GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
cfp CIEMAT física de partículas

Development towards a Higgs/top/EW factory



Mary-Cruz Fouz
CIEMAT

CPAN Ingenio 2010

European Strategy for Particle Physics

A. An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the Euro… proton-proton collider… goals will require innovation and cutting-edge technology:

An electron-positron Higgs factory is the highest-priority next collider.

• the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature s…

• Europe, together with its international partners, should … and financial feasibility of a future hadron collider at CER… energy of at least 100 TeV and with an electron-positron … factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update.

The timely realisation of the electron-positron International Linear Collider (ILC) in Japan would be compatible with this strategy and, in that case, the European particle physics community would wish to collaborate.

…sics experiments relies on innovative …infrastructures. To prepare and realise future experimental research programmes, the community must maintain a strong focus on instrumentation. ***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 …ss and …t large. …provide …l 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.***

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.

B. Innovative accelerator technology underpins the physics reach of high-energy … and … fields… magn… high-…

The European particle physics community must intensify accelerator R&D and sustain it with adequate resources. A roadmap should prioritise the technology, taking into account synergies with international partners and other communities such as photon and neutron sources, fusion energy and industry. Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.

The … sust… takin… such as photon and neutron sources, fusion energy and industry. Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.





Snowmass – Energy Frontier report (20/11/2022)

The Future of US Particle Physics

The Energy Frontier Report

20 Nov 2022

NEW

2021 US Community Study
on the Future of Particle Physics

organized by
the APS Division of Particles and Fields

https://arxiv.org/pdf/2211.11084.pdf

The EF supports a fast start for construction of an e^+e^- Higgs factory (linear or circular), and a significant R&D program for multi-TeV colliders (hadron and muon). The realization of a Higgs factory will require an immediate, vigorous and targeted detector R&D program, while the study towards multi-TeV colliders will need significant and long-term investments in a broad spectrum of R&D programs for accelerators and detectors. These projects have the potential to be transformative as they will push the boundaries of our knowledge by testing the limits of the SM, and indirectly or directly discovering new physics beyond the SM.

The US EF community has also expressed renewed interest and ambition to bring back energy-frontier collider physics to the US soil while maintaining its international collaborative partnerships and obligations.

1.7 The Energy Frontier vision

The Energy Frontier also supports the possibility of a Higgs factory in the US. Given global uncertainties, consideration should also be given to the timely realization of a possible domestic Higgs factory, in case none of the currently proposed global options are realized.

The US community has expressed a renewed ambition to bring back EF collider physics to the US soil, while maintaining its international collaborative partnerships and obligations, for example with CERN. The international community also realizes that a vibrant and concurrent program in the US in EF collider physics is beneficial for the whole field, as it was when Tevatron was operated simultaneously as LEP.

The US EF community proposes to develop plans to site an e^+e^- collider in the US. A muon collider remains a highly appealing option for the US, and is complementary to a Higgs Factory. For example, some options which are considered as attractive opportunities for building a domestic EF collider program are:

- **A US-sited linear e^+e^- (ILC/CCC) Collider**
- **Hosting a 10 TeV range muon collider**
- **Exploring other e^+e^- collider options to fully utilize the Fermilab site**

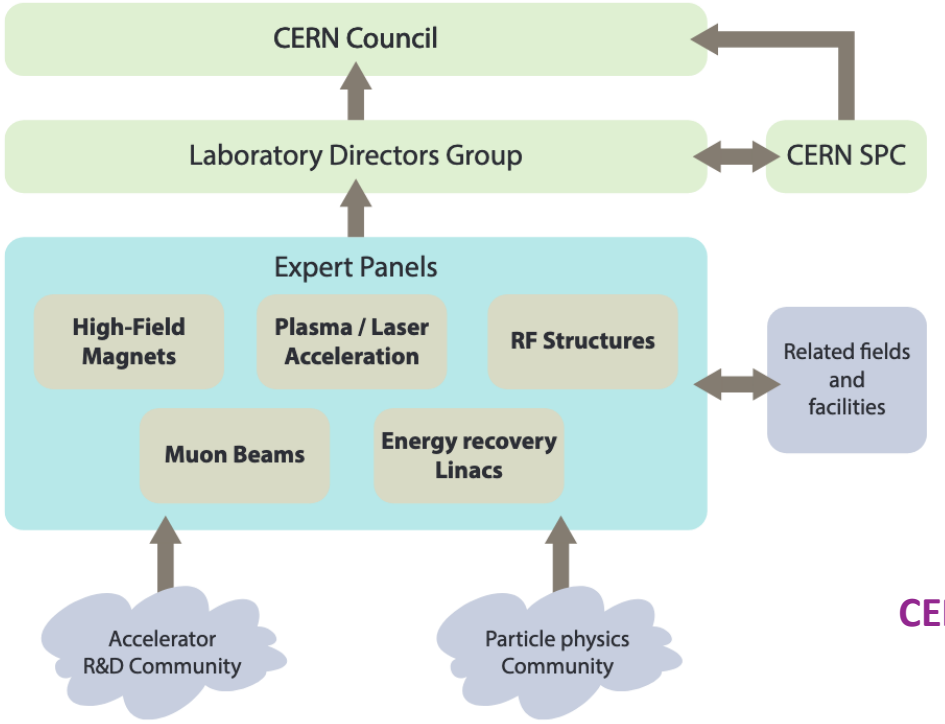
Accelerator R&D Roadmap

- LDG: European "Lab Directors Group" (10 labs)
  - CERN, CIEMAT, DESY, IRFU, IJCLAB, NIKHEF, LNF, LNGS, PSI, STFC-RAL
  - lab-to-lab communications with a view to address together the ESPP
  - current chairperson: Dave Newbold (STFC-RAL)

The Lab Directors group (LDT) has been mandated to develop this roadmap

The ESPPU identified **five key areas** where an intensification of R&D is required to meet scientific goals:

Roadmap panel structure



https://arxiv.org/abs/2201.07895



Approved by CERN Council – Dec 2021

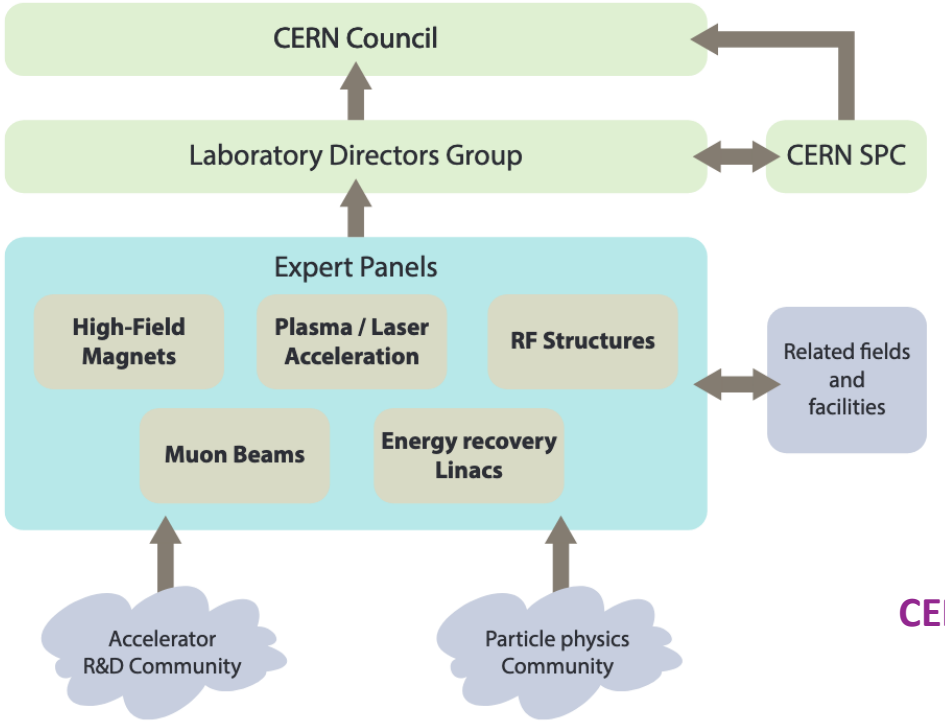
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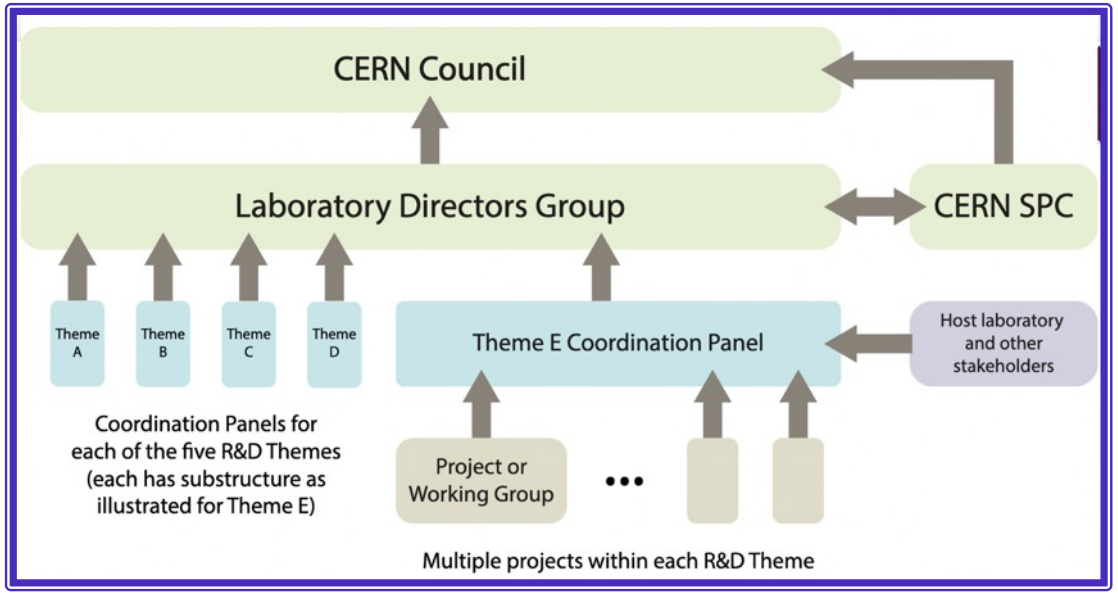


Approved by CERN Council – Dec 2021

Roadmap Implementation

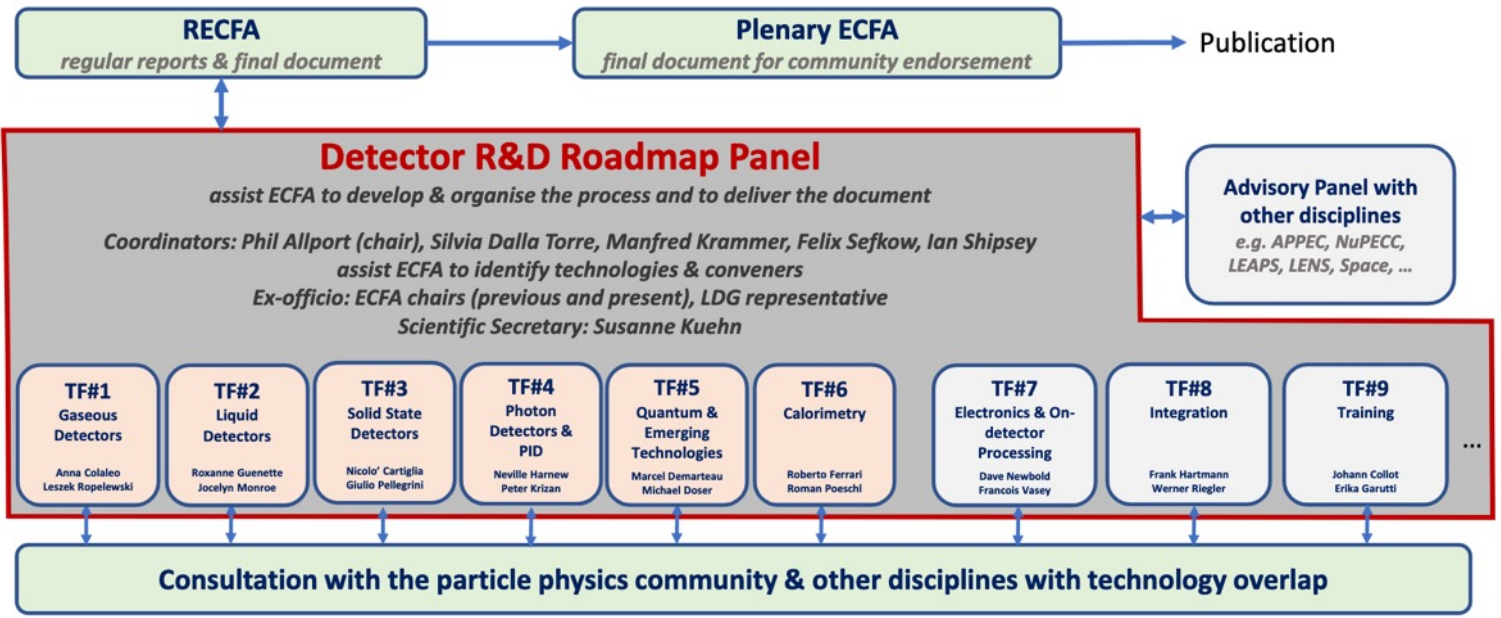
Coordination structure

Approved September 2022



Goal: To have the structure in operation by **December 2022**

Detector R&D Roadmap



Process involved: 67 authors; 12 expert Input Session speakers; ECFA National Contacts; respondents to the Task Force surveys; 121 Symposia presenters; 1359 Symposia attendees and 44 APOD TF topic specific contacts.



http://cds.cern.ch/record/2784893

Approved by CERN Council – Dec 2021

General Strategic Recommendations

GSR 1:	Supporting R&D facilities
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

Detector R&D Roadmap Implementation

Details at this document. Approved on September 2022

https://indico.cern.ch/event/1197445/contributions/5034860/attachments/2517863/4329123/spc-e-1190-c-e-3679-Implementation_Detector_Roadmap.pdf

CERN/SPC/1190

> ….. the highly relevant detector **R&D issues identified in the Roadmap need to be addressed**. However, **the successful completion of the high-luminosity upgrades of the LHC (machine and detectors) must remain a key focus. Large-scale involvement** of many of the institutes involved in the Phase 2 upgrades of ATLAS and CMS **may therefore only become possible once the present construction work has been completed**. **However, the urgent needs of other experiments call for the timely realisation of the structure described**, which also offers longer-term prospects for those engaged in instrumentation work, enhancing the attractiveness of this vital area. **We therefore aim to establish the DRD collaborations, which should start work in January 2024, with a ramp-up of resources through 2024/2025, reaching a steady state by 2026.**

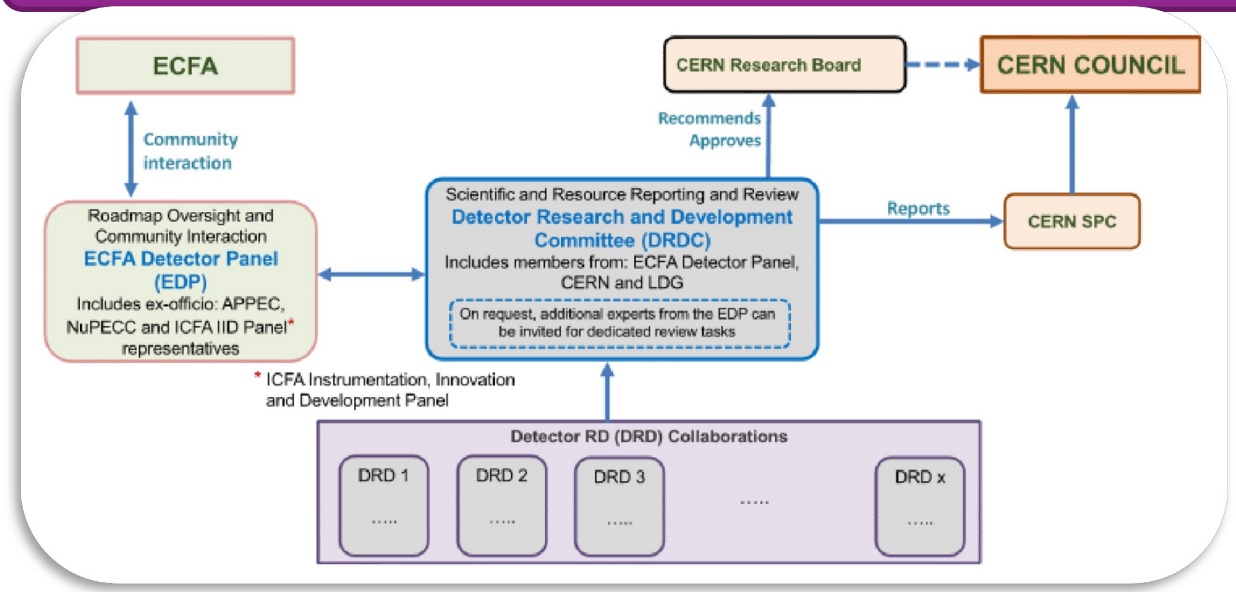
- It is proposed that the long-term R&D efforts be organised into newly established **Detector R&D (DRD) collaborations** (equivalent to the RD collaborations stablished in the 90's for LHC detector technologies)
- That collaborations will be established to address each of the **six detector technology areas identified in the Roadmap**
- For electronics and integration, one or two further DRD collaborations should be anticipated;

Detector R&D Roadmap Implementation (II)

All DRD collaborations should be anchored at CERN, be recognised by CERN and obtain a CERN DRD label.

