Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ
DI PAVIA

Nuclear and Subnuclear physics

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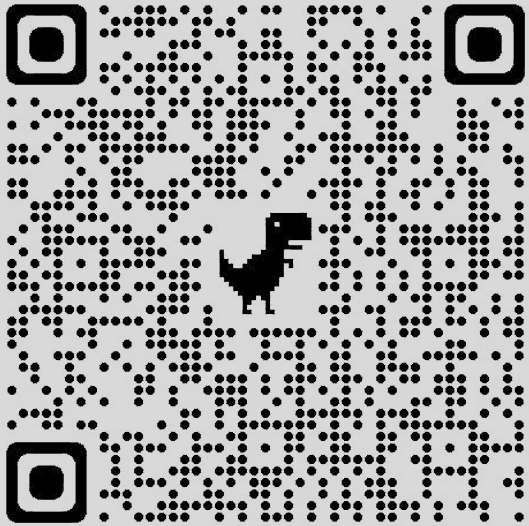
on behalf of the Nuclear and Subnuclear research area

Pavia, 17-18 february 2026

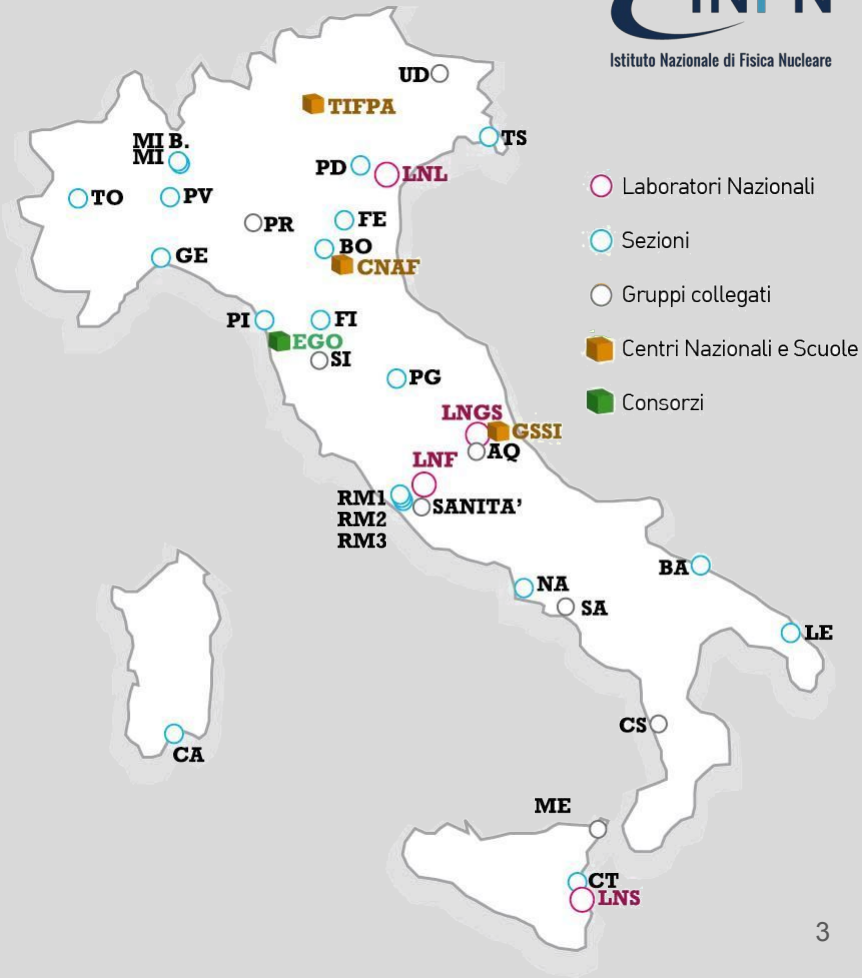
What are we working on?

- Experimental Physics of Fundamental Interactions [link]
- Focus on properties of:
  - atomic nuclei: **Nuclear Physics**
  - subnuclear particles: **Subnuclear Physics**
- And more..
  - astrophysics, space and applied physics
- In Pavia about 70 people involved
  - Including teams from engineering dept., Bergamo and Brescia (through INFN)



Research activities

- In collaboration with **I**stituto **N**azionale di **F**isica **N**ucleare
  - Public research institution
  - Funds research in the sector
  - Sections in major universities
- **Synergy** between PD and INFN
  - University staff integrated into INFN activities and roles
  - INFN researchers with teaching positions at universities



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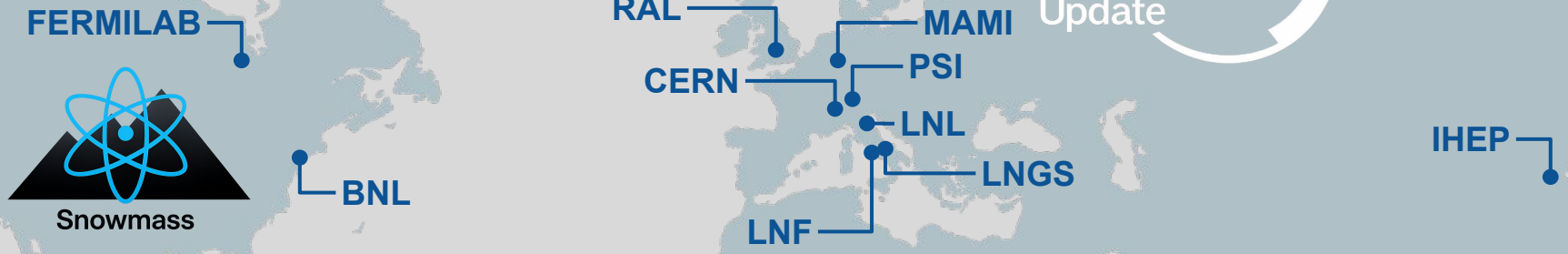
Collaborations in place

- CERN, Geneva
- FermiLab, Chicago
- BNL, Brookhaven
- PSI, Zurich (CH)
- RAL, Didcot (UK)
- Microtron, Mainz and Bonn (D)
- Laboratori INFN di Frascati, Legnaro e Gran Sasso
- IHEP per CepC, Cina
- Lab. di Energia Nucleare Applicata

Collaborations in place



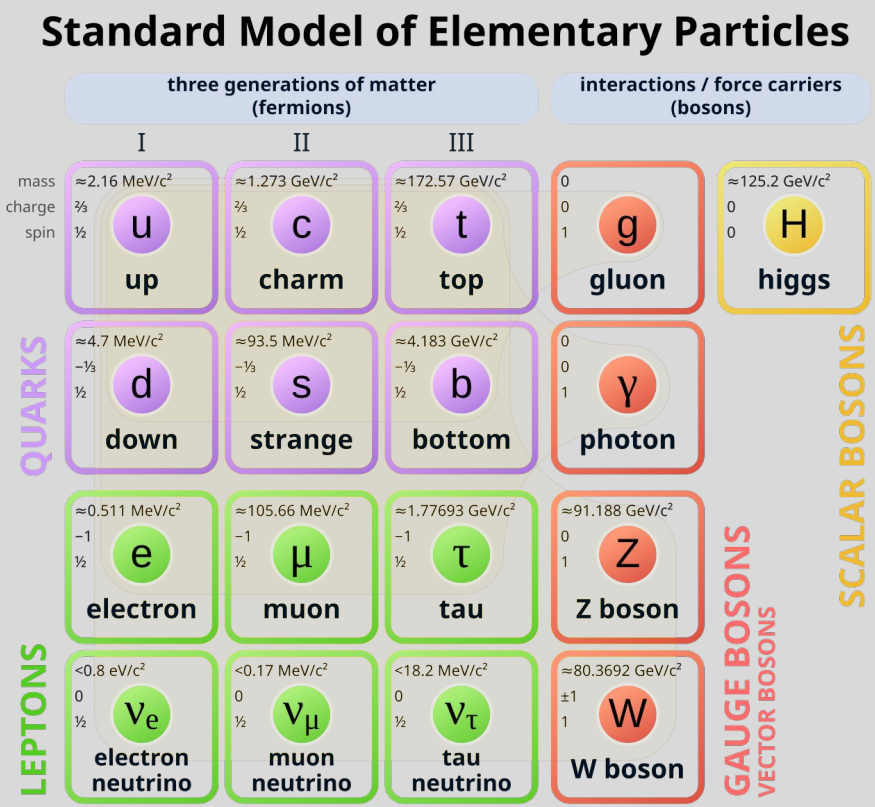
The guidelines for the various research activities are generally established at the European and international levels.

Detector R&D activities are part of the new Detector R&D Collaborations (DRDs) @CERN.

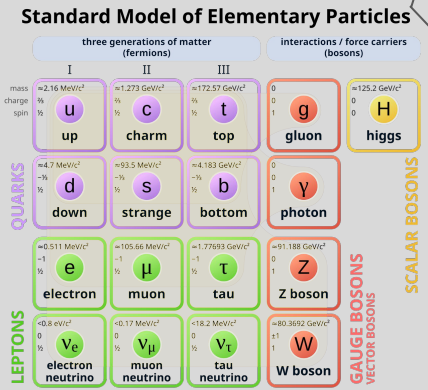
Great collaboration with local workshops

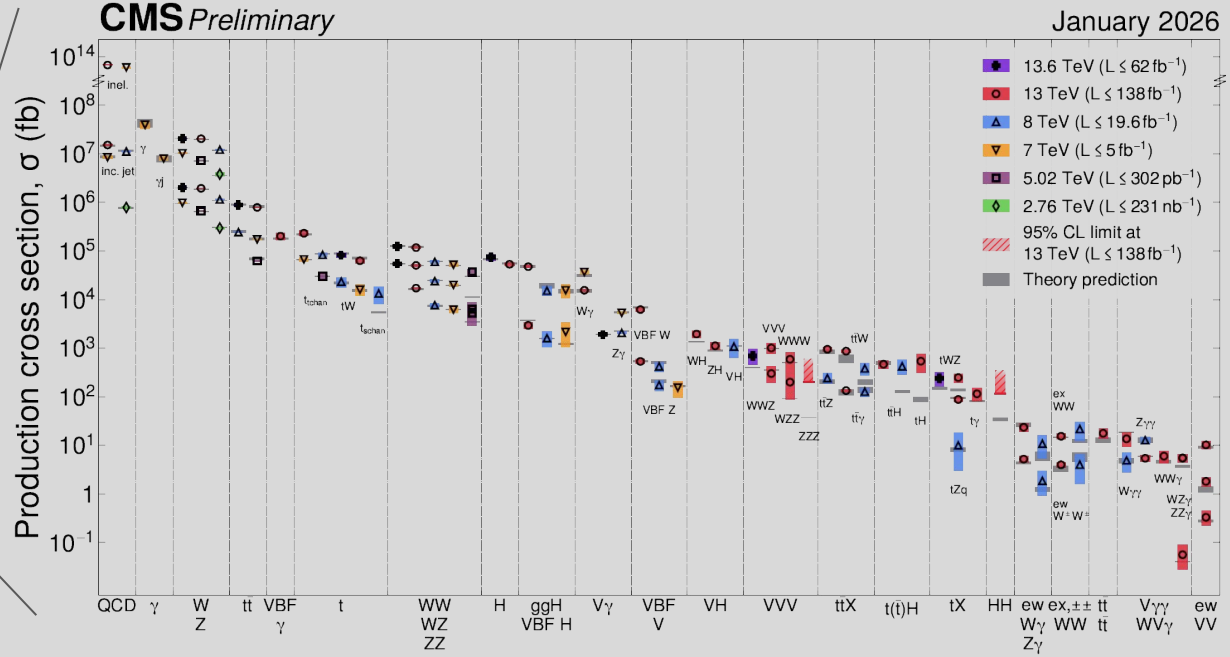
Poster (Wed)

A model that explains everything?

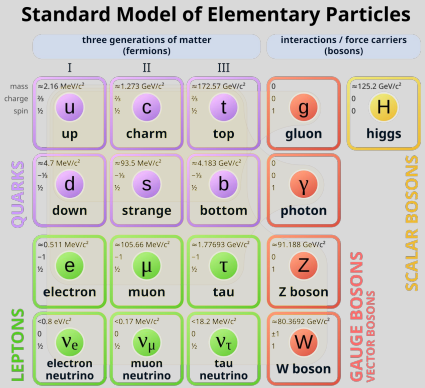


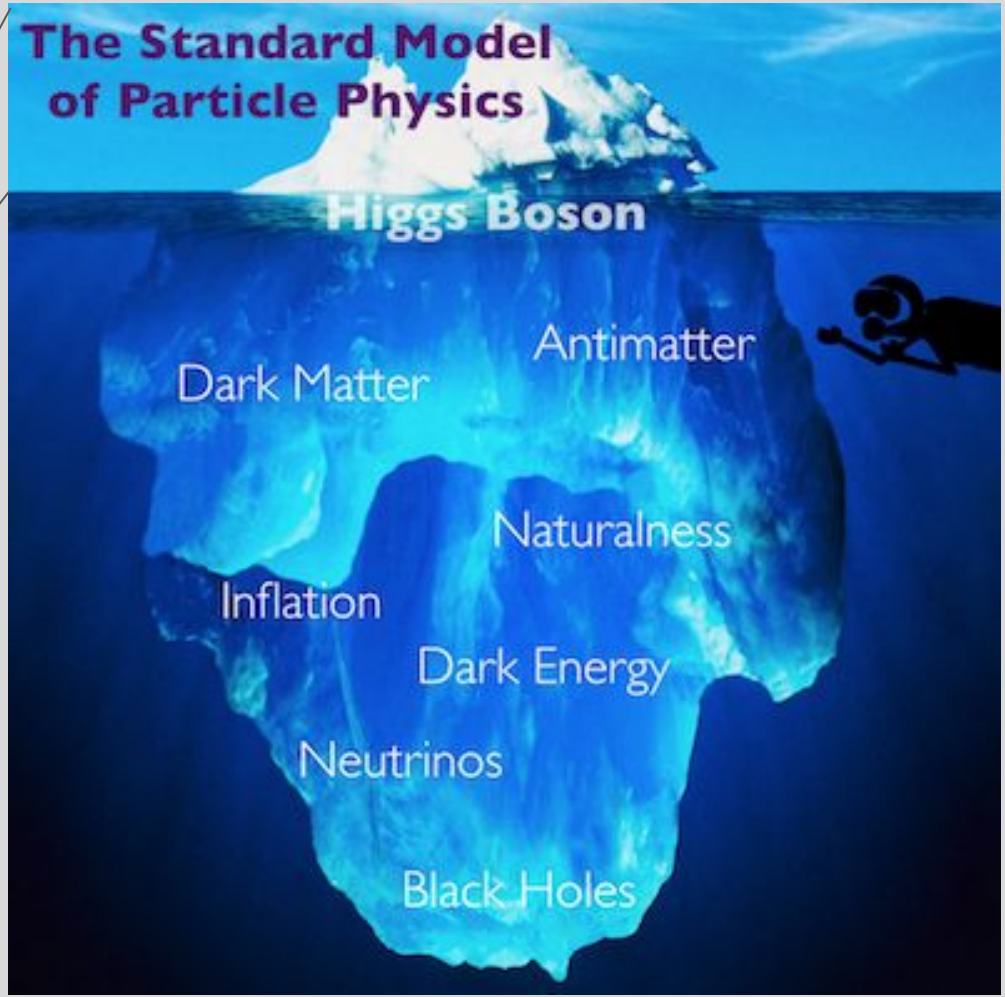
A model that explains everything?



