The European Strategy for Particle Physics Town Hall Meeting

Ferrara – Nov. 6th 2024

European Strategy for Particle Physics

- The **European Strategy for Particle Physics** is a comprehensive framework coordinated by CERN Council to set the priorities and future directions for particle physics research in Europe. It aims at guiding scientific, technological, and financial decisions in particle physics, in Europe, but not only: it impacts on a global scale due to the international collaboration and to the impact of CERN/Europe on the fundamental research worldwide

- This process, typically carried out every 7-8 years, is based on an extensive consultations with the scientific community, stakeholders, and relevant institutions to ensure that the strategy reflects the latest scientific and technological advancements and addresses emerging challenges

https://europeanstrategyupdate.web.cern.ch/welcome

Timeline for the update of the European Strategy for Particle Physics

Steps of the ESPP update process

1. Mandate by the CERN Council:

- The update process begins when the CERN Council issues a **mandate to review and update the current strategy**. This mandate outlines the scope, goals, and timeline for the update. ✓

2. Community Involvement and Call for Input:

- A **public call for input is issued**, inviting contributions from the global particle physics community, including researchers, institutions, and national funding agencies. This step ensures that a wide range of perspectives and ideas are considered. ✓

3. Establishment of the Physics Preparatory Group (PPG):

- A **Physics Preparatory Group (PPG)** is formed, consisting of experts from the field. This group is responsible for collecting input, organizing discussions, and preparing a draft of the updated strategy. The PPG typically includes representatives from CERN, member states, and prominent physicists. ✓

4. Open Symposium:

- An **Open Symposium is held**, gathering scientists and stakeholders to discuss the input received and the key scientific questions that the updated strategy should address. This symposium serves as a platform for debate on the future direction of the field, including potential projects, experiments, and technologies.

23 - 27 June 2025 Venezia

5. Drafting the Strategy Update:

1. Based on the discussions and input, the **PPG drafts the updated strategy**. This draft, **the Briefing Book**, outlines the recommended scientific priorities, technological developments, and necessary investments for the coming years.

6. Submit the European Strategy Update recommendations to the CERN Council :

- The **Briefing Book is reviewed by the European Strategy Group** (ESG), which includes representatives from CERN, member states, and observer states. Additional feedback is sought to refine and adjust the recommendations. A final document based is issued by the ESG to the CERN Council

Mandato del CERN Council all'European Strategy Group (ESG)

From CERN/SPC/1239/Rev.2

The ESG should take into consideration:

- **the input of the particle physics community;**
- the status of implementation of the 2020 Strategy update;
- the accomplishments over recent years, including the results from the LHC and other
- experiments and facilities worldwide, the progress in the construction of the High- Luminosity LHC, the outcome of the Future Circular Collider Feasibility Study, and recent technological developments in accelerator, detector and computing;
- the international landscape of the field

Input alla ESPP e ”Briefing Book”

- To inform the Strategy update, the ESG calls upon the particle-physics community across universities, laboratories and national institutes to provide **input to the process** in various forms and at various stages

- An Open Symposium, at which the community will be invited to debate scientific input into the Strategy update, will take place on 23 - 27 June 2025 in Venice

- A “Briefing Book” based on the input and discussions will then be prepared by the **Physics Preparatory Group (PPG, established by the Council in September 2024).** The Briefing Book will be submitted to the ESG for consideration during a five-day-long drafting session which is scheduled to take place from 1 to 5 December 2025

from Karl Jakobs
July ECFA meeting

Baseline and alternative scenarios

- In this Strategy Update process, we must converge on a preferred option for the next collider at CERN plus alternative options (prioritised)
- This may imply as well strong focus on certain R&D lines
- It will provide the basis for a decision on construction of the next major collider at CERN by Council in 2027/28
- Baseline – justified by 2020 Strategy: FCC integrated programme (FCC-ee followed by a hadron collider of at least 100 TeV)
- Possible alternative scenarios (for next collider, following the HL-LHC):
  - Realisation of a lower-energy hadron collider (50 – 80 TeV) on an earlier timescale (2050 – 2055)
  - Linear Collider at CERN (CLIC, ...)
  - Muon Collider at CERN
  - Further exploitation of the LHC physics programme, eventually with the addition of e-h collisions
- Non-exhaustive list, other scenarios may come up and be proposed by the community

Come possiamo dare input alla ESPP?

- Essenzialmente in due modi:
  - Come comunità (sperimentali e teoriche), ovvero come partecipanti a progetti di interesse → preparazione del Briefing Book (e.g. FCC, Muon Collider, etc.). Possiamo contribuire agli input document che questi progetti sottometteranno con deadline 31 Marzo 2025
  - Come INFN → le comunità nazionali possono dare input sia per il 31 Marzo 2025, che in altre due fasi 26 Maggio 2025 (ovvero prima del simposio) che 14 Novembre 2025 (ovvero dopo la finalizzazione del Briefing Book e prima della stesura del documento di strategia da parte dell'ESG)

Come procederà l'INFN?

- *Fortunatamente, intuendo una accelerazione del processo relativo alla prossima Strategy, l'INFN si è mosso per tempo*

- Il workshop INFN del 6 e 7 Maggio ha anticipato ed è consistente con quanto presentato e discusso da Segretariato ESPP
  - Dobbiamo continuare il lavoro sia sul progetto baseline (FCC) che su progetti complementari o alternativi

- La preparazione dei documenti che si pensa di utilizzare come Input alla prossima ESPP è in linea con quanto richiesto o suggerito

Come procederà l'INFN?

- L'INFN ha istituito un **Gruppo di Lavoro (GdL)** composto dai Presidenti delle Commissioni Scientifiche Nazionali, dai Direttori dei Laboratori Nazionali, dal Coordinatore del MAC e da un rappresentante attività inerenti Calcolo (CNC). Il GdL e' guidato da uno steering group*

- **I Presidenti delle CSN**, oltre ad organizzare eventi interni, inviteranno i loro Coordinatori a avviare **presentazioni e discussioni locali sulle attività di interesse per la ESPP**, in accordo con i rispettivi Direttori. Le conclusioni che scaturiranno da questi incontri saranno condivise con gli stessi Presidenti

- **I Direttori dei Laboratori** avvieranno una discussione, presso la comunità scientifica dei Laboratori da loro diretti, che metta in risalto soprattutto i **contributi che essi possono offrire in base alle infrastrutture di ricerca disponibili presso i Laboratori stessi**

*Steering group : Marco Ciuchini (GE), Sandra Malvezzi (GE), Aleandro Nisati, Roberto Tenchini (Pres. CSN1), Cecilia Borca (Rappresentate ECR)

Come procederà l'INFN?

