

# The Development of Energy Recovery Linacs

Initial Findings and Activity Report for the LDG

## The ERL Panel

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- 7.1. Introduction
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### A. Overview on ERL Facilities

### B. On the Prospects of ERL based $e^+e^-$ Colliders

- B.1. Sub-Panel Charge
- B.2. FCC-ee
- B.3. ERLC

Very recent:

$$e\gamma \rightarrow e\mu/\mu$$

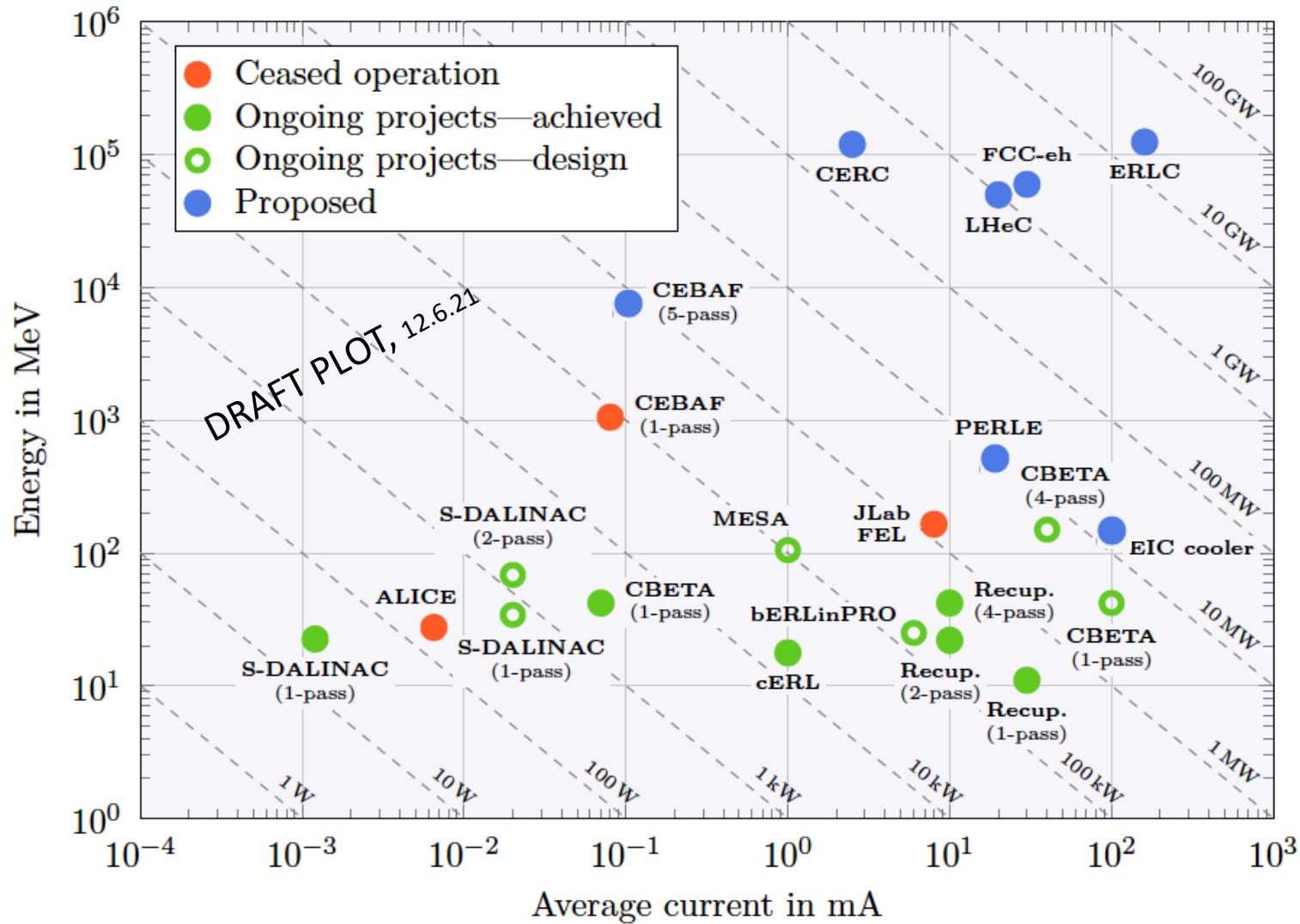
concept of  
100 GeV eERL  
with X ray FEL  
as base for  
muon collider  
10pmrad emittance

