International MUON Collider Collaboration

CERN

Test Facility (Demonstrator)

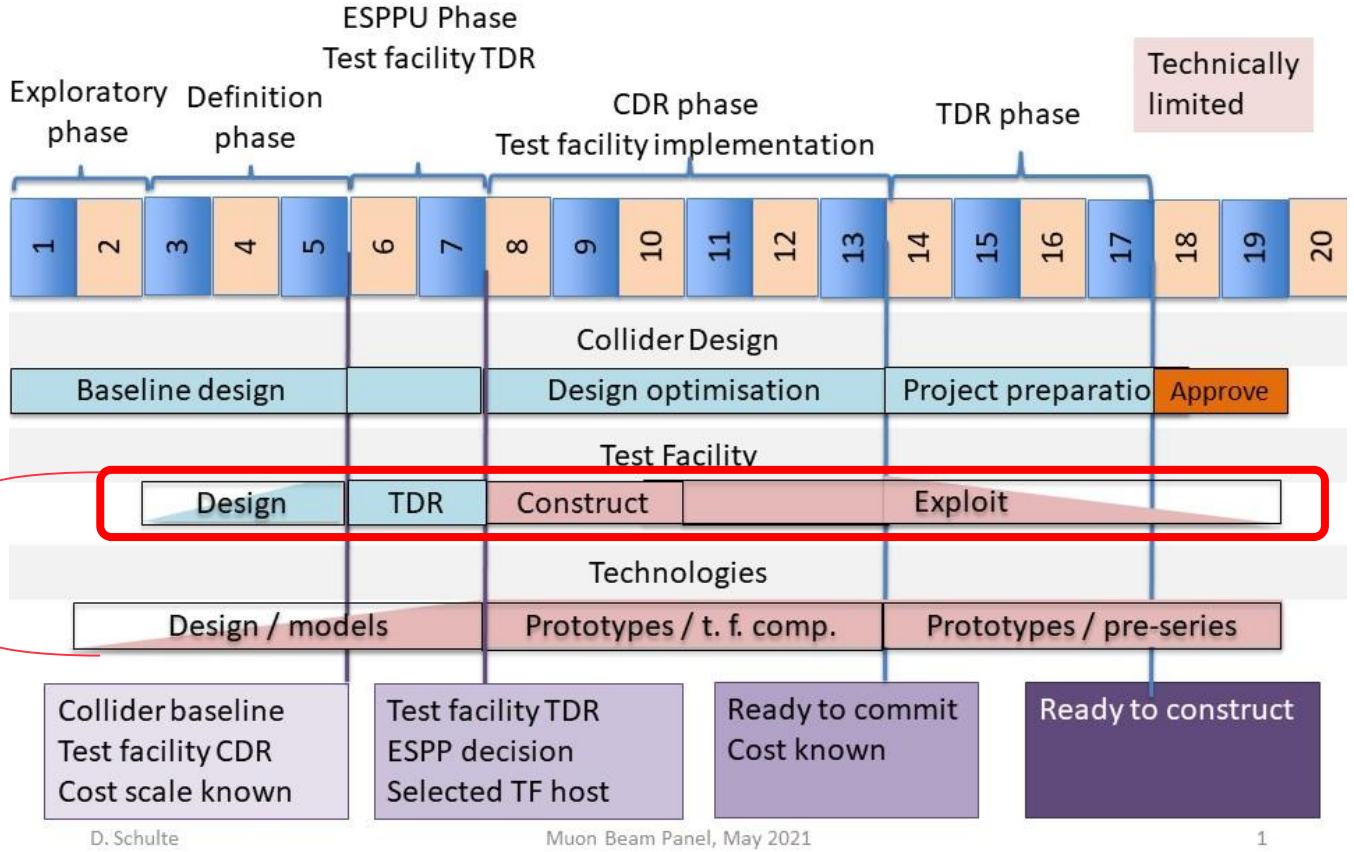
Roberto Losito
CERN-ATS-DO

1st Community meeting of the International Muon Colliders Design Study - 20 May 2021

Discussion topics

- What do we have to demonstrate
- In which timescale
- With which resources
- With which beam energy/power/intensity/time structure…
- In synergy with which facilities
- Road to Roadmap…

