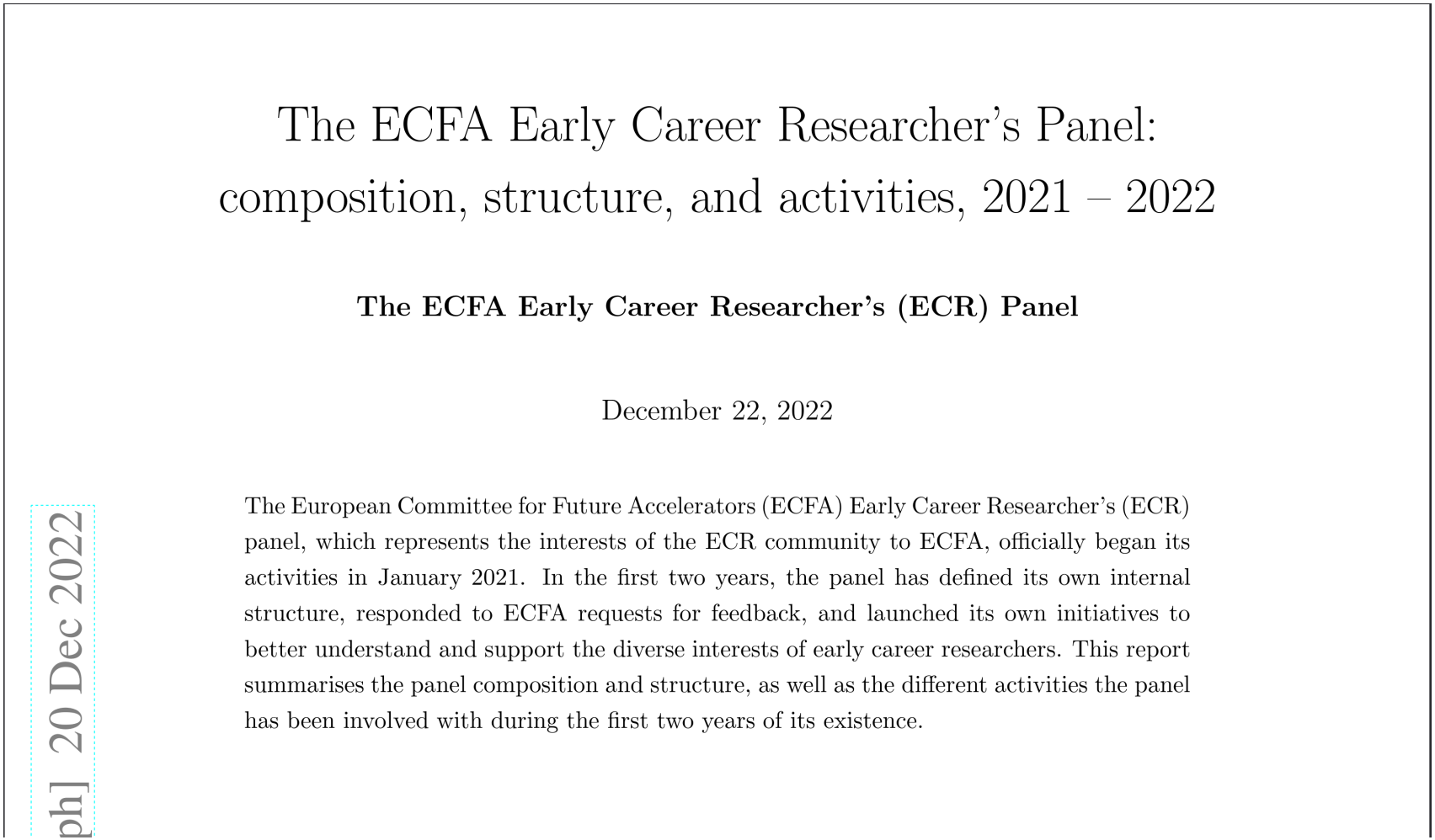
Activities of the ECFA ECR Panel

Emanuele Bagnaschi (INFN LNF)
CERN ECFA ECR panel member 2022-2023

02 July 2024

LNF, Frascati, Italy

Overview of the activities of the panel



The ECFA Early Career Researcher's Panel:
composition, structure, and activities, 2021 – 2022

The ECFA Early Career Researcher's (ECR) Panel

December 22, 2022

The European Committee for Future Accelerators (ECFA) Early Career Researcher's (ECR) panel, which represents the interests of the ECR community to ECFA, officially began its activities in January 2021. In the first two years, the panel has defined its own internal structure, responded to ECFA requests for feedback, and launched its own initiatives to better understand and support the diverse interests of early career researchers. This report summarises the panel composition and structure, as well as the different activities the panel has been involved with during the first two years of its existence.

