Goals and scope of the Demonstrator

(site independent…)

https://indico.fnal.gov/event/64984/

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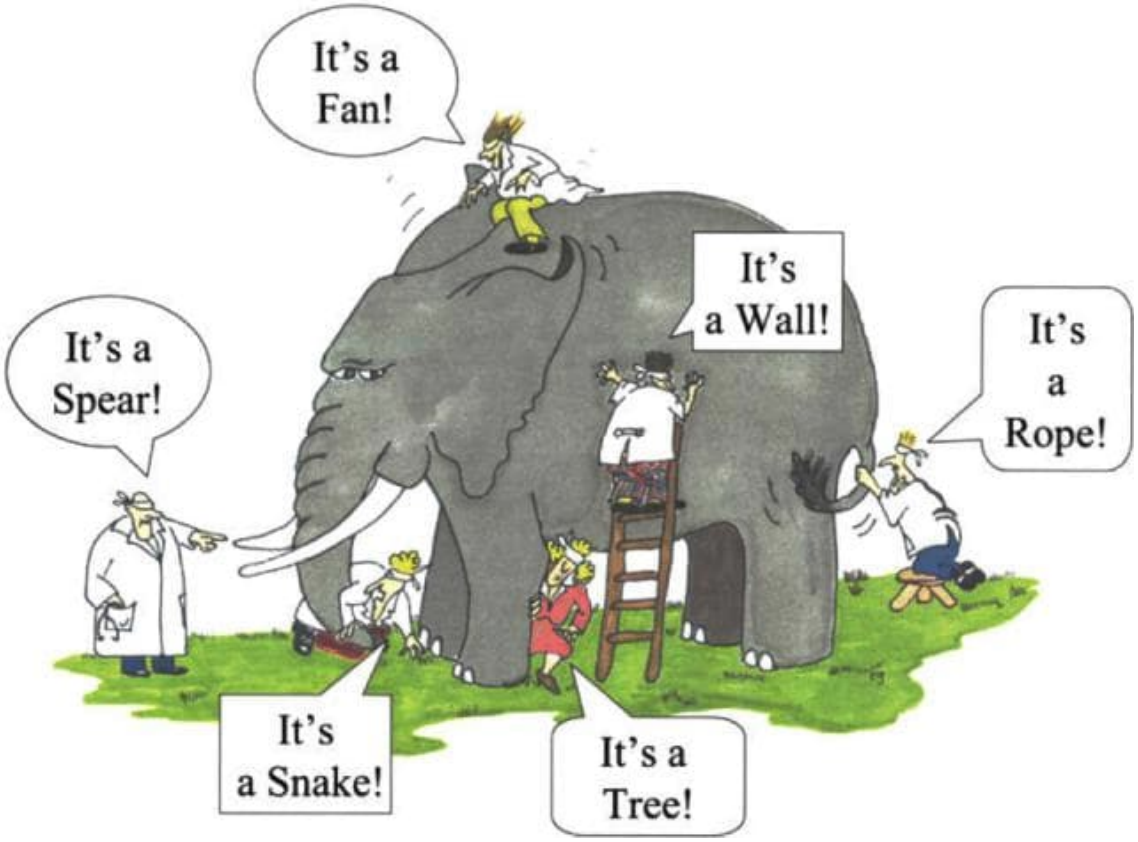
Foreword

- The goal of this presentation is to
  - Stimulate the debate on the motivations for a Demonstrator Facility
  - Show what is requested from different actors in the project
  - Try to understand what is not yet requested but probably necessary
  - Stimulate the debate on the potential of having such a facility
- As such, it will provide more questions than answers…
- Answers are to be developed in the document for the European strategy if we want to have a chance of a positive recommendation!

Outline

- Motivation
- The ideal Demonstrator
- The reality (*constraints related to budget, technology, safety etc*…)
- Propaedeutic R&D
- What else can we do with a demonstrator ?

