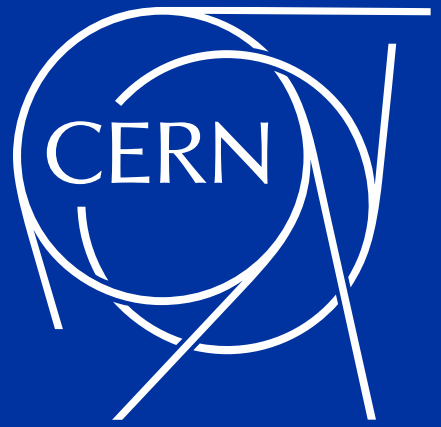


CERN Status Report

Fabiola Gianotti, ECFA, 17 November 2022

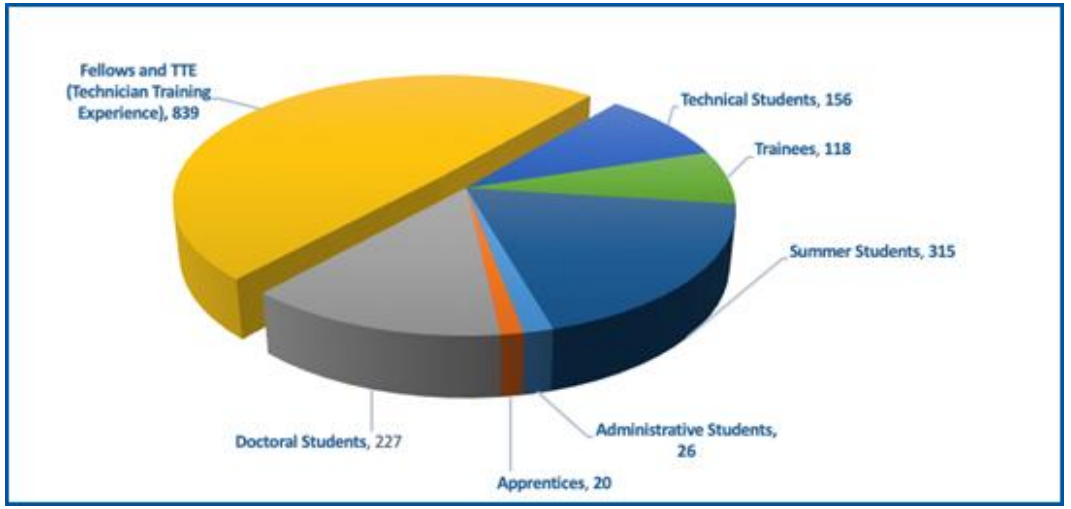
CERN today (in few numbers)

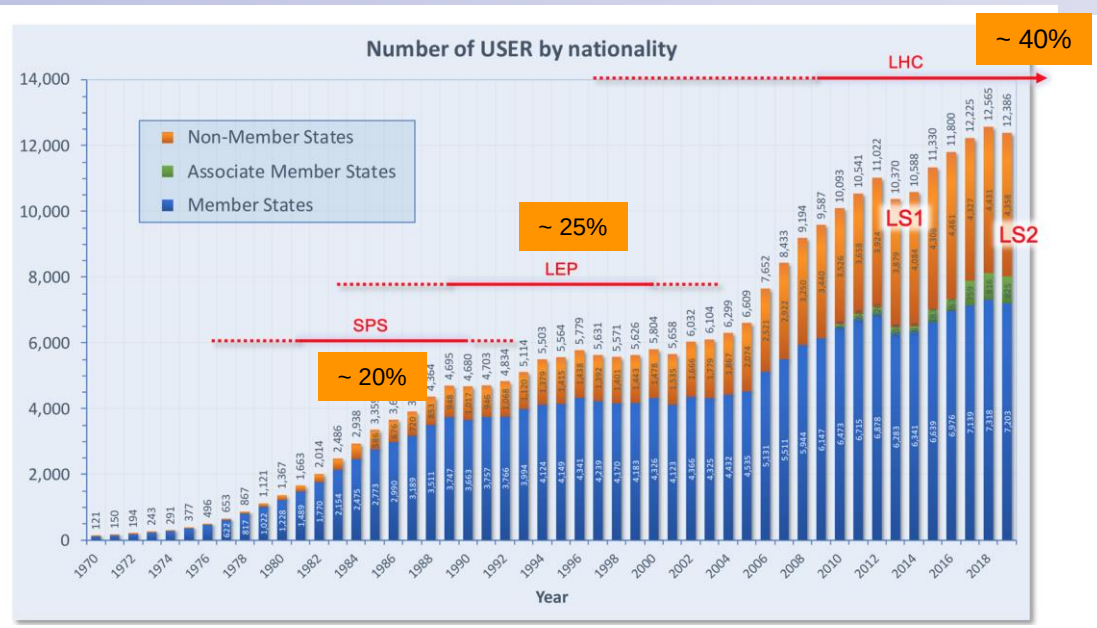
23 Member States, 10 Associate Member States, 4 Observers
→ see later

~ 30 running experiments/facilities
~ 700 papers/year (experiments + theory)

CERN's community: > 16000 people (> 110 nationalities)

- ❑ 2700 staff
- ❑ 800 post-doctoral fellows
- ❑ 12700 users and other associates
- ❑ 3000 PhD students from all over the world
- ❑ 4500 young people trained at CERN at any time





2 main sites, 15 smaller satellite sites
630 hectares, 700 buildings
70 km underground tunnels, > 30 caverns
1000 km technical galleries/trenches
500 hotel rooms, 3000 meals served daily
4000 contractors' personnel
9000 people on site everyday (pre-COVID)

Every year:
150000 visitors to CERN (pre-COVID)
4 million visitors to CERN website
150000 press cuttings
2 million mentions on social media

Overall scientific strategy based on 3 pillars

Based on 2020 update of the European Strategy for Particle Physics (ESPP)

Full exploitation of the LHC:

- ❑ successful Run 3: $\sqrt{s}$ =13.6 TeV
- ❑ High-Luminosity LHC upgrade (construction underway, further upgrades to ALICE and LHCb being planned) → starts in 2029

“Scientific diversity” programme serving a broad community:

- ❑ current experiments and facilities at Booster, PS, SPS and their upgrades (recently AD/ELENA, East Area)
- ❑ participation in accelerator-based neutrino projects outside Europe (presently mainly LBNF in US) through Neutrino Platform

Preparation of CERN’s future:

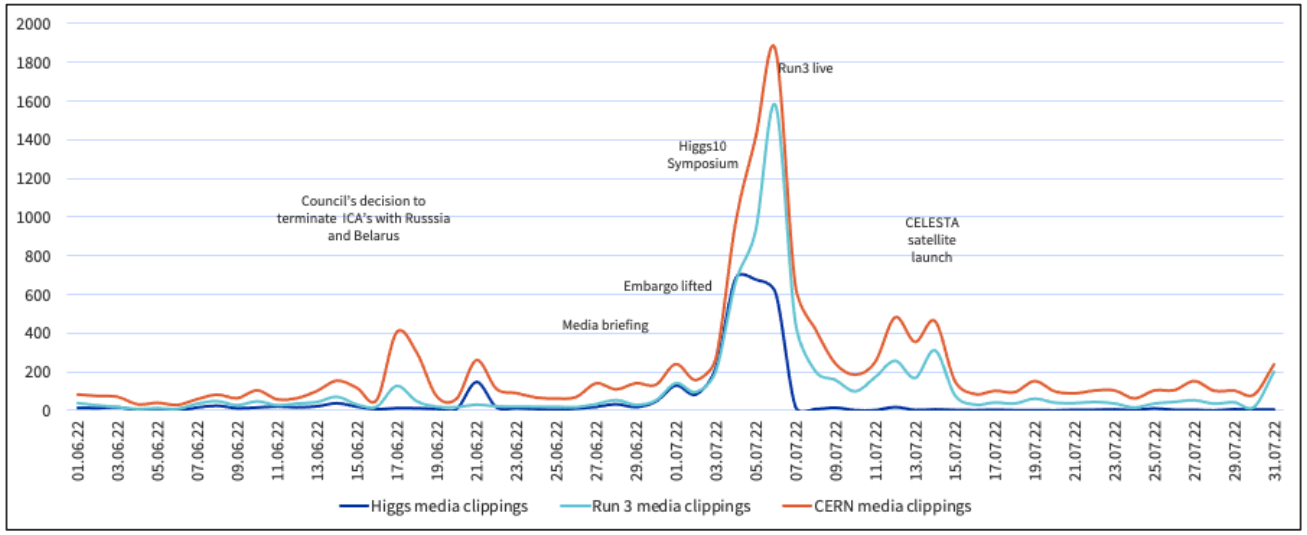
- ❑ intense accelerator R&D programme (including superconducting high-field magnets, SCRF, plasma wakefield, etc.)
- ❑ Future Circular Collider (FCC) Feasibility Study → report to be submitted in 2025
- ❑ R&D and design studies for alternative scenarios: CLIC/ILC, Muon Colliders → reports to be submitted in 2025
- ❑ future opportunities for scientific diversity programme nurtured in “Physics Beyond Colliders” study group

Next ESPP update expected in ~ 2026/2027 → input by end 2025

Higgs boson@10 and start of Run 3: 4-5 July

Higgs boson@10 symposium:

- Morning sessions: review and celebration
- Afternoon sessions: new results
- CERN Auditorium oversubscribed
- Peak online audience (webcast): ~1150 people

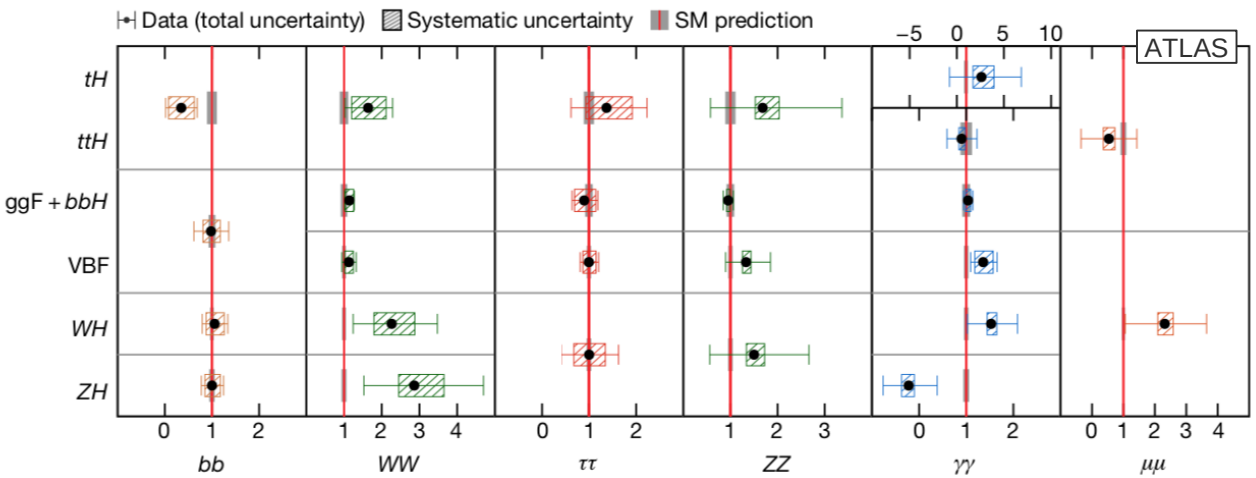


- ~ 7000 articles from 1 June to 31 July
- International and national media outlets, including BBC, NYT, Reuters, Repubblica, The Economist, Deutsche Welle, Libération, El País, SRF, Euronews
- On-site media briefing (30 June): > 60 journalists in person/online, 16 countries
- Large volume of clippings in major national media outlets of Member States and beyond