Structure and summary of the activity of the various working groups in 2021-2022
https://arxiv.org/abs/2212.11238

The ECFA ECR workshop at CERN

Day agenda

- Held at CERN on the 27th of September
- Topical presentations with ample discussion time
- Four main sessions: overview; challenges; different viewpoints; people and money
- Slides and recordings are available on **INDICO**
- INDICO: INDICO page

09:00
- Welcome to the event — Emanuele Angelo Bagnaschi — 222/R-001, CERN — 09:00 - 09:05
- Towards the future of particle physics — Jorgen D'Hondt — 222/R-001, CERN — 09:05 - 09:25
- The future collider landscape — Tatsuya Nakada — 222/R-001, CERN — 09:25 - 10:00

10:00
- Coffee — 222/R-001, CERN — 10:10 - 10:30
- Input from accelerator physicists — Daniel Schulte et al. — 222/R-001, CERN — 10:30 - 10:45

11:00
- Detector technologies and challenges — Mogens Dam et al. — 222/R-001, CERN — 11:00 - 11:15
- Theory challenges: Precision calculations — Federico Buccioni — 222/R-001, CERN — 11:30 - 11:45

12:00
- The Key4hep software stack: Beyond Future Higgs factories — Leonhard Reichenbach — 222/R-001, CERN — 12:00 - 12:05
- Beam-induced background simulations for a multi-TeV muon collider — Daniele Calzolari — 222/R-001, CERN — 12:05 - 12:10
- Proposal on the electromagnetic calorimeter for a muon collider — Carlo Giraldin — 222/R-001, CERN — 12:10 - 12:15
- Bottom quark forward-backward asymmetry at the future electron-positron collider FCC-ee — Leonardo Toffolin — 222/R-001, CERN — 12:15 - 12:20
- Design and Performance of the IDEA Vertex Detector at FCC-ee in Full Simulation and Related R&D on Monolithic Silico… — Armin Ilg
- Machine Detector Interface for $\sqrt{s} = 3\ TeV$ Muon Collider — Luca Castelli — 222/R-001, CERN — 12:25 - 12:30
- Beamstrahlung dump and radiation levels in the experiment IRs — Alessandro Frasca — 222/R-001, CERN — 12:30 - 12:35
- Calorimeter Clustering at FCC-ee with E(n) Equivariant Graph Neural Networks — Gregor Krzmanc — 222/R-001, CERN — 12:35 - 12:40
- Beam-induced background simulations in calorimeter at a muon collider — Shivani Sanjay Lomte — 222/R-001, CERN — 12:40 - 12:45
- Exploring the Hidden Sector with two-particle angular correlations at future e+e- colliders — Emanuela Musumeci — 222/R-001, CERN — 12:45 - 12:50

