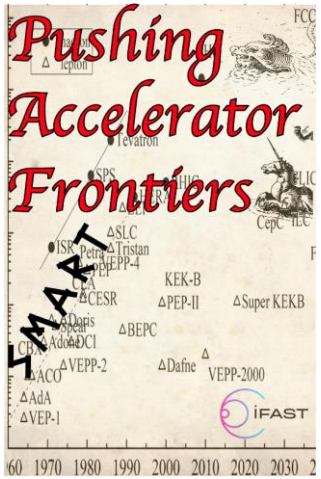
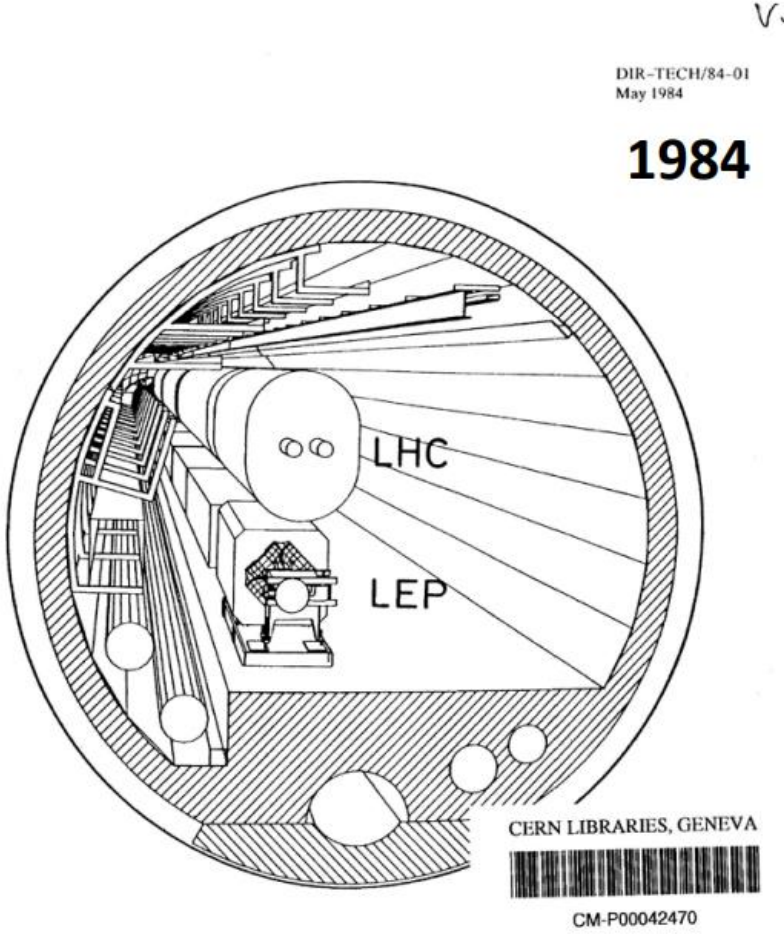


I.CERN, 9 November 2025

electron-proton collisions in the LHC tunnel



"Although the machine operation would become more difficult, it is not unconceivable that the luminosity could eventually approach or even exceed 10^{33} cm^{-2} s^{-1} …"

20 years later – linac-ring type e-LHC collider !

Eur Phys J C **33**, s01, s1064–s1066 (2004)
Digital Object Identifier (DOI) 10.1140/epjcd/s2004-03-1716-2

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Linac-ring type colliders: Second way to TeV scale

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Abstract. Main parameters and the physics search potentials of the linac-ring type lepton-hadron and photon-hadron colliders are discussed. The THERA (TESLA on HERA), "NLC"-LHC and "CLIC"-VLHC proposals are considered.

Proceedings of EPAC 2004, Lucerne, Switzerland

QCD EXPLORER BASED ON LHC AND CLIC-1

D. Schulte, F. Zimmermann, CERN, Geneva, Switzerland

Proceedings of PAC07, Albuquerque, New Mexico, USA THPMN064

LUMINOSITY UPGRADE OF CLIC-LHC EP/γP COLLIDER*

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A.K. Çiftçi, Z. Nergiz, Physics Dept., Science Faculty, Ankara Univ., Ankara, Turkey
D. Schulte and F. Zimmermann, CERN, Geneva, Switzerland.

