FCC Software
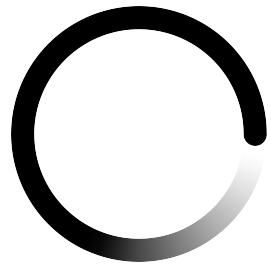
Status and Goals
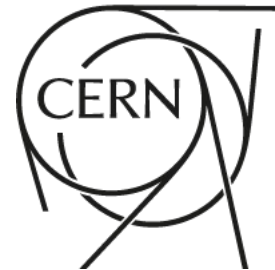
Brieuc Francois (CERN)

7th FCC Workshop, Annecy
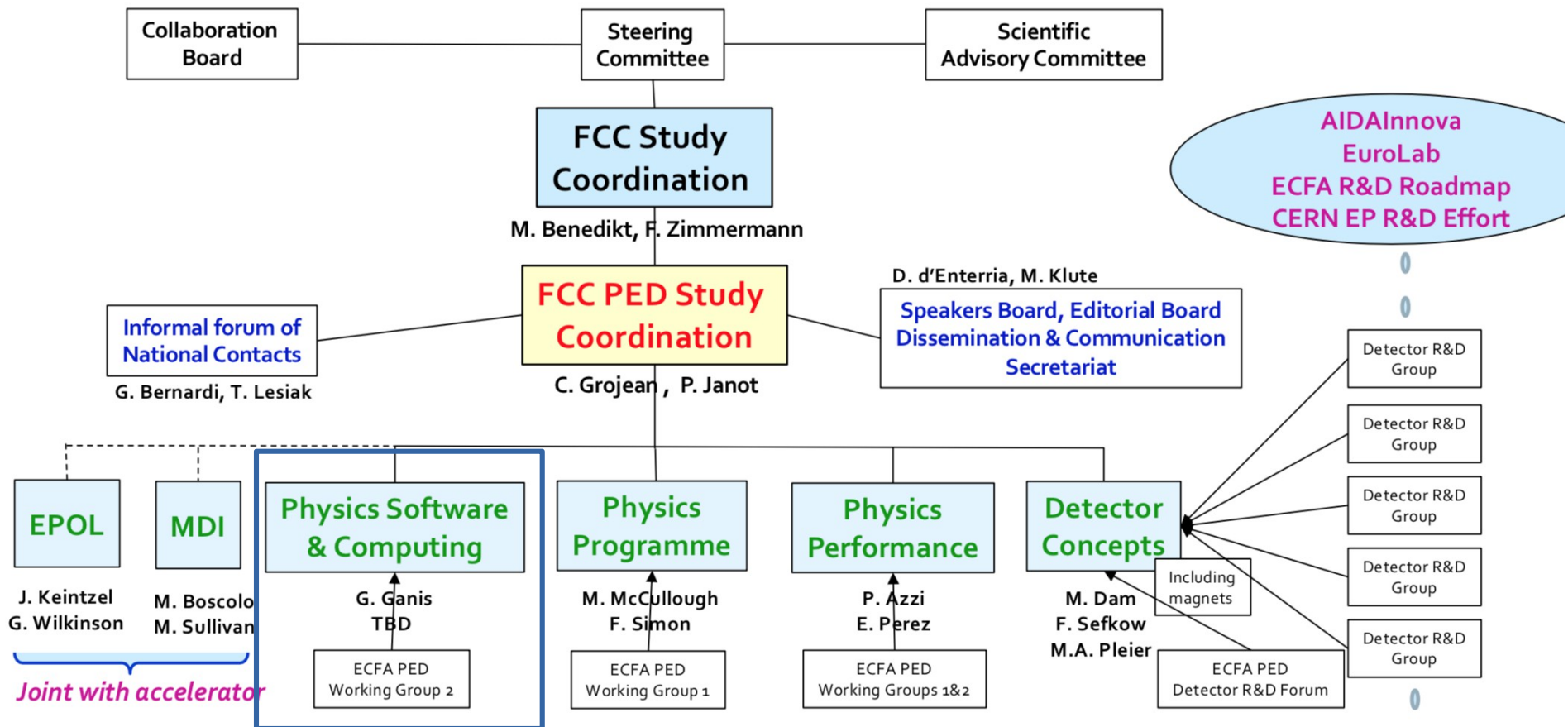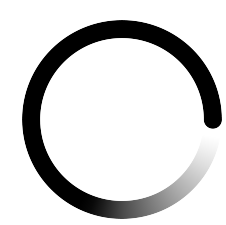Jan. 29th, 2024