Scope and Potential Long-Term Timeline



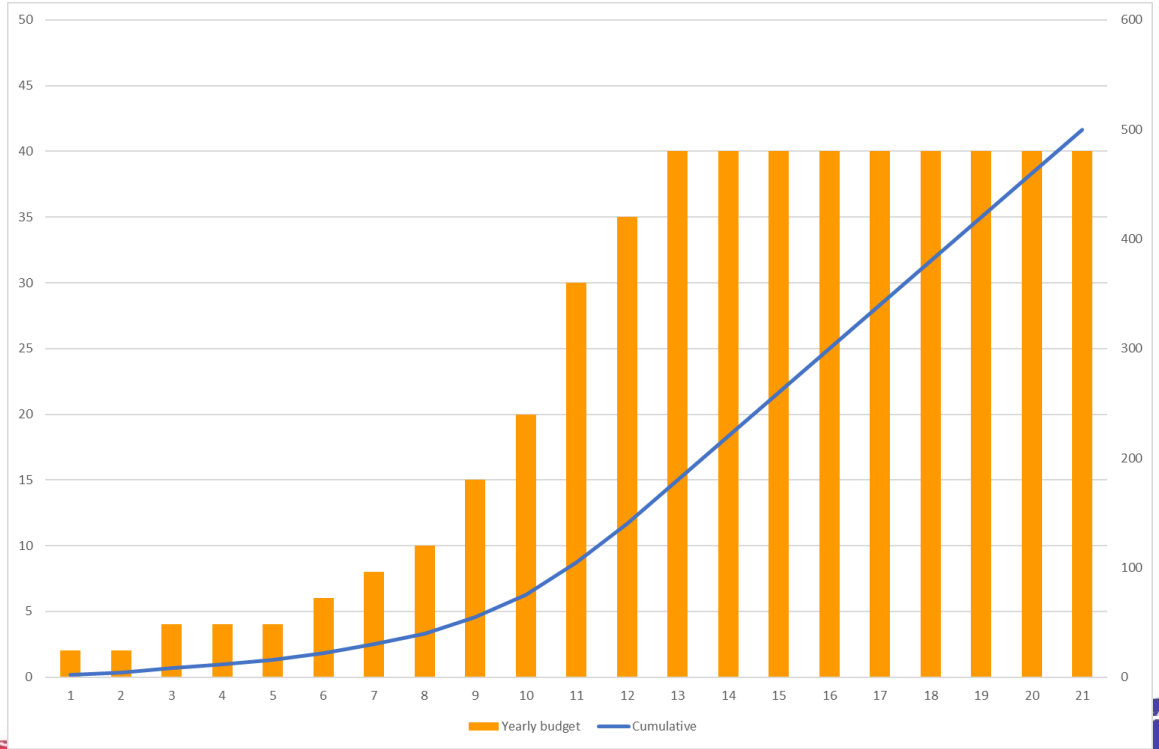
O(500 MCHF)

Resources

- O(500MCHF)
  - What's the share we plan between Test facility and hardware test/prototype
    - Test Facility: ~150 MCHF + operation (50 MCHF)
    - Hardware Prototypes & Technology R&D: ~300 MCHF ?
  - Assuming a baseline of 20 years (see next slides..)

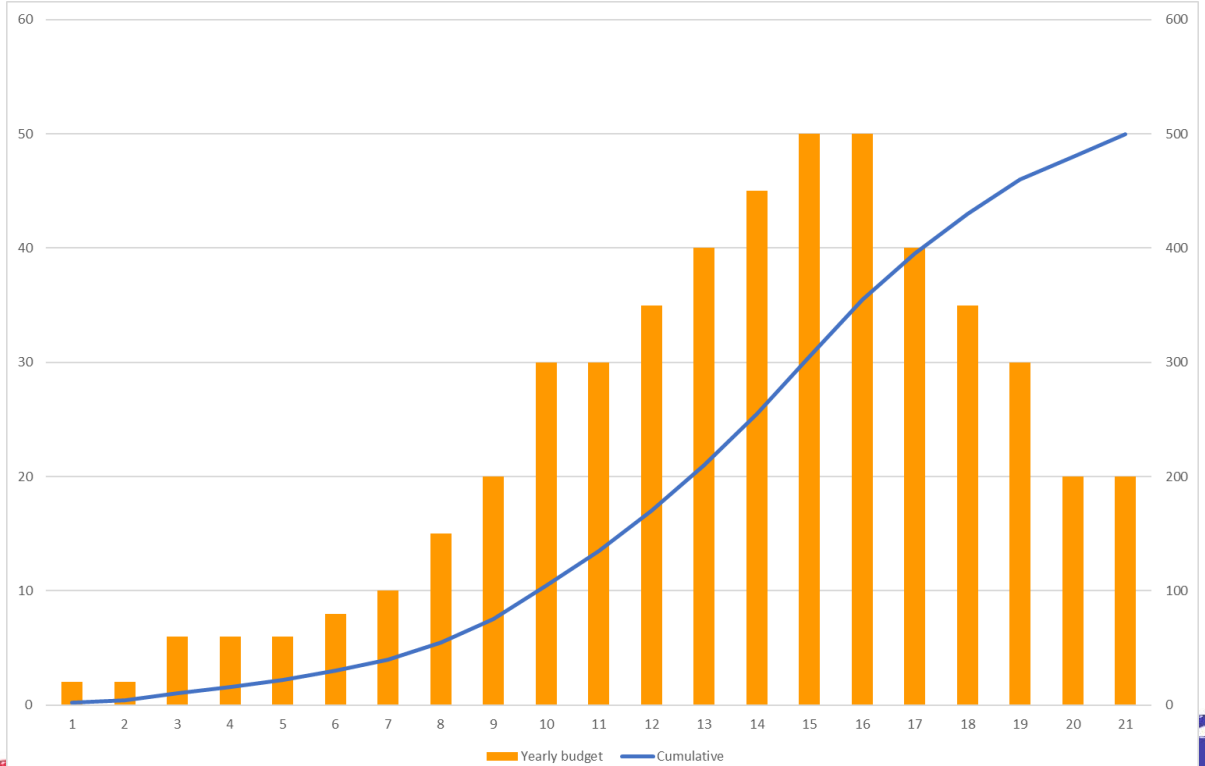
Budget Profiles – 1
[MCHF] Shy

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
2	2	4	4	4	6	8	10	15	20	30	35	40	40	40	40	40	40	40	40	40



