Report from CERN

Fabiola Gianotti, Plenary ECFA, CERN, 15 November 2018

Scientific programme: recent news

Scientific programme : **3** pillars

Full exploitation of the LHC:

- ❑ successful operation of the nominal LHC until end 2023 (Run 2, LS2, Run 3) → 300/fb
- ❑ construction & installation of LHC upgrades: LIU (LHC Injectors Upgrade) and HL-LHC → 3000/fb

Note: expect to move to 14 TeV operation in Run 3. Currently also exploring possibility to achieve "ultimate" energy of 15 TeV in Run4++

Scientific diversity programme serving a broad community:

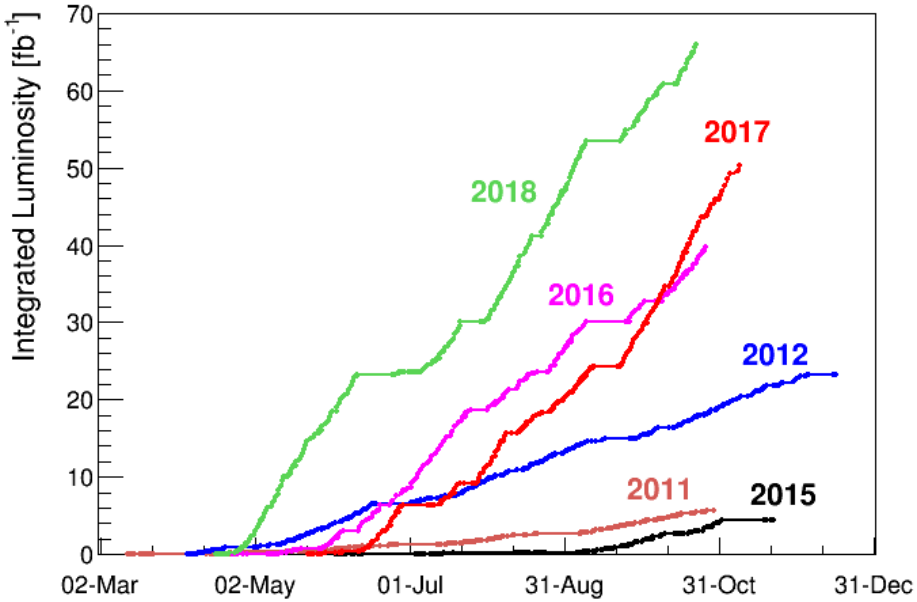
- ❑ ongoing experiments and facilities at Booster, PS, SPS and their upgrades (HIE-ISOLDE, ELENA)
- ❑ participation in accelerator-based neutrino projects outside Europe (presently mainly LBNF in the US) through CERN Neutrino Platform

Preparation of CERN's future:

- ❑ vibrant accelerator R&D programme exploiting CERN's strengths and uniqueness (including superconducting high-field magnets, AWAKE, etc.)
- ❑ design studies for future high-energy accelerators: CLIC, FCC (includes HE-LHC)
- ❑ future opportunities of diversity programme: Physics Beyond Colliders Study Group

Mostly covered tomorrow

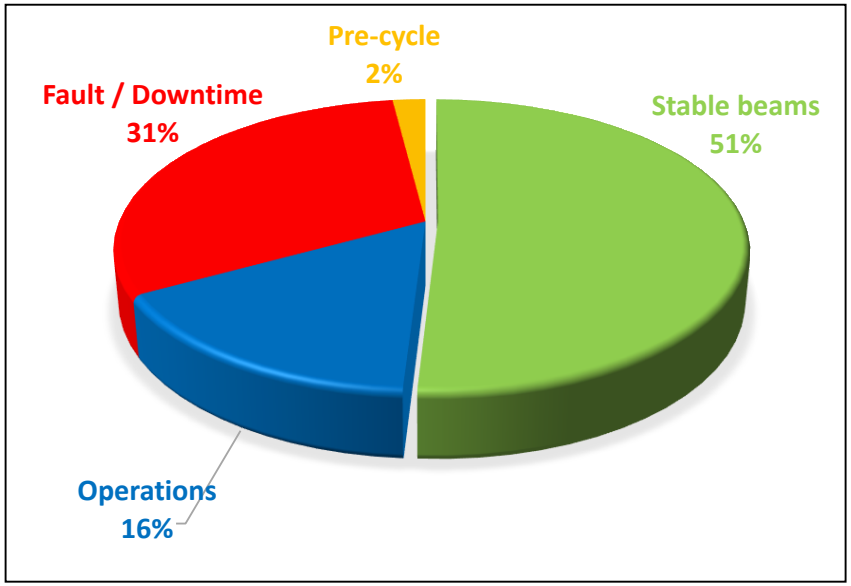
LHC and accelerator complex



In 2018:

ATLAS	65 fb^{-1}	(goal was 60 fb^{-1})
CMS	67 fb^{-1}	(goal was 60 fb^{-1})
LHCb	2.46 fb^{-1}	(goal was 2 fb^{-1})

