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Hadron PID tutorial
$D^* \rightarrow D^0 (\rightarrow K\pi)\pi$

Sam Cunliffe[1], Jake Bennett[2] ← this guy wrote the original scripts

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Pre-B2GM physics performance tutorials.

17 June 2017

U.S. DEPARTMENT OF ENERGY

PNNL-SA-XXXXX

- Everything you need is in a **git repo** and also a **tarball on kekcc**.
  https://stash.desy.de/users/scunliff/repos/b2gm-hadronpid-tutorial-jun2017/browse
- Whilst I'm talking please open up a terminal either onto KEK or somewhere with **`/cvmfs`** mounted and do the following:

- If you like git:

```
$ git clone git clone \
ssh://git@stash.desy.de:7999/~scunliff/b2gm-hadronpid-tutorial-jun2017.git
cd b2gm-hadronpid-tutorial-jun2017/
```

- If you dislike git / are already working at kekcc / like tab completion:

```
$ cp -r ~scunliffe/public/ b2gm-hardronpid-tutorial-jun2017.tar.gz
$ tar -zvxf b2gm-hadronpid-tutorial-jun2017.tar.gz
$ cd b2gm-hadronpid-tutorial-jun2017/
```

- Then normal basf2 setup steps (we're working in **`release-00-08-00`**)

```
$ . /cvmfs/belle.cern.ch/sl6/tools/setup_belle2
$ setuprel release-00-08-00
```

Preamble

- Once you've sourced the Belle II setup script, and setup a release you should have the environment variable **`$BELLE2_RELEASE_DIR`**

```
$ echo $BELLE2_RELEASE_DIR
$ ls $BELLE2_RELEASE_DIR
```

https://stash.desy.de/projects/B2/repos/software/browse

- All of these scripts for this tutorial where copied and adapted from **`$BELLE2_RELEASE_DIR/analysis/validation`**
  - This place is a good source of example scripts in general.

What do we want?

Particle identification performance

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- For physics performance, we care about maintaining a large **efficiency** for a low **fake rate**. Here are some very verbose definitions:
  - **Efficiency** = number of correctly identified particles under their own hypothesis for a some cut on a figure of merit divided by the total true number of particles that really were whatever hypothesis.
  - **Fake rate** = number of incorrectly identified particles under the alternate hypothesis for the same cut divided by the total number of particles that really were the alternate hypothesis.
  - '**Separation**' an imprecise jargony term (in this context) means how far apart the efficiency and fake rate are for two hypotheses. i.e. '**K/π separation**'

- The physics performance group also provides you, the user, with ability to ask the reverse e.g.:
"*I'm prepared to accept 95% efficiency what is the corresponding fake rate and where are the figure of merit cuts?*"

What do we want?

Particle identification performance

- For physics performance, we care about maintaining a large **efficiency** for a low **fake rate**. Here are some maths definitions:
  - **Efficiency**

$$\varepsilon_{\pi id} = n_{\text{true } \pi, \text{ selected}} / N_{\text{true } \pi \text{ total}}$$
$$\varepsilon_{K id} = n_{\text{true K, selected}} / N_{\text{true K total}}$$

  - **Fake rate**

$$R_{K\to\pi} = n_{\text{true K selected as } \pi} / N_{\text{true K total}}$$
$$R_{\pi\to K} = n_{\text{true } \pi \text{ selected as K}} / N_{\text{true } \pi \text{ total}}$$

  - **'Separation'**

loosely: $\varepsilon_{\pi id} - R_{K\to\pi}$ and $\varepsilon_{K id} - R_{\pi\to K}$

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    π/K separation

    K/π separation

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  "*I'm prepared to accept 95% efficiency what is the corresponding fake rate and where are the figure of merit cuts?*"

What we're actually doing:

Physics description of the method

$$D^{*+} \to D^0(\to K^-\pi^+)\pi^+$$

$$D^{*-} \to \overline{D}^0(\to K^+\pi^-)\pi^-$$

What we're actually doing:

Physics description of the method

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$$D^{*+} \rightarrow D^0(\rightarrow K^-\pi^+)\pi^+_{slow}$$

$$D^{*-} \rightarrow \overline{D}^0(\rightarrow K^+\pi^-)\pi^-_{slow}$$

- Reconstruct the 'slow **pion**' and determine it's **charge**...
- …therefore you determine the **charge** of the D*
- …and therefore the **flavour** of the D^0 ($\overline{D}^0$)
- …and therefore **which is which** in the $K^{\mp}\pi^{\pm}$ pair, solely from charge information (because $D^0 \rightarrow K^-\pi^+$ and $\overline{D}^0 \rightarrow K^+\pi^-$)

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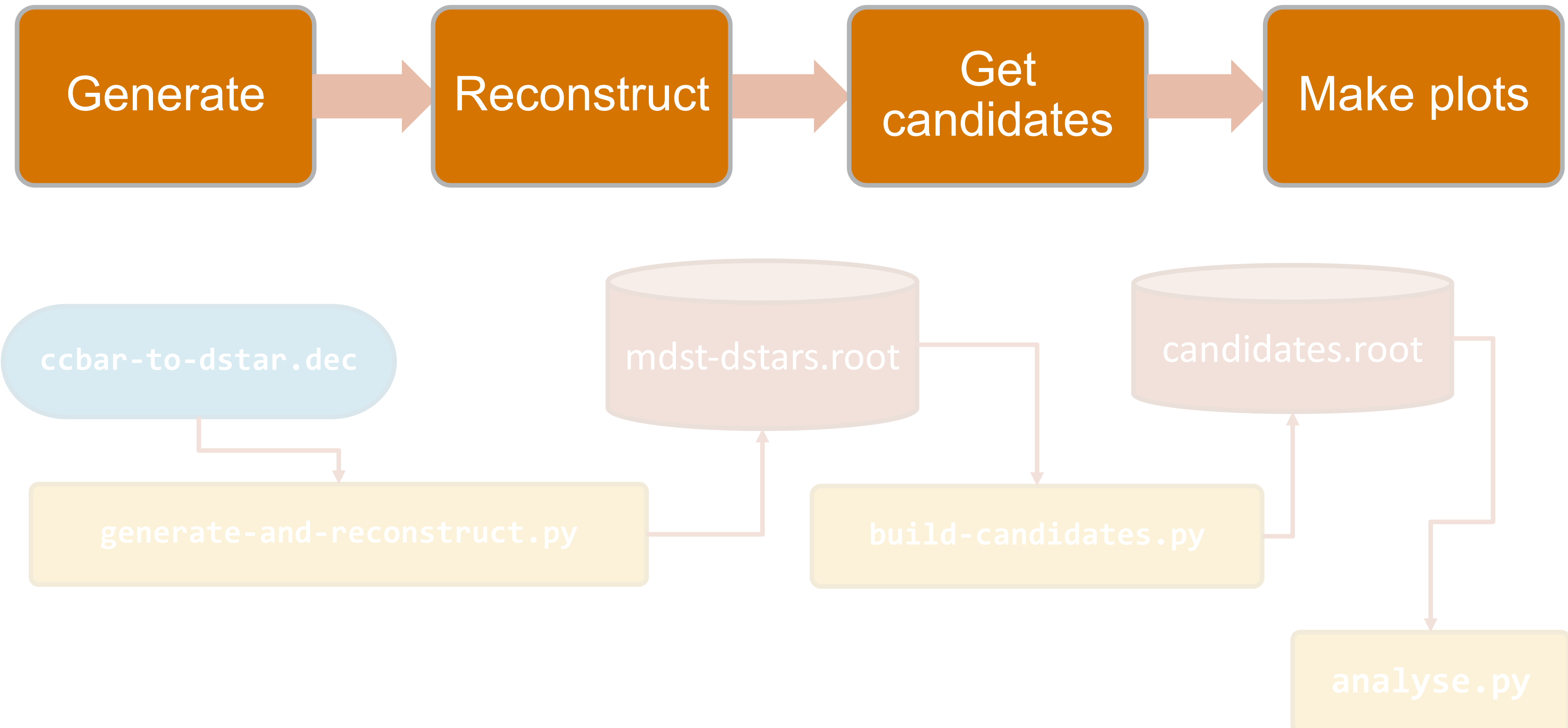
"Mother Nature's MC truth"

The basf2 steps

Scripts in the directory

https://stash.desy.de/users/scunliff/repos/b2gm-hadronpid-tutorial-jun2017/browse



