Welcome

Today: Introduction to our task: The Development of a Roadmap on Energy Recovery Linacs

Remit by LDG*), First Steps, Time+Task [15’]
Introduction of Panel Members [25’]
The Facility Data Base (thanks for your input) [30’]
Discussion on Outline of the Roadmap [30’]
aob [20’]

*) LDG = European Lab Directors Group, chaired by Dave Newbold (RAL), following Lenny Rifkin (PSI)

to the first session of the ERL expert panel, ZOOM, 25 February, 2021. Max Klein with Andrew Hutton

Remit by LDG and first steps we took

Council decided to hand the accelerator development (R&D) over to the larger European laboratories, including CERN, while ECFA steers detector and physics developments. The question has been raised: which technology will be mature enough by ~2026 when sincere strategy decisions may have to be taken? Roadmaps shall include a mid term perspective, for the twenties, and may hint to longer term developments. The roadmap(s) is supposed to inform Council and Funding Agencies and ‘the community’ about desirable directions and opportunities for support.

Accelerator R&D Roadmap Planning: Process and Remit

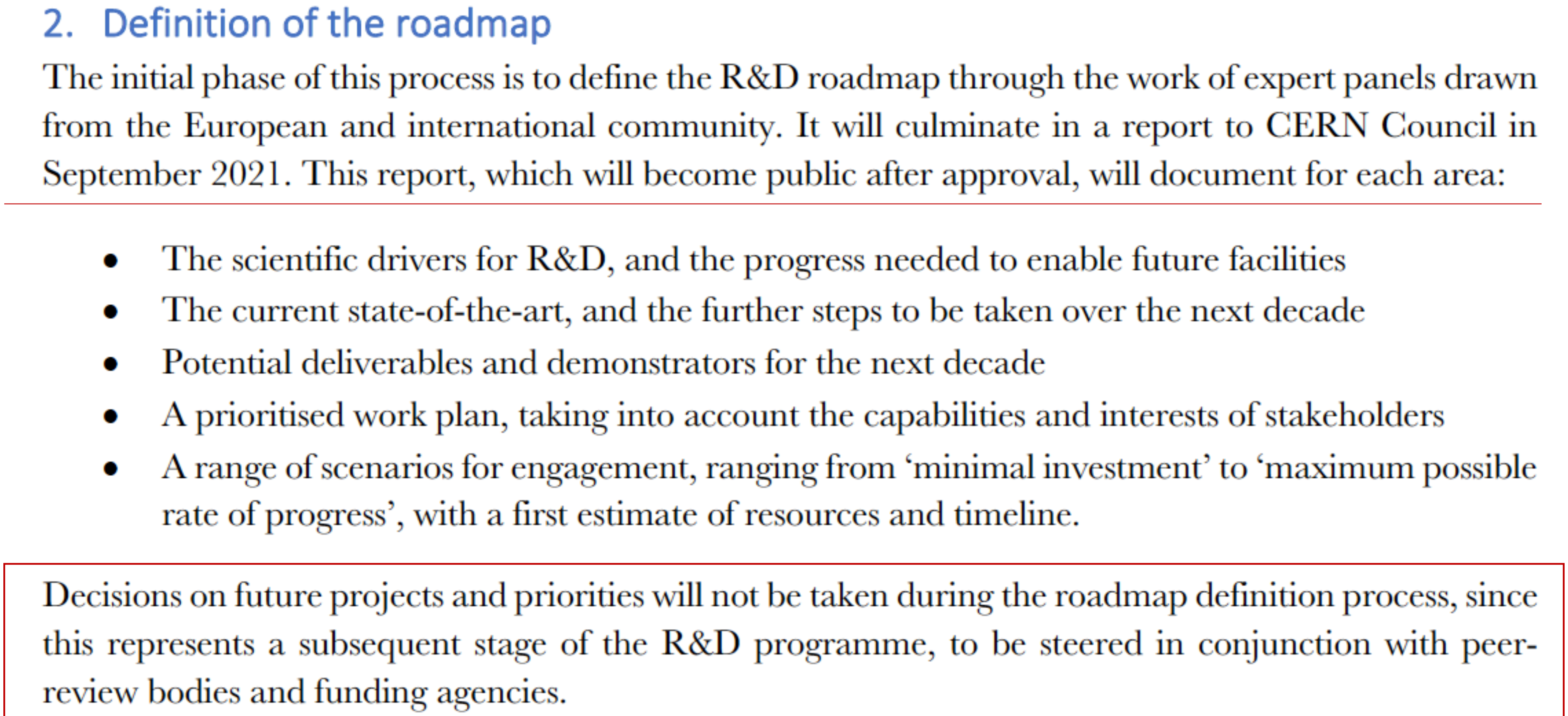
v0, 16th October 2020

This is a draft not for distribution

1. Background

