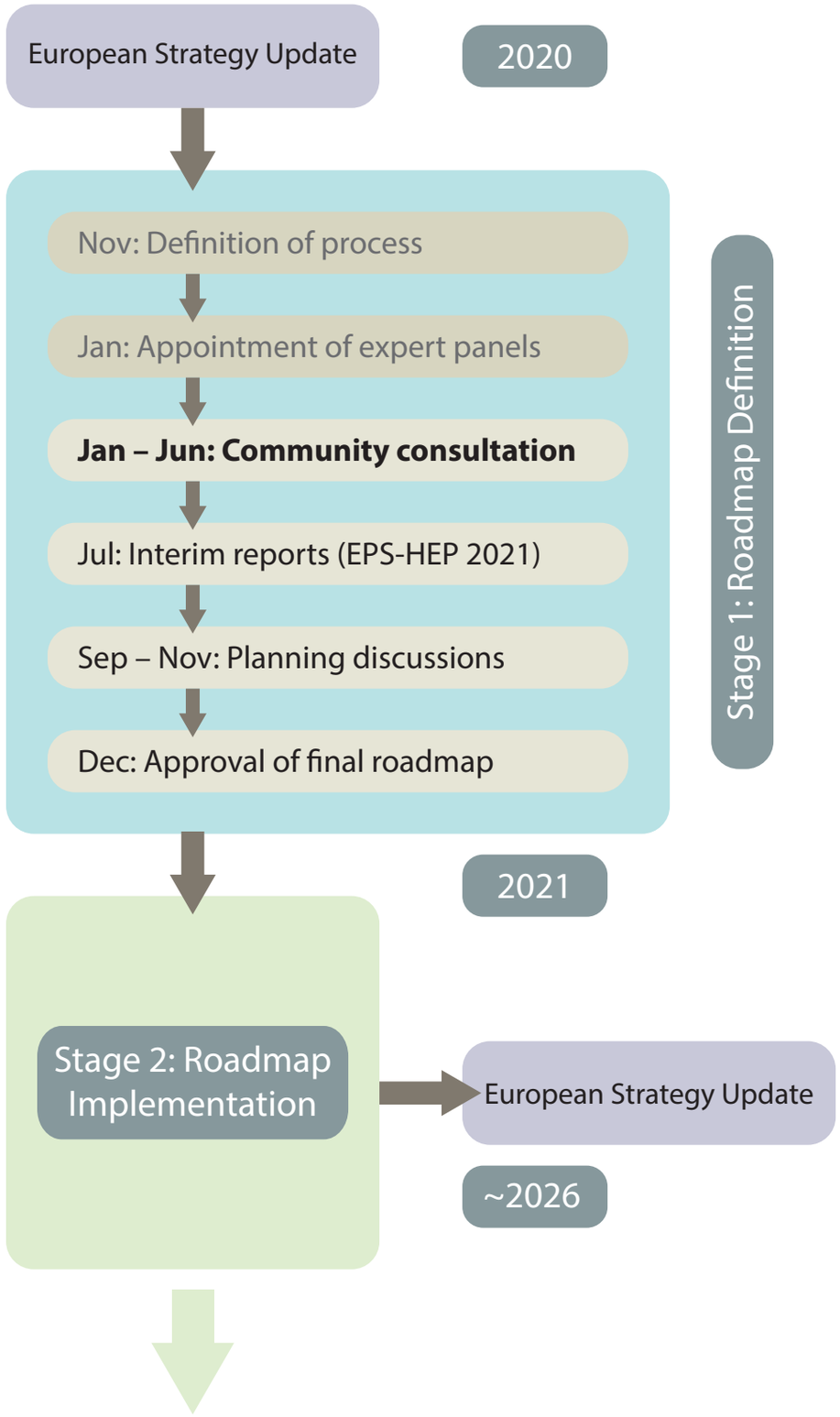
# Starting with the Future…

- Everything is driven by our *science* roadmap
  - Namely, the European Strategy for Particle Physics
    - https://cds.cern.ch/record/2721370
- Goals explicitly (though not exclusively) mentioned
  - Completion, commissioning, exploitation of HL-LHC
  - Delivery of LNBF/ DUNE
  - Electron-positron Higgs factory
  - Energy frontier proton-proton collider
- Also increasingly prominent in discussions: muon collider
- Our past achievements rest on substantial technology R&D
  - At least 15-20 years in the case of the LHC / HL-LHC
  - Substantial R&D and industrialisation of e+e- cavity production
- Future facilities depend yet more strongly on new technology
  - Challenges presented by FCChh and MC in particular

