Discussione progetti R&D acceleratori per European Strategy

Muon Collider

Dario Giove (MI-LASA), Donatella Lucchesi (UniPD e PD)

Riccardo Musenich (GE), Nadia Pastrone (TO), Lucio Rossi (UniMI e LASA) et al.

Gruppi **INFN** *in*:

LNF PD RM1 MI TO TS BO MIB FE PV LNL RM3 BA NA LNS GE

Nuove attività legate allo sviluppo del disegno della facility

Presidenza INFN, 9 novembre 2022

International Design Study facility

Proton driver production as baseline

- **Focus on two energy ranges:**

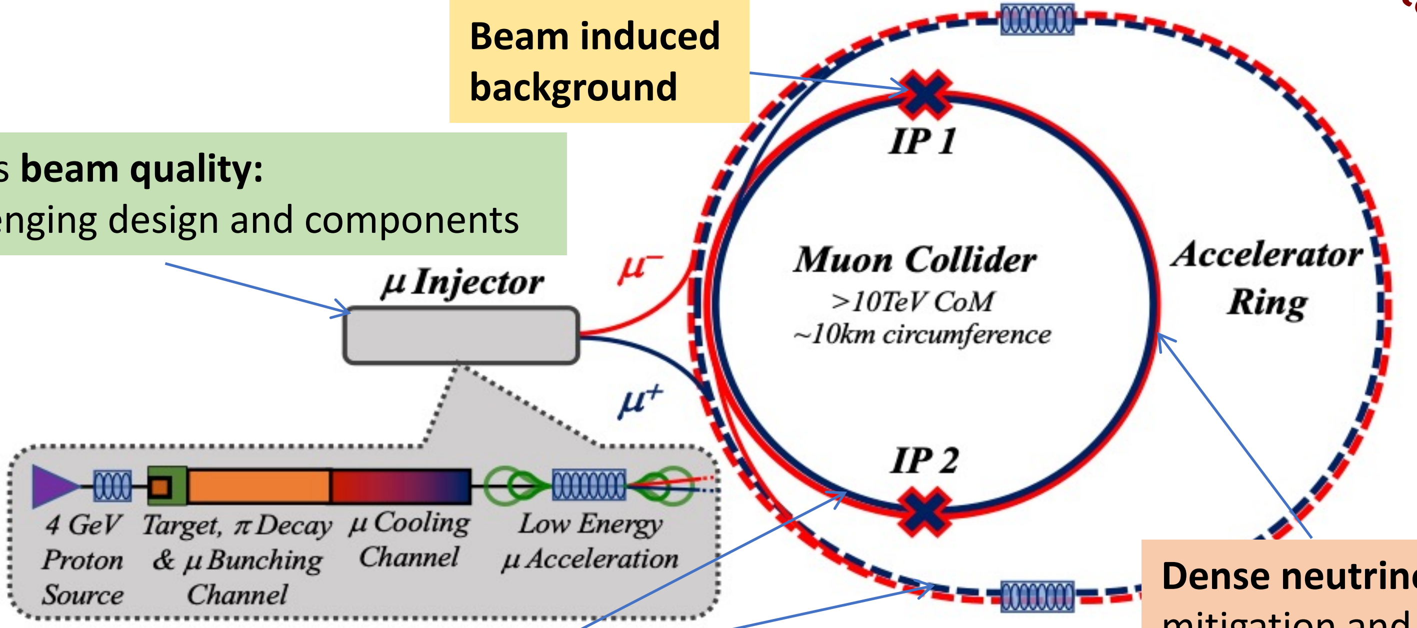
3 TeV technology ready for construction in 10-20 years

10+ TeV with more advanced technology

10+ TeV completely new regime to explore!

Beam induced background

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

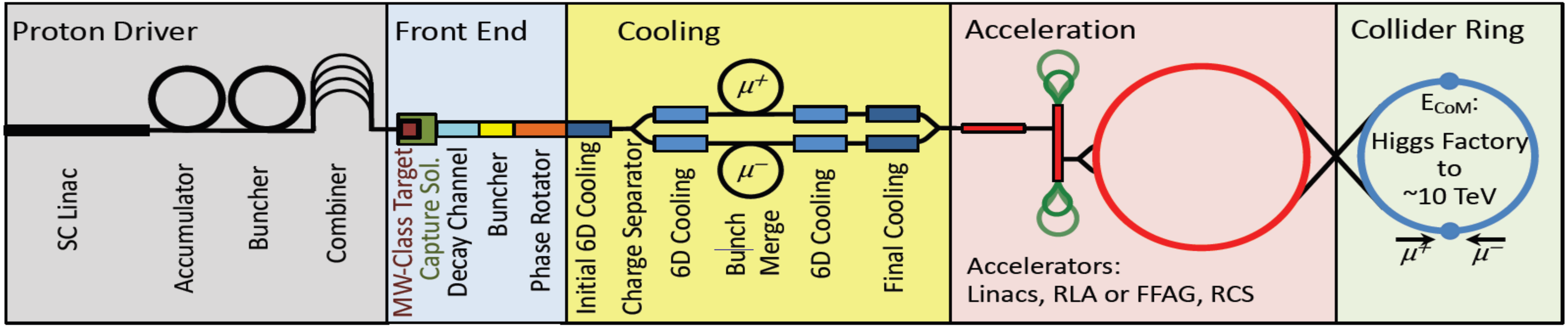


Dense neutrino flux mitigation and site

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

Collider Concept

Fully driven by muon lifetime, otherwise would be easy



Short, intense proton bunch

Ionisation cooling of muon in matter

Acceleration to collision energy

Collision

Protons produce pions which decay into muons
muons are captured

Accelerator R&D Roadmap

Bright Muon Beams and Muon Colliders

Panel members: **D. Schulte**,(Chair), M. Palmer (Co-Chair), T. Arndt, A. Chancé, J. P. Delahaye, A.Faus-Golfe, S.Gilardoni, P.Lebrun, K.Long, E.Métral, **N.Pastrone**, L.Quettier, T.Raubenheimer, C.Rogers, M.Seidel, D.Stratakis, A.Yamamoto
Associated members: A. Grudiev, R. Losito, **D. Lucchesi**

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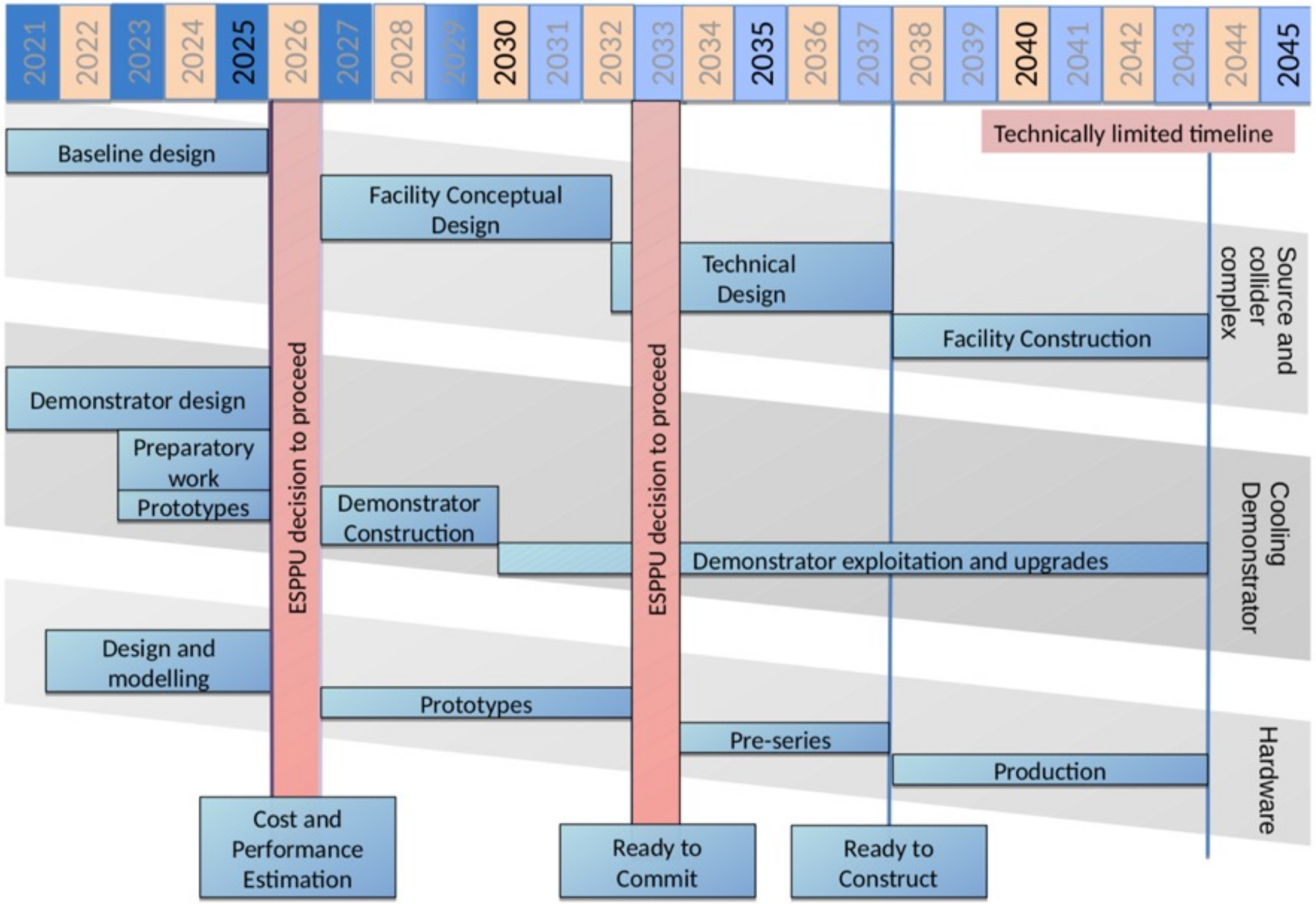
presented to CERN Council in December and published https://arxiv.org/abs/2201.07895