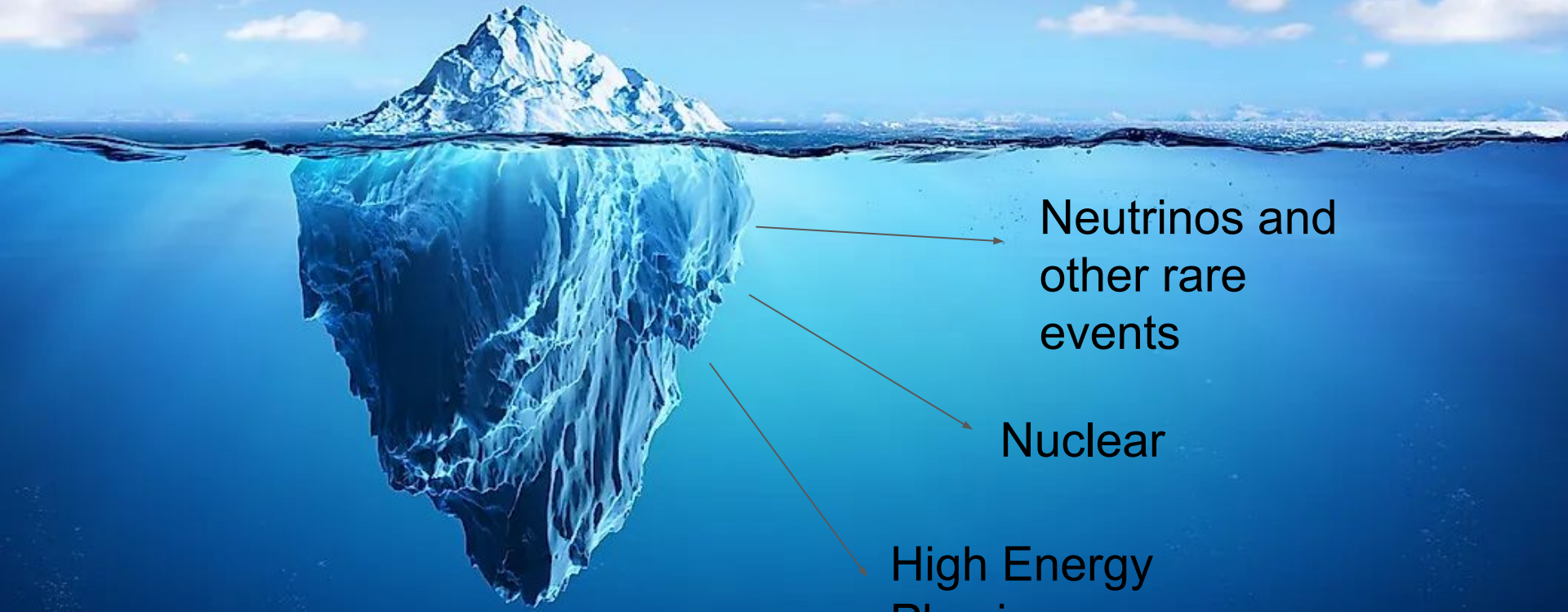


It seems not!


Standard Model of Elementary Particles
three generations of matter (fermions)
interactions / force carriers (bosons)
I
II
III
mass
charge
spin
≈2.16 MeV/c²
≈1.273 GeV/c²
≈172.57 GeV/c²
u
up
c
charm
t
top
g
gluon
≈125.2 GeV/c²
H
higgs
QUARKS
≈4.7 MeV/c²
≈93.5 MeV/c²
≈4.183 GeV/c²
d
down
s
strange
b
bottom
γ
photon
SCALAR BOSONS
≈0.511 MeV/c²
≈105.66 MeV/c²
≈1.77693 GeV/c²
≈91.188 GeV/c²
e
electron
μ
muon
τ
tau
Z
Z boson
GAUGE BOSONS
VECTOR BOSONS
LEPTONS
<0.8 eV/c²
<0.17 MeV/c²
<18.2 MeV/c²
≈80.3692 GeV/c²
νe
electron neutrino
νμ
muon neutrino
ντ
tau neutrino
W
W boson


The Standard Model of Particle Physics
Higgs Boson
Antimatter
Dark Matter
Naturalness
Inflation
Dark Energy
Neutrinos
Black Holes

Different research lines with a common goal



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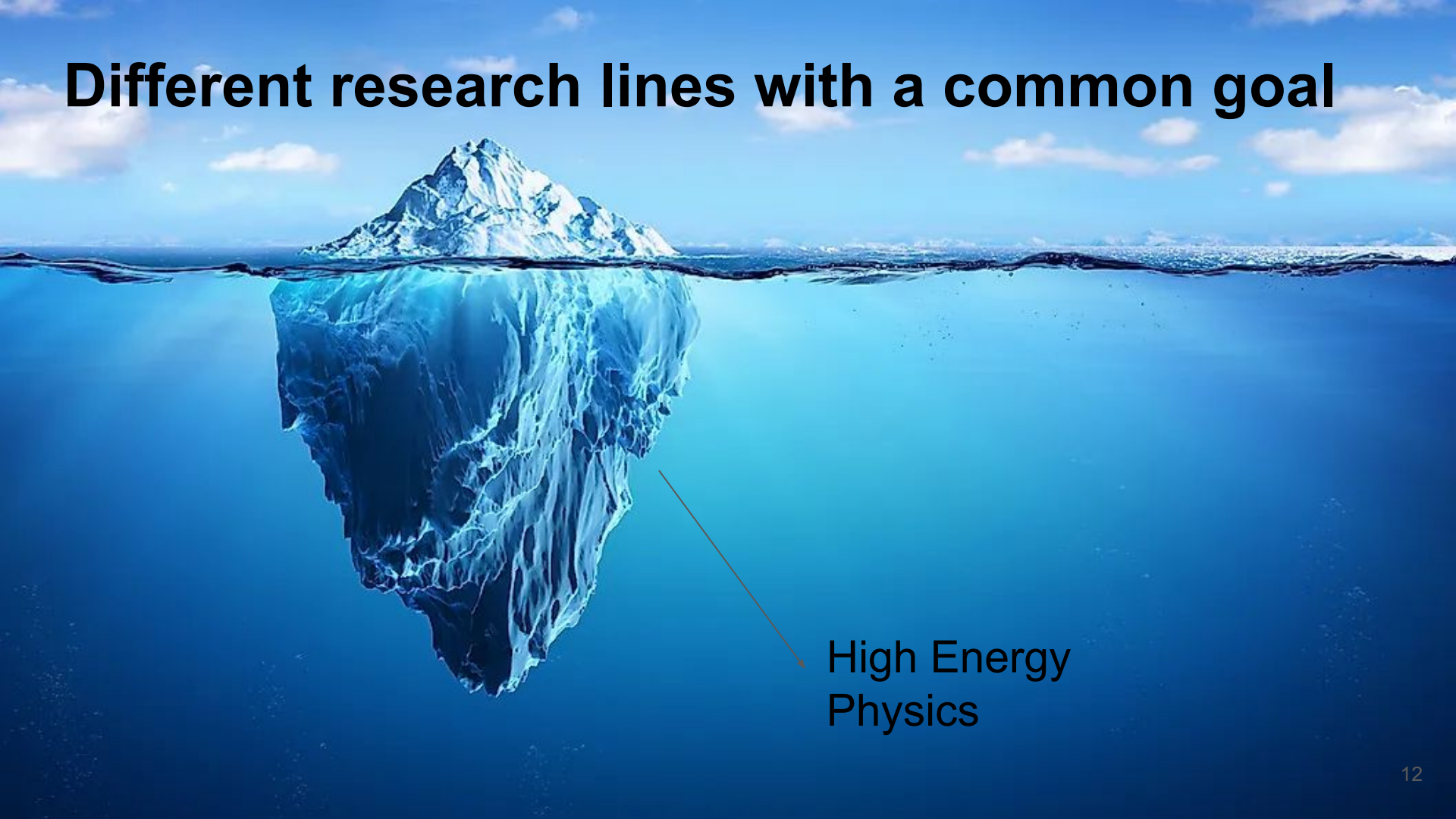


General purpose experiments

ATLAS & CMS at the LHC:

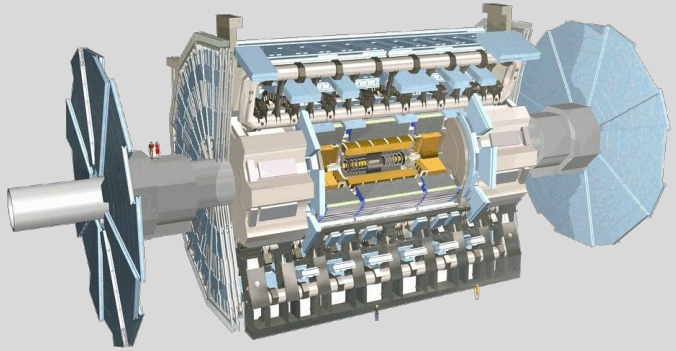
- from precision measurements of the Standard Model
- to new physics searches

LHC Run 3 2022 - 26 → Shutdown → Hi-Lumi LHC 2030 - 41

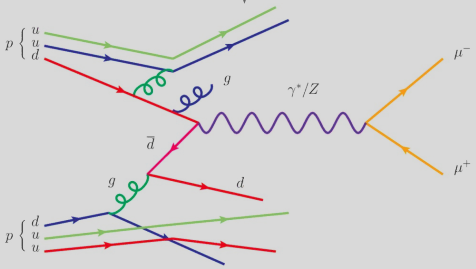
Tools

- Detectors
  - R&D
  - Construction
  - Maintenance
  - Data taking
- Data analysis
  - Simulation
  - Reconstruction
  - Final analysis

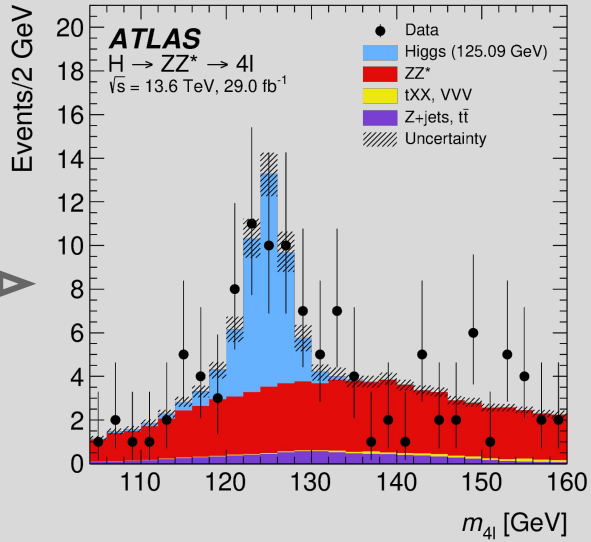
$$\mathcal{L} = -\tfrac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\Psi}\not{D}\Psi + h.c. + \Psi_i y_{ij}\Psi_j\Phi + h.c. + |D_\mu\Phi|^2 - V(\Phi)$$



Data taking



Simulation



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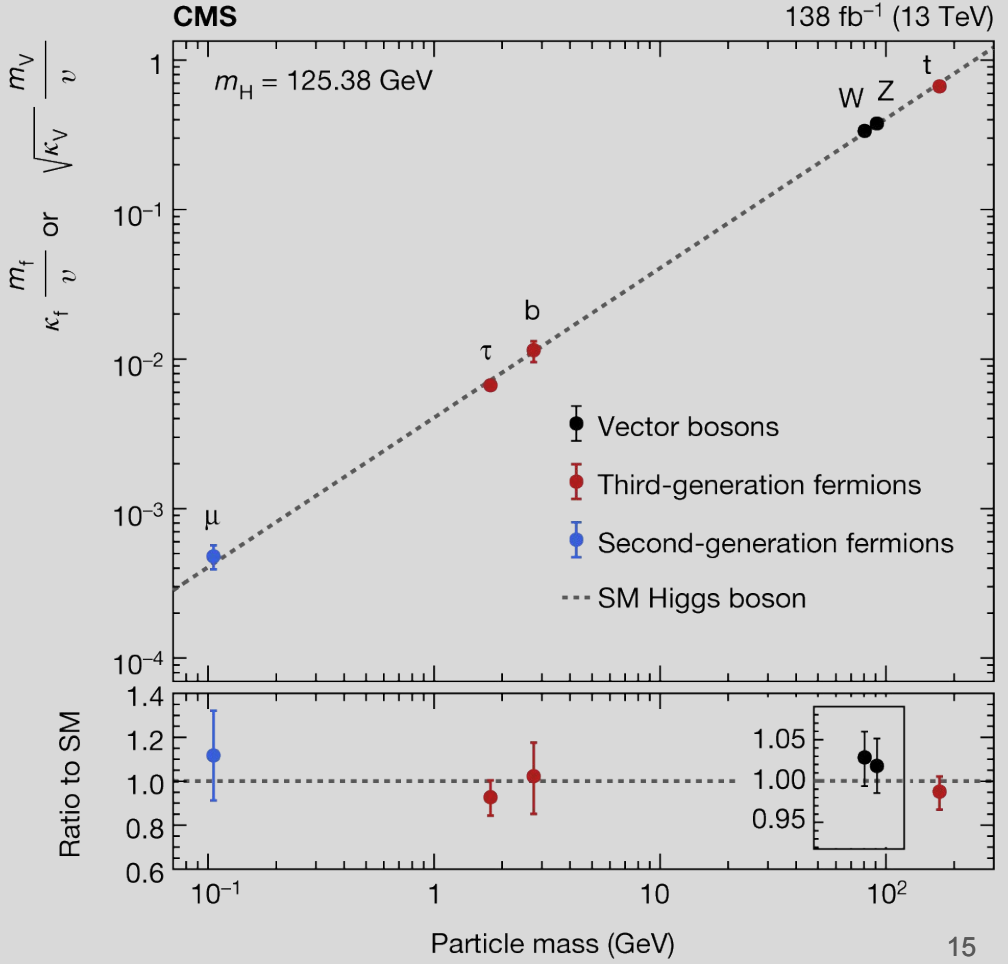
→ data analysis

