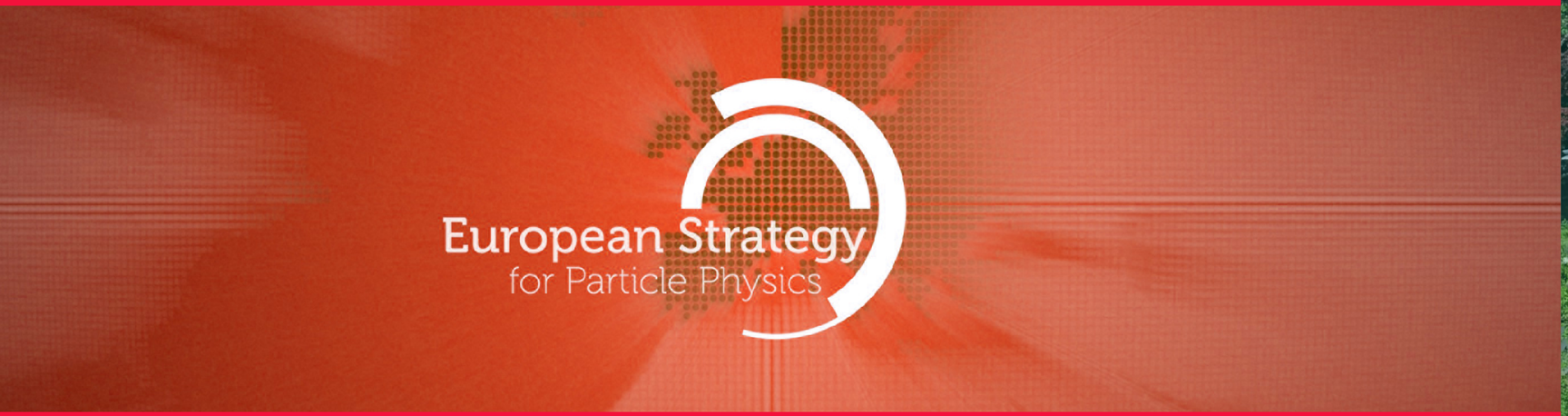
Preparing for the Future

The 2026 Update of the European Strategy for Particle Physics



Ulrich Husemann
Karlsruhe Institute of Technology
Herbstschule HEP, Bad Honnef, September 8, 2025


Image credit: Birds-eye

Lecture Outline

... and some preliminary remarks

A **difficult evening lecture** to give:

- Lots of material, and a moving target
- No textbook or blueprint
- Isn’t lecturing about structures and processes super boring?

Three guiding questions:

I. Where will particle physics be in 2040?

II. What is strategic planning and why should I care?

III. Update of the European Strategy for Particle Physics: what’s going on now?

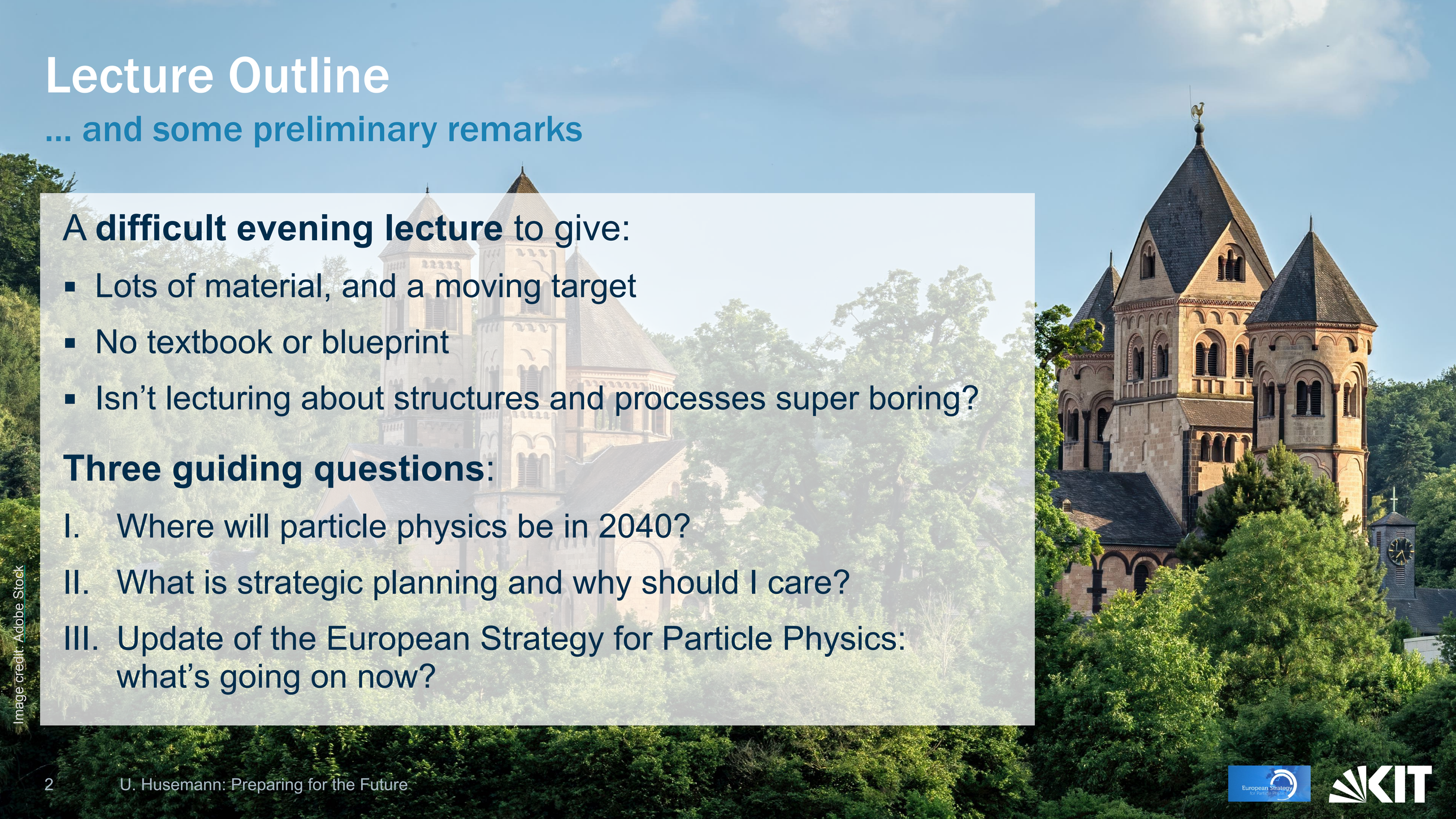


Image credit: Adobe Stock

Image credit: Adobe Stock

Where will particle physics be in 2040?

European Strategy
for Particle Physics

KIT

Open Questions in Particle Physics

In 2025

What is the **structure of the vacuum**?

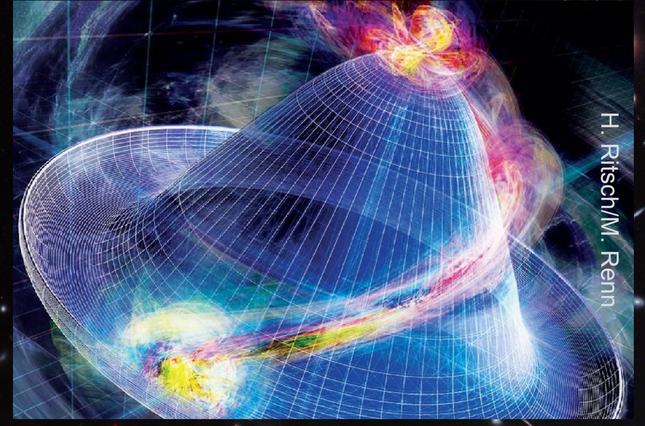
The Higgs potential.

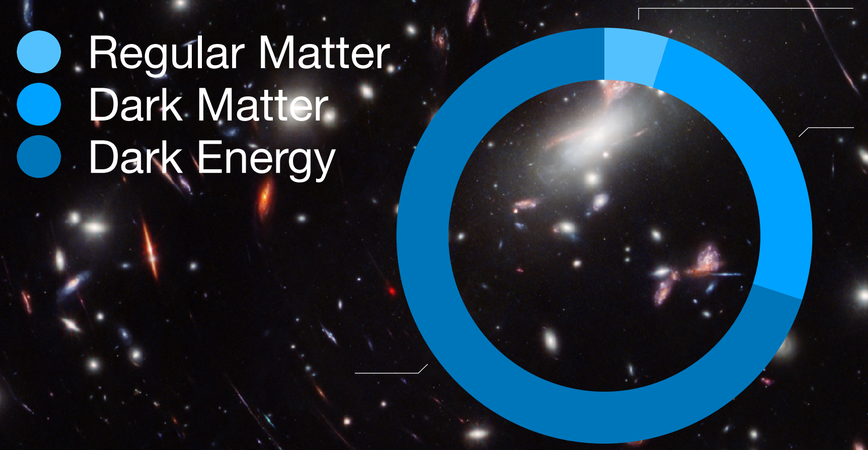
What is the **energy content** of the universe?

