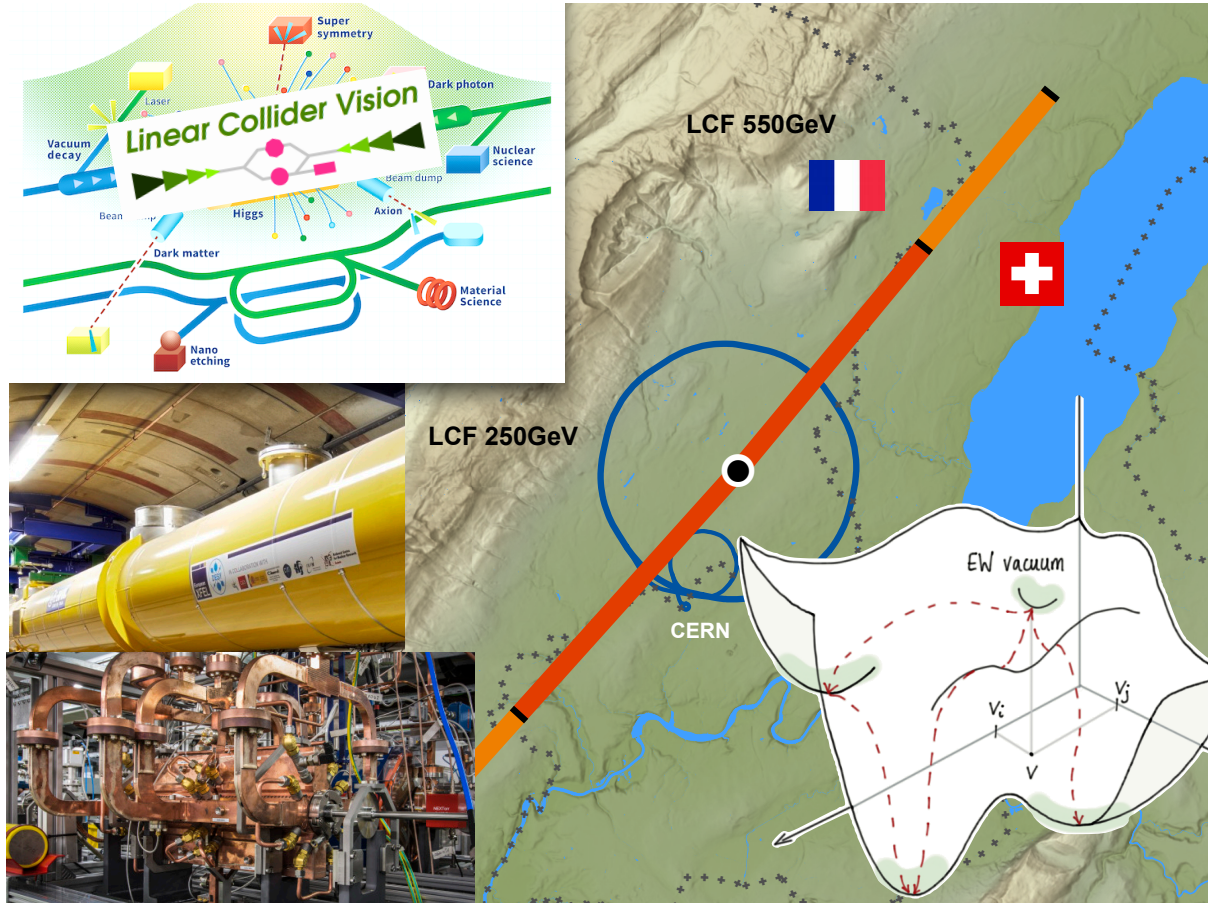
Status of ILC and LCF

Jenny List
ICFA Seminar
November 5, 2026

- Introduction
- ILC
- LCF
- Conclusion & Outlook



Introduction

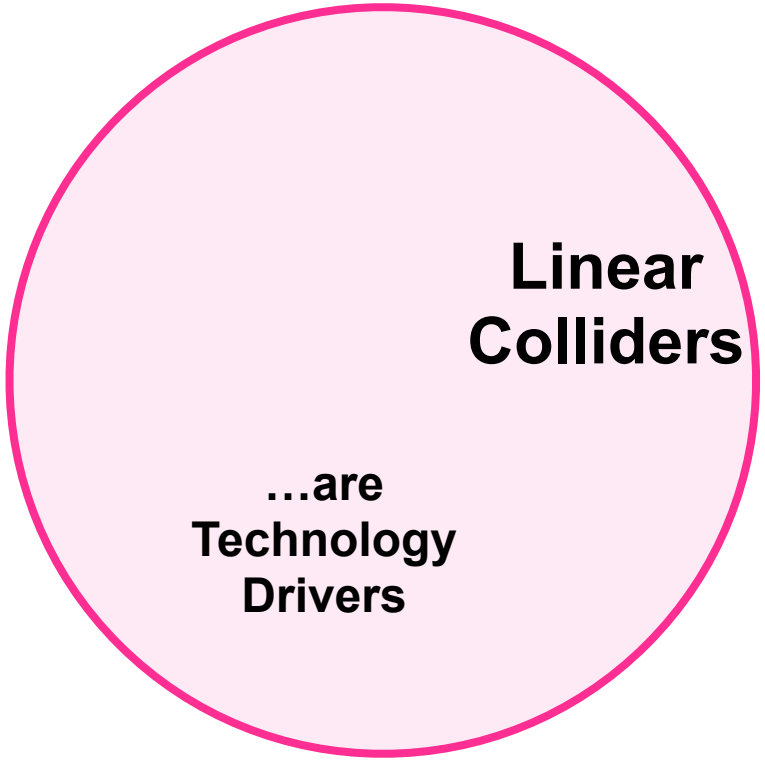
Why we still talk about Linear Colliders

…in the age of FCC-ee

Linear Colliders

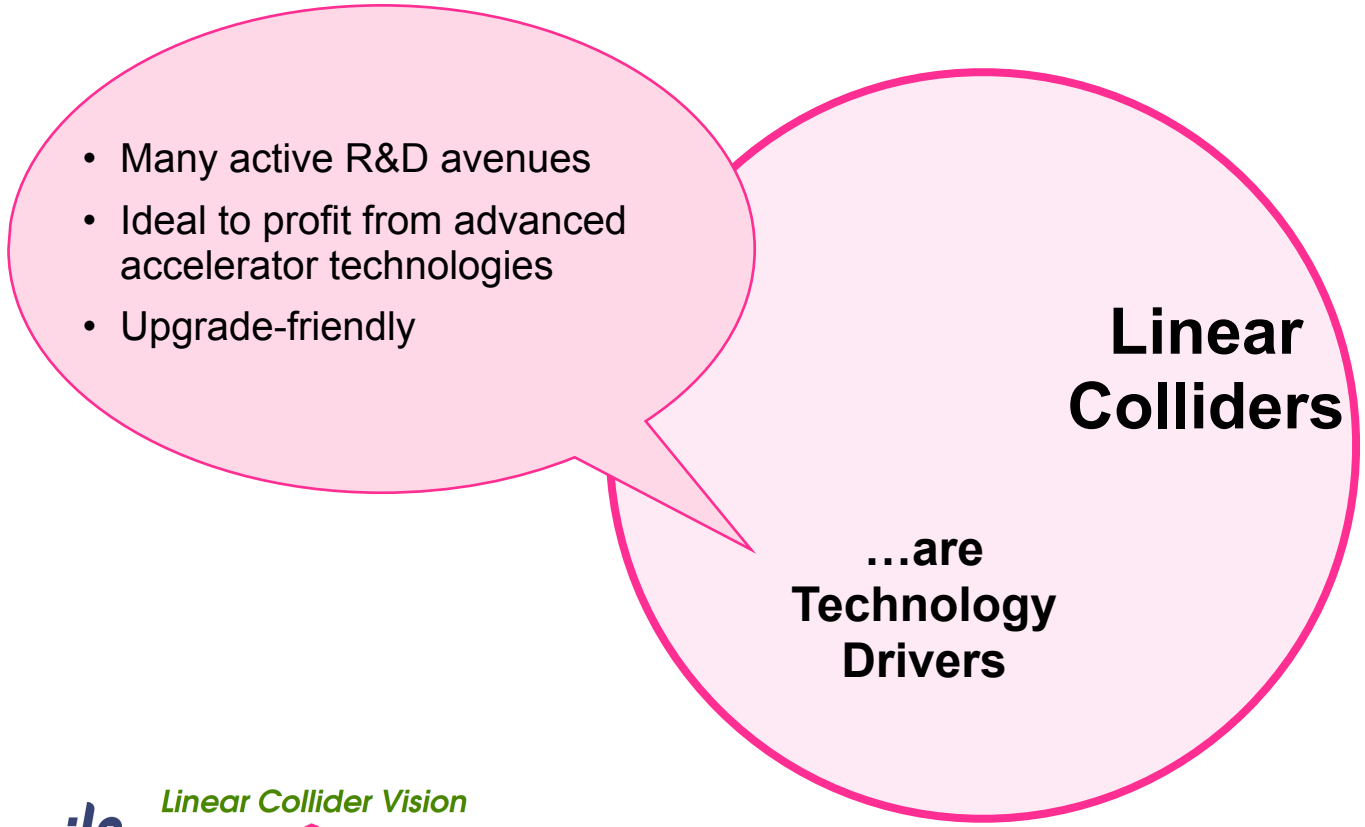
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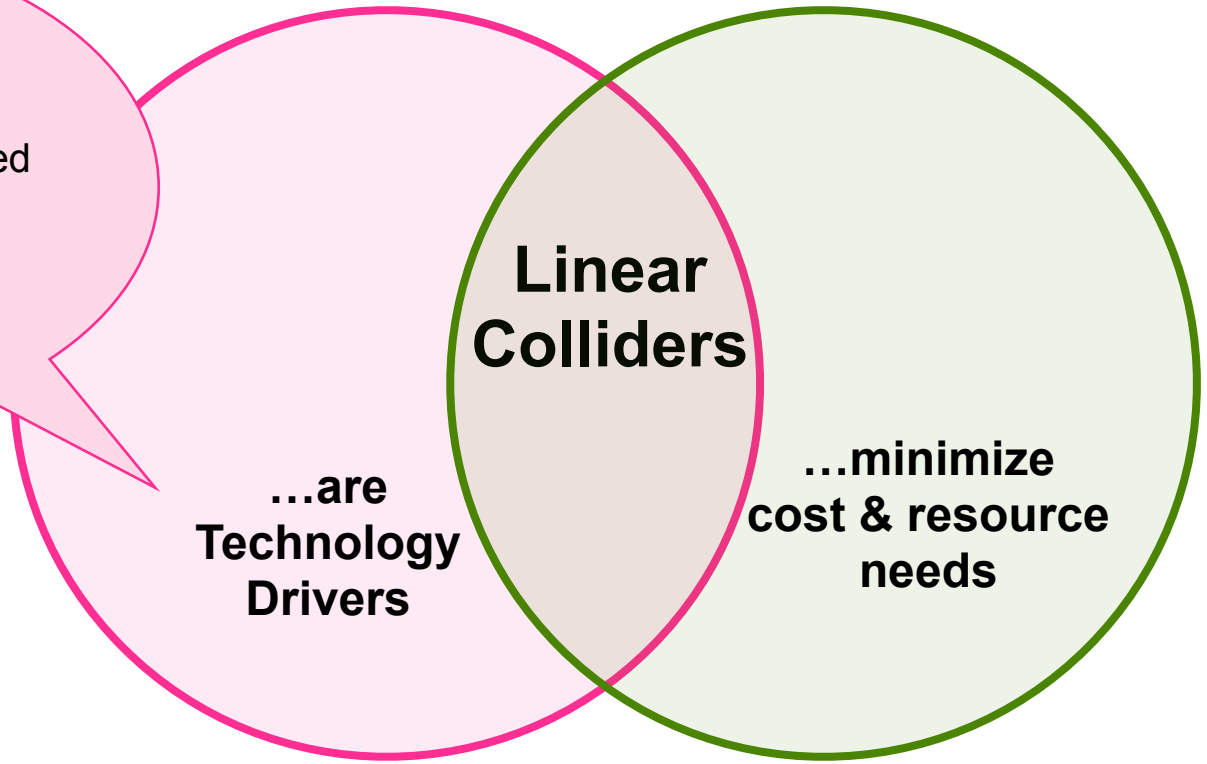
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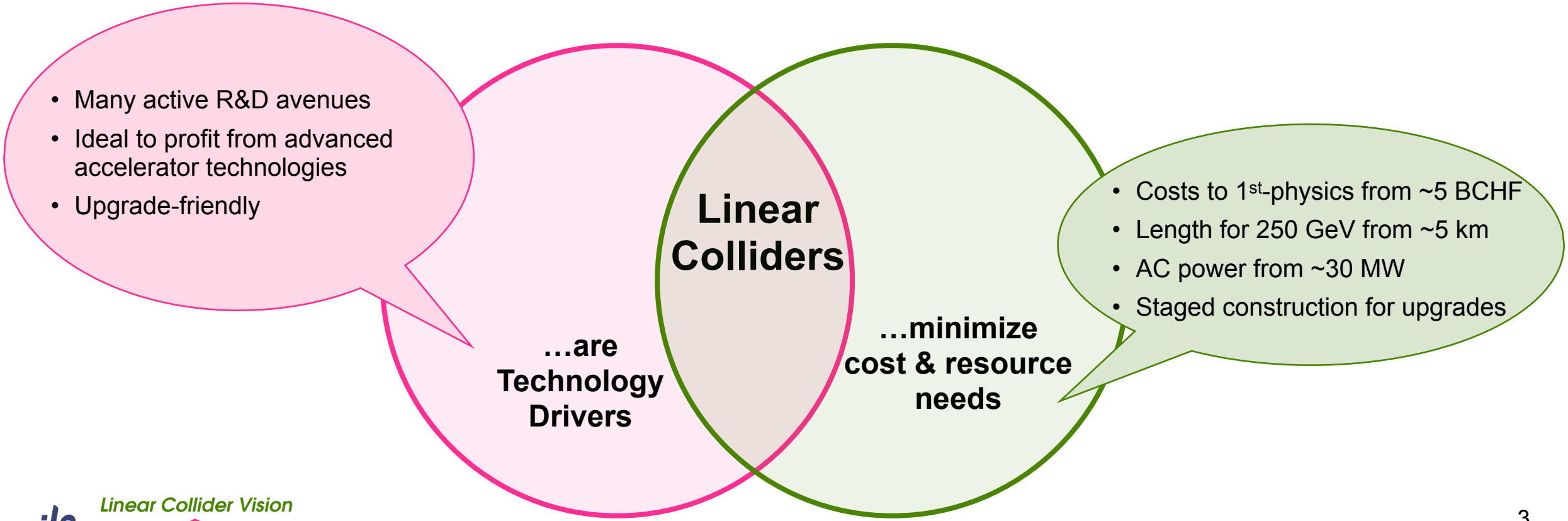
…in the age of FCC-ee

