MINISTERIO DE CIENCIA E INNOVACIÓN

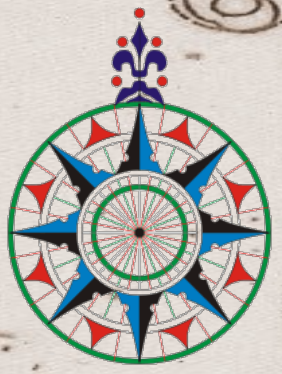
CSIC

IFIC INSTITUT DE FÍSICA CORPUSCULAR

VNIVERSITAT DE VALÈNCIA

AITANA
MATTER AND TECHNOLOGY
https://aitanatop.ific.uv.es/aitanatop/

Spanish linear-collider effort



Juan A. Fuster Verdú – IFIC, València

Jornadas de la red española de futuros colisionadores, Valencia, July 1-2 2024

CLIC Collaborations

https://clic.cern

CLIC accelerator:

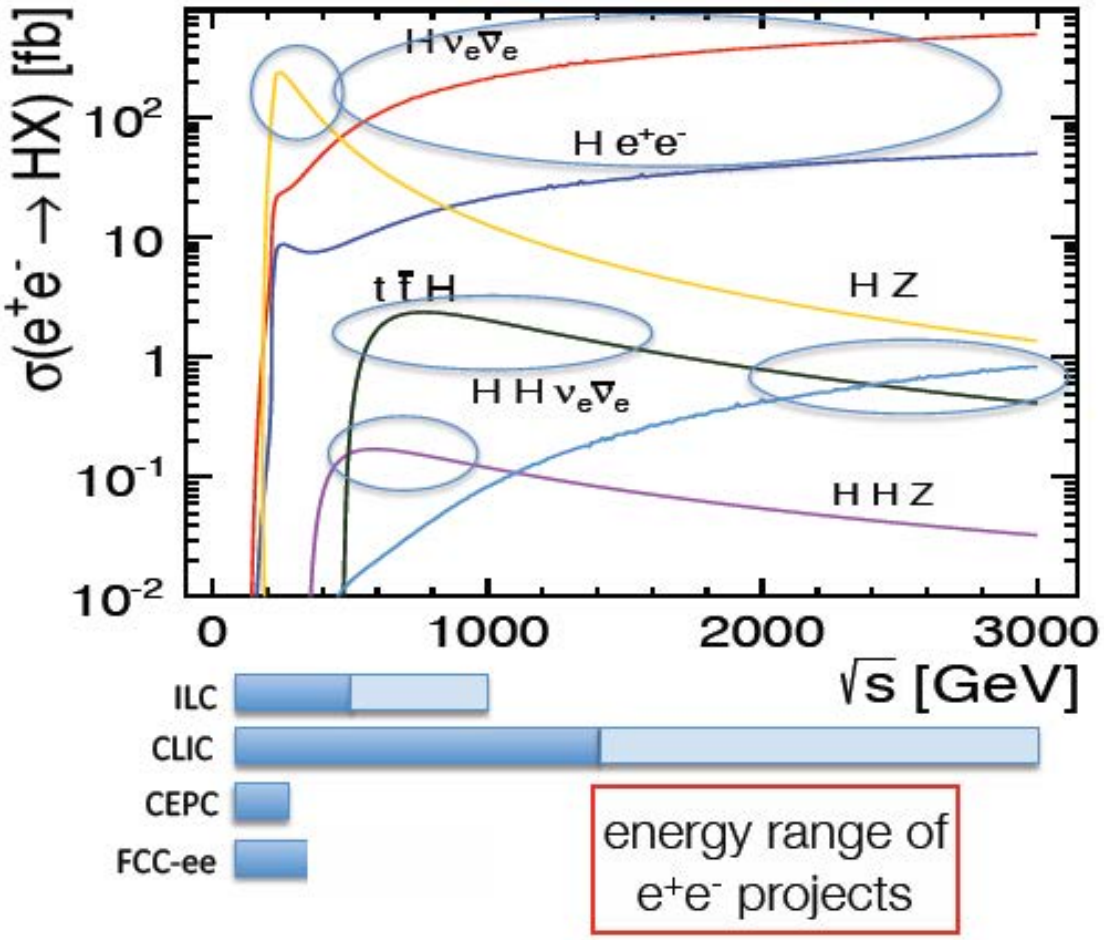
- ~50 institutes from 28 countries
- CLIC accelerator studies, design and development
- Construction + operation of CLIC Test Facility, CTF3

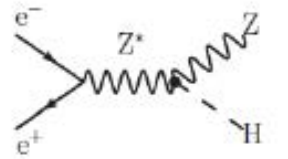
CLIC detector and physics (CLICdp):

- 30 institutes from 18 countries
- Physics prospects & simulation studies
- Detector optimisation + R&D for CLIC

ILC in Japan

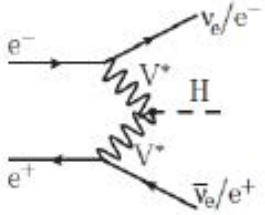

All ILC
Global Design Effort
Physics and Detectors
航空写真
アジア
大西洋
アフリカ
南アメリカ
太平洋
インド洋
オーストラリア
太平洋
Google





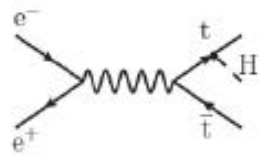
Mass
g_Z (m.i.)
BR's
(LHC)-invisible

≥ 250 GeV



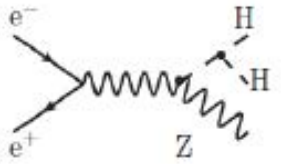
Γ_{tot}

≥350 GeV



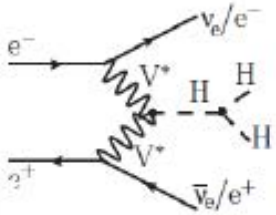
g_t

≥500 GeV



g_{HHH}

≥500 GeV



g_{HHH}

≥ 1 TeV

Many processes at different √s needed & accessible

- e^+e^- collisions $\sqrt{s}$ up to 3 TeV
- Luminosity: a few 10^{34} $cm^{-2}s^{-1}$

CLIC: e^+e^- @ 0.38, 1.4, 3 TeV
Conceptual Design **2013**
Updated Baseline in **2017**
2-beam acceleration

