MuCol kick-off meeting
28 March 2023

International MUON Collider Collaboration

cea CERN

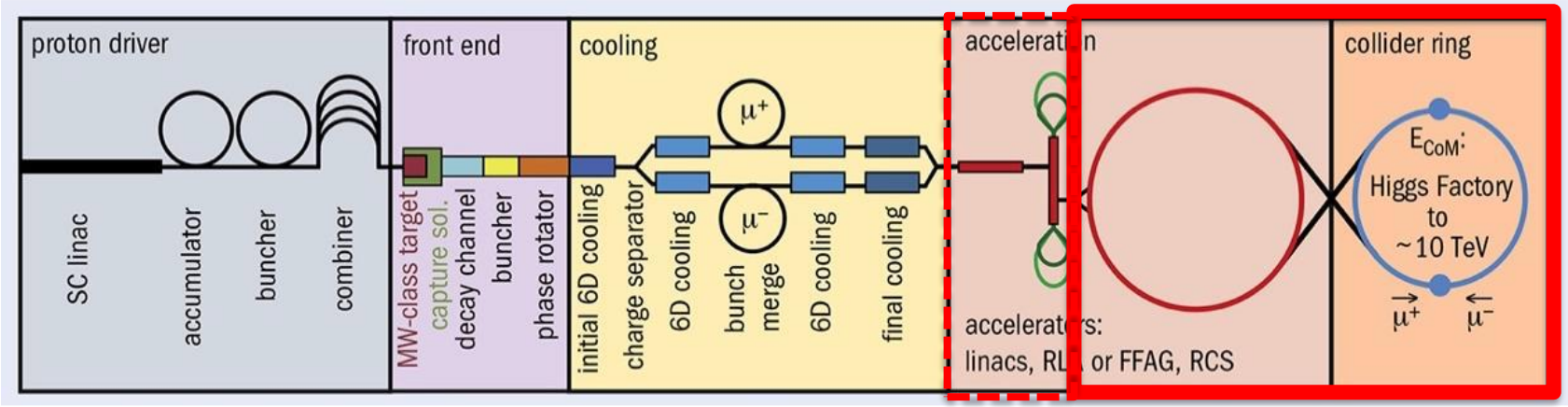
WP5
High energy complex

Antoine CHANCE (CEA), Christian CARLI (CERN)
On behalf of WP5 team

Funded by the European Union under
Grant Agreement n. 101094300

MuCol

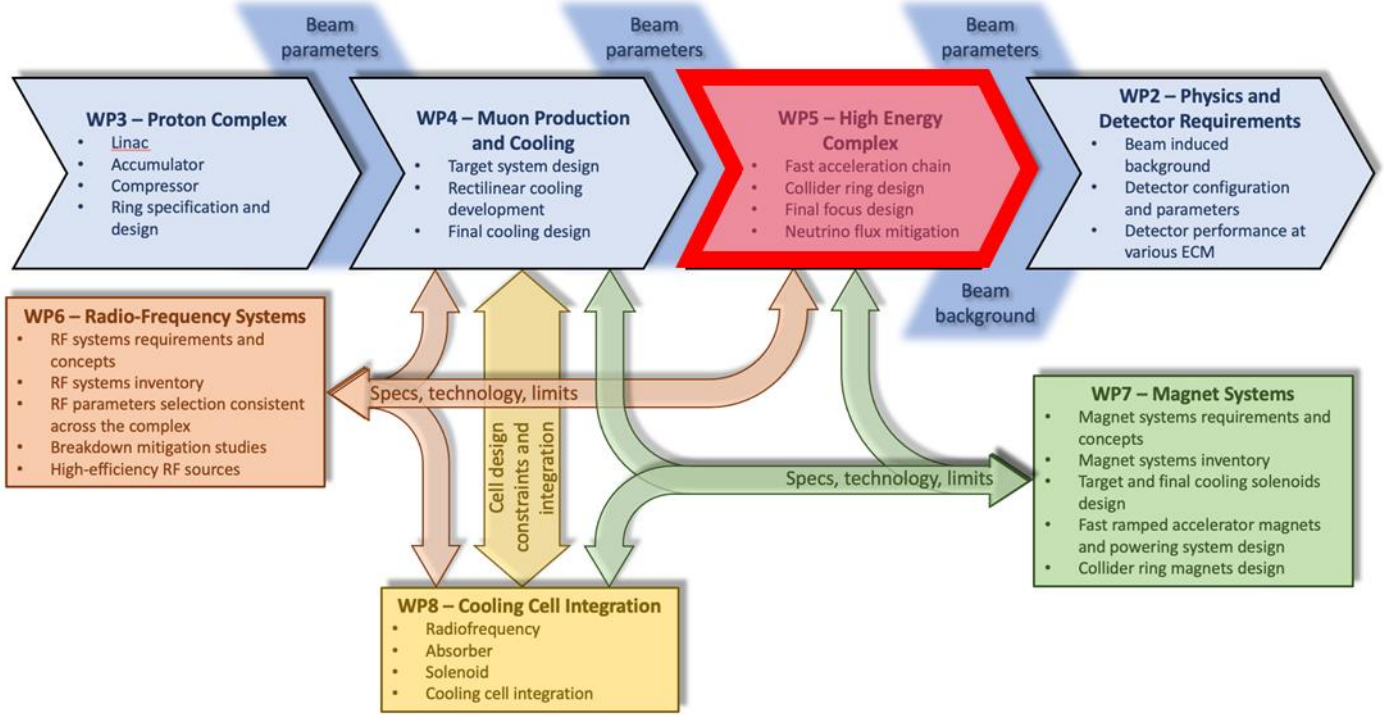
Scope of WP5


proton driver
front end
cooling
acceleration
collider ring
SC linac
accumulator
buncher
combiner
MW-class target
capture sol.
decay channel
buncher
phase rotator
initial 6D cooling
charge separator
6D cooling
bunch merge
6D cooling
final cooling
μ+
μ−
accelerators:
linacs, RLA or FFAG, RCS
E_CoM:
Higgs Factory
to
~10 TeV
μ+
μ−

Description of the Workpackage

- **Design of the acceleration complex**
  - Pulsed synchrotrons
  - Alternative based on FFA
- **Design of the collider** to get the target luminosity
  - Interaction region + shielding design
  - Machine detector interface
  - Background to experiment
- **Limitations due to collective effects.**
- **How to handle the radiation** due to muon decay and other beam losses

Strong interaction with other WPs



- **Strong interaction** with the **WP2 (Physics and detector requirements)**, **WP6 (RF systems)** and **WP7 (magnet systems)**
- **WP4 (Muon production and cooling)** brings the **beam parameter inputs.**

Task 5.1: Collider design
(CERN)

Task leader: Christian CARLI

- **Feasibility and optimization of the muon collider**
  - **Consistent lattice** for a 10 TeV com collider comprising:
    - Interaction region
    - Straights to house necessary equipment (RF, injection, possibly extraction…)
    - Arcs
    - Local chromatic compensation section
    - Matching section
  - **Cost estimate**
- **Particular challenges**:
  - **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
  - **Beam operation with moving beam lines** and non-linear effects

Task 5.2: Pulsed synchrotron and FFA design
(CEA, CERN, STFC, BNL)

Task leader: Antoine CHANCE

- **Feasibility and optimization of the muon acceleration complex** with
  - Cost estimate
  - Upgrade path
  - Reasonable requirements on accelerator elements (RF cavities and magnets)
- **Very fast acceleration**. Power consumption and acceleration inefficiency
- **Two** explored **solutions**:
  - Pulsed synchrotrons
  - FFA
- **Objectives**:
  - Beamline in a **parameter table**
  - **Full set of lattices** with critical technologies identified
  - **Start-2-end tracking** to demonstrate luminosity performance and to validate the bunch compression and emittance preservation during the acceleration process

Task 5.3: Beam dynamics
(CERN)

