November 4, 2026 | Toyama

Community Perspectives

ICFA Seminar 2026

Marcel Demarteau

Oak Ridge National Laboratory



U.S. DEPARTMENT of ENERGY

ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY

ICFA

A working group under IUPAP

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Ensuring Success

- High energy physics has had a remarkable history, launching some of the most ambitious, large-scale and successful science projects.
- Within a rapidly changing world, proposed future projects are **even more ambitious**, by **far exceeding** any prior science – and even infrastructure – projects in scale, cost and time.
- Moreover, discoveries through purely curiosity-driven research are no longer guaranteed.

- **What is needed to make this path sustainable and optimal for the field, and to maximize its prospect to be realized successfully?**



Kikazaru (聞か猿)　　Iwazaru (言わ猿)　Mizaru (見猿)

Tōshō-gū shrine, Nikkō, Tochigi Prefecture

Success Endures When We



Listen Intently **Observe Closely** **Deliberate Openly**

Photo credit: National Geographic / Disney, Underdogs

Outline

The pursuit of our science is to reveal the hidden truth and beauty of nature

- The Community And Its Quest
- An Exciting Era Awaits For Science
- Commitments Needed
- Closing Observation



The Prisoners, Michelangelo Buonarroti, Galleria dell'Accademia di Firenze

Community and Core Mission

In the broadest sense, the community is defined by a shared mission:

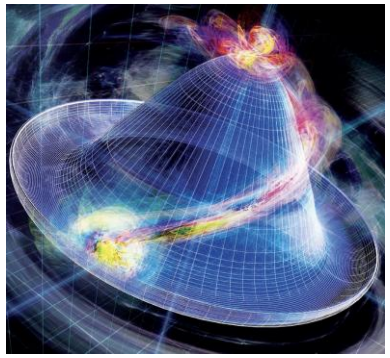
To discover the fundamental constituents of matter and the forces that govern their interactions.

Although there are many different approaches to answer these questions, with faint boundaries between them, they are all unified by the same quest.

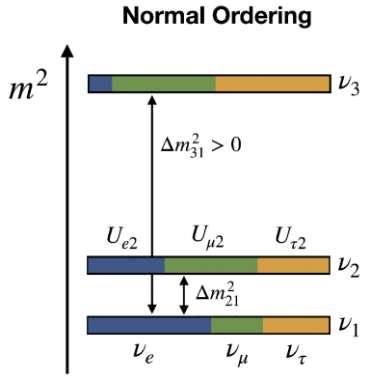
It is an inclusive and large community!