- Many active R&D avenues
- Ideal to profit from advanced accelerator technologies
- Upgrade-friendly



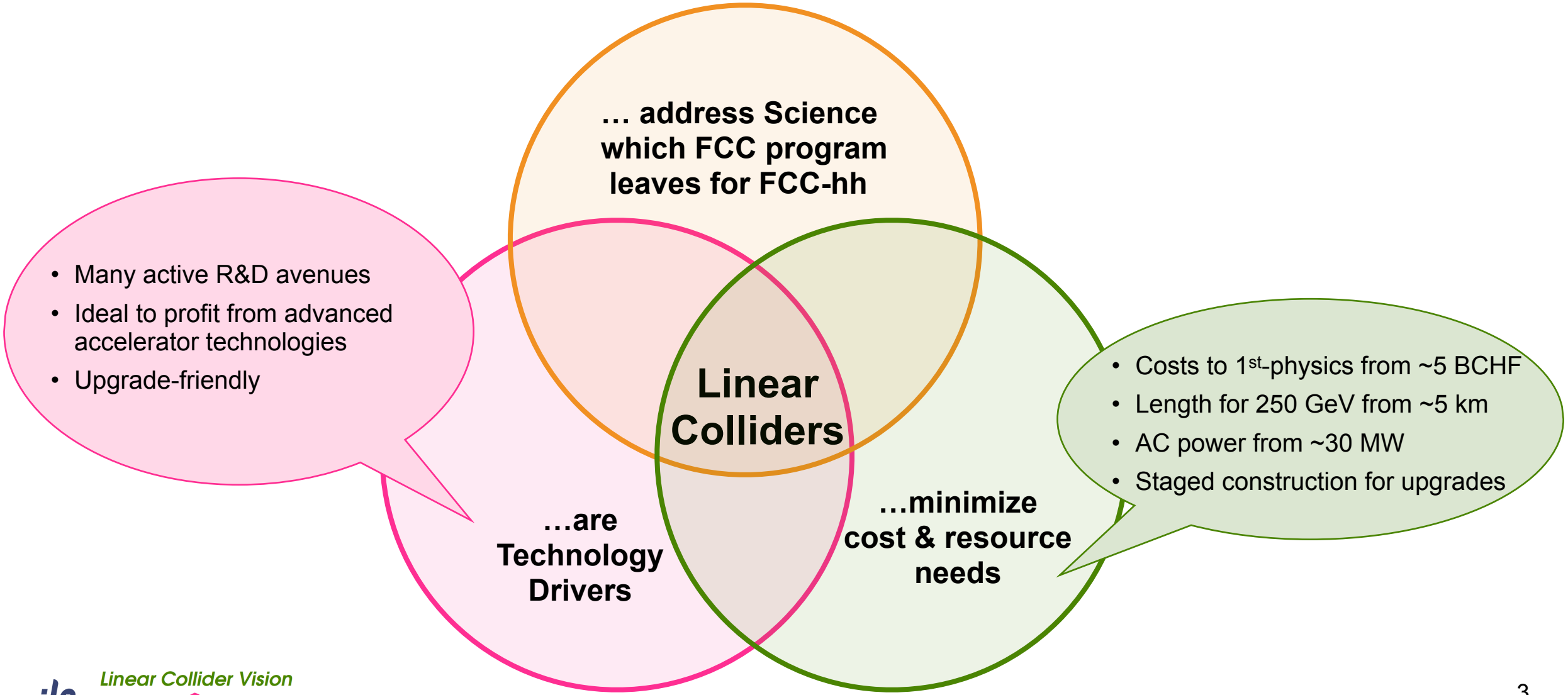
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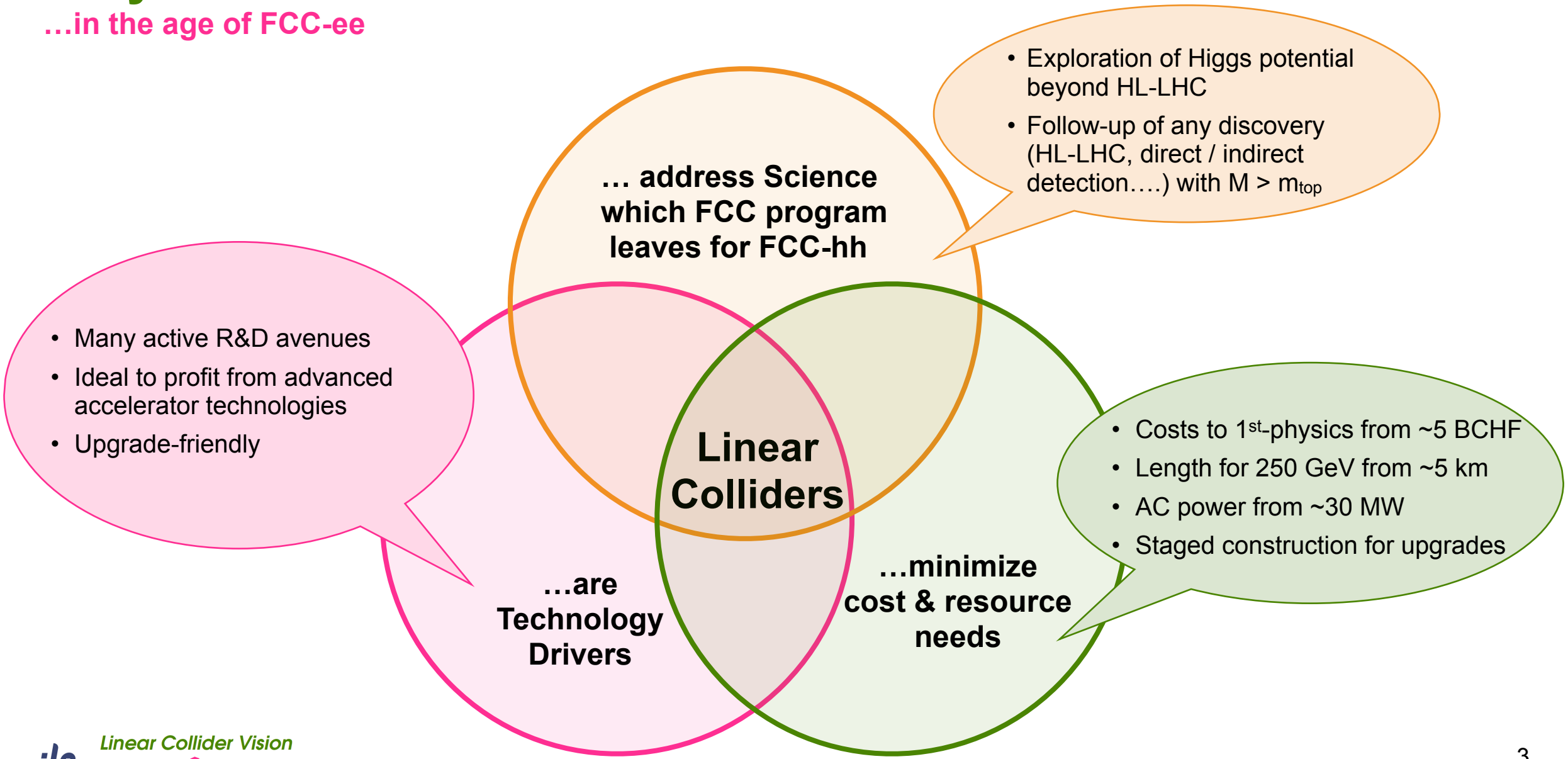
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Why we still talk about Linear Colliders

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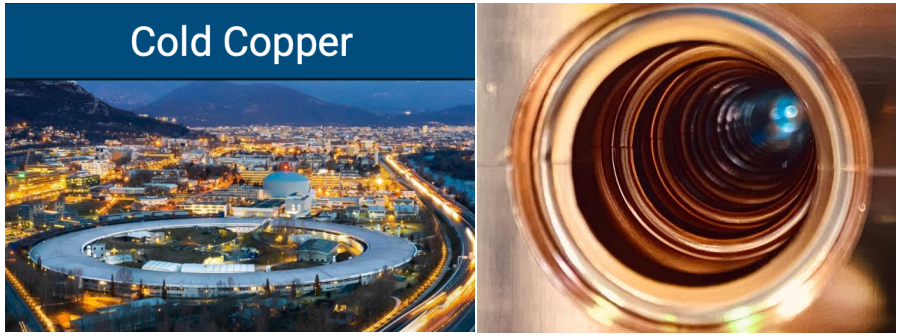


Linear Colliders as Technology Drivers

c.f. also talks by Peter & Emilio

High-Gradient SRF, Drive-beam, C3, HALHF, Ghost Collider, Photon Collider, …

- **Cool Copper Collider:** based on copper cavities at liquid-nitrogen temperatures (77K)
  - Gradients up to 150 MV/m
  - Considered for new injector at ESRF, decision in 2029, construction 2032-2035



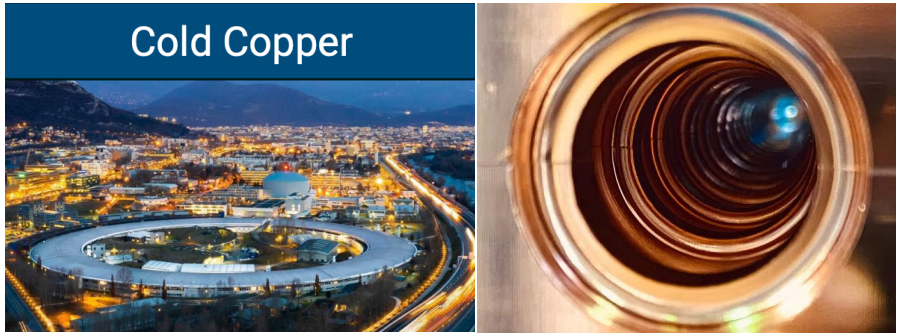
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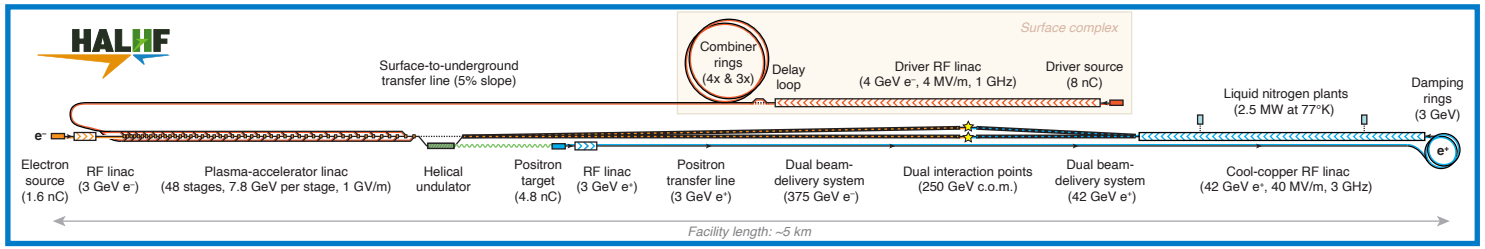
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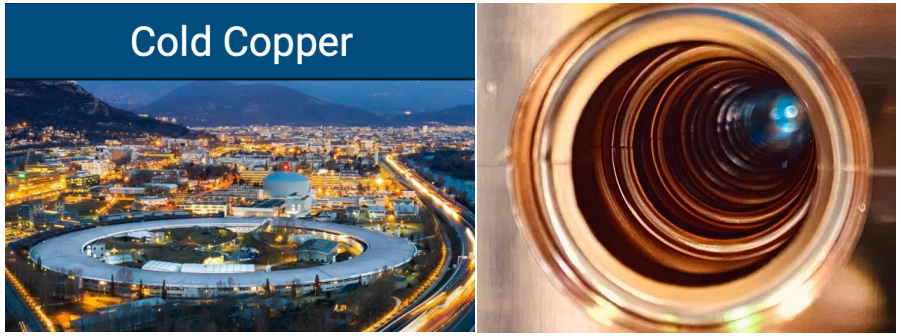
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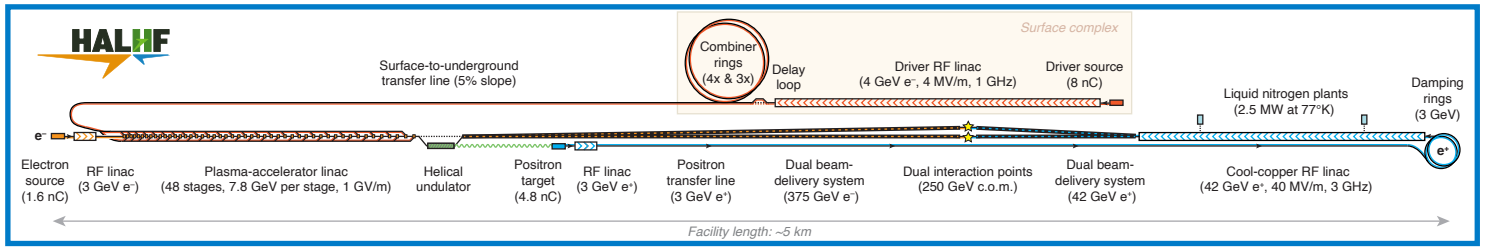
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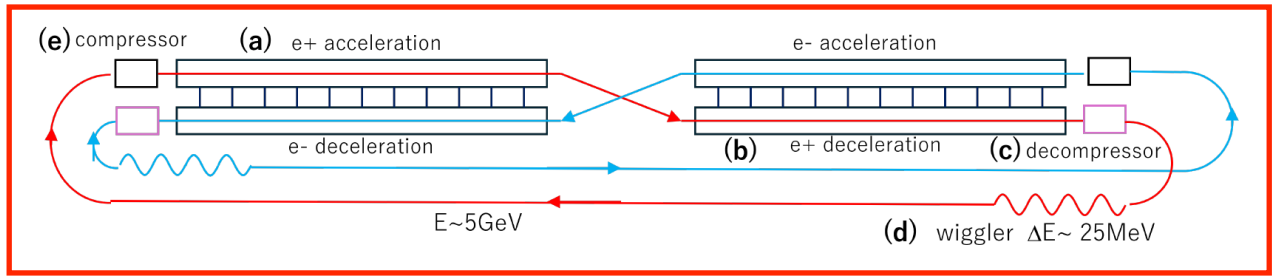
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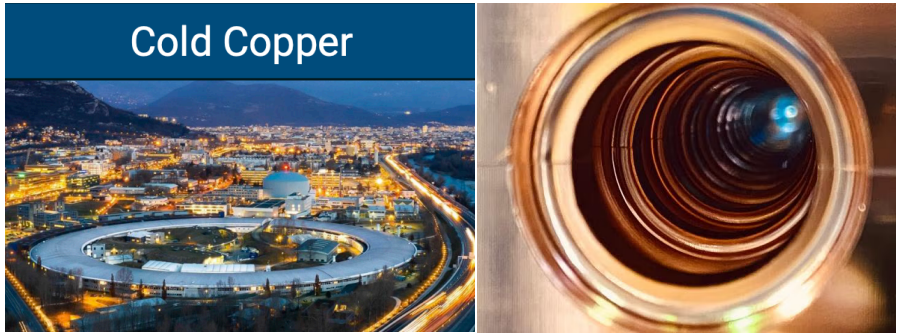


