

2024 - CERN 70 year celebration

NorCC og CERN mot 2040



NORCC

Norwegian Centre for CERN-related Research

Heidi Sandaker - NorCC 03.09.2024

NorCC and CERN towards 2040



Something known and a lot of unknowns, ...

NorCC and CERN 2024-2040



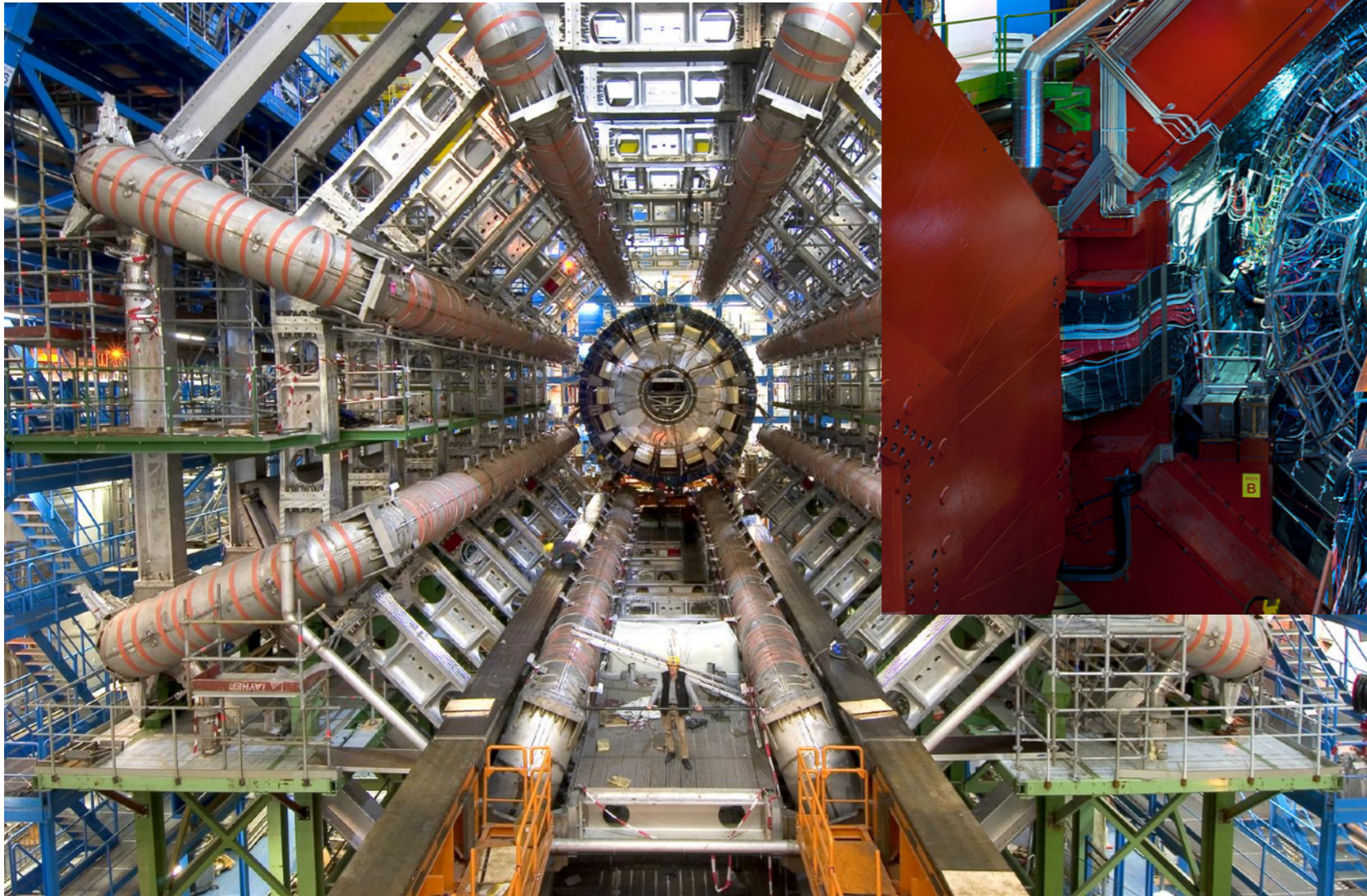
... Wishful Thinking ...

Christmas wish list:

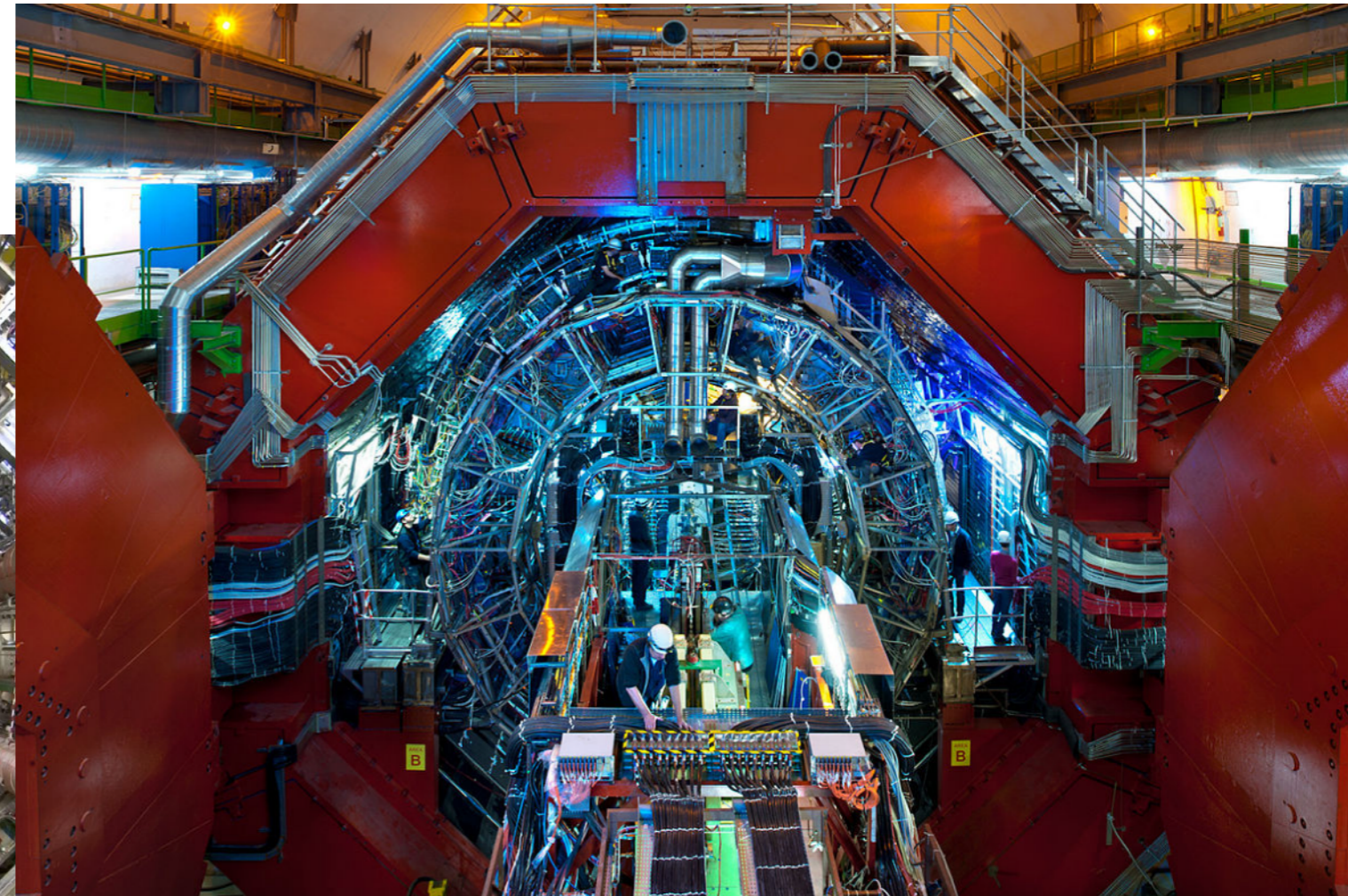
- Find the Higgs boson
- Produce quark-gluon plasma
- Find the properties of the Higgs boson
- Understand quark-gluon plasma
- Find a Dark matter particle
- Go back in time much closer to the big bang
- ...

NorCC and CERN before 2020

Construction of the Experiments



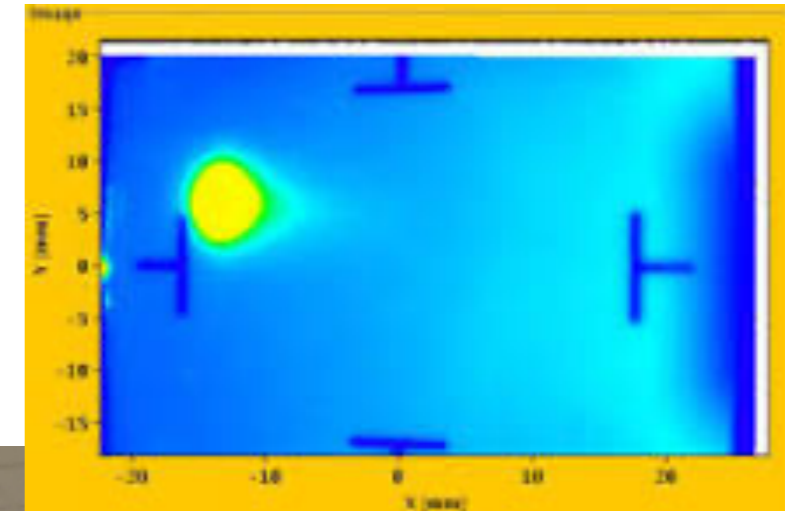
ATLAS



ALICE

NorCC and CERN before 2020

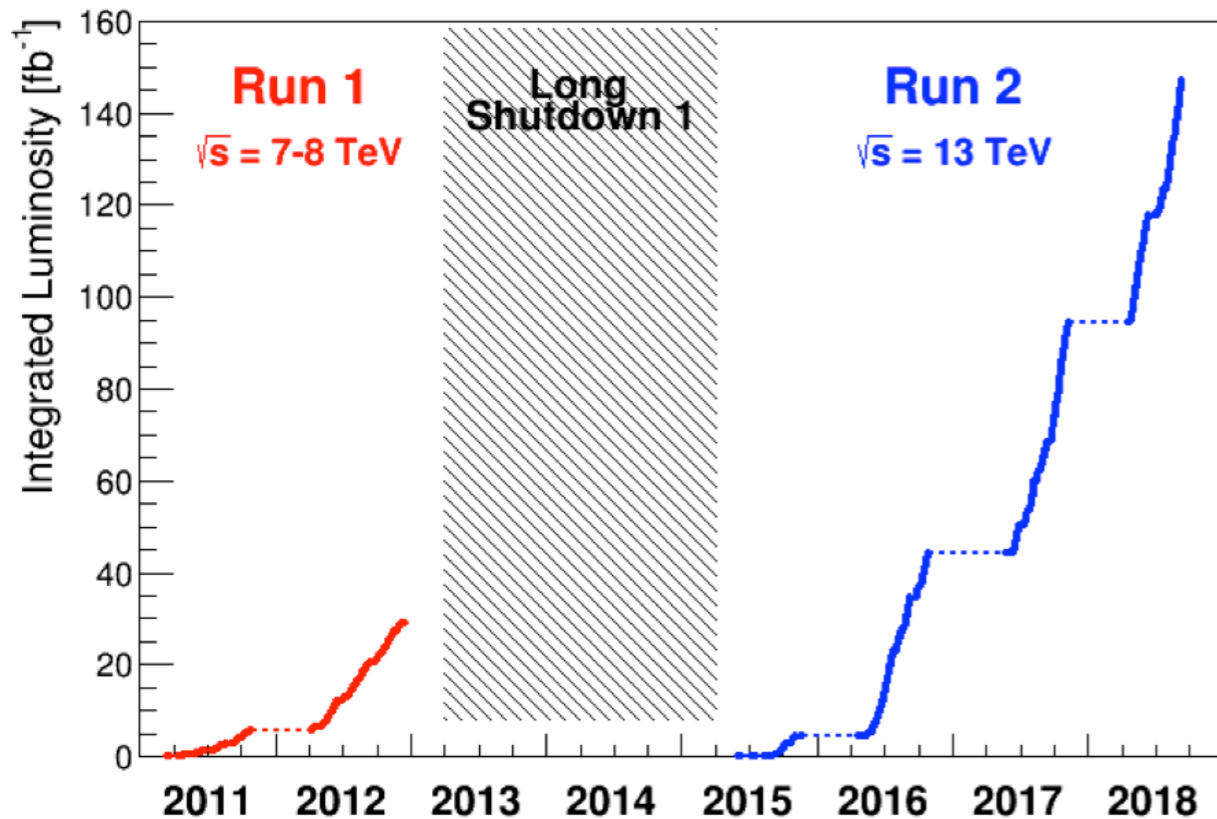
Run 1, Long Shutdown 1 and Run 2



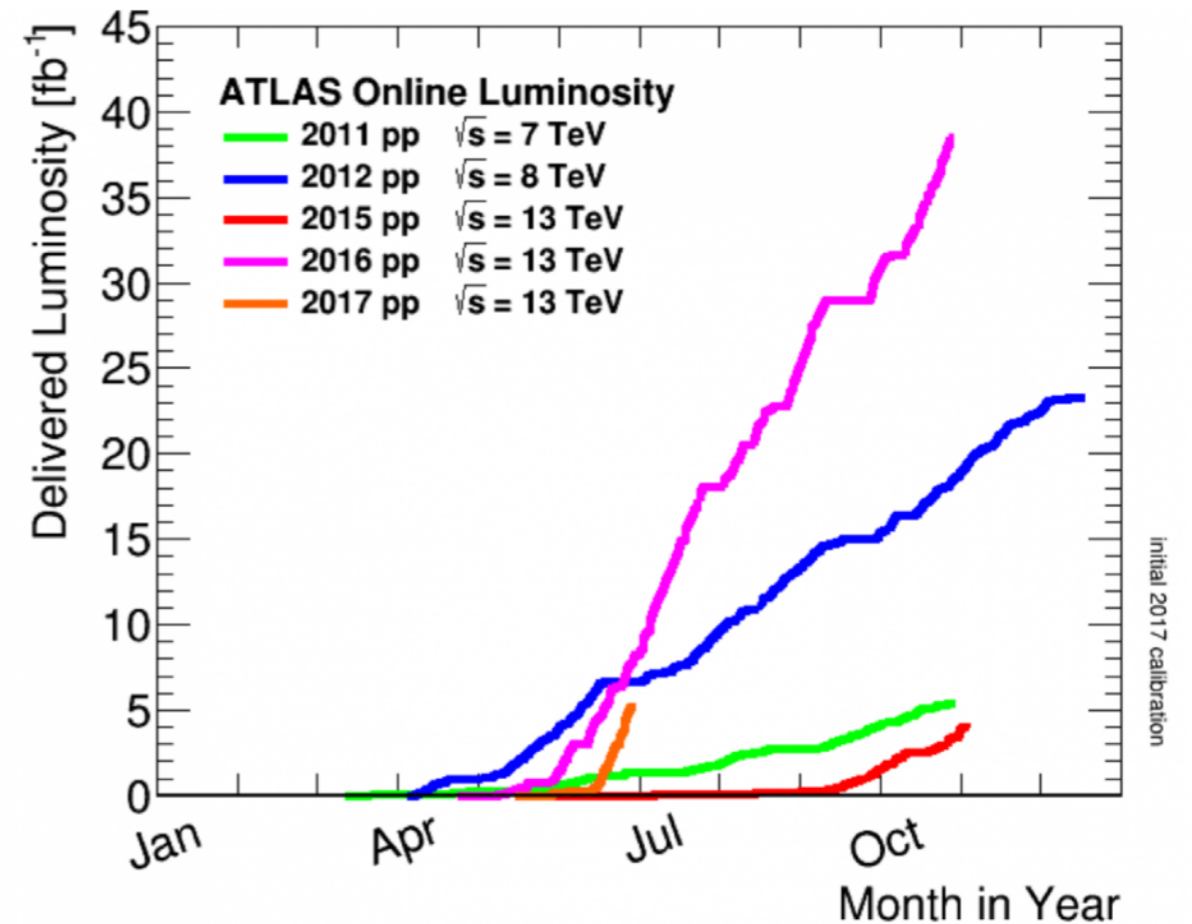
First Beam

NorCC and CERN before 2020

Run 1, Long Shutdown 1 and Run 2



Integrated Luminosity LHC

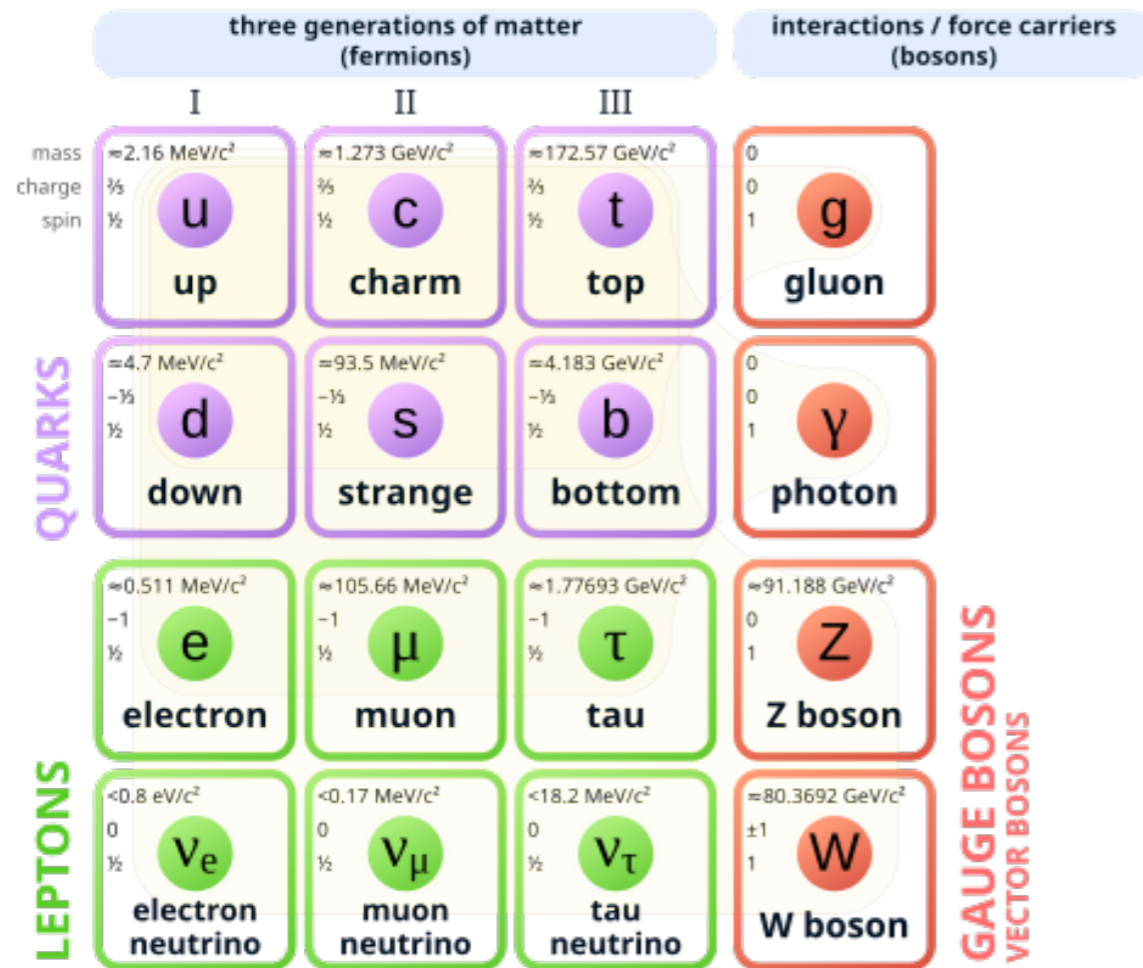


Delivered Luminosity LHC

Does the Higgs boson exist?

Run 1, Long Shutdown 1 and Run 2

Standard Model of Elementary Particles



Voss ski resort - Snow magasin

Standard model tested to a very high precision but does not explain why elementary particles have mass

Does the Higgs boson exist?

