ECFA HEP activities en route to the ESPP update

European Committee for Future Accelerators

Paris Sphicas
CERN & NKUA
EURO-LABS 3rd Annual Meeting
CERN, October 28, 2024

- **Update of the European Strategy for Particle Physics (ESPP)**
  - **Secretariat, EDG, PPG and working groups**
- **HET factory Study**
  - **Quick summary from ECFA HET Workshop (Paris, Oct 2024)**
- **ECFA Detector Panel and DRDs**
  - **New roles, update on MoUs…**
- **Onwards, and from here, where to?**

ESPP: organization, bodies and charges

European Strategy for Particle Physics

Continuous community-driven process

- **First ESPP in 2006** http://europeanstrategy.cern
- **2013 update: HL-LHC decision**
- **2020 update: post-HL-LHC recommendations:**
  - ***An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton- proton collider at the highest achievable energy.***
  - ***Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron 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. [... The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels..***
  - **Successful completion of High-Luminosity LHC must remain key focus**
- **2026 update: just commenced; more on this, later in this talk**

http://dx.doi.org/10.17181/CERN.JSC6.W89E

ESPP (I): launch of next (current) update

- **In March 2024 CERN Council launched the new ESPP process:**
  - **Timeline:**

ESPP (II): Secretariat, EDG, PPG and working groups

- **"Secretariat":**
  - Secretary (chair): K. Jakobs
  - CERN SPC chair: H. Montgomery
  - ECFA chair: PS
  - LDG chair: D. Newbold
    - M. Seidel from 1/1/2025
- **European Strategy Group (ESG):**
  - Secretariat (secretary chairs ESG);
  - One rep per CERN member state;
  - One rep per lab in LDG;
  - CERN DG, CERN DG-elect;
  - Invitees: PPG, President of Council, 1 rep from each Associate Member State and Observer State, 1 rep from EC; chairs of ApPEC, NuPECC, ESFRI
- **Physics Preparatory Group (PPG):**
  - Secretariat (secretary chairs ESG);
  - 4 people nominated by SPC
  - 4 people nominated by ECFA
  - 2 people nominated by Americas
  - 2 people nominated by Asia
  - 1 person nominated by CERN

- **Nine Working Groups (WGs):**
  - Last time's Computing and Instrumentation split (8 WGs of 2020 ESPP→ 9 WGs):
    - Computing WG and
    - Instrumentation WG
- **Increase engagement by HEP community:**
  - Each WG: only one co-convener from PPG
  - Second co-convener from SPC/ECFA lists
  - So: Ex-officio members (ECFA, SPC and LDG Chairs) and representatives from the Americas and Asia are not co-conveners.
- **Role of representatives from Asia and the Americas, and ex-officio members and Chair: maintain coherence of overall effort.**
- **Engage the generation most concerned: Each WG must appoint a scientific secretary who is an Early Career Researcher:**
  - A scientist without an indefinite position and within 10 years from PhD.
  - To be selected by conveners, using nominees collected by ECFA and their own knowledge of the people in the thematic area.

ESPP (II): Working Groups and Conveners

- **Charge to WG conveners:**
  - Selection of Early Career Scientists
  - Definition of sub-topics and appointment of additional WG members
  - Definition of Benchmark processes
  - Organisation of WG meetings
  - Writing the Physics Briefing Book (will be supported by Roger Forty, who has agreed to be Scientific Secretary of the Strategy update)
- **Instrumentation WG:**
  - The "portal" to all that we want the next ESPP to contain
  - Co-convened by Thomas Bergauer and Ulrich Husemann
  - Things to consider: areas of concentration; suggestions for key participants (to Thomas & Ulrich)
  - It would be very useful to have active involvement and contributions by the wide instrum community in this group

Working group	Co-convener	Co-convener
	PPG member	
Electroweak physics	Monica Dunford (DE, exp)	Jorge de Blas (ES, theory)
Strong interaction	Cristinel Diaconu (FR, exp)	Andrea Dainese (IT, exp, HI)
Flavour physics	Gino Isidori (CH, theory)	Marie-Hélène Schune (FR, exp)
BSM physics	Fabio Maltoni (BE/IT, theory)	Rebecca Gonzales-Suarez (SE, exp)
Neutrino physics and cosmic messengers	Pilar Hernandez (ES, theory)	Sara Bolognesi (FR, exp)
Dark matter and dark sector	Jocelyn Monroe (UK, exp)	Matthew McCollough (CERN, theory)
Accelerator science and technology	Gianluigi Arduini (CERN, acc)	Phil Burrows (UK, exp, acc)
Detector instrumentation	Thomas Bergauer (AT, exp)	Ulrich Husemann (DE, exp)
Computing	Tommaso Boccali (IT, exp, comp)	Borut Kersevan (SL, exp, comp)

