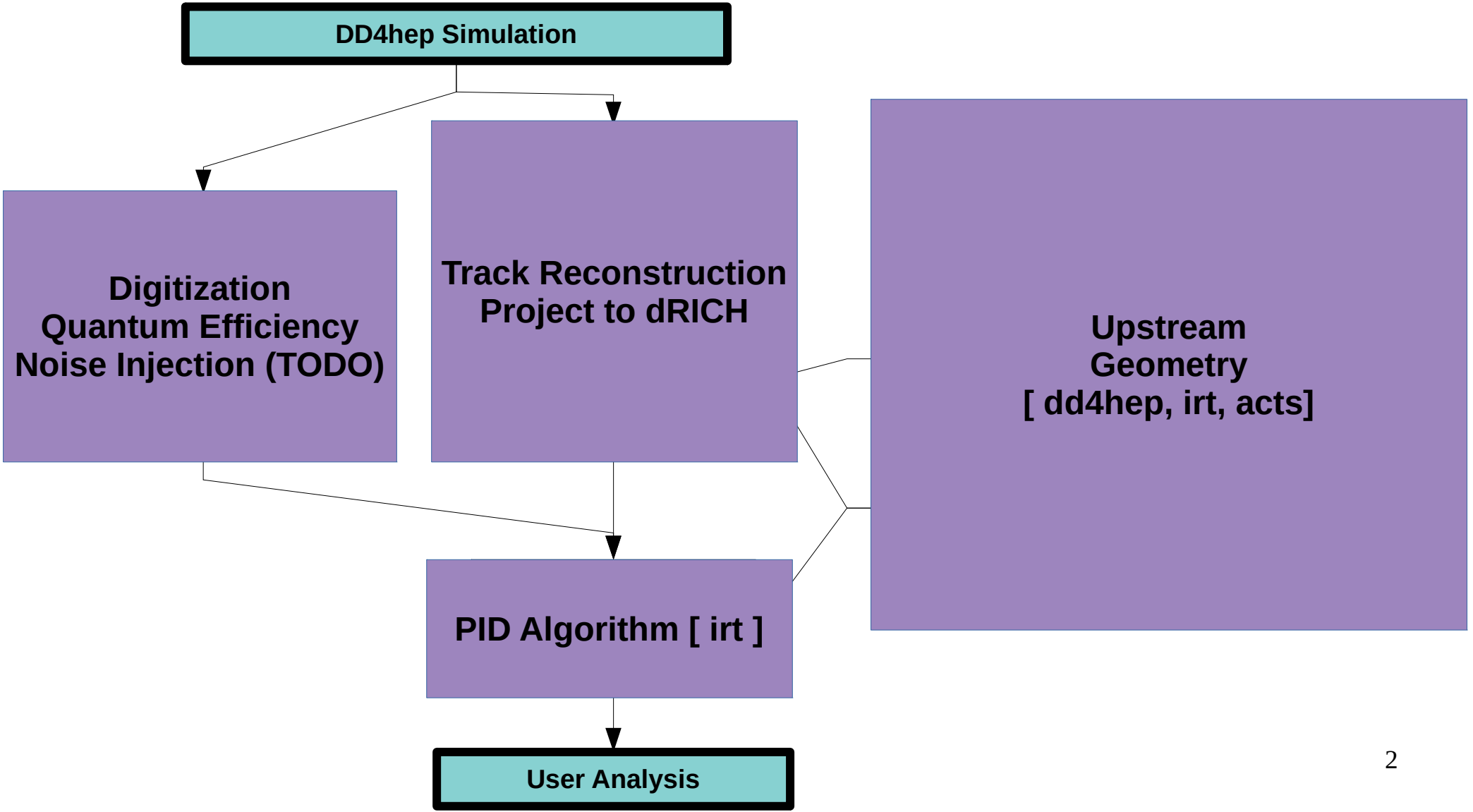
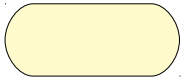
dRICH Reconstruction Update

Christopher Dilks
dRICH Meeting
30 November 2022 / 1 December 2022

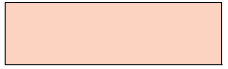

DD4hep Simulation
Digitization
Quantum Efficiency
Noise Injection (TODO)
Track Reconstruction
Project to dRICH
Upstream
Geometry
[dd4hep, irt, acts]
PID Algorithm [irt]
User Analysis

EICrecon (JANA-based) dRICH Reconstruction

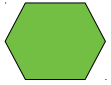
External EIC-recon Independent code (upstream, downstream, etc.)



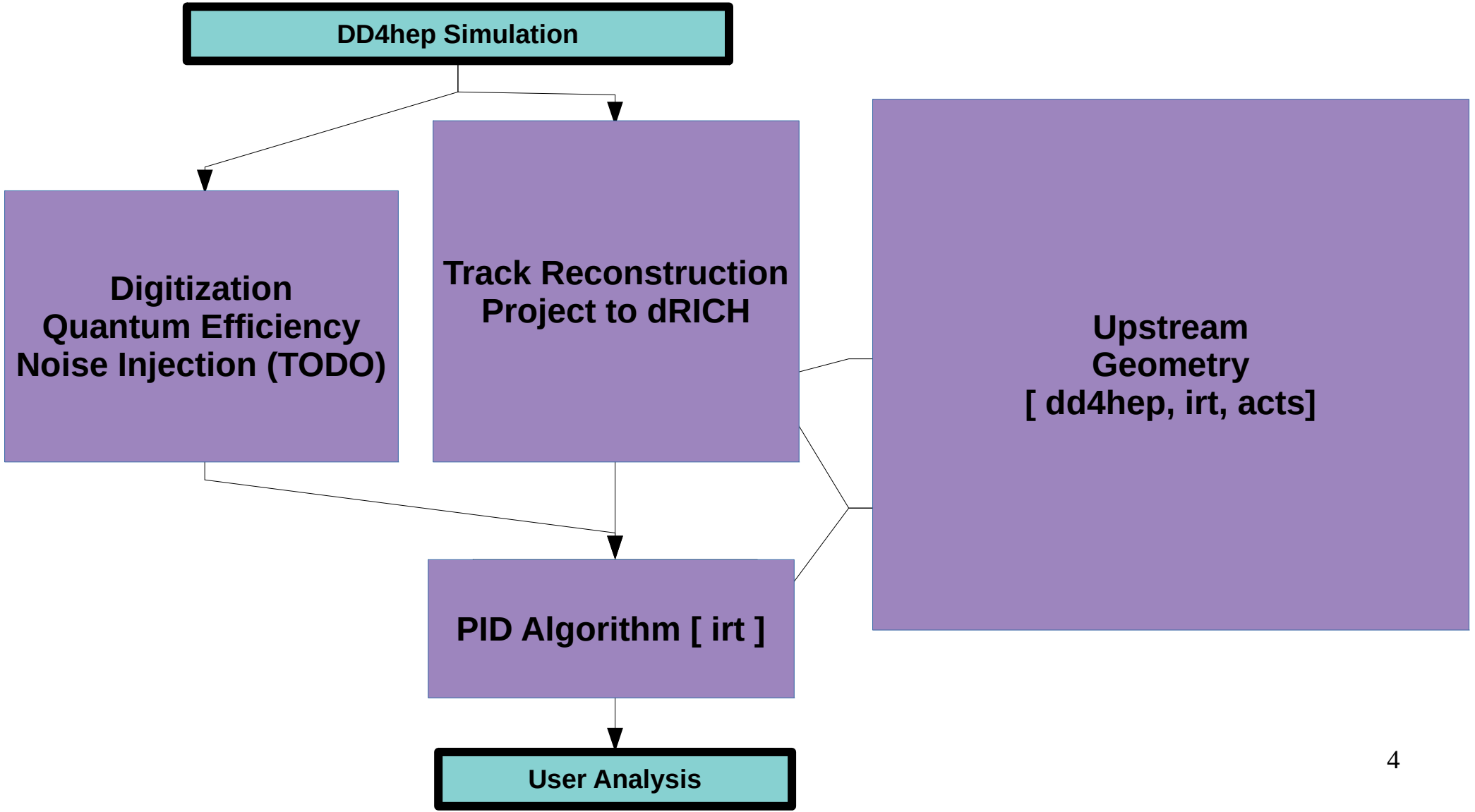
Collection of objects, such as sensor hits or reconstructed track points



