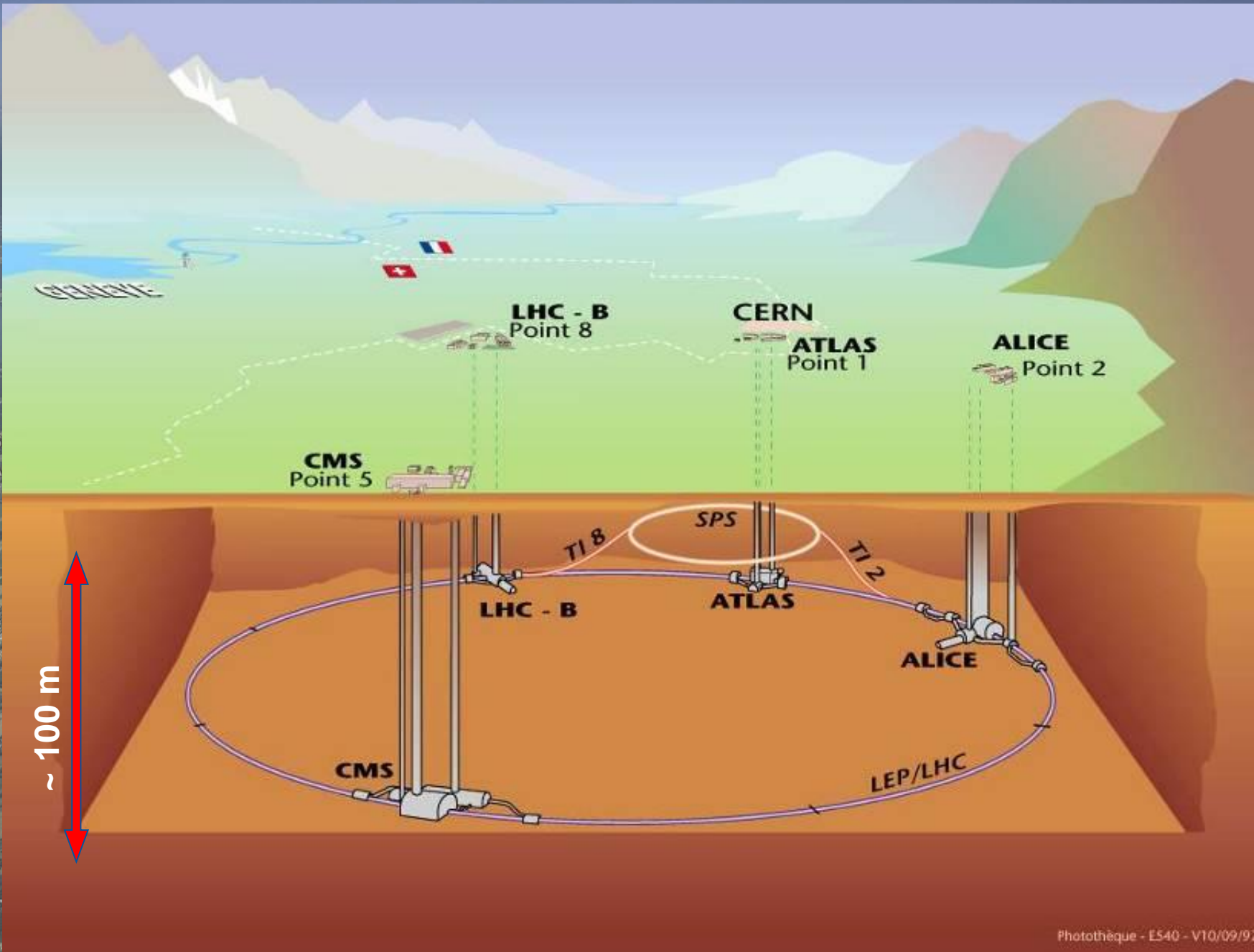


Detectors at CERN



Germany at CERN
28.04.2021
Christian Joram, EP



CERN Research Programme – EP Participation



APPROVED Experiments

- **LHC:** ALICE, ATLAS, CMS, LHCb, FASER, MoEDAL, TOTEM, LHCf
- **SPS:** COMPASS, NA61, NA62, NA63, NA64, NA65
- **PS:** CLOUD
- **AD:** AEgIS, ALPHA, ALPHA-g, ASACUSA, BASE, GBAR
- **Neutrino Platform:** ProtoDUNE, T2K/ND280, ENUBET
- **R&D:** RD42, RD50, RD51, RD53, Crystal Clear, UA9
- **Non-accelerator experiments:** CAST, OSQAR
- **ISOLDE** and **nTOF** facilities