- **I Presidenti delle CSN e i Direttori dei Laboratori dovranno produrre un documento** da inviare allo Steering Group INFN; esso sintetizzerà i risultati del processo all'interno delle CSN e dei Lab e potrà eventualmente essere sottomesso come input alla Strategy

- **Il Coordinatore del MAC** curerà la preparazione di un **documento che raccolga in modo omogeneo gli studi di macchine acceleratrici svolti dall'INFN** e che sono stati finanziati dalla Giunta Esecutiva con fondi dedicati per contribuire allo sviluppo delle raccomandazioni European Strategy 2020

- **Il Rappresentante Calcolo** curerà la preparazione di un documento che raccolga in modo omogeneo gli studi degli aspetti legati al calcolo per i progetti futuri

Come procederà l'INFN?

- Sottometteremo entro il 31 Marzo 2025 i nostri documenti di Input. Il documento principale lo vorremmo sottomette insieme a tutti gli altri. Il Management INFN valuterà se sarà necessario un aggiornamento da parte nostra, da sottomettere dopo il Briefing Book e prima della Drafting Session

- Riunioni svolte e previste dello Steering con il GdL, previsto anche un evento pubblico finale il 4 Febbraio 2025 a Milano – da confermare!
  - Possibili riunioni anche dopo il Simposio e prima della riunione dell' ESG

Today’s meeting

14:00 → 14:12 **Introduction to the ESPP**

Speaker: Gianluigi Cibinetto (Istituto Nazionale di Fisica Nucleare)

20241106_ESPP_FE...

14:12 → 14:34 **Verso la European Strategy for Particle Physics - CSN4 a Ferrara**

Speaker: Massimiliano Lattanzi (Istituto Nazionale di Fisica Nucleare)

14:34 → 14:46 **Opportunities of the LHCb upgrade**

Speaker: Giovanni Cavallero (Istituto Nazionale di Fisica Nucleare)

LHCbFuture.pdf

14:46 → 14:58 **The Future Circular Collider**

Speaker: Giulio Mezzadri (Istituto Nazionale di Fisica Nucleare)

FCC_a_Fe_v1.pdf

14:58 → 15:10 **Future Accelerators for ESPP: FCC-ee & Muon Collider &....**

Speaker: LAURA BANDIERA (Istituto Nazionale di Fisica Nucleare)

EUStrategy-Acceler...

16:00 → 16:12 **Next-generation storage rings for EDM**

Speaker: Paolo Lenisa (Istituto Nazionale di Fisica Nucleare)

16:12 → 16:24 **Probing Particle Physics with CMB-S4**

Speaker: Martina Gerbino (Istituto Nazionale di Fisica Nucleare)

Particle Physics con...

16:24 → 16:36 **Neutrino physics with opaque scintillators**

Speaker: Fabio Mantovani (Istituto Nazionale di Fisica Nucleare)

16:36 → 16:48 **Detector R&D for future experiments**

Speaker: Massimiliano Fiorini (INFN and University of Ferrara)

2024_11_05 - Detec...

16:48 → 17:28 **Round Table**

17:28 → 18:08 **Early Career Researchers Discussion**

Speakers: Marco Scodeggio (Istituto Nazionale di Fisica Nucleare), Nicola Canale

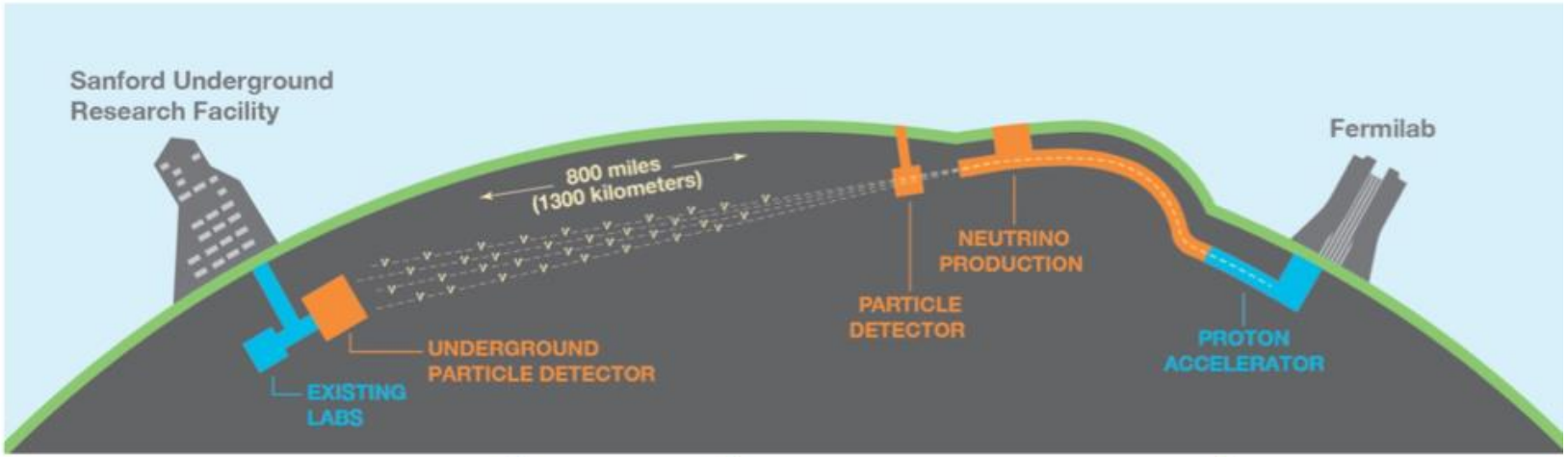
ECR INFN Ferrara.pdf

In addition….