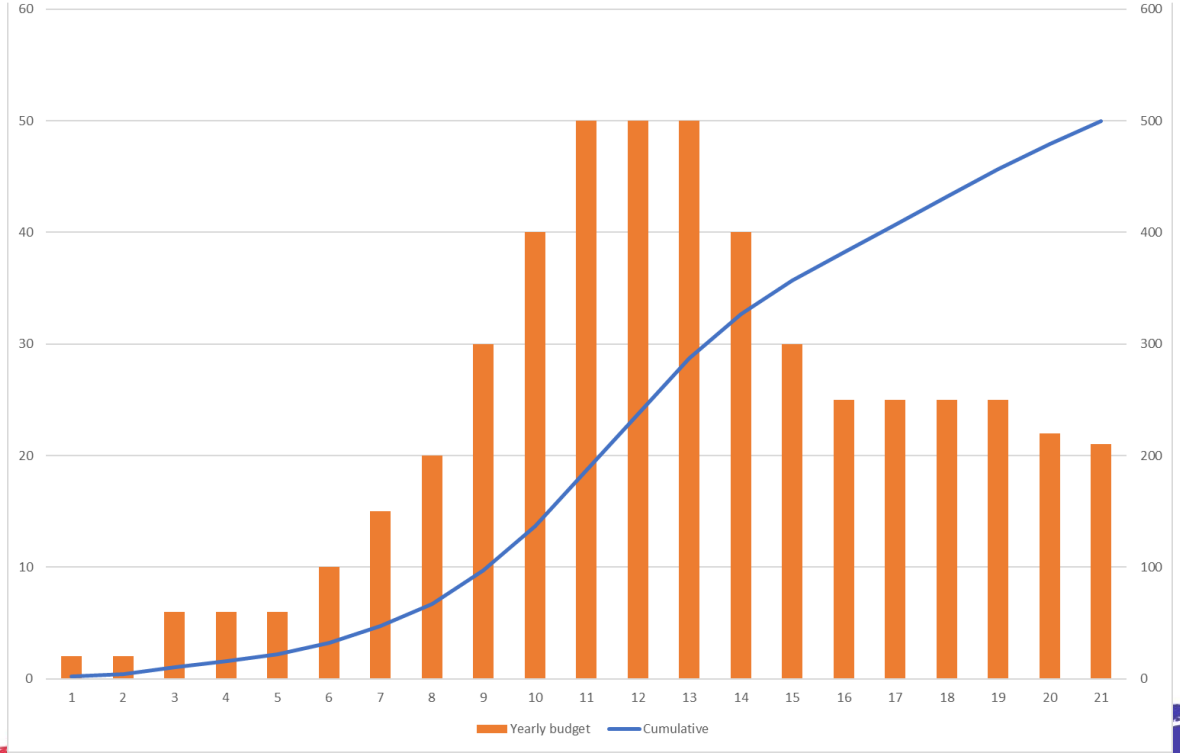
Budget Profiles – 2
[MCHF] Modest

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
2	2	6	6	6	8	10	15	20	30	30	35	40	45	50	50	40	35	30	20	20



Budget Profiles – 3
[MCHF] In line with the roadmap

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
2	2	6	6	6	10	15	20	30	40	50	50	50	40	30	25	25	25	25	22	21



Questions

- Consensus that demonstration of muon production and cooling is key to convince ourselves (and the funding agencies) to move forward ?
- *How?*
  - Beam power at around 1.5 or 4 MW for final machine?
  - Several cooling schemes are being studied. What are the criteria to decide which is the most convenient to test? Performance? Cost? Feasibility?
  - Can we test more than one cooling scheme?
  - A test facility at O(20÷80 kW) is sufficiently convincing? What will be left to demonstrate after?
  - Will we be ready for a go-no-go decision after that?
  - What has to be tested without beams, or with other beams (protons? Leptons?)

Beam Power

- **The design of the facility will depend critically on the desired beam power on target for the final complex.**
- A first decision to be taken quickly in order to prepare an R&D roadmap, is whether we limit to 1.5 MW or keep the 4 MW option.

  - ***It is a critical decision*** since for 1.5 MW there are already concepts that seem (close) to work (JSNS, SNS, ESS, T2K?).