As an outcome of the European Strategy for Particle Physics 2020, CERN Council has mandated the Laboratory Directors Group (LDG) to define and maintain a prioritised accelerator R&D roadmap towards future large-scale facilities for particle physics. The roadmap will define a route towards implementation of the scientific goals of the European Strategy, bringing together the capabilities of CERN, large national laboratories, and other institutes, to carry out R&D and the construction and operation of demonstrators. The roadmap should:

- 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 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 cognate with corresponding roadmaps in detectors, computing and other developments, with a compatible timeline and deliverables
- Be designed to inform, through its outcomes, subsequent updates to the European Strategy.



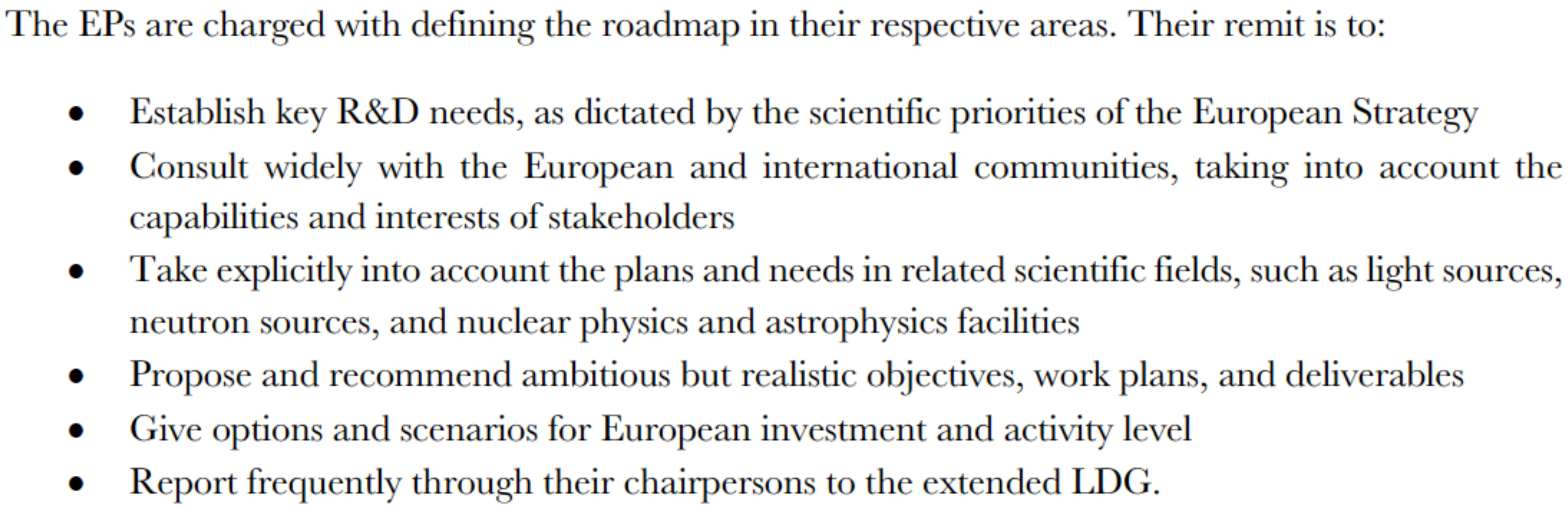
2. Definition of the roadmap

The initial phase of this process is to define the R&D roadmap through the work of expert panels drawn from the European and international community. It will culminate in a report to CERN Council in September 2021. This report, which will become public after approval, will document for each area:

- The scientific drivers for R&D, and the progress needed to enable future facilities
- The current state-of-the-art, and the further steps to be taken over the next decade
- Potential deliverables and demonstrators for the next decade
- A prioritised work plan, taking into account the capabilities and interests of stakeholders
- A range of scenarios for engagement, ranging from 'minimal investment' to 'maximum possible rate of progress', with a first estimate of resources and timeline.

Decisions on future projects and priorities will not be taken during the roadmap definition process, since this represents a subsequent stage of the R&D programme, to be steered in conjunction with peer-review bodies and funding agencies.

Expert Panels



The EPs are charged with defining the roadmap in their respective areas. Their remit is to:

- Establish key R&D needs, as dictated by the scientific priorities of the European Strategy
- 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, such as light sources, neutron sources, and nuclear physics and astrophysics facilities
- Propose and recommend ambitious but realistic objectives, work plans, and deliverables
- Give options and scenarios for European investment and activity level
- Report frequently through their chairpersons to the extended LDG.

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for distribution

Time and Tasks

Timeline (tentative)

January: LDG Invited Chairs

February: 1st Panel Meeting

March: LDG Report to Council

June: Community Meeting (to be discussed) ↔ Consult with the ERL Community

September: Papers ready, Council report

Fall: SPC, integration, evaluation, update of the five roadmaps

December: Final Report to Council

Exact dates to be collected / to be set

Our Tasks

Share our expertise and views

Prepare the ERL Roadmap

Jointly Draft Document (Overleaf, TeX), invite authors where useful

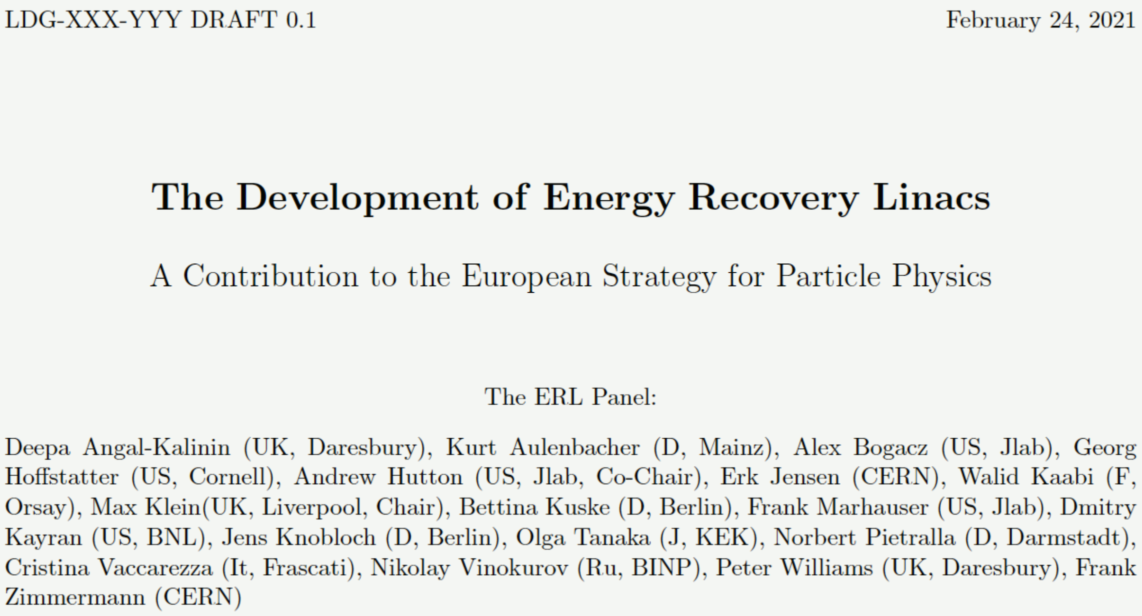
Consult with the ERL Community

Complete Long Write-Up

Endorse Summary

ERL differs from HF Magnets, Muon Collider, Plasma, SRF:
“Newly” established priority, less known use in HEP. Yet it is no less spectacular and important as other technologies, linked to those in various ways. Have to deal with science too.

