



Belle II Trigger/DAQ workshop



KLM TRG STATUS

Horacio Crotte Ledesma

Keisuke Yoshihara
Christopher Ketter

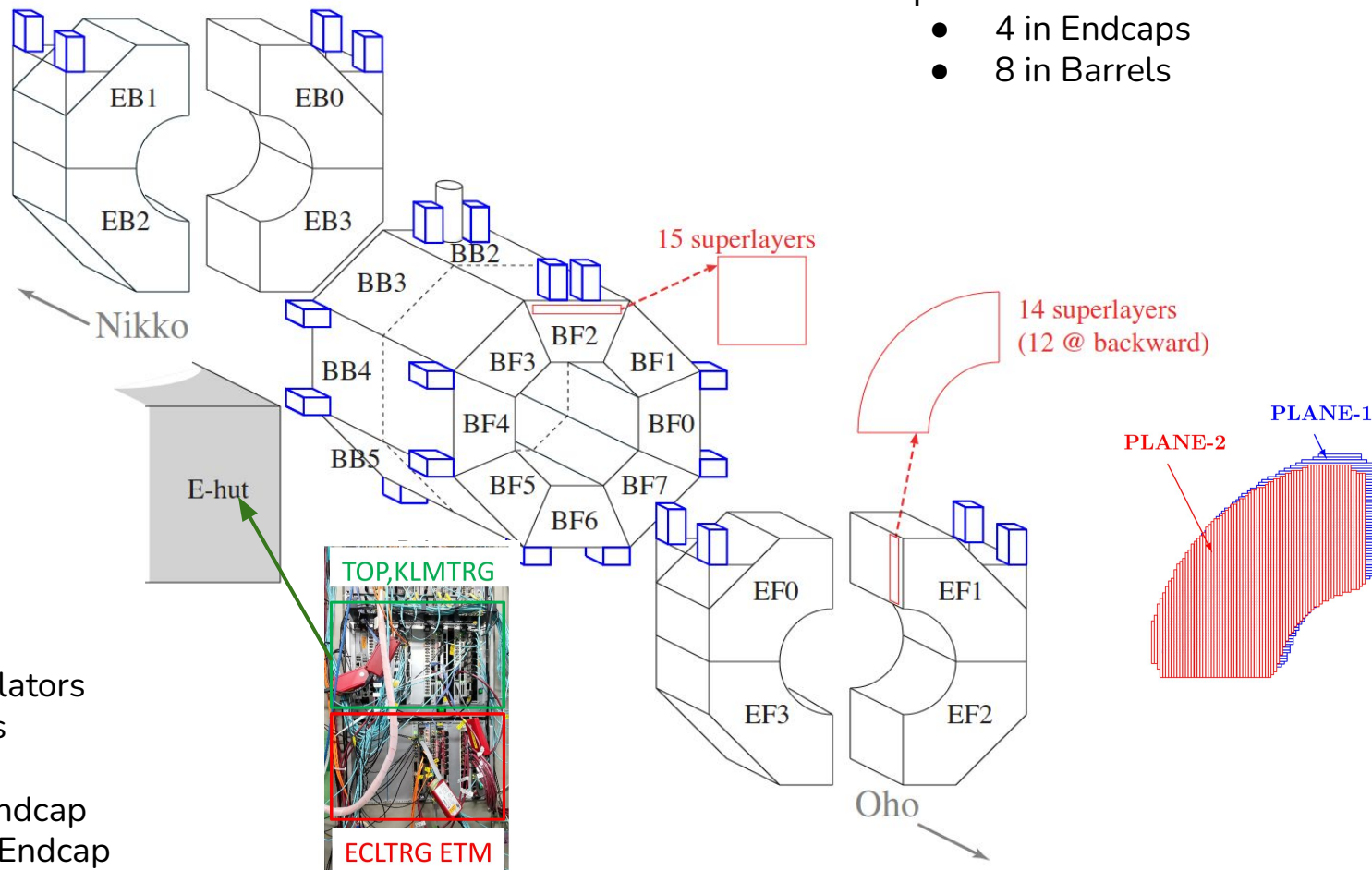
October 22nd, 2025

**With help from Vasily and Koga-san*

KLM STRUCTURE

ϕ Sectors:

- 4 in Endcaps
- 8 in Barrels

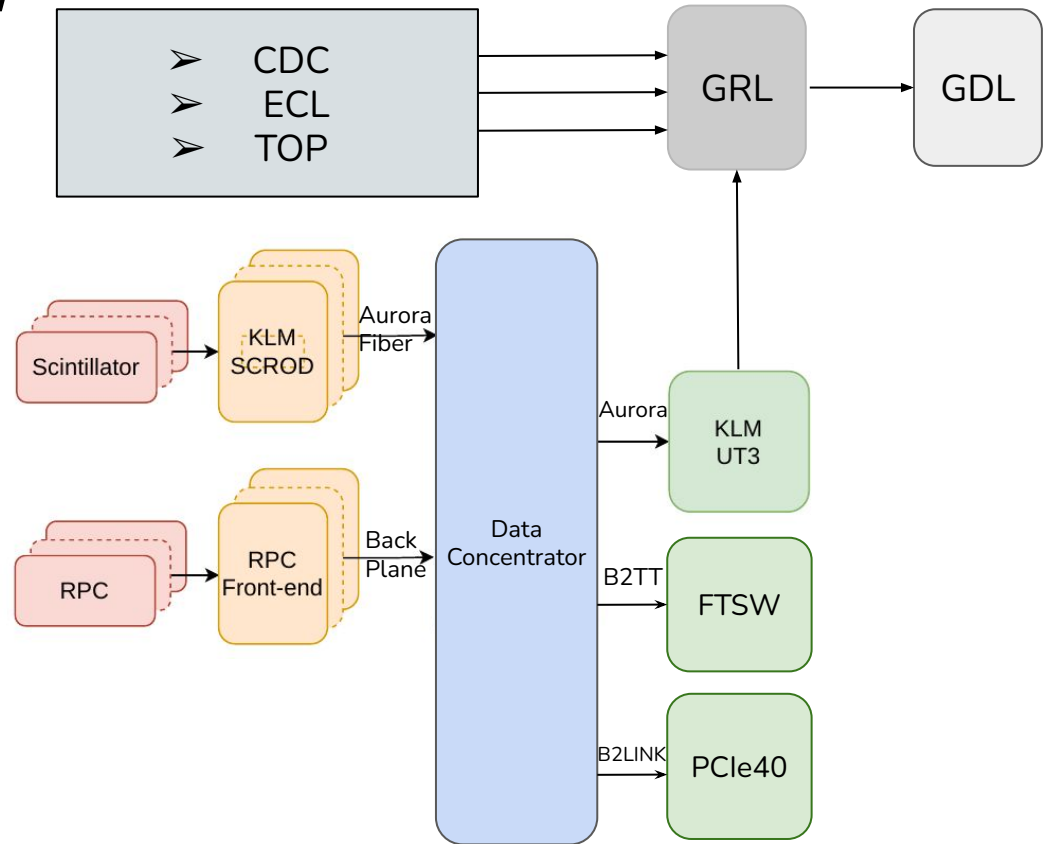


Superlayers:

- 15 in Barrel
 - 2 Scintillators
 - 13 RPCs
- 14 Forward Endcap
- 12 Backward Endcap

ELECTRONICS & DATA FLOW

- RPC and Scintillator hits with are timestamped in the front-ends
- Hits are sent to the DC board
 - And are time ordered
- Data goes through different paths:
 - DAQ via B2LINK to PCIe40
 - TRG via Aurora Links to UT3

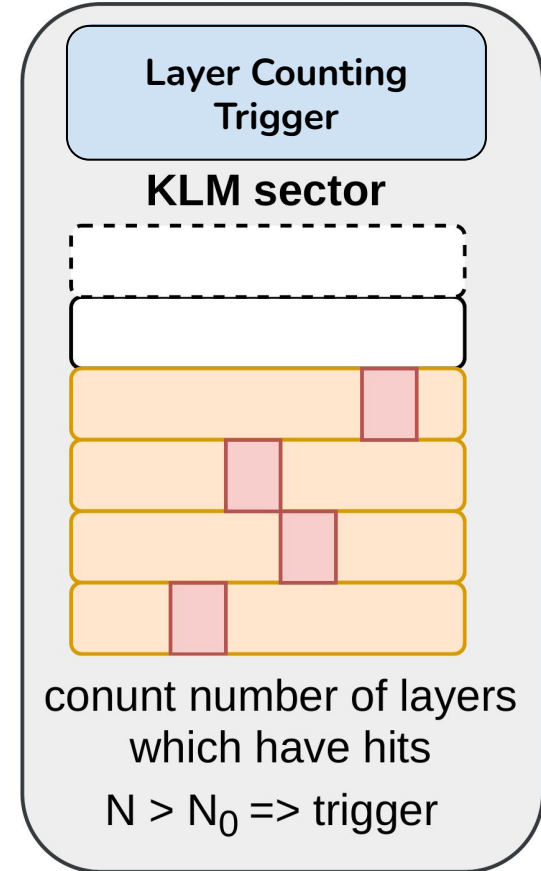


BASIC IDEA OF THE TRIGGER

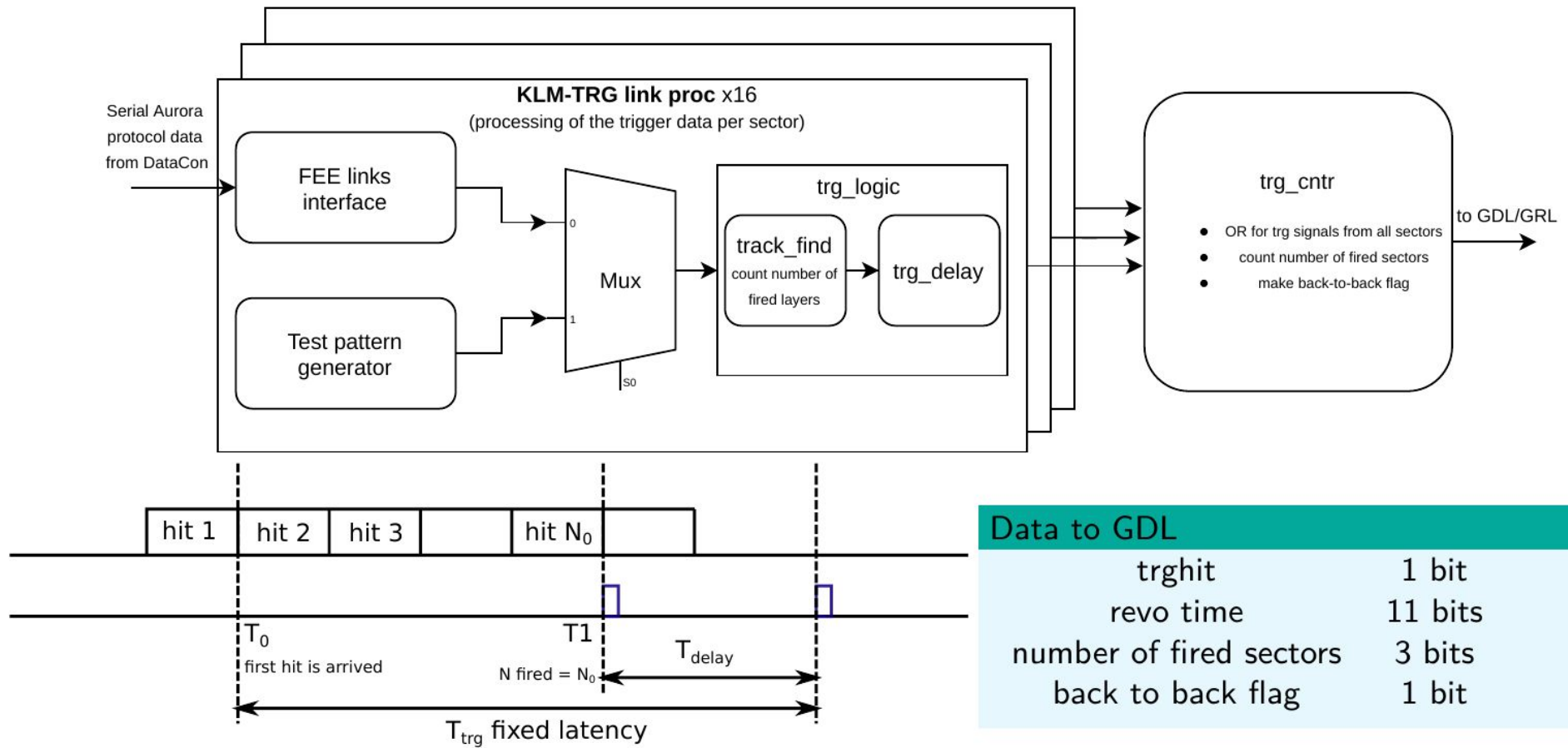
A simple Trigger Logic is based on Layer Counting:

1. Calculate the number of fired layers in a sector.
2. If the number of fired layers is more than 7
 - a. The sector is marked as triggered.
3. Generate the overall KLM trigger:
 - a. Count how many sectors have been triggered
 - b. Set the local trigger flags

This is the basic trigger logic that has been used for KLMTRG during physics operation.



KLM-TRG UT3 firmware



Data to GDL	
trghit	1 bit
revo time	11 bits
number of fired sectors	3 bits
back to back flag	1 bit

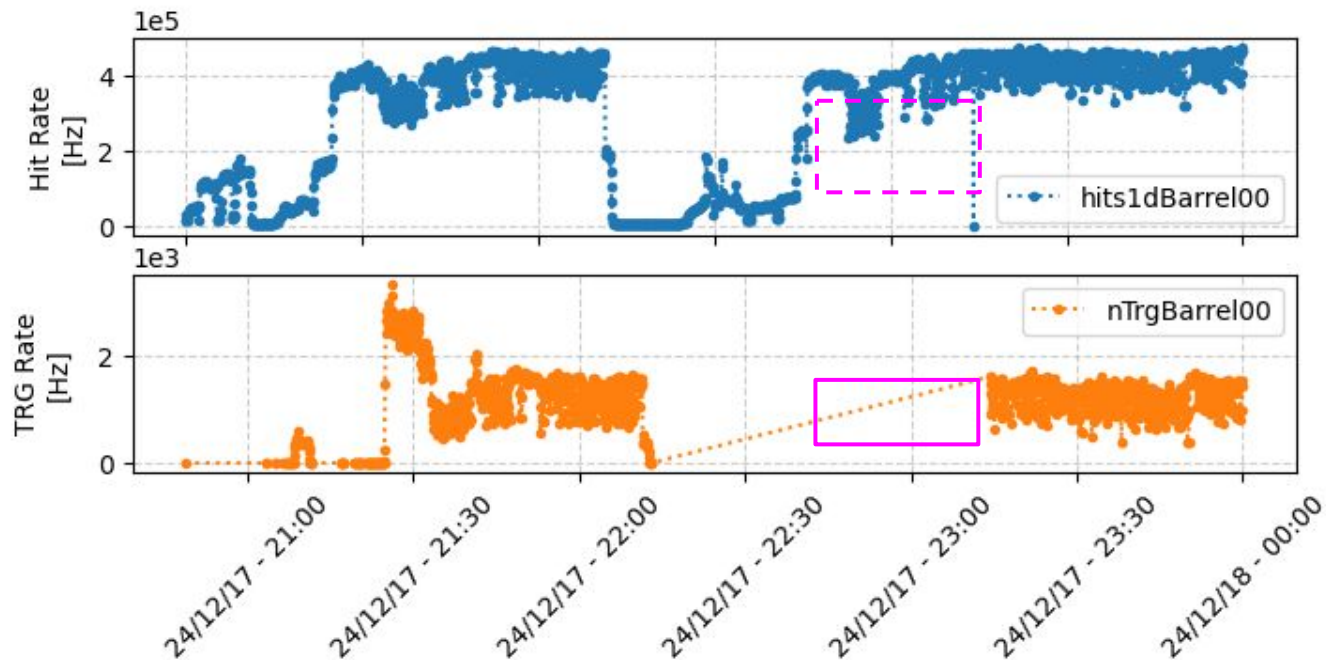
Kindly provided by Vasily ■ No track finding for now. Just count number of fired layers and if $N_{\text{fired}} > N_0$ ($N_0 = 7$ by default), issue a trigger signal

OUTLINE

- Operation Troubles
 - Low Efficiency
 - VME CPU down
- Verification Tool
- Operation Status
 - Rates and DQM Histograms
- Future Prospects (2026c →)

OPERATION TROUBLE: LOW EFFICIENCY

- **Period:** 2024c, observed twice (~30 minutes bad run) → Also observed in 2022
 - [Gitlab issue \(11\)](#)
 - [Gitlab issue \(15\)](#)
- **Solution:** Initialize KLMTRG
- **Task:** add all KLMTRG VME parameters to SLC and set limit to cause automatic ERROR