It would be very welcome if other institutes in Europe, such as major (national) laboratories or universities, were to take the lead in certain collaborations and help provide the necessary administrative support.

Proposed organisational structure for implementation of the Roadmap
(the arrows indicate the reporting lines)



ECFA Detector Panel (EDP) reactivated

Approved on last ECFA meeting (17th Nov 2022)

- provides direct input on DRD proposals, through the appointment of members to the DRDC
- assists in the conduct of annual DRDC reviews of the scientific progress of DRD collaborations; monitors the overall implementation of the ECFA detector roadmap and the specific DRDTs;

MEMBERS

Co-chairs: Phil Allport (Birmingham), Didier Contardo (IP2I Lyon)
Scientific Secretary: Doris Eckstein (DESY) – Solid State Detectors
Silvia Dalla Torre (INFN Trieste) – Gaseous Detectors
Inés Gil Botella (CIEMAT) – Liquid detectors
Roger Forty (CERN) – PID & Photon Detectors
T.B.C - Quantum and Emerging Technologies
Laurent Serin (Orsay LAL) – Calorimetry
Arno Straessner (Dresden) *(leaving 2023),* – Electronics
Valerio Re (Bergamo) – Electronics
Ex-officioL: Karl Jakobs (Freiburg)- ECFA Chair;
Ian Shipsey (Oxford) – IFCA IIDP Chair
Observers: APPEC and NuPECC

NEW

Detector R&D Roadmap Implementation - Timeline

Suggested Implementation Timeline

Through 2023, mechanisms will need to be agreed with funding agencies in parallel to the process below for country specific DRD collaboration funding requests for Strategic R&D and for developing the associated MoUs.

Q4 2022	Outline structure and review mechanisms agreed by CERN Council. Detector R&D Roadmap Task Forces organise **community meetings** to establish the scope and sca wishing to participate in the corresponding new DRD activity. (Where the broad R&D topic area has one or more DRDTs already covered by existing CERN RDs or other internationa need to be fully involved from the very beginning and may be best placed to help bring the community together arou programmes.)
Q1 2023	**DRDC mandate formally defined** and agreed with CERN management; Core DRDC membership appo mandate plus membership updated to reflect additional roles.
Q1-Q2 2023	**Develop the new DRD proposals** based of the detector roadmap and community interest in pa including light-weight organisational structures and resource-loaded work plan for R&D programme and ramp up to a steady state in 2026.
Q3 2023	**Review of proposals by DRDC** leading to recommendations for formal establishment of the DRD collab
Q4 2023	DRD Collaborations receive formal **approval from CERN Research Board**.
Q1 2024	New structures operational for ongoing review of DRDs and R&D programmes underway.

Through 2024, collection of MoU signatures

ECFA European Committee for Future Accelerators — Plenary ECFA meeting, CERN, 17th November 2022

Next steps (cont.)

DRDC Mandate and composition need to be worked out

→ CERN management

In each country / laboratory the DRD proposal process has to be discussed with the respective funding agencies;

RECFA delegates can help to launch this process and to set up the right structures (most likely, it will be different from country to country)

Also the question came up what role the **ECFA Roadmap National Contacts for detectors** should pla
→ We will keep them in "stand-by" for any detector R&D-related issues that will come up over the forthcoming years (e.g. short term: accompany and help in national coordination of the DRD proposal writing process)

Finally: ECFA – LDG working group to address some of the GSRs need to start up its work
→ under discussion, more information in this week's RECFA meeting

From K. Jakobs

Detector R&D Roadmap Implementation – Community meetings

https://indico.cern.ch/event/957057/page/27294-implementation-of-the-ecfa-detector-rd-roadmap

Topic specific community meetings will be held in the coming months.

To sign up for these and to register your interest in participating on the corresponding R&D Collaborations

- TF1 Gaseous Detectors https://indico.cern.ch/event/1214405/
- TF2 Liquid Detectors https://indico.cern.ch/event/1214404/
- TF3 Solid State Detectors https://indico.cern.ch/event/1214410/
- TF4 Photon Detectors and PID https://indico.cern.ch/event/1214407/
- TF5 Quantum and Emerging Technologies https://indico.cern.ch/event/1214411/
- TF6 Calorimetry https://indico.cern.ch/event/1213733/
- TF7 Electronics and On-detector Processing https://indico.cern.ch/event/1214423/
- TF8 Integration https://indico.cern.ch/event/1214428/
- TF9 Training https://indico.cern.ch/event/1214429/



Full community, not restricted to Higgs or colliders



One Spanish coordinator: **Giulio Pellegrini** on Solid State Detectors

ECFA Studies towards a Higgs/EW/Top factory

ECFA recognizes the need for the experimental and theoretical communities involved in physics studies, experiment designs and detector technologies at future Higgs factories to gather. **ECFA supports a series of workshops** with the aim **to share challenges and expertise, to explore synergies** in their efforts and to respond coherently to this priority in the European Strategy for Particle Physics (ESPP).

GOALS:	To bring the entire e+e- Higgs factory effort together, foster cooperation across various projects, collaborative research programs are to emerge



ECFA Studies towards a Higgs/EW/Top factory

*An **International Advisory Committee (IAC)** has been formed.*

ECFA-chair would act as chair: Karl Jakobs
- **From RECFA:** Jean-Claude Brient, Tadeusz Lesiak, Chiara Meroni
- **With (HL-)LHC experience:** Jorgen D'Hondt, Max Klein, Aleandro Nisati, Roberto Tenchini
- **For theory:** Christophe Grojean, Andrea Wulzer
- **For Linear Colliders:** Steinar Stapnes, **Juan Fuster*,** Frank Simon, Aidan Robson
- **For Circular Colliders:** Alain Blondel, Mogens Dam, Patrick Janot, Guy Wilkinson
- **For CERN:** Joachim Mnich

It suggested to establish **three Working Groups**
led by conveners from both experiment and theory

Physics Potential

Juan Alcaraz – CIEMAT*
Jenny List - DESY
Fabio Maltoni - UC Louvain /Bologna
Jorge de Blas - U. Granada*

Physics Analysis Methods

Patrizia Azzi -INFN-Padova /CERN
Fulvio Piccinini - INFN Pavia
Dirk Zerwas - IJCLab/DMLab

Detector R&D

Mary Cruz Fouz – CIEMAT*
Giovanni Marchiori – APC Paris
Felix Sefkow - DESY

(*)members of the Spanish community

A **Yellow Report** will be produced as input to next European Strategy Update



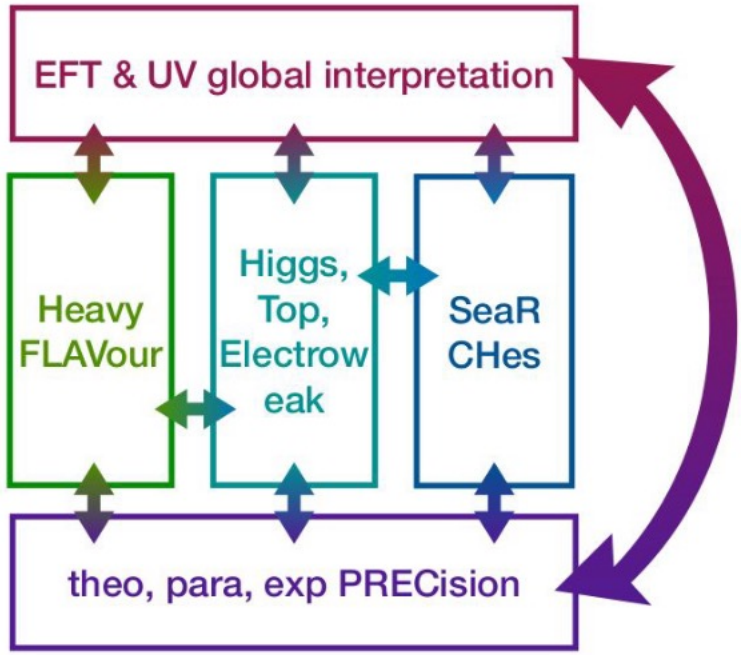
ECFA H/EW/t studies: WG1 - Physics Potential

Juan Alcaraz – CIEMAT Jenny List – DESY,
Fabio Maltoni - UC Louvain/Bologna, **Jorge de Blas - U. Granada**

https://indico.cern.ch/event/1044297/page/23971-wg1-group-activities
https://indico.cern.ch/category/14055/
https://twiki.cern.ch/twiki/bin/view/ECFA/ECFAHiggsFactoryWG1

- Set up a forum on physics potential on future Higgs and top/EW factories
- Identify areas or topics where concrete work should be organized
- Propose new ideas

5 different fronts of activity identify (activities are interconnected)
For each activity leaders have been selected, to help the WG1 conveners



- **WG1-PREC (Precision in theory & experiment):**
  Ayres Freitas (Pittsburgh), Paolo Azzurri (Pisa), **Adrian Irles (Valencia)**, Andreas Meyer (DESY)
- **WG1-GLOB (Global interpretations in (SM)EFT and UV complete models):**
  Sven Heinemeyer (IFCA/IFT), Alexander Grohsjean (DESY), Junping Tian (Tokyo),
  Marcel Vos (Valencia), Jorge de Blas (Granada)
- **WG1-HTE (TOP-HIGGS-EW and connection with LHC):**
  Chris Hays (Oxford), Karsten Koeneke (Freiburg), Fabio Maltoni (Louvain)
- **WG1-FLAV (Heavy Flavours):**
  David Marzocca (Trieste), Stephane Monteil (Clermont Ferrand), Pablo Goldenzweig (KIT)
- **WG1-SRCH (Feebly interacting particles, direct low mass searches):**
  Roberto Franceschini (Rome III), Rebeca Gonzalez (Uppsala), Filip Zarnecki (Warsaw)

ECFA H/EW/t studies: WG1 Workshops (by subgroups)

WG1-PREC https://indico.cern.ch/category/14871/

December 2022
- 16 Dec MiniWorkshop : Luminosity

November 2022
- 02 Nov MiniWorkshop : Collision Energy

July 2022
- 14 Jul MiniWorkshop: parametric uncertainties: α_em

March 2022
- 10 Mar MiniWorkshop: parametric uncertainties: α_s
- 08 Mar MiniWorkshop: high-precision measurements

Mailing list: https://e-groups.cern.ch/e-groups/EgroupsSubscription.do?egroupName=ecfa-whf-wg1-prec

WG1-GLOB https://indico.cern.ch/category/14874/

September 2022
- 23 Sept WG1-GLOB Meeting: Analyses of concrete models

July 2022
- 01 Jul WG1-GLOB Meeting: Global interpretations in (SM)EFT and UV complete models

Mailing list: https://e-groups.cern.ch/e-groups/EgroupsSubscription.do?egroupName=ecfa-whf-wg1-glob

WG1-HTE https://indico.cern.ch/category/14872/

September 2022
- 23 Sept ECFA HTE meeting on Z pole physics

April 2022
- 20 Apr - 22 Apr ECFA WHF WG1: 1st Workshop of the Higgs/Top/EW

Mailing list: https://e-groups.cern.ch/e-groups/EgroupsSubscription.do?egroupName=ecfa-whf-wg1-hte

WG1-FLAV https://indico.cern.ch/category/14873/

June 2022
- 29 Jun ECFA WG1-FLAV: 1st Meeting

Mailing list: https://e-groups.cern.ch/e-groups/EgroupsSubscription.do?egroupName=ecfa-whf-wg1-flav

WG1-SRCH https://indico.cern.ch/category/1486/

May 2022
- 25 May ECFA HF WG1: 1st Workshop of the WG1-SRCH group

February 2022
- 25 Feb WG1-SRCH- Brainstorming session

Mailing list: https://e-groups.cern.ch/e-groups/EgroupsSubscription.do?egroupName=ecfa-whf-wg1-srch

ECFA H/EW/t studies: WG1 Seminars

https://indico.cern.ch/category/13912/

November 2022
•25 Nov ECFA Higgs Factory seminars: Flavor Physics at Future e+e- colliders

June 2022
•10 Jun ECFA Higgs Factory seminars: Precision physics in the e+e- -> WW region
•07 Jun - 17 Jun Precision calculations for future e+e– colliders: targets and tools (FC CERN Unit Workshop)

May 2022
•06 May ECFA Higgs Factory seminars: Higgs self-coupling

April 2022
•08 Apr ECFA Higgs Factory seminars: Physics with light quarks

March 2022
•04 Mar ECFA Higgs Factory seminars: Implications of (g-2)_mu for e+e- Higgs factories: an overview

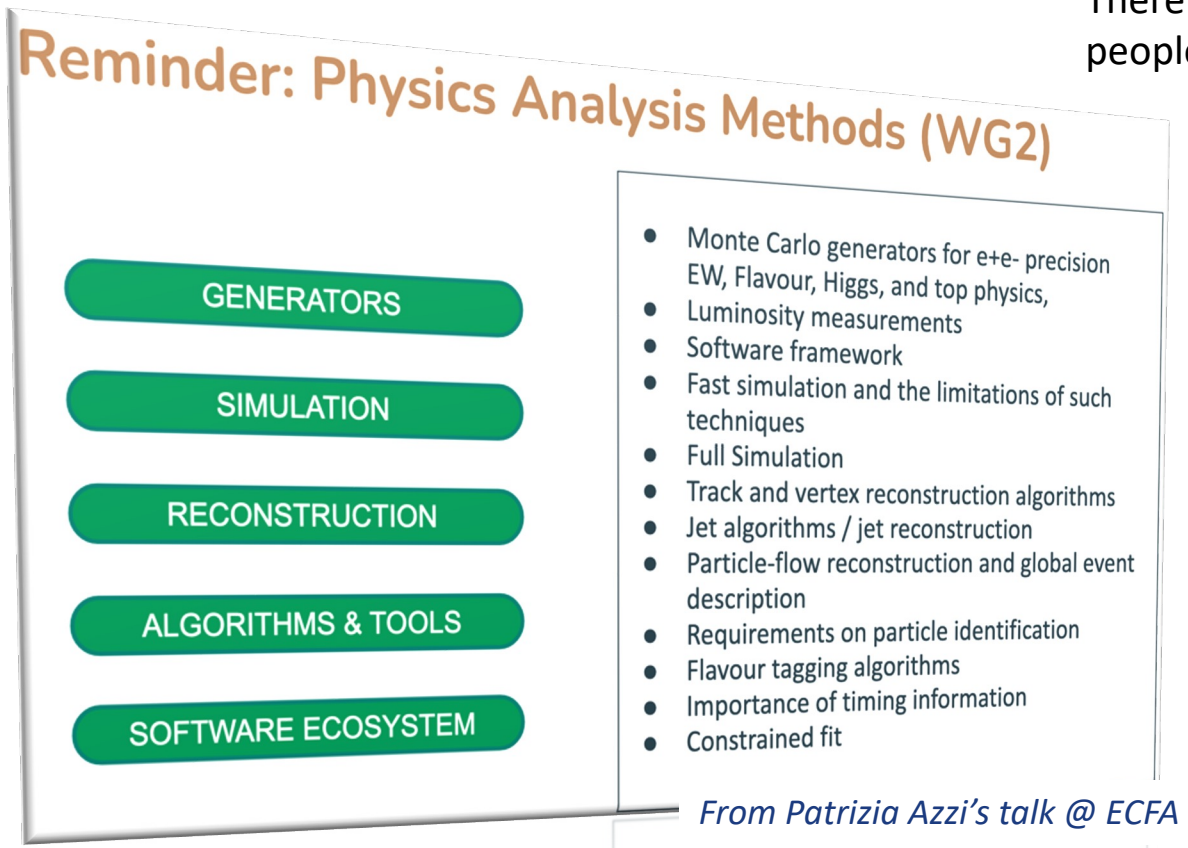


ECFA H/EW/t studies: WG2 - Physics Analysis Methodes

Patrizia Azzi -INFN-Padova/CERN, Fulvio Piccinini - INFN Pavia, Dirk Zerwas - IJCLab/DMLab

