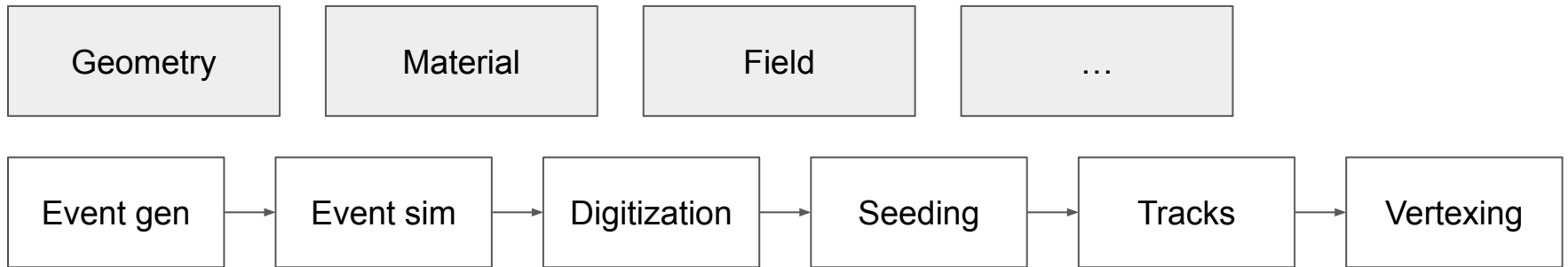


Tutorials: Full chain

ACTS Workshop 2022

Overview

- Full chain = simulation + reconstruction
- Useful for validation, testing
 - *The* integration test for tracking
 - Used in ACTS CI to catch regressions early
- Plug and play for different geometries and algorithms



Which full chain?

- ODD full chain ([Examples/Scripts/Python/full_chain_odd.py](#))
- ITk full chain ([Examples/Scripts/Python/full_chain_itk.py](#))
- physmon full chain ([CI/physmon/physmon.py](#))
- ODD CI full chain ([ci/full_chain_odd.py](#))
- Workshop full chain ([full_chain/full_chain_odd.py](#))

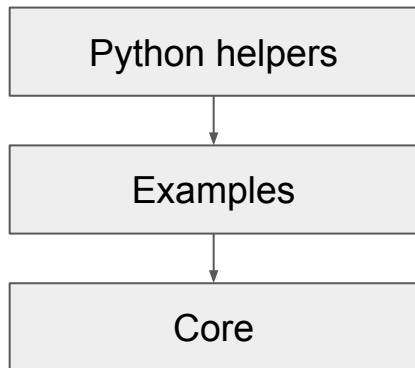
Setup

- I had hoped for using the CI docker images but didn't work because of authentication problems
- Instead I rely on my local setup which will not be very reproducible to install
- My setup
 - Ubuntu 22.04.01
 - Root 6.20.06
 - DD4hep 1.21
 - ACTS master 48a155c
- Alternative from Paul: [ACTS on lxplus \(CentOS 7\)](#)

```
$ cmake -S . -B build_key4hep -GNinja \  
-DACTS_BUILD_PLUGIN_DD4HEP=ON \  
-DACTS_BUILD_EXAMPLES=ON \  
-DACTS_BUILD_EXAMPLES_PYTHON_BINDINGS=ON \  
-DACTS_BUILD_EXAMPLES_DD4HEP=ON \  
-DACTS_BUILD_ODD=ON
```