OPERATION TROUBLE: VMECPU

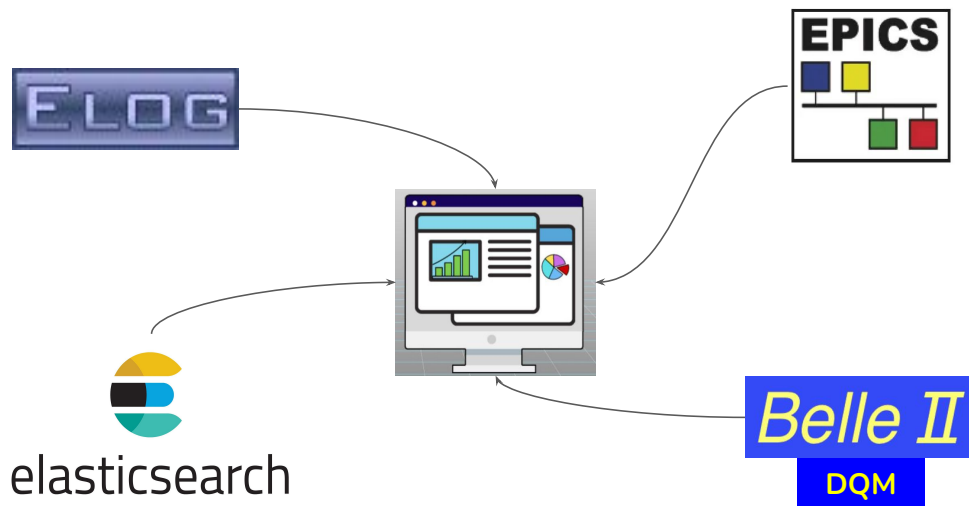
- **Period:** 2022-2024 ~ once per month (No impact to physics runs)
- **Symptoms:** VMETRG10 is frozen. ssh is failed. KLMTRG slow control is down.
- **Solution:** [Power Cycle VME Crate](#)
- **Task:** separate KLMTRG and TOPTRG VME crate and investigate more

ID	JSTTime	Author	Type	Category
912	2024/01/16 17:12 JST	Richard Peschke	KLmtrG	firmware
the wme computer vmetrg10 crashed. restarted via APC website. reprogramed with 2024-01-16_TOP.bit FM				

ID	Date	JSTTime	Author
168	2024/12/22 Sun 02:04 UTC	2024/12/22 11:03 JST	Jing Yuan
At 12/21 (yesterday) 5:41 PM, we had a fatal due to vmetrg10 , and Koga-san has excluded it from SLC temporarily.			

VERIFICATION TOOL

- Developing tools for firmware verification
 - Idea: To join different sources of information in a single place
 - Easily analyze and correlate the information.
 - Create new observables from existing sources
 - **Desired output: a web application**
- Main tools have been developed
 - Accessing Databases using APIs
 - Web Scrapping when needed
 - Create new observables
 - Creating visualizations



OPERATION STATUS

Cosmic Runs organized by CDC have been a great opportunity for my training and to check the status of KLMTRG.

- ✓ Trigger Rates
- ✓ DQM Histograms
- ✓ Initialization Scripts

Input rate	ec timing	✓	OK	998.100	>10Hz
	t2_0	✓	OK	151.700	>10Hz
	toptiming	✓	OK	38.500	>10Hz
	klm_hit	✓	OK	4109.700	>10Hz
	d5	✓	OK	100.700	>10Hz
	cdctop_0		OFF	0.200	>10Hz
	cdcklm_0	✓	OK	35.600	>10Hz
	eklm_hit	✓	OK	1901.500	>10Hz

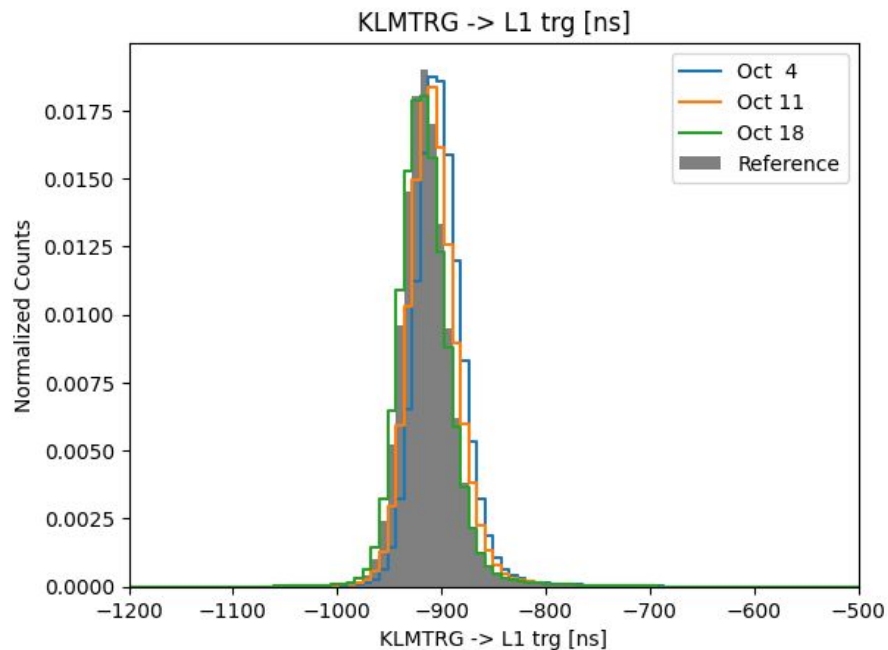
KLMTRG is ready for Data Taking!

SLC		OK	
ECLSLC		OK	
ECL	✓	OK	Detail
TOP		Label text	Detail
KLM	✓	OK	Detail
GRL/CDC	✓	OK	Detail
GDL	✓	OK	Detail