Parameter	2018	Design
Energy [TeV]	6.5	7.0
No. of bunches	2556	2808
Max. stored energy per beam (MJ)	312	362
β* [cm]	30→25	55
p/bunch (typical value) [10^{11}]	1.1	1.15
Typical normalized **emittance** [μm]	~1.8	3.75
Peak **luminosity** [10^{34} cm^{-2}s^{-1}]	2.1	1.0



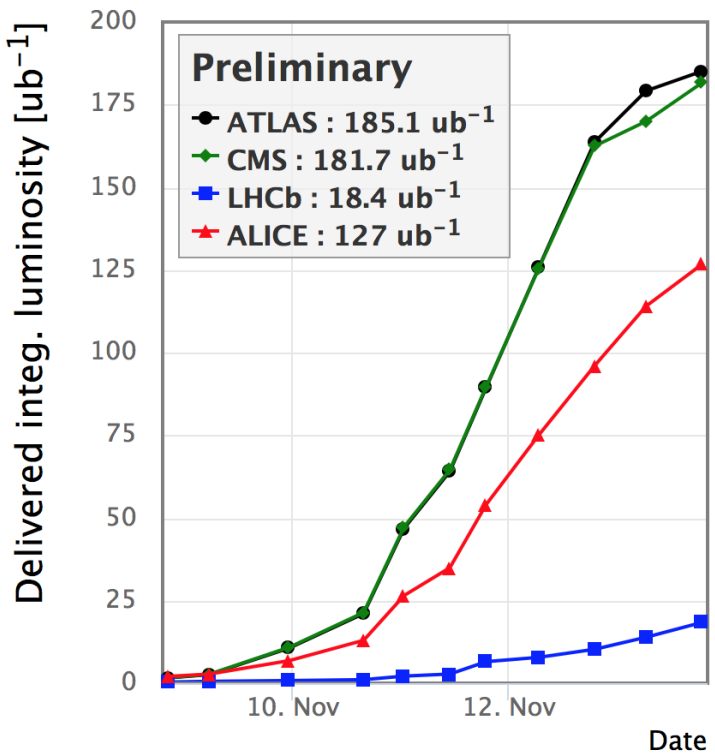
LHC and accelerator complex

Period	Int. Luminosity [fb^{-1}]
Run 1	29.2
Run 2: 2015	4.2
Run 2: 2016	39.7
Run 2: 2017	50.2
Run 2: 2018	66.0
Total Run1 + Run 2	189.3

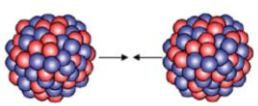
Total Run 2 (13 TeV): 160 fb^{-1}

expected: 150 fb^{-1}

Glorious end of Run 2 for pp !



Now (5 Nov - 2 Dec): Pb-Pb run



$\sqrt{s_{NN}}$ ~ 5 TeV

Peak luminosity so far 2-3x10^{27} $cm^{-2}s^{-1}$
Levelled to 1x10^{27} in ALICE

Long-Shutdown 2 (2019-2020): main activities

LIU (LHC Injectors Upgrade) construction completion and installation (e.g. connection of LINAC4)
→ Provide beams of intensity and brightness required for HL-LHC: 2.3×10^{11} p/bunch, ε~2.1 μm

Phase-1 upgrade of LHC experiments

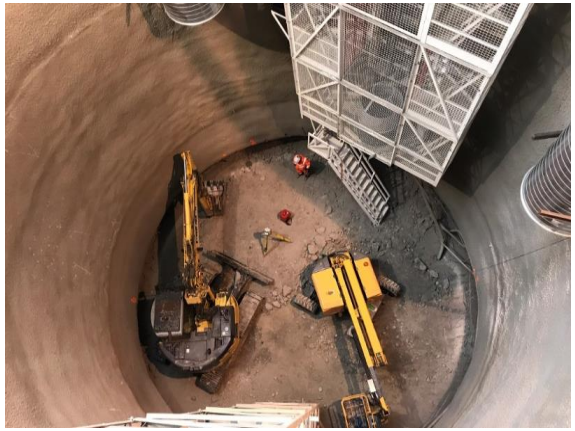
Major maintenance and consolidation work
Dipole diodes insulation consolidation → operation at 14 TeV in Run 3
Replacement of ~20 LHC magnets

Anticipate work for HL-LHC:
Installation of two pairs of 11 T Nb_3Sn dipoles in IR7
HL-LHC Civil Engineering work at IP1 and IP5

