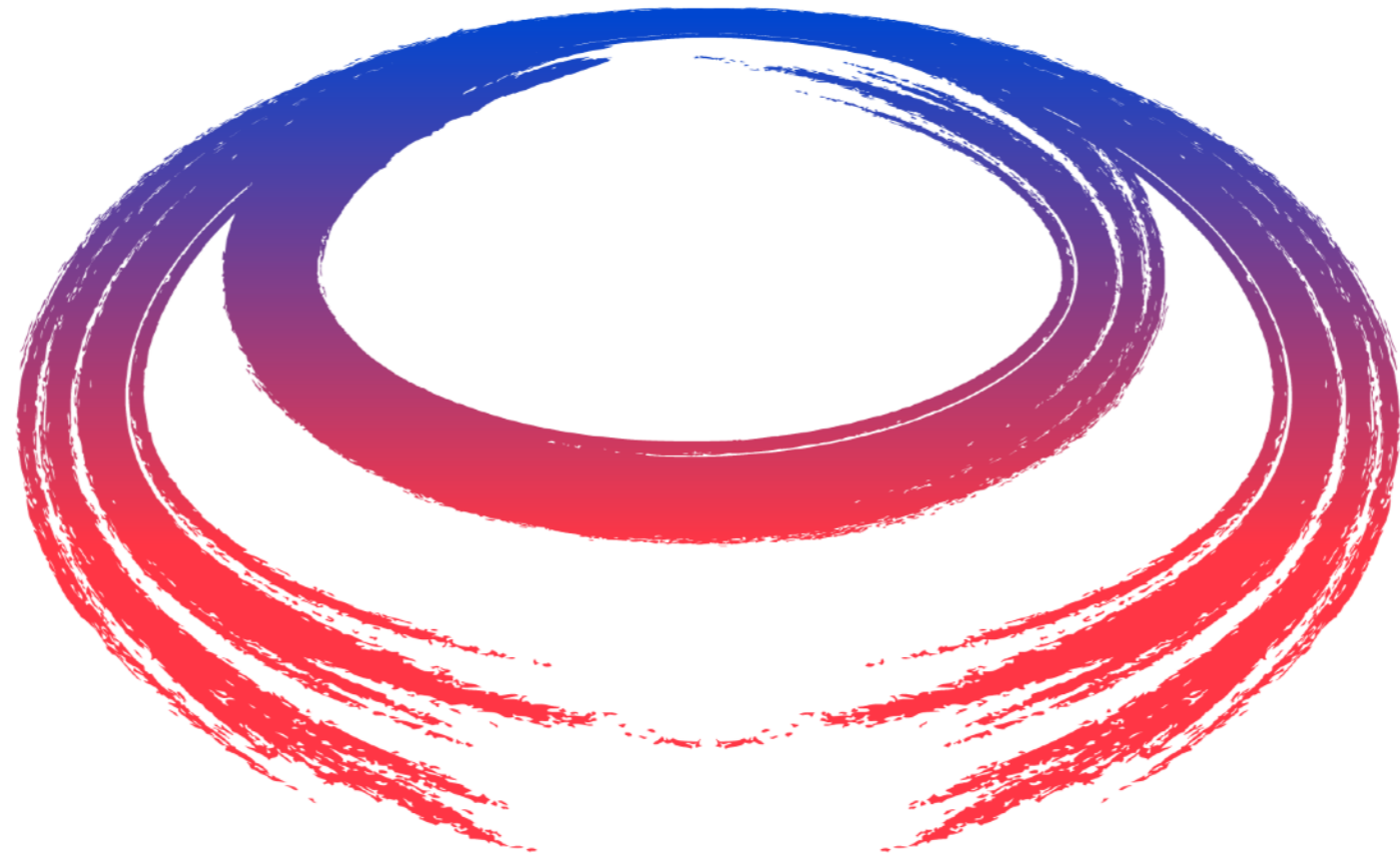


# Accelerator R&D Roadmap



 International  
UON Collider  
Collaboration

# Starting with the Future...

- ▶ Everything is driven by the *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 towards ILC
- ▶ Future facilities depend yet more strongly on new technology
  - ▶ Challenges presented by FCChh and MC in particular

