High energy complex working group summary

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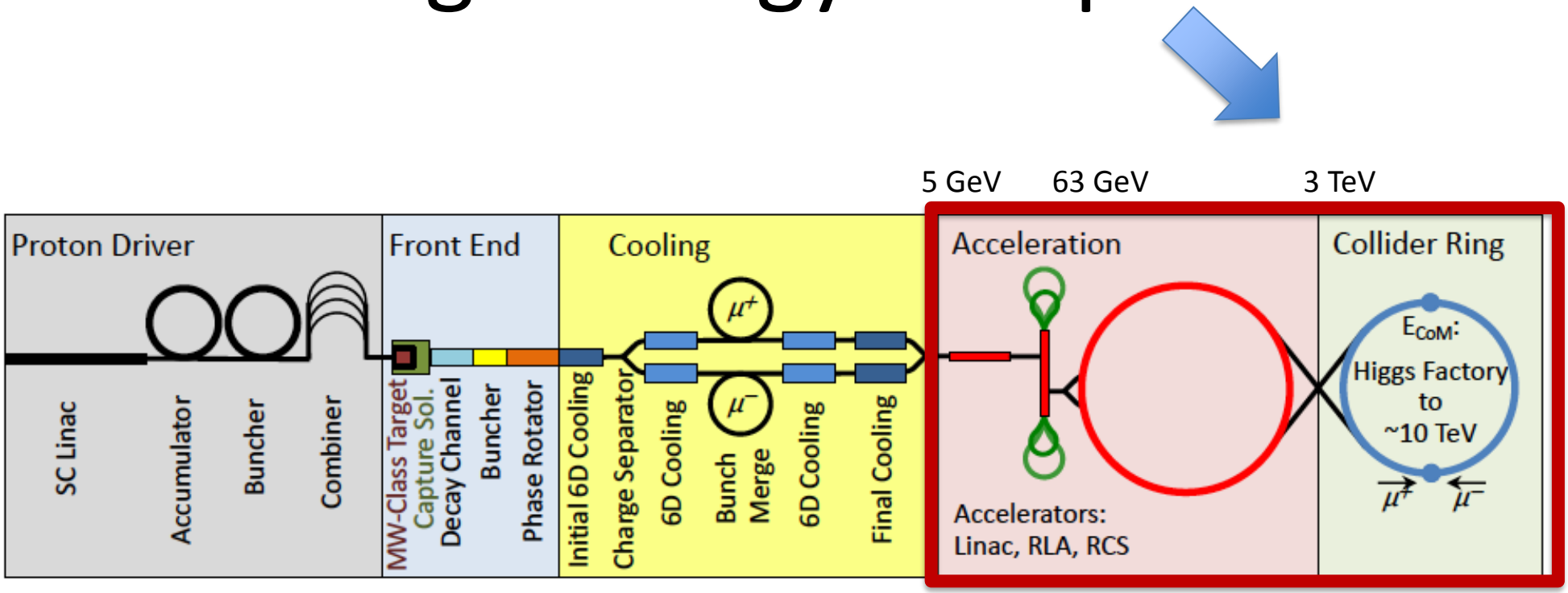
High-Energy Complex



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Muon acceleration

Muon collider

Main challenges

- High-energy acceleration:
  - Very short acceleration time: < a few ms.
    - High RF voltage
    - Short dipole ramp time
    - To preserve beam quality (emittance and bunch length)
  - To optimise operating costs and muon survival.
  - Neutrino radiation.

- Collider
  - Chromatic effects due to the interaction region (small β* and large momentum spread).
  - Control of linear and non-linear momentum compaction to keep small bunch length
  - Acceptable beam induced background levels
  - Control of the neutrino radiation issue.
  - Radiation load, in particular in cryogenic magnets

- **Strong iteration with other work packages like Beam Dynamics (collective effects), MDI, radiation protection, SRF and magnet WPs to validate the feasibility of the machine parameters.**

High-energy acceleration

Work Package Description

Workpackage Description

This work-package is focused on the feasibility and optimization of the muon acceleration complex from the cooling channel to the collider. The main goal is to develop a credible design concept of the high-energy muon acceleration complex with cost estimate, upgrade path, and demonstration facility requirements based on reasonable assumptions on technology development.