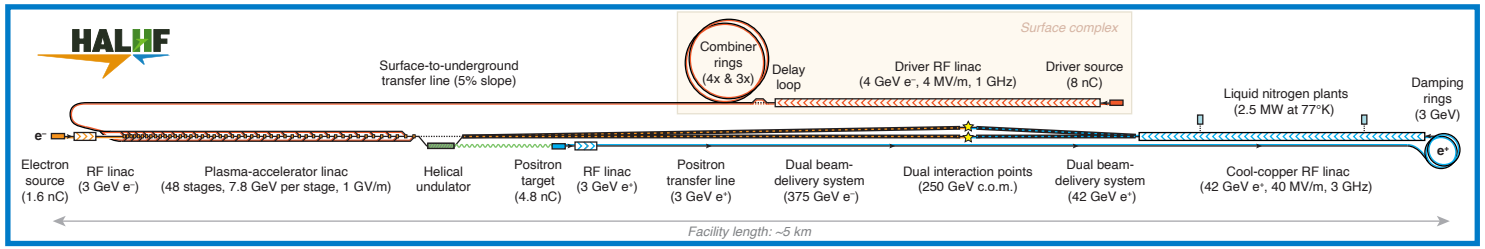
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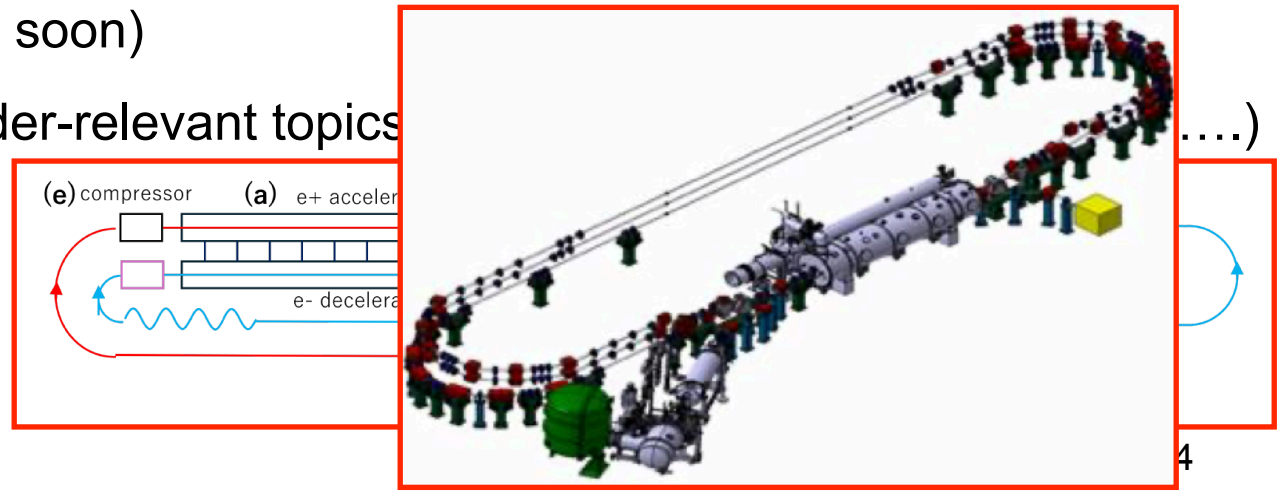
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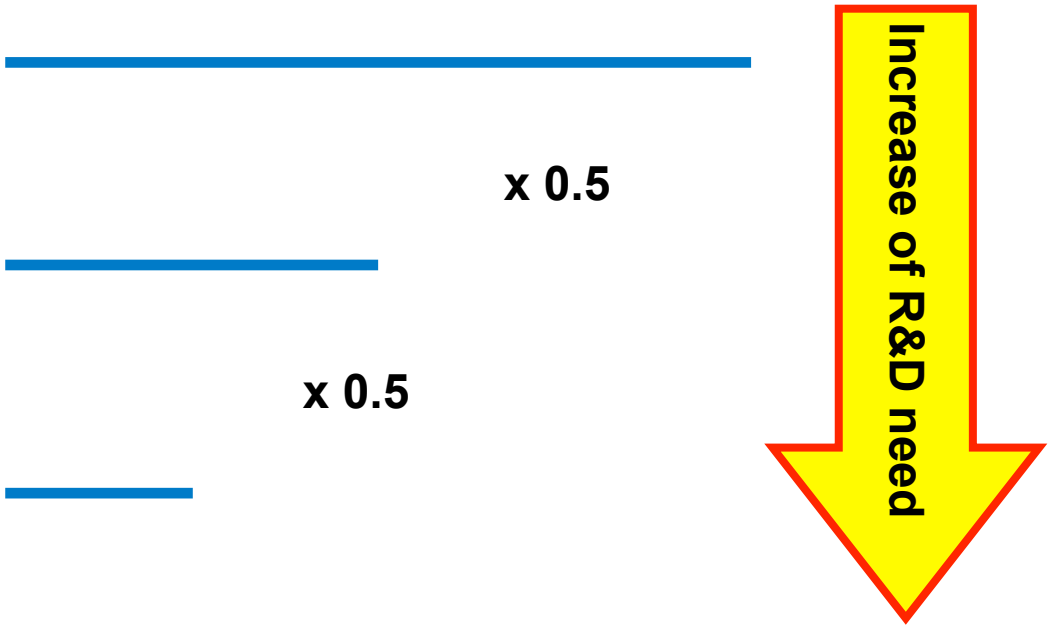
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Linear Colliders minimising resource need

Advanced technologies and staging allow to balance resources vs maturity

- Approximate length & cost* examples for 250 GeV machine
  - ILC-like SRF:
    - 20 km
    - 7…9 BCHF*
  - CLIC / C3:
    - ~8 km
    - ~5 BCHF*
  - HALHF:
    - ~3-5km
    - ~2 BCHF*



*Cost depends on luminosity & AC power etc; excl. R&D

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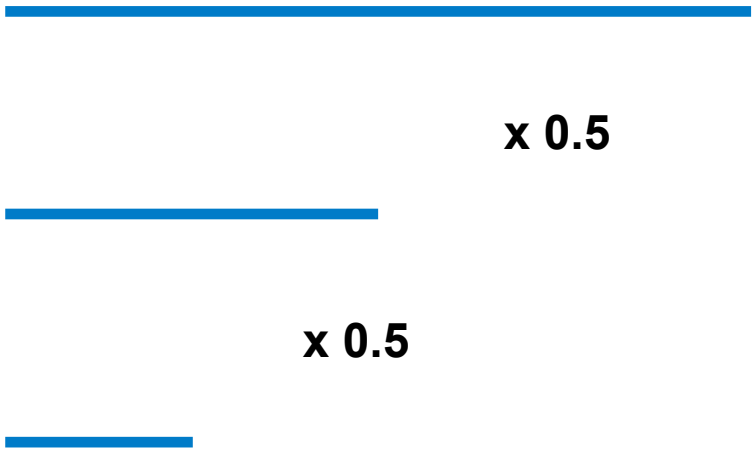
- Where is the sweet spot?
- Can one start more conventionally but compatible with advanced technology upgrades?

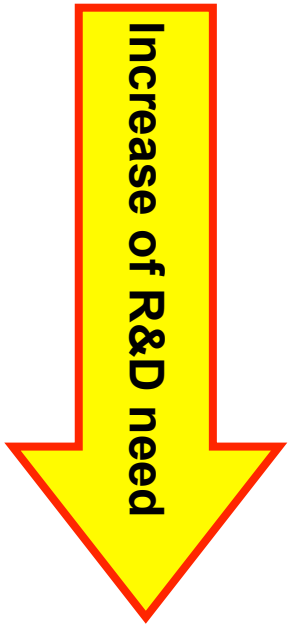
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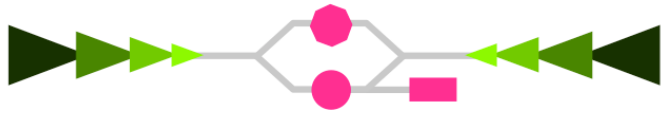
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Linear Collider Vision



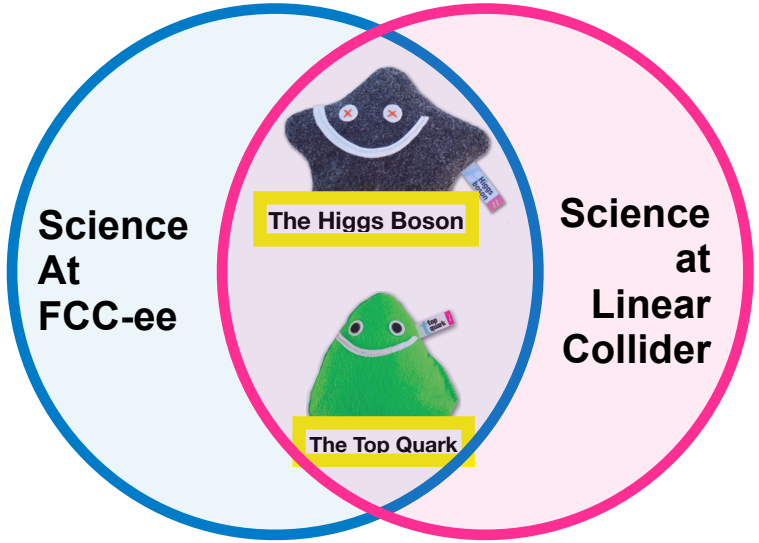
Eur.Phys.J.ST 235 (2026) 6, 1641-1796
arxiv:2503.19983

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Linear Colliders for Scientific Flexibility

Physics beyond the FCC-ee

Opportunities at circular and linear e+e- colliders partially overlapping - and partially complementary

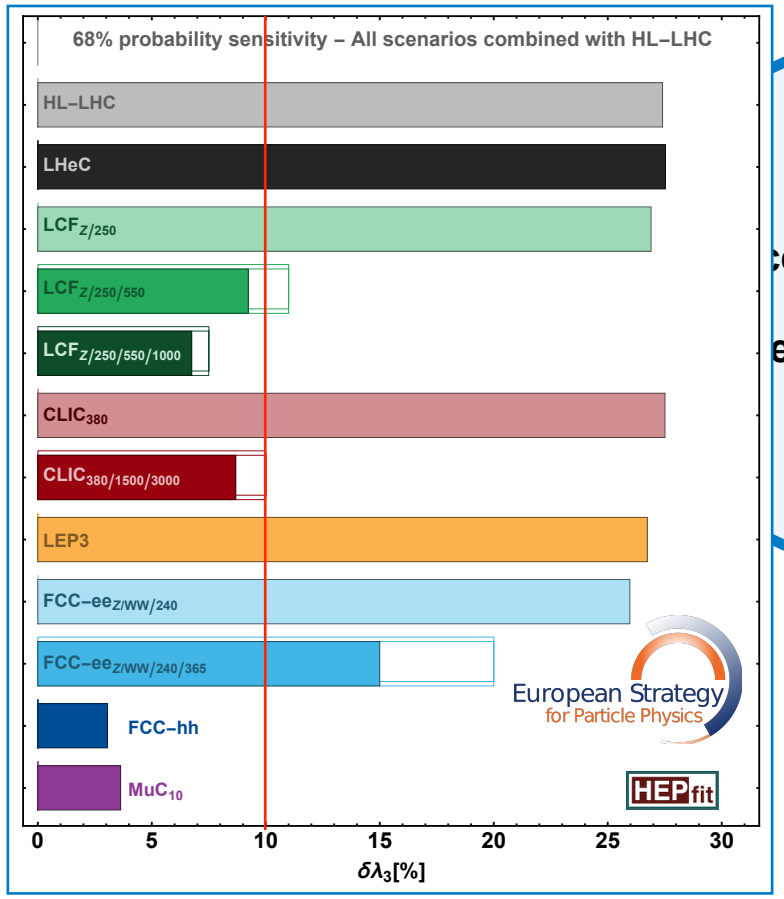


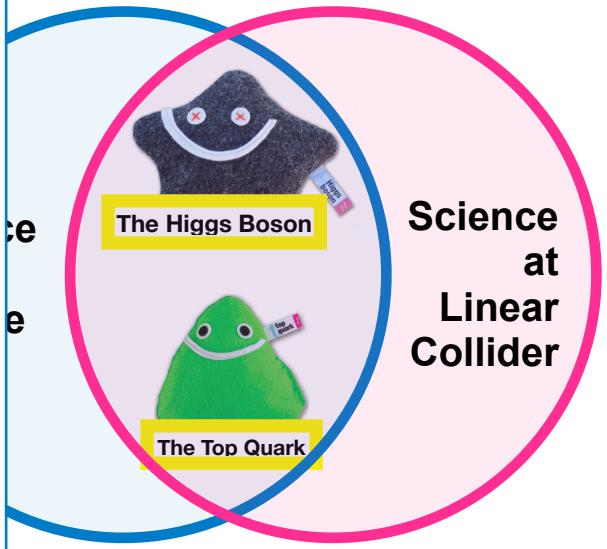
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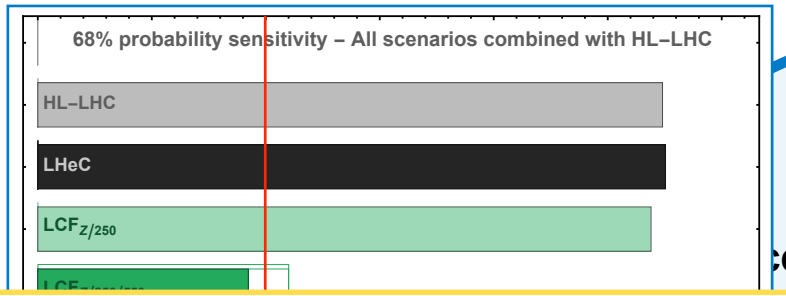