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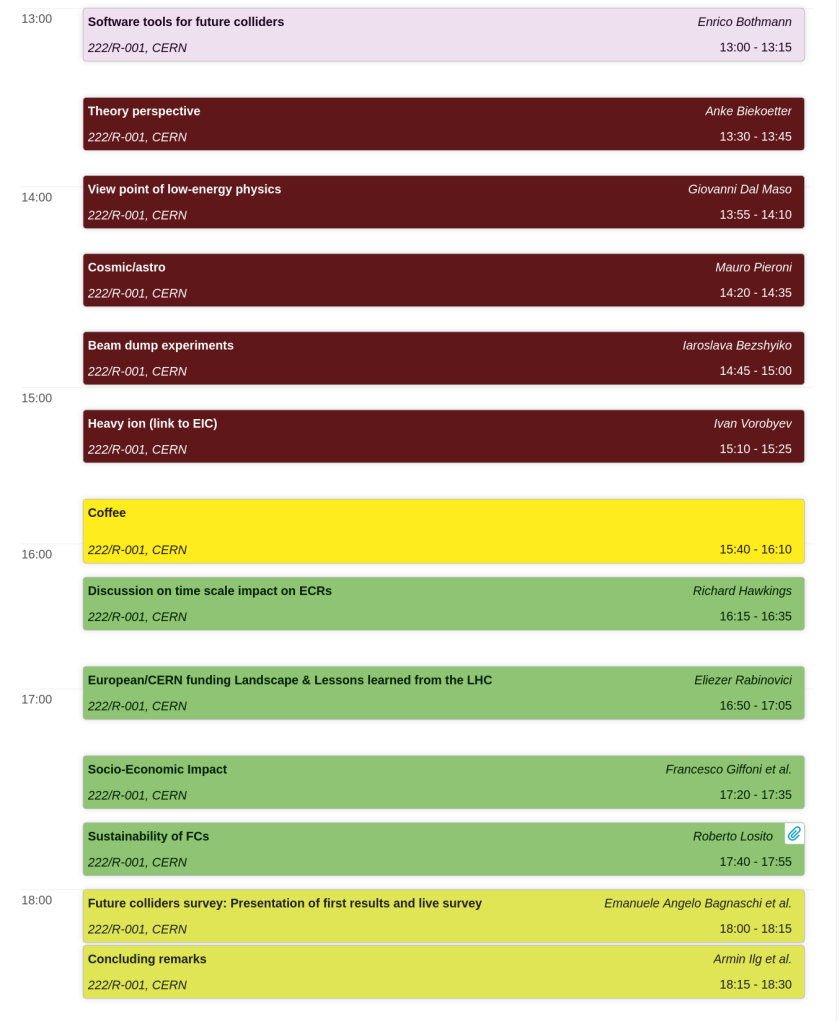
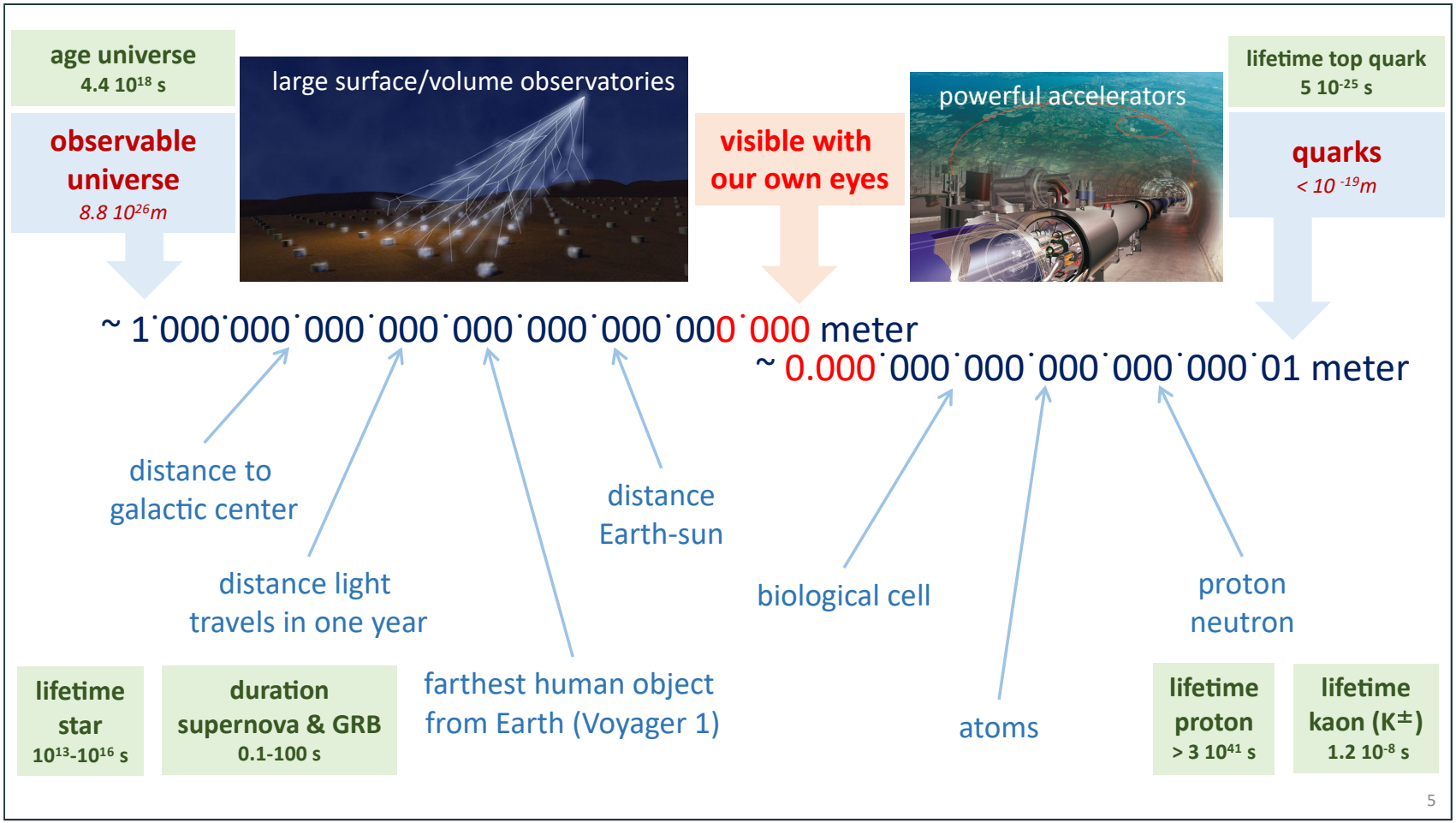




