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# Future plans and strategic timeline

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XUNTA DE GALICIA

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## 1. Quick reminder:

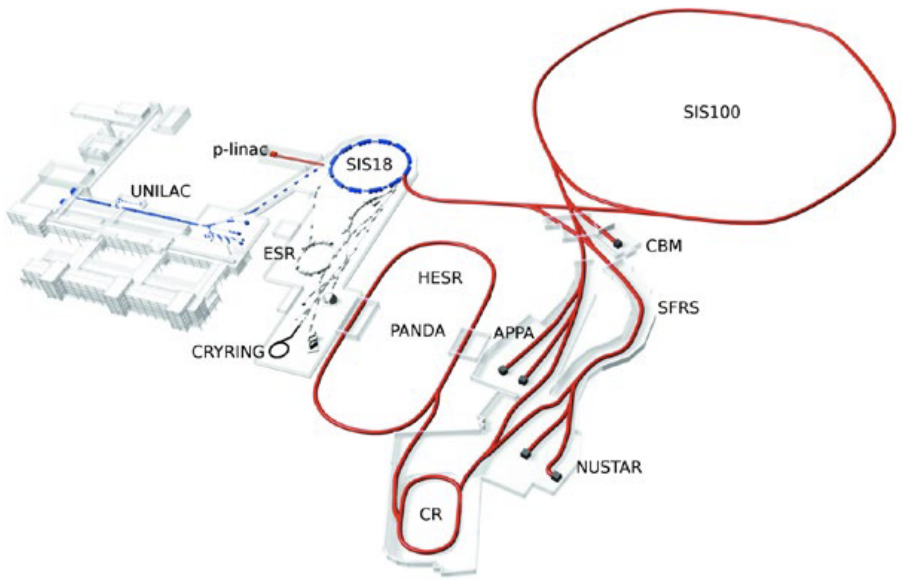
- NuPECC LRP.
- APPEC LRP.
- Status for Particle Physics.
- CERN schedule.

## 2. Some new considerations:

- Participation in the 2020 ESPP update.
- DUNE.
- GWs.
- Instrumentation.

## 3. To discuss: IGFAE.

# NuPECC LRP 2017:

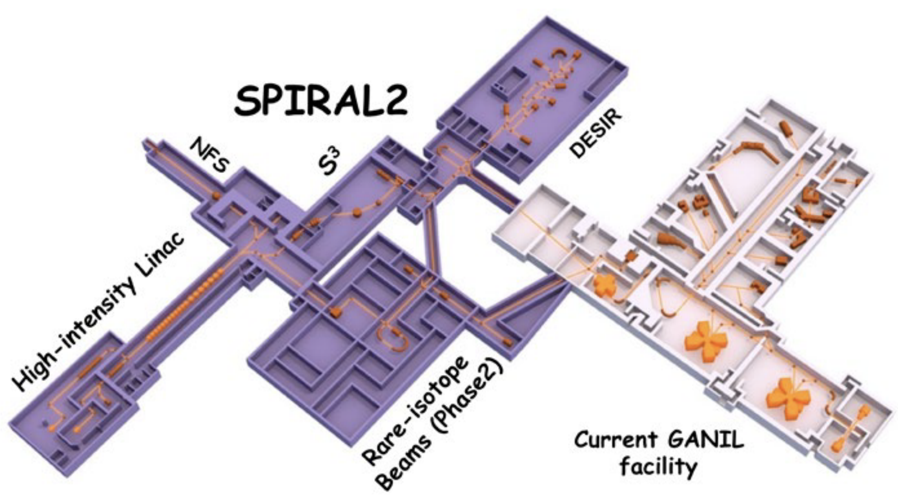


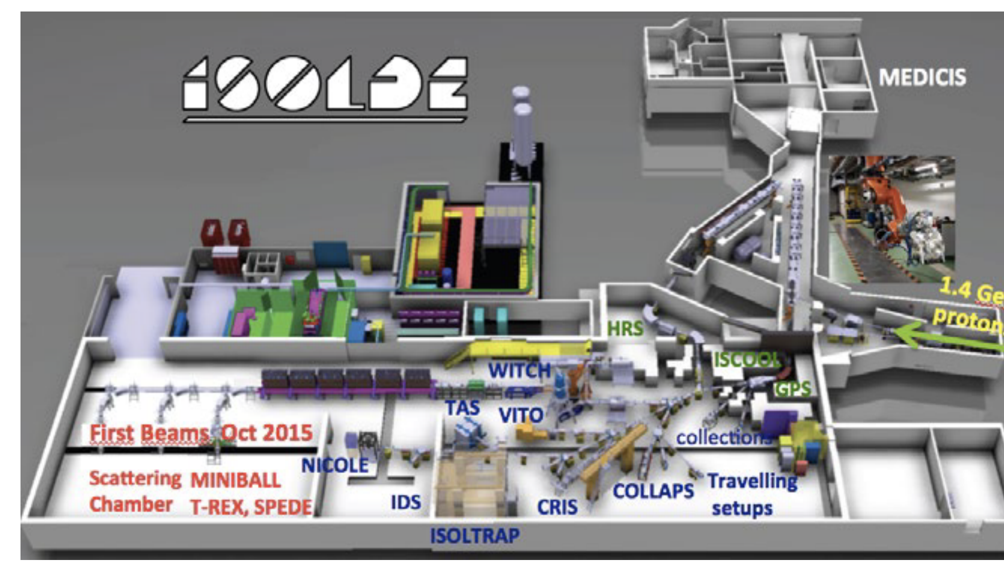

- FAIR development is a top priority, start ~ 2025.

The baseline FAIR research programme includes 14 initial experiments, which form the four scientific pillars of FAIR (in alphabetical order):

- APPA: Atomic and plasma physics, and applied sciences in the bio, medical, and materials sciences.
- CBM: Physics of hadrons and quarks in compressed nuclear matter, hypernuclear matter.
- NuSTAR: Structure of nuclei, physics of nuclear reactions, nuclear astrophysics and radioactive ion beams (RIBs).
- PANDA: Hadron structure and spectroscopy, strange and charm physics, hypernuclear physics with antiproton beams.

- Support GANIL-SPIRAL2 and CERN HIE-ISOLDE (~2021).




- Strong emphasis in applications.

- *Promote the access to large-scale facilities for applications, preserve and support small-size and dedicated installations.*

- Support to HL-LHC for ions.

# APECC LRP 2017:

**Large-scale multi-messenger infrastructures**

To improve understanding of our Universe, APPEC identified as a very high priority those research infrastructures that exploit all confirmed high-energy 'messengers' (cosmic particles that can provide vital insights into the Universe and how it functions). These messengers include gamma rays, neutrinos, cosmic rays and gravitational waves. European coordination is essential to ensuring timely implementation of such infrastructures and enabling Europe to retain its scientific leadership in this field.

- High-energy gamma rays: HESS and MAGIC, Fermi, **CTA** ~ 2023.
- High-energy neutrinos: **KM2NeT** (~2020), IceCube-Gen2.
- High-energy cosmic rays: **AugerPrime** (~2019).
- Gravitational waves: **Einstein Telescope**, **LISA**.

