To: G. Blair, J. Womersley
From: S. Peggs, for the MICE Project Board

Date: April 12, 2016

Cc: RLSR and MPB panels

Report from MICE Project Board Meeting 11

The eleventh meeting of the MICE Project Board (MPB) took place on April 5 and 6, at RAL, jointly with the seventh Resource Loaded Schedule Review (RLSR). Present for the joint committee were: Riccardo Bartolini, Charlotte Jamieson (ex officio), Dave Newbold, Steve Peggs, Ron Prwivo, Ian Robson (RLSR chair), Roger Ruber, Bruce Strauss (ex officio), Thomas Taylor and John Thomason.

The nominal layout for the Cooling Demonstration configuration is shown in Appendix A. The charge to the collaboration and the panel is in Appendix B. Previous recommendations and actions are in Appendix C. The agenda is in Appendix D.

MICE schedule to completion ("Flat cash", see e.g. Whyte slide 16)

Feb 2016	Step IV production data taking begins
Mar 2017	End of Step IV data taking.
Jul 2017	RF system ready for high power commissioning.
Jan 2018	Recovered Downstream Spectrometer Solenoid (SSD) delivered to RAL.
Aug 2018	Cooling Demonstration installation complete.
Feb 2019	CD commissioning complete.
Dec 2019	End of Cooling Demonstration data taking.
Oct 2020	End of data analysis.

The presentations made by MICE collaborators and staff members were of high quality, and the discussions that ensued were stimulating, direct and useful. We thank all the contributors and participants for their hard work, careful thought, and hospitality.

Significant data has already been taken in the Step IV configuration, and data-taking continues. We congratulate the collaboration on the interesting and new results that are emerging from Step IV data analysis, even in the absence of the RF systems that are necessary in the full Cooling Demonstration configuration. Well done, and keep up the good work!

Critical to the future of the Cooling Demonstration, and the future of MICE, is the recovery of the Downstream Spectrometer Solenoid (SSD). Nominal plans are for this U.S. deliverable, which is necessary for the Cooling Demonstration with RF, to be delivered in about January 2018. Topics of active current discussion are the possibility that procurement of a new SSD could be transferred to the UK, or that procurement could be abandoned and MICE terminated at the end of Step IV data analysis. SSD recovery resource issues are discussed at length in the RLSR report, while technical issues are discussed below

TECHNICAL SYSTEMS

RF systems

Good progress with the preparation of the RF system was reported. Work is ongoing on modifying the required parts for the high power RF distribution network and the high power RF amplifiers. The second triode has been tested up to half of its nominal output power, while the high voltage modulator has been upgraded to include a solid-state crowbar that has been tested up to the nominal voltage required for operation in MICE.

Production of the cavity modules is proceeding with the electro-polishing completed, and with test and frequency tuning ongoing. Six power couplers have been manufactured – two for the MTA at Fermilab and four for installation in MICE. The cavity's active frequency tuners are being assembled and tested. Final clean room assembly has been prepared and is awaiting availability of all components, with delivery to RAL scheduled for September 2016.

Good progress was also reported on the RF controls and monitoring, including the Low Level RF. The staffing difficulties at Daresbury Laboratory that were mentioned in the previous MPB report have been solved. An agreement is under discussion with CERN on the exchange and training of staff and expertise.

The layout of the proposed RF monitoring and feedback system was presented. Preliminary tests of the critical muon transit phase detection system method, using data from the cavity tests at the MTA, are encouraging. The RF group has identified suitable electronics hardware and now has to study and decide on the synchronization method for the trigger clock.

Absorbers

The cool down of the liquid hydrogen absorber (FC#2) in the MICE hall was not successful. A study showed that the heat loads by radiation and conduction through the cooling pipes were larger than foreseen. An improvement of the insulation is now foreseen. In addition, two minor vacuum leaks were identified: one on a feed-through; one on the indium seal of the window. Both leaks are being repaired. The system is scheduled to be available again by August 2016. In the meantime the experiment has been using gaseous xenon as an absorber, and is planning to use the lithium hydride absorber (FC#1).

