This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

Report on Task 5.1: MUST MUon collider STrategy network

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INFN - CERN (+BINP) – CEA – IJCLAB – KIT – PSI – UKRI (BNL-USA not beneficiary)

I.FAST Period 1 Review, 09.02.2023

Task structure and objectives

Task 5.1: MUon colliders STrategy network (MUST) M1 – M48

- Support the effort to **design a muon collider** and to **project and plan the required R&D**
- **Consolidate the community** devoted to develop an international future facility
- Prepare the platform to **disseminate** the information (website, meetings, tools)

ESPPU

*[..] an **international design study** for a **muon collider***
***unique opportunity** to achieve a multi-TeV energy domain*

MUST can play a crucial role

- **MS15:** International workshop on muon source design **M18** ➔ *Report*
- **MS16:** International workshop to define R&D plans **M36** ➔ *Report*
- **D5.1:** International collaboration plans towards a multi-TeV muon collider **M46**

Summary of activities in P1 (1)

- **International Muon Collaboration** established soon after EPSSU in July 2020

- **Muon Beam panel** established to prepare the **Accelerator R&D Roadmap** document (arXiv:2201.07895)
  ➔ beneficiaries largely contributed to define the steps towards a design study and the required R&D plan

- **Proton-driver baseline design chosen**
  ➔ based on the previous work done by the U.S. Muon Accelerator Program (MAP)

- **Community Meetings** were organized:
  - CERN – leadership role in establishing the accelerator design framework
  - INFN largely contributed to steer the physics and detector community
  - UKRI, thanks to the know-how by MICE project, leading the effort on the muon cooling
  - CEA leading role in the technological design of the high energy complex (accelerator and collider rings)
  - IJCLAB and PSI are completing their joint studies on hybrid crystal-based positron sources
  - KIT contributes on magnets evaluation and R&D planning

Key Challenges of the facility

- **Focus on two energy ranges:**
  - **3 TeV** technology ready for construction in 10-20 years
  - **10+ TeV** with more advanced technology

$\sqrt{s}$	$\int \mathcal{L} dt$
3 TeV	1 ab^{-1}
10 TeV	10 ab^{-1}
14 TeV	20 ab^{-1}

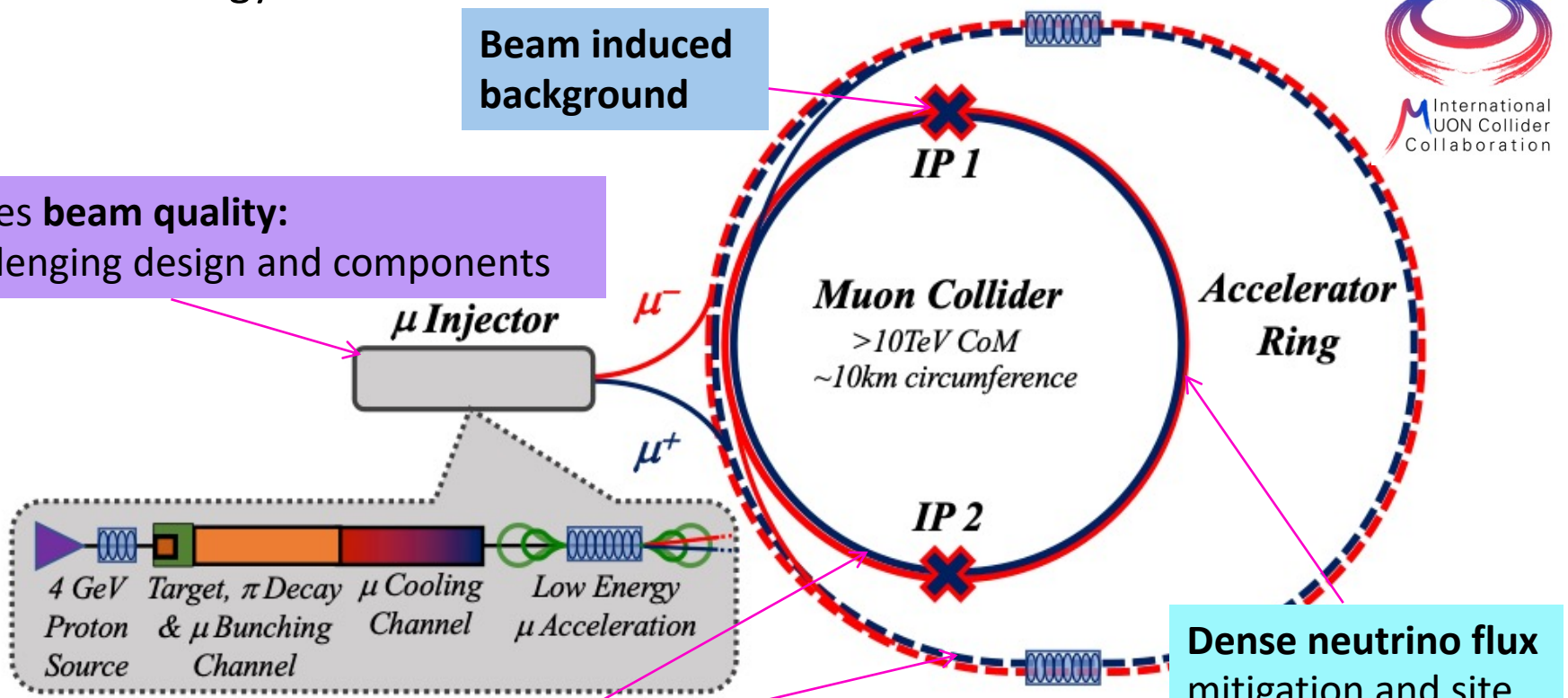
10+ TeV completely new regime to explore!