**Synergies with astronomy, particle physics and cosmology**

To shed light on neutrino mixing and the neutrino mass hierarchy, APPEC is a long-term proponent of experiments using natural neutrinos from the Sun and from Earth's atmosphere as well as neutrinos from nuclear reactors and accelerators. Recognising the increasingly interdisciplinary reach of astroparticle physics, APPEC has broadened the scope of its roadmap to include explicitly two topics referred to in its 2008 science vison: the CMB and Dark Energy. These are flourishing fields of research, as demonstrated by Nobel Prizes awarded in 2006 and 2011. They not only complement core astroparticle physics topics but also yield stringent constraints on neutrino masses and on the role of neutrinos in the early Universe. So far in these recommendations, the focus has been on projects primarily funded by European astroparticle physics agencies. By contrast, for the three topics addressed in this subsection, the main funding is likely to come from US and Asian agencies or from the European particle physics and astronomy communities.

- Dark matter: large volume detectors **DARWIN and ARGO**.
- Neutrino mass and nature: direct and neutrinoless double-beta (NEXT), roadmap to be defined for 2020.

**Medium-scale Dark Matter and neutrino experiments**

APPEC considers as its core assets the diverse, often ultra-precise and invariably ingenious suite of medium-scale laboratory experiments targeted at the discovery of extremely rare processes. These include experiments to detect the scattering of Dark Matter particles and neutrinoless double-beta decay, and direct measurement of neutrino mass using single-beta decay. Collectively, these searches must be pursued to the level of discovery, unless prevented by an irreducible background or an unrealistically high demand for capital investment.

- Neutrino mixing and mass hierarchy: **DUNE**, HyperKamiokande, **JUNO**, ~2025.
- CMB: both satellite (Core) and ground-based developments.
- Dark energy: satellites like **Euclid**, ground-based installations in the US.

# Particle Physics:

• **Last European LRP in 2012 (next under discussion, to come in 2020)**: hadron-hadron → HL-LHC, lepton-lepton → ILC waiting for Japan (👎?), neutrinos → DUNE.

• **Since then**:
➜ **HL-LHC** approved (2017), to start ~ 2025;
➜ **DUNE** approved;
➜ Chinese proposal for CepC/SppC;
➜ US EIC in the 2015 DOE LRP, EU proposals for ep/eA (LHeC);
➜ FCC/HE-LHC proposal launched in 2014, 30-100 TeV pp collisions.
➜ **Non conclusive BSM evidence from the LHC which, together with the economic/political situation, put things in standby.**

# Particle Physics:

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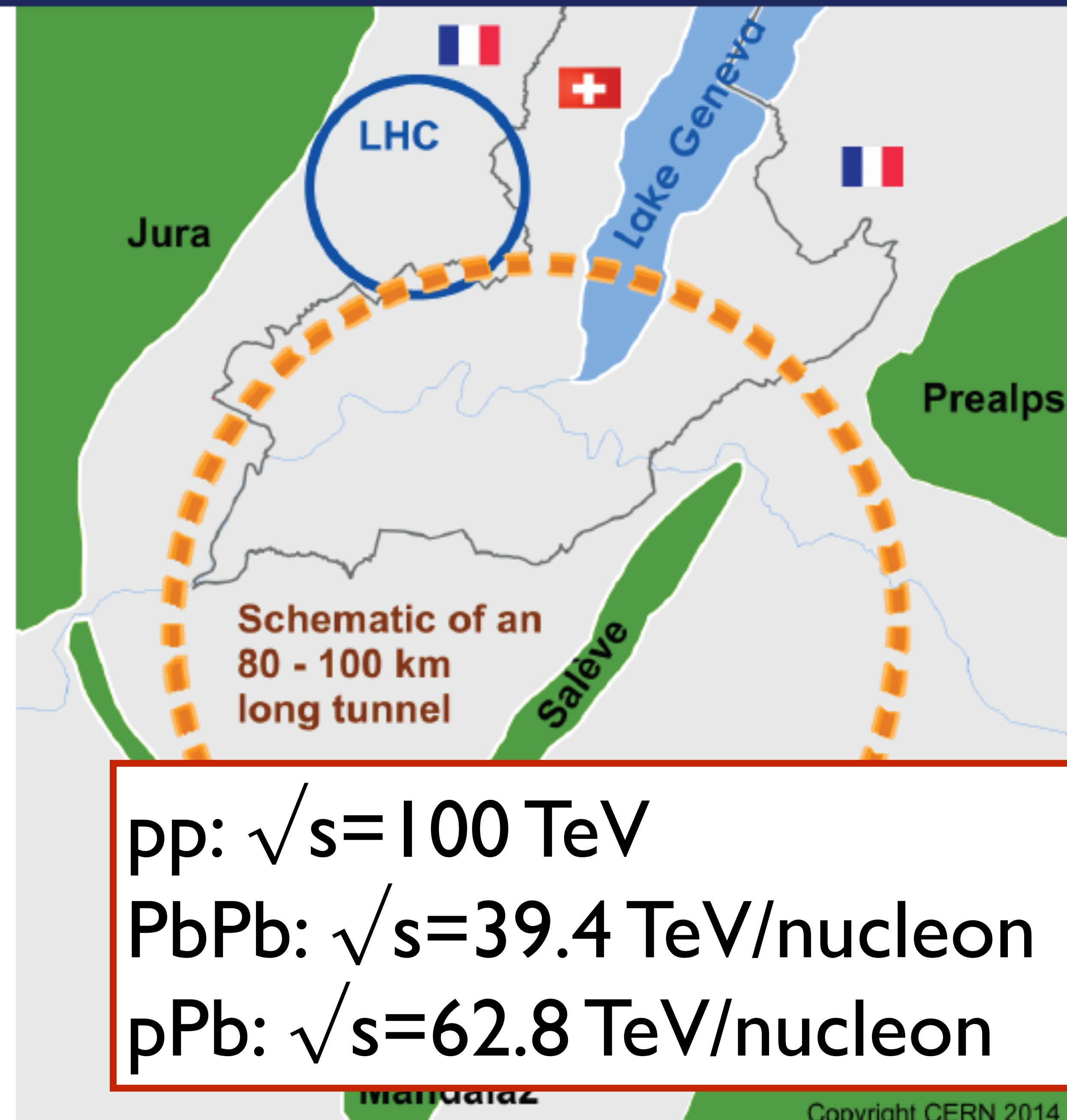
## Future Circular Collider Study - SCOPE
## CDR and cost review for the next ESU (2018)

**Forming an international collaboration to study:**

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km
~20 T ⇒ 100 TeV *pp* in 80 km

- ***e⁺e⁻* collider (*FCC-ee*) as** potential intermediate step
  120-350 GeV
- ***p-e* (*FCC-he*) option**
- **80-100 km infrastructure** in Geneva area




pp: $\sqrt{s}$=100 TeV
PbPb: $\sqrt{s}$=39.4 TeV/nucleon
pPb: $\sqrt{s}$=62.8 TeV/nucleon