Experiments and Projects under Study

- **FCC**
- **BDF facility / SHiP**
- **LHC:** SND
- **SPS:** NA64 μ , MUonE, AMBER, MadMax
- **AD:** PUMA

CERN-EP involvement

Substantial
Significant
Limited
None

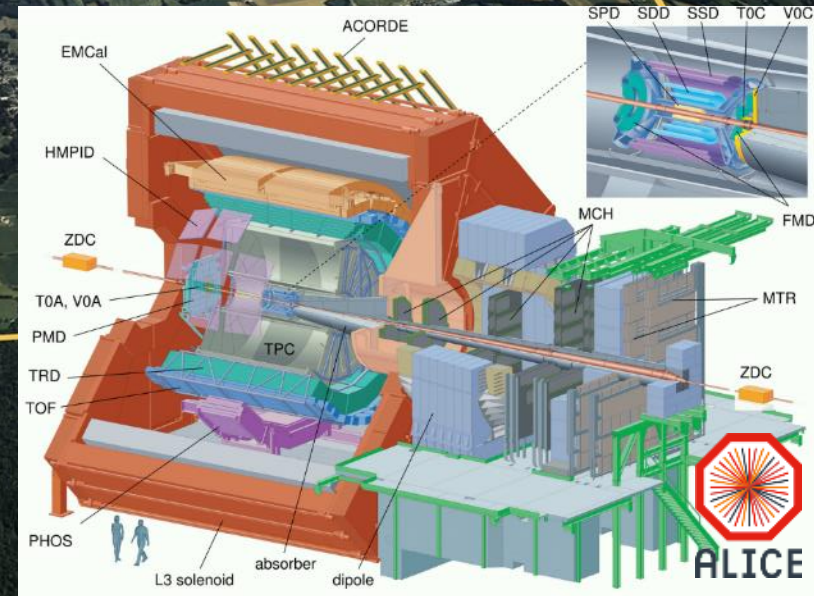
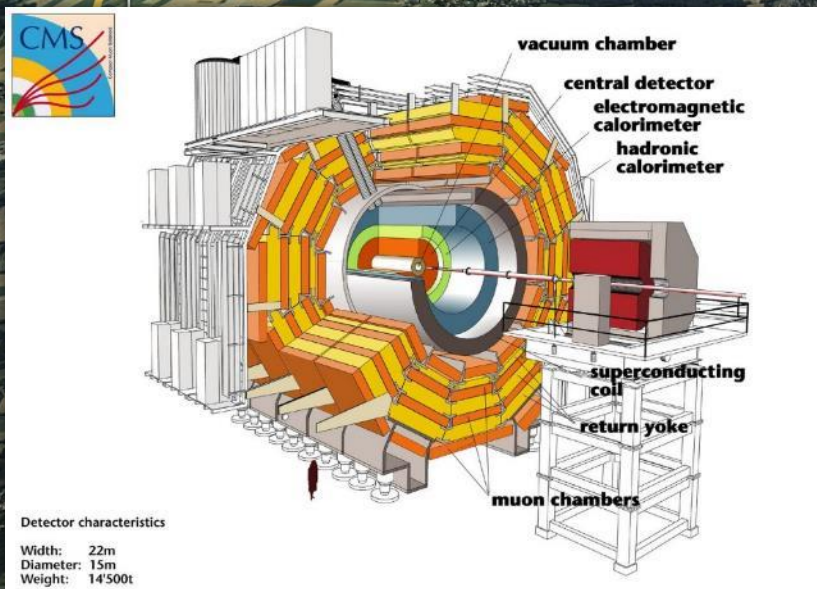
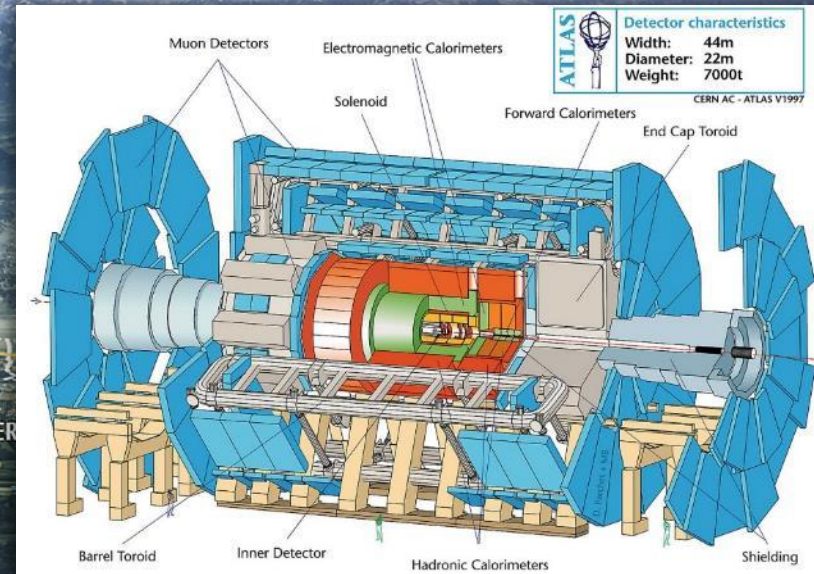
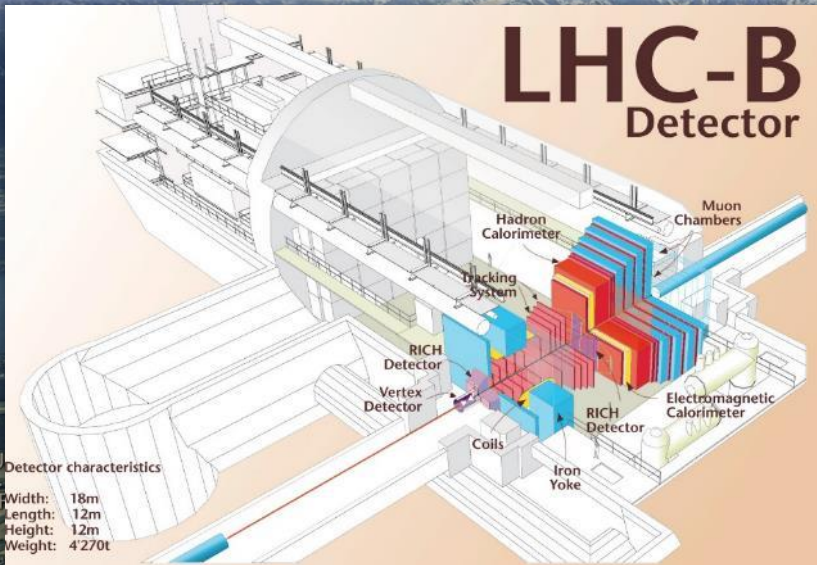
Recognized experiments (Astrophysics etc.)