10 European countries and CERN represented
12 men, 6 women; 13 experiment, 5 theory

ESPP (IV): responsibilities of PPG/WG and ESG

PPG:
Physics + Technology working groups

- Electroweak physics (including Higgs physics)
- Strong interaction
- Flavour physics
- Beyond the Standard Model physics
- Neutrino physics and cosmic messengers
- Dark matter and dark sector
- Accelerator science and technology
- Detector instrumentation
- Computing

à Physics Briefing Book

ESG: Overarching topics

- **National input / roadmaps (à strategic)**
- **Projects (FCC, LC, LE-FCC-hh, MC, ..)**
  (timeline, costs, …. (physics à PPG))
- Comparisons across proposed projects
- Relations with other fields of physics
- Implementation of the Strategy
  (role of CERN and National Labs, coordination of European participation in projects sited outside Europe, …)
- Knowledge and Technology transfer
- Sustainability, environmental impact
- Public engagement, education, communication
- …

ESPP: Some lessons learned from 2020 update

- **Last ESPP: there was a round of receiving "national inputs"**
  - Responses varied widely: For small(er) countries, feedback was ~uniform and easy to interpret; For large(r) countries, feedback was non-uniform, often favoring multiple priorities (e.g. type of next collider)
  - Lesson learned: while it will always be difficult to summarize the "position" of an entire country, at least we can aim at uniform responses and targeted questions.

- **Plan for this round: ECFA to facilitate widest possible discussion(s);**
  - Engage maximum number of colleagues, especially ECRs
  - Guide the formation of the "national inputs" to better inform the ESPP process.
    - National inputs can be collected individually by each single country or a group of countries/region.
    - Formulated set of questions and issues for discussion by national communities
      - Clearly, not an exclusive list, countries/groups could/should add their own issues/concerns/wishes etc

Link to ECFA guidelines

ECFA guidelines for National HEP community inputs

- **ESG remit:**
  - **“The Strategy update should include the preferred option for the next collider at CERN and prioritised alternative options to be pursued if the chosen preferred plan turns out not to be feasible or competitive”.**

- **Remit to ESG also specifies:**
  - **“The Strategy update should also indicate areas of priority for exploration complementary to colliders and for other experiments to be considered at CERN and at other laboratories in Europe, as well as for participation in projects outside Europe.”**

Questions to address

a) Which is the preferred next major/flagship collider project for CERN?

b) What are the most important elements in the response to (a)?

- i) Physics potential
- ii) Long-term perspective
- iii) Financial and human resources: requirements and effect on other projects
- iv) Timing
- v) Careers and training
- vi) Sustainability

c) Should CERN/Europe proceed with the preferred option set out in (a) or should alternative options be considered:

- i) if Japan proceeds with the ILC in a timely way?
- ii) if China proceeds with the CEPC on the announced timescale?
- iii) if the US proceeds with a muon collider?
- iv) if there are major new (unexpected) results from the HL-LHC or other HEP experiments?

d) Beyond preferred option, what other accelerator R&D topics (e.g. high-field magnets, RF technology, alternative accelerators/colliders) should be pursued in parallel?

e) What is the prioritised list of alternative options if the preferred option is not feasible (due to cost, timing, international developments, or for other reasons)?

f) What are the most important elements in the response to (e)?

Prioritisation for non-collider projects:

- a) What other areas of physics should be pursued, and with what relative priority?
- b) What are the most important elements in the response to (a)?
- c) To what extent should CERN participate in nuclear physics, astroparticle physics or other areas of science, while keeping in mind and adhering to the CERN Convention? Please use the current level and form of activity as the baseline for comparisons.

