International
MUON Collider
Collaboration

MuCol Scope

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Study Meeting
12. April 2022

European Accelerator R&D Roadmap

The Accelerator R&D Roadmap has been scrutinised by the LDG and presented to Council in December

- Council requested Implementation Plan

The Roadmap report identifies different R&D scenarios and details the workpackages and deliverables

Three main deliverables are foreseen:

- a **Project Evaluation Report** that assesses the muon collider potential as input to the next ESPPU;
- an **R&D Plan** that describes a path towards the collider;
- an **Interim Report** by the end of 2023 that documents progress and allows the wider community to update their view of the concept and to give feedback to the collaboration.

Project Evaluation Report

The project evaluation report will contain an assessment of whether the 10 TeV muon collider is a promising option and identify the required compromises to realise a 3 TeV option by 2045. In particular the questions below would be addressed.

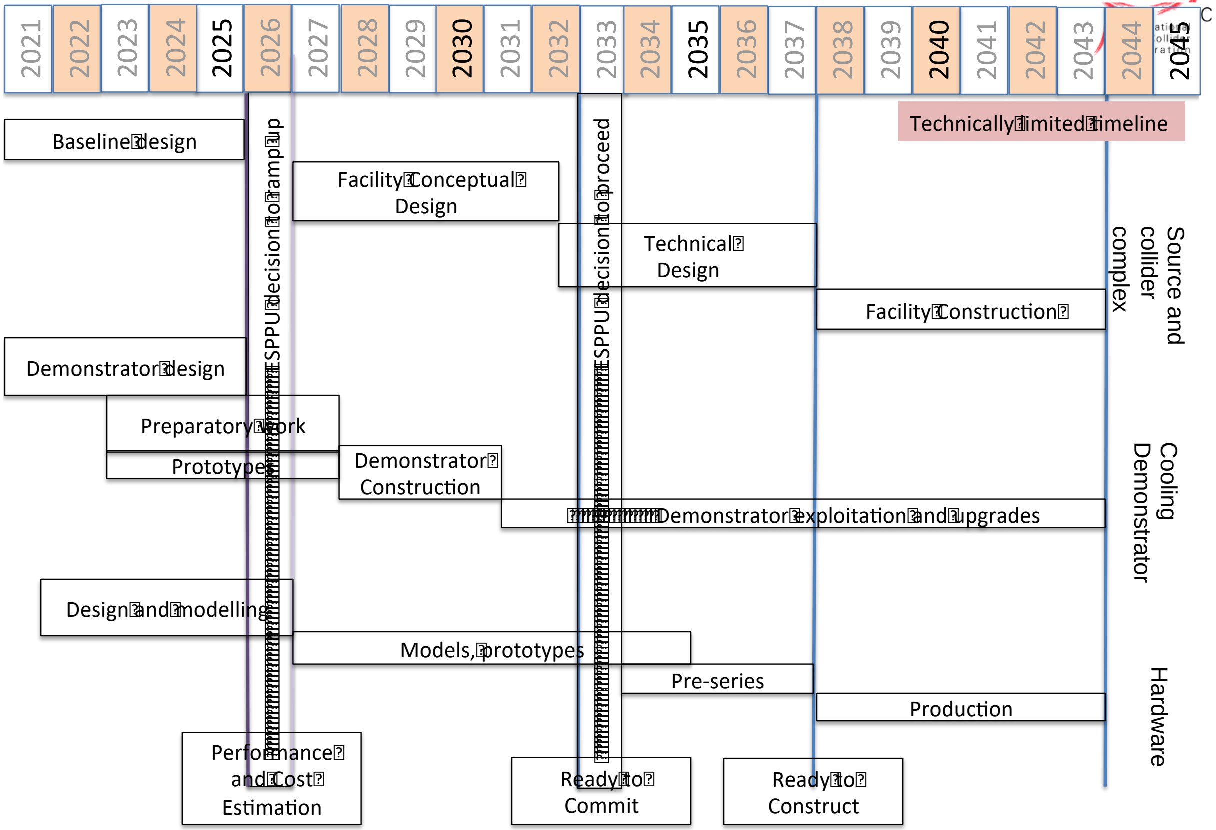
- What is a realistic luminosity target?
- What are the background conditions in the detector?
- Can one consider implementing such a collider at CERN or other sites, and can it have one or two detectors?
- What are the key performance specifications of the components and what is the maturity of the technologies?
- What are the cost drivers and what is the cost scale of such a collider?
- What are the power drivers and what is the power consumption scale of the collider?
- What are the key risks of the project?

