DEEP UNDERGROUND NEUTRINO EXPERIMENT

Data-Acquisition Overview

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Thanks!

Many thanks to Simon Peeters and Giles Barr for leading the UK DAQ project over the last 4 years

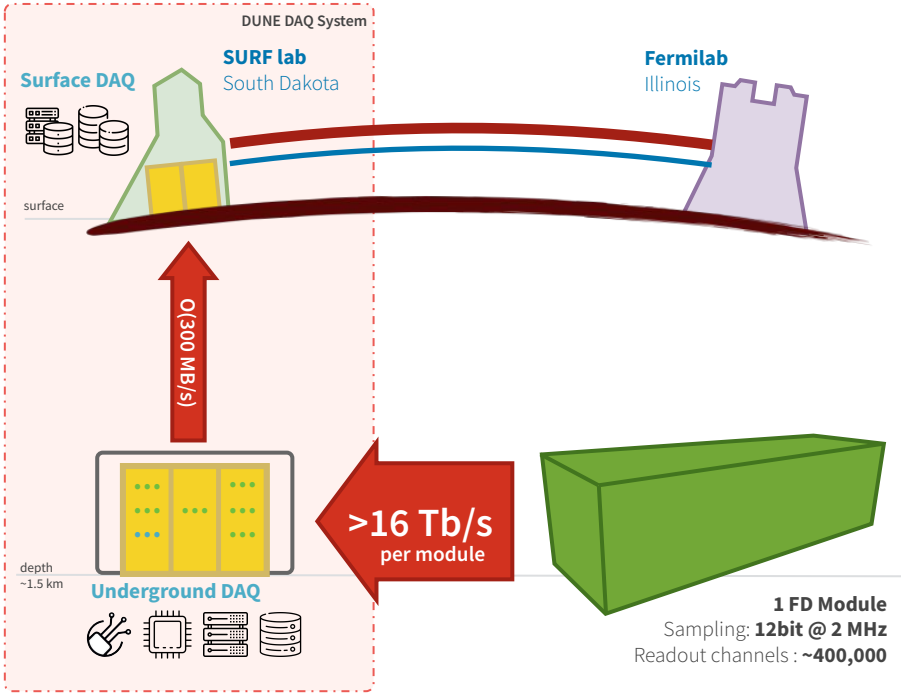
The DUNE Trigger and DAQ system

DUNE DAQ System Goals

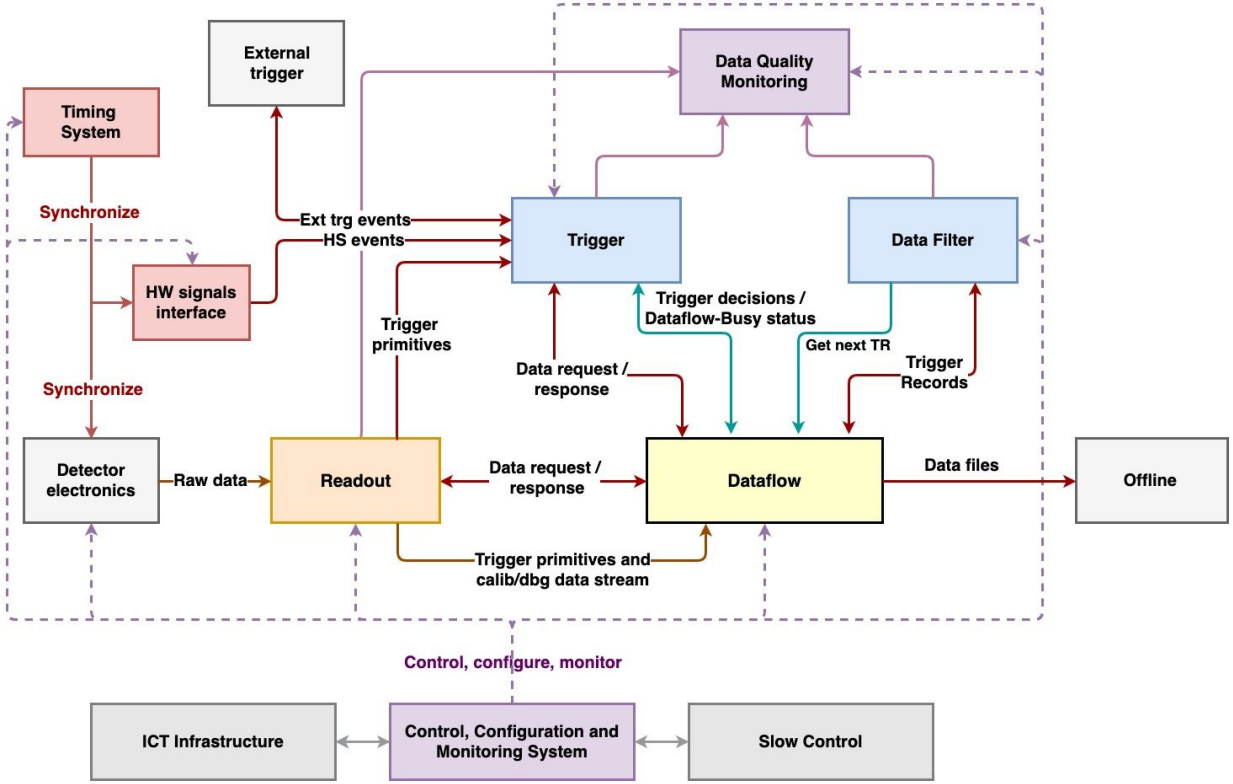
- Distribute clock and unique timestamping to all detector components
- Collect large amount of data from detector
  - Receiving and buffering of detector data with custom high-performance firmware and software
- Selects only interesting interactions
  - Extraction of trigger primitives
  - Triggering on interesting detector activity using software algorithms
- Buffers the full data stream for ~100s for supernova physics
- Deliver selected interactions to permanent storage
- Serve both Far and Near detector

Unique key challenges

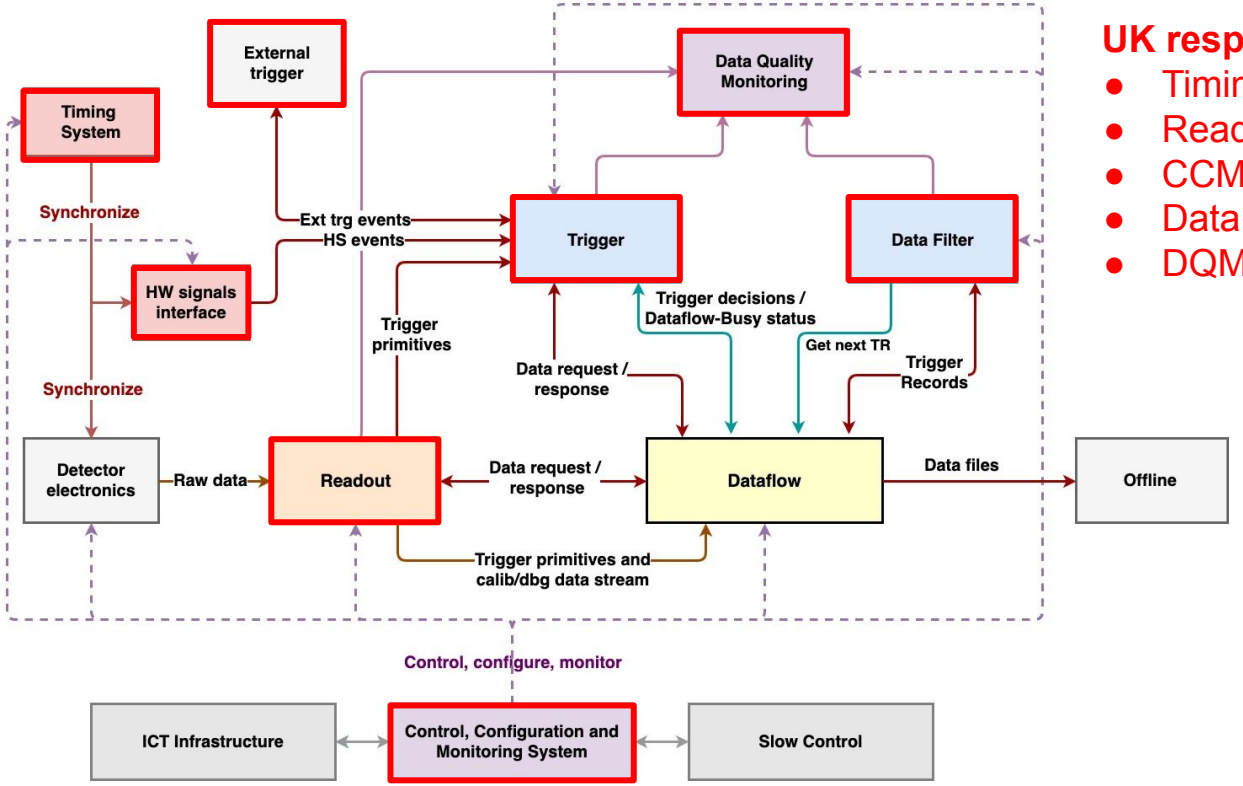
- High, data rate, high uptime
  - Use of commodity networking, computers, and storage
  - High-performance and resilient custom and off-the-shelf software for the remaining DAQ functions
- Remote experimental site
- Deep underground in an active mine



DUNE FD DAQ


External trigger
Data Quality Monitoring
Timing System
Synchronize
Ext trg events
HS events
Trigger
Data Filter
HW signals interface
Trigger decisions / Dataflow-Busy status
Get next TR
Trigger primitives
Data request / response
Trigger Records
Synchronize
Detector electronics
Raw data
Readout
Data request / response
Dataflow
Data files
Offline
Trigger primitives and calib/dbg data stream
Control, configure, monitor
ICT Infrastructure
Control, Configuration and Monitoring System
Slow Control

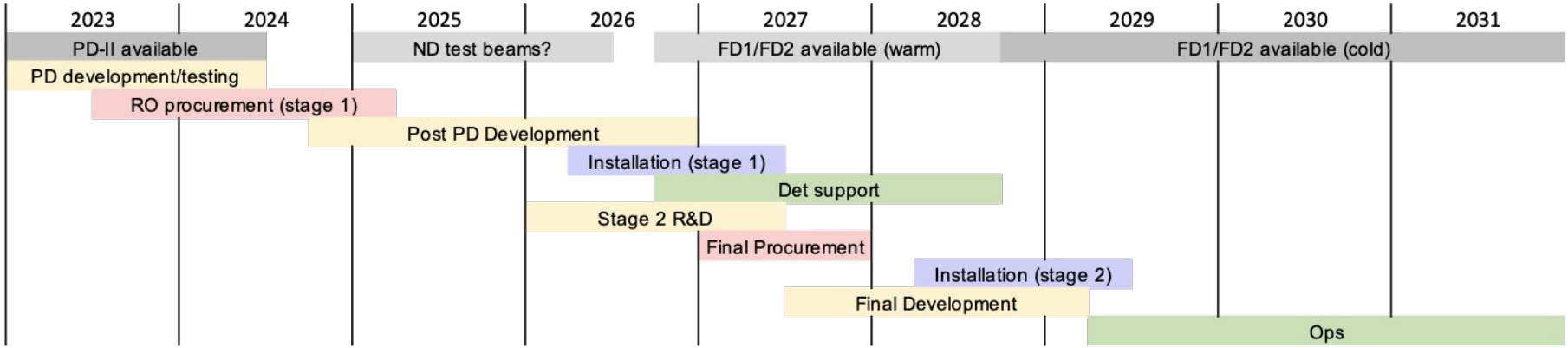
DUNE FD DAQ



UK responsibilities :

- Timing system
- Readout (w CERN)
- CCM
- Data Selection
- DQM

So where are we?



High level schedule (draft)

Outline of DAQ activities from now until physics

Overall DAQ Status

- PDR passed in January 2022
- 2022 DAQ development plan geared to reach a feature full system to operate PD-II HD and, shortly after, PD-II VD
- Several new key features implemented
- Supported APA installation and electronics installation for HD coldboxes and VD coldbox operations
- Started recovery from COVID years, stronger presence of UK staff and students at CERN
- Preparation for the FDR in the endgame

Issues and challenges in 2022

- Loss of key figures to the private sector, P. Rodrigues among others
- Uncertainties keep affecting our capability of planning
  - From global events - PD-II HD delayed due to lack of liquid argon
  - From DUNE - installation schedule in continuous evolution
- Only subset of development goals achieved
  - Important changes in timing, readout and DQM
  - Operations and support load expected, but underestimated (as usual)
  - Implementation time estimates still poor, especially when large codebase chances are required

What to look for in 2023

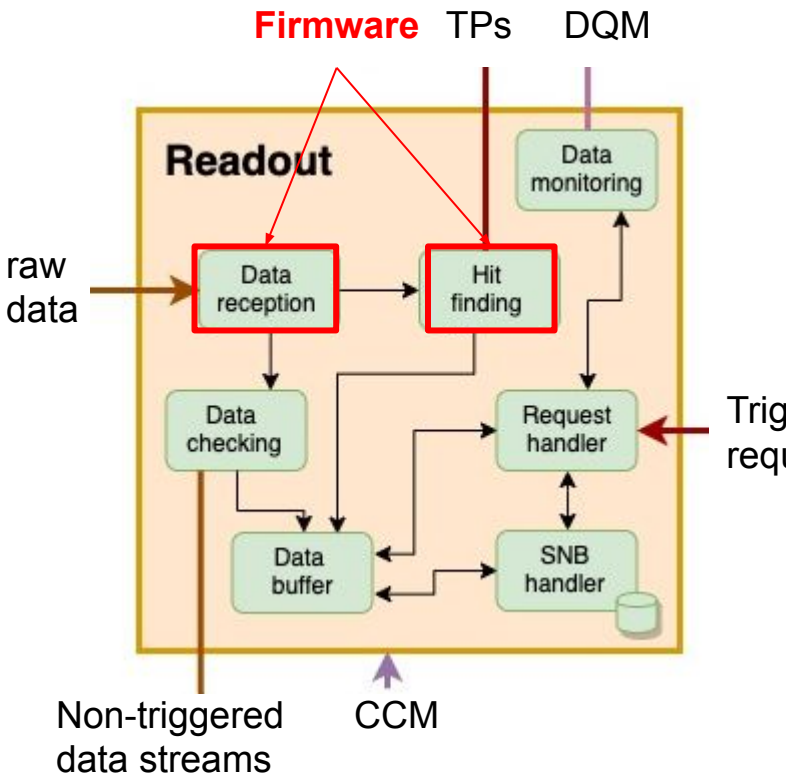
- Integration with detectors
  - VD Top detector electronics
  - PDS electronics
  - Transition to ethernet readout for WIBs
- Commissioning and operations
  - PD-II HD - finally?
  - VD coldbox - looking into using CRP1b to further integration with top/bottom electronics ahead of PD-II (HD and VD)
- Production of the timing system
- Further development/design of CCM/DQM/Data Selection/Readout system
- Presence of UK DAQ personnel at EHN1 will be crucial

UK DAQ Status

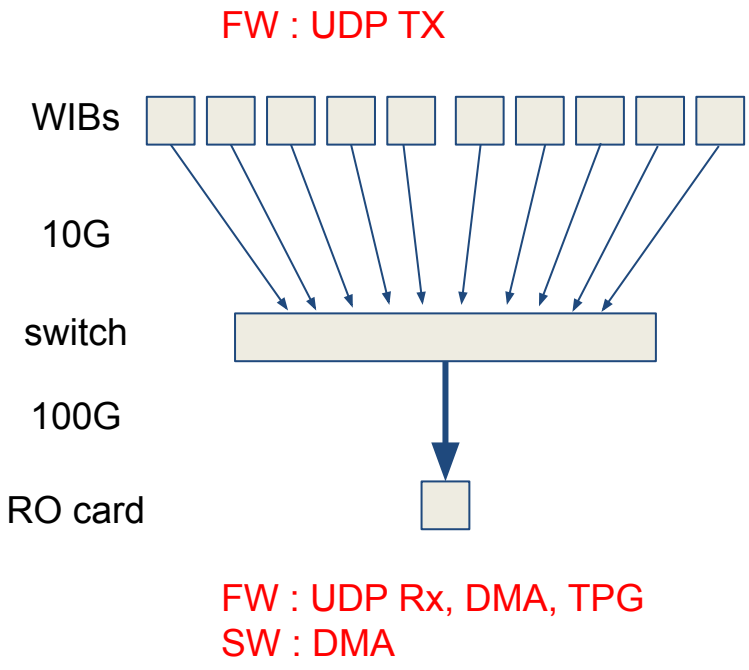
- Readout: focus of many discussions in the past months
  - More in the next slides
- Progress in all areas of UK responsibility but with some struggles
- Mid-term review
  - Offered opportunity to look at sub-WP needs and resources
  - Need to strengthen expertise in several areas and clarify responsibilities
  - Conservative resource estimate prepared for the review
- Towards the PPRP proposal
  - Add details to planning in some areas : CCM, Trigger, DQM
  - Work with institutes to finalise responsibilities and resource requirements

Readout

- The plan has evolved substantially over the past 12 months
- Original plan for FD1 :
  - Data reception + hit-finding in custom card
  - ATLAS FELIX firmware (+protocol)
- Vertical Drift introduced data source (Top Drift Electronics) which transmits data via Ethernet (UDP)
  - Which requires a new firmware stack
- Decided to adopt Ethernet as a common protocol across HD and VD
  - Move to an off-the-shelf FPGA card
  - Reducing risks associated with custom production



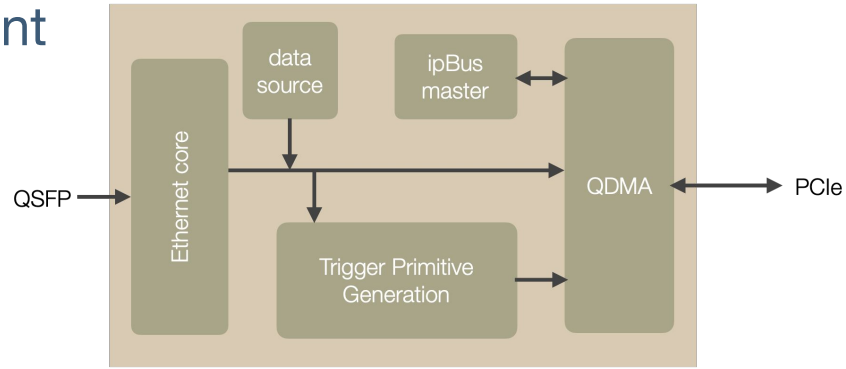
Ethernet Readout



- Readout networks for both TPC and PDS look as shown
  - Non-blocking L2 network
  - 48x10G/8x100G switches
  - 42 switches required for FD1 (38 TPC + 4 PDS)
- VD differs only in topology
  - Bottom drift : 12x10G→100G
  - Top drift : 4x40G→100G
  - 45 switches in total

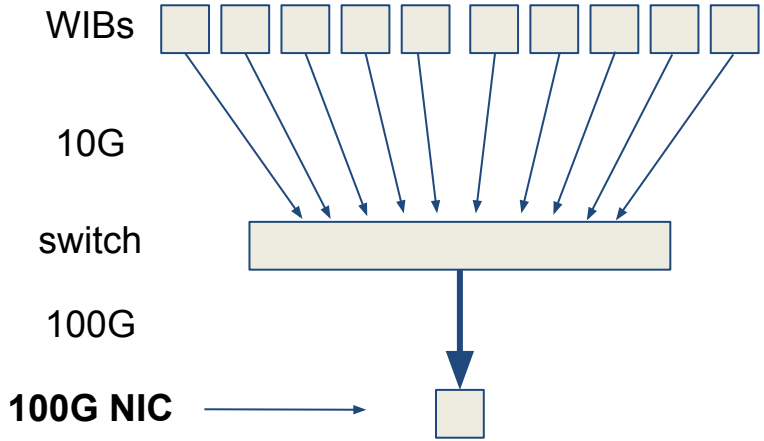
Data Reception & Hit-Finding

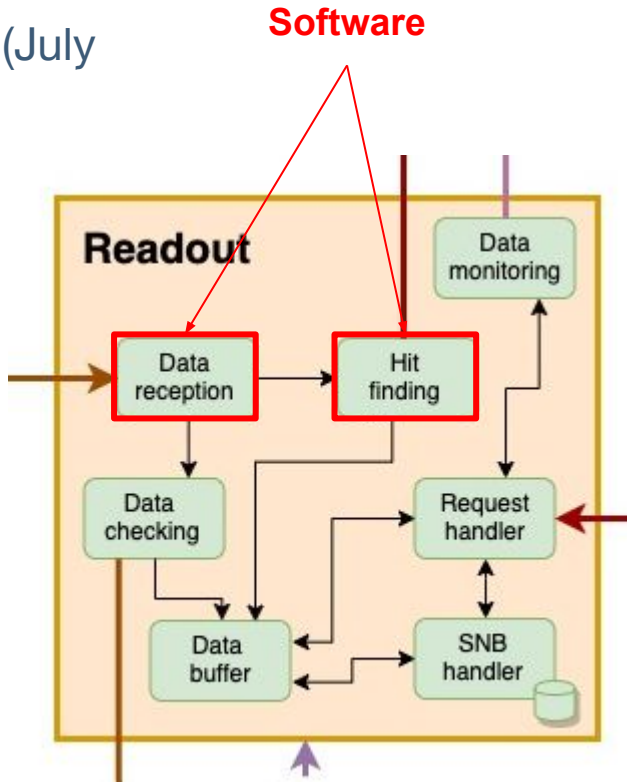
- Firmware
  - Format, transmit, receive data as UDP packets
  - Resilient DMA to host memory
  - Data routing for processing
  - Trigger primitive algorithms
- Software
  - DMA drivers & buffer management
  - Card/firmware control



NIC based solution

- Stopgap to support early detector integration (July ‘22)
- Data reception via 100G network card (NIC)
- Software TP prototype available since 2019
- (Firmware still required for Ethernet Tx component)





Schedule Issues

- By mid 2022, FW development was behind schedule on all fronts : Ethernet Tx+Rx, data reception, TPG
  - Loss of key staff member working on Ethernet
  - Technical challenges in Ethernet data reception
  - TPG FW slippage built up over since 2021
- Schedule problems :
  - **FDR (Jan ‘23)** - working demonstrator will not be available
  - **Procurement (Apr ‘23)** - demonstrator required to specify components
  - **PD-II (mid 2023)** - no platform available to support integration and commissioning with detectors (due to start mid 2022).
- Fundamental issue - shortfall in firmware expertise

New Readout Baseline

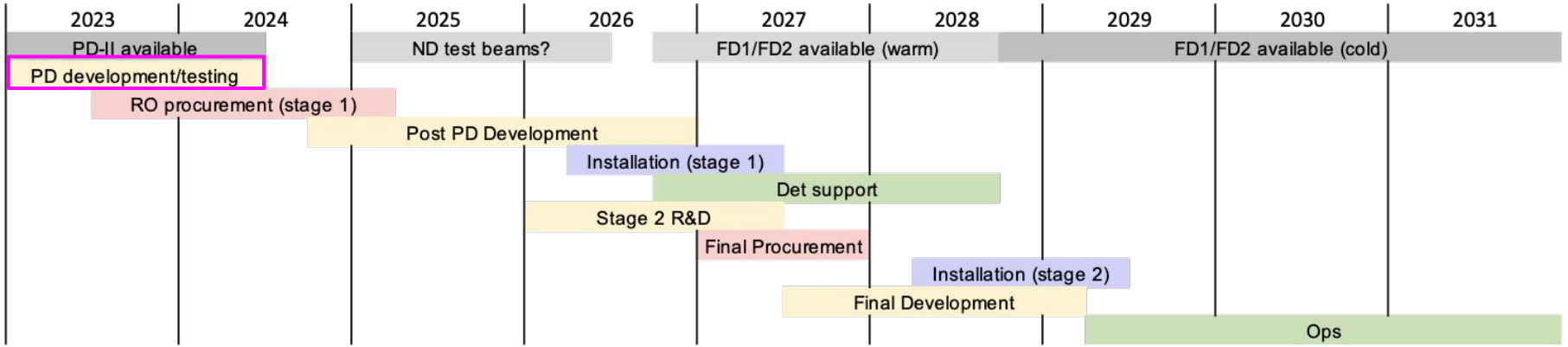
- Detailed plans prepared to estimate effort required to deliver readout - for both FPGA and stopgap NIC approaches
  - Firmware effort associated with FPGA readout could not be surmounted
  - Equipment cost of two solutions comparable
- **NIC adopted as new baseline**

- Next steps for readout :
  - Integration & commissioning activities using existing prototypes
  - Develop next iteration of TP generation code

Staging DAQ Installation

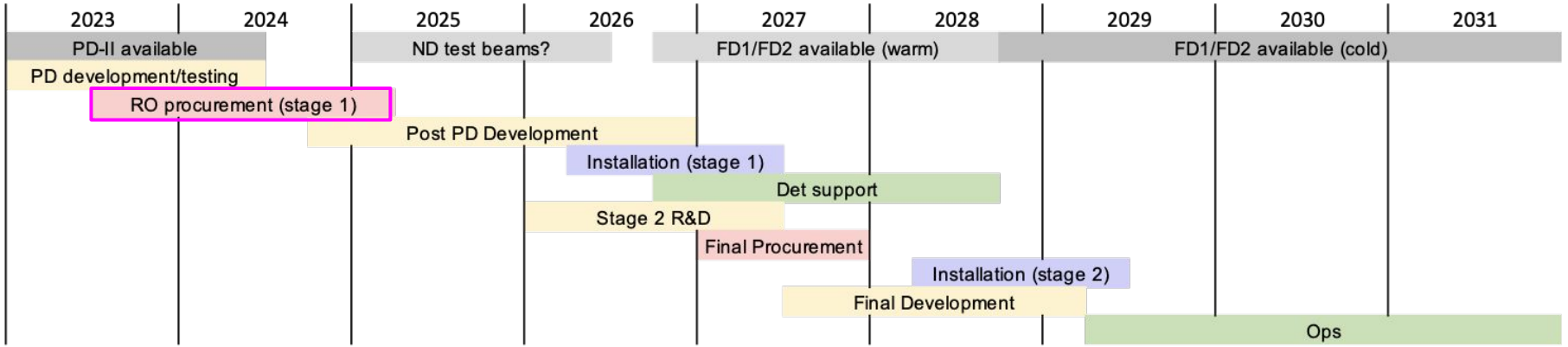
- New readout scheme decouples data reception and TP generation
  - This allows us to adopt a staged approach to DAQ installation
- Current plan has DAQ procured by end ‘25, for installation by end ‘26
  - Needed for detector readout during installation to monitor noise
  - Full DAQ capability not required until detector is cold (end ‘28 ?)
  - DAQ computers will be out of warranty by 2030
- Makes sense to explore the minimal DAQ required for detector installation
  - Purchase and install the full DAQ on timescale it is required
  - Equivalent machines will be cheaper, can explore new architectures etc.

Future Planning : 2023



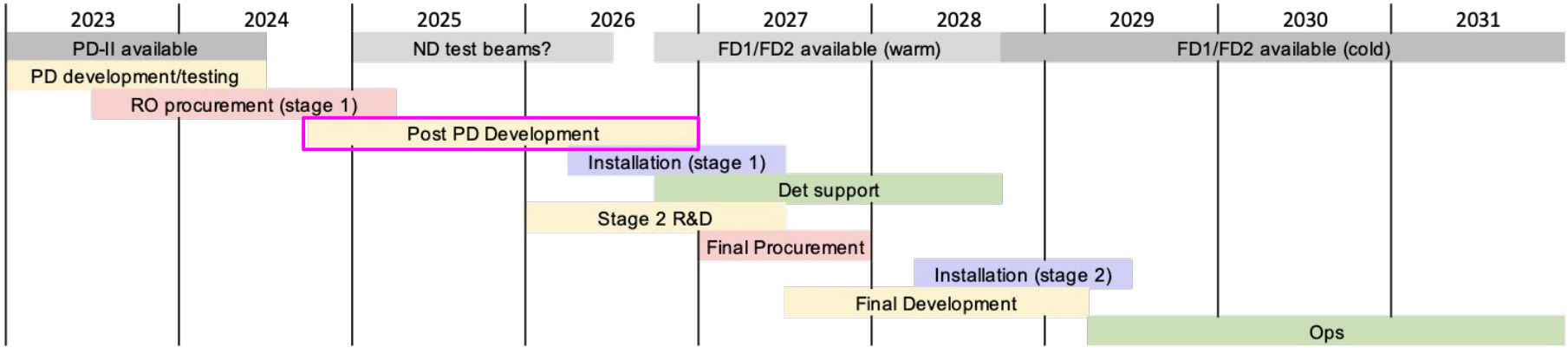
- **Preparation for PD-II**
  - Integration/commissioning activities
  - Development of features in response to experience
  - Timing, Readout, CCM, Data Selection, DQM

Future Planning : 2023



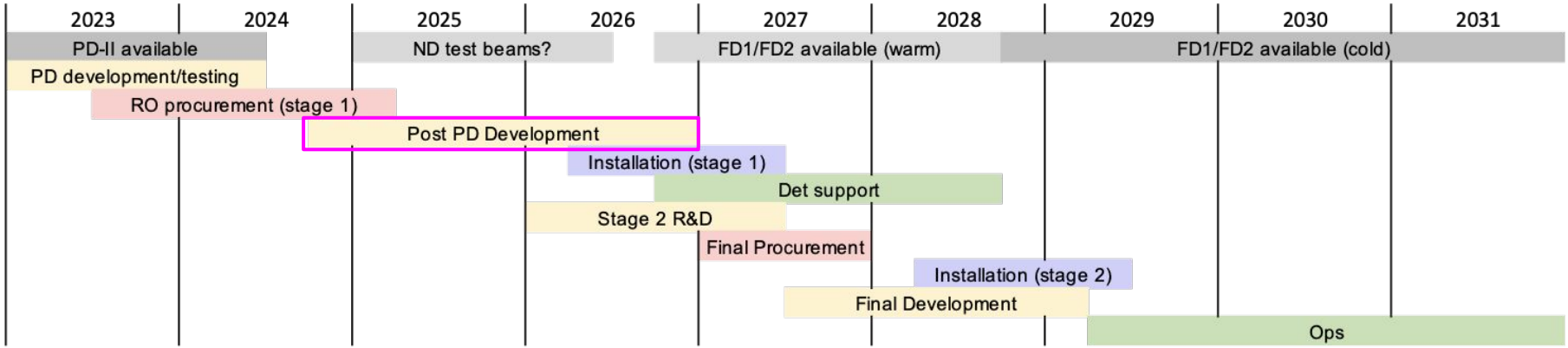
- **Procurement & production**
  - Evaluation & specification of components
    - SSDs (SNB buffer), NICs, servers
  - Production of Timing system hardware

Future Planning : 2024-26



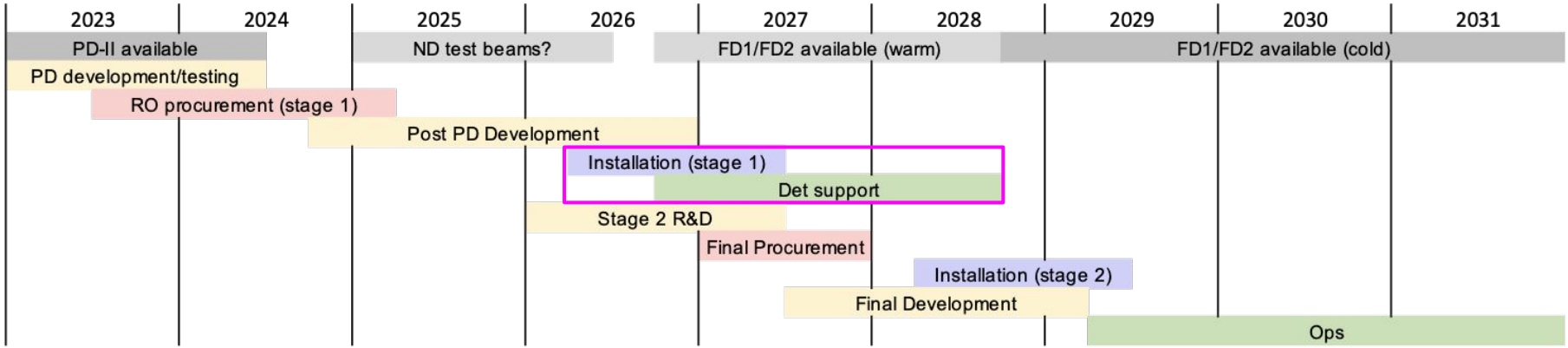
- **Post PDII development phase**
  - Final designs & software development
  - Focus on infrastructure, and baseline (trigger, monitoring) algorithms
  - Refinement of trigger algorithms etc. will continue up until operations

Future Planning : 2024-26



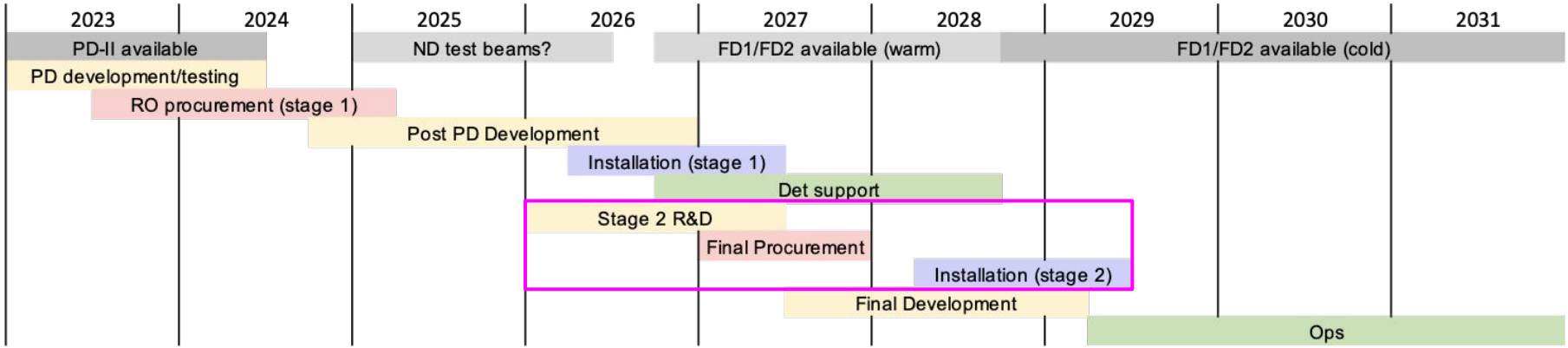
- **Near detector**
  - Use the same architecture and components as FD + ND-specific interfaces etc.
  - Additional posts included in the phase 2 proposal to work on ND DAQ
  - UK will focus on same key areas as FD

Future Planning : 2026-27



- **FD DAQ installation and operations**
  - Install stage 1 DAQ
  - Support detector installation

Future Planning : 2026-27



- **Stage 2 DAQ**
  - Study some (modest) technology updates for the final DAQ
  - Eg. ARM servers, GPUs for hit-finding

Summary

- Many technical developments made in 2022
  - **More details in the following talks**
  - Against a backdrop of uncertainties from global events & evolving international plan
- New readout baseline
  - NIC data reception & trigger primitive generation in software
- Plan for staging FD DAQ installation
  - Install only what is needed for detector installation
  - Full capability in time for cold detector
- UK WP2 planning update underway
  - Focus so far mainly Readout, but detailed plans for other areas will follow
- Plenty to look forward to in 2023
  - Production of timing system
  - Integration/commissioning