

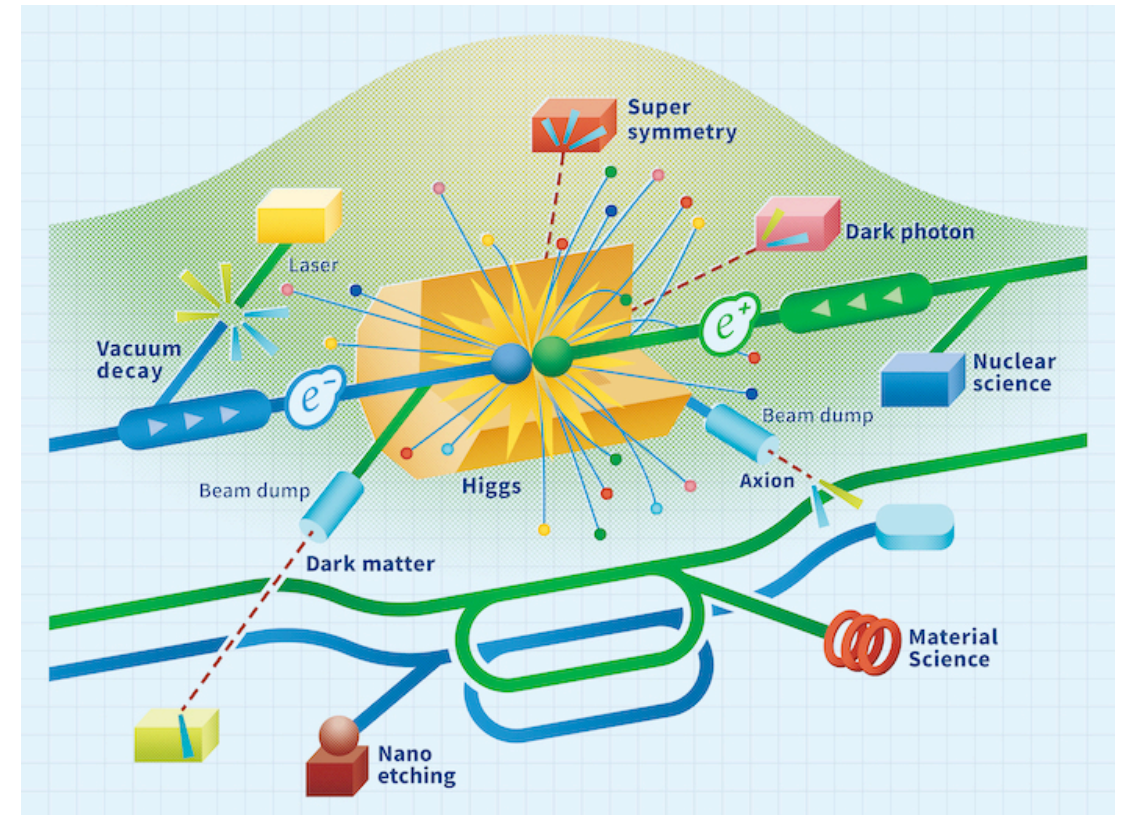
# LCVision Update

ILD Monthly Meeting  
Mar 4, 2025

M. Ishino, [J. List](#), T. Nakada, M. Peskin,  
R. Pöschl, A. Robson, S. Stapnes

## Outline:

- Introduction: general reminder on LCVision
- the LC Vision “generic” / “long” document
- the LCF@CERN strategy submission
- next steps



# Introduction

# LCVision

## Overview and links to more information

- LCVision originated from a bottom-up brain-storming in spring 2024
- Leading up to a first public presentation and discussion at LCWS2024, c.f.
  - <https://newline.linearcollider.org/2024/11/29/>
  - <https://agenda.linearcollider.org/event/10134/timetable>  
=> decision to develop this further into an EPPSU input
- LC Vision Community Event Jan 8-10 at CERN
  - see current newslines: <https://newline.linearcollider.org/>
- Mailing list e.g. for announcement of document drafts:
  - sign-up for LCVision e-group:  
<http://simba3.web.cern.ch/simba3/SelfSubscription.aspx?groupName=LCVision-General>
- **NEW:**
  - LCVision talk collection (incl. sources): <https://agenda.linearcollider.org/event/10617/>
  - indico page for document drafts: <https://agenda.linearcollider.org/event/10624/program>



# LCVision

## Objectives

- make a strong case for Linear Colliders in general
  - based on physics arguments
    - capabilities at low energies (90-380GeV)
    - unique added-value at high energies (500GeV ... 1 TeV ... 3 TeV)
  - and attractive upgrade options
    - based on advanced / new technologies rather than tunnel length
  - independently of the exact implementation (acc. technology, site, ...)
- propose a versatile Linear Collider Facility (LCF)
  - suited to host a long-term program, for instance at CERN
  - starting from an affordable and timely realizable baseline
  - building upon all the important R&D done for all the mature LC concepts
  - with scientifically and technologically exciting upgrade options
- aim for broad, joint support across all Linear Collider concepts



# LCVision

## Objectives

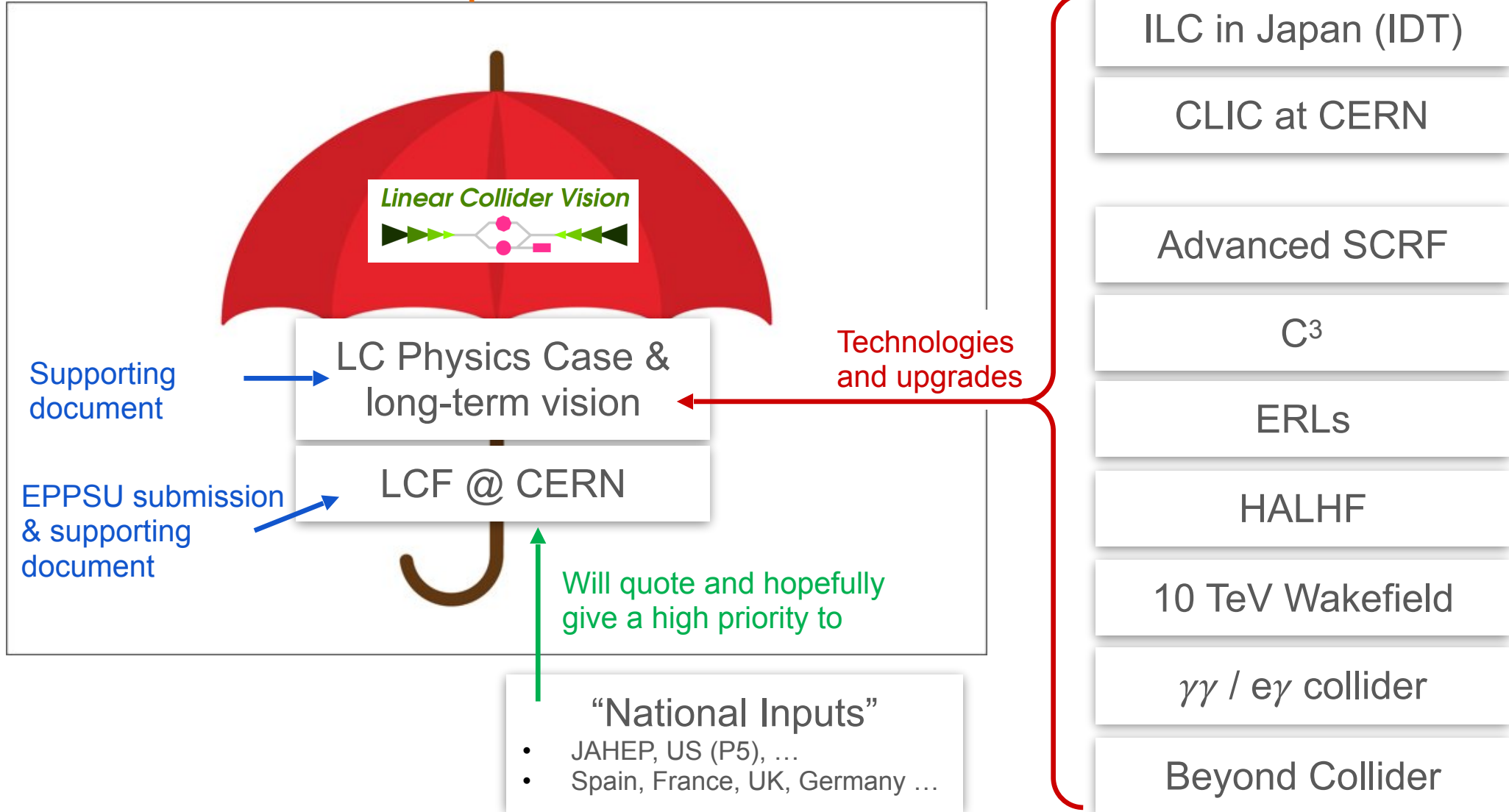
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  - with scientifically and technologically exciting upgrade options
- aim for broad, joint support across all Linear Collider concepts