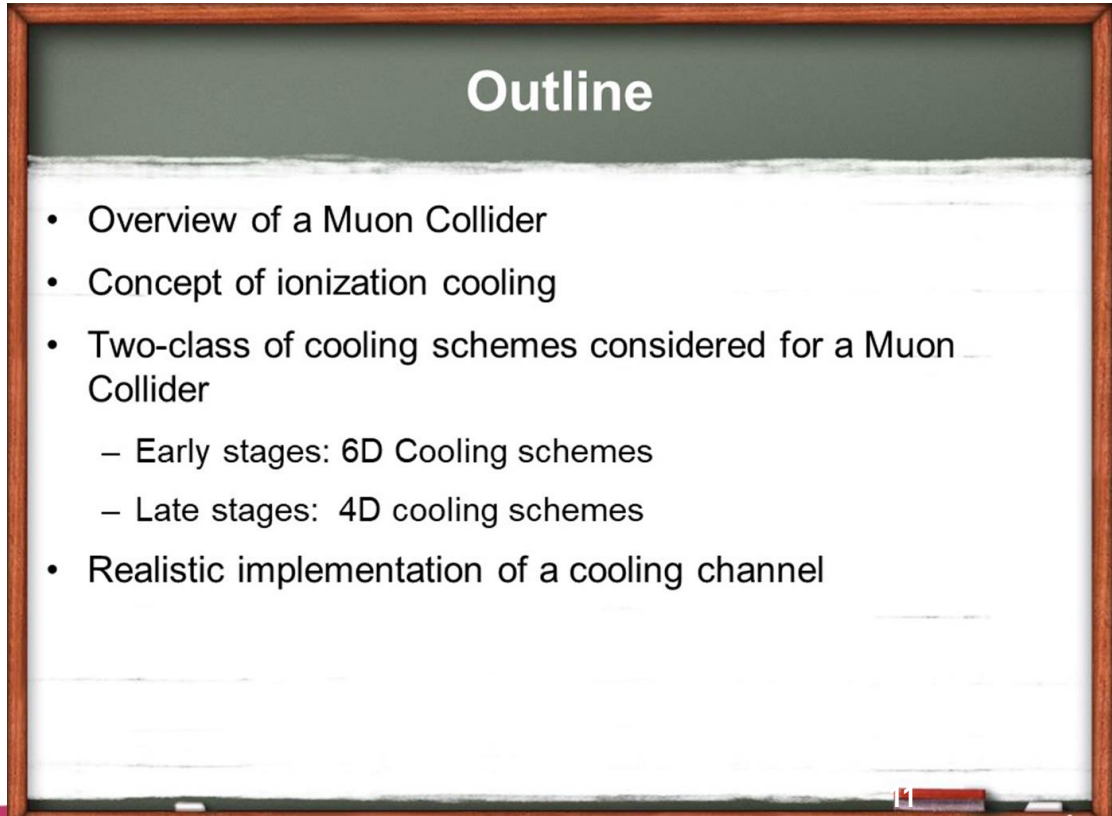
  - The choice of beam power will have a substantial impact on the studies for a ***high gradient capture solenoid***. A test facility would not be credible if it cannot demonstrate that the target station would somehow fit into the solenoid, and that the magnet can survive radiation (both instantaneous and integrated).
  - Impact on downstream elements should also be assessed

Beam Power

- **The design of the facility will depend critically on the desired beam power on target for the final complex.**
  - The design of the final test facility will heavily rely in both cases on extensive remote handling/telemanipulation and environmental confinement. However, 4 MW imposes even more constraints, and solutions might have to be implemented in the test facilities to prove we can do it.
  - The exchange rate of the target station/solenoid in the final complex might be a showstopper **for both** options (but for 4 MW is worse of course).
  - The above implies also to start thinking at the ***disposal path*** of the target material, ***short, medium and long term storage of special radioactive waste***. Local and National authorities will request very early in the CDR phase a clear strategy for radioactive waste minimization and disposal. What studies should we launch to prepare to that request? Will we need to demonstrate anything in this respect in the Facility?

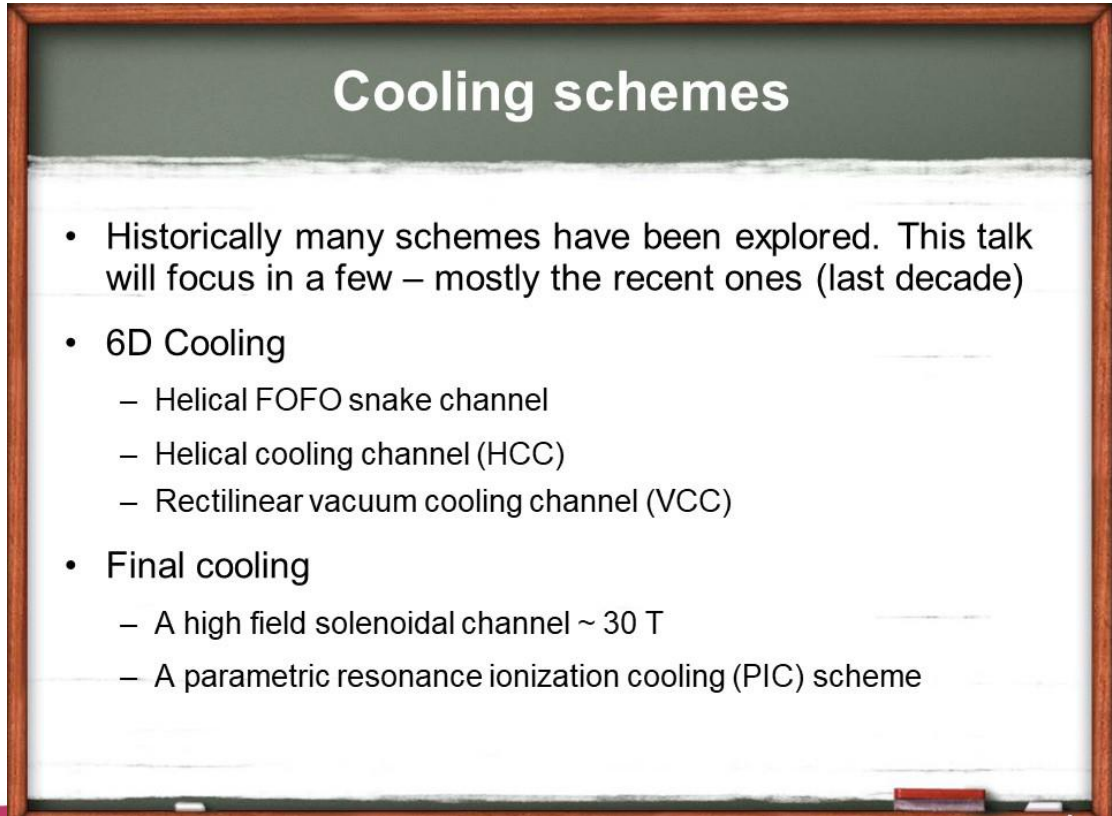
Cooling

- Courtesy D. Stratakis
  (Workshop on Muon Collider Testing Opportunities: https://indico.cern.ch/event/1016248)



