Data Management Package for the novel data delivery system, ServiceX, and Applications to various physics analysis workflows

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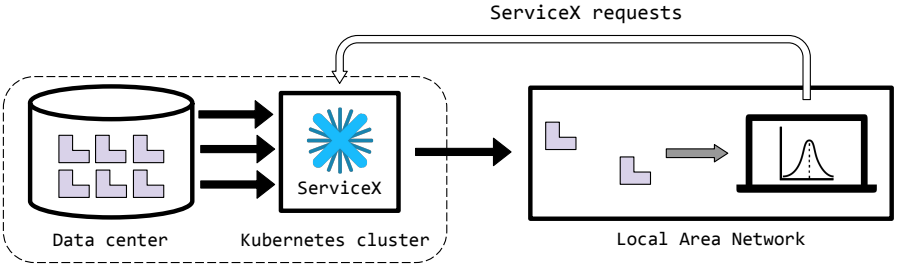
TEXAS
The University of Texas at Austin

ATLAS
EXPERIMENT

What's ServiceX?



- A service to **easily** and **quickly** access large data at remote with **transformation**
- Deployed in a Kubernetes cluster and usually co-located with the data center to allow a wide network bandwidth.
- See more at Ben Galewsky's talk on the ServiceX

ServiceX readthedocs

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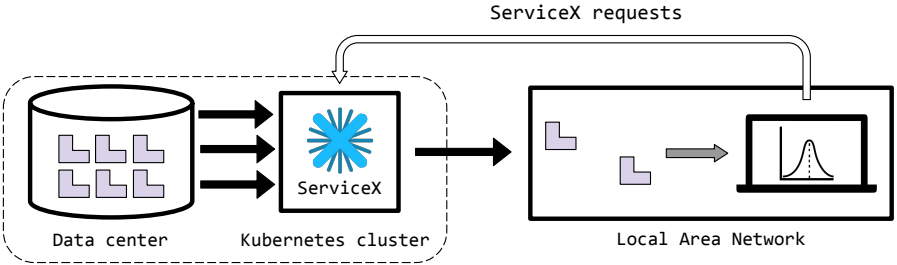

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Why ServiceX?

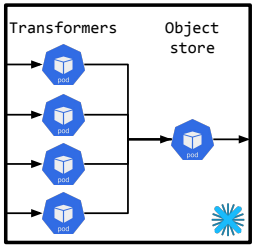
- ✓ A user wants few columns from datasets in the grid for ML study. Grid jobs?
- ✓ What about full-scale analysis?

ServiceX readthedocs

What's ServiceX?

Under the hood

1. ServiceX spawns the so-called **Transformer** pods (Docker container) to read columns and filter events or do whatever it's designed for
2. Transformer pods are also scaled automatically using Kubernetes auto-scaling feature
3. Outputs from each transformer written to object store then delivered to a destination as soon as it becomes available or consumed later



Transformers today

Transformer	Input data format
Uproot (`uproot`)	Flat ROOT ntuple
ATLAS R21 (`atlasr21`)	ATLAS R21 xAOD
CMS Run1 (`cmssw-5-3-32`)	CMS Run-1 AOD
Python (`python`)	*Runs user-provided python function

What is ServiceX DataBinder?

Python library (GitHub , PyPI)