Recommendations

1. Seek the advice of external experts on the proposed methods and hardware for the muon transit phase detection and trigger clock synchronization systems.

SPECTROMETER SOLENOID RECONSTRUCTION

A Spectrometer Solenoid Review was held at Fermilab in December 2015. The committee was provided with information on ongoing work to improve the quench protection of the solenoids, on how to reduce the peak field in the winding, and on an analysis of training quench locations in the magnets. It was confirmed that a sufficient quantity of conductor is available to make two new solenoids.

Solenoid Review recommendations cover implementation and commissioning of improved quench protection systems, finalizing the design of an upgraded solenoid incorporating a minimum of changes from the original design, and planning for the procurement of a new cold mass. The recommendations have been pursued in the intervening months.

The MICE Project Board was presented with a very plausible explanation for the long training endured by these solenoids, and for the loss of this training when the magnets undergo a thermal cycle. This defective behaviour can easily be corrected in a new magnet, with the real hope of substantially reducing the time (and associated cost) required to train a new magnet. These BNL studies will be completed by the end of April.

It is found that the total estimated cost (including contingency) of procuring a new magnet to replace SSD exceeds the funds available in the U.S. To face up to this new challenge, the MICE collaboration made a proposal to transfer the responsibility of procuring the magnet to the STFC, on the understanding that funds earmarked for this procurement will be transferred from the DOE to the STFC. RAL has started to evaluate this possibility.

On the basis of the information available to date, it appears that procuring a complete magnet (including the cryostat) is the path of least risk, at only marginally more cost than procuring just a new cold mass, followed by installation in the old cryostat. The magnet vendor would be supplied with the superconductor and cryocoolers that are available.

Actions

1. Ensure that all measures are taken for the protection of the upstream and downstream solenoids during Step IV runs.

2. STFC (RAL) should plan for the procurement of a single new cold mass, with an option for the supply of the enveloping cryostat. The vendor should be required to make the coil according to a detailed specification based on the knowledge of the previous magnets, supplemented by any intervening studies. Report to STFC as soon as possible – in about 6 months – in order to decide the course of action.

DATA ACQUISITION, SIMULATION & RECONSTRUCTION

This aspect of MICE was comprehensively presented during the meeting. It is clear that all aspects are now in excellent shape for Step IV and beyond – congratulations to those responsible!

The online technical systems of the experiment are now mature, and stable operation of all components is now the norm. Comprehensive online monitoring of the functioning and performance of all sub-detectors is now in place. Robust online reconstruction is available, offering prompt feedback on the overall performance of MICE. Hooks for the addition of the final set of systems for the Cooling Demonstration (including RF monitoring) have been defined.

The offline software suite is now operating sufficiently well to allow the final (publication-quality) analysis of Step IV data, with only a few optimisations remaining to be completed. Following major technical improvements to software, fully adequate computing resources are available to the collaboration for simulation and data analysis tasks, and a robust data curation and distribution strategy is being followed. The correct functioning of the entire software chain has been validated through comparison with Step IV data. Further tuning will continue to take place as the data sample increases.

Overall, MICE is now operating as a complete integrated experiment with good reliability and a well-trained support crew.

Recommendation

2. Ensure sufficient documentation of the "final" software suite, such that the code can be maintained in the long term, across any future personnel changes.

COMMISSIONING, OPERATIONS & DATA ANALYSIS

We congratulate the collaboration on the smooth commencement of production data-taking in Step IV, since the last MPB meeting, despite the inoperability of some of the superconducting magnet coils.

Safety

There have been no significant MICE safety incidents since the last MPB meeting. The team now appears to have safety management well under control, with the implementation of the STFC SHE safety framework now being much more robust. Particular issues regarding working in the confined space inside the PRY are being addressed. Staff safety training has improved. The MICE Liquid Hydrogen Working Group is working towards a revised safety sign off in August 2016.

