A Linear Collider Facility as Alternative for CERN

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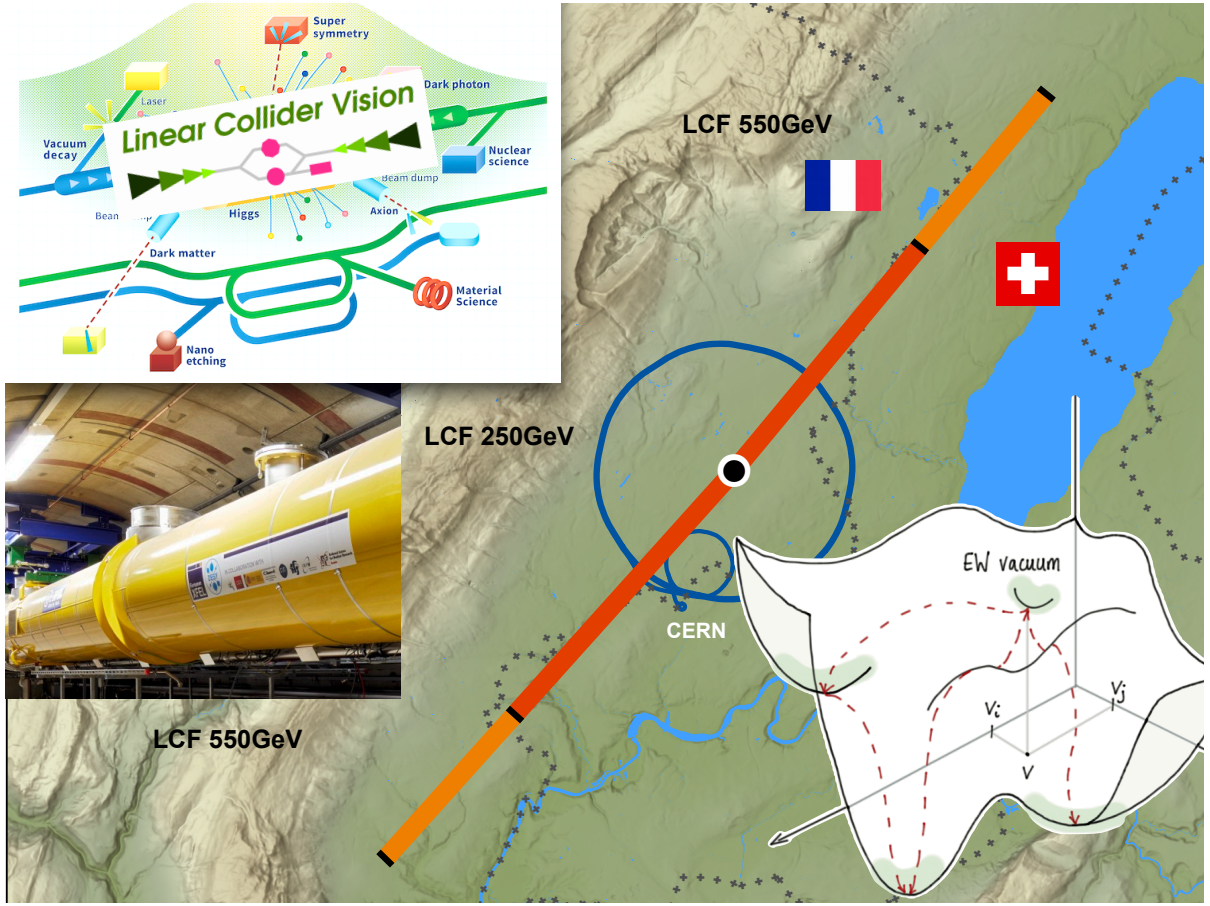
Webinar CNDP

Content:

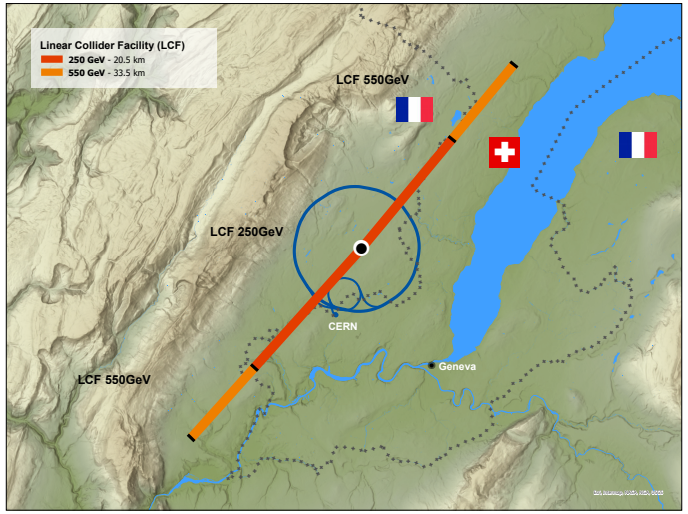
- In a nutshell: What is a Linear Collider?
- A little more on the science
- LCF: Design Philosophy
- LCF: Cost & Environmental aspects
- Summary



In a Nutshell: What is a Linear Collider?

What is similar / different wrt FCC-ee?

- Particles (e^+e^-) are accelerated and collided along *straight line*
  => no energy loss via radiation in curves
  => electric power consumption ~140 MW, similar to LHC
- Length of facility 20-33 km, similar to LHC “unrolled”
- 2 collision points, beam-lines for technology R&D
- Costs 8.6 BCHF initially,
  5.5 BCHF ~10 years later, “staged approach”





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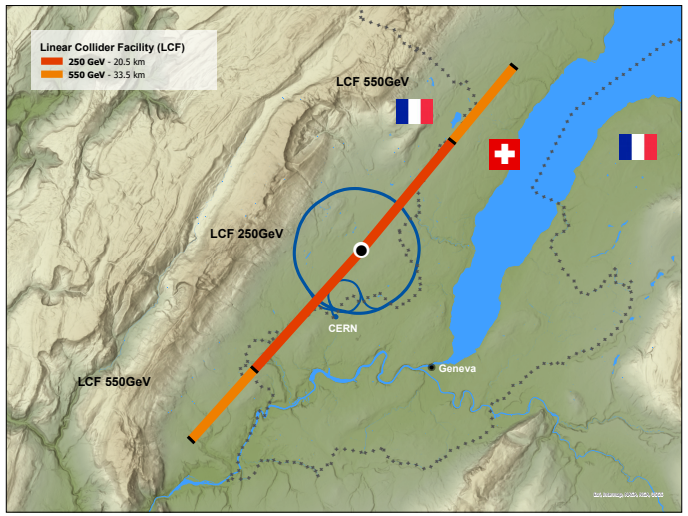
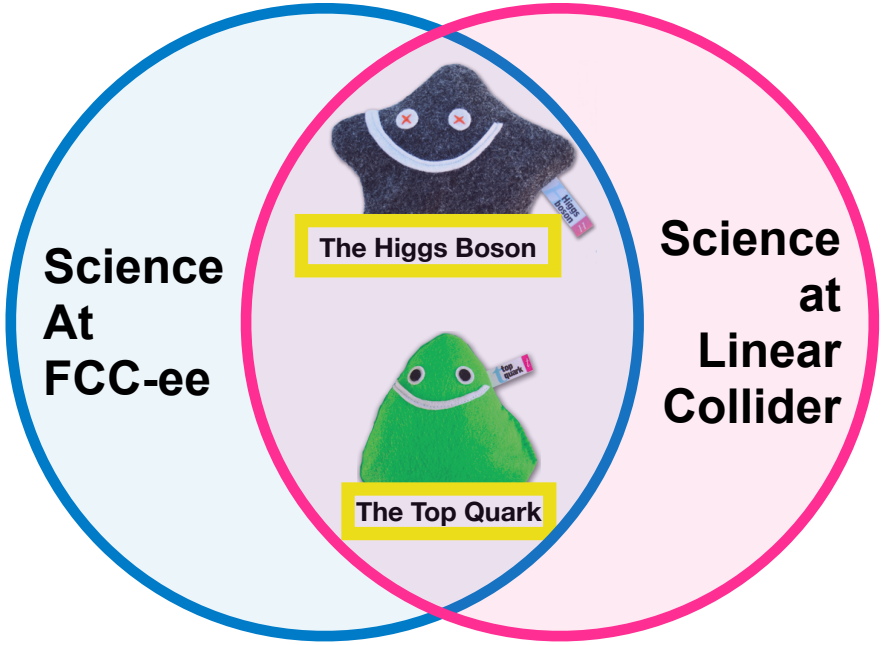