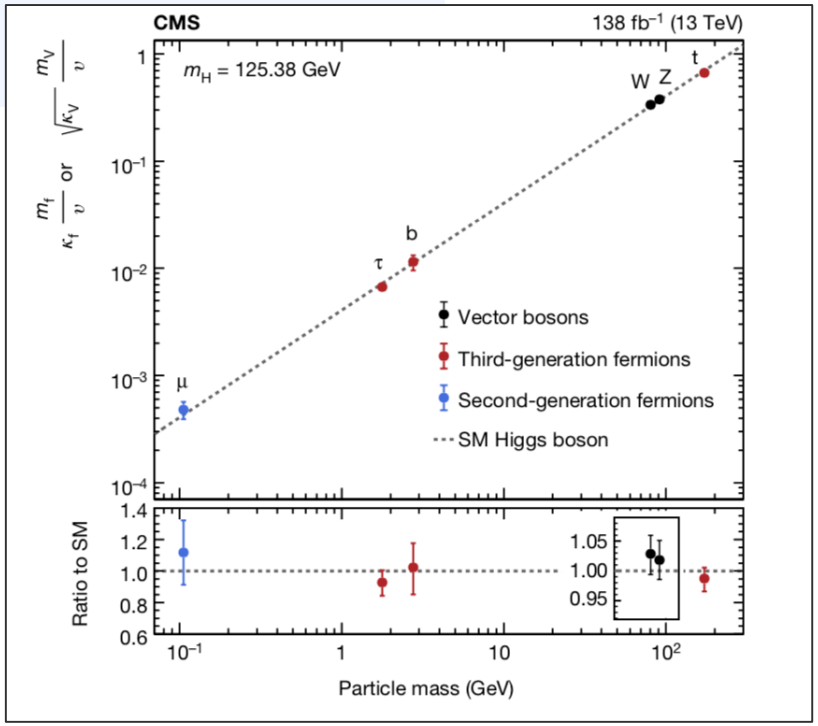
Huge progress over the past 10 years …

- All main Higgs boson production modes (ggF, VBF, VH, ttH+tH) individually established at > 5σ
- Couplings to gauge bosons (established in Run 1) measured to 6-8%
  Couplings to 3rd generation fermions (established in Run 2) measured to 7-11%
  Couplings to 2nd generation fermions: 3σ evidence for H→ μμ; first constraints on H→ cc
- Rare decays (e.g. H→ Zγ; H→ llγ at ~ 3σ level); limits on invisible and exotic decays
- HH production: sensitivity x 3 SM cross-section
- Mass measured to ~ 0.1%
- Width measurement from off-shell/on-shell production demonstrated (3.6σ evidence for H off-shell production)
- $J^{CP}=0^{++}$ (large number of alternative hypotheses excluded > 99.9% C.L.)
- Inclusive studies complemented by increasing variety of differential/exclusive measurements (useful to constrain theory; provide additional constraints on couplings; sensitive to new physics in quantum loops affecting kinematic distributions)
- Searches for additional Higgs bosons (no sign yet …)
- Etc. etc.

Note: some of the above measurements were not expected to be possible in Run 2



Current knowledge summarised in 2 articles published in Nature on 4 July 2022

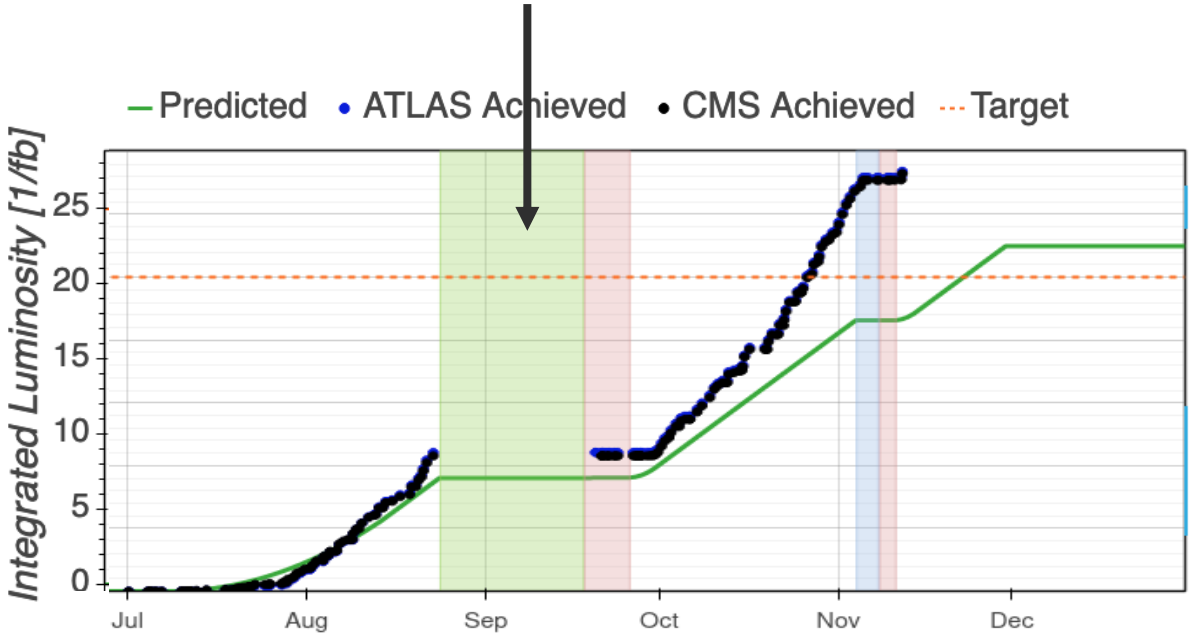


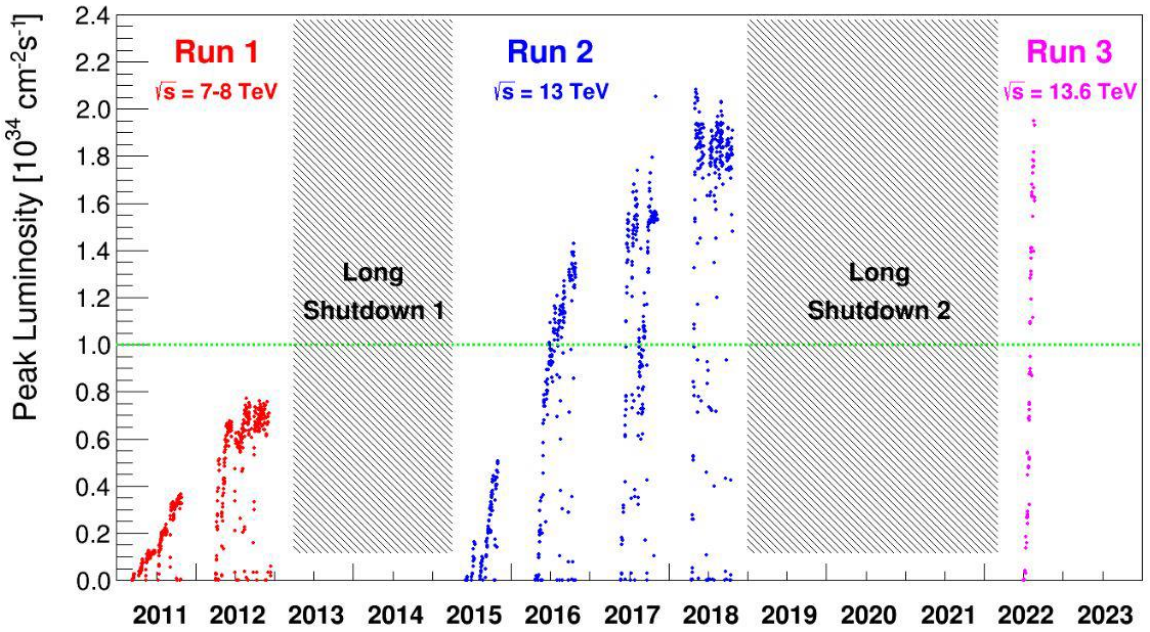
LHC Run 3: a very successful start of the accelerator complex

- First stable-beam collisions at 13.6 TeV on 5 July
- Very fast intensity ramp-up (slope comparable to best Run 2 periods)
- High reproducibilty of the collider after a 3-year shutdown

- Reached ~ $2x10^{34}$ cm^{-2} s^{-1} (2x design value), **β***-leveled to ~ 50 pile-up evts/crossing in ATLAS and CMS

- Despite ~ 3 week stop in Sept due to failure of RF rupture disks following cooling tower problem and He release from cavities, integrated luminosity exceeds 2022 target



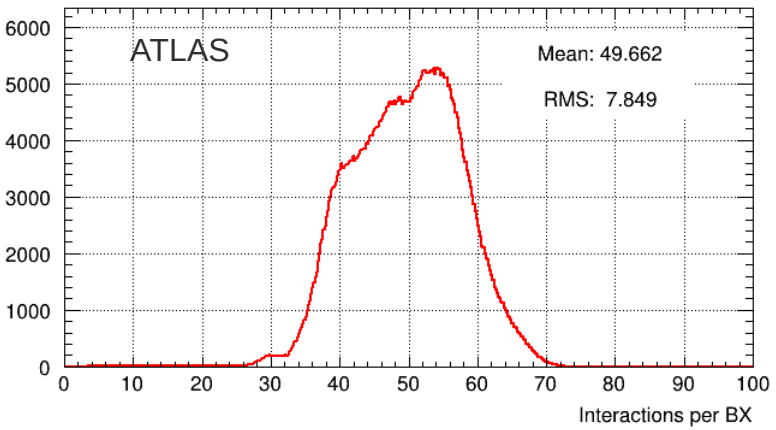


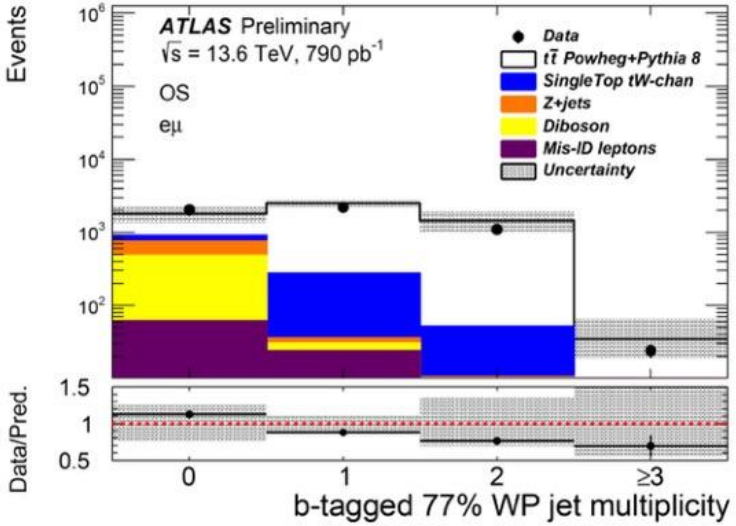
- Year-end technical stop starts 2 weeks (28 Nov) earlier to save energy

- 2023: accelerator complex operation reduced by 20% in response to European energy crisis.