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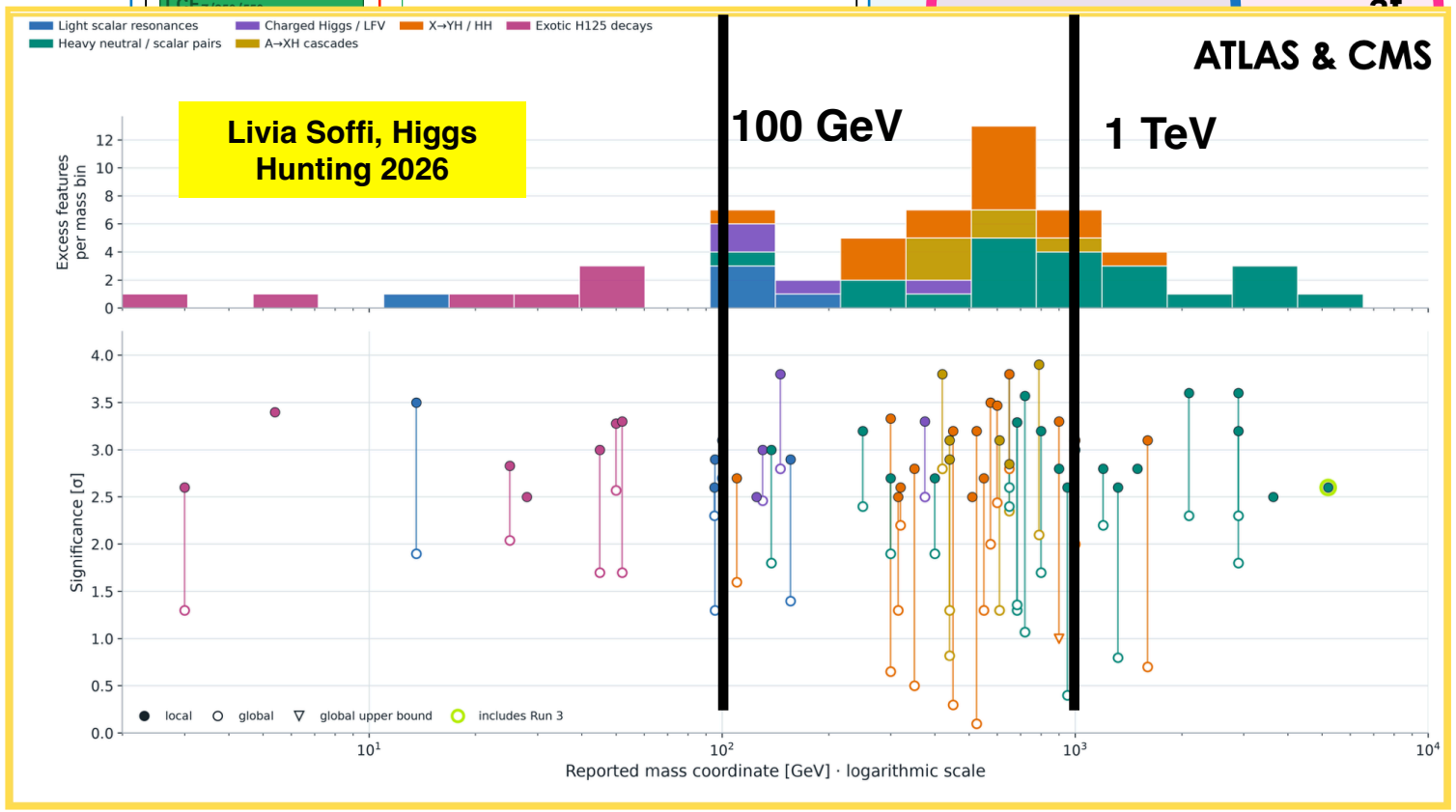
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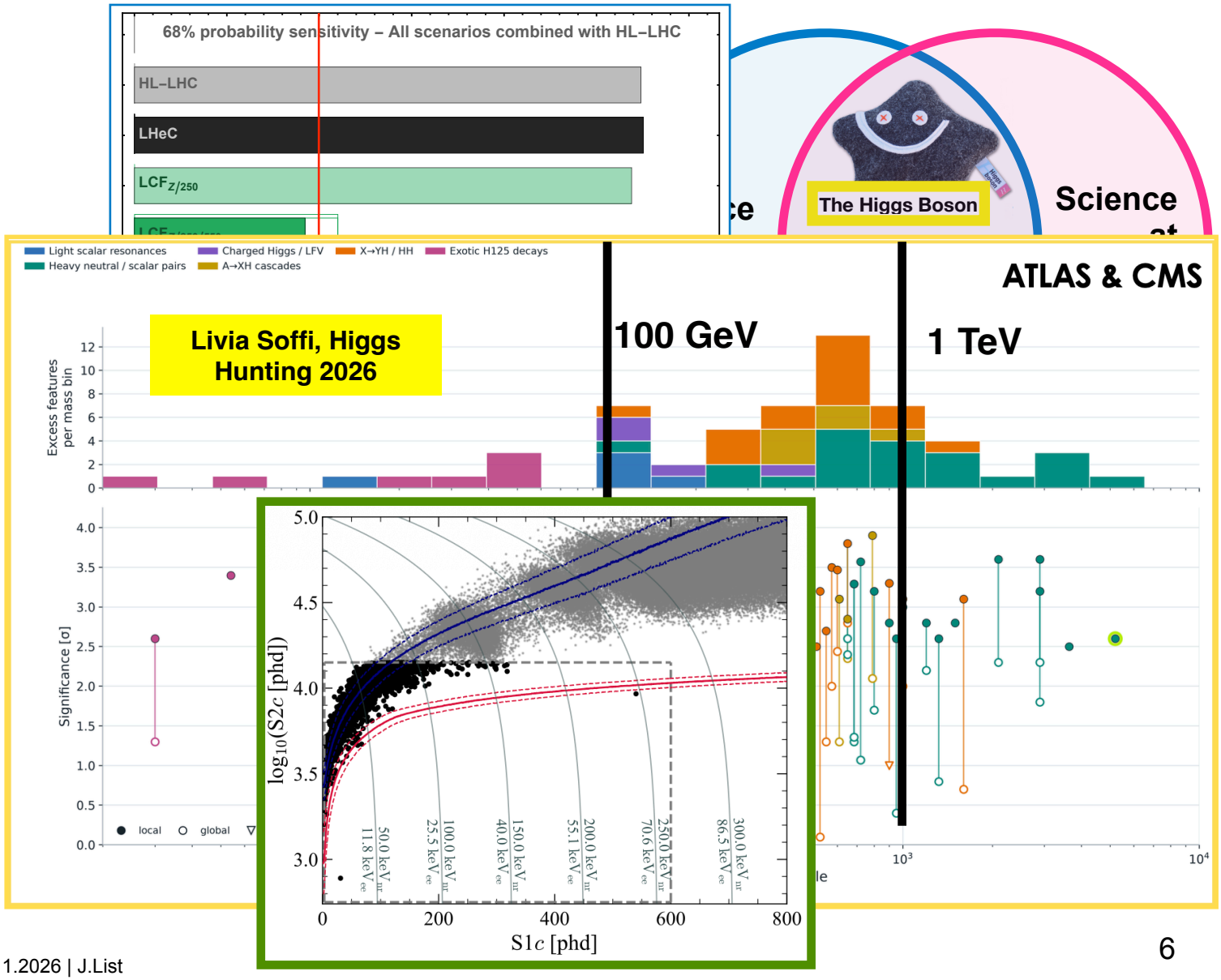


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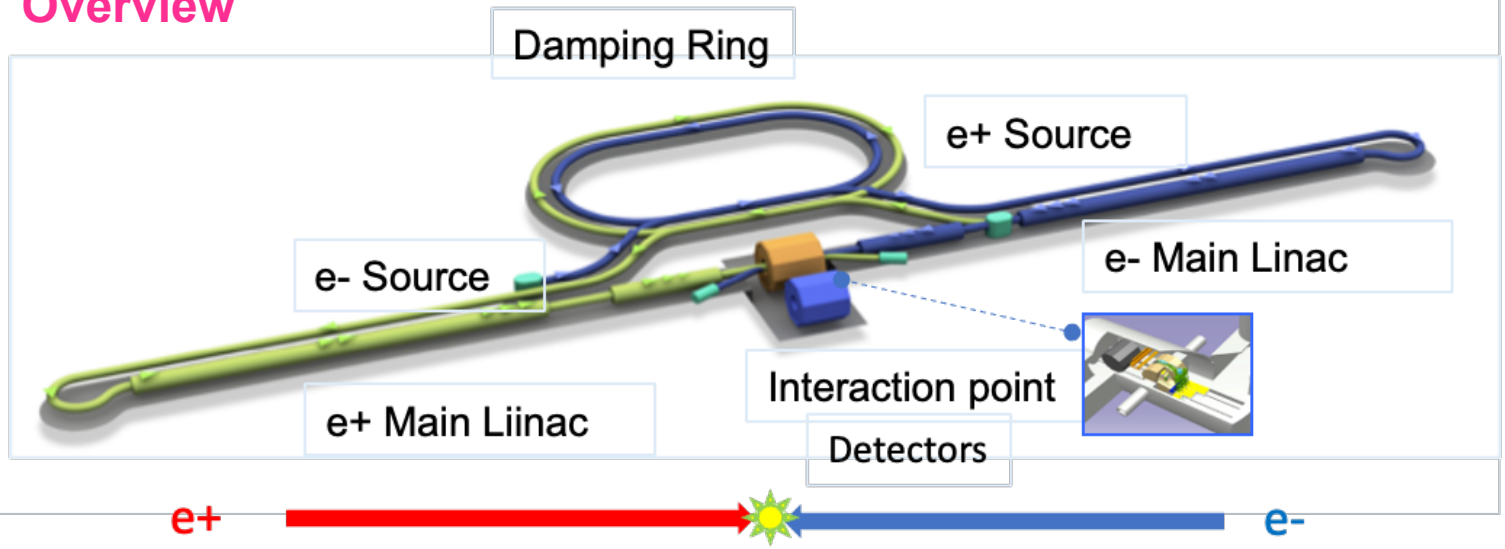
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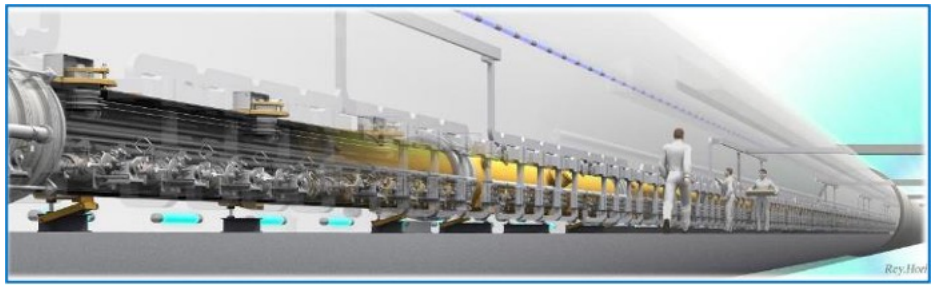


International Linear Collider

The International Linear Collider

Overview





Parameters	Value
Beam Energy	125 + 125 GeV
Luminosity	1.35 / 2.7 x 10^{34} cm^2/s
Beam rep. rate	5 Hz
Pulse duration	0.73 / 0.961 ms
# bunch / pulse	1312 / 2625
Beam Current	5.8 / 8.8 mA
Beam size (y) at FF	7.7 nm
SRF Field gradient	< 31.5 > MV/m (+/-20%) Q_0 = 1x10_{10}
#SRF 9-cell cavities (CM)	~ 8,000 (~ 900)
AC-plug Power	111 / 138 MW

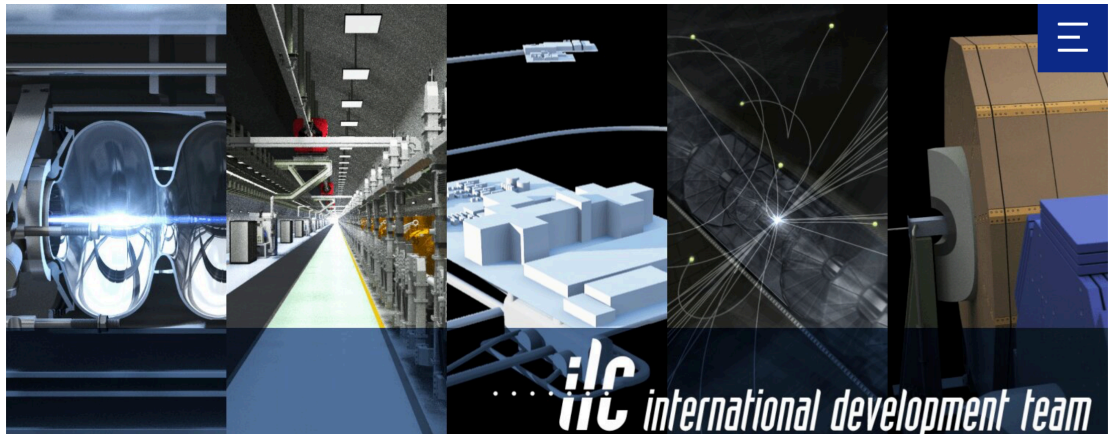
- Considered for construction in Japan as global project
- For cost reasons:
  500 GeV => 250 GeV, 1 IP, limited luminosity
- Maintained: Upgradability up to 1 TeV, both beams polarised
- Activities organised by
  - ILC International Development Team mandated by ICFA
  - ILC Technology Network supported by MEXT & labs

ILC International Development Team

The ICFA-mandated organisation geared towards realising the ILC in Japan

- Prepared proposal for the ILC pre-lab 2021
- **ILC Technology Network** installed in 2023 to move forwards with engineering studies
- ILC250 **cost estimate update** & international expert review in 2024 for the ESPPU2026
- Overseeing the organisation of Linear Collider Workshops
- WG2 (accelerator) & WG3 (physics & detectors) meeting regularly
- Activities in the forthcoming years discussed with ICFA





