HEP landscape in Italy

"a look at the future"

Plenary ECFA Meeting

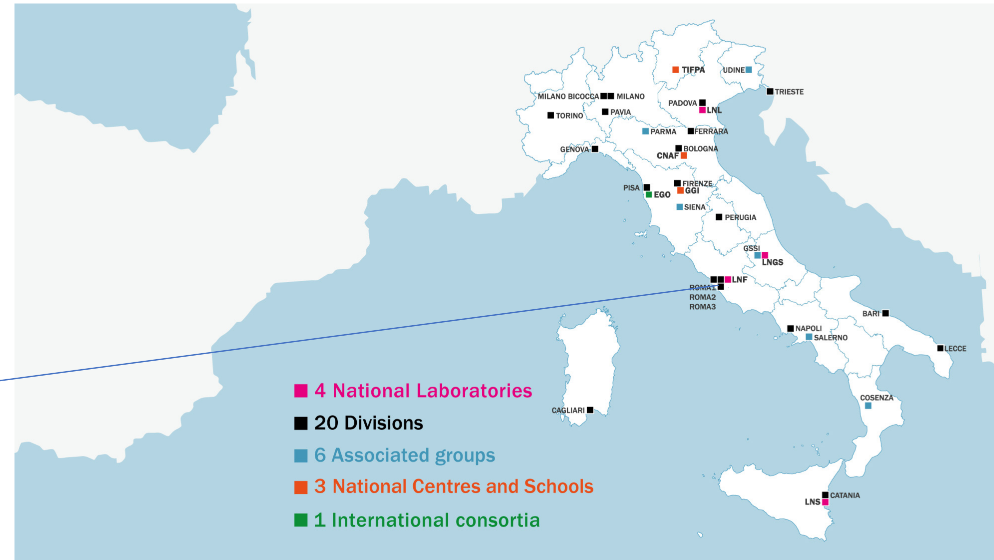
LNF 4-5 July 2024

Sandra Malvezzi
INFN

ECFA
European Committee for Future Accelerators

Where we are today (LNF)

Where we are in Italy



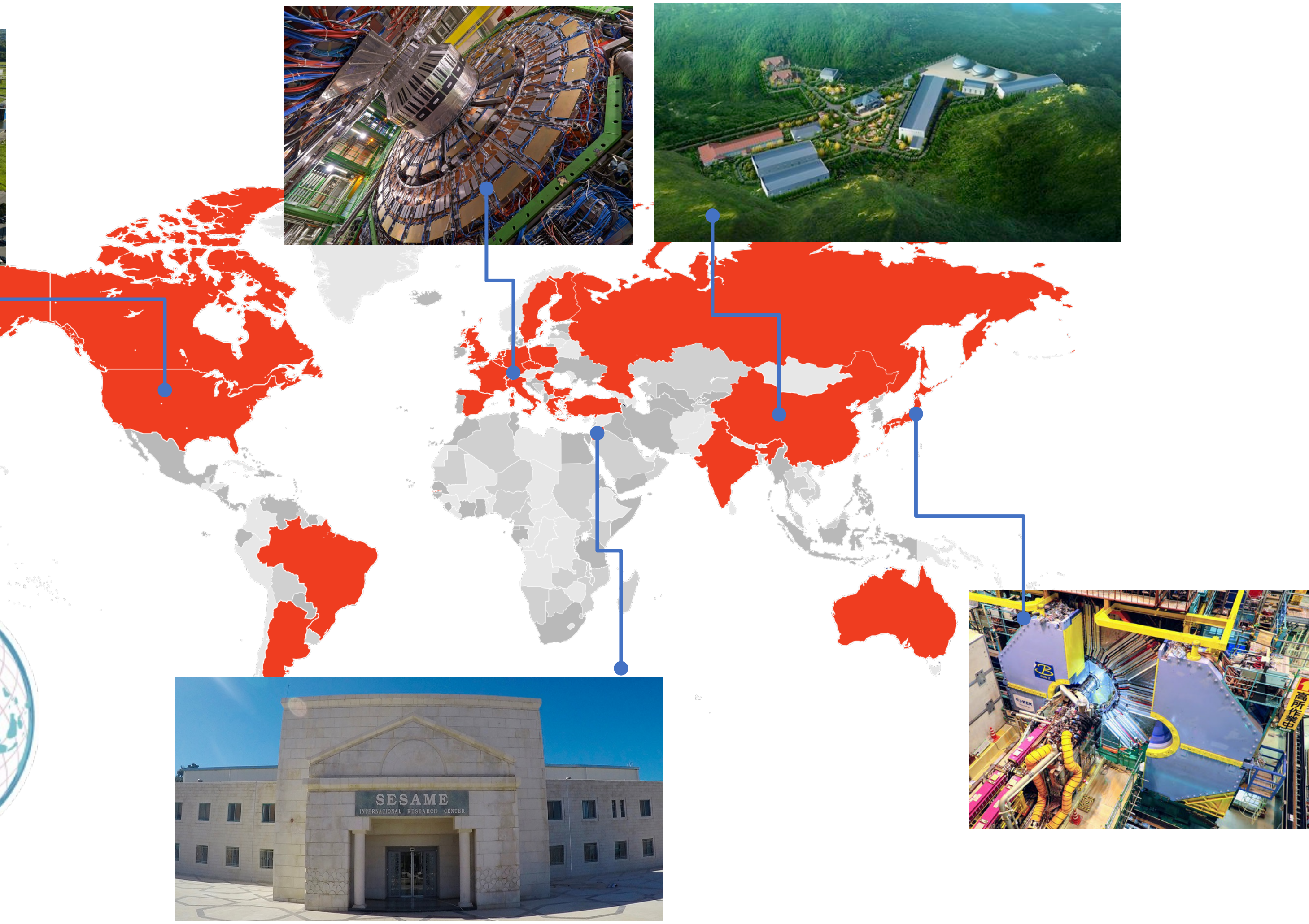
Where we are in Europe

INFN is the Italian research agency dedicated to the study of the fundamental constituents of matter and the laws that govern them, under the supervision of the Ministry of Universities and Research (MUR).

A community of ~7000 people

Italian Population: 58.94 million (2022) World Bank
Geographical size: 302073 km^2

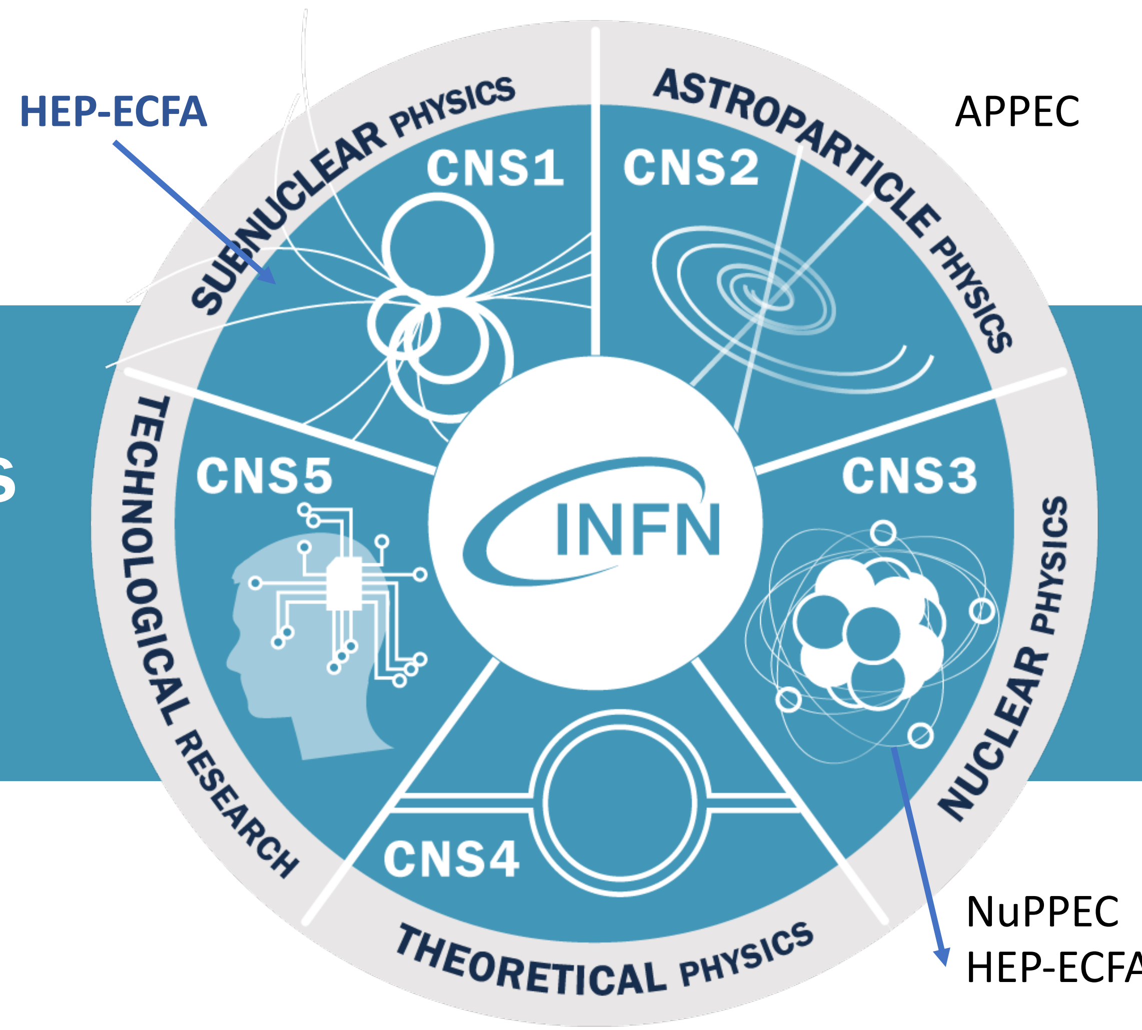
INFN is involved in all the main international scientific projects



an international DNA

The INFN Scientific Committes

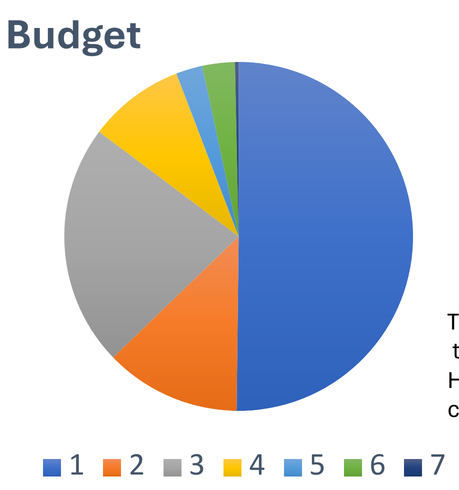
The **5 research lines**
and the National
Scientific Committee



