2nd DRD3 week on Solid State Detectors R&D

Geneva, 3rd December 2024

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

Evangelos – Leonidas Gkougkousis[1], Andre Rummler[2], Anne Dabrowski[2], Aboud Falou[3], Dominik Dannheim[2]

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

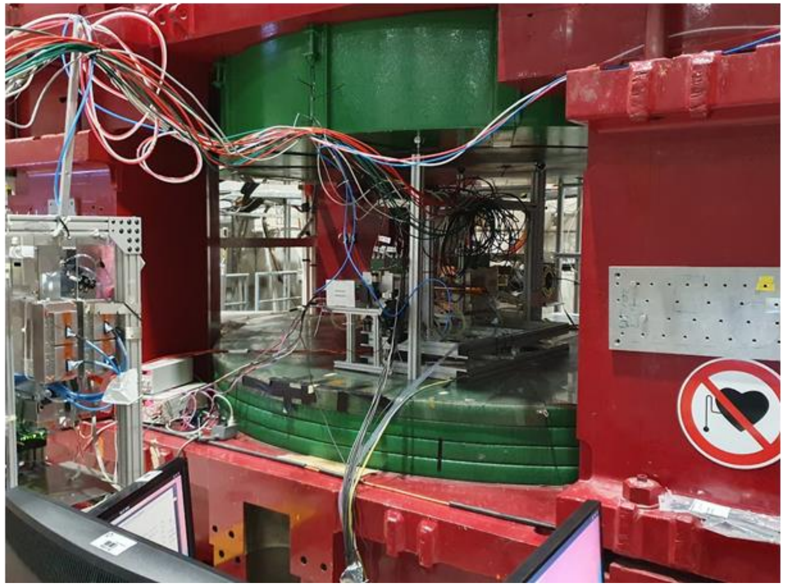
•Introduction

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)

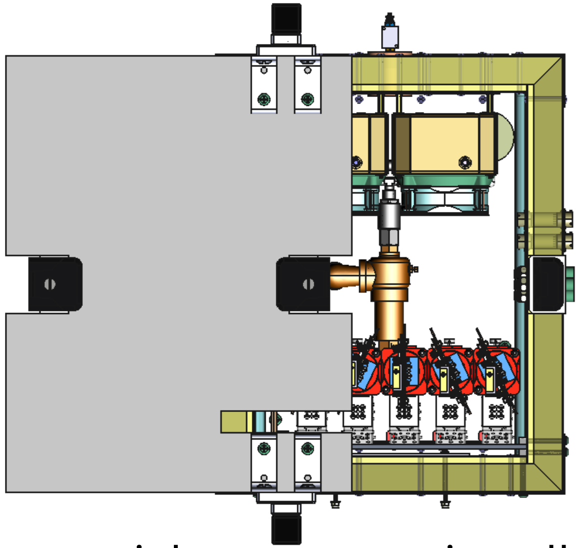
Create a common framework within AIDA INNOVA WP2 to implement necessary infrastructure

Deep Temperature Chiller

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

+

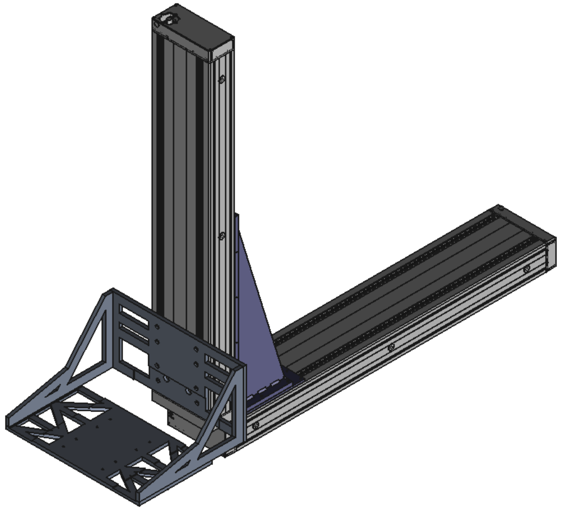
Controllable multi-plane cold box



Low material, permanent installation, removable DUT assembly

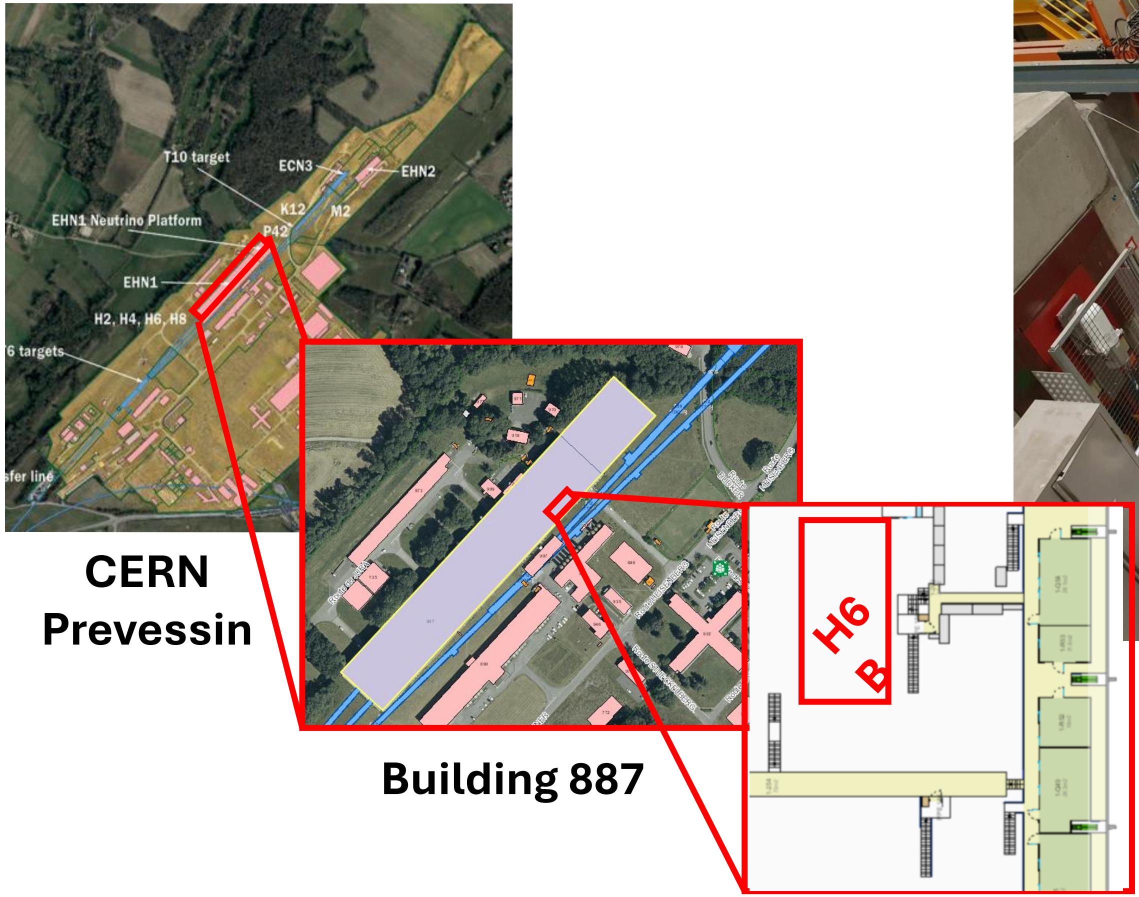
+

High-capacity precision stage, ILE



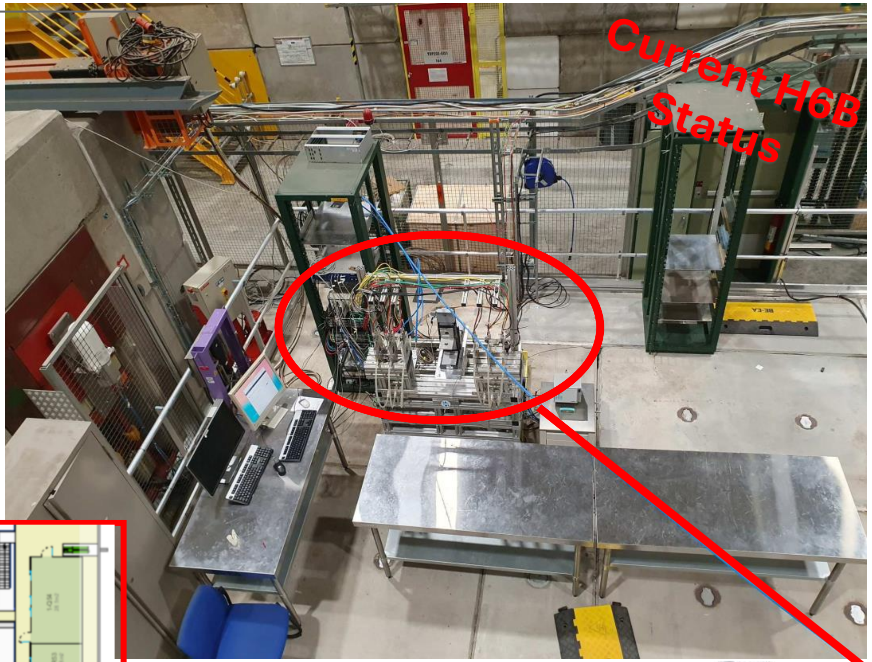
34.2 kN dynamic carrying load, 5 mm pitch, and 1 m travel range