for **easy** configurations of ServiceX delivery requests

and handling of delivered data using a single configuration file

and more

Use-case: Fast column extraction from remote data for ML study

```
General:
  ServiceXName: servicex-uc-af
  Transformer: uproot
  OutputFormat: root
  OutputDirectory: /Users/kchoi/data_for_MLstudy
  WriteOutputDict: fileset_ml_study

Sample:
  - Name: Signal
    RucioDID: user.kchoi:user.kchoi.fcnc_tHq_ML.ttH.v8,
              user.kchoi:user.kchoi.fcnc_tHq_ML.ttW.v8,
              user.kchoi:user.kchoi.fcnc_tHq_ML.ttZ.v8
    Tree: nominal
    FuncADL: DEF_ttH_nominal_query
  - Name: Background1
    XRootDFiles: DEF_ggH_input
    Tree: mini
    Filter: lep_n>2
    Columns: lep_pt, lep_eta
  - Name: Background2
    Transformer: atlasr21
    RucioDID: DEF_Zee_input
    FuncADL: DEF_Zee_query
  - Name: Background3
    LocalPath: /Users/kchoi/Work/data/fcnc

Definition:
  DEF_ttH_nominal_query: "Where(lambda e: e.met_met>150e3). \
              Select(lambda event: {'el_pt': event.el_pt, 'jet_e': event.jet_e, \
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  DEF_ggH_input: "root://eospublic.cern.ch//eos/opendata/atlas/OutreachDatasets\
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```

Base Transformer in this config

File paths of delivered files written in a yaml

4 Samples are defined

Keep configuration tidy! → `Definition` block

OutputFormat can be root or parquet

Path where data will be delivered

Remote data via Rucio (RSE)

Multiple inputs separated by comma

TCut syntax for Uproot (`Filter` only for scalar type variables)

Background2 is only available as DAOD, thus extract using xAOD transformer

Files for Background3 is already at local storage → Just bind it together

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FuncADL for Uproot
FuncADL for xAOD

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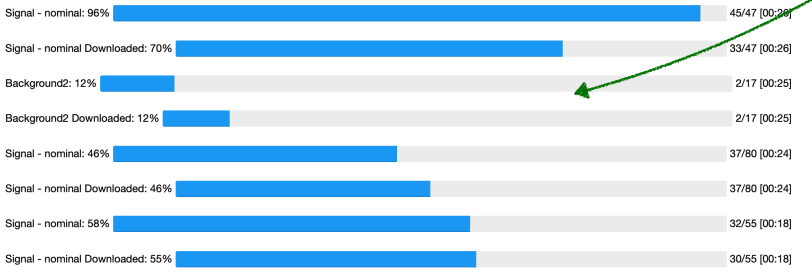
```
In [1]: from servicex_databinder import DataBinder

In [2]: sxdb = DataBinder('config_MLstudy.yaml')

INFO - Loading DataBinder config file: config_MLstudy.yaml
INFO -   4 Samples and 5 ServiceX requests

In [*]: out = sxdb.deliver()

INFO - Deliver via ServiceX endpoint: https://servicex.af.uchicago.edu/
```




```
INFO -   Background1 | mini | ['root://eospublic.cern.ch//eos/opendata/atlas/OutreachDatasets/2020-01-22/4lep/MC/mc_345060.ggH125_ is delivered
```

5 ServiceX requests running in parallel

- Rucio datasets for **`Signal`** in ROOT Ntuple ~200 GB
- Rucio dataset for **`Background2`** in ATLAS xAOD ~75 GB
- Deliver 1-4 columns to my laptop in Norfolk
- **Wall time: 1min 6s**

How to run ServiceX DataBinder?

1. Prepare ServiceX access file ⟹
   - YAML file containing ServiceX endpoint information

```yaml
api_endpoints:
  - name: servicex-uc-af
    endpoint: https://servicex.af.uchicago.edu/
    token: <TOKEN>
    type: uproot
```

2. Prepare DataBinder configuration file ⟹

```yaml
General:
  ServiceXName: servicex-uc-af
  OutputFormat: root

Sample:
  - Name: ggH125_ZZ4lep
    XRootDFiles: "root://eospublic.cern.ch//eos/opendata/atlas/OutreachDatasets\
                  /2020-01-22/4lep/MC/mc_345060.ggH125_ZZ4lep.4lep.root"
    Tree: mini
    FuncADL: "Select(lambda event: {'lep_pt': event.lep_pt, 'lep_eta': event.lep_eta})"
```

3. Deliver!! ⟹