ILC250 Cost Update 2024

In view of ESPPU2026

1 ILCU = 1 USD in 2024

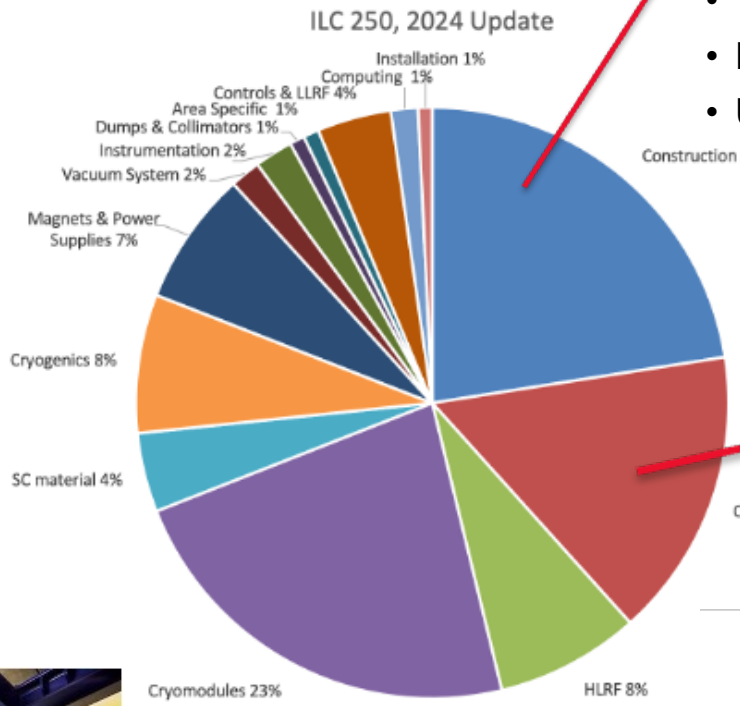
ILCU 2024 Conversions

Cost element type	ILCU→$	ILCU→€	ILCU→¥	ILCU→CHF
Civil construction (PPP)	1	0.596	81.8	0.606
Machinery & Equipment (PPP)	1	0.955	132.8	1.087
Superconducting Material (EX)	1	0.924	149.1	0.887

Comprehensive, bottom-up cost estimate

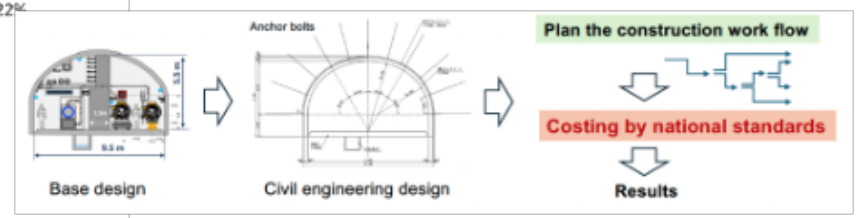
- Based on 2012 TDR methodology and numbers
- Updated to 2024 prices
- International Review Dec 2024 (chair: L. Rivkin)
- Available at [arXiv:2506.00353]

Total: 6.78BILCU + 196BJPY, 29% uncertainty



Construction (in Japan)

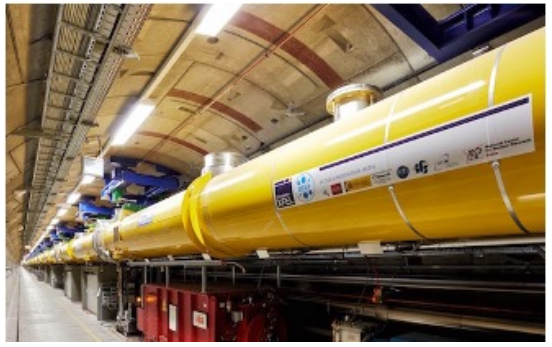
- 196 BJPY
- Follows Japanese costing standard
- Updated in 2024 (latest design, unit costs)



Accelerator

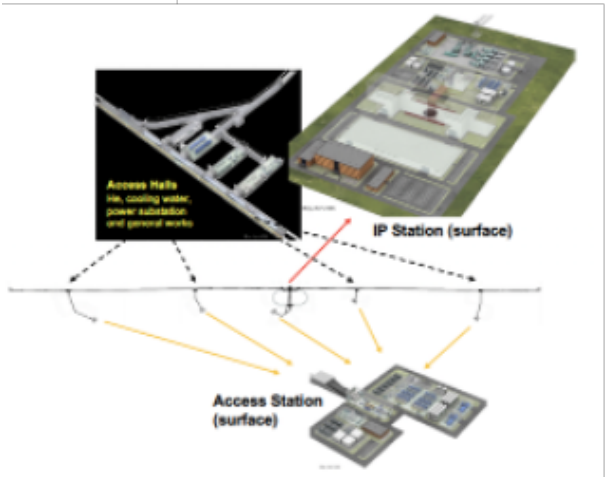


- 5.40 BILCU
- Bottom-up, component-wise
- Industrial quotes and procurement results
- SCRF: Updated prices 2024



Infrastructure

- 1.38 BILCU
- Updated cost estimate, based on industrial study



ILC Technology Network

Addressing high-priority work packages of pre-lab proposal

- Set up via agreements between KEK and participating labs from Asia and Europe (CERN as Hub-lab)
- Supported from MEXT-ATD (7 Oku-yen / year) and matching funds from labs
  => currently until end of March 2028
- >50-page mid-term report submitted in early 2026,
  cf. arXiv:2603.01172 [physics.acc-ph]
- Recent CERN ATS seminar by H. Sakai
- Significant progress on all key topics **SRF** / **sources** / **nano-beams**
- Very successful: **KEK plans to request MEXT a new round of funding**

WPP	SRF & crab	1	Cavity production
WPP		2	CM design
WPP		3	Crab cavity
WPP	Nano-beams e⁺ / e⁻ sources	4	E- source
WPP		6	Undulator target
WPP		7	Undulator focusing
WPP		8	E-driven target
WPP		9	E-driven focusing
WPP		10	E-driven capture
WPP		11	Target replacement
WPP		12	DR System design
WPP		14	DR Injection/extraction
WPP		15	Final focus
WPP		16	Final doublet
WPP		17	Main dump

Interest/capability matrix from 28 labs/universities

SRF	WPP	1	Cavity production	✓		✓	✓	✓			✓	✓	✓				✓	✓	✓		✓	✓		✓	✓	
	WPP	2	CM design	✓				✓				✓			✓	✓	✓	✓	✓	✓			✓		✓	✓	
	WPP	3	Crab cavity			✓	✓							✓					✓			✓	✓		✓	✓
Sources	WPP	4	E- source			✓						✓							✓		✓			✓		
	WPP	6	Undulator target				✓												✓	✓			✓			
	WPP	7	Undulator focusing				✓												✓	✓			✓			
	WPP	8	E-driven target	✓		✓												✓	✓							
	WPP	9	E-driven focusing	✓														✓	✓							
	WPP	10	E-driven capture	✓															✓					✓		
	WPP	11	Target replacement	✓																						
Nano-beams	WPP	12	DR System design	✓	✓				✓	✓		✓							✓				✓	✓		
	WPP	14	DR Injection/extraction	✓					✓										✓				✓	✓		
	WPP	15	Final focus	✓			✓		✓		✓							✓			✓			✓		
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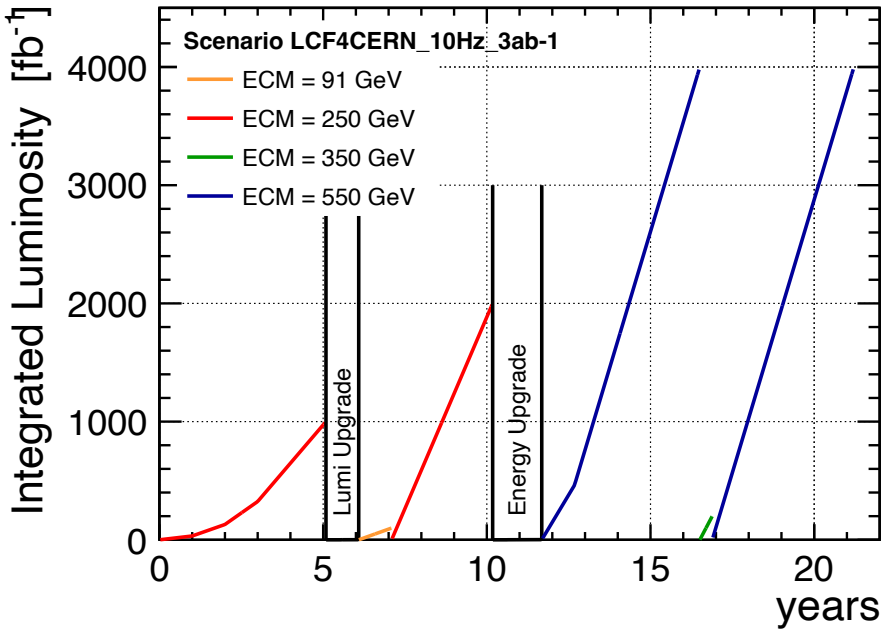
Linear Collider Facility

The Linear Collider Facility

Design Philosophy

- **Start as soon as possible with**
  - A **proven technology**, with well-understood costs, risks etc
  - At **minimal cost** enabling a precision analysis of the Higgs boson as first step
  - A well-defined and cost-controlled second stage, “two-Higgs mode”, 10 years later, **without further civil construction**

LCF proposal for ESPPU
arxiv:2503.24049



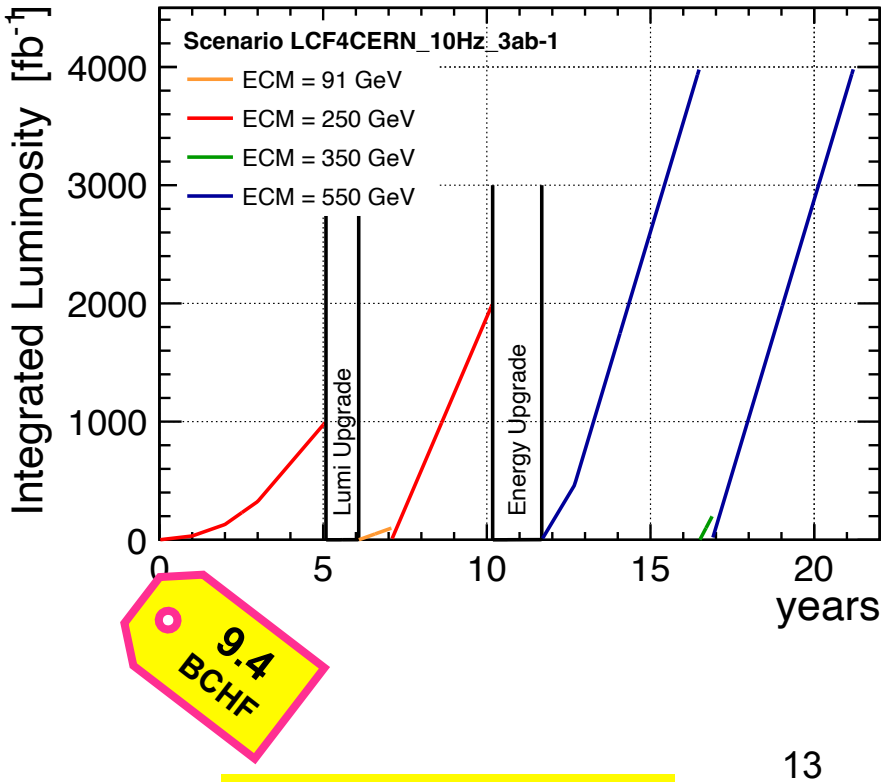
Incl. detectors - 0.8 BCHF for 2 experiments