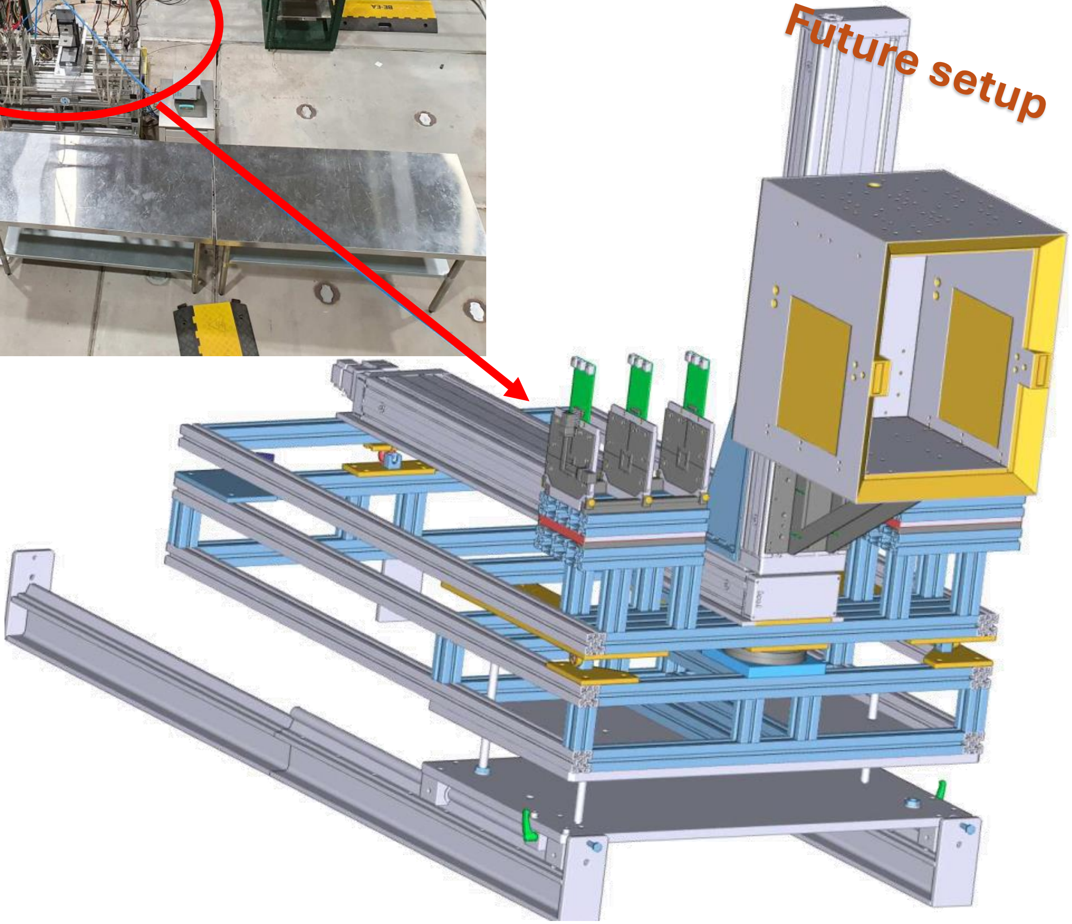
•General Infrastructure: H6B



CERN Prevessin

Building 887

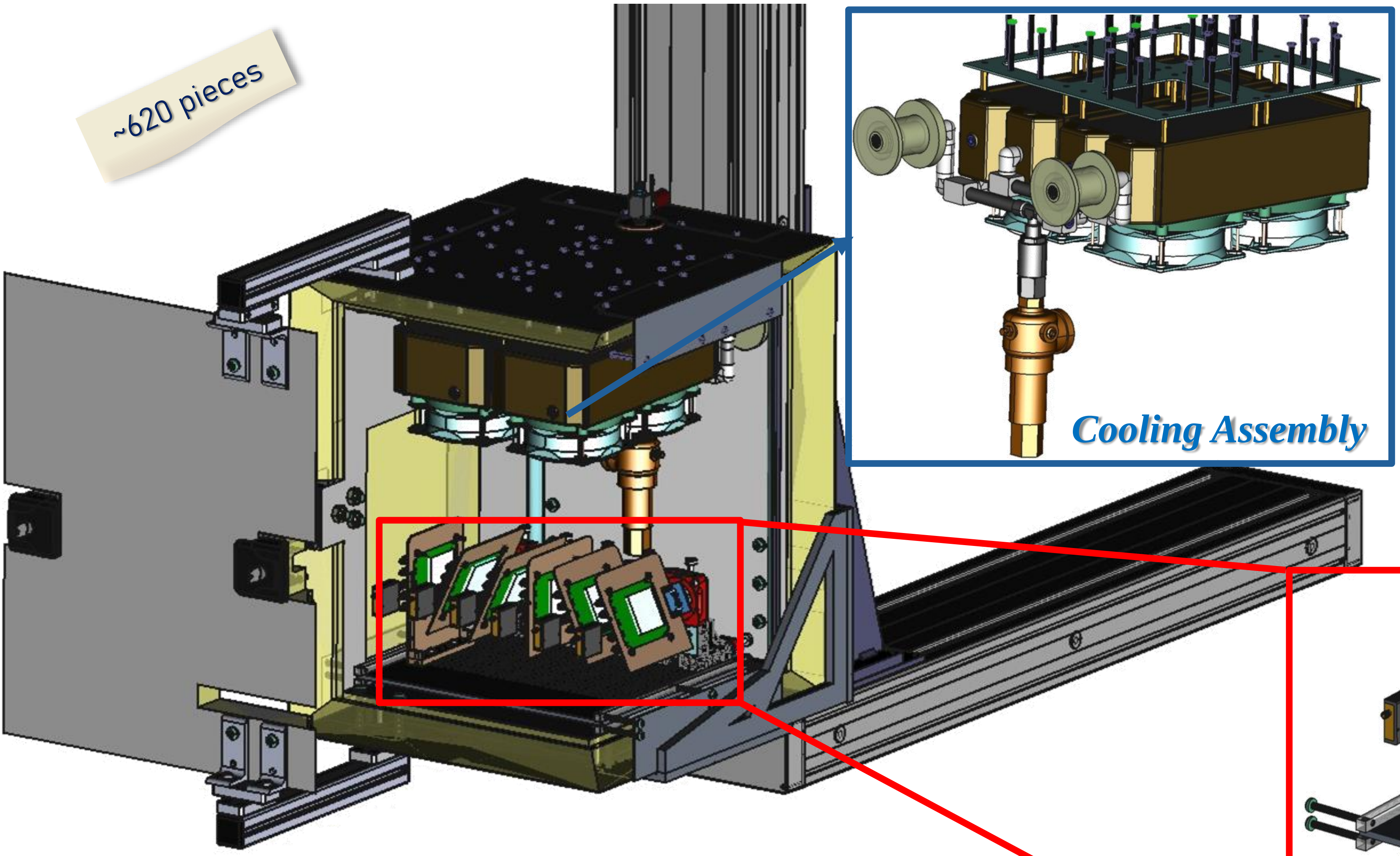




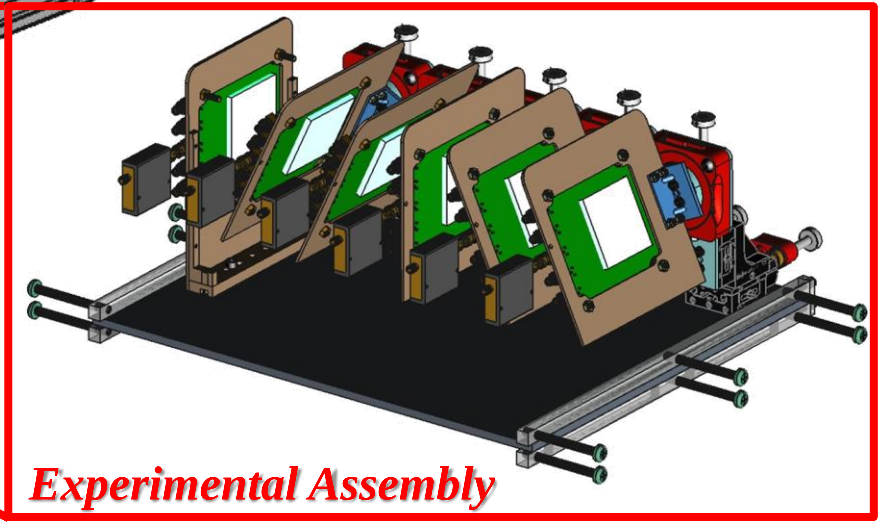
AIDA Telescope in H6B Current setup

- 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)