```python
from servicex_databinder import DataBinder
sx_db = DataBinder('config_minimum.yaml')
out = sx_db.deliver()
```

How to run ServiceX DataBinder?

In the Jupyter notebook,

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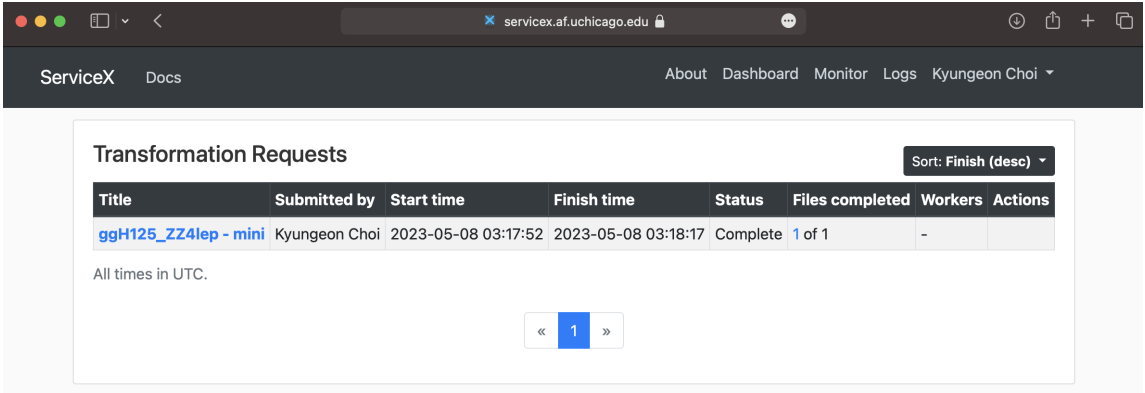
INFO - Deliver via ServiceX endpoint: https://servicex.af.uchicago.edu/

ggH125_ZZ4lep - mini: 0%                                    0/1 [00:05]

ggH125_ZZ4lep - mini Downloaded: 0%                         0/1 [00:05]
```

How to run ServiceX DataBinder?

Also from ServiceX Dashboard,



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In [3]: out = sxdb.deliver()

INFO - Deliver via ServiceX endpoint: https://servicex.af.uchicago.edu/
INFO -   ggH125_ZZ4lep | mini | ['root://eospublic.cern.ch//eos/opendata/atlas/OutreachDatasets/2020-01-22/4lep/MC/
mc_345060.ggH125_ is delivered
INFO - Delivered at /Users/kchoi/Work/UTAustin/Computing/ServiceX/ServiceXDataBinder/ServiceXData
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```
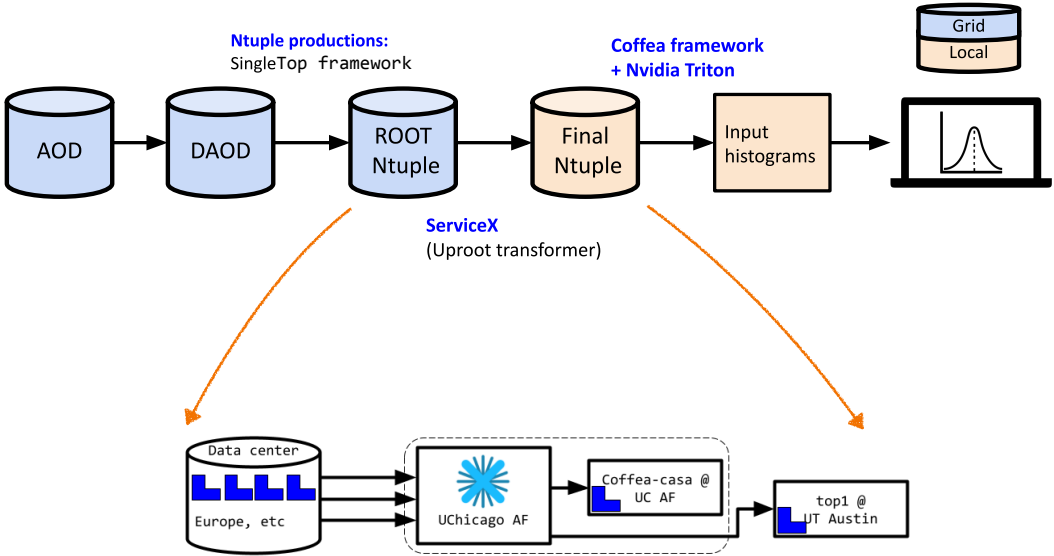

