



Istituto Nazionale di Fisica Nucleare

*Nuove frontiere  
della fisica nucleare  
fondamentale e applicata*



**INFN2024**

**6° INCONTRO NAZIONALE DI  
FISICA NUCLEARE**

**26 | 28 Febbraio 2024  
TRENTO**

- 
- La ricerca tramite le cinque commissioni nazionali
  - La partecipazione ai progetti nei grandi laboratori internazionali
  - Il consolidamento e rinnovamento delle nostre infrastrutture
  - Applicazioni e Trasferimento Tecnologico



# CERN e i Laboratori Internazionali

## Full Report

8 Chapters/Deliverables  
~ 700pp document  
~ 16 editors  
~ 300 contributors

## Executive Summary

8 Chapters/Deliverables  
~ 45pp document  
~ 16 editors

Both documents are available to the CERN community at:  
<https://doi.org/10.17181/mhas5-1f263>

### Future Circular Collider Midterm Report

February 2024

*Edited by:*  
B. Auchmann, W. Bartmann, M. Benedikt, J.P. Burnet, P. Craievich, M. Giovannozzi, C. Grojean, J. Gutleber, K. Hanke, P. Janot, M. Mangano, J. Osborne, J. Poole, T. Raubenheimer, T. Watson, F. Zimmermann



This project has received funding under the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754.

This document has been produced by the organisations participating in the FCC feasibility study. The studies and technical concepts presented here do not represent an agreement or commitment of any of CERN's Member States or of the European Union for the construction and operation of an extension to CERN's existing research infrastructures.

The midterm report of the FCC Feasibility Study reflects work in progress and should therefore not be propagated to people who do not have direct access to this document.

### Executive Summary of the Future Circular Collider Midterm Report

February 2024

*Edited by:*  
B. Auchmann, W. Bartmann, M. Benedikt, J.P. Burnet, P. Charitos, P. Craievich, M. Giovannozzi, C. Grojean, J. Gutleber, K. Hanke, P. Janot, M. Mangano, J. Osborne, J. Poole, T. Raubenheimer, A. Unnervik, T. Watson, F. Zimmermann



This project has received funding under the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754.

This document has been produced by the organisations participating in the FCC Feasibility Study. The studies and technical concepts presented here do not represent an agreement or commitment of any of CERN's Member States or the European Union to construct and operate an extension to CERN's existing research infrastructures.

The midterm report of the FCC Feasibility Study reflects work in progress and should therefore not be propagated to people who do not have direct access to this document.

Please note that the midterm report of the FCC Feasibility Study reflects work in progress and should therefore not be propagated to people without direct access to this page.

You are kindly asked to treat the information with the appropriate level of confidentiality, as defined in the [CERN Data Protection Policy](#).

M. Benedikt

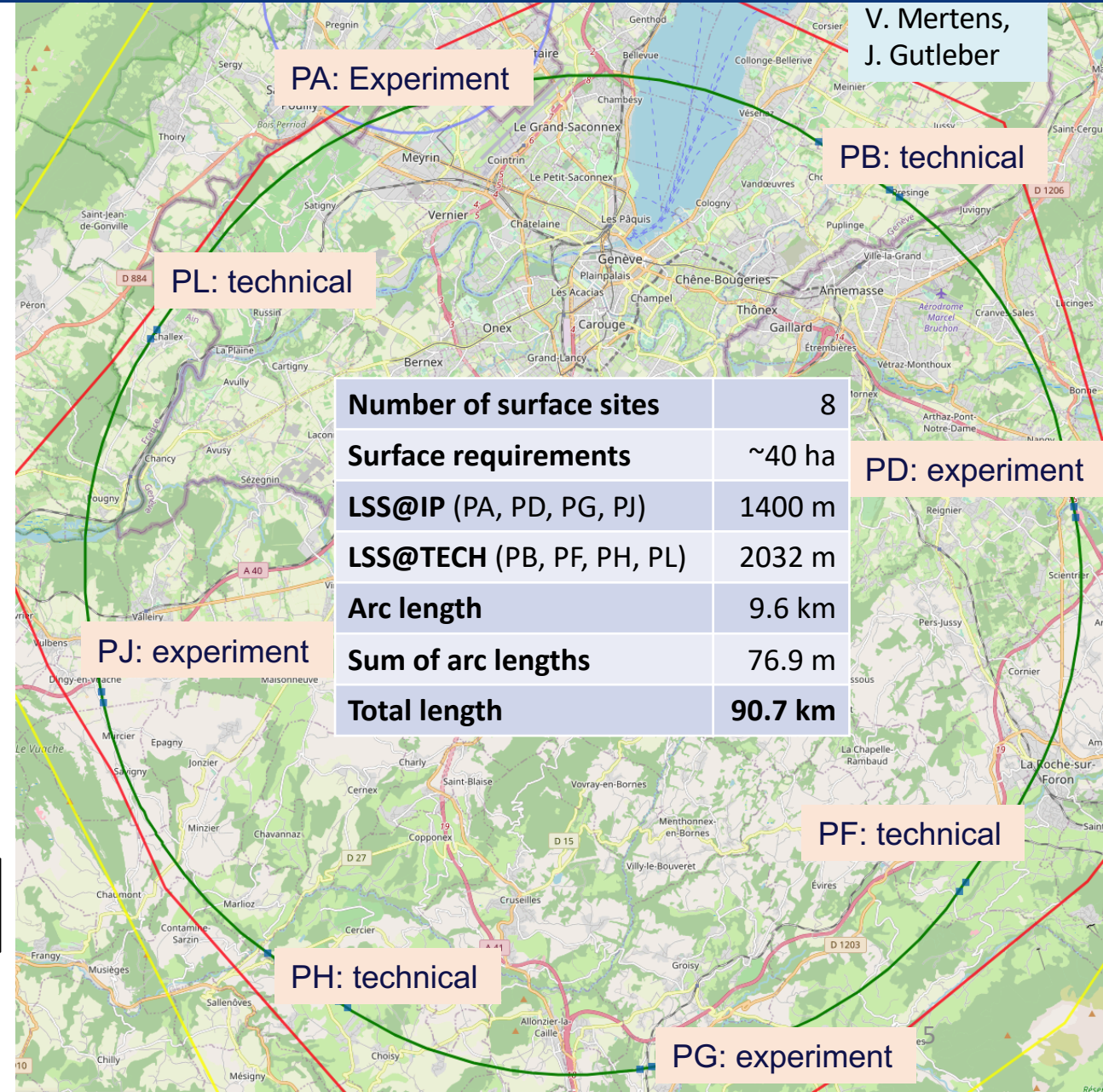
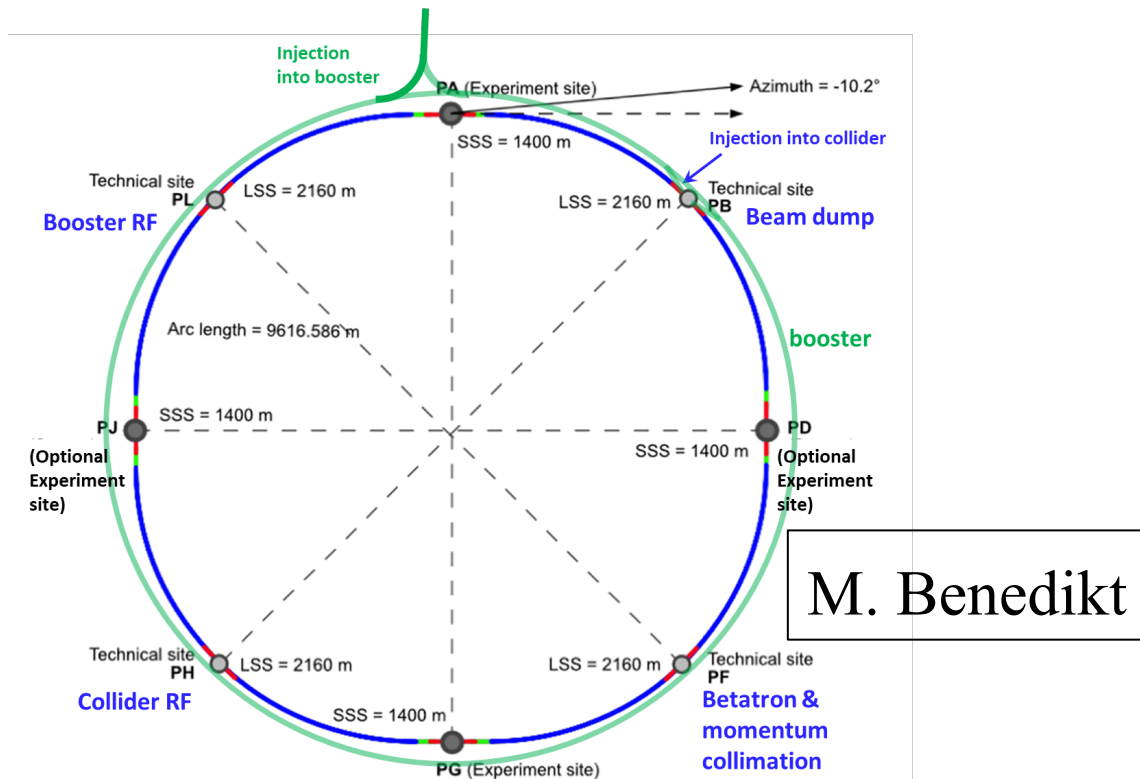


# Optimized placement and layout for feasibility study

Layout chosen out of ~ 100 initial variants, based on **geology** and **surface constraints** (land availability, access to roads, etc.), **environment**, (protected zones), **infrastructure** (water, electricity, transport), **machine performance** etc.