# R&D Roadmap

- ▶ **Strategy contains strong and explicit statements on R&D:**
  - ▶ *The particle physics community should ramp up its R&D effort focused on advanced accelerator technologies [...]*
  - ▶ *The European particle physics community must intensify accelerator R&D and sustain it with adequate resources.*
  - ▶ *A roadmap should prioritise the technology [...]*
  - ▶ *Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.*
- ▶ **Detector R&D, computing R&D, and training also prominent**
  - ▶ *ESPPU is an 'R&D-focussed document', even more so than previous iterations*
- ▶ **This of course was steered by the inputs**
  - ▶ *Accelerator science and technology should be acknowledged as a vital need with the highest priority within the update. (TIARA input)*
  - ▶ *A vigorous new experimental programme in the long term, requires significant investment in detector and accelerator R&D in the medium term. The case for this investment should be clearly spelt out in the European Strategy. (STFC input)*

# Roadmap Requirements

- ▶ Provide an agreed structure for a coordinated and intensified programme of particle accelerator R&D, including into new technologies, to be coordinated across national laboratories
- ▶ Be compatible and commensurate with corresponding roadmaps in detectors, computing and other developments, with a compatible timeline and deliverables
- ▶ Be based on the goals of the European Strategy, but defined in its implementation through consultation with the community and, where appropriate, through the work of expert panels
- ▶ Take into account, and coordinate with, international activities and work being carried out in other related scientific fields, including development of new large-scale facilities
- ▶ Specify a series of concrete deliverables, including demonstrators, over the next decade
- ▶ Be designed to inform, through its outcomes, subsequent updates to the European Strategy.

# Reminder of the LDG Mandate

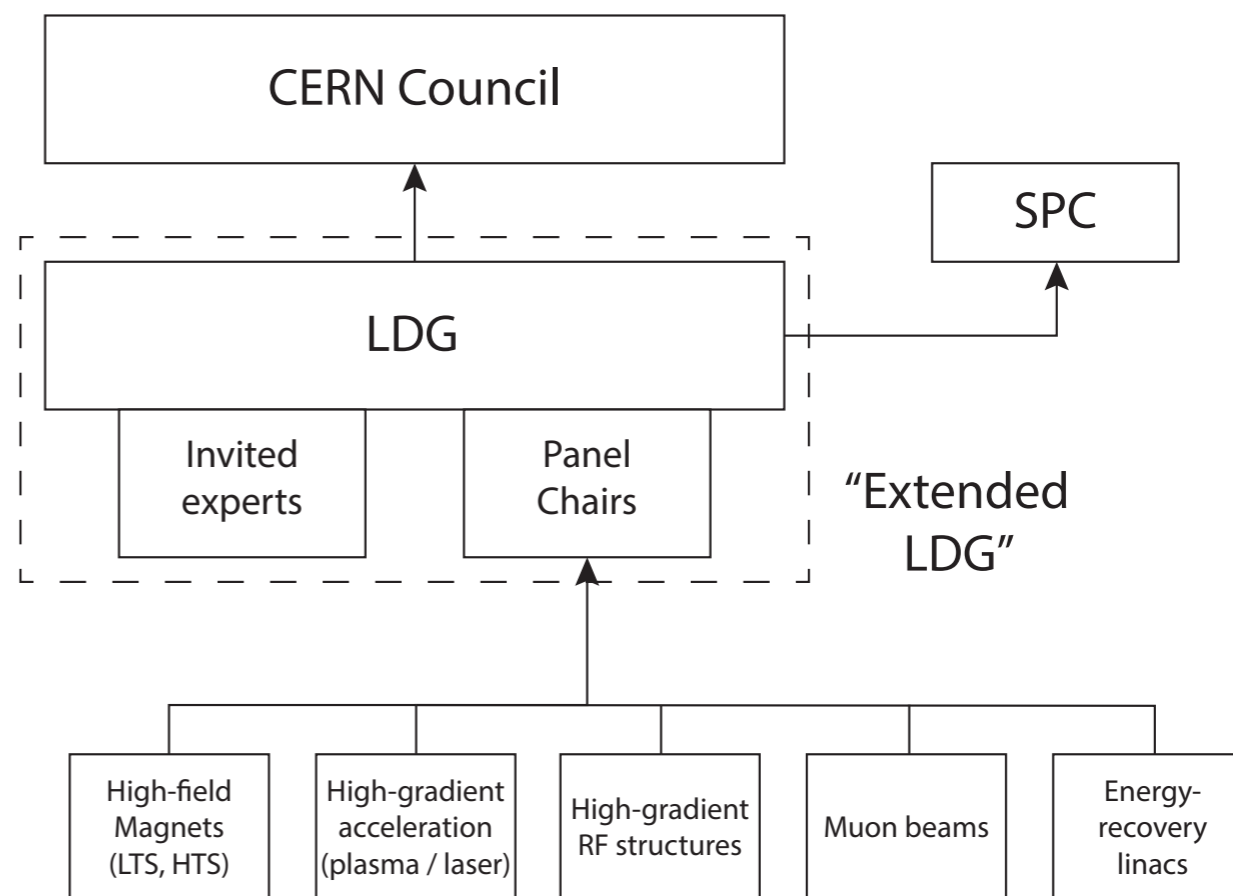
- ▶ Facilitate informal dialogue between the management of member laboratories, including the CERN Directorate.
- ▶ Provide direct input to the European Strategy for Particle Physics.
- ▶ Liaise with the European Commission and national funding agencies, research institutes, and universities.
- ▶ Maximise regional and national benefits of investment in fundamental research and CERN.
- ▶ Maintain awareness of the activities of laboratories outside CERN member states, and of other coordinating groups in particle physics and related fields, and foster dialogue with them.
- ▶ Define and maintain a prioritised accelerator R&D roadmap towards future large-scale facilities for particle physics (defined further in Addendum B).
- ▶ Coordinate accelerator R&D activities within the roadmap, with the aim of strengthening cooperation and ensuring effective use of complementary capabilities.
- ▶ **Recent strengthening of interaction between ECFA and LDG is welcome and timely**