European X-Ray Free-Electron Laser in Hamburg, ~ 1.5km

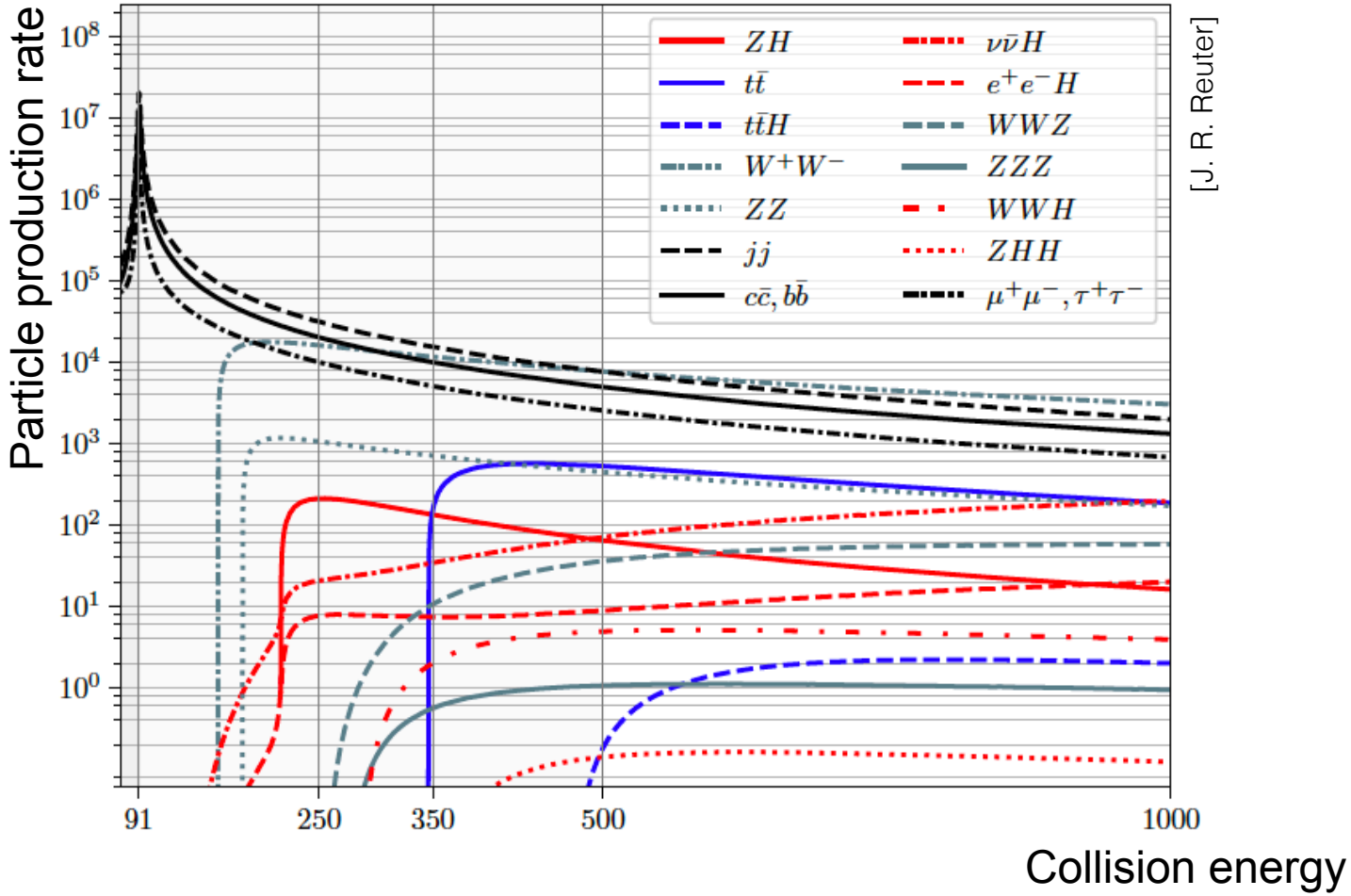


Science:

- The core science goals are the same!
- There's no disagreement about the scientific priorities
- Each collider has its own "extras"

More on Science of Linear & Circular Colliders

Particle production rates vs collision energy



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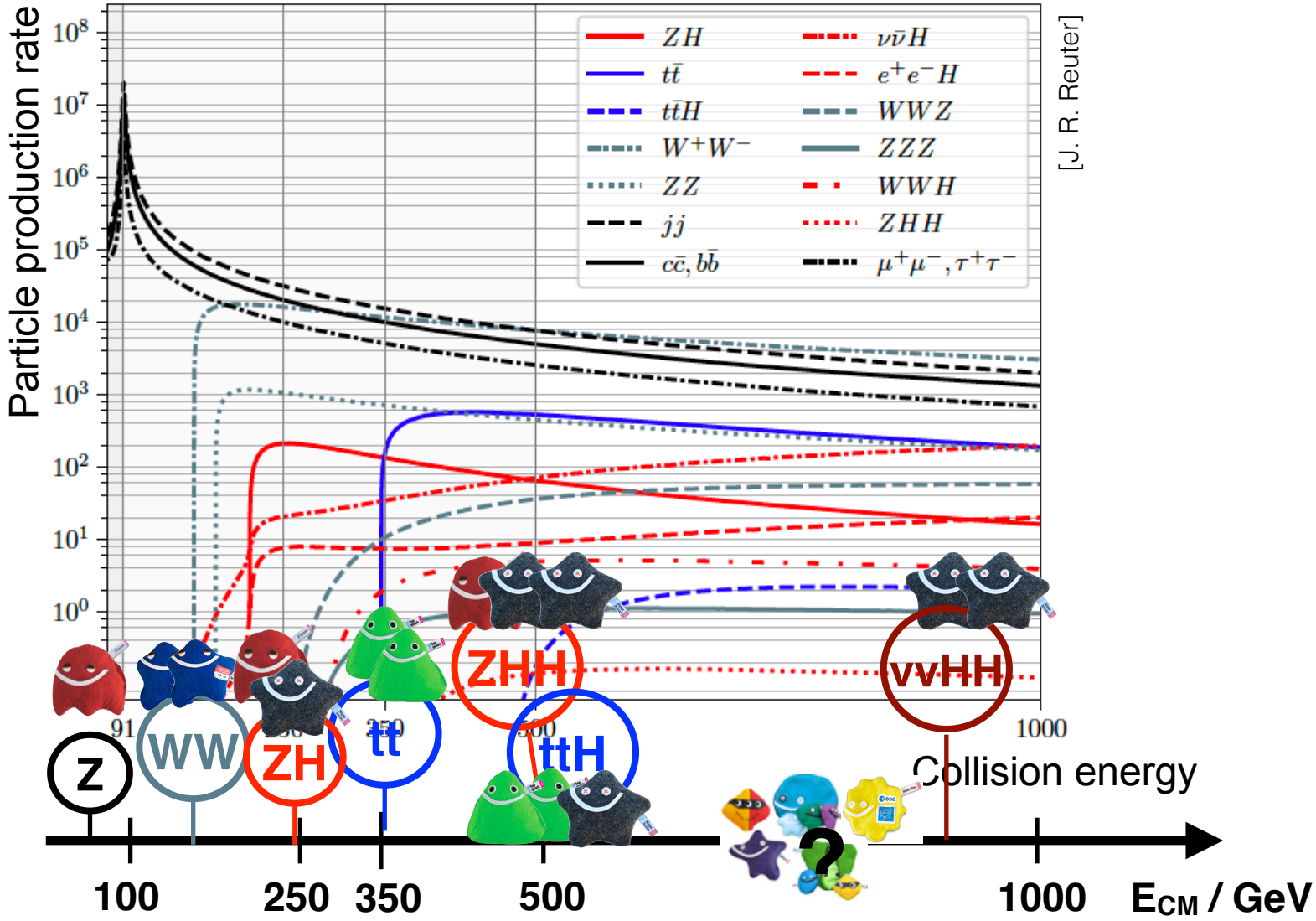