Collider Timeline

Goal is to know by next ESPPU if muon collider is credible option

Timeline depends on strategies and technical progress

Prudently explore if MuC can be option as next project (i.e. operation mid 2040s) in case Europe does not build higgs factory
- strong ramp-up required after 2026



Roadmap Scenarios

Roadmap identifies muon collider challenges and two R&D scenarios to address them

- An **full scenario**
  - full achievement of objectives, about 5 years
- A **reduced scenario**
  - only a subset of objectives can be achieved, 4 years

Scenario	FTEy	M MCHF
Aspirational	445.9	11.9
Minimal	193	2.45

http://arxiv.org/abs/2201.07895

Label	Begin	End	Description	Aspirational		Minimal	
				[FTEy]	[kCHF]	[FTEy]	[kCHF]
MC.SITE	2021	2025	Site and layout	15.5	300	13.5	300
MC.NF	2022	2026	Neutrino flux mitigation system	22.5	250	0	0
MC.MDI	2021	2025	Machine-detector interface	15	0	15	0
MC.ACC.CR	2022	2025	Collider ring	10	0	10	0
MC.ACC.HE	2022	2025	High-energy complex	11	0	7.5	0
MC.ACC.MC	2021	2025	Muon cooling systems	47	0	22	0
MC.ACC.P	2022	2026	Proton complex	26	0	3.5	0
MC.ACC.COLL	2022	2025	Collective effects across complex	18.2	0	18.2	0
MC.ACC.ALT	2022	2025	High-energy alternatives	11.7	0	0	0
MC.HFM.HE	2022	2025	High-field magnets	6.5	0	6.5	0
MC.HFM.SOL	2022	2026	High-field solenoids	76	2700	29	0
MC.FR	2021	2026	Fast-ramping magnet system	27.5	1020	22.5	520
MC.RF.HE	2021	2026	High Energy complex RF	10.6	0	7.6	0
MC.RF.MC	2022	2026	Muon cooling RF	13.6	0	7	0
MC.RF.TS	2024	2026	RF test stand + test cavities	10	3300	0	0
MC.MOD	2022	2026	Muon cooling test module	17.7	400	4.9	100
MC.DEM	2022	2026	Cooling demonstrator design	34.1	1250	3.8	250
MC.TAR	2022	2026	Target system	60	1405	9	25
MC.INT	2022	2026	Coordination and integration	13	1250	13	1250
			Sum	445.9	11875	193	2445

Table 5.5: The resource requirements for the two scenarios. The personnel estimate is given in full-time equivalent years and the material in kCHF. It should be noted that the personnel contains a significant number of PhD students. Material budgets do not include budget for travel, personal IT equipment and similar costs. Colours are included for comparison with the resource profile Fig. 5.7.

Roadmap Implementation

We understand that LDG will oversee the implementation of the Roadmap

- but LDG will not be responsible to provide resources etc.

Need to find our own resources

- Submitted five white papers to the US Snowmass process (physics/detector/facility)
  - more than 200 signatures, more to come
- Will submit a Design Study proposal to the EU for co-funding now
  - and a technology proposal in one or two years
- Requests in several countries to find resources
  - for the moment used as matching funds for the EU proposal
- Request an increase in the MTP

EU Design Study

Initially planned to study design of demonstrator
But does not fit programme description
CDR is not mandatory
- decided to go for muon collider design

At this moment, do not have matching funds for TECH call,
- but interest expressed by collaborators
- need time to secure matching funds
- will try to go for the next call in 2024 (maybe special call in 2023)

HORIZON-INFRA-2022-DEV-01-01: Research infrastructure concept development
Expected EU contribution: 1-3 MEUR,
Total budget 21.8 MEUR
Type of Action: Research and Innovation Actions

Develop a conceptual design for the collider

HORIZON-INFRA-2022-TECH-01-01:
Expected EU contribution: 5-10 MEUR
Total budget 110 MEUR
Type of Action: Research and Innovation Actions

Develop technologies for at least three infrastructures of European interest.