ELENA transfer lines and connection of AD experiments

East Area consolidation

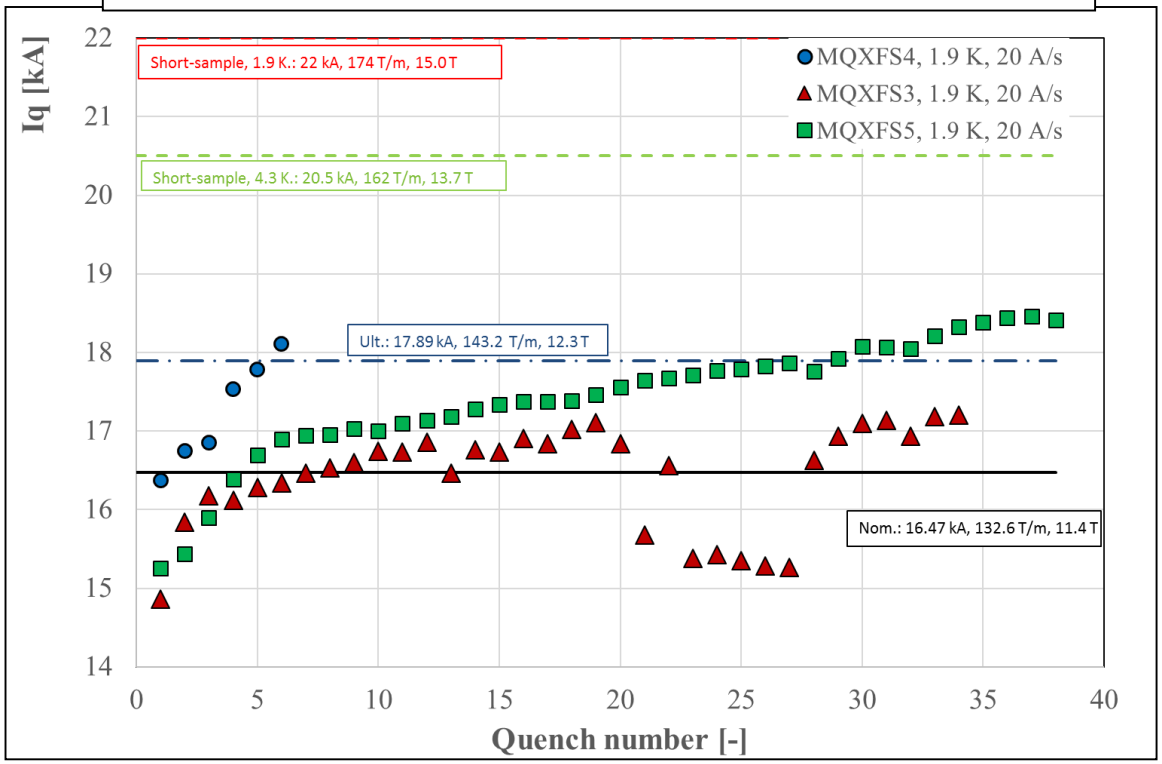
Civil engineering work at IP1 and IP5 started



Nb_3Sn dipoles and inner triples quadrupoles

Construction of full-size (5.5 m) 11 T dipole

Inner triplets quadrupole models
MXFS4 reached ultimate current after 5 quenches (and without quenches after thermal cycles)



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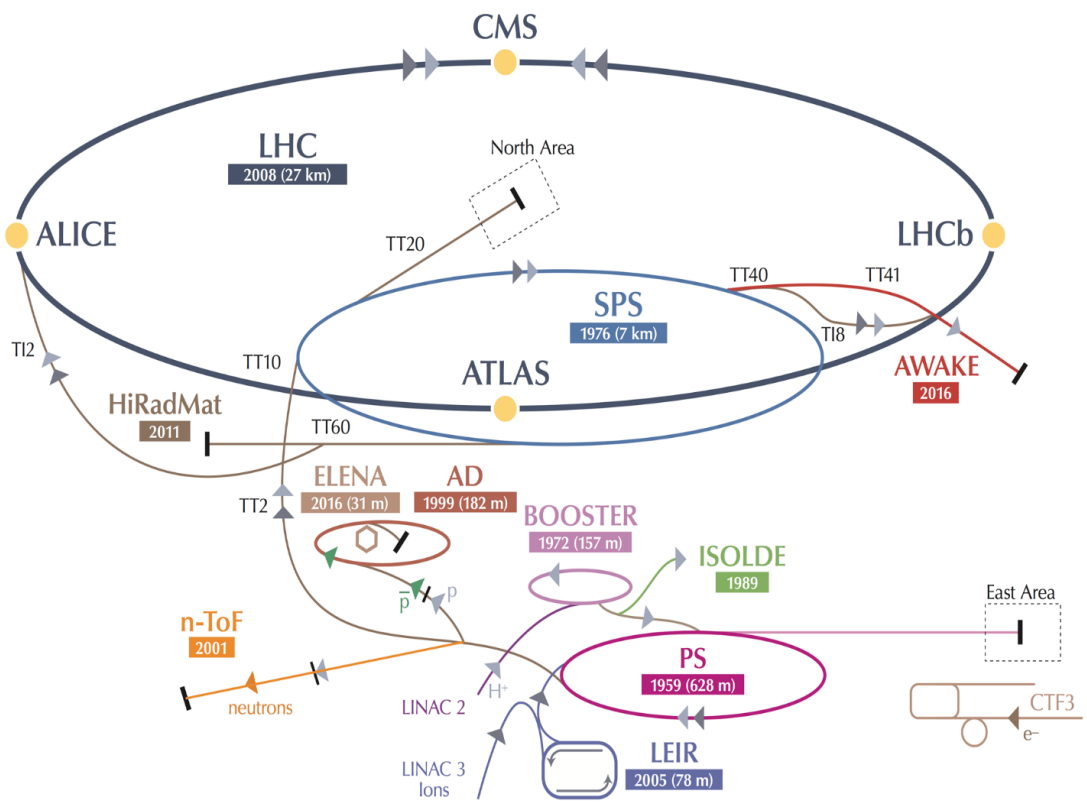
CERN scientific diversity programme