# Reaching a Roadmap

- ▶ Stage 1 (driven by LDG, oversight by CERN Council):
  - ▶ Formal process, continuing the momentum of the strategy groups
  - ▶ Mirrors the style of the ESPPU
    - ▶ Appointment of expert discussion panels
    - ▶ Wide consultation with the community (some inputs already in place from ESPPU)
    - ▶ Determination of goals, needs, priorities
    - ▶ Presentation of initial findings for feedback
    - ▶ Determination of a plan with options for investment
    - ▶ Production of a summary report
  - ▶ Culminates in approval of roadmap by CERN Council – and finishes
  - ▶ Parallel and commensurate process to ECFA R&D roadmap; but some differences
- ▶ Stage 2 (driven by the community, oversight via LDG):
  - ▶ Proposals for activities by the accelerator R&D networks / community
  - ▶ Explicit agreement of possible funding levels and routes
  - ▶ Engagement with funding agencies around specific projects
  - ▶ Continuation of work on training, engagement with other communities, etc
  - ▶ Implementation of the roadmap

# Roadmap Process

- ▶ Five expert panels appointed:
  - ▶ High-field magnets, including use of high-temperature superconductors
  - ▶ High-gradient acceleration (plasma / laser)
  - ▶ High-gradient RF structures and systems
  - ▶ Bright muon beams and muon colliders
  - ▶ Energy-recovery linacs
- ▶ Panel chairs
  - ▶ Magnets: P. Vedrine (IRFU)
  - ▶ Plasma: R. Assmann (DESY)
  - ▶ RF: S. Bousson (IJCLab)
  - ▶ Muons: D. Schulte (CERN)
  - ▶ ERL: M. Klein (Liverpool)
  - ▶ Diverse and international set of panel members now in place and starting work



# Practicalities

- ▶ LDG role (LDG is *not* a panel of experts):
  - ▶ Act as steering committee for the roadmap definition process
  - ▶ Oversee EPs, receiving reports and providing feedback and direction
  - ▶ Produce and present interim and final reports for CERN Council
  - ▶ Take into account the priorities and plans of FAs and laboratories
  - ▶ Initiate and steer the nomination and selection of members of the EPs
  - ▶ Continuously review and adjust the scope of the process.
- ▶ Panel role:
  - ▶ Establish key R&D needs, as dictated by the scientific priorities
  - ▶ Consult widely with the European and international communities, taking into account the capabilities and interests of stakeholders
  - ▶ Take explicitly into account the plans and needs in related scientific fields
  - ▶ Propose ambitious but realistic objectives, work plans, and deliverables
  - ▶ Give options and scenarios for European investment and activity level
- ▶ NOT in scope:
  - ▶ Planning for specific future facilities
  - ▶ Planning of funding routes, beyond the overall cost of the proposed R&D programme
  - ▶ Statements of institutional or national commitment.