Workpackages and Funding

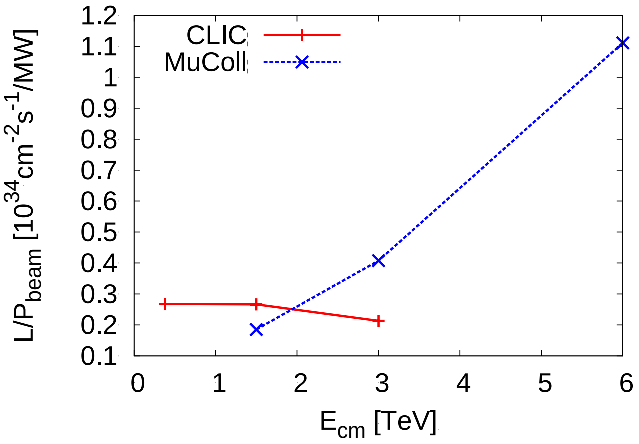
Workpackages

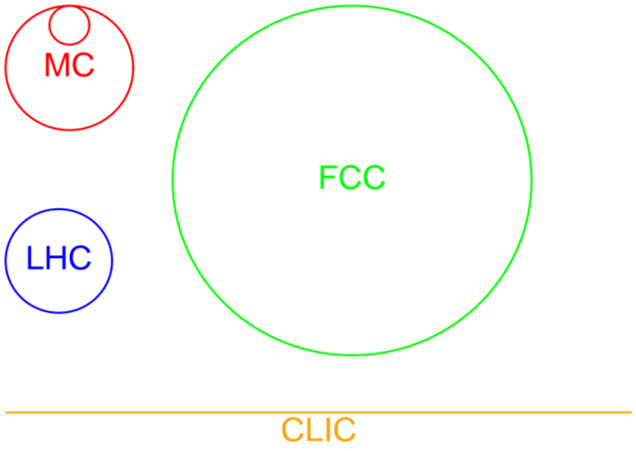
1. Coordination and Communication
2. Physics and Detector Performance Requirements
3. Proton Complex
4. Muon Production and Cooling
5. High-energy Complex
6. RF Systems
7. Magnetic Systems
8. Muon Cooling Cell

Funding

- Total EU request 2.4(+0.6) MEUR
- Matching funds from non-CERN collaborators are ~ 3 MEUR
  - had to squeeze
- CERN is contributing about the same as EU but not requesting
  - except for some administrative cost