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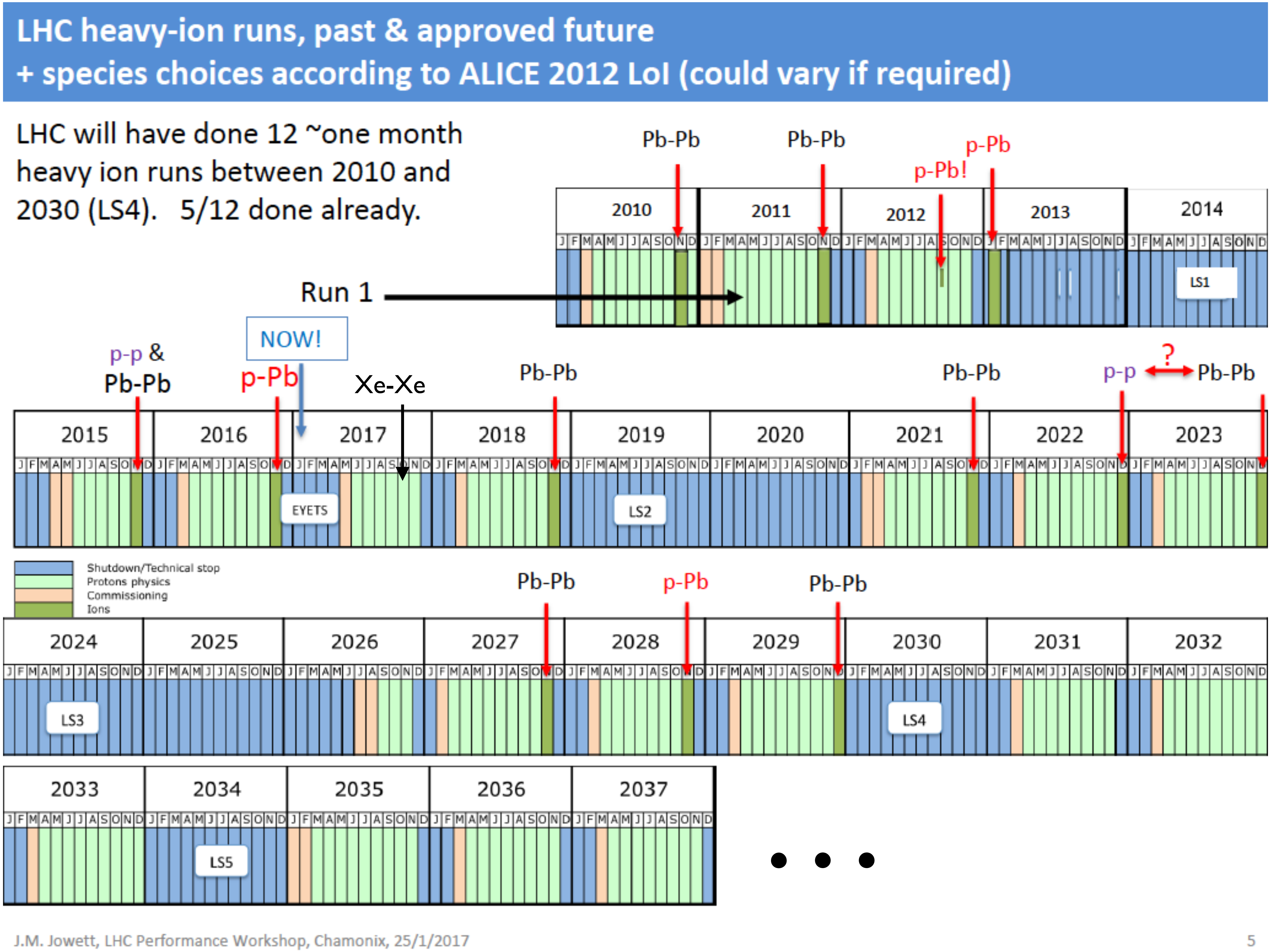
# CERN schedule:



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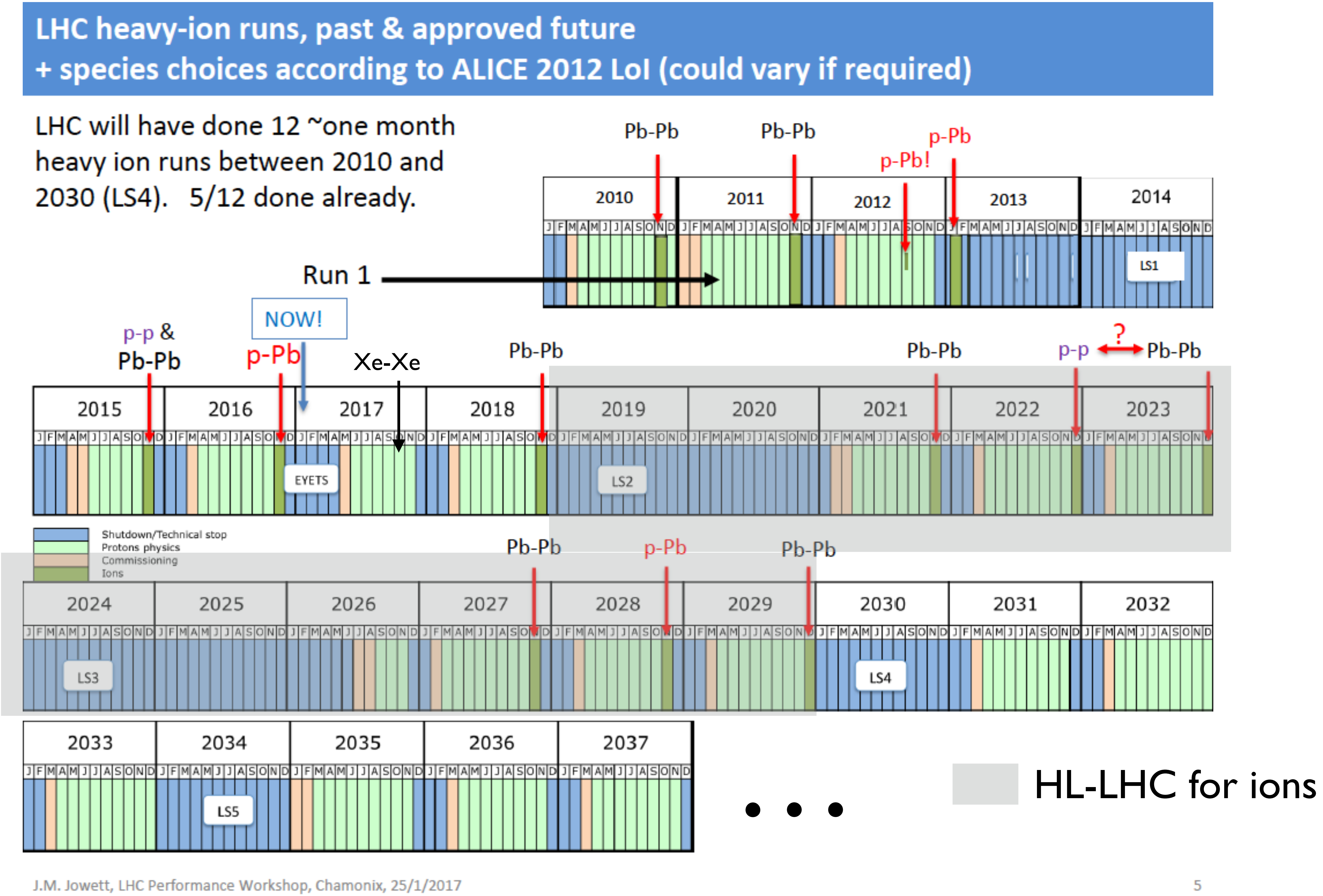
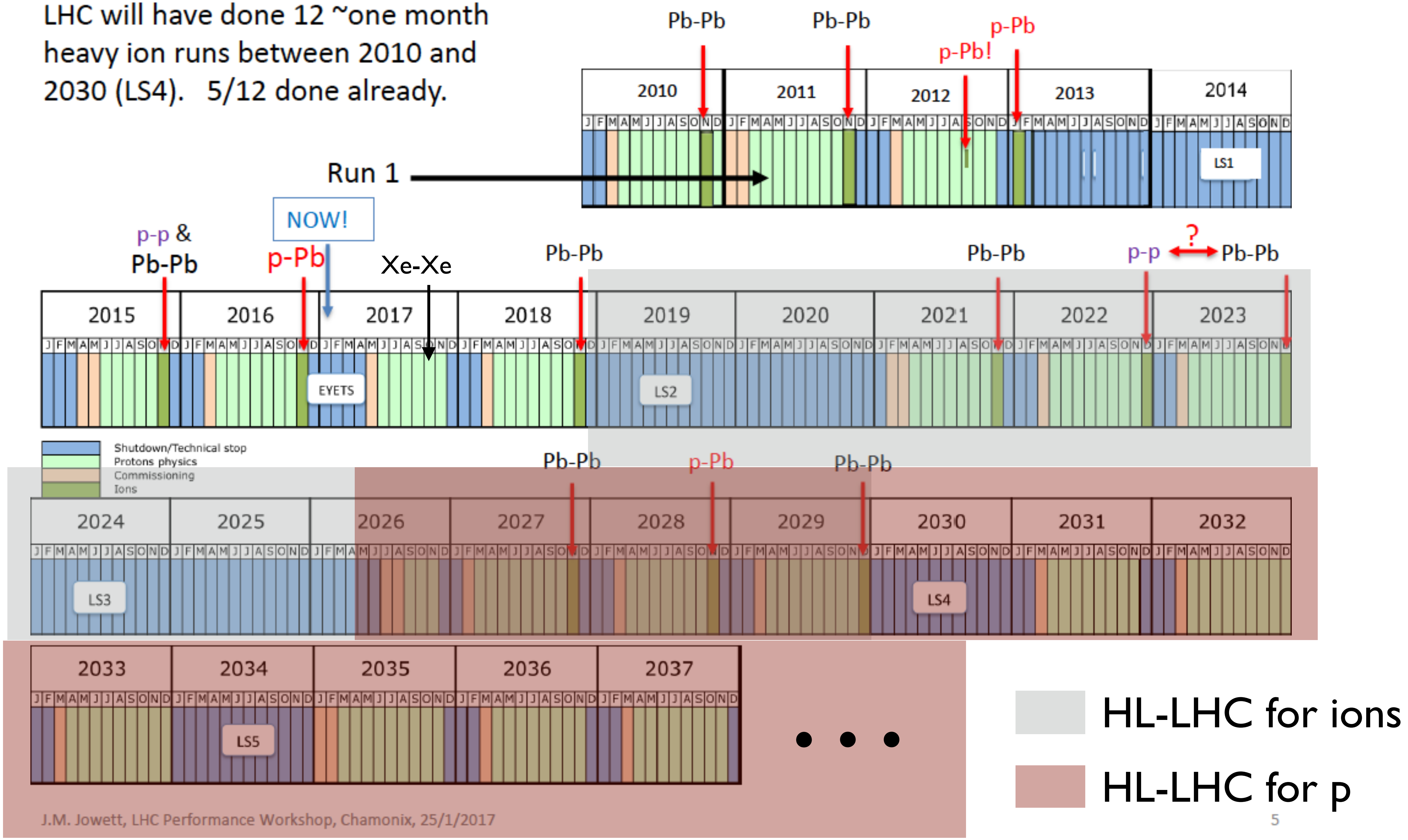


# CERN schedule:

**LHC heavy-ion runs, past & approved future**
**+ species choices according to ALICE 2012 LoI (could vary if required)**

LHC will have done 12 ~one month heavy ion runs between 2010 and 2030 (LS4). 5/12 done already.



# Participation in the 2020 ESPP update:

➜ 10 page documents:

- Fixed target experiments @ LHC: reviewers.
- QCD theory: contributors.
- DIS@LHC - LHeC and PERLE: contributors.
- HI@HL-LHC, LHCb, RD51,…?
- Spanish HEP community document: contributors.

➜ LHCb Upgrade 2 long input: chapter coordinators and contributors.

➜ RD51 long input: contributors.

➜ HL/HE-LHC Yellow Report:

- Heavy-ions @ LHC until 2030 and beyond: chapter coordinators and contributors.
- Flavour Physics: chapter coordinators and contributors.
- BSM Physics: chapter coordinators and editors.

➜ FCC books: (AA, eh) contribution to Volume 1 and FCC-hh/eh physics Volume 4.

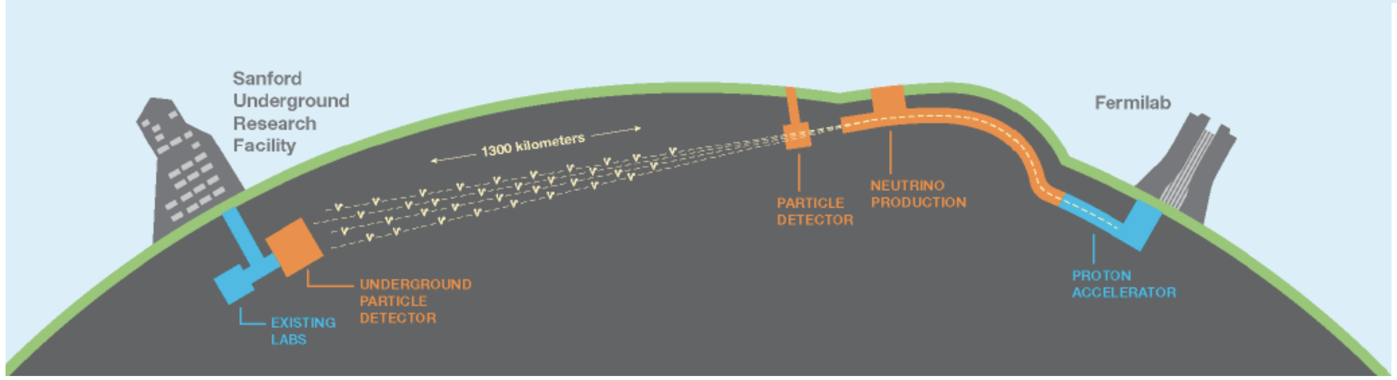
# DUNE:

The *Deep Underground Neutrino Experiment* is a next-generation long-baseline oscillation experiment between Fermilab (Illinois) and the Sanford Underground Research Facility (South Dakota) consisting of

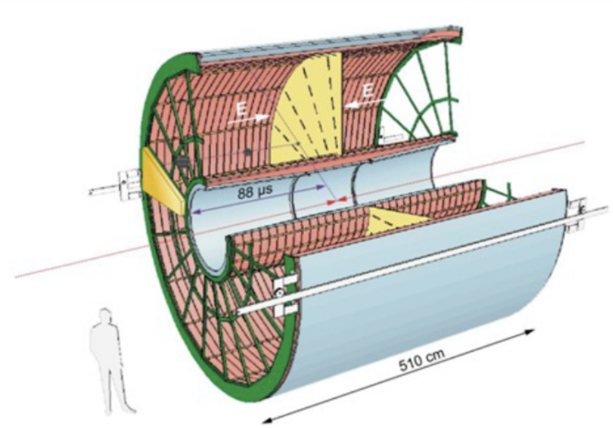
- a new MW-scale neutrino beamline (LBNF);
- a 4×10-kilotonne (fiducial) liquid argon far detector;
- a high-resolution, high-rate near detector.

The primary science program of DUNE includes:

- Long-baseline neutrino oscillations
  - Leptonic CP violation
  - Neutrino mass ordering
  - Precision test of the 3-neutrino mixing framework
- Nucleon decay
- Neutrino astrophysics (e.g. core-collapse supernovae)

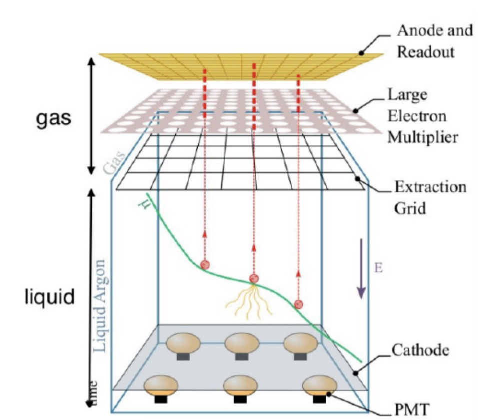



**DUNE NEAR DETECTOR**




The GArTPC has two functions: muon spectrometer for LArTPC and high-resolution standalone experiment with 1 tonne of target mass. The baseline design follows that of the ALICE TPC.

**DUAL-PHASE LArTPC**




Ionization electrons extracted to and amplified in gas phase. Charge readout by segmented (strips) anode plane. Single 12-m drift volume per TPC. Scintillation light collected by PMTs.

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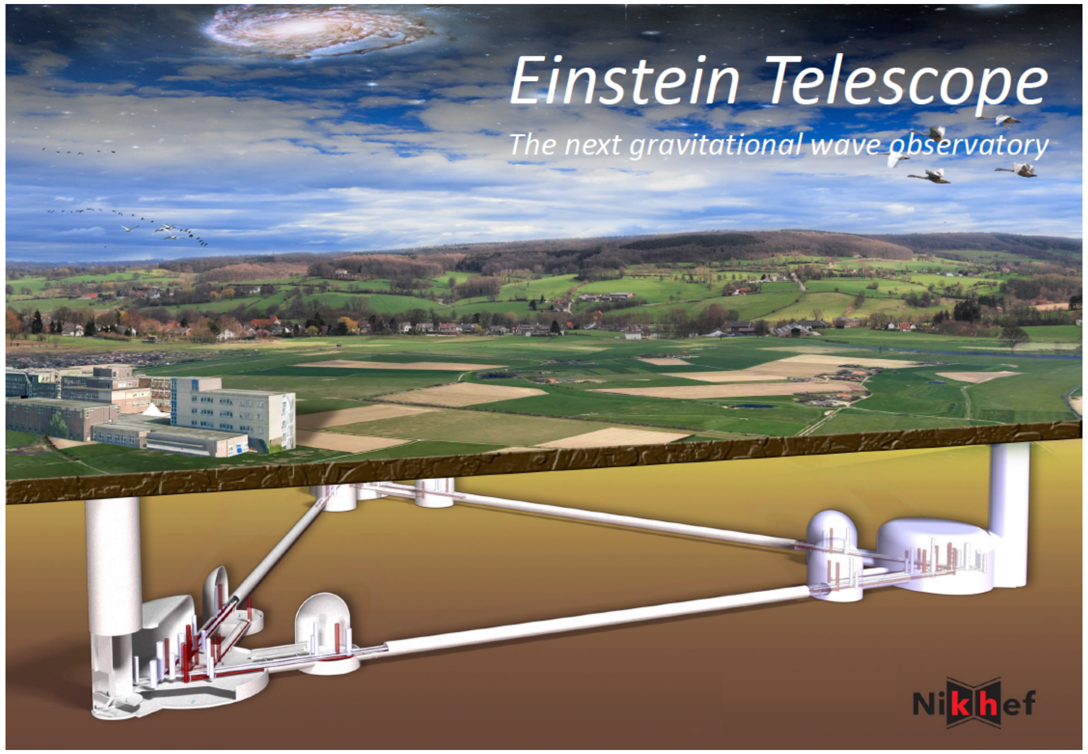
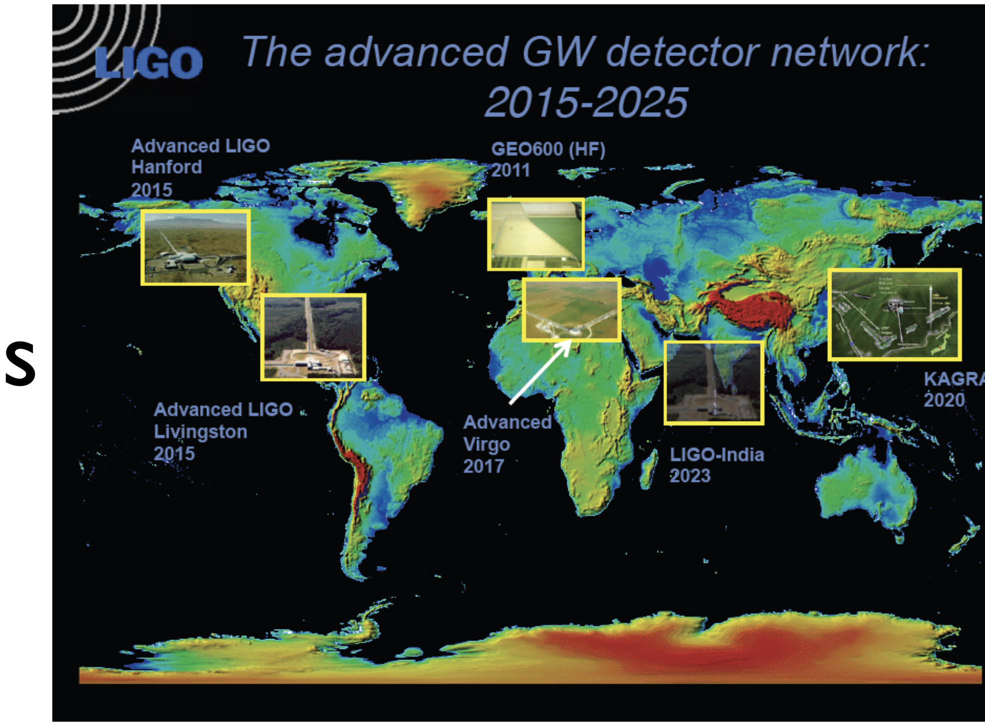
➜ Two first 10 kton modules for 2024, beam in 2026, remaining two for 2027.

