50th B2GM: Trigger Summary

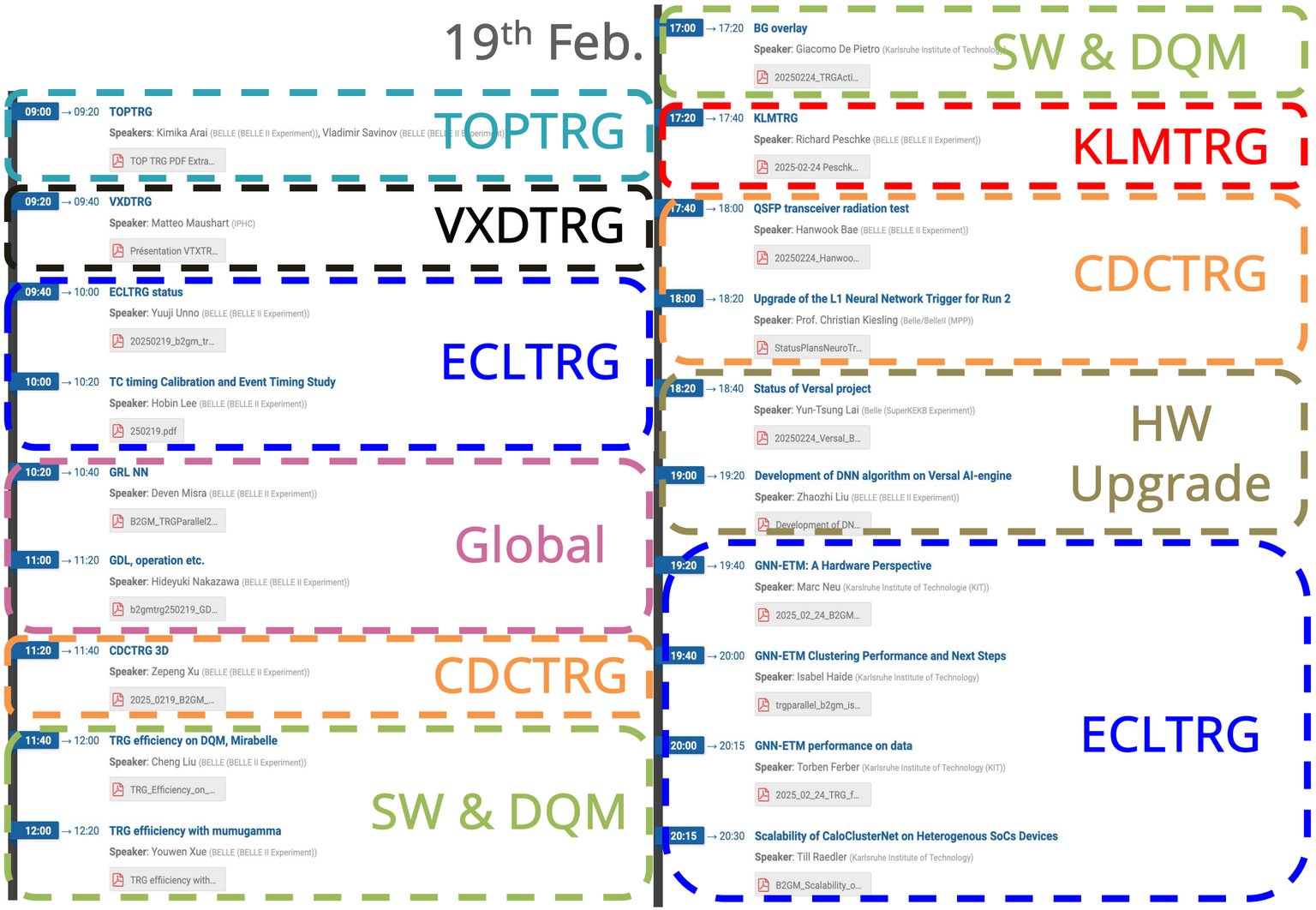
Hanwook BAE on behalf of the TRG group

KEK, Institute of Particle and Nuclear Studies (IPNS)

Trigger Parallel Session @ 50th B2GM

- There are two sessions in 19th and 24th Feb.
  - 19 presentations in total

- In this presentation, we will **summarize the TRG operation** and introduce selected topics on **the TRG system upgrades** during 2024c and **future plans**!

