ECFA Mid-term Status Report

for France

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RECFA visit France in 2021: List of main comments

- We are impressed by the broad programme and the high-quality contributions to frontline research in particle physics, astro-particle physics and cosmology, including smaller-scale precision experiments, with leadership in many areas.

- Also impressed by the very significant contributions to R&D activities accelerators, detectors and computing;

- We appreciate the good alignment of research in theory with experiments.

- Broad coverage also on the theory side.

Structure and Funding in 2021

- Funding structures seem to be well established, strong National Institutes with IN2P3 and IRFU + TGIR support for large projects

- Appreciate to see new research areas (accelerators / computing)

- Take note on changes in institute structures, **with formation of a larger institute IJCLab**; We hope and expect that the creation of this larger structure will be successful and allow to exploit synergies;
  We appreciate expansion in different direction (computing, machine learning, ..), e.g. Toulouse

- We are happy to see general awareness of young researchers about funding opportunities.

- We note that some of the new funding opportunities are probably not so well matched to large-scale, long-term international projects, **e.g. ways should be explored how to replace the LABEX funding;**

- Universities are well integrated, however, there is a **rather low number of PhD students compared to permanent staff researchers**. In addition we note that the **fraction of people recruited for teaching at universities contributing to research is decreasing**

- Efforts to be made to keep expertise in the field; Efforts should be made to **engage postdocs in detector physics and to provide permanent "detector hardware positions"**

Structure and Funding Evolution

- …**formation of a larger institute IJCLab**

IJCLab creation/organization is now finished and the Lab is running smoothly with a strong impact on the field.

- **…ways should be explored how to replace the LABEX funding;**

Unfortunately, this replacement coming from the Universities is not as focused on particle physics as before so less funds (~2/3) are now available.
An ANR special program has been initiated to hire postdocs to exploit large instruments science. This program is now terminated but it has been successful and increased interestingly the overall number of Postdocs in our field.

- **Universities are well integrated, however, there is a rather low number of PhD students compared to permanent staff researchers;**

Trying to increase the fraction (see below with “Chaire Junior”), but only small increase so far.

- **… the fraction of people recruited for teaching at universities contributing to research is decreasing.**
- **… to engage postdocs in detector physics and to provide permanent “detector hardware positions”**

Improvement of the situation with the creation of « Chaire Junior », i.e. tenure track positions at the University at the associate professor level which come with an entry package (typically one postdoc and one student).
Several chaire-junior per year covered jointly financially by IN2P3 and Universities. This allows also to hire more easily detector physics experts.

France and LHC in 2021

- High visibility in large LHC experiments (leadership positions, as well as contributions to analyses)
- Significant contributions to experiments (conception, construction, commissioning and operation)
- Covering broad physics programme, with leading contributions in several areas (e.g. W mass measurement, VBS, Higgs physics (in particular to observation of fermionic Higgs boson decays in Run 2, moving also to di-Higgs production in future (bb gg and bb tt channels), searches of BSM physics.
- Strong contributions via ALICE, CMS and LHCb to the QGP physics programme, with analysis contributions to various legacy projects (charmonium as signature of de-confinement (crucial role, via muon spectrometer), emergence of QGP phenomena in high-particle multiplicity, or Ypsilon suppression (CMS))
- Expect that high level of engagement in LHC experiments (operation, analysis) can be maintained also in future.
- Impressive contributions to large LHC upgrade projects (true for all experiments with participation in innovative projects (real-time analysis in LHCb, thin silicon tracker in ALICE, ITk pixel and Timing detector in ATLAS, Outer tracker and HGCal for CMS).
- Acknowledge the excellent support on the electronics engineering side by Omega (all experiments) and expect that this support can be kept in the future

France and LHC / Current situation

- **LHC Physics analysis** going strong in all domains
- A team from **Irfu (CEA) joined LHCb** in 2024 focusing on its heavy-ion program.
- **Phase 1 Upgrades** were successful: Completion, installation and operation (14+8 MCHF from IN2P3+Irfu)

  ATLAS: - LAr EM calo trigger/readout electronics, NSW muon

  ALICE: - IT2 (ALPIDE chips, modules), MFT (full project w/ CEA, MUTRK, MUID, O2 |

  LHCb: - SciFi, EM calo electronics, DAQ 40MHz, Real-Time-Analysis

- **Phase 2 Upgrades** in progress (53+27 MCHF from IN2P3+Irfu):

  Significant progress on all fronts though calendar still tight. Transitioning to preproduction and production:

  ATLAS: - ITK (module production, module loading, mechanics OuterBarrel),
  - EM Calo LAr (ASICs, electronics),
  - HGTD (ASIC, electronics, mechanics),
  - Tile HAD Calo (electronics),
  - Muon System (barrel)

  CMS: - Tracker (TEDD mechanics, TB2S module loading, ASIC CIC),
  - HGCAL (ASIC HGCROC, mechanics, trigger),
  - Muon RPC (electronics), MTD (electronics/DAQ),
  - Laser monitoring system

- **“Intermediate” Upgrades**:

  ALICE - On-going for ITS3 (CMOS sensors, electronics) for LS3

  LHCb - Decision soon for LHCb LS3 upgrades (EM calorimeter electronics+mechanics, DAQ, RTA and Tracking)

France with Flavour and Neutrinos in 2021

- Represented in a well-focused effort in Flavour Physics (LHCb and Belle-II) with significant physics contributions, in particular on studies of anomalies (B → μμ , B--> μμ (γ), R_{D^*}, hadron spectroscopy) in LHCb, as well as in Belle-II (angle γ and ϕ_s)
- Significant share on LHCb Upgrade I (real-time analysis (RTA) project, DAQ, calorimeter, scintillating fibres) and targeting interesting projects for Upgrade II

- Participation in many ongoing (T2K, JUNO, ORCA, ...) and future long-baseline neutrino experiments (T2K-2, T2HK, (proto)-DUNE)
- Historical leading role in T2K; extended by proposing upgrade of Near Detector for next generation
- In addition, participation several other neutrino projects, e.g. neutrino-less double-beta decay (0n-bb)
- Far future: **engagement in both DUNE and Hyper-K may lead to overlap in time and thereby overlap of resources** (financial, human,…)
- Overall impression: many projects…. We have slight concerns about spreading too thin, some **prioritization would be necessary to guarantee a critical size in experiments to be able to make visible and sustainable contributions.**

→ Prioritisation is established, with for instance at IN2P3 > 30 physicists on DUNE vs. <15 in HyperK. However given the complementarity of the experimental techniques, we want to contribute to both experiments like many other countries

Neutrinos / Current Status

- Neutrinos/T2K:
  → Successful upgrades of ND280: electronics & mechanics for High-Angle TPC, electronics for Super FGD)

- Neutrinos/DUNE:
  → Major progress with the completion of the NP02 Vertical Drift ProtoDUNE prototype at CERN (data taking in 2025), Vertical Drift technology (IN2P3+CERN+US) selected to be used for the 1st far detector module of DUNE.
  First major tendering contracts done in 2024, on track for finishing our deliverables in 2026
  Main deliverables: top electronics & mechanical chimneys, top charge readout plane, HV system with cathode
  → contribution to PIP-II progress for DUNE.

- Neutrinos/Hyper-Kamiokande:
  → MoUs signed, progress on main contributions: time generation & distribution system, digitization electronics, test benches, computing

- Neutrinos/JUNO:
  → electronics for the small PMTs completed and installed, top tracker electronics production almost finished, installation of top tracker to come in 2025

- Two ERC projects started at Irfu: BINGO and TINY, to optimize neutrinoless double beta decay detection with scintillating bolometers

- New results from STEREO
- Long background run with NUCLEUS.

Low-energy precision experiments in 2021

- France is involved in interesting and important low-energy precison experiments;
- Small but relevant and diverse selection of experiment was made, with contributions of a small number of people and labs
- Adds to the diversity of physics programme in France.

Astroparticle Physics & Cosmology in 2021

- Strong and broad participation in astro-particle physics
  (participation in all major research areas, participation with strong groups in many projects
  (e.g. > 100 people in Virgo (22%), Lisa (130 people))
- The contribution made are very large, highly visible and diverse;
- Targeting also future project, e.g. from Xenon to Darwin… and also and CTA;
- We feel that France is very well positioned to take a leading role multi-messenger physics exploitation

➔Creation in 2024 of the Astrophysics Centre for Multimessenger studies in Europe – ACME
(Financed by EU, coordinated by CNRS, follows recommendation from APPEC and ASTRONET)

France and Theory in 2021

- Broad coverage on the theory side, with leadership in some areas;
  We are pleased to see very good alignment between theory and experiment

- Surprised about limited presence at universities (and maybe some indication of decrease).