Web page:
http://muoncollider.web.cern.ch

Proton driver production
Baseline @ International Design Study

Beam induced background

Drives **beam quality:**
challenging design and components



Dense neutrino flux mitigation and site

Cost and **power** consumption drivers, limit energy reach
e.g. 30 km accelerator for 10/14 TeV, 10/14 km collider ring

Summary of activities in P1 (2)

Among the main challenges: the design of **Machine Detector Interface** (MDI), because of Beam Induced Background (BIB)

➔ CERN designed the **first lattice at the 10 TeV centre of mass energy**

➔ detailed studies were carried on both at CERN and INFN on Interaction Region affecting Detector Design

The community largely contributed to the U.S. Snowmass2021 Strategy process in the Muon Collider Forum and

to present documents by March 2022, discussed at the Seattle Snowmass Summer Meeting in Seattle (July 17-26, 2022)

➔ **EPJC paper ready to be submitted**

CERN, CEA, INFN, KIT. PSI and UKRI submitted by April 2022 a Design Study project to HORIZON-INFRA-2022-DEV-01

➔ **MuCol** now approved, **planned to start March 1, 2023**

IJCLAB is finalizing work on intense positron source with crystals in collaboration with INFN and also task 5.2

Deliverables and Milestones P1

MS15: International workshop on muon source design **M18** ➔ ***Report APPROVED***

- *IMCC Annual Meeting held in person at CERN October 11-14, 2022: https://indico.cern.ch/event/1175126/*
- *Main goals: to assess the progress of the study and to define the future work programme, in particular regarding the share of tasks among all Collaborators.*
  ➔ *This will include the organization of the MuCol Design Study (positive answer from the EU end of July)*
- *MS15 – specific objective of MUST : to review advances and promote collaboration on the moun source*
- *Collaboration Board met for the first time and started activities within the scope of the study.*

