# Functional Analysis Description Language (FuncADL)

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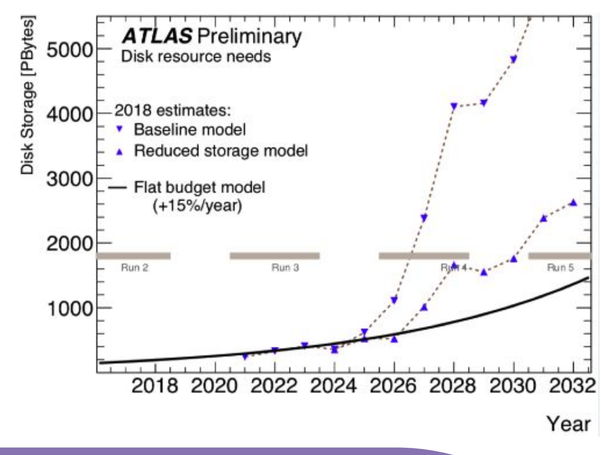
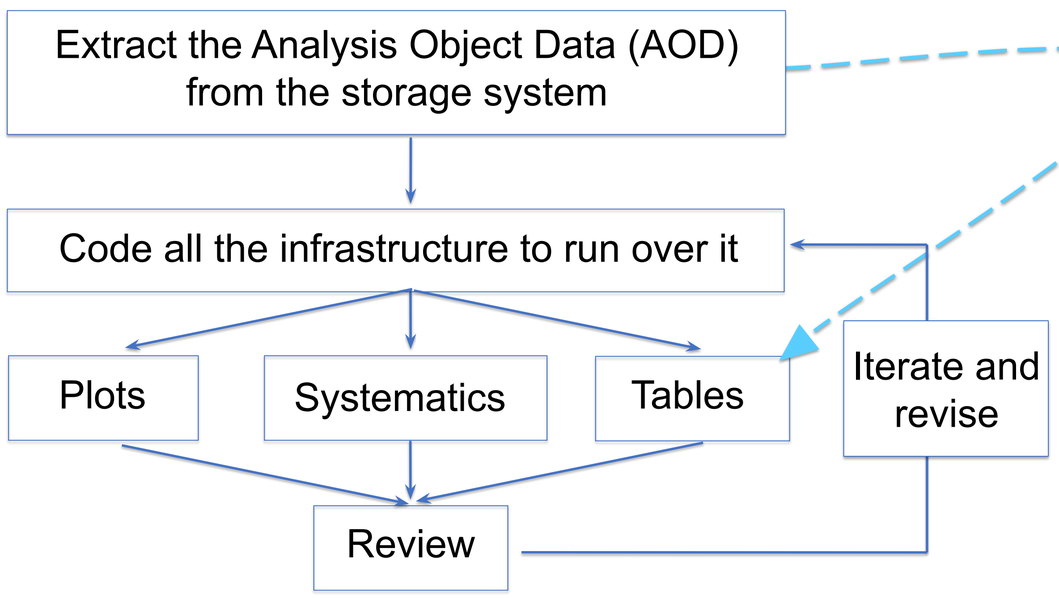
## Introduction

- High Luminosity LHC (HL-LHC) will collect ~10 times as much data as all the LHC runs in 2010-2023
  - New data formats, but we can't rewrite our analysis code for every new file format
- The challenge that we're trying to address:
  - New query-based analysis interface: a functional, declarative analysis language (within Python)
  - Main GitHub repository: https://github.com/iris-hep/func_adl




## Functional ADL

In a large HEP experiment, each analysis team must:




**Analysis language**: goes from AODs to plots and tables

**Declarative analysis:**

- The physicist specifies *what* they want from the data rather than *how* to implement it procedurally
- Columnar operations—no explicit loops

```
In [3]: %%time
        f = EventDataSet(fname)
        events = f.AsATLASEvents()
        Wall time: 0 ns
```
Get input file as ATLAS xAOD

```
In [4]: %%time
        event_info = events \
                    .Select("lambda e: (e.EventInfo('EventInfo'), e.Jets('AntiKt4EMTopoJets'), e.Tracks('InDetTrackParticles').Where(lambda t: t.pt() > 1000.0))")
```
Get electrons and tracks with pt>1 GeV

```
In [7]: jet_info = event_info \
                    .SelectMany('lambda e1: e1[1].Select(lambda j: (e1[0],j,e1[2].Where(lambda t: DeltaR(t.eta(), t.phi(), j.eta(), j.phi())< 0.2)))')
```
SelectMany function changes sequence from event into jets

```
In [8]: jet_data = jet_info \
                    .Select('lambda jinfo: (jinfo[0].runNumber(), jinfo[0].eventNumber(), jinfo[1].pt()/1000.0, jinfo[1].eta(), jinfo[2].Count())')
```
Generate the tuple of data we want to write out

```
In [9]: jet_filtered = jet_data \
                      .Where('lambda jinfo1: jinfo1[2] > 40.0')
```
Keep only jets with pt > 40 GeV

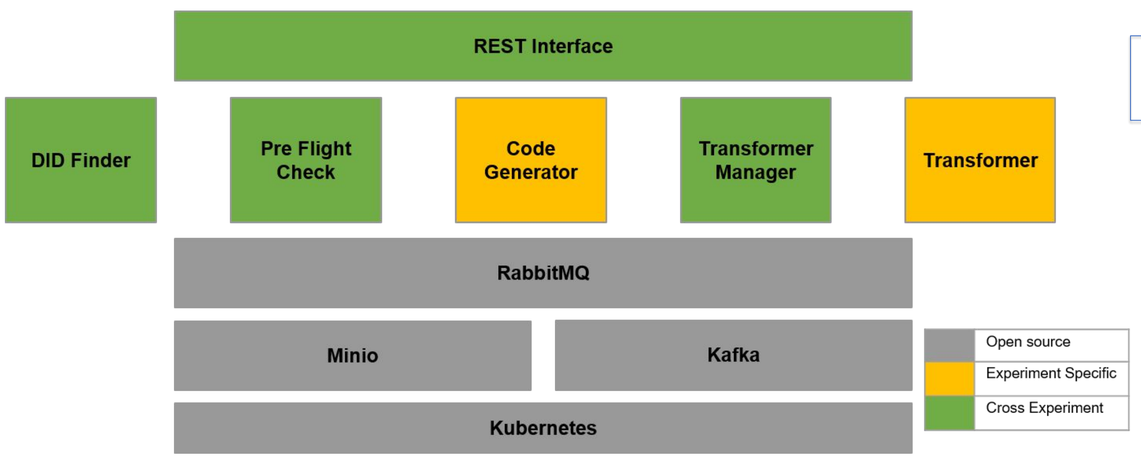
```
In [10]: %%time
         training_df = jet_filtered.AsPandasDF(columns=['Run', 'Event', 'JetPt', 'JetEta', 'nTracks'])
         Wall time: 0 ns
```
Turn it into a pandas data frame

```
In [11]: %%time
         df = training_df.value()
         Wall time: 38.6 s
```
Execute

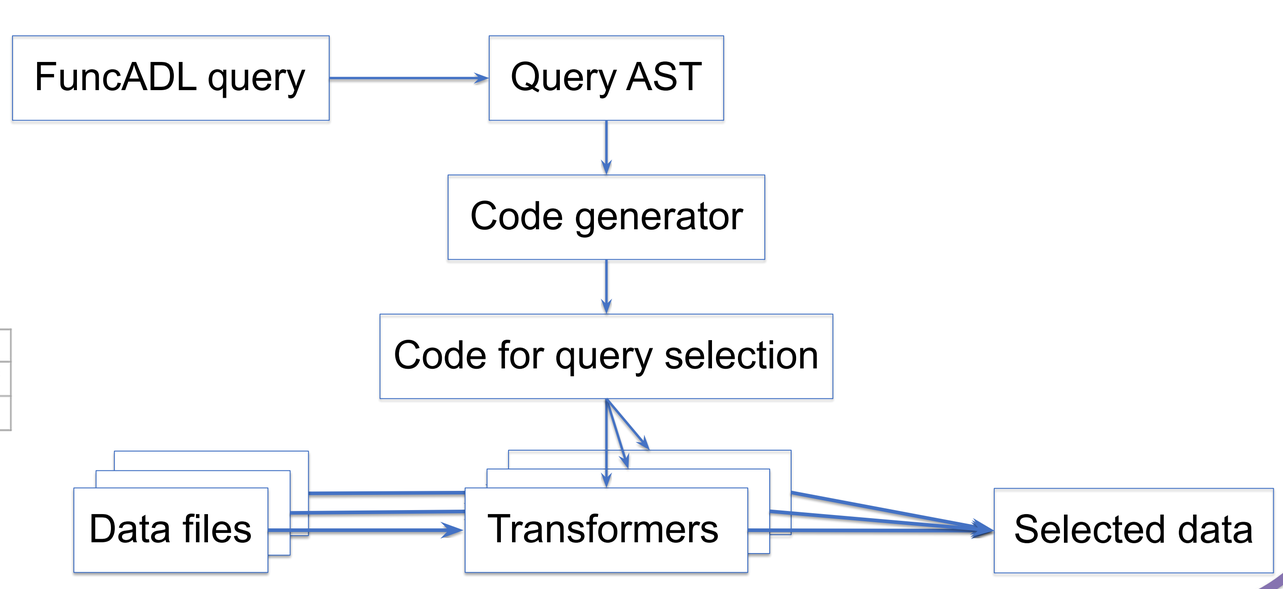
- Developing declarative analysis language based on queries
- Can be run on different file formats; currently implemented for:
  - xAOD (ATLAS)
  - Flat ROOT TTrees, using either uproot or RDataFrame
- Model being used in a full Run 2 analysis in ATLAS
- Benefits for the LHC community:
  - Analysis preservation that goes beyond the lifetimes of experiments
  - Facilitating the abstraction, design, combination, interpretation, and overall communication of the contents of LHC analyses

## Integration with ServiceX

- ServiceX is a suite of services developed by IRIS-HEP that provides high-performance data delivery for analysis
- Low-level extraction and selection of data on different file formats is done by FuncADL
- This is accomplished by two types of services: code generators and transformers
  - Data query from user is passed to code generator as an abstract syntax tree (AST)
  - Code generator translates the AST into selection code appropriate for the underlying file format
  - Transformers run the generated code and return the selected data
- Separation of these steps allows parallelizing transformation on large datasets with common generated code




Components of ServiceX. FuncADL provides the backend implementations for the services in yellow.

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