[Jorgen D'Hondt, *Towards the future of particle physics*]
[slides, recording]

Requirements for the next HEP machine

- From pure physics
  - Capable of H and t physics complementary to/beyond LHC and HL-LHC
  - Capable of Z and W physics beyond currently known
    ⇒an e^+e^- collider covering a region of 90-350 GeV centre of mass energy (cme)
- Somewhat physics related issues
  - It is good to start data taking with some overlap with the HL-LHC operation since the results might influence each other's scientific programme.
    ⇒A machine which can be built within the next 10~15 years.
  - Can be upgraded to probe higher energy scales if physics result motivates.
  - Should not damage the diversity of particle physics activities.
    ⇒A machine with a reasonable cost
- HEP sociology
  - Continuity in the HEP programme to sustain the community
- Other issues have become increasingly important
  - Environmental impact, energy consumption, resource availability, attractivity in technology, impact on industries, spinoffs, …

27/09/2023 T. Nakada Landscape for the future colliders 9

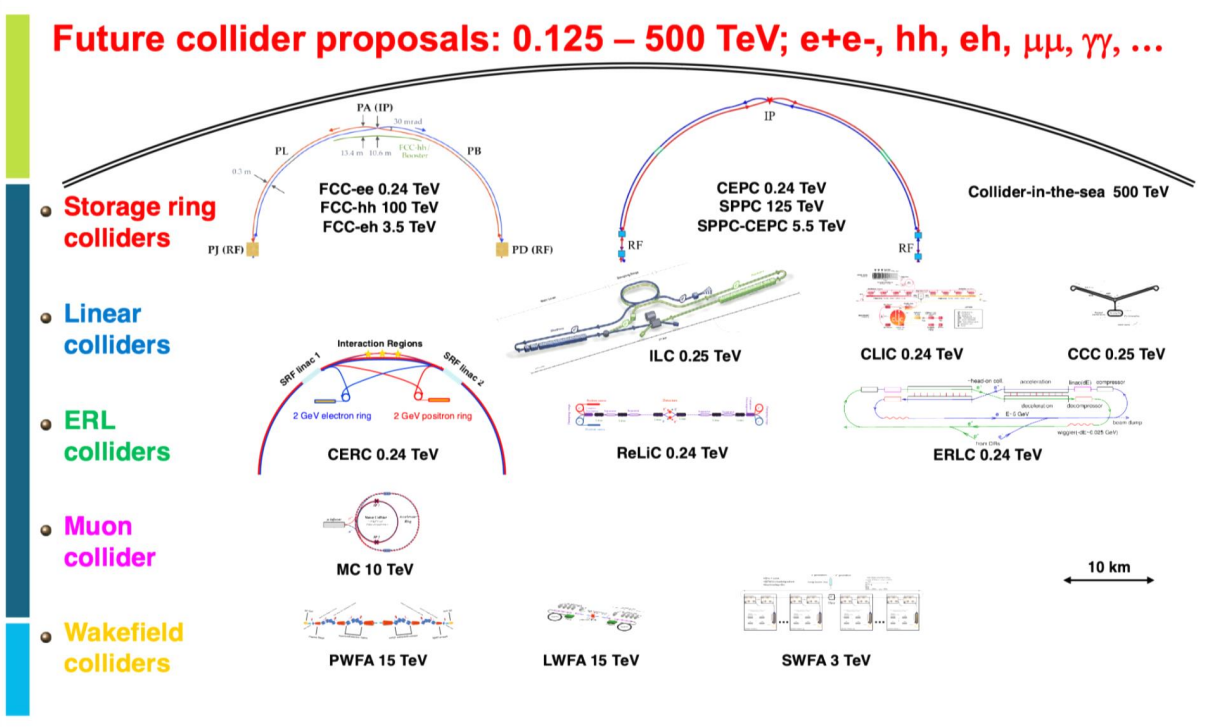
[Tatsuya Nakada, *The future collider landscape*]
[slides, recording]

Collider Proposals at Snowmass

Implementation Task Force (ITF) looked at many different proposals

Cannot cover them all

Select according to European view



[Daniel Schulte & Tatiana Pieloni, *Input from accelerator physicists*]
[slides]

Precision measurements at FCC-ee

Baseline FCC-ee operation model (+ potential resonant Higgs for electron Yukawa)

