FCC-contacts / July 29th

- News FCC / ECFA / Snowmass / IN2P3
- Discussion ressources

PED events until Fall 2023

- Workshop on precision calculations at e+e- colliders, 7-17 June 2022 https://indico.cern.ch/event/1173707/
- Summer conferences
- Snowmass final meeting in Seattle, 17-26 July 2022 https://indico.fnal.gov/event/22303/
- Next PED coordination meeting, 25 August 2022
- PED BSM and Flavours mini-workshops in September (stay tuned)
  - Other topical mini-workshop useful in view of progressing on PED deliverables ?
- 6th PED Workshop in Poland, focused on PED deliverables, 23-27 Jan 2023

  https://indico.cern.ch/event/1176398/

  → Expect several Scientific Programme Committee meetings from end August onwards

  With Pillar and Work-Package coordinators, Physics Group conveners
- FCC Week 2023, 5-9 June 2023, in UK (probably London)
  - Deliverables internal review
- Summer 2023 : write the short reports
- Autumn 2023
  - FCC Feasibility mid-term review by the Council

1. Implementation of the 2021 ECFA Detector R&D Roadmap

- Approved by Plenary ECFA on 18 Nov 2021
- Released in December 2021, after presentation to CERN Council

  Documents available: https://cds.cern.ch/record/2784893
- CERN Council has mandated ECFA to work out a detailed implementation plan
  (in close collaboration with the SPC, the funding agencies and the relevant research organisations in Europe and beyond)
- Likewise, the European Lab Director Group (LDG) was mandated to work out an implementation plan for the **Accelerator R&D Roadmap**

- ECFA **Roadmap Coordination Group*** has worked out a proposal, which was discussed in RECFA and presented to SPC and Council in March and June 2022
  **(Phil Allport, Silvia Dalla Torre, Jorgen D'Hondt, Karl Jakobs, Manfred Krammer, Susanne Kuehn, Felix Sefkow, Ian Shipsey)*

  Some discussions still ongoing, aim for a final plan in September (SPC, Council)
- In the following: short summary of the plan, more detailed presentation by Phil Allport tomorrow

Interactions with Funding Agencies

- Presentation to the Open LHC-RRB on 25th April 2022:
  https://indico.cern.ch/event/1133070/timetable/

- **In general: Support for the plan to set up structured, long-term Detector R&D activities; No major objections raised**

Issues to be clarified: Funding schemes need to be adapted, further iteration on review process, inclusion of non-European partners, industry and neighbouring fields, …

Proposed implementation plan

- We propose to organise long-term R&D efforts into **newly established Detector R&D (DRD) Collaborations**

  Detector technology areas: larger DRD collaborations should be considered
  (one for each of the six areas and an additional similar structure for the transversal topics)

- **DRD Collaborations should be anchored at CERN** → CERN recognition, DRD label

- **Taking full account of existing, well-managed and successful ongoing R&D collaborations and other existing activities**
  (CERN EP R&D programme, EU-funded initiatives, collaborations exploring particular technology areas for future colliders)

- The **formation of new DRD collaborations** should adopt a **community-driven approach;**
  Supported by existing ECFA Detector R&D Roadmap Task Forces;
  Aim to have new structure in place in January 2024

Review and Approval Process

1. Scientific and Resource Reporting and Review by a Detector Research and Development Committee (DRDC)

   Assisted by the ECFA Detector Panel (EDP): the scope, R&D goals, and milestones should be vetted against the vision encapsulated in the Roadmap. (EDP: http://cds.cern.ch/record/2211641/files/, exists, hosted at DESY)

2. Funding Agency involvement via a dedicated Resources Review Board (~once every two years)

3. Yearly follow-up by DRDC → report to SPC → Council

Additional Comments

- As projects develop, **some aspects should be expected to transition into approved experiment-specific R&D** (outside the DRD programme)
- In addition, as stated in the General recommendations (GSR7) funding possibilities for "Blue-sky" R&D" should be foreseen

→ Three areas of Detector R&D:

1. Strategic R&D via DRD Collaborations (long-term strategic R&D lines)
   (address the high-priority items defined in the Roadmap via the DRDTs)

2. Experiment-specific R&D (with very well defined detector specifications)
   (funded outside of DRD programme, via experiments, usually not yet covered within the projected budgets for the final deliverables)

3. "Blue-sky" R&D
   (competitive, short-term responsive grants, nationally organised)

Status of implementation:

- Discussions with existing RD50 and RD51 Collaborations (semiconductor and gaseous detectors, respectively) are ongoing, on how the transition can be realised

- Consensus by all that new structure is needed and should be in place when HL-LHC detector construction is completed (HL-LHC deliverables have to be prioritised by many/all institutes);
  Since both collaborations are only approved until end of 2023, a "natural" date for start-up of the new DRD collaborations seems to be **1. January 2024**

- Aim: - **Ramp-up of the proposed resources (personnel, money) through 2025**
  - **Steady state by 2026**

- **Same start-up dates planned for the DRD collaborations in the other areas;**
  Strong support of the plan as well by other technology areas

- Setting up of new DRD collaborations should be done in a bottom-up approach involving the full community;
  To be coordinated by the ECFA Task Force leaders with strong participation of existing RD managements

- Aim to get final endorsement of the structure in September / December Council

- CERN DRD Collaborations are open to all institutes (world-wide) to participate!