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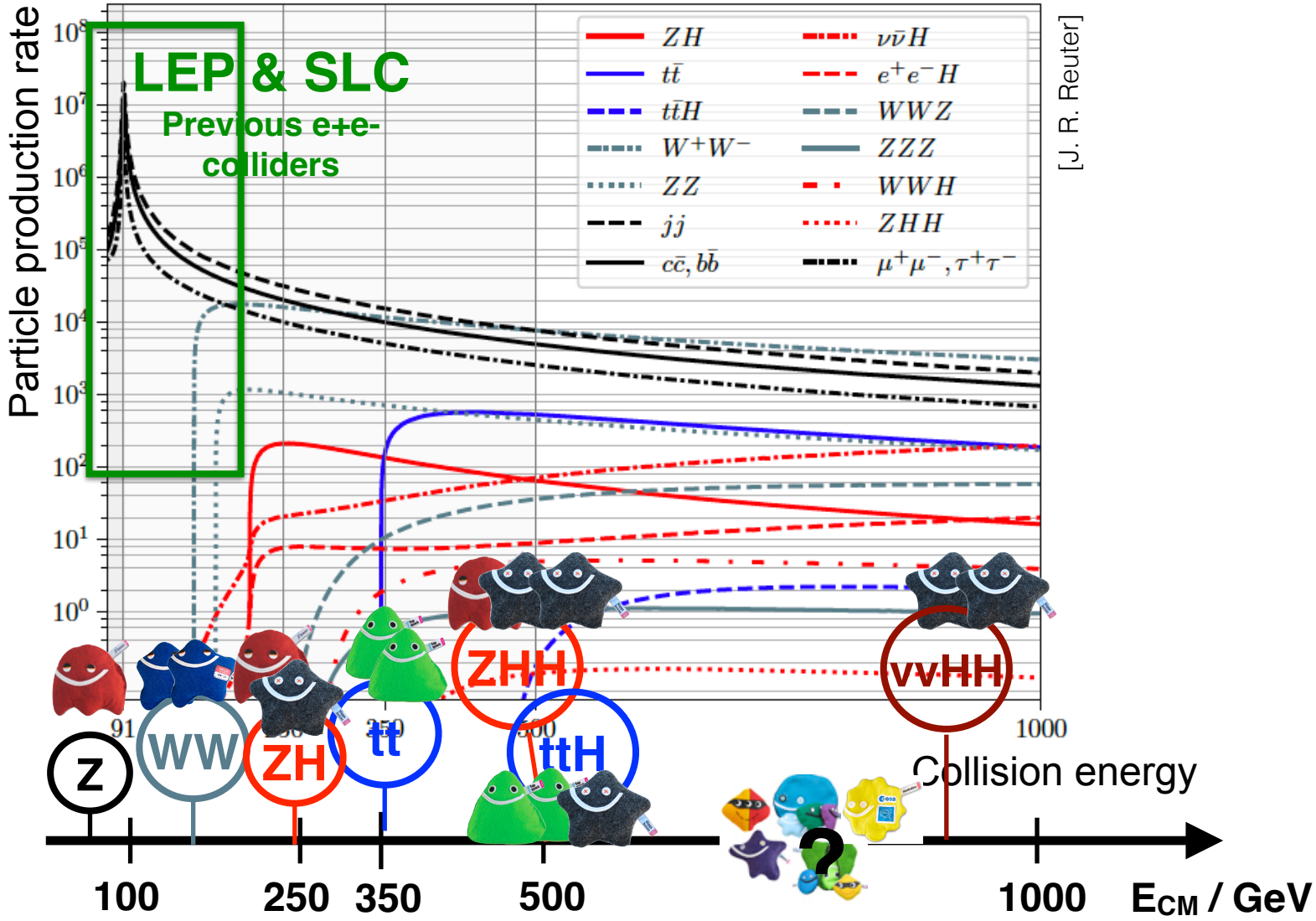

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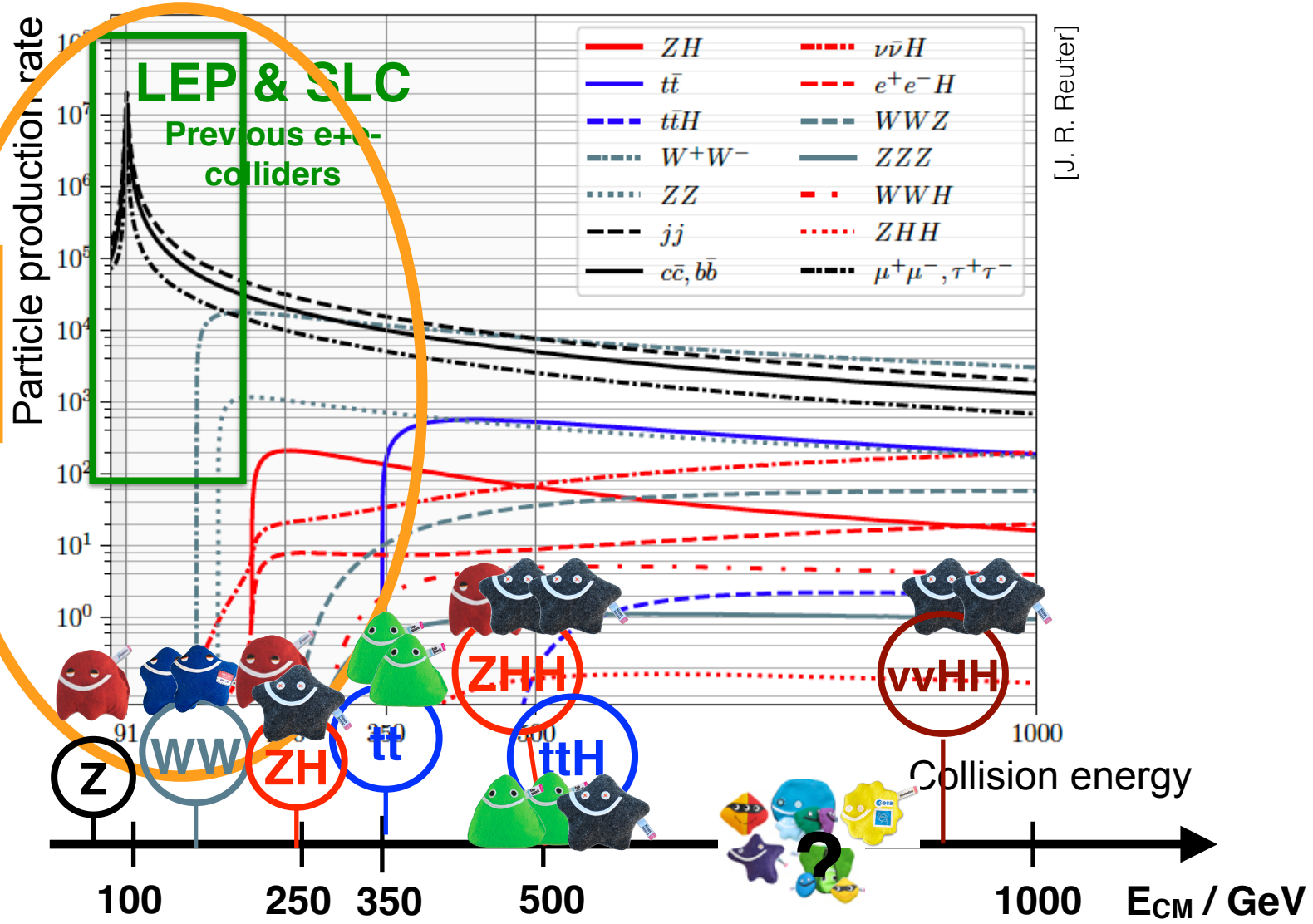
Particle production rates vs collision energy