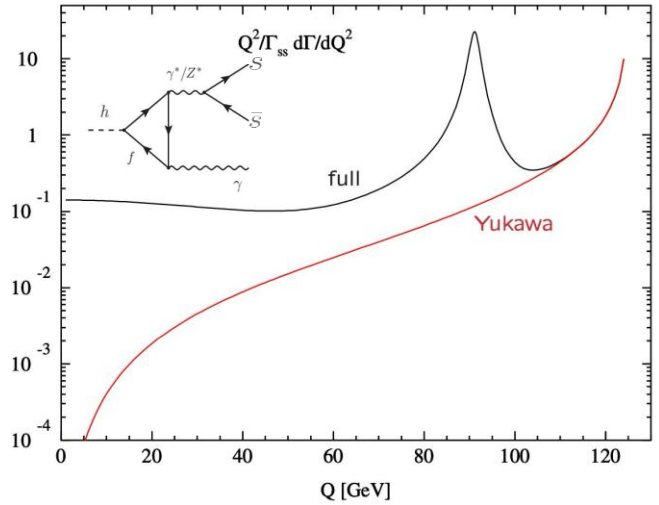
National HEP community inputs: ECFA guidelines

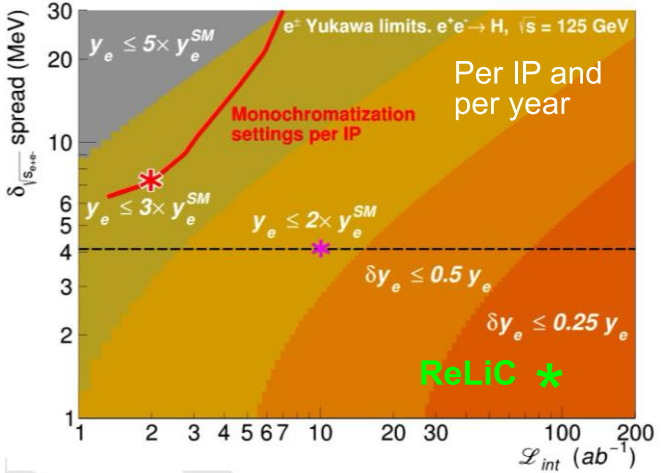
ECFA HET Factory 2024

- **Third and last in HET Factory workshops**
  - First ECFA Workshop on e+e- HET Factories: 2022 @ DESY (GE).
  - Second ECFA Workshop on HET Factories: 2023 @ Paestum (IT).
  - Third (and last) ECFA Workshop on e+e- HET Factories: 2024 @ Paris (FR).
- **Full review of the three working groups:**
  - **WG 1, Physics Potential:** Jorge de Blas (Univ. Granada), Patrick Koppenburg (Nikhef), Jenny List (DESY), Fabio Maltoni (UC Louvain/ Bologna).
  - **WG 2, Physics Analysis Methods:** Patrizia Azzi (INFN-Padova / CERN), Fulvio Piccinini (INFN Pavia), Dirk Zerwas (IJCLab/DMLab).
  - **WG 3: Detector R&D (WG3 web page):** Mary Cruz Fouz (CIEMAT Madrid), Giovanni Marchiori (APC Paris), Felix Sefkow (DESY).

WG1 example (I): Higgs-EWK-Top group

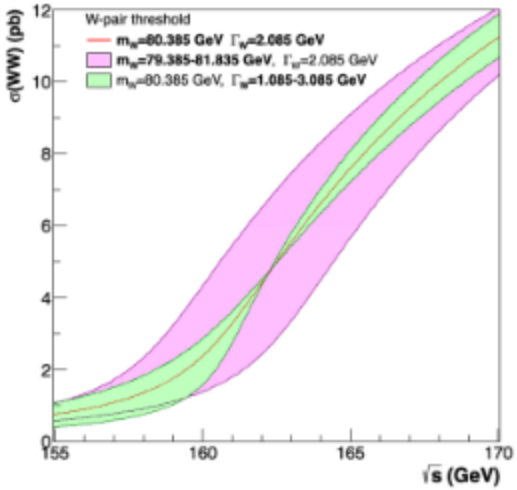
- **ZH production and angular studies**
  - Can probe CP-odd in ZH
    - Polarization in LC an advantage; though CC close
- **ZZH anomalous couplings**
- **H → $s\bar{s}$ (BR: 0.024%...)**
  - Strange-Yukawa interpretation of BR(H→$s\bar{s}$)
  - Measurements at 240 and 365 GeV
  - Strong and weak Dalitz decays seem to not be a major problem on the determination of the strange Yukawa coupling
- **Higgs mass**
  - FCC-ee: Want to get $\Delta M_H \sim \Gamma_H = 4$MeV for ee→H
  - 240 GeV, ~11ab^{-1}.
- **Can one get the electron Yukawa coupling?**
  - Energy precision (very important)