**Contribute both the generic case and the LCF@CERN to the EPPSU**



# LC Vision Documents

and their relations to other EPPSU inputs



# LCVision Organisation

## Coordination Group & Expert Team Leaders

**Chairs: J. List, S. Stapnes**

### Coordination Group

Halina Abrahamovic, Erik Adli, Ties Behnke, Ivanka Bosovic, Phil Burrows, Marcel Demarteau, Yuanning Gao, Carsten Hensel, Mark Hogan, Masaya Ishino, Daniel Jeans, Imad Laktineh, Andy Lankford, Benno List, Kajari Mazumar, Shin Michizono, Emmanuela Musumeci, Tatsuya Nakada, Mihoko Nojiri, Dimitris Ntounis, Jens Osterhoff, Ritchie Patterson, Aidan Robson, Daniel Schulte, Taikan Suehara, Geoffrey Taylor, Caterina Vernieri, Marcel Vos, Georg Weiglein, Filip Zarnecki, Jinlong Zhang, Patrick Koppenburg, Hitoshi Murayama, Laura Monaco, Jochen Schieck

#### Expert Team 1

“Physics-driven run plan  
and EPPSU documents”  
Roman Poeschl,  
Michael Peskin

#### Expert Team 3

“SCRF upgrades”  
Sergey Belomestnykh,  
Hiroshi Sakai,  
Marc Wenskat

#### Expert Team 5

“ERL upgrades”  
Walid Kaabi,  
Vladimir Litvinenko,  
Kaoru Yokoya

#### Expert Team 7

“Beyond Collider”  
Stefania Gori,  
Yasuhito Sakaki,  
Ivo Schulthess, Mihoko Nojiri

#### Expert Team 2

“LCF@CERN”  
Steinar Stapnes,  
Thomas Schörner

#### Expert Team 4

“C3/CLIC upgrades”  
Angeles Faus-Golfe,  
Enrico Nanni

#### Expert Team 6

“Plasma upgrades”  
Brian Foster,  
Spencer Gessner

#### Expert Team 8

“Alternative Collider Modes”  
Tim Barklow, Gudi Moortgat-  
Pick, Ariel Schwartzman



# LCVision Organisation

Document Writing - Core Editing Team, Physics Team & Expert Teams

## Core Editing Team

Masaya Ishino, Jenny List, Tatsuya Nakada, Michael Peskin, Roman Poeschl, Aidan Robson, Steinar Stapnes

### Higgs at 250 GeV

Dirk Zerwas, Caterina Vernieri, Kei Yagyu

### EW from Z pole to highest E

Graham Wilson, Adrian Irlles, Taikan Suehara

### Higgs at high(est) E

Shinya Kanemura, Georg Weiglein, Johannes Braathen, Margarete Muehleitner

### Global Interpretations

Junping Tian, Jorge de Blas

### Top from threshold to highest E

Marcel Vos, Gauthier Durieux, Ken Mimasu

### Direct BSM

Filip Zarnnecki, Sabine Kraml, Sven Heinemeyer, Howard Baer, Natsumi Nagata

### ttH and VV

Juergen Reuter, Wolfgang Kilian, Jan Strube, Koji Tsumura

### Alternative Collider Modes & Beyond-Collider

=> physics covered by respective expert teams





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=> more contributors welcome, please get in touch!



# Behind the scenes

## Work, work, work...

- Agreeing on LCF parameters => details in the following
  - length, # IRs, crossing angle(s)
  - SCRF specs
  - ...
- Updated ILC cost estimate for EPPSU
  - review by international expert committee in December
  - final numbers for ILC250 in Japan:
    - 6.7 BILCU (= USD in 2024) for accelerator => **basis for LCF@CERN accelerator costing**
    - 196 BJPY for civil construction => for LCF@CERN replaced by CERN CFS costing
- Assess via consistent recipe by same experts for all CERN proposals
  - CFS design & costing: first preliminary numbers (last Thu) turned out very consistent with escalated ILC@CERN costs from TDR :)
  - operation costs: recipe in final agreement stage...
  - environmental aspects => LDG Sustainability Group recipe, LCF will be included in LDG report tables



# The LCVision “generic” document

# A Linear Collider Vision for the Future of Particle Physics

## Introduction, Operating Scenarios, Experimental Environment

- 1 Introduction 2 pages, Michael, Roman 4
- 2 Operating Scenarios and Experimental Environment 2 pages, Caterina, Aidan, Jenny, Dirk, ... 6
  - 2.1 Operating Scenarios . . . . . 6
  - 2.2 Experimental Environment and Detector Requirements . . . . . 8

### CLIC

	380	1500	3000
$\int \mathcal{L} \text{ (ab}^{-1}\text{)}$	2.2 (4.3)	4	5
beam polarization ( $e^-/e^+$ ; %)	80/0	80/0	80/0
(-, +0) (%)	(50,50)	(80,20)	(80,20)

Table 2: The updated baseline CLIC operation model (December 2024). Two options for 380 GeV-running are given, with 50 Hz and 100 Hz repetition rates, respectively. Running at  $\sqrt{s} = 91$  GeV is an option.

### ILC

	91 GeV	250 GeV	350 GeV	500 GeV	1000 GeV
$\int \mathcal{L} \text{ (ab}^{-1}\text{)}$	0.1	2	0.2	4	8
beam polarization ( $e^-/e^+$ ; %)	80/30	80/30	80/30	80/30	80/20
(-, -+, +-, ++) (%)	(10,40,40,10)	(5,45,45,5)	(5,68,22,5)	(10,40,40,10)	(10,40,40,10)

Table 1: Centre-of-mass energy, integrated luminosity and beam polarisation of the various stages of the straw-man ILC operating scenario.

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or 60% ?



# A Linear Collider Vision for the Future of Particle Physics

## The Portal to New Physics

Higgs / EW  
at  
high(est)  
energies

Direct BSM

Photon Collider  
& Co

<b>3</b>	<b>The Portal to New Physics 25 pages, eds. Michael, Roman</b>	<b>9</b>
3.1	Scrutinizing the Higgs boson via single-Higgs production <i>Caterina Vernieri, Kei Yagyu, Dirk Zerwas</i>	9
3.1.1	Impact of Beam Polarization on Higgs Production	9
3.1.2	Higgs Mass and Total Cross Section	10
3.1.3	Branching Ratio Measurements	11
3.1.4	CP properties	13
3.1.5	Interpretation	13
3.2	Two and four fermion production - Z-pole and above 5 pages <i>Graham Wilson, Adrian Irlas, Taikan Suehara</i>	14
3.2.1	Z-pole	14
3.2.2	Quark pair production	15
3.2.3	Improvements on jet flavor tagging and more	16
3.3	Higgs at high(est) energies 6-7 pages <i>Shinya Kanemura, Georg Weiglein, Johannes Braathen, Margarete Mühlleitner</i>	17
3.3.1	Higgs Self-Coupling	17
3.3.2	Overlap with other fields of science - Gravitational Waves	22
3.4	Electroweak Physics at highest energies: Multi-boson processes 5 pages <i>Jürgen Reuter, Wolfgang Kilian, Jan Strube, Koji Tsumura</i>	23
3.4.1	Scrutinizing electroweak interactions at high(est) energies	23
3.4.2	Triple and quartic gauge couplings	25
3.4.3	Vector boson fusion and scattering	27
3.5	top physics programme - From threshold to highest energies 5 pages <i>Marcel Vos, Michael Peskin, Gauthier Durieux, Ken Mimasu</i>	28
3.5.1	The top quark mass and width	28
3.5.2	Top quark Yukawa coupling	29
3.5.3	The top quark EW couplings	30
3.5.4	Quantum Observables in top quark pair production	32
3.5.5	Top quark FCNC interactions	33
3.5.6	Top quarks and axions	35
3.6	Direct searches for BSM including SUSY 5 pages <i>Aleksander Filip Zarnacki, Sabine Kraml, Sven Heinemeyer, Howard Baer, Natsumi Nagata</i>	36
3.6.1	LC reach for light EW SUSY	36
3.6.2	LC reach for light exotic scalars	39
3.6.3	LC reach for Heavy Neutral Leptons	40
3.6.4	LC reach for dark matter scenarios	41
3.6.5	BSM Higgs bosons and Triple Higgs Couplings at the LC	41
3.6.6	LC sensitivity to unexpected new physics	43
3.7	Global Interpretations 5 pages <i>Junping Tian, Jorge de Blas</i>	44
3.7.1	Inputs and assumptions of the global SMEFT interpretation	44
3.7.2	Global fit results	45
3.7.3	BSM interpretation	46
3.8	$\gamma\gamma, e\gamma$ and $e^-e^-$ -Collisions	46
3.8.1	Higgs sector	47
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	Physics at main dumps	52
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	Axion-like particles	54
	Leptophilic Scalar	55
	Heavy neutral leptons(HNL)	55
	Dark Matter	55
3.9.2	Strong-Field QED	56
	Electron-Laser Interaction	57
	Beam-Beam Interaction	58