now under implementation by LDG + Council…



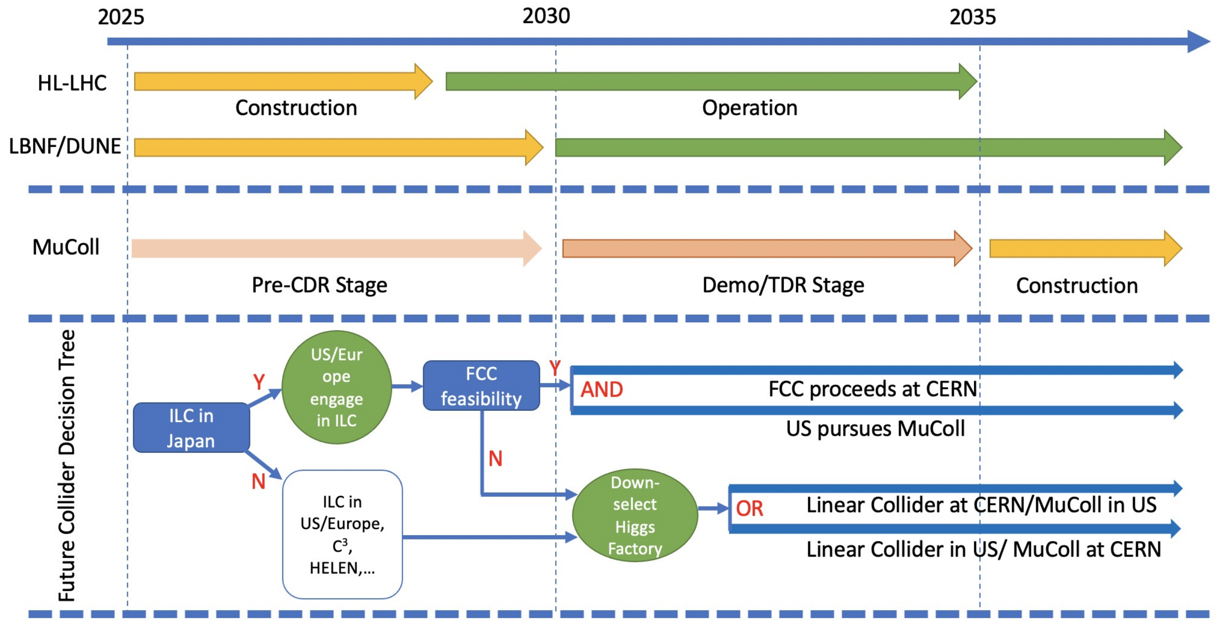
Technically limited timeline

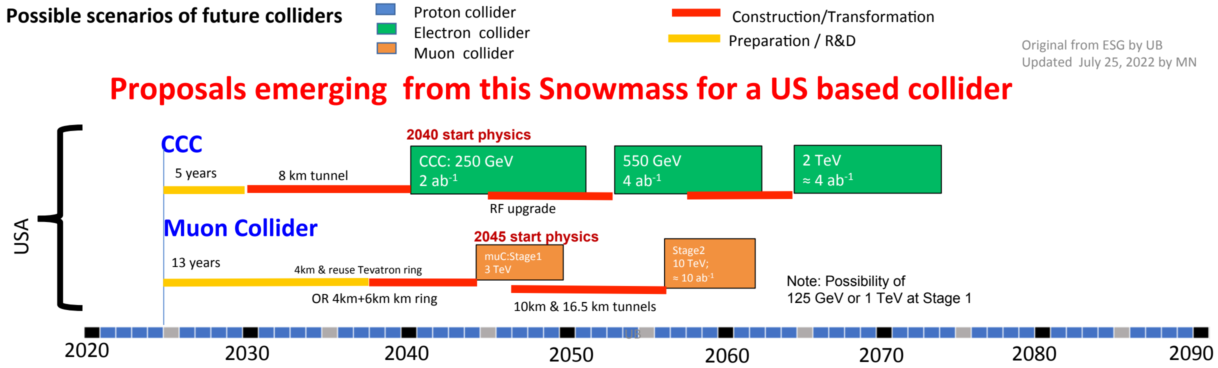
The panel has identified a development path that can address the major challenges and deliver a 3 TeV muon collider by 2045

Long-term future: a multi-TeV collider from Snowmass

- **For the next decade and beyond**
  - **2025-2030**:
    - Develop an initial design for a first stage TeV-scale Muon Collider in the US (pre-CDR)
    - Support critical detector R&D towards EF multi-TeV colliders
  - **2030-2035**: Demonstrate principal risk mitigation and deliver CDR for a first-stage TeV-scale Muon Collider
  - **After 2035**:
    - Demonstrate readiness to construct and deliver TDR for a first-stage TeV-scale Muon Collider
    - Ramp up funding support for detector R&D for EF multi-TeV colliders

Muon Collider Forum Report **arXiv:2209.01318 [hep-ex]**





- **Timelines technologically limited**
- Uncertainties to be sorted out
  - Find a contact lab(s)
  - Successful R&D and feasibility demonstration for CCC and Muon Collider
  - Evaluate CCC progress in the international context, and consider proposing an ILC/CCC [ie CCC used as an upgrade of ILC] or a CCC only option in the US.
  - International Cost Sharing
- Consider proposing hosting ILC in the US.

Forum Conveners: K.M. Black, S. Jindariani, D. Li, F. Maltoni, P. Meade, D. Stratakis

Roadmap Plan

The panel has identified a development path that can address the major challenges and deliver a 3 TeV muon collider by 2045

MDI

dipoli e solenoidi ad alto campo (Nb3Sn, HTS?)

Cavità RF SC e NC

Cooling cell Dimostratore

Label	Begin	End	Description	Aspirational [FTEy]	Aspirational [kCHF]	Minimal [FTEy]	Minimal [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

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Scenarios

Aspirational [FTEy]	Aspirational [kCHF]	Minimal [FTEy]	Minimal [kCHF]
445.9	11875	193	2445

~70 Meu/5 years

Nuove attività e richieste in CSN1

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Progetto Design Study APPROVATO luglio '22

HORIZON-INFRA-2022-DEV-01-01:

Total EU budget: 3 Meu starting Jan '23 – 4 years
18(+14) beneficiaries (associated)

INFN	**510 keu**
UniMI	300 keu
UniPD	100 keu
Personale ~ 90%	

- **WP 2: Physics and Detector Requirements**
  Leader D. Lucchesi Univ. PD + INFN (M. Casarsa) + many + + Univ. PV
- **WP 5: The High-energy Complex**
  Leader CEA(Antoine Chance)-CERN-STFC-INFN (F. Collamati – RM1-TO) MDI
- **WP 6: Radio Frequency Systems**
  Leader CEA(C. Marchand)+INFN(D. Giove Deputy - MI – LNL – LNS - NA)-CERN++++
- **WP 7: Magnet Systems**
  Leader CERN(L. Bottura)-CERN+++ INFN(GE, MI, BO) + Univ. BO
- **WP 8: Cooling Cell Integration**
  Leader CERN(R. Losito)+Univ. MI (L. Rossi)-STFC-INFN(M. Statera mag. e D. Giove RF)

Richieste CSN1 - 2023 per lo schema di Cooling Channel:

- cavi e magneti SC ==> 1 km cavo SC HTS ~120-150 keu **==> non assegnato**
- cavità RF NC ==> componenti per RF ~ 60 keu **==> assegnati 50 keu**

Sviluppo/integrazione cooling cell

INFN-RF e magneti lavorano insieme per studiare soluzioni di integrazione per la cooling cell