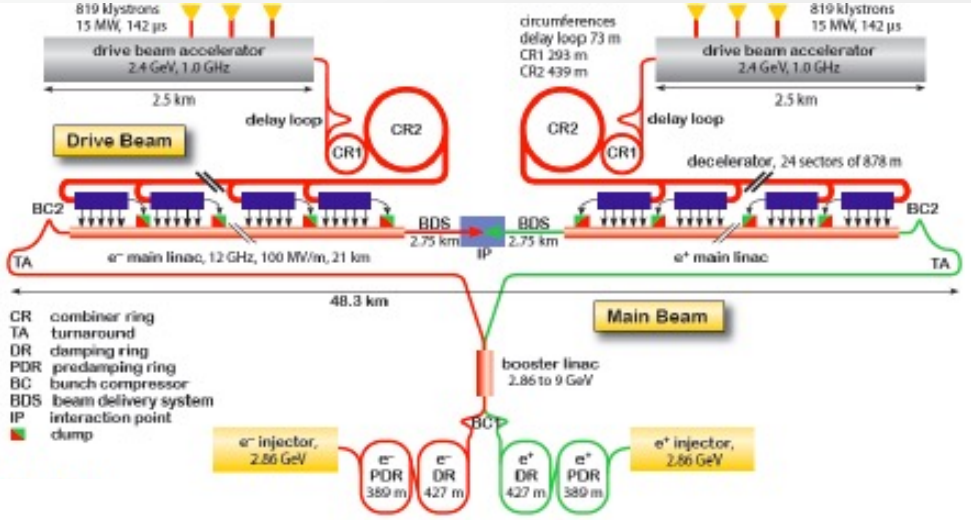
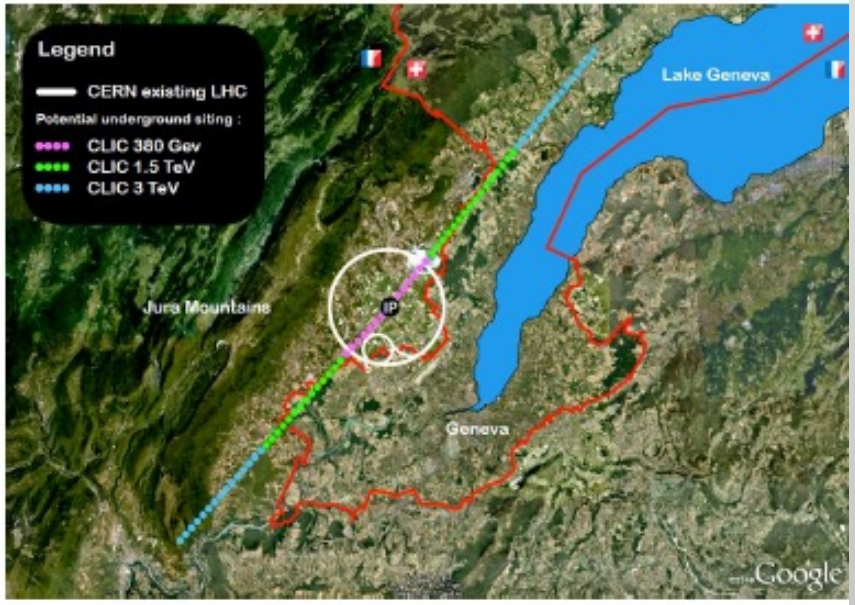


Fig. 3.1: Overview of the CLIC layout at $\sqrt{s} = 3$ TeV.

Parameter	Unit	380 GeV	3 TeV
Centre-of-mass energy	TeV	0.38	3
Total luminosity	$10^{34}cm^{-2}s^{-1}$	1.5	5.9
Luminosity above 99% of √s	$10^{34}cm^{-2}s^{-1}$	0.9	2.0
Repetition frequency	Hz	50	50
Number of bunches per train		352	312
Bunch separation	ns	0.5	0.5
Acceleration gradient	MV/m	72	100
Site length	km	11	48



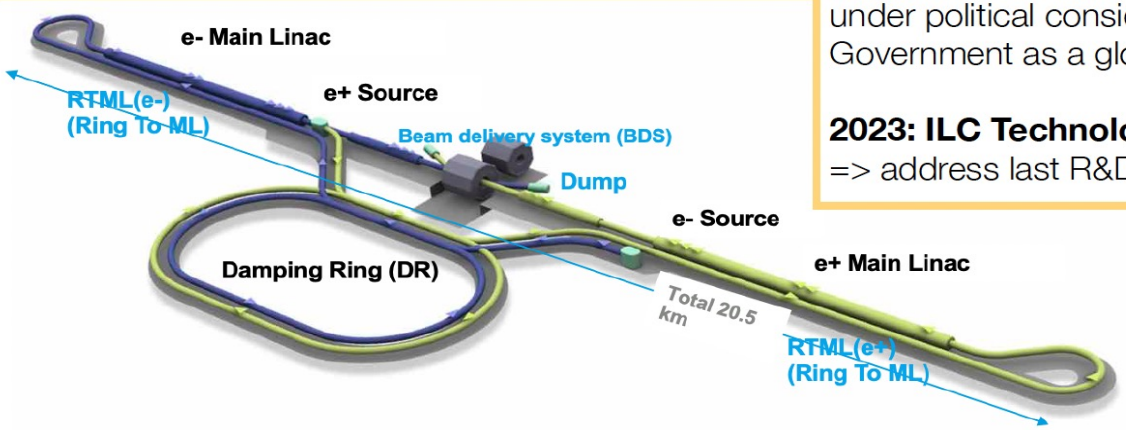
International Linear Collider

Status overview

ILC: e^+e^- @ 90, 160, **250,** 350, **500 GeV, 1TeV**
TDR in **2012; 2017:** staged start at **250 GeV**
Superconducting RF

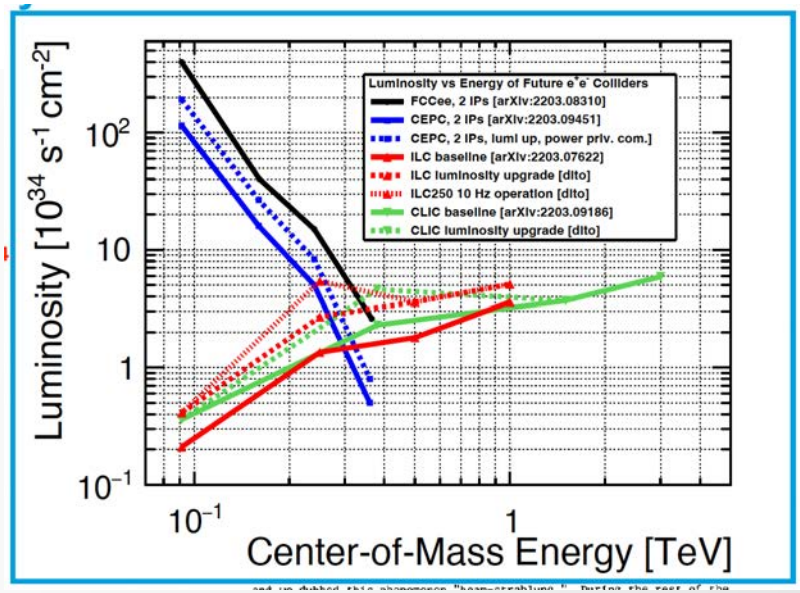
under political consideration by Japanese Government as a global project

2023: ILC Technology Network
=> address last R&D questions on accelerator



Linear Colliders

- ILC, CLIC, C^3, …
- length 250 GeV: 4…11…20 km
- high luminosity & power efficiency at **high energies**
- **longitudinally spin-polarised beam(s)**



Long-term upgrades: energy extendability

- same technology: by increasing length
- **or by replacing accelerating structures with advanced technologies**
  - RF cavities with high gradient
  - plasma acceleration ?