Python examples

- Are on top of the Python bindings, Example framework, Core
- Small Python library with helper functions ([Examples/Python/python/acts/examples/](#))
 - Since recently ACTS will install some Python modules ([CMakeLists.txt](#))
- simulation.py and reconstruction.py
 - Capture different steps/algorithms of the chain
 - Patter: addSomething(sequencer, ...)



```
andreas@andreas-xps-miracl: ~  
andreas@andreas-xps-miracl:~$ ls -la ~/cern/install/acts/python/acts/examples/  
total 132  
drwxr-xr-x 4 andreas andreas 4096 Sep 21 14:19 .  
drwxr-xr-x 4 andreas andreas 4096 Sep 21 14:19 ..  
-rw-r--r-- 1 andreas andreas 803 Mar 2 12:26 dd4hep.py  
-rw-r--r-- 1 andreas andreas 320 Aug 5 11:29 edm4hep.py  
drwxr-xr-x 2 andreas andreas 4096 Sep 21 14:19 geant4  
-rw-r--r-- 1 andreas andreas 316 Aug 5 11:29 hepvc3.py  
-rw-r--r-- 1 andreas andreas 11647 Sep 20 10:05 __init__.py  
-rw-r--r-- 1 andreas andreas 18826 Sep 20 10:05 itk.py  
-rw-r--r-- 1 andreas andreas 2117 Sep 20 10:05 odd.py  
drwxrwxr-x 2 andreas andreas 4096 Sep 21 14:19 __pycache__  
-rw-r--r-- 1 andreas andreas 43496 Sep 20 10:05 reconstruction.py  
-rw-r--r-- 1 andreas andreas 23087 Sep 20 10:05 simulation.py  
andreas@andreas-xps-miracl:~$
```

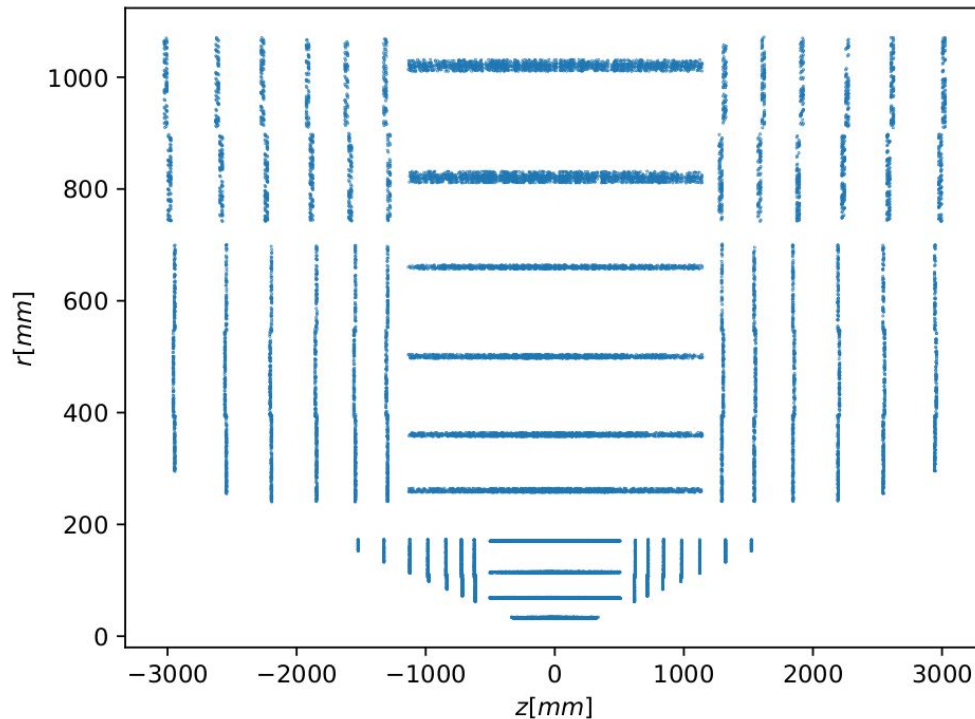
Python helpers

```
49 def addParticleGun(  
50     s: acts.examples.Sequencer,  
51     outputDirCsv: Optional[Union[Path, str]] = None,  
52     outputDirRoot: Optional[Union[Path, str]] = None,  
53     momentumConfig: MomentumConfig = MomentumConfig(),  
54     etaConfig: EtaConfig = EtaConfig(),  
55     phiConfig: PhiConfig = PhiConfig(),  
56     particleConfig: ParticleConfig = ParticleConfig(),  
57     multiplicity: int = 1,  
58     vtxGen: Optional[EventGenerator.VertexGenerator] = None,  
59     printParticles: bool = False,  
60     rnd: Optional[RandomNumbers] = None,  
61     logLevel: Optional[acts.logging.Level] = None,  
62 ) -> None:  
63     customLogLevel = acts.examples.defaultLogging(s, logLevel)  
64  
65     # Preliminaries  
66     rnd = rnd or RandomNumbers(seed=228)  
67  
68     # Input  
69     evGen = EventGenerator(...)  
70  
71     s.addReader(evGen)  
72  
73     if printParticles:  
74         s.addAlgorithm(  
75             ParticlesPrinter(  
76                 level=customLogLevel(),  
77                 inputParticles=evGen.config.outputParticles,  
78             )  
79         )
```

```
81  
82     if outputDirCsv is not None:  
83         outputDirCsv = Path(outputDirCsv)  
84         if not outputDirCsv.exists():  
85             outputDirCsv.mkdir()  
86  
87         s.addWriter(  
88             CsvParticleWriter(  
89                 level=customLogLevel(),  
90                 inputParticles=evGen.config.outputParticles,  
91                 outputDir=str(outputDirCsv),  
92                 outputStem="particles",  
93             )  
94         )  
95  
96     if outputDirRoot is not None:  
97         outputDirRoot = Path(outputDirRoot)  
98         if not outputDirRoot.exists():  
99             outputDirRoot.mkdir()  
100  
101         s.addWriter(  
102             RootParticleWriter(  
103                 level=customLogLevel(),  
104                 inputParticles=evGen.config.outputParticles,  
105                 filePath=str(outputDirRoot / "particles.root"),  
106             )  
107         )  
108     return s
```