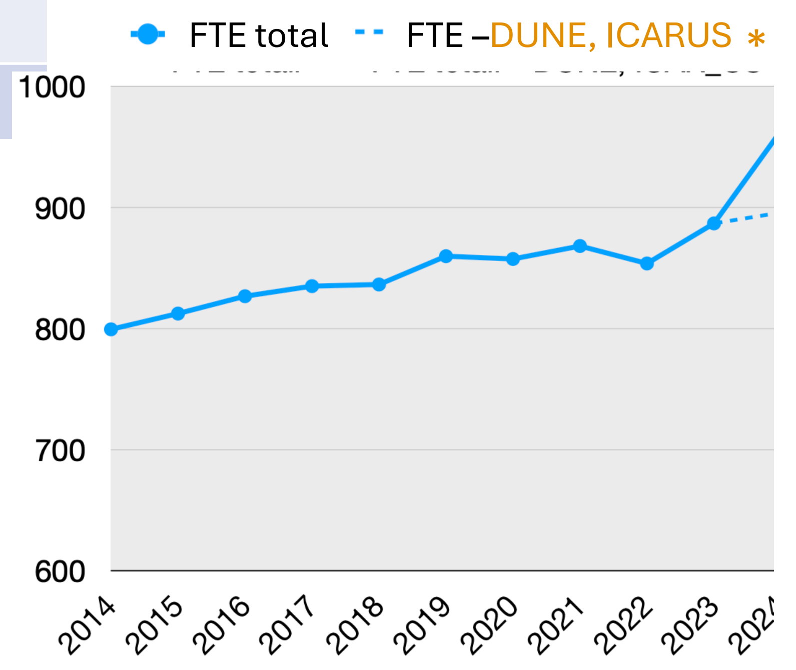
HEP is mainly CSN1
plus ALICE in CSN3

CSN1: topics and a bit of statistics

Research Lines CSN1 2024	FTE(%)	Budget(%)
Physics at hadron colliders (LHC)	50,71	50,19
Neutrino Physics @accelerators *	9,10	12,6
Flavour Physics (LHCb & Belle2)	27,11	22,45
Charged Lepton Physics	5,73	8,95
Proton Structure	2,61	2,46
R&D for Future Accelerators	3,76	3,01
Dark Sector	0,99	0,34



This budget does not include
the external fund complementing
HL-LHC and DUNE detector
construction, Tier2 computing

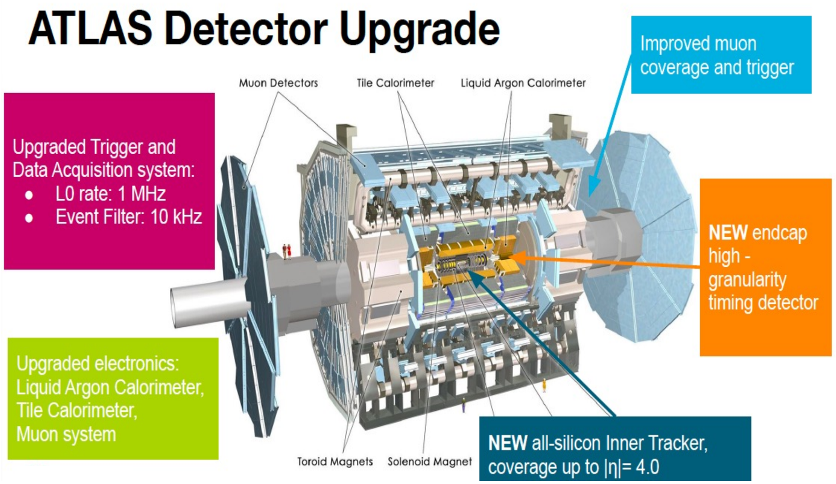


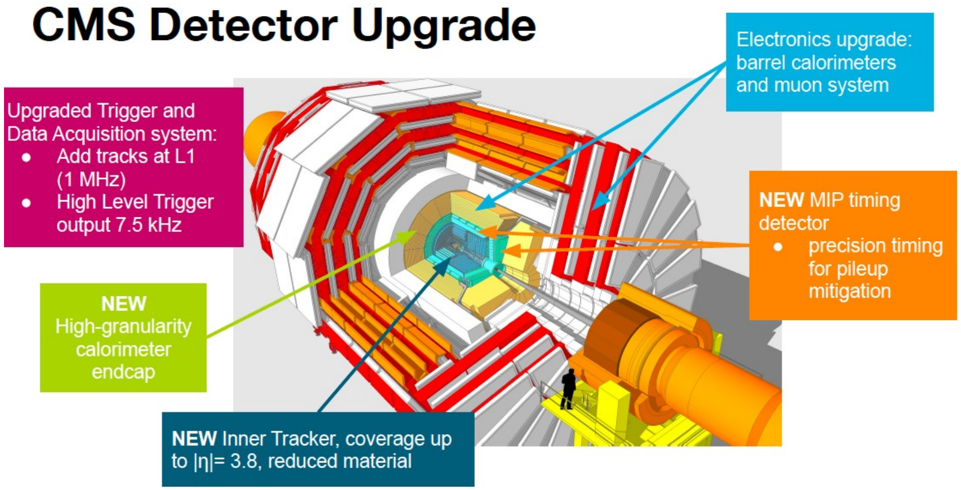
Female fraction ~20-25%

Physics at hadron colliders

ECFA
European Committee for Future Accelerators

ATLAS and CMS upgraded detectors (Phase 2)





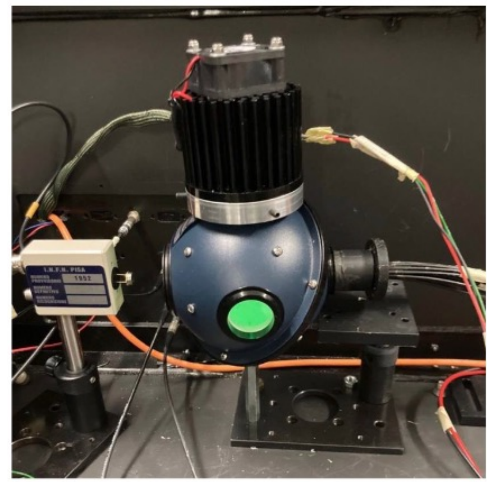
Main INFN INVOLVEMENTS:
- Tracker (ITK)
- Liquid Argon Calorimeter
- Tile Calorimeter
- MUON
- TDAQ

MAIN INFN INVOLVEMENTS:
- Tracker (inner and outer)
- MTD timing layer
- ECAL
- MUON

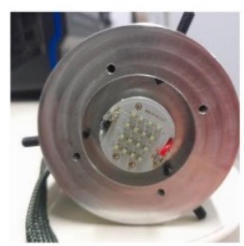
ATLAS Phase 2 @INFN

Electronics LAr, prototype

Tile Calorimeter: Integrating sphere + DC LED matrix in Pisa

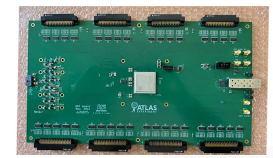


16 green LED array



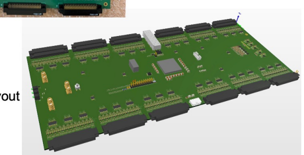
heat sink and fan

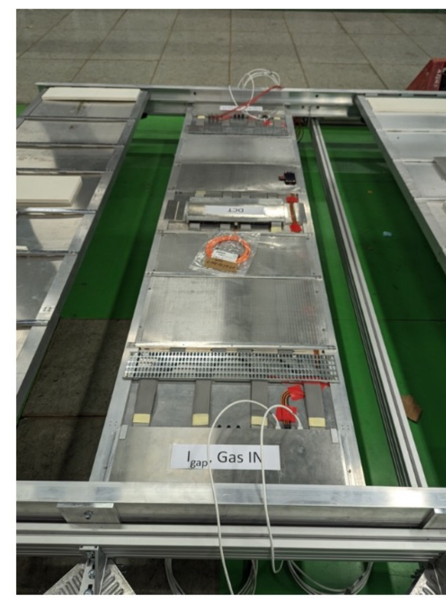
RPC electronics



BMBO DCT (2nd prototype)