Step IV operations

Commissioning, operations and data analysis have proceeded throughout ISIS Cycles 2015/03 and 2015/04, with the focus on:

a) Cycle 2015/03 (November – December 2015): Absorber and LH2 system work; Decay solenoid PSU repair; SS power supply and vacuum work; Focus coil commissioning; Xe/He absorber running.

b) Cycle 2015/04 (Feb 2016 – March 2016): Calibration and alignment; Decay solenoid PSU re-commissioning; Empty and LiH absorber running.

Data taking during 2015/03 and (in particular) 2015/04 went very smoothly, with good communication between shifters, MICE Operations Managers (MOMs), and experts, with rapid first pass reconstruction and data analysis. The programme for remainder of Step IV during calendar year 2016 looks achievable, if all equipment continues to operate successfully, with the highest risk being the further failure of SSD. Step IV data taking may well continue into 2017, depending on the revised Cooling Demonstration schedule.

Ways to enhance data rates for future runs are being studied: by making better use of the beam loss "allocation" afforded by ISIS; and by sacrificing some of the initial purity of the muon beam, using time of flight methods to separate muons from pions. The aim is now to saturate user runs with data taking.

Shift patterns and shift training are now well established and robust. Three Duty Coordinators (DCs) have now been appointed and are proving effective – all have received STFC safety training and have been appointed by the PPD Director. The DC is expected to be present in the MICE control room at all times if 24/7 commissioning and maintenance is in operation. The implementation of the DC/MOM system has enhanced coordination between the operations and commissioning phases of the experiment, and means that the MOMs now only need to be rostered during user cycles.

Interaction with ISIS on run coordination and issue management continues to go well, with regular operations meetings being held. RF engineering co-operation with ISIS has made significant progress, to the extent that a MICE RF engineer has now been embedded into the ISIS management structure, and ISIS is leading the recruitment campaign for another.

Initiatives to enhance international effort have been fruitful, particularly with the advent of magnet, RF and accelerator science experts from China (IHEP), negotiations on collaboration and staff exchange with CERN, and Korean representatives expected to attend the July 16 MICE collaboration meeting.

Data Analysis

The MPB presentations on data analysis and reconstruction were a pleasure. It was also good to see presented a clear plan for both technical and physics publications, with identified collaborators responsible for these outputs.

The data taken in October 2015 have now been thoroughly analysed, and a first set of emittance measurements was presented. The analysis benefitted significantly from the discussions and the recommendations of the MICE Optics Review that was held in January 2016. In particular, the subsampling of the muon phase space at ToF1, and the reduction of the 6D phase space in energy slices to take account of the effects of the dispersion of the transfer line from MICE, have been taken into account and were clearly explained in the presentation. Amplitude cuts remove large amplitude particles and energy filters minimise the impact of chromatic aberrations. The resulting emittance was shown to be constant along the upstream tracker, as expected.

The MPB heard that a different tune of the incoming transfer line produces what is called a "pionic beam", with a factor of 5 increase in the muon rate. The lack of magnet coil M1 does not significantly affect the transmission efficiency – 90% levels are maintained. It was surprising to hear that 70% efficiencies would also be maintained if M2 also failed, in addition to M1. The impact that the lack of M2 would have on the process of emittance reconstruction is not fully clear. It was stated that the optics Twiss functions become uncontrolled in TS2, although the transmission is still reasonable.

Recommendations

3. Carry on with Step IV, and good luck with data taking and analysis.

4. Conduct comprehensive and systematic studies of transfer line optimization, in order to ensure the maximum possible return on the available ISIS beam time.

5. Fully quantify the expected performance of the experiment for emittance measurement in the absence of the SSD M2 coil, including an analysis of the systematic uncertainties in the measurement caused by possible acceptance effects.