arXiv:2106.03255  
Curatolu, Serafini

ERL concepts now  
for ep,  $e^+e^-$ ,  $\gamma\gamma$   
+ muon colliders

Figure 3: Draft table of contents of the about 250 pages paper in preparation describing the ERL developments and prospects [1]. A similar order of topics will be used for the shorter roadmap input, complemented by chapters on milestones, cost and options for the ERL future.

A selection of past, present and proposed ERL facilities vs energy and current



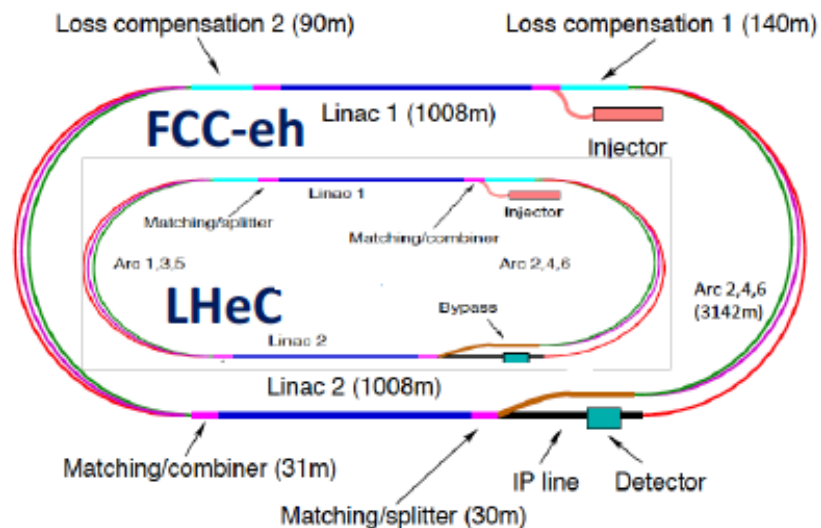
### ERL Features:

Very high luminosity through high electron current and small preserved injector emittance. Economic use of power  $P_o/(1 - \eta)$  through recovery in multiple linac passing (recirculator or head-on). Non-radiative beam dump at injection energy. → orders of magnitude improved performance at same or reduced power, **a new era for accelerator, HEP, NP and applications**

“The ERL concept is well proven and the technology is well developed. Many demonstrator facilities exist worldwide with increasing sophistication. It needs a facility comprising all essential features simultaneously: high-current, multi-pass, optimised cavities and cryo-modules and a physics quality beam eventually for experiments”. (Bob Rimmer)

Figure 1: Electron energy vs current for ERL facilities, draft plot from long write-up [1].

