FCC Physics simulation framework and activities

FCC Physics Workshop

January 15, 2017

Joschka Lingemann
EP-SFT CERN

On behalf of the FCC software team

Introduction: Software for the FCC design study

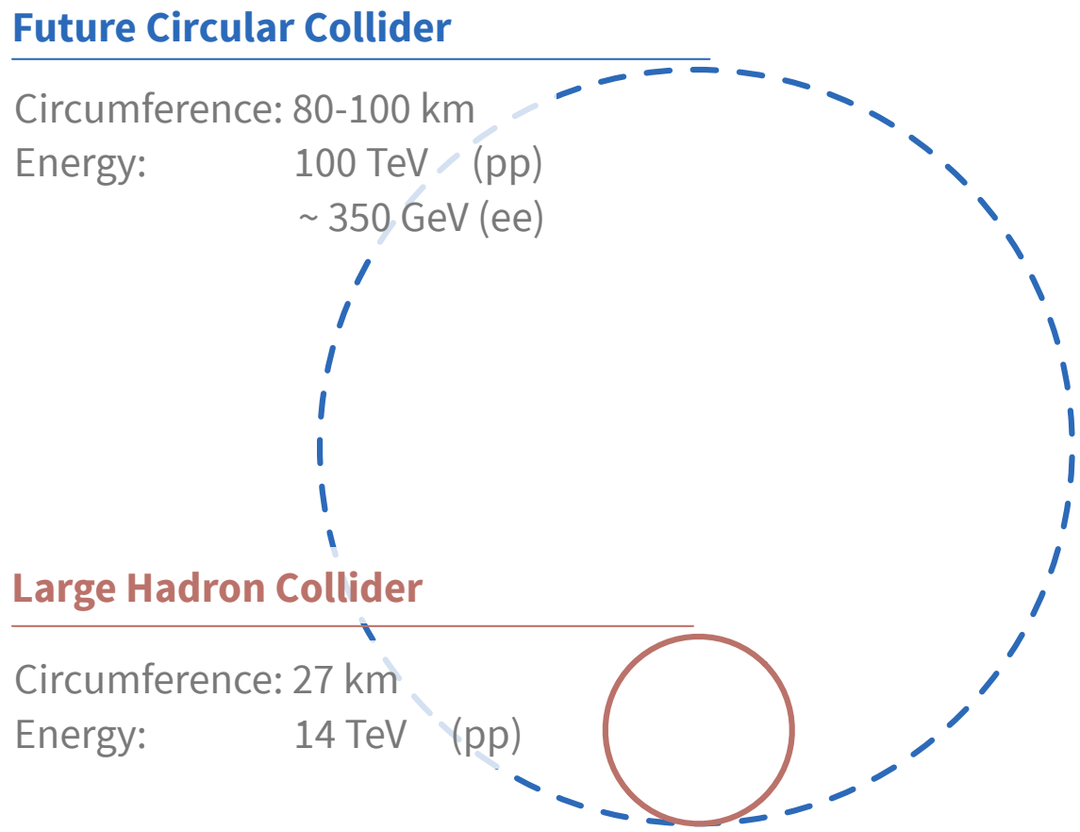
Different requirements: ee vs pp vs ep

Support physics and detector studies:

- Detector concepts: Moving targets
- Both fast and full simulation essential

LHC experiments approach:

- Dedicated software for each experiment
  - Effort duplication
- LHCb and ATLAS started a collaborative approach
  - Gaudi* as underlying framework
  - Also used for FCC software

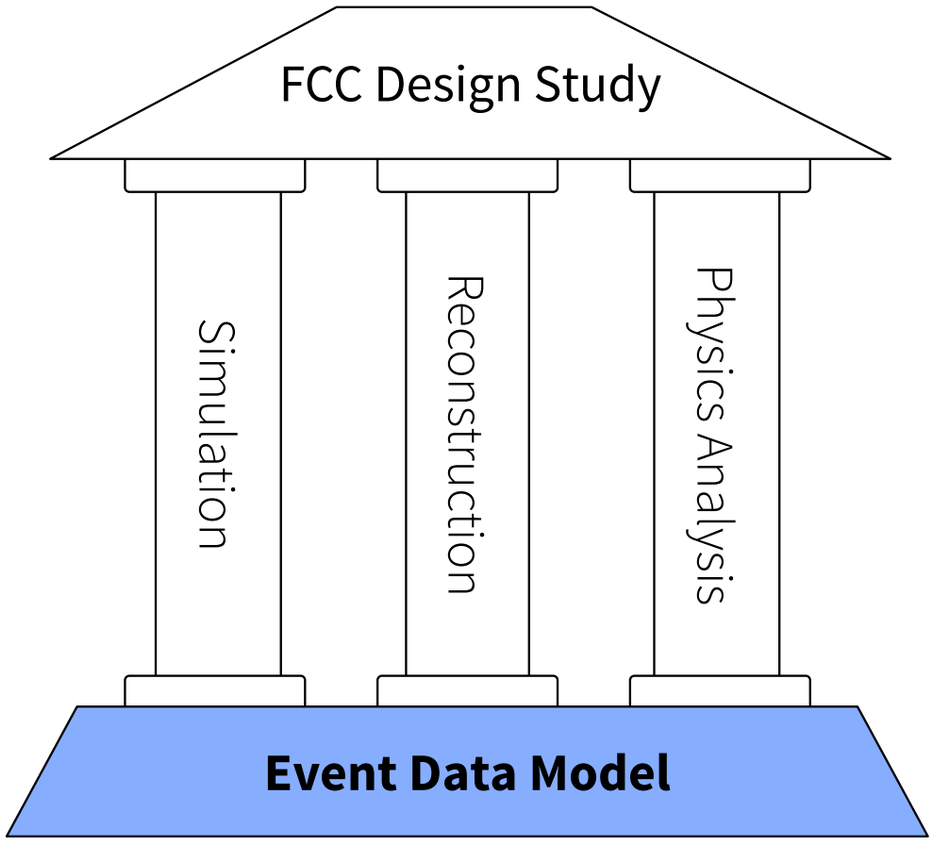


Our aim: **One software stack to support all experiments**.

*http://proj-gaudi.web.cern.ch/proj-gaudi/

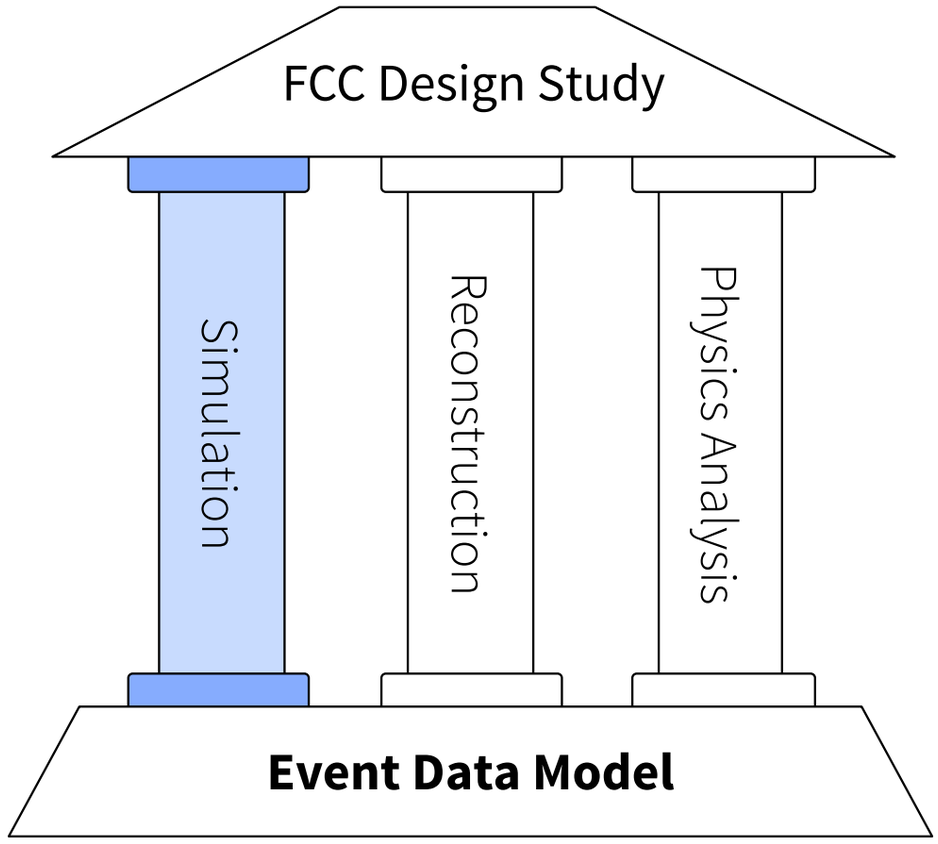
What are the ingredients?