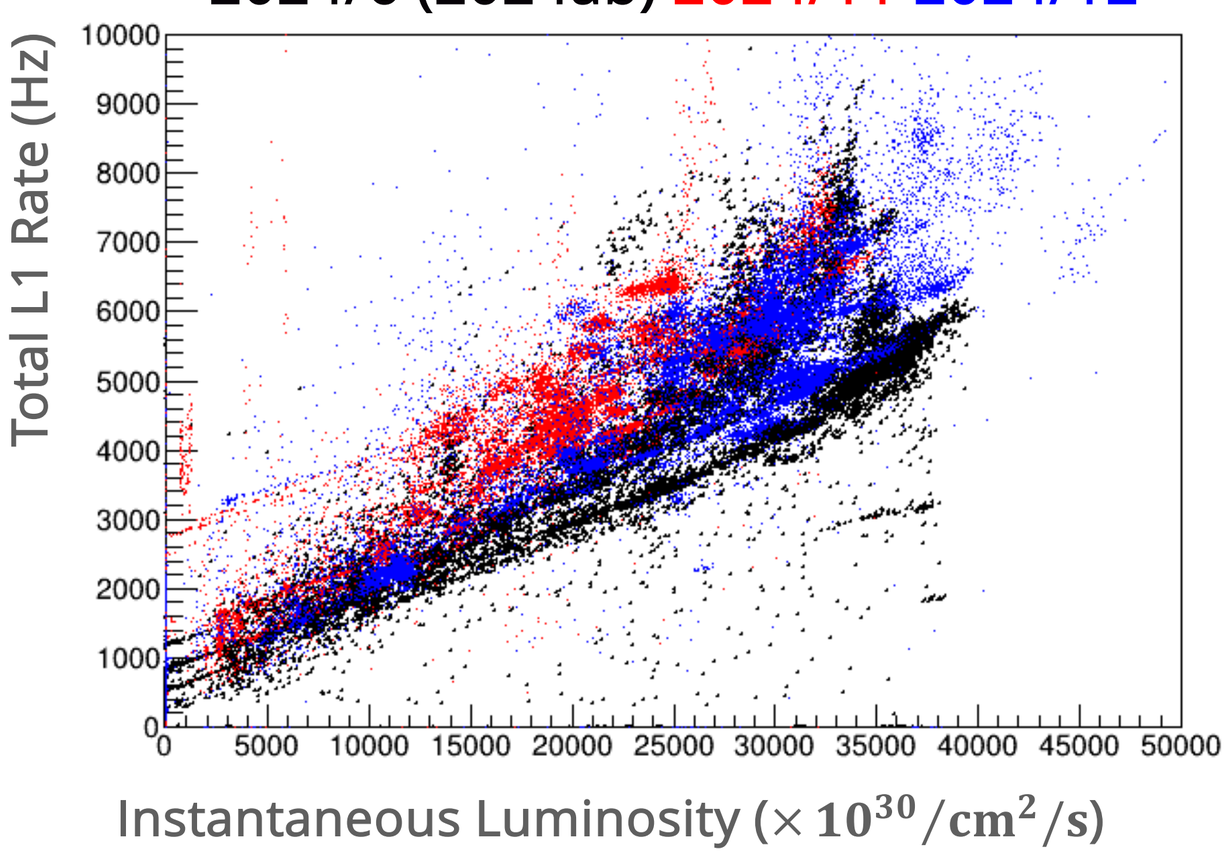


Level 1 Trigger Rate Summary (T. Koga)

- The L1 rate per luminosity in 2024c is about the same order.
  - No changes in the trigger menu

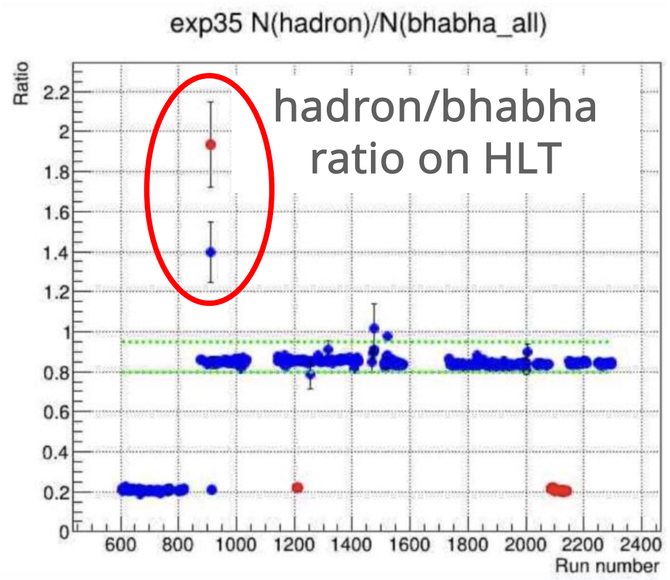
- Better 👍 than 2024ab
  - Introduction of ADC cuts of CDCTRG
  - Improved injection veto (less leakage)