Future Neutrino Experiments @accelerator. Already in the ESPP

DUNE:

- > 2 MW beam
- Liquid-Argon TimeProjection Chamber (LArTPC) technology
- ≥ 40 kton far detector fiducial mass
- First physics in ~2029

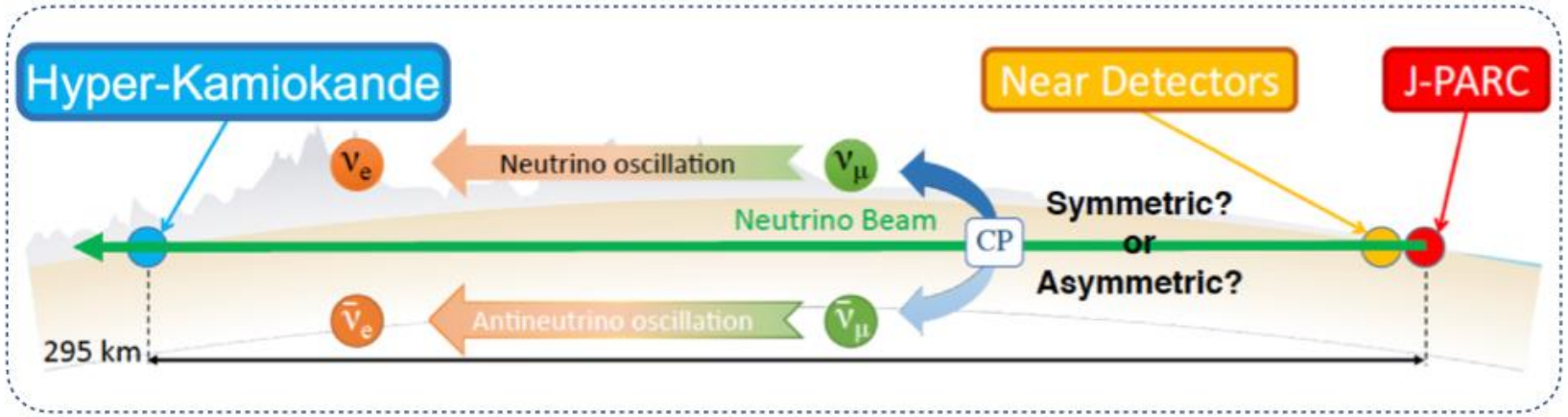


Large degree of complementarity:

	matter effects	energy spectrum	detection systematics
DUNE	large	wide band, higher energy	LArTPC
Hyper-Kamiokande	small	narrow band, lower energy	Water Cherenkov

Hyper-Kamiokande:

- 1.3 MW beam
- Water Cherenkov far detector
- 190 kton far detector fiducial mass
- First physics in ~2027



From T. Nakadaira's talk at ICHEP 2024

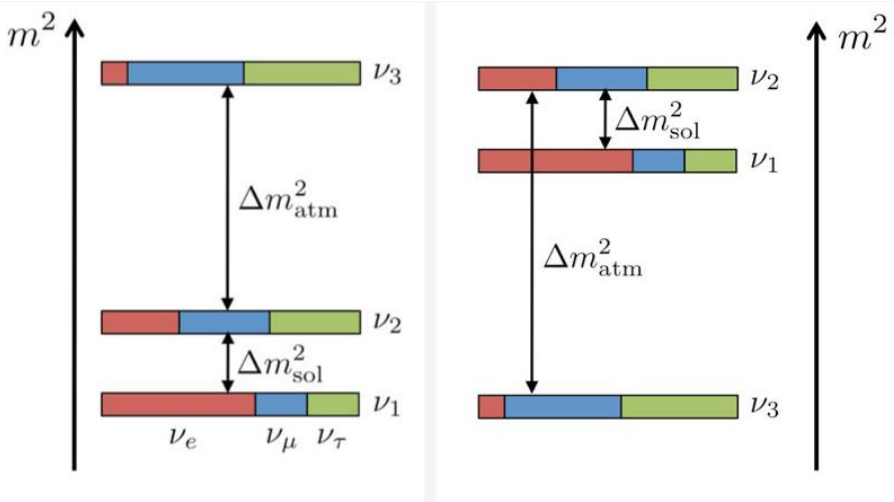
From J. Pedro Ochoa-Ricoux @ICHEP2024

- Mass ordering:
  - DUNE: 5σ between 1 and 3 years (depending on how kind nature is)
- Precision measurement of oscillation parameters:
  - Long term high precision for Δm^2_{31} and θ_{13} sensitive to new physics in comparison with reactor measurements
- CP violation:
  - Long term establishment of CP violation at 3σ over 75% of δ_{CP} values
  - Similar 10-year precision of ~6-18° in δ_{CP} in both experiments

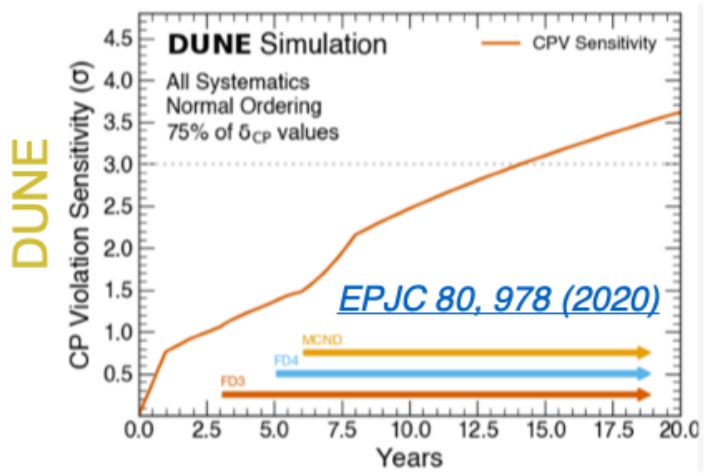
Pontecorvo-Maki-Nakagawa-Sakata (PMNS) matrix U

$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \begin{pmatrix}1 & 0 & 0\\ 0 & \cos\theta_{23} & \sin\theta_{23}\\ 0 & -\sin\theta_{23} & \cos\theta_{23}\end{pmatrix}\begin{pmatrix}\cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta_{CP}}\\ 0 & 1 & 0\\ -\sin\theta_{13}e^{i\delta_{CP}} & 0 & \cos\theta_{13}\end{pmatrix}\begin{pmatrix}\cos\theta_{12} & \sin\theta_{12} & 0\\ -\sin\theta_{12} & \cos\theta_{12} & 0\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

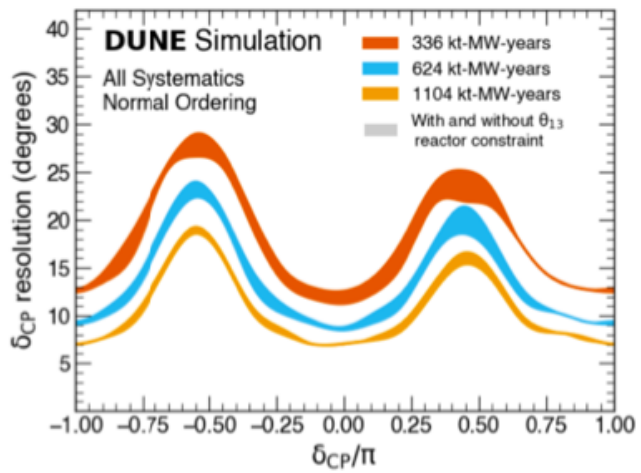
Atmospheric (+Accelerator) | Reactor (+Accelerator) | Solar (+Reactor)



