DAQ and Slow Control

Nuno Barros

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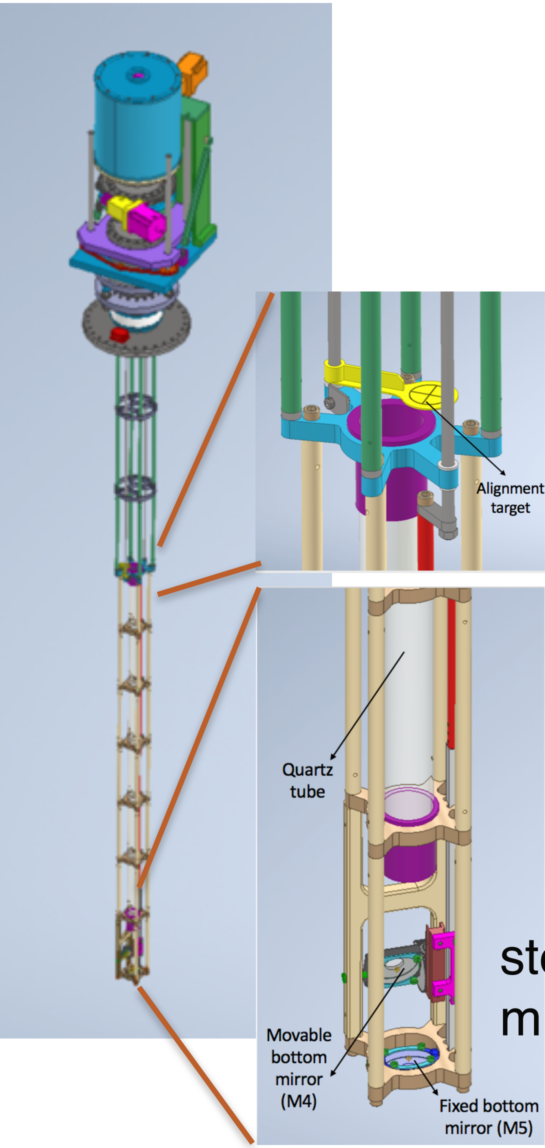
LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

Ionisation laser overview

Ionisation laser

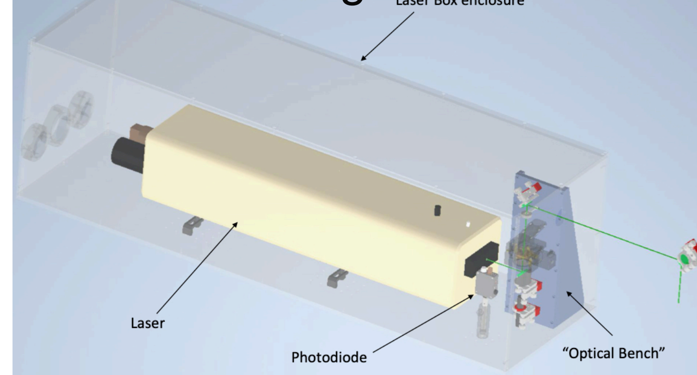


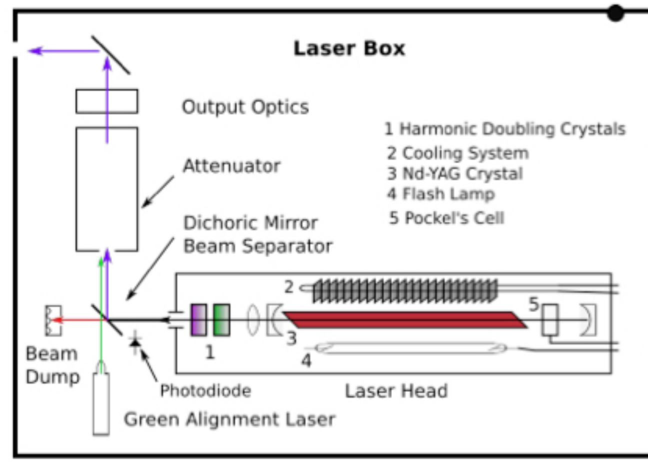
steerable mirror

- Steerable mirror (1)
  - Motor drive
  - Encoder
- Rotary stages (3)
- Limit switch
- Alignment target

- **Laser box**
  - Control & Monitor (LV)
    - Interlock control
    - Attenuator
    - Iris
    - Monitor photodiode
    - Alignment laser
    - Mirror mounts

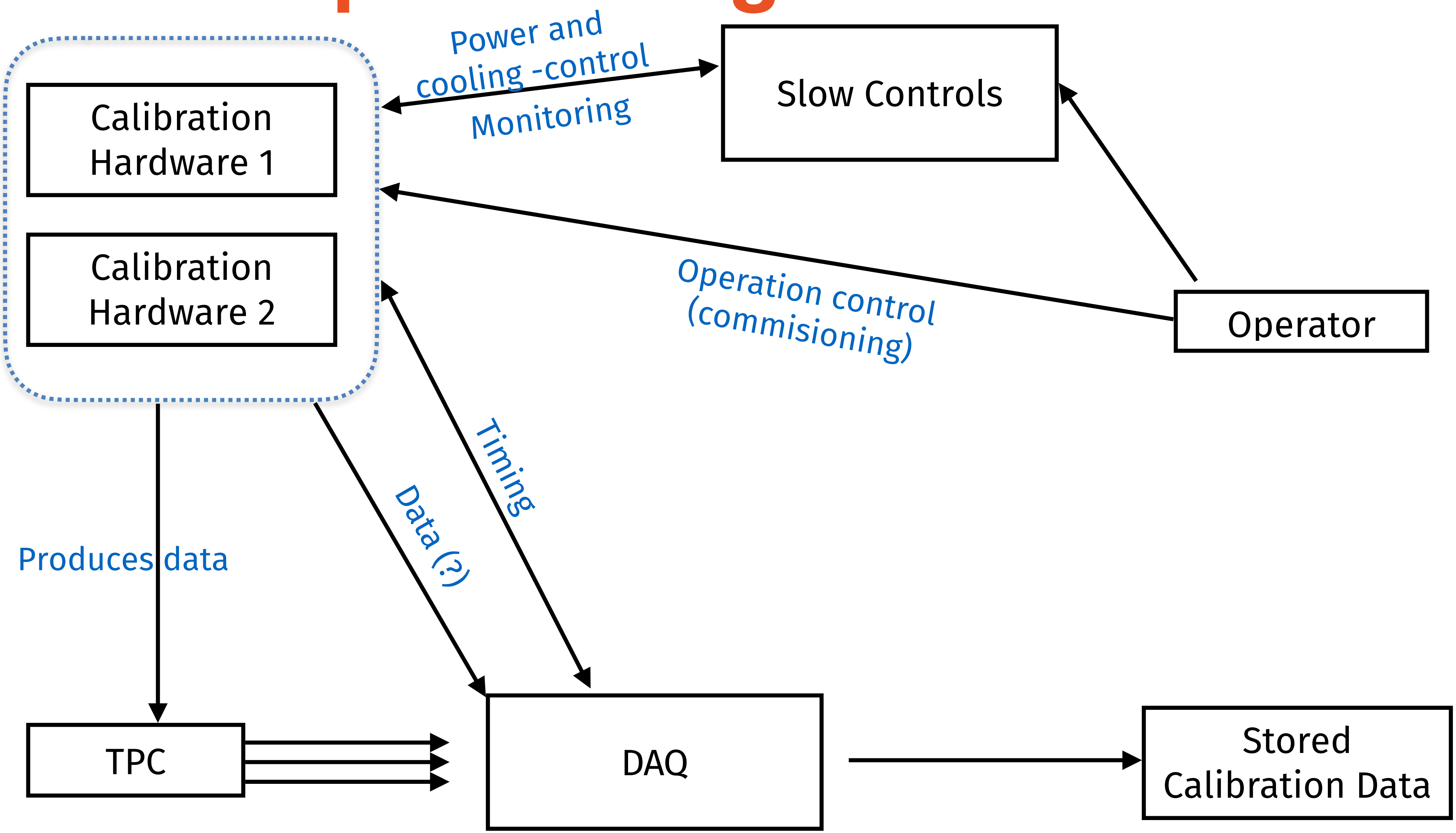
266 nm Nd:Yag laser





- Power (HV)
- Cooling

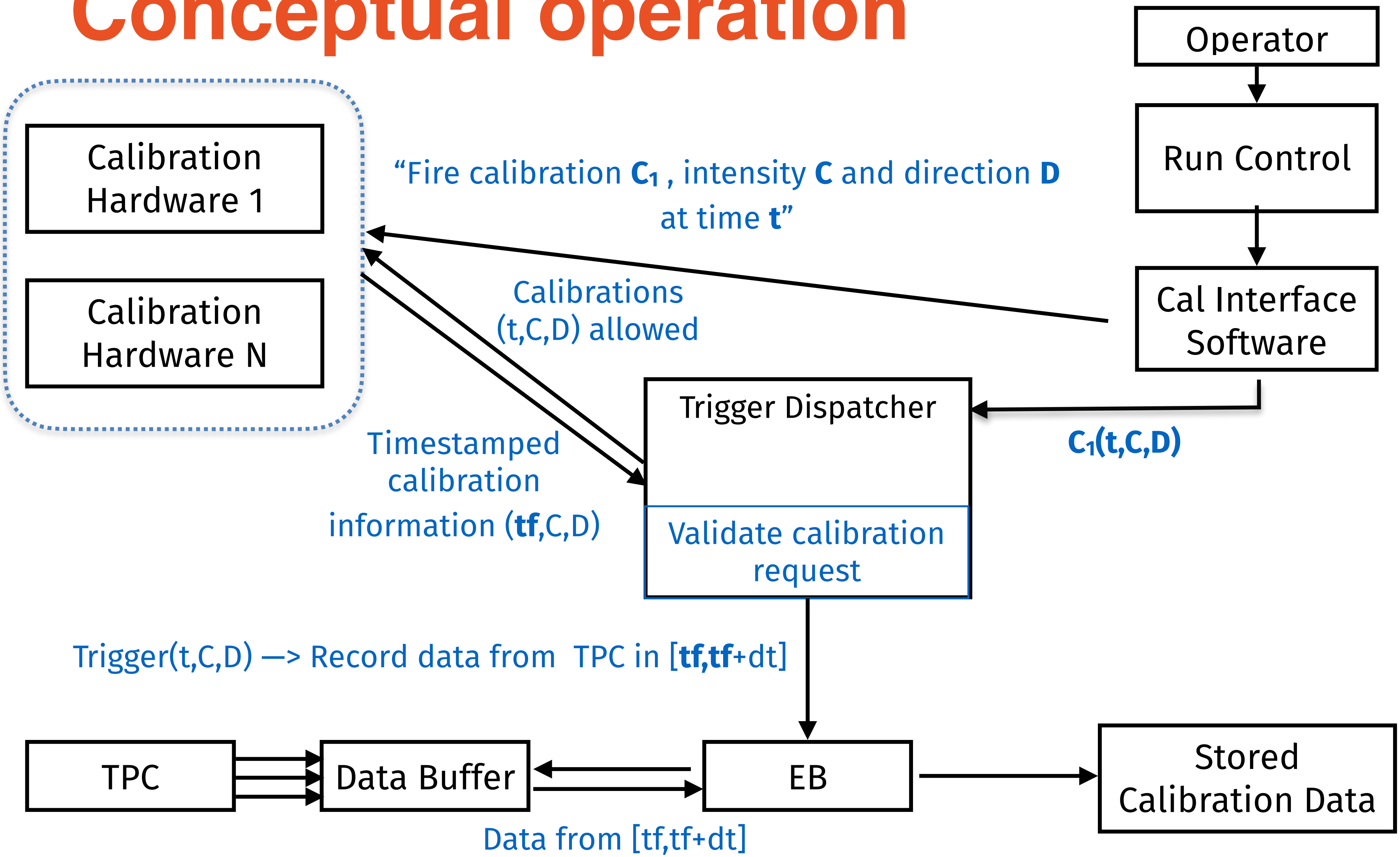
Conceptual design



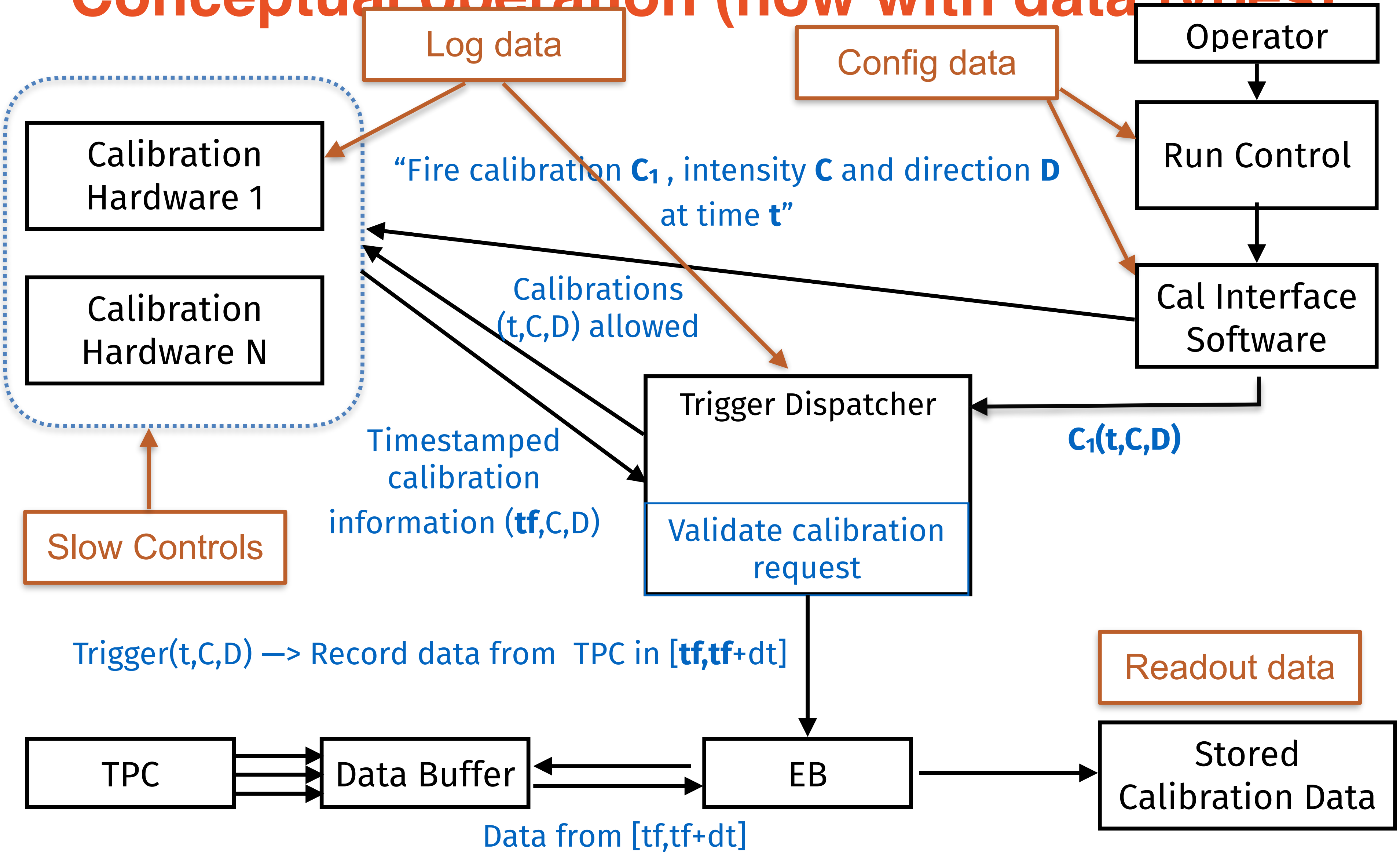
Types of data produced in a calibration run

- **Readout data [O(GB) - O(TB) per run]**
  - TPC or Photon detector channel readout (either or both)
  - Per-event data. The bulk of the "calibration data".
    - Likely need to introduce data reduction techniques (time window selection or others)
- **Configuration data [O(MB) per run]**
  - Per run data.
  - Identifies which systems are operated and their common settings
  - Additionally, list of positions, directions intended (needs discussion)
  - Not necessarily used in analysis, but important for bookkeeping and operation of DAQ/Cal in sync
- **Slow control [O(GB) per run]**
  - Readout of all components of calibration systems
  - Encoders, actuators, switches, diodes, voltages, etc
  - Need to set individual requirements to provide to Slow Control system
    - Readout/sampling frequency
    - Data access from analysis
  - Information important for Monitoring/ Data Quality and possibly data analysis
    - Some data redundant with DAQ storage
- **Logging of operation [O(MB) per run]**
  - Redundant with slow control
  - Debugging specific to the control operator electronics.
  - Not used in analysis, but important for troubleshooting

Conceptual operation

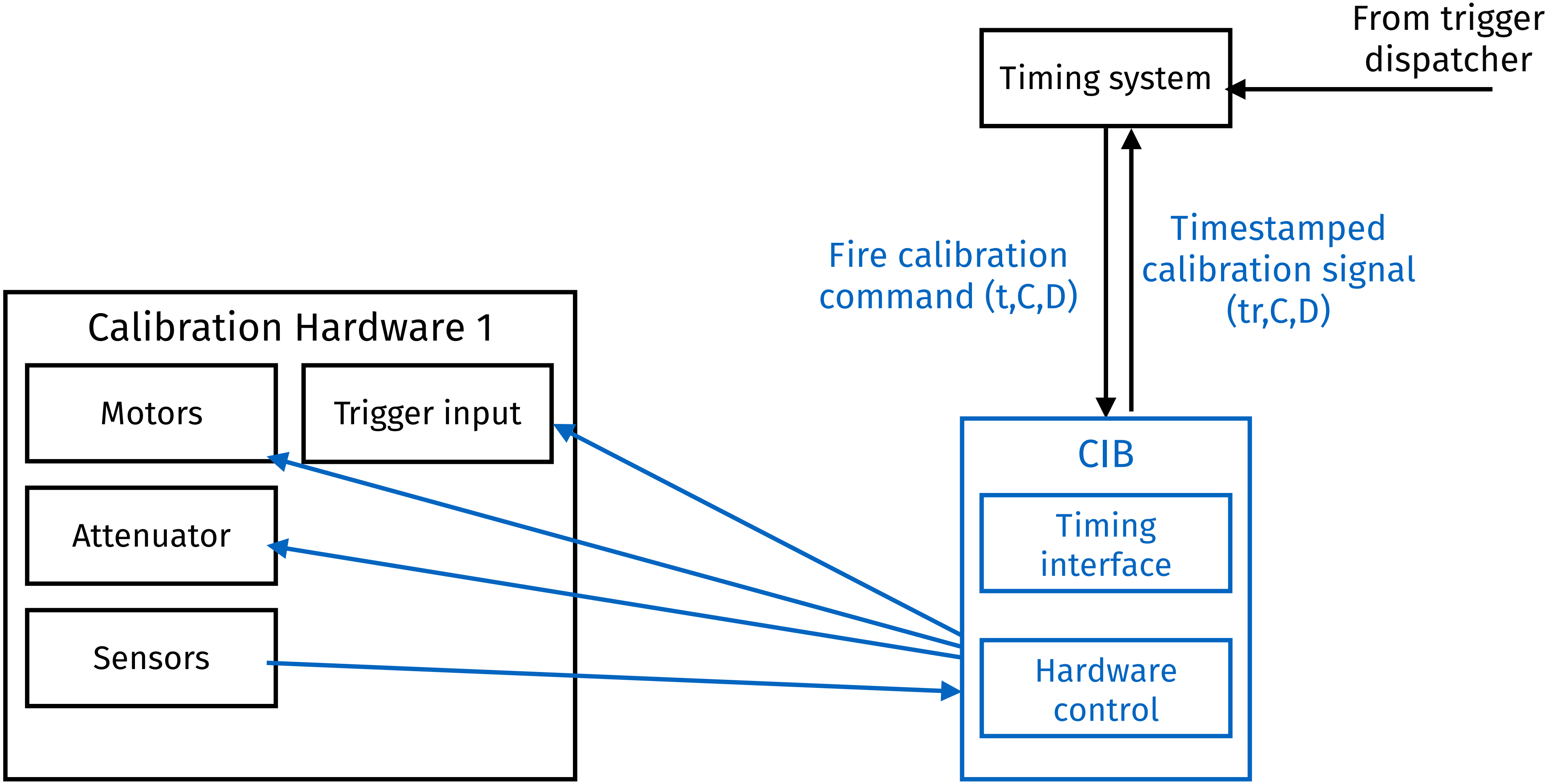


Conceptual operation (now with data types)

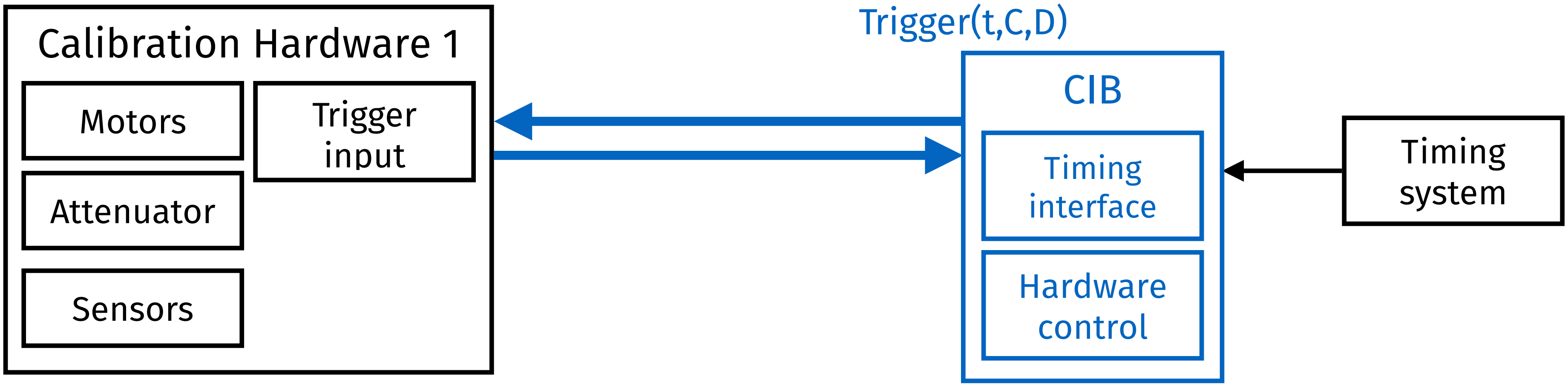


Calibration Interface Board (CIB)

Zooming into the calibration “block”



CIB (Calibration interface board)



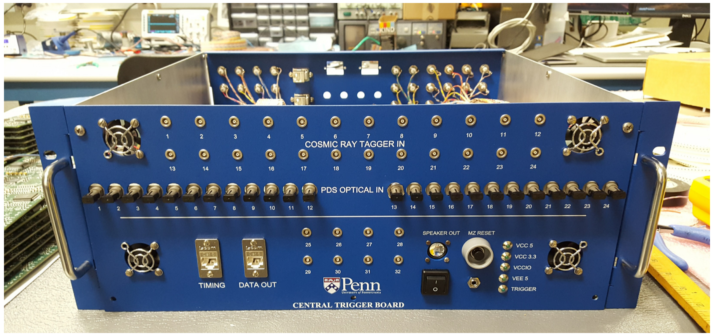
- Act as interface layer between the DAQ/SC and the calibration systems (as a whole)
  - Receive DAQ commands through the timing system (+ethernet)
  - Translate commands into low level actions in the hardware (or respective interfaces)
  - Drive calibration firing (synchronous with DAQ timing)
  - Receive information from the hardware (sensor data)
- Reduce individual interfaces to SC
- Aggregate low level information
  - E.g.: Combine 3 encoder readouts to obtain beam direction

What will the CIB implement?

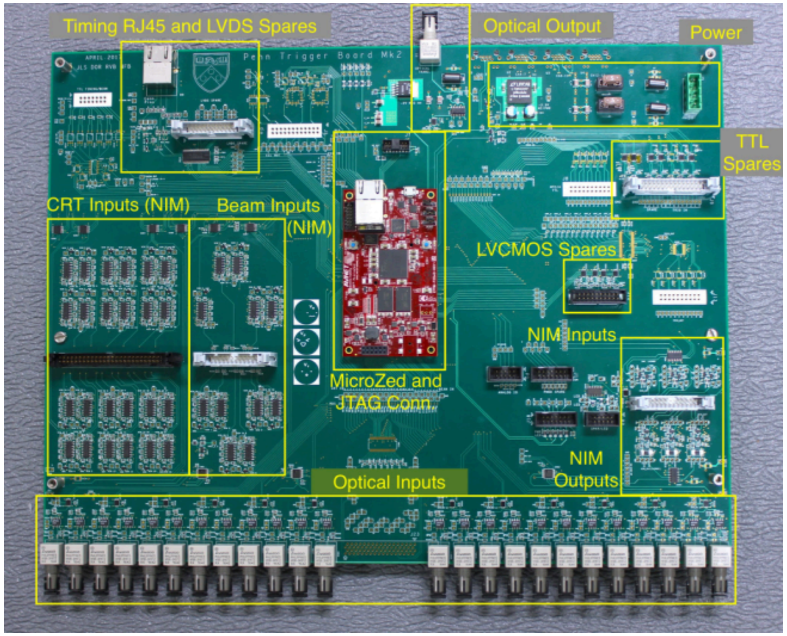
- **Timing system interface**
  - The only connection to the DAQ currently assured
- (in discussion) Data interface to the DAQ
  - Eg.: Get accurate encoder mirror position by checking laser firing time with DAQ
  - CPU + network interface
- (optional) Data interface to monitoring/slow control/database
  - CPU + network interface
- **Translate Control commands into low level hardware commands**
  - Easily done with an FPGA
  - Alternatively network interface to pass software commands
- Live in the same ground as the calibration hardware
  - Simpler than overly complicated ground isolation over hardware interfaces

The Calibration Interface Board (CIB)

- Based on the trigger (CTB) implemented at Penn for ProtoDUNE-SP
  - Re-use as much as possible of existing design



- Hardware electronics consisting of a motherboard with a system-on-module (SoM) including an FPGA and CPU
  - **Motherboard** :
    - implements the physical interfaces
  - **FPGA** performs the fast logic:
    - Timing interface
    - LL control logic of hardware
  - **CPU** performs HL functions:
    - HL communication to operator
    - Output Data stream
    - Monitoring data stream



Current status

- Collecting list of interfaces with IoLaser instrumentation
  - Physical media, number of channels
- Revising design to evaluate changes to be implemented
  - Fiber links (timing, control, data)
  - Timing interface hardware
- Arranging to have a spare shipped to LIP to run prototyping tests
  - Integrated tests with motor driver and encoder
- Software and firmware will be revised as needed to accommodate changes in purpose
  - Different DAQ interface
  - Different firmware logic

Slow Controls

Overview

- **Ongoing discussion between CALCI and DAQ consortia to draft interface document**
  - Ongoing working document:
    - https://edms.cern.ch/ui/#!master/navigator/document?P:100233199:100646719:subDocs

- **Slow Control interface through OPC Unified Architecture (OPC-UA) protocol**
  - Physical Interface communication over ethernet
  - Details of the implementation still under discussion

- **Sources of Slow Control Data**
  - Laser HV (control, readout) and cooling (readout)
  - LV (control, readout)
  - Encoders (readout)
  - Attenuators(readout)
  - Motor driver (readout)
  - Laser photodiode (readout)

- **Assuming 5 Hz operation of laser system, all readouts should be sampled at about 10 Hz**

Implementation design

- **Power supplies**
  - Off-the-shelf units.
  - Models support direct interface to slow control systems
  - Control, monitoring
- **Remainder of instrumentation (drivers, encoders, laser box)**
  - CIB will aggregate Slow Control interface to individual parts and implement OPC-UA server that communicates with SC
  - **Needs to be implemented and tested**

DAQ

Overview

- **Ongoing discussion between CALCI and DAQ consortia to draft interface document**
  - https://edms.cern.ch/ui/#!master/navigator/document?P:100233199:100646719:subDocs
  - Several open questions still being discussed to find optimal solution
    - Mostly related on the relation (push-pull) between DAQ and CAL

- 3 possible DAQ interfaces identified
  - Timing
  - Control, configuration and monitoring
  - Data

- Each with both a physical and software aspect

Timing Interface

- **ProtoDUNE timing system (PDTS) used to distribute timing, synchronisation and control messages**
    - Protocol described in https://edms.cern.ch/document/2209895

- On the IoLaser side, CIB acts as single point timing interface
    - All timestamping operations start here
    - Sync commands and other messages parsed and relayed from here
    - Possibility to provide derived clock in sync with PDTS to component FEs

- Discussions with PDTS group (Bristol) to procure prototype boards for testing

Control, Configuration and Monitoring

- **Ethernet socket (over fibre, for ground insulation) will be used to establish links to the DAQ for CCM**

- Calibration specific software will be necessary to be implemented on DAQ side
  - DAQ provides the infrastructure
  - CALCI provides the people power for implementation of Cal specific code

- Identification of the parameters and best format implementation of CCM is still ongoing
  - Two pronged approach for configuration:
    - Some parameters configured directly through SC (eg.: HV, LV)
    - Some parameters configured through DAQ (eg.: positions, directions, intensity settings)

- Ongoing discussion within Cal group on specific implementation of the configuration procedure
  - For early commissioning, useful to be able to control IoLaser outside of PD DAQ

Data

- **The need and implementation of data stream to DAQ is not yet established**

- **Multiple questions to address**
  - Can the DAQ select calibration data without any input from CAL?
  - Do we need data reduction techniques?
    - What input is necessary from CAL to implement them?
  - Can precisely timestamped information be accessed for analysis and monitoring from the Slow Controls Database?
    - Use case 1: quality control of requested direction and encoder readouts
    - Use case 2: data reduction on calibration readout
      - Calibration produces a lot of data
      - If beam direction is known in DAQ, can optimise readout windows

- **Discussion of the requirements both from CAL and DAQ are still ongoing**

Prototyping and testing

- **Ongoing plans to prototype communication with motor driver and encoders at LIP**
  - Ongoing discussions between involved parties
  - Borrowing a CTB from UPenn for prototype tests

- **Local implementation tests**
  - Testing of communication protocol with FE components (encoders, motor drivers)
    - Both control and feedback
  - Measurement of latencies
    - CIB responsible for timestamping
  - (optional,desirable) Test of OPC-UA protocol
    - For posterior testing with ProtoDUNE-SC
  - Testing of PDTS interface

- **Integration Tests**
  - Initial integration tests in vertical slice tests (dates TBD)
  - Planned tests:
    - Power supplies control/monitoring
    - Readout of Cal devices through CIB

Open questions (DAQ)

- **Model of information flow**
  - DAQ actively control the calibration or passively receiving information from CAL
  - Discussion with DAQ consortium still ongoing
  - Depends on other questions

- **Can the TriggerPrimitive select Calibration data?**
  - Is it necessary to receive position+direction from calibration instrumentation?

- **How to act if a laser position/direction fails/is skipped?**
  - Multiple solutions available (predefined scan positions, feedback from monitoring,etc)

- **Ongoing discussions with DAQ consortium to draft a complete interface document**
  - **A major goal is to minimize back-and-forth communication between DAQ and Cal**

Summary

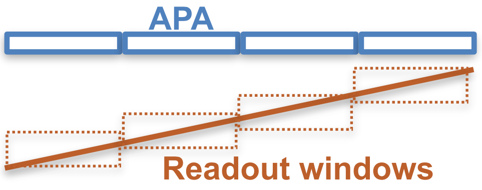
- **Slow Control integration through OPC-UA**
  - Power supply control through built-in infrastructure
  - Laser component parts through CIB
    - OPC-UA protocol to be implemented and tested

- **DAQ interface discussions ongoing**
  - **First draft of interface document available**
  - Open questions still being discussed to find optimal solution
    - Amount of information needed by DAQ to select calibration data
    - Flow of configuration/control information between DAQ and Cal (push/pull)

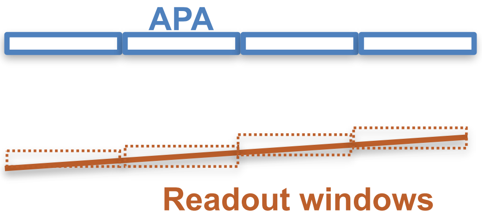
Support slides

Laser system information

- **Time between firing request and firing time**
  - From the laser documentation, there is a delay of **180 μs** when running in (externally) triggered mode
  - Additionally there is a **jitter** of **10 ns** (irrelevant for TPC readout purposes)
  - Should also account any additional signal propagation between the DAQ and the laser/calibration



- **Total running time per calibration run**
  - TDR assumes 800k laser pulses per calibration run (**2 runs per year**)
    - Size of readout window dependent on specific laser direction
  - Running sequentially (firing one laser at a time), this translated into :
    - **3 live days per scan (~1 week per year)**
  - **Some notes:**
    - “reach of the laser” unclear (length of the tracks)
    - We can in principle fire more than one laser at a time
    - In TDR laser frequency assumed as 10 Hz
      - **Can the DAQ handle this?**



Such a scheme requires precise knowledge of laser direction at firing moment

800,000/scan/10 kt × 100 μs × 1.5Bytes/sample × 2 MHz × 384,000 channels = 92 TB/scan/10 kt.

IoLaser Operation scenarios (not limited to these)

- **Scenario 1: DAQ is aware of directions/positions to be sampled and the initial directions of the mirrors**
  - Receives from cal (via IB) when motors start movement
  - Calculates TS when required mirrors will be at right place.
  - Sends to Cal the “request” to fire (no SN ongoing)
  - Receives the cal “true firing” time (to make sure of the exact direction of the laser)
  - Fetches the correct data from buffer for the relevant APA’s
  - **Restrictions:**
    - What to do if for some reason the laser didn’t fire at the exact expected time?
      - Skip the point (and tell DAQ about it)
      - Feedback new direction (how? ethernet?)
    - How to control that the mirrors are where the DAQ expects them to be at each moment?

- **Scenario 2: DAQ is only aware of directions/positions to be sampled**
  - DAQ receives (from configuration) a list of laser positions/directions
  - If cal should be vetoed (SN), send to DAQ command vetoing operation (valid until cancellation command sent)
  - Receives from cal (via IB) when the laser was fired
  - Fetches the data from the buffer corresponding to the direction in the list
  - **Restrictions:**
    - Assumes that the positions/directions will happen in a specific order