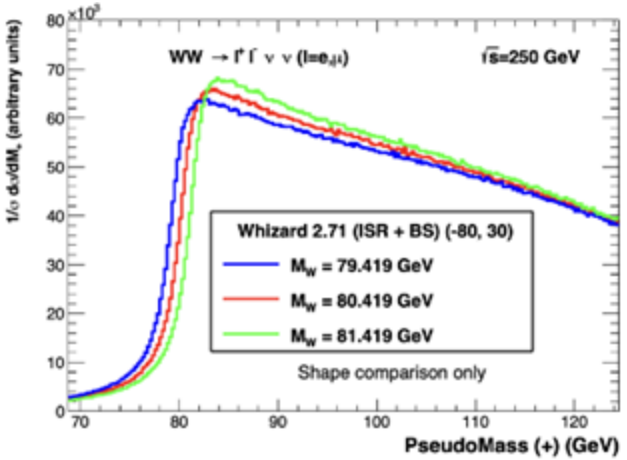




WG1 example (II) Precision focus group

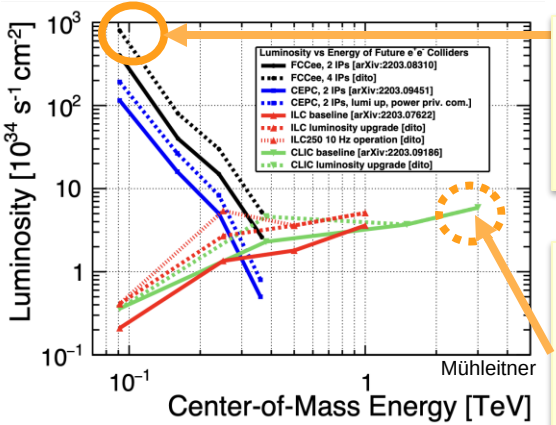
- **LUMInosity**
  - Need: 10^{-4} absolute, 10^{-5} point-to-point
  - Small-angle Bhabha Scattering; Diphotons
  - PLUG-Cal: Precision Luminosity Ultra-Granular Calo
- **Wmass**
  - Cross-section (CC: Δm_W=0.3-0.4 MeV, $\Delta\Gamma_W$=1 MeV)
    - Challenges: Theory and systematics
  - Decay kinematics (ok for LC; Δm_W=2 MeV)
    - Challenges: systematics (E calibration)
- **BCfrag/GSplit**
  - b/c-Fragmentation: Insufficient knowledge of fragmentation/hadronization of heavy quarks → significant uncertainties (A_{FB}(b/c), Higgs BFs, …)
  - Gluon splitting: g→bb/cc introduces additional complication for heavy-flavor tagging
    - Re-studying LEP data with modern tools
    - Theory/modeling work in context of LHC studies
- **Two-fermion production**
  - Understand ee → ff on- and off-Z pole for precision tests of SM/BSM
    - Theory, ML methods, taus…





HET Factory study: example from WG3 (detectors)

Detectors at a HET factory

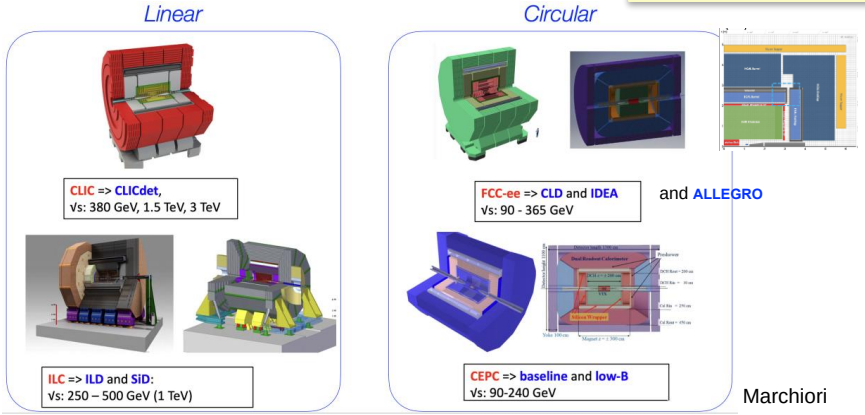


Tera-Z@FCCee: most extreme challenges still to be tackled

CLICdet @ high E extensively studied 2010-2020: 0.5 ns pile-up of hadronic γγ background manageable