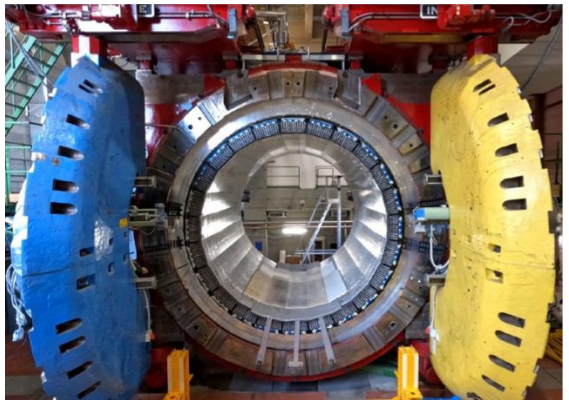
CP violation sensitivity

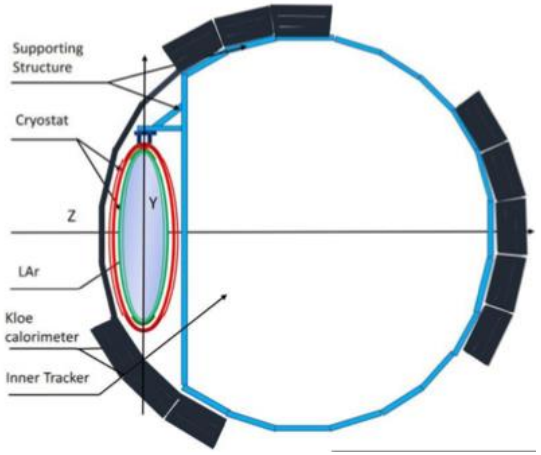


δ_{CP} resolution



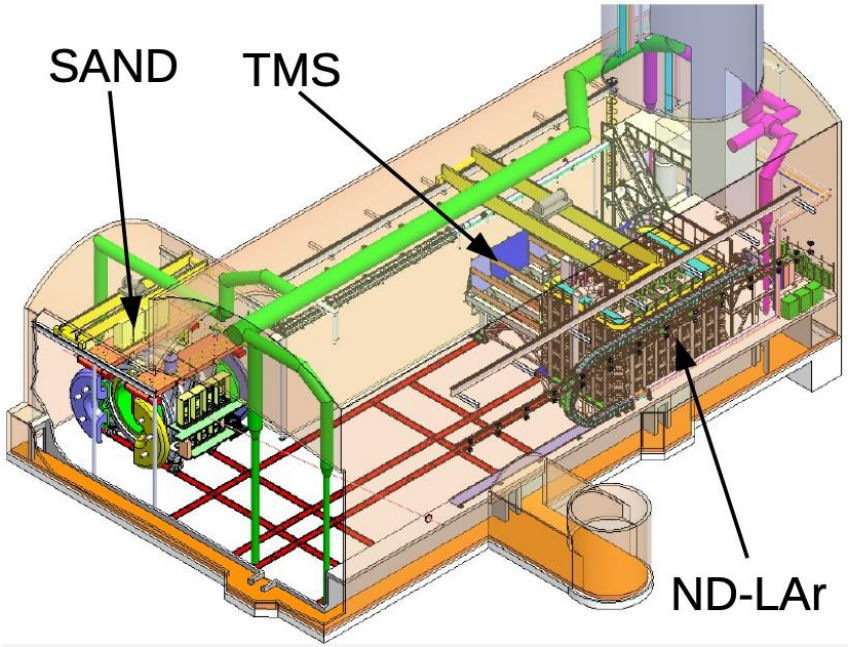
From J. Pedro Ochoa-Ricoux @ICHEP2024





- ND → SAND
  magnet + ECAL from KLOE
  - Tracker
  - GRAIN

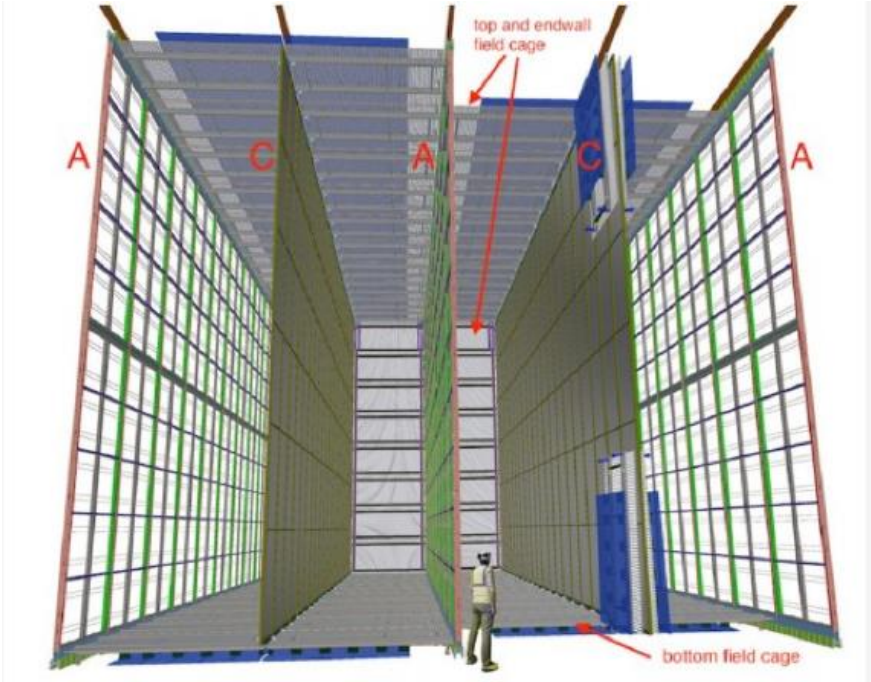
  - Monitor ν/ν on-axis spectra to detect beam variations on a weekly basis
  - ν_μ, ν_e on-axis flux measurement
  - Perform neutrino cross-section studies on different nuclear targets



