Software for Future Experiments

SFT GROUP MEETING

Joschka Lingemann
EP-SFT CERN

Working at SFT

Started my Fellowship in September 2015

- First few months ramping down previous activity in CMS
- Previously worked on CMS hardware trigger

Project: Work on software to support the FCC design study

- Development: Simulation framework, event processing framework, …
- Infrastructure: Installations, continuous integration, …

Very small group of a handful of contributors

Design study timeline: First drafts in the beginning of 2018

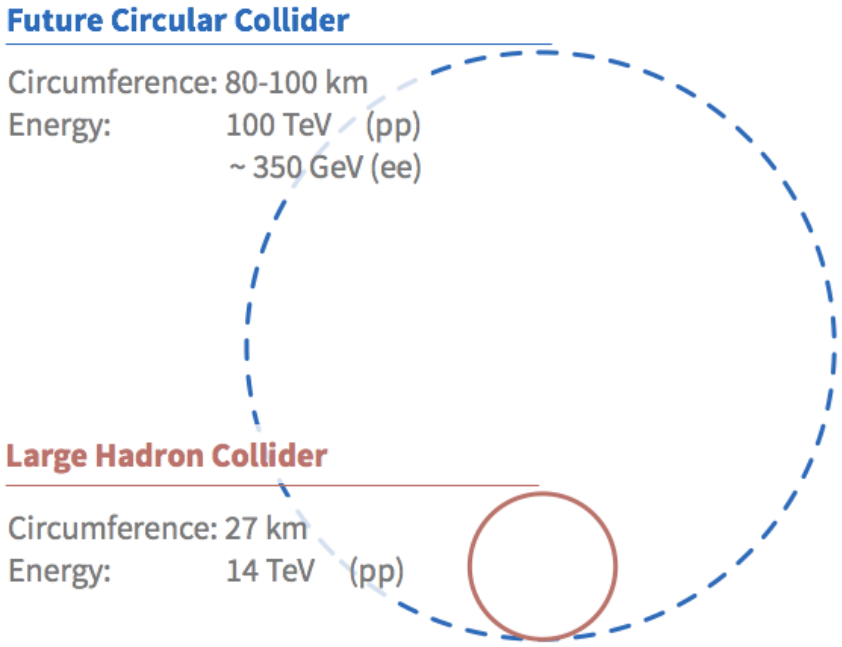
The FCC software goal

Support experiments for all colliders: ee, hh & eh

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

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

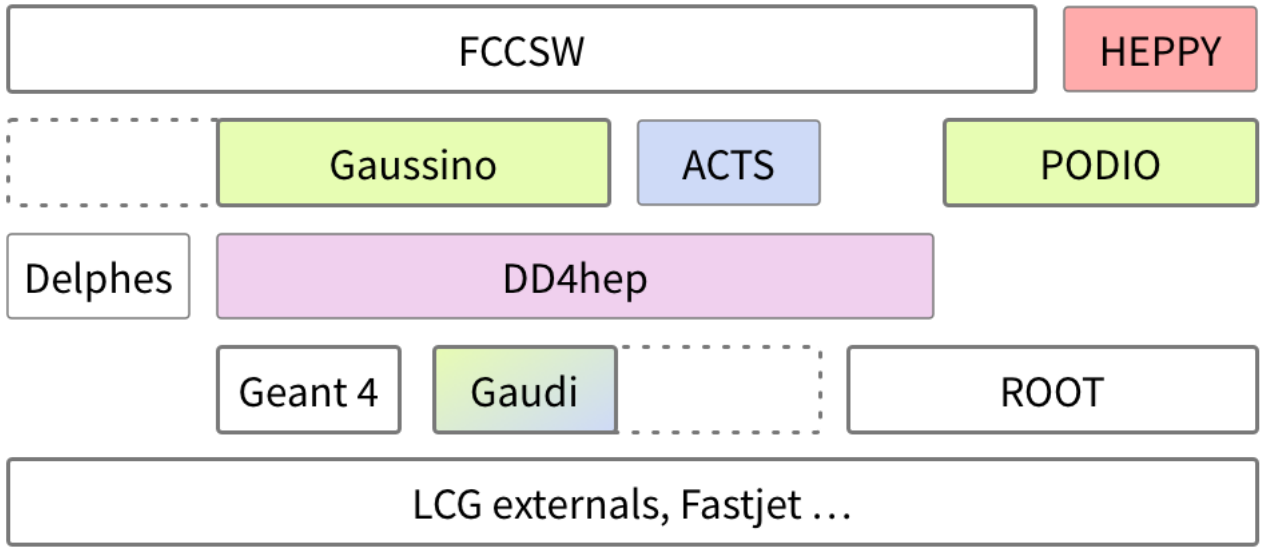
Collaborative approach:
- Extract from the LHC experiments if possible
- Invest into new solutions where necessary
- Benefit from AIDA / HSF efforts



