Physics Performance the road to 2025

Patrizia Azzi (INFN/CERN), Emmanuel Perez (CERN)

Deliverables for Physics, Experiment & Detectors (1)

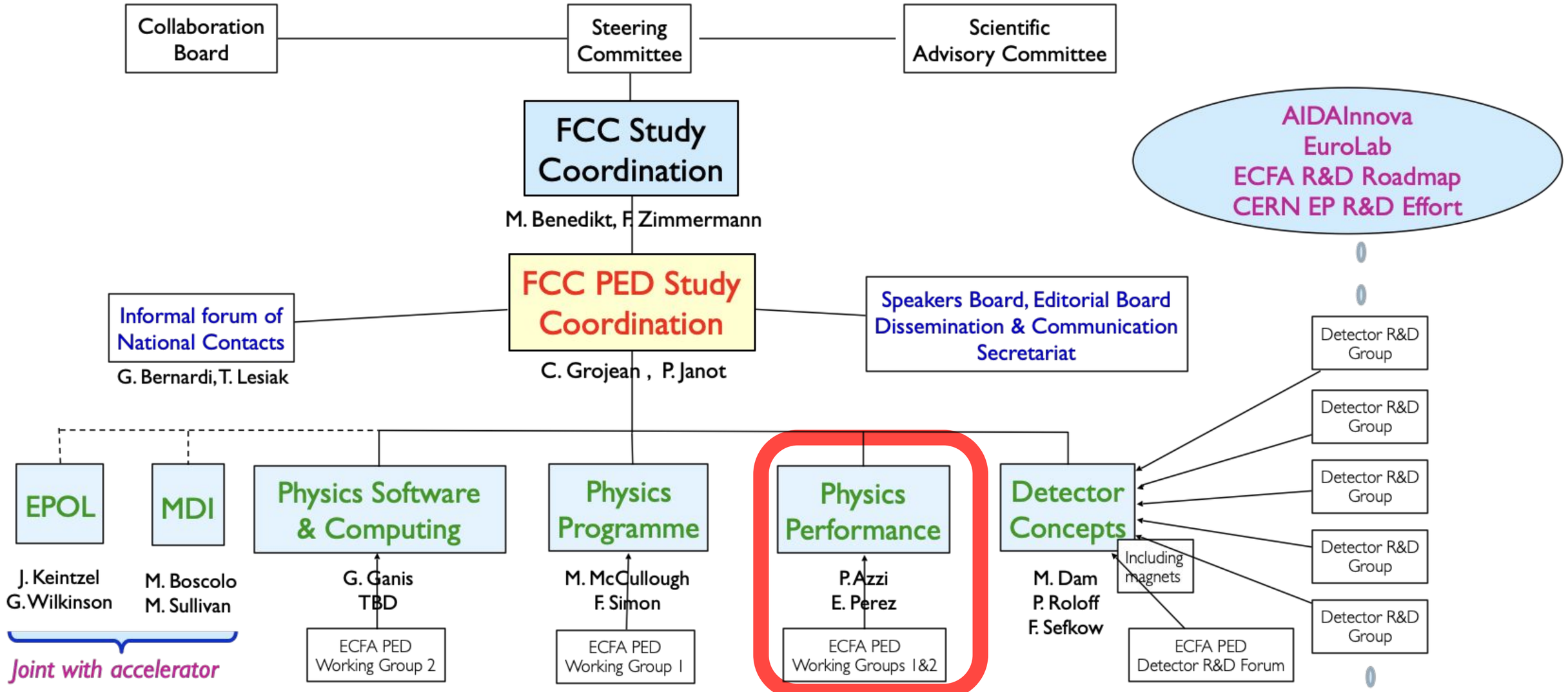
1. Documentation of the specificities of the FCC-ee and FCC-hh physics cases and their complementarity for the characterisation of the Standard Model Higgs boson and other processes;
   - Consolidation of the physics case and detector concepts for both colliders
   - …()… for FCC-ee several detector concepts are being considered and benchmarked to meet the requirements of ultra-precise Higgs boson and electroweak measurements.
   - …()…Detector design and R&D will proceed in collaboration with the R&D for future detectors initiative at CERN, and with the activities that will emerge from the Detector Roadmap being developed under the auspices of ECFA.