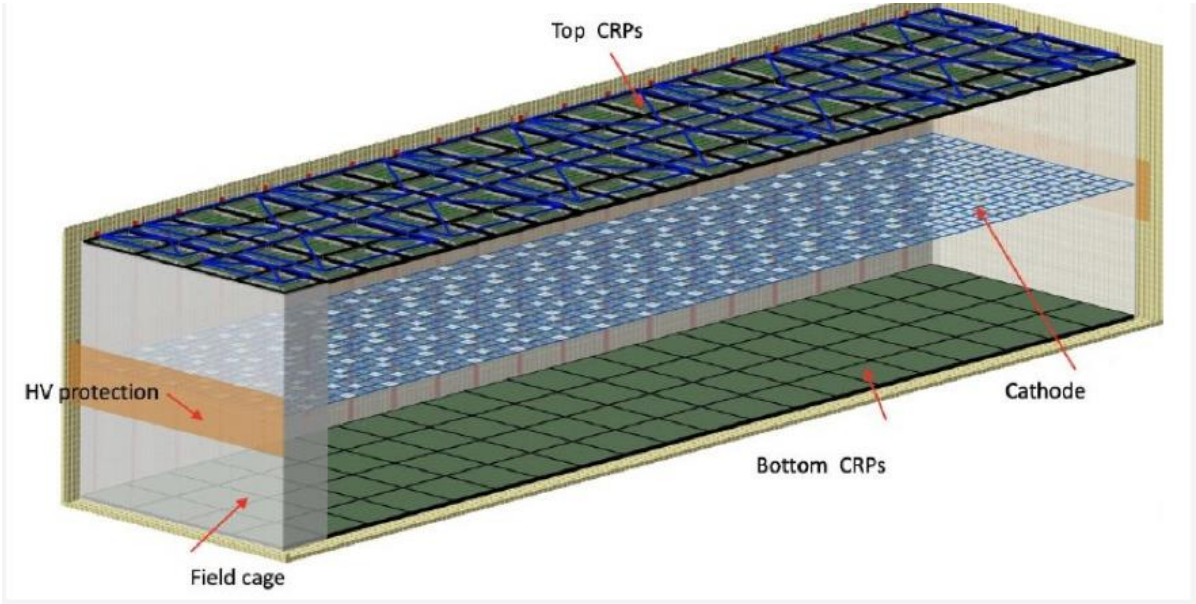
ECAL simulation/reconstruction + ND software integration

From Chris Marshall @Neutrino24

- FD-HD
  - 4 drift regions, wire readout planes
  - PDS



- FD-VD
  - 2 drift regions, central cathode
  - PDS

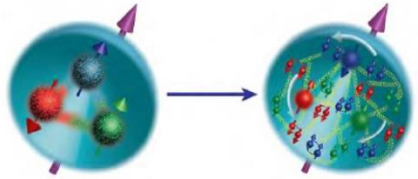


From Chris Marchall @Neutrino24

Electron Ion Collider

- Variable c.m. energy
- Polarized electron/ligh-ion beams
- High luminosity $10^{33\text{-}34}$ $cm^{-2}s^{-1}$

Goal: Be ready for Physics in early '30s

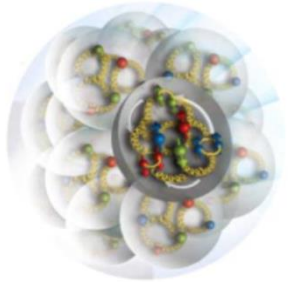


Origin of spin:

How does the spin-1/2 of the nucleon arise from the spin of quarks, gluons and their orbital angular momenta?

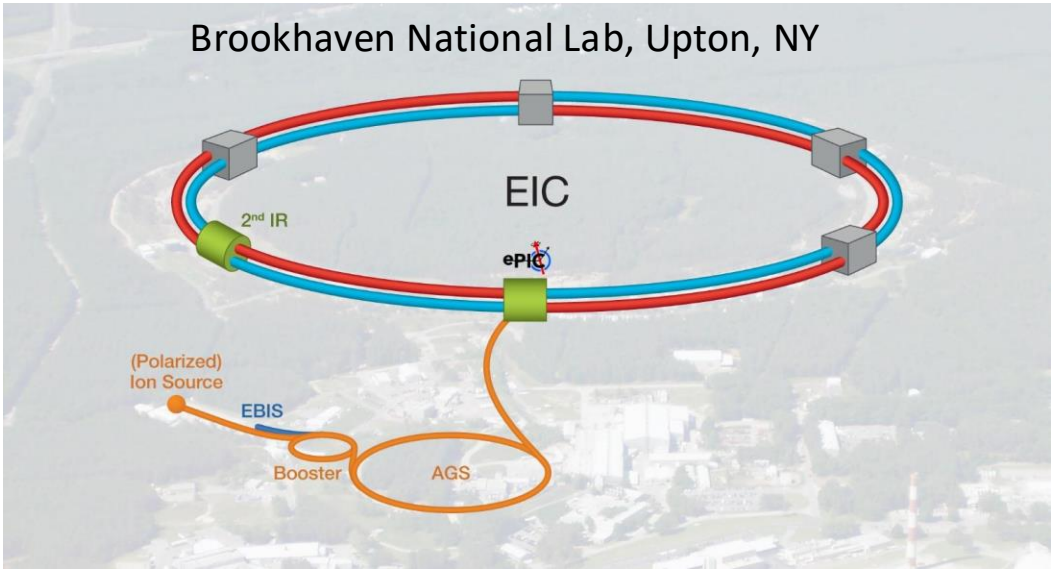
Origin of mass:

How do massless gluons make up for most of the nucleon mass?



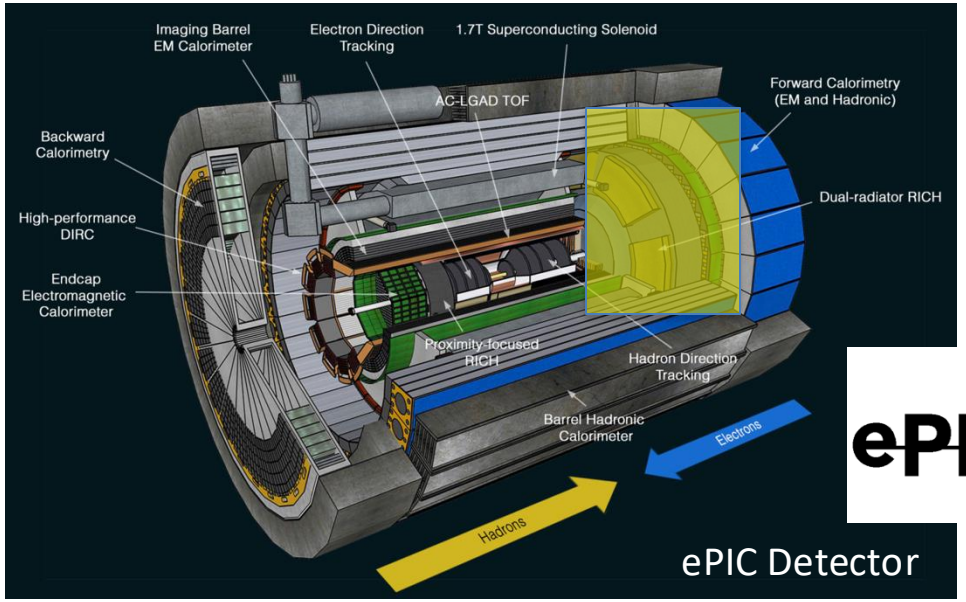
Gluons in nuclei:

Does gluon density saturate at high energy giving rise to a new regime of matter?



EIC User Group (~ 1500 members)

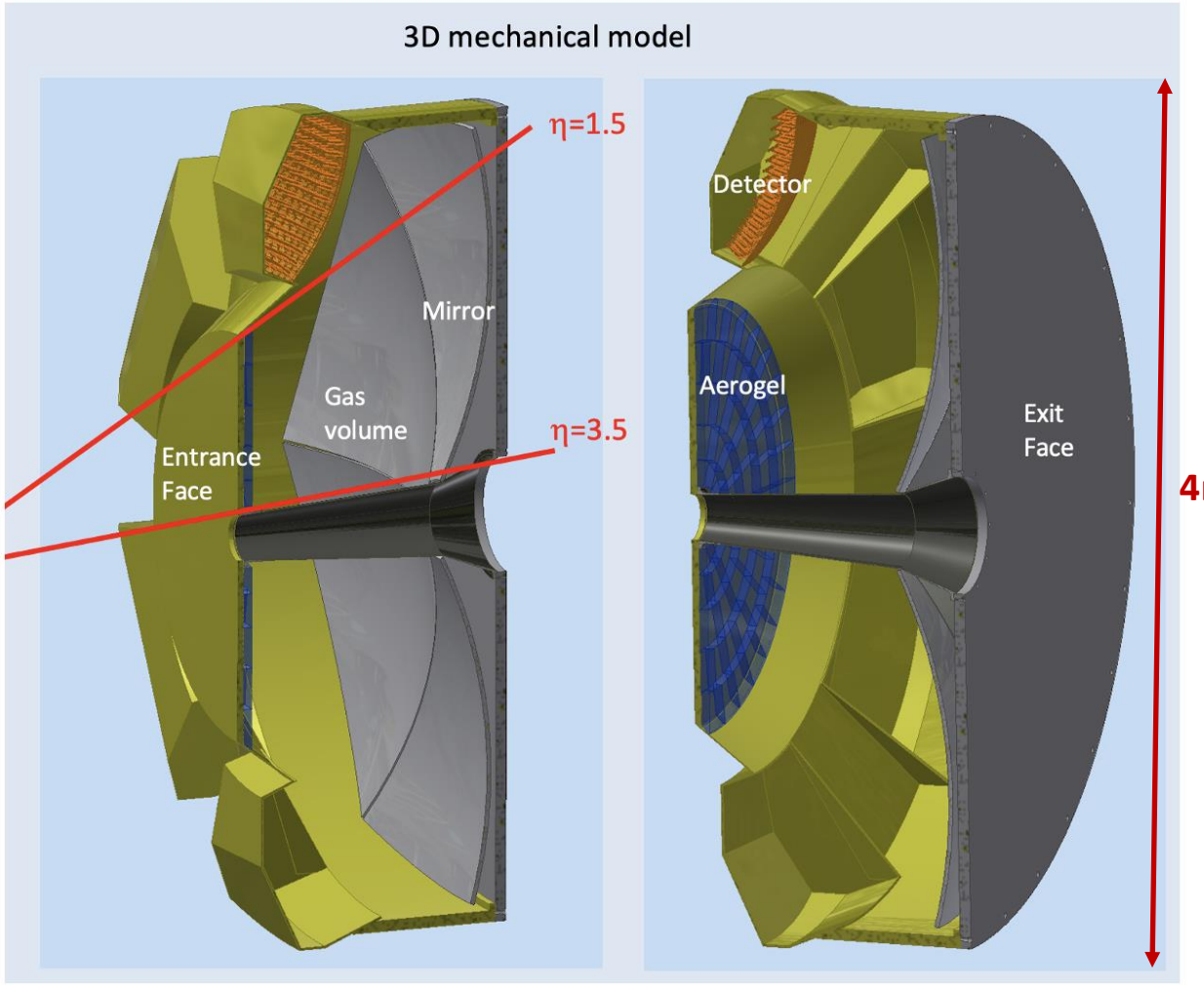
Forward PID @ ePIC



Dual-radiator Ring-imaging Cherenkov Detector (dRICH)