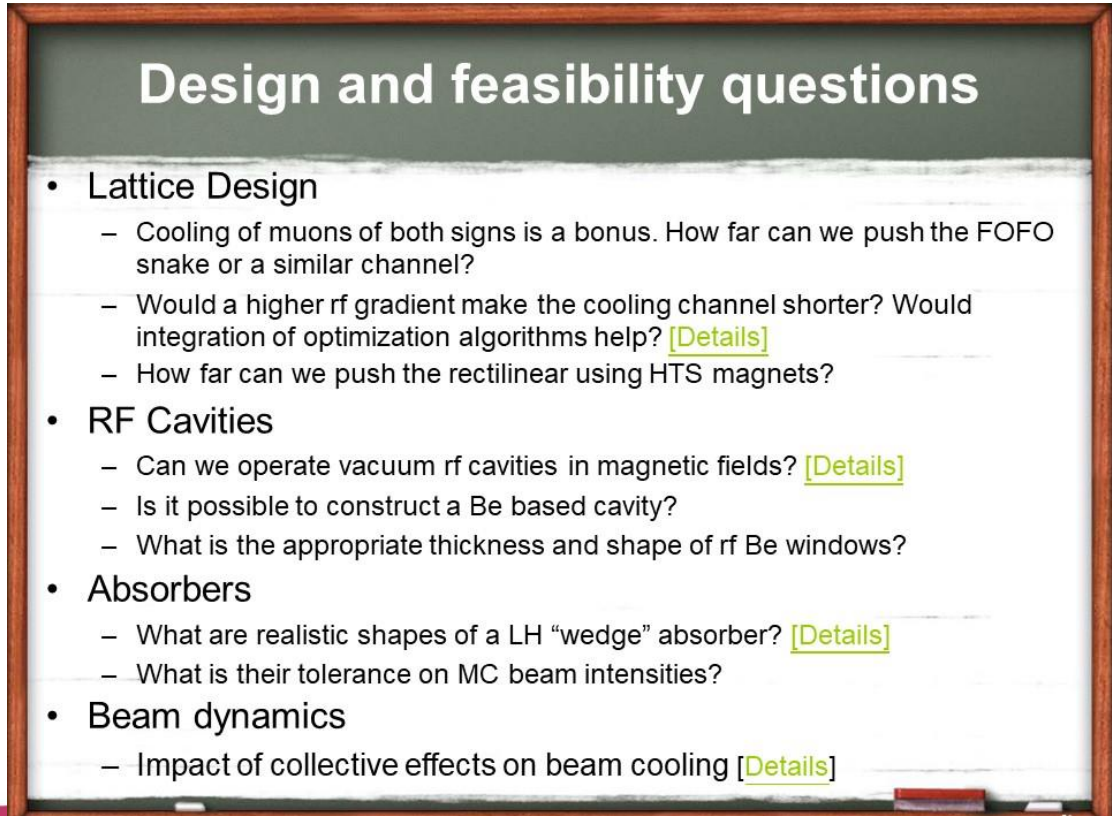
Cooling

- Courtesy D. Stratakis
  (Workshop on Muon Collider Testing Opportunities: https://indico.cern.ch/event/1016248)