➜ Spanish participation to be defined (next CIFPA meeting?).



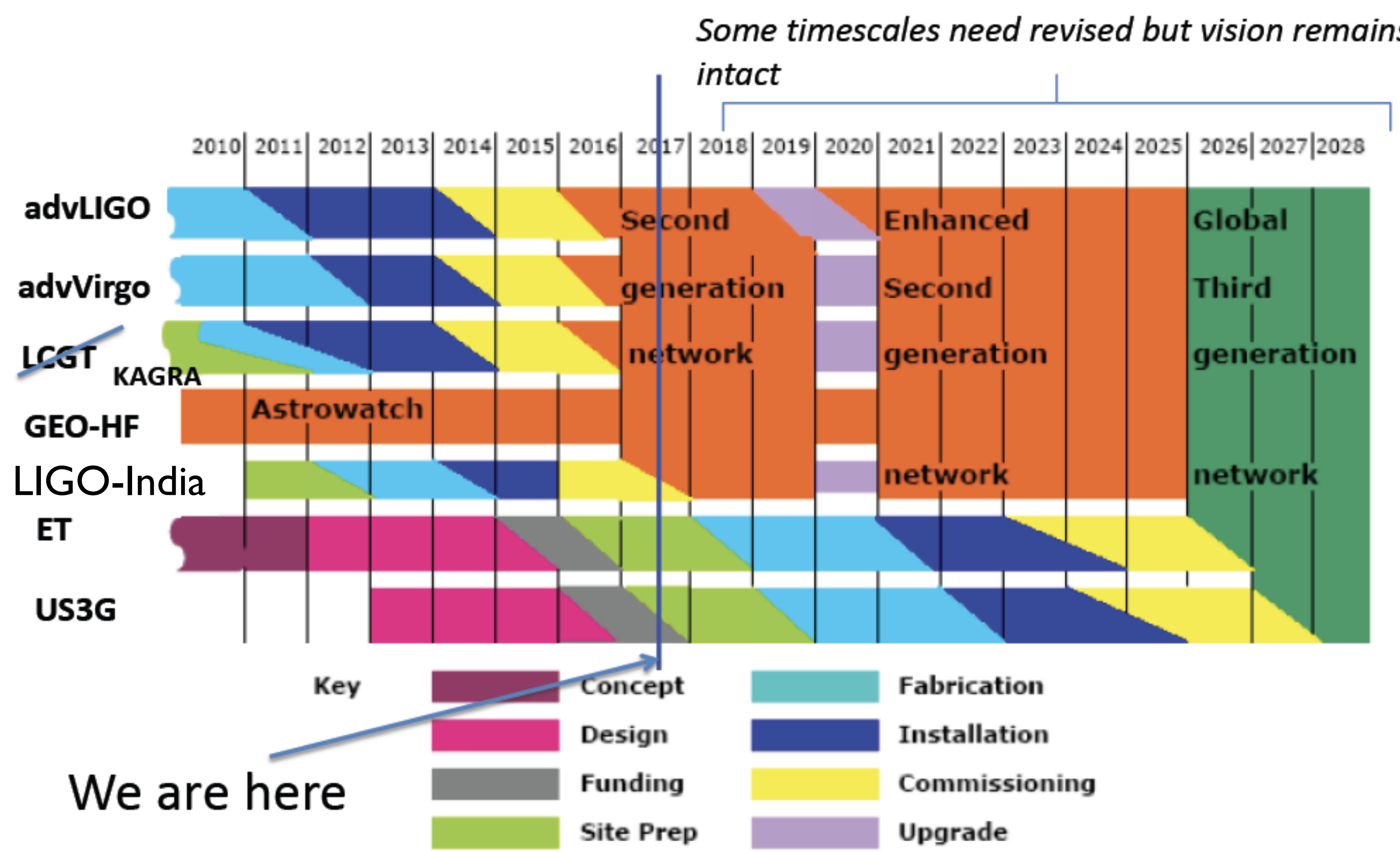

# GWs:

➜ ESA launches **LISA** in 2034.




GWIC Gravitational Wave International Committee

## The global GW roadmap




S. Rowan at GWPAW 2017

From the Gravitational Wave International Committee (GWIC roadmap - available at: http://gwic.ligo.org/roadmap/ ) 4

# Instrumentation:

➜ We have expertise in:

- Si detectors (LHCb): LHC upgrades.
- Gaseous detectors: neutrino experiments.
- Calorimetry: nuclear physics.
- Electronics: miscellaneous.
- Laser-induced plasma acceleration: L2A2.

➜ **Could/should not this expertise be better coordinated in a transversal line, in terms of exchange of knowledge, common installations,...?**

