First Observation of Normalised Emittance Reduction through Ionization Cooling

The MICE collaboration

Abstract paragraph 1.

Abstract paragraph 2.

1 Introduction

Author: Chris Rogers

Strategy - the aim of the paper is to show that MICE reduces normalised emittance and this is consistent with MC. In order to demonstrate this, we select 2016/04 1.2 and 2016/04 1.5 as the cooling channel settings to use (they are likely to have best cooling and 1.5 also supports Ao's IPAC paper). The analysis is intended to be a 'minimal' analysis, i.e. we get just enough to prove emittance reduction. We don't have to do all the fancy analyses yet, but we do have to be correct and rigorous.

1.1 Ionisation Cooling

Description of ionisation cooling and usual blah blah.

1.2 The Muon Ionisation Cooling Experiment

Description of the equipment (hardware perspective) i.e. detectors, magnets, etc.

1.3 Data Taken in 2016/04

During 2016/04, data was recorded for several settings.The cooling channel magnet set currents and the beam optical parameters assuming the paraxial approximation are listed in table 1. This note concerns analysis of two cooling channel settings '2016-04 1.2' and '2016-04 1.5'.

Beam data was taken with the two settings with beam momentum 140 MeV/c and three emittance settings. Additionally, data was taken with 170, 200 and 240 MeV/c data in order to measure the magnetic alignment of the cooling channel.

2 Cuts

Author: Chris Rogers

Here we describe how we selected a sample of events. E.g. PID cuts, momentum cuts, various good event cuts.

Nb: We have to discuss the cuts first because we need to exclude non-muon events from the plots, especially data quality type plots. Somehow there is a logical challenge because we need to explain the cuts before we have proved that the detectors (etc) work, so we have to invite the reader to believe that our detectors work and prove it in the next section...

May decide to go "lite" here, push this into section 01 and push more into section 05.

Table 1: Magnet parameters for 2016/04. Trim power supplies on SSU and SSD were not operational. Focus coils were powered in solenoid mode. Match coils on SSD were not powered.

Setting	2016/04 1.3	2016/04 1.2	2016/04 1.5	2016/04 2.3	2016/04 2.4
Start time	18/11 20:00	28/11 16:50	05/12 13:20	08/12 16:30	12/12 14:20
End time	23/11 14:10	05/12 11:00	08/12 14:10	12/12 11:20	14/12 03:20
Nominal FC $\beta_\perp$ [mm]					
Nominal momentum [MeV/c]	140	140	140	200	240
SSU Center Coil [A]	205.5	205.86	208.0	208.0	208.0
SSU Match Coil2 [A]	208.6	171.9	187.4	172.9	193.1
SSU Match Coil1 [A]	102.3	211.7	178.1	239.2	177.7
FC Coil [A]	41.5	57.9	55.2	56.2	78.8
SSD Center Coil [A]	205.5	205.86	208.0	208.0	208.0

3 Detectors

Author: Ed Overton

Note also that the downstream efficiency (TKD, TOF2) is much more important than the upstream efficiency; it may not make sense to make the distinction yet.

3.1 Tracker

Description of tracker and reconstruction (few words but mostly citation).

Proof that the field is understood within tracker region - Hall probes.

Proof that the resolution is understood - Kalman pulls and chi2.

Proof that the efficiency is understood (and good); probably something like number of 5 point, 4 point tracks and demonstration that this is consistent with expected noise/dead channels? Look at straight tracks data?

3.2 TOF

Description of the TOFs and reconstruction (few words but mostly citation).

Proof that the resolution is understood - e.g. plane 0 vs plane 1 for each TOF station.

Proof that the efficiency is understood - e.g. number of plane 0 hits vs number of plane 1 hits for each TOF station.

4 Other detectors

Do we want to pull the other detectors in?

5 Cooling Channel

Author: Chris Rogers

Description of magnets. Mostly citation.

Description of absorber. Mostly citation.

5.1 Magnets

Demonstrate stability of magnets over the operational period of the experiment - archiver and hall probes.

Demonstrate that we understand the magnetic channel; extrapolate tracks and show that they join up.

5.2 Absorbers

Demonstrate that we understand the absorbers? Show that mean, RMS of extrapolated tracks is consistent with models for energy loss/straggling and MCS.

6 Cuts

Author Rogers

Describe the sampling.

6.1 Good TOF0/TOF1 Cut

Reject events that don't get a clean signal in TOF0 and TOF1

6.2 Good TKU Cut

Reject events that don't get a clean signal in TKU.

6.3 Aperture Upstream Cut

Reject muons going through upstream apertures (e.g. diffuser)

6.4 PID Cut

Reject muons based on TOF01 vs tracker. Show that this is consistent with PID cuts in other detectors. May need a whole section to discuss PID (e.g. do we want to go into Ckov, EMR, "global PID"?), depending on how things go.

6.5 TKU momentum cut

Reject muons based on TKU momentum; this is to reduce chromatic aberration.

6.6 Aperture cut

Depending on what plots go into the "Results" section, we may want to make an aperture cut based on projected TKU tracks.

7 Results

Author Rogers

Describe the results.

7.1 Optics

Demonstrate that the optics is consistent with expectation i.e. projected beam upstream looks like measured beam downstream (beta functions?)

7.2 Emittance

Demonstrate that the emittance is consistent with expectation.

Show amplitude distribution upstream vs amplitude downstream.

8 Uncertainties

Discuss how we deal with various uncertainties. I imagine two classes of uncertainty: (i) those that affect the measurement; (ii) those that affect the model.

8.1 Measurement Uncertainties

author: Rogers

The actual resolutions/etc have been introduced in the detectors section - so the job here is to make statistical/MC arguments about how they tie in to the data. E.g. how does TKD inefficiency affect emittance calculation?

- Detector resolution
- Detector noise and efficiency
- Magnetic field in reconstruction region

8.2 Model Uncertainties

author: Liu

We measure a given emittance change and try to tie it into a model. The model can be wrong because e.g. the fields were wrong, the absorber was wrong, etc. We have following sources of uncertainty:

- Field uncertainty (alignment, current, etc)
- Absorber uncertainty (thickness, density, etc)
- Other material budget
- Not sure, maybe if we are projecting upstream tracks we should include the uncertainty on the upstream measurement? This is a bit circular...

9 Conclusions

Author: Rogers

blah blah.

References

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