APPENDIX A – COOLING DEMONSTRATION LAYOUT

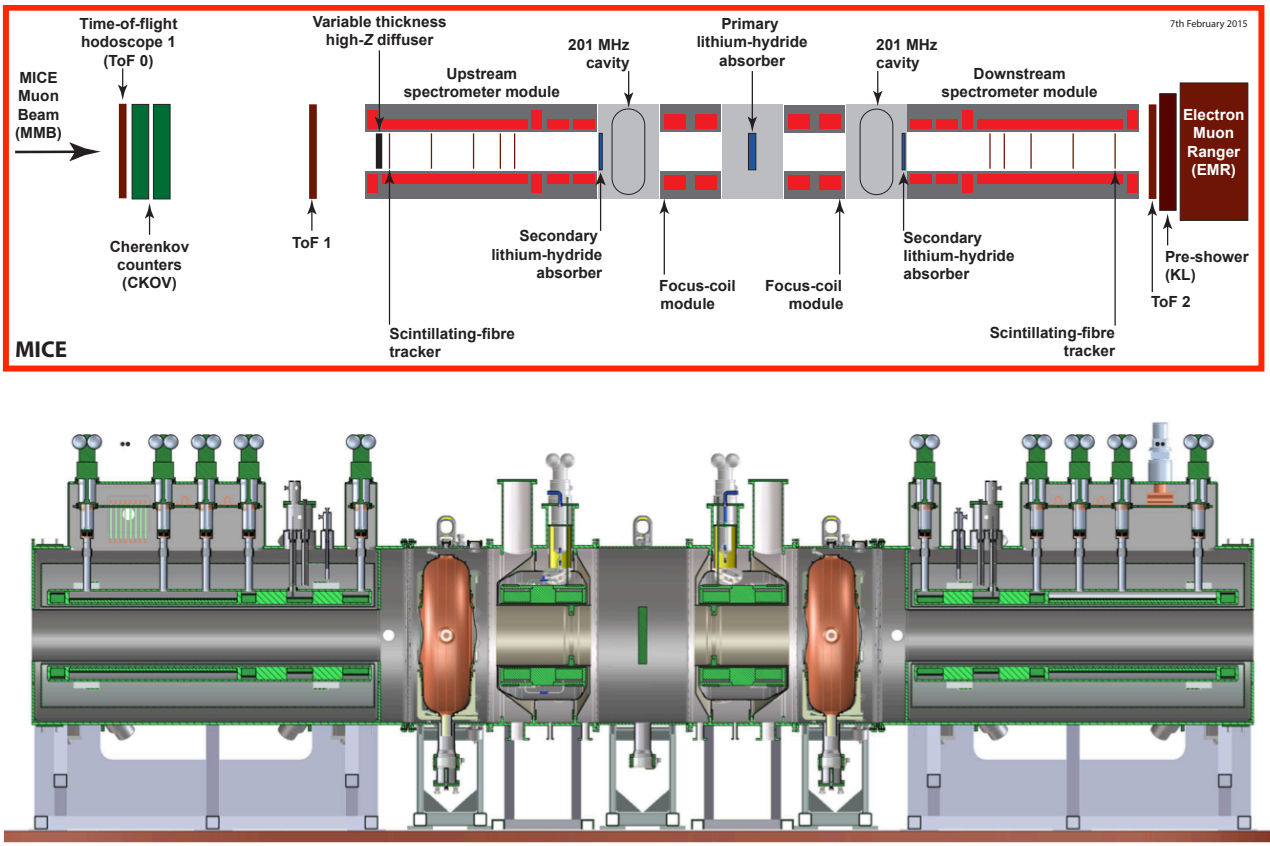

Figure 1. The nominal layout for the MICE Cooling Demonstration, with RF.

