Muon Collider
EU Design Study – WP6
Magnets

authors

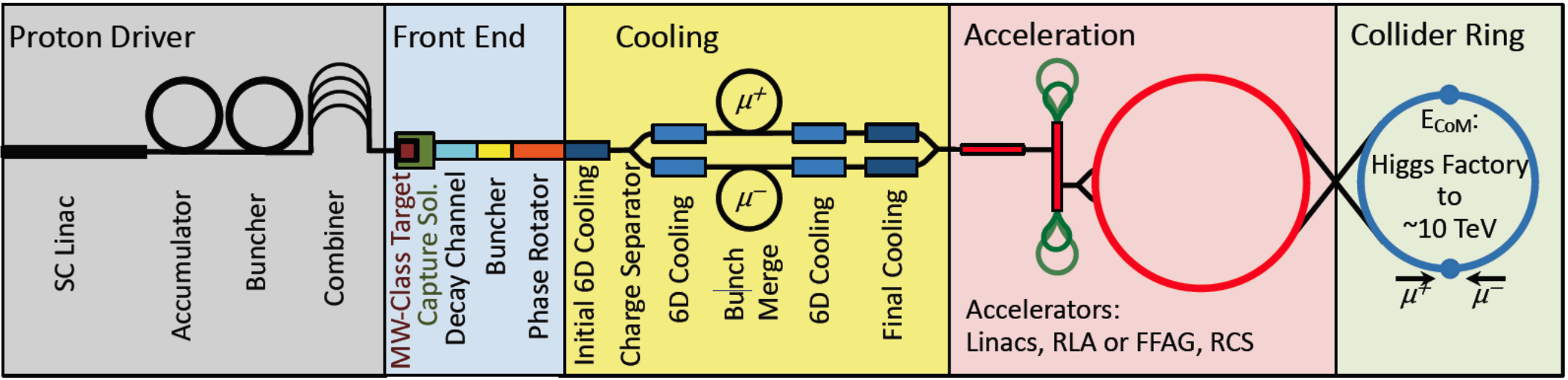
Proton-driven Muon Collider Concept

Muons production and capture

The proton beam impinges on a target, producing pions that decay into muons. Muons are captured by **solenoid magnets** around the target, decay and capture channel

Muons acceleration

Bunched and cooled muon beams are accelerated to the desired collision energy by a sequence of LINAC's, RLA's and RCS's (or FFAG's). The beams are steered and focused by **fast ramped dipole and quadrupole** magnets



Proton beam

Short and intense proton bunches are produced by the proton driver

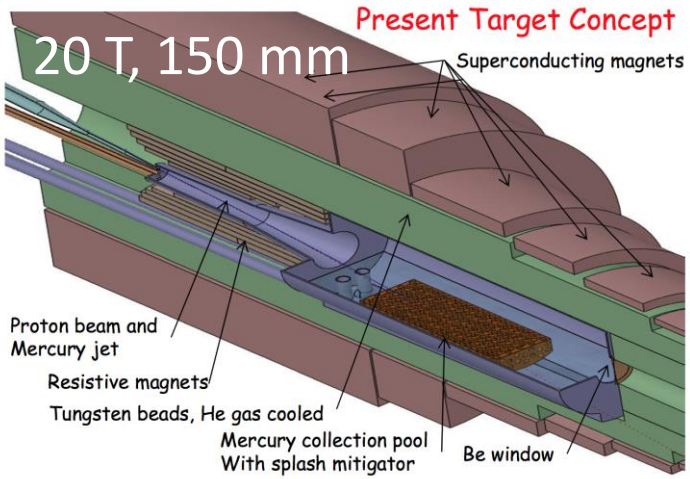
Muons cooling

Captured muons are cooled in 6D through interaction with light matter and subsequent acceleration by RF cavities. The beam is steered and focused by a sequence of **solenoid magnets**