Factory, that turns input collection(s) into a single output collections. Typically comes with a JANA-independent algorithm



Service: define once, used in many places; handles common needs such as geometry and I/O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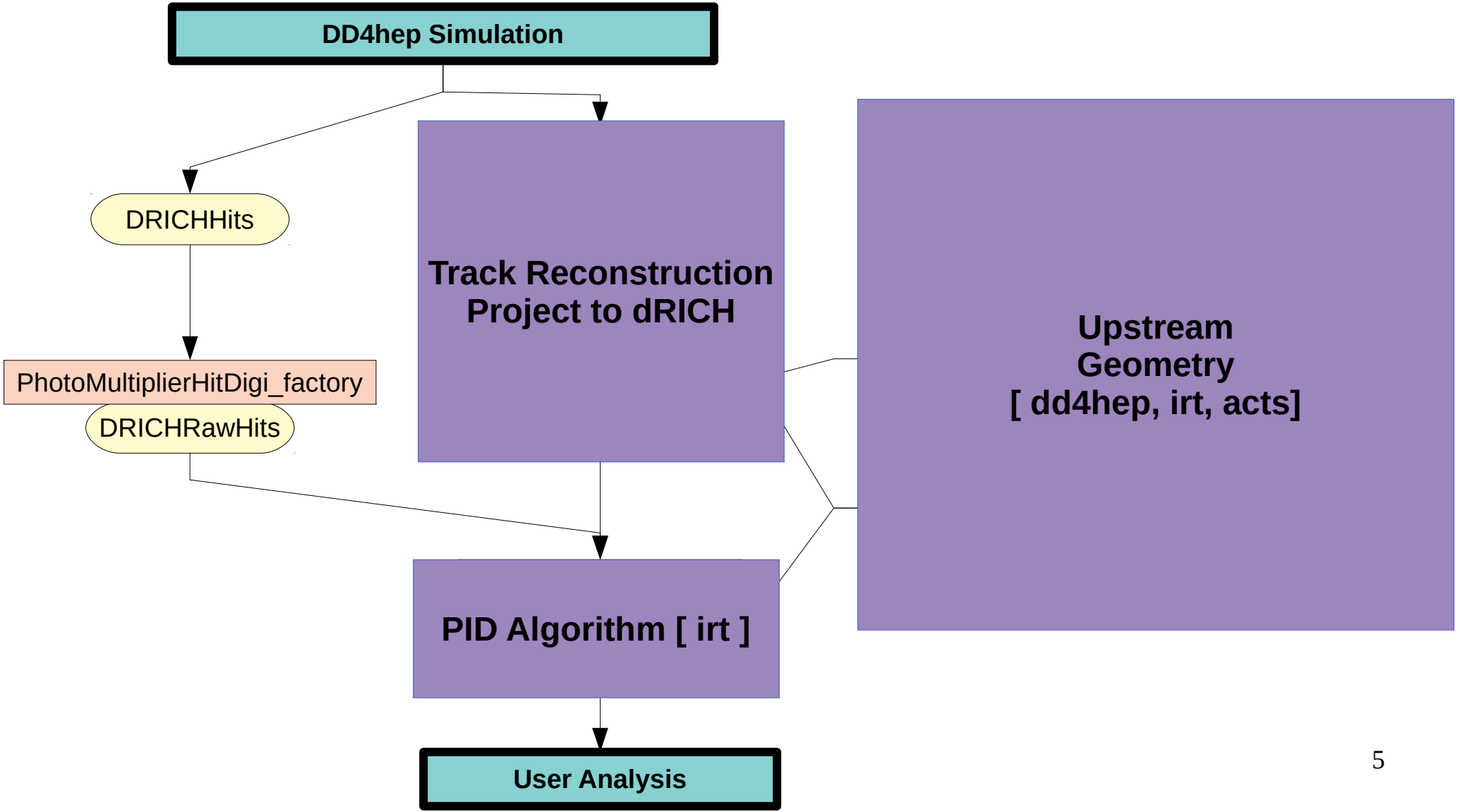
