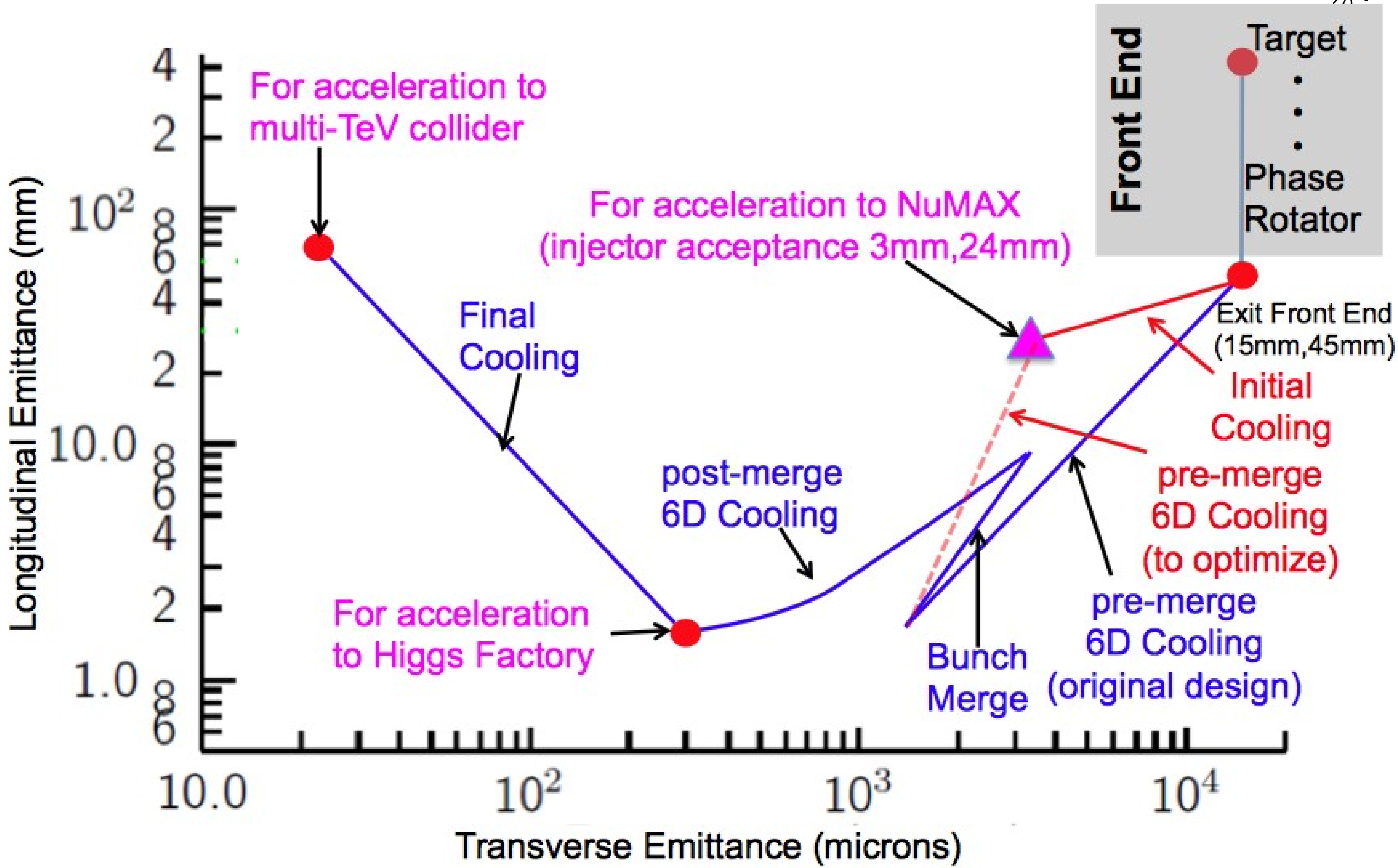
MICE Status and Plans

C. T. Rogers, on behalf of the MICE collaboration
ASTeC Intense Beams Group
Rutherford Appleton Laboratory

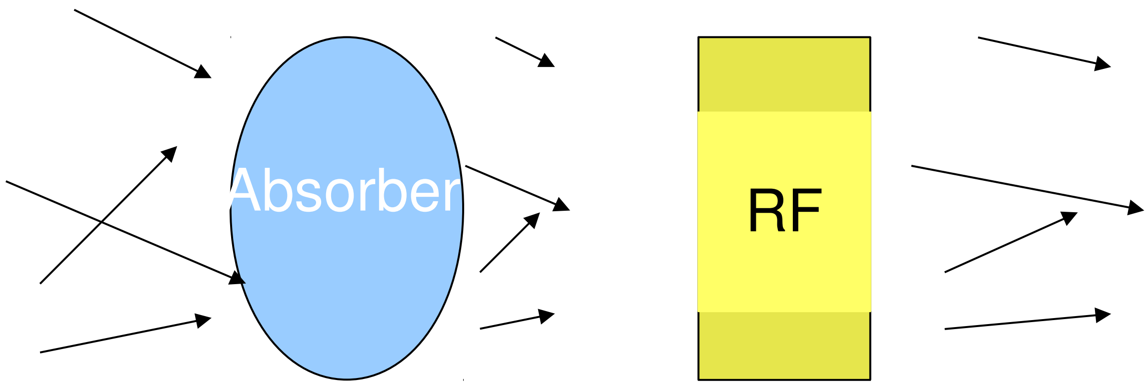
Overview

- Reminder of purpose and design of MICE
- Status of diagnostics
- Status of magnets
- Plans for operations
- Analysis of data
- Route to full demonstration of ionisation cooling

