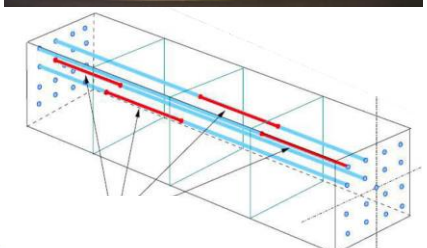
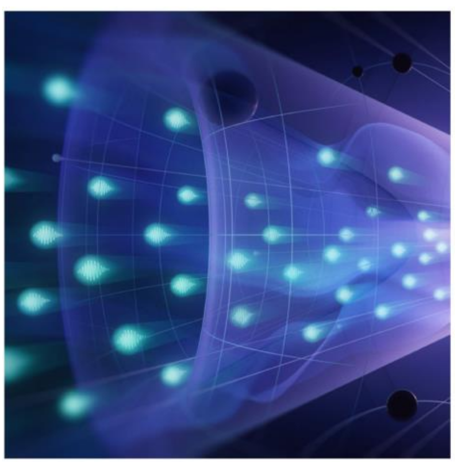
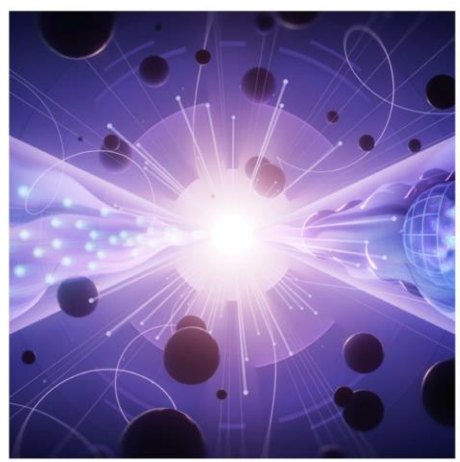
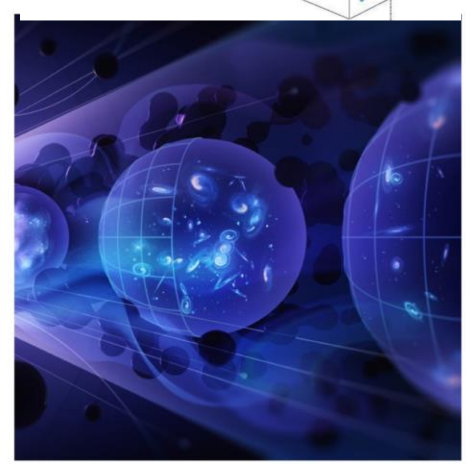
高能物理国际势态

未来高能加速器-探测器-技术前沿









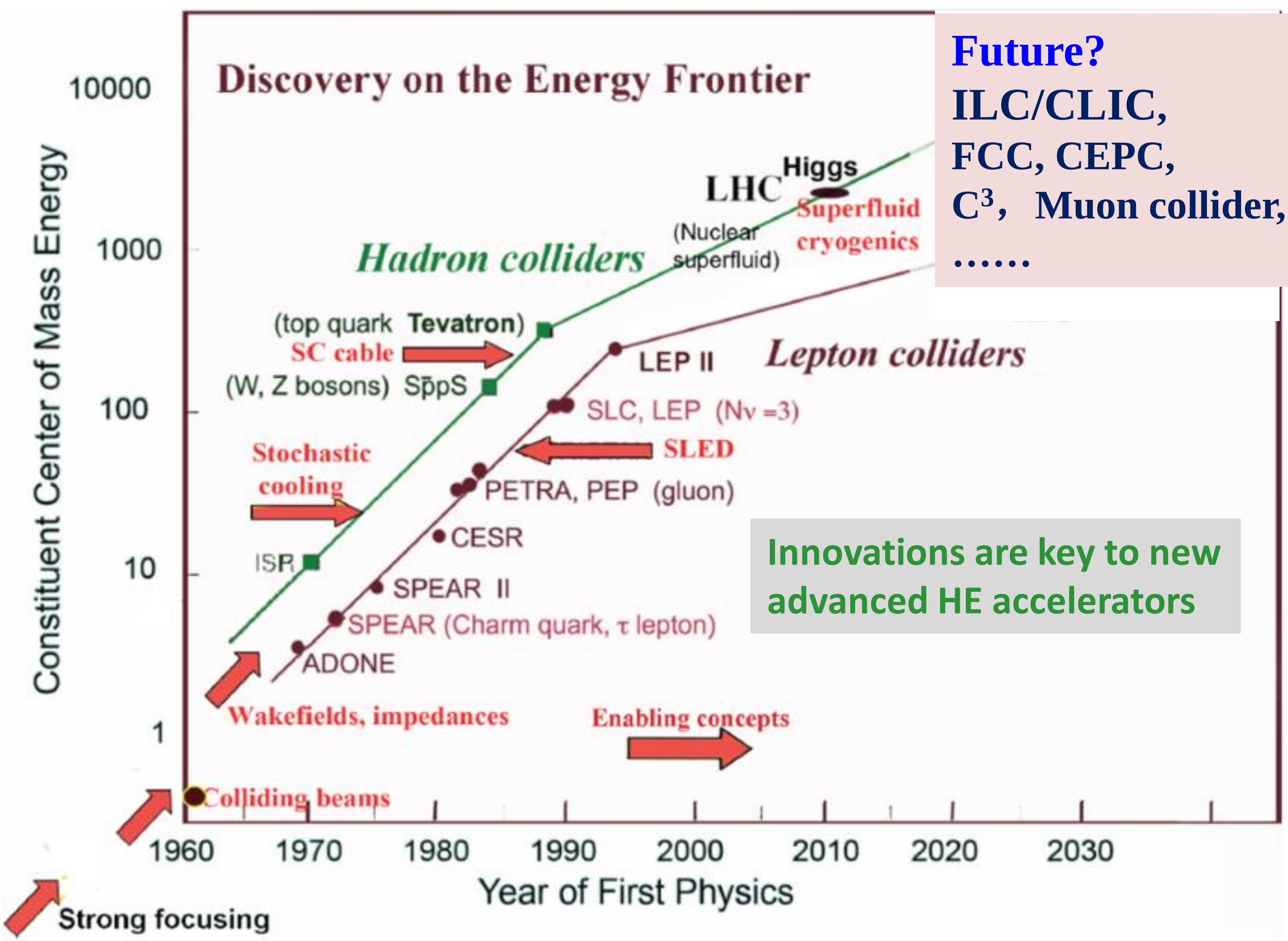
Talk Contents
高能物理国际势态

- A bit of introduction
- Landscapes and national roadmaps
- Organized & dedicated R&D
- Observation & remarks
- Discussion

高能物理国际势态

A bit of introduction

A bit of history of highest energy colliders



Future?
ILC/CLIC,
FCC, CEPC,
C^3, Muon collider,
……

Innovations are key to new advanced HE accelerators

⇒ discoveries, deep understanding of nature

High Energy Physics

essentials for success

- Innovations in technology & design
- S&T leadership + organization
- Planning and execution of the plan (hard work)
- Intensive theoretical development
- Creative mind, dedicated professionals, and many very bright young scientists in the pipeline
- Strong government support and continuous funding
- ……

collaboration is in our "blood"

- Highly globalized
- Relying on large facilities (intl., domestic)
- Hosting + participating in global projects at national & international labs
- Research is fundamental; no "secret"; International collaboration essential

HEP should be an exemplary field for International exchange and cooperation in science in China

We should be on top with global HEP development and plans

高能物理国际势态

Landscapes and national roadmaps

Europe – EPPSU, FCC, R&D programs, …

United States – P5, muon collider, C^3, …

Japan – continuing with the ILC, …

Europe
Landscapes and national roadmaps

Future Accelerators

FCC(ee,hh), CLIC, and muon collider R&D
FCC feasibility study
comprehensive and intensive technology-system R&D projects

Execution of European Particle Physics Strategy Update 2020

Has begun the process of EPPSU 2024-6

Europe

European Strategy on Particle Physics

Continuous process driven by the community

- First defined 2006
- **Update 2013** brought us HL-LHC decision
- **Update 2020** brought us decisions for post-HL-LHC times:
  - ✦ *Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadr on collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage.*
  - ✦ ***Detector R&D programmes** and associated infrastructures should be supported at CERN, national institutes, laboratories and universities. **Synergies** between the needs of different scientific fields and **industry should be identified** and exploited to boost efficiency in the development process and increase opportunities for more **technology transfer benefiting society** at large. **Collaborative platforms and consortia** must be adequately supported to provide coherence in these R&D activities. The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels.*
  - ✦ *Europe should maintain its capability to perform innovative experiments at the boundary between particle and nuclear physics, and CERN should continue to **coordinate** with **NuPECC** on topics of mutual interest.*
  - ✦ ***Synergies** between particle and **astroparticle physics** should be strengthened through scientific exchanges and **technological cooperation** in areas of common interest and mutual benefit.*
- **Update 2026** on the horizon with input proposals by spring 2025

http://europeanstrategy.cern/

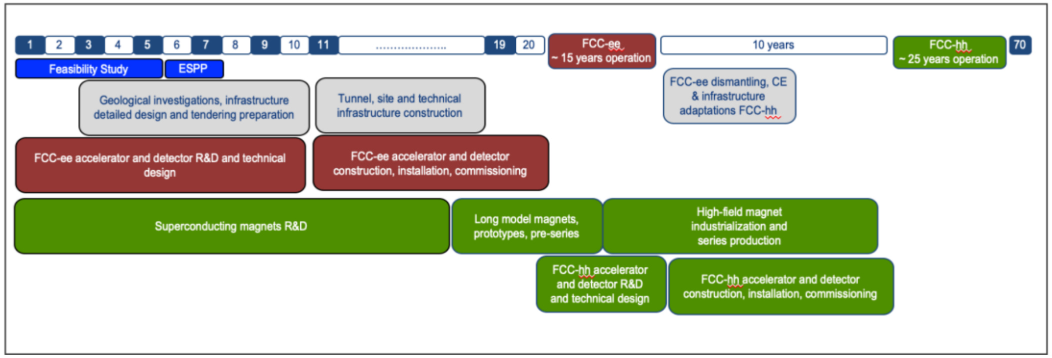
CERN's comprehensive, well organized technology-system DRD collaborations
(I will cover this shortly)

Europe

FCC Conceptual Design Study started in 2014 leading to CDR in 2018

FCC integrated program – timeline

2021- 25: Feasibility Study → **2028:** project approval by CERN Council → **2032:** construction starts → **2041:** HL- LHC ends → **2045:** Operation of FCC-ee → **2070:** Operation of FCC-hh



"Realistic" schedule taking into account:

- past experience in building colliders at CERN
- approval timeline: ESPP, Council decision
- that HL-LHC will run until 2041

Can be accelerated if more resources available

FCC feasibility study

FS Mid-Term Review passed !

Deliverables:

D1 : Definition of the baseline scenario
D2 : Civil engineering
D3 : Processes and implementation studies with the Host States
D4 : Technical infrastructure
D5 : FCC-ee accelerator
D6: FCC-hh accelerator
D7: Project cost and financial feasibility
D8: Physics, experiments and detectors

Documents:

- Mid-term report (all deliverables except D7)
- Executive Summary of mid-term report
- Updated cost assessment (D7)
- Funding model (D7)

Approved deliverables: https://indico.cern.ch/event/1197445/contributions/5034859/attachments/2510649/4315140/spc-e-1183-Rev2-c-e-3654-Rev2_FCC_Mid_Term_Review.pdf

All deliverables met, no technical showstoppers

Full Report
8 Chapters/Deliverables
~ 700 pp document
~ 16 editors
~ 500 contributors

Review process:

- Oct 2023:
  - Scientific Advisory Committee (sci. and tech. aspects)
  - Cost Review Panel (ad hoc committee; cost and financial asp.)
- Nov 2023:
  - SPC and FC
- 2 Feb 2024:
  - Council

→ **70-80 recommendations**

Main goals 2024/ beginning 2025

Completing technical work for Feasibility Study until end 2024

- Implementation of recommendations from the mid-term review
- Focus on "feasibility items" and items with important impact on cost/performance
- Develop a risk register
- Update cost estimate to reach cat 3 level on cost uncertainty.
- Further develop the funding model based on discussions with the Council

Continue work with host states on:

- project definition and responsibilities
- authorization procedures
- excavation material strategy
- regional implementation development

Complete FS by March 2025 as input for ESPP update

ɡus

Michael Benedikt, Frank Zimmermann, CERN

Europe: FCC

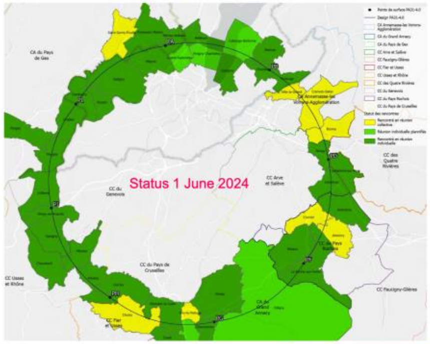
Regional implementation activities

Meetings with municipalities in France (31) and Switzerland (10)

- •**PA – Ferney Voltaire** (FR) – experiment site
- •**PB – Présinge/Choulex** (CH) – technical site
- •**PD – Nangy (FR)** – experiment site
- •**PF – Roche sur Foron/Etaux** (FR) – technical site
- •**PG – Charvonnex/Groisy** (FR) – experiment site
- •**PH – Cercier** (FR) – technical site
- •**PJ – Vulbens/Dingy en Vuache** (FR) experiment site
- •**PL – Challex (FR)** – technical site

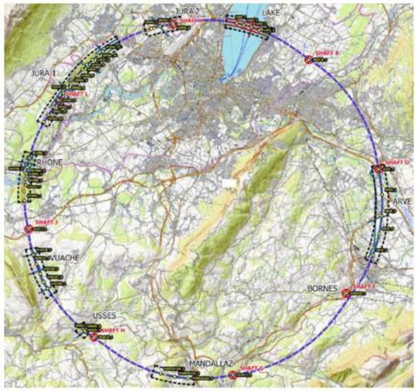
Detailed work with municipalities and host states

- identify land plots for surface sites
- understand specific aspects for design
- identify opportunities (waste heat, techn.)
- reserve land plots until project decision



→ **The support of the host states is greatly appreciated and essential for the study progress!**

Status site investigations



Site investigations to identify exact location of geological interfaces:

- Molasse layer vs moraines/limestone
- ~30 drillings
- ~100 km seismic lines

→ Start in July/August 2024

→ **Vertical position and inclination of tunnel**

Drilling work on the lake

Public information / engaging sessions

First public information and discussion meeting at the Science Gateway on 24 April at CERN

- Meeting for local community (CH, F)
- Discussion about "Progress of the Feasibility Study of the Future FCC circular collider"

La Roche-sur-Foron - Haute Savoie international fair, 27 April to 6 May

- CERN's participation enhanced by help of volunteers from the FCC team
- Discussions with over 2000 locals
- Various topics (from the required technological. advancements to sustainability measures)

On 15 May, RTS (Radio Télévision Suisse) broadcasted a special program celebrating CERN's 70th anniversary and hosted at CERN's Science Gateway.

