

Searching for Dark Matter with XENONnT and Pegasus

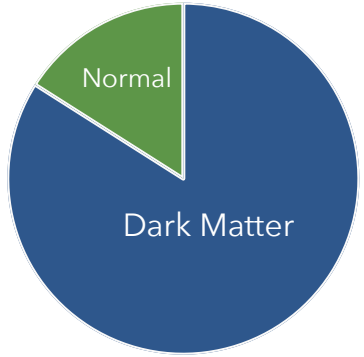
Evan Shockley

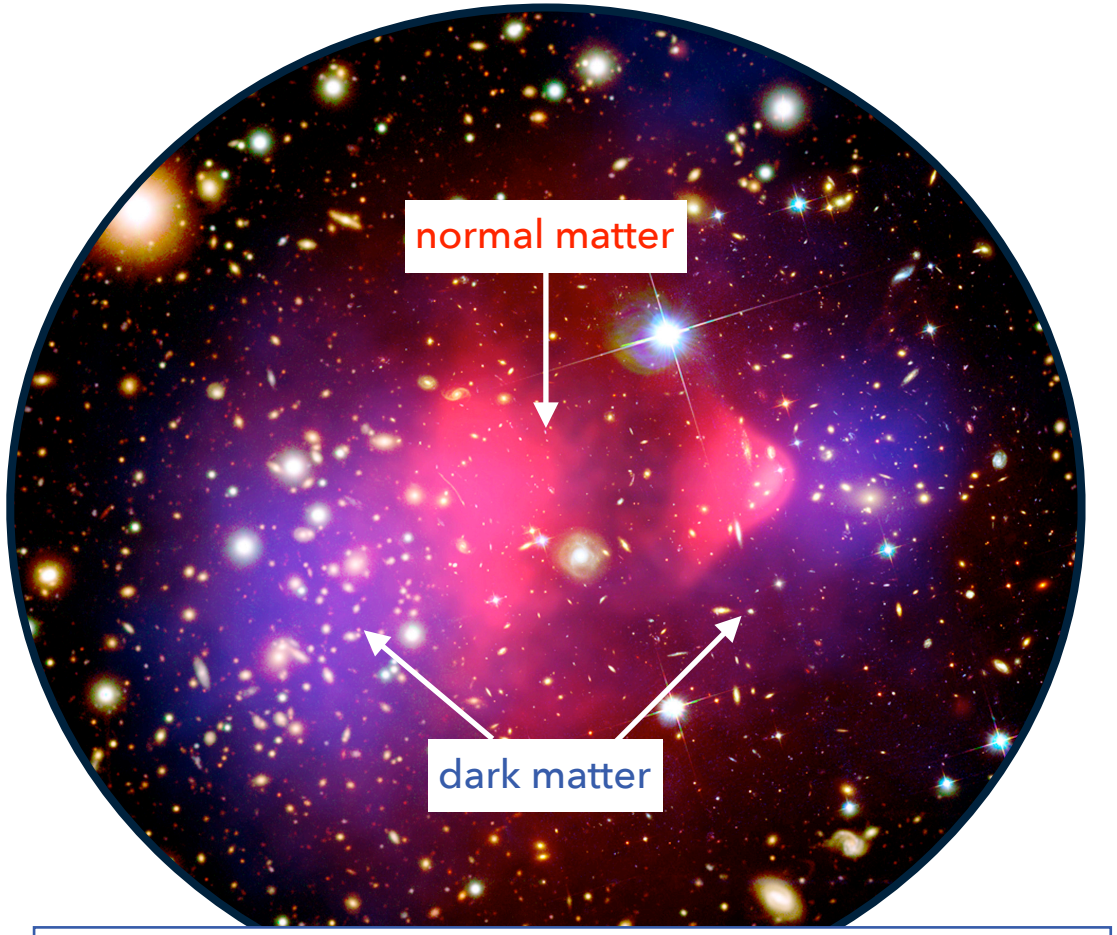
UC San Diego and the XENON collaboration

PUG 2021. 23 Feb 2021

Dark Matter

- Insurmountable evidence from gravitational effects
- Maybe a new fundamental particle?
  - has *mass*
  - interacts *rarely*
  - is *stable*





A DIRECT EMPIRICAL PROOF OF THE EXISTENCE OF DARK MATTER *

Douglas Clowe[1], Maruša Bradač[2], Anthony H. Gonzalez[3], Maxim Markevitch[4,5], Scott W. Randall[4], Christine Jones[4], and Dennis Zaritsky[1]

