University of Zurich[UZH]

ECFA ECR Panel: Detector R&D and future colliders activities

CALICE Collaboration Meeting, 27-29. September 2023

Armin Ilg, University of Zürich

2020 Update of the European Strategy for Particle Physics

Year-long process, 20 strategy statements.

Most important for us:

> Particle physics, with its fundamental questions and technological innovations, attracts bright young minds. Their **education and training** are crucial for the needs of the field and of society at large. For **early-career researchers** to thrive, the particle physics community should place strong emphasis on their **supervision and training**. Additional measures should be taken in large collaborations to **increase the recognition of individuals developing and maintaining experiments, computing and software**. The particle physics community commits to placing the principles of **equality, diversity and inclusion** at the heart of all its activities.

Short history of ECFA ECR

The ECFA ECR panel was created as a follow-up to the ECFA Early-Career Researchers input to the 2020 Update of the European Strategy for Particle Physics (rather ad-hoc, not a panel)

*The objective of the ECFA Early-Career Researchers (ECR) Panel is for its members to discuss **all aspects** that contribute in a broad sense to the **future of the research field of particle physics**. In its advisory role to ECFA, the panel reports to ECFA on a regular basis. An annual report of the ECFA ECR Panel is added as a standing item to the agenda of Plenary ECFA meetings.*

→ The ECFA ECR panel is tightly linked with the Update of the European Strategy → Actively working to make sure we're in the loop from the beginning

ECFA ECR Panel composition and activities

Members are, in general, ***PhD students and postdocs, either with a non-permanent contract or with up to eight years after obtaining the PhD****. Up to* ***three members*** *(+1 for countries with LDG lab), among them at least one PhD student and one postdoc, can be nominated* ***by each ECFA country*** *represented in ECFA for a* ***mandate of two years****,* ***extendable for another two years****. Nominations are to be endorsed by Plenary ECFA. Members act as individuals, but should be able to represent the views of early-career researchers in particle physics in the nominating country.*

- From PhD students to young assistant professors
- Theoreticians, phenomenologists, experimentalists, …

→ Diversity in cultural background, career and research, trying to represent the whole community

- 3-4 panel meetings per year, handled by *Organization Committee (3 members)*
- 5 ECR delegates in Plenary ECFA, 1 delegate in Restricted ECFA

Actual work is done in **working groups** that are flexible. See arXiv:2212.11238 for a summary of 2021-2022

Detector R&D

Detector R&D WG

Motivated by call for input to *Training in Instrumentation* symposium in ECFA Detector R&D Roadmap → Creation of working group

- Town hall meeting to gather what is important for ECRs in detector R&D
- Survey about training in instrumentation, both to ECRs involved and not (yet) involved, total of 473 responses!

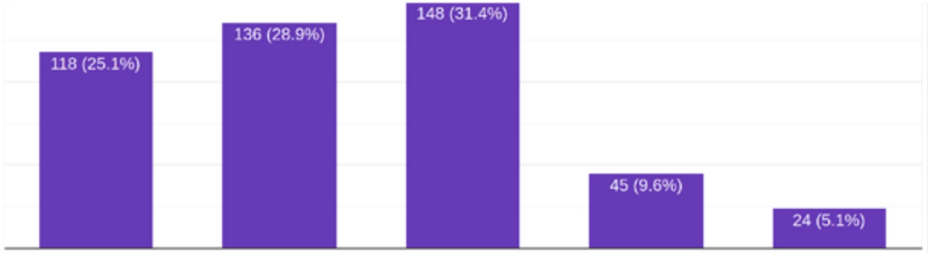
➔ Training symposium input

➔ Detailed report (arXiv:2107.05739)

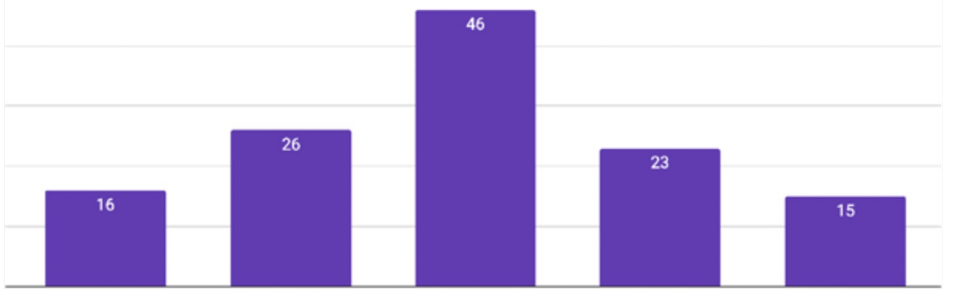
➔ Discussion with instrumentation community at *15th Pisa Meeting on Advanced Detectors* (doi:10.1016/j.nima.2023.168022)

Detector R&D WG: Some results

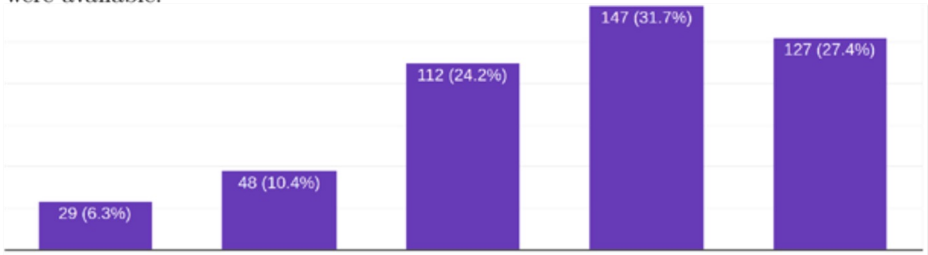
How informed do you feel about opportunities in instrumentation training?