Poster (Tue)
Poster (Tue)
Poster (Wed)



General purpose experiments

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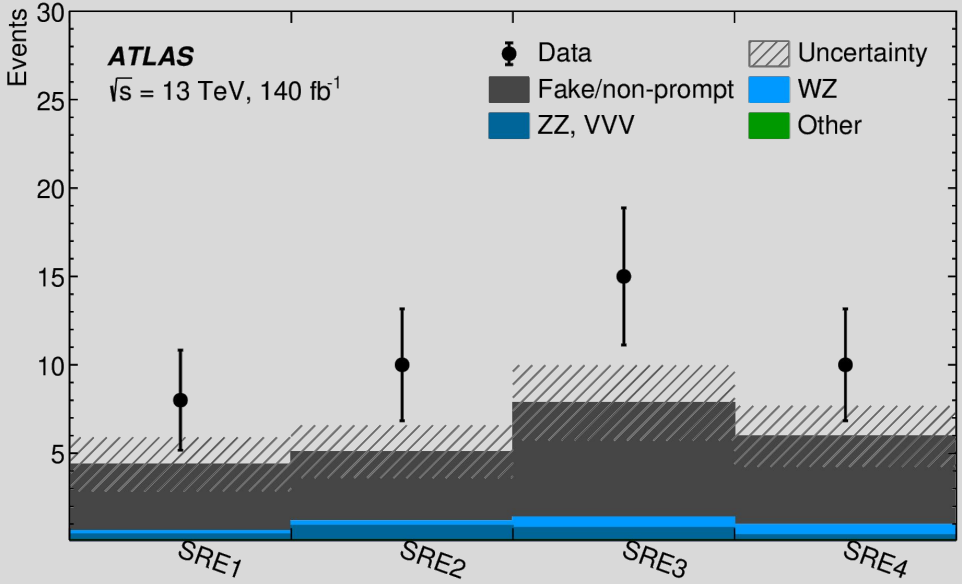
→ data analysis

Dark matter search

Leptonic signature, *heavy neutral lepton model*



Poster (Tue)

Poster (Tue)

Activities on detectors

Detectors

- Construction and maintenance of current detectors
- R&D for High-Luminosity LHC
- Data taking

LHC Run 3 2022 - 26 → Shutdown → Hi-Lumi LHC 2030 - 41

Poster (Tue)
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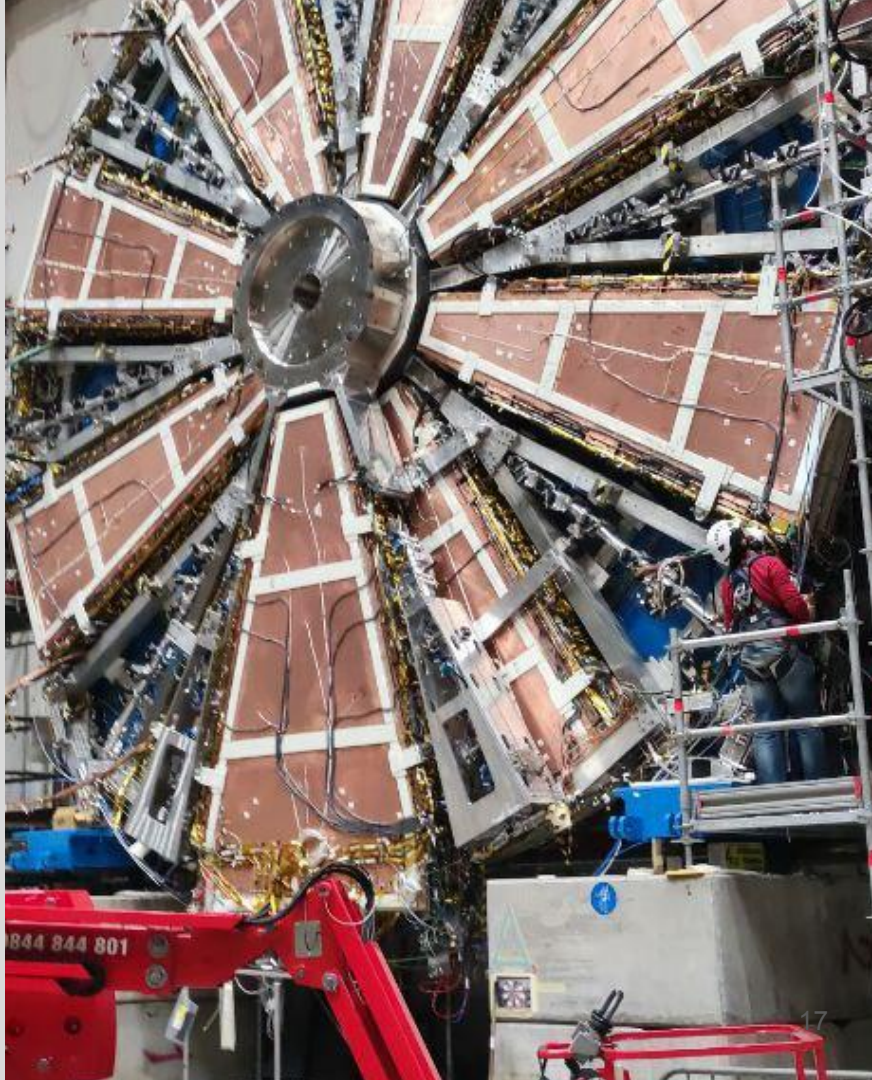

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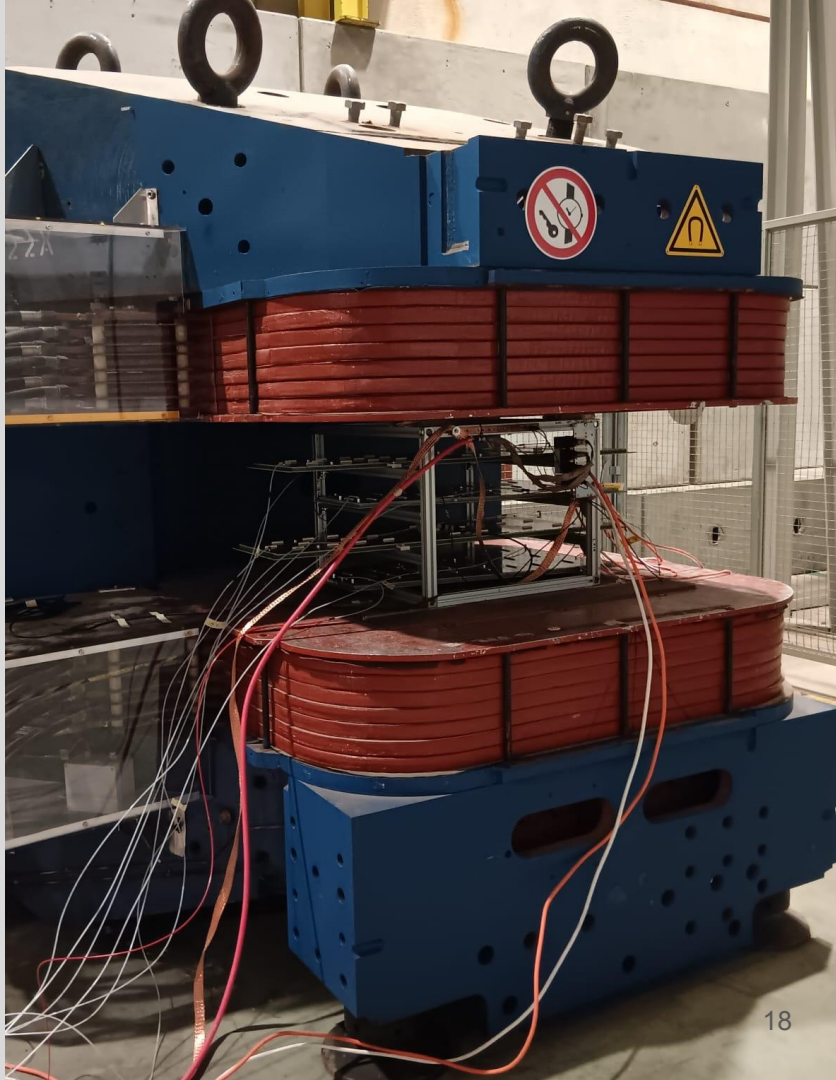

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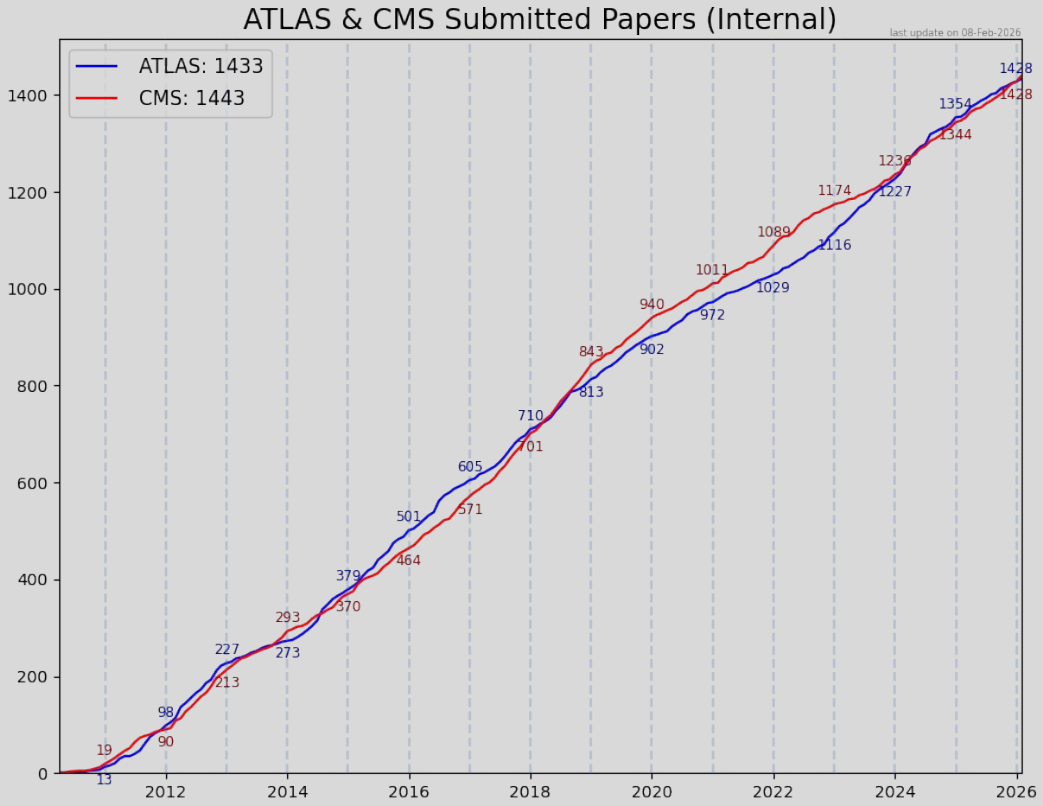
LHC Run 3 2022 - 26 → Shutdown → Hi-Lumi LHC 2030 - 41

Poster (Wed)

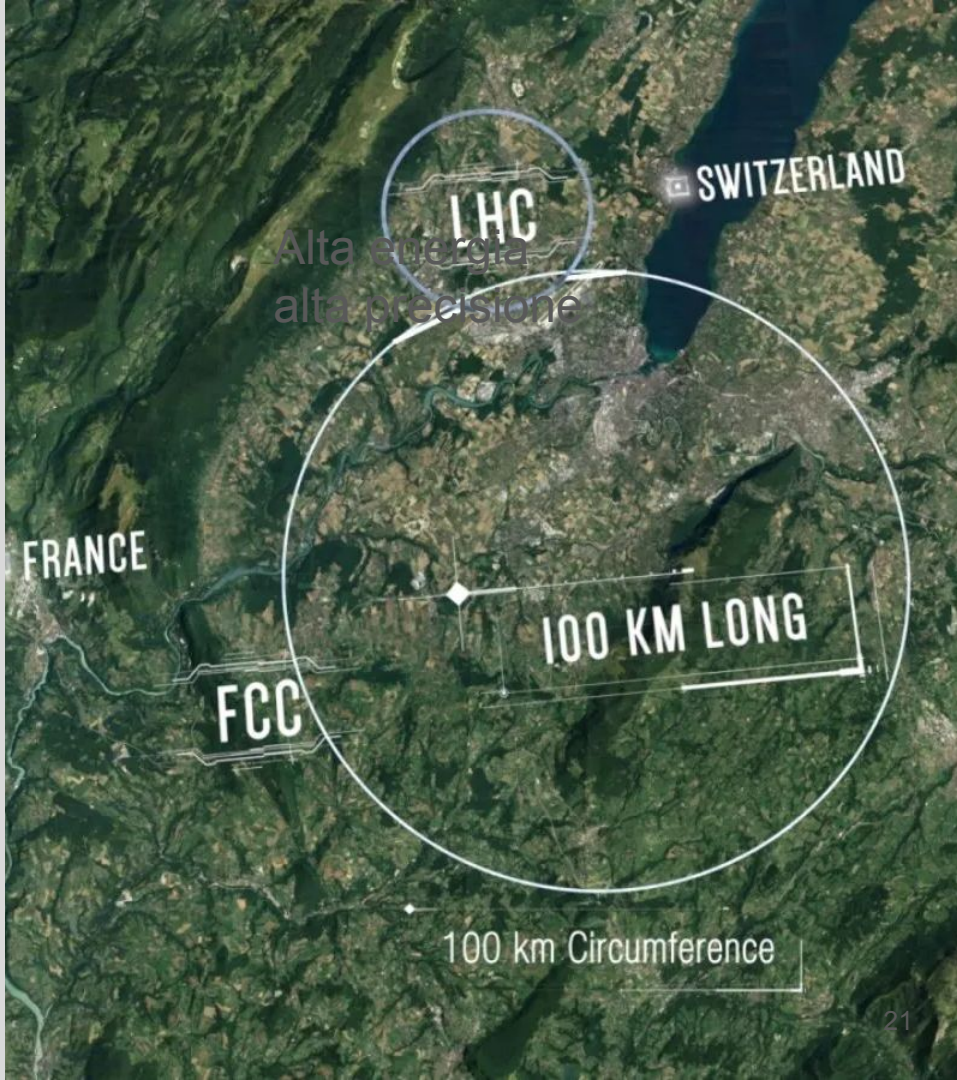
Impact

- On average, 100 publications per year per experiment
- Pavia:
  ~10 coordination roles in CMS and ATLAS organigram and ~5 group responsibilities