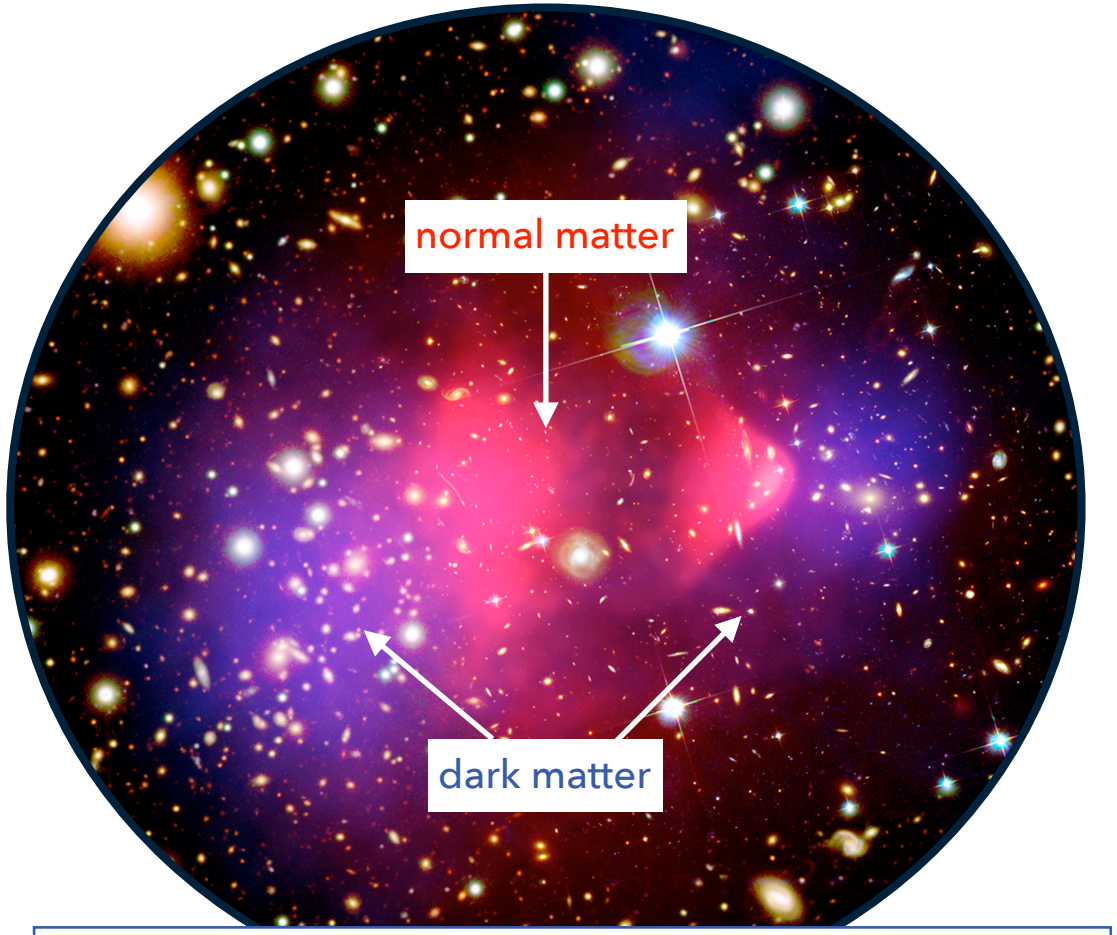
ApJ Letters in press

ABSTRACT

We present new weak lensing observations of 1E0657−558 ($z = 0.296$), a unique cluster merger, that enable a direct detection of dark matter, independent of assumptions regarding the nature of the

Dark Matter

- Insurmountable evidence from gravitational effects
- Maybe a new fundamental particle?
  - has *mass*
  - interacts *rarely*
  - is *stable*
- We have theoretical predictions for what it *might* be
- **Has never been detected directly.**



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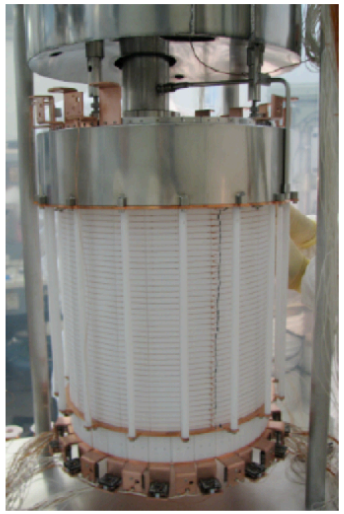
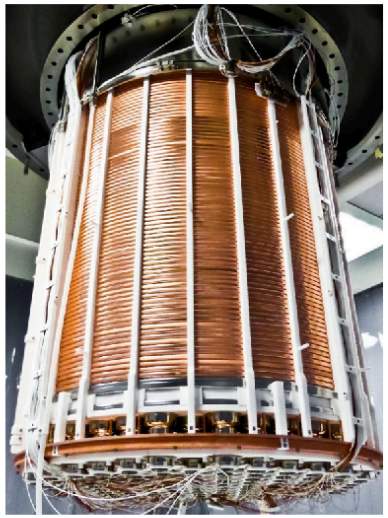
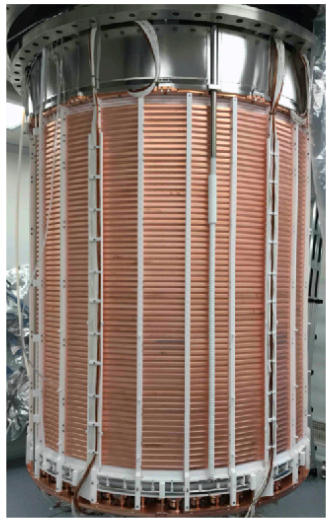
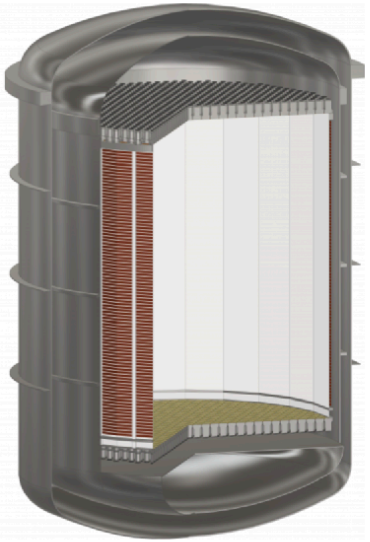
We present new weak lensing observations of 1E0657−558 ($z = 0.296$), a unique cluster merger, that enable a direct detection of dark matter, independent of assumptions regarding the nature of the

XENON

- Deep under the Gran Sasso mountains, Italy
- Searches for interactions of dark matter in the liquid xenon detector
- Liquid Xenon Time Projection Chamber (LXe TPC)



