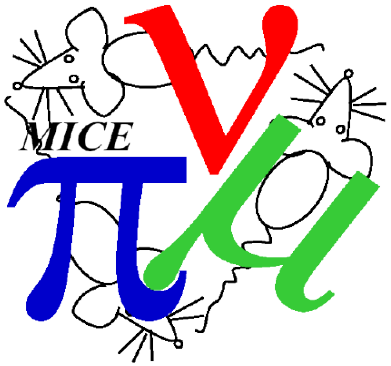
Physics programme and Step IV data taking plan



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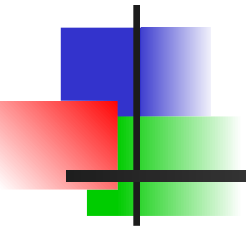
ASTeC

Status

- Completed all Step I publications
  - **Published:** Pion contamination in the MICE muon beam
  - **Published:** Electron-Muon Ranger: performance in the MICE Muon Beam
- **Demo Paper** distributed to collaboration
- **Two further publications** in progress
  - Direct measurement of emittance using the MICE scintillating fibre tracker
  - Multiple Coulomb Scattering of muons in Lithium Hydride
  - See subsequent talks
- Next round of publications brewing
  - Direct measurement of transfer matrix
  - Magnetic alignment of the channel
  - Beam transport in SSU/FC/SSD lattice
- Plans
  - Step IV data taking plan
- Not included Demo descope work



Analysis of Existing Data

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Data taking up to CM44

June/July 2015	Tracker Commissioning incl. 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
December 3rd - 7th	FC alignment study
December 13th - 16th	Scattering in Xenon and empty
February 23rd – March 24th	Alignment studies
	Empty absorber data
	Scattering in LiH
	Pionic beamline studies

Data taking since CM44

Date	Data Taken
July 8th - 10th	TOF Calibration; Detector Alignment
July 14th - 15th	FC alignment study (+50 A)
July 16th - 17th	Detector alignment; proton absorber study
July 19th (2.5 hrs)	SSD only at 140 A
July 20th (5 hrs)	SSU + SSD at 140 A
July 21st - 25th	FC alignment study (+/- 50 A)
July 26th - 27th	SSU + FC + SSD at 140 / 50 / 140 A
July 27th - 28th	SSU only at 140 A

- I don't have much on data taken in the last week

Detector Alignment (F. Drielsma)

- See talk at CM44 for method
- Aligned to TOF0/1 axis (in MICE hall coordinate system)

	x_T [mm]	y_T [mm]	α_T [mrad]	β_T [mrad]
TKU	0.209±0.119	-1.670±0.114	3.286±0.041	0.727±0.041
TKD	-2.280±0.117	2.387±0.117	-0.660±0.041	1.030±0.041

Table: September-December 2015

	x_T [mm]	y_T [mm]	α_T [mrad]	β_T [mrad]
TKU	-0.297±0.240	-0.474±0.237	3.201±0.078	0.912±0.073
TKD	-2.307±0.223	2.402±0.220	-0.615±0.070	1.363±0.072

Table: February-March 2016

	x_T [mm]	y_T [mm]	α_T [mrad]	β_T [mrad]
TKU	2.281±0.094	-0.482±0.093	3.510±0.030	-0.293±0.025
TKD	-2.915±0.086	2.899±0.086	-1.234±0.024	0.933±0.024

Table: July 9/10 2016

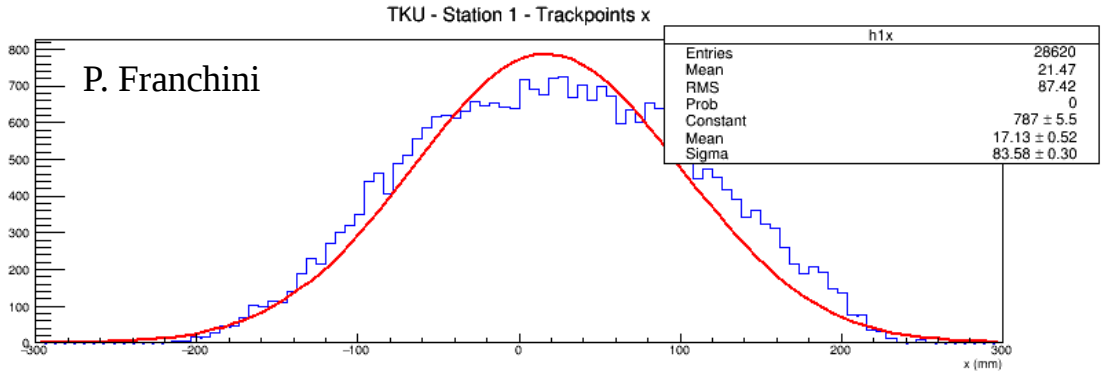
	x [mm]	y [mm]	α [mrad]	β [mrad]
TKU	2.008 +/- 0.183	-0.247 +/- 0.170	3.545 +/- 0.053	-0.270 +/- 0.046
TKD	-3.015 +/- 0.157	3.009 +/- 0.155	-1.113 +/- 0.045	1.075 +/- 0.045

Table: July 16/17 2016 - preliminary

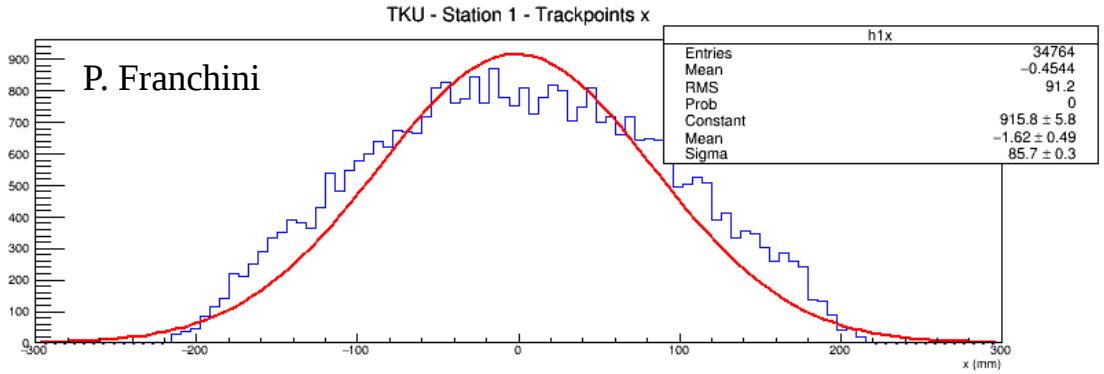
Beamline Commissioning

- Renewed interest in the beamline
  - Would like to run with pions
  - Means reviewing/reoptimising the beamline and matching
- Various open issues outstanding for ~ 5 years
  - What is source of disagreement between MC and data?
  - Do we understand the matching?
  - Do we understand the momentum selection?
  - Do we understand the input beam?
  - How stable is the beamline?
    - Hysteresis, etc