Dark matter and dark energy.

Why is there so much **more matter than antimatter** in the universe?

Violation of the charge-parity (CP) symmetry.





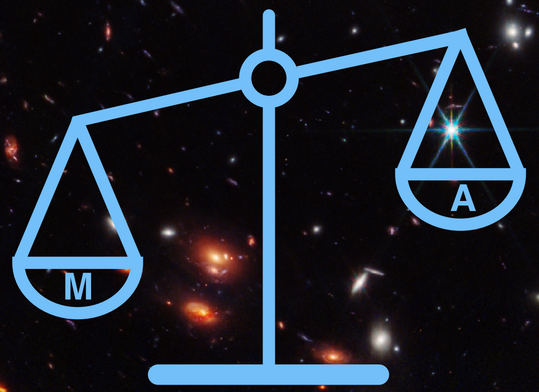
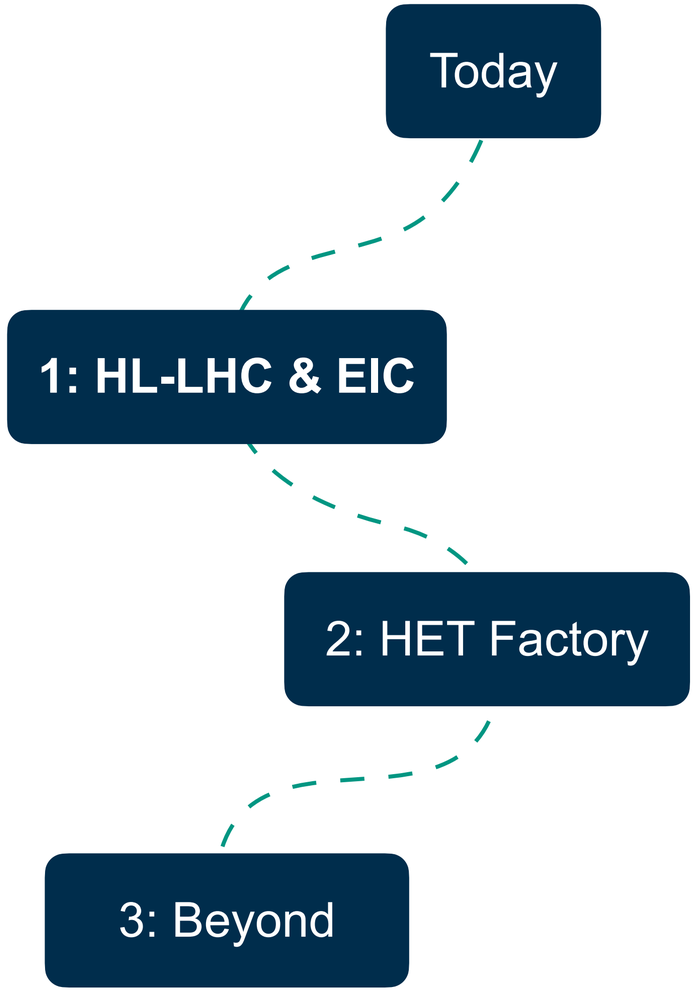


Image credit: NASA/ESA/CSA

Where will particle physics be in the 2040s?

Colliders



European flagship: **HL-LHC**
– high-luminosity upgrade of the CERN LHC

- Accelerator upgrades → **more luminosity**
- Detector upgrades → **innovative instrumentation**

Further **experiments** globally:

- **Belle II** at SuperKEKb in Japan
- **ePIC** at the EIC in the US
- Further experiments at DAΦNE in Italy, BEBC in China, VEPP in Russia, …

What can we expect beyond the 2040s?

The Next Flagship Collider

From the 2040s: **Higgs/EW/Top Factory** (“HET Factory”)

Today

1: HL-LHC & EIC

2: HET Factory

3: Beyond

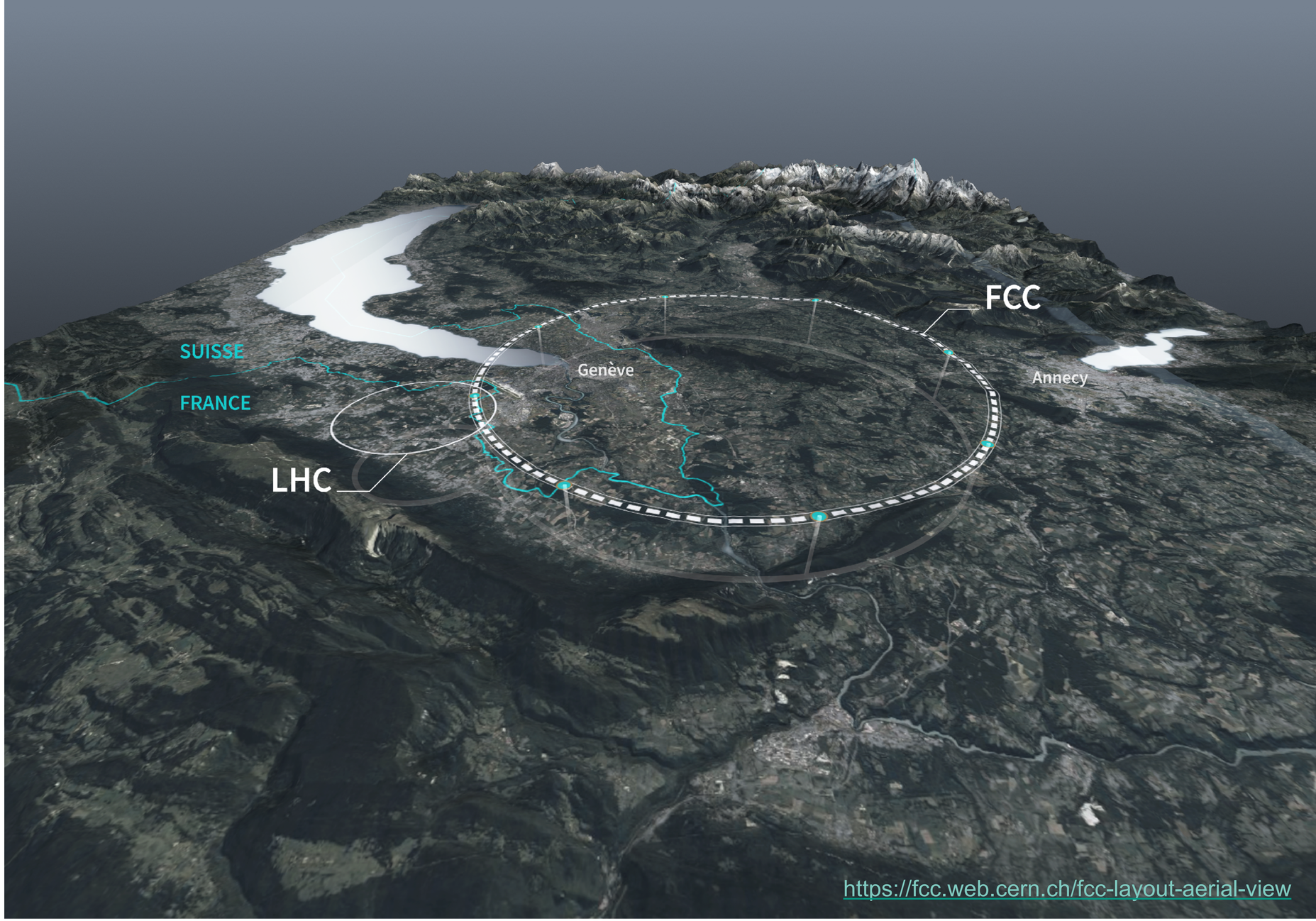
FCC-ee

The Circular Option

90.7 km ring,
from 91.2 GeV (Z) to
365 GeV ($t\bar{t}$)

Integrated program:
hadron collider in
the FCC tunnel
after FCC-ee
(like LEP → LHC)