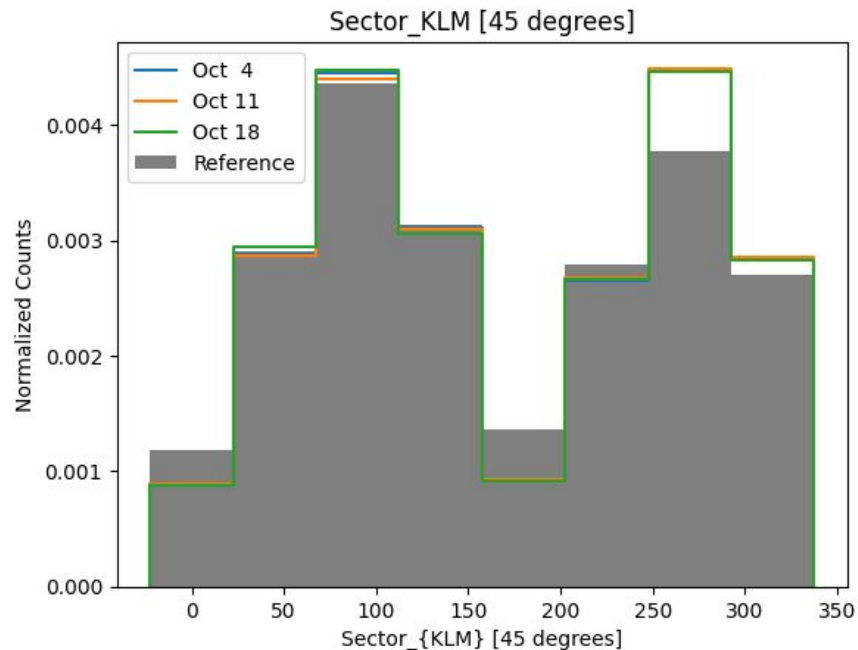
OPERATION STATUS

DQM Monitoring: 2 DQM Histograms are monitored for GRL

Latency of KLMTRG hit



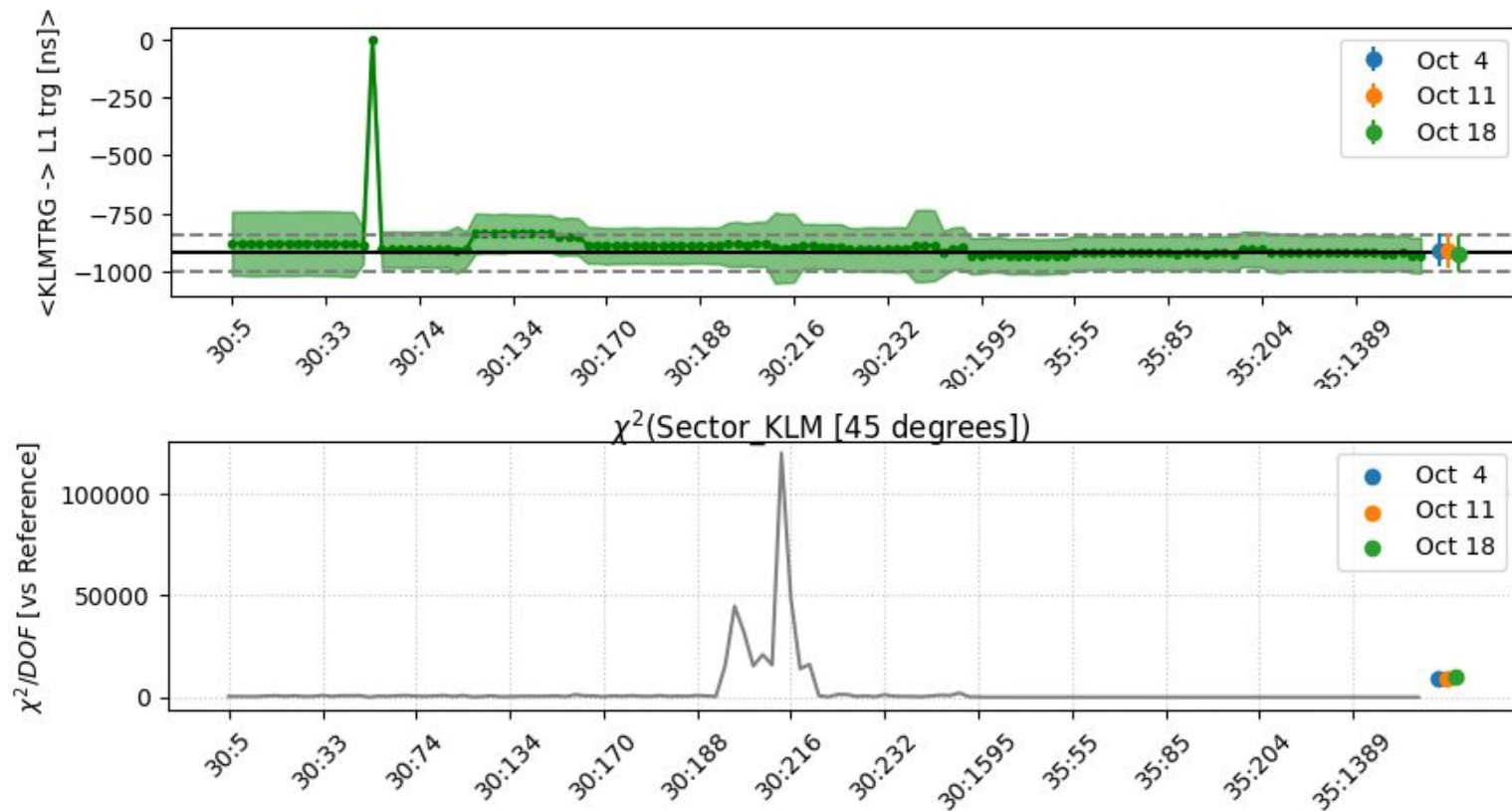
ϕ angle distribution of KLMTRG hit



OPERATION STATUS

Using monitoring tools we can easily check if the distributions are behaving as expected

