FCC Analyses and RDataFrame

From the past (Heppy) to the future (EDM4hep)

PPP Developers Meeting October 2019

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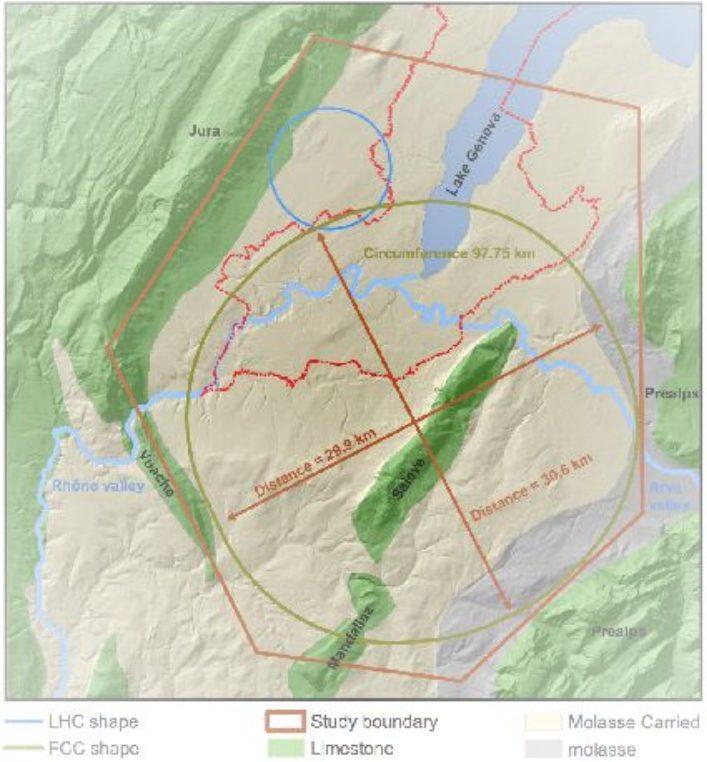
Future Circular Collider Design Study



Conceptual Design Report based on

- 150 TB of full simulation data
- 100 TB of Delphes events

produced with Gaudi-based framework FCCSW

FCC-hh(ee) Framework

Fully integrated analysis chain
Links between various steps

1. GridPack producer
   - Makes MG5_aMC@NLO GridPacks, need to understand if other GEN can do it
2. LHE Producer
   - Produce LHE files on condor queues, either from step 1) or on the fly. Need a detailed review of the possibilities offered by other GEN (this has started as we have just seen)

Creates a database of LHE events

3. FCCSW
   - Runs Pythia8 parton shower+hadronisation and Delphes with FCC detector
     http://fcc-physics-events.web.cern.ch/fcc-physics-events/Delphesevents_fccee_v01.php
     Also need to support later other parton showers

Creates a database of FCC events

4. Analysis pre-selection
   - Python framework produces flat ROOT trees

Use the events in the database to produce analyses templates

5. Analysis final selection
   - Python framework for optimising analysis cut flows and producing

Use the events produced at pre-selection to create stacked plots

6. Final analyses (custom, but we have limit setting tool for instance)

FCC-hh(ee) Framework

Fully integrated analysis chain
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1. fcc-physics-events.web.cern.ch

Home | About | Contact | 100TeV FCC Physics | 27TeV HE-LHC Physics | Full Simulation FCChh | FCCee Physics | Stat

Delphes FCC Physic events v0.2

Search for names..

NO	NAME	NEVENTS	NWEIGHTS	NFILES	NBAD	NEOS	SIZE (GB)	OUTPUT PATH	MAIN PROCESS	FINAL STATES	CROSS SECTION (PB)
1	mgp8_pp_hh_lambda096_5f_htautau	980,000	0	98	1	99	45.63	/eos/experiment/fcc/hh/generation/DelphesEvents /fcc_v03/mgp8_pp_hh_lambda096_5f_htautau/	HH, H->bb, H undec., kl = 0.96		1.47359
2	mgp8_pp_hh_lambda097_5f_htautau	1,000,000	0	100	0	100	46.55	/eos/experiment/fcc/hh/generation/DelphesEvents /fcc_v03/mgp8_pp_hh_lambda097_5f_htautau/	HH, H->bb, H undec., kl = 0.97		1.46195
3	mgp8_pp_hh_lambda098_5f_htautau	990,000	0	99	0	99	46.13	/eos/experiment/fcc/hh/generation/DelphesEvents /fcc_v03/mgp8_pp_hh_lambda098_5f_htautau/	HH, H->bb, H undec., kl = 0.98		1.45039