# Timeline

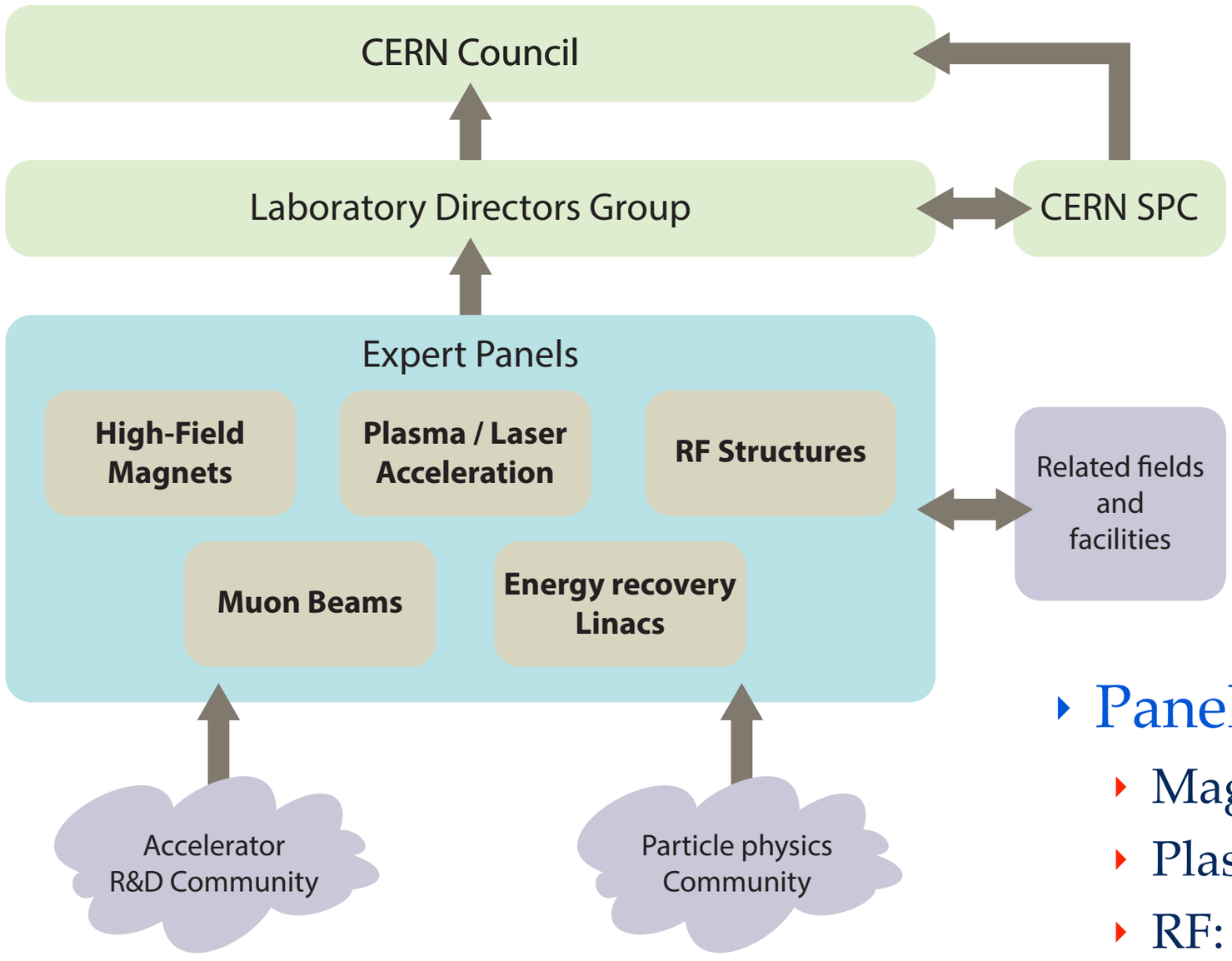



- Key dates
  - 9th July: Symposium for the PP community
    - Thanks to RECFA delegates for dissemination
  - July EPS-HEP: reports by panels, summary report
    - Key findings – roadmap planning is next stage
  - September SPC / Council: consideration discussion of interim report; distribution via RECFA representatives
  - September – October: 'closed process' to define draft roadmap, scoped plans
  - November: Review and feedback by SPC subcommittee
  - December Council: approval of roadmap
    - Corresponding time line for ECFA detector R&D roadmap
- First draft of the Interim Report now with LDG for comments

# Roadmapping Approach

- Stage 1 (overseen by LDG, mandate from CERN Council)
  - Formal process, continuing the momentum of the strategy groups
  - Mirrors the style of the ESPPU
    - Expert discussion panels
    - Wide consultation with the community (some inputs already in place from ESPPU)
    - Determination of a plan with options for investment
  - Culminates in approval of roadmap by CERN Council – and finishes
  - European process, but with strong international inputs
- Stage 2 (driven by the community, LDG in support)
  - Proposals for activities by accelerator R&D networks / community
  - Explicit discussion of possible funding levels and routes
  - Engagement with funding agencies around specific projects
  - Implementation of the R&D roadmap