BI DCT layout





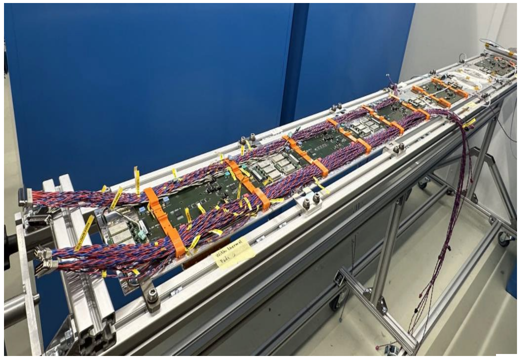
Service integration test

CMS Phase 2 @INFN

Tracker support tube

CROC Chip Readout Chip / Pixel Inner Tracker

Timing layer BTL tray



MUON GEM

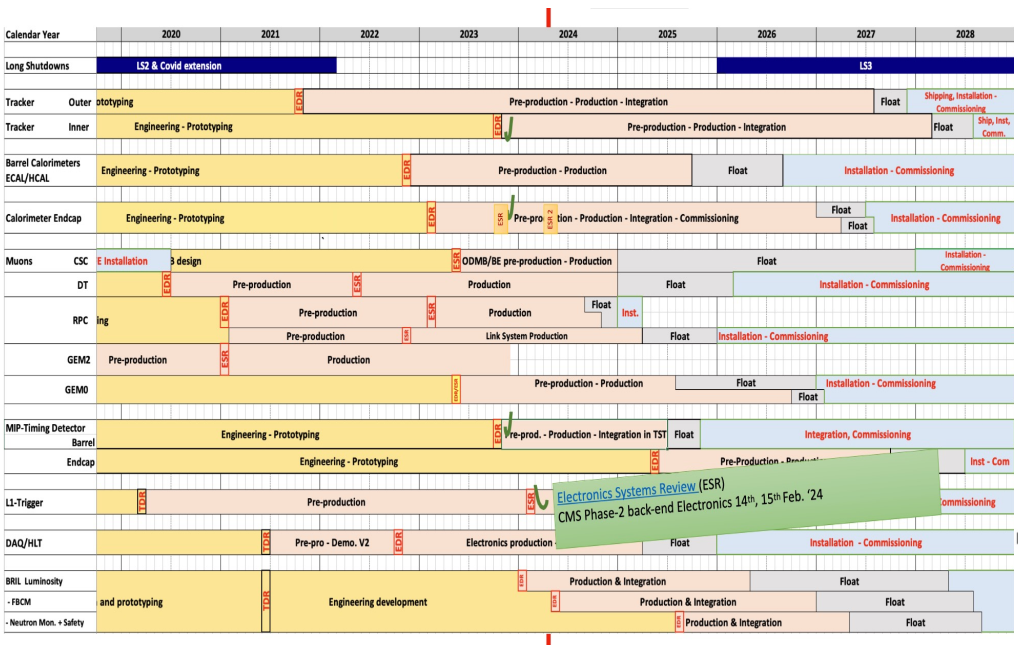
Beam test tracker final modules

ECAL new “enforneur”