Abstract

An energy frontier or QCD Explorer ep and γp collider can be realized by colliding high-energy photons generated by Compton backscattered off a CLIC electron beam, at either 75 GeV or 1.5 TeV, with protons or ions stored in the LHC. In this study we discuss a performance optimization of this type of collider by tailoring the

where α_0 denotes the collision angle between laser beam and electron beam, ω_0 the energy of a laser photon and E_b the initial energy of electrons. In the case of head on collision and with practical units x=15.3E_b[TeV]ω_0[eV]. The maximum energy of backscattered photons is

2008: linac-ring studies for LHeC

LINAC-LHC ep COLLIDER OPTIONS

F. Zimmermann, F. Bordry, H.-H. Braun, O.S. Brüning, H. Burkhardt, A. de Roeck, R. Garoby, T. Linnecar, K.-H. Mess, J. Osborne, L. Rinolfi, D. Schulte, R. Tomas, J. Tuckmantel, CERN, Switzerland; A. Eide, EPFL, Switzerland; F.J. Willeke, BNL, U.S.A.; S. Chattopadhyay, Cockcroft I., UK; B.J. Holzer, DESY, Germany; J. Dainton, M. Klein, Liverpool U., UK; A. Vivoli, LAL, France; S. Sultansoy, TOBB ETU, Turkey; A.K. Ciftci, Ankara U., Turkey; H. Aksakal, Nigde U., Turkey

Possible linac-ring scenarios include a n.c. linac, a pulsed s.c. linac, and a cw s.c. linac with or without energy recovery in various configurations, as shown in Fig. 1.

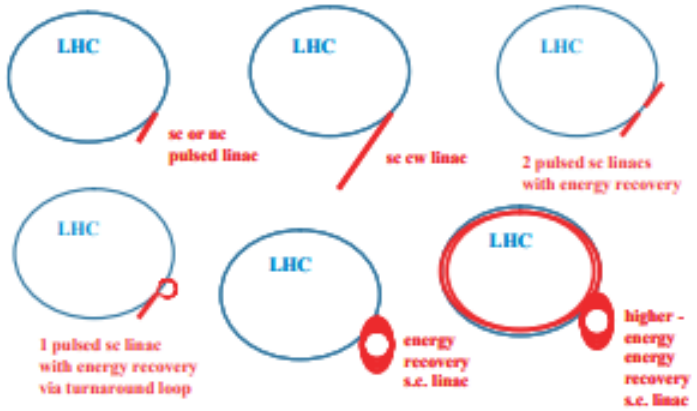

Figure 1: Scenarios for the linac-ring ep collider.

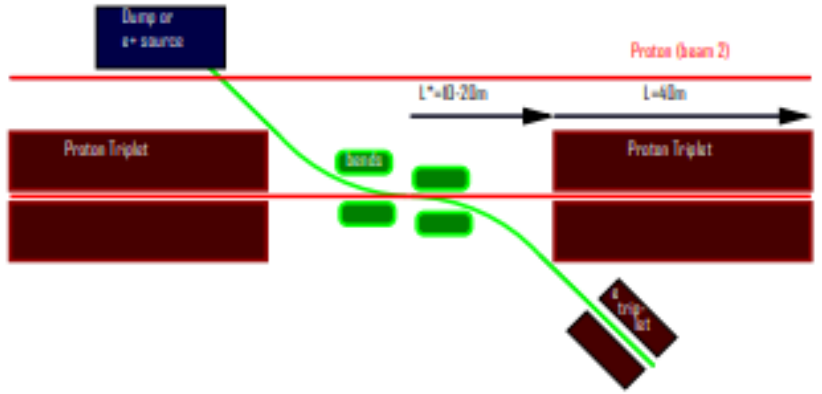

Figure 8: Schematic of linac-ring interaction region.

