



# Workshop Goals

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# 2<sup>nd</sup> Community Meeting Charge



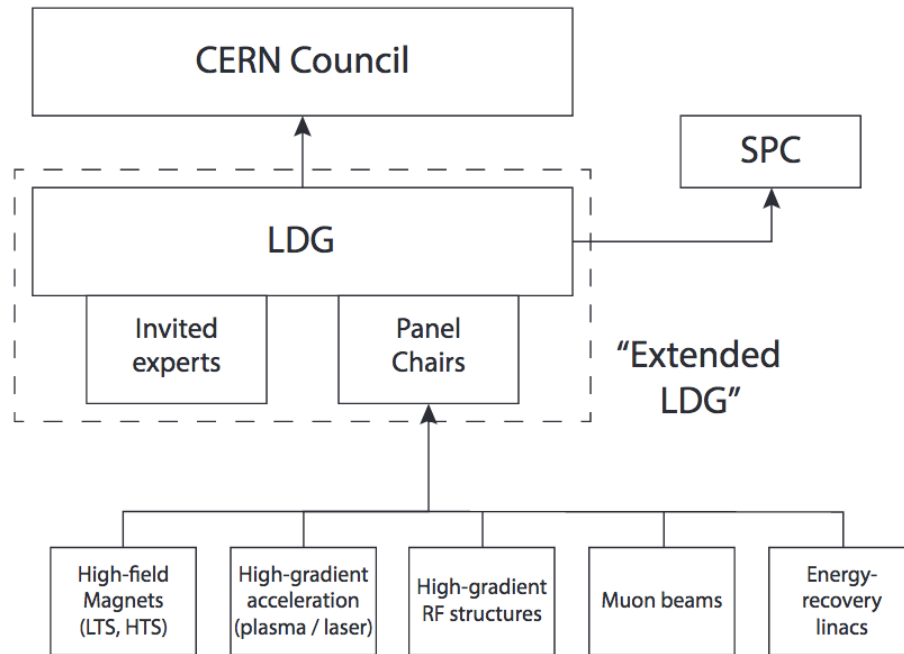
- During the 1<sup>st</sup> community meeting, we identified a set of challenges in the delivery of the muon collider.
- The goal now is to confirm those challenges and to develop them into a prioritised and resource loaded R&D list. In particular:
  - Identify the R&D that has to be carried out before the next ESSU-PP ([assume to submit by end 2025](#)) to scientifically justify the investment into a full CDR for the muon collider and the corresponding demonstration programme.
  - Identify the main components of the demonstration programme together with the corresponding preparatory work.
  - Realistic but ambitious targets for the performance goals of the different collider systems.

This includes R&D to develop a baseline collider concept, well-supported performance expectations and an assessment of the associated key risks, cost and power drivers.

Also the working groups should consider what could be assumed for the demonstration programme, i.e. in one or more test facilities starting in 2026, as well what one can anticipate to be available in 2035-2040 for a first collider stage and in 2050 for an energy upgrade.

- Collect expression of interest (EOI) from potential collaborators interested to contribute to any specific work package (task)

# Muon Beam Panel



## Community meetings:

- **March 24+25:** Testing opportunities for the muon collider
- **May 20+21:** Identify R&D challenges, first scope
- **July 12-14:** Identify the R&D for next five years, internal priorities, resource estimates
- **July 16:** Submission of Interim Report to LDG
- **September:** Collaboration will continue to develop programme and answer questions of LDG

Daniel Schulte (CERN, chair)  
Mark Palmer (BNL, co-chair)  
Tabea Arndt (KIT)  
Antoine Chance (CEA/IRFU)  
Jean-Pierre Delahaye (retired)  
Angeles Faus-Golfe (IN2P3/IJClab)  
Simone Gilardoni (CERN)  
Philippe Lebrun  
(European Scientific Institute)  
Ken Long (Imperial College London)  
Elias Metral (CERN)  
Nadia Pastrone (INFN-Torino)  
Lionel Quettier (CEA/IRFU),  
Magnet panel link  
Tor Raubenheimer (SLAC)  
Chris Rogers (STFC-RAL)  
Mike Seidel (EPFL and PSI)  
Diktys Stratakis (FNAL)  
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## Contributors:

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# General News



Interim report should be confidential until Council has seen it (in September)

- We will discuss the content but are not allowed to share the text

Deadline for draft: July 16<sup>th</sup> to the LDG

LDG meeting on July 19<sup>th</sup> to discuss progress

Interim Report ready by end of July (probably still true)