In this aim, this work package will completely describe the beamline by gathering all relevant information in a parameter table. This work package will provide a full set of lattices with critical technologies identified and will have start-2-end tracking of full system to demonstrate luminosity performance and to validate the bunch compression and emittance preservation during the acceleration process.
This work package will identify outstanding challenges with possible mitigation approaches.

This work package will have an iterative and collaborative process in the collective effects part with the Beam Dynamics and with the technology work packages like SRF and magnet WPs to validate the feasibility of the machine parameters.

Objectives, Deliverables and Resources

Objectives
Basic: Develop a credible design concept High-energy muon acceleration complex with cost estimate, upgrade path, and demonstration facility requirements based on reasonable assumptions on technology development.
Complete beamline description with lattices and ideally have start-2-end tracking of full system to demonstrate luminosity performance and bunch compression during the process.
Identify outstanding challenges with possible mitigation approaches.
High-level Deliverables
Priority 1: Immediate) Overall design parameters
Priority 1: Immediate) Rapid Cycling System (RCS) design
Priority 2: Urgent) Linac and Recirculating Linac (RLA) design
Priority 2: Urgent) Alternative to RCS: FFA

Resources	1	2	3		1	2	3
Staff	0.5	1	0.3	PhD	3	3	
Postdoc	4	3		Material			

Interested partners
BNL (FFA + RCS), CEA (RCS), IJCLab-In2p3 (RLA), JLAB (Linac), UKRI-STFC (FFA)

Resources are given in total number of FTE-years for the whole duration and in kEuro for material

Tasks and Resources

1	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Get a baseline layout and gather all parameters in a table including cost estimation and powering budget.	0.1	1.5		
	Start to end simulations of HEC complex	0.1	0.5	0.5	
	Lattice optics design and single particle dynamics in the RCS	0.2		2.5	
	Tolerance studies (alignment and field quality)	0.1	2		
	Evaluate the collective effects in the RCS	In Beam Dynamics package			
	Radiation mitigation in the arcs	In Radiation protection package			

2	Task description	staff	postdoc	PhD	material
	Assess the key issues of the linac +RLA system (muon decay effects on SRF cavities, injection, alignment, …)	0.1	1		
	Lattice optics and single particle dynamics of the linac and RLA	0.2	2		
	Assess the potential benefits of FFA as an alternative	0.3			
	Lattice optics design and single particle dynamics, in FFA	0.4		3	
	Evaluate the collective effects in the linac system	In Beam Dynamics package			
	Evaluate the collective effects in FFA	In Beam Dynamics package			