**Using cosmic runs where KLM was active and at HV PEAK larger than 15 minutes*

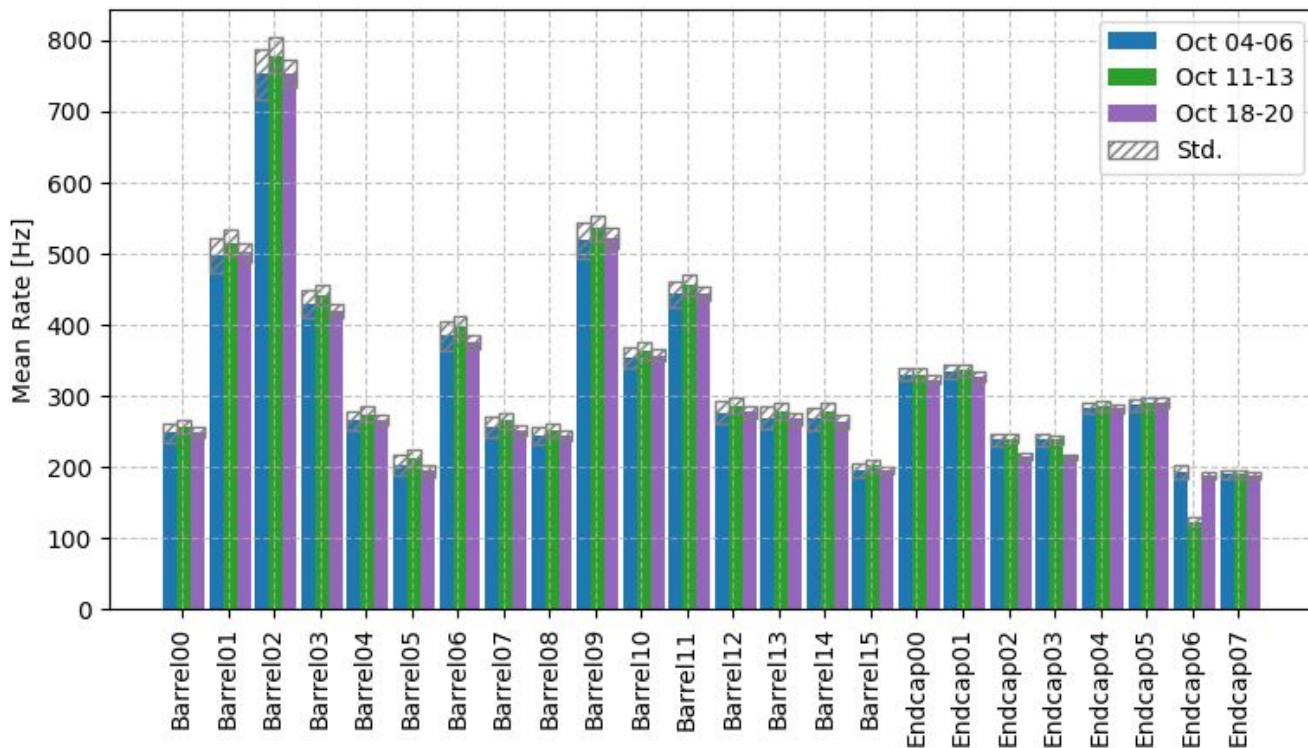


OPERATION STATUS

Individual rate sectors are OK.

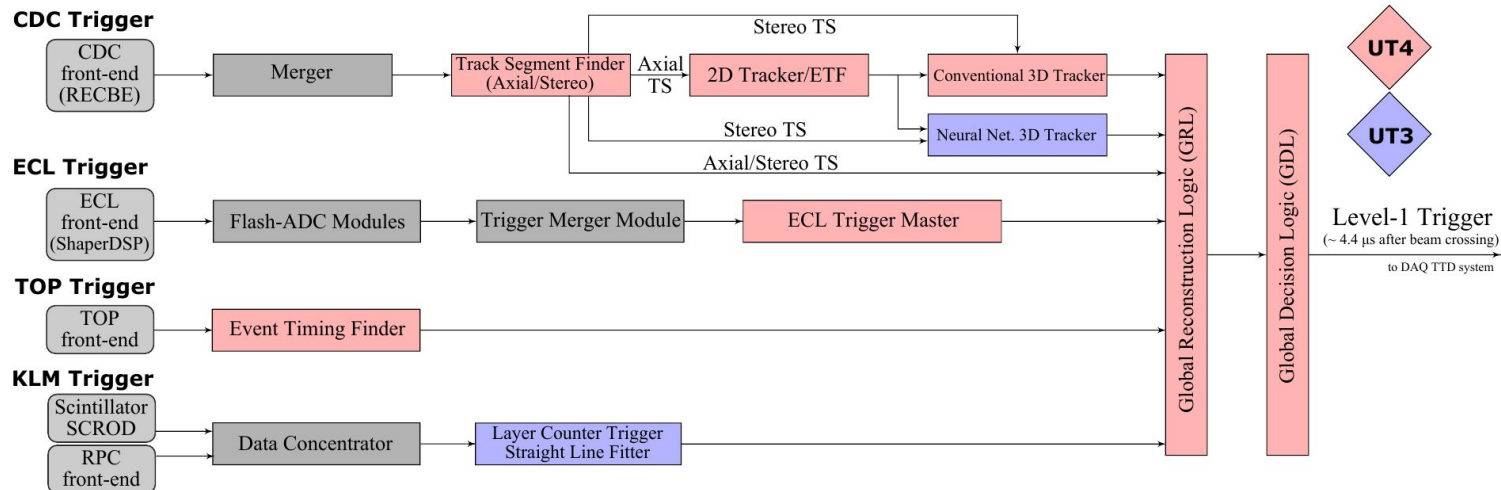
Small deviation on **Endcap06** due to known reasons.

- Link in Sector EB2 had to be masked.
- Now is recovered.