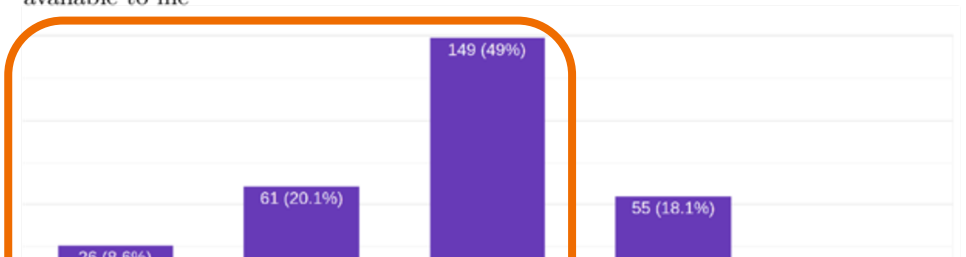
My identity as under-represented minority has impacted my training experience



I would be more willing/eager to take on instrumentation work if more training were available.



I am satisfied with networking opportunities for ECRs in instrumentation available to me



Let's create a WG to try to address this!

Networking in instrumentation WG

Event to foster discussion and networking among ECRs in instrumentation

- ➔ **Early-Career Instrumentation Forum**
- Panel discussion + break-out rooms to discuss directly with panelists
- Topic: Careers in HEP instrumentation
- ~50 participants, on Zoom
- Hope to have future iterations focusing on different topics

ECFA Training Panel

Newly formed ECFA Training Panel, following Detector R&D Roadmap

DCT 1 - Establish and maintain a European coordinated programme for training in instrumentation. First: Webpage with links to instrumentation schools

DCT 2 - Develop a master's degree programme in instrumentation.

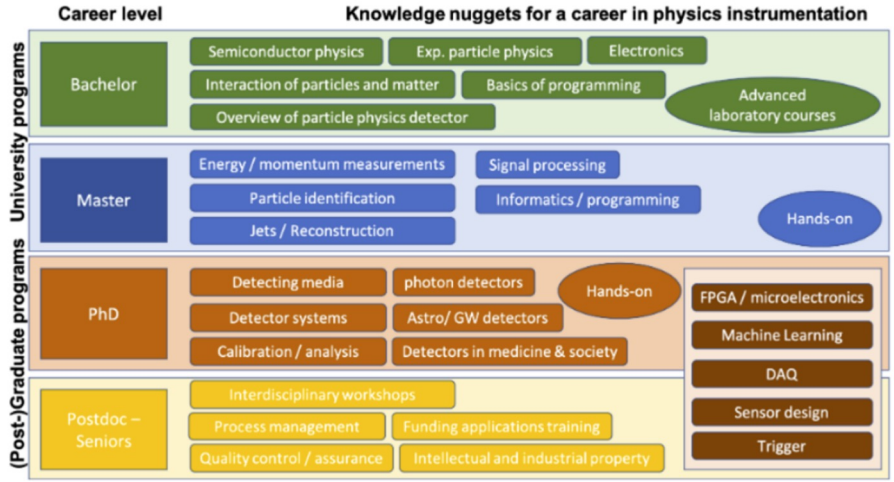


Figure 1: Possible structure of a training plan recommendation from ECFA. The knowledge expected at different levels for an career in HEP instrumentation are shown.

Future colliders

Future colliders WG

Goal: Inform ECRs about future collider options and development, enabling them to shape their own vision on future colliders

This Wednesday: ***Future colliders for early-career researchers***

Short presentations on prospects, lots of time for discussions. Can serve as reference information for ECRs.

Back to the future

Jorgen d'Hondt (experimental view): *The Future doesn't exist yet*

Federico Buccioni (theory view): T*omorrow is today!*

Let's instead write: *The future is ours!*
As Prof. Rabinovici also said

So which future collider do we want?

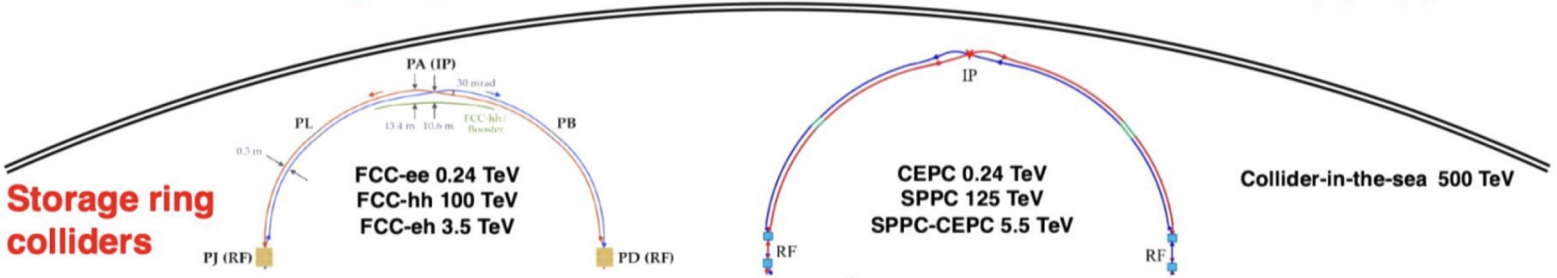
Requirements for the next HEP machine

- 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, …

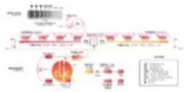
Tatsuya Nakada

Future collider proposals: 0.125 – 500 TeV; e+e-, hh, eh, μμ, γγ, …

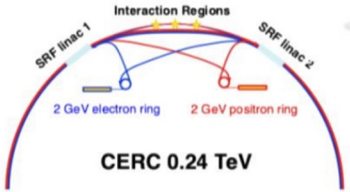
- **Storage ring colliders**
- **Linear colliders**
- **ERL colliders**
- **Muon collider**
- **Wakefield colliders**