Discrepancy between MC and Data

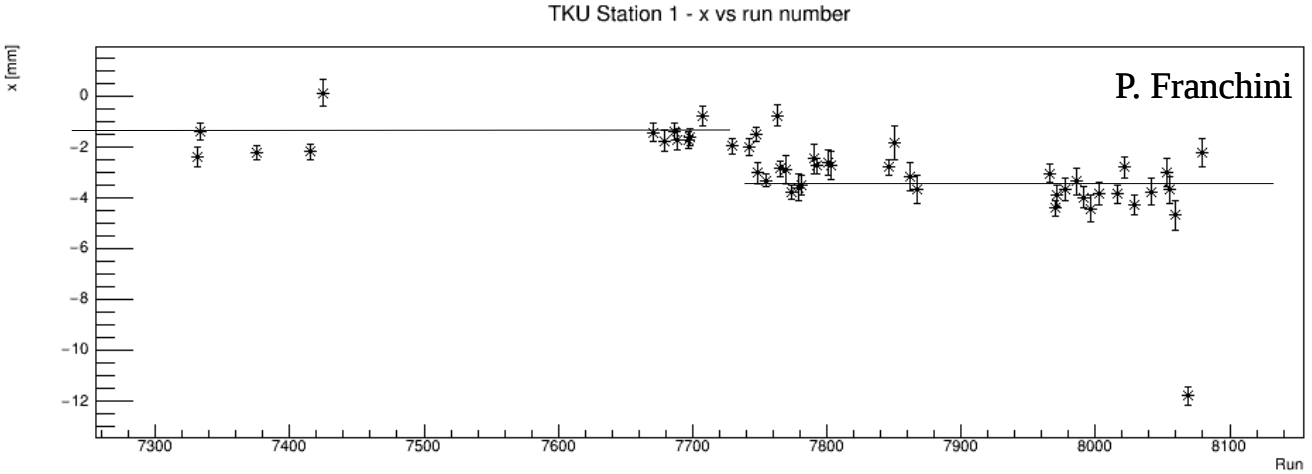


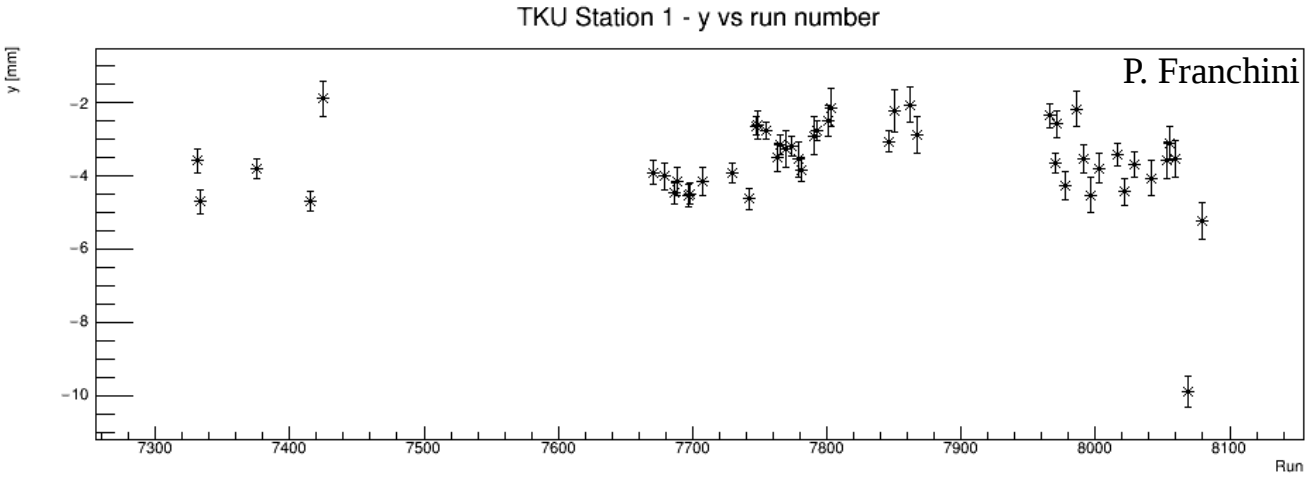
D2 at 78.9 A
Mean(x) = 21.5 mm



D2 at 70.0 A
Mean(x) = -0.5 mm

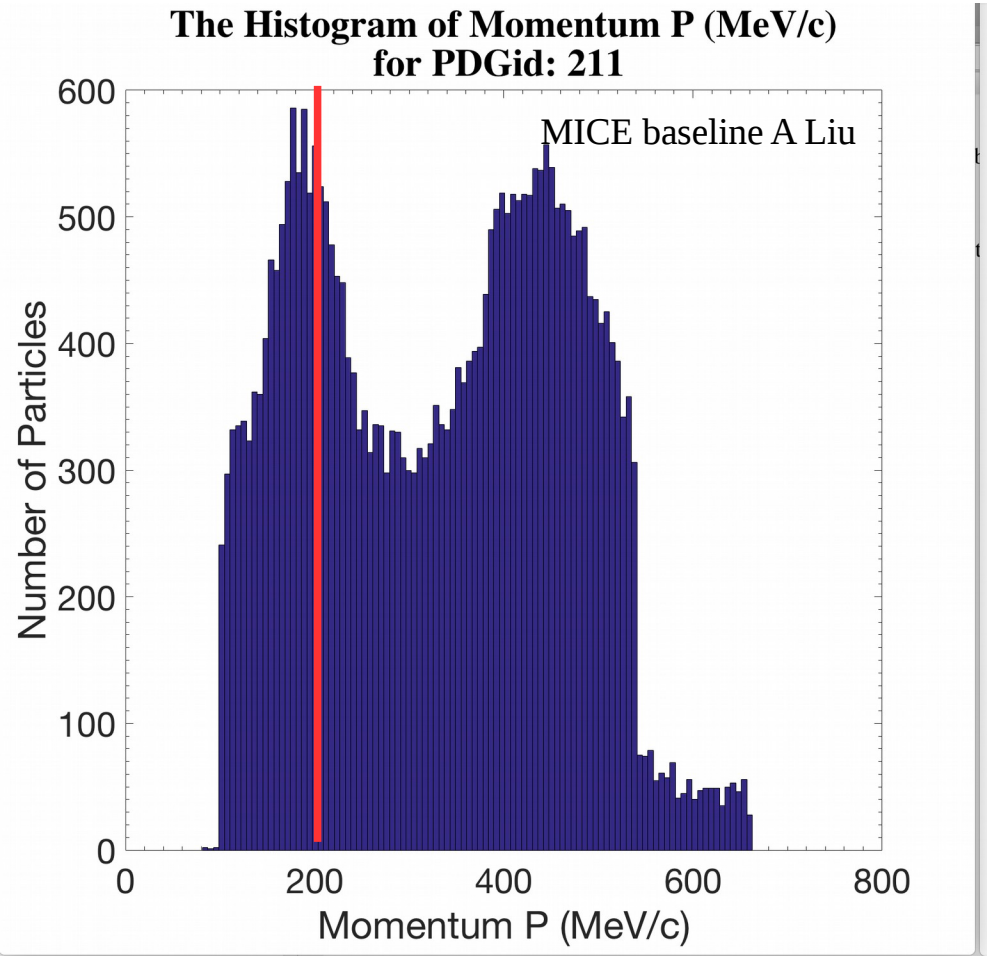