Muon Accelerators

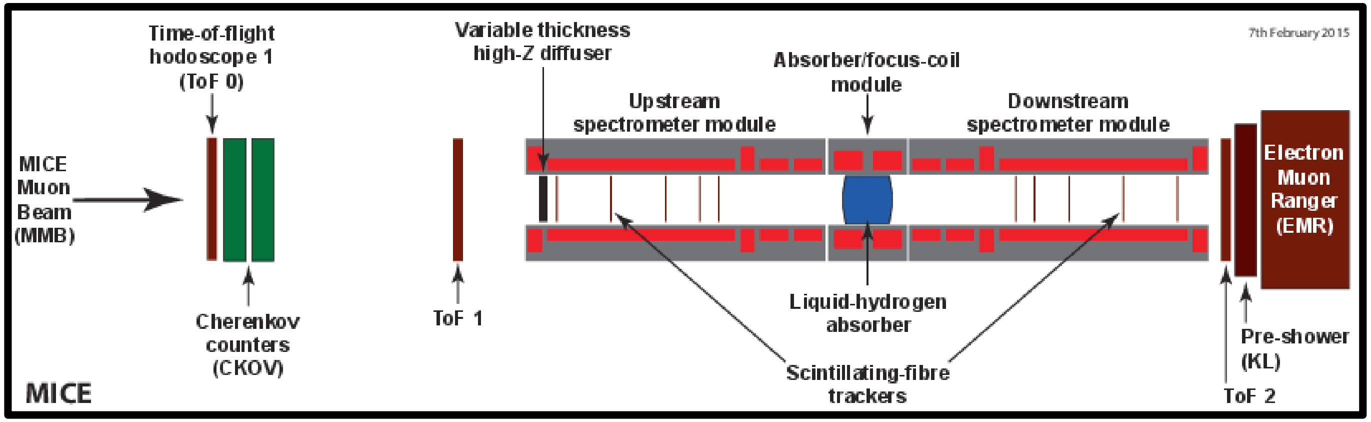


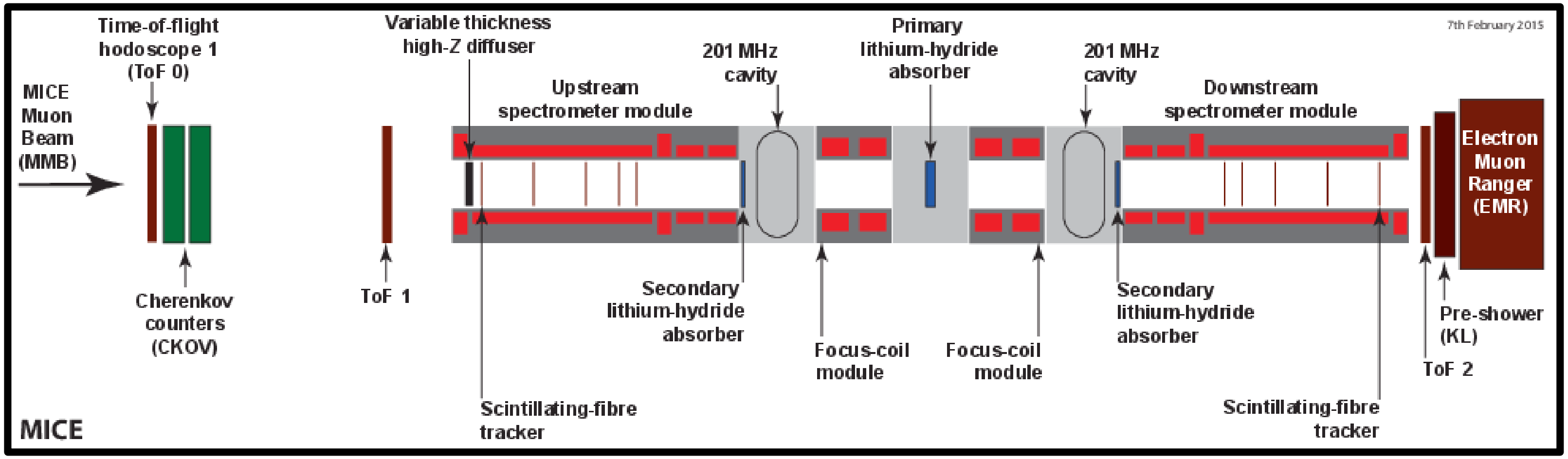
4D Ionisation Cooling



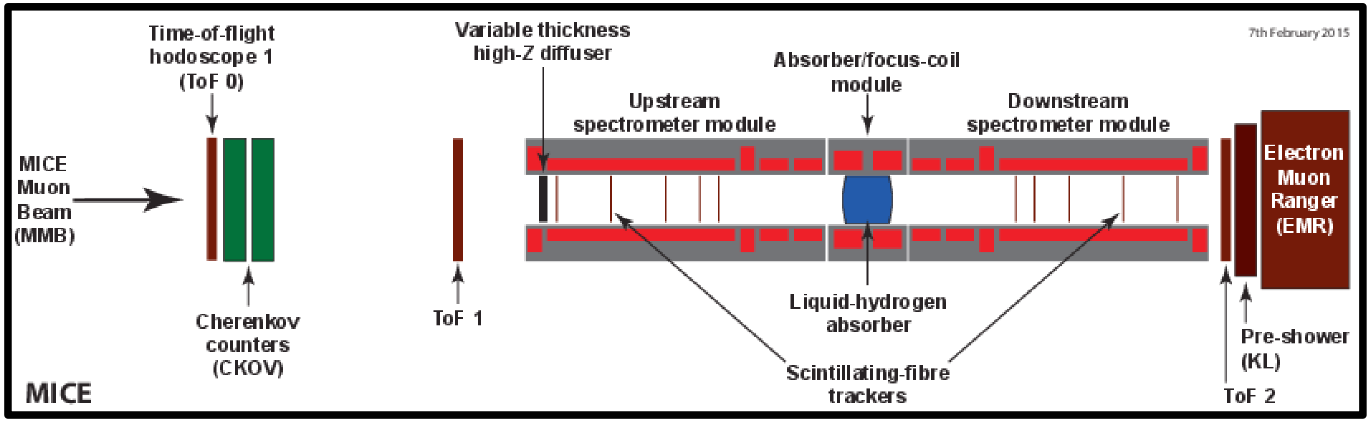
- 4D (transverse) cooling achieved by ionisation energy loss
  - Absorber removes momentum in all directions
  - RF cavity replaces momentum only in longitudinal direction
  - End up with beam that is more straight
- Stochastic effects ruin cooling
  - Multiple Coulomb Scattering increases transverse phase space volume
  - Energy straggling increases longitudinal phase space volume

MICE – Ionisation Cooling PoP

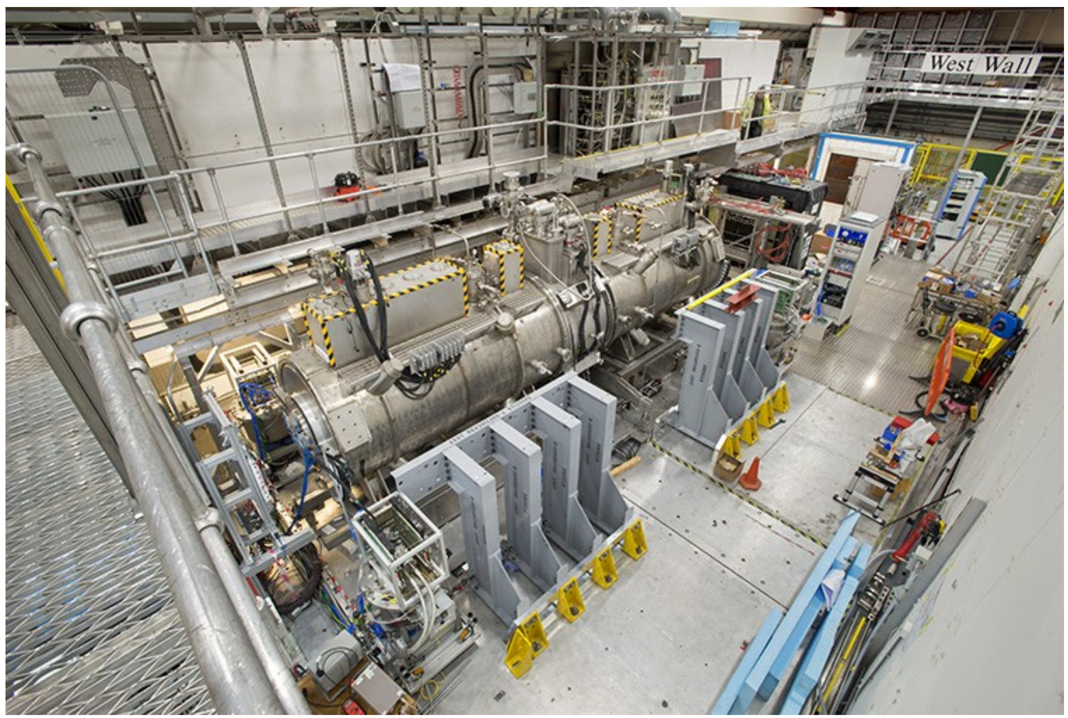




MICE Aims



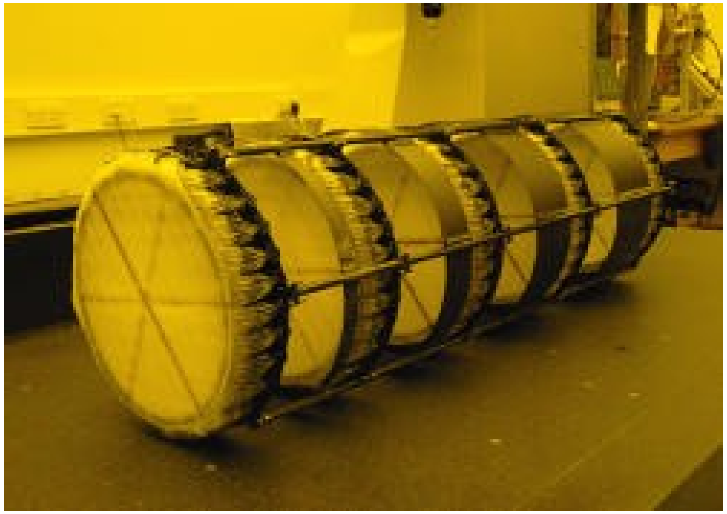
Time-of-flight
hodoscope 1
(ToF 0)
Variable thickness
high-Z diffuser
7th February 2015
Absorber/focus-coil
module
Upstream
spectrometer module
Downstream
spectrometer module
MICE
Muon
Beam
(MMB)
Electron
Muon
Ranger
(EMR)
Cherenkov
counters
(CKOV)
ToF 1
Liquid-hydrogen
absorber
Pre-shower
(KL)
Scintillating-fibre
trackers
ToF 2
MICE