WG 1: Physics Potential

Conveners: Juan Alcaraz (CIEMAT - Madrid), Jorge de Blas (Granada), Jenny List (DESY) and Fabio Maltoni (UC Louvain / Bologna)

WG 2: Physics Analysis Methods

Conveners: Patrizia Azzi (INFN-Padova / CERN), Fulvio Piccinini (INFN Pavia) and Dirk Zerwas (IJCLab)

Setting up WG3 (Detector R&D)

- There is consensus that the R&D activities for a future e+e- collider should be integrated into the Roadmap structure

  Many key issues are in line with the major roadmap detector R&D themes

- Despite this, we consider it useful to have a WG3

  - Interface between RD activities and various e^+e^- collider initiatives

  - Follow-up and update of developing detector requirements

  (Mandate defined)

- Conveners: Mary-Cruz Fouz (Madrid), Giovanni Marchiori (APC Paris), Felix Sefkow (DESY)

Example: Solid State Detectors (TF3)

2022 ECFA e^+e^- Workshop in Hamburg 5 – 7 October 2022

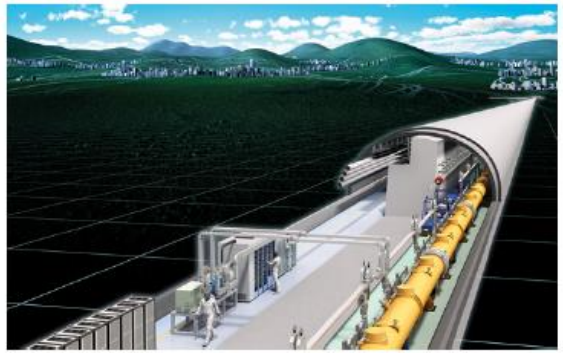
- Status of Working Group activities
- Discussion of future plans
- Interaction between theory and experiments
- "Public Talk" on importance of future e^+e^- collider / new era
  Speaker: Hitoshi Murayama
  + panel discussion
  (involving Fabiola Gianotti, ..)

Registration is open!

https://indico.desy.de/event/33640/

Broad participation is highly welcome!

5. ILC News, KEK and ICFA statements



- KEK has been working on the realization of the International Linear Collider (ILC) in Japan, together with ILC Japan, a community organization under the Japan Association of High Energy Physicists (JAHEP), the **ILC International Development Team (IDT),** established by ICFA and other supporting organizations around the world.

- In June 2021, IDT published the "Proposal for the ILC Preparatory Laboratory (Pre-lab)," which proposes an outline of the organizational framework, an implementation model, work plan and required resources for the preparatory phase of the ILC.

- At the same time, KEK and JAHEP submitted a report to the Ministry of Education, Culture, Sports, Science and Technology (MEXT) that summarizes progress on ILC activities over the past three years. In response to these developments, MEXT organized an expert panel in July 2021.

- MEXT expressed its view that it could not proceed toward the Pre-lab before having a prospect for the international cost sharing. The Advisory Panel of MEXT for the ILC concluded that it was premature to proceed toward the Pre-lab and recommended re-evaluation of the roadmap of the ILC project in a global context taking into account the progress in other Higgs factory studies.

→ Clear mismatch of views: "International" vs. "Global Project"

Recommendations of the MEXT Panel*:

On 14 February, the panel issued their recommendations, pointing out following five main points:

1. The panel recognizes the academic significance of particle physics and the importance of the research activities, including that of a Higgs factory, and understands the value of international collaborative research. However, the **panel found that it is still premature to proceed into the ILC Pre-lab phase**, which is coupled with an expression of interest to host the ILC by Japan as desired by the research community proposing the project.

2. Given the increasing strain in the financial situation of the related countries, **the panel recommends the ILC proponents to reflect upon this fact and to reevaluate the plan. They should reexamine the approach towards a Higgs factory in a global manner taking into account the progress in the various studies such as the Future Circular Collider (FCC) and ILC.**

3. The panel recommends that the **development work in the key technological issues for the next-generation accelerator should be carried out** by further strengthening the international collaboration among institutes and laboratories, shelving the question of hosting the ILC.

4. For realizing a very large project such as the ILC, cultivating a framework where the related countries can exchange information on their situations and discuss required steps would be important.

5. The panel recommends that the research community should **continue efforts to expand the broad support from various stakeholders in Japan and abroad** by building up trust and mutual understanding through bi-directional communication with the people concerned.

KEK statement*:

In light of the panel's findings, **KEK will make an effort to reexamine the path for realizing the ILC** as a Higgs factory, taking into account the progress in various fronts including the FCC feasibility study. In this process, the interaction with the domestic and international research community as well as the opportunities in the exchange of information through ICFA will be crucial. Also, in collaboration with the IDT, **KEK will propose a framework to ICFA to address some of the pressing accelerator R&D issues** for the Pre-lab, where joint developments will be done by the participating laboratories on the selected subjects. KEK and the Japanese ILC community is committed to further advance important technological and engineering development in the accelerator area and to continue the effort for the realization of the ILC.

Furthermore, KEK, in collaboration with ILC-Japan, will establish a **new organization that will centrally manage ILC communications activities.** The new organization will strengthen activities to communicate the significance of the ILC to all parties involved, such as the general public, academia, or industry, focusing on communicating the importance to build an international laboratory for basic science, which will contribute greatly to the development of a new generation of scientists and advancement of knowledge, science and technology.

Next steps proposed by IDT (June 2022)

IDT will organise international discussions, supported by KEK and with MEXT cognisance;

Chaired by Tatsuya Nakada (EPFL Lausanne)

- Develop a general description of the evolution and decision process of a global project, applicable to the ILC, followed by
- Discussion of the specific case of the ILC, i.e. adaptation of the process and possible implementation models

The discussions shall be carried out by an ***International Expert Panel*** consisting of scientists who are experienced in working with large international collaborations and well connected with both the particle physics community and government authorities and CERN

Panel members will make sure that government authorities and CERN are well informed about the status of the discussion and its progress.

