^2 size and constructed with 200 foils of 17 micron thick polypropylene. They are used to identify the beam particles, mainly to distinguish the Σ particles from the π particles in the beam. The contribution of the other hyperons is very small [5].

The silicon detectors (BSSD) are placed after the BTRD. They are in the vertex region. The BSSD determines the trajectory of the incoming hyperon to a precision of 3μm using 20 μm pitch silicon strip detectors.

There are five interaction targets used in the experiment. These are, in order, two copper and three diamond (carbon) targets. Each target is 1.5 cm thick and has a cross sectional area of 4 cm^2. They are placed with a separation of 1.5 cm spacing in between.

The targets were placed between the BTRD and the vertex region. Vertex region includes all the BSSDs, beam scintillators, and the vertex silicon detectors.

2.4 M1 Spectrometer

The M1 spectrometer was located right after the vertex region. The aim of the M1 spectrometer is to track the particles (very low momentum) around 2.5 GeV/c. The momenta of the particles are calculated from the deflection angle. The deflection angle is proportional to the magnetic field. If the magnetic field is increased, the

deflection angle also increases. However, we have to keep in mind that in the M1 spectrometer very low momentum particles are to be tracked. If the magnetic field is too high, it will deflect the charged particles so much that they will not be able to reach the other detectors located downstream of the magnet.

The three large proportional wire chambers (PWCs) and the two drift chambers located downstream of the M1 magnet are used to determine the trajectory of the particles deflected out of the beam direction by the M1 magnet [6].

2.5 M2 Spectrometer and RICH

The M2 magnet and the accompanying detectors are used to study the high momentum particles. There are Large Angle Silicon Detectors (LASDs) in the M2 spectrometer. The aim of these LASDs is to improve the decay track resolution and separation in this area.

The LASDs are placed in three locations. One LASD station is placed at the entrance of the M2 magnet and one station at the exit of it. There is also one other station at the exit of the M1 magnet. The M2 magnet is operated at a higher momentum range (around 15 GeV/c).

There are PWCs (14 planes in 7 modules) located downstream of magnet M2 which are important for the M2 spectrometer. These chambers are used to find momenta and coordinates of the charged particles.

There are also three Electron Transition Radiation Detectors (ETRD) to help identify the electrons. These ETRDs are proportional chambers and contain 6 x-planes in 6 modules to seperate the electrons from the hadrons.

The Ring Imaging Cherenkov Radiation detector is placed downstream of the ETRDs. In the "RICH" detector, incoming charged particles interact with the gas

atoms (Neon at 1.05 atm) which subsequently emit photons. These photons are reflected from a mirror placed at the downstream end of the vessel to the photomultipliers at the upstream end. The image is in the form of rings and by measuring the radius of the rings the speed of the particle is determined. There are 3000 photomultiplier tubes. Using the momentum measured in M2, the mass of the incoming charged particles can be calculated. In general, π^-, π^+, μ^-, μ^+, p, and K^- are determined in RICH [7].

Next, there are Vee-chambers (Drift Chambers) located right after the RICH. This first Vee-chamber station (Station A) has 3 chambers and each chamber has 8 planes. There are 8 u-planes in the first chamber, 8 y-planes in the second, and 8 x-planes in the third chamber. The aim of these drift chambers is to improve the precision in the reconstruction of the trajectories of the charged particles downstream of the M2 spectrometer.

2.6 M3 Spectrometer

The M3 spectrometer is designed mainly to track the decay products of very high momentum charmed baryons like Λ_c. The so called Lambda chambers are located after M3 magnet to track these charged particles. There is also 1 Vee-chamber stations. One is placed before the M3 spectrometer (Station B) and the other placed after the PWCs in M3 spectrometer (Station C). These drift chambers are used to determine the trajectory of the charged particles to a higher degree of accuracy and as a backup to the PWCs.

2.7 Other Hardware

There are three leadglass photon calorimeter arrays located throughout the setup. These are used to study charm baryon decays that produce π^0's and also used

for Primakoff physics studies.

There is also a neutron calorimeter at the very end of the setup to track neutron for the reconstruction of the charm decay.

CHAPTER 3

MAGNETS IN SELEX

There are four magnets in the SELEX setup, hyperon magnet for the secondary beam and the M1, M2, and M3 magnets corresponding to a section of the entire SELEX spectrometer. All these magnets are, evidently, crucial to the experiment for the momentum determination.

It is important to operate these magnets correctly and to determine the field values accurately. Otherwise, the reactions will not happen under desired conditions and the particle trajectories will be determined incorrectly, resulting in large systematic errors and inaccuracies.

3.1 Properties of the Magnets

Hyperon Magnet

The hyperon magnet is the magnet used in selecting the correct composition and momentum (650 GeV) of the hyperon beam. It is located at the entrance of the PC4 experimental area in the Proton Center facility at Fermilab.

The hyperon magnet has a field region of 7.3 m. The hyperon beam production target is placed at the beginning of this field region in the enterance of the magnet. The primary proton beam interacts with the Be (or Cu) target producing various secondary particles. The hyperon beam composition and nominal momenta of the beam particles are selected by setting the magnetic field in the hyperon magnet properly. To keep the momentum spread of the beam particles to a minimum, a collimator

made of tungsten blocks is constructed inside the field region. The tungsten collimator is built as a curved tunnel with a radius of curvature of 700 m to accommodate the bending of the beam particles in the field. The rectangular aperture of the tunnel slowly increases as it gets to the end, and it is 0.6x0.2 cm^2 at its downstream end. Fig 2 displays the physical construction of the Hyperon magnet. The hyperon magnet is a dipole magnet usually operated at the field values 650 GeV at 35 kGauss, 3700 A near the field saturation [10] of the iron [4].

M1 Magnet

The M1 magnet is located at the upstream end of the M1 spectrometer and 191 cm downstream of the charm target. The M1 magnet is the main component of the M1 spectrometer. The magnetic field in M1 is set to such a value that the low momentum particles will be bent significantly. All the low momentum particles with momentum values around 2.5 GeV/c will be tracked through the PWCs downstream of the magnet. The data analysis, will try to match the trajectories obtained from the PWCs in this area to the trajectories of the particles in the vertex region.

The current in the M1 magnet is set to a nominal value of 2200 A With this current. The field value reaches 12 kGauss.

M2 Magnet

The M2 magnet is at the upstream and, of the corresponding spectrometer. It is 745 cm away from the charm target. It is a dipole magnet operated at a nominal current value of 2675 A at 15 kGauss. The field obtained at this current setting is suitable for analyzing particles with momentum values around 15 GeV/c. The amount of bending for these particles and the subsequent trajectories after exiting the magnet is optimum for passing through all the chambers placed downstream of the magnet. Partial or ambiguous trajectories would be obtained for all the other

low momentum particles. The M2 spectrometer is placed to analyze the energetic particles produced in the charm productions and in the decay of the charm particles.

M3 Magnet

The M3 magnet is the furthest downstream magnet and forms the upstream end of M2 spectrometer and forms the upstream end of the M3 spectrometer. It is a dipole magnet similar to the M1 and M2 magnets. The M3 magnet current is also set to 2675 A at 14 kGauss. However, towards the end of the experiment there were some problems in the power supply. Because of that, the current was set to half of its previous value. This third spectrometer is designed to select the decay products of the more energetic charm particles, such as Λ_c, by separating the forward trajectories of the decay products. Without the magnetic field, the trajectories of the decay products may be indistinguishable from each other.

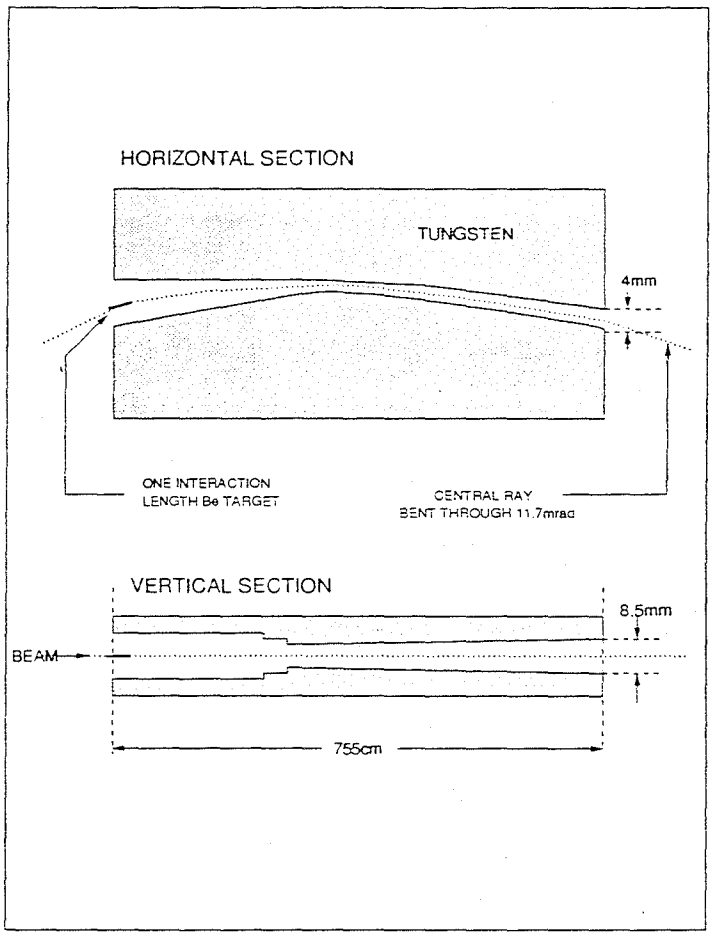


Figure 2: Hyperon Magnet

3.2 Expected Field Versus Current Values

It is expected that a scatter plot of the field versus the current values should show almost all the data bunched around a point. These additional values should be consistent with the excitation curve of a specific magnet.

Here it is assumed that all the field and current measurements are taken synchronously and during the time the field value is at a full value which is setup for each spill. Each spill lasts 1 minute, 20 second beam-on, 40 sec beam-off.

For each run an average field value is recorded. This average value is obtained over the full data set for a specific run. The individual measurements for each spill are, evidently, also recorded.

During the run, the field values versus the current passing through the magnet have been recorded continuously (Table 1). Each measurement (spill) is tagged with the corresponding run number (Epilog program).

In principle, by plotting the average field values versus the average current readings taken for each run, one should be able to see the excitation curve for the corresponding magnet. The complete excitation curve can be seen because there are special cases where the field value is not at its full value and some measurements are taken with special runs with low momentum, that is, low field value, low current. For the Hyperon magnet the expected plot should look like the plot displayed in (Figure 3), a saturation [10] curve (s-curve) due to the presence of a paramagnetic material in the middle of the hyperon magnet, hyperon channel. The plot in this figure gives a good example of the excitation curves measured for both the E781 and E761 experiments. The separated curves are due to replacement of the iron channel

by tungsten in the hyperon magnet.

On the other hand, the M1, M2, and M3 magnets are operated in their linear functions, so their corresponding average field value versus average current value plots should display a straight line since there is no core in these magnets.

3.3 Problems in the Magnetic Field Measurement

For all the magnets in the Selex spectrometer, it is obvious that a wrong field results in a reaction that is not planned or desired. On the other hand, using a wrong field value would yield trajectories pointing to different places than to where they are supposed to come from.

As seen in the Figures 4-7 the magnetic fields are set to the correct value for most of the time. Hyperon magnet has to be set to the full field value all the time to keep the beam coming in to the experiment.

The M1, M2, and M3 magnets are usually set to their nominal values for the interaction runs. Interaction runs are those runs where most of the data are taken, producing charmed particles through the interaction of the secondary beam with the carbon target in the vertex region. However, during the alignment runs these magnets are turned off to make sure that the beam goes through straight and provides a reference line for aligning the position sensitive detectors or checking the alignment for the M3 magnet, as mentioned above because of the power supply problems towards the end, the current is lowered to half. All the other points in between, with a small exception for special runs, indicate that something has gone wrong.

The values on these plots are taken from the OCS tables produced from the output of the main Fermilab control program called Epicure. OCS Table is a set of parameters used in the offline code called SOAP–Selex Offline Anaylisis Program

for the trajectory reconstruction of the charmed particles. The value for each run is a straightforward average over all the readings taken during that run. In fact, this straight averaging complicates things further Figure 12.

The problem can be seen more clearly if the magnet data are plotted as a scatter plot of field values versus the current readings. In such plots, one would expect to see a condensation of data around the points where the field and current values are at their nominal values and around the origin corresponding to those runs during which the field is turned off. Of course the field would be on all the time for the Hyperon magnet. One other feature that might be expected is the field and current values lower than the nominal values. This might happen if the data were taken either mostly during the special runs for low momentum measurement for Primakoff physics or polarization studies or during the ramp cycle due to out of synchronization of the read-out systèm.