  - Necessarily a programme with a fully international context
- The roadmap is the 'consensus document' that will open the subsequent discussion on funding and implementation

# SPC Update: Accelerator R&D Roadmap




- Panels
  - Magnets: P. Vedrine (IRFU)
  - Plasma: R. Assmann (DESY)
  - RF: S. Bousson (IJCLab)
  - Muons: D. Schulte (CERN)
  - ERL: M. Klein (Liverpool)
  - May co-opt additional people for input on ‘crosscutting issues’

# Observations so far

- Engagement
  - Success in engaging the (international) accelerator physics community
  - Over 50 meetings / workshops, several hundred people involved
  - Some panels already producing 'long reports' summarising all inputs
- Diversity
  - Clearly, the five areas are at a range of scope and maturity
  - The final roadmap must balance medium- and long-term R&D carefully
  - Keep in mind the focus on informing decisions at the next EPPSU
- Synthesis
  - In the end, we require one roadmap not five – also leaving some 'freedom'
  - The final prioritisation is a matter for Council and its advisors
    - These are long-term strategic questions of science, funding and organisation
  - But: PP community may wish to provide short-term feedback on the 'level of ambition' / 'level of urgency' across the topics
    - What are the real technical barriers in the limit of infinite resources?
- In summary: strong progress, and an excellent start by the panels