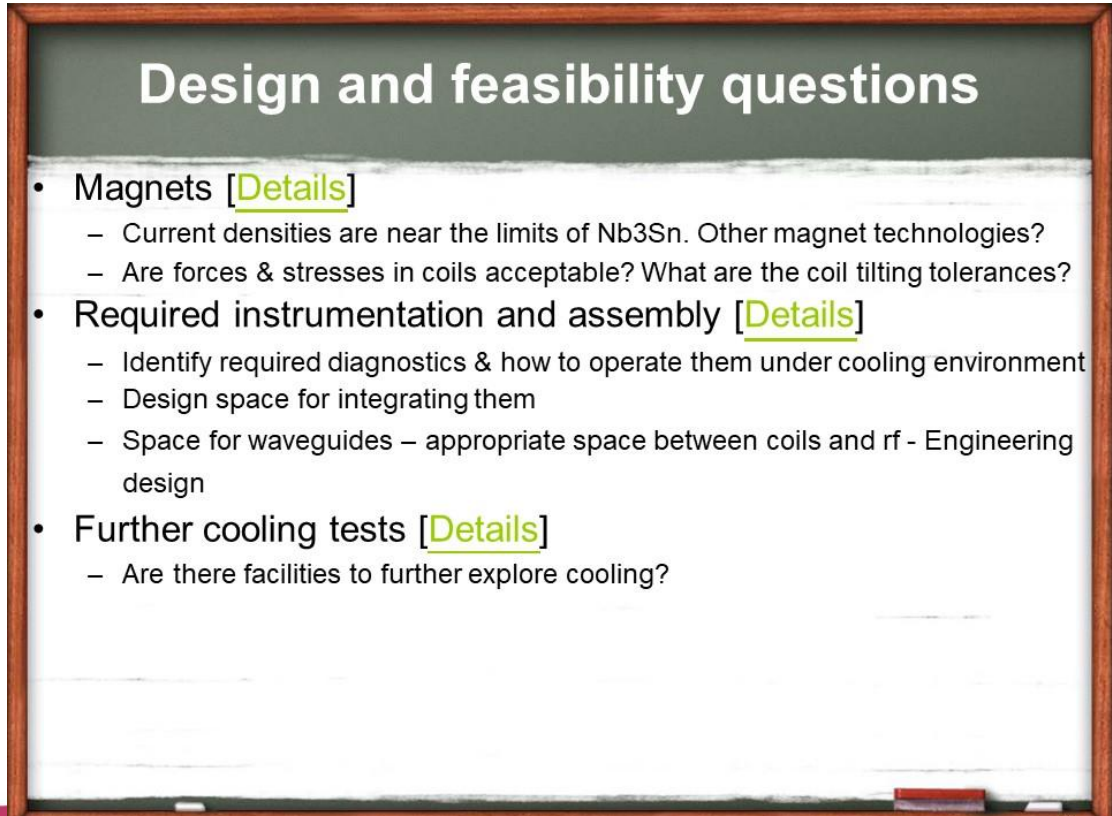
Cooling

- Courtesy D. Stratakis
  (Workshop on Muon Collider Testing Opportunities: https://indico.cern.ch/event/1016248)



Cooling

- Courtesy D. Stratakis
  (Workshop on Muon Collider Testing Opportunities: https://indico.cern.ch/event/1016248)



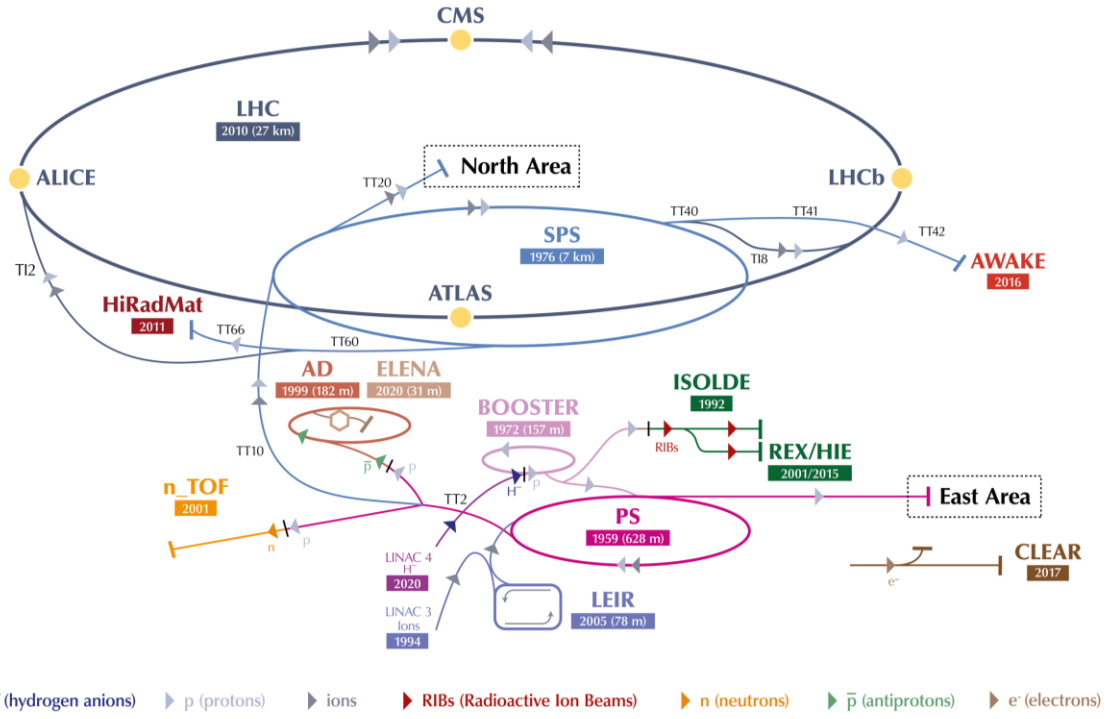
Cooling

- Further questions:
  - We believe simulations are ok (?). Is there any specific development/benchmark needed?
  - How many schemes can we test? One or more?
  - …

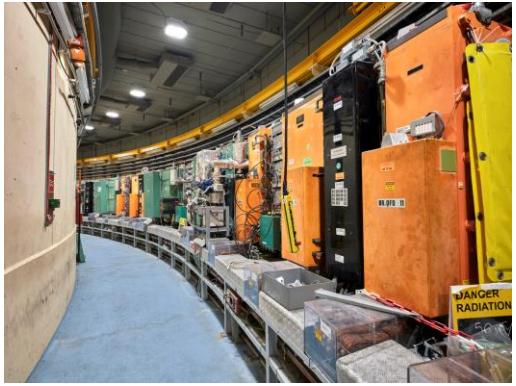
Targetry/Solenoid

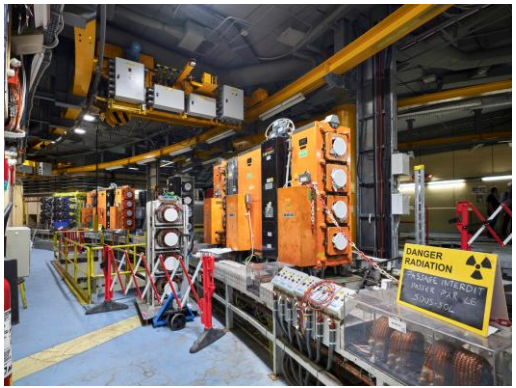
- 1.5 MW:
  - Less to demonstrate for the target, still integration with the Solenoid has to be studied and tested
- 4 MW:
  - Target concept to be decided and demonstrated
- For both:
  - can the solenoid and downstream magnets survive instantaneous power (quench limit) and integrated dose (what shielding needed)