Run 1, Long Shutdown 1 and Run 2

Standard Model of Elementary Particles

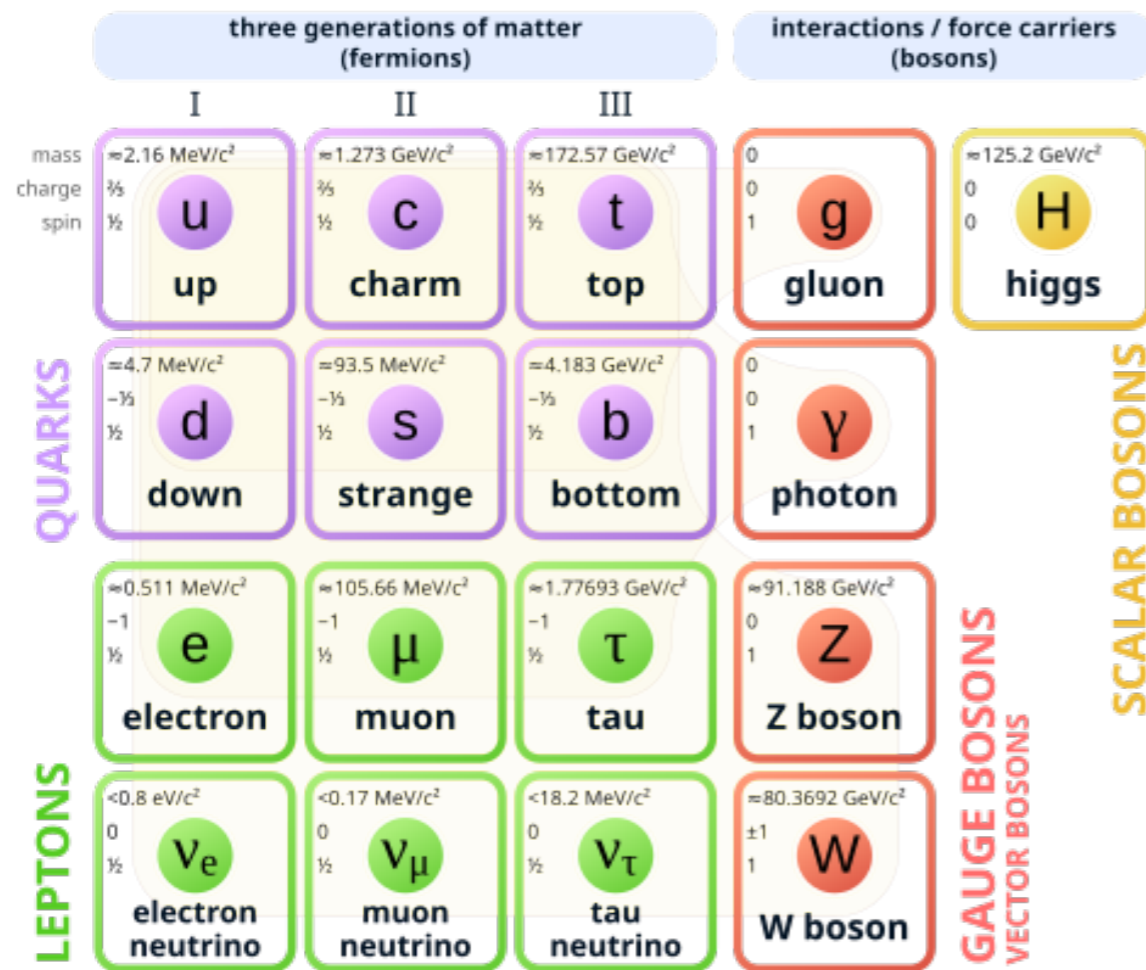


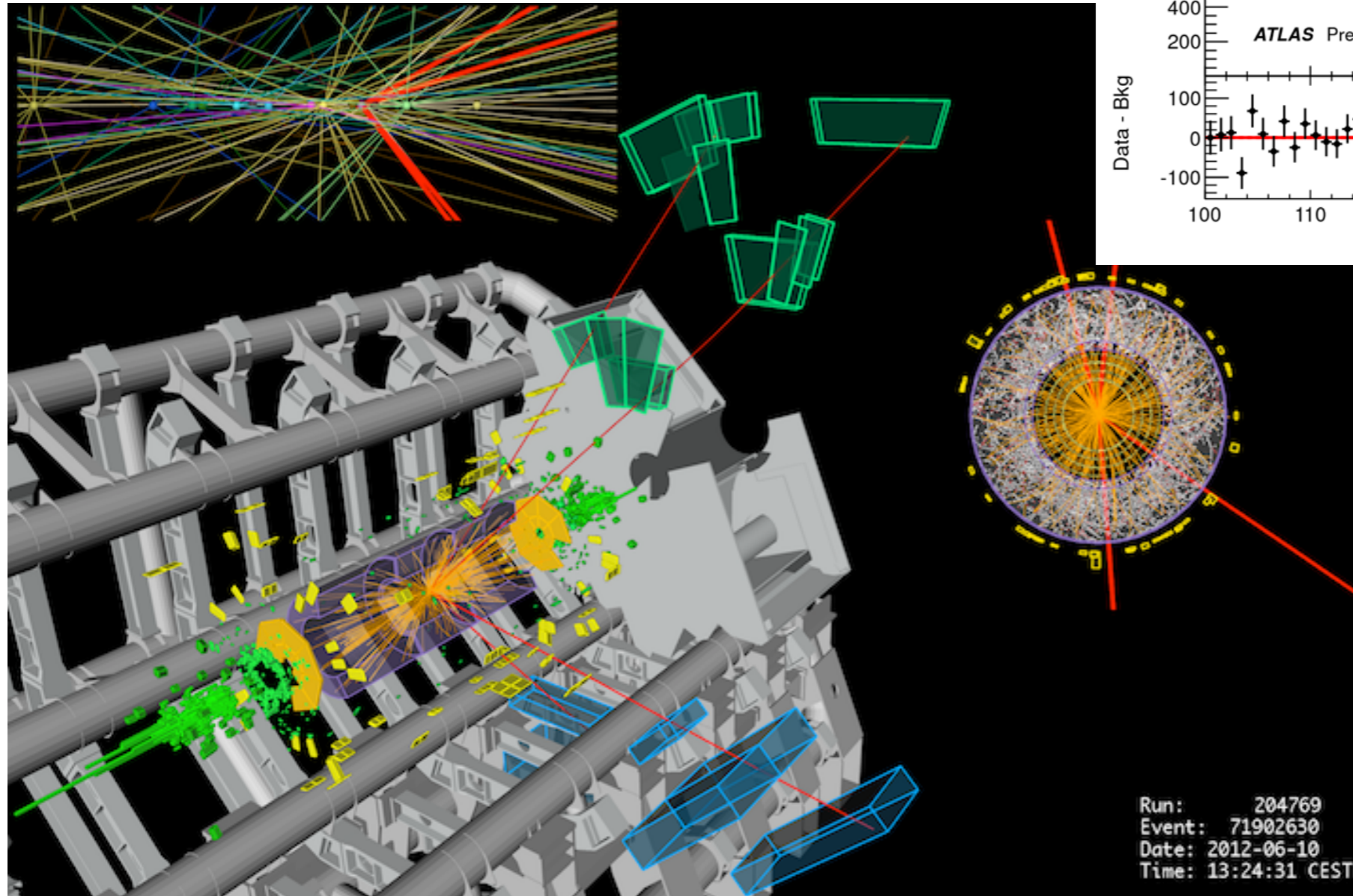
Photo: Sverre Hjørnevik

Standard model tested to a very high precision but does not explain why elementary particles have mass

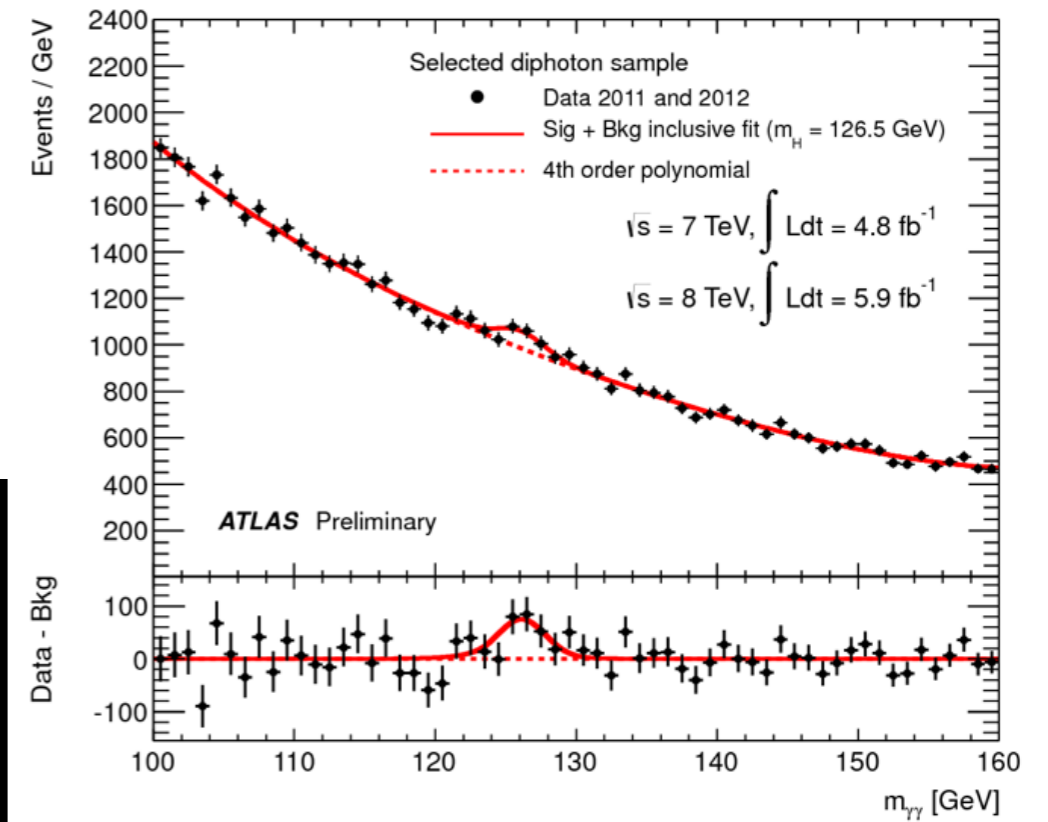
NorCC and CERN before 2020

Run 1, Long Shutdown 1 and Run 2

Discovery !



Candidate Higgs event

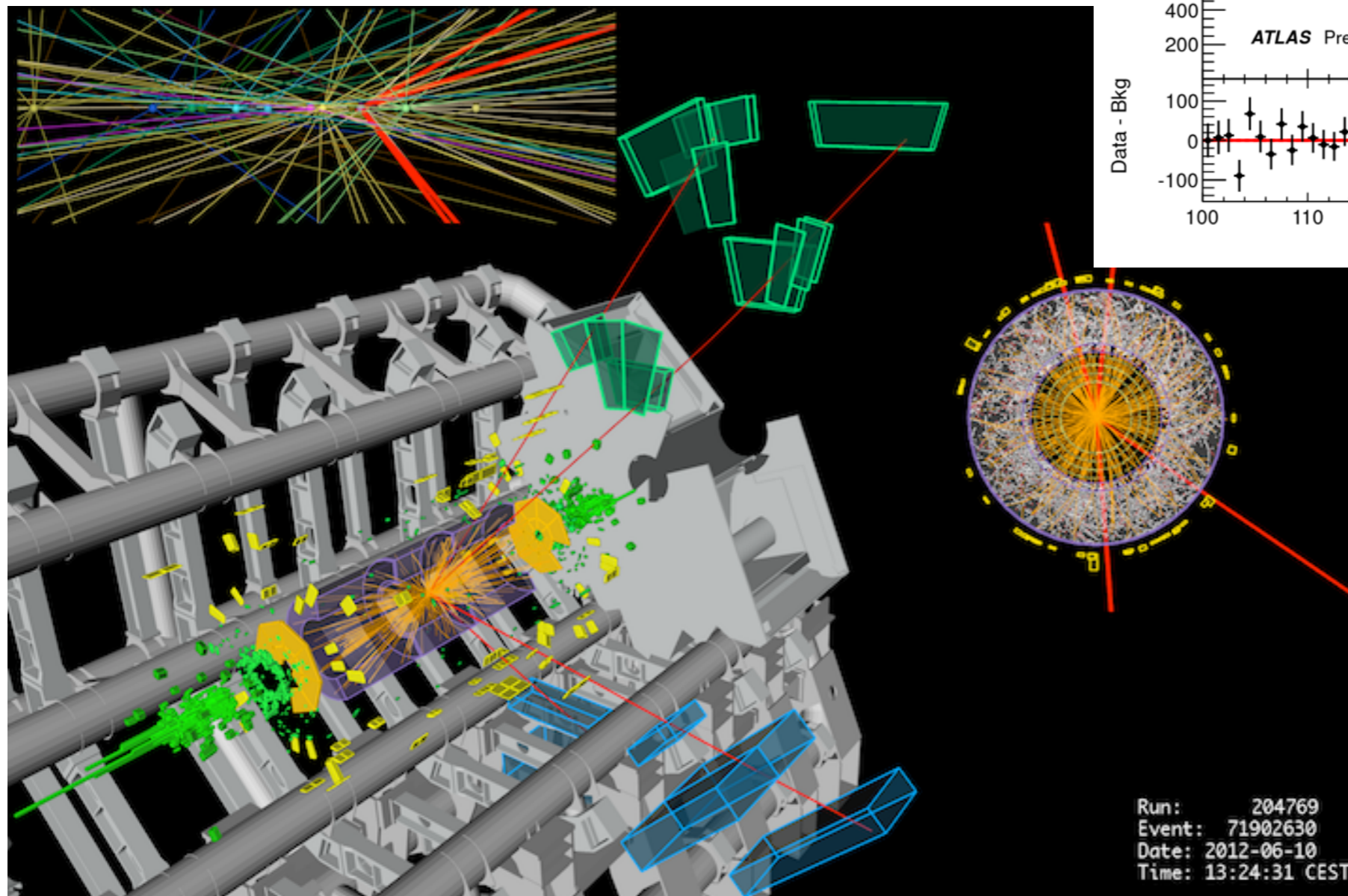


Candidate Higgs event

NorCC and CERN before 2020

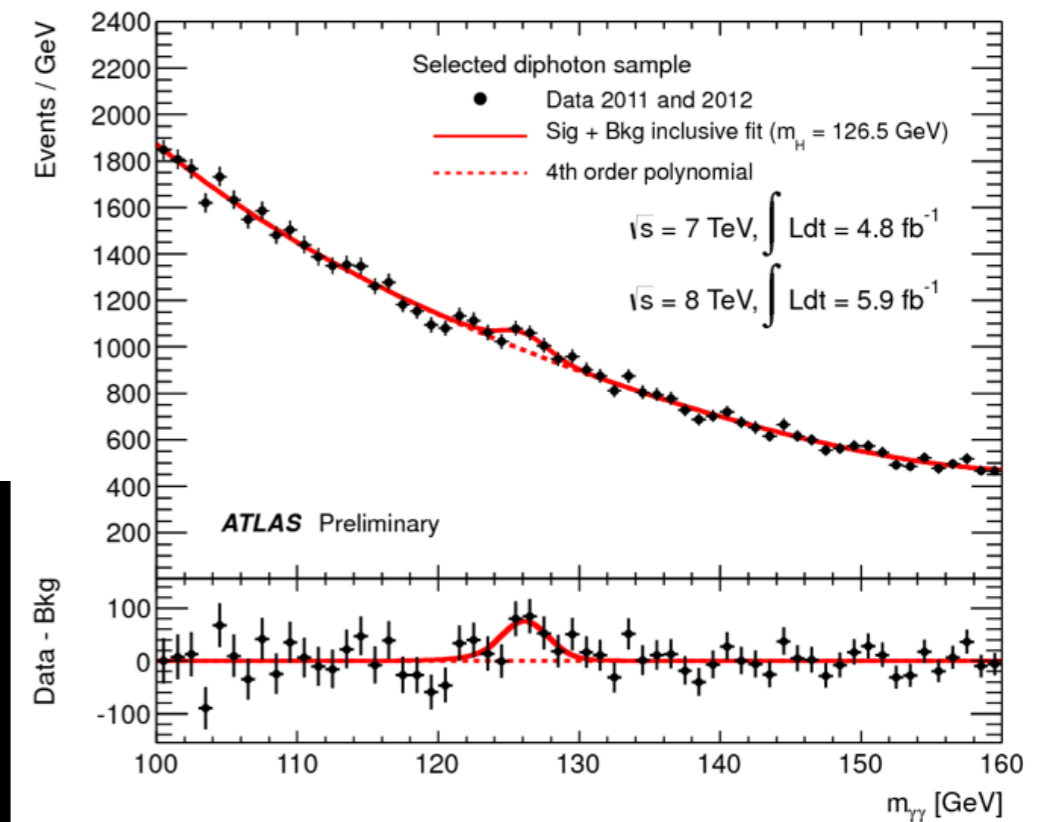
Run 1, Long Shutdown 1 and Run 2

Discovery !



Candidate Higgs event

Candidate Higgs event



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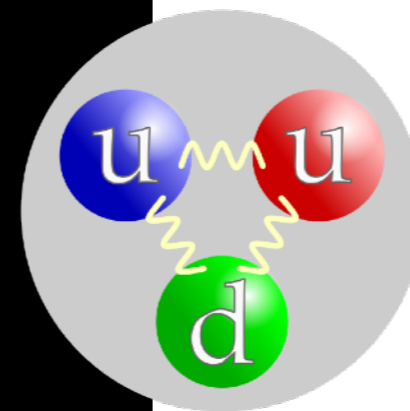
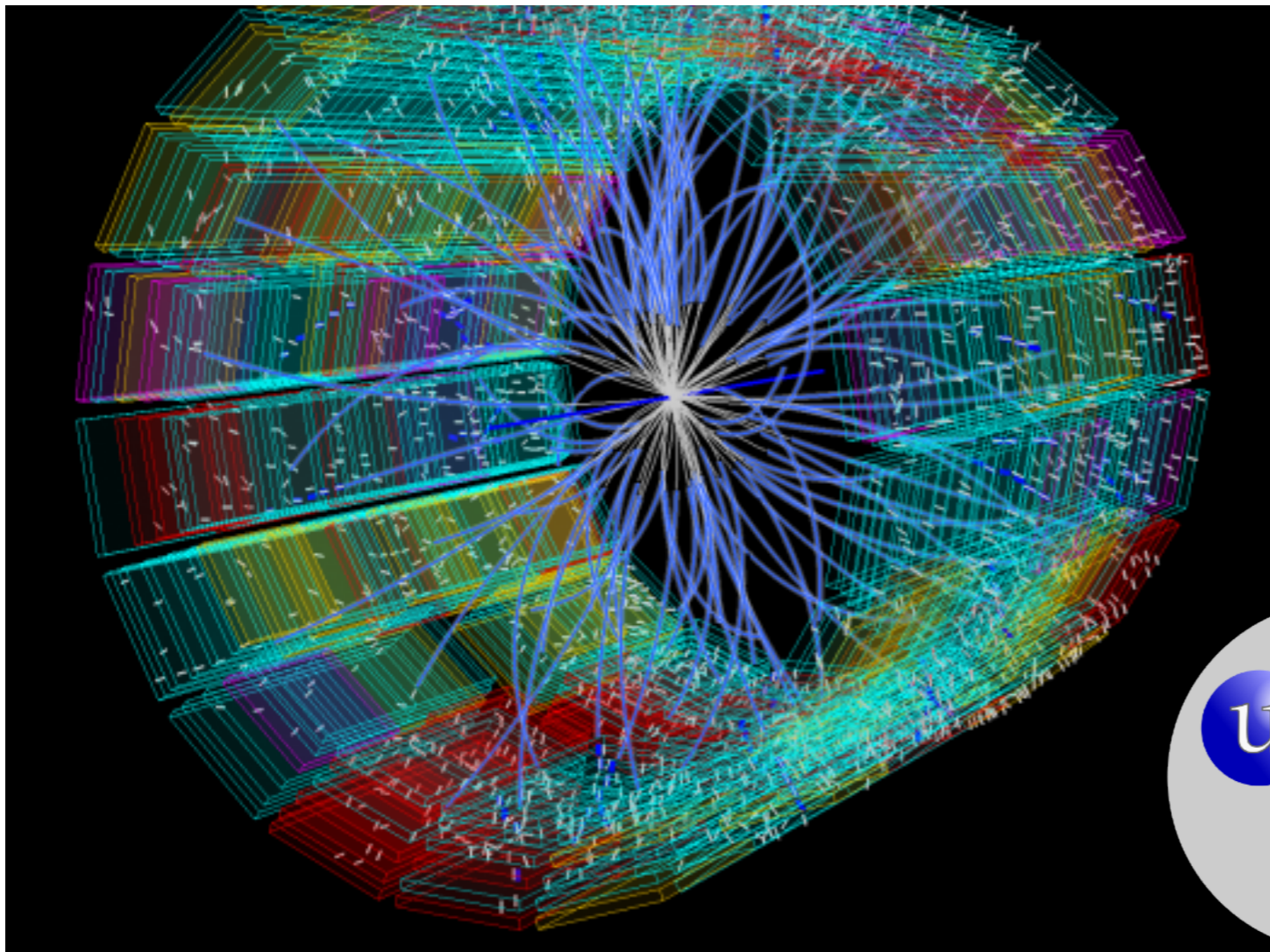
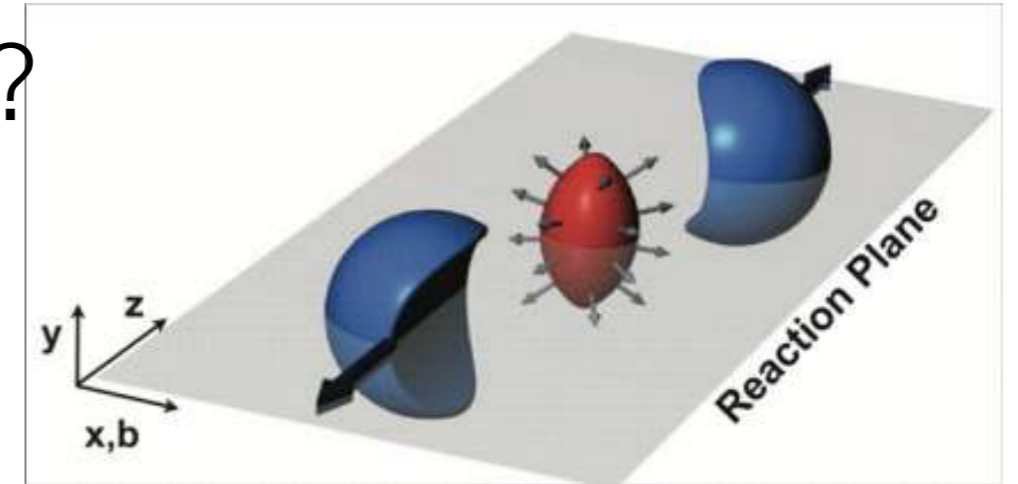
What about quark-gluon plasma?

