NCAL progress report

IKP Group Meeting
April 10th, 2025

Dachi Okropiridze

Outline

NCAL - Neutron Calorimeter

- **Scintillator Material:**
  BC-416 plastic scintillator
  → *Polyvinyltoluene-based*, Chemical formula: (C_9H_{10})□
  → C:H ratio = 9:10

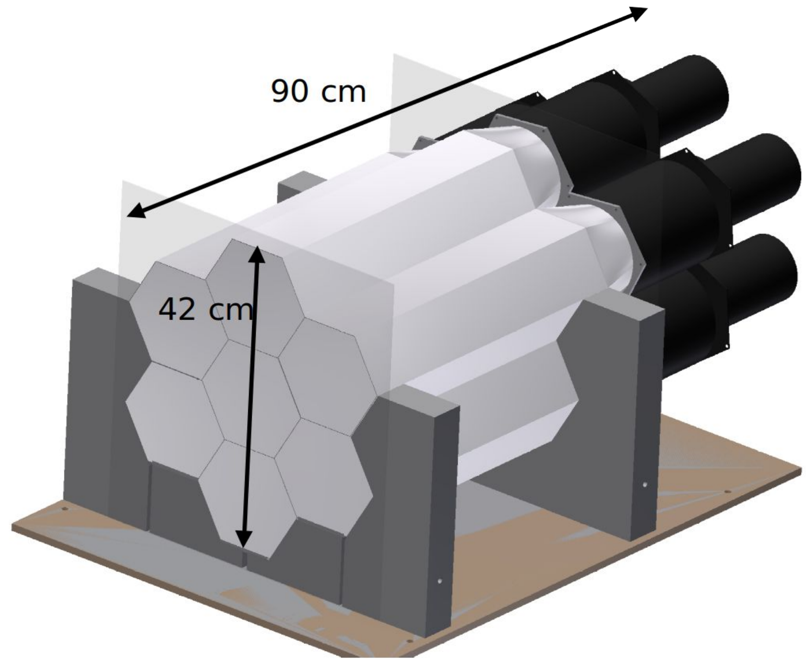
- **Geometry:**
  → Hexagonal cross-section, side ≈ 8 cm
  → Length: 45 cm per module
  → Modules: 86 planned, test setup uses 7 modules
  → Mounted on mobile, height-adjustable frames

- **Photodetector:**
  → Photonis XP4592/PA PMTs
  → Coupled via optical silicone gel

- **Readout Electronics:**
  → RICH readout system, using Time-over-Threshold (ToT)
  → Requires calibration for energy conversion

- **Deployment**:
  → Distance from target: ~4 m
  → Participated in 5 beamtime runs (Au, Ni, Ag at 1.2–1.5 AGeV)

- **Simulated Neutron Detection Efficiency:**
  → ~50% (matches ~40% from COSY at 2.7 GeV/c)



VETO detector

- **Purpose**:
 → Detect charged particles before NCAL and veto them (neutral particle selection)

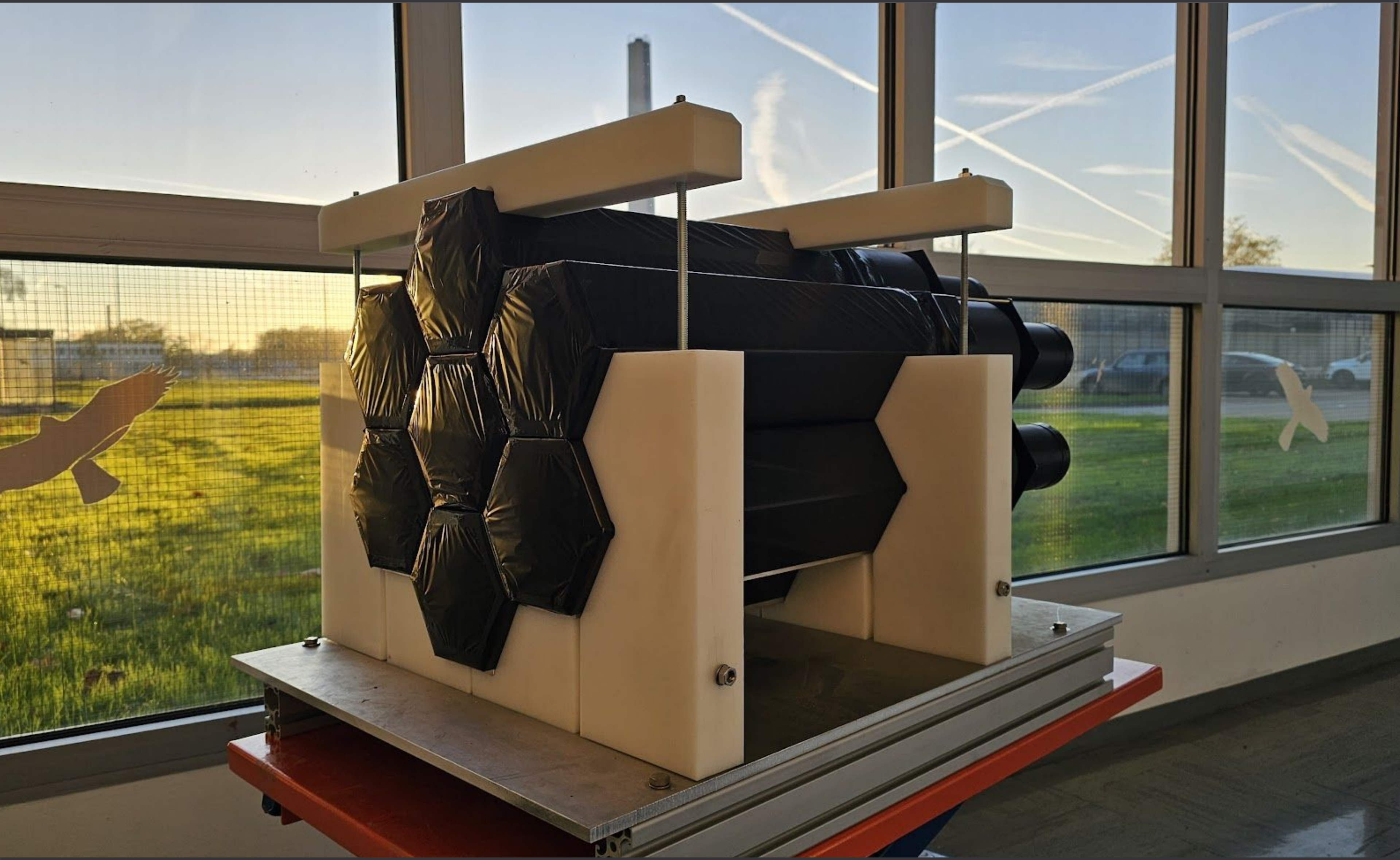
- **Scintillator Material**:
 Plastic scintillator (type not explicitly specified, likely BC-404/BC-412 equivalent)
 → Thin plate: **50 cm × 10 cm × 0.4 cm**

- **Geometry**:
 → Vertically hanging, **5 modules** in front of NCAL
 → **1 cm overlap**, modules slightly tilted for full coverage

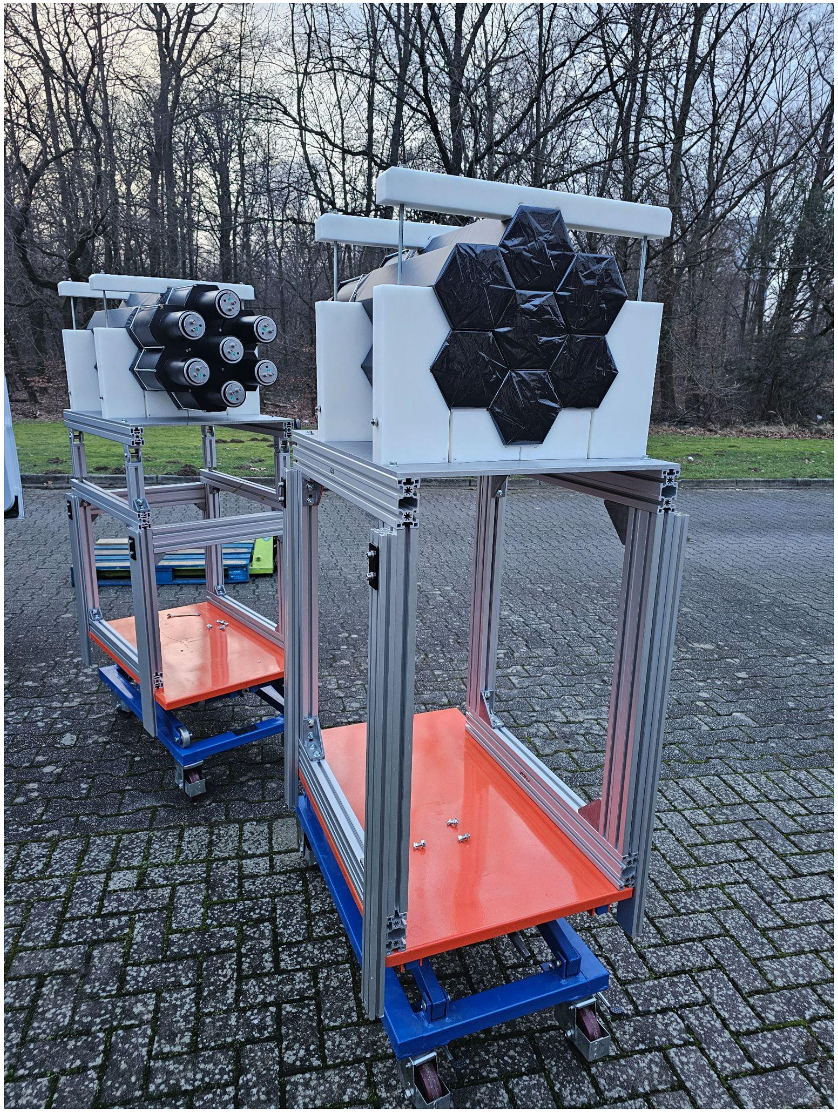
- **Photodetectors**:
 → **ET Enterprises 9954B** PMTs (one on each end of each plate)
 → Allows for **position estimation via timing difference**

- **Integration**:
 → Uses same **RICH readout chain**, ToT-based signal digitization

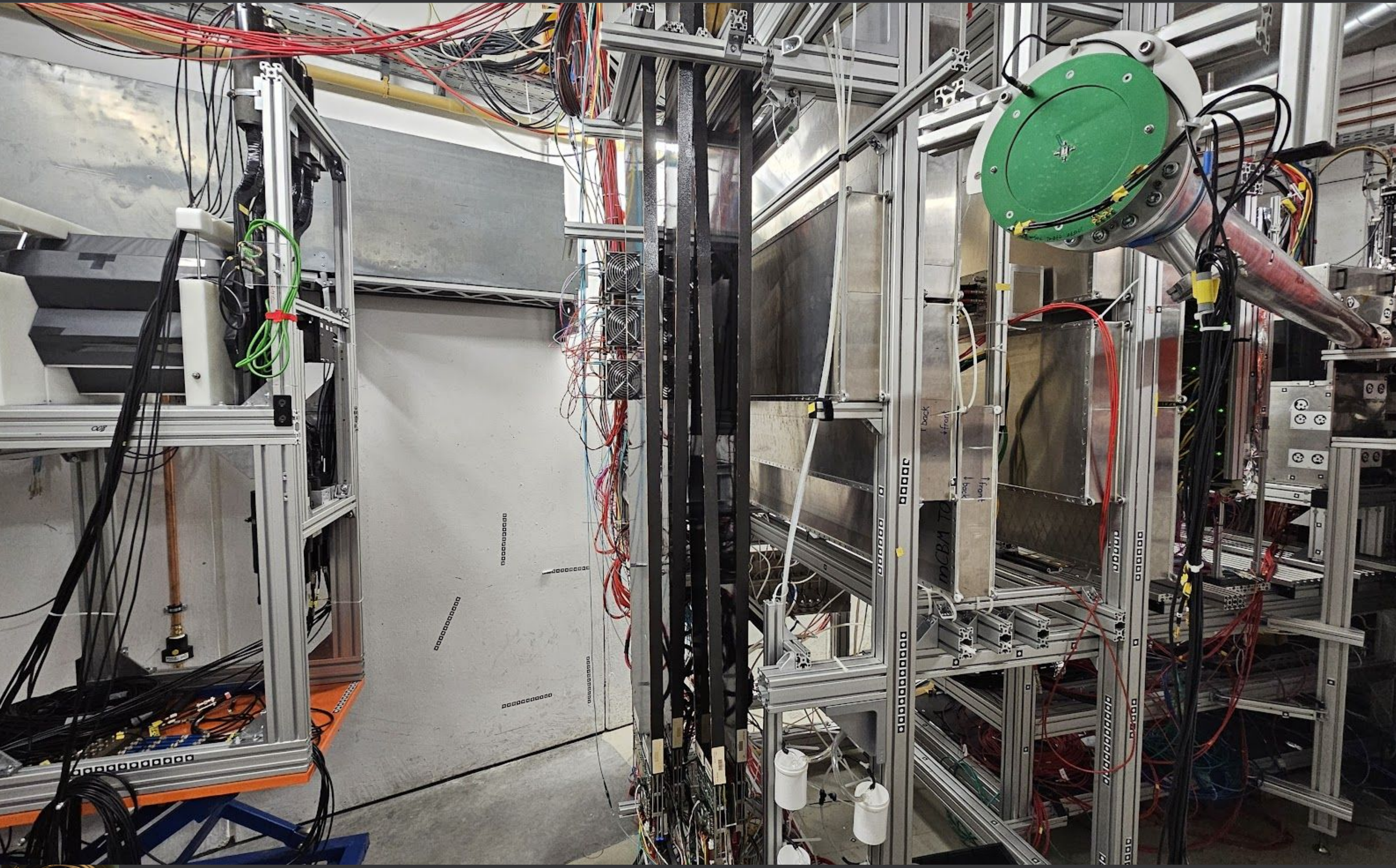
FSD, NCAL, VETO



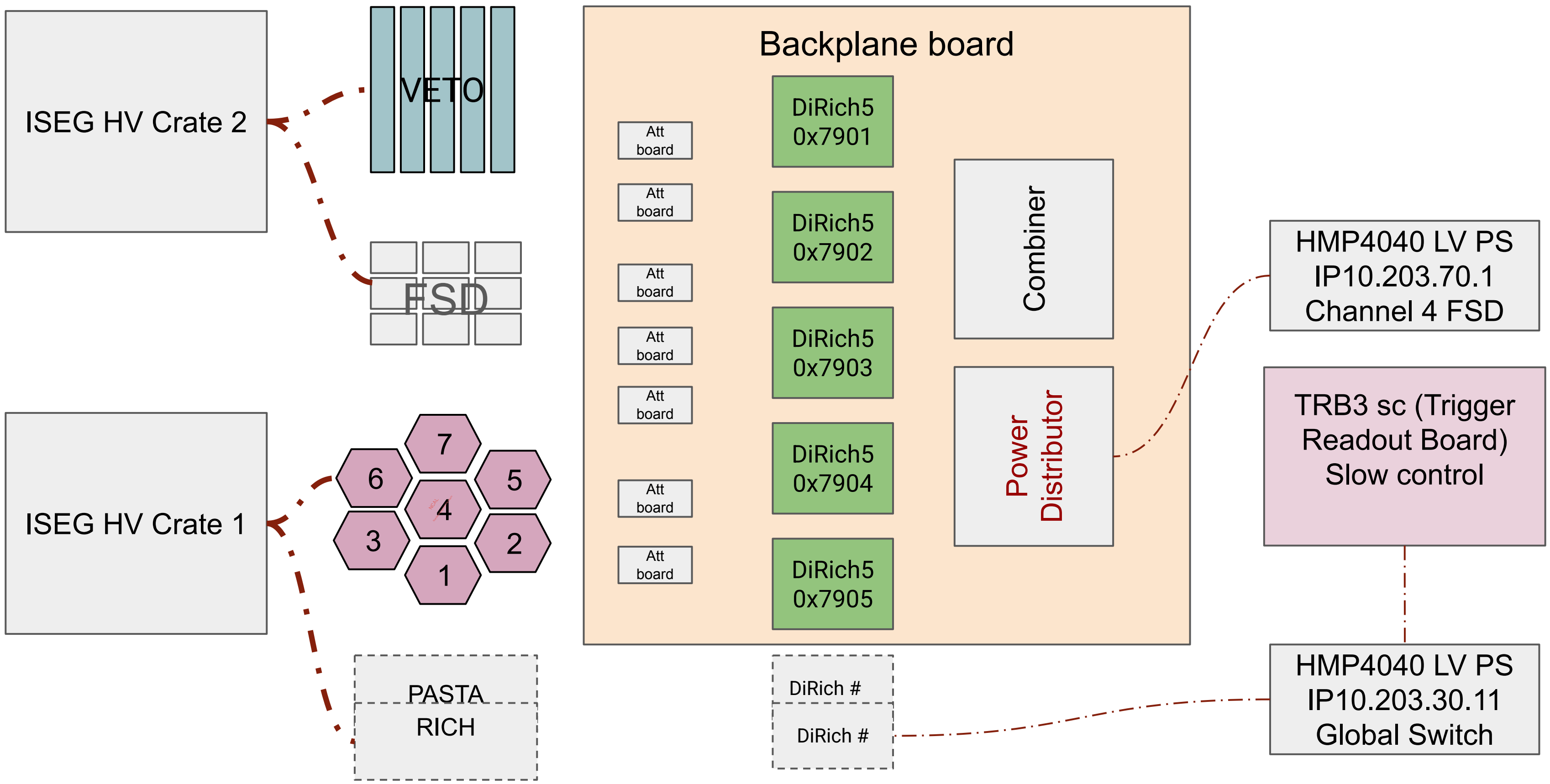
FSD, NCAL, VETO



FSD, NCAL, VETO



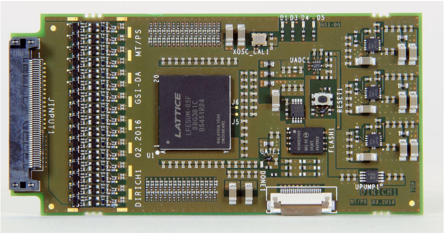
FSD, NCAL, VETO HV / LW Power

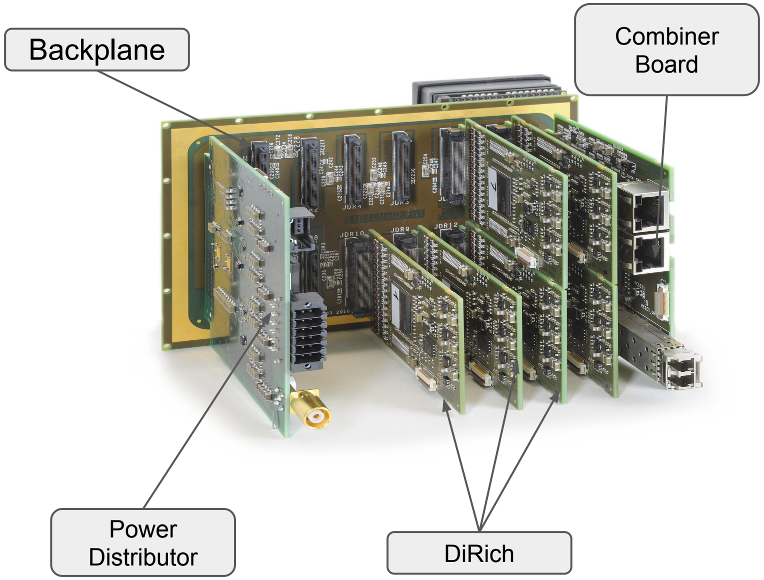


DAQ

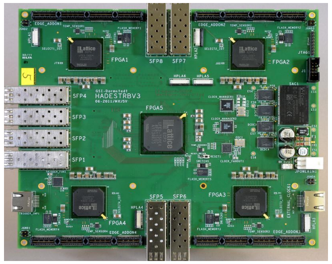
The DiRich board serves as a data acquisition platform that interfaces with photon detectors, collecting and digitizing signal information. It performs time measurement using Time-to-Digital Converters (TDCs) to accurately record signal arrival times. The board then transmits the processed timing data to the TRB3 system for synchronization and event building.