Competing project in
China: CEPC



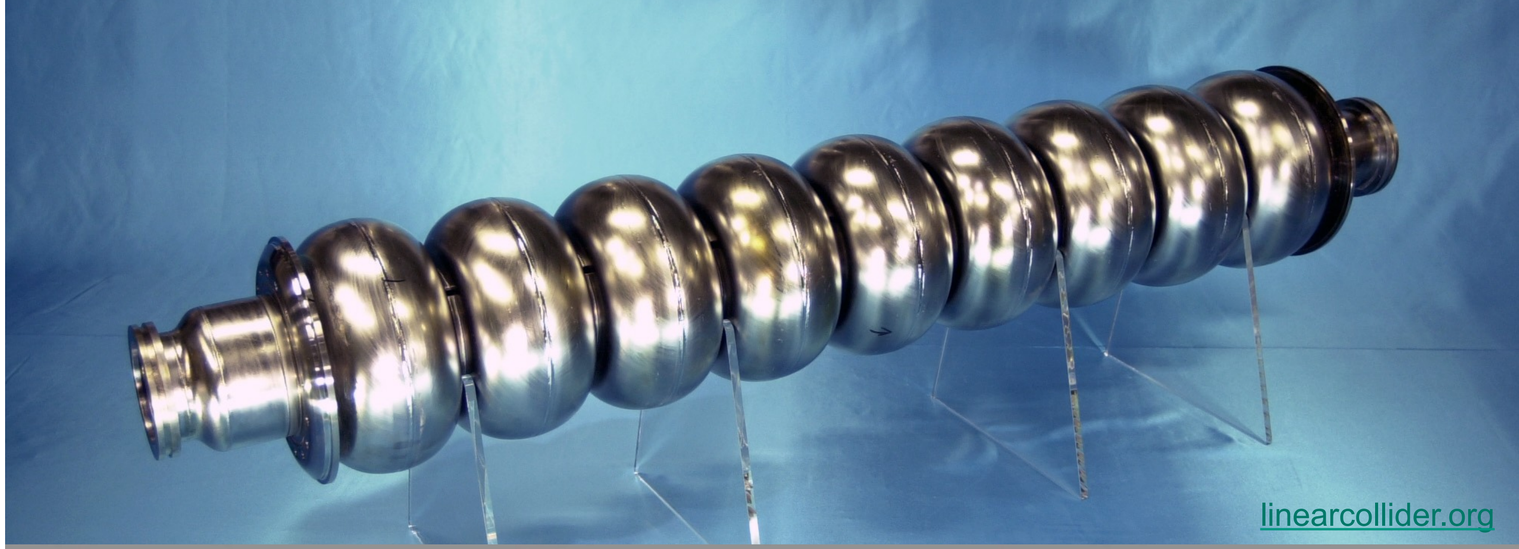
https://fcc.web.cern.ch/fcc-layout-aerial-view

LCF at CERN

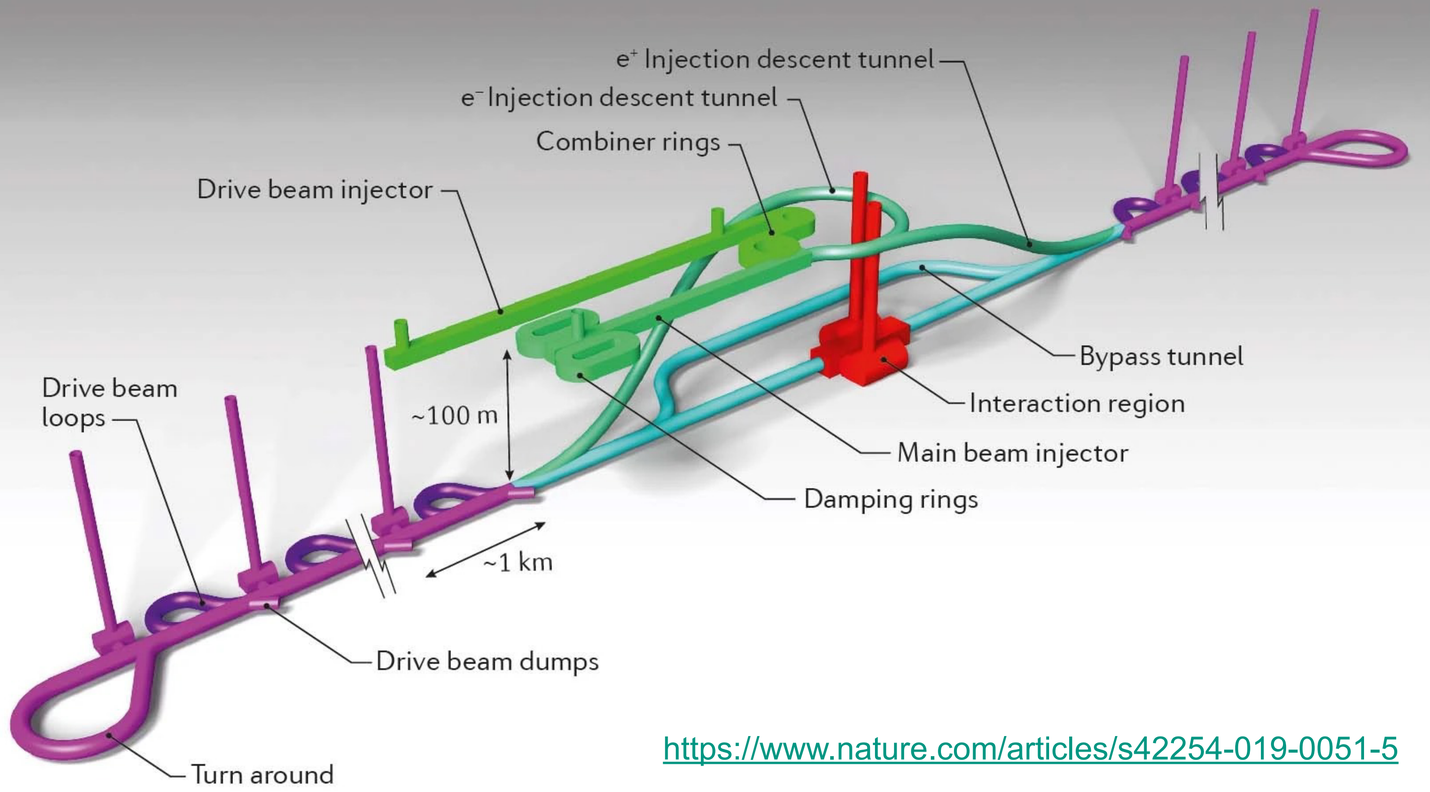
The Linear Option

Linear Collider Facility:

- ILC-like: **superconducting** radiofrequency (RF) cavities, 250 GeV, 550 GeV
- CLIC-like: normal-conducting RF cavities and **drive beam,** 380 GeV, 1.5 TeV