Run 1, Long Shutdown 1 and Run 2

August 2012, ALICE produced quark-gluon plasma

Temperature at around 5.5 trillion kelvins

The highest temperature mass achieved in any physical experiments thus far

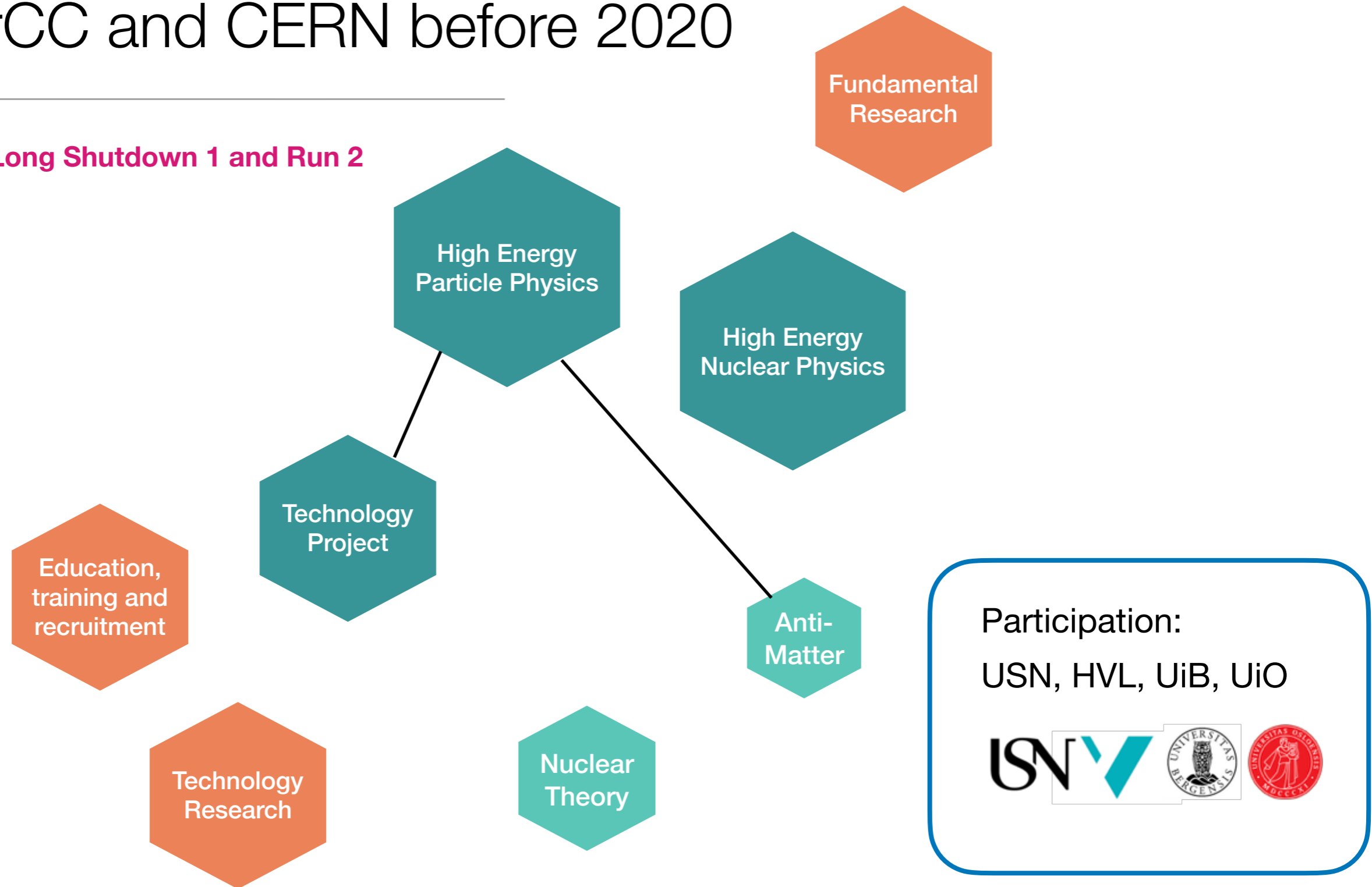


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NorCC and CERN before 2020

Run 1, Long Shutdown 1 and Run 2



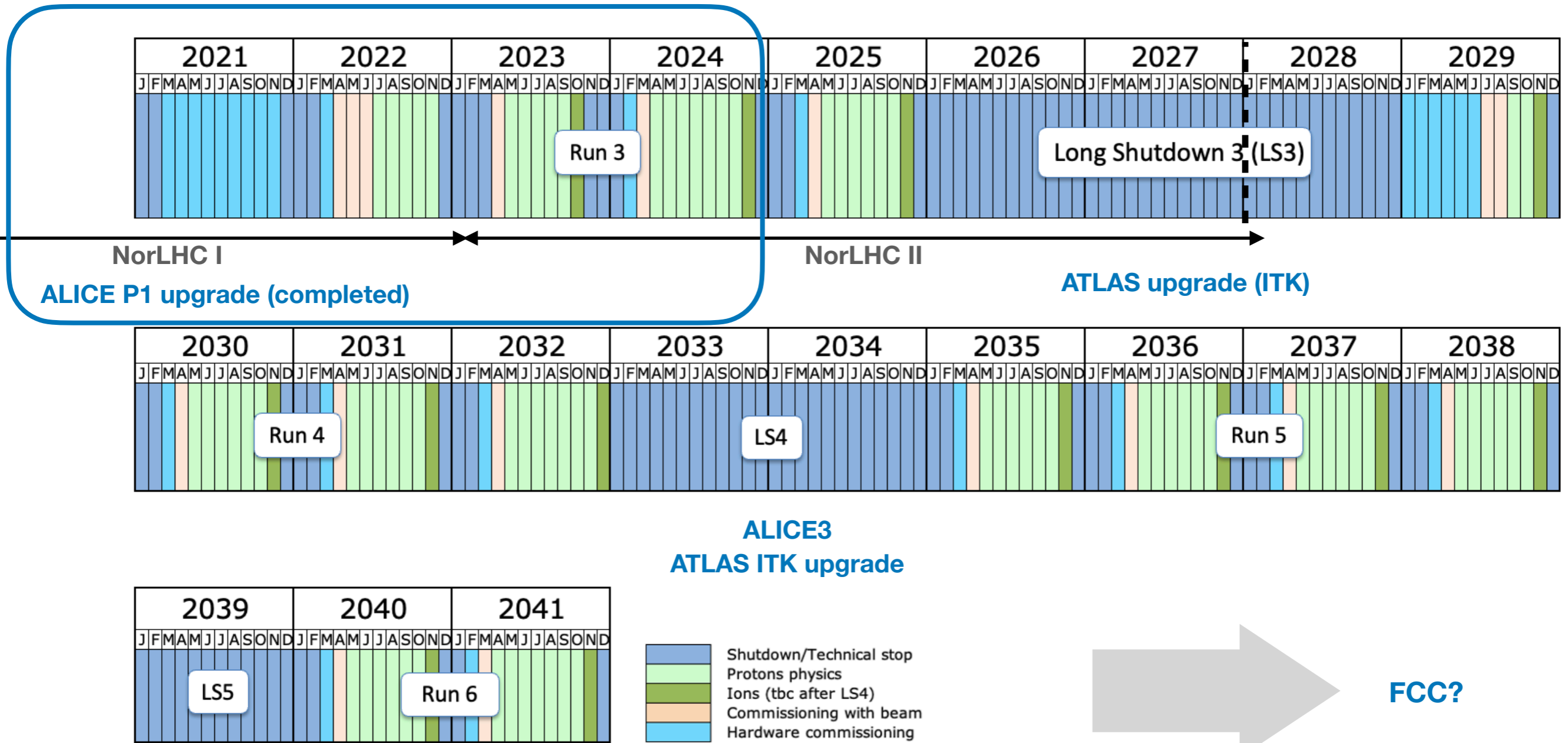
NorCC and CERN before 2020

High school visits, >120 pupils per year
Visit from courses UiB and UiO
Entrepreneur school (NTNU)



NorCC and CERN 2020-2024

Run 3 and Long Shutdown 3



Last update: June 24

Data analysis continues

NorCC and CERN 2020-2024

Long Shutdown 2 and Run 3

- After 3 years of shutdown LHC started again in 2022 - Run 3

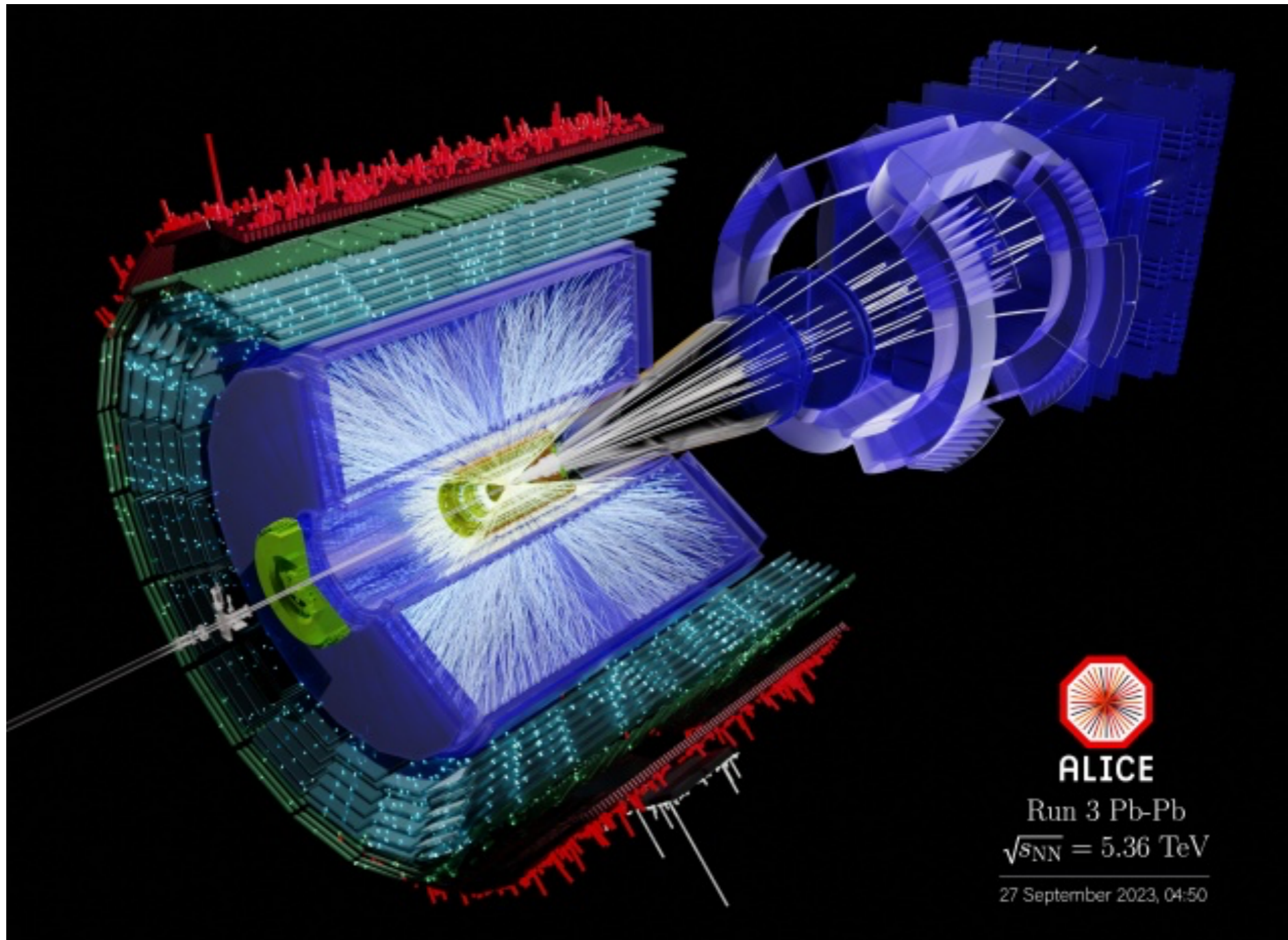


NorCC and CERN 2020-2024

increased energy of 5.36 TeV per nucleon pair (compared to 5.02 TeV previously) and the collision rate has increased by a factor of 10

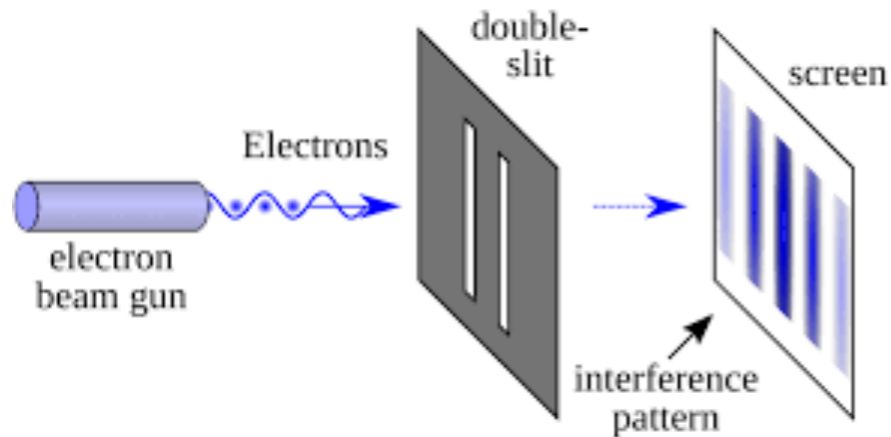
entirely new mode of data processing storing all collisions without selection

Long Shutdown 2 and Run 3

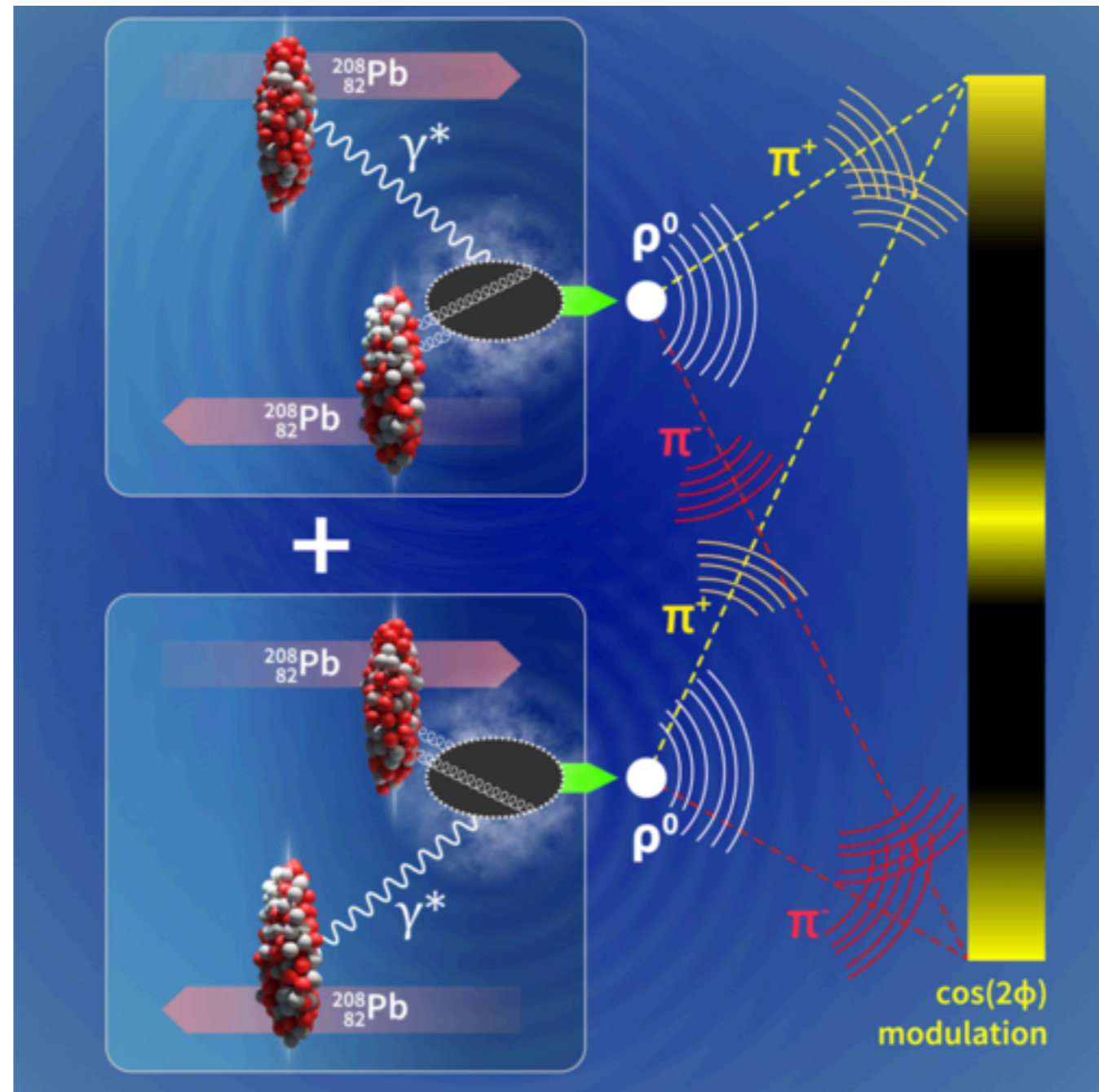


NorCC and CERN 2020-2024

Double slit experiment at femto scale



In the photoproduction of ρ^0 mesons in ultra-peripheral collisions between two lead nuclei, the interference between the two possibilities shown in this illustration (Image: CERN)



NorCC and CERN 2020-2024

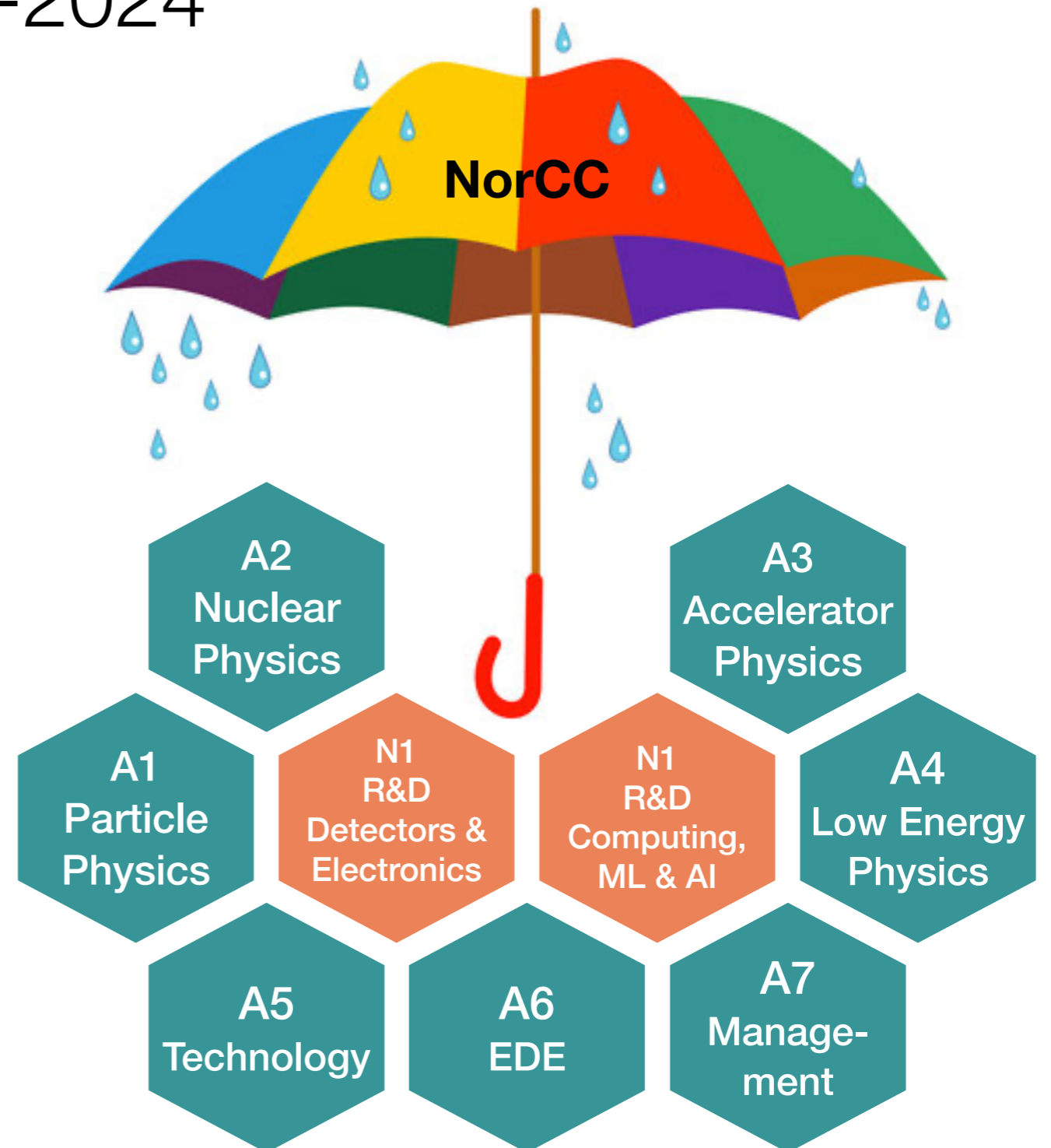
- Established in 2020, collecting several Norwegian CERN-related projects into one centre
- About 200 people total
- **Open to all interested institutions:**

Participation:

NTNU, UiA, USN, HVL, UiB, UiO



- Research is focussed mainly on:
 - **Experiments:** UiB, UiO, HVL, USN, UiA
 - **Technology:** NTNU, UiA, USN, HVL
 - includes also some **theoretical** activities
- The centre is lead by UiB and UiO together and hosted by UiO



NorCC organisation

◆ 5 research activities

- A1 - Particle Physics
- A2 - Nuclear Physics
- A3 - Accelerator Physics
- A4 - Low Energy Physics
- A5 - Technology

