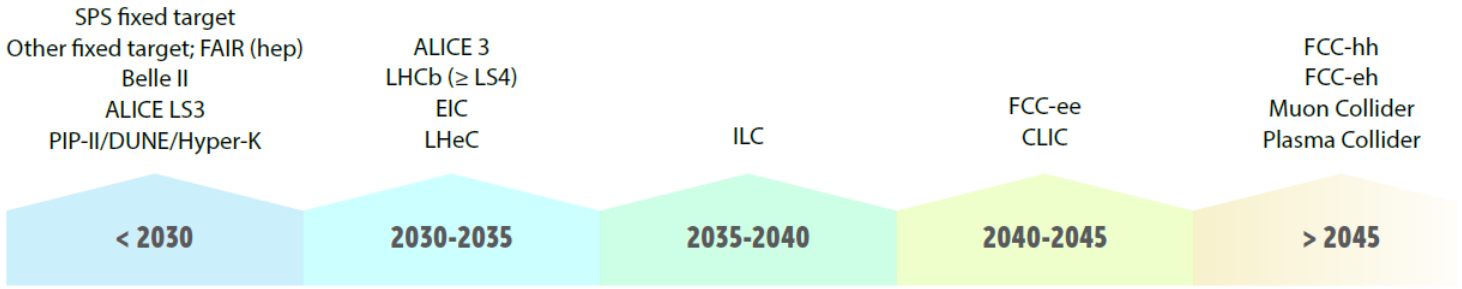
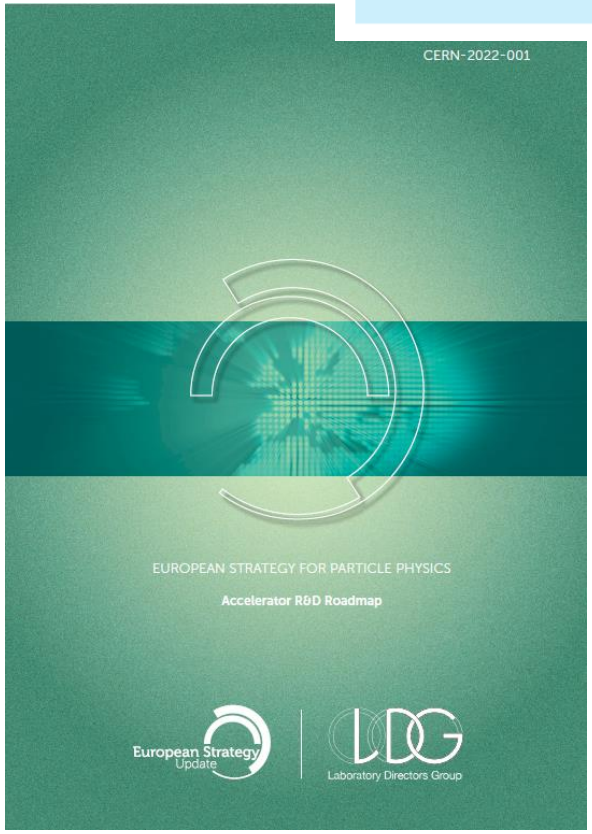
Progress report from the RF coordination panel
in the ESPP Accelerator R&D

G. Bisoffi (INFN), P. McIntosh (STFC)
for the LDG RF Coordination Panel

LDG and Accelerator R&D Workshop, BNL, June 6-7 2024

Scope: Implementation of an approved R&D strategy





2020-2022: ESPP Accelerator R&D Roadmap, presented to CERN-SPC in March 2022

RF items by: S. Bousson (IJCLab), H. Weise (DESY). G. Burt (ULAN); G. Devanz, T. Proslier (CEA); A. Gallo (INFN); F. Gerigk, A. Grudiev (CERN); D. Longuevergne (IJCLab); R. Ruber (Uppsala), + experts

- ✓ Superconducting RF: bulk niobium cavities, surface preparation, thin films
- ✓ NC structures: fundamental limitations, surface preparation, manufacturing techniques
- ✓ High power RF sources, accelerating structures ancillaries (couplers, tuners…), LLRF and AI

RF = increase beam energy efficiently and reliably

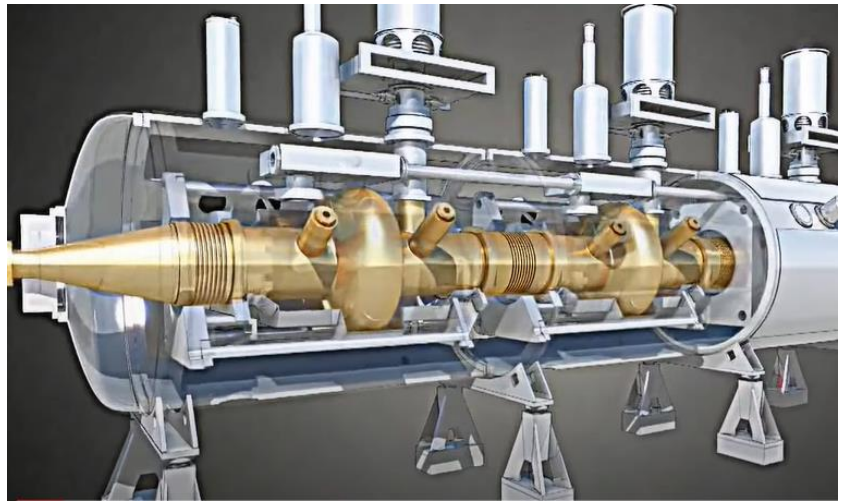
November 2022: RF Coordination Panel nominated, to follow the concrete implementation of the roadmap recommendations":

FROM:

- ✓ **What** R&D needs to be done, priorities, time/resources, dependencies among activities, scope of demonstrators and intermediate outputs, what is applicable outside the PP scopes

TO:

- ✓ **Coordinate the plan of R&D for HEP accelerator** across national institutes and CERN, *albeit not prescriptive on actions or investments for countries, laboratories, or institutes*
- ✓ **Its implementation** must serve the anticipated update of ESPP on benefits, challenges, feasibility, risk and costs (construction, operation, environment) of each new development, with top priorities to make needed technology jumps.



