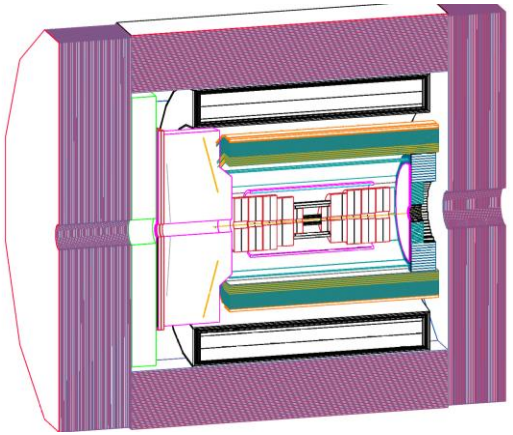
STATUS OF TRACK FINDING AND FITTING USING ACTS IN JUGGLER ANALYSIS FRAMEWORK



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For Athena Software Working Group

07/27/2021

Athena Software

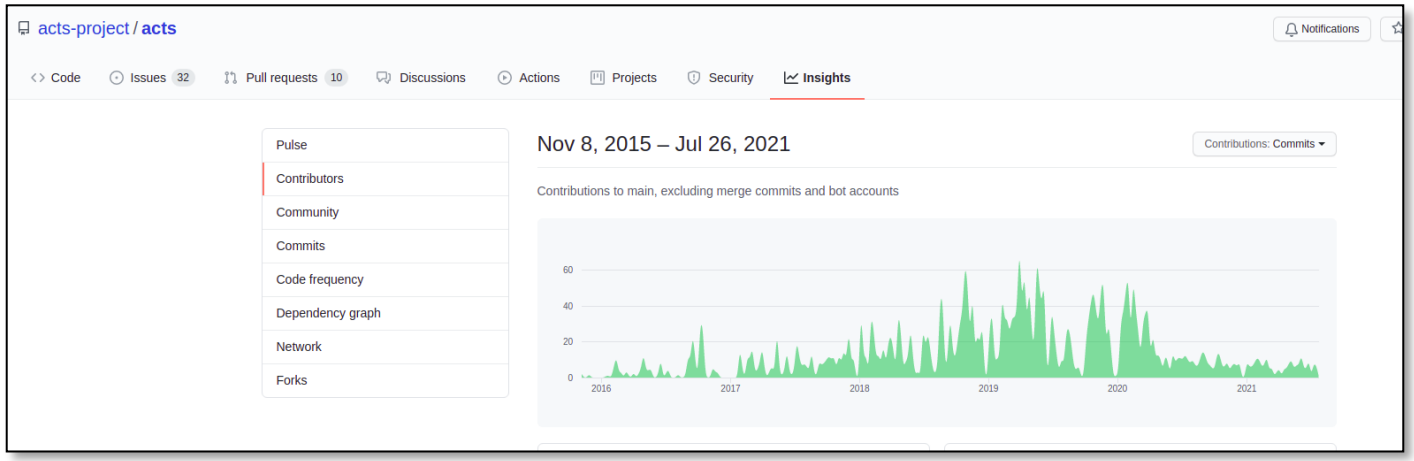
- Simulation with DD4hep https://eicweb.phy.anl.gov/EIC/detectors/athena
  - Subdetector plugins for Athena detector

- Data model: EICD https://eic.phy.anl.gov/eicd
  - Built upon PODIO
  - Flat data structure, connect tracks, hits, clusters with indices

- Analysis framework: Juggler https://eicweb.phy.anl.gov/EIC/juggler
  - Built upon GAUDI framework
  - Algorithms and tools for digitization, clustering, tracking, …

Acts for Tracking

- Acts is a particle track reconstruction toolkit that is widely used in high energy physics
  - Common algorithms for track propagation and fitting, seed finding, and vertexing
  - Independent of tracking detectors
  - Actively developing and well maintained
  - Native support for geometry description using DD4hep