◆ 2 supporting activities

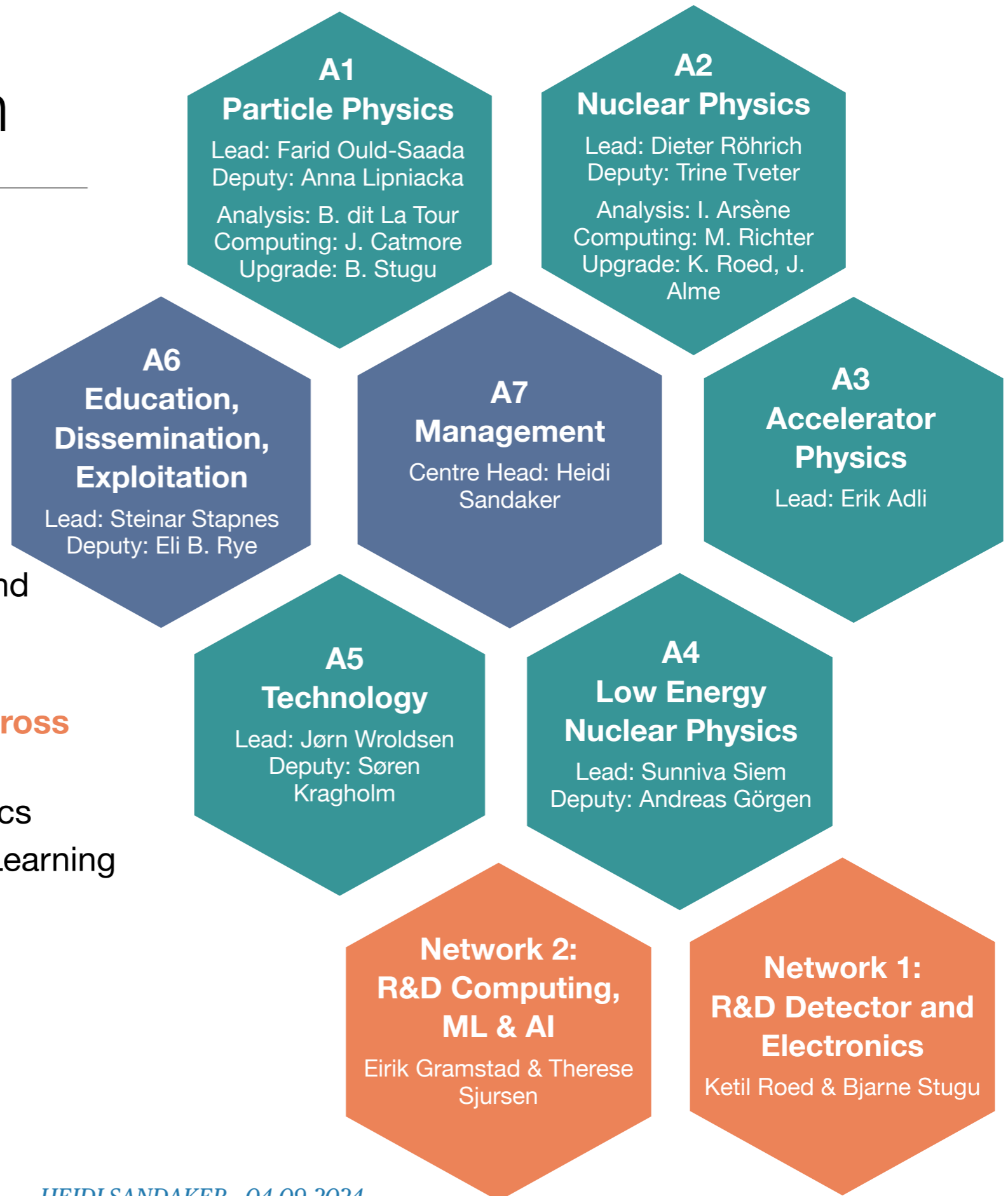
- A6 - Education, Dissemination and Exploitation
- A7 - Management

◆ 2 networks enabling synergies across the research activities

- N1 - R&D Detector and Electronics
- N2 - R&D Computing, Machine Learning and AI

◆ Laboratories and infrastructure

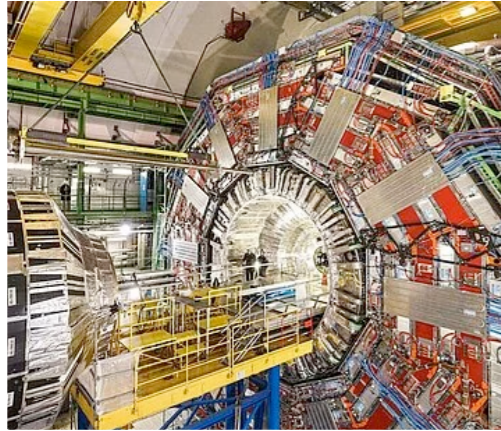
- NorLHC I & II
- NorFab (USN)



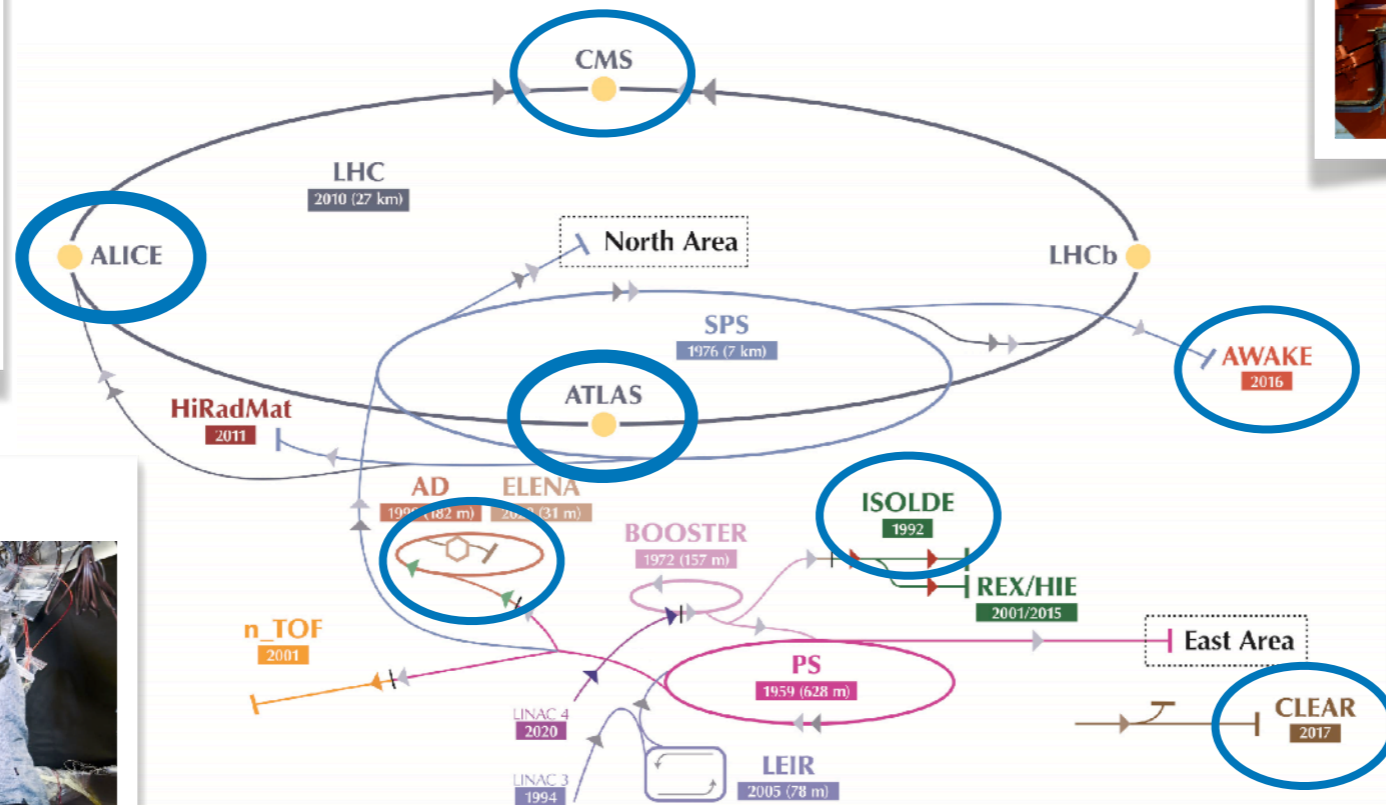
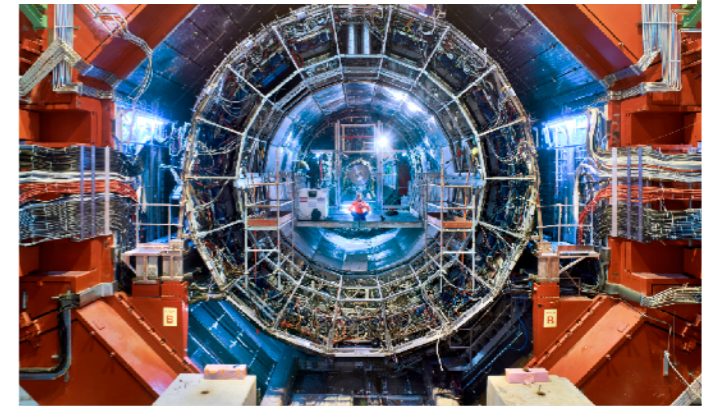
NorCC @ CERN Experiments

Technology is needed everywhere

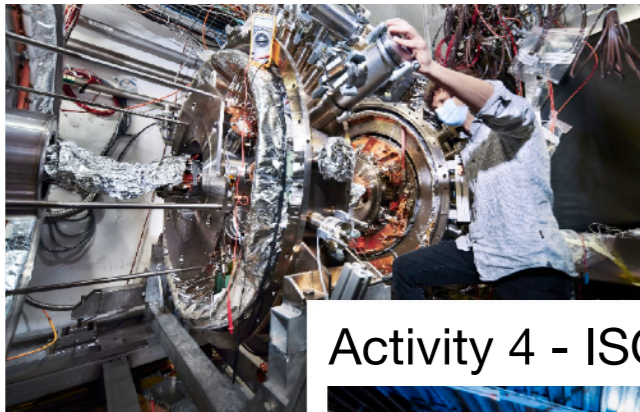
Activity 5 - CMS



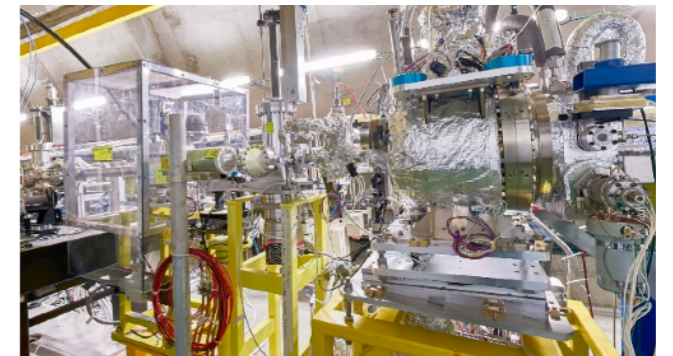
Activity 2 - ALICE



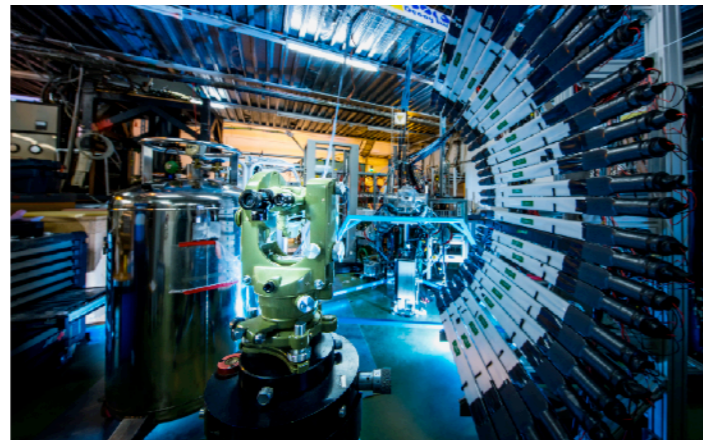
Activity 4 - AEGIS



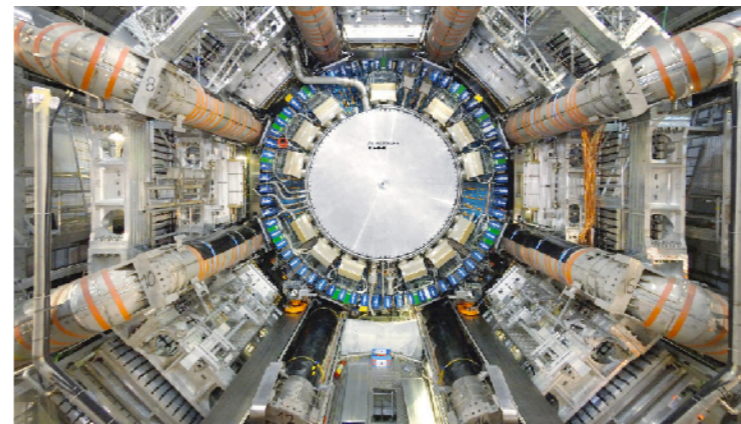
Activity 3 - CLIC, AWAKE



Activity 4 - ISOLDE

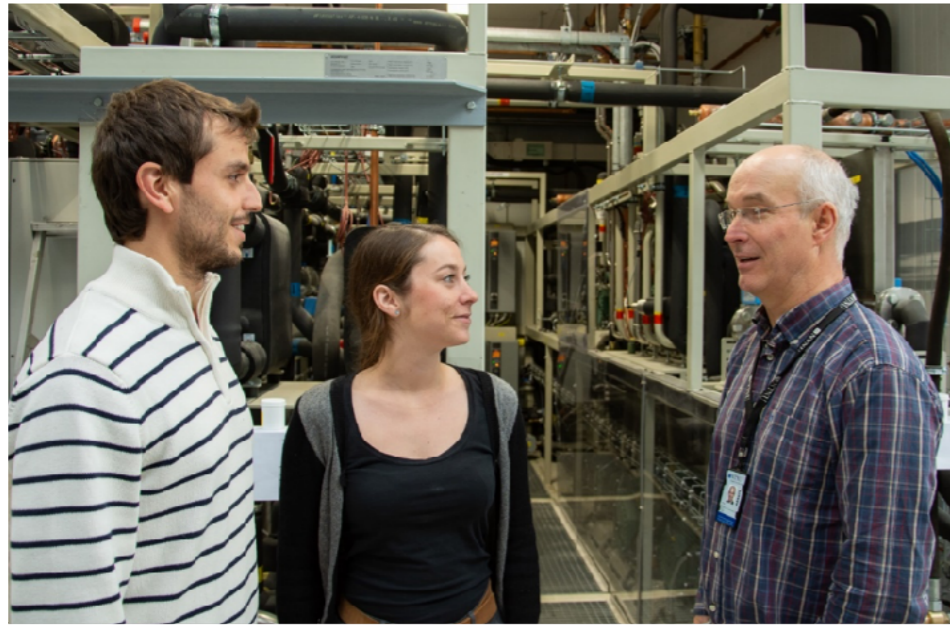


Activity 1 - ATLAS



Technology Research

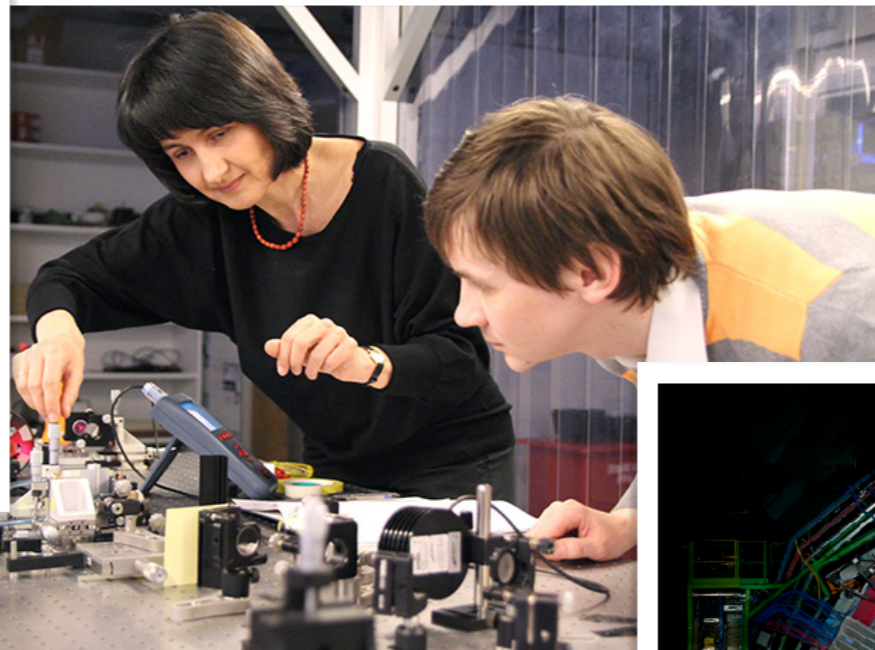
Activity 5 - Technology



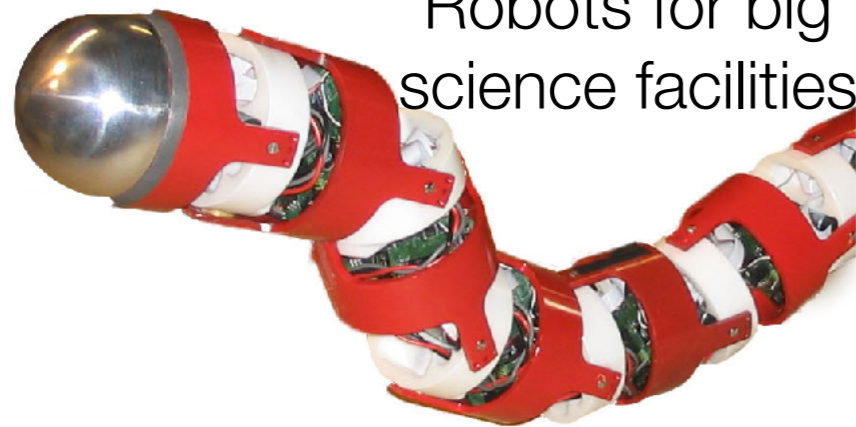
Advanced laser research



Entrepreneurship

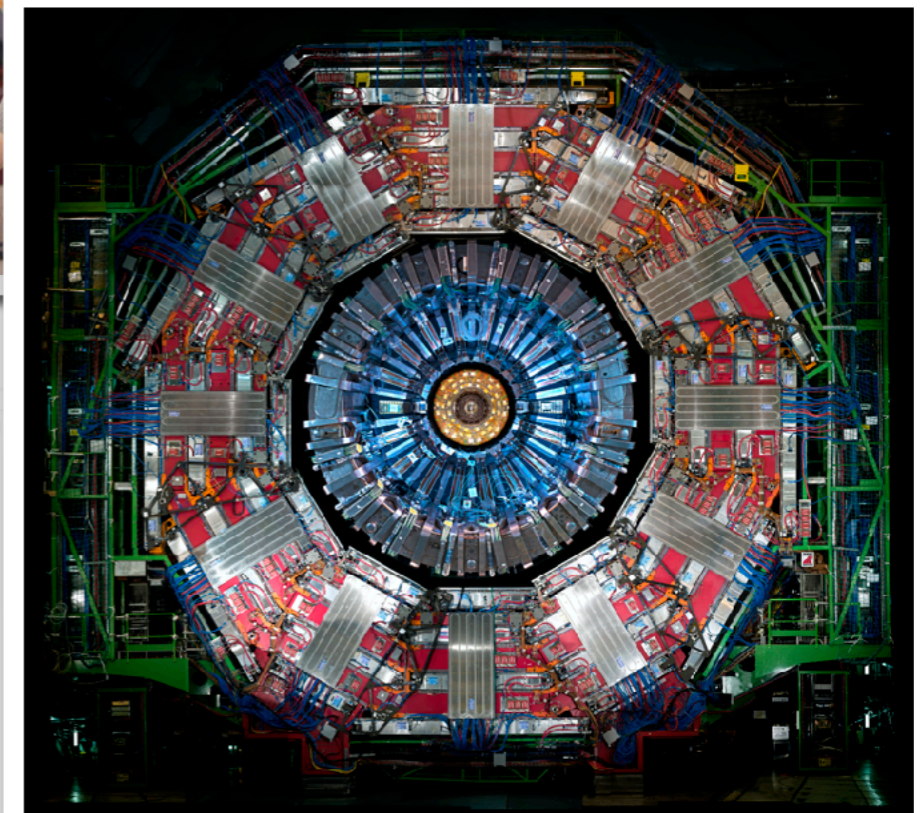
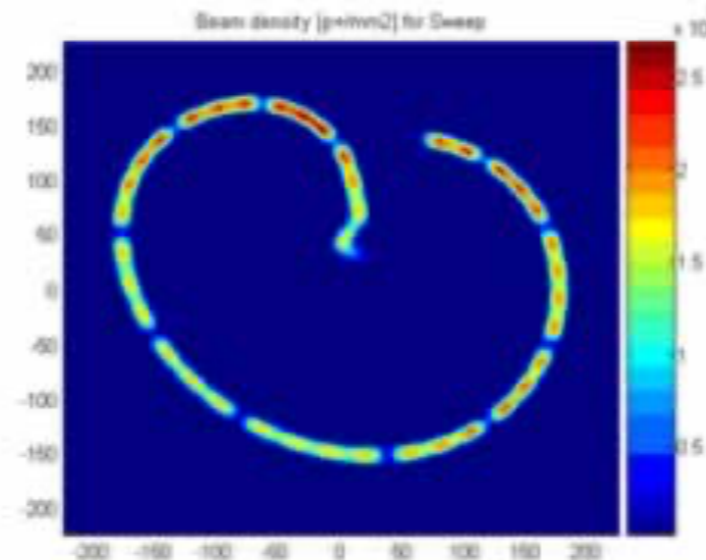


CO2 cooling systems



Robots for big science facilities

Material studies



Detector Control Systems and Machine Learning

Currently 8 PhD students co-financed with CERN

NorCC and CERN 2020-2024

High school visits reduced

Visit from courses UiB and UiO

Summer@CERN (UiB, UiO, HVL, NTNU, USN, UiA + UiS)

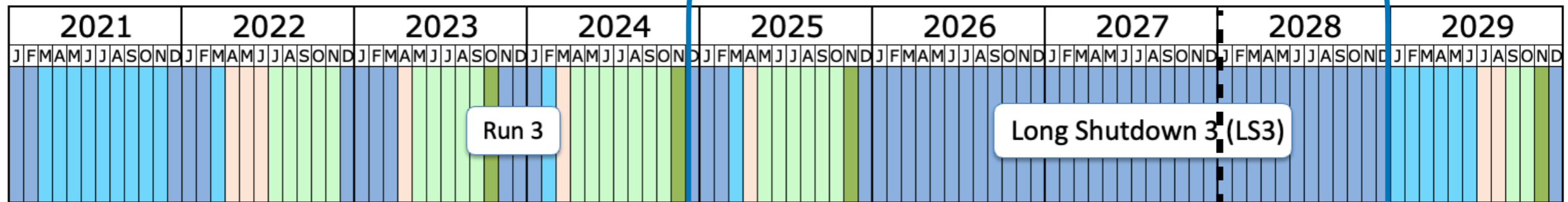
Entrepreneur/Innovation school (NTNU+HVL)