Becuse of the microstructure if the beam, magnets are operated during the beam-on periods and ramped up or down, before and after these periods, respectively. Data points seen anywhere else are an indication of a problem in the data taking. The scatter plots of all four magnets are given in Figures 8-11. The problem occurring in the power supplies and current settings are usually known through other means and taken care of separately.

It is clear to see that all the expected features of these plots are there. Condensation of points around the nominal field and current values, intermediate values caused by the ramping, linear excitation curve for M1, M2, and M3 magnets, and the S-curve for hyperon magnet. But, there are also data points scattered around and some strange correlations such as the mirror reflection of the straight-line on one quadrant (for example, Figure 10). Randomly scattered data points obviously have

problems. However, the points lying on the mirror reflection of the straight line might have a problem that can be fixed easily. In fact, it turns out that these reflection are caused by wrong signs of the field and current values in the Epicure readout files. Investigation of the measured field values over the whole run period for all four magnets uncovered some problems with the magnetic field data recorded. The problems are listed in the tables 1 and 2. Possible solutions are given in the next chapter with an algorithm to obtain the right average field value for a given run or to make a decision whether to keep or to eliminate a run from the data analysis.

In summary, the problems in the magnet data are as follows:

Readings taken during the ramp cycle (maybe recoverable). Mismatch in the current and the field signs (recoverable). Real problems in data acquisition or recording as shown in Figure 12.

In the next chapter, two ways of dealing with these problems will be explained. One of them actually takes care of the general problem caused by straight averaging over the whole data set by reaveraging with some constraint.

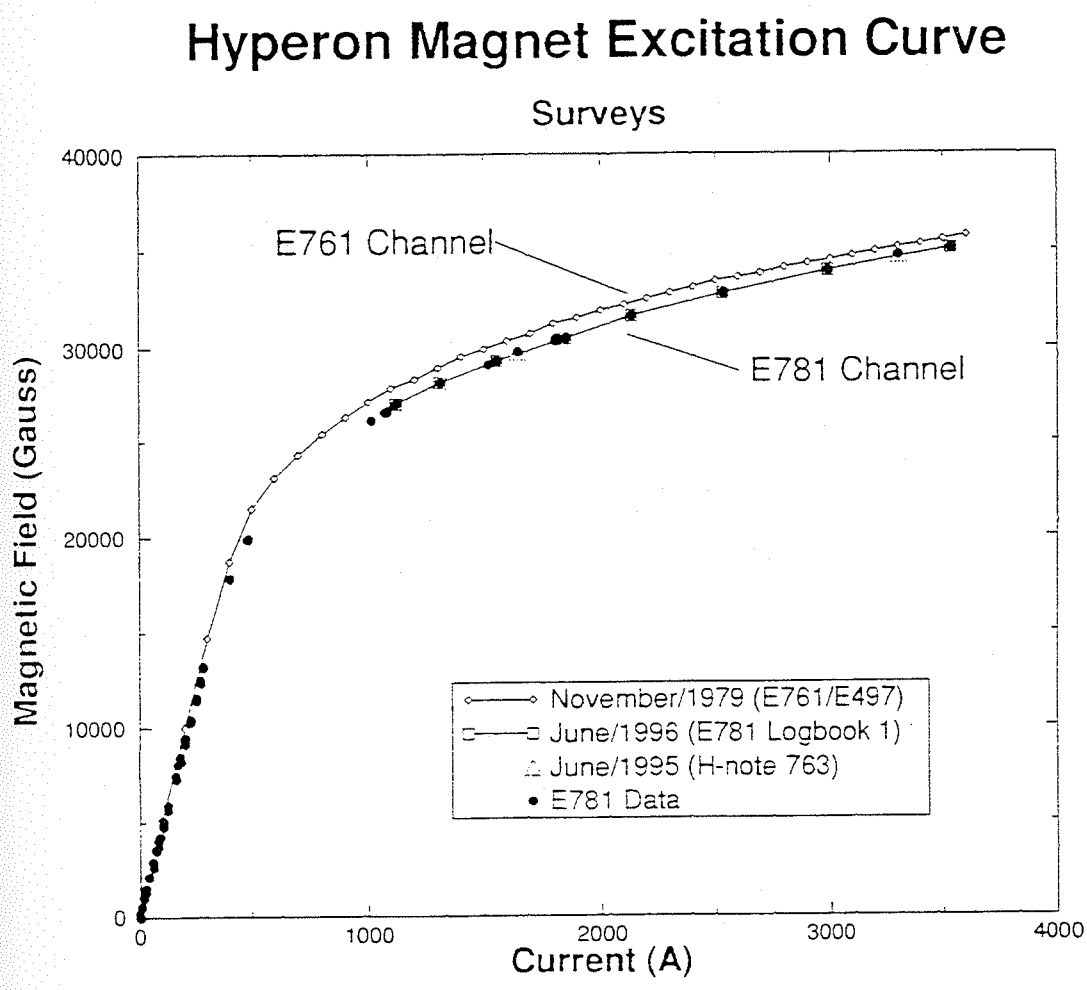


Figure 3: Hyperon Magnet Excitation Curve

Table 1: Epilog Output of Epicure Read-out on a Spill by Spill Basis (I).

RUN	Hyperon	M1	M2	M3
10021	Field/spill	Field/spill	Field/spill	Field/spill
Interaction	-34447.	-11977.5	-14656.	-6848.
	-34447.5	-11977.5	-14656.5	-6848.
	-34447.	-11977.5	-14656.	-6848.
	-12716.	8.	-6.5	12.
	-258.5	11.	-4.	14.
	-196.	12.	-4.	14.5
	-189.	12.	-6.	14.5
SQL Average	$< -14KG >$	$< -4KG >$	$< -5KG >$	$< -2KG >$
Pass1 Average	$< -14775. >$	$< -4893. >$	$< -5998.9 >$	$< -2793. >$
10338	Field/spill	Field/spill	Field/spill	Field/spill
Interaction	-34480.	-11982.	-14665.	-6849.
	0.	0.	0.	0.
	-34480.	-11982.	-14665.5	-6849.5
	0.	0.	0.	0.
	-34480.	-11982.	-14665.	-6849.
SQL Average	$< -33KG >$	$< -11KG >$	$< -14KG >$	$< -6KG >$
Pass1 Average	$< -33629. >$	$< -11686. >$	$< -14303. >$	$< -6679.9 >$
10729		Field/spill		
Interaction		10.		
		10.5		
		10.		
		10.		
		-11984.5		
		-11985.5		
		-11985.5		
SQL Average		$< -9KG >$		
Pass1 Average		$< -9986.2 >$		

Table 2: Epilog Output of Epicure Read-out on a Spill by Spill Basis (II).

RUN	Hyperon	M1	M2	M3
10737	Field/spill	Field/spill	Field/spill	Field/spill
Interaction	-34469.	-11985.5	-14665.	-6848.
	-34469.	-11985.5	-14664.	-6848.
	-6356.5	2.	-12.5	19.
	-220.	15.5	-5.	24.5
	-182.	17.	-4.5	24.5
	-176.5	17.5	-4.5	25.
SQL Average	$< -9KG >$	$< -2KG >$	$< -7KG >$	$< -1KG >$
Pass1 Average	$< -9527.9 >$	$< -2985.6 >$	$< -7335.3 >$	$< -1694.1 >$
10858	Field/spill	Field/spill	Field/spill	Field/spill
Interaction	-34461.5	-11984.5	-14664.	-6849.
	0.	0.	0.	0.
	-34461.5	-11984.5	-14665.	-6849.
	0.	0.	0.	0.
	-34461.5	-11984.5	-14665.	-6849.
SQL Average	$< -33KG >$	$< -11KG >$	$< -14KG >$	$< -6KG >$
Pass1 Average	$< -33792. >$	$< -11751. >$	$< -14380. >$	$< -6716. >$
10974				Field/spill
Interaction				6901.
				6901.5
				43.5
SQL Average				$< 6KG >$
Pass1 Average				$< 6766.6 >$
11320	Field/spill			
Special	30311.5			
	30311.5			
	11976.			
	273.			
	223.			
	217.5			
	215.5			
SQL Average	$< 24KG >$			
Pass1 Average	$< 24440. >$			