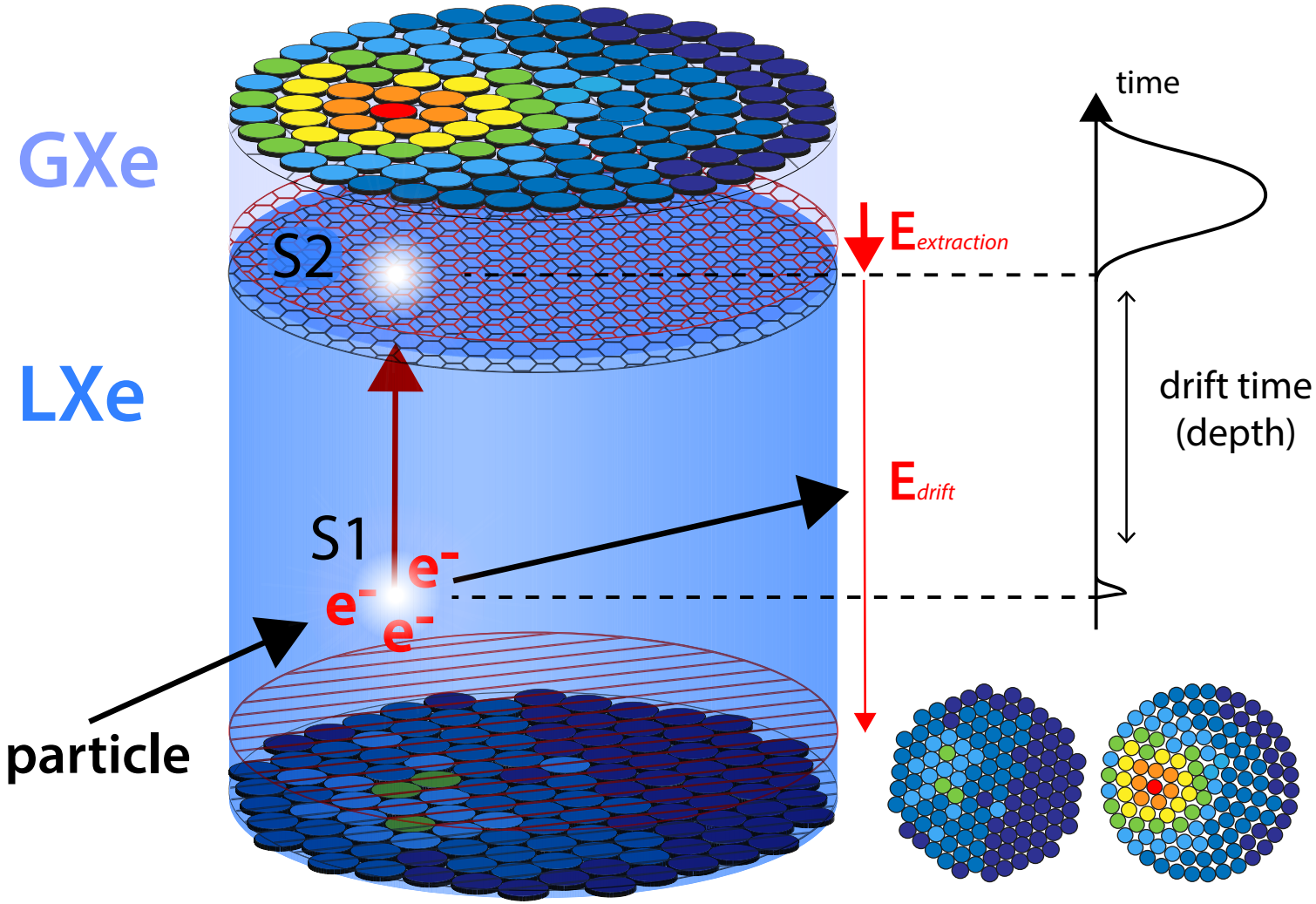
The XENON Program

	XENON10	XENON100	XENON1T	XENONnT	DARWIN
					
operation	2005-2007	2008-2016	2012-2018	2020-2025	2027–
total mass	15 kg	161 kg	3200 kg	8400 kg	50 tonnes
detector radius	15 cm	30 cm	96 cm	150 cm	260 cm
WIMP σ	~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2	~10^{-49} cm^2

Currently being commissioned

XENON TPC

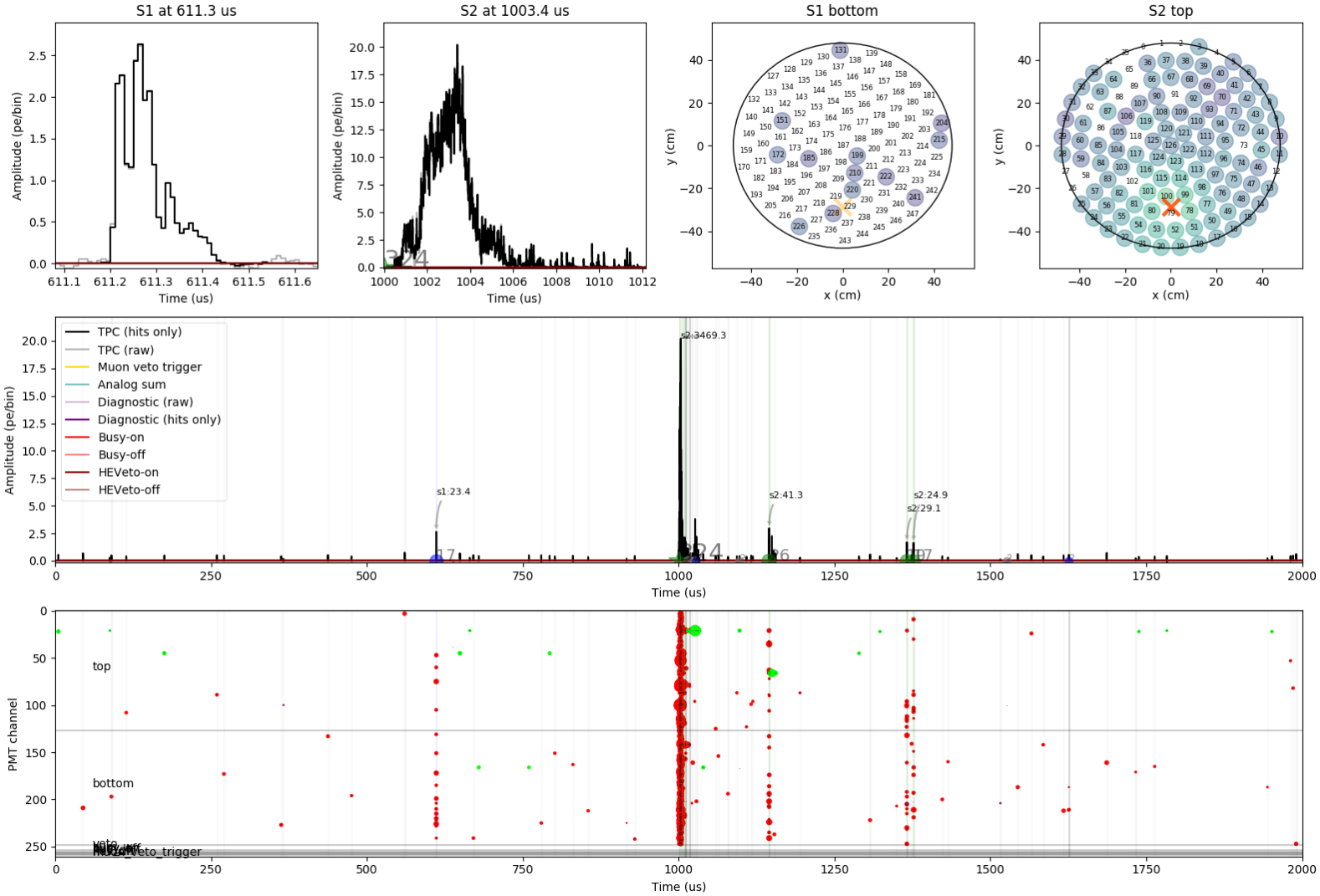
- Particle detector with
  - low background
  - low threshold
  - large exposure
- Energy + 3D position reconstruction
- Particle Identification
  - Electronic recoils
  - Nuclear recoils