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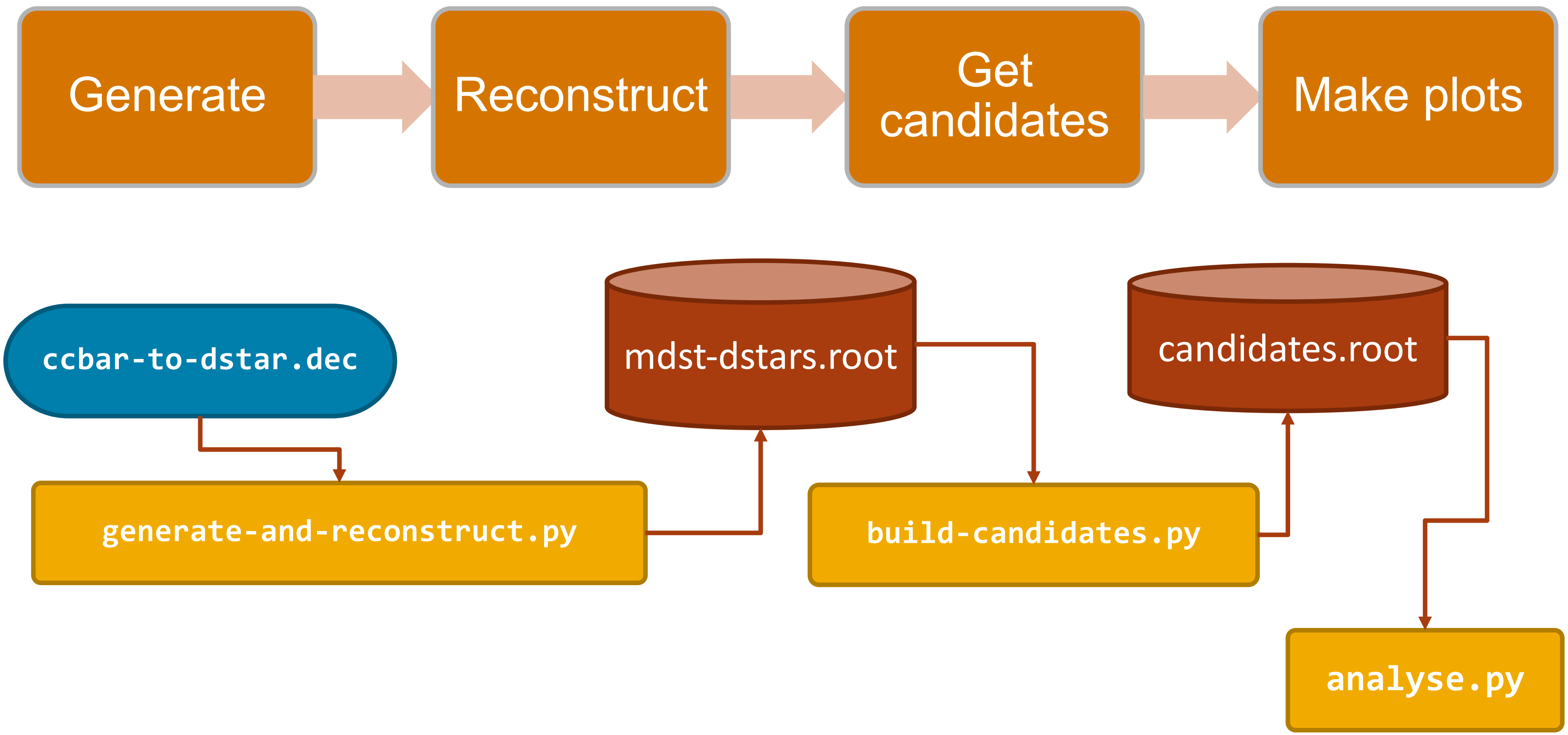