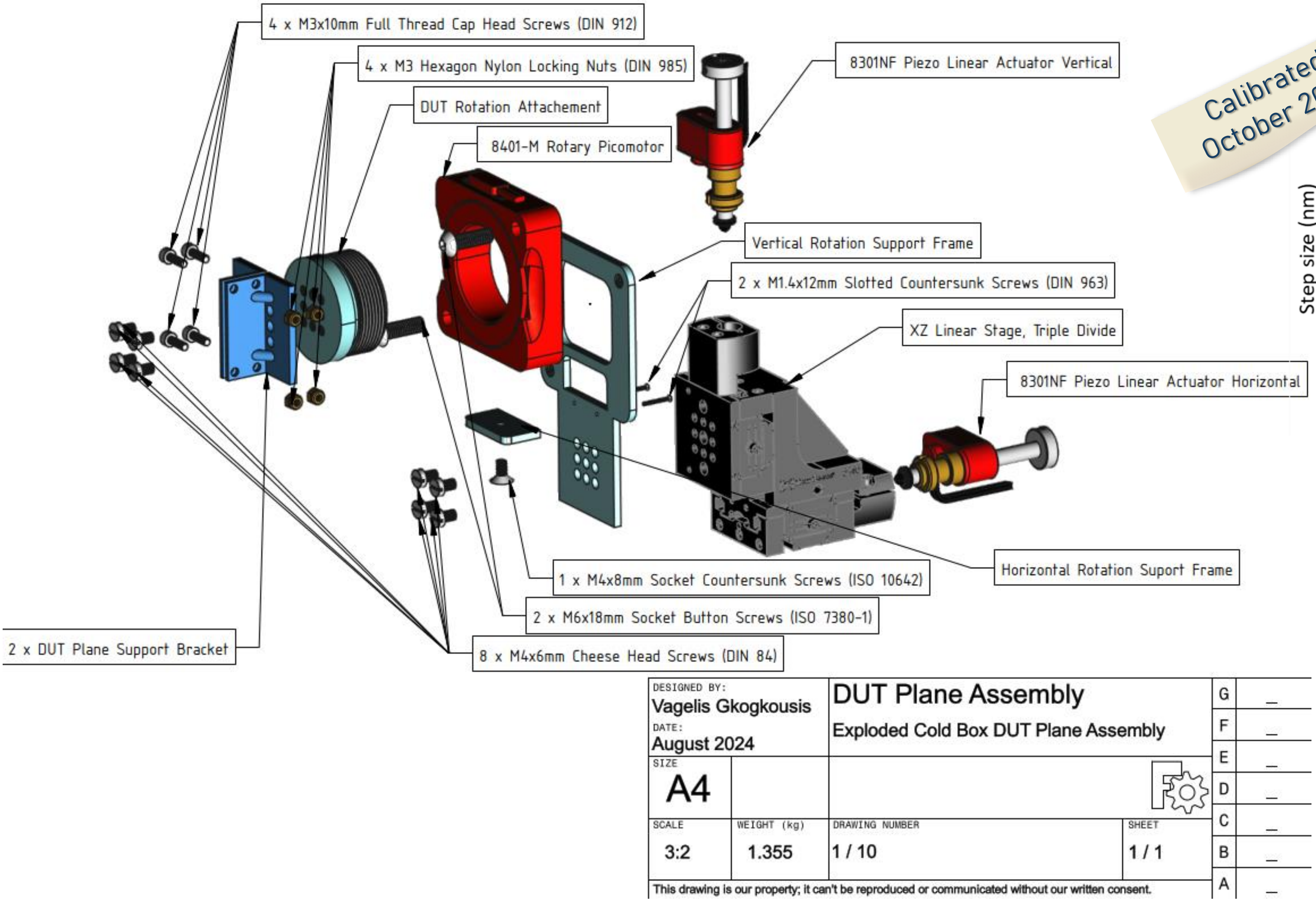


- - 60 °C with ethanol cooling
- 20 % ^{0}X for pions using aluminum clad XPS fly-ash reinforced-core wall, 8 % in the beam region (2 x 5 cm XPS foam)
- Carbon-fiber impregnated hydraulic pass though
- 5 plane X-Y independent DUT translation
- Independent DUT rotation up to 35°



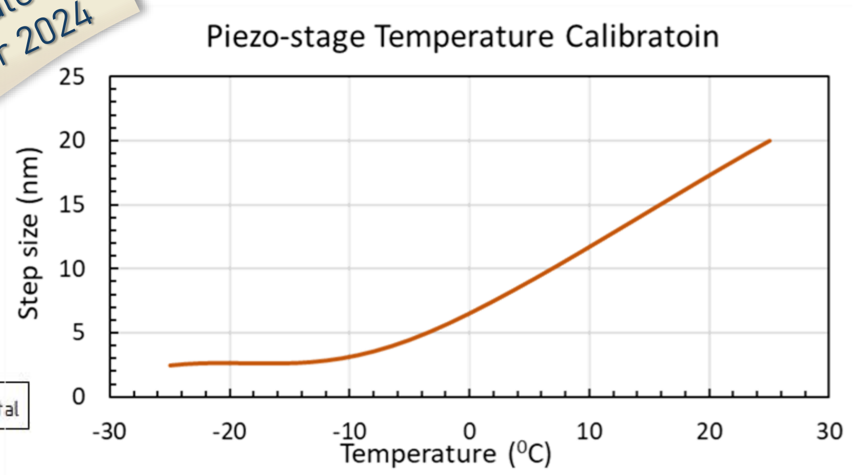
Complete drawings and step files:
https://github.com/VGkougkousis/VBox/tree/main

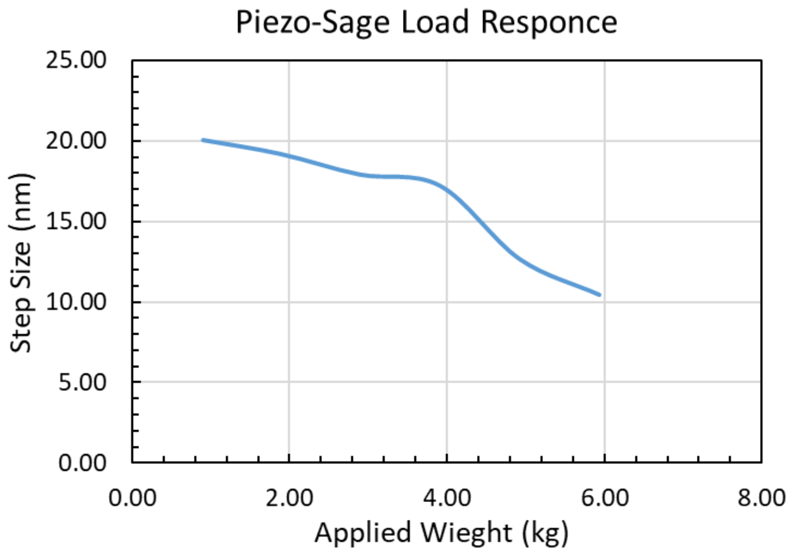
•Individual Stage Assembly



Performance and precision depends on temperature and mechanical stress:

Calibrated October 2024

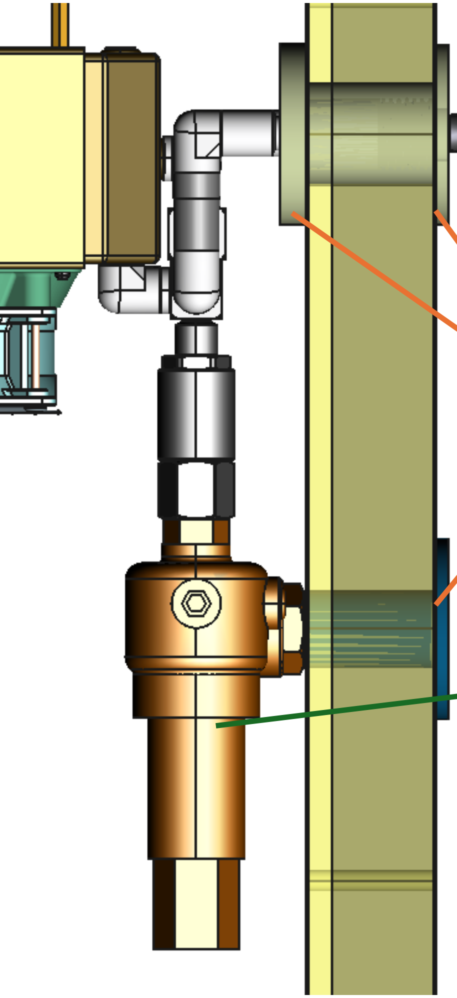




•Important Design Elements

Use of Ethanol = **Increase safety precautions**

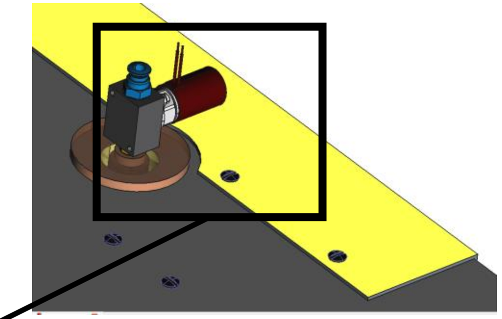
Under discussion with CERN safety for exemption