Spanish Network on Future Colliders

Spanish Network on Future Colliders
Chairs: Marcel Vos (IFIC) & Alberto Ruiz (IFCA)

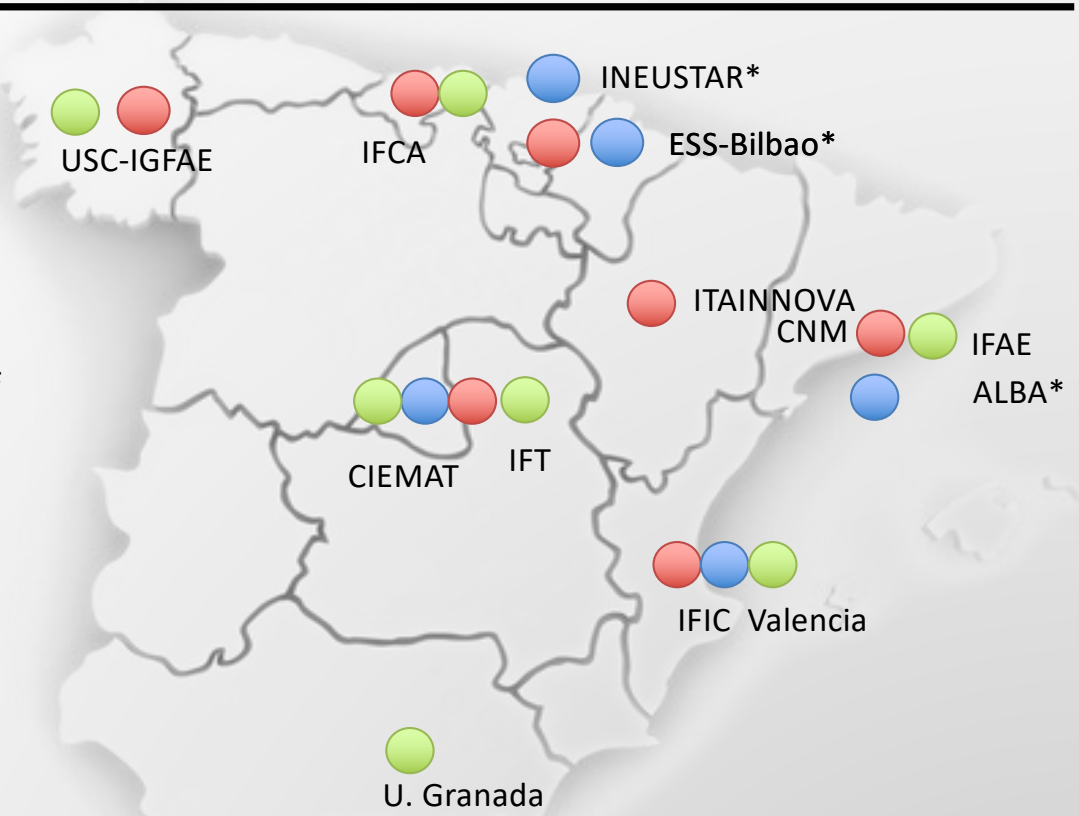
Scope:

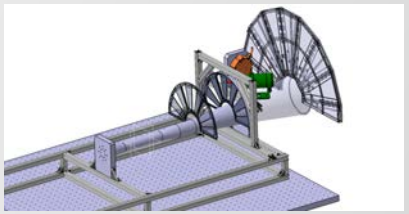
The main objective of this Thematic Network is to coordinate the Spanish activities on physics studies and development of new technologies in view of future colliders for Particle Physics, linear collider ILC & CLIC and also FCC

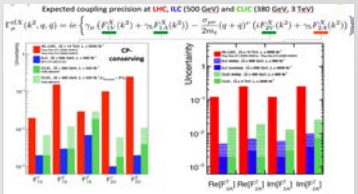
Includes: Accelerator, Theory, Experimental and Technological groups

Keeps contact with industry (INDUCIENCIA, INEUSTAR)

Active since 2005







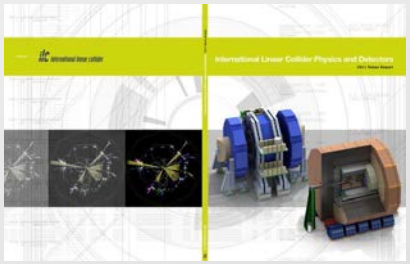
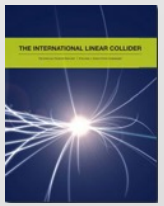
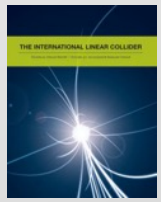
Activity	# Groups
Accelerator	5
Detectors	7
Phenomenology	7

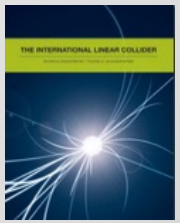
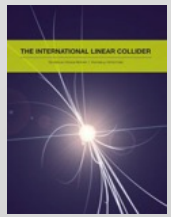
ILC Physics and Detector Roadmap

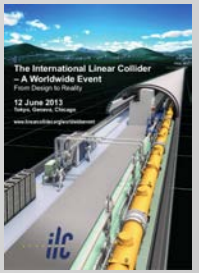
Aug. 2007	Detector Concept Report, Four detector concepts: LDC, GLD, SiD, 4th
Oct. 2007	ILCSC calls for LOIs and appoints Research Director (RD)
Jan. 2008	RD forms detector management
Mar. 2008	IDAG formed, Three LOIs gropus identified
Mar. 2009	Three LOIs submitted (detector description, s… &D, GEANT4 simulation, benchmark process…
Mar. 2009	IDAG began monitoring the prog…
Aug. 2009	IDAG recommends vali… two (2) and ILCSC approves
Oct. 2009	Work plan of t… ted groups
End 2011	Interim… being produced http://w…v.linearcollider.org/about/Publications/interim-report
End 2012	Physics at the International Linear Collider (ILC TDR Vol. 2) Detailed Baseline Design Report (ILC TDR Vol. 4) http://www.linearcollider.org/ILC/Publications/Technical-Design-Report
June 12th 2013	Public TDR Launch event worldwide http://www.linearcollider.org/events/2013/ilc-tdr-world-wide-event