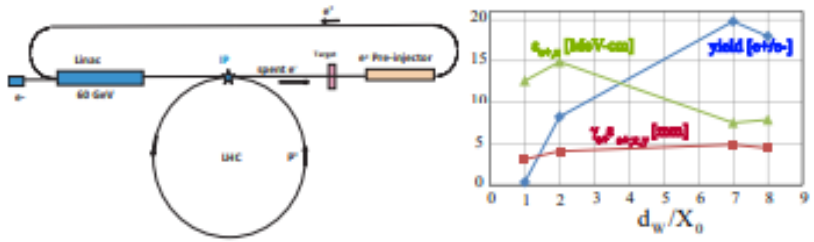

Figure 7: Schematic linac-ring collider with integrated positron production (left) and simulated e^+ yield for amorphous W target of varying thickness hit by a 60-GeV e^- beam [$\gamma_e\epsilon_e = 20\ \mu$m, $\sigma_{x,y,e} = 20\ \mu$m, $\beta = 10$ m] (right).

2009: ring-ring & ERL-based linac-ring LHeC

Proceedings of PAC09, Vancouver, BC, Canada FR1PBC05

THE LARGE HADRON-ELECTRON COLLIDER (LHeC) AT THE LHC

F. Zimmermann, F. Bordry, H.-H. Braun, O.S. Brüning, H. Burkhardt, A. Eide, A. de Roeck, R. Garoby, B. Holzer, J.M. Jowett, T. Linnecar, K.-H. Mess, J. Osborne, L. Rinolfi, D. Schulte, R. Tomas, J. Tückmantel, A. Vivoli, CERN; A.K. Ciftci, Ankara U.; T. Omori, J. Urakawa, KEK; F. Willeke, BNL, New York; S. Chattopadhyay, J. Dainton, Cockcroft Inst., Warrington; H. Aksakal, U. Nigde; S. Sultansoy, TOBB ETU, Ankara; M. Klein, U. Liverpool, UK

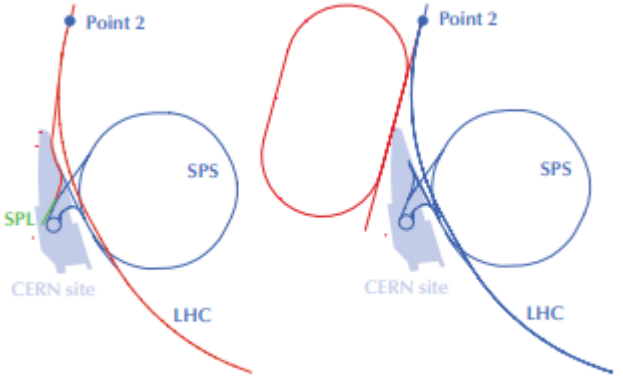

Figure 1: RR (left) & RL (right) LHeC layouts [11].

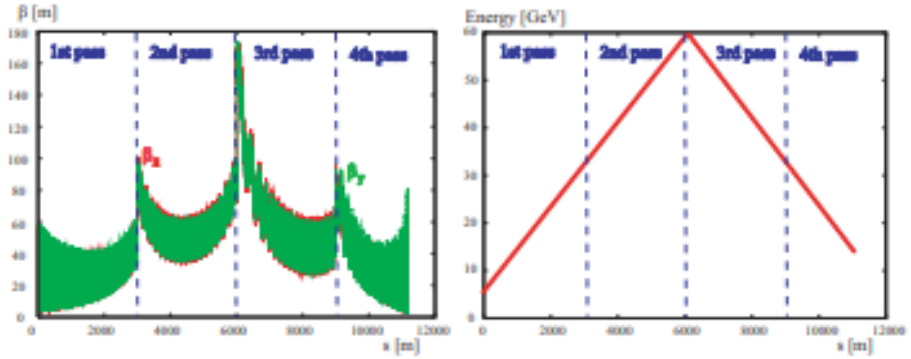

Figure 2: Beta functions (left) and beam energy (right) during two accelerating and two decelerating passes through the same linac for the LHeC-RL high-luminosity ERL option [the return arcs are not shown].

CONCLUSIONS

An LHeC could provide high-energy high-luminosity $e^{\pm}p$ and $e^{\pm}A$ collisions. Two major designs are under study, a ring-ring option with luminosities of 10^{33} cm^{-2}s^{-1} and energies limited to 80 GeV, and a linac-ring option with similar luminosity using energy recovery and the possibility of an extension to higher energies. Injection to the ring may be provided by operating the SPL as an electron accelerator, possibly complemented by recirculation to reach a few tens of GeV electron beam energy.

