Riunione Referee RD_MUCOL

31 agosto 2022

Agenda

Stato collaborazione internazionale e attività INFN in corso e future
(incluso: Attività bersagli: simulazioni - misure di laboratorio - R&D su fascio)

Attivita' di fisica e full simulation including MDI

Calcolo

Calorimetro e.m. simulazione e misure su prototipo CRILIN

Detector R&D: HCAL

Detector R&D: fast muon detector

Detector R&D: tracking

Attivita' Design Study facility (Magneti e RF)

Cristalli

Quadro generale in breve

INFN	EU/CERN	years	U.S.A.	
LEMMA	MICE	2011-2016	MAP	
RD_FA	EU Strategy	2017-2019		
	Collaboration	2020	Snowmass	
IMCC MoC	CERN MTP	2021		MuColl Forum
	EU Roadmaps			
	EU MuCol	2022		
		2023	P5	
		2024		
		2025		
	EU Strategy	2026		
		….		
		2029-2030	Snowmass	

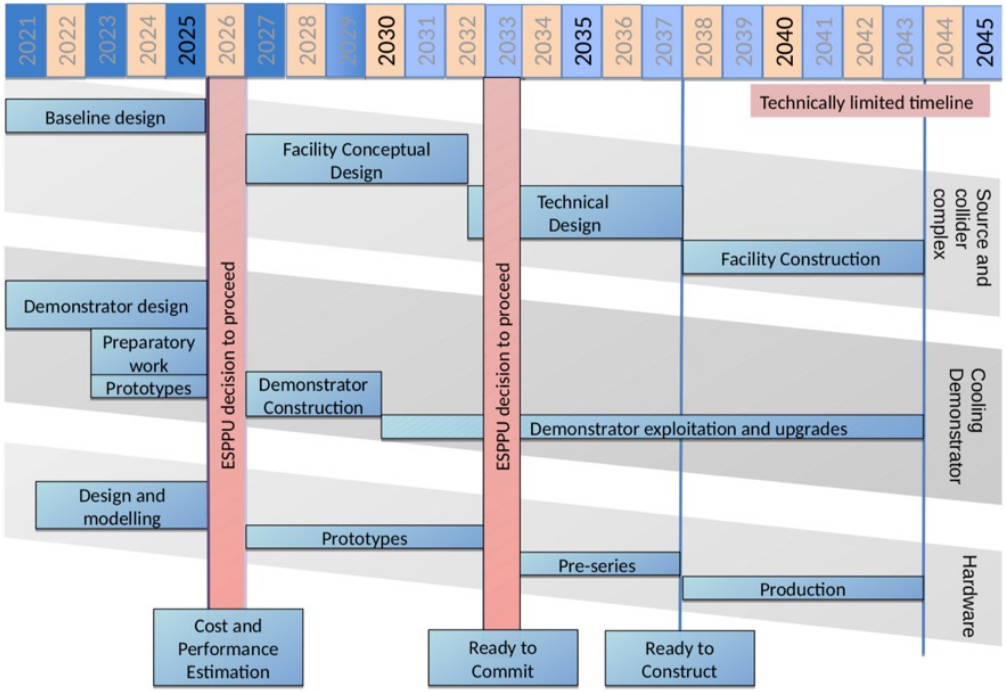
Accelerator R&D Roadmap

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**

Intense preparation and review activities in 2021:
3 Community Meetings (May, July, October) and
a dedicated Muon Collider Physics and Detector Workshop

presented to CERN Council in December and published https://arxiv.org/abs/2201.07895
now under implementation by LDG + Council…



Technically limited timeline

**A 3 TeV muon collider could be ready by 2045,
as reviewed by the Roadmap**

Plan

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

Scenarios

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

~70 Meu/5 years

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

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** ➔ **presented to December Council 2021**
  dedicated Muon Beams Panel - but also synergies in High field magnets, RF and ERL
- European ECFA **Detector R&D Roadmap** ➔ **presented to December Council 2021**
  Muon collider @ 10 TeV is one of the targeted facilities emerging from the EPPSU
- US SnowMass Muon Collider Forum **since 2021** *share ideas and studies across frontiers*
- Snowmass/P5 process in the US ➔ **ready by 2023**
- HORIZON-INFRA-2022-DEV-01-01 EU project MuCol for Design Study **approved July 2022**
  Research infrastructure concept development ➔ **supported by TIARA**