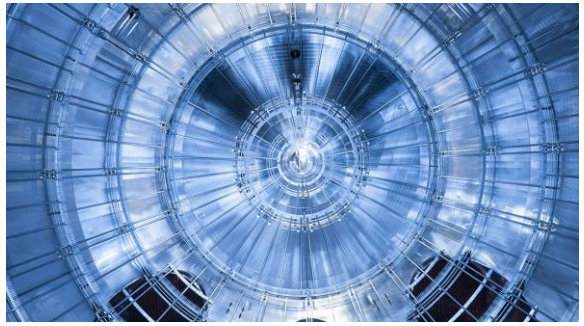
The Many Puzzles



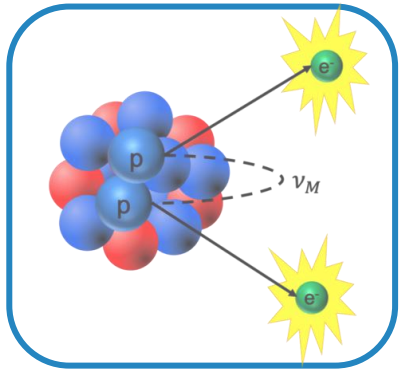
Spin 0 Higgs and its role



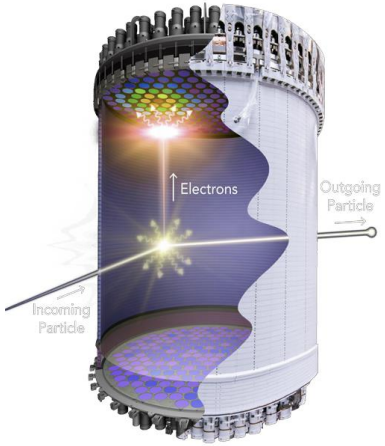
Neutrino mass ordering and CP violation



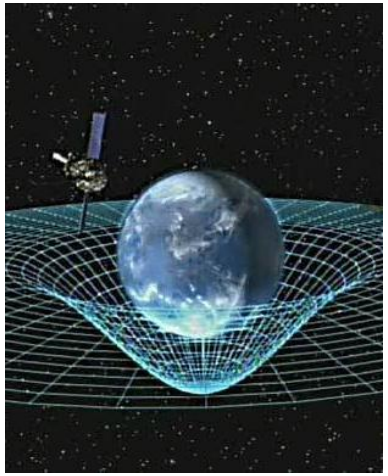
Neutrino mass and its mass generation



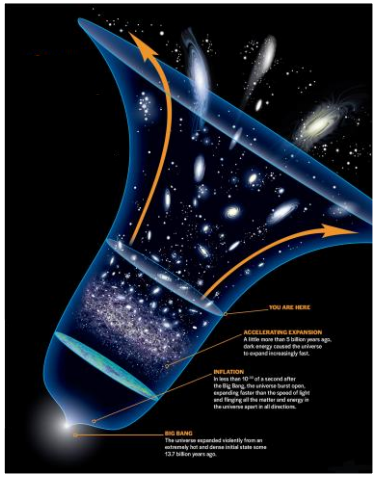
Nature of the neutrino



Dark Matter



Quantum Gravity



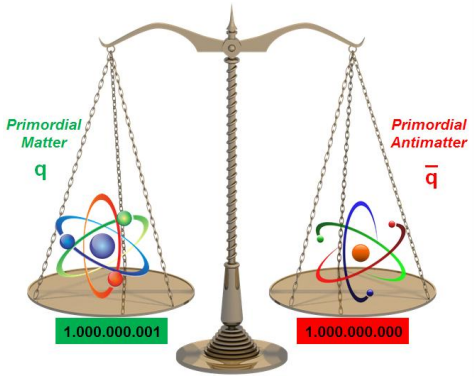
Cosmic Inflation and dark energy



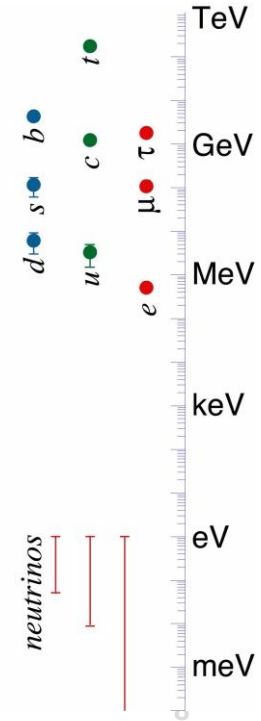
Mass Gap and QCD



θ-QCD problem

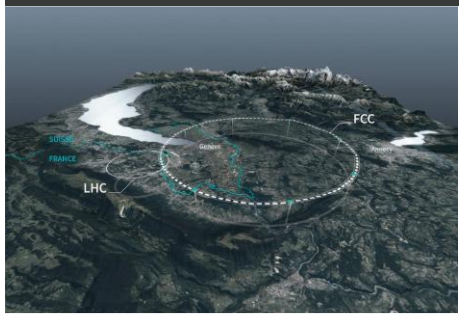


Matter – Antimatter Asymmetry

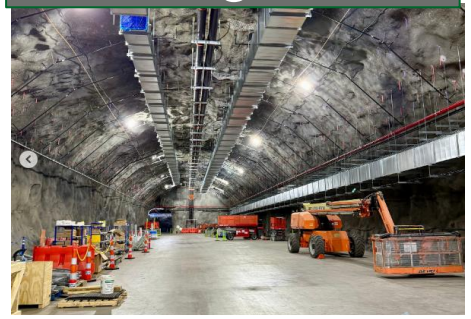


The Many Approaches

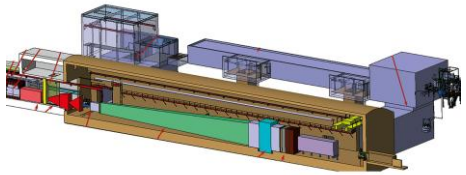
Colliders



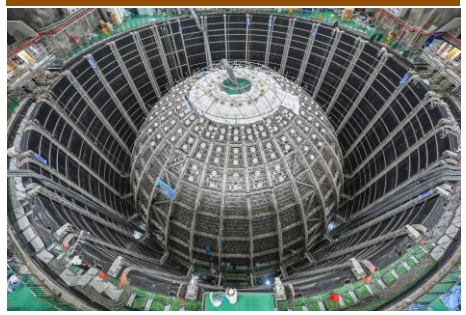
Underground



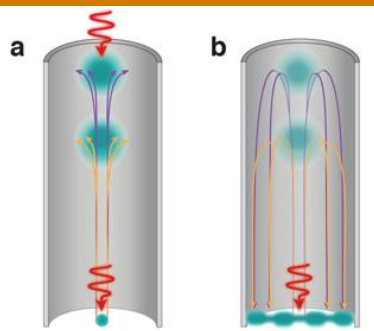
Fixed Target



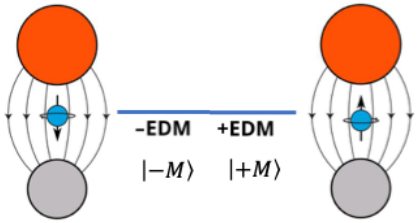
Reactor



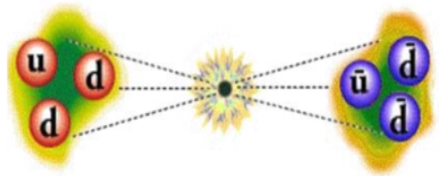
Interferometer



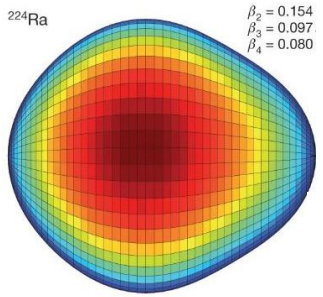
EDM



n-nbar



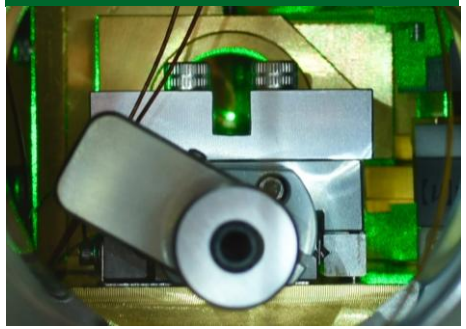
Octuple-Nuclei



Telescopes



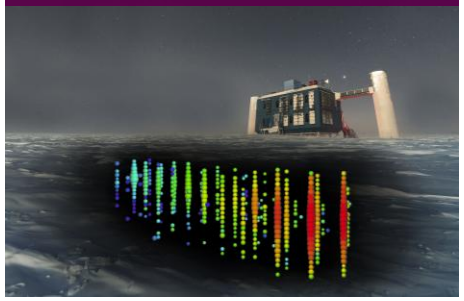
Levitation



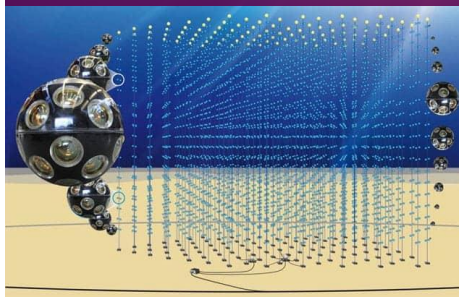
CMB



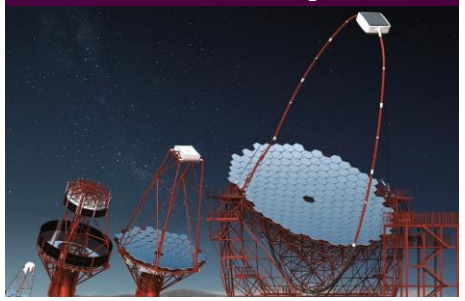
Artic Ice



Oceans



Č-Array



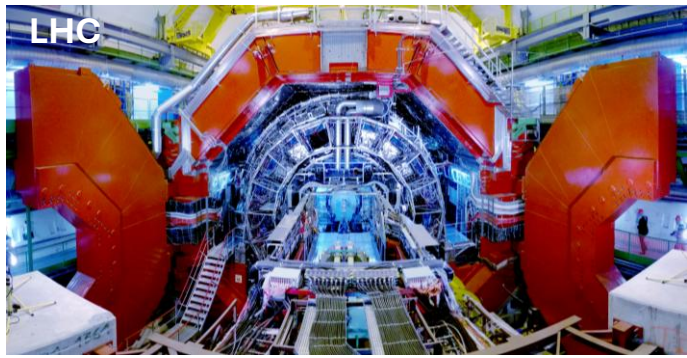
+ many, many more …

Opportunities For Discovery

We live in an era with palpable excitement for **“imminent” discoveries”** coupled with nervousness about the **“long-term scale of planning”**.