Motivations and Stakeholders



Picture from this source

Motivation and Stakeholders: Ideal Demonstrator

- What:
  - We want to demonstrate 6D reduction of emittance by a factor 2 (***C. Rogers***)
  - We want to benchmark simulations to convince we understand all aspects of the cooling process.
  - We want to test the cooling cell technology in an operational environment.

- How:
  - Using the cooling cell technology to be used in the real Muon Collider:
    - Magnets: HTS, 20K, cooled by LH_2
    - RF: Warm, multicell, High Gradient, High Efficiency Klystron
    - Absorbers: Hydrogen and LiH

- When:
  - **As soon as possible**. If we want to start a MC before 2050, we should confirm the methodology **and** the technology at least 10÷15 years before

Motivation and Stakeholders: Constraints

- *What:*
  - *We want to demonstrate 6D reduction of emittance by a factor 2 (**C. Rogers**)*
  - *We want to benchmark simulations to convince we understand all aspects of the cooling process.*
  - *We want to test the cooling cell technology in an operational environment.*

- In none of the present proposals we will have the baseline intensity (~ 10^{12} μpp) :
  - What is the minimum intensity we can accept? Is $10^2 \div 10^4$ acceptable?
  - If yes, what will be the remaining uncertainties? Collective effects? Radiation? …

- In a facility you normally want to install a lot more instrumentation to measure any effect:
  - Can we sacrifice some longitudinal space to allow for instrumentation?
  - *We are writing a document for the EUSPP to define in greater detail what we want to measure, the dynamic range, the type of instrumentation needed etc…*

Motivation and Stakeholders: Constraints

- *How:*
  - *Using the cooling cell technology to be used in the real Muon Collider:*
    - *Magnets: HTS, 20K, cooled by LH_2*
    - *RF: Warm, multicell, High Gradient, High Efficiency Klystron*
    - *Absorbers: Hydrogen and LiH*

- In none of the present proposals we will have the baseline intensity (~10^{12} μpp) :
  - Does it make any difference for technology? E.g., Radiation tolerance?
  - The real cooling cell might require a larger bore for shielding…

- In reality, we will not have all the technologies available at the same time, and for a reasonable cost:
  - Are there technologies that MUST be there to convince?
    - E.g. can we use LTS if we can? Can we work at lower than 20K?
    - What if we cannot use LH_2 as an absorber?
  - Can we imagine an evolutive facility, and can we define appropriate milestones?

