# Status and plans of the LMU CRF trigger for L0MDT testing

**NICK SCHNEIDER,** LMU MUNICH, AG BIEBEL

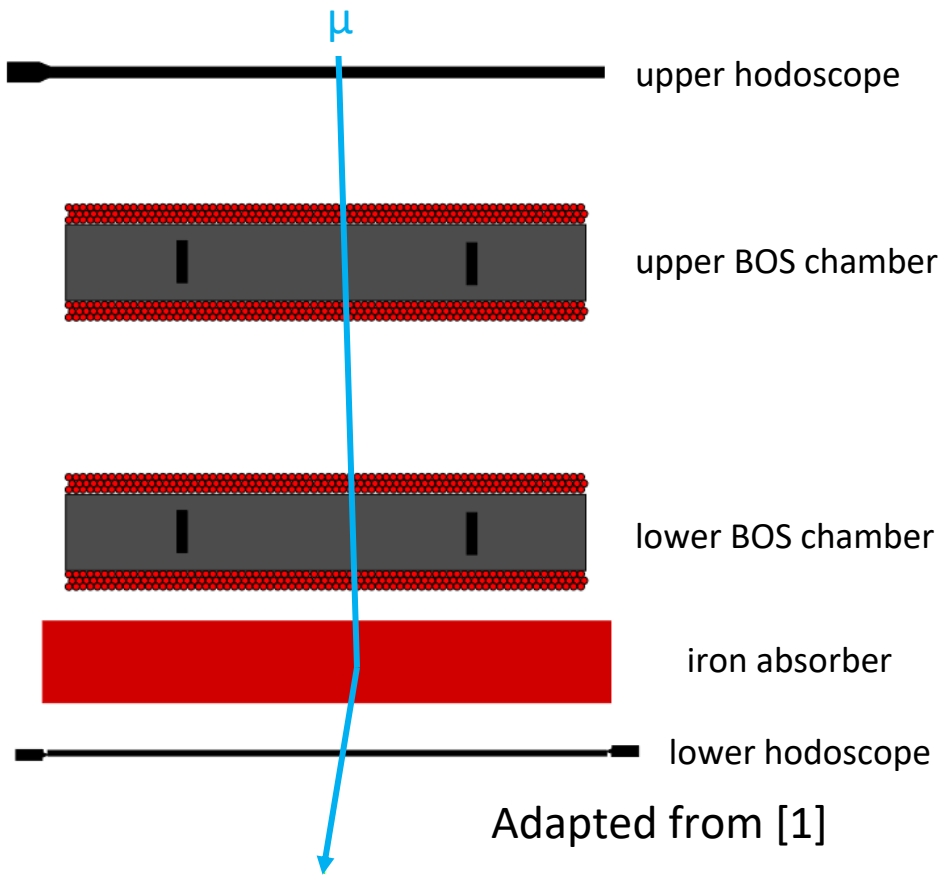
JOINT PARTICLE SEMINAR, 22.01.2025

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

FSP ATLAS
Erforschung von Universum und Materie

# What is the CRF ?

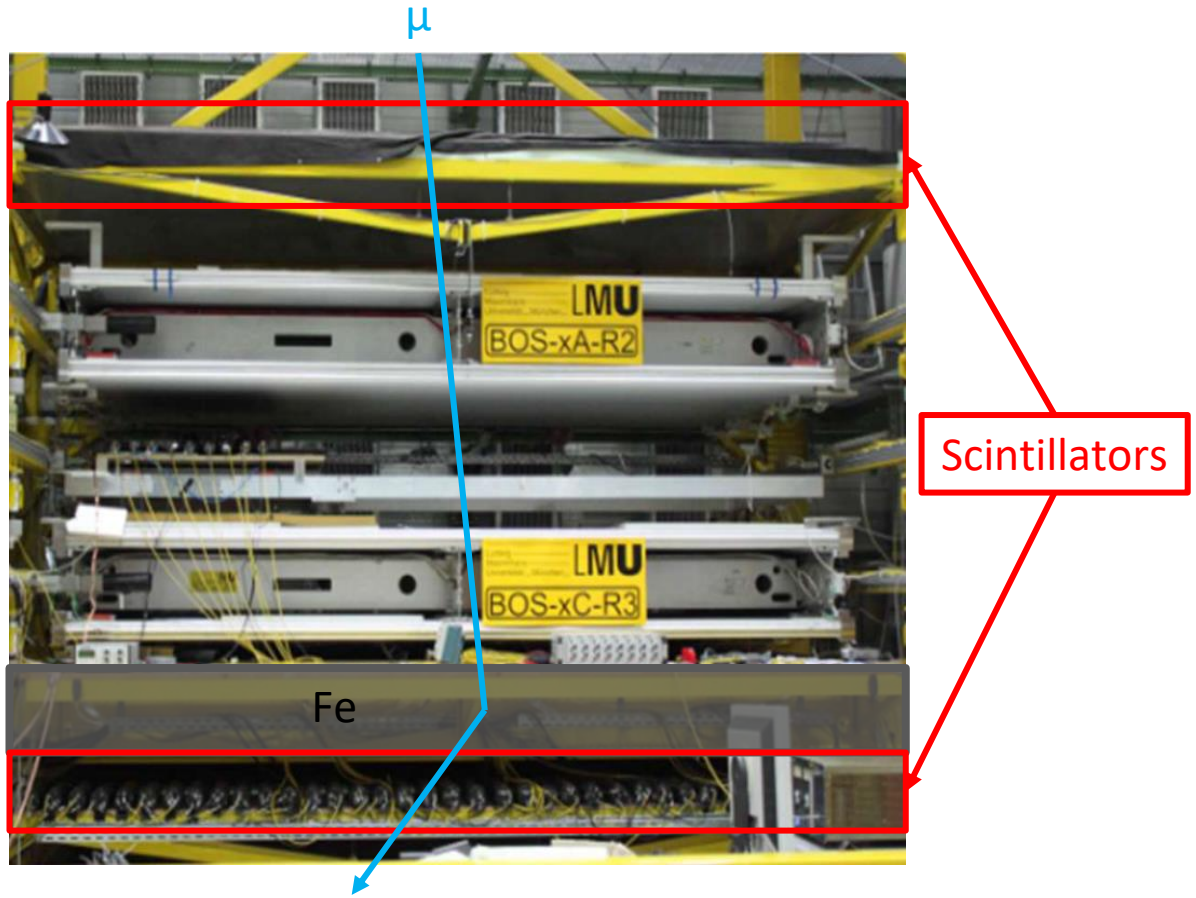
- 2 MDT BOS chambers with legacy electronics
  - Calibrated with X-ray-tomography
- Scintillator hodoscopes perpendicular to tube direction
- Iron absorber for 600 MeV energy cut
- Possibility to insert a 3rd detector




Adapted from [1]

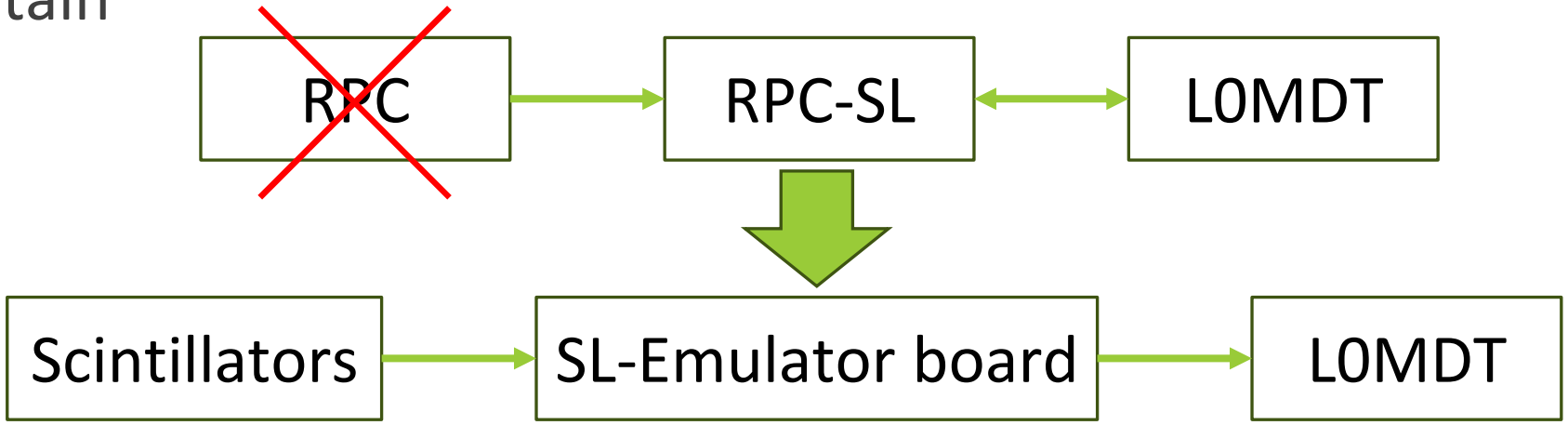
# What is the CRF ?

- Past:
  - MDT BOS series production testing/calibration
  - NSW SM2 series production testing/calibration
- Present:
  - Undergoing upgrade to Phase-2 electronics
- Future ?: L0MDT test stand ?