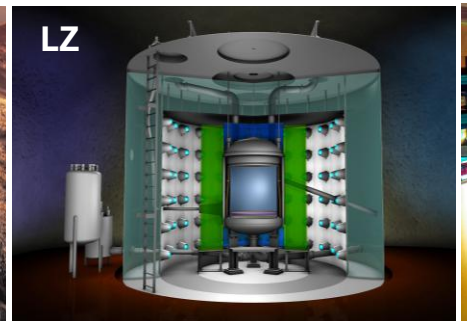








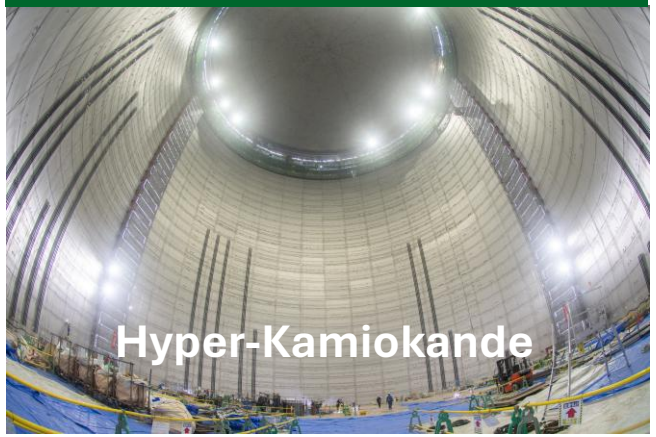






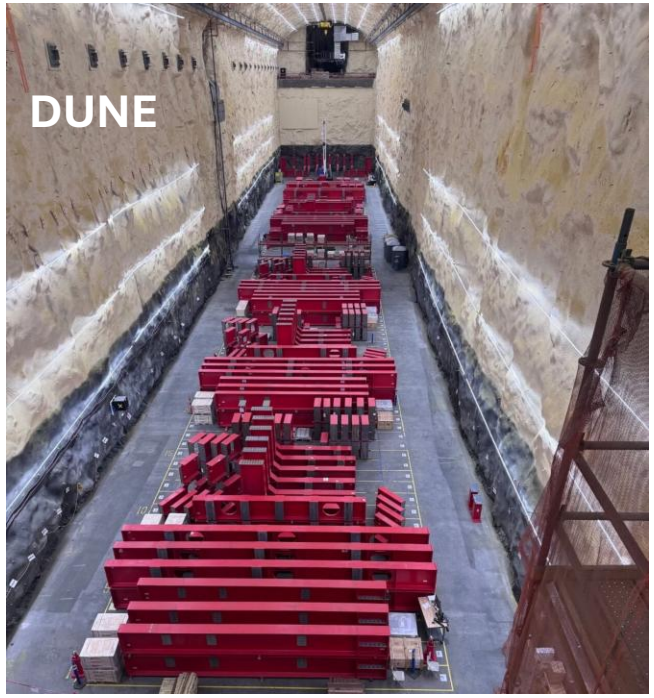
Opportunities Ahead

Immediate Future

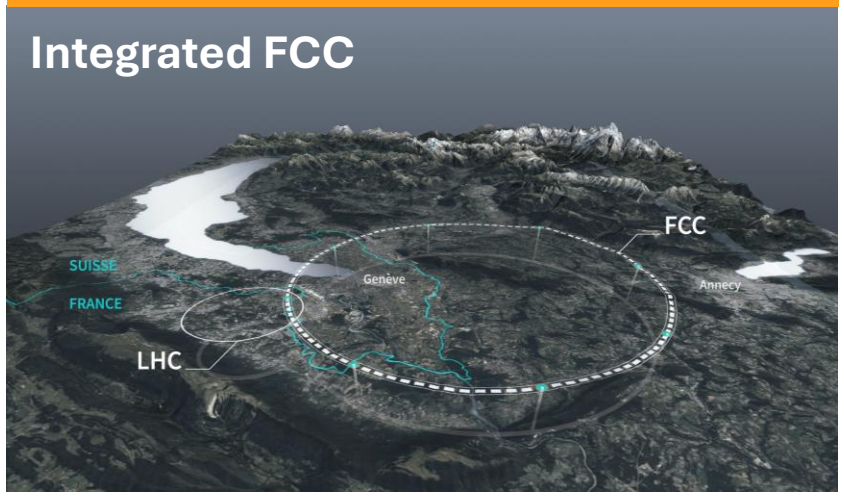


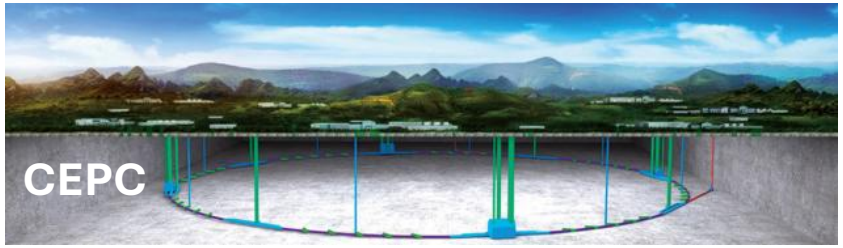
Near Future





Medium/Far Future





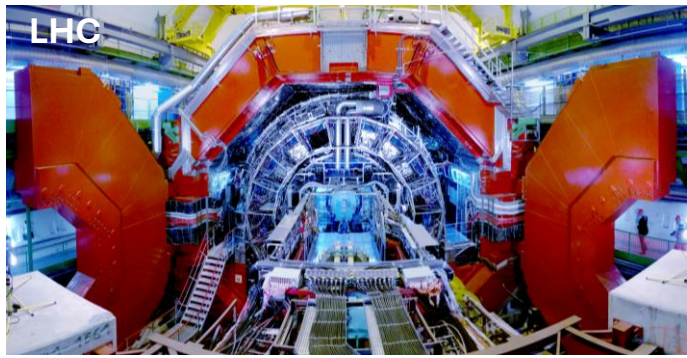
Opportunities For Discovery

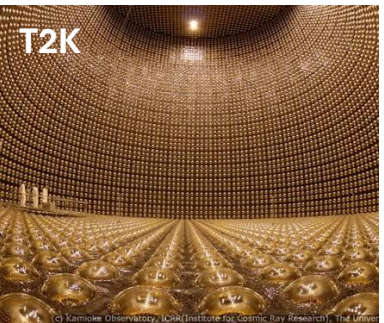
We live in an era with palpable excitement for **“imminent” discoveries”** coupled with nervousness about the **“long-term scale of planning”**.

And the field can look back on some **major achievements** that reach far beyond particle physics.



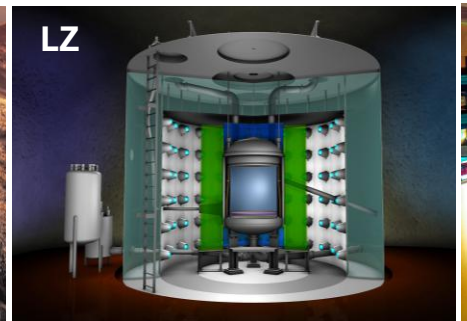










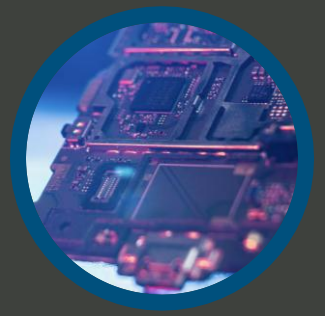




Broad Impact On Society At Large

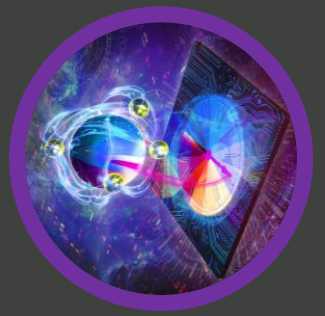

Workforce


Computing


Micro-Electronics


Neutron Sources


X-ray Detectors

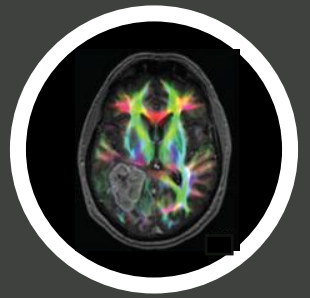

Quantum

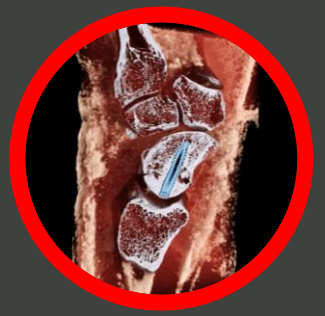

Patrimoine



Indico / Zenodo


Proton Therapy


Medical Geant


Bio-Imaging


Space Radiation



SC Magnets


SCRF

and many more ….