- Efforts should be made keep presence of our field at universities, which is essential to have a direct link to students

➔Several theorists have been hired at the Universities in these last 3 years

France and Future Colliders in 2021

- Highly significant and important studies on physics potential and detector concept for future Higgs factories (FCC-ee and IDT), with visible involvement in many key activities.

- Engagement in ECFA Workshops highly appreciated bringing ILC and FCC activities together.

➔ FCC strongly supported by IN2P3 and Irfu.
➔ Active Community engaged in the FCC feasibility study and in the European Strategy.

France and Accelerators in 2021

- A particular strength of the French particle physics community is the existence of many groups working on detector and accelerator R&D.

- French institutes are making very comprehensive contributions to many projects, i.e. they participate in major research lines (high-field magnets, high-gradient plasma and laser accelerators, high-gradient radiofrequency structures and systems, energy-recovery linacs, etc.)

- Being discussed as part of the European roadmap for accelerator R&D

France and Accelerators / current status report

- **DUNE/PIP-II @FNAL:** End of prototyping phase (conception/design, conditioning and validation) for the Single Spoke Resonator (SSR2) 325 MHz superconducting elements (cavities, tuners and couplers). Start of the program of qualification of all (35) SSR2 series superconducting elements. Design, manufacturing, assembly and test of one pre-production and nine production LB 650 cryomodules with 650 MHz low beta elliptical cavities

- **FCC-ee @CERN:** 7 lines of R&D dedicated to the feasibility study of FCC-ee in place at national level in four IN2P3 labs; lines of research in : Nanobeam handling, stabilization and monitoring; luminometry and backgrounds; high intensity positron sources; laser polarimetry; dynamic vacuum and surface phenomena; Multipactor effect on SWELL and 800 MHz cavities; High-Q cavity receipt @ 800; recent new involvements in discussion (HTS magnets and MDI); design studies for the booster (CEA)

- **PERLE @IJCLab:** Significant funding secured for high power Energy Recovery Linac developments for PERLE experiment at Orsay from EU and national CNRS program. DC-gun, photocathode production facility, laser, delivered at Orsay. Injector and 800 MHz LINAC cryomodule funded. European project iSAS in progress.

- **GANIL / S3 @CAEN:** Installation of Superconducting Separator Spectrometer (S3) at the National Heavy Ion Facility of GANIL. First beam expected by the end of November 2024 for a 18-month commissioning period; data taking for physics is expected in 2026.

- **ESS @LUND:** Delivery of all 13 Cryomodules Spoke Superconducting RF 352 MHz cavities for the Low Beta Section at Lund, and of the Cooling Distribution System (IN2P3); Delivery of RFQ and of medium and high-beta cryomodules (CEA). Inauguration of the accelerator at Lund by the French president in January 2024

- **EIC @BNL:** Project CNRS/CEA under construction (agreement signed with DOE in 2023, 40ME) with a contribution to the detectors: Tracking, Forward Calorimeter + electronics, Roman Pot electronics and a contribution to the accelerator: Solenoid Magnet and spin-rotators (CEA), Rapid Cyclotron Synchrotron (RCS), Superconducting RF (591 MHz) and Cryomodules construction (IN2P3)

France and Detectors in 2021 and today

- On detectors: involved in key detector technologies with some innovative contributions.. (silicon sensors, hybrid, CMOS, LGAD) or gaseous detectors (large contributions to muon systems, incl. modern technologies), but also on calorimeters (Accordion, Particle flow, CALICE, …)