Goal: inter-governmental discussions of the ILC should start such that the Pre-lab and international negotiations on the sharing of contributions and responsibilities can be realised

Energy Frontier
Large Experiments

Snowmass Community Summer Study (CSS)

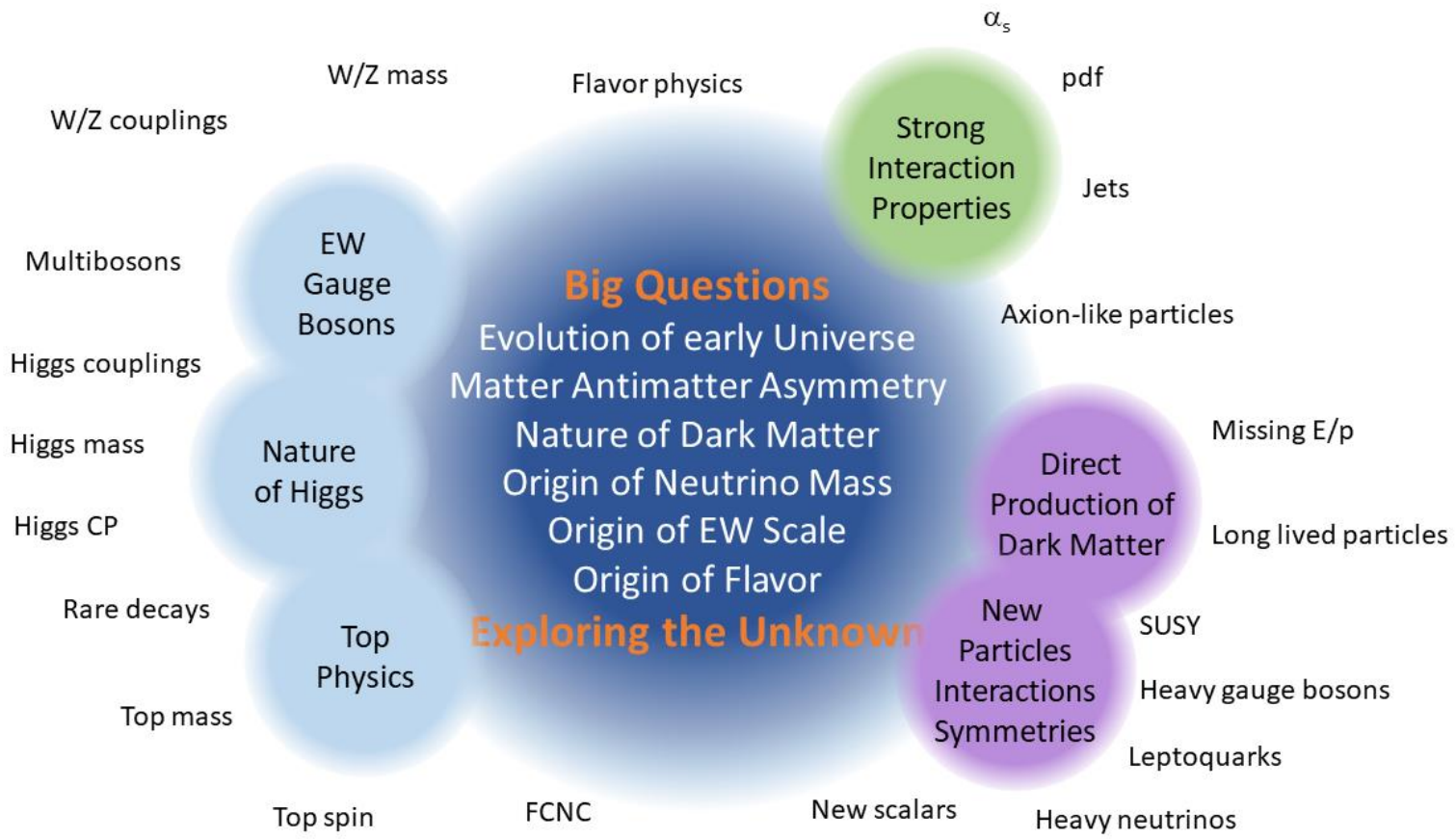
Seattle, July 17-26, 2022

Laura Reina (FSU), Meenakshi Narain (Brown U.), Alessandro Tricoli (BNL)

Snowmass EF wiki: https://snowmass21.org/energy/start

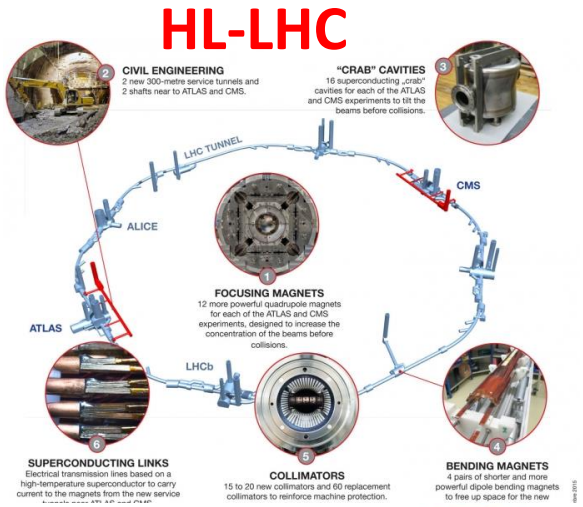
Energy Frontier: explore the TeV energy scale and beyond