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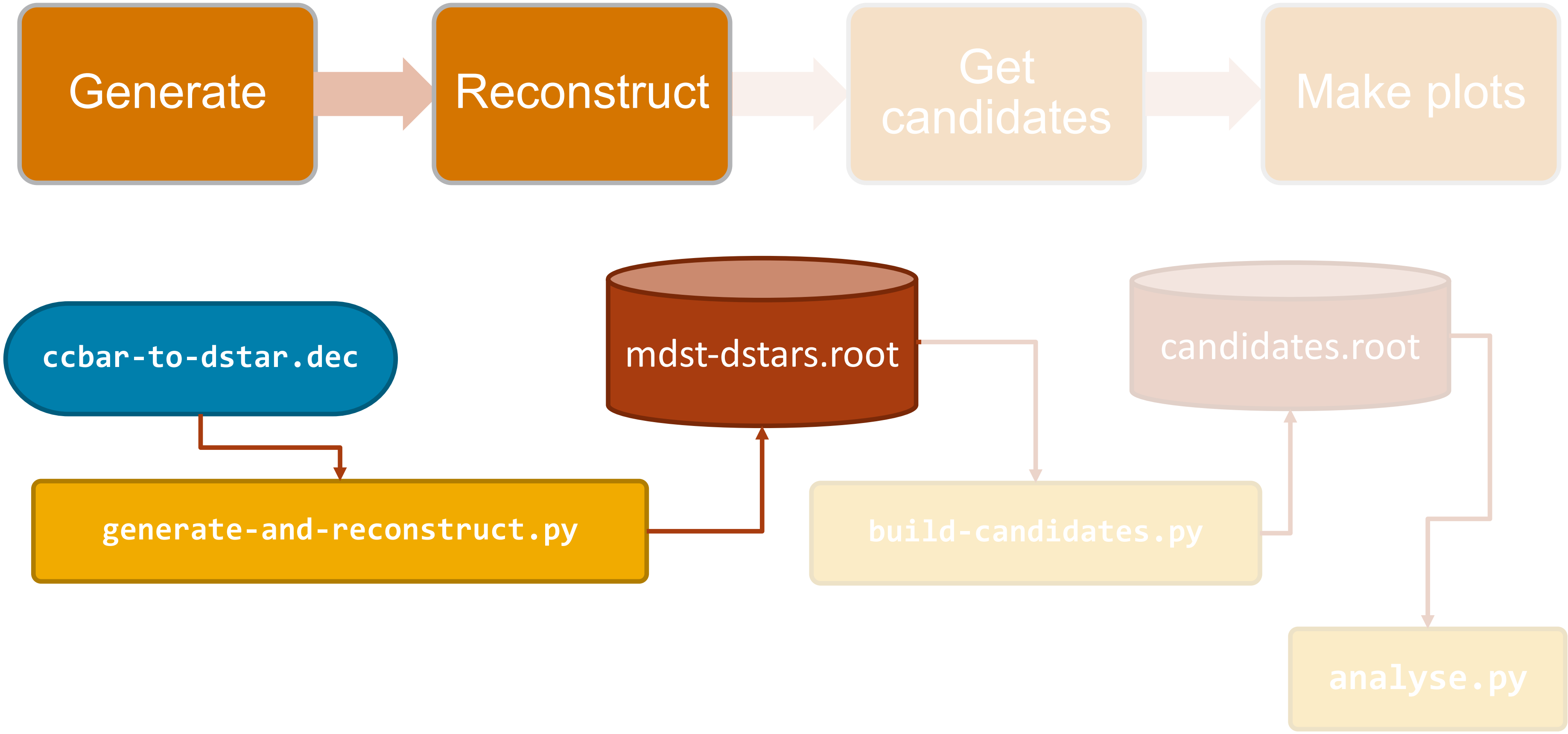

Input

EvtGen decay file

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- Belle II uses EvtGen to take cc continuum generated by PYTHIA into specific final-state hadrons
  - User defined 'decfile'
  - Falls back on '**`DECAY_BELLE2.dec`**' containing all the SM processes, measured branching fractions etc
- Look at **`ccbar-to-dstar.dec`**
  - Note that the relevant stuff is line 41 onwards.
  - Jet-Set parameters beyond the scope of this
    - Only tweak if you're an expert.

```
41 # ----- define D* decays for K/pi samples -----
42
43 Alias MyD0 D0
44 Alias MyAntiD0 anti-D0
45 ChargeConj MyD0 MyAntiD0
46
47 Decay D*-
48 1.000 MyAntiD0 pi-      VSS;
49 Enddecay
50
51 Decay D*+
52 1.000 MyD0 pi+          VSS;
53 Enddecay
54
55 Decay MyD0
56 1.000 K- pi+           PHSP;
57 Enddecay
58 CDecay MyAntiD0
59
60 End
ccbar-to-dstar.dec
```