Forum to efficiently share technical knowledge, not only concerning **lepton colliders**,
but also coming from the **LHC experience and B-factories**

There is not WG2 internal organization, but thinking on identify people responsible to lead the work on specific topics



From Patrizia Azzi's talk @ ECFA Workshop Oct 2022

Optimize solutions for common issues and attack new (specific) needs providing the solutions within **a software ecosystem that will allow a general usage**

ECFA H/EW/t studies: WG2 - Physics Analysis Methodes

Patrizia Azzi -INFN-Padova/CERN, Fulvio Piccinini - INFN Pavia, Dirk Zerwas - IJCLab/DMLab

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Reminder: Physics Analysis Methods (WG2)

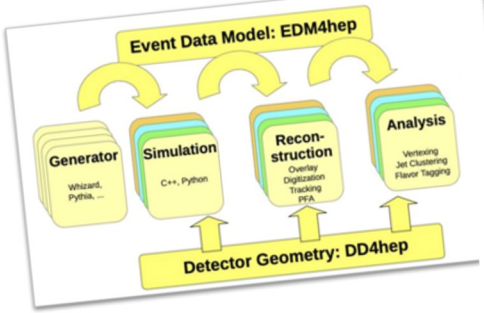
- GENERATORS
- SIMULATION
- RECONSTRUCTION
- ALGORITHMS & TOOLS
- SOFTWARE ECOSYSTEM

- Monte Carlo generators for e+e- precision EW, Flavour, Higgs, and top physics,
- Luminosity measurements
- Software framework
- Fast simulation and the limitations of such techniques
- Full Simulation
- Track and vertex reconstruction algorithms
- Jet algorithms / jet reconstruction
- Particle-flow reconstruction and global event description
- Requirements on particle identification
- Flavour tagging algorithms
- Importance of timing information
- Constrained fit

Software Ecosystem - Key4hep

Create a software ecosystem integrating in optimal way various software components to provide a ready-to-use full-fledged solution for data processing of HEP experiments

- ***Key4hep* federates FCC, ILC, CLIC , CEPC and other experiments**
- In use or medium term migration plan
- Supported by R&D efforts (AIDA, CERN EP etc.)
- **KEY4HEP coordinators consulted and involved in the organisation of all WG2 meetings**
  - Frank Gaede
  - Gerardo Ganis



From Patrizia Azzi's talk @ ECFA Workshop Oct 2022

Optimize solutions for common issues and attack new (specific) needs providing the solutions within **a software ecosystem that will allow a general usage**

ECFA H/EW/t studies: WG2 - Meetings

https://indico.cern.ch/category/13912/

February 2022
•01 Feb - 02 Feb ECFA Higgs Factories: 1st Topica Meeting on Simulation

January 2022
•12 Jan Focus Meeting: Beamstrahlung

November 2021
•09 Nov - 10 Nov ECFA Higgs Factories: 1st Topical Meeting on Generators

May 2022
•04 May - 05 May ECFA Higgs Factories: 1st Topical Meeting on Reconstruction



ECFA H/EW/t studies: WG3 – Detector R&D

Mary Cruz Fouz – CIEMAT, Giovanni Marchiori – APC Paris, Felix Sefkow - DESY

This working group has been created recently (end spring 2022), more than one year after the previous (WG1, WG2) waiting for the end of the R&D detector roadmap process

Main goals of WG3

To demonstrate, as input to the next EPPSU, that **detectors matching the precision physics potential of future Higgs factories can be built**. The level of the demonstrations should be comparable between the different Higgs factory proposed

To provide **guidance for coherent detector R&D efforts** to address the priority requirements of Higgs factory experiments

- **Foster the interaction between the detector R&D groups and future collider physics and detector studies with the aim of minimising duplication**
  - Sharing experience
  - Encouraging cross participation in detector R&D and physics/detector studies
  - Promoting low-level simulation of the different technologies integrated in the common software framework (key4hep, dd4hep, edm4hep)
  - exploring synergies and complementarity between the benchmark physics processes guiding the detector optimization;
  - Collecting detector requirements on the colliders and relating them to the R&D studies of the technological options
  - integrating the input from physics and detector studies in the planning of test-beam

⇒ **R&D effort on a certain technology can be beneficial to several detector concepts based on the same technology**

⇒ **Different technological solutions might provide similarly well-suited options for subdetector X of detector concept** Y

ECFA H/EW/t studies: WG3 – Detector R&D

Existing activities can be broadly classified in two categories:

detector concept studies

(within the different Higgs factory collaborations)

and **detector R&D efforts**

(using groups from ECFA R&D Roadmap)

2 contact persons identify for each community

ILD **SID** **CLICdet + CLD** **IDEA** **Lar** **CEPC**	Karsten Buesser, Ulrich Einhaus Marcekl Stanitzki, Adrew White Dominic Danheim, Frank Simon Margherita Primavera, Romualdo Santoro Nicolas Morange, Brieuc Francois Haijun Yang, Jianchun Wang
TF1 – Gas **TF3 – Si** **TF4 – PD/PID** **TF6 – Calorimeter** **TF7 - Electronics** **TF8 – Mechanics**	Ricado Farinelli, Maxim TiTov Daniela Bortoletto, Didier Contardo Neville Harnew, Peter Krizan Gabriella Gaudio, Vincent Boudry Dave Newbold, Federico Faccio Frank Hartmann, Werner riegler

A **series of workshops** are planned for **2023** aiming efficient exchange between concepts and R&D and delivering input to R&D reviews on how efficiently groups address Higgs factory needs

https://indico.cern.ch/category/14055/

Topics not fully decided but the "suspicious" are:

- Tracking and Vertexing for Higgs factories
- Calorimetry and Particle ID for Higgs factories
- Electronics and integration
- Alignment and Calibration



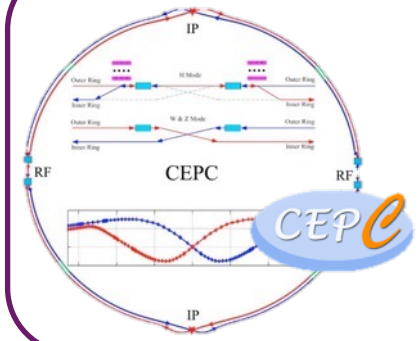


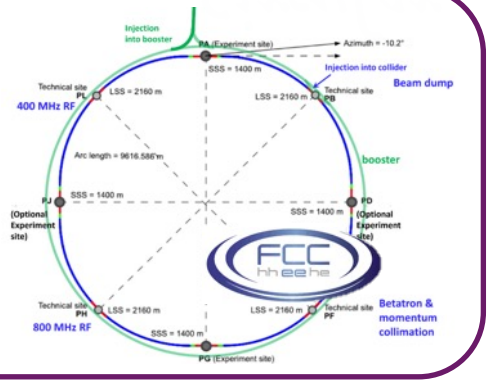
https://twiki.cern.ch/twiki/bin/view/ECFA/ECFAHiggsFactoryWG3

Panoramic view - Colliders

e+e- Colliders

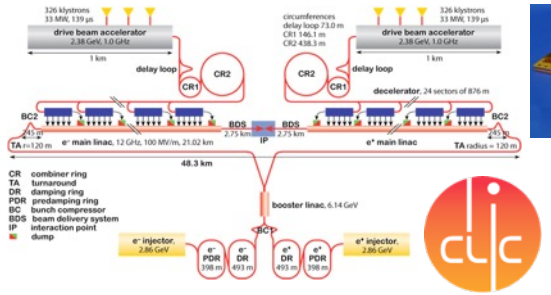
Circular

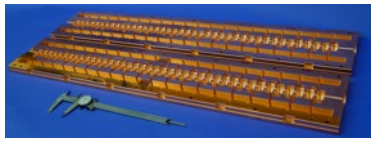




Linear





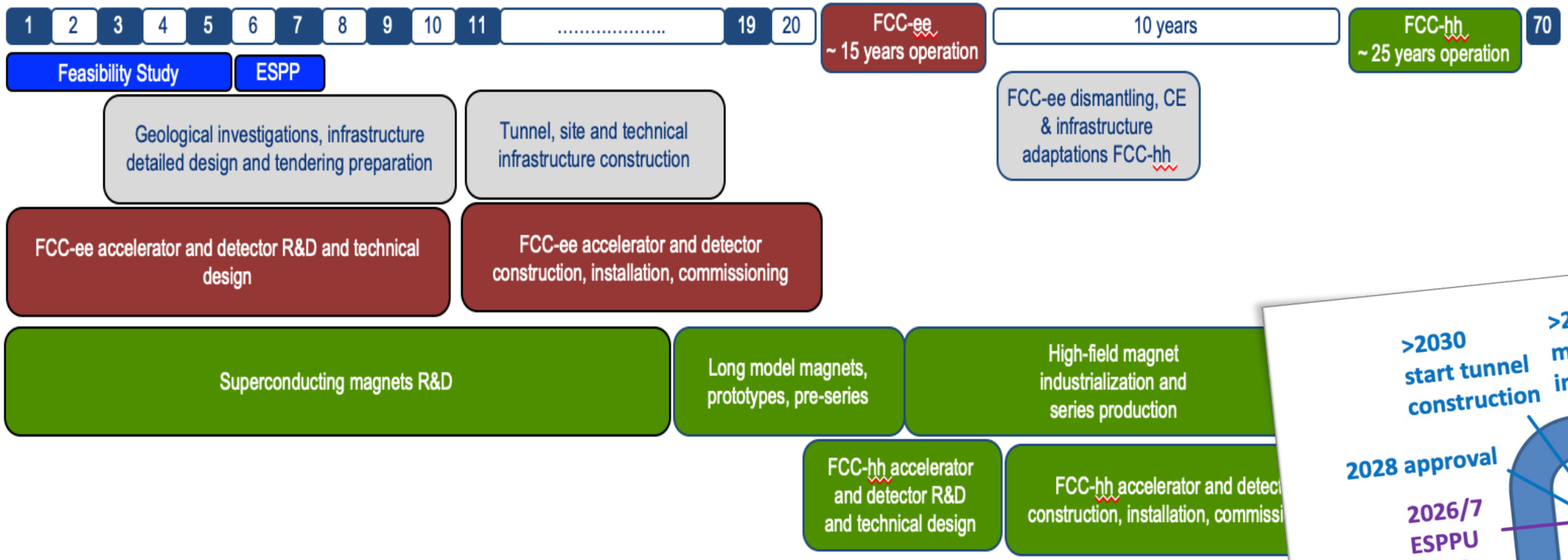


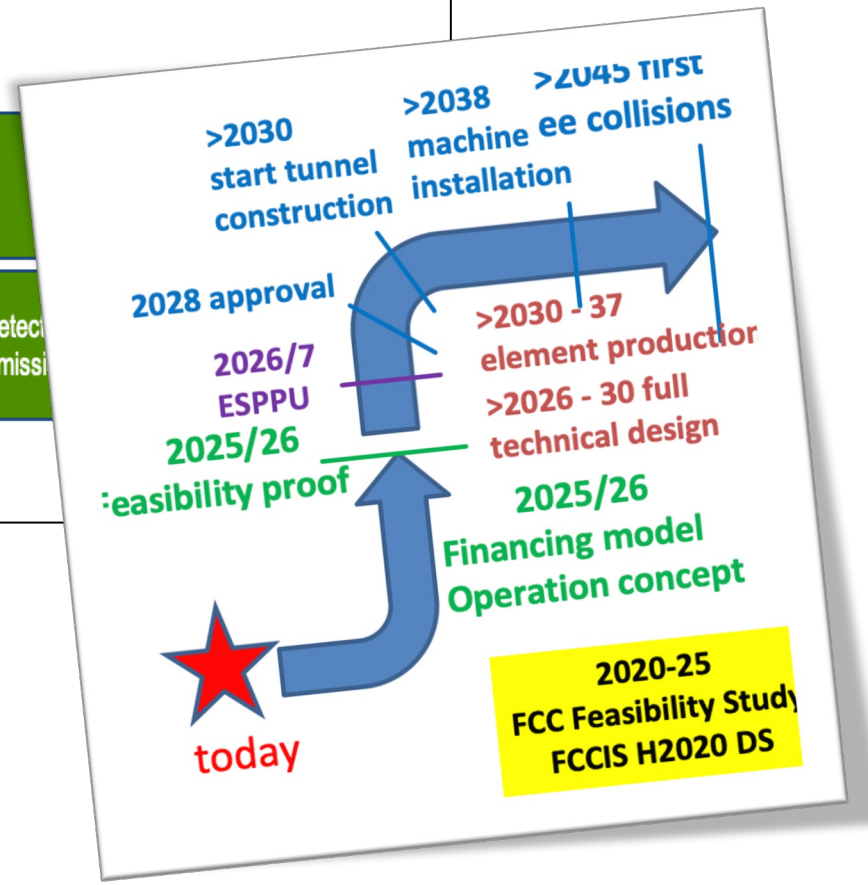
C³

Future Facilities Time Line

< 2030	2030-2035	2035-2040	2040-2045	> 2045
SPS fixed target Other fixed target; FAIR (hep) Belle II ALICE LS3 PIP-II/DUNE/Hyper-K	ALICE 3 LHCb (≥ LS4) EIC LHeC	ILC	FCC-ee CLIC	FCC-hh FCC-eh Muon Collider Plasma Collider