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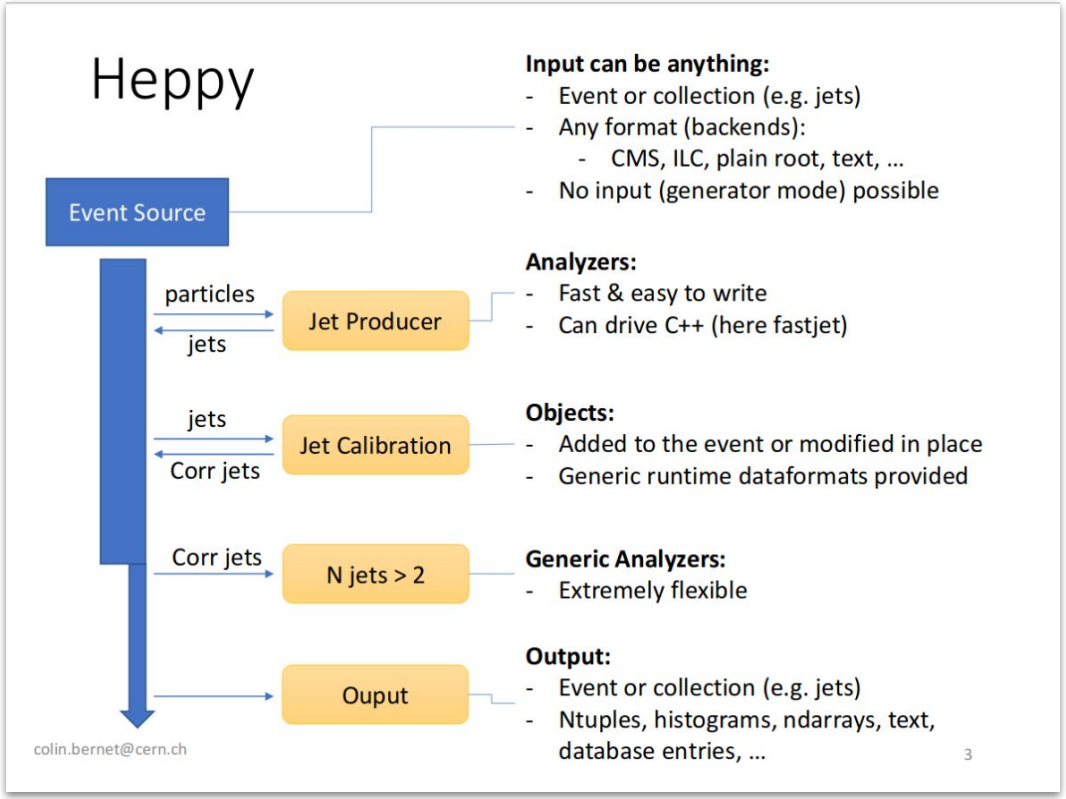
HEPPY

- See **Colin's Talk** giving a general overview



Problems: Performance and Maintainance

- Original Authors no longer around
- Pure Python Loop ➔ Slow! Using tth_4l analysis as a test case:

```
~/$ heppy_loop.py output analysis.py
    event 100 (17.8 ev/s)
    event 200 (21.9 ev/s)
    event 300 (24.6 ev/s)
    event 400 (26.1 ev/s)
    ….
```

Problems: Performance and Maintainance

- Clear that event loop needs to be moved to C++.
  - Coincided with first RDataFrame implementations
  - Spent last summer rewriting one analysis
- Speedup of 30x (6 seconds vs 3 minutes for one file on eos containing 7000 events)
- Not yet running with MultiThreading

HEPPY

```
def process(self, event):
  sqrts = self.cfg_ana.sqrts
  to_remove = getattr(event, self.cfg_ana.to_remove)
  recoil_p4 = TLorentzVector(0, 0, 0, sqrts)
  for ptc in to_remove:
     recoil_p4 -= ptc.p4()
  recoil = Recoil(0, 0, recoil_p4, 1)
  setattr(event, self.cfg_ana.output, recoil)
```

RDataframe:

```
struct recoil {
  recoil(float arg_sqrts) : m_sqrts(arg_sqrts) {};
  float m_sqrts = 240.0;
  std::vector<fcc::ParticleData> operator()
(std::vector<fcc::ParticleData> in) {
    std::vector<fcc::ParticleData> result;
    auto recoil_p4 = TLorentzVector(0, 0, 0, m_sqrts);
    for (auto & v1: in) {
      TLorentzVector tv1;
      tv1.SetXYZM(;
      recoil_p4 -= tv1;
    }
      auto recoil_fcc = fcc::ParticleData();
      recoil_fcc.core.p4.px = recoil_p4.Px();
      recoil_fcc.core.p4.py = recoil_p4.Py();
      recoil_fcc.core.p4.pz = recoil_p4.Pz();
      recoil_fcc.core.p4.mass = recoil_p4.M();
      result.push_back(recoil_fcc);
      return result;
  }
};
```