FCC-ee parameters		Z	W+W-	ZH	ttbar
√s	GeV	91.2	160	240	350-365
Luminosity/IP	10^{34} cm^{-2}s^{-1}	143	20	7.5	1.38
Bunch spacing	ns	25	160	680	5000
"Physics" cross section	pb	35,000	10	0.2	0.5
Total cross section	pb	70,000	30	10	8
Event rate	Hz	100,000	6	0.5	0.1
"Pile up" parameter [ ]		10^{-6}	2,500	1	1	1

Z peak	√s ~ 88, 91, 94 GeV	4 yrs	~200 ab^{-1}	6.10^{12} $e^+e^- \rightarrow Z$
WW threshold	√s ~ 157.5, 162.5 GeV	2 yrs	~10 ab^{-1}	10^8 $e^+e^- \rightarrow WW$
ZH maximum	√s ~ 240 GeV	3 yrs	~10 ab^{-1}	2.10^6 $e^+e^- \rightarrow ZH$
[s-channel H option	*√s ~ 125 GeV*	*5? yrs*		*~5000 $e^+e^- \rightarrow H$*
Top threshold	√s ~ 345 – 365 GeV	5 yrs	~3 ab^{-1}	2.10^6 $e^+e^- \rightarrow t\bar{t}$



x 10-50 improvements on all EW observables.
up to x 10 improvement on Higgs coupling (model-independent) 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 in mass range 5-100 GeV.
Up to 4 interaction points: robustness, statistics, possibility of specialised detectors.

Rich, excellent physics program → challenging detectors

F. Sefkow (ECFA HET Wkshp 2024)

Higgs Factory Program
- 2M ZH events at $\sqrt{s}$=240 GeV
- 75k WW→H events at $\sqrt{s}$=365 GeV
- Higgs Couplings
- Higgs self-couplings (2-4σ) via loop diagrams
- Unique: $e^+e^- \rightarrow H$ at $\sqrt{s}$ = 125 GeV

→
- **Momentum Resolution $\sigma(p_T)/p_T \simeq 10^{-3}$ @ $p_T \sim$ 50 GeV**
- **Jet σ(E)/E ≈ 3-4% in multi-jets for Z/W separation**
- **Impact parameter resolution for b, c tagging**

Precision EW and QCD Program
- 6 x 10^{12} Z and 10^8 WW events
- m_Z, Γ_Z, Γ_{inv}, $\sin^2\theta_W$, m_W, Γ_W, …
- 2 x 10^6 tt events
- m_{top}, Γ_{top}, EW couplings
- Indirect sensitivity to new physics

→
- **Absolute normalisation of luminosity to 10^{-4}**
- **Relative normalisation to 10^{-5} (eg Γ_{had}/Γ_l)**
- **σ(p)/p limited by multiple scattering → minimise material.**
- **Track angular resolution < 0.1 mrad**
- **Stability of B-field to 10^{-6}.**

Heavy Flavor Program
- 10^{12} bb, cc; 1.7 x 10^{11} ττ (all clean): 10x Belle
- CKM matrix, CP measurements,
- rare decays, CLFV searches, lepton universality

→
- **Superior impact parameter resolution**
- **Precisely identify secondary vertices and measure lifetimes**
- **ECAL resolution at few %/$\sqrt{E}$**
- **Excellent π^0/γ separation for tau identification**
- **PID: K/π separation over wide p range → e.g. timing, …**

Feebly coupled particles Beyond SM
- Opportunity to directly observe new feebly interacting particles with masses below m_Z
- Axion-like particles, dark photons, Heavy neutral leptons
- Long-lifetime LLPs