AD: Antiproton Decelerator for antimatter studies

CAST, OSQAR: axions

CLOUD: impact of cosmic rays on aeorosols and clouds → implications on climate

COMPASS: hadron structure and spectroscopy

ISOLDE: radioactive nuclei facility

NA61/Shine: heavy ions and neutrino targets

NA62: rare kaon decays

NA63: interaction processes in strong EM fields in crystal targets

NA64: search for dark photons

Neutrino Platform: ν detectors R&D for experiments in US, Japan

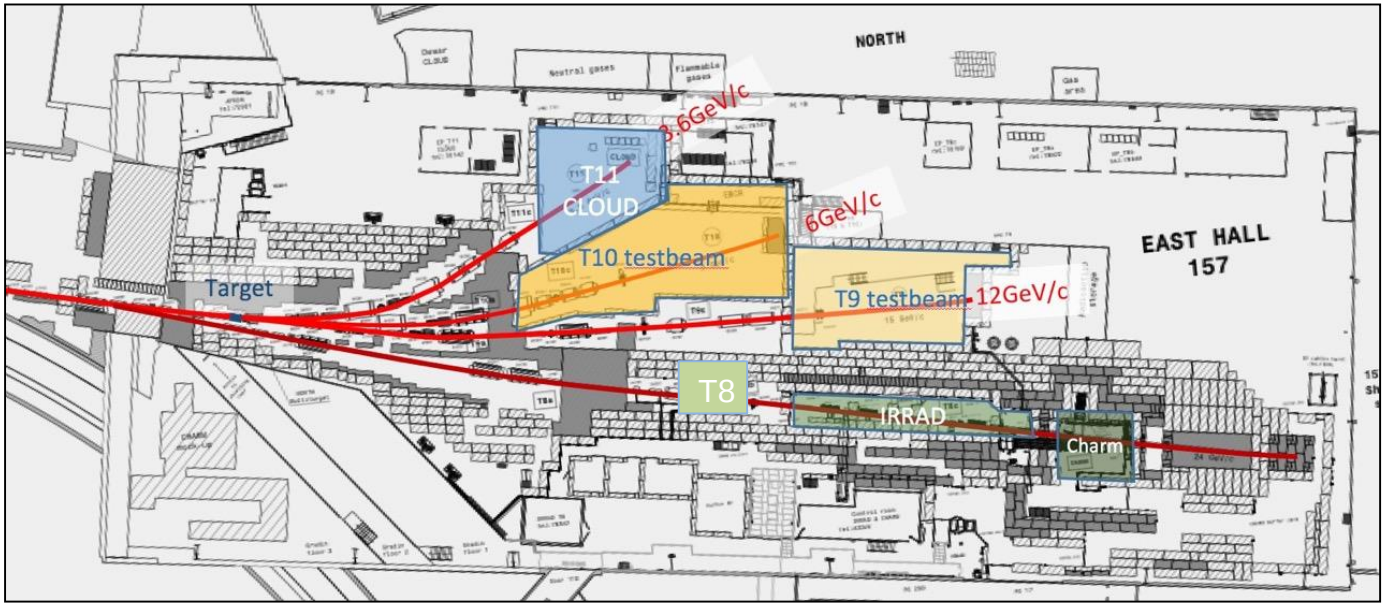
n-TOF: n-induced cross-sections

UA9: crystal collimation

Future opportunities being studied by "Physics Beyond Colliders" Study Group: proton EDM, rare decays, beam dump or electron scattering facilities to search for dark-sector particles, etc.