496 photodetectors in XENONnT

XENON data

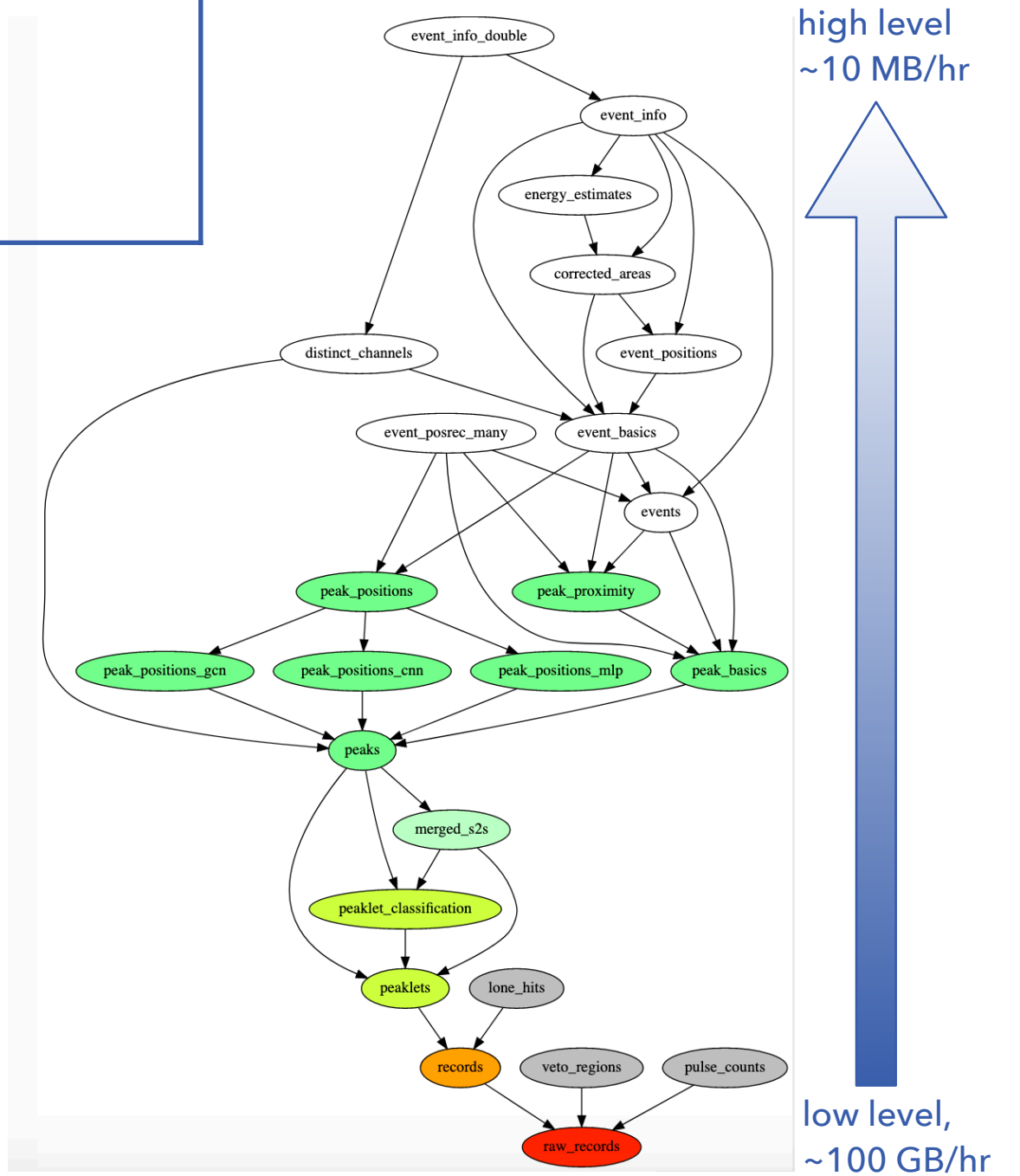
- Example waveform from XENON1T
- Each event O(ms) long, read out by all PMTs
- PMTs trigger on single photon (>90% acc.)
- **Although it's a rare event search, the data size is (relatively) large**



The data processor: `strax(en)`

- **`straxen`**: XENONnT-specific software; depends on **`strax`**, the general framework

- Nodes represent *data types*, edges represent processor *plugins*
  - Version control handled by deterministic hash of the version/configuration of the plugins