FCC-ee or a Linear Collider



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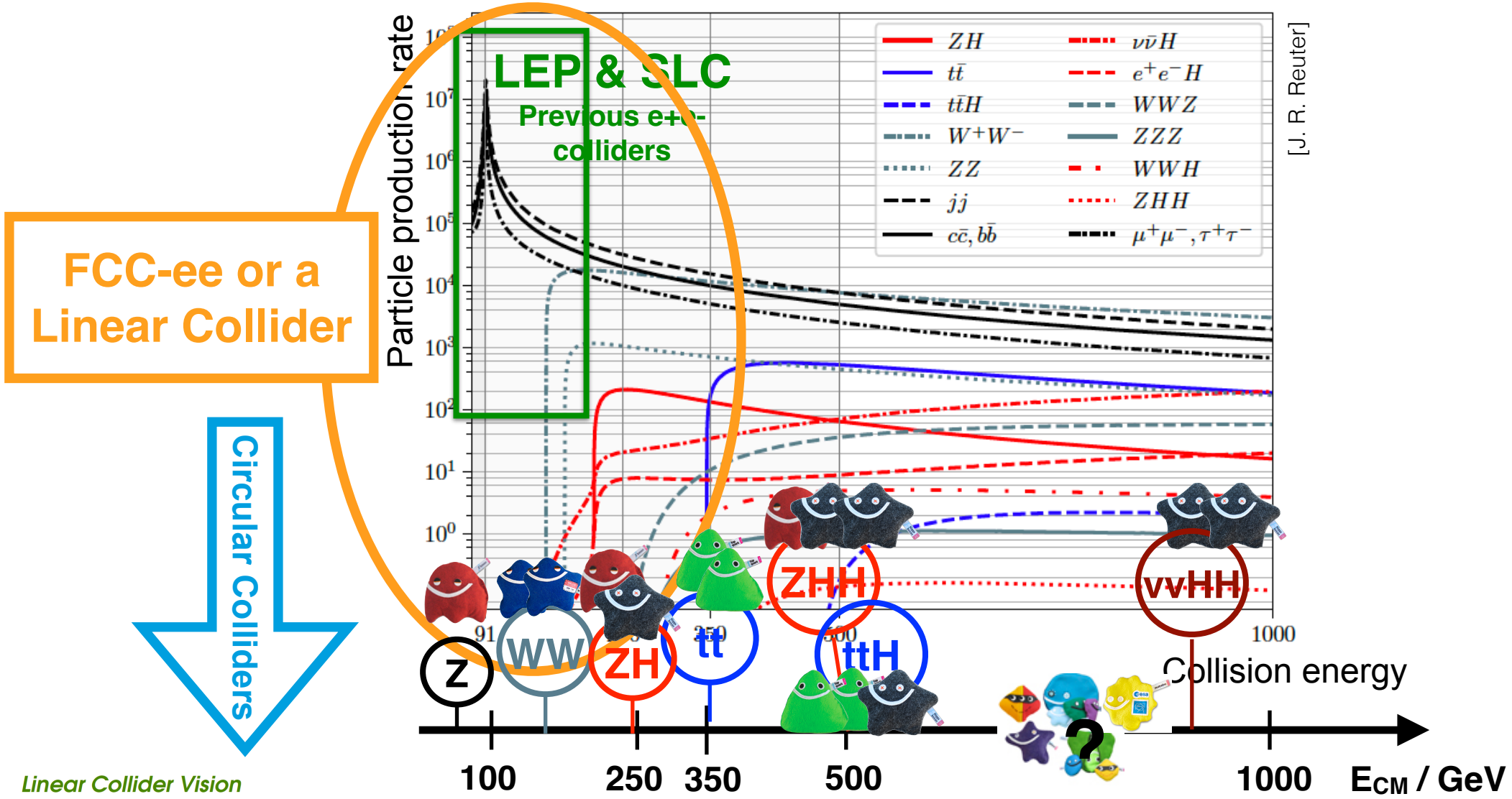

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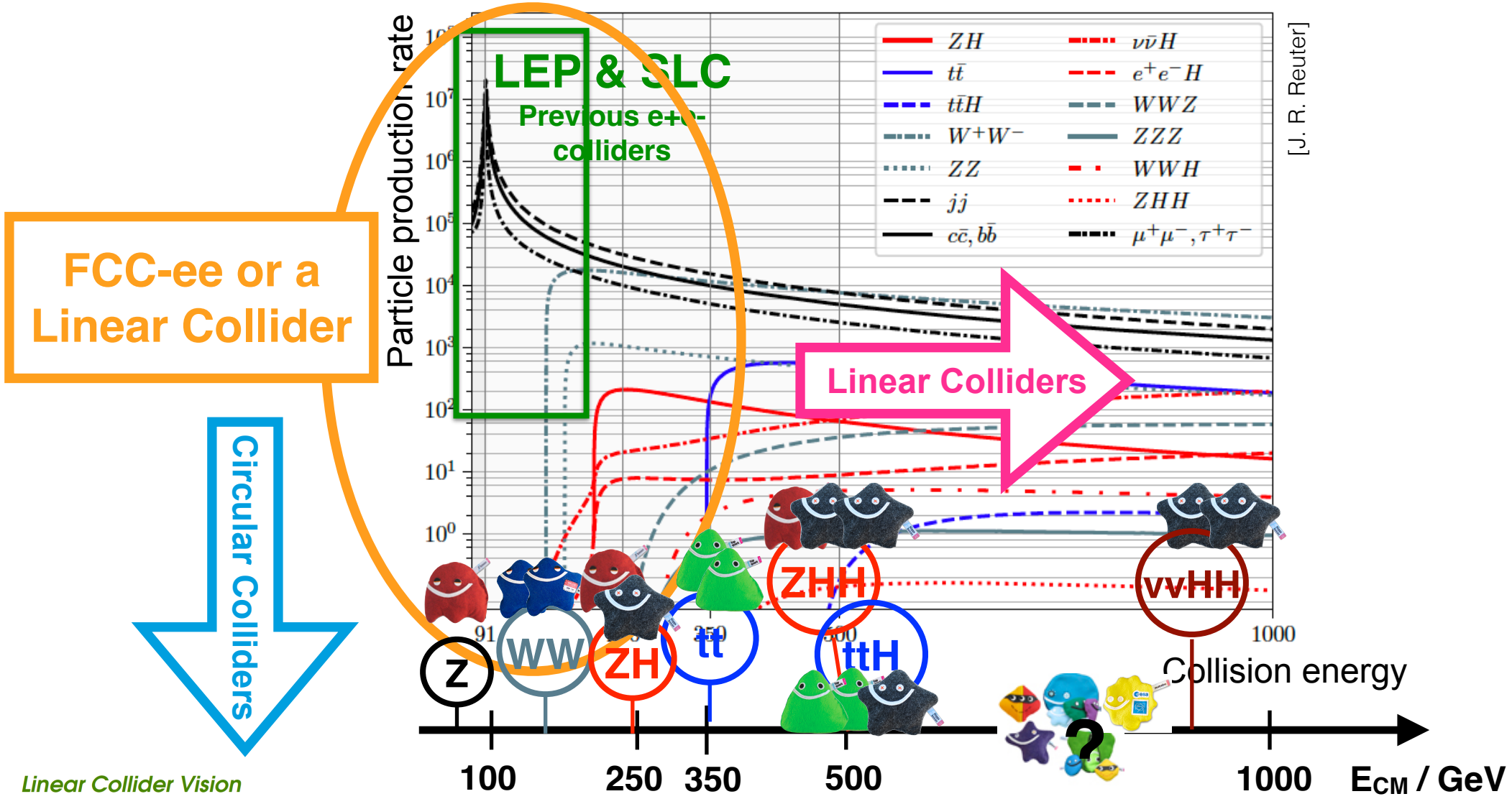