Deliverables for Physics, Experiment & Detectors (2)

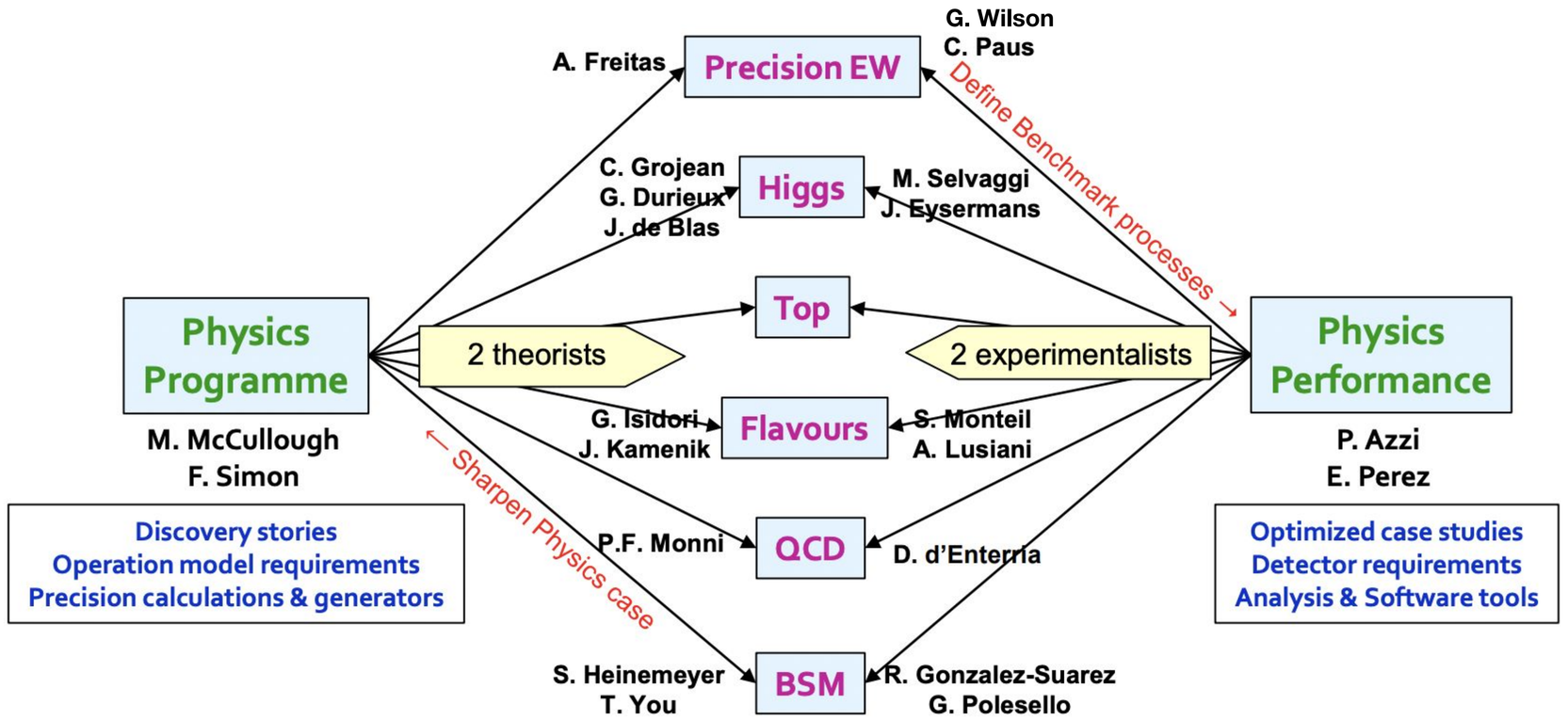
2. Strategic plans for the **improved theoretical calculations** needed to reduce the theoretical uncertainties towards matching the FCC-ee expected statistical precision for the most important measurements.
3. First documentation of the **main detector requirements** to be able to fully exploit the FCC-ee physics opportunities, in particular to **reduce the experimental systematic uncertainties** with a view to matching the expected statistical precision for the most important measurements.

- **Improve the evaluation of the requirements for FCC-ee experiments using key physics processes that drive the physics case as benchmarks.** This will be done using fast or fully simulated data, to extract the necessary performances that satisfy the ultimate desired measurement uncertainty.
- Particular **emphasis on identification of the main systematic uncertainties and on strategies to reduce them to meet the expected statistical precision.**
- **Development and evaluation of experiment concepts**, for both general-purpose detectors and detectors primarily targeting specific physics cases, such as flavour.

How to get there? – Tailored PED pillar organisation



Integrated organization of the Physics WPs



Full integration between Phys.Programme and Phys. Performance

Integration with new Detector Concept WP ramping up

Monthly Physics meetings with flexible agenda to accomodate "transverse" topics

How to get there? Software & Computing

- Main driver:
  - One software to support all cases (FCC-ee, hh, eh) with a modular structure to allow for evolution
- Necessary functionalities:
  - Parameterized (fast) simulation with same output as full simulation
    - Algorithm development possible before Full Simulation becomes available
  - Sub-detector Geometry Plug&Play mechanism: easy switch of detector solution
- Computing:
  - Simulation of all cases unrealistic
  - Interplay of full/fast/parameterized simulation crucial

CRUCIAL SYNERGY WITH PHYSICS PERFORMANCE AND DETECTOR CONCEPTS WPs

where are we now – Active case studies

- **M(H) and σ(ZH) in HZ, Z→ll/jj**
- **Invisible Higgs**
- **Higgs couplings (bb, cc, s, gg)**
- **ee→H coupling, s-channel prod.**