Are We Prepared For The Road Ahead?



Campo Felice, Apennines, L'Aquila, Abruzzo, Italy.

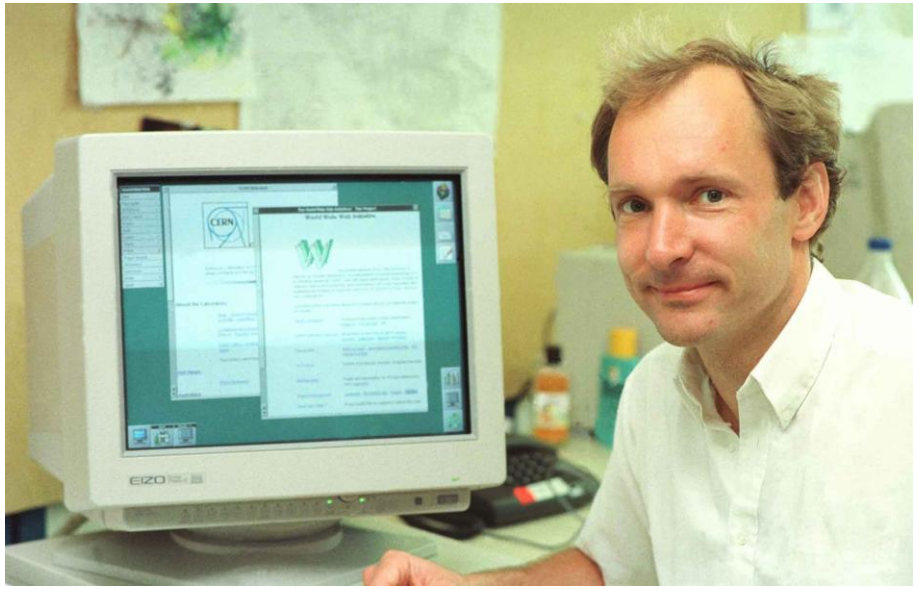
The Crossroads of Perception and Understanding

There are currently no “no-lose theorems”

Will our planned facilities successfully address the big questions?



Fast-Changing Landscapes



Particle Physics drove innovation in many technology areas

1989 Birth of WWW at CERN

Tim Berners-Lee submits proposal for what becomes the www

1998 Google is founded

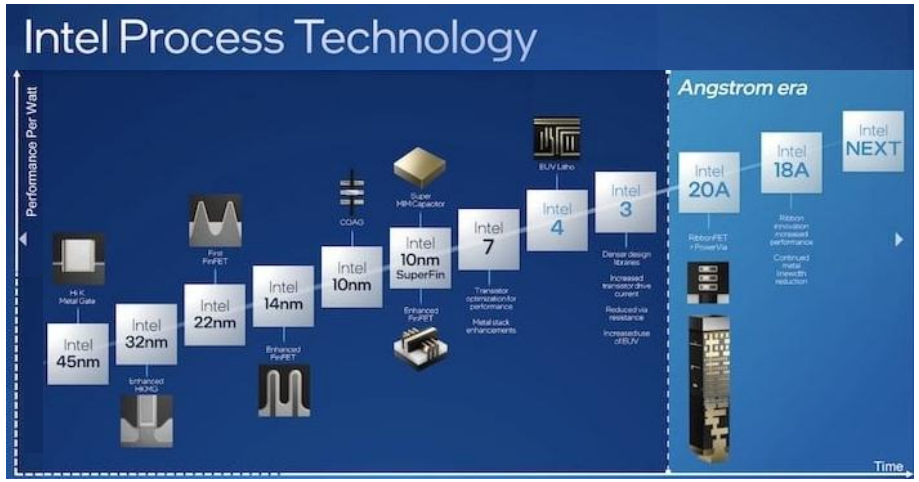
In the garage of particle physicist Stan Wojcicki

2007 Release of First iPhone

Following the successful Nano devices

2026 Big Data and Data Centers

LHC: 0.1– 1 EB
AWS: 50 – 100 EB
2030: > 600 ZB projected for world



1997 CMOS 0.25μm Introduced

Deep sub-micron technology introduced to replace DMIL

1999 HEP develops 0.25μm ASICS

Radiation tolerant ASICs developed for the Tevatron collider experiments

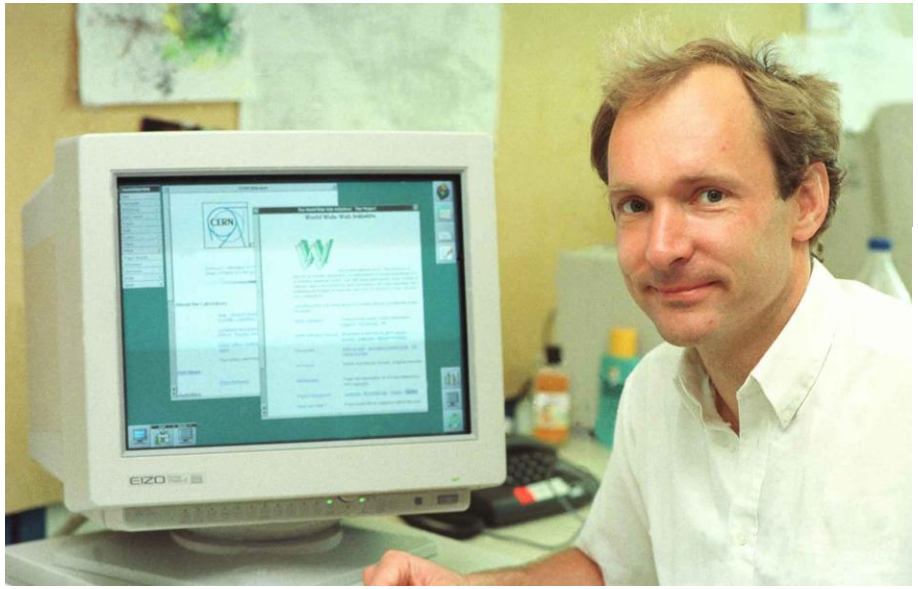
2026 18Å nodes

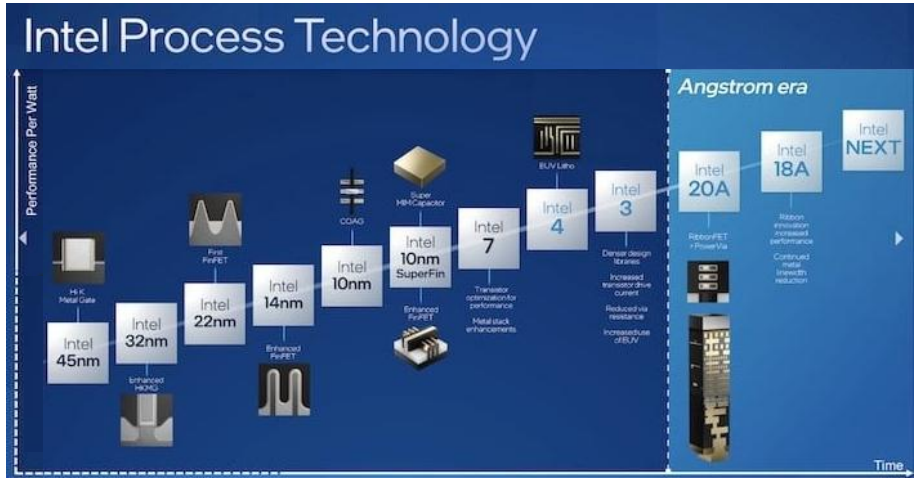
Particle physics at 28nm, 8 generations behind state of the art

2030 EUV-ERL

Lithography based on FELs or Energy Recovery Linac design.