A one-page summary yesterday delivered to Dave Newby



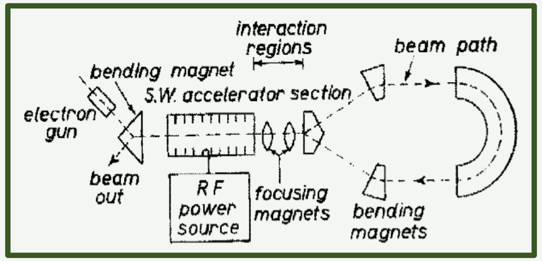
LDG-XXX-YYY DRAFT 0.1 February 24, 2021

The Development of Energy Recovery Linacs

A Contribution to the European Strategy for Particle Physics

The ERL Panel:

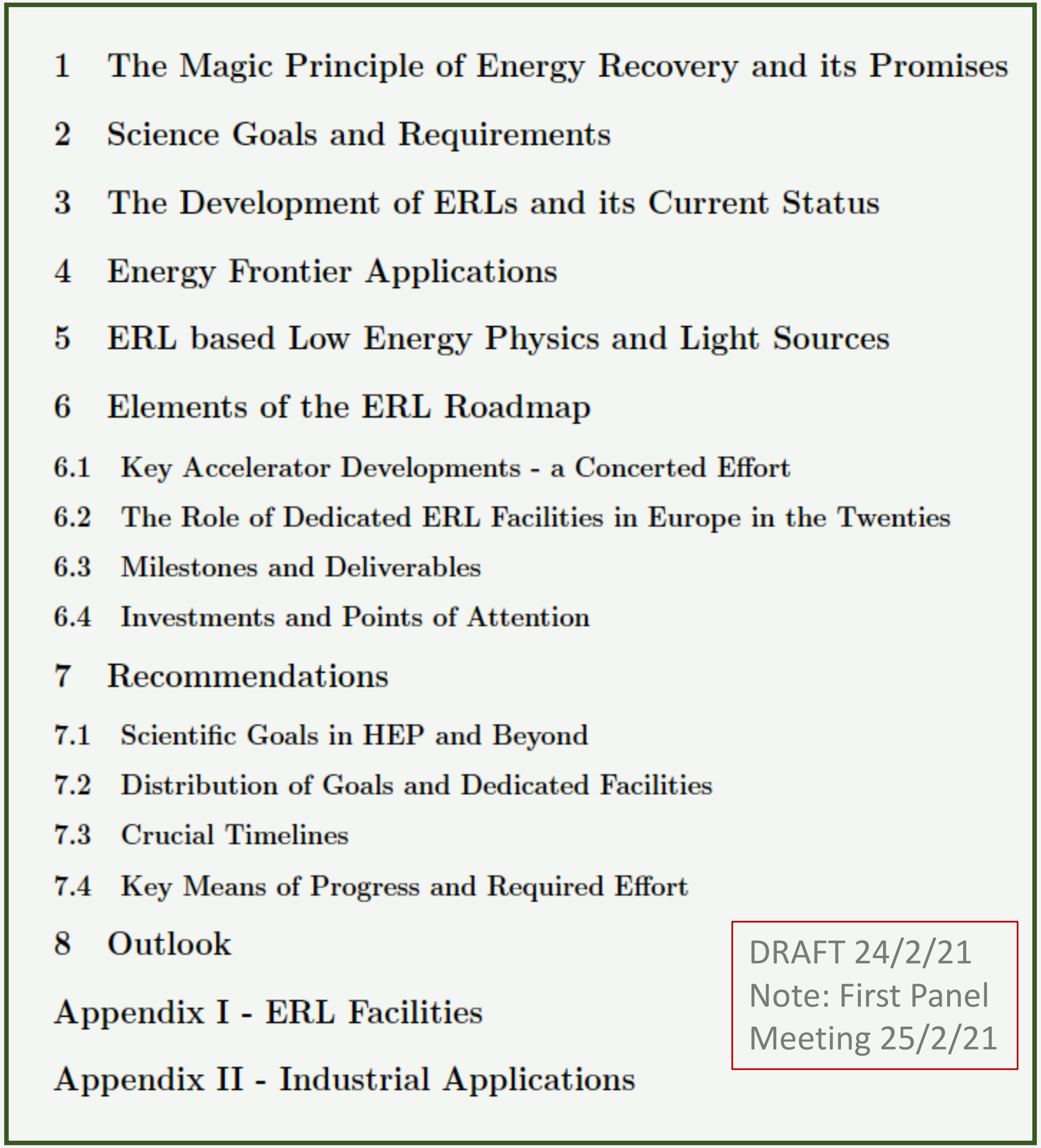
Deepa Angal-Kalinin (UK, Daresbury), Kurt Aulenbacher (D, Mainz), Alex Bogacz (US, Jlab), Georg Hoffstatter (US, Cornell), Andrew Hutton (US, Jlab, Co-Chair), Erk Jensen (CERN), Walid Kaabi (F, Orsay), Max Klein(UK, Liverpool, Chair), Bettina Kuske (D, Berlin), Frank Marhauser (US, Jlab), Dmitry Kayran (US, BNL), Jens Knobloch (D, Berlin), Olga Tanaka (J, KEK), Norbert Pietralla (D, Darmstadt), Cristina Vaccarezza (It, Frascati), Nikolay Vinokurov (Ru, BINP), Peter Williams (UK, Daresbury), Frank Zimmermann (CERN)