RF Panel coordination		G. Bisoffi INFN-I, P. McIntosh STFC-UK
WG1	Bulk Nb	M. Baylac CNRS-F, C. Madec CEA-F, L. Monaco INFN-I
WG2	Thin films	C. Antoine CEA-F, O. Malyshev STFC-UK
WG3	Couplers	F. Gerick CERN, E. Montesinos CERN, A. Neumann HZB-D
WG4	NC High gradient	W. Wünsch CERN, D. Alesini INFN-I
WG5	RF Power sources	I. Syratchev CERN, G. Burt STFC-UK, M. Jensen ESS-S
WG6	LLRF, AI, ML	Z. Geng PSI-CH, W. Cichalewski U-Lodz-P

Activity in the last 12 months

- November 2023 status report (progress status, milestone status, challenges), free access on https://ldg-rfcp.com/

  (its short version then submitted to LDG and CERN)
- Building upon list and institutes given in the status report, elaborate on proposals for additional resources from the national funding agencies.
- April 2024: progress report update, prepare material for the RFCP web page
- June-December 2024: the progress report will serve as basis for Europe-coordinated approach to the next ESPP and next EU-funded R&D activities)

Survey of the teams/Follow up of the roadmap

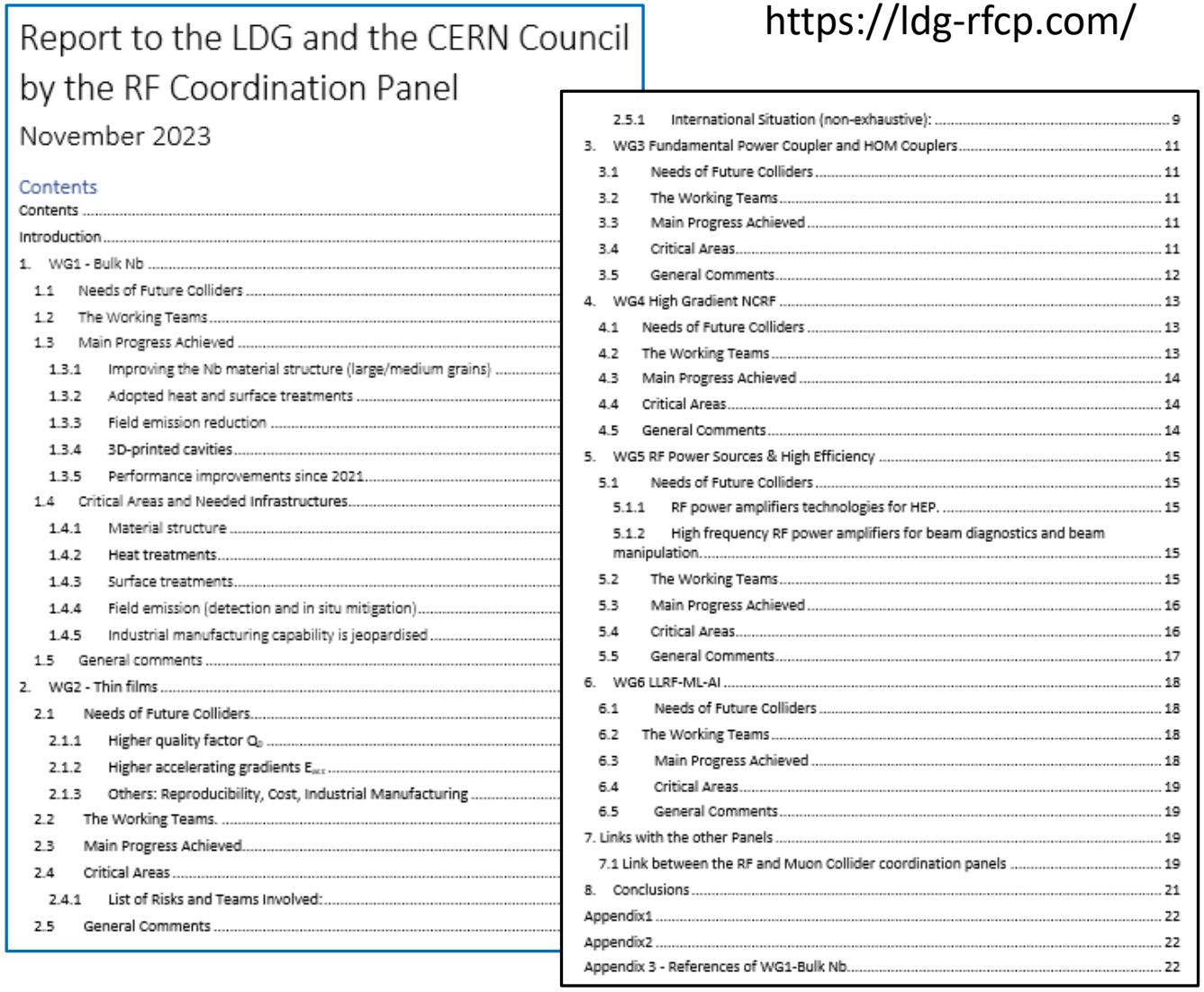
The RF Coordination Panel has surveyed all European teams in the 6 Working Group (WG) theme areas.