- **A_{FB}(bb,cc)**
- *aTGCs with WW*

- **Anomalous coupling of the top (FCNC) at √s=240 and √s=365GeV**
- **EFT interpretations**
- *Electroweak Couplings*

- **$B_u/B_c \to \tau\nu$ (paper under review)**
- $B_s \to D_s K$
- **$B \to K^* \tau\tau$**
- $B_s \to \phi\phi$
- $B^+ \to D^0 K^+$
- **$B \to s\nu\nu$**

- **Heavy Neutral Leptons**
- **ALPS**
- **Exotic Higgs**

Many talks given at this Physics Week

from today to mid-term review – The case studies

Extract CONCRETE detector requirements. Some examples from current case studies:

- ➔ from Higgs mass: Track momentum resolution
- ➔ from Higgs hadronic decays: Calorimeter resolution
  - for now using Delphes to smear the resolution of jets, missing mass, etc.
- ➔ from B^0->pi^0pi^0, (H->$\gamma\gamma$?): ECAL resolution
- ➔ from B->K*tautau: vertexing resolution
- ➔ from invisible BSM final states: hermeticity
- ➔ from BSM LLP studies: several options, need to define clear benchmarks

from today to mid-term review – Datasets & Tools

Providing CENTRAL & VALIDATED samples

➔ Generators:
- several being used and tested (Pythia, Whizard, KKMC, etc..)

➔ FastSimulation:
- Improved Delphes (track cov. matrix, LLP, etc)
- re-Tuning with FullSim (CLD, IDEA)
- Produce full set of signal and backgrounds with baseline+variations to extract requirements

➔ FullSimulation:
- small samples for performance studies and tuning of FastSimulation
- bigger samples for development of reconstruction algorithms
- some samples for physics studies (CLD that already provides full reconstruction)

➔ Tools:
- Edm4Hep output in conjunction with FCCAnalysis
- Development of vertexing, flavor tagging, jet clustering etc.

from today to mid-term review – the organization

STRENGHTENING the group & reinforcing the communication lines:

➔ regular working meetings of the subgroups are extremely useful to progress

- Higgs and BSM(LLP) well attended and focused on analysis development
- Flavor: lots of ongoing work, but meetings not focused on analyses review yet
- EWK meetings focusing on proposing topics to engage newcomers

➔ Physics Performance monthly meeting on transverse topics

- keep update “Welcome page” to help newcomers
- keep clear organization of Phys Performance GitHub: division by topics
- Nominated “MC Contacts” to help with the datasets generation/validation/bookeeping

➔ Analyses documentation in internal Analysis Notes and journal papers

- Preliminary list for the mid-term document: “Higgs cross-section and mass”, “Higgs couplings”, “Higgs invisible”, “Higgs self-coupling”, “Top Anomalous couplings”, “AFB(b)”, “B->K*tautau”
- Bc->taunu paper is the first one in official review with internal referees

How to evolve toward 2025

Detailed description of the concrete requirements on the detectors in terms of what we lose/limit for specific physics measurements

- ➔ evaluation of the impact on systematics and sensitivities
  - definition of clear benchmarks
- ➔ enlarge the set of case studies to cover all the different needs and phase spaces.
  - EWK, BSM, Top
  - Addition of processes that rely on FullSimulation (i.e. taus)
- ➔ extend studies to different detector concepts
  - will need FullSimulation samples in different configurations
  - will need reconstruction algorithms and their validation
  - distributed computing and reliability of key4hep essential
- ➔ publish papers not only on the “case studies” but also on flagship measurements
  - update older analyses from Fast to FullSim

Why join the Physics Performance Group

Case studies are a great way to get started

- especially for colleagues new to lepton colliders
- profit of common work and discussions within the ECFA EWK/Higgs/top factory workshop

➔ Right now, FastSimulation being exploited along with Key4hep to get developments of algorithms and analysis ongoing

- new generators being also studies and validated

➔ MC production evolution along with distributed computing to allow complete physics studies for publication (FullSim samples will need more space and CPU!)

THIS IS GREAT MOMENT TO JOIN THE PHYSICS PERFORMANCE GROUP EXPLORING THE BEST PHYSICS BENCHMARKS TO EVALUATE YOUR FAVORITE DETECTOR TECHNOLOGY

Winning strategy: seamless coordination in PED

The Physics Programme activities are complementary to the ongoing work in Physics Performance

→ through the proposal of new benchmarks to extend the physics potential exploration using the tools developed within Physics Performance

The Detector Concept activities will help speed up the development and validation of FullSimulation response to explore new design and technologies

→ A nice feedback from “case studies” result will inform and guide detector designs that will need to be proposed at the end of the Feasibility Study

June FCC Week will be the showcase for the material going to the mid-term report. Work ongoing in parallel to set the stage for the next-level of studies with the FullSimulation