Future accelerators

- Beyond LHC
  - Many activities ongoing
- R&D future colliders (~2040)
  - Future circular collider FCC @ CERN 100 km long
    - electron-positron and hadrons
  - muon collider



Future Circular Collider

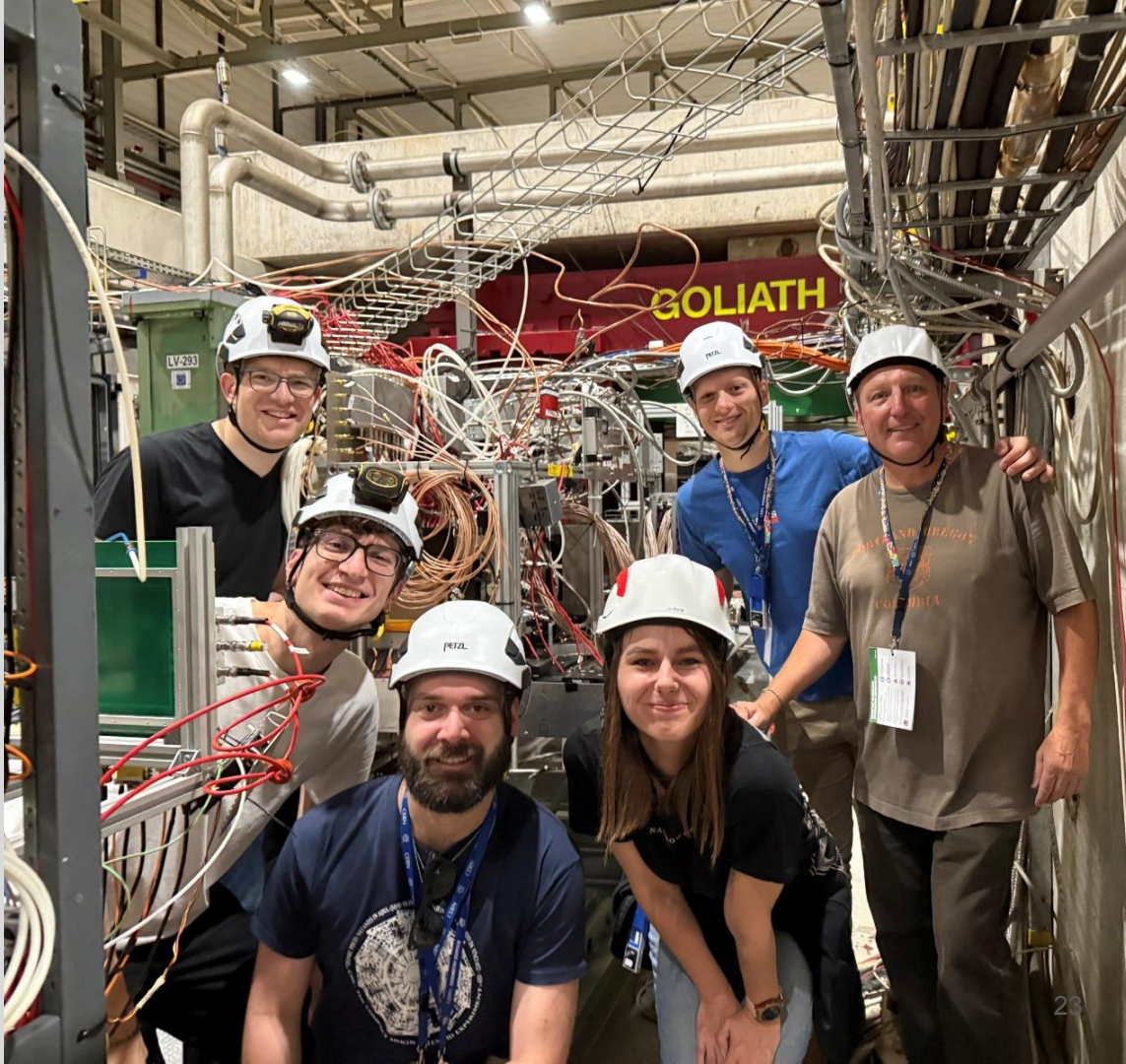
- Detectors
  - R&D
  - Construction
- Data analysis
  - Simulation
  - Sensitivity studies

LHC Run 3 2022 - 26 → Shutdown → Hi-Lumi LHC 2030 - 41 → ... → FCC

Poster (Tue)
Poster (Tue)

Muon Collider

- Detectors
  - R&D
  - Construction
- Data analysis
  - Simulation
  - Sensitivity studies



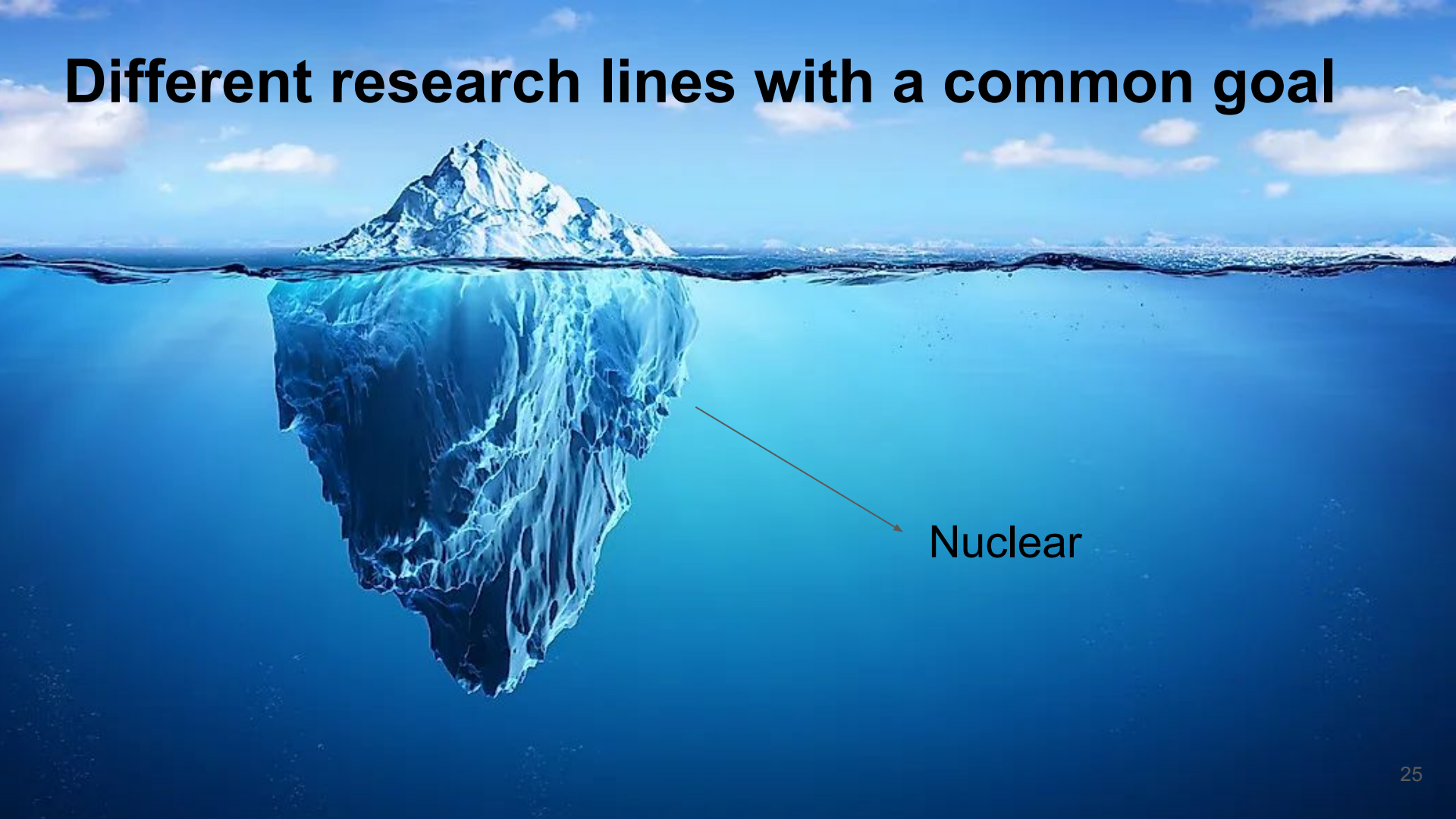
Poster (Tue)

Muon Collider

- Detectors
  - R&D
  - Construction
- Data analysis
  - Simulation
  - Sensitivity studies

Poster (Tue)

Different research lines with a common goal

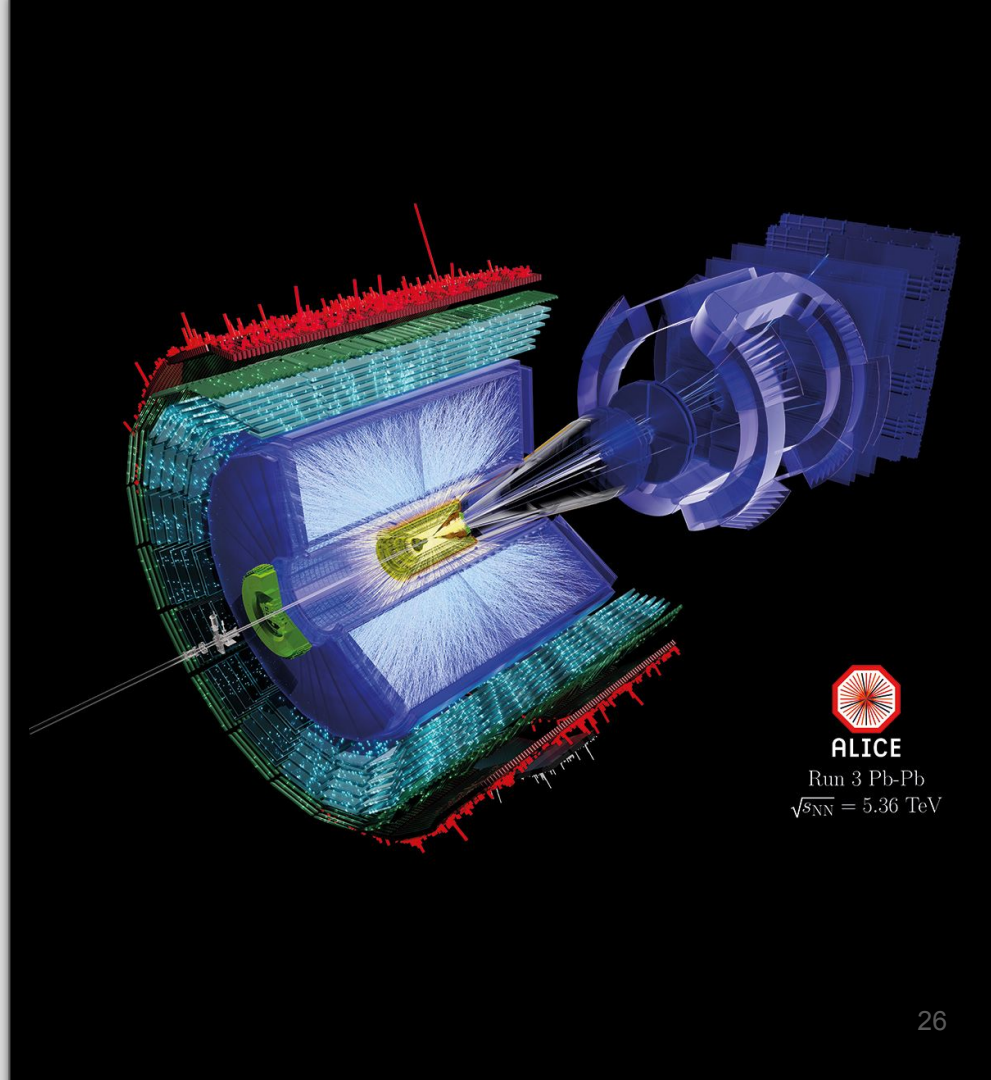


ALICE

A precision instrument for nuclear matter under ***extreme conditions***

Speciality:

- Low momentum
- High multiplicity



ALICE

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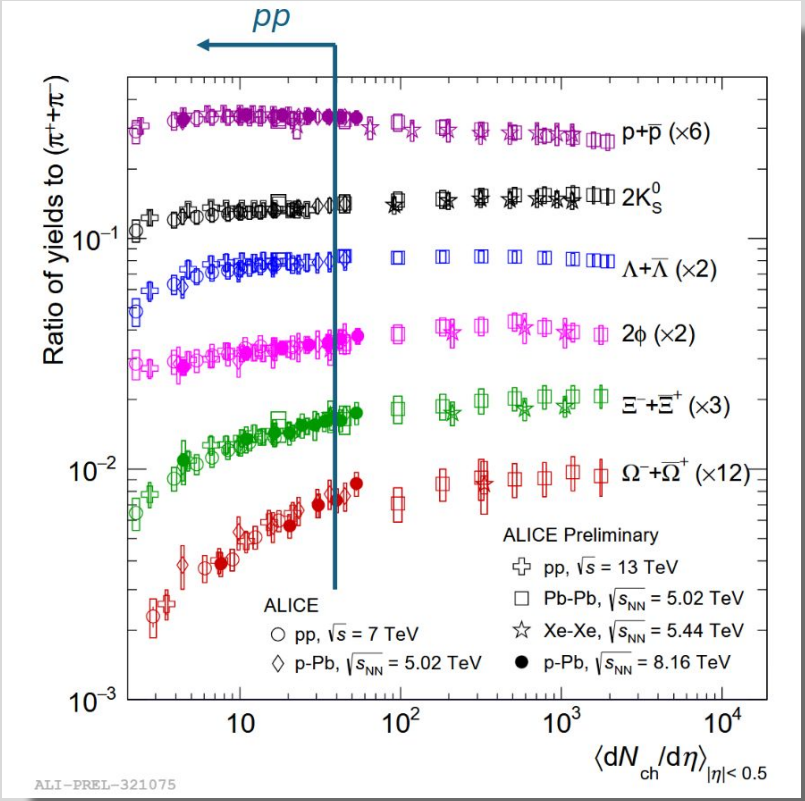
Speciality:

- Low momentum
- High multiplicity

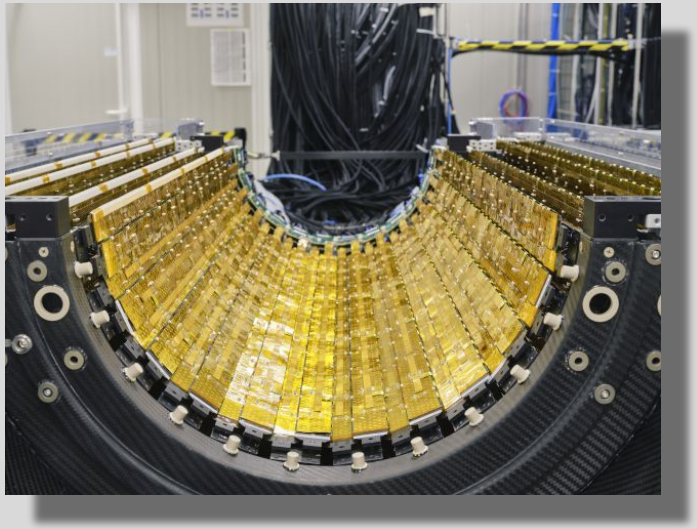
Rich physics programme, with both protons and ions

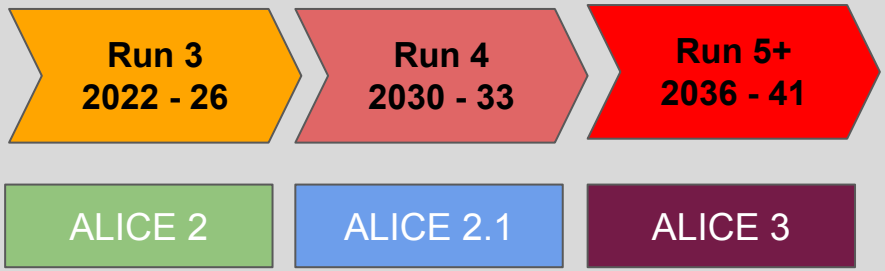


ALICE @ Pavia

& gruppo collegato di Brescia

- “Inner Tracking System”: Commissioning, data taking
- Upgrades for LHC Run 5
- Data analysis
- Handling analyses on Grid





Poster (Tue)

EIC / ePIC

The *Electron-Ion Collider* at Brookhaven

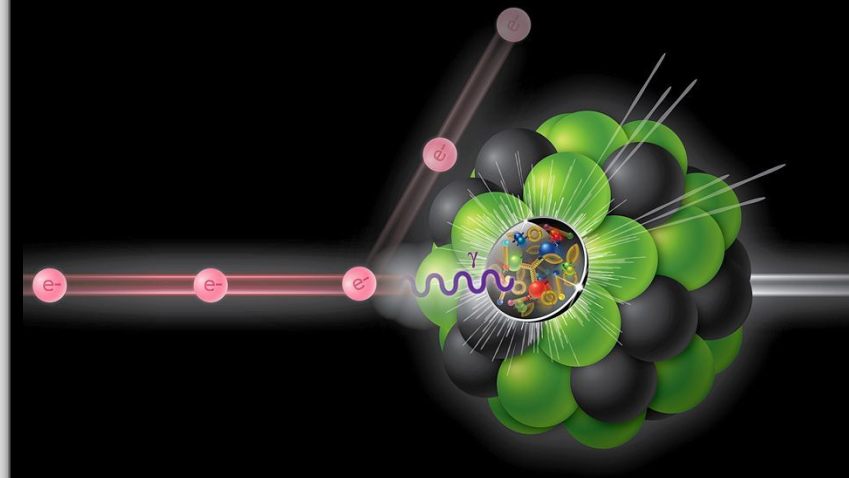
quarks and gluons dynamics → *mass, spin, … nuclear effects*

Polarized electrons and protons + wide range of ions

- Detector “on the floor” by 2032
- Strong italian involvement

ePIC

193 institutes
25 countries
27% Europe

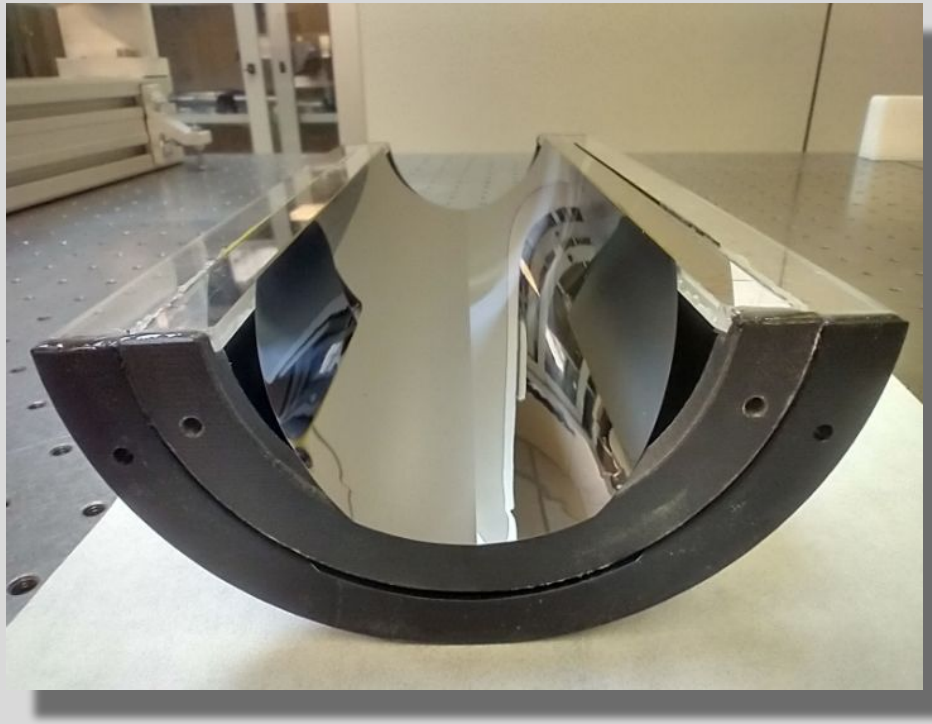


ePIC @ Pavia

Group born in 2024

Synergy between theory and experiment

- Analysis and simulation
  SIDIS + detector benchmarks
- Silicon Vertex Tracker



Poster (Wed)


ENERGY

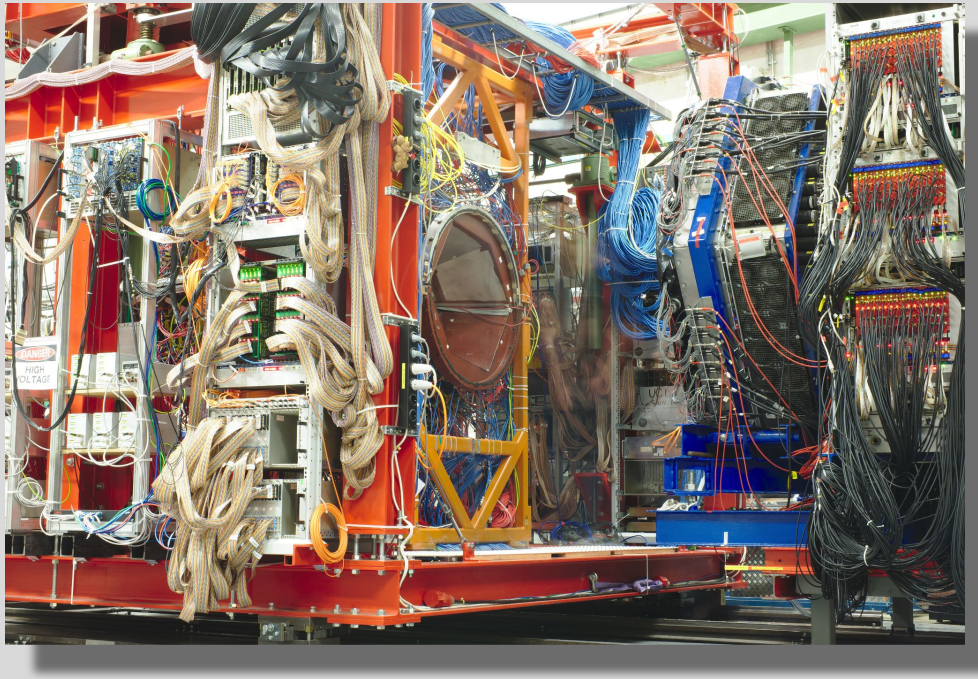
MAMBO

ELSA (Bonn) + MAMI (Mainz)

Study of nuclear structure at low energy

Highlights:

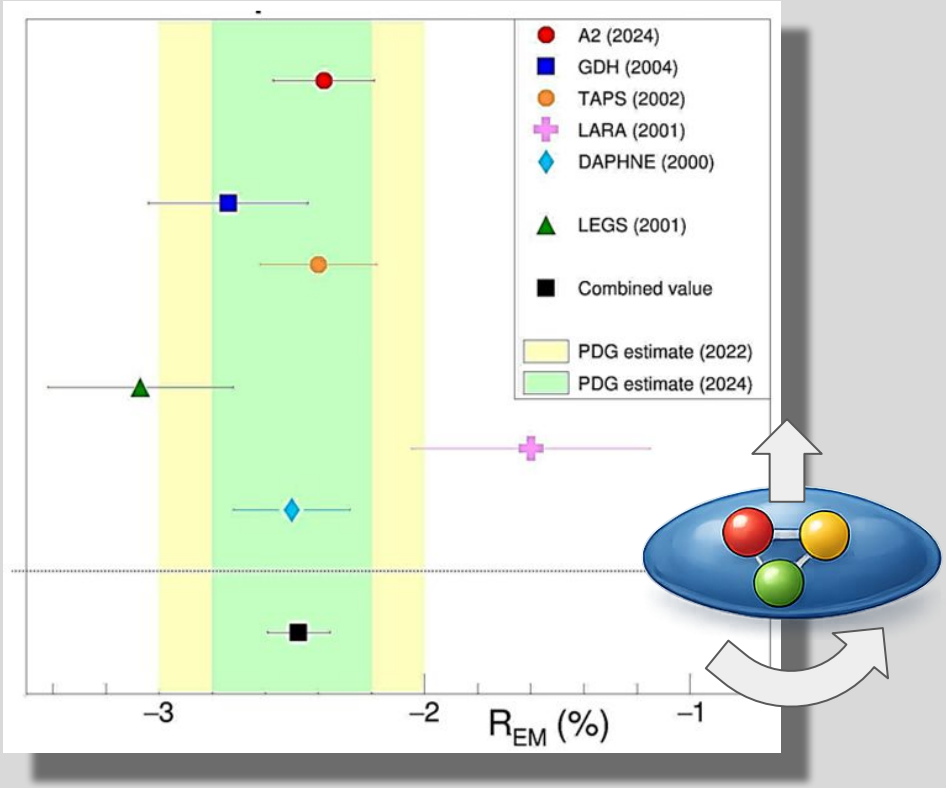
nucleon polarizability,
E2/M1 (proton shape),
…



MAMBO @ Pavia

- Data analysis
  - Statistical methods
  - Models, synergy with theoretical group
- Vertex detectors

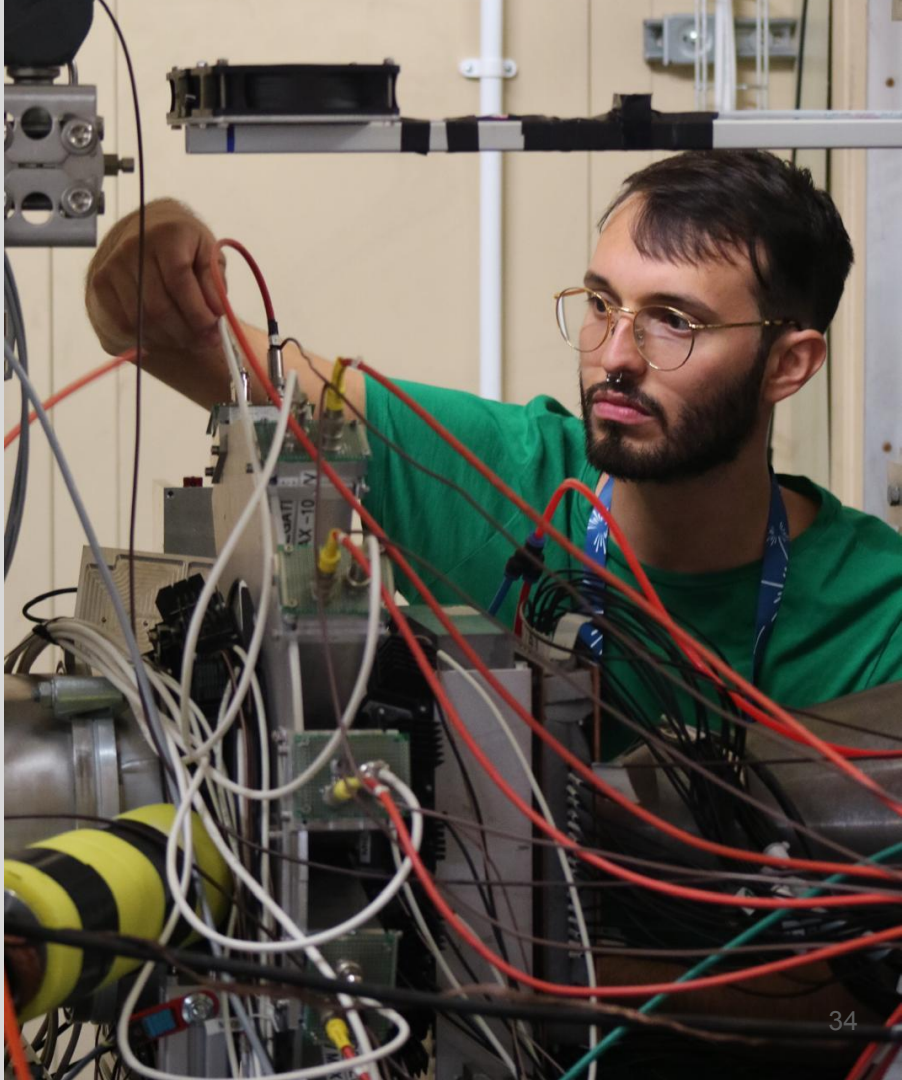
E2/M1



FAMU

Muonic atoms at RIKEN-RAL (UK)