Progress Report with:

1. **RF needs** of proposed future colliders;
2. **Activities/resources/collab./infrastr. of the teams** across Europe; main labs worldwide;
3. Main progress achieved since the Roadmap (2022), critical areas, needed infrastructures.

Light update April 2024, next one: Nov 2024)

https://ldg-rfcp.com/



Report to the LDG and the CERN Council by the RF Coordination Panel

November 2023

Contents

1. Bulk Nb, 2. Thin films, 3. Couplers, 4. NC RF, 5. HPRF, 6. Controls

Science and Technology Facilities Council

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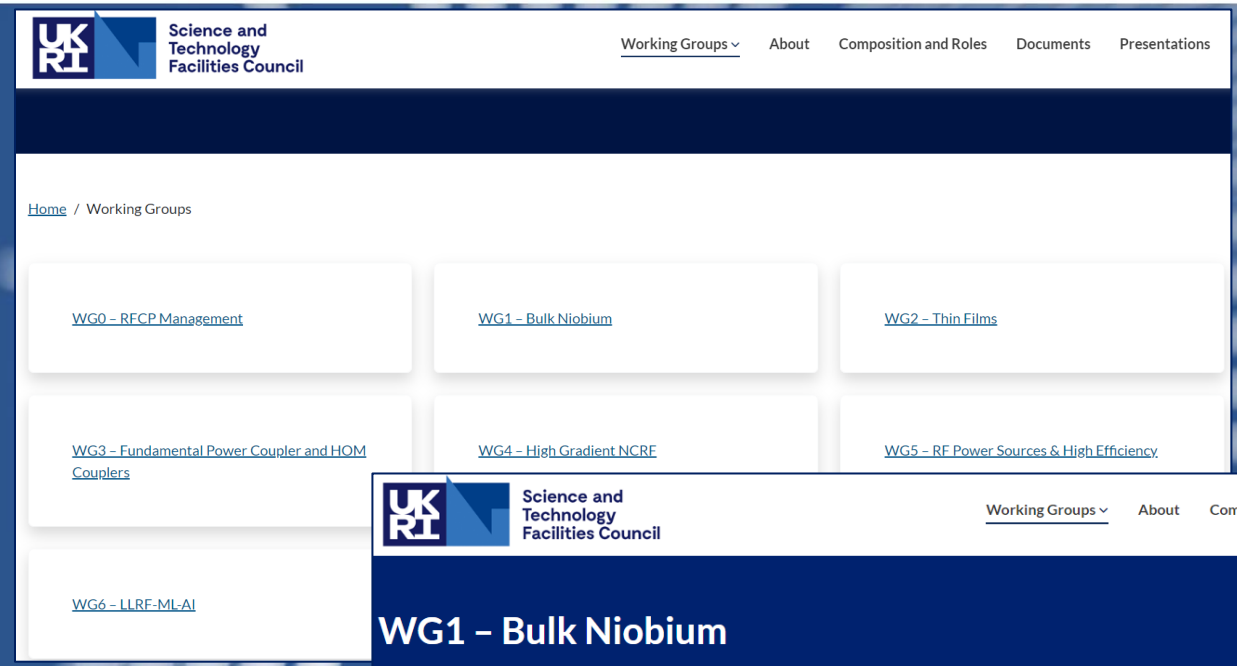
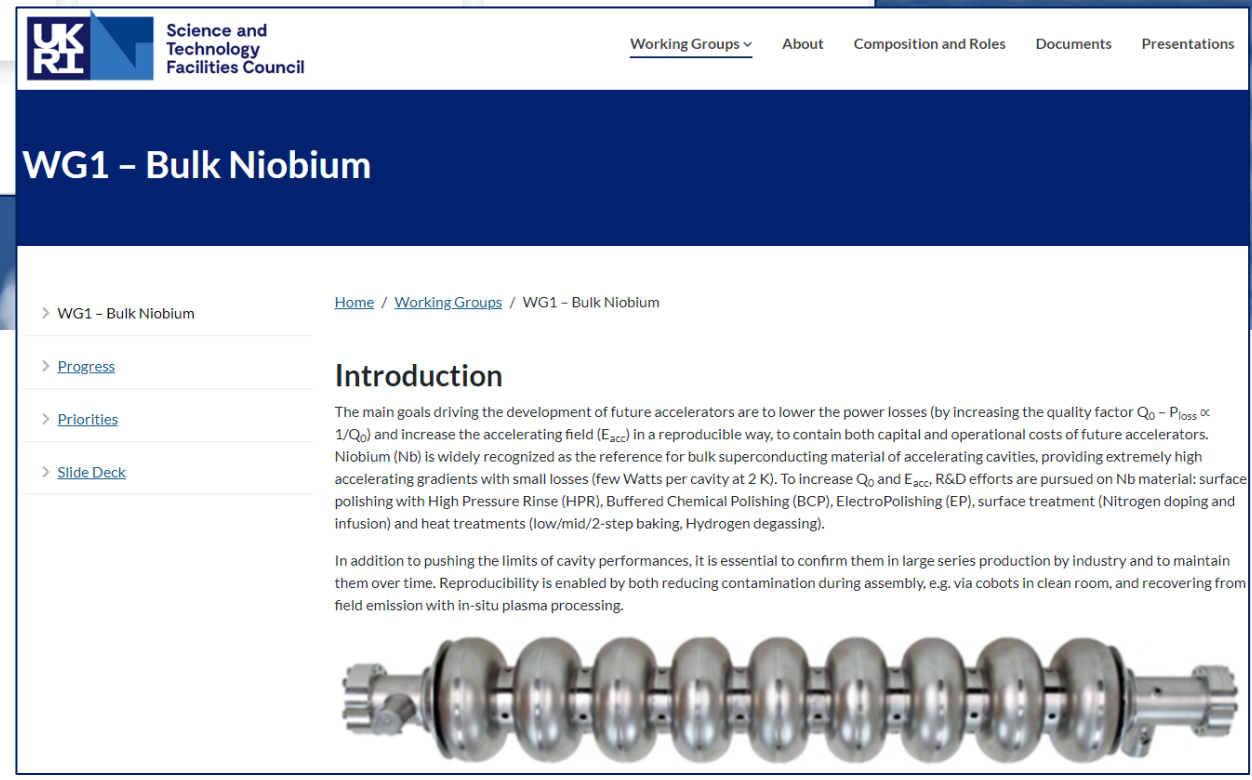
European Strategy Update