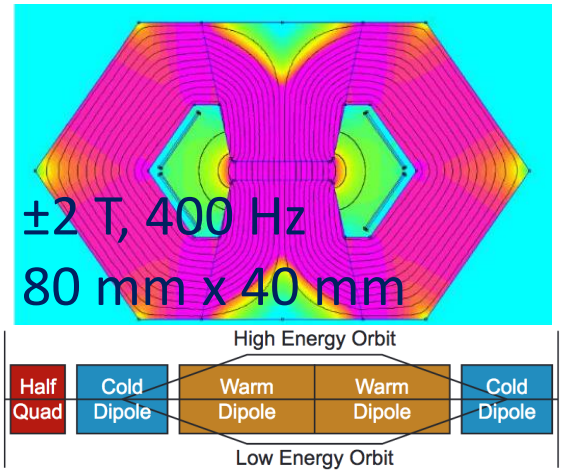
Muons collision

High energy muon beams are stored and collided in a collider ring consisting of **dipole and quadrupole magnets**

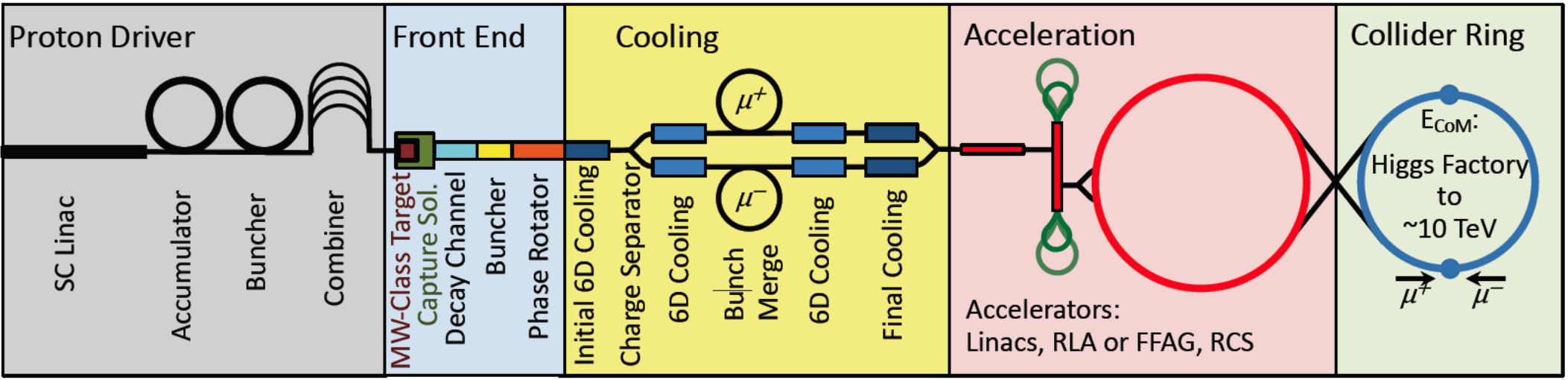
Magnet Demands



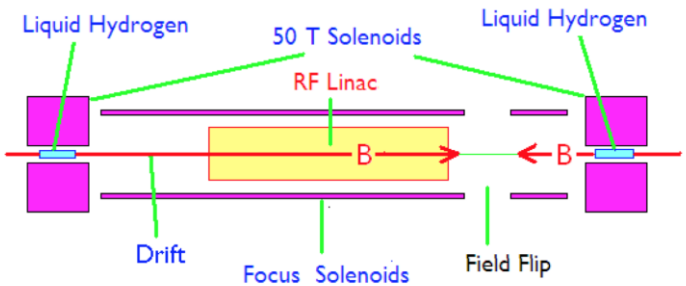
High-field and large aperture target solenoid with heavy shielding to withstand heat (100 kW/m) and radiation loads



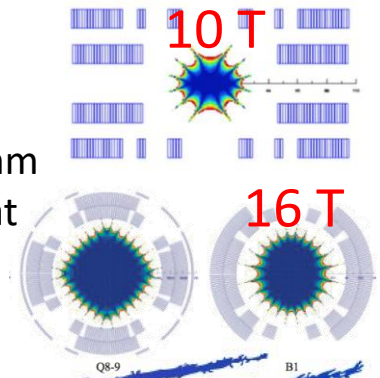
Combination of DC SC magnets (10 T) and AC resistive magnets (± 2T)