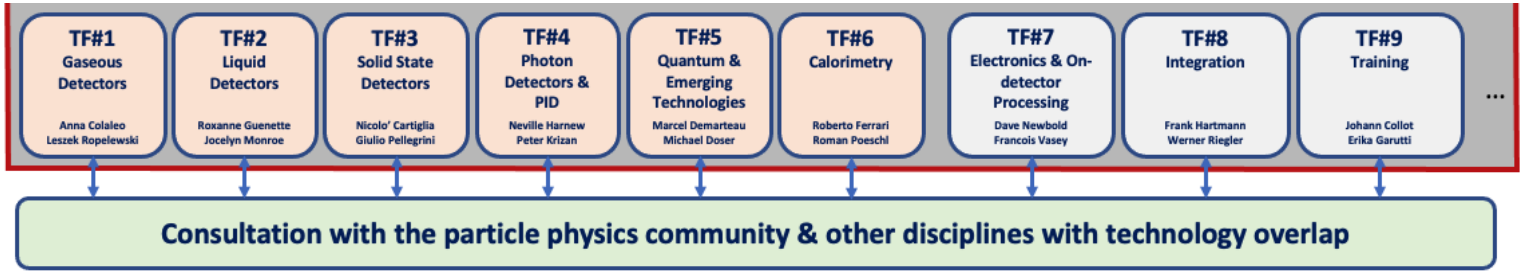
→
- **Sensitivity to (significantly) detached vertices**
- **Tracking: more layers, "continuous" tracking**
- **Calorimeter: granularity, tracking capability**
- **Large decay length → extended decay volume**
- **Precise timing**
- **Hermeticity**

ECFA Detector Panel
& DRD Collaborations

ECFA Detector R&D Roadmap & Implementation plan

2021: ECFA released full roadmap (200 pages) and synopsis (~10 pages) based on a community-driven effort 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 later slides)**
- **Nine Technology domains with Task Force areas**
  - **Most urgent R&D topics in each domain: Detector R&D Themes (DRDTs)**

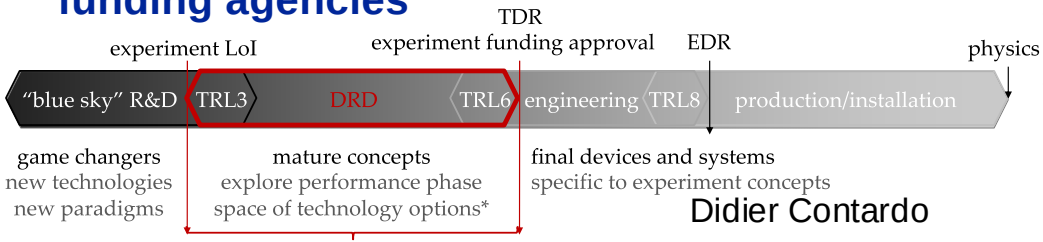


- **Implementation plan: Approved by CERN SPC and Council in Fall 2022 (CERN/SPC/1190 ; CERN/3679)**
  - **CERN to host DRD collaborations**
  - **DRD interface to CERN through DRDC**
  - **DRD interface to ECFA via ECFA Detector panel: https://ecfa-dp.desy.de.**

Strategic R&D

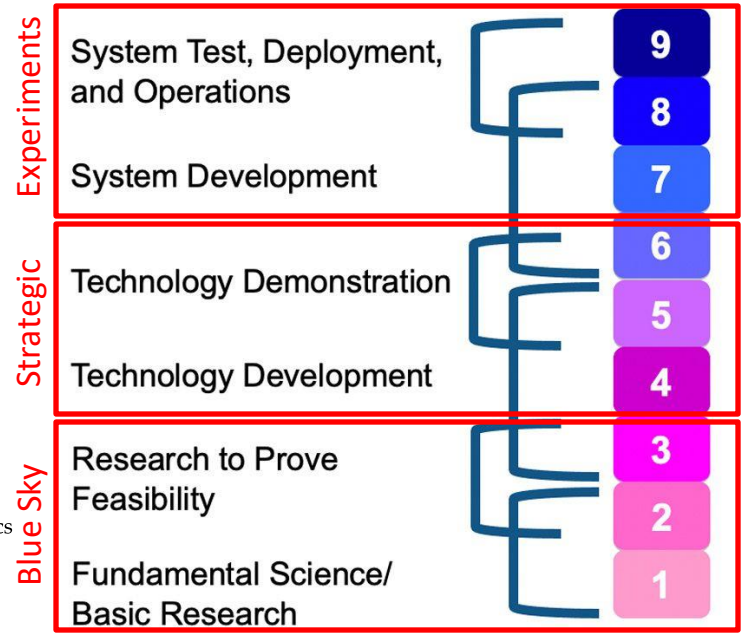
Strategic R&D bridges the gap between the idea ("blue sky research", TRL 1-3) and the deployment and use in a HEP experiment (TRL 8-9)

- **Detector R&D Collaborations 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**