East area renovation

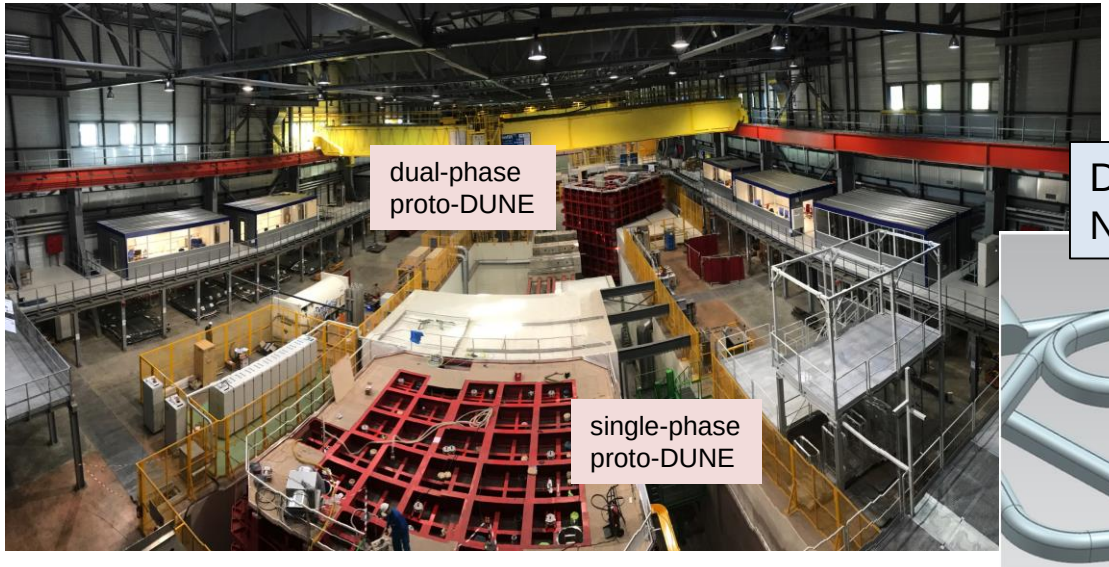
Unique facility in Europe: provides hadron beams down to ~ 1 GeV, large availability, easy access
→ used by a broad community:
- ❑ experiments: CLOUD (previously DIRAC, HARP); Beam-Line-for-School
- ❑ test beams: LHC, COMPASS, LC detectors, SHiP, …
- ❑ irradiation facilities: IRRAD (detector components), CHARM (accelerator R2E)



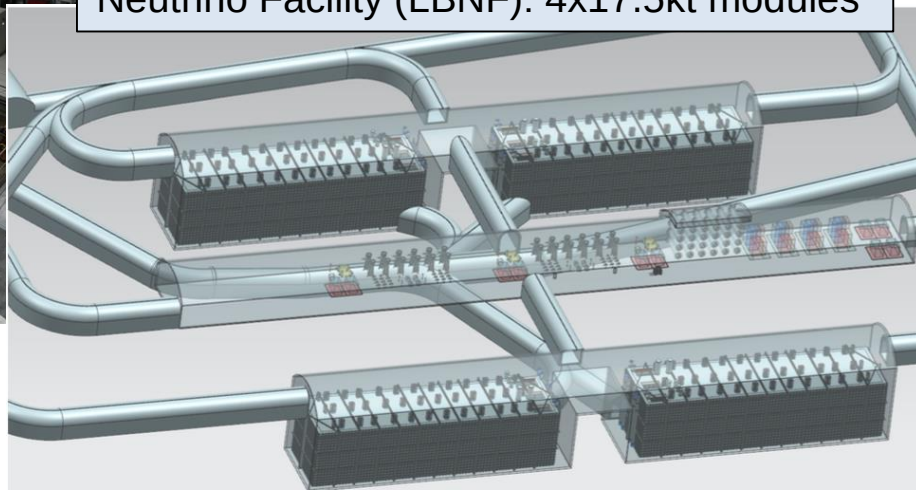
EA renovation during LS2:
- ❑ very old equipment, lack of spares, manpower- and time-consuming interventions
  → new pulsed magnets, power converters, cooling and ventilation, electrical infrastructure
  → energy saving of ~ 600 kCHF/year
- ❑ increase beam energy up to 15 GeV (→ overlap with NA beams), better particle separation

CERN Neutrino Platform

- supports European participation in accelerator-based neutrino projects in US and Japan
- North Area extension → provides charged beams and test space for (big) neutrino detectors
- R&D to demonstrate large-scale LAr technology (cryostats, detectors, …); participation in construction and test of two prototypes of DUNE detector: single and dual-phase LAr TPC, ~ 6x7x7 m^3, ~ 750 tons each
- construction of cryostat for first DUNE module
- efforts started also on near detectors (bringing together DUNE and T2K communities)

