Setting up and Operating the MICE beamline

September 2009

m.apollonio@imperial.ac.uk
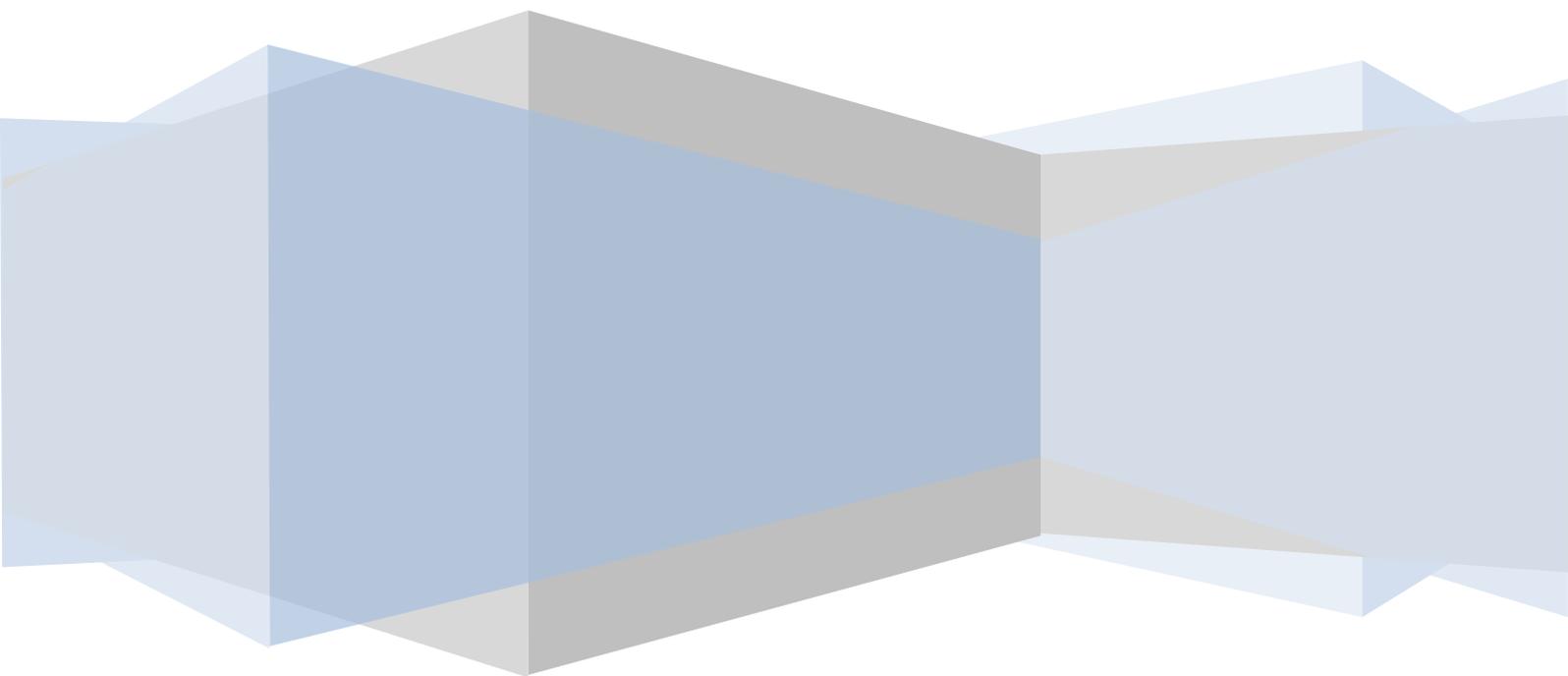
Introduction

The muons used in the MICE experiment are the result of a sequence of events starting from the impact of ISIS protons onto the MICE target, the transport of secondary pions trough the line into the Decay Solenoid, the capture and transport of muons towards the diffuser. This documents describes the operations needed to set up a beamline for several cases and purposes.

1   Beamline Elements

The MICE beamline comprises 11 conventional magnets and 1 superconducting solenoid. Their location along the beamline and main features are summarized in Tab. 1. A visualization of the beamline can be found on Fig. 1.