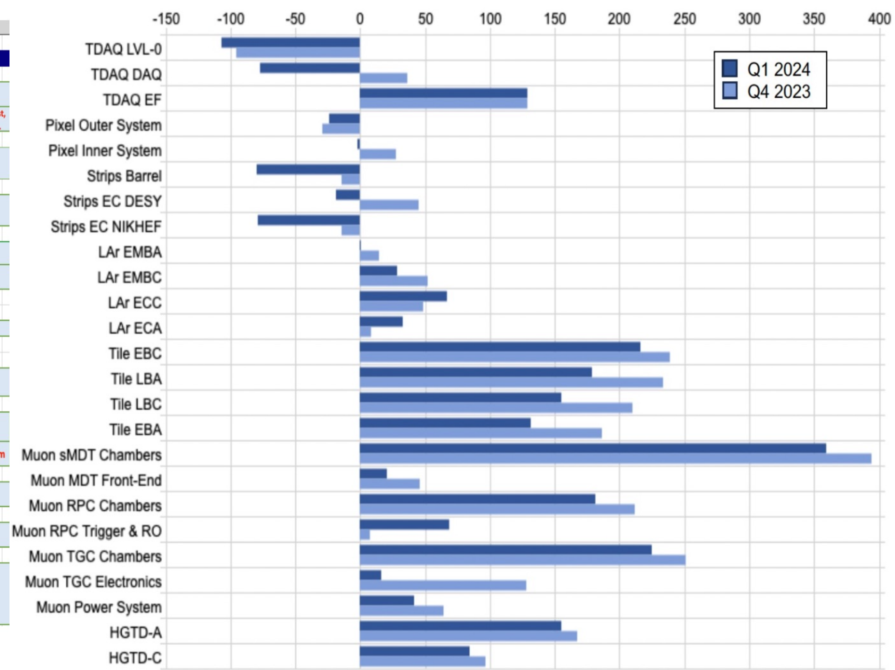
MUON GEM module test

Concerns for the schedule, reduced contingency

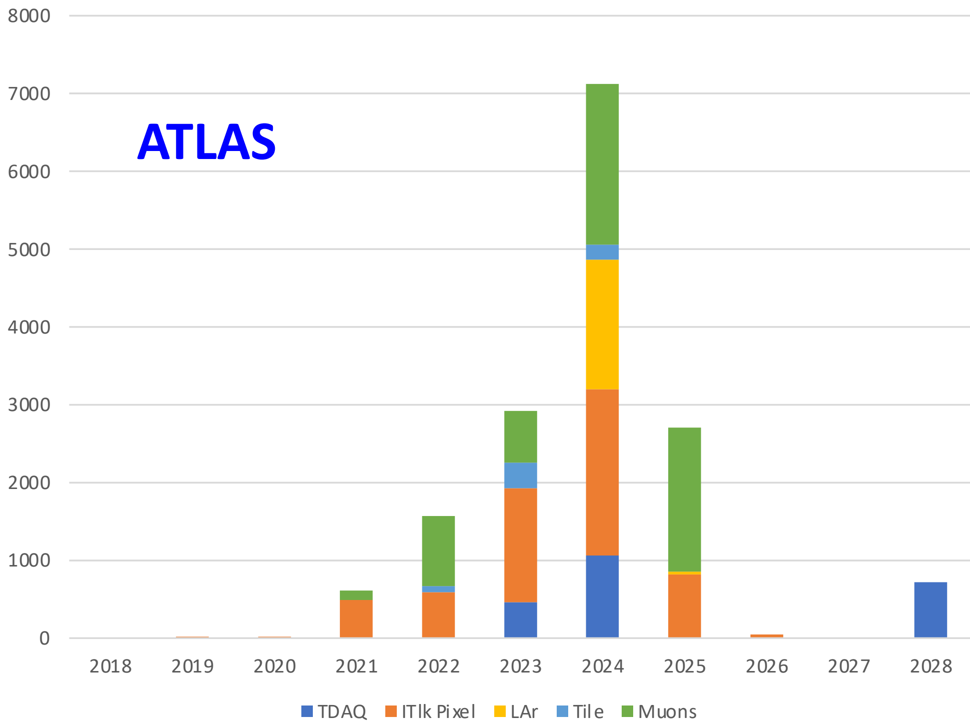
CMS construction schedule

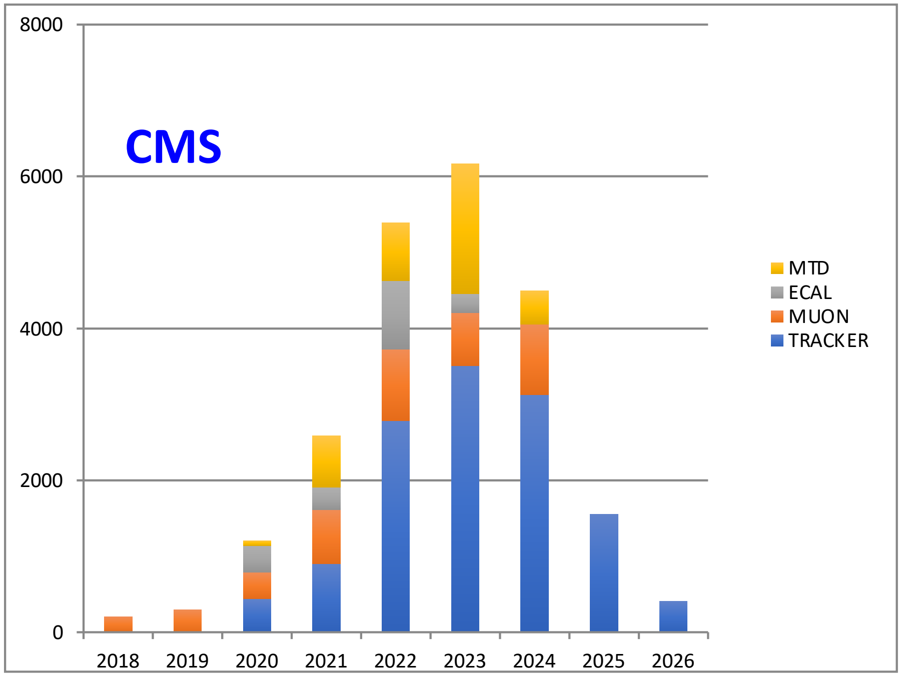


ATLAS Time Contingency, typically less than 1 year



LHC phase 2 core construction time profile





INFN has spent approximately 70 % of the *allocated* budget

Extra costs not (yet) included: ~20% total additional costs

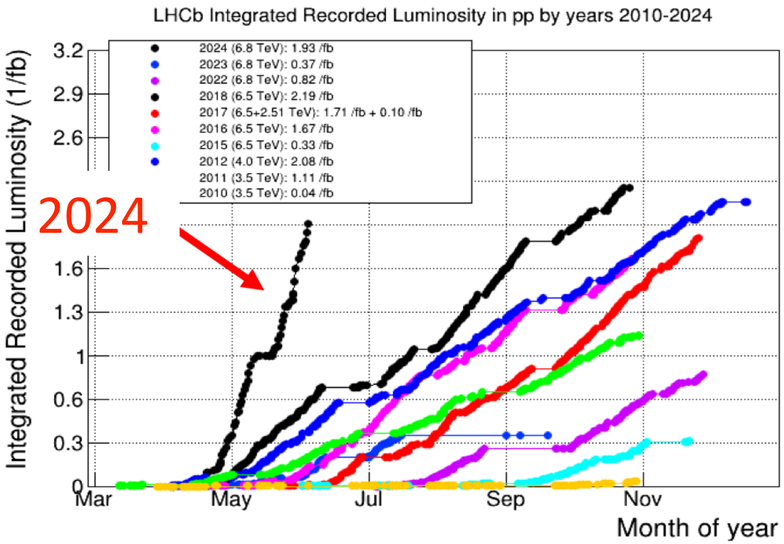
Flavour Physics

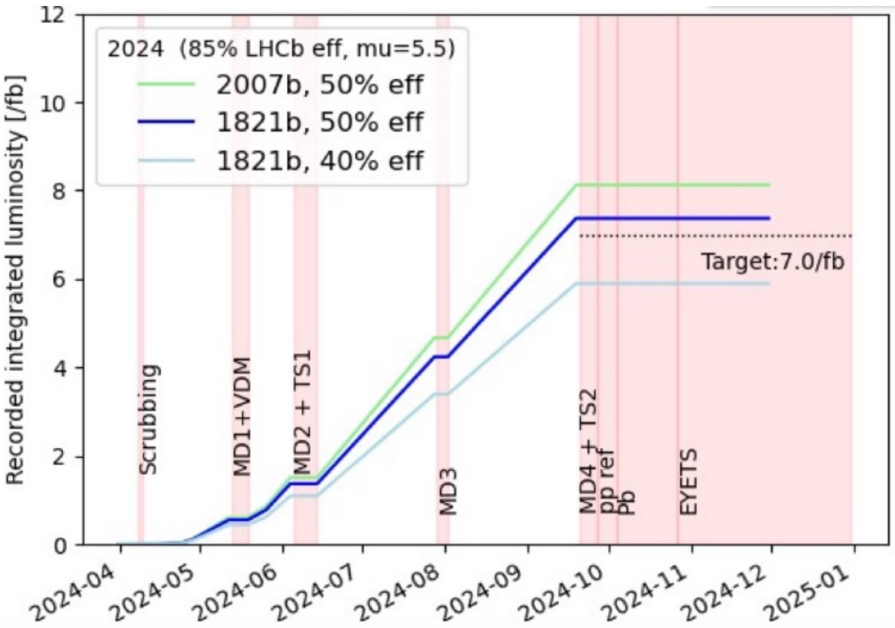
ECFA
European Committee for Future Accelerators

LHCb – now and future

V. Vagnoni Spokesperson

- LHCb has recovered from a difficult 2023 year
  - VELO open , UT not integrated, Limited luminosity (fraction of fb^{-1}) collected
- Goal for 2024
  - Integrate a high-quality sample corresponding to 7/fb of pp collisions





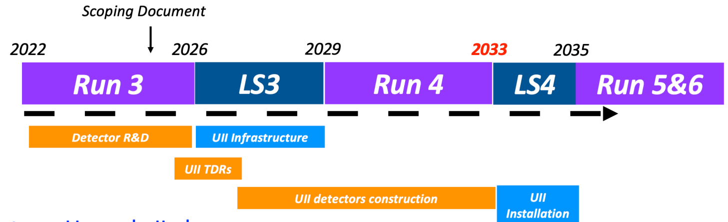
LHCb Upgrade Phase 2

LHCC-2021-012

Approved March 2022

- Detector design and technology options
- R&D program and schedule
- Cost for baseline, options for descoping
- National interests

Constraints on timeline



Constraints on Upgrade II plans

- All detector components fully ready at beginning of LS4, in 2033
- LS4 duration of 2 years will be fully needed for Upgrade II installation

Mitigation strategy

- Start detector element construction during LS3
- Anticipate some detector & infrastructure work to LS3 as a part of consolidation work (ECAL, RICH, Magnet stations, RTA under discussion)

Detector	Baseline (kCHF)
VELO	14800
UT	8900
Magnet Stations	2300
MT-SciFi	22400
MT-CMOS	19500
RICH	15600
TORCH	9900
ECAL	34800
Muon	7100
RTA	17400
Online	8900
Infrastructure	13500
Total	175100

- The project consists of a major change of the detector during LS4, in order to sustain an instantaneous luminosity of up to 1.5×10^{34} $cm^{-2}s^{-1}$ and integrate 50/fb per year during Run 5 and Run 6 of LHC (target ~300/fb)

Scoping document in preparation →

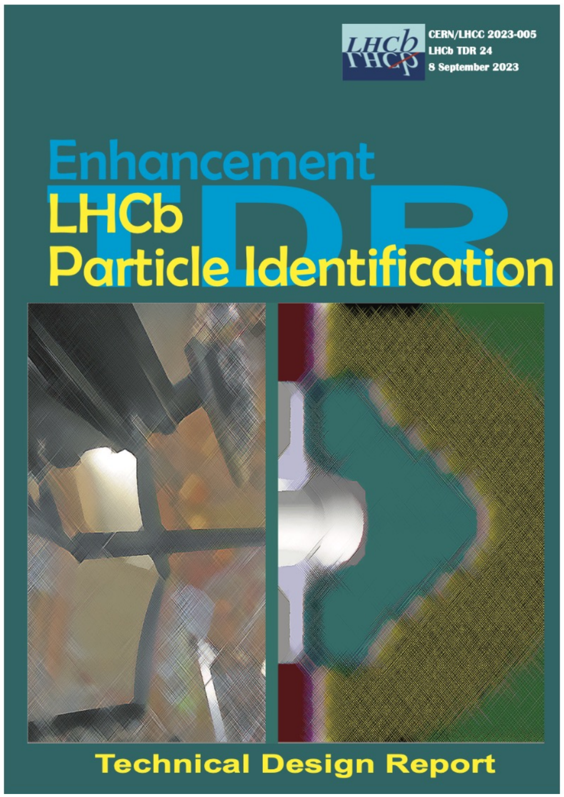
- In the FTDR we indicated two main directions to explore: reduce peak luminosity (from 1.5×10^{34} $cm^{-2}s^{-1}$ down to 1.0×10^{34} $cm^{-2}s^{-1}$) and optimise and/or reduce detector features
- The FTDR has an ambitious baseline cost of 175 MCHF → we are now exploring descoping scenarios at the level of ~85% and ~70% of max envelope

- ❑ Internal INFN review of the LHCb U2 project to define the participation of the Italian community
    - ❑ In the meanwhile CSN1 is supporting some dedicated R&Ds (RD_Flavour)