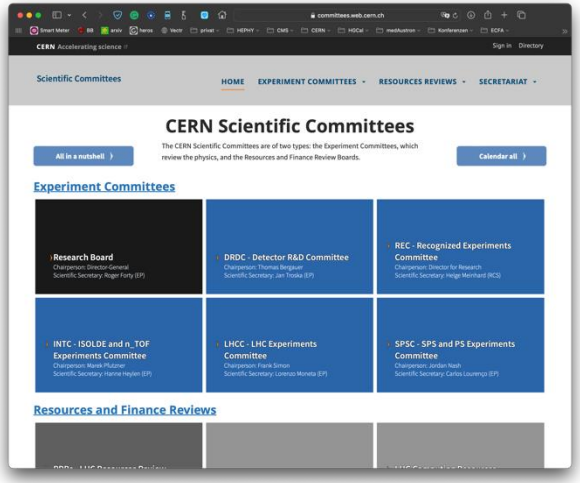
Technology Readiness Levels (TRLs) 1-9:

Method for estimating the maturity of technologies

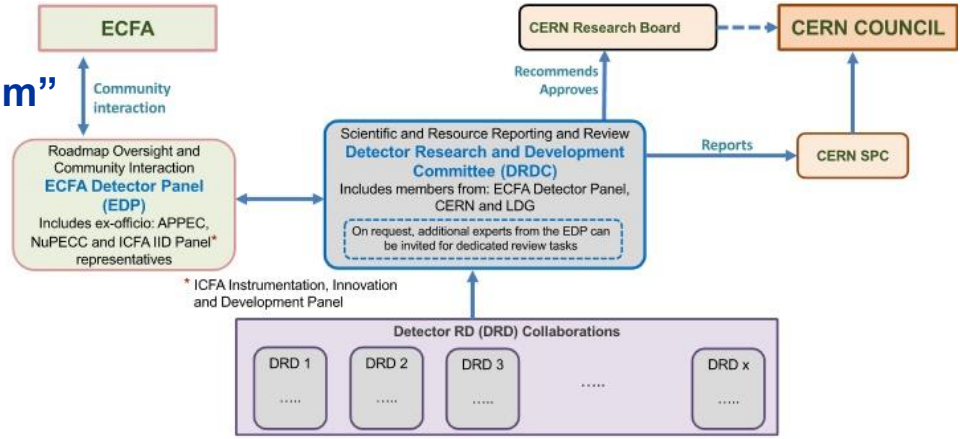


DRD Committee (DRDC)

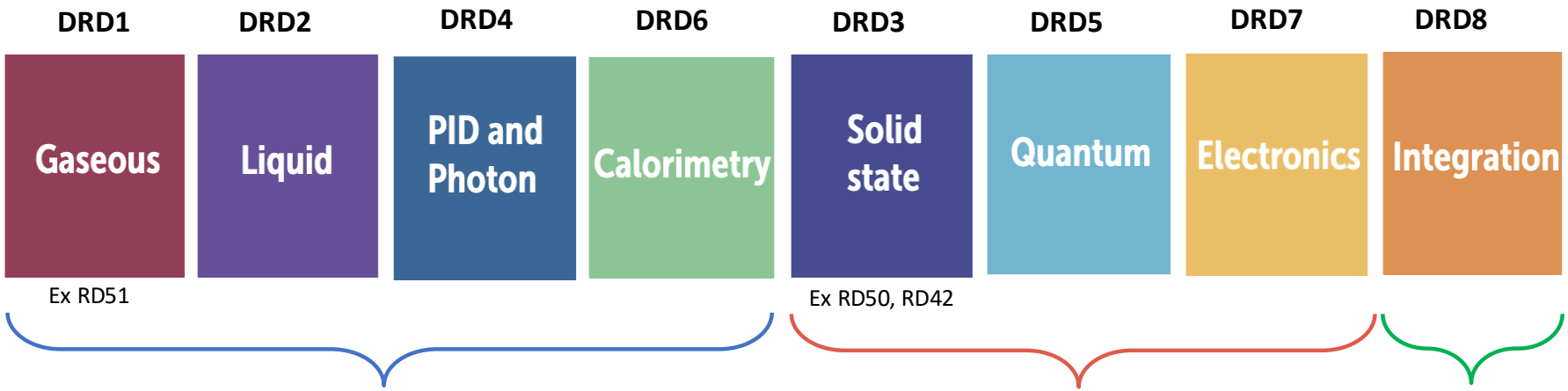
- **Autumn 2023: DRDC**
  - Detector R&D Committee: new CERN committee, same level as SPSC and LHCC.
- **Detector R&D Committee (DRDC):**
  - Reviewing body
  - Monitoring milestones and deliverables
  - Embedded in CERN's organization: Scientific Committee reporting to Research Board