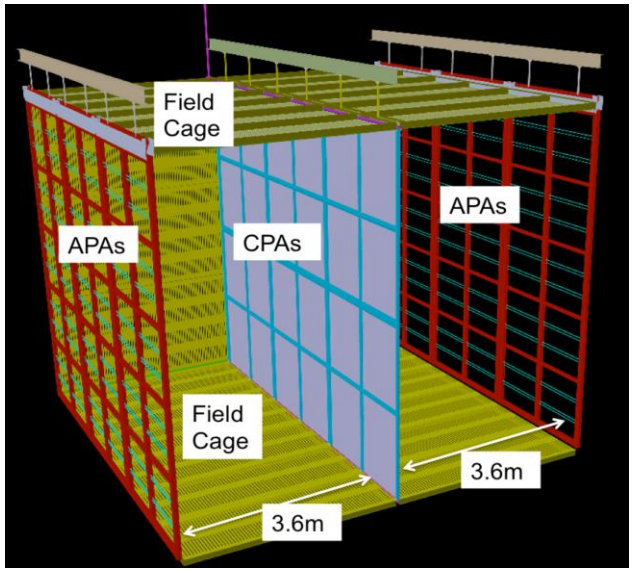


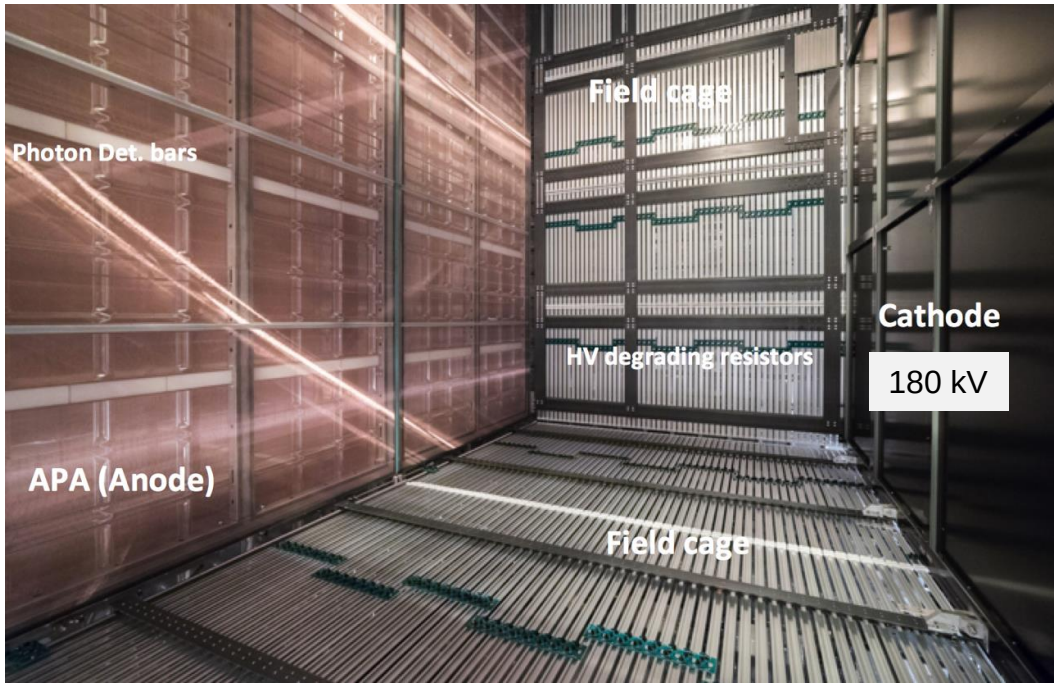
DUNE detector at the Long Baseline Neutrino Facility (LBNF): 4x17.5kt modules



1 DUNE module: x 20 proto-DUNE

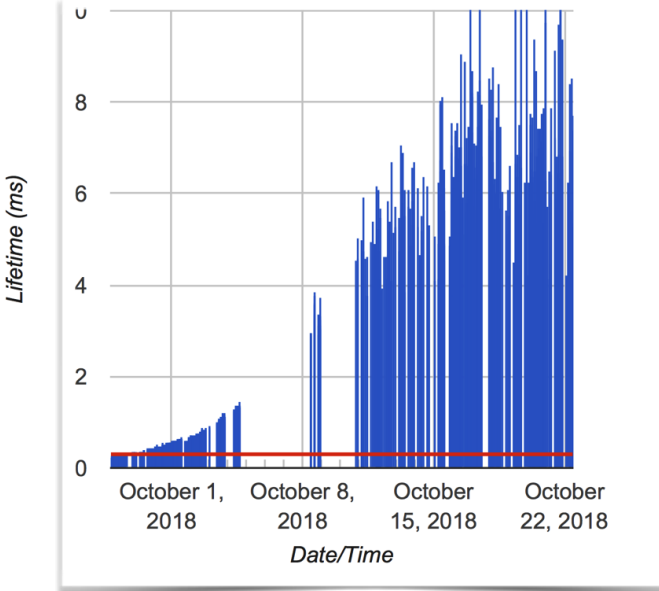
Single-phase detector prototype for DUNE