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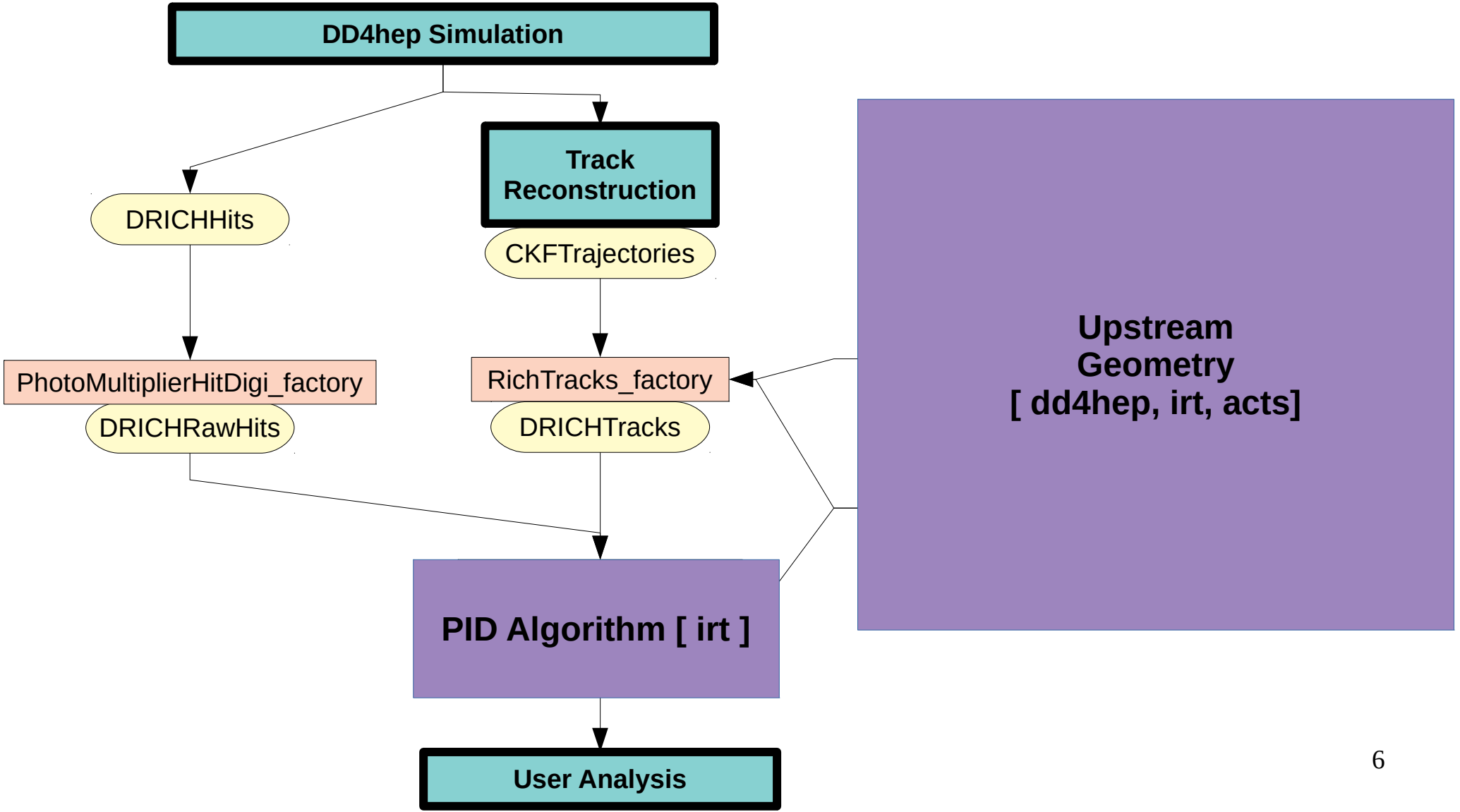
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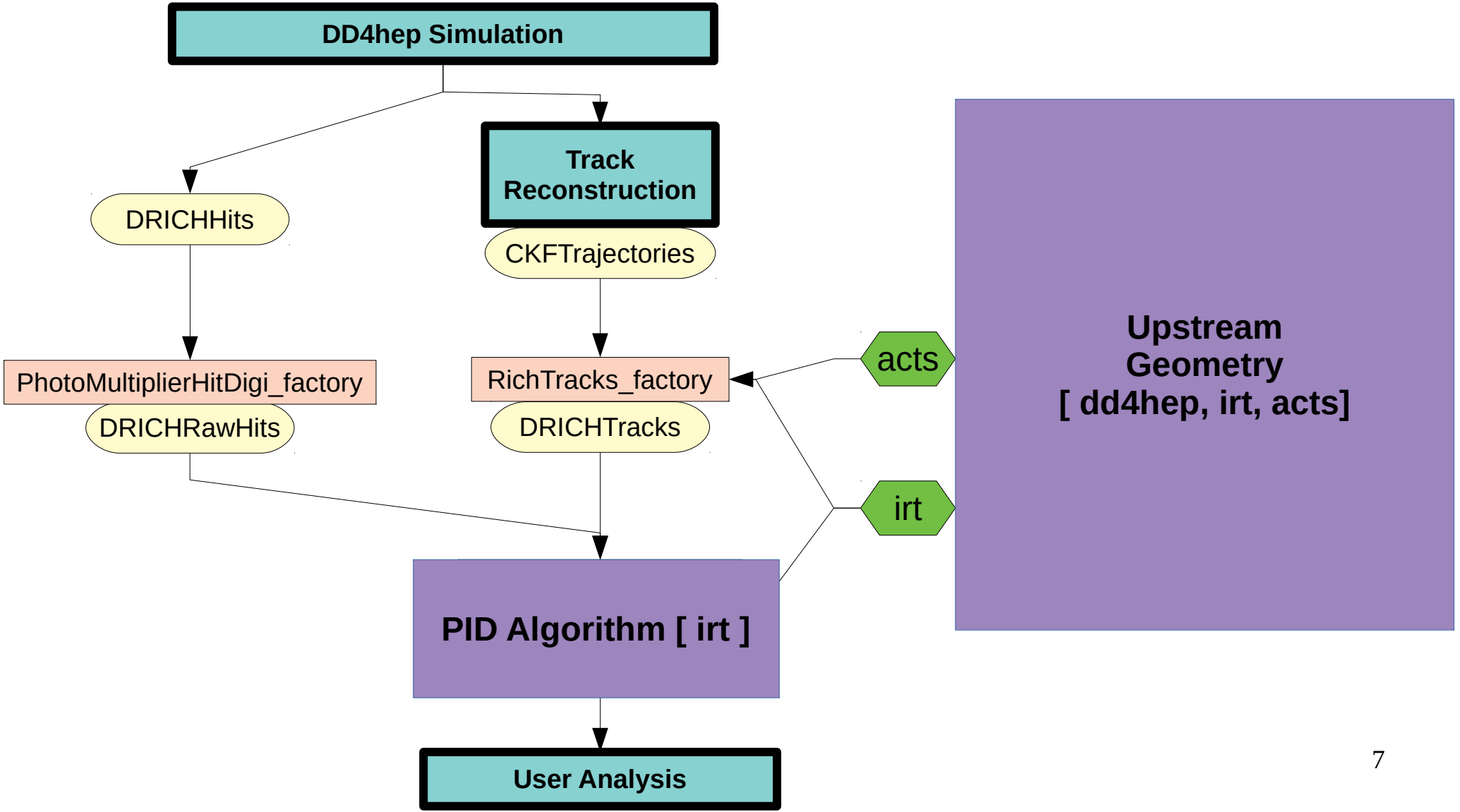
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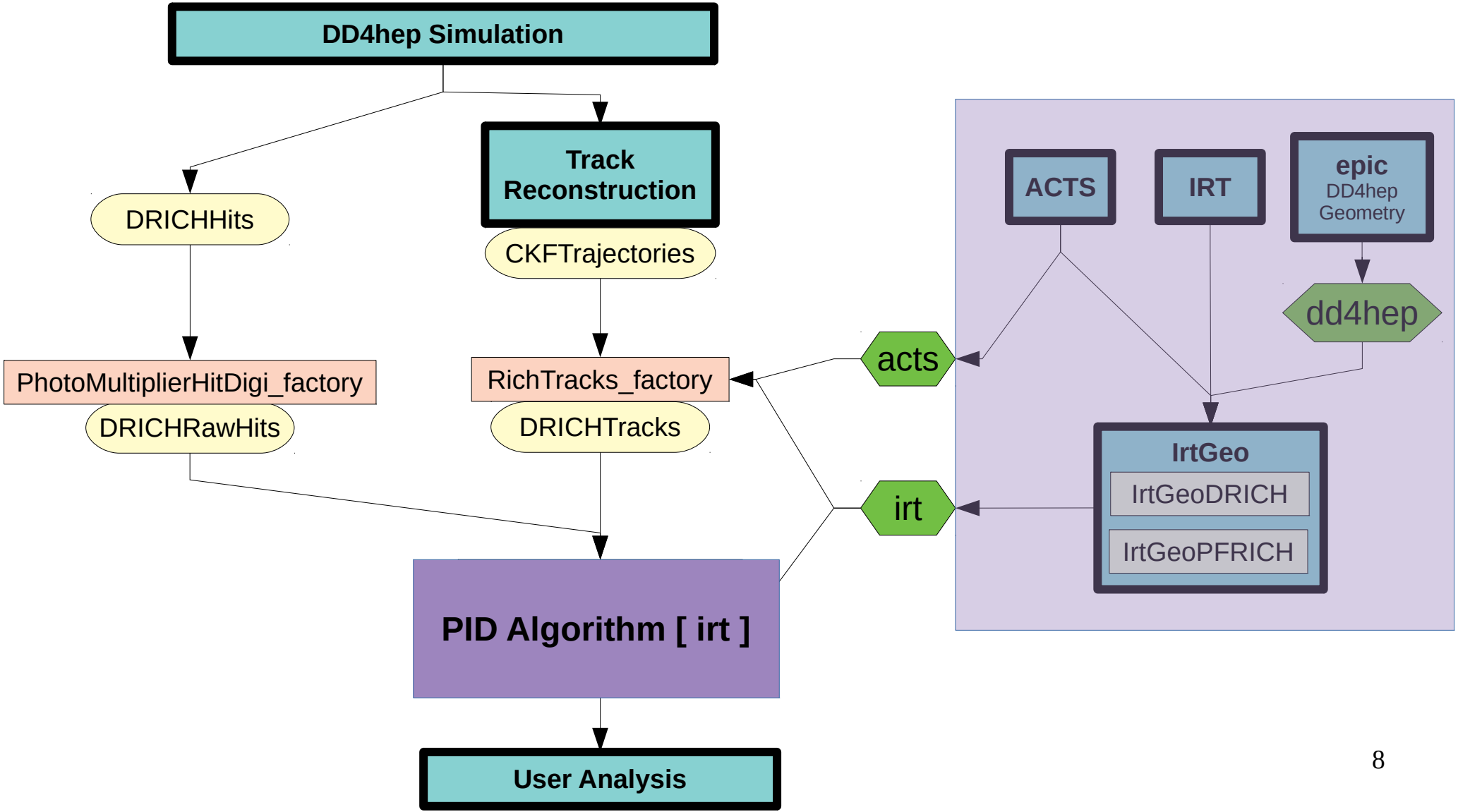
