LDG Update

- LDG role and composition
- Accelerator R&D progress
- Sustainability assessment
- Community meetings

- LDG: forum / representative body / working group of major labs
- Coming years will bring challenge and opportunities
  - European Strategy update process first steps in 2024 – LDG has a ‘structural’ role
  - Major challenges to operations and delivery for all major labs
  - Positioning / delivery for next generation of large science infrastructures
    - Including, but not limited to, the next particle colliders
    - Some of these infrastructures are becoming ‘global projects’
  - Practical support for the detector and accelerator R&D programmes
LDG Remit

- Remit approved by CERN Council
  - Facilitate informal **dialogue** among the Directors of the LNLs and CERN
  - Provide direct **input** to the **European Strategy** for Particle Physics
  - **Liaise** with the European Commission and national funding agencies, research institutes and universities, ensuring that LNLs speak with a single voice
  - Maximise the regional and national **benefits** of investment in fundamental research and in CERN
  - Keep abreast of the activities … being undertaken in laboratories outside CERN’s Member States, and of other **coordinating groups** in particle physics and related fields, and foster dialogue with them
  - Draw up and maintain a prioritised accelerator R&D **roadmap** towards future large-scale facilities for particle physics
  - **Coordinate** the accelerator R&D activities on the roadmap, with the aim of strengthening cooperation and ensuring effective use of complementary capabilities
LDG Composition

- Laboratory representatives
  - S. Bentvelsen (NIKHEF)
  - F. Bossi (LNF)
  - J. Clarke (DL)
  - N. Colino (CIEMAT)
  - F. Gianotti (CERN)
  - B. Heinemann (DESY)
  - D. Newbold (RAL – Chair)
  - E. Previtali (LNGS)
  - F. Sabatie (IRFU)
  - M. Seidel (PSI)
  - A. Stocchi (IJCLab)

- Standing observers
  - K. Jakobs (ECFA Chair)
    - -> P. Sphicas (ECFA Chair-Elect)
  - M. Lamont (CERN Directorate)
  - J. Mnich (CERN Directorate)
  - H. Montgomery (SPC Chair)

- Secretary
  - E. Tsemelis (CERN)
  - Scientific secretary… TBA

- Extended LDG members
  - G. Bisoffi + P. Macintosh (RF)
  - W. Leemans + R. Patahill (Plasma)
  - S. Stapnes + D. Schulte (Muons)
  - J. D’Hondt + M. Klein (ERL)
  - P. Vedrine (HFM)

Close cooperation between LDG and ECFA continues
Vehicle for cooperative, coordinated, focussed R&D towards the future machines

- Structure now mature, regular LDG / SPC review cycle in operation
- Next review and report to Council in November / December 2023
Comprehensive work plan
- HLT & LTS – different maturity today
- Conductors, cables, and prototypes
- Controls, modelling, and facilities
- Dipoles and other applications

Development of Novel Magnet Protection Method
E-CLIQ: External Coil Coupled Loss Induced Quench

E-CLIQ in development for an SMC magnet demonstrator
- Able to generate local dB/dt of > 100 T/s
- Compact envelope, width of a Nb₃Sn cable

Design tested to withstand loads of over 200 MPa
### RF Implementation Panel

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

---

**Diagram:**

- **WG1**: SC-Bulk Nb
- **WG2**: SC-Thin Film
- **WG4**: NC-High gradient

**WG3**: Cavity

- Coupler

**WG5**: Amplifier

**WG6**: LLRF Controller

---

Plenary ECFA, 16th November 2023  
Dave.Newbold@stfc.ac.uk
WG1: Niobium cavity R&D goals & direction

Most R&D benefits several future PP colliders (FCC, MC, ILC, ERLC)

HINTS FOR THE FUNDING AGENCIES

1. More funding & HR for treatments:
   - FE studies, cost optimisation, industrial manufacture.
2. Contributions from other disciplines:
   - Robotics - cavity prep. in cleanrooms.
   - Chemistry - Plasma proc. for FE recovery.
3. Maintain/improve infrastructures:
   - ISO4 cleanrooms for preparation & assembly.
   - Vertical low power test stand
WG2: Thin-film cavities

To facilitate expedited multi-cell coated cavity verification, 1.3 GHz and lower

**Intensify R&D:**
- more SC materials to explore, various techniques, targets
- surface/material characterization and SC property measurements.
- Cu-cavity production and their polishing.
- laser and flash-lamp annealing on Cu samples/cavities.