# Trigger path to L0MDT

- Regular trigger path to the L0MDT requires RPCs
- Installing RPCs in the CRF is not feasible due to several problems
- In contrast, scintillators can be produced in house and are easy to maintain



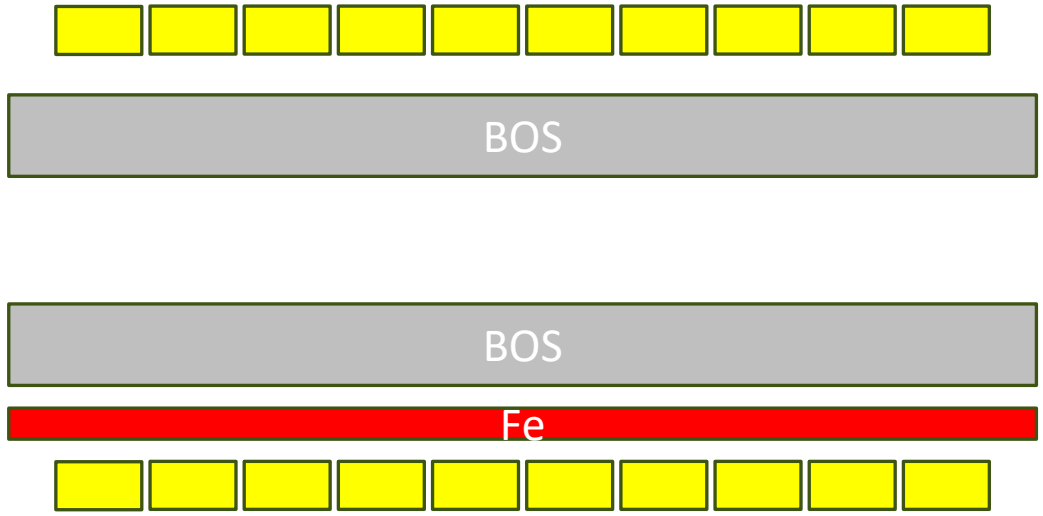

Technical development by Ioannis Mesolongitis (West Attica)

# Planned setup

- Instead of RPC width 6 mm => Scintillator width ~100 mm
- 10 scintillators on top and on bottom of the BOS chambers in parallel to the tubes

=> Response time depends on hit position along scintillator

=> Due to their height muons can hit neighbouring scintillators




Not to scale

# Response time interval

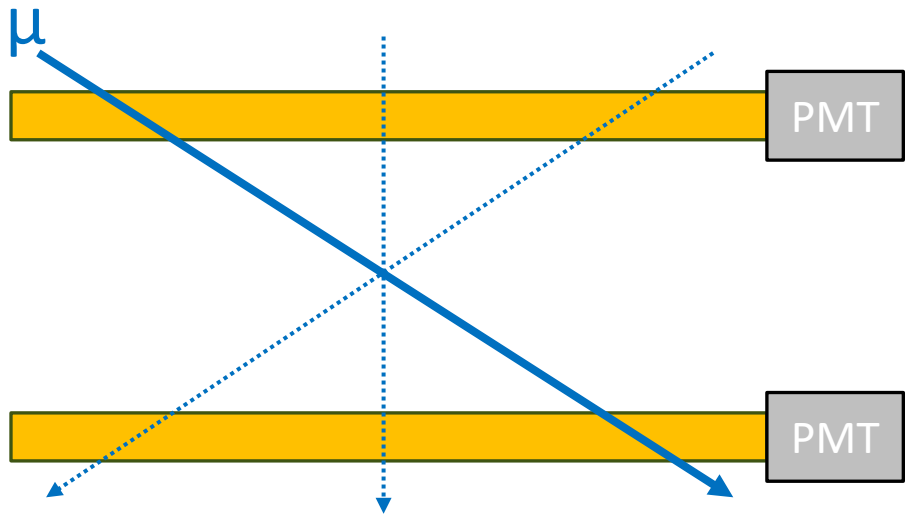
- Depending on the angle of the muon the scintillator response time changes
- Difference from top to bottom can be geometrically estimated as

$$t_{top} - t_{bot} = [-5.1 : 31.78] \text{ ns}$$

- Introduce delay and estimate error

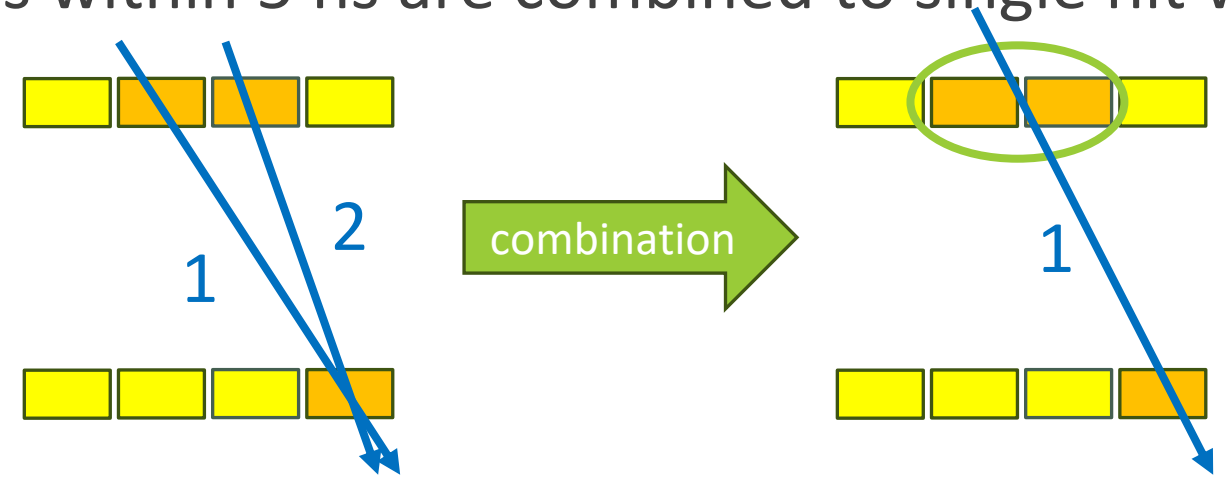
$$\Delta t = [0 : 40] \text{ ns}$$

- Taken care of by the SL-emulator

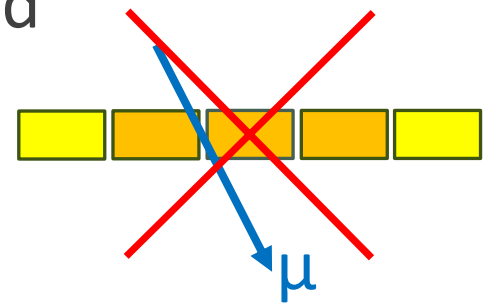


# Resolving neighbouring hits

- 2 neighbouring hits within 5 ns are combined to single hit with
  - $z_{comb} = \frac{z_1 + z_2}{2}$
  - $t_{comb} = t_1$

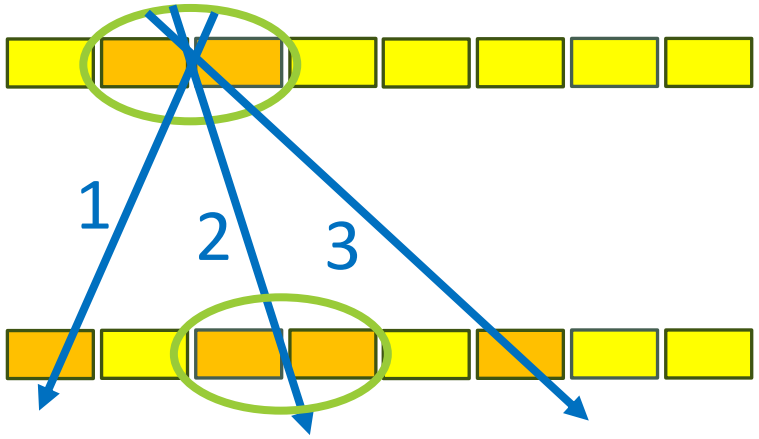


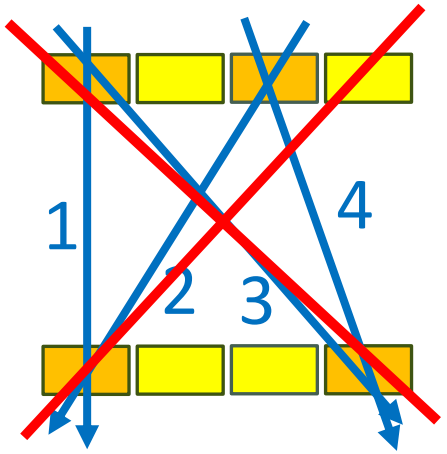

- 3 neighbouring hits are rejected



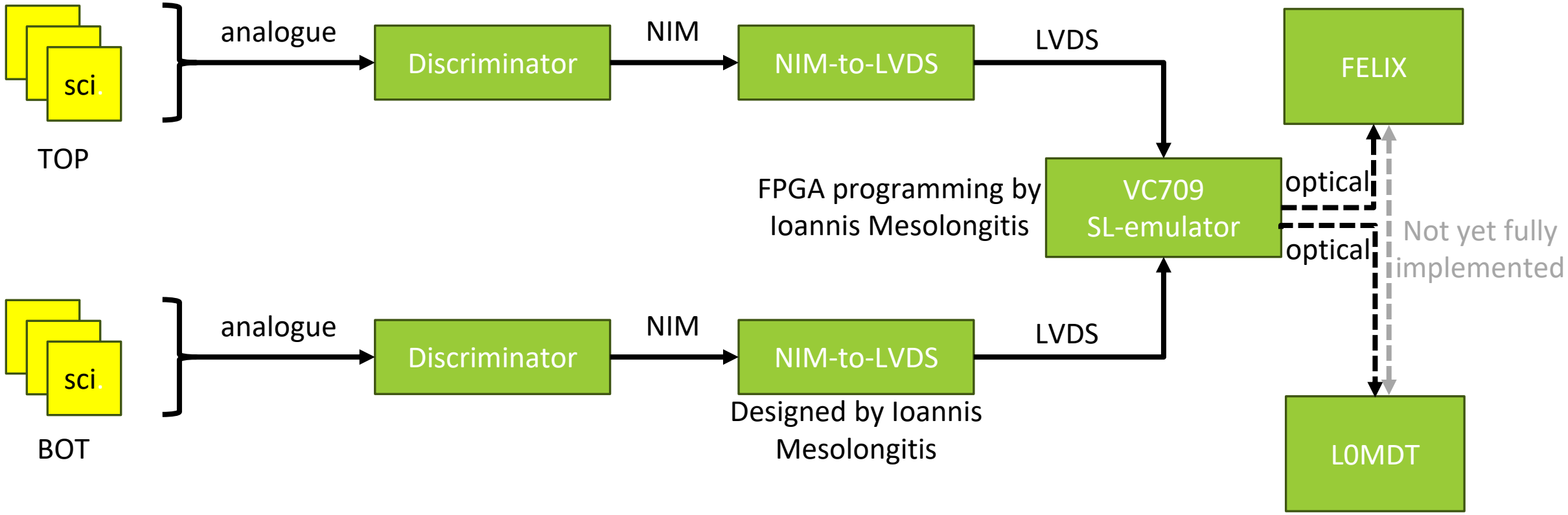
# Track candidates to L0MDT

- L0MDT is **limited** to **max.** 3 track candidates (TC)
- TCs are given to L0MDT **after** combination of neighbouring hits
- Events with 4 TC are not passed on