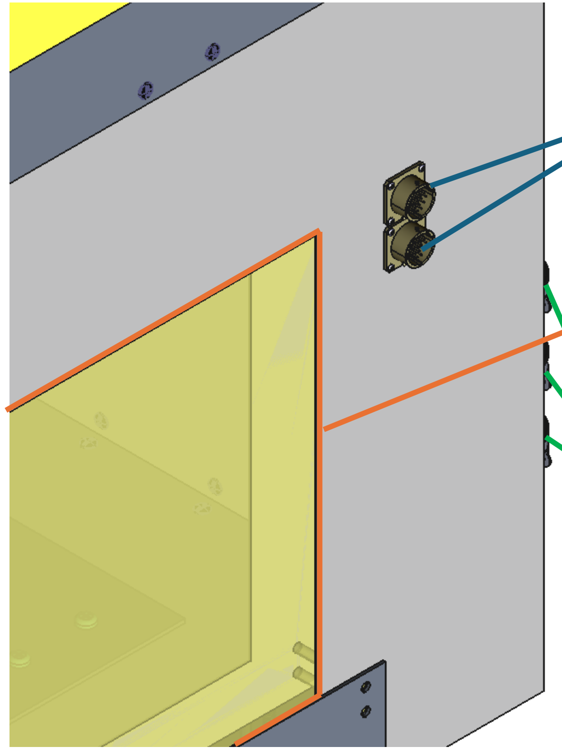


Low temperature spill-les quick disconnect, clean cut (-60°C)

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^{0}C to 215^{0}C range

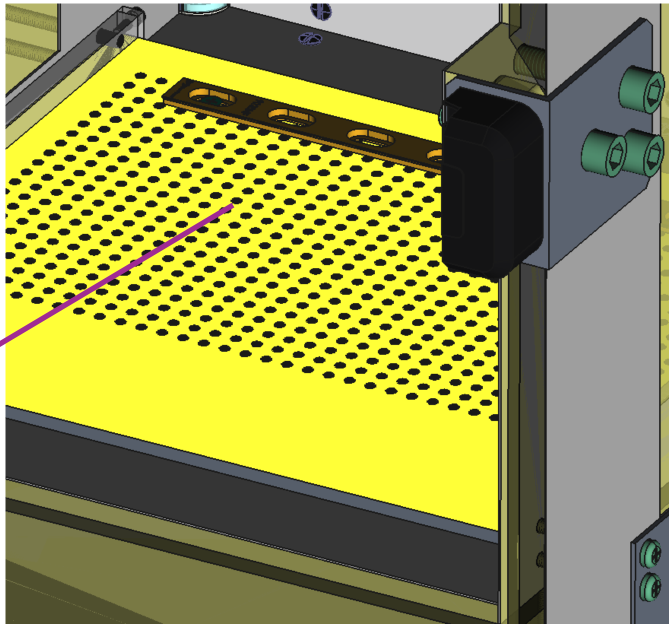




2 x 16 contact bayonet gold coated circular pass-through per side

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

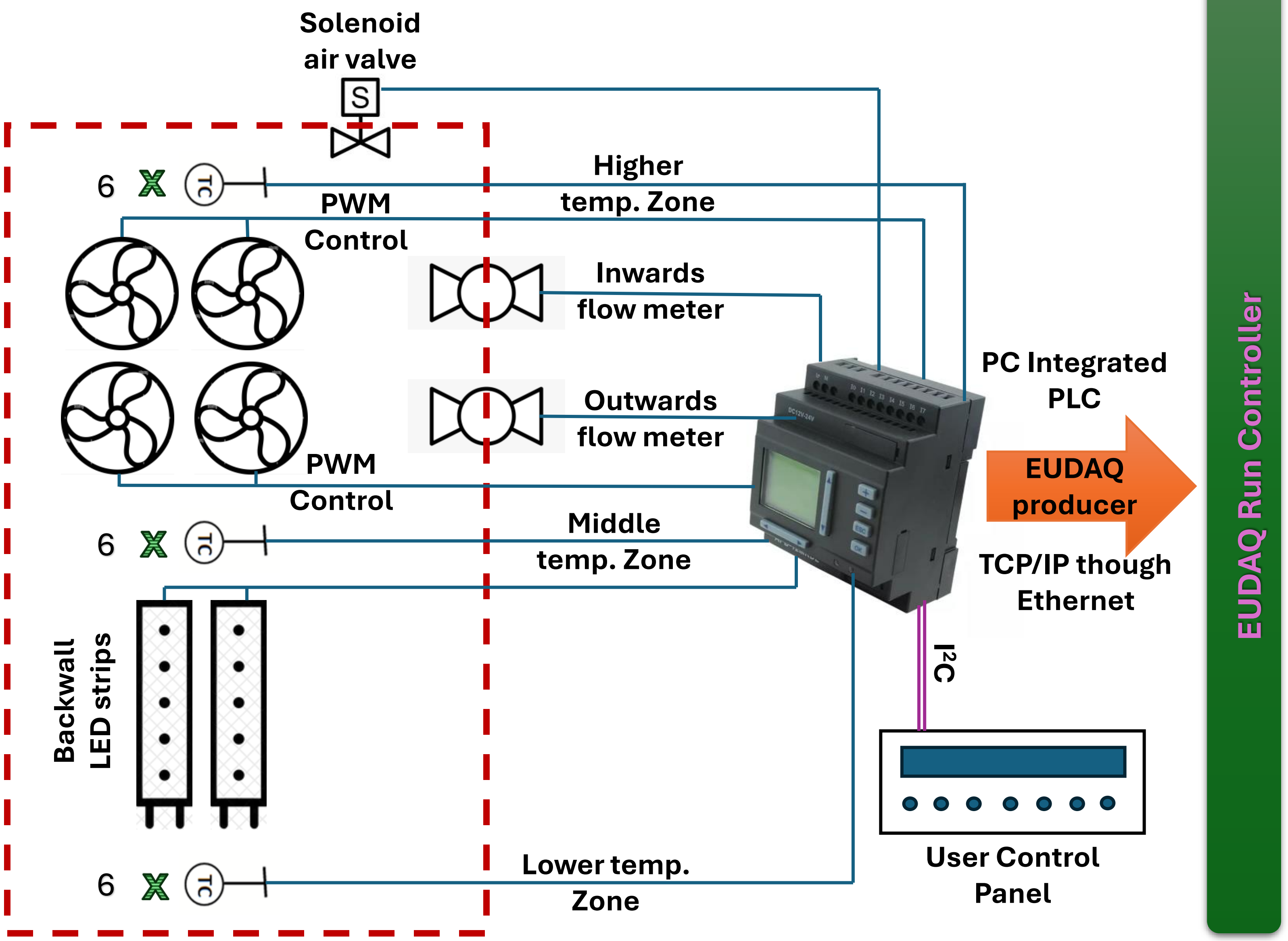
3 x 50 mm diameter steel pipe clamps for cooling circuit hose retention per side



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

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

Seniors	
Flow (In / Out)	2
Temperature	6 x 3 zones
Controlled Parameters	
Fan Speed	4
Internal Lightning	2
Rotation	5
X-Y displacement	5