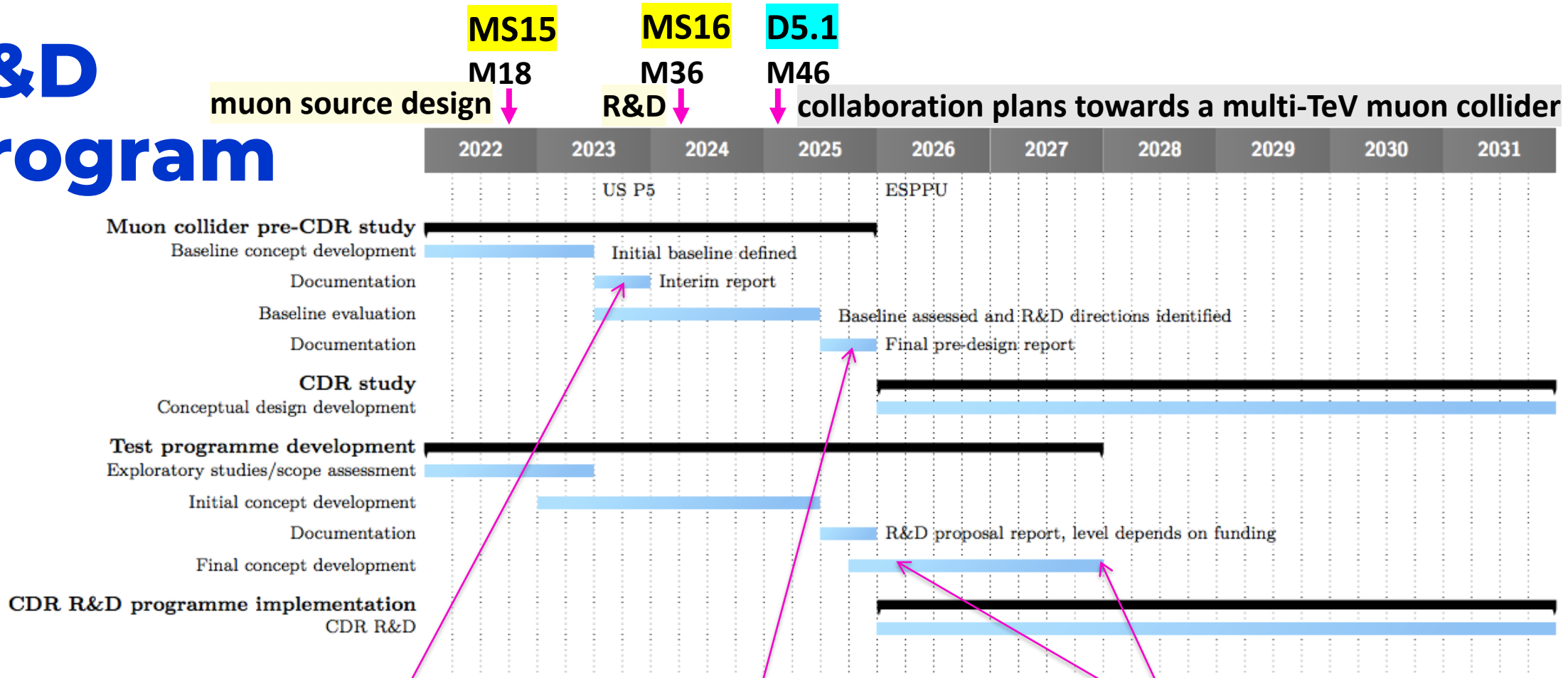
MAIN ITEM DISCUSSED:

- proton driver parameter optimization, linked to possible siting
- the target physics and engineering requirements as well the related radiation studies of the system
- ionizing cooling require integrating a newly developed high field solenoid to be coupled to a normal conducting cavity
- sketch out the baseline design of the a 6D cooling demonstrator: mandatory goal to prepare for the next ESPPU

➔ consensus to work towards a common baseline and to develop a list of technical issues to be addressed

➔ synergies explored within I.FAST, mostly on target materials and thin window for target and cooling system in WP4