RF Coordination Panel





https://ldg-rfcp.com/

WG1: Niobium Cavities

GOALS

1. Further increase Q and E_{acc}
2. Improve reproducibility of high-E_{acc} fields
3. Reduce the cost
4. Risk of losing manufacturing capability?

WHO

CEA, CNRS-IJCLab, CERN, DESY, Uni-Hamburg, HZB, ESS, INFN-LASA, INFN-LNL, STFC

PR. REPORT

- Studies on MG and LG Nb; Eddy Current Scanning;
- FE mitigation R&D with novel infrastructures for CM assembly (candidate: ESS),
- Novel infrastructure for cobotization;
- Novel infrastructure for in-situ plasma processing (candidate: CEA)
- Additional ovens for cavity treatments (high temperature, candidate: CEA; single cell, candidate: INFN-LASA)
- Strategy to keep cavity-manufacturing capabilities in the labs

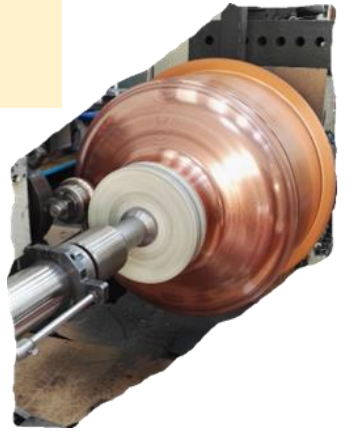
work in progress

ESPP Acc R&D fresh funding from **INFN**, on bulk-Nb preparation recipe; **CEA**: budget request submitted, for additional funding; **CERN**: interested in collaborating with FNAL on 800 MHz developments (FCCee)

WG2: Thin-film Cavities

GOALS

High Q_0 @ 4.2K; much higher E_{acc} (Nb/Cu, Cu base surface preparation; novel materials; multilayers; AM; …)

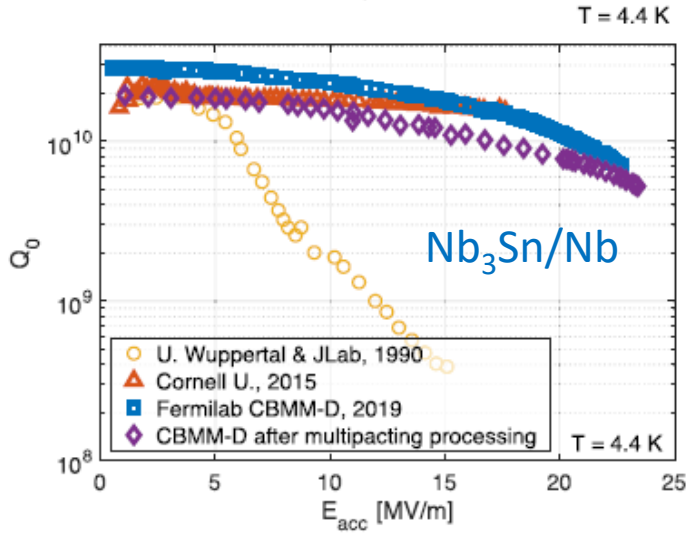


WHO

CEA, CERN, DESY, Hamburg U, HZB, HZDR, INFN, IEE, Riga Technical U, STFC/CI and USI, (I.FAST-WP) Jlab, MEPHI, PTI Minsk, …

PR. REPORT

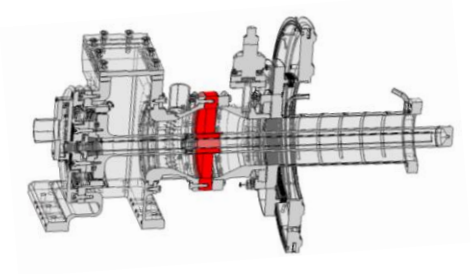
- Identify priority actions for I.FAST2 (from all I.FAST partners and more)
- Identify specific initiatives, which might be appealing for FCC (in pilot labs, to be identified, plus collaborators)
- Converge on joint proposals of infrastructures, on specific sites but that may be used by many? (in reference labs, e.g INFN-LASA, …)