Sustainability



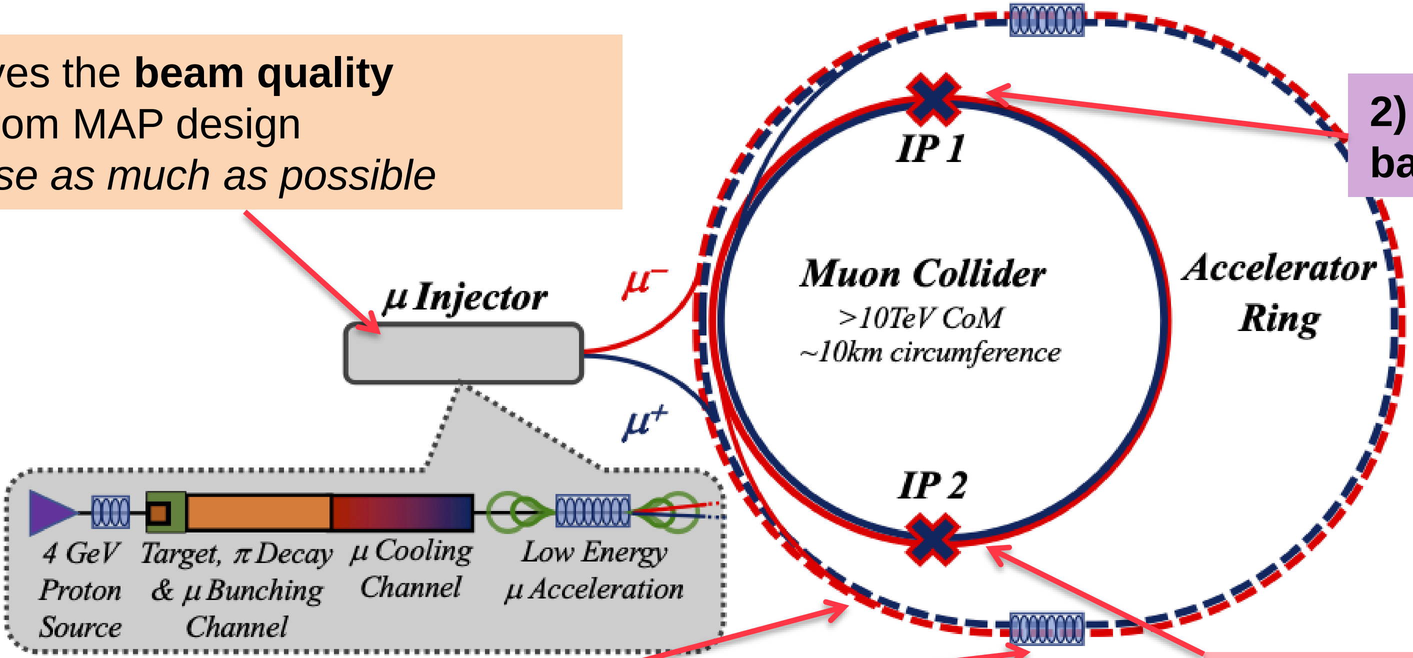


Specific advantages are

- Luminosity to power ratio
- Compact size

Challenges

4) Drives the **beam quality**
start from MAP design
optimise as much as possible



2) Beam-induced background

1) Dense neutrino flux
mitigated by mover system and site selection

3) Cost and **power** consumption limit energy reach
e.g. 32 km accelerator for 10 TeV, 10 km collider ring
Also impacts **beam quality**

Challenge/Workpackage Interfaces

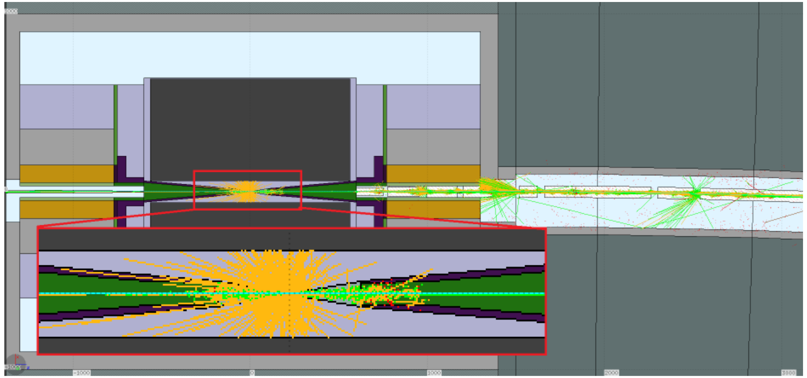
Physics and Detector Requirements

- Provide link to physics community
- Question: Can we realise the physics potential?

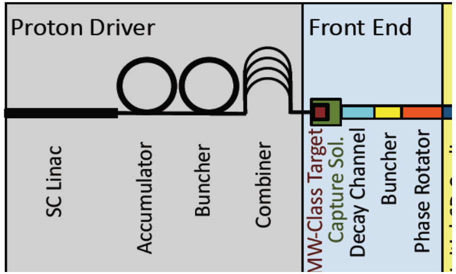
- At 10 TeV, O(50,000) muons decay per m and bunch passage

- **Mitigate background** to not compromise physics potential

- Provide **simple detector performance specification** (DELPHES card) (WP 2)
- Provide background description (WP 2+5)
- Provide **detector simulation** infrastructure (WP 2)