Long time Spanish contribution to ILC



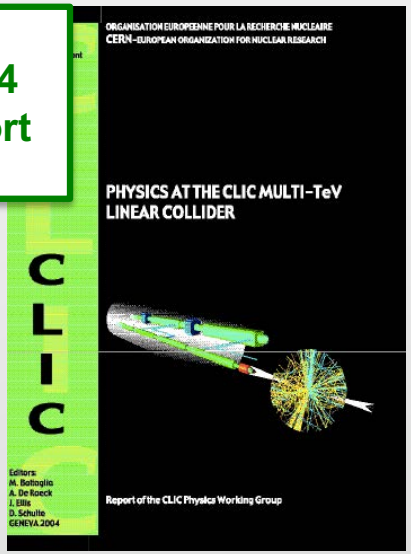



CLIC Physics and Detector Roadmap

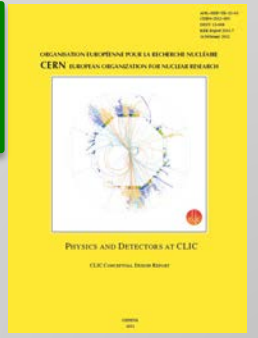
2001	"Physics motivations for future CERN accelerators" http://arxiv.org/pdf/hep-ex/0112004v1
2004	"Physics at the CLIC multi-TeV linear collider" Report on physics potential http://inspirehep.net/record/667395?ln=en
2008	New start of CLIC physics and detector studies First meetings between ILC and CLIC physi Start Linear Collider Detector (LCD) eff ERN
2009	IDAG meeting: Plan ILC-CLIC co Pursue ILD & SID concept CDR
2012	Publication of "Phy Detectors at CLIC", CDR, http://arxiv.org/ 3940 with >1300 signatories Publicati e CLIC Programme: Towards a Staged e+e- Line exploring the Terascale", CDR, and *input to Europ n Strategy process* http://arxiv.org/abs/arXiv:1209.2543 Establishing a *"memorandum on Cooperation"* (MoC) for CLIC detector and Physics study, with CERN as the host laboratory
2013	*CLIC input to the Snowmass process* (with many new Higgs physics studies), http://arxiv.org/abs/1307.5288 20 institutes have signed the MoC

Long time Spanish contribution to CLIC

2004 report



CDR 2012



Present involvement and responsibilities by Spanish community

ECFA Study on Higgs / EW / Top factories

Based on the recommendations of the European Strategy for Particle Physics Update, the European Committee for Future Accelerators (ECFA) has launched a series of workshops on physics studies, experiment design, and detector technologies towards a future electron-positron Higgs/EW/Top factory. The aim is to bring together the efforts of various e+e- projects, to share challenges and expertise, to explore synergies, and to respond coherently to this high-priority strategy item.

To set up the relevant structures and to define a path towards such workshops, an International Advisory Committee (IAC) was formed, which established three Working Groups led by conveners from both experiment and theory:

- International Advisory Committee
  - 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

WG 1: Physics Potential

Conveners: Jorge de Blas (Univ. Granada), Patrick Koppenburg (Nikhef), 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/DMLab)

WG 3: Detector R&D

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

Working subgroups:

- Adrián Irles
- Marcel Vos
- Sven Heinemeyer

Present involvement and responsibilities by Spanish community

International Expert Panel: Antonio Pich representing Spain

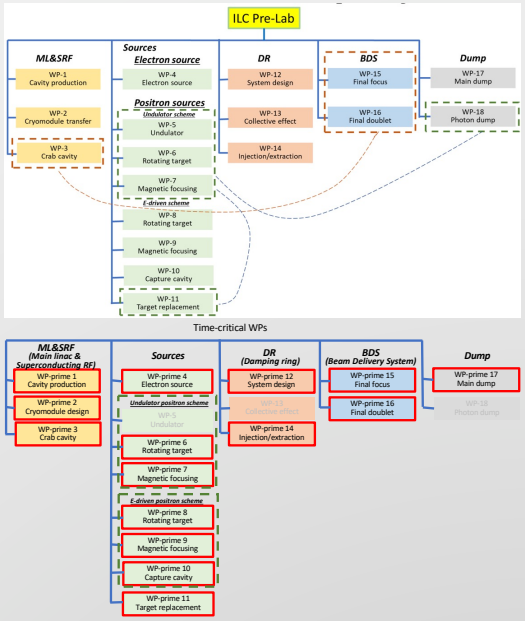
ILC Technology Network (ITN)

The initial planning for the ILC preparation phase (2022-2026) – see upper figure - leading to a complete Engineering Design as needed for construction was reviewed by a MEXT appointed committee and deemed premature, referring to that the prospects for an international sharing for ILC are not clear.

However increased support for technical developments was indicated as possible.

A result a subset of the technical activities of the full preparation phase programme have been identified as critical. We call this an **ILC Technology Network (ITN) -** see lower figure, and this presentation (briefly) summarized this work, with a European focus.

The goal is that in parallel with starting with these technical activities international discussion can proceed and open for addressing the Engineering Design in full, such that the changes in the ILC timescale are not too large overall.



Reducing the number of WPs
and reducing the size of the WPs:
From 60 M$ to 15 M$
From 360 FTEy to 112 FTEy

	P1	P2	P3	P4	C1	C2	C3	C4	C5	C6 …
Previous	Pre-lab ~4 years				Construction ~10 year					
	Y1	Y2	Y3/P1?	Y4/P2?	C1	C2	C3	C4	C5	C6 …
Now	Time critical WPs ~4 years									
			Pre-lab 3~4 years		Construction ~10 year					

The European ITN activities – 2023

European ITN studies are distributed on five main activity areas:

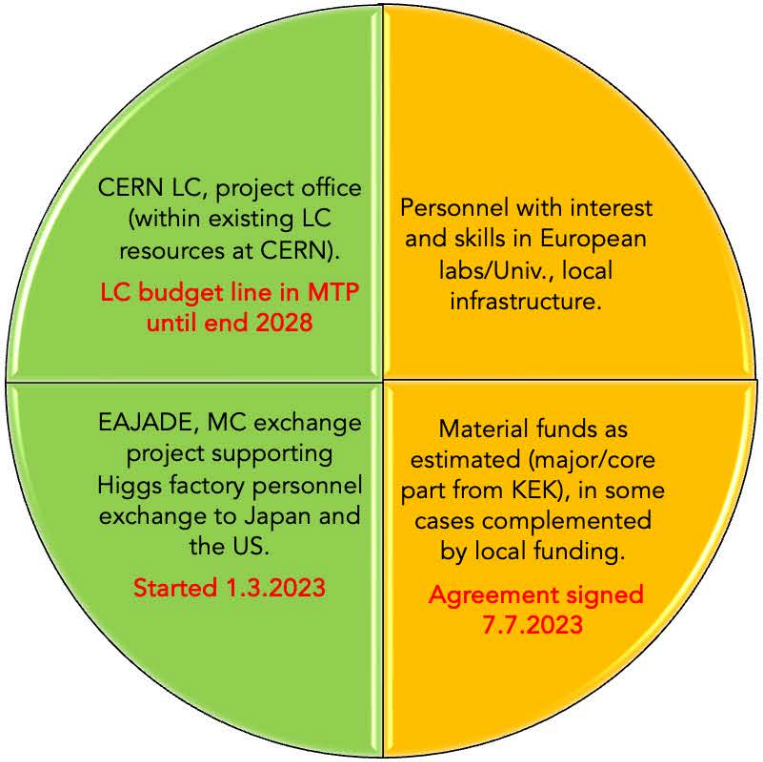
A1 with three SC RF related tasks
- SRF: Cavities and Cryo Module (INFN, CEA, DESY, IJCLAB?)
- Crab-cavities (STFC, CERN?)
- Main Linac elements: ML quads and cold BPMs (CIEMAT, IFIC)

A2 Sources
- Pulsed magnet (Uni.H, DESY, CERN)
- Wheel/target (the same and UK groups)

A3 Damping Ring including kickers
- Low Emittance Ring lab(s) (UK?)

A4 ATF activities for final focus and nanobeams
- On-going/restarted (Oxford, DESY, IJCLAB, CEA, CERN, IFIC)
- MDI here ?

A5 Implementation including Project Office
- Dump, CE, Cryo – earlier efforts at CERN, possible follow up being considered
- Sustainability, Life Cycle Assessment (CERN, DESY, CEA, UK groups?)
- EAJADE started (EU funding) SHOW groups?



EAJADE: Information at LINK

Present involvement and responsibilities by Spanish community

EAJADE (link): The Europe-America-Japan Accelerator Development Exchange Program

EAJADE is a Marie Sklodowska-Curie Research and Innovation Staff Exchange (SE) action, funded by the EU under Horizon-Europe Grant agreement ID: 101086276

Addresses the urgent need of exchange of ideas on R&D and implementation of future accelerators for particle physics, in particular for a future Higgs factory, but also for generic technical development and for investigations into new technologies and the potential for sustainability.

Associate academic partners

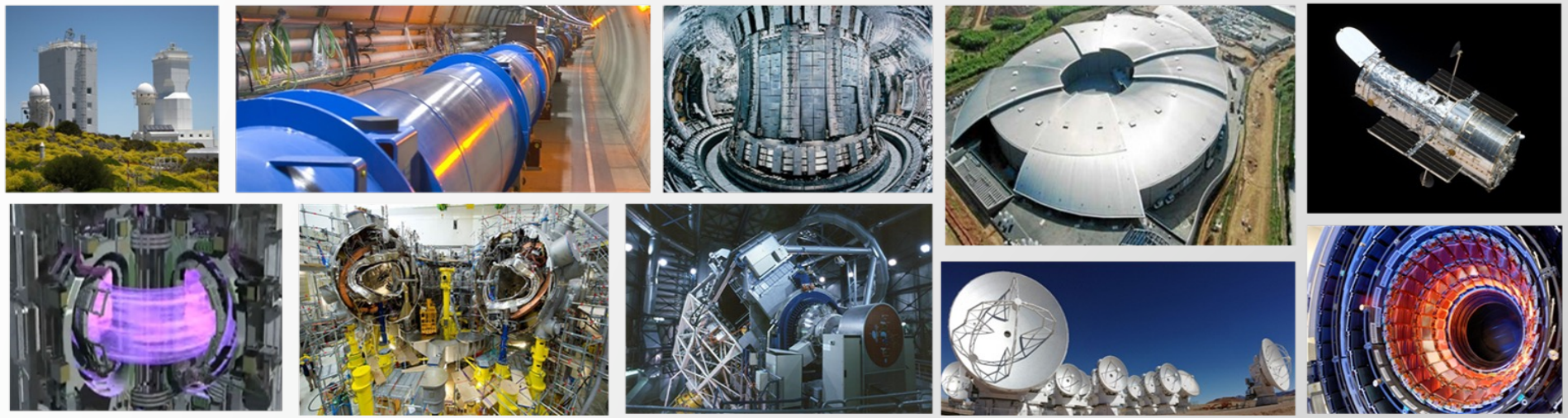
- Canada: U Victoria
- Japan: KEK, U Tokyo, U Tohoku
- USA: LBNL, BNL, FNAL, Cornell, JLAB, SLAC

Associate non-academic partners (in EU)

- CPI TMD (UK), INEUSTAR (Spain), ZANON (Italy), ScandiNova (Sweden), Research Instruments (Germany)

Industrial Platform: INDUCIENCIA, INEUSTAR

SCIENCE INDUSTRY is the economic sector which includes the companies devoted to the design, engineering, construction, updating and keeping of scientific research facilities, its equipment and other related instruments