FCC Software General Overview

General FCC PED Organization

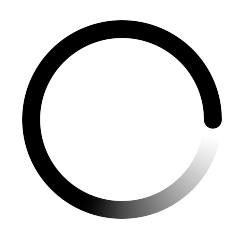> The Physics Software & Computing develops, maintains and provides support for software **tools used by the other PED pillars**
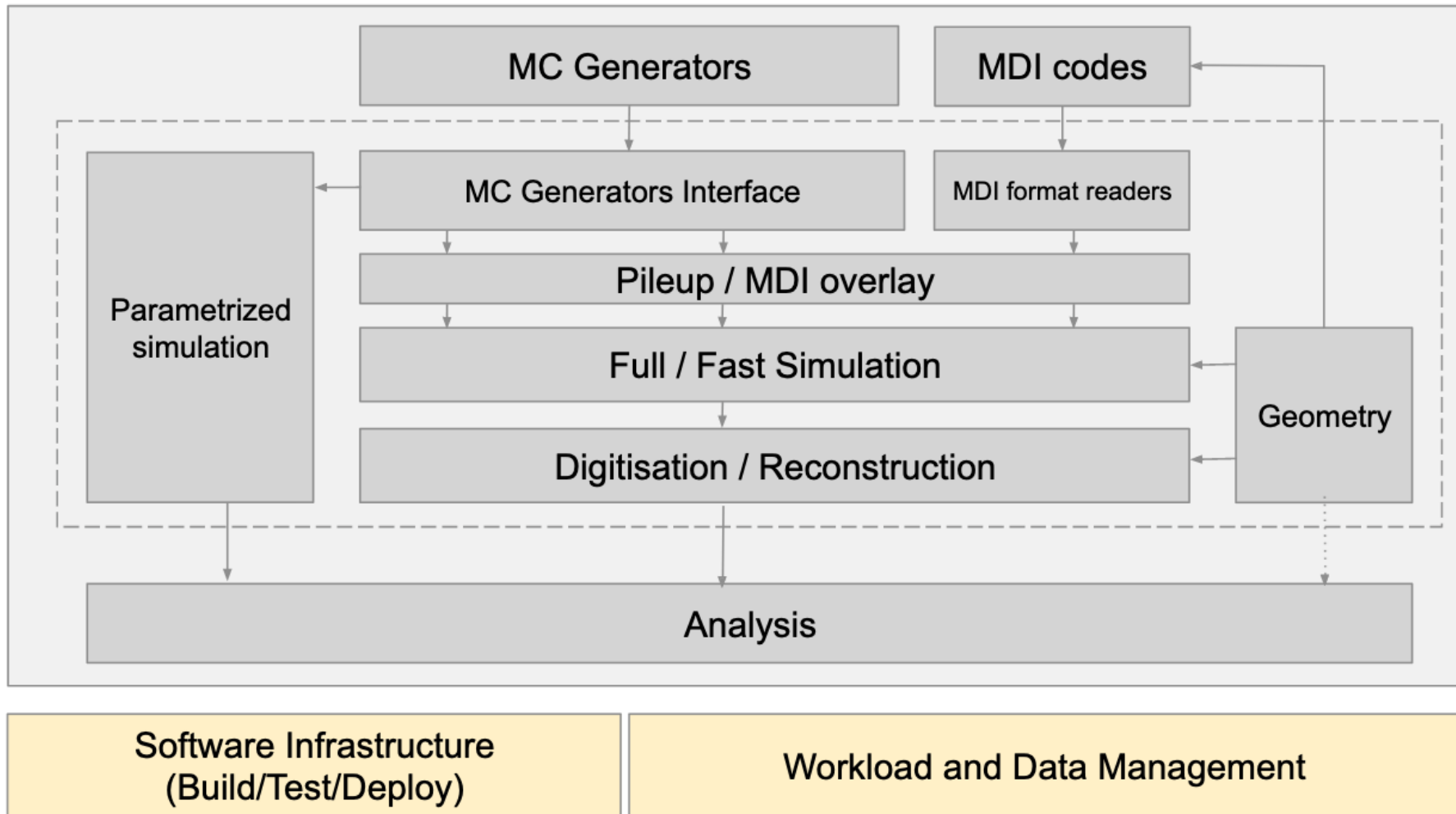>> Particular mandate