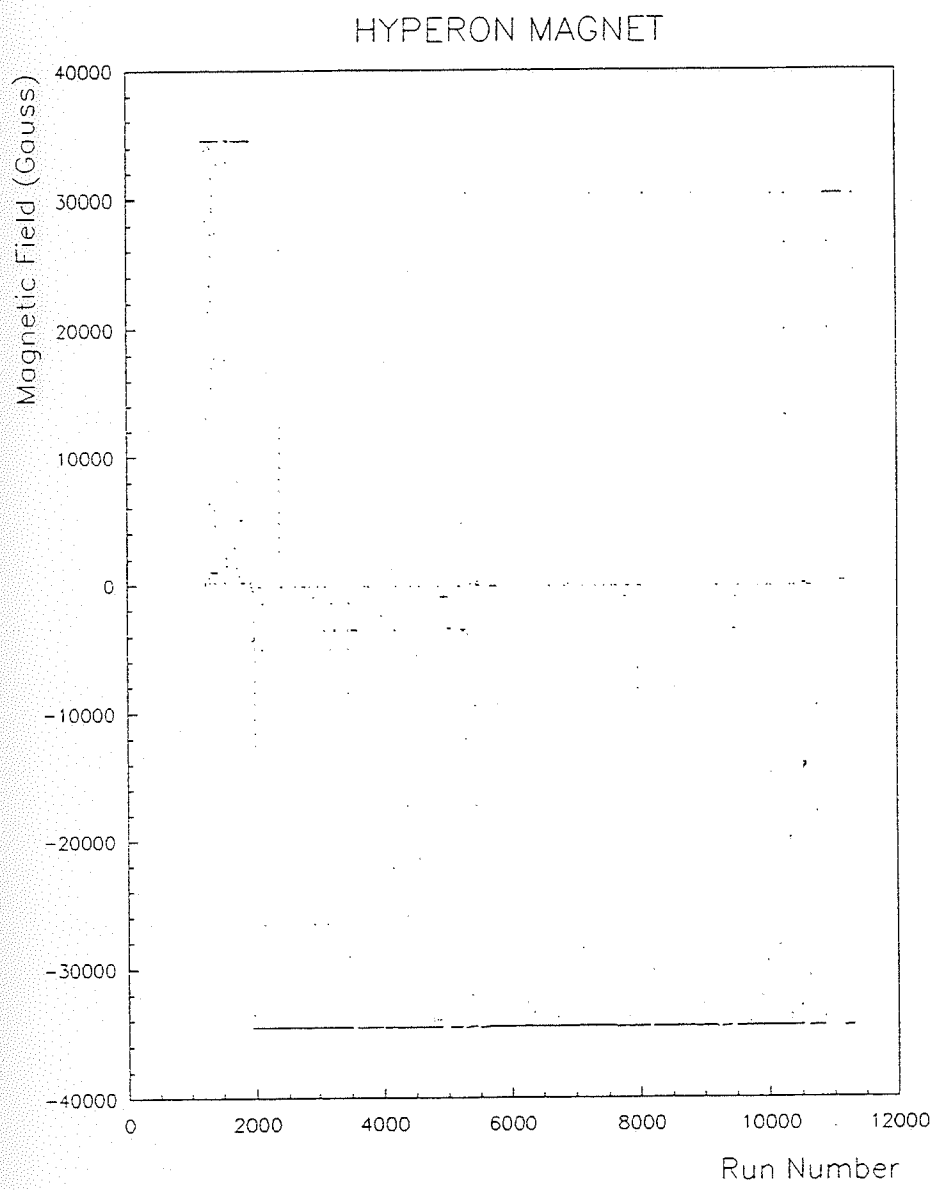


Figure 4: Hyperon Magnet Magnetic Field vs Run Number

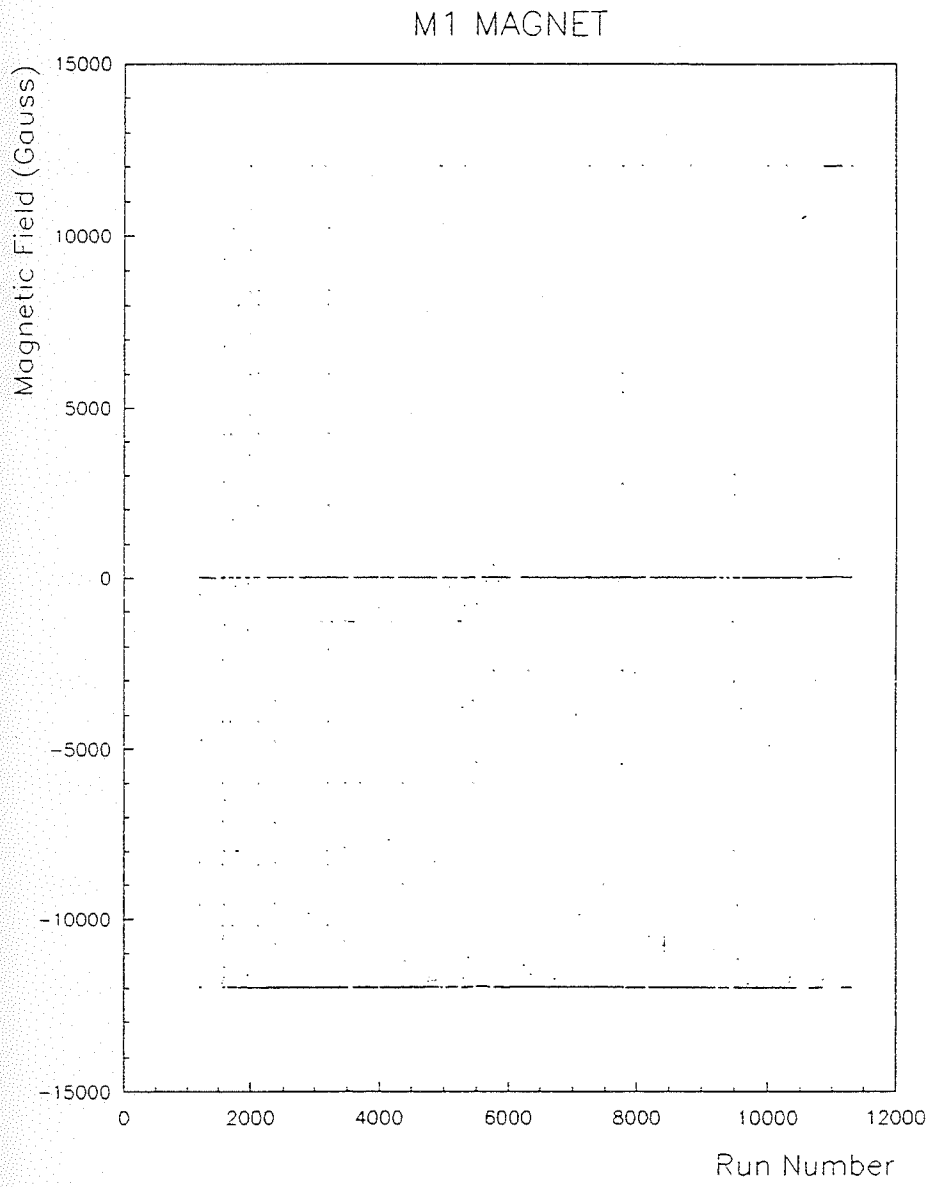


Figure 5: M1 Magnet Magnetic Field vs Run Number

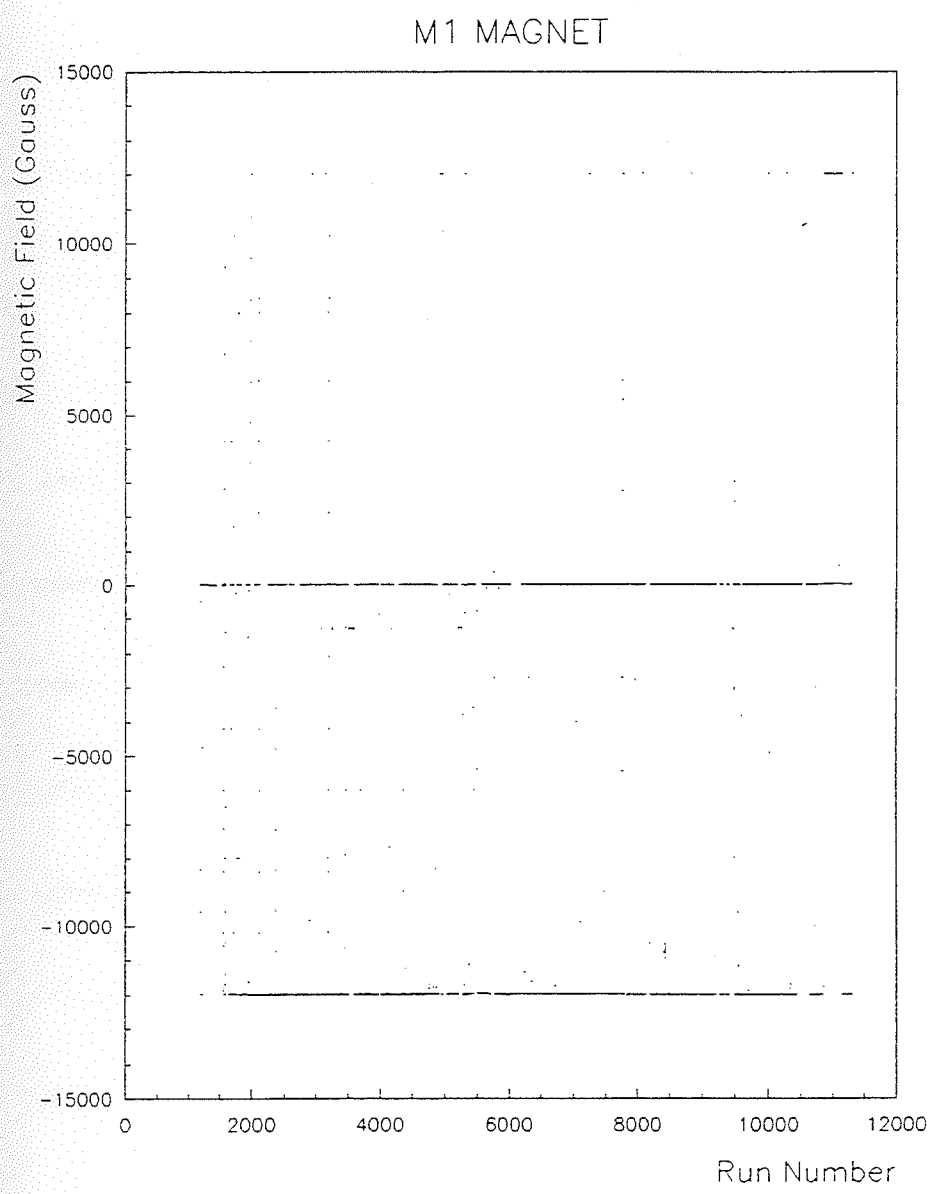


Figure 5: M1 Magnet Magnetic Field vs Run Number

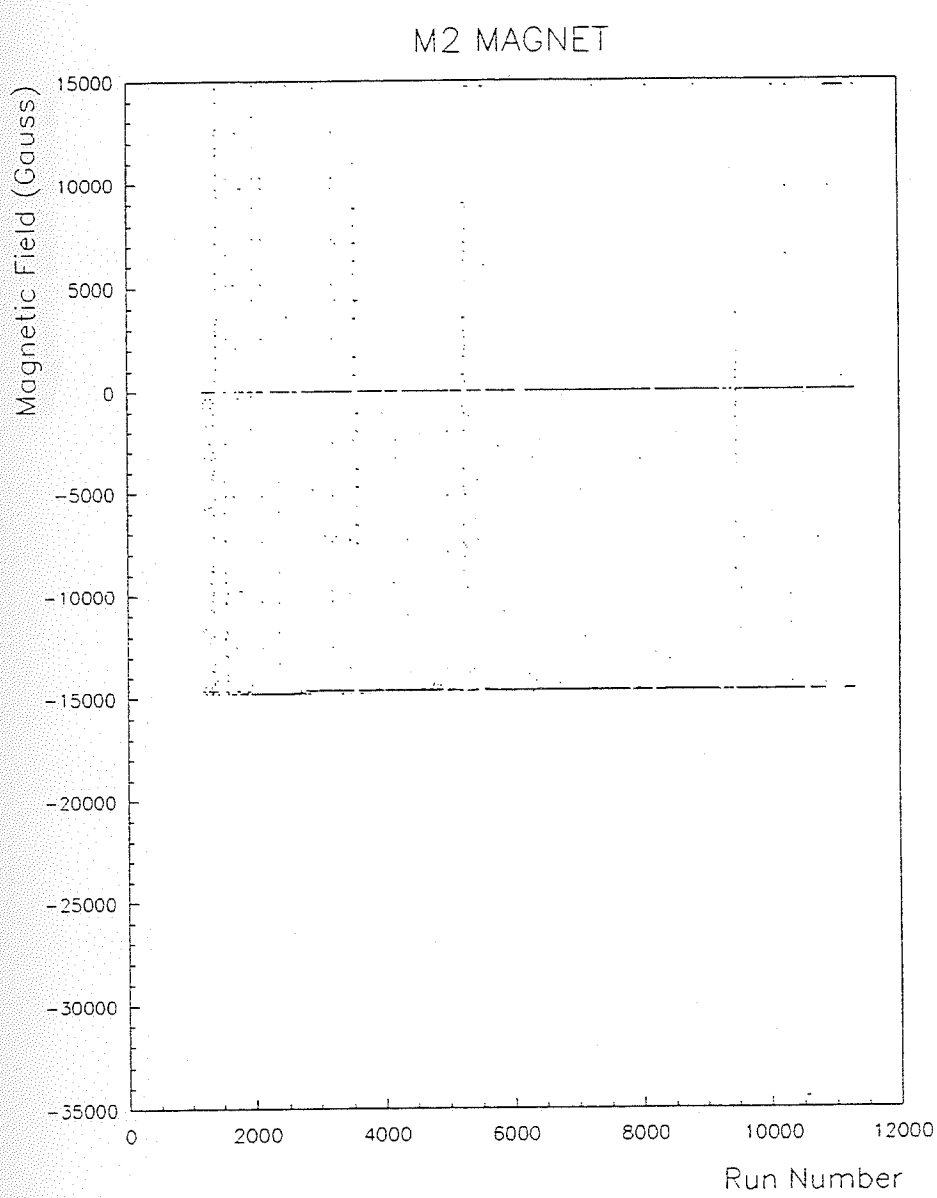


Figure 6: M2 Magnet Magnetic Field vs Run Number

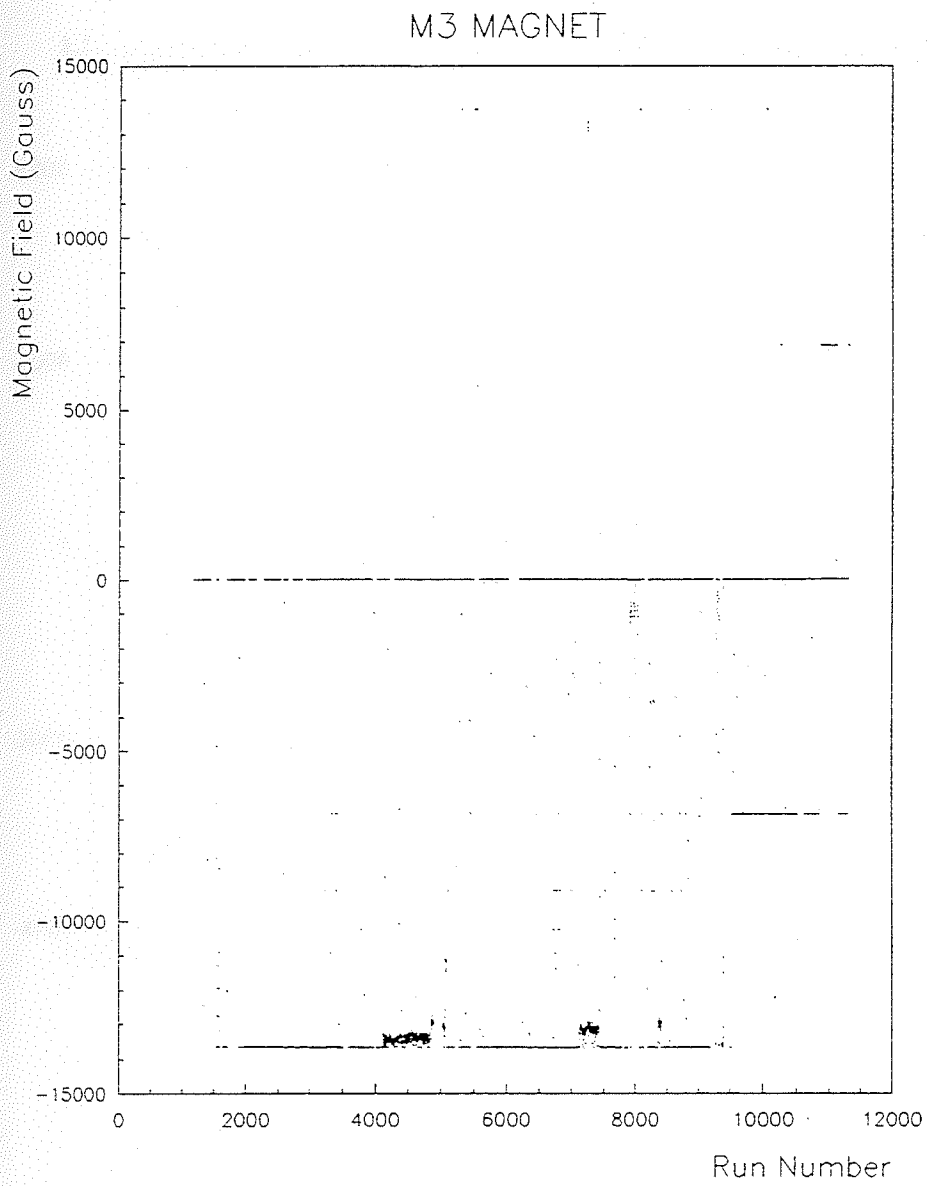


Figure 7: M3 Magnet Magnetic Field vs Run Number

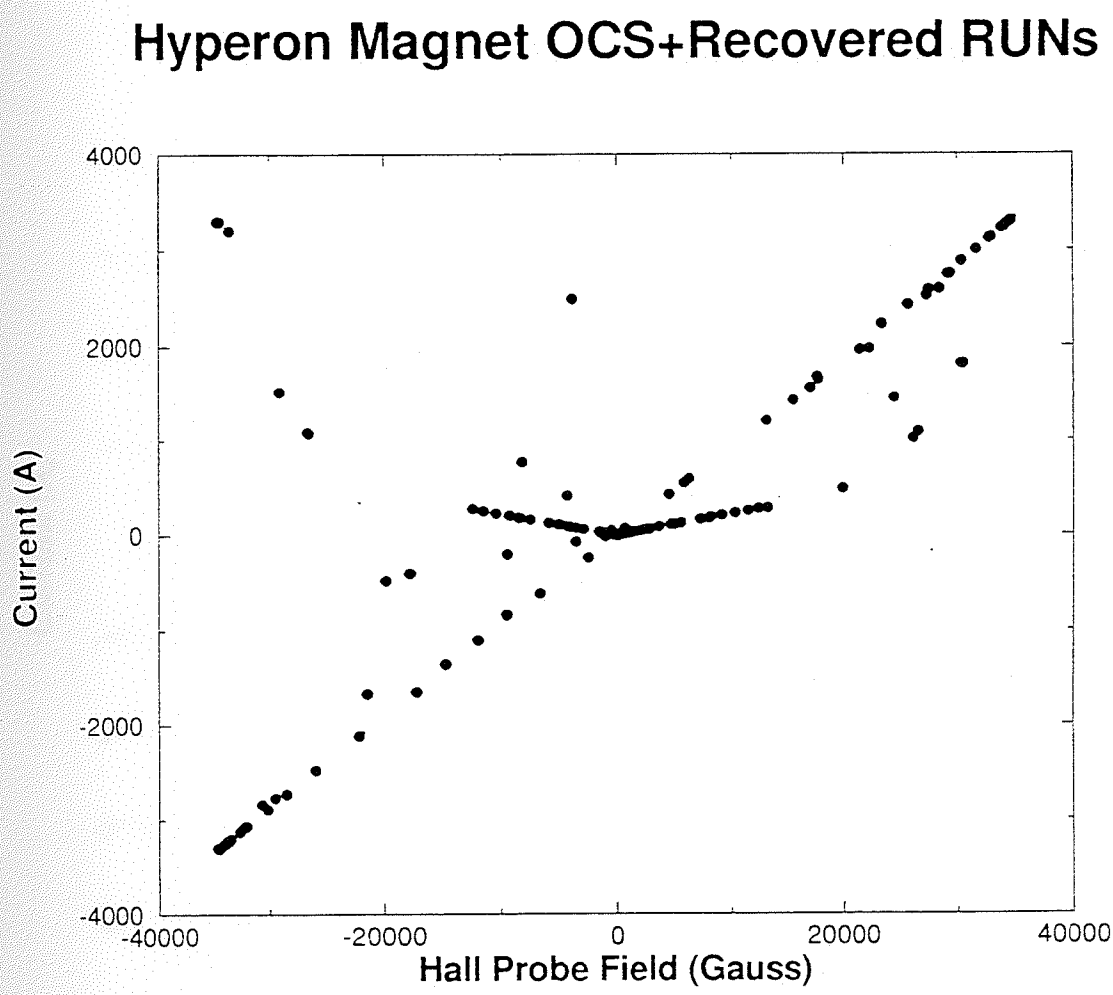


Figure 8: Hyperon Magnet Field vs Current

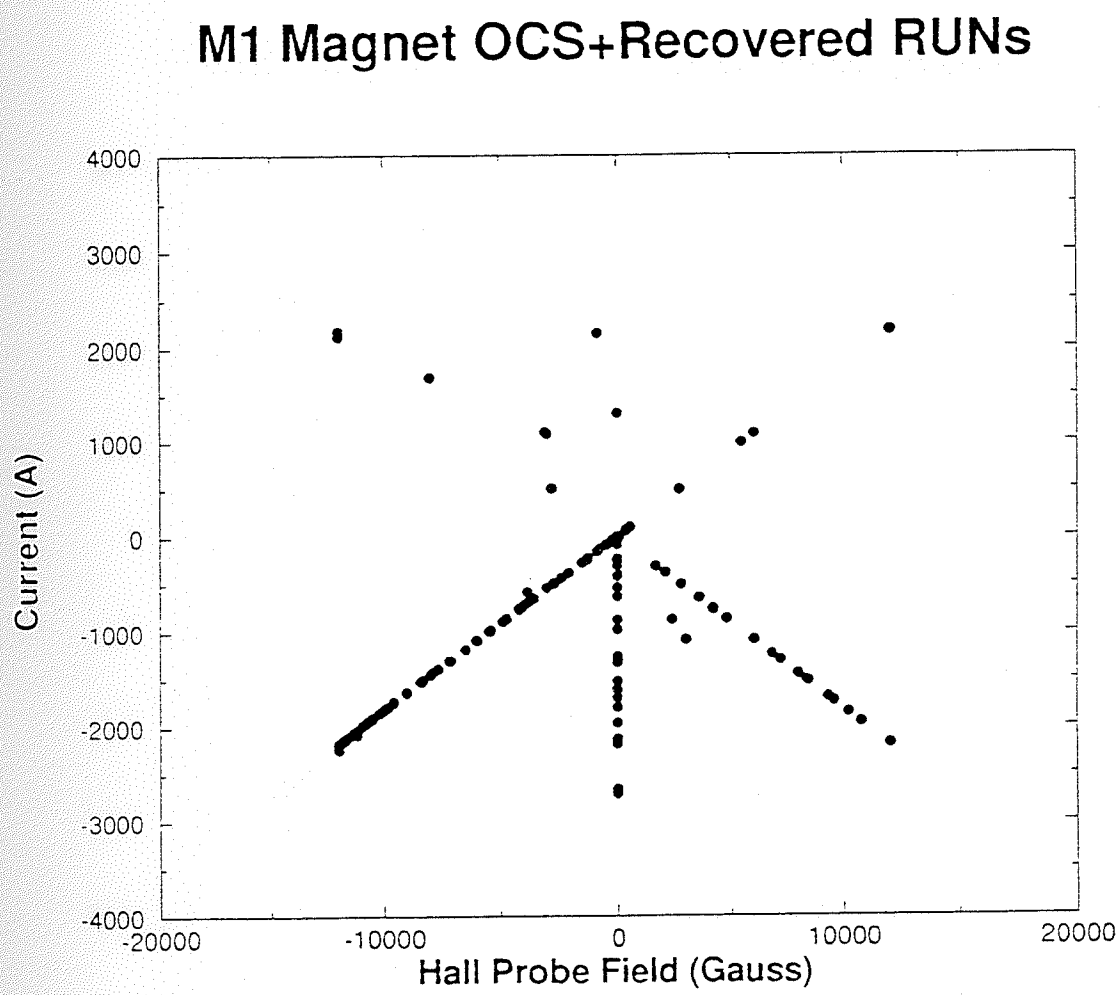


Figure 9: M1 Magnet Field vs Current

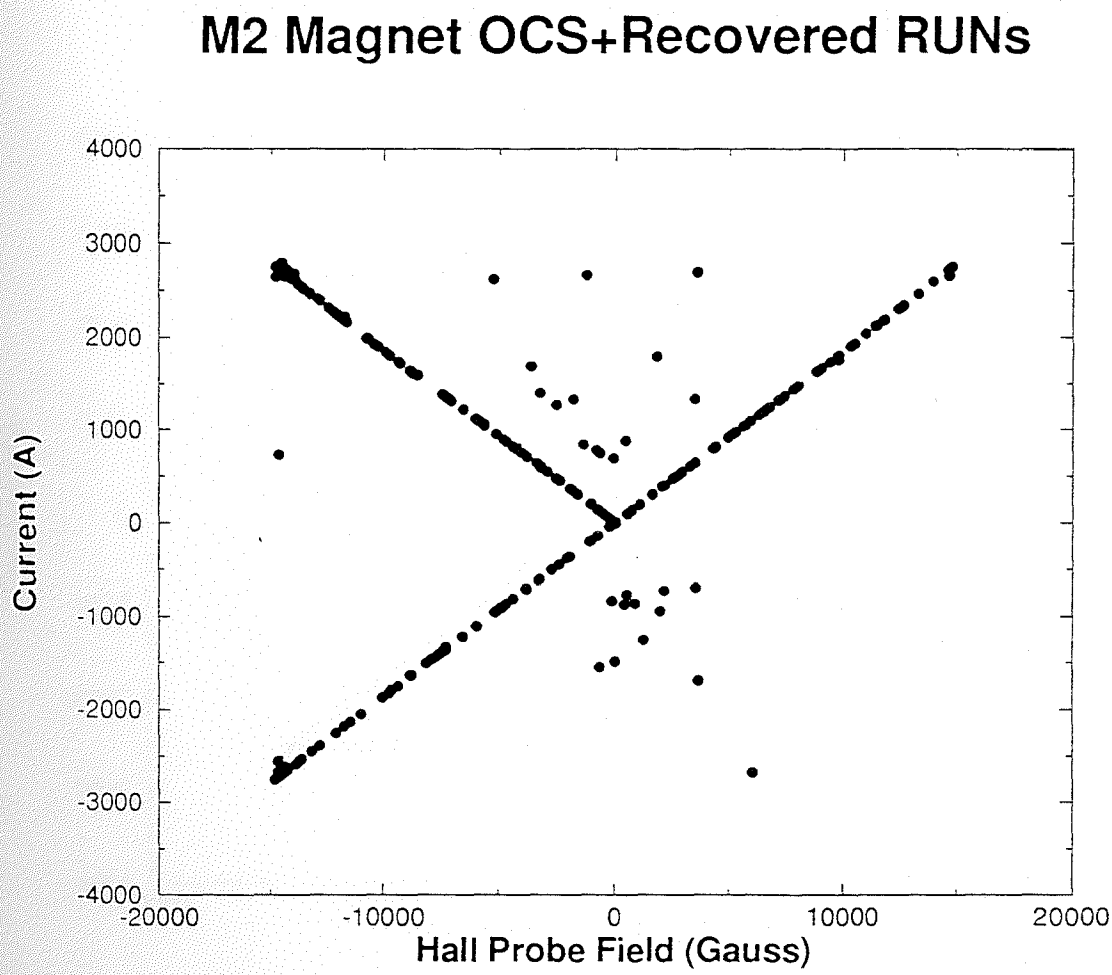


Figure 10: M2 Magnet Field vs Current

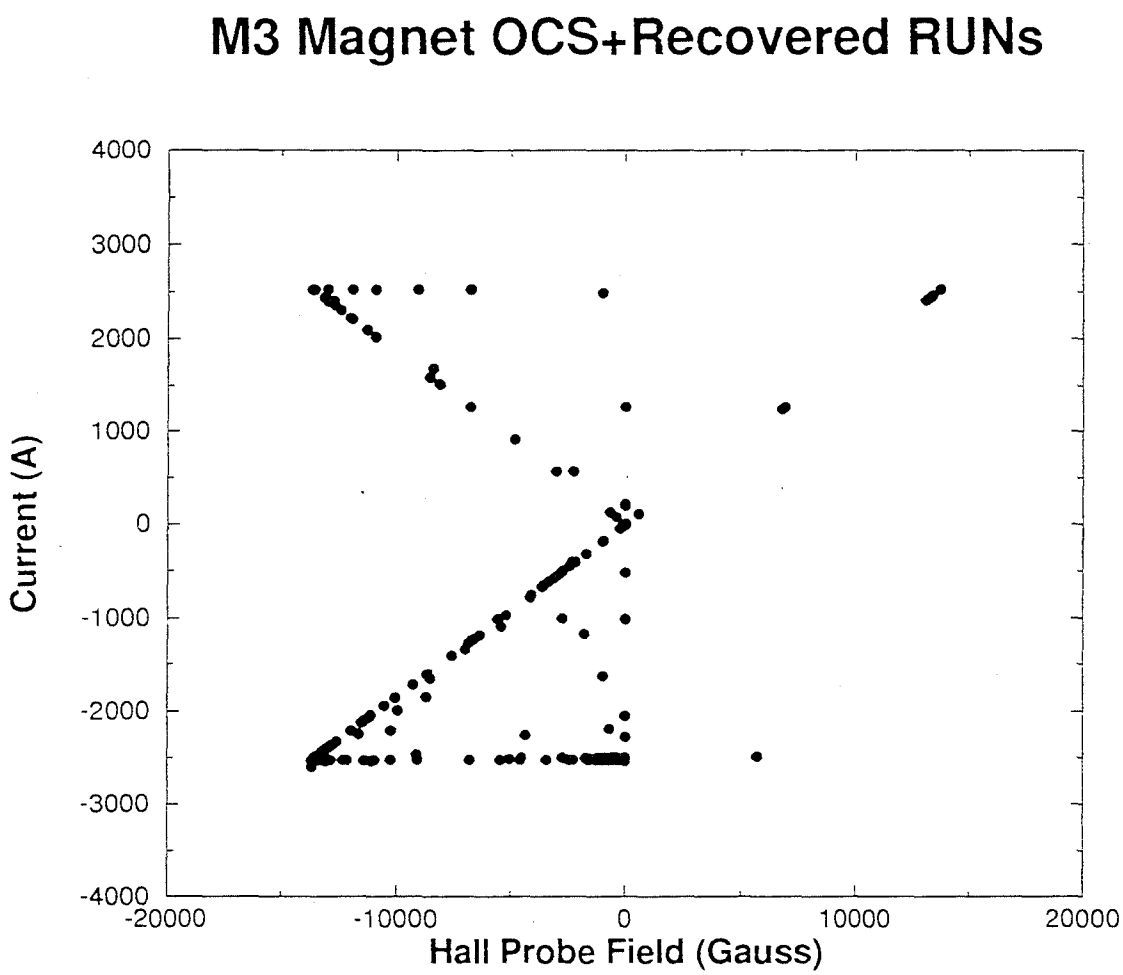
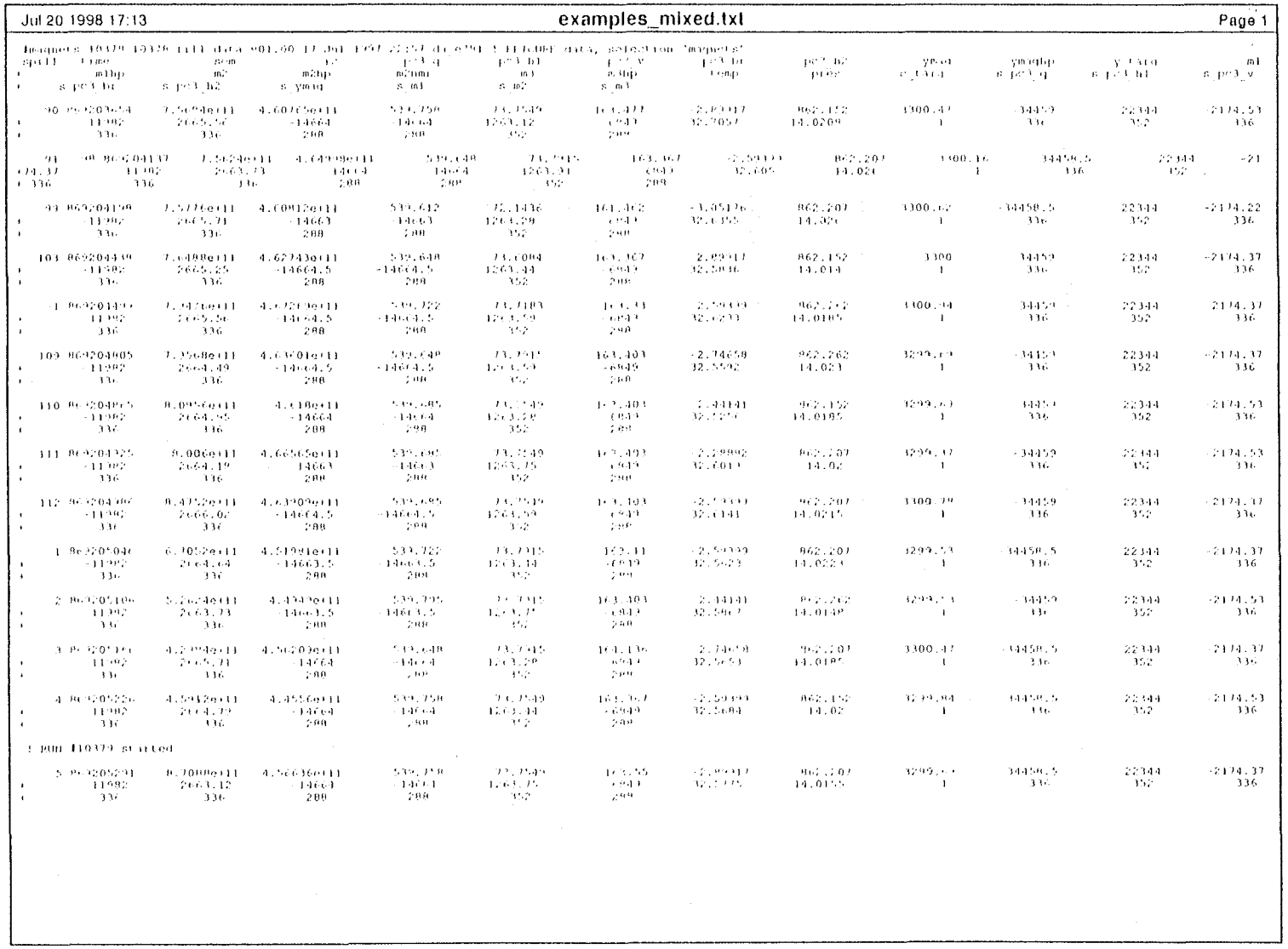


Figure 11: M3 Magnet Field vs Current



Jul 20 1998 17:13 examples_mixed.txt Page 1

```
Beamnets 10379 10379 1111 data v01.00 17 Jul 1998 27:57 dr.e791 5 111:004 data, selection 'mmpnets'
spill   time        scm        tr        pc3_q      pc3_hl     p_c_v      pc3_br     pc3_h2     ymed       ymmqhp     y_1ard        ml
+       mlhp        m2         m2hp      m2nm       m1         m3hp       temp       pres       s_1ard     s_pc3_q    s_pc3_hl      s_pc3_v
+     s_pc3_br    s_pc3_h2    s_ymmq     s_m1       s_m2       s_m3

   90 869204054   7.5e9e+11   4.6075e+11   533.750    73.7549   163.477   -2.83417   862.152   1300.47   34459    22344   -2174.53
+     11982       2665.56     -14664     -14664     1263.12    6949     32.7057    14.0209    1         336      352      336
+     336         336         288        288        352        289

   91 869204137   7.5e9e+11   4.6499e+11   539.648    73.7415   163.067   -2.59133   862.207   1300.16   34458.5   22344   -21
+74.37  11982     2663.73     14664      14664      1263.31    6949     32.605     14.024     1         336       352
+ 336   336        336        288        288        352        289

   93 869204190   7.5776e+11   4.6091e+11   539.612   72.1436   161.362   -3.05176   862.207   1300.62   -34458.5   22344   -2174.22
+     11982       2665.71     -14663     -14663     1264.29    6949     32.6155    14.026     1         336       352      336
+     336         336         288        288        352        289

  103 869204439   7.648e+11   4.62743e+11   539.648   73.6084   163.367   2.09417   862.152   1300      34459    22344   -2174.37
+     -11982      2665.25     -14664.5   -14664.5   1263.44    6949     32.5836    14.014     1         336       352      336
+     336         336         288        288        352        289

    1 869204444   7.747e+11   4.6729e+11   539.722   73.7183   163.43    2.59133   862.262   1300.34   34459    22344   2174.37
+     11982       2665.56     -14664.5   -14664.5   1263.59    6949     32.6233    14.0185    1         336       352      336