- Flexible event data model
- Flexible detector description
  - Detector concepts: Moving targets



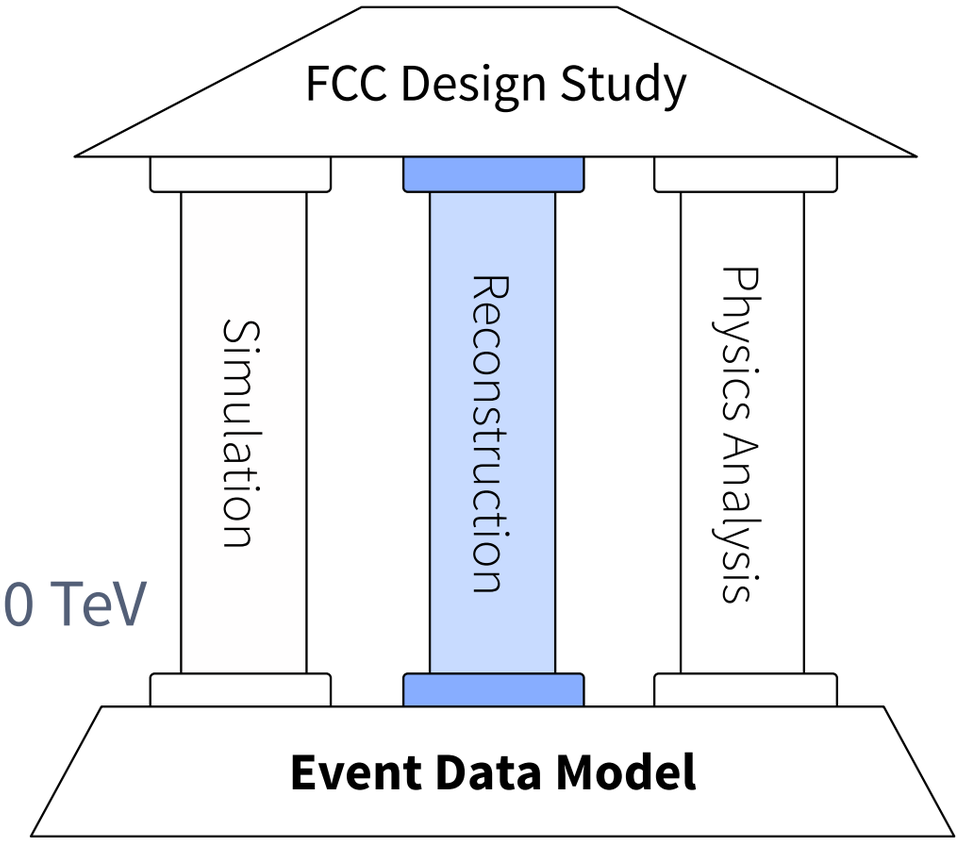
What are the ingredients?

- Flexible event data model
- Flexible detector description
  - Detector concepts: Moving targets
- Simulation
  - Full simulation for detector studies
  - Fast simulation for physics benchmarks



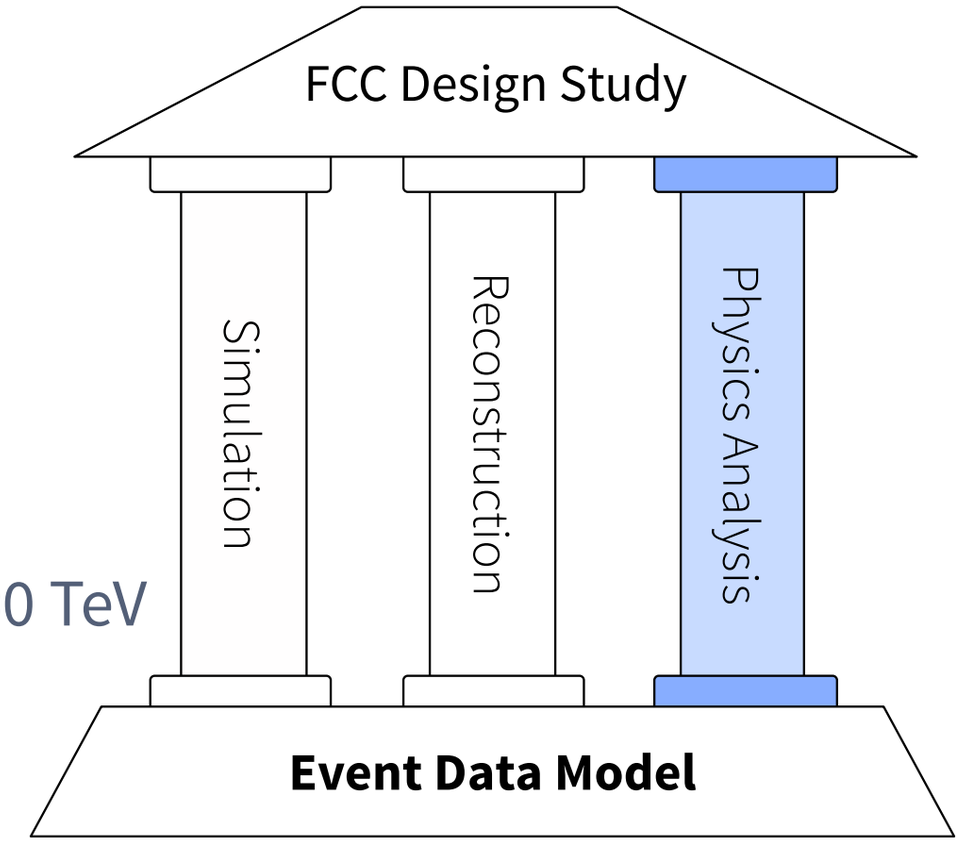
What are the ingredients?

- Flexible event data model
- Flexible detector description
  - Detector concepts: Moving targets
- Simulation
  - Full simulation for detector studies
  - Fast simulation for physics benchmarks
- Reconstruction
  - FCC-hh: Extreme pile-up, extrapolation to 100 TeV
  - FCC-ee: Achieve the best possible precision

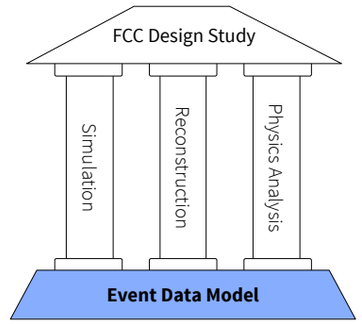


What are the ingredients?

- Flexible event data model
- Flexible detector description
  - Detector concepts: Moving targets
- Simulation
  - Full simulation for detector studies
  - Fast simulation for physics benchmarks
- Reconstruction
  - FCC-hh: Extreme pile-up, extrapolation to 100 TeV
  - FCC-ee: Achieve the best possible precision
- Physics analysis
  - Allow use outside of framework
  - Python flexibility & C++ performance



Event data model



Reviewing existing experiment solutions:

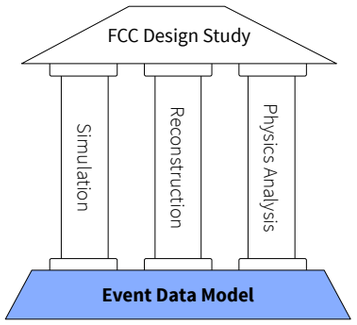
- LHC experiments: Usually not extractible and complicated
- Linear Collider Input/Output (LCIO): Good starting point, hard to adapt

Decided to invest: Plain Old Data Input/Output (PODIO)

- Focus on reusability + flexibility
  - Code generated: Simply describe data in text files
  - Easily adapt data model to changed requirements
- Designed with parallelism in mind
- Python & C++ supported by EDM on same footing

B. Hegner, et al.

Event data model



Reviewing existing experiment solutions:

- LHC experiments: Usually not extractible and complicated
- Linear Collider Input/Output (LCIO): Good starting point, hard to adapt

Decided to invest: Plain Old Data Input/Output (PODIO)

- Focus on reusability + flexibility
  - Code generated: Simply describe data in text files
  - Easily adapt data model to changed requirements
- Designed with parallelism in mind
- Python & C++ supported by EDM on same footing

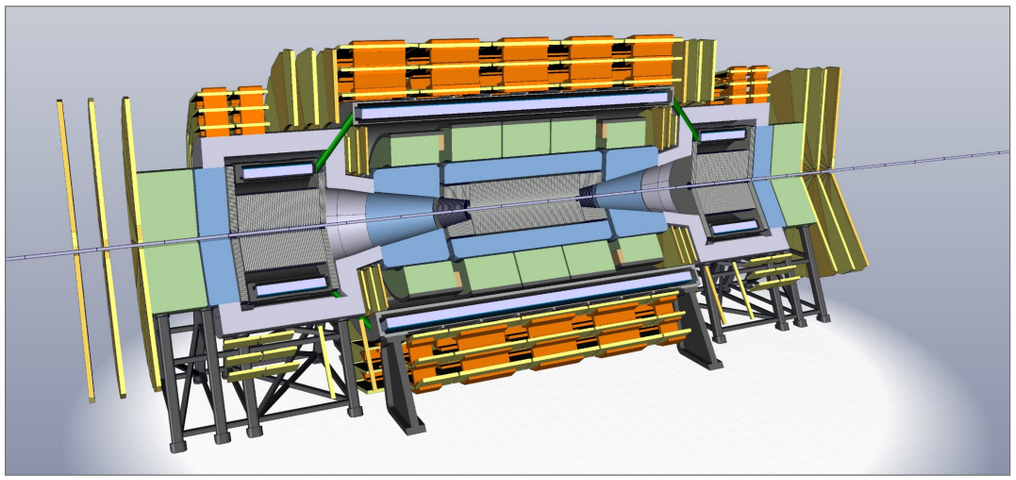
~Feature complete, used throughout the software

Detector Description and existing Concepts

Underlying framework: DD4hep (Linear colliders; LHCb(?))

FCC-hh

- Baseline concept exists*



- Sub-detectors in FCC software
- First full simulation results
- First calo reconstruction

FCC-ee

- Starting with FCC-ee geometry based on CLIC concept
- Porting to FCC software
  - First material scans
  - ~2 months work, one fellow (N. Tehrani)

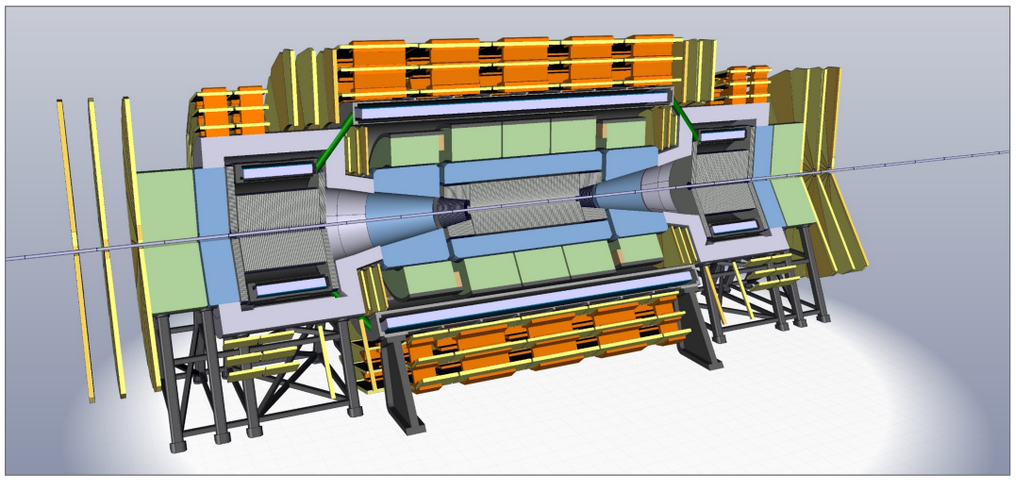
*see M. Selvaggi's talk

Detector Description and existing Concepts

Underlying framework: DD4hep (Linear colliders; LHCb(?))