# Interim Report

## Contents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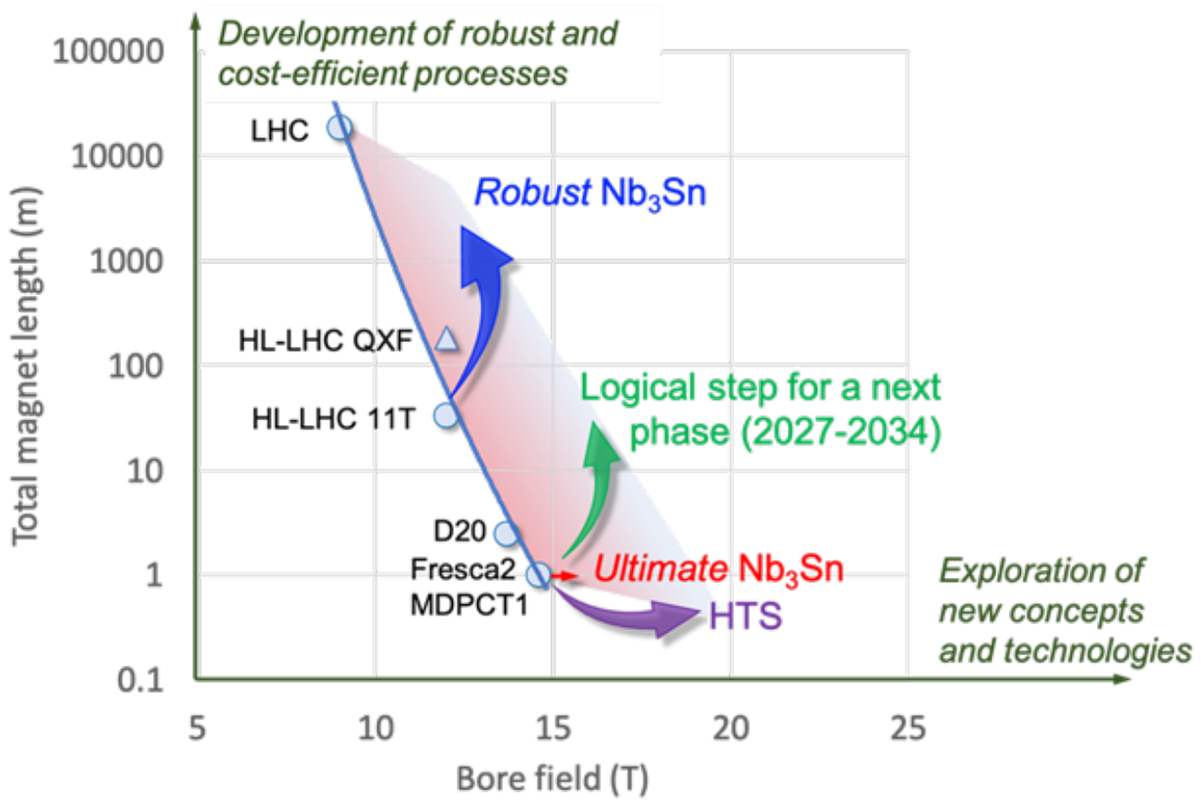
- Purpose of report
  - Provide a prior indicate of the scope and direction of travel of the process
  - Summarise the findings from the 'consultation' phase
  - Provide a first view of the structure of the final roadmap
  - Opportunity for feedback from SPC / Council / accelerator community
- Contributions of four of the five panels now in place
  - 'Key findings' and outline R&D objectives only
  - No attempt at synthesis across panels (this will be an important feature of the final report)

# HFM R&D Objectives

## Goals of a High Field Magnets R&D Program

- **Demonstrate $Nb_3Sn$ magnet technology for large scale deployment, pushing it to its practical limits, both in terms of maximum performance as well as production scale**
  - Demonstrate $Nb_3Sn$ full potential in terms of ultimate performance (target 16 T)
  - Develop $Nb_3Sn$ magnet technology for collider-scale production, through robust design, industrial manufacturing processes and cost reduction (benchmark 12 T)
- **Demonstrate suitability of HTS for accelerator magnet applications, providing a proof-of-principle of HTS magnet technology beyond the reach of $Nb_3Sn$ (target in excess of 20 T)**




- **Other key parameters:**
  - Cost of Magnets & R&D
  - Timeline of a realistic development

# Plasma-Laser R&D Objectives

## HIGH GRADIENT PLASMA AND LASER ACCELERATORS

*Accelerator R&D Roadmap Pillars*

### FEASIBILITY, PRE-CDR STUDY

***Scope***: 1st international, coordinated study for self-consistent analysis of novel technologies and their particle physics reach, intermediate HEP steps, collider feasibility, performance, quantitative cost-size-benefit analysis

***Concept***: Comparative paper study (all concepts included)

***Milestones***: Report high energy $e^-$ and $e^+$ linac module case studies, report physics case(s)

***Deliverable***: Feasibility and pre-CDR report in 2026 for European, national decision makers

### TECHNICAL DEMONSTRATION

***Scope***: Demonstration of critical feasibility parameters for $e^+e^-$ collider and 1st HEP applications

***Concept***: Prioritised list of R&D that can be performed at existing, planned R&D infrastructures in national, European, international landscape

***Milestones***: HQ $e^-$ beam by 2026, HQ $e^+$ beam by 2032, 15 kHz high eff. beam and power sources by 2037 (sustainability)