•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

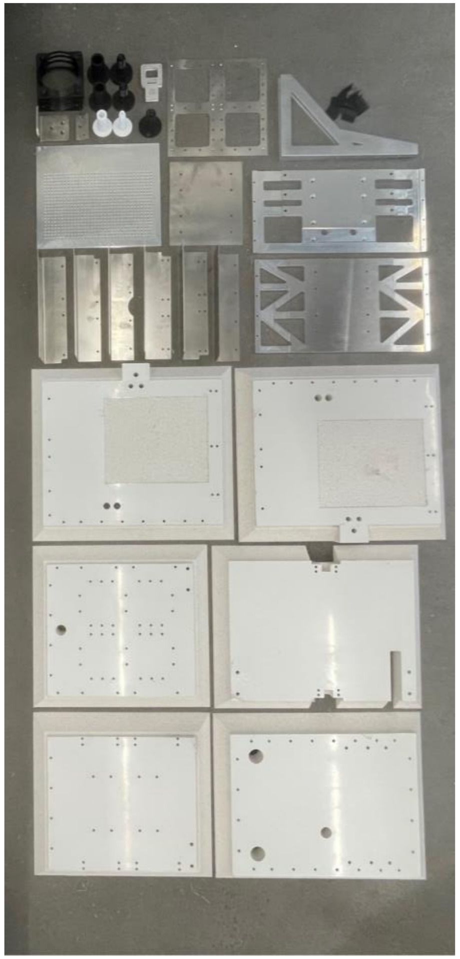
	Material	Density (kg/m³)	Glass Transition Temperature (°C)	Thermal Conductivity (W/m·K)
Metals	Aluminum	2600	N/A	205
Metals	Austenitic stainless steel	8000	N/A	16
Composites	CoraPan Al 85	85	100 (XPS part)	0.035
Composites	Carbon Fiber Reinforced PEEK (CFK)	1500	140 – 150	0.5 (transversal)
Composites	White Acrylic	1100	105	0.25
Composites	TECAPEEK ELS	1450	150	0.46
Composites	Polyamide	1150	50 (PA66)	0.23
Composites	Polyethylene Plastic	940	-110	0.40

Design Variant Dimensions

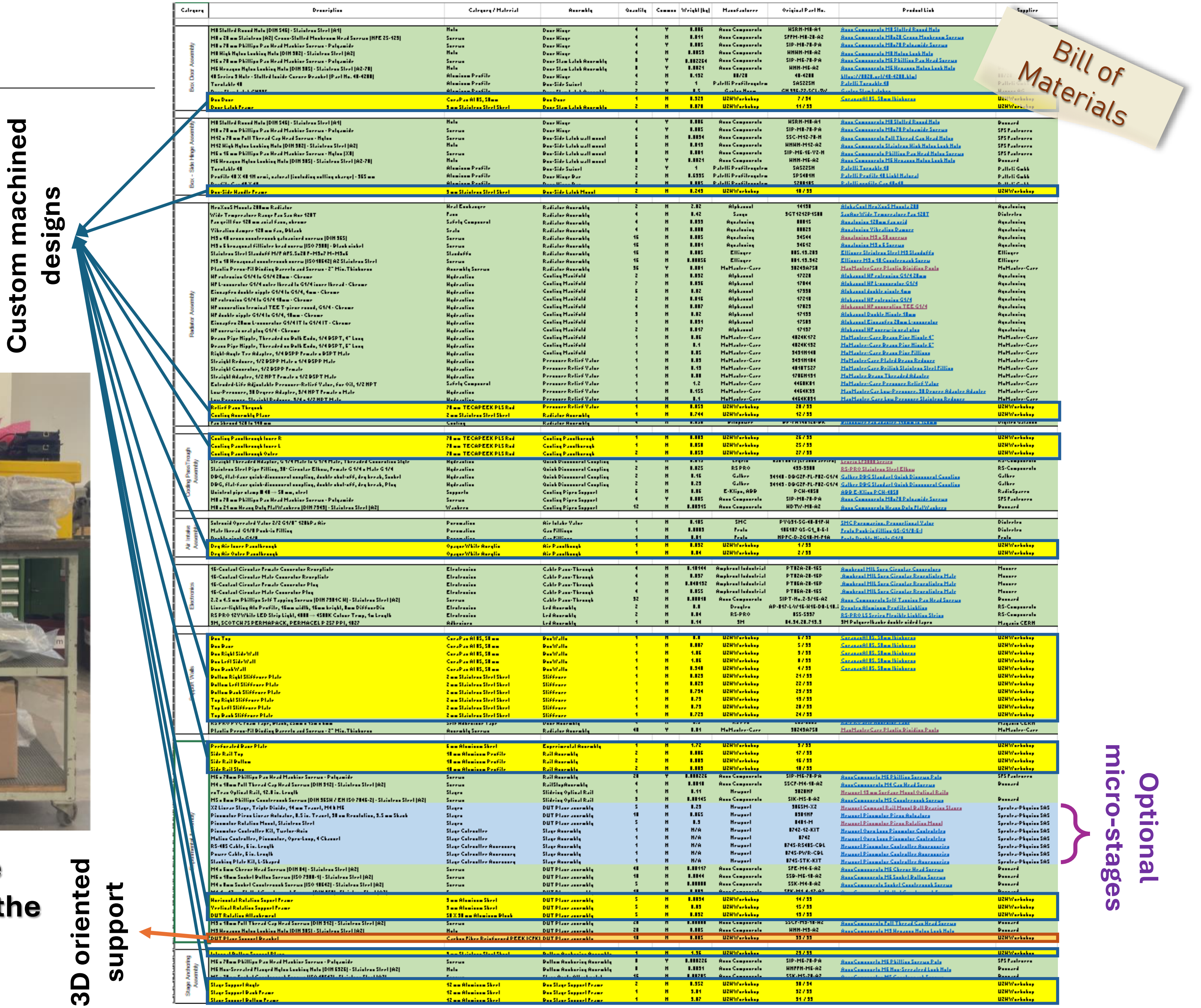
	Dimensions	CERN	DESY	Climate Chamber
Outer	Height (mm)	600	600	930
Outer	Width (mm)	475	285	475
Outer	Length (mm)	520	520	520
Inner	Height (mm)	500	500	830
Inner	Width (mm)	375	185	475
Inner	Length (mm)	420	420	520
Usable	Height (mm)	314	314	644
Usable	Width (mm)	375	185	475
Usable	Length (mm)	320	320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



•Fast Trigger Generator

The issue

1. Current AIDA TLU requires ~ 120 nsec 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 kSamp./event @ 5GHz

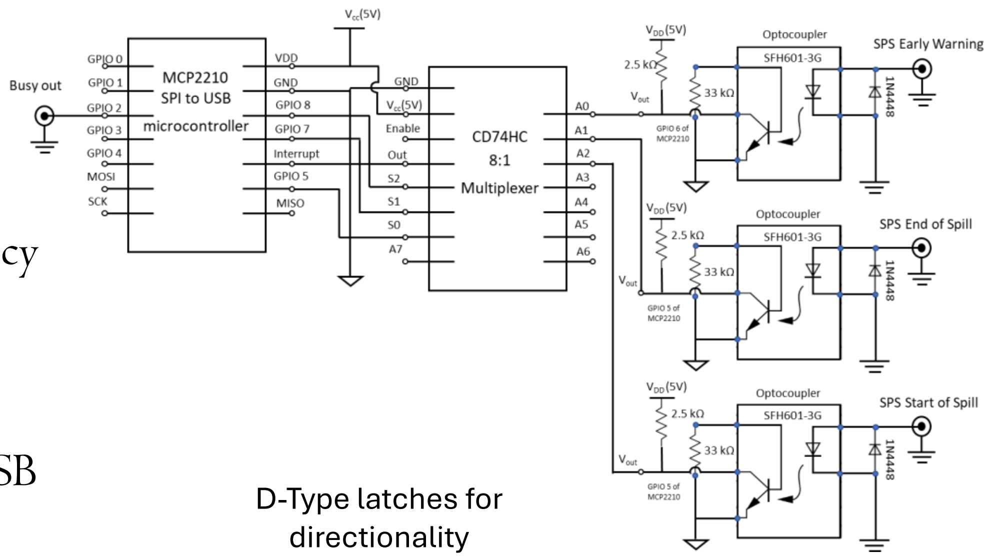
Result: Loss of waveform due to out of time trigger delivery