APPENDIX B – CHARGE

Charge to MICE Project Board meeting 11, 5th & 6th April, 2016

This review will again be split, with the Resource Loaded Schedule Review (RLSR) aspect being covered in the first part of the meeting, followed by sessions with a technical focus. As at previous meetings members of the panel will remain the same throughout to avoid unnecessary repetition. The outcome of the RLSR and MICE Project Board (MPB) will be reported to the MICE Funding Agency Committee (FAC) meeting that will take place in the afternoon of 6 April and will be chaired by John Womersley. A written report will also be submitted to Grahame Blair and John Womersley.

The events with the downstream spectrometer solenoid have had a major impact on the experiment. Understanding the recovery route and the implications that this has on the schedule and costs will be important in this meeting as will understanding the risks to all aspects of the project and its stakeholders.

The main focus of this meeting is to;

1. Confirm the goals and criteria for scientific/technical success,
2. define technical issues to be solved for,
    a. Superconducting magnets
    b. Balance of systems
3. consider the revised schedule taking account the DOE and STFC integrated funding profiles,
4. advise the funding agencies on clear go/no-go decision points associated with the spectrometer solenoid recovery plan,
5. consider whether the goals can be achieved in light of currently available information.

The RLSR section will concentrate on the human, financial and technical resources that are required to achieve the key milestones, and for completion of the MICE program within the known funding profiles (i.e. the US profile for the 3 fiscal years starting in 2015 of $9M, $6M $3M, flat cash at £3M/year in the UK and the continued contributions of the funding agencies supporting the non-UK, non-US members of the collaboration). The panel will want to consider the implications of a resource limited approach, and to understand fully the assumptions being made by the project and the experimental collaboration, as well as their assessment of the potential schedule delays.

The focus for the remaining sections of the MPB will be progress towards the achievement of scientific and technical objectives of the project, and the implications of the technical challenges on the final goal: to demonstrate ionisation cooling. The panel will consider the MICE analysis of the major active and future technical risks on the scientific outcome, and the responses being taken to mitigate them.

The collaboration is asked to;

1. Present in the RLSR section of the meeting a revised schedule that takes account of the spectrometer solenoid issues and in doing so to;
    a. Examine DOE and STFC integrated funding profiles.
        i. Consider realistic time lines and end dates
        ii. Acknowledge and define the uncertainties associated with different recovery routes and the decision points
    b. Define available specific human resources needed.
        i. UK Side
        ii. US Side

    The scientific aspects of the project should not be included at this stage and the focus should be on setting out clearly the current status of the resources (staff/cash), schedule and risks to achieve Step IV and to demonstrate ionisation cooling. This should identify, with the resources available,
        i. progress against the established key milestones,
        ii. the remaining risk factors as well as any newly identified risks, and
        iii. the most likely schedule and subsequent cost when these risks are fully incorporated.
2. In the MPB sections of the meeting the collaboration is asked to present its progress to date and future plans for the fullest possible exploitation of the MICE experiment at Step IV as well as the final cooling demonstration, for example considering
        i. staffing from broad geographical regions, and from multiple disciplines and areas of expertise
        ii. multiple data analysis techniques, perspectives, and preparatory simulations

The panel is asked to;

1. Advise on the implications of the current slippage in terms of cost and to the science goals.
2. Highlight the outstanding risks and comment on their management and cost analysis, taking into account the progress to date.
3. Monitor integrated project management performance, where appropriate.
4. Comment on whether the goals can be achieved.
5. Comment on the scientific output to date.
6. Outline the steps and timescale needed to put in place a recovery plan for the spectrometer solenoid.

APPENDIX C – PREVIOUS RECOMMENDATIONS & ACTIONS

Recommendations from RLSR-6

1. The project is recommended to go ahead and procure the LiH secondary discs as soon as possible using prepayment and accruals (advice can be obtained from STFC on this procedure).

2. The Panel strongly recommends that the DoE offers some formal alleviation to the current hard schedule end-date and 9:6:3 funding profile. While this goes against the grain for top-level project management, the Panel is convinced that it is now necessary to relax these boundaries/constraints to reduce ongoing risk and maximise the probability of success for the MICE project to achieve its goals and hence maximise return for the funding agencies.