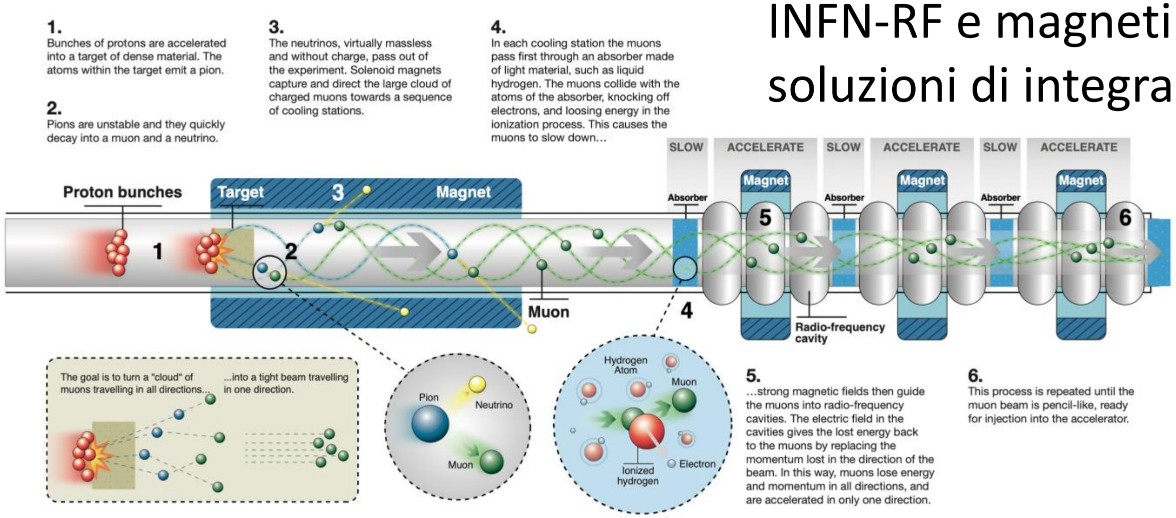
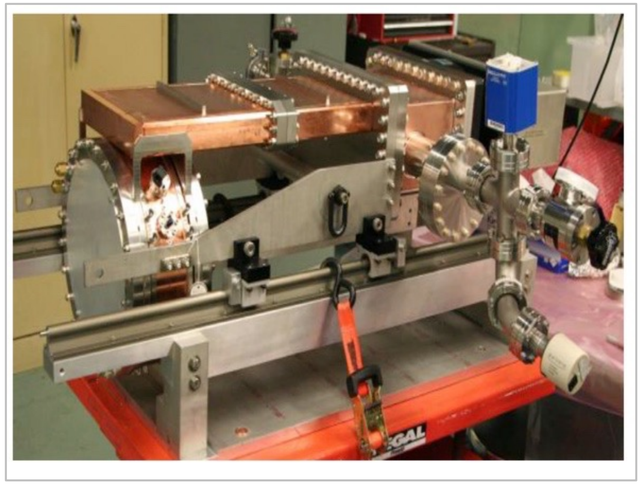
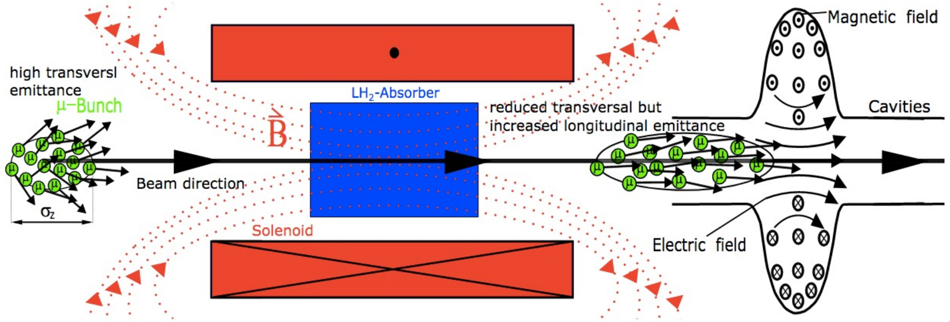
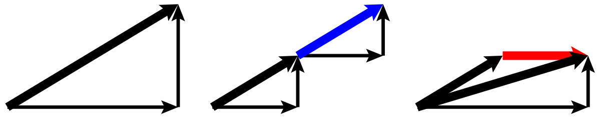


Fig. 3: Principle of the Muon Ionisation Cooling







MuCool: demonstrated cavity with >50 MV/m in 5 T solenoid

- H2-filled copper cavities
- Cavities with Be end caps

Need to develop full cooling demonstrator

Demonstrator Facility: a crucial step!

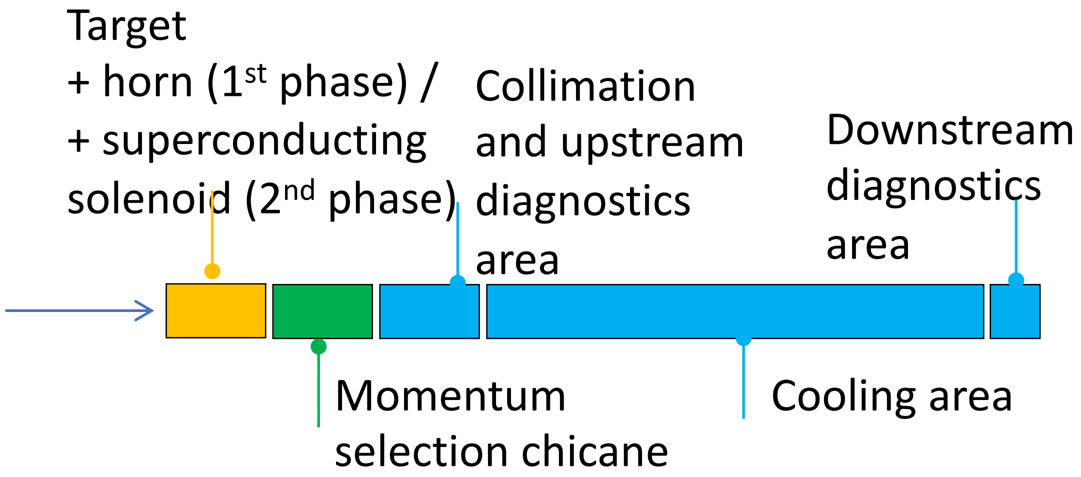
Planning **demonstrator** facility with muon production target and cooling stations

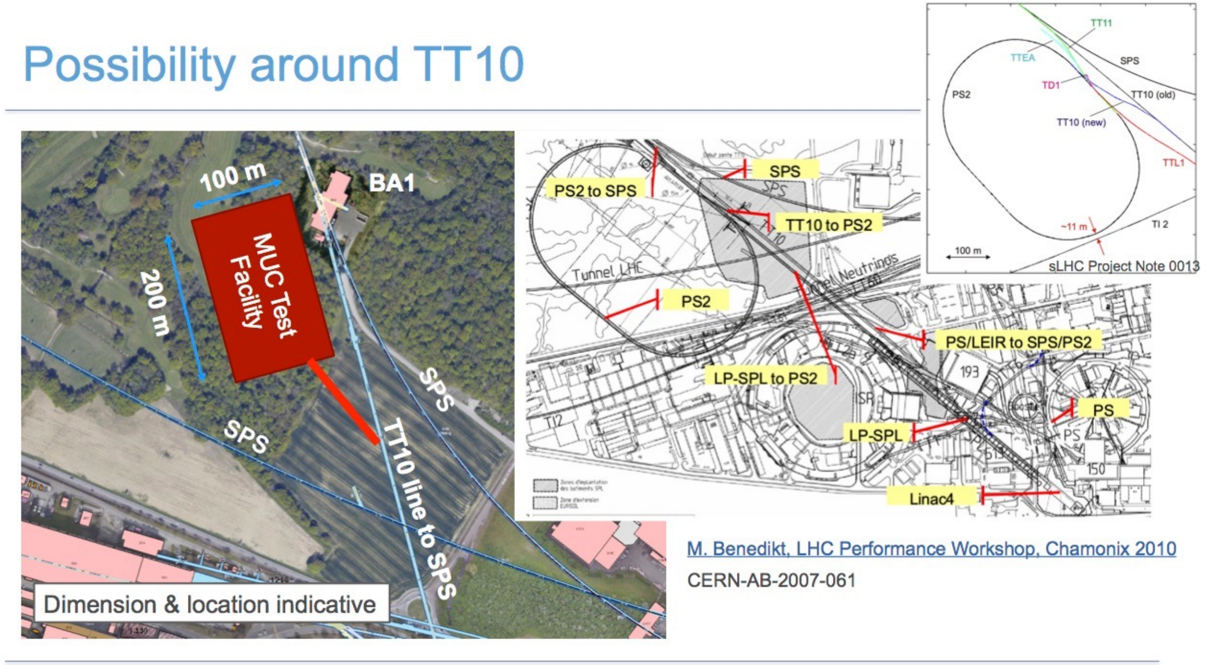
Suitable **site exists** on CERN land and can use **PS proton beam**

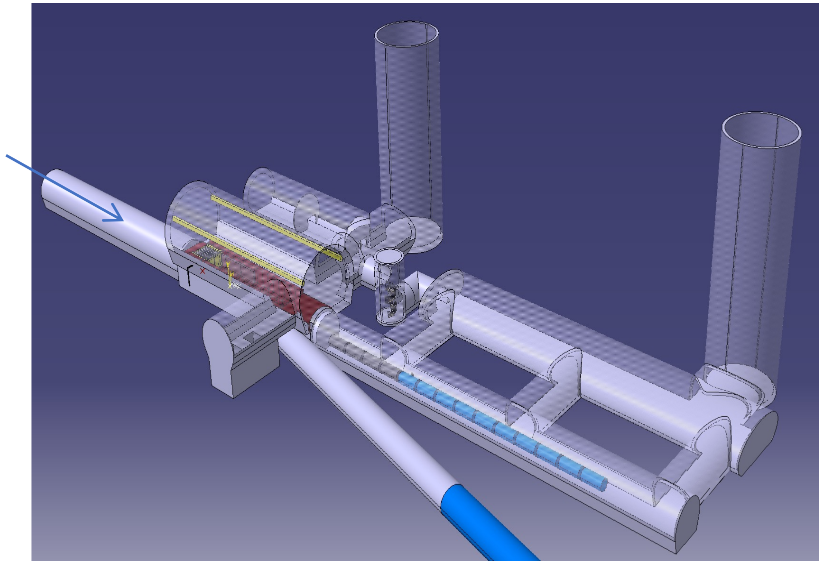
- could combine with **NuStorm** or other option

Other sites should be explored (FNAL?)