OpenDataDetector

- Constructed via DD4hep
- Can be found on [Gitlab](#)
- Design
 - Full silicon
 - 4 pixel layers + 7 endcaps
 - 4 short strip layers + 6 endcaps
 - 2 long strip layers + 6 endcaps



Full chain

```
32 detector, trackingGeometry, decorators = getOpenDataDetector(  
33     geoDir, mdecorator=oddMaterialDeco  
34 )  
35 field = acts.ConstantBField(acts.Vector3(0.0, 0.0, 2.0 * u.T))  
36 rnd = acts.examples.RandomNumbers(seed=42)  
37  
38 s = acts.examples.Sequencer(events=100, numThreads=-1, outputDir=str(outputDir))  
39  
40 addParticleGun(  
41     s,  
42     MomentumConfig(1.0 * u.GeV, 10.0 * u.GeV, transverse=True),  
43     EtaConfig(-3.0, 3.0, uniform=True),  
44     ParticleConfig(2, acts.PdgParticle.eMuon, randomizeCharge=True),  
45     rnd=rnd,  
46 )  
47  
48 addFatras(  
49     s,  
50     trackingGeometry,  
51     field,  
52     rnd=rnd,  
53     outputDirRoot=outputDir,  
54 )  
55  
56 addDigitization(  
57     s,  
58     trackingGeometry,  
59     field,  
60     digiConfigFile=oddDigiConfig,  
61     rnd=rnd,  
62     outputDirRoot=outputDir,  
63 )
```

```
65 addSeeding(  
66     s,  
67     trackingGeometry,  
68     field,  
69     geoSelectionConfigFile=oddSeedingSel,  
70     outputDirRoot=outputDir,  
71 )  
72  
73 addCKFTracks(  
74     s,  
75     trackingGeometry,  
76     field,  
77     CKFPerformanceConfig(ptMin=1.0 * u.GeV, nMeasurementsMin=6),  
78     outputDirRoot=outputDir,  
79 )  
80  
81 addVertexFitting(  
82     s,  
83     field,  
84     TrackSelectorRanges(pt=(1.0 * u.GeV, None), absEta=(None, 3.0), removeNeutral=True),  
85     vertexFinder=VertexFinder.Iterative,  
86     trajectories="trajectories",  
87     outputDirRoot=outputDir,  
88 )  
89  
90 s.run()  
91
```