In [4]:
```
out
```

Out[4]:
```
{'ggH125_ZZ4lep': {'mini': ['/Users/kchoi/Work/UTAustin/Computing/ServiceX/ServiceXDataBinder/ServiceXData/ggH125_ZZ4lep/mini/root___192.170.240.18_1094__root___eospublic.cern.ch__eos_opendata_atlas_OutreachDatasets_2020-01-22_4lep_MC_mc_345060.ggH125_ZZ4lep.4lep.root.root']}}
```

Use-case: ATLAS Run-2 Physics Analysis



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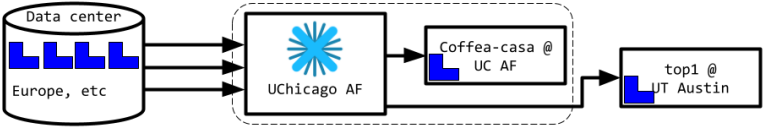
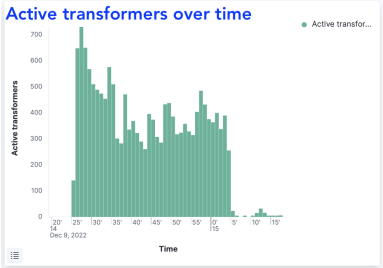


- ServiceX spawns 140 Uproot transformer pods and scaled up/down (up to ∼800 pods) to extract 30-70 columns from 130 trees out of ∼1.1TB ROOT ntuples (>600 Rucio datasets)
- Wall time: ∼53mins to UC Analysis Facility (AF)
- DataBinder configuration file only about 400 lines
- Returned fileset from DataBinder is directly passed to `coffea` as input
- Accommodate various needs
  - ✓ Delivered data can be also processed with ROOT
  - ✓ Data can be delivered to AF, or University cluster



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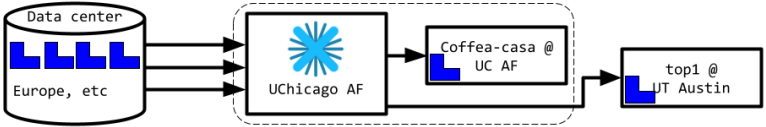

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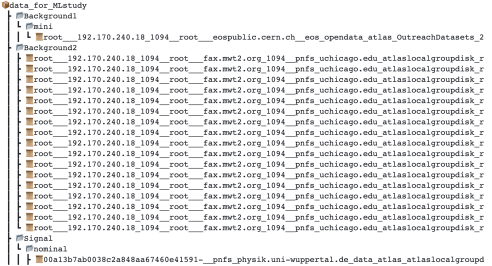
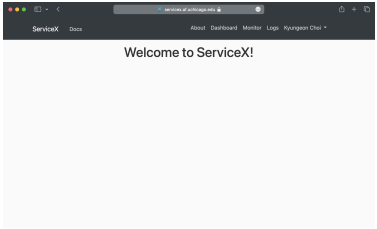


Where is ServiceX?

https://servicex.af.uchicago.edu



https://coffea.casa

https://coffea-opendata.casa

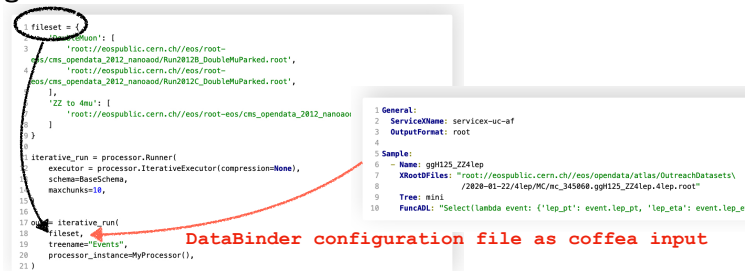
- https://servicex.af.uchicago.edu at University of Chicago Analysis Facility for ATLAS users
- https://coffea.casa at University of Nebraska-Lincoln (UNL) for CMS users
- https://coffea-opendata.casa at UNL for OpenData access