The Linear Collider Facility

Design Philosophy

- **Start as soon as possible with**
  - A **proven technology**, with well-understood costs, risks etc
  - At **minimal cost** enabling a precision analysis of the Higgs boson as first step
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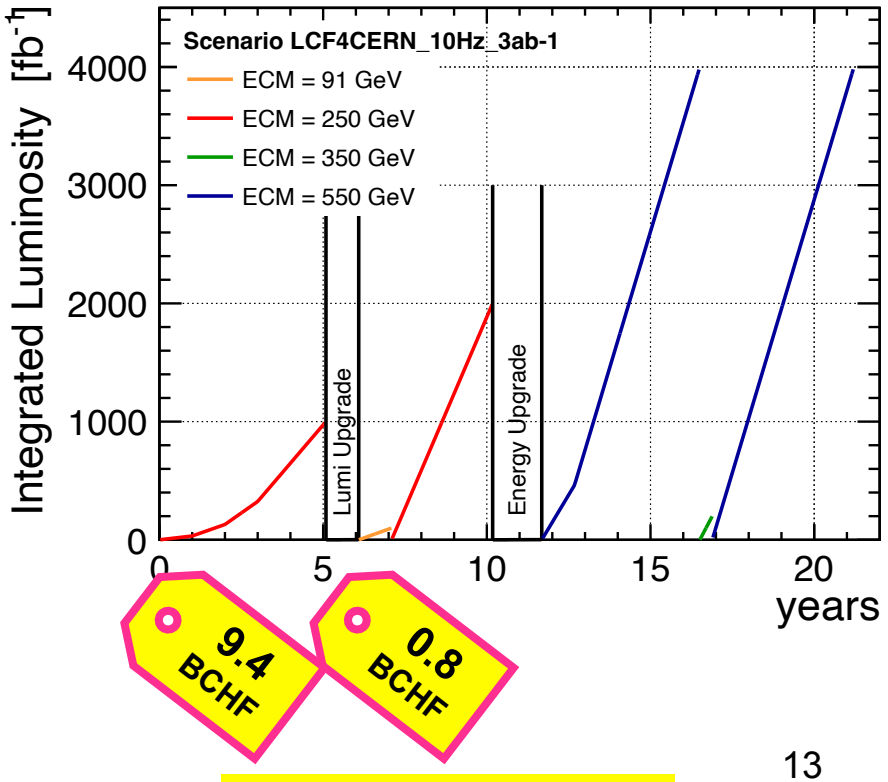
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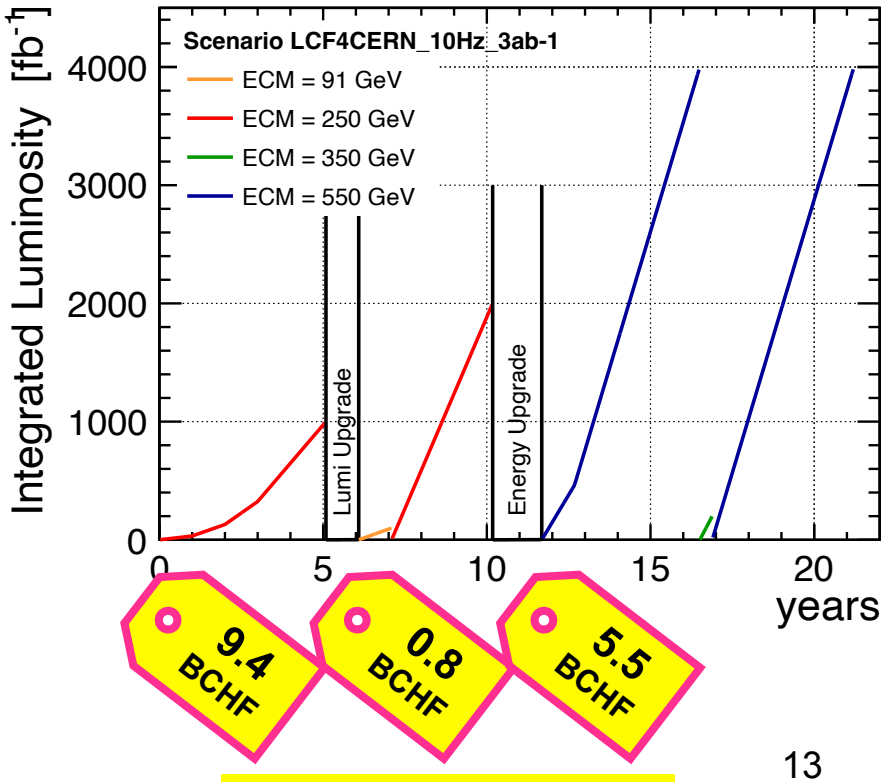
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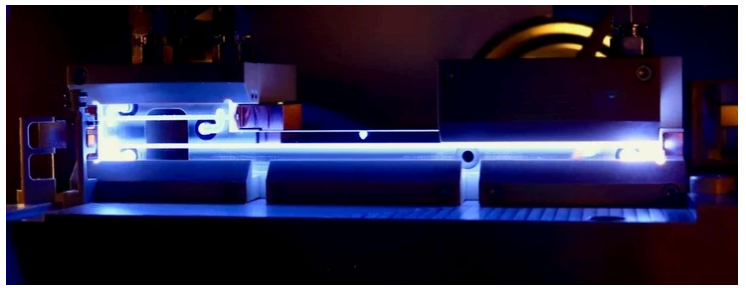
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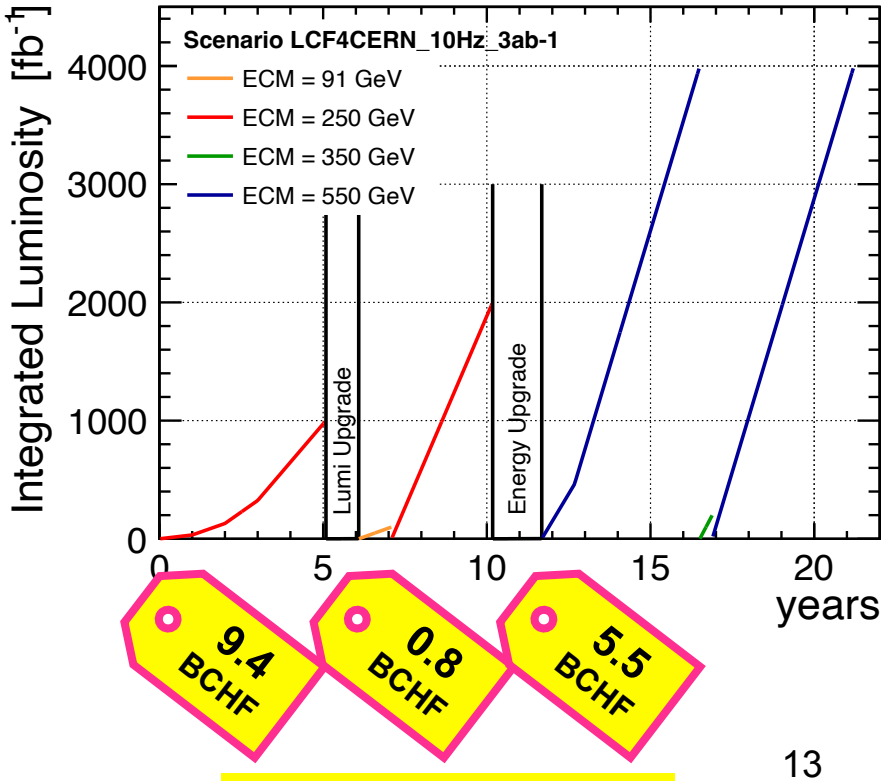
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- **Stay flexible** with regard to the long-term future
- Develop facility based on **scientific developments** => initial design compatible with developing & exploiting **advanced technologies**
- Benefit from **technological developments** - or even break-throughs
  - Better (“higher-gradient”) accelerating structures (“cold niobium” or “cool copper”)
  - Plasma-acceleration
  - Combine particle beam with laser beams “photon collider”
  - Energy (& particle) recovery
  - ….





Incl. detectors - 0.8 BCHF for 2 experiments

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As proposed for the ESPPU 2026

Superconducting RF technology (like ILC):

- successful construction & operation of Eu.XFEL, LCLS-II…
  => no large-scale demonstrator step needed
- lab experience and production capacities in industry globally
- **choice for fastest implementation & most attractive for global (in-kind) contributions**

Scope project to be a flagship project for CERN:

- 33.5 km to reach di-Higgs production with today's technology
- 2 interaction regions
- 2-4x higher luminosity than ILC
- add-on facilities (Beyond Collider, R&D / irradiation facilities)

Like ILC:

- both beams polarised: e-: 80% / e+: 30% (60%)
- operation at Z pole (eg 100fb^{-1}) / WW threshold (eg 500fb^{-1}) as needed

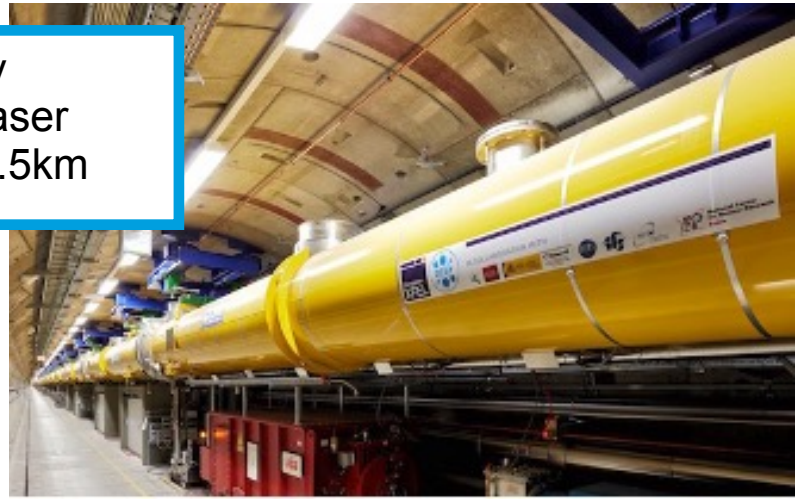
Adapted to CERN site:

- Round TBM tunnel
- Civil construction &
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European X-Ray
Free-Electron Laser
in Hamburg, ~ 1.5km



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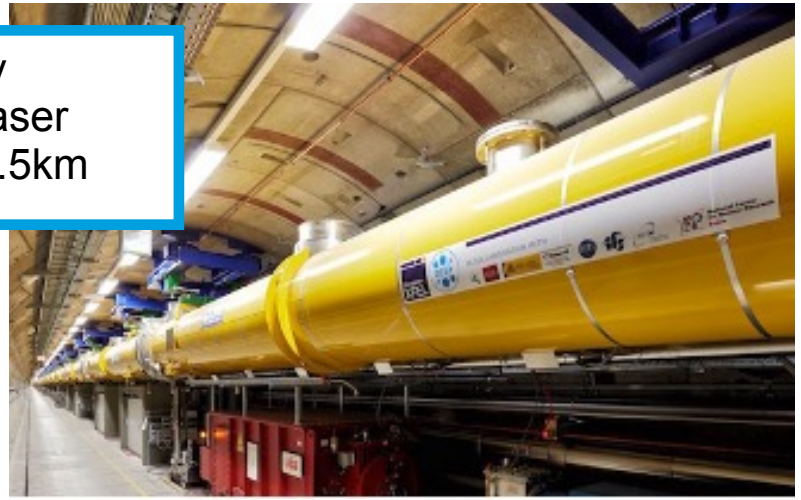
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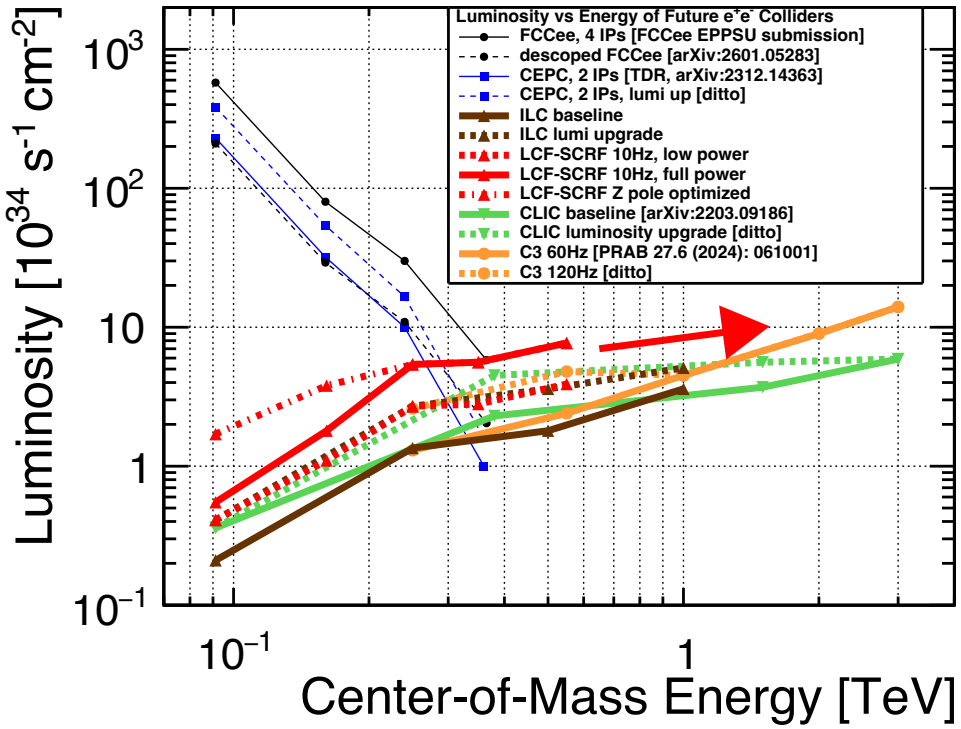
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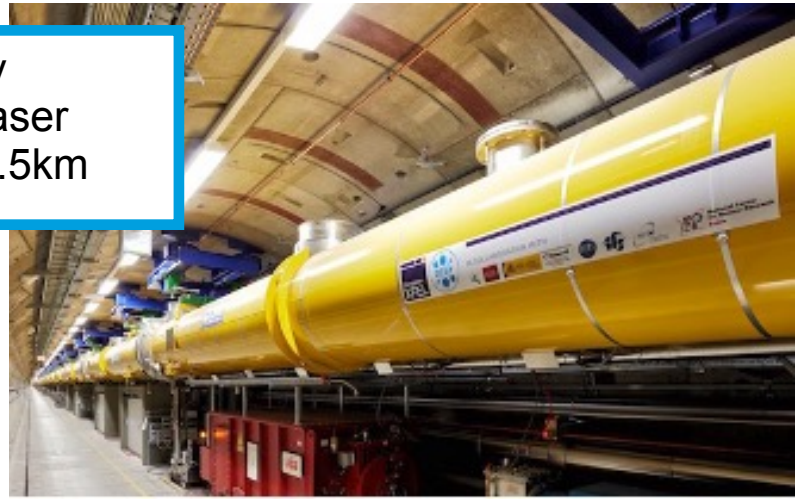
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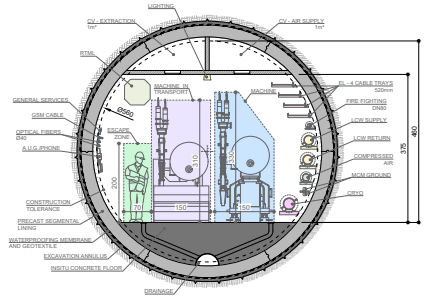
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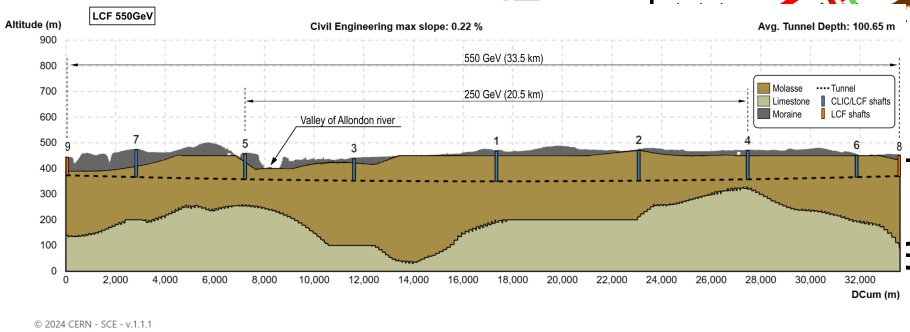
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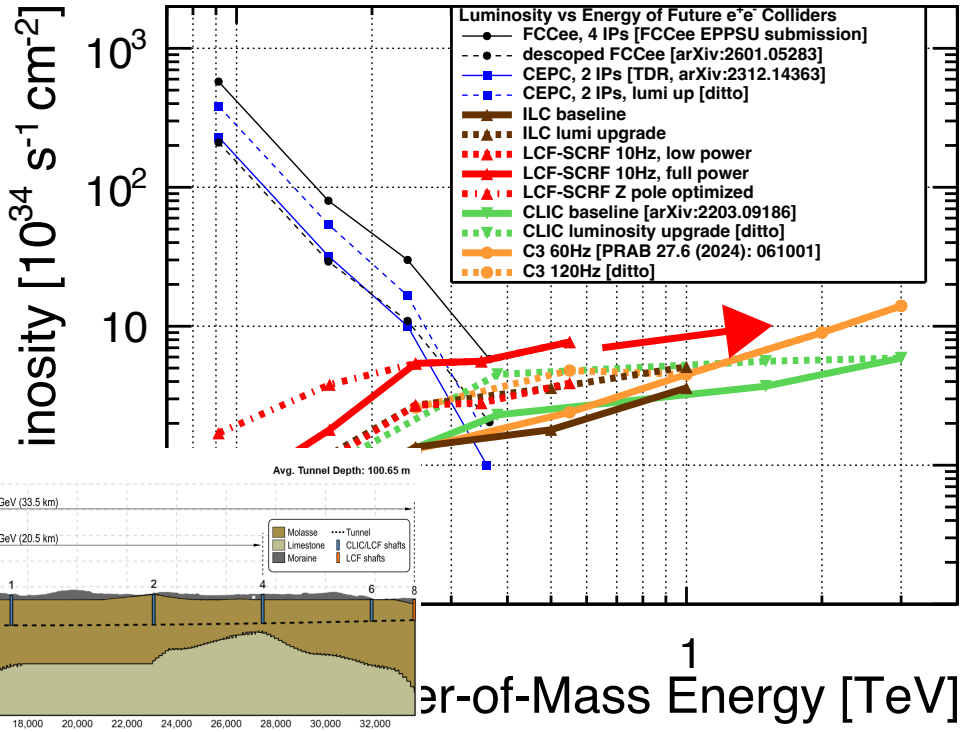
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LCF proposed and fostered by LCVision Team

Global bottom-up initiative started at LCWS 2024

- Bi-weekly zoom meetings of LCVision Coordination Group
- Comprises representatives of
  - all LC flavours / technologies (LCF, ILC, CLIC, C3, HALHF, ERL-based schemes, Photon Colliders, full PWA, …)
  - Physics, detectors, software, theory, beyond collider, …
- Annual 2-day workshops with 220-250 participants
  - Jan 8-10, 2025 https://indico.cern.ch/event/1471891/
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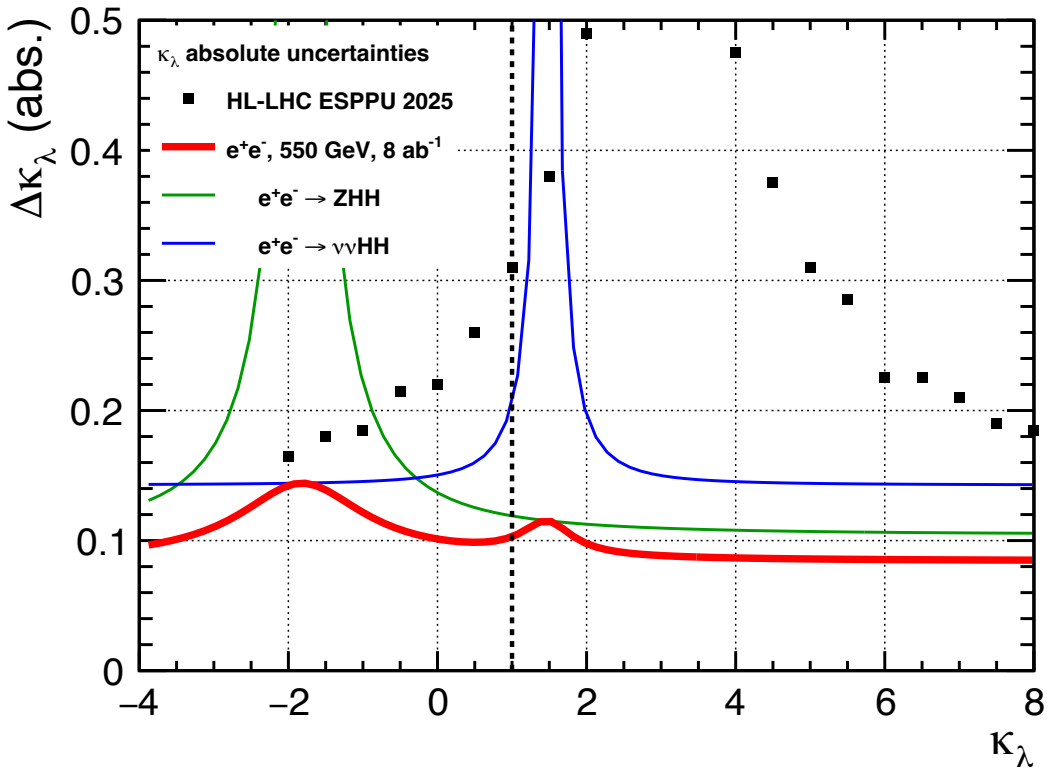


Open, bottom-up community activity => anybody interested is welcome to get in touch!

Example of an LCVision activity

Exploration of Higgs potential beyond HL-LHC: di-Higgs, extra Higgs bosons, EW phase transition

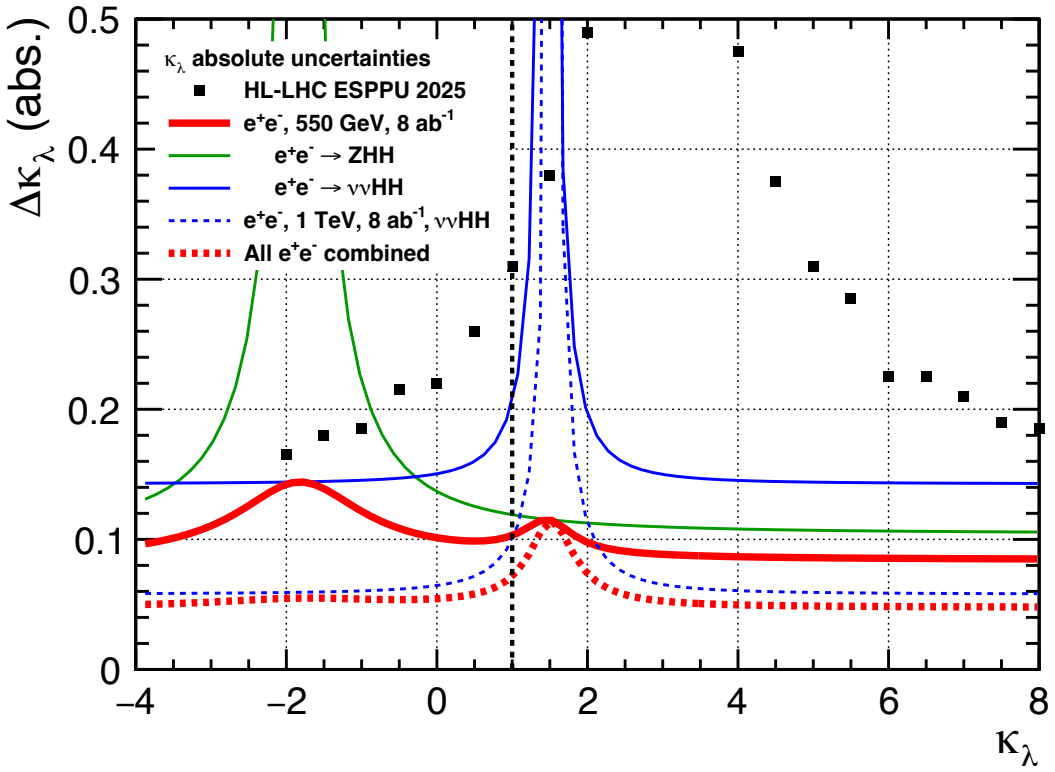
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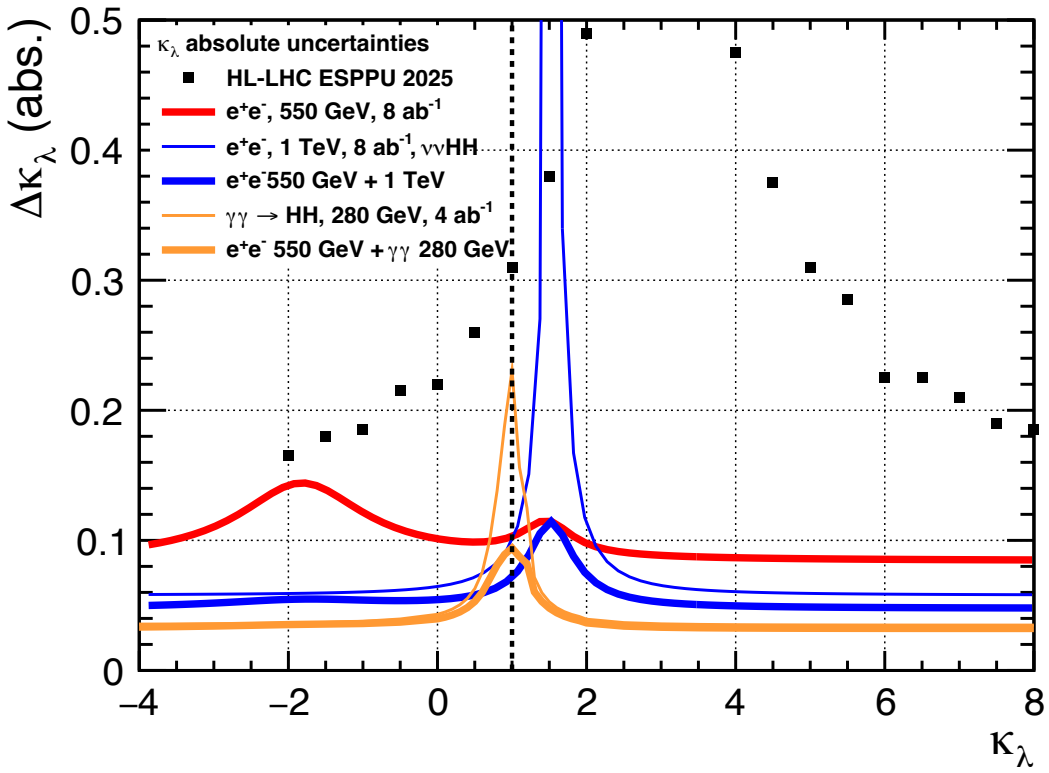
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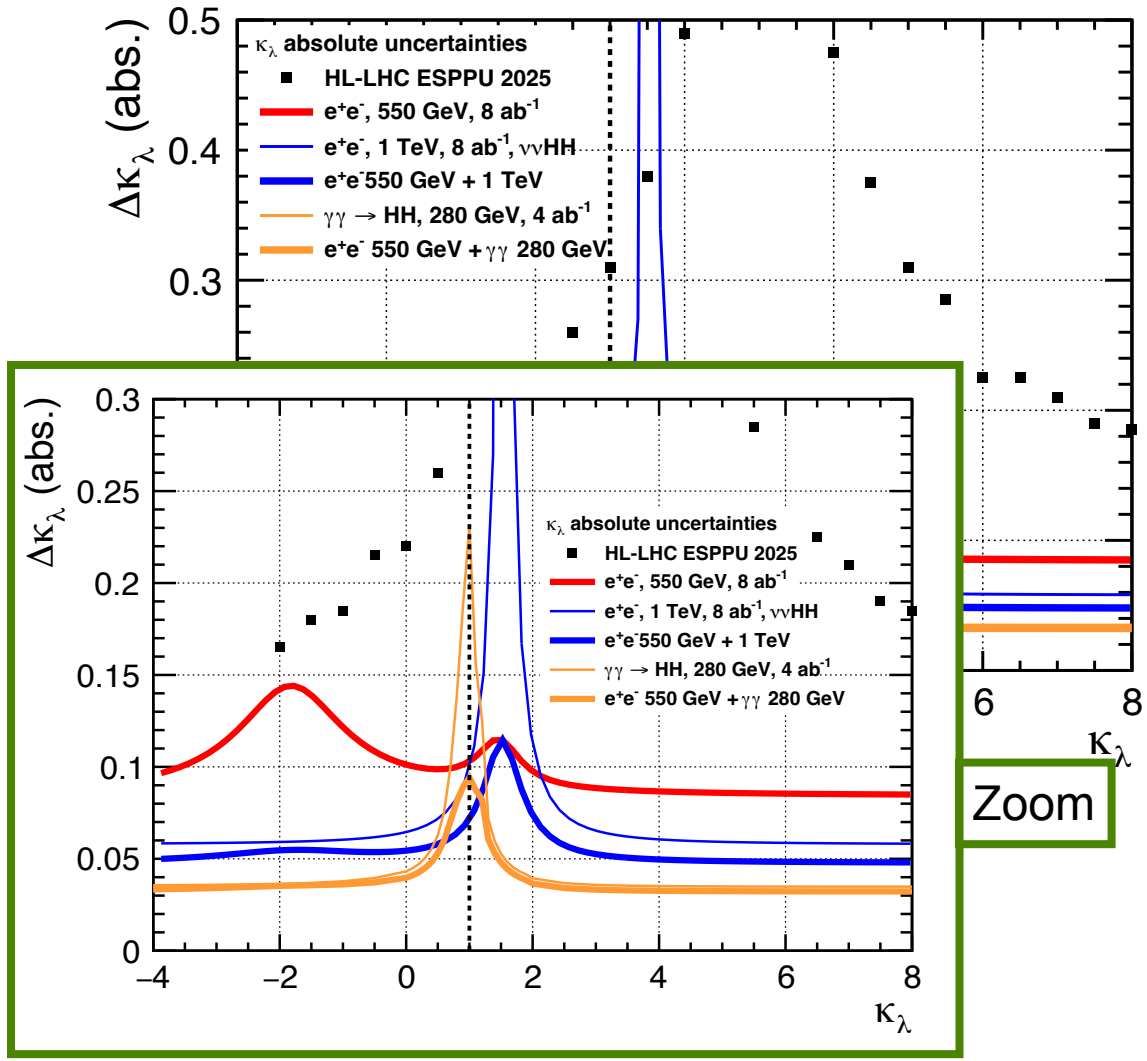
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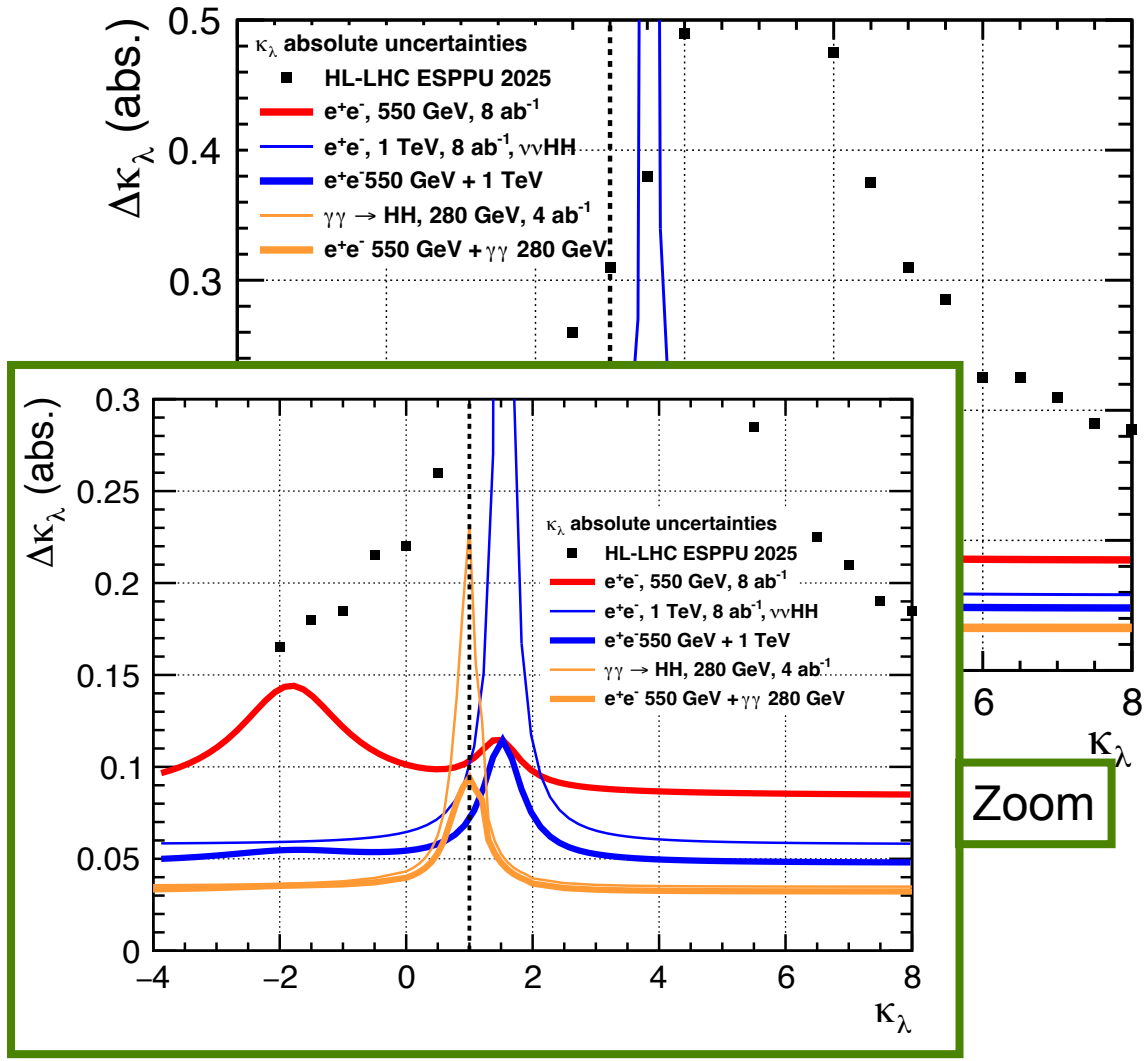
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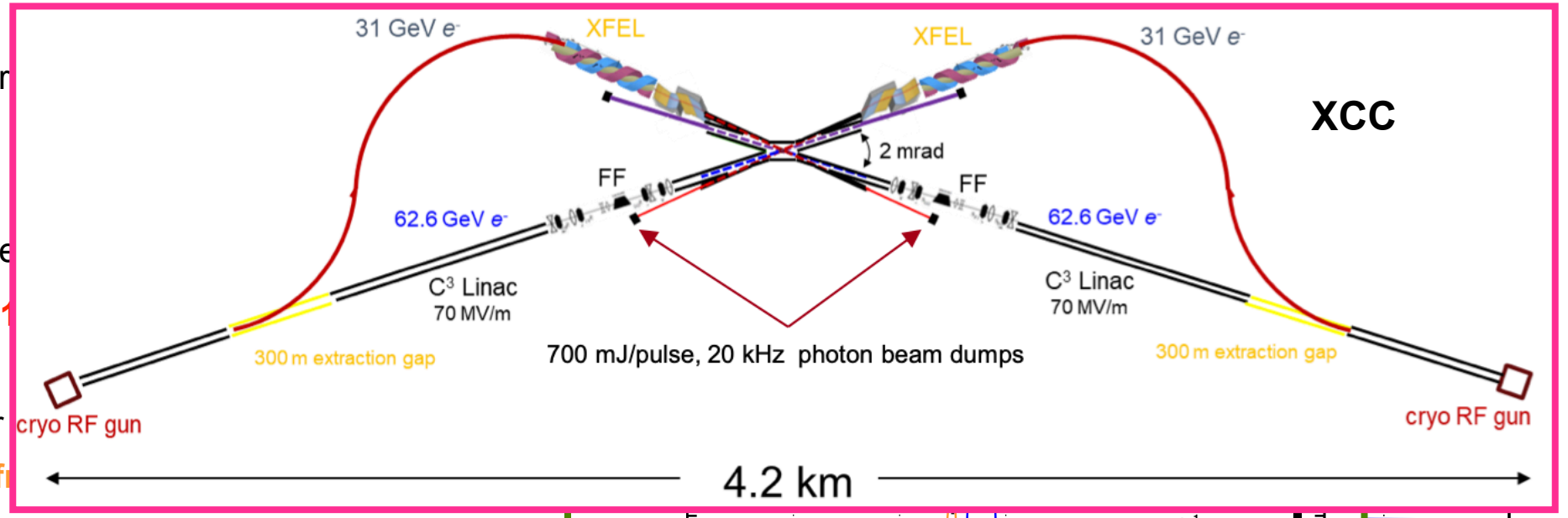
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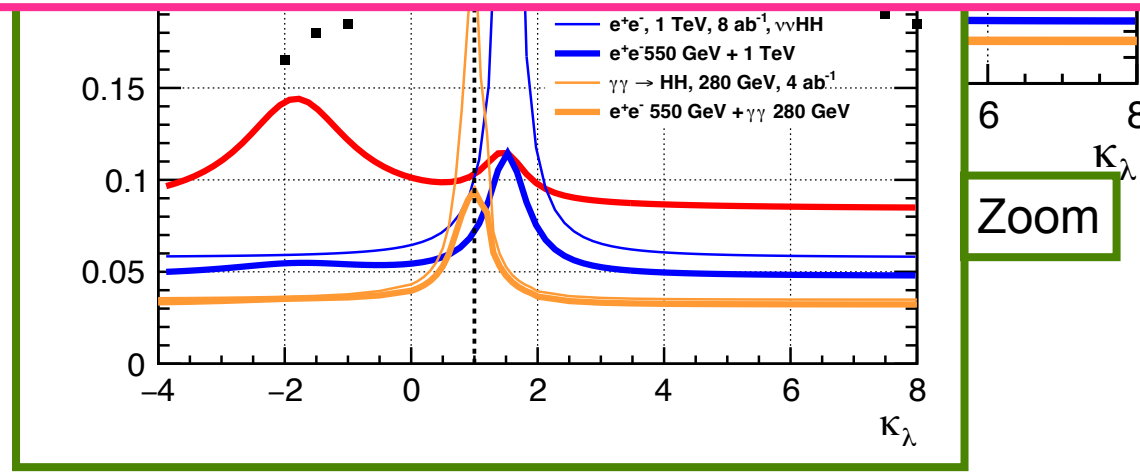