since its activities are cross-cutting in essence
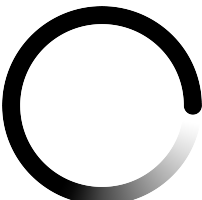>> Needs strong connection with other PED activities
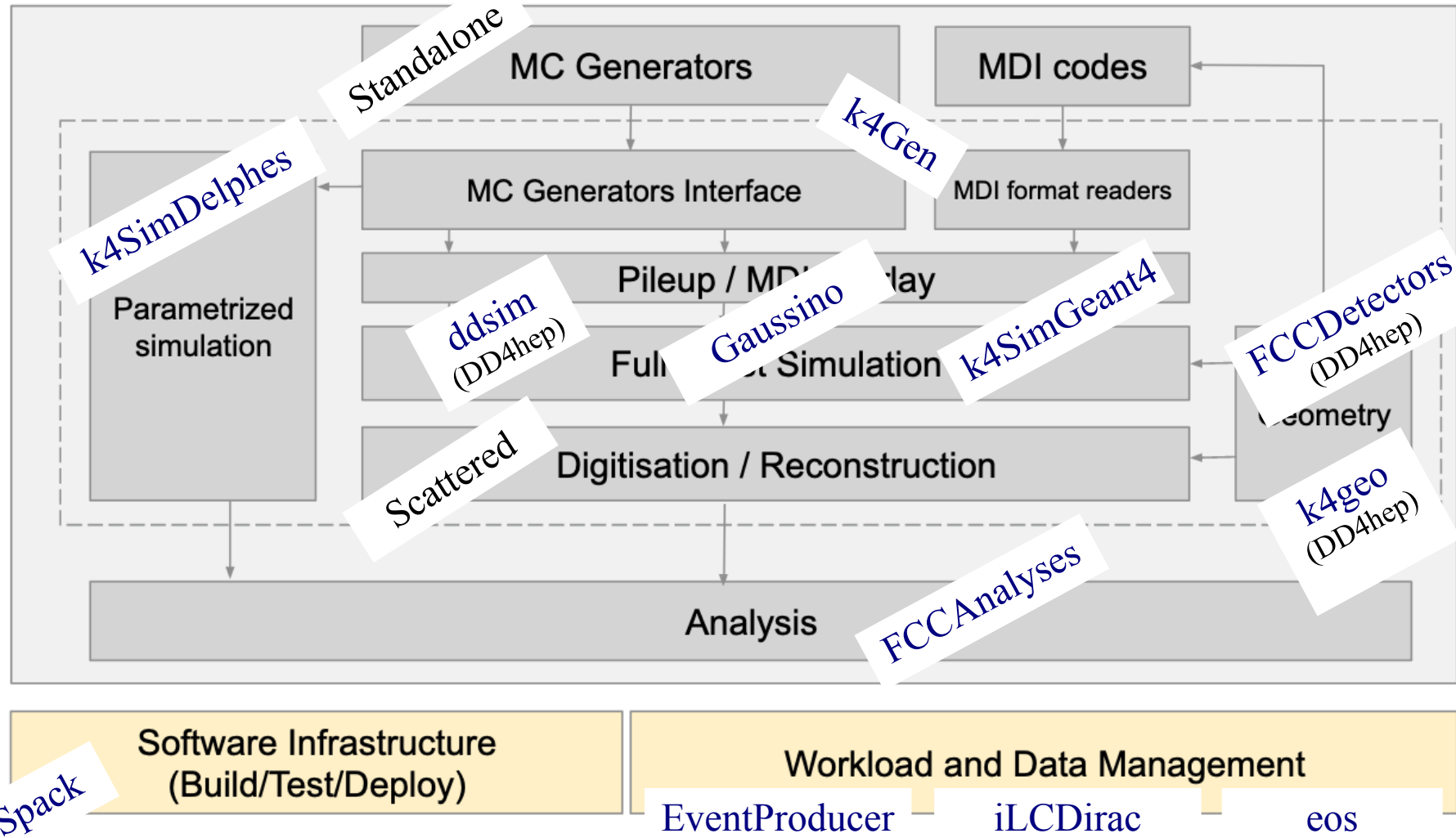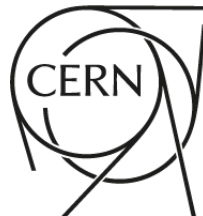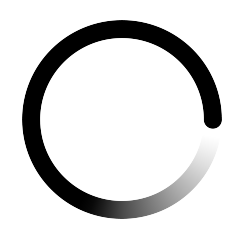
HEP Software Building Blocks