# Trigger hardware implementation

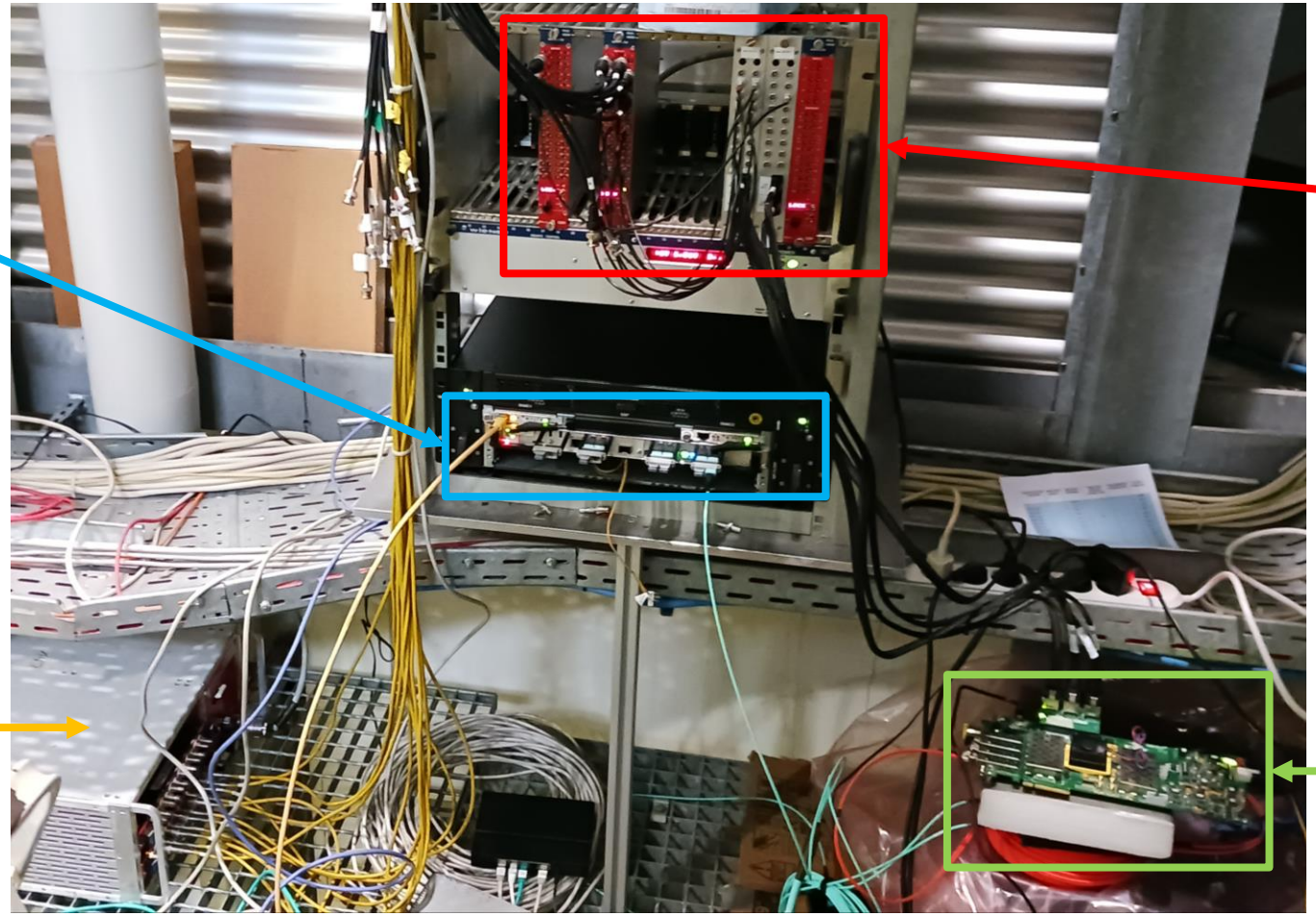



SL-emulator will be able to send data to L0MDT and Felix

# Status – Setup

L0MDT demonstrator board

Provided by Davide Cieri from MPP



Discriminators & NIM-LVDS

HV

VC709 SL-emulator

# Status – Scintillators

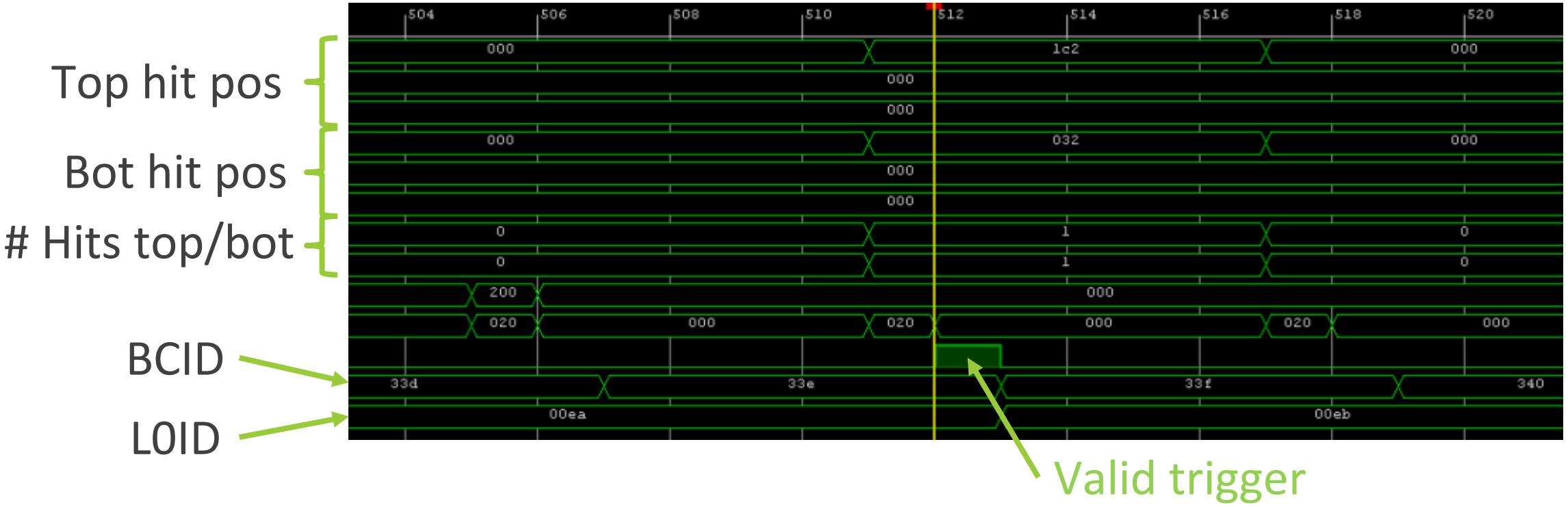
- 20 scintillators produced and placed in parallel to the tubes
- Connected with BNC and SHV cables
- Covered with black cloth if needed


# Status – SL-emulator

- All scintillators give meaningful signals
- NIM-LVDS converters are functional
- Logic of SL-emulator works as intended
- Clock recovery from and data sending to FELIX runs without problems
- Connection to L0MDT established, data transmission is work in progress