Working point	Z, years 1-2	Z, later	WW	HZ	$t\bar{t}$		(s-channel H)
$\sqrt{s}$ (GeV)	88, 91, 94		157, 163	240	340-350	365	m_H
Lumi/IP ($10^{34}\,cm^{-2}s^{-1}$)	115	230	28	8.5	0.95	1.55	(30)
Lumi/year (ab^{-1}, 2 IP)	24	48	6	1.7	0.2	0.34	(7)
Physics Goal (ab^{-1})	150		10	5	0.2	1.5	(20)
Run time (year)	2	2	2	3	1	4	(3)
Number of events	5×10^{12} Z		10^8 WW	10^6 HZ + 25k WW → H	$10^6 t\bar{t}$ +200k HZ +50k WW → H		(6000)

Physics at the Z-pole, W^+W^-@threshold ~ m_W, Higgs factory, tt@threshold ~ m_t

great opportunities for precision QCD: a_s, jets, hadronization models...

The foreseen precision is staggering:

this poses astounding but also attractive challenges on theory predictions

- calculations within the SM of equivalent accuracy needed to exploit full discovery/exclusion power
- theory will serve as an input in many measurements, e.g. electroweak pseudo observables (EWPOs)

[Blondel, Janot 2106.13885]

Observable	present value ± error	FCC-ee **Stat.**	FCC-ee Syst.	Comment and leading exp. error
m_Z (keV)	91186700 ± 2200	**4**	100	From Z line shape scan Beam energy calibration
Γ_Z (keV)	2495200 ± 2300	**4**	25	From Z line shape scan Beam energy calibration
$\sin^2\theta_W^{\rm eff}(\times 10^6)$	231480 ± 160	**2**	2.4	from $A_{FB}^{\mu\mu}$ at Z peak Beam energy calibration
$1/\alpha_{QED}(m_Z^2)(\times 10^3)$	128952 ± 14	**3**	small	from $A_{FB}^{\mu\mu}$ off peak QED&EW errors dominate
R_ℓ^Z $(\times 10^3)$	20767 ± 25	**0.06**	0.2-1	ratio of hadrons to leptons **acceptance for leptons**
$\alpha_s(m_Z^2)$ $(\times 10^4)$	1196 ± 30	**0.1**	0.4-1.6	from R_ℓ^Z above
σ_{had}^0 $(\times 10^3)$ (nb)	41541 ± 37	**0.1**	4	peak hadronic cross section luminosity measurement
$N_\nu(\times 10^3)$	2996 ± 7	**0.005**	1	Z peak cross sections Luminosity measurement
R_b $(\times 10^6)$	216290 ± 660	**0.3**	< 60	ratio of $b\bar{b}$ to hadrons stat. extrapol. from SLD
$A_{FB}^{b,0}$ $(\times 10^4)$	992 ± 16	**0.02**	1-3	b-quark asymmetry at Z pole from jet charge
$A_{FB}^{pol,\tau}$ $(\times 10^4)$	1498 ± 49	**0.15**	<2	τ polarization asymmetry τ decay physics
τ lifetime (fs)	290.3 ± 0.5	**0.001**	0.04	radial alignment
τ mass (MeV)	1776.86 ± 0.12	**0.004**	0.04	momentum scale
τ leptonic ($\mu\nu_\mu\nu_\tau$) B.R. (%)	17.38 ± 0.04	**0.0001**	0.003	e/μ/hadron separation
m_W (MeV)	80350 ± 15	**0.25**	0.3	From WW threshold scan Beam energy calibration
Γ_W (MeV)	2085 ± 42	**1.2**	0.3	From WW threshold scan Beam energy calibration
$\alpha_s(m_W^2)(\times 10^4)$	1170 ± 420	**3**	small	from R_ℓ^W
$N_\nu(\times 10^3)$	2920 ± 50	**0.8**	small	ratio of invis. to leptonic in radiative Z returns
m_{top} (MeV/c^2)	172740 ± 500	**17**	small	From $t\bar{t}$ threshold scan QCD errors dominate
Γ_{top} (MeV/c^2)	1410 ± 190	**45**	small	From $t\bar{t}$ threshold scan QCD errors dominate
$\lambda_{top}/\lambda_{top}^{SM}$	1.2 ± 0.3	**0.10**	small	From $t\bar{t}$ threshold scan QCD errors dominate
ttZ couplings	± 30%	**0.5 − 1.5 %**	small	From $\sqrt{s} = 365$ GeV run

[Federico Buccioni, *Theory challenges: precision calculations*]
[slides, recording]

QED initial-state radiation

Careful treatment of QED-ISR is fundamental for FCC-ee phenomenology (precision observables)