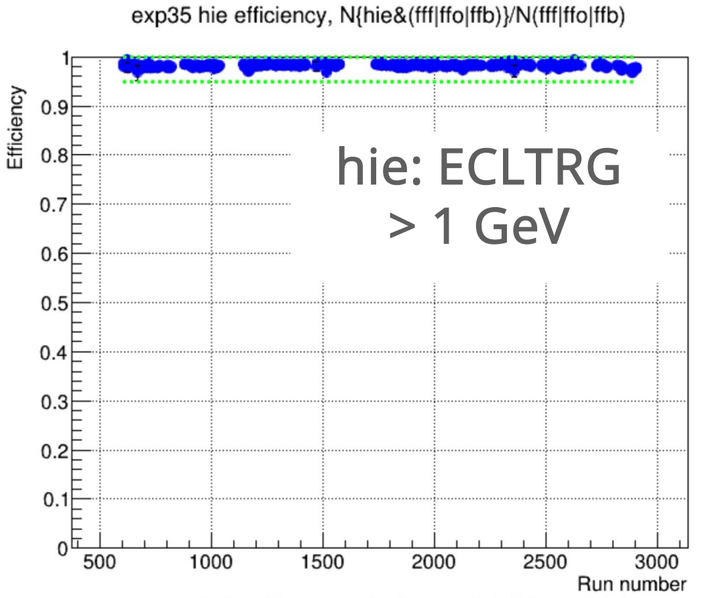
- Worse 😢 than 2024ab
  - The beam background was 1.5-4 times stronger than that in 2024ab

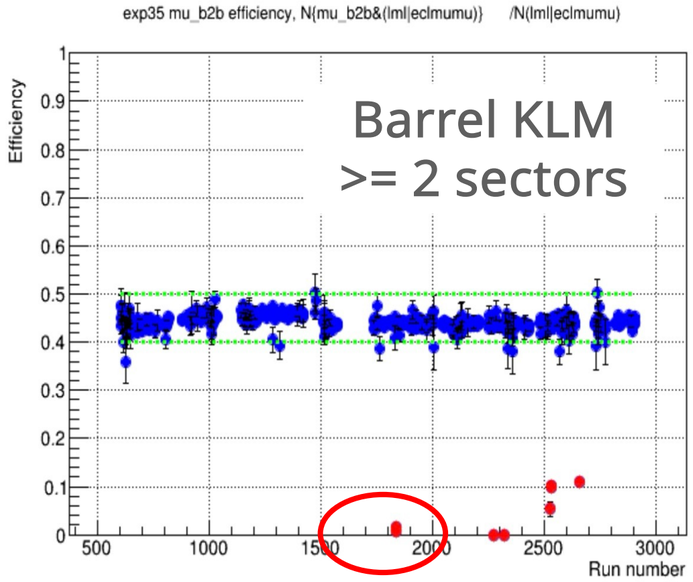


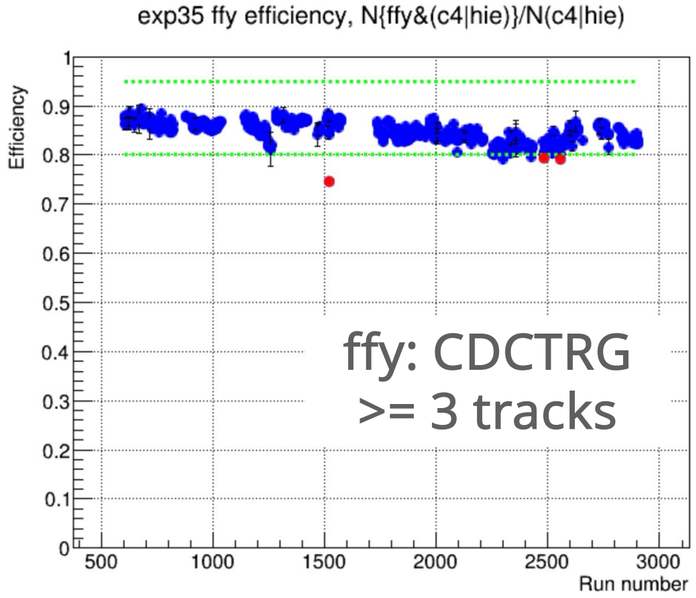
Trigger Efficiency Summary (C. Liu and J. Yuan)

- The trigger efficiencies were stable over the 2024c run period in overall
  - ECLTRG and CDCTRG show stable plot, but HLT and KLMTRG have anomalies
- Most anomalies are understood and marked as RECOVERABLE runs.
- Total length of BAD runs: about 2 hrs. Example:
  - r911/912 : HLT hadron ratio due to ECL
  - r1836: KLMTRG issue due to detector
  - r2321: Too big hadron ratio (x40 bigger)