Essential to access flavor information

International joint-venture effort under INFN leadership



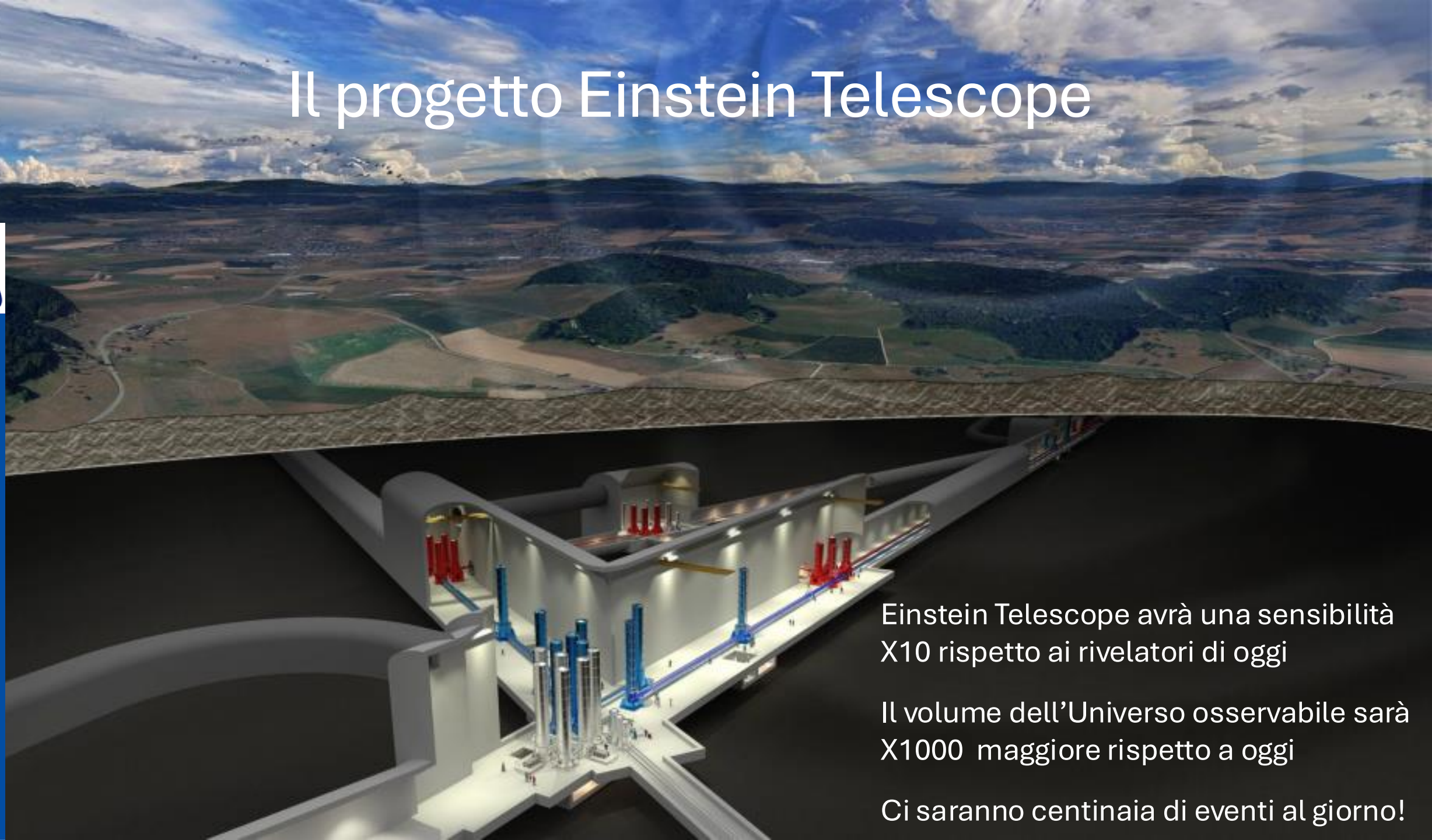
dRICH Features:

Extended 3-50 GeV/c momentum range --> Dual radiator
Single-photon detection in high Bfield --> SiPM
Limited space --> Compact optics with curved detector

Ferrara responsibilities:

dRICH Coordination (M. Contalbrigo)
dRICH Machanics (A. Saputi)

Il progetto Einstein Telescope



Einstein Telescope avrà una sensibilità X10 rispetto ai rivelatori di oggi

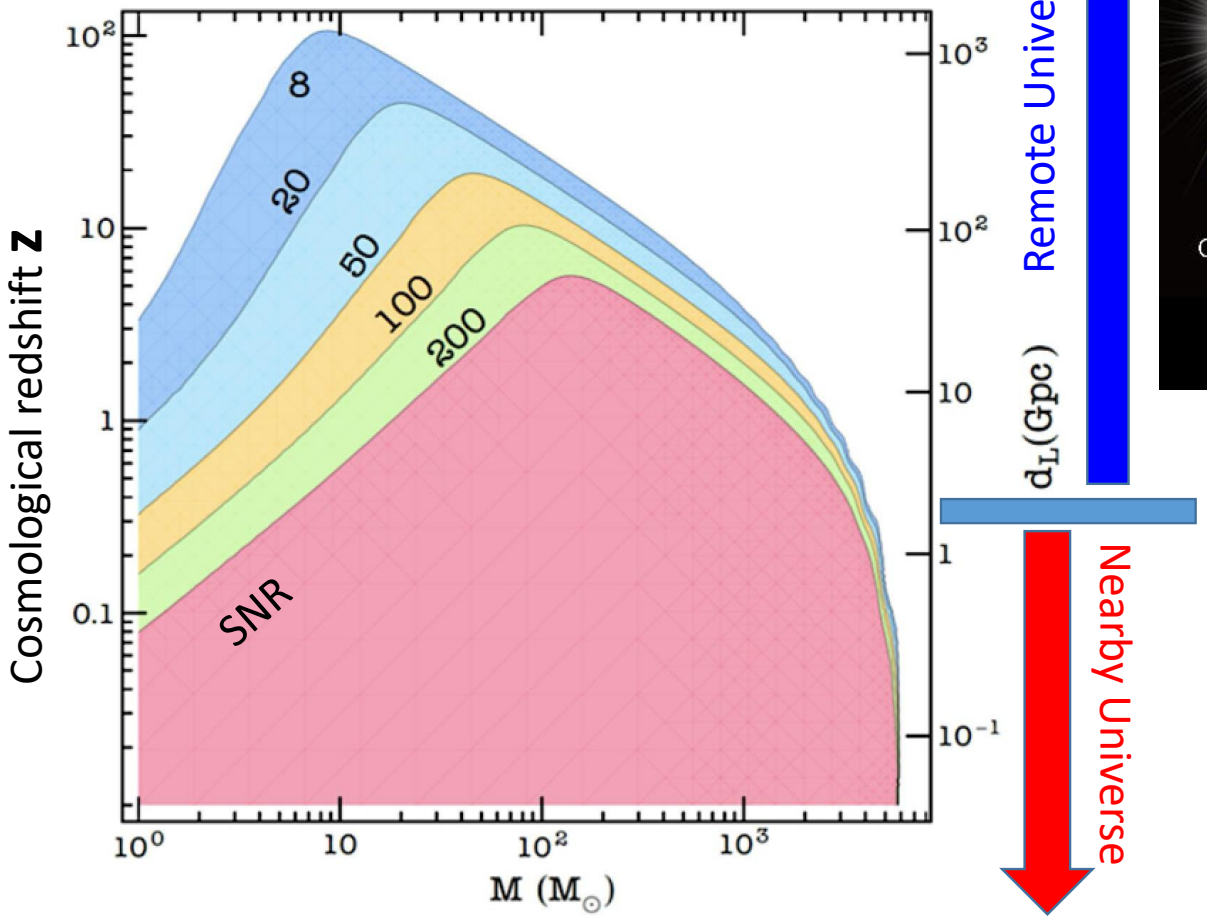
Il volume dell'Universo osservabile sarà X1000 maggiore rispetto a oggi