LHeC design report – ring-ring & linac-ring

CERN-OPEN-2012-015
LHeC-Note-2012-002 GEN
Geneva, June 13, 2012

A Large Hadron Electron Collider at CERN

Report on the Physics and Design
Concepts for Machine and Detector

LHeC Study Group

J L Abelleira Fernandez et al 2012 J. Phys. G: Nucl. Part. Phys. 39 075001

2013: linac-ring LHeC as a Higgs factory

Proceedings of IPAC2013, Shanghai, China MOPWO054

THE LHeC AS A HIGGS BOSON FACTORY

F. Zimmermann, O. Brüning, CERN, Geneva, Switzerland; M. Klein, U. Liverpool, UK

Abstract

The LHeC is designed to collide a new 60 GeV energy electron beam, from a 3-pass ERL, with the 7 TeV energy LHC proton beam. At the present target ep luminosity of 10^{33} cm^{-2}s^{-1}, the LHeC would produce a few 1000 Higgs bosons per year, allowing for precision coupling measurements, especially of the $H \to b\bar{b}$ decay in charged current deep inelastic scattering ($ep \to \nu H X$). With a significant increase of the luminosity, rarer channels become accessible, as the charm decay. Here such an increase, to the level of 10^{34} cm^{-2}s^{-1} or even beyond, is considered from a combination of improvements, namely with a smaller proton beam emittance, with a further reduction of the proton IP beta function, an increase of the proton bunch intensity and with doubling the lepton beam current, compared to the canonical values assumed in the CDR.

tons, together with the choice of the LHeC circumference to be equal to a third of the LHC's in order to allow for ion-clearing gaps in the ERL without perturbing LHC steady-state operation [1, 2].

LHeC has been designed under the constraint that the total electrical power for the LHeC lepton branch should not exceed 100 MW (about half the present maximum CERN site power). The LHeC electrical power budget is dominated by the RF and by the cryo power for the two 1-km long SC linacs. The cryo power and, therefore, also the size of the cryoplants (as well as the maximum lepton current) are directly linked to the unloaded quality factor of the cavities, Q_0. With a Q_0 of 2.5×10^{10} and a cavity gradient of 20 MV/m, the total main-linac cryopower is estimated at about 20 MW. The RF power needed for RF microphonics control is about 22 MW, and the extra-RF power needed for compensating SR losses at 6.4-mA current to 24 MW. The re-

2021 LHeC design report update - linac-ring only

This report represents an update to the LHeC's conceptual design report (CDR), published in 2012.

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IOP Publishing
Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. **48** (2021) 110501 (364pp)
https://doi.org/10.1088/1361-6471/abf3ba