3. The US Project Director should not undertake a fully resource-loaded schedule for the second Solenoid Review but rather investigate more than one option that provides a 'good-enough' solution and subsequently spend time working on the resource loaded impacts in detail to report to the funding agencies in ~January.

4. The STFC and DoE need to jointly agree on the future funding for MICE over the next three months – this is the most important recommendation/action from the entire Review.

Actions from RLSR-6

1. The STFC needs to communicate concerns about potential transferred risks to the US project side prior to the second Solenoid Review.

2. The STFC needs to be made aware of the consequences of the flat-cash funding profile on the schedule of the project (action on the RLSR Chair).

3. The Project Spokesperson is actioned to approach other agencies involved in MICE to determine if appropriate resource for construction and commissioning could be injected into the project – especially in the RF area.

4. The collaboration must be fully informed of input to and outputs from the second Solenoid Review.

5. The output from the second Solenoid Review must be fed into the Beam Dynamics review of early December.

6. The case for extending the data-taking for Step IV into ISIS run 2016/2 must be very carefully considered in terms of the risk to the overall schedule to completion (and thus increased cost) and this must be presented to the next RLSR/PMB.

Recommendations from MPB-10

Technical systems

1. Investigate the required resources to make the first amplifier chain available in the MICE hall simultaneously with the first cavity. Report back at the next MPB.

2. Prepare a plan that finds the extra staff resources required to put the RF project on track with the MICE schedule requirements, if the flat cash funding profile is relieved, by January 2016.

Data Acquisition, Simulation and Reconstruction

3. Put into place a strong change management regime such that the status of the entire apparatus can be understood for future data analysis, thereby minimizing risk for future exploitation of the data.

4. Finish the evaluation and optimization of the optics configuration for Step IV, such that clear statements can be made about the reach of the experiment at the Beam Dynamics Review.

5. Carry out a similar program, investigating the reach of the experiment in a scenario with no M1 coil in the Cooling Demonstration with RF.

Commissioning, Operations and Data Analysis

6. Ensure that adequate effort is available, and arrangements put in place, such that any and all data-taking opportunities can be exploited.

7. Reserve reasonable time on the test schedule of the first RF module-amplifier chain for the validation of the Low Level RF system and the muon-RF phase-timing scheme.

Actions from MPB-10

Technical systems

1. Show that the organization, effort and resources allocated to the RF work package are adequate with respect to the requirements of the experiment's goal and time schedule, at the next MPB.

2. Respond to the RF system recommendations of the September 2015 RF Review, and report at the next MPB.

Commissioning, Operations and Data Analysis

3. MICE must continue to operate a safety-first policy at all times, even under the pressure of operational setbacks.

Recommendations from Spectrometer Solenoid Review

1. Prepare technical, cost, schedule and risk information to an equivalent level for the Second Spectrometer Solenoid Review (in November or December) such that a preferred path going forward is confirmed.

2. Develop the preferred option from that review in more detail such that a full project plan is available for review in (about) January 2016.

3. Consider one team for fabrication and test of a new coil assembly at one location (for instance Fermilab), and another team for integration into the cryostat at a second location (for instance Europe).

Actions from Spectrometer Solenoid Review

1. Review and implement changes to the spectrometer solenoid power supply integrated system including a means for energy extraction before any further powering of either solenoid.

2. Present conductor specifications, coil load line, operating point information, and a mechanical analysis of the coil and bobbin assembly at the Second Spectrometer Solenoid Review, so that any proposed design changes to the spectrometer solenoid in option (2) are well documented.

3. Confirm the charge and scope of the Second Spectrometer Solenoid Review by November 7 2015.

4. Confirm the optics and performance limitations of various options at the Beam Dynamics Review, and keep the collaboration fully informed of these options.