First `basf2` procedural step

Generate and reconstruct decays

- Look at **`generate-and-reconstruct.py`**
- Adds standard reconstruction and simulation modules (in the correct order)
  `add_simulation()`
  `add_reconstruction()`
- **Exercise**: find these functions in the software…
  - Hints: $BELLE2_RELEASE_DIR or stash.desy.de
- When you're happy, run it:

```
$ basf2 generate-and-reconstruct.py -n 10 # if this works then try 1k
$ basf2 generate-and-reconstruct.py -n 1000
```

The basf2 steps

Scripts in the directory

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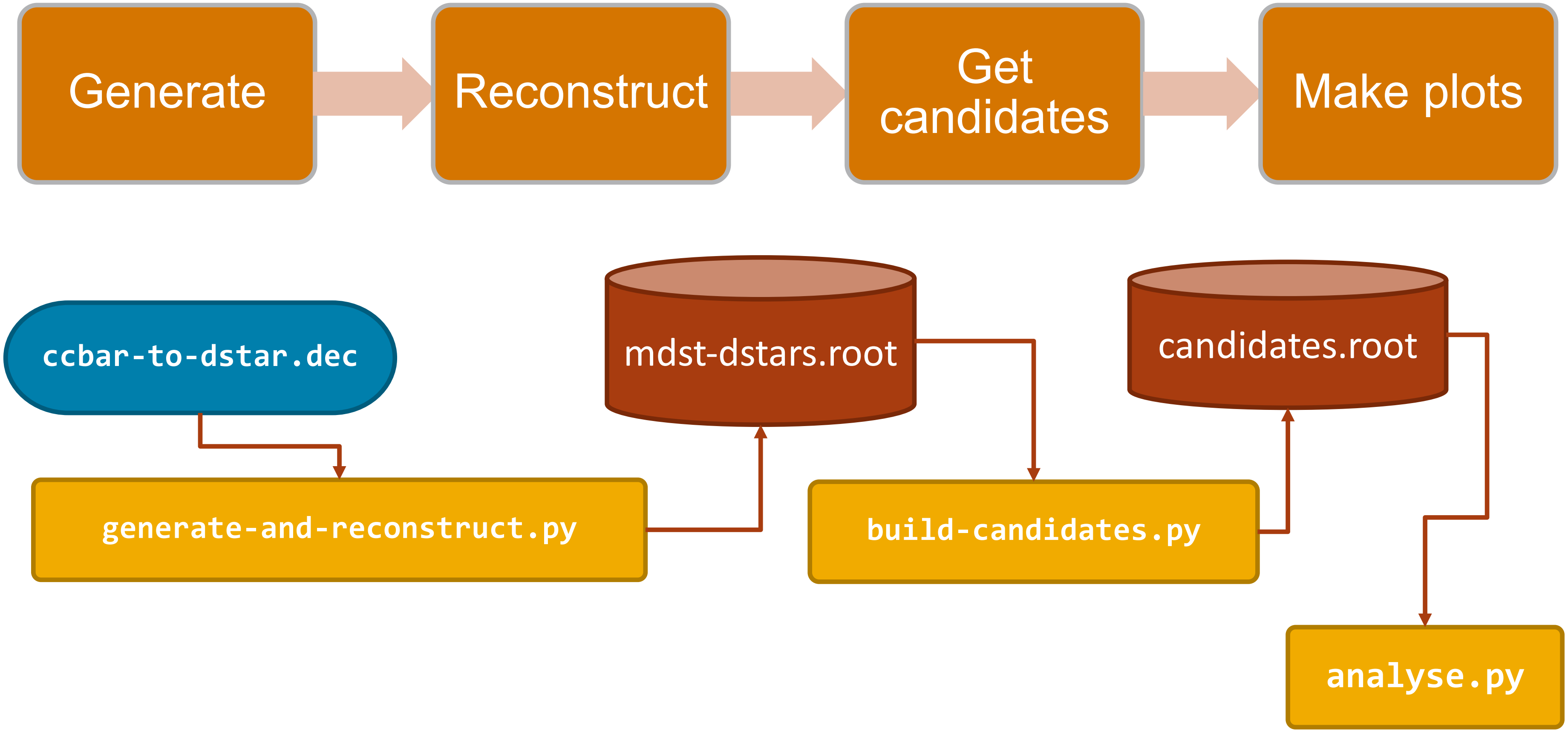