+     336         336         288        288        352        289

  109 869204805   7.3568e+11   4.6301e+11   539.648   73.7415   163.403   -2.74658   862.262   1299.69   -34459   22344   -2174.37
+     -11982      2664.49     -14664.5   -14664.5   1263.59    6949     32.5592    14.023     1         336       352      336
+     336         336         288        288        352        289

  110 869204845   8.095e+11   4.118e+11   539.685   73.7549   163.403   2.44141   862.152   1299.69   34459    22344   -2174.53
+     -11982      2664.55     -14664     -14664     1263.29    6949     32.5755    14.0185    1         336       352      336
+     336         336         288        288        352        289

  111 869204925   8.006e+11   4.66565e+11   539.685   73.7349   163.403   -2.29892   862.207   1299.47   -34459   22344   -2174.53
+     -11982      2664.19     -14663     -14663     1263.75    6949     32.6013    14.02      1         336       352      336
+     336         336         288        288        352        289

  112 869204987   8.4152e+11   4.6390e+11   539.685   73.7549   163.403   -2.73333   862.207   1300.39   -34459   22344   -2174.37
+     -11982      2666.07     -14664.5   -14664.5   1263.59    6949     32.6141    14.0215    1         336       352      336
+     336         336         288        288        352        289

    1 869205040   6.7052e+11   4.5198e+11   533.722   73.7415   163.11   -2.59333   862.207   1299.53   -34458.5   22344   -2174.37
+     -11982      2664.64     -14663.5   -14663.5   1263.14    6949     32.5623    14.0224    1         336       352      336
+     336         336         288        288        352        289

    2 869205106   5.2624e+11   4.4345e+11   539.795   73.7415   163.403   2.14141   862.262   1299.53   -34459   22344   -2174.53
+     11982       2663.73     -14663.5   -14663.5   1263.37    6949     32.5807    14.0149    1         336       352      336
+     336         336         288        288        352        289

    3 869205166   4.2794e+11   4.5620e+11   539.648   73.7415   163.136   2.74658   862.207   1300.47   -34458.5   22344   -2174.37
+     11982       2665.71     -14664     -14664     1263.29    6949     32.5653    14.0185    1         336       352      336
+     336         336         288        288        352        289

    4 869205226   4.5412e+11   4.4556e+11   539.758   73.7549   163.367   -2.59133   862.152   1299.84   -34458.5   22344   -2174.53
+     11982       2664.79     -14664     -14664     1263.44    6949     32.5684    14.02      1         336       352      336
+     336         336         288        288        352        289

! run 10379 started

    5 869205291   8.7080e+11   4.5636e+11   539.758   73.7549   163.55   -2.83417   862.207   1299.[illegible]   34458.5   22344   -2174.37
+     11982       2663.12     -14663     -14663     1263.75    6949     32.5775    14.0155    1         336       352      336