Initialisation

- Units alias
- Geometry paths
- Output directory
- Geometry config
- Algorithm config
- Geometry construction
- Magnetic field
- Random numbers

```
22 u = acts.UnitConstants
23 geoDir = getOpenDataDetectorDirectory()
24 outputDir = pathlib.Path.cwd() / "odd_output"
25
26 oddMaterialMap = geoDir / "data/odd-material-maps.root"
27 oddDigiConfig = geoDir / "config/odd-digi-smearing-config.json"
28 oddSeedingSel = geoDir / "config/odd-seeding-config.json"
29 oddMaterialDeco = acts.IMaterialDecorator.fromFile(oddMaterialMap)
30
31 detector, trackingGeometry, decorators = getOpenDataDetector(
32     | geoDir, mdecorator=oddMaterialDeco
33     )
34 field = acts.ConstantBField(acts.Vector3(0.0, 0.0, 2.0 * u.T))
35 rnd = acts.examples.RandomNumbers(seed=42)
```

Sequencer

- Stears the event processing
- Events can be processed in parallel because they are independent
- Algorithms, Reader, Writer are added to the Sequencer
- Sequencer calls Reader, Algorithms, Writer in order for each event

```
37 s = acts.examples.Sequencer(events=100, numThreads=-1, outputDir=str(outputDir))
89 s.run()
```

```
20:18:56 Sequencer INFO Added reader 'EventGenerator'
20:18:56 Sequencer INFO Added algorithm 'ParticleSelector'
20:18:56 Sequencer INFO Added algorithm 'FatrasSimulation'
20:18:56 Sequencer INFO Added writer 'RootParticleWriter'
20:18:56 Sequencer INFO Added writer 'RootParticleWriter'
20:18:56 Sequencer INFO Added writer 'RootSimHitWriter'
20:18:56 Sequencer INFO Added algorithm 'DigitizationAlgorithm'
20:18:56 Sequencer INFO Added writer 'RootMeasurementWriter'
20:18:56 Sequencer INFO Added algorithm 'TruthSeedSelector'
```

Event generation

- Particle gun (alternative: Pythia8)

```
39  addParticleGun(  
40      s,  
41      MomentumConfig(1.0 * u.GeV, 10.0 * u.GeV, transverse=True),  
42      EtaConfig(-3.0, 3.0, uniform=True),  
43      ParticleConfig(2, acts.PdgParticle.eMuon, randomizeCharge=True),  
44      rnd=rnd,  
45  )
```

```
1  particle_id,particle_type,process,vx,vy,vz,vt,px,py,pz,m,q  
2  4503599644147712,13,0,0,0,0,0,-4.42938805,5.41367865,1.74514735,0.105658367,-1  
3  4503599660924928,-13,0,0,0,0,0,2.69452524,1.82695782,-13.3078556,0.105658367,1
```

Fatras and digitization

- Fast track simulation (alternative: Geant4)
- Hit smearing (alternative: geometric pixel activation)

```
50  addFatras(  
51      s,  
52      trackingGeometry,  
53      field,  
54      rnd=rnd,  
55      outputDirRoot=outputDir,  
56  )
```

```
58  addDigitization(  
59      s,  
60      trackingGeometry,  
61      field,  
62      digiConfigFile=oddDigiConfig,  
63      rnd=rnd,  
64      outputDirRoot=outputDir,  
65  )
```

Seeding

- For more details about the seeding: [Monday session](#)
- (alternative: truth tracking)

```
67 addSeeding(  
68     s,  
69     trackingGeometry,  
70     field,  
71     geoSelectionConfigFile=oddSeedingSel,  
72     outputDirRoot=outputDir,  
73 )
```

2:00 PM


Seeding & Pattern

Speakers: Luis Falda Coelho (CERN), Mr Stephen Nicholas Swatman (University of Amsterdam (NL))

 ACTS workshop - se...  orthogonal_seeding...


Seed Finder

Speaker: Luis Falda Coelho (CERN)

 ACTS workshop - se...

Orthogonal Seed Finder

Speaker: Mr Stephen Nicholas Swatman (University of Amsterdam (NL))

 orthogonal_seeding...

🕒 30m

🕒 10m

🕒 10m

Track finding

- For more details about the track finding/fitting: [Monday session](#)

```
75 addCKFTracks(  
76     s,  
77     trackingGeometry,  
78     field,  
79     CKFPerformanceConfig(ptMin=1.0 * u.GeV, nMeasurementsMin=6),  
80     outputDirRoot=outputDir,  
81 )
```

2:30 PM

Fitting 🕒 30m

Speakers: Alexander J Pfleger (University of Graz (AT)), Benjamin Huth, Xiaocong Ai (DESY)

📎 ACTS_KF.pdf 📎 ACTS_Workshop_20... 📎 ACTS_workshop_gs...