Fast-Changing Landscapes





Particle Physics no longer commands the central position in shaping technology and society and addressing its needs.

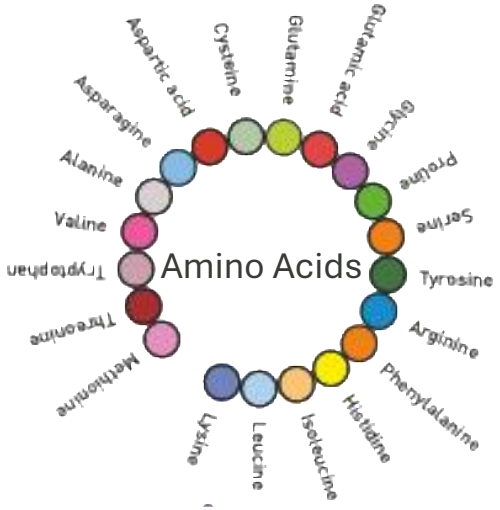
The Rise Of AI

The “50-year-old grand challenge in biology”:
How do proteins fold, that determines their function.

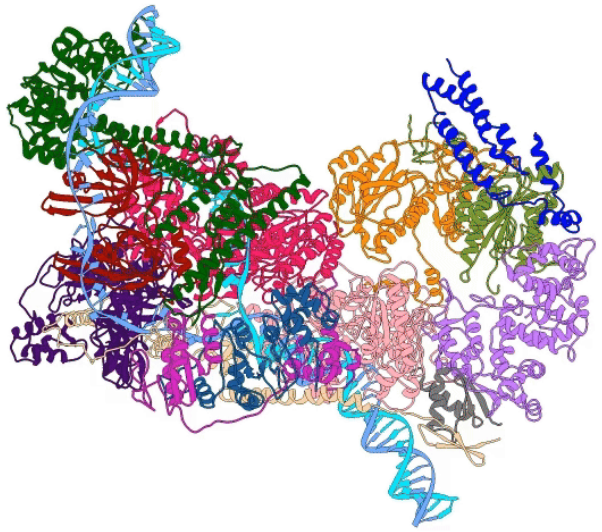




Christian Anfinsen 1972



Possible conformations for a 100-amino-acid residue protein: ~ 10^{47}



Nucleotide excision repair
Nat Commun 15, 8511 (2024).

Google DeepMind

AlphaFold 3









David Baker Demis Hassabis John Jumper

Nobel Prize in Chemistry 2024 "for computational protein design” (David Baker) and "protein structure prediction” (Demis Hassabis, John Jumper)

The impact of AI is unknown, but will be big

Images source: https://www.nobelprize.org

The Rise Of …

Quantum Computing

1000 Logical qubits, error rate 10^{-7}

Advanced Materials Science

2d materials
meta materials
quantum materials

Photonics

ultrafast, non-linear optics, imaging, …

Quantum Sensing

laser manipulation, entangled sources, …

Metrology

atomic or nuclear clocks, precision spectroscopy

Energy Science

Catalysis, plasma and battery science, fusion

Data-intensive Science

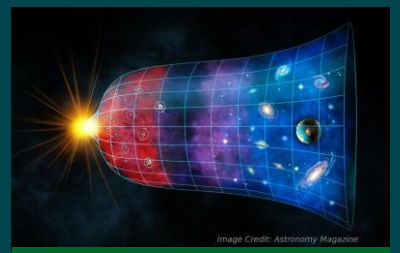
sensor fusion, real-time analysis, autonomous labs, …

Robotics

agentic control, AI, data collection, …

All Opportunities and Challenges

The Many Shades Of “Big”



Big Questions

Big Budgets





Big Projects

Big Collaborations





Big Data



Big Timescales

Big Ambitions

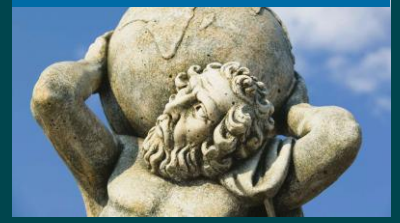
The New York Times

Mankind's Quest Resolved !