Timeline of the FCC integrated programme

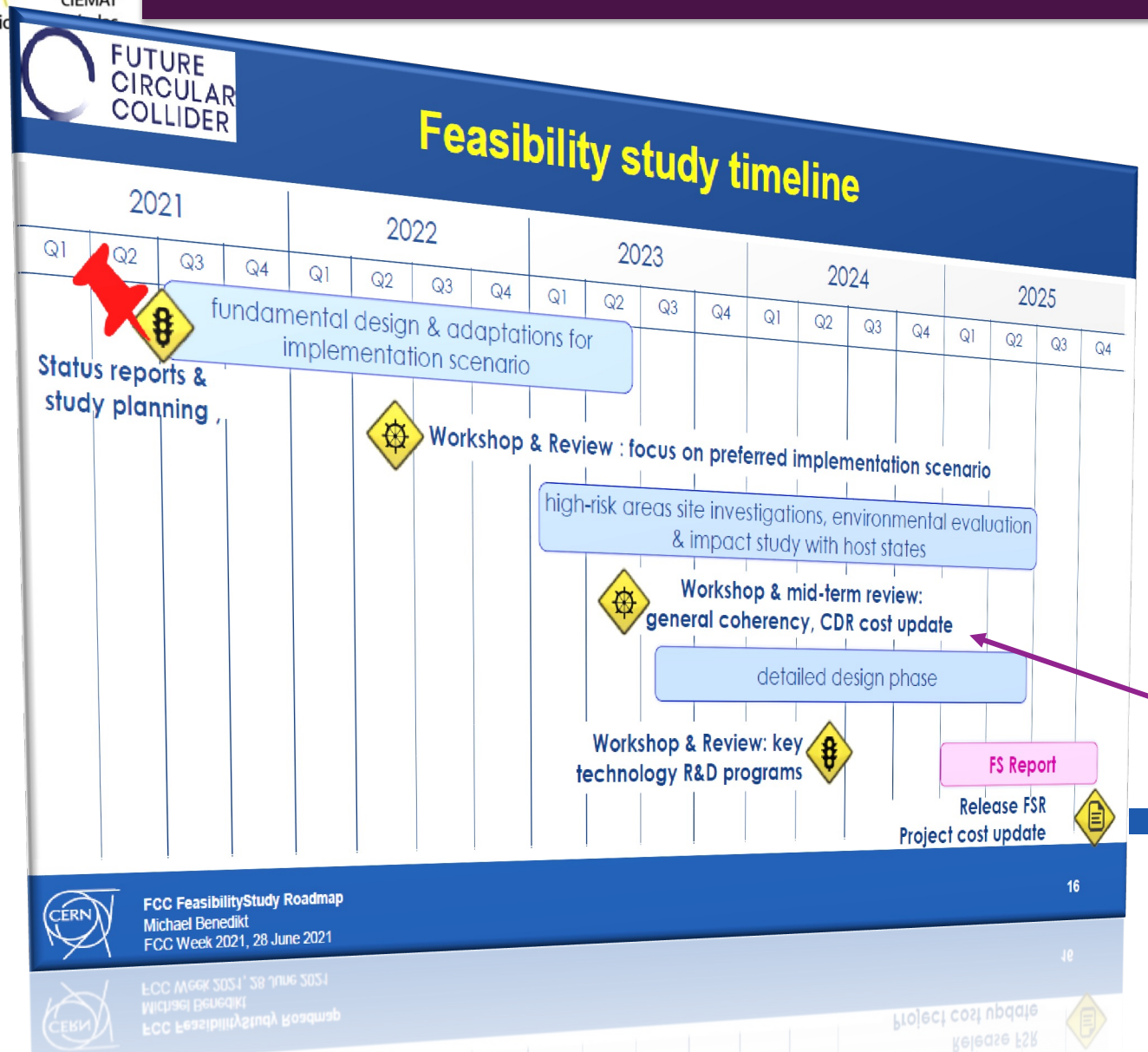




- Feasibility Study: 2021-2025
- If project approved before end of decade → construction can start beginning 2030s
- FCC-ee operation ~2045-2060
- FCC-hh operation 2070-2090++

F. Gianotti

FCC Feasibility Study Timeline



Fabiola Gianotti: "CERN vision and goals until next strategy update" FCCIS Kick-Off, 9 Nov. 2020

- Financial feasibility
- Technical and administrative feasibility of tunnel:
  no show-stopper for ~100 km tunnel
- Technologies of machine and experiments:
  magnets; minimise environmental impact;
  energy efficiency & recovery
- Gathering scientific, political, societal and other support

Mid-term review 2023
important milestone

ICFA ILC International Development Team

International Committee for Future Accelerators

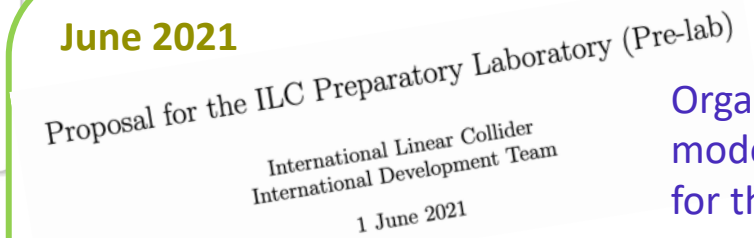


https://linearcollider.org/team/

In **August 2020** ICFA approved the formation of the **ILC International Development Team (IDT)** as the first step towards the preparatory phase of the ILC project, with a mandate to make preparations for the ILC Pre-Laboratory (Pre-Lab) in Japan.

The Team is hosted by the High Energy Accelerator Research Organization (KEK) in Japan.

June 2021


Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider
International Development Team

1 June 2021

Organizational framework, implementation model, work plan and required resources for the preparatory phase of the ILC

https://arxiv.org/abs/2106.00602

KEK and JAHEP submitted a report to MEXT (Ministry of Education, Culture, Sports, Science and Technology) summarizing progress over the last 3 years

MEXT organized an expert panel in **July 2021**

ICFA ILC International Development Team

February 2022

MEXT Expert panel issued their recommendations

Conclude that **it still premature to proceed into the ILC Pre-lab phase** and, due to the financial situation, **re-evaluate the plan** and 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.

KEK

KEK will **reexamine the pa**th for realizing the ILC, taking into account the progress in various fronts including the FCC feasibility study.

KEK and the Japanese ILC community is **committed to further advance in the accelerator area**

KEK in collaboration with ILC-Japan, will establish a **new organization that will centrally manage ILC communications** activities focusing on communicating the importance to build an international laboratory for basic science

› https://www.kek.jp/en/topics-en/202202251335

ICFA ILC International Development Team

February 2022
MEXT Expert panel issued their recommendations

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› https://www.kek.jp/en/topics-en/202202251335

ICFA Statement Regarding Higgs Factory Development and the ILC (April 2022)

https://icfa.hep.net/wp-content/uploads/ICFA_Statement_April2022_Final.pdf



…oncerning the International Linear Collider (ILC), ICFA reaffirms its position that the concept for the ILC is technically robust and has reached a level of maturity which supports its moving forward with the engineering design study toward its timely realization. Indeed, recent accelerator projects across the globe confirm the readiness of the foundational superconducting accelerator technology.

ICFA commits to continuing efforts within the International Development Team (IDT) over the next year to coordinate the global research community's activities toward further developing and realizing the ILC in Japan. In particular, the IDT will work to further strengthen international collaboration among institutes and laboratories, and to expand the broad support from various stakeholders. ICFA will monitor developments over the next year to assess availability of resources and progress in international discussions.

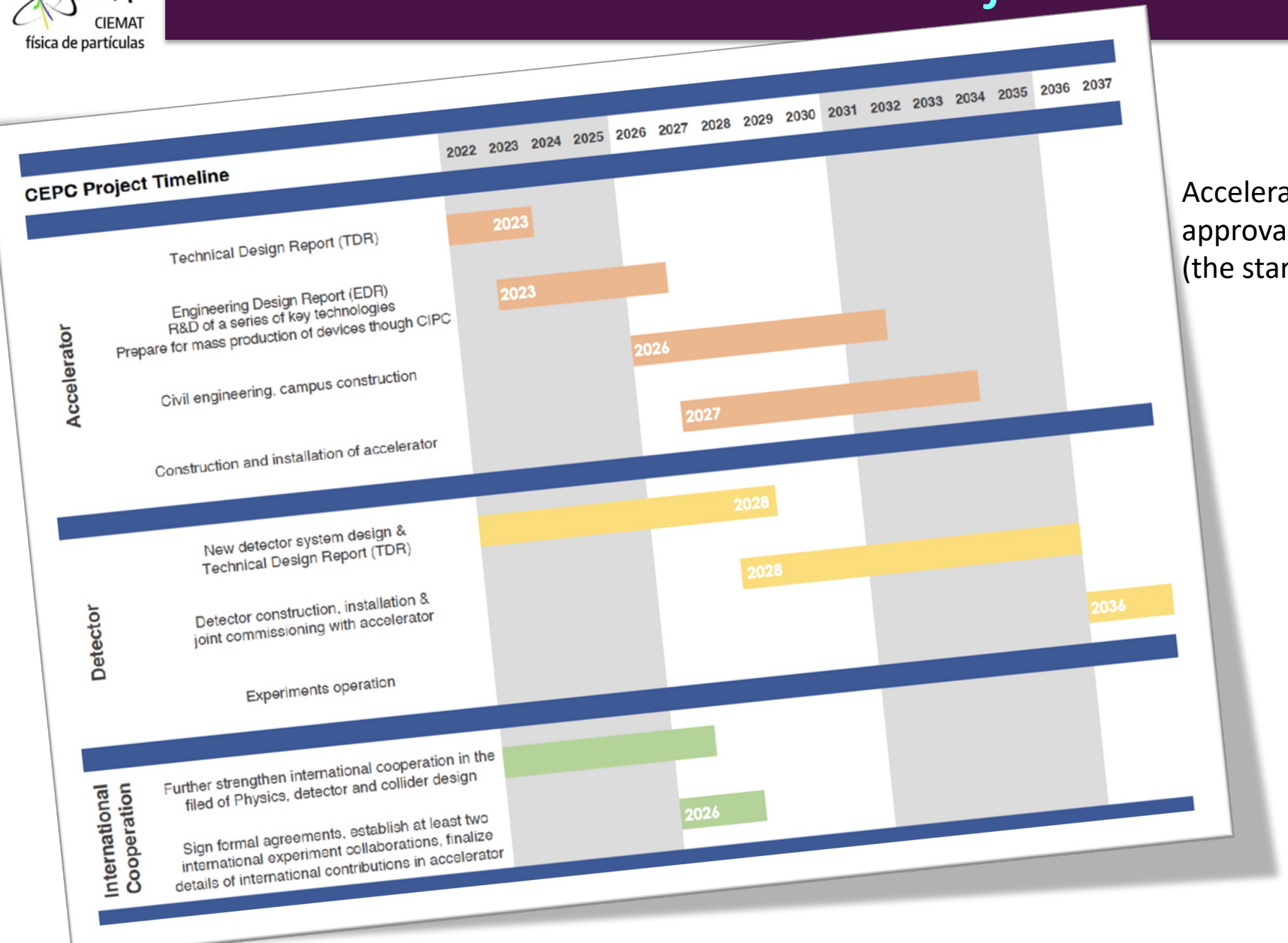
ICFA continues to encourage inter-governmental discussion between Japan and potential partner nations to advance international collaboration toward important research and development activities as well as coordination toward realization of an ILC.

An **IDT International Expert Panel (Decision process for a global project applicable to the ILC)** has been created

It discusses a general description of the evolution of a **global project** from conception to operation, which could be applicable to the ILC. Followed for a description pf the full lifecycle of the ILC project, suggesting processes decisions and potential consequences.

https://linearcollider.org/team/international-expert-panel/

CEPC Project Timeline

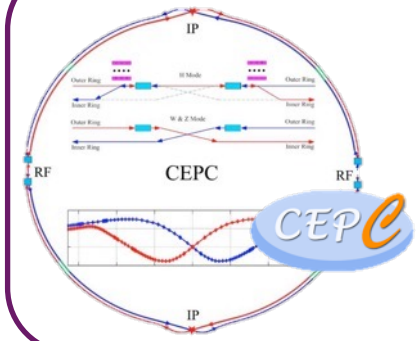


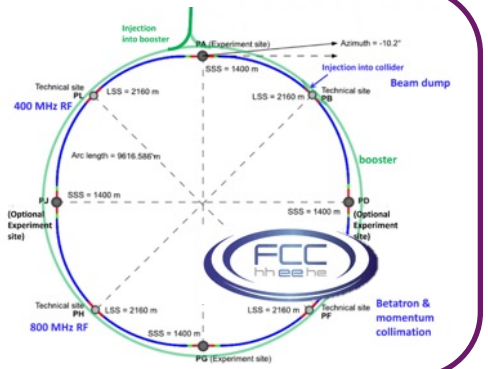
Accelerator EDR document completed for government's approval of starting construction around 2026
(the starting of the "15th five year plan" of China)

Panoramic view

e+e- Colliders

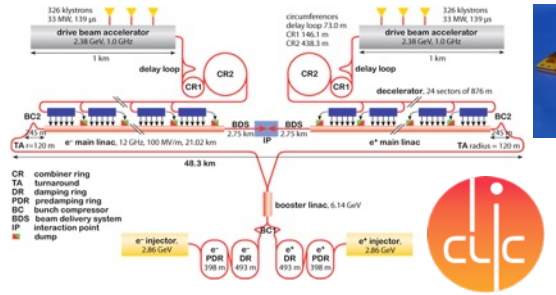
Circular

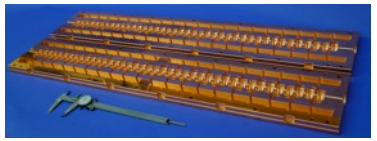




Linear

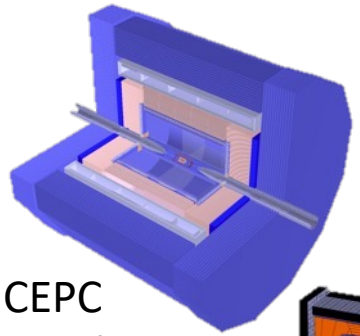




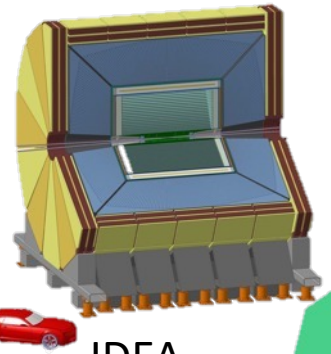


C3

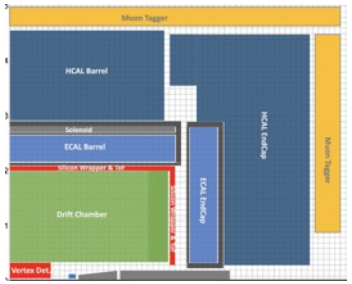
Detector Concepts



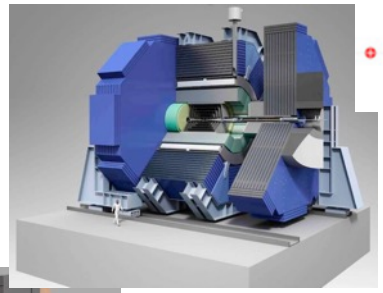
CEPC Baseline



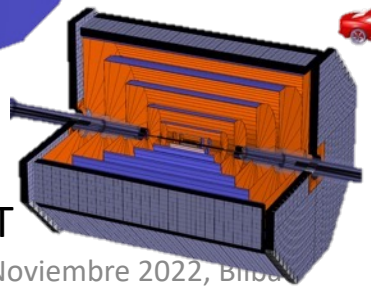
IDEA



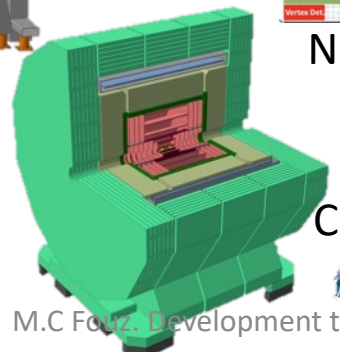
Noble LAr/LCr



SiD

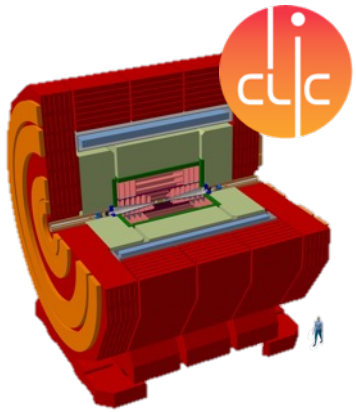


FST



CLD





Detector requirements

Precision measurements requires **detectors with high precision**, beyond the performance of present experiments

Vertex resolution $\sigma(d_0) \sim 5 \oplus 15/p[\text{GeV}]\sin^{3/2}\theta$ μm

Excellent track momentum resolution at high energies

$\sigma(p_T)/p_T \lesssim 2\text{x}10^{-5}\ \text{GeV}^{-1}$

Jet energy resolution $\sigma(E)/E \approx$ 3-4%

Good particle identification

Precision imposes important **challenges** on detectors, in **the detector technology** itself, but also on **electronics** and **mechanics**

Tracking: Very low material budget & smaller possible inner radius & excellent resolution

Reduced dead material between tracker and calorimeter

Compact calorimeters

For circular machines, is the active cooling needed? Which is the impact?