Photo: Eli Rye

NorCC and CERN 2025-2028

Run 3 and Long Shutdown 3

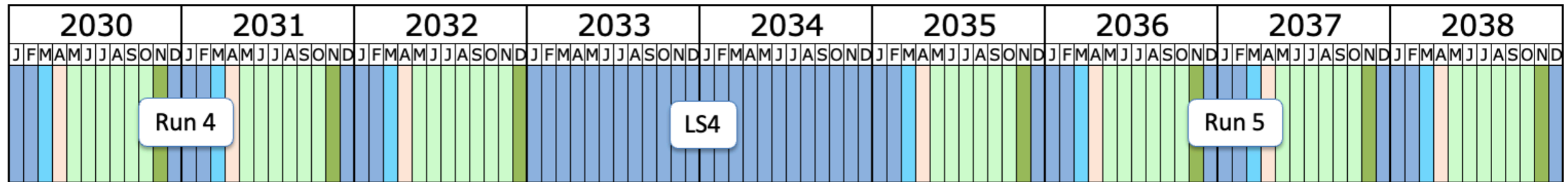


NorLHC I

NorLHC II

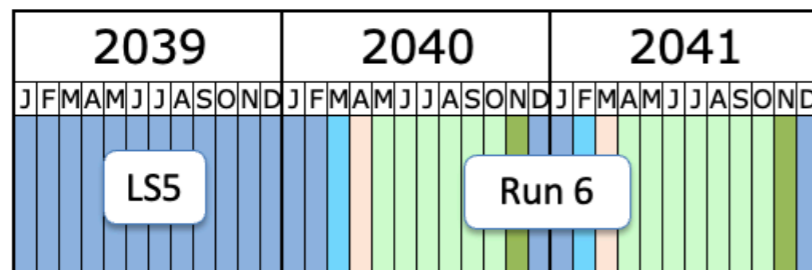
ALICE P1 upgrade (completed)

ATLAS upgrade (ITK)

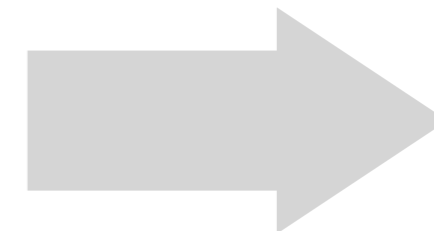


ALICE3

ATLAS ITK upgrade



- Shutdown/Technical stop
- Protons physics
- Ions (tbc after LS4)
- Commissioning with beam
- Hardware commissioning



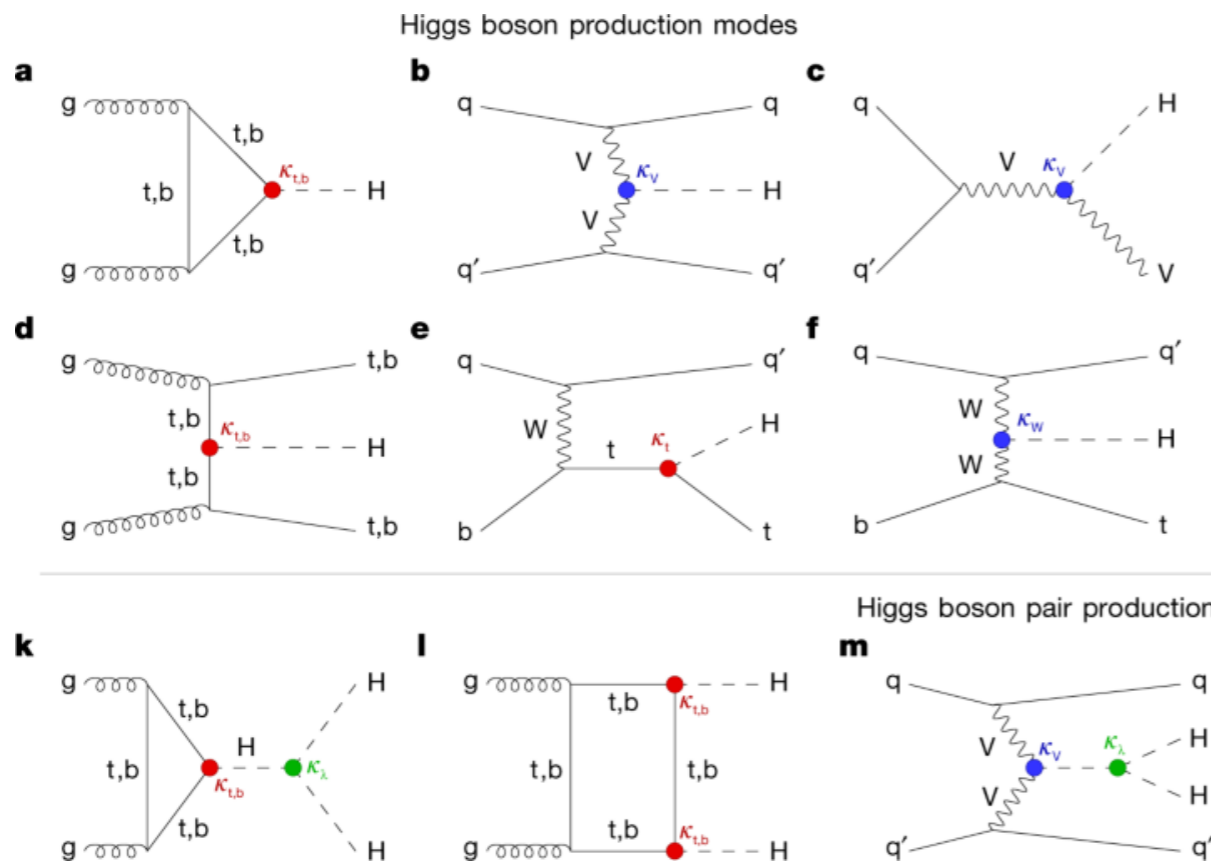
FCC?

Data analysis continues

Last update: June 24

NorCC and CERN 2025-2028

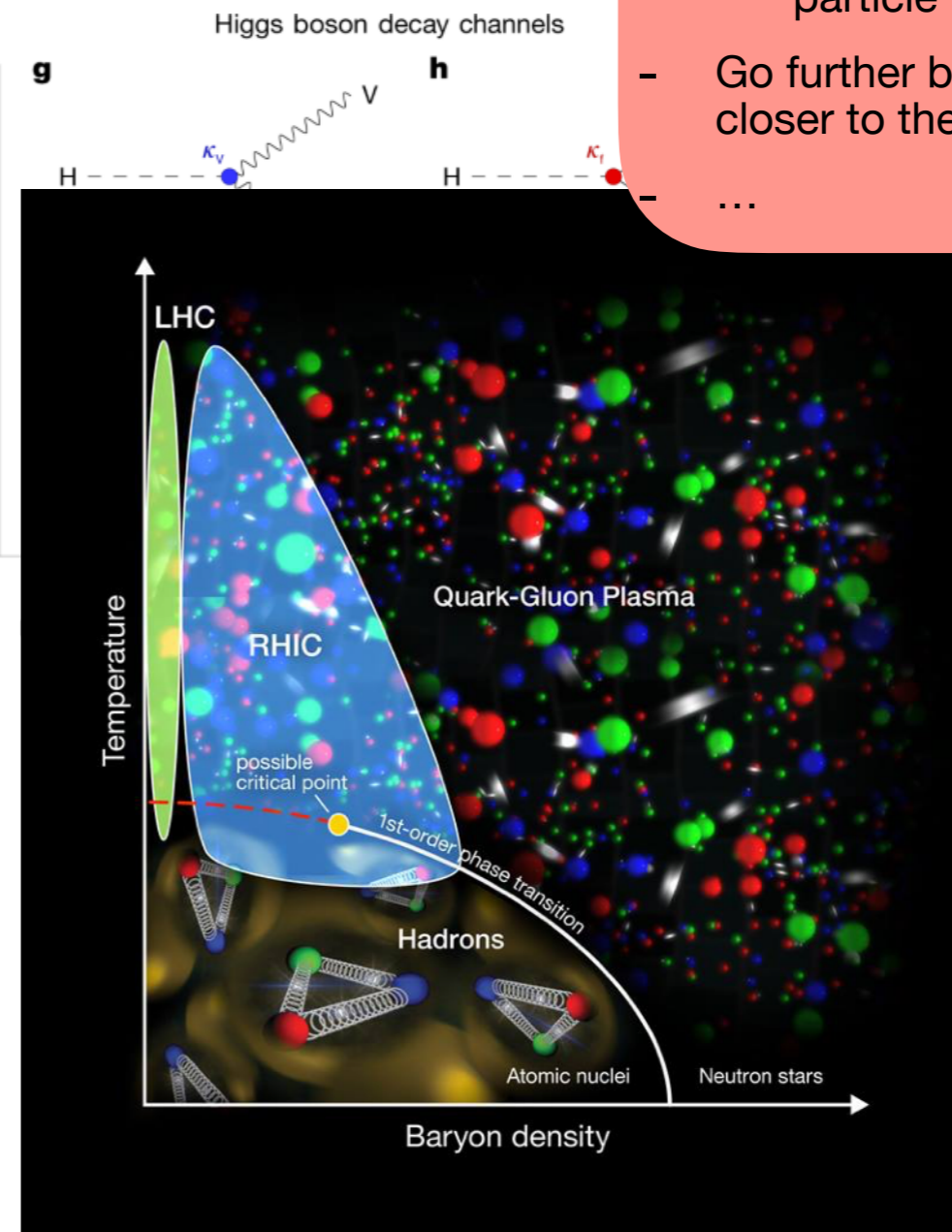
Long Shutdown 2 and Run 3



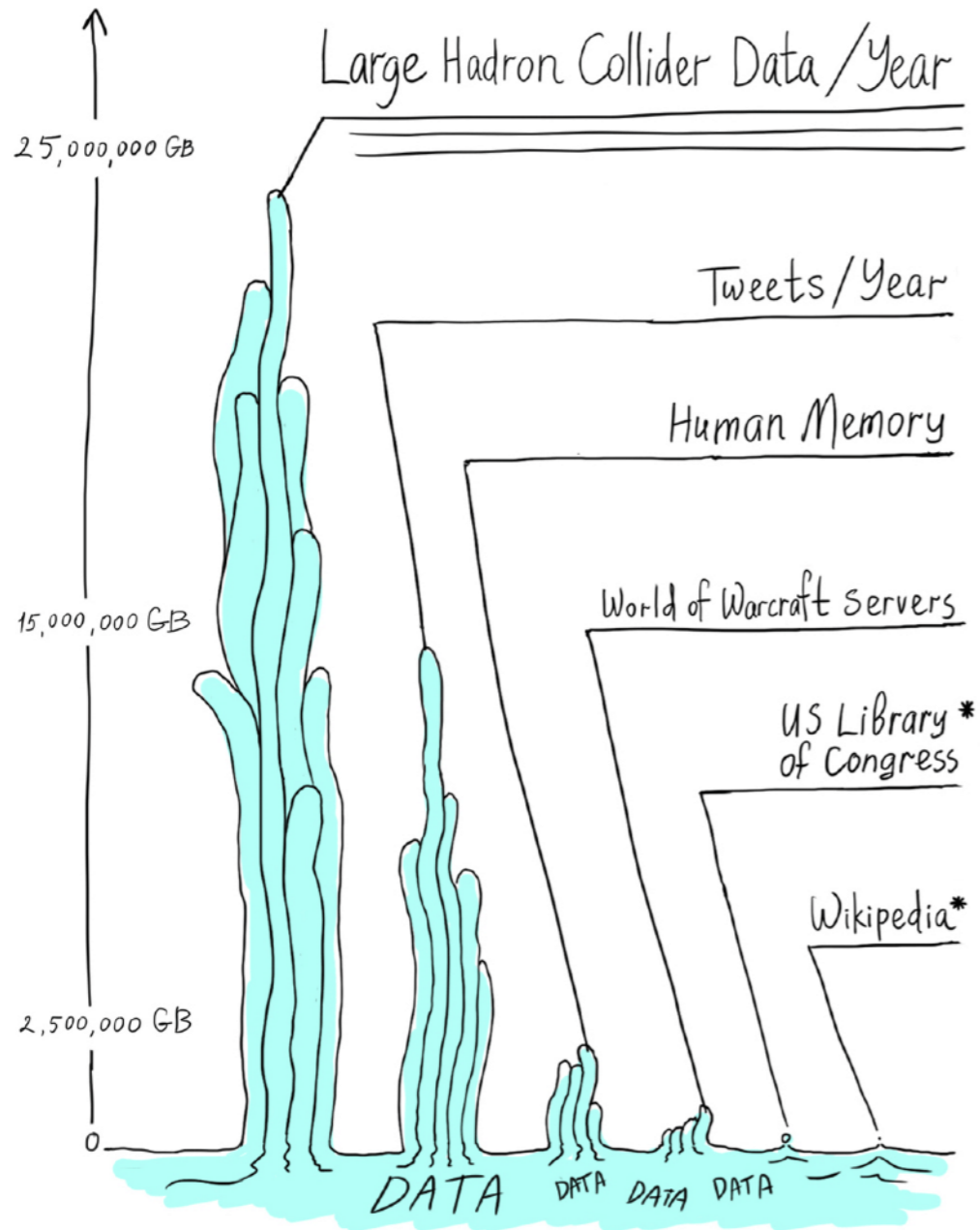
Christmas wish list:

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- Go further back in time closer to the big bang
- ...

**More Higgs and more quark-gluon plasma
Strong hints on physic beyond the SM !**

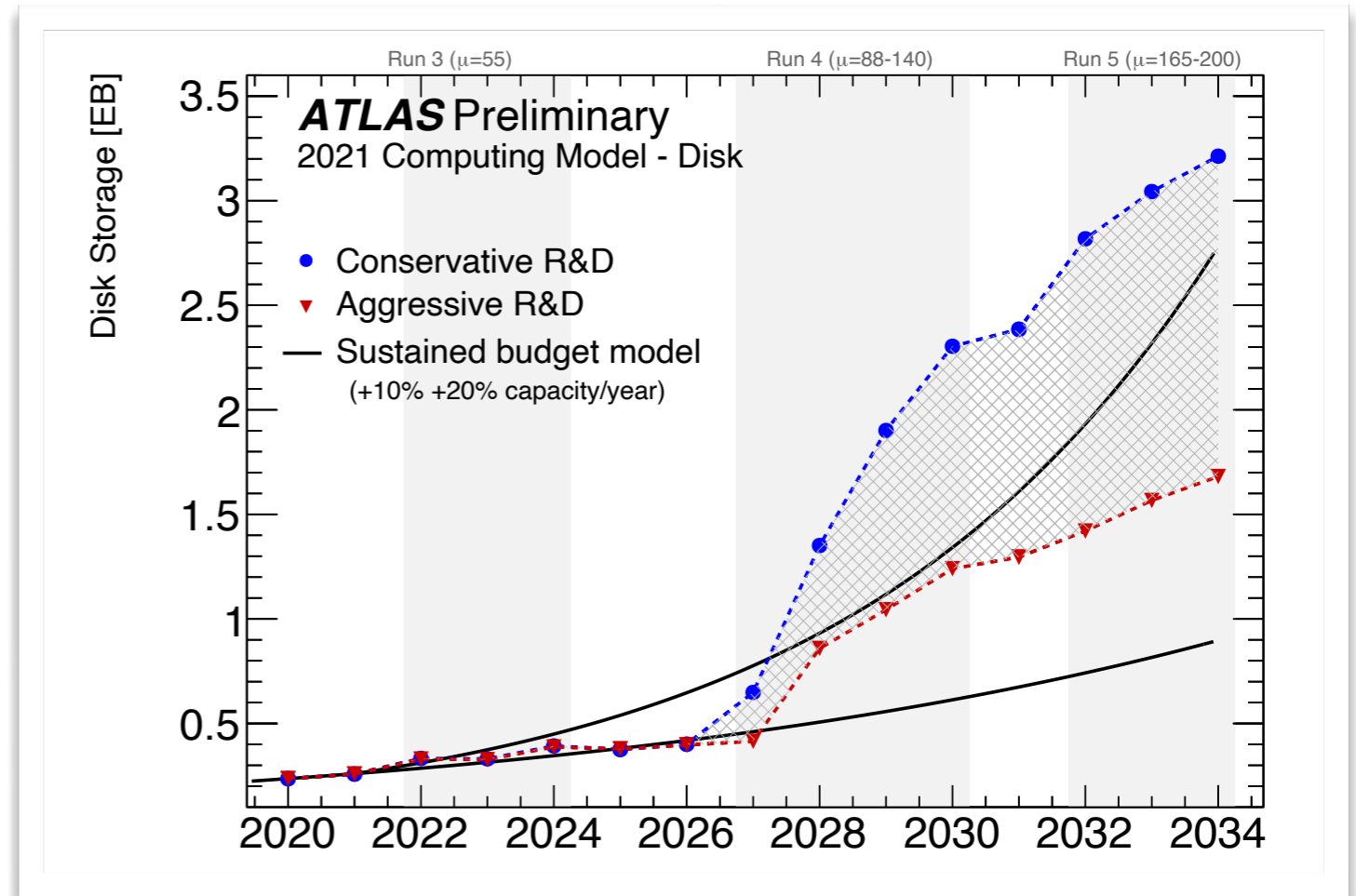


ALICE and ATLAS Computing Upgrade



All numbers approximate.

* Binary Data



Challenging future !

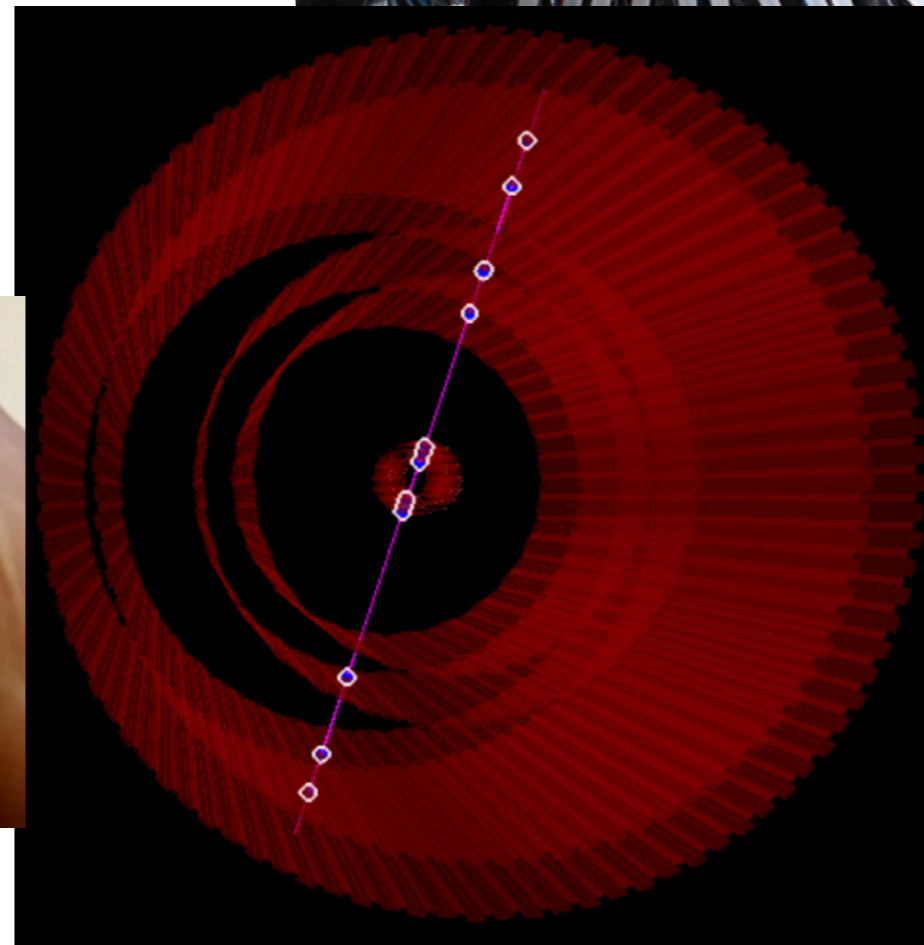
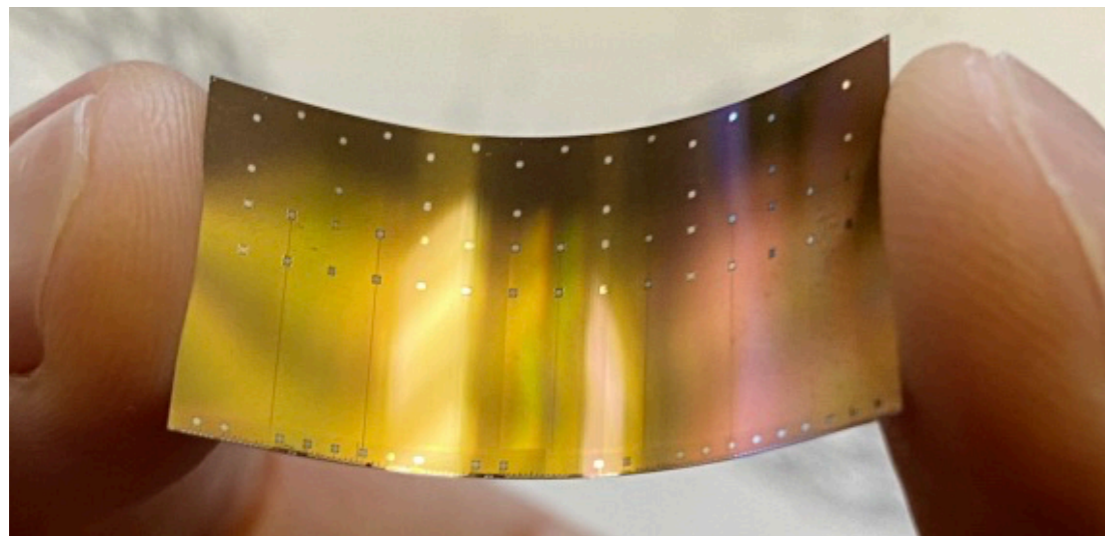
ALICE Upgrade

ITS3 - to be installed in LS3 (2026-2028)

- To achieve even better tracking precision and vertexing performance than ITS2
- New CMOS technology, stitching + thinning, enables wafer scaled curved sensors (low mass)

FoCal - to be installed in LS3 (2026-2028)