West Wall

Diagnostics

Trackers



- Muons pass through scintillating fibre planes across solenoid
  - Fit a helix to the particle trajectories to reconstuct momentum
  - Principle detector for phase space reconstruction
- Tracker hardware is installed in spectrometer solenoids
- Successfully read out tracker electronics in the hall in January
- Ongoing work in cabling, readout, unpacking and reconstruction
- Talk by Ed Overton on Thursday

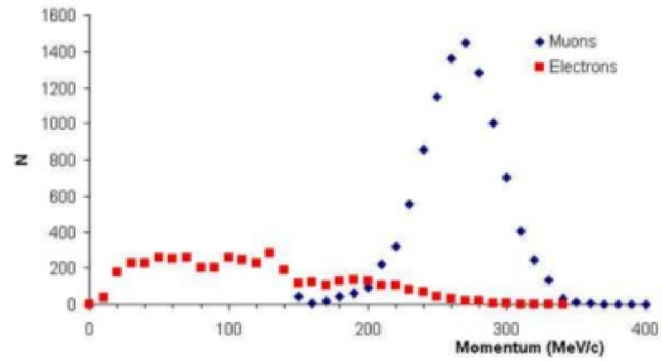
EMR

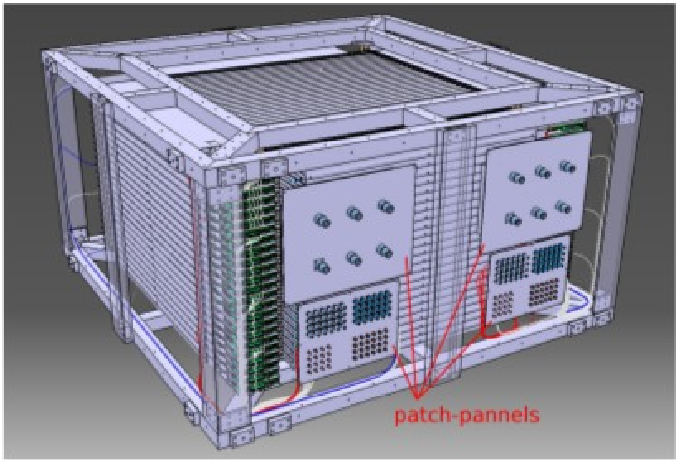
Pupose of the EMR in MICE:

- Reject the muons that decayed inside the cooling channel and their decay products
- Redundant measurements of the trajectories and momenta

The EMR is fully active scintillator tracker calorimeter

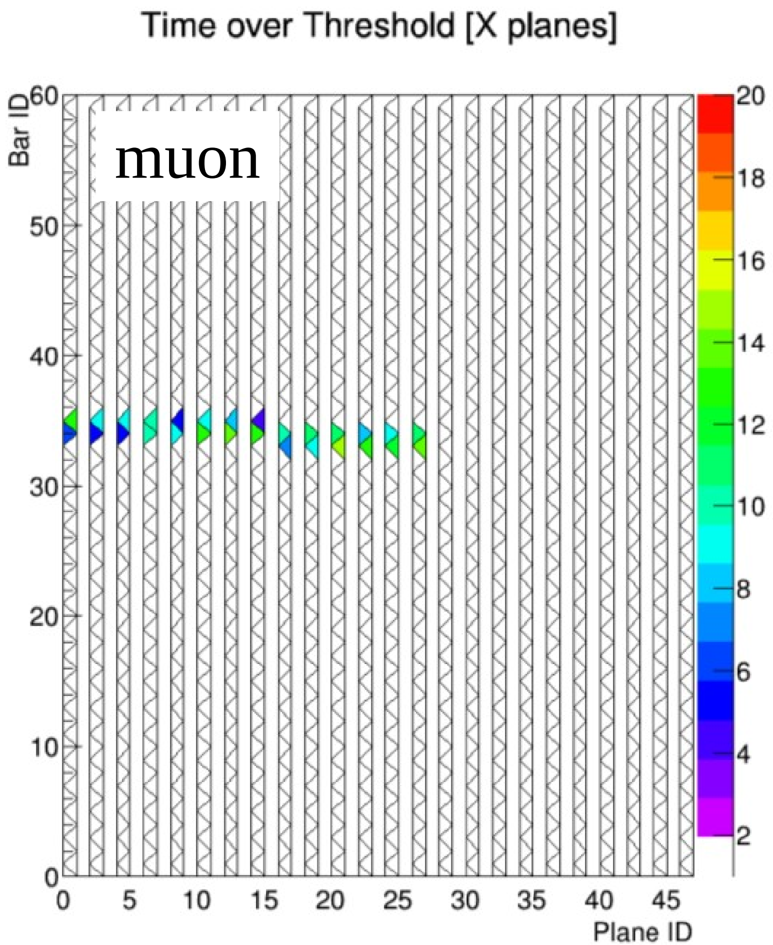
- 48 planes of 59 triangular scintillator bars
- Readout by multi-anode and single-anode PMTs

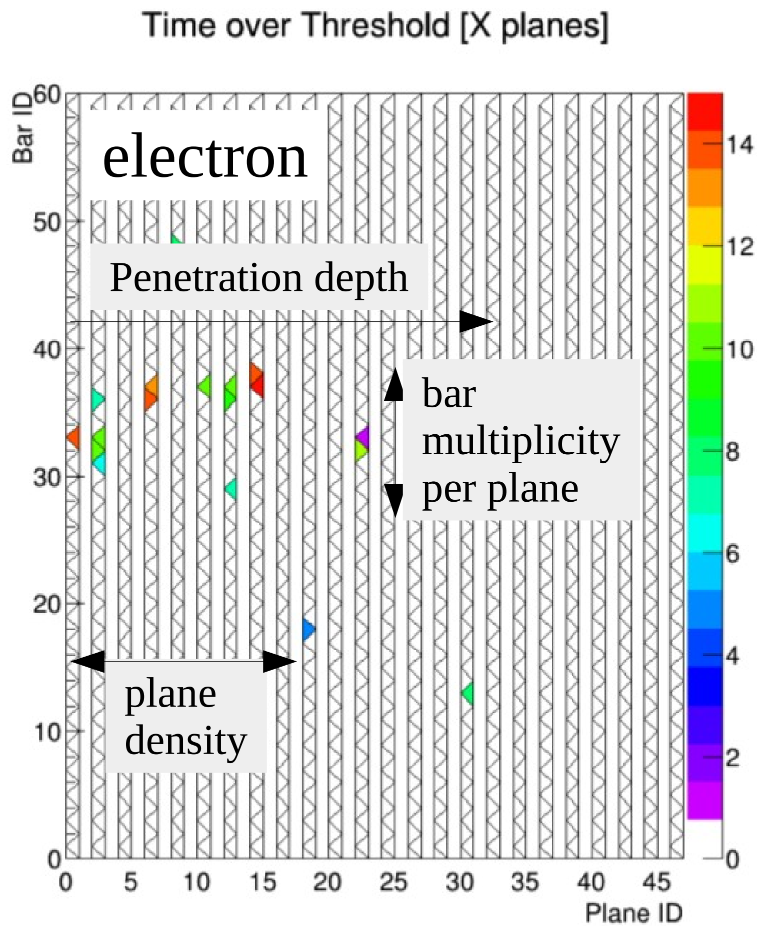




Francois Drielsma et al.