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

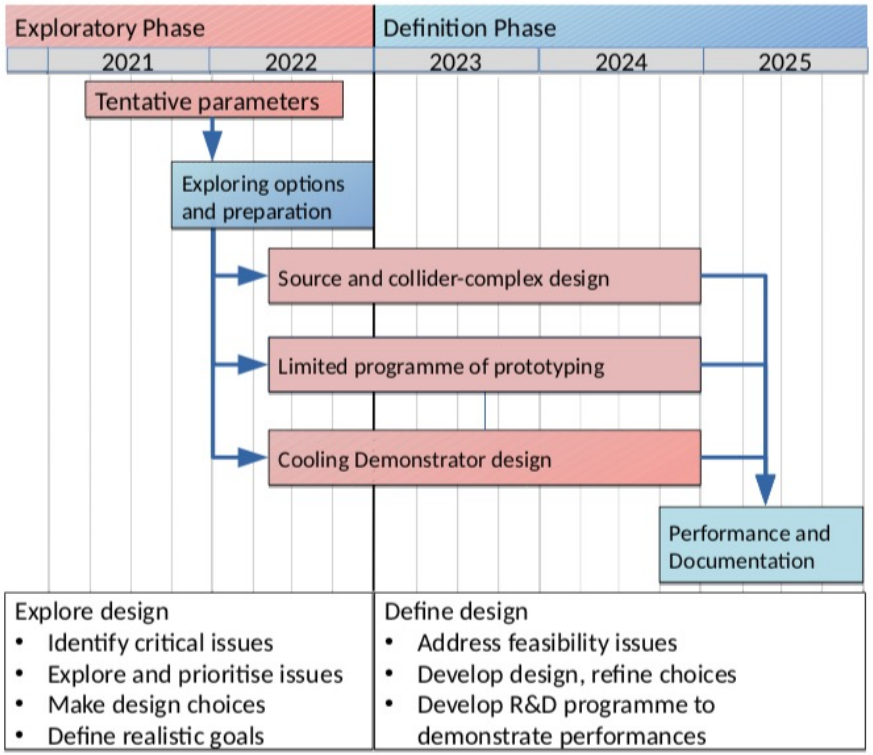
- **High-energy systems** after the cooling (acceleration, collision, ...)
  - Fast-ramping magnet systems **NEW!!**
  - High-field magnets (in particular for 10+ TeV) **NEW!!**

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

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

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

Plan for next 5 years



- **End-to-end design with all systems**
- **Key performance specifications**
- **Evidence to achieve luminosity goal:**
  - beam parameters, collective effects, tolerances …
- **Evidence that the design is realistic:**
  - performance specification supported by technology
  - key hardware performances
  - radiation protection, impact and mitigation of losses
  - cost and power scale, site considerations
- **A path forward**
  - Test facility
  - Component development
  - Beam tests
  - System optimisation