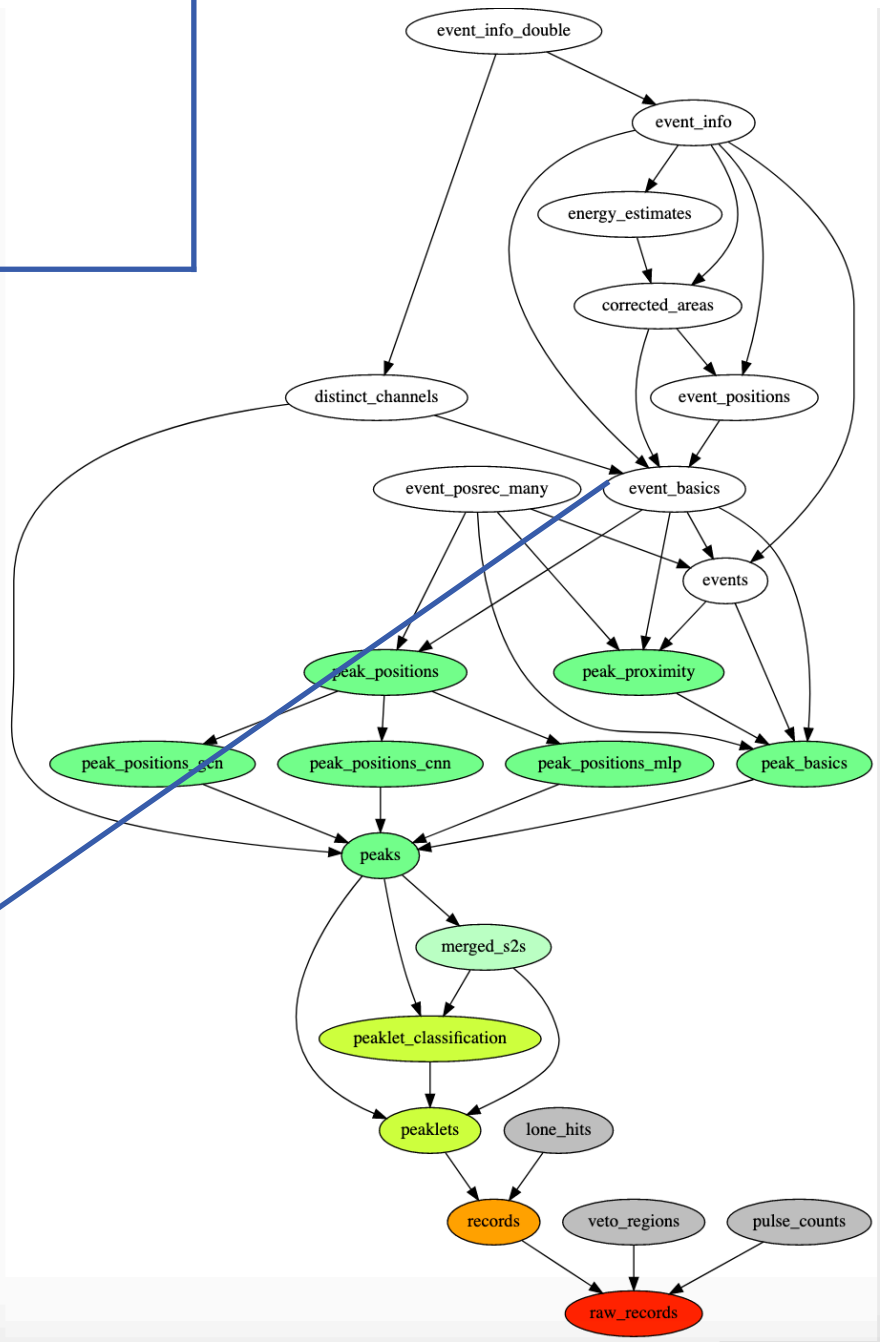
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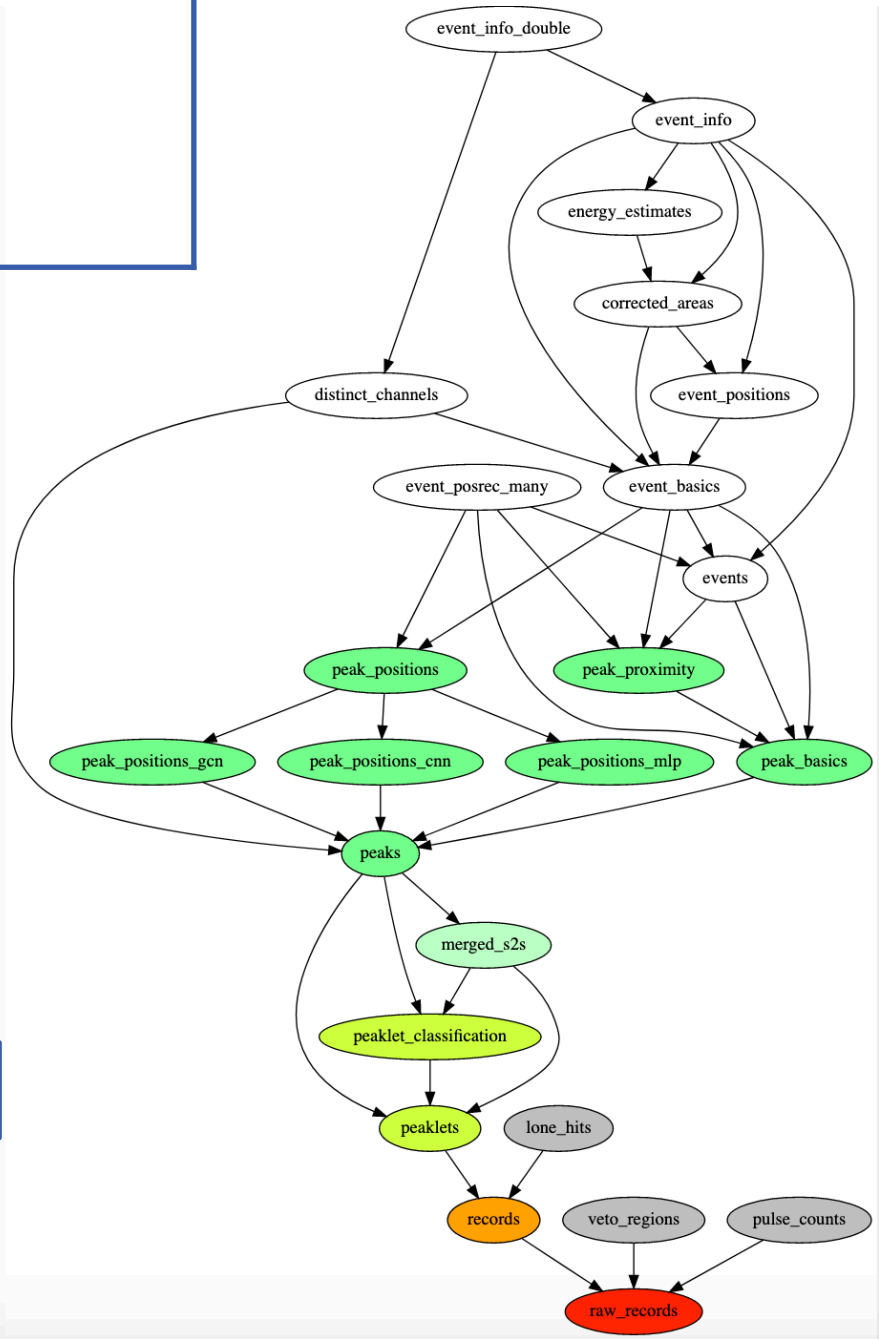
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```
012000-event_basics-kp55iw5x4w
012000-event_basics-fgmqnmxq2c
012000-event_basics-zqr3yrnipb
012000-event_basics-6uhrjyer67
```



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- Nodes represent *data types*, edges represent processor *plugins*
  - Version control handled by deterministic hash of the version/configuration of the plugins
- Low-level data distributed across multiple sites in US/Europe
  - Managed using **`rucio`**

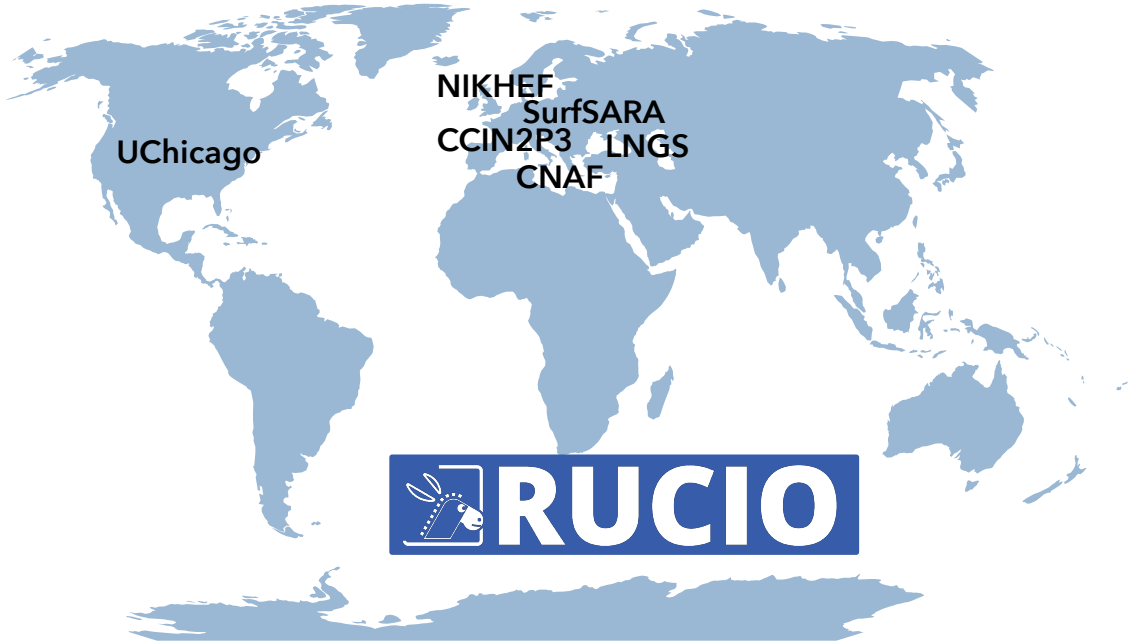


high level
~10 MB/hr

low level,
~100 GB/hr

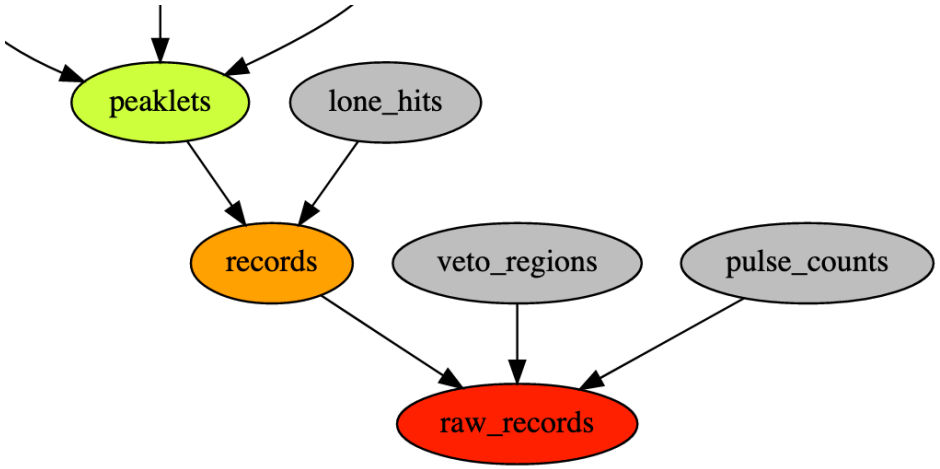
Data processing w/ OSG and Pegasus

- **`outsource`**: wrapper around **`pegasus`**
- Processes single *chunks* of data in parallel
  - usually ~500 chunks per hour of data
- Submit jobs to where the data is!
  - Leverages the Open Science Grid (OSG) and European Grid Infrastructure (EGI)