Particle Characterisation

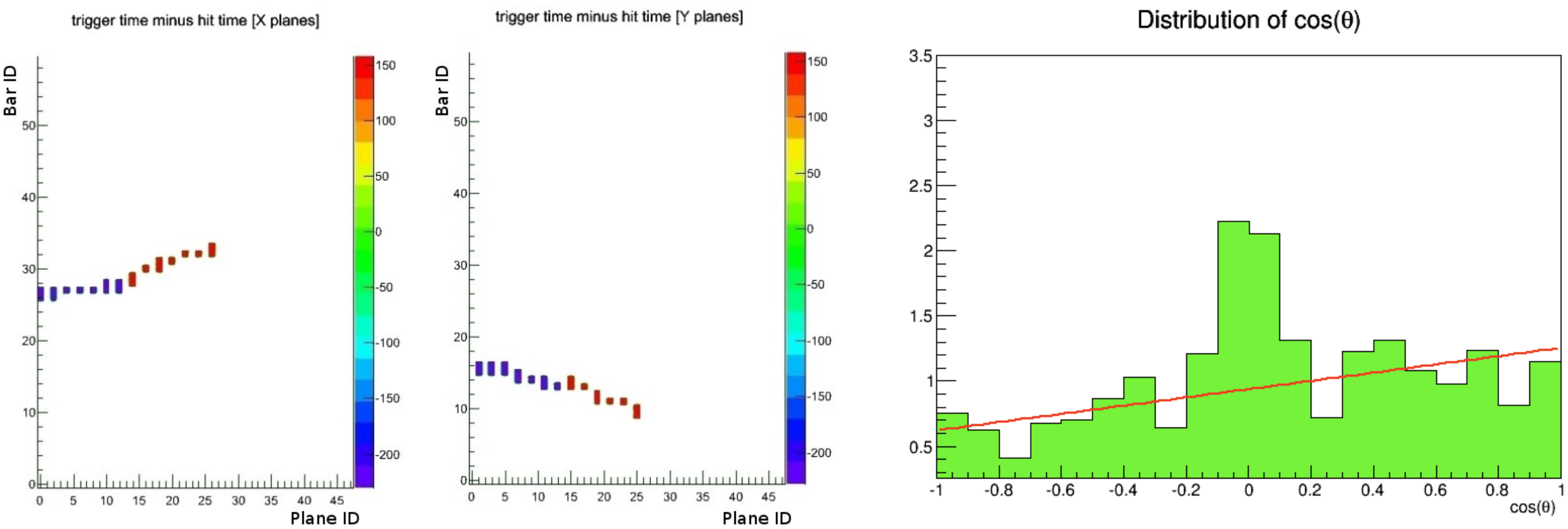




Francois Drielsma et al.

- EMR commissioned and calibrated
  - Paper in preparation

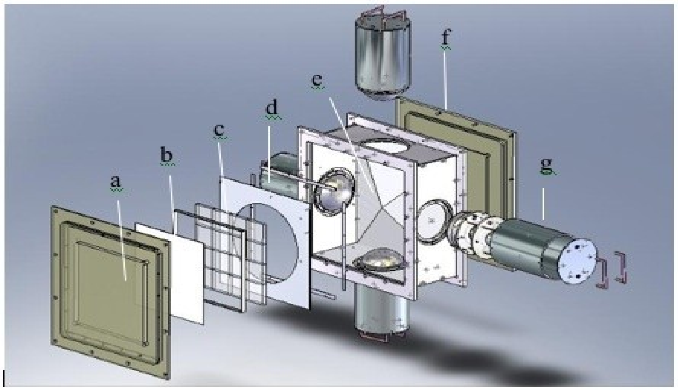
Beam Polarisation



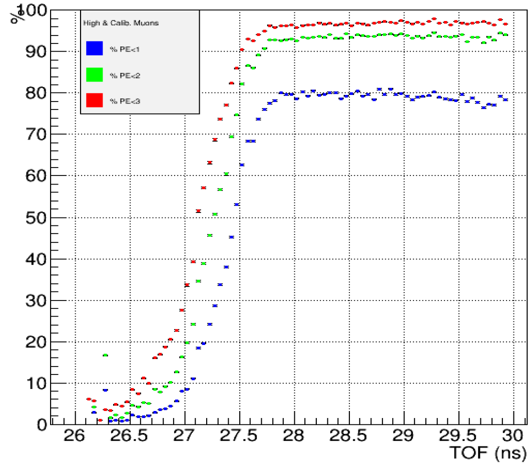
Sophie Middleton et al.

- Beam polarisation can affect positron impurities downstream
- May be possible to measure beam depolarisation due to material
- Calculate angular distribution of decay positrons in EMR
  - Deduce beam polarisation