Two main approaches: Collinear factorization vs YFS

soft-photons resummed to all-orders

well established framework

implemented already in several MC generators

priority to soft logarithms

Great recent progress on formulation of coll. factorisation beyond LL [Frixione 1909.03886, 2105.06688; Bertone et al 1911.12040, 2207.03265]

lepton PDFs with with coll. logarithms resummed to NLL accuracy

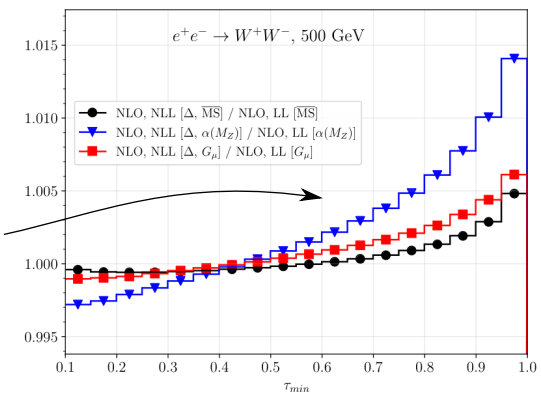
$$d\sigma_{e^+e^-} = \sum_{ij} \int dz_+ dz_- \, \Gamma_{i/e^+}(z_+, \mu^2, m_e^2)\, \Gamma_{j/e^-}(z_-, \mu^2, m_e^2)\, d\hat{\sigma}_{ij}(z_+ p_{e^+}, z_- p_{e^-}, \mu^2) + \mathcal{O}(m_e^2/Q^2)$$

NLL resummation is absolutely necessary for target precision:

Future avenues:

- Reaching NNLL would be ideal (hard but within timeline)
- Thinking of simultaneous resummation of soft and collinear emissions

~1% level effect

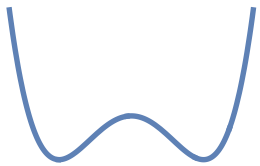


(NLO_EW + NLL_PDFs)/(NLO_EW + LL_PDFs)

[Federico Buccioni, *Theory challenges: precision calculations*]
[slides, recording]

Higgs physics

What we know



$$V = -\mu^2 |\phi|^2 + \lambda |\phi|^4$$

Anke Biekötter - JGU Mainz 3

[Anke Biekötter, *Theory perspective*]
[slides, recording]

Higgs physics

What we actually know

$$V = -\mu^2 |\phi|^2 + \lambda |\phi|^4$$

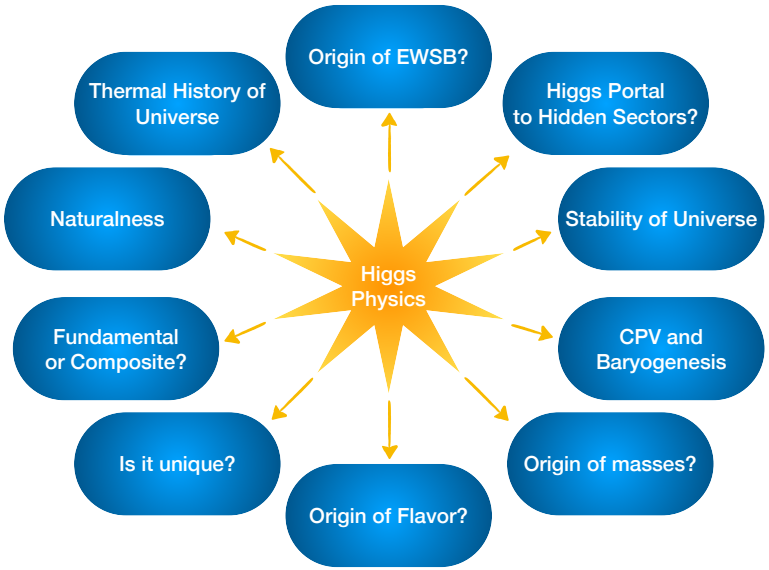
[Anke Biekötter, *Theory perspective*]
[slides, recording]

Higgs physics

What we actually know

$$V = -\mu^2 |\phi|^2 + \lambda |\phi|^4$$

Good reasons to believe that the Higgs is related to BSM physics



[Dawson et al. (2209.07510)]

[Anke Biekötter, *Theory perspective*]
[slides, recording]

Reflections

- ECRs need to be involved in future projects – it is **your** future
  - In the early stages, these projects are driven by experienced senior colleagues
    - They have the luxury/duty of preparing the future, but todays ECRs will benefit from this and actually carry out the science – get involved, you can make a difference ...
- Participating in running experiments gives invaluable experience
  - Real data is not simulation, but ATLAS SCT works a lot better than the testbeam
  - Experience the full chain from detector operations to paper acceptance
  - A different experience of collaboration, analysis WGs/hierarchies, getting results
    - Some colleagues worked only on LHC expts. from 1990 until now – I'm glad I did not
- Expertise is transferrable between experiments / projects
  - Figure out what you are interested in and good at – look for synergies
    - I have worked on tracking/b-tagging & precision measurements at OPAL and ATLAS
- Say yes to leadership opportunities even if it upsets your plans
  - Explore different areas, learn new skills, broaden your horizons
    - Less-attractive tasks are still vital, people appreciate that you take them on
- Be prepared for setbacks, surprises and successes – good luck !