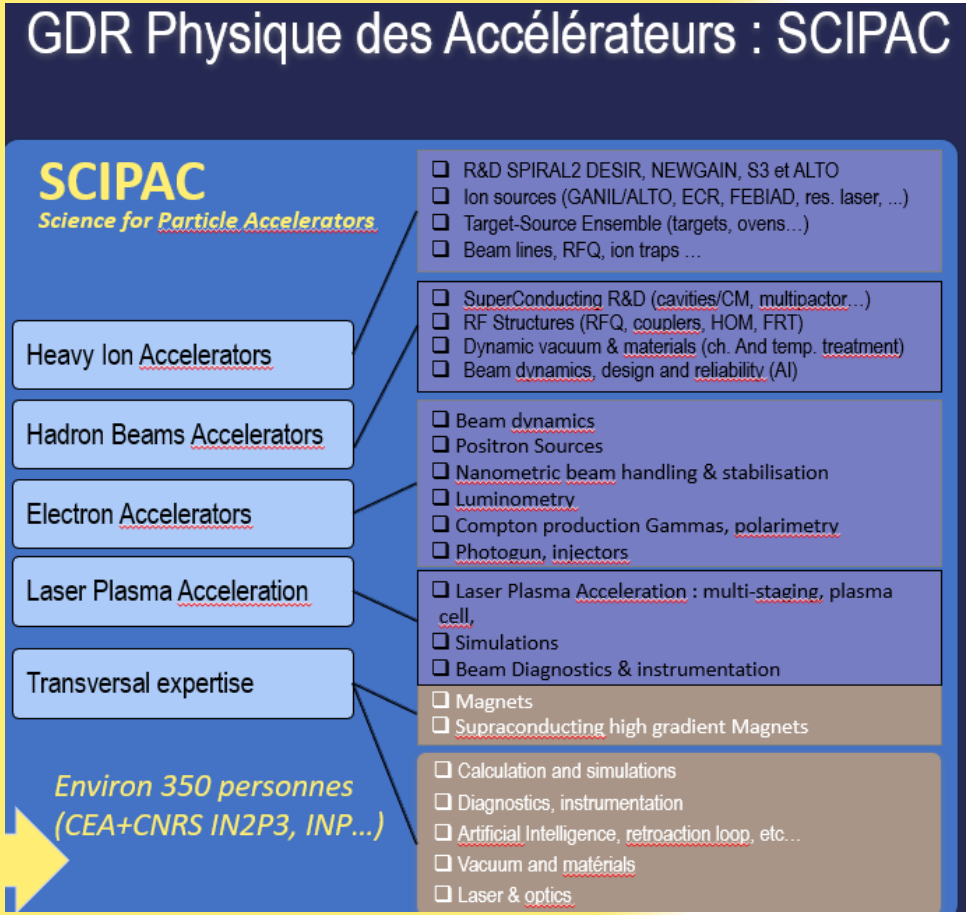
- **RECFA recommends very strongly that the present level of engineering and technical support, which is the key for success in detector and accelerator R&D and indispensable for the design and construction of future facilities and experiments, be maintained.**

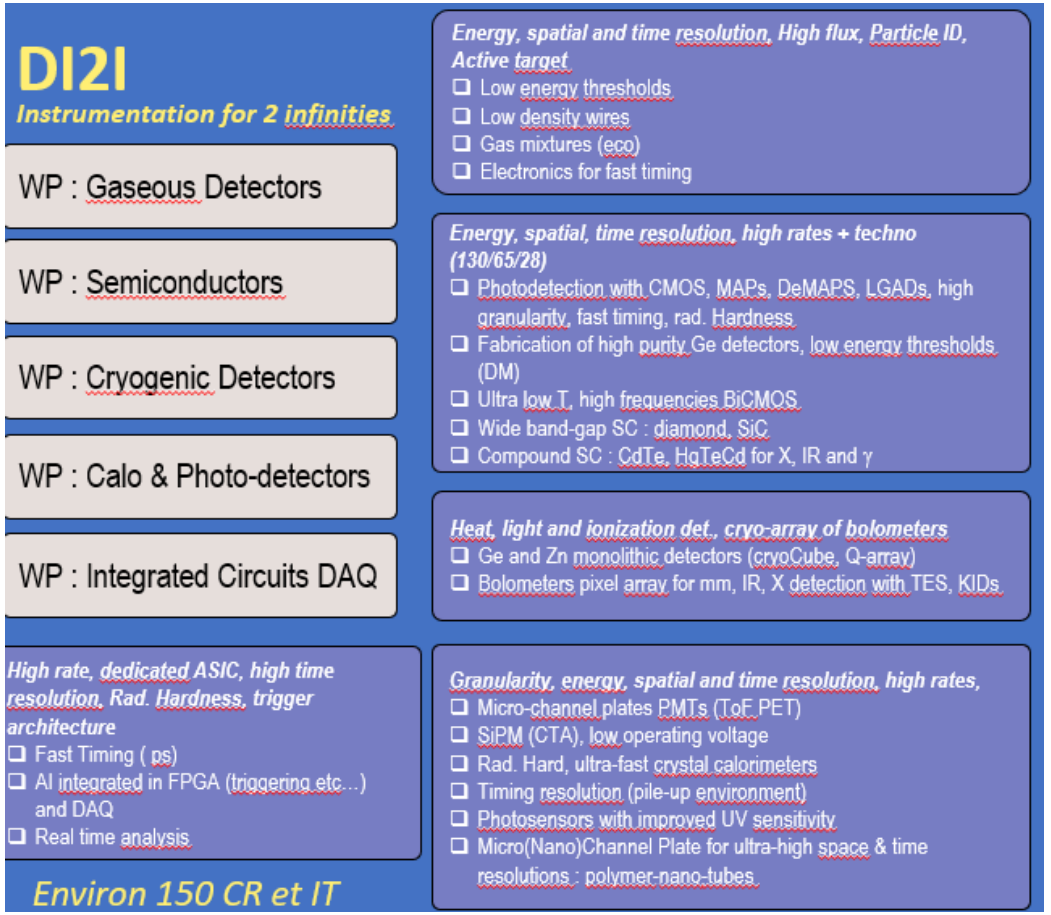
➔**France got strongly involved in 2023/2024 in all DRD collaborations, with many positions of responsibility (in DRDC, spokesperson of DRD collaboration, WP coordinators)**