# Interim Report Proposed Structure



## Introduction (5pp)

- Relation to strategy
- Process
- Remit of panels
- What is to come in final report

## Panel section (10pp each)

- Executive summary of findings to date
- Motivation
- Panel activities
- State of the art\*
- R&D objectives\*
- Key points of roadmap\*
- Facilities and infrastructure

Need to develop objectives  
at community meeting

Need to agree on key points of roadmap

# Tentative Interim Report Conclusion



Note: the report should be confidential until it has been seen by Council  
So only show spirit of Panel Conclusion  
However, all discussion will be reflected in report

The muon collider is based on novel concepts and is not as mature as other collider options. However, it promises a unique opportunity of a high-energy, high-luminosity lepton collider.

The panel has identified a viable baseline parameter set and a development path that can address the major challenges. The Panel will propose the R&D effort that it considers adequate to address these challenges during the next five years to a level that allows to assess whether the muon collider is a credible option. Ongoing developments in underlying technologies will be exploited as they arise in order to ensure the best possible performance. This will allow the next ESPPU to make fully informed decisions. It will also benefit equivalent strategy processes in other regions.

# International Muon Collider Collaboration



## Objective:

In time for the next European Strategy for Particle Physics Update, the study aims to **establish whether the investment into a full CDR and a demonstrator is scientifically justified.**

It will provide a baseline concept, well-supported performance expectations and assess the associated key risks as well as cost and power consumption drivers. It will also identify an R&D path to demonstrate the feasibility of the collider.

## Scope:

- Focus on two energy ranges:
  - **3 TeV**, if possible with technology ready for **construction in 10-20 years**
  - **10+ TeV**, with more advanced technology, **the reason to do muon colliders**
- Explore synergy with other options (neutrino/higgs factory)
- Define **R&D path**

## Deliverable (in 5 years):

- Report supporting that the muon collider is a realistic option, including description of required R&D programme to arrive at CDR
- Design of test facility

# Collaboration Timeline Goals



## 3 TeV collider option

- Important step up in energy after a higgs factory
- Goal: have one option ready to take data before 2045
  - Could be next project in Europe, e.g. if ILC or CepC would be built
  - How do we consider construction in other regions?
    - for Roadmap European perspective is most important
    - for the collaboration international perspective is most important
  - Need to have some scenarios where muon collider is next project
- Maximum energy of CLIC
  - CLIC integrated cost is 18 GCHF and it uses 590 MW power
  - Aim for significantly lower cost and power consumption
- One option with technologies expected to be available in 15-20 years
  - Will adjust design accordingly