ILC 0.25 TeV

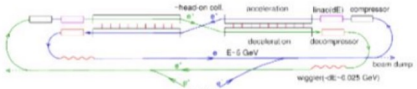

CLIC 0.24 TeV

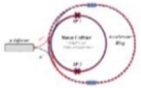

CCC 0.25 TeV



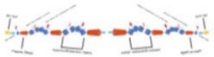
CERC 0.24 TeV

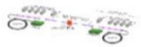

ReLiC 0.24 TeV


ERLC 0.24 TeV


MC 10 TeV

10 km

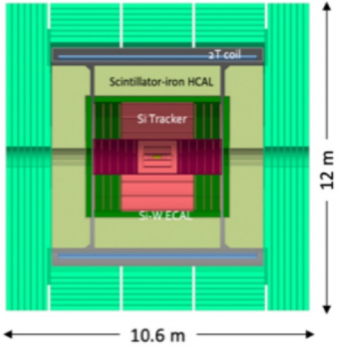

PWFA 15 TeV


LWFA 15 TeV


SWFA 3 TeV

CLD

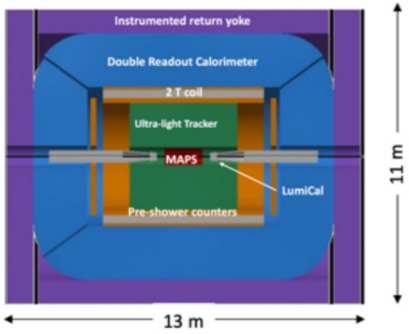
https://arxiv.org/abs/1911.12230 and FCC CDS vol. 2



CDR

IDEA

FCC CDR vol. 2



Allegro

M.Aleksa @ FCC Week, 2022

new

Well established design
- ILC -> CLIC detector -> CLD

Full Si vtx + tracker; CALICE-like calorimetry; large coil, muon system

Engineering and R&D needed for
- reduction of tracker material budget
- operation with continous beam (no power pulsing: cooling of Si sensors for tracking + calorimetry)

Possible detector optimizations
- Improved σ_p/p, σ_E/E
- PID: timing and/or RICH?

- Less established design
  - But still ~15y history: ILC 4th Concept
- Si vtx detector; ultra light drift chamber w powerfull PID; compact, light coil; monolitic dual readout fibre calorimeter; muon system
  - Possibly augmented by crystal ECAL
- Active community
  - Prototype designs, test beam campains, …

- A design in its infancy
- High granularity Noble Liquid ECAL is core
  - Pb+LAr (or denser W+LCr)
- Drift chamber; CALICE-like HCAL; muon system.
- Coil inside same cryostat as LAr, possibly outside ECAL
- Active Noble Liquid R&D team
  - Readout electrodes, feed-throughs, electronics, light cryostat, …
  - Software & performance studies

And even muon collider now!

Mogens Dam and Nadia Pastrone

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	tt̄		(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)

Federico Buccioni

[Blondel, Janot 2106.13885]

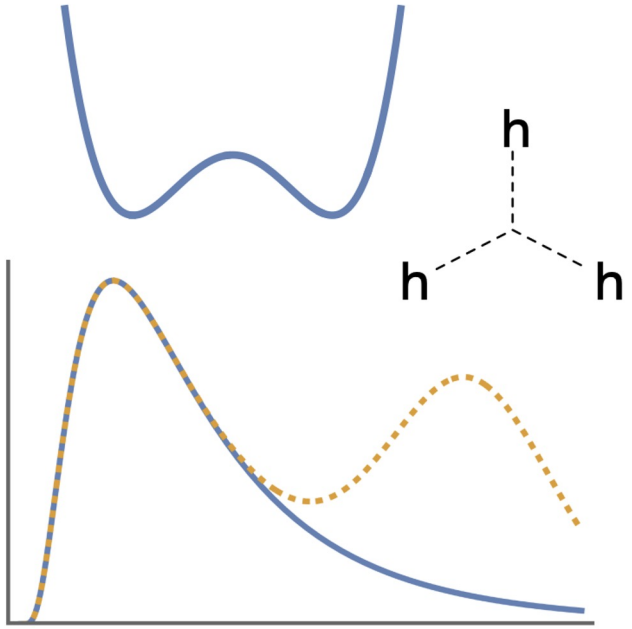
Observable	present value ± error	FCC-ee Stat.	FCC-ee Syst.	Comment and leading exp. error
m_Z (keV)	91186700 ± 2200	**4**	100	From Z line shape scan Beam energy calibration
Γ_Z (keV)	2495200 ± 2300	**4**	25	From Z line shape scan Beam energy calibration
$\sin^2\theta_W^{\rm eff}(\times 10^6)$	231480 ± 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
Γ_W (MeV)	2085 ± 42	**1.2**	0.3	From WW threshold scan Beam energy calibration
$N_\nu(\times 10^3)$	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

Summary

Exciting times ahead if a future collider is built!