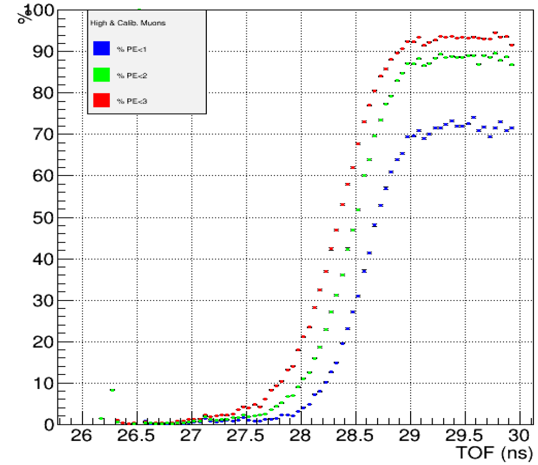
Cerenkov



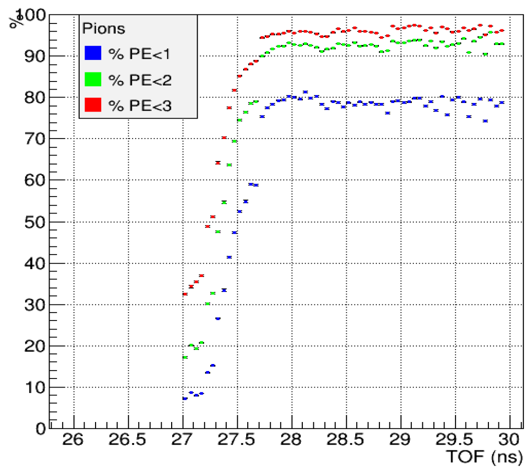
Muons CkovA: % PE vs TOF



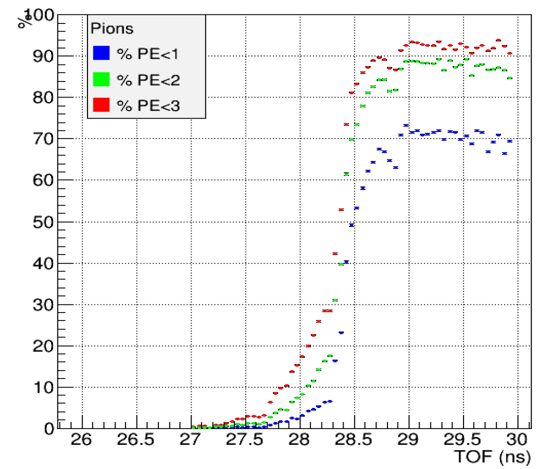
Muons CkovB: % PE vs TOF



Pions CkovA: % PE vs TOF

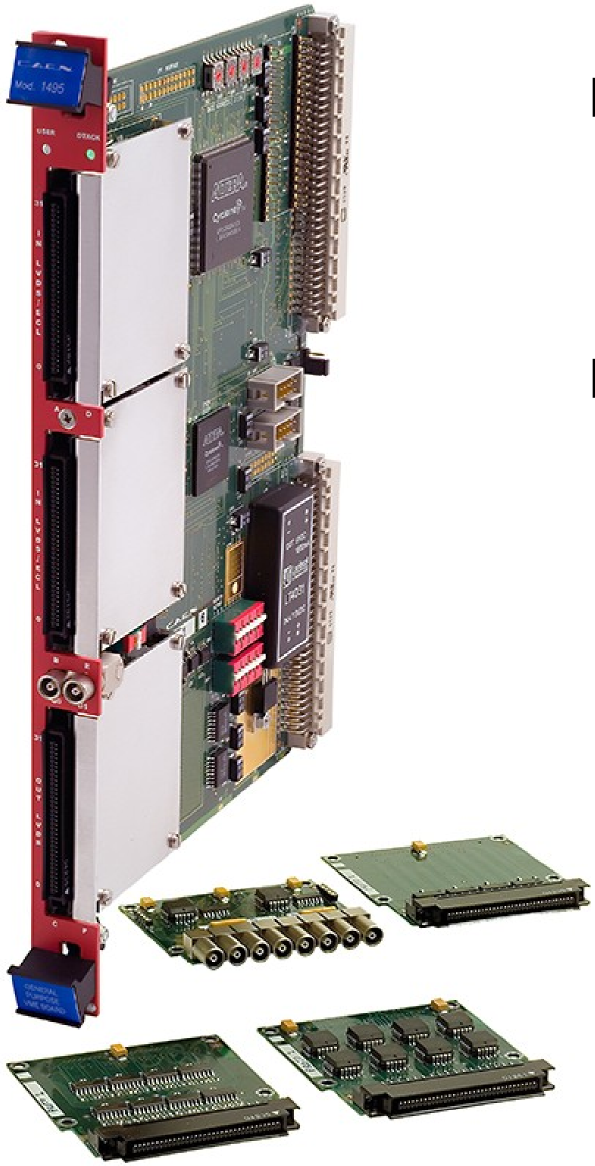


Pions CkovB: % PE vs TOF



Cremaldi/Winter

DAQ trigger system



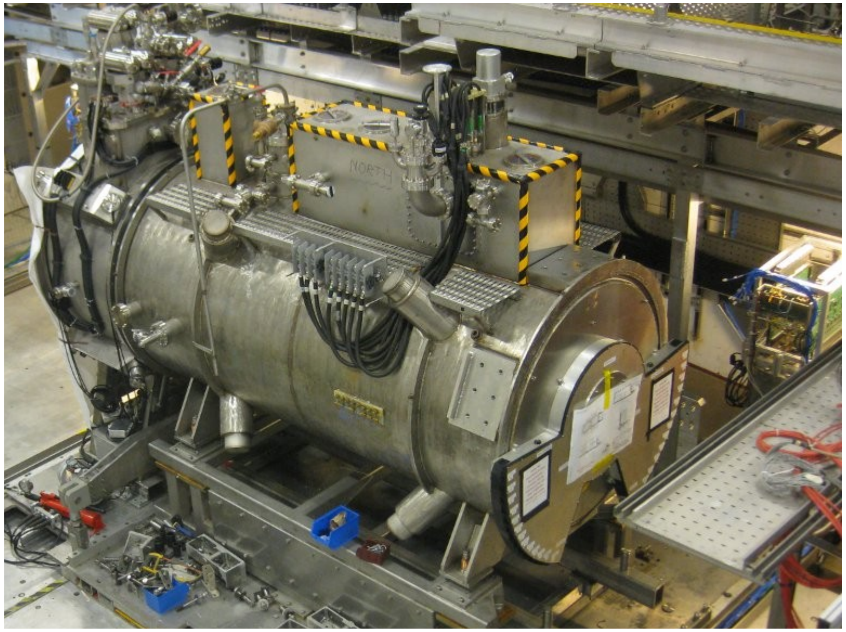
New trigger based on CAEN V1495 FPGA

- Replaces maze of wiring
- More functionality
- Less fragile

Now accepted as production trigger

Magnets

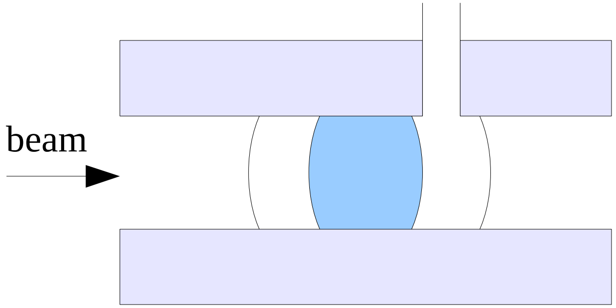
Spectrometer Solenoid



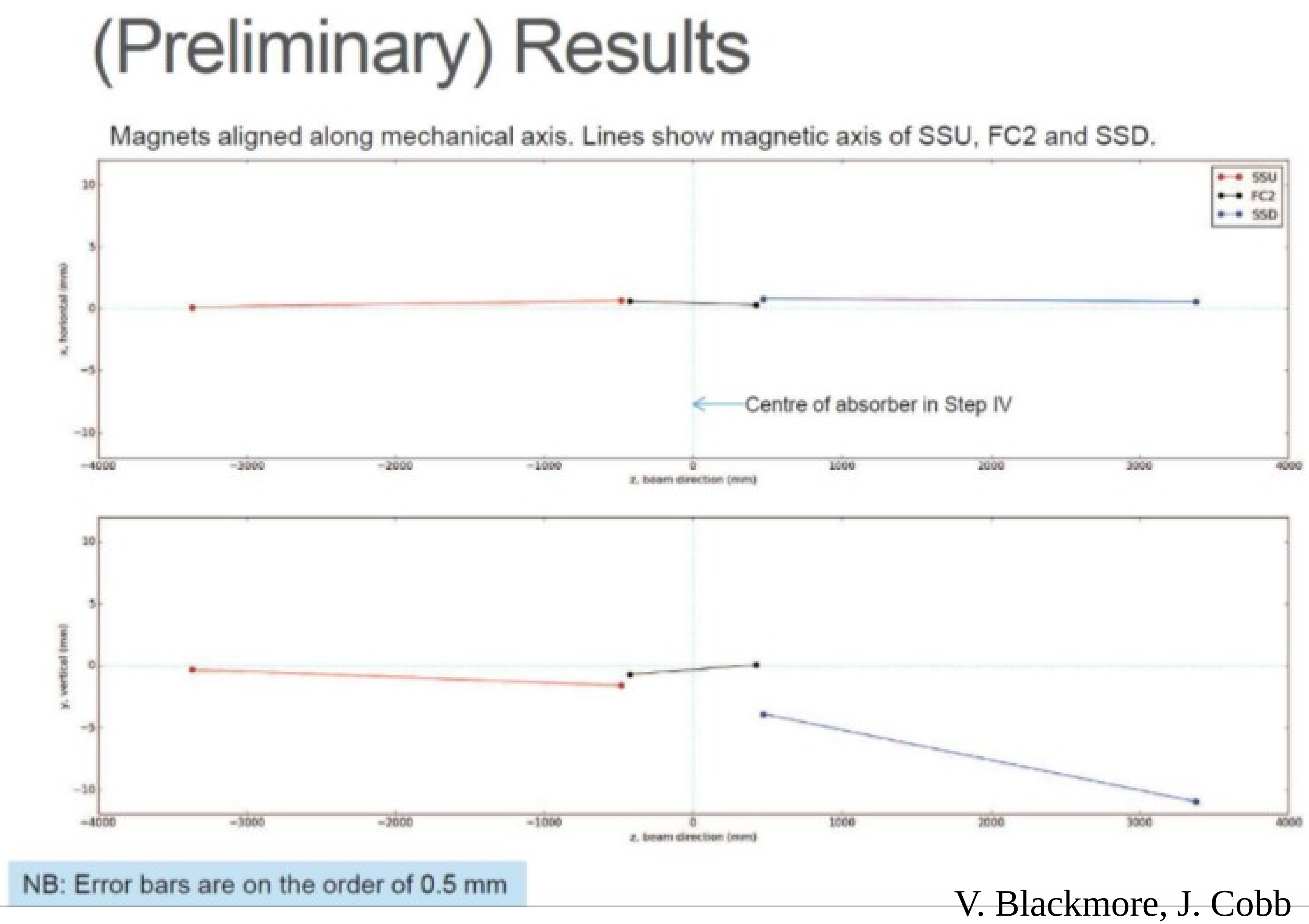
- Both spectrometer solenoids are on the beamline
- Solenoid refurb was completed following spectrometers transport to RAL
- Refurb on helium and vacuum system
- Compressor installation
- Ongoing work on cryocoolers
- Small leak on bellows

Absorber and Focus Coil

- FC2 is on the beamline
- FC1 has now been accepted by the collaboration
  - Achieved current is lower than design current
  - But required current is lower due to lattice revisions
- Focus coil power supply glitches
  - Detecting false quenches; investigation ongoing
- Readiness review for lH2 operation in January 2015
  - Relief-line for lH2 safety window not large enough diameter
  - Requested further testing of lH2 safety windows
  - Step IV will start with LiH while lH2 team review options