M. Tigner
N.Cim 10(1965)1228

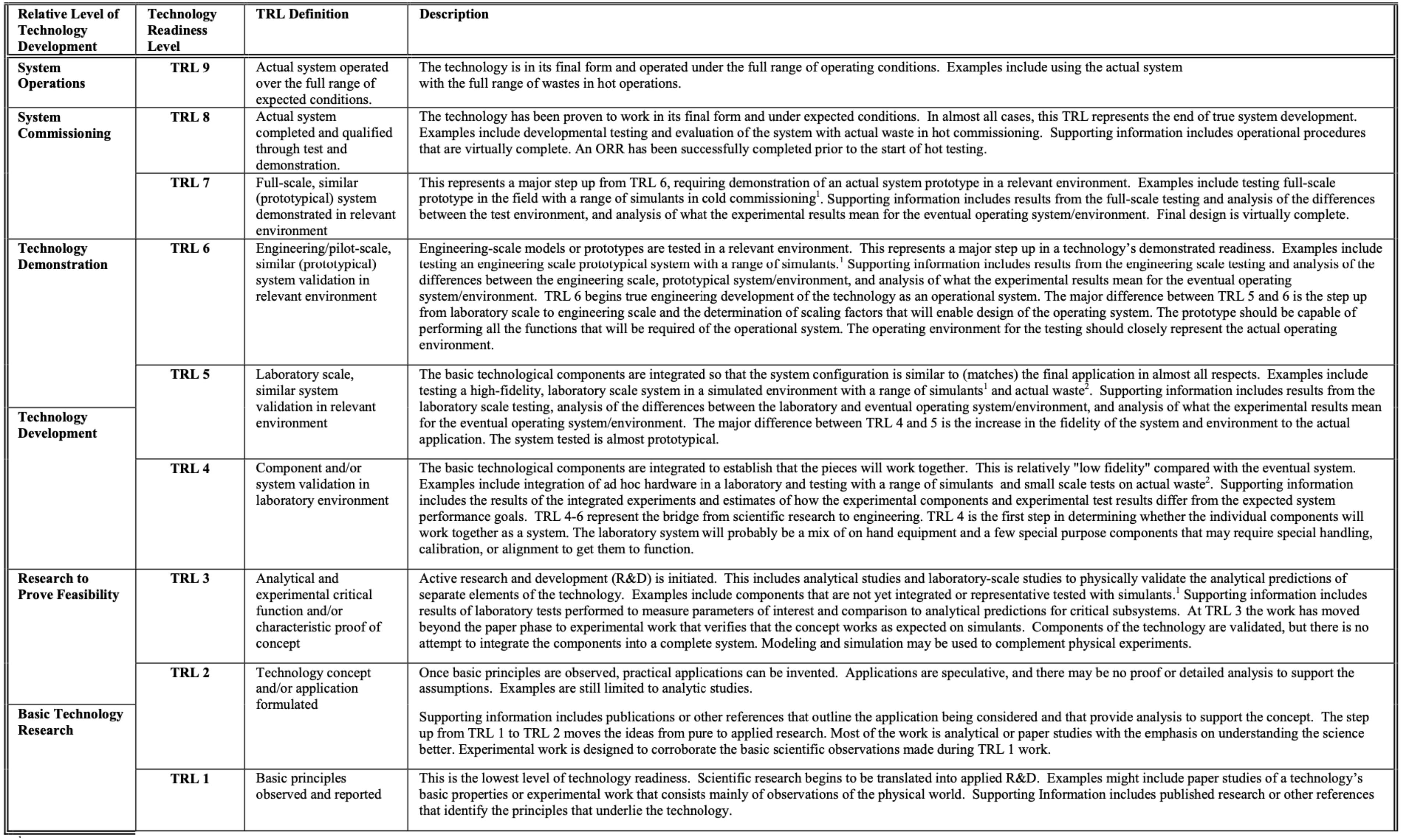
Goal: ERL at an order of magnitude increased power of 10 MW through high brightness sources and multi-turn loops → **innovative, high luminosity (1000 ELI, 1000 HERA), green accelerator concept for 21st century,** for HEP, NP and Industrial applications

Concerted effort of existing and dedicated new facilities. Consult community in June 2021, write up + executive summary: fall 21



DRAFT 24/2/21
Note: First Panel
Meeting 25/2/21

Technical Readiness Levels (time)



Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
System Operations	**TRL 9**	Actual system operated over the full range of expected conditions.	The technology is in its final form and operated under the full range of operating conditions. Examples include using the actual system with the full range of wastes in hot operations.
System Commissioning	**TRL 8**	Actual system completed and qualified through test and demonstration.	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning. Supporting information includes operational procedures that are virtually complete. An ORR has been successfully completed prior to the start of hot testing.
	TRL 7	Full-scale, similar (prototypical) system demonstrated in relevant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning[1]. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.
Technology Demonstration	**TRL 6**	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants.[1] Supporting information includes results from the engineering scale testing and analysis of the differences between the engineering scale, prototypical system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment.
Technology Development	**TRL 5**	Laboratory scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants[1] and actual waste[2]. Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.
	TRL 4	Component and/or system validation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small scale tests on actual waste[2]. Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRL 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function.
Research to Prove Feasibility	**TRL 3**	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative tested with simulants.[1] Supporting information includes results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.
Basic Technology Research	**TRL 2**	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies. Supporting information includes publications or other references that outline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.
	TRL 1	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental work that consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.

https://www.energy.gov/sites/prod/files/em/Volume_I/O_SRP.pdf

ERL Panel Members

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Peter Williams (UK, Daresbury)

Frank Zimmermann (CERN)