CERN accelerator complex



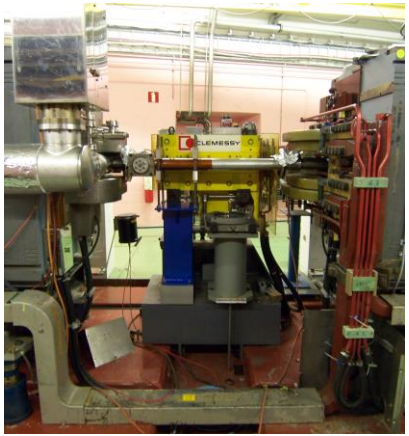
PSB main features

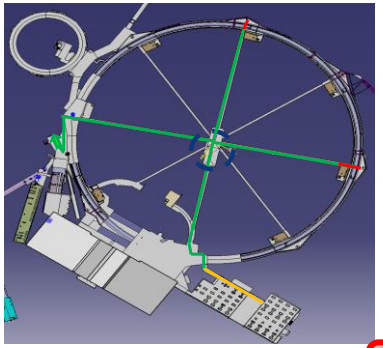




- Injection
  - 160 MeV H^-
  - Multiturn charge exchange injection with transverse and longitudinal painting up to thousand turns
- 4 superimposed ring magnetically coupled
- Lattice: Triplet, FDF
  - Operating below transition
- Acceleration cycle
  - ~ 700 ms
  - 1.2 cycling period
- RF: Finemet
  - Operation with h=1 and h=2
- Extraction:
  - 2 GeV (1.4 GeV)
  - Single turn fast extraction with vertical recombination
- Particles types:
  - Protons, (Ions - O, S, In, Xe)
- Max total intensity: ~ 4e13 ppp
- External Exp. Area: ISOLDE

PS main features





- Injection
  - 2 GeV protons
  - 70 MeV/n lead ions
  - Single turn injections
- Lattice: FODO with combined-function magnets
  - Transition crossing with gamma-jump at 6.1 GeV
- Acceleration cycle
  - Up to 3.6 s depending on final user
  - 1.2 cycling period
- RF:
  - 10 MHz ferrite loaded main RF system
  - 20, 40, 80 MHz for LHC beams production
  - 200 MHz for beam recapture after de-bunching
  - h=7, 8,16, 21, 42, 84,168
  - Finemet as longitudinal feedback system
- Extraction:
  - Fast extraction at 20 GeV and 26 GeV
  - Multiturn (5 turns) extraction at 14 GeV
  - Slow extraction 24 GeV
- Particles types:
  - Protons, Ions (Pb, O, S, In, Xe)
  - In the past: anti-protons, e+, e-
- Max total intensity: ~ 4e13
- External Exp. Area: East hall, AD

SPS main parameters

- Injection
  - 14 GeV or 26 GeV protons
  - 26 GeV proton equivalent Pb ions
  - Multi-batch injection from PS
- Lattice: FODO with dispersion free SS
  - Transition crossing for injection below 20 GeV. No gamma-jump
- Acceleration cycle
  - Up to 21.6 s (depending on user)
  - 1.2 cycling period
- RF:
  - Main system: 200 MHz travelling wave
  - 800 MHz to control longitudinal emit.
- Extraction:
  - Slow extraction at 400 GeV
  - Fast extraction at 450 GeV
- Operation in p-pbar collider mode
  - Machine on indefinite coast @ 270 GeV
- Particles types:
  - Protons, Pb, pbar, e+,e-, O, In, S, Xe
- Max total intensity: ~5.3e10^{13}
- External Exp. Area: North Area, HIRADMAT, AWAKE, Neutrino Platform

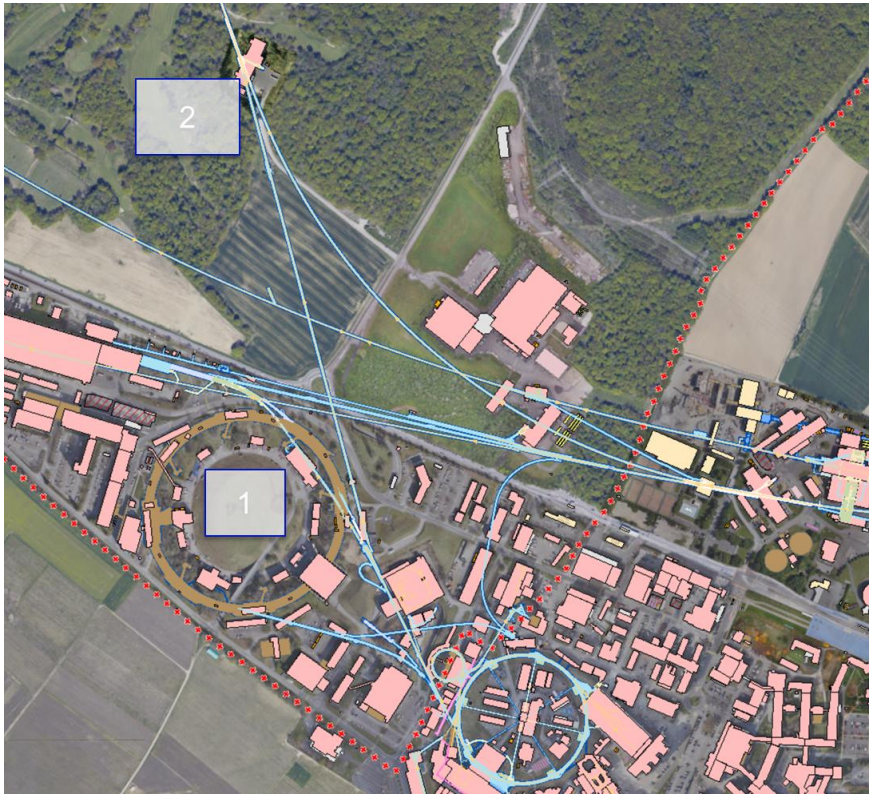
Which beams ?