FCC-hh

- Baseline concept exists*

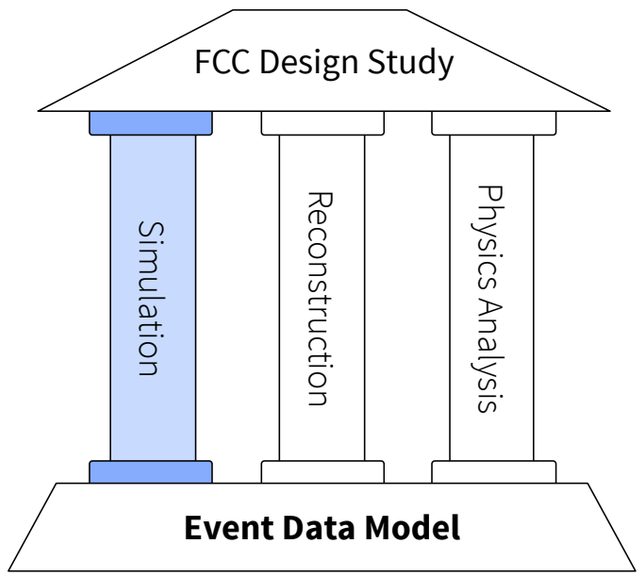


- Sub-detectors in FCC software
- First full simulation results
- Tutorials on how to describe a detector in FCC software

FCC-ee

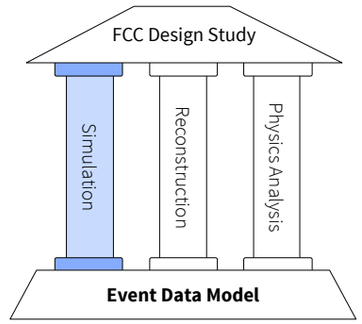
- Starting with FCC-ee geometry based on CLIC concept
- Porting to FCC software
  - First material scans
  - ~2 months work
  - one fellow (N. Tehrani)

*see M. Selvaggi's talk


FCC Design Study
Simulation
Reconstruction
Physics Analysis
Event Data Model

SIMULATION

Event Generation and Geant4 Simulation



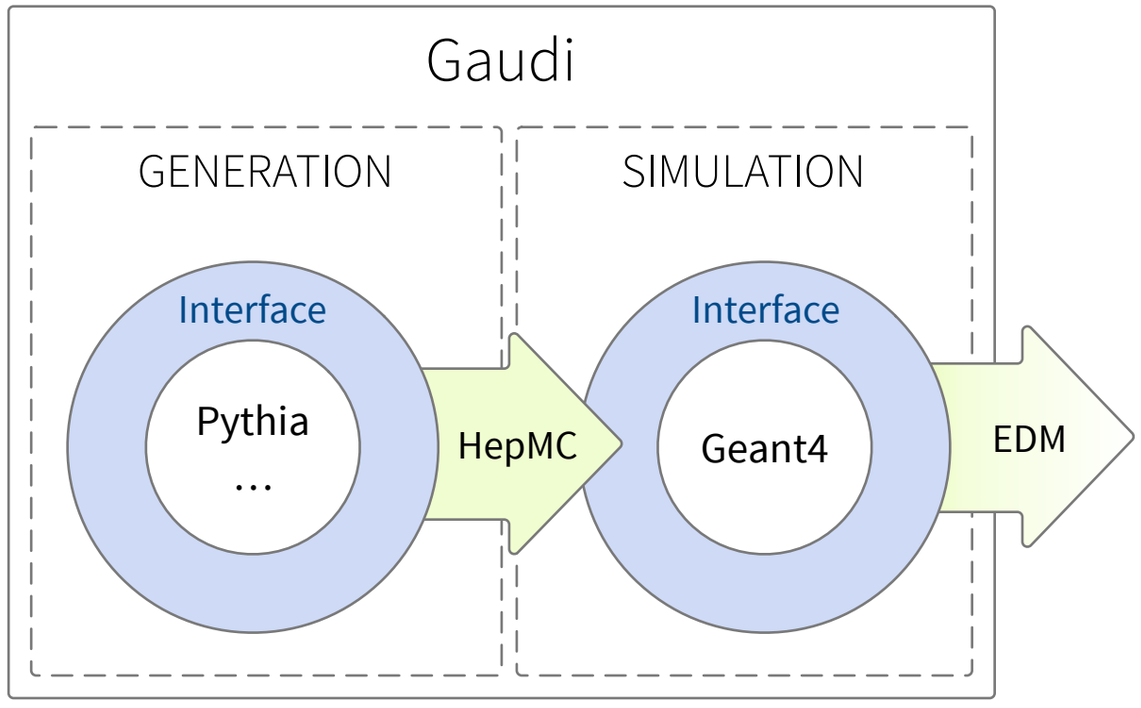
Event Generation

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

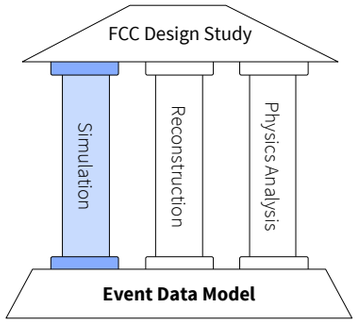
Simulation with Geant 4

- Integrated full & fast simulation
- Existing tutorials and examples
- Feature complete for Design Study

Collaboration with LHCb “Gaussino”



Getting started with Geant4 simulation



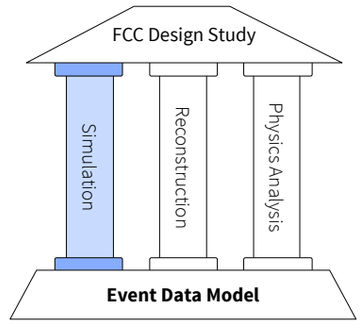
How to add a new detector concept:

- You have: Standalone description + simulation
- Volumes and segmentations pre-defined in FCCSW:
  - Write xml file that describes your detector
    - E.g. a first iteration: Simple cylinder segmented in φ & η

    (Bonus: easy to adapt to other detector concepts / dimensions)
- Port detector specific code to FCC software
  - E.g. *Special* read-out of energy deposits
- Run and compare the results

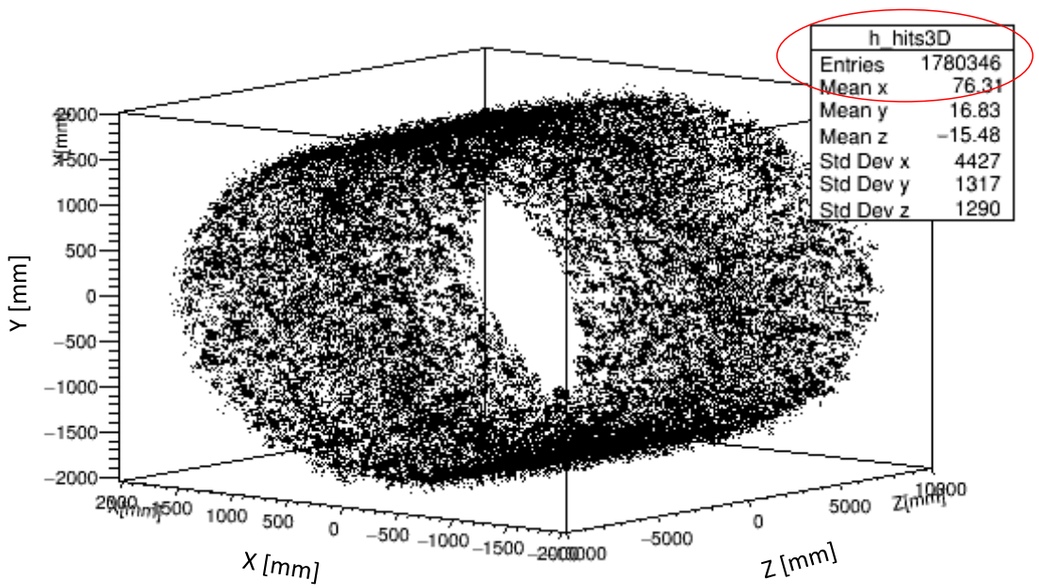
More information

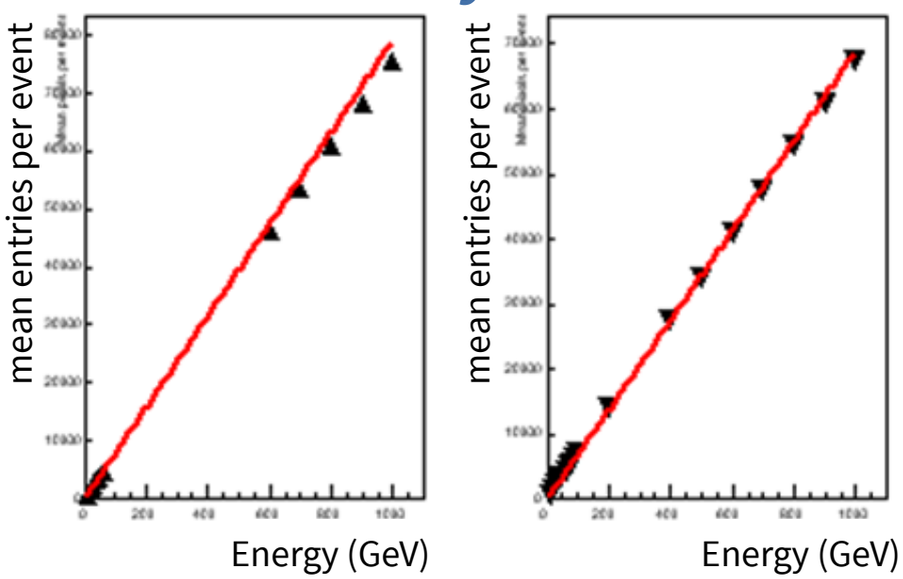
Getting started with Geant4 simulation II