# Energy Frontier Collider Applications of Energy Recovery Linacs

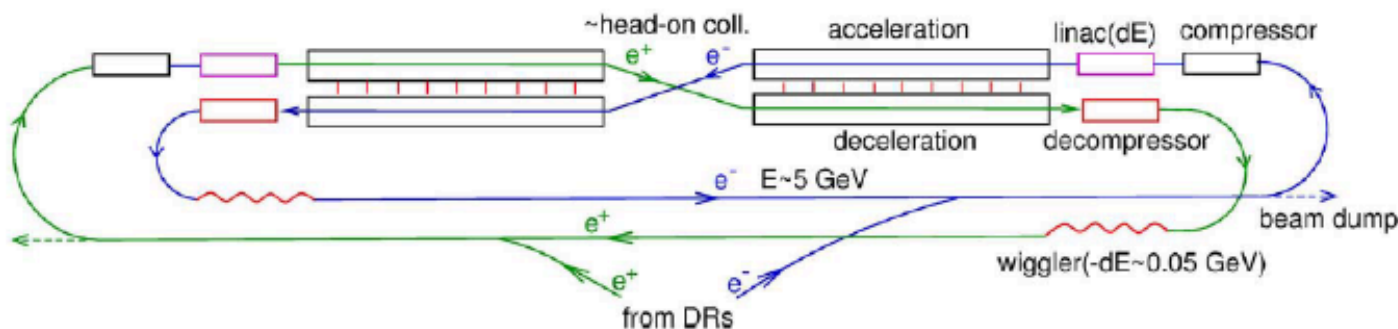
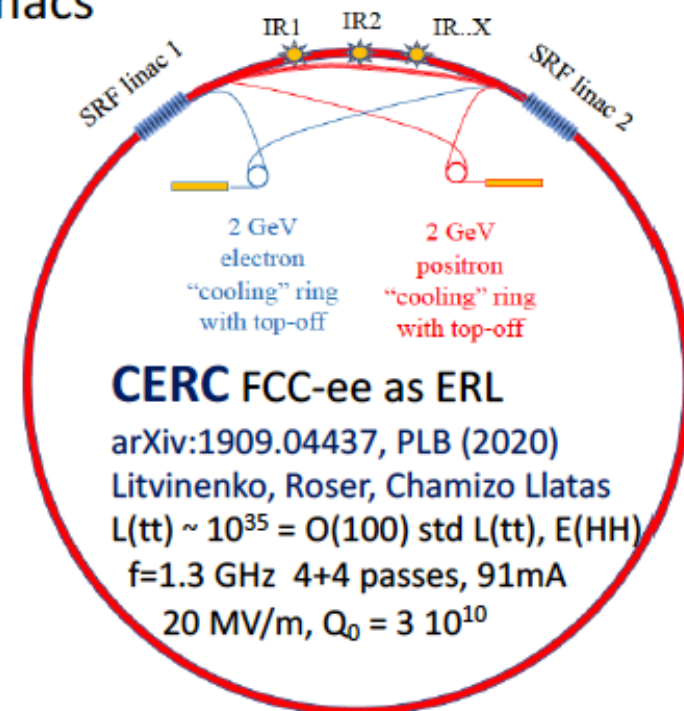


$$\sqrt{s_{ep}} = 1-4 \text{ TeV}$$

$L(\text{HERA}) \times 1000$   
(ERL and LHC)

1206.2913, JPhysG  
2007.14491, JPhysG

$f=802\text{Mz}$ ,  
3+3 passes: 20mA x 6  
20 MV/m,  $Q_0 > 10^{10}$



## ERLC ILC as ERL

V. Telnov at LCWS → arXiv:2105.11015  
 $L(\text{ERLC}) \sim 10^{36} = O(100)$  std  $L(\text{ILC})$   
This yields  $O(10^7)$  HZ events in 3 years.  
1+1 passes,  $l=160\text{m}$   
 $f=750 \text{ MHz}$ , 20 MV/m,  $Q_0 > 10^{10}$

Figure 2: Sketch of possible future colliders based on ERLs: left top: LHeC and FCC-eh; right top: CERC; bottom: ERLC. For more information see the arXiv references displayed.

## Evaluation of ERL concepts for FCC-ee [CERC] and the ILC [ERLC]

Vladimir Litvinenko+ <https://doi.org/10.1016/j.physletb.2020.135394> ;  
Valery Telnov, <https://arxiv.org/abs/2105.11015>

The Sub-Panel should evaluate the technical and financial implications of the two novel concepts compared to the FCC-ee and ILC projects:

**What are the technical advances, specifically in luminosity?**  
**What are the technical solutions + obstacles requiring R&D?**  
**How much time would that additionally require?**  
**What is the rough cost implication (to about 10%)**

### Sub-Panel members

Chris Adolphsen (SLAC)	Reinhard Brinkmann (DESY)
Oliver Brüning (CERN)	Andrew Hutton (JLab) – Chair
Sergei Nagaitsev (Fermilab)	Max Klein (Liverpool)
Peter Williams (STFC)	Akira Yamamoto (KEK)
Kaoru Yokoya (KEK)	Frank Zimmermann (CERN)

## The $e^+e^-$ ERL Sub-Panel

### Dates for the sub-Panel

Kick-off meeting held June 9, 2021

Completion by September 3, 2021

### Deliverable:

A short report (~20 pages) detailing the conclusions of the evaluation, which should be agreed and supported by the entire sub-Panel and published as Appendix B to the full Panel report.

