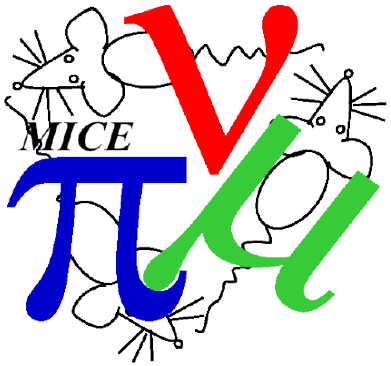
MICE Analysis Status and Plans



C. Rogers,
ASTeC Intense Beams Group
Rutherford Appleton Laboratory

ASTeC

Status

- 2015 data taking so far
  - Detector alignment
  - Magnet alignment
  - First look at PID
- Plans
  - Implications of SSD without Match coil 1
  - Updated run plan
- In this session:
  - “Tracker Alignment, Efficiency and Resolution” - Chris Hunt
  - “Demonstration of Ionisation Cooling Update” - J Pasternak

Outline Data Plan

- Commission hardware
- Beam-based alignment of detectors with field off
- Beam-based alignment of magnets with field on
  - Power one module at a time, then all magnets
- Check beam quality through the lattice
- Optics and momentum scans with/without absorber

- First pass analysis should follow data ASAP
- At least two analyses for every (major) measurement

2015 physics data

March 28th – 29th	Ckov momentum scan
April 19th-20th	Beamline studies
April 26th-27th	Beamline studies
June 2nd	Beamline studies
June 19th-27th	Detector alignment (no field)
July 3rd – 4th	Detector alignment (no field)
July 22nd – 23rd	SSD at 1.5 T
September 21st – 22nd	SSU at 1.5 T
September 25th – 29th	Ckov momentum scan
	Magnetic field remnant study
	Beam polarisation measurement
October 7th	4 T in SSU
October 14th	TOF0 alignment

Summary of Data Analysis

Measurement	Coordinator	Principle of Measurement	Laptop Studies	Batch MC & Analysis	Final Run Settings	Data Taking	First Analysis & Data Checks	Final Analysis	Write up
				Step IV					
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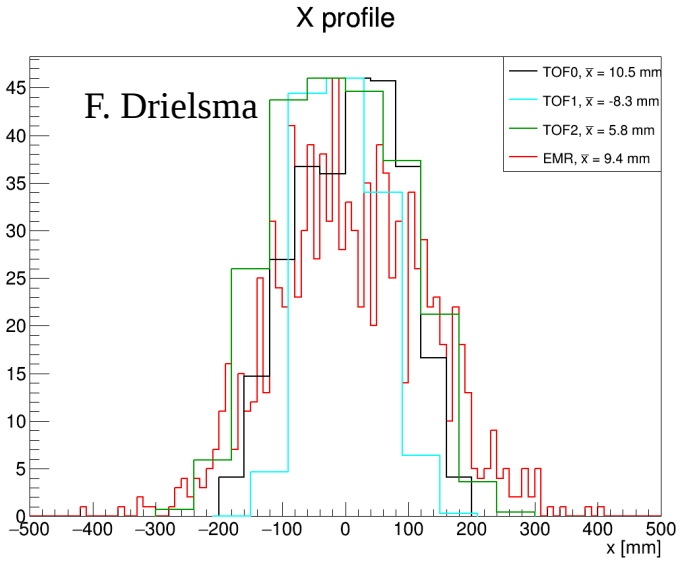
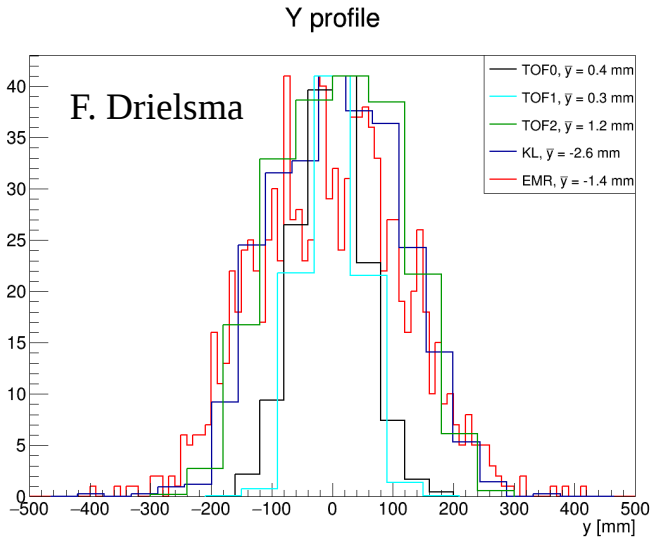
Beamline commissioning