Beyond  
Collider

In corporate physics  
case studies for *all*  
linear colliders  
(dominated by ILD and CLICdp)

top from  
threshold  
to high(est)  
energies

Global  
interpretations



# A Linear Collider Vision for the Future of Particle Physics

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top from  
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Global  
interpretations

In corporate physics  
case studies for *all*  
linear colliders  
(dominated by ILD and CLICdp)

ILD & LCF Highlight:  
with 8 ab<sup>-1</sup> at 550 GeV,  
self-coupling precision = 10...11%





# A Linear Collider Vision for the Future of Particle Physics

## A Linear Collider Facility - Baseline and Roadmap

**“ready to go”<sup>1</sup>: SCRF drive-beam**

**Energy upgrades for initial SCRF machine**

**Luminosity upgrades**

<b>1. A Linear Collider Facility - Baseline and Roadmap</b>	<b>Jenny, Michael, Roman</b>	<b>58</b>
4.1 First Stage based on Superconducting Radio Frequency (SCRF) Cavities	Jenny, Steinar, Marc, Sergey, Benno	58
4.1.1 SCRF Specifications for the Baseline	Hiroshi, Marc, Sergey, Akira	61
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4.2 First Stage based on Drive-Beam Technology	3 pages Steinar Stapnes, Aidan Robson, Angeles Faus-Golfe	63
4.3 Beam Delivery System Considerations	Angeles	63
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4.4.1 “Straightforward” - Upgrade with higher gradient cavities	5 pages Sergey Belomestnykh, Hiroshi Sakai, Marc Wenskat, Enrico Genni, Akira Miyazaki	66
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Necessary civil construction and environmental impact		69
4.4.2 Upgrade using CLIC technology	10 pages, Steinar Stapnes, Aidan Robson, Angeles	69
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Necessary civil construction and environmental impact		70
4.4.3 Upgrade using C3 technology	5-10 pages, Caterina Vernieri, Emilio Nanni	70
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4.4.4 Upgrade with Wakefield Accelerator Technology	10 pages total, Brian Foster, Spencer Gessner	74
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4.5.2 “Straightforward” by e.g. increasing the number of bunches	B. List	80
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4.5.3 Energy recovery technologies	5-10 pages, V. Litvinenko, W. Kaabi, Kaoru Yokoya	81
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Time and R&D needed		84
ERLC		84

### BDS: 2 IRs

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Twin-Axis Cavity	85	
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Possible Parameters	85	
4.6 Alternative collider modes	5-10 pages, Tim Barklow, Gudi Moortgat-Pick	86
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Necessary civil construction and environmental impact	88	

### Photon Collider & Co



# A Linear Collider Vision for the Future of Particle Physics

## Beyond Collider, Detectors, ....

### Beyond Collider

<b>5 Beyond-Collider Facilities</b>	<b>10 pages, Stefania Gori, Yasuhito Sakaki, Ivo Schulthess, Claude Vallée</b>	<b>88</b>
5.1 Beam Dump Facilities		88
5.1.1 Main Beam Dump Facility		88
5.1.2 Tune-Up Dump Facility		90
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Laser Facility		91
5.1.3 Neutron and Muon Facilities		91
Irradiation Facility		91
Facility for Radionuclide Production		91
5.2 Plasma-Wakefield Accelerator R&D Facility		92

### Detectors

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6.2 Concepts	Ties Behnke, Andy White, Aidan Robson	94
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6.3 New Technologies – short term	all	98
6.4 New Ideas	Marcel Demarteau	98
<b>7 Scientific and societal impact of LC research programme</b>	<b>3-5 pages, Hitoshi Murayama</b>	<b>98</b>
<b>8 Summary and Conclusion</b>	<b>2 pages max., Michael, Roman, Jenny, Steinar</b>	<b>98</b>
<b>9 References</b>		<b>99</b>

as of today:  
447 references :)



# A Linear Collider Vision for the Future of Particle Physics

## Conclusion on long document status

- This will be a very interesting document, complementary to many past LC reports
- A lot of work done already by all authors, among them many from ILD
- as of today ~100 pages + 447 references
- => many, many thanks to all contributors!
- However, still a lot to do:
  - some sections (for good & noted reasons...) are behind
  - main editors have still a lot to do to make it coherent document
- arxiv identifier needed in time so that EPPSU submissions can quote it
- to be clarified:
  - will we need also a formal 10-page submission to the EPPSU with the long document as “back-up”?
  - when will draft be public?
- after March 31, submit to EPJ ST (agreed with EPJ ST editors)



# The LCF@CERN Proposal

# The LCF@CERN

## Basic Considerations

- Philosophy:
  - leverage all the excellent work done for ILC & CLIC in the past
    - reliable costing etc
    - “ready to build”
  - but modernize / push back on minimal machine to turn into attractive project for CERN
- SCRF technology (31.5 MV/m,  $Q_0=2E10$ )
  - successful construction & operation of Eu.XFEL, LCLS-II, construction of more (SHINE...)  
=> no large-scale demonstrator step needed
  - lab experience and production capacities in industry globally  
=> opportunity to take burden off CERN’s shoulders
  - choice for fastest implementation
- Scope project to be a flagship project for CERN
  - 2 interaction regions
  - higher luminosity
  - add-on facilities (Beyond Collider, R&D / irradiation facilities)
  - attractive upgrade perspectives with advanced technologies
  - but stay affordable