Long term stability

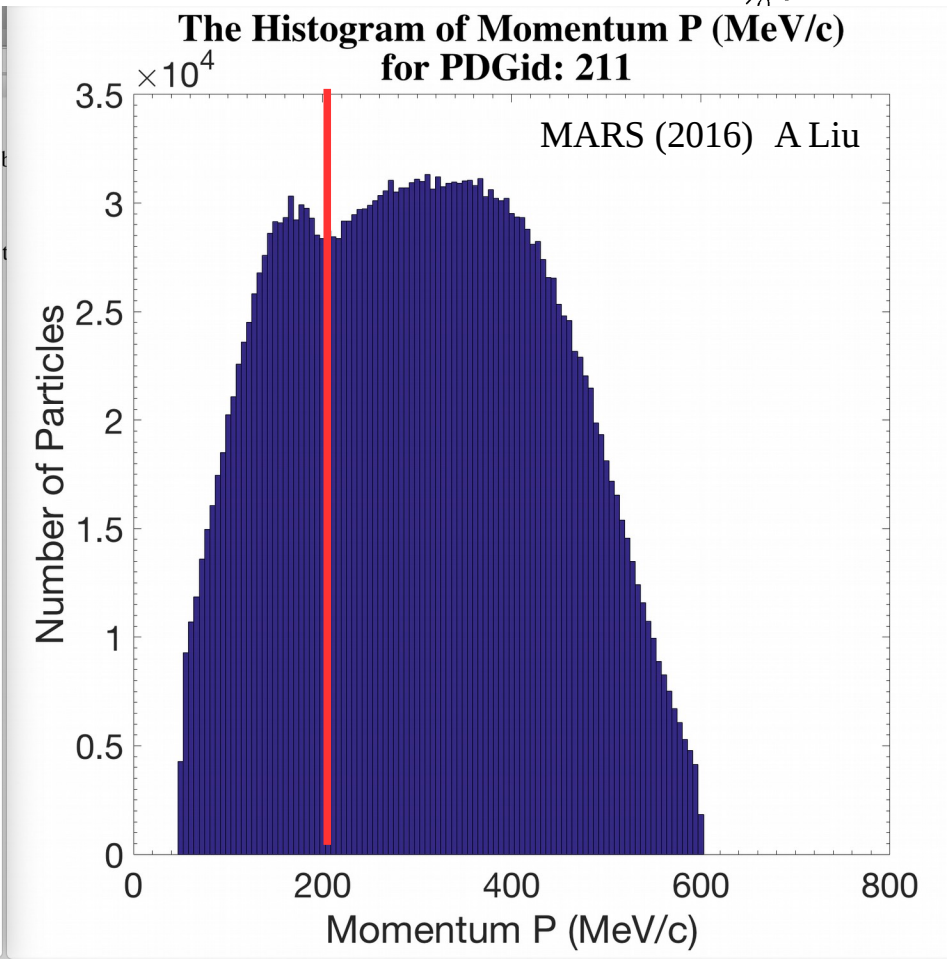




- Reference runs (DS on)

Target Simulation





- Pion momentum distribution from the target

Focus Coil Alignment (Transfer Matrix Measurement)