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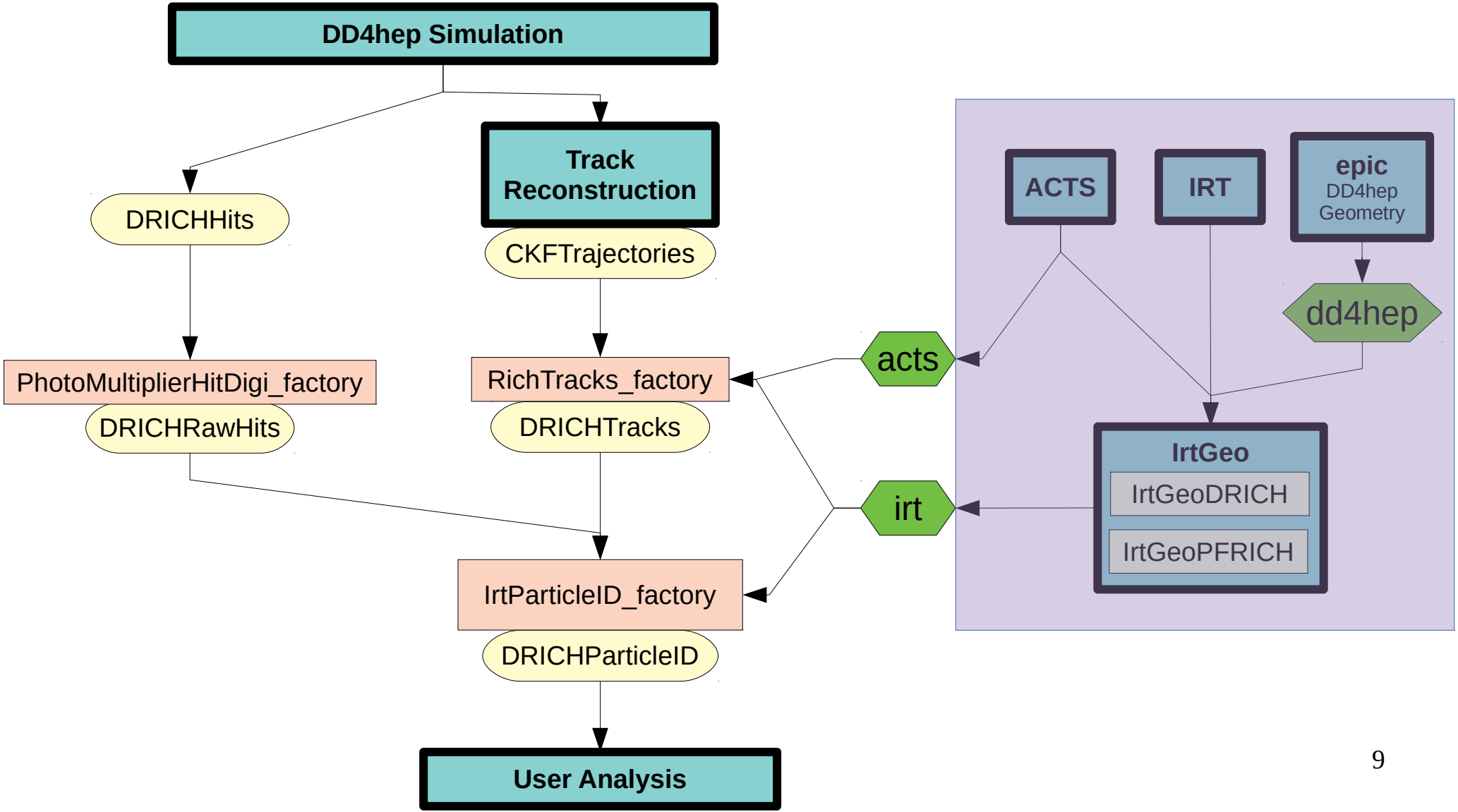
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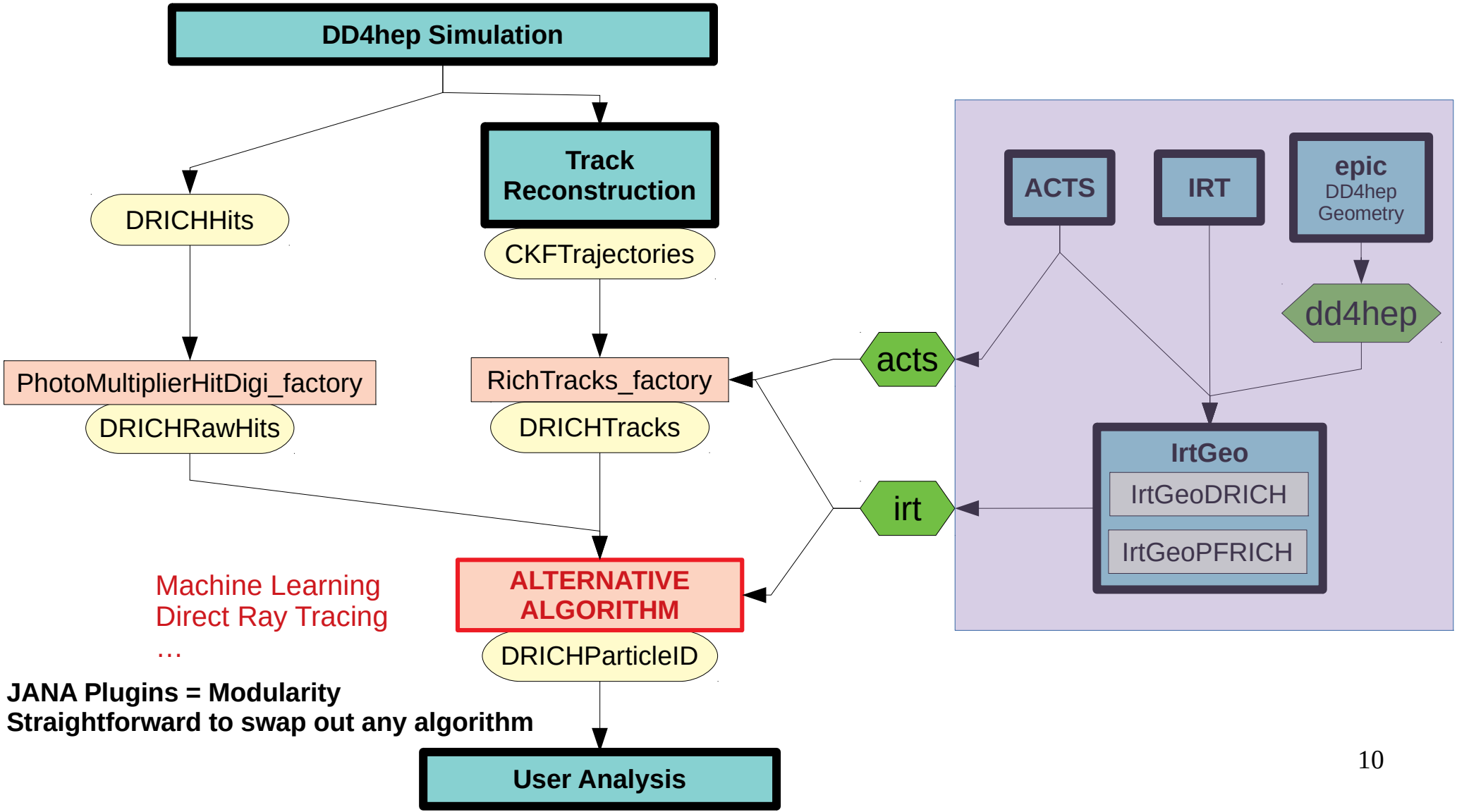
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…
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DRICHParticleID
JANA Plugins = Modularity