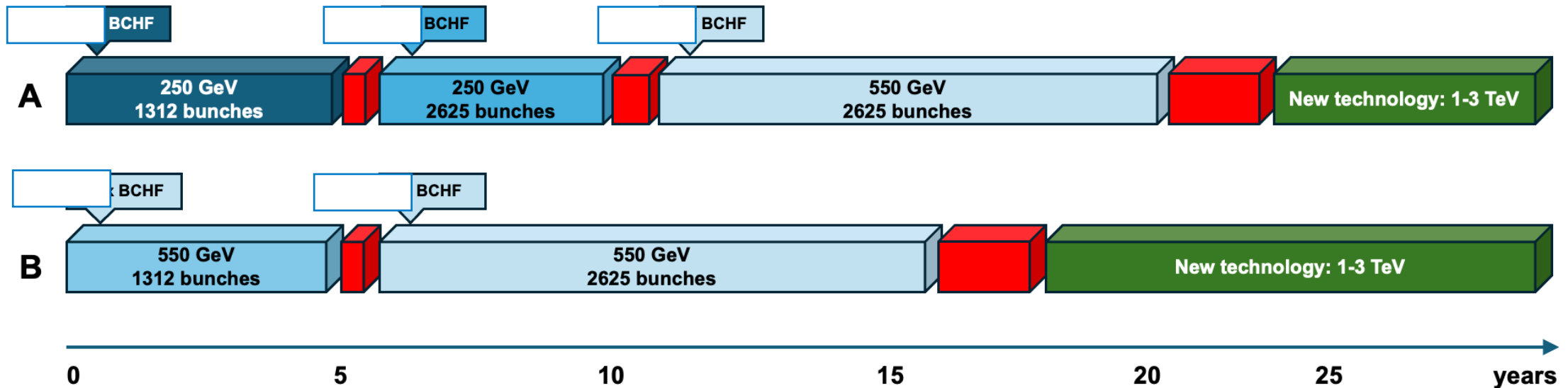


# The LCF@CERN

## The proposal

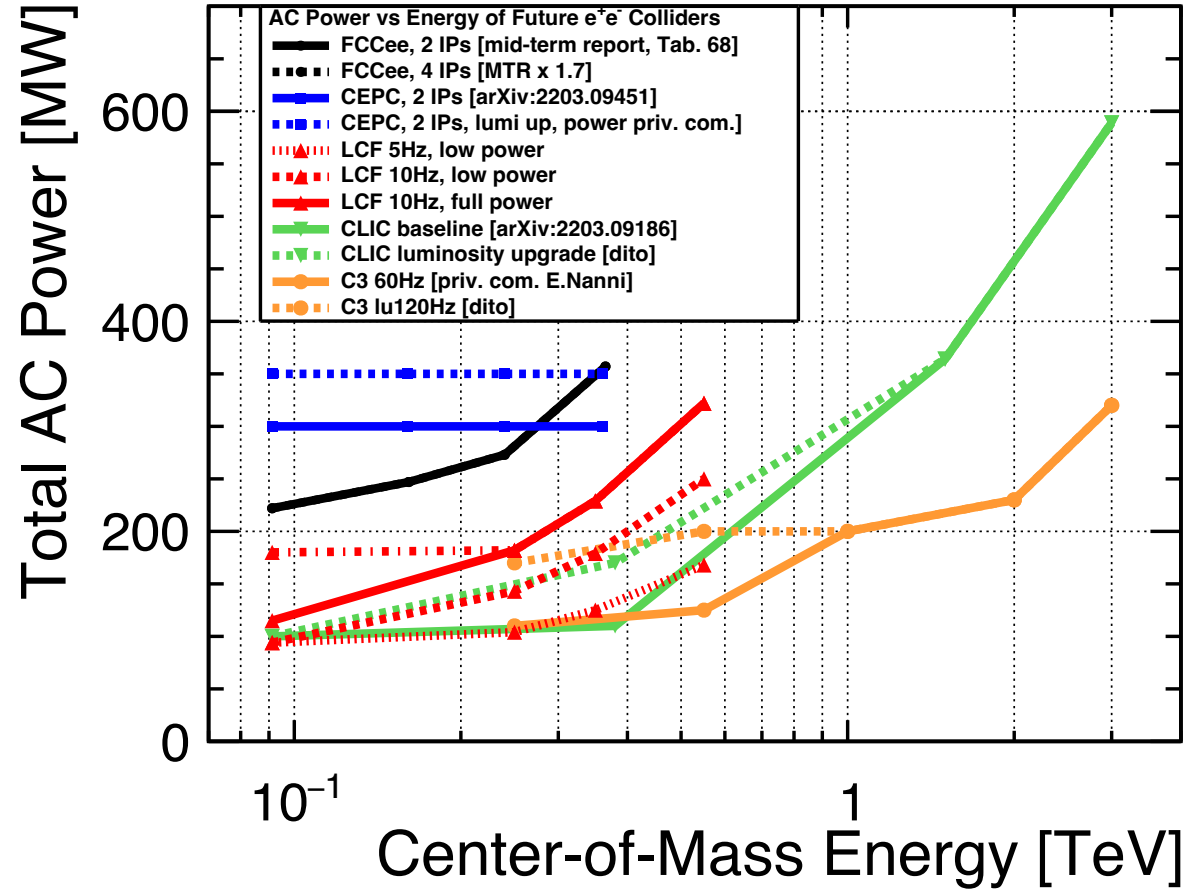
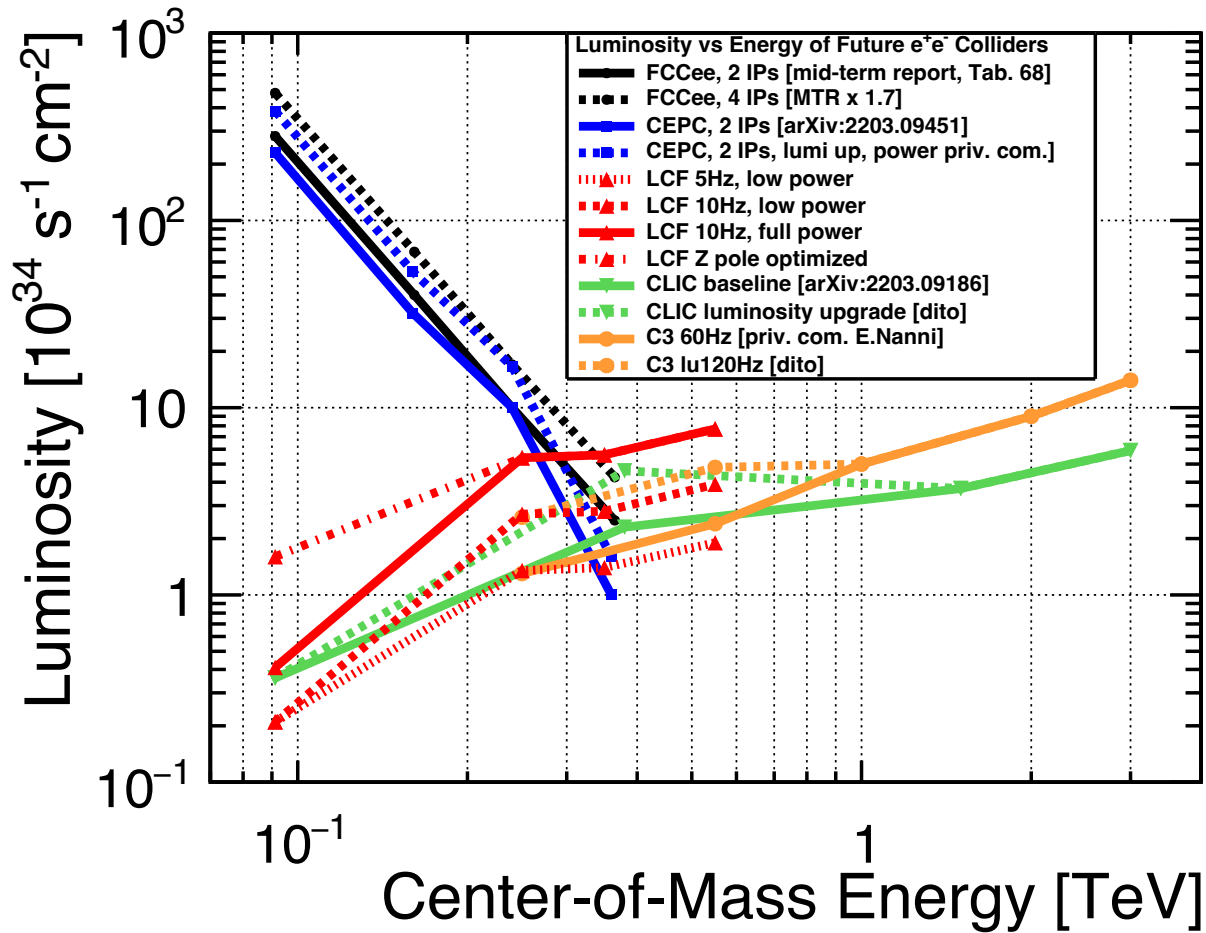
- a 33.5km facility => enough to reach 550 GeV even with 31.5MV/m
- operate at 10 Hz (due to higher Q0, power increase is not prohibitive...)
- with 2 IRs
- undulator source ;)
- scenarios:

Linear Collider Facility @ CERN: 33.5 km, 2 beam delivery systems, 10 Hz operation