Use of CERN resources should be marginal

- RE1 AMS
- RE2b Pamela
- RE3 Auger
- RE6 Antares
- RE7 Fermi
- RE8 LISA-PF
- RE10 IceCube
- RE11 MICE
- RE12 MEG
- RE13 T2K
- RE14 Katrin
- RE17 Magic
- RE18 ArDM
- RE19 CREAM
- RE20 Belle II
- RE21 CBM
- RE22 Panda
- RE23 CTA-PP
- RE25 CALET
- RE26 Borexino
- RE27 NEXT
- RE28 Virgo
- RE29 DAMPE
- RE30 KM3NeT
- RE31 Euclid
- RE33 LIGO
- RE34 JUNO
- RE35 SNO+
- RE36 Mu3e
- RE37 DarkSide-20k
- RE38 DAMIC-M
- RE39 sPHENIX
- RE40 POLAR-2

All experiments are designed, built, financed and operated by international collaborations. CERN is just a member of the collaboration. → Lots of procurement happens through the collaborating institutes. Sometimes CERN performs procurement for collaborating institutes.

The Largest Experiments at LHC



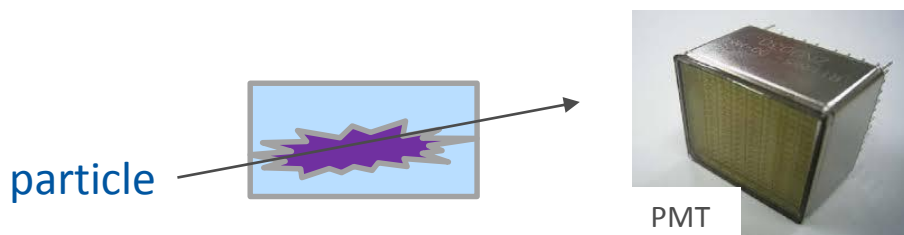
Principles of particle detection

To be detected, a (charged) particle needs to interact with matter.