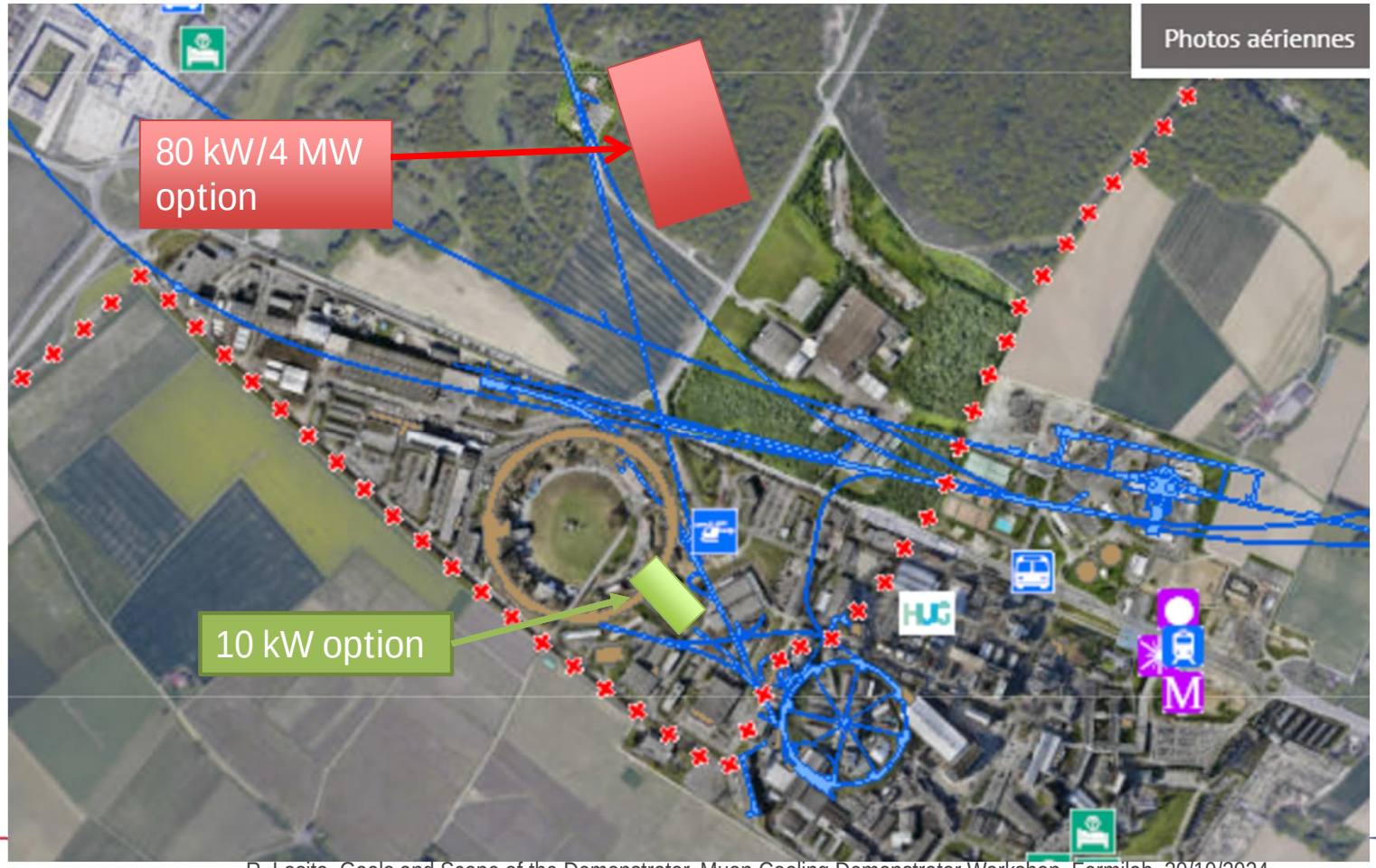
Motivation and Stakeholders: Constraints

- *When:*
  - *As soon as possible. If we want to start the MC before 2050, we should confirm the methodology **and** the technology at least 10÷15 years before*