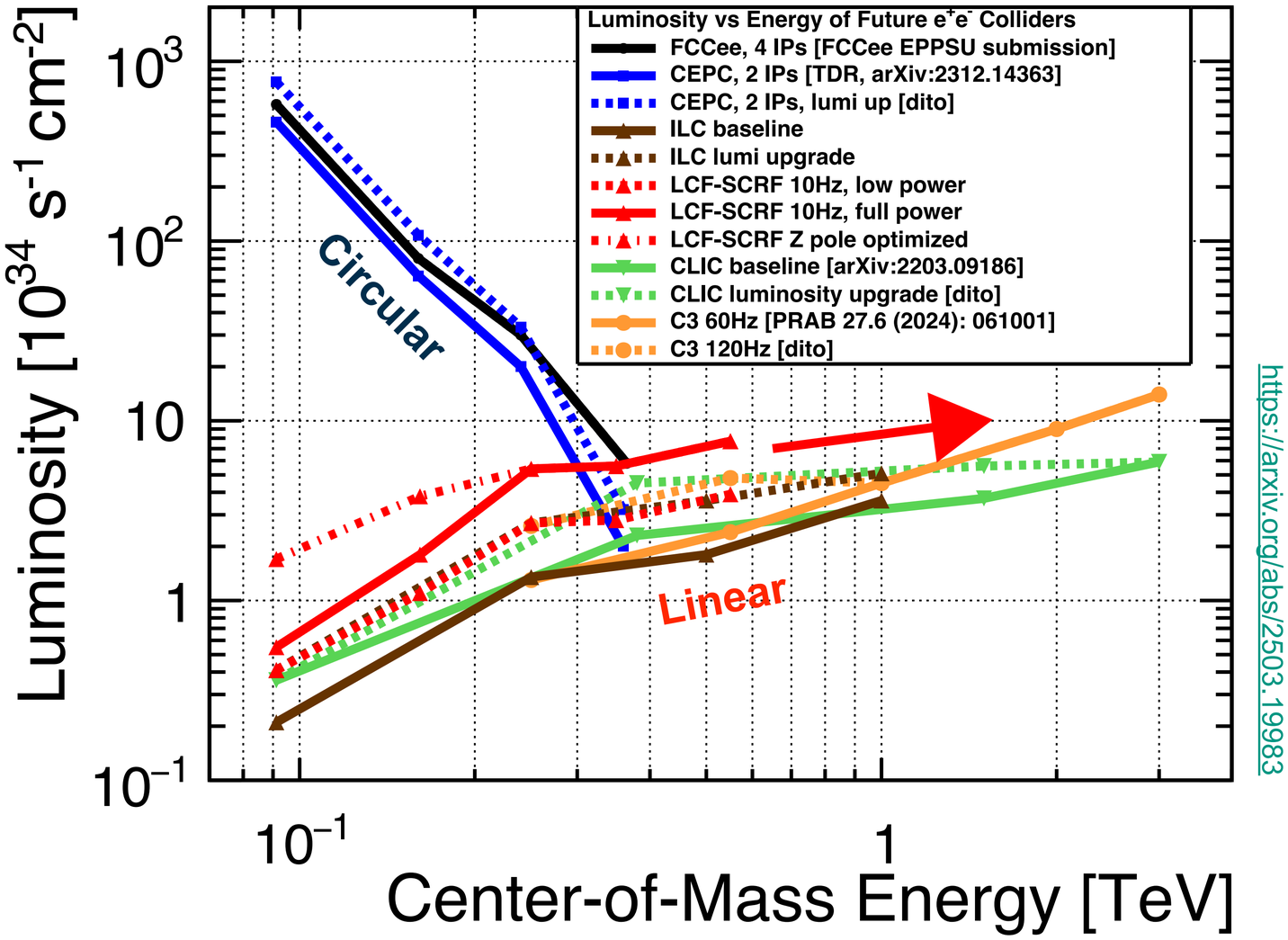
linearcollider.org



https://www.nature.com/articles/s42254-019-0051-5

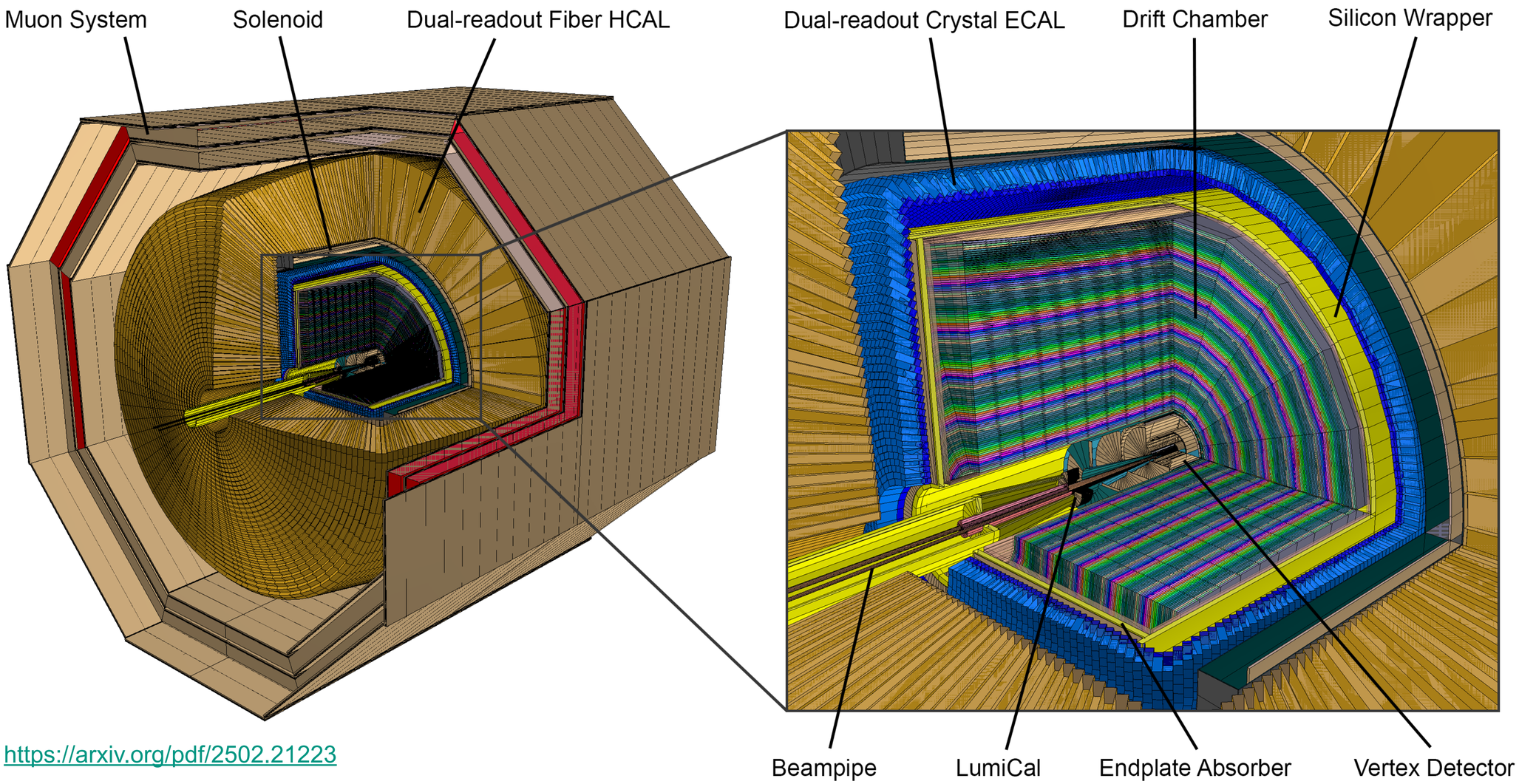
Linear or Circular?

Luminosity vs. Center-of-Mass Energy



Detector Concepts for a Higgs/EW/Top Factory

Example: IDEA – Dual Readout Calorimetry for the FCC-ee



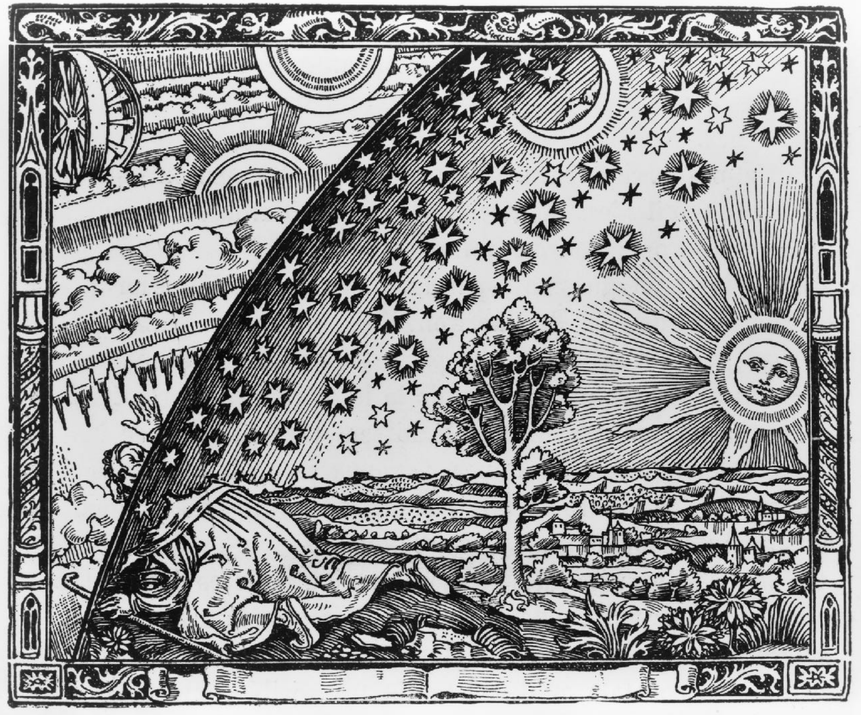
https://arxiv.org/pdf/2502.21223

What can we expect beyond the 2040s?