Collaborating where we can

Not re-inventing the wheel for FCC:

- Take existing solutions
- Invest to extract from experiment
- Collaborating with
  - LHCb
  - ATLAS
  - CMS
  - CLIC / ILC



Event Data Model: PODIO

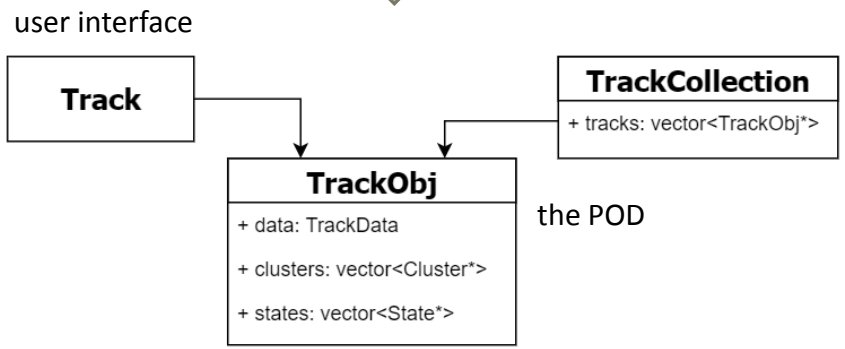
Plain Old Data I/O (PODIO)

- 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
- For more details, see past talks by Benedikt

FCC is the first user of the library, several features added:

- Namespacing of the datatypes
- Support for arrays
- Usability improvements & bug fixes

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



Event Data Model: Using PODIO for FCC

Event Data Model with PODs => No object inheritance

- Composition instead of inheritance
- Re-usability of client code: Use composing objects
  - E.g.: Jet clustering code runs both on MC particles and reconstructed particles
  - Both have the same “core” particle that can be used for clustering code

Forbid changes to collections after creation: Again composition (e.g. tagged jet = tag + jet)

Reviewed the first iteration of our datamodel

- Fix small inconsistencies
- Reviewed how users approach problems, given our EDM:
  - unclear usage from user point of view
  - Renaming to clarify and remove unnecessary components
- Add some missing components

Important part:
User support & good examples

Generic Detector Description: DD4hep

DD4hep is a generic tool for detector description

- For details see recent presentation by Marko P.

FCC and Linear Collider Community are the first users:

- Feedback important to try and keep goals aligned
- Bi-weekly developers meeting
- Workshop on conditions (esp. alignment data)
- Keep FCC integration up to date with changes in DD4hep

Move FCC implementations upstream where it makes sense:

- Generic things like eta-phi segmentation for early prototype detectors

User support in FCC:
How do I implement my detector?

Event Processing with Gaudi for FCC

Event processing framework used by LHCb and ATLAS

- Chosen as framework for FCCSW
- Mostly a good experience and positive feedback from users
- A lot of infrastructure out-of-the box:
  - Testing
  - Build tools
    - Although they could be simplified :)