@ CERN







Machine Detector Interface

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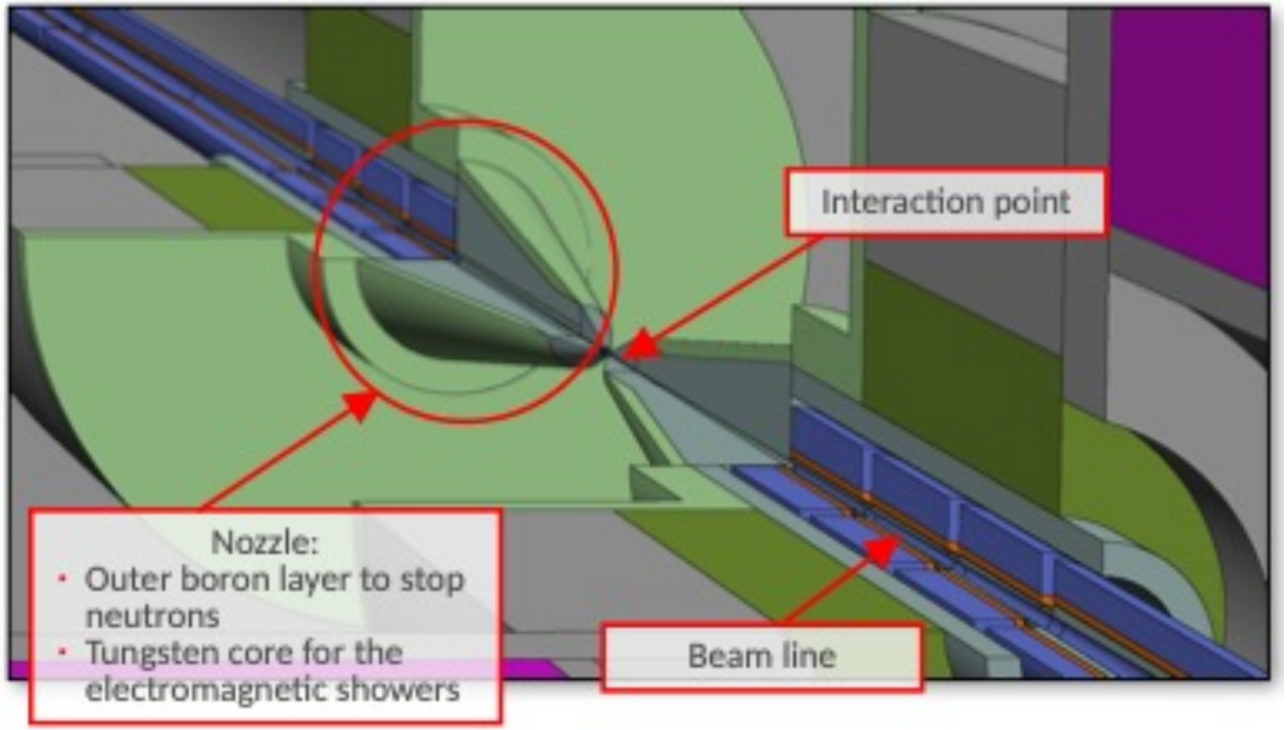
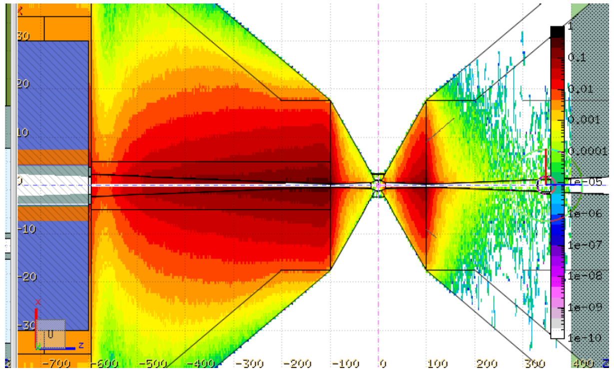
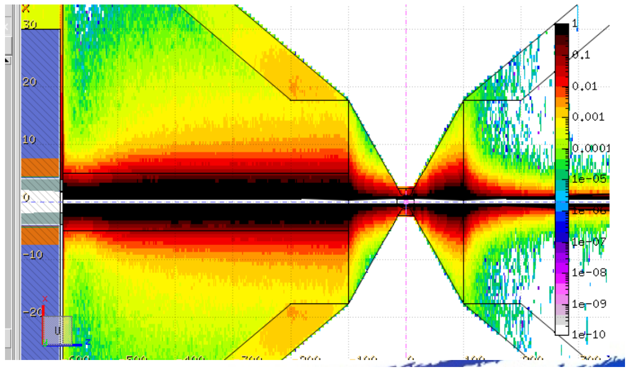


Neutron fluence



Photon fluence



1) Muon decay along the ring
2) Incoherent e^+e^- production at during bunch crossing at IP
3) Beam halo losses

- At low energy, $\sqrt{S} = 3$ TeV, **1)** dominates. Studies performed with the MAP configuration
- At high energy, $\sqrt{S} \approx 10$ TeV, **1), 2), 3)** under evaluation

Collaborazioni:

- CERN
- UK in discussione all'interno MuCol
- Fermilab (per ora in Snowmass, aspettando P5)

IMCC:

Coordinamento MDI, ottimizzazione degli assorbitori e studio dei fondi nel rivelatore.

Progetto MuCol:

- Coordinamento WP2 "Physics and Detector requirements" in cui c'è design del punto di interazione macchina+rivelatore.
- Importante coinvolgimento in WP4 "High Energy Complex" task "MDI design and background to experiment".

Personale coinvolto:
Roma 1 INFN: 0.3 FTE
Padova INFN+Università: 0.4 FTE
Trieste INFN: 0.1 FTE
Torino INFN: 0.5 FTE

Nel 2022 MDI INFN ha perso:

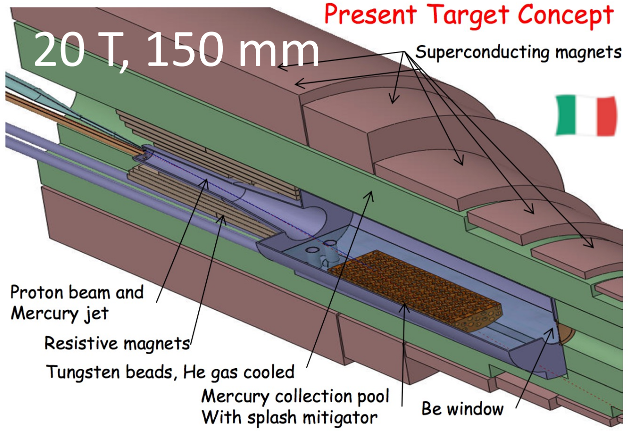
- ricercatore CNAO per impegni pressanti
- AR scaduto
- esperta di FLUKA.

Nel 2023 potremo perdere il contributo di Torino.

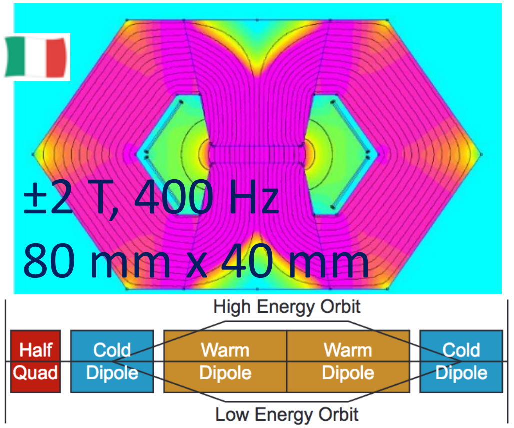
Richieste:

- ricercatore a TD per non perdere le competenze acquisite e continuare a collaborare a livello internazionale. In MuCol abbiamo un AR (da capire)
- Risorse di calcolo per le simulazioni

Magnet Demands @ Muon Collider



High-field and large aperture target solenoid with heavy shielding to withstand heat (100 kW/m) and radiation loads



Combination of DC SC magnets (10 T) and AC resistive magnets (± 2T)

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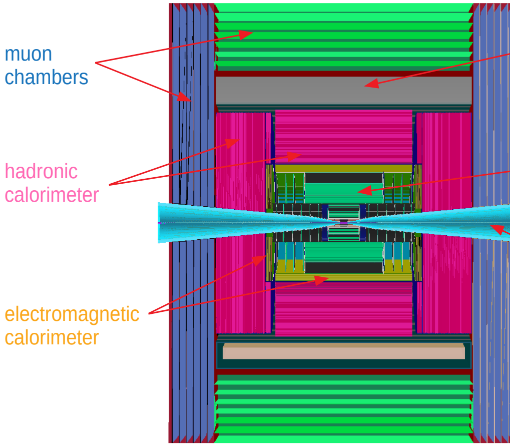
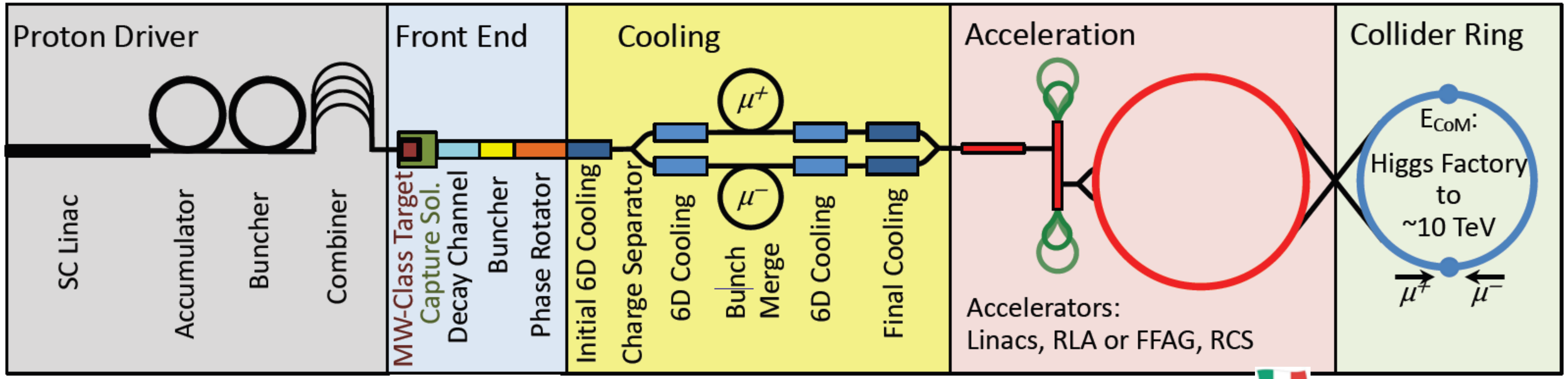
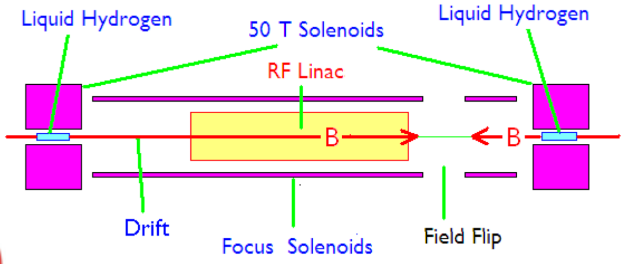