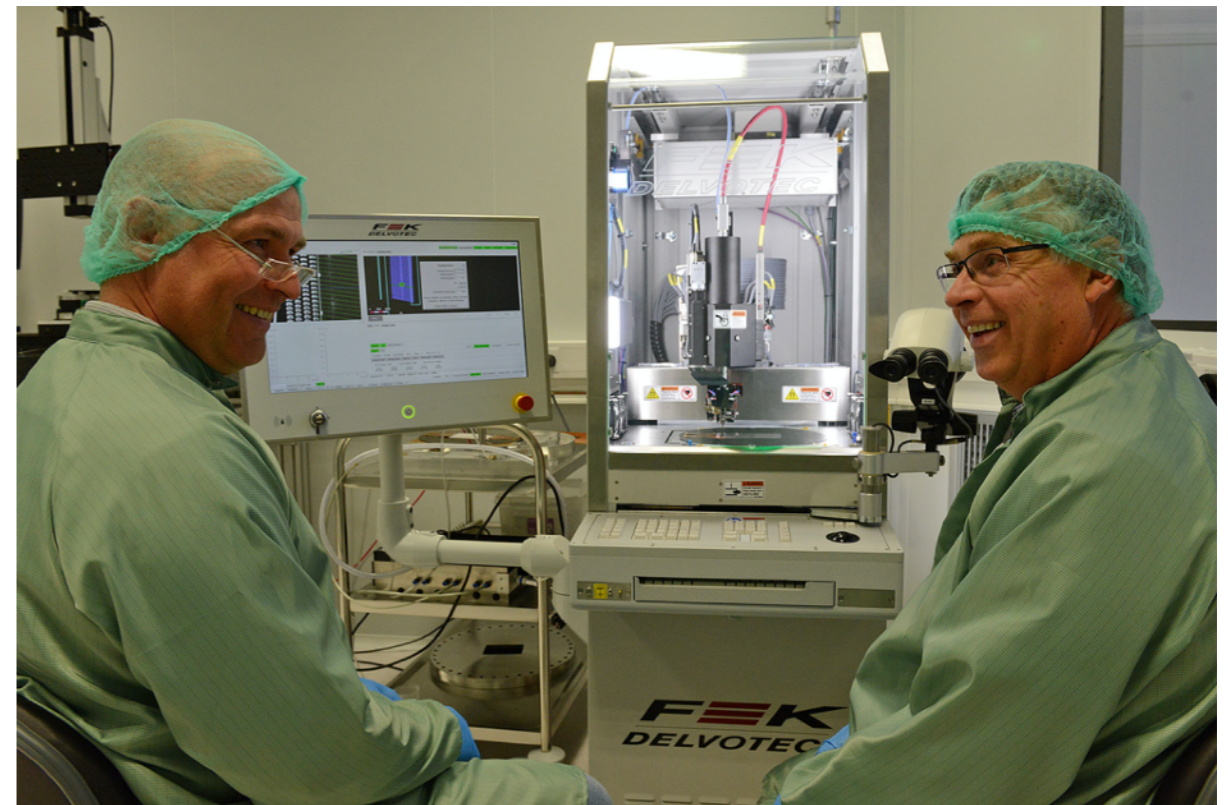
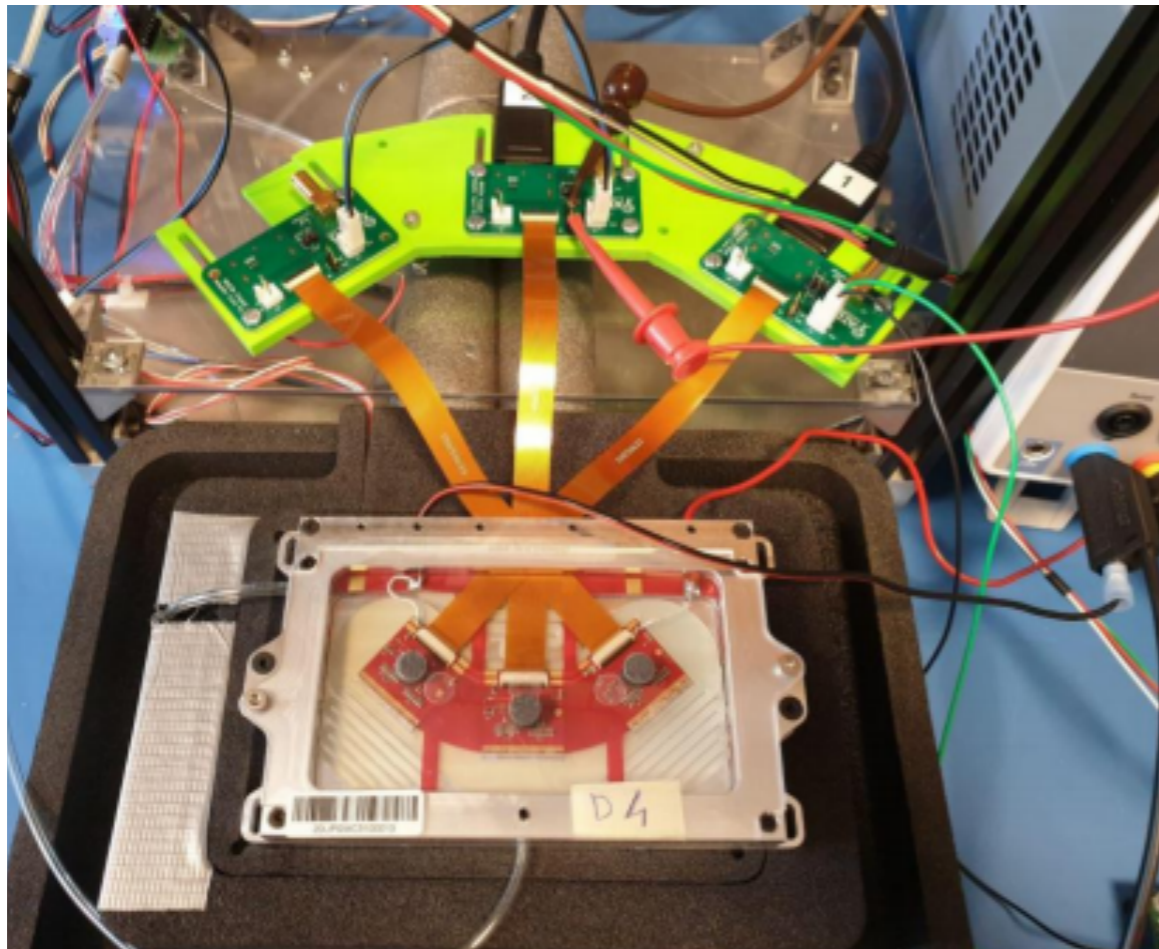
- Extend the coverage into the forward region close to the beam pipe
- Sheets of tungsten interleaved with sheets of silicon detectors (FoCal-E)



LS3 - ATLAS Upgrade

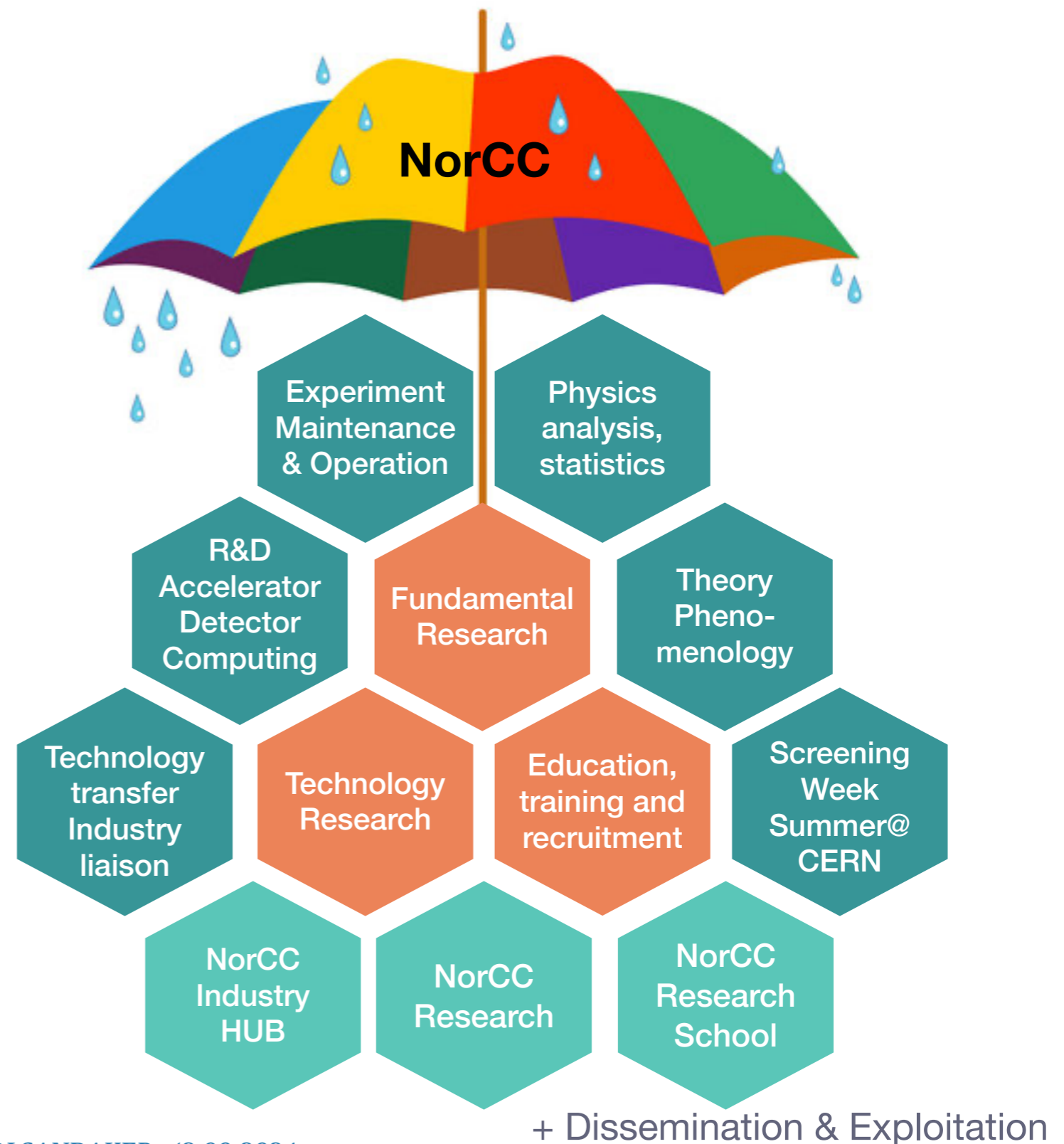
ATLAS ITK

- The ATLAS Inner Detector will be replaced by an all-silicon detector (14 m² of instrumented area)
- Due to the high radiation levels the innermost layer will use 3D pixel sensors
- Some 300 of the 3D pixel modules are planned to be assembled and tested in Norway
- Improved tracking resolution and precision !



Norwegian Centre for CERN-related research (NorCC)

- > 200 people total
- **Open to all interested institutions, currently:**
 - **UiB, UiO, HVL, USN, UiA, NTNU +**
- Research is focussed mainly on:
 - **Experiments:** UiB, UiO, HVL, USN, UiA
 - **Technology:** NTNU, UiA, USN, HVL
 - includes also some **theoretical** activities
 - Strong collaboration between **technology research and industry**
 - More Norwegian hired by CERN



NorCC organisation

Changes

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- A1 - Particle Physics
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◆ 2 supporting activities

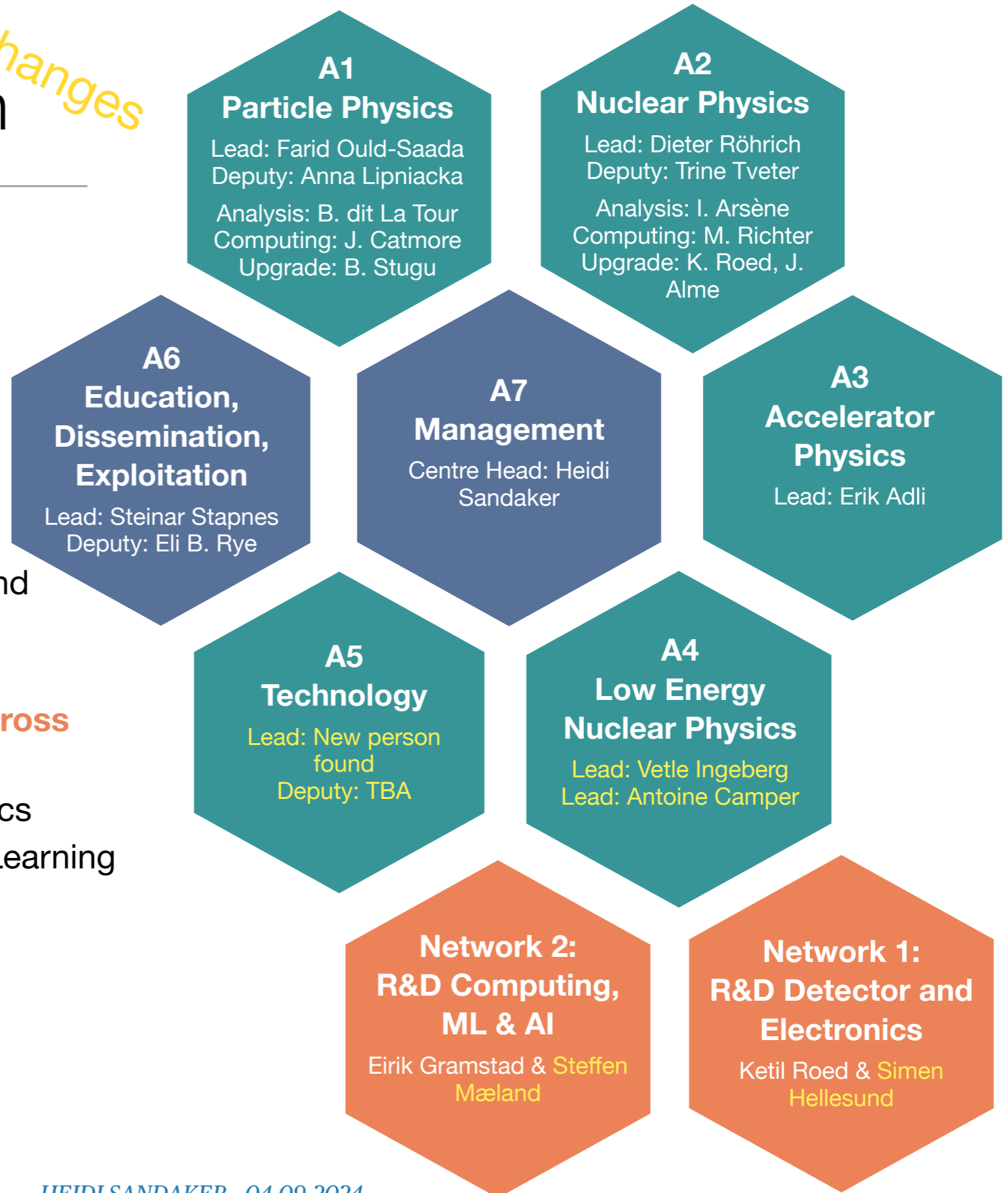
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◆ 2 networks enabling synergies across the research activities

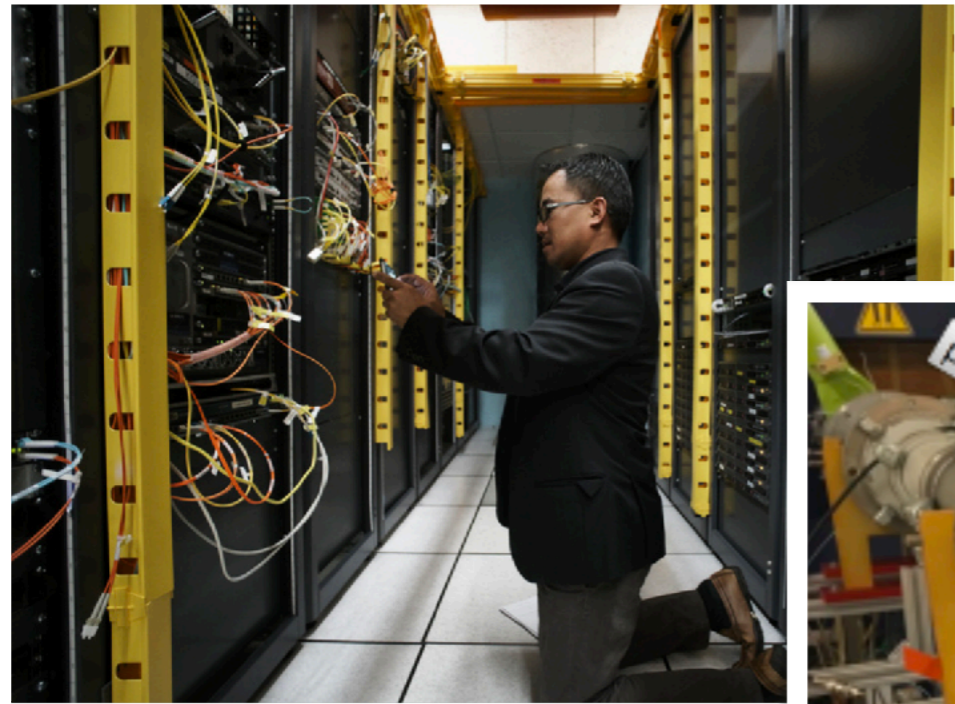
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- N2 - R&D Computing, Machine Learning and AI

◆ Laboratories and infrastructure

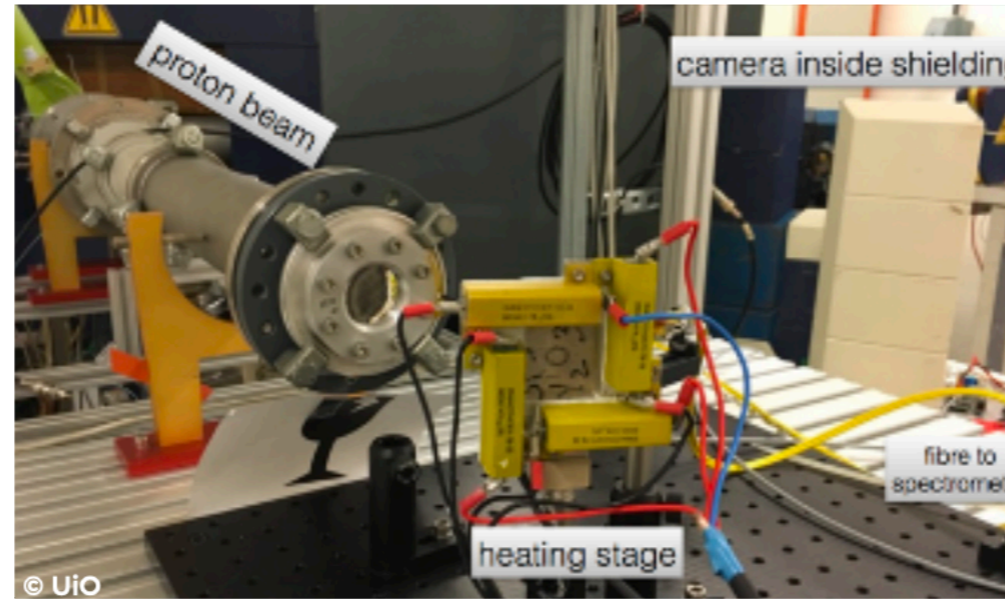
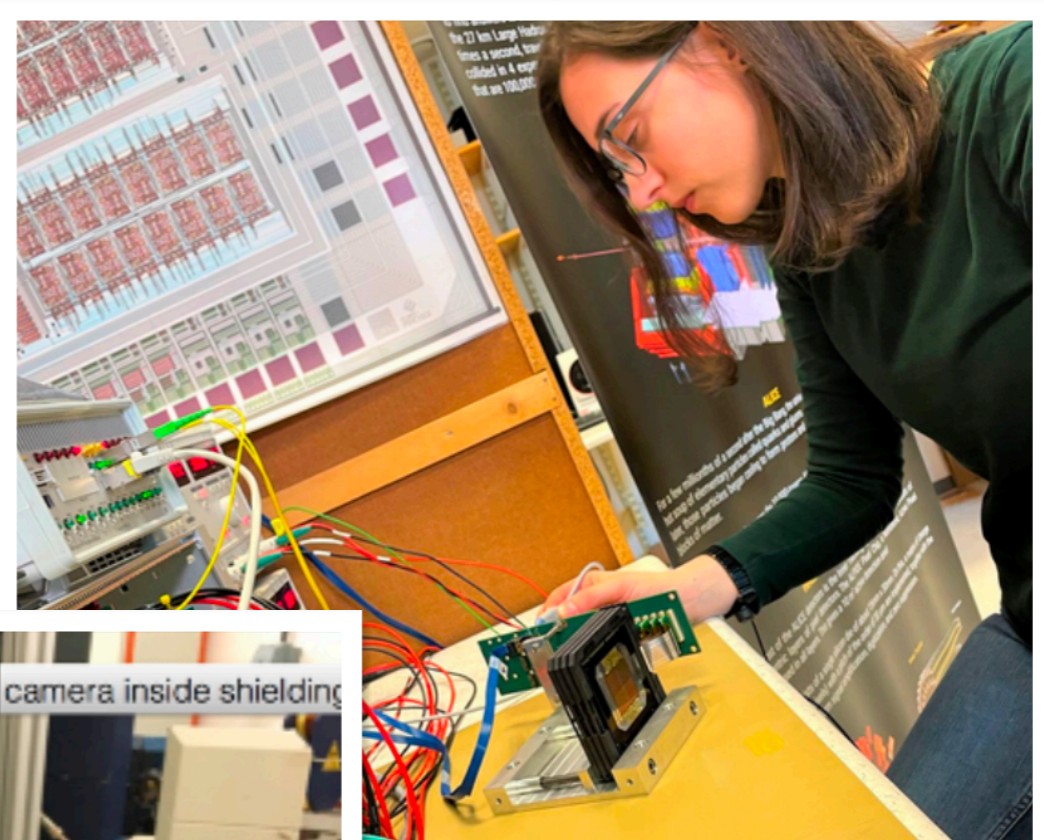
- NorLHC I & II
- NorFab (USN)