➢ Typical workflow to be supported by the Physics Software and Computing group

FCC Software Building Blocks

FCC Software Considerations

- A two-fold mission with some tensions
  - Deliver 'ultimate' software for the future, with greatest and latest features
  - Deliver working solutions in a short time with low manpower (e.g. for the FSR)
    - Priority given to the latter while keeping the former in mind
- Software is the backbone for most things we do but takes significant time and resources to develop
  - Requires special profiles: good **coding skills**, but still must be **physicist** (except for some deep core components)
  - Efficient resource usage is key: **one software ecosystem for all**
    - Initially for *all FCC cases* (ee, hh, eh), became for all future collider projects
- Very different software needs than for operating experiments
  - Established VS ever evolving detectors → **Flexibility**
  - Single VS diverse communities to serve → **Versatility**
  - Difficult VS needed code sharing → **Interoperability**
- The result is the **Key4hep** software ecosystem (next slide)
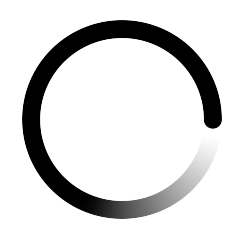
Key4hep in a Nutshell

Key ingredients in Key4hep allowing us to maximize synergies

- Common algorithm **orchestration framework**: **Gaudi** (LHCb, ATLAS)
- Common **data format** for algorithm input/output: **edm4hep**
- Common **detector geometry** construction tool: **DD4hep** (plug-and-play)
- A set of **packages** of general interest is provided through the **Spack** package manager

```
source /cvmfs/sw.hsf.org/key4hep/setup.sh
```

- Strategy: re-use/adapt existing solutions whenever possible
- Multiple OS supported (CentOS 7, Alma 9, Ubuntu 22.04)
- More details tomorrow morning!

FCC Software Status and Goals

Generators

- Many generators directly available in Key4hep

  - MadGraph5_aMC@NLO, Pythia6/8, Herwig3, Whizard, BabaYaga, KKMCee, Guinea-Pig, Sherpa, EvtGen, …

- Any generator with suitable output format (hepmc2/3, hepevt, pairs, stdhep, …) can be used to feed Geant4 simulations through ddsim

- Many topics to look into (some can be handled 'outside' of generators)

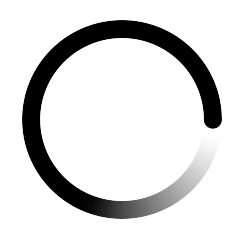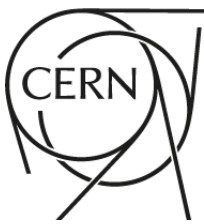 - ISR treatment, accuracy, Beam Energy Spread, crossing angle (+ spread), effect of the beams on final state, …
  - Activities on e^+e^- generation should be stimulated