“**Avoid-reduce-compensate**” principle of EU and French regulations

**Overall lowest-risk baseline: 90.7 km ring, 8 surface points,**  
Whole project now adapted to this placement



V. Mertens,  
J. Gutleber

PA: Experiment

PB: technical

PL: technical

Number of surface sites

8

Surface requirements

~40 ha

LSS@IP (PA, PD, PG, PJ)

1400 m

LSS@TECH (PB, PF, PH, PL)

2032 m

Arc length

9.6 km

Sum of arc lengths

76.9 m

Total length

90.7 km

PD: experiment

PJ: experiment

PF: technical

PH: technical

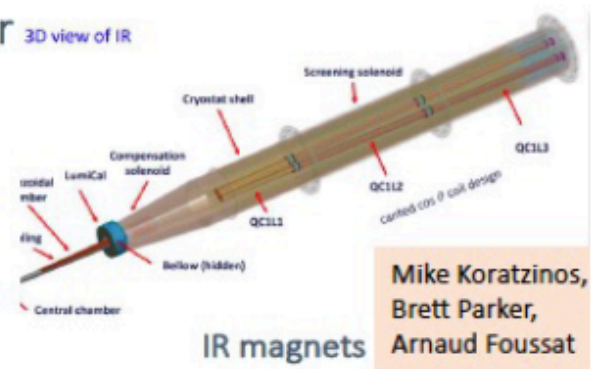
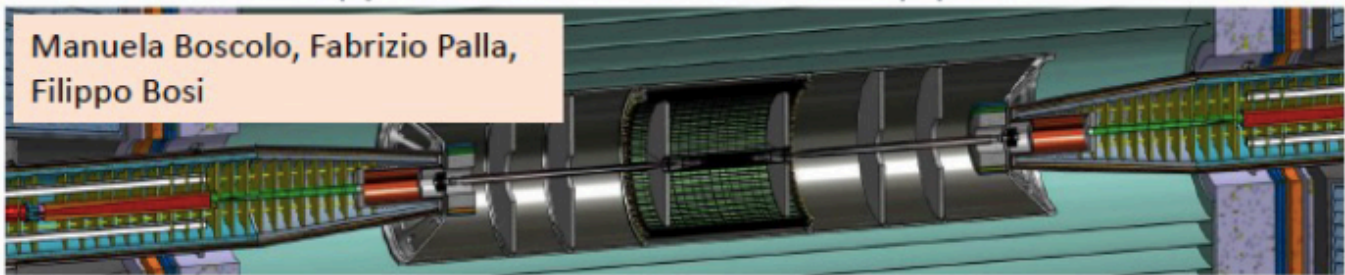
PG: experiment

# FCC Contributo Italiano



- Studio e ottimizzazione della macchina
- Simulazioni
- Sviluppi strumentali
- Mock-up della regione centrale di interazione a LNF

## Novel outer support tube for central beam pipe and vertex detector



- Inside the same volume of the support tube that holds also the LumiCal
  - Vertex detector supported by the beam pipe
  - Outer Tracker (1 barrel and 6 disks) fixed to the support tube

A. Zoccoli





## Meetings with municipalities concerned in France (31) and Switzerland (10)

PA – Ferney Voltaire (FR) – site experimental

PB – Présinge/Choulex (CH) – site technique

PD – Nangy (FR) – site experimental

PF – Roche sur Foron/Etaux (FR) – site technique

PG – Charvonnex/Groisy (FR) – site experimental

PH – Cercier (FR) – site technique

PJ – Vulbens/Dingy en Vuache (FR) site experimental

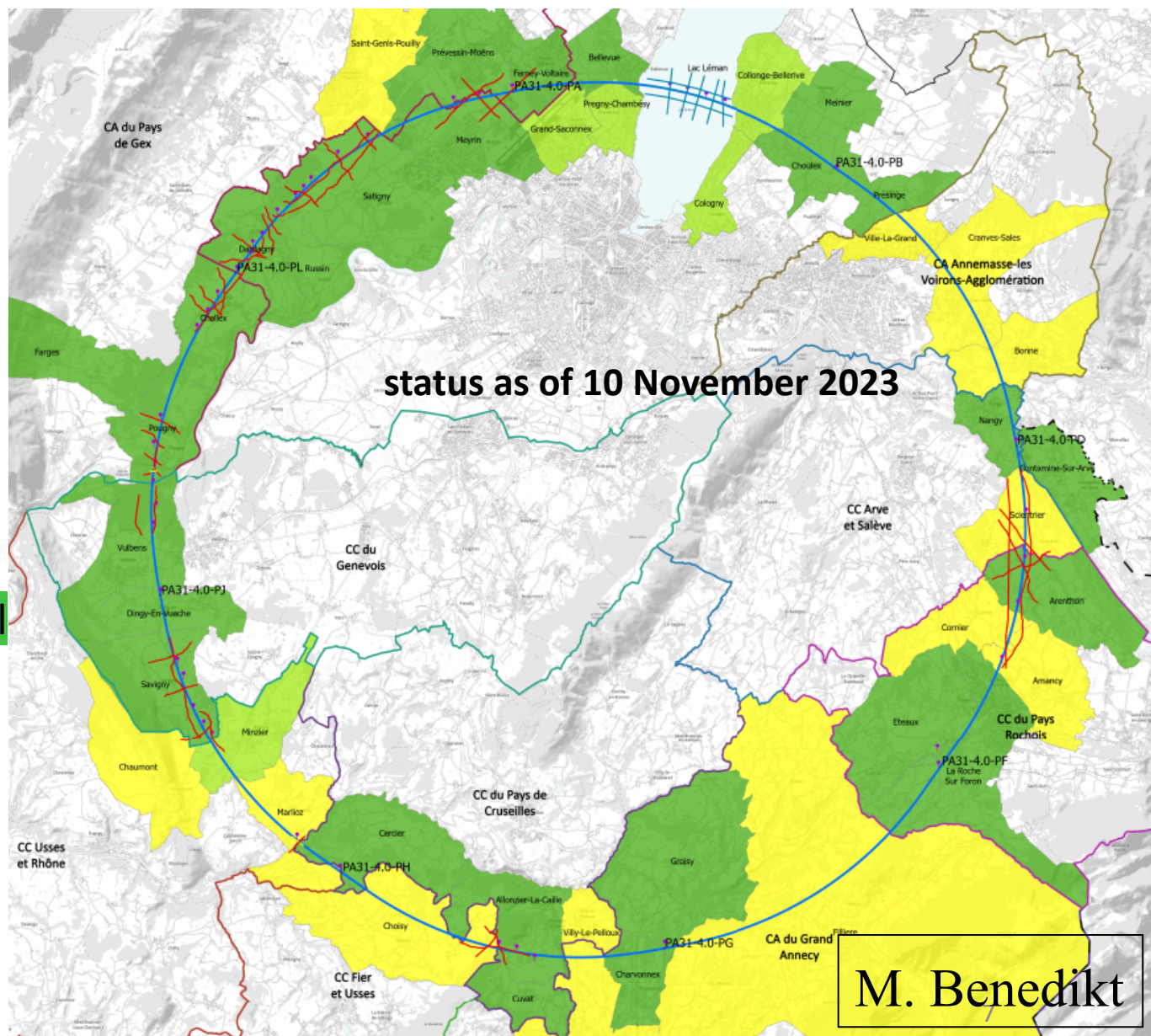
PL – Challex (FR) – site technique

Individual meeting

Individual meeting planned

Collective meeting

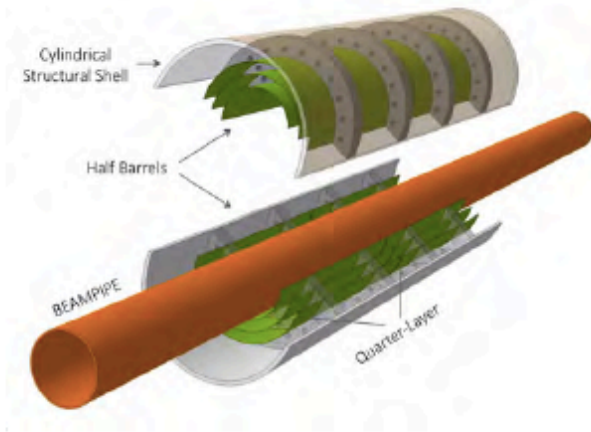
The support of the host states is greatly appreciated and essential for the study progress!