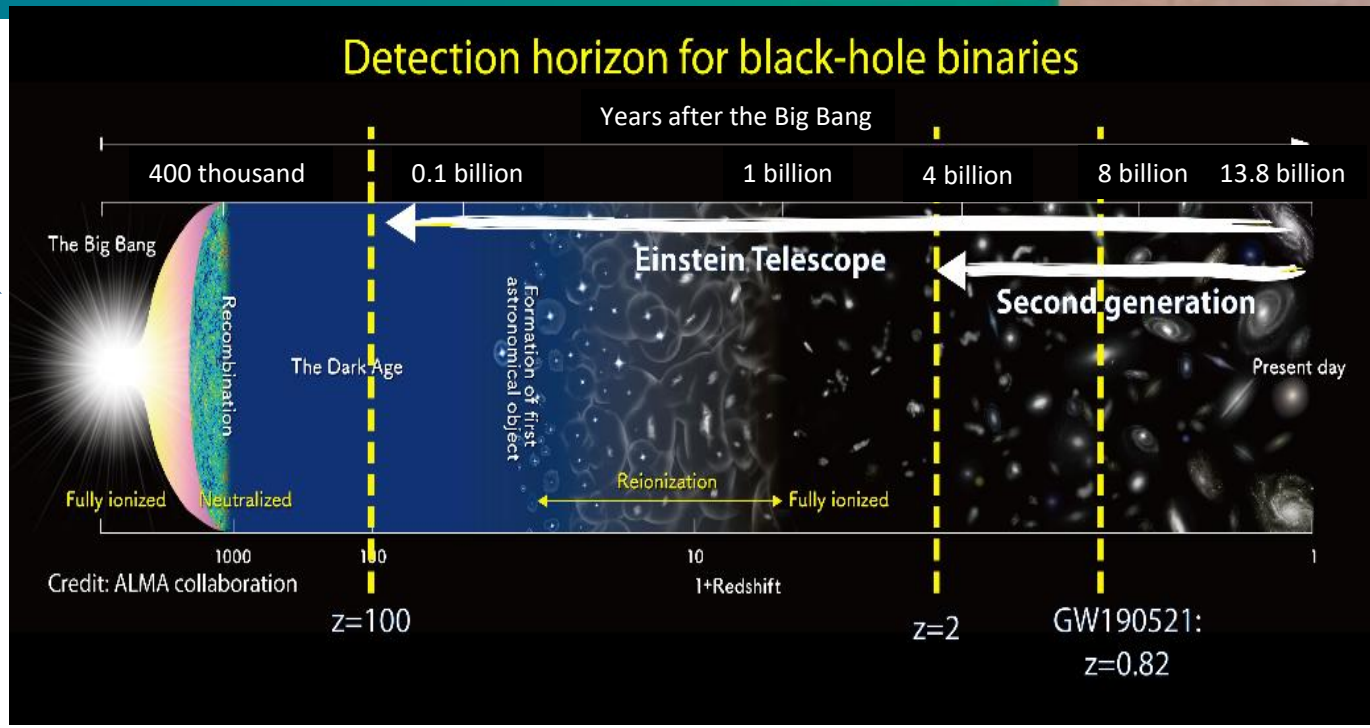
Ci saranno centinaia di eventi al giorno!

INFN Istituto Nazionale di Fisica Nucleare
Università degli Studi di Ferrara
Italiadomani
Ministero dell'Università e della Ricerca
Finanziato dall'Unione europea NextGenerationEU

ET Science in a nutshell

- ET is the pioneer project of the 3G GW observatory in Europe
- Few words on ET science hereafter





The combination of

- distances and masses explored
- number of detections
- detections with very high SNR

will provide a wealth of data expected to generate **revolutions in astrophysics, cosmology and fundamental physics**

ET Science in a nutshell

ASTROPHYSICS

- **Black hole properties**
  - origin (stellar vs. primordial)
  - evolution, demography
- **Neutron star properties**
  - interior structure (QCD at ultra-high densities, exotic states of matter)
  - demography
- **Multi-band and -messenger astronomy**
  - joint GW/EM observations (GRB, kilonova,...)
  - multiband GW detection (LISA)
  - neutrinos
- **Detection of new astrophysical sources**
  - core collapse supernovae
  - isolated neutron stars
  - stochastic background of astrophysical origin

FUNDAMENTAL PHYSICS AND COSMOLOGY

- **The nature of compact objects**
  - near-horizon physics
  - tests of no-hair theorem
  - exotic compact objects
- **Tests of General Relativity**
  - post-Newtonian expansion
  - strong field regime
- **Dark matter**
  - primordial BHs
  - axion clouds, dark matter accreting on compact objects
- **Dark energy and modifications of gravity on cosmological scales**
  - dark energy equation of state
  - modified GW propagation
- **Stochastic backgrounds of cosmological origin**
  - inflation, phase transitions, cosmic strings

Ferrara Science and Technology target in ET

Experimental component:

Guido Zavattini (Staff-Ass. Prof.)	Ellipticity measurements; high finessse F.P.;
Aurelie Mailliet (Post-Doc)	Pulsed lasers; Sagnac interferometry;
Andrea Mazzolari (Staff-Tenure track)	Silicon for channeling; surface treatment and stress simulation;
Federico Della Valle (Staff-Univ. Res.)	Ellipticity measurements; high finessse F.P.;
Emilio Mariotti (Staff-Ass.Prof.)	Ellipticity measurements; high finessse F.P.;
Giovanni Di Domenico (Staff-Ass. Prof)	Ellipiticity measurements

- measure the static birefringence maps of various substrate materials
- measure the static birefringence maps of reflective coatings
- measure the birefringence noise of high finesse reflective coatings

Analysis/theoretical component:

Michal Bejger (Staff-INFN)
Matteo Scialpi (PhD)

- Application of physically-informed neural network to gravitational waves detection and parameter estimation for planned sensitivity curves. Application of machine learning to simulation and analysis of birefringence measurements.

Mattia Bulla (Staff-Tenure Track)

- Modelling of electromagnetic signals applied to neutron star mergers selected in the gravitational wave analysis. Assessing the impact of birefringence measurements on multi-messenger astronomy in the ET era

Alessandro Drago (Staff-Full Prof.)
Giuseppe Pagliara (Staff-Ass. Prof.),
Mirco Guerrini (PhD)

- Study of the equations of state of compact object and modelling of merger ringdown signals