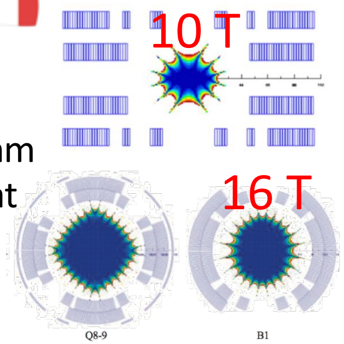
Detector Magnet to be designed for 10TeV



Ultra-high-field solenoids (40…60 T) to achieve desired muon beam cooling



Open midplane or large dipoles and quadrupoles in the range of 10…16 T, bore in excess of 150 mm to allow for shielding against heat (500 W/m) and radiation loads



Solenoid zoo for Muon Collider

- Target solenoid

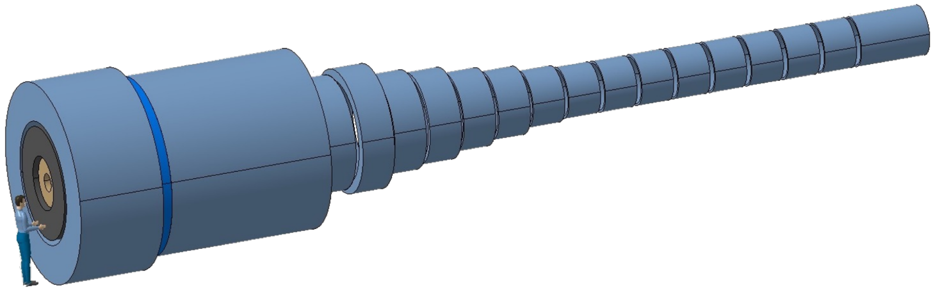
  1.5 m 20 T 2MW

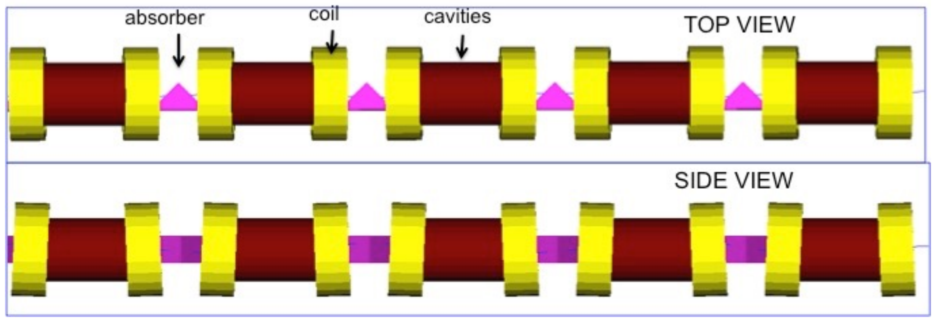
- Muon cooling

  1km 2 T to14 T

- Final cooling

  8.5 m – 40 T or 60 T





Common Challenges

Cost optimization

Sustanaibility

Cooling solenoids R&D plan

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- The conceptual design of UHF solenoids has started, exploring limits of performance (field and stress), operating efficiency (temperature), lean and compact designs (mass and cost)
- **We are defining a *Solenoid Coil Demonstrator* (SCD),**
  a representative test configuration (20 T, 50 mm, 500 MPa)
  to support the conceptual design with a strong experimental basis.
  This configuration could be a basis for collaborative work across laboratories
- Some 10 SCD's per year will be needed (manufacturing and testing). Each SCD requires approximately 150 m of 12 mm HTS tape
- **HTS tape, initially in the range of 1 to 1.5 km (12 mm) is the single most critical item to start manufacturing and experimental work**

  - **Define initial experimental needs by performing material characterization**
  - **Provide material for the manufacturing of the first SCD's**

INFN-LASA engagement
1-1.2 km of HTS tape for SCD

Programma 2023 e 2024-2026

- Assumere leadership dei test dei conduttori e dei test effettuati su bobine dimostratrici
- Assumere coordinamento design di tutte le famiglie di solenoidi per MuColl (bersaglio, cooling cell, final cooling)
- Prendere leadership nel procurement e qualifica dell' HTS tape (REBCO)
- Contribuire alla costruzione della prima bobina (attività principalmente svolta al Cern)
- Derivare parametri per design Bobina per RF test
- Collaborazione: CERN, INFN, Univ di Twente (NL), Univ. di Ginevra, KIT, CEA ecc…
- **Il costo conduttore è valutato in ca 120 k€ per 1 km di tape (+ IVA) → ca. 150 k€**

Programma 2024-2026

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- 2024
  - Test bobina nella Variable Temperature Facility (VTF) in corso di preparazione 2022-2023
  - **Design magnete SC HTS: 1 in MgB2 e 1 in REBCO da integrare con cavità RF . Operating temperature: 10-20 K. se RF è 650 MHz → large apert.→ 2-3 T Se RF è 1.3 GHz → smaller aperture → 3- 5 T**
  - Lanciare costruzione in Industria dei due magneti
    - HTS conductor (half REBCO Half MgB2) : 10 km → ca 0.5 M€
    - HTS Magnet fabrication: → ca. 1.3 M€ (con cooling system)
- 2025-26 follow up fabrication
- 2026 cold test (prima in single mode poi con RF)
- NOTA: il programma è piu orientato alla cooling cell ma le tecnologie REBCO sono simili anche per magneti del ring (di cui la task leadership è INFN)

Partecipating institutes

CERN-EP, Contact person: A. Dudarev

LNCMI, contact person: Dr. X. Chaud, Dr. F. Debray

PSI, contact person: Dr. B. Auchmann

University of Geneva,

contact person: Prof. C. Senatore

INFN LASA, contact person: Marco Statera

University of Southampton,

contact person: Prof. Y. Yang

University of Twente, Prof. A. Kario

CEA, Dr. L. Quettier

NC RF system for muon capture and cooling

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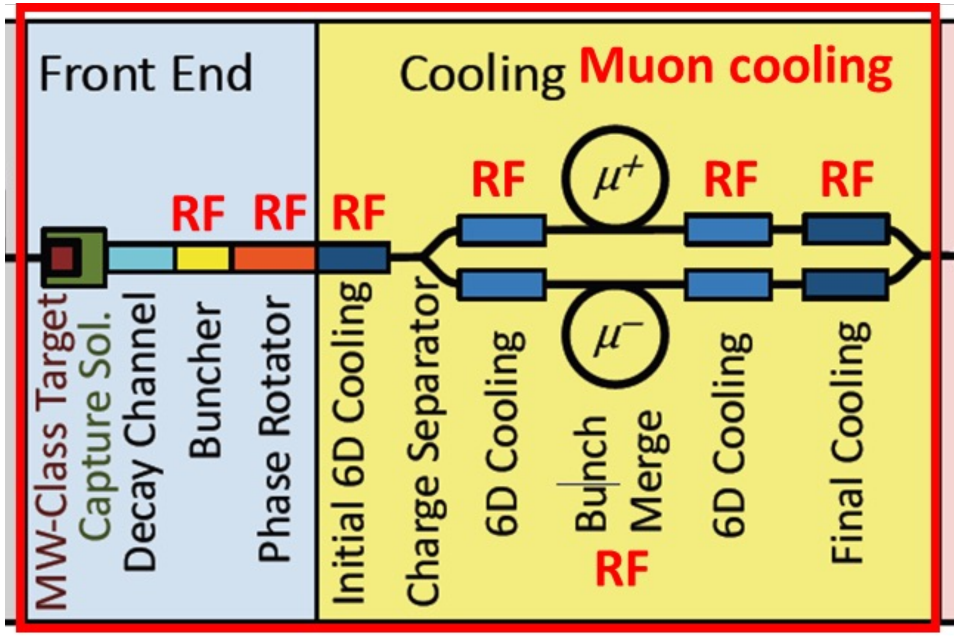
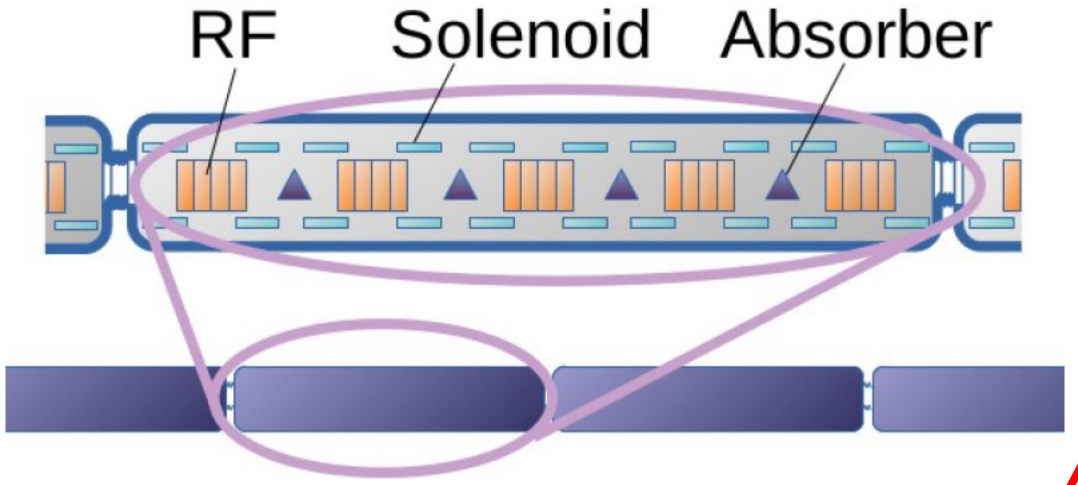
Region	Length [m]	N of cavities	Frequencies [MHz]	Peak Gradient [MV/m]	Peak RF power [MW/cav.]
Buncher	21	54	490 - 366	**0 - 15**	1.3
Rotator	24	64	366 – 326	**20**	2.4
Initial Cooler	126	360	325	**25**	**3.7**
Cooler 1	400	1605	325, 650	**22, 30**	
Bunch merge	130	26	108 - 1950	**~ 10**	
Cooler 2	420	1746	325, 650	**22, 30**	
Final Cooling	140	96	325 - 20		
Total	**~1300**	**3951**			=> **~12GW**