## ALICE: from ITS2 (2021) to ITS3 (2025) ....

Innermost 3 Layers with new ultra-light, bent sensors



**Interest in MAPS from NA60+ proposal** for fixed target experiment @SPS focussed on critical point QGP measurements

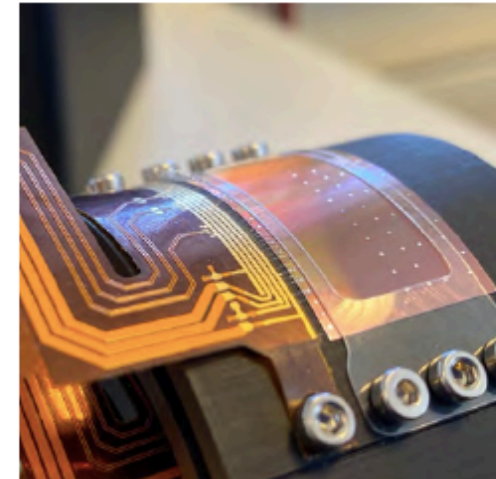
### ITS2 → ITS3

CMOS	180 → 65 nm (first test done 2022)
Thinning	down to 20-40 $\mu\text{m}$
Pixel size	30x30 → 15x15 $\mu\text{m}^2$
Total sensors	432 → <b>6 Stitching</b> (28cm x 9.4 (L2), 7.55 (L1), 5.65(L0) cm)
$X_0$	0,35 → 0,02-0,04 first layer
Inner radius	23 mm → 18 mm

tipo attività	2021 (k€)	2022 (k€)	2023 (k€)	2024 (k€)	2025 (k€)	2026 (*)?
R&D	200	300	150			
Costruzione			250	400	400	100
<b>totale</b>	<b>200</b>	<b>300</b>	<b>400</b>	<b>400</b>	<b>400</b>	<b>100</b>

R. Nania

INFN circa 30% totale  
1800/6000 kCh€





## ...to ALICE3 ( 2034):

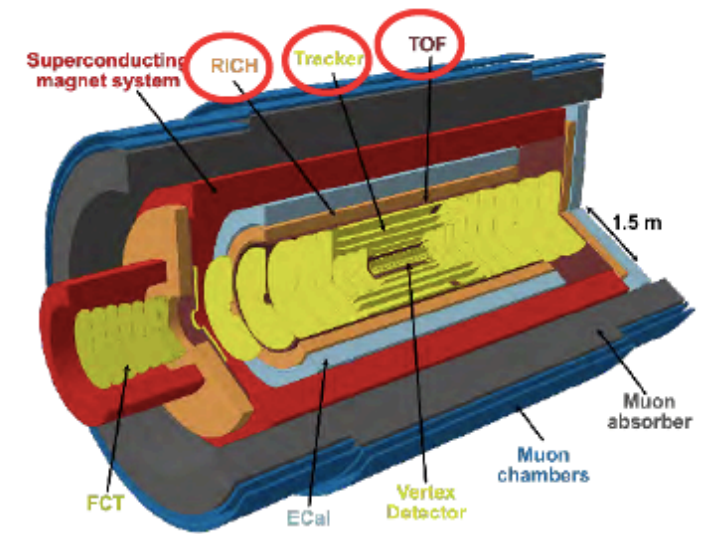
Positively received from LHCC

<http://cds.cern.ch/record/2803321/files/LHCC-149.pdf>

Total Budget exstimate 140-175 MCHF

Italian groups particularly engaged in

- Tracker with MAPS,
- PID R&D : TIMING Layer MAPS-high gain, LGAD, RICH-AEROGEL with SiPM



A Large Ion Collider Experiment

### Planning



LoI

<https://cds.cern.ch/record/2803563/files/LHCC-I-038.pdf>

2023 – 2025: selection of technologies, small-scale proof of concept prototypes (~25% of R&D funds)

2026 – 2027: large-scale engineered prototypes (~75% of R&D funds) ⇔ Technical Design Reports

2028 – 2030: construction and testing

2031 – 2032: contingency

2033 – 2034: installation and commissioning

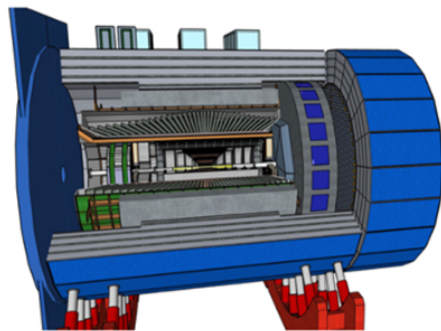
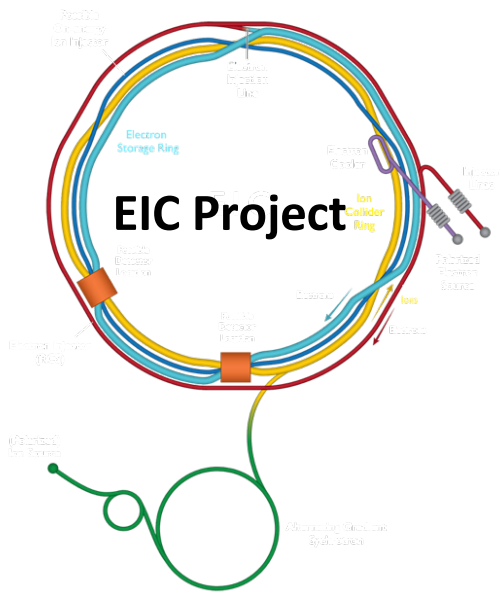
2035 – 2042: physics campaign

### Meeting with GE already in November 2021

Special RRB on 27<sup>th</sup> June for expression of interest from funding agencies (DB for INFN)

In 2023-24 **Scoping Document (SD)** to establish a plausible cost scenarios, in close exchange between the relevant stakeholders (Funding Agencies, CERN management, experiments, review bodies).

R. Nania



**EPIC Collaboration**

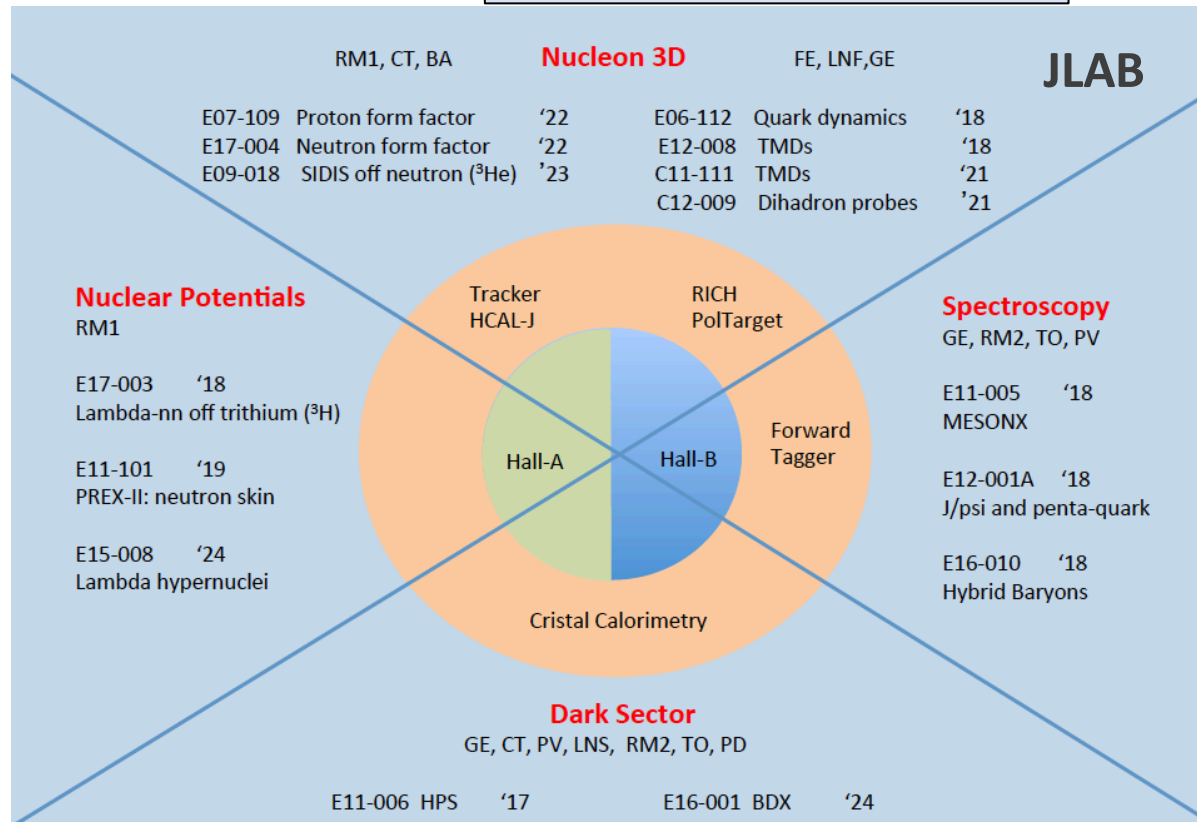
### EIC INFN Contribution

- dRICH Project
  - Vertex Detector
- Physics Interests
- SIDIS
  - Diffractive
  - Heavy Flavour