Linear Collider Vision

More on Science of Linear & Circular Colliders

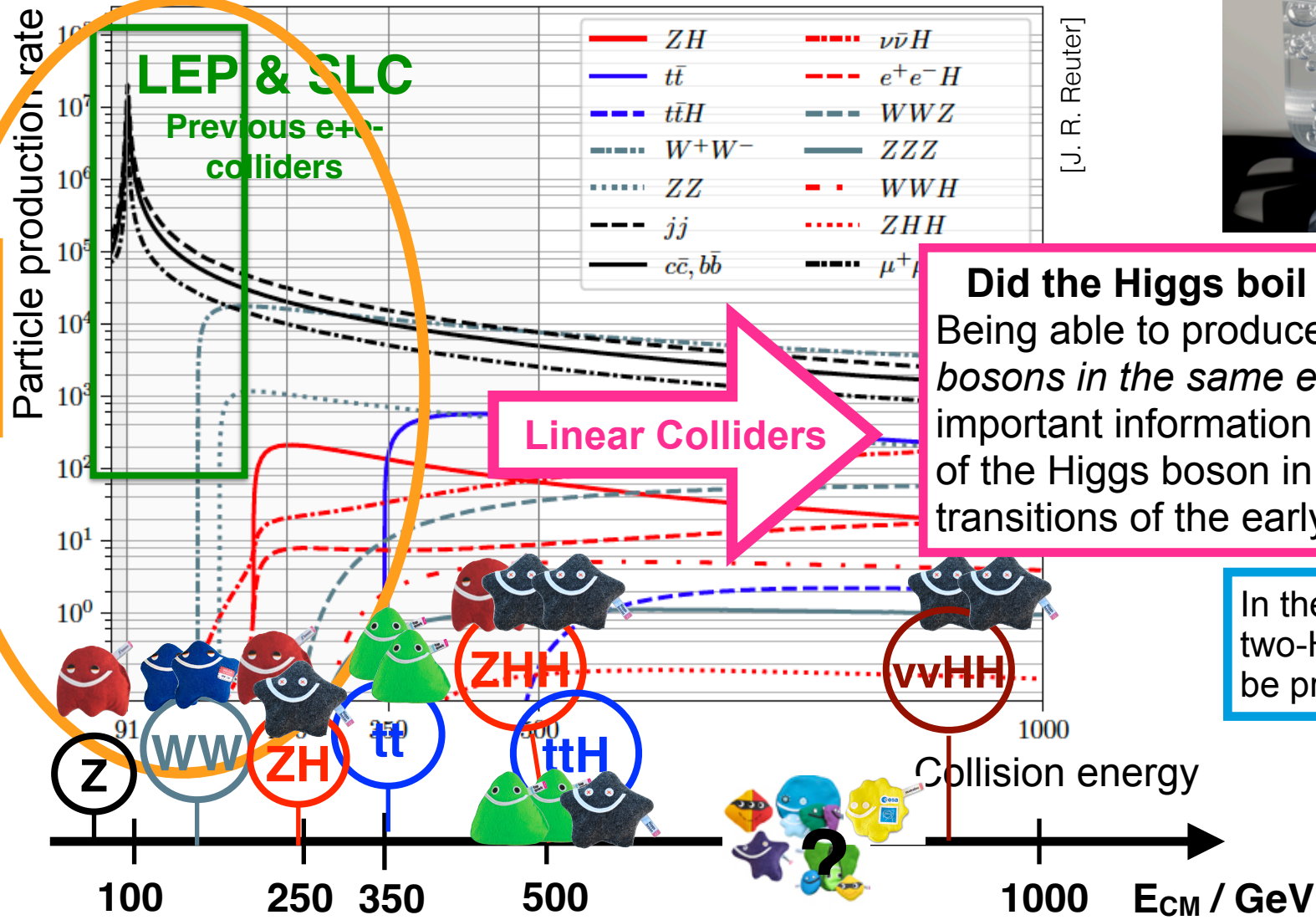
Particle production rates vs collision energy



[J. R. Reuter]

FCC-ee or a Linear Collider

Circular Colliders



Did the Higgs boil the Universe?

Being able to produce *two Higgs bosons in the same event* gives important information about the role of the Higgs boson in the phase transitions of the early universe!

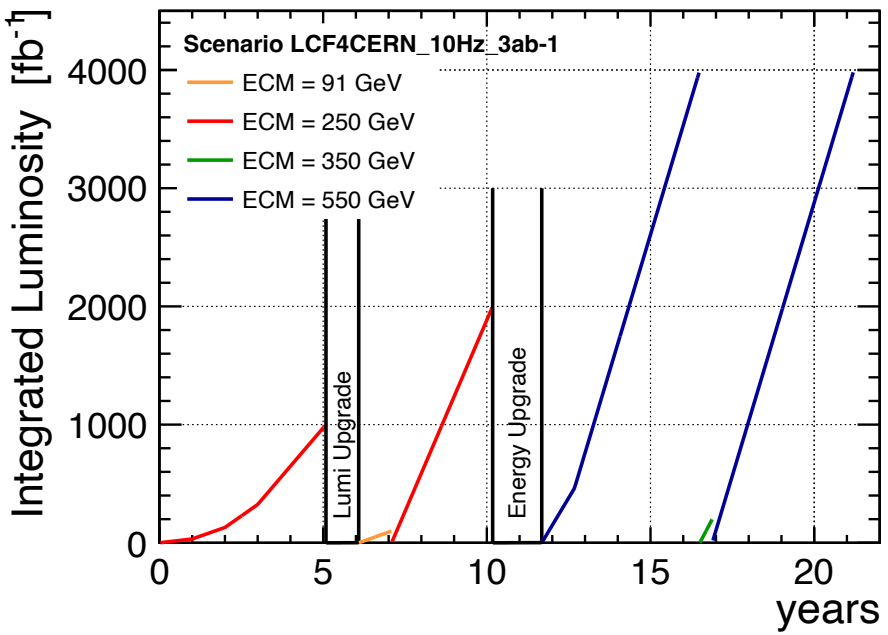
In the FCC program, two-Higgs events will be produced at FCC-hh

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**





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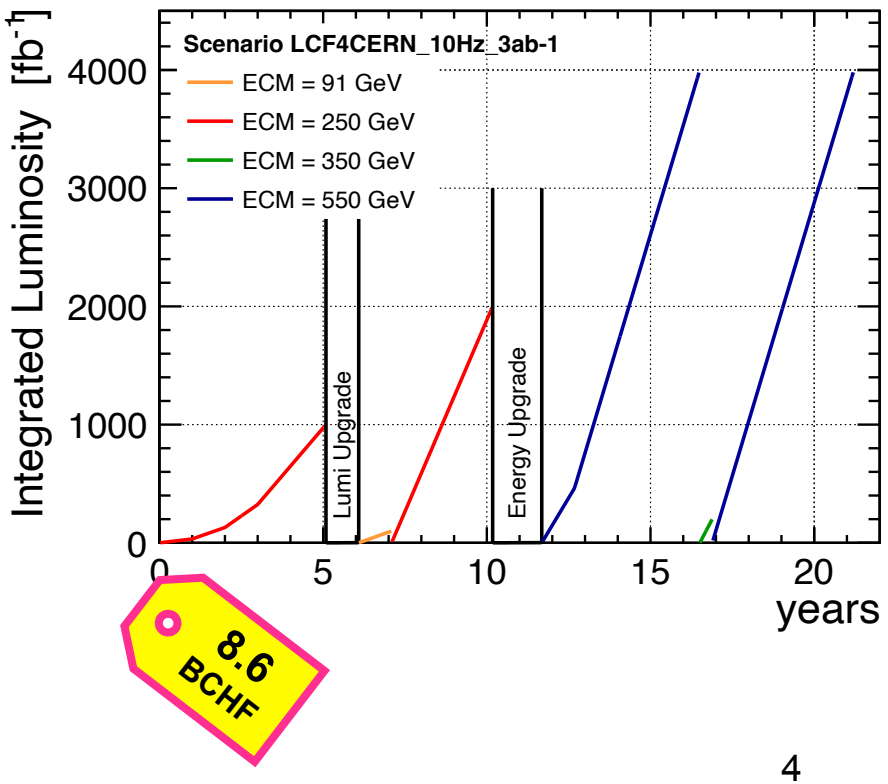

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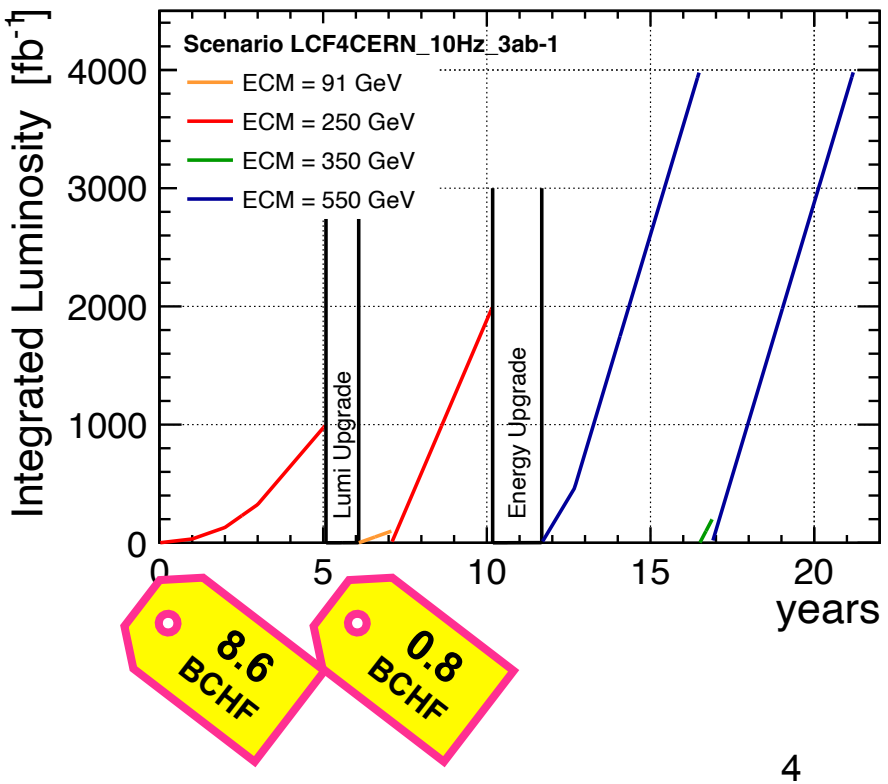