# Collaboration Timeline Goals

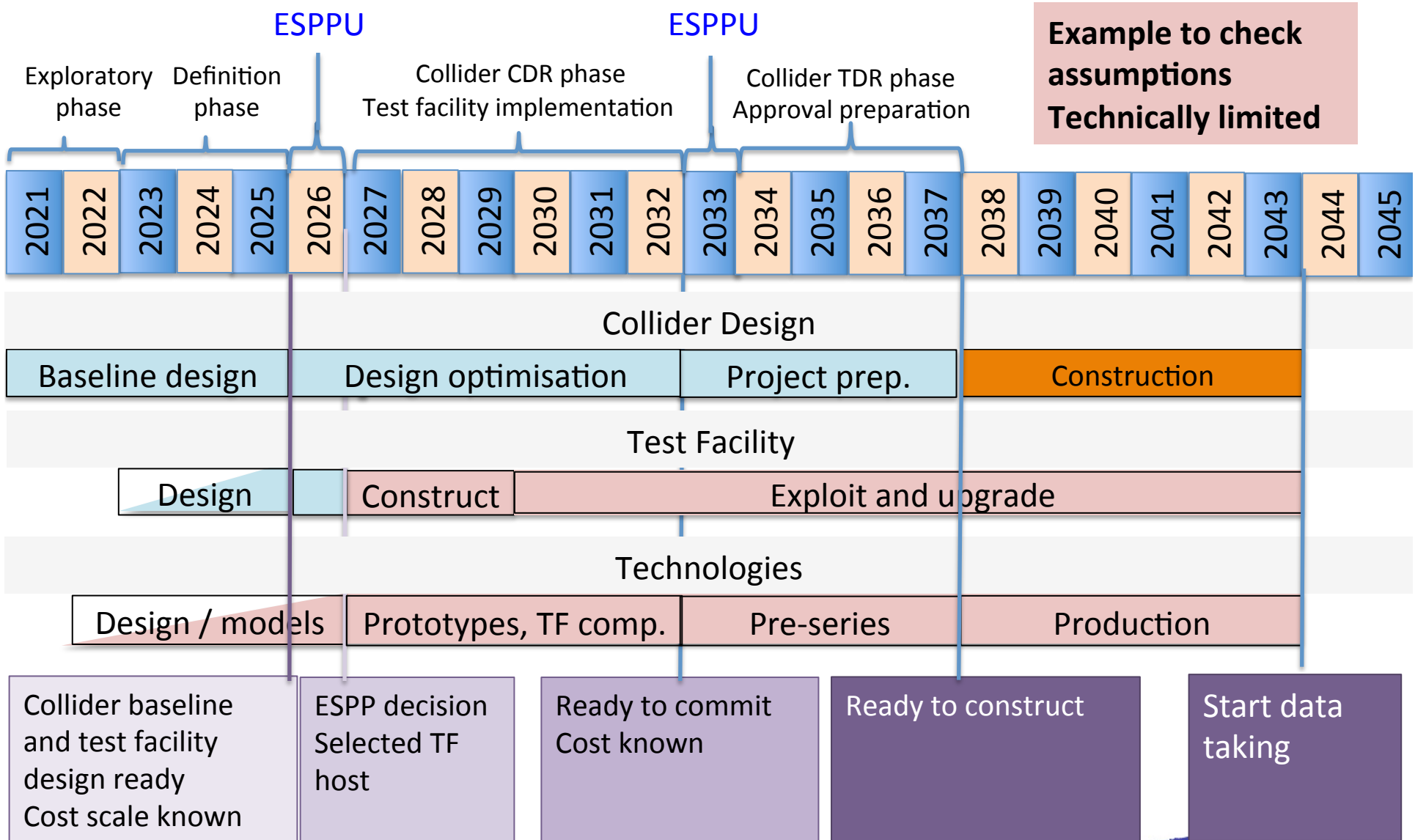


## 10+ TeV collider option

- Goal: Highest lepton energies, well above the reach even of CLIC
- To explore energy reach for a realistic collider and understand if muon collider is right direction for long-term future
- Competitive with FCC-hh
  - aim for competitive cost and power (FCC-hh 24 GCHF and 580 MW)
  - need to justify that this appears possible
- Employing advanced technologies, not yet concerned about schedule
- Could be upgrade of a 3 TeV collider
  - splitting the cost into two stages, only 3 TeV collider ring cost is lost

# Tentative Target for Long-Term Timeline

to asses when 3 TeV could be realised



# Need to Develop Scenarios



Roadmap should contain different scenarios ranging from minimal investment to maximum rate of progress

Feel that all R&D issues raised in first meeting need to be addressed

- Scenarios will consist of different levels of addressing them
- **Aim of this meeting is to define these levels**

We need to start discussing the resources

- The level required for different scenarios
- Who is going to do what
- However, this is an iterative process
  - Some people take longer to commit

Potential timelines are important

- more support in Europe if muon collider can be the next project in Europe
  - e.g. EU co-funding requires this
- international participation is important
  - have to find a good way to deal with P5 process

# Goals for 2025



Convince the community that the muon collider is a realistic option:

- Physics case based on supported energy and luminosity reach and considering background conditions as well as detector technologies
- Technical risks are understood and considered acceptable
  - obviously here we will have a full range of opinions
  - have to make sure that the community at large is convinced
  - have to understand what the community considers as challenges together with what we see as challenges
    - will need to expose the concept to the community as soon as possible to make sure that we indeed address the right issues
  - different funding scenarios will allow to reach different levels of confidence
- The project must be affordable (based on cost scale)
- Power consumption must be acceptable
- At least one realistic sites must exist

# Baseline Development



Need to define parameters for several interfaces

- e.g. between cooling and acceleration complex
- Will start from MAP parameters with some adjustments
- Will need input to the parameters:
  - Question: What is the budget for emittance dilution in the linacs?
  - Answer: What do your initial studies of emittance dilution indicate is a reasonable budget?