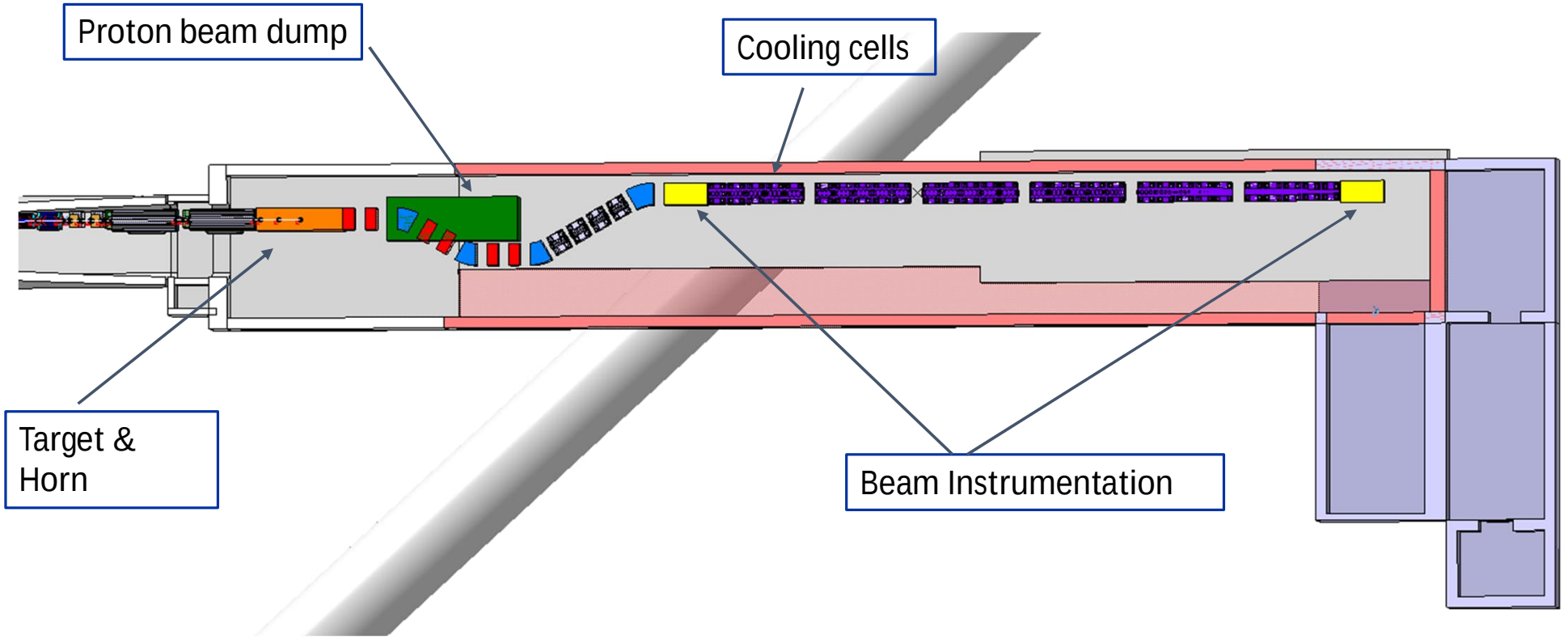
- What if we do not reach a factor 2 in emittance reduction, but a factor 1.5, or 1.2?
  - Would we be convinced?
  - Would referees be convinced?
  - Would deciders be convinced?
  - Is it sufficient to benchmark our codes?

- What amount of budget *(EU budget accounting)* we believe is reasonable to invest:
  - Is it 100 MCHF ? 150 MCHF? 200 MCHF? (1 CHF = 1.16 $)
  - We should be ambitious, but where is the borderline between ambition and insanity?
  - Let's not forget that the Demonstrator shall have to be matched by R&D for technology development and other test facilities…

Demonstrator at CERN



Present layout for the CERN option



Constraints

- Civil Engineering & RF
  - Unfortunately, there is no place (that I know) where one can build a demonstrator without additional or completely new civil engineering
  - Mostly due to the very bulky RF infrastructure
  - Unavoidable if we want high RF gradients
  - Only feasible if High Efficiency Klystrons will become available.
  - The RF technical gallery has to be in the vicinity of the accelerator(cooling) tunnel to minimise costs.
- Civil Engineering & Technical Infrastructure
  - In addition, we need space for the more conventional infrastructure:
    - HVAC
    - Cryogenics
    - Power Converters
    - Controls
  - For this we probably have more flexibility, can be at distance.

- More details in the presentation of Lukasz tomorrow for CERN's proposal!

Technologies

- Target & Horn
  - For the time being we privilege (for the CERN proposal) a solution with a horn due to:
    - Cost
    - Low intensity
  - With 10 kW power, no R&D on target is possible, *will need to provide alternative facilities for Target R&D*
  - We have not yet a detailed study of the target/horn efficiency. Paul will present the present configuration, but someone should study it in detail to determine and optimise the yield.
    - In CERN AD we use a horn with >400 kAmp, so there is maybe margin for optimisation.

Technologies

- Solenoids
  - We will test, at least initially, only medium field solenoids (7T or similar)
  - The 20T target solenoid will be too expensive and too bulky for such a facility. *We therefore need to have a parallel program to demonstrate its feasibility*
  - It is important to show that we can operate smoothly for long periods such magnets without major issues (e.g. protection, quench etc…).
    - Would we expect more problems with high intensity (10^{12} μpp @ 5 or 10 Hz?)
    - If yes, how can we test ? Would a proton beam provide equivalent challenges?
  - How to deal with fringe fields? Will we need anti-solenoids at each end? Will beam instrumentation impose a limit?