Straightforward to swap out any algorithm
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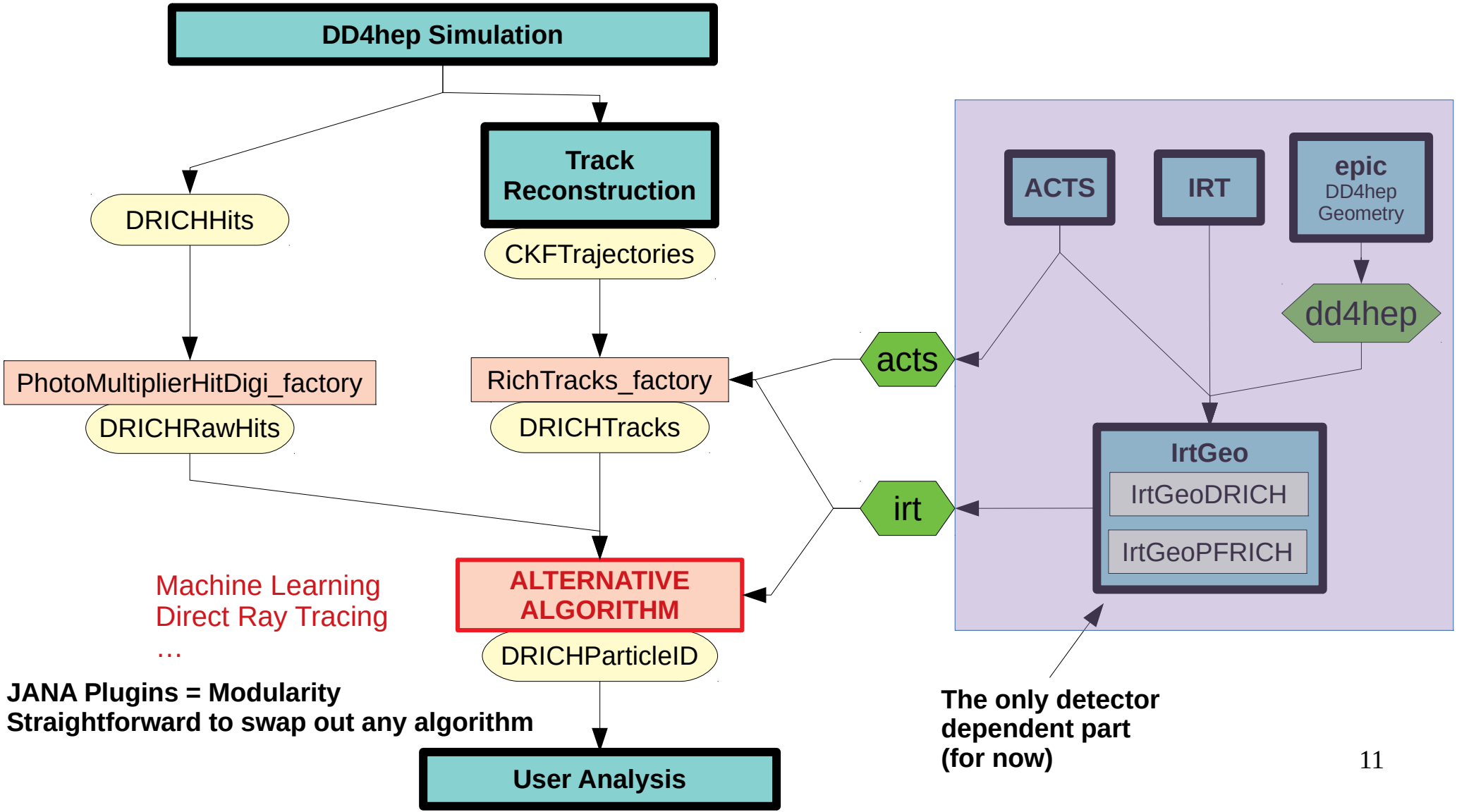
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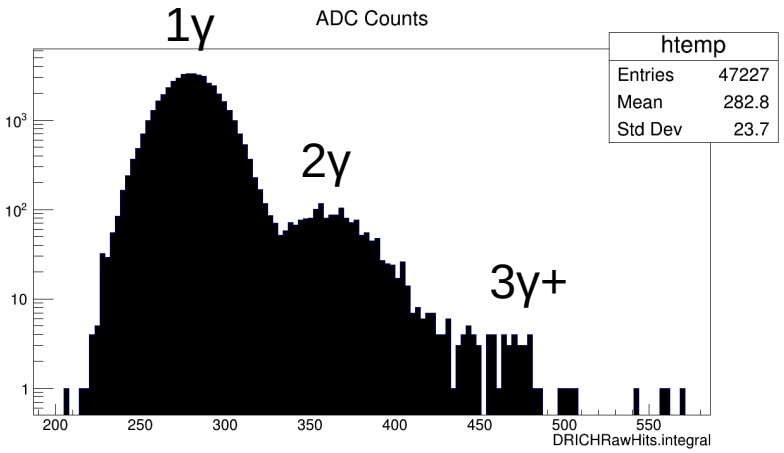
Straightforward to swap out any algorithm
The only detector dependent part (for now)

