

# WT3: Work package description

Project Number <sup>1</sup>	261905	Project Acronym <sup>2</sup>	TIARA
-----------------------------	--------	------------------------------	-------

## One form per Work Package

Work package number <sup>53</sup>	WP7	Type of activity <sup>54</sup>	RTD
Work package title	Ionisation Cooling Test Facility		
Start month	1		
End month	36		
Lead beneficiary number <sup>55</sup>	9		

## Objectives

The principal objective of this work package is to deliver detailed design reports of the RF power infrastructure upgrades that the Ionisation Cooling Test Facility at the Rutherford Appleton Laboratory requires for it to become the world's laboratory for ionization cooling R&D.

Muon storage rings have been proposed for use as sources of intense high-energy neutrino beams at the Neutrino Factory and as the basis for multi-TeV lepton-antilepton collisions at the Muon Collider. To optimize the performance of such facilities requires the phase-space compression (cooling) of the muon beam prior to acceleration and storage. The short muon-lifetime makes it impossible to employ traditional techniques to cool the beam while maintaining the muon-beam intensity. Ionization cooling, a process in which the muon beam is passed through a series of liquid-hydrogen absorbers followed by accelerating RF-cavities, is the technique proposed to cool the muon beam. A globally unique Ionisation Cooling Test Facility (ICTF) is under construction at the Rutherford Appleton Laboratory to provide the infrastructure required to allow the first steps in an ionization-cooling R&D programme to be carried out.

The ICTF presently serves the international Muon Ionisation Cooling Experiment (MICE) collaboration by providing a muon beam and the necessary infrastructure to carry out the first steps of the MICE programme. MICE is a collaboration of roughly 150 physicists and engineers from Europe, Japan, and the USA. The international MICE collaboration will provide the equipment that makes up the MICE cooling channel and the muon spectrometer systems. The value of these contributions has been estimated to be ~€40M. The goal of the MICE collaboration is to construct a single lattice cell of the Neutrino Factory cooling channel and to measure its performance in a variety of beam conditions and lattice configurations. The collaboration seeks to carry out the experiment in time for the results to inform the decision point (roughly 2012) on the future direction of the neutrino programme in Europe as identified by the Strategy Session of CERN Council. The importance of the MICE experiment and the ICTF to the European accelerator R&D programme is widely recognized and resources to allow Transnational Access to the facility have been approved by the Commission through the EuCARD Integrating Activity.

It is planned that the MICE experiment will be built up in six 'Steps'. Step I, which is being carried out at the moment, will perform a detailed characterization of the ICTF muon beam to establish that it can deliver the range of emittance and momentum required by the experiment. It is anticipated that Step I will be complete by the end of summer 2010. The muon spectrometer system will be implemented in Step II (first quarter 2011) and Step III (third quarter 2011) and the first liquid-hydrogen absorber and focus-coil (AFC) system will be implemented in Step IV (2011). Step V will add a first section of linac and a second AFC module and is expected to be complete in the second quarter of 2012/13. The upgrades to the ICTF that will be carried out within TIARA-pp will therefore enable Step V of MICE to be implemented and the first demonstration of ionization cooling to be made. The final configuration of the experiment will be reached at Step VI (2013) with the inclusion of the second section of linac and the third AFC module.

The design of the infrastructure that is required for the ICTF to serve MICE up to Step IV is in hand, supported by the STFC. The work within TIARA-pp described below is required to allow the detailed design and specification of the RF power distribution system by which the ICTF can support Step V of MICE. In addition, by carrying out the design work required to further upgrade the RF power infrastructure, the ICTF will be able to support Step VI of MICE as part of the TIARA distributed network of European infrastructures for accelerator R&D.

# WT3: Work package description

A future Muon Collider would require an even more aggressive ionization cooling system that would reduce the size of the beam in all six phase-space dimensions. Various schemes have been proposed to achieve this. The US Muon Collider Task Force (MCTF) and Neutrino Factory and Muon Collider Collaboration (NFMCC) have taken the lead in the development of conceptual and engineering designs for 6D cooling lattices. The NFMCC and the MCTF are now collaborating under the umbrella of the US Muon Accelerator Programme (MAP). One particular proposal, MANX, which is based on a helical transport channel filled with high-pressure hydrogen gas, has already been proposed as a possible user of the ICTF once the MICE experiment has been completed. The MANX collaboration has initiated discussion of the implementation of the experiment at the ICTF using the MICE spectrometer systems with the MICE collaboration and resources have been made available in the US for design work on the 6D cooling experiment to continue.