Example: Digital ECal for FCC-hh

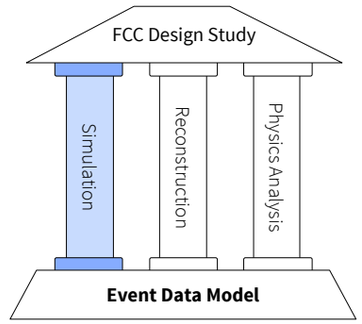
- One Post-Doc with experience in Geant4 and with the detector concept (T. Price)
- First results after ~2 months
- e.g. deposits from [100 pile-up events and linearity studies]





3mm Air 5mm Air

Integrated fast simulation with Geant4



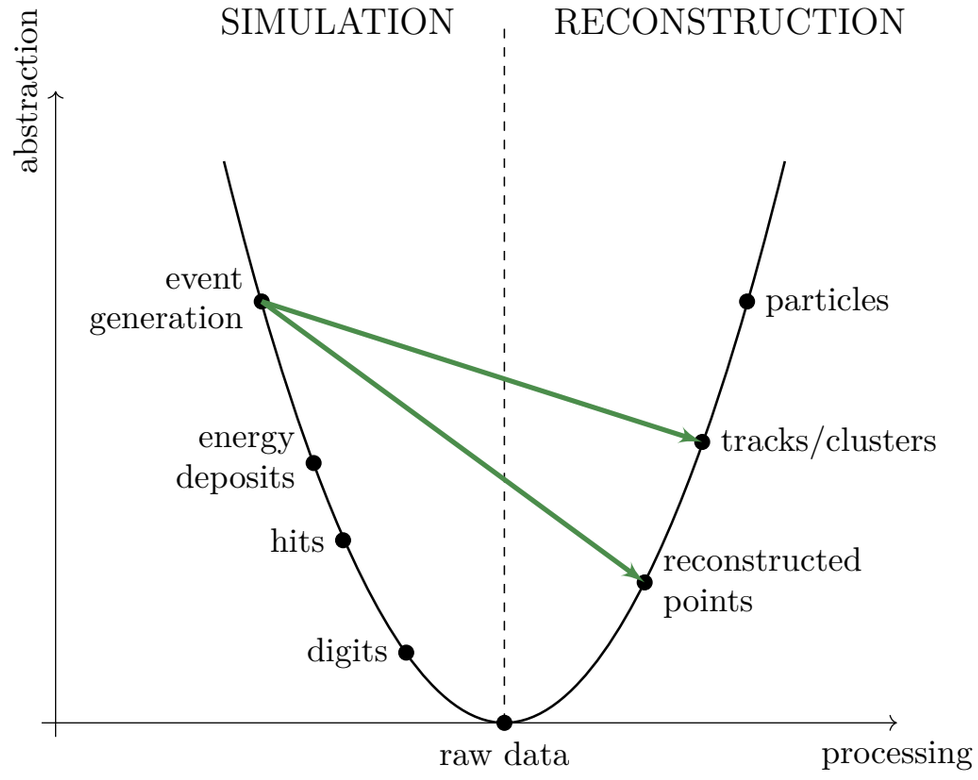
What does “integrated” mean?

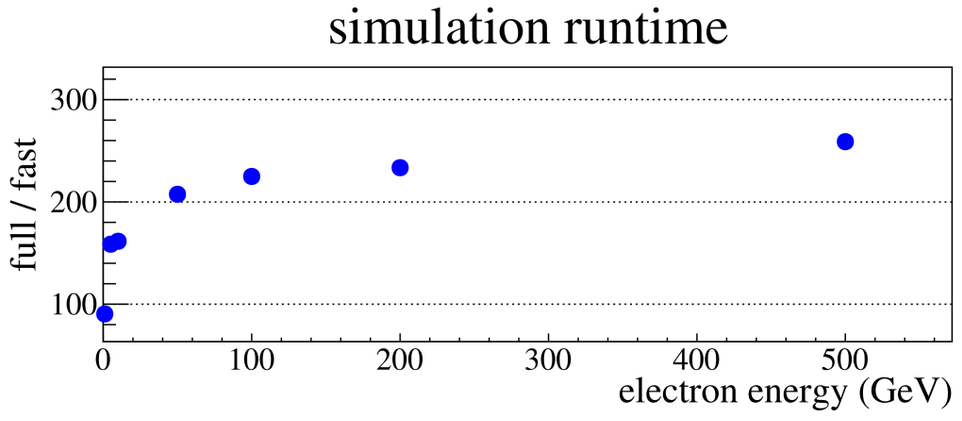
- A la ATLAS: Full and fast simulation in the same event
- Switch based on particle properties, detector region, …

Existing fast simulation methods:

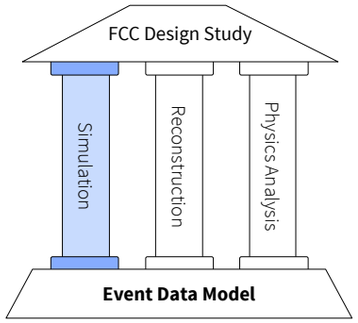
- Param. electromagnetic showers
- Particle momentum smearing

Plans to extend this further



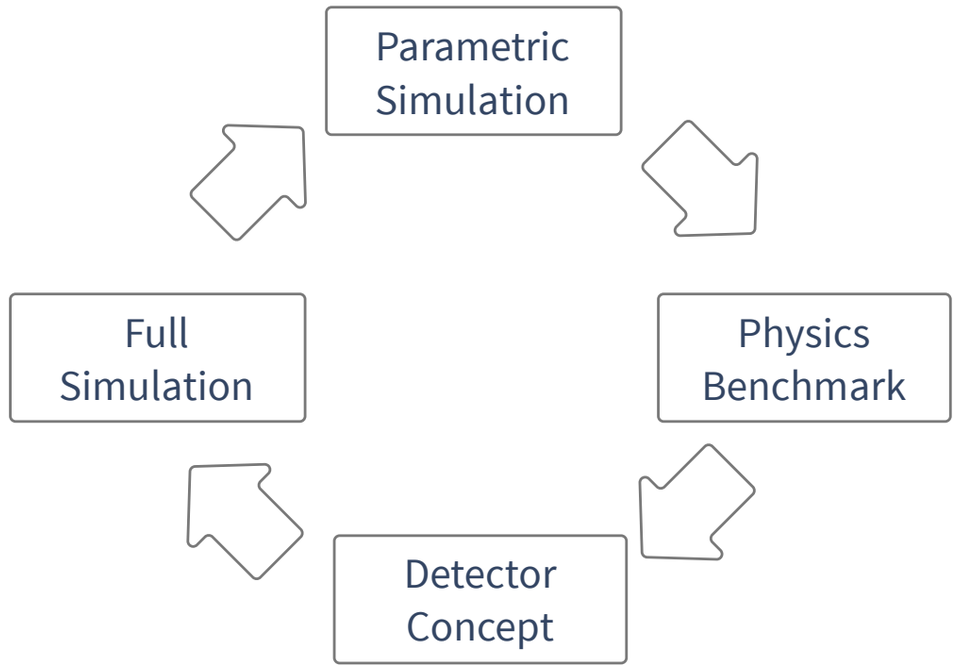


Parametric Simulation



Why do we need parametric simulation?

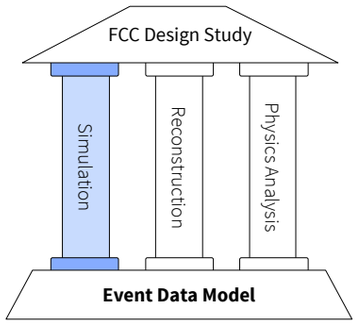
- Define physics benchmarks
- Scan detector parameters
- Redo simulation and analyses



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

- Both integrated in FCC software (easy to cross-check)
- More details about Delphes and FCC-hh detector description:
  - Presentation by M. Selvaggi; Tutorial with example analysis