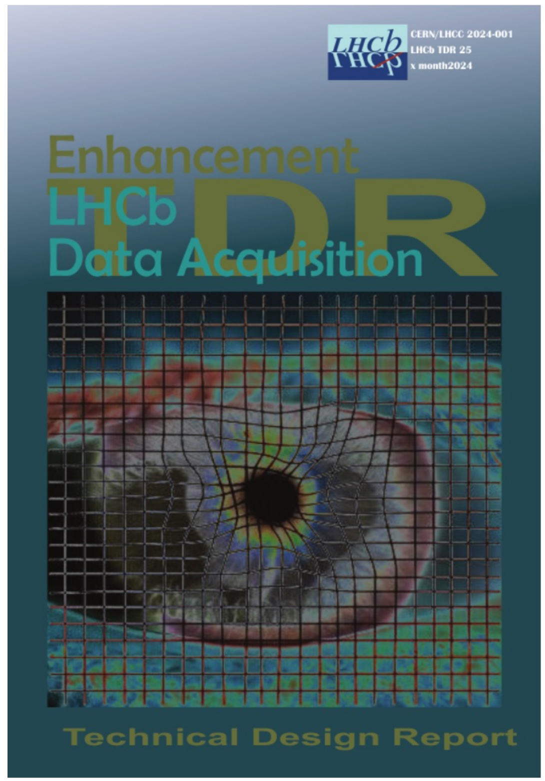
Detector enhancement at LS3

an intermediate step between Upgrade 1 and Upgrade 2

ECAL and RICH

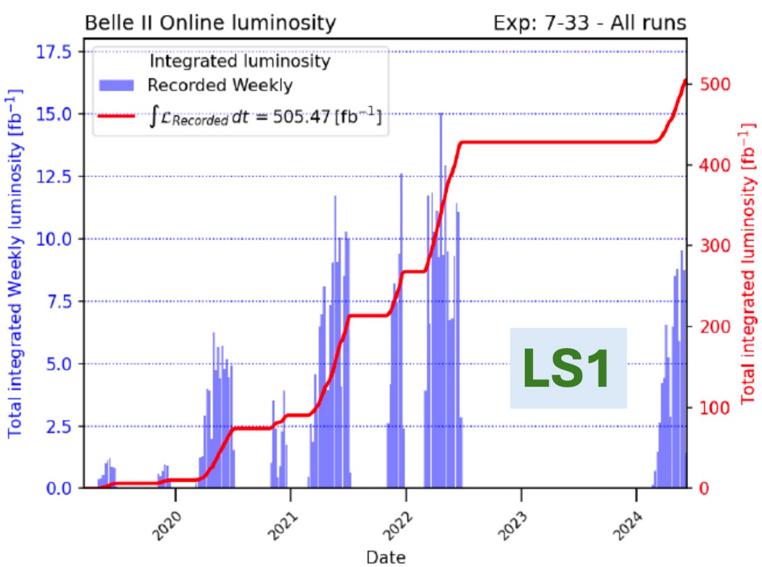


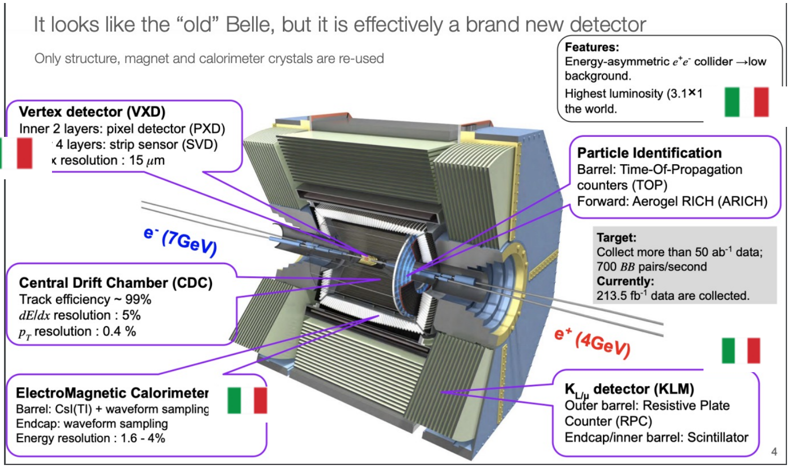
DAQ – (real time reconstruction)



INFN review within CSN1 underway (~ 2 M€ proposal)

Belle 2 and the detector upgrade (LS2)

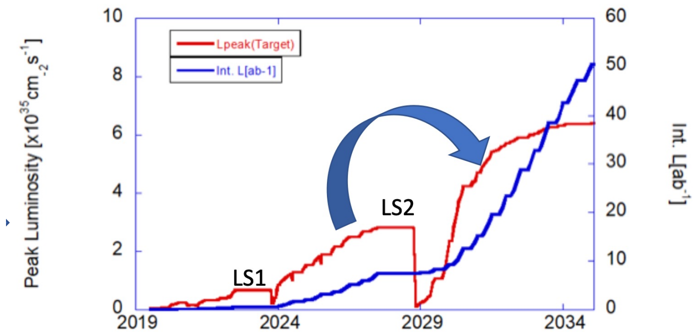




troubles when restarting : unexpected beam losses

«Beam loss that occurs within 1 turn (10 ms) without precursory phenomena»

- Belle 2 completed Long Shutdown 1 (LS1)
- Data taking restarted in February
- Accelerator consolidation at LS1 should allow the machine to reach 2.5 X 10^{35} cm^{-2} s^{-1} luminosity
- More work and ideas needed to reach the design luminosity of 6 X 10^{35} cm^{-2} s^{-1}



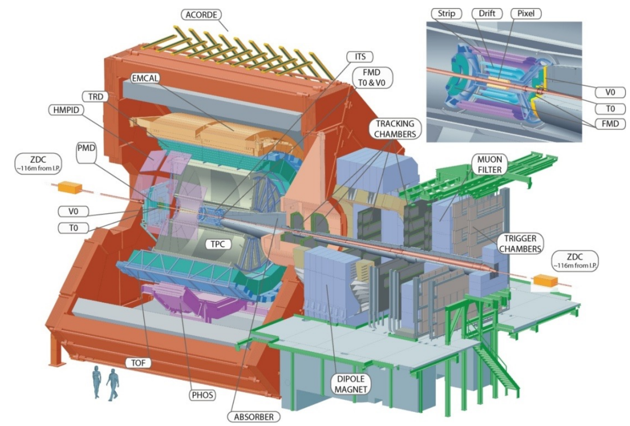
INFN groups interested in R&D for detector upgrade in LS2

→ could enter the DRD efforts

The ALICE experiment

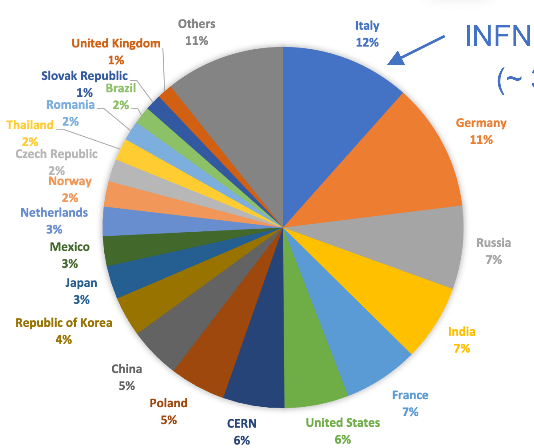
INFN CSN3

1069 authors, 176 institutes, 40 countries



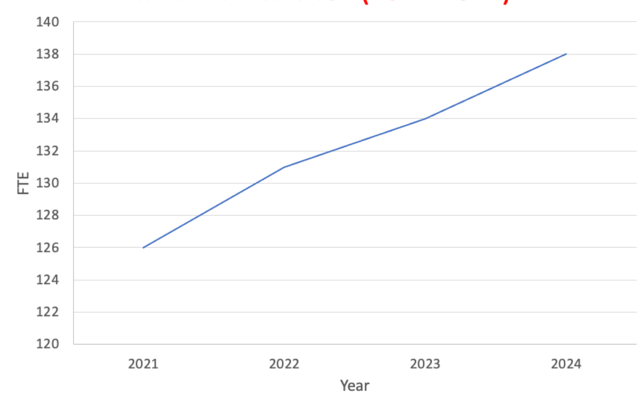
Study of deconfined QCD matter

ALICE MEMBERS



INFN is the largest contingent (~ 30% of CSN3 budget)

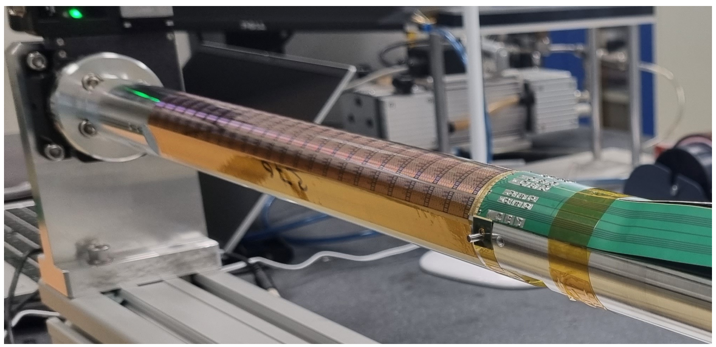
INFN FTE in ALICE (2021-2024)



ALICE

Phase 2a (LS3): ITS3

curved, wafer-scale MAPS vertex detector

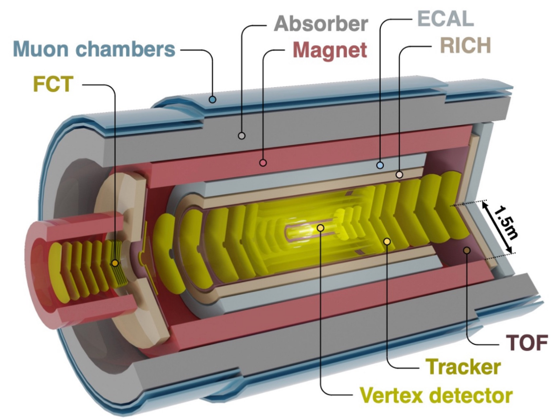


TDR endorsed by LHCC in March 2024

INFN involvement

largest contingent in project
development of **MAPS technology**
chip design, bending/stitching studies
ITS project leadership

Phase 2b (LS4): ALICE 3



System	Technology	Cost (MCHF)
Tracker	MAPS	30.5
TOF	Monolithic LGADs	14.8
	Hybrid LGADs[6]	26.4
RICH	Aerogel and monolithic SiPMs	20.9
	Aerogel, analogue SiPMs + readout[6]	34.0
ECal	Pb-scintillator + $PbWO_4$	17.0
MID	Steel absorber, scintillator bars, SiPMs	7.0
FCT	MAPS (solenoid + separate magnet)	5.3
	MAPS (solenoid + dipoles)	2.3
Magnet system	Superconducting solenoid + FCT magnet	25.0
	Superconducting solenoid and dipoles	40.0
Computing	Data acquisition and processing	6.0
Common items	Beampipe, infrastructure, engineering	15.0
Total		141.5

LOI recommended by LHCC in 2022: https://arxiv.org/2211.02491
scoping options under study → Scoping Document in preparation

INFN R&D in CSN3

Inner Tracker (Vertex + Middle Layers)
Time Of Flight
RICH
SC magnet

Neutrino Physics

ECFA
European Committee for Future Accelerators

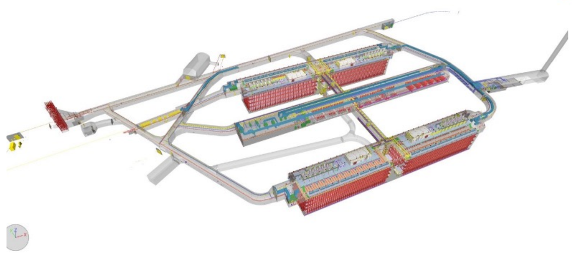
Neutrinos @accelerators in CSN1

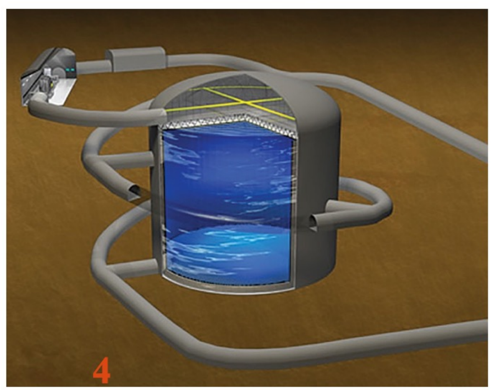
...the new entry

SND@LHC	(since 2021)
DUNE	(since 2024)
Icarus	(since 2024)
HyperK +T2K	(since 2025)
ENUBET*	(since 2025)