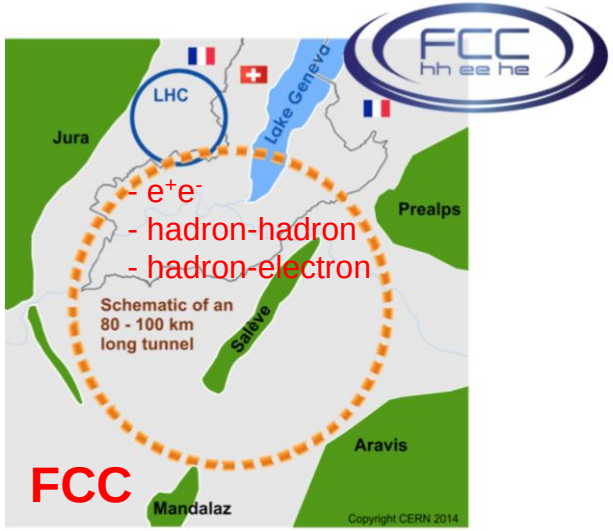
Aims at investigating open fundamental questions and exploring the unknown, using various probes to discover and characterize the nature of new physics, through the breadth and multitude of collider physics signatures

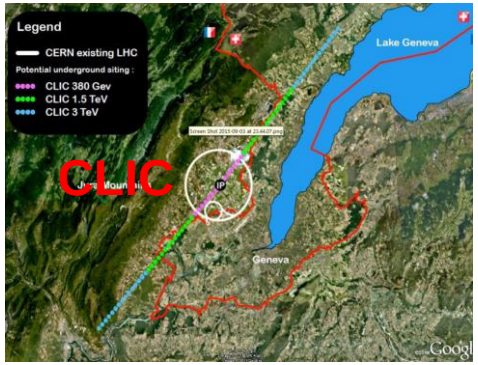


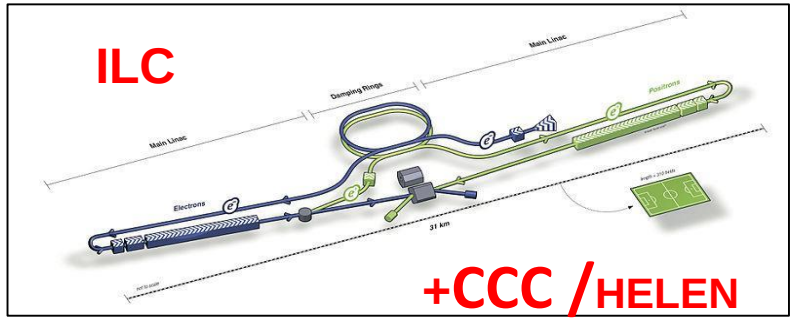
Which machines?

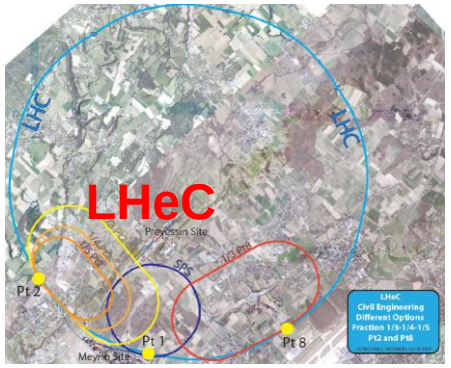
- **Looking for indirect evidence of BSM physics**
  - Need **factories of Higgs bosons** (and other SM particles) to probe the TeV scale via precision measurements
- **Search for direct evidence of BSM physics at the energy frontier**
  - Need to directly reach the **multi-TeV scale**