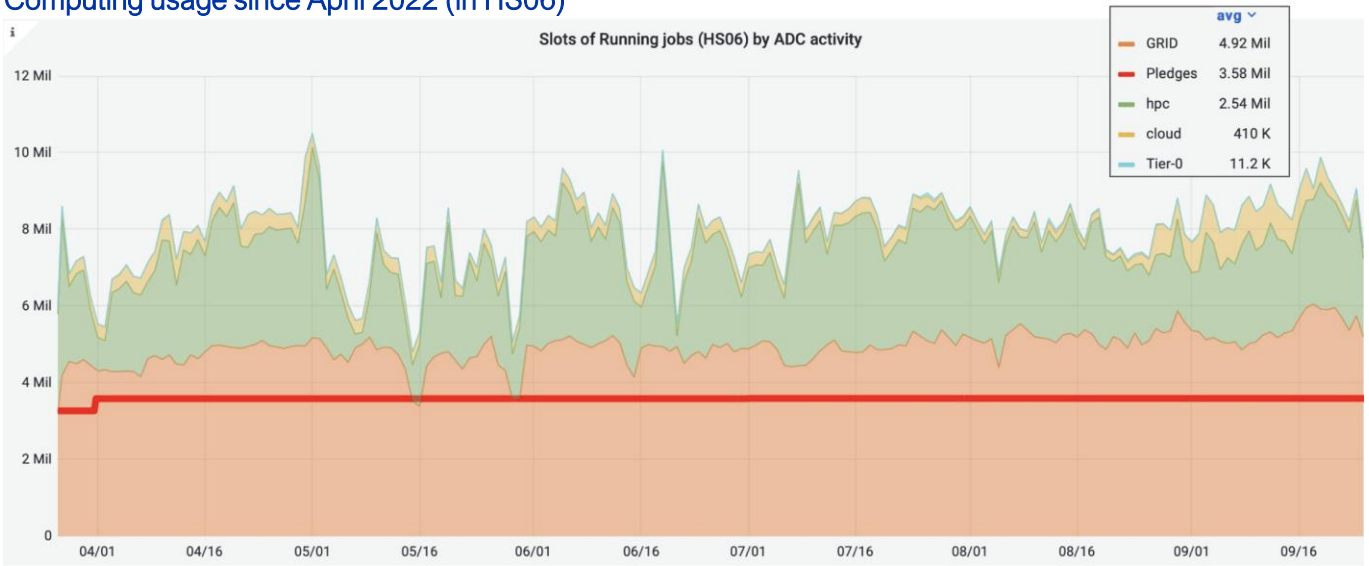
- Luminosity targets for Run 3:
  250 fb^{-1} (ATLAS and CMS), 25-30 fb^{-1} (LHCb), 7 nb^{-1} (ALICE, Pb-Pb)

LHC Run 3: first data look good! ATLAS





Computing usage since April 2022 (in HS06)

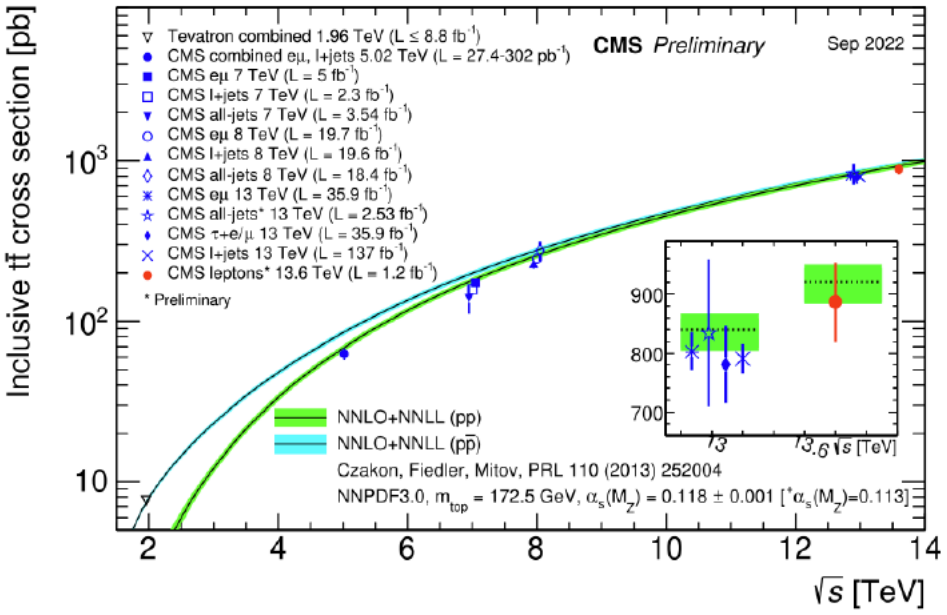


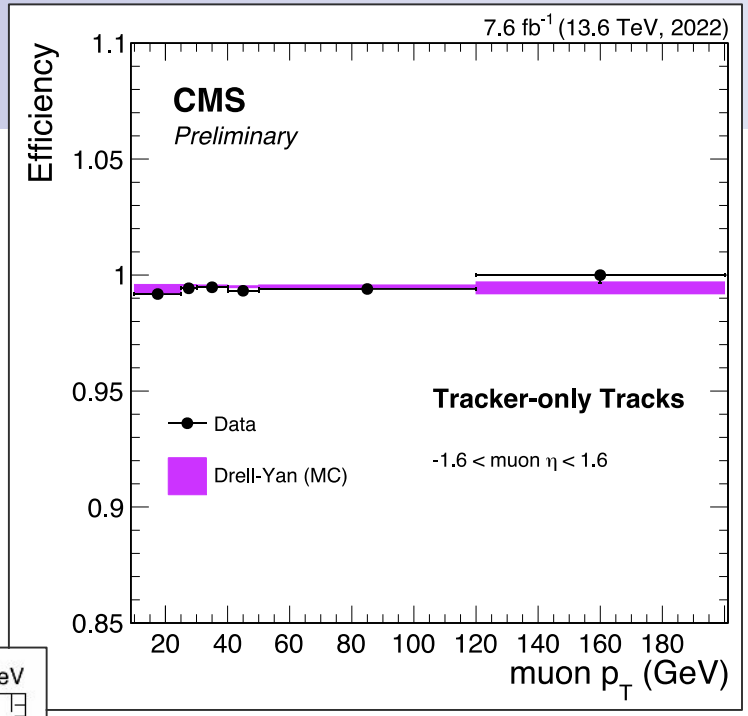
LHC Run 3: first data look good! CMS

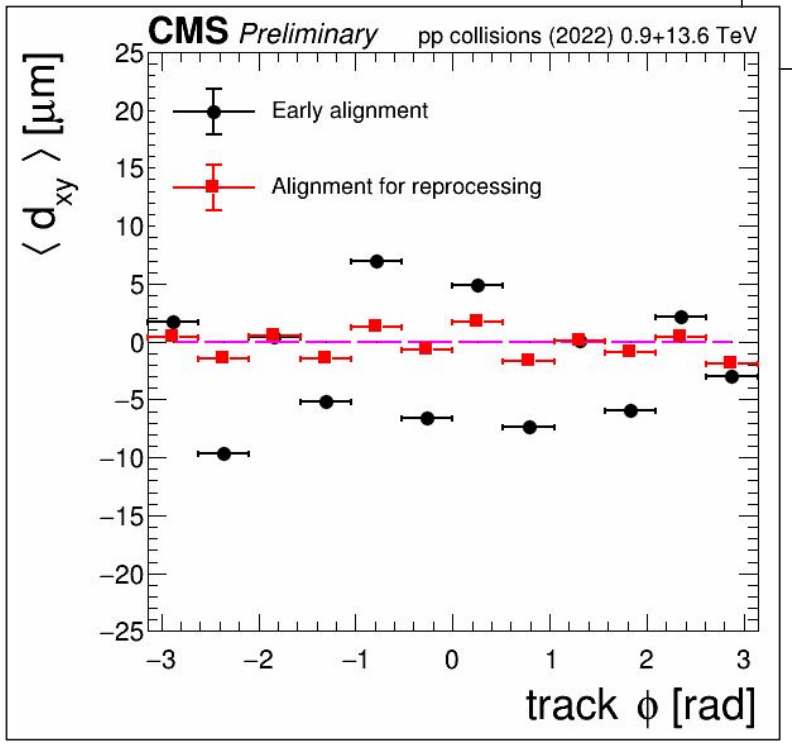
First measurement of top-pair cross-section at 13.6 TeV

$$\sigma_{tt} = 887^{+43}_{-41}\ (\text{stat} + \text{syst}) \pm 53\ (\text{lumi})\ \text{pb}$$