Excitation

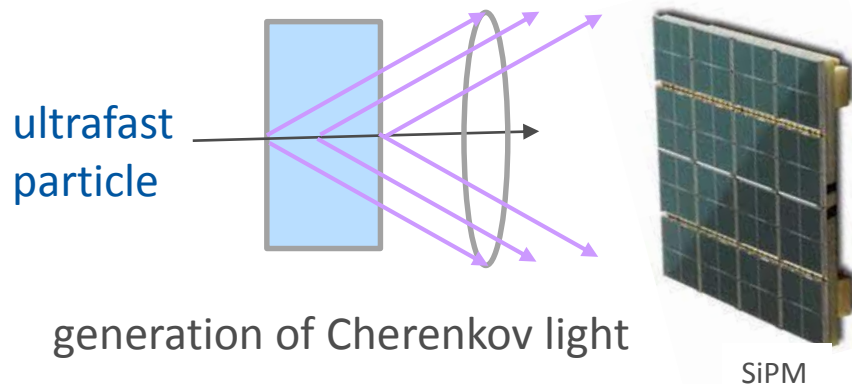
of matter

Ionisation



light generation in a scintillator

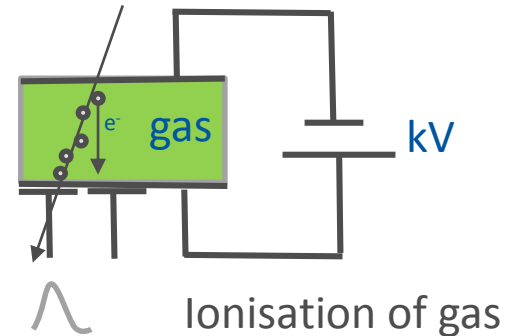
Very fast cameras
(40 M shots/s)