- Comprehensive look at CERN's history, achievements, and future ambitions (FCC)
- Study experts interacting with the audience explaining the Future Circular Collider (FCC) project

FCC Week 2024

Complete status of the FCC Study and all the latest advancements were presented at the Future Circular Collider Week 2024, in San Francisco, 10-14 June 2024

https://fccweek2024.web.cern.ch/

Michael Benedikt, Frank Zimmermann, CERN

Europe: FCC

FCC-ee main machine parameters

Parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45.6	80	120	182.5
beam current [mA]	1270	137	26.7	4.9
number bunches/beam	11200	1780	440	60
bunch intensity [10^{11}]	2.14	1.45	1.15	1.55
SR energy loss / turn [GeV]	0.0394	0.374	1.89	10.4
total RF voltage 400/800 MHz [GV]	0.120/0	1.0/0	2.1/0	2.1/9.4
long. damping time [turns]	1158	215	64	18
horizontal beta* [m]	0.11	0.2	0.24	1.0
vertical beta* [mm]	0.7	1.0	1.0	1.6
horizontal geometric emittance [nm]	0.71	2.17	0.71	1.59
vertical geom. emittance [pm]	1.9	2.2	1.4	1.6
vertical rms IP spot size [nm]	36	47	40	51
beam-beam parameter x_x / x_y	0.002/0.0973	0.013/0.128	0.010/0.088	0.073/0.134
rms bunch length with SR / BS [mm]	5.6 / 15.5	3.5 / 5.4	3.4 / 4.7	1.8 / 2.2
luminosity per IP [10^{34} cm^{-2}s^{-1}]	140	20	≥5.0	1.25
total integrated luminosity / IP / year [ab^{-1}/yr]	17	2.4	0.6	0.15
beam lifetime rad Bhabha + BS [min]	15	12	12	11
F. Gianotti	4 years 5 x 10^{12} Z LEP x 10^5	2 years > 10^8 WW LEP x 10^4	3 years 2 x 10^6 H	5 years 2 x 10^6 tt pairs

Design and parameters to maximise luminosity at all working points:

- allow for 50 MW synchrotron radiation per beam
- Independent vacuum systems for electrons and positrons
- full energy booster ring with top-up injection, collider permanent in collision mode

Improvements:

- x10-50 on all EW observables
- up to x 10 on Higgs coupling (model-indep.) measurements over HL-LHC
- x10 Belle II statistics for b, c, τ
- indirect discovery potential up to ~ 70 TeV
- direct discovery potential for feebly-interacting particles over 5-100 GeV mass range

Up to 4 interaction points

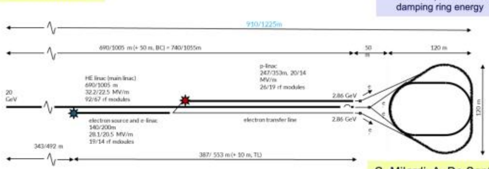
→ robustness, statistics, possibility of specialised detectors to maximise physics output

Europe: FCC

FCC-ee Injector

P. Craievich et al

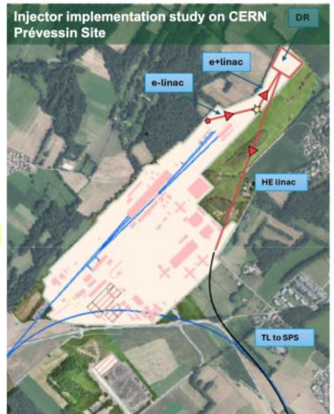
Overall injector parameter optimisation
- Operation frequency, gradient, etc…
- Positron production energy, damping ring energy



C. Milardi, A. De Santis et al.

"Positron production experiment" at PSI's SwissFEL, beam tests from 2025/26

J. Kosse, T. Michlmayr, H. Rodrigues



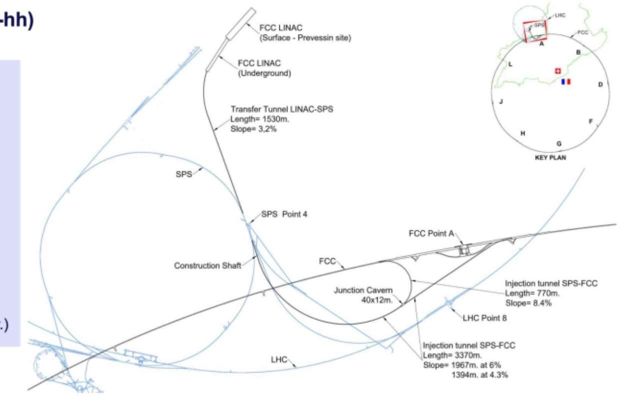
P. Craievich, W. Bartmann, Y. Papaphilippou, C. Milardi

Transfer line FCC-ee

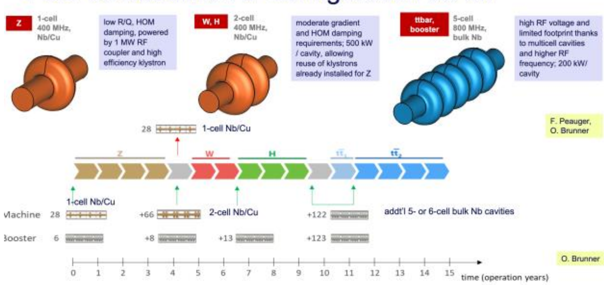
(option with SPS for FCC-hh)

LINAC and Injection Tunnels

- Enables injection
  - from SPS as pre-booster
  - from a new HE Linac sited at Prevessin
- Single tunnel with spur to enable anticlockwise injection
- Design allows re-use for FCC-hh if injector in the SPS tunnel (SC-SPS option)
  - SPS Point 4 to FCC (clockwise)
  - SPS Point 6 to FCC (counter-c.w.)



FCC-ee baseline RF configuration so far

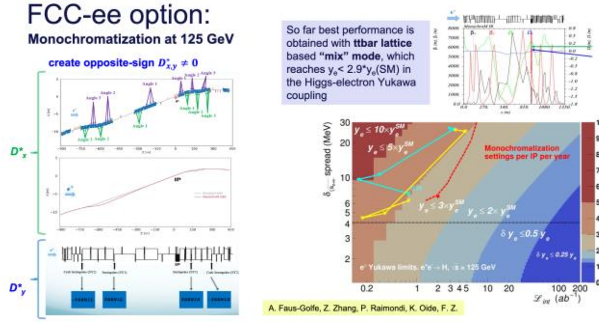


FCC-ee option:

Monochromatization at 125 GeV

create opposite-sign $D^*_{x,y} \neq 0$

So far best performance is obtained with **ttbar lattice** based **"mix" mode**, which reaches y_e< 2.9*y_e(SM) in the Higgs-electron Yukawa coupling



A. Faus-Golfe, Z. Zhang, P. Raimondi, K. Oide, F. Z.

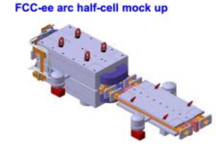
Arc layout and integration optimisation

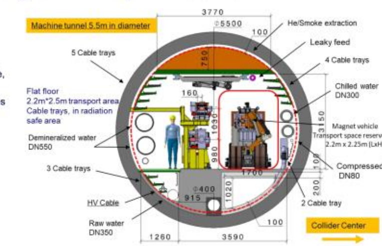
Arc cell optimisation – 80 km total length, dedicated working group active.

- including support, girder and alignment systems, shielding systems
- vacuum system with antechamber + pumps, dipole, quadrupole + sext. magnets, BPMs
- cabling, cooling & technical infrastructure interfaces
- safety aspects, access and transport concept

→ **Confirmation of tunnel diameter**

FCC-ee arc half-cell mock up

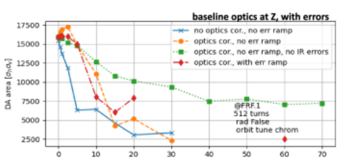




F. Carra, CERN; F. Valchkova

FCC-ee dynamic aperture with alignment errors

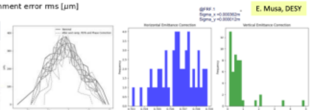
S. Liuzzo, ESRF



>100 μm alignment errors in the arcs acceptable for present baseline optics

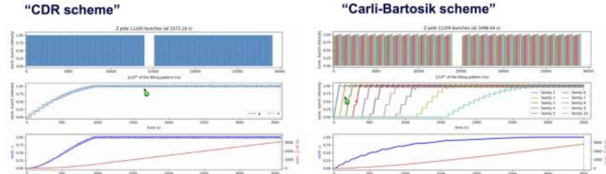
E. Musa, DESY

50 seeds (mean values)		rms orbit x (μm)	rms orbit y (μm)	Δβx/βx %	Δβy/βy %	Δ ηx (mm)	Δ ηy (mm)	ϵ_h (nm)	ϵ_v (pm)
100 μm on arc quads & sexts	With err	6224.8	7276.7	1e-6	1e-4	11985	73458	-	-
	After Sext ramping	8.55	8.35	5.98	9.91	45.23	45.96	0.71	9.61
	RDTs & ηy Cor	8.58	8.42	6.01	9.94	45.09	4.49	0.71	2.32
	Phase Cor	8.55	8.35	0.35	0.79	2.94	4.36	0.70	0.88
	Final cor. result	8.55	8.35	0.35	0.89	2.94	4.37	0.70	0.73



FCC-ee filling scheme & e-cloud mitigation

"CDR scheme" **"Carli-Bartosik scheme"**



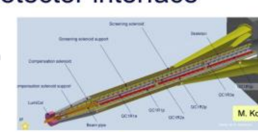
only 1/10 of intensity per booster cycle
→ vacuum pressure-tolerant
only 1/10 of collider bunches at intermediate intensity
→ anti e-cloud build up

→ **yet same integrated luminosity as for CDR scheme !**

H. Bartosik, C. Carli, L. Mether, F. Zimmermann

Machine detector interface

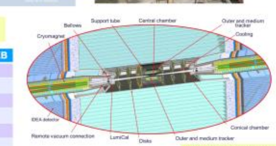
Key topics:
- SC IR magnet system & Cryostat design
- 3D integration
- IR mock-up at INFN Frascati !



M. Koratzinos, PSI

P. Tavares , CERN
J. Seeman, SLAC

Machine		FCCee	CEPC	ILC	SuperKEKB
Crossing-angle	mrad	30	33	14	83
L*	m	2.2	1.9	3.5	0.935
Vertical β_y^* at IP	mm	0.7-1.6	0.9-2.7	0.4	0.3
Detector soln field	T	2/3	3	3.5/5	1.5
Detector stay clear	mrad	100	118/141	90	350/436
Two beam ΔX at L*	mm	66	62.7	49	77.6
He temperature	K	1.9	4.2	4.5	4.5



M. Boscolo, F. Palla, INFN

Europe

Progress on international collaboration

Joint Statement of Intent between The United States of America and The European Organization for Nuclear Research concerning Future Planning for Large Research Infrastructure Facilities, Advanced Scientific Computing, and Open Science

The United States and CERN intend to:

- Enhance collaboration in future planning activities for large-scale, resource-intensive facilities with the goal of providing a sustainable and responsible pathway for the peaceful use of future accelerator technologies;
- Continue to collaborate in the feasibility study of the Future Circular Collider Higgs Factory (FCC-ee), the proposed major research facility planned to be hosted in Europe by CERN with international participation, with the intent of strengthening the global scientific enterprise and providing a clear pathway for future activities in open and trusted research environments; and
- Discuss potential collaboration on pilot projects on incorporating new analytics techniques and tools such as artificial intelligence (AI) into particle physics research at scale.

Should the CERN Member States determine the FCC-ee is likely to be CERN's next world-leading research facility following the high-luminosity Large Hadron Collider, the United States intends to collaborate on its construction and physics exploitation, subject to appropriate domestic approvals.

26 April 2024

White House Office of Science and Technology Policy Principal Deputy U.S. Chief Technology Officer Deirdre Mulligan signed for the United States while Director-General Fabiola Gianotti signed for CERN.