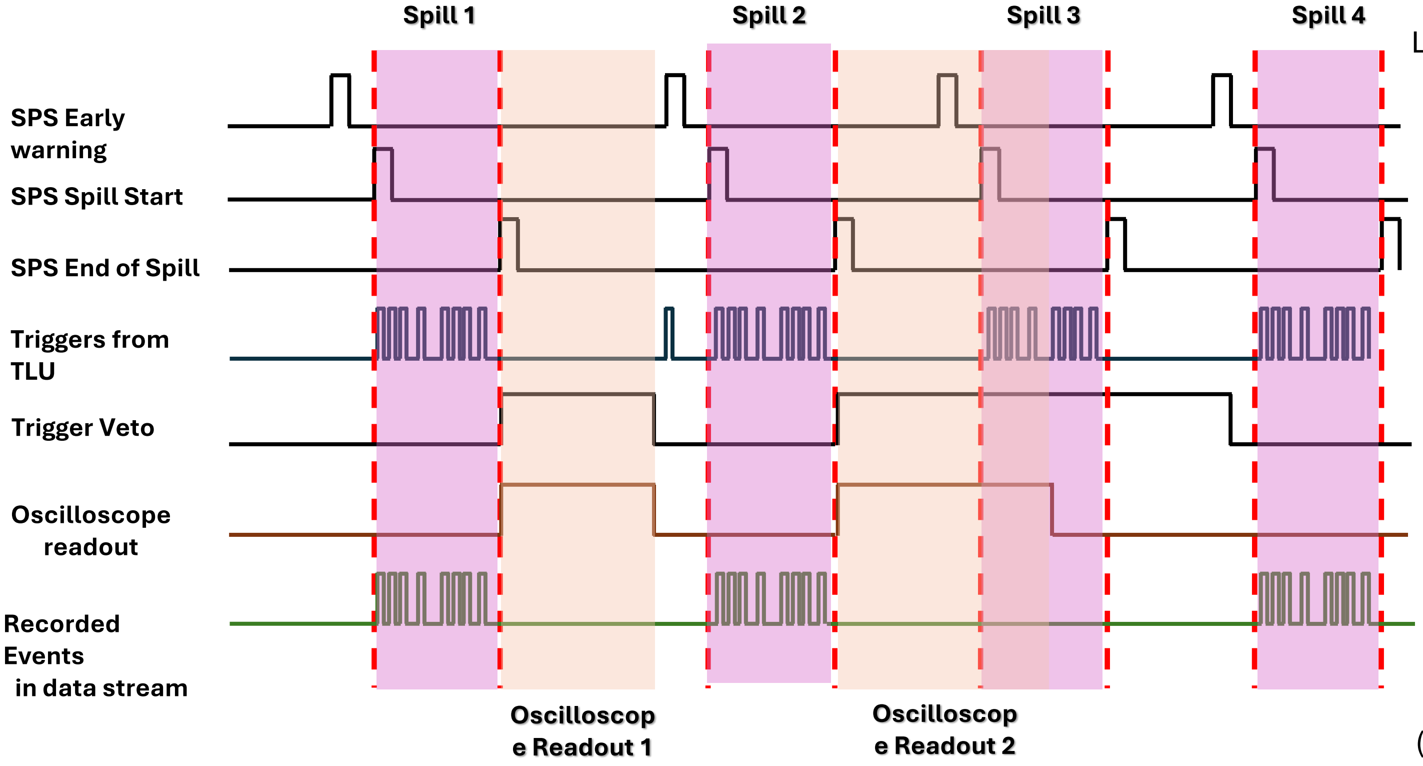
Proposed solution:

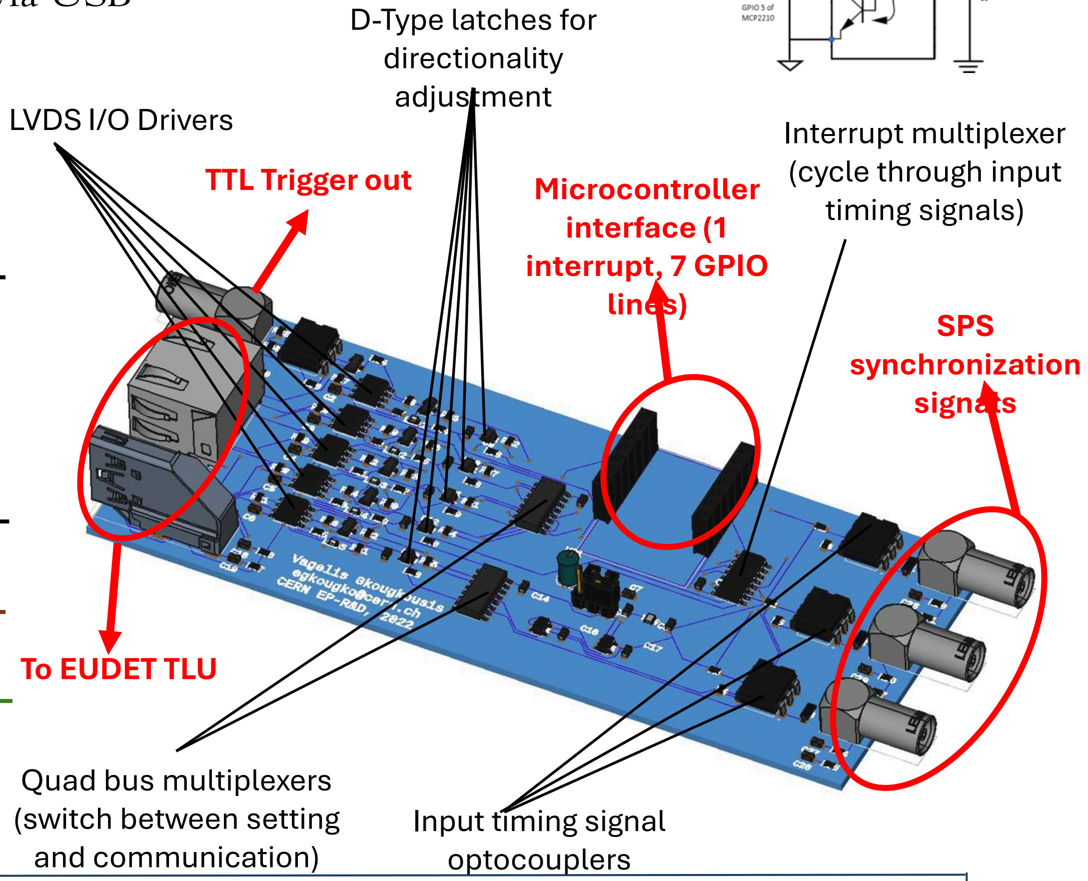
- ✓ Custom Trigger logic board delivering Trigger within 20 ns
- ✓ Function in tandem with AIDA TLU with a EUDAQ style producer
- ✓ Capable of managing fast (>1GHz) omni-polarity (positive/negative) inputs
- ✓ Work in sync with SPS clock for efficient data readout within spills
- ✓ Fully customizable logic matrix with external trigger input and adjustable thresholds

•Trigger Interface Board (TiB)

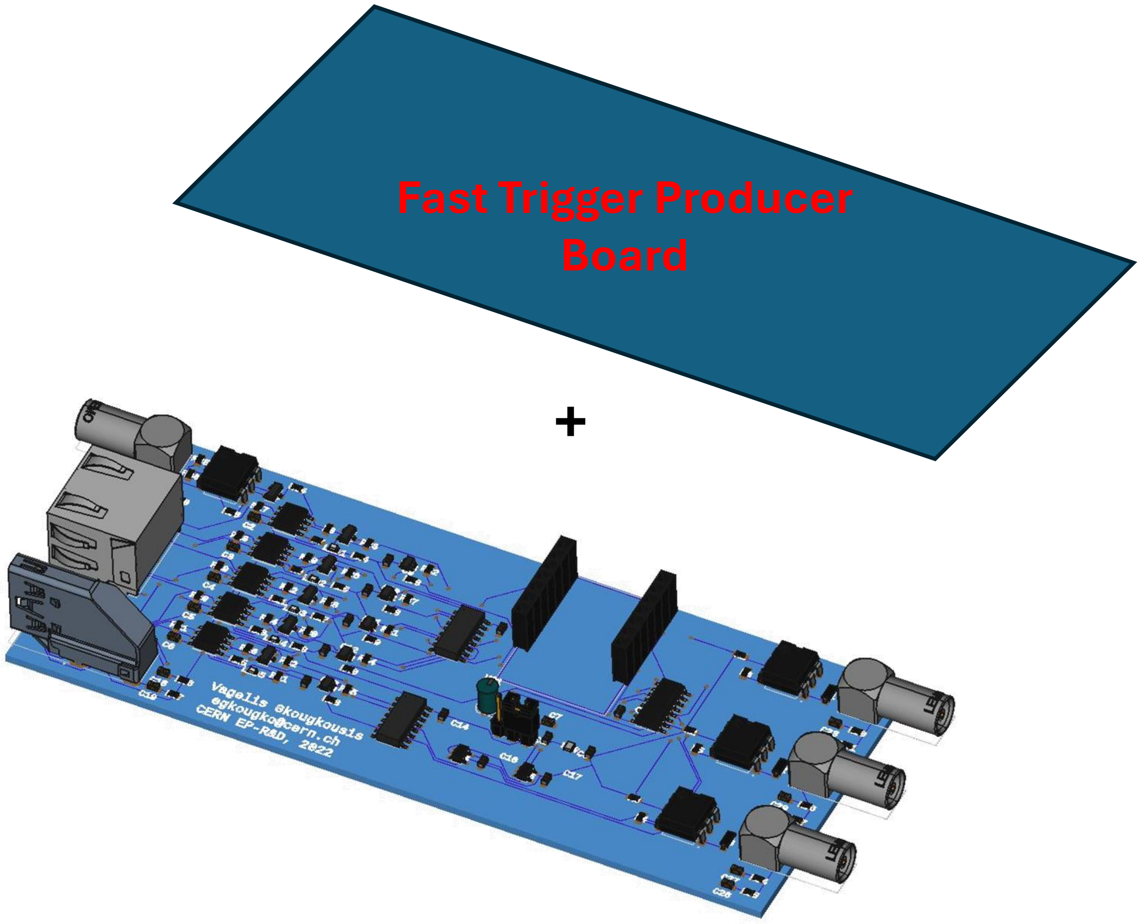
- Oscilloscope in fast readout mode with binary format
- Event readout only between SPS-spills or when event buffer full to increase efficiency
- TLU Synchronization by vetoing data taking during read-out
- RJ-45 or HDMI for EUDET TLU communication (EUDET 2 compatible)
- Versatile design, I/Os Reconfigurable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