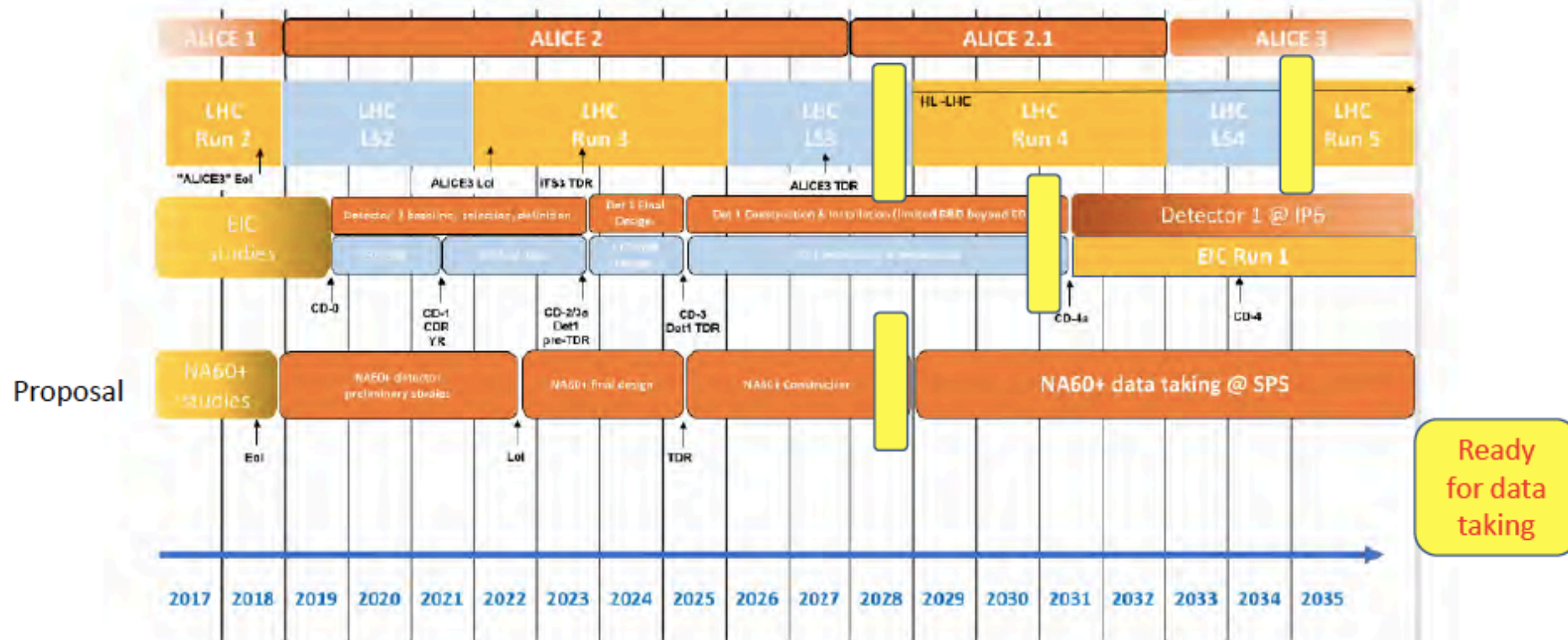
### Collaboration on EIC Accelerator

- BS prototype qualification for hadron ring vacuum chamber
  - SEY Measurements for BS mass production
- MoU between EIC-INFN

### EPIC Solenoid Magnet



**Synergies on detector R&D activities between INFN groups working on  
ALICE-ITS3/ALICE3, EIC\_NET and NA60+ ( and ECFA roadmap, AIDAInnova ...)**  
Signed document June 2022 : <https://www.dropbox.com/s/hvisuzcmx06hofc/ALICE-EIC-NA60%2B-synergies-Jun22.pdf?dl=0>



**Possible common items**

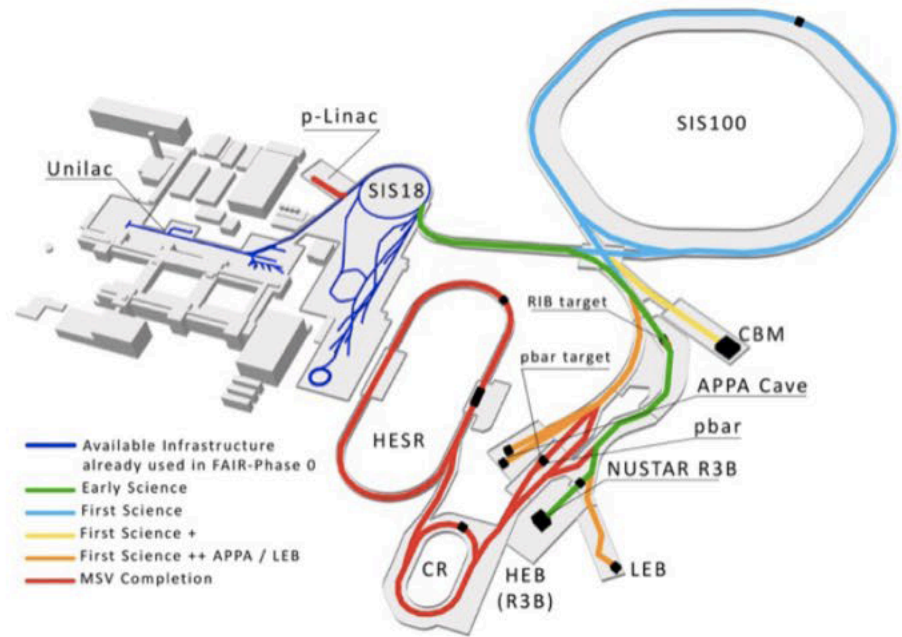
- development of **MAPS sensors** for tracking and vertexing detectors : ALICE leadership
- The **aerogel** development by Chiba University (Japan)
- Development of Silicon Photomultipliers (**SiPM**) radiation hard, +ASIC, +digital and tracking
- Triggerless DAQ

**The three INFN sigle (ALICE, EIC\_NET, NA60+...) commit to collaborate in the development of these R&D in synergy, manpower and avoiding any duplication of costs.**

ALICE and EIC July 2021  
<https://indico.cern.ch/event/1059080/>  
ALICE and EIC June 2022  
June 2022 <https://indico.ph.tum.de/event/7014/>

CERN R&D Days June 2022  
<https://indico.cern.ch/event/1156197/>

# FAIR

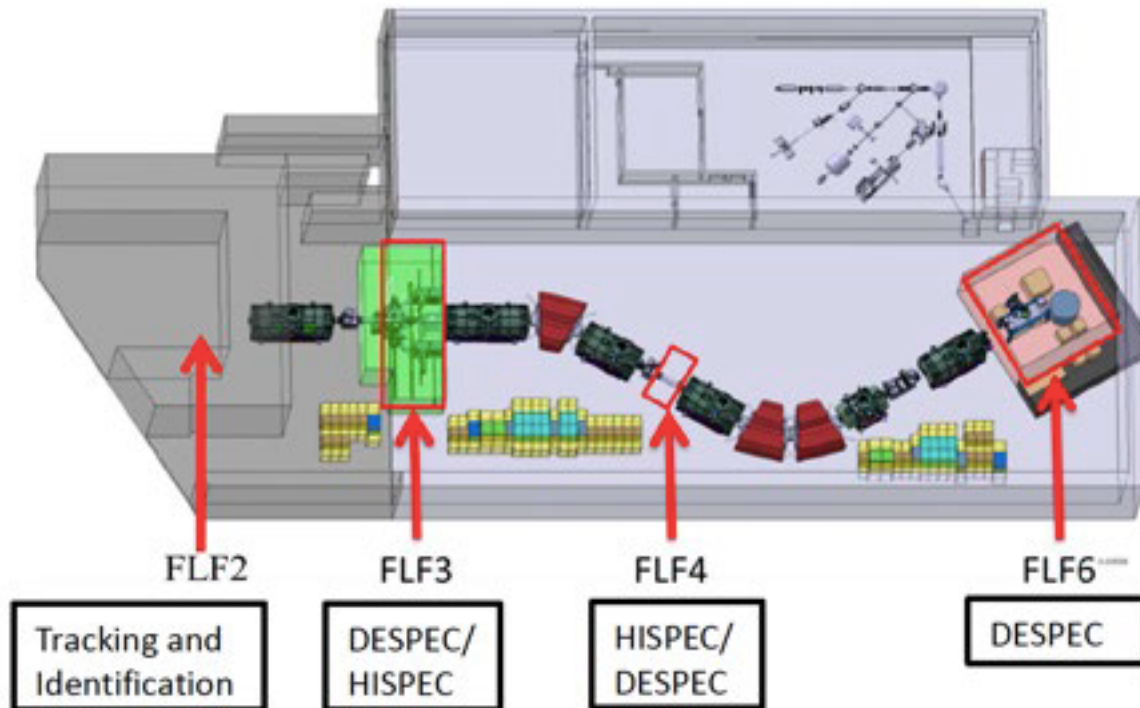


← until 2028 (ES,FS,FS+)

← after 2028



# NUSTAR



- Low Energy Branch available only after 2030
- Effort by collaboration to enable access to LEB Hall already in 2028
- Requires new magnets
- Would enable installation of AGATA in FLF3