  $\Rightarrow$ ServiceX endpoint accessible only inside UNL coffea-casa facilities but ServiceX access file is pre-generated for users

More about coffea-casa at Oksana's Plenary talk

Future plans

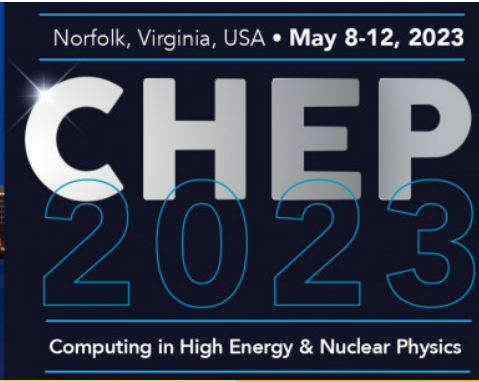
- ✓ **Support other ServiceX data delivery options**
  - Streaming from ServiceX object-store or from local path
- ✓ **Better integration into `coffea` framework**



- ✓ **Support (upcoming) ServiceX updates**
  - multi-tree Uproot transformer, Python transformer, ATLAS R22 transformer, ...
- ✓ **Towards more generic data management package**

Questions?

Special thanks to the ServiceX team!



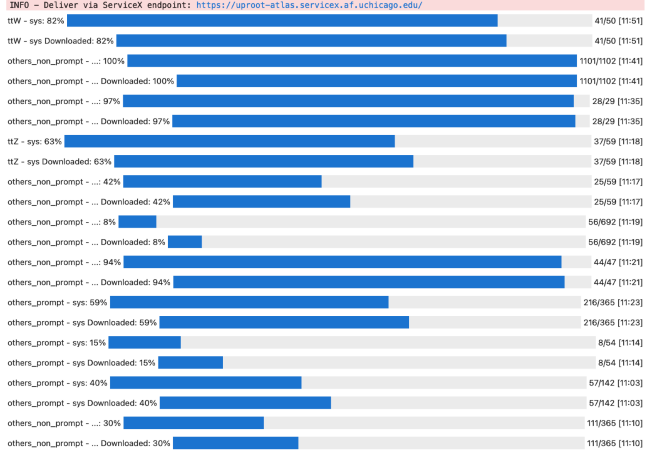
Backup

Delivery of full datasets - a snippet of DataBinder config

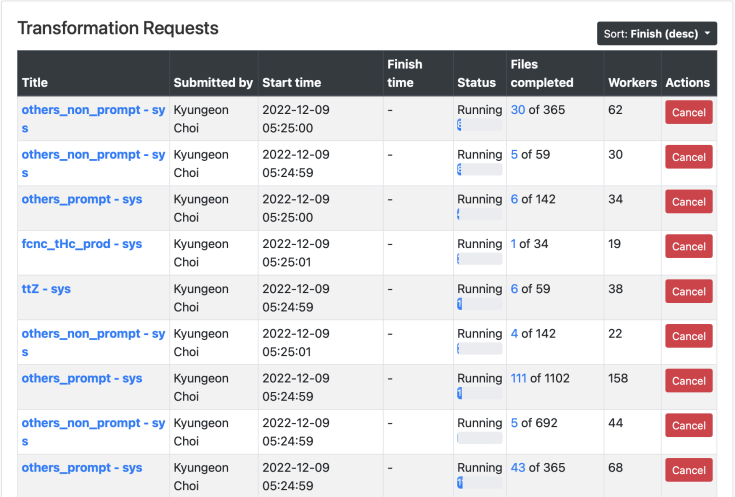
```yaml
General:
    ServiceXBackendName: uproot_uc_af
    OutputDirectory: /data_ceph/kyungeon/fcnc_tHq_ML/ServiceXData_v7
    OutputFormat: root
    WriteOutputDict: out_paths_v7

Sample:
  - Name: ttH
    RucioDID: user.kchoi:user.kchoi.fcnc_tHq_ML.ttH.v7
    TransformerImage: kyungeonchoi/servicex_func_adl_uproot_transformer:fcnc_nominal
    Tree: nominal
    FuncADL: DEF_funcadl_prompt_NOMINAL

  - Name: ttH
    RucioDID: user.kchoi:user.kchoi.fcnc_tHq_ML.ttH.v7
    TransformerImage: kyungeonchoi/servicex_func_adl_uproot_transformer:fcnc_fullsim
    Tree: sys_fullsim
    FuncADL: DEF_funcadl_prompt_SYS

    ...

Definition:
  DEF_funcadl_prompt_NOMINAL: "Where(lambda e: e.el_truthIFFClass.Where(lambda i: i==2).Count() == e.el_truthIFFCl
  Where(lambda e: e.mu_truthIFFClass.Where(lambda i: i==4).Count() == e.mu_truthIFFClass.Count()).
  Select(lambda e: {'mu_pt': e.mu_pt, 'mu_eta': e.mu_eta, 'mu_phi': e.mu_phi, 'mu_e': e.mu_e, 'mu_charge': e.mu_ch
                    'el_pt': e.el_pt, 'el_eta': e.el_eta, 'el_phi': e.el_phi, 'el_e': e.el_e, 'el_charge': e.el_ch