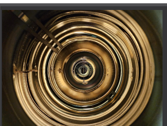
1. 32 channels
2. galvanic isolation of PMT to FEE (transformer)
3. ~factor 30 gain amplifier, 12mW
4. individual threshold for each discriminator
5. TDC with ~10ps intrinsic time precision (ToT measurement)
6. data acquisition system included (TRBNet)
7. data is sent out on the same connector
8. only one connector for everything => cable-free system



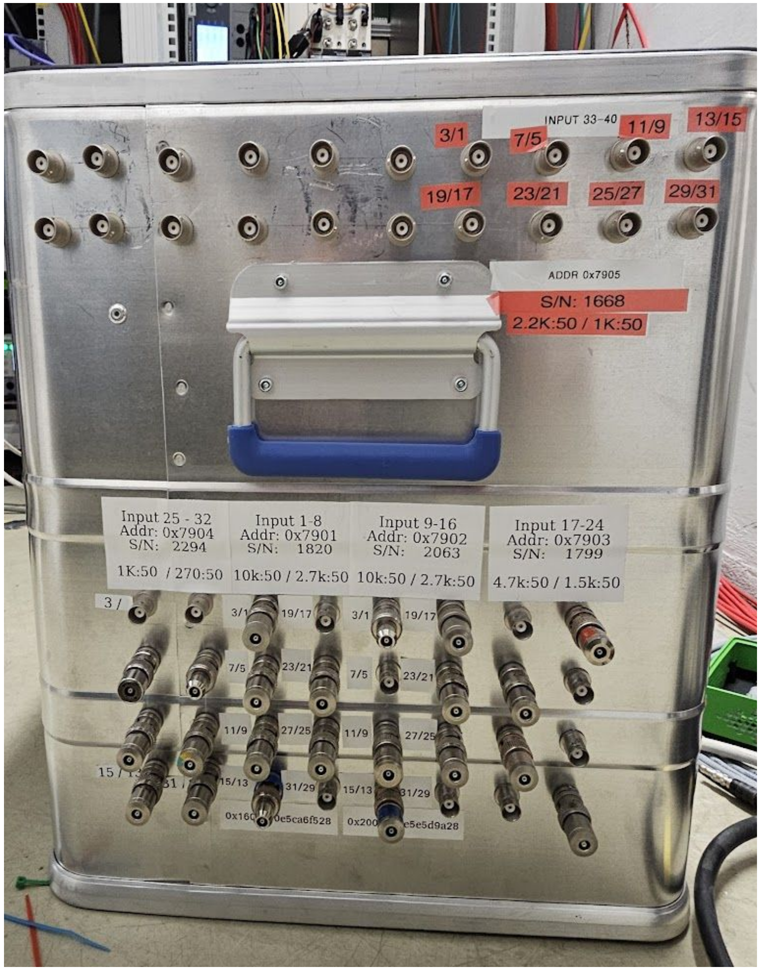


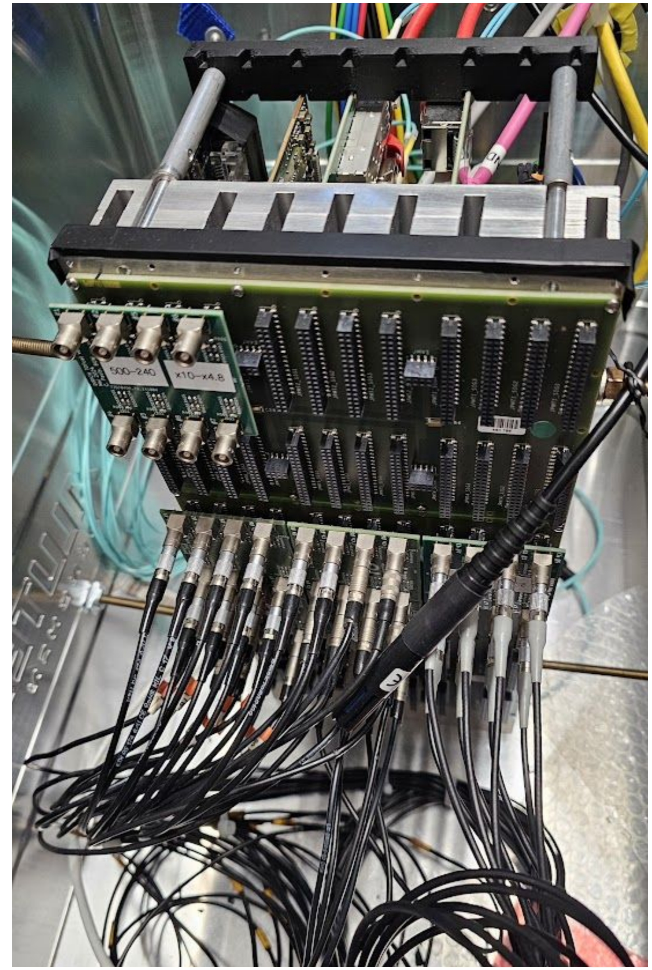
In the DiRich scheme for CBM, the TRB3 serves as the central trigger and data acquisition platform. It generates timing signals, collects data from the DiRich detectors, and synchronizes the data streams. The TRB3 aggregates the data into coherent events and transmits them to the Eventbuilder for further processing. It also manages system control, monitoring, and error detection, ensuring smooth operation during experiments.



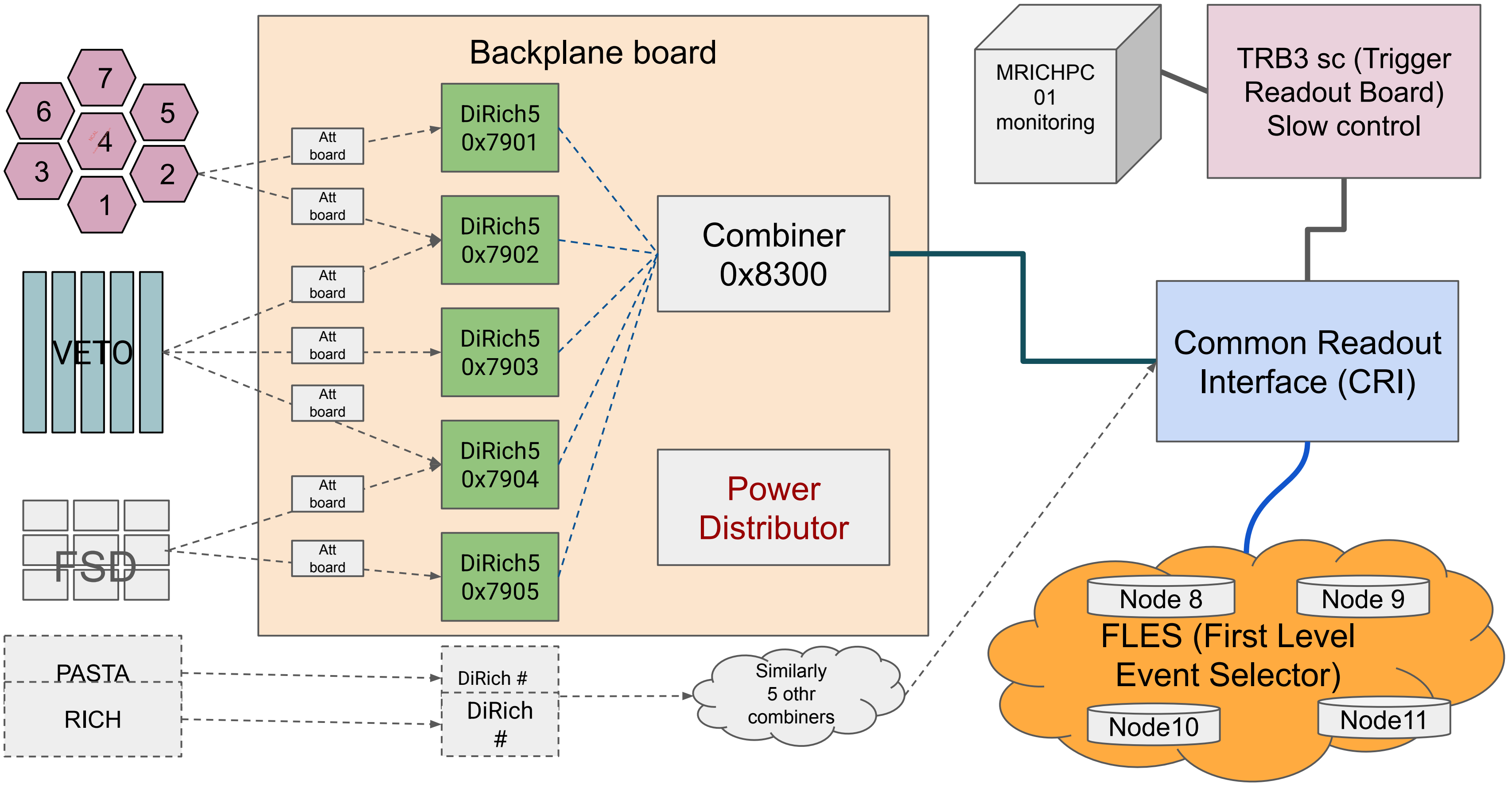


Pandora box


INPUT 33-40
3/1
7/5
11/9
13/15
19/17
23/21
25/27
29/31
ADDR 0x7905
S/N: 1668
2.2K:50 / 1K:50
Input 25 - 32
Addr: 0x7904
S/N: 2294
1K:50 / 270:50
Input 1-8
Addr: 0x7901
S/N: 1820
10k:50 / 2.7k:50
Input 9-16
Addr: 0x7902
S/N: 2063
10k:50 / 2.7k:50
Input 17-24
Addr: 0x7903
S/N: 1799
4.7k:50 / 1.5k:50



FSD, NCAL, VETO DAQ Flowchart



FSD, NCAL, VETO mapping

FSD, NCAL, Veto: HV & Dirich configuration

All Dirich Thresholds are set -50mV, All HV are negative polarity

Against the beam

Detektor	Detector Module	HV line / addr / ch	DIRICH Module	Adapter Input#	DIRICH Channel	Att. Factor	HV Value
NCAL	1	0 / 3 / 9	0x7902	7	25 / 27	~ 100	
	2	0 / 3 / 10	0x7901	6	21 / 23	~ 100	
	3	0 / 3 / 11	0x7901	3	09 / 11	~ 100	
	4	0 / 3 / 12	0x7902	6	21 / 23	~ 100	
	5	0 / 3 / 13	0x7901	4	13 / 15	~ 100	
	6	0 / 3 / 15	0x7902	3	09 / 11	~ 100	
	7	0 / 3 / 15	0x7902	4	13 / 15	~ 100	
	NCAL is on Crate 1 - "big"						
	Veto is on Crate 2 - "small" in the cave						
VETO	11	0 / 0 / 1	0x7904	4	13 / 15	~ 10	
	12	0 / 1 / 1	0x7904	6	21 / 23	~ 10	
	21	0 / 0 / 2	0x7903	2	05 / 07	~ 50	
	22	0 / 1 / 2	0x7904	7	25 / 27	~ 10	
	31	0 / 0 / 3	0x7903	3	09 / 11	~ 50	
	32	0 / 1 / 3	0x7903	8	29 / 31	~ 50	
	41	0 / 0 / 4	0x7904	8	29 / 31	~ 10	
	42	0 / 1 / 4	0x7902	5	17 / 19	~ 100	
	51	0 / 0 / 5	0x7903	5	17 / 19	~ 50	
	52	0 / 1 / 5	0x7902	2	05 / 07	~ 100	

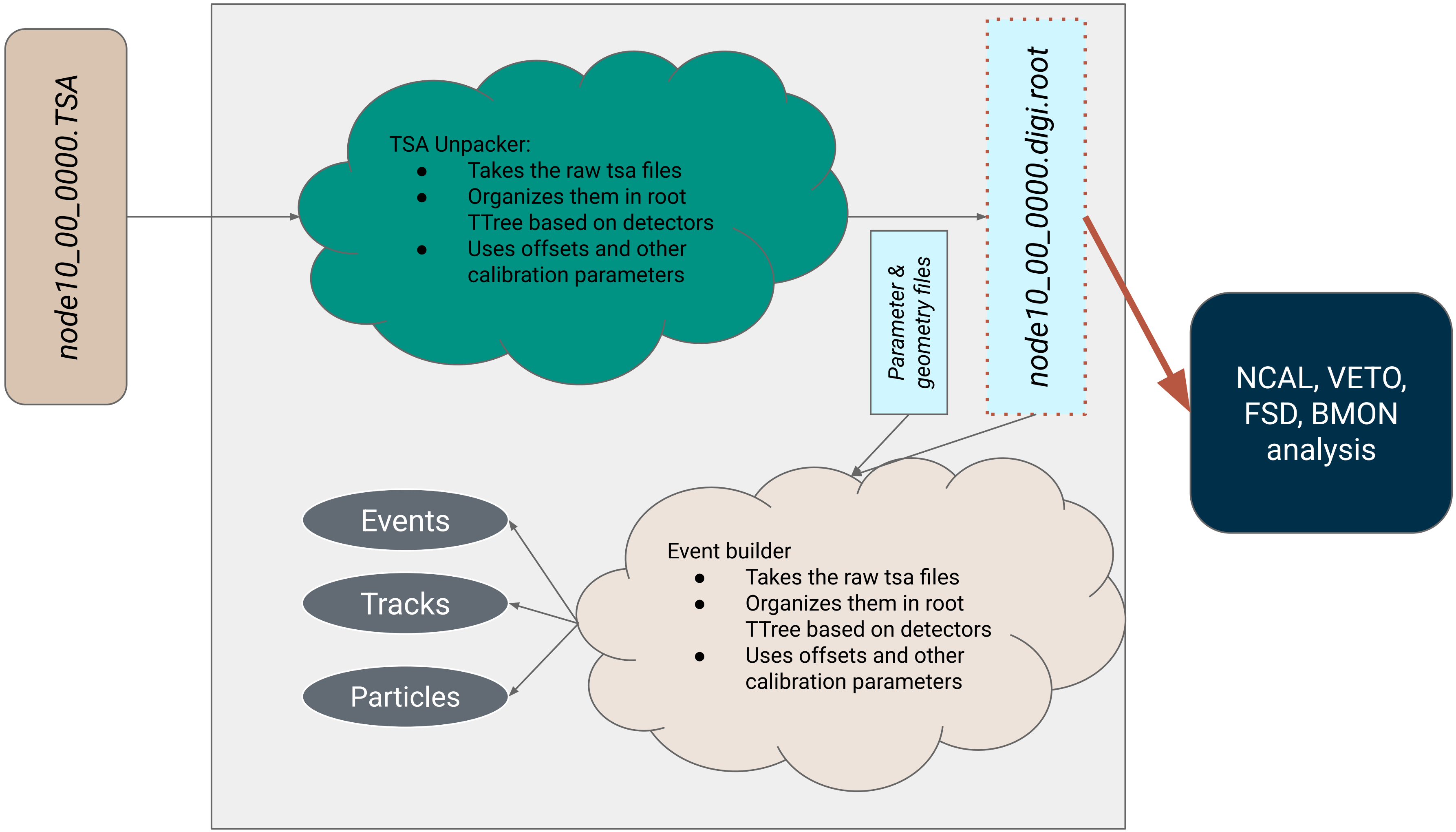
FSD
beam direction

#	1x1	1x2	1x3
DIRICH ADDR	0x7905	0x7905	0x7905
Dirich ch	3/1	5/7	11/9
ATTENUATOR	2.2k - 1k	2.2k - 1k	2.2k - 1k
Voltage	-1150	-1150	-1150
HV Channel	Crate 2, module 0, CH 6	Crate 2, module 0, CH 6	Crate 2, module 0, CH 6
#	**2x1**	**2x2**	**2x3**
DIRICH ADDR	0x7905	0x7905	0x7905
Dirich ch	13/15	17/19	21/23
ATTENUATOR	2.2k - 1k	2.2k - 1k	2.2k - 1k
Voltage	-1000	-1000	-1000
HV Channel	Crate 2, module 0, CH 7	Crate 2, module 0, CH 7	Crate 2, module 0, CH 7
#	**3x1**	**3x2**	**3x3**
DIRICH ADDR	0x7905	0x7905	0x7903
Dirich ch	25/27	29/31	23/21
ATTENUATOR	2.2k - 1k	2.2k - 1k	4.7k - 1.5k
Voltage	-1100	-1100	-1100
HV Channel	Crate 2, module 1, CH 6	Crate 2, module 1, CH 6	Crate 2, module 1, CH 6

	ISEG Board	ISEG IP Add:	Channel numbers:	crate module address
HV crate 1 (RICH)	3:7400041	10.203.0.74	ch a0,a1,a2,a3,a4,a5	u300,u301,u302,u304,u305,u306
HV crate 1 (NCAL)	3:7400041	10.203.0.74	a9,a10,a11,a12,a13,a14,a15 (ncal)	u303,u307,u308,u309,u310,u311,u312,u313,u314,u315
HV crate 2 FSD, Veto	0:7400121 0:7400122	10.203.70.2	kein script	

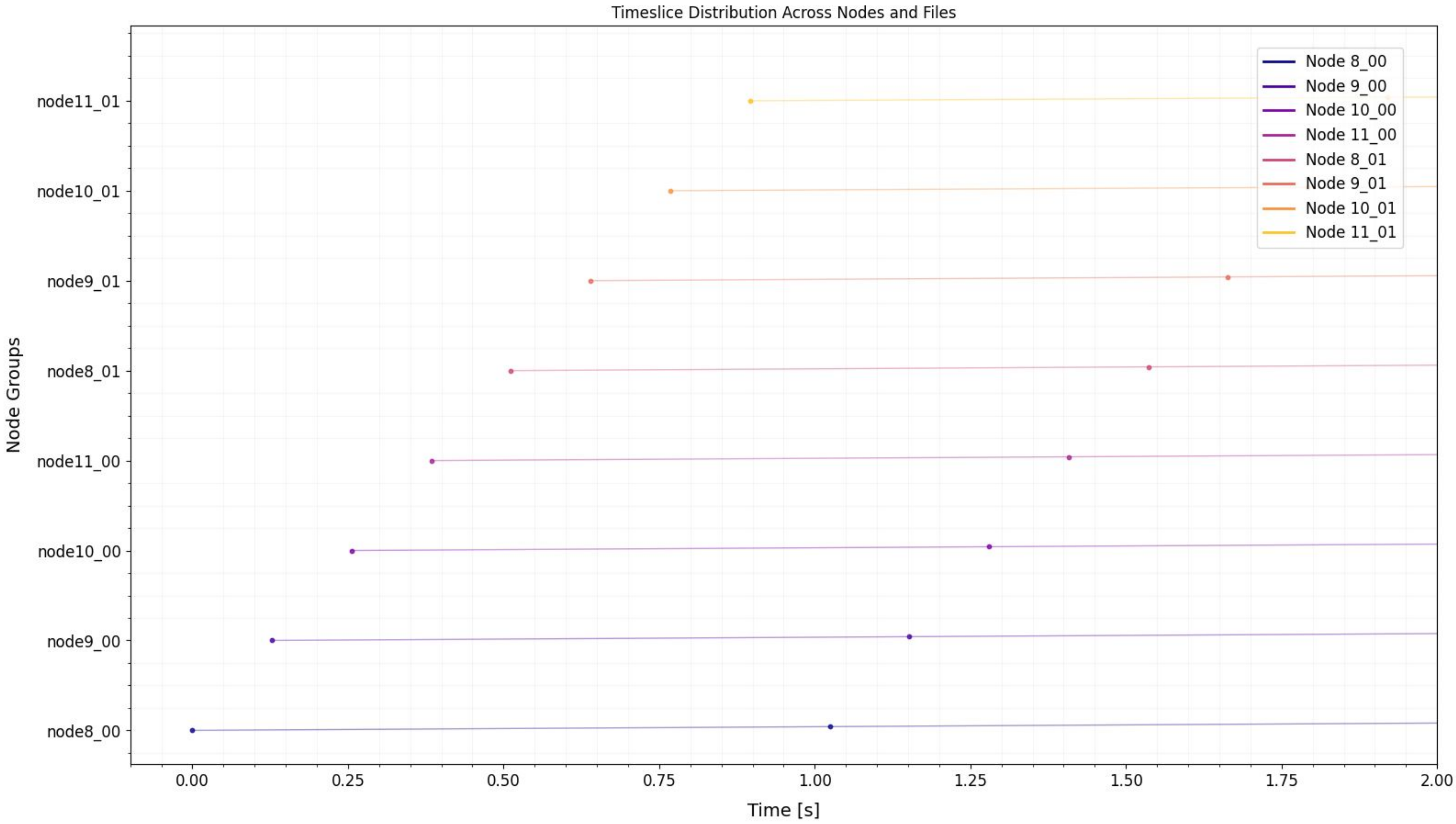
Note: There are two versions of NCAL and Vetos , this document belongs to the one in mCBM cave

CBMROOT Analysis flowchart

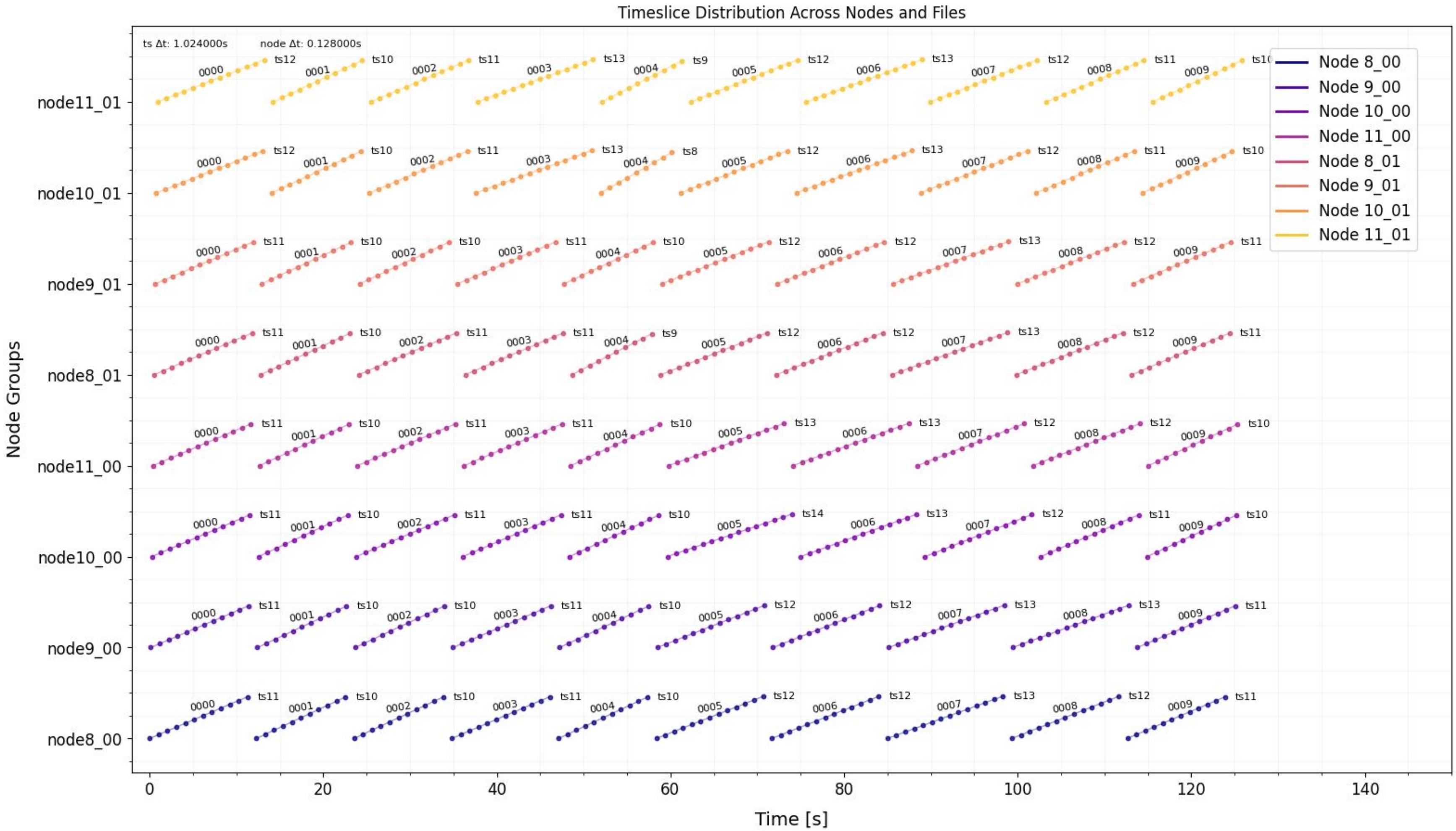


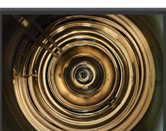
Data Analysis

Beamtime Data Structure



Beamtime Data Structure





Run Information Summary

Run Details:

- Start time: 16/02/2025 01:53:39
- Run number: 3511

Beam parameters:

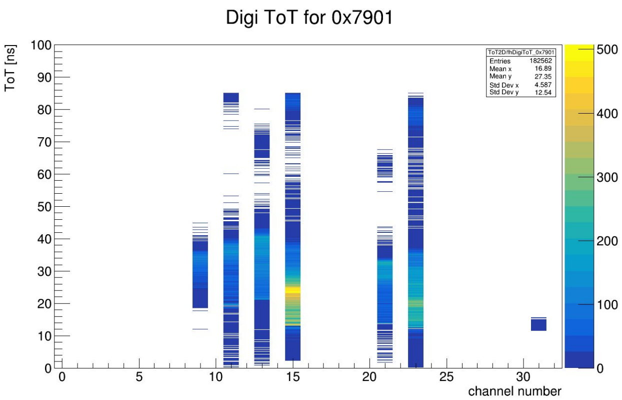
- First run with new energy: T=1.23 AGeV
- Beam intensity: 1.5×10^7 particles per spill
- Spill duration 9s

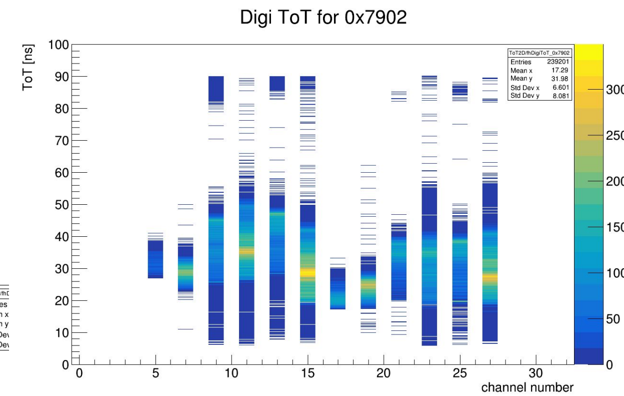
Target Configuration:

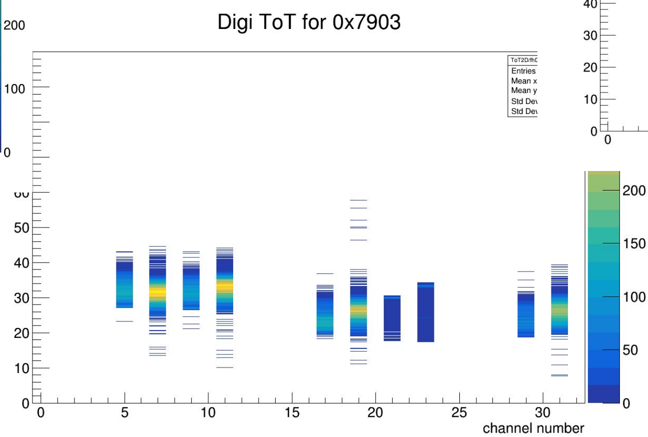
- Moved to position 5
- Material: Silver (thick)
- Thickness: 4.20 mm
- Position change occurred at run 3502

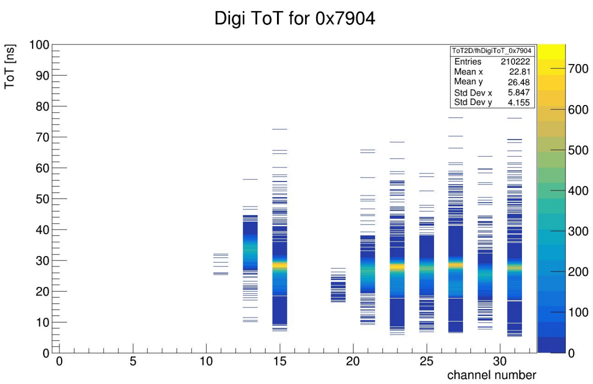
File: **3511_node10_00_0000.digi.root**

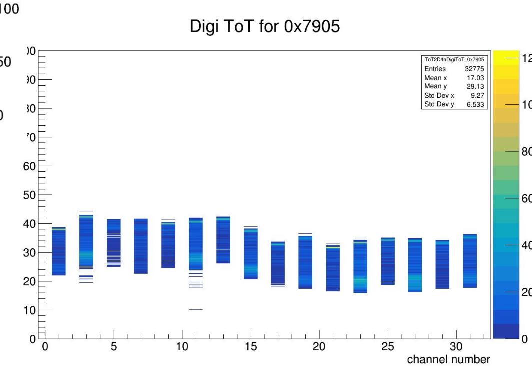
TOT distributions





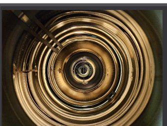






Challenges

- Optimizing Voltage and Attenuation settings
- Offsets need to be calibrated; there are a few options:
    - Generated pulse injection
    - Cosmic runs using T0 (Bmon) and Geometry
        - BMON is not calibrated!
- Timewalk corrections
- Charged particle separation using VETO
- Hit position approximation using VETO
- TOT to Integral to Energy conversion for calorimetry
- TOF(Bmon) vs TOT(NCAL), dE/dx(FSD) vs TOT(NCAL)
- Charged/neutral particle separation, PID
- CBMROOT software upgrades for our detector systems:
    - Including NCAL, FSD, VETO in unpacking algorithm
        - Parameter files, Geometries
    - Including detectors in Event building, Track finding and PID algorithms
- Advanced algorithms, machine learning, multiplicity studies …



BMON (T0) Correlations

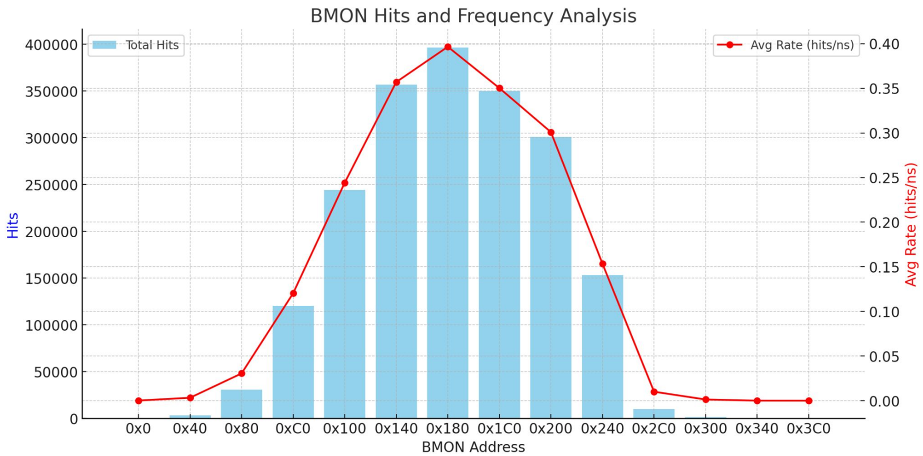
BMON Digi Analysis Summary

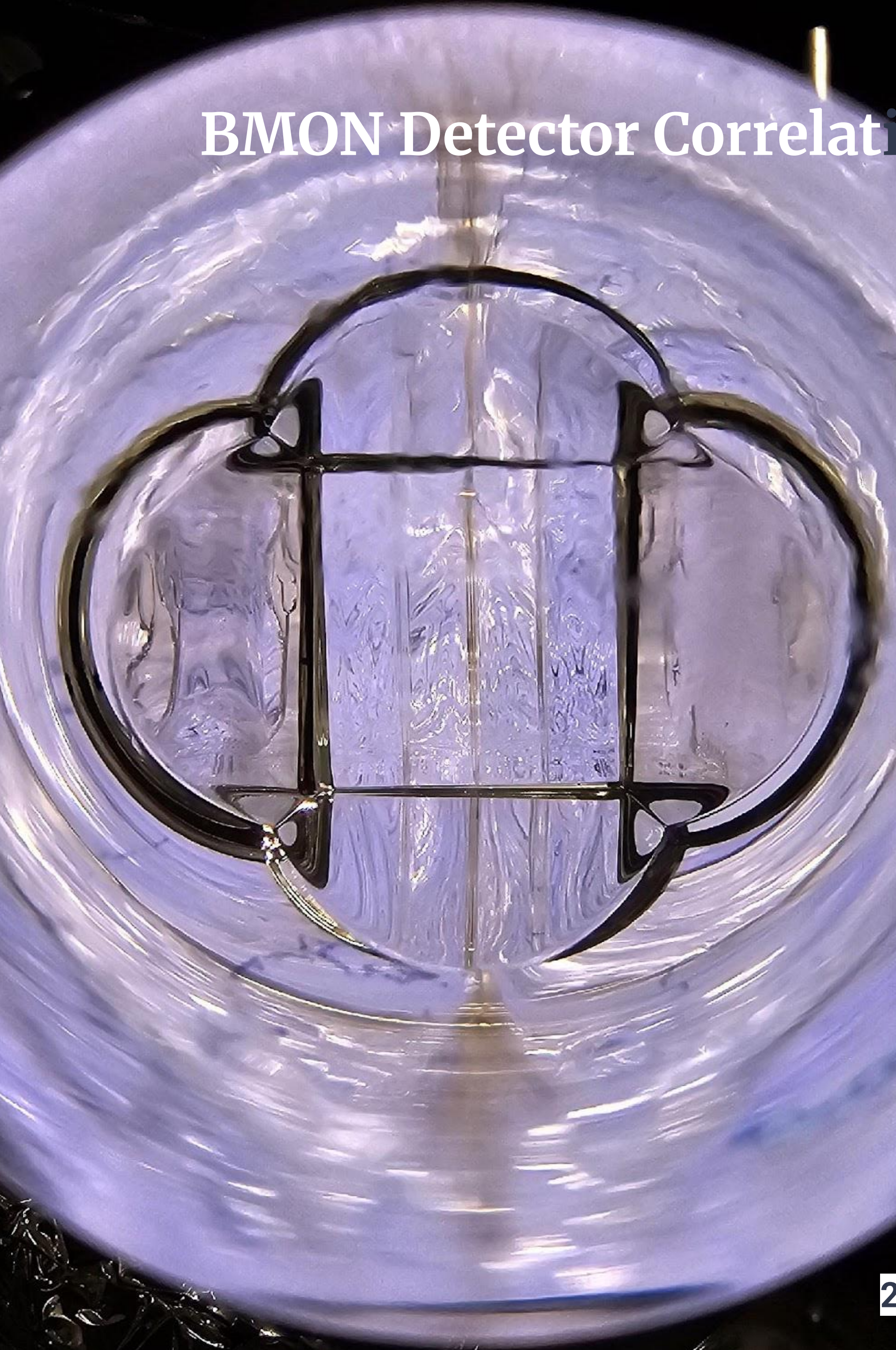
Dataset Size:
- 1,967,749 total BMON digis across 12 tree entries
- 383,614 BMON digis in first entry alone

Detector Characteristics:
- 14 unique BMON addresses detected
- Most active addresses: 0x01802806 (20.15%) and 0x01402806 (18.14%)
- Five addresses account for >80% of all hits (0x01002806 through 0x02002806)

Signal Properties:
- Digi structure includes Address, Time, and Charge
- Time values measured in nanoseconds
- Data stored in fAddress, fTime, and fCharge branches in ROOT file

Address Distribution:
- Highly non-uniform distribution across address space
- Peripheral addresses (0x00002806, 0x03C02806) show minimal activity (<0.01%)
- Middle addresses show highest activity concentration





BMON Detector Correlation Analysis: Key Points

Purpose: Analyzes timing correlations between Beam Monitor (BMON) and other CBM detectors (NCAL, FSD, VETO)

Time Management:

- Uses 150 ns correlation window
- All times referenced relative to TimeSlice start (each ~129 ms)
- No cross-TimeSlice correlations permitted

Correlation Method:

- Maps BMON hits by address and time
- Uses binary search to efficiently find hits within time window
- Calculates delta time (dt = detector_time - bmon_time)

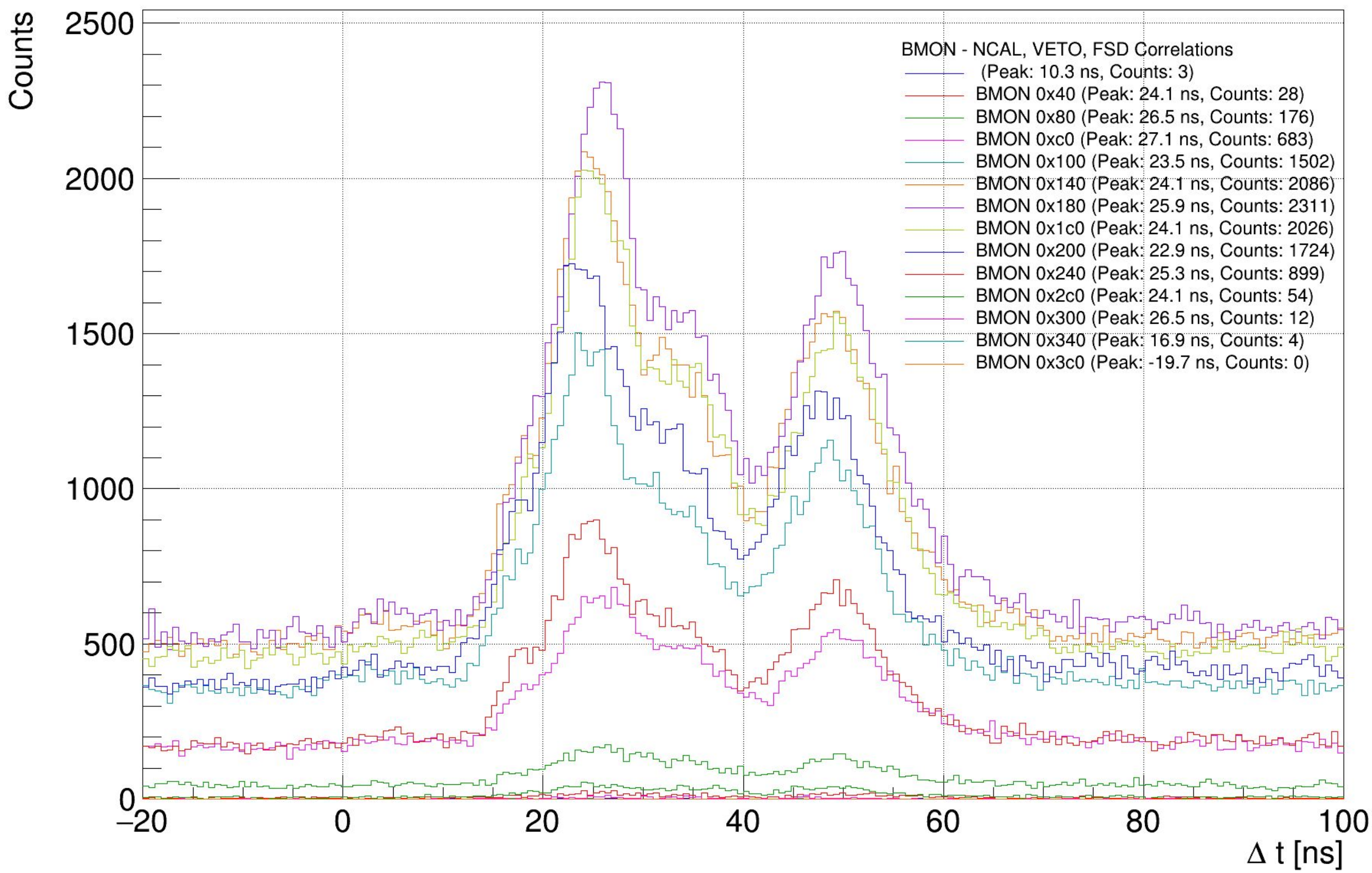
Technical Implementation:

- Processes detector data separately by type and channel
- Optimized with sorted time arrays and binary search
- Outputs organized in hierarchical directory structure

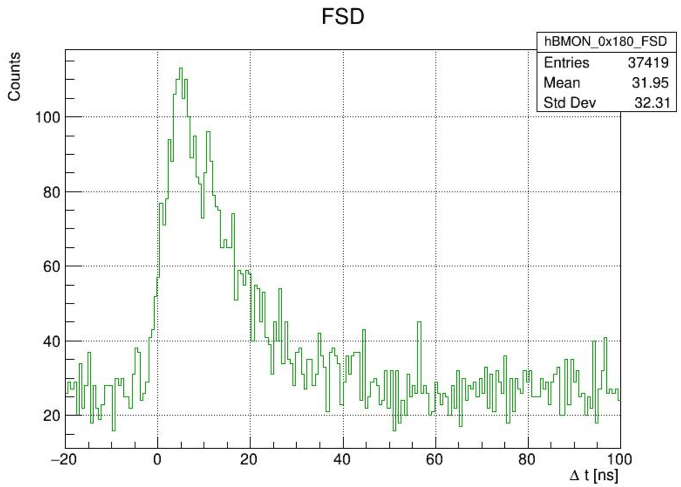
Result Visualization:

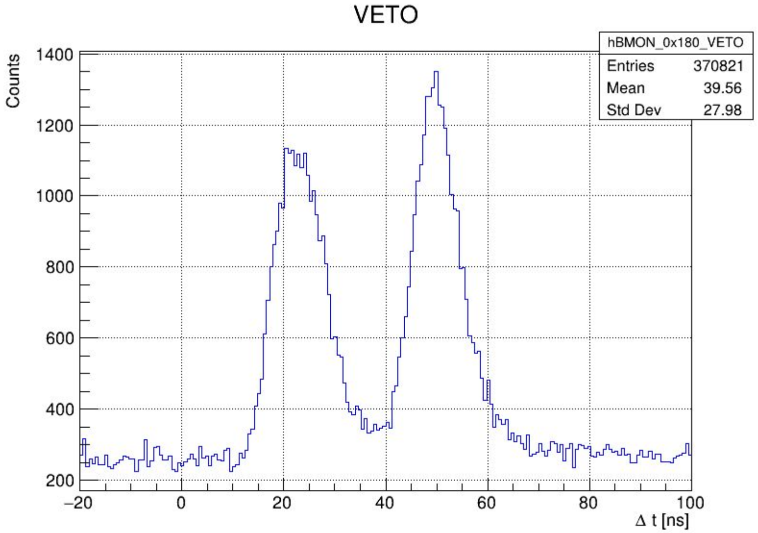
- Time difference histograms (-20 to 100 ns range, 0.6 ns/bin)
- Separate analysis by detector type, DiRICH board, and channel

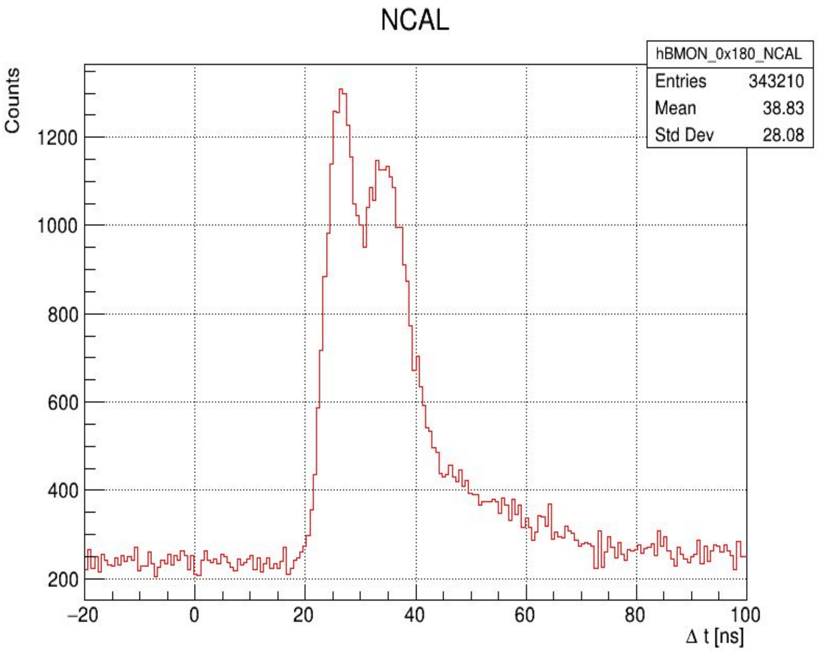
BMON channels vs NCAL, FSD, VETO combined correlations



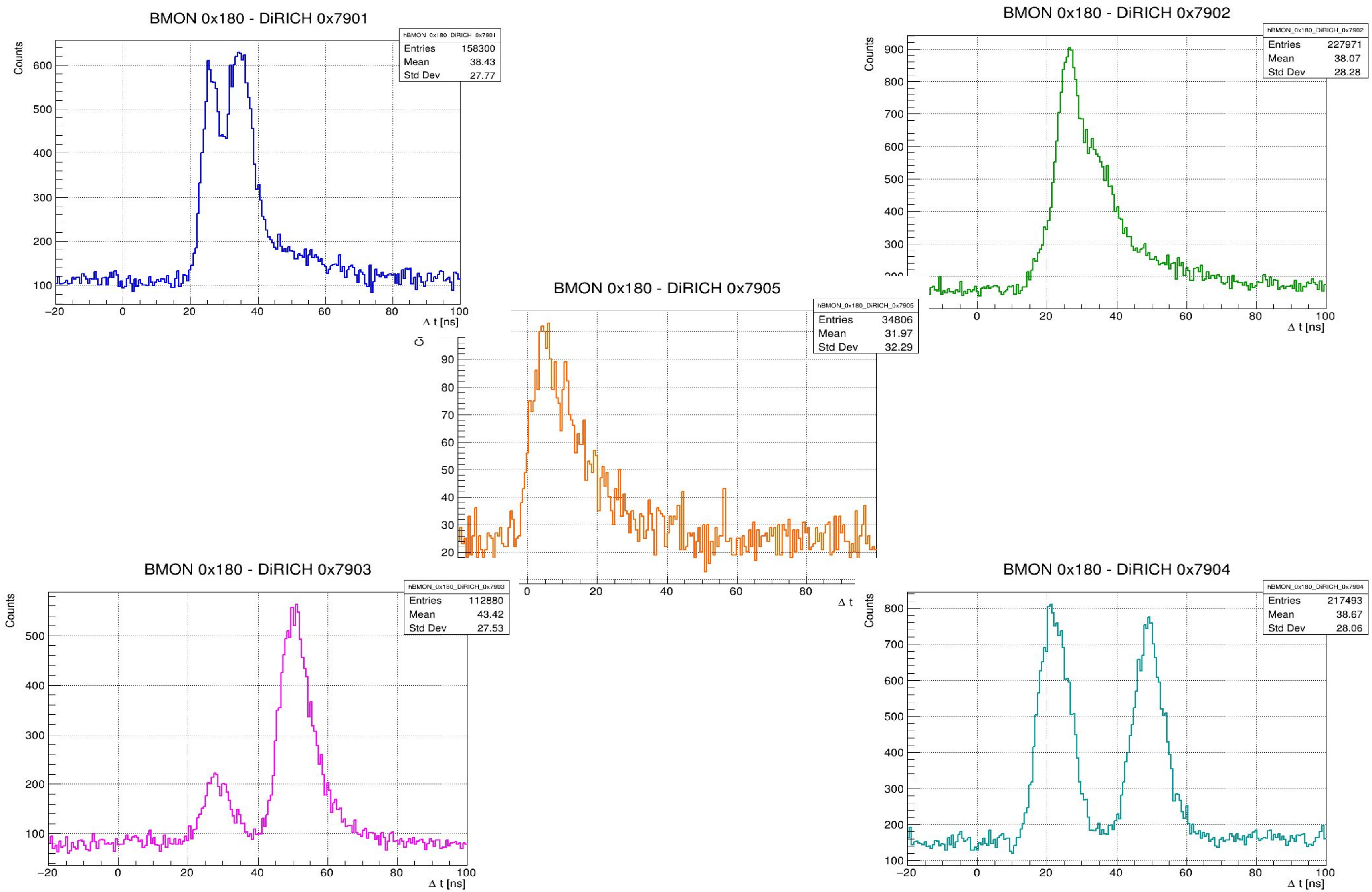
BMON 0x180 vs FSD, NCAL, VETO



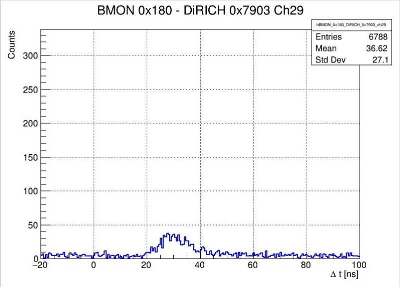


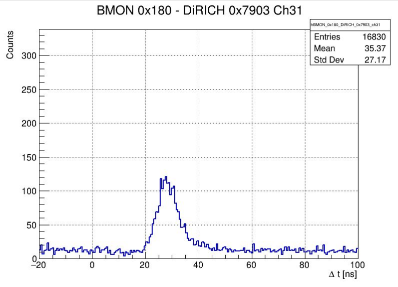


BMON 0x180 vs DiRich

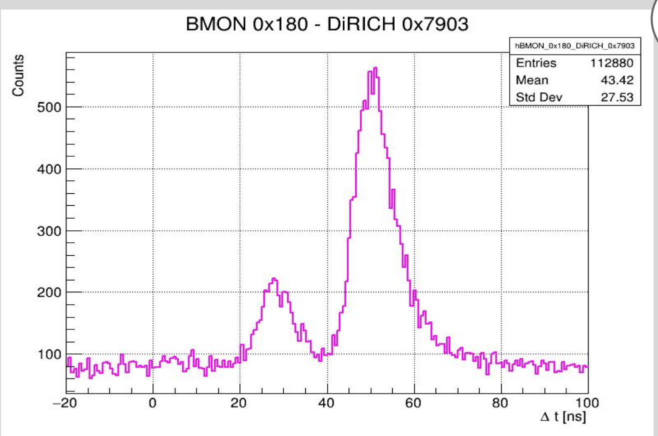


BMON 0x180 vs Veto Channels

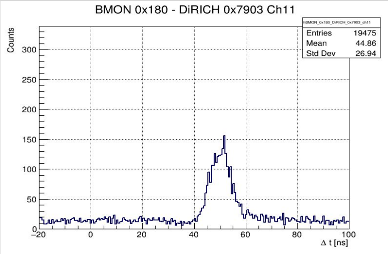




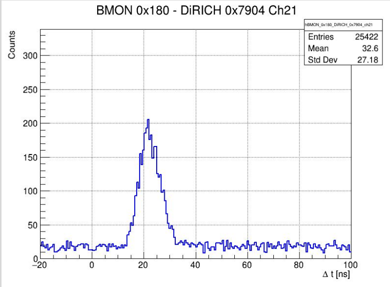
VETO 32

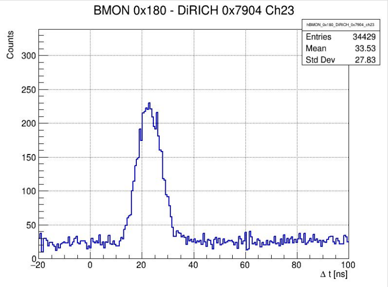


VETO 31

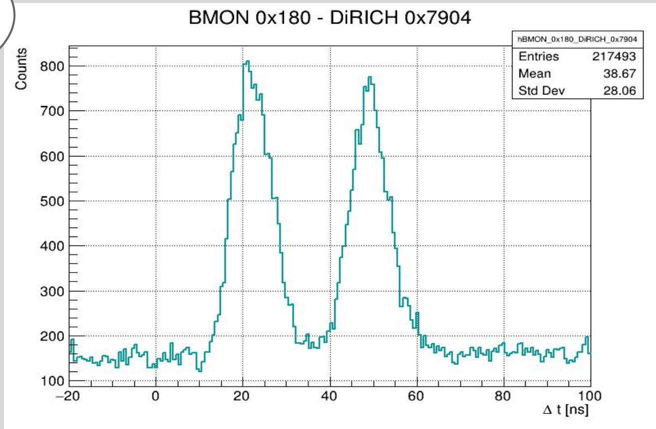


Is our system not centered on the beam plane?

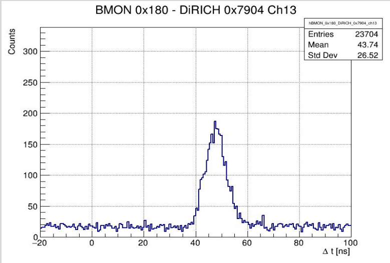


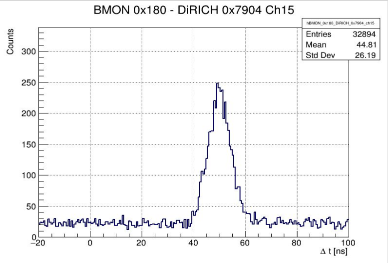


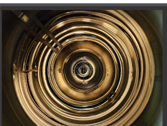
VETO 12



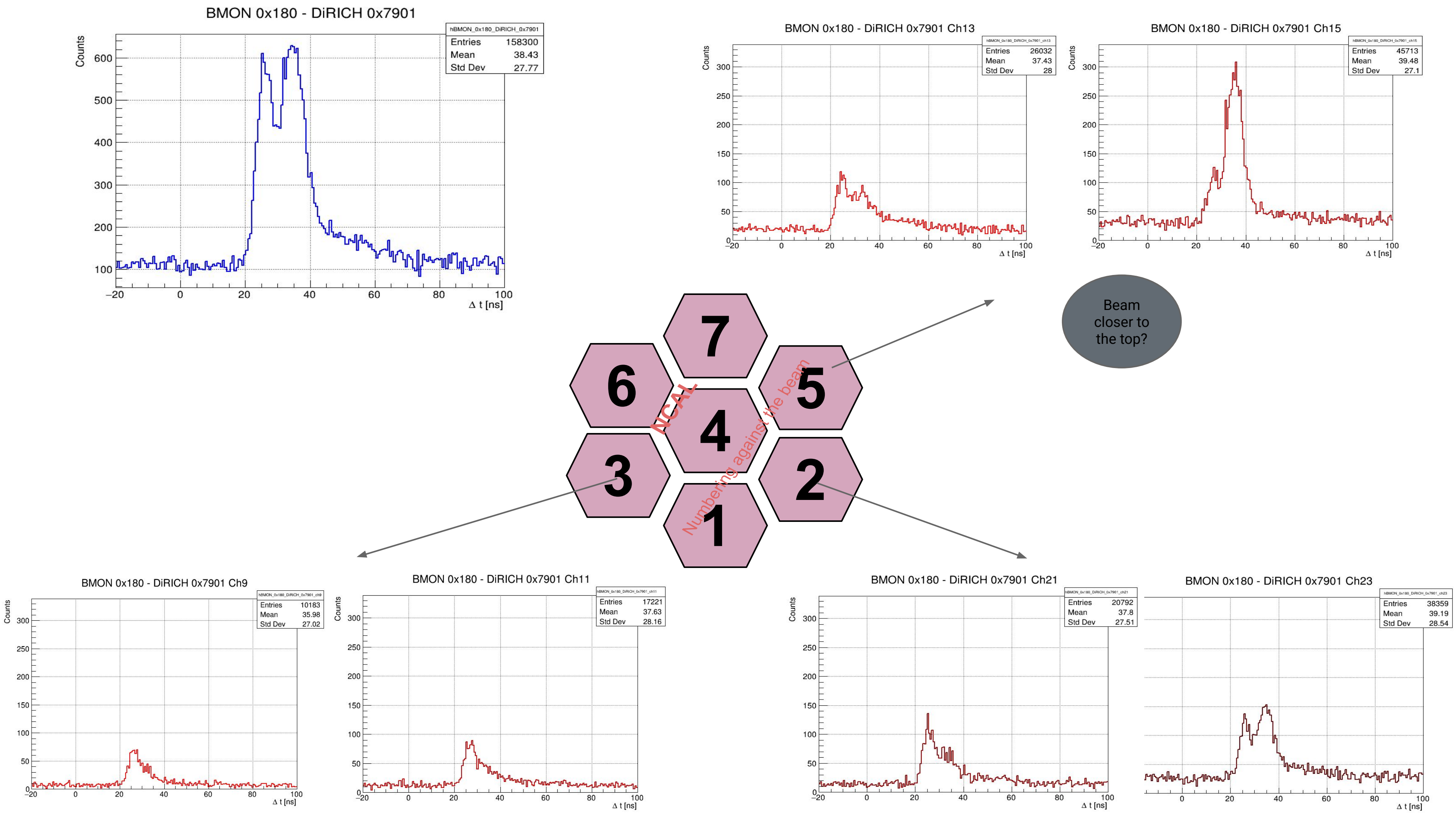
VETO 11



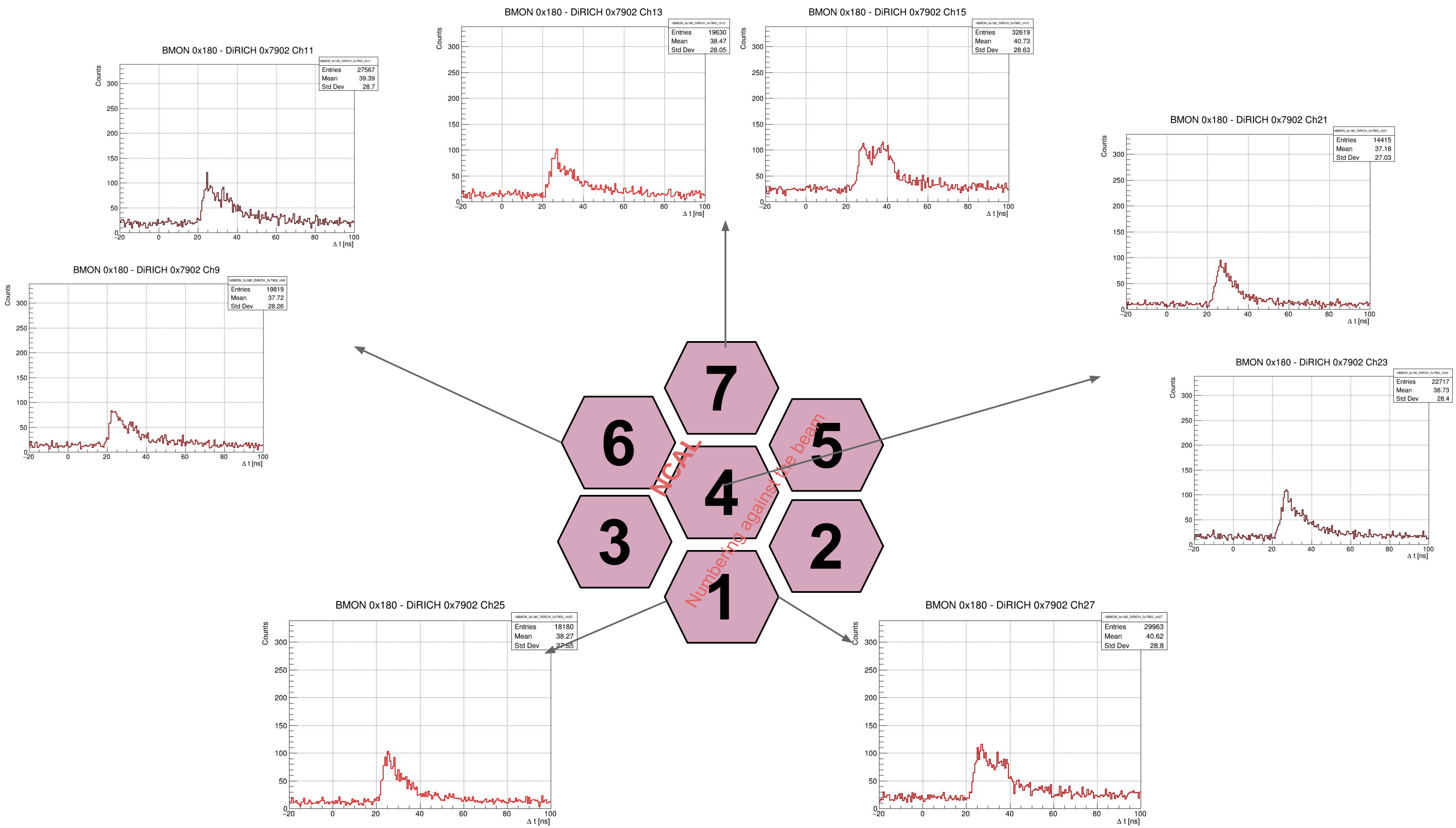




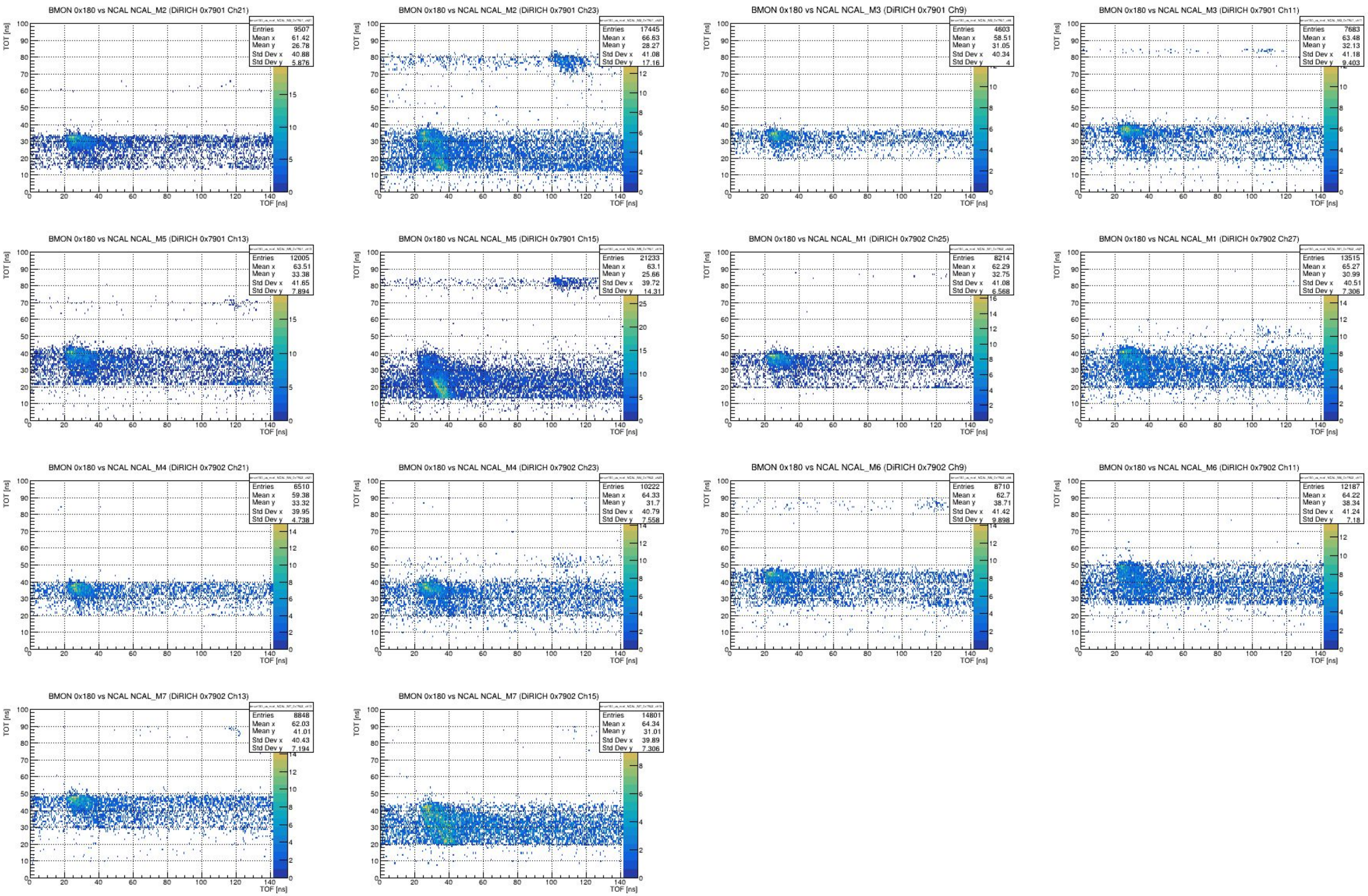
BMON 0x180 vs NCAL 7901 Channels



BMON 0x180 vs NCAL 7902 Channels



BMON 0x180 vs NCAL: TOF vs TOT



VETO - NCAL correlations / exclusions

Correlation Method:

- Analysis performed within each TimeSlice separately
- VETO correlation window: ±40 ns
- Hits are matched using local timeslice times
- Binary search for efficient hit finding

Three Categories per Channel:

- Total ToT distribution (black)
- VETO-correlated hits (red)
- VETO-excluded hits (blue)

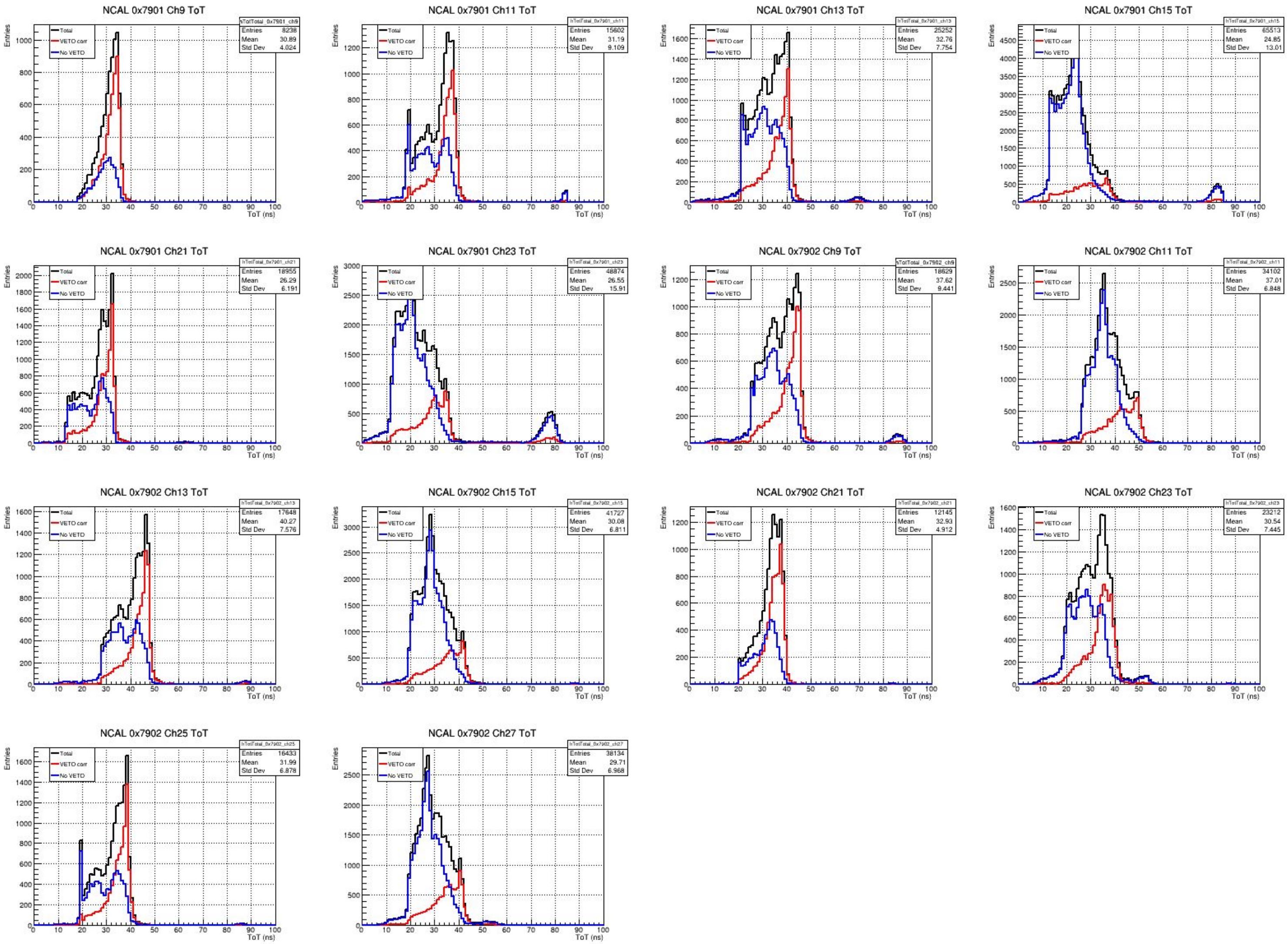
Channel Types:

- NCAL (0x7901, 0x7902): ToT range 0-100 ns
- FSD (0x7903, 0x7905): ToT range 10-50 ns
- VETO (0x7902-0x7904): Used for correlation

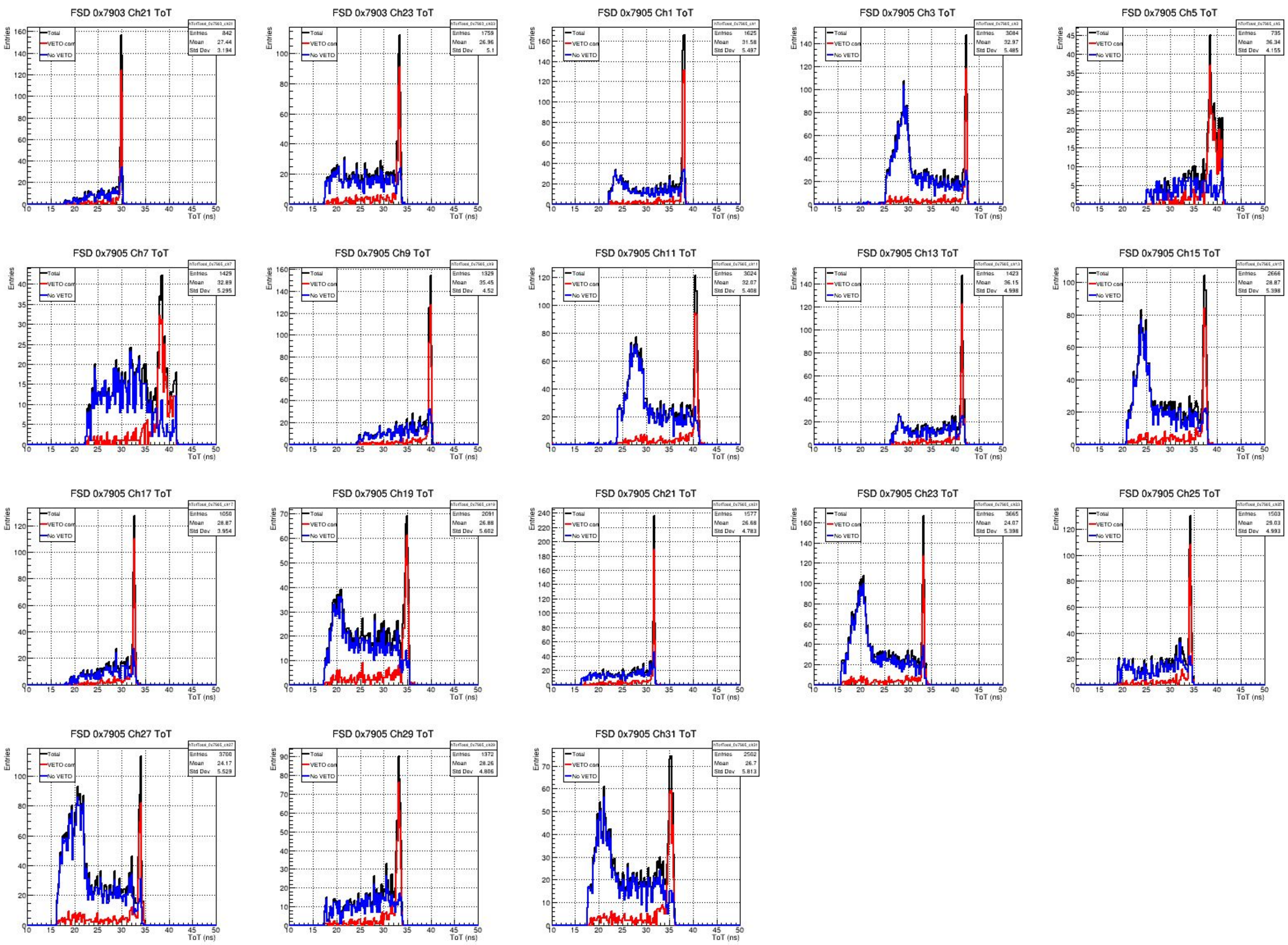
Output:

- Individual channel histograms
- Linear and log summary plots
- Correlation statistics per channel

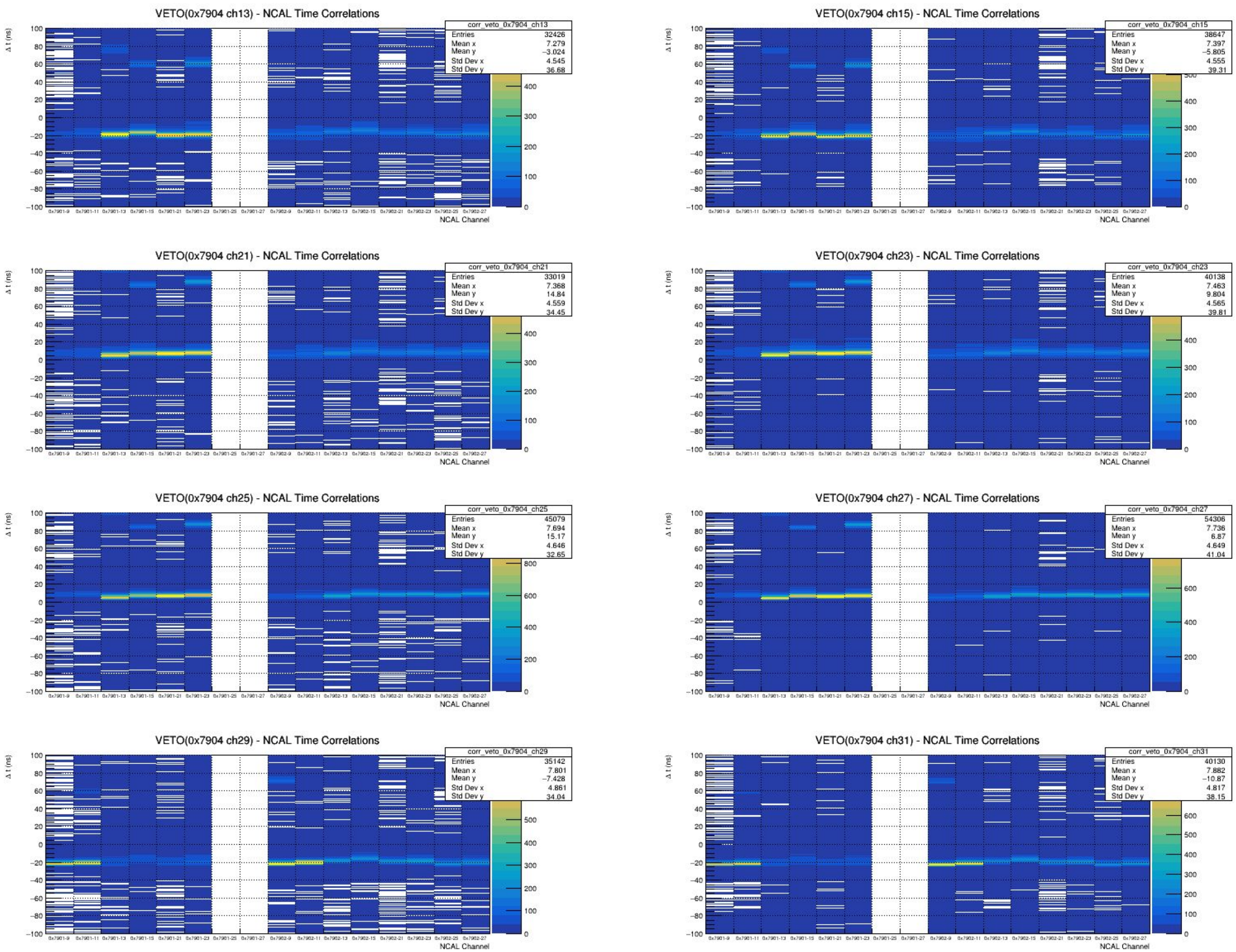
Veto NCAL correlations - 40 ns window



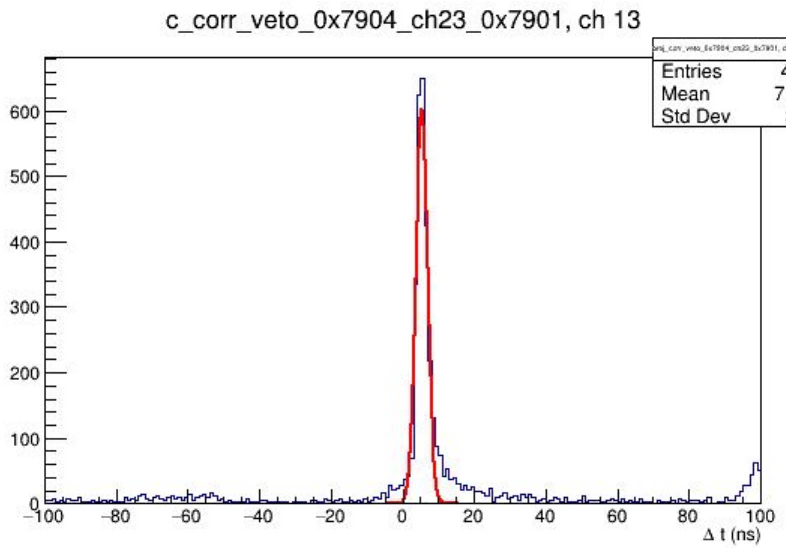
Veto NCAL correlations - 40 ns window

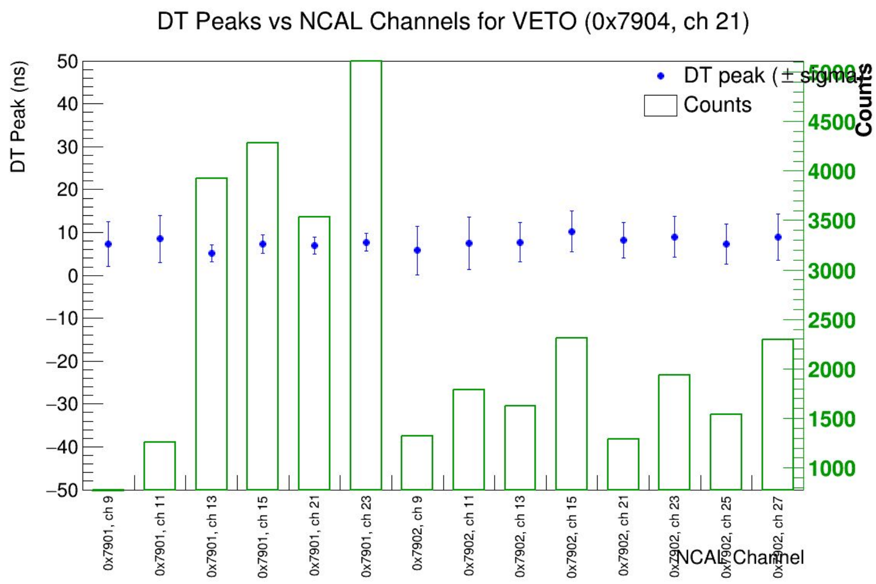


Veto NCAL correlations

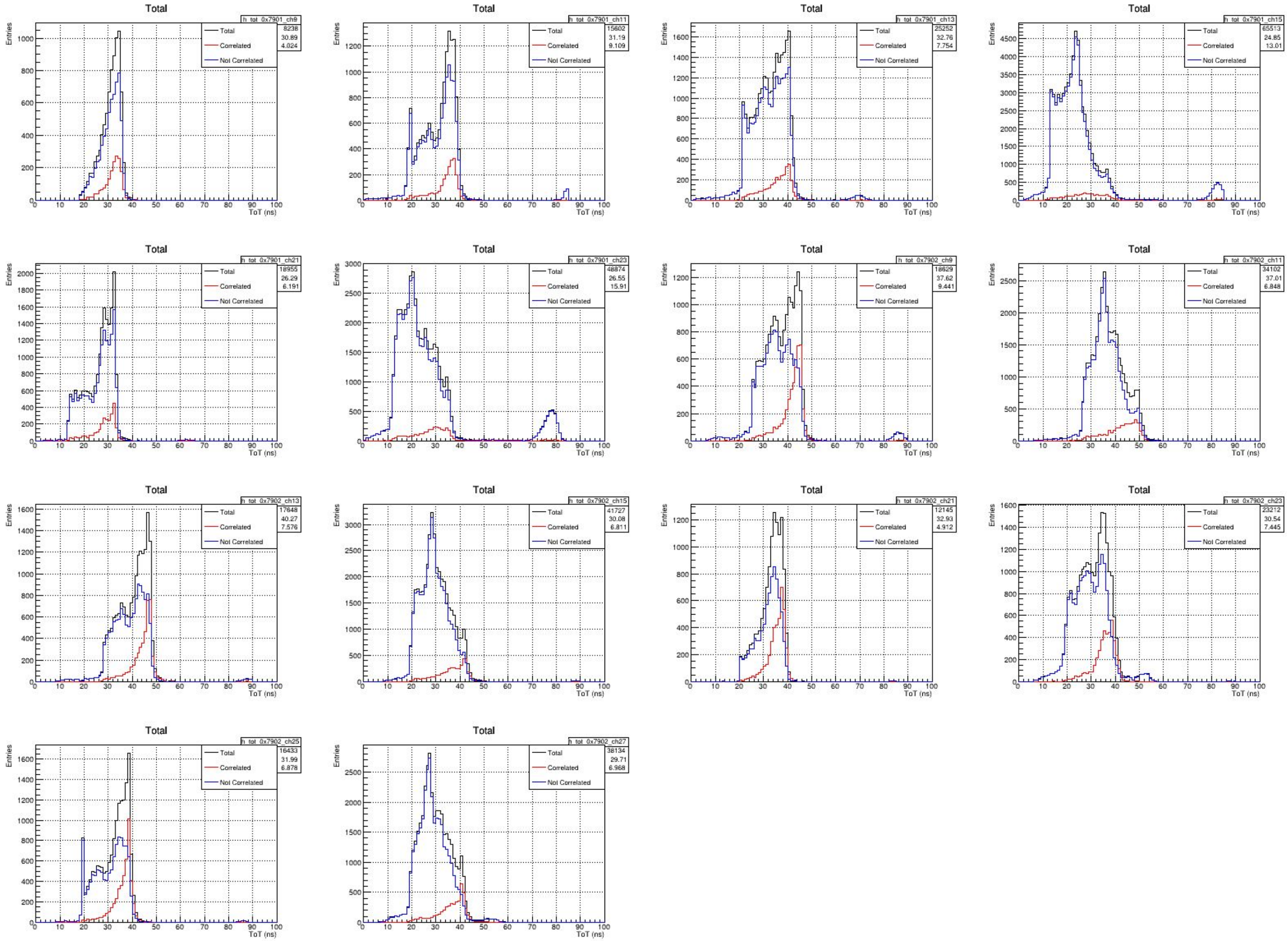


Veto NCAL correlations





Veto NCAL correlations - variable 3 sigma window



Time Walk Corrections

Correlation and Timewalk Correction Overview

1. Triplet Formation

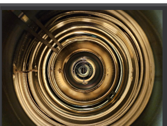
- **Objective**: Correlate **FSD High**, **FSD Low**, and **NCAL** hits.
- **Steps**:
  - Match **FSD High** and **FSD Low** hits within a **50 ns time window**.
  - Correlate matched FSD hits with **NCAL hits** within a **300 ns time window**.
  - Store triplets with FSD High/Low and NCAL time, TOT, and channel information.

2. Fitting

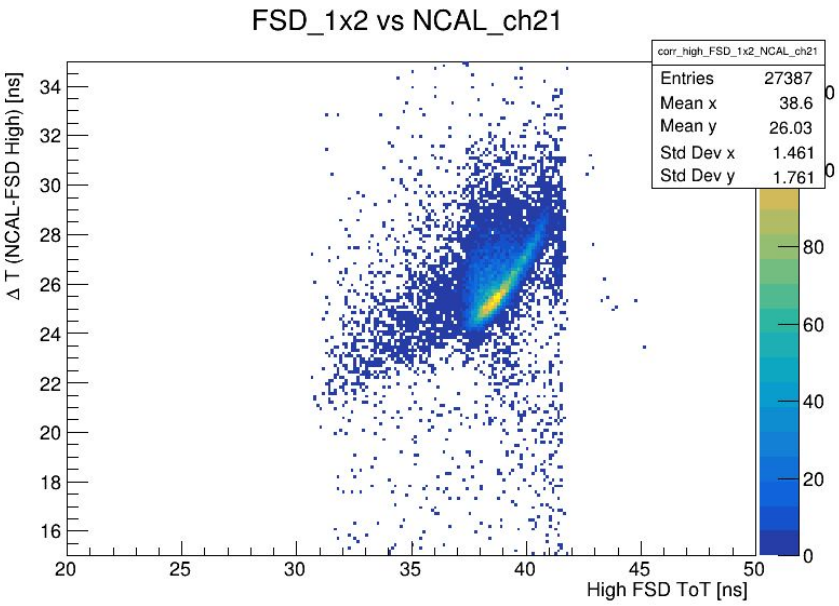
- **Objective**: Fit timewalk correction functions to (\Delta T) vs TOT data.
- **Steps**:
  - Generate histograms for FSD High/Low and NCAL TOT vs (\Delta T).
  - Fit correction functions to reduce TOT dependence.

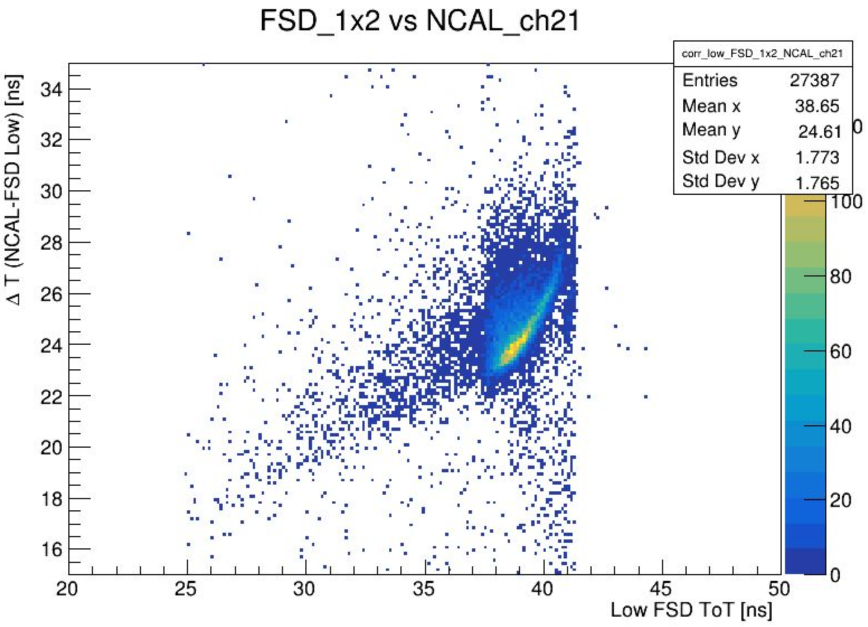
3. Correction

- **Objective**: Apply corrections to (\Delta T) values.
- **Steps**:
  - Calculate corrections using fit functions.
  - Apply corrections to (\Delta T) and fill corrected histograms.

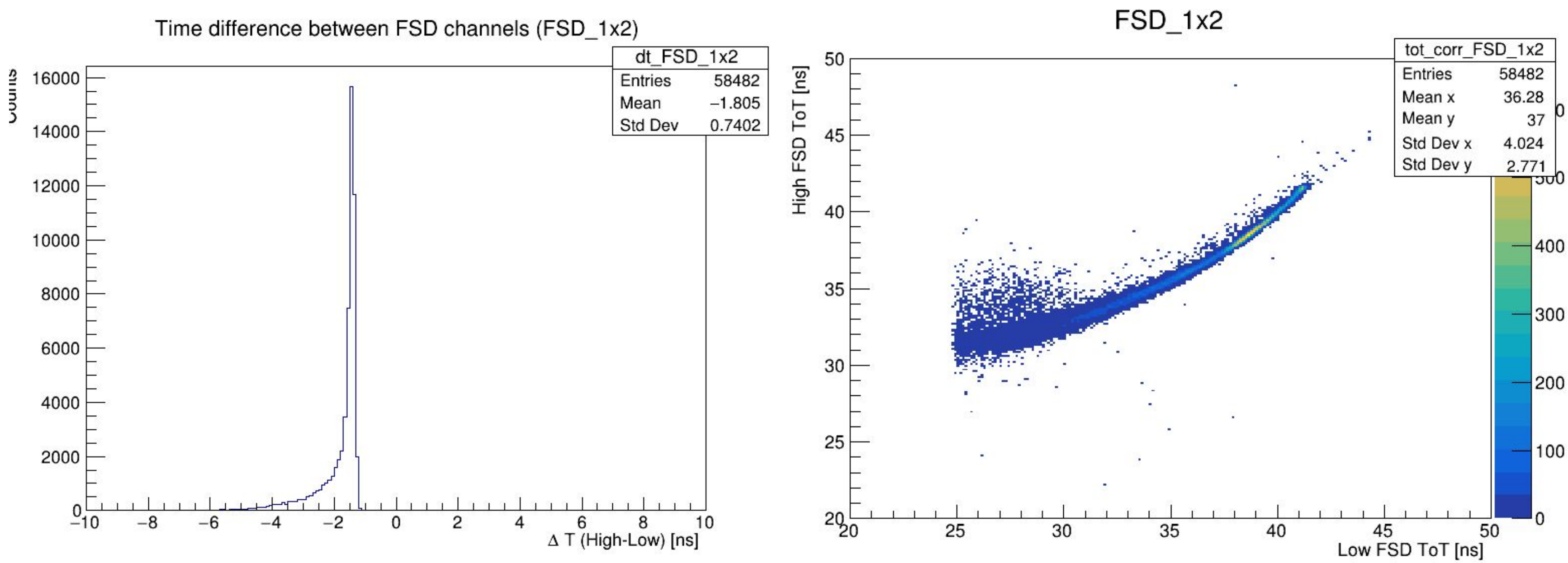


FSD TOT vs dT NCAL Correlations

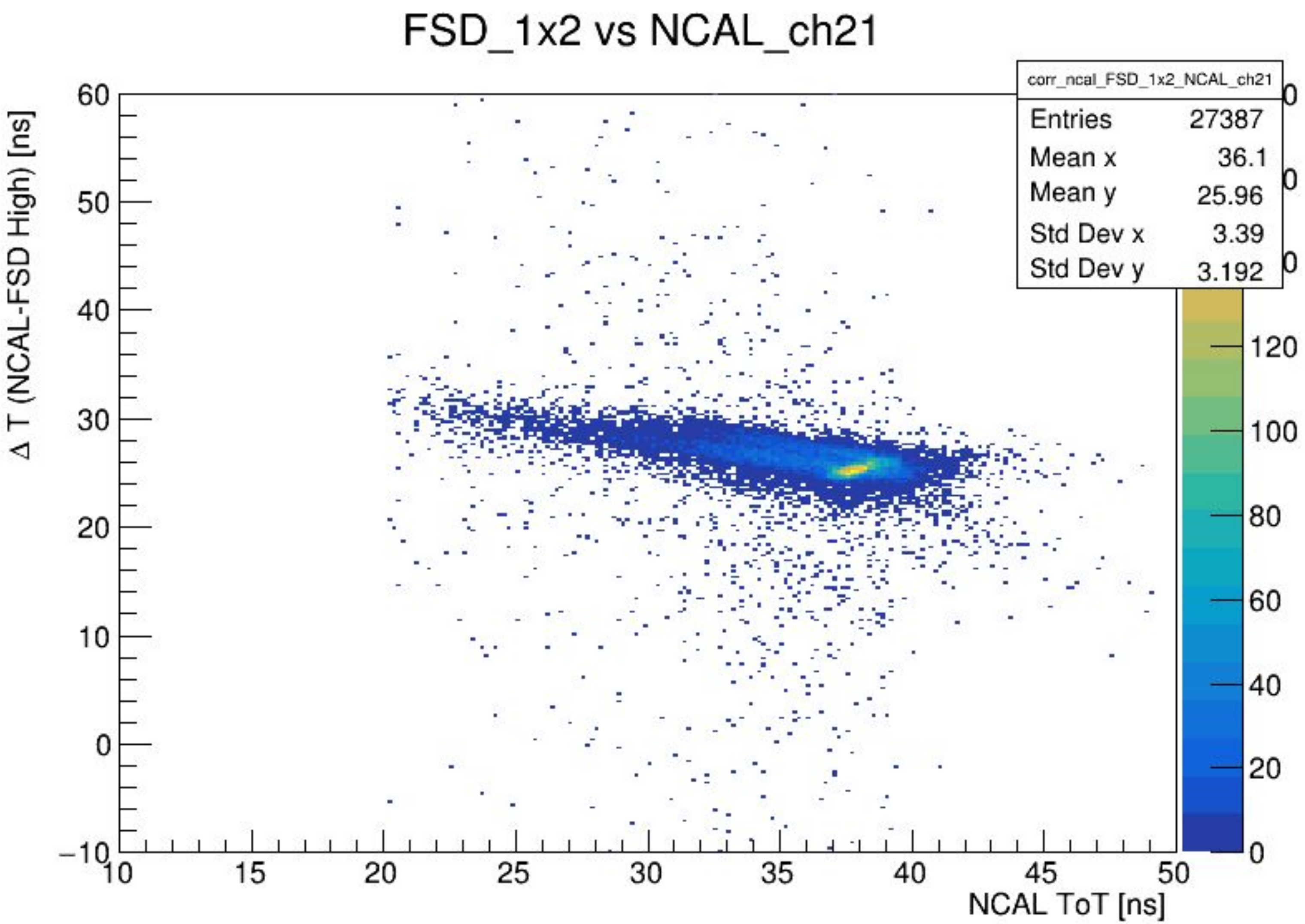




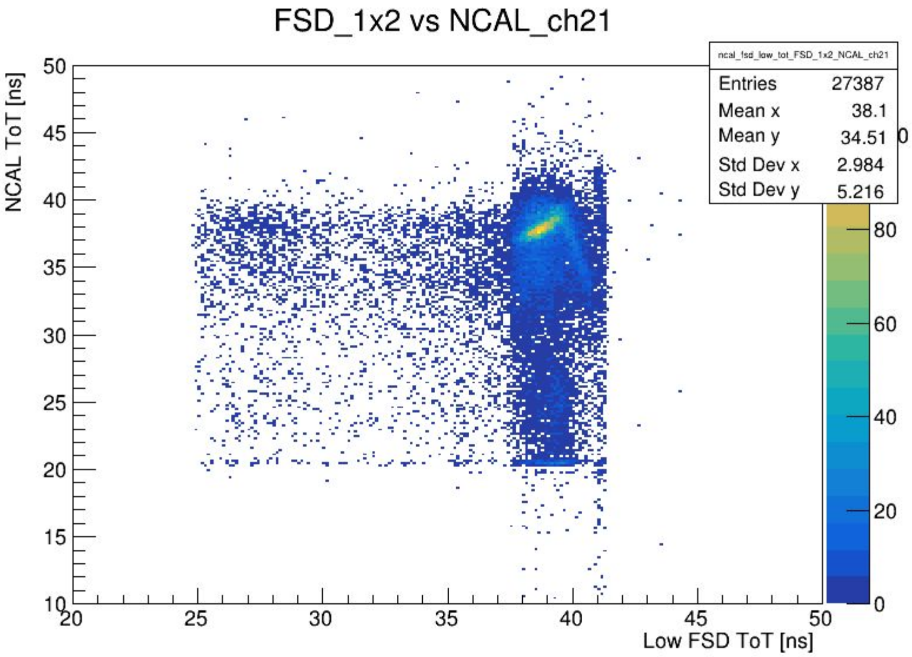
FSD high - FSD low correlations

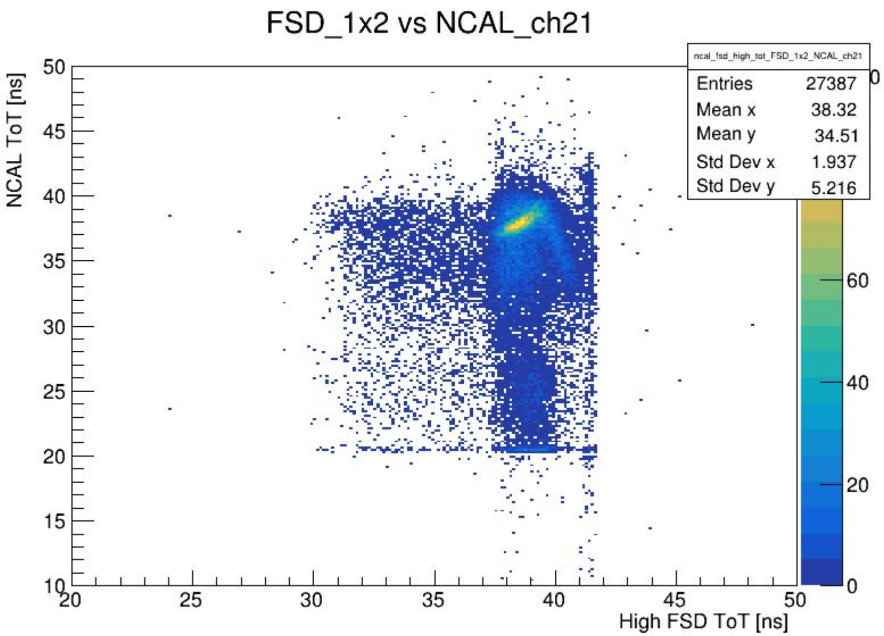


NCAL TOT vs dt FSD

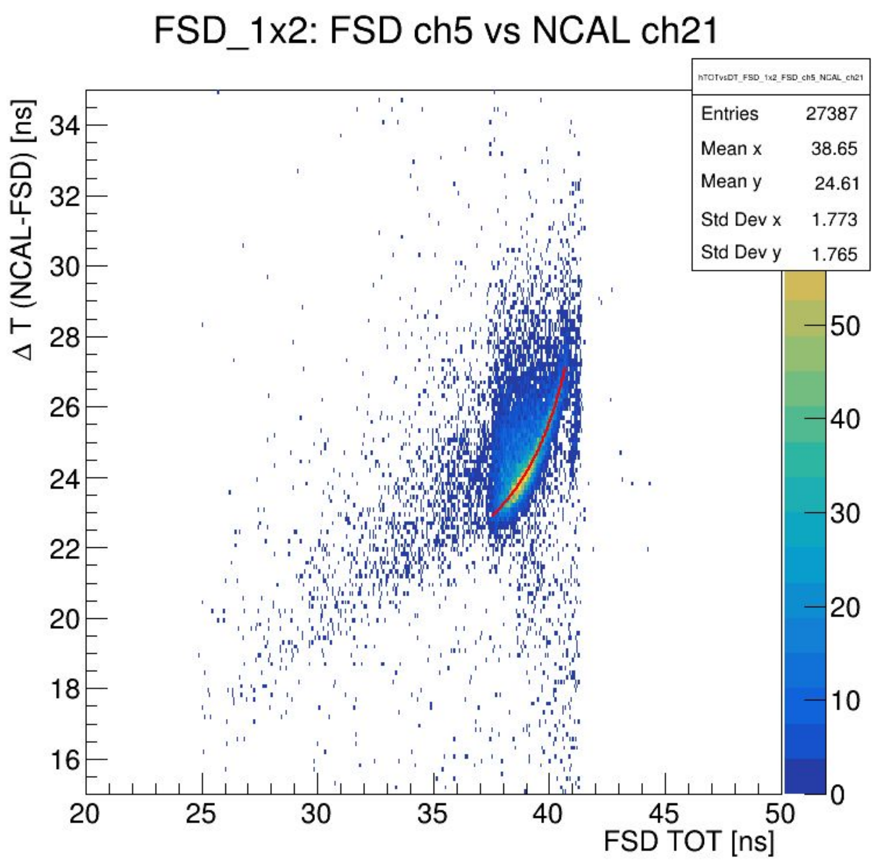


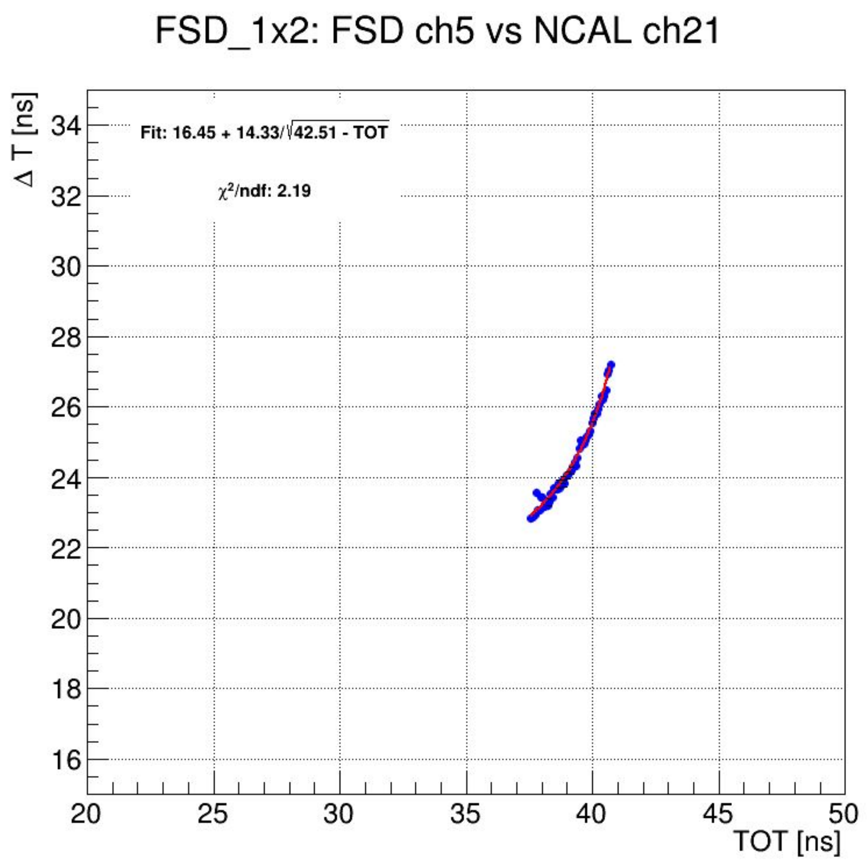
FSD TOT vs NCAL TOT



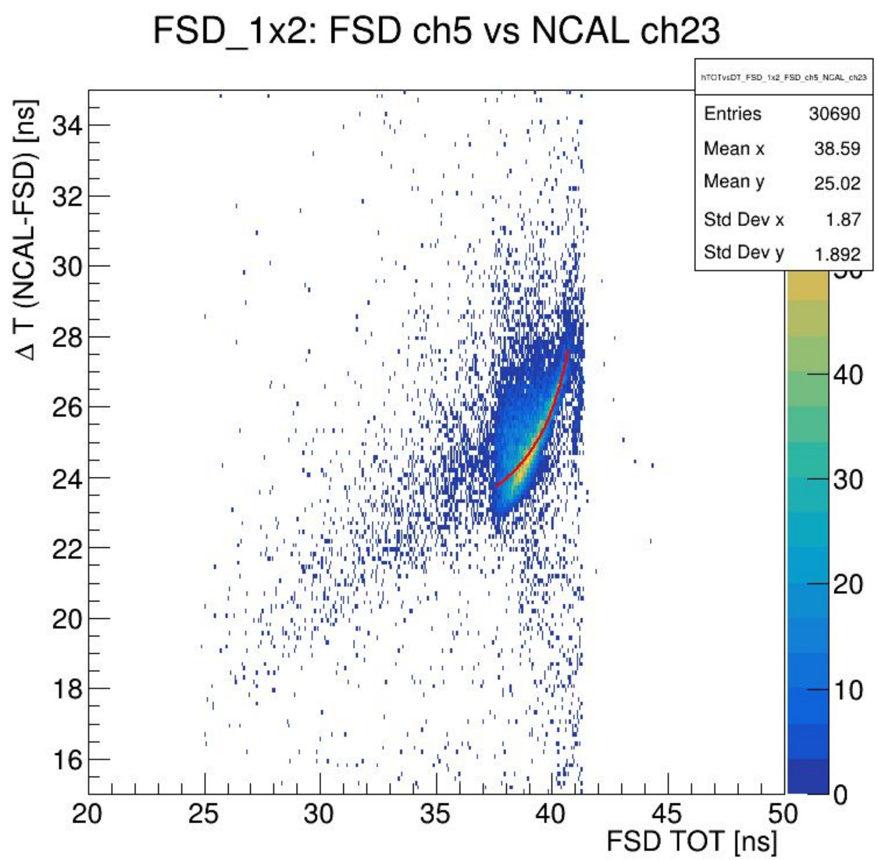


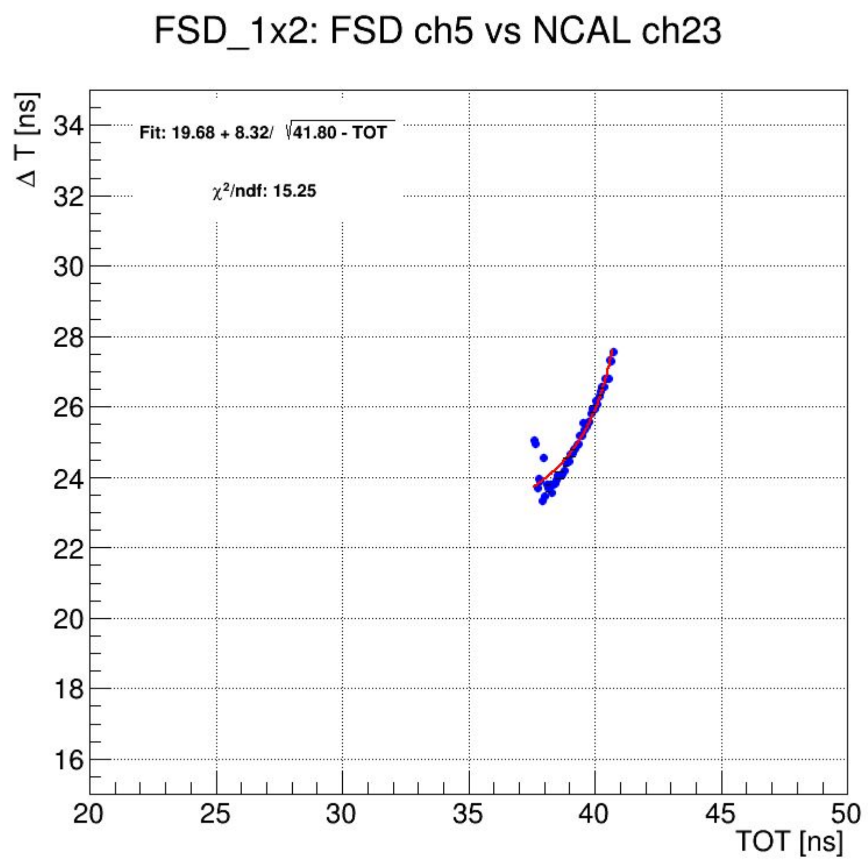
FSD NCAL Timewalk Corrections



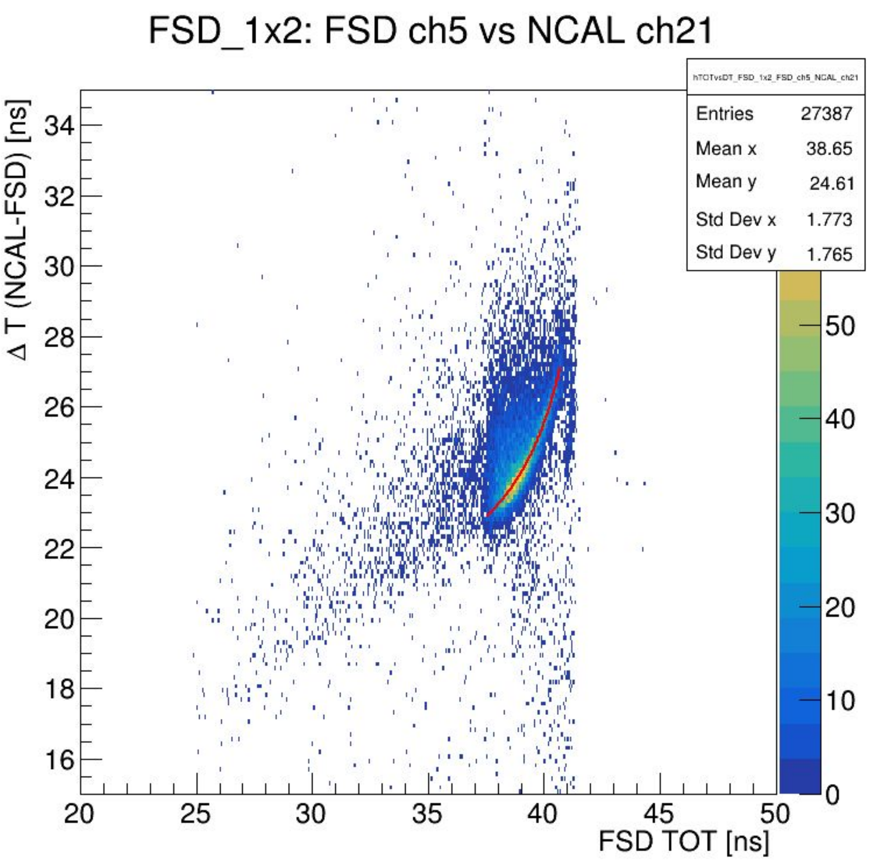


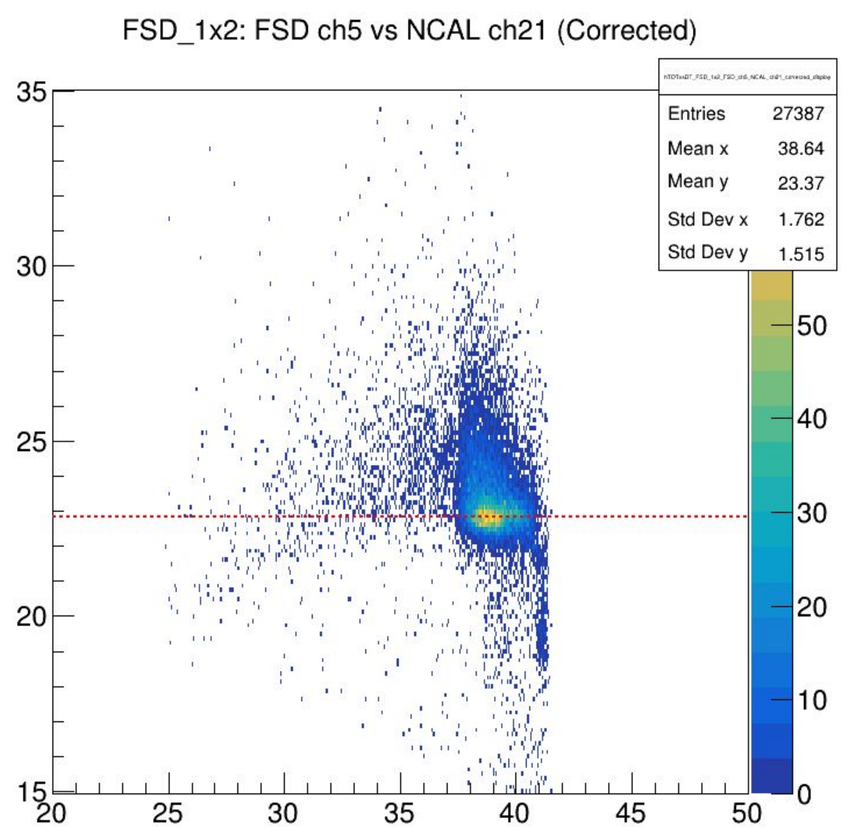
FSD NCAL Timewalk Corrections

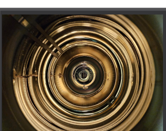




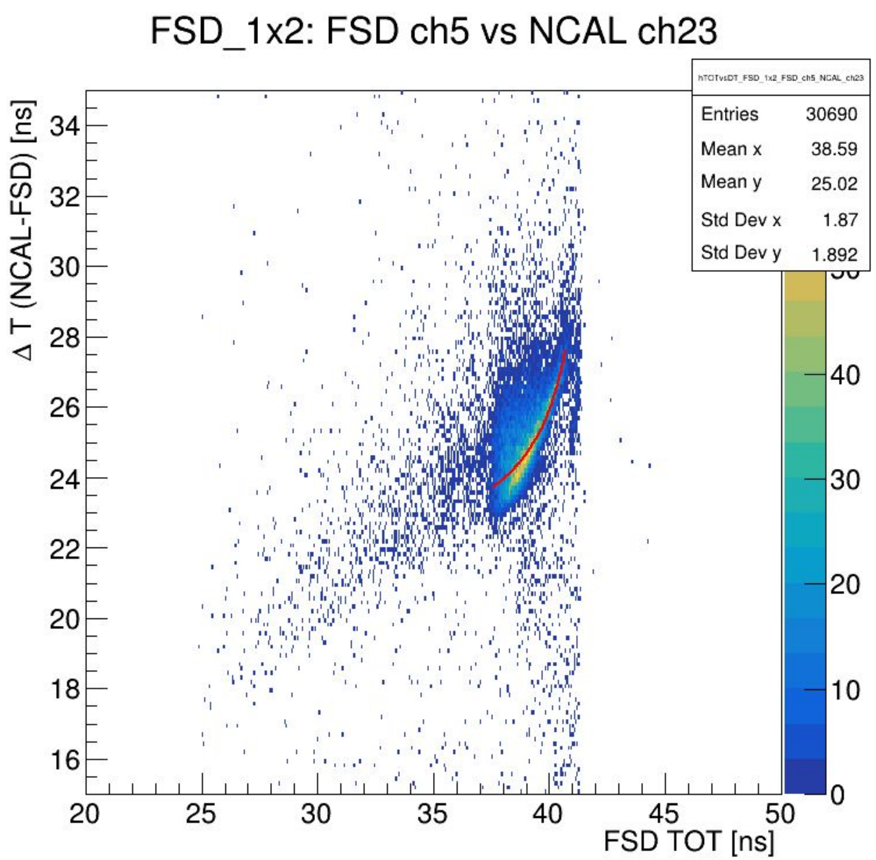
FSD NCAL Timewalk Corrections

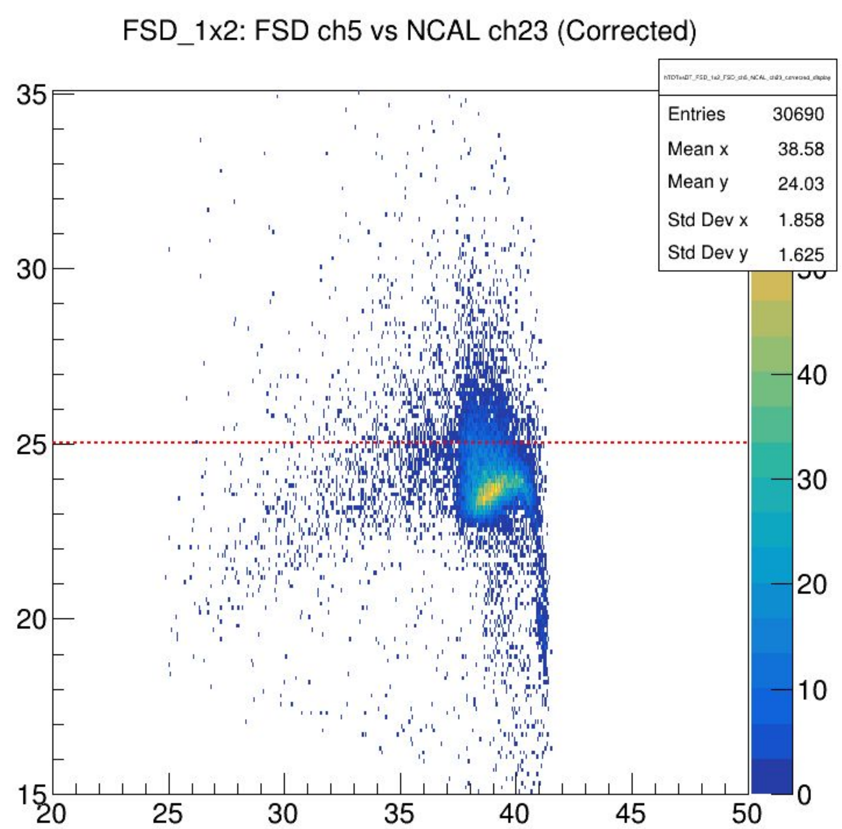




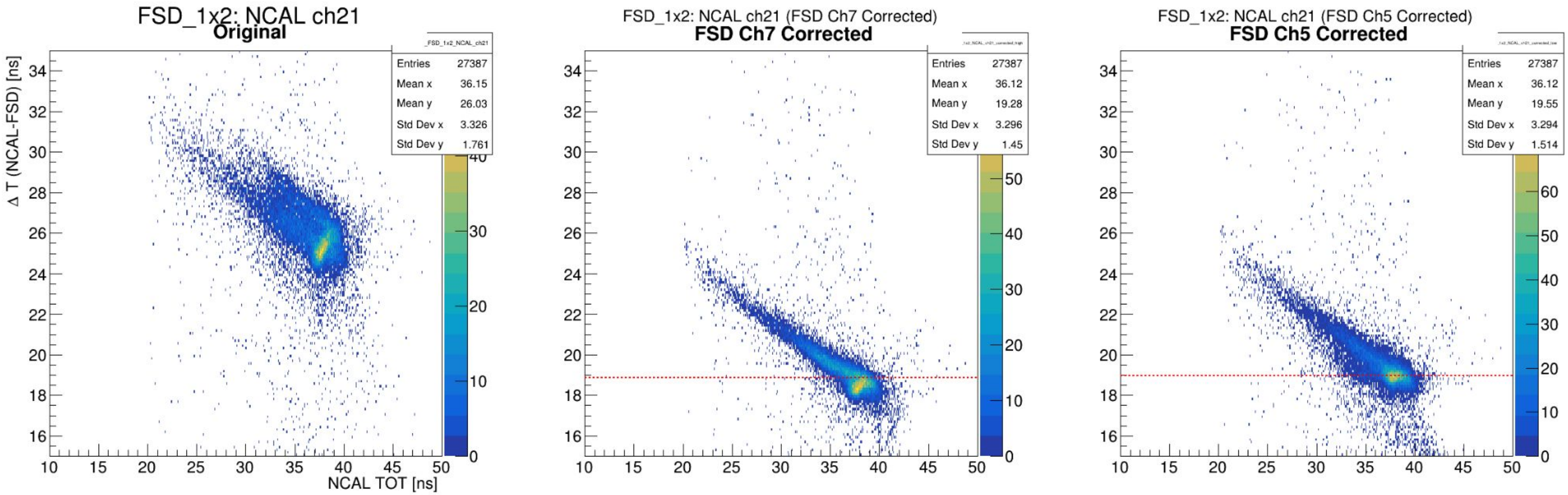


FSD NCAL Timewalk Corrections





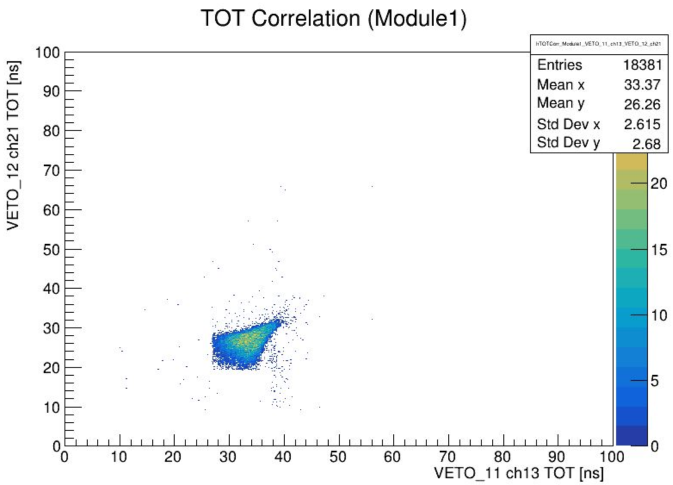
FSD NCAL Timewalk Corrections

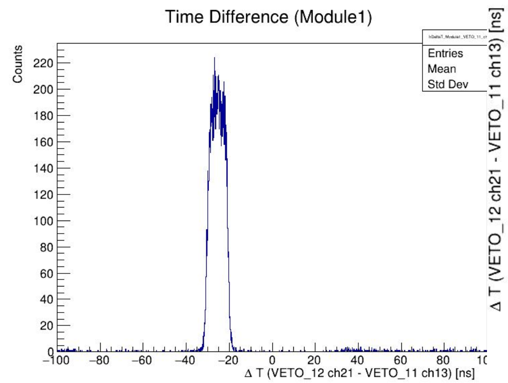


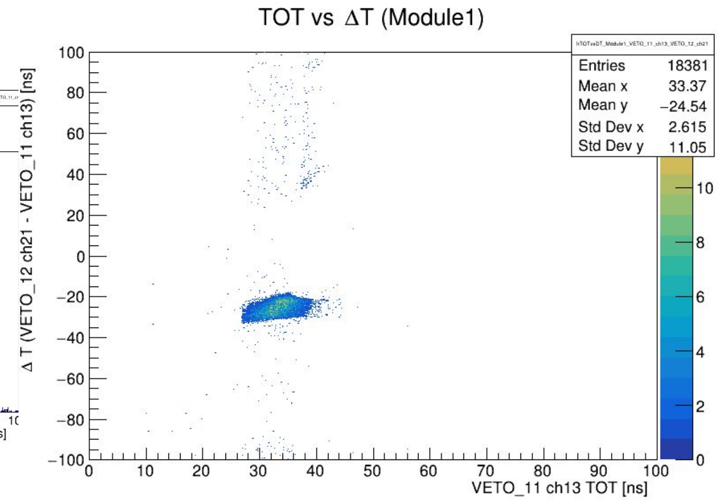
FSD NCAL Timewalk Corrections

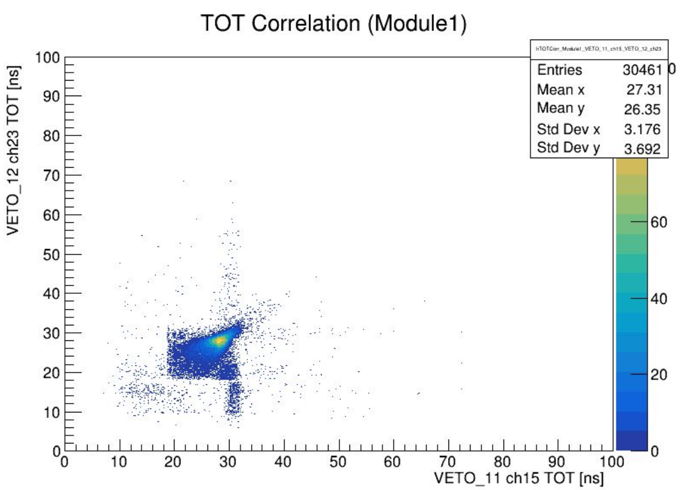
VETO Correlation

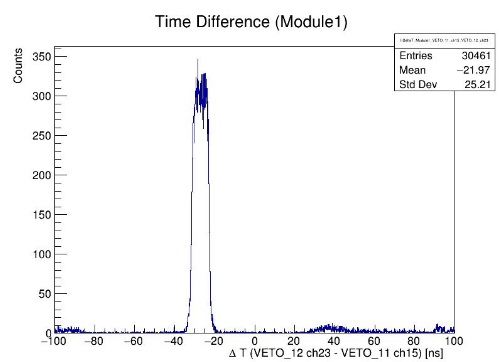
VETO Correlations

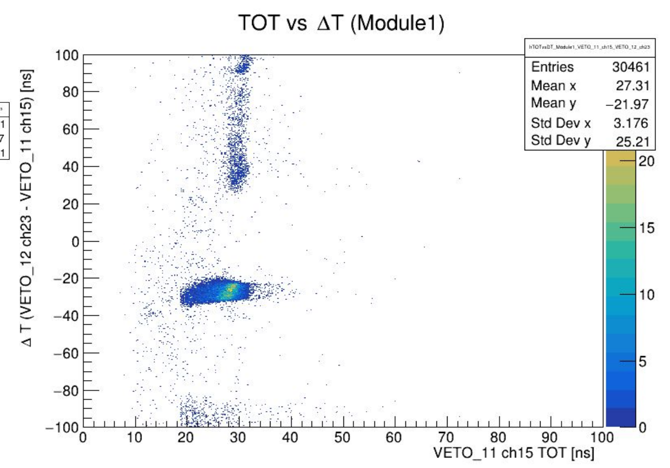




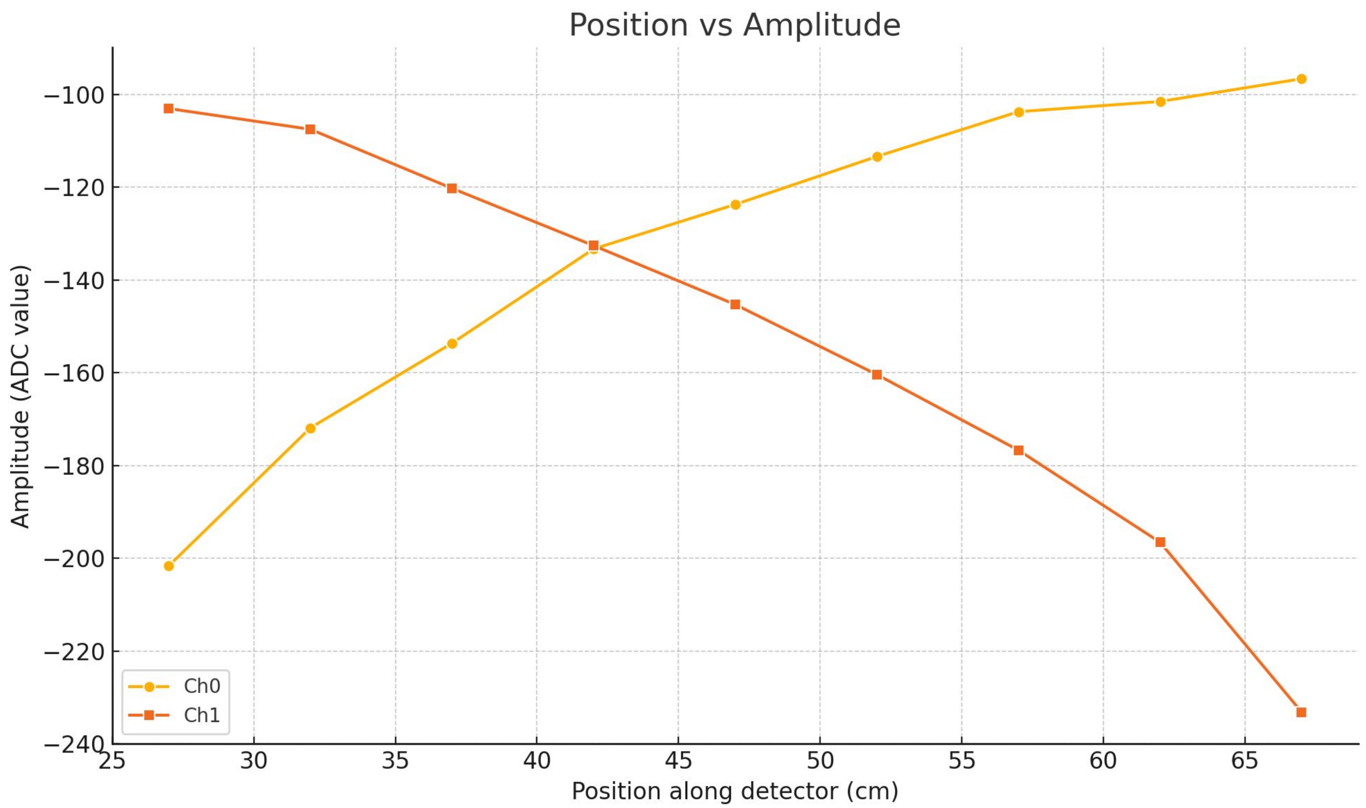






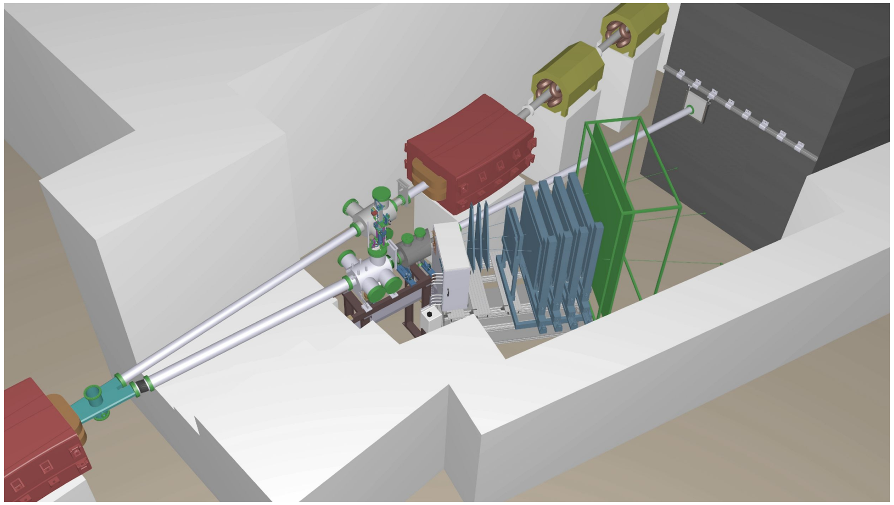


VETO Position Studies

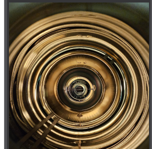