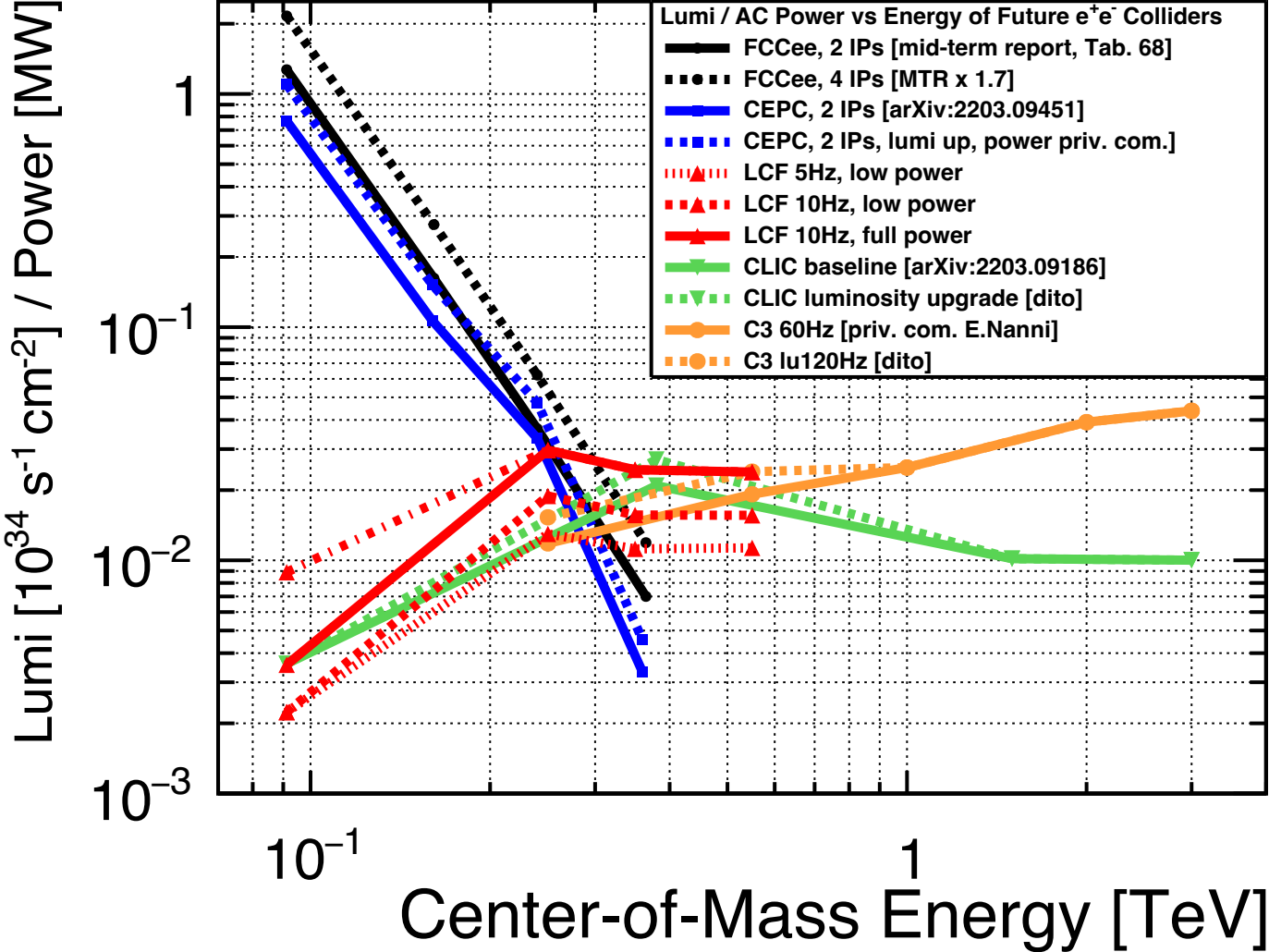
# Lumi, Power & all that

LCF et al



# Lumi per Power

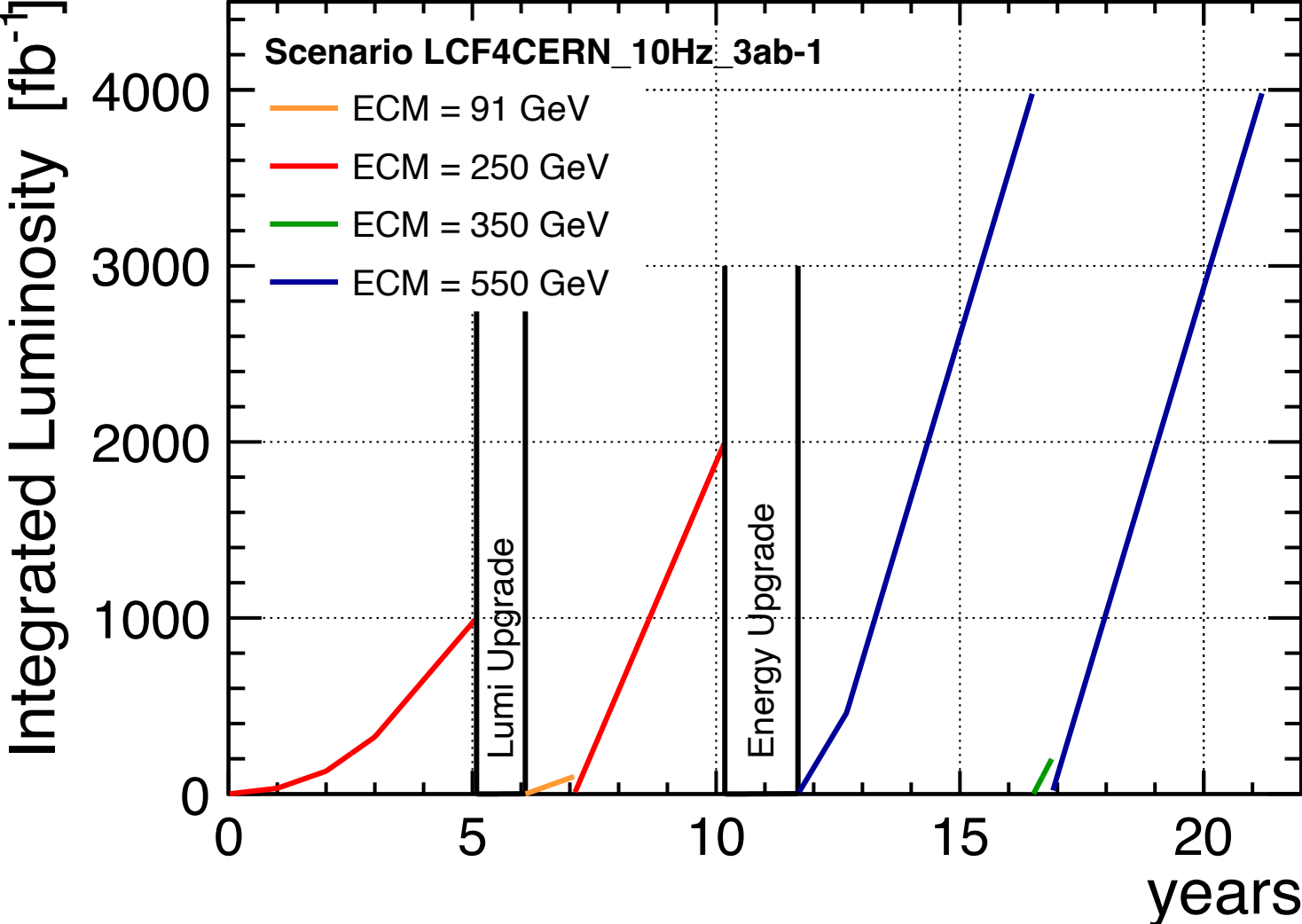
LCF et al





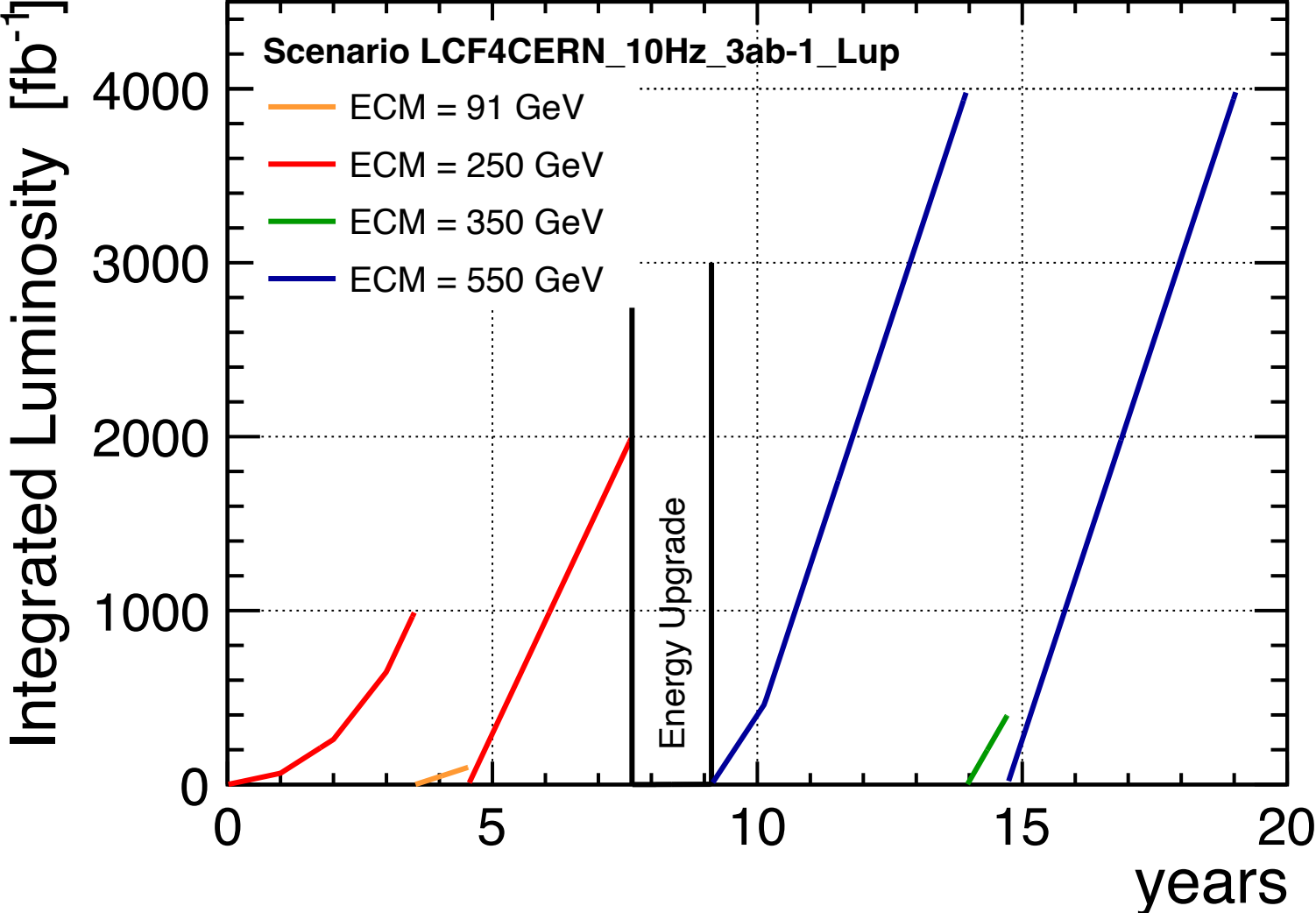
# Running Scenarios

baseline ?