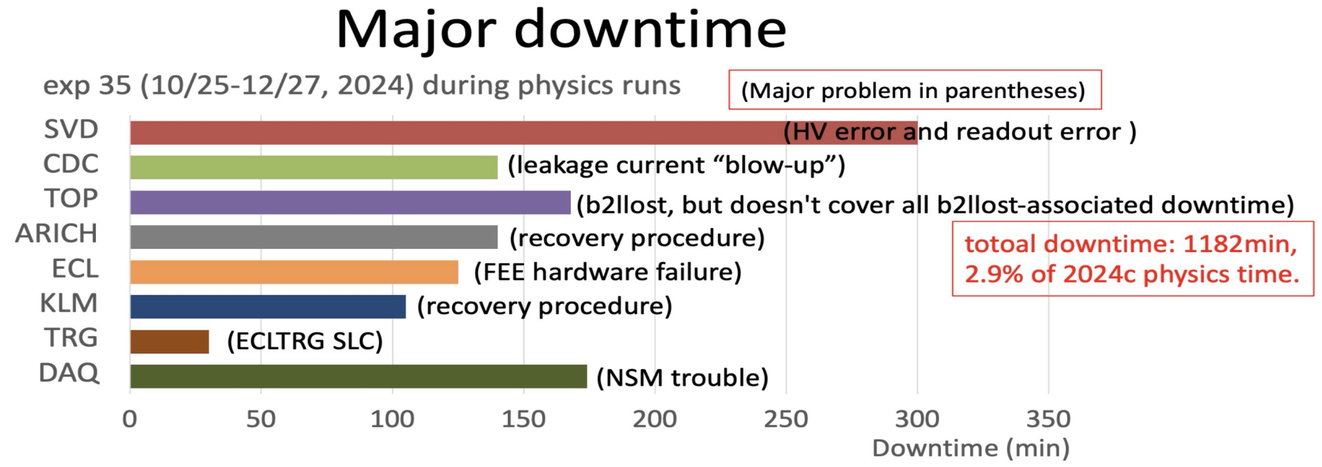






Trigger Operation in 2024c (H. Nakazawa)

- Trigger was stable during 2024c
  - Clock unification (Slides @ 49th B2GM) improved the stability of GDL
    👉 TRG **downtime reduced**!

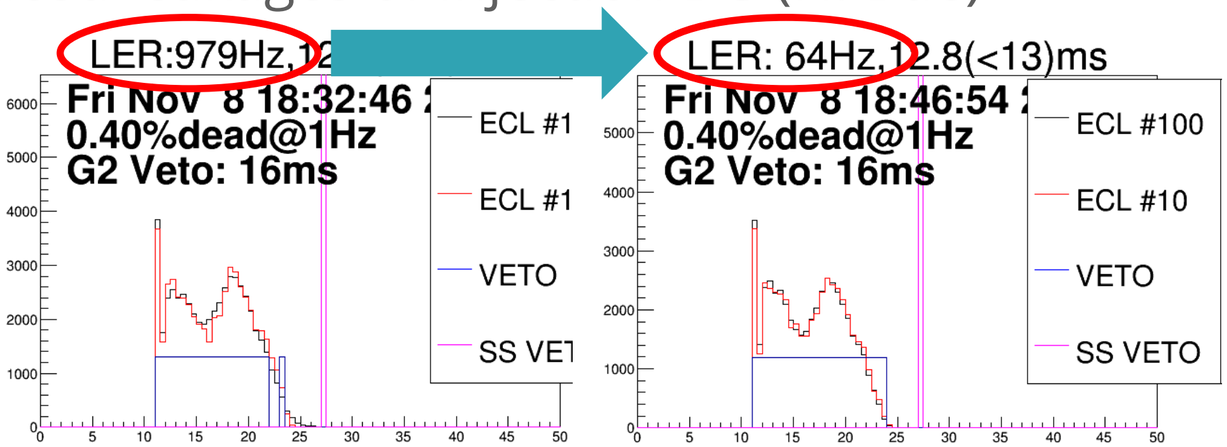


- TRG caused delays in Data Production due to the following troubles
  - Data quality flags in rundb and payload production for GDL