- Guaranteed deliverables:
  - Precision measurements
  - Higgs self-coupling

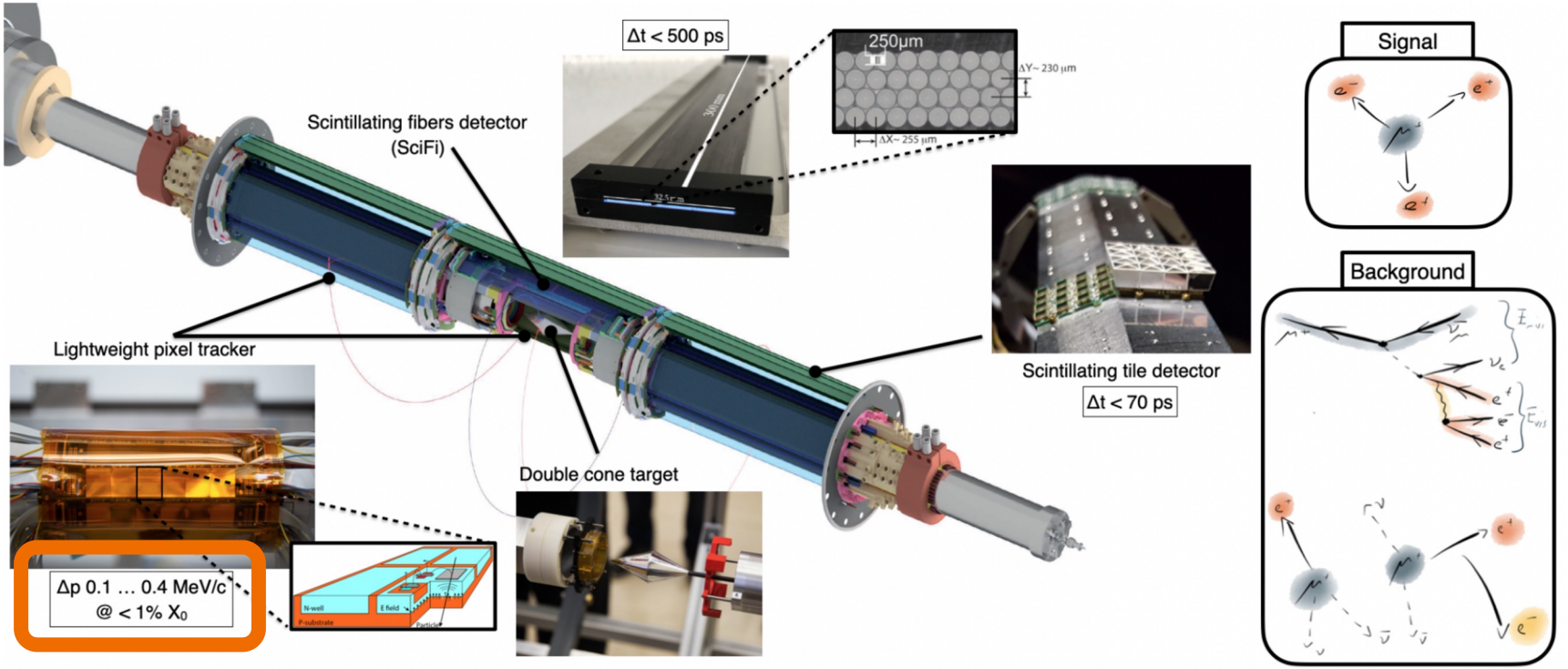
- Potential direct discoveries



Anke Biekoetter

Mu3e detector

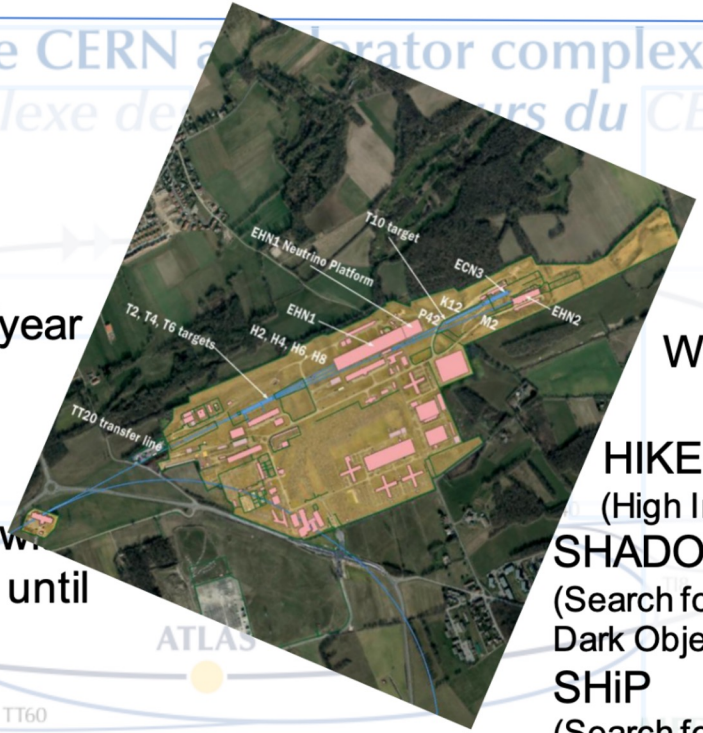
The aim is to improve the current limit of $\mathcal{B}(\mu \to eee) < 1.0 \times 10^{-12}$ (90 % C.L.) to S.E.S. $< 10^{-16}$[2].



- ECN3 - part of the SPS NA
- 400 GeV
- high intensity up to 10^{19} pot/year
- high duty cycle

Currently :

the NA62 experiment w… an approved program until LS3.



What is after LS3?

HIKE
(High Intensity Kaon Experiment)
SHADOW
(Search for Hidden And Dark Objects With the SPS)
SHiP
(Search for Hidden Particles)

Iaroslava Bezshyiko

What cool things can we do with ATLAS/CMS/LHCb/ALICE leftovers after HL-LHC?
Using waste particles: Beam dumps at future colliders?

Conclusions

(Ultra-relativistic) heavy-ion collisions: unique tool to study QCD matter under extreme conditions

Next decades will be crucial to shape the post-LHC future of heavy-ion field!