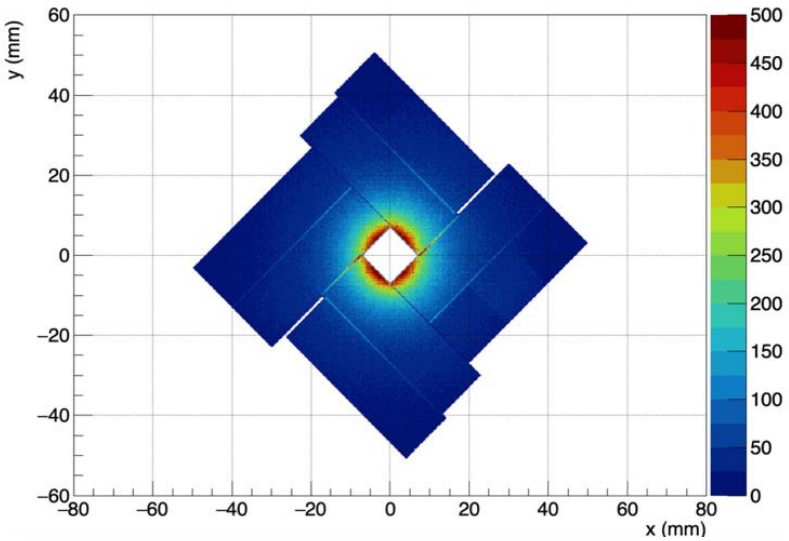
Theory prediction: 921^{+29}_{-37} pb

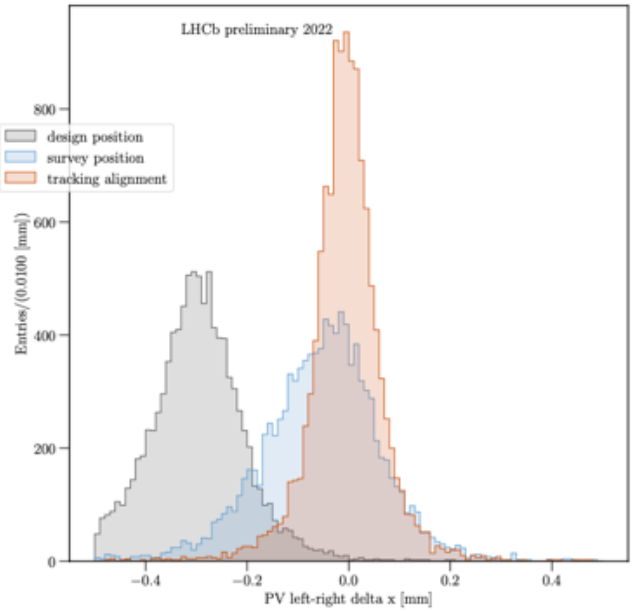


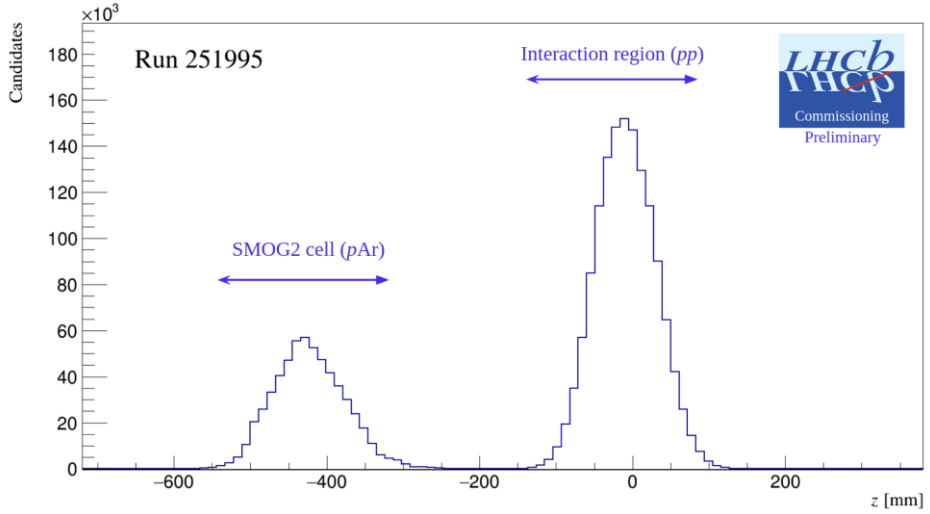


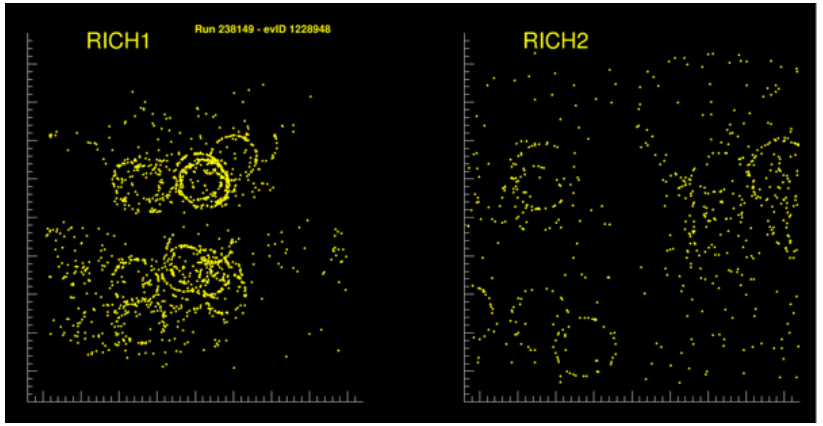


LHC Run 3: first data look good! LHCb

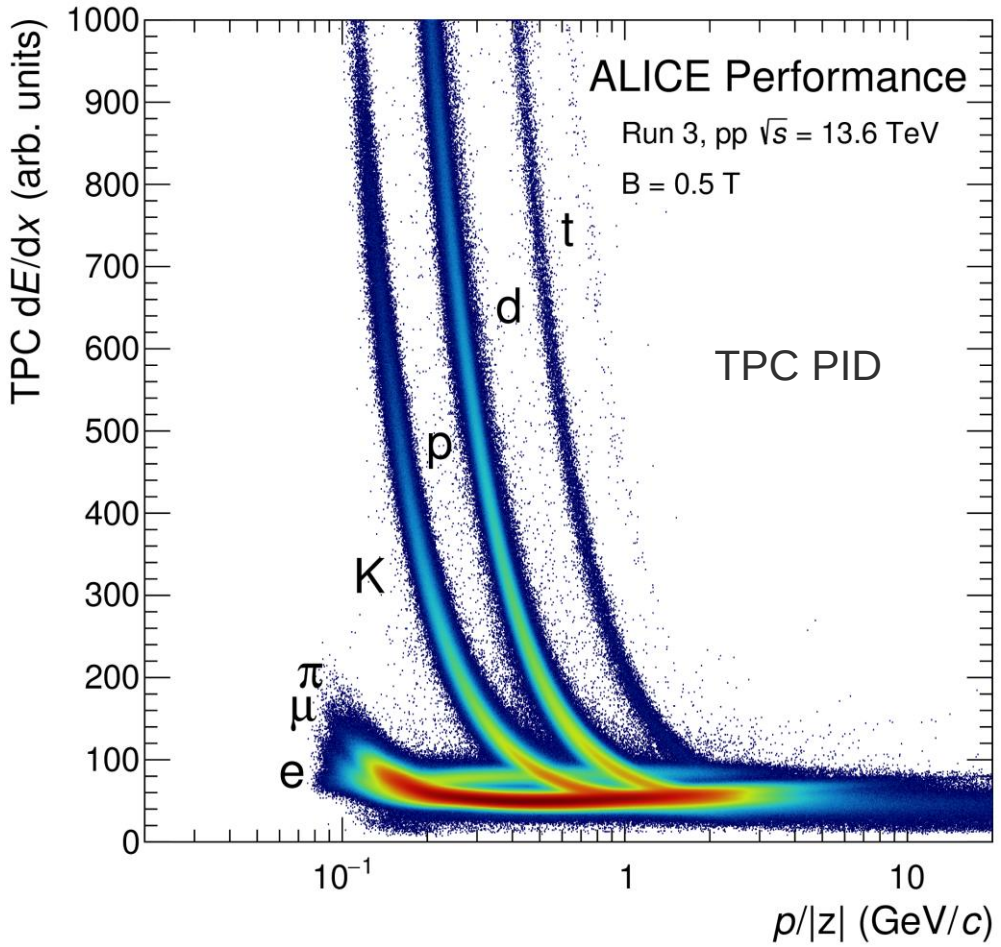


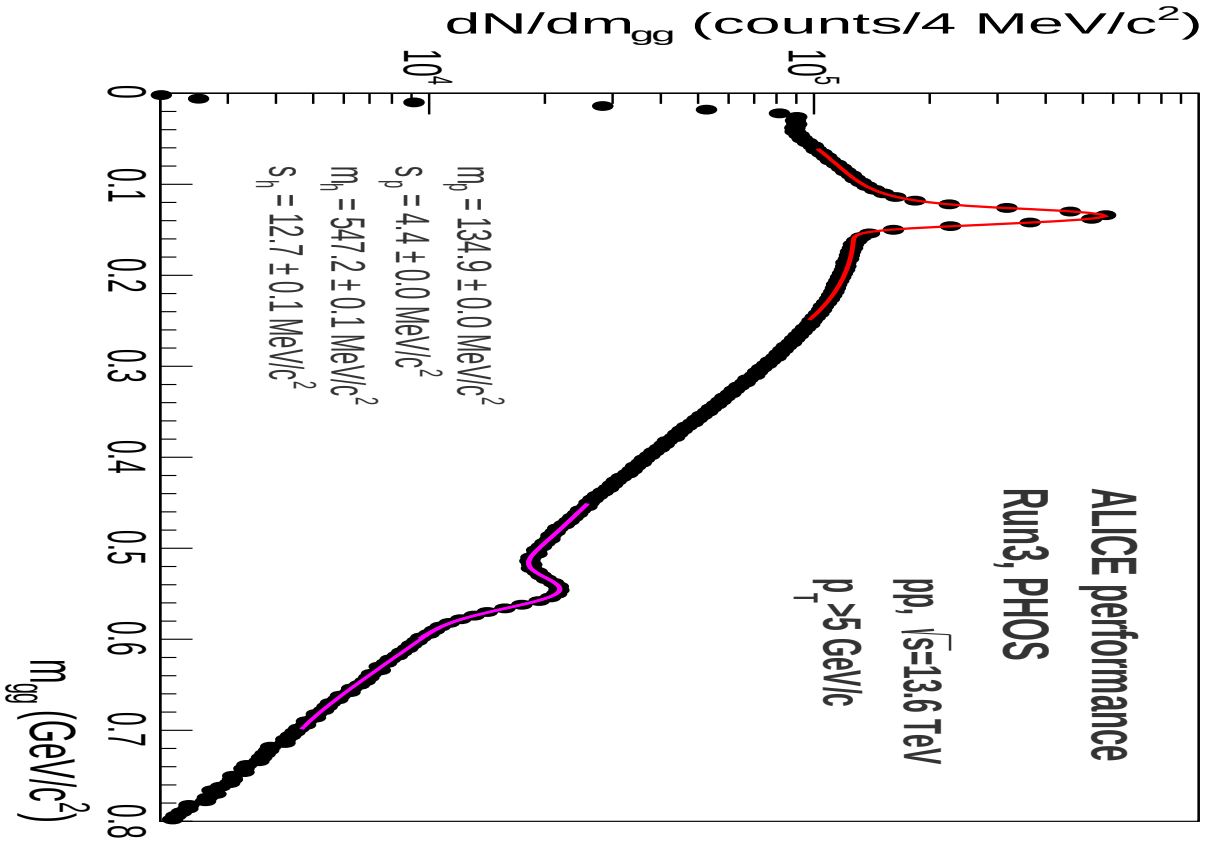






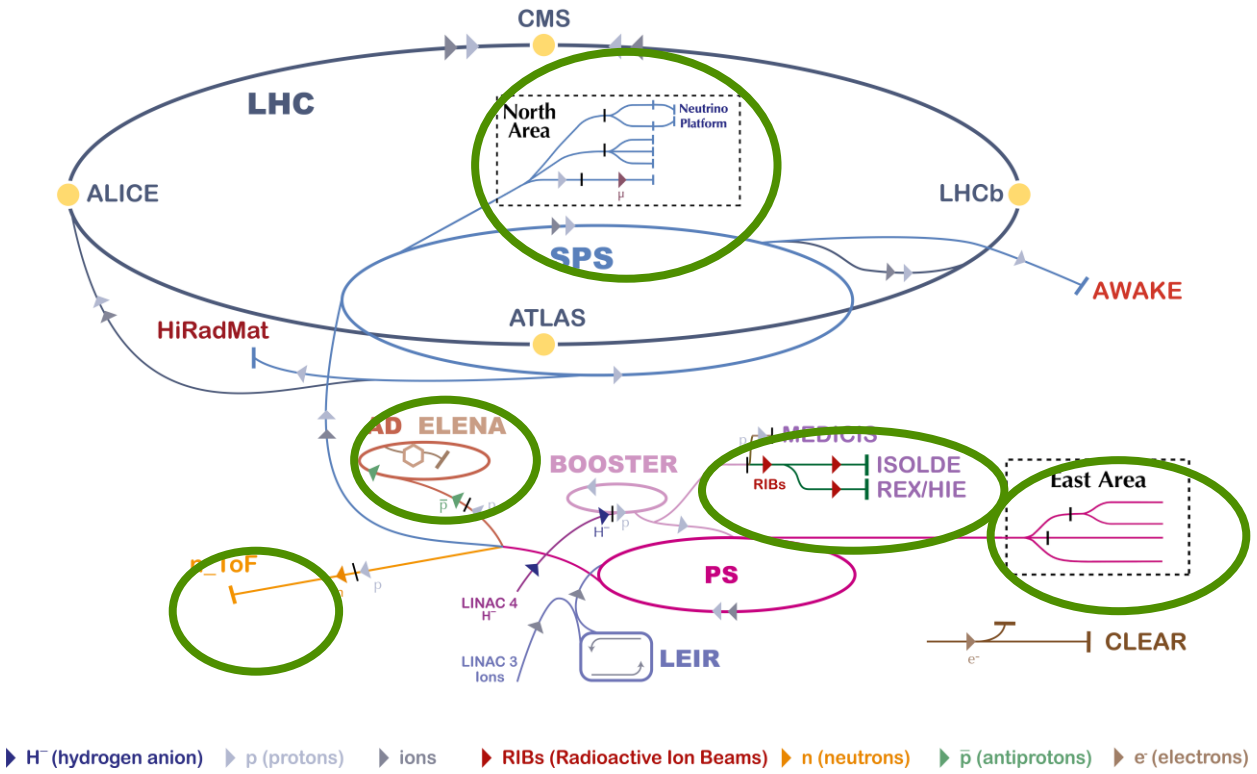
LHC Run 3: first data look good! ALICE





Availability of injector complex

Facility	Destination	Expected 2022 Total [%]	Achieved 2022 Total [%]*
LINAC4	-	95	96.8
PSB	PS	90	94.8
	ISOLDE		
PS	SPS	87	89.6
	nTOF		
	AD		
	East Area		
SPS	LHC	84	91.3
	North Area		71.9
	AWAKE		92.9
	HiRadMat		95.4