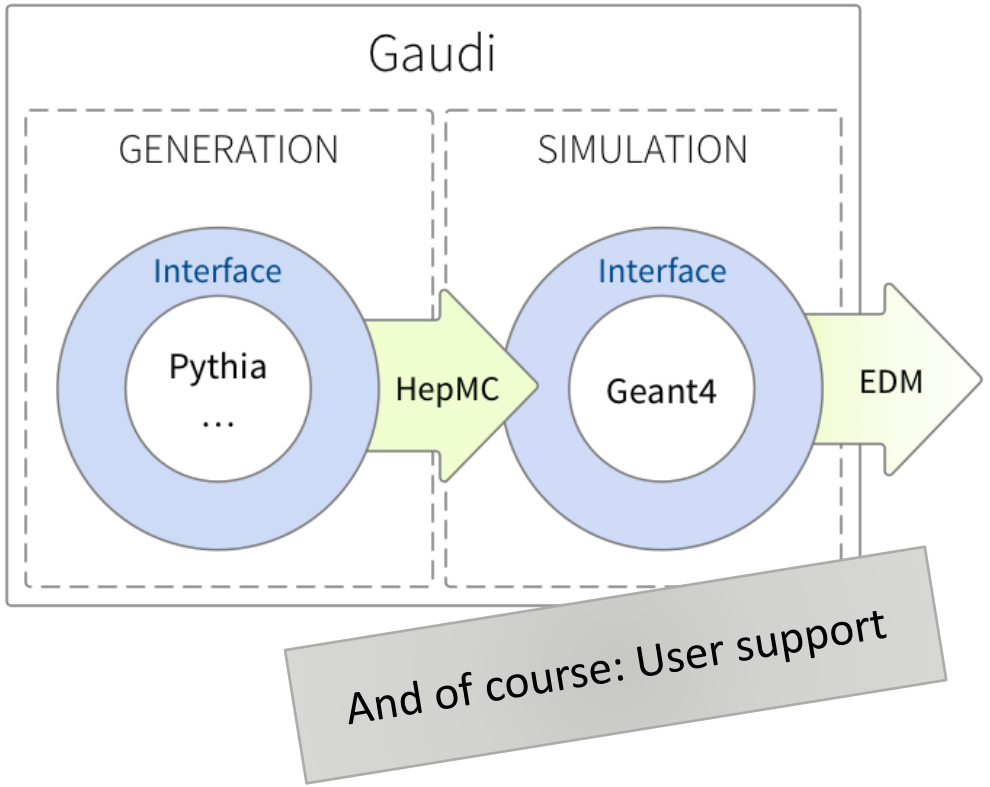
Missing: Documentation and guidelines

- Improved a lot with the software upgrade in LHCb
- Sometimes not on the Gaudi-level but LHCb-specific
- We also started some documentation (should be unified)

Event Generation and Geant4 Simulation: Gaussino

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

Simulation with Geant4
- Integrated full & fast simulation
  - See presentation by Anna
- Simplifying simulation from Gaussino
- **Simulation is feature complete for Design Study and used**
- Re-integration with LHCb Gauss pending



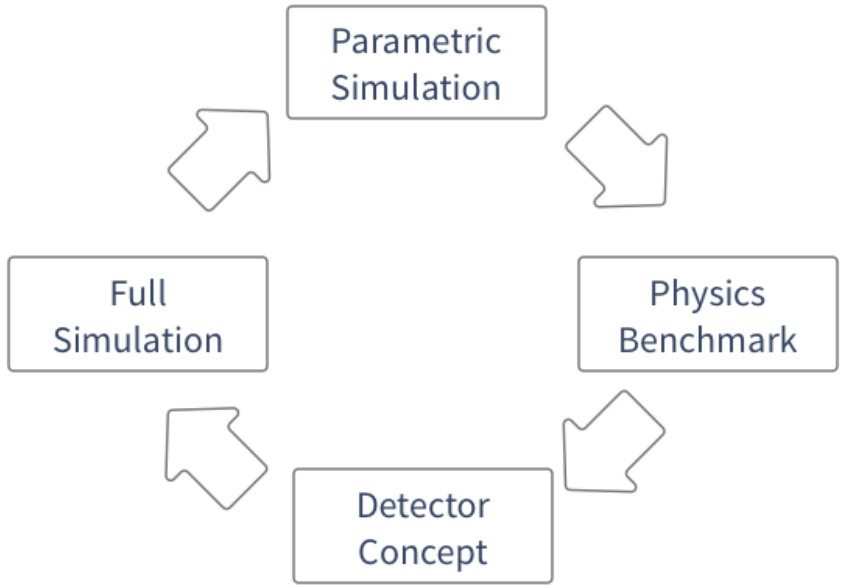
Parametric Simulation

Why parametric simulation?