- Believed to be first direct measurement of transfer matrix from particle tracks (check)
- Transfer matrix describes lattice optics independent of transverse beam properties
  - Pz dependent

$$x^d = M_{00} + M_{01}x^u + M_{02}Px^u + M_{03}y^u + M_{04}Py^u, \quad (1)$$

$$Px^d = M_{10} + M_{11}x^u + M_{12}px^u + M_{13}y^u + M_{14}Py^u, \quad (2)$$

$$y^d = M_{20} + M_{21}x^u + M_{22}px^u + M_{23}y^u + M_{24}Py^u \quad (3)$$

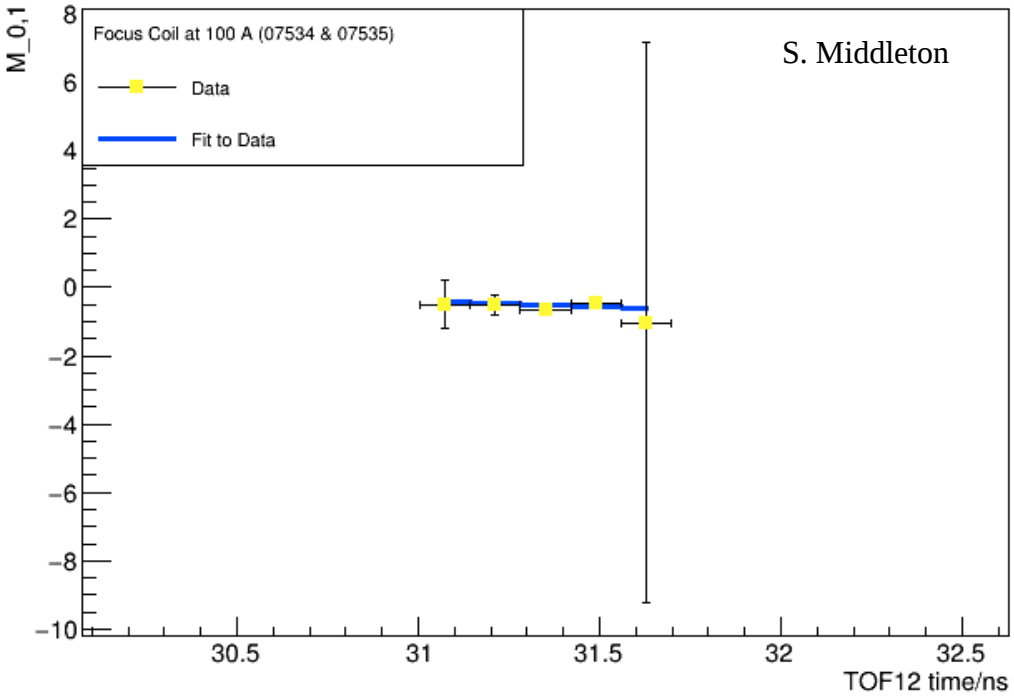
$$Py^d = M_{30} + M_{31}x^u + M_{32}px^u + M_{33}y^u + M_{34}Py^u \quad (4)$$

Dipole terms
arise due to misalignment

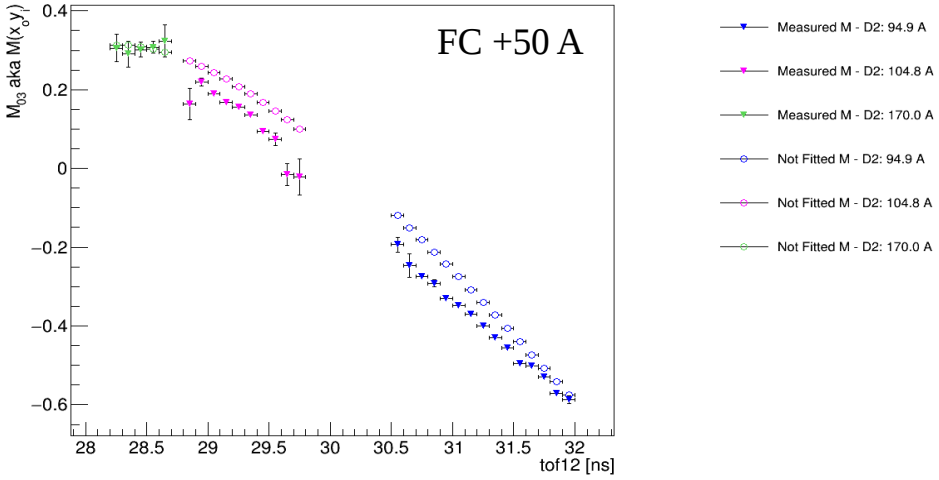
Focussing terms
Describe optical properties
of the magnet

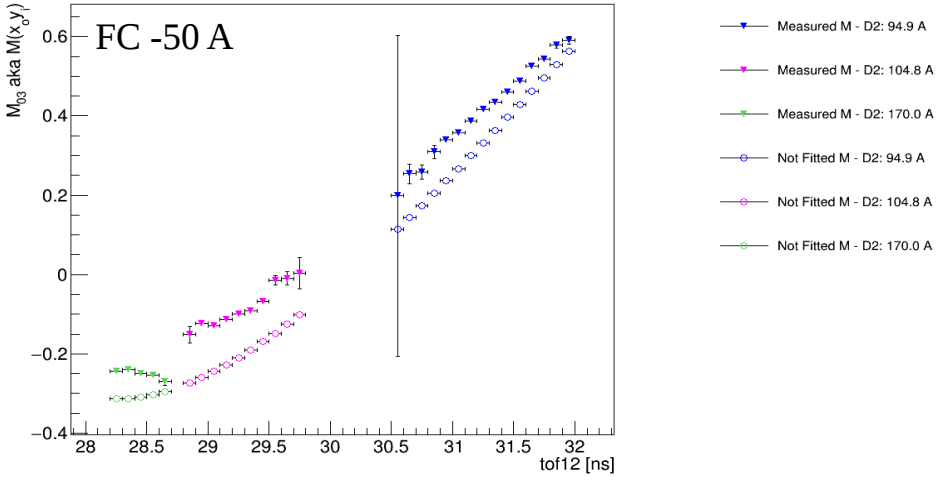
Focus Coil Alignment (Transfer Matrix Measurement)

- Believed to be first direct measurement of transfer matrix from particle tracks (check)
- Data from December 2015 using FC in flip mode
- Limited statistics; limited momentum range
  - no DS, mu beam