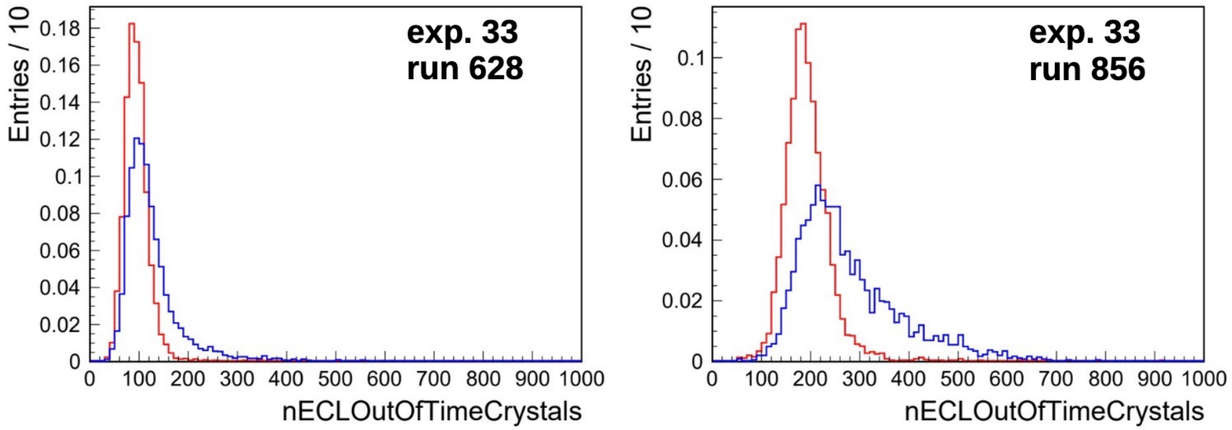
- We planned some improvements to avoid the above troubles:
  - The progress for data quality and payloads will be reported in the weekly TRG meeting
  - Improve SLC to detect and monitor errors or anomalies (e.g., Injection veto and so on)

Injection Veto

- Enabling ECL partwise-cut for active IV reduced leakages of injection BG (H. Bae)
  - Partwise-cut for N(TC): (Slides @ 49th B2GM)
  - The leakage rate **significantly reduced** after enabling the partwise-cut (8th Nov. 2024)



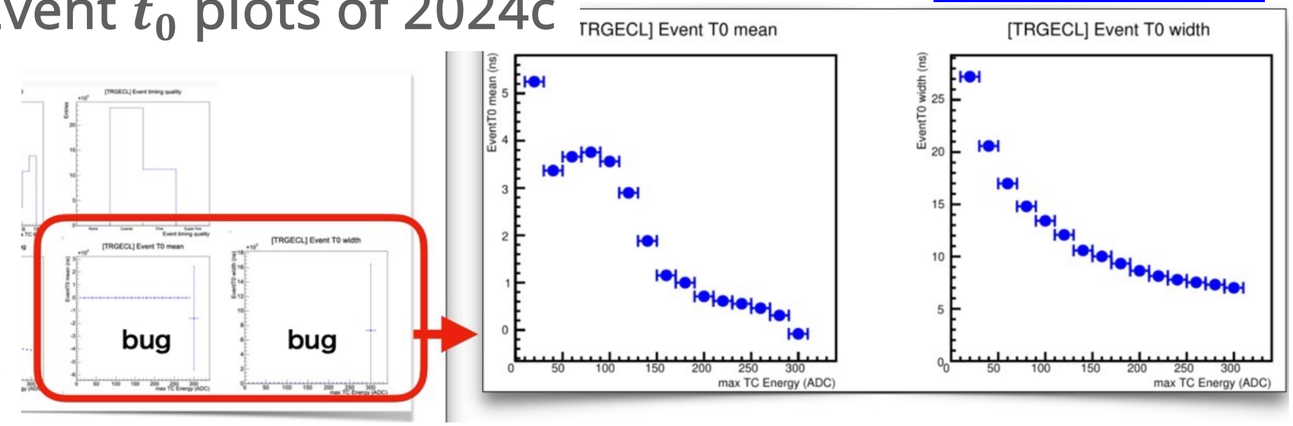
- BG-Overlay generation for the active injection veto (G. De Pietro)
  - A new basf2 module is implemented to overlay the digits within the active IV window
  - Red: Passive IV == 0 (Not vetoed events by IV)
    Blue: Passive IV == 1 && Active IV == 0
    (Inside AIV window)



Status of ECLTRG (Y. Unno and H. Lee)

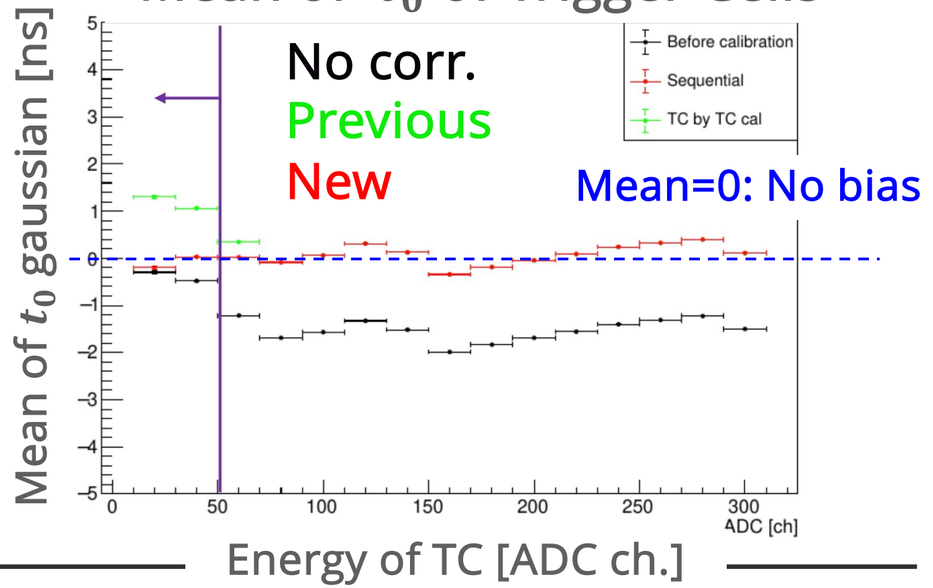
- Optical link instability of ECLTRG
  - We confirmed the reason. Countermeasure will be implemented
- GNN-ETM included to the DAQ readout
- Bugs in the DQM plots were fixed