Ultra-high-field solenoids (40…60 T) to achieve desired muon beam cooling



Open midplane or large dipoles and quadrupoles in the range of 10…16 T, bore in excess of 150 mm to allow for shielding against heat (500 W/m) and radiation loads



Magnet Demands Summary

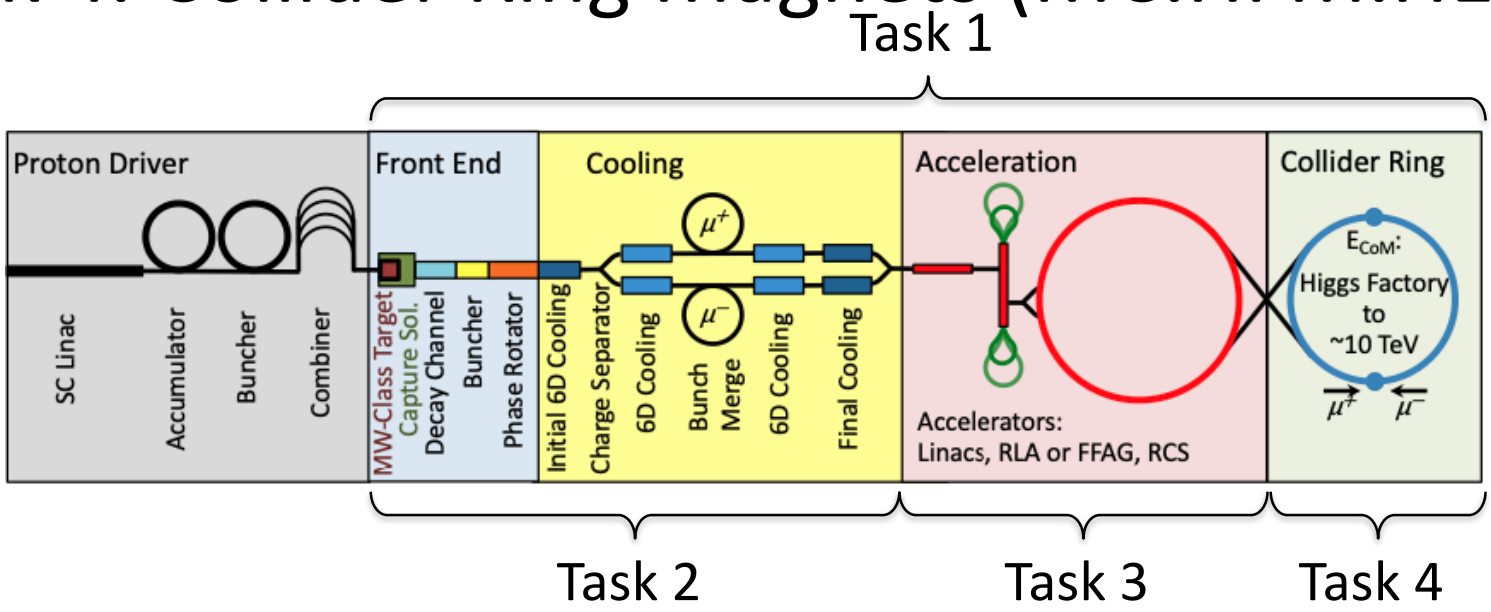
International MUON Collider Collaboration

Work in Progress !!!