*measurement of the positrons produced in the decay tunnel of conventionalneutrino beams: these particlessignal uniquely the generation of an lectron neutrino at source

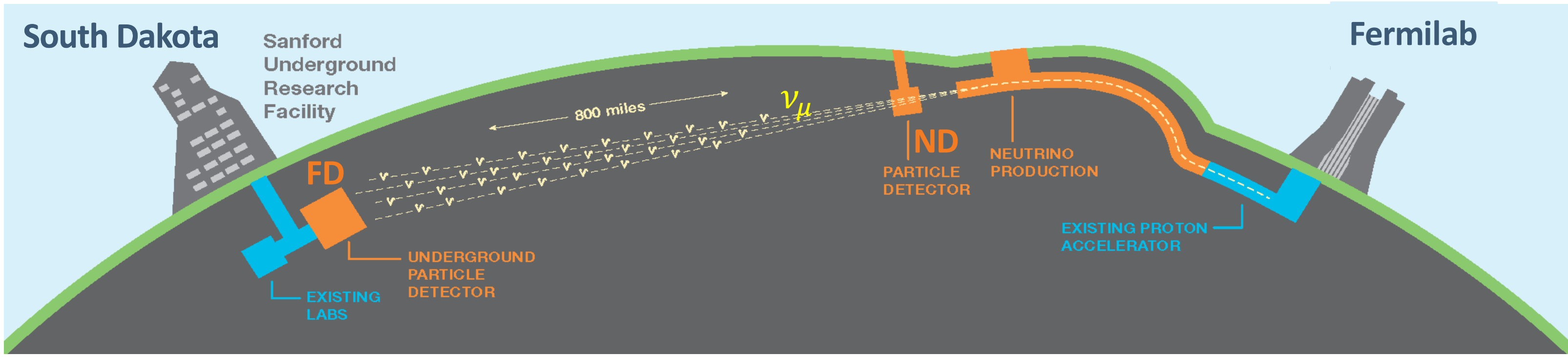
DUNE and Hyper-K: different detectors, different strategy





- DUNE:
  - Very long baseline → large matter effect
  - Broadband neutrino beam → high statistics over full oscillation period
  - LArTPC → imaging + calorimetry for ν-Ar interactions at ~2.5 GeV
  - Highly-capable near detector to constrain systematic uncertainties
- Hyper-K:
  - Shorter baseline → small matter effect
  - Off-axis location creates narrow beam → very, very high statistics at oscillation maximum, less feed-down
  - Water Cherenkov → kinematic measurement of E_ν from ν-O interactions at ~0.6 GeV
  - Highly-capable near detector to constrain systematic uncertainties

The Deep Underground Neutrino Experiment (DUNE)



A new generation Long Baseline – 1300 km – neutrino oscillation experiment based on

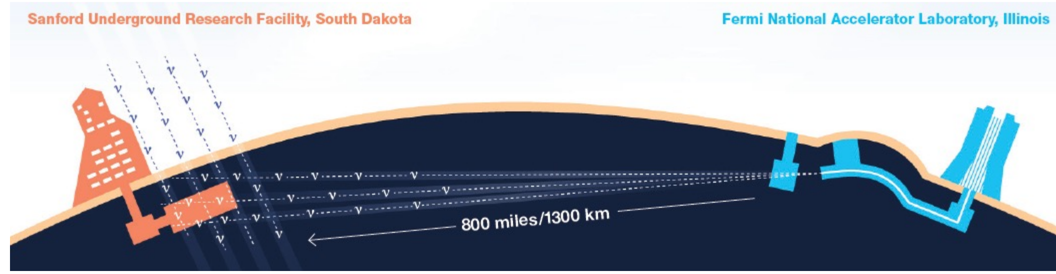
- a wide band high intensity (1.2 MW upgradable to 2.4 MW) $\nu/\bar{\nu}$ neutrino beam produced at Fermilab
- a large total mass (~70 kton) Far Detector at the Sanford Underground Neutrino Facility (SURF) 1.5 km underground exploiting the Liquid Argon Time Projection Chamber (LArTPC)* technology
- a Near Detector complex (ND) at Fermilab providing control of systematic uncertainties, enabling a rich physics program

Some physics goals (phase 1)

Oscillation Physics:
- Definitive resolution of the mass ordering
- Sensitivity to maximal CP violation (δCP ~ ± π/2)
- World-leading measurement of mass splitting (Δm2atm)

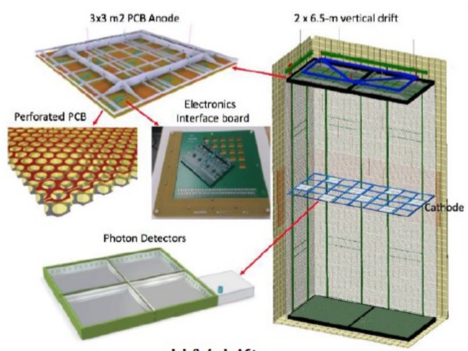
*Liquid Argon TPC, a new concept for neutrino detectors by C. Rubbia 1977 developed in Icarus

INFN @ DUNE



collaboration agreement DOE/INFN signed in April

DUNE Far - Photon Detection System (PDS)

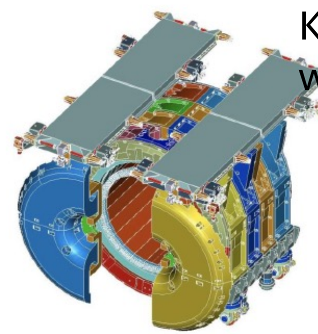


H/V drift

European site for WLS evaporation

INFN plays a very important role in the PDS Consortium, which handles the construction of the DUNE PDS

DUNE Near from KLOE→ SAND



KLOE Magnet and calorimeter will be integrated in SAND

- provide an independent measurement of the **flux**
- measure the **flavor** content of the neutrino beam
- contribute to remove **degeneracies** when the other components are off-axis
- add robustness to the ND complex to keep **systematics** under control
- provide a reasonable **control** of the systematics (SAND installed since Day-1 of data taking)
- exploit the high statistics to perform other **high precision neutrino physics** measurements and BSM searches without any ad-hoc modification

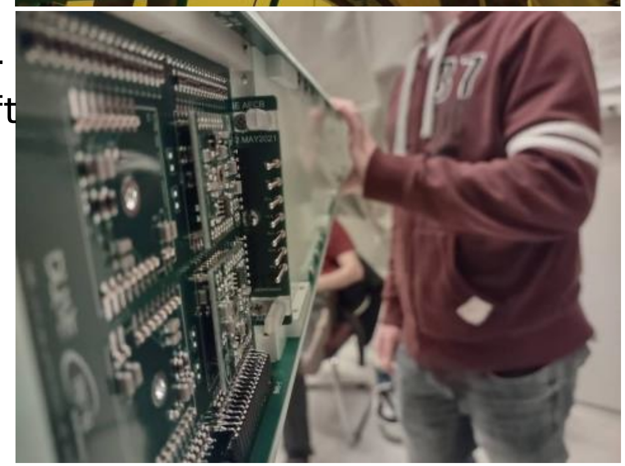
Joint effort of several INFN Units and Labs

DUNE FD PDS (Photon Detector System) @INFN

SiPM tender is underway

Integration of
a PDS module
In lab

Installation of
a PDS module
in ProtoDUNE-
Horizontal Drift



Test of x-arapuca
of the Vertical Drift

Physics in 2028 or early 2029
Beam physics with Near Detector 2031

Hyper-K

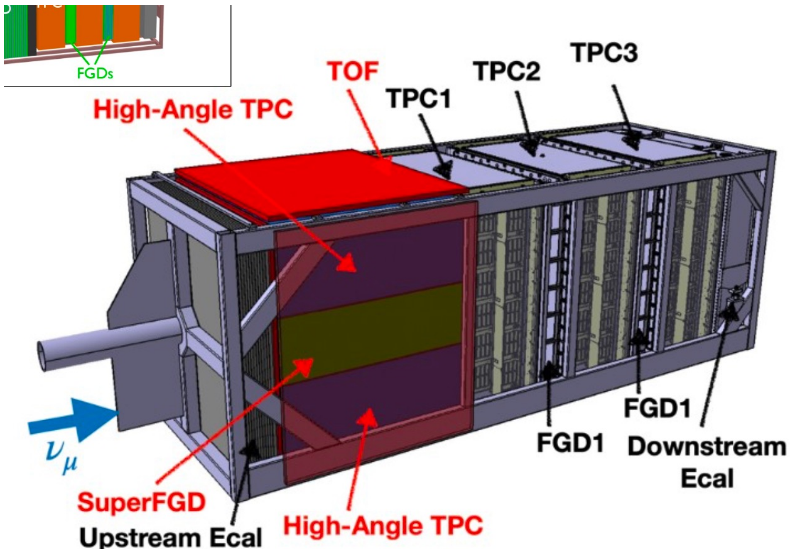
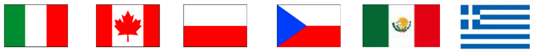
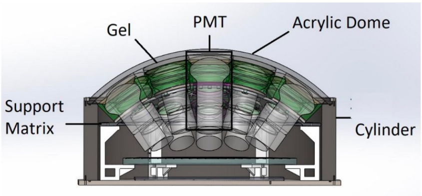