[Richard Hawkings, *Discussion on time scale impact on ECRs*]
[slides, recording]

COMMON: MAINTAIN A LEADERSHIP VIA A VISION

CERN TO PROVIDE THE BEST SCIENCE AND TECHNOLOGY ARENA.

- **WHAT VISION? CONSIDERATIONS AND CONCERNS**

- **Scientific (Higgs and?)**
- **Technological (HL and High Field Magnets)- RECFA MAP**
- **New Detectors – NEW "ALICE", "ATLAS", "CMS", "LHCb", NEW!-RECFA MAP**
- **Construction: Geology , Environment**
- **Financial**
- **ECRs**
- **Politics and overlap issue.**

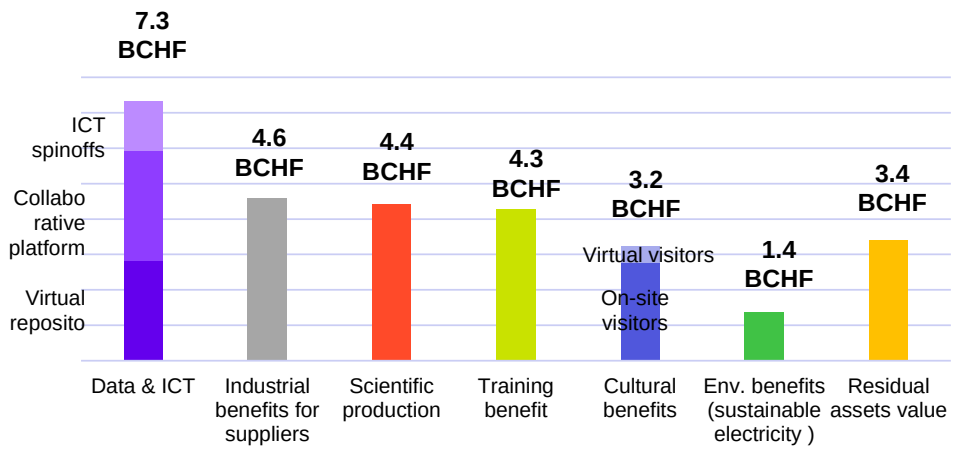
THE FUTURE REQUIRES SCIENTIFIC AND TECHNOLOGICAL VISION.

EXCELLENCE IS EXTREMELY HARD TO ACHIEVE AND SO EASY TO LOOSE.

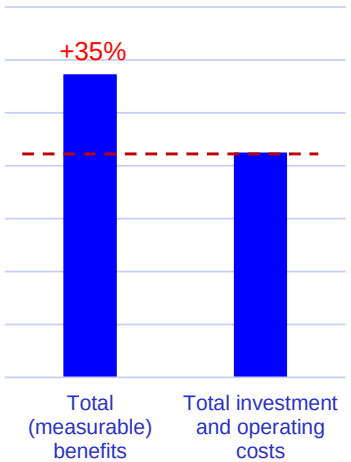
[Eliezer Rabinovici, *The view from the CERN council and ECRs*]
[slides, recording]

A preview of results of the quantitative model

Share of measurable socio-economic benefits directly attributed to FCC-ee (preliminary)



Benefit vs costs (preliminary)

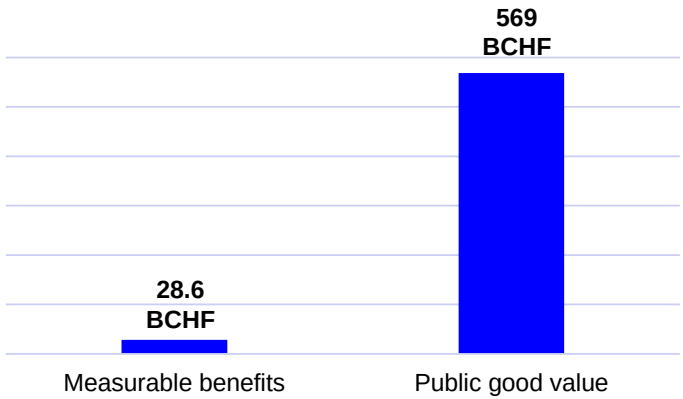


Benefits and costs are discounted at a Social Discount Rate of 2%.