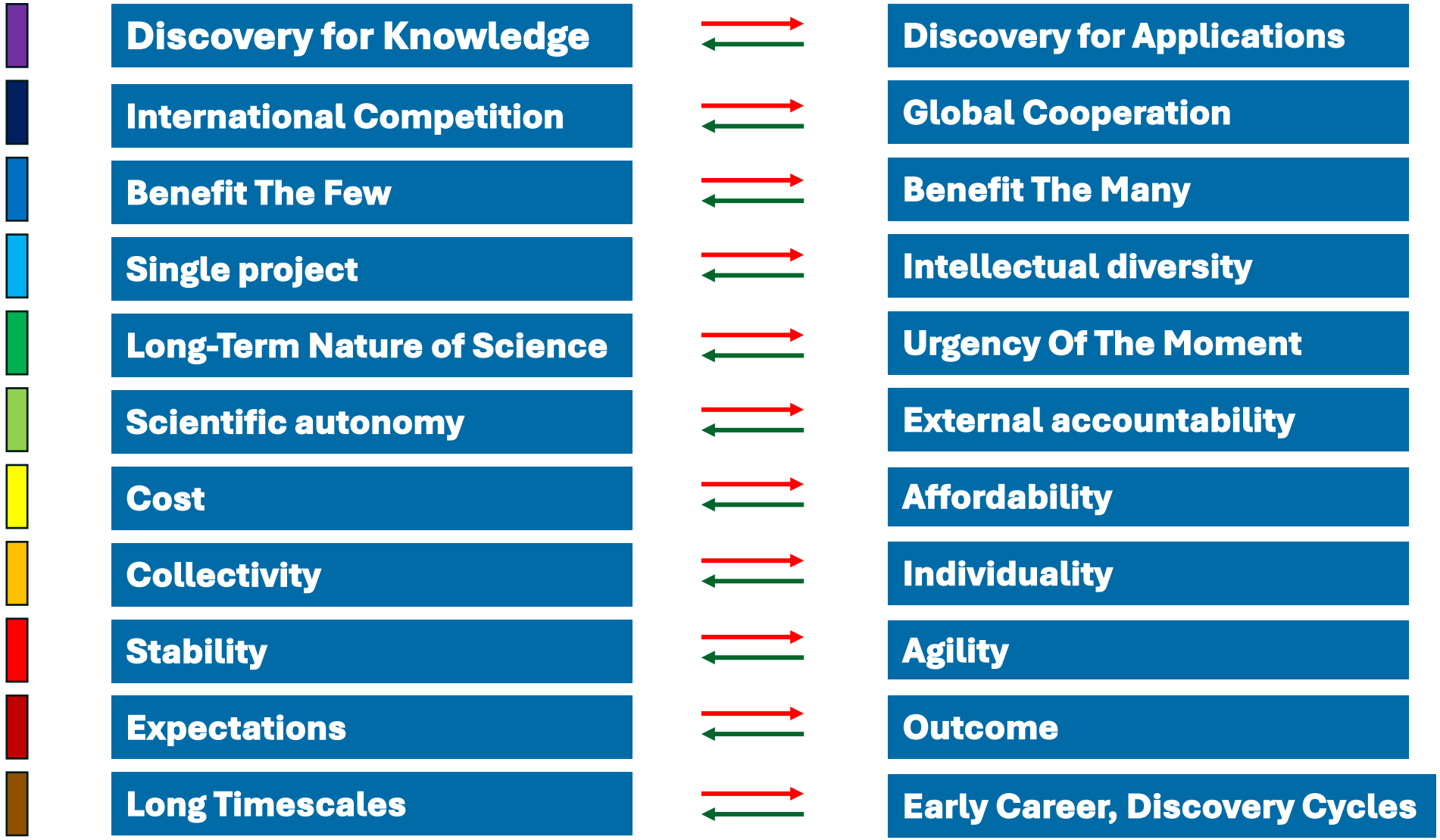
Big Governance

Big Responsibility



• • •

A Delicate Long-term Balance



Commitments For Success

1	**Global Coordination**	**Coordination and diversity of approach** reduces scientific fragility and keeps the field responsive to unexpected opportunities. The past has shown that surprises come out of unexpected corners.
2	**Protect Intellectual Diversity.**	**Support for unconventional ideas** should be maintained, avoiding concentrating a single pathway (machine, theory), will retain agility of the field.
3	**Cultivate Talent**	The long-term health depends on the ability to **attract, support, and retain researchers**, requiring a commitment to stable career pathways and strong mentorship at all career levels
4	**Broaden The Definition Of Success**	A sustainable discipline is one that remains intellectually confident even when transformative discoveries do not arrive quickly. **Emphasize any and all advances** and the training of the workforce.
5	**Earn Broad Trust**	**Understand the audience**, be socially responsible and support the broader science community. Engage with accountability, inclusion, and responsibility.
6	**Prioritize Science Diplomacy**	As a global field of science, it comes with a **global responsibility** uniting the world through **science for peace**. Broad support for fair participation in governance builds long-term legitimacy.

1: Global Coordination



Develop Strategy and Adjust

A sustainable program includes support for flagship facilities alongside a suite of smaller experiments, and invests in exploratory high-risk research.

Emphasize Portfolio Approach

A broad portfolio approach protects the field from stagnation if one dominant path yields limited returns or is stretched in time.

"The dark energy is not exactly zero, but the first 122 decimal points are zero. That's crazy".

– Leonard Susskind

On the discovery of Dark Energy, 1998

Retain Agility

With the fast-paced technological developments, retaining agility to respond quicky and pivot towards new promising developments is key. Many discoveries were not anticipated and were transformative. **Expect the Unexpected.**

These points were the central tenets of the 2023 P5 report

1: Fund and Collaborate Broadly

National and Regional

Foundational funding, mostly **competitive**, to ensure sustained support for local and global research programs.

Alignment with national and regional priorities



Industry

Public-Private partner-ships maintains contact with state-of-the-art technology and mitigates obsolescence

Mutually attractive **intellectual challenges,** environment for **continuous deployment and transfer** of new technologies;

Philanthropy

Can supplement research projects

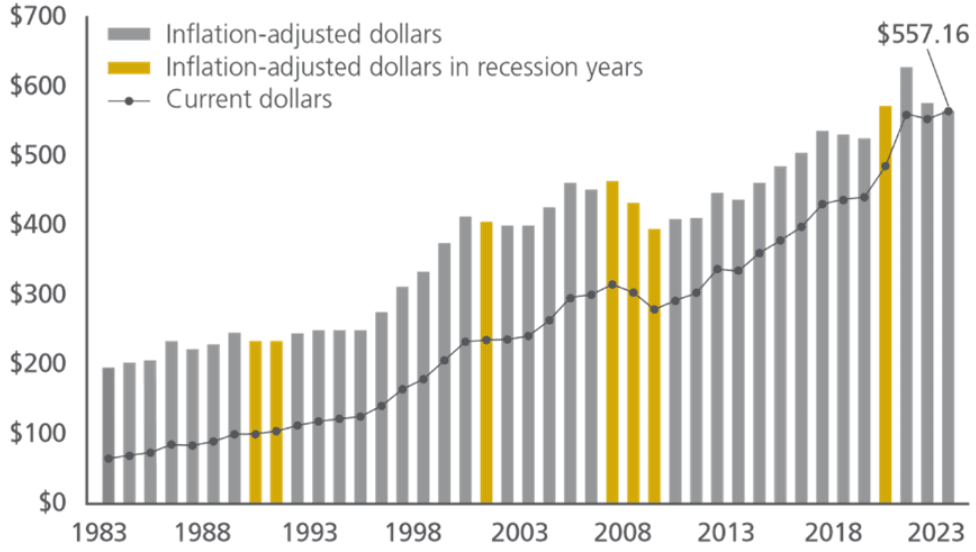
Amplifies investments by other agencies

Enables **filling gaps** and provides support for **broader program**

1: Fund and Collaborate Broadly

United States

Source: https://givingusa.org/



All charitable contributions

$ 660.5

Europe

Source: https://ernop.eu/

€ 52.0 Individuals + **€ 8.4** Bequests + **€ 21.5** Corporations + **€ 20.6** Foundations + **€ 1.9** Charity = **€ 104.5** Total

India

Source:/www.bain.com/

€ 2.2 Foreign + **€ 3.7** Corporations + **€ 3.2** Individuals + **€ 3.1** CSR = **€ 12.2** Total

Philanthropy

Can supplement research projects

Amplifies investments by other agencies

Enables **filling gaps** and provides support for **broader program**

Numbers in billions

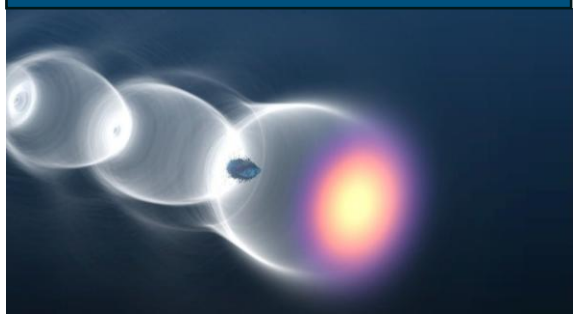
2022 for Europe and US
2024 for India

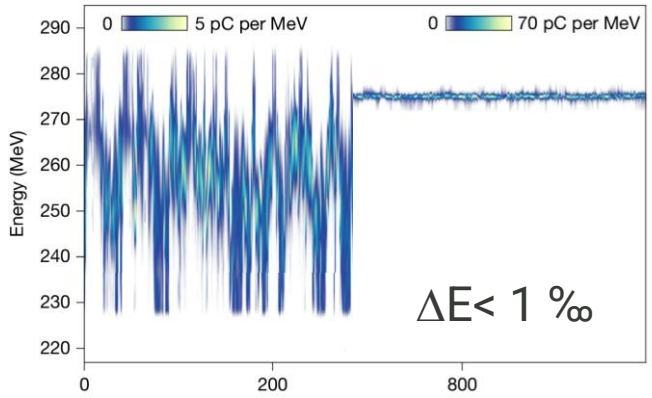
2: Protect Intellectual Diversity

Support for unconventional ideas should be maintained, avoiding concentrating a single pathway (machine, theory), to retain the agility and flexibility of the field.