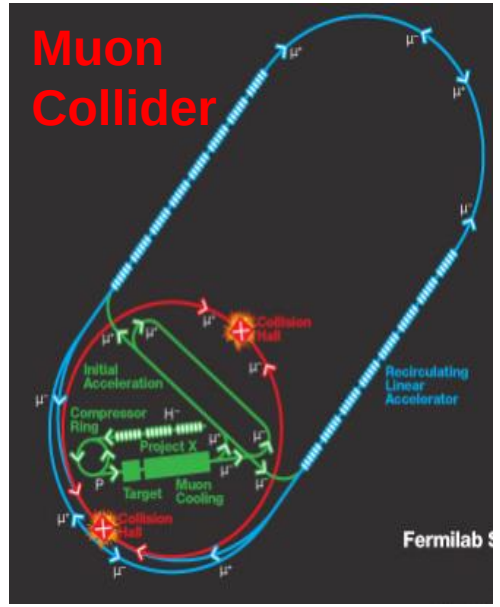


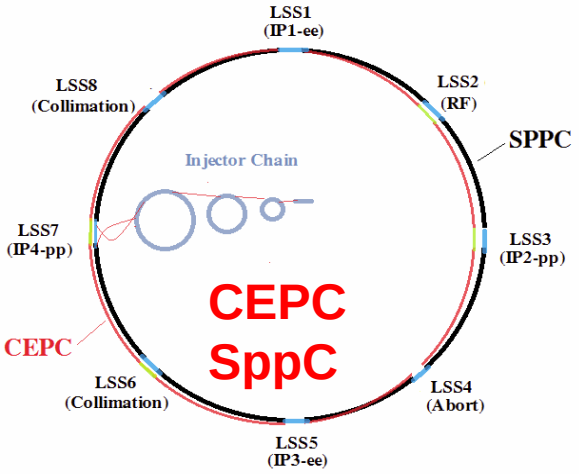












Energy Frontier Benchmark Scenarios

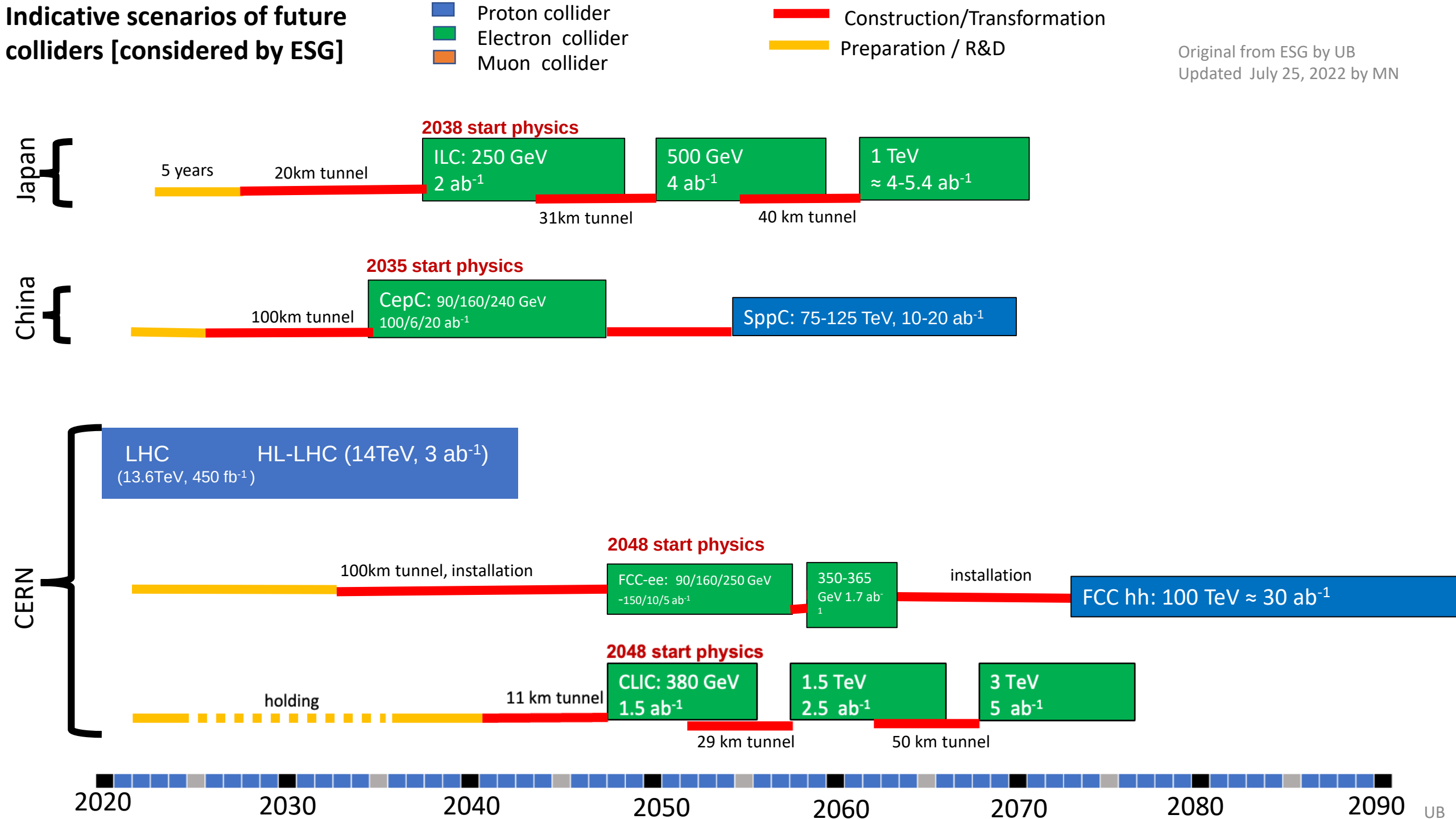
Higgs-boson factories (up to 1 TeV c.o.m. energy)

Collider	Type	$\sqrt{s}$	$\mathcal{P}[\%]$ e^-/e^+	$\mathcal{L}_{\rm int}$ $\rm ab^{-1}$ /IP	Start Date Const.	Start Date Physics
HL-LHC	pp	14 TeV		3		2027
ILC & C^3	ee	250 GeV	$\pm 80/\pm 30$	2	2028	2038
		350 GeV	$\pm 80/\pm 30$	0.2		
		500 GeV	$\pm 80/\pm 30$	4		
		1 TeV	$\pm 80/\pm 20$	8		
CLIC	ee	380 GeV	$\pm 80/0$	1	2041	2048
CEPC	ee	M_Z		50	2026	2035
		$2M_W$		3		
		240 GeV		10		
		360 GeV		0.5		
FCC-ee	ee	M_Z		75	2033	2048
		$2M_W$		5		
		240 GeV		2.5		
		2 M_{top}		0.8		
μ-collider	$\mu\mu$	125 GeV		0.02		

Multi-TeV colliders (> 1 TeV c.o.m. energy)

Collider	Type	$\sqrt{s}$	$\mathcal{P}[\%]$. e^-/e^+	$\mathcal{L}_{\rm int}$ $\rm ab^{-1}$/IP	Start Date Const.	Start Date Physics
HE-LHC	pp	27 TeV		15		
FCC-hh	pp	100 TeV		30	2063	2074
SppC	pp	75-125 TeV		10-20		2055
LHeC	ep	1.3 TeV		1		
FCC-eh		3.5 TeV		2		
CLIC	ee	1.5 TeV	$\pm 80/0$	2.5	2052	2058
		3.0 TeV	$\pm 80/0$	5		
μ-collider	$\mu\mu$	3 TeV		1	2038	2045
		10 TeV		10		