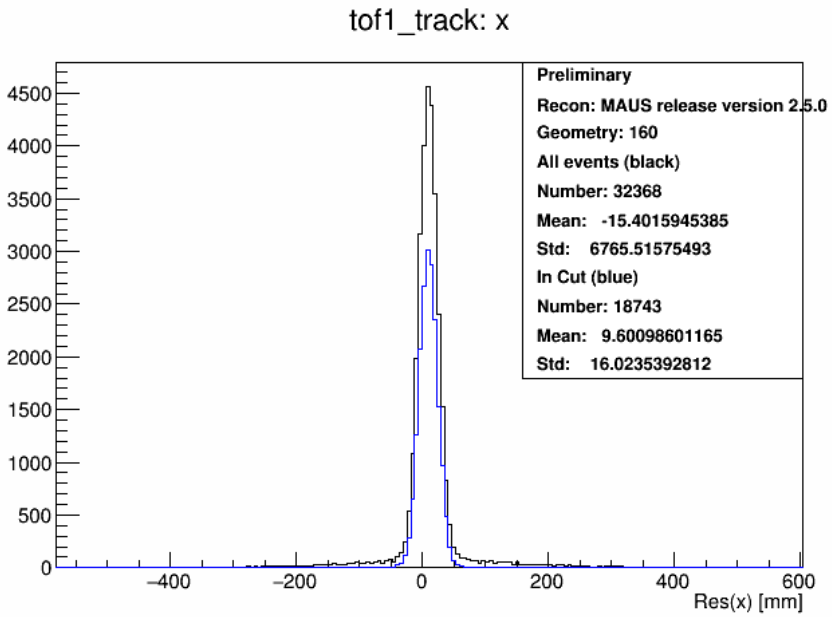
Focus Coil Alignment (Transfer Matrix Measurement)

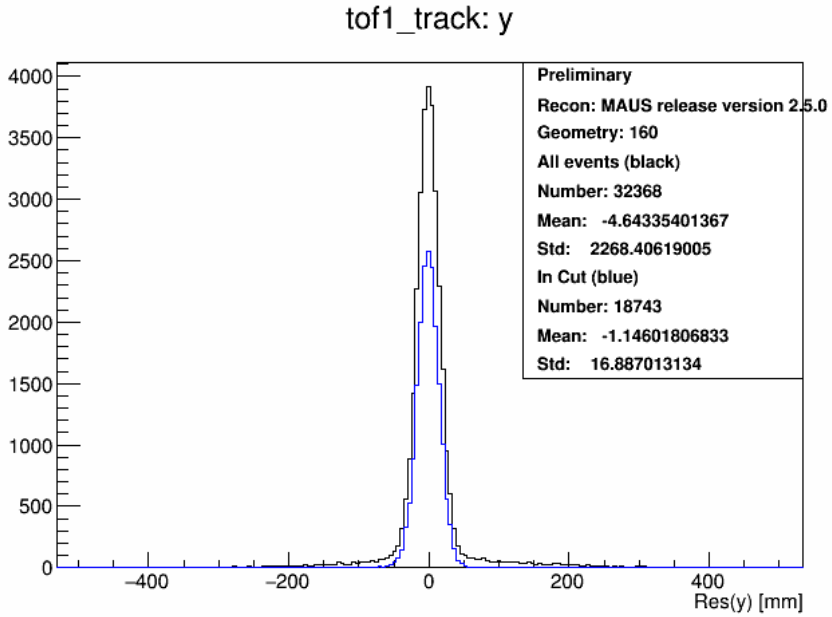




- Data from July in solenoid mode
- DS operational
- Pion beam
- More data, more momenta
- Systematic error to be understood better
- Need July detector alignment to be tied into recon

Residuals-Based analysis

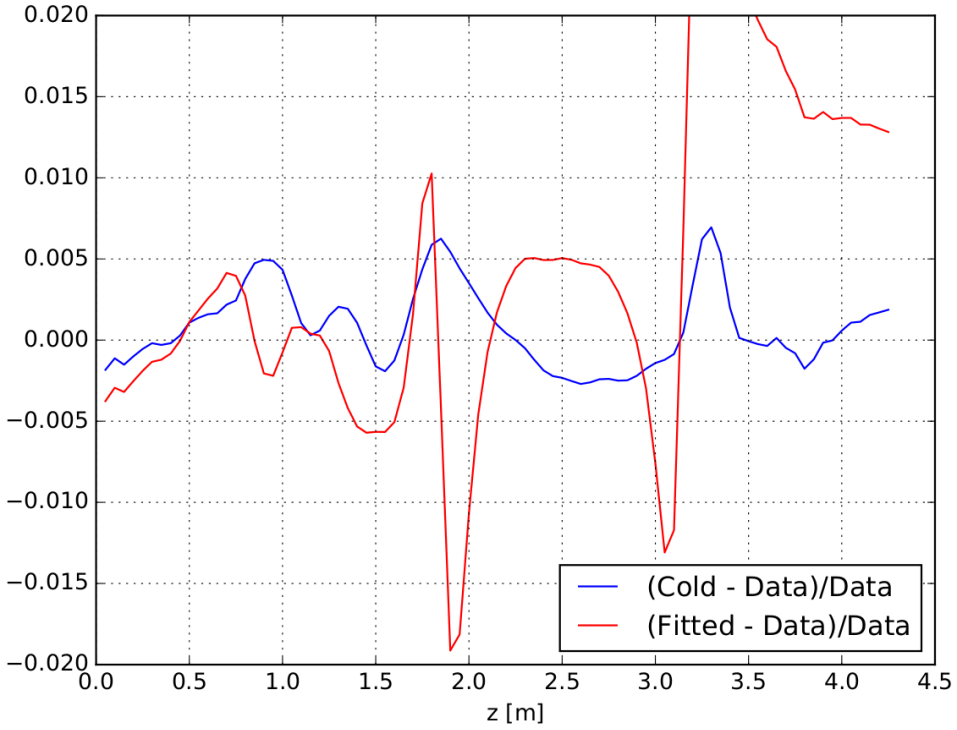




- Extrapolate tracks between detectors, through the fields
  - E.g. compare extrapolated tracks from TKU to TOF1
- Note the offset of the mean
  - Indicates magnet misalignment
  - Magnet misalignment needs to be quantified
- → Tie this into July data