Event t_0 plots of 2024c



- Energy-dep. t_0 correction for Trigger Cell (TC)
  - New method: Using a global coef. to compensate insufficient statistics of individual TCs
  - Significantly reduced bias of t_0 timings for TCs with the low energies!

Mean of t_0 of Trigger Cells



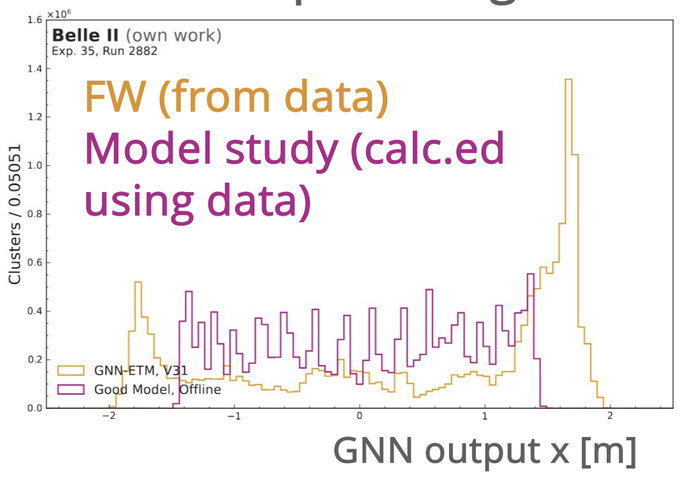
- Improving ECLTRG timing decision logic is ongoing

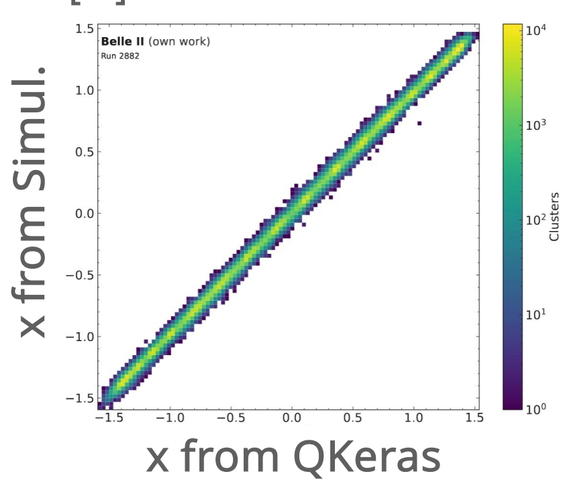
Updates of GNN-ETM (I. Haide and T. Ferber)

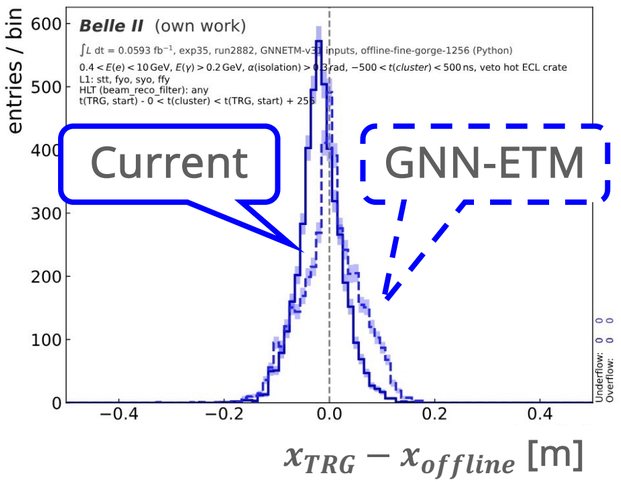
- GNN-ETM: New ECL trigger logic using Graph-Neural-Network. Under devel.
- We took a special physics run at Dec. 2024 with FW of GNN-ETM (e35r2882)
  - recording input data for GNN-ETM: can be used for the GNN studies with various models
  - Agreement studies between FW sim. & QKeras