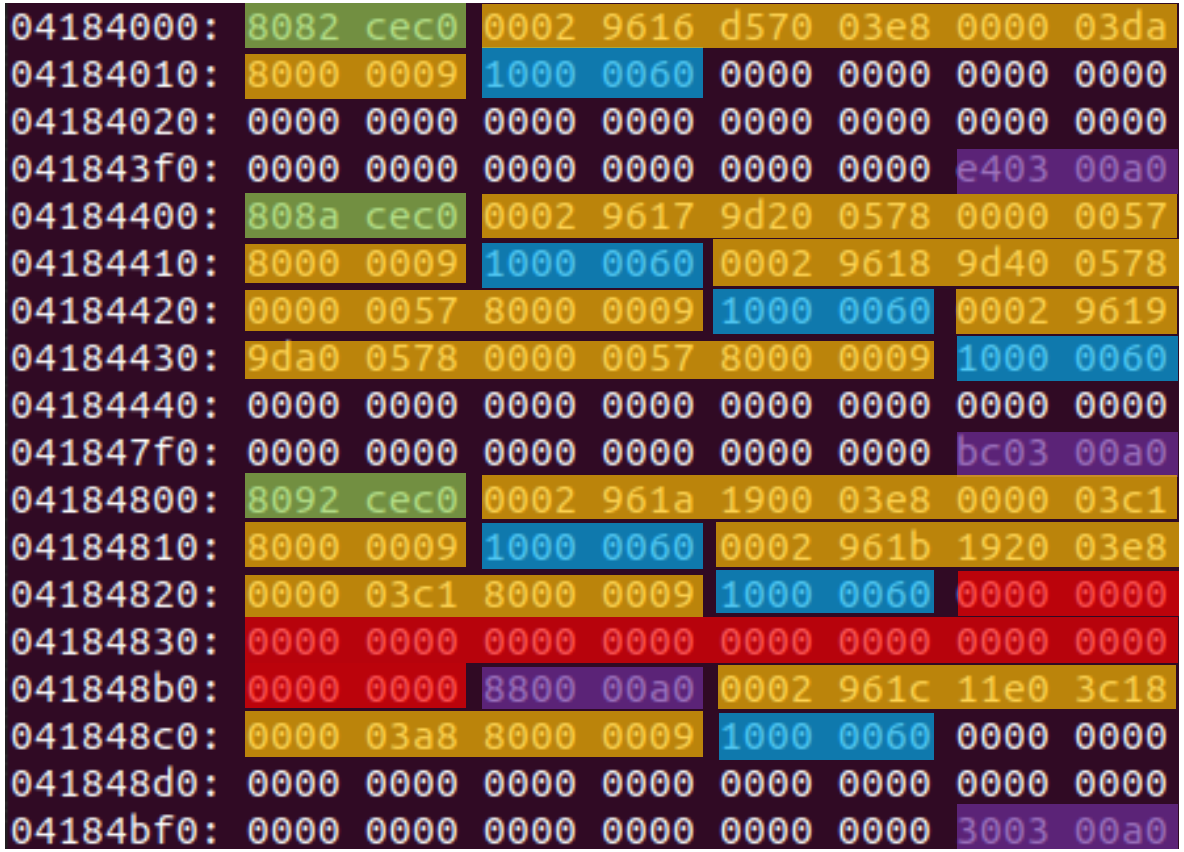
# Status – SL-emulator

- Example of SL-emulator internal logic:
  - Top layer scintillator @ 450 mm + bottom layer scintillator @ 50 mm



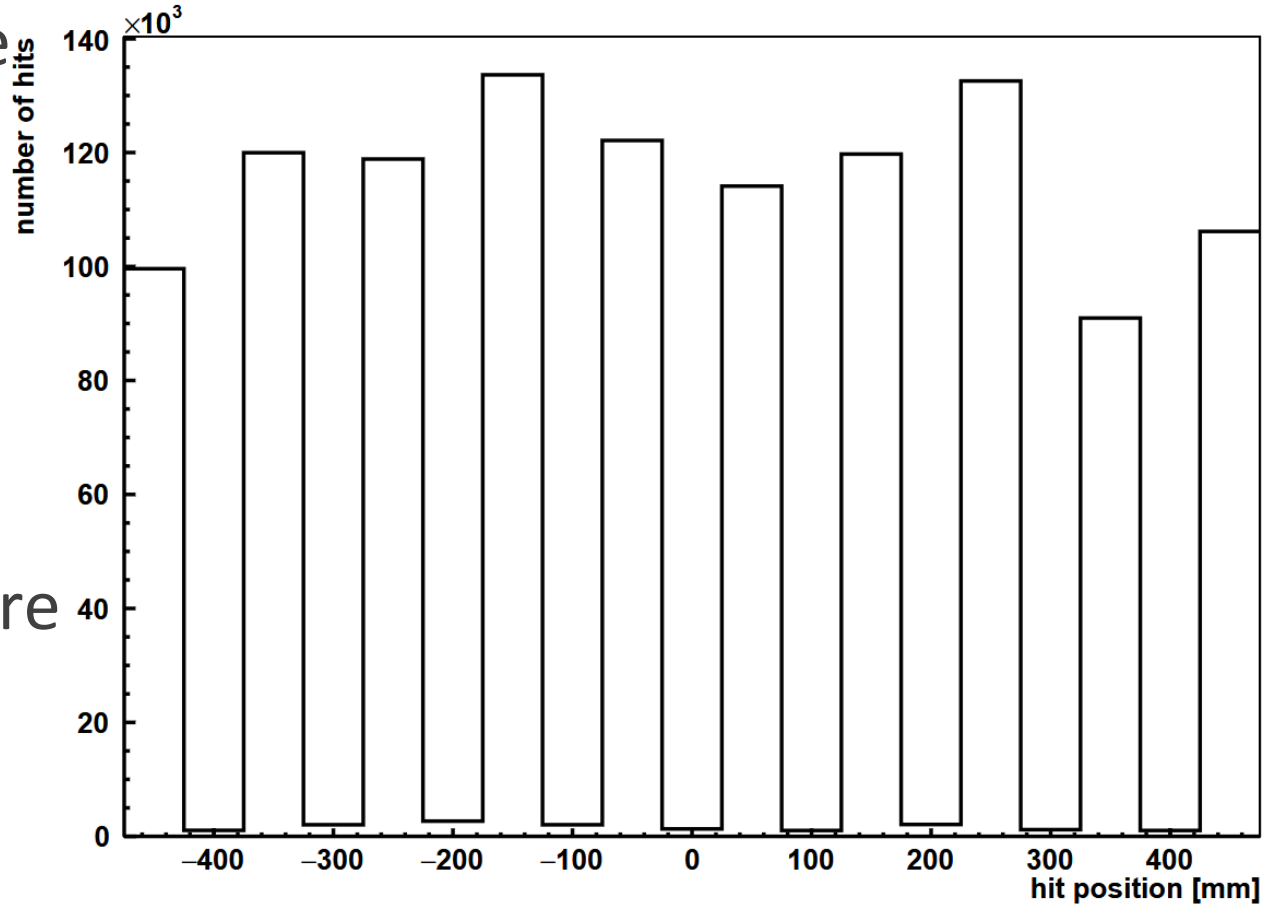
# SL-emulator -> FELIX: Raw data structure

- 1kB blocks containing:
  - Block header (32 bit)
  - Data chunk (128 bit)
  - Chunk trailer (32 bit)
  - Timeout trailer (i.e. 0-padding)
  - Zero-padding within block
- Multiple scenarios visible to the right (continuous 0-lines suppressed)



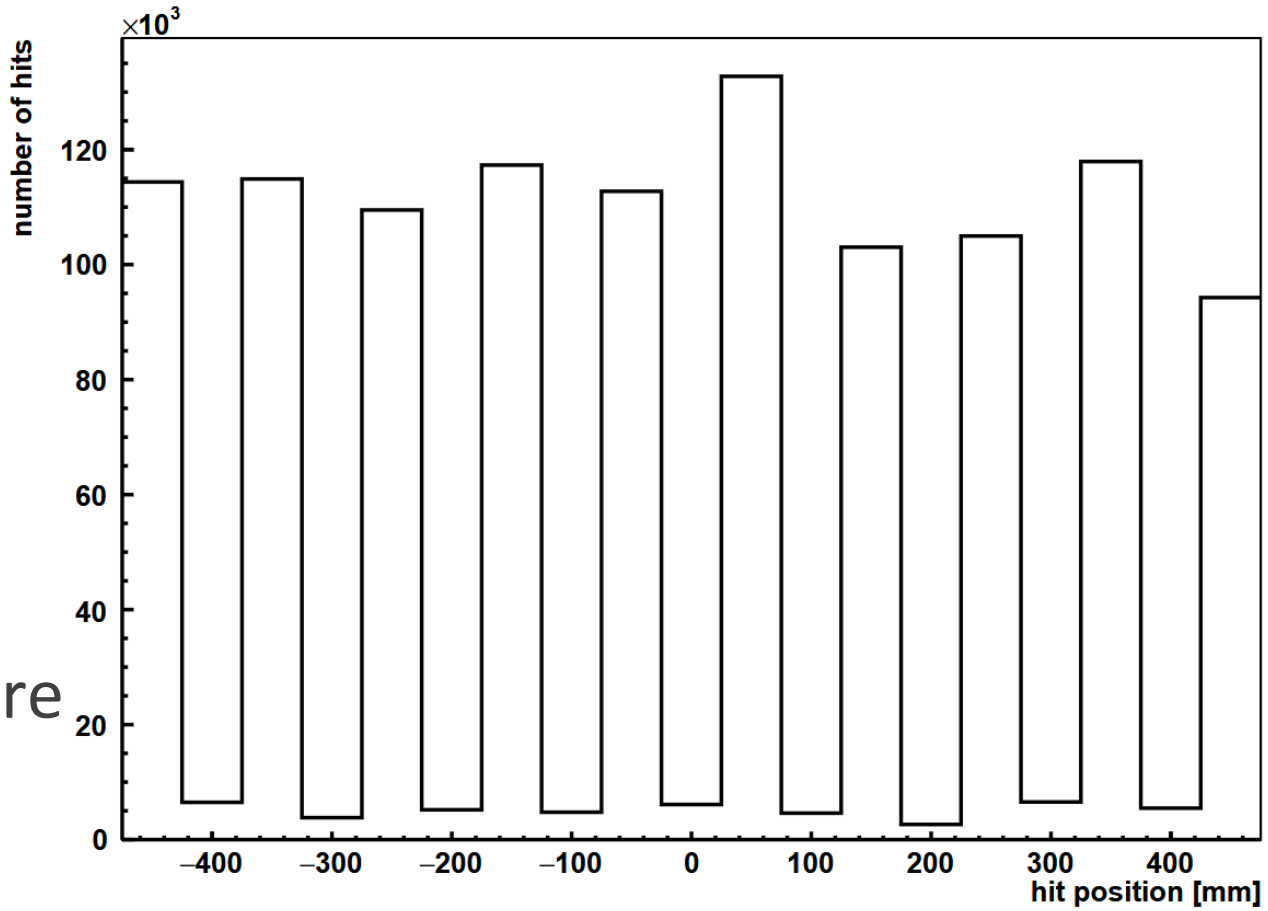
# Scintillator hit distribution

- Only top scintillators shown here
- Data reveals:
  - Scintillators are performing somewhat homogenously
  - Differences due to individual properties/efficiency
  - Hits of 2 adjacent scintillators are rear but visible at $\lesssim 2\%$ of the mean single hits