***Deliverable***: Technical readiness level (TRL) report in 2026 for European, national decision makers

### INTEGRATION & OUTREACH

***Synergy and Integration***: Benefits for and synergy with other science fields (e.g. structural biology, materials, lasers, health) and projects (e.g. EuPRAXIA, …)

***Access***: Establishing framework for well-defined access to distributed accelerator R&D landscape

***Innovation***: Compact accelerator and laser technology spin-offs and synergies with industry

***Training***: Involvement and education of next generation engineers and scientists

# HGRF R&D Objectives

| | Particle sources | Magnet and Vacuum systems | High Field SC magnets | Normal Conducting RF structures | Superconducting RF cavities | RF power sources | Cryogenics | Instrumentation |
|---|---|---|---|---|---|---|---|---|
| ILC | • | | | | • | • | • | • |
| FCC | • | • | • | | • | | • | • |
| PIP-II, MYRRHA | | | | | • | • | • | • |
| JLEIC | • | | • | • | | • | | • |
| eRHIC, LHeC | | | | | • | | • | • |
| DIAMOND2, SLS2 | | • | | | | • | | • |
| LCLS2-HE, SHINE | | • | | | • | | • | • |
| DONES | • | • | | • | • | • | • | • |
| DEMOs | • | | • | | | • | • | |
| PERLE | | | | | • | • | | • |
| BELA, compact neutron sources | • | | | • | | | | • |

**Key Technology Areas → *Needed Developments***

Particle sources → *High intensity heavy ions, positron sources, polarized beams*

Magnets and vacuum systems → *Permanent magnets, small chambers evacuation*

High field SC magnets → *High-Tc conductors, cost reduction*

Normal Conducting RF structure → *High precision fabrication and tuning, RF breakdown*

Superconducting RF cavities → *Surface treatments, robotics, cost reduction*

RF power sources →*CW sources, Solid State Amplifiers, high efficiency*

Cryogenics → *High efficiency, cryo-coolers, cryo-safety*

Beam instrumentation → *Optical and RF diagnostics, fast electronics and feedback*

# Muons R&D Objectives

## Goals

The initial goal is to establish, within the next five years, whether the investment into a full programme is scientifically justified.

- Develop a sufficiently detailed design of key systems to demonstrate that beam parameters can be achieved and allow cost and power consumption scale to be determined

- Develop an R&D programme that can demonstrate performance specifications where they are beyond the state of the art
  - In particular a test facility design

- A limited experimental programme to address technologies unique to the muon collider will help to support the performance predictions and timely implementation of the test facility, including fast-ramping magnets and muon cooling RF

This will allow the next ESPPU to make fully informed decisions and support similar strategy processes in other regions. Based on these decisions a significant ramp-up of resources could be made to accomplish construction of the collider by 2045.

# Muons R&D Objectives

## Tentative Work Breakdown Structure

**Accelerator Design**
- Proton complex
- Muon production
- Muon cooling
- High-energy acceleration complex
- Collider ring
- Machine detector interface

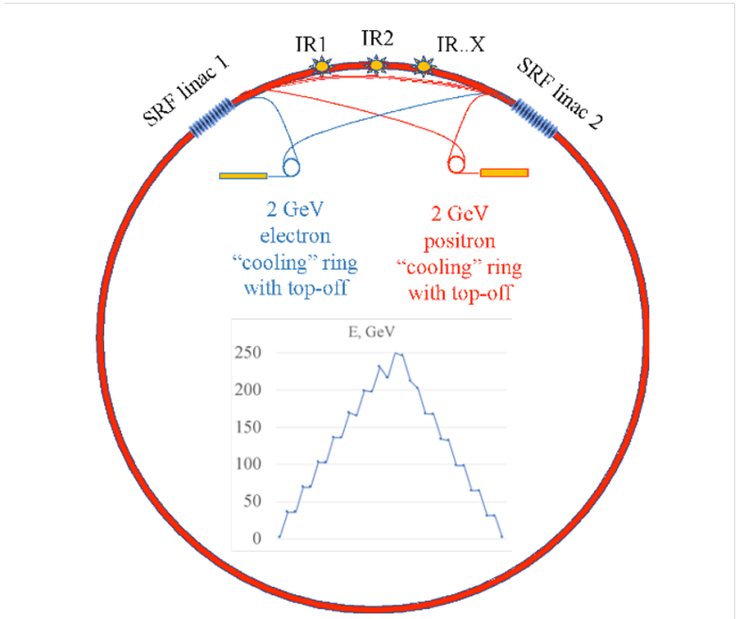
**Implementation Studies**
- Parameters and layout
- Integrated beam studies
- Radiation protection
- Civil engineering siting studies
- Cost scale determination
- Power consumption scale determination