---

# ESFRI Roadmap e Stato Progetti Nazionali e Internazionali



## **EUPRAXIA @ LNF**

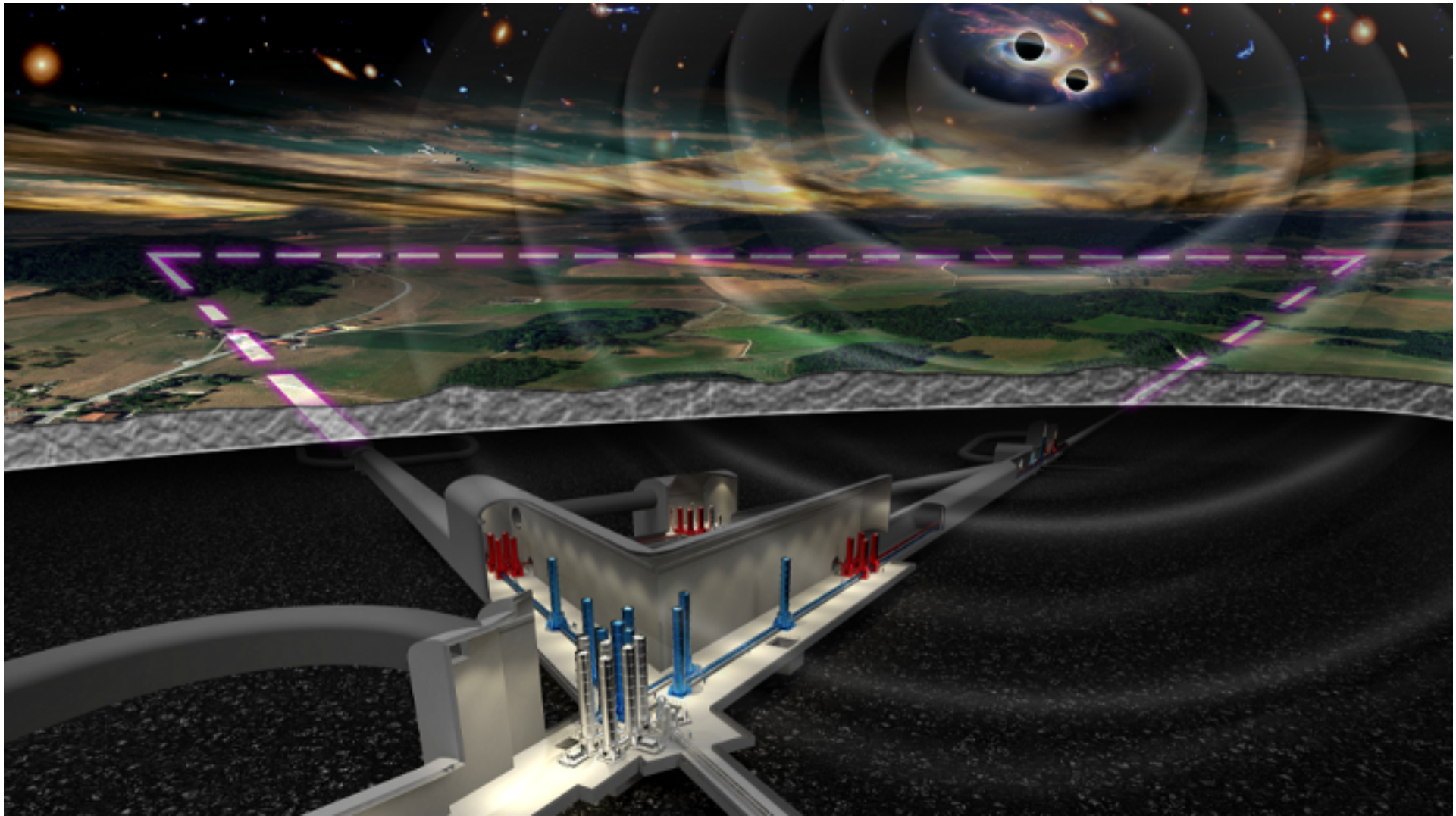
### **Finanziamenti ottenuti:**

- **108 M€ fondi infrastrutture MUR**
- **22 M€ EUAPS (sorgente betatrone)**
- **7 M€ Regione Lazio**





# Einstein Telescope





**ETIC**  
**Einstein Telescope**  
**Infrastructure**  
**Consortium**

## Einstein Telescope (ET)

Research Infrastructure for the observation of gravitational waves

**Where:** in Sardinia (IT) or Holland

Global cost **1.8 G€** over the next **10** years  
 (50% to be covered by the host state).

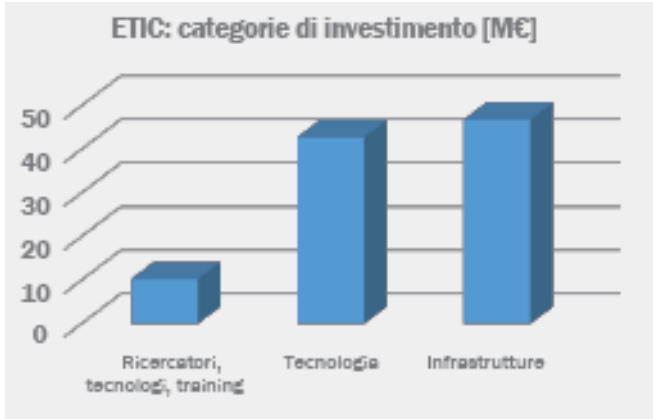
## ETIC: Research Infrastructure to implement

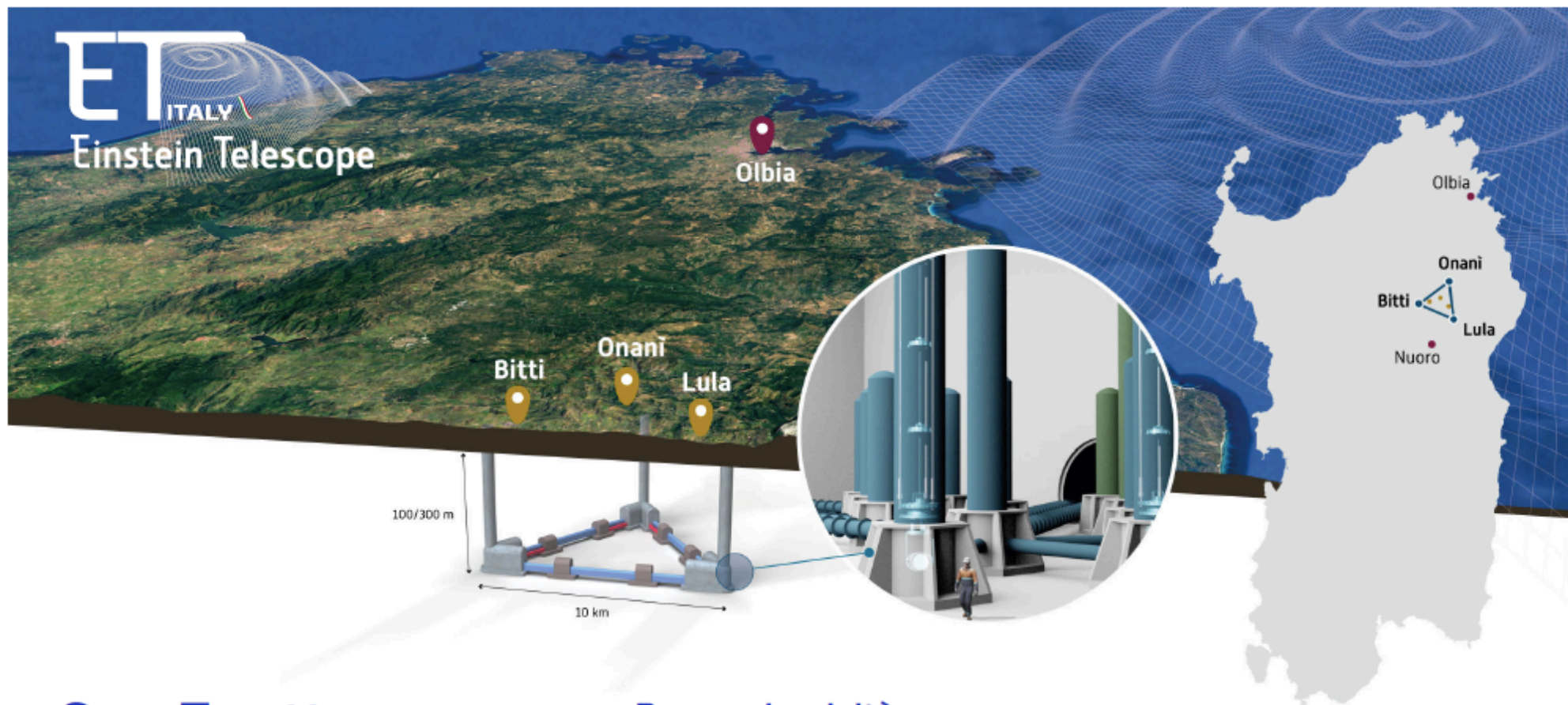
- A network of laboratories and interdisciplinary skills to develop cutting-edge technologies needed for ET
- The executive project for Sardinia

Budget: **100 M€** (52% in Southern Regions).