# To start the discussion:

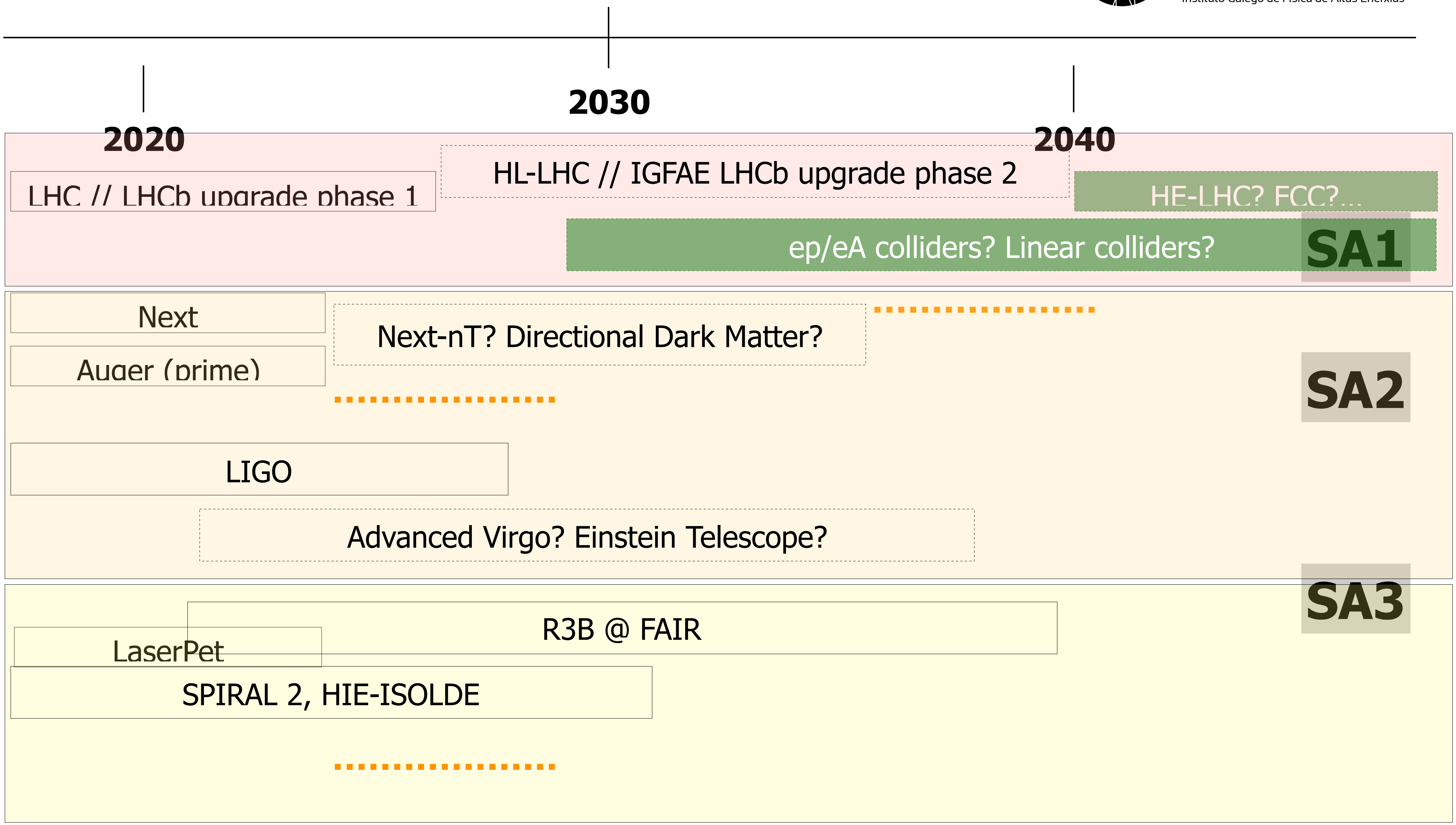
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | … |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RL1** | LHCb: upgrade 1 | | | | | | | | | | | | | | | | | | | | | |
| **RL1** | | | | LHCb: upgrade 2? | | | | | | | | | | | | | | | | | | |
| **RL2** | RHIC-II, HL-LHC for ions | | | | | | | | | | | | | | Ions at the LHC in the 30's: lighter? | | | | | | | |
| **RL2** | | | | ep/eA colliders | | | | | | | | | | | | | | | | | | |
| **RL3** | Applications to hot and dense QCD, thermalisation, condensed matter, cosmology; **NEW: integrability** | | | | | | | | | | | | | | | | | | | | | |
| **RL4** | Auger to AugerPrime | | | | | | | | | | | | | | | | | | | | | |
| **RL5** | NEXT, RD51 | | | | | | | | | | | | | | | | | | | | | |
| **RL5** | | | | NEXT-nT?; RD51 for directional DM?; DUNE? | | | | | | | | | | | | | | | | | | |
| **RL6** | GSI, GANIL, ISOLDE | | | | | | | | | | | | | | | | | | | | | |
| **RL6** | FAIR (R³B, something else?), SPIRAL2, HIE-ISOLDE | | | | | | | | | | | | | | | | | | | | | |
| **RL6** | LaserPet as an isotope factor proof-of-concept, plasma acceleration, laser facility | | | | | | | | | | | | | | | | | | | | | |
| **RL8** | | | **NEW: LIGO, VIRGO?,…?**; relation with RL3 and RL4 | | | | | | | | | | | | | | | | | | | |
| **TH** | Our missing items: BSM, cosmology, new perturbative techniques,… | | | | | | | | | | | | | | | | | | | | | |
| **EXP** | Another LHC experiment?; ILC?; CTA?; Neutrinos?; SKA?; …? | | | | | | | | | | | | | | | | | | | | | |

**Note: research lines are not isolated, everything mixed,…**

RL1: BSM with LHCb
RL2: Hot and dense QCD
RL3: String theory
RL4. Extremely energetic cosmic rays and neutrinos
RL5. Dark Matter and the nature of neutrinos
RL6. Nuclear structure and its astrophysical and cosmological implications
RL7. Laser Laboratory for Accelerator and Applications
RL8. Gravitational Waves

# Backup:

# Timeline



2020
2030
2040
LHC // LHCb upgrade phase 1
HL-LHC // IGFAE LHCb upgrade phase 2
HE-LHC? FCC?...
ep/eA colliders? Linear colliders?
SA1
Next
Auger (prime)
Next-nT? Directional Dark Matter?
SA2
LIGO
Advanced Virgo? Einstein Telescope?
SA3
R3B @ FAIR
LaserPet
SPIRAL 2, HIE-ISOLDE

# The LS2 Upgrade and beyond: Timeline

2015 2016 2017 2018 2019 **2020** 2021 2022 2023 2024 **2025** 2026 2027 2028 2029 **2030** 2031 2032 2033

| Run 2 | LS2 | Run 3 | LS3 | Run 4 | LS4 | Run 5,6,… |
|---|---|---|---|---|---|---|

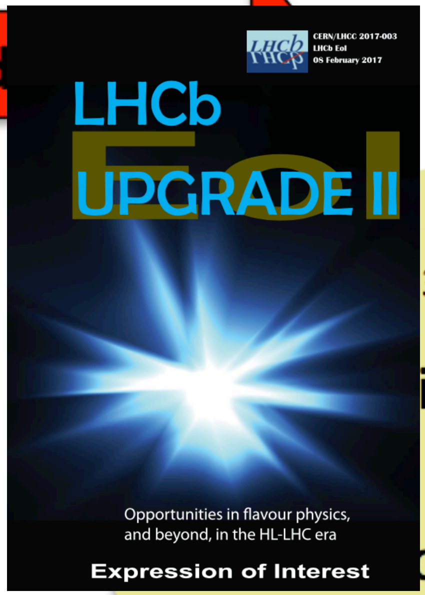
- LS2: Install LHCb Upgrade (**Phase I**)
- LS3: Potential 'stepping stone' projects to prepare for Phase II
- LS4: HL-LHC: **Phase II upgrade**

**Current detector** → **Fully Approved Funding Secured** → **Phase-I Upgrad** → **Phase-II ?**

$\mathcal{L} = 4 \times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
1.1 visible interactions / crossing
**8 fb$^{-1}$** collected

$\mathcal{L} = 2 \times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ **(5×)**
5.5 visible interactions / crossing
**50 fb$^{-1}$** collected