Table 1 location of magnets along the beamline and typical field strengths for a pi-mu configuration.

Element	Position	Effective Length	Quad Pole Tip Radius[1]	Vertical ½Aperture	Horizontal ½Aperture	Field Strengths	Units
	M	m	cm				
Drift Space	0.0			10	10		
Type 4 NIM Qd -Q1	2.5733	0.8534	10.15	10.15	10.15	1.16726	T/m
Drift Space	3.4267			10	10		
Type 4 NIM Qd -Q2	3.9733	0.8534	10.15	10.15	10.15	-1.45908	T/m
Drift Space	4.8267			10	10		
Type 4 NIM Qd -Q3	5.3733	0.8534	10.15	10.15	10.15	1.01574	T/m
Drift Space	6.2267			10	10		
Type 1 NIM Dipole - B1 (bend angle 60°)	7.4342	1.038		10	33	1.42772	T
Drift Space	8.5212			10	10		
Decay Solenoid	9.6647	5.0		6 (diamtr)	6 (diamtr)	4.21313	T
Drift Space	14.6647						
C2H4 Proton Absorber	15.0459			10	33		
Drift Space	15.0959						
Type 1 NIM Dipole - B2 (bend angle 30°)	15.2817	1.038		10	33	0.42933	T
Drift Space	16.3316						
Q35 Qd - Q4	17.3316	0.66	17.82	23.6	23.6	0.98966	T/m
Drift Space	17.9916						
Q35 Qd -Q5	18.4916	0.66	17.82	23.6	23.6	-1.32561	T/m
Drift Space	19.1516						
Q35 Qd - Q6	19.6516	0.66	17.82	23.6	23.6	0.87959	T/m

---

[1] The pole tip radius is the radial distance between the central axis of the quadrupole and its pole tip.

| Drift Space	20.3116						
TOF0	20.8116						
Drift Space	20.8624						
CKOV1	21.0624						
Drift Space	21.5674						
Q35 Qd - Q7	24.9637	0.66	17.82	23.6	23.6	0.88758	T/m
Drift Space	25.6237						
Q35 Qd - Q8	26.1237	0.66	17.82	23.6	23.6	-1.34275	T/m
Drift Space	26.7837						
Q35 Qd - Q9	27.2837	0.66	17.82	23.6	23.6	1.14749	T/m
Drift Space.	27.9437						
TOF1	28.8437						
Drift Space	28.8945						
Iron Shield	28.9691						
Drift Space	29.0691						
0.95cm Pb Diffuser				10	10		
End Coil 1.1 Begins Here	29.4748						
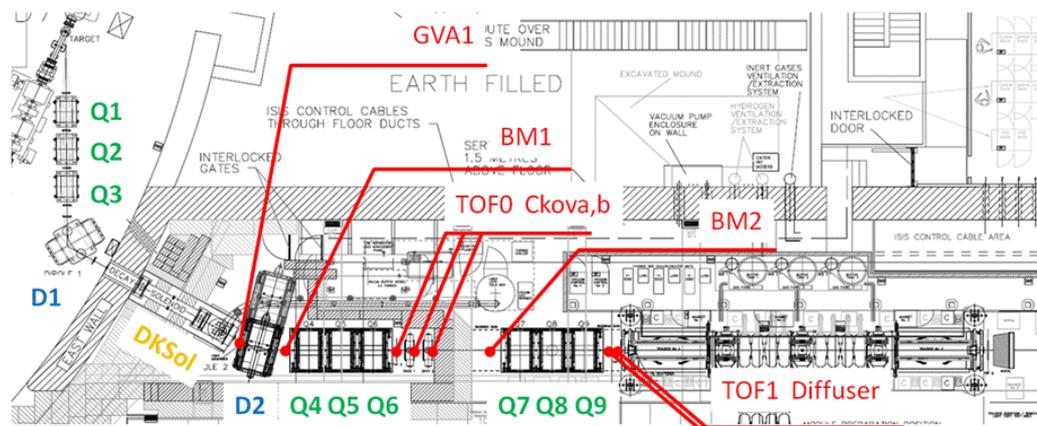
Figure 1 view of the MICE Beam Line as of September 2009.