Magnet Mapping

- Tying this back into the magnet mapping
  - Plot shows (calculated field – measured field)
- Fit is overconstrained – so a-priori calculation has smaller residuals



Red – fit to mapping data (J. Langlands)
Blue – calculated field (H. Witte)

Planning for Future User Runs

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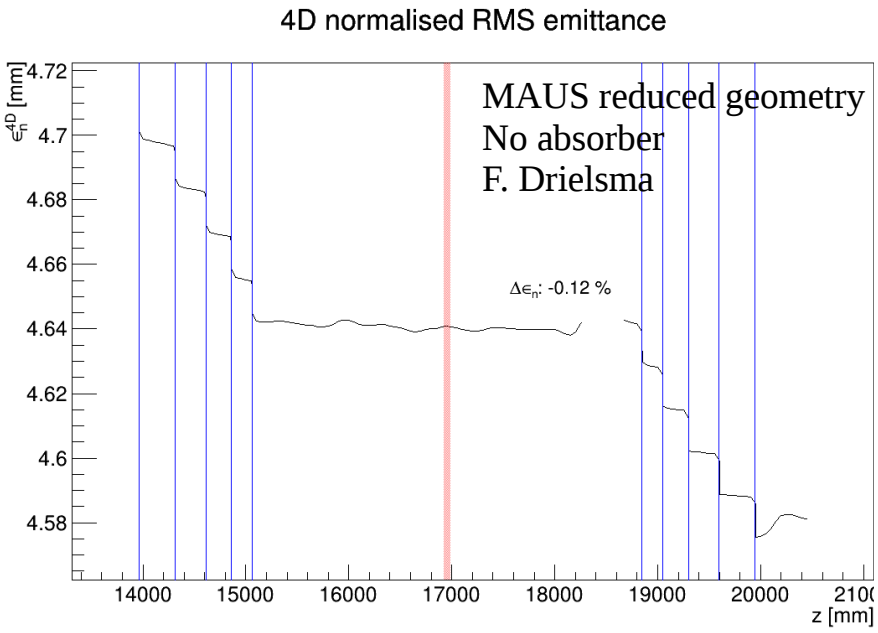
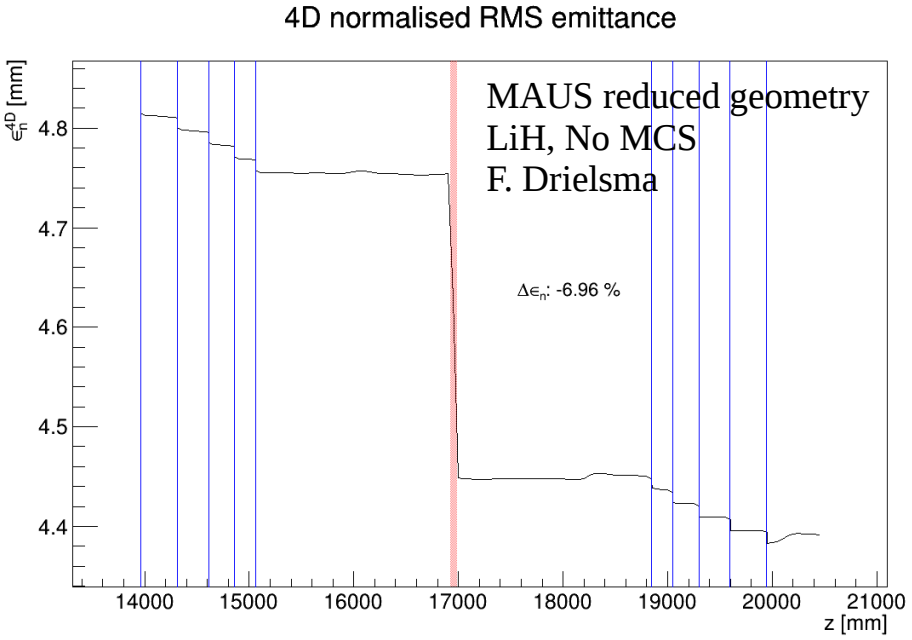
Step IV Run Settings

- Step IV Run Settings are now stable
  - Little/no change since CM44
- Run plan with a “pragmatic baseline” assuming SSU M1/M2, FC, SSD (no Ms) and solenoid mode
  - Hope to run using this baseline in the next user cycle
- Now need to work up a run plan for 2016/03, with feedback from the magnet group on their status

Outstanding Issues

- Outstanding issues
  - Simulation/validation in full MAUS geometry?
  - Can we observe cooling without M2D i.e. transmission bias?
  - Can we manage non-linearities in the analysis?
- Cross check with reduced geometry looks okay
  - Move on to full geometry