FUTURE PROSPECTS

- **Neural Network-based Trigger** [Gitlab Issue](#)
 - In mid-/long-term, the main focus will shift toward NN-based trigger design to further improve background rejection.
- **Migration to UT4** [Gitlab Issue](#)
 - Required to implement NN using HSL-based technologies. (UT3 tools lack HLS support)



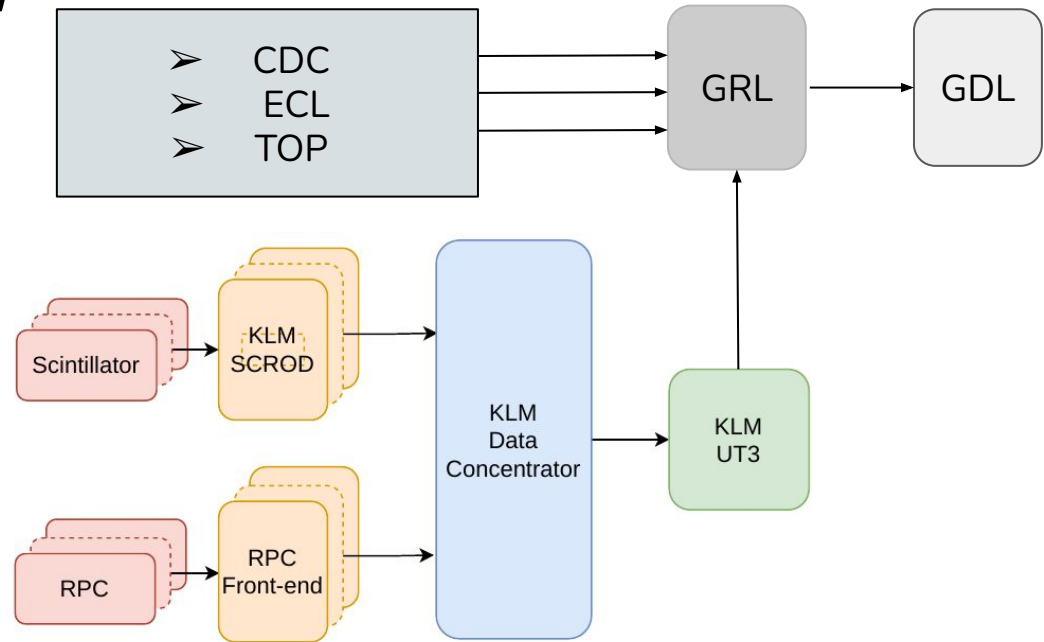
SUMMARY

- Previous problems in KLMTR are identified
 - Low efficiency & VMECPU instability
 - Solutions for each are provided.
 - Reminding tasks to improve the identification of the problems.
- Monitoring during cosmic runs
 - Initialization scripts are working
 - Rates are as expected
 - Efficiencies with small variations
 - Investigation ongoing
 - Do not represent a show-stopper
- VMECPU Update by TRG group last week
 - Some instabilities at the beginning of the run (Friday 17th)
 - Solved it with a lot of help from Hanwook Bae, Nakazawa-san and Koga-san!
 - System stable through the weekend

Backup

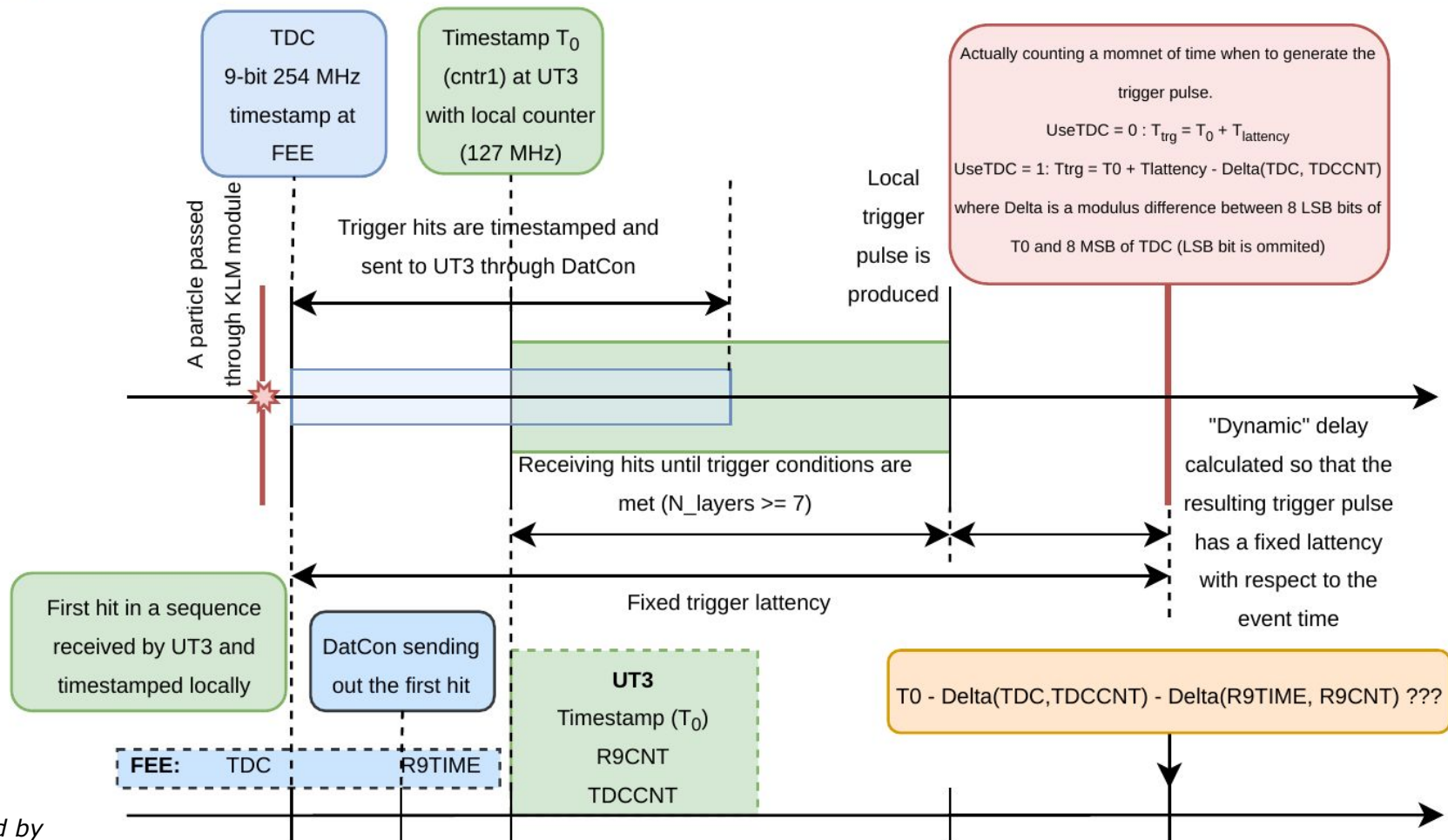
ELECTRONICS & DATA FLOW

- RPC and scintillator hits with amplitudes exceeding a threshold are timestamped in the front-ends
 - With a double-rate TTD system clock
- Hits are sent to the DC board
 - The DC orders the hits by time, and add the CTIME
 - The time when the data appeared at the DC
- Data goes either to a DAQ channel, and Trigger data goes into UT3 module using Aurora interface.