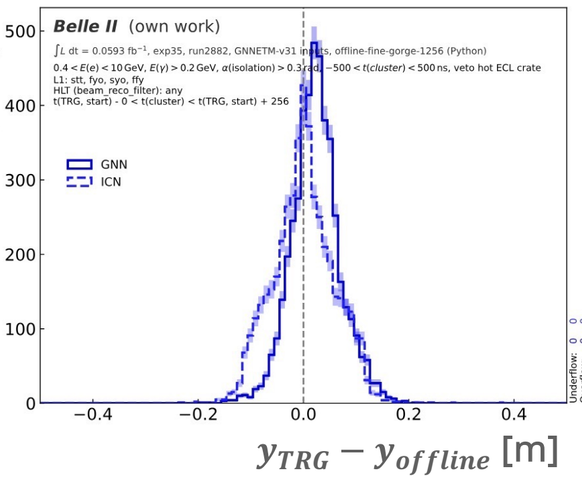
- Performance analysis using e35r2882
  - GNN-ETM shows better resolution for the TC positions than the current ETM (ICN)
  - Additional studies are ongoing (e.g., validation for the signal classifiers)

GNN output using data







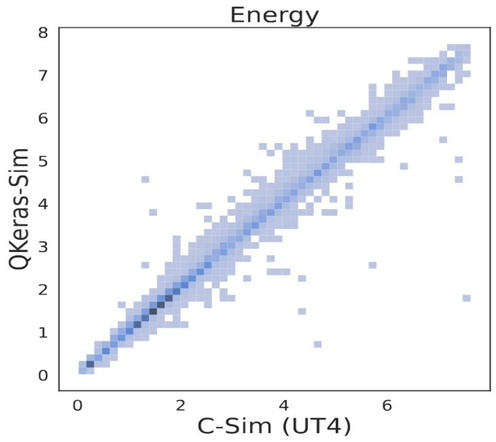


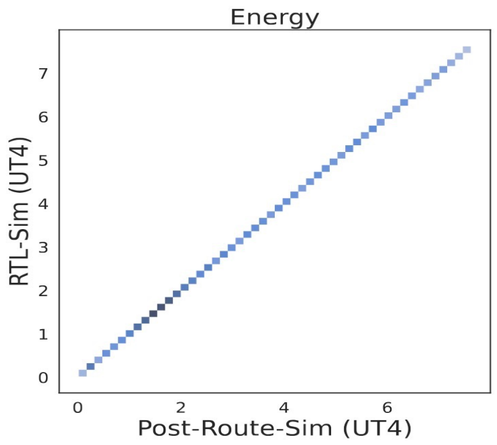
Impl. Studies for GNN-ETM (M. Neu and T. Rädler)

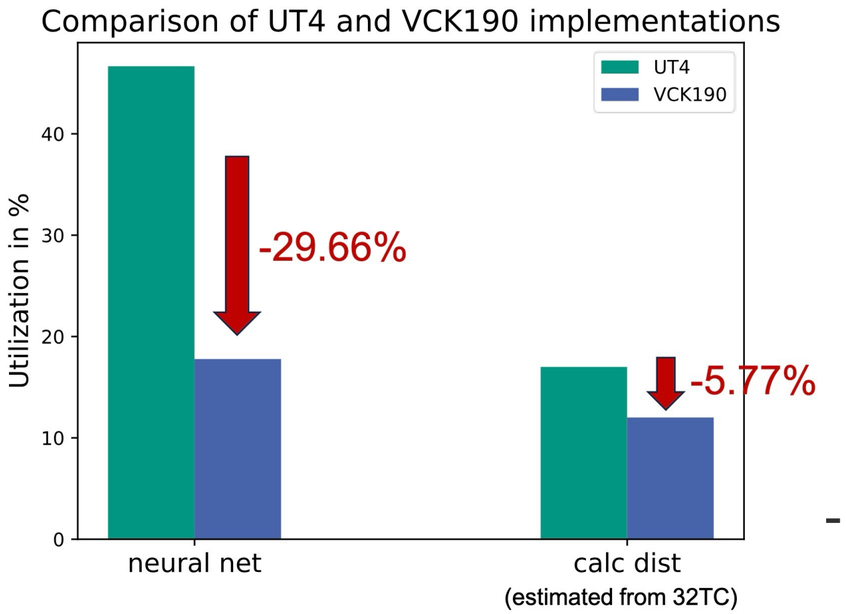
- GNN-ETM is successfully implemented w/ UT4
  - working well in the data-taking (@ Dec. 2024)
  - 3us latency: need to be reduced

- Simulation framework for GNN FW is ready.
  - FW simulation and QKeras shows good agreement
  - Output from hardware (UT4) and simulation does not match. Investigation is ongoing

- Studies to implement GNN-ETM on Versal
  - Increasing the number of input TCs from 32 to deal with the higher beam BG environment
  - On the Versal architecture, we can achieve 128 TC inputs with the lower utilization!