- **ECFA Detector Panel (EDP):**
  - "Advising body", full mandate here.
  - Organizes (recently) "DRD Managers Forum"
    - Organizing exchange across different DRDs
    - Define common terminology
    - Heritage from "full panel" meetings during proposal preparation
  - Providing input to European Strategy for Particle Physics Update 2026



Status of DRD collaborations



- **DRD reports at open session of last DRDC meeting**
- **Indico: Category "Experiments / R&D"**
- **Full DRD proposals in CERN CDS**
  - **Contents: strategic R&D needs and definition of work packages, milestones & deliverables**
  - **Strategic funding to be agreed with funding agencies/institutions**
  - **Next step is to prepare and sign DRD MoUs**
  - **Proposal by DRD8 by the end of this year**

MoU Drafts → DRD Collaborations

JENAA
(Joint ECFA, NUPECC, APPEC Activities)

JEANAA: Expressions of Interest (EoIs)

- **Webpage: https://nupecc.org/jenaa/**
- **List of submitted EoIs:**
  - **Dark Matter - iDMEu**
  - **Gravitational Waves for fundamental physics**
  - **Machine-Learning Optimized Design of Experiments - MODE**
  - **Nuclear Physics at the LHC**
  - **Storage Rings for the Search of Charged-Particle Electric Dipole Moments (EDM)**
  - **Synergies between the Electron-Ion Collider and the Large Hadron Collider experiments**
  - **European Coalition for Artificial Intelligence (AI) in Fundamental Physics EUCAIF.**
- **EoIs in the form of a brief letter, elaborating on the synergy topic, the objectives, the initial thoughts and the potential communities are submitted to the chairs of the committees/consortia.**
  - **Potentially the start of further communications on the expressed interest.**
- **JENA Symposium 2025: at RAL, April 8-11, 2025**
  - **This will be the third JENAS (First: Orsay; Second: Madrid)**

JENAA: Computing Initiative (I)

- **At JENA Symposium in May 2022 in Madrid: plenary presentations and closed session of funding agency representatives:**
  - **There is increased need for discussions on the strategy and implementation of European federated computing at future large-scale research facilities.**
- **The status, needs and plans on a European level for large infrastructures are diverse and not coherent, e.g.,**
  - **In particle physics, the concept for HL-LHC computing is being discussed, in particular how the WLCG concept can be adapted to cope with the increased demands**
  - **in nuclear physics, the computing is currently organized mainly facility based and the community has limited access to the national computing centers**
  - **in astroparticle physics, various totally different computing models for the distributed large-scale infrastructures exist**
- **For all these research areas, issues of scaling will be the challenge of the next decade. Within JENA, synergies and commonalities will be of utmost importance in this scaling.**

JENAA: Computing Initiative (II)

- **JENA Computing Workshop**
  - **First JENA Computing Workshop: held on June 12 - 14, 2023, in Bologna.**
  - **Led to the Executive Summary and next steps, featuring the formation of five Working Groups:**
    - **HPC and HTC: WG1 web page.**
    - **Software and Heterogeneous Architectures (Software): WG2 web page.**
    - **Federate Data Management, Virtual Research Environments and FAIR/Open Data (Data): WG3 web page.**
    - **Machine Learning and Artificial Intelligence (AI): WG4 web page.**
    - **Training, Dissemination, Education (TDE): WG5 web page.**

- **Aiming for a very first draft summary by end of the year**

- **(Repeat of Unpaid Ad): JENA Symposium 2025: at RAL, April 8-11, 2025**

Onwards, and from here, where to?

Outlook

- **This time, we must, i.e., we absolutely must, converge on a crystal-clear, unambiguous choice for the next collider at CERN – with the widest possible consensus**

- **After we converge, we should leave disagreement(s) behind us.**
- **The fastest (and surest) way to getting no new collider is non-convergence of the community on one choice that will be supported very widely by the HEP community.**

- **There is no room for delaying the choice either. The timescales involved are such that we must start now.**
  - **Because it takes a minimum of ~20 years to get a new machine**
  - **And because our junior colleagues (and not only…) need a bold vision**

- **The best has yet to come!**