Technologies

- RF
  - **RF is challenging:**
    - Need a facility for test of maximum gradient and breakdown rate in magnetic field
    - Present state of the art is quite below the requirements (see Dario's presentation).
    - *We probably cannot wait to have a solution, so what is the impact on the results if we cannot have 30 MV/m, but remain limited to, say, 15 or 20 MV/m?*
    - Can **C³** technology be tested in magnetic field? What else?
  - **Need a lot of Power! Order of 20 MW per multicell cavity…**
    - Prerequisite is the development of a High Efficiency Klystron!
    - 650 MHz in US, 704 MHz in Europe (both for good reasons!)
    - Difficult to imagine we will develop HEK at both frequencies in the next 5 years
    - If we will not have any, it might be a showstopper!
    - More details in Igor's presentation tomorrow!
  - **Windows/diaphragms still an open question**
    - Can we do without? (low gradient, size etc..)
    - Can we do with? (cost, complication etc…)

Technologies

- Absorbers
  - For the time being we don’t know how to deal with H2 absorbers
    - We would need a serious R&D for those cases where we think we can use them
  - For the demonstrator, we should start with LiH, but be flexible enough to allow future upgrade.
  - **We need to define a design, construction and test programme, including testing facilities!**
  - I assume we know how to deal with LiH …
    - probably true for the intensities of the Demonstrator,
    - Need to have R&D for 10^{12} μpp?

Timeline

- **CERN**
  - The next European Strategy Update is the best occasion we have to get support
  - We need to work on a realistic scenario by March 2025…
    - We will discuss it with CERN management (present and future?) to understand what are the margins…
  - **Target scenario**:
    - Approval of EUSPP **June 26**
    - Definition of CERN MTP in **March 27**
    - Budget available from **January 28**
  - Additional Budget for specific programmes (e.g. magnets, HEK…) might become available through different sources (EU…)

- **Fermilab**
  - **2025-2026**: Demonstrator studies via laboratory discretionary funds. Goal is to prepare a demonstrator conceptual design with US sitting options
  - **2027-2028** (estimate): A targeted panel will review demo facilities in the collider R&D portfolios
  - **2028+**: With positive outcome, dedicated DOE funding towards demonstrator R&D , prototyping and component fabrication is expected to appear
  - **2031**: Construction of the Demonstrator facility can begin

R&D

- RF
  - High Gradient in Magnetic field facility and test programme
  - Cavities with diaphragms (Be? Al?)
  - HEK: a prototype needs to be built asap
  - C^3 technology to reach the desired gradient and breakdown rate?
- Solenoids
  - Need parallel R&D to explore higher gradient than the 7T we are considering
  - Need R&D for radiation tolerance (for real MC)
  - detailed study of the need of anti-solenoids at each end
- Absorbers
  - Need a real R&D programme, with the goal of benchmarking the simulations and learning to use the materials.
- Cryogenics
  - See Patricia's talk:
  - We will start with He, however need a vigorous R&D to understand whether and how we can use Liquid H_2
- Target
  - Only technology for which the Demonstrator (at least as foreseen today at CERN) does not provide any useful insight. Will need a dedicated R&D programme for targets
- Beam Instrumentation
  - We can do some very useful work in the demonstrator. Need to build a collaboration around instrumentation.

Synergies

- Lots of discussions but nothing obvious today
- µSTORM only interested for a relatively High Power beam.
- We need to do more in this respect…

Conclusions

- **CERN** and **Fermilab** both have **realistic sites**, that could bear results in time with a Muon Collider starting before 2050, provided funding is released soon.

- Building a Demonstrator is not the end of the story. **We will need a lot of parallel R&D**, so we need to define objectives for the demonstrator, to limit cost and leave space for all the parallel R&D.

- We need to work on synergies

The debate can start!

Thank you

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