Advanced laboratories in Norway



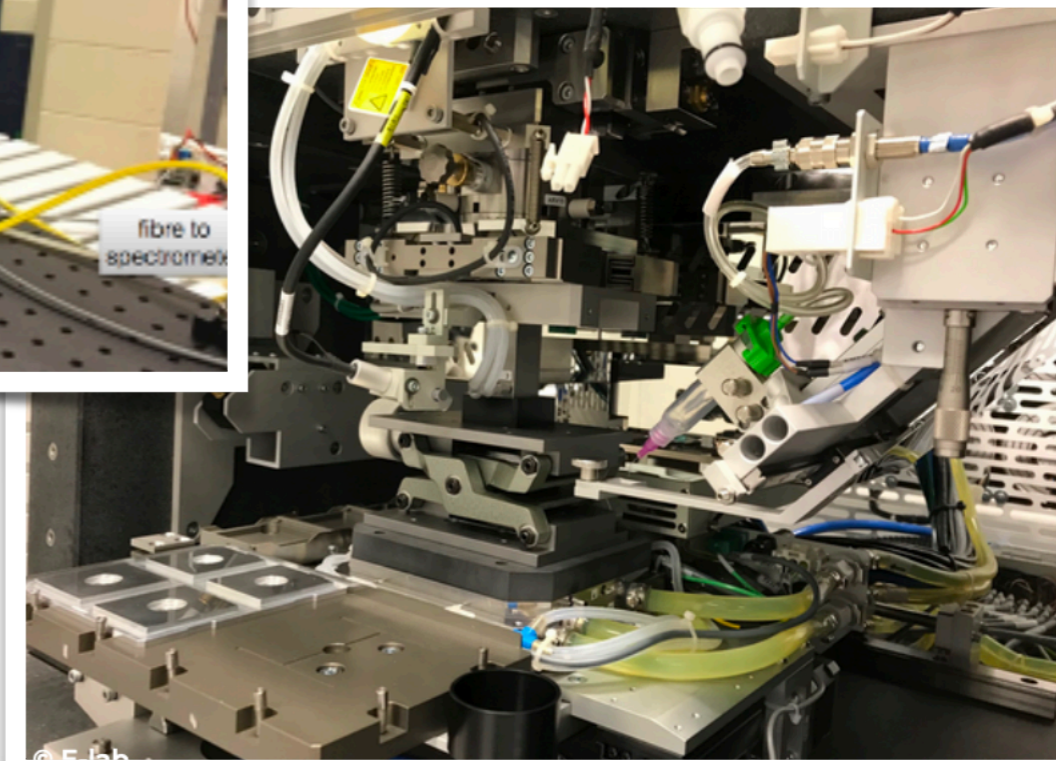
Oslo
Cyclotron
Laboratory



Advanced computing



NorFab USN



Electronics and
instrumentation laboratories

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NorCC and CERN 2025-2028

High school visits back to normal?
NorCC researcher school (all institutes)
NorCC Entrepreneur/Innovation school (all institutes)
Common courses in Norway



NorCC and CERN 2025-2028



CERN Green Village
Village size testbed

Norwegian Industry

Societal change



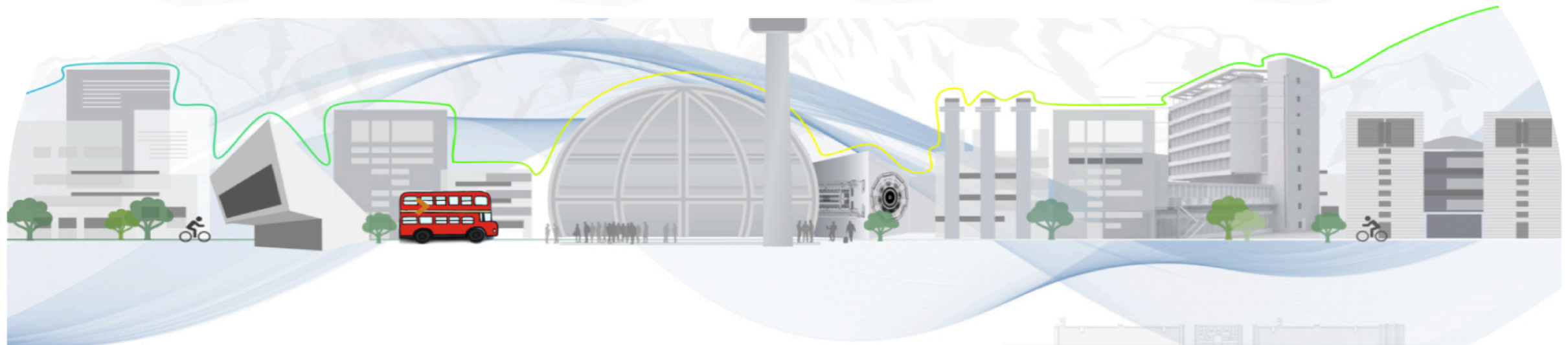
Goal: Accelerate the green transition of society and make research greener



Researchers at CERN and in Norway
New knowledge

Innovation & Entrepreneur School

Training & Recruitment



CERN | SCE
Site and Civil Engineering

667
BUILDINGS

3
RESTAURANTS

450
HOTEL ROOMS

17.3km
TECHNICAL GALLERIES

64km
TUNNEL

9000
PERSONS/DAY

8500+
OFFICE WORKING STATIONS

54km
ROADS

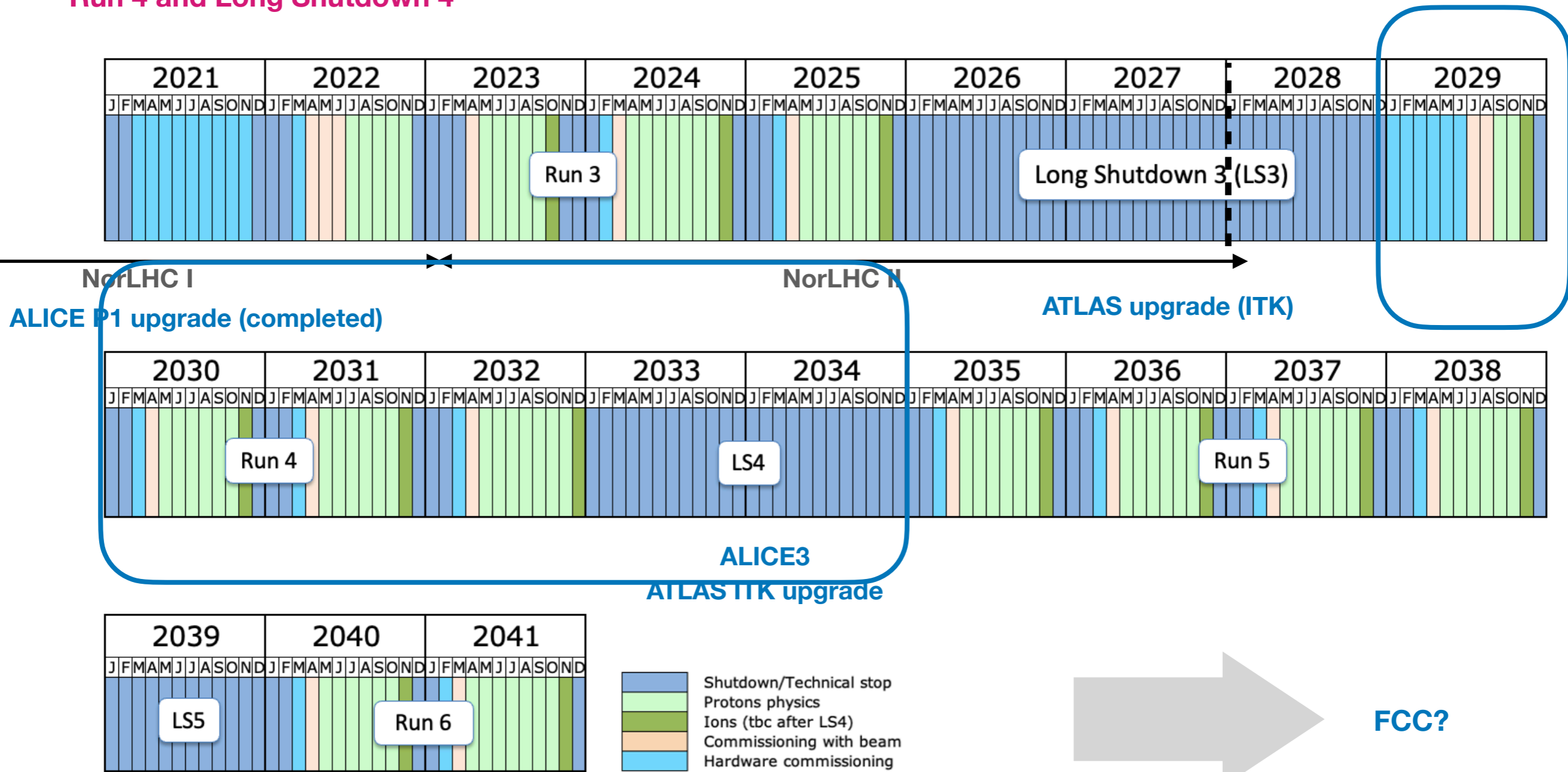
111ha
GREEN SPACES

400ha
FIELDS & FORESTS

625ha
TOTAL AREA

NorCC and CERN 2029-2034

Run 4 and Long Shutdown 4



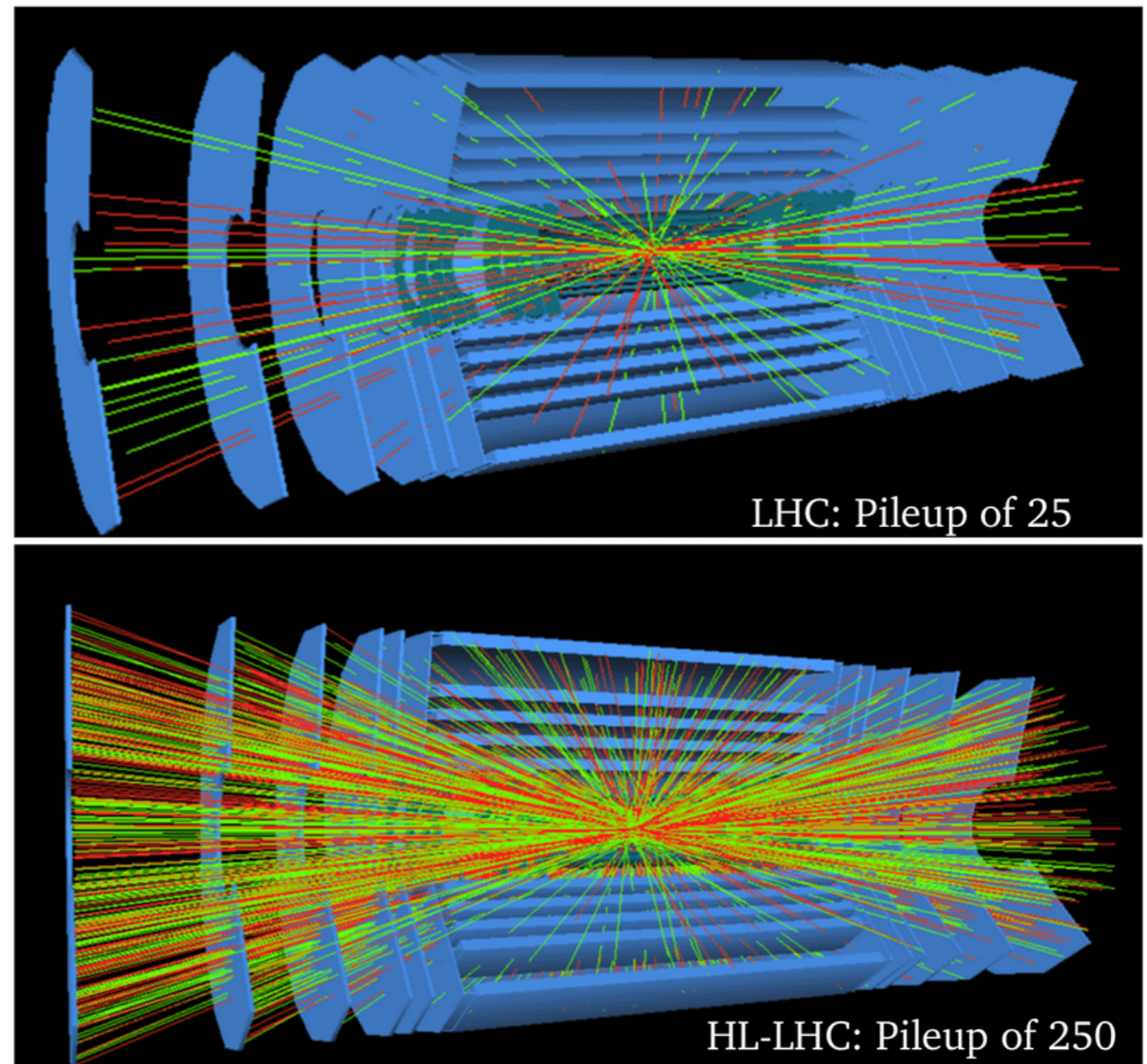
Last update: June 24

Data analysis continues

NorCC and CERN 2029-2034

Run 4 and Long Shutdown 4

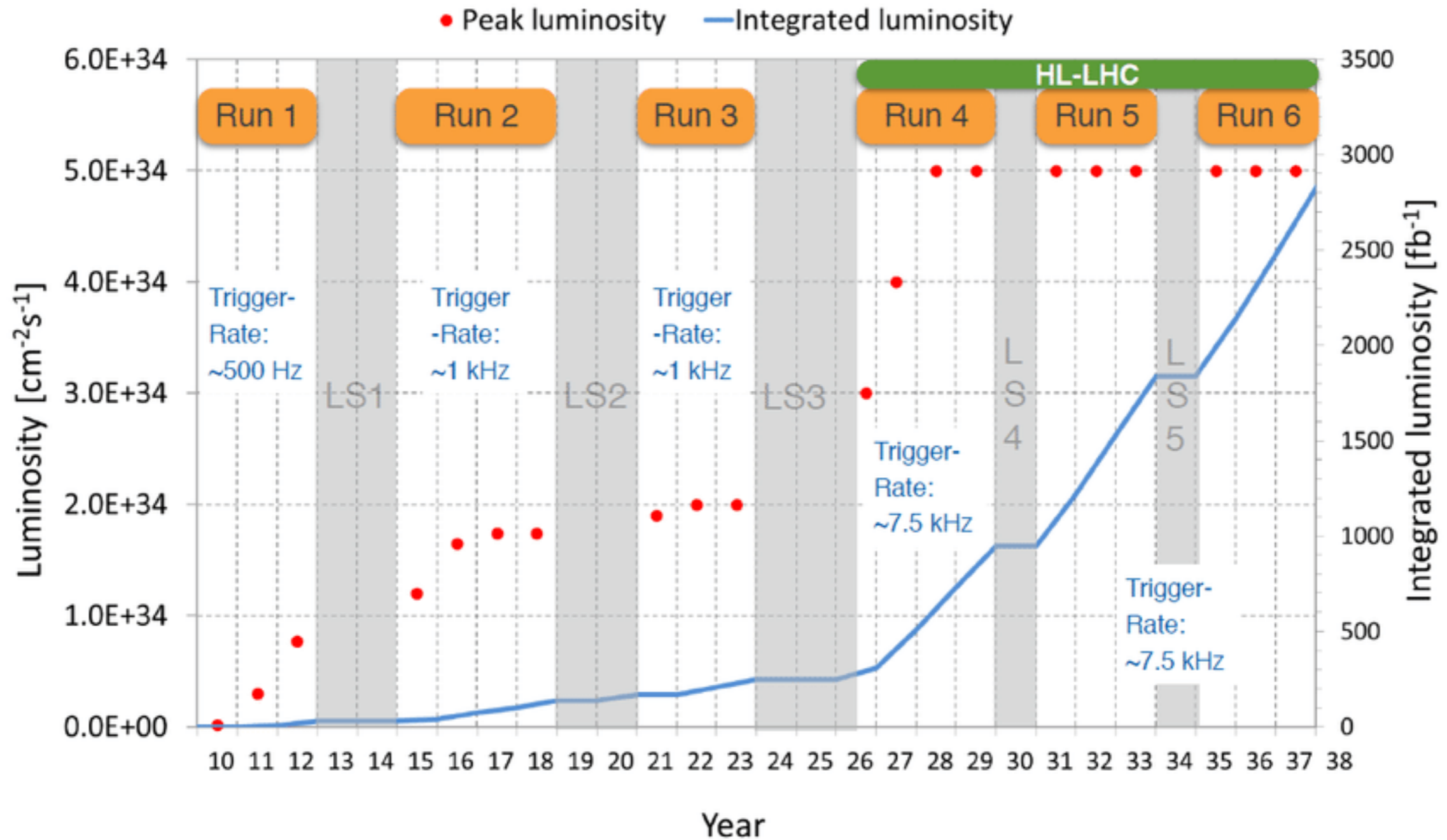
- HL-LHC collision rate is **5 times larger** than for LHC
- We need more statistics to find rare phenomena (Beyond Standard Model, Dark Matter)
- NorCC participate in the upgrades of ALICE and ATLAS both for **computing and detector upgrade**
- Financed by NFR infrastructures
 - NorLHC-I (2018-2022)
 - NorLHC-II (2020)
- Part of the ESFRI roadmap



HL-LHC will deliver 170 million Higgs bosons over 10 years

NorCC and CERN 2029-2034

Run 4 and Long Shutdown 4



NorCC and CERN 2029-2034

Run 4 and Long Shutdown 4 - Finding Dark matter?



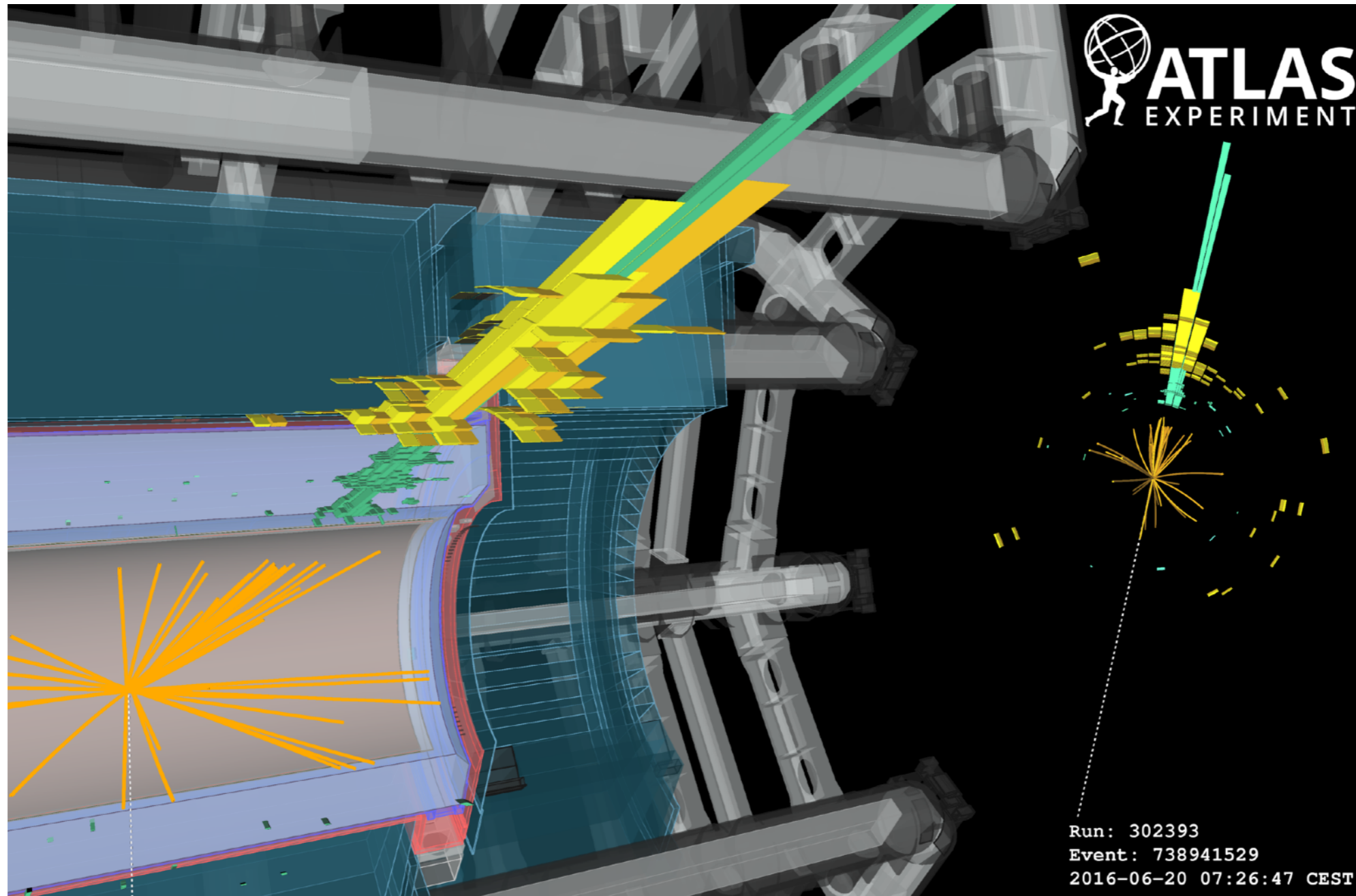
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This view of the massive galaxy cluster Cl 0024+17 (ZwCl 0024+1652) reveals the bent and amplified light of distant galaxies. The left view is in visible light with odd-looking blue arcs appearing among the yellowish galaxies. These are the magnified and distorted images of galaxies located far behind the cluster. The right image holds added blue shading that indicates the location of invisible dark matter. The shape and position of the gravitationally lensed galaxies we see in the left-hand image, mathematically requires the presence of this dark matter. NASA, ESA, M.J. Jee, and H. Ford (Johns Hopkins University)

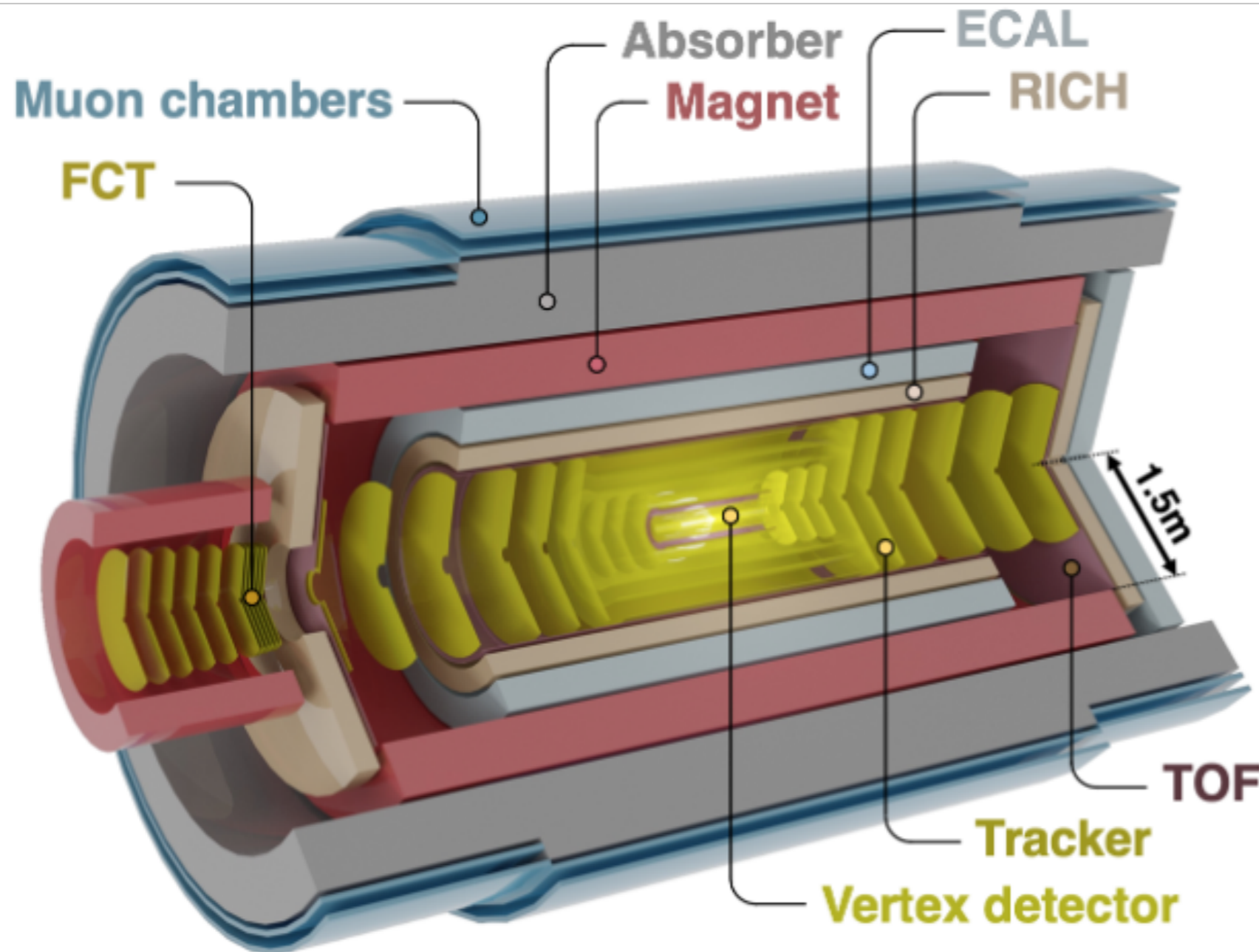
NorCC and CERN 2029-2034

Run 4 and Long Shutdown 4 - Finding Dark matter?