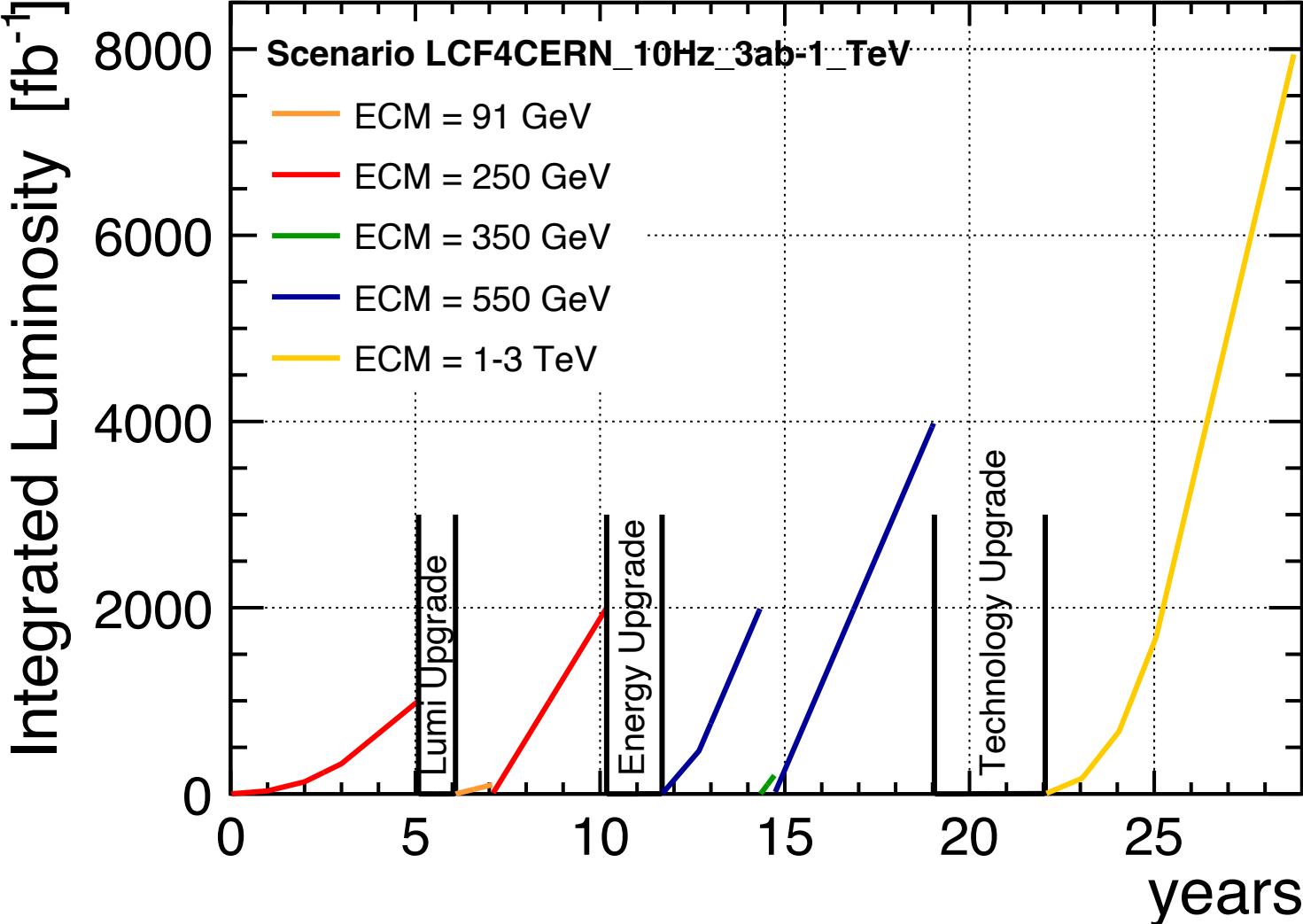
# Running Scenarios

start with full power



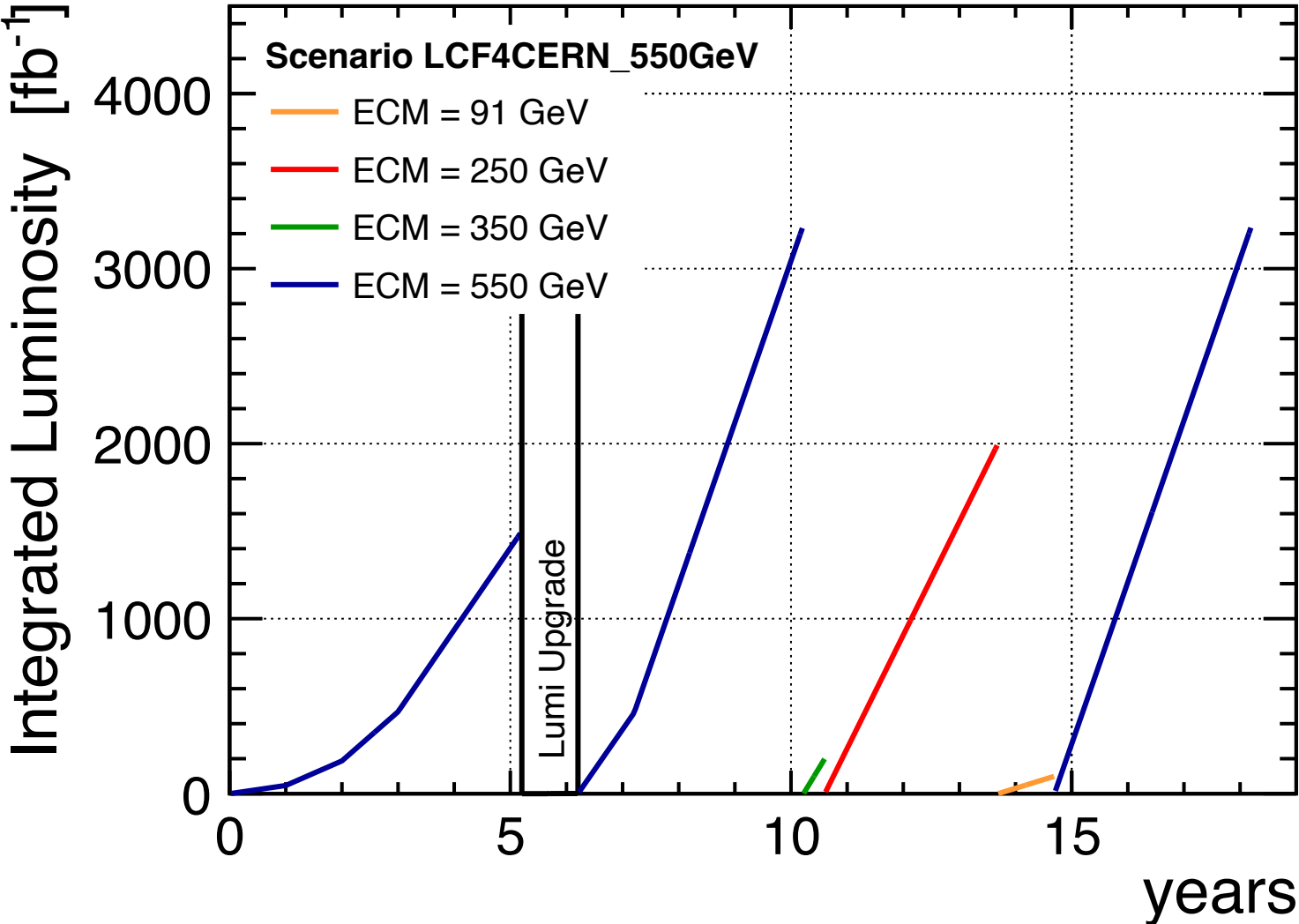
# Running Scenarios

shorten 550 