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

Delphes & PAPAS (**Pa**rametrized **Pa**rticle **S**imulation)

- Both integrated in FCC software (allow cross-checks)
- Use particle flow algorithms from PAPAS



Delphes integration: Re-written to be more modular & configurable

PART II: INFRASTRUCTURE

Collaborating: The downsides

Fragmented code base: Several small dedicated repositories

- Confusing to newcomers
- Unclear where to contribute
- Getting a working installation: 5+ repositories clone & compile + dependencies
- Documentation mostly in the repositories
  - Hard to find what you need to know

User confusion is guaranteed

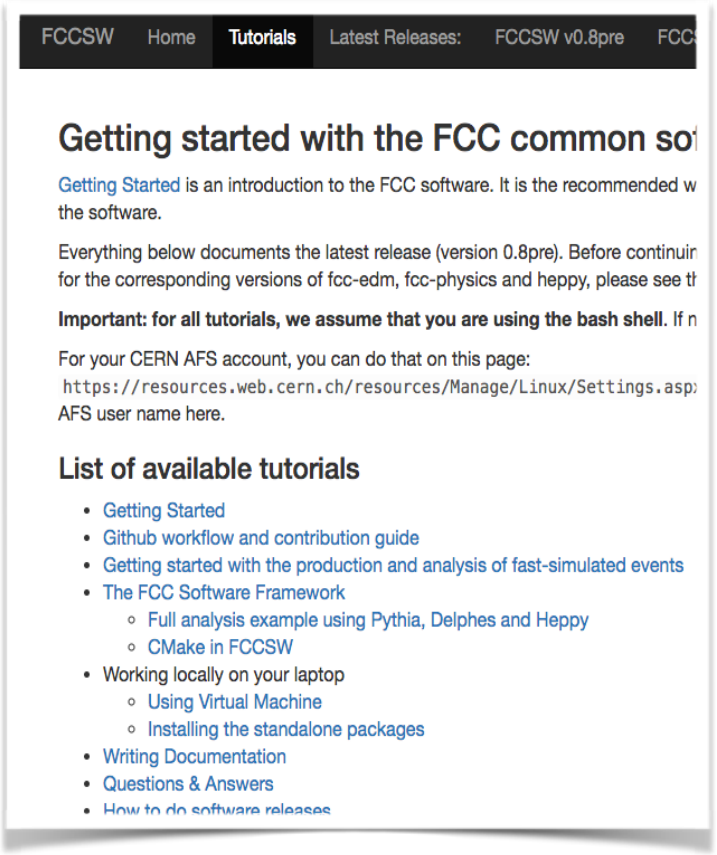
=> Automate & simplify as many of these processes as possible

Documentation

When I started: markdown in several repositories + Twiki
- Hard to maintain & confusing

New FCC-software website with Jekyll:
- Static web-pages, markdown support out of the box
- Bootstrap step with python:
  - Collect all markdown files with python using GitHub API
  - Few adaptations to make the website self-contained
- Yaml file with release information (dependency versions, etc.)
- Moved Twiki to git repository solely for tutorials

One point to start: fccsw.web.cern.ch



Supporting contributors

Introduced an off-week “technical meeting”:

- Room for discussion of questions and problems with the software
- Meant to also discuss design ideas / questions about implementation
- Feedback: Quite useful to resolve questions easily
- Sometimes meeting very short (O(10 mins)) but good to touch base

Mattermost: Chat client supported by CERN

- Created for users to give feedback / ask questions
- Fast communication
- Unfortunately, not widely used after first week(s)

Deploying the software: Spack

Package management / distribution system:

- Developed in HPC community, favoured by HSF community
- Candidate to replace LCG-CMake (see Javier's presentation)
- Some generic HEP software packages maintained by HSF

The FCC-specific needs:

- Our own packages (obviously)
- Build against LCG software stack on cvmfs
  - Use LCG text files describing package specs in the release
  - Create yaml configuration file to allow spack to build against that stack
- Nicely synchronises information used for website creation

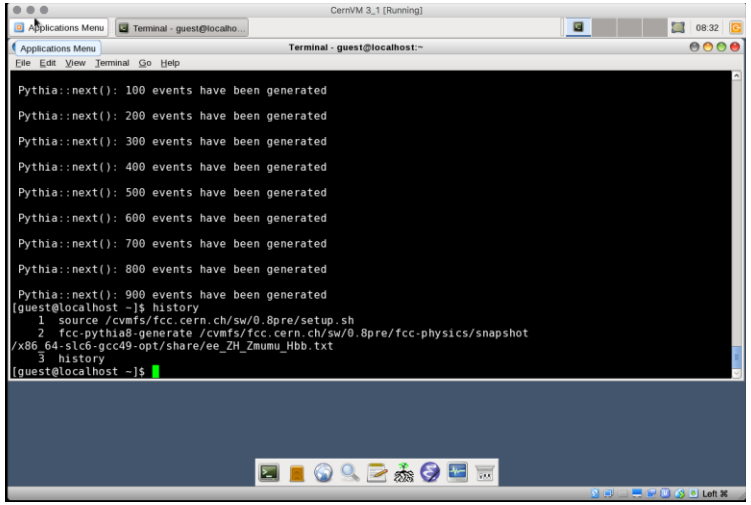
Nice test-bed for the tool: Our software stack is not very extensive

Virtual Machines

Virtual machine for use on laptop, CernVM

- CVMFS installation + CernVM = Easy to use virtual machine
- Image can be minimal
- Very convenient to maintain
  - No overhead for the maintainers (uses CVMFS)
  - Standard setup for users with favoured Hypervisor
- Caching of CVMFS problematic for some users
  - Offline work only partly possible

Investigate an alternative to use additionally



Docker images vs. virtual machines

Alternative to Virtual Machine: Docker containers

- Minimal overhead compared to VM
- Can be built automatically
- Useful in Continuous Integration
- FCC Docker image based on ubuntu image:
  - Base image = ubuntu + ROOT (1.5 Gb), build time 40 mins
  - FCC image including our software (200 Mb), build time 10 mins
  - Dockerfiles are very simple thanks to spack
- Allows to fully work offline (with partial stack)

Good initial feedback…

- Could be extended to full stack (large images)

```
$ docker run -ti --name fccsw --rm fccimage
+-----------------------------------------------
            FCC  ##        .
           ## ## ##       ==    Welcome to the FCC
          ## ## ## ##     ===    REMINDER: Containe
     /"""""""""""""""""\___/ ===              Keep you
 ~~{~~ ~~~~ ~~~ ~~~~ ~~ ~ /  ===-~~
     \_____ o          __/
       \    \        __/         Documentation: fcc
        \____\______/
+-----------------------------------------------
fccuser@f7a751e6d89c:~$ fcc-pythia8-generate $FCCB
start processing
output file: ee_ZH_Zmumu_Hbb.root
*-----------------------------------------------
|
|  *--------------------------------------------
|  |
|  |
|  |   PPP   Y   Y  TTTTT  H   H  III    A      We
|  |   P  P   Y Y     T    H   H   I    A A     Th
|  |   PPP     Y      T    HHHHH   I   AAAAA    La
|  |   P       Y      T    H   H   I   A   A
|  |   P       Y      T    H   H  III  A   A    No
```

Continuous integration

Uses SFT Jenkins instance

- Check pull-requests of all our repositories
- Nightlies:
  - Build of all repositories
  - Integration test, checking if masters are synchronised
  - Nightly install if integration test works (WIP)

Usefulness heavily relies on users to implement proper tests

- We have many examples and some documentation
- When we started this: Added first tests
- Usually in the first PR have to remind ppl but after that self-reliant

