System testing and exploitation

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ProtoDUNE-SP DAQ Review

3-4 Nov. 2016

Introduction

- Primary goals
  - Follow the APA timeline and have DAQ infrastructure in place to qualify front-end
  - Reception tests of components both DAQ and Front-end
  - Development of DAQ infrastructure, HW, SW, FW in parallel
  - Preparation for data taking/Commissioning
- Outline
  - Test centres
  - Timelines
  - Testing infrastructure, people
  - Exploitation – calibration, run modes
  - Risk mitigation

Charge items

2. Are DAQ system risks captured and is there a plan for managing and mitigating these risks?
3. Does the design lead to a reasonable production schedule, including QA, installation and commissioning? Does the DAQ schedule allow sufficient time for testing of other components?

8. Are operation conditions listed, understood and comprehensive? Are interfaces to calibration systems and plans well understood? Are proposed triggering schemes sufficiently well understood? Has appropriate consideration been made for collection of both zero suppressed and non-zero suppressed data?
9. Are the DAQ system analyses sufficiently comprehensive for safe handling, installation and operation at the CERN Neutrino Platform? Is the installation plan sufficiently well developed?
10. Have applicable lessons-learned from previous LArTPC devices been documented and implemented into the QA plan? Are the DAQ quality control test plans and inspection regimes sufficiently comprehensive to assure efficient commissioning and adequate operational performance of the NP04 experiment?

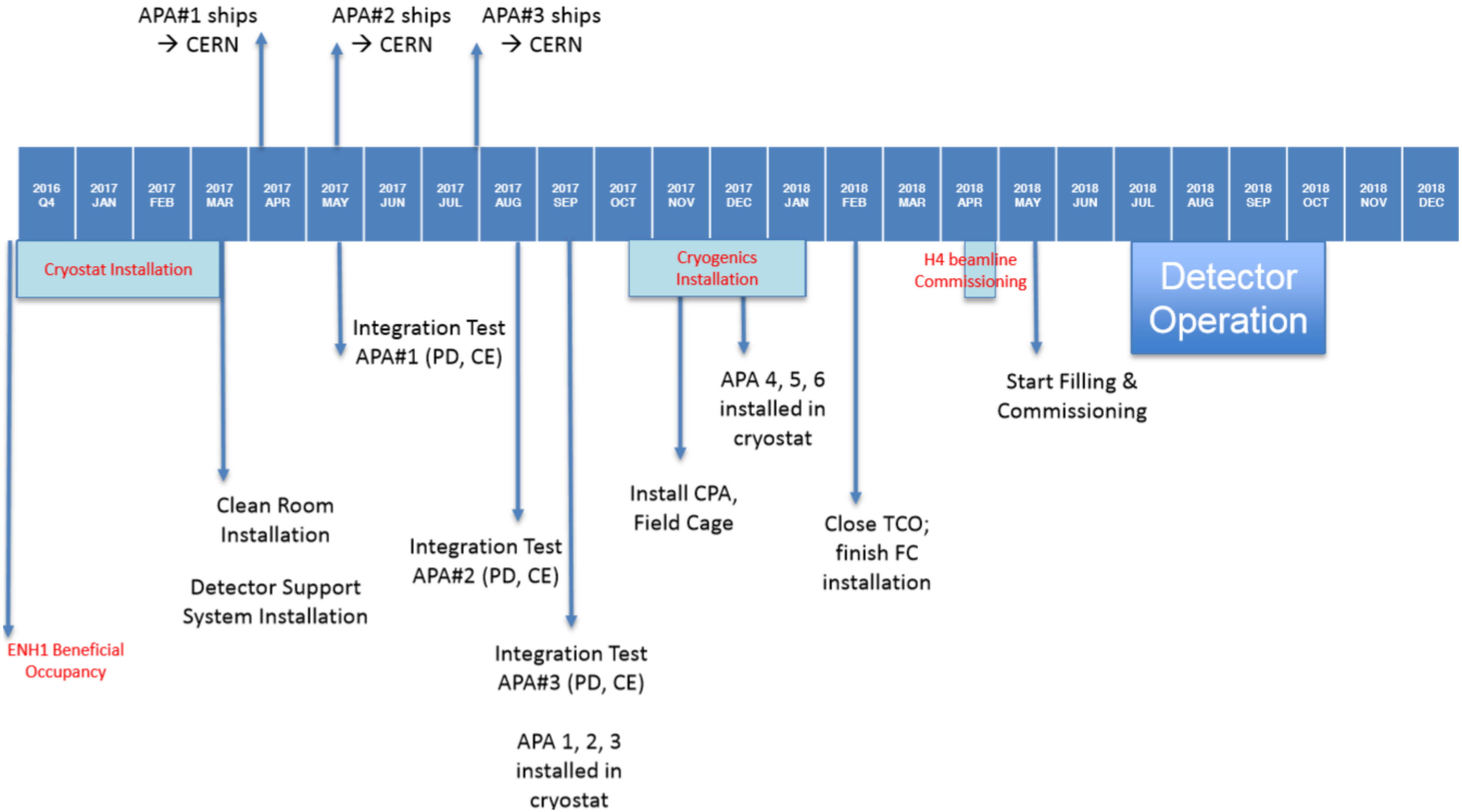
In short: this talk will attempt to answer questions on testing & QA

Interfaces

- Interfaces for the individual components have been mentioned in the previous talks.
- Here we also focus on the extra dimension of time – that the components arrive so as not to delay overall progress
  - This is typically outlined on some unreadable Gantt chart (which I strive to avoid here).
  - The testing must serve both the DAQ testing and a system must be in place to check out the FE electronics.