+     336         336         288        288        352        289
```

Figure 12: Example of spill/run anomalies in the Epicure/Epilog output.

CHAPTER 4

OBTAINING THE MAGNETIC FIELD AVERAGES

4.1 Three-sigma Selection

One way of obtaining the correct average field values is to use the Epicure output files with some filtering. In this section a procedure for selecting the average values that have been calculated correctly and also recovering the others is suggested. All the runs corresponding to these average field values can be included in the offline analysis.

In principal, plotting the averaged field versus the averaged current values for a specific magnet for every run should yield a distribution resembling the excitation curve for that magnet. In case of the hyperon magnet, a full excitation function should be seen since it is run at almost the saturation field values for tungsten $\sim$ 35 kGauss. On the other hand, all the other magnets are run at lower field values $\sim$ 12, 15, 14 kG for M1, M2 and M3, respectively, which has linear excitation curves. As seen in the two dimensional plots displayed in (Figures 8-11), excitation function is clearly there. However, there are data points seen elsewhere. The runs having inconsistent signs for the field and current values yield secondary lines. These lines are mostly the mirror reflection of the proper lines. Assuming that the field values always have the correct sign (since they come from the hall-probe measurements), the sign of the current values for these runs are changed to bring them onto the proper excitation curve in the scatter plot. Of course this will not solve the problem for these

cases where the field value has the wrong sign for some reason.

In principle, all the runs whose field versus current values result in a point somewhere on this proper excitation curve should be selected as a good run.

A systematic way of selecting the good runs would be as follows. First, data points lying along the proper excitation curve are fit to an excitation curve. The parametric function obtained from this fitting would give us a way to calculate the field values. The function would be a simple straight line in the case of M1, M2, and M3 magnets and a more complicated function for the hyperon magnet (in fact, the data for the hyperon magnet are fit to a five-parameter function with the help of MINUIT minimization package [8]). Then, using this function, all data is projected onto its line and so the distances between the fit line and the data points (I,B) averaged over spills per run, are histogrammed. Field value for each average current value is calculated. Next, the difference between the calculated and the actual field value (average) is histogrammed. The resulting histograms for all four magnets are displayed in (Figures 13-16).