Intellectual diversity will enhance HEP relevance for other fields and applications.

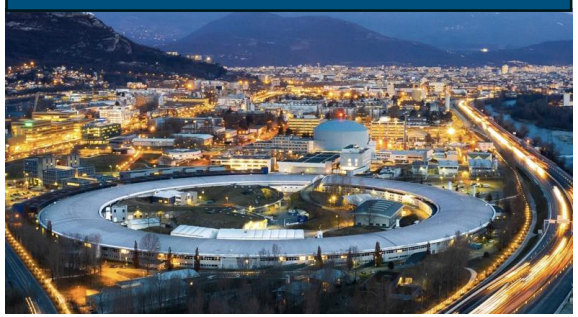
Laser Wakefield

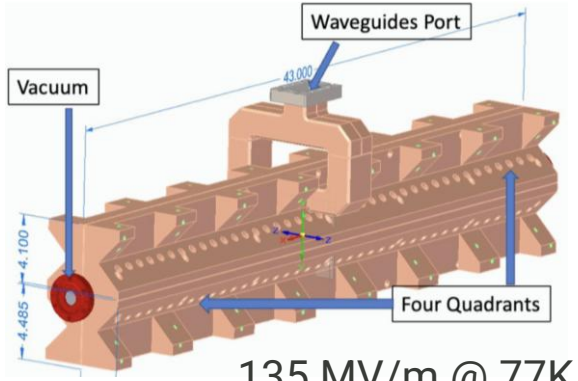




Nature 640, 907 (2025)

Cold Copper

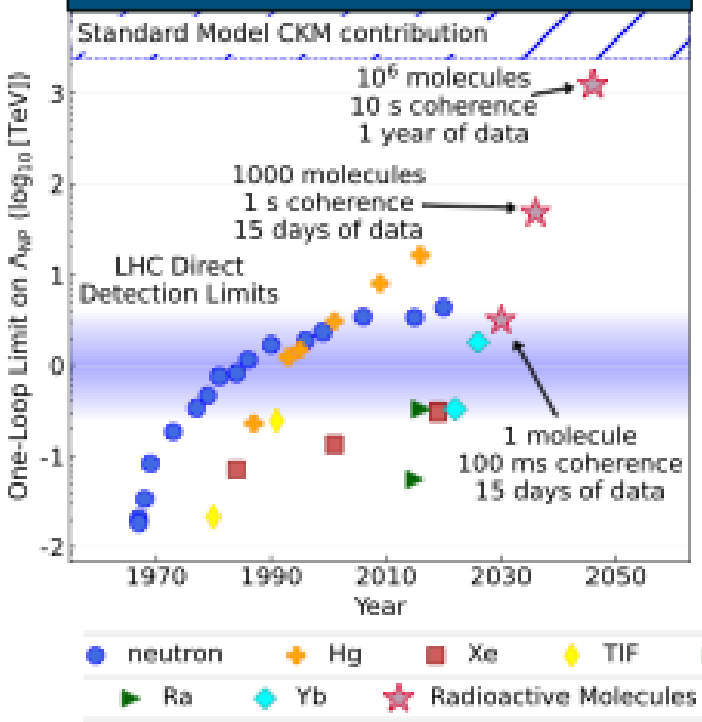




135 MV/m @ 77K

*JINST **18** (2023) P09040*

AOM



Nature Rev.Phys. 8 (2026) 8, 521-530

AOM = Atomic, Optical and Molecular physics

3: Attract Talent

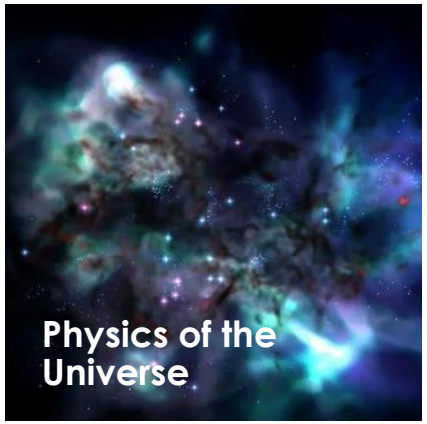
The most important asset to success is the people !

Given the scale, complexity and duration of proposed new projects, the community needs to address several serious challenges

- **Attract the very best**
  - Most compelling physics questions
  - Most vibrant intellectual community
  - Most demanding technology challenges









3: Cultivate Talent

The most important asset to success is the people !

Given the scale, complexity and duration of proposed new projects, the community needs to address several serious challenges

Gain Brains

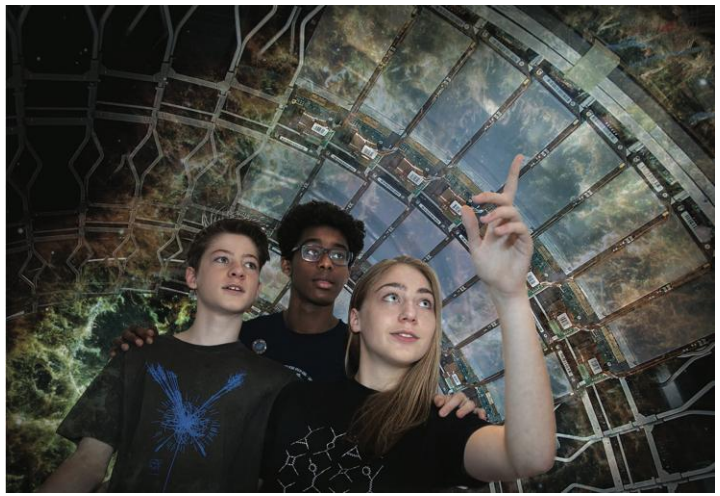


Photo credit: Michael Hoch (CERN)

- Outreach to develop a pipeline of enthusiastic new scientists

Train Brains

- Train a new fluent workforce

























3: Retain Talent

The most important asset to success is the people !

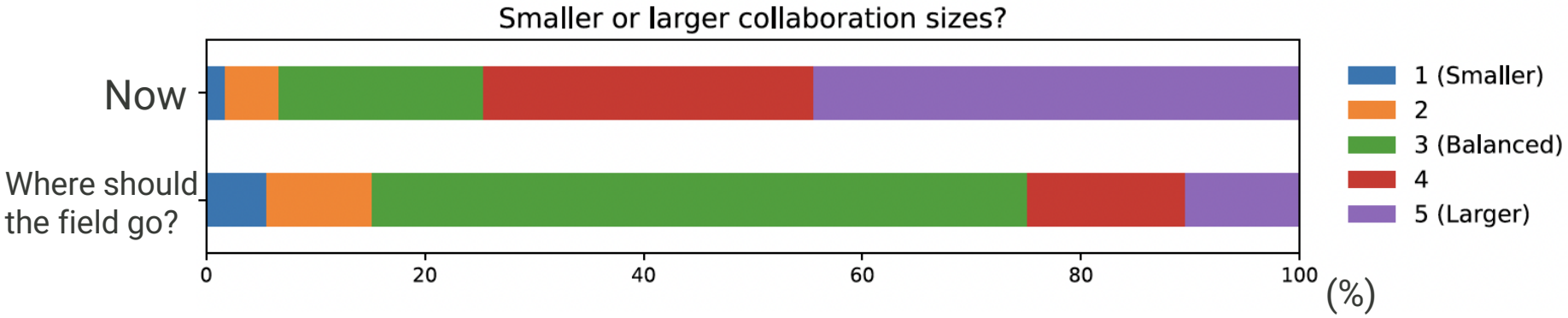
Given the scale, complexity and duration of proposed new projects, the community needs to address several serious challenges

Core Values

- Be mentored
- Be challenged
- Be promoted
- Be involved
- Be appreciated
- Be trusted
- Be empowered
- Be valued

Early Career Scientist

- Arguably the most important asset to the field!
- One-experiment professional careers have become commonplace.
- Mentor and provide professional development opportunities, also for positions outside the field.
- Support and recognition needs to be provided for “service efforts”.



Snowmass 2025 Survey *https://arxiv.org/html/2210.12004v2*

3: Retain Talent

The most important asset to success is the people !

Given the multi-generational nature of projects, knowledge transfer will become critically important and continued intellectual motivation.

Core Values

- Be mentored
- Be challenged
- Be promoted
- Be involved
- Be appreciated
- Be trusted
- Be empowered
- Be valued

Mid and Senior Career

- Retain the workforce by continuously providing intellectual challenges and provide continuous education to keep up with new technology developments.
- Provide an environment for continuous deployment of new technologies;
- Consider industrial sabbaticals for engineering-oriented staff

Outside attraction will be very strong.

3: Retain Talent

The most important asset to success is the people !

Given the scale, complexity and duration of proposed new projects, the community needs to address several serious challenges

Core Values

- Be mentored
- Be challenged
- Be promoted
- Be involved
- Be appreciated
- Be trusted
- Be empowered
- Be valued

University Engineering and Technical Staff

- It is becoming increasingly more difficult to retain experienced research engineering and technical staff at Universities, and even national laboratories, a resource critical for the field.
- Engagement with, and education of, Funding Agencies and University Administrators is required to ensure that this resource is maintained.



See Cambridge case study.

4: Broaden The Definition Of Success

The benefit to humanity of all aspects of the scientific endeavor needs to be highlighted through **persistent outreach**.

- Foundational scientific progress
- Instrumentation
- Accelerator Technology and Applications
- Advanced methods in Computing, Data
- Analysis, Statistics, Simulation Tools
- Curated Datasets
- Training and Workforce development
- Medical Imaging
- Materials Science
- Quantum Technologies
- Global Equity and Access
- …



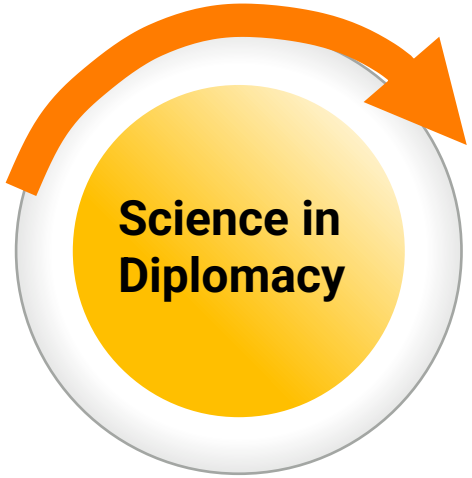
5: Earn Broad Trust

General Public	Policymakers	Science Colleagues
Educate The Public **Create Awareness Through Open Dialogue** **Bring Value to the Community**	**Strong Advocacy** **Emphasize Tangible and Intangible Return On Investment**	**Support Shifting Science Priorities** **Collaborate and Support Adjacent Science Domains** **Bickering Scientists Lose**

There will be many other competing science, infrastructure and construction projects that over time will become a priority; the field should actively engage in helping those projects succeed where it can.

6: Prioritize Science Diplomacy

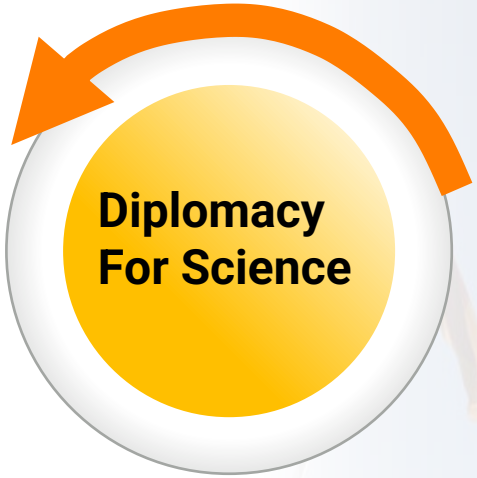
Particle Physics is global, which brings opportunity and responsibility



Science informs foreign policy and international negotiations



Scientific collaboration builds trust and builds peaceful relations



Diplomacy helps enable international scientific cooperation



6: Science Diplomacy

SESAME international laboratory in Jordan, opened in 2017, built under the auspices of UNESCO with critical support from CERN and the particle physics community.

A success story to be repeated!



SESAME=Synchrotron-light for Experimental Science and Applications in the Middle East
https://doi.org/10.1080/10619127.2025.2529129



Source: https://lightsources.org

Nature Reviews Physics volume 5, pages 74–75 (2023)

Community support for the African Light Source (AfLS) would remove Africa from being the only continent with no light source

Science diplomacy is integral to the mission, creating goodwill by promoting science and bringing nations together.

Strategy and Governance

Strategy is not an end in itself, but provides a direction

- It is a bridge, not the destination and provides a set of choices



SWOT Analysis

- A Strength – Weakness – Opportunity – Threat analysis anchors the plan
- Provides transparency and excitement for the science goals



Governance decides on control, accountability and execution.

- Allows to adapt to reality and stay attuned to an unfolding reality



For a global project there should be a global governance that cannot be (too) institution-centric

Concluding Observations

- This is a time of **major transitions**. There are no **entitlements**.
- The aspirations of the field **have grown** and it proposes to embark on one of the most ambitious science projects ever (and is even considering doing that twice).
- To be successful, friends are needed in all places and at all levels.
- High Energy Physics has a lot to offer but support has to be reciprocated; intellectual diversity will enhance HEP relevance for other fields and applications.

Photo credit: Marie-Lan Nguyen (Wikipedia)



Janus
The God of Transitions

- **We need to be prepared for the natural cycle of rise and fall of support.**
- **Retaining diversity and agility is critical.**

Concluding Suggestions

Outward Facing
Other sciences **Embrace, support and collaborate**



Janus
The God of Transitions

- Support other sciences when the capabilities and expertise match.

Concluding Suggestions

Outward Facing	Inward Facing	
Other sciences	**Experiments**	**Facilities**
Embrace, support and collaborate	Robust Scientific Competition, Matching Focus with Scale	Vigorously Coordinate and Collaborate



Janus
The God of Transitions

- Support other sciences when the capabilities and expertise match.
- Collaborate more on facilities, à la colliders for underground facilities, for example.

Success Endures When We



Listen Intently **Observe Closely** **Deliberate Openly**

And adapt wisely and decisively!

Photo credit: National Geographic / Disney, Underdogs

Thank you!

With many thanks to: Pierluigi Campana, Dmitri Denisov, Michael Doser, Roger Forty, Cameron Geddes, Paul Grannis, Steven Hoekstra, Manfred Krammer, Alison Lister, Tatsuya Nakada, Ritchie Patterson, Naohito Saito, Hiro Tanaka, Caterina Vernieri and apologies to those I forgot to mention.