* Availability since start of physics for the machine concerned: Linac4, PSB, PS since 28.03.2022 and SPS since 25.04.2022

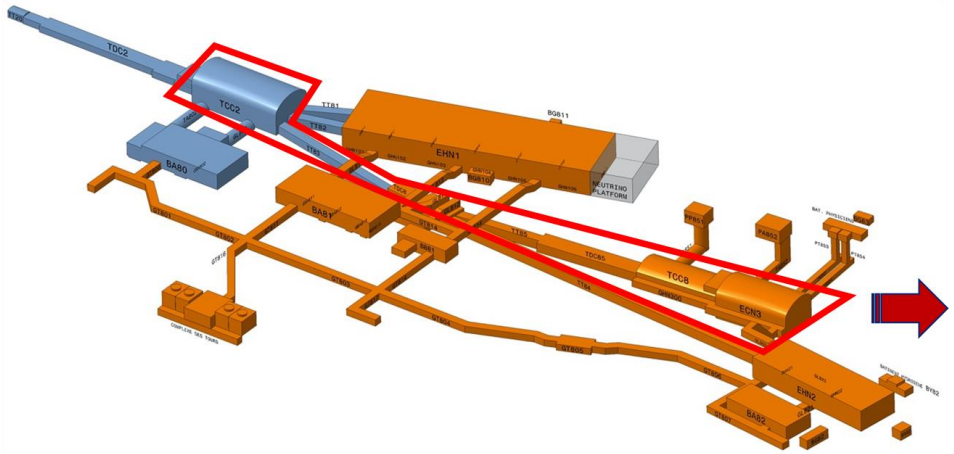
SPS for the North Area suffered from three long faults during the first weeks of the run.
Recently record intensity achieved: 4×10^{13} p/spill

LIU (LHC Injectors Upgrade project) target parameters achieved in some cases

Future opportunities for scientific diversity programme: example

→ see C. Vallée's talk

Consolidation Phase 1 (funded): 2019 – 2027

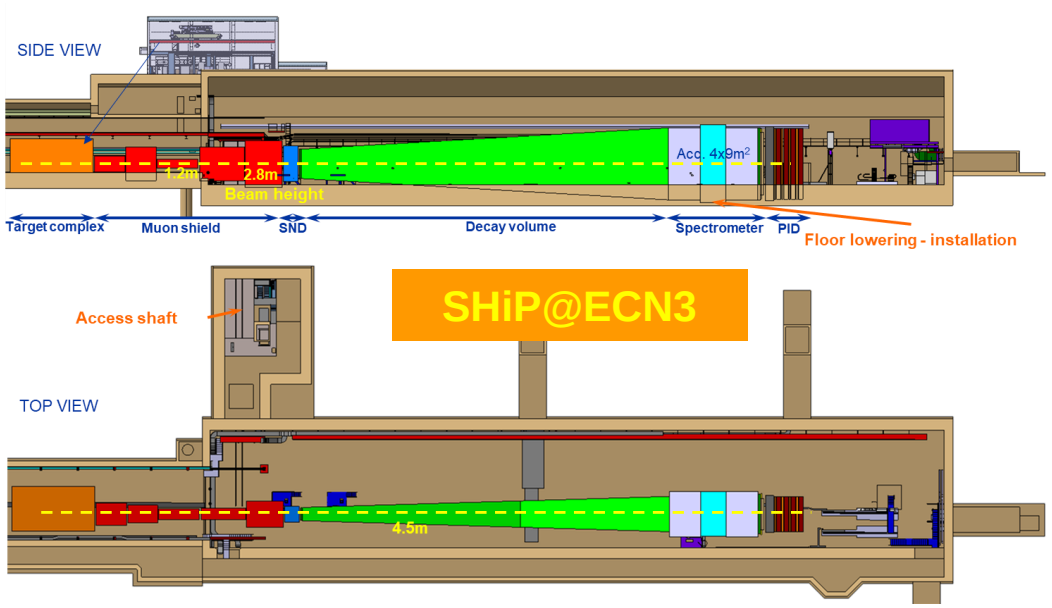


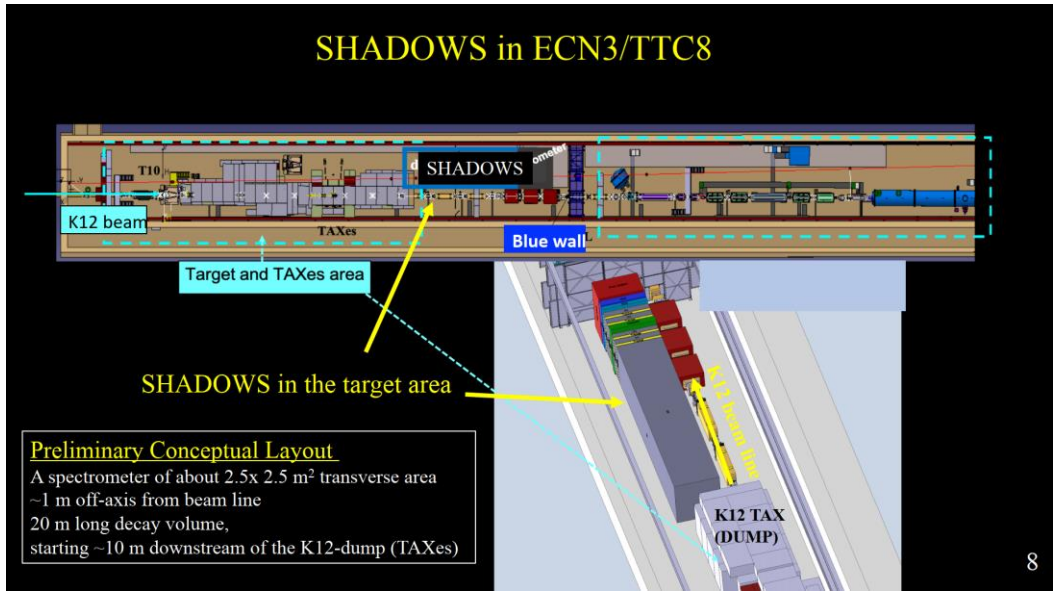
Areas concerned with high intensity beams

North Area upgrade to higher-intensity beams:
up to ~ 4 x 10^{19} POT/year (slow extraction) post-LS3 (exp. request: 6-20x today's perf.)
Current interest: kaon physics (HIKE), beam dump experiments for dark sector and other studies (SHADOW, SHiP), lepton-flavor violation through τ → 3μ (TauFV), …
If work done during LS3 → operation can start ~ 2029

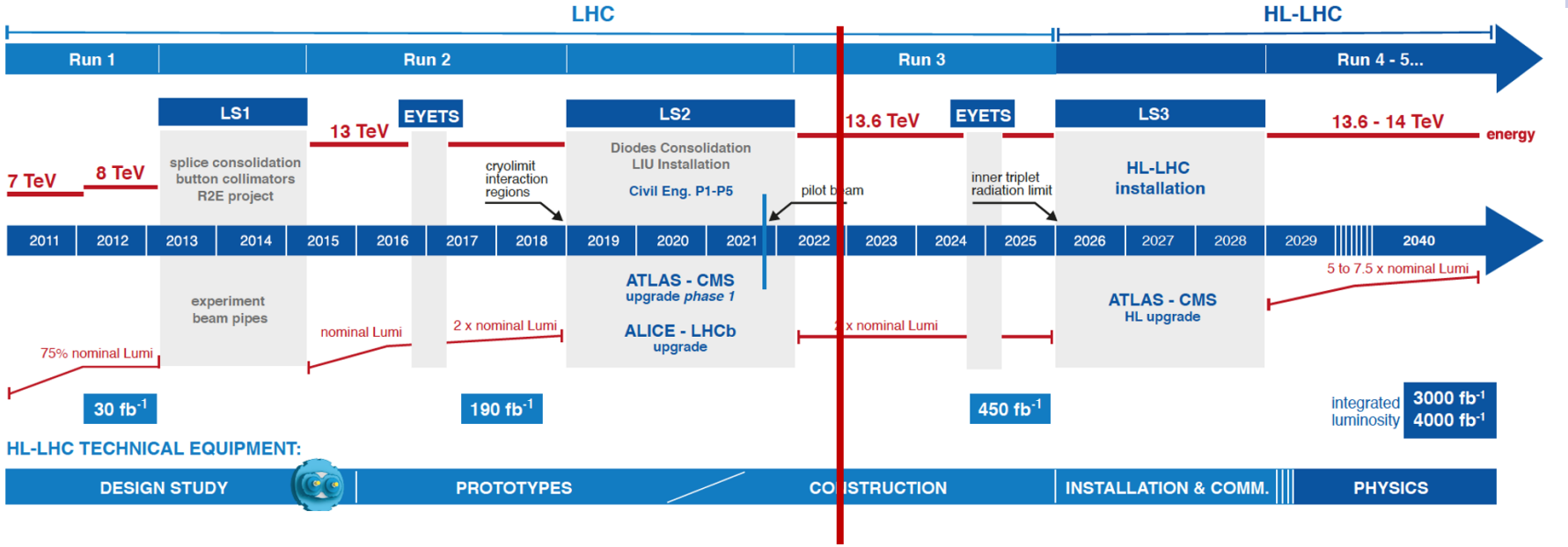
Two "task forces" established to assess physics case (within worldwide context) and technical aspects
→ Experiment(s) may be selected by end 2023