- Upstream
  - Only TOF0 was powered during beamline commissioning
  - Beam distributions look identical at TOF0 independent of Q123 currents
  - Only rate is changed
    - Existing settings appear optimal
- Downstream
  - Some studies made with TOF0 and TOF1 only
    - Optimisation for field off running
  - First pass analysis indicates not much improvement
  - Detailed analysis is ongoing
    - Reviving/refitting TOF tracks analysis
  - Further commissioning requires tracker in field

PID Detector alignment (1)

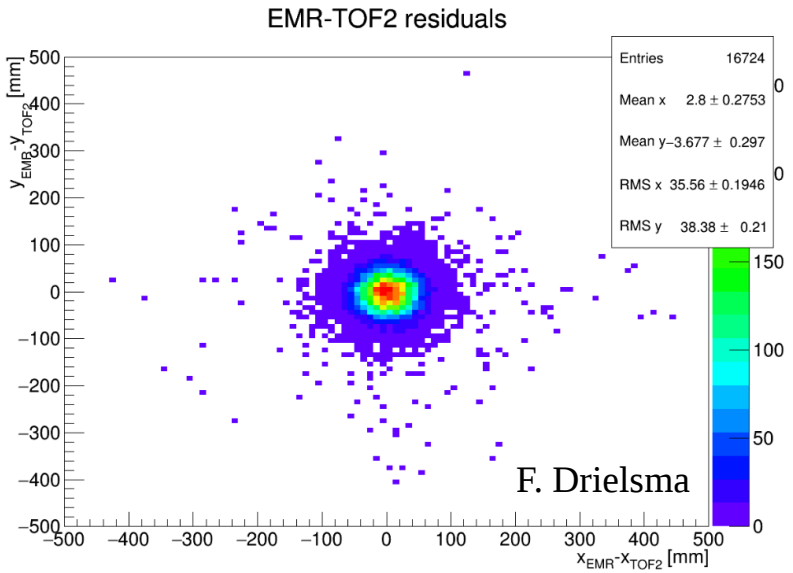
- Beam centroid
  - Look at evolution of beam centroid
  - Compare with surveyed positions
  - Consistent with survey