Measurement of the hyperfine structure in muonic atoms → proton radius



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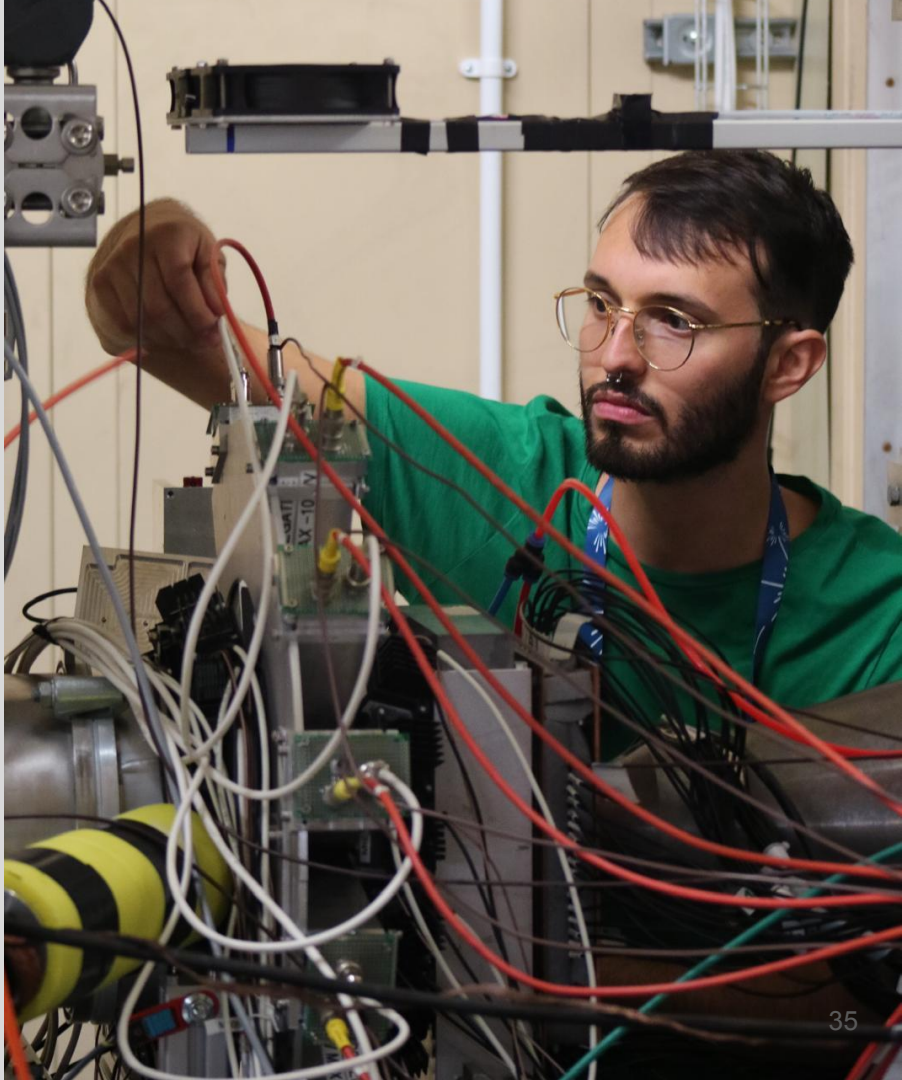
… @ Pavia

- Data taking
- Beam monitor
  - Development and maintenance

  → Collaboration between ISIS e UniPV

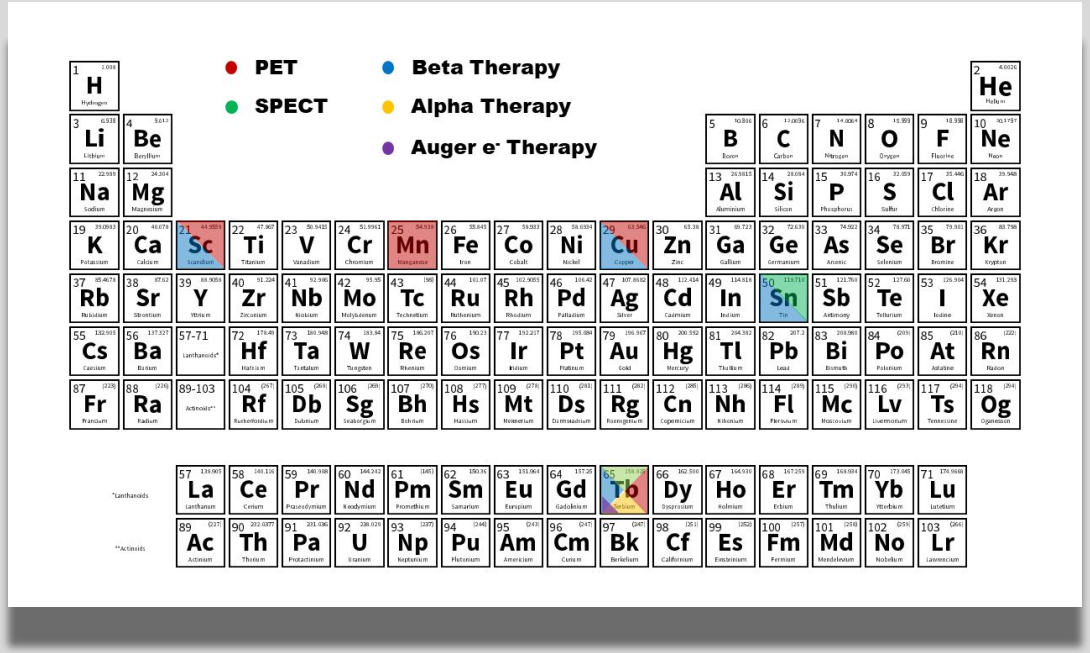
Poster (Wed)



Radionuclides, REMIX (SPES)

Optimization of nuclear reaction models, in particular for ^{155}Tb (REMIX), and previously ^{67}Cu, ^{47}Sc and ^{52g}Mn

Characterization of unexplored reactions



Poster (Tue)

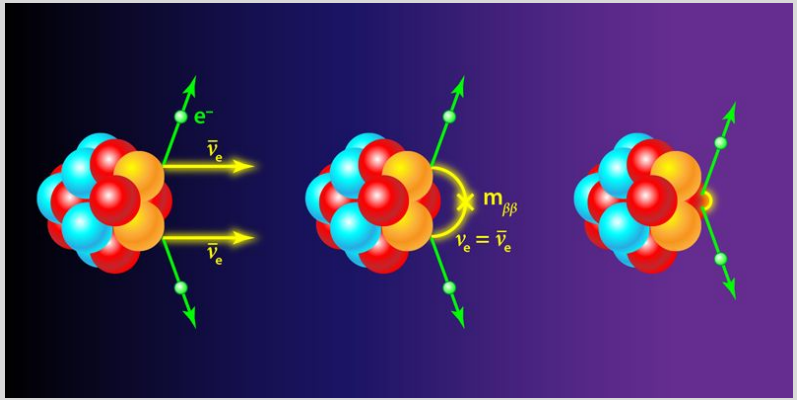
Different research lines with a common goal

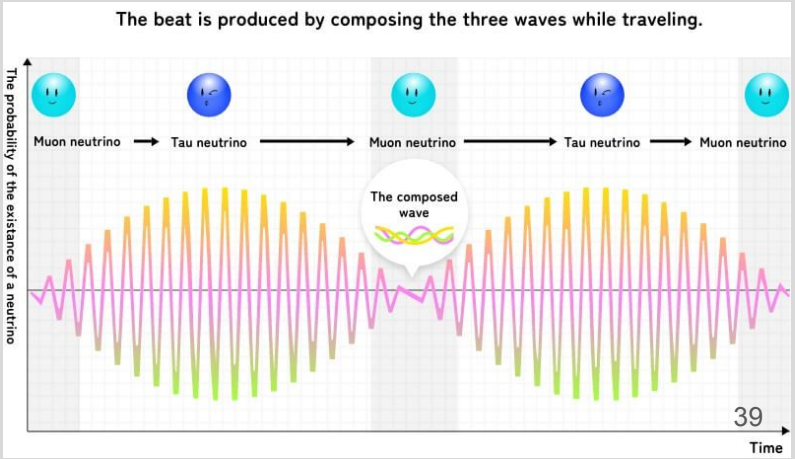
Neutrinos…
and other rare events

- Massive neutrinos: BSM physics!
  - Neutrino mixing
  - Majorana neutrinos?

Neutrinos…
and other rare events

- Massive neutrinos: BSM physics!
  - Neutrino mixing
  - Majorana neutrinos?
- Experimental observables:
  - Neutrinoless Double-Beta Decay
  - Lepton Flavor Number Violating Decays
  - Neutrino Oscillations





Massive Neutrinos

CUORE/CUPID @ LNGS

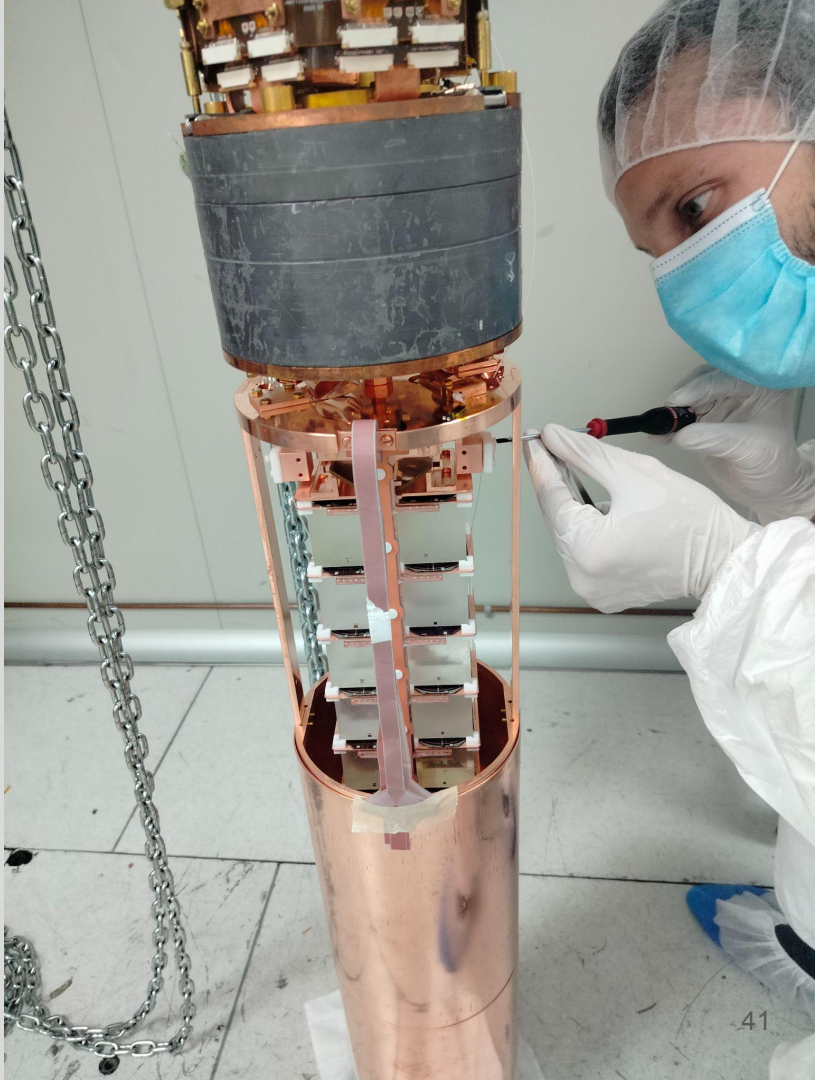
- Neutrinoless double-beta decay (0νββ)
- Dark Matter (axions)
- Other rare events

Poster (Wed)

CUORE/CUPID

- Activities on CUPID detectors:
  - R&D OIS
  - Construction of OIS
- CUORE/CUPID data analysis:
  - OIS simulation (CUPID)
  - Data processing
  - Data analysis

Poster (Wed)



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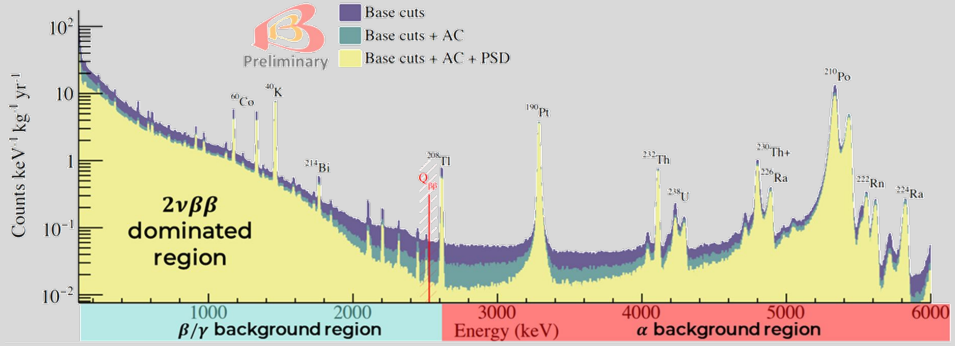
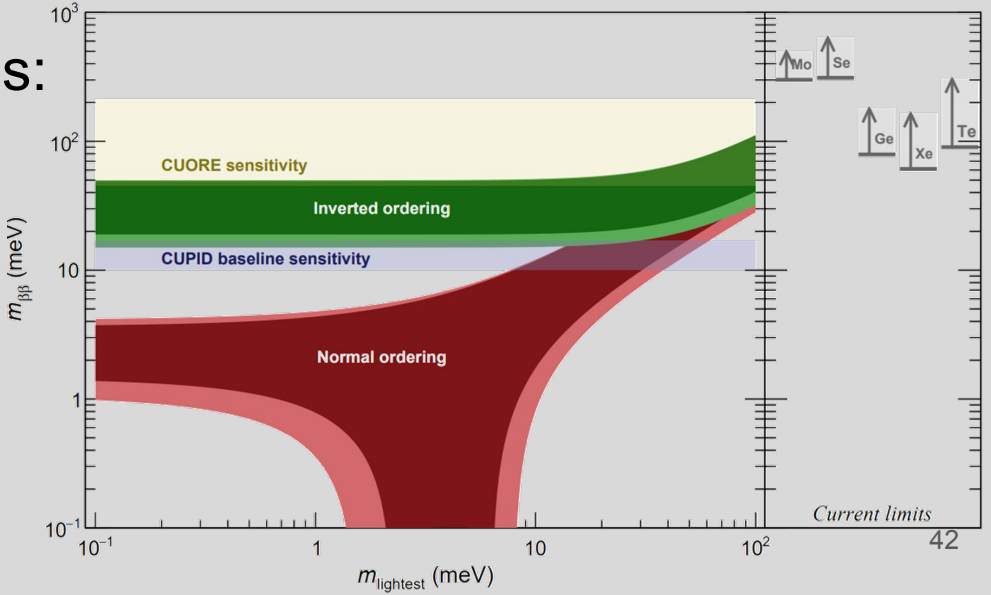