```
~ls 008756-raw_records-rfzvpzj4mf

raw_records-rfzvpzj4mf-000000  raw_records-rfzvpzj4mf-000007  raw_records-rfzvpzj4mf-000014
raw_records-rfzvpzj4mf-000001  raw_records-rfzvpzj4mf-000008  raw_records-rfzvpzj4mf-000015
raw_records-rfzvpzj4mf-000002  raw_records-rfzvpzj4mf-000009  raw_records-rfzvpzj4mf-000016
raw_records-rfzvpzj4mf-000003  raw_records-rfzvpzj4mf-000010  raw_records-rfzvpzj4mf-000017
raw_records-rfzvpzj4mf-000004  raw_records-rfzvpzj4mf-000011  raw_records-rfzvpzj4mf-000018
raw_records-rfzvpzj4mf-000005  raw_records-rfzvpzj4mf-000012  raw_records-rfzvpzj4mf-000019
raw_records-rfzvpzj4mf-000006  raw_records-rfzvpzj4mf-000013  raw_records-rfzvpzj4mf-metadata.json
```



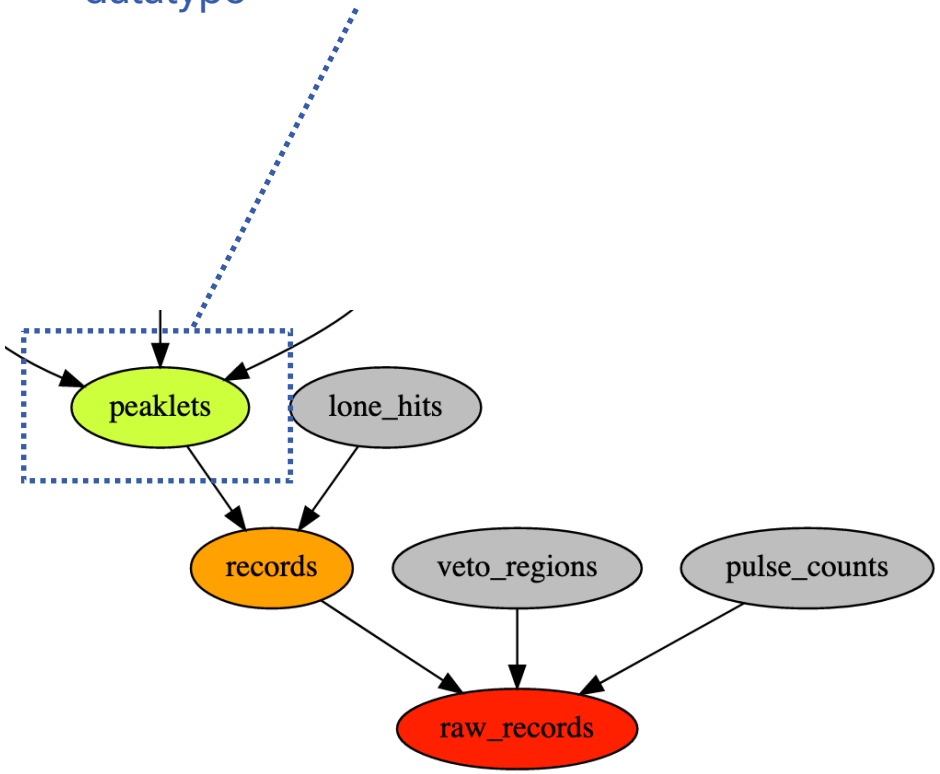
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raw_records-rfzvpzj4mf-000000  raw_records-rfzvpzj4mf-000007  raw_records-rfzvpzj4mf-000014
raw_records-rfzvpzj4mf-000001  raw_records-rfzvpzj4mf-000008  raw_records-rfzvpzj4mf-000015
raw_records-rfzvpzj4mf-000002  raw_records-rfzvpzj4mf-000009  raw_records-rfzvpzj4mf-000016
raw_records-rfzvpzj4mf-000003  raw_records-rfzvpzj4mf-000010  raw_records-rfzvpzj4mf-000017
raw_records-rfzvpzj4mf-000004  raw_records-rfzvpzj4mf-000011  raw_records-rfzvpzj4mf-000018
raw_records-rfzvpzj4mf-000005  raw_records-rfzvpzj4mf-000012  raw_records-rfzvpzj4mf-000019
raw_records-rfzvpzj4mf-000006  raw_records-rfzvpzj4mf-000013  raw_records-rfzvpzj4mf-metadata.json
```

If update to the `peaklet_processing` plugin, need to remake the `peaklets` datatype