Magnet Mapping

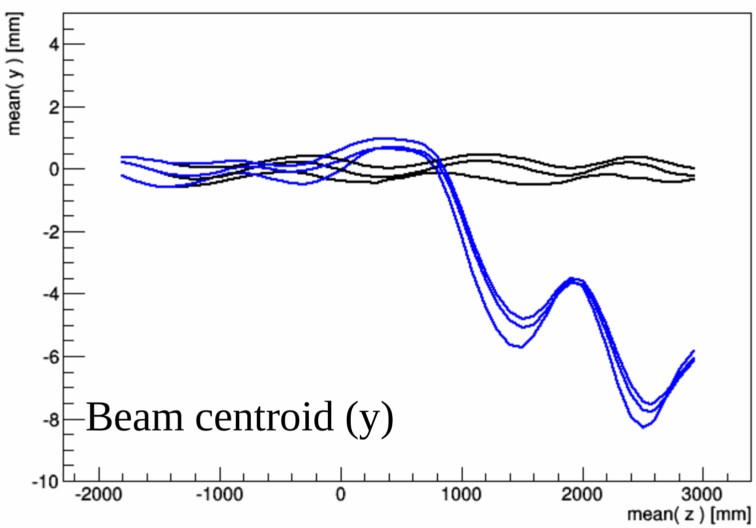


V. Blackmore, J. Cobb

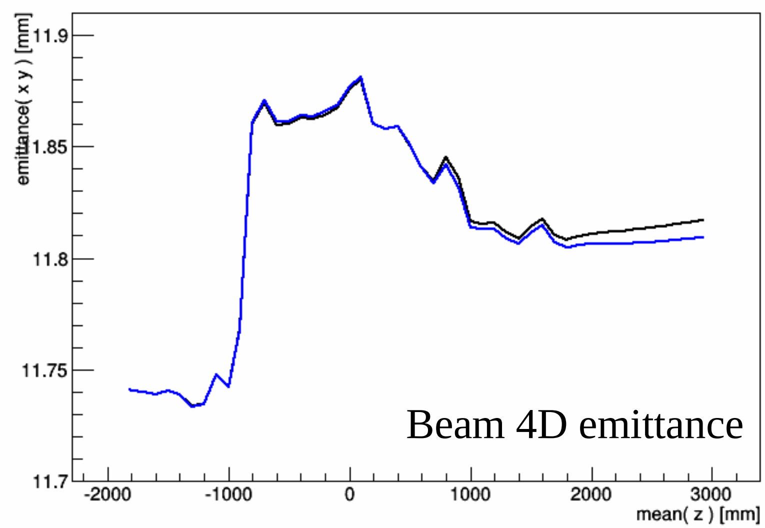
- Additional concern about flange alignment to bore

Effect on Beam (Preliminary)

10k muons



10k muons



- Now track sample of particles through the cooling channel
  - All magnets powered
  - Random seed = initial emittance
- BLACK: magnets with perfect alignment
- BLUE: magnets with measured alignment
- Plan to “bolt and be damned”

Operations

Operations Status

- Shifts
  - In normal running mode, data taking will be 24/7
  - To be included on publications, a shift quota must be fulfilled
    - 3 x 5 shift blocks, subject to confirmation
  - Shifters need to do some training and observe two shifts
- On-call/experts
  - Subsystems will provide on-call and system experts
- Few weekends data taking in March/April
  - Shake down readout and debugging controls systems
  - Beamline pre-commissioning; try a few newly optimised settings
  - Excercise the readout → data movement → reconstruction data flow
- Talk by Milorad Popovic on Thursday

Plan for User Run 2015/01

- Constraints
  - Magnet training has priority over data taking
    - May take the entire user run
  - 1 shift per night during first part of the user run (01a)
  - 3 shifts per day during second part of the user run (01b)
- Two outline run plans prepared
  - Baseline scenario
  - Pessimistic scenario
- Priorities:
  - Commission the tracker
  - Check integrated detector resolution/efficiency
  - Beam-based measurement of detector and magnet alignment
  - MICE muon beamline to MICE cooling channel matching
  - Demonstrate cooling channel optics
- Initially no absorber
- Talk by Paul Soler

Optimistic run plan

Task	Number of Shifts	Magnets	Shifts Per Day	ISIS	Start Date	End Date
TOF Calibration and Ckov Commissioning	2	SS	1	01a	02/06/15	04/06/15
Tracker Hardware Commissioning	6	SS	1	01a	04/06/15	10/06/15
Tracker Validation	2	SS	1	01a	10/06/15	12/06/15
Beamline Pre-commissioning	4	SS	1	01a	12/06/15	16/06/15
EMR Commissioning 1	1	SS	1	01a	16/06/15	17/06/15
ISIS Maintenance Day	0	FC	0	Maintenance	17/06/15	18/06/15
EMR Commissioning 2	3	FC	1	01a	18/06/15	21/06/15
EMR Commissioning 3	2	CT	1	01a	21/06/15	23/06/15
Complete magnet training	0	CT	0	01a	23/06/15	25/06/15
Tracker External Alignment	1	Done	1	01a	25/06/15	26/06/15
Alignment to Other Detectors	1	Done	1	01a	26/06/15	27/06/15
Beam-Based Alignment 1	7	Done	1	01a	27/06/15	04/07/15
ISIS Machine Physics	0	Done	0	Machine Physics	04/07/15	14/07/15
Beam-Based Alignment 2	2	Done	3	01b	14/07/15	14/07/15
Validation of Track Matching	1	Done	3	01b	14/07/15	15/07/15
Validation of Particle Identification	2	Done	3	01b	15/07/15	15/07/15
Beamline Commissioning	15	Done	3	01b	15/07/15	20/07/15
Optics Validation	21	Done	3	01b	20/07/15	27/07/15

- Blue – external constraint
- Red – ran out of time
- 9 shifts required to complete commissioning after 01b

Pessimistic run plan

Task	Number of Shifts	Magnets	Shifts Per Day	ISIS	Start Date	End Date
TOF Calibration and Ckov Commissioning	3	SS	1	01a	02/06/15	05/06/15
Tracker Hardware Commissioning 1	12	SS	1	01a	05/06/15	17/06/15
ISIS Maintenance Day	0	SS	0	Maintenance	17/06/15	18/06/15
Tracker Hardware Commissioning 2	3	SS	1	01a	18/06/15	21/06/15
Tracker Validation 1	4	SS	1	01a	21/06/15	25/06/15
Tracker Validation 2	5	FC	1	01a	25/06/15	30/06/15
Beamline Pre-commissioning 1	4	FC	1	01a	30/06/15	04/07/15
ISIS Machine Physics	0	CT	0	Machine Physics	04/07/15	14/07/15
Beamline Pre-commissioning 2	2	CT	0.75	01b	14/07/15	16/07/15
EMR Commissioning	9	CT	0.75	01b	16/07/15	28/07/15

- Blue – external constraint
- Red – ran out of time
- 68 shifts still required to complete commissioning after 01b