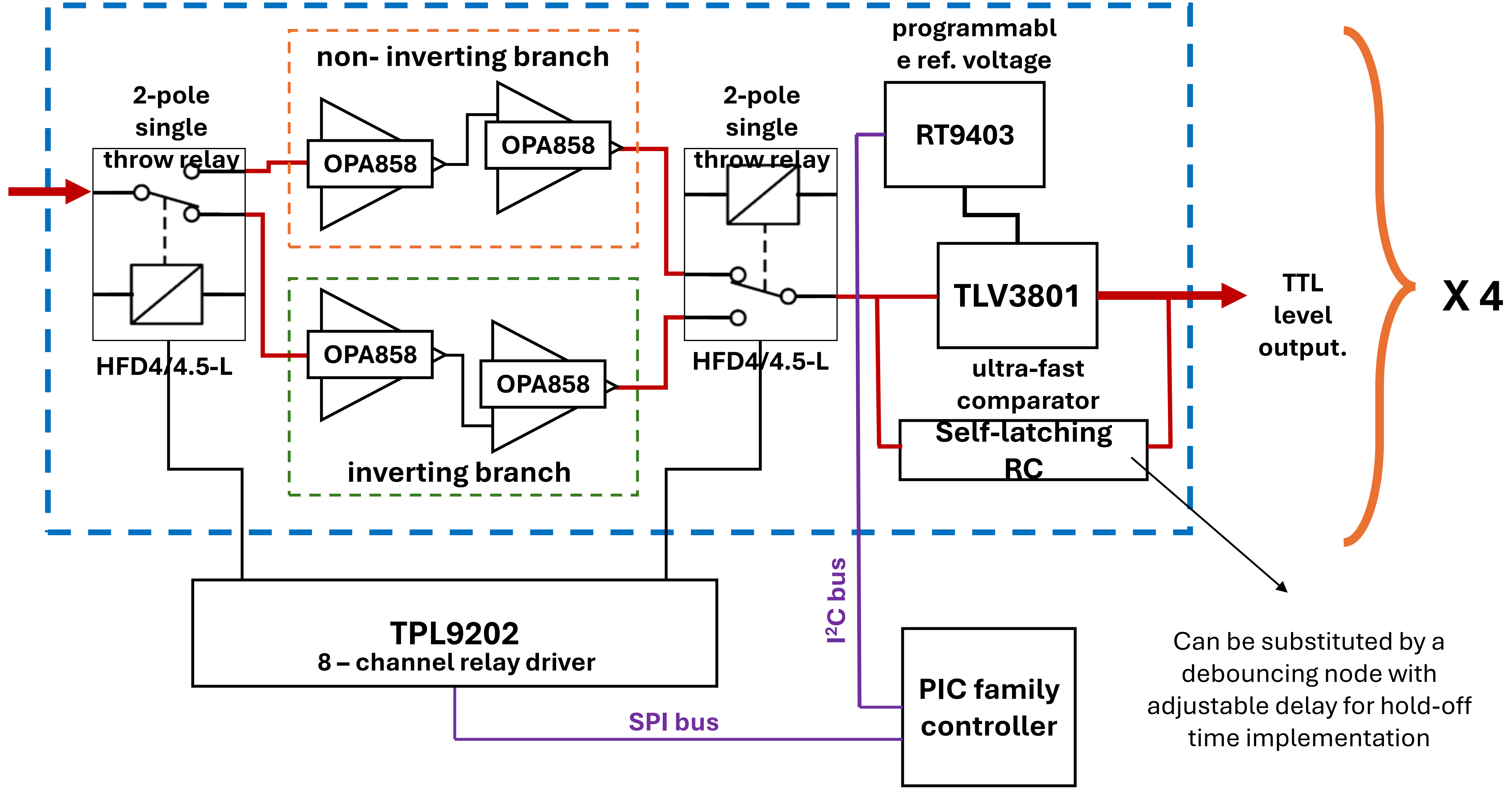




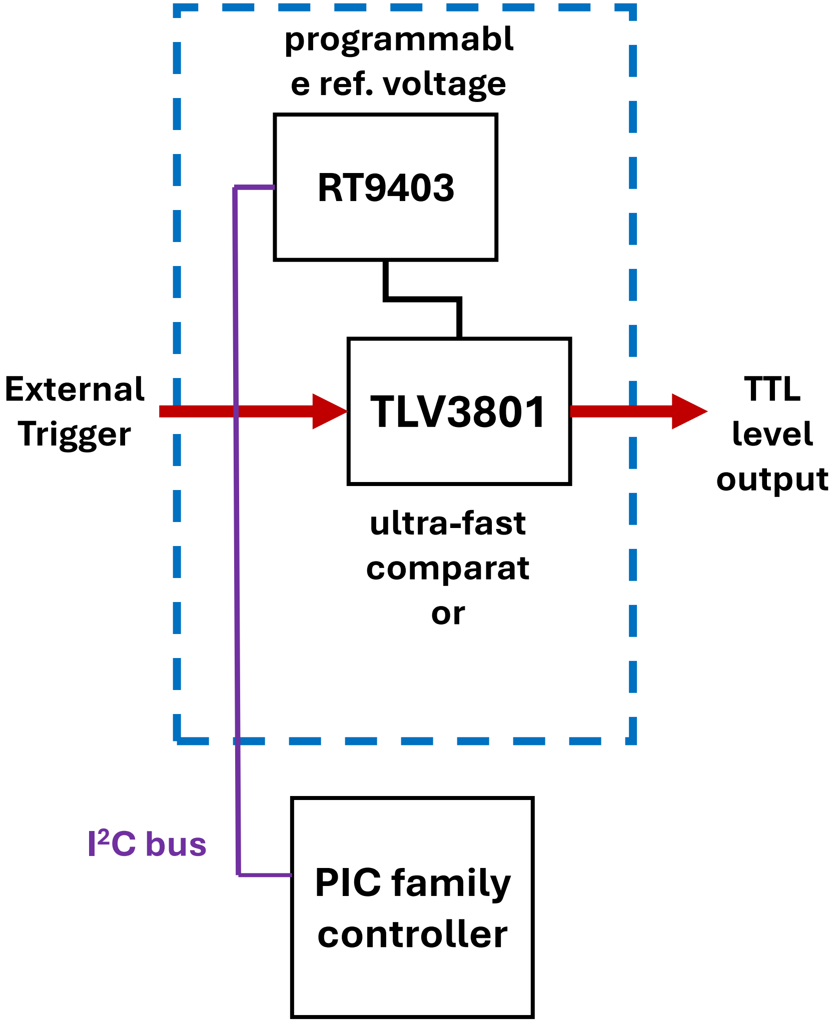
•Fast Trigger Producer

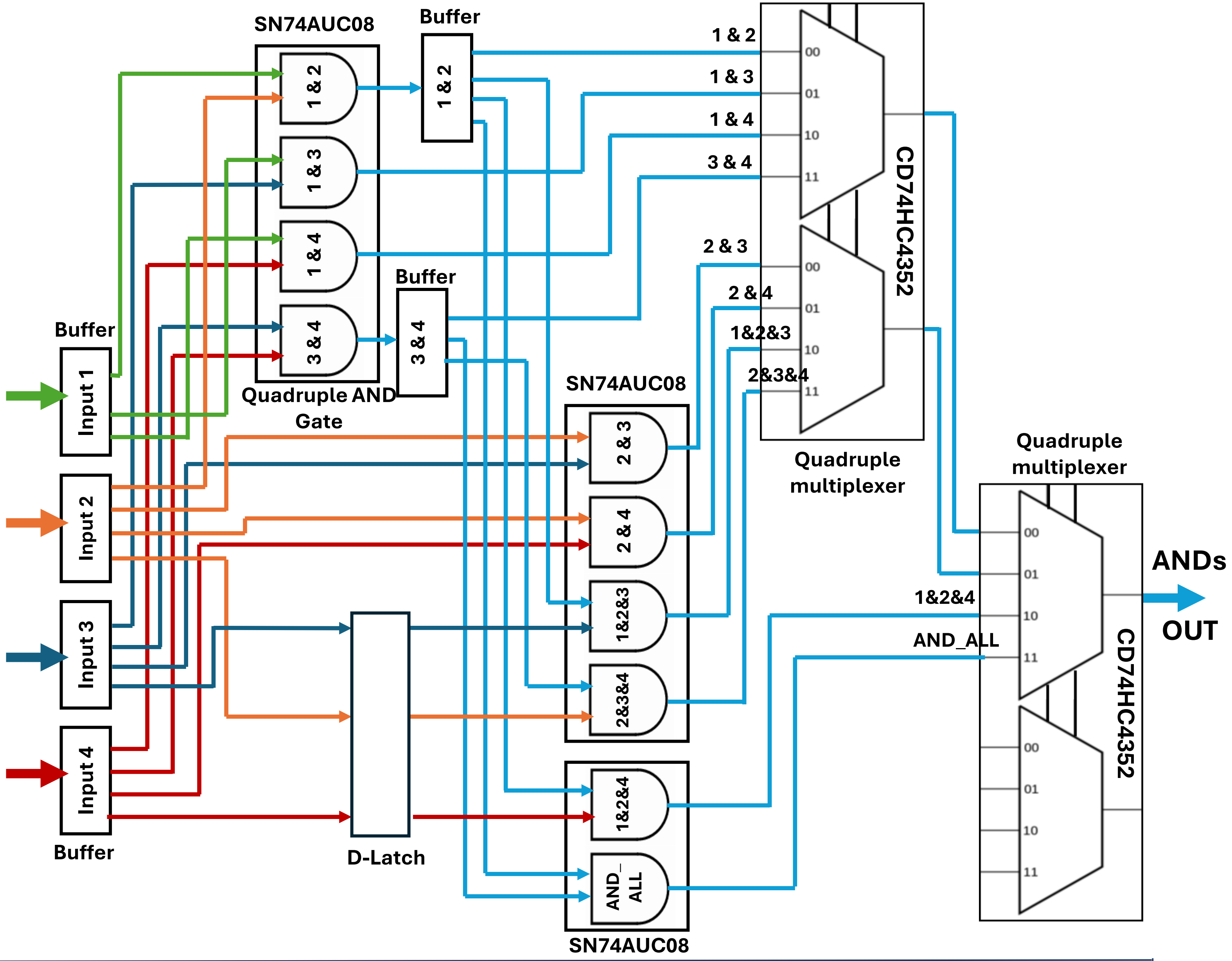


•Trigger input channel

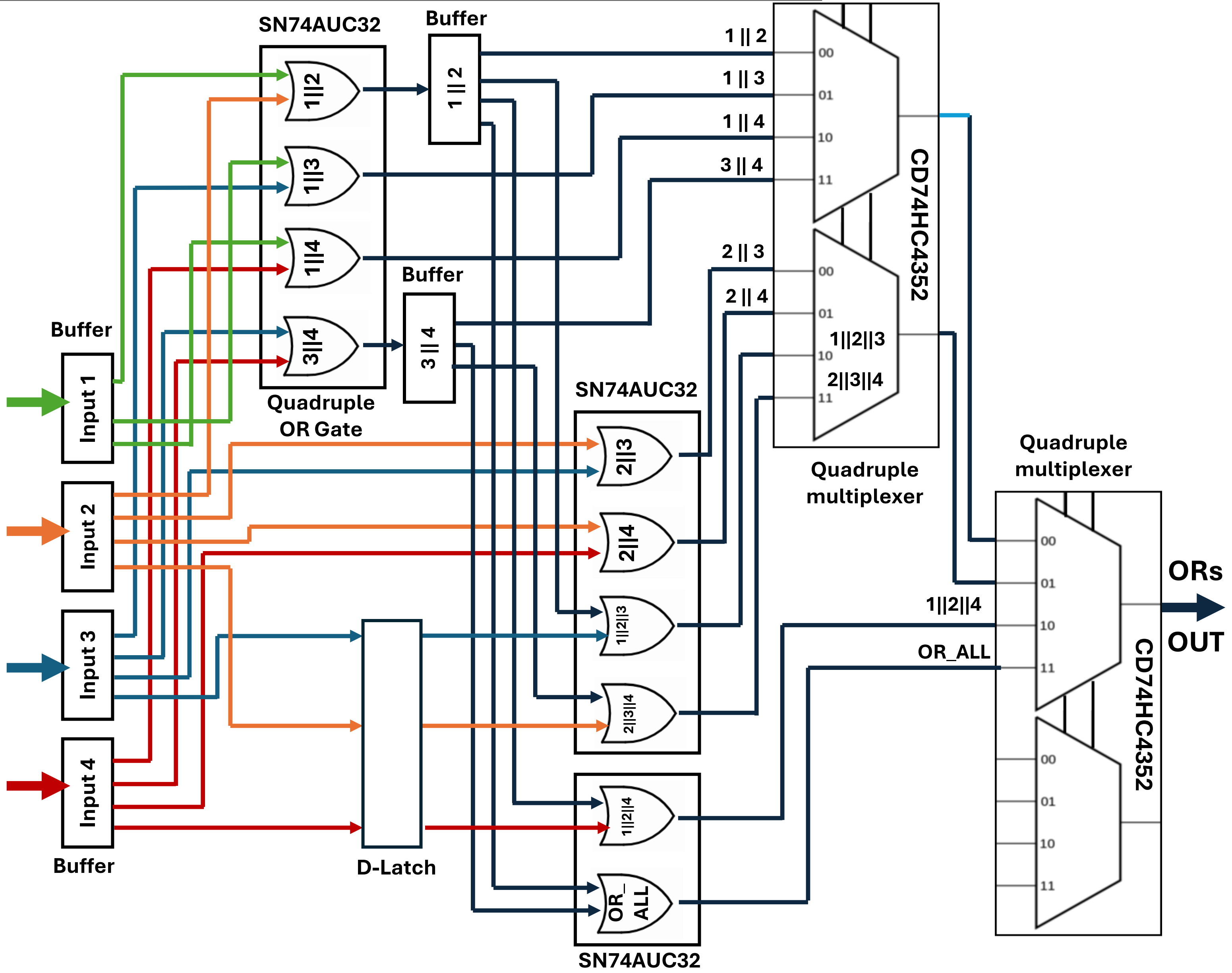