**More funds/people/higher priority for:**
- facilities (people, liq-He, electricity, ...); for many cells, various frequencies
- furnace + new ALD coating set-up.
- access to clean rooms.
- Have more test installations available (so far some at CERN, HZB and DESY, INFN; in preparation at STFC).
- Have more sample characterization stations available.

### Staff, PhD students, Funds/yr (k€)

<table>
<thead>
<tr>
<th></th>
<th>Staff</th>
<th>PhD students</th>
<th>Funds/yr (k€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>30</td>
<td>9</td>
<td>870</td>
</tr>
<tr>
<td>Ideal</td>
<td>60</td>
<td>18</td>
<td>2100</td>
</tr>
</tbody>
</table>

**HINTS FOR THE FUNDING AGENCIES**

- Tightly-knit network, very well connected worldwide.
- Small teams, limited budgets, technical support and access to RF tests.

Labs: CEA-Saclay, CERN, HZB, HZDR, INFN, STFC, USI, Hamburg U. (DESY), (I.FAST-WP) JLAB, KeK and FNAL

Plasma Electrolytic Polishing

Flash Lamp Annealing

SIS multilayer coating (Nb/AlN/Nb3Sn) on Ta
The principle of Energy Recovery Linacs

ACCELERATE
energy in cavities is given to the particle beam

DECELERATE
energy of particle beam goes back to cavities

energy recovered to accelerate the next particle beam

other beam for collisions

>99.9999% particles

experiment

100% particles

ACCELERATOR CAVITIES

phase-shift 180°

multiple turns towards higher energies

① beam dump at low energy

③ beam brightness is maintained from the injector

② beam dump at low energy
**Energy Recovery Linacs (ERL): reaching higher luminosities with less power requirements**

ERL to enable high-power beams that would otherwise require one or more nuclear power plants.

**Future ERL-based Colliders**

- $H$, $HH$, $ep/eA$, muons, ...

**R&D Roadmap**

bERLinPro & PERLE
- essential accelerator R&D labs with ambitions overlapping with those of the particle physics community
- towards high energy & high power

**Energy Recovery demonstrated**

- great achievements on all aspects and large research infrastructures based on Energy Recovery systems have been operated successfully
ERL: iSAS

ISAS is now an approved Horizon Europe project
Grant Agreement has been signed this week – project starts on March 1, 2024
Spread over 4 years: ~1000 person-months of researchers and ~32.6M EUR
(of which 5M EUR was requested to Horizon Europe)

Innovate for Sustainable Accelerating Systems (iSAS)
https://indico.ijclab.in2p3.fr/event/9521/
develop a new design of an SRF cryomodule
integrating the most impactful energy saving technologies (incl. RF & ERL aspects)

ELECTRON SOURCES
for higher intensities

BEAM DYNAMICS & INSTRUMENTATION
for high-power beams at different energies & currents

SOURCE INJECTOR DUMP

HIGHER-ORDER MODE DAMPING
efficient HOM extraction w/o increasing cryoload

HIGH-TEMPERATURE SC TECHNOLOGY
towards 4.2 K operation

FRT/RF power source
efficient RF operation

ENABLE EFFICIENT ENERGY RECOVERY & FURTHER REDUCE POWER REQUIREMENTS

+ Industrial companies: ACS Accelerators and Cryogenic Systems (France), RI Research Instruments GmbH (Germany), Cylelectron GmbH (Germany), TFE Thin Film equipment (Italy), Zanon Research (Italy), EuclidTechLab (USA)
Potential impact of ERL technology

2020’ies
- iSAS
- PERLE
- bERLinPro

demonstrate multi-turn high-power ERL

2030’ies
- EIC
- ERL application electron cooling

ERL application electron cooling

2030-2040’ies
- high-power ERL
  - e’ beam in collision (ep/eA @ LHC program)

2040-2050’ies
- high-power ERL for e’+e’ Higgs Factories (Z/W/H/top/HH program)
- ERL FCC-eh
- reuse ERL
- 2 ERL beams