Indicative scenarios of future colliders [considered by ESG]



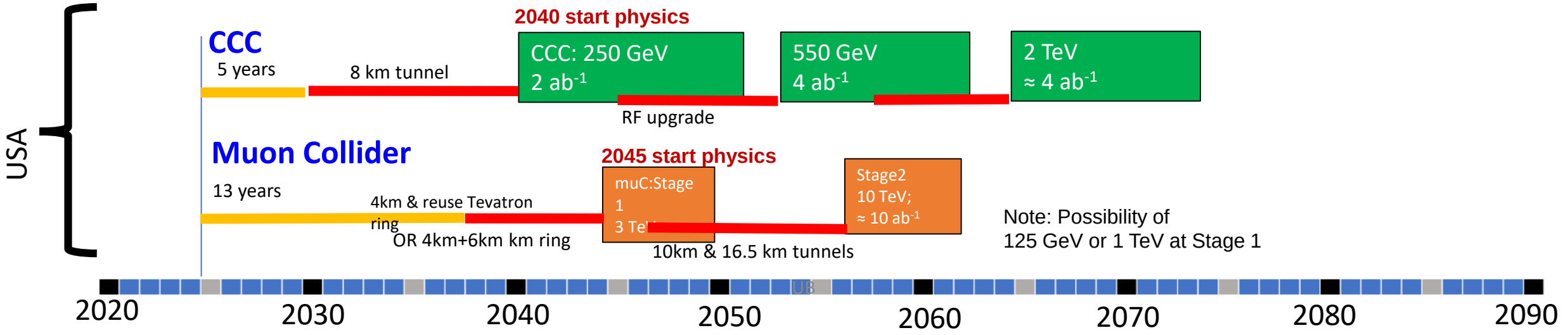
Possible scenarios of future colliders

Proton collider
Electron collider
Muon collider

Construction/Transformation
Preparation / R&D

Original from ESG by UB
Updated July 25, 2022 by MN

Proposals emerging from this Snowmass for a US based collider



- **Timelines technologically limited**
- Uncertainties to be sorted out
  - Find a contact lab(s)
  - Successful R&D and feasibility demonstration for CCC and Muon Collider
  - Evaluate CCC progress in the international context, and consider proposing an ILC/CCC [ie CCC used as an upgrade of ILC] or a CCC only option in the US.
  - International Cost Sharing

- Consider proposing hosting ILC in the US.

Large Projects

Project	Construction Start date (yr)	Construction End date (yr)	Construction Cost B$
Higgs Factories			
CepC	2026	2035	12-18
CCC (higgs Fac)	2030	2040	7-12
ILC (higgs Fac)	2028	2038	7-12
CLIC	2041	2048	7-12
FCC-ee	2033	2048	12-18
Multi-TeV Colliders			
Muon Collider (3 TeV)	2038	2045	7-12
Muon Collider (10 TeV)	2042	2052	12-18
SppC	2043	2055	30-80
HE CCC	2055	2065	12-18
HE CLIC (3 TeV)	2062	2068	18-30
FCC-hh	2063	2074	30-50

Cost estimates from the ITF report by AF. Please refer to the document for explanations now they were estimated and associated caveats

Link to the report on AF wiki

Medium Project Scale R&D requests

Project	R&D Start date (yr)	R&D End Date (yr)	R&D cost M$
Higgs Factory detector R&D	now	2035	~100-150
CCC higgs factory	2024	2028	~100
CCC High Energy	2045	2050	~200
Muon Collider (1-3 TeV)	now	2040	~300
Muon Collider (10 TeV)	2040	2047	~200

Estimated US Contributions
In the spirit of Snowmass numbers are very preliminary. They give an approximate scale.

Need to be vetted further.

Accelerator & Detector R&D Needs

Higgs Factories

Support a fast-start for construction of an e+e- Higgs Factory

Viability of Facilities and Challenges (from AF)

- ILC:
  - Ready to go, polarization
  - Long, e+ source,
  - consider CCC technology for upgrades
- FCCee & CEPC :
  - Ongoing feasibility study
  - Longest, $$, power consumption
- CLIC:
  - Lowest power needs, shortest
  - 2-beams (or klystrons?), tolerances
- Cool Copper Collider or HELEN:
  - **new proposals from Snowmass**
  - lower cost option to ILC/CLIC
  - large gradients at least 70MV/m (HELEN) CCC capability up to 120-155 MV/m

Multi-TeV Machines

Support for R&D for EF multi-TeV colliders

Viability of Facilities and Challenges (from AF)

- CLIC-3 TeV :
  - Established CDR, demo facilities
  - Long, $$$, huge power consumption
- FCChh-100 TeV:
  - Re-use FCCee tunnel, high-L, LHC exp.
  - 20(?) yrs for 16 T magnets, $$$, power
- SPPC-125 TeV:
  - Re-use CepC tunnel, ep 0.12+62.5 TeV
  - (N) yrs for 20 T magnets, $$$, power
- Muon Collider-10(14) TeV:
  - Potentially lowest cost, best Lumi/TWh
  - 6D cooling R , D on many subsystems

Detector R&D Needs

Preparation of a Technical Design for a Detector needs an R&D program

- Highly segmented detectors with good resolution were simulated to make the case for physics studies for Higgs Factories & Multi-TeV Colliders.
- **We do need complex/cutting-edge detectors to meet the ambitious physics goals!** The needs extend beyond generic R&D.
  - Address the specific detector challenges for e^+e^- colliders.
- **Such a program needs to start now**
  - to explore the technology to build a full-scale e^+e^- collider detector
  - It takes about 10 years from CD0 to end of construction of a collider detector.
  - **Thus investment in targeted detector R&D for a Higgs Factory has to start soon**!