NorCC and CERN 2029-2034

Run 4 and Long Shutdown 4 - ALICE 3 + ATLAS upgrades

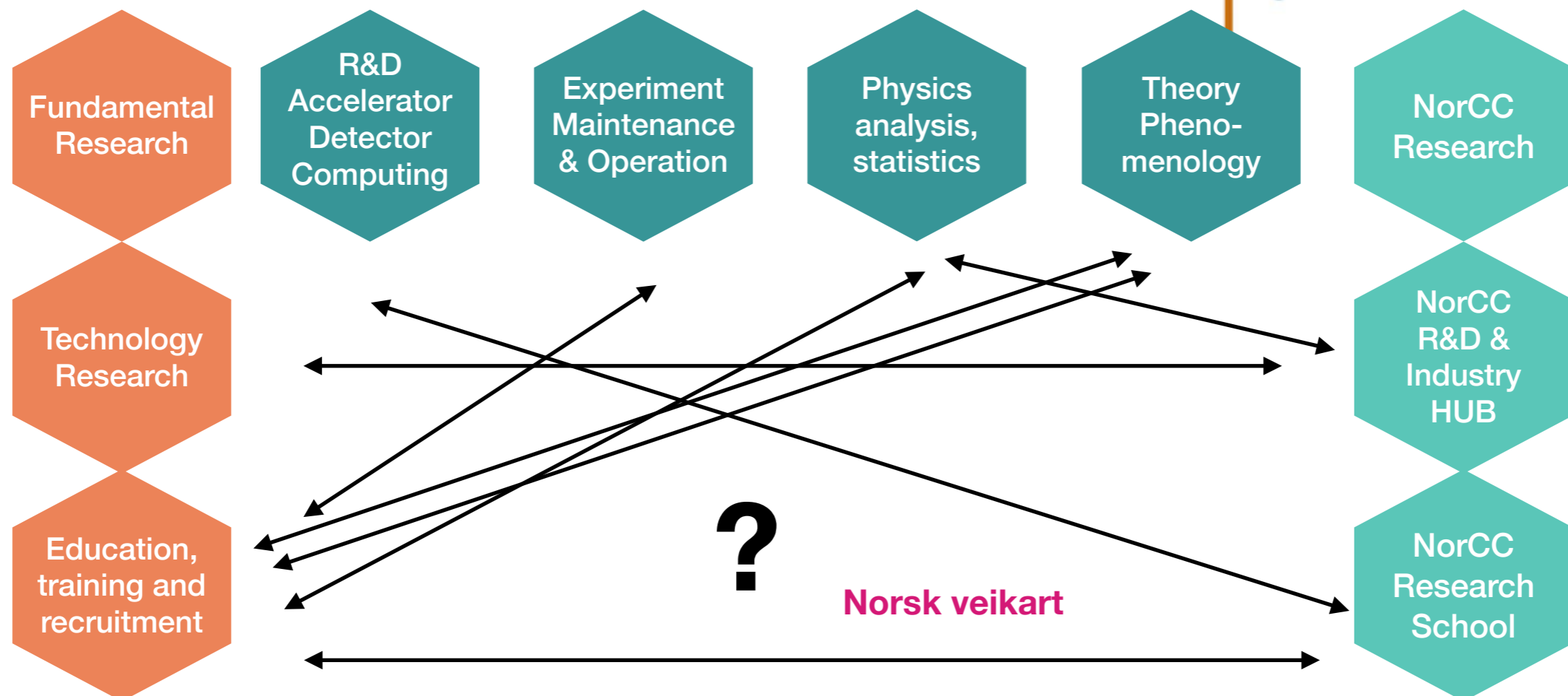


The aim is to build:

- a nearly massless barrel detector consisting of truly cylindrical layers
- based on curved wafer-scale ultra-thin silicon sensors with MAPS technology
- featuring an unprecedented low material budget of 0.05% X_0 per layer
- with the innermost layers possibly positioned inside the beam pipe

Norwegian Centre for CERN-related research (NorCC)

- > 300 people total
- **Open to all interested institutions, currently:**
 - **UiB, UiO, HVL, USN, UiA, NTNU +**
- Research may have a different approach - matrix?



NorCC and CERN 2035-2041

Run 5, Long Shutdown 5 and Run 6 - Final Run

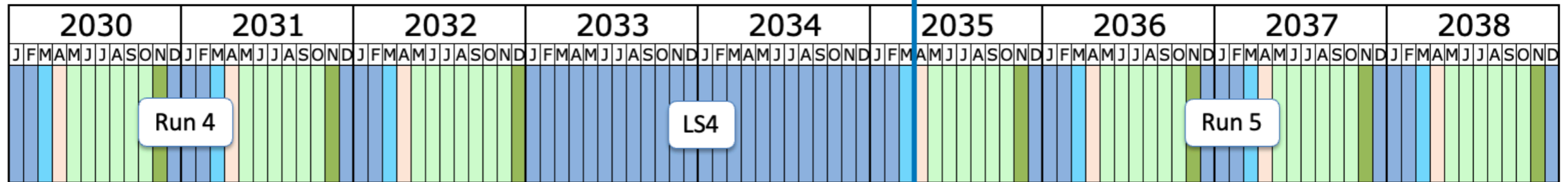


NorLHC I

NorLHC II

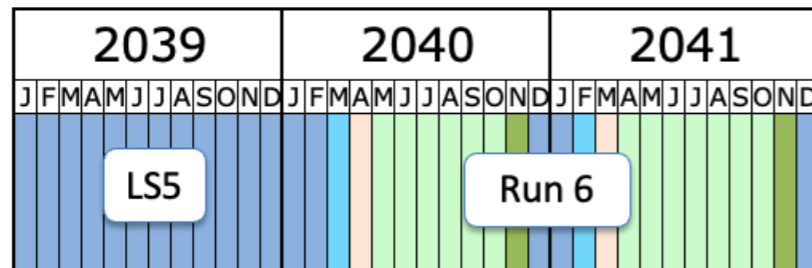
ALICE P1 upgrade (completed)

ATLAS upgrade (ITK)



ALICE3

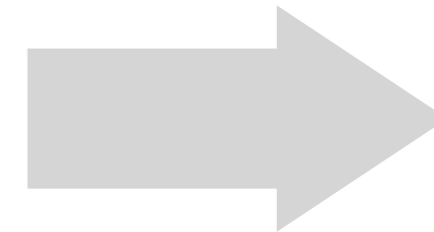
ATLAS ITK upgrade



Last update: June 24

- Shutdown/Technical stop
- Protons physics
- Ions (tbc after LS4)
- Commissioning with beam
- Hardware commissioning

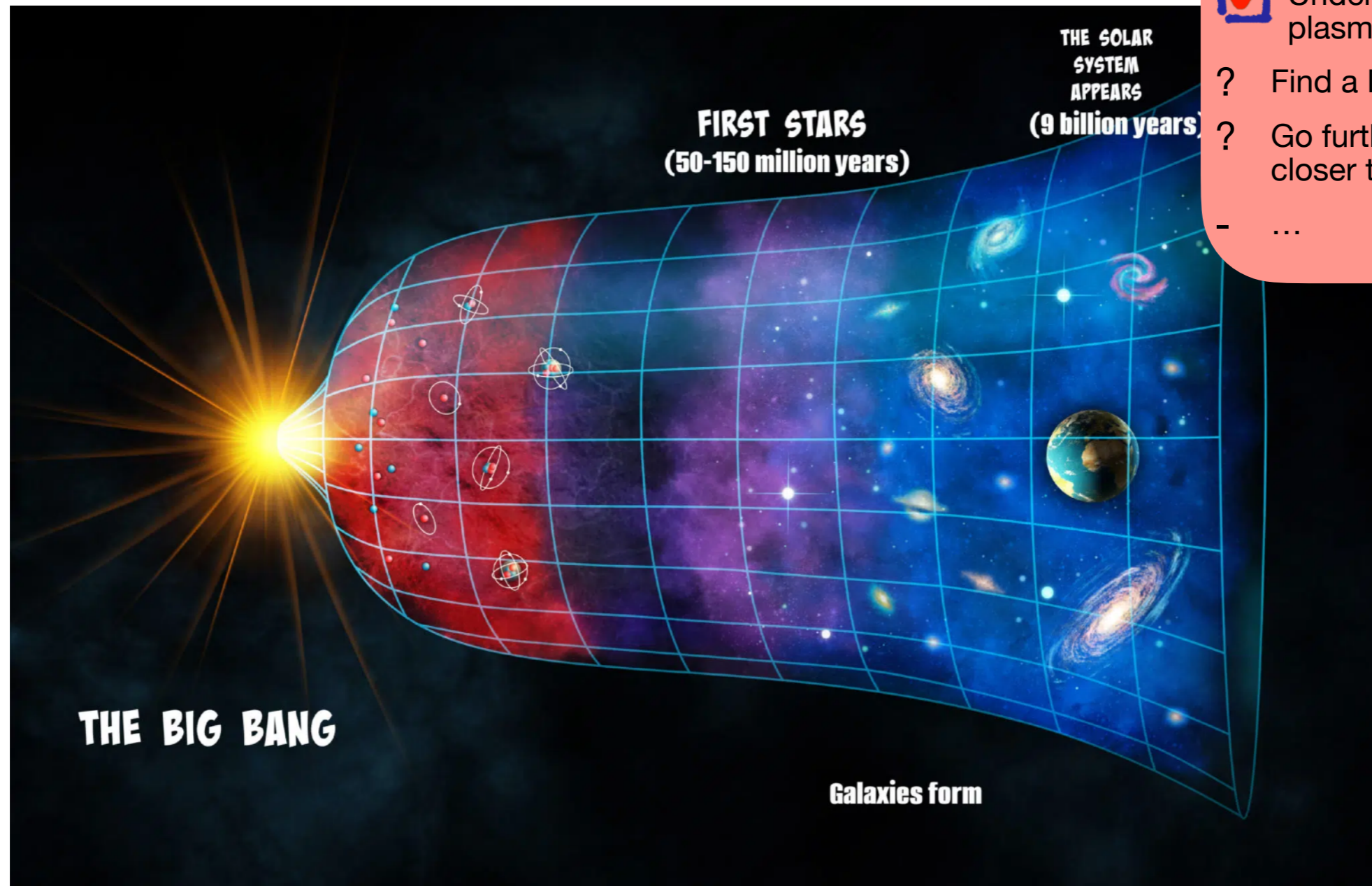
Data analysis continues



FCC?

NorCC and CERN 2035-2041

Run 5, Long Shutdown 5 and Run 6 - Final Run



Christmas wish list:

- Find the Higgs boson
- Produce quark-gluon plasma
- Find the properties of the Higgs boson
- Understand quark-gluon plasma
- ? Find a Dark matter particle
- ? Go further back in time closer to the big bang
- ...

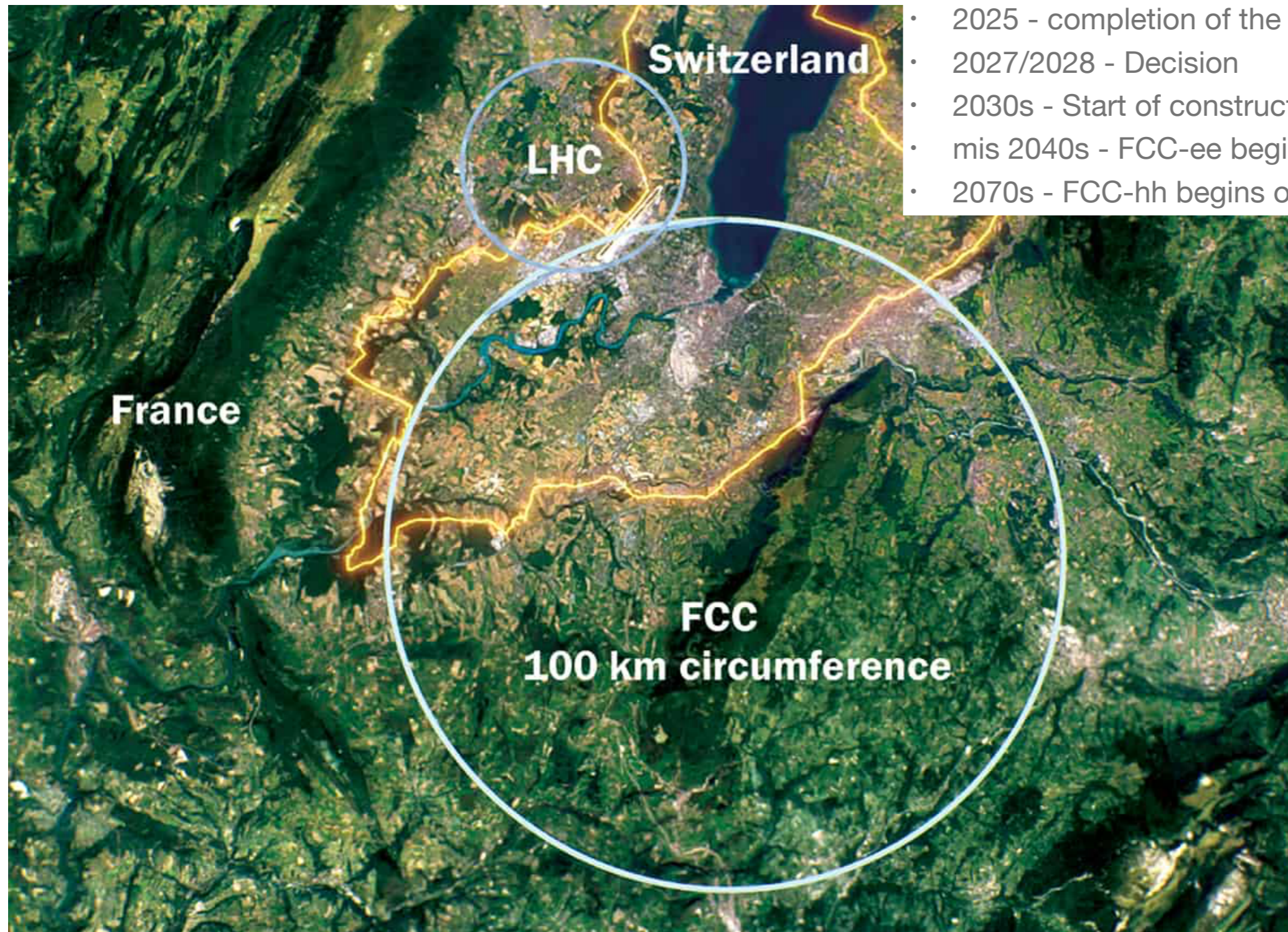
New exciting physics with ALICE 3 !

Norwegian Centre for CERN-related research (NorCC)

Many High School visits CERN
Large NorCC researcher school (all institutes)
NorCC school of innovation (all institutes)
Common courses in Norway and open internationally



NorCC and CERN 2042-2070



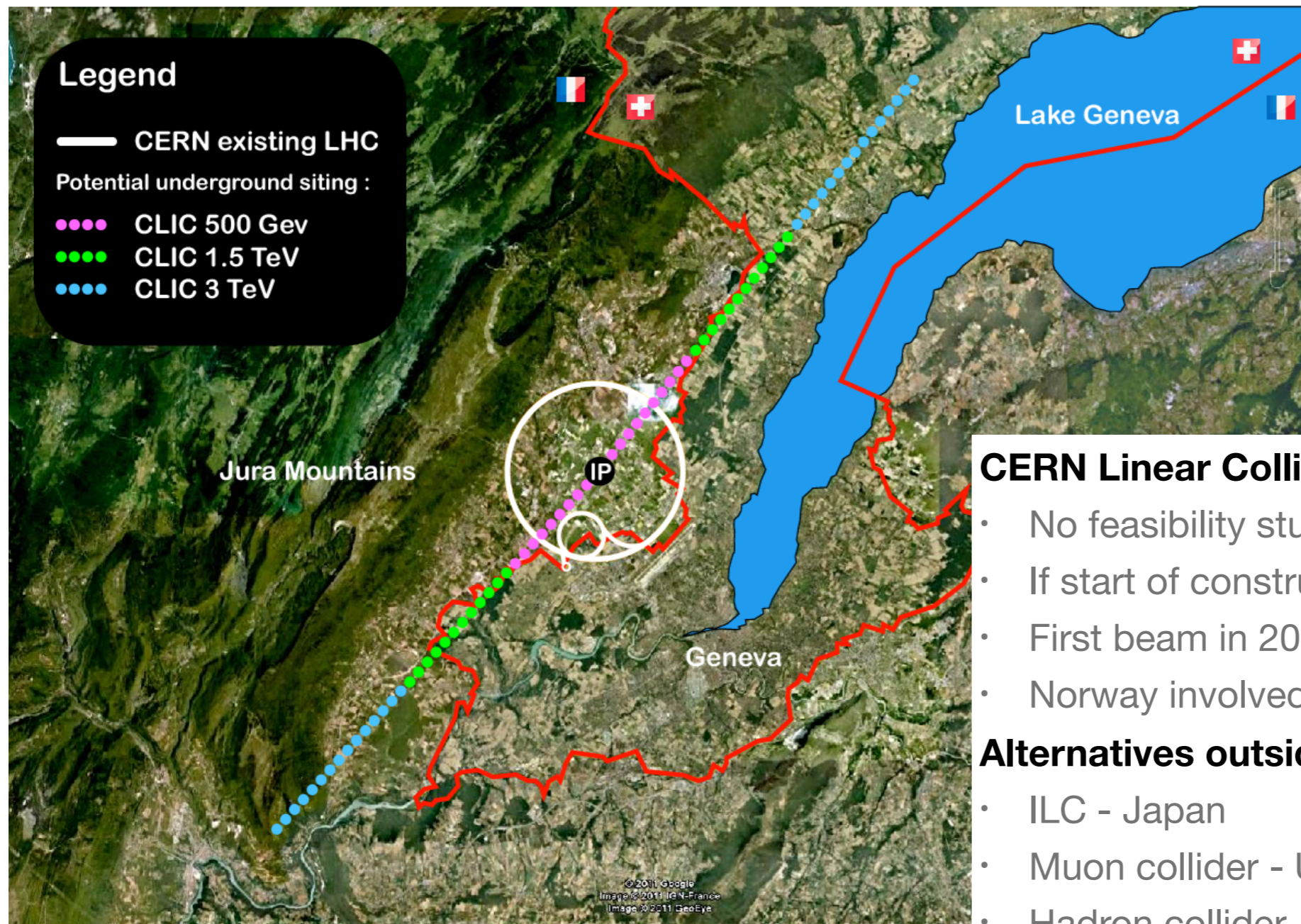
Future Circular Collider

- 2025 - completion of the Feasibility Study
- 2027/2028 - Decision
- 2030s - Start of construction
- mid 2040s - FCC-ee begins operation (15 years)
- 2070s - FCC-hh begins operation (25 years)

NorCC and CERN 2042-2070

Beyond HL-LHC

New accelerator = new physics and technology opportunities for Norway



CERN Linear Collider

- No feasibility study
- If start of construction is 2026:
 - First beam in 2035 (25-30 years operation)
 - Norway involved in looking at FCC alternatives

Alternatives outside of Europe

- ILC - Japan
- Muon collider - US
- Hadron collider - China

Update of European Strategy for particle physics

Timeline for the update of the European Strategy for Particle Physics



- Hope to arrive at a clear message for FCC and alternatives to FCC
- Is earlier than planned

NorCC and CERN 2070+

- **Particle, astroparticle, astrophysics ...**

A vast field of galaxies, including spirals, ellipticals, and irregular shapes, scattered across a dark background. The galaxies are in various colors, including yellow, blue, and purple. The text "Gratulerer med dagen !" is centered in the image.

Gratulerer med dagen !