# Magnets Report Structure

## Executive Summary **P. Vedrine, L. Garcia-Tabares**

Reference to Remit **0,5 p**

Summary of work **0,5 p**

Main conclusions and top-level roadmap **1p**

## Abstract **P. Vedrine, L. Garcia-Tabares 0,5 p**

## Motivation for a High Field Magnet R&D Program

Historical perspective **L. Bottura 1 p**

## State of the Art **L. Bottura**

Highest Field Attained **2 p**

Discussion **1 p**

## Objectives of a High Field Magnets R&D Program **P. Vedrine, L. Garcia-Tabares 2 p**

## Challenges of High Field Magnets

Superconductor **C. Senatore/A.Ballarino 1,5 p**

Forces and stresses (electromechanical induced stresses)  
**E. Rochepault/B.Auchmann 1,5 p**

Stored energy. **Ph. Fazilleau, L. Bottura 1,5 p**

Cost **L. Rossi, M. Noe 1,5 p**

## High Field Magnets R&D Program Drivers **L. Bottura 2 p**

## Proposed Program Structure and Deliverables

Nb3Sn conductor **C. Senatore/A.Ballarino 1,5 p**

HTS conductor **C. Senatore/A.Ballarino 1,5 p**

Nb3Sn accelerator magnet development **E. Rochepault/B.Auchmann 1,5 p**

Nb3Sn magnet technology **E. Rochepault/B.Auchmann 1,5 p**

HTS magnet technology **L. Rossi, M. Noe, Ph. Fazilleau 1,5 p**

Materials and insulation technology, **S. Prestemon, B. Baudouy, B. Shepherd 1,5 p**

Magnet protection **Ph. Fazilleau, L. Bottura 1,5 p**

Infrastructure for development, manufacture, test and measurement **A. Ballarino, B. Shepherd 1,5 p**

## Roadmap, Work Plan and Timeline **P. Vedrine, L. Garcia-Tabares**

Nb3Sn Roadmap **2 p**

HTS Roadmap **2 p**

## Impact of a High Field Magnet R&D Program

Applications to Other Fields and Society **L. Garcia-Tabares, M. Noe 2 p**

Industrial Ecosystem **L. Rossi, M. Noe 1 p**

Training and Education **C. Senatore, B. Baudouy, 1 p**

## Scenario of Engagement and Investments **P. Vedrine, L. Garcia-Tabares 2 p**

### Sustainability **1 p**

Sustainability a mandatory consideration in all areas

# ERL Report Structure

- 1 Introduction - 5p
  - 1.1 The Magic Principle of Energy Recovery, its Promises and P
  - 1.2 Science Goals and Requirements . . . . .
- 2 ERL - Facilities and Current Status - 20p
  - 2.1 Completed Facilities . . . . .
    - 2.1.1 ALICE at Daresbury . . . . .
    - 2.1.2 JLab FEL . . . . .
    - 2.1.3 CEBAF Single Pass . . . . .
  - 2.2 Ongoing Activities . . . . .
    - 2.2.1 sDALINAC at Darmstadt . . . . .
    - 2.2.2 bERLinPRO . . . . .
    - 2.2.3 cERL at KEK . . . . .
    - 2.2.4 Recuperator at Novosibirsk . . . . .
    - 2.2.5 CBETA at Cornell . . . . .
- 3 ERL - New Facilities in the Twenties - 20p
  - 3.1 Europe . . . . .
    - 3.1.1 MESA at Mainz . . . . .
    - 3.1.2 PERLE at Orsay . . . . .
  - 3.2 Non-European Facilities . . . . .
    - 3.2.1 CEBAF 5-Pass at Jlab . . . . .
    - 3.2.2 Electron Cooler at BNL . . . . .
- 4 Key Challenges - a Concerted Effort - 30p
  - 4.1 High Current Sources . . . . .
  - 4.2 Low Emittance Injectors . . . . .
  - 4.3 High Quality SRF: Cavity and Cryomodules . . . . .
  - 4.4 Multi-turn Operation and the Art of Arcs . . . . .
  - 4.5 ERL Operation Challenges . . . . .
  - 4.6 Interaction Region . . . . .
  - 4.7 Power to ERLs . . . . .
  - 4.8 Cryogenics . . . . .