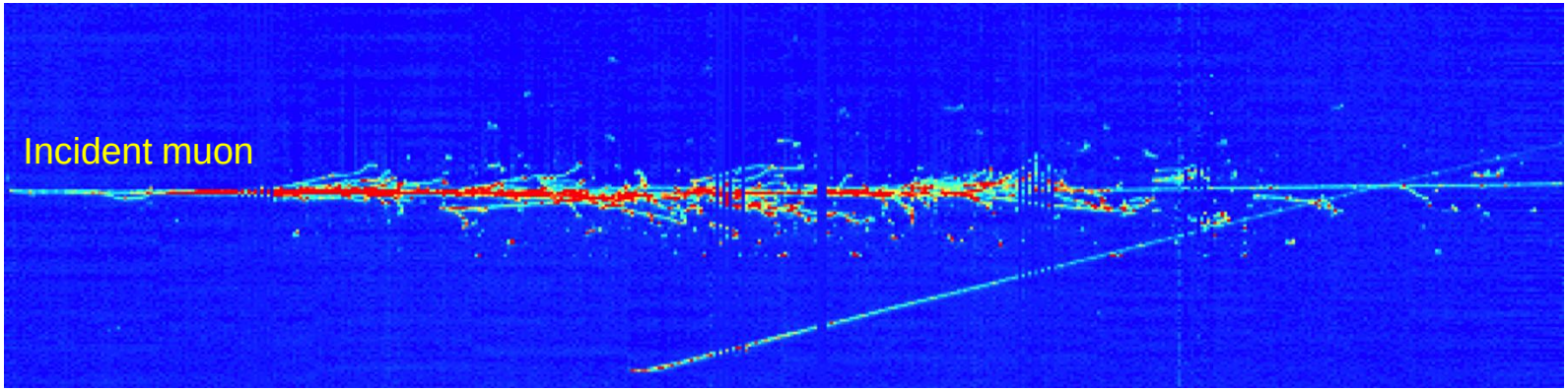


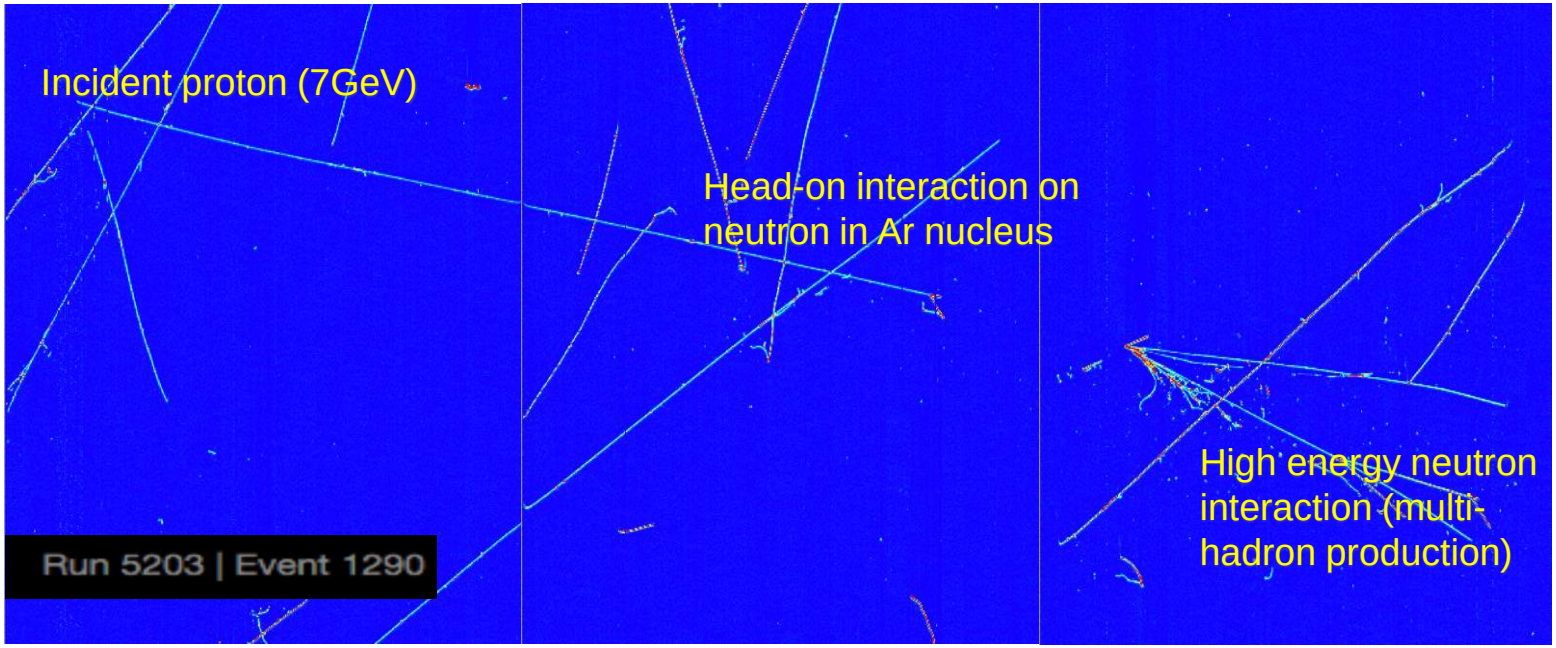


- 2 LAr TPC sharing same cathode → 3.6 m drift
- Cathode at 180 kV → 500 V/cm
- Anode Plane Assembly: 2.3 m x 6 m; 3 planes/APA (0^0, $\pm$ 35.7^0), 5 mm wire pitch
- FE electronics (amplifier, shaper, ADC) inside cryostat
- Light collecting bars read out by SiPMT