While no decision has yet been reached on use of the ICTF by MANX, their interest demonstrates the broad applicability and generic value of the Ionisation Cooling Test Facility at the Rutherford Appleton Laboratory as an accelerator R&D infrastructure to be included in TIARA. It is the only facility in the world capable of providing the necessary infrastructure to develop the technologies required for muon cooling for the Neutrino Factory and Muon Collider communities. MICE is expected to be completed by 2014 after which the six-dimensional (6D) ionization cooling R&D programme will be initiated. It is likely that the 6D cooling programme will take 10 years to complete, therefore it is crucial that the ICTF infrastructure be sustainable until at least 2024. It is therefore essential that preparations are made to replace the triode-based amplifiers in a future upgrade. For this reason, it is proposed to carry out a design study of a novel Diacrode-based high-power amplifier that will form the basis of a future upgrade to the ICTF RF power system.

The work that will be carried out in this work package will allow the ICTF to realize its full potential as the world's ionization-cooling R&D infrastructure. The upgraded ICTF will become part of the internationally-open TIARA network of infrastructures for accelerator R&D in Europe, allowing Europe to contribute a unique facility to the international accelerator R&D effort and ensuring continued European leadership in this area.

## Description of work and role of partners

The work within this WP will be carried out in two top-level tasks through which design reports for the RF power upgrades required to serve MICE Steps V and VI will be produced, and a design study of a Diacrode-based amplifier to ensure the long-term sustainability of the ICTF will be carried out.

Critical to the success of this programme is the close collaboration of specialist electrical and RF engineers at CERN and at the STFC Daresbury and Rutherford Appleton Laboratories (DL and RAL respectively). RF amplifiers for the Ionisation Cooling Test Facility (ICTF) have been refurbished at CERN and at DL. The design of the RF-power distribution system must take into account the safety requirements arising from the use of liquid and gaseous hydrogen as well as the constraints imposed by personnel safety and the restricted space in the ICTF Hall. The CERN RF group has an established track record and a substantial depth of experience in the area of high-power RF systems. RF systems of similar specification to those required for the ICTF are used on the ISIS injector linac and for CERN's planned SPS upgrade. Both CERN and STFC RF specialists therefore have extensive experience in the design, implementation, commissioning, and maintenance of these systems. By pooling their expertise the TIARA WP7 team will be able to create the robust and flexible system required for the long-term viability of the ICTF. In addition, the close collaboration that will be forged through the work proposed here will be invaluable in the future development of the ICTF to serve the more demanding, six-dimensional cooling programme in the TIARA era.

### Upgrade to ICTF power infrastructure

The work within this task will be to coordinate the work at CERN, DL, and RAL on the the specification, detailed design, and installation and test of the first power-amplifier system.

#### Task 7.1: ICTF RF power infrastructure

The principal aim of this subtask is to deliver the complete design of the RF power distribution system. The work will proceed by reviewing the layout and RF power requirements of the ICTF in order to produce a specification document for the RF power distribution system. This will be done in two steps – the first half system will be sufficient for Step V of the MICE experiment, while the full system will be required for Step VI of MICE and for the full ICTF implementation.

The second ICTF high power RF amplifier will be assembled at Daresbury Laboratory and tested with the existing ICTF RF System #1 there. Subsequently the complete RF System #1 will be dismantled, packed and

# WT3: Work package description

shipped to RAL where it will be installed and commissioned in the ICTF Hall, thus providing a source of RF power for the MICE experiment. The installation of the equipment in the ICTF Hall will be carried out by the ICTF installation team, under the supervision and with the support of the personnel supported by TIARA WP7. Commissioning of the system will be the responsibility of the TIARA WP7 personnel.

Once the installation and commissioning of the first RF Amplifier system is complete, the focus of the work will move to the design of the RF power distribution system required for the full scope of the ICTF.