The standard deviation (σ) of the central peak of the projection distribution in each histogram gives us, indirectly, the resolution in the field values. These are as follow: 0.008% at 12 kGauss for M1 magnet, 0.013% at 15 kGauss for M2 magnet, 0.017% at 14 kG for M3 magnet, and between 0.06% and 0.12% at 35 kG for hyperon magnet. For the hyperon magnet standart deviation is much better than the expected value of 0.7%. Hence, selecting the runs that fall within $\pm$ 3σ range of the central peak should include all the good runs while still keeping to the initial criteria for the field values. Statistically, more than 99% of confidence for a Gaussian distribution. In this case the distribution of the projected data points should be centered at zero if the fitting is done correctly. All the other runs, whose field versus current values fall

somewhere outside the excitation curve, will be outside of this 3σ interval. Hence, all these runs that have field and current values with unrecoverable problems will be eliminated

This procedure is obviously a very simple approach to solve the problem. For some runs that are eliminated by the procedure, there might be a way to correct the problem and include that run in the analysis. The second procedure explained in the next section actually claims to do that.

4.2 Reaveraging

In the previous section, the selection criteria for good runs is based on the pre-averaged field and current values. These are provided by the Epicure and stored in the relevant OCS tables. However, the field and current values for each spill are also available

An algorithm is developed (Figure 17, [9]) to recalculate the averages by using the values recorded for each spill since the problems uncovered, as shown in tables 1 and 2 [9]. In this algorithm, all the spills that have obvious problems are either left out of the averaging or the values are corrected if possible. Common problems are zero readouts, inconsistent signs between the current and the field values, switched current and field values, synchronization problems field and current values belonging to the previous spill or run, duplicate sets of data, etc. Most of these spills are dropped in calculating the new averages. The final average field and current values are displayed in Figures 18-21, [9]. All the points are on a proper excitation curve. Even though this result is expected, the plots are still remarkably clean of any background or any point with some problem. Hence the obvious conclusion would be to recalculate the averages using the spill by spill data.

The projection histograms obtained from these re-averaged values are displayed in Figures 22-25, [9]. The projections are done as explained in the previous section assuming only sign corrections for the current values, not field, since 3σ selection does not depend on that. As seen in these figures, the distributions have very sharp peaks.