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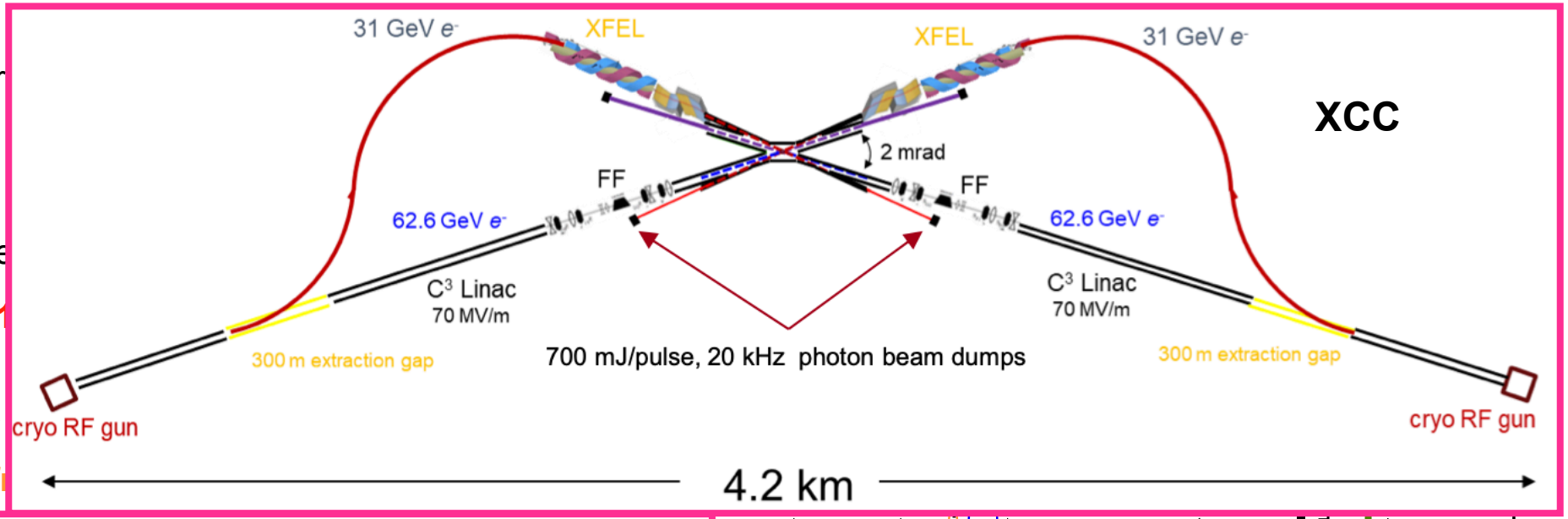




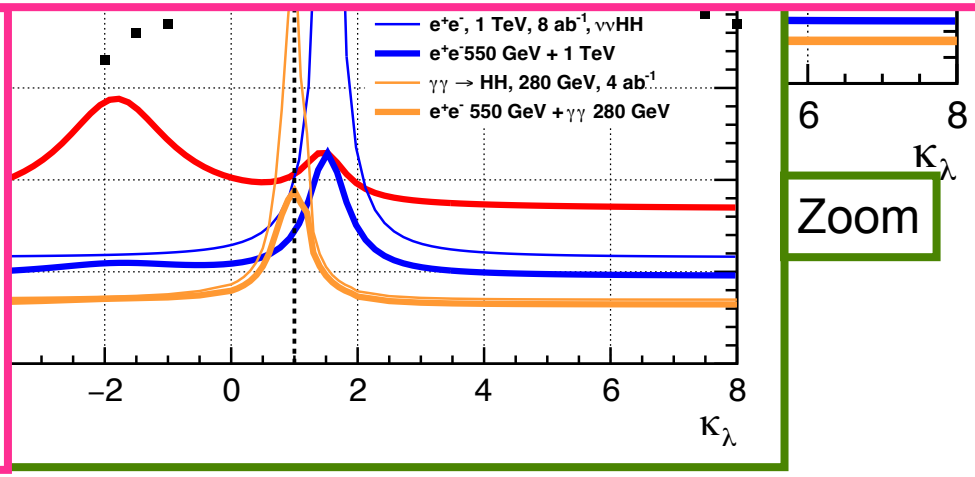
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- **LCVision approach:**
  - Use integrated extracted beam facility for first single-beam tests
  - Use 2nd IP with small fraction of bunches for collider tests
  - Dedicate significant luminosity once routine photon collision established



LCF250 Options-Analysis Study at CERN

As part of the FCC-ee decision process

- To support the decision-making process on FCC-ee, CERN will coordinate the preparation of documentation (for LEP3 and one LC concept) on technical readiness, cost, risks, future R&D needs **and the scientific and strategic reasons why these are not identified as CERN's future flagship project**

Mark Thomson | FCC Week 2026 | Welcome and Introduction 8 June 2026 22

- Led by Alessandra Lombardi
- Deliverable: 10-20 page report
  - Externally reviewed **design**, **based** largely **on existing LCF / ILC documentation**, with particular attention to technical infrastructure and any identified gaps
  - Externally reviewed **cost model** with uncertainties
  - Assessment of **technical risks**
  - Possible **roadmap and timeline for subsequent R&D**
  - Possible **timeline for potential implementation**
- Milestones
  - **June 2027**: mid-term gap analysis to identify where additional work is required
  - **December 2027**: external review of technical readiness, cost, cost uncertainty and risk
  - **April 2028**: submission of the options analysis documentation to CERN Council

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Started October 30

- regular technical meetings planned
- https://indico.cern.ch/category/21890/ (non-public)

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Conclusions & Outlook

LCWS 2026 - next week at KEK

November 9-13

- https://agenda.linearcollider.org/event/11000/
- ~240 registered participants
- ~150 parallel session talks
  - e+e- physics
  - detectors and software
  - accelerator
- plenary sessions on
  - Future colliders round the world
  - Upgrade paths
  - e+e- physics
  - Detectors & software
  - ITN, LCF
  - Sustainability, Industry connections
  - AI & Quantum information



Conclusions

and outlook

- **LCs remain a technologically mature and financially & technologically stageable option**
  - To study Higgs, top and EW if FCC-ee would turn out to not be financially feasible
  - To bring advanced accelerator R&D to use in colliders
  - To react on surprises from HL-LHC - and/or direct / indirect detection experiments
- **ICFA is discussing to exploit the ITN framework for the future HEP e+e- colliders**
- **CERN has set up an LCF study (as part of an FCC-ee option analysis)**
  - Deliverables for early 2028
  - Review / milestone schedule for 2027

    => 2027 will be a busy year!
- **LCVision remains the open, bottom-up, community driven forum**
- **Upcoming open events:**
  - LCWS 2026 Nov 9-13 at KEK
  - LCVision Event 2027 March 15-17, 2027