# Scintillator hit distribution

- Only bottom scintillators shown here
- Data reveals:
  - Slightly more uniform than the top layer
  - Differences due to individual properties/efficiency
  - Hits of 2 adjacent scintillators are rear but visible at $\approx 4\%$ of the mean single hits

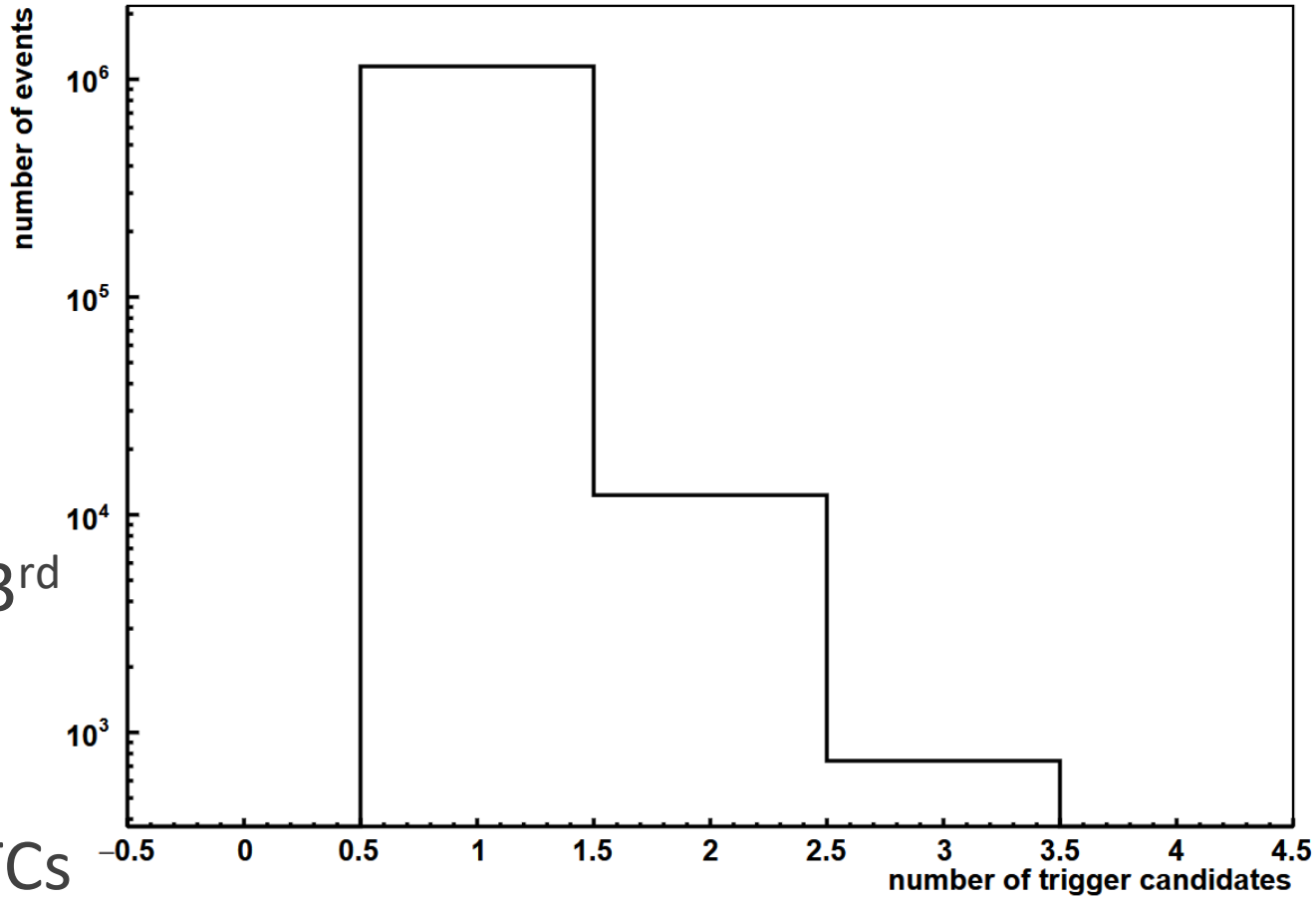


# Number of trigger candidates per event

- Mean number of TCs per event for the top layer is 1.012
- Chance of 1 TC $\approx 98.88\%$
- Chance of 2 TCs $\approx 1.06\%$
- Chance of 3 TCs $\approx 0.06\%$

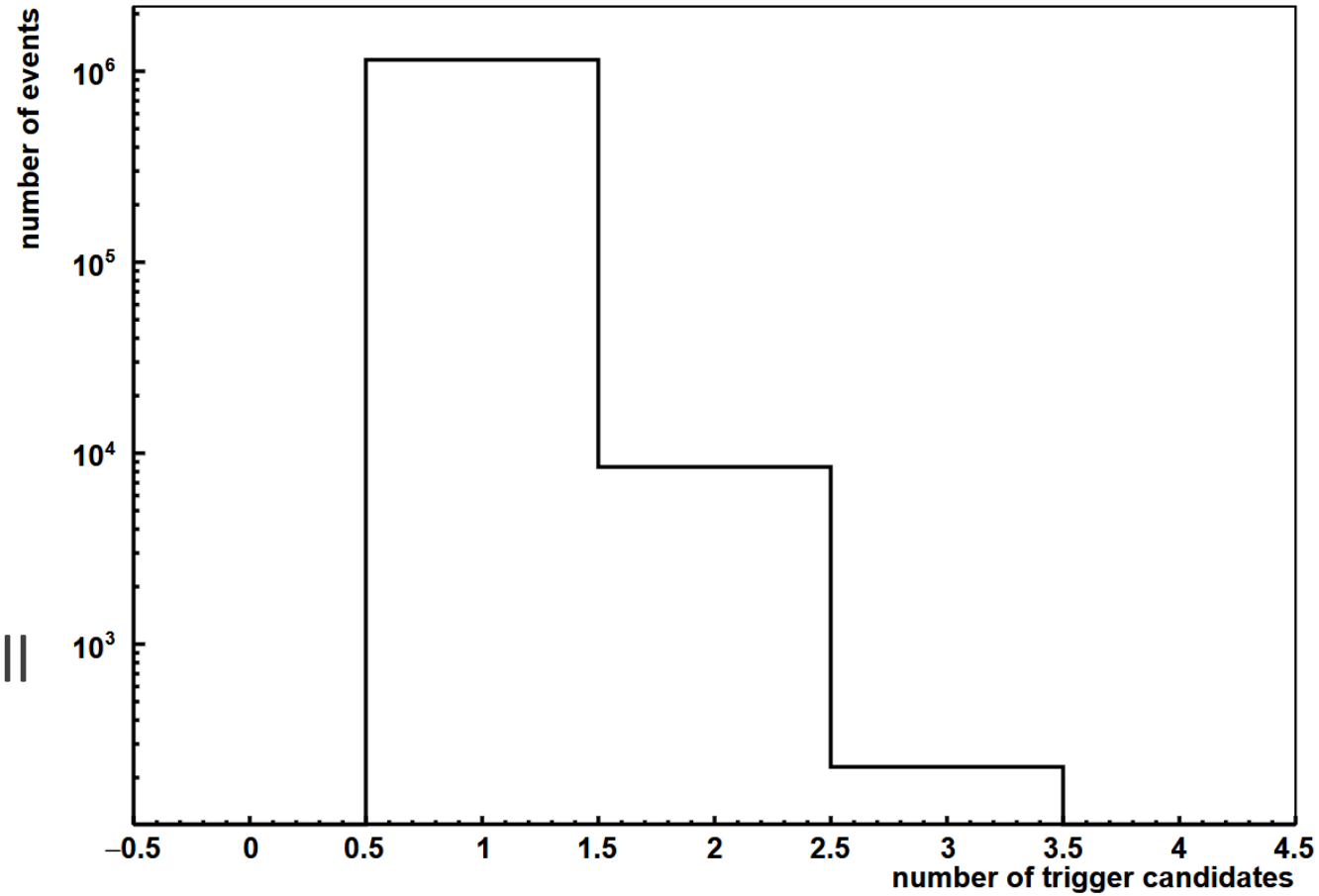
$\Rightarrow$ Connections sending 2nd and 3rd TC to L0MDT won't be used to capacity