It is a very large and complex RF system with high peak power

RF cavities for muon cooling cells



- Normal conducting cavities
- $f \sim 325\ MHz, 650\ MHz$
- Short RF pulses (~μs)
- High acceleration gradients (~30 MV/m)
- High magnetic solenoidal field (up to13 T)

Creates problematics of **break-down** that needs to be mitigated

RF cavities in the Cooling Channel

The performance of a normal conducting cavity may degrade when the cavity is operated in strong magnetic fields (Operational experience and numerical studies)

==> the magnetic fields cause RF cavity breakdown at high gradients

relevant technical challenge for the design of a high-efficient ionization cooling channel

RF cavities has been designed, built and demonstrated stable operation at ~10 MV/m

Data: mainly 201 MHz and 805 MHz cavities with different surface quality enhancements and low Z materials

INFN proposed contribution is:

- Design the compact multiple-cavity module, with efficient frequency tuning and RF power feeding systems. In the cooling channel, the voltage in each segment requires multiple cavities or one LINAC with multiple cells. In order to have strong solenoid fields, the cavity design should be as compact as possible in the transverse direction

- Study the possibilities offered by improved copper surface qualities, new copper based alloys or low Z materials as Berillium to improve the braeakdown properties of a NC cavity

- Look into a suitable RF frequency choice (in the range 805 to 325 MHz) to define a trade off between the above discussed phenomena and the magnet design

  To contribute to the proposal of a demonstrator of a cooling channel section

For the past decades, R&D efforts have been carried out to understand the breakdown mechanism in the presence of a strong magnetic field. In this framework RF cavities has been designed, built and demonstrated stable operation at ~10 MV/m

The experimental data available on the subject are related mainly to 201 MHz and 805 MHz cavities with different approaches involving the application of surface quality enhancements and low Z materials.

The contribution that we will provide in the framework of the European project may be summarized in the following issues:

- Design the compact multiple-cavity module, with efficient frequency tuning and RF power feeding systems. In the cooling channel, the voltage in each segment requires multiple cavities or one LINAC with multiple cells. In order to have strong solenoid fields, the cavity design should be as compact as possible in the transverse direction.

- Study the possibilities offered by improved copper surface qualities, new copper based alloys or low Z materials as Berillium to improve the breakdown properties of a NC cavity.

- Look into a suitable RF frequency choice (in the range 805 to 325 MHz) to define a trade off between the above discussed phenomena and the magnet design. This will contribute to the proposal of a demonstrator of a cooling channel section.

For 2023 we get a small funding from CSN1 to evaluate the possibility to carry out some tests on selected materials and polishing technologies on a DC HV (10 MV/m) test set up in magnetic field (1 T) @ LASA.
This may be considered as the starting point of a more ambitious program.

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1. study of innovative materials to create electrodes to be tested with a high DC static field in the presence of a magnetic field of at least 1 T or higher
2. study of surface finishing and cleaning techniques for the above materials
3. DC high static field test in the presence of a magnetic field of at least 1 T or higher
4. design of single cells at different frequencies in the 650-1300 Ghz range to verify the feasibility of structures with a reduced number of brazing (against joining techniques that allow the parts to be removed)
5. low frequency test
6. high power tests
7. test in magnetic fields of at least 5 T of single cells with RF power.

The first year would be dedicated to the first two points as well as to a timely review of the world panorama in the sector, with a broad vision of NC cavities with a high gradient even not operating in a magnetic field.

The second year should lead to a focus on those solutions deemed most promising by experiences and indications received from the various groups operating in the sector.
Experimental measurements could be carried out as per point 3 and at the same time point 4 could be addressed.

Then, depending on the availability of adequate resources, we could proceed as per points 5-7 in the framework of a program up to 2027.

In the context of these activities, a common laboratory (at LASA ?) could be thought of for the low-power qualification of these cavities. If this laboratory could count on a new and dedicated staff resource, it could also take care of transferring and increasing the know-how available in the context of LLRF systems and integrate with similar national and international initiatives.

The activities listed above, in the face of a recent survey, met the interest of the groups working on NC RF cavities of the following structures:

- LNS (e.m. design power coupler design)
- Naples (e.m. design)
- Milan (e.m. design, measurements, tests and sample preparation)
- LNL (limited to the analysis part of the surface finishes of materials)

To date, there is a defined involvement with CEA for which Dario Giove is deputy leader on the WP dedicated to the RF of the cooling channel of the European proposal.

Baseline concept of the RF system for acceleration of the High Energy Complex

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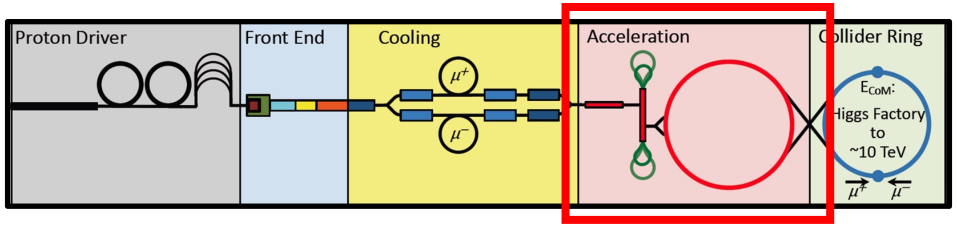
- Provide a **preliminary design concept** for the SRF cavities for acceleration in the Rapid Cycling Synchrotrons (RCS) of the HEC of the muon collider.
    - For the acceleration stage of the HEC, the short muon lifetime requires the highest possible acceleration rate to reach energy gains on the order of 10 GeV per turn. This is foreseen to be provided with **very high voltage SRF cavities**.
- **Select a suitable cavity technology**, including the accelerating cavity type, shape and main RF frequency, the cavity material and its possible surface treatments will be determined for this system.
- **Strong transient beam loading** effects, as well as **strong wake field effects** due to the very high intensity of the muon bunches will also have to be addressed in the cavity optimization.
- In cooperation with beam dynamics working package, a **full set of parameters for the RF cavities** that address longitudinal beam dynamics and stability will be established (R/Q, Vmax, k_{loss}…) for the fundamental mode and HOMs' suppression.
- This will provide **input specifications** for the **design concept of the RCSs cavities**
- At present, **reference cavity** is the **TESLA 1.3 GHz** operated at **30 MV/m.**

HE Complex

Multiple RF station along Acc. Ring with
1.3 GHz, pulsed SRF cavity, are being studied by Batsch at al.



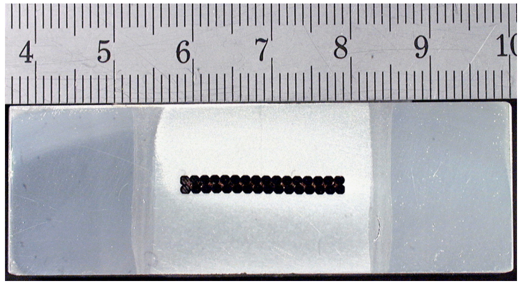
New concept for detector magnets

Strong synergy among several projects: MUCOL, FCC_ee, DUNE

International MUON Collider Collaboration

Main characteristics of superconducting magnets for particle detectors:

- Large volume
- Moderate magnetic field (0.5 to 4 T)
- Transparency to particles is often required
- Generally, solenoidal or toroidal shape



The CMS conductor

At present, only Al stabilised NbTi conductors are used for detector magnets.

However, fabrication of conductors requires cabling and co-extrusion, an expensive and delicate industrial process. Currently, there are no more industries that produce Al-stabilized conductors among those that have a proven track record in the field.*

* Toly Electric, in China, is interested in the business and started producing conductors in 1.5 km length.