Outlook

- Complete Timewalk Corrections
- Offset corrections
- Voltage, Attenuation calibrations
- Upcoming beamtimes
- Prague tests data analysis
- Additional simulations
- CBMROOT software development
- PID algorithms



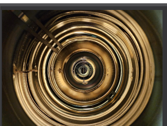
Questions and Discussions



Thank you for your attention!

Dachi okropiridze

10/04/2025, IKP



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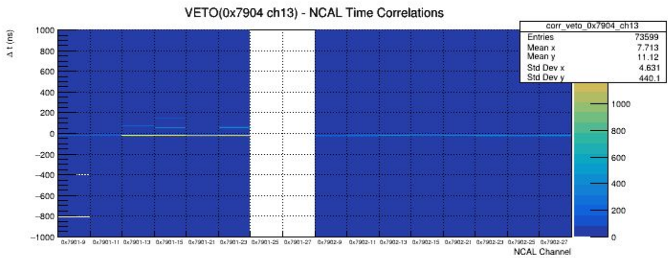
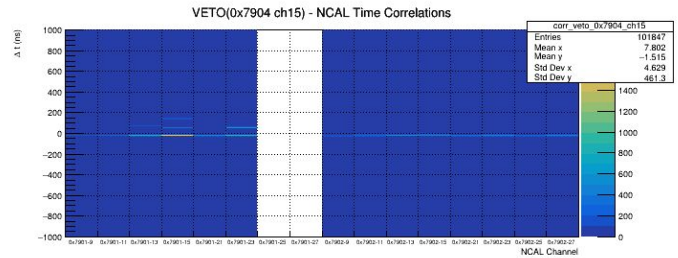
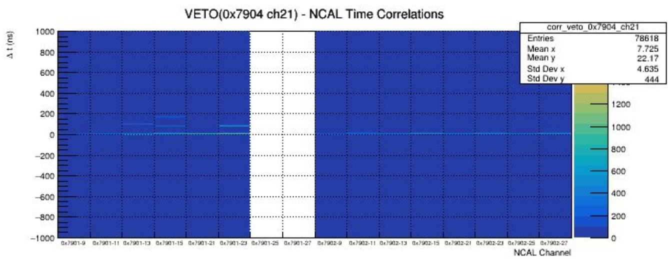
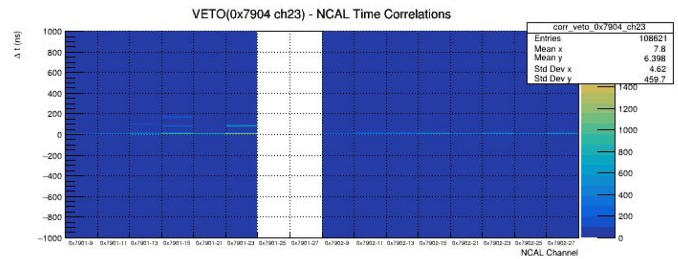
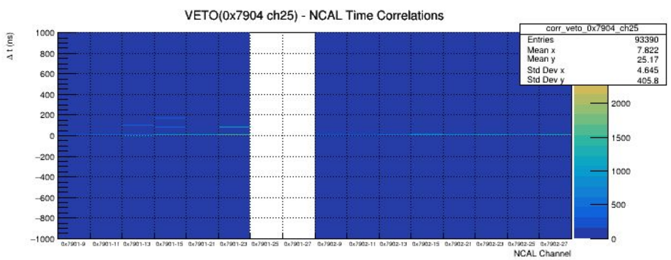
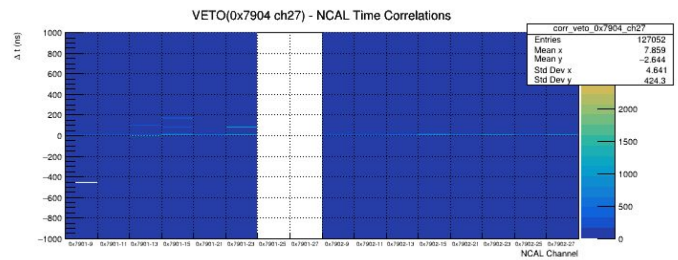


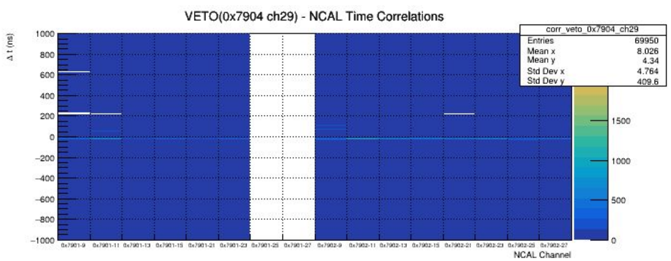


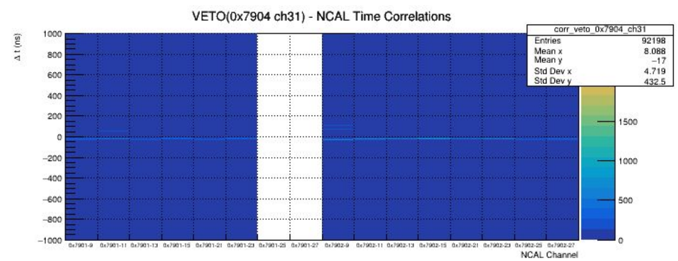


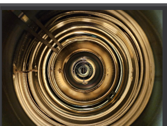




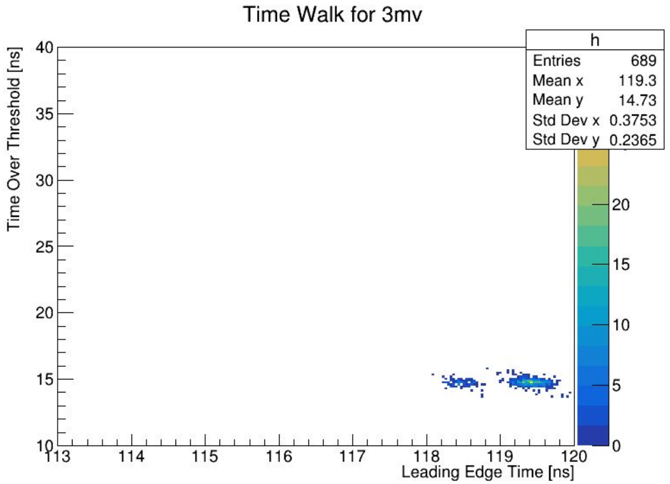


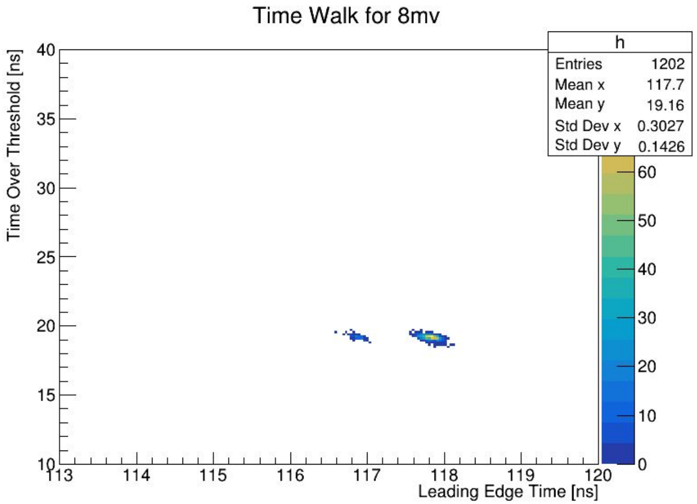


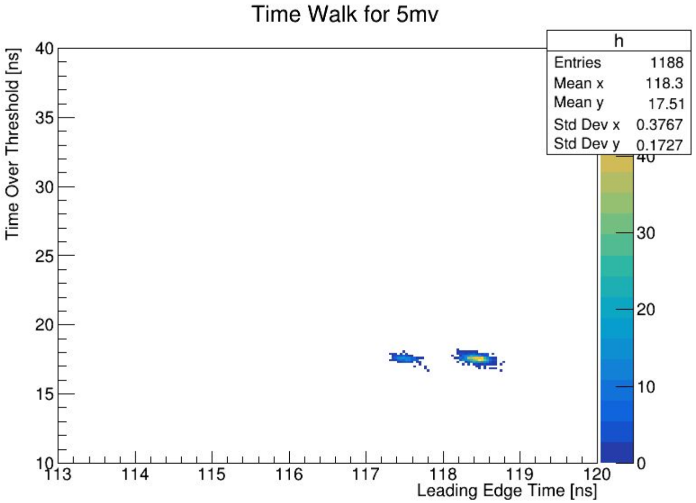


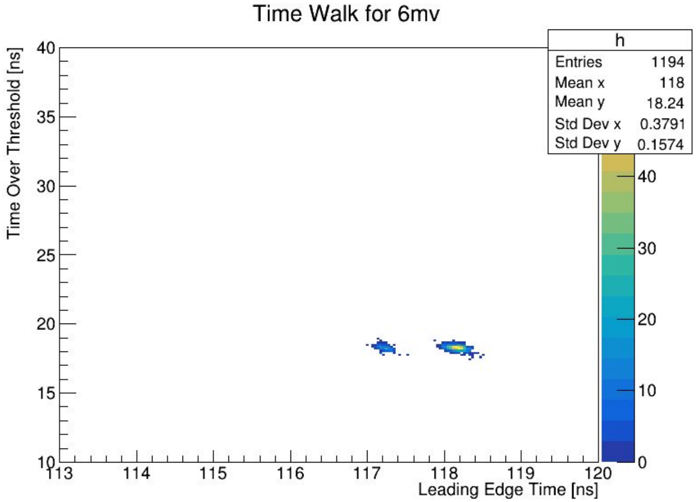


Time Walk - Generated signal

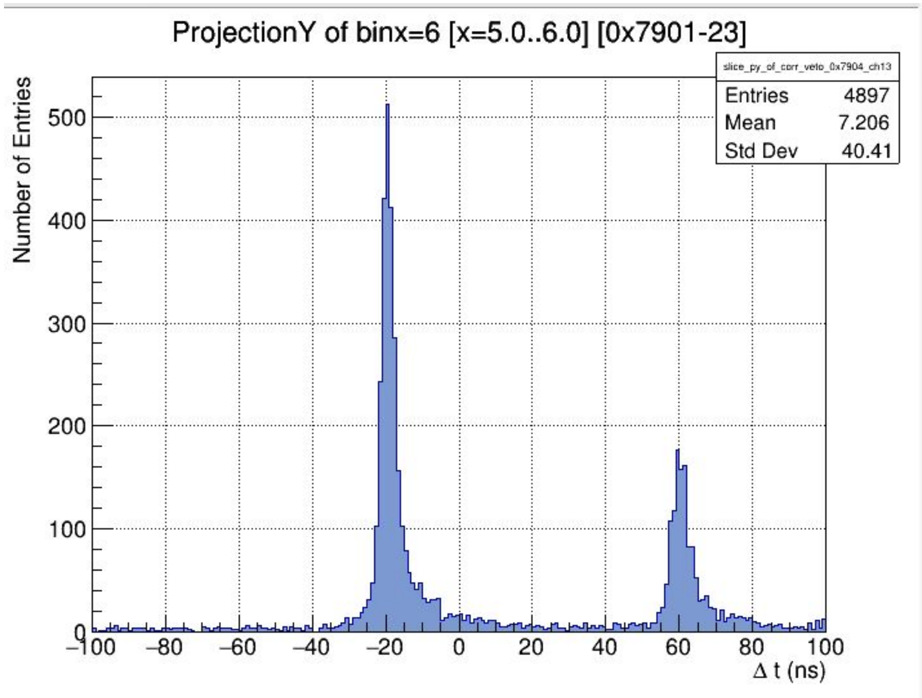


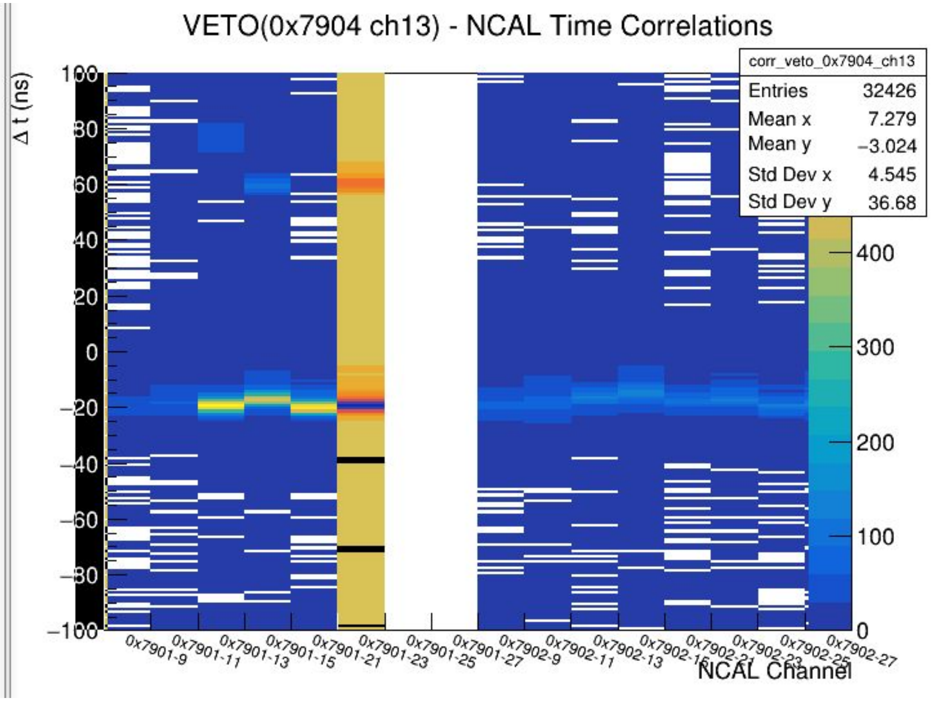






Questions and Discussions





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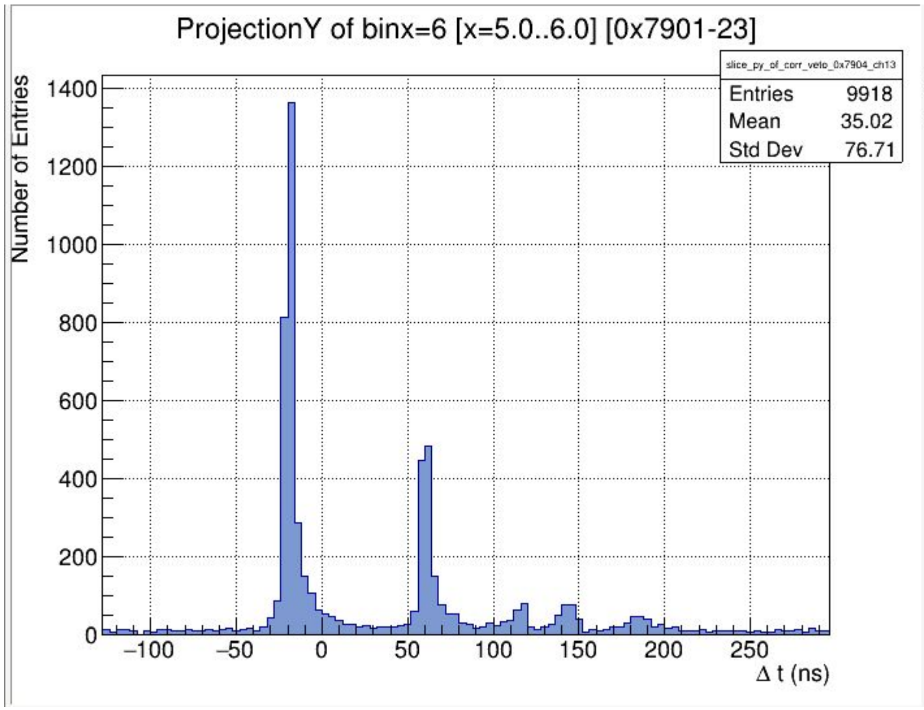

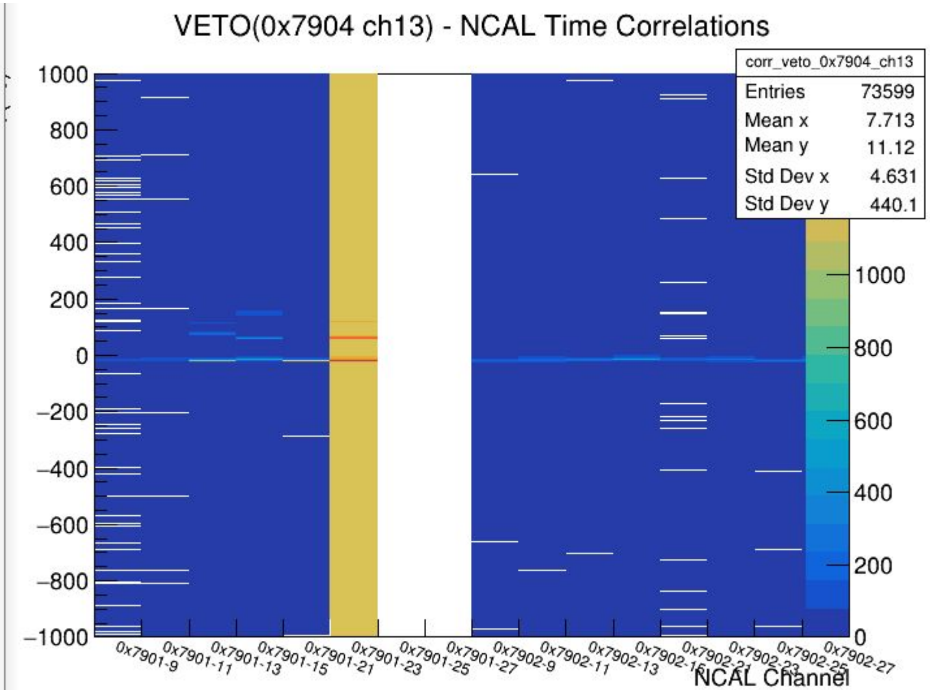

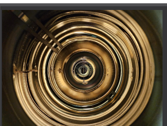

Questions and Discussions