US: DOE and NSF Higgs factory organisation

Europe

Update of the European Strategy

- In March 2024, the CERN Council approved the timeline for the next update of the European Strategy for Particle Physics with a completion date in June 2026

- The proposed timeline is determined by physics (LHC, HL-LHC, results from other colliders) and strategic considerations:

- **Physics landscape**: physics results from the LHC and other colliders, HL-LHC upgrades ongoing, exploration of the Higgs sector remains central

- Excellent progress at CERN and beyond on the preparation for future colliders

*** FCC Feasibility Study**
(mid-term report presented, excellent progress on the technical side - no showstoppers identified for an FCC-ee as a first stage of an integrated FCC programme)
Planned to complete the study in March 2025

*** Clearer view on the international landscape for future colliders**
- ILC in Japan as a global project; so far no commitments
- P5 process in the US (→ participation in an off-shore Higgs factory (ILC, FCC-ee)
- Technical Design Report for CEPC in China released in Dec 2023;
  Aim for adoption of the project in the next 5-year funding cycle(s) in 2025

→ Very relevant information will become available by the end of 2025

Europe

The Strategy Secretariat and European Strategy Group (ESG)

Strategy Secretariat: Organising and running the ESPP process

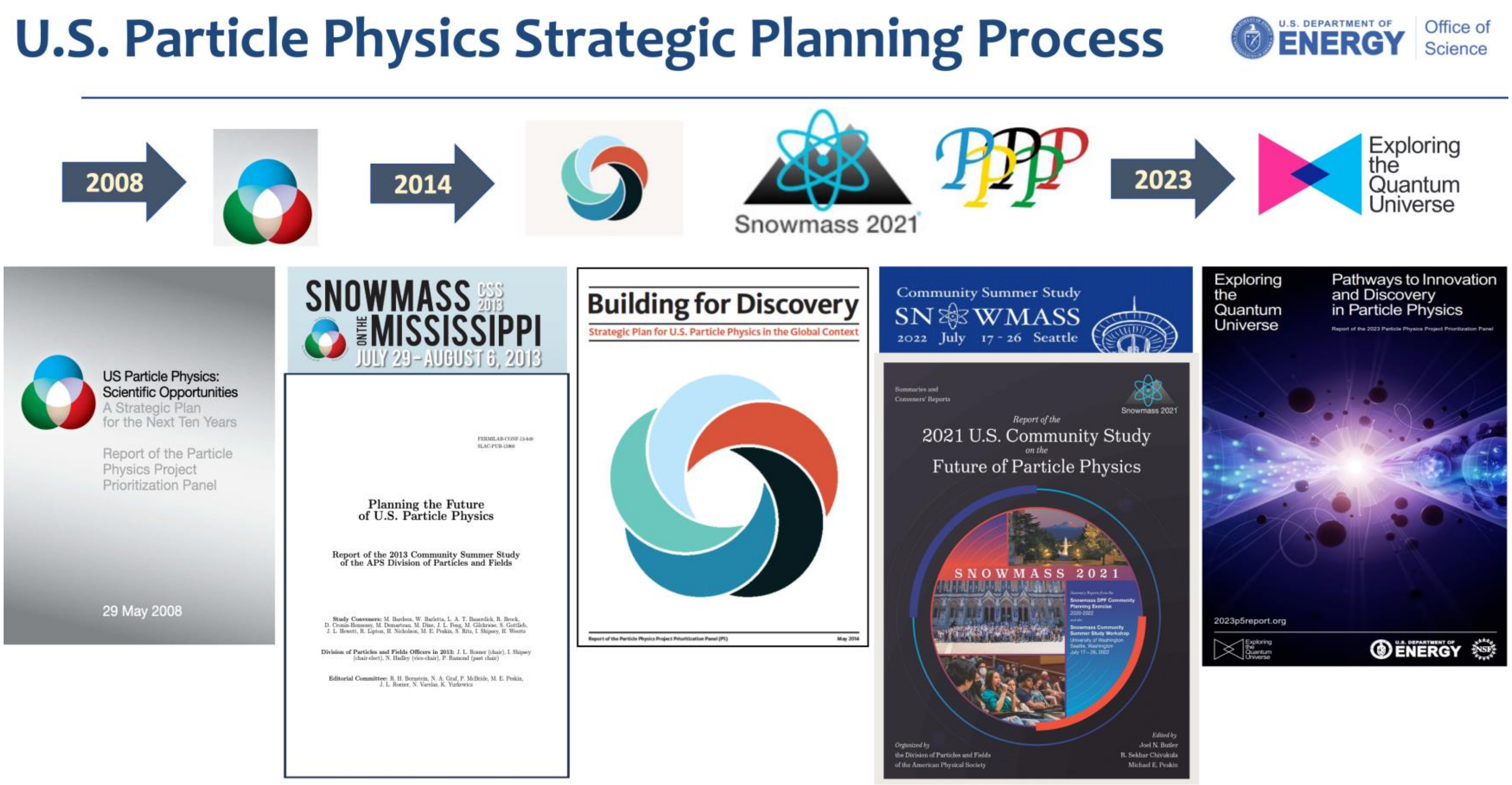
Karl Jakobs (Strategy Secretary, Chair)
Hugh Montgomery (SPC Chair)
Dave Newbold (LDG Chair)
Paris Spicas (ECFA Chair)

The Physics Preparatory Group (PPG)

Physics Preparatory Group (PPG): collects input from the community, organises the Open Symposium, prepares the Briefing Book

- Strategy Secretary (acting as Chair)
- **Four members appointed by Council on the recommendation of the SPC**
- **Four members appointed by Council on the recommendation of ECFA**
- **One representative appointed by CERN**
- Two representatives from the Americas and two representatives from Asia (appointed by the respective regional representatives in ICFA)
- The SPC Chair
- The ECFA Chair
- The LDG Chair

United States
Landscapes and national roadmaps

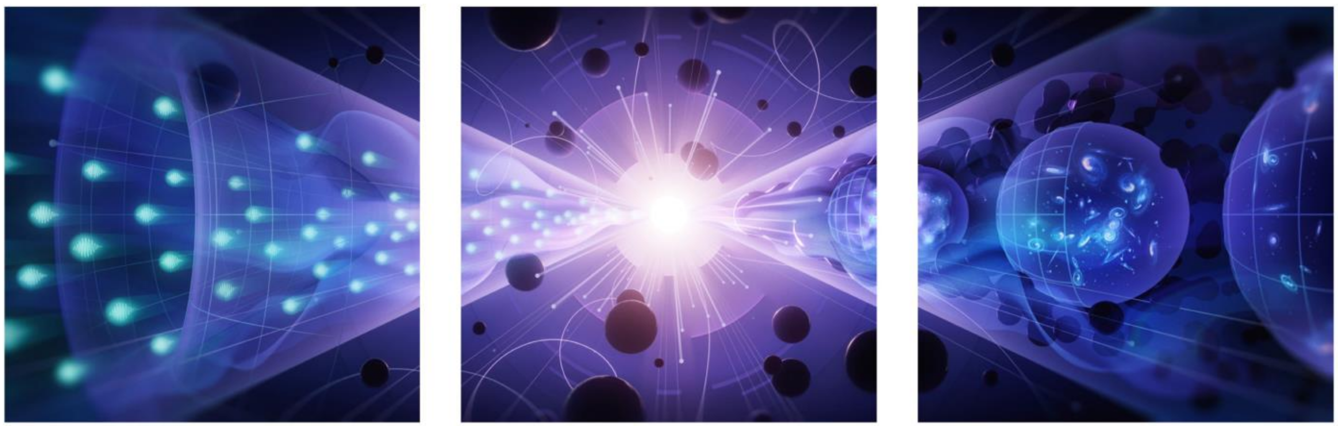


https://agenda.linearcollider.org/event/10134/

United States
Landscapes and national roadmaps

2023 P5 Strategy:
3 Science Themes and 6 Science Drivers *or* Focus Areas

U.S. DEPARTMENT OF ENERGY | Office of Science



Decipher the Quantum Realm	Explore New Paradigms in Physics	Illuminate the Hidden Universe
Elucidate the Mysteries of Neutrinos	Search for Direct Evidence of New Particles	Determine the Nature of Dark Matter
Reveal the Secrets of the Higgs Boson	Pursue Quantum Imprints of New Phenomena	Understand What Drives Cosmic Evolution

Abid Patwa, LCWS 2024, Tokyo

United States
Landscapes and national roadmaps

Off-shore Higgs Factory: 2023 P5 Strategic Report

U.S. DEPARTMENT OF ENERGY | Office of Science

From 2023 P5:

- **Recommendation 2, Priority #3 out of 5:** *An* ***off-shore Higgs factory****, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson.* ***The current designs of FCC-ee and ILC meet our scientific requirements.*** *The U.S. should actively* ***engage in feasibility and design studies.*** *Once a specific project is deemed feasible and well-defined (see also P5 Recommendation 6), the U.S. should aim for a contribution at funding levels commensurate to that of the U.S. involvement in the LHC and HL-LHC, while maintaining a healthy U.S. on-shore program in particle physics (P5 section 3.2).*

- **Recommendation 6:** *Convene* ***a targeted panel*** *with broad membership across particle physics later this decade that makes decisions on the U.S. accelerator-based program* ***at the time when major decisions concerning an off-shore Higgs factory are expected****, and/or significant adjustments within the accelerator-based R&D portfolio are likely to be needed. A plan for the Fermilab accelerator complex consistent with the long-term vision in this report should also be reviewed. The panel would consider the following:*
  - a) *The level and nature of U.S. contributions in a specific* ***Higgs factory*** *including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.*
  - b) *Mid- and large* ***test and demonstrator facilities*** *in the accelerator and collider R&D portfolios.*
  - c) *A plan for the* ***evolution of the Fermilab accelerator complex*** *consistent with the long-term vision in this report, which may commence construction in the event of a more favorable budget situation.*

DOE does not envision a single panel to address Recommendation 6; rather we plan to work with NSF, the DOE national labs, and community-at-large to convene three separate panels that each will address one of the topics.

Abid Patwa, LCWS 2024, Tokyo

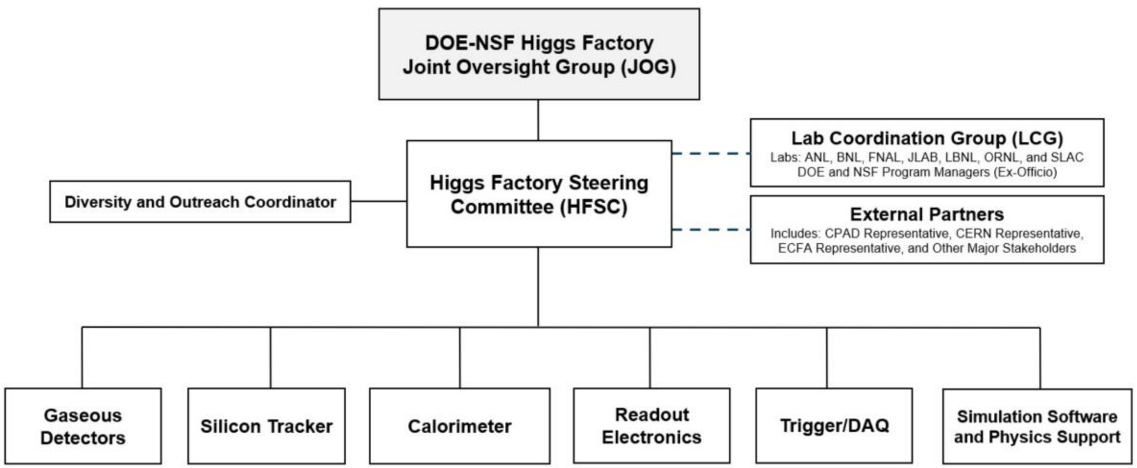
United States

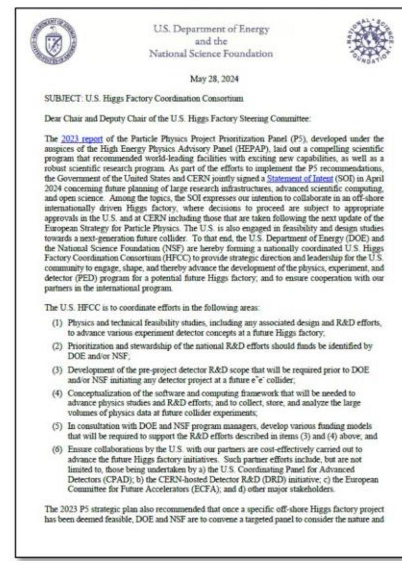
Landscapes and national roadmaps

U.S. Organization for Higgs Factory Coordination and Development – PED (I)

U.S. DEPARTMENT OF ENERGY | Office of Science

- **Jointly, DOE and NSF recently issued a charge forming a *nationally coordinated* U.S. Higgs Factory Coordination Consortium (HFCC) to coordinate and develop the physics, experiments, and detectors (PED) program**
  - U.S. HFCC includes: 1) Higgs Factory Steering Committee (HFSC); 2) a Lab Coordination Group (LCG); and 3) various detector systems that naturally map onto the CERN Detector R&D (DRD) initiative





U.S. Department of Energy
and the
National Science Foundation

May 28, 2024

SUBJECT: U.S. Higgs Factory Coordination Consortium

Dear Chair and Deputy Chair of the U.S. Higgs Factory Steering Committee:

The 2023 report of the Particle Physics Project Prioritization Panel (P5), developed under the auspices of the High Energy Physics Advisory Panel (HEPAP), laid out a compelling scientific program that recommended world-leading facilities with exciting new capabilities, as well as a robust scientific research program. As part of the efforts to implement the P5 recommendations, the Government of the United States and CERN jointly signed a Statement of Intent (SOI) in April 2024 concerning future planning of large research infrastructures, advanced scientific computing, and open science. Among the topics, the SOI expresses our intention to collaborate in an off-shore internationally driven Higgs factory, where decisions to proceed are subject to appropriate approvals in the U.S. and at CERN including those that are taken following the next update of the European Strategy for Particle Physics. The U.S. is also engaged in feasibility and design studies towards a next-generation future collider. To that end, the U.S. Department of Energy (DOE) and the National Science Foundation (NSF) are hereby forming a nationally coordinated U.S. Higgs Factory Coordination Consortium (HFCC) to provide strategic direction and leadership for the U.S. community to engage, shape, and thereby advance the development of the physics, experiment, and detector (PED) program for a potential future Higgs factory; and to ensure cooperation with our partners in the international program.

The U.S. HFCC is to coordinate efforts in the following areas:

(1) Physics and technical feasibility studies, including any associated design and R&D efforts, to advance various experiment detector concepts at a future Higgs factory;

(2) Prioritization and stewardship of the national R&D efforts should funds be identified by DOE and/or NSF;

(3) Development of the pre-project detector R&D scope that will be required prior to DOE and/or NSF initiating any detector project at a future e^+e^- collider;

(4) Conceptualization of the software and computing framework that will be needed to advance physics studies and R&D efforts; and to collect, store, and analyze the large volumes of physics data at future collider experiments;

(5) In consultation with DOE and NSF program managers, develop various funding models that will be required to support the R&D efforts described in items (3) and (4) above; and

(6) Ensure collaborations by the U.S. with our partners are cost-effectively carried out to advance the future Higgs factory initiatives. Such partner efforts include, but are not limited to, those being undertaken by a) the U.S. Coordinating Panel for Advanced Detectors (CPAD); b) the CERN-hosted Detector R&D (DRD) initiative; c) the European Committee for Future Accelerators (ECFA); and d) other major stakeholders.

The 2023 P5 strategic plan also recommended that once a specific off-shore Higgs factory project has been deemed feasible, DOE and NSF are to convene a targeted panel to consider the nature and

Abid Patwa, LCWS 2024, Tokyo

United States
Landscapes and national roadmaps

U.S. Organization for Higgs Factory Coordination and Development – PED (II)

U.S. DEPARTMENT OF ENERGY | Office of Science

- **The Consortium is to ensure that collaborative activities by the U.S. with our international partners are prioritized and cost-effectively carried out for Higgs factory initiatives**
- **The Lab Coordination Group (LCG) is an integral part of the Consortium and includes a representative from each of our DOE national labs:**
  - ANL, BNL, FNAL, JLAB, LBNL, ORNL, and SLAC
  - During the P5 process and soon after the P5 roll-out, these labs expressed an interest to participate in Higgs factory R&D efforts
  - Representatives for the LCG are being identified by the management of each lab
- **Representatives in the Consortium also include external partners and other major stakeholders**
  - Such as those from APS/DPF's Coordinating Panel for Advanced Detectors (CPAD) in the United States and the CERN-hosted Detector R&D (DRD) initiative
- **Various detector systems that report to the Steering Committee**
  - Nominations now progressing for Level-2 and Level-3 R&D coordinator roles

Higgs Factory Steering Committee – PED

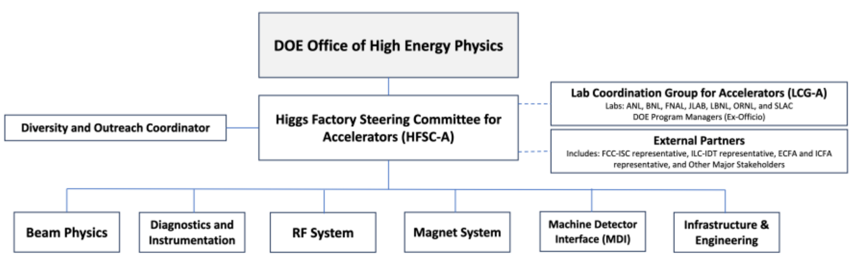
U.S. DEPARTMENT OF ENERGY | Office of Science

- **Goals and tasks of the U.S. HFCC include:**
  - Coordinate U.S. community efforts, **bringing together** both the **linear** and **circular collider communities**
  - To be done during the phase which precedes the development of a specific future project
- **DOE and NSF selected members of the Steering Committee from the leadership of the community-driven *FCC-ee* P5 input group and the Americas' Linear Collider Community:**
  - Srini Rajagopalan (*Chair*); Sarah Eno
  - Ritchie Patterson (*Deputy Chair*); Marcel Demarteau
- **No lead DOE laboratory is designated for this Consortium**
  - Each lab collaborating in Higgs factory efforts is represented through the Lab Coordination Group

U.S. Organization for Higgs Factory Coordination and Development – Accelerators

U.S. DEPARTMENT OF ENERGY | Office of Science

- **DOE plans to issue a charge later this month [July] that forms a *nationally coordinated* U.S. Higgs Factory Coordination Consortium (HFCC) for developing the accelerators program**
  - In general, similar structure as the U.S. HFCC for PED; includes appropriate partners and accelerator systems
  - Membership in the Higgs Factory Steering Committee for Accelerators (HFSC-A) is being finalized now, and leaders are to be identified soon.



U.S. Higgs Factory Development – PED and Accelerators

U.S. DEPARTMENT OF ENERGY | Office of Science

- **Efforts to be coordinated under each respective Consortia include:**
  - Physics and technical feasibility studies, including associated design and R&D efforts, to advance the accelerator (HFCC-A) and the various experimental detector concepts (HFCC-PED) at a future e^+e^- collider
  - Prioritization and stewardship of national R&D efforts under any available funding
  - Pre-project R&D prior to DOE (for PED and Accelerators) and/or NSF (for PED) initiating any associated detector or accelerator projects in the U.S.
  - Conceptualization of appropriate software and computing framework to advance the respective physics, experiments, and accelerator
- **Correspondingly, each U.S. HFCC – PED and Accelerators – will be positioned to inform deliberations of the future targeted panel envisioned by P5 (*i.e.*, P5 Rec. 6a)**
  - One that will consider the specific nature of U.S. contributions in a future Higgs factory, and which is to convene following completion of the next European Strategy for Particle Physics update process

United States

Recommendation 6

Decision without waiting for the next P5

Not Rank-Ordered

Recommendation 4

Investment in the future

a. Support **vigorous R&D toward a cost-effective 10 TeV pCM collider** based on proton, muon, or possible wakefield technologies, including an evaluation of options for US siting of such a machine, with a goal of being ready to build **major test facilities and demonstrator facilities within the next 10 years** (sections 3.2, 5.1, 6.5, and Recommendation 6).

b. Enhance research in **theory** to propel innovation, maximize scientific impact of investments in experiments, and expand our understanding of the universe (section 6.1). **$15M/yr increase**

c. Expand the **General Accelerator R&D (GARD)** program within HEP, including stewardship (section 6.4). **$10M/yr increase**

d. Invest in R&D in **instrumentation** to develop innovative scientific tools (section 6.3). **$20M/yr increase**

e. Conduct **R&D** efforts to define and enable new projects in the next decade, including detectors for an e^+e^- Higgs factory and 10 TeV pCM collider, Spec-S5, DUNE FD4, Mu2e-II, Advanced Muon Facility, and line intensity mapping (sections 3.1, 3.2, 4.2, 5.1, 5.2, and 6.3). **$8+9M/yr increase**

f. Support key **cyberinfrastructure** components such as shared software tools and a sustained R&D effort in computing, to fully exploit emerging technologies for projects. Prioritize **computing and novel data analysis techniques** for maximizing science across the entire field (section 6.7).

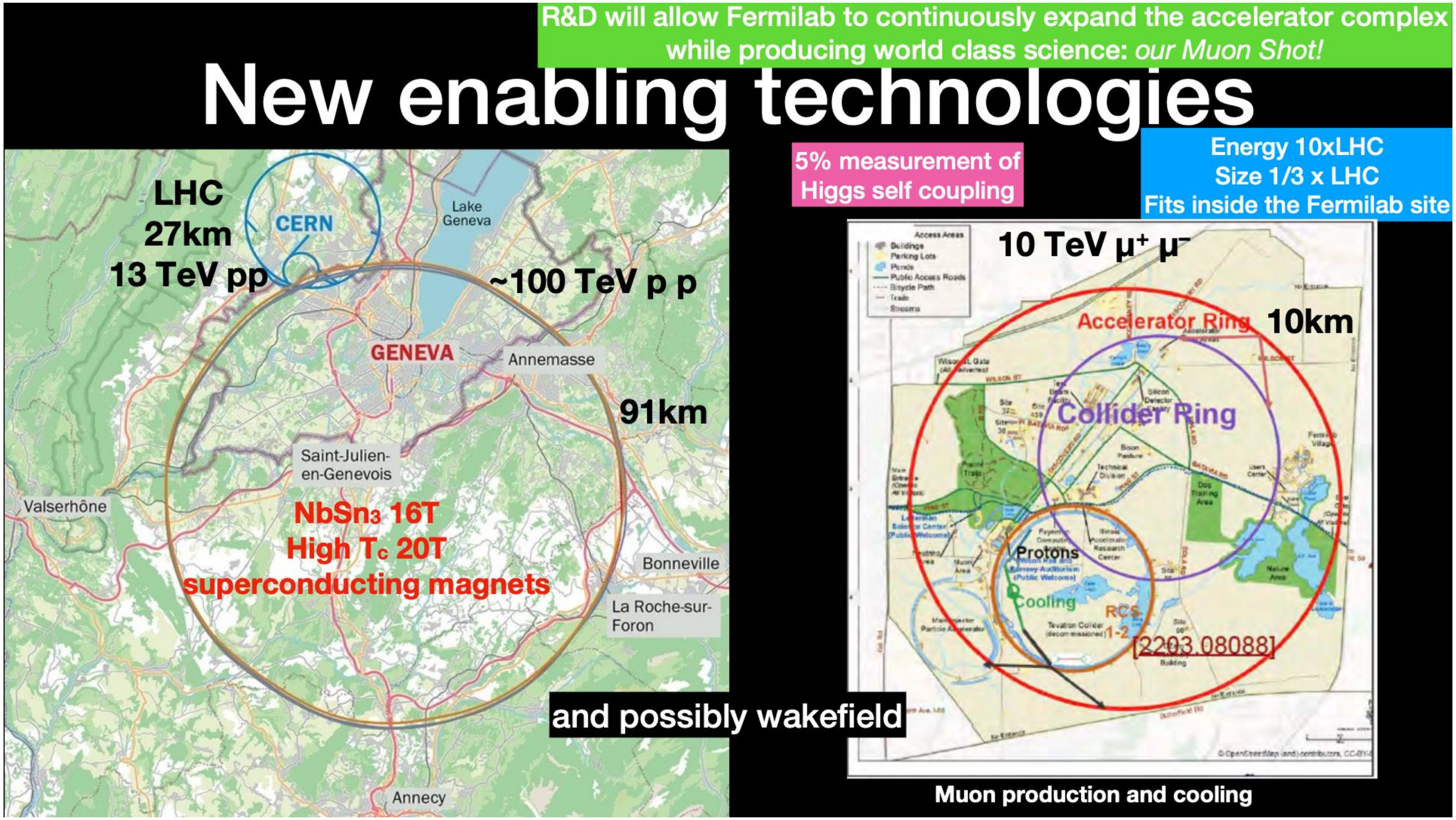
g. Develop plans for improving the **Fermilab accelerator complex** that are consistent with the long-term vision of this report, including neutrinos, flavor, and a 10 TeV pCM collider (section 6.6).

We recommend specific budget levels for enhanced support of these efforts and their justifications as **Area Recommendations** in section 6.

18

United States

Muon collider for far future at FNAL

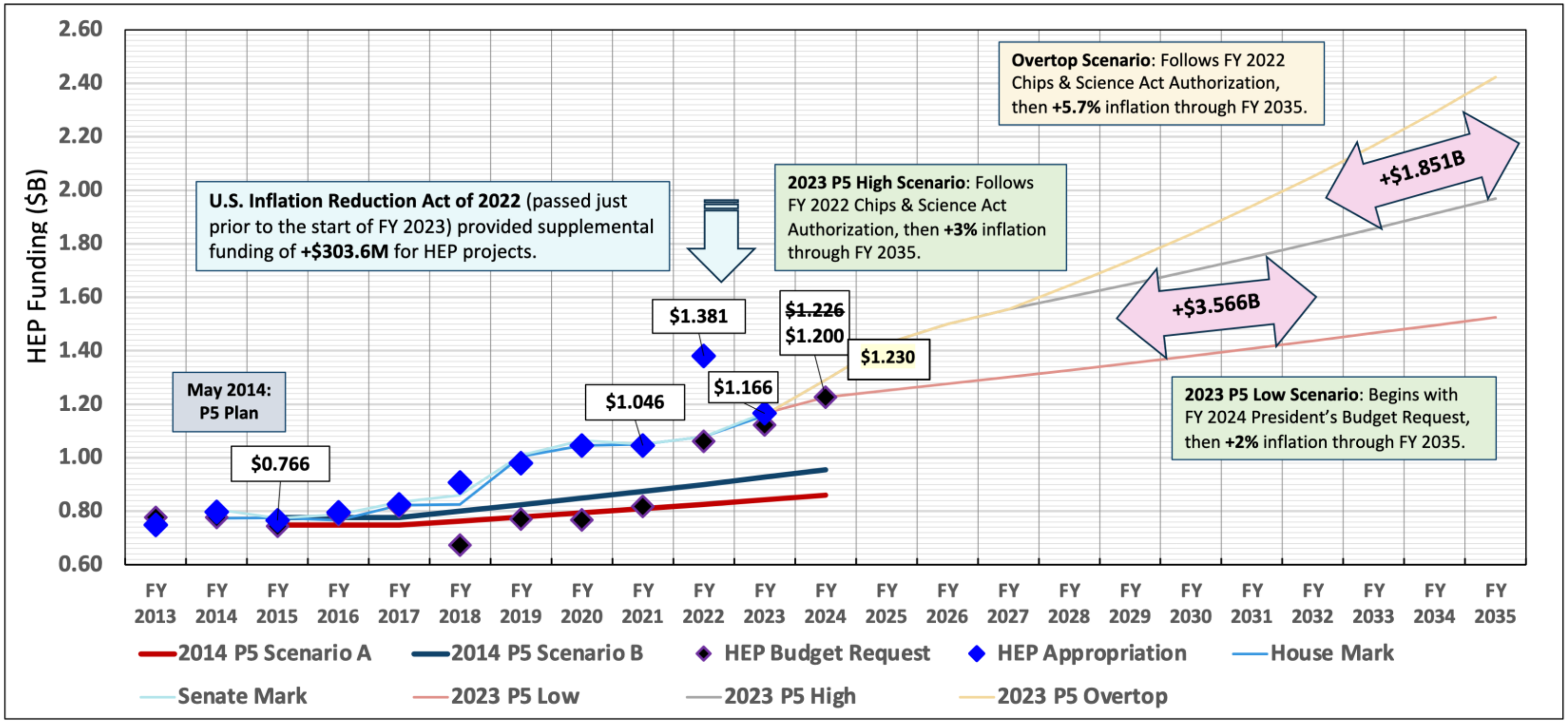


Hitoshi Murayama, ICHEP 2024, Prague

United States
Landscapes and national roadmaps

Budget Scenarios Considered by 2023 P5 Panel

U.S. DEPARTMENT OF ENERGY | Office of Science



Abid Patwa, LCWS 2024, Tokyo

Japan
Landscapes and national roadmaps

Japan's Strategy for Energy Frontier (since 2017)

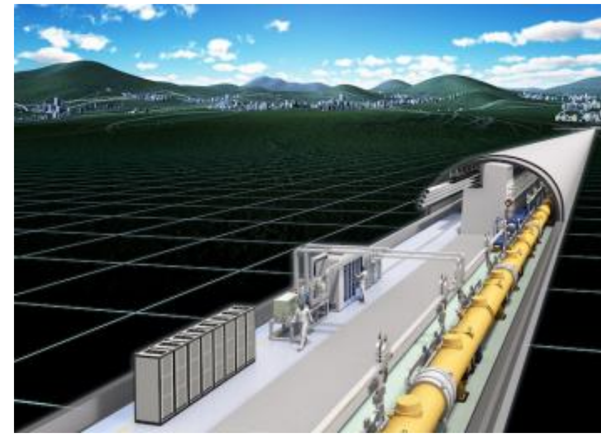
- **Current HE research concentrates on (HL-)LHC**

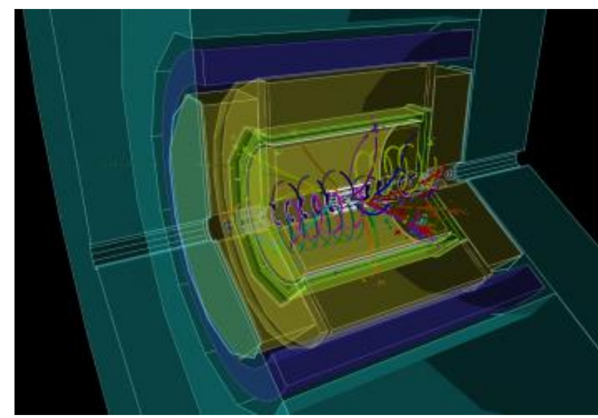
"… continuing studies of new physics should be pursued using the LHC and its upgrades."

- **Future HE project in Japan is the ILC**

"… construction of the International Linear Collider with a collision energy of 250 GeV should start in Japan immediately without delay so as to guide the …. through the research of the Higgs particle …."

Final Report by the Committee on Future Projects in High Energy Physics, September 2017
http://www.jahep.org/files/20170906-en.pdf



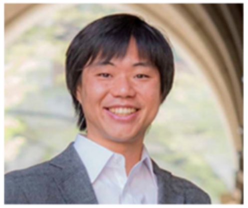


Japan

New JAHEP Future Projects Committee

https://www.jahep.org/en/fproject.html

- **The global HEP situation is changing dramatically.**
  - New recommendations from US P5.
  - New European Strategy is launched.
  - Progress of the CEPC project in China
- The importance of the Higgs boson is growing.
  - Higgs Factory is the next collider as a consensus of the HEP community.
- New Future Projects Committee was launched in 2024.
  - Dr. Y. Okumura is chair of the committee.



- The Japanese HEP community is updating its strategy for future projects.
  - An input to European Strategy

Your input is very welcome and important.

2024.1~		
Yasuyuki OKUMURA	The University of Tokyo・ICEPP	Chairperson
Yoshinori ENOMOTO	KEK・ACCL	Secretary
Hideyuki OIDE	KEK・IPNS	Secretary
Kazuyuki SAKAUE	The University of Tokyo	Secretary
Tsunayuki MATSUBARA	KEK・IPNS	Secretary
Kazuki UENO	Osaka University	
Kenta UNO	KEK・IPNS	
Yuji ENARI	The University of Tokyo・ICEPP	
Hidetoshi OTONO	Kyushu University	
Shusei KAMIOKA	KEK・IPNS	
Ryuichiro KITANO	KEK・IPNS	
Takayuki KUBO	KEK・ACCL	
Koji SHIOMI	KEK・IPNS	
Taikan SUEHARA	The University of Tokyo・ICEPP	
Yu NAKAHAMA	KEK・IPNS	
Natsumi NAGATA	The University of Tokyo	
Koji TSUMURA	Kyushu University	
Junping Tian	The University of Tokyo・ICEPP	
Kaori HATTORI	AIST	
Shigeki HIROSE	University of Tsukuba	
Megan Friend	KEK・IPNS	
Yasuhiro FUWA	JAEA	
Takahiko MASUDA	Okayama University	
Kodai MATSUOKA	KEK・IPNS	
Kenji MISHIMA	KEK・IMSS	
Gaku MITSUKA	KEK・ACCL	
Roger Wendell	Kyoto University	
Hiroko WATANABE	Tohoku University	

高能物理国际势态

Organized & dedicated R&D

欧洲高能物理战略 – 探测器研究路线图

自2021年开始，欧洲粒子物理战略 **EPS** 研讨决定，旨在建立合作组织 **DRD**：

- 国际上各前沿对撞机物理实验的成功，依赖于创新的仪器和最先进的探测技术（**驱动目的**）
- 为准备和实现未来的实验研究计划、 制定探测器研发路线
- **短期目标：**未来十年的研发重点，为一系列中、小规模高能物理实验项
- **长期目标：**未来二十年研发重点，为未来 20 多年的大型对撞机项目铺平道路

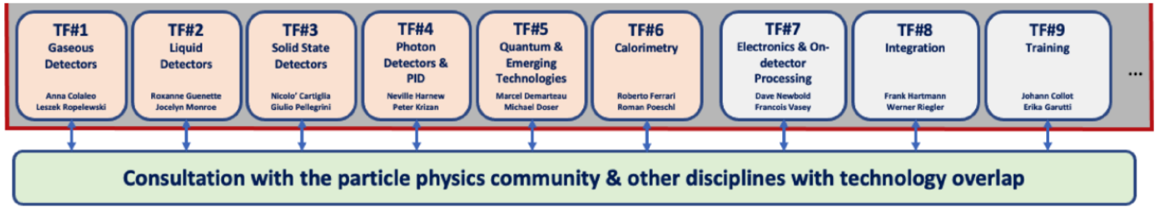
整理：H.R.Qi

ECFA Detector Roadmap

European Committee for Future Accelerators (ECFA) released in 2021 a full document (200 pages) and synopsis (~10 pages) based on a community-driven effort

The full document can be referenced as DOI: 10.17181/CERN.XDPL.W2EX

- Overview of **future facilities** (EIC, ILC, CLIC, FCC-ee/hh, Muon collider) or major **upgrades** (ALICE, Belle-II, LHC-b,…) and their **timelines**
- Ten "**General Strategic Recommendations**" (full list in backup slides)
- **Nine Technology domains** with **Task Forces** areas
  - The **most urgent R&D topics** in each domain identified as **Detector R&D Themes** (DRDTs)



平衡考虑技术探测技术研究的难度、成本、人员等因素，新架构具有以下特点：

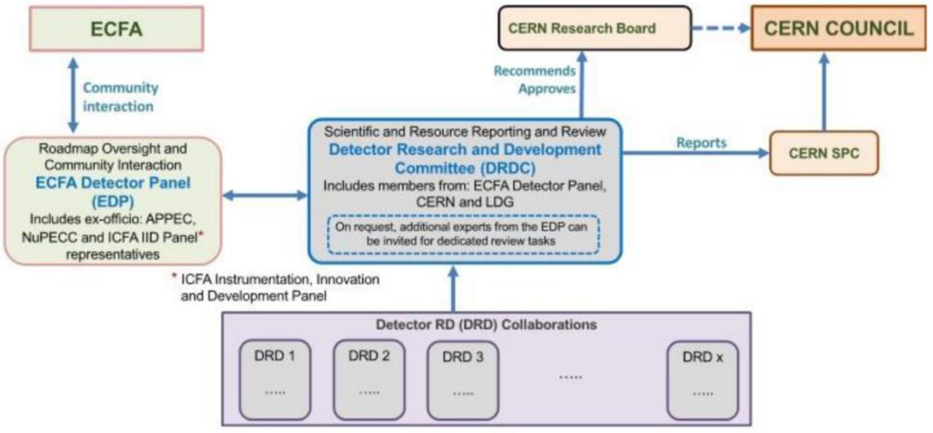
- 确定和瞄准共同的技术目标：国际合作+国际协调 （**现在的科学人员**）
- 为下一代实验粒子物理学家、工程师和技术人员培训和技能发展 （**下一代的科学人员**）
- 提供与工业合作伙伴建立良好的有意义的长期合作（**合作的科技人员**）

整理：H.R.Qi

Roadmap implementation plan

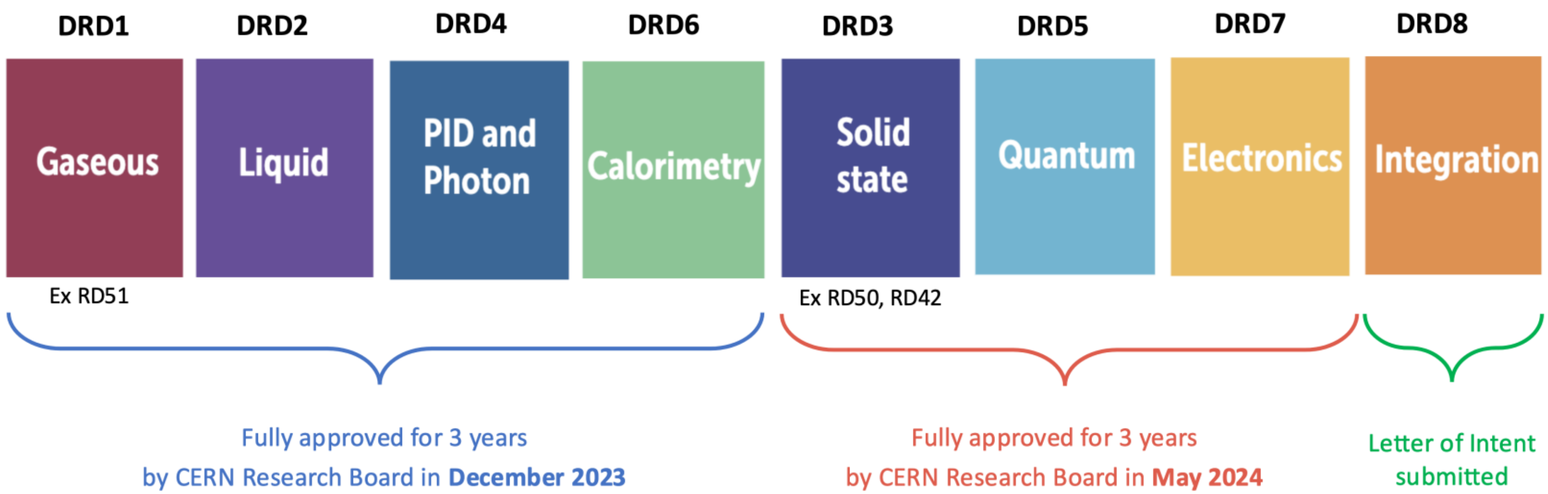
- Approved by CERN SPC and Council in fall 2022 (CERN/SPC/1190 ; CERN/3679)
- **CERN will host DRD collaborations**
  - ✦ Interaction between DRD collaborations and committees through DRDC
  - ✦ Interface to ECFA via ECFA Detector panel (EDP): https://ecfa-dp.desy.de

- Distinction between reviewing body (DRDC) and advisory body (EDP)
- **DRDC** reviews DRD progress, monitor milestones & deliverables, and reports to CERN Research Board
- **EDP** (full mandate to be found here) monitors ECFA Detector Roadmap, organizes "DRD managers forum" and provides input to the next Strategy update



DRDC same level as SPSC and LHCC: review proposals and progress
http://committees.web.cern.ch/drdc

欧洲高能物理战略 – 探测器研究路线图：Status



DRD reports & proposals

- DRD **reports** at open session of DRDC meeting:
  https://indico.cern.ch/event/1356910/
- **Indico**: Category "Experiments / R&D"
  https://indico.cern.ch/category/6805/
- Full DRD **proposals** in CERN CDS
  - Proposal by DRD8 to be written by the end of this year
  - They contain **strategic R&D** needs and definition of work packages, milestones & deliverables
  - **Strategic funding** to be agreed with funding agencies/institutions
  - **Progress** tracked by annual DRDC review
- **Next step** is to prepare and sign DRD **MoUs**

MoU template

- CERN has recently provided a **template** for the Memorandum of Understanding between all institutes of each DRD collaboration (and CERN)
  - To be in agreement with CERN's *General Conditions for the execution of experiments*, legal service, KT office
  - Should be almost identical for all DRD collaborations
- **Main MoU** is the only one which is physically/electronically **signed by each collaborating institution/Funding Agencies**; Contains: Obligations of CERN as host laboratory, industrial involvements, common fund, definitions:
  - **Working Groups** shall reflect the internal structure of the Collaboration. They are expected to be long-lasting
  - **Work Packages** shall reflect time-limited resource-loaded activities with clearly defined **objectives** and **deliverables**
- **Annexes**: everything that can change over time
  - Does not necessarily need a physical signature by funding agencies, but agreement/vote at Resource Board (with representatives of funding agencies)
- **Status**: First draft of MoU template is under discussion with management of DRD collaborations

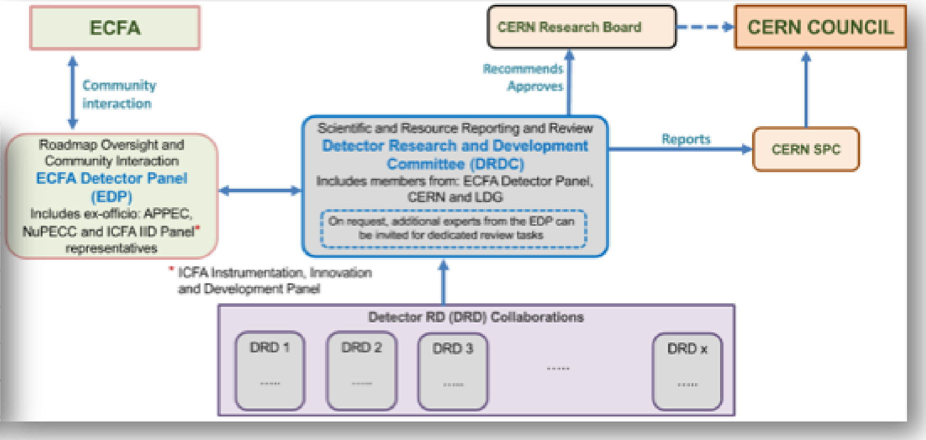
- Annex 1: Collaborating Institutions and their Contact Persons
- Annex 2: Funding Agencies and their Representatives
- Annex 3: Organisational Structure of the Collaboration
- Annex 4: Financial Participation of the Funding Agencies
- Annex 5: Working Groups
- Annex 6: Work Packages and deliverables
- Annex 7: Background IP
- Annex 8: CERN General Conditions Applicable to Experiments

欧洲高能物理战略 – 探测器研究路线图：合作组现状

- CERN DRD架构现状：
  - 从气体、闪烁体、液体、固体等探测器到技术研发配套，共8个大合作组
  - 以 ECFA 和 CERN 作为主要管理层，每个DRD的内部管理由每个合作组自行决定
  - **截止2024年8月，**大部分完成整体组织架构，部分发布公开网页
- 2023年全面启动并过渡到新的DRD合作组，2024年起正式运行DRD合作组，参与单位需签署MoU

https://drd1.web.cern.ch/
https://drd3.web.cern.ch/
https://drd4.web.cern.ch/
https://drd5.web.cern.ch/

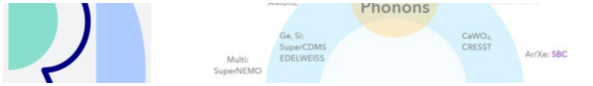
DRD-1	Gaseous detectors
DRD-2	Liquid detectors
DRD-3	Semiconductors
DRD-4	PID and Photon Detectors
DRD-5	Quantum and emerging technologies
DRD-6	Calorimeters
DRD-7	Electronics & Data Processing
DRD-8	Large scale detector systems - infrastructure



整理：H.R.Qi

欧洲高能物理战略 – 探测器研究路线图：各组进展

DRD1: Gaseous Detectors
DRD2: Liquid Detectors



DRD3: Solid State Detectors
DRD4: Photon Detectors & Particle ID
DRD5: Quantum Sensors

Quantum		
		technologies to particle physics
	DRDT 5.3	Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies
	DRDT 5.4	Develop and provide advanced enabling capabilities and infrastructure

DRD6: Calorimetry

Calorimetry		
		energy and timing resolution
	DRDT 6.2	Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods

DRD7: Electronics
DRD8: Integration

- Initial TF convenors did not continue as proposal preparation team
- New proponents had to be searched for, which were found by the group around the "Forum on Tracker Mechanics" workshop organizers
  - Burkhard Schmidt (CERN) and Andreas Mussgiller (DESY)
- Community survey replied that there is an interest in going forward
- Community Meeting on December 6, 2023
- LoI received by end of February 2024 with the aim to write a full proposal by the end of this year
  - LoI does not cover all DRDTs, as they are quite diverse
  - Focus on vertex detector mechanics and cooling

Integration		
	DRDT 8.1	Develop novel magnet systems
	DRDT 8.2	Develop improved technologies and systems for cooling
	DRDT 8.3	Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.
	DRDT 8.4	Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects

欧洲高能物理战略 – 探测器研究路线图：战略考虑

The General Strategic Recommendations (GSR) topics are:

- GSR 1: Supporting R&D facilities (**test beams, large-scale generic prototyping and irradiation)**
- GSR 2: **Engineering support** for detector R&D
- GSR 3: Specific **software** for instrumentation
- GSR 4: **International coordination** and organisation of R&D activities
- GSR 5: Distributed R&D activities with **centralised facilities**
- GSR 6: Establish long-term strategic **funding programmes**
- GSR 7: “**Blue-sky**” R&D
- GSR 8: Attract, nurture, recognise and sustain the **careers of R&D experts**
- GSR 9: **Industrial** partnerships
- GSR 10: **Open Science**

欧洲高能物理战略 – 探测器研究路线图

通过高能物理分会提醒大家，向DRD组织反馈中方参加的情况

关于欧洲未来加速器委员会提出的探测器研究合作意向性调研

2023-07-17

2021 年，欧洲未来加速器委员会(ECFA)发布了探测器研发路线图，针对未来加速器实验开展粒子探测器关键技术预研（https://cds.cern.ch/record/2784893）。

2022 年，ECFA 考虑整合现有的探测器研究合作组（譬如 CERN EP R&D, AIDAinnova, RDxy, CALICE, LCTPC 等），重新组织和规划新的探测器研究合作组（DRD – Detector R&D Collaboration）。2023 年全面启动并过渡到新的 DRD 合作组，2024 年起，将正式运行 DRD 合作组，参与单位需签署 MoU。

DRD 合作组旨在打造全球性的面向未来加速器实验及先进粒子探测技术的研究组织。根据探测器预研主题分为八类，如下所示：

- DRD1 – 气体探测器 (Gaseous Detectors)
- DRD2 – 液体探测器 (Liquid Detectors)
- DRD3 – 固态探测器 (Solid State Detectors)
- DRD4 – 粒子鉴别和光子探测器 (PID and Photon Detectors)
- DRD5 – 量子探测器 (Quantum Detectors)
- DRD6 – 量能器 (Calorimetry)
- DRD7 – 电子学 (Electronics)
- DRD8 – 系统集成 (Integration：包括磁铁，冷却，机械结构，MDI，以及环境、辐射及束流监测等系统)

最近，我们收到 ECFA 主席 Karl Jakobs 教授的邀请，希望有更多中国的高校和研究机构积极参与 DRD 合作组，开展相关探测器关键技术的研发及应用，并作出重要的贡献。为了便于国内感兴趣单位的组织协调，我们希望开展意向性调研和收集参与单位的相关信息，包括：

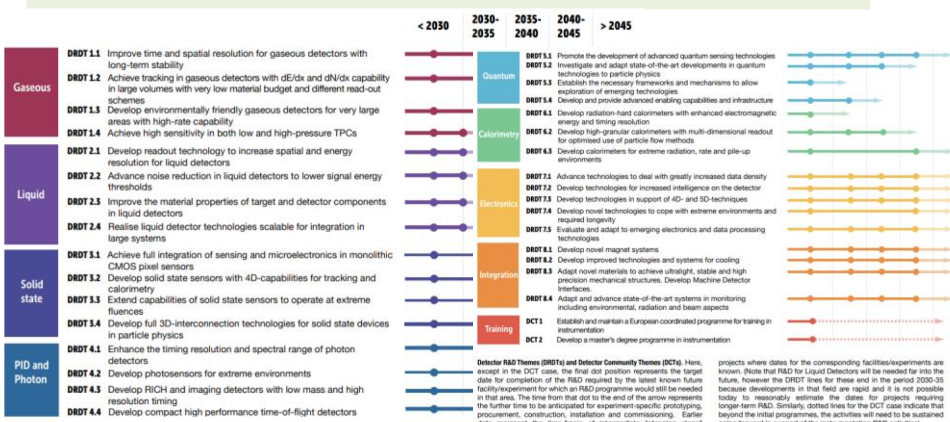
- 单位名称，负责人，联系方式
- 研究课题，研究基础及成果
- 探测器技术的应用（在哪些粒子物理实验？粒子物理之外的实际应用？）
- 已参与的探测器研究合作组
- 拟参与的 DRD 合作组课题
- 预期投入的人力和经费

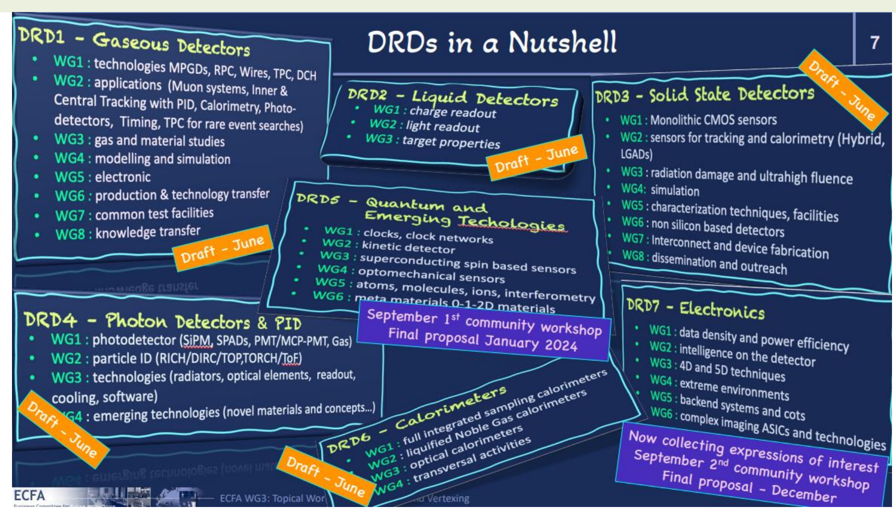
请于 7 月 31 号前把相关信息发给高能物理分会邱雯收集(qiuw@ihep.ac.cn)。

非常感谢大家的积极参与和配合！

联系人：娄辛丑，Joao Guimaraes da Costa，阮曼奇，王建春（高能所）

刘建北（中国科学技术大学），杨海军（上海交通大学）





欧洲高能物理战略 – 探测器研究路线图

中国方面参与 DRD 的整体情况（部分未公布）

	中国方面参与单位（截止：2024.08）	研究单位数量
DRD1 气体探测器	中国科学院高能物理研究所，中国科学院近代物理研究所，吉林大学，南开大学，山东大学，深圳高研院，上海交通大学，清华大学，中国科学技术大学，武汉大学，香港大学，香港中文大学，香港科技大学	13
DRD2 液体探测器	中国科学院高能物理研究所 (Proposal征集中)	1
DRD3 固态探测器	鲁东大学，吉林大学，中国科学院高能物理研究所，中国科学技术大学，大连理工大学	5
DRD4 粒子鉴别/光子探测器	中国科学技术大学，中国科学院高能物理研究所	2
DRD5 量子探测器	中国科学院高能物理研究所 (Proposal 征集初稿)	1
DRD6 量能器	中国科学院硅酸盐研究所，中国科学院高能物理研究所，上海交通大学，中国科学技术大学，李政道研究所	5
DRD7 电子学	中国科学院高能物理研究所 (Proposal征集中)	1
DRD8 系统集成	中国科学院高能物理研究所 (Proposal征集中)	1

国内各单位“牵头人”情况

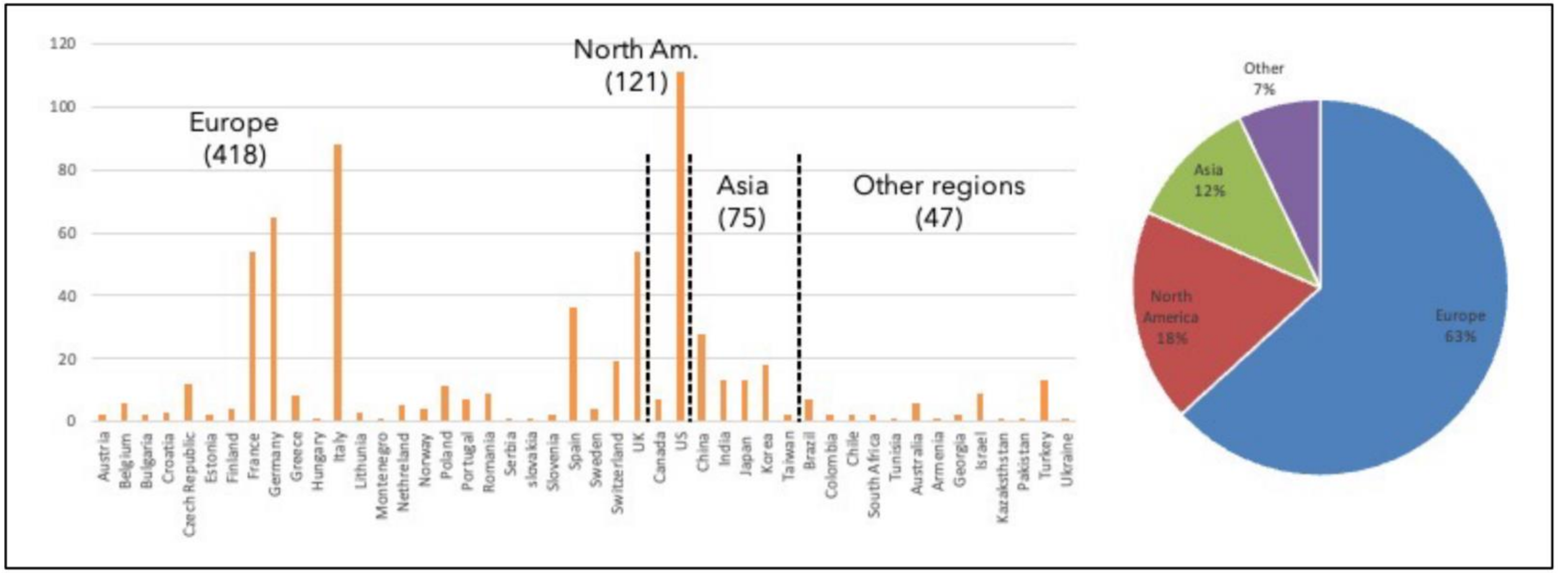
DRD	Institute	CB Rep	DRD	Institute	CB Rep
1	HKU	Yanjun Tu	2	IHEP	Yi Wang
	IHEP	Huirong Qi	3	IHEP	Jianchun Wang
	IMP	Limin Duan		LDU	Zheng Li
	JLU	Weimin Song		USTC	Yanwen Liu
	NKU	Chunxu Yu	4	IHEP	Sen Qian
	SDU	Chengguang Zhu		USTC	Jianbei Liu
	SIAT	Zheng Liu	6	IHEP	Yong Liu
	SJTU	Haijun Yang		SIC	Junfeng Chen
	THU	Zhi Deng		SJTU	Haijun Yang
	USTC	Jianbei Liu		TDLI	Shu Li
	WHU	Zhenyu Zhang		USTC	Jianbei Liu

Source: H.R.Qi

中国同事积极参加
持续的经费支持需要在国家层面落实
国内相应的学术和规划应该有组织地进行
……

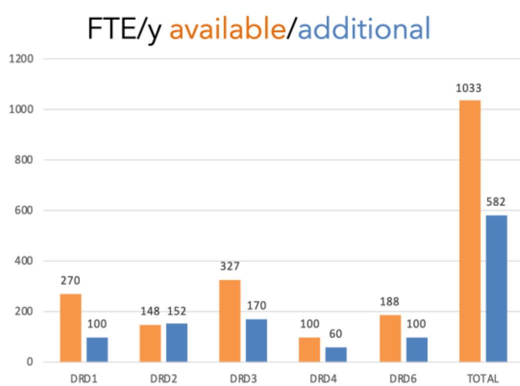
欧洲高能物理战略 – 探测器研究路线图：人力和经费

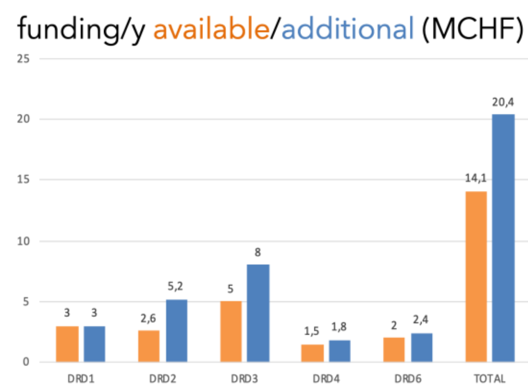
proposals received vs. country-region



FTE- funding in proposals received vs. DRD collaboration

expected FTE/y & funding/y
≃ average over 3 first years
available ≃ current situation
additional ≃ expected to fulfil progr.
break-down of FTE exists
Physicists/PhD/Technical Staff





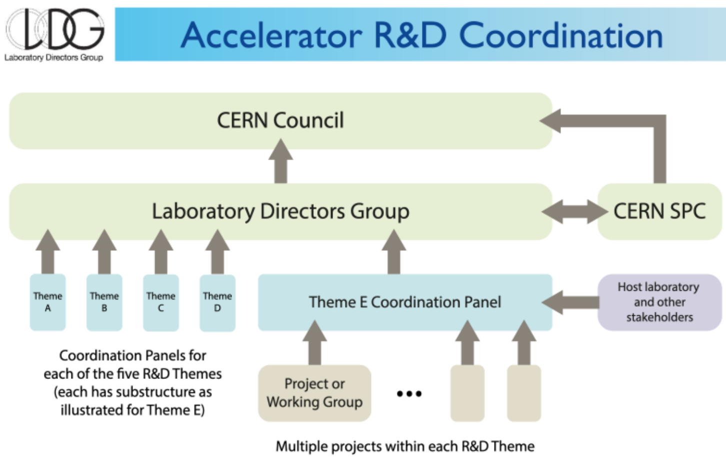
美国高能物理战略 – 探测器研究路线图

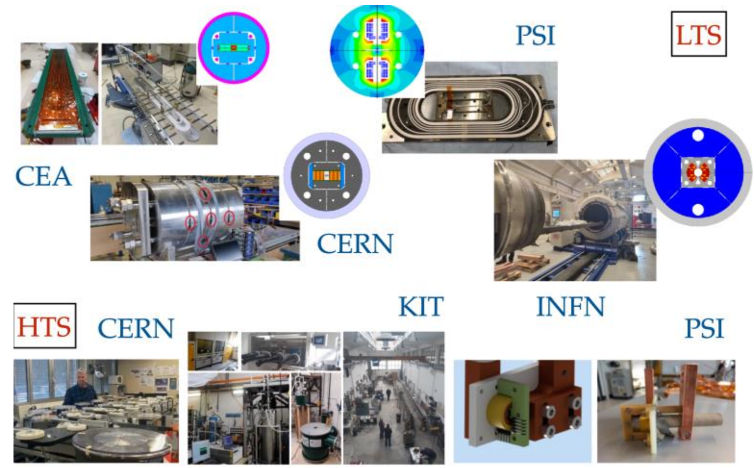
- Result from US Snowmass process: recommendation to create Detector R&D collaborations in the US
  - ✦ Organized by CPAD (Coordinating Panel for Advanced Detectors) of the APS/DPF
  - ✦ They created 11 RDCs (R&D Collaborations) and appointed coordinators (see https://cpad-dpf.org/?page_id=1549)
  - ✦ Recently started to reach out to the community and work on detailed planning at CPAD workshop 7-10 Nov 2023
- DRD collaborations are open for US participation
  - ✦ No concurrency, but synergy
  - ✦ Overlap to DRDs through people/groups involved in both and liaisons

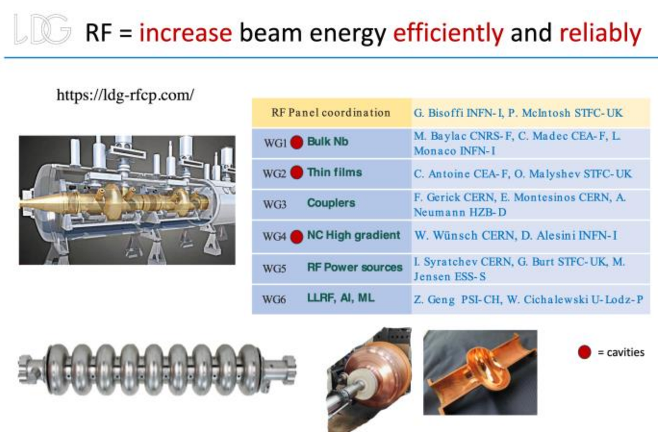
RDC#	TOPIC
1	Noble Element Detectors
2	Photodetectors
3	Solid State Tracking
4	Readout and ASICs
5	Trigger and DAQ
6	Gaseous Detectors
7	Low-Background Detectors
8	Quantum and Superconducting Sensors
9	Calorimetry
10	Detector Mechanics
11	Fast Timing

Organized & dedicated R&D

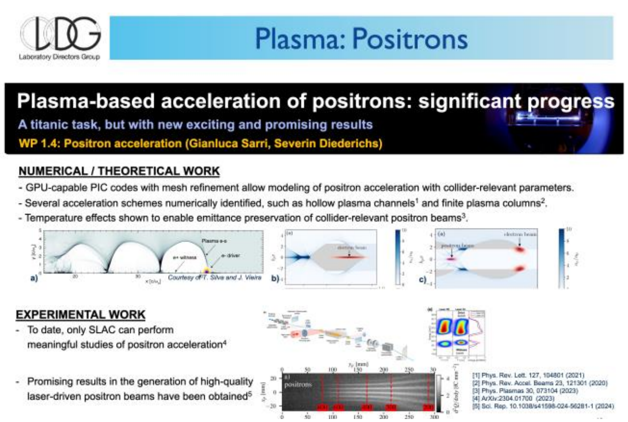
European national labs pursue R&D for future and for sustainability







RF Panel coordination	G. Bisoffi INFN-I, P. McIntosh STFC-UK
WG1 Bulk Nb	M. Baylac CNRS-F, C. Madec CEA-F, L. Monaco INFN-I
WG2 Thin films	C. Antoine CEA-F, O. Malyshev STFC-UK
WG3 Couplers	F. Gerick CERN, E. Montesinos CERN, A. Neumann HZB-D
WG4 NC High gradient	W. Wünsch CERN, D. Alesini INFN-I
WG5 RF Power sources	I. Syratchev CERN, G. Burt STFC-UK, M. Jensen ESS-S
WG6 LLRF, AI, ML	Z. Geng PSI-CH, W. Cichalewski U-Lodz-P



ERL

Sustainability WG

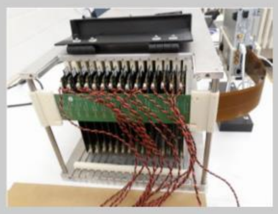
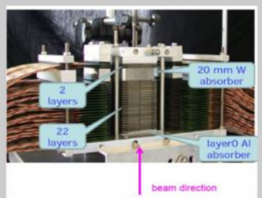
Muons

Plasma: AWAKE

Organized & dedicated R&D

Highlight of innovative ideas and R&D reported recently

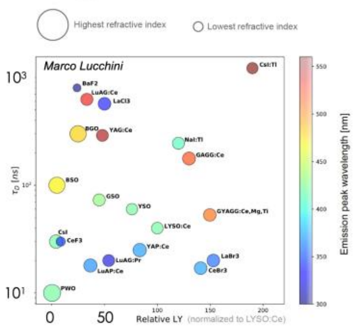
imaging calorimeters

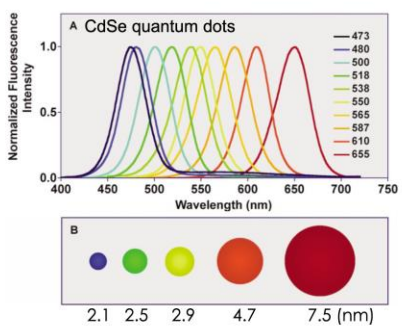
Si-W ECAL	(ALICE FoCAL)	Scint-W ECAL	AHCAL	SDHCAL
				
0,5×0,5 cm² ×15 (→30) Si layers + W	0,003×0,003 cm² × 24 MIMOSA layers + W	0,5×4,5 cm² ×30 Scint+SiPM lay. + SS	3×3 cm² × 38 Scint+SiPM lay. + SS	1×1 cm² × 48 layers GRPC + SS

From V. Boudry, Calor 2024

Crystal Calorimetry

- Traditionally, crystal – fully absorbing – calorimetry has obtained the best energy resolution

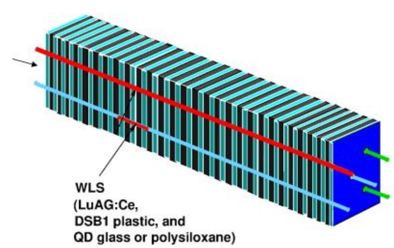


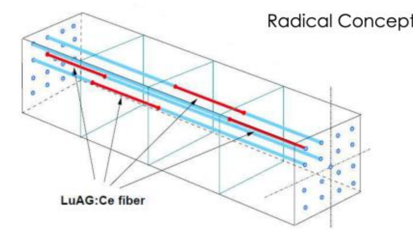


A. Smith, https://doi.org/10.1039/B40498N

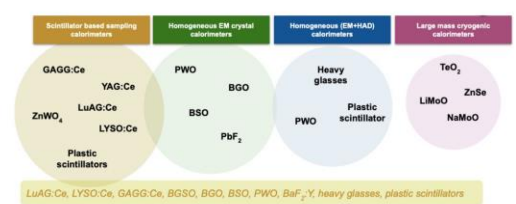
- Huge range of possibilities through **quantum engineering** of materials

5D Calorimetry





- Energy Measurement:
  - WLS fiber extends over full length of module
- Timing Measurement:
  - WLS are positioned at strategic locations, such as shower maximum



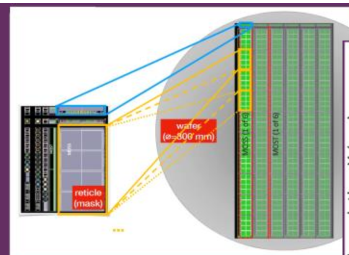
Large parameter space + matching of fiber materials

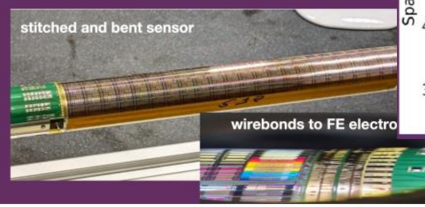
Organized & dedicated R&D

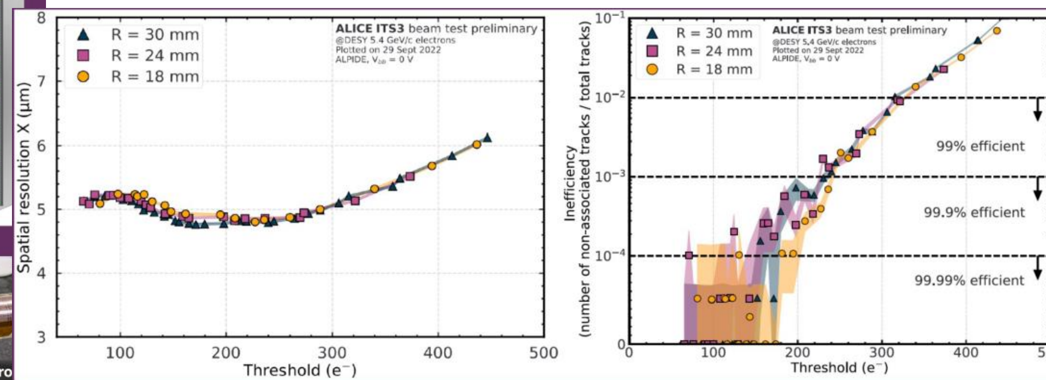
Highlight of innovative ideas and R&D reported recently

Sensor Stitching

- Chip size is traditionally limited by CMOS manufacturing (“reticle size”)
  - typical size of few cm^2
  - modules are tiled with chips connected to a flexible printed circuit board
- New developments: stitching
  - aligned exposures of a reticle to produce larger circuits
    - actively used in industry
    - a 300mm wafer can house a chip to equip a full half-layer
    - requires dedicated chip design
- Final circuit is concatenation of different parts of the mask





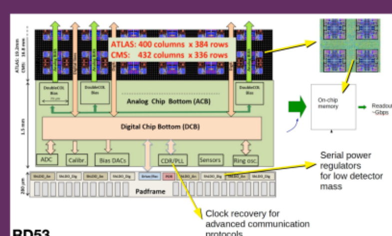


More Intelligent Detectors

Pack more and more functionality onto chip

- communication, power distribution, monitoring
- optical and wireless
- FPGA and AI/ML functions now straightforward to include
- Big challenge: SEU tolerance, power consumption

→ Next-gen ASICs will be developed in 28nm technology



→ more complex systems have increased need for on-chip data storage

Use Machine Learning on ASIC for physics motivated data reduction on detector

- filter on e.g. incidence angle, pt, hit position, uncertainty, time information, etc.