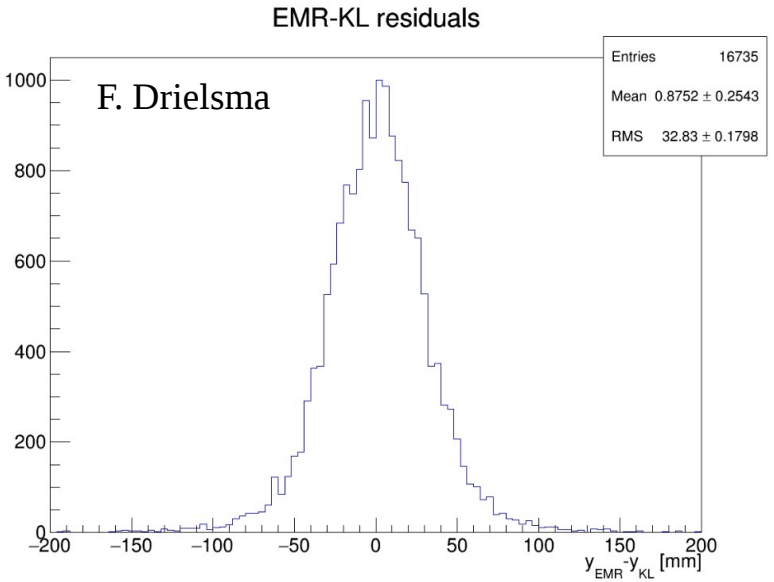




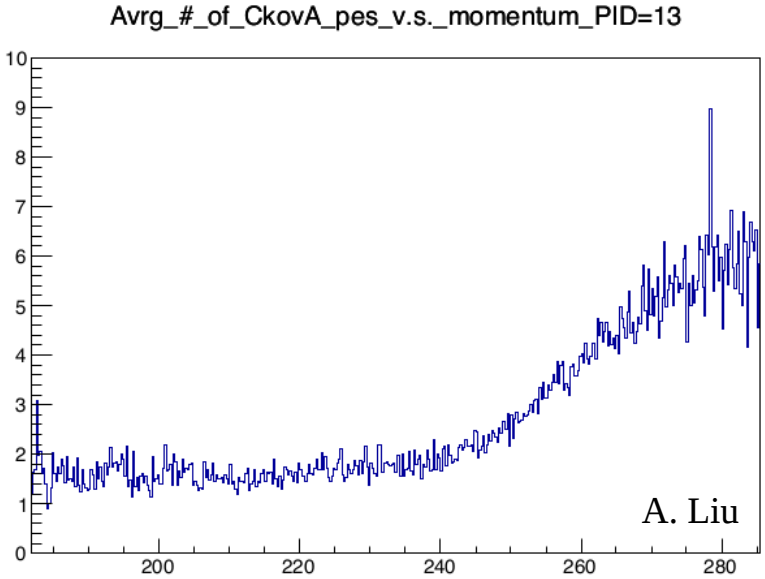
PID Detector alignment (2)

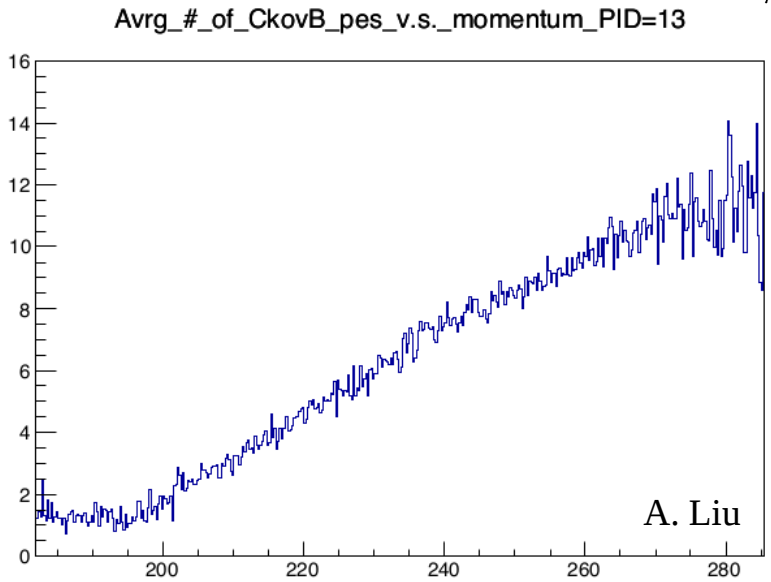
- Minimise residuals
  - Extrapolate tracks from tracker outwards
    - Blocked by MAUS geometry issues
  - Extrapolate tracks from EMR backwards
- Noted issue in KL extrapolation
  - Z position of KL is incorrect OR
  - Spacing of KL reconstructed hits is incorrect
- Noted issue in extrapolation of tracker tracks
  - MAUS geometry issue