Testing and Planning

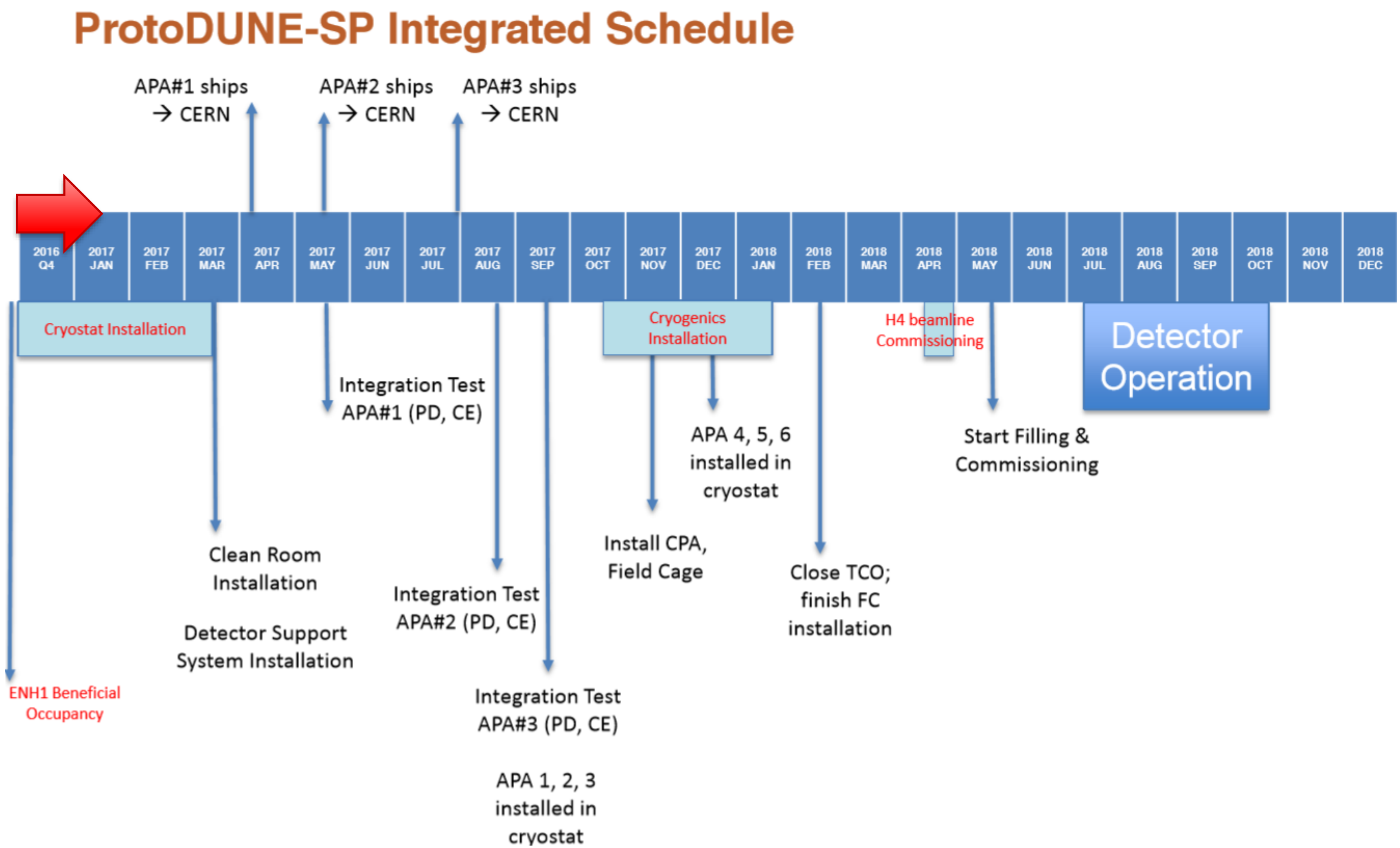
ProtoDUNE-SP Integrated Schedule



Testing sites and focus

- Four testing sites
  - UK
    - Slice Setup with RCE and SSPs to BoardReaders
  - US
    - Testing of dataflow through artDAQ and performance improvements thereof
  - PNNL + NIKHEF
    - FELIX – testing & development
  - CERN
    - Run Control, data challenges, injection tests…
    - Full integration and reception testing
    - Eventually everything migrates to CERN

From now to Jan



UK testing

- Use 35t setup as a starting point
  - Gain experience necessary to deploy a working ProtoDUNE DAQ
  - RCE and SSP setup and 10 G networking infrastructure
  - Validate readout software and firmware
  - So far tested
    - 1 COB in data emulator mode sending data to BoardReader PC
    - 1 SSP in external triggered mode to BoardReader PC
    - Data written to disk
- To do
  - Update above to ProtoDUNE components/firmware/software
  - Test first timing prototypes (one end-node, then many)
    - Configuration interface and BoardReader
    - Test both RCE and SSP
  - Test new RCE components and FW
  - Test monitoring
  - Add WIB emulator to slice, test interaction with RCE, and read-out

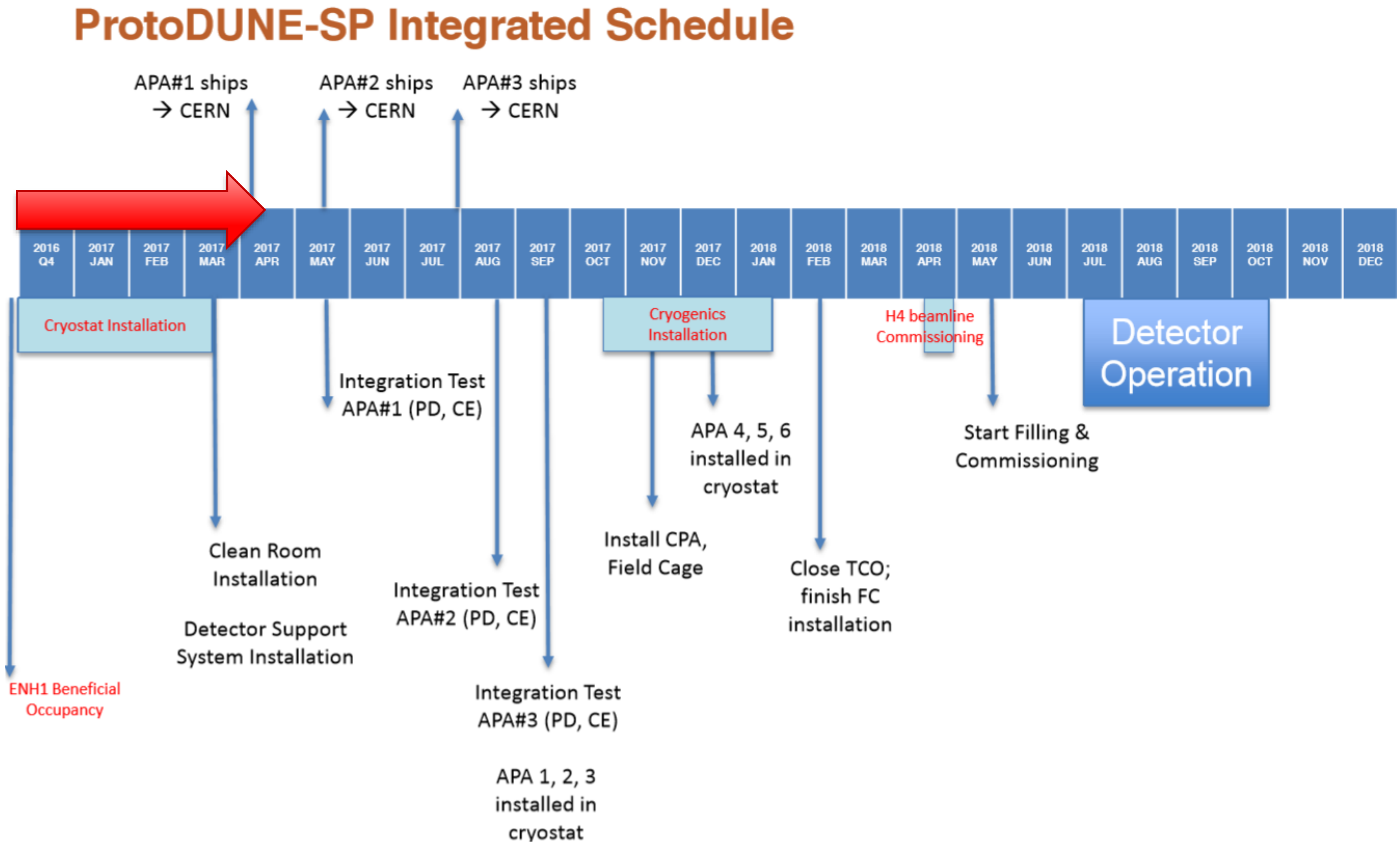
US Testing

- 35t migration
  - Like UK, using what works and migrating from there
  - artDAQ software focused developments
- Current testing – based on artDAQ-demo
  - Unit testing of individual computing components
    - BoardReaders -> EventBuilders -> storage
  - Finding hardware throughput limits before testing software
  - Then adding artDAQ software and benchmarking
  - 10 G networking
  - CERN CentOS7
- Ongoing:
  - Test enhancements to artDAQ
  - The FNAL testing site will remain in operation after CERN migration as a means of cross-checking on-site problems
  - Also acts as a development area prior to deployment
    - Many artDAQ developers situated in Fermilab
  - Test WIB-RCE interaction (data protocol, timing, sync, new RCE components/FW, burn-in, etc).
  - Run control developments
  - Online Monitoring

PNNL+NIKHEF Testing

- FELIX testing
  - New firmware releases
    - Simpler GBT mode
  - Loopback testing
    - In principle, FELIX is data agnostic – only throughput matters
  - Developing artDAQ BoardReader for FELIX
- Todo (Nov)
  - WIB testing
  - Investigating compression schemes (both CPU and FPGA)
  - Investigating BoardReader implementation on FELIX host PC
    - Can interfere with DMA throughput
  - High rate testing (200 Hz)

From Jan to 1st APA



CERN Testing

- Some common ground between all other sites as CERN will be the final destination
  - Gain experience in hardware setup early
  - Components will migrate to CERN
- Reception testing
  - Has anything broken in transit?
  - Common suite of tests between host and CERN
  - Integration into CERN infrastructure
- Robustness testing
  - “Burn-in” tests – running for extended periods without error
  - Full system tests – running the system in “shift mode”, as if it were the real thing

From Jan to 1st APA

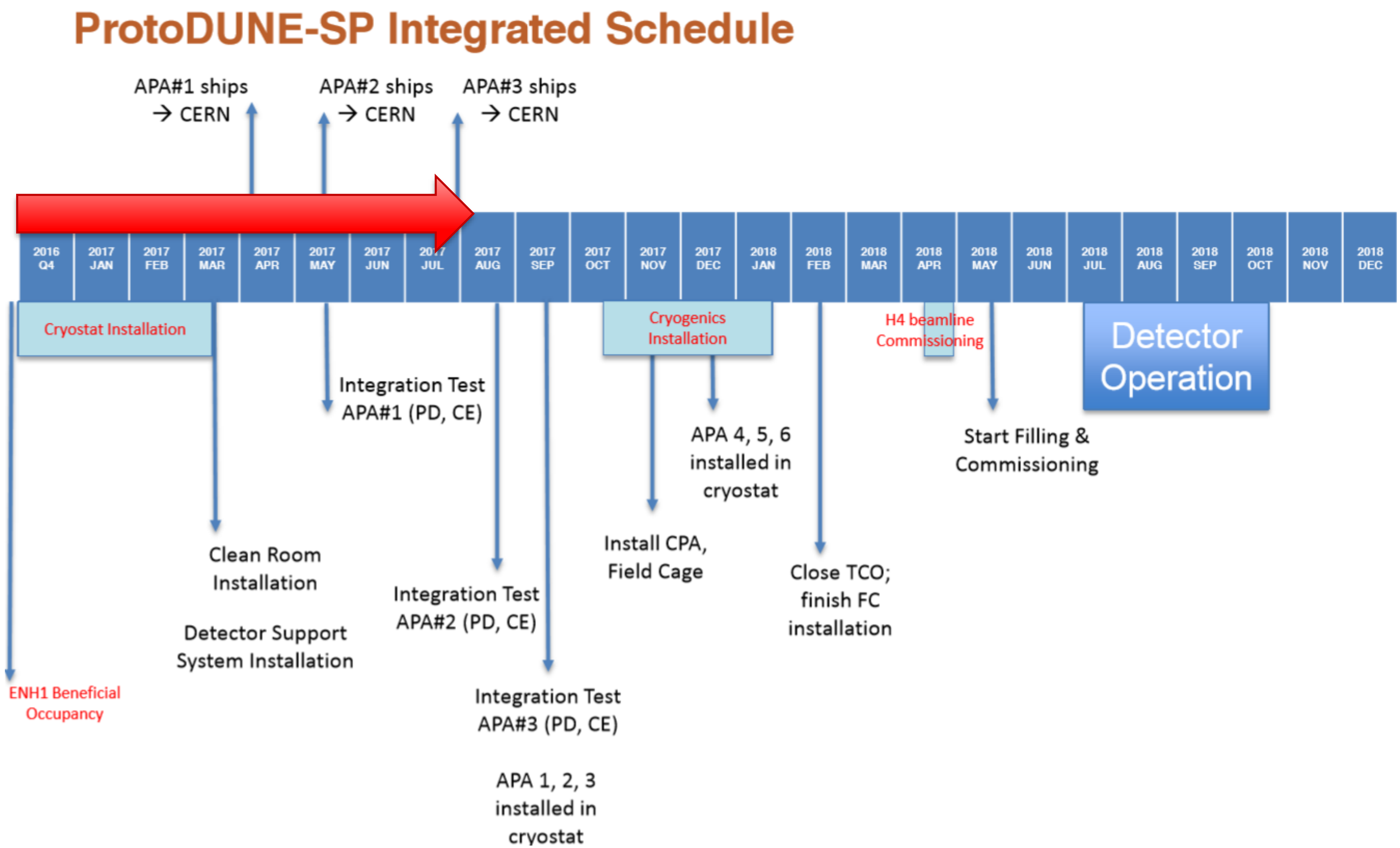
- Integration
  - Basic online computing infrastructure (more later)
  - Initial assembly of components in racks
  - Power and networking and other cabling to computing
  - Clone test stand software setup from UK-test or FNAL-test
  - Initial tests initialization FEMB-WIB-RCE from artDAQ
  - Setup of some SSPs at CERN
- Extensive testing of above
- Sync tests (pulse FEs) appear in data at same time
- Initial Run Control with artDAQ (JCOP to follow)

1^{st} APA arrival

- At this point need to partition DAQ into two slices – **Reception testing** and **DAQ development**

1. **Reception testing**
    - used to test the APA, FE electronics and all new DAQ equipment arriving at CERN
    - Step-by-step commissioning of APA test area DAQ
    - Requires a DAQ we can hand over to operators (basic config, run control, read-out)
    - 35t software will be used where ProtoDUNE is not ready

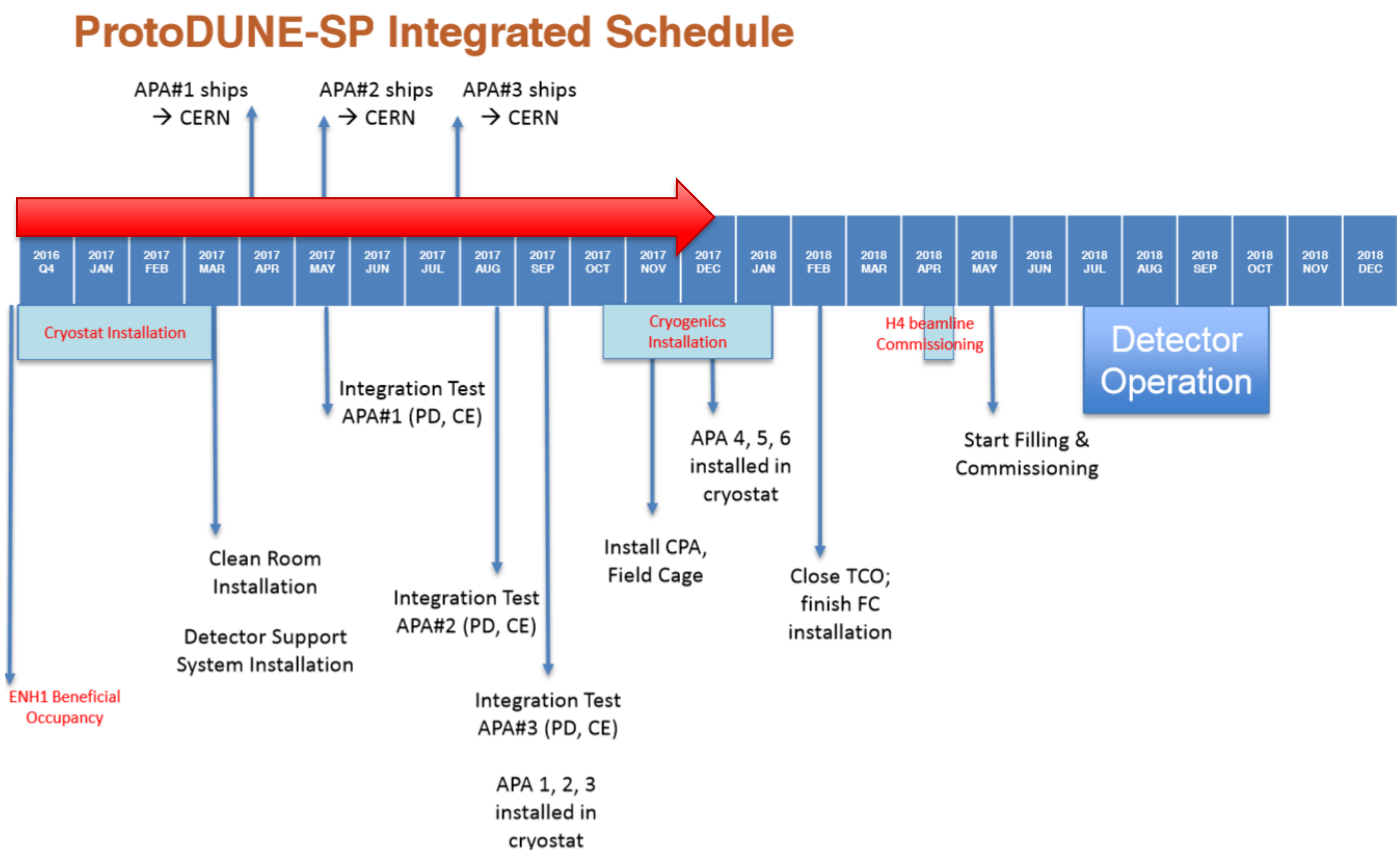
From 1st APA to 3rd APA



From 1st APA to 3rd APA

2. **DAQ development**
    - As equipment is qualified, it can be added to the second partition
    - Develop new RC, HW and DQ monitoring
    - Mock data challenge from DAQ to storage
    - Test new firmware revisions
    - Add beam counter and BPM hardware, commission trigger

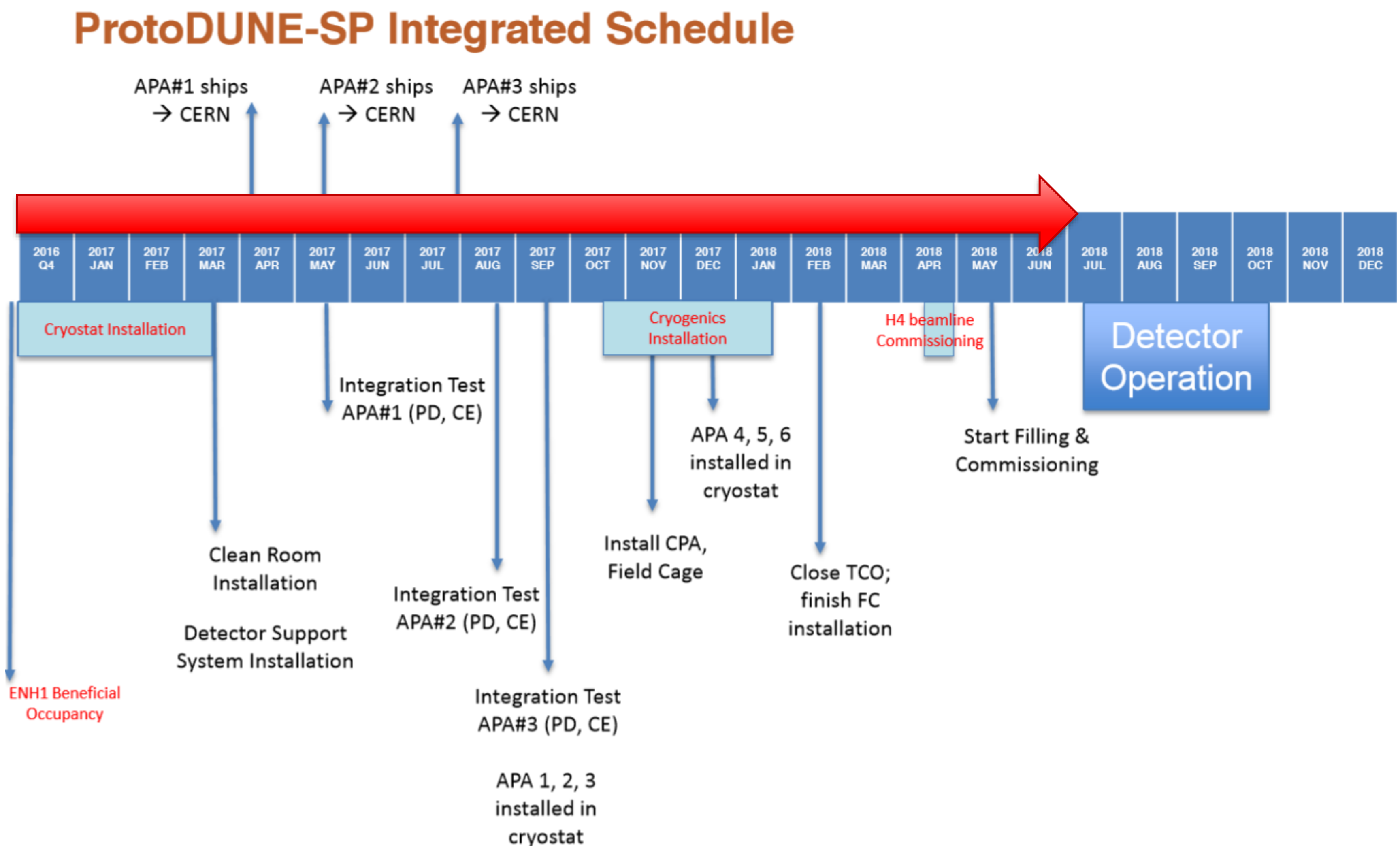
From 3-6 APAs – full system



From 3-6 APAs – full system

- **Reception testing in full swing**
  - Full set of COBs, aTCA, RTMs arrive at CERN
  - Full set of SSPs arrive at CERN
  - Full set of WIBs, flanges, FEMBs for APA#n arrive at CERN
  - Full set of computers arrive at CERN
  - Step-by-step commissioning as new APAs installed DAQ
- **Development slice**
  - Final timing system arrives at CERN
  - EVB Software developments
  - Monitoring
    - Dataflow, HW, Data Quality
  - Run Control with artDAQ and JCOP - basic functionality
  - Configuration Control with JCOP - test functionality

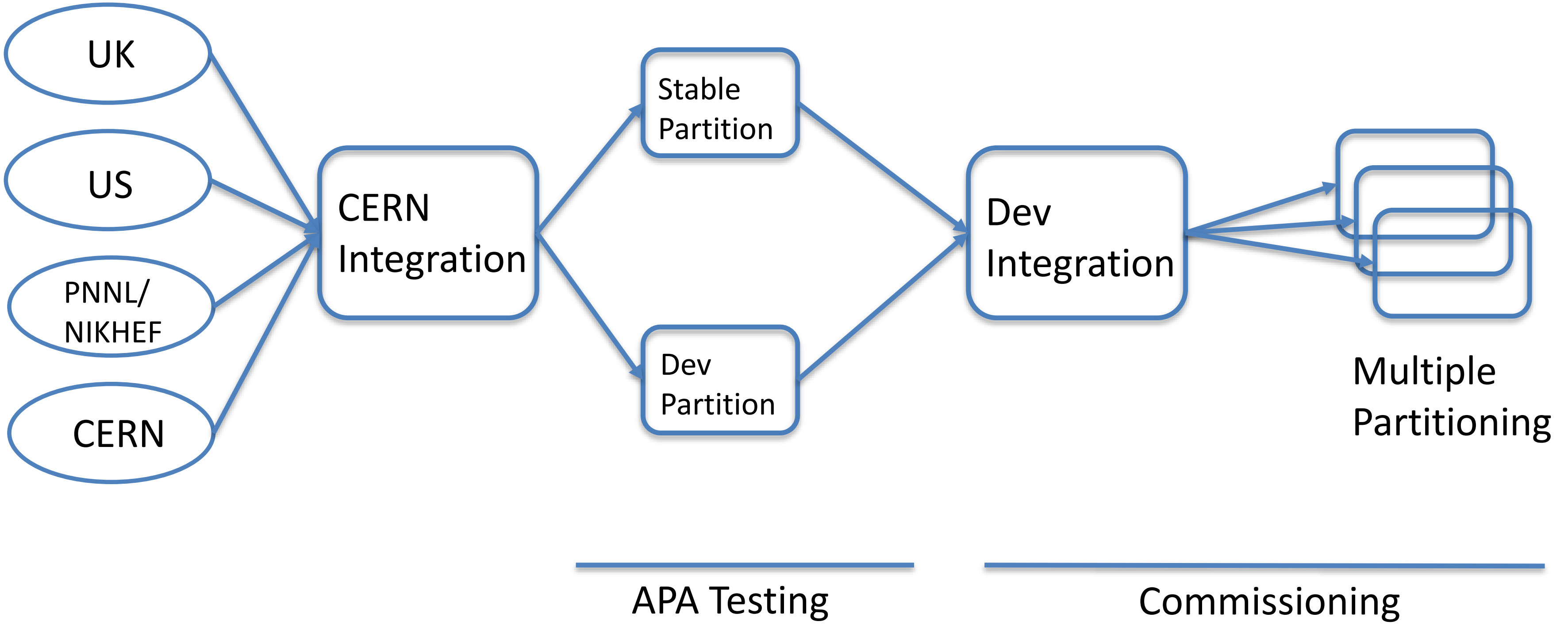
2018 – commissioning



Commissioning

- Integrate all hardware into the system
- The first reception test slice will essentially disappear at point
- And the second development slice will become the primary system
  - But partitioning still available for parallel testing/developments
- Testing will focus on integrating beam instrumentation, tests with cosmics and robustness of the system
  - Move to a system that can be operated by shifters and not just experts
  - Since BI and CRT we have special “nearline” data taking modes for these interfaces, that have to be merged with “standard” DAQ data, we have to test/commission this early in conjunction with other groups

Testing Plan Summary



Key tests and requirements

APA response calibration

- Detector response will have to be done in conjunction with other groups (CE, PDS)
  - We expect (also listed in other groups QA/QC plans):
    - TPC noise characterisation
    - APA Wire testing/Cable-Channel Mapping
    - SSP threshold scans – for signal optimisation
    - TPC drift time calibration – may take 5ms of drift time, but prefer more post-trigger info than pre-trigger.
    - HV scans
    - …
- From the DAQ perspective we need to provide the data taking mechanisms for these calibrations
  - Necessary data taking paths and bandwidth
  - Special Board Reader configurations
    - If data format differs to standard
  - Special monitoring for calibrations
    - Data vs. expectation comparisons
    - Signal finding routines, pattern checking, etc.

Sync tests – timing system

1. First simplest slice = 1 FEMB > 1 WIB > 1 RCE > 1 BR > 1 EB > analysis/monitoring FEMBs have pulse injection, so we can fake signals and check that they arrive at the RCEs, and hence in the data as we expect
2. Repeat with 2 of everything except EB. Synchronised pulse injection on both FEs.
3. Repeat (1) with PDS and LED pulser
4. Repeat (2) with combined TPC and PDS readout.
5. Automate
6. Repeat with trigger inputs during Beam Inst. commissioning (1-4 allow us to set "detector timing", but does not mean we are in phase with the beam).

Data Challenge

- Can "generate" data in multiple ways:
  - In-FPGA data generators
  - Low signal thresholds to match cosmic rate (i.e., boost noise hits count)
  - Cosmics
- Test the elements piecemeal:
  - Data consumption by Board Readers – monitor buffers, backpressure
  - Repeat adding successive layers: Event Builders, Aggregators, Storage, EOS.
  - Further challenges can include prompt processing in coordination with offline computing group
- First challenge = 1 APA
- Last challenge = 6 APAs, Beam Inst., Cosmic Tagger
- Commissioning = real data becomes the challenge

Testing and data taking infrastructure

- Material tracking database and web front-end
- Logbook – many options
- Documentation site – twiki or similar
  - Probably want a strict structure/manager for these as it quickly gets out of control and impossible to find anything
- Databases
  - Run database
  - Configuration database
- User accounts – probably make all these CERN SSO facilities
- Needs to be accessible outside CERN
- In general, leverage CERN solutions where possible

System Exploitation

Calibration modes (without beam)

- Qualify detector as much with cosmics as far in advance of data taking with beam as possible
  - As this will be the dominant source of particles, detector occupancy should be close to beam conditions
  - Use a fake spill trigger
  - High rate testing (how far can we push the system)
  - Useful test of all monitoring
  - Complete system noise can be qualified early
- Cosmic mode – full data taking
- Photon Detector mode
- TPC triggerless modes
- Beam Instrumentation and Cosmic Tagger

Run Modes – with beam

- Most of the time we will have standard physics running
- Special calibration runs for:
  - Photon Detector
    - Allow taking data with just Photon Detector
    - Full waveform data essential for calibration
  - Inter-spill cosmic data
    - Background count
  - Beam Trigger
    - Threshold scans with different beam modes

Risks

- Monitoring
  - Need more people actively working on this on all aspects (HW, DQ, dataflow)
  - *Have basic 35t monitoring software as backup*
- New critical components
  - E.g. WIB
  - Anything late or having serious design flaws can cause serious knock-on effects
  - *Will have WIB-emulator*
- Channel mapping
  - Mistakes lead to incomprehensible data, very difficult to fix on the spot
  - *Labelling, database tracking, verification of channel mapping with pulse injection*

Risks

- Delays to EHN1
  - Have other areas at CERN (ready) which can be used for DAQ installation and testing.
  - However, “cold box” is destined for EHN1, therefore overall test schedule of Cold Electronics could fall behind
  - Can seriously affect schedule
- High noise affecting compression
  - *Reduce inter-spill data taking to compensate*
  - *Reduce drift margin (currently taking 2x drift time)*
  - *Try different compression algorithms*
- Backpressure
  - *Reset buffers by end of spill cycle – always in same state at start of spill*
  - *Detailed monitoring of buffers*
  - *Software trigger throttle*

35t lessons learned

- We have several documents on lessons learned from the 35t
  - Principle problem was that of system noise
    - *A taskforce is in place to ensure ProtoDUNE cryostat is sufficiently isolated from external noise sources. Care has been taken to plan exactly what components are on detector power and what is on building power*
    - *From the DAQ – optical will be used whenever connecting to the detector*
  - Need sufficient number of people "on the ground" to ensure deadlines are met
    - *(Signed and agreed) list of people to be at CERN in the crucial 2017 commissioning year – number expected to grow as funding requests get approved, and new groups join*
    - *Need to also minimise people turnover and ensure knowledge transfer for those being replaced*

35t lessons learned

- Data taking stability
  - Problems with backpressure
    - *Plan to monitor backpressure in detail and have throttle mechanisms (in SW) to reduce trigger rate if necessary*
  - Software instabilities
    - *Need to have well-tested stable releases of SW. Separation of testing and stable paths*
- Monitoring
  - Lack of online displays, event monitors
    - *Need extensive online monitoring for problem tracing and resolution*
    - *Need automated alerts*

Conclusion – charge items revisited

- We are aware of the big risk items. Most have fallback strategies, others need manpower
- Outlined the plan for component testing and the infrastructure necessary for QA
- Detailed what needs to come online and when for progressive stages of commissioning and installation
- Detailed the run modes, calibration modes, special data runs and lead times
- Have a lot of re-usable monitoring from 35t and other LAr experiments, but monitoring is an understaffed area
- Need to attract new groups and encourage physics groups to participate further
- Have a detailed catalogue of lessons learned from the 35t prototype – most of which involve noise isolation, and meeting deadlines

Supporting Documentation

- Documentation for this talk
  - http://docs.dunescience.org:8080/cgi-bin/ShowDocument?docid=1897
- 35t lessons learned
  - http://docs.dunescience.org:8080/cgi-bin/ShowDocument?docid=1315
- Risk register
  - https://docs.google.com/document/d/1-sa5M29dshODIRxJVc7A5Zde4Pv_u9h8JeV3t2mNLvY/edit?usp=sharing
- Detailed Testing plan
  - https://docs.google.com/spreadsheets/d/10qfOsnc2UKal0J8Bkml8FM-dLaWvlgMO5IDiAU41JA8/edit?usp=sharing