Precise timing will play an important role

Improve PID

Beam-induced background rejection

Pile-up rejection

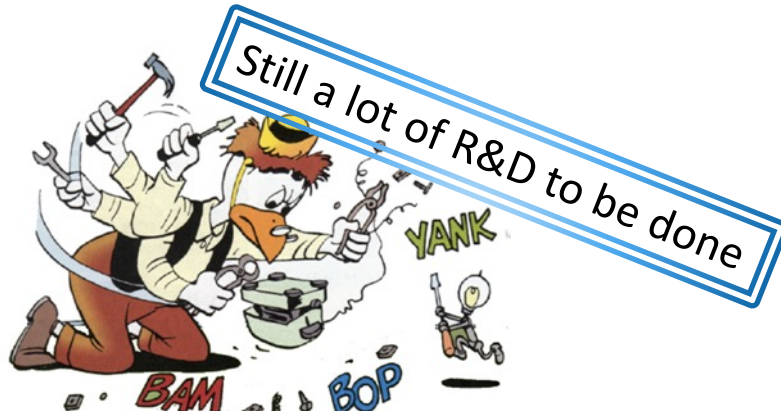
Improve calorimeter/tracker reconstruction

About the Z pole (Tera Z)

Very High rates (up to 100KHz)

Detector capabilities for flavor physics (b/c tagging, particle ID)

Needs optimization but it **cannot compromise the performance for Higgs Physics**



Some technologies under consideration - Tracker

Vertex detector

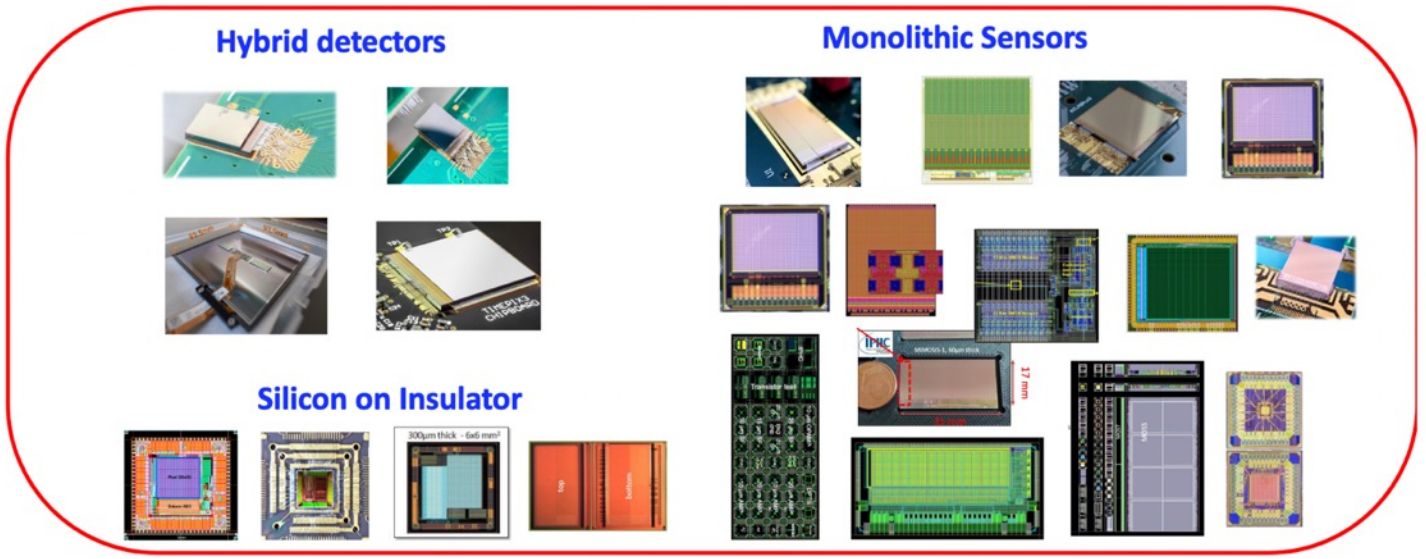
Silicon pixel detectors

Tracker options

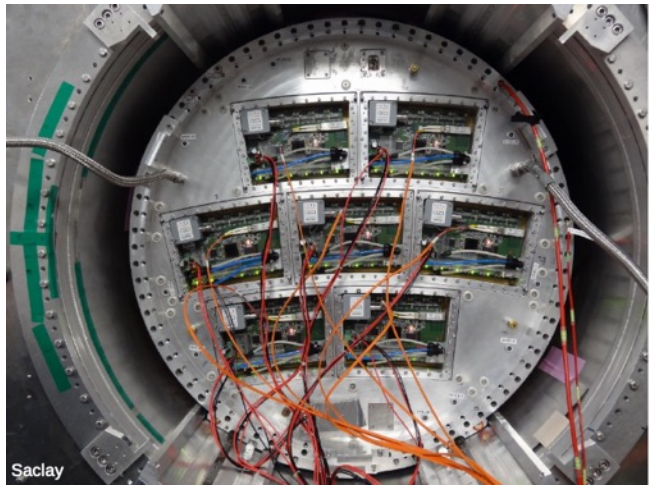
Silicon pixels/strips

TPC – (GEM/μMEGAS readout)
(complemented or not with Silicon Layers)

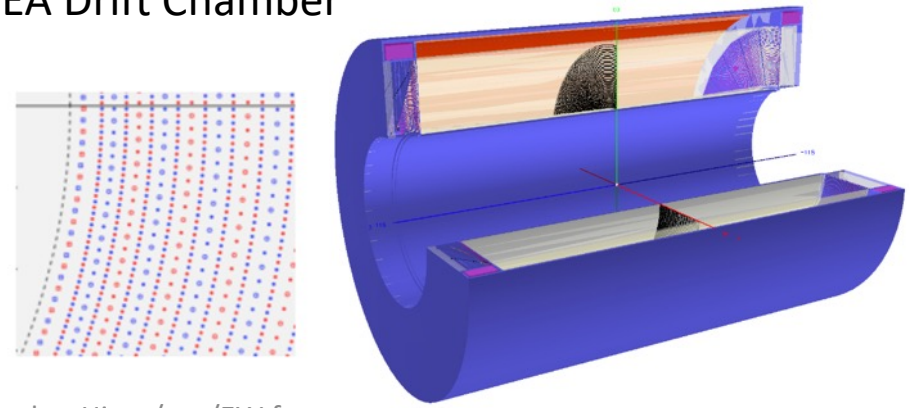
Drift Chambers (complemented with Silicon Layers)



From Dominik Dannheim's talk @ ECFA Workshop Oct 2022



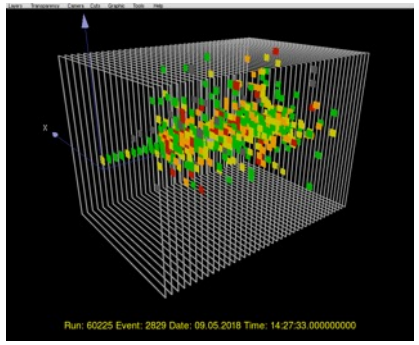
IDEA Drift Chamber

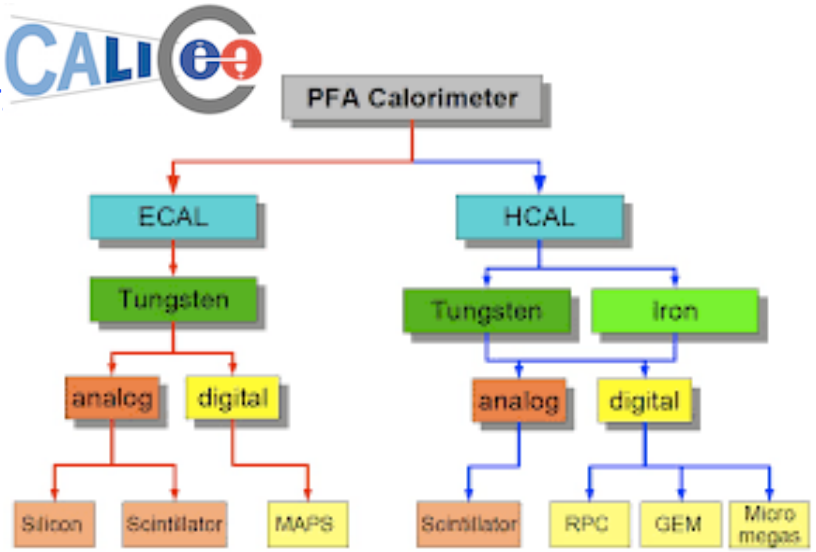


Some technologies under consideration - Calorimeter

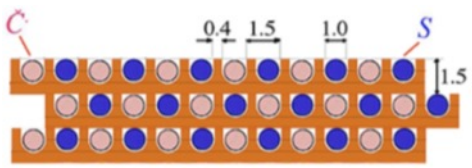
Calorimeters

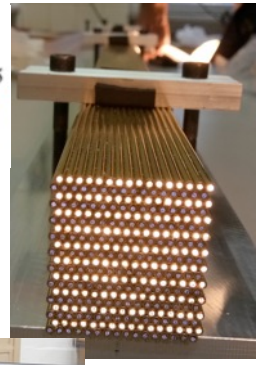
Highly segmented imaging calorimeter optimized for PFA





Dual read-out calorimeter





Fiber readout:

C - Cherenkov - e.m

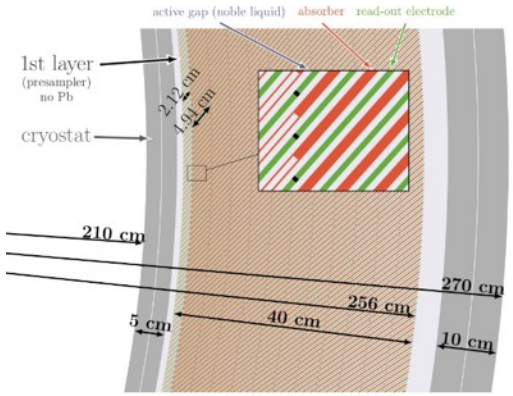
S - Scintillation Signal



Liquid Noble calorimeter

High granularity:

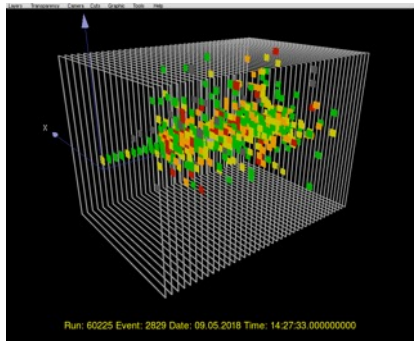
$\Delta\phi$ x $\Delta\theta$ = 16.4 x 10 mrad²

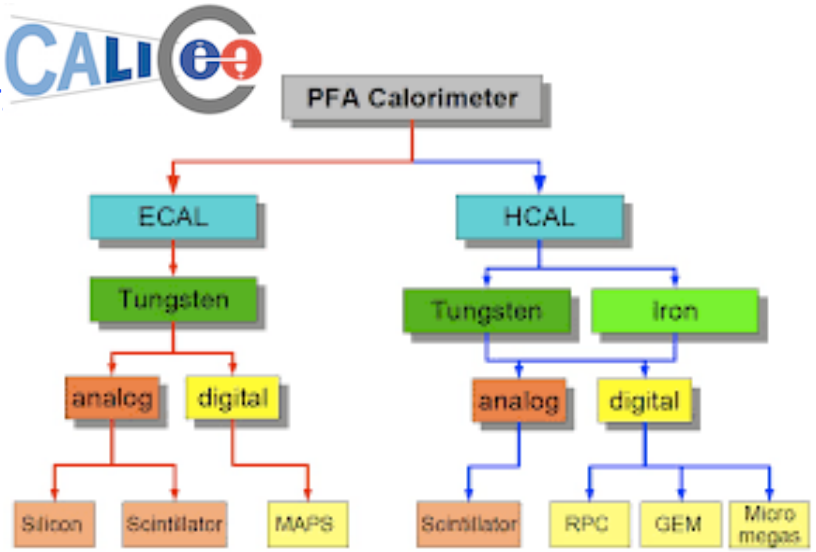


Some technologies under consideration - Calorimeter

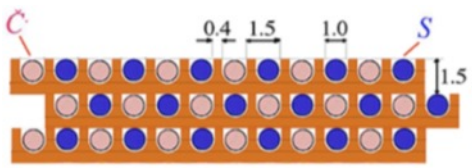
Calorimeters

Highly segmented imaging calorimeter optimized for PFA





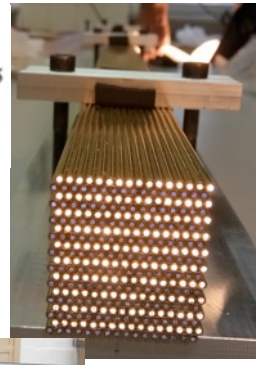
Dual read-out calorimeter

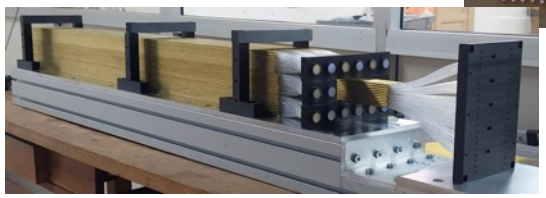


Fiber readout:

C - Cherenkov - e.m

S - Scintillation Signal

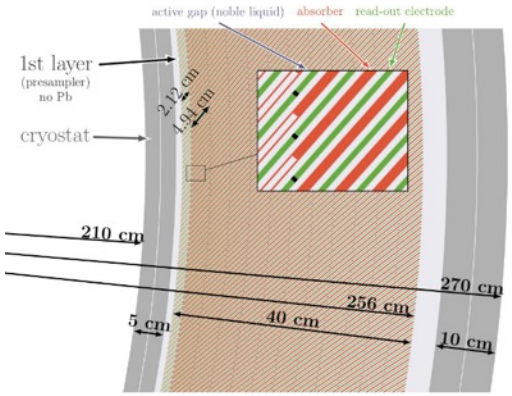




Liquid Noble calorimeter

High granularity:

$\Delta\phi$ x $\Delta\theta$ = 16.4 x 10 mrad²

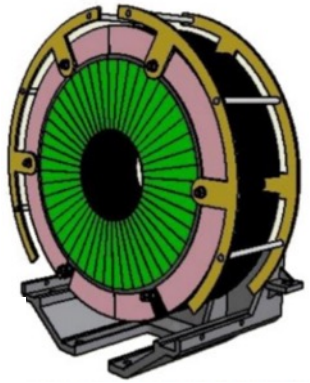


Forward Calorimeters

LumiCal:

Precise luminosity measurement using Bhabhas

Si-W sampling calorimeter
30 layers (1 X0 each)

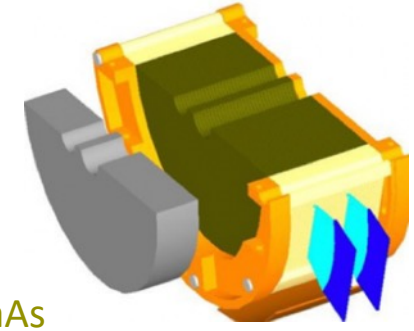


BeamCal:

Fast luminosity measurement using beamstrahlung

XX-W sampling calorimeter
30 layers (1 X0 each)

