Deliverable Plan

C. T. Rogers
On behalf of
Muon Production and Cooling Working Group

Work Package Description

Workpackage Description
Muon production and cooling is a key element of the muon collider and entirely novel: * The muon collider demands a **high power target** capable of capturing an incredibly high flux of pions. The euronu and MAP concept considered a solenoid-based capture system that **exceeds** equivalent mu2e systems **by orders of magnitude** in both **power** and **field**. * The muon collider requires **ionisation cooling** to deliver high luminosity. This is a **unique system** that determines the eventual collider luminosity. Such a system has never been built. MAP showed capability for reduction in emittance by several orders of magnitude, roughly consistent with the requirements for a collider, but no integrated design was available. This is a performance driver for the entire facility.

6D cooling

International MUON Collider Collaboration

Objectives							
Basic: Develop a realistic 6D cooling scheme.							
Develop the existing component designs to make an integrated 6D cooling scheme. This is essential to deliver a realistic performance estimate.							
High-level Deliverables							
1) Develop a baseline 6D cooling system, taking as input MAP and euronu concepts and assuming reasonable parameters for other parts of the muon production system (e.g. capture, charge separation, bunch merge, etc).							
2) Optimise the 6D cooling system, taking into account likely available RF gradients and magnetic fields.							
2) Develop other elements of the capture and cooling system. In particular, re-optimise the capture chicane and muon front end; design a charge separation system; optimise the bunch merge system							
3) Understand potential material physics issues, collective effects in ionisation cooling. Look at engineering integration issues. Look at absorber design including heat load and its removal. Assess possibility for experimental verification of any simulation issues.							
Resources	1	2	3		1	2	3
Staff	0.5	0	2	Student		6	4
Postdoc	3	4	6	Material	(compute)	0	0
Interested partners							
RAL, resources partly in place, FNAL, BNL							

Tasks and Resources

1	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Monte-Carlo simulations to develop baseline 6D cooling lattice		3		
	Maintenance of codes	0.5			
	Optimisation of 6D cooling lattice		1	1.5	
	Capture chicane and front end optimisation		1	1.5	
	Charge separation system design		1	1.5	
	Bunch merge optimisation		1	1.5	
	Study sensitivity to material physics model		2		
	Engineering integration issues	1			
	Absorber design (incl. Heat load)	1			
	Simulation of collective effects		2	2	
	Experimental validation of collective effects		2	2	
	Develop appropriate RF cavities	In RF package			
	Develop appropriate magnets	In magnet package			

Final cooling

Objectives

Basic: Develop an optimised final cooling scheme.

The final cooling scheme is a performance driver for the entire facility, so it has been picked out as especially deserving effort.

High-level Deliverables

1) Optimised final cooling scheme, taking into account current and future availability of high-field solenoids.

2) Performance estimates for alternate final cooling schemes to reach extremely low emittances that can yield vastly improved facility performance. Schemes such as PIC, frictional cooling and emittance exchange should be considered.

3) Assessment of engineering integration issues – in particular the absorber engineering where there is large instantaneous heat load and challenges in integrating Hydrogen cryogenics with magnet systems.

Resources	1	2	3		1	2	3
Staff	0.5	0	2	Student		6	
Postdoc	4	4	0	Material	(compute)	0	

Interested partners

RAL, CERN, FNAL, BNL, Jlab, maybe PSI?

Tasks and Resources

1	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Optimised final cooling scheme		4		
	Maintenance of codes	0.5			
	Parametric Ionisation Cooling scheme design and performance estimate		1.3	2	
	Frictional cooling scheme design and performance estimate		1.3	2	
	Emittance exchange scheme design and performance estimate		1.3	2	
	Engineering integration issues	1			
	Absorber design	1			
	Develop appropriate magnets	In magnet package			

Target facility

Objectives							
Basic: Assess the target facility and perform targeted engineering studies to deal with significant risks.							
The existing magnet pion capture scheme has a number of outstanding issues which will be assessed, in particular radiation and heat load on the capture solenoid. The target complex itself has not been developed; for example, a viable solution for cooling of the target shielding and design of an appropriate proton beam dump is required.							
High-level Deliverables							
1) Estimate the heat load on the target and superconducting coils. Develop further the shielding scheme to ensure that the SC magnet has a reasonable cryogenic system and radiation damage is not prohibitive.							
1) Make a preliminary study on target complex design							
2) Study the cooling system for the target shielding and ensure that heat can be removed.							
2) Study the potential performance of a target horn as a fall back if any risks on the solenoid capture scheme are realised.							
2) Perform experiments to validate the effects of radiation on a SC wire.							
3) Development of essential engineering aspects of the target facility, including remote handling, target complex design and preliminary prototyping							
3) Development of a concept for a full power test of such a target on the CERN site.							
Resources	**1**	**2**	**3**		**1**	**2**	**3**
Staff	2	7	10	Student		0	
Postdoc	3	7	13	Material	15	0	700
Interested partners							
RAL, CERN, Warwick, Fermilab							

Tasks and Resources

	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Estimate the heat load on the target and superconducting coils. Develop further the shielding scheme to ensure that the SC magnet has a reasonable cryogenic system and radiation damage is not prohibitive.	2	3		
	Make a preliminary study on target complex design				15
	Study the cooling system for the target shielding and ensure that heat can be removed.	2	3		
	Study the potential performance of a target horn as a fall back if any risks on the solenoid capture scheme are realised.	2	2		
	Perform experiments to validate the effects of radiation on a SC wire.	3	2		
	Development of essential engineering aspects of the target facility, including remote handling, target complex design and preliminary prototyping	4	7		500
	Development of a concept for a full power test of such a target on the CERN site.	6	6		200

Target

Objectives

Basic: Develop the target itself.

MAP considered Hg as a target material which is not viable in Europe. A more conventional graphite target will be adopted as a baseline, with appropriate estimates for heat load and pion yield; alternate solutions should also be studied.

High-level Deliverables

1) Estimate shock load and pion yield of a graphite target. Assess potential mitigation schemes.

2) Optimise the graphite target for improved pion yield and shock load. Perform preliminary engineering assessments.

2) Consider appropriate non-solid target designs e.g. powder jet, eutectic, packed bed.

3) Study experimentally the impact of high shocks on target designs at HiRadMAt or equivalent facility

3) Further develop the engineering design for the graphite target.

Resources	1	2	3		1	2	3
Staff	1	5	2	Student		0	
Postdoc	3	5	2	Material	0	230	450

Interested partners

RAL, CERN, Warwick

Tasks and Resources

	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Estimate shock load and pion yield of a graphite target. Assess potential mitigation schemes.	1	3		
	Optimise the graphite target for improved pion yield and shock load. Perform preliminary engineering assessments.	2	2		80
	Consider appropriate non-solid target designs e.g. powder jet, eutectic, packed bed.	3	3		150
	Study experimentally the impact of high shocks on target designs at HiRadMAt or equivalent facility				450
	Further develop the engineering design for the graphite target.	2	2		