Also in the nightlies: Documentation, website creation, etc

Code quality and CI

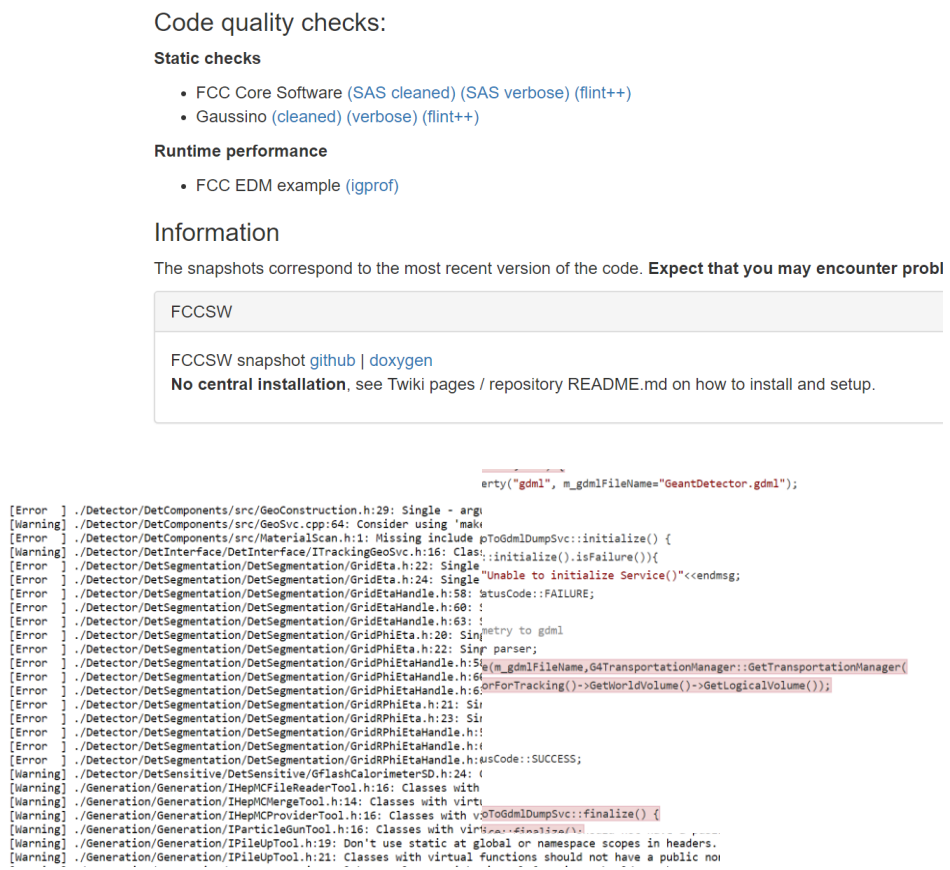
Important part to keep a code base maintainable:
- Coding conventions for uniformity
- Defined when I started, based on LHCb / Google

Help people to follow these conventions
- Clang-format for formatting
- SAS for naming conventions (and all tests it brings)
  - Some contributions + supervision of summer student

Further static tests done with Flint++
- very light weight and fast

Made sure to follow up and fix warnings, etc.

All comes together in the webpage…



What I take away from here

Working on FCC software is nice because:

- A lot of freedom to experiment
- Quick turn around times (small code bases)

=> Very well suited to learn from your own mistakes

Concretely I learned a lot:

- About automation and continuous X
- Maintaining infrastructure that scales
- User support is time consuming and important ;)

What’s next?