Complex	Magnet	Field Gradient (T) / (T/m)	Field rate (T/s)	Aperture (mm)	Length (m)	Heat load (kW/m)	Candidate Technologies
Target and Capture	Solenoid	20	N/A	150	1	100	Hybrid (SC+resistive) All-SC (LTS+HTS)
Cooling	Solenoid	40…60	N/A	50	0.5		All SC (LTS+HTS)
Accelerator	NC Dipole	± 2	500 to 10,000	80x40			SC (LTS) DC + NC AC SC (LTS) DC + SC (HTS) AC FFAG
Collider	Dipole	16	N/A	150	15	0.5	Nb_3Sn or Nb-Ti+HTS
	Quadrupole	250…300	N/A	150	10	TBD	Nb_3Sn or Nb-Ti+HTS

PROPOSED tasks

- Task 1. Coordination and Communication
- Task 2. Target, Capture and Cooling Magnets (MC.HFM.SOL)
- Task 3. Accelerator Ring Magnets (MC.FR)
- Task 4. Collider Ring Magnets (MC.HFM.HE)



Task 1 - Coordination and Communication

- Overall coordination of magnet design studies and R&D
- Communication among partners within the WP, and with the other WP's of the study
- Organization of WP meetings and topical workshops (coordinated at the level of the study)
- Support in documentary and administration matters
- Establish and maintain a **magnet catalog**
- Consolidation of **power and cost estimates** for the whole magnet system
- Interface for safety and environmental aspects of the study

Task 2 - Target, Capture and Cooling Magnets

- Coordination of magnet activities for the target, capture and cooling complex
- Survey magnet design options and produce preliminary magnet performance specification
- Produce **conceptual designs** for target, capture and final cooling magnets (in close collaboration with physics and target WP's), and "integrate" design of cooling cell magnets in the magnet catalog (in close collaboration with cooling cell WP)
- Study **magnet cooling** options and define **power requirements**
- Evaluate **radiation load** and define requirements
- Provide a preliminary **cost estimate**

Task 3 - Accelerator Ring Magnets

- Coordination of magnet activities for the accelerator complex
- Survey magnet design options and produce preliminary magnet performance specification
- Produce **conceptual designs** for AC+DC magnet system, either NC+SC hybrid or all-SC (in close collaboration with physics WP)
- Produce **conceptual design** of power management system (in close collaboration with power converter activities)
- Define **power requirements**
- Provide a preliminary **cost estimate**

Task 4 - Collider Ring Magnets

- Coordination of magnet activities for the collider complex
- Survey arc and IR magnet design options and produce preliminary magnet performance specification
- Produce **conceptual designs** for arc and IR magnet systems, (in close collaboration with physics and MDI WP's)
- Study **magnet cooling** options and define **power requirements**
- Evaluate **radiation load** and participate to mitigation studies
- Provide a preliminary cost estimate

A final word

- An initial and biased list of high-priority topics, crucial to performance that we should address for the strategy update

Topic	Relevance
What is the maximum field that can be achieved in HF (20 T) and UHF (40…60 T) solenoids ?	The luminosity delivered is proportional to the field of the final cooling stage, and to some extent to the field of the capture and cooling stage
Can we devise NC or SC ramped accelerator magnet concepts (± 2 T at a ramp-rate of 0.5 to 10 kT/s) well beyond present technology ?	Swift acceleration (order of ms per stage or less) is critical to maximize muons lifetime in the collider, hence integrated luminosity
How to manage the power required by the muons ramped accelerator, likely to be the hungriest stage in the accelerator complex ? (FFAG…)	A power estimate that includes a suitable powering concept and addresses sustainability of the whole complex is crucial to acceptance
Are radiation heat and damage in the extreme conditions of a muon collider manageable ?	Radiation type, spectra and intensity are likely to impact both cooling (operating cost, sustainability) and lifetime of the accelerator complex

PROPOSAL of next steps

- Please use the WBS file as a working tool (see next) to:
  - Comment and propose (THIS IS A DRAFT !!!)
  - Signify interest in participation and specific proposed contribution (task, activity)
  - Quantify a proposed level of engagement (M+P)
- Preparation phase is now “hot”
  - Draft document due by end of February
  - We have two weeks to compile proposals in a coherent form
- We will use the framework of the “muons magnets working group” (mmWG) meetings to consolidate the proposal
  - Is the proposed day and time suitable for weekly meetings during the preparation phase ?