### Comitato Tecnico Scientifico

Giorgio Parisi  
 Ettore Sequi  
 Marica Branchesi  
 Nando Ferroni  
 Antonio Zoccoli





**Sos Enattos  
è il luogo ideale**

- Bassa sismicità
- Area rurale
- Solidità della roccia del sottosuolo

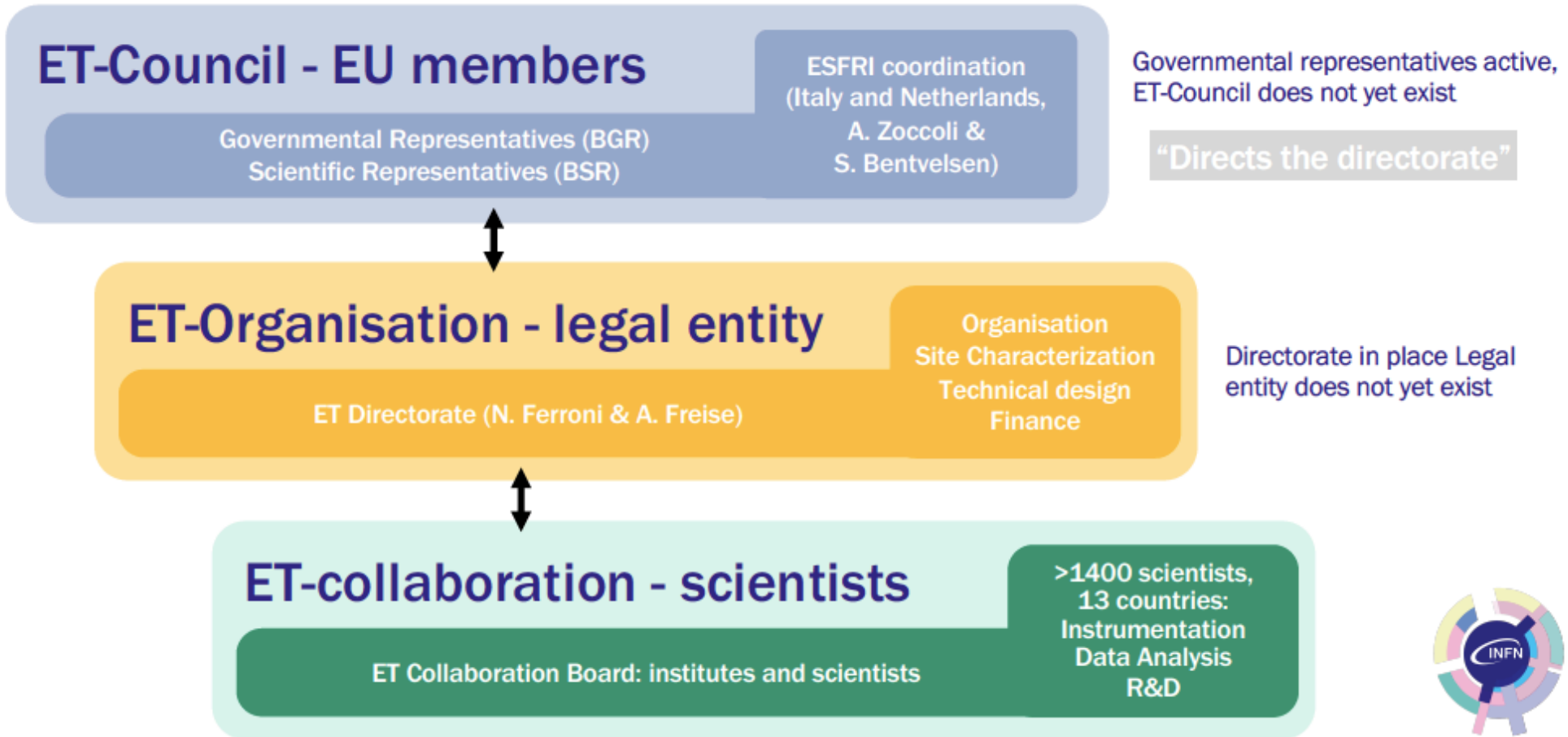
A. Zoccoli







# European governance set-up



A. Zoccoli



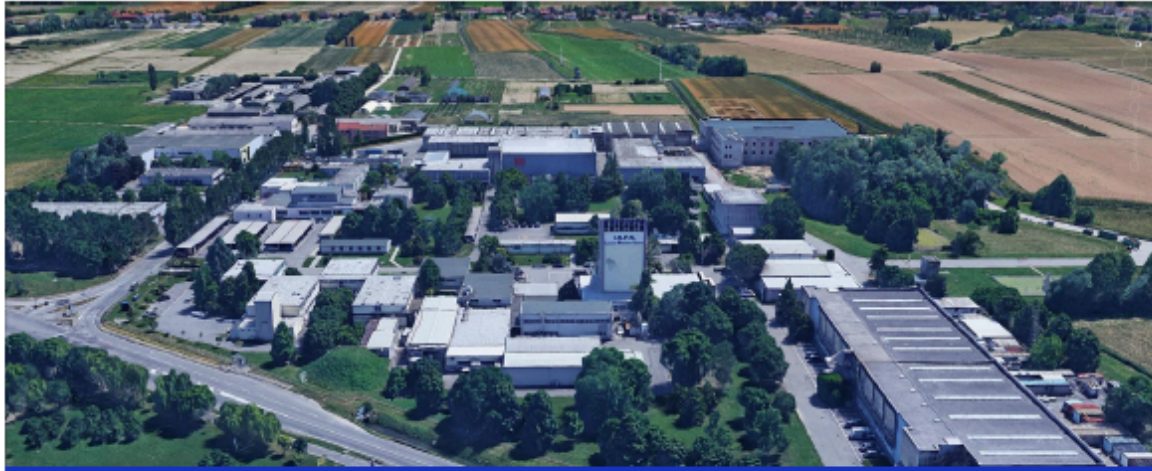
## Mandato del Project Directorate

1. Impostare l'organizzazione e le operazioni dell'ETO (Einstein telescope Organization).
2. Confrontare la geometria del triangolo con la geometria di due infrastrutture a forma di L
3. Sviluppare un piano di budget e un programma per la di progettazione e preparazione di Fase 1.
4. Dirigere e supervisionare gli studi e la preparazione della documentazione

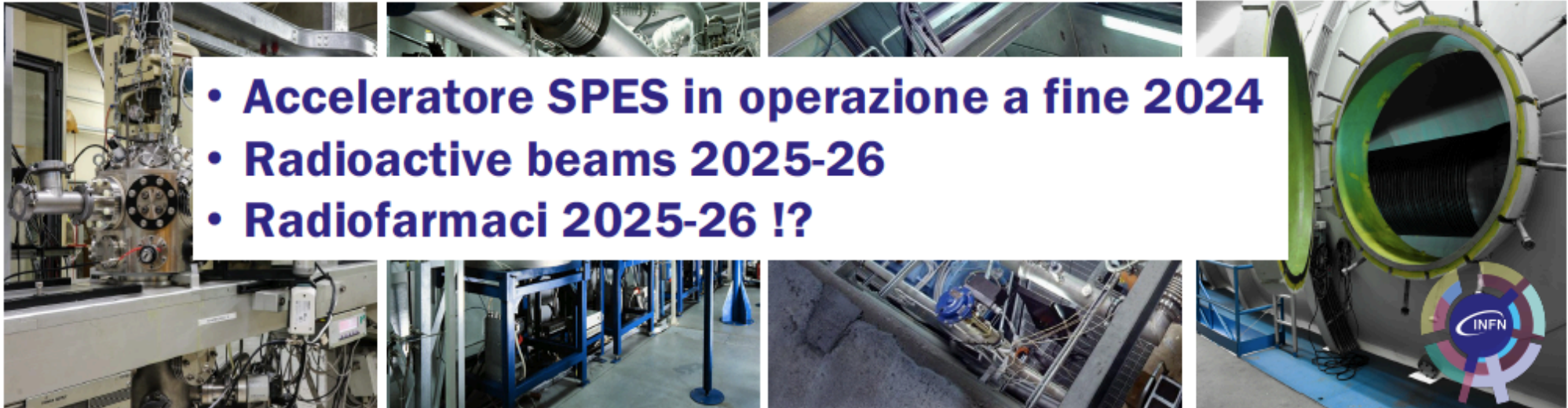
A. Zoccoli







## Acceleratori LNL



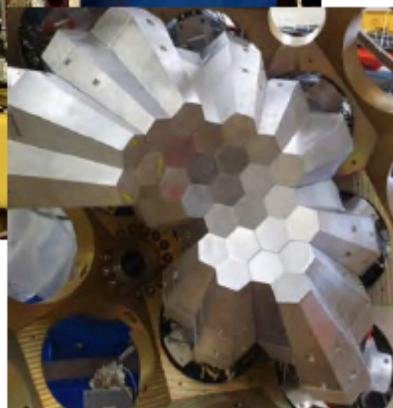
- **Acceleratore SPES in operazione a fine 2024**
- **Radioactive beams 2025-26**
- **Radiofarmaci 2025-26 !?**

A. Zoccoli



Celebration 10(+2)  
LNL 9th June

## AGATA: Advanced Gamma-ray Tracking Array

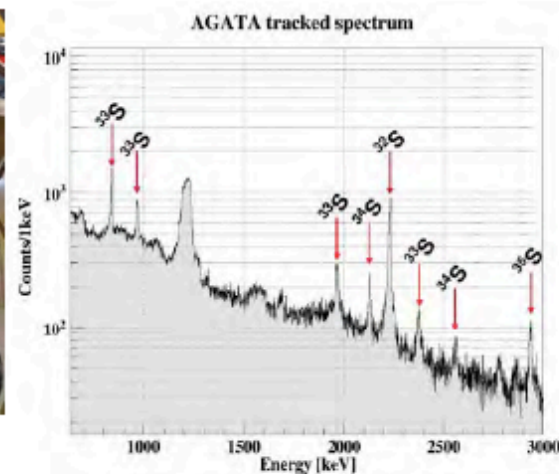


Full detector  $4\pi$  coverage: 60 Triple cluster Ge Detectors

MoU Phase 2 Delibera Luglio 2021 toward a  $3\pi$  coverage :  
add 25 new Triple Ge,

INFN ~4500 k€ dal 2021 al 2031 (+130/anno maintenance)