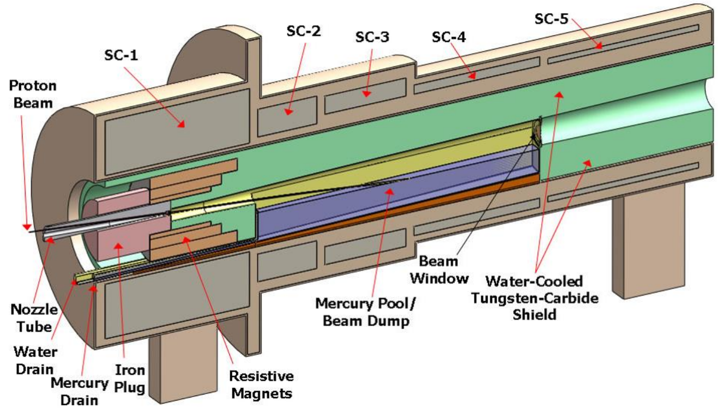
Proton Beam and Muon Production



2 MW Proton beam power

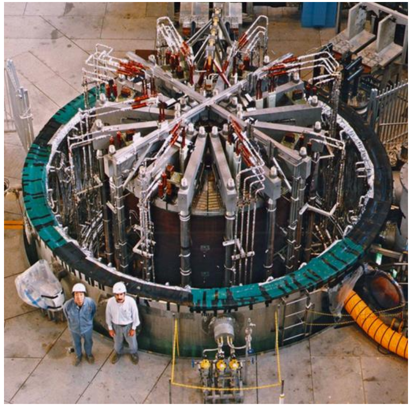
- **Combination into 400 kJ pulses at 5 Hz** (WP 3)

O(15 T) aperture LTS solenoid resistive insert
or O(20 T) aperture HTS solenoids

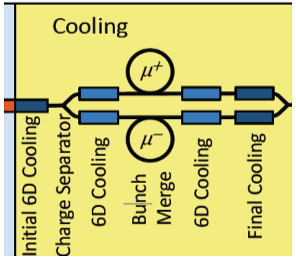


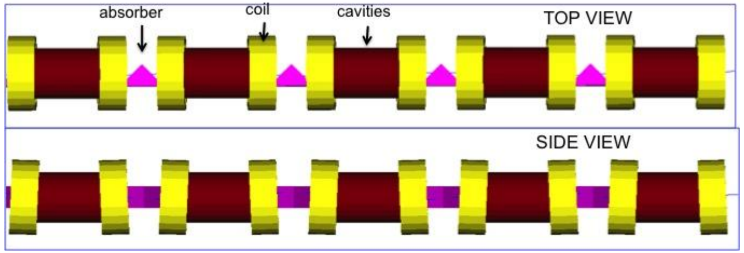
- **Shock wave and heating of target** (WP 4)
- **Radiation mitigation in solenoid** (WP 4)
- **Large aperture solenoid design** (WP 7)

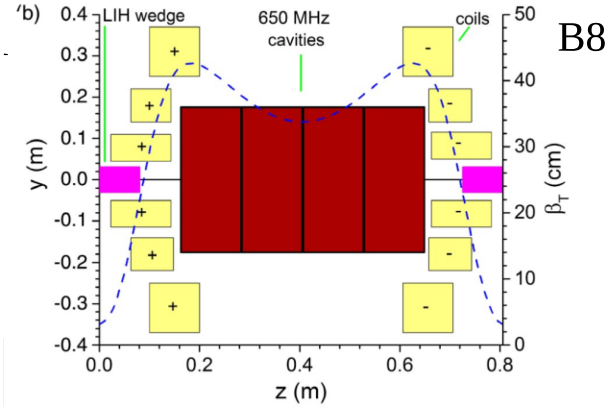
ITER Central Solenoid
Model Coil
13 T in 1.7 m (LTS)



Muon Cooling

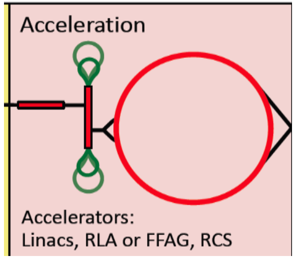




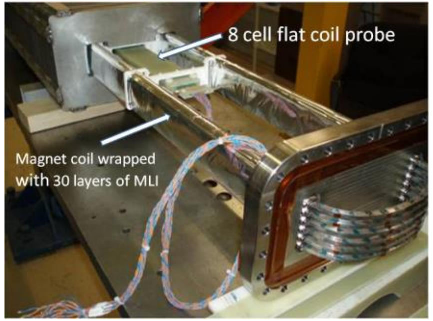


- **Muon cooling chain concept** (WP 4), with realistic targets for
  - RF (WP 6)
  - magnets (WP 7)
  - integration into cell (WP 8)