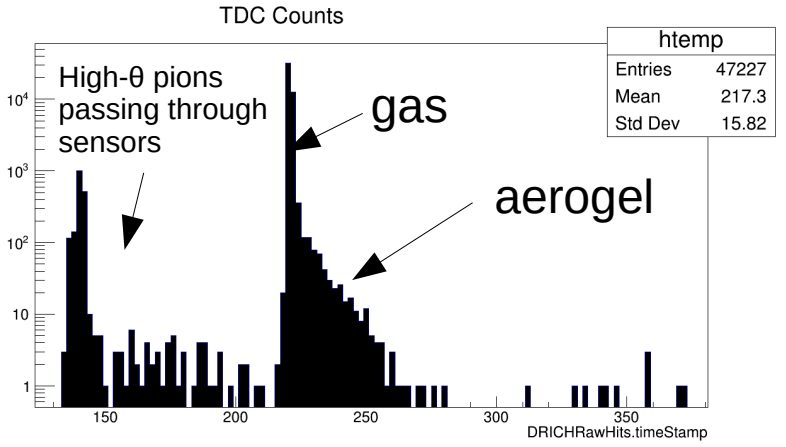
Digitization

- **TODO: validate configuration parameters**
  - Trigger parameters (gate, pedestal, etc.)
  - Quantum Efficiency
  - Safety Factor 70%
  - Pixel Gap cuts
  - TODO: Noise injection

```
std::vector<std::pair<double, double> > quantumEfficiency = {
  {325*dd4hep::nm, 0.04},
  {340*dd4hep::nm, 0.10},
  {350*dd4hep::nm, 0.20},
  {370*dd4hep::nm, 0.30},
  {400*dd4hep::nm, 0.35},
  {450*dd4hep::nm, 0.40},
  {500*dd4hep::nm, 0.38},
  {550*dd4hep::nm, 0.35},
  {600*dd4hep::nm, 0.27},
  {650*dd4hep::nm, 0.20},
  {700*dd4hep::nm, 0.15},
  {750*dd4hep::nm, 0.12},
  {800*dd4hep::nm, 0.08},
  {850*dd4hep::nm, 0.06},
  {900*dd4hep::nm, 0.04}
};
```

```
// triggering
double hitTimeWindow = 20.0*dd4hep::ns;
double timeStep      = 0.0625*dd4hep::ns;
double speMean       = 80.0;
double speError      = 16.0;
double pedMean       = 200.0;
double pedError      = 3.0;
```





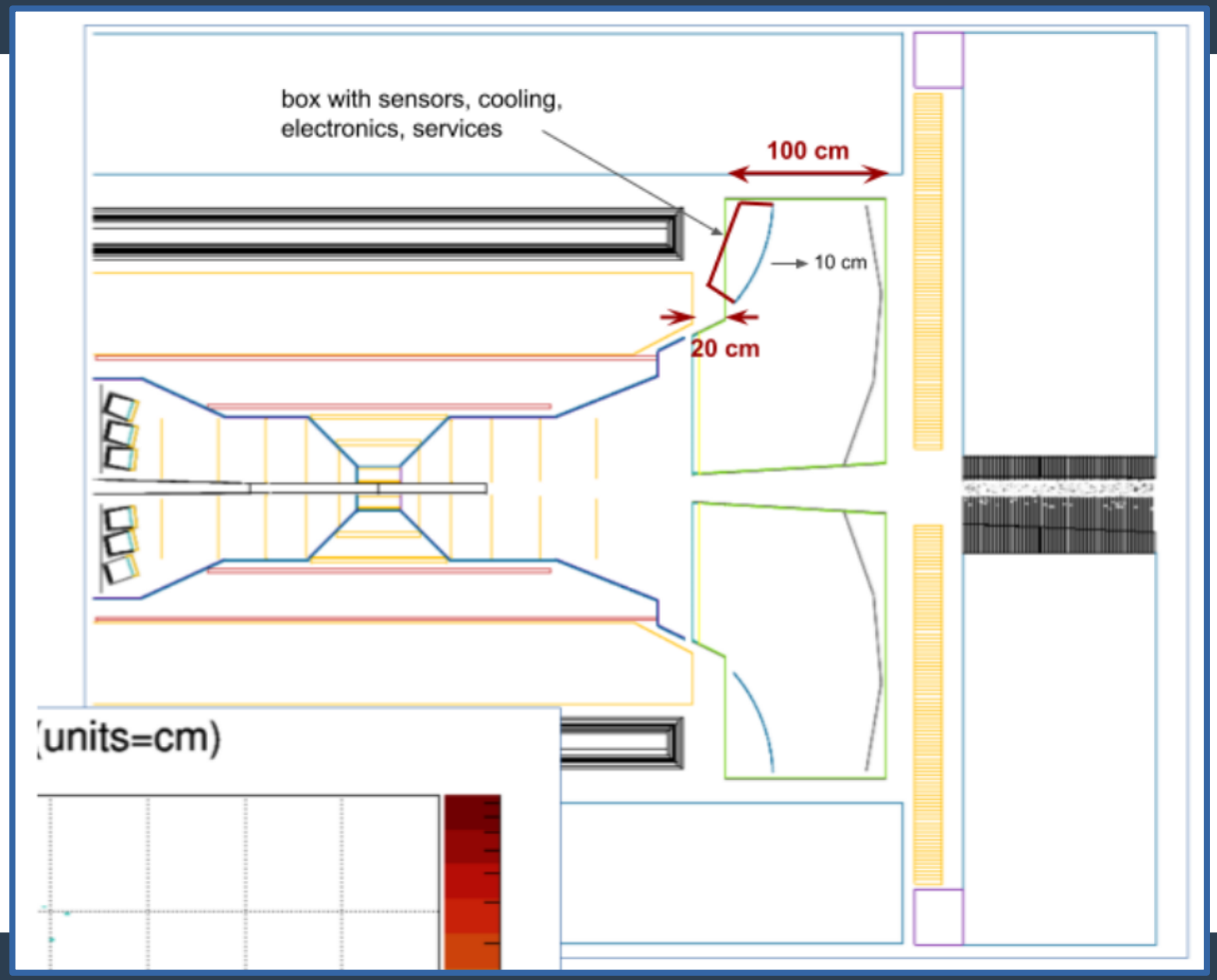
Noise Injection

- SiPM Noise injection could be added to PhotoMultiplierHitDigi
  - https://github.com/eic/EICrecon/issues/352
  - See G4SiPM for ideas and models
  - Longer term beyond dRICH scope: DDDigi