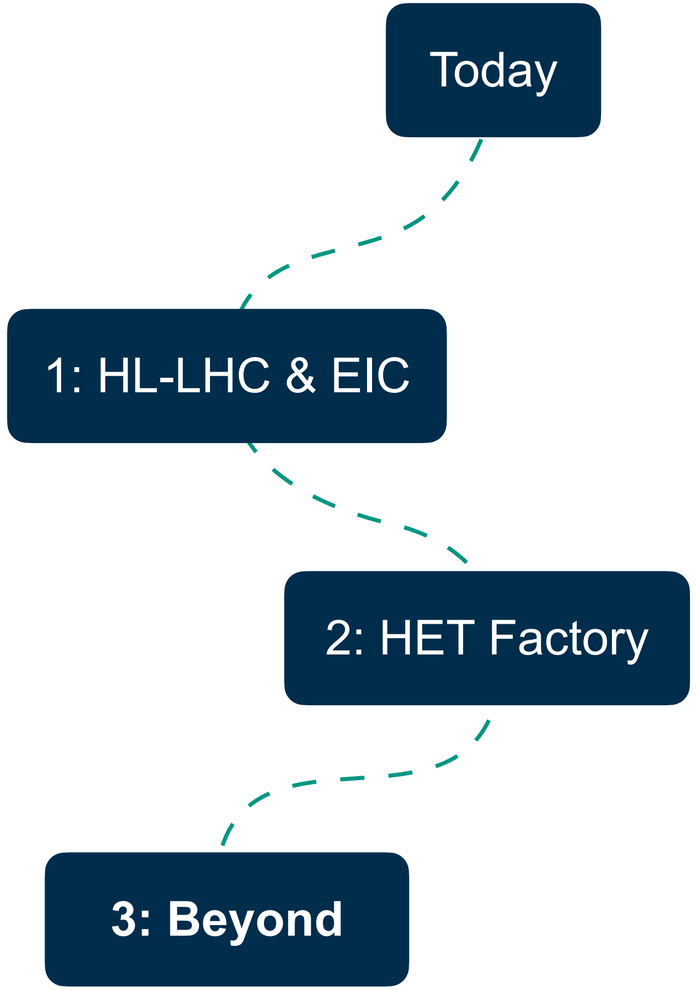
The Next Flagship Collider

From the 2040s: **Higgs/EW/Top Factory** (“HET Factory”)

Beyond 2050: **hadron or muon collider** with
at least 10 TeV partonic center-of-mass energy



C. Flammarion, *L'atmosphère : météorologie populaire*



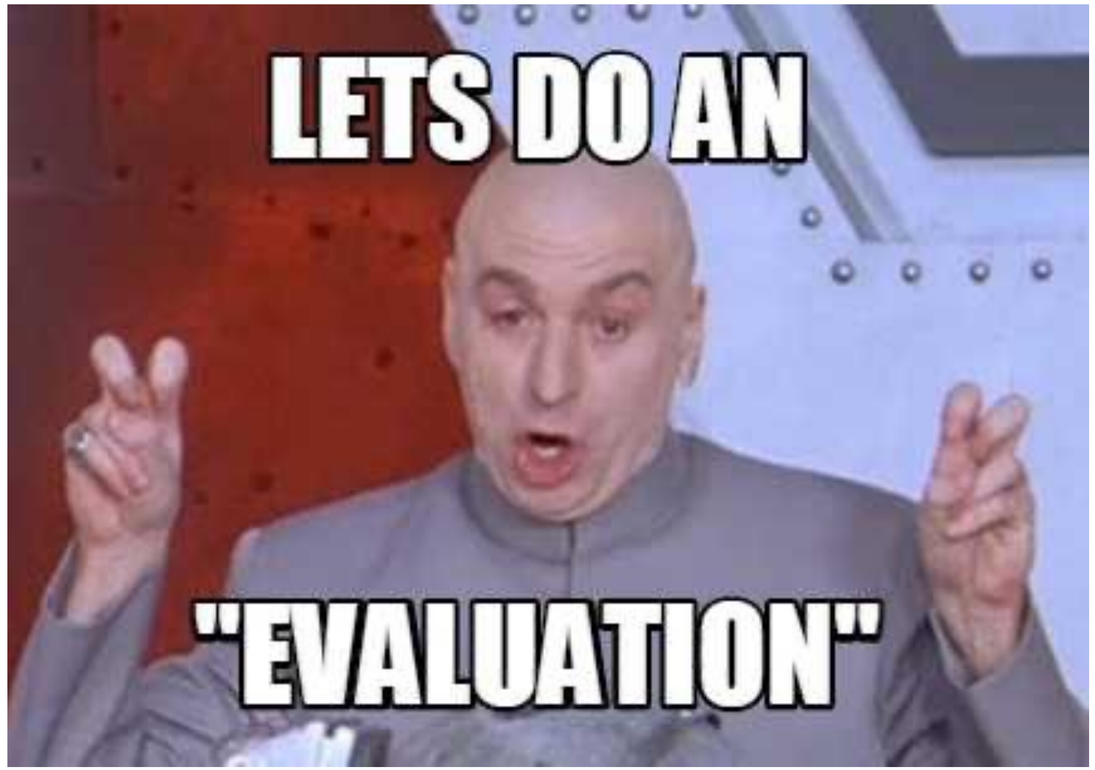
Evaluating and Comparing Future Projects

Finding the Right Metric

Goal: pick projects with largest **interest in particle physics community** and largest **scientific impact**

Boundary conditions: **technology readiness**, **political** and **financial** feasibility, **environmental** and **societal impact**

Important: need **fair comparison** of competing projects → **benchmarks**



https://www.mihaileric.com/posts/model-evaluation/

Which future projects would you embark on?

A Gretchen Question

Please answer this question using the audience response system **Pingo** (hosted at KIT)

https://pingo.scc.kit.edu/events/361709

Food for thought: would it make sense to let the particle physics community **vote on the next big project**?

J. Tissot, La Rencontre de Faust et de Marguerite, (1860, Musée d'Orsay)

Your Preferred Future Project

Survey Results

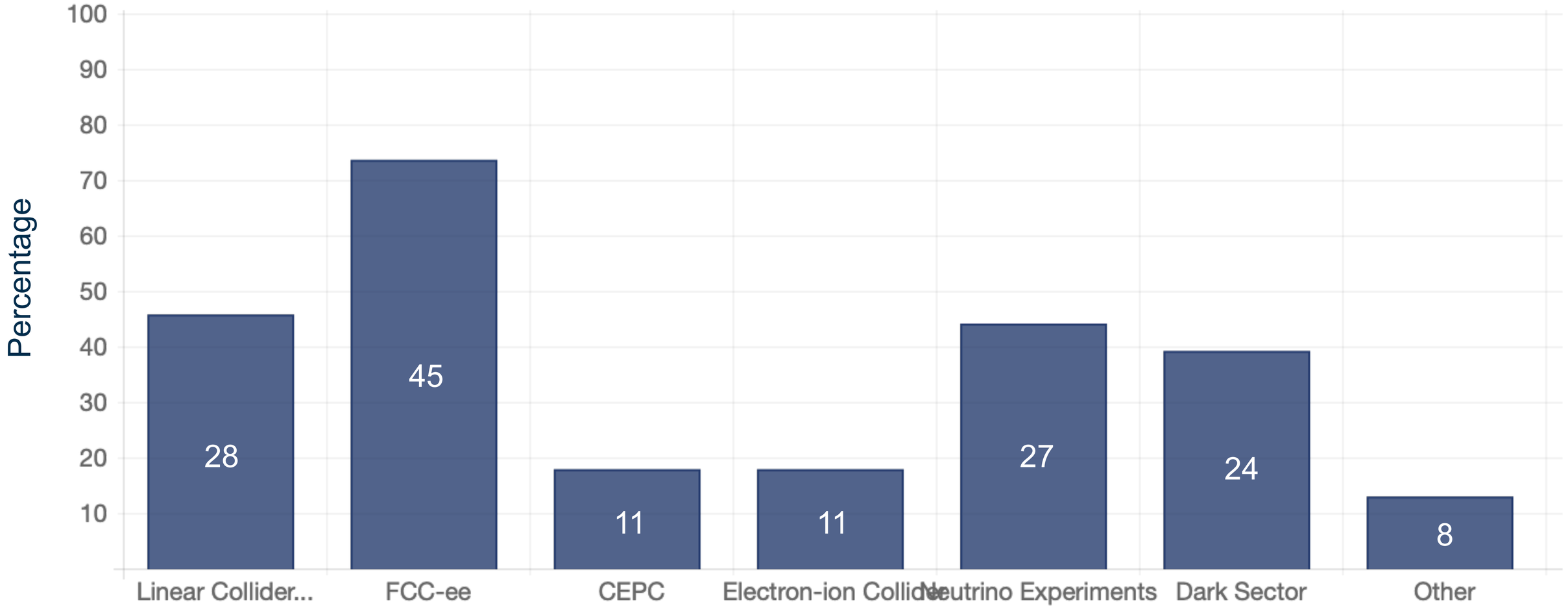


Image credit: Birds-eye

What is strategic planning and why should I care?