THANK YOU

plus
Max Klein (UK, Liverpool) and **Andrew Hutton (US,Jlab)**

18 Members - Europe: 11, USA: 5, Russia: 1, Japan: 1

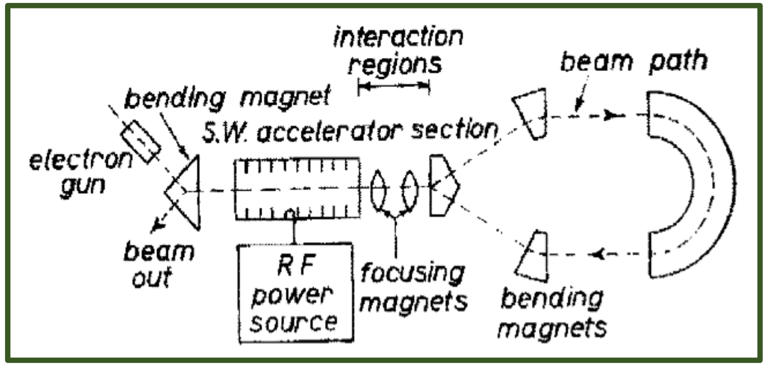
February 2021

backup

Development of Energy Recovery Linacs

Elements of an ERL Roadmap

Max Klein (University of Liverpool) and Andrew Hutton (Thomas Jefferson Laboratory, VA)



Performance of a 55 year old idea with the technology of today and tomorrow:
M Tigner A Possible Apparatus for Electron Clashing-Beam Experiments, N.Cim 10(1965)1228

Recirculation lattice to recycle kinetic beam energy of a decelerating beam for acceleration of a newly injected low energy beam. Avoid synchrotron loss initiated emittance growth as in storage rings. Minimize power consumption (by an order of magnitude) and dump at E_{inj}: **a high luminosity (1000 ELI, 1000 HERA), 'powerful' green accelerator concept for 21st century**

Science: Energy Frontier – Higgs, Substructure, BSM; Medium Energy – Spin; Low Energy: unique Nuclear, Photo-Nuclear + PP experiments.

Roadmap: Focussed effort shall rely on existing + forthcoming ERL facilitiies. Evaluate their goals, complementarity + determine further needs.

Facilities: operational: sDALINAC (Darmstadt), CEBAF (Jlab), CBETA (Cornell), cERL(KEK), BINP (Novosibirsk) [ERL in Europe first ALICE UK]
forthcoming in the next years: MESA (Mainz), PERLE (IJCLab Orsay), eCOOLER (BNL), bERLinPro (?).

Reference for an introduction: C Tennant, ERLs, in "Challenges and Goals for Accelerators in the XXI Century", O Bruening, S Myers, World Scientific, 2019

Short Introduction for the Meeting of the Laboratory Directors Group (LDG), 22 January, 2021

Elements of the ERL Roadmap

1. **Goal:** ERL at an order of magnitude increased power of 10 MW
2. **Advance in Critical Parameters:** 50mA current, 1nC charge, 5 GeV energy, …
3. **Major Components:** High Current /Charge: Sources and High Q_0 (> 10^{10}) and high gradient (< 25MV/m - CW), dressed cavities
4. **Characteristics of ERL Roadmap:** have and need several ERL facilities to address different aspects of high power ERL operation
5. **Specialities:** polarised e ERL: MESA; high E_e: CEBAF; multi-turn: cBETA, PERLE; very high current: cERL, eCooler
6. **Technical and Industrial Applications – "Impact":** (X)FELs; Lithography; Hrad Xray sources for scanning shipments…
7. **Synergy:** ERL and Racetrack options for FCC-ee and its injector; FCC-eh; increase L(EIC); high gradient SRF developments; ..
8. **Technology Innovations:** Cavity production, FFAG Magnets, Fast Reactive Tuner, …
9. **Timeline (to 2025 and 2030) and Milestones**
10. **Longer Term Plans:** France, UK, Germany, US, ..

22.1.21

PERLE: unique as "global effort for a clean-sheet optimised design for a new generation of high .. power efficient ERL based machines" [1705.08783]