- Achieved e^- lifetime 6-8 ms (~40 ppt O_2 eq.): nominal is 3 ms
- Test beam data recorded since end September: ~1-7 GeV tertiary e, p, μ, π beams




Incident muon


Incident proton (7GeV)
Head-on interaction on neutron in Ar nucleus
High energy neutron interaction (multi-hadron production)
Run 5203 | Event 1290

Status of geographical enlargement

22 Member States:

Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom

8 Associate Member States:

Cyprus*, India, Lithuania (8/1/2018), Pakistan, Serbia*, Slovenia*, Turkey, Ukraine
* in the pre-stage to Membership

6 Observers:

Japan, Russia, USA, European Union, JINR, UNESCO

~50 ICA (International Cooperation Agreements):

with non-Member States, some with countries with developing particle physics communities (CERN mission is also to help build capacity and foster growth of particle physics worldwide).

Serbia is in the process of transitioning to full Member
Croatia is in the process of becoming an Associate Member
Estonia has submitted an application for Membership

In June, the Council established a WG to review some aspects of the geographical enlargement procedures since last policy (2010)

Since 2010: 14 formal applications received

2 countries joined as Member States
Israel (2014), Romania (2016, with pre-2010 procedure)

3 countries joined as Associate Members in pre-stage to Membership
Serbia (2012), Cyprus (2016), Slovenia (2017)

5 countries joined as Associate Members
Turkey (2015), Pakistan (2015), Ukraine (2016), India (2017), Lithuania (2018)

3 applications for Associate Membership in progress or pending
Brazil (applied 2012), Croatia (applied 2014), Estonia (applied 2018)

Two countries withdrew applications for Associate Membership
Azerbaijan (2016), Russian Federation (2017)

Update on the Science Gateway project

A new facility for education and outreach, located near the Globe. Activities will target the general public of all ages. It will be an integral part of CERN's site and a component of the visit circuit. It will also include a ~1000-seater Auditorium.
It will be built entirely with external donations.

Motivation and main goals

CERN receives every year **~130 000** visitors worldwide
(~ 80% come from > 700 km away; > 60% are high-school students)

But: > 300 000 requests/year and all our education/outreach activities are over-subscribed.

→ A clear sign of the great interest in science and in CERN's unique research facilities
→ CERN is an ideal location for a dedicated scientific learning and outreach centre open to the general public, with the goal in particular of encouraging young people to choose careers in Science, Technology, Engineering and Mathematics (STEM).
Note: <20% in Europe today, while number of STEM jobs grows x3 faster than any other job

⬇

Science Gateway will allow us to:

- ❑ expand and diversify CERN's portfolio of education, communication and outreach actions aimed at the general public.
- ❑ satisfy the > 300 000 visit requests received every year
- ❑ cover all ages (~5 to 100+ years!) with targeted initiatives
  (currently minimum age for education activities on site: 16 years)
- ❑ increase opportunities of collaborations with similar initiatives in CERN Member States and beyond → contribute to a network of facilities aiming at promoting science

Educational programme, funding, timeline

Activities will be tailored to specific age groups, e.g. primary-school children, high-school students, families, senior people. Preliminary ideas:

- Mini-workshops and labs for hands-on educational activities (from age of ~5)
- Interactive screens to explore physics (e.g. the smallest constituents of matter, the fundamental forces, the concept of space-time) in a simple and entertaining way
- Virtual visits of CERN
- Temporary and permanent exhibitions, highlighting e.g.:
  -- science personalities and the figureheads of particle physics
  -- societal impact of CERN's scientific discoveries and technological innnovations
  -- when science meets the arts (*Arts@CERN* programme)
- Live connections with other science centres or international partners (universities, museums, etc.) for interesting scientific events
- ~ 1000-seater auditorium (divisible) for Collaboration meetings, scientific conferences, public lectures and science events organised in the Geneva area (desperate need for it at CERN and in the region).

Total project cost (for building size ~ 7000 m^2): **79 MCHF (65 M building + 14 M content)**
Project will be financed by external donations, i.e. from outside CERN's budget.
57 MCHF secured so far.

(Optimistic) schedule: opening to the public second half 2022

Implementation plan approved by the Council in September

Conclusions

- Close to the end of a very successful Run 2, during which the accelerator complex and the experiments performed extremely well (beyond expectation in many cases)
- Preparation for LS2, LIU/HL-LHC and detector upgrades are progressing on schedule
- Final rush to finalise input to the European Strategy, including results from current experiments and facilities, physics and design studies for future projects (CLIC, FCC, Physics Beyond Colliders), R&D work, etc.
- Lot of work and interesting projects over the full spectrum of CERN's activities