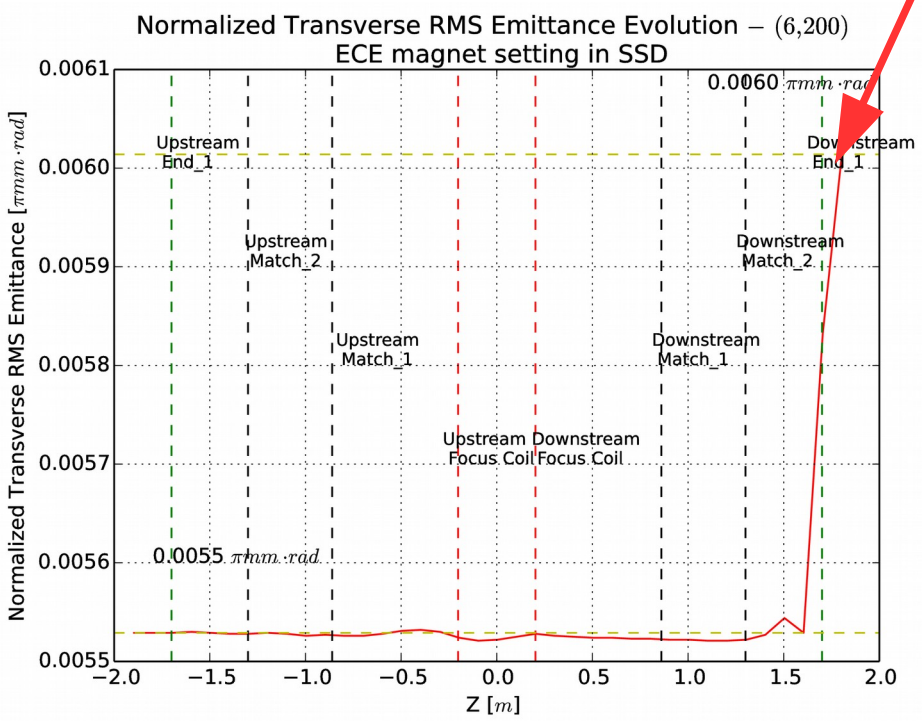




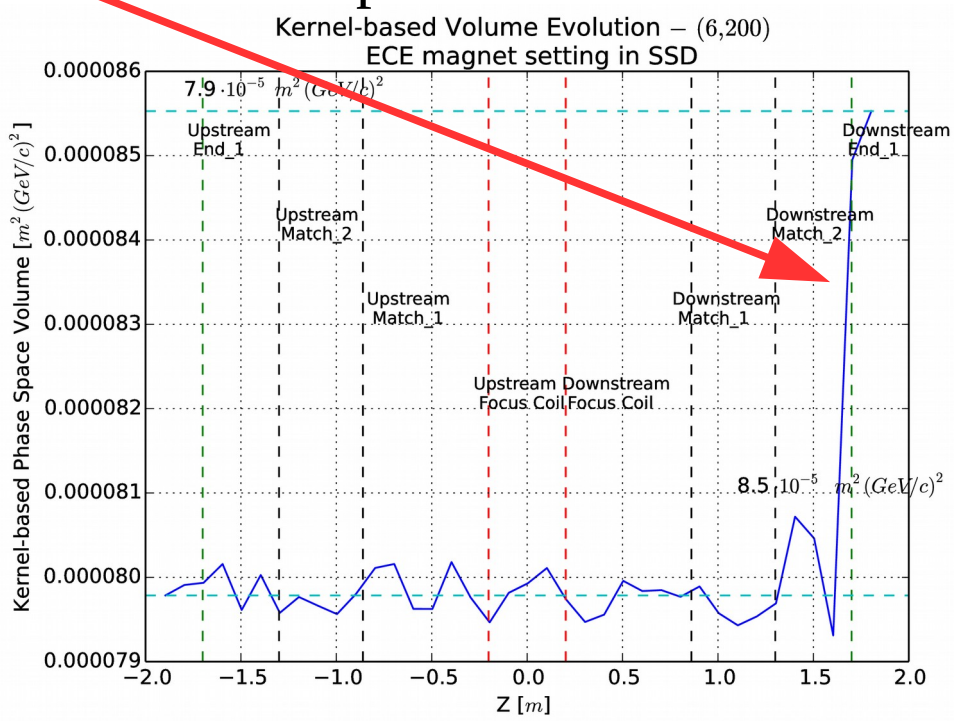
Non-linearities

Urk!