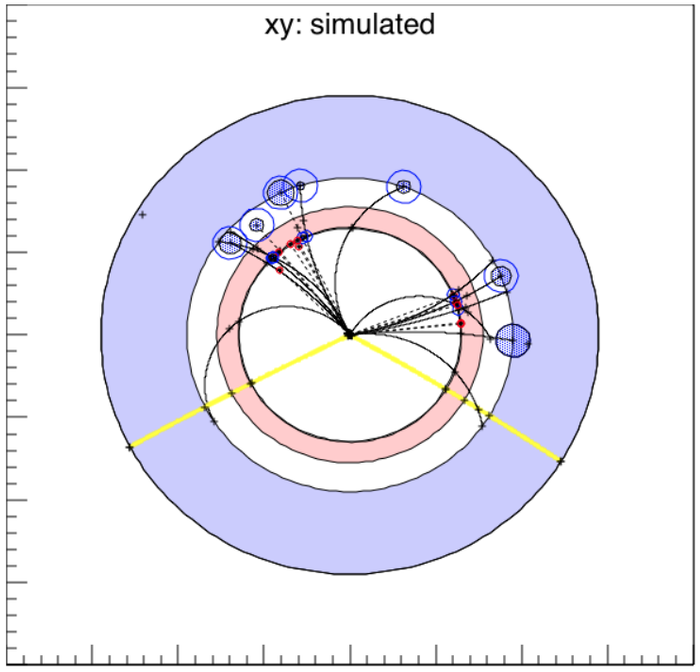
Parametric Simulation in FCC-ee: PAPAS

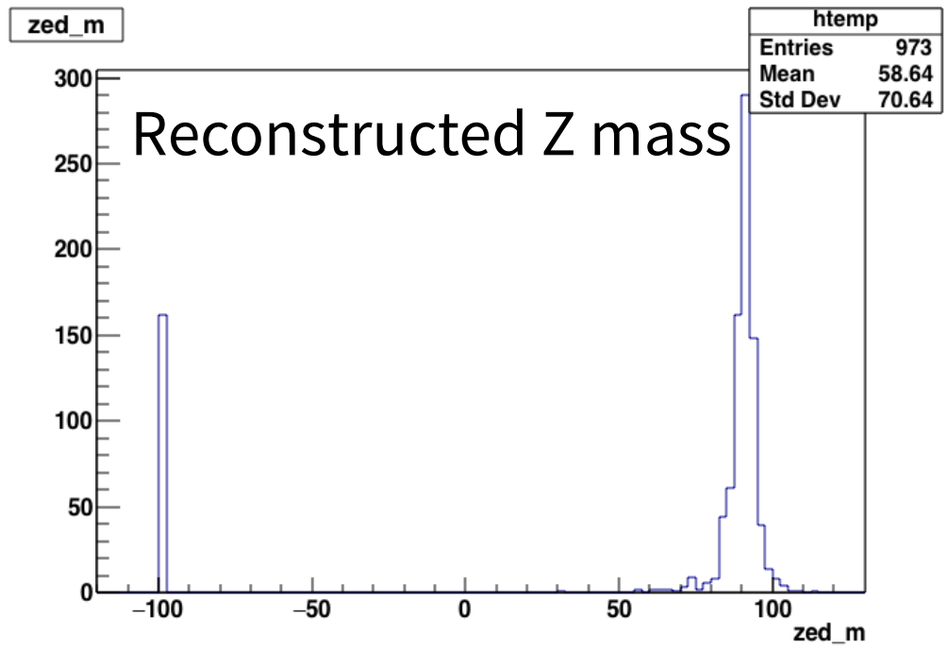


Simulate particle flow inputs

- Inner tracker
  - Simple geometry
  - momentum smearing: resolution model
  - acceptance model
- Calorimeters
  - Simple geometry + material
    - hadron showers in ECal
  - Energy resolution + response
  - Acceptance model
  - Cluster size to model calorimeter granularity

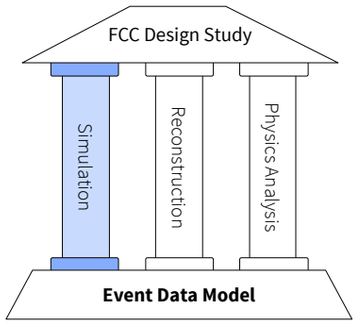
Run particle flow reconstruction





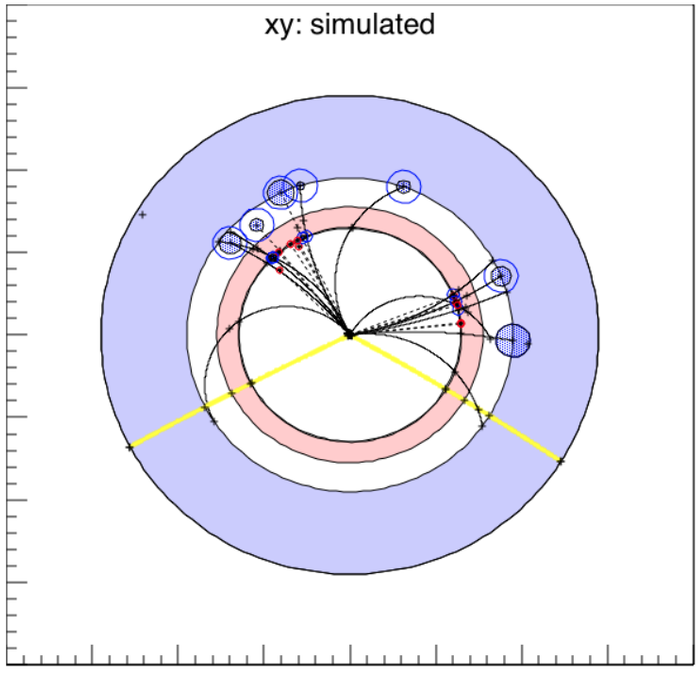
C. Bernet, A. Robson, et al.

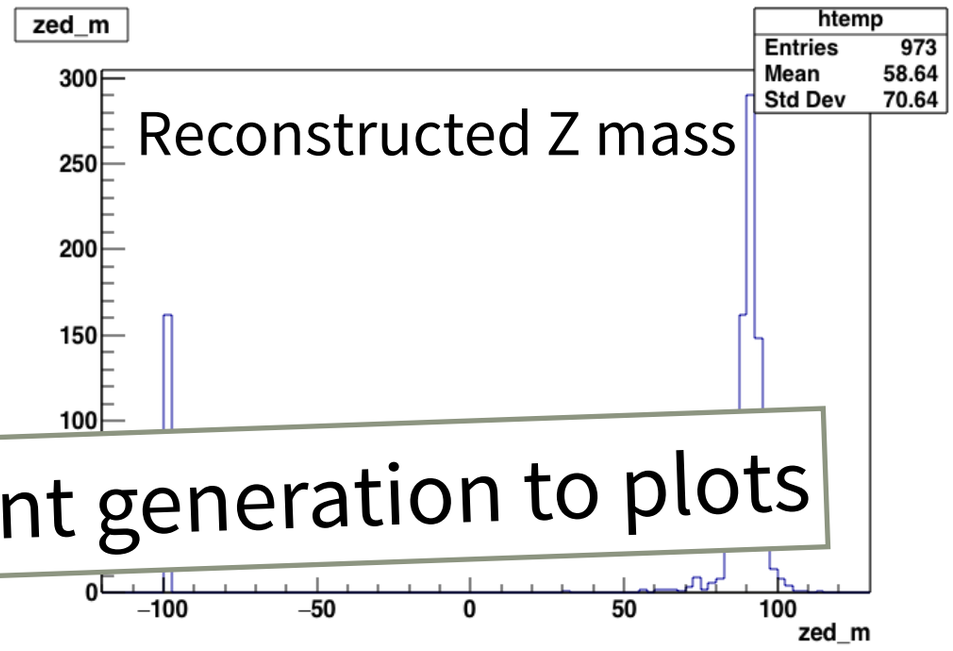
Parametric Simulation in FCC-ee: PAPAS



Simulate particle flow inputs

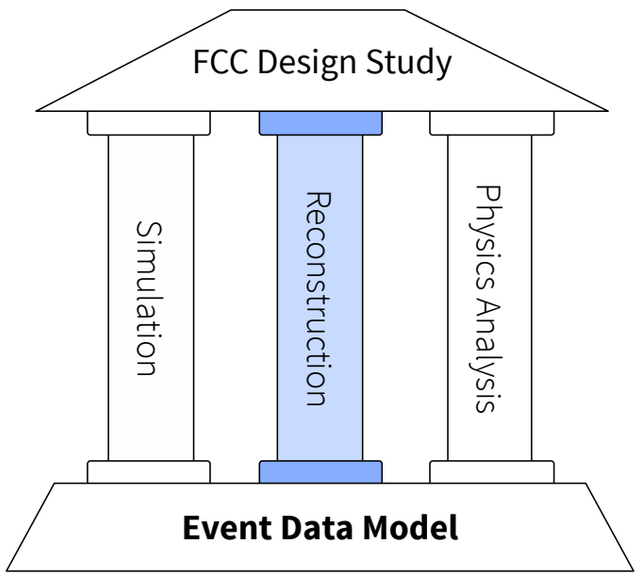
- Inner tracker
  - Simple geometry
  - momentum smearing: resolution model
  - acceptance model
- Calorimeters
  - Simple geometry + material
    - hadron showers in ECal
  - Energy resolution + response
  - Acceptance model
  - Cluster size to model calorimeter granularity





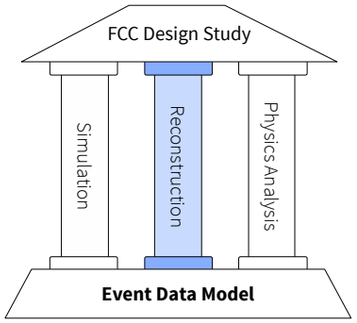
[Example and Tutorial](): From Pythia event generation to plots

C. Bernet, A. Robson, et al.



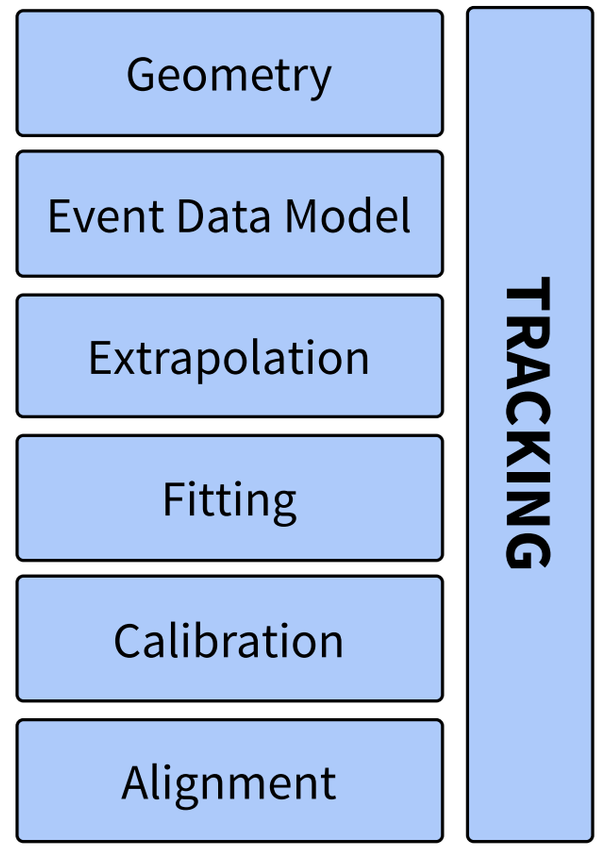
RECONSTRUCTION

A Common Tracking Software



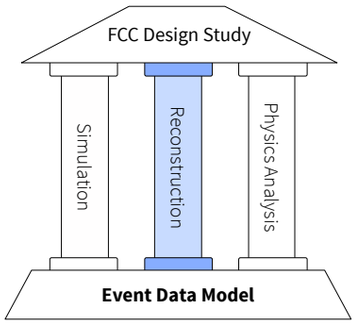
Extracting ATLAS tracking software into a standalone toolkit