## Task 7.3: Novel pulsed RF power amplifier design

The existing ICTF power amplifiers are based on relatively old technology, using high power triodes with glass envelopes. While sufficient tubes are being procured to allow the ICTF to serve the MICE experiment, the production of these tubes will be discontinued. For this reason, future multi-megawatt RF power systems will use more modern high power tubes, for example Diacrodes®. For the ICTF to serve the ionization cooling R&D programme of the future, for example 6D cooling experiments such as MANX, it is essential to develop an alternative 201 MHz power source. Therefore, it is planned to perform a design study of a 201 MHz, 2—3 MW, pulsed power amplifier in the framework of TIARA-pp. This design study will fully exploit synergy, since similar RF systems will be required at many other high-power facilities in the future, including, for example, the proposed upgrade to CERN's SPS and the possible upgrade of the ISIS facility at RAL to a multi-MW, pulsed neutron spallation source.

## Summary tasks and sub-task breakdown

Task Num Short Name Description

7 ICTFPwr Upgrade to ICTF power infrastructure

7.1 RFP ICTF RF power infrastructure

7.1.1 RevLO Review of layout and requirements in ICTF Hall

7.1.2 DSStpV Design and specification of the RF power distribution system for MICE Step V

7.1.3 Amp#2Ass Assembly of RF High Power Amplifier #2

7.1.4 Amp#2Tst Test of RF High Power Amplifier #2 (at DL)

7.1.5 Amp#1Pck Dismantling & packing of RF System #1

7.1.6 Amp#1Shp Transport of RF System #1 to RAL

7.1.7 Amp#1Inst Installation of RF System #1 in ICTF Hall (with dummy load)

7.1.8 Amp#1Com Commissioning of RF System #1 in ICTF Hall

7.1.9 DSStpVI Design and specification of the RF power distribution system for MICE Step VI

7.2 NRFamp Novel pulsed RF power amplifier design

7.2.1 ICTFRFNds Specify ICTF RF system upgrade needs

7.2.2 RFSurv Survey for relevant existing RF power systems

7.2.3 PSSpec Specify power supply and protection circuitry

7.2.4 SimDiac Computer simulation of Diacrode with input/output circuits

7.2.5 IOMock Build input and output circuit lab mock-ups

7.2.6 LPTst low power tests of the lab mock-ups

7.2.7 IntStud Integration of power amplifier, power supply and diacrode study

7.2.8 SysAna Overall system analysis and performance predictions

7.2.9 RedactRep Redaction of design report

## Person-Months per Participant

Participant number <sup>10</sup>	Participant short name <sup>11</sup>	Person-months per participant
2	CERN	12.80
9	STFC	34.70
	Total	47.50

# WT3:

## Work package description

### List of deliverables

Deliverable Number <sup>61</sup>	Deliverable Title	Lead beneficiary number	Estimated indicative person-months	Nature <sup>62</sup>	Dissemination level <sup>63</sup>	Delivery date <sup>64</sup>
D7.1	RFSysV-Spec	9	10.00	R	PU	15
D7.2	RFamp1-Test	9	17.00	R	PU	33
D7.3	RFSysVI-Spec	9	8.50	R	PU	36
D7.4	RF_Ampl-DR	2	12.00	R	PU	36
Total			47.50			

### Description of deliverables

- D7.1) RFSysV-Spec: Report on the design and specification of ICTF RF power distribution system for MICE Step V [month 15]
- D7.2) RFamp1-Test: Report on commissioning of the first RF amplifier system in the ICTF Hall. [month 33]
- D7.3) RFSysVI-Spec: Report on the design and specification of ICTF RF power distribution system for MICE Step VI (full ICTF implementation) [month 36]
- D7.4) RF\_Ampl-DR: Design report of a 3 MW power amplifier [month 36]

### Schedule of relevant Milestones

Milestone number <sup>59</sup>	Milestone name	Lead beneficiary number	Delivery date from Annex I <sup>60</sup>	Comments
MS27	RFSysReq	9	8	Report on RF system layout and requirements
MS28	SymDiac	2	19	Simulation of Diacrode complete