R&D Program



2023
Interim Report to gauge progress
Initial baseline defined

2025
Assessment Report

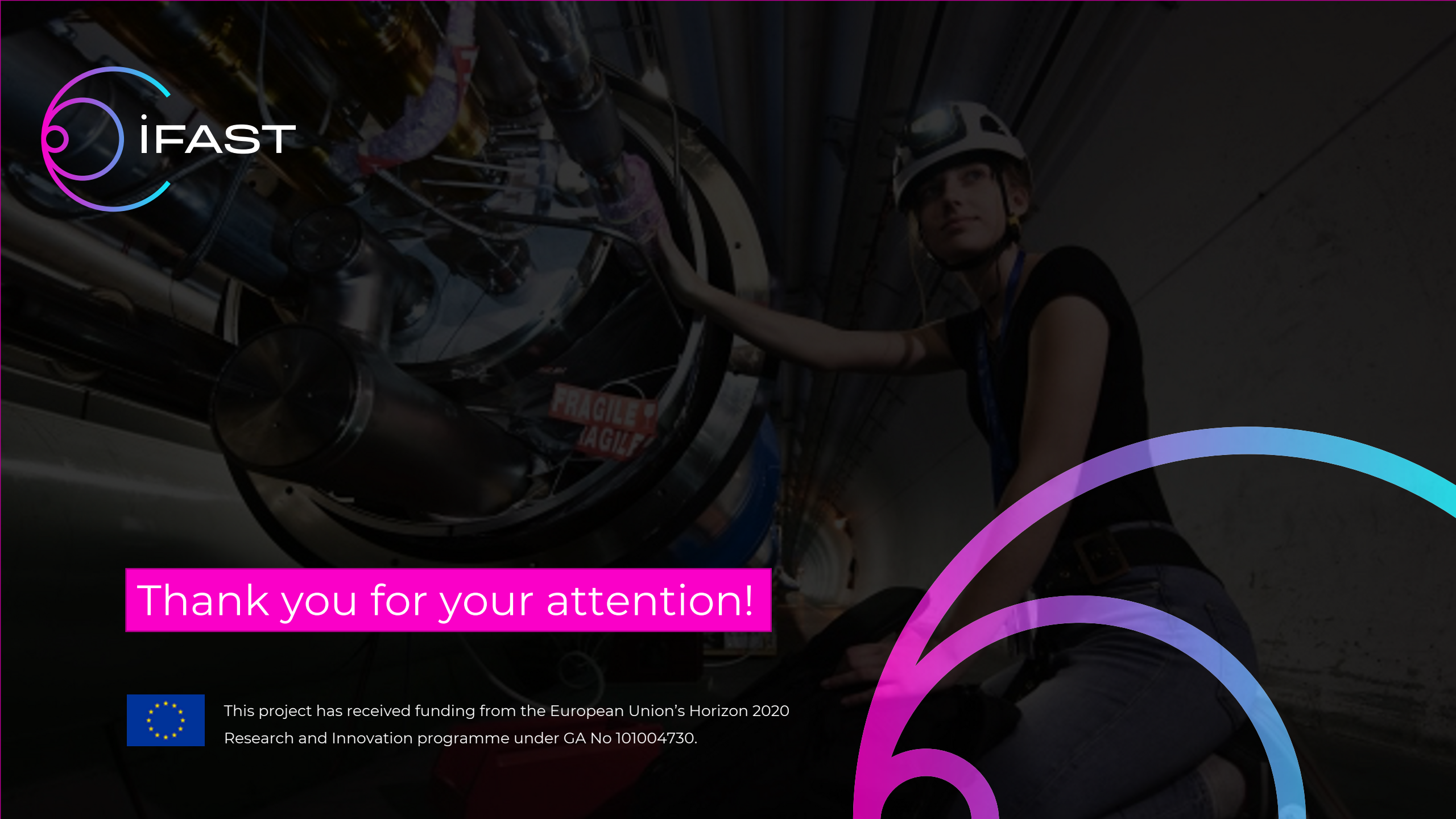
2025-2027
R&D plan will be refined

Relevance of objectives and impact

- An International Collaboration hosted by CERN is in place collecting all the EU –U.S. – Asia communities

  ➔ **Memorandum of Collaboration** signed by many institutes
- Panel to devise European Accelerator R&D Roadmap ➔ **Community Meetings**
- Led definition of R&D programme and implementation plan
- Work to develop implementation plan to be presented to CERN Council
- Integration of collaboration in implementation plan for European Accelerator R&D Roadmap
- Governance model and study organisation
- Strong participation during Snowmass21 and support ➔ **s**ubmission of white papers ➔ **EPJC paper soon**
- First muon collider annual meeting ➔ MS15: review of muon source
- HORIZON-INFRA-2022-DEV-01 **MuCol project** now approved, **planned to start March 1, 2023**

IMCC and MUST identified specific topics for a dedicated workshop on synergies in 2023 during the Annual Meeting



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Accelerator Key Challenge Areas

- **Physics potential** evaluation, including **detector concept and technologies**

- Impact on the environment
  - The **neutrino flux mitigation** and its impact on the site (first concept exists)
  - The **machine induced background** impact the detector, and might limit the physics

- **High-energy systems** after the cooling (acceleration, collision, ...)
  - Fast-ramping magnet systems
  - High-field magnets (in particular for 10+ TeV)

- **High-quality muon beam production**
  - Special RF and high peak power
  - Superconducting solenoids
  - Cooling string demonstration (cooling cell engineering design, demonstrator design)

- **Full accelerator chain**
  - e.g. proton complex with H- source, compressor ring ➔ test of target material

- Some technology challenges more important at 10 than at 3 TeV
  - higher dipoles fields in collider (O(15 T))
  - stronger final focus quadrupoles (O(18-20 T))
  - shorter bunches in cavities of last accelerator ring
  - more performant accelerator ring systems to cut length and cost