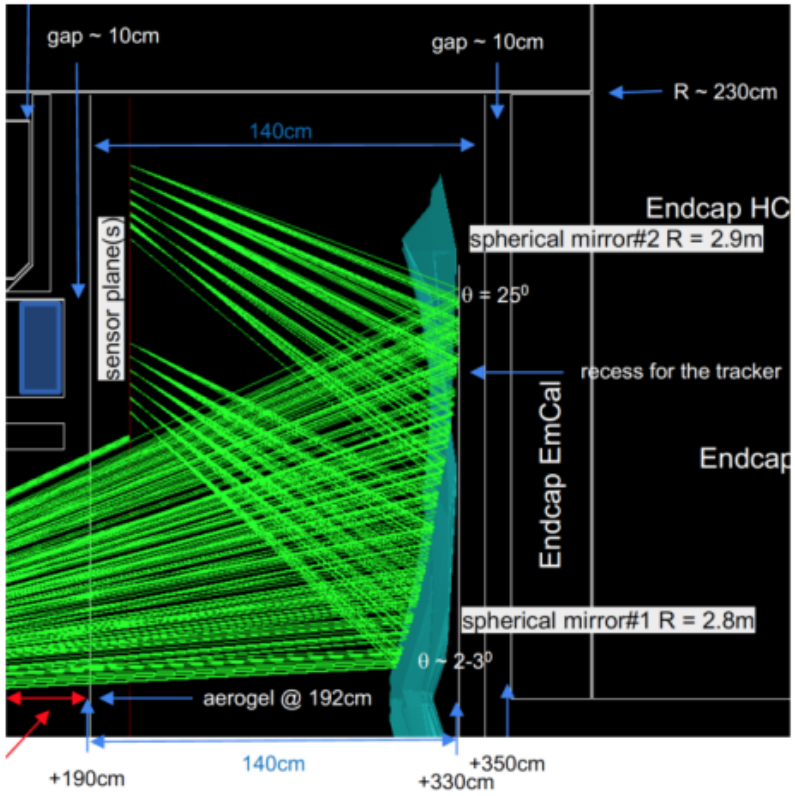
Keep in mind other sources of noise, in both the simulation and reconstruction levels…

Modeling Services

- https://github.com/eic/epic/issues/175
- Add service material for the sensors
  - Resin substrates, Bases, Support, Cooling, …
  - **What materials?**
  - **What thickness?**
- Need to shift the sensors forward, and re-focus the mirror



Multiple Mirrors → Sensor Placement Flexibility



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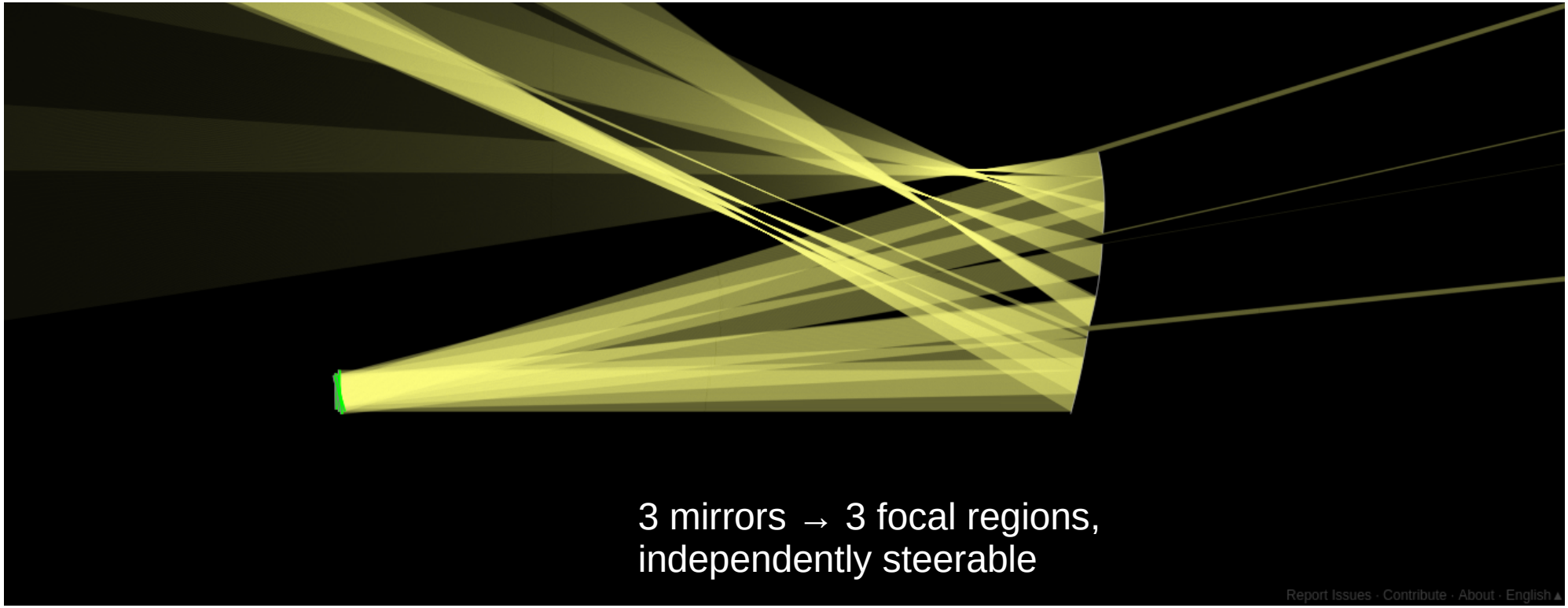