Summary

- An opportunity for US to take leadership in colliders

- US EF community strongly supports

1. A fast start of construction of an e+e- Higgs Factory (FCC-ee, ILC, C^3, CLIC) [Large Project]
2. Request for targeted detector R&D for Higgs Factory [in the range of small project costs]
3. Request for investment in R&D towards lowering of costs for Higgs Factory [lower end of medium project costs]
   a. interest in new technologies from early career scientists
4. Request for investment in R&D towards multi-TeV colliders
   a. significant interest for adding muon collider R&D. [lower end of medium project costs]

News de l'IN2P3

Master-Projets

- Le timing des Master Projets n'est pas encore finalisé
- Plus d'informations en Septembre
- Laurent sera présent lundi 21/11, premier jour de FCC-France-Italie

Post-Docs

- Un post-doc ATLAS-FCC attribué à l'APC (embauche urgente)
  - Search for HH in bbyy or bbtautau on ATLAS
  - L.Argon simulation and Higgs Physics on FCC
- Demandes Postdocs pour 2023

Demandes ressources financières

	VARSOVIE	LONDRES	FCC-France	CERN	ECFA	MISC	TOTAL		Physiciens impliqués à 15% ou plus	Physiciens impliqués entre 5 et 10%	total FTE
COUT VOYAGE	1500	1800	300	500	1000	stage M2/info			(FCC ou ECFA)	(FCC ou ECFA)	detaillé
CPPM											
IJC Lab											
IPHC											
IP2I											
LAPP											
LLR											
LPNHE											
LPC	3000	1800	900	1000	2000		9700		RM,SM,PG,LR	TM,HC	2
LPSC	1500	0	300	500	1000	1800	5100		Etudiant-M2	FM	0,3
APC+FCC-FR	3000	3600	1200	3000	2000	1800	14600		GB, GM, AL,PostDoc-fcc-atlas,M2		2
TOTAL							29400				

Demandes ressources humaines

En 2022: 3 Postdocs LHC-FCC attribués:

IPHC : CMS / FCC (tracking for FCC)

LLR : CMS / FCC (Calice for FCC)

APC : ATLAS / FCC (L.Argon simulation for FCC)

Demandes 2023 ??

LPSC : Etudiant ATLAS / FCC

APC : Etudiant ATLAS / FCC

?

Préparation FCC France-Italie 21-23 Novembre à Lyon

- Première discussion informelle avec les italiens sur une possible organisation:

Gregorio Bernardi, Didier Contardo, Suzanne Gascon, Angeles Faus Golfe, Giacomo Cacciapaglia,
Franco Bedeschi, Roberto Tenchini, Aleandro Nisati, Manuela Boscolo, Fulvio Piccinini

- Lundi 21/11 démarrage à 12h30 avec lunch commun, puis session plénière introductive.
- Mardi 22/11 2 sessions parallèles: PED (incluant theorie) et Accélérateurs
- Mercredi 23/11 Session plénière de conclusion

Plus de discussions à la FCC week la semaine prochaine
Plus de Francais et d'Italiens dans l'organisation.

F. Bedeschi : specifically for the detectors I see some obvious macro-areas that we may want to cover

1. Silicon tracking detectors
    a. Both France and Italy have large communities involved, but the impression is that they are pretty much decoupled. We could have a couple of talks covering the current scenario in both countries followed by a discussion on the potential for future work. For Italy the ARCADIA project and R&D on ATLASPIX3 are presently connected with FCC work, but other experts currently busy with LHC upgrade could also enlarge the picture.

2. Gas trackers
    a. Also here there are large communities involved in large gas trackers with a preference for TPC in France and one for drift chambers in Italy. There is also a wide community on muon trackers RPC and chambers of many types. An important topic is the use of large trackers for PID using cluster counting or dE/dx and the associated electronics. Also in this case a couple of overview talks followed by a guided discussion could be a way to proceed.

3. Calorimeters
    a. Here our two countries are high polarized: France for PF and Italy for Dual Readout, but in the end things a becoming more and more related. Indeed DR with timing could become a good PF detectors and there are many common electronics issues to deal with the enormous number of readout channels. For instance the development digital SiPM could be of interest to both.
    b. A crystal based EM calorimeter could be of common interest and there are already strong collaboration for CMS and its upgrade.
    c. Since calorimetry is so complex I think we should take more time and separate the hadronic and EM with two overview talks each and guided discussion.

4. Simulation and physics case studies
    a. This is another are of interest where reaching a critical mass is important.

Main PED deliverables for the 2023 Mid-Term Review

Consolidation of the physics case and detector concepts for ee&hh colliders

official deliverables promised to council →

Physics, experiments, detectors:

- Documentation of FCC-ee and FCC-hh physics cases
- Plans for improved theoretical calculations needed to reduce the theoretical uncertainties towards matching the FCC-ee statistical precision for the most important measurements.
- First documentation of the main detector requirements to fully exploit the FCC-ee physics opportunities

- Documentation of the **specificities and complementarity** of the FCC-ee and FCC-hh physics cases, in particular for the Standard Model **Higgs** boson characterization.
- Strategic plan for improved calculations needed to reduce **theoretical uncertainties** towards matching the FCC-ee expected statistical precision on the most important measurements.
- Coherent sets of preliminary detector requirements to fully exploit the FCC-ee physics opportunities, in particular reduce **experimental uncertainties** towards matching the FCC-ee expected statistical precision on the most important measurements.