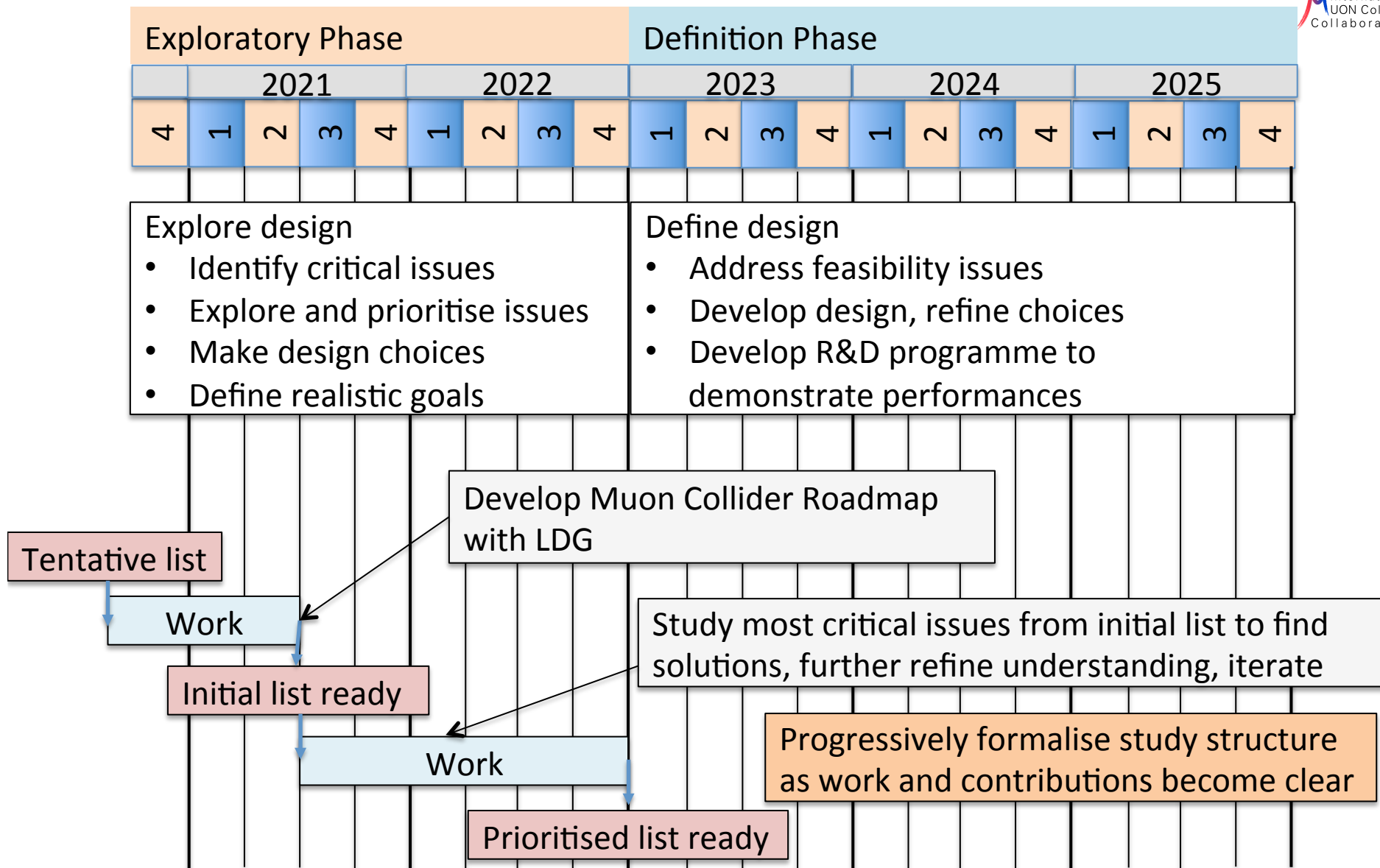
Need to fix general design parameters

- e.g. which gradient can be used in the superconducting cavities of the accelerator complex
- Need input from the magnet and RF working groups

Need to make a number of choices

- e.g. RCS or FFA or a mixture?
- Need some studies on both options before we can converge

# Timeline until next ESPPU



# Baseline Development



In 2021 define tentative parameters based on MAP and Roadmap

- Use these tentative parameters to start working
- Derive first feedback

Toward end of 2022

- Based on feedback propose initial baseline parameters
- Make choices where possible
  - but maintain useful alternatives

Toward end of 2023

- Adjust parameters to final baseline parameters
- Make final choices for baseline
- Maintain useful alternatives