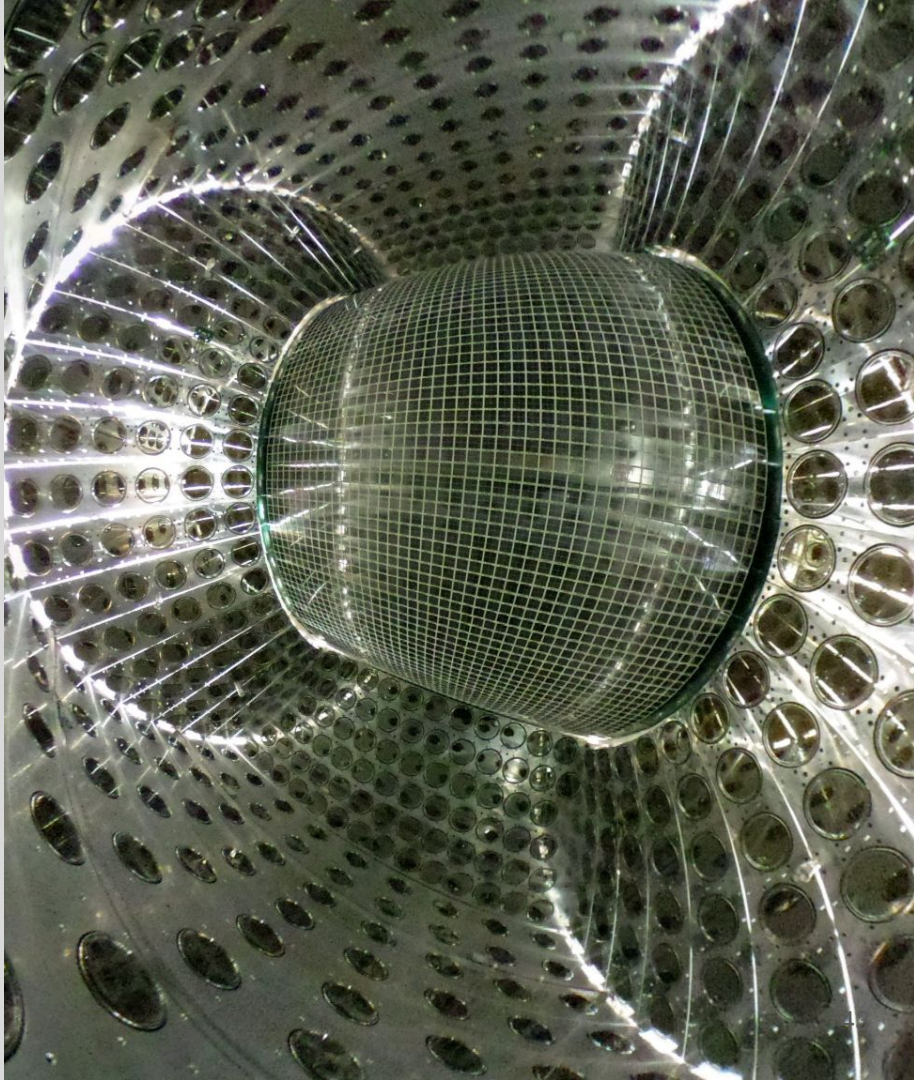
Poster (Wed)

MEG

MEG @ PSI

- Lepton Flavor Number Violation
  - $\mu \rightarrow e + \gamma$ decay
  - Forbidden in Standard Model

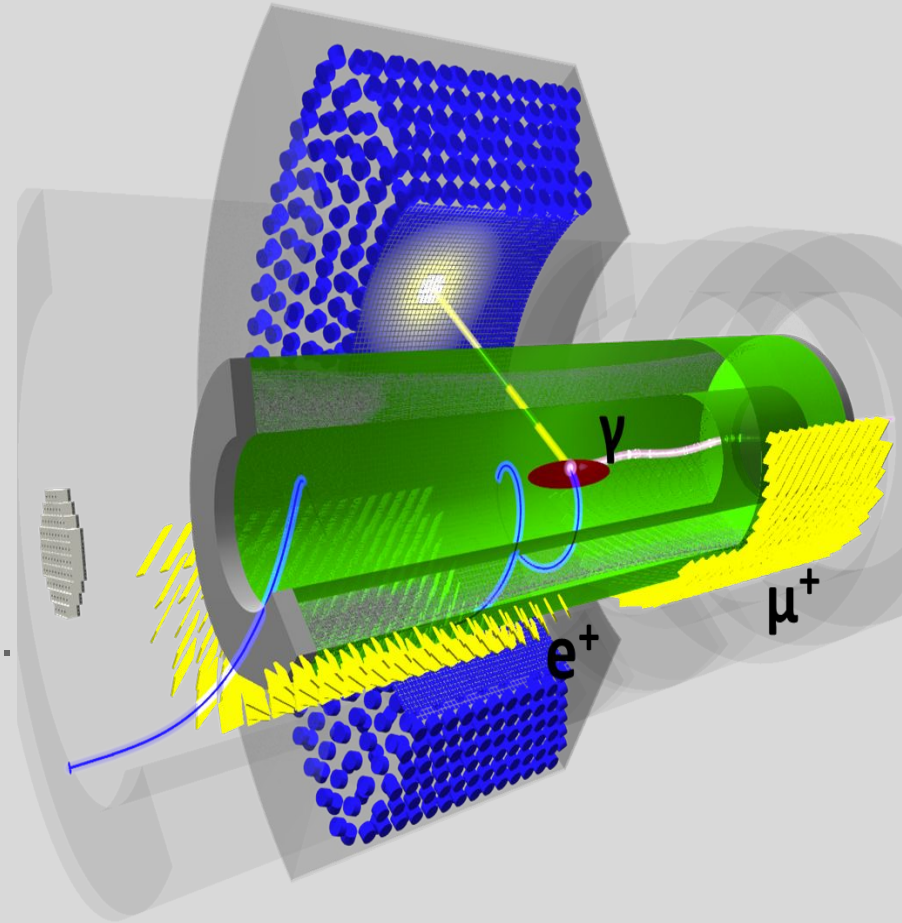
Poster (Wed)



MEG

MEG @ PSI

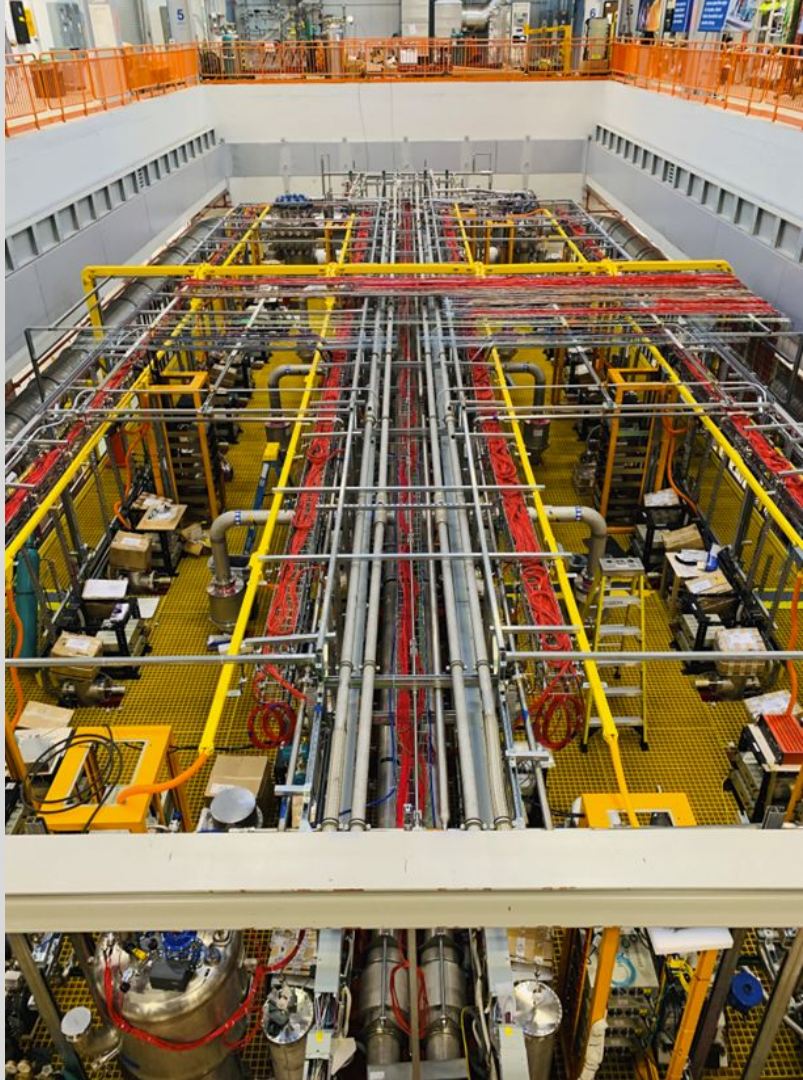
- Lepton Flavor Number Violation
  - $\mu \rightarrow e + \gamma$ decay
  - Forbidden in Standard Model
  - Data taking 2021-2026
  - BR($\mu \rightarrow e\,\gamma$) < 1.5 10^{-13} 90% C.L. with 2021-2022 data
- Pavia: Timing Counter (yellow)



Poster (Wed)

ICARUS

- ICARUS@Fermilab
  - Neutrino Oscillations
  - Neutrino-Argon Cross-Sections
  - Beyond Standard Model Physics
- Data taking for physics since 2022: first results coming!



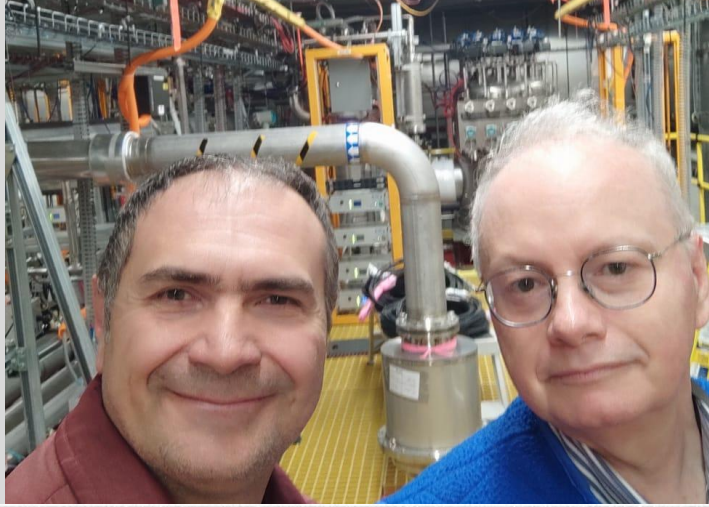
ICARUS

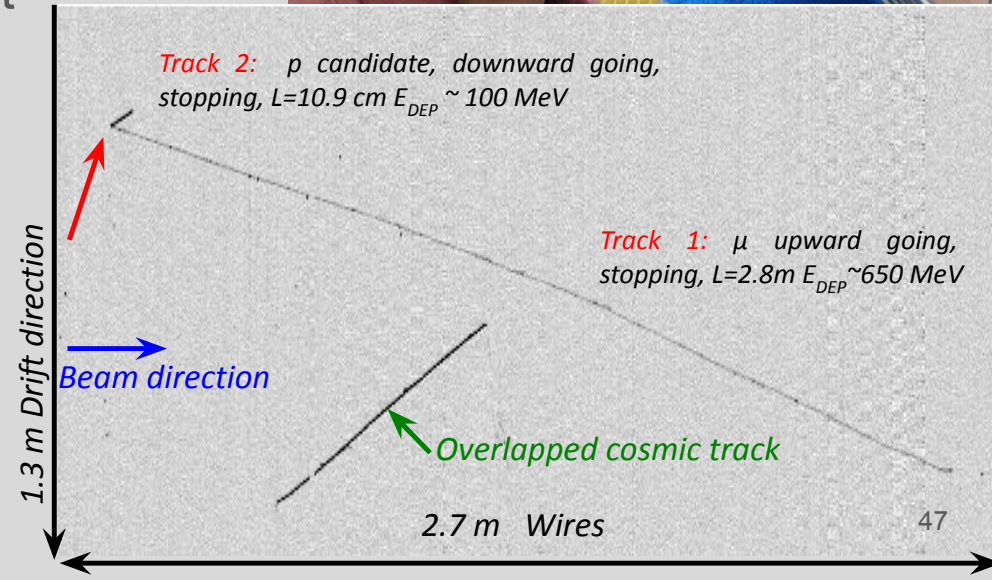
- Pavia: detector responsibilities:
  - Time Projection Chamber (TPC)
  - Photo-Detection system (360 PMTs)
  - ICARUS trigger management

Poster (Wed)

ICARUS

- Pavia: detector responsibilities:
  - Time Projection Chamber (TPC)
  - Photo-Detection system (360 PMTs)
  - ICARUS trigger management
- Pavia: data analysis:
  - Photo-detection calibrations
  - Analysis of PMT/TPC signals