- Is bunch length important for the demonstrator? What is the upper limit?
- What intensity on the single bunch? What time structure?

- Beam power: 10 kW? 80 kW?
- Should we build directly for a target area/cooling channel cavern compatible with 1/4 MW? ($$$)

Working hypothesis

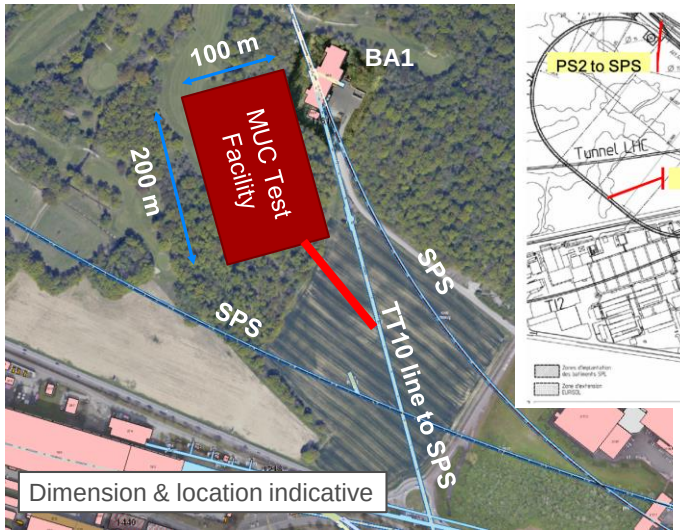
- #1 – inside of ISR
  - No upgrade possible to future muon complex (<10 kW or RP issue)
- #2 – on TT10, transfer line to SPS
  - Compatibility with future upgrades towards a collider and HP-SPL to be studied.
  - O(80kW) should be easily feasible by going sufficiently underground.
  - 4 MW to be studied, but not impossible a priori.

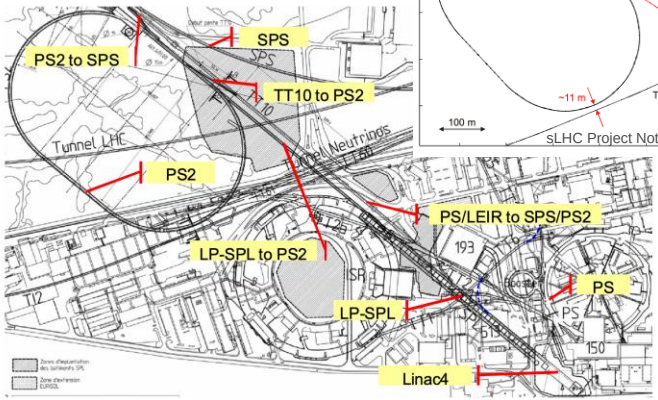


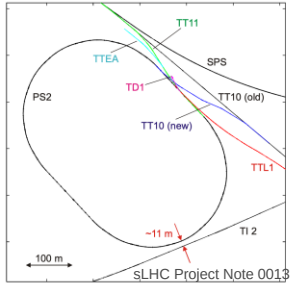
Most attractive option

- We will discuss what is needed to confirm full compatibility with a 4 MW option.
- Some information already available from past studies.
- Some requirements have to be provided to feed Civil engineering integration

Possibility around TT10







sLHC Project Note 0013

M. Benedikt, LHC Performance Workshop, Chamonix 2010

CERN-AB-2007-061

In synergy with which facilities

- ESS
  - Interested to promote studies for an Initial Cooling Experiment (C.Rubbia)
- PSI, STFC
  - Have muon beams available for testing of components
  - Any plans to host the Demonstrator?
- US, Asia?

Road to roadmap

- Need to have a few meetings to discuss for the facility:
  - Deliverables (must do and nice to have).
  - Beam parameters & 1.5 or 4 MW
  - Cooling strategies to study
  - Geometry of the facility (size, depth, shielding, confinement)
  - Budget profile and timescale

Conclusion

- There are possible options for building at CERN a Demonstrator after the next upgrade. Budget profiles, in the most optimistic scenarios, allow to start tests with beam around 2032/33, in line with the present roadmap, only if a substantial budget line is added in CERN's and other institutes MTP before the next update of the European Strategy. If not, the start dates probably shifts towards 2035
- Additional resources are needed as from next year in order to be ready in 2025 with a CDR of the facility. (EU Design Study is an option, but no guarantee of success)
- Need to define parameters, as time is running fast and there is a lot of work to do.
- CERN can profit of existing beams (PS?) to setup quickly (within 3÷5 years) a test facility once a decision is taken.
- Support from other Institutes of the collaboration is needed!
- Did not discuss facilities for detectors…
- Looking forward to discussions tomorrow at 18.25

International MUON Collider Collaboration

CERN

Thank you
for attention