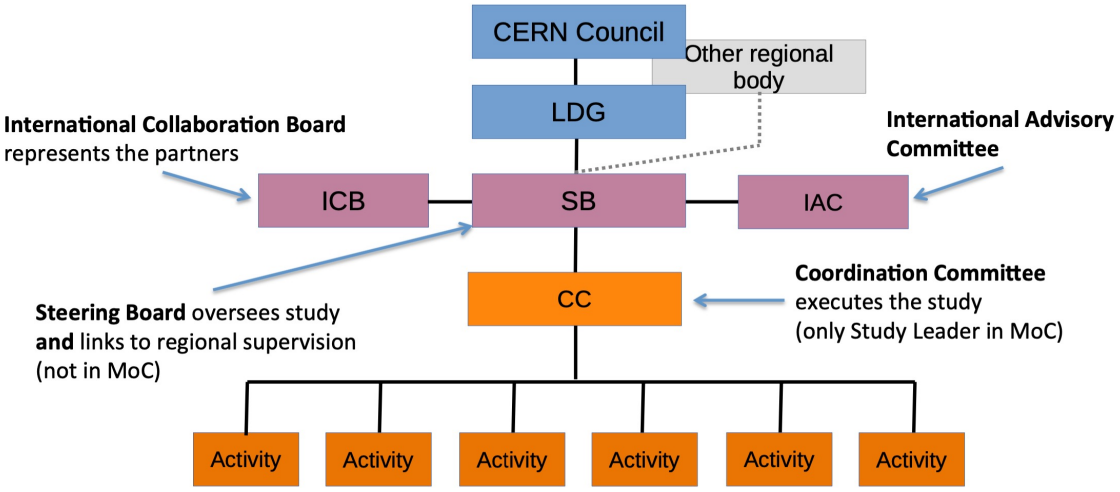
Organization after the Roadmap

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

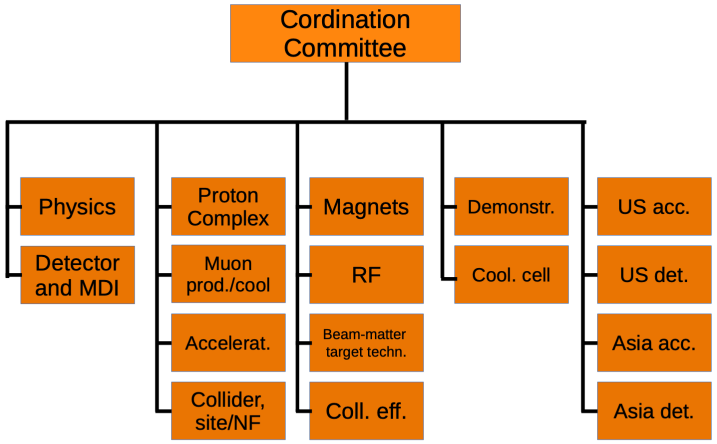
  ==> implementation detail including LDG/Council requests

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



Coordination Committee



International Muon Collider Annual Meeting
@ CERN October 11-14, 2022
https://indico.cern.ch/event/1175126/

Governance proposal – July 1 2022

Proposed CC Members

To be endorsed by SB

Physics	Andrea Wulzer
Detector and MDI	Donatella Lucchesi

Protons	Natalia Milas
Muon production and cooling	Chris Rogers
Muon acceleration	Antoine Chance
Collider	Christian Carli

Magnets	Luca Bottura
RF	Alexej Grudiev
Beam-matter int. target systems	Anton Lechner
Collective effects	Elias Metral

Cooling cell design	to be filled after EU decision
Demonstrator	Roberto Losito

US (detector)	Sergo Jindariani
US (accelerator)	Mark Palmer
Asia (China)	Jingyu Tang
Asia (Japan)	tbd

Once EU Design Study is approved add WP leaders:

EU RF WP	Claude Marchand
Cooling cell	Lucio Rossi

Proposal for deputies (to be endorsed by ICB):
Andrea Wulzer
Donatella Lucchesi
Chris Rogers

Resource coordination:
Roberto Losito

For few cases insitute has to confirm availability

Resource Task Force to monitor contributions at any level

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

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

WP 6: Radio Frequency Systems

Leader CEA(C. Marchand)+INFN(D. Giove- 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.

MUon collider STrategy network – MUST

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

May 1, 2021 – April 30, 2024

Task 5.1

….

It will serve as the common ground for a growing international muon-collider collaboration

MUST will support to establish an international collaboration and develop an optimized R&D roadmap towards a future muon collider, including the definition of optimum test facilities and possible intermediate steps

1 January 2022 - 31 December 2025 EU RISE project

aMUSE further provides an excellent platform for an ambitious EU-US network to advance the development of muon beams.

Objectives WP3 – leader: Donatella Lucchesi

- Study techniques of unstable particles beam cooling muon beams at different energies, aiming to validate the simulation with experimental tests
- High energy muon beams: determine the optimal interaction region configuration by studying the beam induced background and new detector technologies able to handle it
- Design and simulate detector for different centre of mass energies
- Evaluate the radiation hazards related to the neutrino flux emitted by the muon beams.