European Strategy
for Particle Physics

Preparing for the Future

Challenges for Big Projects

Long time scales

LHC upgrades: 25–30 years from first ideas to data-taking

Major investments

in large-scale research infrastructures

A rapidly changing world

microelectronics, manufacturing, AI, second quantum revolution, …

Image: ChatGPT

ChatGPT prompt: *generate a picture of a big future particle physics project considering the long time scales, the major infrastructure investments and the rapidly changing world*

Strategic Planning

What IS a strategy, anyway?

Image: ChatGPT

Strategic Analysis of New Projects

SWOT: Strengths, Weaknesses, Opportunities, Threats

Xhienne, SWOT en.svg, CC-BY-SA2.5

Image: ChatGPT

Why You Should Care About Strategy

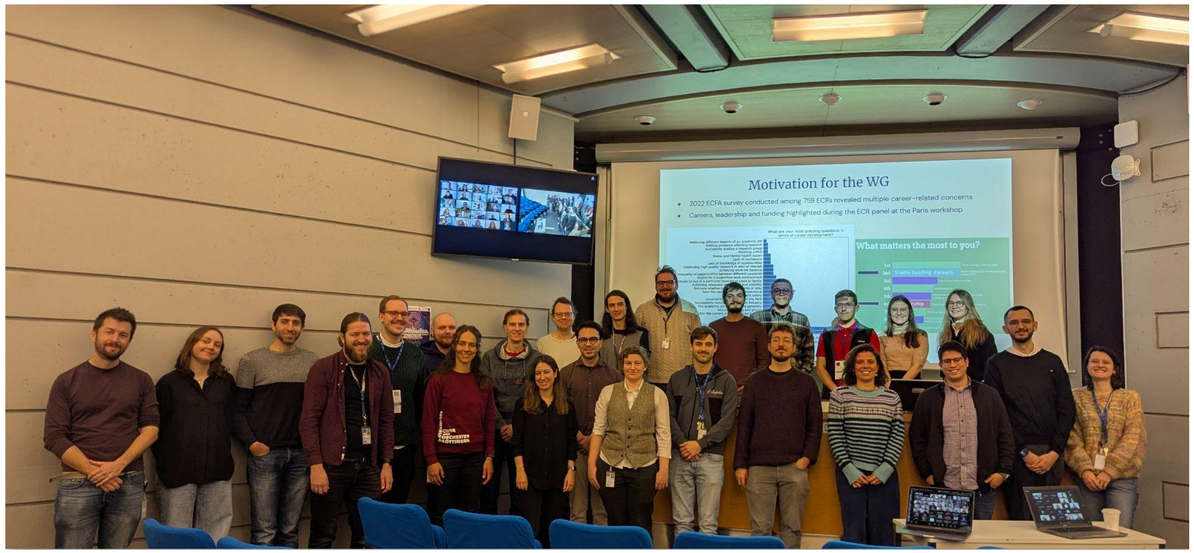
if you are an Early Career Researcher today

Today's Early Career Researchers (ECRs)…

- … will be **tomorrow's leaders**
- … will make projects **sustainable**
- … will define how we **work together**
- … deserve **challenging projects**, **recognition**, and **attractive career paths**

→ ECRs should **participate** in today's decisions

ECR Open Symposium 2025



C. Dimitriadi, U. Einhaus, ESPP Open Symposium 2025

The Global Context

Scientific Collaboration in a Multipolar World

Political and societal **boundary conditions** became more difficult in recent years

World regions aiming for **technological sovereignty** and **competitiveness**

LHC: very successful model of **worldwide scientific collaboration**
→ **global particle physics network**

Which Story Do We Tell about Our Projects?

Science Communication

How can we convincingly communicate our science and projects to **different target audiences**?

A. Our peers

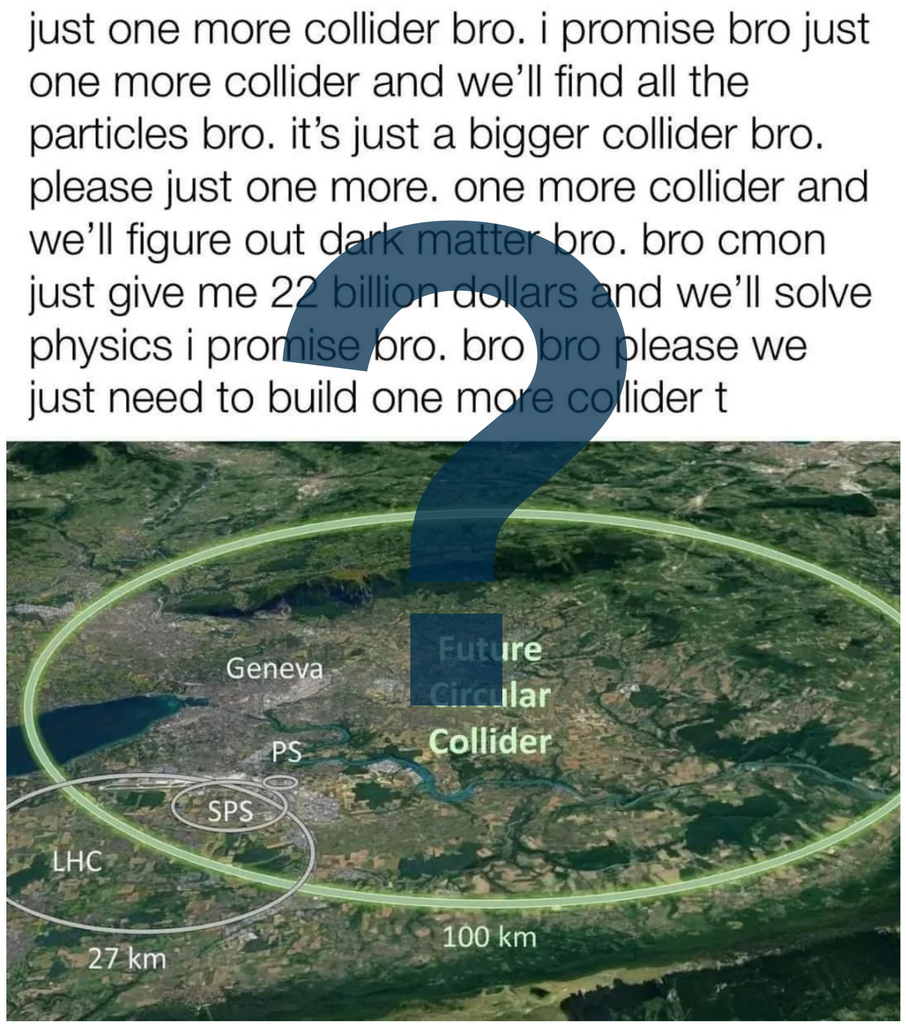
B. Young generation

C. General public

D. Policymakers

Challenge: create a one-minute elevator pitch for any of the target audiences above
(please indicate which)
https://pingo.scc.kit.edu/events/361709

Memes can be very telling…



Source: I. Arthur

One-Minute Elevator Pitch

Survey Results

Curiosity drives our exploration of nature
B: we can find things which we only dream of today.
It's like lhc but better.
D: our country will be the leader in this field and we will set global standards
D: pleeeeease give us money, you won‘t regret it
My theory provides predictions for a phase space regime unavailable so far. in order to keep me employed, please let us build the next collider such that my theory can be valsified, but i already habe three new theories in store to explain why i am wrong. will need anpther collider tho
We'll understand nature, it'll advance us
A-d: accelerator-based cancer therapy, d: competitiveness
General public: facility will have technological developments useful for medical facilities besides doing physics
B. bigger is better, bro
Just believe me bro im scientist
Cern made the internet (all)
We will find new particles and develop new technologies
B: see, it's very fun to build something new that has not been here before! think like the fastes car ever build! but additionally it's the smallest! that's cool!
For audience b: bro imagine how cool it would be to make two particles go nyooooooom. it's literally sonic irl

Image credit: Adobe Stock

European Strategy for Particle Physics – What's Going On?

