

FCC Physics, Experiments, and Detectors (PED)

Introduction
Goals of the Meeting



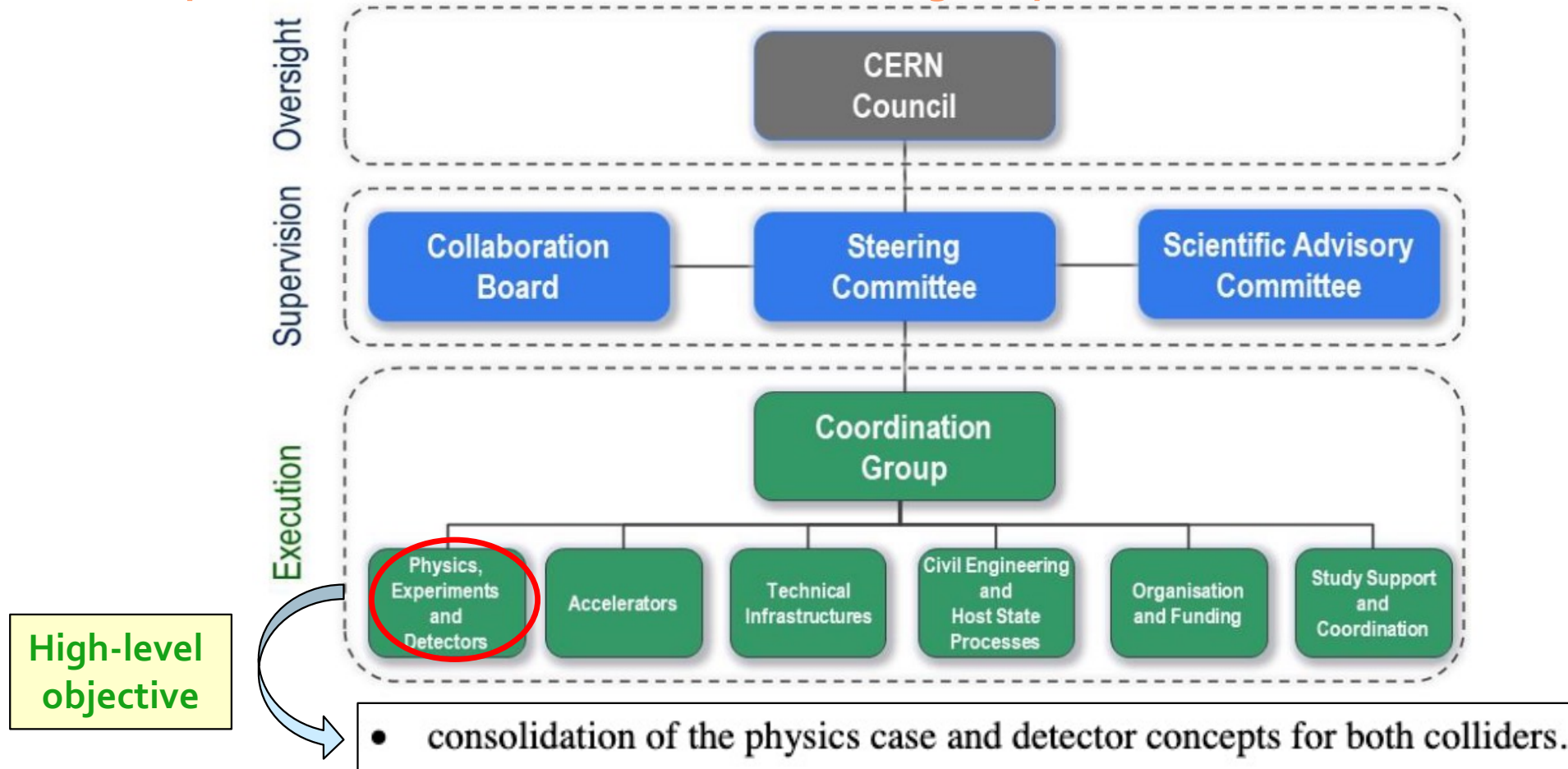
*This project is supported from the European Union's
Horizon 2020 research and innovation programme
under grant agreement No 951754.*



FCC Feasibility Organization and PED

From CERN Council document: FCC FS Main Deliverables and Milestones

◆ <http://cds.cern.ch/record/2774007/files/English.pdf>



The PED feasibility study work is clearly cut out

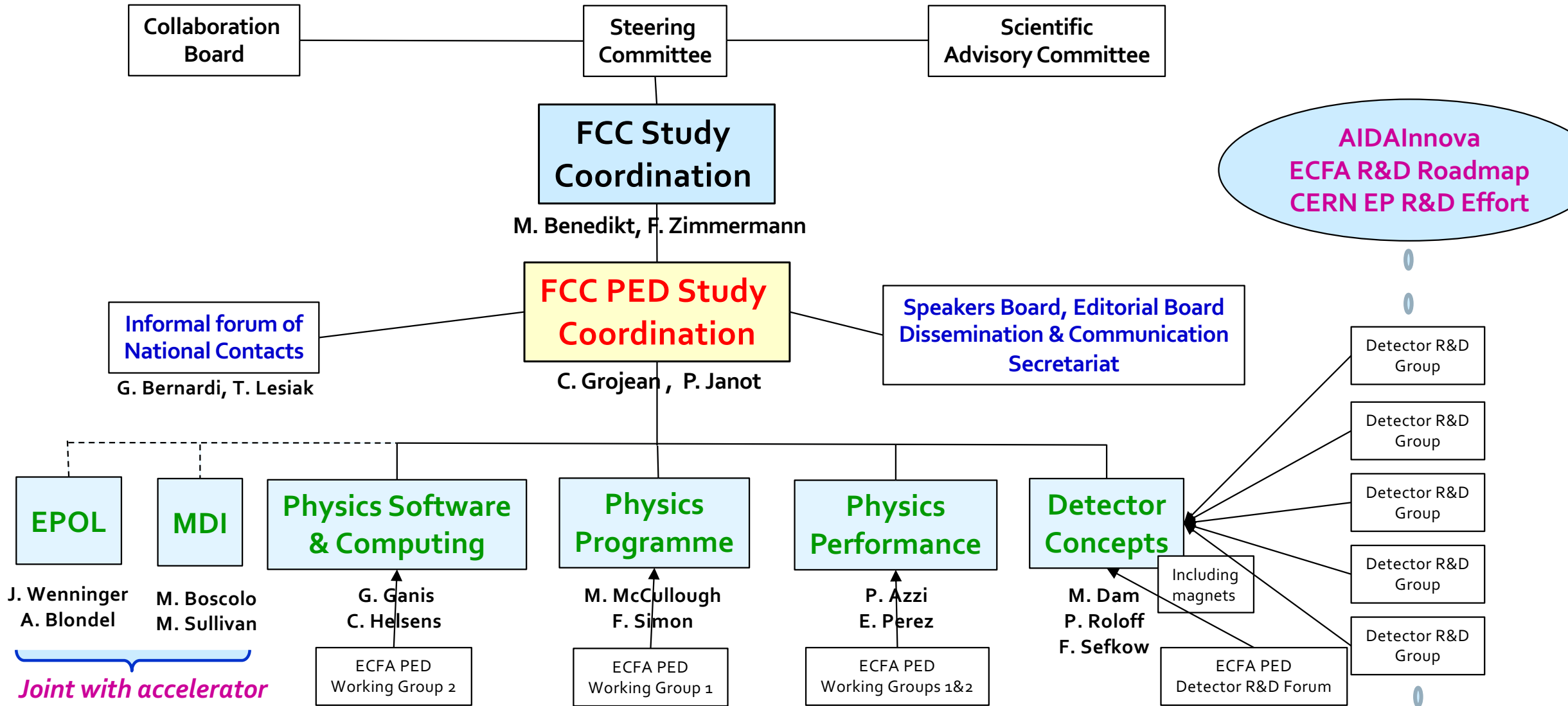
- **Design the experimental setup and prepare the theoretical tools**
 - ◆ To be able, demonstrably, to fully exploit (and communicate) the FCC capabilities
 - ◆ To prepare the ground towards detector operation and data analysis in 2040+

- **A proactive preparation is necessary from all sides**
 - ◆ Consolidate the physics case for both colliders of FCC
 - ◆ Develop the necessary theoretical calculations
 - ◆ Tune the accelerator design and running mode to optimize the physics case
 - ◆ Provide coherent sets of detector requirements and physics analysis tools & methods
 - ◆ Benchmark several (at least four) detector concepts for FCC-ee to match these requirements
 - ◆ Develop a common software infrastructure
 - ◆ Evaluate computing requirements

- **Last but not least**
 - ◆ Build an international community of particle physicists around the project

From my presentation
at P-ECFA, Nov. 2021

Tailored PED pillar organisation & conveners



FCC/PED Actions to widen the community support

□ From the FCC submission to the ESPP'2020

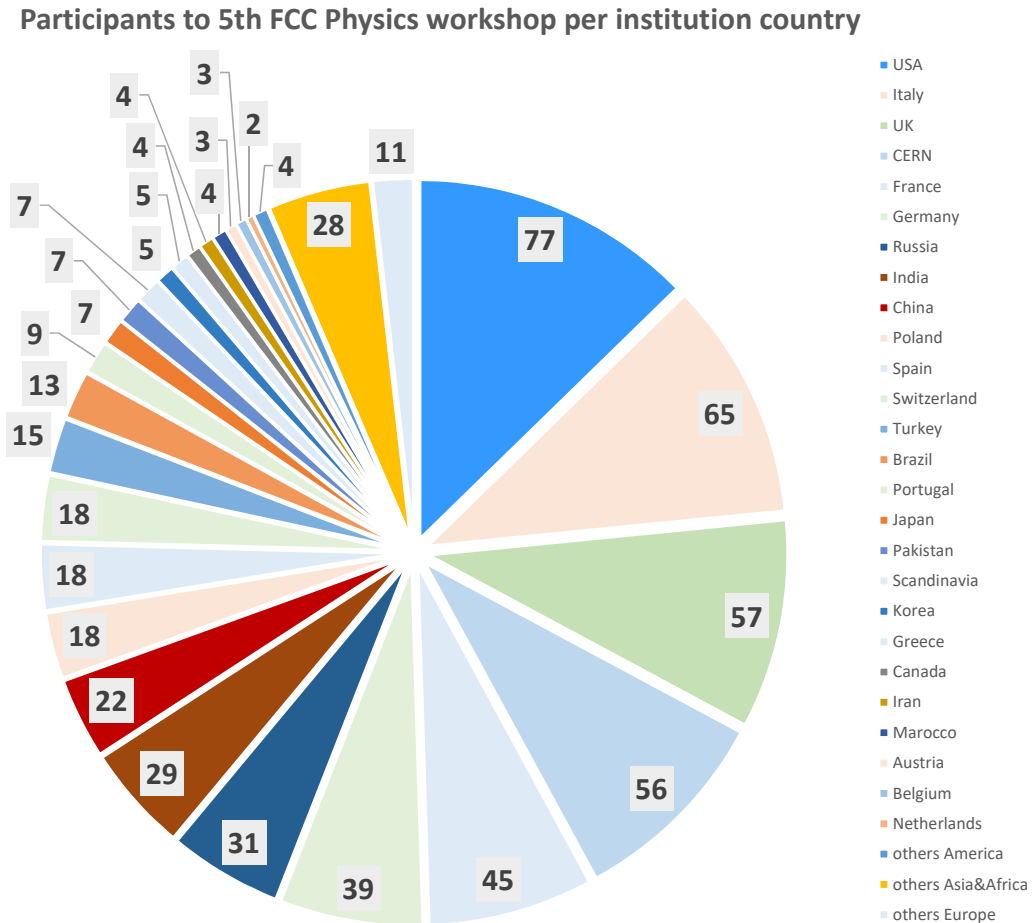
"The greatest remaining challenge is the creation of a world-wide consortium of scientific contributors who reliably commit resources to the development and preparation of the FCC science project from 2020 onwards"

- ◆ Meanwhile, the Council approved the FCC Feasibility Study and the related funds
 - Giving us solid basis to communicate about the FCC project and encourage participation
 - ◆ Several networking efforts to build the community are motives of great hopes
 - E. Tsesmelis' work as Global Collaboration WG coordinator
 - G. Bernardi, T. Lesiak & M. Chrzaszcz animation of the Informal Forum of National Contacts
 - P. Charitos' relentless communication work
- ## □ Important goal of the meeting
- ◆ Foster and organize the commitment of national institutes with (human) resources
 - Dedicated IFNC session on Thursday afternoon (17:00 UK time, 18:00 Geneva time)

Workshop international participation (as of 5 Feb.)

□ Another motive of great hope

USA	77
Italy	65
UK	57
CERN	56
France	45
Germany	39
Russia	31
India	29
China	22
Poland	18
Spain	18
Switzerland	18
Turkey	15
Brazil	13
Portugal	9
Japan	7
Pakistan	7
Scandinavia	7
Korea	5
Greece	5
Canada	4
Iran	4
Marocco	4
Austria	3
Belgium	3
Netherlands	2
others America	4
others Asia&Africa	28
others Europe	11
unidentified	28
grand total	634



Courtesy: Alain Blondel, 5 Feb 2022

Limited resources call for prioritization

□ The highest priority of the European Strategy Update is our guide

An electron-positron Higgs factory in the highest priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy.

- ◆ The FCC Financial Feasibility Study focusses on the FCC first stage (tunnel + FCC-ee)
- ◆ We are also convinced that FCC-ee is the most pragmatic and safest way towards FCC-hh
 - Going directly to FCC-hh seems technically and financially not feasible
 - FCC-ee provides the common infrastructure, a staged budget, time for HFM R&D
 - FCC-ee has a very strong and unique physics case (TeraZ, High luminosity, \sqrt{s} calibration, ...)
 - The ee/hh scientific synergies magnify the FCC-hh and the integrated FCC physics cases
- ◆ There is no feasibility study in Europe (or elsewhere) without FCC-ee as the 1st stage for hh
 - e.g., CEPC/SPPC in China; Other projects that went directly to hh failed (SSC).
- ◆ The FCC-ee proto-collaborations will be our first “clients” once the project is approved
 - With the ground work from the PED study as a solid basis

The PED priorities until the next ESU

- **We are therefore focussing our work on FCC-ee Physics, Experiments and Detectors**
- **The work on keeping up-to-date the FCC-hh physics capabilities continues**
 - ◆ Expand the exploration of the physics reach of FCC-hh
 - ◆ Stimulate the discussion of the complementarity and synergy between FCC-ee and FCC-hh
 - ◆ Encourage the cross-talk between the ee and pp/LHC communities
 - ◆ Stimulate the early engagement of the hadron community in the ee activities
 - Theorist and experimentalists alike
- **The work on the FCC-hh baseline detector concept is being finalized as we speak**
 - ◆ Complete 300-pages CDR given to the Yellow Report Editors at the beginning of March
 - ◆ Significant add'l work might have to wait for the end of the feasibility study
 - When feedback from HL-LHC detector upgrades is fully available (end of LS₃)
 - If the physics Landscape has significantly evolved (end of LHC Run₃)

The PED ultimate objectives until the next ESU

- **Match detectors with the physics opportunities offered by the facility**
 - ◆ Establish a coherent set of detector requirements from physics studies
 - To fully benefit from statistics, variety of channels, new physics sensitivity→ [Physics Programme](#)
 - ◆ Provide a coherent set of detector solutions (or path to solutions)
 - To maximally exploit the new collider layout compatibility with four interaction points
 - To deliver preliminary infrastructure requirements and cost estimates→ [Physics Performance](#)
→ [Detector Concepts](#)

- **This ought to happen in time for (proto)collaborations to**
 - ◆ Pick up the wealth of knowledge acquired and common tools developed on the way
 - ◆ Present EoI's to the next strategy, and
 - ◆ Run away with the project once approved→ [Software & Computing](#)

- **Best would be that at least four (proto)collaborations propose a detector**
 - ◆ Serious funding will arise at this point
 - ◆ More precise costs and demands on infrastructure will be elaborated

New opportunities create new challenges

EPJ+ special issue "A future Higgs and EW Factory: Challenges towards discovery"

2	Introduction [1] (2 essays)	3
2.1	Physics landscape after the Higgs discovery [2]	3
2.2	Building on the Shoulders of Giants [3]	4
3	Part I: The next big leap – New Accelerator technologies to reach the precision frontier [4] (6 essays)	4
3.1	FCC-ee: the synthesis of a long history of e^+e^- circular colliders [5]	4
3.2	RF system challenges [6]	4
3.3	How to increase the physics output per MW.h for FCC-ee? [7]	5
3.4	IR challenges and the Machine Detector Interface at FCC-ee [8]	5
3.5	The challenges of beam polarization and keV-scale center-of-mass energy calibration [9]	5
3.6	The challenge of monochromatization [10]	5
4	Part II: Physics Opportunities and challenges towards discovery [11] (15 essays)	6
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4.6	Hunting for rare processes and long lived particles at FCC-ee [17]	7
4.7	The W mass and width challenge at FCC-ee [18]	8
4.8	A special Higgs challenge: Measuring the electron Yukawa coupling via s-channel Higgs production [19]	8
4.9	A special Higgs challenge: Measuring the mass and cross section with ultimate precision [20]	9

MDI, \sqrt{s}

Challenges to match statistical precision

All 34 references in this Overleaf document:
<https://www.overleaf.com/read/xcssxqyhtrgt>

4.10	From physics benchmarks to detector requirements [21]	9
4.11	Calorimetry at FCC-ee [22]	9
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5.1	FCC-ee: Physics Motivations [28]	11
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5.3	QCD at the FCC-ee [30]	12
5.4	New Physics at the FCC-ee: Indirect discovery potential [31]	12
5.5	Direct discovery of new light states [32]	12
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5.7	Challenges for tau physics at the TeraZ [34]	12
	Part IV: Software Dev. & Computational challenges [35] (4 essays)	12
6.1	Key4hep, a framework for future HEP experiments and its use in FCC [36]	13
6.2	Offline Computing resources for FCC-ee and related challenges [37]	13
6.3	Accelerator-related codes and their interplay with the experiment's software [38]	13
6.4	Online computing challenges: detector & readout requirements [39]	14

Detector requirements & possible solutions

Theory challenges

Software and computing challenges

Physics Programme: Goals of the meeting

- **Presentation of the plans/objectives by the Physics Programme coordinators** Friday
 - ◆ Matthew McCullough (CERN) and Frank Simon (MPP Munich)

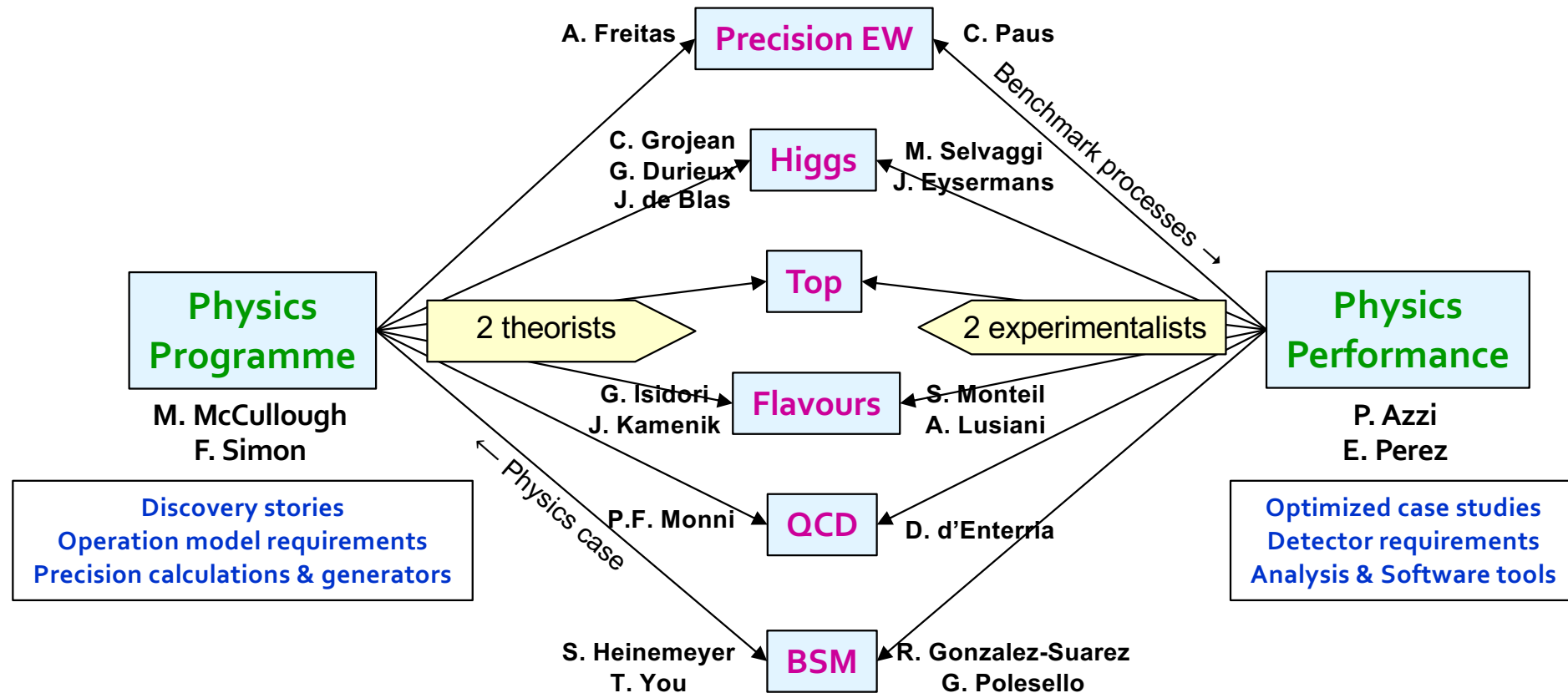
- **Physics Groups installation**
 - ◆ Higgs , Precision EW, Flavours , QCD , BSM (direct searches), Top
Monday Thursday Tuesday Wednesday Thursday (Postponed)

- **The Workshop will help address the following Physics Groups goals**
 - ◆ Consolidate/elaborate FCC discovery potential and main physics deliverables
 - ◆ Identify new discovery opportunities and observables
 - ◆ Strengthen the FCC community and enhance links between particle physics subfields

- **The Workshop will help build a close collaboration with Physics Performance**
 - ◆ Interactions will happen via the Physics Groups

Physics groups (with conveners)

- The link between Physics Programme and Physics Performance is explicit
 - ◆ We have converged towards “common” groups rather than “mirrored” groups



- Physics Group kick-offs will proceed with topical workshops (t.b.a.)

Physics Performance: Goals of the meeting

- **Presentation of the plans/objectives by the Physics Performance coordinators** Friday
 - ◆ Emmanuel Perez (CERN) and Patrizia Azzi (INFN Padova)

- **Check point for the progress of the benchmark analyses, with formal presentations**
 - ◆ Set up of the strategy, presentations of the tools Mostly Higgs (Monday)
 - ◆ Connection to detector requirements and Flavours (Tuesday)

- **The workshop will help move to the full exploration, a.k.a. “case studies”**
 - ◆ Define what can be done with fast simulation, and what aspects need full simulation
 - ◆ Explore the factors limiting the precision of the analysis outcome
 - ◆ Define the path that connect the limiting factors to specific detector requirement(s)

- **Define work organization within the Physics Groups**
 - ◆ From benchmark processes to detector requirements

Precision EW Case Studies
to be initiated a.s.a.p.
Presentation by J. Alcaraz on Friday

Detector Concepts: Goals of the meeting

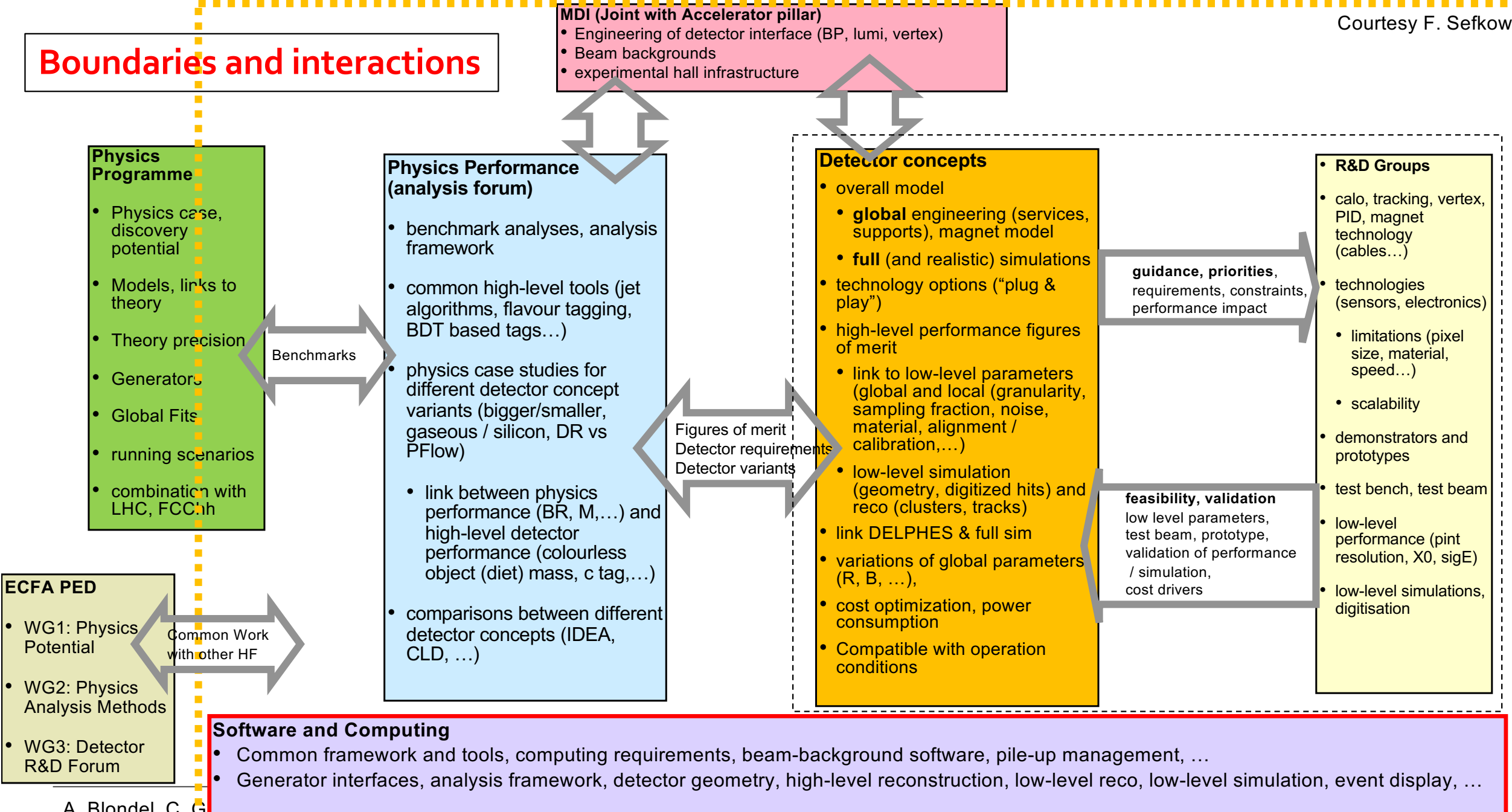
- **Presentation of the plans/objectives by the Detector Concepts coordinators** Friday
 - ◆ Mogens Dam (NBI Copenhagen)
 - ◆ Philipp Roloff (CERN)
 - ◆ Felix Sefkow (DESY) – in charge of the relation with R&D groups
 - Note: Coordinator team is complete only since the end of last week !

- **Detector session, with a panorama of the ongoing work, is scheduled on Wednesday**
 - ◆ This session help address the following goals for the Detector Concepts group
 - Demonstrate that detectors can be built to fully exploit the FCC physics opportunities
 - Provide guidance for coherent detector R&D efforts to address FCC detector requirements

- **Start discussing connections and communications between the PED branches**
 - ◆ Physics Programme, Physics Performance, Detector Concepts, Detector R&D, MDI
 - And of course Software, the underlying tissue connecting all branches
 - ◆ A dedicated workshop (summer 2022) is in preparation

Joint discussion
on Friday Morning

Boundaries and interactions



Software and Computing: Goals of the meeting

- **Software coordinators: Gerardo Ganis (CERN) and Clément Helsens (KIT, Karlsruhe)**
 - ◆ Discuss/present the updated group mandate Friday, by David Lange, chair of the “Software Task Force”

- **The workshop will help address the following goals for the Software group**
 - ◆ Advertise status of things and step-by-step how-to
 - ◆ Trigger discussions on available workflows, esp. distributed computing
 - Discuss possible role of national contributions to resources
 - ◆ Engage the community towards full simulation and reconstruction
 - ◆ Address technical aspects of detector concept implementation
 - ◆ Strengthen connections with all the other branches in PED
 - In particular with the new-born Detector Concepts group

- **ESSENTIAL: Stress that the software solidity requires the contribution of skilled users**
 - ◆ The community in general should feel engaged in supporting/fostering the effort
 - If we want to have the software we need well before 2025 (!)

Specific session
on Tuesday Morning

Joint discussion
on Friday Morning

MDI and EPOL: Goals of the meeting

- **Presentation of the plans/objectives by the MDI coordinators** Friday
 - ◆ Manuela Boscolo (INFN Frascati) and Mike Sullivan (SLAC)

 - **The workshop is expected to trigger discussion on the MDI aspects related to PED**
 - ◆ Interaction region design
 - ◆ Luminosity measurement, luminometer integration
 - ◆ Beam diagnostics and radiation monitor at the IP, beam backgrounds in the detector

 - **Contributions to the human resources required to achieve the goals are essential**
 - ◆ This aspect must be addressed during this meeting
-
- **EPOL coordinators: Alain Blondel (LPNHE Paris) and Jörg Wenninger (CERN)**
 - ◆ Advertise the activities and the plans of the group Friday, by Jacqueline Keintzel (CERN)
 - ◆ Address the $\sqrt{s} = 125$ GeV run specificities, especially the \sqrt{s} monochromatization Tuesday

But there is more to it

- **The workshop is also an opportunity (especially on Monday) for PED to**
 - ◆ **Begin discussion with the CERN management (Welcome by Joachim Mnich)**
 - HL-LHC/FCC-ee transition; Resources from CERN; PED priorities; proto-collaboration forming; ...
 - ◆ **Establish constructive collaboration with linear collider teams (ECFA, by Karl Jakobs)**
 - Physics, Analysis methods, Software, Detector concepts, Group conveners, Collaborators, ...
 - ◆ **Strengthen the connections with Snowmass and US physicists (by S. Eno)**
 - FCC Snowmass white paper by US authors
 - ◆ **Seek resources and collaborators within national institutions, laboratories and universities**
 - Informal Forum of National Contacts

- **Altogether, the workshop proposes a very rich program, expected to**
 - ◆ **Help newcomers find interesting topics to work on**
 - ◆ **Encourage the community to gather around the project**

- **I will miss the pints in Liverpool pubs – maybe we'll make it in Summer 2022 ...**

Congratulations to
Alain, Gavin, and the SPC
Carsten and the LOC
Julie and the FCC secretariat