## The Development of Energy Recovery Linacs Table of Contents of Long Write-Up (1.5.21)

- 5 Energy and Intensity Frontier Physics - 30p
  - 5.1 High Energy Colliders . . . . .
    - 5.1.1 LHeC and FCC-eh . . . . .
    - 5.1.2 FCC-ee as an ERL . . . . .
    - 5.1.3 ILC as an ERL . . . . .
    - 5.1.4 Photon-Photon Collider . . . . .
  - 5.2 Low Energy Particle Physics . . . . .
    - 5.2.1 Elastic Electron-Hadron Scattering . . . . .
    - 5.2.2 Weak Interaction at Low Energy . . . . .
    - 5.2.3 Dark Photons . . . . .
  - 5.3 Low Energy Nuclear Physics . . . . .
  - 5.4 Photo-Nuclear Physics . . . . .
- 6 Applications - 15p
  - 6.1 ERL Driven High Power FEL . . . . .
  - 6.2 EUV-FEL Semiconductor Lithography . . . . .
  - 6.3 ICS Gamma Source . . . . .
- 7 ERL and Sustainability - 10p
  - 7.1 Introduction . . . . .
  - 7.2 Beam Energy Recovery . . . . .
  - 7.3 Technology and Infrastructure . . . . .
- 8 Conclusions - 5p
- 9 Appendix - ERL Facilities - 5p

About 35 authors, see page 1

**Two ERL Papers**  
Status (1.5.21)

**Long write-up (<200p)**

**7 Chapters + Appendix**  
for publication in 21  
followed by genuine  
**ERL Roadmap paper**

**Next Steps May/June**  
Two panel+author  
meetings early May:

**One on Chapter 4**  
- key developments  
**One on Chapter 5.1**  
- energy frontier

**Draft 1 by May 17, 21**

**Town Meeting 2.6. (tbc)**

**Updates.. → Roadmap**

# Some MC-Specific Interpretations

- ▶ “Be designed to inform, through its outcomes, subsequent updates to the European Strategy”
  - ▶ This seems particularly crucial here
  - ▶ Consider the balance between feasibility proofs, optimisation
- ▶ “Planning for specific future facilities”
  - ▶ Clearly a difference between the work of the R&D panel, and of the overall IMCC
  - ▶ Document as many options as possible at this early stage
  - ▶ May be impossible to avoid considerations of existing infrastructure at labs
- ▶ “Ambitious but realistic objectives, work plans, and deliverables”
  - ▶ Important to focus on concrete deliverables, and the need for investment
  - ▶ Roadmap is the consensus ‘proof of need’ on which future funding requests are made
- ▶ “Options and scenarios for European investment and activity level”
  - ▶ Need to present a range of possibilities
  - ▶ Worst case: make no investment – what are the consequences?
  - ▶ Best case: go as fast as possible – how fast? Where does it get us in 5, 10 years?
  - ▶ Perhaps two balanced scenarios in between

# Status, Timeline and Outcome

## ▶ Process is now fully under way

- ▶ Several panel meetings already, full open workshops being held
- ▶ Key questions and issues now identified
- ▶ Structure and scope of interim and final reports being devised

## ▶ Timeline

- ▶ March Council: presentation of roadmap scope and process
- ▶ June Council: final approval of LDG mandate and roadmap scope
- ▶ June: Open workshop for PP community to seek input / feedback
- ▶ July EPS-HEP: presentation in ECFA session of interim findings
- ▶ September Council: presentation of interim report (findings, but no planning)
- ▶ September – October: ‘closed’ definition of draft roadmap and scoped plans
- ▶ November: Review and feedback by SPC subcommittee - last chance to change
- ▶ December Council: approval of the final roadmap

## ▶ Outcome

- ▶ Public summary report covering finding plus a scoped roadmap
  - ▶ Plus, published reports of ‘background material’ collated by the expert panels (~few hundred pages)
- ▶ SPC / Council recommendations on priorities and next steps in the process