DevOps at

TARSIER STUDIOS

Automation + infrastructure for development

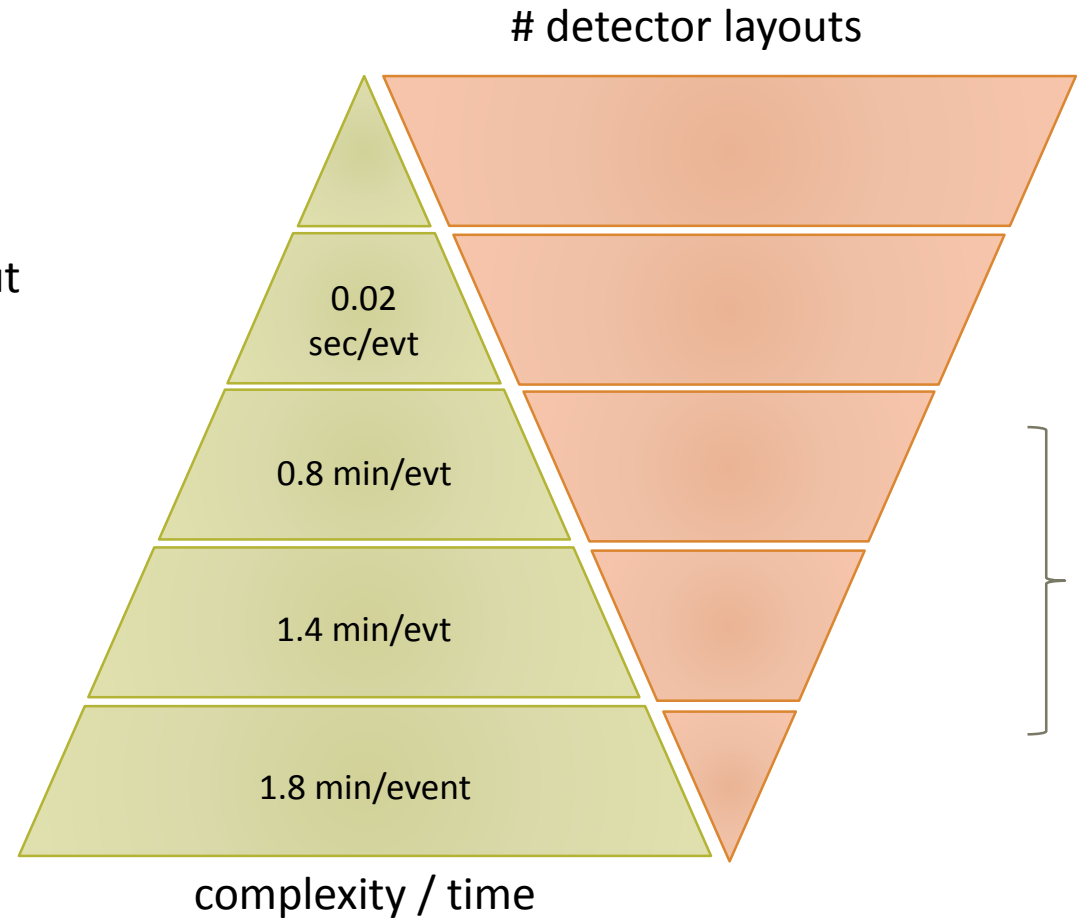
Thank you

It has been a very interesting time at SFT. One of the nicest groups @ CERN.

Special thanks to Anna, Valentin and Benedikt: It was a pleasure!

BACKUP

The right tools for the right job



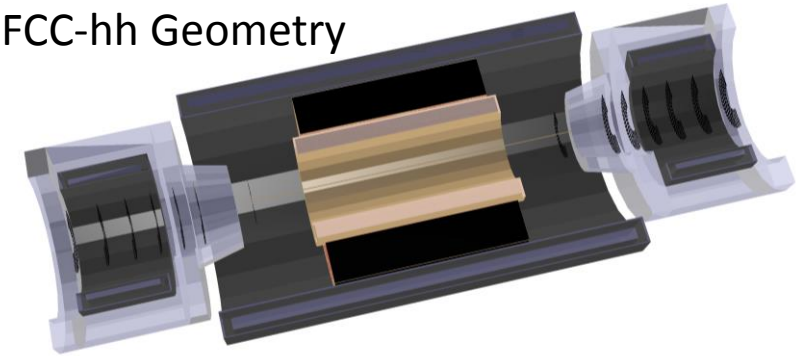
Status: Detector Description

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

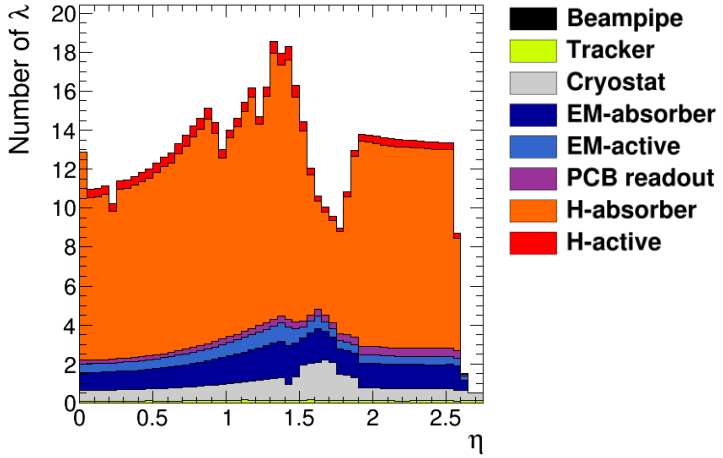
FCC-hh: Baseline concept exists and is now fixed
- All sub-detectors being mainly developed in FCCSW
  - So far concentrating on non-forward detectors
- First simulation + reconstruction results shown at FCC week

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

FCC-hh Geometry



Material scan
(barrel only)