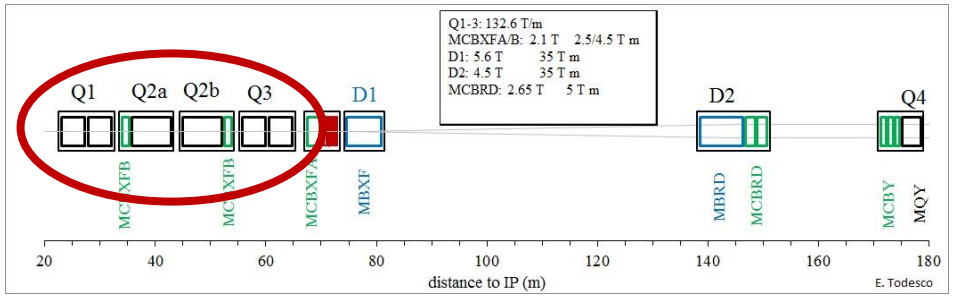
Consolidation Phase 2 (not yet funded): 2028 – 2033



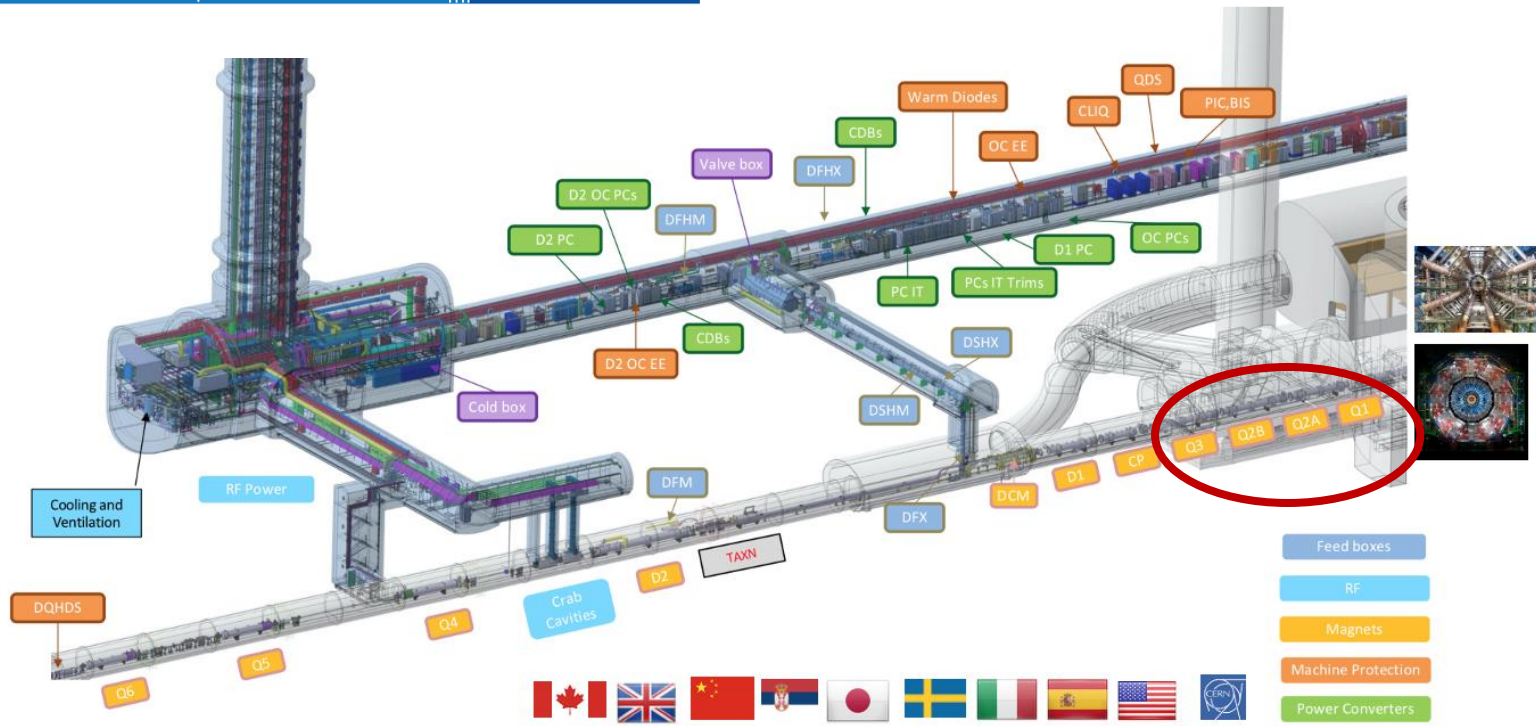


High-Luminosity LHC (HL-LHC)

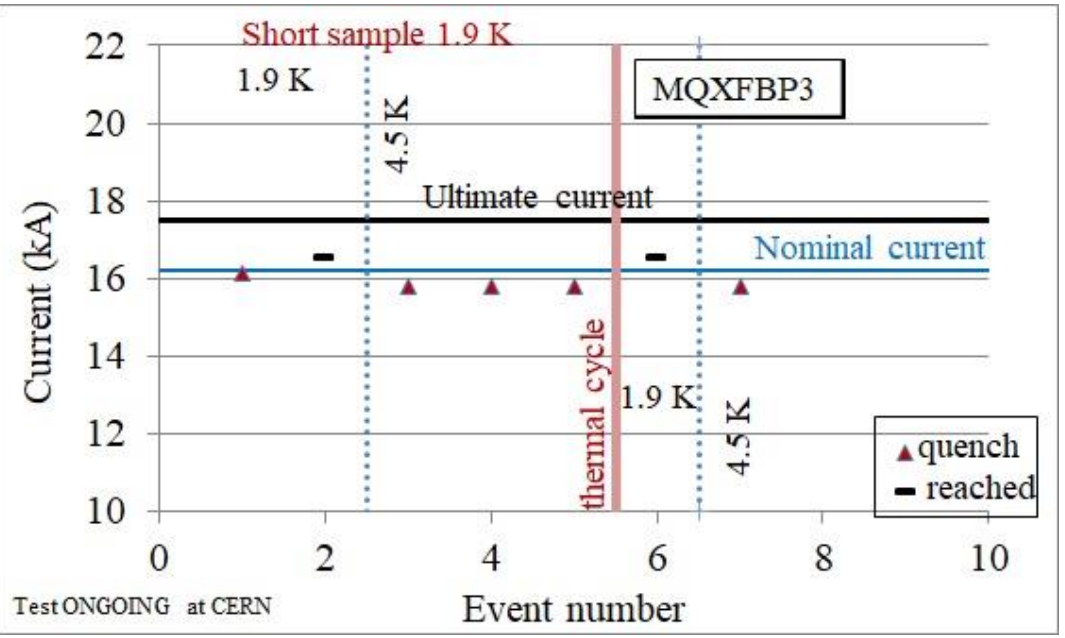




Q1, Q3 (MQXFA): Nb_3Sn, 4.2 m, US
Q2 (MQXFB) : Nb_3Sn, 7.2 m, CERN

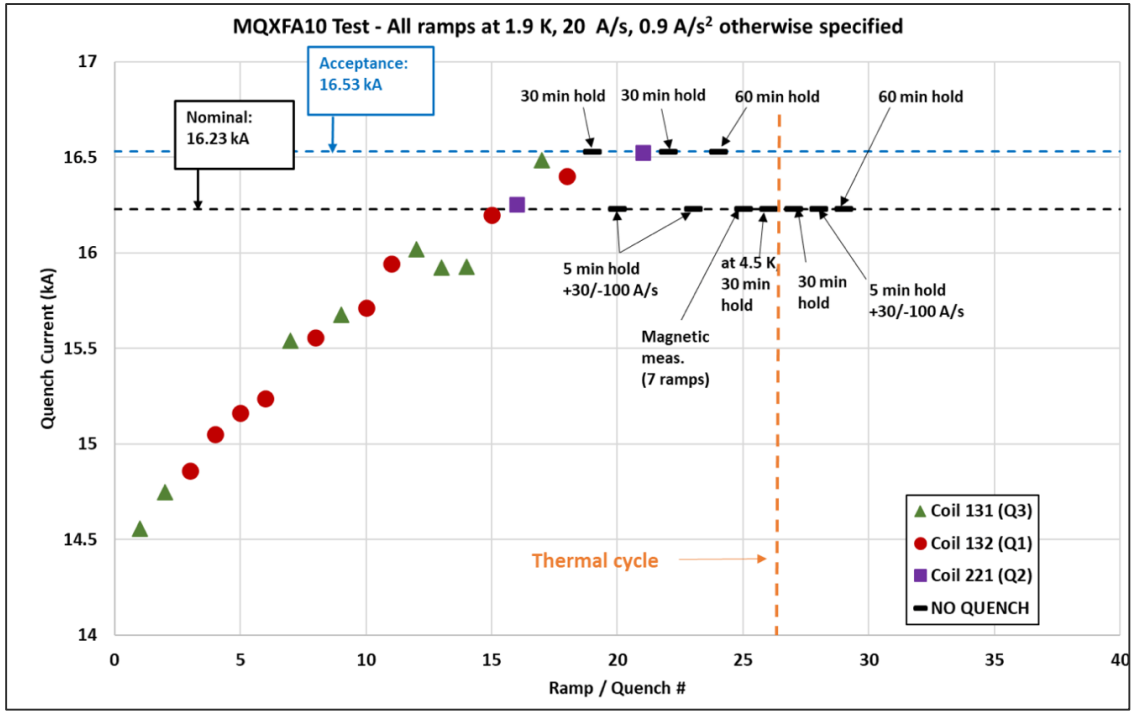


Inner triples quadrupoles



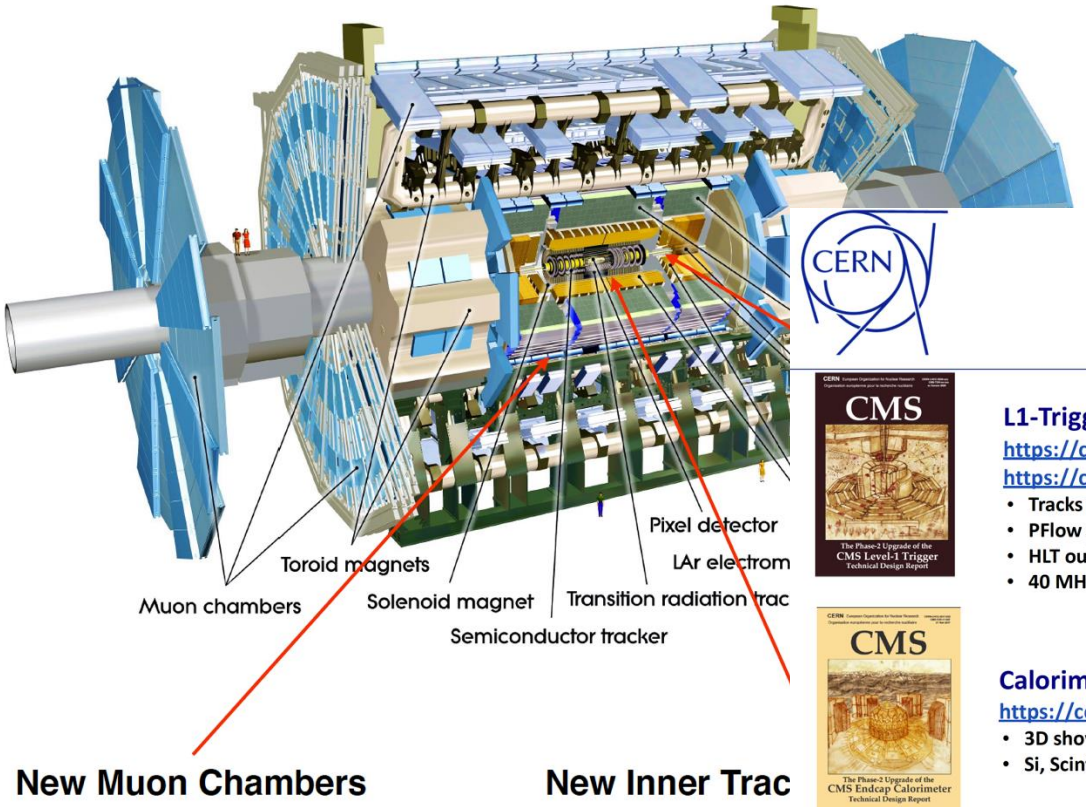
MQXFB (CERN):
first 2 full-length prototypes did not reach nominal; recently 3rd prototype successfully tested at nominal + 300 A. No performance degradation after 2 thermal cycles.