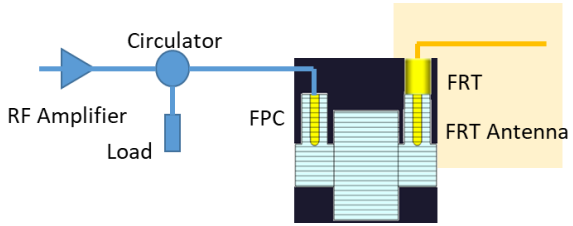


work in progress

On top of **IFAST2**: ESPP Acc R&D fresh funding from **INFN**, on Nb3Sn/Cu cavities; **CERN**: investing on R&D for Nb_3Sn/Cu, Nb/Cu, Nb_3Sn/Nb, multilayers, … for 400 MHz, 800 MHz (FCCee): room for R&D until 2040-2045 (t-tbar phase).

WG3: Fundamental Power Couplers (FPC) and HOM





GOALS

FPC couplers - transmitting hundreds of kW (W's in the cold mass) reliably through thin ceramic windows (diameter ~ 5÷ 50 cm) into SRF cavities; **HOMs couplers** (see iSAS proposal): R&D on 800, 1300 MHz multicell; ~ kW RF power out of the cold mass

WHO

IJCLab/CNRS-Paris Saclay University, DESY, HZB, CERN

PR. REPORT

Identify sections of interest for FCC, where contributions from other labs or industries can be made to converge (CERN + other labs)
EIC developments: maybe proposal from CERN + other labs, industry…
Any programme for investigating on ceramic windows, with several institutes involved, to obtain more funding (within or outside an I.FAST2 framework, identify actors)?

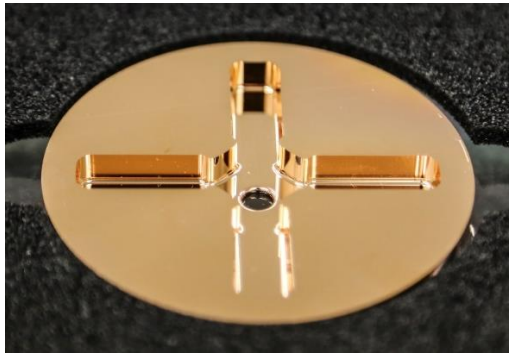
work in progress

On **FPC**: **CERN** collaboration searched at **PIP2**, **LCLS-II**, **iSAS** (but much lower power), INFN and CERN on RF **windows** (lobbying phase)
On **FRT** (compensates u-phonics and transient detuning): **CERN** contacts with **Lancaster, STFC** (their FEL applications), Jlab – iSAS European programme kicked off

WG4: HG Normal-Conducting RF

GOALS

CLIC - HG (70 to 100 MV/m), X-Band with very low breakdown rate (cost, efficiency). Good alignment, mitigation of HG-beam dynamics interplay (wakefields).
Muon Collider - Muon capture, HG with high external magnetic field.
Synergistic with applications outside HEP



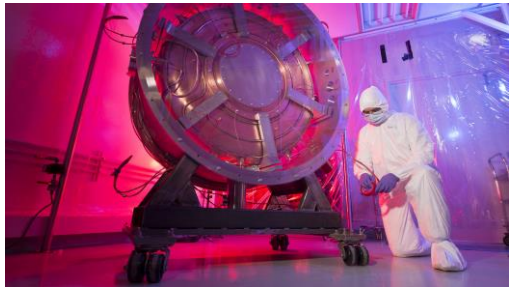
WHO

CERN, PSI, DESY, INFN, STFC, ULAN, IFIC, Uni-Uppsala, Uni1-Rome, Elettra, Uni-Tartu, Uni-Helsinki, Hebrew Uni-Jerusalem, TechUni-Eindhoven

PR. REPORT

Joint R&D programme on high-gradient and high-average-power capabilities, required by the FCC, that require further improvements (CERN + other labs)

The investment plans for the MC test stands: a collaborative effort from the many partners involved (CEA, INFN, CERN, Cockroft, Uppsala, …)



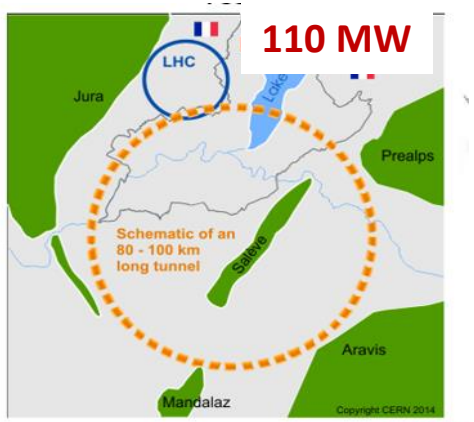
work in progress

CLIC focus: X-band structures - also in linacs outside HEP, and high efficiency RF sources, to strenghten industrial base with limited new investments; **MC** HG-in-High-B test stand: community glad to join, very stimulating topic; **FCCee** ~18-20 GeV electron injector: they could contribute (but pending as potential Swiss contribution); **C^3** – so far only US project

WG5: High Efficiency Amplifiers

FCCee

380 kly
600 SSPAs



FCC ee: CW, 0.4/0.8 GHz, P_{RF} total= 110 MW

GOALS

- **High efficiency RF power sources** for future large-scale particle accelerators (**LHC** and **FCC_{ee}** first)
- **In collaboration with industry to secure** to ensure decades of industry support.