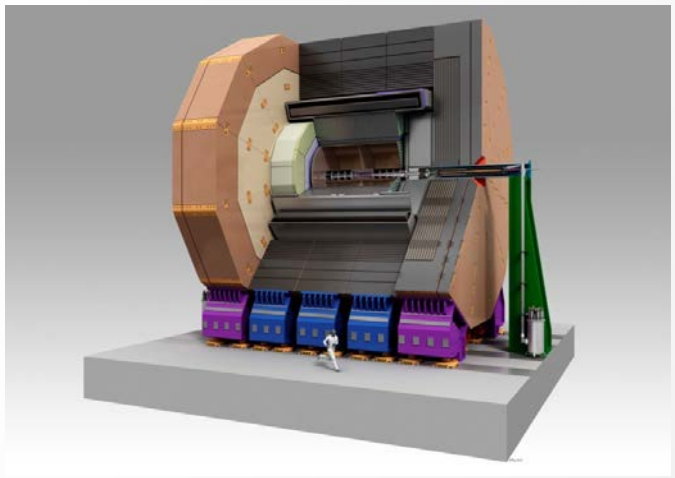


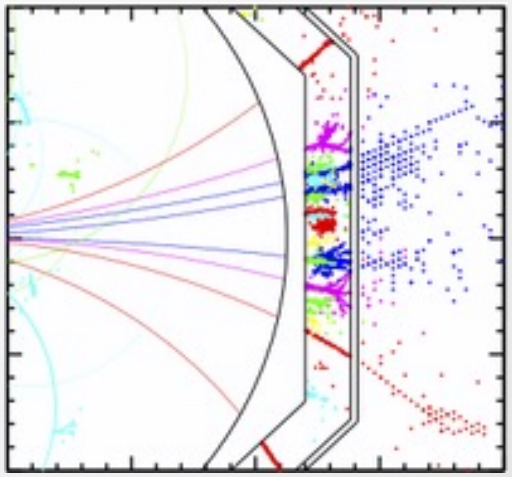
induciencia

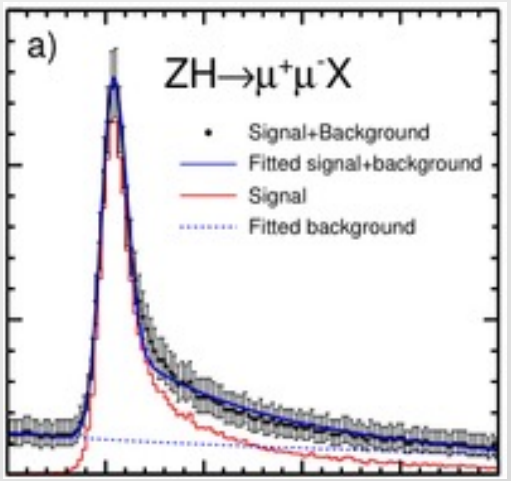
ineustar
Asociación Española de la Industria de la Ciencia

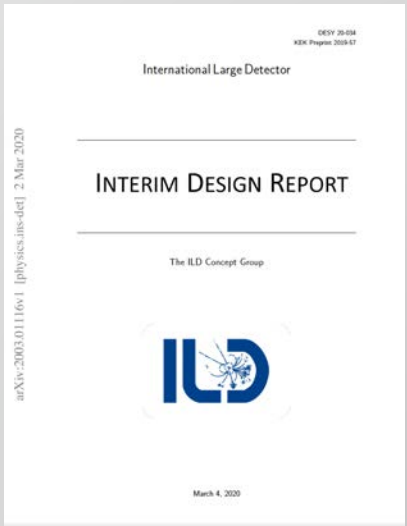
Present involvement and responsibilities by Spanish community

ILD Concept Group









M.C.Fouz: Technical Coordinator & Member of the Executive Team
M. Vos: Member of the Executive team

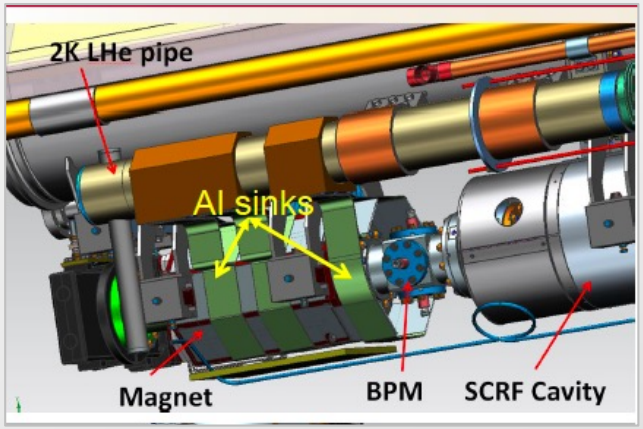
ILD: Now looking forward also to circular colliders, engaged in studies to make the case for an ILD-like detector at FCC-ee in particular

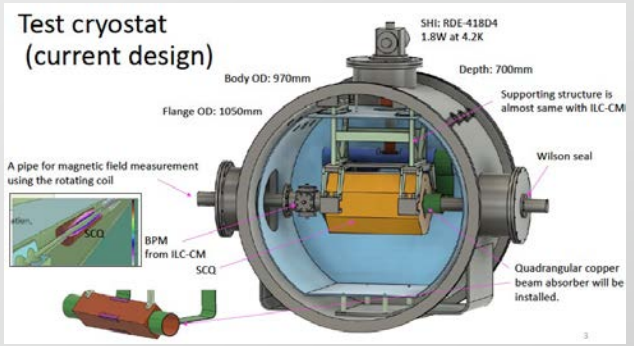
IFIC contribution/interest on ITN activities

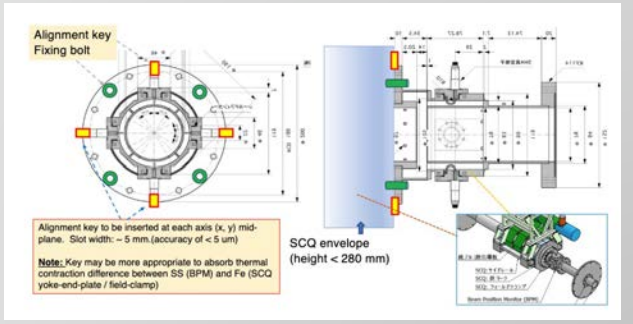
In 2021 the Spanish network for Future Colliders identified as a promising contribution from CIEMAT and IFIC groups to the ILC the development of the splitable quadrupole magnet (CIEMAT) and its associated Beam Position Monitor (IFIC) of the Main Linac.

IFIC is now contributing to the European ITN Activity 1 on the task on R&D of Main Linac elements in particular on the development of a cold cavity Beam Position Monitor (BPM).

In 2023, we have started the collaboration with CIEMAT (L. García, F. Toral, O. Durán) and KEK (A. Yamamoto, H. Hayano) on this development.







❑ **General requirements for the BPM performance:**

- High precision BPM with a time nanometer resolution (< 369 ns) and a spatial resolution < 1 µm
- ILC beam bunch by bunch measurements (fast readout electronics)
- Low beam dynamics impact (wakefields studies)
- Ultra high-vacuum and cryogenic temperatures performance
- Special mechanical design for ease cleaning

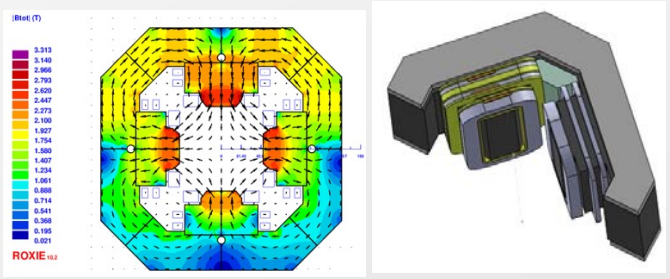
Present activities by Spanish community: Accelerator