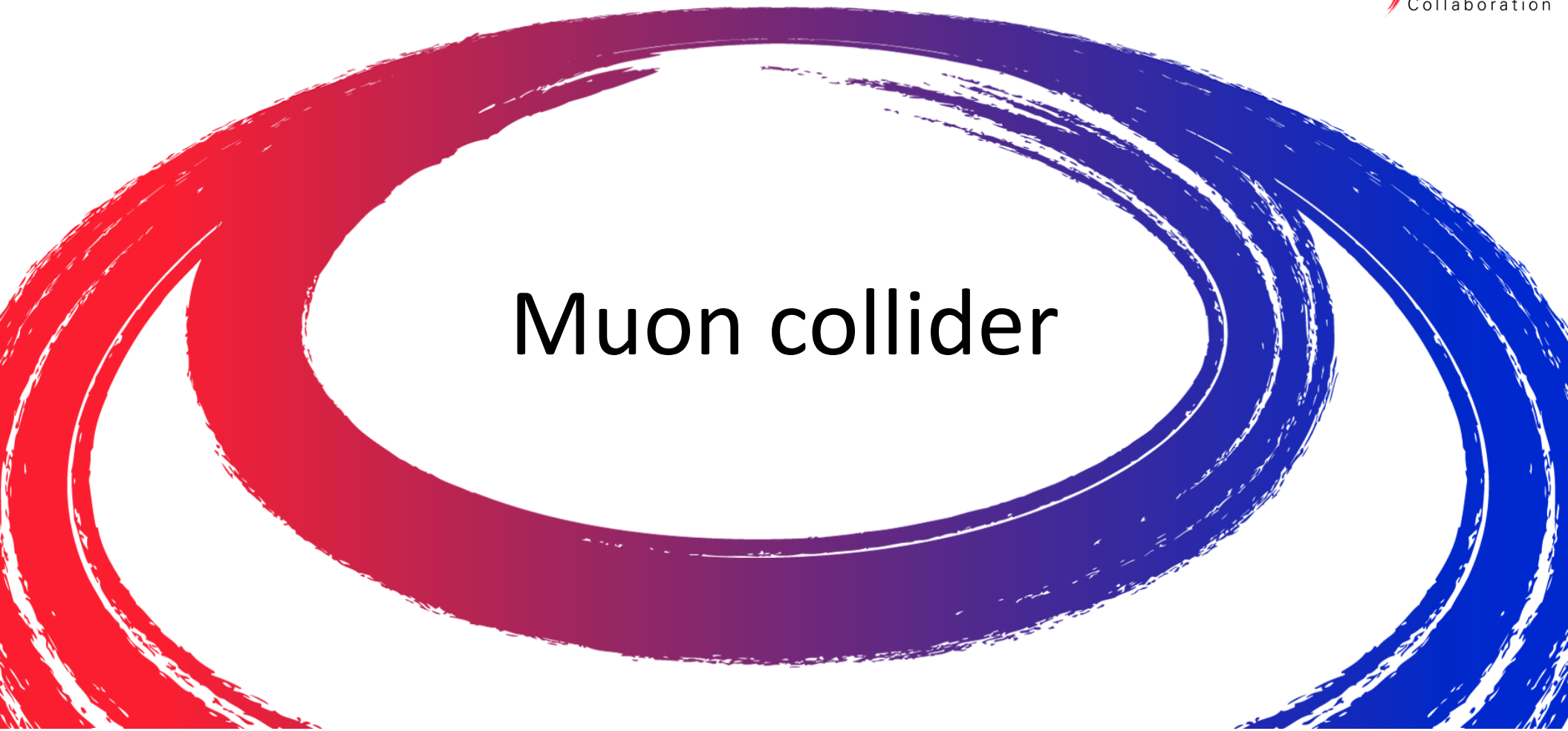
3	Task description	staff	postdoc	PhD	material
	Build a synergy around FFAs (spallation sources for instance)	0.3			

Technology program needs

1	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Short cycling magnets (including HTS)	In Magnet package			
	Efficient, reproducible and stable power supplies (stored energy management)	In Other Technology package ?			
	High gradient and High-Q SRF cavities	In RF package			
	Simulation tools developments	With Beam dynamics package			

2	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	SC magnets requirements and conceptual design, including cryostats	In Magnet package			
	Cryogenics for SC magnets and RF	In Magnet package			
	Magnets for FFA	In Magnet package			

3	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Beam diagnostics	In Other Technology package ?			
	Vacuum system	In Other Technology package ?			



Muon collider

Work Package Description

Workpackage Description

This work-package is focused on study of the feasibility and optimization of the muon collider. The main goal is to develop a credible design concept of the muon collider with cost estimate.

A consistent lattice for a 10 TeV com collider comprising an IR, straights to house necessary equipment (RF, injection, possibly extraction …) and arcs will be developed. Particular challenges are chromatic effects due to the small β^* and large momentum spread and their correction, control of linear and non-linear momentum compaction to keep small bunch length, acceptable beam induced background levels, control of the neutrino radiation issue and, possibly, non-linear effects.

This work package will iterate with several other work packages as, e.g., on IR design issues with the WP Machine Detector Interface, on the neutrino hazard issues with WP Radiation protection, on magnets with the WP magnets and on collective effects with the WP Beam Dynamics.

An alternative design of the muon collider ring based on skew quadrupoles will be studies by UKRI-STFC.

Studies within the CERN STI group address the radiation load to the collider ring, in particular cryogenic magnets, by means of Monte Carlo simulation tools. A magnet shielding shall be developed and optimized, in order to mitigate the risk of magnet quenches, to manage the load to the cryogenic system and to avoid magnet failures due to long-term radiation damage in magnet coils and insulation. The shielding must be developed iteratively in close collaboration with optics and lattice experts. The studies shall also assess whether a protection system and/or an extraction system is needed for irregular beam losses.