GeV to go to TeV range earlier



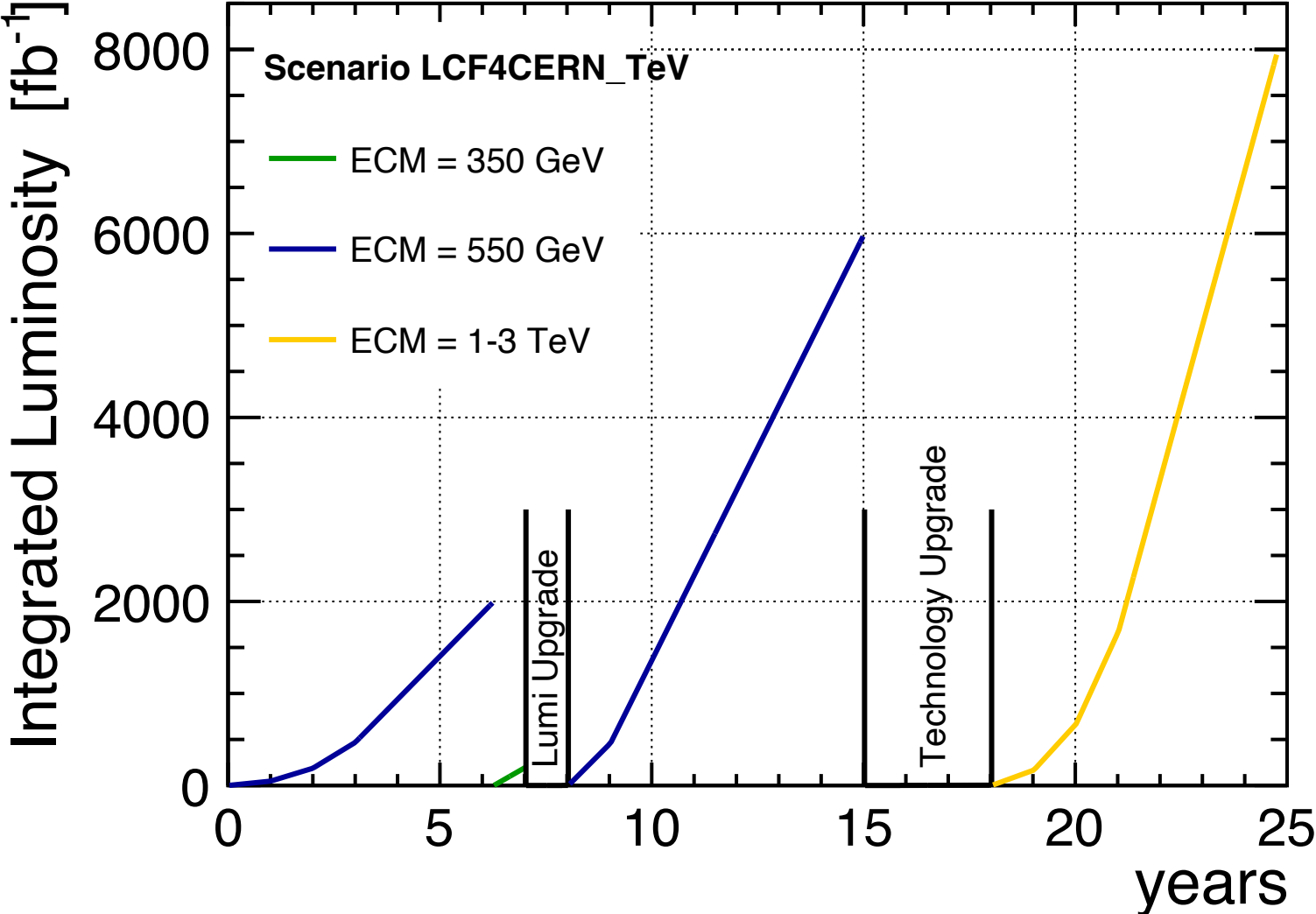
# Running Scenarios

start with 550 GeV - cross-check CEPC with polarised data ?