PED internal deliverables →

- Develop the physics arguments for having **two or four** interaction regions
- Provisional (horizontal) footprint of FCC-ee detectors in the experimental caverns
- Detailed documentation of the **FCC-hh detector** concept
- Status of the common **simulation framework**, in particular for easily interchangeable detector configurations (a.k.a. "Plug & Play")
- Status of the common **analysis framework**
- Status of the international **community building** around the FCC particle physics effort, with support from the FCC Collaboration Board, the FCC Global Collaboration Working Group, and the Informal Forum of National Contact

Main PED deliverables for the 2023 Mid-Term Review

How to move forward? Timeline?

- The work package coordinators are already tasked to identify set of observables. Feedback welcome!
- Coordination with detector concepts is essential
- Has any important deliverable been forgotten?
  - new one are emerging in the course of Snowmass: complementarity FCC-hh vs Muon Collider
- Extensive discussion expected at the FCC physics week in Cracow next January. Be ready!
- Final presentation at the FCC week in London next June.
- Written (short) report delivered to the Council in the Autumn.

Main PED deliverables for the 2023 Mid-Term Review

e.g. estimation of statistical precision

Work already done
in our EPJ+ essay collection

2106.13885

Table 3. Measurement of selected precision measurements at FCC-ee, compared with present precision. The systematic uncertainties are initial estimates, aim is to improve down to statistical errors. This set of measurements, together with those of the Higgs properties, achieves indirect sensitivity to new physics up to a scale Λ of 70 TeV in a description with dim 6 operators, and possibly much higher in specific new physics (non-decoupling) models.

Observable	present value ± error	FCC-ee **Stat.**	FCC-ee Syst.	Comment and leading exp. error
m_Z (keV)	91186700 ± 2200	**4**	100	From Z line shape scan Beam energy calibration
Γ_Z (keV)	2495200 ± 2300	**4**	25	From Z line shape scan Beam energy calibration
$\sin^2\theta^{\rm eff}_W(\times10^5)$	23148 ± 160	**2**	2.4	from $A^{\mu\mu}_{FB}$ at Z peak Beam energy calibration
$1/\alpha_{QED}(m_Z^2)(\times10^3)$	128952 ± 14	**3**	small	from $A^{\mu\mu}_{FB}$ off peak QED&EW errors dominate
R^Z_ℓ $(\times10^3)$	20767 ± 25	**0.06**	0.2-1	ratio of hadrons to leptons **acceptance for leptons**
$\alpha_s(m_Z^2)$ $(\times10^4)$	1196 ± 30	**0.1**	0.4-1.6	from R^Z_ℓ above
σ^0_{had} $(\times10^3)$ (nb)	41541 ± 37	**0.1**	4	peak hadronic cross section luminosity measurement
$N_\nu(\times10^3)$	2996 ± 7	**0.005**	1	Z peak cross sections Luminosity measurement
R_b $(\times10^6)$	216290 ± 660	**0.3**	< 60	ratio of bb to hadrons stat. extrapol. from SLD
$A^b_{FB},0$ $(\times10^4)$	992 ± 16	**0.02**	1-3	b-quark asymmetry at Z pole from jet charge
$A^{pol,\tau}_{FB}$ $(\times10^4)$	1498 ± 49	**0.15**	<2	τ polarization asymmetry τ decay physics
τ lifetime (fs)	290.3 ± 0.5	**0.001**	0.04	radial alignment
τ mass (MeV)	1776.86 ± 0.12	**0.004**	0.04	momentum scale
τ leptonic ($\mu\nu_\mu\nu_\tau$) B.R. (%)	17.38 ± 0.04	**0.0001**	0.003	e/μ/hadron separation
m_W (MeV)	80350 ± 15	**0.25**	0.3	From WW threshold scan Beam energy calibration
Γ_W (MeV)	2085 ± 42	**1.2**	0.3	From WW threshold scan Beam energy calibration
$\alpha_s(m_W^2)(\times10^4)$	1170 ± 420	**3**	small	from R^W_ℓ
$N_\nu(\times10^3)$	2920 ± 50	**0.8**	small	ratio of invis. to leptonic in radiative Z returns
m_{top} (MeV/c^2)	172740 ± 500	**17**	small	From $t\bar{t}$ threshold scan QCD errors dominate
Γ_{top} (MeV/c^2)	1410 ± 190	**45**	small	From $t\bar{t}$ threshold scan QCD errors dominate
$\lambda_{top}/\lambda^{SM}_{top}$	1.2 ± 0.3	**0.10**	small	From $t\bar{t}$ threshold scan QCD errors dominate

TODO
similar tables
for flavour, Higgs, top, BSM

set up priorities
established the need for fullsim
detector requirements

Main PED deliverables for the 2023 Mid-Term Review

- Complementarity ee+hh: breath of the programme of both colliders in isolation, enhanced by the combination
- Interplay with high pT measurements at HL-LHC
- List of selected physics cases to explore further with full detector simulations
- Theoretical framework for global analysis of Higgs/EW/top data
- Prospective study of intensity frontier from Z-pole run (flavour observables, feebly interacting particles…)
- List of flavour observables to be measured at FCC-ee. Implications for Higgs physics
- Estimates on the sensitivity of various Dark Sector models.