The basf2 steps

Scripts in the directory

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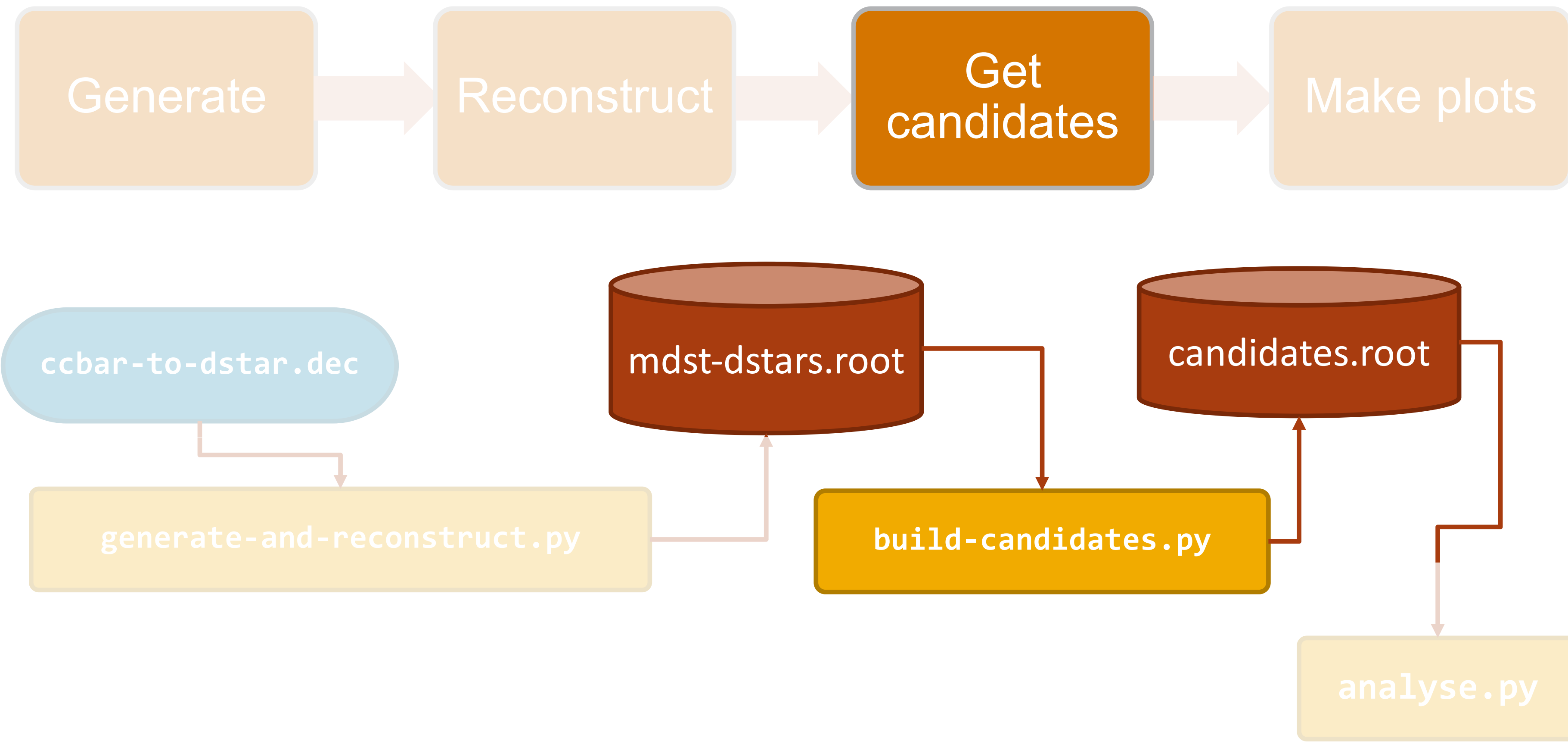