$\Rightarrow$ Supply L0MDT with multiple TCs



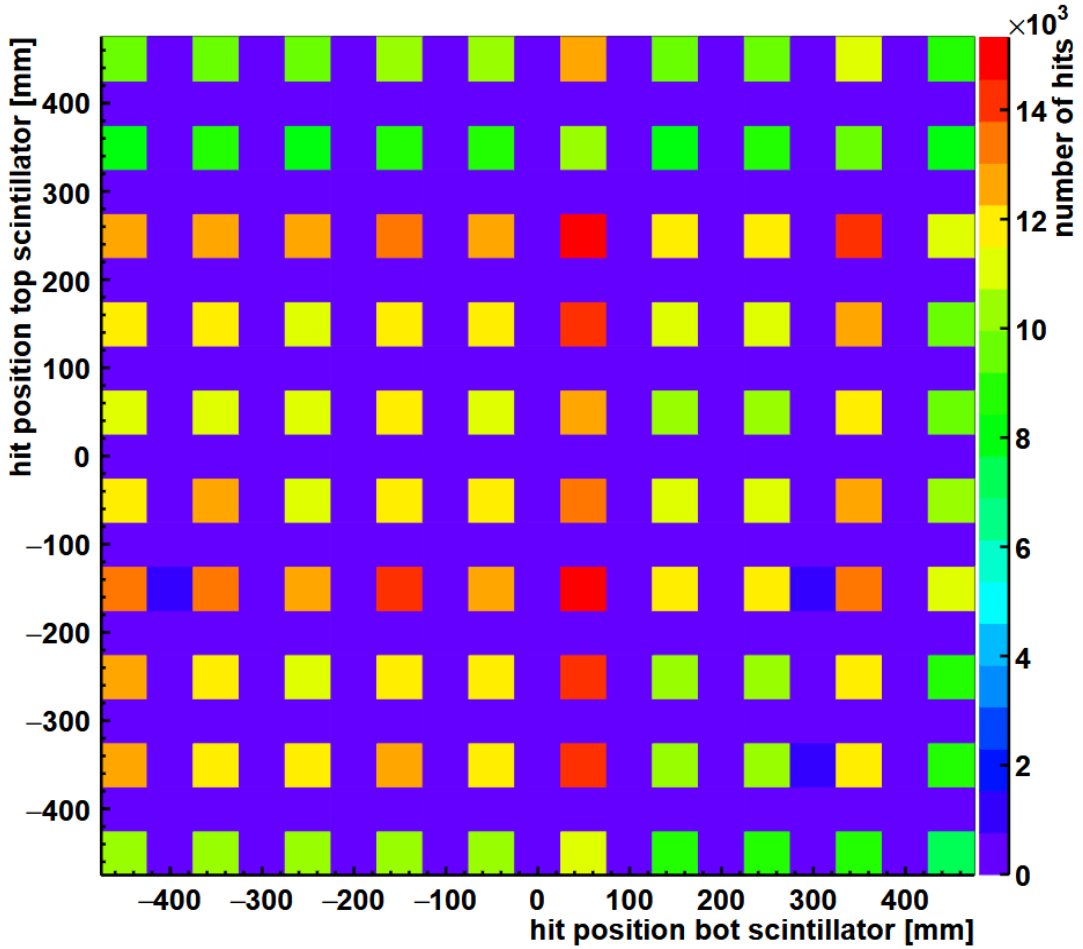
# Number of trigger candidates per event

- Mean number of TCs per event for the bottom layer is 1.008
- Chance of 1 TC $\approx 99.25\%$
- Chance of 2 TCs $\approx 0.73\%$
- Chance of 3 TCs $\approx 0.02\%$
- Reason for slight difference between top and bottom layer still under investigation



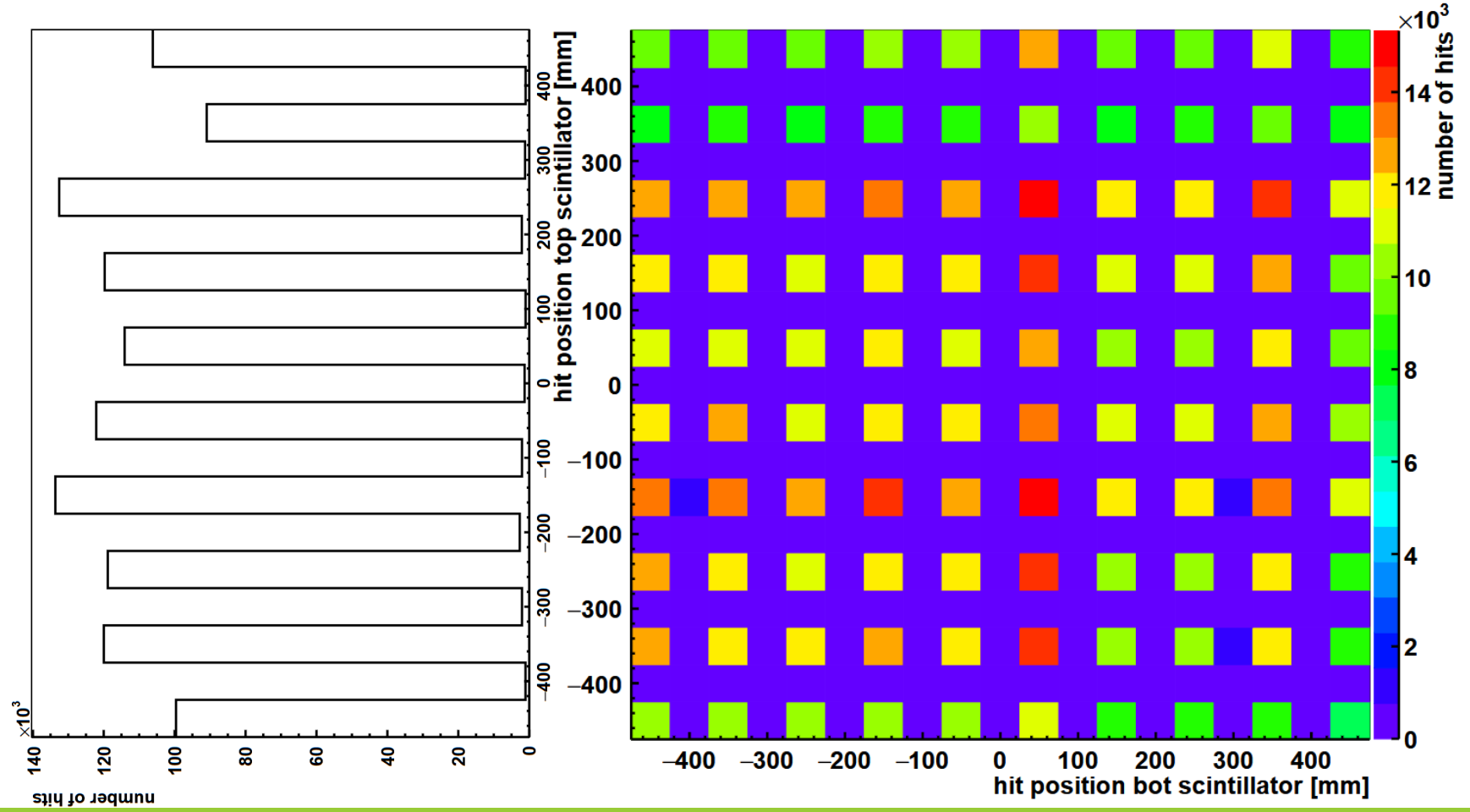
# 2D Hit Position Correlation

- All possible combinations realised
  - Even very rare combinations of combined hits (i.e. 400/400)
- No clear angular dependence visible (less entries towards top-left and bottom-right)
- Some combinations favoured due to the individual scintillators being more responsive