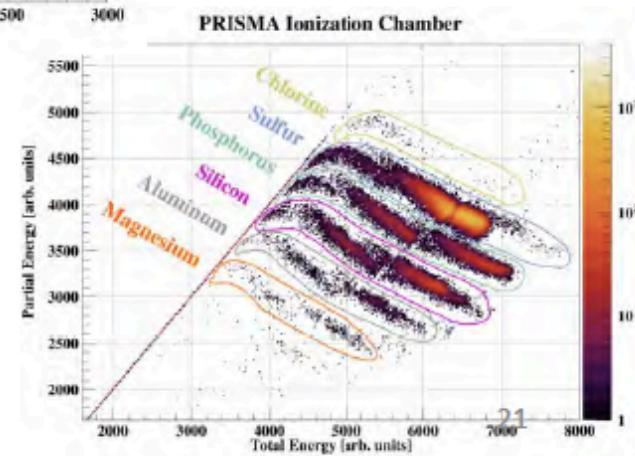
Possible extension of data taking at LNL to 2026-2027



Taking data with PRISMA  
using beam from TANDEM:  
 $^{32}\text{S}(160\text{MeV}) + ^{124}\text{Sn}$



Order for new HV in PRISMA  
completed: thanks to 300 k€  
recovered in 2021 from  
missions



R. Nania





## Acceleratori LNS



- **Consegna magneti ciclotrone entro 2024**
- **Acceleratore in operazione 2025 (?)**
- **Finanziato su fondi PON**

A. Zoccoli



# Attività @ LNGS



CRESST



DarkSide



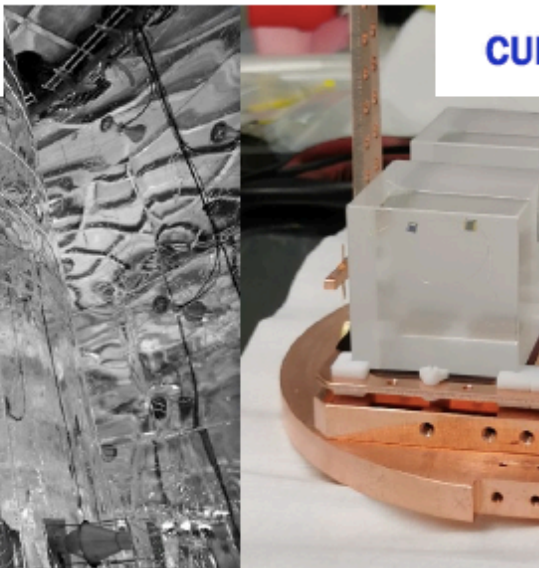
XENON



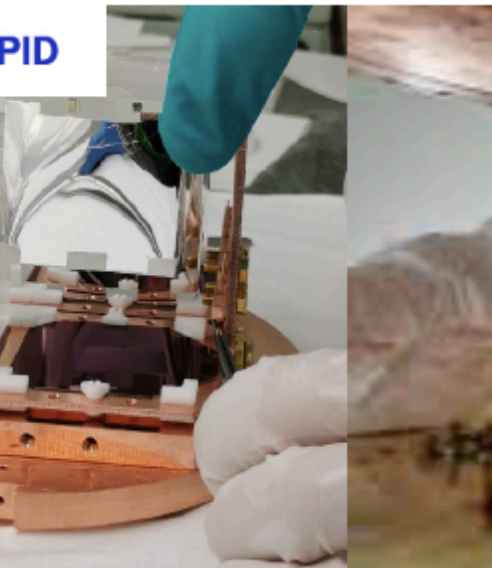
DAMA



GERDA



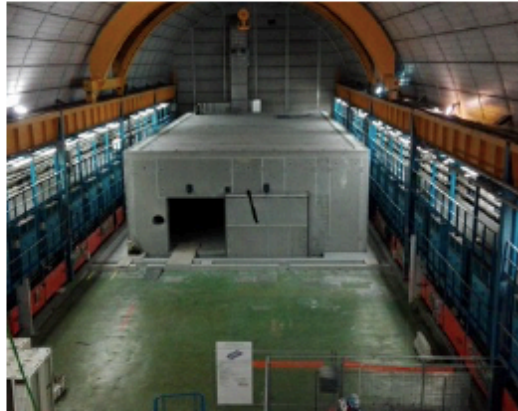
CUPID



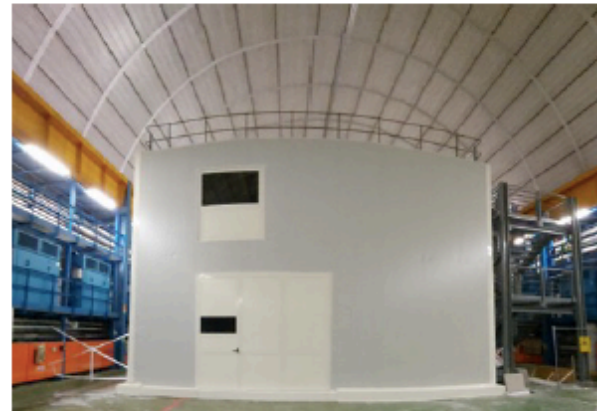
CUORE

# Enrico Bellotti Ion Beam Facility

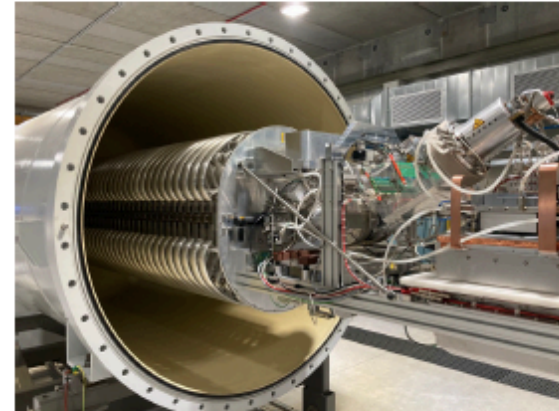
- **19 giugno 2023:** primo fascio dall'acceleratore da 3.5 MV per una misura di fisica.
- Prima reazione sotto indagine  $^{14}\text{N}+p$
- Il PAC (Program Advisory Committee) è in carica da Aprile 2023



*Bunker Acceleratore 3.5 MV*



*Sala Controllo dell'acceleratore*





# Esperimenti Doppio Decadimento Beta



Tre esperimenti sono stati individuati per la futura ricerca del Doppio Decadimento Beta senza Neutrini

	$T_{1/2}$ ( $10^{28}$ years)		$m_{\beta\beta}$ (meV) $3\sigma$ Discovery	
	Excl. Sens.	$3\sigma$ Discovery	Median	Range
<b>CUPID</b>	0.14	0.10	15	12 to 20
<b>LEGEND-1k</b>	1.60	1.30	12	9 to 21
<b>nEXO</b>	1.35	0.74	11	7 to 32

E' auspicabile realizzare tutti gli esperimenti in accordo con le agenzie finanziatrici di Europa e Nord America



**Obiettivo: due di questi tre esperimenti a LNGS**



A. Zoccoli

# Esperimenti Doppio Decadimento Beta @ LNGS



Proposta sul tavolo per LNGS:

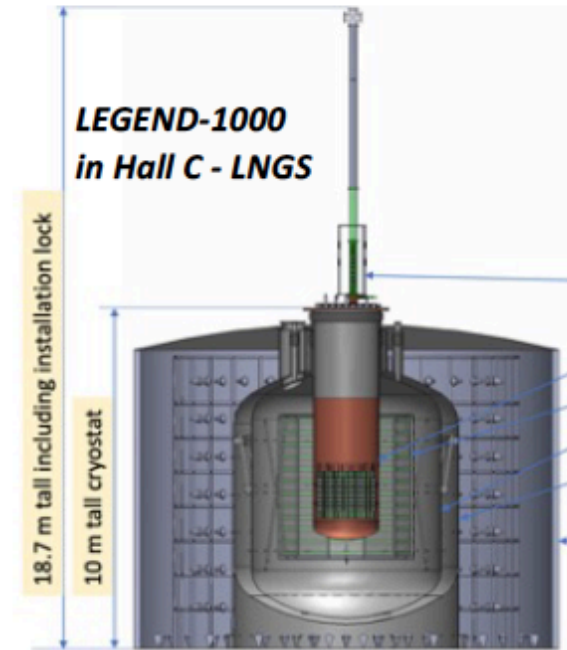


## CUPID (successore di CUORE)

- Bolometri scintillanti basati su cristalli di  $\text{Li}_2\text{MoO}_4$
- Elevata risoluzione in energia
- Discriminazione di particelle alfa/beta
- Possibilità di selezionare altri isotopi

## LEGEND-1000

- Rivelatori al Ge (Inverted Coaxial)
- Lunga tradizione (Gerda, Majorana, Legend200)
- Elevatissima risoluzione in energia
- Pulse shape analysis
- Bassissimo fondo radioattivo già mostrato in GERDA



La realizzazione dei due esperimenti a LNGS sarebbe un grande successo per l'INFN e per il Laboratorio



**Darkside  
cryostat  
installation  
@LNGS**



A. Zoccoli



# Calcolo scientifico Tier1 @ Tecnopolo



A. Zoccoli



A. Zoccoli



# INFN Tier1 @ Tecnopolo

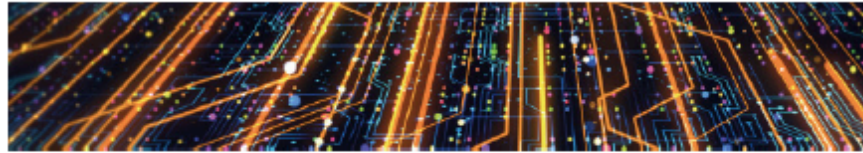


A. Zoccoli

# PNRR



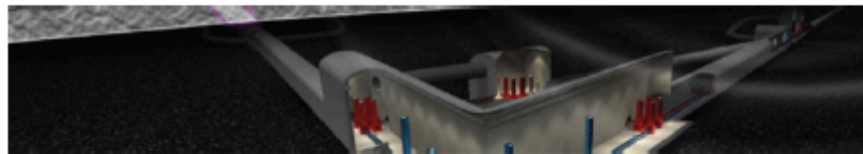
Piano Nazionale  
di Ripresa e Resilienza