generation of Cherenkov light

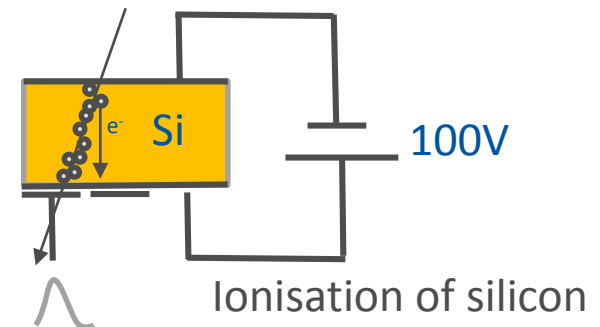
SiPM

$\sim 100 \text{ e}^-/\text{cm}$

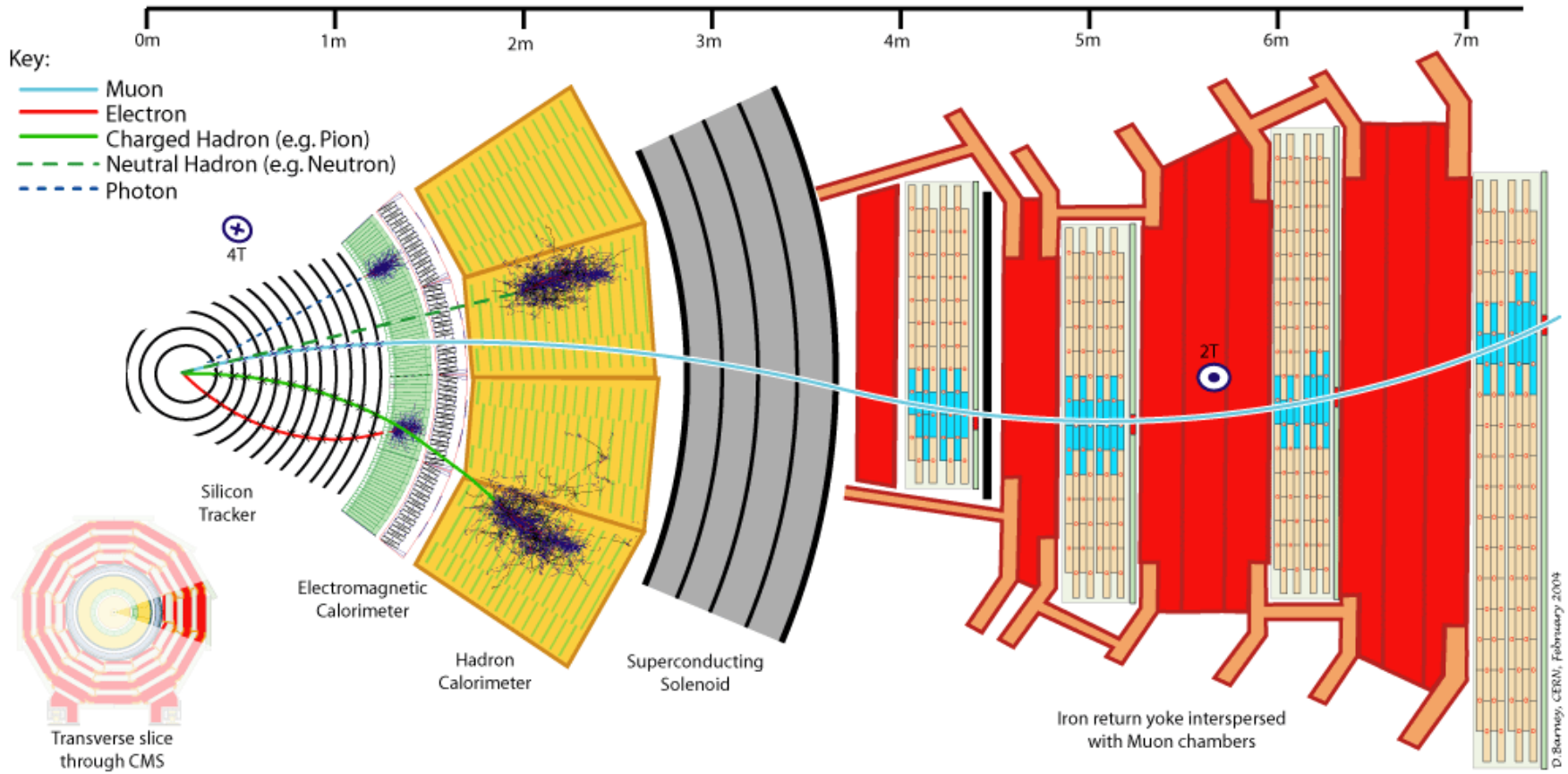


Ionisation of gas

$\sim 75 \text{ e}^-/\mu\text{m}$



Ionisation of silicon



A LHC detector comprises several *sub-detectors*
 = different specialized *measurement* subsystems, e.g. for
 Vertex reconstruction, tracking, calorimetry, particle ID, muon tracking, triggering

LHC Detector Upgrades

Major upgrades ALICE & LHCb
Relatively minor upgrades ATLAS and CMS

Major upgrades ATLAS & CMS
Relatively minor upgrades ALICE and LHCb



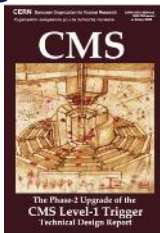
HL-LHC upgrade
 5-7 × nominal luminosity
 14 TeV
 Collect 3000 fb⁻¹

CMS Phase-2 Upgrade



- Replace 100% electronics
Increase bandwidth
- Replace / add several sub-detectors

L1-Trigger



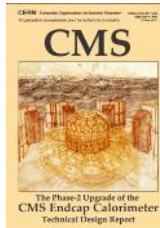
L1-Trigger HLT/DAQ

<https://cds.cern.ch/record/2714892>

<https://cds.cern.ch/record/2283193>

- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
- HLT output 7.5 kHz
- 40 MHz data scouting

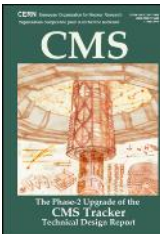
DAQ/HLT TDR Q2.2021



Calorimeter Endcap

<https://cds.cern.ch/record/2293646>

- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS



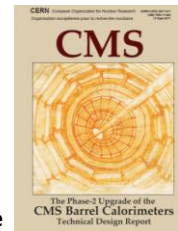
Tracker <https://cds.cern.ch/record/2272264>

- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \approx 3.8$

Barrel Calorimeters

<https://cds.cern.ch/record/2283187>

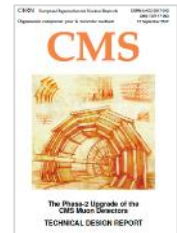
- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards



Muon systems

<https://cds.cern.ch/record/2283189>

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \approx 3$

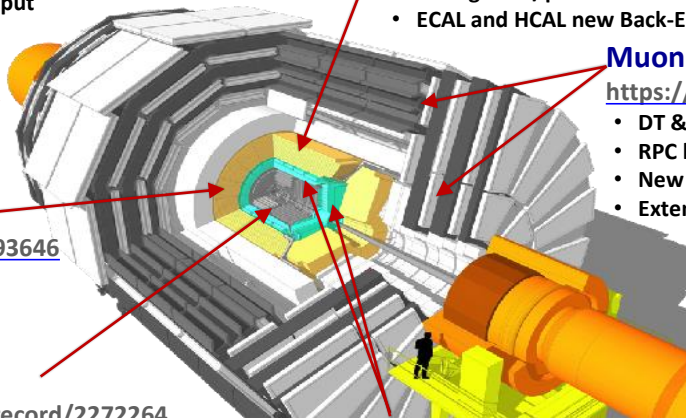


Beam Radiation Instr. and Luminosity

<http://cds.cern.ch/record/002706512>

- Bunch-by-bunch luminosity measurement: 1% offline, 2% online

TDR Q2.2021

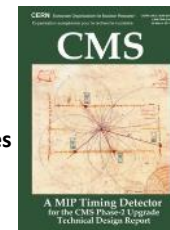


MIP Timing Detector

<https://cds.cern.ch/record/2667167>

Precision timing with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes



ATLAS Phase-2 Upgrades

Major upgrade!