European Strategy
for Particle Physics

KIT

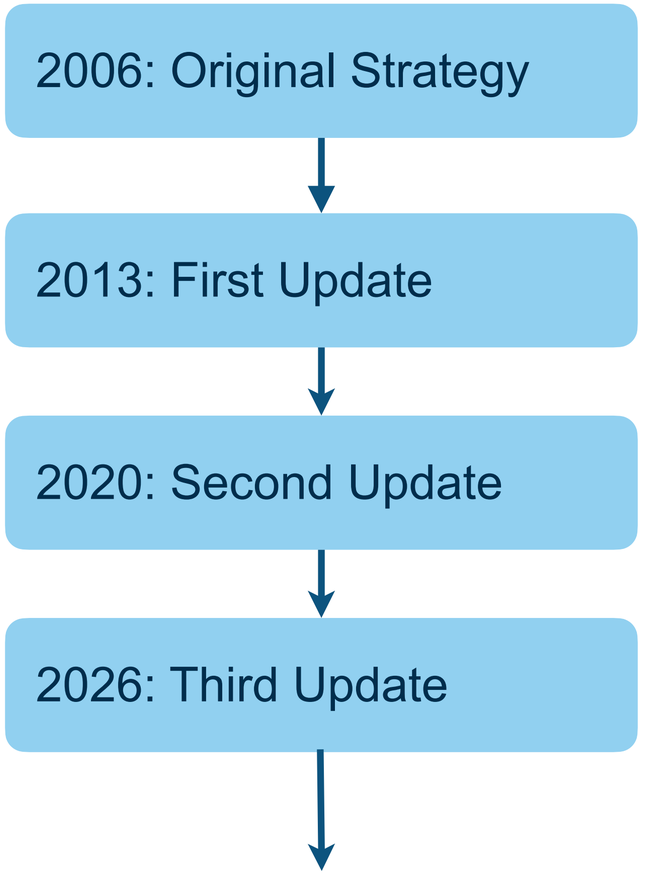
European Strategy for Particle Physics (ESPP)

Cornerstone of European Decision-making on the Long-Term Future of Particle Physics

Challenge: decision-making with $O(10^4)$ scientists

Five major steps:

- Mandate from **CERN Council**
- Broad **consultation**
- Development of **strategic recommendations** for Council
- **Council decides** on strategy
- European particle physics community **implements** strategy

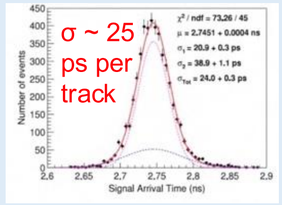


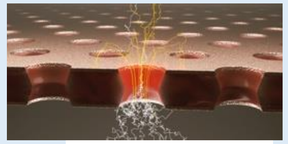
The ESPP Does Make a Difference: ECFA Detector R&D Roadmap

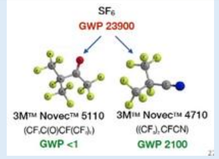
+ close collaboration and efforts in the US, Japan, and China

DRD1: Gaseous Detectors

Large · Fast · eco-friendly gases · MPGD, e.g. GEMs



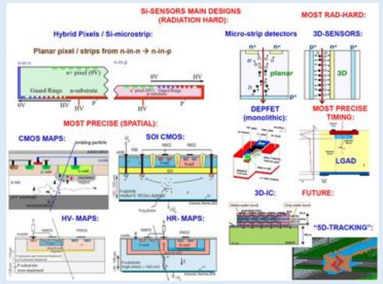




PICOSEC: NIMA903 (2018) 317

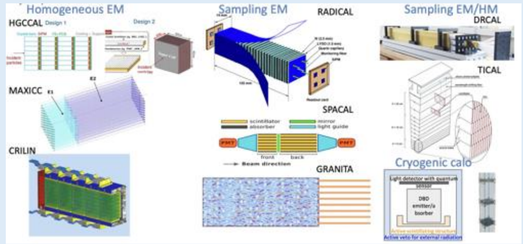
DRD3: Semiconductor Det.

Monolithic CMOS · LGADs · radiation hardness · interconns.



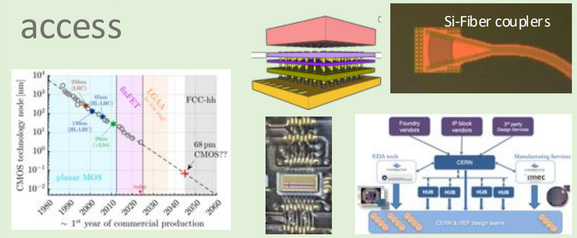
DRD6: Calorimetry

Energy resolution · High granularity · dual readout · particle flow · sandwich · optical



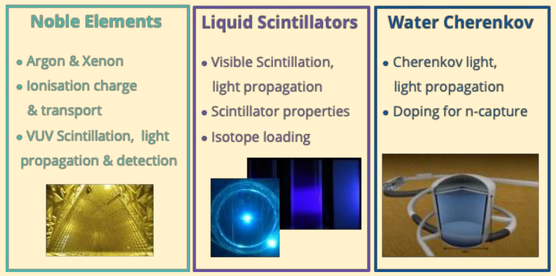
DRD7: Electronics

ADC/TDC IP Blocks · Opto-electronics · packaging · power · extreme environments · COTS · intelligence on detector · foundry access



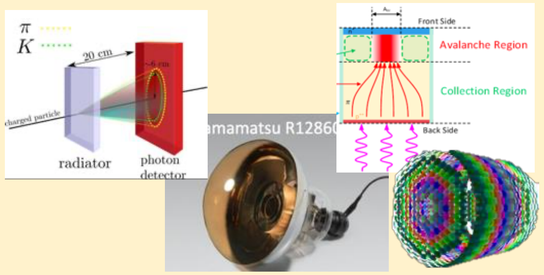
DRD2: Liquid Detectors

for Neutrinos · Dark Matter · 0vbb



DRD4: Photon detectors

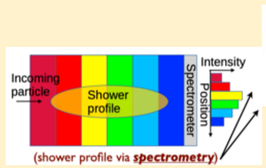
vacuum, solid-state (SiPM), hybrid single-photon and SciFi detectors · applications in PID, RICH, tracking

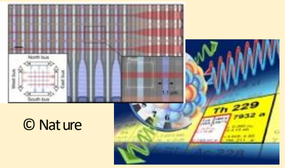


DRD5: Quantum Sensors

Quantum dots · superconduct. nanowires · bolometers · TES · MMC · nuclear clocks

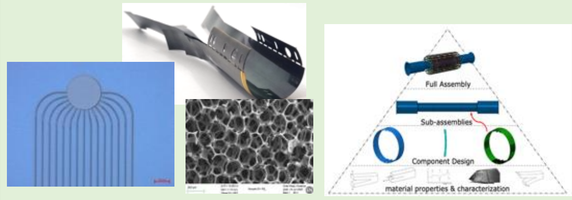
Applications in LEPP, first projects in HEPP happening





DRD8: Mechanics

Ultra-thin beam pipes · CF foam and new materials · curved, retractable sensors · air & micro-channel cooling · eco-friendly cooling fluids · robots · augmented reality



T. Bergauer

ESPP: What are we supposed to do and who is involved?

What are ECFA, the ESG, and the PPG?

European Committee for Future Accelerators (ECFA)

long-range planning and advisory for CERN management

Paris Sphicas, ECFA Chair

European Strategy Group (ESG)

proposal for medium-and long-term priorities of the field

Karl Jakobs, Strategy Secretary

Physics Preparatory Group (PPG)

preparation of scientific input for ESG proposal

Timeline for the update of the European Strategy for Particle Physics

https://europeanstrategyupdate.web.cern.ch/process-0

Interlude: Top-Down vs. Bottom-Up Approaches

Which approach is superior in science?