Muon Acceleration

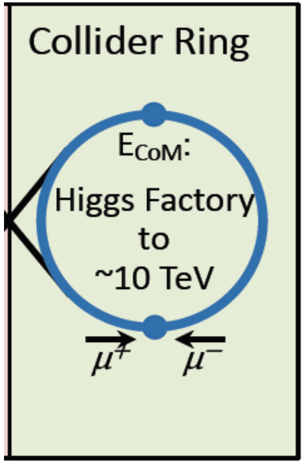


- **Cost and power efficient acceleration**
  - Lattice design (WP 5)
  - Fast-ramping magnets and power recovery (WP 7)
  - Longitudinal beam dynamics and RF design (WP 6)



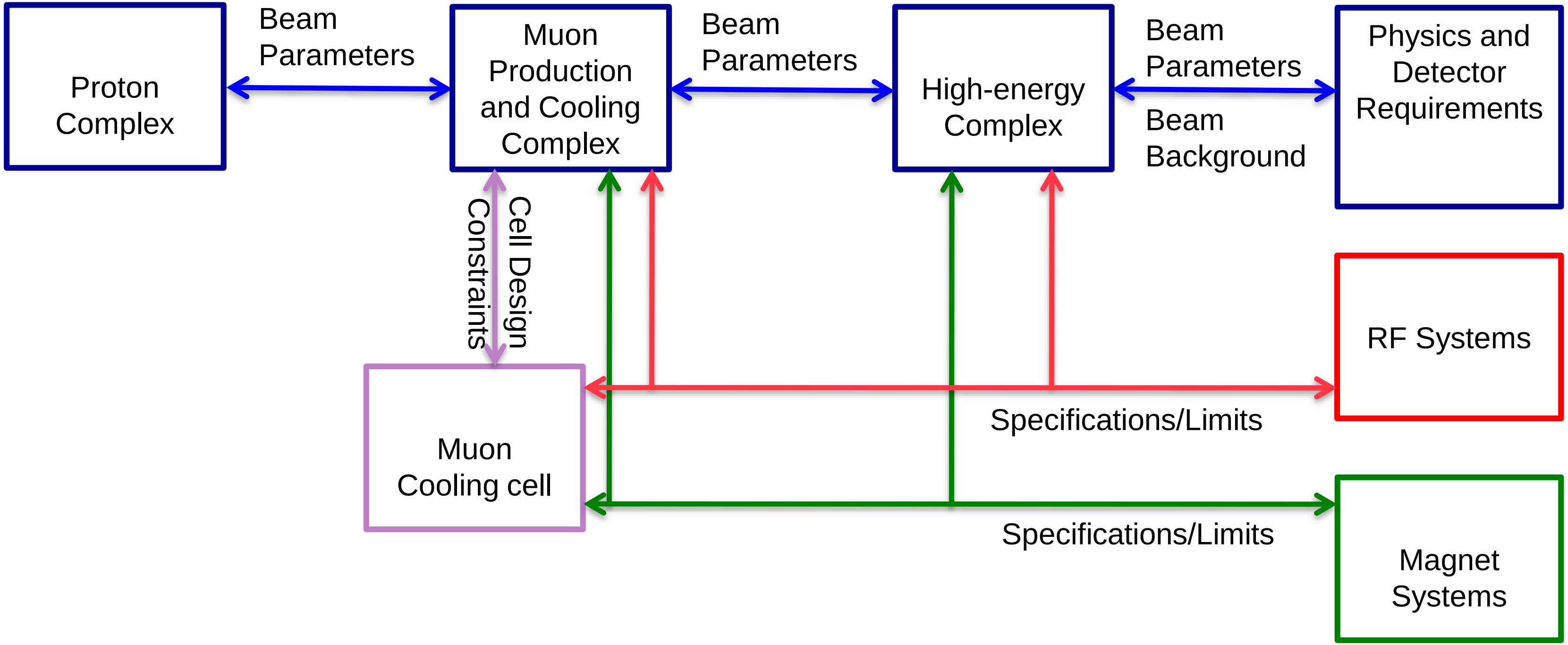
Test of **fast-ramping normal-conducting magnet** design