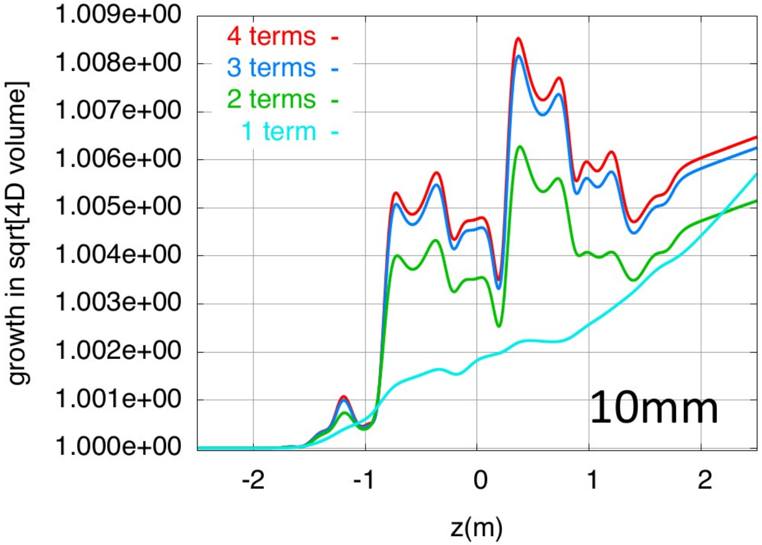
Plan for subsequent user runs

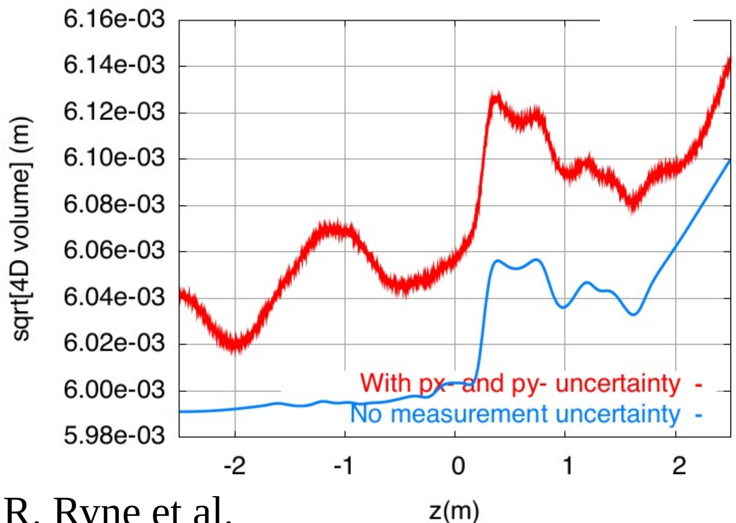
User Period	Run Type	Absorber	Focus Coil Mode	Run-time (days)	Total (days)
2015-02	Physics	Empty	Solenoid	15	
	LiH Install			8	
	Physics	LiH	Solenoid	15	38
2015-03	Calib/Setup			7	
	Physics	Empty	Flip	15	
	LiH Install			8	
	Physics	LiH	Flip	15	45
2015-04	Calib/Setup			7	
	Physics	lH2	Flip	18	
	Physics	lH2	Solenoid	18	43
					126

- Lithium Hydride will be installed before liquid Hydrogen
  - Extra 6 days for LiH install in each run eats into our contingency
- Subject to progress in 2015-01

Analysis and Optics

Effect of Non-Linear Dynamics





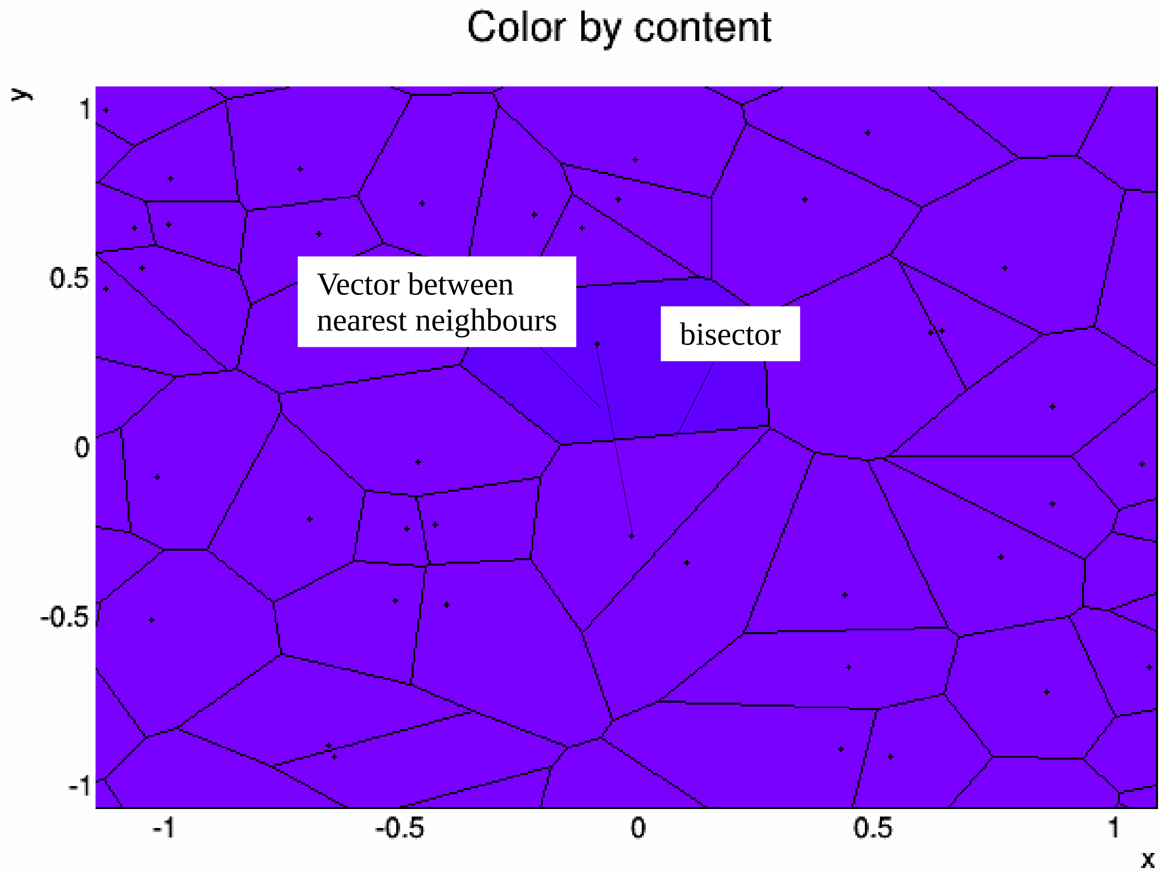
R. Ryne et al.

- Non-linear emittance growth can ruin the ionisation cooling effect
  - Appears to arise due to high-order terms in solenoidal field expansion
- Mismatch makes problem worse

Beam weighting

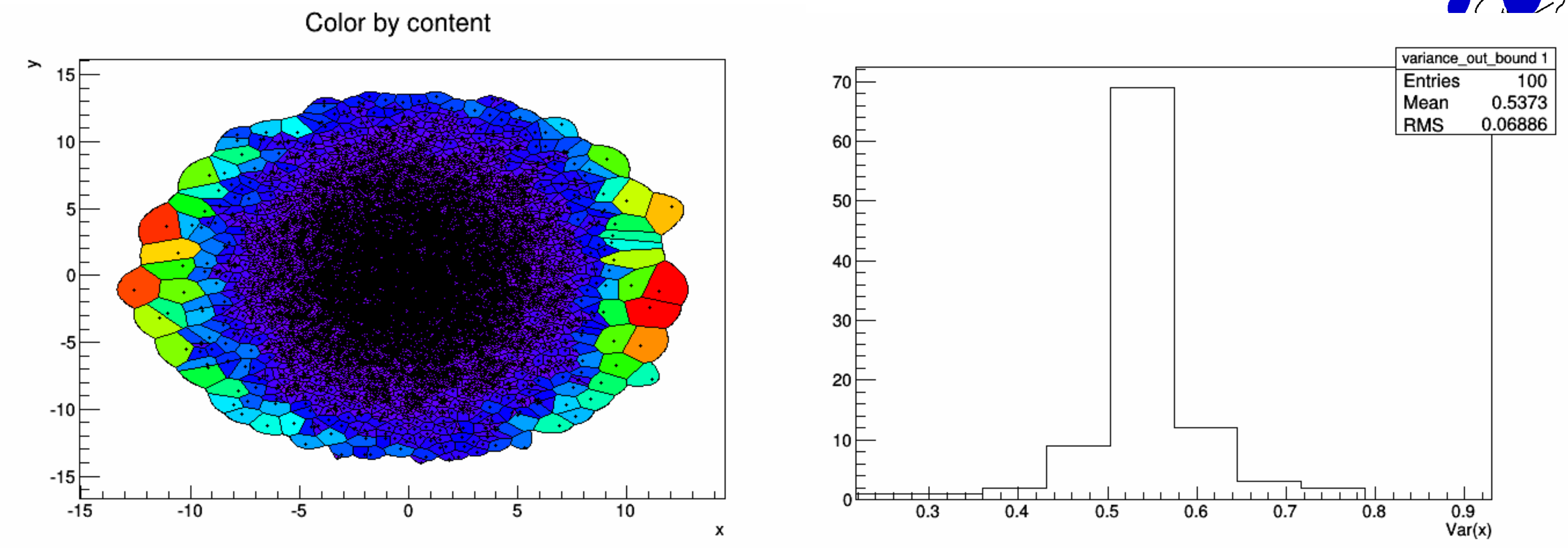
- Beam **selection** samples the beam events to try to find a sample of beam events that match some desired distribution
  - Try to select events in under populated regions
- Beam **weighting** applies statistical weights to events
  - Events in under-populated regions we count more than once
  - Events in over-populated regions we count less than once
  - We are allowed to apply fractional weights to these events
- Beam weighting algorithm
  - Decide which regions are over-populated or under-populated
  - Apply an appropriate statistical weighting
- How do we decide which regions are over-populated?
  - In a high dimensional space like 4D or 6D

Beam weighting (ND)



- Introduce “Voronoi tesselation”
  - For each point, find nearest neighbour vectors
  - Bisect nearest neighbour vectors to define a tile
  - Determines region nearest to a particular point
  - Content of the region is “phase space volume” of the point

Boundary effects



- Does it work?
  - Go from Var(x), Var(y) = 1, 1 to Var(x), Var(y) = 0.5, 1
  - Try applying weighting 100 times
  - Close enough?