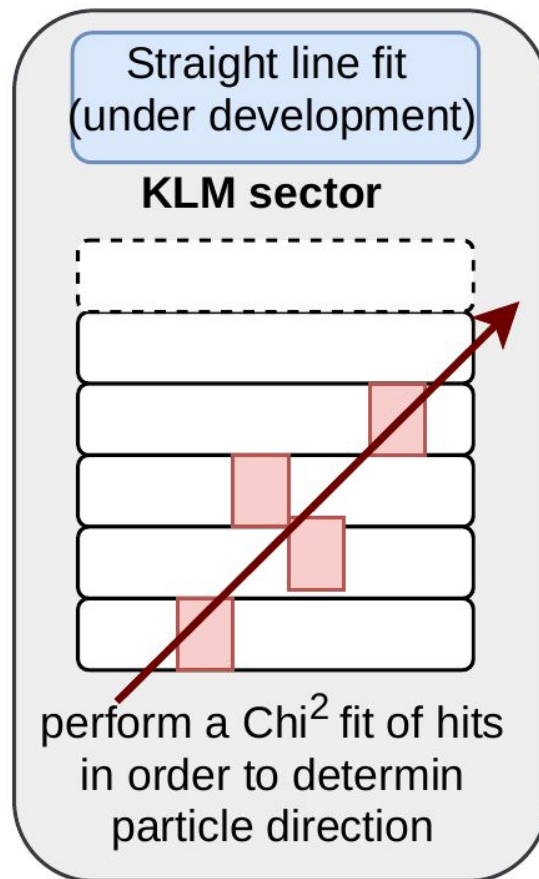


WORD	BITS[15:0]			
1	CTIME[15:0] <i>Added by Data Concentrator</i>			
2	TBD[2:0]	LANE[4:0]	AXIS[0]	CHANNEL[6:0]
3	TDC[8:0]			<i>Data from FEE</i>

Trigger timings

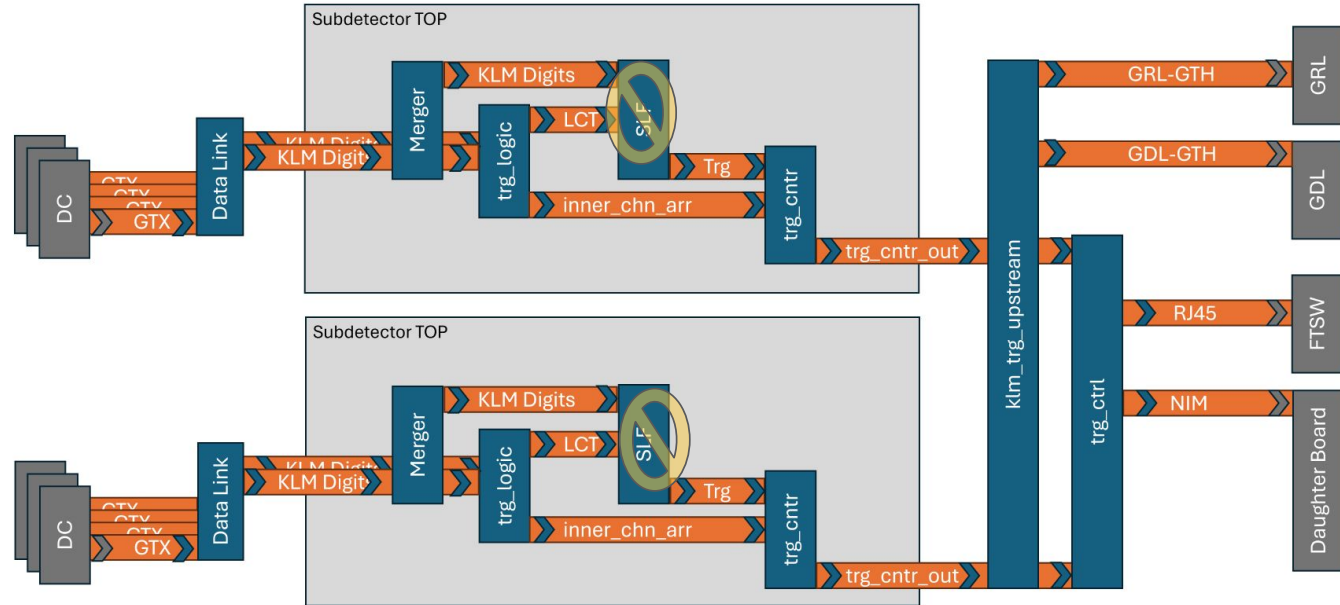


STRAIGHT LINE FIT



UT3 FIRMWARE

- KLMTRG is implemented on a UT3 Board
- The firmware is constructed around a dual data path
- To handle flows for the endcap KLM and barrel KLM
 - *The main developer of the Straight Line Fitter is no longer working on this project.*
 - Only used during special cosmic runs.
 - **It has not been used for physics data taking**



GDL/GRL MASKS FOR KLM TRIGGER BITS

KLMTRG has been used to trigger on muons

GRL

- CDC-BKLM matching ≥ 1
- CDC-EKLM matching ≥ 1
- ECL-EKLM matching ≥ 1

GDL

- EKLM back to back flag
 - One or more triggered sector in forward part
AND one or more sector in backward
- BKLM back to back flag
- EKLM sectors ≥ 1 AND BKLM sectors ≥ 1
- EKLM sectors ≥ 2