WHO

On **klystrons** CERN, ULAN , with Thales, CPI, Canon; on **SSPA**: Uppsala (L-band (1kW) IFAST); on **mm-wave sources**: KIT, Strathclyde, INFN, ULAN and CERN

PR. REPORT

Klystrons: a "real" project could involve labs beyond CERN for realisation/tests, more funding, in coll. with industry

SSPA: will they evolve under next European projects, on other frequencies? (beyond Uppsala, w/industry)

work in progress

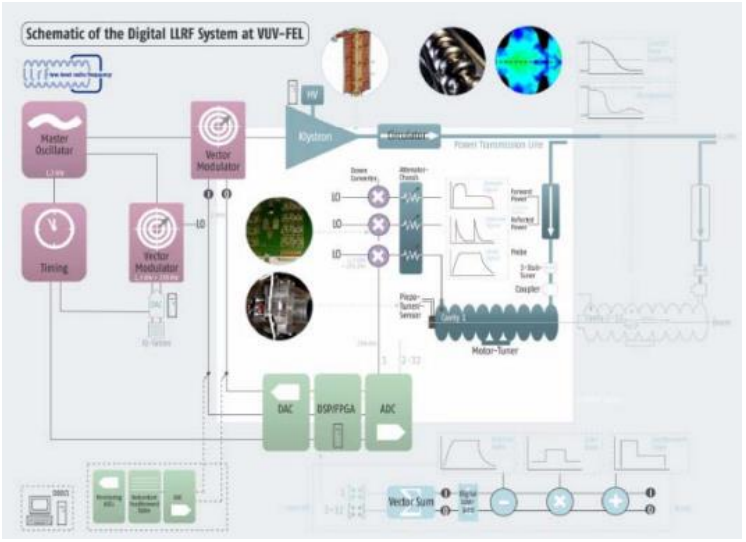
FCC: kly/MB-IOT, 400-800 MHz, prot-2028, series (295) by 2035+, CERN and ULAN. **FCC booster**: IOT/SSPA, 800 MHz, prot-2029/2024, CERN and Uppsala. **MC**: kly 352/704 MHz, prot-2030+, series (100) 2040+, CERN ULAN from 2026

(industrial progress: where numbers are potentially high)

WG6: RF Control – LLRF, ML and AI

GOALS

- **Standardised LLRF** system platform, HW, SW firmware
- Advanced **automation**/optimization algorithms for **RF** systems
- **ML** for SC cavity quench detection, RF faults classification
- **LLRF** high-level applications



WHO

Surveyed: Uni-Lodz, Poland National Centre for Nuclear Research, HZB, Freia Lab, Uni-Uppsala, DESY, IJCLab, STFC

PR. REPORT

Standardization of LLRF hardware, firmware and software (PSI, new countries/institutions? plus industry)

LLRF high-level applications (DESY, new countries/institutions? plus industry)

work in progress

Only one WG coordinator: PSI stepped down, DESY did not join

Link to the ERL Panel: RF topics

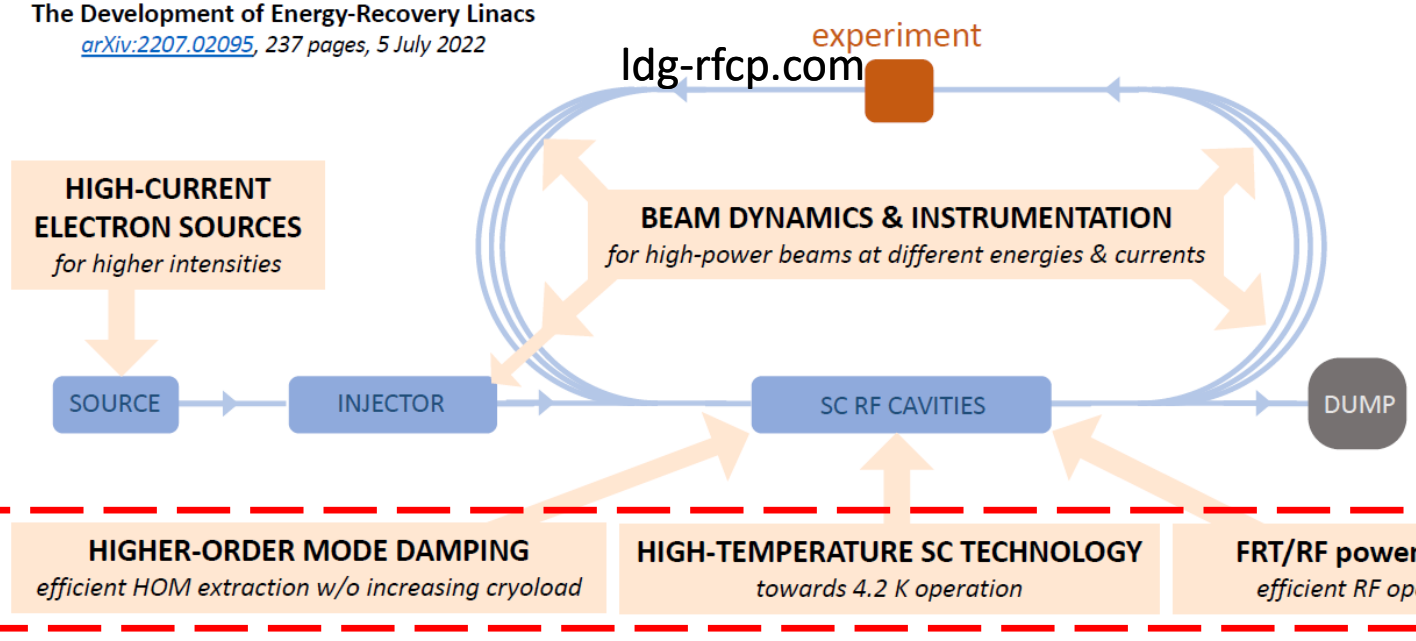
M. Baylac (CNRS)