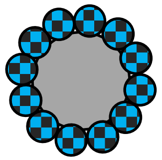
MgB_2 is an excellent material as candidate to manufactur conductors for detector magnets

MgB_2 allows operating magnets at $T > 10\ K$:

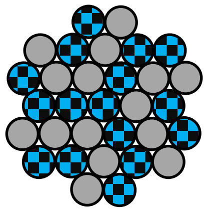
- intrinsically stable magnets more efficient cryogenics

Aluminium in parallel is for protection:

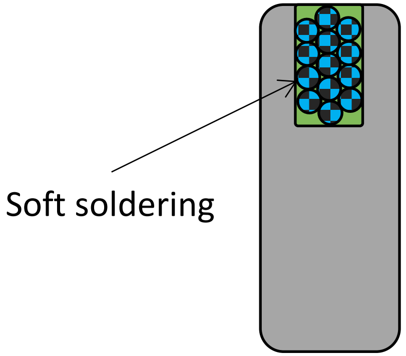
- <u>Good bonding between cable and aluminium is not necessary (no co-extrusion)</u>
- <u>High purity aluminium is not necessary</u>



MgB_2 wires around Al core



MgB_2 and Al wires assembled together



MgB_2 cable soldered in the grove of an Al bar

Development of a conductor prototype for space applications

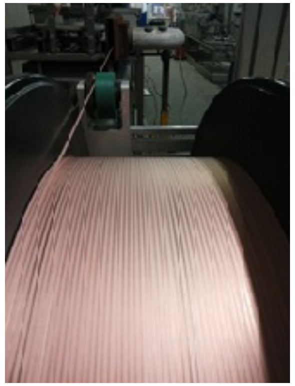
(SR2S project):

Titanium clad MgB_2 tape + Aluminium strip

R. Musenich et al., IEEE Trans on Appl. Supercond26 (4), 2016

360 m Ti-MgB_2

Ti-MgB_2 tape during copper plating



copper plated Ti-MgB_2 tape

A remarkable example of MgB_2 wire cabling: the LHC superconducting links

A. Ballarino, Supercond. Sci. Technol. 27 (2014) 044024

Attività – Collaborazioni richieste personale e materiale

International MUON Collider Collaboration

ATTIVITÀ	COLLABOR	SINERGIA	PERSONALE		MATERIALE	
			2023-2024	2025-2026	2023-2024	2025-2026
MDI	CERN, UK +USA		1 TD	1 TD	calcolo	calcolo
MAGNETI	CERN, CEA, PSI + Univ EU		1 RIC + 1 TECN MI 1 RIC + 1 TECN GE	1 RIC + 1 TECN MI 1 RIC + 1 TECN GE		0.5 + 1.3 Meu
HTS - SCD	CERN, KIT, CEA + Univ EU				150+100 keu	
RF - NC	CEA		1 TECN cavità 1 TECN LLRF	1 TECN cavità 1 TECN LLRF		
RF - SC	Uni Rostock					
DET-MAG		FCCee DUNE				

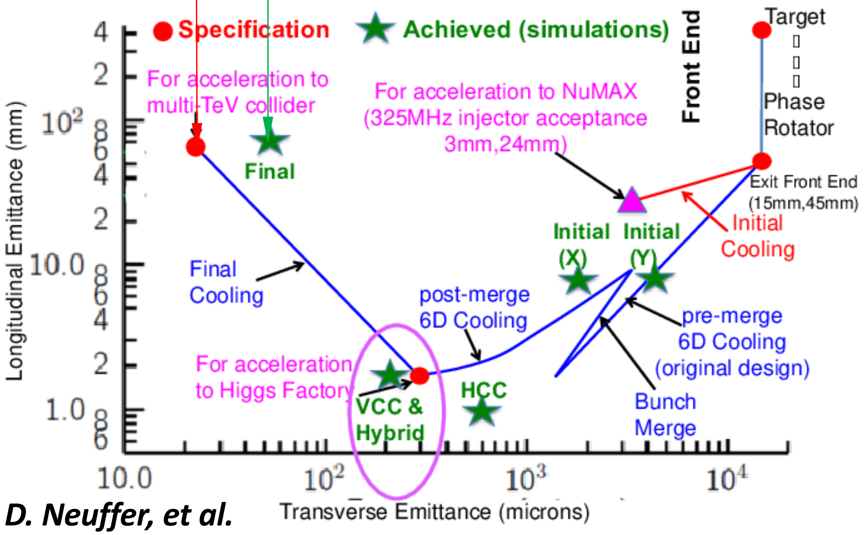
extras

Cooling solenoids

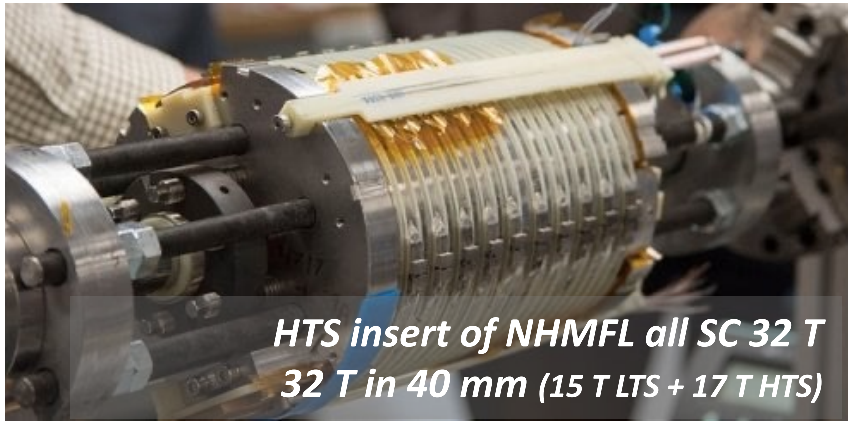
40…60 T required

30 T assumed in MAP

***A field of 40 T (minimum), up to 60 T (target) is needed** to meet emittance specification at the end of the cooling stage*



D. Neuffer, et al.



Present state of the art is the 32T all-SC solenoid in operation at NHMFL.

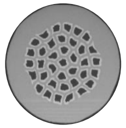
Novel technology is required (NI/PI) for compact, UHF solenoids operating without (or minimal) helium

***Solenoids for a muon collider need to be compact** (reduce cost),*
***mechanically strong** (withstand extraordinary e.m. forces)*
***and well protected against quench** (large stored energy)*

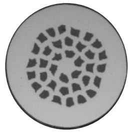
Targeted R&D is required to address these challenges

Present status of ex-situ MgB_2 conductors

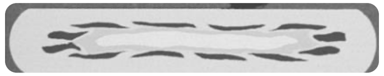
Wire 1



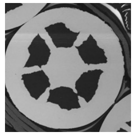
Wire 2

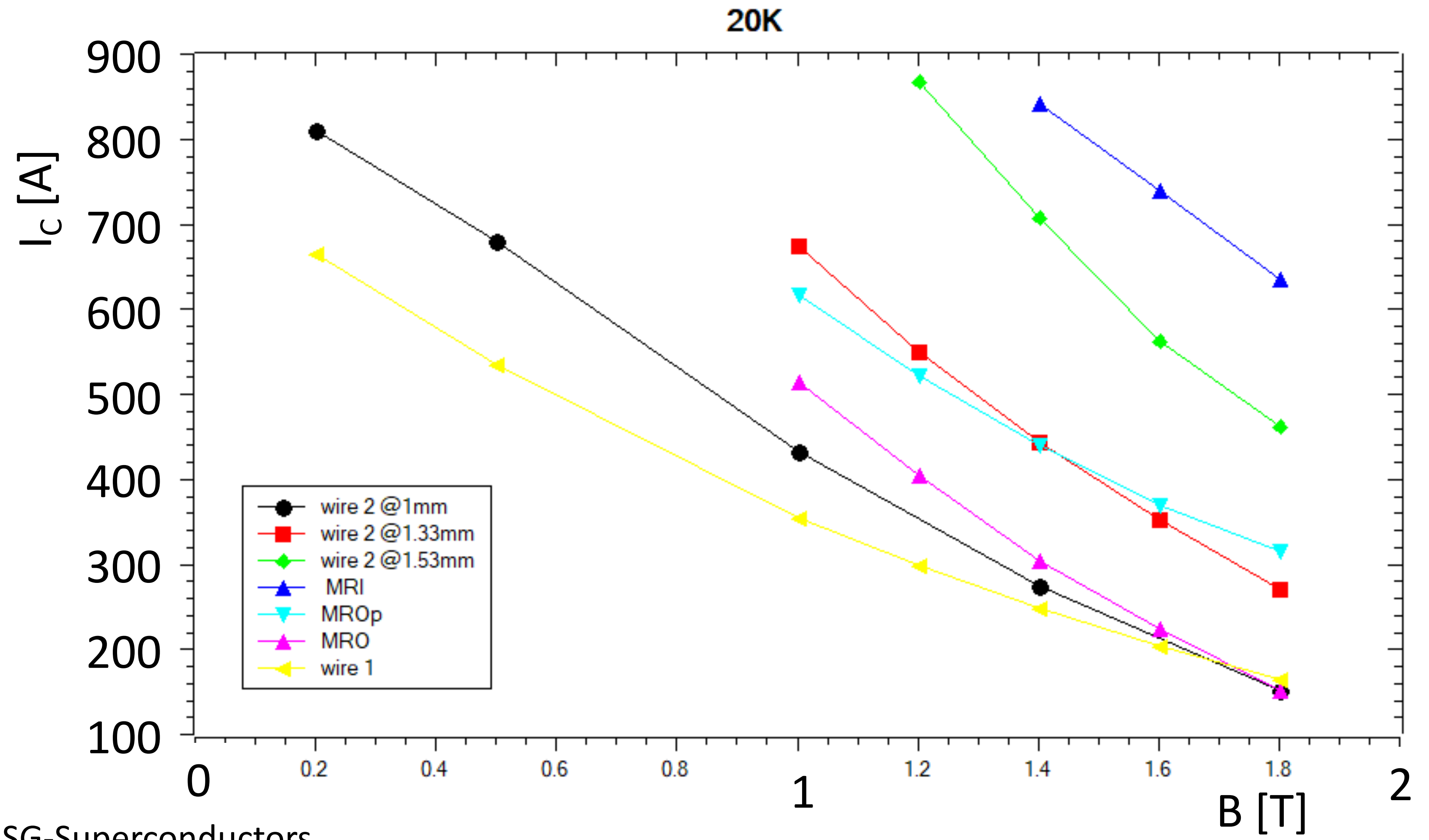


MRO/MRO+



MRI (1,53 mm)





Courtesy of Tiziana Spina, ASG-Superconductors

INFN and the International Community

CONTEXT:

- **Laboratory Directors' Group (LDG) initiated a muon collider collaboration July 2, 2020**
- CERN Medium Term Plan 2021-2025 - dedicated budget line – ~2MCHF/year
- **International Design Study based at CERN → MoC signed by INFN July 2021**
  the project encompasses physics, machine, detector and Machine Detector Interface
- European LDG **Accelerator R&D Roadmap → implementation after Council Dec 2021**
  dedicated Muon Beams Panel - but also synergies in High field magnets, RF and ERL
- European ECFA **Detector R&D Roadmap → implementation after Council Dec 2021**
  Muon collider @ 10 TeV is one of the targeted facilities emerging from the EPPSU
- US SnowMass Muon Collider Forum **since 2021 Muon Collider Forum Report Sept 2022**
- Snowmass/P5 process in the US → **ready by Summer 2023**
- HORIZON-INFRA-2022-DEV-01-01 EU project **MuCol** for Design Study approved **July 2022**
  Research infrastructure concept development → **supported by TIARA**

Collaboration Meeting of the Muon Collider Study @ CERN
October 11-14, 2022 https://indico.cern.ch/event/1175126/

Key Challenge Areas

- **Physics potential** evaluation, including **detector concept and technologies**
- Impact on the environment
  - – **Neutrino flux mitigation** and its impact on the site (first concept exists)
  - – **Machine Induced Background** impact the detector, and might limit physics
- **High-energy systems** after the cooling (acceleration, collision, ...)
  - – Fast-ramping magnet systems **NEW!!**
  - – High-field magnets (in particular for 10+ TeV) **NEW!!**
- **High-quality muon beam production NEW!!**
  - – Special RF and high peak power
  - – Superconducting solenoids
  - – Cooling string demonstration (cell engineering design, demonstrator design)
- **Full accelerator chain**
  - – e.g. proton complex with H- source, compressor ring ➔ test of target material

High energy complex requires known components
➔ synergies with other future colliders

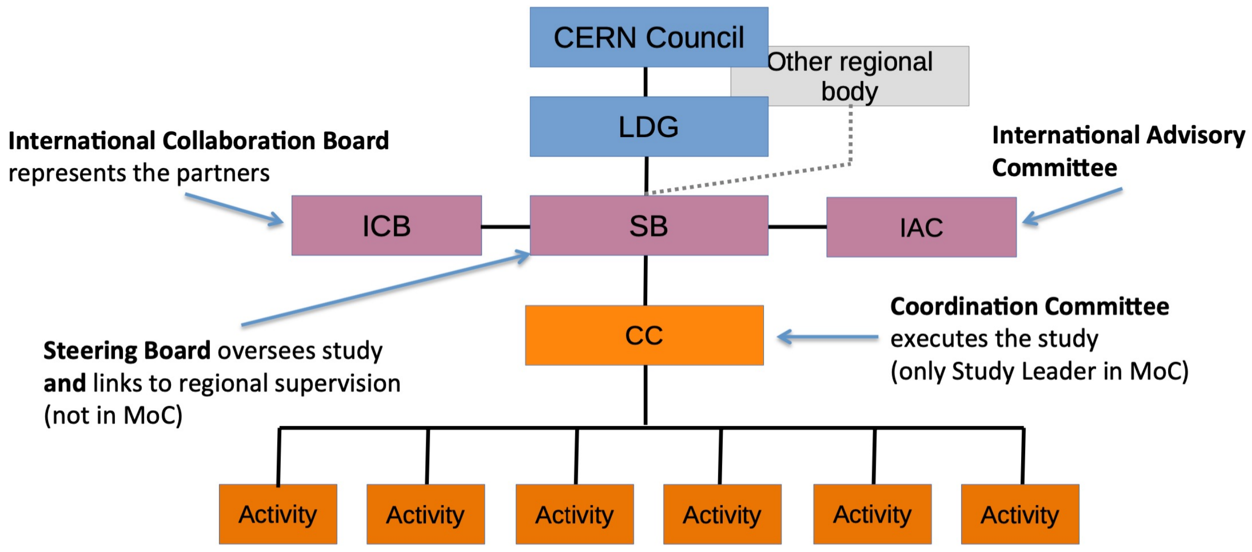
Organization after the Roadmap

- After the MoC a Governance Structure of the International Muon Collider Collaboration document by D. Schulte, M. Lamont

  ==> implementation detail including LDG/Council requests

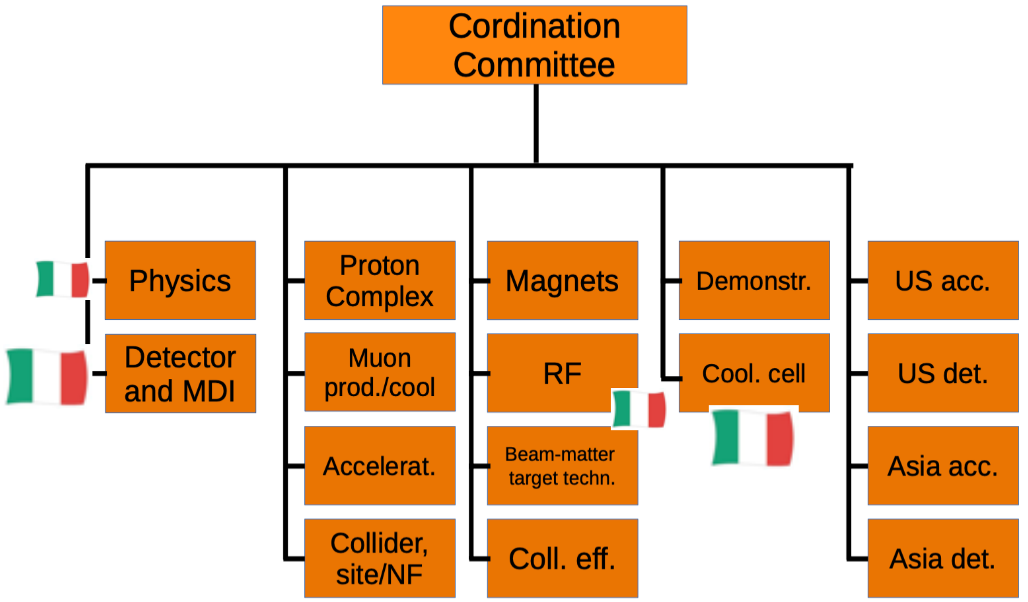
Proposed Governance

CERN is host organisation, can be transferred to other partner on request of CERN and with approval of ICB
Will review governance in 2024, US could join at that time



MoC signed by CERN CEA INFN STFC-RAL ESS IHEP and different universities in EU, US, China

Coordination Committee



Design Study activities: EU project MuCol

Total EU budget: 3 Meu starting Jan '23 – 4 years
18(+14) beneficiaries (associated)

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

International MUON Collider Collaboration

INFN 510 keu 362 keu Personnel - 18 keu travel - 28 keu other - 102 keu OH
UniMI 300 keu e UniPD 100 keu

The MuCol study will produce a coherent description of a novel particle accelerator complex that will collide muons of opposite charge at the energy frontier. The study will target a centre-of-mass energy (ECM) of 10 TeV with 3 TeV envisaged as a first stage.

The main outcome of MuCol will be a report documenting the facility design that should demonstrate that:

- the physics case of the muon collider is sound and detector systems can yield sufficient resolution and rejection of backgrounds;
- there are no principle technology showstoppers that will prevent the achievement of a satisfactory performance from the accelerator or from the detectors side;
- the muon collider provides a highly sustainable energy frontier facility as compared to other equivalent colliders;
- exploiting synergies with other scientific and industrial R&D projects, a valuable platform to provide Europe a leading edge not only in terms of discovery potential, but also for the development of associated technologies.

The final report will include a thorough assessment of benefits and risks of the accelerator and detector complex, including an evaluation of the scientific, industrial and societal return beyond high-energy physics, the cost scale and sustainability of the complex and the impact arising from an implementation on the CERN site.

EU project: WP

WP 2: Physics and Detector Requirements

Leader D. Lucchesi Univ. PD + INFN (M. Casarsa) + many + + Univ. PV associated

Link to the physics and detector studies, to provide a database with Beam-Induced Background (BIB) to the physics community and maintain a simplified model of the detector for physics studies. Based on feedback from the physics community, it will provide feedback and guidance to the accelerator design.

WP 3: The Proton Complex

Leader ESS-CERN-UU

key challenge of the proton complex design, the accumulation of the protons in very high-charge bunches and determine the required basic parameters of the complex.

WP 4: The Muon Production and Cooling

Leader STFC-CERN+ UK

Production of the muons by the proton beam hitting a target and the subsequent cooling

WP 5: The High-energy Complex

Leader CEA(Antoine Chance)-CERN-STFC-INFN (F. Collamati – RM1-TO) only MDI

Acceleration and collision complex of the muons. Interaction Region and Machine Detector Interface.

EU project: WP

International MUON Collider Collaboration

WP 6: Radio Frequency Systems

Leader CEA(C. Marchand)+INFN(D. Giove Deputy - MI - LNL)-CERN++++

Radio Frequency (RF) systems of the muon cooling and the acceleration complex.

WP 7: Magnet Systems

Leader CERN(L. Bottura)-CERN+++ INFN(GE, MI, BO) + Univ. BO associated

Most critical magnets of the muon collider. In particular focus on the solenoids of the muon production and cooling, which are specific to the muon collider. The fast-ramping magnet system, which has ambitious requirements on power flow and power efficiency and limits the energy reach of the collider,

WP 8: Cooling Cell Integration

Leader CERN(R. Losito)+Univ. MI (L. Rossi)-STFC-INFN(M. Statera – mag. e D. Giove – RF)

Design of the muon cooling cell, which is a unique and novel design and which faces integration challenges: interact to address the challenges of the muon collider concept.