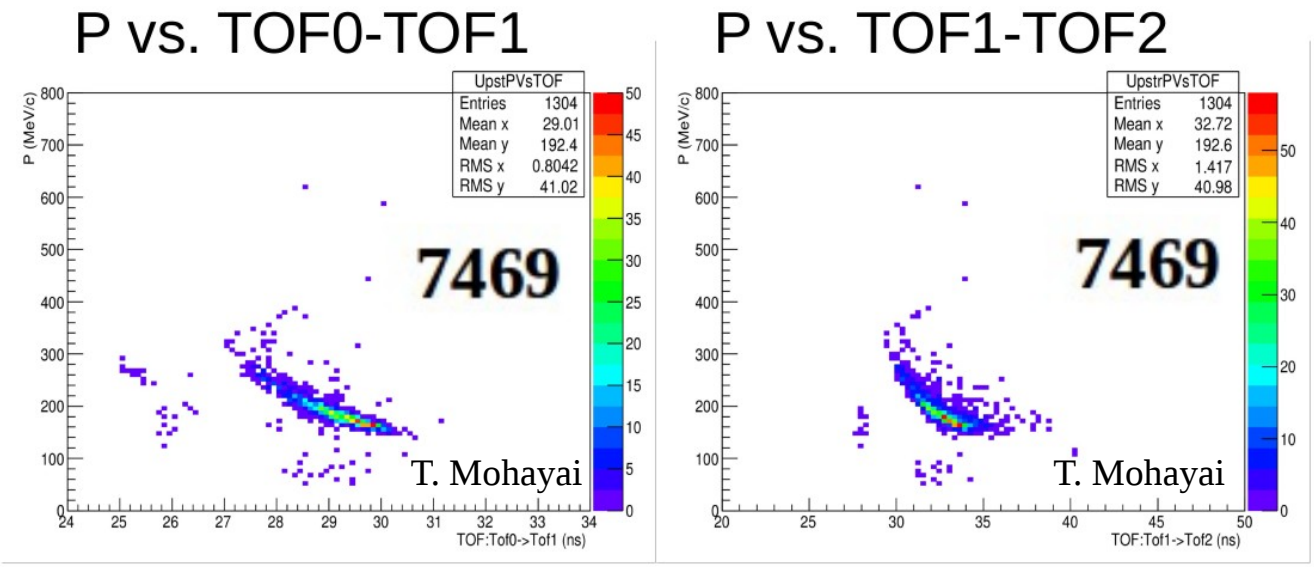
Cerenkov Light Threshold





- Calculate turn on curve for CkovA and B for muon and pion samples
  - For data taken in September
  - Compare with historical data in note 473
- Observe significant discrepancy, as seen in spring 2015
- Three analyses, three analysers, three MAUS versions
- Need (Step I and Step IV) data reprocessing

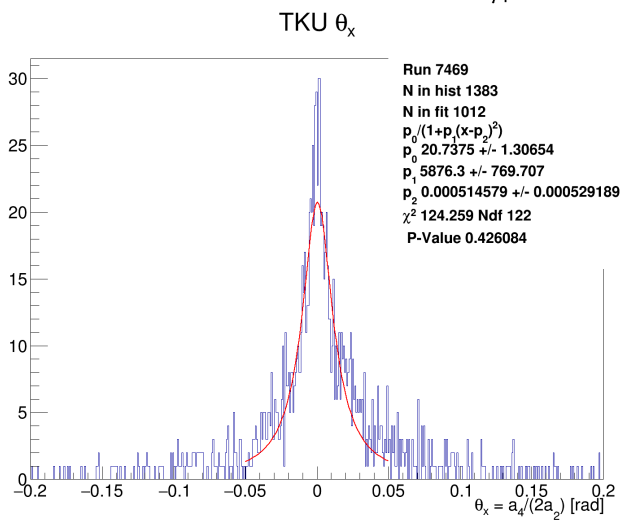
PID Measurement

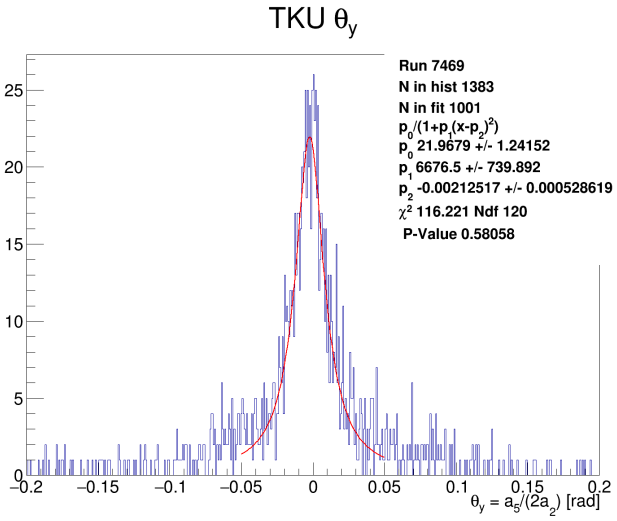


- Examine data and MC plots
- Look at distributions
- Define muon-like regions of parameter space
- Reject other regions

Magnet alignment to tracker

- Cycloid fit
  - Particles make tilted helix if tracker and solenoid are misaligned
  - Generates a cycloid assuming perfect solenoid and no energy loss
  - Look at tilt of cycloids particle by particle
  - Systematic error due to handedness of helix
- Kalman fit analysis to follow