ray optics simulator: https://ricktu288.github.io/ray-optics/simulator/

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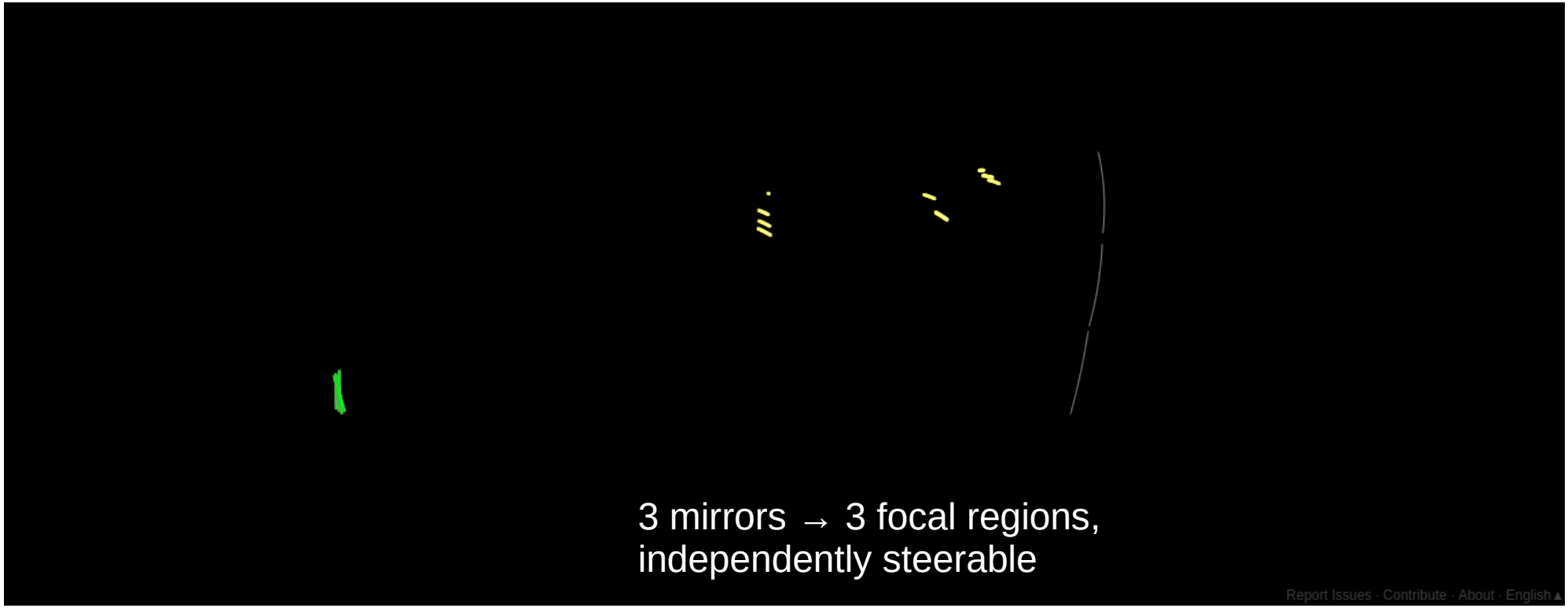

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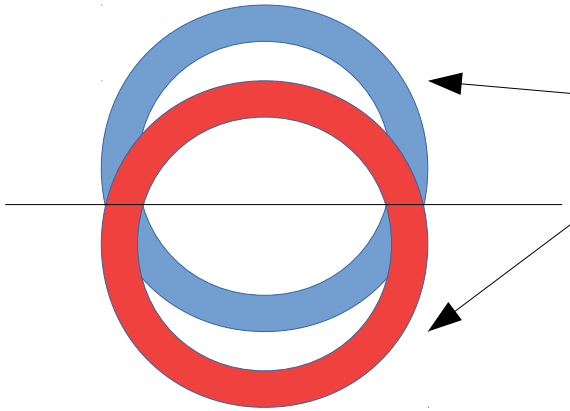


- Intersection of spheres is a plane
- Take “divergent” combination:
  - Blue mirror above the plane
  - Red mirror below

- Recover old PR from `athena`…. and make it work!
- Use Connor’s focus-finder to help with sensor positioning
- Guidance from a more sophisticated ray-tracing library?
- Future: machine learning optimization?

PID Parameterization

- Parameterization generator code:
  - Efficiency in bins of (η,p), for pairs in {π,K,p}
  - Configuration for Delphes fast simulation (screenshot)
  - Could make a format usable in full simulation analysis

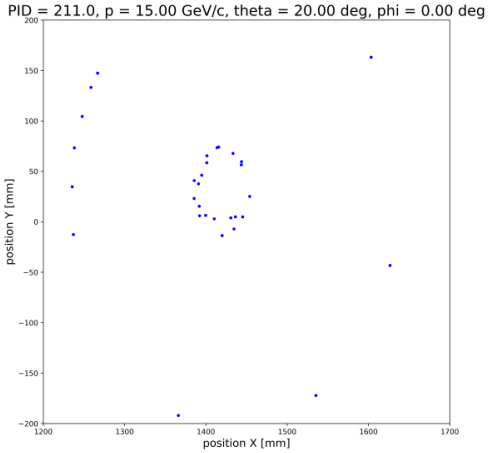
```
add EfficiencyFormula {211} {321} {
  (eta<  1.20 || eta>=  3.60 || pt * cosh(eta) <    0.90 || pt * cosh(eta) >=   27.00) * ( 0.00 ) +
  (  1.20 <= eta && eta <   1.60) * (   0.90 <= pt * cosh(eta) && pt * cosh(eta) <    1.40) * (0.000000) +
  (  1.20 <= eta && eta <   1.60) * (   1.40 <= pt * cosh(eta) && pt * cosh(eta) <    2.90) * (0.000000) +
  (  1.20 <= eta && eta <   1.60) * (   2.90 <= pt * cosh(eta) && pt * cosh(eta) <    4.20) * (0.000000) +
  (  1.20 <= eta && eta <   1.60) * (   4.20 <= pt * cosh(eta) && pt * cosh(eta) <    5.50) * (0.000000) +
  (  1.20 <= eta && eta <   1.60) * (   5.50 <= pt * cosh(eta) && pt * cosh(eta) <   10.00) * (0.000000) +
  (  1.20 <= eta && eta <   1.60) * (  10.00 <= pt * cosh(eta) && pt * cosh(eta) <   15.00) * (0.000381) +
  (  1.20 <= eta && eta <   1.60) * (  15.00 <= pt * cosh(eta) && pt * cosh(eta) <   20.00) * (0.026793) +
  (  1.20 <= eta && eta <   1.60) * (  20.00 <= pt * cosh(eta) && pt * cosh(eta) <   27.00) * (0.140689) +
  (  1.60 <= eta && eta <   2.00) * (   0.90 <= pt * cosh(eta) && pt * cosh(eta) <    1.40) * (0.000000) +
```

Machine Learning – for Reconstruction

AI4EIC 2022 Hackathon:
https://indico.bnl.gov/event/16586/page/435-hackathon

eventID	PID	momentum	theta	phi	X0	...	X59	Y0	...	Y59	Z0	...	Z59
0	211 or 321	p [GeV/c]	θ (deg)	ϕ (deg)	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
1	211 or 321	p [GeV/c]	θ (deg)	ϕ (deg)	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
..	211 or 321	p [GeV/c]	θ (deg)	ϕ (deg)	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
..	211 or 321	p [GeV/c]	θ (deg)	ϕ (deg)	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
N	211 or 321	p [GeV/c]	θ (deg)	ϕ (deg)	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]

Table 1: Table summarizing the data format for the hackathon problems



- Challenge: use ML and these data to classify between pions and kaons, under scenarios of increasing difficulty
- The most difficult scenario involved varying momenta, noise hits, and B-field
- Future idea: integrate into EICrecon and compare to baseline IRT