2070’ies

enables the ultimate upgrade of the LHC program

increases the performance of the next major colliders
Muons

Muon Collider Progress

Collaboration goals
- Develop muon collider concept
  - Focus on 10 TeV (integrated luminosity 10 ab⁻¹)
  - Consider potential initial stage (maybe 3 TeV, integrated luminosity 1 ab⁻¹)
- By 2026
  - Assessment report
  - R&D plan toward collider
- Currently writing Interim Report, as promised, ready March 2024
  - Provided tentative parameter document

Collaboration is growing
- 68 signatories, several from US, other partners
- EU co-funded Design Study is now fully active
- Strong US interest: community ask in P5: ramping up to 50 FTE for accelerator, 30 FTE for the detector

Technical progress
- Make adequate progress on the subjects we are working on
- Progress resource-limited, new collaborators important (in particular larger US contribution)
Muons

Muon Collider Progress

Lattice design

RF and collective effects

Long. Distribution assumed at injection in RCS1

HTS solenoids

Cooling module model design

Fast-ramping magnet power converter

Beam-induced radiation in detector

And more
Reviewing timeline (still evolving)
• Uncertainties from physics case (e.g. HL-LHC), budget profile etc.
• On the critical path
  • Muon cooling technologies and integration
  • Magnet technology
  • Detector technologies
• Initial stage to start physics before 2050 appears possible
  • To be confirmed before next ESPPU

Potential site next to CERN identified
• Mitigates neutrino flux
  • Points toward mediterranean and uninhabited area in Jura
• Detailed studies required (280 m deep)
• Will look for other sites, looks promising
• FNAL and other sites will also be studied
  • FNAL takes test facility into account in their ACE plans

Magnets
Has been reviewed by expert panel
Experts anticipate technology to be mature in O(15 years):
• HTS solenoids in muon production target, 6D cooling and final cooling
  • HTS tape can be applied more easily in solenoids
  • Strong synergy with society, e.g. fusion reactors
• Nb₃Sn 11 T magnets for collider ring (or HTS if available)
For second stage can use HTS or hybrid collider ring magnets
Outcome of the HALHF Collaboration Meeting held at DESY
Hybrid meeting with the HALHF community in Hamburg and online (56 participants, 33 people on site)

Goals of the meeting were:
- Update on current status of the HALHF concept
- Plan for staging demo
- Assess impact on detector design
- Assess challenges in
  - Conventional accelerator systems
  - Plasma systems
- Make the HALHF design realistic and realizable

HALHF:
- An end-to-end preliminary collider design presented by Brian Foster, Richard D’Arcy and Carl Lindstrøm
- Asymmetric energy e+e- collider design with a 500 GeV electron arm and a 31 GeV positron arm.
- Plasma-accelerator driven electron arm and a positron-arm based on conventional linac

B. Foster et al., New J. Phys. 25, 093037 (2023)

HALHF:
- An end-to-end preliminary collider design presented by Brian Foster, Richard D’Arcy and Carl Lindstrøm
- Asymmetric energy e+e- collider design with a 500 GeV electron arm and a 31 GeV positron arm.
- Plasma-accelerator driven electron arm and a positron-arm based on conventional linac

B. Foster et al., New J. Phys. 25, 093037 (2023)
Outcome of the discussions
How to continue and push HALHF – prospective funding sources promising (ERC, STFC, Oxford)

- **Start-to-end simulations**: high fidelity, full physics modeling
  - Include non-linear QED effects in extreme regime
- **Need a plan for staging demonstrator**:
  - “Staged approach”:
    - What does a multi-stage demonstrator look like?
    - Are there current facilities that can be used without major (>1M€) investment needed?
    - What investment is needed for a full-fledged demonstrator?
- **Develop base line parameters for drive linac** and collaborate with drive linac experts
- **Work out parameters for ILC-like positron source using spent e⁻ beam**
- **Detector concept development** needs to continue
- **Produce a “pre-CDR”** in the next few months – a HALHF scheme in which all conventional parts are specified and believably implementable, all PWFA parts clearly defined and coherent machine described.