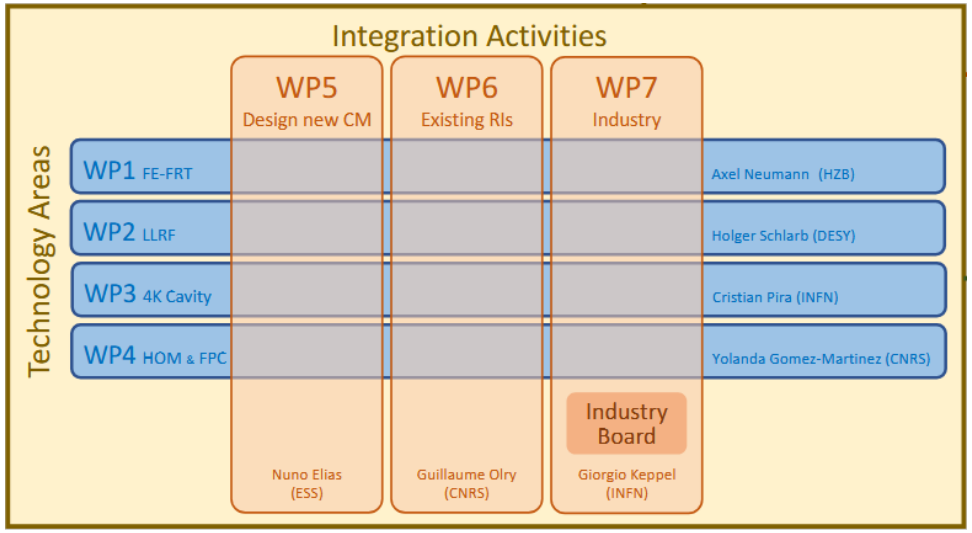
ERL/RF Panel collaboration: iSAS project (kickoff meeting April 15-16, 2024):

Identified the key aspects for an Energy Recovery accelerator

towards high-energy & high-intensity beams to be used at particle colliders

The Development of Energy-Recovery Linacs
arXiv:2207.02095, 237 pages, 5 July 2022