Generators: tomorrow late morning

11:00 → 12:30 Parallel 3: Software & Computing: Generators

11:00 Generators for FCC-ee: status of things ⏱ 30m
Speakers: Juergen Reuter (DESY Hamburg, Germany), Jürgen Reuter

11:30 Generators for FCC-ee: reaching the required precision ⏱ 25m
Speaker: Stefano Frixione (INFN)

11:55 MadGraph for FCC-ee ⏱ 25m
Speaker: Giovanni Stagnitto (Universita & INFN, Milano-Bicocca (IT))
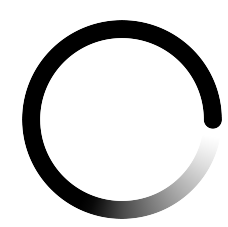
Progress on Detector Full Sim
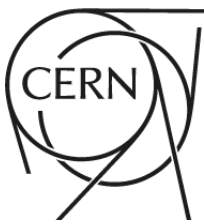
- ➤ Main focus on DD4hep detector geometry implementation so far

  - ➤ New beampipe description (smaller radius)

  - ➤ **IDEA** DD4hep detector description **almost complete**

    - ➤ Calorimeter(s) being integrated

  - ➤ **CLD is fully available, with reconstruction, in different flavors (e.g. with PID detector)**

    - ➤ Integrated the new smaller beampipe and adapted the vertex detector to it

  - ➤ A **first** complete version of **ALLEGRO** is **available**

    - ➤ Some detectors are still over-simplified, realistic ECAL endcap on its way

- ➤ Shifting now (part of) the effort to the digitization and reconstruction

FCC Full Sim webpage

Bi-weekly working meeting
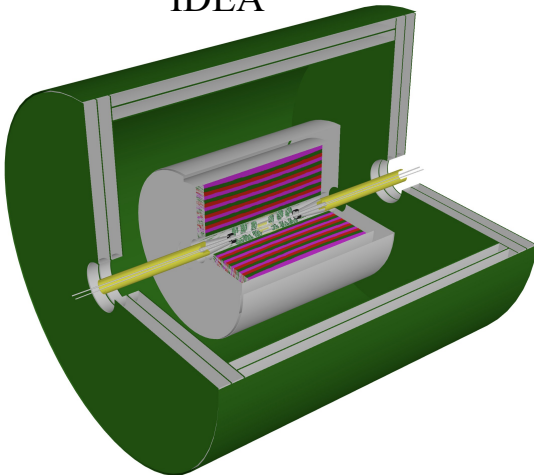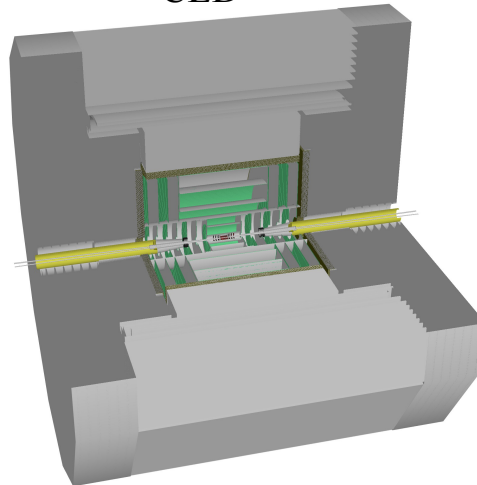
IDEA   CLD   ALLEGRO
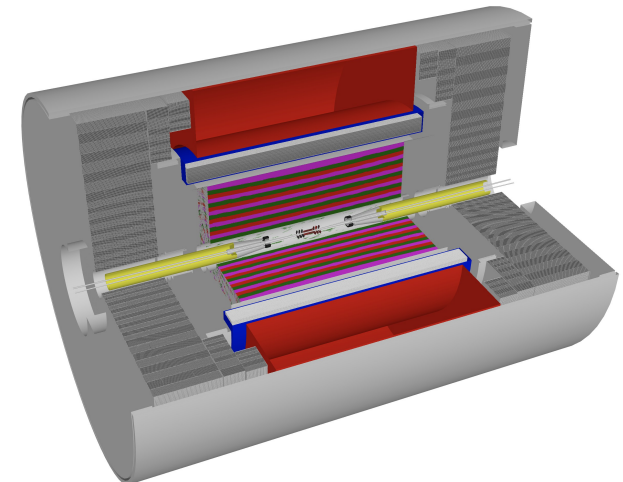
Progress on Detector Full Sim
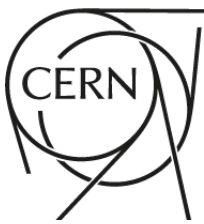
➤ Detector implementation and digitization/reconstruction will be extensively discussed