- Simplified geometry description optimised for tracking
  - Converter plugins available for FCC (DD4hep)
- Internally use simple EDM
- All necessary tracking tools included
- Add-on: Alternative fast simulation of inner detector
- **Completely independent of experiment**
  - **Usable for FCC-hh, FCC-ee and FCC-eh**



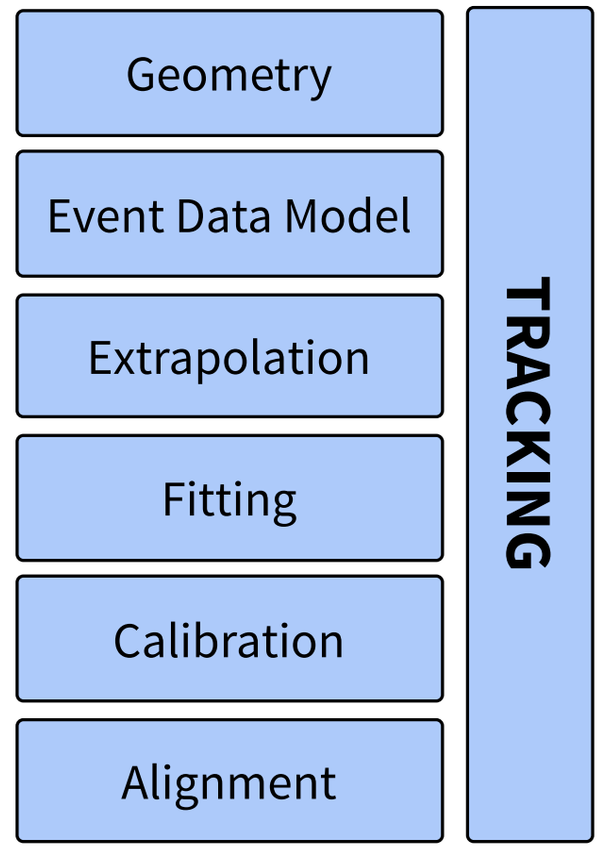
J. Hrdinka, A. Salzburger, V. Volkl et al.

A Common Tracking Software



Extracting ATLAS tracking software into a standalone toolkit

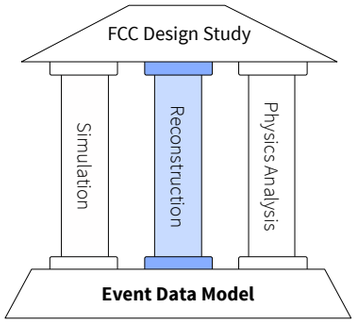
- Simplified geometry description optimised for tracking
  - Converter plugins available for FCC (DD4hep)
- Internally use simple EDM
- All necessary tracking tools included
- Add-on: Alternative fast simulation of inner detector
- **Completely independent of experiment**
  - **Usable for FCC-hh, FCC-ee and FCC-eh**



Toolkit ready for tests; FCC software integration in progress

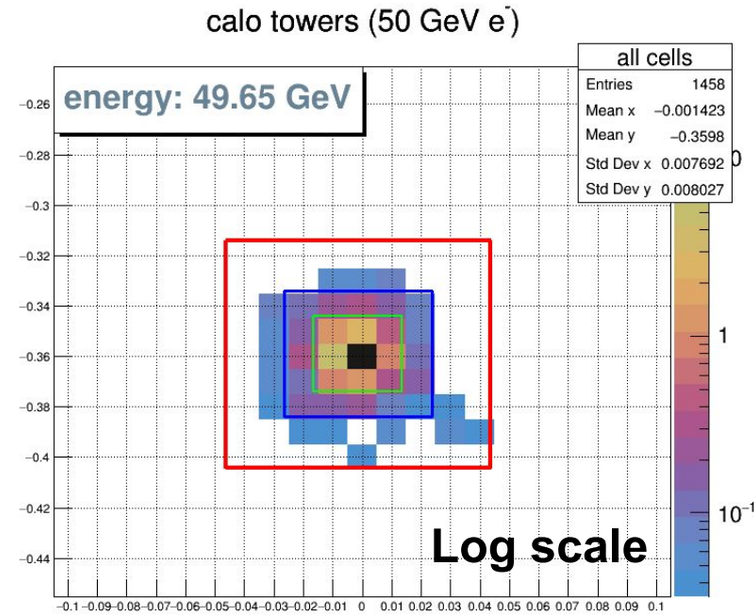
J. Hrdinka, A. Salzburger, V. Volkl et al.

Calorimeter reconstruction



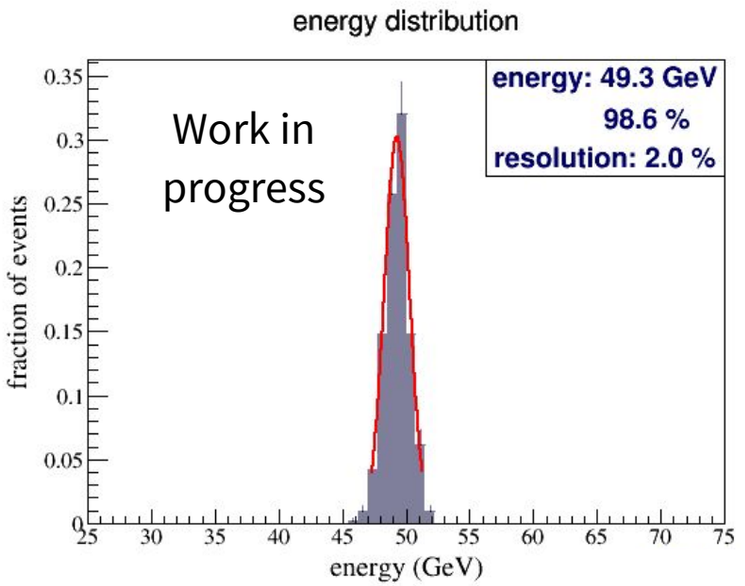
First version of calorimeter reconstruction

- Digitisation (cell energy reconstruction, simulation of noise)
  - Noise also includes in-time and out-of-time pile-up
- Start with: dedicated e/gamma reconstruction
  - Sliding window clustering algorithm
  - Proof of principle working for FCC-hh baseline



Plans and on-going work:

- Currently testing with HCal; combined calorimetry
- Topo-clustering
- Particle flow algorithm



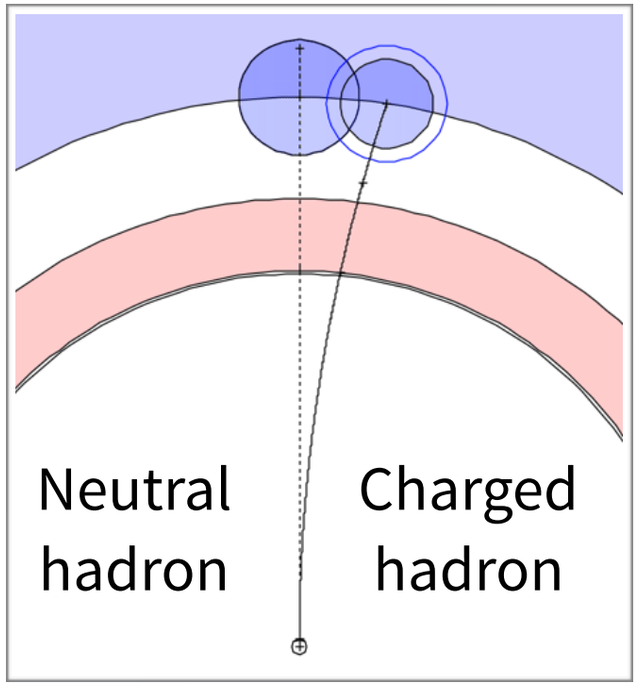
M. Aleksa, J. Faltova, C. Helsens, C. Neubuser, A. Zaborowska, et al.