(Combinatorial) Kalman Filter 🕒 10m

Speaker: Xiaocong Ai (DESY)

📎 ACTS_KF.pdf

Global Chi2 Fitter 🕒 5m

Speaker: Alexander J Pfleger (University of Graz (AT))

📎 ACTS_Workshop_20...

GSF 🕒 5m

Speaker: Benjamin Huth

📎 gsf_status_update...

Vertexing


- For more details about the vertexing: [Monday session](#)
- (alternative: AMVF)

```
83 addVertexFitting(  
84     s,  
85     field,  
86     TrackSelectorRanges(pt=(1.0 * u.GeV, None), absEta=(None, 3.0), removeNeutral=True),  
87     vertexFinder=VertexFinder.Iterative,  
88     trajectories="trajectories",  
89     outputDirRoot=outputDir,  
90 )
```

3:00 PM

Vertexing

Speaker: Rocky Bala Garg (Stanford University (US))

 ActsWorkshop2022...

🕒 20m

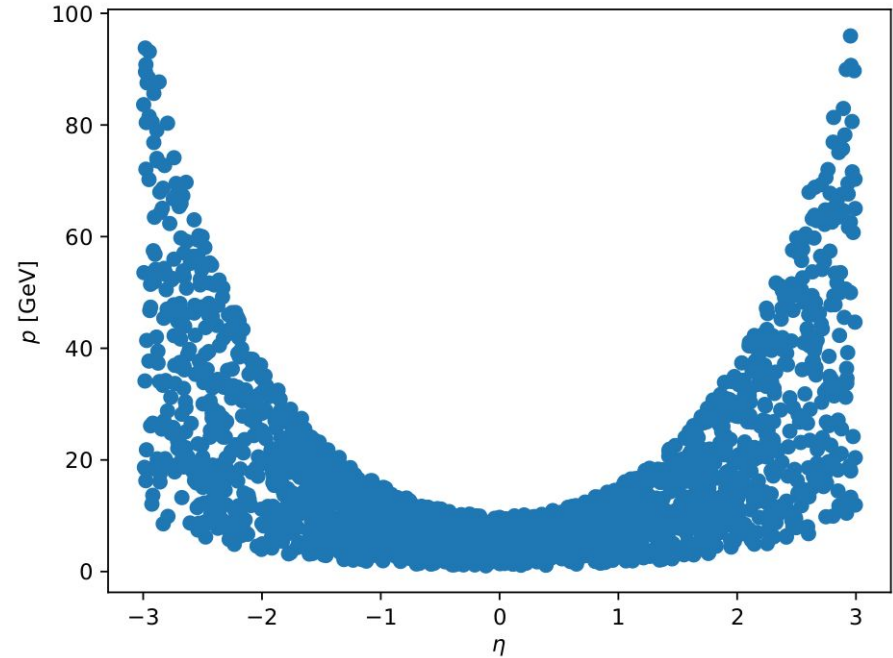
Resources

- <https://github.com/andiwand/acts-workshop-2022>
- <https://acts.readthedocs.io/>
- <https://github.com/acts-project/acts>
- <https://indico.cern.ch/event/1184037>
- https://codimd.web.cern.ch/A108z_6tRiWJala5yAabdg