ICSC  
National Centre for HPC,  
Big Data and Quantum Computing



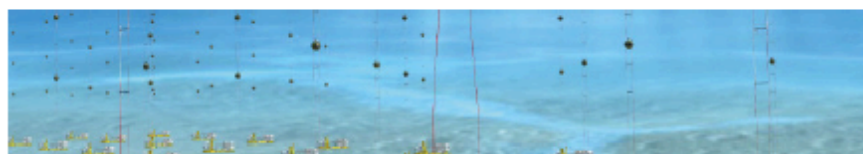
TeRABIT



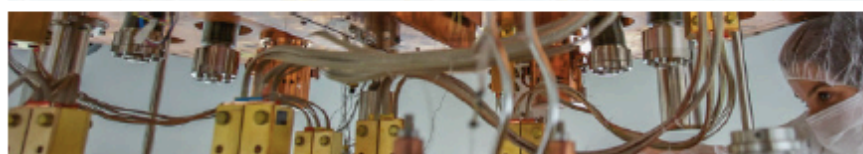
ETIC  
Einstein Telescope  
Infrastructure Consortium



IRIS  
Innovative Research Infrastructure on  
applied Superconductivity



KM3NeT



LNGS: Gran Sasso National  
Laboratory upgrade



EuPPS  
LNF

A. Zoccoli



# PROGETTI PNRR M4C2



## 1.3 PARTENARIATI ESTESI

Progetto	Ruolo INFN	Budget INFN
FAIR	Membro Hub, Affiliato Spoke 6, Spoke 8, Spoke 10	1.632.014 €
NQSTI	Affiliato Spoke 3, spoke 4, spoke 6, Spoke 8, spoke 9	6.416.929,00 €

**PE - 8,048 Mln**

## 1.4 CENTRI NAZIONALI

Progetto	Ruolo INFN	Budget INFN
ICSC	Membro fondazione (Hub), Co-Leader Spoke 0 e Spoke 3, Leader Spoke 2, Affiliato Spoke 8 e Spoke 10	56.550.130 €

**CN - 56,550 Mln**

## 1.5 ECOSISTEMI DELL'INNOVAZIONE

Progetto	Ruolo INFN	Budget INFN
RAISE	Affiliato Spoke 4	427.960 €
ECOSISTER	Membro fondazione (Hub), Affiliato Spoke 6	477.291 €
THE - Tuscany Health Ecosystem	Membro fondazione (Hub), Affiliato Spoke 1	539.250 €
ROME TECHNOPOLE	Membro fondazione (Hub), Affiliato Spoke 5 e 6	2.885.369 €
SAMOTHRACE	Membro fondazione (Hub), Leader Spoke 5	6.631.035 €

**ECS - 10,960 Mln**

## 3.1 INFRASTRUTTURE DI RICERCA E INNOVAZIONE

Progetto	Ruolo INFN	Budget INFN
IRIS	Proponente	39.572.238 €
KM3NeT4RR	Proponente	59.330.290 €
ETIC	Proponente	33.867.823 €
LNGS-FUTURE	Proponente	19.645.377 €
TeRABIT	Proponente	31.334.000 €
EuAPS	Proponente	14.935.838 €
CTA+	Co-proponente	12.675.343 €
IIINERIS	Co-proponente	5.071.697 €
EBRAINS-Italy	Co-proponente	430.000 €

**IR - 216,862 Mln**



A. Zoccoli

# PROGETTI PNRR



**Piano nazionale complementare al PNRR, Iniziative di ricerca per tecnologie e percorsi innovativi in ambito sanitario e assistenziale**

Progetto	Ruolo INFN	Budget INFN
ANTHEM	Membro fondazione (Hub), Affiliato Spoke 4	12.413.397,3 €
DARE	Membro fondazione (Hub), Affiliato Spoke 1	3.500.000 €

**PN - 15.913 Mln**

**PNRR – M2C1 – 3.2 Green Communities**

Progetto	Ruolo INFN	Budget INFN
La sfida che si pone la Green Community Costa degli Etruschi è quella di gestire in maniera condivisa, coordinata ed integrata tra ambiti di intervento la lotta ai cambiamenti climatici, la povertà energetica, idrica, la gestione sostenibile dei sottoprodotti di lavorazioni produttive per il contenimento degli scarti in logica di economia circolare	Partecipante	200.000 €

**M2C1 – 200.000 €**

**PNRR – M6C2 – 2.1 Valorizzazione e potenziamento della ricerca biomedica del SSN**

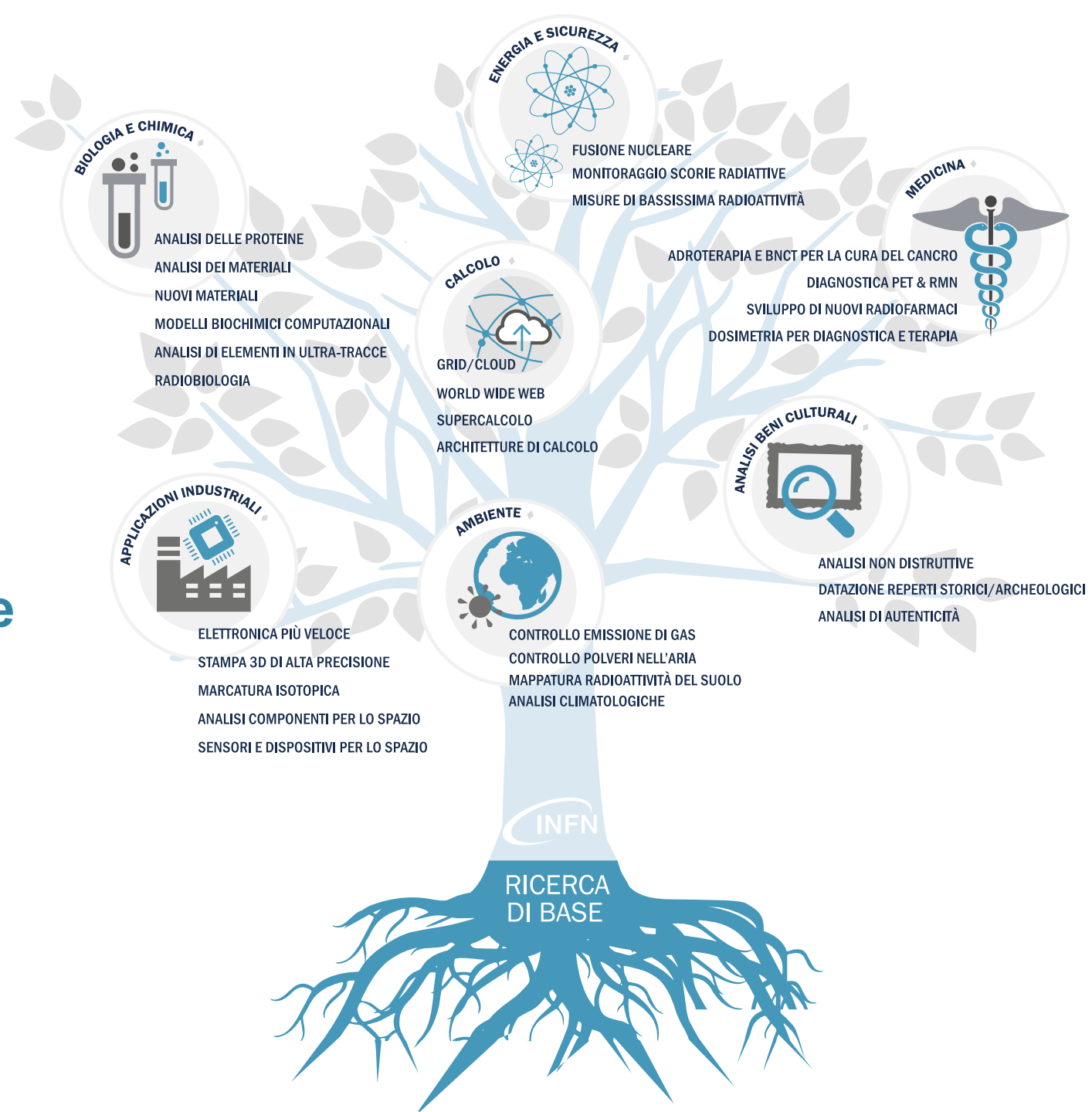
Progetti	Ruolo INFN	Budget INFN
Predictive tools for precision medicine in prodromal stages of neurodegeneration from Lewy Body to Alzheimer's Disease: quantification of molecular imaging and integration with other biomarkers	Partecipante	153.935 €
Development of advanced MRI methods and of tailored signal processing for the quantitative characterization of neurodegenerative diseases through novel biomarkers identification	Partecipante	192.000 €

**M6C2 - 345.935€**



A. Zoccoli

# Applicazioni e Trasferimento delle conoscenze





Thank you