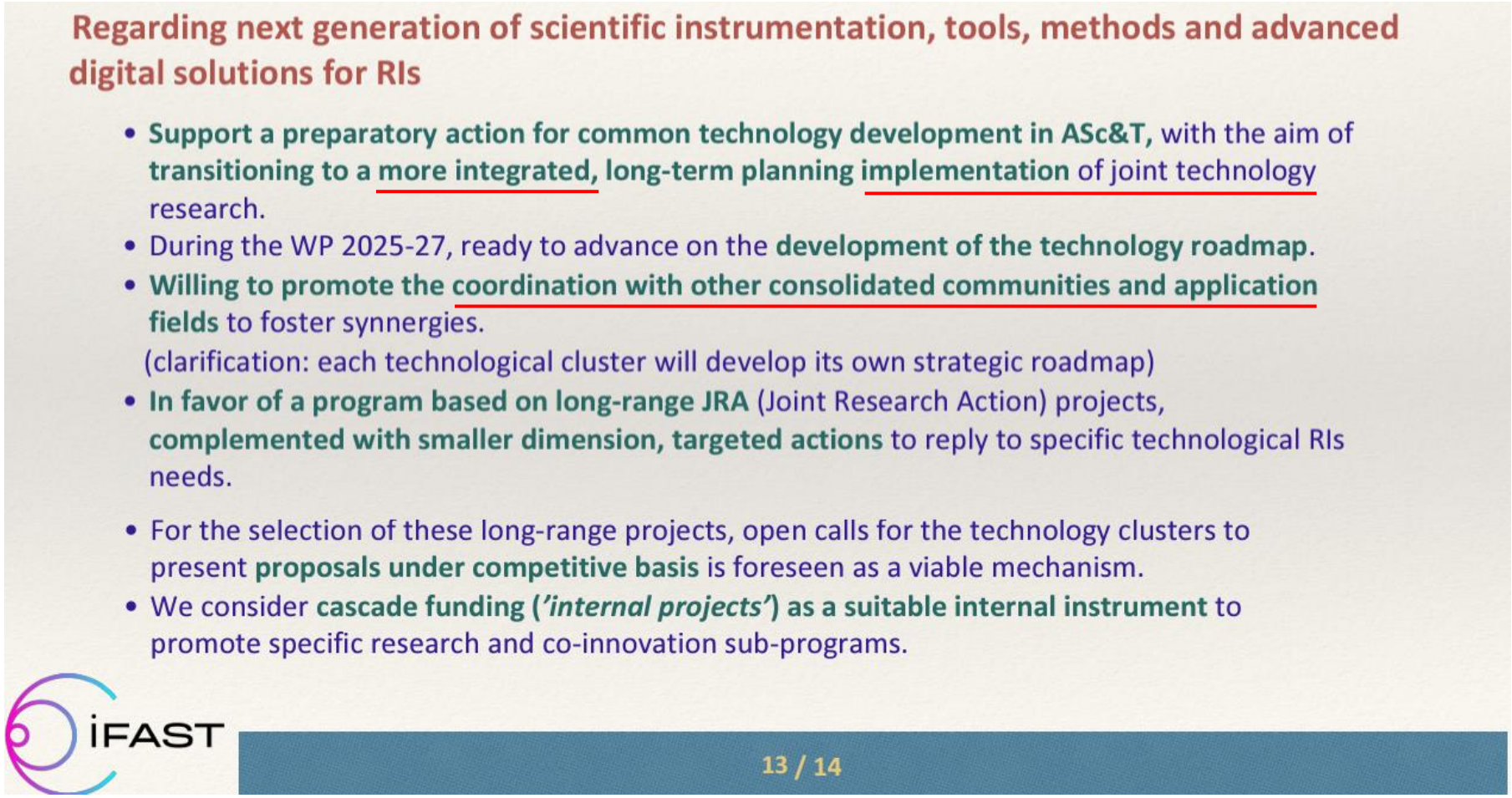




CNRS, CERN, ESS, DESY, VUB, CEA, HZB, INFN

(WG2-Thin films, WG3-Couplers, WG5-Power Sources, WG6-LLRF, ML and AI)

European Programmes opportunities



Integrated, long-term technology, common to several communities: consider whether to include in a common AS&T project or propose an independent one

J.M. Perez-TIARA, at IFAST Annual meeting, Paris, April 2024

Running and proposed EU projects with RF content

FCC-IS

Future Circular Collider Innovation Study

H2020-INFRADEV-2019-3. Nov 2020 - Nov 2024; 7.4 (3) M€

HITRI+

Heavy Ion Therapy Research Integration *plus*

H2020-INFRAIA-2020-1. April 2021 - Sept 2025; 5 (5) M€

MuCol

A Design Study for a Muon Collider complex at 10+ TeV center of mass

HORIZON-INFRA-2022-DEV-01. March 2023 - Feb 2027, 7 (2.2) M€

RITIFI

Research Infrastructure and Technology Infrastructure For Impact

HORIZON-INFRA-2022-DEV-01. April 2023 - Sept 2025, 1.5 (1.5) M€

iFAST

Innovation Fostering in Accelerator Science and Technology

H2020-INFRAINNOV-2020-2. May 2021 - April 2025; 10.6 (10.0) M€

EUROLABS

EUROpean Laboratories for Accelerator Based Science

HORIZON-INFRA-2021-SERV-01. Sept 2022 - Aug. 2026; 1.2 (0.9) M€

ESSnuSB+

Study of the use of the ESS facility to accurately measure the neutrino cross-sections for ESSnuSB leptonic CP violation measurements and to perform sterile neutrino searches and astroparticle physics

HORIZON-INFRA-2022-DEV-01. March 2023 - Feb 2027, 5 (2.2) M€

iSAS

Innovate for Sustainable Accelerating Systems

HORIZON-INFRA-2023-TECH-01-01. March 2024 - Feb 2028, 12.6 (5) M€

IFIGENIA: linear accelerators fon novel methods/tools for RI production for medical applications

ARTIFACT: ARTificial Intelligence For Accelerators, user Communities and associated Technologies

Including RF items

J.M. Perez-TIARA, at IFAST Annual meeting, Paris April 16-19, 2024

Lessons learned (RFCP): stay global!

- Not always easy to identify a collective «RF HEP-collider community» beyond CERN, as the other European RF teams work for diverse R&D objectives
- Very many RF items are in common to several applications (colliders, smaller-energy science machines, light sources, medical applications, neutron science, …)
- Important to continue nurturing an attitude towards clustering RF communities serving different programmes, not only HEP, as it will positively affect all
- European programmes may be used to foster a «network of RF disciplines for multiple goals»
  - Some RF programmes are included in I.FAST
  - The specific collider goals may be better addressed through such a multi-disciplinary programme (~IFAST2, 2025)
  - The next «programme» (strategic plan 2025-2027 within Horizon Europe) is a challenge and an opportunity

Lessons learned (RFCP-to-LDG, bottom-up):

As a structured follow-up of the accelerator R&D strategy is a novelty of the present ESPP exercise (with a commitment to pull additional funds), the RFCP wishes to contribute to a broader «lessons-learned» effort:

- RFCP has no strong enough voice to address the funding agencies on its specific priorities, and the funding agencies will hardly interact with the 5 Accelerator R&D panels independently (magnets, rf, ERL, MC, PLA)

  → A global LDG-coordinated effort is necessary (accelerator experts in the 5 Accelerator R&D panels can help in listing priorities)

- Structured feedback from LDG and Council to the Accelerator R&D panels

  → it will be ensured through a review exercise with independent experts

Session on RF

Progress report from the RF panel of the ESPP Accelerator R&D — *Giovanni Bisoffi*
Building 1005S 3rd floor, Brookhaven National Laboratory — 10:55 - 11:10

RF priorities for the FCC — *Frank Gerigk*
Building 1005S 3rd floor, Brookhaven National Laboratory — 11:15 - 11:30

RF frontiers for particle physics, the US view — *Sergey Belomestnykh*
Building 1005S 3rd floor, Brookhaven National Laboratory — 11:35 - 11:50

Progress on SRF accelerating cavities for future colliders — *Anne-Marie Valente-Feliciano*
Building 1005S 3rd floor, Brookhaven National Laboratory — 11:55 - 12:10

EU R&D lines for all collider options

Focus on the higher priority FCC

RF from Snowmass/P5 and the MC

R&D on cavities