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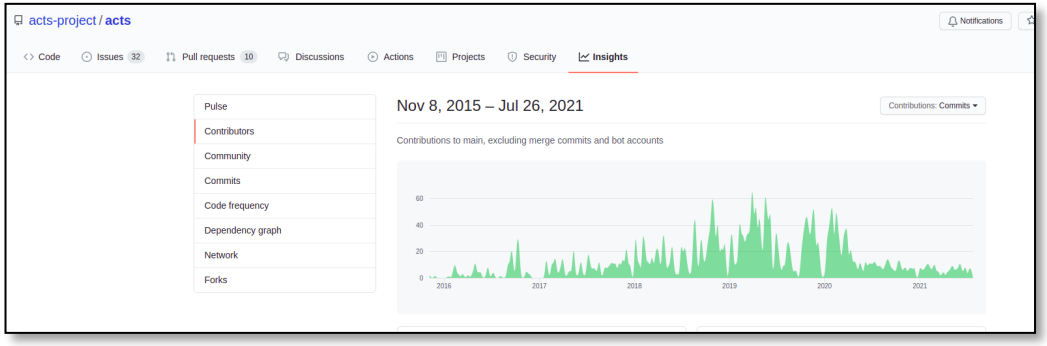
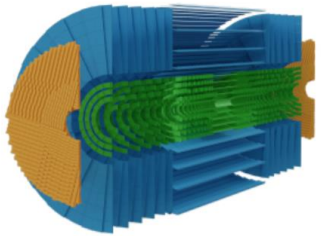
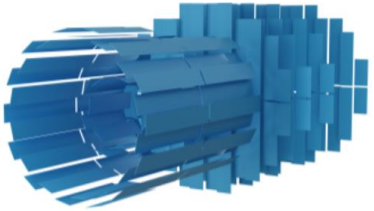


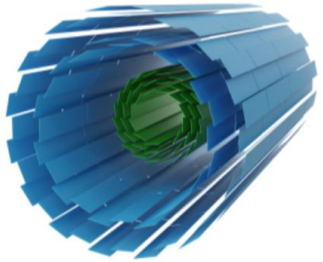
ATLAS ITk



PANDA silicon detector



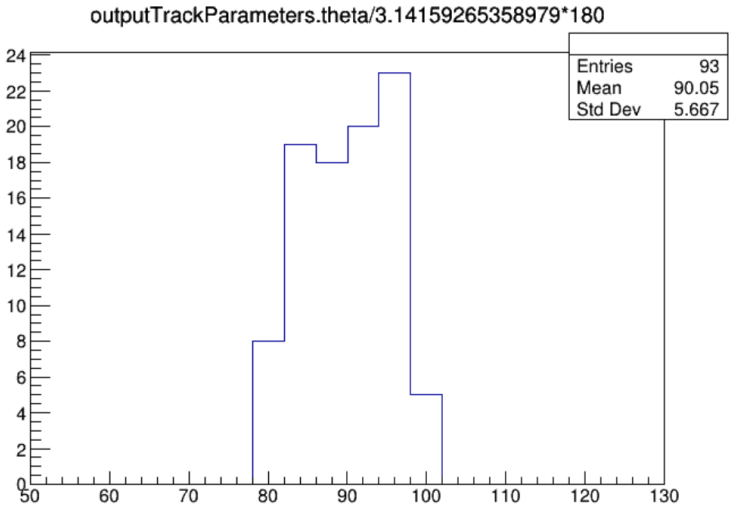
sPHENIX silicon trackers



Acts Tracking with DD4hep and Juggler

- Acts is now working in Athena software
  - Simulation output from DD4hep
  - Digitization, track finding and fitting with Acts::CKF in Juggler framework
  - Implemented example algorithms from Acts in Juggler (W. Armstrong)

    https://eicweb.phy.anl.gov/EIC/juggler/-/tree/master/JugTrack
  - Tested truth seeding and track finding/fitting with Combinatorial Kalman Filter
  - CKF with barrel trackers give reasonable results