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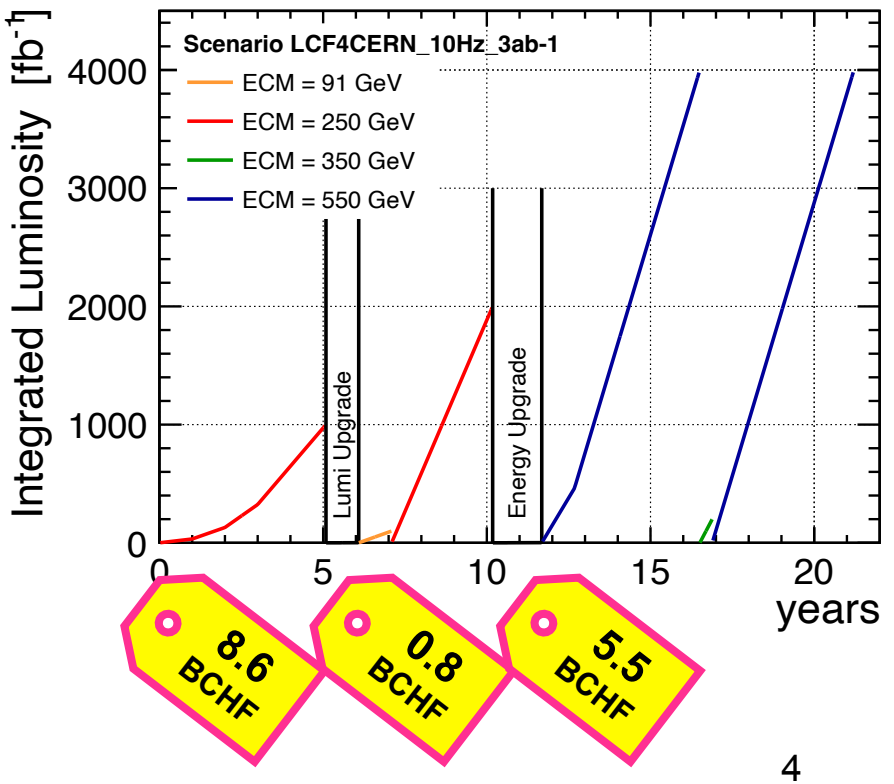

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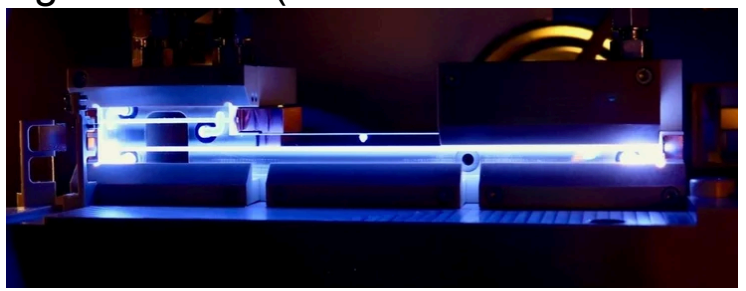
- **Stay flexible** with regard to the long-term future
- Develop facility based on **scientific developments** => initial design compatible with developing & exploiting **advanced technologies**
- Benefit from **technological developments** - or even break-throughs
  - Better (“higher-gradient”) accelerating structures (“cold niobium” or “cool copper”)
  - Plasma-acceleration
  - Combine particle beam with laser beams “photon collider”
  - ….



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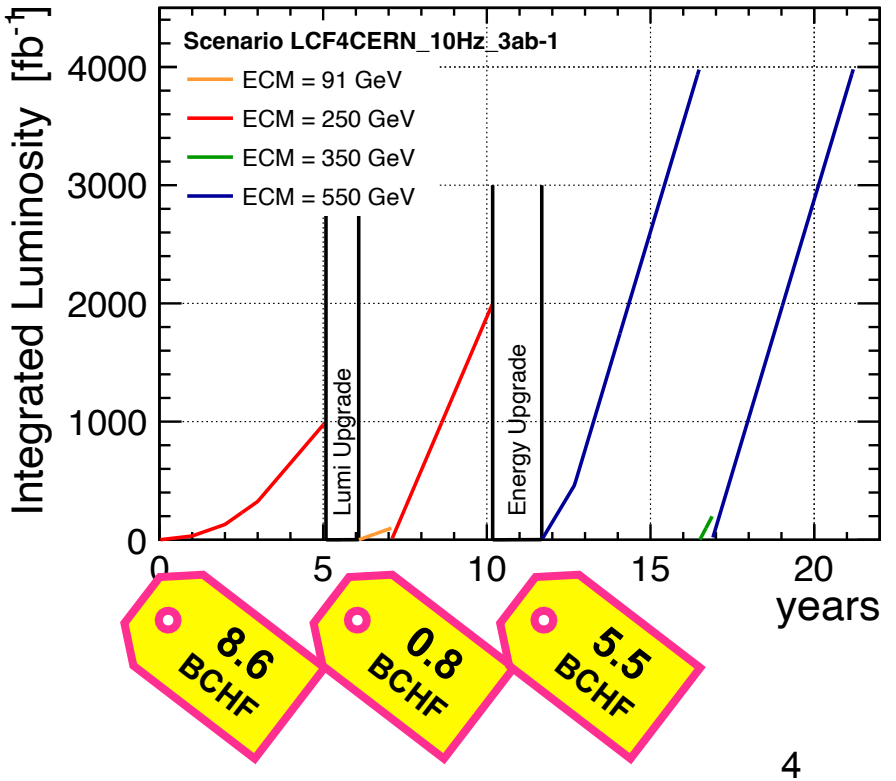
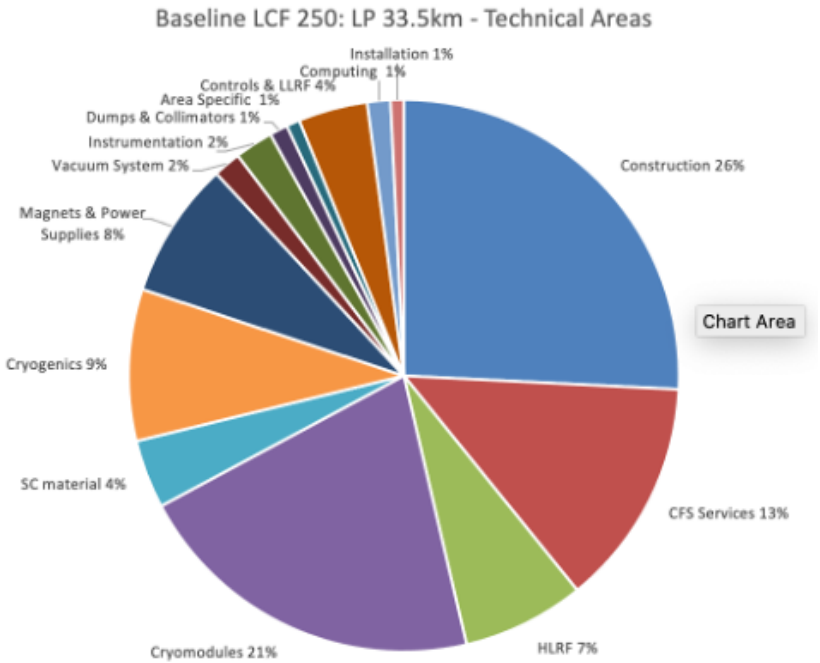
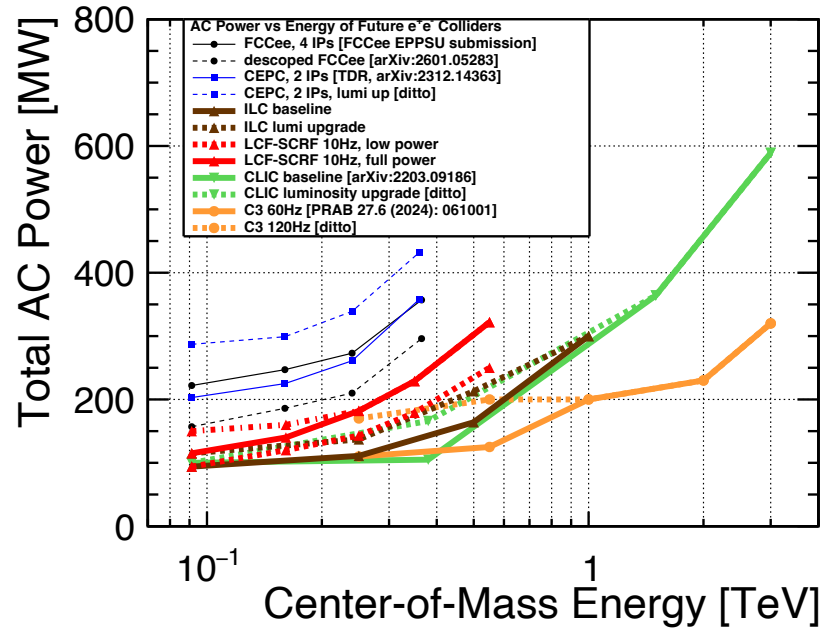