- Whole new opportunities for heavy-ion studies with colliders like FCC
- EIC will *complement* these future heavy-ion studies by exploring cold QCD
- New (and unconventional) ideas are welcome!

Future colliders need you 👊
Thank you for your attention!

Ivan Vorobyev

Reflections

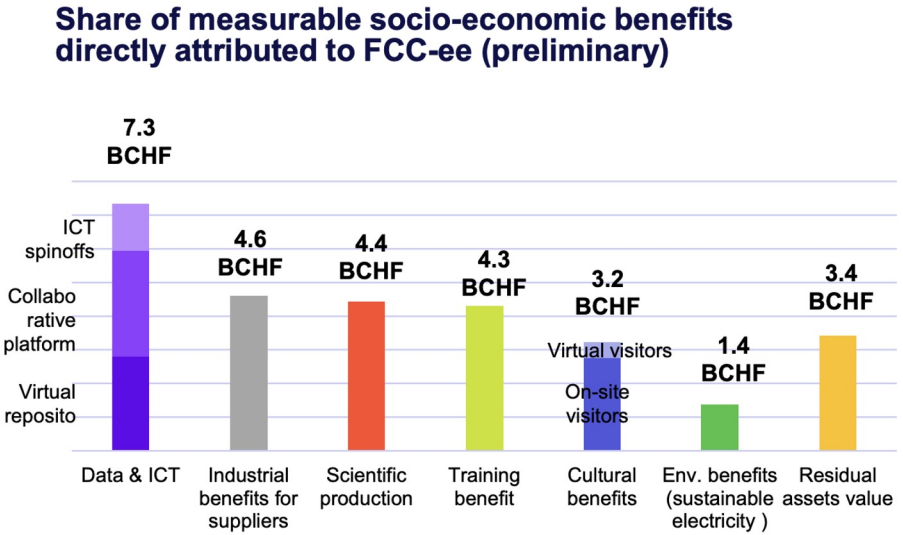
- ECRs need to be involved in future projects – it is **your** future
  - In the early stages, these projects are driven by experienced senior colleagues
    - They have the luxury/duty of preparing the future, but todays ECRs will benefit from this and actually carry out the science – get involved, 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 !

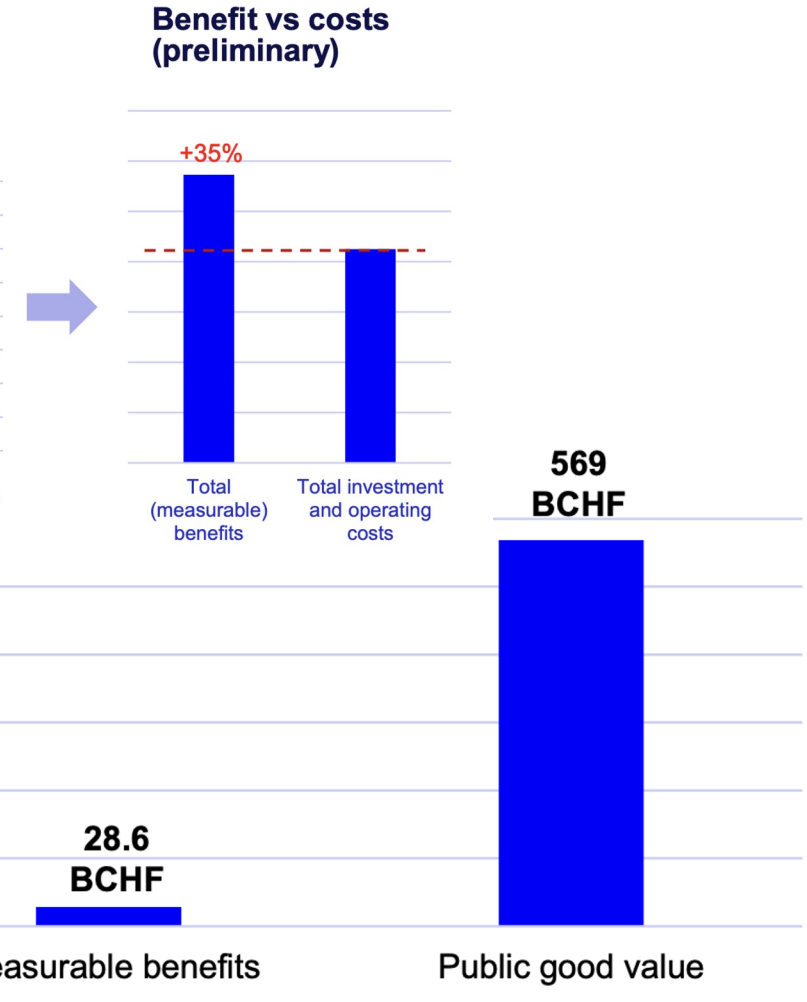
Richard Hawkings

ECRs: This is YOUR TIME, YOUR FUTURE

- BIRMINGHAM ONE FULL DAY, PARIS TWO HOURS, CAMBRIDGE, LONDON TWO HOURS, UK ECR+, GENEVA ONE FULL DAY.
- COUNCIL VIEW INFORMED ACTION
- ECR INFORMED ACTION

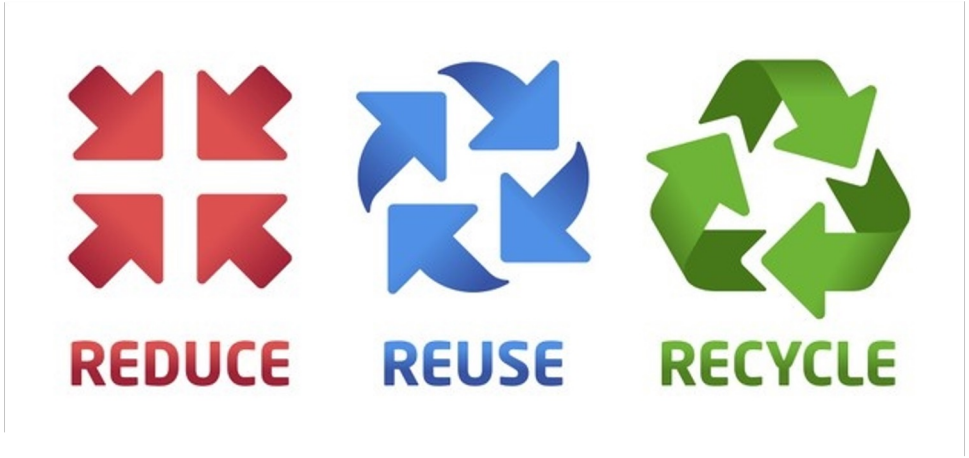
Eliezer Rabinovici



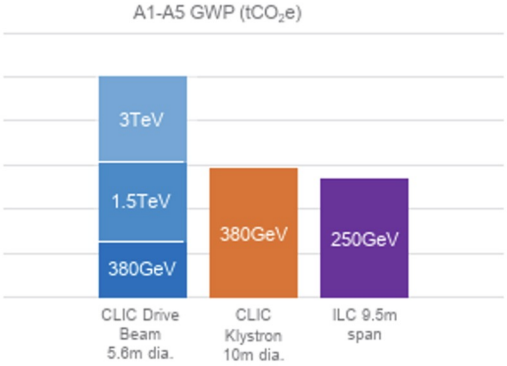


Future colliders are *worth it*!

Francesco Giffroni and Massimo Florio



LifeCycle Assessment: CLIC & ILC



UN Breakthrough Outcomes for 2030

For the built environment sector, the UN breakthrough outcomes for 2030 detail that 100% of projects due to be completed in 2030 or after are net zero carbon in operation, with at least 40% less embodied carbon compared to current practice. This has been set to make sure the sector is on track for 100% projects to be net zero carbon across the whole life cycle by 2050.

https://climatechampions.unfccc.int/system/breakthroughs/

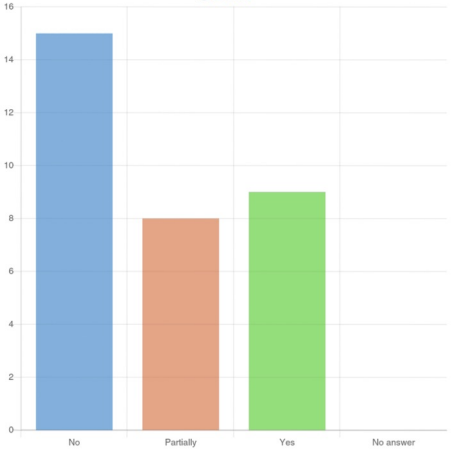
- **We need to consider how to get to net zero carbon operation and 40% less impacting construction for our future projects….**

Roberto Losito

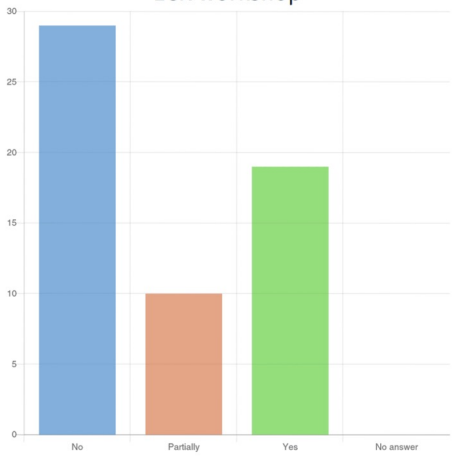
CERN and ECR Workshop survey (full presentation here)

- Are you currently working on projects connected to future colliders?

CERN



ECR workshop

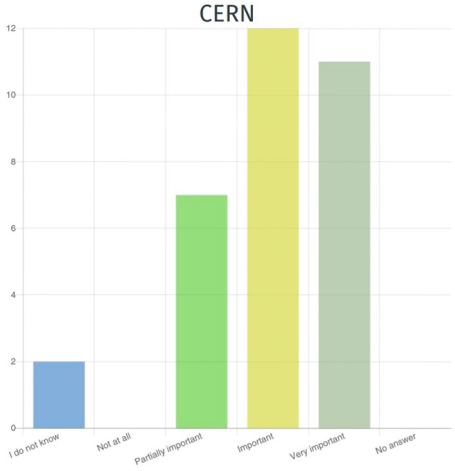


- Majority already working (partially or fully) on future collider projects

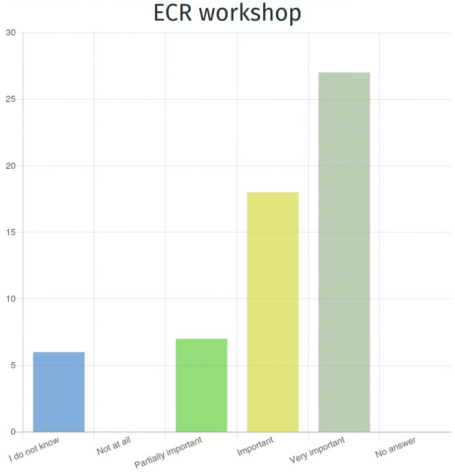
- Majority already working (partially or fully) on future collider projects

- How important is the future collider programme for your career?

CERN



ECR workshop



- A future collider program is considered important by (almostt) everyone

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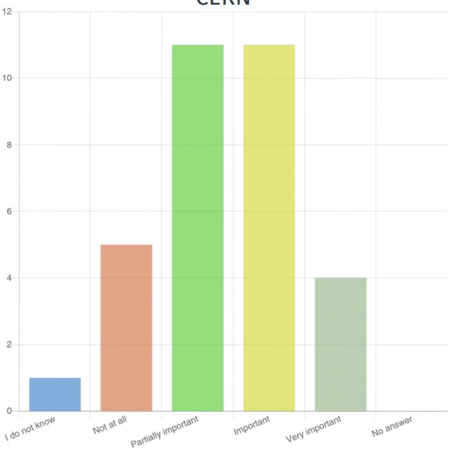
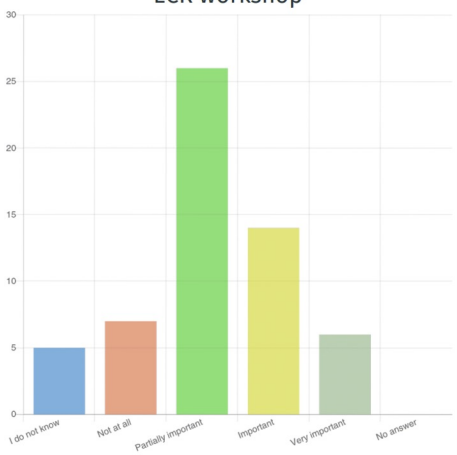
CERN and ECR Workshop survey (full presentation here)

- Is the choice of a specific future collider over another important for your career?

CERN



ECR workshop

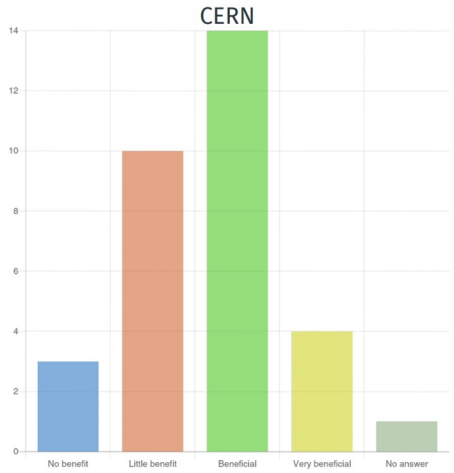


- The choice of the collider seems to matter, in part or completely

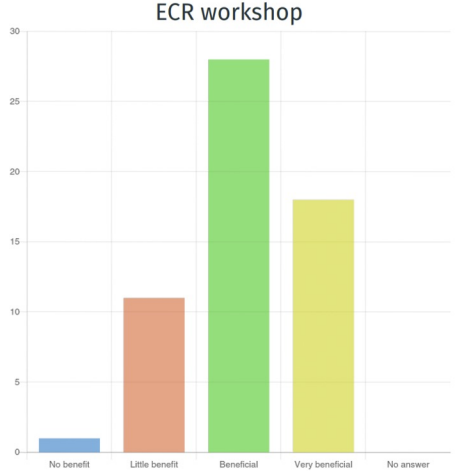
- The choice of the collider seems to matter, in part or completely

- Do you consider including future-collider related projects in your activities as beneficial to your career?

CERN



ECR workshop

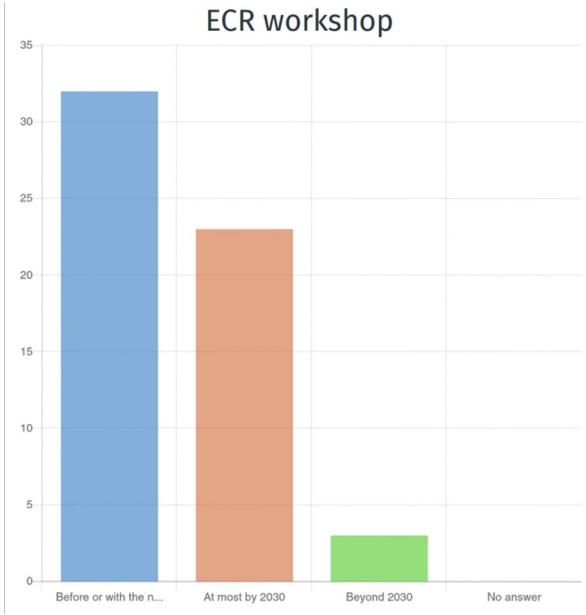


- Sizable 'little benefit' choice

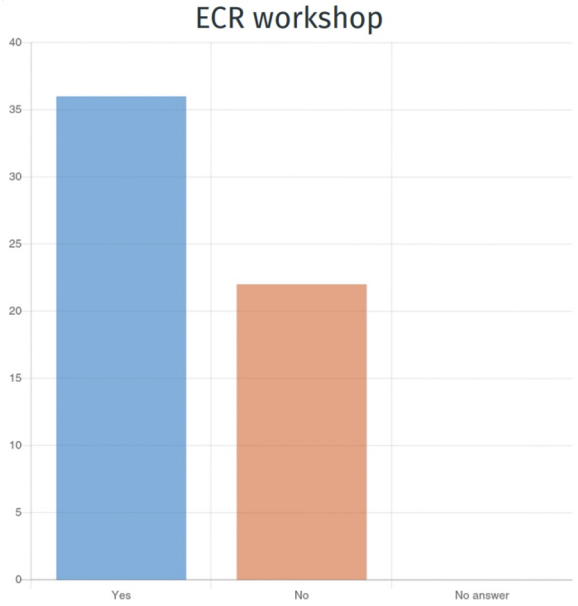
- More positive outlook

CERN and ECR Workshop survey (full presentation here)

In light of your career prospects, how long do you think it is acceptable to wait before the decision of which machine to build is made



Would you accept to work nearly full time on a project connected to a future collider, while the decision on the next machine is still pending? If yes, under which conditions



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

What's next?

The studies continue…

- Second ECFA Workshop on e+e- Higgs/EW/Top Factories, 11-13.10.2023, low fees for ECRs!

From ECFA to the national communities

- Follow-up the ECFA-wide event with national, in-person events on future colliders, directing discussions into the ECFA countries as some issues are country dependent
- A lot to be organised still! Let us know if you'd be willing to help!

Keep in touch with us

- Our webpage to find your country ECR representative, ecfa-ecr-organisers@cern.ch
- Subscribe to ecfa-ecr-announcements e-group to get notified about our activities!

Consider joining us when a panel slot becomes free in your country!

Thanks!

Career Prospects and Diversity in Physics Programme WGs

Designed a survey to collect information about…

- What is the impact of the collaboration size on ECRs? What is working and not working in large/small collaborations?
- Assess the career situations of ECRs, how can our panel help?
- What do ECRs think is needed for a successful career versus what is actually needed for a successful career?

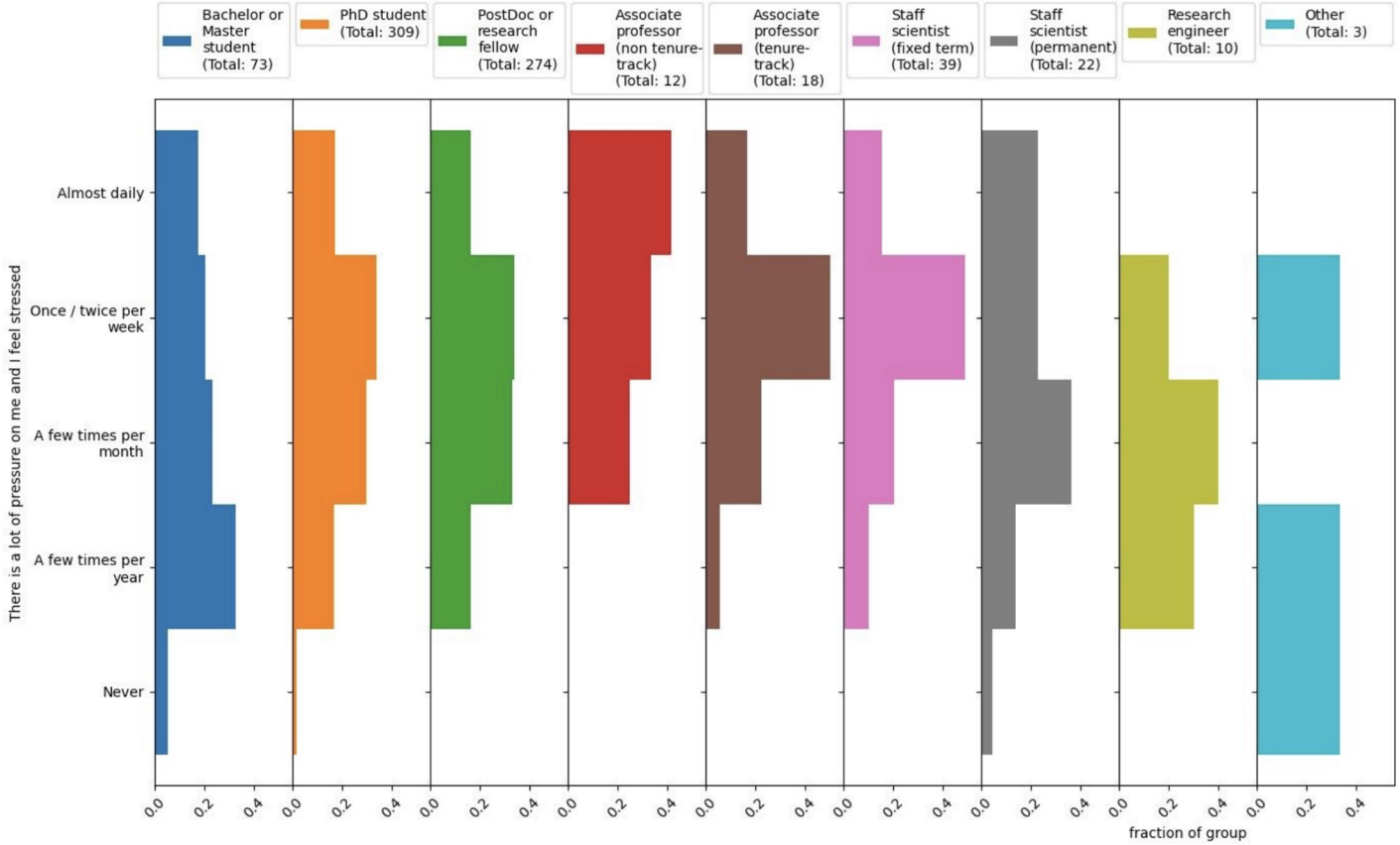
Circulated to ECR community (760 responses!) and also to ECFA national contacts (shorter version)

Structure of the survey

- ❑ Personal data
- ❑ Field of work
- ❑ Collaboration and working group
- ❑ Diversity of Physics
- ❑ Career perspective and planning
- ❑ Work-life balance
- ❑ Leaving academia
- ❑ Recognition and visibility
- ❑ Final questions, feedback and remarks

Survey status update (K. Jarkovská, O. Lelek, H. Pacey)

Career Prospects and Diversity in Physics Programme WGs: First result



➔ Compile and release report similar to the other survey