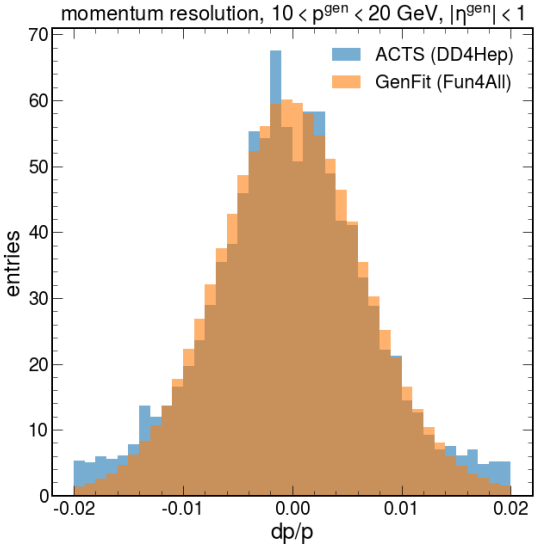
Tracking with DD4hep and Juggler

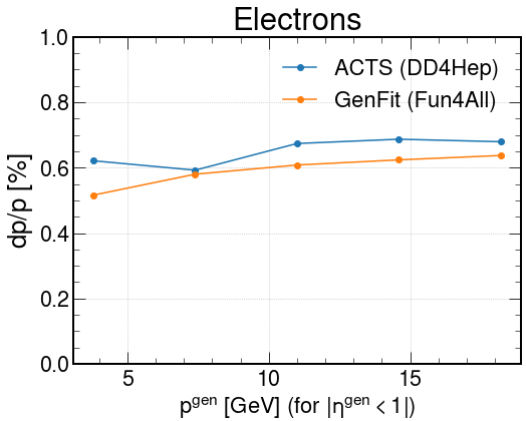
- Known issues in the software
  - Geometry issue with endcaps and outer barrel, Acts cannot determine the container volume for Barrel + Endcaps
  - Might be due to missing information to Acts or just typos

- Ongoing works
  - Debugging the geometry issue
  - Testing more algorithms from Acts Example (vertexing, seeding from clusters, …)
  - Finalizing data model for tracking outputs

Some Tests

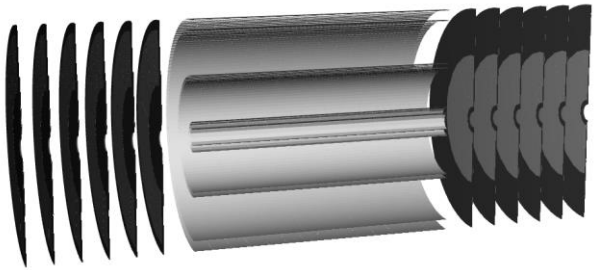
- Tracking tests from **Miguel Arratia, Wouter Deconinck, and Reynier Cruz Torres**
  - DD4hep detector (modified OpenDataDetector from Acts Examples)
  - Acts with Juggler





Plots courtesy of Miguel Arratia

Modified OpenDataDetector



A Working Example

- Using barrel trackers of the current Athena implementation
  https://eicweb.phy.anl.gov/EIC/benchmarks/reconstruction_benchmarks/-/tree/master/benchmarks/tracking
- run_tracking_benchmarks.py

Simulation (particle gun)

```
if 'sim' in procs:
    # generate particles
    gen_cmd = ['python', gen_script, gen_file,
            '-n', '{}'.format(args.nev),
            '-s', '{}'.format(args.seed),
            '--etamin', '{}'.format(args.etamin), '--etamax', '{}'.format(args.etamax),
            '--pmin', '{}'.format(args.pmin), '--pmax', '{}'.format(args.pmax),
            '--particles', args.particles]
    subprocess.run(gen_cmd)
    # simulation
    sim_cmd = ['npsim',
            '--part.minimalKineticEnergy', '1*TeV',
            '--numberOfEvents', '{}'.format(args.nev),
            '--runType', 'batch',
            '--inputFiles', gen_file,
            '--outputFile', sim_file,
            '--compact', args.compact,
            '-v', 'WARNING']
    if args.seed > 0:
        sim_cmd += ['--random.seed', args.seed]
    return_code = subprocess.run(sim_cmd).returncode
    if return_code is not None and return_code < 0:
        print("ERROR running simulation!")
        exit(1)
    subprocess.run(['rootls', '-t', sim_file])
```

Reconstruction (digi. + tracking) and analysis

```
if 'rec' in procs:
    # export to environment variables (used to pass arguments to the option file)
    os.environ['JUGGLER_SIM_FILE'] = sim_file
    os.environ['JUGGLER_REC_FILE'] = rec_file
    os.environ['JUGGLER_COMPACT_PATH'] = args.compact
    os.environ['JUGGLER_N_EVENTS'] = '{}'.format(args.nev)

    juggler_xenv = os.path.join(os.environ.get('JUGGLER_INSTALL_PREFIX', '../local'), 'Juggler.xenv')

    rec_cmd = ['xenv', '-x', juggler_xenv, 'gaudirun.py', os.path.join(sdir, 'options', option_script)]
    return_code = subprocess.run(rec_cmd).returncode
    if return_code is not None and return_code < 0:
        print('ERROR running juggler ({})!'.format(opt))
        exit(1)
    process = subprocess.run(['rootls', '-t', rec_file])


if 'ana' in procs:
    os.makedirs('results', exist_ok=True)
    ana_cmd = ['python', analysis_script, rec_file,
               '--mc-collection', 'mcparticles2',
               '--tracking-collection', 'outputTrackParameters',
               '-o', 'results']
    return_code = subprocess.run(ana_cmd).returncode
    if return_code is not None and return_code < 0:
        print('ERROR running analysis ({})!'.format(ana))
        exit(1)
```