RMS Emittance

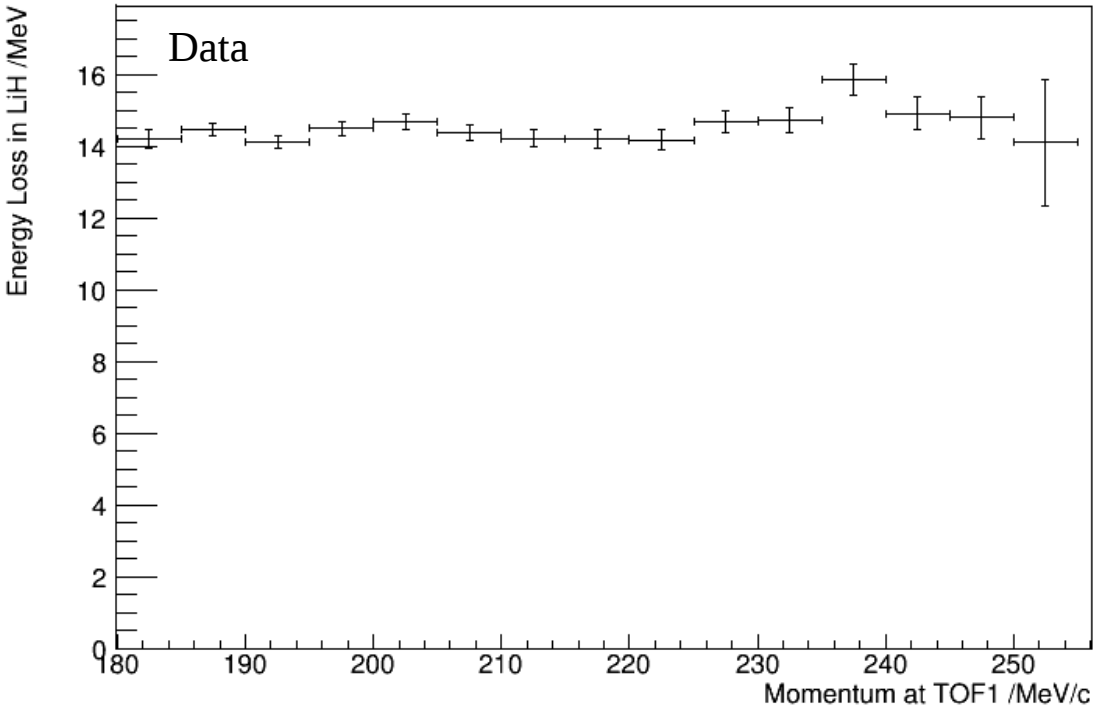


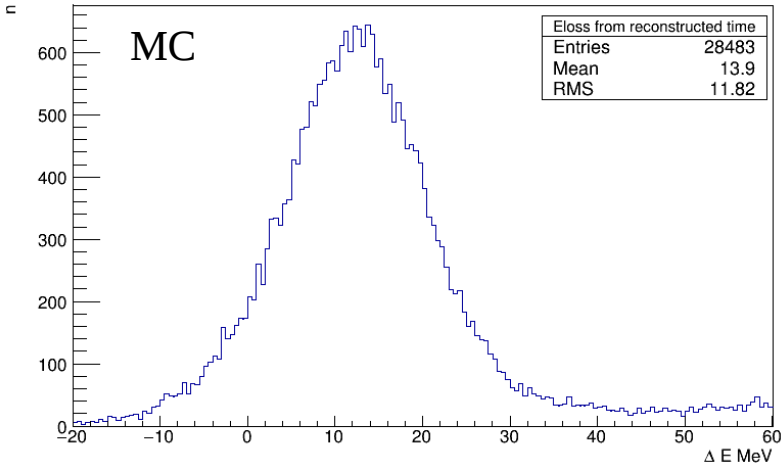
Phase Space Volume

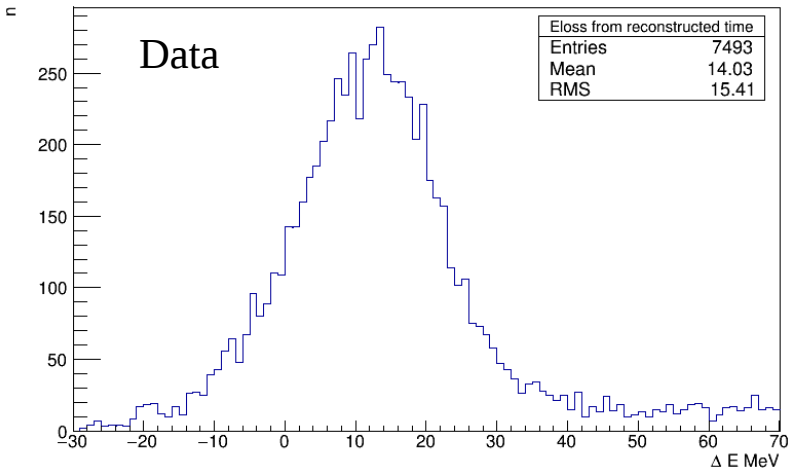


- Can we deal with beam deformation/non-linear optics issues?
  - Smooth the particle distribution and then measure volume occupied by the beam (KDE technique)
  - Still see effect of beam deformation in the phase space volume calculation

Energy Loss Measurement (Field off)

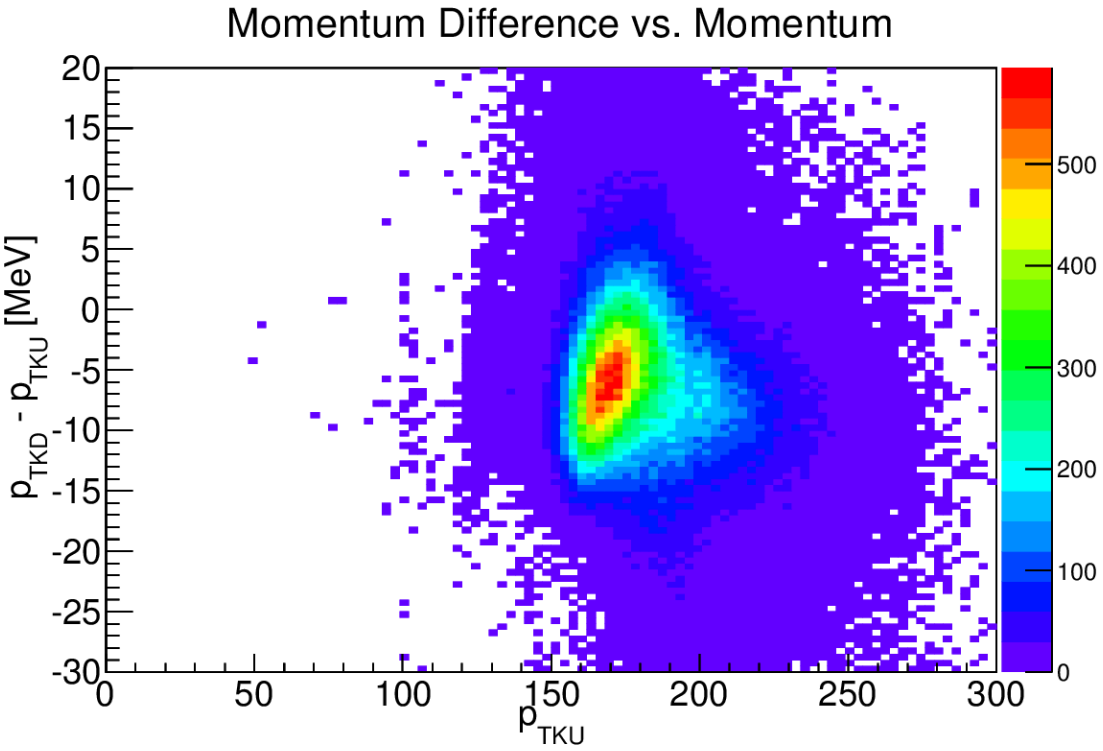






- Use TOF01 vs TOF12 to estimate energy loss in absorber
  - Assume some energy loss model for intervening material
  - Test with empty absorber data and field-on data

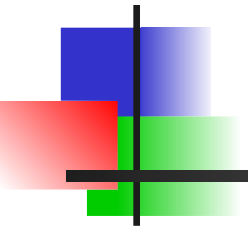
Energy Loss Measurement (Field on)



- Starting to dig into energy loss measurement
- First pass indicates significant instrumental effects
  - Muon beam
  - No absorber

Demo/Descope

- Full alignment and tolerances analysis has been completed for the demonstration of ionisation cooling lattice
  - Alan Young
- Significant body of work to understand whether Demo can run without SSD
  - Yes it can, EMR is a nice detector!
  - Durga Rajaram, many others



Conclusions

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Summary

- Step I publications are complete
- Demo paper has gone to referees
- Two further collaboration publications are in progress
- More are starting to work their way through the pipeline
- Physics group is looking forward to full magnet operation
- A lot of fun to come!