Task leader: Elias METRAL

- **Transverse collective effects** all along the muon accelerator chain
  - Impedance effects
  - Feasibility of the very quick acceleration phase due to high intensity
- **Detailed proposed work plan:**
  - Compute and store the r**esistive-wall impedance** and wakefield
  - Perform simulations of **transverse beam stability** with single bunch
  - **Scan the relevant parameters** to set limits on the performance reach
  - Choose and include **RF cavity impedance models**
  - Extend the previous parameters scan to set new limits to RF impedances
  - Re-do the same analysis with the RF cavities distributed along the machines
  - Re-do the same analysis with the 2 counter-rotating bunches
  - **Propose possible mitigation measures** and study in particular if pulsed synchrotrons need sextupoles

Task 5.4: MDI design and background to experiment
(CERN, INFN, STFC)

Task leader: Anton LECHNER

- **Goal**: **Develop a conceptual interaction region design** with:
  - A detector shielding together with the detector envelope
  - Final focus system
  - Other requirements (e.g. neutrino, shielding of magnets etc.)
- Quantification of **particle fluxes** and **time dependence** with respect to the bunch passage:
  - Muon decay in the collider ring
  - Incoherent electron-positron pair production at the interaction point
  - Beam halo losses
- **Shielding design** with respect to different contributions
- Other possible **background mitigation techniques** on the machine side
- The need of a **halo-removal system** for background reduction
- Estimates of the **long-term radiation damage** in the detector

Task 5.5: Radiation studies for the accelerators (CERN)

Task leader: Anton LECHNER

- **Simulation** and **mitigation of radiation-related effects** including the neutrino hazard
- To quantify the **heat load distribution** and **long-term radiation damage** in SC magnets due to muon decay and beam halo losses
- To develop a **shielding design for arc magnets** in order to:
  - Avoid quenches
  - Sustain the thermal load to the cryogenic system
  - Prevent magnet failures due to long-term radiation damage
- To quantify the **radiation environment** in the tunnel and caverns
  - To assess the need of machine protection systems
  - Design of a beam extraction system (if needed)
  - Input for the design of a beam loss monitoring system
- Effect and optimization of the lattice design on the neutrino distribution
- **To refine the dose kernel** for assessing the surface dose arising from neutrino-induced particle showers, considering the different neutrino flavours

List of Deliverables

Deliverable (number)	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (in months)
5.1	Final report on the design of the high energy acceleration complex	5.3, 5.4, 5.6	CEA	R	PU	44
5.2	Final report on the collider ring design	5.2, 5.4, 5.5, 5.6	CERN	R	PU	45

List of Milestones

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
M5.1	Mini-Workshop with pulsed magnets	5, 7	15	Indico site
M5.2	Tentative design of the interaction region	5, 2	18	Optics files
M5.3	Tentative optics of the collider ring and pulsed synchrotrons	5	19	Optics files
M5.4	Tentative design of the FFA	5	25	Optics files
M5.5	Tentative impedance budget in the collider and pulsed synchrotron	5	25	Dataset
M5.6	Preliminary evaluation of collider ring and pulsed synchrotrons	5	32	Report

Risk Analysis

Description of risk (indicate level of (i) likelihood, and (ii) severity: Low/Medium/High)	Work package(s) involved	Proposed risk-mitigation measures
Hiring difficulty (medium, high)	All	To exploit hiring strategies (websites, Professional networks, socials etc…) of all the participating Institutes to enlarge as much as possible the platform of publication of open positions.
Significant delay on deliverables (low, medium).	All	Progress will be regularly monitored via the Management Board and achievement of Milestones and Deliverables. Appropriate measures, if necessary will be addressed by the Governing Board

International MUON Collider Collaboration

cea CERN

Thank you for attention

Funded by the European Union under
Grant Agreement n. 101094300

MuCol

Table 3.1b

Work package number	5		**Lead beneficiary**			CEA
Work package title	High energy Complex					
Participant number	5	1	6			
Short name of participant	CEA	CERN	INFN			
Person months per participant:	24	0	12			
Start month	1			**End month**	48	