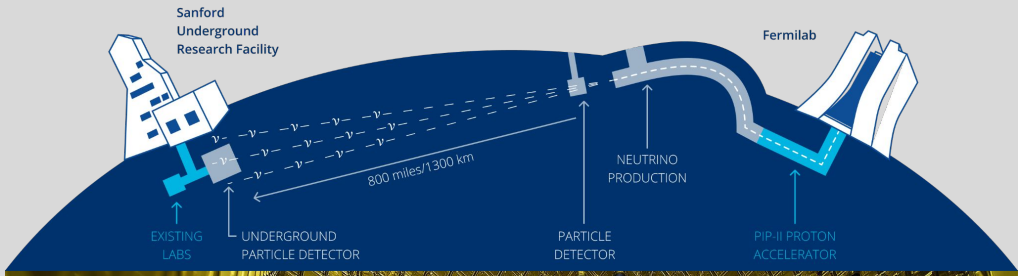


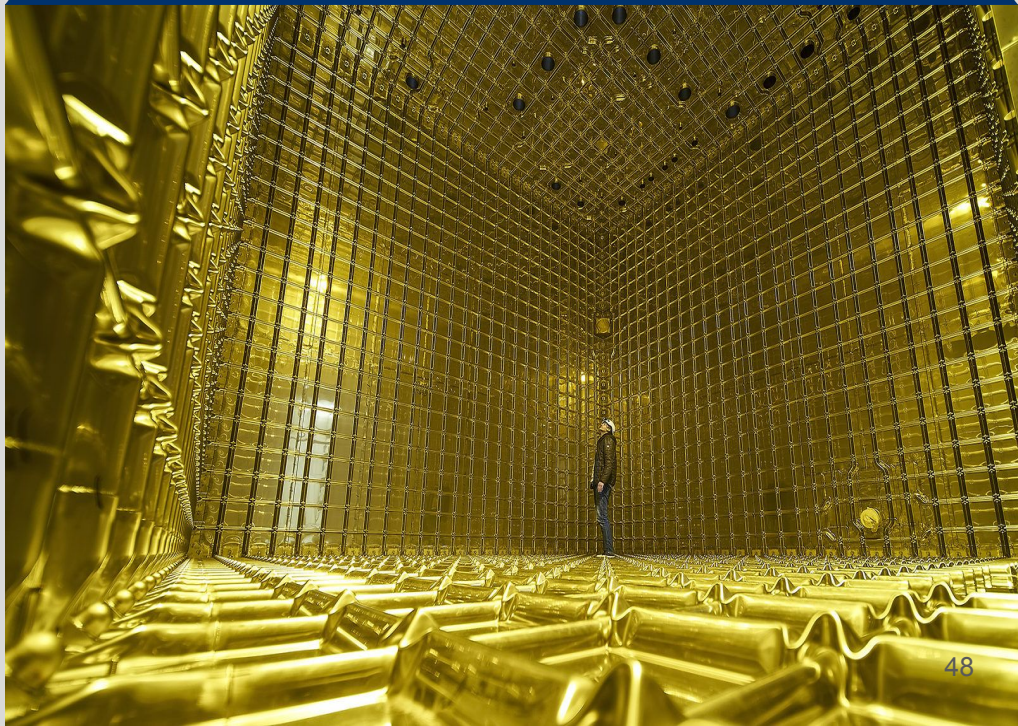
Poster (Wed)

DUNE

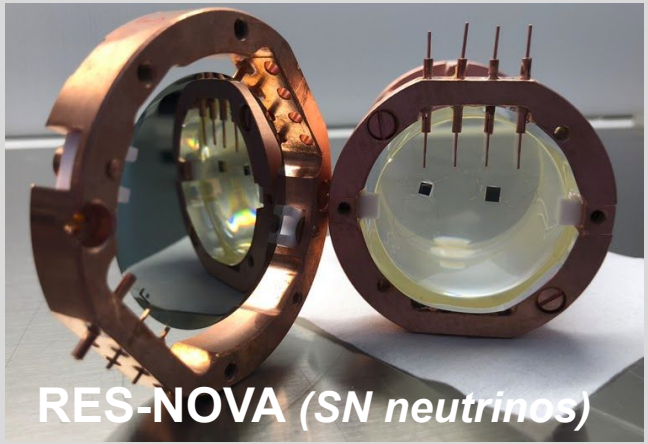
(Deep Underground Neutrino Experiment)

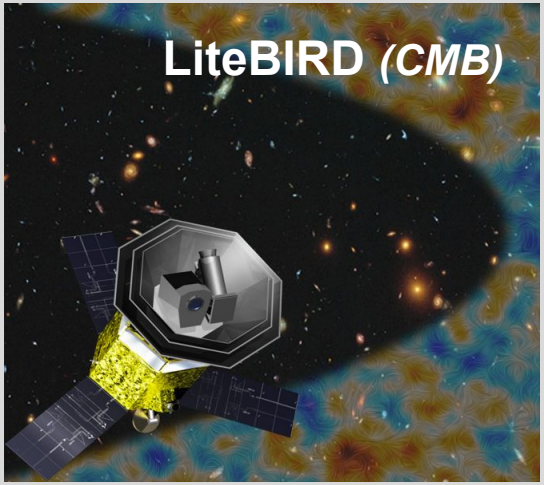
- DUNE@Fermilab+SURF
  - Neutrino mixing precise measurements
  - Nucleon decay searches
  - Astrophysical neutrinos
- DUNE-Pavia activities:
  - Near Detector (SAND)
  - Photo-detectors + SiPM
- Start: 2030

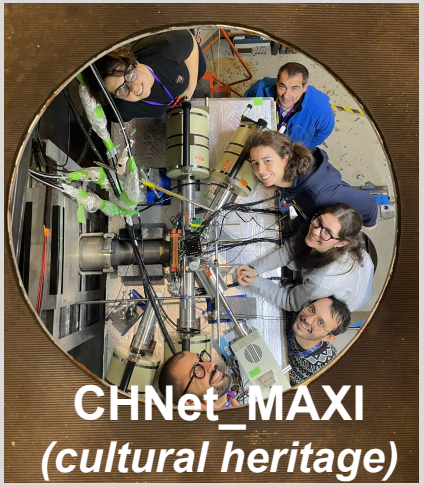


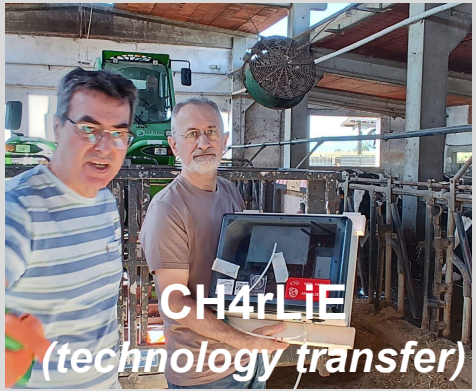


… and much more!









Poster (Wed)

How are we funded?

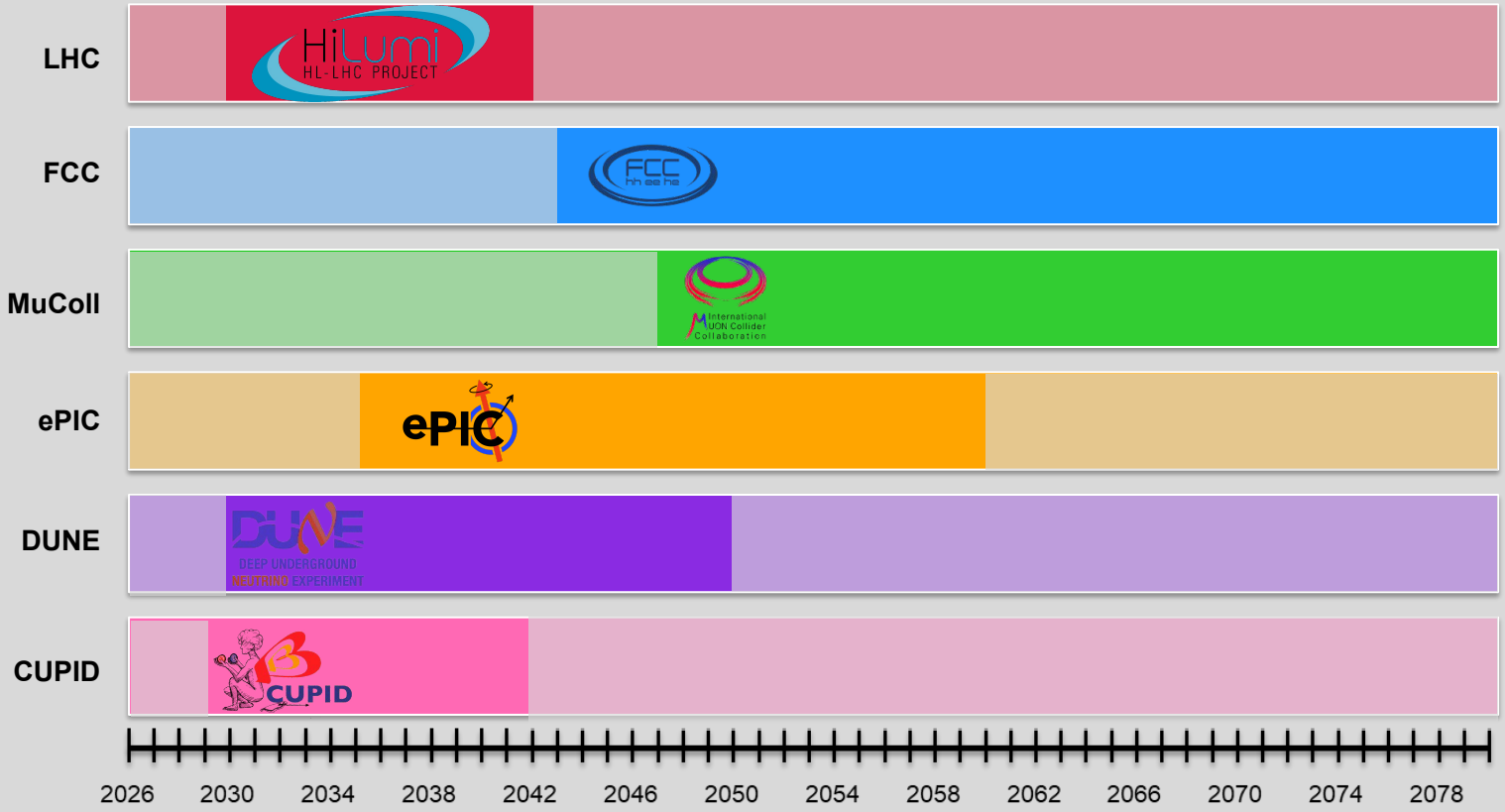
CSN1 ***(accelerators) ATLAS, CMS, MEG, ICARUS, DUNE, …***

CSN2 ***(astro-particles) - CUORE, CUPID, …***

CSN3 ***(nuclear) - ALICE, ePIC, FAMU, MAMBO, REMIX***

Annual funding following reviews conducted by referees appointed by the National Scientific Committees.

A long-term planning…



Contatti su sito Dip [link]

S. AbuZeid, C. Aimè, G. Biella, G. Boca, F. Boffelli, G. Bonomi, A. Braghieri, M. Brunoldi, C.M. Carloni Calame, S. Carrà, P.W. Cattaneo, M. Chiesa, S. Copello, S. Costanza, T. Cresta, G. Danese, A. De Bari, C. De Vecchi, R. Ferrari, L. Gaioni, G. Gaudio, M. Ghilardi, G. Giannandrea, G. Introzzi, A. Kourkoumeli-Charalampidi, A. Lanza, P. Lazzaroni, R. Lea, F. Leporati, G. Manco, N. Manenti, M. Manghisoni, E. Marenzi, A. Menegolli, G. Montagna, P. Montagna, C. Montanari, A. Negri, O. Nicrosini, D. Pagano, A. Pareti, P. Pedroni, M. Pelliccioni, F. Piccinini, G. Polesello, M. Radici, A. Rappoldi, G.L. Raselli, L. Ratti, V. Re, D. Rebuzzi, C. Riccardi, E. Riceputi, E. Romano, M. Rossella, R. Rossini, P. Salvini, R. Scaglioni, A. Tamigio, E. Torti, G. Traversi, F.P. Ucci, C. Vacchi, I. Vai, N. Valle, V. Vercesi, P. Vitulo, N. Zurlo

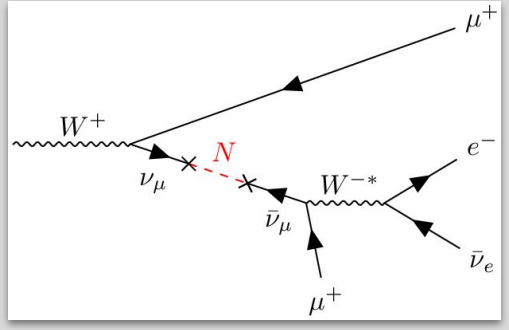
*) Lista non esaustiva

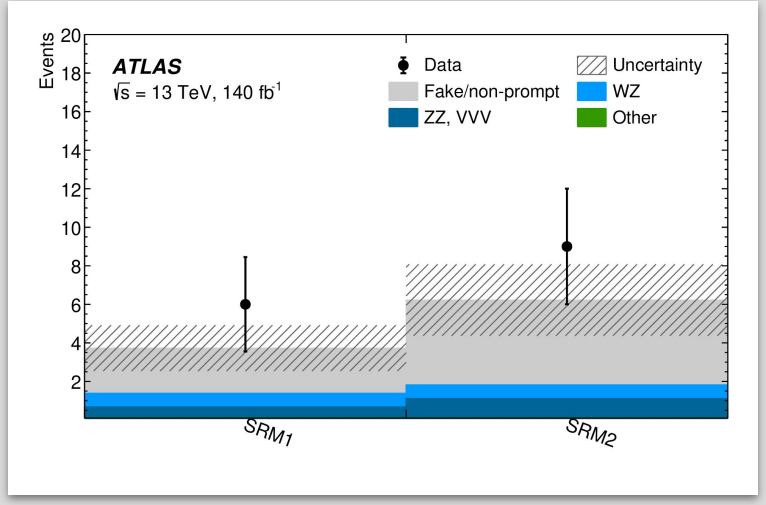
SLIDE DI BACKUP

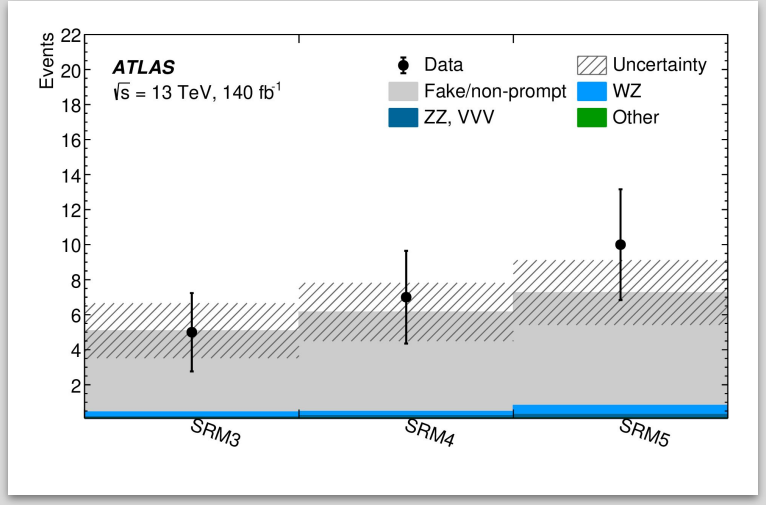
Search for Dark Matter @ ATLAS

arXiv 2508.20929

- *Heavy neutral lepton model*, predicting right-handed heavy Majorana neutrinos, with leptonic number violation
- Signature: 3 leptons, combinations of electrons and muons, and missing transverse momentum
- Observed data compatible with Standard Model prediction







Outreach activity

- Sharper - European researchers night
- MasterClass
- OCRA - Cosmic rays
- PID for high school teachers
- Lab2Go
- STAGE for high school students
- INFN game