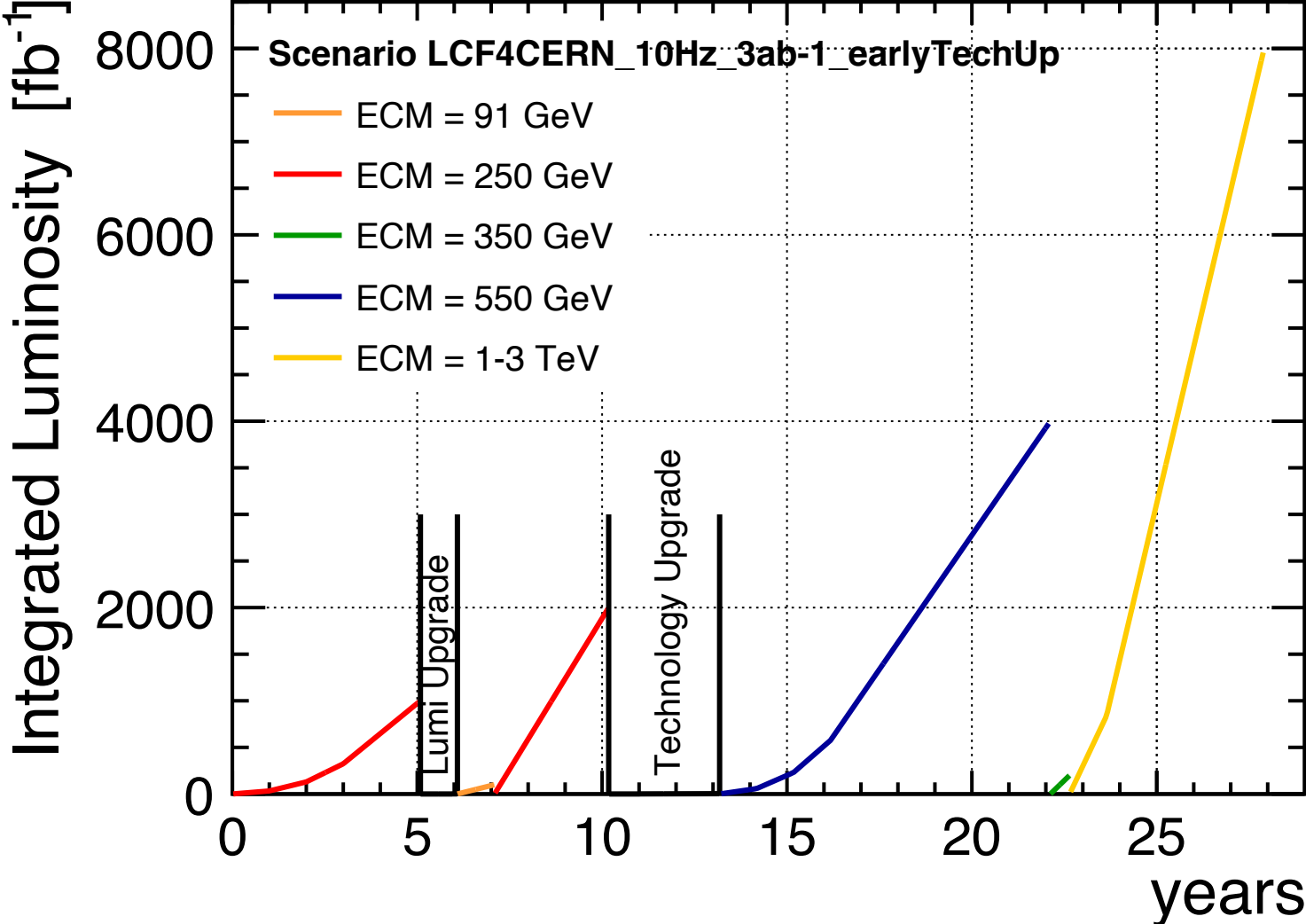
# Running Scenarios

start with 550 GeV - or go to TeV range earlier



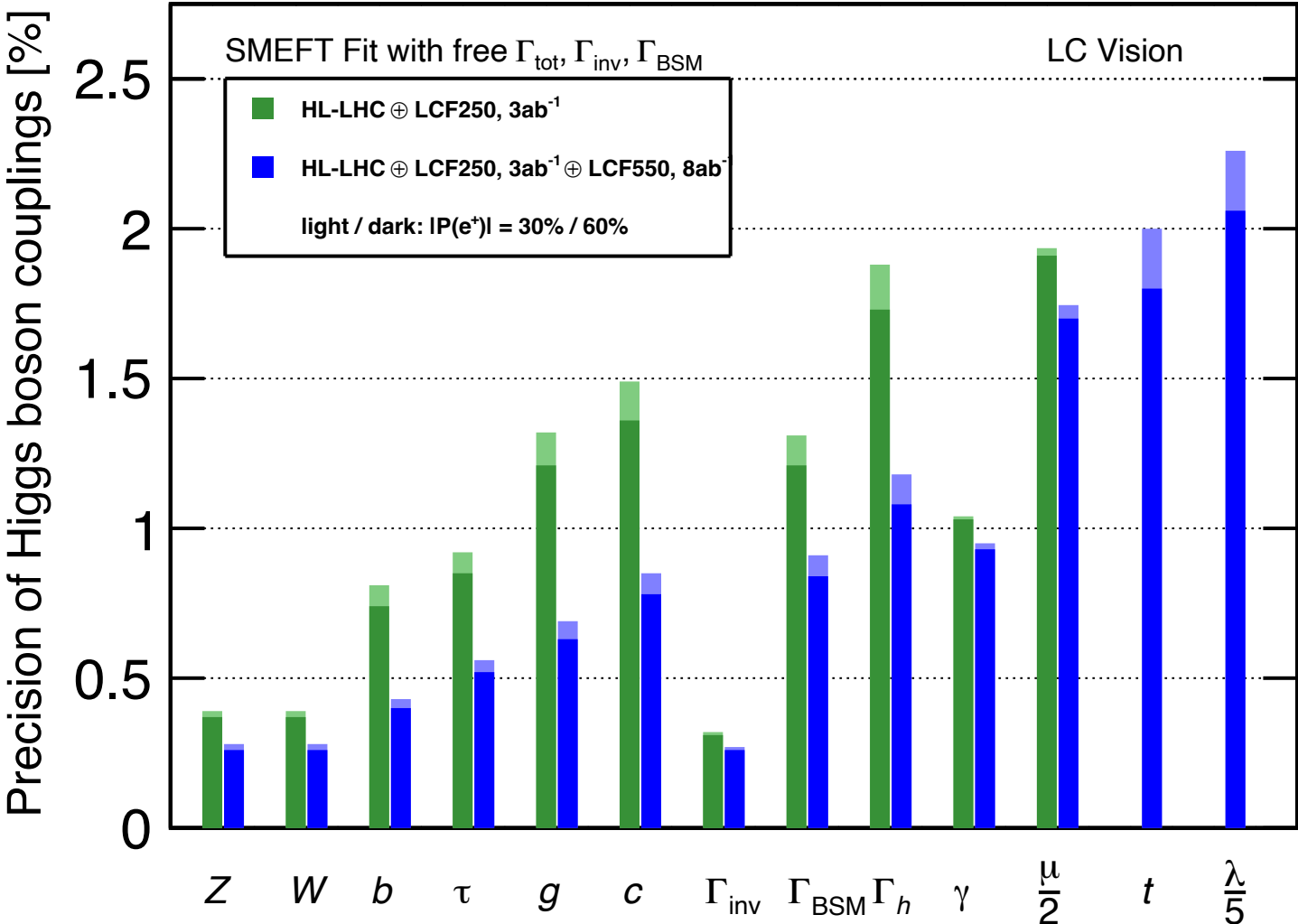
# Running Scenarios

## Early Technology upgrade



# Higgs Coupling Precisions

3ab-1 @ 250 GeV + 8ab-1 @ 550 GeV



# What we ask from the EPPSU

## as first concrete step

- a “small” preparatory study, ideally starting directly in 2027
  - 3..5 years ????
  - 75...150 MCHF ????
- **An engineering design** of the LCF facility including the collider, the injectors, and all technical infrastructures that are required to construct and operate them will be prepared. This includes updated cost, power and risk assessments. A number of technical studies are foreseen during the engineering design phase, optimising the LCF technologies and design, and preparing industrial productions:
  - SCRF industrialisation for a design based on more ambitious goals for cavity quality factors ( $Q_0$ ) and power (klystron) efficiency, with higher repetition rate and hence cryogenic needs than foreseen in the ILC TDR design.
  - A detailed study of the Interaction Region for two experiments, including re-optimised Beam Delivery Systems.
  - Detailed studies of the Cryogenics system and Infrastructure Systems (e.g. cooling and ventilation, electrical, access and safety systems, transport and installation) adapting them to standard solutions used by CERN and industry.
  - Studies of the implications for Civil Engineering and the equipment used in the initial SCRF based facility, in order to allow collider upgrades in the future, and to accommodate the beyond the collider physics described in "ref section above".
  - Design and parameter optimization of the entire machine including further nanobeam studies.
- **Detector and Collaborations** need to be prepared and set up, building on the experience of the numerous detector concepts for Higgs factories, but also embracing new ideas.
- ....





# Next Steps

# Next steps

## Count down for March 31

- LCF@CERN:
  - 10-pager (actual strategy submission): well advanced, draft is circulating to LCVision Coordination Group, discussion meeting tonight  
=> public draft on the weekend?
  - back-up document (addendum to submission with more technical details, supporter list etc): well advanced, converging quickly
- LC Vision “long document”:
  - v1 needs to go to the arxiv in 3 weeks => obtain identifier for quoting by EPPSU submissions
  - **schedule for circulation / comments / revisions very tight**
  - circulate v0 (with some sections missing) to Coordination Group and selected individuals on Friday
  - tbd tonight at Coord. Group meeting:
    - do ~weekly updates, always including comments until a few days before, e.g.:
      - v0 March 7
      - v0.1 March 13 (incl comments until March 11) = first public version?
      - v0.2 March 19 (incl comments until March 17)
      - v1 (arxiv) March 25 (incl comments until and author list snapshot of March 22)
  - v2 shortly after March 31 ...
  - submission to EPJ ST



**Any Questions?**