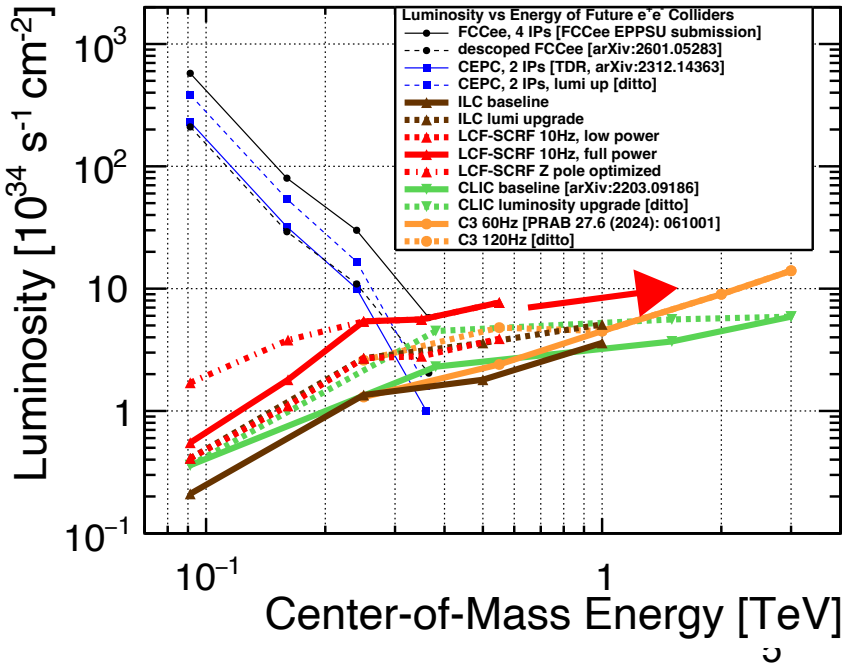
The Linear Collider Facility

Cost & Environmental Aspects

- Construction cost
- Operation cost
  incl. power consumption,
  cooling needs, …
- Spending profile
- Life-cycle assessment
  & CO2 budget







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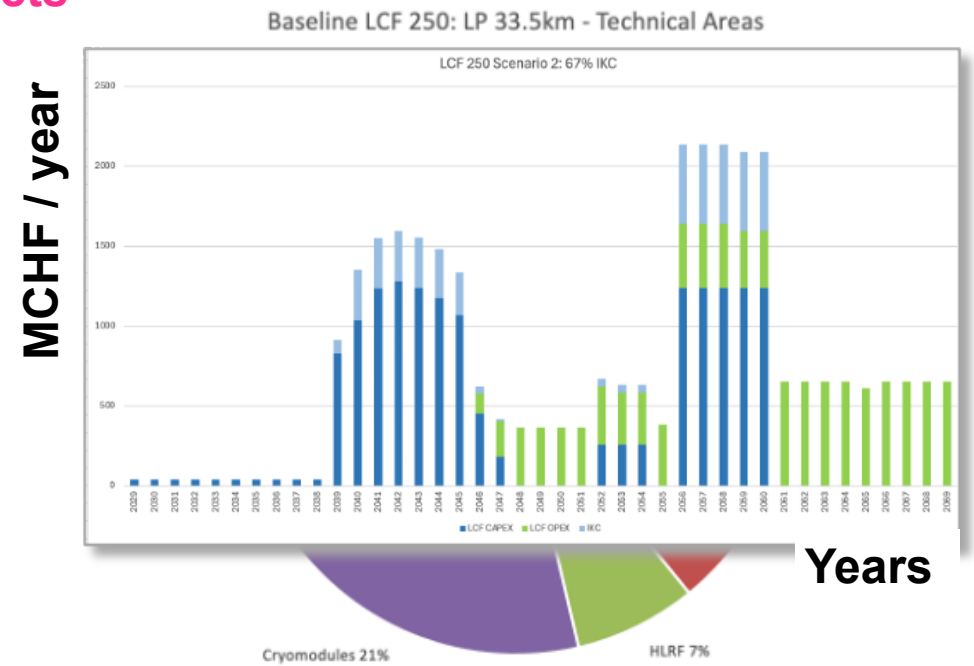