A Working Example

- Reconstruction option file
  - call algorithms developed in Juggler
  - options/truth_seeded_tracking.py

- **Digitize: simulation hits -> readout signals.** noise, resolution smearing, time jitters could be added here.
- **Reconstruct: Readout signals -> hits** Only readout unit info is available here (position, signal strength, timing). “calibration” could be implemented here.

```
48  trk_b_digi = TrackerDigi("trk_b_digi",
49          inputHitCollection="TrackerBarrelHits",
50          outputHitCollection="TrackerBarrelRawHits",
51          timeResolution=8)
```

```
68  trk_b_reco = TrackerReco("trk_b_reco",
69          inputHitCollection = trk_b_digi.outputHitCollection,
70          outputHitCollection="TrackerBarrelRecHits")
```

- **Source link:** prepare data to feed Acts. Link measurements (rec_hits) to Acts surfaces (geometry information)
- **Seeding:** truth seeding from MC particles Other seeding algorithms from Acts are migrated but not thoroughly tested yet.

```
83
84  sourcelinker = TrackerSourcesLinker("trk_srcslnkr",
85          inputHitCollections=["VertexBarrelRecHits", "TrackerBarrelRecHits"],
86          outputSourceLinks="TrackerSourceLinks",
87          outputMeasurements="TrackerMeasurements",
88          OutputLevel=DEBUG)
89
90  ## Track param init
91  truth_trk_init = TrackParamTruthInit("truth_trk_init",
92          inputMCParticles="mcparticles",
93          outputInitialTrackParameters="InitTrackParams",
94          OutputLevel=DEBUG)
```

- **Tracking: Track finding and fitting with CKF** Combinatorial Kalman Filter from Acts.

```
96  # Tracking algorithms
97  trk_find_alg = TrackFindingAlgorithm("trk_find_alg",
98          inputSourceLinks = sourcelinker.outputSourceLinks,
99          inputMeasurements = sourcelinker.outputMeasurements,
100         inputInitialTrackParameters= truth_trk_init.outputInitialTrackParameters,
101         outputTrajectories="trajectories",
102         OutputLevel=DEBUG)
```

A Working Example

- **Run the example**

Install EIC container

```
mkdir $HOME/eic && cd $HOME/eic
curl https://eicweb.phy.anl.gov/containers/eic_container/-/raw/master/install.sh | bash
```

Run EIC container

```
./eic-shell
```

Get Reconstruction benchmarks

```
git clone https://eicweb.phy.anl.gov/EIC/benchmarks/reconstruction_benchmarks.git
cd reconstruction_benchmarks
```