XX Candidates: Saphire, CVD Diamond, GaAs



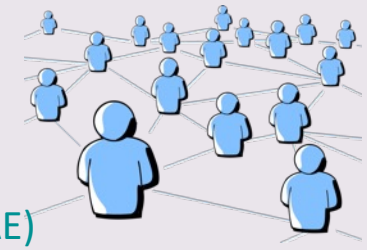
DEVELOPMENTS FOR FUTURE HIGGS FACTORIES IN SPAIN

The Spanish community is involved in developments for future e+e- colliders **since ~2006**, first focused in **linear colliders** (ILC and CLIC), **playing major roles in the international activities**, and after extended them to the **circular machines** proposed more recently

The Spanish contribution to this activities has been articulated with the support of the **Spanish network for future accelerators and detectors**

At present **12 institutes** participate in this **network**, including the most relevant **institutes of particle physics and technological centers for accelerator and detectors**. In addition, the association **INEUSTAR/INDUCIENCIA** is an **associated member** to extend the contacts with the Spanish industry

ALBA/CELLS
CIEMAT
CNM-IMB
ESS Bilbao
IFAE (ICREA/IFAE)
IFCA (CSIC-Univ. Cantabria)



IFIC (CSIC-Univ. Valencia)
IFT – Instituto de Física Teórica
ITAINNOVA
U. de Granada
U. de Santiago de Compostela
U. de Sevilla

ACTIVITIES

- ✓ **Phenomenological** studies for the potential of future Higgs/top factories
- ✓ **Accelerator** developments: On **magnets** and **acceleration cavities**
- ✓ **Detector**: R&D, design and operation, centered on **silicon detectors and calorimeters**



Developments on accelerators for Higgs Factories

Groups involved

- ALBA
- CIEMAT — Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
- IFIC — Institut de Física Corpuscular

Developments on accelerators for Higgs Factories - ALBA

Ciemat
cfp CIEMAT
física de partículas

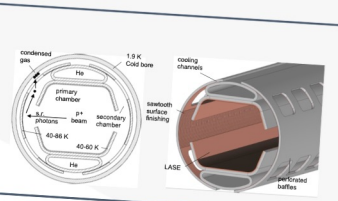
Generalitat de Catalunya

ALBA

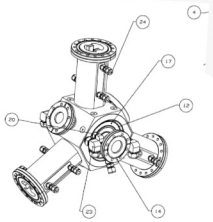


ALBA Contribution to Future Colliders

- EU H2020 Project EuroCirCol (2018-21)
  - WP4: FCC **Cryogenic Beam Vacuum System**



- Contract KE with CLIC-CERN (2017-2020):
  - WP1: Damping Ring Stripline Kicker tests
  - WP2: Collective Effects
  - WP3: **Beam Instrumentation & Diagnostics**
  - WP4: Damping Ring **RF System**

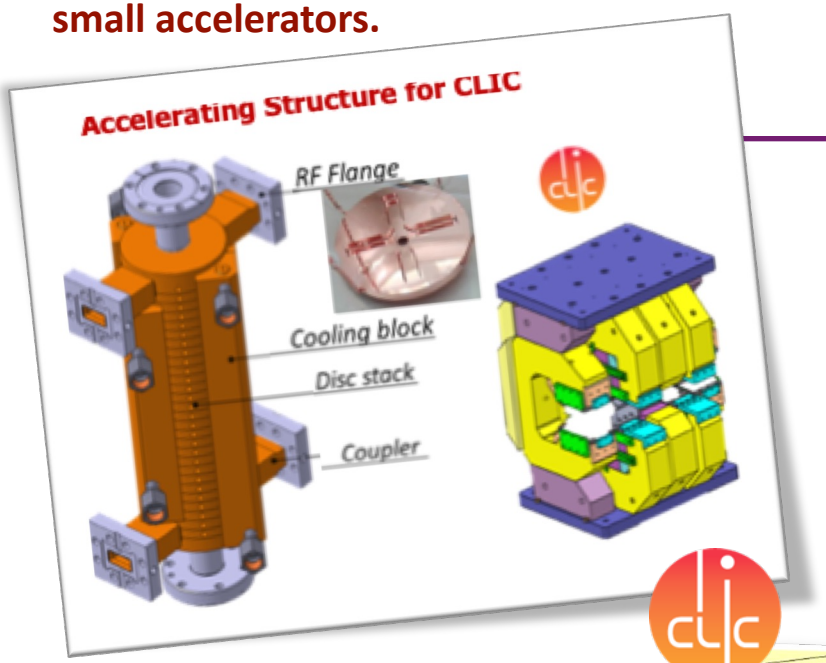


- Contract KE with FCC-CERN (2018-2021-2023):
  - **High Temperature Superconductors** for the **FCC Vacuum Screen**
- EU H2020 - ARIES – ADA (2017-2021)
  - WP8: **Diagnostics** for future accelerators
- Contract KE with FCC-CLIC-CERN (2018-2021-2024)
  - Novel **electron imaging diagnostics** for future accelerators

Developments on accelerators for Higgs Factories - CIEMAT

Within the Electrical Engineering Division (ascribed to the Technology Department), the Accelerator Technology Unit develops different activities related to accelerator components, basically **superconducting, conventional and special magnets and RF components as well as complete small accelerators.**





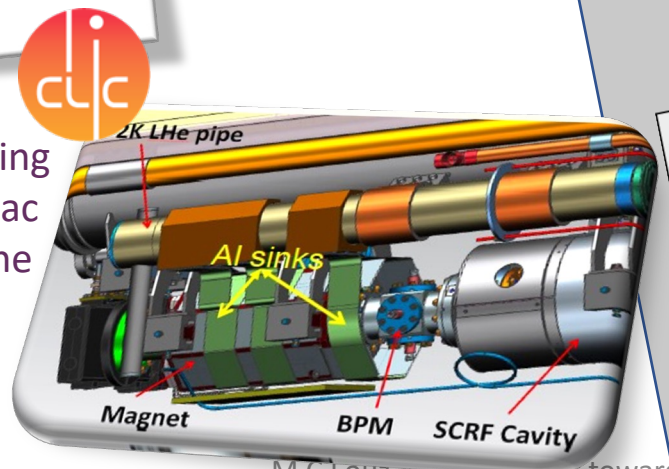
CIEMAT

Centro de Investigaciones Energéticas, Medi

The PRISMAC Program

PRISMAC: A CIEMAT-CDTI Collaboration Program for Research on High Field Magnets, Supported by SGI/MCI & CERN

	CERN	CIEMAT	CDTI	SECRETARIA GENERAL DE INVESTIGACIÓN
HL-LHC MCBXF Magnets In-Kind Contribution Facility for very high field superconducting magnet prototypes Development of FCC model magnets	• Training & Support on magnets and facilities • Use of Facilities during the set-up of CIEMAT Laboratory • Qualification of CIEMAT as a Technological Partner	• Providing a team, facilities and economical resources to all the activities • Prototype Development • Technology Transfer to Industry • Series Fabrication Follow-up • Qualification of Industry as Industrial Partners • Management of IK contribution to CERN	• Project Funding • Industrial exploitation of the associated technologies (Early Alert) • Dissemination of the developed technologies to other fields (i.e. Space. Fusion, Light Sources, Energy..)	• Funding the series production, components and new personnel • Supporting the Spanish Traineeship Program (FTEC) • Supporting the R&D Program on Key Technologies



Conduction cooled superconducting magnets allocated in the Main Linac Cryomodules to focus and steer the beam.

The contribution includes the **Magnet Power Supply and the Beam Position Monitor.**

Developments on accelerators for Higgs Factories - IFIC

Development of ILC BPM (IFIC)

Financiado por la Unión Europea NextGenerationEU

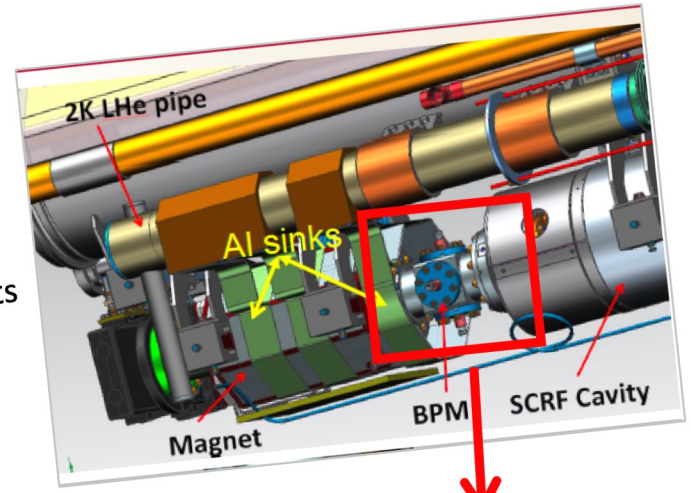
Grupo de aceleradores de partículas del IFIC:

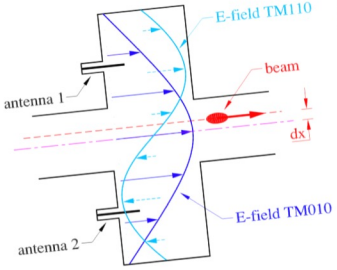
J. Fuster, B. Gimeno, D. Esperante, N. Fuster-Martínez, C. Blanch, D. González-Iglesias, P. Martínez-Reviriego, P. Martín-Luna, A. Menéndez.

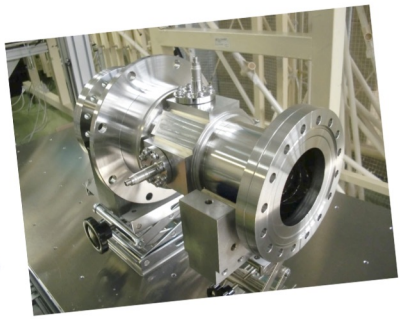
https://aitanatop.ific.uv.es/aitanatop

- **Reentrant cavity BPM** (Beam Position Monitor)
  - High precision BPM with nanometer resolution.
- To be integrated with the splittable superconducting magnets allocated in the Main Linac Cryomodules:
  - Collaboration with CIEMAT proposed by 2020.
- Design and construction of a reentrant cavity BPM.
  - Baseline prototype already existing. To be provided by KEK.
  - Design studies commencing beginning 2023.
  - Construction foreseen for 2024 by Spanish company.
  - Tests with beam proposed for 2025.
  - Part of the R&D will be based on performance and cost optimization of the already existing prototypes.
- Readout electronics to be developed as well.
  - Aim to build a readout protype at IFIC.

- Funded by Valencian Government (end of 2022), Next Generation EU.

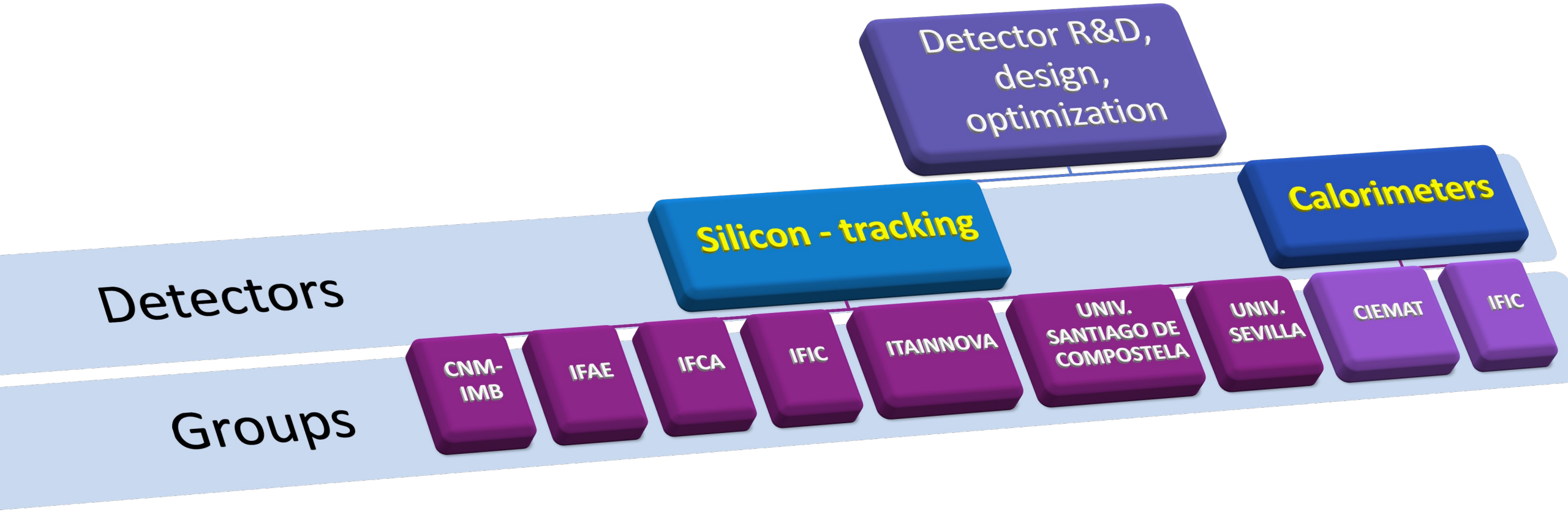






IFIC

Spanish institutes working on detector developments for future Higgs factories



Developments on silicon detectors for Higgs Factories & LHC Synergies

Main silicon detector R&D in the Spanish groups related to:
3D detectors, LGADS, CMOS-DMAPS.

Synergies with the developments for **HL-LHC** and **Run3 LHC**

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CMOS Technology **Radiation hardness, low material budget**

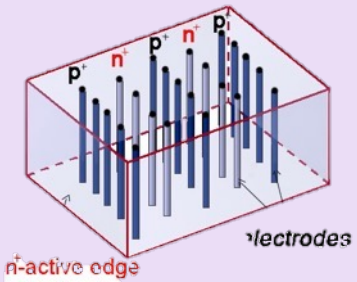
In ***Run3 LHC upgrade*** for **LHCb VELO:**
VeloPix a 130 nm CMOS technology

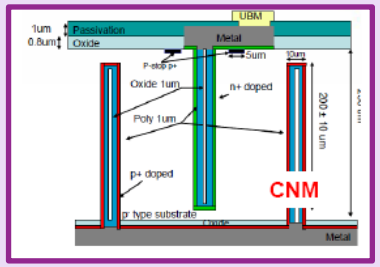
Developments on silicon detectors for Higgs Factories & LHC Synergies

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3D detectors

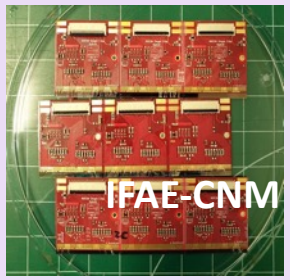
Radiation hardness, timing





In ***HL-LHC upgrades*** for inner layers of:

- **ATLAS ITK**
- **CMS pixel**



Prototype modules for the ATLAS Tracker Upgrade for HL-LHC (ITk)

CMOS Technology

Radiation hardness, low material budget

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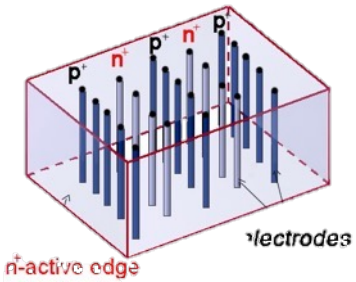
CMOS Technology

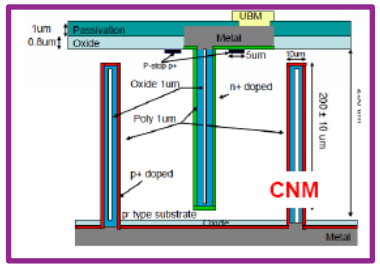
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In ***Run3 LHC upgrade*** for **LHCb VELO:**
VeloPix a 130 nm CMOS technology

3D detectors

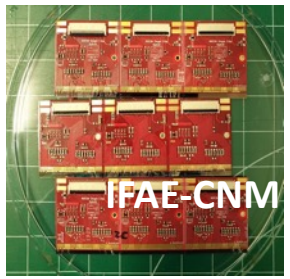
Radiation hardness, timing





In ***HL-LHC upgrades*** for inner layers of:

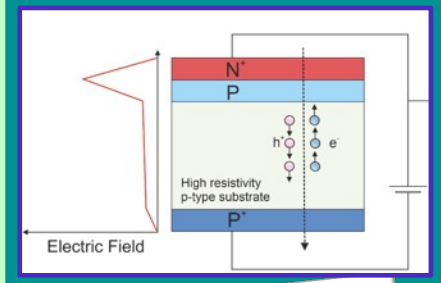
- **ATLAS ITK**
- **CMS pixel**

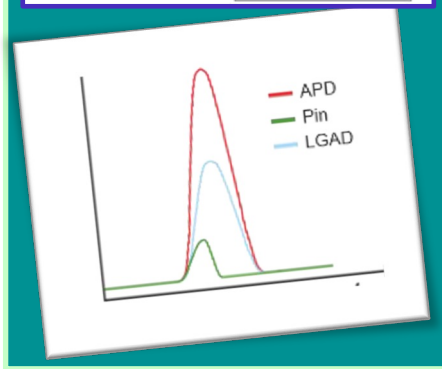


Prototype modules for the ATLAS Tracker Upgrade for HL-LHC (ITk)

LGADs

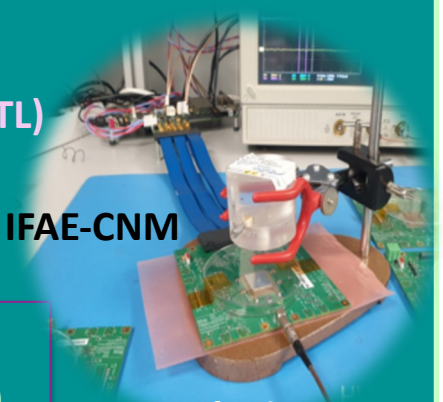
Low Gain Avalanche Detectors (LGADs), introduced in HEP by the Institute of Microelectronics of Barcelona **(IMB-CNM)** ~10 years ago





In ***HL-LHC upgrades*** for

- **ATLAS High Granularity Timing Detector (HGTD)**
- **CMS Endcap Timing Layer (ETL)**



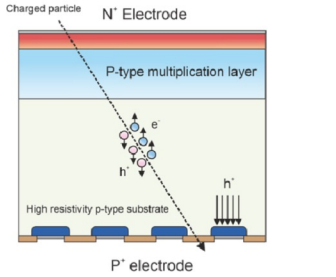
Prototype for the ATLAS HGTD for HL-LHC

It is the *most promising **Time and Position**-Sensitive Detector* (TPSD) to implement the **4D tracking concept**.

Developments on silicon detectors for Higgs Factories

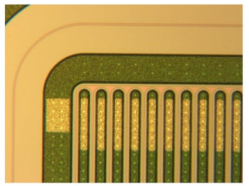
R&D to enable the high-precision 4D tracking concept

R&D on several LGAD-based TPSD sensors inside the AIDAInnova and RD50 collaborations: I-LGADs and AC-LGADs.

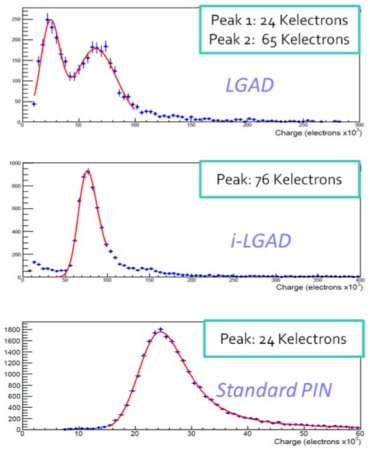


iLGAD TECHNOLOGY (iLG1)

- Multiplication extended over the electrode.
- Hole collection
- Complex double side process



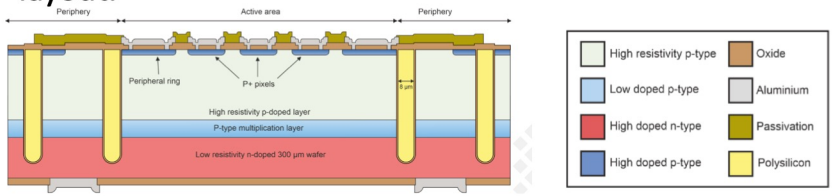
Gain Spatial Uniformity: Collected Charge



Proof-of-concept from IMB-CNM microstrip prototype demostrated at test beam in 2018
(300um thick and no time readout).

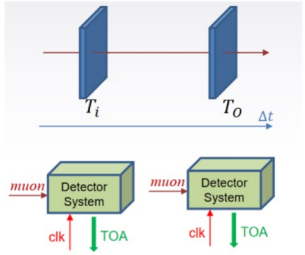
I. Vila, 13th Trento Workshop, February 2018

New production (to be ready by Q2 - 2023) of thin ILGAD being manufactured at **IMB-CNM** with timepix layout.



Basic layout for thin single-sided ILGADs

ITAinnova working in a high precision clock distribution system for multilayered timing detectors based on CERN *White rabbit protocol.*

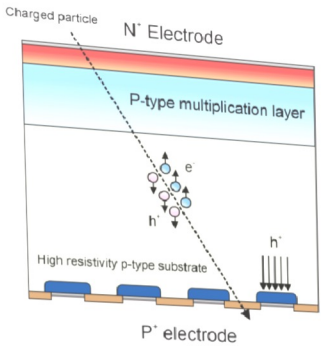




Developments on silicon detectors for Higgs Factories

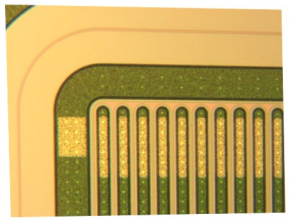
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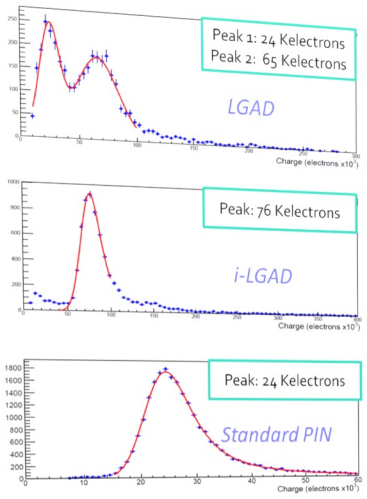


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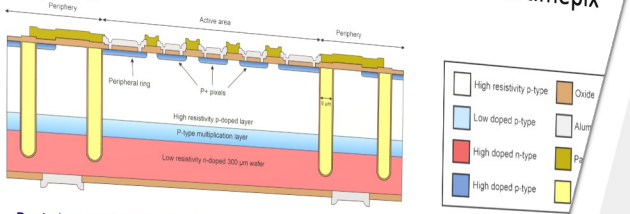
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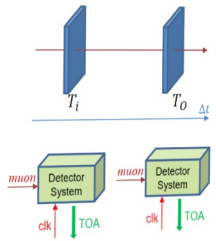
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RD50

AIDA innova

Plan de Recuperación, Transformación y Resiliencia

Universidad de Sevilla

Grupo Ingeniería Electrónica, Escuela Técnica Superior de Ingeniería

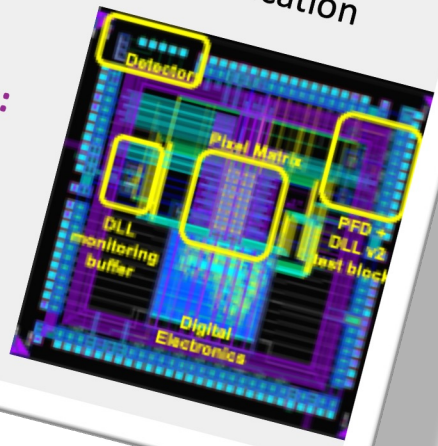
New Depleted **Monolitich Active Pixel Sensors (DMAPS)** fabricated in the LFoundry 150 nm HV-CMOS process developed inside RD50

Participation in **tests and design**
RD50-MPW2 under tests
RD50-MPW3 sent to fabrication

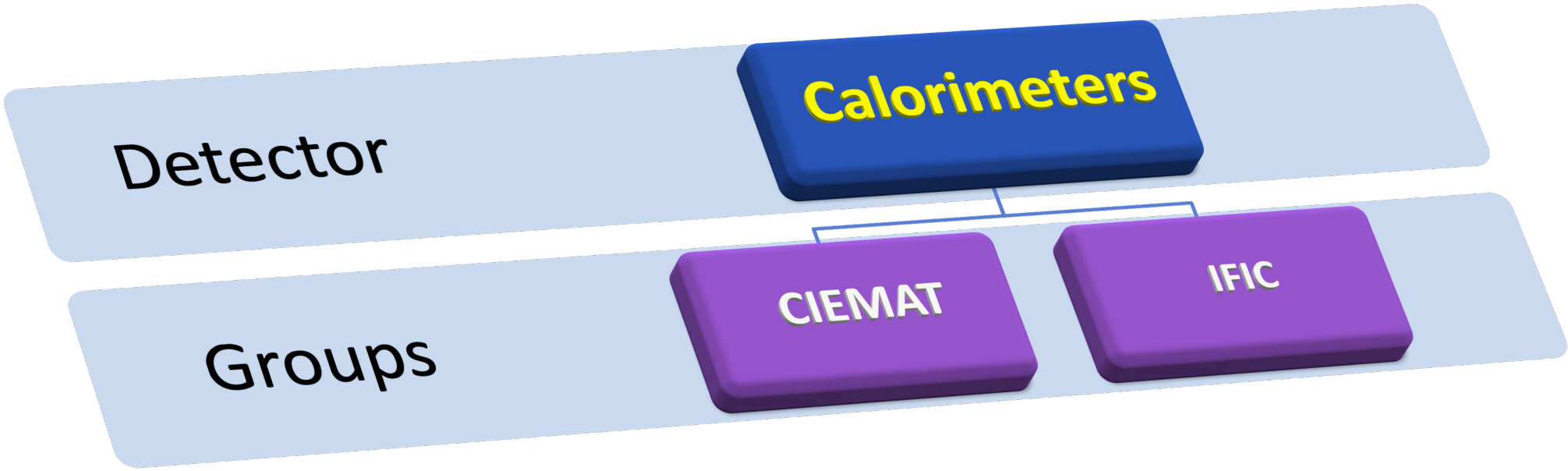
RD50

A new detector developed at U. Sevilla: NANOMAPS

Based on MPW3 but with modifications in pixel size and front-end electronics



Developments on calorimetry for Higgs Factories



Developing highly granular calorimetry optimised for particle flow reconstruction for future electron-positron colliders.

336 physicists/engineers, 60 institutes,18 countries across the world

Calorimetry Developments in Spanish Institutes

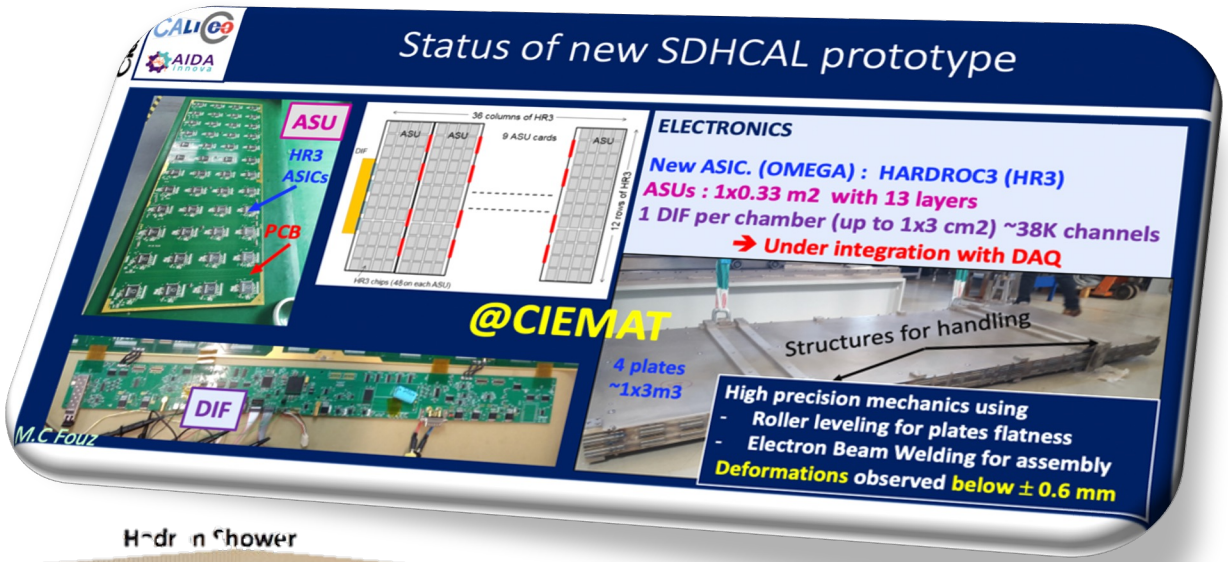
Ciemat

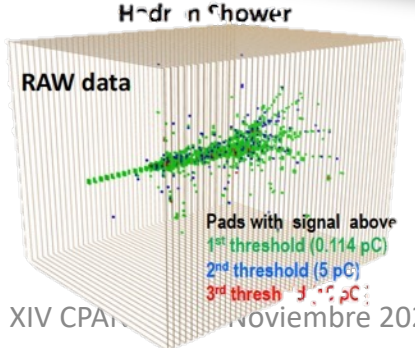
SINCE 2007

Main contributions to **SDHCAL**
SemiDigital Hadronic CALorimeter
Stainless Steal+RPC Readout 1cm² pads
Responsibilities in **Mechanics, Electronics and data analysis**



Status of new SDHCAL prototype





Next Steps

Include timing ➔5D Calorimeter
Multigap RPC + new ASICs

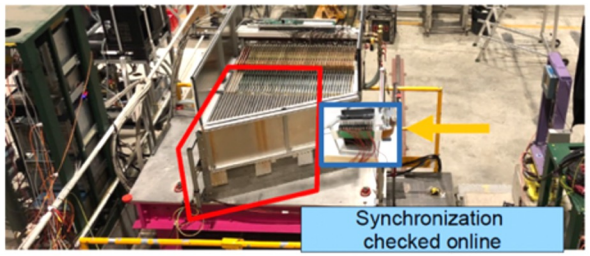
IFIC INSTITUT DE FÍSICA CORPUSCULAR

Main contributions to **Si-W ECAL**
Tungsten + Silicon 0.5x0.5 cm2 pads

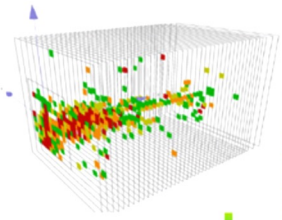
SINCE 2019

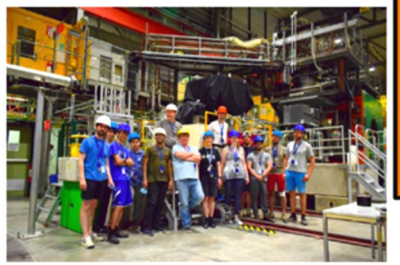
Common beam test CERN SPS 06/2022

AHCAL :
- 38 layers 72×72 cm²
- 3×3 cells scintillator + SiPM
- 1.7 cm Stainless Steel (~4λ)
- 6t, 1×1×1.5 m³



SiW-ECAL
- 15 layers 18×18 cm²
- 0.5×0.5 cm² Si cells
- 2.8+5.6 mm W (21 X₀)
- 100 kg, 0.4×0.4×80 cm³





IFIC (A. Irles) was in charge of:
- full detector commissioning
- Common DAQ
- Detector calibration (with contributions from CIEMAT – H. García)
- Run Coordination

Same for DESY beam tests (Nov 2021, March 2022)

Presentations at CALOR2022, ICHEP2022. CALICE Collaboration Meeting in Valencia – April 2022

adrian.irles@ific.uv.es

IFIC

Some very recent contributions

Physic studies

Contribution on bottom quark mass prospects – for Snowmass

- J. Aparisi et al., Prospects for , arXiv:2203.16994
- D. d'Enterria et al., The strong coupling constant, arXiv:2203.08271
- J. Aparisi et al., mb(mH), PRL128 (2022) 12, 122001

Contribution on the top quark physics program – for Snowmass

- G. Durieux et al., prospects for top quark couplings, arXiv:2205.02140
- J. de Blas et al., Global SMEFT fit at Future Colliders, arXiv:2206.08326
- A. Belloni et al., Report on EW precision and new physics, arXiv:2209.08078
- K. Agashe et al., Report on top physics and heavy flavour, arXiv:2209.11267
- F. Maltoni et al., Report on theory for collider physics, arXiv:2210.02591

Others

- J. Alcaraz et al, The Z lineshape challenge. arXiv: 2107.00616

10-20% of working time of a student/post-doc can produce a small paper



Physic studies & detectors

- ILC white paper, arXiv:2203.07622

- FCC white paper, arXiv:2203.06520

Summary

Physics collider community is very focused on the HLC and HL-LHC (people and budget) but ***the continuation of the collider physics area*** requires to put some ***efforts on developments for the next collider***
(long path since the firsts studies of a new collider till the execution of the project).