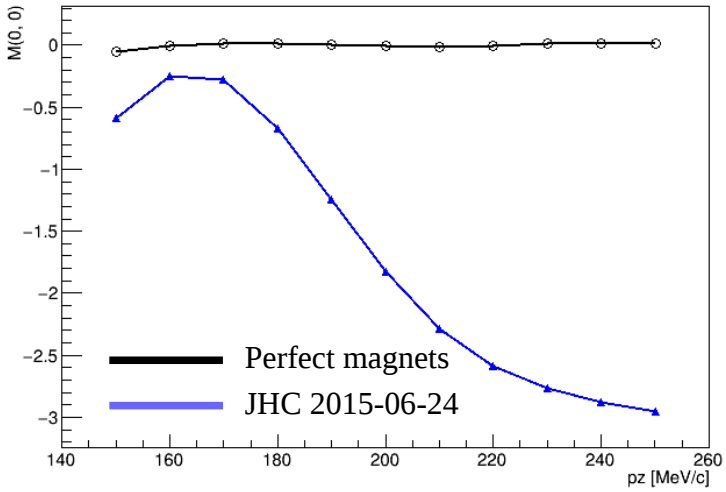




General magnet alignment

- Transfer Matrix
  - Calculate transfer matrix
  - Relies on good track recon
  - Useful algorithm for accelerator side
  - Analysis on pure MC looks okay
  - Now looking at data
    - Track reconstruction causing problems

Position of beam at TKD, perfectly aligned in TKU
(M_{00} element of transfer matrix)



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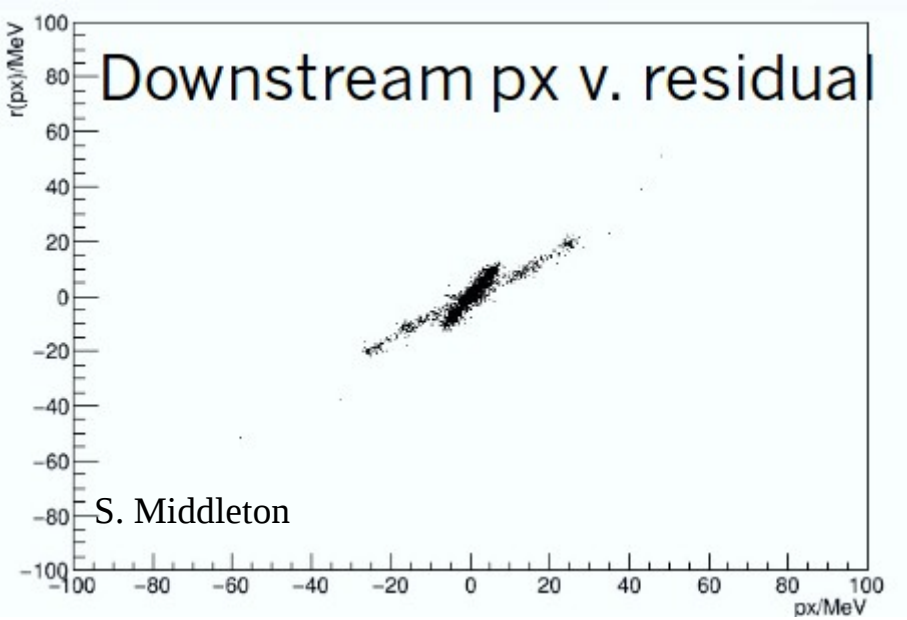
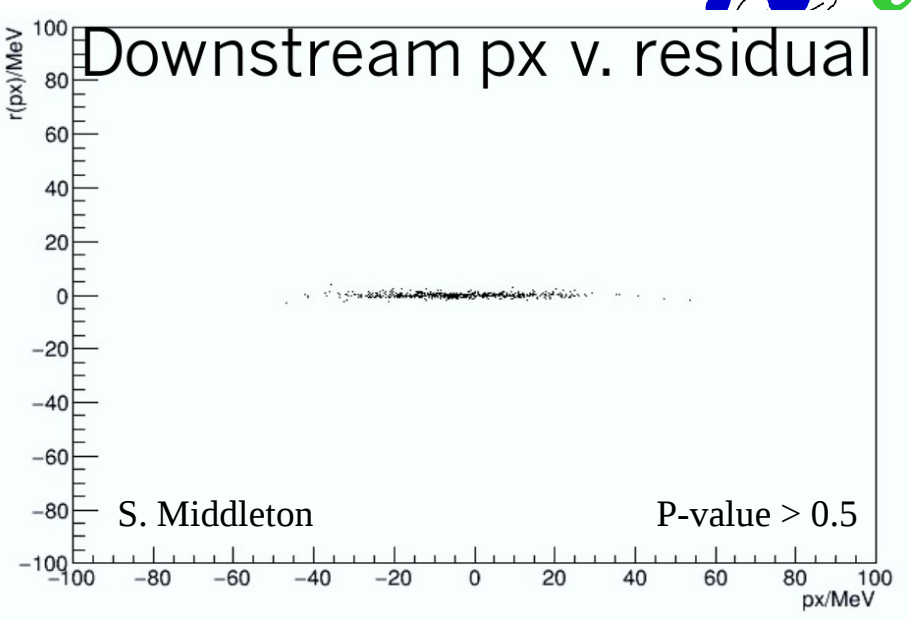




- Transfer Matrix
  - Calculate transfer matrix
  - Relies on good track recon
  - Useful algorithm for accelerator side
  - Analysis on pure MC looks okay
  - Now looking at data
    - Track reconstruction issues
    - P-Value cut improves things; but insufficient tracks

Material Physics

- Multiple Coulomb Scattering
  - Field off approach gets worse statistics but better resolution
  - Field on approach gets better statistics but worse resolution
  - Measuring a distribution width – so statistical detector errors make systematic measurement errors
    - Measurement error depends on unfolding detector resolution
  - No field-off running in the current run plan
    - Estimate 5 days of running with each material + empty absorber
- Energy loss
  - Combined track fit with all detectors, minimising residuals and allowing energy loss in the absorber
  - Track fit upstream; track fit downstream; look at difference in energy
  - Resolution is around width of energy straggling distribution
  - No existing measurement in the literature for muons around 200 MeV/c

Step I Papers

- Pion contamination paper
  - Final round of comments received from collaboration
  - Author list finalised
  - Final edits going in before submitting to journal
- EMR paper
  - Submitted to arxiv

Analysis Machinery

- Measurement coordinator for each measurement
  - Experimental settings
  - Data Analysis
- Physics shifter responsible for first data validation
  - Supported by physics devil software tool
- Physics shifter role largely successful
  - Better support by measurement coordinator helps
- Physics devil tool in process of upgrade (S. Wilbur)
  - Better integration with reconstruction software
  - Will provide all “online” recon plots, but running against “offline” recon data

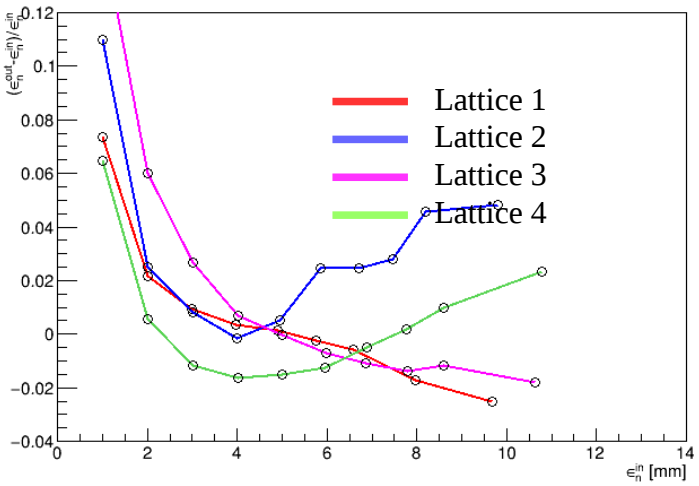
Blockers

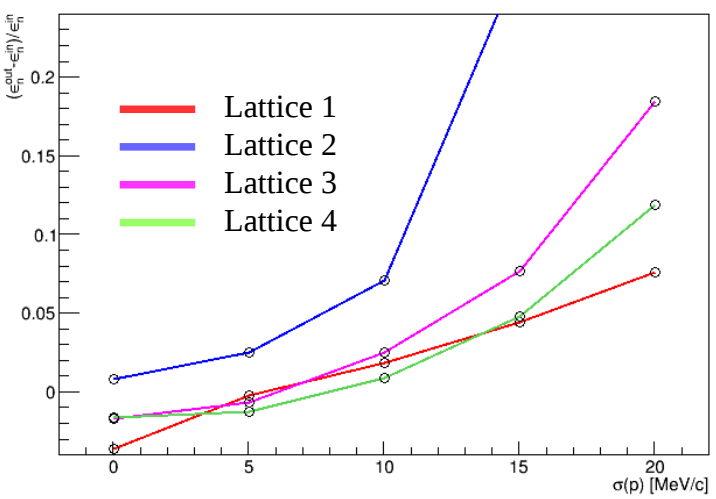
- Issues which are blocking analysis
  - Tracker reconstruction
  - Geometry
  - “Global” track extrapolation through fields
- Then data reprocessing to follow

M1/SSD

- Match coil 1 in SSD failed about a month ago
- Material physics measurements are largely unaffected
  - May be some detriment in rate
- Reduction in normalised emittance measurement needs study
- Indirect measurement should be possible
  - Project tracks to the absorber from upstream and downstream
  - Study emittance change
- Direct measurement is desirable
  - Measure emittance at the upstream and downstream tracker
  - Study emittance change
- To maintain direct measurement, seek revised optics
  - Means loosening “matching” constraints
- Details in MICE Note 475

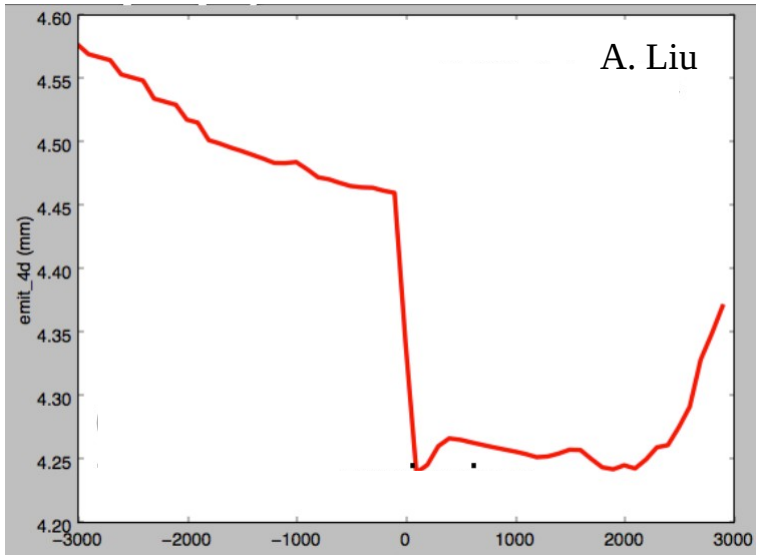
M1/SSD – Tracking (optics optimisation)





- Consider 4 lattices
  - Lattice 1 – B_z 1.2 T in solenoids, fields asymmetric
  - Lattice 2 - fields symmetric, beta not constant in solenoids
  - Lattice 3 - fields symmetric, beta not constant in solenoids
  - Lattice 4 - fields asymmetric, beta not constant in solenoids
- Some cooling
  - But reduced performance due to non-linearities
  - Non-linear match may recover baseline performance
  - Lattice 4 has M2 US 0; M1 US 277.53

M1/SSD – Tracking (tracking optimisation)