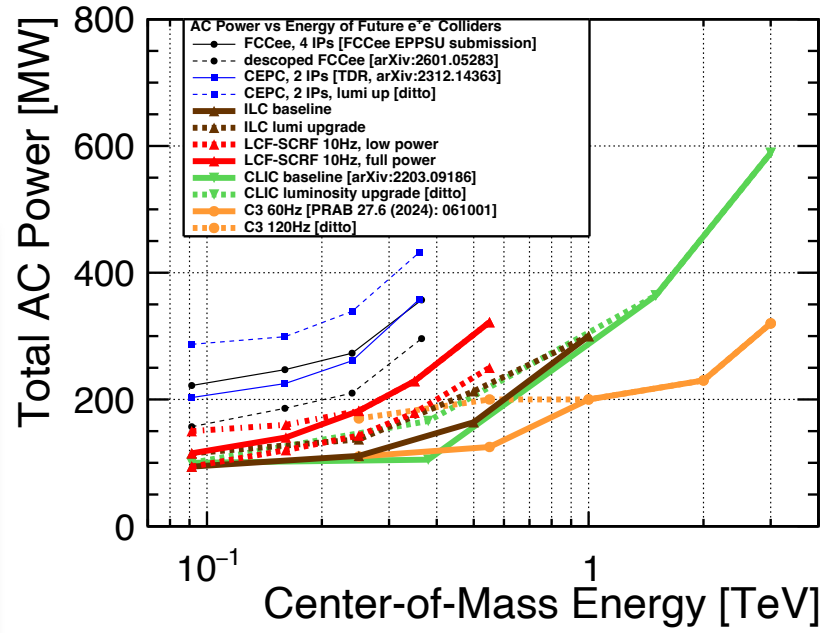

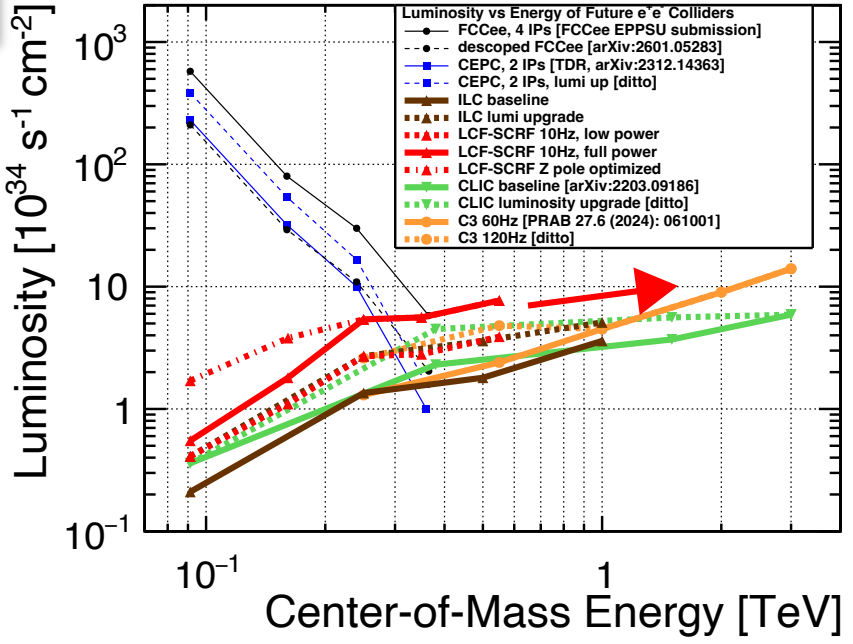

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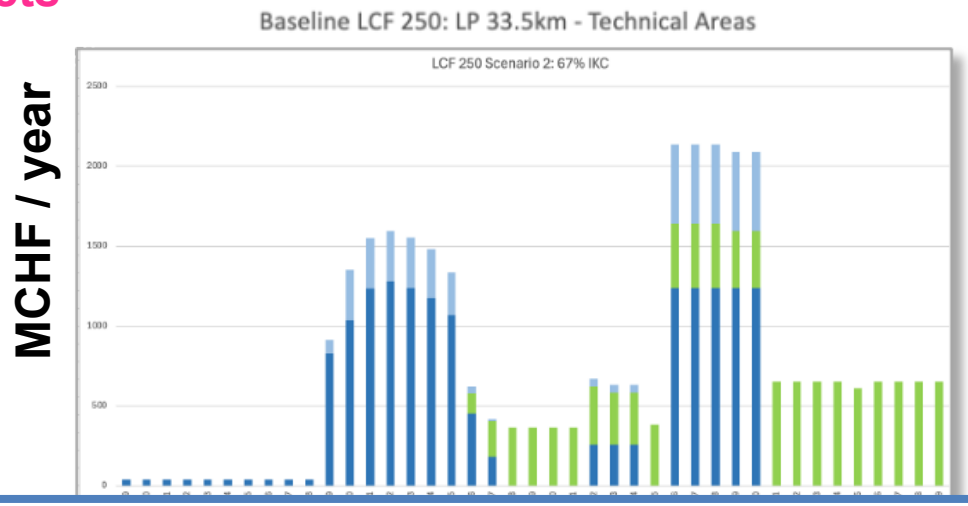
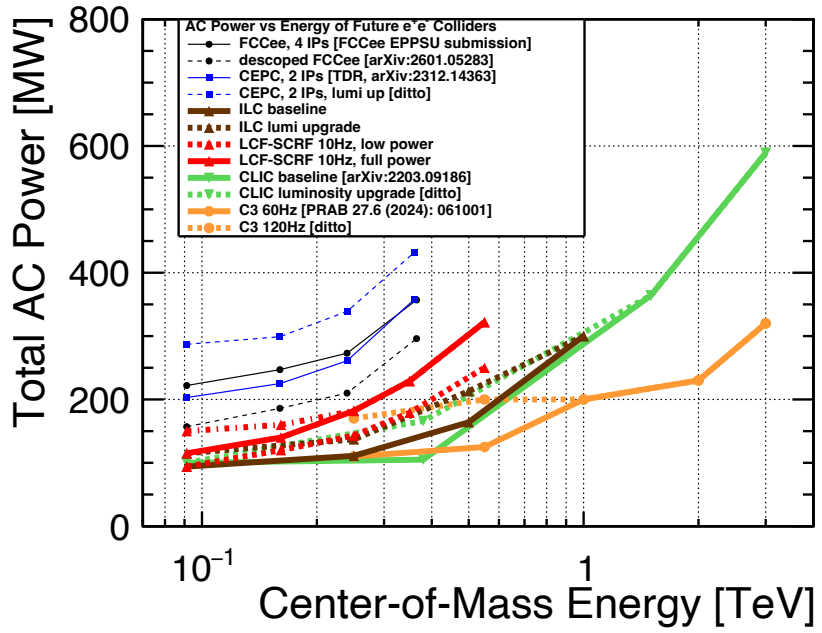
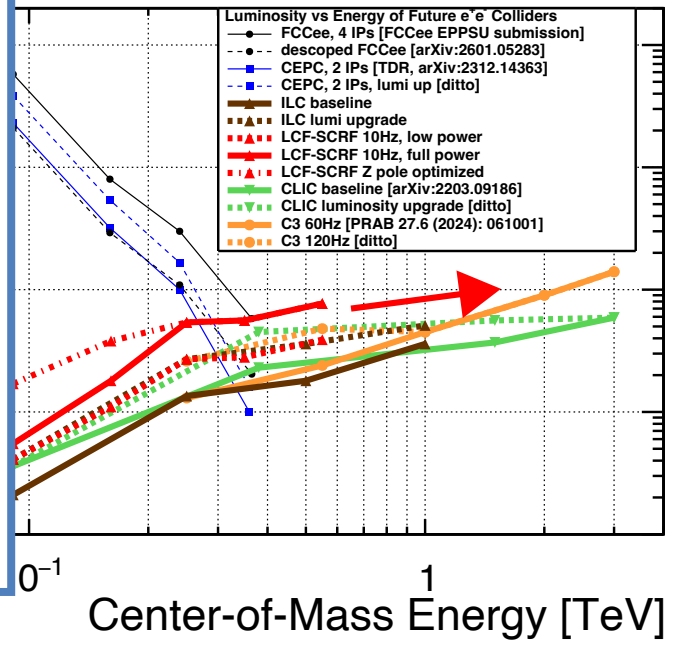




c.o.m. energy [GeV]	CLIC (2 IPs) 380	FCC-ee (4 IPs) 91.2	160	240	365	LCF (2 IPs) 250 LP 250	250 FP 91.2	250
Civil engineering (A1 – A5)								
Underground [kt CO_2 eq.]	134 – 268	480 – 1000				206 – 411[a]		
Surface sites [kt CO_2 eq.]	59 – 118	50 – 184				N/A		
Total GHG emissions from CE [kt CO_2 eq.]	193 – 386	530 – 1184				>206 – 411		
Operation period with CE infrastructure [years]	20[b]	39[b]				20[b]		
Accelerators, technical infrastructure, detectors								
Accelerators (A1 – A3) [kt CO_2 eq.]	105 – 140	N/A[c]				169 – 225	+18 – +24 [d]	
Technical infrastructure (A1 – A3) [kt CO_2 eq.]	14 – 19	N/A[c]				24 – 32 [e]		
Detectors (A1 – A3) [kt CO_2 eq.]	71 – 94	142 – 186[f]				71 – 94[g]		
Total GHG emissions for accelerator, TI and detector HW [kt CO_2 eq.]	190 – 253	N/A				>264 – 351	>282 – 375	
Number of years of physics operation	10	4	2	3	5	5	1	3
Electricity consumption								
Carbon intensity of electricity generation [g CO_2 eq. per kW h]	14 – 18							
Accelerators and detectors [TW h/y]	0.82	1.2	1.3	1.4	1.9	0.8	0.7	1.0
Off-line computing [TW h/y]	0.07 – 0.14	0.14 – 0.28				0.07 – 0.14		
GHG emissions/year of physics operation [kt CO_2 eq./y]	12 – 17	18 – 26	20 – 29	22 – 31	29 – 40	13 – 17	10 – 14	15 – 20



Summary

Take home messages

- **Studying the Higgs boson and its closest relatives is the key to understanding our universe**
- **The FCC is the *by far* favoured approach by CERN and European Particle Physics Strategy Group — *but not without alternatives***
- **A Linear Collider can do a significant part of the FCC physics program with**
  - tunnel length comparable to LHC
  - cooling needs, AC power, …similar to LHC
  - cost to initial science ~8.6 BCHF,
    with “two-Higgs mode” similar to descoped FCC-ee
  - fostering and leveraging advanced accelerator technologies for long-term development
  - initial facility planned with flexibility for upgrades — choices based on *science & technology progress!*