- ➤ Plenary on Simulation and Reconstruction: Status and Needs tomorrow late afternoon

- ➤ Two dedicated parallel sessions: **Joint Detector & Software (simulation), Reconstruction**

- ➤ Other interesting talks: IDEA Vertex and SiW (Tue. morning), LumiCal (Wed. afternoon)

- ➤ Note: we discuss more than the technical SW implementation, join even if you are not a SW expert!

Simulation: Wednesday late morning

11:00 → 12:30 Parallel 3: Joint session: Detectors & Software & Computing

11:00 **Progress on ALLEGRO calorimeters implementation**
Speaker: Giovanni Marchiori (APC, CNRS/IN2P3 and Université Paris Cité)

11:20 **muRWELL**
Speakers: Mahmoud Ali, Mahmoud Ali (FCC)

11:40 **Towards CLD Tracker optimization**
Speaker: Gaelle Sadowski (Centre National de la Recherche Scientifique (F

12:00 **ILD'/CLD concept studies with a TPC**
Speaker: Thomas Madlener (Deutsches Elektronen-Synchrotron (DESY))

Reconstruction: Thursday late morning

11:00 → 12:30 Parallel 3: Software & Computing: Reconstruction

11:00 **Particle Identification with the ARC**
Speaker: Alvaro Tolosa-Delgado (CERN)

11:20 **ACTS in Key4HEP**
Speaker: Leonhard Reichenbach (University of Bonn (DE))

11:40 **PandoraPFA in Key4HEP**
Speaker: Swathi Sasikumar (CERN)

12:00 **Towards Dual Readout Crystal Reconstruction**
Speaker: Flavia Cetorelli (INFN, Milano-Bicocca (IT))
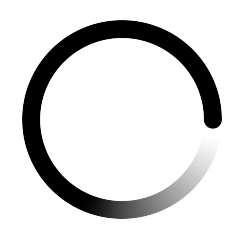
Analyses

- A set of centrally produced parametrized simulation (Delphes) samples is available
  - /eos/experiment/fcc/ee/generation/DelphesEvents/winter2023/IDEA/
  - CLD Full Sim samples will come soon (more later)

- FCCSW team provides and maintain an analysis framework: FCCAnalyses
  - Samples handling, high-level variables definition, event filtering, histogramming (incl. weight handling), plotting (incl. systematics handling), …
  - Based on RDataFrames (multi-threading) with edm4hep input (by default)

- Examples of recent/ongoing improvements
  - Documentation: link
  - RDataSource: make edm4hep/podio functionalities survive the RDataFrame building
  - Better logging: easier to diagnose the source of errors
  - Modular ways to interact with FCCAnalyses
    - import FCCAnalyses: better Python integration
    - fccanalysis build/run/test

FCCAnalyses: Thursday early morning

09:00 → 10:30 **Parallel 3: Software & Computing: Analyses**

09:00 **FCCAnalyses today**
Speaker: Juraj Smiesko (CERN)

09:30 **Discussion about future directions for analysis**
Chaired by Jan Eysermans

What is ahead of us?
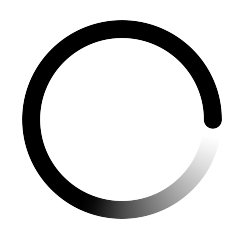
Computing Resources