                    'met_met': e.met_met, 'met_phi': e.met_phi,
                    'jet_pt': e.jet_pt, 'jet_eta': e.jet_eta, 'jet_phi': e.jet_phi, 'jet_e': e.jet_e, 'jet_tagWeig
                    'weights': e.weight_mc*e.weight_pileup*e.weight_leptonSF*e.weight_bTagSF_DL1r_Continuous*e.wei
                    'mcChannelNumber': e.mcChannelNumber, 'runNumber': e.runNumber, 'eventNumber': e.eventNumber,
                    'mc_generator_weights': e.mc_generator_weights,
```

Delivery of full datasets - Run DataBinder in Jupyter Notebook

```
[2]: from servicex_databinder import DataBinder

[9]: sx_db = DataBinder('config_fcnc_v7.yml')

INFO – Loading DataBinder config file: config_fcnc_v7.yml
INFO –   21 Samples and 61 ServiceX requests

[*]: %%time
out = sx_db.deliver()

INFO – Deliver via ServiceX endpoint: https://uproot-atlas.servicex.af.uchicago.edu/
```



Delivery of full datasets - Dashboard



Transformation Requests

Sort: **Finish (desc)**

Title	Submitted by	Start time	Finish time	Status	Files completed	Workers	Actions
others_non_prompt - sys	Kyungeon Choi	2022-12-09 05:25:00	-	Running	30 of 365	62	Cancel
others_non_prompt - sys	Kyungeon Choi	2022-12-09 05:24:59	-	Running	5 of 59	30	Cancel
others_prompt - sys	Kyungeon Choi	2022-12-09 05:25:00	-	Running	6 of 142	34	Cancel
fcnc_tHc_prod - sys	Kyungeon Choi	2022-12-09 05:25:01	-	Running	1 of 34	19	Cancel
ttZ - sys	Kyungeon Choi	2022-12-09 05:24:59	-	Running	6 of 59	38	Cancel
others_non_prompt - sys	Kyungeon Choi	2022-12-09 05:25:01	-	Running	4 of 142	22	Cancel
others_prompt - sys	Kyungeon Choi	2022-12-09 05:24:59	-	Running	111 of 1102	158	Cancel
others_non_prompt - sys	Kyungeon Choi	2022-12-09 05:24:59	-	Running	5 of 692	44	Cancel
others_prompt - sys	Kyungeon Choi	2022-12-09 05:24:59	-	Running	43 of 365	68	Cancel