MQXFA (US):
6 full-length prototypes out of 8 successfully tested vertically.
First horizontal test inside cryostat end November.



Phase-2 upgrades of ATLAS and CMS

ATLAS Phase-II upgrade



Upgraded Trigger and Data Acquisition system

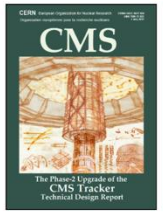
L0 at 1 MHz

Improved High-Level Trigger

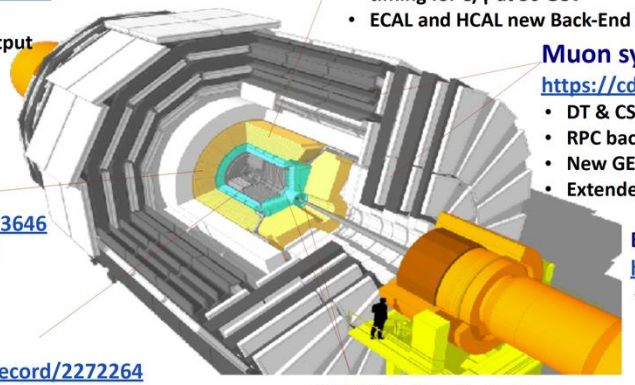
CMS Upgrades for HL-LHC

L1-Trigger/HLT/DAQ
https://cds.cern.ch/record/2714892
https://cds.cern.ch/record/2759072
- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
- HLT output 7.5 kHz
- 40 MHz data scouting

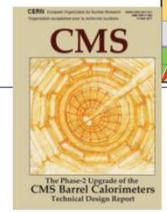
Calorimeter Endcap
https://cds.cern.ch/record/2293646
- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS



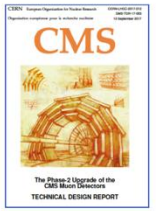
Tracker https://cds.cern.ch/record/2272264
- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to η ≃ 3.8



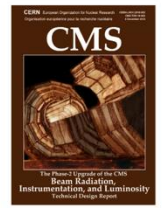
Barrel Calorimeters
https://cds.cern.ch/record/2283187
- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards



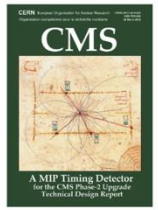
Muon systems
https://cds.cern.ch/record/2283189
- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC 1.6 < η < 2.4
- Extended coverage to η ≃ 3



Beam Radiation Instr. and Luminosity
http://cds.cern.ch/record/2759074
- Bunch-by-bunch luminosity measurement: 1% offline, 2% online



MIP Timing Detector
https://cds.cern.ch/record/2667167
Precision timing with:
- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes



→ see tomorrow's talks on ALICE3 and LHCb Phase-2 (installation expected in LS4)

New paradigms (design/technology) for a HEP experiment to fully exploit HL-LHC luminosity

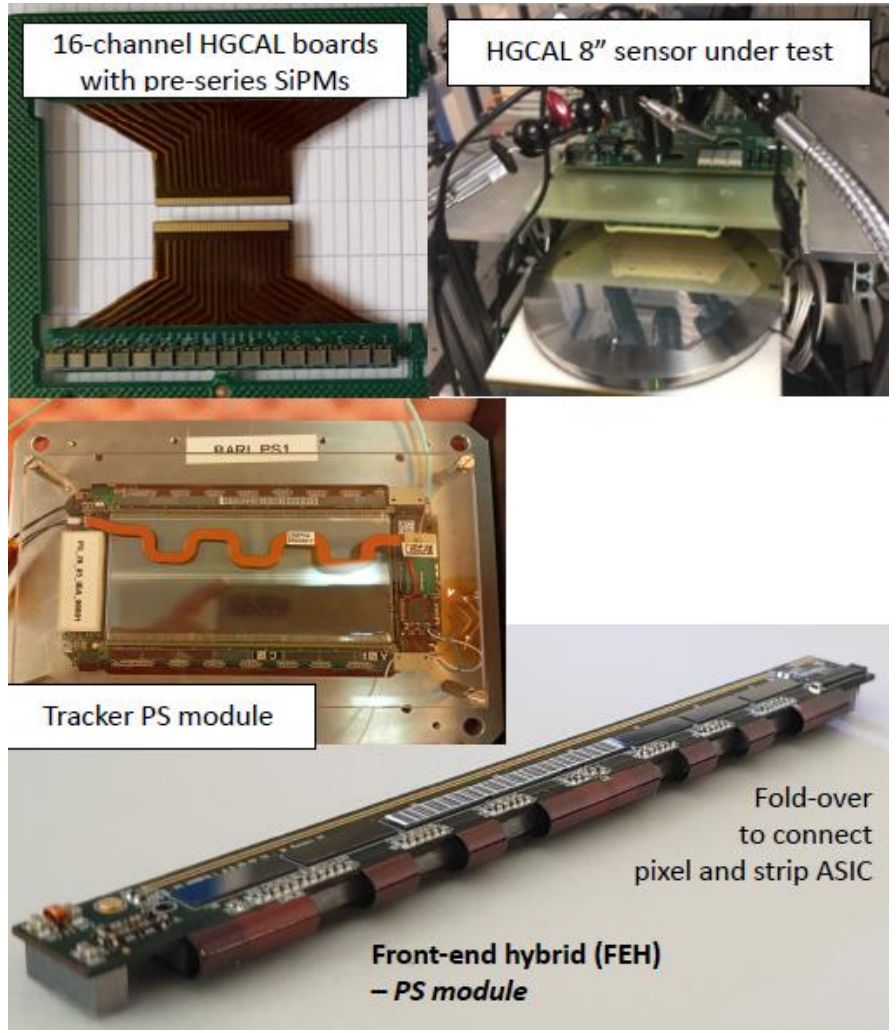
Phase II

Good progress for ATLAS and CMS

Area of concern: ASIC design, validation and procurement

CMS (examples):

- ❑ HGCAL
  - ❑ Si-sensor production Readiness Review successfully passed
  - ❑ 5 module assembly centres qualified for pre-series
  - ❑ Concentrator ASICs progressing – but on critical path
- ❑ Inner Tracker
  - ❑ Planar sensor tender contract in preparation
  - ❑ Irradiation & test beam of 3D and planar modules completed
  - ❑ Delay in readout ASICs
- ❑ Outer Tracker
  - ❑ Sensor production continues
  - ❑ Hybrid contract signed
  - ❑ Final module prototypes built

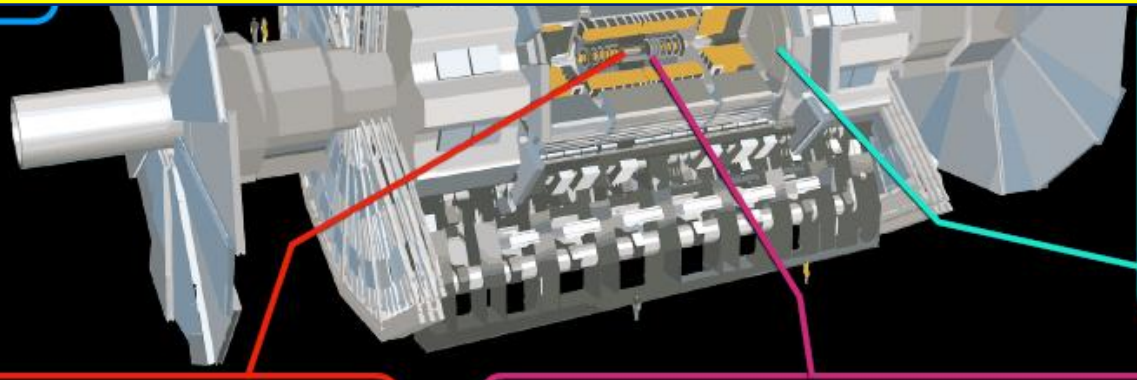


ATLAS
Upgrade project status

TDAQ:
- Resource conflicts with Phase-I commissioning
  - L0Calo, EF tracking
- EF technology choice 2025

Muons:
- sMDT good progress
- RPC FE ASIC discussed CERN CHIPS — progres but schedule slippage

Challenges for the ATLAS and CMS Phase-2 upgrades:
- ❑ Price increases and procurement issues
- ❑ Contributions from institutes in Russia



HGTD:
- Sensor FDR passed
- Delayed submission of ALTIROC_V3 — critical path

ITk Pixel: critical path, 6 months contingency
- Module FDR passed, Loaded Local Support FDR anticipated Nov ’22
- Readout chip ITkPixV2 submission Nov ’22
- Attention: data cables, routing, carbon foam

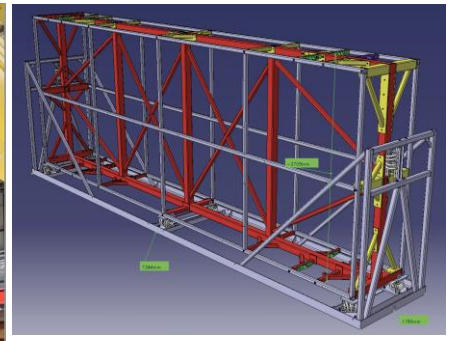
ITk Strips:
- Sensor delivery accelerating but still watched
- FE AMACStar Production Readiness Review passed
- Noise issues under investigation (split endcap modules, DCDC converters)

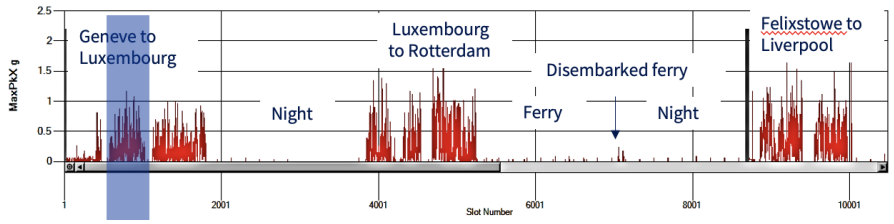
Neutrino Platform – related activities

LBNF/DUNE equipment handling, transport and preparation for lowering in SURF shaft

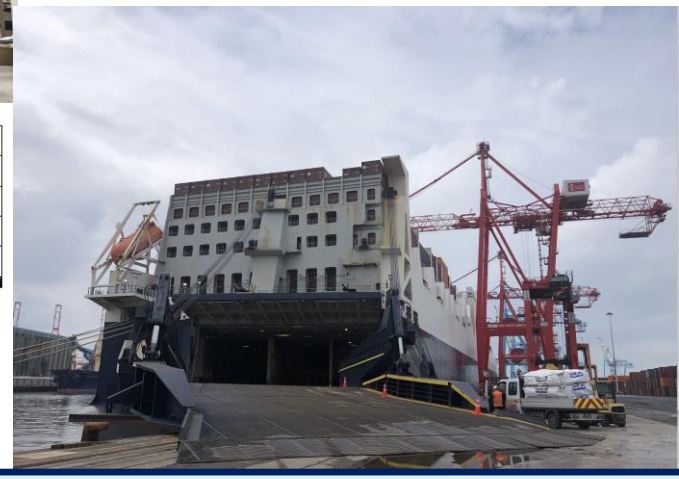
150 DUNE APAs (Anode Plane Assembly) will be transported from Daresbury and CERN to SURF via FNAL from 2023 to 2027.
The risk assessment of the transport strategy and the structural behaviour validation of the APAs and their transport frame is ongoing.