$^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ **(50×)**
interactions
ollected




25/10/2017 Abraham Gallas CPAN2017 2

# Future plans: Astroparticle Physics IGFAE group

**Auger** has significantly advanced our understanding of Ultra-High Energy Cosmic Rays:

- ✓ Dipole anisotropy observed by the first time
- ✓ Muon excess observed not explained by hadronic models
- ✓ Insights about composition at the highest energies
- ✓ Very accurate spectrum measured including the flux suppression at the highest energies
- ✓ Proton-air cross section measured at the highest energies ever
- ✓ Best neutrino limits …

**With strong scientific contribution** of **IGFAE-Astro group**

**But key questions stay to be answered**: origin of flux suppression at highest energies, pin-down sources, UHE proton astronomy, hadronic physics, UHE $\nu$´s

1

## Future in the short – mid term

- ❑ Continue participation in the Pierre Auger Observatory
- ❑ Exploit **AugerPrime** data to further address these open questions
  - construction ends in 2019, data taking 2018 - 2025

Answers to these questions will determine the prospects of the future UHECR & UHEν detectors: Cannot foresee how the field of UHECR & UHEν physics will evolve in the forthcoming years

## Future in the short – mid term

- ❑ Exploit expertise of IGFAE-Astro group on **radio detection of UHE particles:** data to further address these open questions:
  - Many experimental initiatives in the planning stage
  - First scientific contributions from IGFAE-Astro to some of them: SKA, GRAND
- ❑ New opportunities are emerging in the field of Astroparticle Physics:
  - Multi-messenger Astronomy (gamma rays, neutrinos…)

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# NEXT main goals

- **NEW Run-II (2017):**
  - NEW has been operated at 7-9 bar and has been **very stable** during 2017
  - Detector has been **calibrated** using $^{83}$Kr, $^{22}$Na, $^{60}$Co, $^{136}$Cs, $^{208}$Tl sources
    - Results on energy are excellent (extrapolated **0.8 % at Qbb**)
    - Results on tracking on-going, but very promising

- **NEW Run-III (2018-2019)**
  - Measure of the **background spectrum**
  - Measure spectrum with $^{136}$Xe, measure $T_{1/2}$ of **bb2nu**!

- **NEXT-100 (2018-2024):**
  - Construction of NEXT-100. Operation of NEXT-100, *calibration, reconstruction, background model,* measurement of $T_{1/2}$ of $^{136}$Xe **bb0nu**!

- **NEXT-nT (2018-20?)**
  - **Design studies:** *SiPM full coverage, low temperature, sensibility*
  - **Detector improvements:** *Gas mixtures and EL tiles* (see D. Gonzalez talk)

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present collaborators

| | framework | Spokesperson/PI | Number of Institutes | official status |
|---|---|---|---|---|
| NEXT | Spanish Ministry | J.J. Gomez Cadenas (IFIC)/ D. Nygren (Texas Arlington) | ~10 | existing MOU |
| Detector development | RD51 | L. Ropelewski (CERN) / S. Dalla Torre (INFN) | ~90 | existing MOU |
| fission TPC | Xunta | M. Caamaño (IGFAE) | 1 | gentlemen's agreement |
| directional dark matter | RD51 common project | E. Baraccini (INFN) | 6 | No MOU yet (?) |
| precision x-section measurements / DUNE | Proposal submitted to CERN-SPSC | J. Monroe (Royal Holloway) | ~20 | No MOU yet (?) |
| Forest fire detection and monitoring | SUDOE proposal under preparation | J. Veloso (Aveiro) | 5-10 | - |

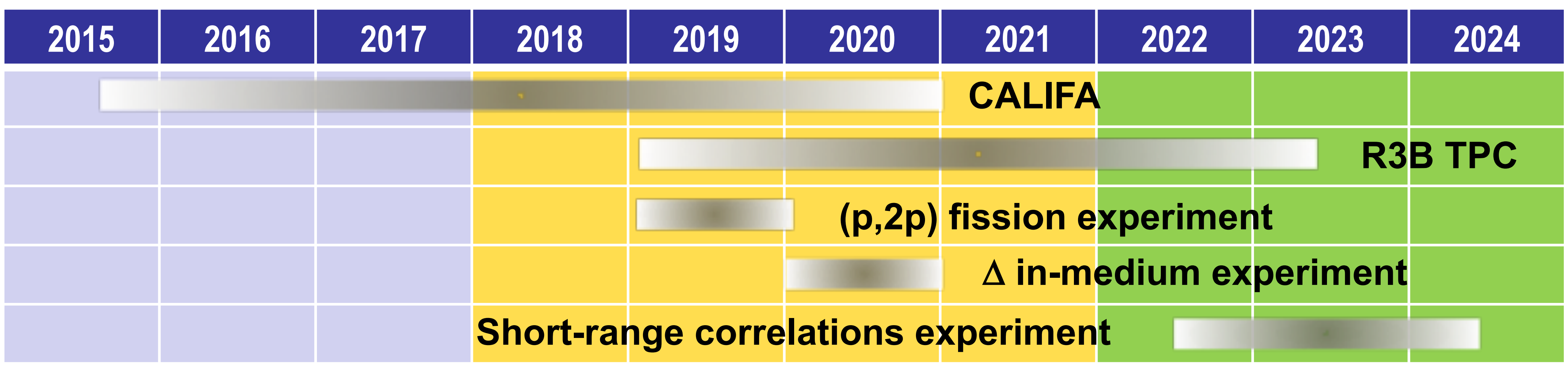
# Conclusions and perspectives

✓ R3B@FAIR offers unique opportunities to investigate neutron star matter and binary neutron star mergers nucleosynthesis.

✓GENP/IGFAE has a large impact in the experiment: spokesperson (D. Cortina), simulation and data analysis WG convener (H. Alvarez), leading physics runs (J. Benlliure)

Physics interests: structure of nuclei far from stability, fission, Eos of asymmetric nuclear matter….

Hardware contribution: CALIFA (25%), future TPC under consideration




✓ Green fields non or poorly covered by NP@IGFAE:

Hypernuclei and Eos of asymmetric dense nuclear matter.

R3B, Panda, CBM @ FAIR, ALICE@CERN

# Laser Laboratory for Accelerator and Aplicactions (L2A2)

- Today L2A2 is an important research infrastructre, fully opperational @ USC (Designed and built in a record time and with very limited resources)
- The laser-plama acceleration system is a young and interesting research field that requires input from well established disciplines as it is Nuclear Physics
- The firts milestone on the beam production is achieved →electron acceleration → laser-driven x-ray source (see Lucia´s talk)
- We are ready to initiate the production of first proton and light ion beams → step 0 for the completion of the LaserPET experiment
- We have established national /international networking and defined a medium/long term research program
- L2A2 allows to keep in-house the knowledge on many technologies and expertise required in larger research infrastructures → educational purpose

**2012** CDR → **2013-14** TDR → **2015** Construction → **2016-2017** Experiments design and implementation → **2018 …** Commisionning