Muon Collisions



- **Collider ring design** (WP 5), considering
  - **Losses leading to background** (WP 5+2)
  - **Mitigation of losses** (WP 5+7)
  - **Magnet design** (WP 7)
  - **Neutrino flux** (outside of study)

Interfaces


Proton Complex
Beam Parameters
Muon Production and Cooling Complex
Beam Parameters
High-energy Complex
Beam Parameters
Beam Background
Physics and Detector Requirements
Constraints
Cell Design
Muon Cooling cell
Specifications/Limits
RF Systems
Specifications/Limits
Magnet Systems

Organisation

Conclusion

- European Accelerator R&D Roadmap is the basis for our Design Study
  - Work programme
  - Deliverables
- One main deliverable for Design Study
  - Assessment report
  - Challenge: could be end of 2025 or later

Reserve

Workpackages

SITE	Site studies, radiation, civil engineering, neutrino flux mitigation strategy
NF	Neutrino flux mitigation
MDI	Machine detector interface studies
ACC	Accelerator design
HFM	High-field magnets
FR	Fast-ramping magnet system
RF	RF systems
TAR	Target and target area
MOD	Muon cooling module design
DEM	Demonstrator
INT	Integration

Schedule

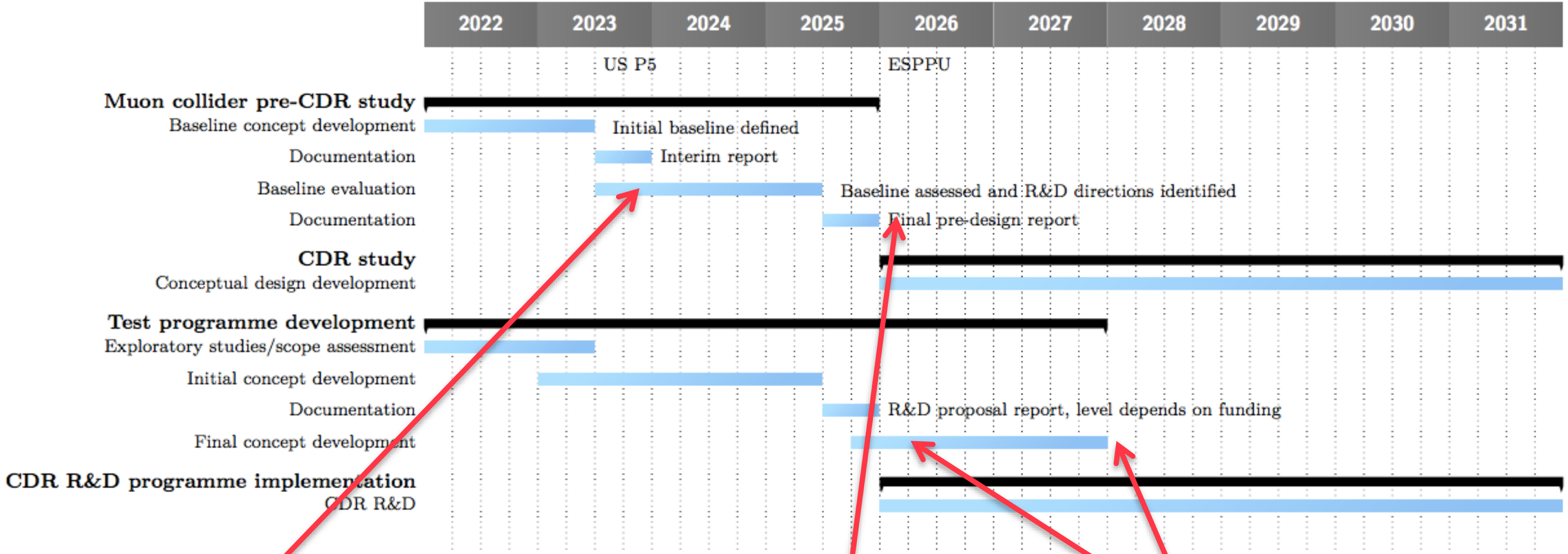


Fig. 5.4: Overall timeline for the R&D programme.

2023
Interim Report to gauge progress
Initial baseline defined

2025
Assessment Report

2025-2027
R&D plan will be refined