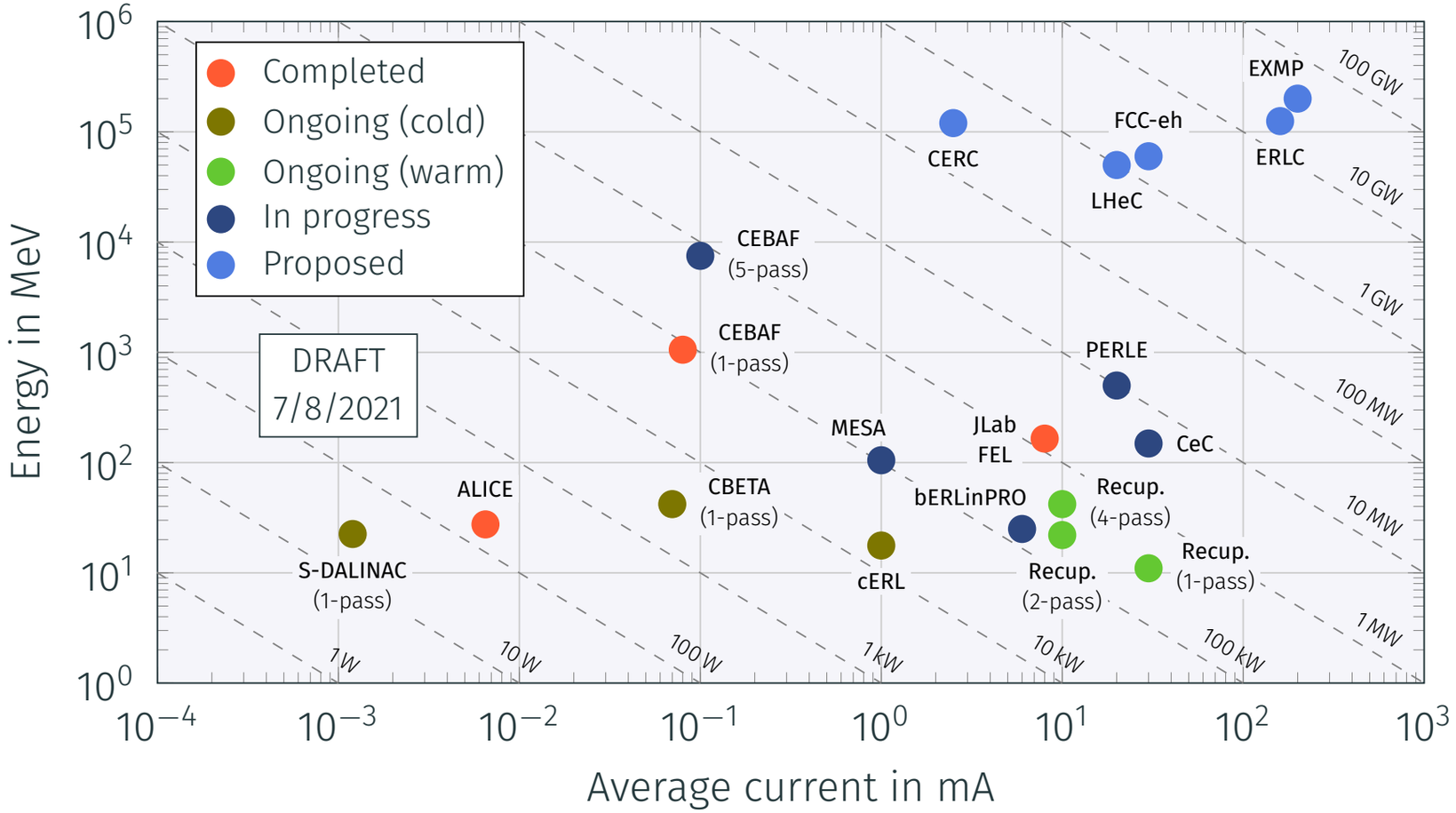
**Test Programme Development**
- Integrated engineering design of cooling cell
- Neutrino radiation mitigation system
- Test facility using other workpackages
- Specific studies for test facility implementation: civil engineering, proton complex, …