Decisions to be taken in form of some review

# Tentative Project Breakdown Structure



## Proton complex

- H- source
- linac
- accumulator
- buncher
- combiner

## Muon generation complex

- Target system
- Decay channel
- Chicane, capture and buncher
- Dump

## Muon colling complex

- Initial cooling
- 1rst 6D cooling
- Merger system
- 2nd 6D cooling
- Final cooling
- Matching and transfer

## High-energy acceleration

- Linac
- 1rst recirculating linac
- 2nd recirculating linac
- RCS 1 / FFA 1
- RCS 2/ FFA 2
- RCS 3 /FFA 3 ?
- RCS HE / FFA HE

## Collider Ring

- Collider ring 3 TeV
- Collider ring 10 TeV

### Note:

- Transfer between systems should typically belong to the first system
- seems to make interface simpler

### To be reviewed

Input from working groups required



# Workpackage Considerations



- How much will the workpackage contribute to convincing ourselves and the community that the muon collider is realistic?
  - Not just feasibility but also cost and power as well as risks.
  - To same extend we talk about opinions.
- Will the workpackage contribute to making the fast timeline (project before 2045) realistic?
  - Preparing technologies that would otherwise take too long.
  - Preparing the test programme.
- How can we integrate other regions if they need more time to decide on resources?

# Proposed Workpackage Description



A short text describing the workpackage goals and content

# Proposed Workpackage Tasks



A bullet point list of the tasks in the workpackage with a very short description

# Proposed Workpackage Timeline



A rough timeline for the work

In particular when you need information from some other group and when you will deliver some information

Please refer to Timeline on next slide

# Proposed Workpackage Resources



A table of the initial estimated required resources in FTE years, specifying staff, post-doc and student. If possible, resources should be associated with the tasks.

This is only indicative to get over the shock of having to fill such tables.

Task	Staff [pm]	postdoc [pm]	student [pm]	Cash [kEUR]	Comment

Also a list of who is interested in participating to define the work and carry it out. There is no commitment required.

# Tentative Potential Workpackages



## Workpackages including muon collider specific experiments

- Fast-ramping magnet systems
- Cooling RF test
- Target material tests
- Neutrino mitigation tests

## Design studies exploiting technology progress in R&D Roadmap and elsewhere

- Cooling RF design
- Superconducting RF
- Efficient RF power systems
- High-field solenoids
- High-field dipoles / combined function magnets
- Target system
- Neutrino radiation mitigation system

## Design studies

- Proton complex
- Muon production and cooling
- High-energy complex
- Collective effects
- Integrated cooling cell design
- Radiation protection
- Accelerator radiation (target, collider ring)
- MDI
- Other technologies

## Test facility design

- Application of above workpackages to test facility (should be the same people)
- Studies for test facility implementation: civil engineering, proton complex, ...

To be refined at this meeting

# Roadmap Scenarios



- Key points already required for the interim report
  - slight surprise
- The panel will have to devise them
  - but we will make proposals
  - Discussion in the Parameters WG today
  - Discussion on Wednesday
- Might assume they cover some range
  - Fully consistent with long-term timeline
  - Will have some limited delays and risks
  - Will have significant delay and risk
  - Will advance the muon collider but not be able to stick to timeline goal

# EU Design Study



Will attempt to prepare an EU Design Study

Priority for particle physics is not clear at this moment

Design study volume is up to 3 MEUR from EU

Non-EU partners can participate but not receive substantial funding

Initial goal had been to submit proposal for test facility design

But wording of EU and discussion in TIARA indicate it is better to submit study for whole muon collider

⇒ come back to it on Wednesday

For those interested:

**HORIZON-INFRA-2022-DEV-01-01: Research infrastructure concept development**



# Meeting Organisation



## Monday:

- Working groups will define the R&D effort over the next five years and the resources required.
- They will also collect who is interested to participate to the refinement of the workprogramme and potentially contribute to the work (also if no commitment can be made at this time).

## Tuesday:

- Plenary session to collect input from working groups

## Wednesday:

- Starting to define roadmap scenarios
- Discuss the findings of the working groups
- Which input is missing and what can we do about it?
- Try to summarise resources
- Identify who has interest to contribute

# Conclusion



This meetings goal is to start developing resource-loaded workplan scenarios

Need to ensure that we can have a collider before 2045

Will start organising EU co-funded bid on Wednesday

- but have cannot rely on it

Need to include all regions in a good way