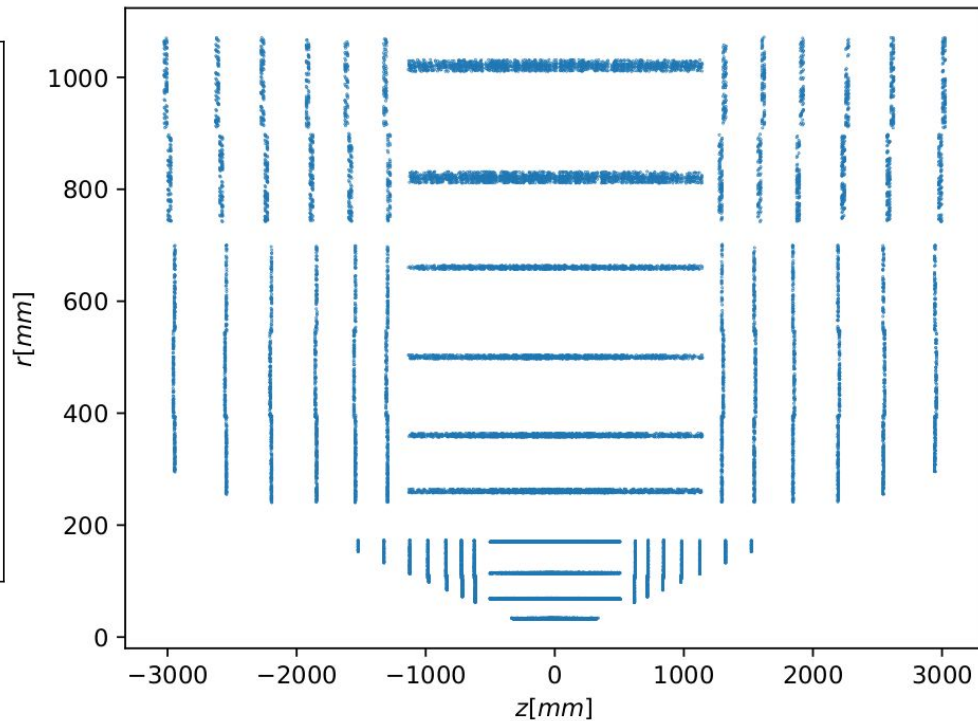
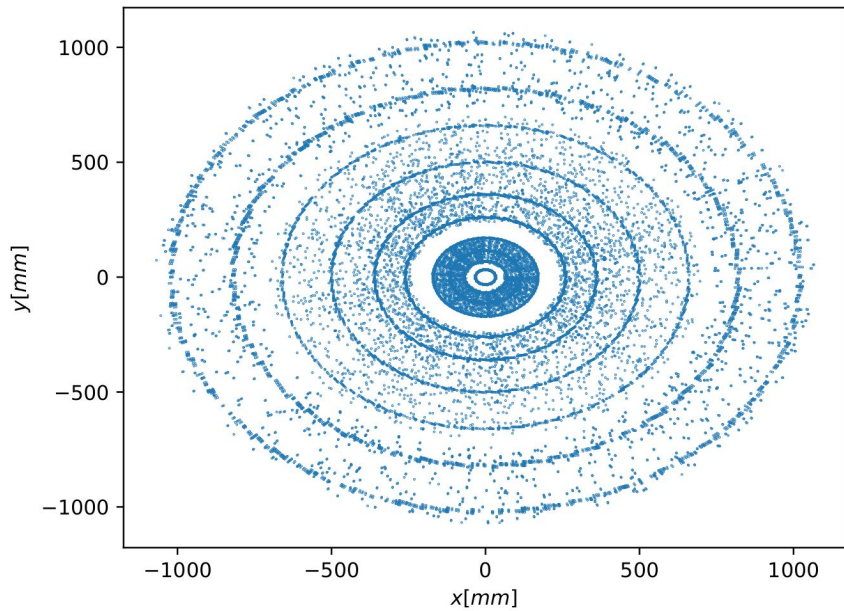
Backup

Particle gun

```
39 addParticleGun(  
40     s,  
41     MomentumConfig(1.0 * u.GeV, 10.0 * u.GeV, transverse=True),  
42     EtaConfig(-3.0, 3.0, uniform=True),  
43     ParticleConfig(2, acts.PdgParticle.eMuon, randomizeCharge=True),  
44     rnd=rnd,  
45 )
```



Fatras



Vertexing

```
83 addVertexFitting(  
84     s,  
85     field,  
86     TrackSelectorRanges(pt=(1.0 * u.GeV, None), absEta=(None, 3.0), removeNeutral=True),  
87     vertexFinder=VertexFinder.Iterative,  
88     trajectories="trajectories",  
89     outputDirRoot=outputDir,  
90 )
```