**Intermediate milestones:**
- Collaboration meeting ~ 6 months from now. Venue: Oslo (tbc)
- “Erice” expert meeting to draft “pre-CDR” 03.-08.10.2024 (tbc) limited to ~30 experts
- Collaboration meeting end of 2024 / early 2025 to “sign off” pre-CDR and launch ”funded” R&D phase.
Strategies of PWFA facilities align with pre-CDR work
Plan covers major plasma accelerator challenges – need extra resources for coordination

WP 3.1 Electron-beam driven PWFA experiments
Scaling to HALHF-relevant energies and parameters

2018
Plasma dechirper
• D’Arcy et al., PRL 122, 034801 (2019)

2019
Energy depletion and energy doubling
Wakefield sampling
• Schröder et al., Nat. Commun. 11 5984 (2020)

2020
Energy spread preservation by beam loading control
• Lindstrøm et al., PRL 126, 014801 (2021)
• Lindstrøm et al., submitted (2022)

2022
Emittance preservation

2024
kHz-to-GHz plasma response
• D’Arcy et al., Nature 603, 58 (2022)

2026
10 kW avg. power operation

2030
FLASH: increase FEL energies, access oxygen K-edge at 2.33 nm wavelength

Update Plasma Accelerators | HALHF Collaboration Meeting | 16 November 2023 | Leemans & Pattathil
Options:

1) Expand CO2-free energies
   → factor ~12 in 7 years required;

2) Increase energy efficiency
   → factor ~2 in 7 years
   e.g. Electrification of engines (factor 3-5 vs. combustion engine)
   e.g. LEDs for lighting (factor 10 vs. light bulb)

3) Save energy
   → factor ~2 in 7 years
   e.g. Less travel: online conferences, holidays nearby
   e.g. Fewer consumer items, more repair options
   e.g. Energy priority for essential things

For options 2)+3) an increase in renewables of a factor of 3 needed to cover increase from naive extrapolation is needed.
Sustainability

- LDG Working Group on “Sustainability assessment of accelerators”, to define and identify:
  - Key indicators to be reported
    - Peak / instantaneous lifetime- and performance specific (per luminosity) energy consumption
    - Lifetime and specific Global Warming Potential (GWP) including construction
    - Include margins of uncertainty and possibly an assessment of the potential for improvement
  - Methodology and assumptions allowing a transparent and objective determination and comparison of these metrics across the proposals.
    - The maturity of a proposal should be determined, for example early concept phase, CDR, TDR or TRL levels
  - Other high level environmental impacts that may be relevant for all or specific collider proposals.
  - Application to accelerators of European best practices for defining GWP

- Convenor to be appointed at the upcoming LDG meeting
  - Will work closely with – and draw upon – internal sustainability projects of individual labs
Other (more technical) objectives:

- Treatment of future carbon intensity of electricity and materials: what scenarios should be assumed?
- Assessing the potential for dynamic operation of the various facilities, i.e. the ability to adapt to a fluctuating energy supply
- Treatment of regional vs global parameters: How to treat differences e.g. in carbon intensity between different host countries?
- Carbon intensity / lifecycle inventory (LCI) studies of materials specific to accelerator projects: high-purity niobium, permanent magnet alloys etc
- Use of open-source LCI databases and Lifecycle Assessment (LCA) tools to ease/automate the assessment for future research infrastructures
- Extending the recommendations for colliders to other scientific endeavours related to HEP
- How HEP labs can share/build up expertise jointly

Connects directly to R&D work on sustainable technologies
Community Engagement

- Two ‘new’ events held in Frascati this summer
  - First open meeting of the LDG, with involvement of international labs
    - Nineteen major laboratories involved on three continents – can improve!
    - [https://agenda.infn.it/event/35700/](https://agenda.infn.it/event/35700/)
  - Community report on accelerator roadmap
    - Intended to bring HEP community and accelerator R&D experts together
    - [https://agenda.infn.it/event/35579/](https://agenda.infn.it/event/35579/)
    - Limited attendance by the HEP community

- Engagement is crucial
  - Scope and scale of the accelerator R&D is growing
  - This is the crucial supporting activity for long-term new machines
    - With obvious relevance to the performance and sustainability of shorter-term machines
  - HEP community involvement makes sure that the goals of the European Strategy are kept ‘front and centre’

- Next open LDG meeting / workshop – please plan to attend!
  - Brookhaven, June 6-7, 2024 (FCC workshop in US is following week)
  - Great opportunity to reflect on alignment of P5 priorities and European Strategy
    - At the start of the next phase of the US programme, and just as we enter the update process