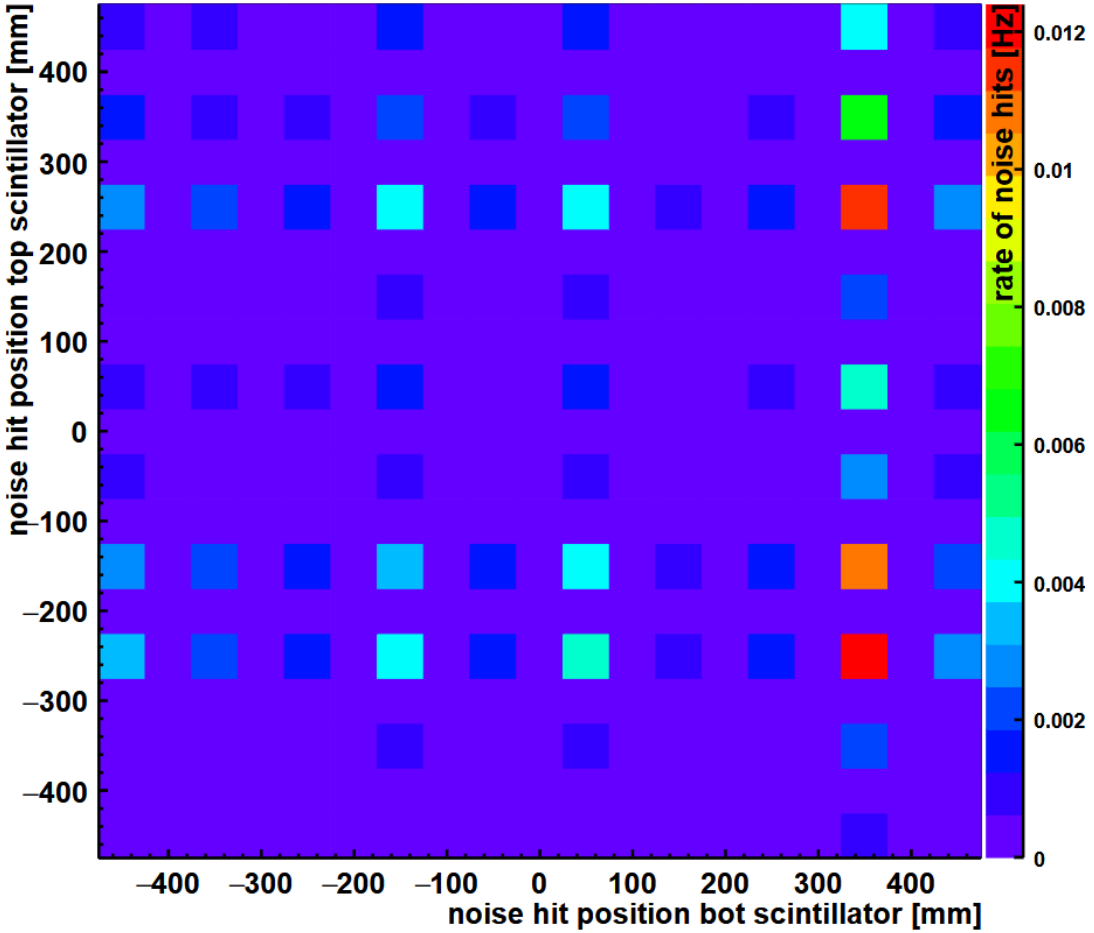
# 2D Hit Position Correlation

- One can recognise the individual scintillator performance in the 2D plot



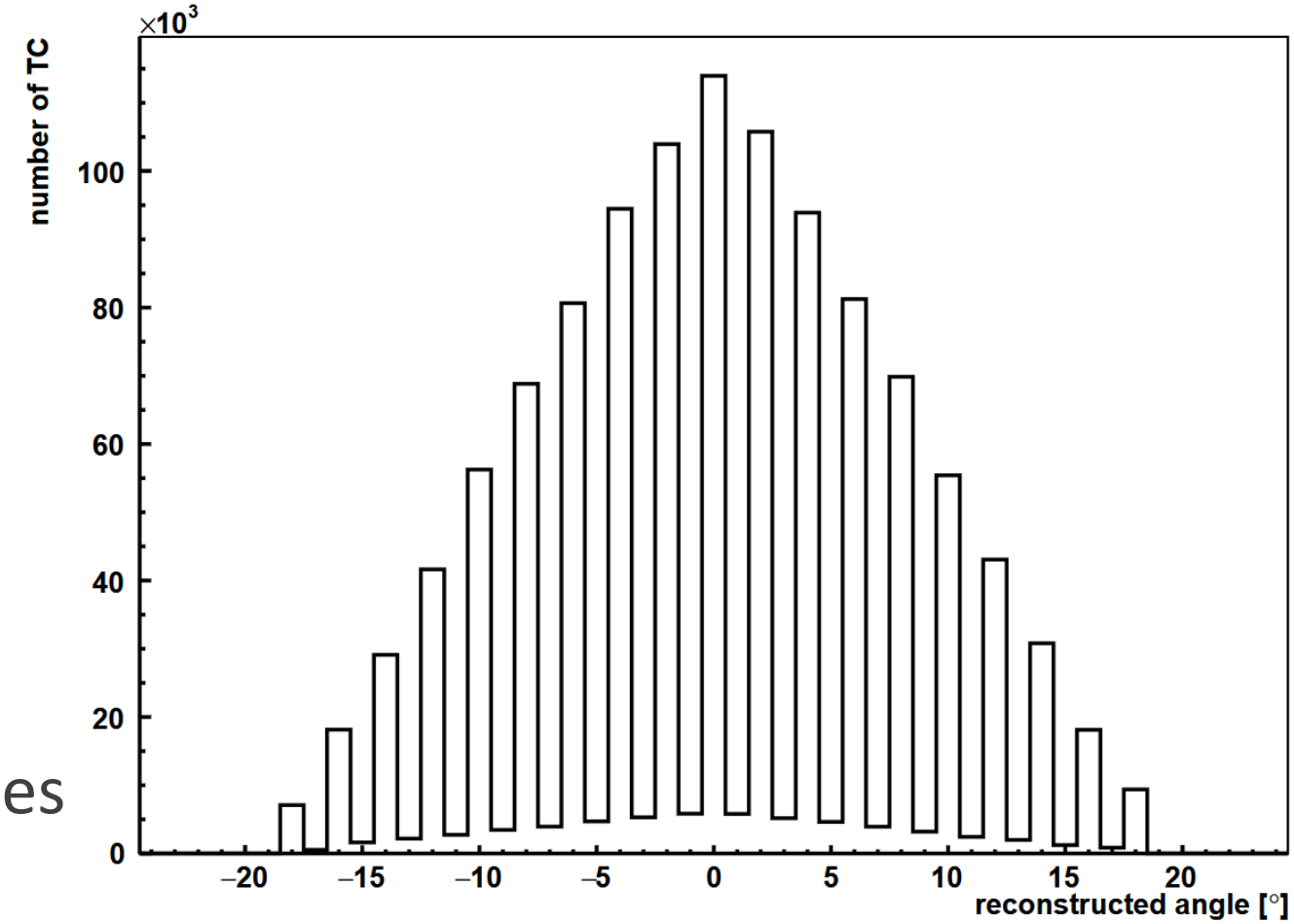
# 2D Noise Hit Position Correlation

- Untriggered response rate of all individual scintillators measured with a rate meter (all < 1kHz)
- Rate of combined hits calculated with the neighbouring rates and 5 ns coincidence window
- 2D position random coincidence determined with 40ns coincidence time window
- All noise rates ≪ 0.1 Hz

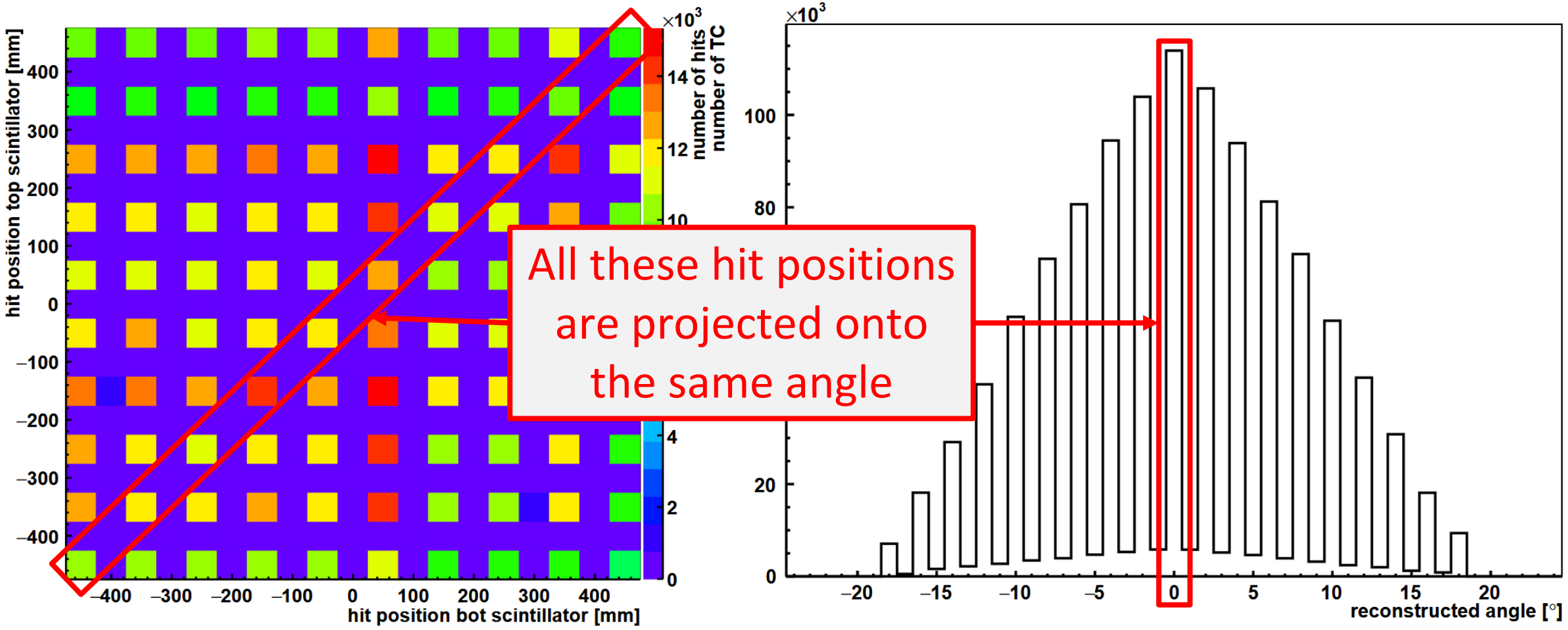


# Angular Distribution

- Almost symmetric
- Full angle coverage on both sides
- Small entries come from tracks with one combined “two-scintillator” hit and a single scintillator hit
- Pyramid shape due to multiplicity of realisable angles