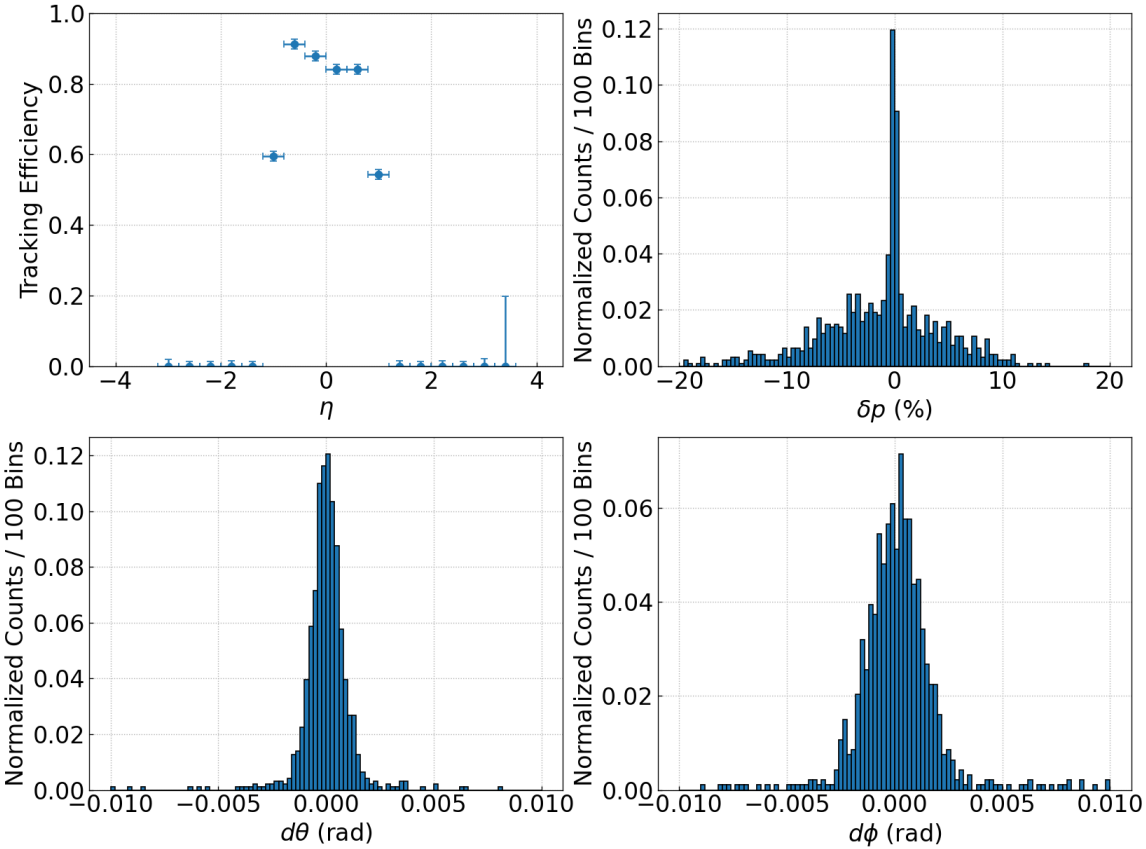
Setup environment variables needed by the run script

```
source /opt/detector/setup.sh
export DETECTOR_PATH=/opt/detector/share/athena
export JUGGLER_DETECTOR=athena
export JUGGLER_INSTALL_PREFIX=/usr/local
```

Run benchmark

```
python benchmarks/tracking/run_tracking_benchmarks.py --etamin=-3 --etamax=3 -n 100
```

Barrel Tracker Benchmark (Truth Init.)



Developing

- **Develop based on the example (after “run the example”, assumed in container)**

  Install Athena detector

```
cd $HOME/eic
git clone https://eicweb.phy.anl.gov/EIC/detectors/athena.git && cd athena
mkdir build && cd build
cmake .. -DCMAKE_INSTALL_PREFIX=$ATHENA_PREFIX
make -j install
export DETECTOR_PATH=$ATHENA_PREFIX/share/athena

cd $HOME/eic
git clone https://eicweb.phy.anl.gov/EIC/detectors/ip6.git && cd ip6
mkdir build && cd build
cmake .. -DCMAKE_INSTALL_PREFIX=$ATHENA_PREFIX
make -j install
cp –r ../ip6 $DETECTOR_PATH/
```

  Modify/adding detector

  See software tutorial
  https://eic.phy.anl.gov/tutorials/eic_tutorial/part1/simple_detector
  https://eic.phy.anl.gov/tutorials/eic_tutorial/part2/adding_detectors

Developing

- **Develop based on the example (after “run the example”)**

Install Juggler

```
cd $HOME/eic
git clone https://eicweb.phy.anl.gov/EIC/juggler.git && cd juggler && git checkout v1.8.0
mkdir build && cd build
cmake .. -DCMAKE_INSTALL_PREFIX=$ATHENA_PREFIX
make -j install
export JUGGLER_INSTALL_PREFIX=$ATHENA_PREFIX
```

Modify/adding algorithms

See software tutorial
https://eic.phy.anl.gov/tutorials/eic_tutorial/part3/running_juggler

Run benchmark with modified detector and Juggler

```
cd $HOME/eic/reconstruction_benchmarks
python benchmarks/tracking/run_tracking_benchmarks.py --etamin=-3 --etamax=3 -n 100
```