FCC software overview

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on behalf of the software team
Introduction – The FCC software

Support experiments for all colliders: ee, hh & eh

Support physics and detector studies
  ◦ Detector concepts: Moving targets
  ◦ Both fast and full simulation essential

Collaborative approach:
  ◦ Extract from the LHC experiments if possible
  ◦ Invest into new solutions where necessary

One software stack: Support all experiments from event generation to physics analysis
The Ingredients

- Flexible event data model & detector description
- Simulation
  - Full simulation for detector studies
  - Fast simulation for physics benchmarks
- Reconstruction
  - pp: Extreme pile-up, extrapolation to 100 TeV
  - ee: Achieve the best possible precision
- Physics analysis
  - Allow standalone workflows
  - Python flexibility & C++ performance
Event Data Model

After reviewing existing solutions:
◦ LHC experiments: Complicated and not extractable
◦ Linear Collider I/O: Starting point, hard to adapt

Decided to invest: Plain Old Data I/O (PODIO)
◦ Focus on re-usability and flexibility
◦ Code fully generated from text files
◦ Simply describe your data, PODIO does the rest
◦ Easily adapt data model to changing requirements
◦ Python & C++ supported on the same footing

```cpp
fcc::Track:
  Members:
  - float chi2
  - unsigned ndf
OneToManyRelations:
  - fcc::TrackCluster clusters
  - fcc::TrackState states
```
Detector Description

Underlying framework: DD4hep
- Collaborative effort with Linear colliders and LHCb

FCC-hh: Baseline concept exists and is stabilizing
- All sub-detectors being mainly developed in FCCSW
  - So far concentrating on non-forward detectors
  - First simulation + reconstruction results shown this week

FCC-ee: Starting with geometry based on CLIC concept
- First working implementation integrated in FCCSW
  - Material scans + first simulation results

Tutorials on how to add a detector to FCCSW with DD4hep
SIMULATION
Event Generation and Geant4 Simulation

Event Generation
- On the fly: Pythia & Particle gun
- Read LHE files during showering
  - Existing workflow for MadGraph

Simulation with Geant4
- Integrated full & fast simulation
- **Feature complete for Design Study**
- Existing tutorials and examples
Integrated Fast Simulation

Integrated fast and full simulation:
- Use pre-defined hooks within Geant4
- Mix fast and full simulation in the same event
- Allow to switch based on particle properties, detector region, ...

Existing implementations:
- Parametric electromagnetic showers
- Particle momentum smearing

Plans to extend these models

Tutorials and examples to get started with Geant4 simulation
Parametric Simulation

Why parametric simulation?
- Define & study physics benchmarks
- Scan detector parameters
- Validate simulation and analyses

Delphes & PAPAS (Parametrized Particle Simulation)
- Both integrated in FCC software (allow cross-checks)
- Tutorials available at
  - Delphes (FCC-hh)
  - PAPAS (FCC-ee)
- More details on plans and status for PAPAS, this session by A. Robson
Special-Purpose Simulation

Quick turn-around for initial tracker design: **TkLayout**
- Developed for tracking studies in CMS (Phase2 Upgrade)
- Analytical software to study tracker performance
- Invested some work: refactor to ease non-CMS usage
  - TkLayout-lite: [https://github.com/tkLayout/tkLayout/tree/masterLite](https://github.com/tkLayout/tkLayout/tree/masterLite)

Specialised geometry extraction for the FCC ecosystem:

![Diagram showing TkLayout-lite, compact xml, DD4hep, Tracking Geometry, and Geant4 Geometry]
The right tools for the right job

Pen & Paper
Delphes, TkLayout
Fast sim & digi + truth tracking
Partial fast sim + full reco
Geant4 full sim + full reco

# detector layouts

0.02 sec/evt
0.8 min/evt
1.4 min/evt
1.8 min/event

complexity / time

Analysis benchmarks, high statistics
Reco benchmarks, detector studies
Detector studies, full pile-up model
RECONSTRUCTION
Reconstruction status

Tracking
◦ Extraction of the ATLAS tracking code into standalone package (ACTS)
◦ Geometry converted to optimized geometry via ACTS plugin using DD4hep
◦ More information later in this session by V. Völkl & J. Hrdinka

Calorimetry
◦ Developed within FCCSW, inspired by ATLAS
◦ Started with dedicated reco for e/gamma
◦ First results on combined calorimetry
◦ More details on Thursday by J. Faltova, C. Neubüser & T. Price
PHYSICS ANALYSIS
Analysis Front-End

Python based package: HEPPY
◦ Originally developed in the CERN-CMS group
◦ Highly configurable, easy to set up
◦ Includes PAPAS simulation

Long term: Python performance issues?
◦ Combine strengths of C++ and Python
◦ Python to allow testing ideas and prototype
◦ Invest to port performance critical code to C++
  ◦ Use ported Functionality from Python

More information later in this session by A. Robson
Infrastructure

Ease batch and grid submission: Decided to use DIRAC as a framework
- Effort started by LHCb, now used by several communities, including ILC
- Abstraction layer between users and resources
- First steps done: Integrate FCCSW, currently in review

```python
from ILCDIRAC.Interfaces.API.NewInterface.FccJob import FccJob
from ILCDIRAC.Interfaces.API.NewInterface.Applications.Fcc import FccSw

job = FccJob()

fccApp = FccSw(
    fcc_conf_file='my_configuration.py',
    fccsw_path='/cvmfs/fcc.cern.ch/sw/0.8.1/fccsw/0.8.1/x86_64-slc6-gcc62-opt',
    number_of_events=1000)

job.append(fccApp)

jobID = job.submit()
```
Collaborating where we can
Conclusion & Looking forward

A lot of progress in several areas in the last year
◦ Infrastructure for physics studies and analysis
  ◦ Central simulation production with Delphes
  ◦ Tutorials for Python ecosystem with HEPPY and PAPAS
◦ Effort to ease contributing and getting started for new users
  ◦ Centralized and improved our documentation
  ◦ Continuous integration: Automatic checks of pull-requests & more
◦ Progress on reconstruction (Calorimetry and Tracking)

Still quite a lot of areas to improve and for you to contribute:
◦ Detailed studies of reconstruction / detectors
◦ Particle flow algorithms and studies
◦ Additional infrastructure: Code skeletons, better event display, ...
Where does this leave you?

Web: [fccsw.web.cern.ch](fccsw.web.cern.ch)
- Tutorials and other resources

FCC software e-group
- fcc-experiments-sw-dev
- Ask your questions

FCC software Mattermost
- Chat service provided by CERN
- [Join us!](https://indico.cern.ch/category/7969/)

Welcome to our meetings
- Every other Wed 11:00
- [https://indico.cern.ch/category/7969/](https://indico.cern.ch/category/7969/)
First FCC-ee software workshop

3-4 July 2017 at CERN

On the agenda - https://indico.cern.ch/event/639736/
  ◦ Introduction for analysis
  ◦ Fast simulation with PAPAS & Delphes
  ◦ Status of Geant4 geometry in FCCSW for FCC-ee
  ◦ Feedback from Users

Especially well suited for students