Accelerator/Detector updates

- Two « Groupements de Recherche (GDR) » created in these two last years, related to the ESPP :

1) focused on accelerators (SCIPAC): network of 3 IN2P3 institutes + CEA with about 350 persons
2) focused on Detector R&D (DI2I) with a WP structure and about 150 persons





France and Computing in 2021

- France has a strong involvement in the computing projects for particle physics with the operation of a TIER1 centre within the worldwide LHC computing grid..
- Very strong contributions as well on software, modern machine-learning techniques, distributed computing
- Expansion towards HPCs and modern computing architectures appreciated
- **For the secondary TIER2 centres, the periodic replacement of aged equipment remains a worry in addition to maintaining people in the computing area.**

Computing Infrastructures Status

Global French contribution to WLCG constant above 10% of the world resources

- 12-15% for CC-IN2P3 T1, 5-15% for T2s depending on the experiments
- High quality level of T1 and T2 site resource and service delivery to experiments
- Data challenge successful

CC-IN2P3

- Key infrastructure for all our experiments providing production and analysis resources (3rd T1s in terms of contribution to WLCG)
- FITS project : CNRS Federated IT Services for research infrastructures. IDRIS-CC-IN2P3 portal for the access to HPC/HTC
- Greenhouse gas assessment done to reduce footprint. Extension of the datacenter : start at the beginning of 2025

French WLCG TIER 2

- Resources contribution stable for LHC experiments but for ALICE (2 T2s have stopped)
- HR renewed for several T2s, stabilized at a sufficient level to ensure quality production.
- T2s funding is a mixed of local university and CNRS/CEA fundings

Software, R&D technologies and AI status today

Software

Continuous developments for Software and Interware

- Involvement continues on LHC software, Geant4 , SMILEI,…
- Middle-interware and databases
  - DIRAC. usage extends outside LHC (Belle II, CTA, Auger, JUNO..)
  - AMI ATLAS file database
  - Development/deployment of CREST in ATLAS

RTA Trigger @LHCb

Successful commissioning / nominal running of HLT1

- Decisive involvement of IN2P3 teams

Open science

- IN2P3 strategy and structuration project, workshop leading to recommendations for beginning of 2025

New technologies and R&D

- **Heterogenous computing**
  - ARM architecture tested at CC
  - R&D on embedded AI NN on FPGA/GPU/neuromorphic circuits
  - HPC : progress of the FITS project
- **Software R&D**
  - Several PhD thesis in collaboration with labs in computer science
- **AI**
  - projects using AI at all levels (simulation, reco, analysis, accelerators)
  - strong AI R&D developments : AI and uncertainties, anomaly detections, track reconstruction (ACTS)
  - series of international workshops organized in AISSAI framework
- **Quantum computing**
  - R&D project on QML for calo reconstruction

➜ **Strengthening HR with recent recruitment of researchers with expertise in AI and heterogeneous computing**

Outreach in 2021

- Impressive, well-structured and organised Outreach programme (with core-stuff); Many activities, large number of tools and resources, reaching out to politicians, public,... including well-organised Education programmes

➔ More work being done for the future

Student Talk in 2021

- Interesting talk, well presented;
- Picture not very different from the one on other countries.. ..
- We are happy to see that there is large interest in obtaining a permanent position in France! (70% is a high number)

Summary / Conclusions

- France HEP is progressing well.
- The vast majority of the ECFA recommendations have been followed.
- As usual in these times, some worries about human ressources and financing are present.
- French Strategy is progressing well with hopefully a brilliant future in front of us!