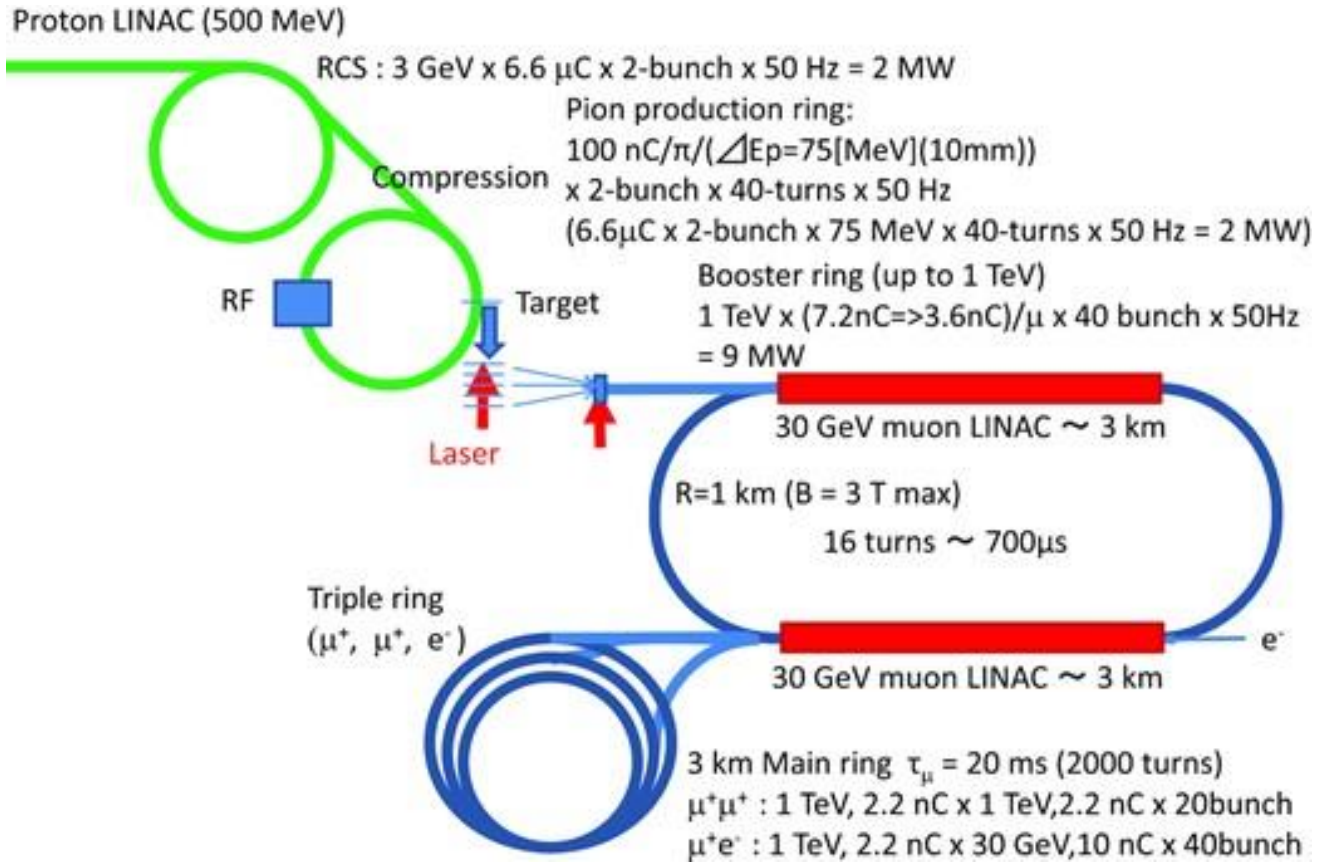
Major Report

The Large Hadron–Electron Collider at the HL-LHC

2022: $\mu^+\mu^+$, μ^+e^- collider – μTRISTAN

Y. Hamada, R. Kitano, R. Matsudo, H. Takaura, and M. Yoshida, μTRISTAN, Progress of Theoretical and Experimental Physics 2022, 53 (2022).

The **ultra-cold muon technology developed for the muon g − 2 experiment at J-PARC provides a low-emittance μ^+ beam** which can be accelerated and used for realistic collider experiments. We consider the possibility of new collider experiments by accelerating the μ^+ beam up to 1 TeV. Allowing the μ+ beam to collide with a high-intensity e− beam at the TRISTAN energy, Ee− = 30 GeV, in a storage ring with the same size as TRISTAN (a circumference of 3 km), one can realize a collider experiment with the center-of-mass energy **$\sqrt{s}$ = 346 GeV**, which allows the production of Higgs bosons through vector boson fusion processes. We estimate the deliverable luminosity with existing accelerator technologies to be at the level **of 5×10^{33} cm^{-2} s^{-1}**, with which the collider can be a good Higgs boson factory. $\mu^+\mu^+$ colliders up to $\sqrt{s}$ = 2 TeV are also possible using the same storage ring. They have the capability of producing the superpartner of the muon up to TeV masses



2022 μ-hadron collider – the new kid on the block !

epl A Letters Journal Exploring the Frontiers of Physics

April 2022

EPL, **138** (2022) 24002 www.epljournal.org
doi: 10.1209/0295-5075/ac4f98

Luminosity and physics considerations on HL-LHC– and HE-LHC–based μp colliders

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[2] *Department of Engineering Physics, Ankara University - Ankara, Turkey*
[3] *Department of Materials Science and Nanotechnology Engineering, TOBB University of Economics and Technology Ankara, Turkey*
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published online 19 May 2022

Abstract – Construction of the future muon collider tangential to the Large Hadron Collider will give opportunity to realize μp collisions at multi-TeV center-of-mass energies. Using the nominal parameters of high-luminosity and high-energy upgrades of the LHC, as well as the design parameters of muon colliders, it is shown that $L_{\mu p}$ of the order of 10^{33} cm^{-2}s^{-1} is achievable for different options with $\sqrt{s_{\mu p}}$ from 4.58 TeV to 12.7 TeV. Certainly, the proposed μp colliders have a huge potential for clarifying QCD basics and searches for new physics.