- We are now preparing physics sample production on the Grid with ILCDirac

  - Current FCC Grid sites: Cern, Bari and CNAF (CPU + storage), Glasgow (storage)

- FCC queue available on the CERN batch system (group_u_FCC)

- CERN storage status

  - 500 TB (157 TB free) for central productions

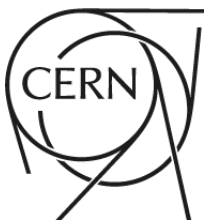 - In addition to the above, 200 TB for analyses groups specific samples

    - Started to assign 10 or 20 TB per group, expandable

- Full Sim samples are coming: CLD first, then integrate ALLEGRO and IDEA when mature enough → more space will be needed

  - Need to assess minimal statistics required for each sample (signal and backgrounds)

  - Need to establish a list of priority for Full Sim samples to be produced

  - Estimate the storage and CPU needs

  - Will be done in collaboration with other PED pillars (especially Physics Performance)

09:00 → 10:30 Parallel 3: Software & Computing: Resources requirements and exploitation

09:00 **Computer resource needs**
Speaker: Gerardo Ganis (CERN)

09:25 **FCC @ iLCDirac**
Speaker: Lorenzo Valentini (Universita e INFN, Padova (IT))

09:45 **Fast simulation: status and use at FCC-ee**
Speaker: Anna Zaborowska (CERN)
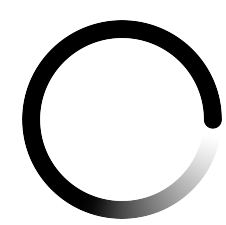
Human Resources

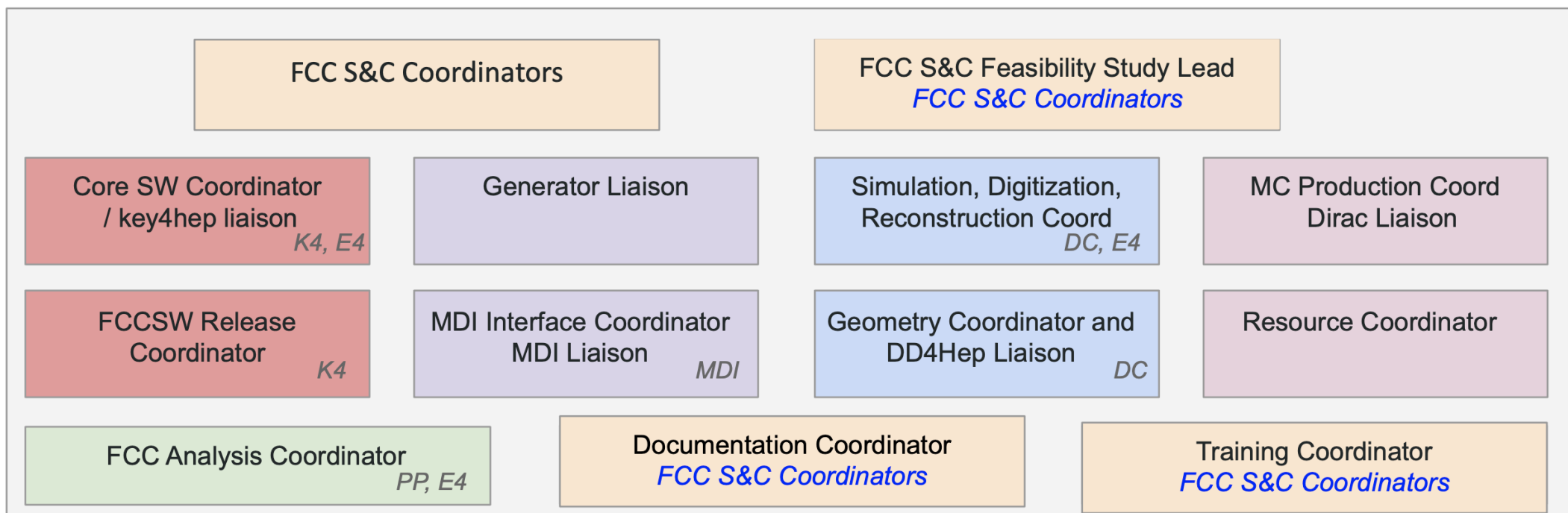- ➤ FCC Software CERN core team: ~1.5 FTE Staff, 2 FTE Fellows
- ➤ Additional contributions (inside and outside CERN) on a best effort/interest basis
  - ➤ No guarantee of alignment between group interests and FCC Software priorities
- ➤ Need to structure better the effort and assign 'official' responsibilities, contact us!