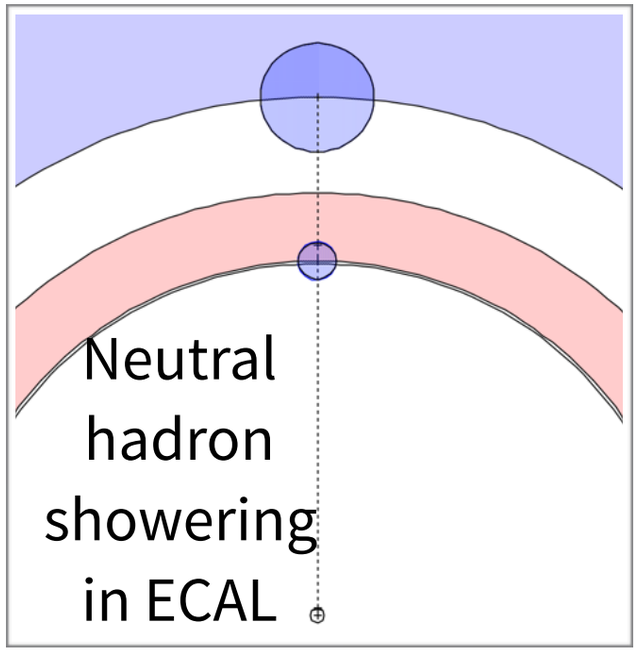
Particle Flow Reconstruction

Algorithm existing within PAPAS a la CMS

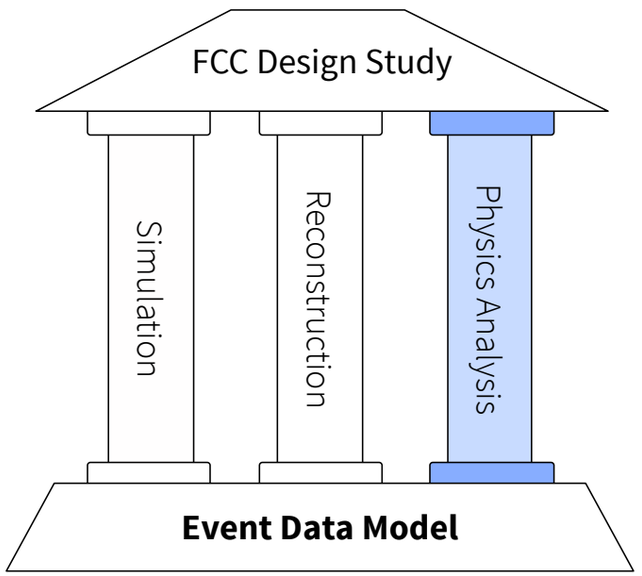
- Reconstruct hadrons, photons, leptons
- Reconstruct jets via fastjet
  - Parametrised tagging performance for flavour tags
- Prototyped in Python, gradually ported to C++
- Port integration into FCC framework
  - (The same applies to parametric simulation)

Running as part of PAPAS fast simulation



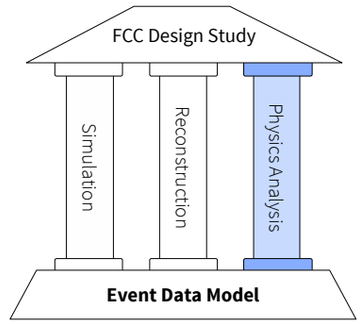


C. Bernet, A. Robson, et al.



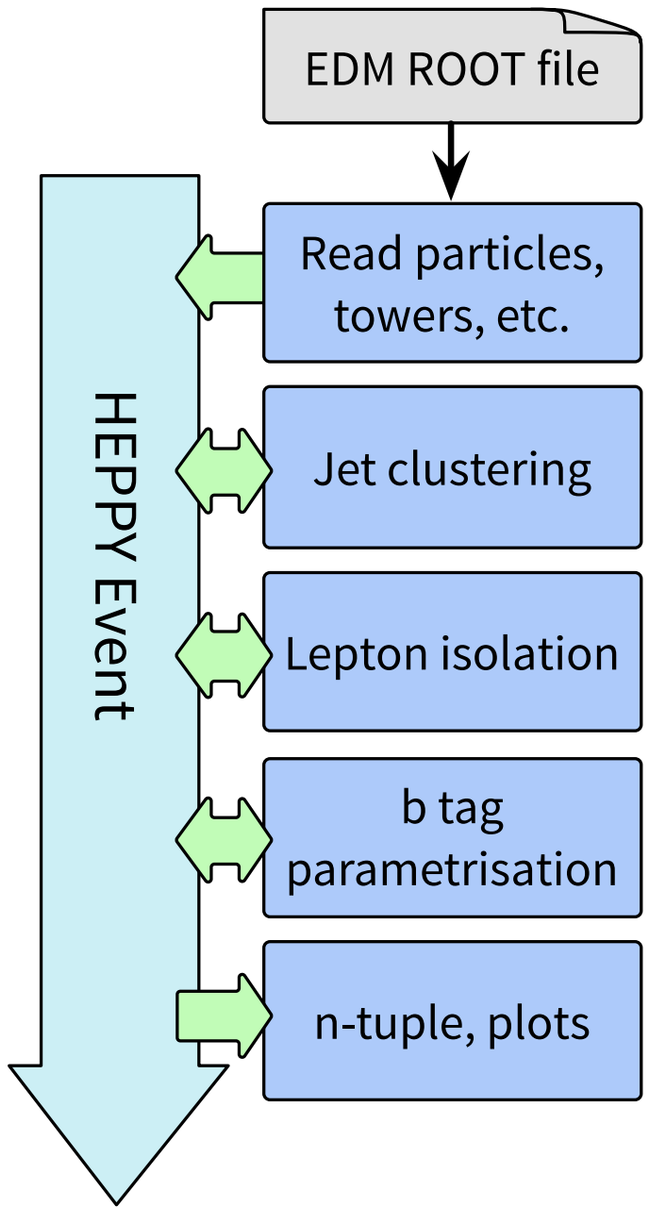
PHYSICS ANALYSIS

The Analysis Front-End

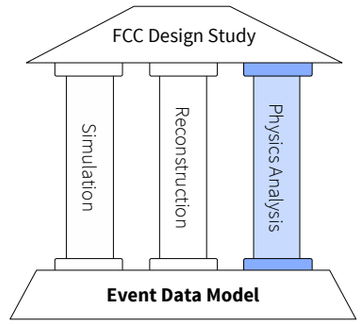


Python-based analysis: HEPPY

- Highly configurable, easy to setup
- Includes PAPAS simulation
- Python: Testing ideas and prototyping of algorithms
- Gradual port of code from Python to C++
  - Use ported functionality from Python

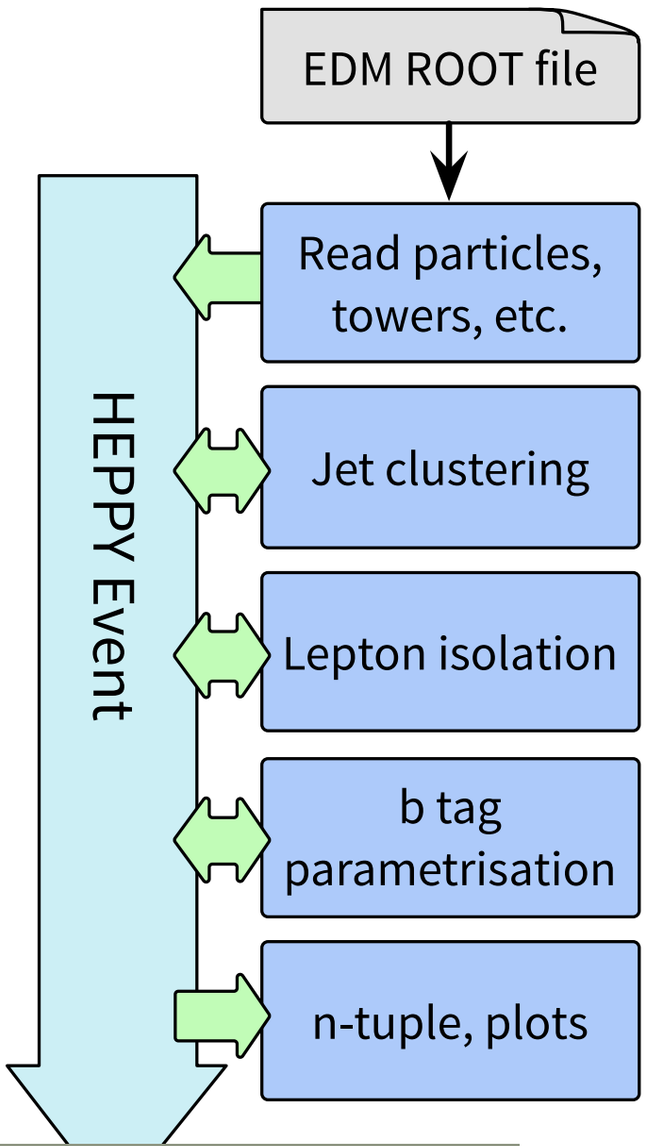


The Analysis Front-End



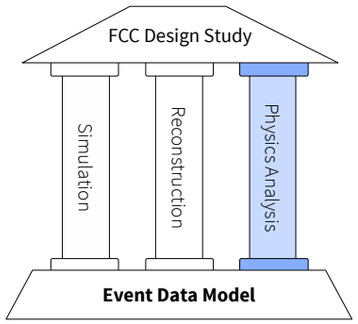
Python-based analysis: HEPPY

- Highly configurable, easy to setup
- Includes PAPAS simulation
- Python: Testing ideas and prototyping of algorithms
- Gradual port of code from Python to C++
  - Use ported functionality from Python



Examples and tutorials exist (see also talk by M. Selvaggi)

Getting started with analysis framework

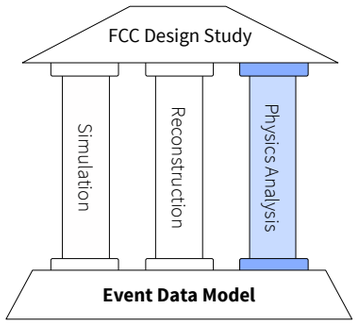


Setup of analysis framework on lxplus or SLC6 machine

```
source /afs/cern.ch/exp/fcc/sw/0.8pre/setup.sh
git clone git@github.com:HEP-FCC/heppy.git
cd heppy/
source ./init.sh

mkdir Workdir
cd Workdir/
cp $HEPPY/test/analysis_ee_ZH_cfg.py .
```

Getting started with analysis framework



Setup of analysis framework on lxplus or SLC6 machine

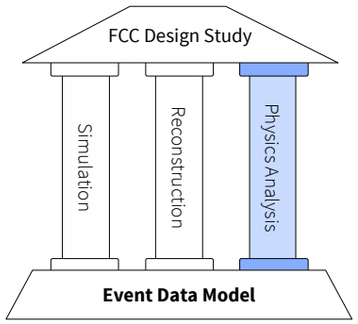
```
source /afs/cern.ch/exp/fcc/sw/0.8pre/setup.sh
git clone git@github.com:HEP-FCC/heppy.git
cd heppy/
source ./init.sh

mkdir Workdir
cd Workdir/
cp $HEPPY/test/analysis_ee_ZH_cfg.py .
```