5. Confirm the timing and expectations for the follow-on review and meetings (around January) with the collaboration and the funding agencies.

APPENDIX D – AGENDA

RLSR-7 & MPB-11 outline agendas – April 5 & 6, 2016.

	05 April 2016		
09:00-09:20	**RLSR closed session – introduction**		
09:20-10:00	Project overview: 01-2016-04-05-Long.pptx	K. Long	30' + 10'
10:00-10:15	Coffee		15'
10:15-12:45	**RLSR presentations & questions**		
10:15-11:15	Downstream spectrometer solenoid recovery plan: 02-2016-04-05a-Palmer.pptx , 02-2016-04-05b-Wanderer.pptx	M. Palmer / P. Wanderer	40' + 20'
11:15-11:50	Schedule to completion, project risks, overview of critical resources and interaces, magnet commissioning: 03-2016-04-05-Whyte.pdf	C. Whyte	25' + 10'
11:50-12:15	US project plan for MICE (including financial plan and risks): 04-2016-04-05-Garbincius.pptx	P. Garbincius	20' + 5'
12:15-12:40	UK project plan (including financial plan and risks): 05-2016-04-05_Grant.pptx	A. Grant	20' + 5'
Added	UK procurement process and timelines for SSD: 05-2016-04-05a-Boehm.pdf	J. Boehm	20' + 5'
12:45-13:15	**Lunch**		
13:15-14:30	**RLSR closed session session--critical findings**		
14:30-17:30	**MPB: Step IV commissioning, operations and control**		
14:30-14:55	Step IV commissioning and operation: 06-2016-04-05-Boyd.pdf	S. Boyd	20' + 5'
14:55-15:15	Online environment and controls: 07-2016-04-05-Hanlet.pdf	P. Hanlet	15' + 5'
15:15-15:30	Interleaving commissioning, maintenance and operations at Step IV: 08-2016-04-05-Hodgson.pdf	P. Hodgson	15' + 5'
15:30-15:45	**Tea**		
15:45-16:05	Liquid-hydrogen absorber recovery: 09-2016-04-05-Bayliss.pdf	V. Bayliss	15' + 5'
16:05-16:25	Spectrometer Solenoid operations in Step IV: 10-2016-04-05-Bross.pptx	A. Bross	15' + 5'
16:25-16:45	Step IV highlight 1: initial study of action and emittance: 11-2016-04-05-Blackmore.pdf	V. Blackmore	20' + 5'
16:45-17:05	Step IV highlight 2: initial scattering study: 12-2016-04-05-Bayes.pdf	R. Bayes	20' + 5'
	Physics programme and Step IV data taking plan: 13-2016-04-05-Rogers.pdf	C. Rogers	20' + 5'
17:30-18:00	**Closed session, report writing**		
18:00	**Adjourn**		

	06 April 2016		
08:30-09:30	**Reconstruction, simulation and data flow**		
	Status and performance of the MAUS reconstruction: 14-2016-04-06-Dobbs.pdf	A. Dobbs	15' + 5'
	Status and performance of the MAUS simulation: 15-2016-04-06-Drielsma.pdf	F. Drielsma	15' + 5'
	MICE data processing and data flow: 16-2016-04-06-Rajaram.pdf	D. Rajaram	15' + 5'
09:30-10:30	**Cooling demonstration integration, SC magnets and RF**		
	Cooling demonstration integration: 17-2016-04-06-Tarrant.ppt	J. Tarrant	
	Super-conducting magnets at Step IV and for the cooling demonstration: 18-2016-04-06-Boehm.pdf	J. Boehm	15' + 5'
	RF system: status of preparation and plans for commissioning and implementation for the cooling demo: 19-2016-04-06-Ronald.pdf	K. Ronald	15' + 5'
10:30-10:45	**Closed session, report writing**		
10:45-12:00	**Close-out with MICE management**		
13:00	**Adjourn for report writing**		