•External input & AND decision matrix





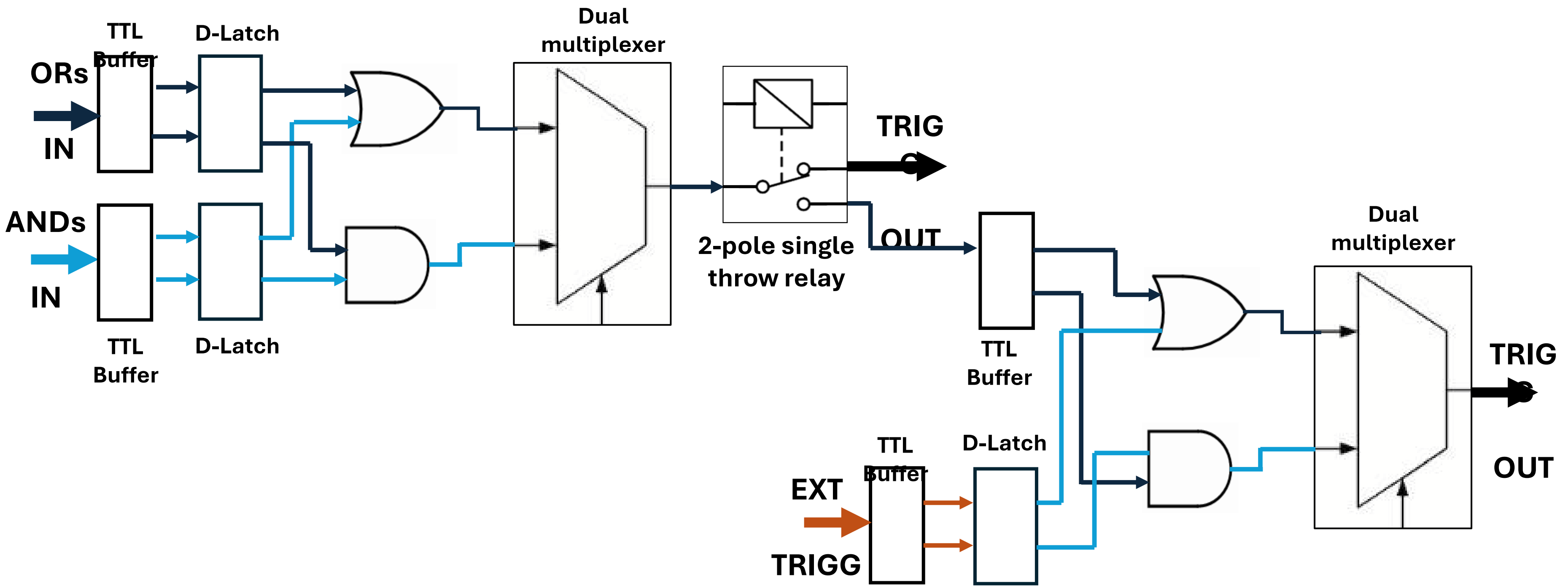
•OR decision matrix



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 I²C/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**