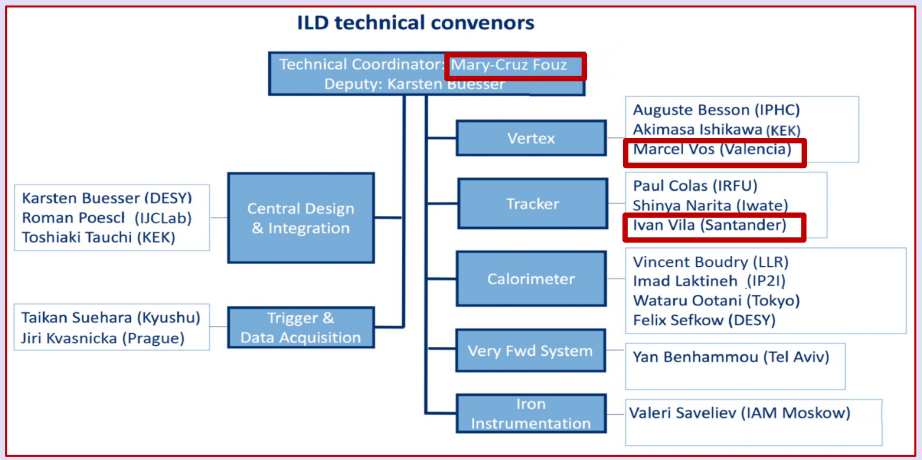
Important effort in Europa towards the preparation for next collider: ***e+e- Higgs factory***

Spanish community has contributed significantly to the

⇒ design of **experiments** for future e+e- colliders (**detector & physic studies**), as for example
Contributions to the CLIC Conceptual Design Report (CDR)
Contributions to the LOI of the ILD experiment for ILC, arXiv:1006.3396
Strong involvement on the ILC DBD Vol4 arXiv:1306.6329
Editors (*J. Fuster-IFIC*) & sub-editors (*MC Fouz-CIEMAT, A. Ruiz Jimeno-IFCA, I. Vila-ICFA, M. Vos-IFIC*)

⇒ to accelerator

Spanish community,
has also coordination positions for the ILD detectors,
for **vertex, tracker,**
and as **Technical coordinator**



Members of **our community** occupy **coordination positions** on the ***ECFA studies*** for the next Higgs/top/EW factory

For contributions or just follow activities

To follow the ongoing ECFA activities and workshops

- Subscribe to the ECFA-Workshop-Higgs-factory CERN mailing list
- General page for meetings/workshops/seminars. https://indico.cern.ch/category/14055/

Interested on participating in this effort?

Contact the WG1, WG2, WG3 coordinators:

ECFA-Workshop-Higgs-factory-coords@cern.ch



A lot of space for contributions, both in ***detector*** and ***benchmark physics studies***.

Projecto *PID2021-122134NB-C22* financiado por

MINISTERIO DE CIENCIA E INNOVACIÓN

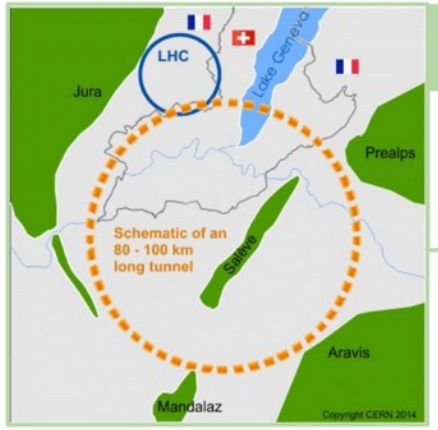
AGENCIA ESTATAL DE INVESTIGACIÓN

THANK YOU FOR YOUR ATTENTION



BACK-UP

Future e^+e^- colliders

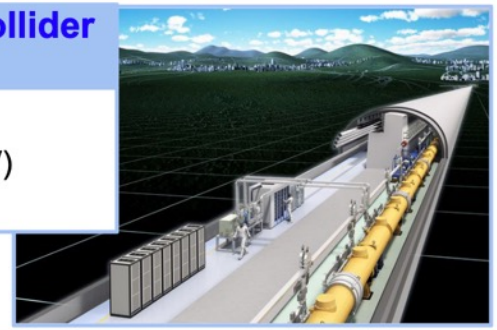


Future Circular Collider (FCC-ee)

CERN
e^-e^+, $\sqrt{s}$: 90 - 365 GeV
(followed by pp, $\sqrt{s}$: ~100 TeV)
Circumference: 97.75 km

International Linear Collider (ILC)

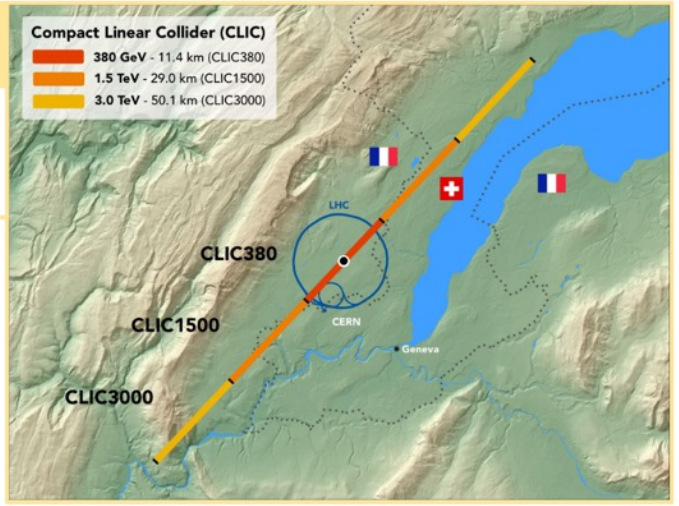
Japan (Kitakami)
e^-e^+, $\sqrt{s}$: 250 GeV (500 GeV)
Length: 17 km (31 km)





Compact Linear Collider (CLIC)

CERN
e^-e^+, $\sqrt{s}$: 380 GeV, 1.5 TeV, 3 TeV
Length: 11 km, 29 km , 50 km



Circular Electron Positron Collider (CEPC)

China
e^-e^+, $\sqrt{s}$: 90 – 240 GeV
(followed by pp, $\sqrt{s}$: ~100 TeV)
Circumference: ~100 km

CLIC, CERN

380 GeV,	8 y	→ 1 ab^{-1}
1500 GeV,	7 y	2.5 ab^{-1}
3000 GeV,	8.5 y	5 ab^{-1}

ILC, Japan

250 GeV,	11 y	→ 2 ab^{-1}
500 GeV,	8.5 y	4 ab^{-1}
1000 GeV,	8.5 y	8 ab^{-1}

CEPC, China

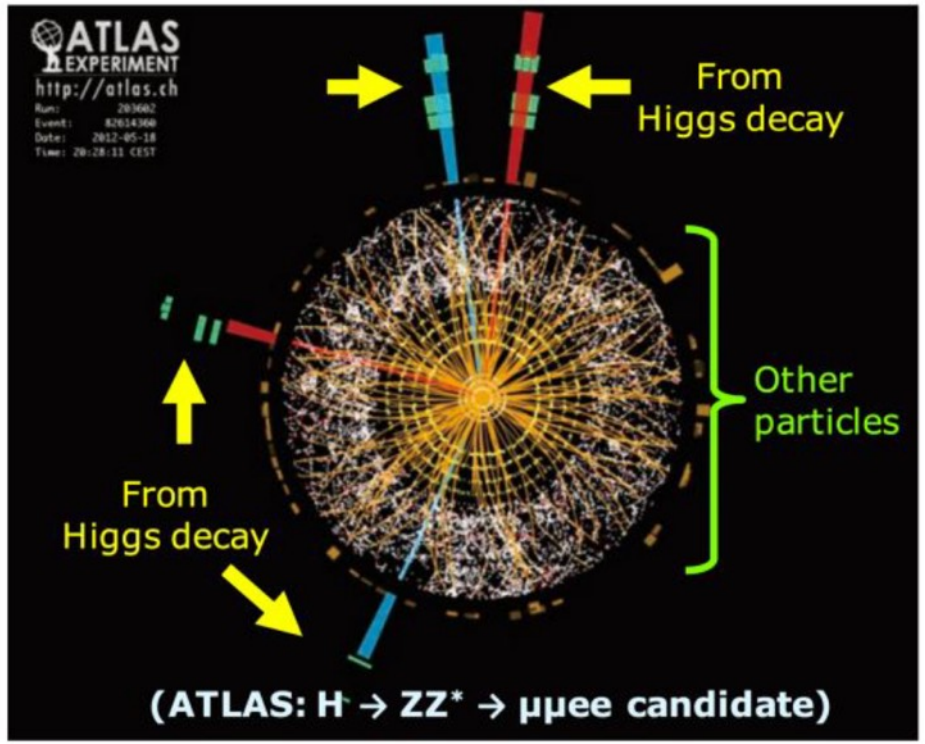
m_Z,	2 y	→ 16 ab^{-1}
2 x m_W,	1 y	→ 2.6 ab^{-1}
240 GeV,	7 y	→ 5.6 ab^{-1}

FCC-ee, CERN

m_Z,	4 y	→ 150 ab^{-1}
2 x m_W,	1-2 y	→ 10 ab^{-1}
240 GeV,	3 y	→ 5 ab^{-1}
2 x m_{top},	5y	→ 1.5 ab^{-1}

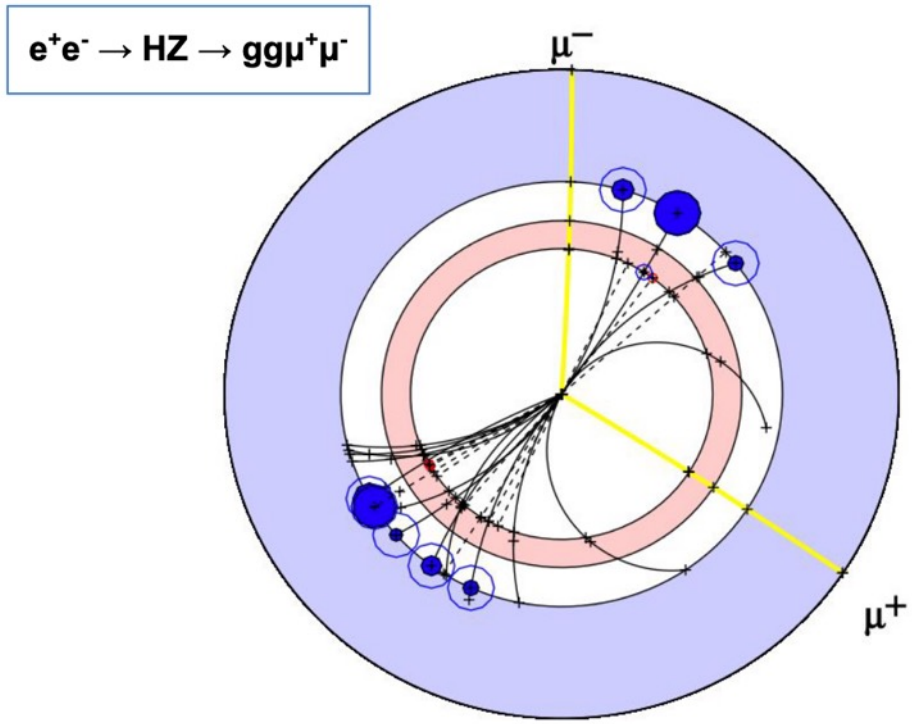
Hadron vs. lepton colliders

pp collisions



Proton-proton collision: Search for small signal in a large background

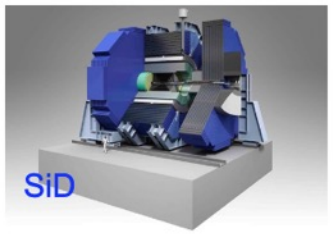
e^+e^- collisions

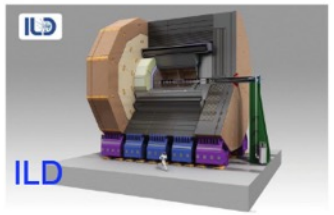


Electron-electron collision: Measure everything and precisely

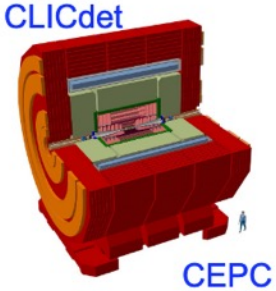
Vertex/tracking detector concepts

Collider	ILC		CLIC	FCC-ee			CEPC	
Detector Concept	SiD	ILD	CLICdet	CLD	FCC-ee IDEA	Noble LAr/LCr	CEPC baseline	CEPC IDEA
B-field [T]	5	4	4	2	2	2	3	2
Vertex inner radius [mm]	14	14	31	17 → **12**	17 → **12**	17 → **12**	16	16
Tracker out. radius [m]	1.25	1.8	1.5	2.2	2.0	2.0	1.81	2.05
Vertex	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel
Tracker	Si-strips	TPC/ Si-strips	Si-pixel	Si-pixel	DC/ Si-strips	DC/Si-strips or Si-pixel	TPC/Si-strips or Si-strips	DC/ Si-strips

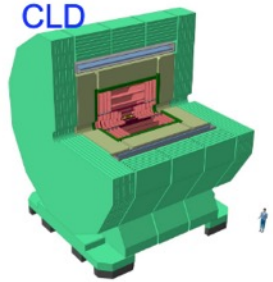




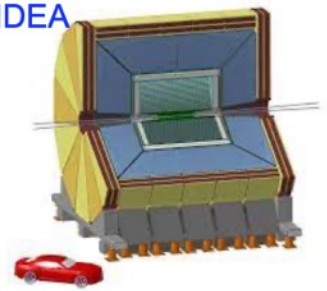
CLICdet



CLD



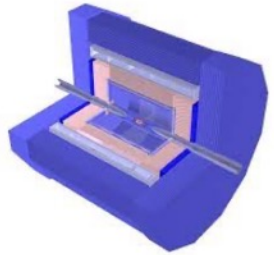
IDEA



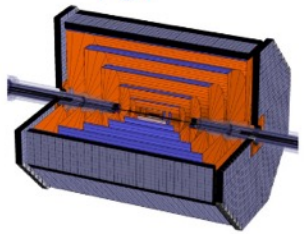
Noble LAr/LCr



CEPC baseline



FST



LHC Timeline till Higgs discovery

✓	~1980:	First ideas for a muli-TeV proton collider at CERN
✓	Oct 1990:	ECFA LHC Workshop in Aachen
✓	16 Dec 1994:	CERN Council approved the LHC project
✓	Feb 1996:	Approval ATLAS and CMS
✓	Apr 1998:	Begin of construction
✓	7 Mar 2005:	Installation of the first dipole magnet
✓	26 Apr 2007:	Installation of the last dipole magnet
✓	10 Sep 2008:	First circulating proton beams
✓	Oct 2009:	First proton-proton collisions
✓	Jul 2012:	Discovery of the Higgs