Integrated Fast Simulation

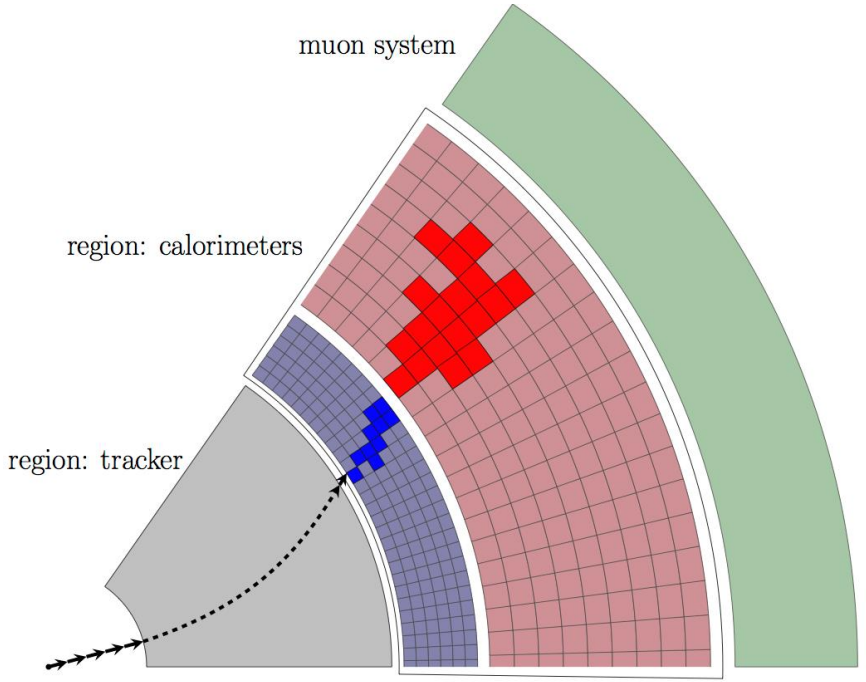
Integrated fast and full simulation:

- 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



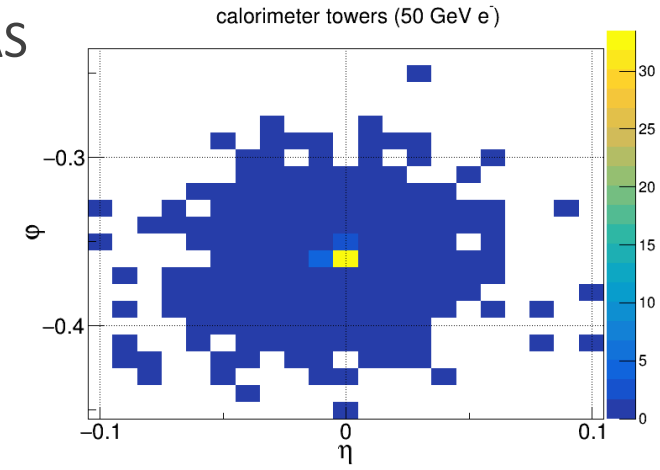
Reconstruction status (for completeness, no hands-on contribution)

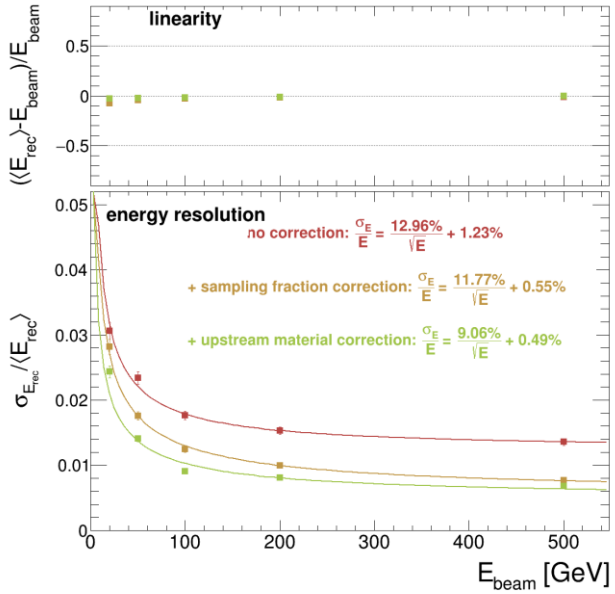
Tracking

- Extraction of the ATLAS tracking code into standalone package (ACTS)
- Geometry converted to optimized geometry via ACTS plugin using DD4hep
- Valentin Völkl & Julia Hrdinka

Calorimetry

- Developed within FCCSW, inspired by ATLAS
- Started with dedicated reco for e/gamma
- First results on combined calorimetry
- Anna Zaborowska, Jana Faltova, Coralie Neubüser & Tony Price





Analysis Front-End

(for completeness, no hands-on contribution)

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

Contacts: Alice Robson and Colin Bernet