DUNE COMPUTING STATUS

Heidi Schellman, Oregon State University

12/7/18

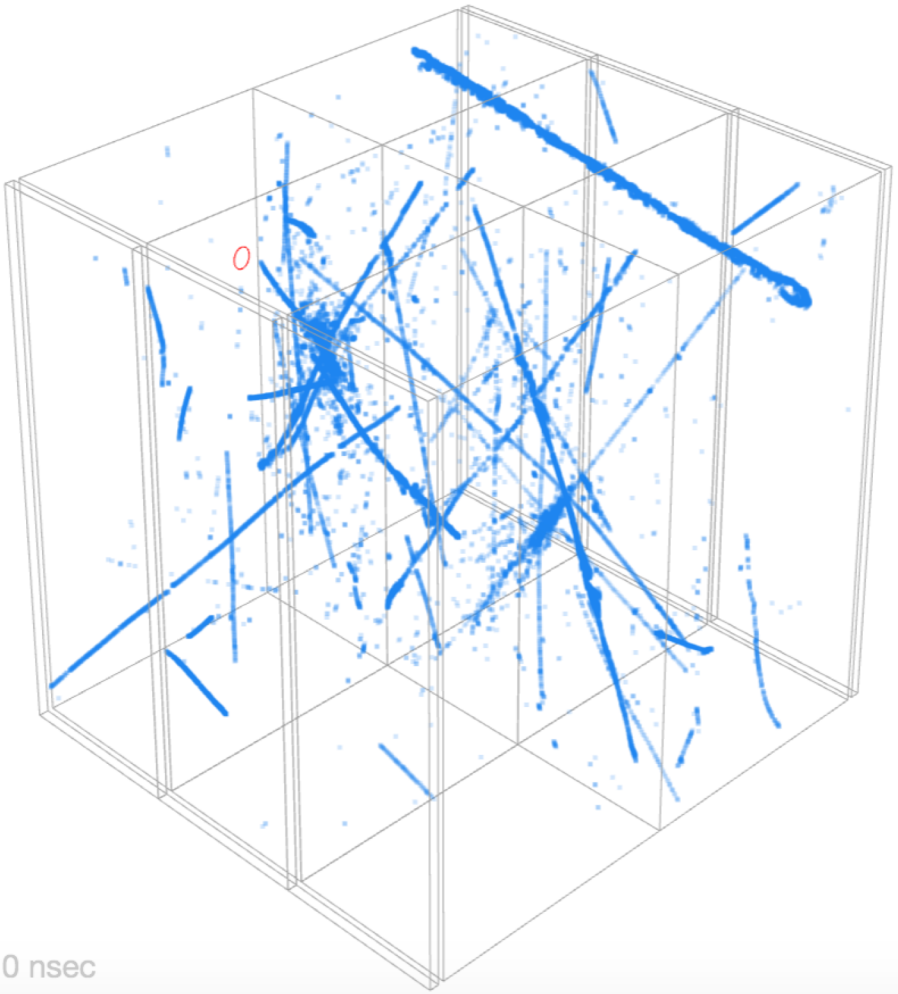
Overview

- Update on ProtoDUNE and what we learned
- Consortium status
- TDR status

https://www.phy.bnl.gov/twister/bee/set/protodune-live/event/1/?camera.ortho=false&theme=dark