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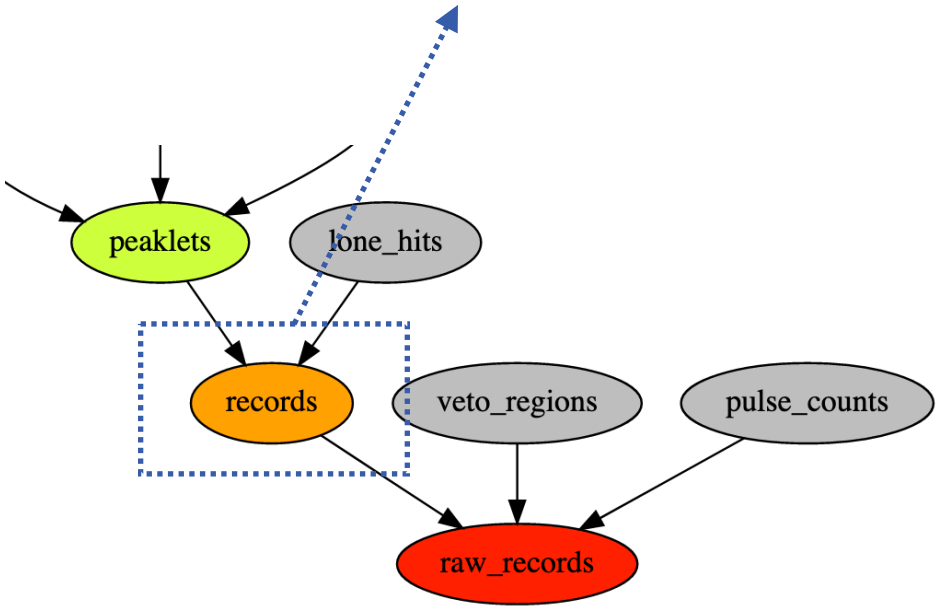
raw_records-rfzvpzj4mf-000000  raw_records-rfzvpzj4mf-000007  raw_records-rfzvpzj4mf-000014
raw_records-rfzvpzj4mf-000001  raw_records-rfzvpzj4mf-000008  raw_records-rfzvpzj4mf-000015
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raw_records-rfzvpzj4mf-000006  raw_records-rfzvpzj4mf-000013  raw_records-rfzvpzj4mf-metadata.json
```

Create 1-layer diamond(-ish) DAG

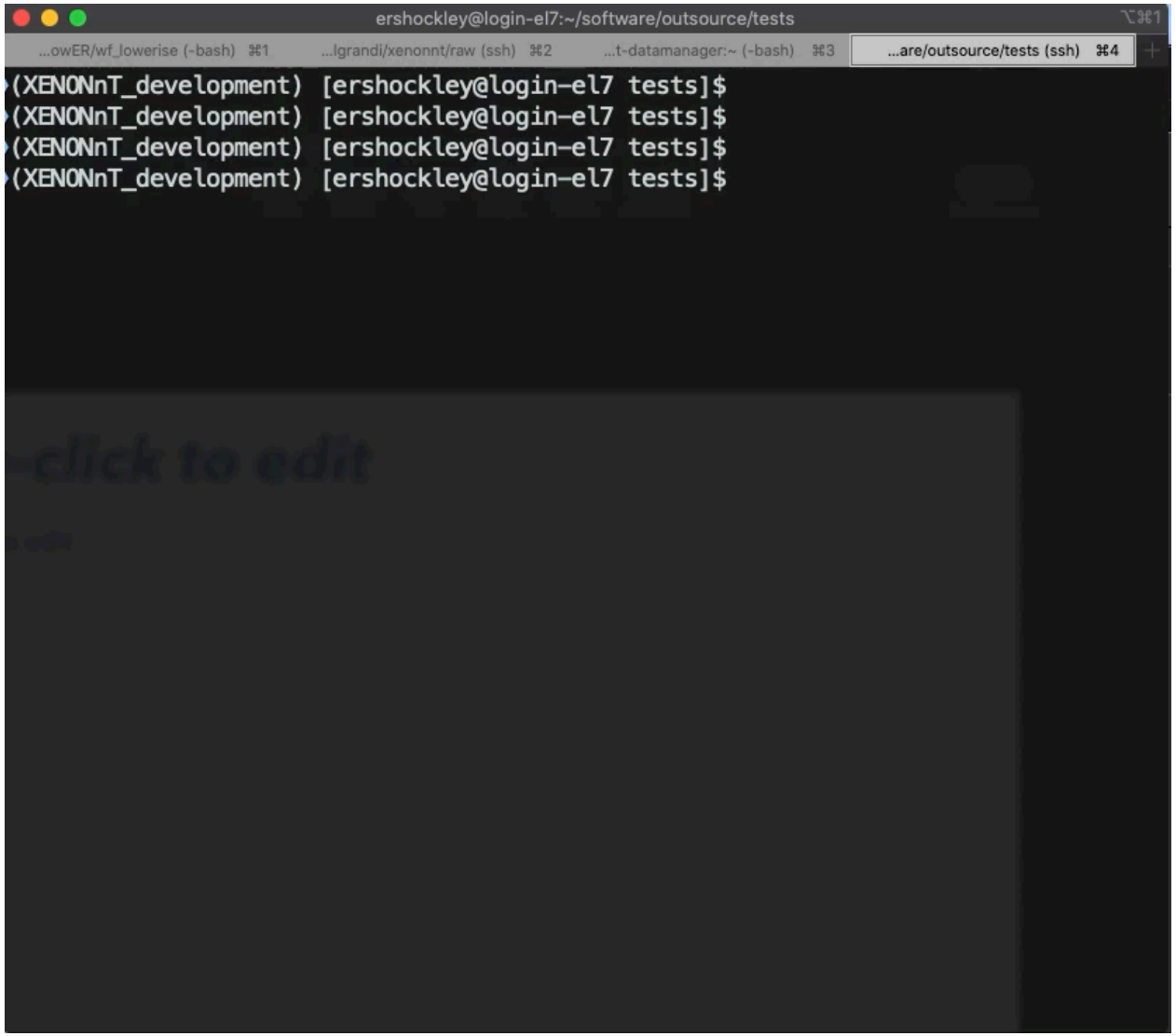
Also need to remake `records`! Needs 2-layers

YES **NO**

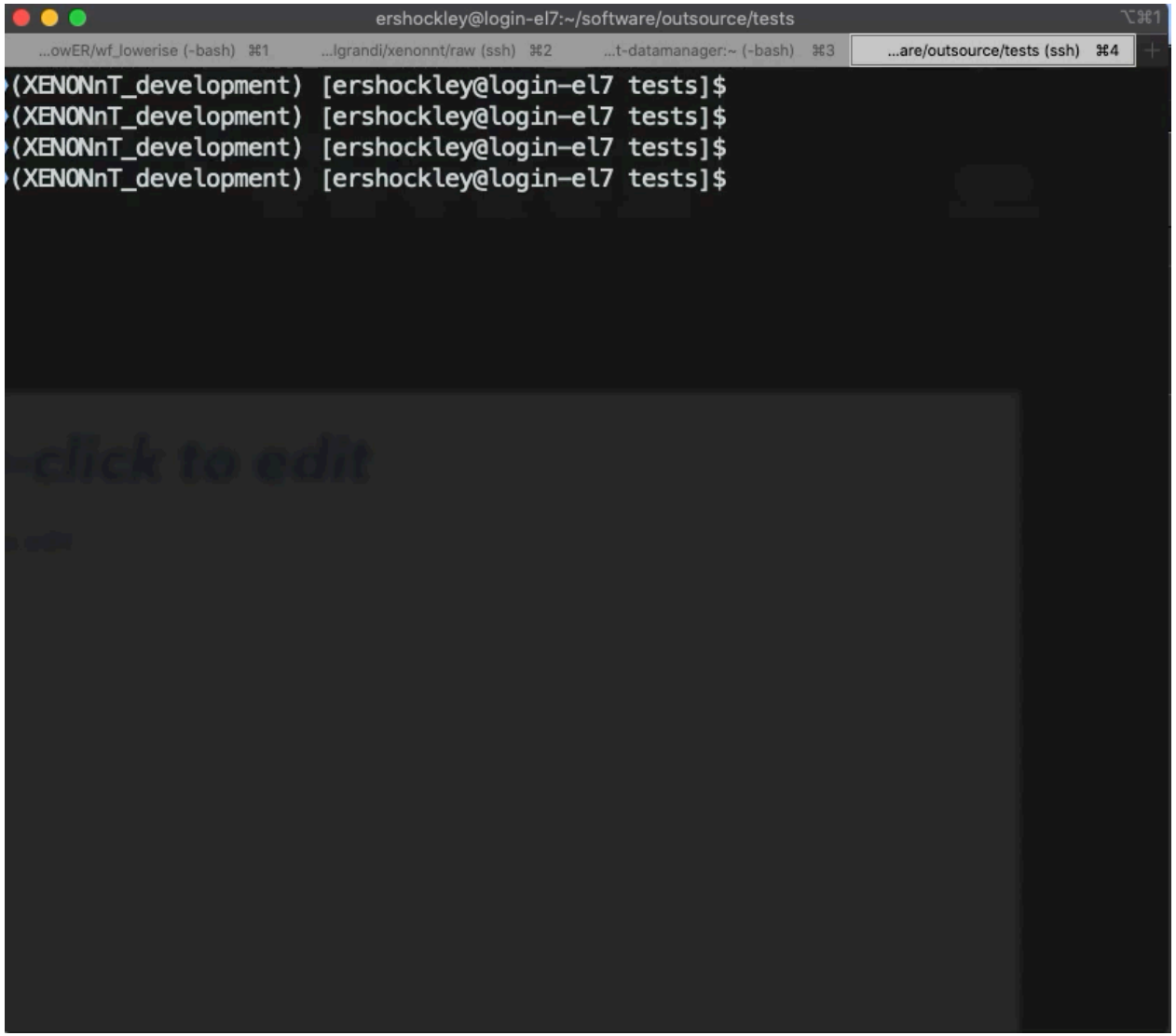
The specified version of `peaklets` calls for a specific version of `records`. Does that version exist?



Example workflow



Example workflow



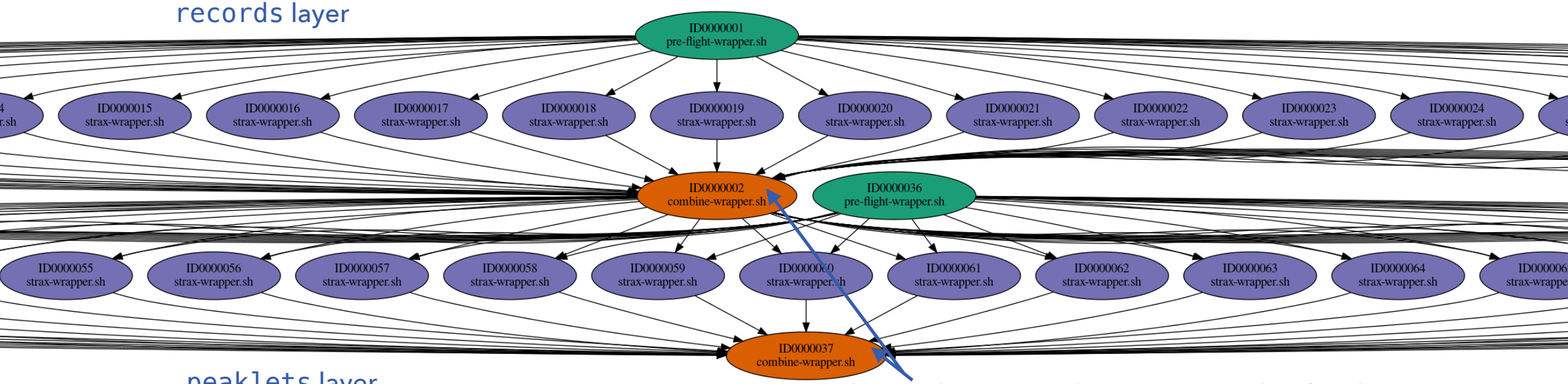
Example workflow

1. Download chunk(s) w/ rucio
2. Process chunk(s) w/ strax
3. Stage output(s) for merging
4. Merge outputs and upload to rucio
5. Repeat (if necessary)

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records layer

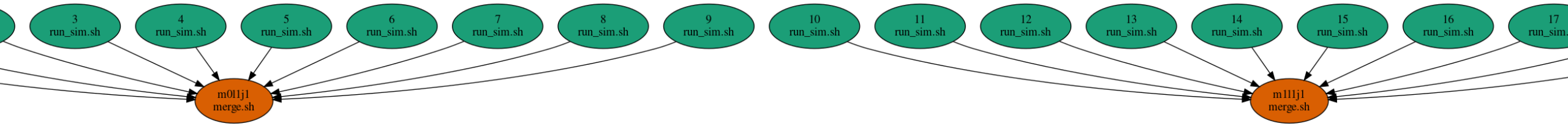


peaklets layer

combine jobs merge the outputs and upload to rucio

Monte Carlo production w/ Pegasus

- Simulate interactions of various sources in the XENONnT detector using Geant4
- Pass output of Geant4 to the XENON waveform simulator… which then can go through full processing like normal data
- Very similar workflow to data processing
  - OSG and Pegasus
  - Will also use rucio for data storage (under development)
  - Produce ‘raw’ data and then ‘processed’ data (under development)



Output batched into reasonable sizes, and uploaded to rucio

Summary

- The nature of dark matter is one of the biggest open questions in physics today
- XENONnT will search for dark matter with unprecedented sensitivity with real discovery potential
- Pegasus is critical component in the data flow and the Monte Carlo production, and thus in the science that we do.
- Huge thank you to Mats Rynge and rest of Pegasus team for all your support!



Our Pegasus Feedback



Things I love:

- The monitoring and statistics!
- The way transfers are handled! Can stage data somewhere really easily
- The workflow graphviz!

One super small thing is it would be nice if pegasus-graphviz could output directly to png or pdf. For this talk I had to convert the .dot (which is also fine). Or is this possible already?

During development I often want to quickly modify an executable after a failure, and then submit the rescue. But this changes the checksum of the file and resubmission fails. Is there a way around this?



Thank You!