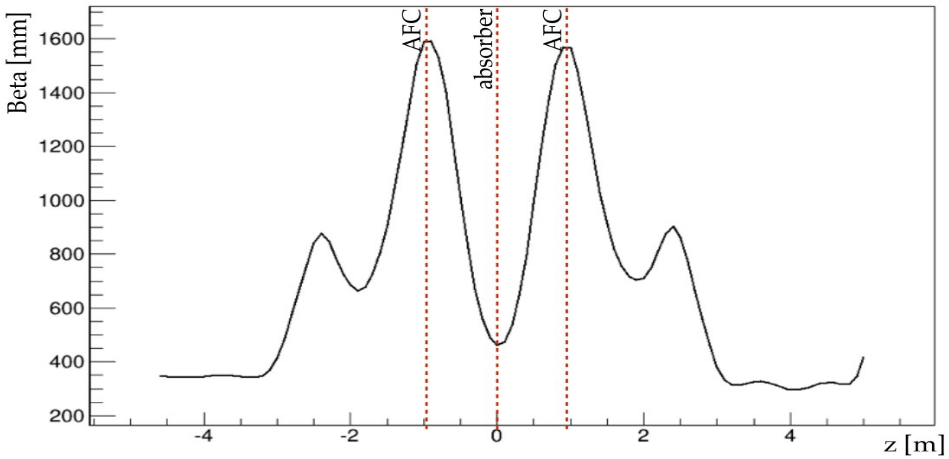
Bayesian Methods

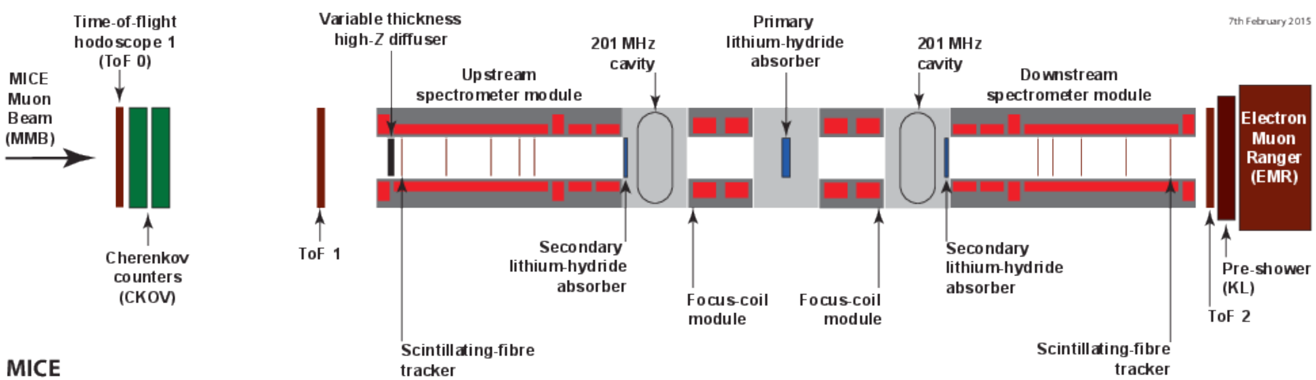
- Use Bayesian method to validate cooling channel model
  - No beam selection required!
  - e.g. magnet currents and measurement errors (toy MC)

param	exact	μ_{prior}	μ_{post}	σ_{prior}	σ_{post}
θ_1	151.634	147.	151.623	40.	.0185
θ_2	123.807	131.	123.752	40.	.0615
θ_3	142.602	135.	142.762	40.	.0722
θ_4	118.863	113.	118.930	40.	.0496
θ_5	103.874	104.	103.743	40.	.0652
θ_6	-101.920	-104.	-101.668	40.	.0918
θ_7	-108.330	-112.	-108.203	40.	.0753
θ_8	-132.950	-140.	-132.786	40.	.0976
θ_9	-127.378	-131.	-127.736	40.	.1266
θ_{10}	-133.948	-147.	-134.162	40.	.0669
τ_1	6.250e6	5.e6	6.256e6	1.0e6	.0903e6
τ_2	2500.	5000.	2434.	2236.	33.8
τ_3	6.250e6	5.e6	6.351e6	1.0e6	.0867
τ_4	2500.	5000.	2508.	2236.	36.7

Demonstration of Ionisation Cooling

Demonstration of Ionisation Cooling

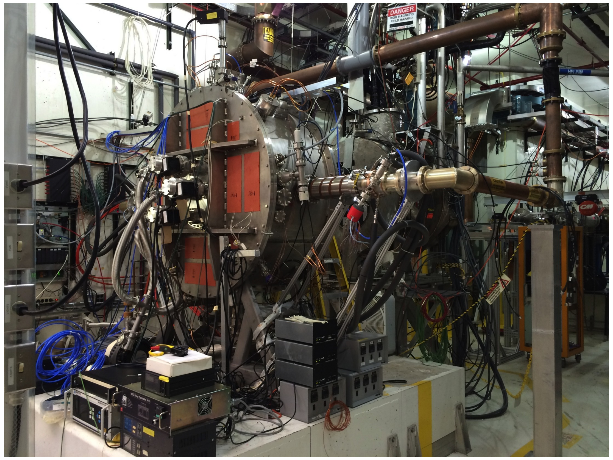


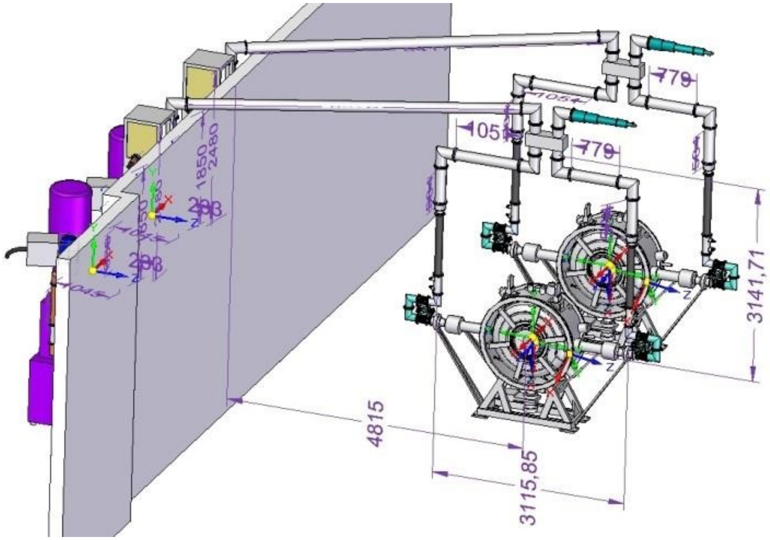


- Secondary absorber design decisions:
  - Baseline material is LiH – fallback is plastic
  - Baseline position is on radiation shutters – fallback is in SS bore
- Need to finalise FC->FC gap length – optics decision
- Talk by JB Lagrange on Thursday

Demonstration of Ionisation Cooling

- RF cavity operation in 0 B-field demonstrated
- More to hear about operation in > 0 T field later in the week
- RF power distribution system under design
  - Parts have been purchased, some retrofitting
- RF session on Thursday afternoon





To Conclude...

Conclusions

- Reminder of purpose and design of MICE
- Status of diagnostics
- Status of magnets
- Plans for operations
- Analysis of data
- Route to full demonstration of ionisation cooling

WINTER IS COMING
DATA
risovach.ru