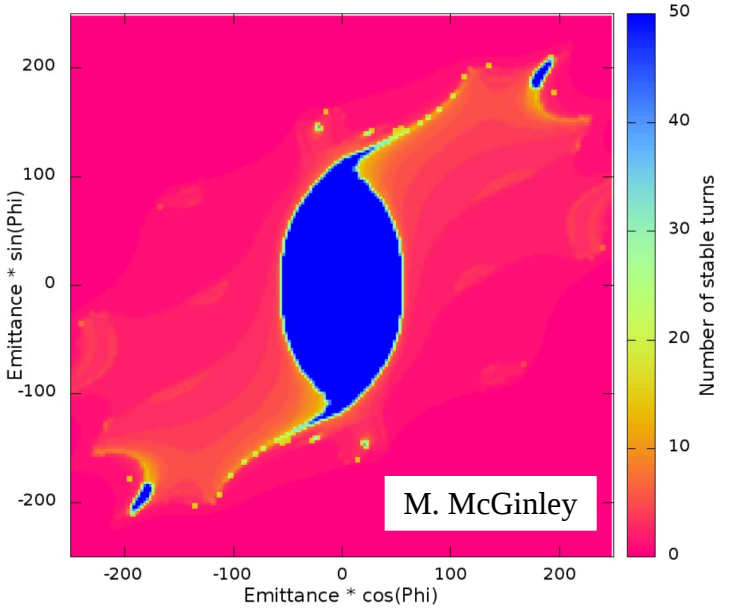


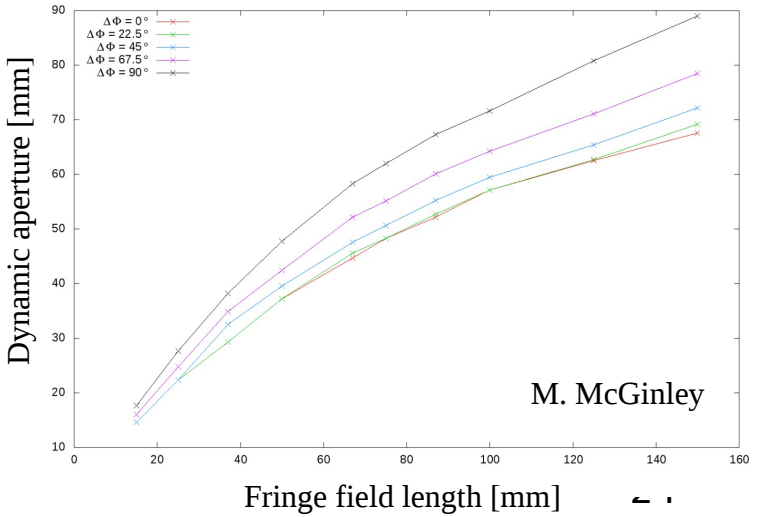
- 200 MeV/c
- 6 mm emittance
- ~ 3.5 T in trackers
- Asymmetric focus coils
- **75.5 % transmission**
- **5-6 % emittance change**

- Consider 4 lattices
  - Lattice 5 – B_z <= 4 T in solenoids, fields asymmetric, Beta constant in SSU but beta beating in SSD
- Better cooling, reduced transmission (maybe)
  - Rogers has not done transmission analysis properly
  - Rogers optimises emittance change from TKU Station 1 to TKD Station 1
  - Liu optimises emittance/transmission from TKU Station 5 to TOF2

Dynamic Aperture

- Non-linear emittance growth is a thing
- What is the cause?
  - Can we give optics folks a clue as to how their lattice should be optimised?
- Look at dynamic aperture
  - 3rd order symplectic transfer map
  - Repeating single magnet lattice
  - Look at dynamic aperture over many cells





Run plan

- November 2014 run plan assumed 3 physics run periods
  - 2015/03, 2015/04, 2016/01
- Now assume magnet commissioning extends to 2015/03
- Parameter space of beta, emittance, momentum
- Previously made a grid in parameter space
  - 3 emittances * 3 beta * 3 momenta = 27 settings
- Now we make a cross shape in parameter space
  - 5 emittances + 5 beta + 5 momenta = 15 settings
    - Pending optics without M1 in SSD
  - Reduced solenoid mode for lH_2
    - No momentum scan or emittance scan in solenoid mode
    - This is done in flip mode
- Enables better understanding of the trends (more points)
- Extrapolate to get to parameter space corners
  - Material physics is only “new physics”
  - Optics is specific to MICE Step IV

December Running

- Aim to
  - Demonstrate high precision measurement of emittance
  - Demonstrate dE/dx and scattering measurement
- Require
  - Trackers, TOFs, SSU+SSD ECE, something in the absorber
- Data taking plan
  - 2 mock data runs
  - Fill absorber
  - 1 day field off running @ 200 MeV/c
  - Field on running, momentum scan
  - Empty absorber
  - Field on running, momentum scan
  - Ramp down
  - 1 day field off running @ 200 MeV/c
- A bit more detail here
  - http://micewww.pp.rl.ac.uk/documents/161
- Not confirmed – shift organisation/etc needs to start now

December Running (no SS)

- Aim to make scattering measurement with straight track data
- Require
  - Trackers, TOFs, something in the absorber
- Data taking plan
  - 2 mock data runs
  - Fill absorber
  - ~ few days field off running (TBC)
  - Empty absorber
  - ~ few days field off running (TBC)

Physics Workshop

- Optics review
  - Tuesday 8th December – 10th December
  - See Ken Long slides
- Consider analysis workshop around that time also
  - Discuss the things we don't want to show the review committee
  - Alternative is follow up to December running in mid-January

Final Thoughts

- Step I papers are being pushed to the journals imminently
- Analysis has followed the data taking reasonably well
  - First pass analyses are keeping up with data taking
  - Final analyses/MICE notes pending in a number of areas
- M1/SSD issue – we have options
- Ramping on “writing up” - notes and papers
  - Step IV “technical description” needs functioning magnet line
  - Step IV “measurement of emittance (no cooling)” is under way
    - Likely will need more data