Objectives, Deliverables and Resources

Objectives
Basic: Development of a credible design concept for a Muon Collider ring with cost estimate and investigation of feasibility of a high energy muon collider. Identification of the main difficulties and measures for their mitigation and potential showstoppers
Complete beamline description with lattices
Identification of outstanding challenges with possible mitigation approaches.
High-level Deliverables
Priority 1: Immediate) Parameter table of muon collider
Priority 1: Immediate) Design of a muon collider lattice comprising interaction regions, straight sections for all necessary equipment and arcs. Critical aspects are the neutrino radiation issue and chromatic effects.
Priority 1: Immediate) Operational concept of muon collider including squeezing methodology
Priority 2: Urgent) Alternative optics of muon collider (UKRI-STFC)

Resources	1	2	3		1	2	3
Staff	2.5	0.5		PhD	0		
Postdoc	5.0	1.5		Material			

Interested partners
CERN, resources partly in place, UKRI-STFC for alternative optics, BNL for collider ring

Resources are given in total number of FTE-years for the whole duration and in kEuro for material

Tasks and Resources

1	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Get a baseline layout and gather all parameters in a table including cost estimation and powering budget.	0.5	1		
	Development of full lattice including IRs, straights, arcs …	1	2	0	
	Chromatic compensation and non-linear effects (tolerance)	0.5	1		
	Develop an operation concept consistent with the neutrino flux mitigation	0.5	1		
	Evaluate the collective effects in the muon collider	In Beam Dynamics package			
	Neutrino radiation mitigation measures	In Radiation protection package			

2	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Alternative optics using skew quadrupoles	0.5	1.5		

Objectives, Deliverables and Resources

Objectives
Basic: Study the radiation load to magnets and other accelerator systems in the collider ring arising from muon decay and possible other kinds of beam losses
Develop a conceptual shielding design which allows for a safe operation with acceptable heat deposition and radiation damage in magnets and assess the need for protection systems, including beam extraction
High-level Deliverables
Priority 1: Immediate) Quantify the radiation load to collider ring magnets and develop a shielding design for different collider options ($\sqrt{s}$=3 TeV and $\sqrt{s}$=10 TeV)
Priority 3: Important) Shower studies to assess the need of protection system for accidental beam losses, including extraction system for different collider options

Resources	1	2	3		1	2	3
Staff	0.7		0.3	Student			
Postdoc	2		0.5				

Interested partners
CERN STI

Resources are given in total number of FTE-years for the whole duration and in kEuro for material

Tasks and Resources

1	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Implement a simulation model (in FLUKA) to quantify the heat load and long-term radiation damage in superconducting magnets due to muon decay and beam halo losses	0.35	1		
	Develop a magnet shielding design to avoid quenches, sustain the thermal load to the cryogenic system and prevent magnet failures du to long-term radiation damage.	0.35	1		

3	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Generic shower simulation studies for assessing the effects of accidental beam losses and the need of protection systems	0.15	0.25		
	Contribute to design studies of protection systems for accidental beam losses, including extraction system (if needed)	0.15	0.25		

Requires a close collaboration with accelerator Work Packages (Magnets, Beam Dynamics, MDI). Resources concerning related activities like lattice design and magnet development are not included the table above, but will be accounted for by the relevant work packages.

Technology program needs

1	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Collider arc magnets: combined function magnets, possibly study of open mid-plane dipoles…	In Magnet package			
	Beam induced Background (BiB) mitigation	In MDI package			
	Global alignment techniques and girder studies, survey	In Other technology package			
	Simulation tools developments	With Beam dynamics/MDI package			

2	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	RF system and integration (possibly modest system)	In RF package			
	Machine protection system and shielding	In Other technology package			
	Cryogenics for RF and magnets	In RF and Magnet package			
	Magnets for alternative optics	In Magnet package			

3	Task description	Resource estimate staff [FTEy]	postdoc [FTEy]	PhD [FTEy]	material [kEuro]
	Beam diagnostics	In Other Technology package ?			
	Vacuum system	In Other Technology package ?			


THANK YOU FOR YOUR
ATTENTION!