ITk Pixel TDR: <https://cds.cern.ch/record/2285585>

Inner Tracker (ITk)
New All-Silicon inner Tracker

ITk Strips TDR: <https://cds.cern.ch/record/2257755>

Muon Chambers
Chamber replacement in the inner barrel

TDR: <https://cds.cern.ch/record/2285580>

Electronics Upgrades
LAr, Tile, Muons

LAr TDR: <https://cds.cern.ch/record/2285582>

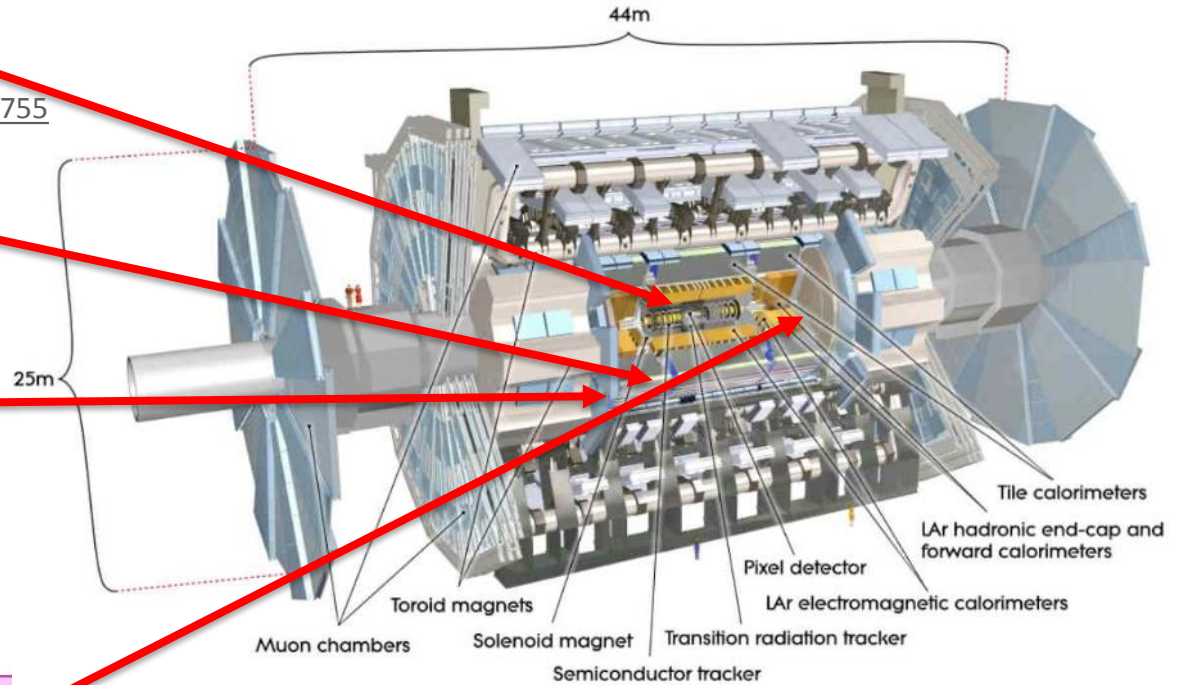
Tile TDR: <https://cds.cern.ch/record/2285583>

Trigger/DAQ
Upgrade to LO-based system at 1 MHz

TDR: <https://cds.cern.ch/record/2285584>

HGTD
High Granularity Timing Detector
Forward timing coverage from LGADs, 30-50 ps resolution for MIPs

TDR: <https://cds.cern.ch/record/2719855>

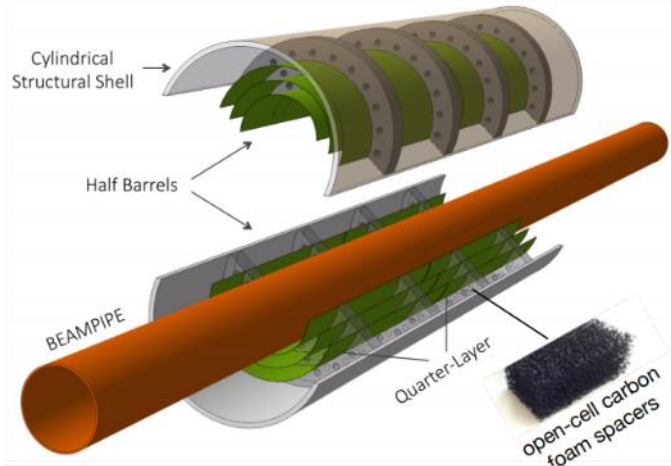


Goal:

- Best possible performance in tracking, b-tagging, E_T^{miss} ,
- Low p_T thresholds for trigger.
- Extension of tracking coverage up to large η

Challenge: High radiation and high pile-up

(Possible) Upgrades during LS 3 (not yet fully approved)



New inner part of tracker ITS-3. Truly cylindrical Si sensors. ($\sim 0.2 \text{ m}^2$ of Si)



"Minor" upgrade!

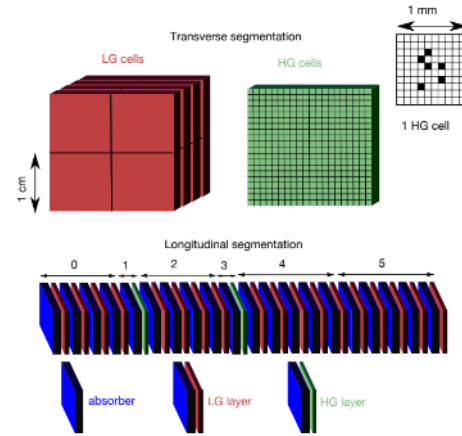
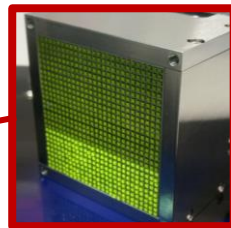
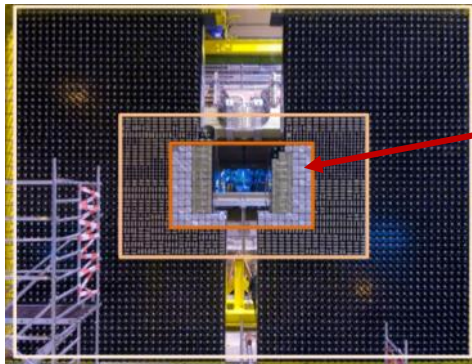


Fig. 21: Schematic view of the structure of the FoCal-E detector.

Forward calorimeter based on very high granularity Si/W technology (16 m^2 of Si).

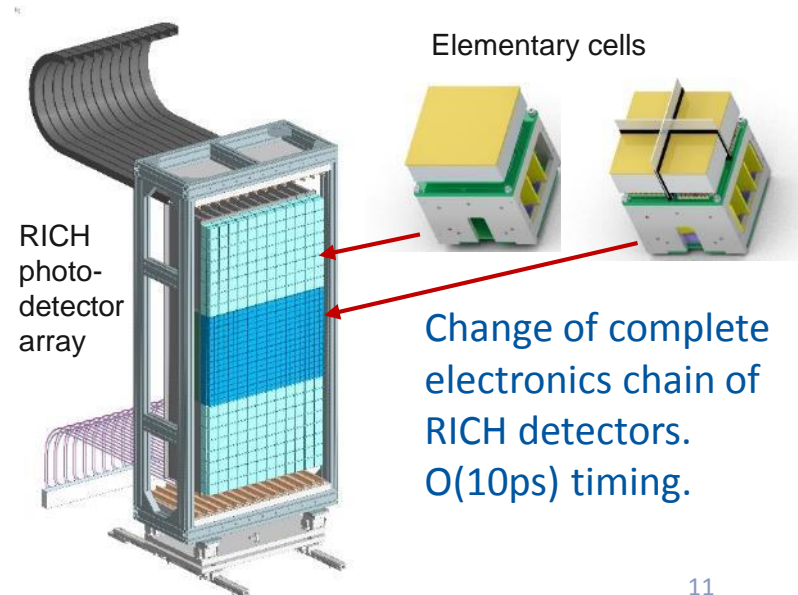


"spaghetti type" module $12 \times 12 \text{ cm}^2$



New inner region of electromagnetic calorimeter. "Spaghetti type" sampling calorimeter, $O(10\text{ps})$ timing.

"Minor" upgrade!



Change of complete electronics chain of RICH detectors. $O(10\text{ps})$ timing.