1.1 UPSTREAM line

The US beamline is constituted by 3 quadrupoles Q1-2-3 and the first dipole D1 (bending angle 60 degrees). All these elements are located inside the ISIS vault which poses strong access limitations during Machine Physics and Users Run times. As far as the optics is concerned the Decay Solenoid (DKSol) can be also considered part of the

US line. In the Decay Solenoid pions generate the muons eventually transmitted in the second half of the beamline. D1 is used to select the momentum and bend the beam by 60 degrees towards the entrance of the Decay Solenoid.

1.2 DOWNSTREAM line

The DS line is formed by the dipole D2 (30 degrees bending angle) and the two triplets of quadrupoles Q4-5-6 and Q7-8-9. D2 is another momentum selector steering particles along the second half of the line. The quadrupoles are tuned to define a desired optics.

2 Optics

In the past a lot of time has been devoted to define the best optics for a beamline transporting pions-muons from the production point to the diffuser. This must be sufficiently flexible in order to cover all the possible combinations of emittance and momentum required by the MICE programme. Those studies led to the definition of a "central optics" for a momentum around 200 MeV/c (in the tracker) and an emittance of about 6 mm rad (past the diffuser).

From this starting configuration most of the optics can be derived simply by rescaling the current for each magnet according to the *local momentum* of the particle we want to transport. An excel spreadsheet combining specific energy loss for a particle species, magnet calibration and the reference optics is the tool used to define our first optics. A better tuning is left to more detailed simulations which are not dealt with in this document.

When on shift you will be probably using a **pre-defined optics** as published on http://mice.iit.edu/bl/Documentation/index_doc.html and choose one of the cases as pointed on Fig. 2.

In case you wish to define your optics from scratch follow the instructions in par. 2.1 / 2.2.

 http://mice.iit.edu/bl/Documentation/index_doc.html

You can chose now choose between two possibilities. A single particle beamline or a pi-mu beamline.

2.1   SINGLE PARTICLE BEAMLINE

-   Go to http://mice.iit.edu/bl/Documentation/index_doc.html
-   On *create your Beam Line* chose the particle you want to transport, say pions. Click on PION (ddmmyy). An excel sheets will open up showing something like Fig.3 (the page could be slightly different depending on the version, but the general content is the same).
-   Introduce an initial momentum in box B3; the table automatically evaluates the energy loss along the beamline and defines the currents of all the magnets for an

Figure 2 web page with general documentation showing in RED the pointers to some pre-defined beamline for the 5/6 September 2009 run. In GREEN the pointer to the tool to define a PION beamline. This page is subject to changes according to the incoming programme.

optics with and one without the Decay Solenoid. These currents are shown along two separate columns together with the fields or gradients for every magnet.

- Over-current indicators inform the operator that a given choice is incompatible with the maximal current for a given device.

- You can tune you line according to a desired value on D1 or at TOF0 or at the Diffuser US plane.

A user is meant to deal with the FRONT PAGE of this excel sheet. All the other pages are protected and can be read (but not written). In particular MAIN Sheet contains the material budget table of the beam line, MAGNET CONV TABLE (WITH/WITHOUT SOLENOID) contain the reference optics and conversions (current – field/gradient). If you need to modify a page use the *unprotect sheet* tool with password *beamline*.

Use this table to define a beamline for special studies, calibrations and in general whenever you need to focus on a single particle species.