**Methodology:** Sessions with proponents to begin with. Sessions open to other ERL panel members

Procedure agreed with the proponents

Valeri Telnov and Vladimir Litvinenko, Tomas Roser



**Chair:** Bettina Kuske (HBZ, Berlin)

13:00 **Welcome by the Lab Directors Group** 10m  
Prof. Dave Newbold (STFC R.Appleton Laboratory)

13:10 **Introduction** 10m  
Max Klein (University of Liverpool)

13:20 **ERL Facilities** 25m  
Andrew Hutton (Jefferson Laboratory)

13:45 **High Current Electron Sources** 15m  
Boris Militsyn (STFC)

14:00 **SRF Developments for ERLs** 25m  
Robert Alan Rimmer (Jefferson Laboratory)

14:25 **ERL Prospects for High Energy Colliders** 25m  
Oliver Bruning (CERN)

14:50 **Coffee/tea Break** 10m

**Chair:** Olga Tanaka (KEK)

15:00 **Low Energy Physics with ERLs** 20m  
Jan Bernauer (Stony Brook University)

15:20 **Industrial ERL Applications** 20m  
Peter Williams (Daresbury Laboratory)

15:40 **Energy Recovery and Sustainability** 20m  
Erk Jensen (CERN)

**Chairs:** Andrew Hutton and Max Klein

16:00 **Discussion** 55m

# ERL Symposium

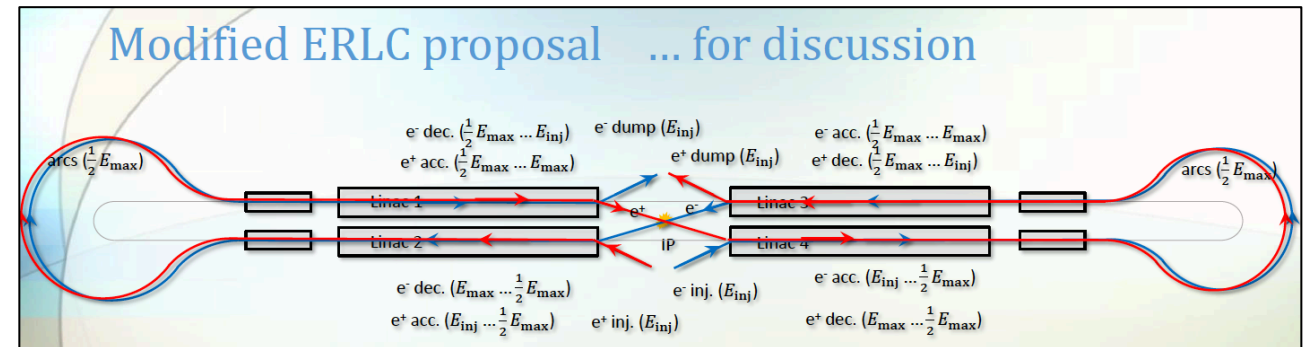
Friday 4.6. 1-5pm CEST

<https://indico.cern.ch/event/1040671/>

An initial observation (not only) by the panel:  
ERLs are more than an appealing technology:

They (cor)respond to **A NEW ERA** in  
particle and several other fields of physics,  
industry, accelerators .. in a world that cannot  
proceed without renewed care for our planet.

Energy Recovery Linacs are novel technologies  
with far reaching impacts on science + society.



The symposium was an important event for information, consultation and formation of a more coherent R&D ERL effort.