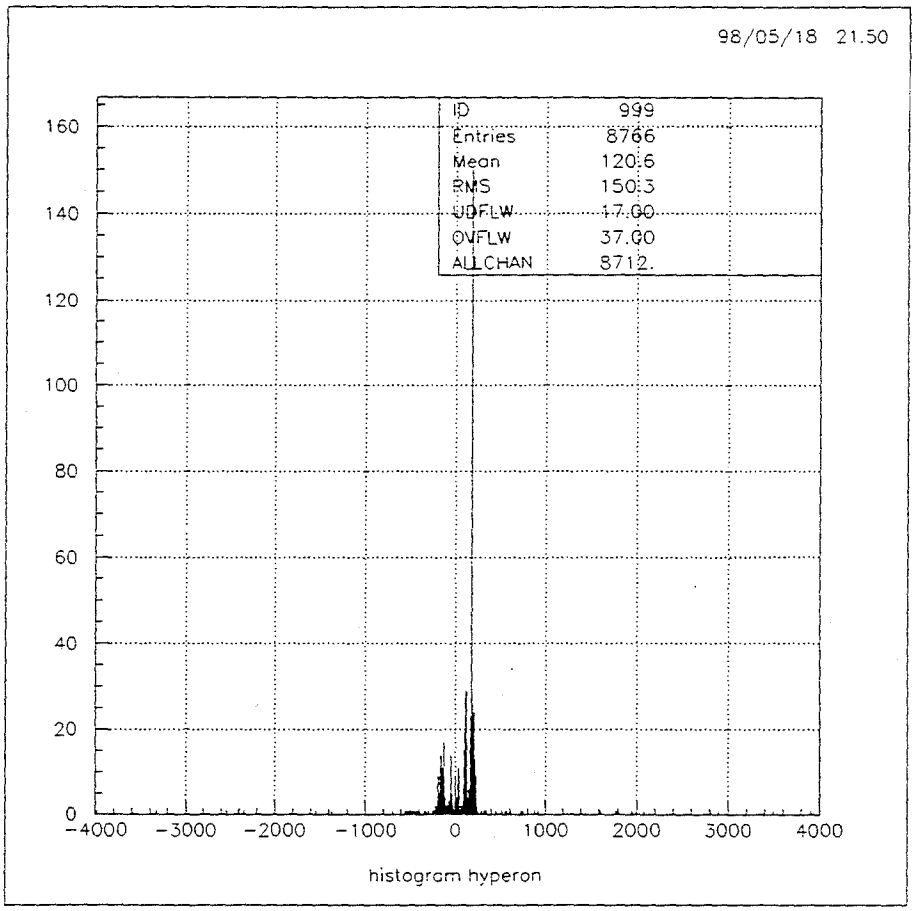


Figure 13: Hyperon Projection Distribution

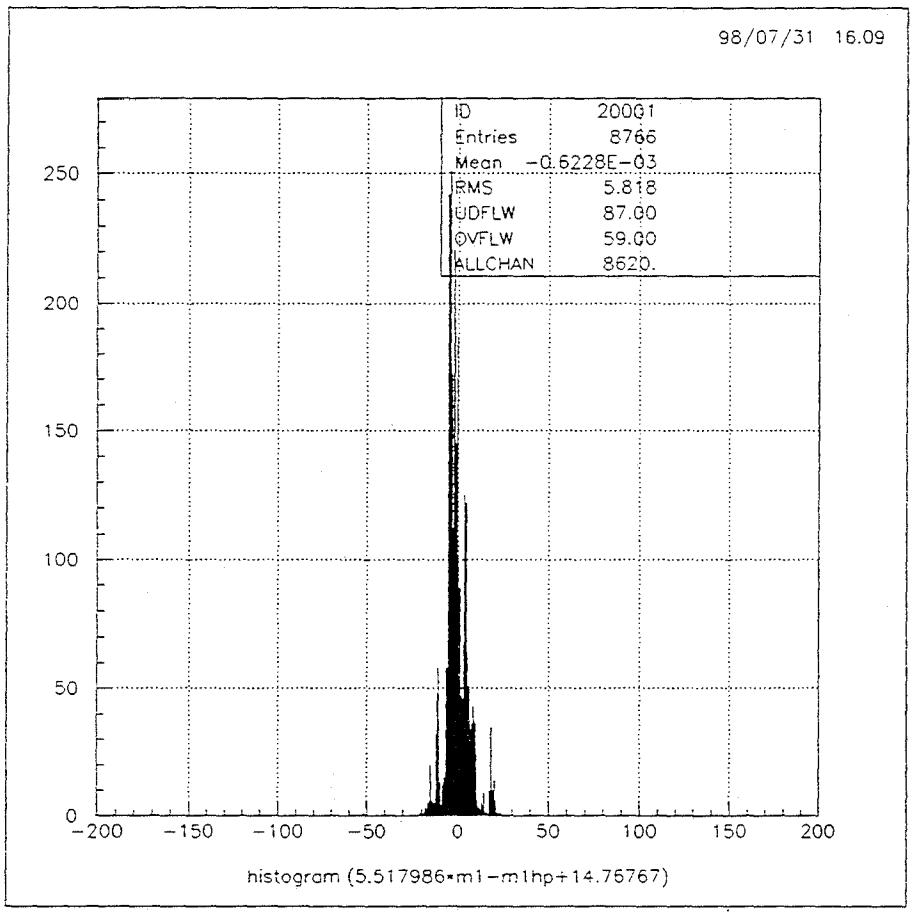


Figure 14: M1 Projection Distribution

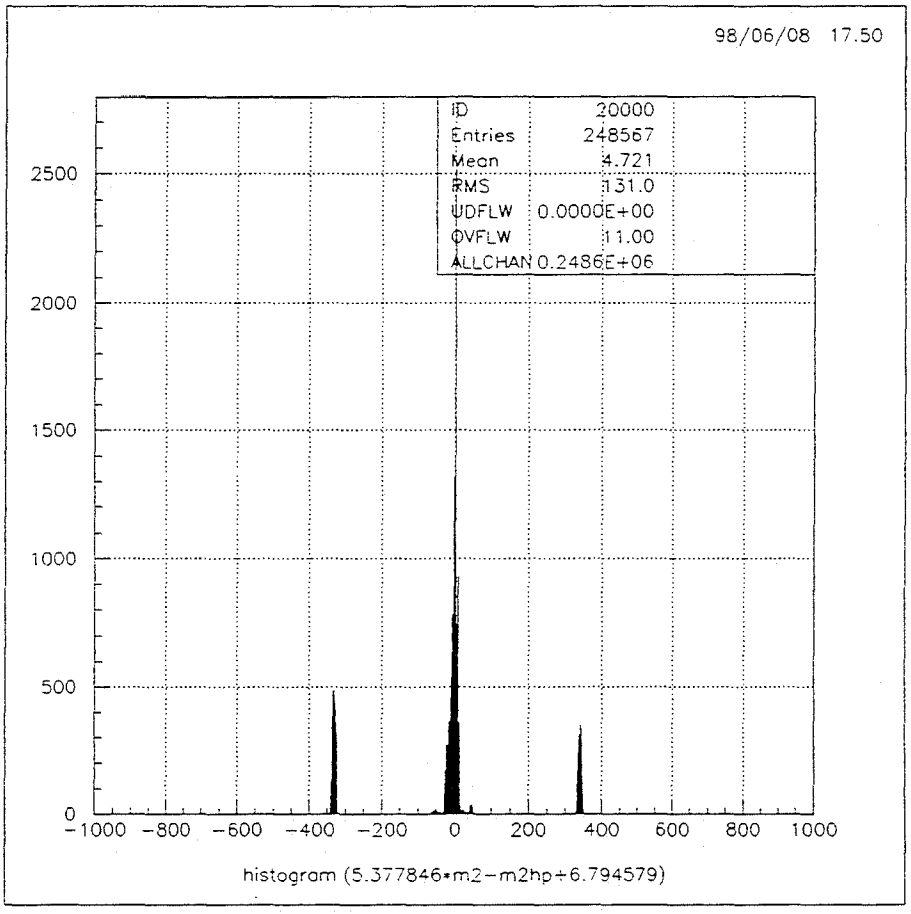


Figure 15: M2 Projection Distribution

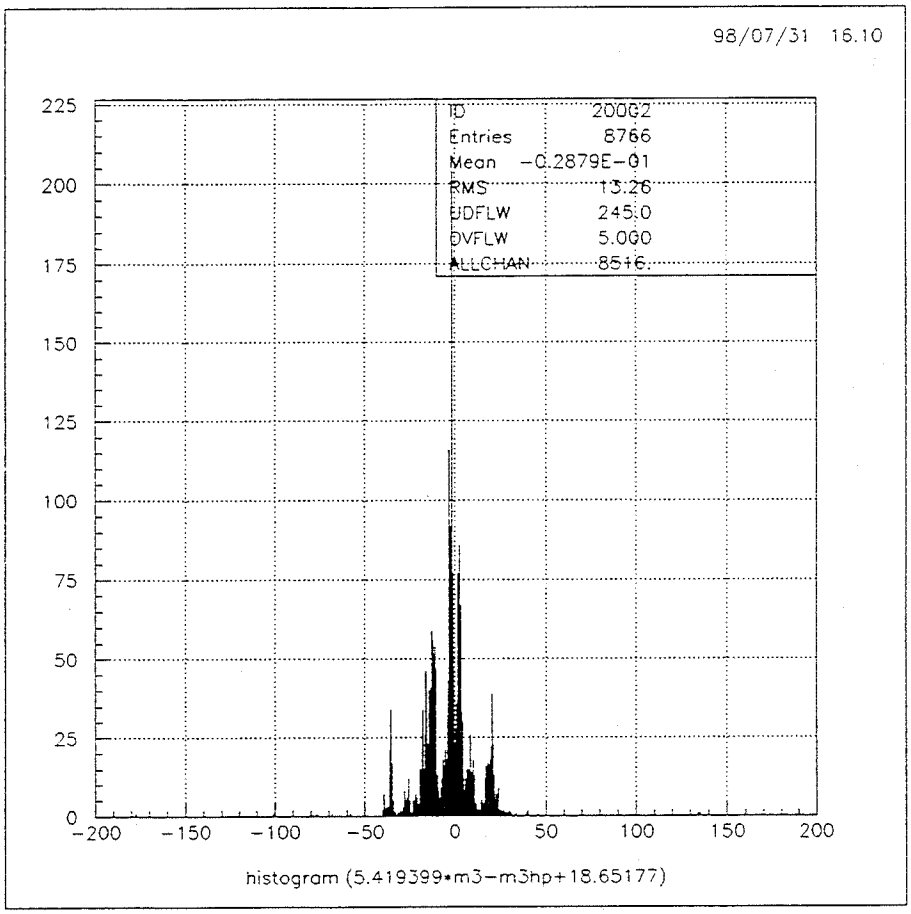


Figure 16: M3 Projection Distribution

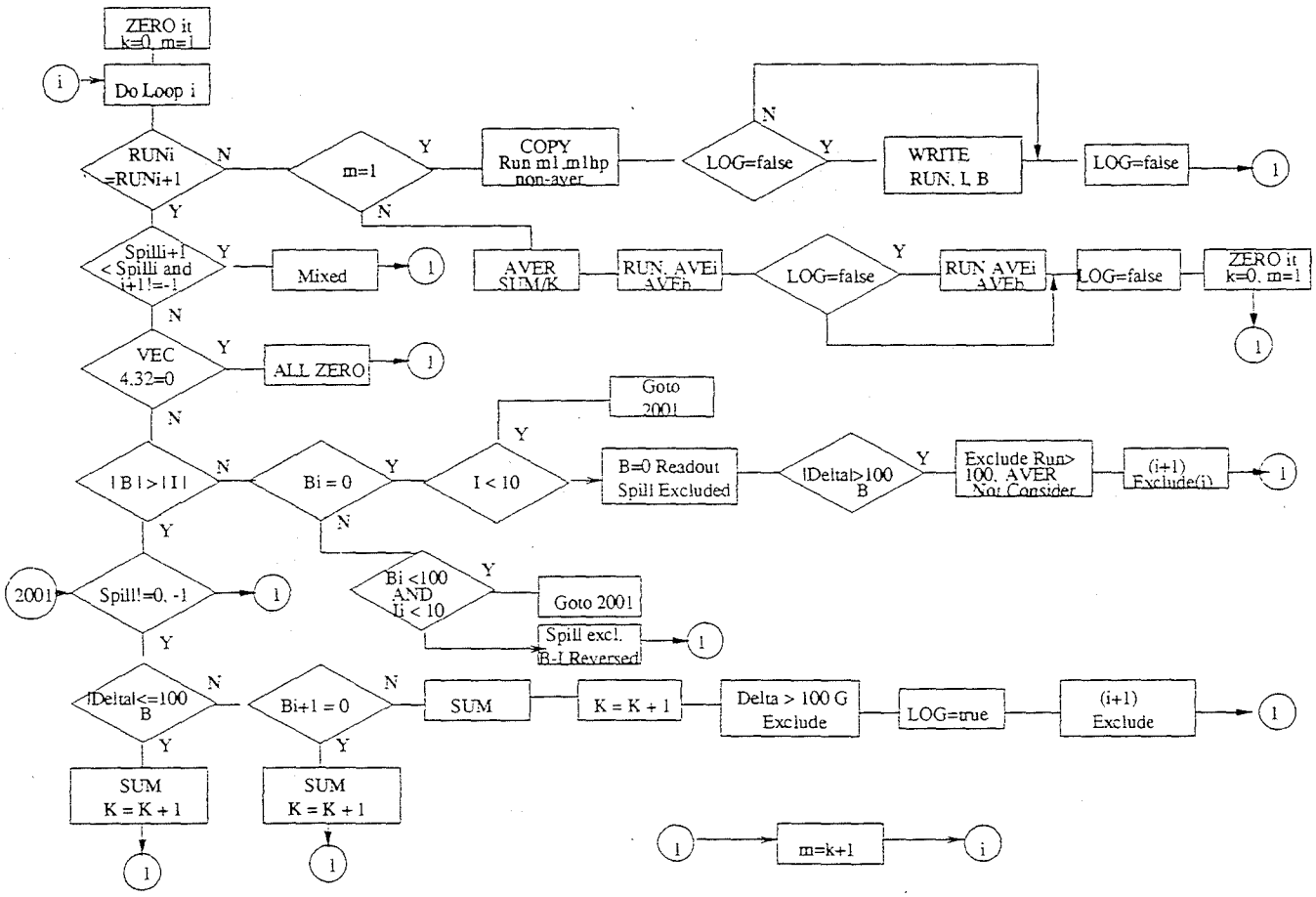


Figure 17: Algorithm – Flowchart of code for re-averaging over spills of a magnet's field and current.