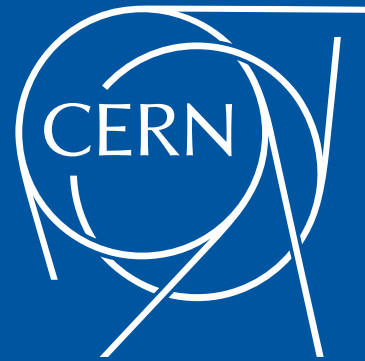
Summary

- Experiments at CERN are built and operated by international collaborations.
- In Long Shutdown 3 (2025-2027), ATLAS and CMS undergo MAJOR upgrades, ALICE and LHCb relatively minor upgrades.
- Lots of new electronics
- Many new sub-detectors, with silicon, gas, scintillator technology

For further information, please contact ...

Experiment	Technical Coordinator (TC)	Deputy TC
ALICE	Werner Riegler	Arturo Tauro
ATLAS	Ludovico Pontecorvo	Martin Aleksa
CMS	Wolfram Zeuner	Paola Tropea
LHCb	Rolf Lindner	Eric Thomas

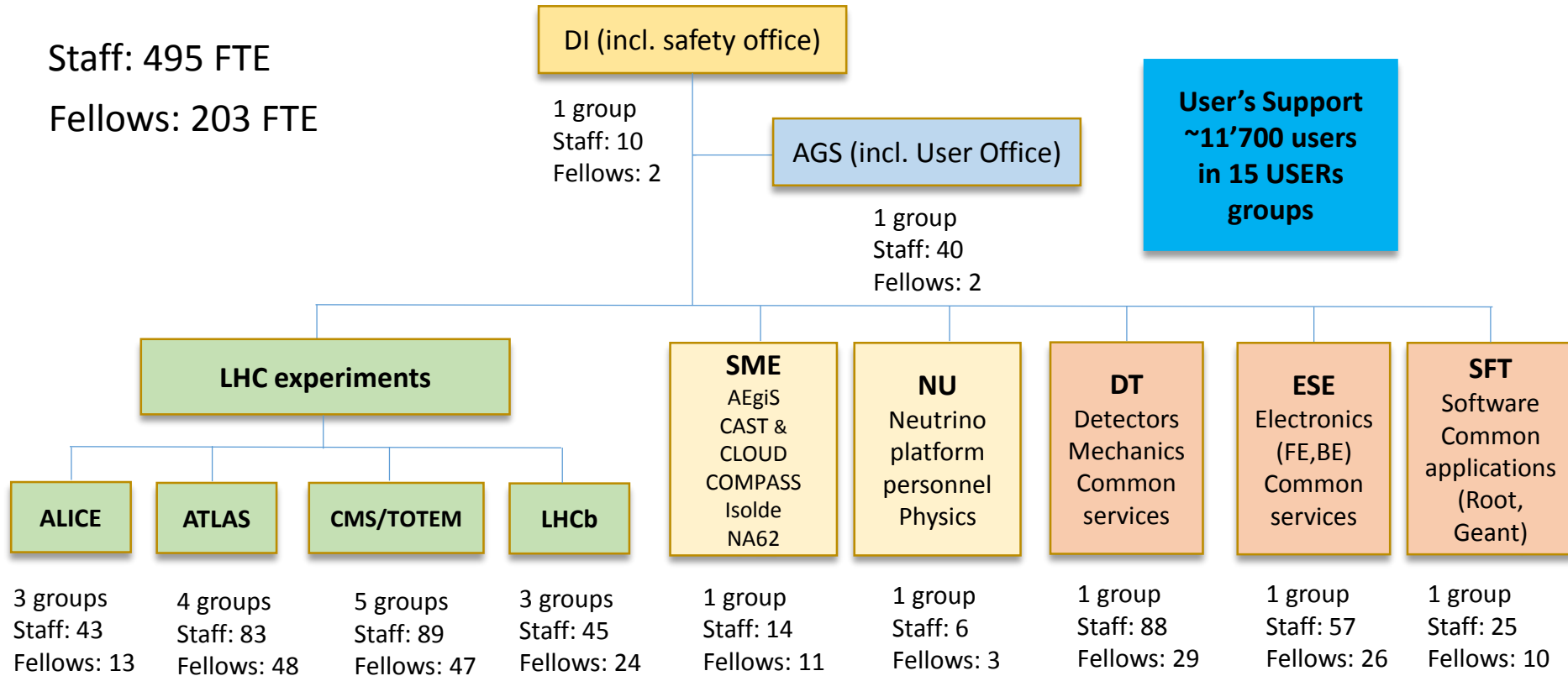
Email = firstname.familyname@cern.ch



EP Department Structure



Staff: 495 FTE
Fellows: 203 FTE



~90% of resources are focused on LHC experiments and their upgrades