Typical protoDUNE event

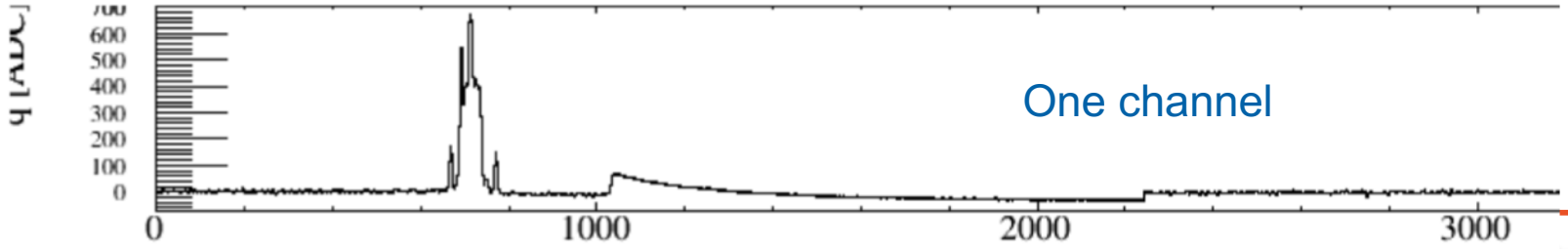
7 Gev Beam
+ cosmics



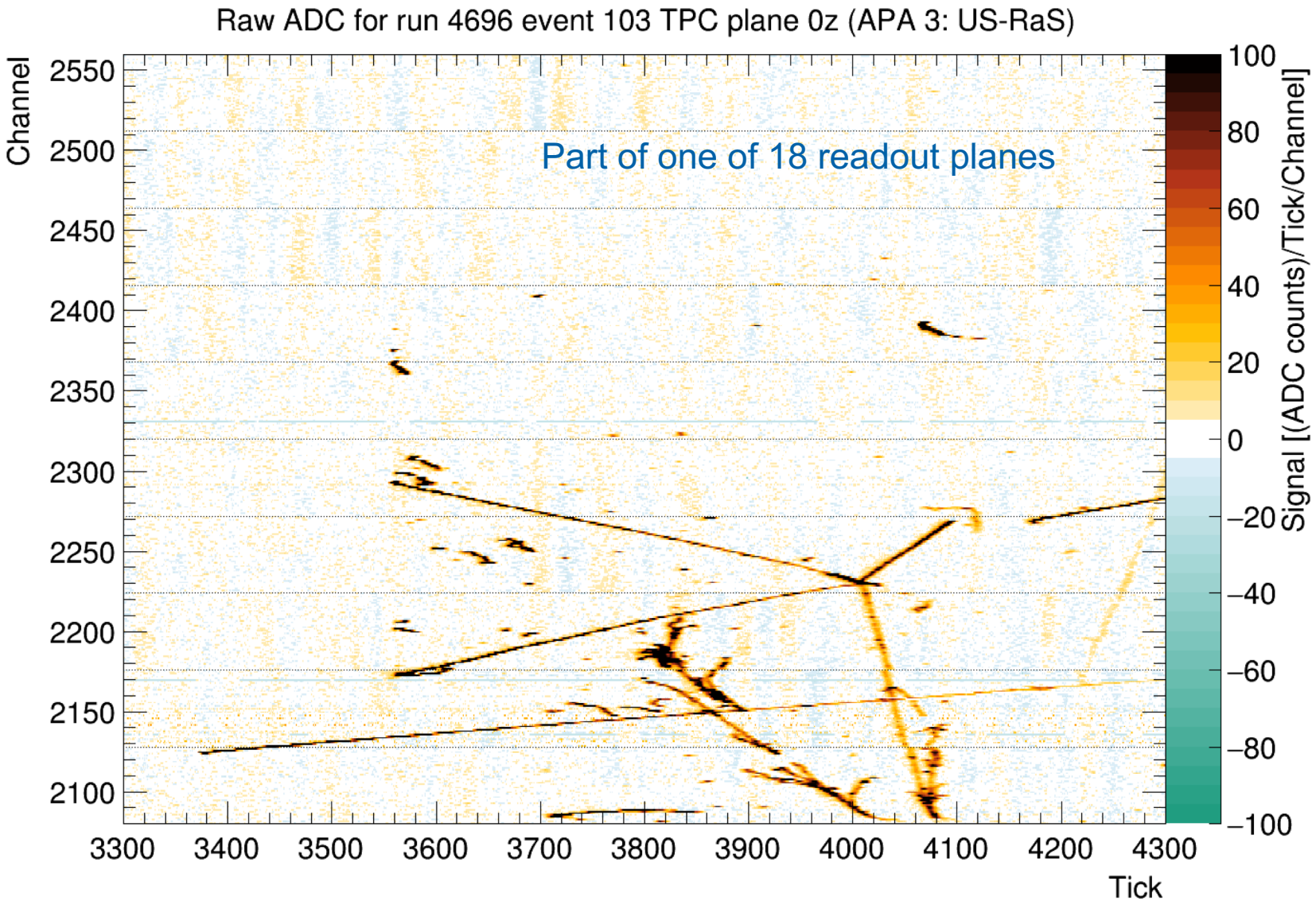
Event: 5144 - 1 - 47293 | trigger: 12
Wed, 10 Oct 2018 20:36:35 +0000 (GMT) + 0 nsec

ProtoDUNE @CERN

- Two walls of the cryostat are covered with 3 planes of wires spaced 0.5 cm apart. Total of **15,360** wires
- The electrons take ~ 3msec to drift across and you need to detect and time them for the full time
- Each wire is read out by 12-bit ADC's every 0.5 microsecond for 3-5 msec. Total of around **6,000** samples/wire/readout.
- Around **230 MB/readout → 80-100 MB compressed**
- ProtoDUNE was read out at **10-25 Hz for a 6 week test run**
  - **2.5 GB/sec --> < 1 GB/sec after compression**
- One issue – this is a **1%** prototype of the real 4-module beast
- The big one won't read out as often….



Raw data


Raw ADC for run 4696 event 103 TPC plane 0z (APA 3: US-RaS)
Part of one of 18 readout planes
Channel
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
3300
3400
3500
3600
3700
3800
3900
4000
4100
4200
4300
Tick
100
80
60
40
20
0
−20
−40
−60
−80
−100
Signal [(ADC counts)/Tick/Channel]

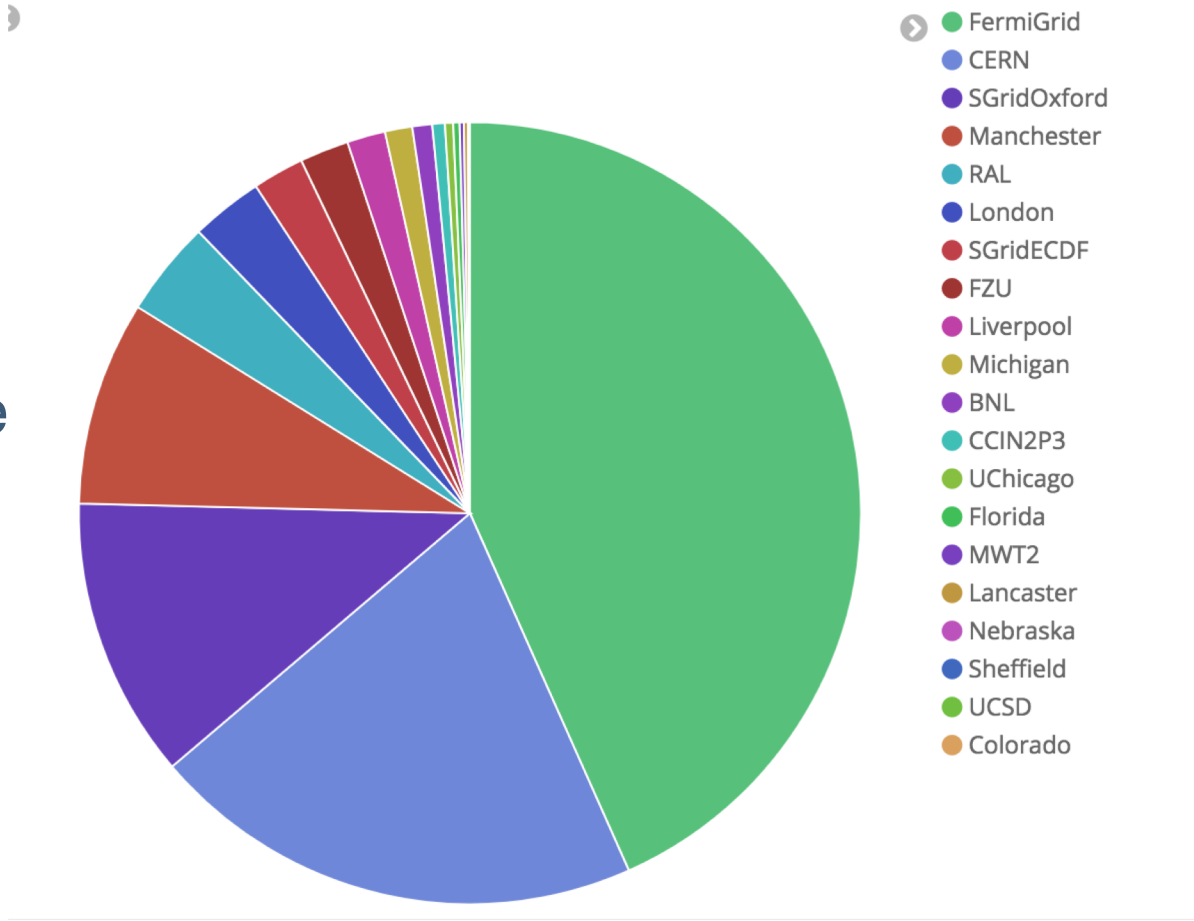
Data processing pass 1 complete

- Total 42M raw events acquired through commissioning, detector calibration and physics running (1.8 PB)
- 7.9 M events in good physics runs (all triggers, not just beam) acquired for physics analysis (509 TB)
- All good beam data processed in November (~ 2.5M wall-hrs)
  - 1.04 PB of reconstructed data events
- Also produced 14M reconstructed MC events in MCC11

Worldwide contributions

- Location of grid jobs November 1-24
- A total of ~250,000 reconstruction and simulation jobs were run.
- Up to 17,000 jobs at once

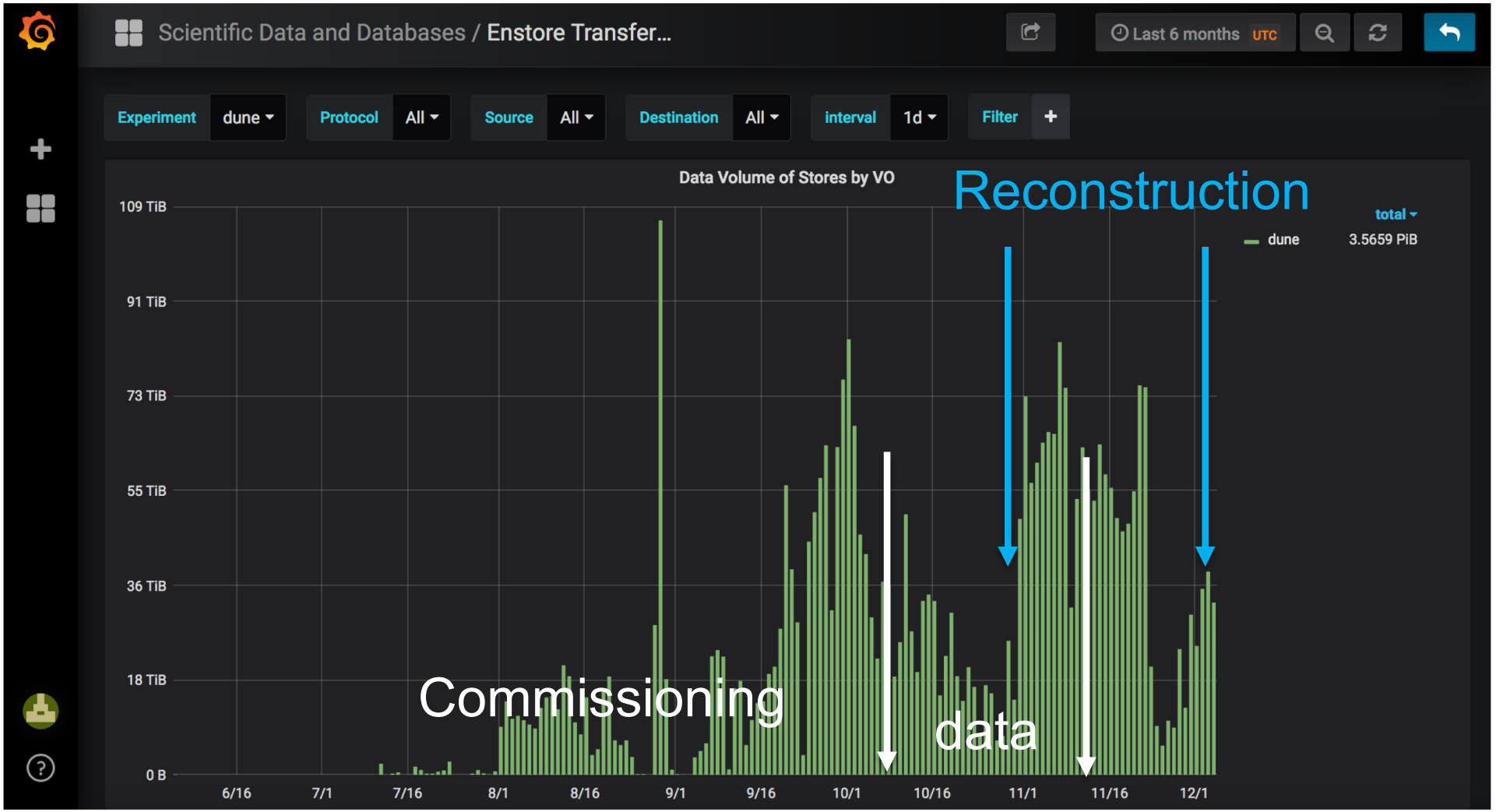
  ~10 (up to 24) hrs/job
- 60% were external to the dedicated resources at FNAL



Storage

- Using dCache/pnfs at FNAL, EOS/CASTOR at CERN
  - Moving some samples to UK
- Successes
  - Able to safely store data at rates of up to 2.5 GB/s
  - Reconstruction code is already able to produce high quality results
- Test version of Rucio able to control large datasets and interface with the SAM catalog
- Issues
  - Data location and cache access
  - Getting info needed to catalog data fully

Enstore TB/day



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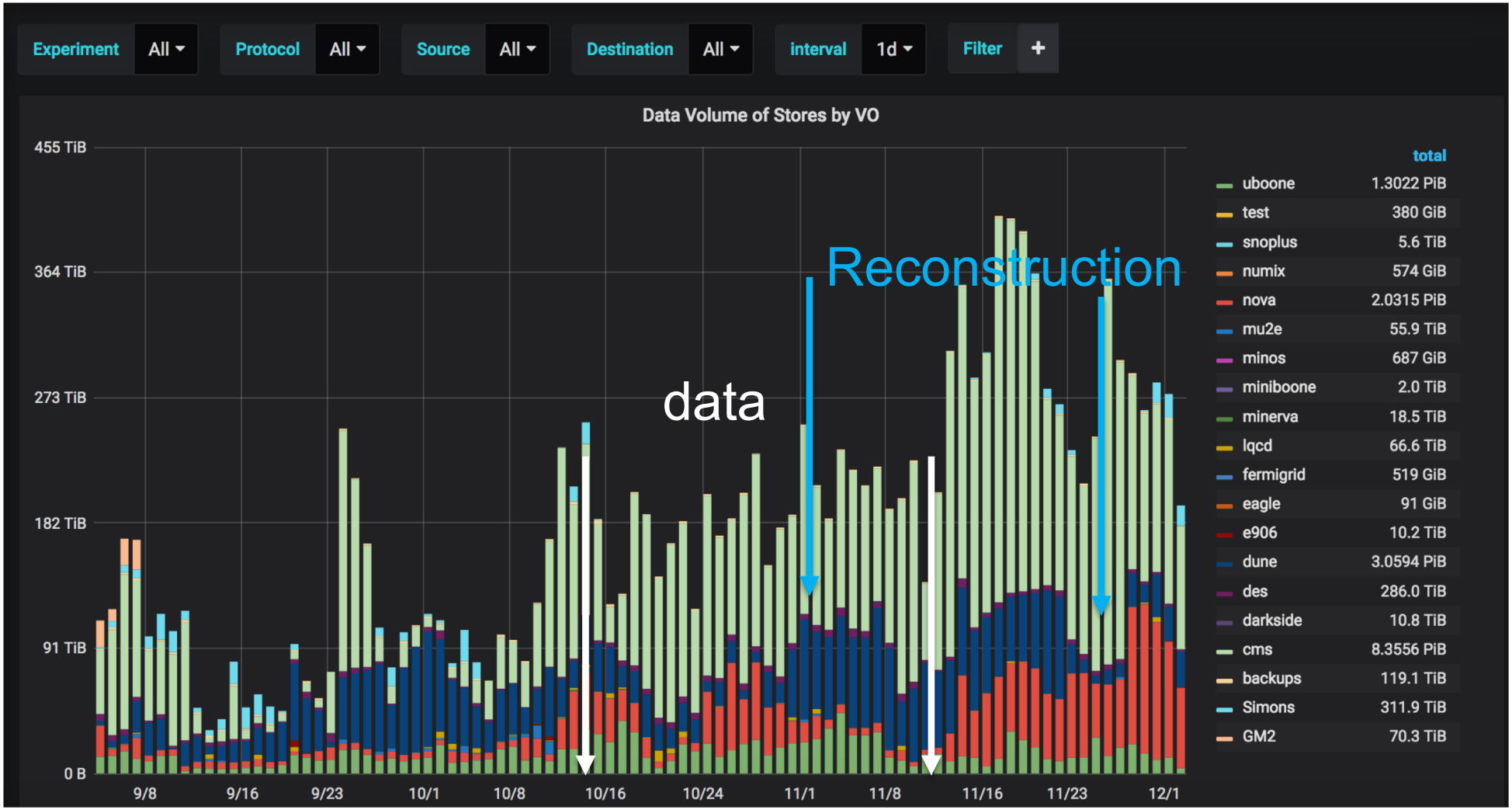
Context

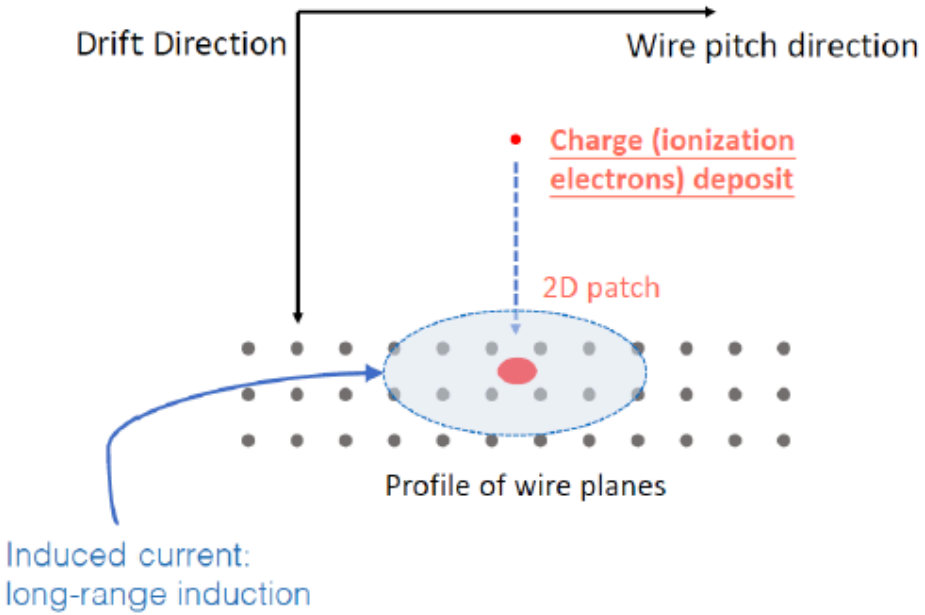
(DUNE is dark blue)



Upcoming: Wirecell deconvolution

Wenqiang Gu on behalf of the Wire-Cell team

Long-range induction → 2D deconvolution



- However, the induction from neighboring ionization electrons has to been considered

$$\begin{pmatrix} M_1(\omega) \\ M_2(\omega) \\ \dots \\ M_{n-1}(\omega) \\ M_n(\omega) \end{pmatrix} = \begin{pmatrix} R_0(\omega) & R_1(\omega) & \dots & R_{n-1}(\omega) & R_n(\omega) \\ R_1(\omega) & R_0(\omega) & \dots & R_{n-2}(\omega) & R_{n-1}(\omega) \\ \dots & \dots & \dots & \dots & \dots \\ R_{n-1}(\omega) & R_{n-2}(\omega) & \dots & R_0(\omega) & R_1(\omega) \\ R_n(\omega) & R_{n-1}(\omega) & \dots & R_1(\omega) & R_0(\omega) \end{pmatrix} \cdot \begin{pmatrix} S_1(\omega) \\ S_2(\omega) \\ \dots \\ S_{n-1}(\omega) \\ S_n(\omega) \end{pmatrix}$$

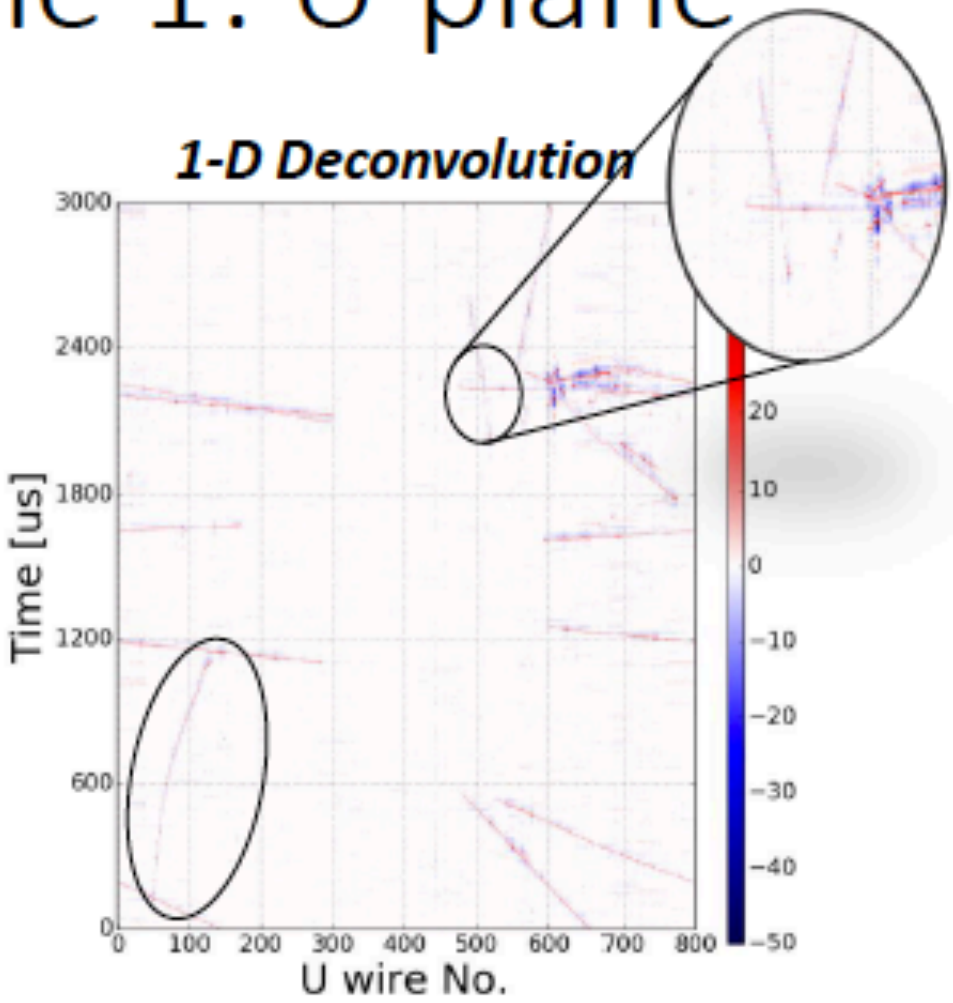
The inversion of matrix R can again be done with deconvolution through 2-D FFT

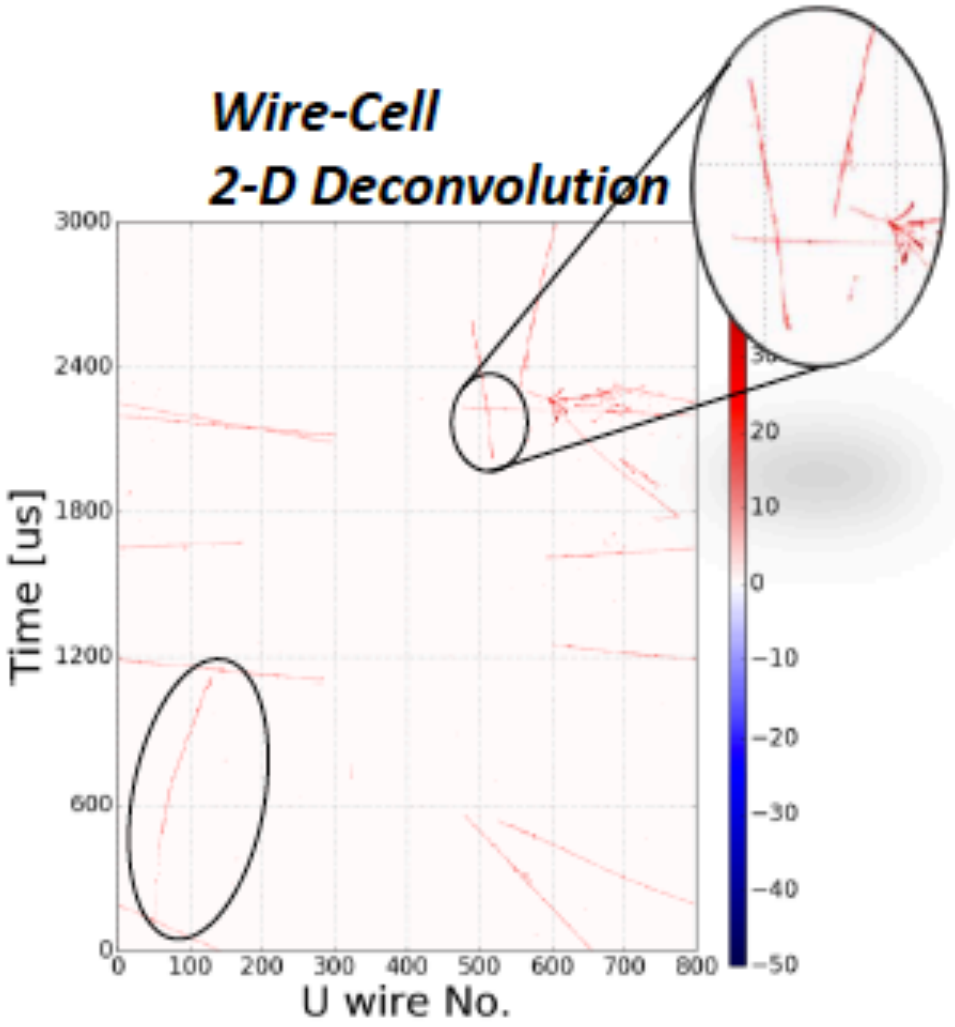
2D: both time and wires dimensions

Liquid Argon TPC Signal Formation, Signal Processing and Hit Reconstruction
Bruce Baller, *JINST 12 (2017) no.07, P07010*

Current 1D --> 2D

ole 1: U plane





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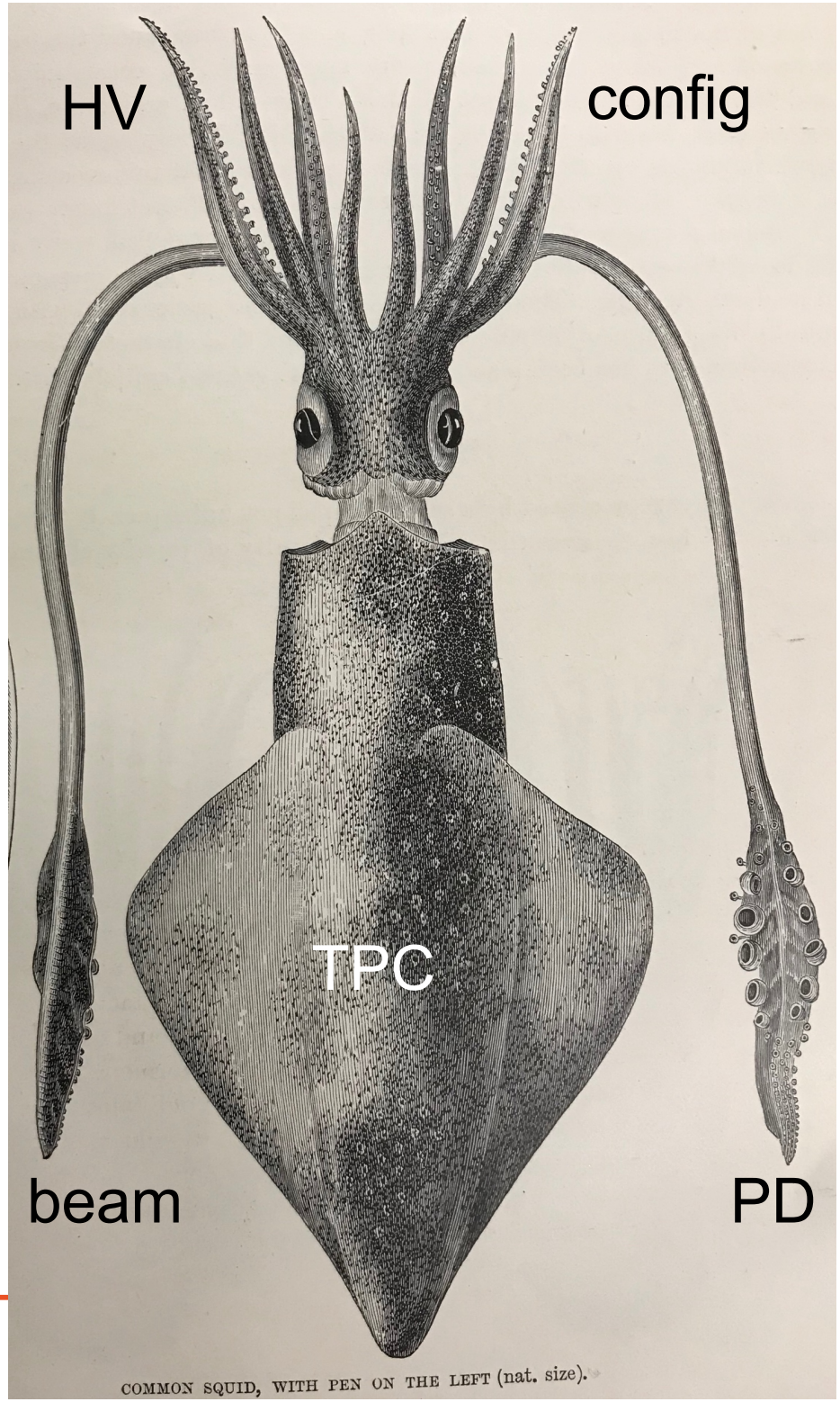
Lessons learned

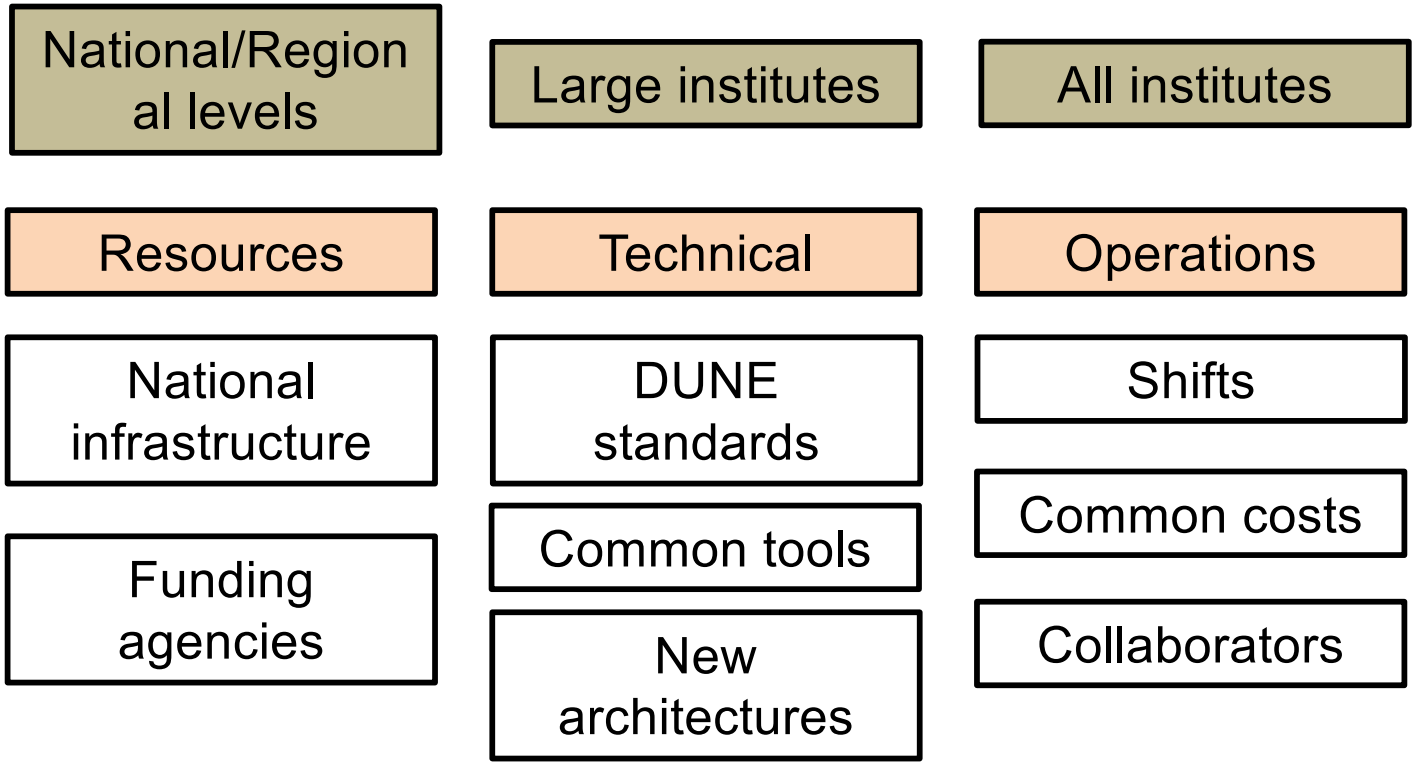
- LAr works!
- Larsoft/wirecell work paid off
- Data challenges were very important
- Many inputs needed aside from the “big” data
  - 3 detector systems (LAr, PD, CRT)
  - Run quality
  - slow controls
  - Beamline info
  - Configurations
  - Logbook
- A lot of high quality data



Part II - Consortium

- DUNE is in the process of forming a **Consortium** to coordinate resources worldwide
- In computing most of the **materials cost** comes from maintaining and providing services during the data-taking phase of the experiment.
- Prior to commissioning and data-taking, much of the contributions will be needed in **people-power** to adopt and build software needed by DUNE.

Three pronged approach to contributions



Countries / Organizations Already Contributing Substantial CPU Resources to DUNE Computing

- **FNAL** + contributions from **US labs and Universities**
- **CERN**
  - Has been discussing* broadening scope to HEP-wide computing for over a year. There is general support, DUNE could be a catalyst.
- **Czech Republic** - Already contributing and poised to continue.
- **United Kingdom** - Eagerly participating (3PB disk for protoDUNE) and have already taken steps to solicit funds for DUNE from their agency
- **France** – IN2P3 has started contributing resources – emphasis on dual-phase

India, Korea, the Netherlands, Spain, Italy and Switzerland have expressed interest but not yet integrated into production

Future DUNE computing scope

- Far Detector
  - Estimate from **IDR** of ~16 PB/year per FD module uncompressed. Dominated by cosmics and triggers primitives.
  - Negotiated limit of **30 PB/year**
  - With reasonable triggers/data reduction,
    - instantaneous data rates at **30 PB/year ~ ProtoDUNE**
- Near Detector
  - Unknown but rate will be ~ 1 Hz with many real interactions/gate and a complicated set of detector systems.
- These rates are doable but need to be kept that way.

DUNE needs: Large scale resources

- Many are **already accessible** thanks to WLCG/OSG
  - Requests for enhanced resources through national funding agencies
  - Access resources at institutions dedicated to local scientists
- Requires **local experts** to help with integration
  - This has been done successfully at multiple sites
- We need **tools** to monitor/optimize resources
- DUNE computing resources board will need to **assess, track and allocate resources** contributed by collaborating institutions and nations

DUNE needs: Technical Projects

These require highly trained experts. We will try to use pre-existing infrastructure where possible but need to integrate into DUNE

- **RUCIO** for file management
- Databases
- Accounting and monitoring systems to track performance/access
- Job management systems – need to evaluate and integrate
- Code and configuration management
- **Authentication**
- Adapting DUNE algorithms to use HPC's for large scale processing

All need to be evaluated and upgraded where necessary

DUNE needs: Operations/Policies

Need people to keep everything running – these may be students, or computer professionals.

- **Interfaces with Physics/Detector groups**

  → **Through membership in the technical board**

- **Data model! Who needs what when and where!**
- Monitoring and steering data flow
- Monitoring and tracking reconstruction processing
- Maintaining access lists and grid maps
- Maintaining metadata relevant to physics analyses
- Databases
- Algorithms
- Generate and upload calibrations

Summary

- We learned a **lot** from ProtoDUNE.
- DUNE is a truly **international** collaboration like the LHC experiments.
- We propose following an appropriately **modernized WLCG** model for DUNE computing.
- Do not reinvent the wheel – borrow or share where possible.
- The **whole collaboration** will supply computing resources. We're building the consortium to do that.
- Funding for LHC computing started 7 years before data taking. It is not premature to find mechanisms to support DUNE pre-operations computing.

Major issues/concerns

- **Data volumes and reconstruction needs**
  - We're optimistic after ProtoDUNE!
- **Resource models**
  - Many different models worldwide
  - Can't wait until 2024 to set up operations
- **Computing technologies**
  - HPCs
  - GPUs
  - Cloud
  - Processor developments
- Need **some dedicated people**
- **Interfaces/communication** with rest of DUNE

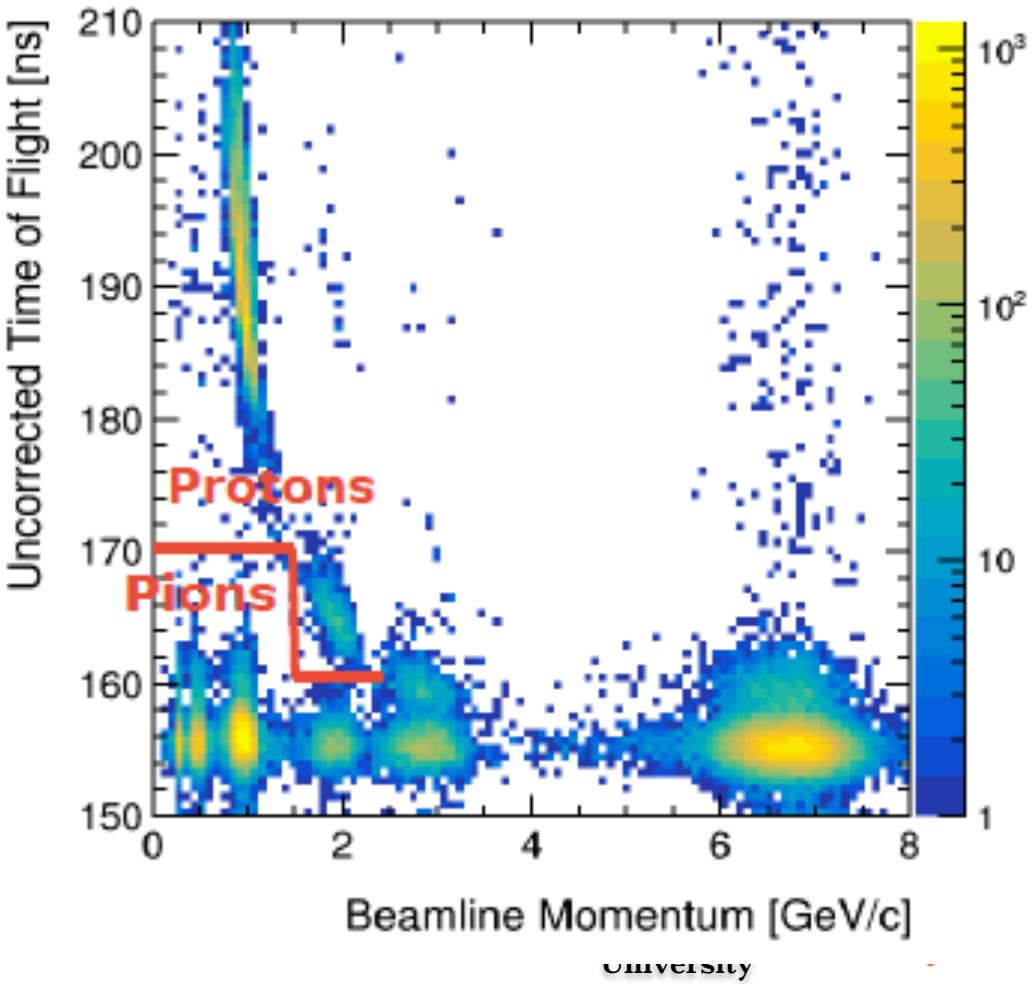
TDR/CDR Prep

- **Computing strategy section** to go into the TDR
- Short white papers by subgroups
  - Data Model – Andrew Norman/Georgia Karagiorgi
  - Data Management – Steve Timm/Adam Aurisano
  - Production – Ken Herner/Ivan Furic
  - Databases – Norm Buchanan
  - Data prep algorithms – David Adams/Tom Junk
  - Code management – Tom Junk (mostly done)
  - Integration – Schellman's holiday…
  - Due "soon" and go into docdb as standalone documents
- Schellman then does integration into a summary for the TDR
- **CDR** timeline is longer and **will involve the full Consortium**

Backup slides

IFBeam database -> events

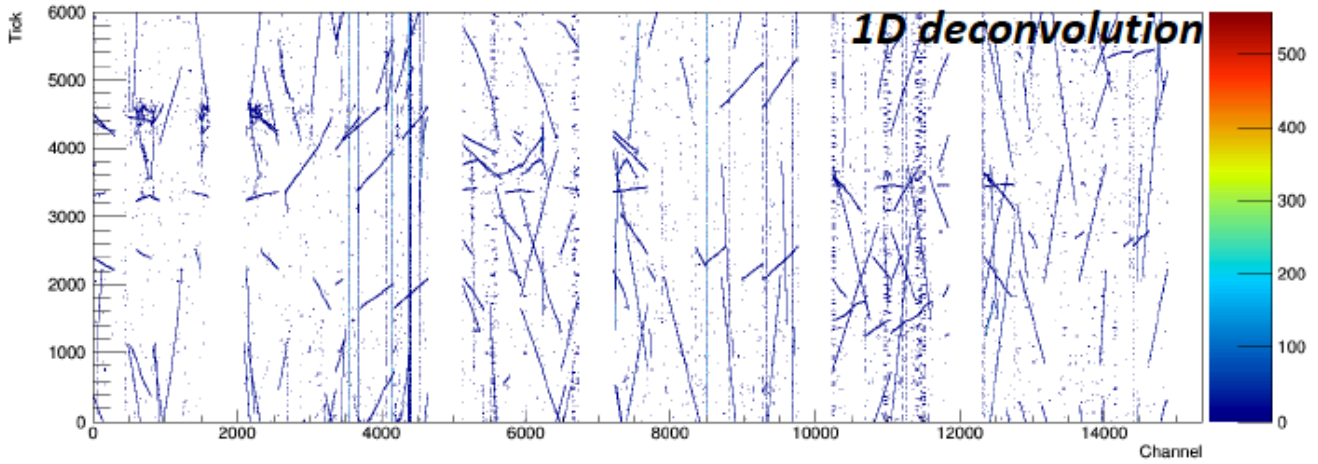
- Information from the beamline matched into the art record from the IFBEAM database
- 1% of data



Typical Event – 100 MB of compressed data

SP Performance in protoDUNE beam data

Run 5141, Event 23865
Threshold: 5
From the offline reco chain (protoDUNE_reco_data.fcl)



Run 5141, Event 23865
Threshold: 3σ noise
Unit: # of electrons
From Wire-Cell toolkit

**: There is still room for improving the software filter and some thresholds, etc.*
***: Noise filtering has not been applied here for both 1D & 2D.*