Second `basf2` procedural step

Get candidates from the mdst

- Do an **`ls`** in the local directory… see **`mdst-dstars.root`** ?
- This file format is **mDST** = **m**ini **D**ata **S**ummary **T**able
  - Nicer to have a flattened **`TTree`** to easily make plots.
  - https://confluence.desy.de/display/BI/Main+Glossary
- In **`basf2`** we need to get candidates from the mDST
- Look at **`build-candidates.py`**
- When you're happy, run it:

```
$ basf2 build-candidates.py --input mdst-dstars.root
```

- Then look at the output:

```
$ root candidates.root
root [0] TBrowser browser
```

Run over a skim

- Now, we've only generated 1k events. Which is not enough statistics.
- I've run a job with 100k events.

```
$ basf2 build-candidates.py --input ~scunliff/public/mdst-dstars.root
```

- So please run over that.

- [If we can get Racha's skims in time. Better to run over those.]

The basf2 steps

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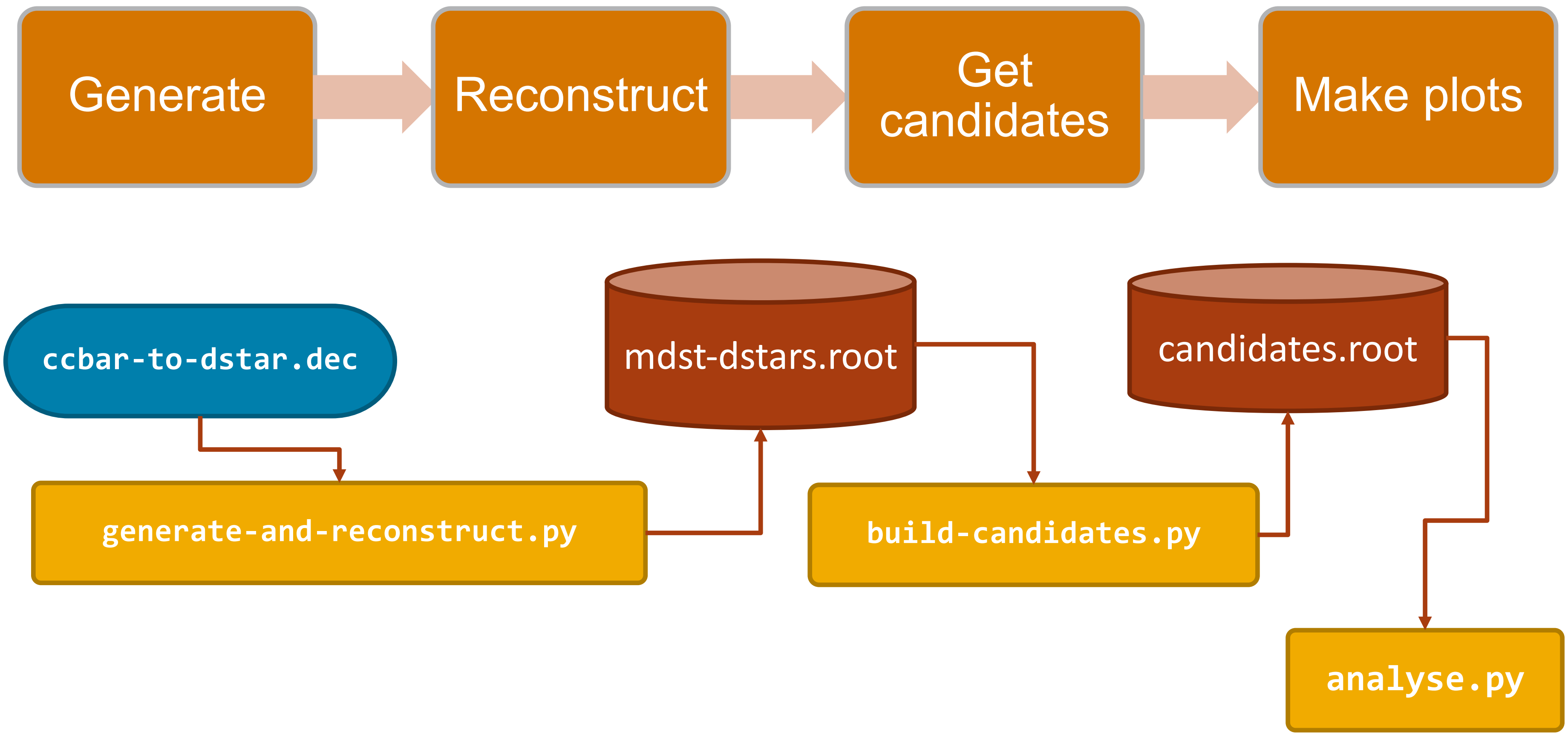