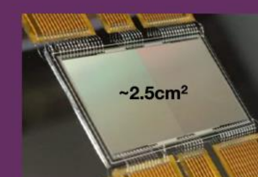
Synergies with Neutrino and DM Detectors and Medical Imaging

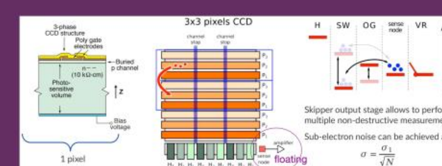
Detecting sub-GeV Particle-like DM

Low threshold technologies to explore the dark sector:

- Very promising: Skipper-CCDs
- Extremely low noise → single electron/photon counting
- Downside: slow readout

  → R&D to speed up, e.g. regional r/o, energy-dependent r/o, double-sided r/o, background suppression through masking or freezing





design by S.Holland, LBNL

高能物理国际势态

Observation & remarks

Observation & remarks

- Europe, Japan have plans for future energy frontier accelerators; US may come up with a muon collider program; they all aim high and have a dream
- Strong & well organized R&D in Europe & US, positioning HEP for future; plenty opportunities for collaboration; we should be active and creative part of this
- Accelerator + detector system designs train top ST team; we ought to be connected
- There are competition/collaboration; we should manage the relationship properly
- Chinese physicists' prominent presence at major international conferences limited; encourage young Chinese scientists to be proactive, creative and leading …
- Real challenges with travel-visa, full fledge participation in projects-planning, sustainability; find ways to improve, stable funding, …
- Internationally there are very many top ST scientists and technical professionals; we need to produce more top of world scientists; cultivate young people now.

高能物理国际势态

Discussion

Discussion

- China's participation in CERN's DRD projects
- Keep China's HEP an exemplary field for international cooperation in ST
- New initiatives and projects to place China on the map
- CERN associate membership – is the door still open?
- EPPSU 2024-6 – participation and contribution
- Green-sustainability of experiments is trends– what should we do?
- Early career and opportunities to grow for young scientists
- …

Special Acknowledgement:

Michael Benedikt, Frank Zimmermann

Abid Patwa

Karl Jacobs, Ines Gil Botella, Marcel Demarteau

Tsuyoshi NAKAYA

Additional Slides

Post P5, motivating accelerator R&D

P5 report

Enabling the machines of the future

"Incorporate innovative concepts like cryogenic **cool copper** in the normal conducting RF program"

Area Recommendation 8: Future test facilities could include the **second stage cool copper** test for high gradient RF technology

Accelerator technologies play a key role in **sustainability**

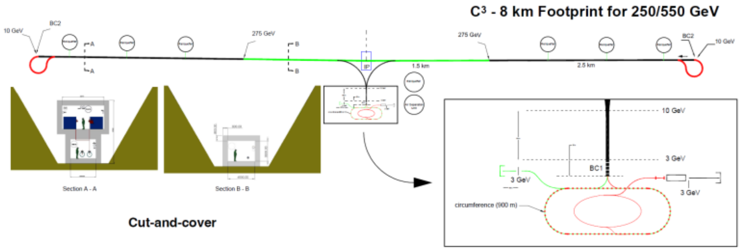
"Accelerator structure improvements can also play an important role, including higher quality factor, and concepts like **cool copper**."

Area Recommendation 20: HEPAP, potentially in collaboration with international partners, should conduct a dedicated study aiming at developing a sustainability strategy for particle physics.

C³ Accelerator Complex

8 km footprint for 250/550 GeV CoM ⟹ 70/120 MeV/m
- 7 km footprint at 155 MeV/m for 550 GeV CoM

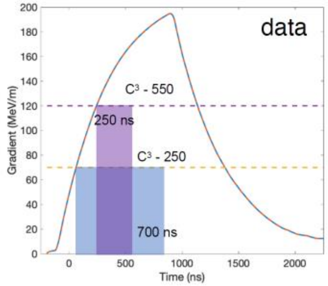
Large portions of accelerator complex compatible between LC technologies
- Beam delivery / IP modified from ILC (1.5 km for 550 GeV CoM)
- Damping rings and injectors to be optimized with CLIC as baseline

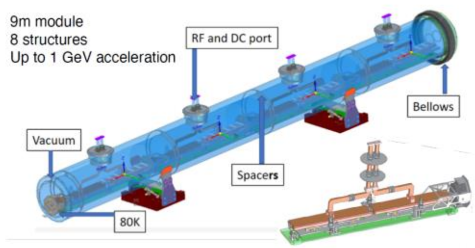


C³ Cool Copper Collider

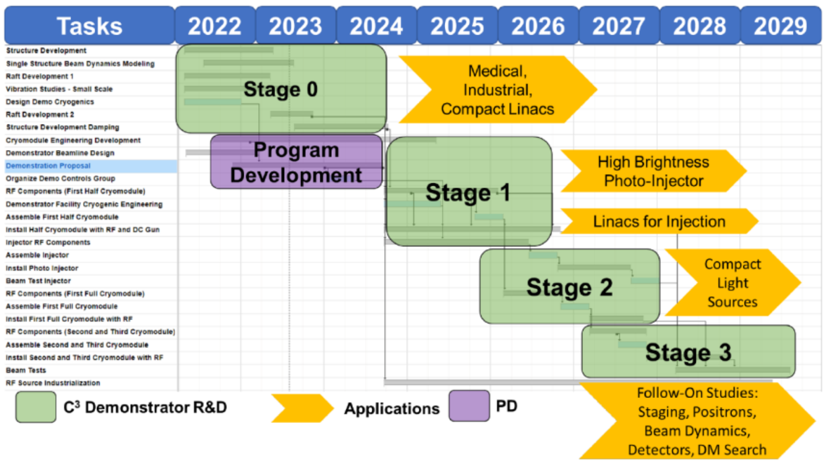
arXiv:2110.15800
Bulletin of the American Physical Society (2024)

- Planning for operations at high gradient **at 550 GeV, 120 MeV/m**
  - **Start at 70 MeV/m for C³-250**
- Beam parameters optimized to record the same ILC luminosity within the same time frame and match physics goals





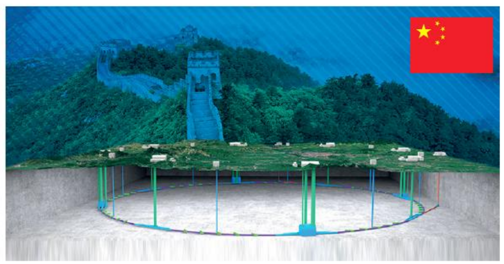
C³ Demonstration R&D Plan Timeline *



Higgs Factories

P5 report

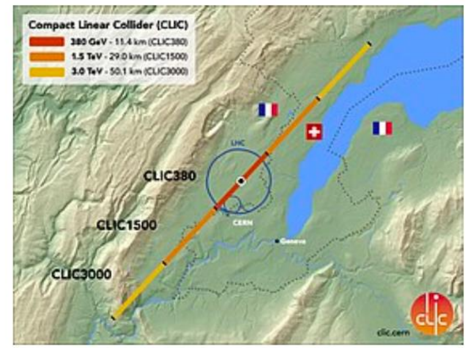
250/500 GeV

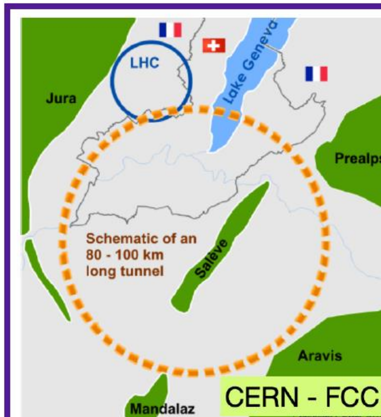


CEPC 240 GeV

250/550/… GeV

CLIC 380/1500/3000 GeV





FCC-ee

90/240/365 GeV

欧洲高能物理战略 – 探测器研究路线图

Gaseous	DRDT 1.1	Improve time and spatial resolution for gaseous detectors with long-term stability
	DRDT 1.2	Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes
	DRDT 1.3	Develop environmentally friendly gaseous detectors for very large areas with high-rate capability
	DRDT 1.4	Achieve high sensitivity in both low and high-pressure TPCs
Liquid	DRDT 2.1	Develop readout technology to increase spatial and energy resolution for liquid detectors
	DRDT 2.2	Advance noise reduction in liquid detectors to lower signal energy thresholds
	DRDT 2.3	Improve the material properties of target and detector components in liquid detectors
	DRDT 2.4	Realise liquid detector technologies scalable for integration in large systems
Solid state	DRDT 3.1	Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
	DRDT 3.2	Develop solid state sensors with 4D-capabilities for tracking and calorimetry
	DRDT 3.3	Extend capabilities of solid state sensors to operate at extreme fluences
	DRDT 3.4	Develop full 3D-interconnection technologies for solid state devices in particle physics
PID and Photon	DRDT 4.1	Enhance the timing resolution and spectral range of photon detectors
	DRDT 4.2	Develop photosensors for extreme environments
	DRDT 4.3	Develop RICH and imaging detectors with low mass and high resolution timing
	DRDT 4.4	Develop compact high performance time-of-flight detectors
Quantum	DRDT 5.1	Promote the development of advanced quantum sensing technologies
	DRDT 5.2	Investigate and adapt state-of-the-art developments in quantum technologies to particle physics
	DRDT 5.3	Establish the necessary frameworks and mechanisms to allow exploration of emerging technologies
	DRDT 5.4	Develop and provide advanced enabling capabilities and infrastructure

- The most urgent R&D topics in each Task Force area are identified as **D**etector **R&D** **T**hemes.
- The **timeframe** illustration for requirements in each **DRDT** area, in both the brochure and the main document, are based on the more detailed information and charts in the individual chapters.

Calorimetry	DRDT 6.1	Develop radiation-hard calorimeters with enhanced electromagnetic energy and timing resolution
	DRDT 6.2	Develop high-granular calorimeters with multi-dimensional readout for optimised use of particle flow methods
	DRDT 6.3	Develop calorimeters for extreme radiation, rate and pile-up environments
Electronics	DRDT 7.1	Advance technologies to deal with greatly increased data density
	DRDT 7.2	Develop technologies for increased intelligence on the detector
	DRDT 7.3	Develop technologies in support of 4D- and 5D-techniques
	DRDT 7.4	Develop novel technologies to cope with extreme environments and required longevity
	DRDT 7.5	Evaluate and adapt to emerging electronics and data processing technologies
Integration	DRDT 8.1	Develop novel magnet systems
	DRDT 8.2	Develop improved technologies and systems for cooling
	DRDT 8.3	Adapt novel materials to achieve ultralight, stable and high precision mechanical structures. Develop Machine Detector Interfaces.
	DRDT 8.4	Adapt and advance state-of-the-art systems in monitoring including environmental, radiation and beam aspects
Training	DCT 1	Establish and maintain a European coordinated programme for training in instrumentation
	DCT 2	Develop a master's degree programme in instrumentation

https://cds.cern.ch/record/2799303

backup

DRD EDP panel, Strategy; Summary

Committee Members

ECFA Detector Panel (EDP):

- Co-chairs: ***Phil Allport*** *(Birmingham),* ***Didier Contardo*** *(Lyon), Felix Sefkow*
- Scientific secretary: *Doris Eckstein (DESY)*
- Gaseous Detectors: *Silvia Dalla Torre (Torino)*
- Liquid Detectors: ***Inés Gil Botella*** *(CIEMAT)*
- Solid State Detectors: *Doris Eckstein, Phil Allport*
- PID & Photon Detectors: ***Roger Forty*** *(CERN)*
- Quantum and emerging Technologies: *Steven Hoekstra (Groningen)*
- Calorimetry: ***Laurent Serin*** *(IJCLab)*
- Electronics: *Valerio Re (Bergamo)*
- Ex Officio: *ECFA Chair (Paris Sphicas), ICFA Detector Panel (Ian Shipsey), DRDC chair (**Thomas Bergauer**), APPEC & NuPECC observers*

Detector R&D Committee (DRDC):

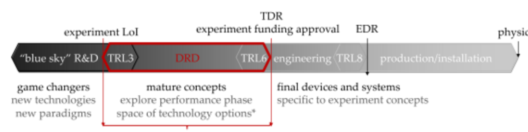
- ***Thomas Bergauer*** (HEPHY Vienna), Chairperson
- *Jan Troska* (CERN), scientific secretary
- *Stan Bentvelsen* (NIKHEF; LDG contact)
- *Shikma Bressler* (Weizmann)
- *Dimitry Budker* (Mainz)
- ***Roger Forty*** (CERN; RB contact)
- *Claudia Gemme* (INFN and U. Genoa)
- ***Inés Gil Botella*** (CIEMAT)
- *Petra Merkel* (Fermilab; US contact)
- *Mark Pesaresi* (Imperial College)
- ***Laurent Serin*** (IJCLab)
- Ex-officio: **P. Allport, D. Contardo** (EDP)

Names in bold in both committees

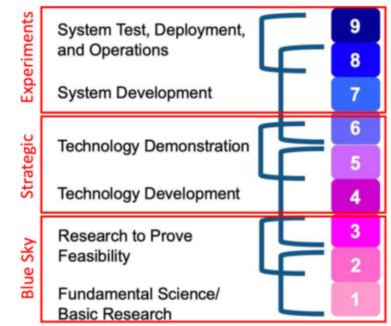
Strategic R&D

Strategic R&D bridges the gap between the idea ("**blue sky research**", TRL 1-3) and the **deployment and use in a HEP experiment** (TRL 8-9)

- Detector R&D Collaboration should address TRLs from 3 to 7, before experiment-specific engineering takes over
- Covers the development and maturing of technologies, e.g.
  - ✦ Iterating different options
  - ✦ Improving radiation hardness
  - ✦ Scaling up detector area, number of layers,..
- Backed up by **strategic funding**, agreed with funding agencies



Technology Readiness Levels (TRLs) 1-9:
Method for estimating the maturity of technologies



Didier Contardo

Summary

- New CERN-hosted Detector R&D (DRD) collaborations are currently being set up following ECFA Detector roadmap to pave the way for the next decades and address the future instrumentation needs.
  - ✦ First DRD collaborations already starting up, and the others following soon.
- **Next steps** of the collaborations: completing organization structure, electing and endorsing convenors, re-defining deliverables, MoU writing, getting financial commitments from funding agencies, and start working together
- DRDC will review the progress of DRDs
  - ✦ DRDC 13-14 Nov 2024: DRD1, 2, 4 & 6 status reports after one year
  - ✦ DRDC 24-25 Feb 2025: DRD3, 5 & 7 status reports