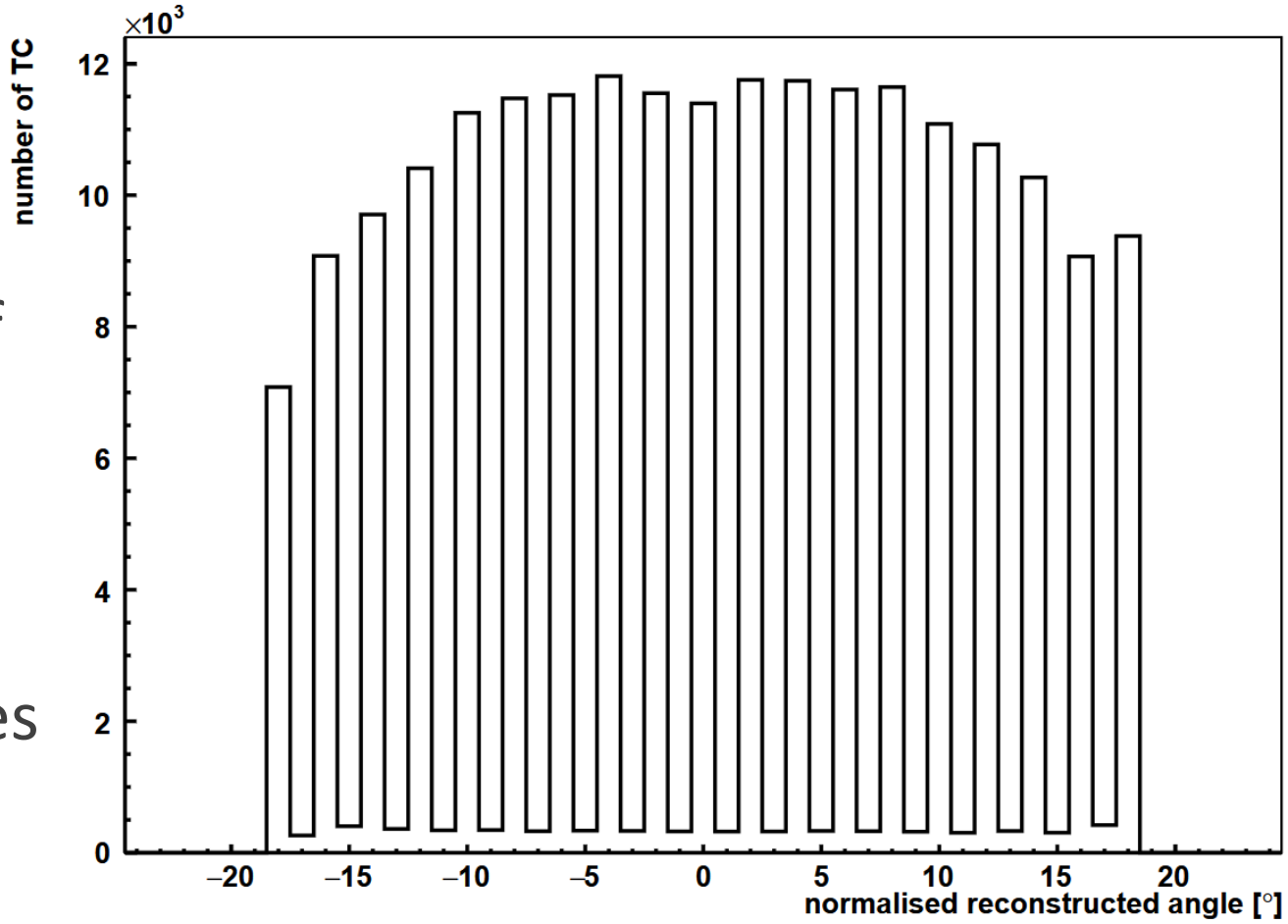


# Angular Distribution



# Corrected Angular Distribution

- Corrected to factor out the angle multiplicity
- Slightly asymmetric cosine-like shape indicating offset of top and bottom layer
- Full angle coverage on both sides
- Interestingly the small entries seem uniformly distributed



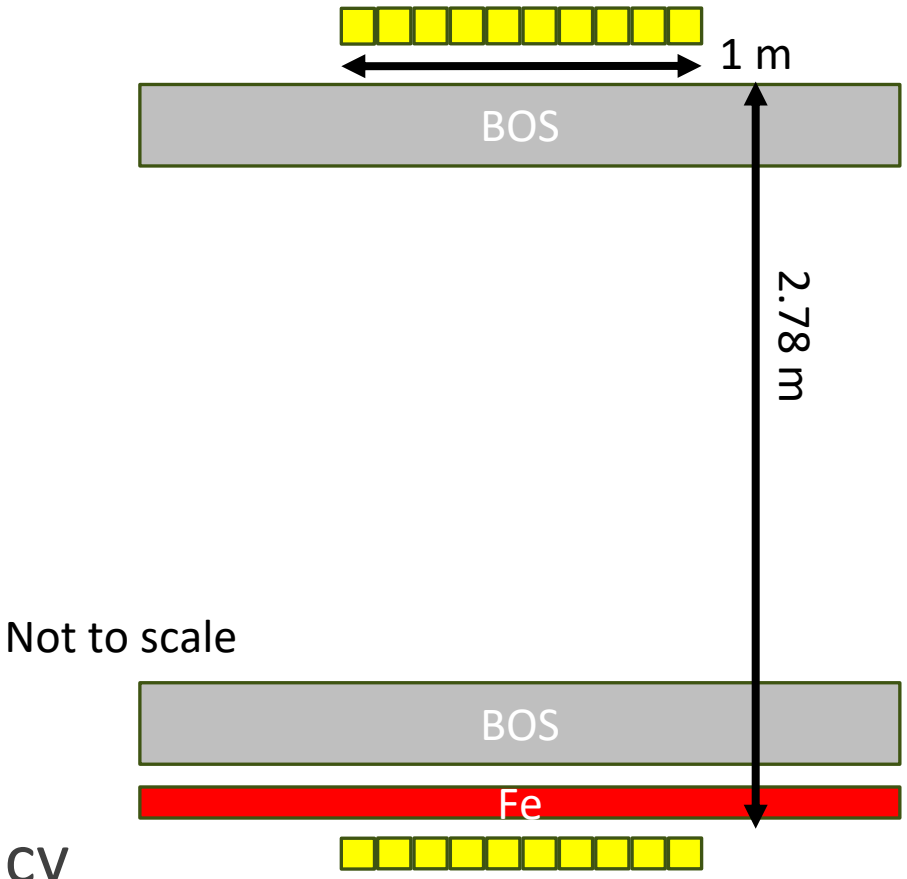
# Event Rate

- Cosmic muon rate $\approx 1\ dm^{-2}s^{-1}$
- Area $A \approx 1\ m * 2.4\ m = 2.4\ m^2$
- Due to angular limitations ($\alpha < 20°$) and distance of the two layers ($d = 278\ cm$) the rate must be scaled by $\varepsilon = 0.142$

$\Rightarrow$Expected rate $\approx 34\ Hz$

$\Rightarrow$Measured rate $\approx 27\ Hz$

- Difference due to scintillator efficiency



# Summary

- All scintillators are in place and running
- SL-emulator logic and the readout via FELIX is working as intended
- Received data is meaningful and DAQ rate is in the order of what is expected
- Connection of L0MDT with SL-emulator and FELIX is established and needs further testing/debugging
- Future: Connect MDTs to L0MDT and exercise full DAQ and trigger path

# Questions or comments ?

# References

[1]: Kortner, Oliver; PhD Thesis: ”Schauerproduktion durch hochenergetische Myonen und Aufbau eines Höhenstrahlungsprüfstandes für hochauflösende ATLAS-Myonkammern“; Mar 2002

# Data from SL-emulator to L0MDT

- SL-emulator data transfer is the same as the from RPC-SL
- Some (“useless”) parameters set to specific values
- Header:

| Bits | Usage | Values (* normal use) | comments |
|---|---|---|---|
| 12 | BCID | * | |
| 3 | # of TCs | [0:3] | # of TCs sent from SL->MDTTP (at max 3) |
| 3 | # of mTCs | 0 | # of mTCs sent from MDTTP->SL (not needed) |
| 3 | # of mTCs | 0 | # of mTCs sent from SL->MUCTPI (not needed) |
| 1 | Overflow TC | 0 | never more than 4 TC |
| 10 | Reserved | | |

# Data from SL-emulator to L0MDT

- Data (part 1):

| Bits | Usage | Value (* normal use) | comments |
|---|---|---|---|
| 3 | TC ident | * | Id number of TC |
| 1 | TC->L0MDT | * | TC sent to L0MDT (sent 1, not send 0) |
| 14 | Position η | 0 | Not used in L0MDT directly |
| 9 | Position ϕ | 0 | Only one set of MDT chambers -> arbitrary |
| 8 | RPC $p_T$ | 255 (100GeV) | No B-field -> no bending -> set to maximum |
| 4 | $p_T$ threshold | 15 | No B-field -> no bending -> set to maximum |
| 1 | Charge | 0 | No B-field -> no bending -> arbitrary |
| 3 | Coin. type | 0 | 0 -> RPC0-RPC3, only 2 RPC coincidence type |

# Data from SL-emulator to L0MDT

- Data (part 2):

| Bits | Usage | Value (* normal use) | Comments |
|---|---|---|---|
| 3 | Coinc. Type | 0 | 0 -> RPC0-RPC3, only 2 RPC coincidence type |
| 12 | $z^{RPC0}$ | * | Top scintillator pos, [-450:450] mm used |
| 12 | $z^{RPC1}$ | 0 | Not used |
| 12 | $z^{RPC2}$ | 0 | Not used |
| 12 | $z^{RPC3}$ | * | Bot scintillator pos, [-450:450] mm used |
| 37 | Reserved | | |

# Data from SL-emulator to L0MDT

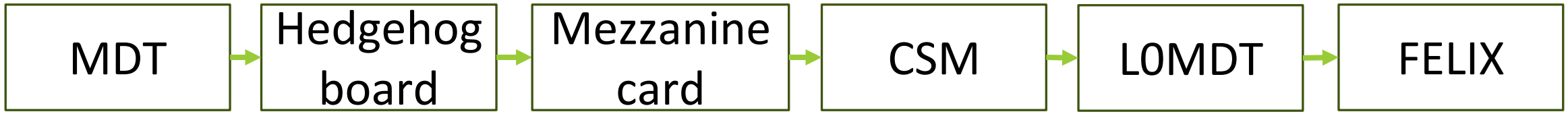
- Trailer:

| Bits | Usage | Value (* normal use) | Comments |
|---|---|---|---|
| 8 | Comma | * | K28.5, K character of 8b10b encoding |
| 6 | Board ID | 0? | Unclear if valid ID |
| 4 | Fiber ID | * | |
| 8 | CRC | * | 8-bit for cyclic redundancy check |
| 6 | Reserved | | |

- Tigger information will also be written from SL-emulator to FELIX directly for storage and validation

# DAQ path through L0MDT

- Regular DAQ path to/from L0MDT




- Currently implemented path