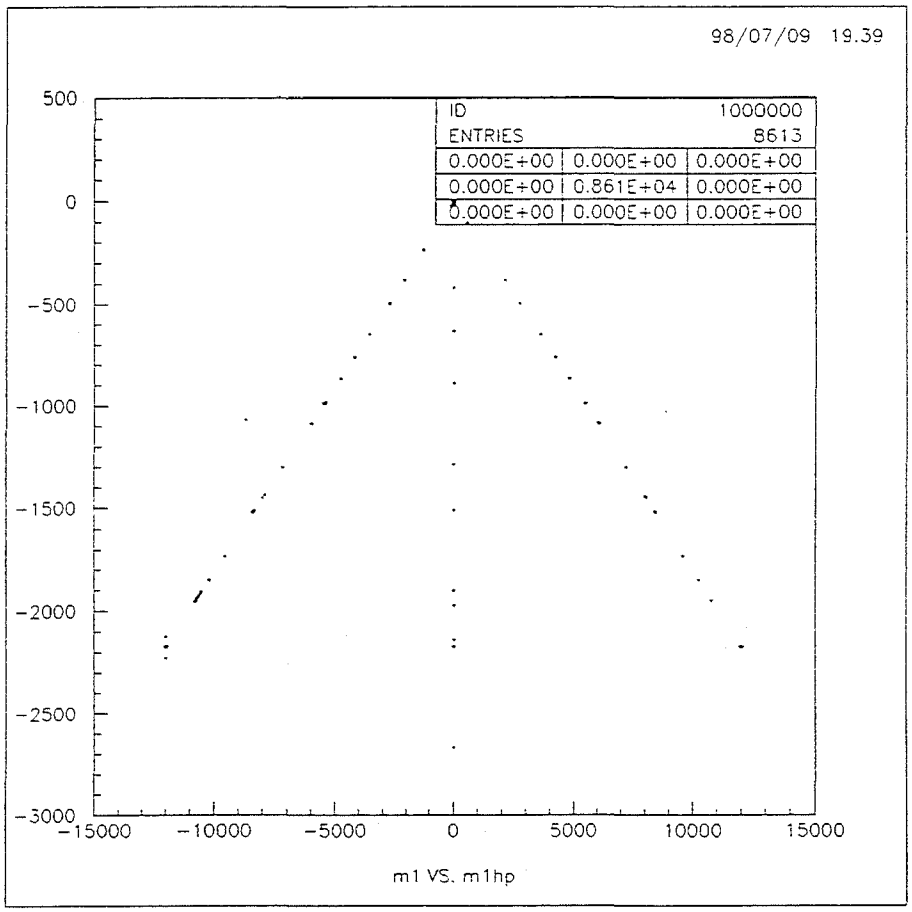


Figure 18: M1 vs M1hp

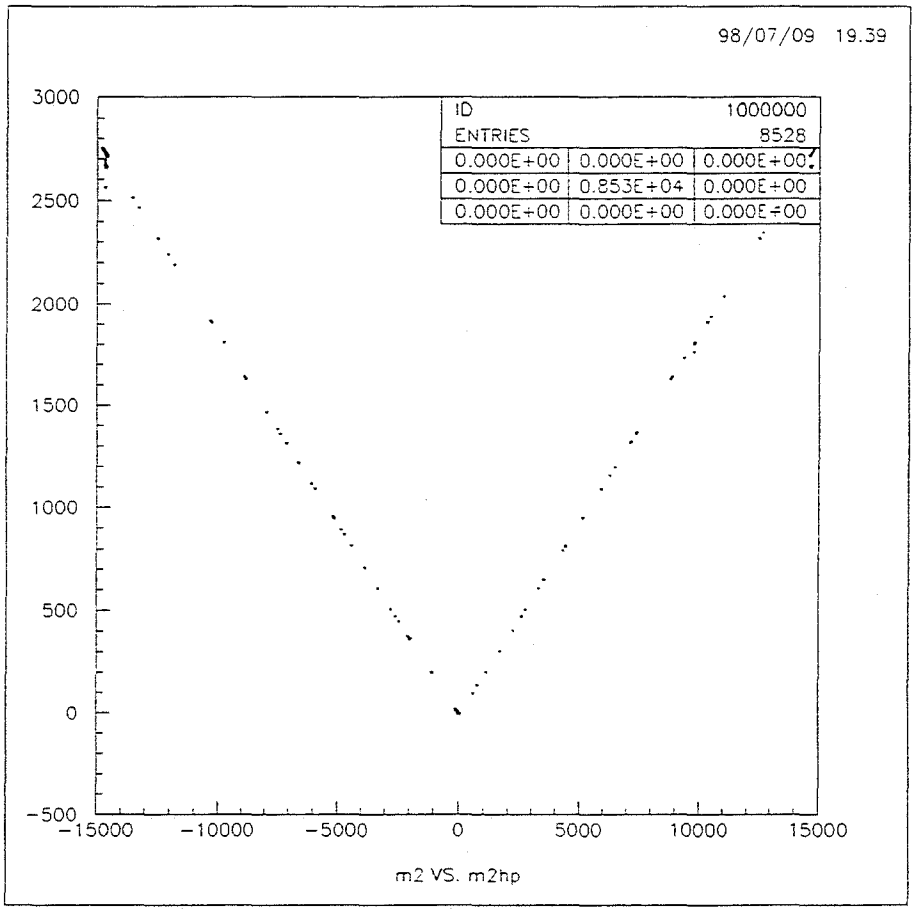


Figure 19: M2 vs M2hp

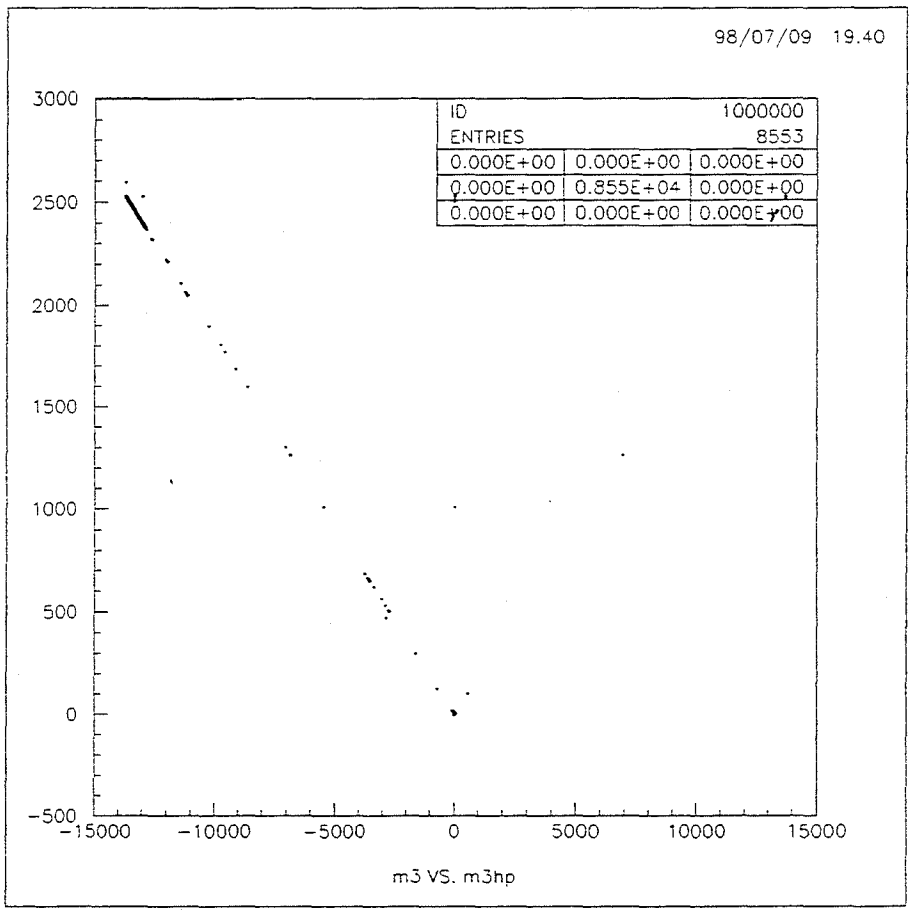


Figure 20: M3 vs M3hp

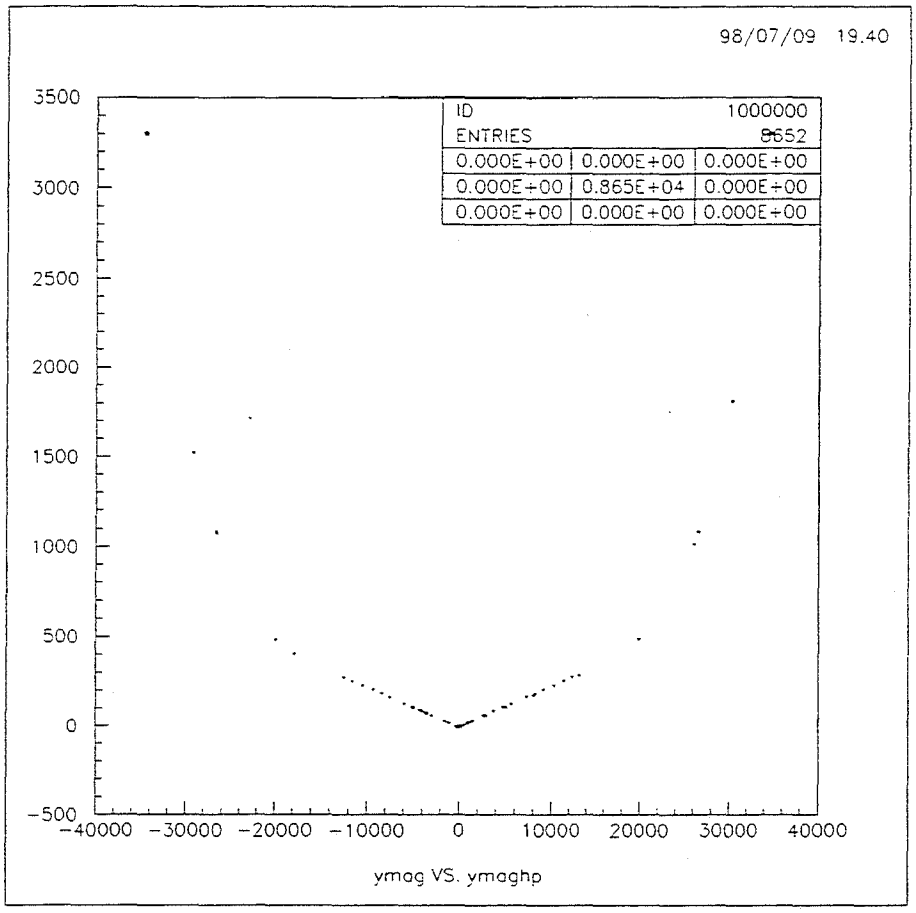


Figure 21: Ymag vs Ymaghp

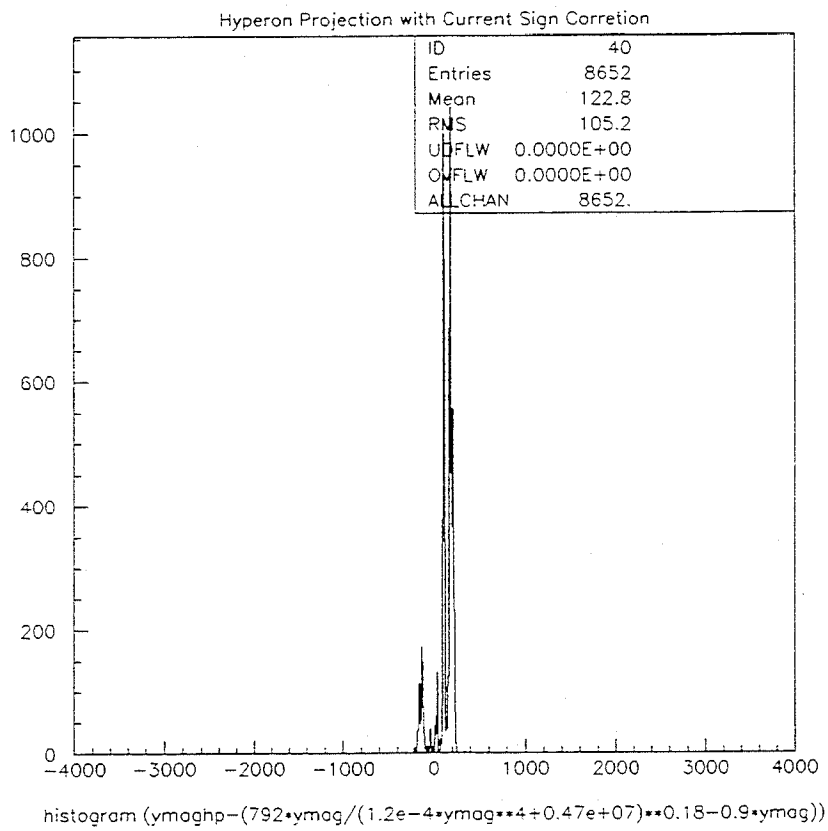


Figure 22: Hyperon Projection after Re-Averaging

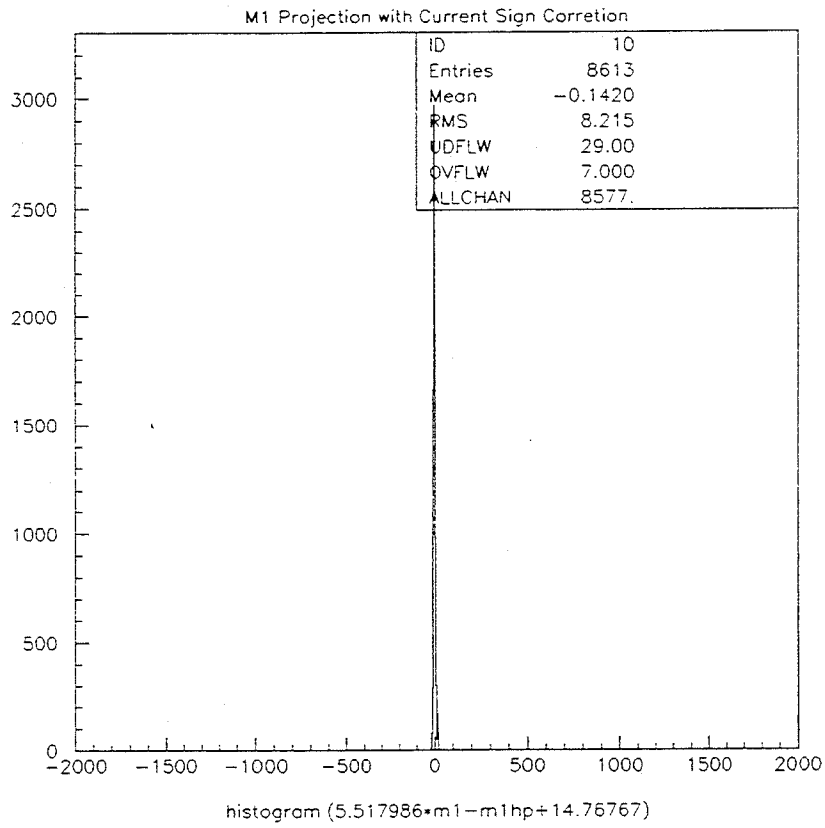


Figure 23: M1 Projection after Re-Averaging

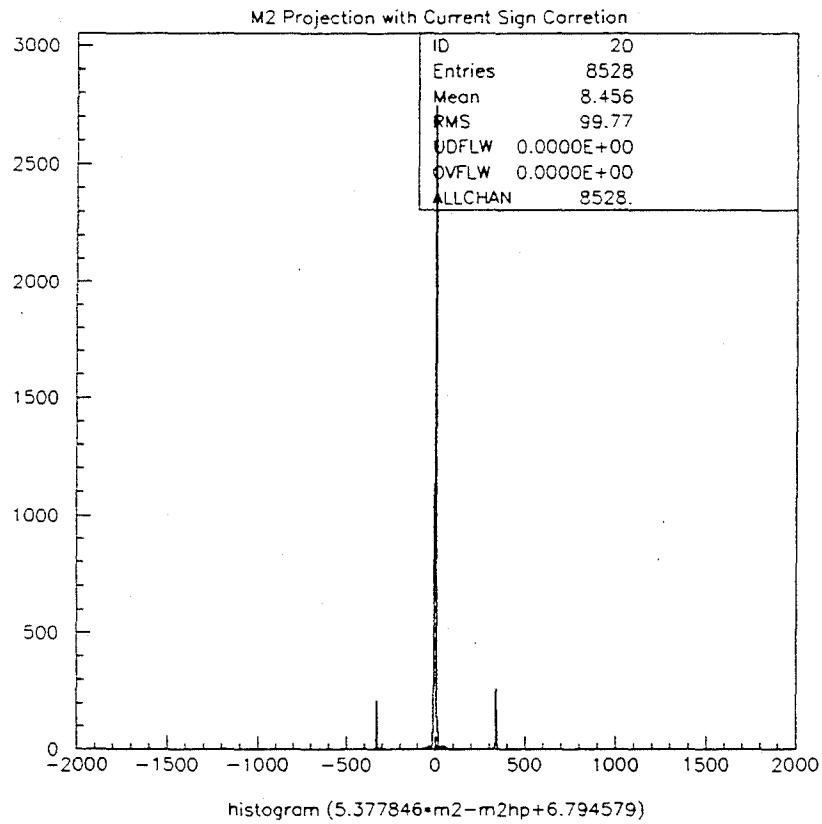


Figure 24: M2 Projection after Re-Averaging

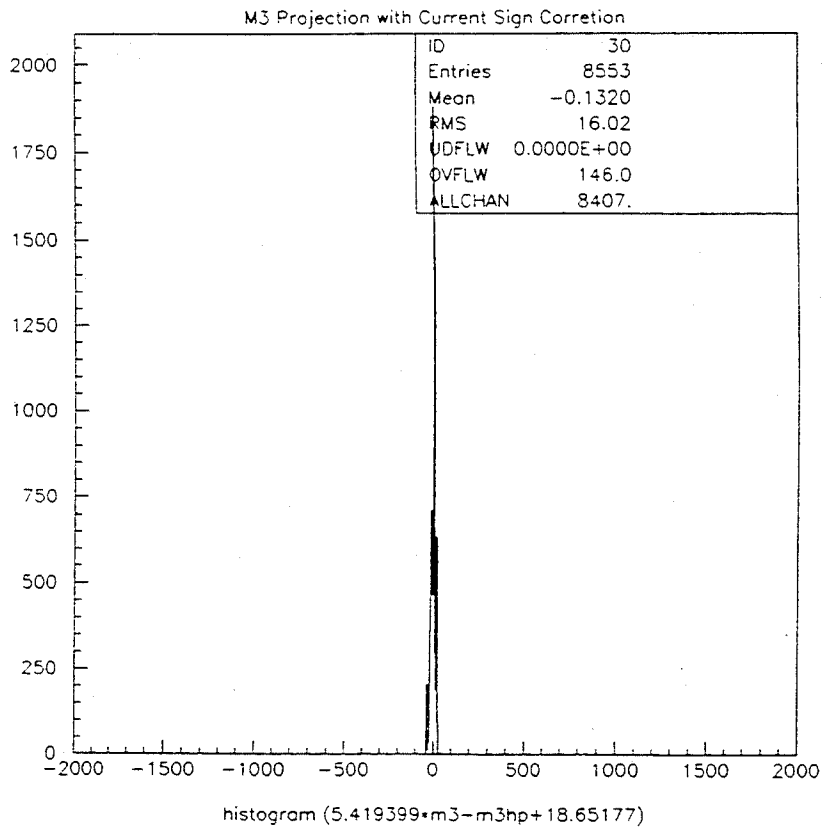


Figure 25: M3 Projection after Re-Averaging

CHAPTER 5

CONCLUSION

In this thesis, the problems related with the recorded magnetic field and current values are investigated and some procedures to deal with these problems are developed.

In using the recorded average field values, one can use the three-sigma selection procedure as explained in the previous chapter. However, this procedure does not handle those cases where there is a problem in the sign of the field value. Developing an additional procedure to correct the sign of the field value when it is known to be wrong will be the next step in our studies.

A second procedure is to recalculate the average field values by using the field data recorded for individual spills. In this reaveraging, those spills with obvious problems are not included in the calculation. With this procedure very clean results for the field values can be obtained. Any problem in the sign of the field is not corrected in this procedure.

Using the second procedure, new average field values have been calculated. These can be found in files located in fsgi02.

new_average_hyperon.ocs

new_average_m1.ocs

new_average_m2.ocs

new_average_m3.ocs.

These OCS tables are very important in the Selex E781 experiment for the offline analysis, tracking, etc...

It would be interesting to see the effect of these new field values in the final offline analysis, in the physics output of the experiment, for example, in reconstructing the Λ_c^+ trajectories and comparing the S/N ratio for the mass distribution.

Finally, a combination of these two methods would be more efficient in selecting the good runs.

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