The basf2 steps

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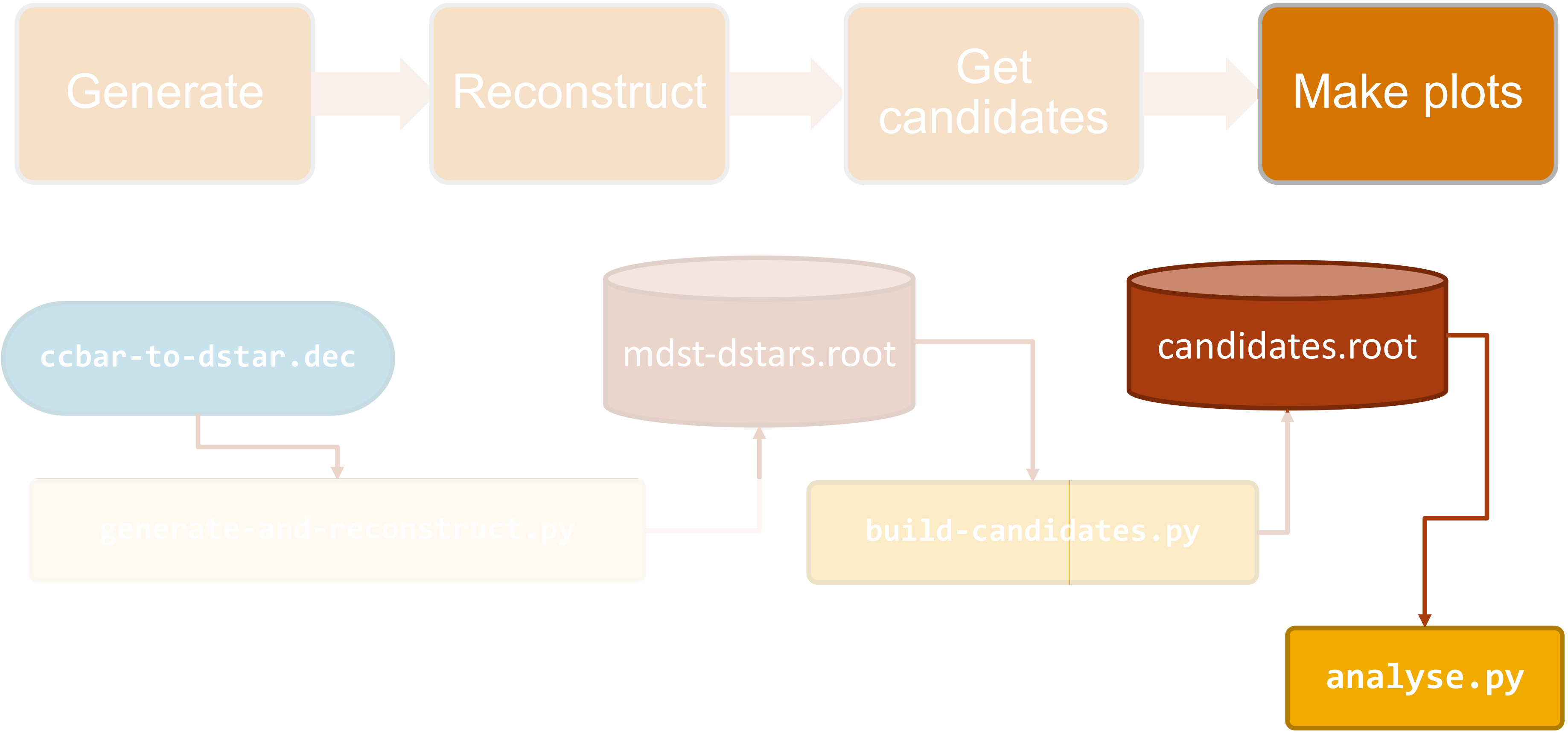

Run the plotting script to analyse

- Look at **`analyse.py`**
- When we're happy, run it:

```
$ python3 analyse.py
```

- Then look at the output: