2nd DRD3 week on Solid State Detectors R&D

Geneva, 3rd December 2024

# SPS test-beam infrastructure extension for low temperature, fast triggering applications

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1: University of Zurich
2: CERN
3: Université Paris-Saclay

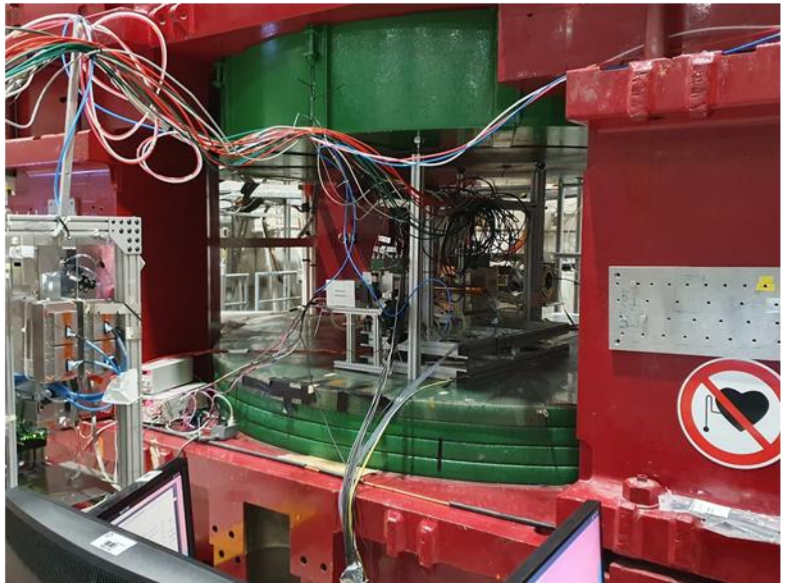
# •Introduction

**3 EUDET telescopes available**
- Mimosa26 planes featuring 4µm resolution
- EUDAQ1/2 and TLU1/2 as options
- Can be booked as an option in PS/SPS beam request
- For information and help with usage contact André Rummler (telescope maintenance and support); particularly if anything special is needed

**ACONITE**
- ✓ Permanently installed in SPS/H6A
- ✓ Equipped with cold box allowing stable -60°C using two ethanol cooled deep temperature chillers

- FE-I4 timing and ROI
- Controlled PI stages
- Used by various groups
- 35 weeks across all telescopes
- 7 different user groups; including Operation inside H4 magnet
- Full set of Mimosa26 planes procured by ATLAS and CMS)

**AIDA**
- ✓ Permanently installed in SPS/H6B



**AZALEA**
- ✓ Mobile telescope
- ✓ Primarily used at PS but also transported to SPS

# •Introduction

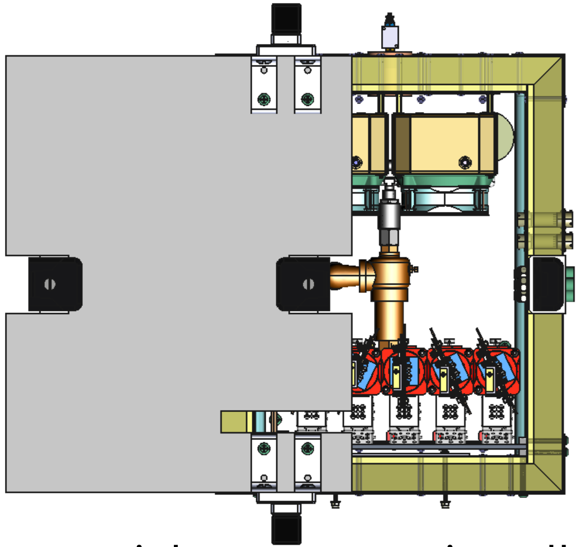
**Problem:** Low temperature environment needed for leakage current mitigation at high fluences >$10^{15}$ $n_{eq}/cm^2$ and charge carrier mobility for impact ionization-based technologies (LGADs)

**Create a common framework within AIDA INNOVA WP2 to implement necessary infrastructure**

**Deep Temperature Chiller**

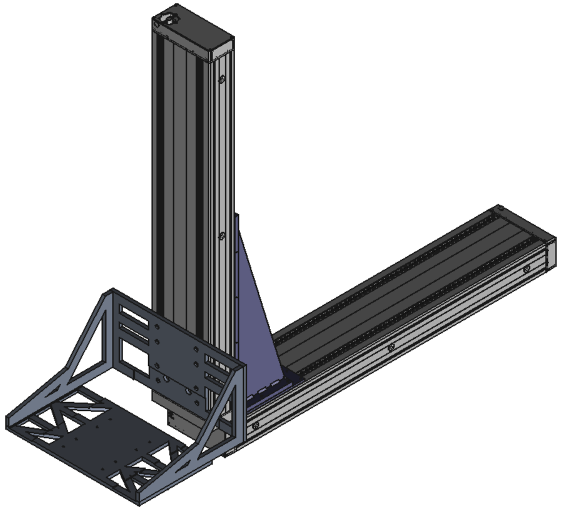
Hubert P815W with 3 Bar pump
1.2 kW, water-cooled, -60 °C

**Controllable multi-plane cold box**



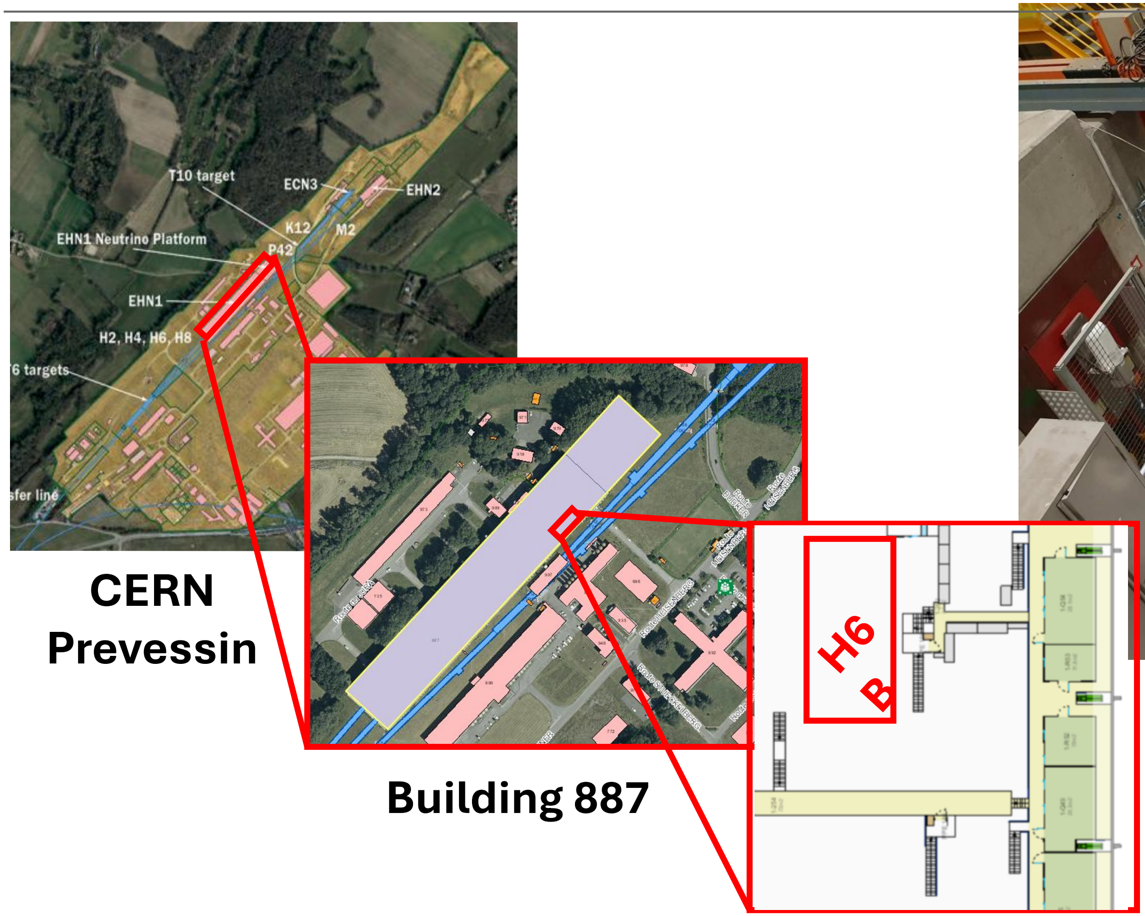
Low material, permanent installation, removable DUT assembly

**High-capacity precision stage, ILE**



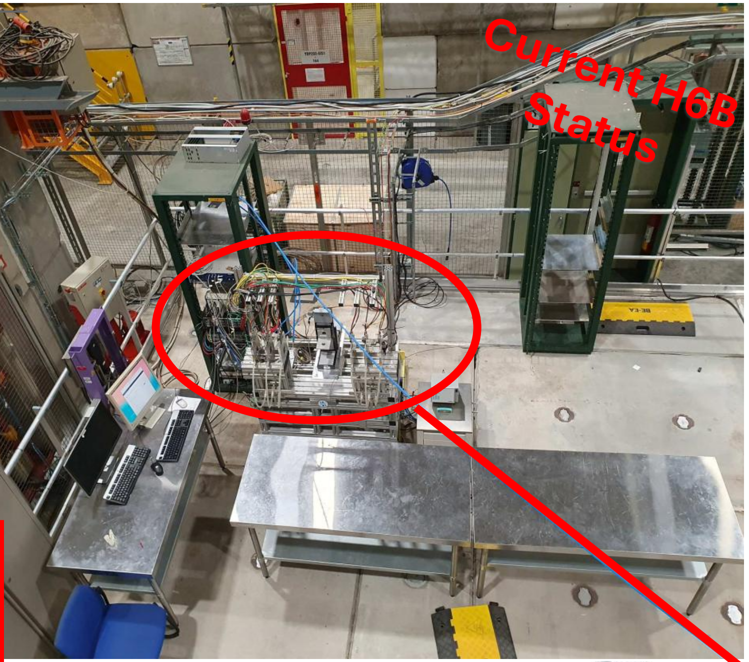
34.2 kN dynamic carrying load, 5 mm pitch, and 1 m travel range

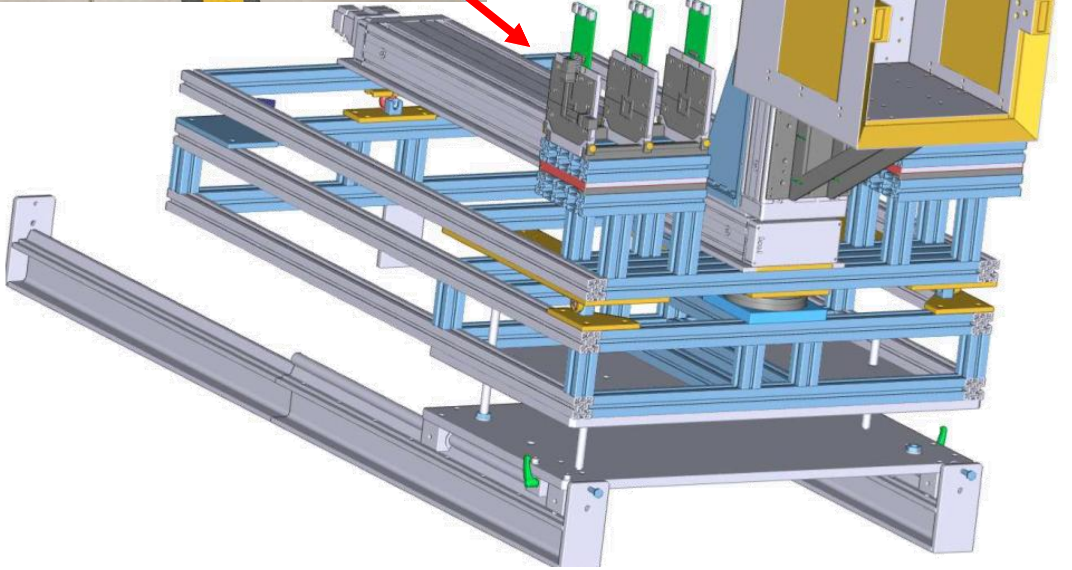
# •General Infrastructure: H6B



**CERN Prevessin**

**Building 887**

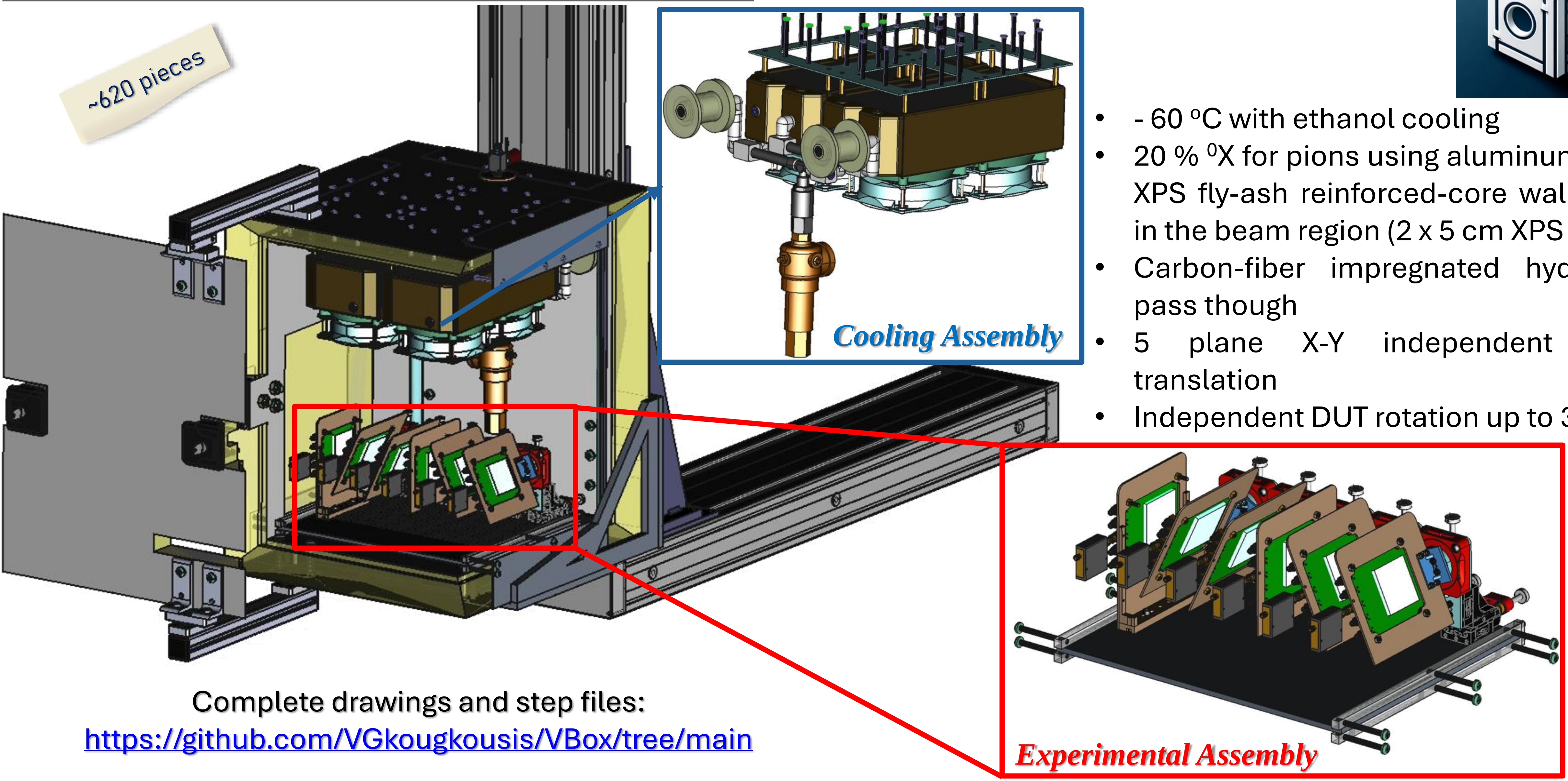




## AIDA Telescope in H6B Current setup

- 6 MIMOSA 26 planes
- One 2-axis PI stage, up to 20 kg support
- No DUT cooling infrastructure
- Nitrogen gas supply line in the area

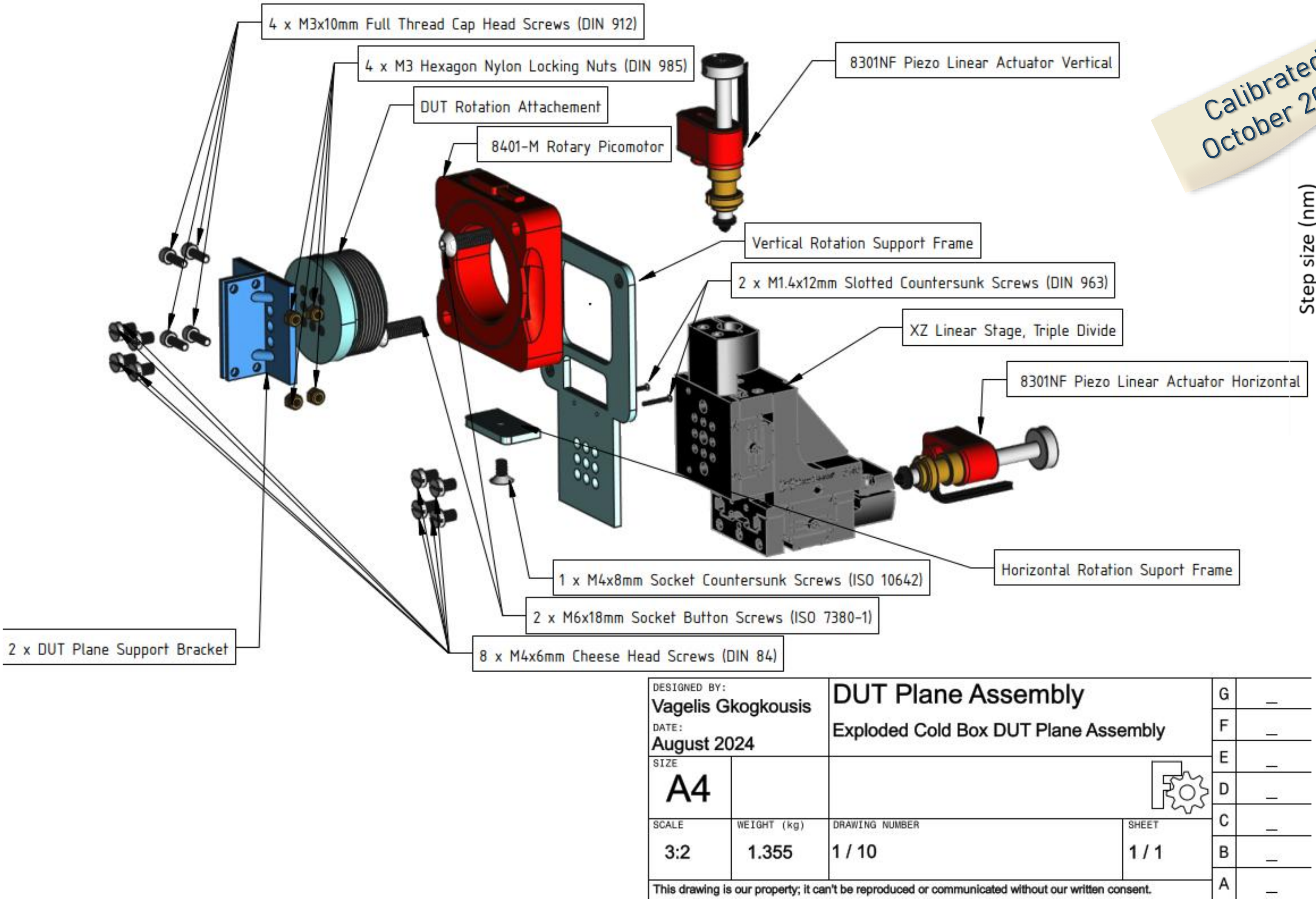
# •General Infrastructure: ColdBox (VBox)



- - 60 $^{o}$C with ethanol cooling
- 20 % $^{0}$X for pions using aluminum clad XPS fly-ash reinforced-core wall, 8 % in the beam region (2 x 5 cm XPS foam)
- Carbon-fiber impregnated hydraulic pass though
- 5 plane X-Y independent DUT translation
- Independent DUT rotation up to 35$^{o}$

Complete drawings and step files:
https://github.com/VGkougkousis/VBox/tree/main

# •Individual Stage Assembly



DESIGNED BY:
Vagelis Gkogkousis
DATE:
August 2024

**DUT Plane Assembly**
Exploded Cold Box DUT Plane Assembly

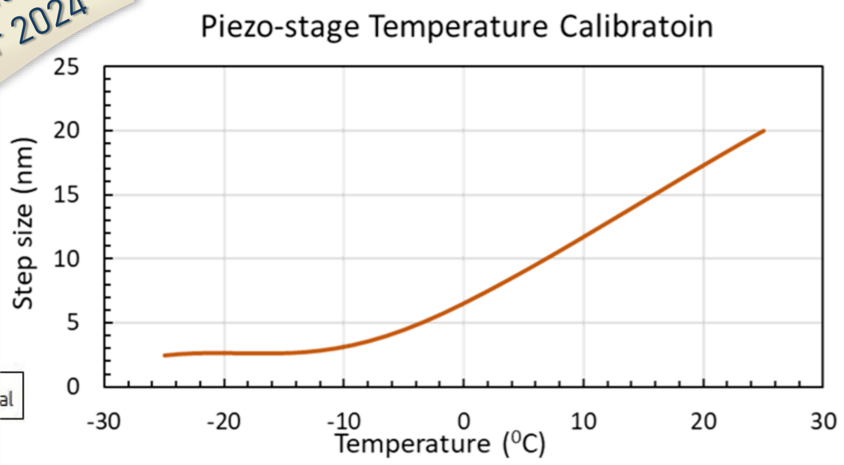
SIZE
A4

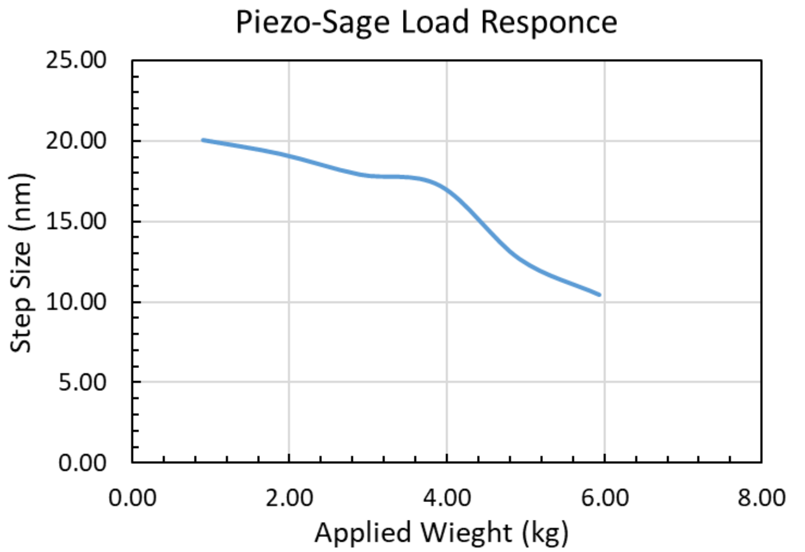
| SCALE | WEIGHT (kg) | DRAWING NUMBER | SHEET |
|---|---|---|---|
| 3:2 | 1.355 | 1 / 10 | 1 / 1 |

This drawing is our property; it can't be reproduced or communicated without our written consent.

**Performance and precision depends on temperature and mechanical stress:**

Calibrated
October 2024

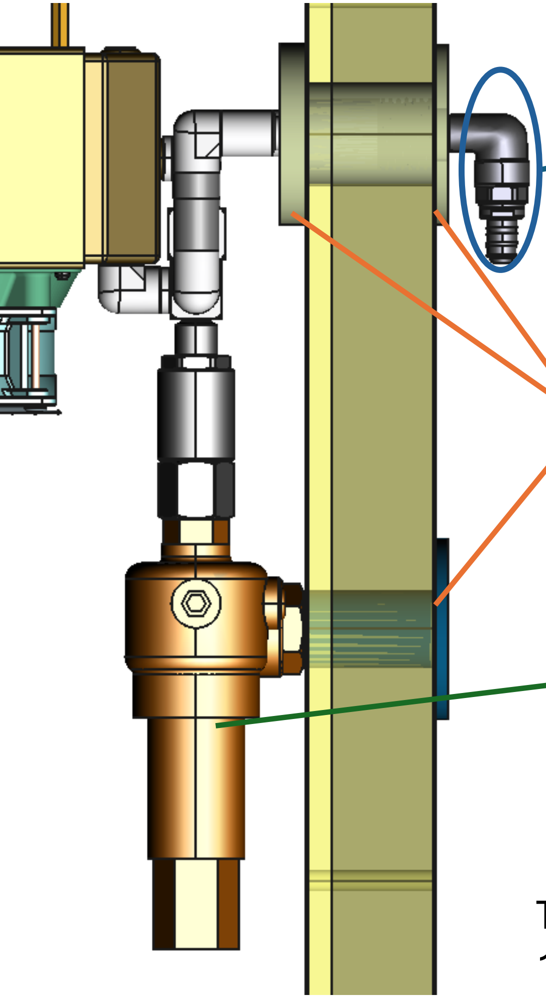

Piezo-stage Temperature Calibratoin


Piezo-Sage Load Responce

# •Important Design Elements

**Use of Ethanol** = **Increase safety precautions**

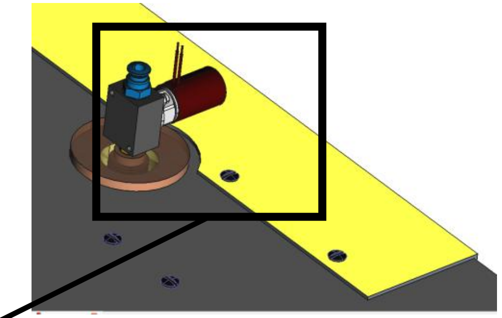
**Under discussion with CERN safety for exemption**



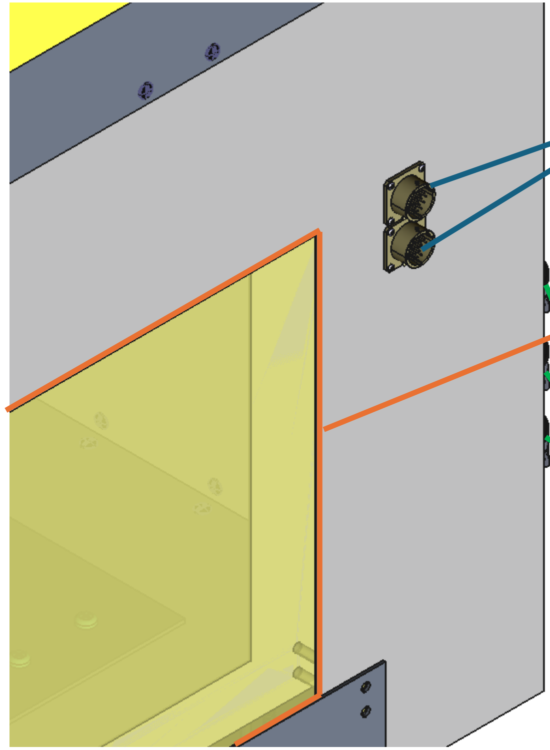
Low temperature spill-les quick disconnect, clean cut (-60°C)

Conductive carbon fiber reinforced PEEK 2-part hydraulic pass- throughs to avoid static electricity build-up

Calibrated 15 psi expansion valve with oil safety certification -200°C to 215°C range



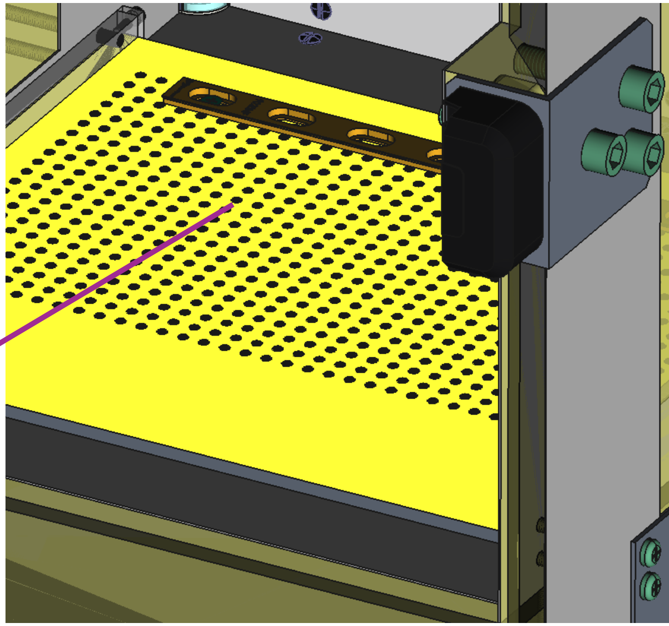
Top side regulated solenoid valve, 100l/min max flow, 10% hysteresis, 2M cycles, < 1MPa, FESTO press fittings



2 x 16 contact bayonet gold coated circular pass-through per side

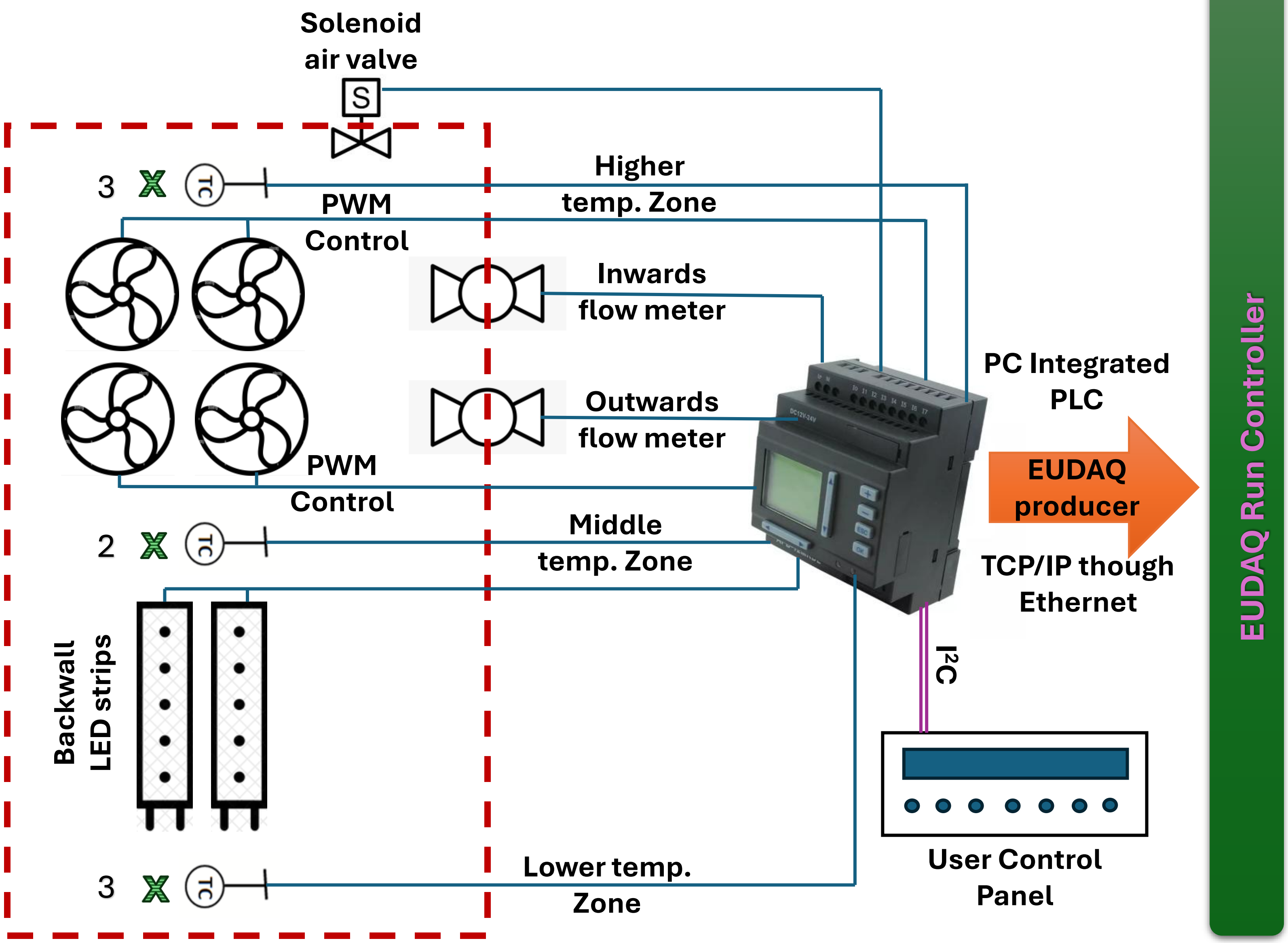
250 x 300 mm beam window aligned with DUT center, removed Al cladding (1 mm)

3 x 50 mm diameter steel pipe clamps for cooling circuit hose retention per side



M5 X 10 Grid with optical rail for independent DUT placement on removable drawer

# •Control and electronics



- ✓ Industrial PID (Proportional Integral Derivate) control system with PC capabilities
- ✓ Integrated control with an independent front panel and Local/Remote mode
- ✓ EUDAQ integration in a producer style concept to be initialized by Run Controller
- ✓ Combined "Infrastructure" producer integrating chiller, stages and pico-motor control
- ✓ Plans for future LV an HV integration with multi-instrument support

| | Sensors | |
|---|---|---|
| Cooling loop | Flow (In / Out) | 2 |
| | Pressure (In/out) | 2 |
| | Temperature (In/out) | 2 |
| Water Loop | Flow (In / Out) | 2 |
| | Pressure (In/out) | 2 |
| | Temperature (In/out) | 2 |
| Box Interior | Temperature | 3 x 3 zones |
| | Humidity with in. heater | 3 |

# •Tables - dimensions

- **Three available design variations:**
  - ✓ $\pi^{0,\pm}$ & other high energy particle beams → 5 DUT + 1 REF
  - ✓ $e^-$ beams → **2 DUT + 1 REF**
  - ✓ Climate Chamber variant for lab environment → **Extended Height** **(foreseen to fir CMS end cap TEPIX disk)**

**Mass, Coolant & DUT Planes**

| Design Variant | Total weight ex. Coolant (kg) | | | Estimated Coolant Volume (l) | Max. No. of DUT Planes |
|---|---|---|---|---|---|
| | Box Mass | Sages Mass | Total | | |
| CERN | 37.51 | 3.71 | 50.64 | 1.65 | 5 |
| DESY | 22.5 | 1.5 | 31.2 | 0.85 | 2 |
| Climate Chamber | 38.91 | 3.71 | 42.62 | 1.65 | 5 |

**Material Properties table**

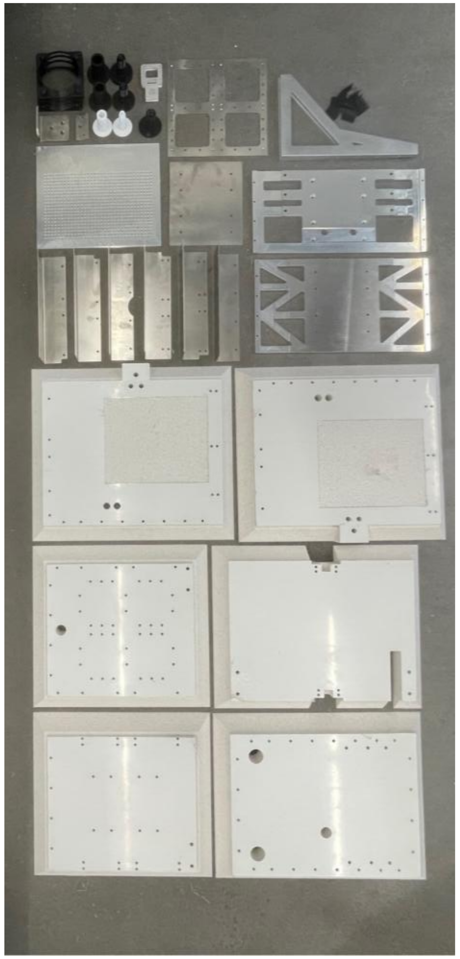
| | Material | Density ($kg/m^3$) | Glass Transition Temperature (°C) | Thermal Conductivity (W/m·K) |
|---|---|---|---|---|
| Metals | Aluminum | 2600 | N/A | 205 |
| | Austenitic stainless steel | 8000 | N/A | 16 |
| Composites | CoraPan Al 85 | 85 | 100 (XPS part) | 0.035 |
| | Carbon Fiber Reinforced PEEK (CFK) | 1500 | 140 – 150 | 0.5 (transversal) |
| | White Acrylic | 1100 | 105 | 0.25 |
| | TECAPEEK ELS | 1450 | 150 | 0.46 |
| | Polyamide | 1150 | 50 (PA66) | 0.23 |
| | Polyethylene Plastic | 940 | -110 | 0.40 |

**Design Variant Dimensions**

| | Dimensions | CERN | DESY | Climate Chamber |
|---|---|---|---|---|
| Outer | Height (mm) | 600 | 600 | 930 |
| | Width (mm) | 475 | 285 | 475 |
| | Length (mm) | 520 | 520 | 520 |
| Inner | Height (mm) | 500 | 500 | 830 |
| | Width (mm) | 375 | 185 | 475 |
| | Length (mm) | 420 | 420 | 520 |
| Usable | Height (mm) | 314 | 314 | 644 |
| | Width (mm) | 375 | 185 | 475 |
| | Length (mm) | 320 | 320 | 520 |

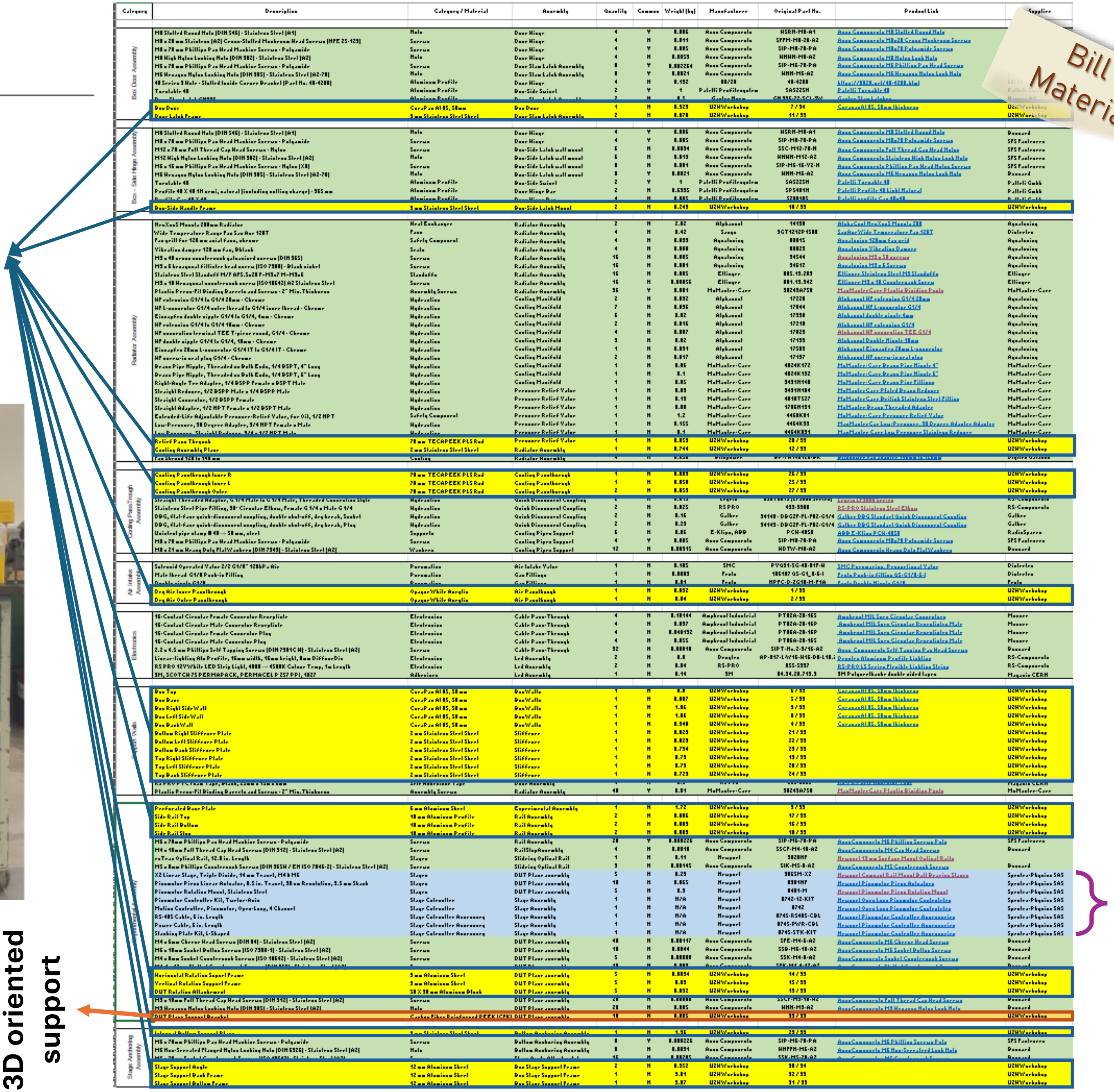
# •Bill of Materials & Assembly

| Part Count | |
|---|---|
| No. of Machined designs | 32 |
| No. of 3D printed designs | 1 |
| Total Machined Parts | 51 |
| Total 3D Printed Parts | 10 |
| **Total Part Count** | **619** |



- **Fabrication complete**
- **Assembly within the week @ UZH**

**Custom machined designs**



**3D oriented support**

**Optional micro-stages**

E. L. Gkougkousis

# •Fast Trigger Generator

**The issue**

1. Current AIDA TLU requires ~ 120 ns for trigger generation (TLU 2) and 71 ns (TLU 1)
2. CAEN Digitizer (WDT5742BXAAA) and other multi-channel digitization devoices have limited waveform buffer memory at high sampling rates (~ 200 ns) -> 1 kSmp./event @ 5GHz

**Result: Loss of waveform due to out of time trigger delivery**

**Proposed solution:**

✓ Custom Trigger logic board delivering Trigger within 20 ns

✓ Function in tandem with AIDA TLU with a EUDAQ style producer

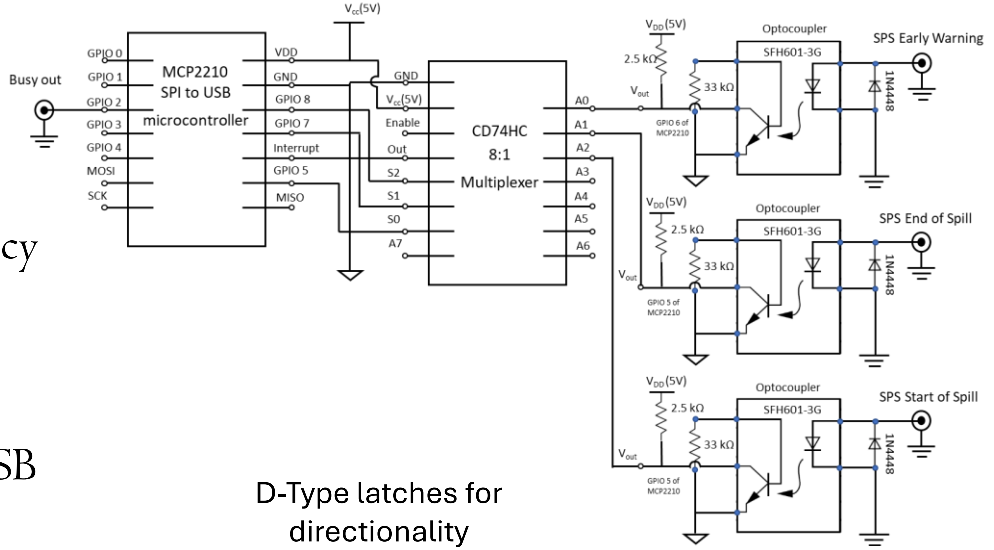
✓ Capable of managing fast (>1GHz) omni-polarity (positive/negative) inputs

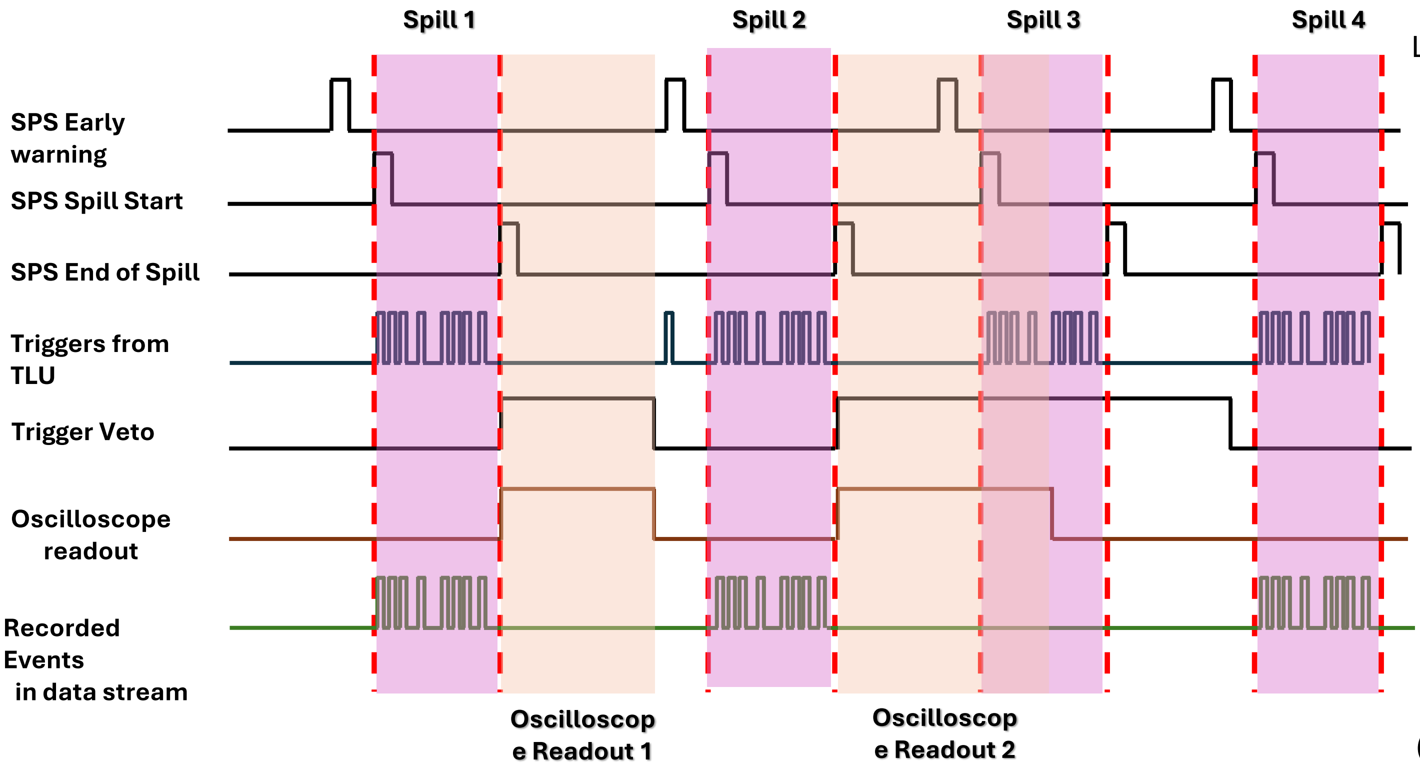
✓ Work in sync with SPS clock for efficient data readout within spills

✓ Fully customizable logic matrix with external trigger input and adjustable thresholds

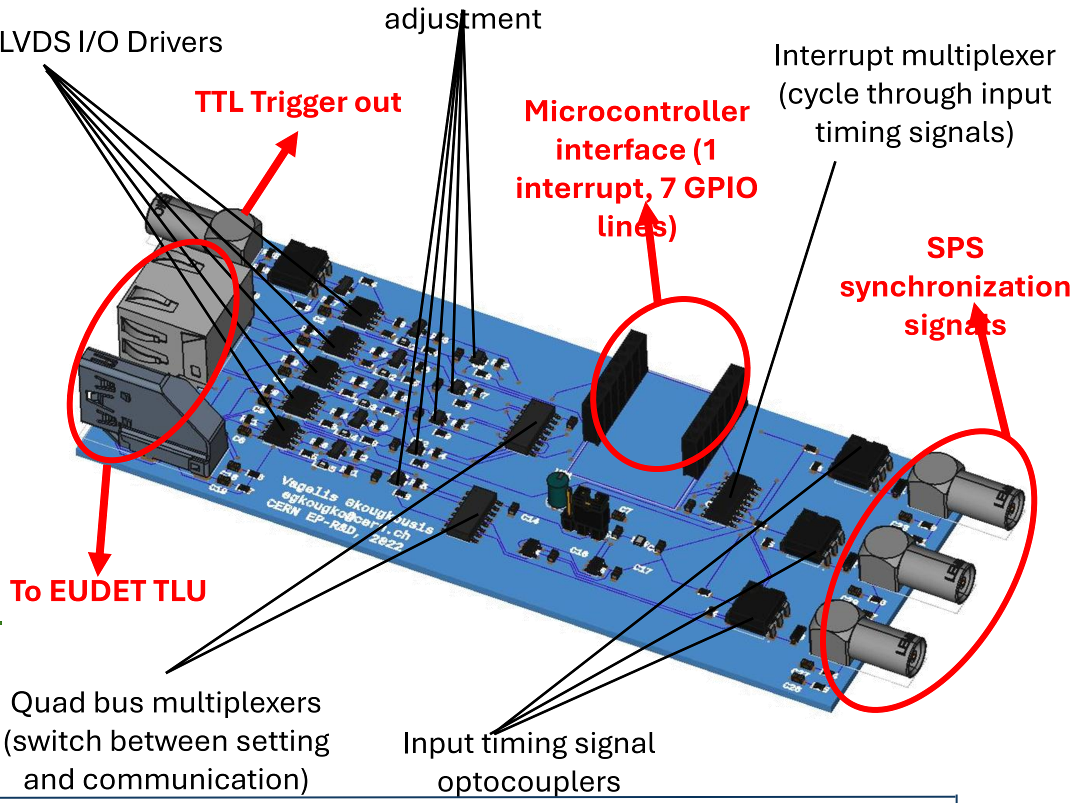
# •Trigger Interface Board (TiB)

- Oscilloscope in fast readout mode with binary format
- Event readout only between SPS-spills or when event buffer full to increase efficiency
- TLU Synchronization by vetoing data taking during read-out
- RJ-45 or HDMI for EUDET TLU communication (EUDET 2 compatible)
- **Versatile design**, I/Os **Reconfigurable** and microcontroller **Reprogrammable** via USB





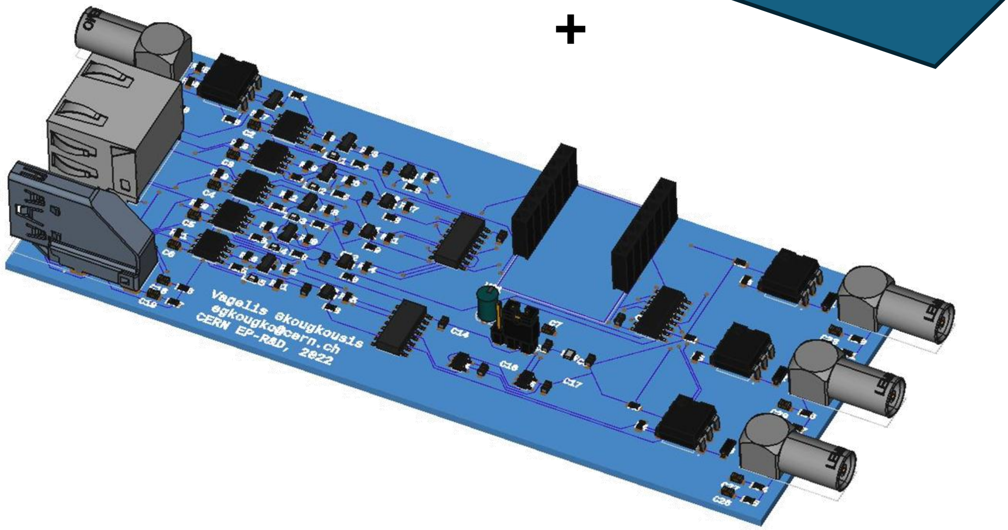
D-Type latches for directionality adjustment



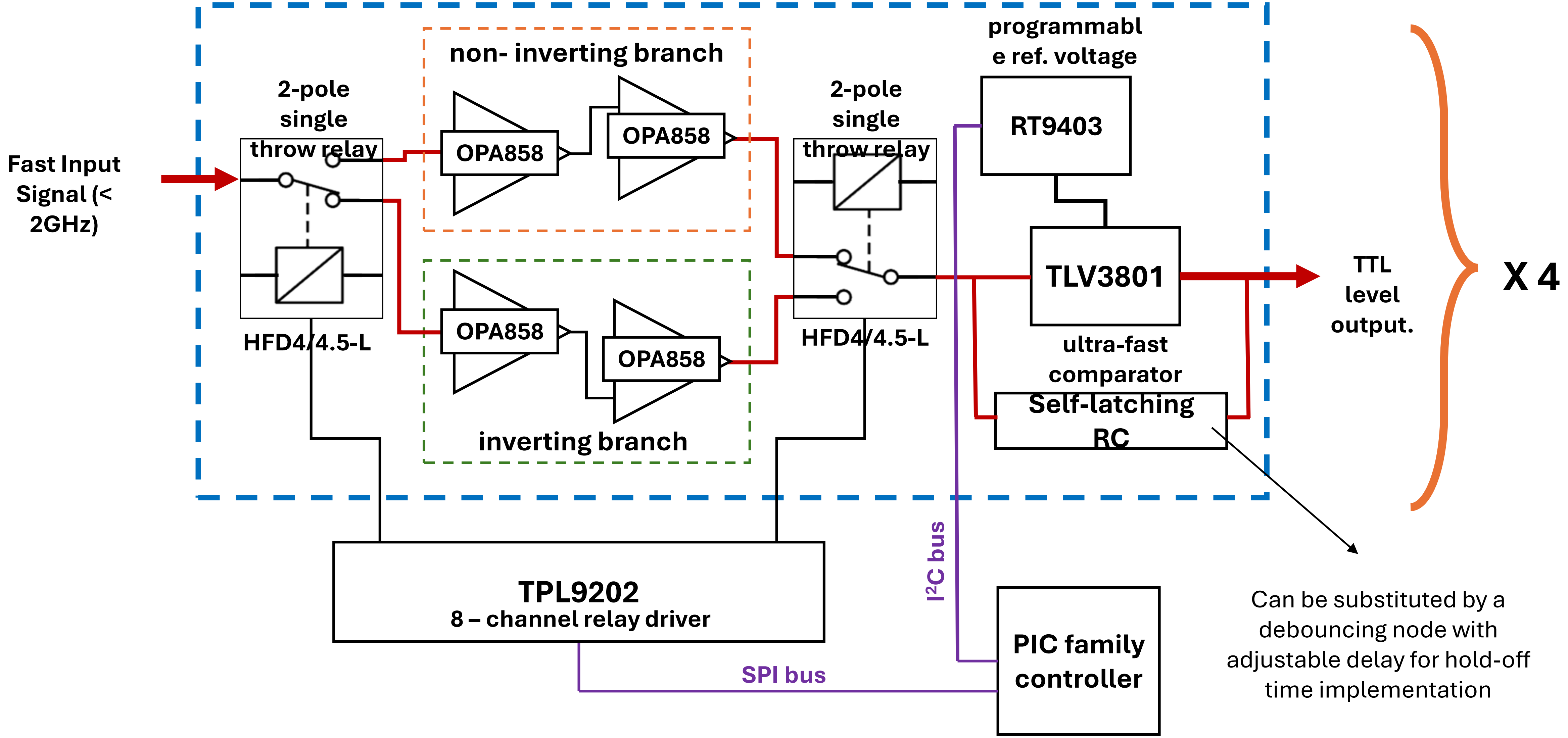
# •Fast Trigger Producer

**Fast Trigger Producer Board**

\+

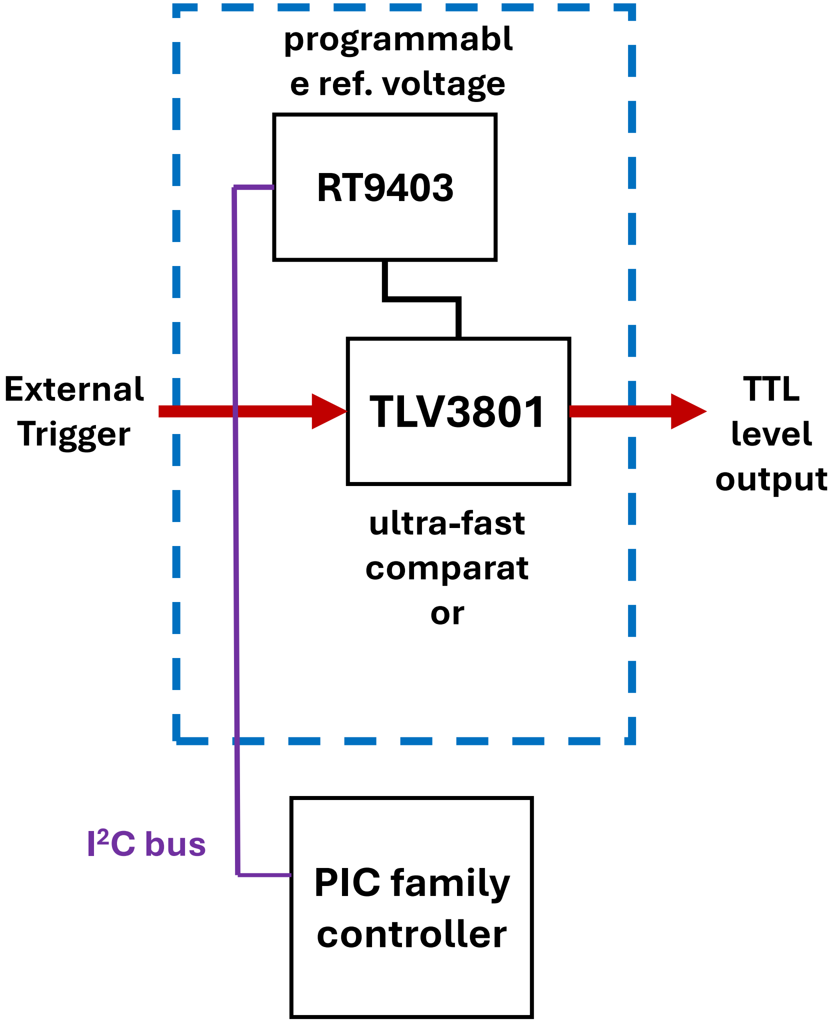


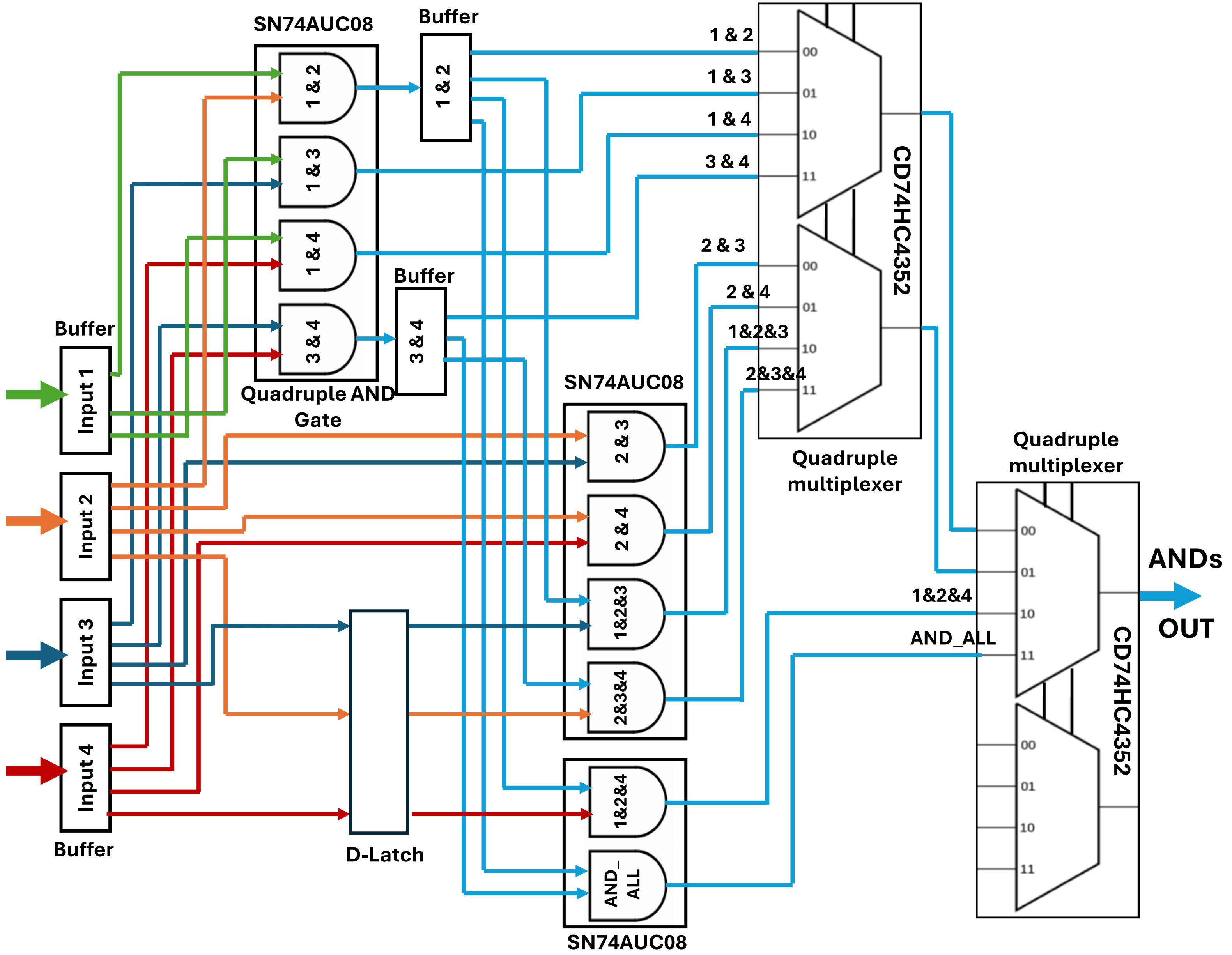
# •Trigger input channel



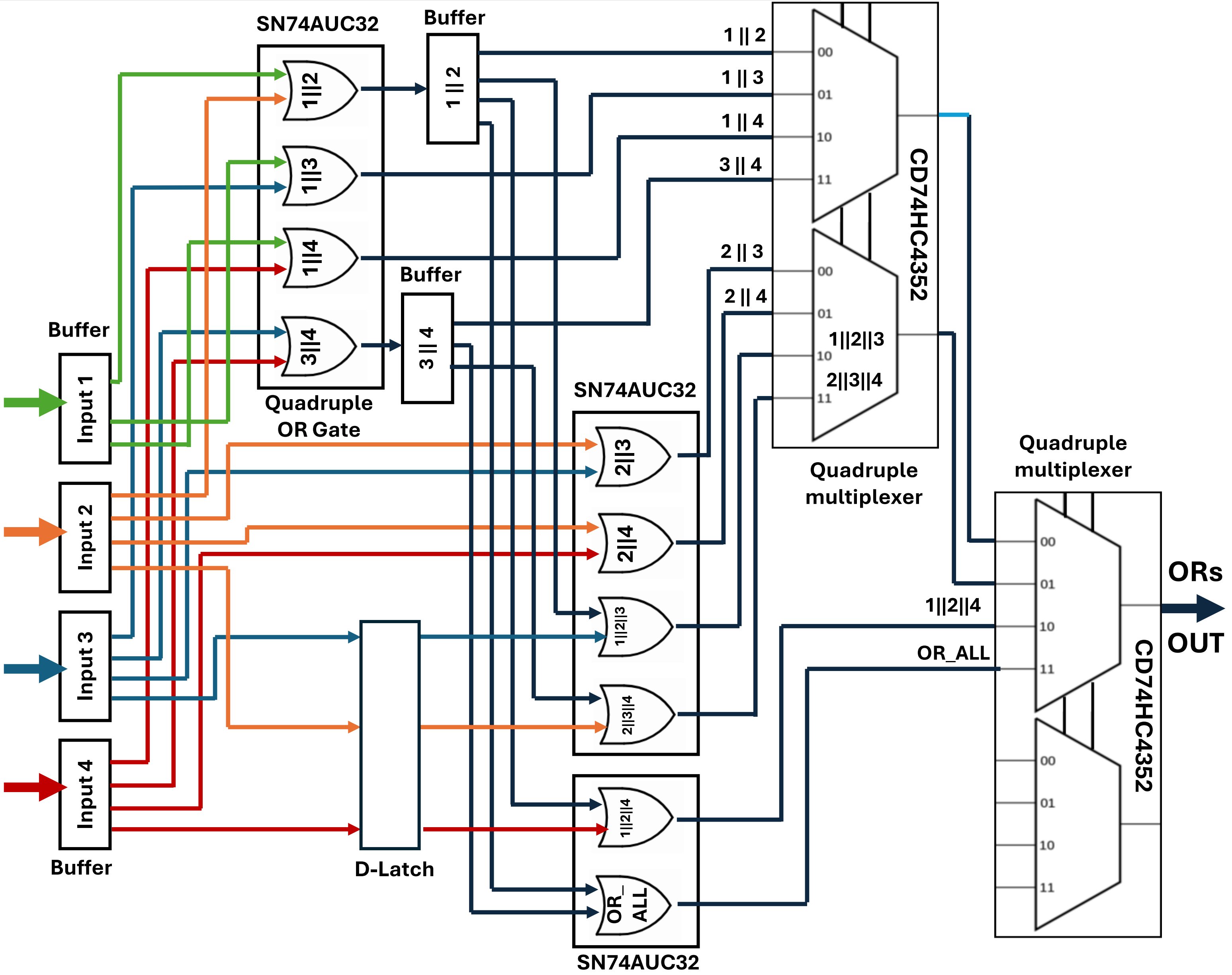
Can be substituted by a debouncing node with adjustable delay for hold-off time implementation

# •External input & AND decision matrix





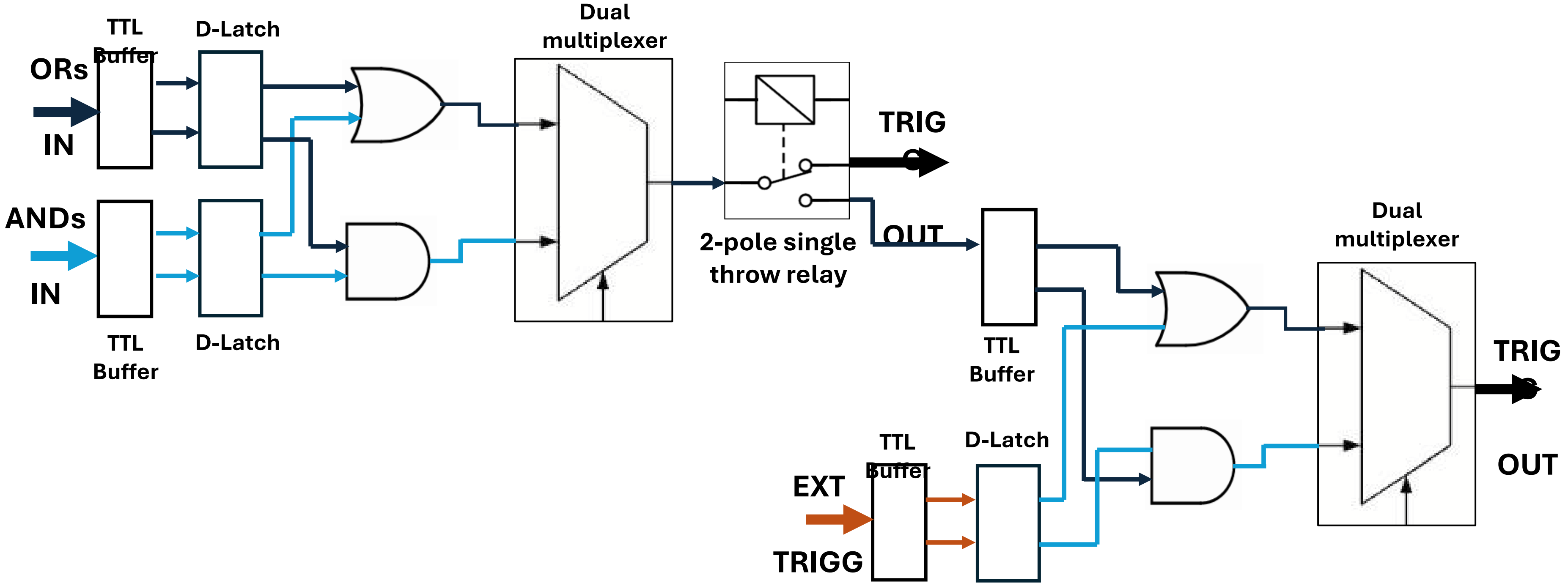
# •OR decision matrix



**Open issues**

1. Select quad and dual TTL buffers
2. Select input relays
3. Select Latches for all stages
4. Configure the de-bouncing/ auto-latching circuit for comparator
5. Clocking and clock distribution
6. Microcontroller selection and I$^2$C/SPI bus configuration
7. Proper full simulation for timing and clocking

# •Post decision Matrix



## Clocking considerations

Three stage configuration:

1. AND/OR matrices decision tree ($f_{1st.\ stage}$)
2. ANDs/ORs combination branches at post-trigger logic $f_{2nd.\ stage}$)
3. Ingestion of external Trigger ($f_{ext.} = 40 – 50$ MHz)

**For a 200 MHz first stage frequency, the combined propagation time of the AND/OR logic and the TTL buffer at the first stage should be < 5 nsec**

| Frequency calculation | |
|---|---|
| $f_{ext.}$ | 40 – 50 MHz |
| $f_{2nd.\ Stage} = 2*f_{ext.}$ | 80 – 100 MHz |
| $f_{1st.\ Stage} = 2*f_{2nd.\ Stage}$ | 160 – 200 MHz |

# •Conclusions & Outlook

## Cold Box Infrastructure

- Stage and Chiller already procured and delivered at CERN
- Three cold box designs available, DESY / SPS / Climate Chamber
- SPS Cold box fabricated, assembly at the end of the week in Zurich
- Working on basic infrastructure services at CERN (power, water delivery, ect)
- Installation to start at the YETS (next week?) – plan for operation early next year
- **Future common fund required to equip other AIDA telescopes (2 @CERN and 2@DESY)**
- Electronics to be implemented

## Fast Triggering implementation

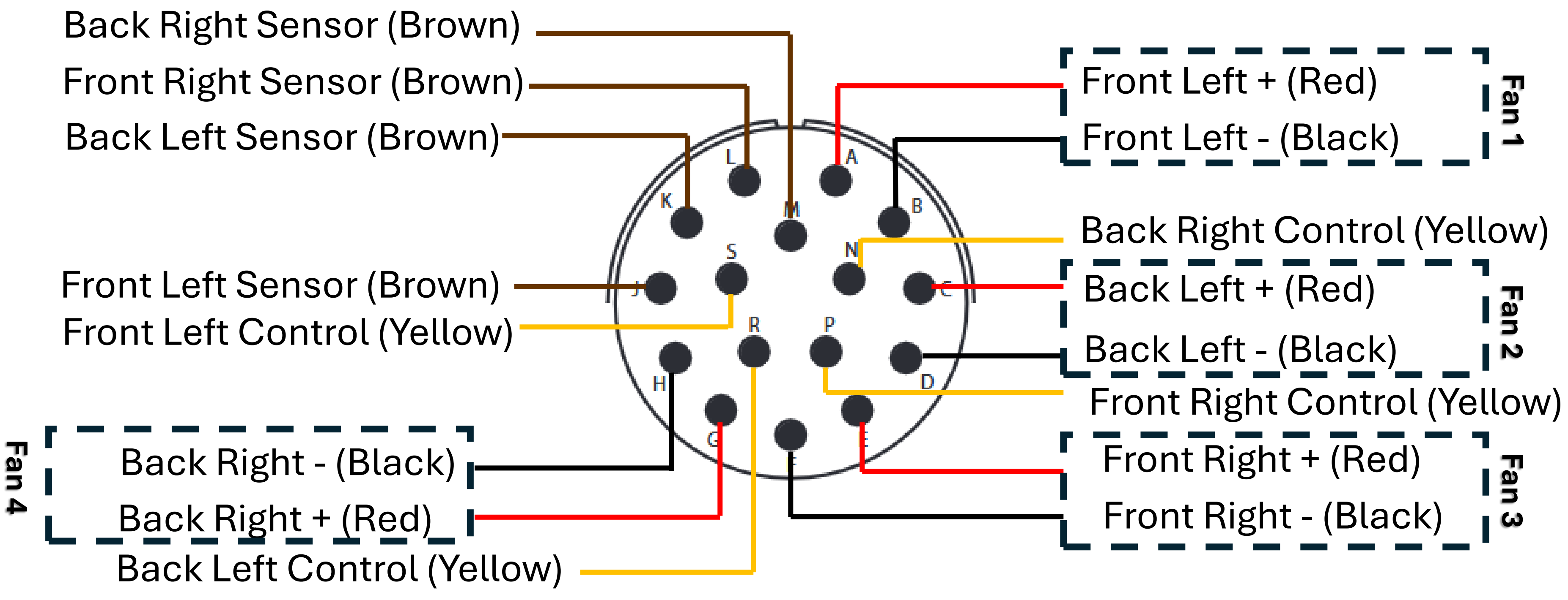
- Preliminary 4-channel board design with discreet logic
- Interacts as producer with standard TLU and EUDAQ
- < 20ns propagation / decision time
- Synchronous operation, if necessary, with external clock input
- Fast high bandwidth input amplifiers, low TOT for channel activation
- **First tests March/April 2025**

# •Backup

# •Fan Cabling Diagram

16-Contact Circular Male Connector Plug

PT06A-20-16S



Back Right Sensor (Brown)
Front Right Sensor (Brown)
Back Left Sensor (Brown)
Front Left Sensor (Brown)
Front Left Control (Yellow)

**Fan 4**
Back Right - (Black)
Back Right + (Red)

Back Left Control (Yellow)

**Fan 1**
Front Left + (Red)
Front Left - (Black)

Back Right Control (Yellow)

**Fan 2**
Back Left + (Red)
Back Left - (Black)

Front Right Control (Yellow)

**Fan 3**
Front Right + (Red)
Front Right - (Black)

**Suggested connection point:** Top Left passthrough

| **Fan Connectivity** | |
|---|---|
| **Pin No.** | **Function** |
| A | Fan 1 + |
| B | Fan 1 - |
| C | Fan 2 + |
| D | Fan 2 - |
| E | Fan 3 + |
| F | Fan 3 - |
| G | Fan 4+ |
| H | Fan 4 - |
| J | Fan 1 Sensor |
| K | Fan 2 Sensor |
| L | Fan 3 Sensor |
| M | Fan 4 Sensor |
| N | Fan 4 Control |
| P | Fan 2 Control |
| R | Fan 3 Control |
| S | Fan 1 Control |