FCC S&C Coordinators		FCC S&C Feasibility Study Lead *FCC S&C Coordinators*	
Core SW Coordinator / key4hep liaison *K4, E4*	Generator Liaison	Simulation, Digitization, Reconstruction Coord *DC, E4*	MC Production Coord Dirac Liaison
FCCSW Release Coordinator *K4*	MDI Interface Coordinator MDI Liaison *MDI*	Geometry Coordinator and DD4Hep Liaison *DC*	Resource Coordinator
FCC Analysis Coordinator *PP, E4*	Documentation Coordinator *FCC S&C Coordinators*		Training Coordinator *FCC S&C Coordinators*

- ● Core software group at CERN
- ● External contributions warmly encouraged
- ● Connection with other PED groups

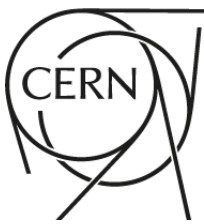|	
PP	Physics Performance
DC	Detector Concepts
MDI	Machine Detector Interface
K4	Key4hep
E4	EDM4hep
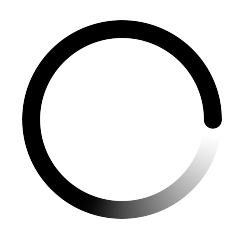
The clock is ticking!
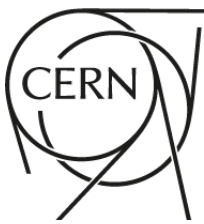
- We have been so far advancing on all fronts, trying to get as much as possible **for the FSR**

  - But the clock is ticking: < 1.5 years left!

  - We should establish a **list** of detailed **deliverables** that we want to **produce imperatively** for the FSR

    - Will allow us to better channel our limited resources

    - Making sure that we deliver robust results, maybe with a narrower scope than originally hoped

      - Instead of ending up with a lot of "almost ready" components

    - Can still try to have IDEA/ALLEGRO ready for physics analyses, but very ambitious

      - A minima, we have to provide robust detector performance studies

- Manpower is needed for

  - Coordination, sample production, package or detector software responsibilities, group liaison, …

  - Technical developments

  - Physics validation (incl. comparison with test beam data)

  - Detector performance estimation and physics studies

- **We are lacking users to give feedback and help to validate existing software!**
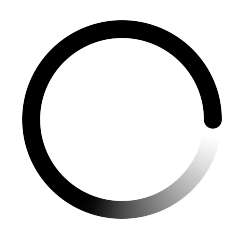
Examples of Tasks

- ➢ Some examples of open tasks
  - ➢ Study Particle Flow performance of CLD with/without ARC detector
  - ➢ Exercise the background overlay tools and migrate it to an EDM4HEP native algorithm
  - ➢ CLD flavor tagging algorithm
    - ➢ edm4hep migration, training upon geometry change, adaptation of the Delphes flavor tagging algo to CLD
  - ➢ Tau reconstruction
  - ➢ IDEA drift chamber digitization and tracking
    - ➢ edm4hep data format extension
  - ➢ ALLEGRO muon system implementation
  - ➢ Technical maintenance of existing packages, e.g. k4RecCalorimeter, k4Gen, …
  - ➢ Central implementation of detector performance production routines
  - ➢ **Prepare and maintain Full Sim physics analyses** (with CLD first, applied to other detectors with minimal changes)
- ➢ Contact us if you wish to contribute!