CIEMAT contribution/interest on ITN activities

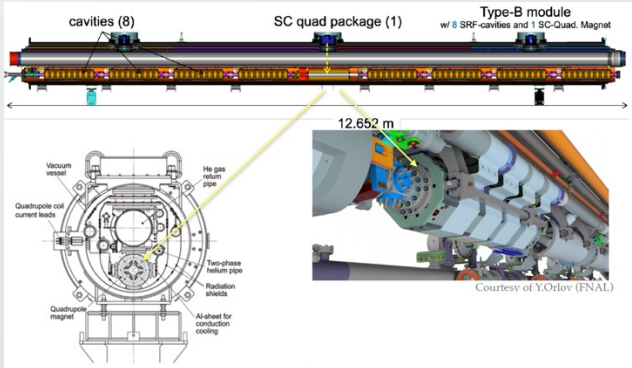
The SCQ Package for the ILC Cryomodule within the A1 Activity Area

A SC Quadrupole (SCQ) package is placed at the center of the cryomodule, type B, of the SRF string for beam acceleration at ILC.

- The SCQ package consists of a main quadrupole magnet combined with dipole corrector and beam-position monitor (BPM) (IFIC Contribution).
- The SCQ magnet should be splittable for assembly out of the clean area and conduction cooled to avoid the need of a He cryostat.
- Dark-Current energy absorption in the SC-coils compromises the operational temperature margin of the superconductor (need for a high margin > use of superconductors with the highest possible T_c).
- CIEMAT focuses on **High Energy version Cross-Section** with **Low Energy version Length** and **Nb_3Sn** technology for the coils.
- Present activities funded under the national MAGNEXT Project: the current scope includes the design, fabrication and characterization of a test coil.
- Additional funding is needed for completing the full magnet prototype



Electro-magnetic and Thermo-mechanical design ongoing



Parameters	Unit	Low Energy (5-25 GeV)	High Energy (25-250 GeV)
Dimensions:			
Physical length	m	0.25	1
Magnetic length	m	0.20	0.95
Iron-pole radius	m	0.045	
Quadrupole field:			
Field gradient (G)	T/m	19	40
G-Integral (required)	T	3.8	38
B_G at pole	T	0.86	1.8
Dipole field:			
B0	T	0.05	0.11
B-integral (required)	T • m	0.01	0.10
B max:			
in coil	T	~1.5	~3

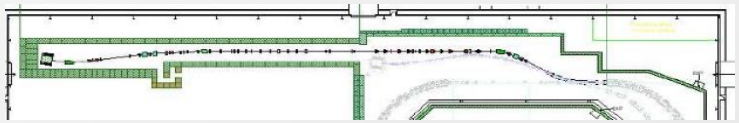
ARIMOTO *et al.*: Design Study of a Superconducting Quadrupole Magnet System Sustainable Under Dark Current Heating in ILC Main Linac

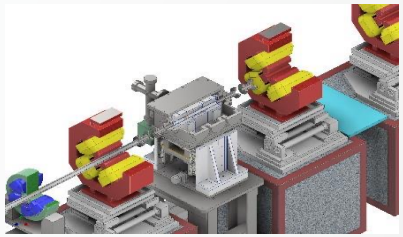
Present activities by Spanish community: Accelerator

ATF3 programme (final focus, nanobeams)

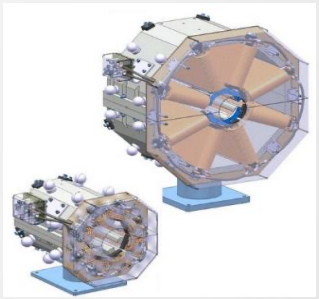
- ATF2 beamline is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important topics to be pursued at the ATF.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning
- The technical research at ATF2 beamline has proceeded, and should continue to be based on the ATF international collaboration, or its extension (welcome to new collaborators).

ATF2 beamline

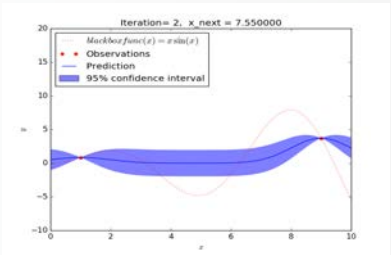




Wakefield test station



Octupole magnets for higher-order aberration



Maximum search algorithms to be applied to beam tuning (Machine Learning)

Very relevant studies for any linac and Higgs factory closely related to low emittances and nano beams, e.g. alignment, stabilisation, instrumentation, beam-dynamics, etc.

- Strong European leadership with several group from **France, UK, Spain, Germany and also CERN, also extensively used for PhD training**
- A future ATF3 programme has been defined and reviewed internationally, supported also by MC researcher exchange programmes as EJADE and EAJADE

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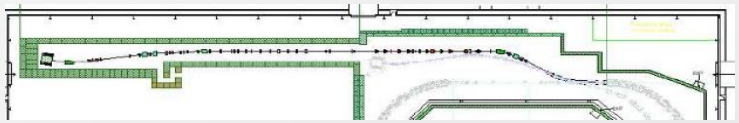

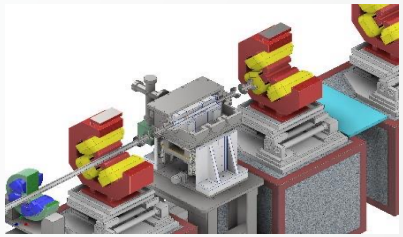

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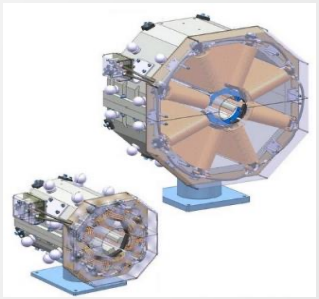

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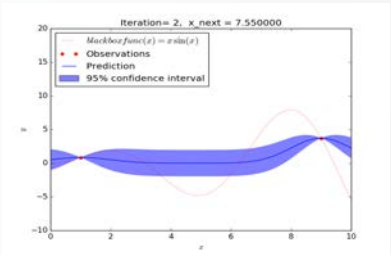