[Francesco Giffoni & Massimo Florio, *Socio-economic impact*]
[slides, recording]

Measurable benefits vs the total public good value

- **On-line surveys** to representative samples of population in France, Switzerland, Germany, Israel, Italy, Japan, Poland, UK, USA: **10,448 total respondents.**
- **Estimation of their willingness to financially support FCC-ee, because of its perceived utility for humankind.**
- **Extrapolation of estimates** to other potential FCC-ee contributing countries.



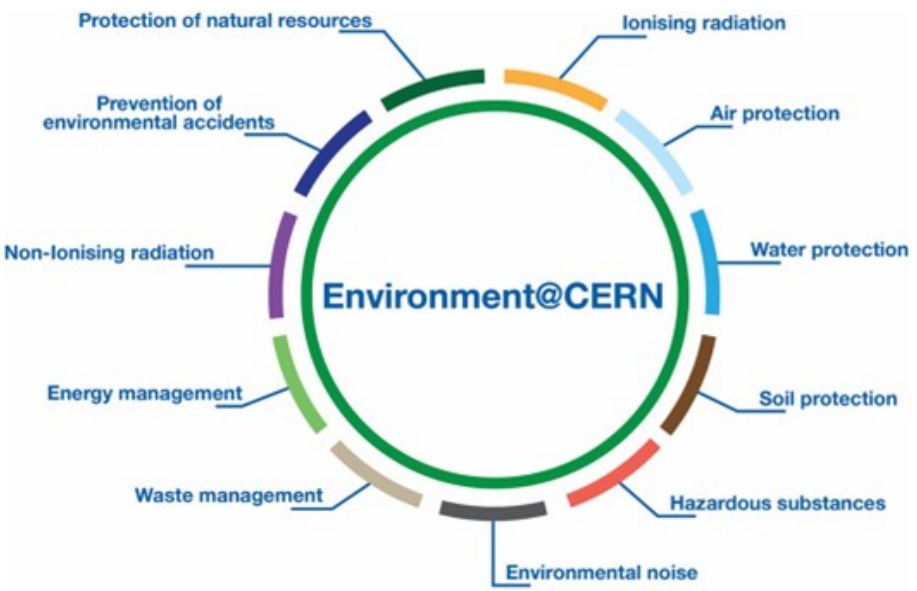
The values are discounted at a Social Discount Rate of 2%.

Secci, L., Giffoni, F., and Delugas, E. (2023). The value of particle physics research at CERN as public good (1.0). Zenodo. https://doi.org/10.5281/zenodo.7766949

[Francesco Giffoni & Massimo Florio, *Socio-economic impact*]
[slides, recording]

CERN Environmental Protection Steering Board

- **Main body for prioritization and implementation of environmental objectives**
- **Created in 2017, involves members of the ED, line management and units for management of energy and environmental footprint.**
- **Steers projects for about 40 MCHF**
  - Retention basins and new STEP to control effluents
  - Cooling towers upgrades
  - Dismissal of oil-based transformers
  - Replacement of GHG in detectors
  - Inventory of Scope 1, 2, 3 emissions, biodiversity, Noise & waste managements….
- **Coordinates the editing of the CERN Environmental report**



[Roberto Losito, *Sustainability of FCs*]
[slides, recording]

What are the considerations for choosing the next step

What do **WE** (the ECR community) find most important in the considerations for a next collider

We will not pick the next collider today, but we ask the questions that need answering

- What are the physics questions we want answered?
- How can we make sure that the probable physics is diverse enough?
  - Are several smaller colliders preferable over one large collider for the diversity of the achieved physics program?
- What are the upgrade possibilities of proposed projects?
- How precise can we get, taking realistic improvements in theory predictions into account?
- How can we make sure the collaboration with other energy range experiment is ensured?
- Is the future collider programme compatible with ECR careers considering possible large time gaps after HL-LHC runtime?
  - Would/could muon colliders make it in time to follow the HL-LHC?
- Can we bridge the gap between HL-LHC and a large future collider with enough attractive projects?
- How can we make a next collider is sustainable in terms of energy use?
- At what time-scale should the ECR community dedicate itself to one particular proposal?
- How can ECRs make the impact they desire on the decision making process?

Additional questions; please email them to; ecfa-ecr-future-colliders@cern.ch

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[Lydia Brenner, *Final remarks*]
[slides]

Future activities of the ECFA ECR panel

Outlook

- Follow-up events at the national level, organized by local committees of the ECFA countries
- Goal: discuss country-dependent issues/aspects (e.g. funding sources, role of the national agencies etc.)
- Goal: help the formation of a cohese ECR community at the national level
- Send an email to ecfa-ecr-future-colliders@cern.ch to participate
- Italian community effort?