Changing the Heppy “backend”

- Heppy seems to have found a nice “syntax” for the analyses though
  - That and the sheer number of analyses to port cited as arguments against dataframe
- Started to investigate if configuration files can be kept
- fccflatprod

```
sys.modules["heppy"] = __import__("fccflatprod")
```

  - Each analyzer then maps to one Define

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Main issues:

- Python lambdas in filters
- heppy idiosyncracies in I/O
- Analyzers that modify data in place

EDM4HEP

- Effort to converge to common datamodel for Future Collider Communities (CLIC/ILC, FCC and CEPC, and wider community where useful!)
- HSF Project
  - https://github.com/HSF/EDM4HEP
- Content close to more mature LCIO edm
  - Already ported to podio (“plcio”) by Frank Gaede
- Rapidly approaching first prototype
- FCC will certainly migrate as soon as possible

Implementation Podio

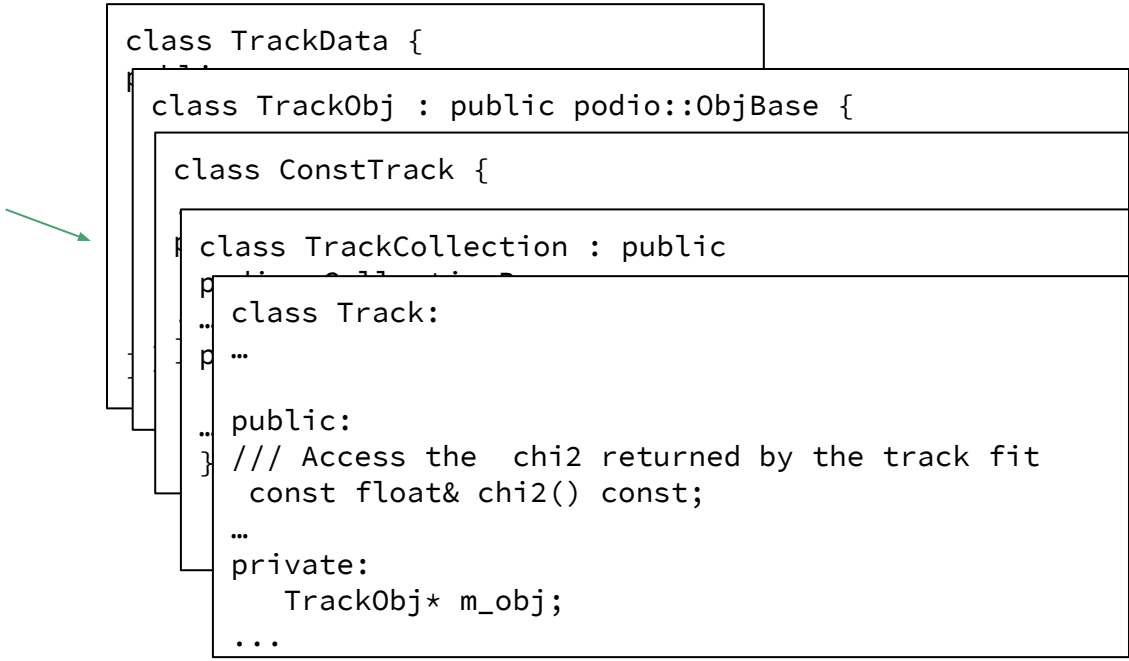
```
fcc::Track:
  Members:
   - float chi2 // from track fit
   - unsigned ndf //
   - unsigned bits // stores flags
  OneToManyRelations :
   - fcc::PositionedTrackHit hits
   - fcc::TrackState states
```



```
class TrackData {
public:
  float chi2;  ///< chi2
  unsigned ndf;  ///
  unsigned bits;  ///< Stores flags
  unsigned int hits_begin;
  unsigned int hits_end;
  unsigned int states_begin;
  unsigned int states_end;
};
```

Implementation: PODIO

```
fcc::Track:
  Members:
    - float chi2 // from track fit
    - unsigned ndf //
    - unsigned bits // stores flags
  OneToManyRelations :
    - fcc::PositionedTrackHit hits
    - fcc::TrackState states
```



Plans for the Future

- Working with the **Plain Old Data** is sufficient for basically all of the current FCC usecases for heppy
- Constructing a DataFrame from the plain root file is a feature
- Could distribute a library + dictionary of lambdas replacing analyzers
- Investigating **Bamboo**