Bear in mind that when defining e.g. a *pion* beamline you merely optimise your optics for pions, however you still have some acceptance for other species which varies depending on their momentum and specific energy loss.
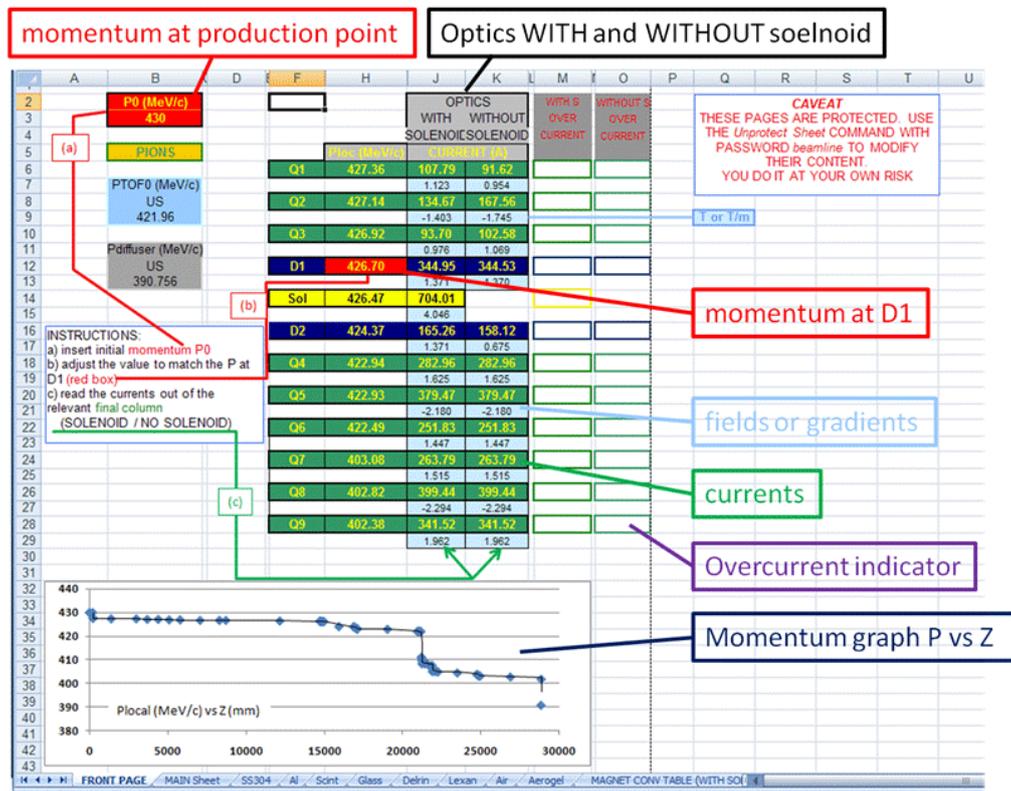

Figure 3 the Excel sheet FRONT PAGE for the definition of a PION optimized beamline.

2.2 PION-MUON BEAMLINE

(CAVEAT: you DO NOT NEED THIS TOOL until October 1st 2009)

This case in not conceptually different from the previous one, however the look of the table is different and some care is needed to define the beamline properly (Fig. 4).

- There are two entry points now:
- Enter P0 for the initial pion momentum at production point,
- Enter Psol, the muon momentum past the solenoid and upstream of GVA1.
- Read the output currents, fields/gradients, local momenta at TOF0-US and Diffuser-US.

Use this table to define a dual line with muon production.

Avoid using this table during special tests and calibrations where the single tables are more than sufficient for your goals.
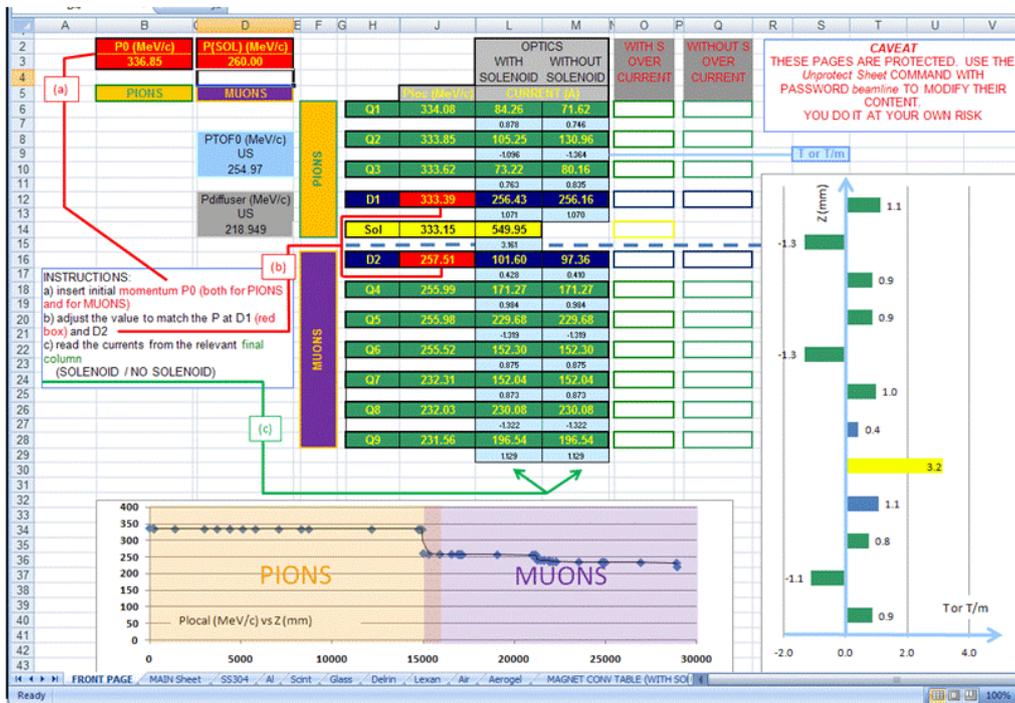