Generate with a standard Pythia 8 card

```
fcc-pythia8-generate \
          $FCCPHYSICS/share/ee_ZH_Zmumu_Hbb.txt
```

Getting started with analysis framework



Setup of analysis framework on lxplus or SLC6 machine

```
source /afs/cern.ch/exp/fcc/sw/0.8pre/setup.sh
git clone git@github.com:HEP-FCC/heppy.git
cd heppy/
source ./init.sh

mkdir Workdir
cd Workdir/
cp $HEPPY/test/analysis_ee_ZH_cfg.py .
```

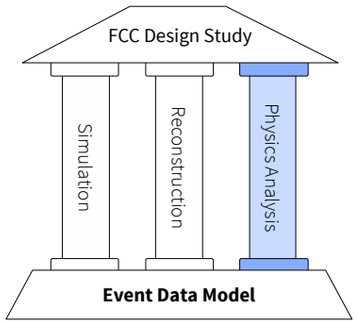
Generate with a standard Pythia 8 card

```
fcc-pythia8-generate \
         $FCCPHYSICS/share/ee_ZH_Zmumu_Hbb.txt
```

Submit simulation & analysis to batch

```
heppy_batch.py -o Ntuples/ \
               analysis_ee_ZH_cfg.py \
               -b ‘bsub -q 8nh < batchScript.sh’
```

Getting started with analysis framework



Setup of analysis framework on lxplus or SLC6 machine

```
source /afs/cern.ch/exp/fcc/sw/0.8pre/setup.sh
git clone git@github.com:HEP-FCC/heppy.git
cd heppy/
source ./init.sh

mkdir Workdir
cd Workdir/
cp $HEPPY/test/analysis_ee_ZH_cfg.py .
```

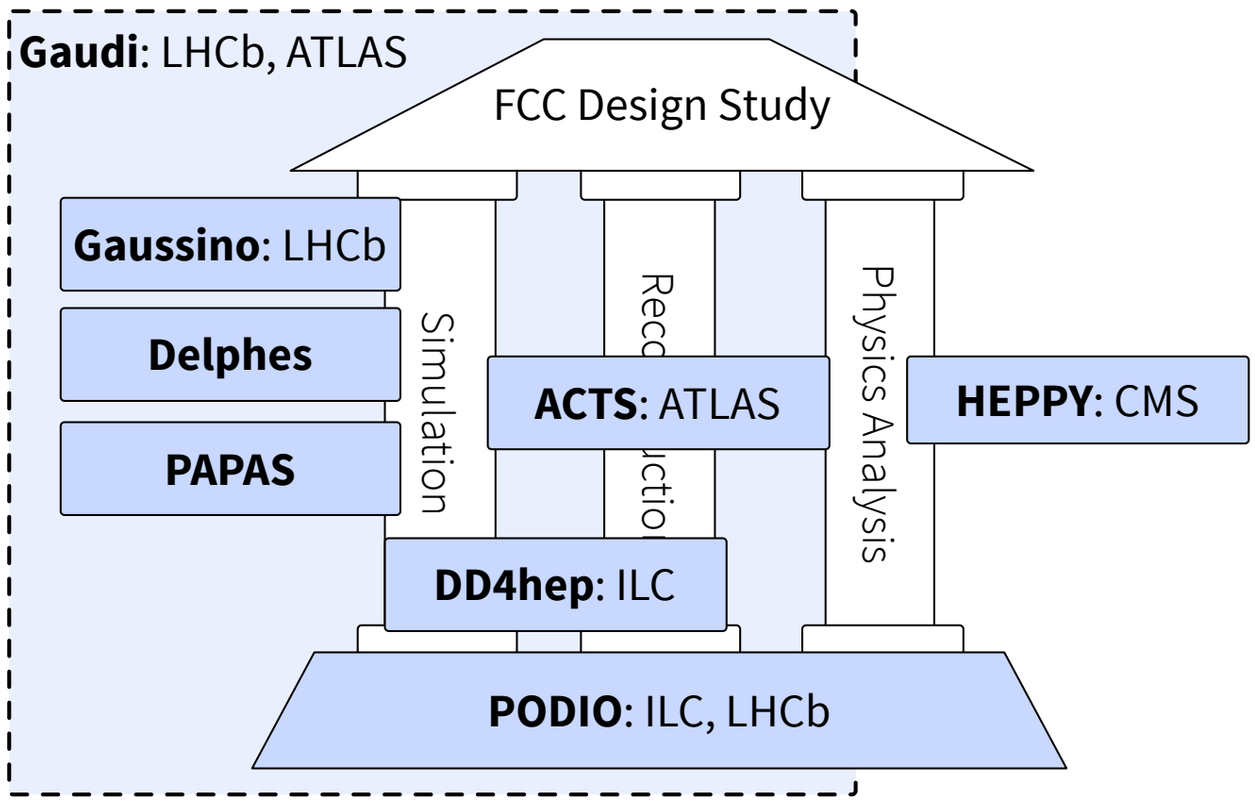
Generate with a standard Pythia 8 card

```
fcc-pythia8-generate \
          $FCCPHYSICS/share/ee_ZH_Zmumu_Hbb.txt
```

Submit simulation & analysis to batch

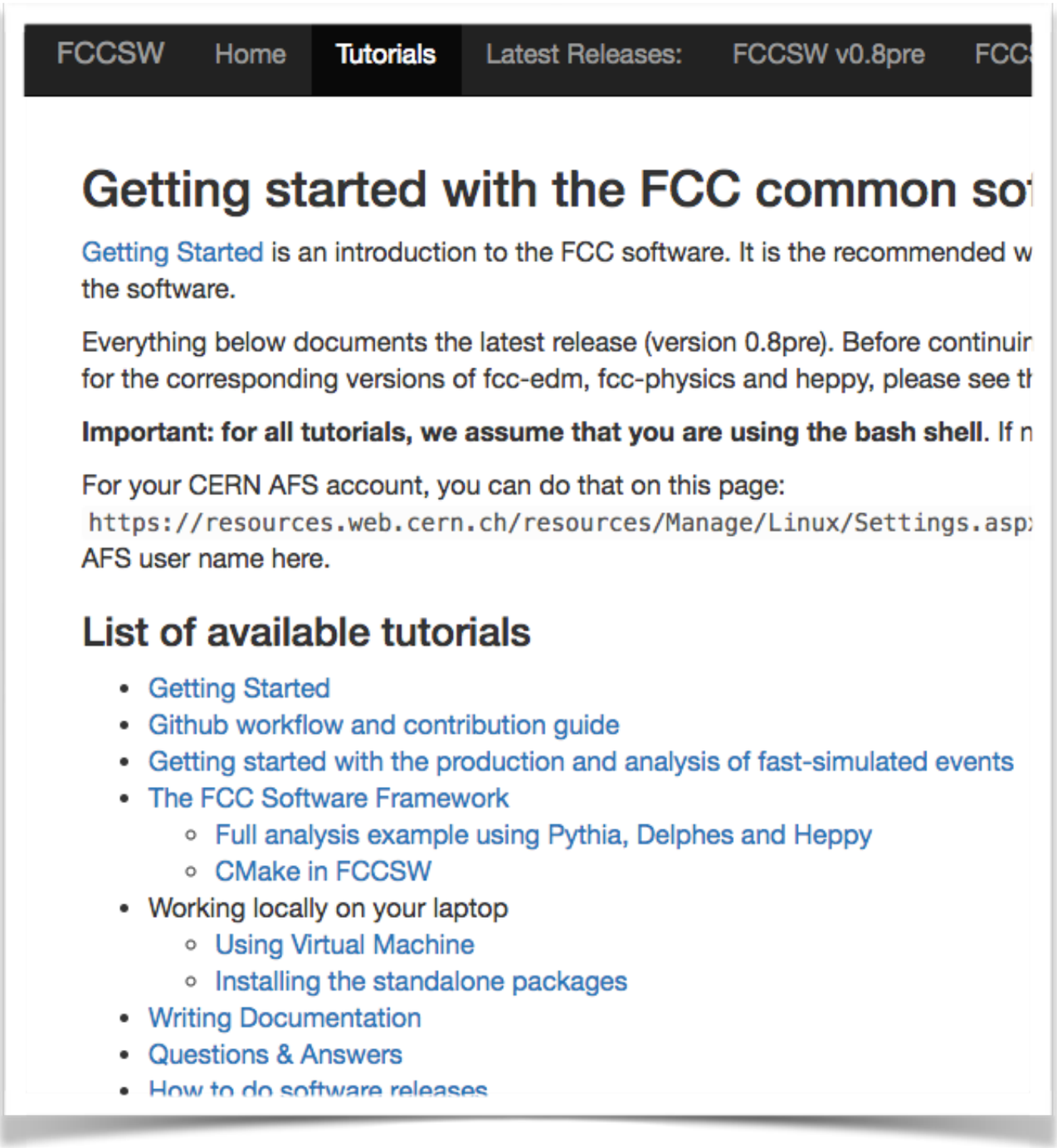
```
heppy_batch.py -o Ntuples/ \
               analysis_ee_ZH_cfg.py \
               -b ‘bsub -q 8nh < batchScript.sh’
```

Similar workflows to use Delphes and Geant4


Gaudi: LHCb, ATLAS
FCC Design Study
Gaussino: LHCb
Delphes
PAPAS
Simulation
Reco
ACTS: ATLAS
HEPPY: CMS
Physics Analysis
DD4hep: ILC
PODIO: ILC, LHCb

SUMMARY

Last but not least: Where do you start?



Web: fccsw.web.cern.ch

- Tutorials already scattered through slides

FCC software e-group

- fcc-experiments-sw-dev
- Ask your questions!

Welcome at our meetings:

- Every other Wed, 11:00 h

Conclusion

A lot of activity in various areas:

- Full & Fast Simulation is ready to be used
- Reconstruction algorithms being developed

Tutorials and examples are ready!

Conclusion

A lot of activity in various areas:

- Full & Fast Simulation is ready to be used
- Reconstruction algorithms being developed

Tutorials and examples are ready!