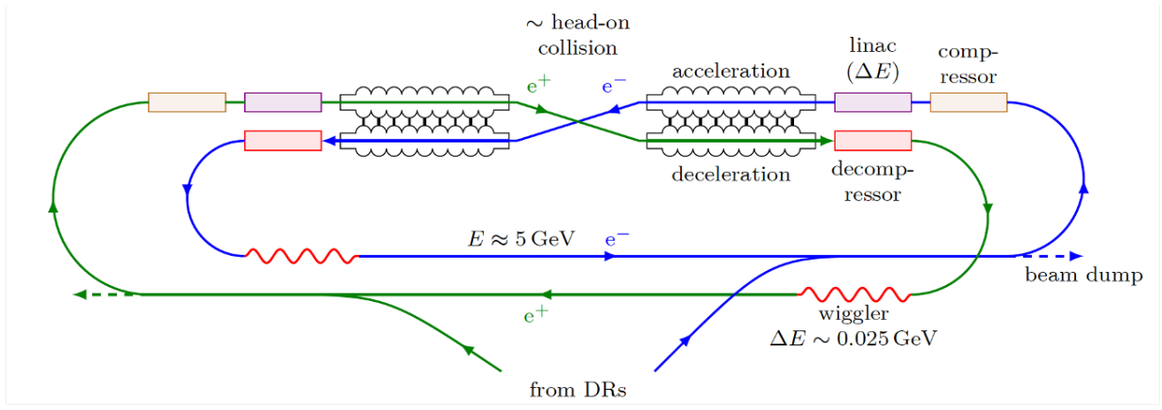
**Technology Design Studies**
- Cooling RF design
- Superconducting RF
- Efficient RF power systems
- Fast ramping magnets and powering
- High-field solenoids
- High-field dipoles / combined function magnets
- Target system
- Beam-matter interaction
- Other technologies

**Experimental Programme**
- Fast-ramping magnet component tests
- Cooling RF tests
- Low-frequency superconducting cavity tests
- Target material tests
- Neutrino mitigation system tests

# ERL Progress




- Sub-panel on high-energy e+e- colliders now in place
  - Andrew Hutton (SLAC) chair
  - Will evaluate potential, cost, feasibility, challenges of the new concepts
  - Report in September (not for interim report)

# Relevance to the Science

- Roadmap should answer the questions posed in ESPPU process
  - Or at least, provide a plan to to answer them in the next five years
- Key questions on R&D
  - What needs to be done towards future facilities? What are the priorities?
  - How long might it take? What is the fastest technically-limited schedule?
  - How much will it cost?
  - What different options and trade-offs exist?
  - What are the linkages between activities?
  - What science can be done on the way?
- What about all the *other* things that must be done?
  - Other important (and nearer term) R&D topics – incl. detectors and computing
    - May wish to mention these in summary form in the final report, for the purposes of balance
  - Planning and preparation of specific new facilities
  - Construction and commissioning of HL-LHC
- The final balance of activities is a question for Council
  - And of course the funding agencies, in their response to the roadmaps

# Conclusion

- The end product
  - Report for Council (200pp; panel reports plus synthesis)
  - Summary report in 'glossy' format for funding agencies etc (10pp)
  - Long reports from panels, possibly published
- From January 2021, the 'implementation phase' should begin
  - Follow-up process is still to be determined for both roadmaps
- Relevance to FCC programme
  - Careful balance needed between short term planning and longer term R&D
  - New technologies (ERL?) may still have some medium-term relevance
  - The longer term prospects of a 100km machine rest on R&D to be completed in the next decade
- All feedback is welcome
  - Distribution of interim findings via RECFA will shortly follow September SPC
  - Any and all feedback from the Swiss community is welcome