Figure 4 Excel sheet FRONT PAGE for the definition of a PION-MUON optimized beamline.

3 Operating the Magnets

Once the optics have been defined you are left with implementing it in the actual beamline. The thorough procedure to start up the magnets is described in the manual ***MICE Muon Beam: conventional magnet power supplies: operating instructions*** [1].

This paragraph will tell you what to do once the relevant PSU (Power Supply Unit) is on and set in **REM**ote mode.

- Go to the **miceoppc1** screen in the LCR
- start the **Application Launcher**. A little window appears with several choices.
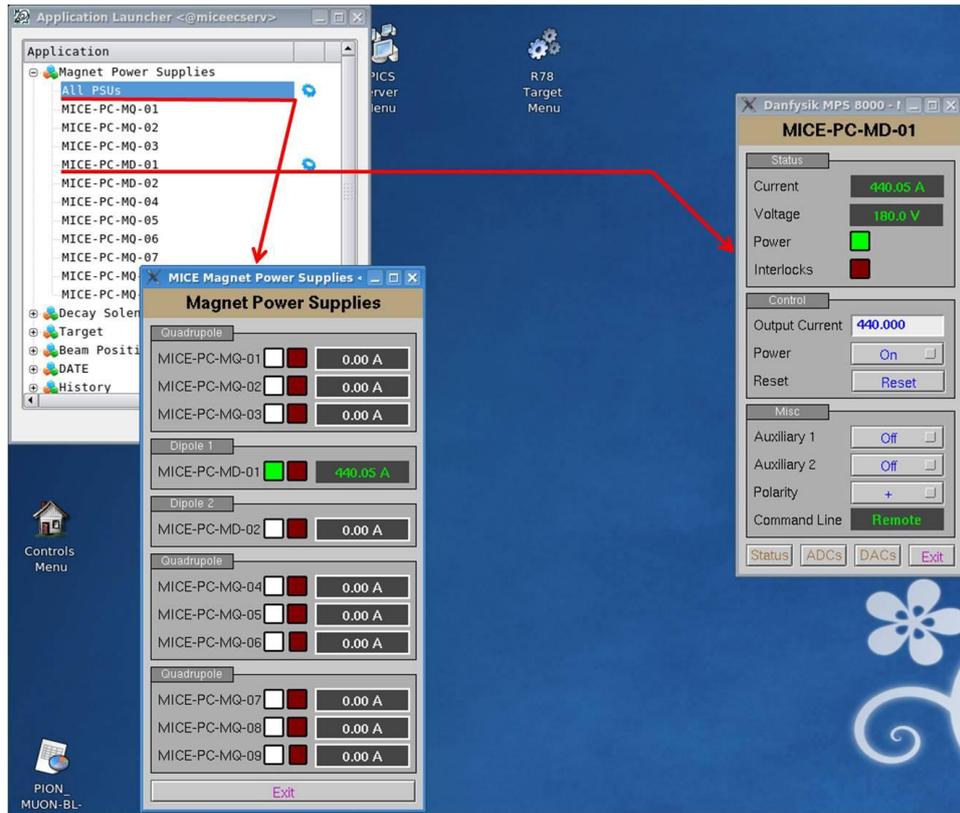- as an example click **All PSUs** and **MICE-PC-MD-01**

Figure 5 a screen shot from miceopipc1 machine in the MICE LCR showing the Application Launcher, the Power Supplies monitor and the Dipole1 (D1) control panel.