Table 2: Work package 2, High Angle TPCs detector deliverables in kCHF

TPC	Sum	Krakow	RWTH	CERN	INFN	IN2P3	Saclay	Warsaw	IFAE
Field Cage	555				549				6
Micromegas	278			248			30		
TPC mechanics	193	39				24	130		
Electronics	380					170	170	21	19
Gas system	276			276					
HV, LV	134		74			20	40		
GMC	34		34						
Shipment from CERN to J-PARC	50			50					
Total	**1900**	**39**	**108**	**574**	**549**	**214**	**370**	**21**	**25**

INFN contribution in Hyper-K

- Multi-PMT 
  - 300 mPMTs, out of 808 mPMTs in total. Initially proposed by the Italian group
- Elettronica
  - Front-end digitizer 20" PMTs (+OD 3" PMTs digitizer design, in collaboration with UK)
  - Timing distribution (in collaboration with LPNHE and IRFU/CEA)
- Computing
  - ~25% of Hyper-K computing 2023-27 at CNAF. Development of WAS, collaborative tools, database. Preparation of analysis tools
- Near Detector
  - Construction of two new TPCs for near detector upgrade di T2K (it will be part of the Hyper-K near detector). In collaboration with France, CERN, Spain, …



mPMT design review 09/2021-09/2022

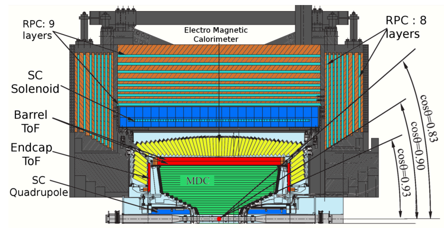
Contracts & procurement, final prototyping 2024

Mass production 2025-2026

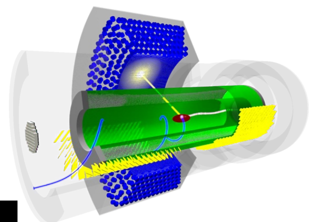
First Physics 2027

Current CSN1 activities

BESIII @BEPCII

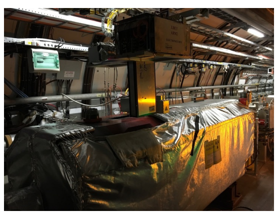


MEG II @PSI



AMBER
Apparatus for Meson and Baryon Experimental Research

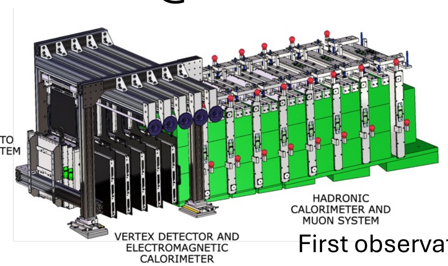
LHCf



UA9

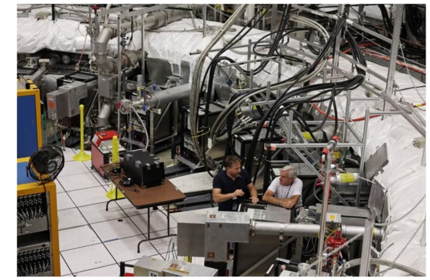
IGNITE
INFN Ground-up INITiative for μElectronics developments

SND@LHC



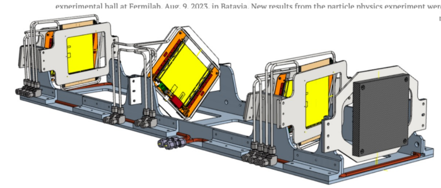
First observation of collider Neutrinos by SND and FASER

Chicago Tribune



Researchers have a discussion while performing tasks at the Muon g-2 superconducting ring magnet inside an experimental hall at Fermilab, Aug. 9, 2023, in Batavia. New results from the particle physics experiment were to be

MUonE

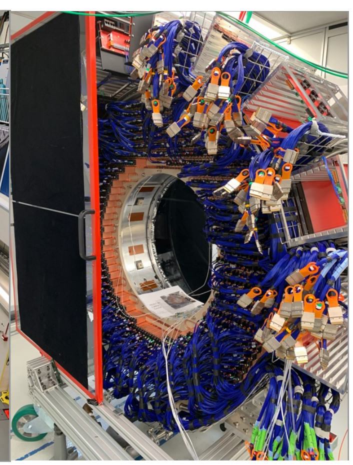


KLOE

Mu2e

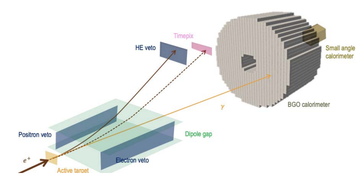
Important progress for Mu2e@FNAL.
INFN responsabilities

Transport Solenoid (AGS)



Calorimeter disk

PADME



NA62

R&D for Future Accelerators & the new ESPPU

ECFA
European Committee for Future Accelerators

INFN and the European Strategy for Particle Physics

INFN activities for the Feasibility Study of the FCC collider, for the accelerator roadmaps (High Field Magnets, Muon Collider, RF Cavity and detectors

https://www.roma1.infn.it/conference/infn-espp-2024/ **6-7 maggio 2024**

INFN will continue with initiatives within the CSNs, Laboratories and Units, encouraging the involvement of young people

«FCC is the project that will allow CERN to extend our knowledge beyond the limits that will be reached by HL-LHC and maintain the world leadership in the fundamental physics research.

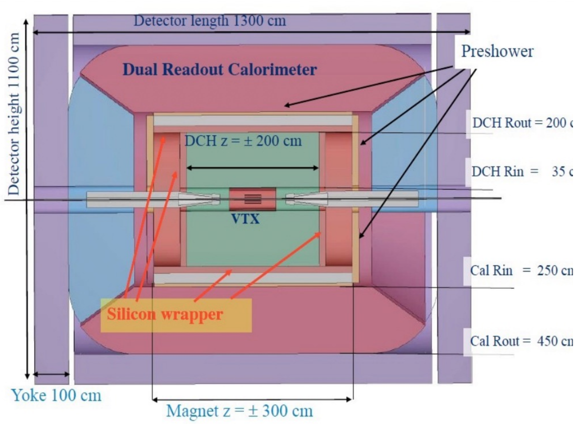
It is important to maintain the greatest flexibility in the study and development of the technologies necessary to test new concepts for future colliders and exploit the expertise/skills present in the INFN community"

Preparing the longer-term future @ INFN (I)

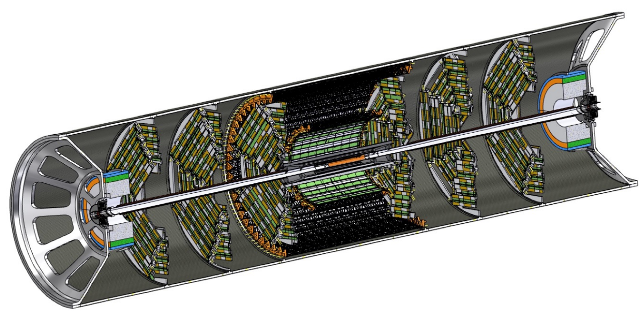
CSN1: RD_FCC

CSN1 funds & EU grants for detector studies and R&D

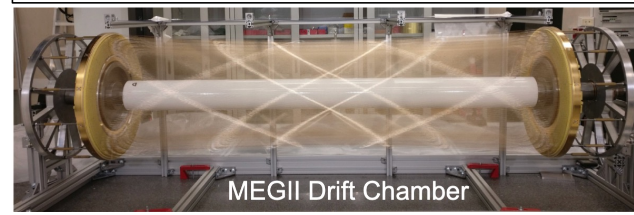
IDEA detector for FCC-ee



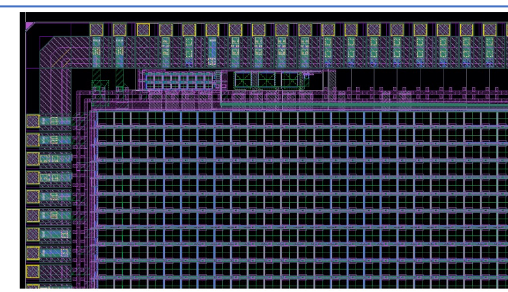
Example: developed a detailed design of the vertex detector region, with MAPs based silicon sensors. Integration takes into account crossing angle and other accelerator constraints



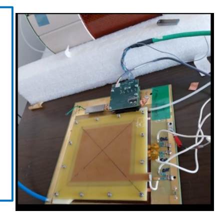
INFN MEG II Drift Chamber as a prototype for FCC Tracking



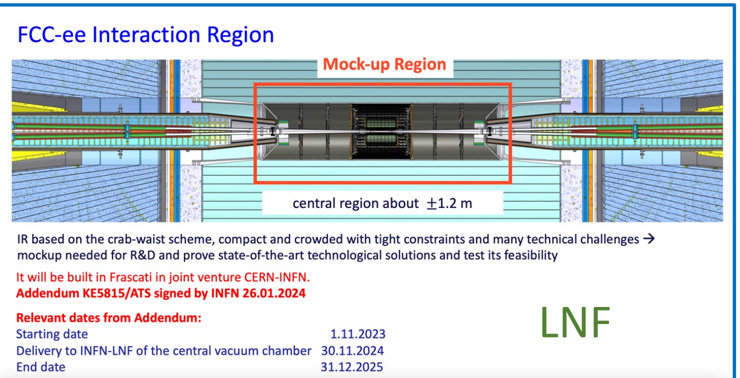
Collaboration with FBK for Digital SiPM CMOS dedicated to fiber calorimeter