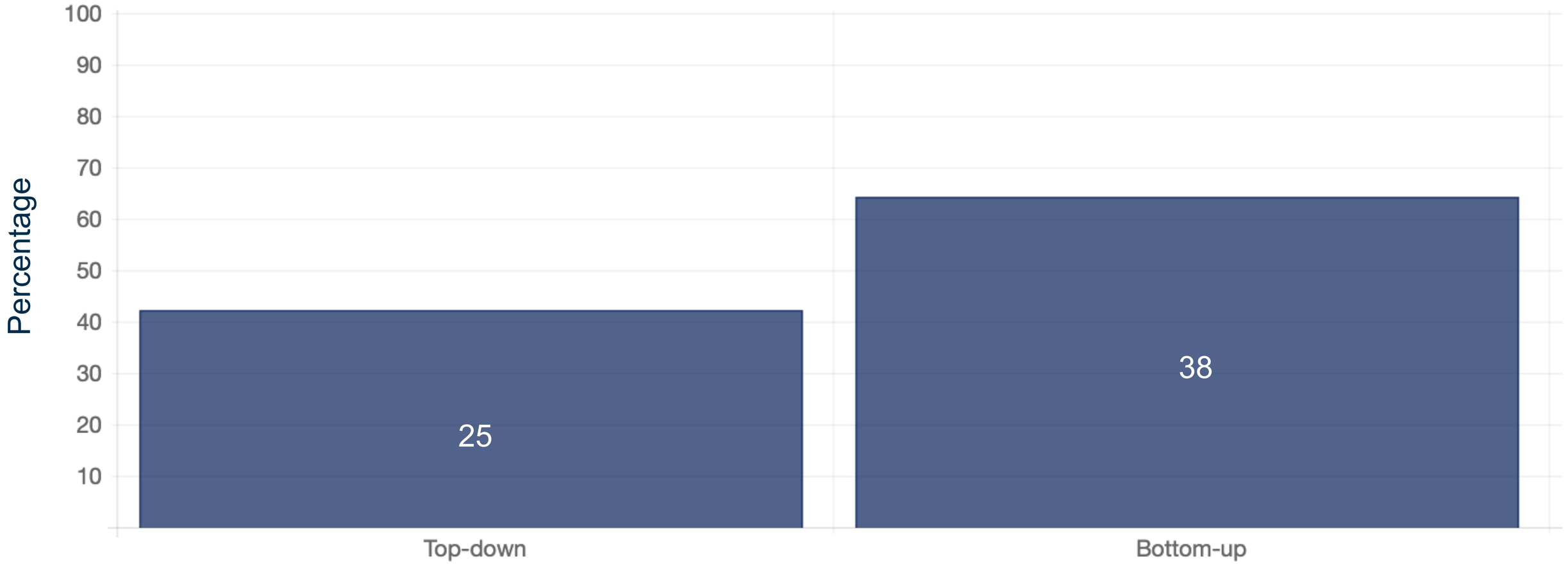
Update of the European Strategy for Particle Physics 2026:
mixture of **top-down and bottom-up elements**

Challenge: what would be your approach to organizing a big project?

https://pingo.scc.kit.edu/events/361709

Top-Down vs. Bottom-Up

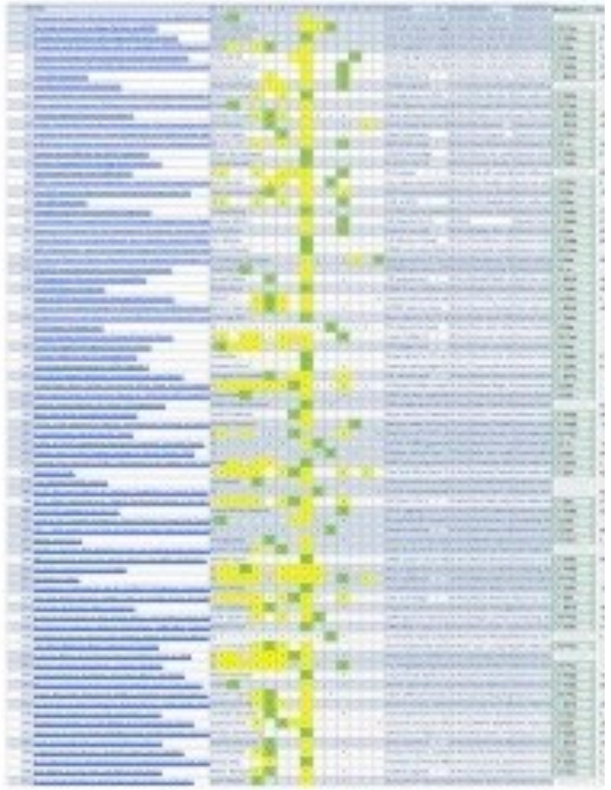
Survey Result



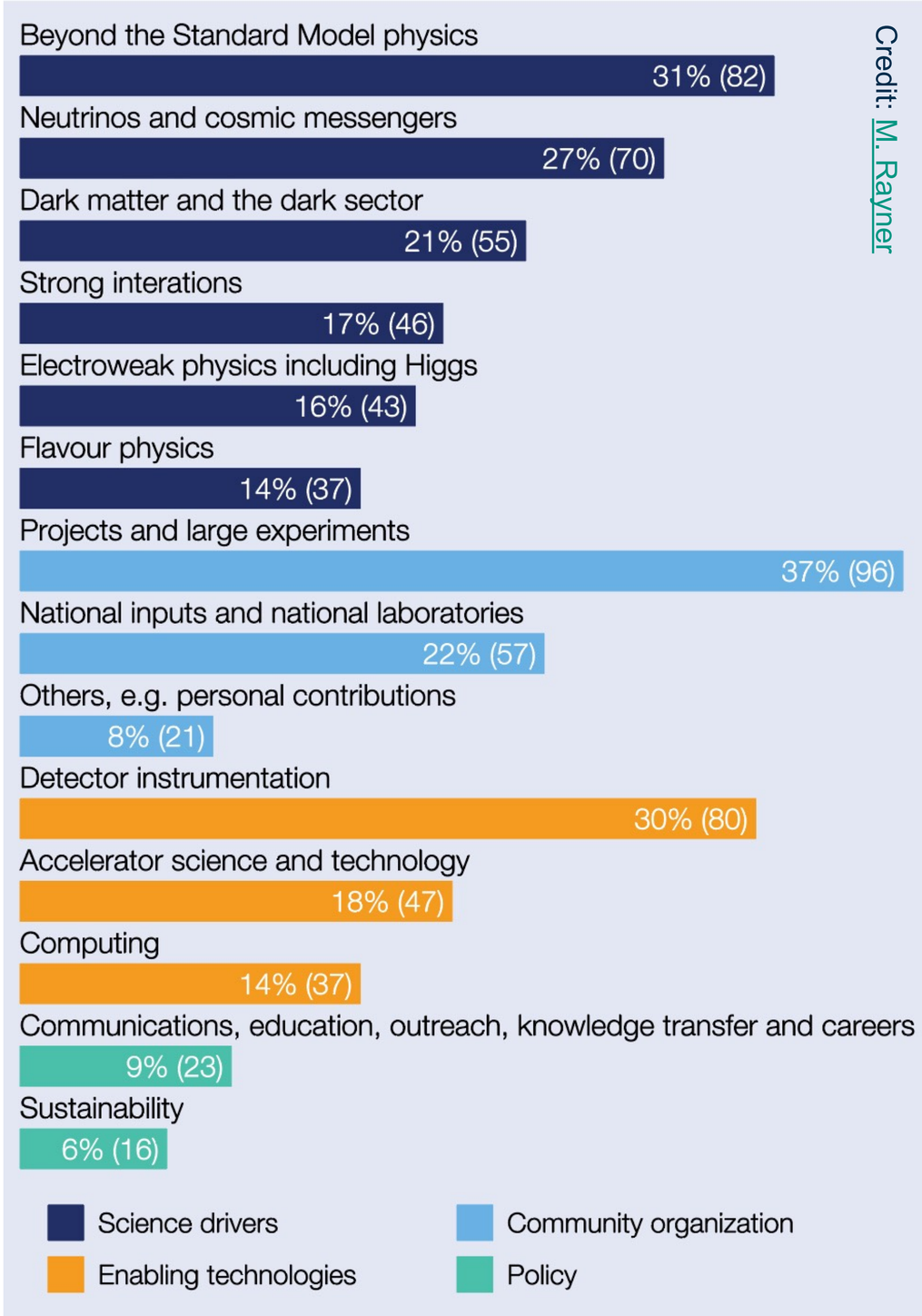
Input from the Scientific Community

266 Contributions – A Big Reading Assignment

PPG Instrumentation Spreadsheet



Public link to contributions:
https://indico.cern.ch/event/1439855/contributions/



European Strategy for Particle Physics

One-week **Open Symposium** in Venice

- Debate scientific **input** → lots of **discussion**
- Define **scientific goals and priorities**
- Indico link: https://agenda.infn.it/event/44943

Inputs and outcome of discussions
→ **Physics Briefing Book** (due Sep 30, 2025)

23-27 JUNE 2025 Lido di Venezia

Next Steps

Towards A European Strategy Update in 2026

September 2025: Physics Briefing Book published

November 2025: Final inputs from national communities

December 2025: European Strategy Group drafts strategy

January 2026: Strategy submitted to CERN Council

March/June 2026: CERN Council updates strategy

In Summary...

Particle physics in 2025: **vivid field**, broad range of **physics objectives** and detailed plans for **future projects**

2026 Update of the **European Strategy for Particle Physics**: **structured** and **inclusive** strategy process, influencing particle physics in Europe **for decades to come**

Image credit: Birds-eye