- Fig. 5 shows you get two extra panels:
  - the **Magnet Power Supplies** monitors all the PSUs telling us (in this case) that D1 is on (green LED) at a current of 440.05A.
  - on **MICE-PC-MD-01** a new panel appears which allows you to monitor (in closer detail) **D1** and also control it, provided that **REM**ote mode has been set in the relevant PSU. The MICE-PC-MD-01 panel shows the Current/Voltage Status of the magnet, whether is on (green LED), or interlocks are active (red LED).
  - To **change the current in D1**, type a new value in the **Control Output Current** white box and <enter>. The **Status Current** box should change until the desired value is reached.
  - Power can be set to ON/OFF using the proper button, however **it is recommended to ramp down to 0** the magnet at the end of a run session. REMEMBER: the ON/OFF switch set the PSU accordingly. At that point any

modification of the Control Current is followed by the system. For a detailed description of the Magnet Operation please refer to [1].

4   Ramp Up Procedure

It has been noticed in the recent August soak test that ramping up the magnets to high currents can introduce **instabilities** if the process is done too quickly. The chiller can fall in an unstable condition and the total current required to feeding all the line can have a sudden glitch before stabilising to the actual level. While waiting for an automatic control of the ramping (which needs some hardware intervention on the PSUs) **we need to rely on a manual procedure**. Please follow this procedure:

- Define an optics and the currents needed for each magnet
- Turn on all the **magnet control windows** you need (as described in par. 3)
- Verify no interlocks are present. If interlock is found follow [1] to clear it.
- Increase each magnet current in **steps of 25/50A** according to Tab. 2 (the philosophy is 25 A for magnets with a MAX Current of 200A, 50A for magnets with a MAX Current of 400 A)
- Wait **a minute** before any following increment
- Repeat until the defined value has been reached

Table 2 RAMP UP PROCEDURE for BEAMLINE CONVENTIONAL MAGNETS

Magnet	Step (A)		MAX Current (A)
Q1	25		200
Q2	25		200
Q3	25		200
D1		50	440
D2	25		200
Q4		50	400
Q5		50	400
Q6		50	400
Q7		50	400
Q8		50	400
Q9		50	400

5   Ramp Down Procedure

At the end of a run session:
- Follow the same steps as for the Ramp Up Procedure (par. 4) in reverse order.

- When magnets reach **0 current** turn them **Off.**

6   Beam Polarity

At the moment the MICE beamline is set to select positive particles (p,π+,μ+,e+ ...). In order to select negative species a hardware intervention is required which consists in a cable swap at the PSU units. For detailed information please refer to manual [1] and to MICE-note [2].

7   What if in trouble?

A typical problem is the occurrence of an Interlock. You can try and reset it in remote mode, however if the problem persists you will need to access the Hall and assess the nature of the fault at the PSU. Follow the procedure described in [1] to locate the Interlock on the PSU. Once cleared re-set the PSU in REMote mode and report interlock faults in the Logbook. In doubt discuss with MOM on action to be taken.

8   Contacts

Mice Operation Manager (MOM): MICE-OM@rl.ac.uk
Beam Line expert On Call (BLOC): (xxxxxxxxxx)
M.Apollonio: m.apollonio@imperial.ac.uk (07899717228)

9   References

[1] MICE Muon Beam: conventional magnet power supplies: operating instructions (in http://mice.iit.edu/bl/Documentation/MMB-conventional-magnet-power-suppliesinstructions-v2-2.pdf)
[2] MICE-Note 198 (http://mice.iit.edu/ and look in MICE-Notes)