APAs are costly and fragile → their handling and transport are classified as “critical” by DOE and FNAL regulation





Accelerations monitored during transport



CERN
Fall 2021 to March 2022 – design and prototyping of a transport frame installed on shock and vibrations absorbers
Installation of 2 protoDUNE APAs
Validation of the handling procedures

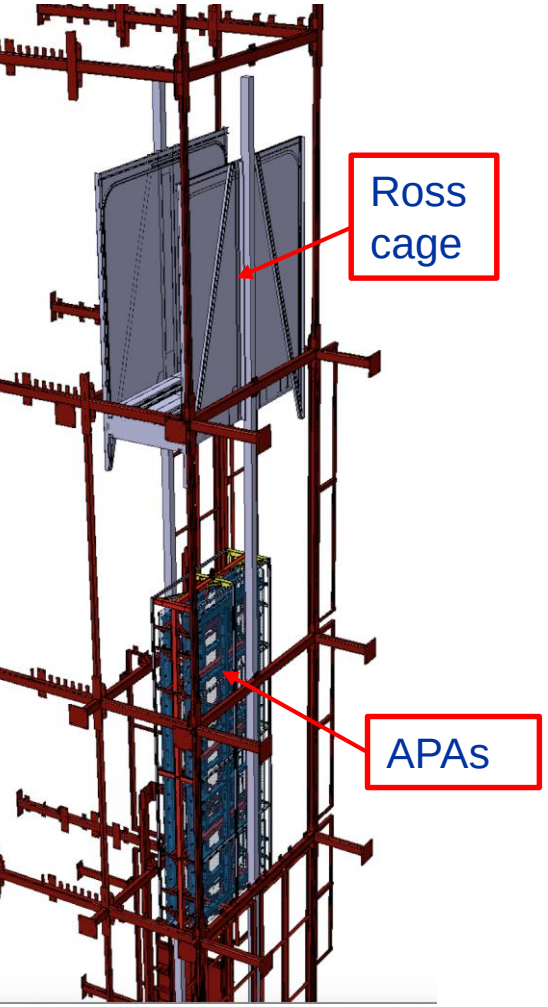
From CERN to Daresbury
April 2022 – Transport by truck and ferry.
Measurement of accelerations, inclinations
Validation of the APAs structural design.
Shock and vibrations on EU or UK roads measured within acceptable values

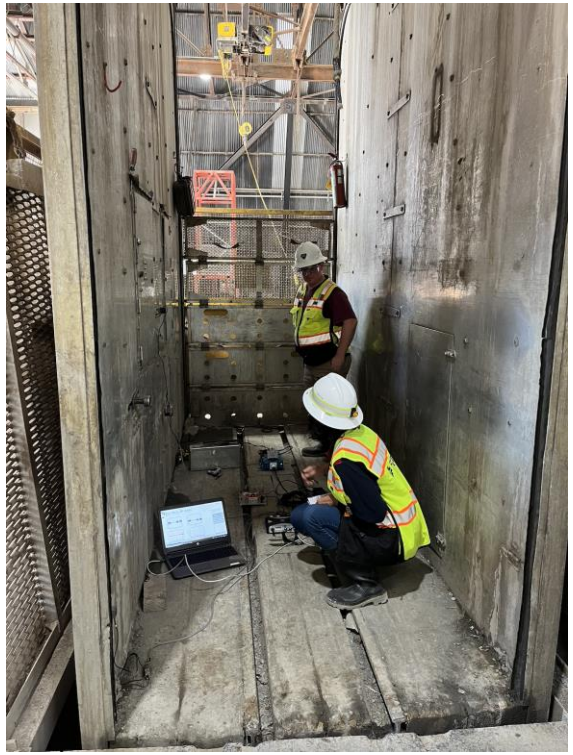
Transport from UK to Fermilab
July 2022 – Transport by truck and sea vessel to Fermilab via Baltimore port
Sea transport strategy is validated.
Low acceleration and inclination levels

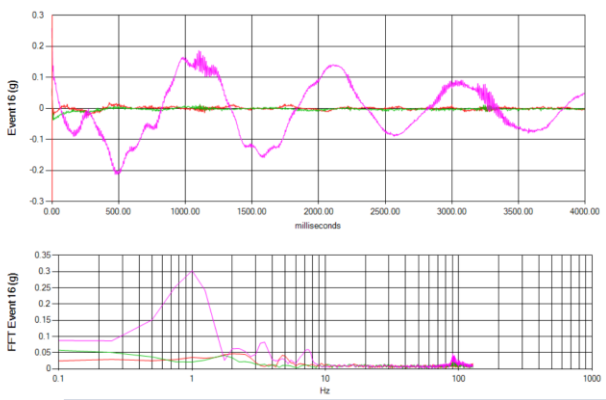
Neutrino Platform – related activities

To prepare for lowering of frame prototype with 2 APAs at SURF (Ross Shaft) in Nov 2022:

- ❑ characterisation of the Ross cage dynamic behaviour (inclination,accelerations)
- ❑ tests of emergency stops of the elevator – assessment of safety for equipment and personnel





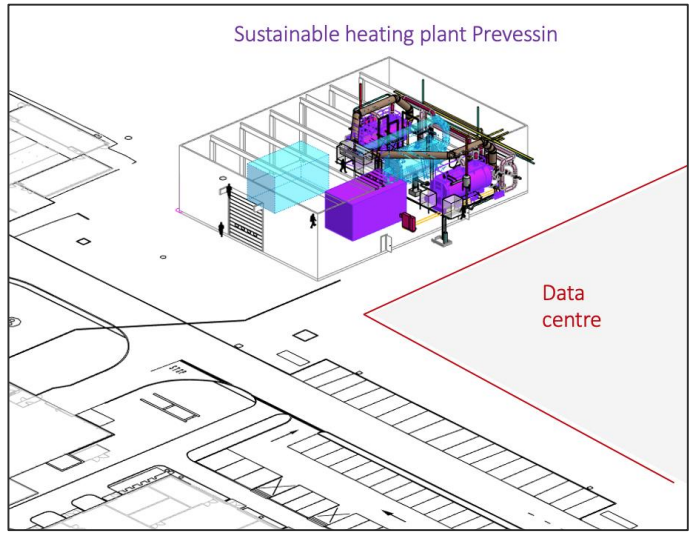


Ross cage vertical 1 Hz mode

Accelerations measured at Ross elevator

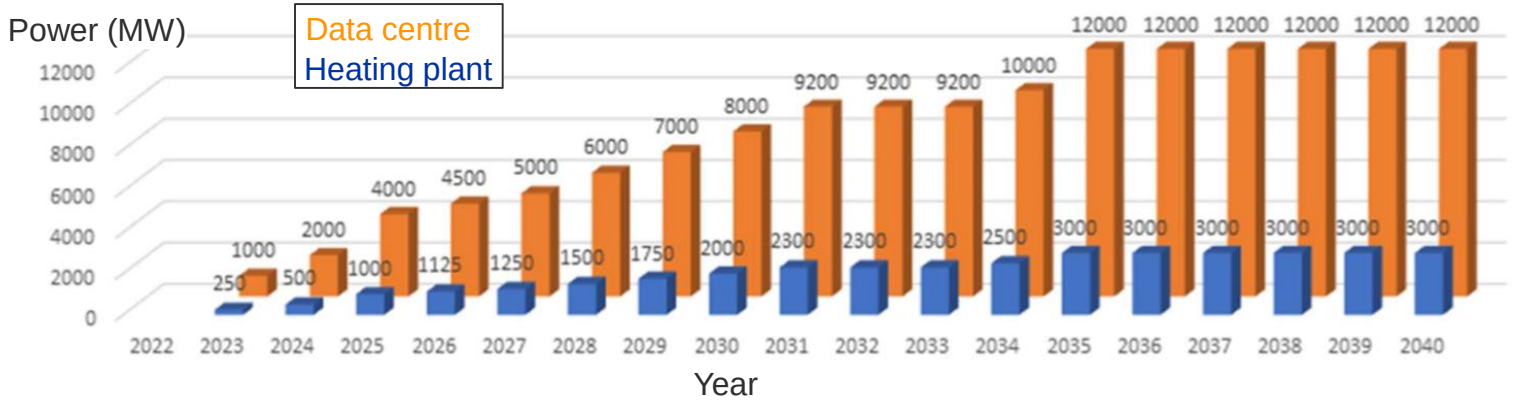
Determination of the structural modes of the Ross cage
DUNE sub-systems will be transported at very low speed: 100 ft/min → 50 min from surface to undergound (1.5 km)
Low accelerations and inclinations were measured.
→ Ready to lower the first DUNE sub-systems under the Ross elevator in Nov. 2022

New CERN Data Centre on the Prévessin site



- Operational end 2023
- Needed to fulfil Tier-0 obligations for end of Run 3 (needed resources: ~ 1.8 x 2018) and HL-LHC (~ 4 x 2018).
- Initial power up to 4 MW, with upgrade capability to 12 MW
- Low PUE (Power-Usage Effectiveness: ratio of the total amount of energy used by a data centre to the energy delivered to its computing equipment): ~ 1.1

Part of waste energy will be recovered to heat the buildings on the Prévessin site
→ emissions reduced by ~ 70%



CERN family

23 Member States:

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

10 Associate Member States:

Croatia, Cyprus*, Estonia*, India, Latvia, Lithuania, Pakistan, Slovenia*, Turkey, Ukraine

* in the pre-stage to Membership

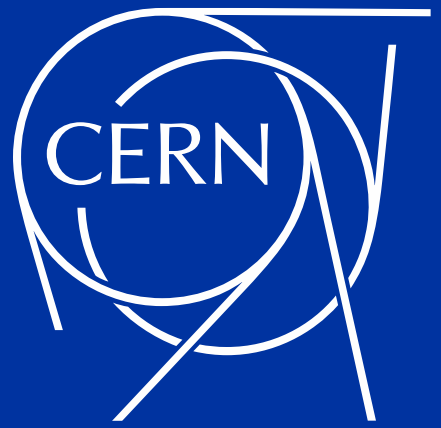
4 Observers:

Japan, USA, European Union, UNESCO
(Russia and JINR status suspended)

~60 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).

3 March 2022: agreement granting Brazil the status of Associate Member State signed. Internal ratification by the country ongoing (somewhat delayed by recent Presidential elections)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