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The ECFA Higgs/Top/EW

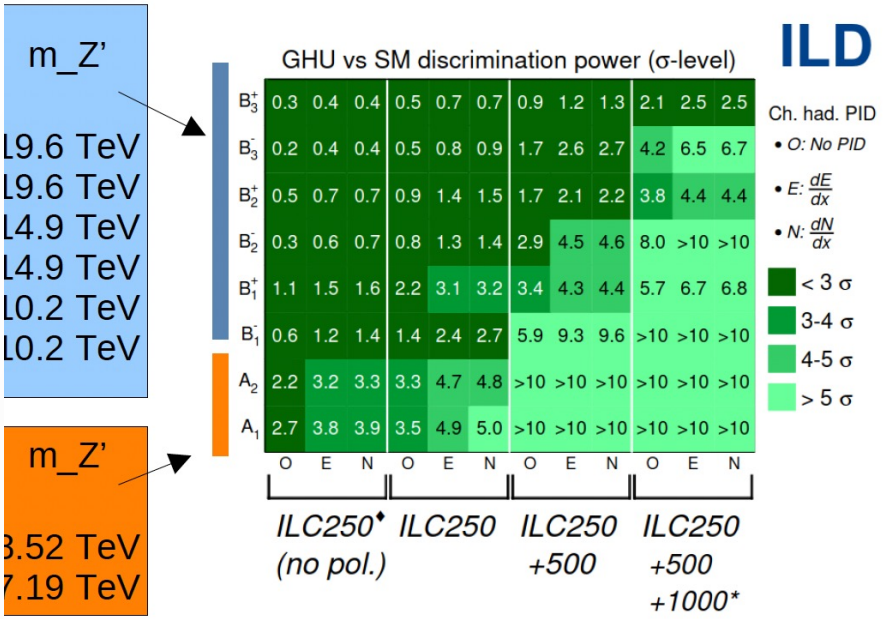
WG1

- Global interpretations (WG1-GLOB) → M. Vos
- Precision (WG1-PREC) → A. Irles
- Higgs/Top/EW (WG1-HTE):
- Flavour (WG1-FLAV):
- Searches (WG1-SRCH)

FOCUS Topics document https://arxiv.org/abs/2401.07564

- ttbar-threshold topic
  - M. Vos (coordinator), A.Irles, A. Saibel, D. Melini members of expert team
- W-mass, Luminosity measurements, fragmentation uncertainties
  - 3 topics with A.Irles as co-coordinator (PREC) convener
- Two Fermion Final states
  - A.Irles as coordinator and member of expert team
- Contributions to BSM searches
  - Hidden Valley searches (V. Mitsou, A. Irles as contact persons).

Studies with ILD simulation



Eur.Phys.J.C 84 (2024) 5, 537
ILD-PHYS-PUB-2023-001
ILD-PHYS-PROC-2023-013

- Recent publication: **phenomenology + experimental of a long standing effort (ICHEP2020-ICHEP2024)**
  - IFIC (Irles, Márquez, Saibel)
  - IJCLab, Tohoku U., Kyoto U.
- **Forward-backward asymmetry for b and c-quark** pairs.
- Study comparing **scenarios** (energy reach, beam polarisation) and **GHU** models.
- This plots "hides" years of **involvement** int **detector optimization**:
  - Study of **forward tracking and calo** region
  - **Flavour tagging** optimization → including dEdx or novel detector solutions (pixel TPC for cluster counting)
  - **Quark-Charge measurement** algorithms.
  - Study of **timing** capabilities for hadron identification

Present activities by Spanish community: Detector R&D + Physics Studies

CIEMAT R&D developments for future Colliders - timeline

SDHCAL= SemiDigital Hadronic Calorimeter

Joining CALICE — 2007

ILD LOI — 2010

ILC – ILD TDR — 2013

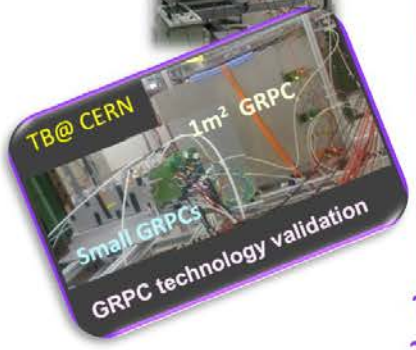
ILD IDR — 2019

2020

2021

2022

Small GRPC → 1m² GRPC → 1M³ SDHCAL Technical prototype (Construction, TestBeam, Performance, PID, Reconstruction) → Larger prototypes → 5D Calo (Timing) → .... → Higgs factory



1m³ prototype
~500K channels

New Detector InterFace board

Mechanics R&D

2024

RD1-GAS
RD6-CALO

T-SDHCAL

5D Calorimeter
Implementing precise timing
GRPC → Multigap RPC
New electronics

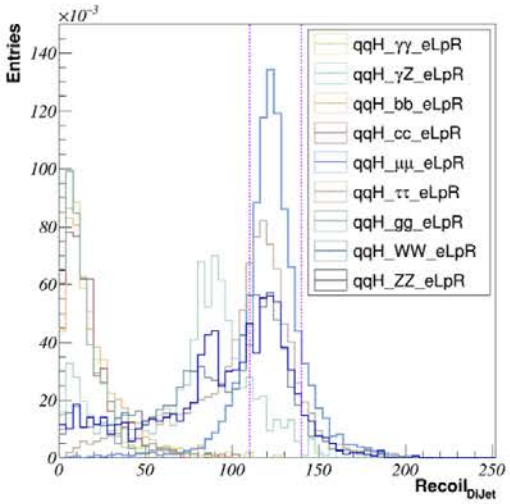
FOR ANY E+E- COLLIDER
LINEAR AND CIRCULAR

Present activities by Spanish community: Detector R&D + Physics Studies

Physics studies for future colliders at ILD for ILC

- **Prospect of the ZH hadronic channel**

  Part of H. García Cabrera PhD thesis. Supervisor M.C Fouz



Ciemat
cfp
CIEMAT
física de partículas

ILD Concept Group

M.C.Fouz. Technical Coordinator & Member of the Executive Team
Now looking forward also to circular colliders, engaged in studies to make the case for an ILD-like detector at FCC-ee in particular

ECFA
European Committee for Future Accelerators

ECFA Physics, Experiments & Detectors (PED) Study at Higgs/top/EW/Flavour Factories

J: Alcaraz. Former co-convener of the **WG 1: Physics Potential**
M.C.Fouz. Co-convener of the **WG 3: Detector R&D**

Summary

Spanish community has a long tradition in contributing to the future Higgs Factory international effort and in particular to the Linear Collider options: ILC and CLIC.

The internal organization –specially the existence of the Spanish Future Colliders Network- keeps Spanish cooperation putting together all interested communities: Phenomenology, Detector R&D, Accelerator development and industry.

The creation of the ILC International Technological Network allows to continue the global effort for a future Linear Collider though focused on accelerator aspects where Spain is also contributing via the CIEMAT and IFIC groups.

Spanish physicists are major players in the ECFA Study on Higgs/Top/Electroweak Factories.

At present Spanish community keeps a reasonable activity in the development for a future Higgs Factory based on the linear collider option despite the lack of resources.

For the discussion:

A Linear Collider at CERN ? Cost ? Technology readiness ? Number of Experiments ? CEPC factor ?