Anagrafica RD_MUCOL

TOTALE: 111 PERSONE - 19.6 FTE

SEZIONE	SIGLA	PERSONA	TOT (incl synergies)	RD_MUCOL	MuCol	I.FAST	AIDAinnova
			%FTE	%FTE	%FTE	%FTE	%FTE

BA (16 PERSONE - 2.5 FTE)
BO (8 PERSONE - 1.25 FTE)
FE (3 PERSONE - 0.4 FTE)
LNF (8 PERSONE - 1.1 FTE)
LNL (6 PERSONE - 0.45 FTE)
LNS (3 PERSONE - 0.45 FTE)
MI (9 PERSONE - 1.5 FTE)
MIB (3 PERSONE - 0.3 FTE)

NA (3 PERSONE - 0.3 FTE)
PD (15 PERSONE - 3.6 FTE)
PV (9 PERSONE - 2.1 FTE)
RM1 (8 PERSONE - 2.85 FTE)
RM3 (5 PERSONE - 0.4 FTE)
TO (13 PERSONE - 2 FTE)
TS (2 PERSONE - 0.4 FTE)

GE will appear on MuCol EU project

Missioni

- 2022:
  - Annual Meeting @ CERN 11-14 Ottobre
  - Meeting RD_MUCOL novembre-dicembre

  ==> comunicheremo eventuali avanzi entro 6/9

- 2023: totale richieste 231 keu + 35 keu sj
  - Meeting in Italia e al CERN (Snowmass??)
  - Test beam R&D detector e cristalli

Attività bersagli sottili

simulazioni - misure di laboratorio - R&D su fascio

RM1, RM3, LNL

- Varie attivita' su bersagli sottili per LEMMA

  ==> occorre completare misure in laboratorio ma soprattutto su fascio

  ==> pubblicazioni in preparazione

- Discussione per contribuire agli studi di finestre sottili per gli assorbitori delle celle di cooling – in corso di definizione

Test Beam – fascio positroni @ CERN

Reuse from previous LEMMA test beams:

- Muon Chambers (drift tubes) – 4+2 now fully commissioned
- Calorimeters

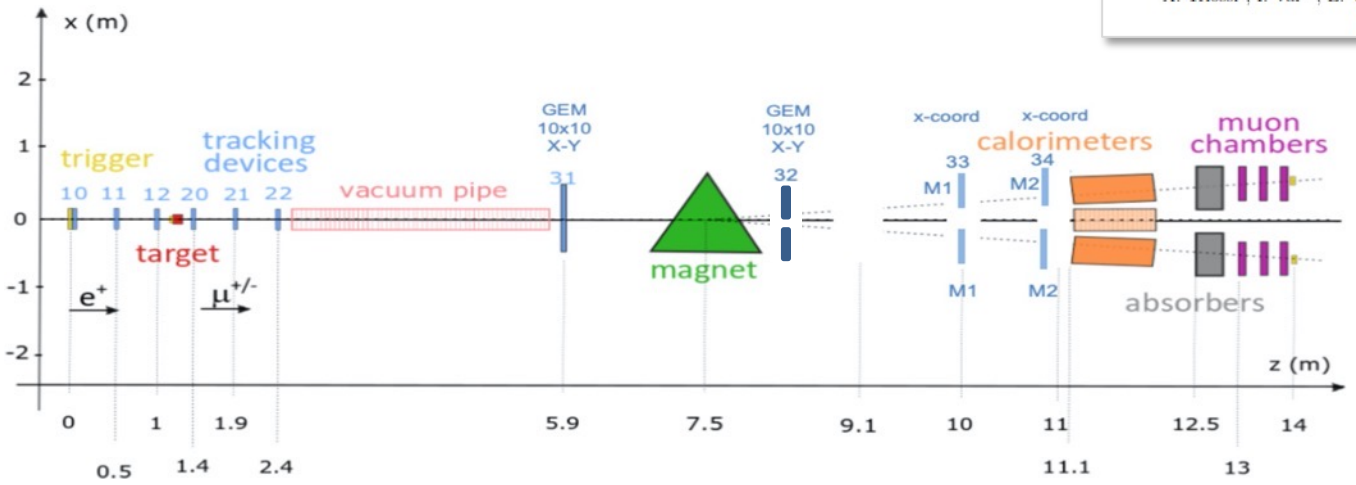
BA, PD, PV, RM1, TO

New for LEMMA test beam:

- Pixel Trackers (CMS-like) **==> TO BE commissioned**
- Triple-GEM trackers **==> done and commissioned**

LEMMA-TB: an experiment to measure the production of a low emittance muon beam

N. Amapane[a,b], M. Antonelli[e], F. Anulli[d], N. Bacchetta[h], N. Bartosik[b], M. Bauce[d], A. Bertolin[h], M. Bianco[m], C. Biino[b], O. R. Blanco-Garcia[c], M. Boscolo[c], A. Braghieri[q], A. Cappati[a,b], F. Casaburo[l,d], M. Casarsa[i], G. Cavoto[l,d], N. Charitonidis[*m], A. Colaleo[p], F. Collamati[d], G. Cotto[a,b], D.Creanza[p], C. Curatolo[h], N. Deelen[t], F. Gonella[h], S. Hoh[n,h], M. Iafrati[e], F. Iacoangeli[d], B. Kiani[b], D. Lucchesi[n,h], V. Mascagna[e,f], S. Mersi[m], A. Paccagnella[n,h], N. Pastrone[b], J. Pazzini[n,h], M. Pelliccioni[b], B. Ponzio[c], M. Prest[e,f], C. Riccardi[q,r], M. Ricci[c], R. Rossin[n,h], M. Rotondo[e], P. Salvini[q], O. Sans Planell[a,b], L. Sestini[h], L. Silvestris[p], A. Triossi[o], I. Vai[q,s], E. Vallazza[f], R.Venditti[p], S. Ventura[h], P. Verwilligen[p], P. Vitulo[q,r], and M. Zanetti.[n,h]



ASSIGNED 2022: 20 keu for DAQ @ PD and 5 keu for trigger @ TO

Due to lack of experts and Run3 duties ==> test beam request postponed

Attività sviluppo Acceleratore

Progetti comuni INFN + CERN + Istituzioni Internazionali
FCC e Muon Collider

quattro aree identificate di interesse INFN:

1. FCC-ee

Machine Detector Interface, MDI, accordo INFN-CERN FCC-GOV-CC-0104 KE4831

sviluppo dell'iniettore per FCC-ee, accordo INFN-CERN FCC-GOV-CC-0205 KE4907

2. MDI per Muon Collider

3. Sviluppo studi su Cavità a RadioFrequenza Super e Normal Conduttrici

4. Sviluppo studi dipoli e solenoidi ad alto campo magnetico (Nb3Sn, HTS?)

Attività sviluppo Acceleratore

Indagine per Piano Operativo R&D su Acceleratori

RICHIESTA DOCUMENTAZIONE scadenza 15 settembre

- *Breve riassunto piano attività che si intende sviluppare in un arco temporale di 3-4 anni*
- *Unita' (INFN, Università, etc) coinvolte, indicando per ciascuna il livello di impegno in #FTE, e a grandi linee il tipo di contributo che viene offerto*
- *Risorse necessarie (materiale, consumi) per sviluppo piano di attività e distribuzione temporale*
- *Risorse personale (strutturato) disponibile presso le strutture*
- *Risorse personale nuovo da assumere strettamente necessario per lo svolgimento delle attività, oltre a quello gia' strutturato e coinvolto (AdR o equivalente): professionalita' e distribuzione temporale*
- *Possibili coinvogimenti con altri Istituti di Ricerca (Nazionali, Internazionali, incluso il CERN) specificando la distribuzione dei compiti in un contesto di collaborazione*
- *Osservazioni ulteriori e commenti*

Richieste 2023

- **Missioni** Totale 231 keu + 35 keu sj

Meeting in Italia e al CERN ==> Snowmass??

- **Calcolo** 50 keu @ PD (87 keu @BA PON ??)
- **Acceleratori** 150 keu 1 km cavo HTS + 60 keu RF@ MI
  10 keu licenza @ NA (totale 30keu)
  Bersagli ~10 **Cristalli** ~20
- **R&D Rivelatori** **CRILIN** **HCAL** **picosec**
  tracker ==> 20 keu sj ‘22 50 keu ‘23