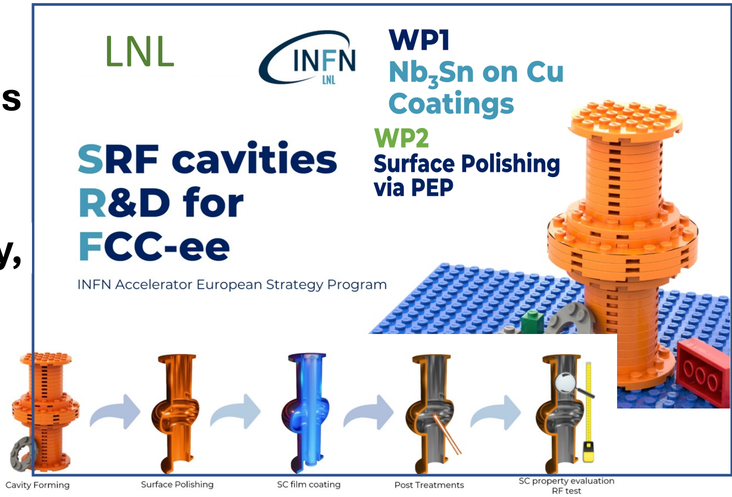
Prototype of μRWELL detector for muon chambers , tested with new TIGER low noise electronics

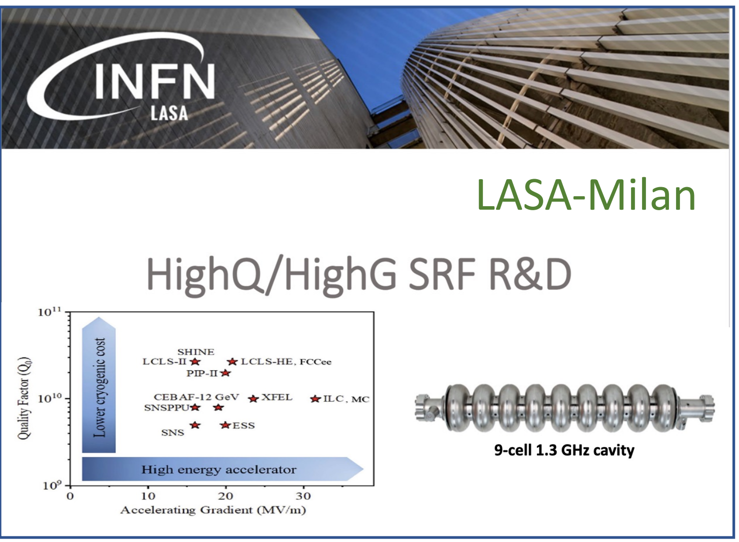


Preparing the longer-term future @ INFN (II)



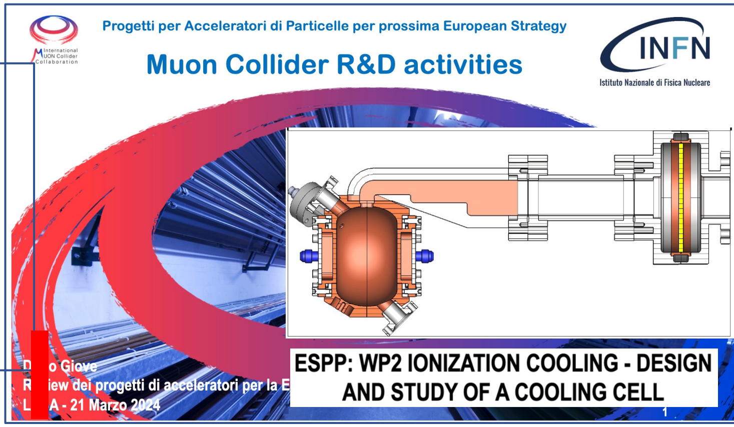
Coordinating the efforts to boost participation and include the INFN accelerator community, in synergy with other projects





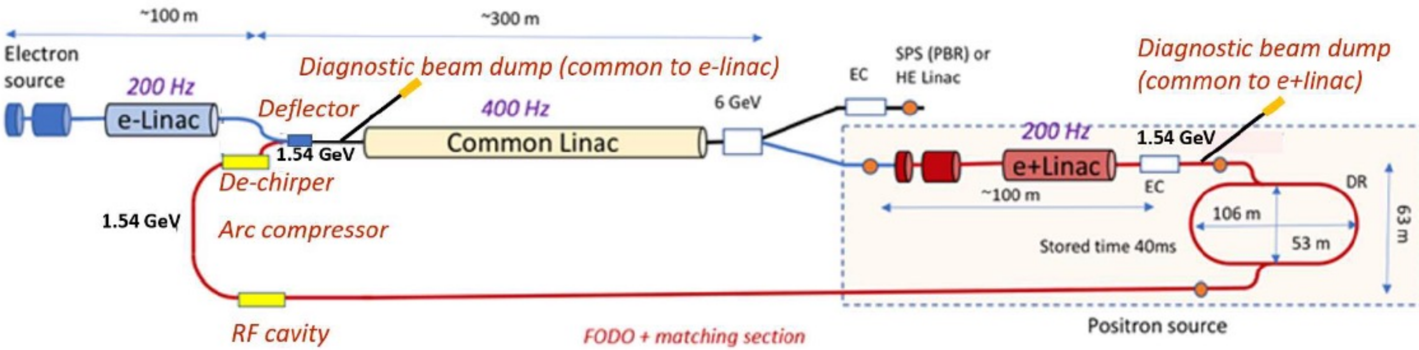
Four flagship projects with special INFN Funds (≈ 2 MEUR+personnel)

Common review by CSN1 and MAC committees



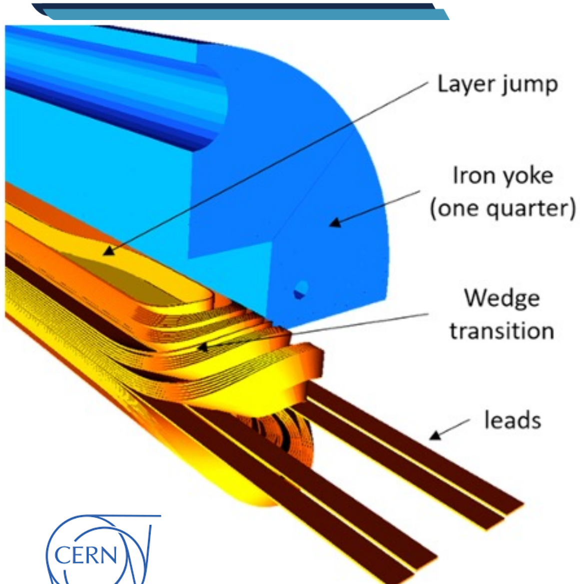
INFN : RD_MuCol
EU: HORIZON MuCol

Other CERN- INFN agreements



Damping Ring for FCC-ee -Addendum of the MoU for the FCC study CERN-INFN-LNF

FALCON DIPOLE



The FalconD program (**F**uture **A**ccelerator post-**L**HC **C**os-theta **O**ptimized **N**b$_3$Sn **D**ipole)) is being developed in accordance with a CERN/INFN agreement.

First dummy coil will be ready by 2024

First 23 Nb$_3$Sn coils ready by 2025

First 12 T dipole assembled and tested in single aperture mode in 2026

New Nb$_3$Sn program under approval:

First 14+ T dipole ready by 2030

First 12 T dipole assembled and tested in double aperture mode in 2026/2027

FalconD plays a crucial role in the CERN HFM program's structure

CERN

ASG SUPERCONDUCTORS

INFN Istituto Nazionale di Fisica Nucleare

Techonogical challenge for the future: HF-HTS magnets

IRIS Innovative Research Infrastructure on applied Superconductivity

PNRR

The DRD collaborations

New CERN-hosted Detector R&D (DRD) collaborations are currently being set up following ECFA Detector roadmap

Fully Approved for an initial period of 3 years by CERN Research Board in December 2023 {

- Gaseous Detectors (DRD1) [ex RD51]
- Liquid Detectors (DRD2)
- Photodetectors & Particle ID (DRD4)
- Calorimetry (DRD6)

Reports at open session of DRDC meeting: https://indico.cern.ch/event/1356910
Full Proposals in CERN CDS

Conditionally approved {

- Semiconductor Detectors (DRD3) [ex RD50, RD42,..]

Final proposals submitted {

- Quantum Sensors (DRD5)
- Electronics (DRD7)

Both aimed for approval in June
Talks at open session June 3 rd

Letter of Intent submitted {

- Integration (DRD8)

Full Proposal to be written by the end of this year

- ❑ INFN colleagues in responsibility roles (Spokesperson, CB-chair)
- ❑ Waiting for MoU and Annexes
- ❑ INFN review inter-CSN for financial commitments

Summary

- Strong INFN involvement in HEP experiments
- PHASE 2 ATLAS and CMS for HL-LHC major commitment of CSN1 at present - immediate future
- New projects for flavour physics (LHCb U2, Belle 2 upgr) to be discussed
- ALICE experiment future to be discussed in CSN3
- Accelerator neutrino physics in CSN1 (Dune, Icarus, SND@LHC, Hyper-K, ENUBET)
- Significant CSN1 commitment to Future Accelerator projects for HEP and detector R&D
  - Various INFN initiatives to contribute to the update of the European Strategy for Particle Physics (ESPPU)
- Other on-going activities not discussed due to limited time: NA62, MEG 2, MU2E, G-2, AMBER, UA9, PADME, MUonE, BES 3, KLOE, IGNITE ...