Eur. Phys. J. Plus (2025) 140:317
https://doi.org/10.1140/epjp/s13360-025-06184-5

The European Physical Journal Plus

Regular Article

μTRISTAN- and LHC-/Tevatron-/FCC-/SppC-based antimuon–hadron colliders

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μLHC: Antimuon Ring and HL-LHC based μ^+p Collider

2025

D. Akturk[1], A. C. Canbay[2], H. Dagistanli[3], B. Dagli[1], U. Kaya[4], B. Ketenoglu[2], A. Kilic[5], F. Kocak[5], A. Ozturk[6], S. Sultansoy[1,*], I. Tapan[5], F. Zimmermann[7]

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[7]*European Organization for Nuclear Research (CERN), Geneve, Switzerland*

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challenge: ultracold muon generation

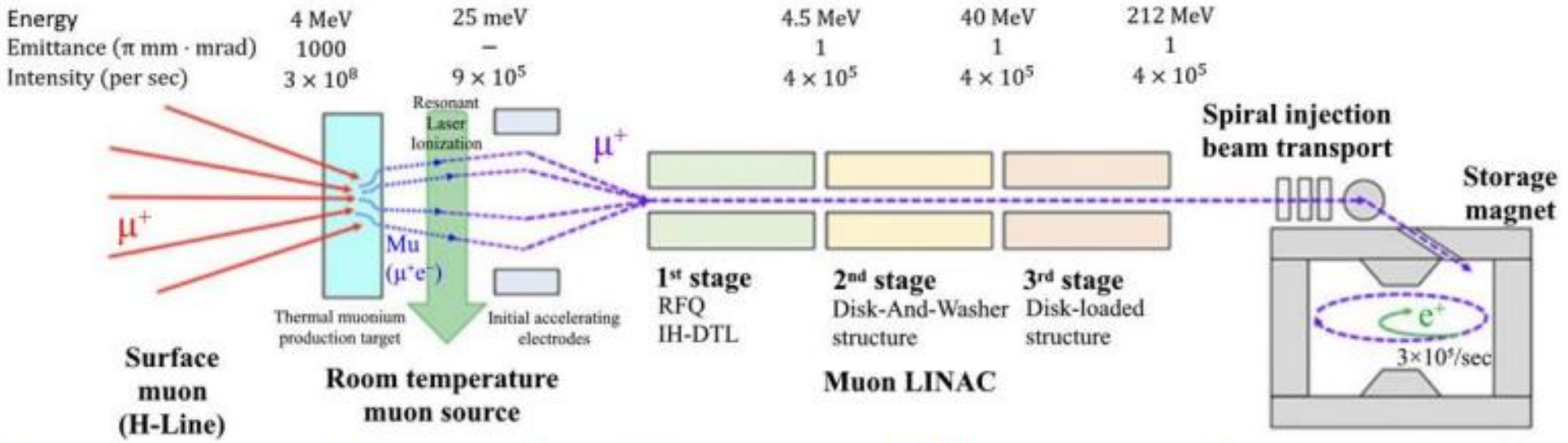

Figure 2. Conceptual layout of the J-PARC muon g-2/EDM experiment, highlighting the ultra-cold muon beamline and storage ring [54].

"The **ultra-cold muon production rate can be enhanced by a factor of $\mathcal{O}(10^5)$ compared to the J-PARC MLF configuration**. This significant improvement results primarily from the efficient use of forward-going pions, which are transported to a large-scale multi-layered stopping target rather than being lost after the initial production. In contrast to the MLF configuration, where only pions that stopped within a thin region of the graphite target contributed to muon production, the μTRISTAN design introduces a recirculating 5 proton beam system for pion production. Each proton bunch is recirculated 40 times over a 10 mm graphite target, leading to an enhanced pion yield of 0.016 pions per proton. … This system integrates a dedicated compression ring with the existing RCS ring at MLF, enabling protons to repeatedly traverse the target for maximized pion generation."