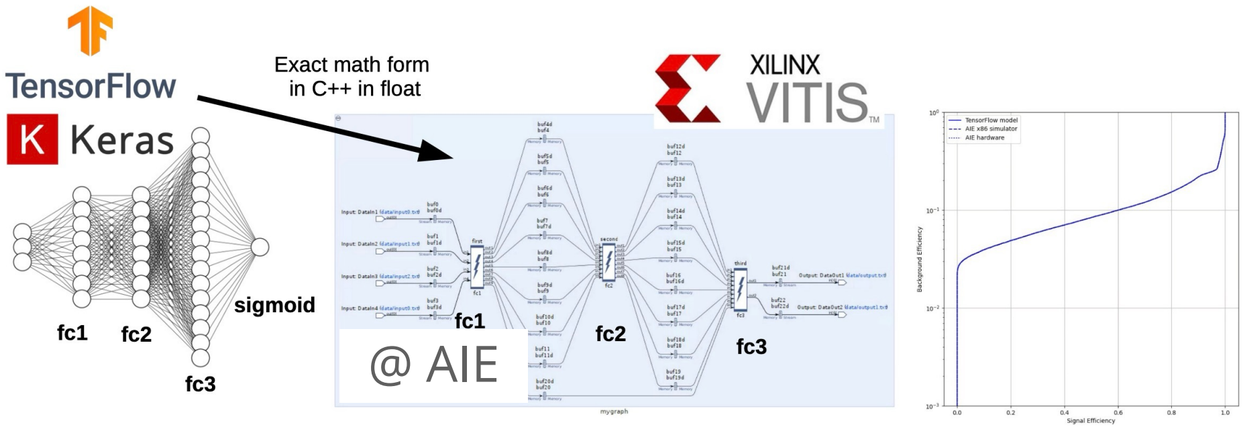




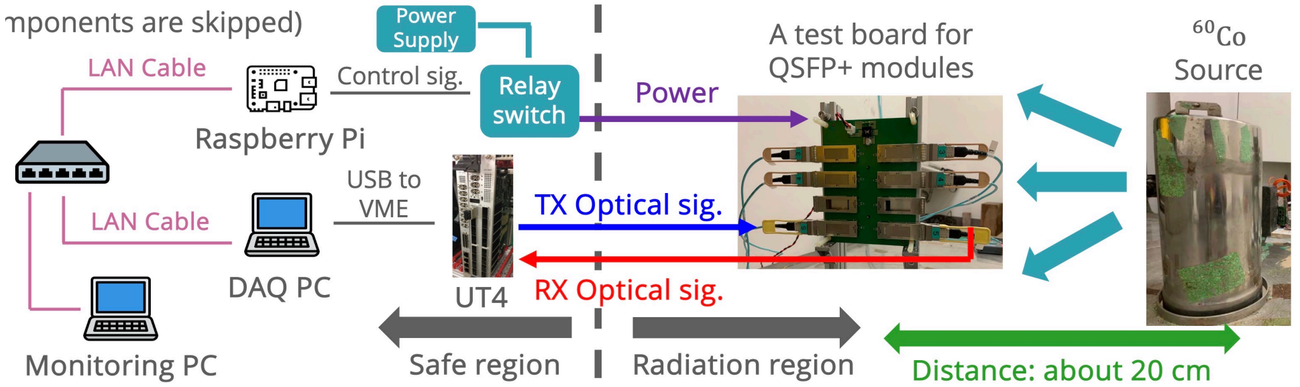
Hardware Infrastructure

- UT5 and Versal (Y. Lai and Z. Zhao)
  - Studies for AI Engine in the Versal arch. are ongoing: NN of the existing triggers tested
  - Active student activity (5 students) and basic infrastructures are being prepared.

AI Engine (AIE): ML-designated cells of the Versal arch.



- Irradiation tests of the QSFP+ modules for the new CDCFE electronics (H. Bae)
  - γ-ray tests with over 1 kGy total doses
  - neutron tests with 10^{12} fast neutrons
- We selected a proper QSFP+ module to endure 10 years w/ our radiation cond.



Summary

- TRG operation and L1 rates were stable in the previous run period (2024c)
  - The L1 rate increasing due to the higher BeamBG (x4) is suppressed thanks to some upgrades

- Many upgrades and studies have been performed during 2024c
  - Partwise-cuts for the active IV reduced the injection BG leakage a lot!
  - GNN-ETM implemented on HW and showed good position resolution than current logic
  - Irradiation tests of optical modules for the future CDCTRG performed and a proper one found
  - Other many upgrades and plans for TOPTRG, KLMTRG, VXDTRG, and CDCTRG (See backups!)

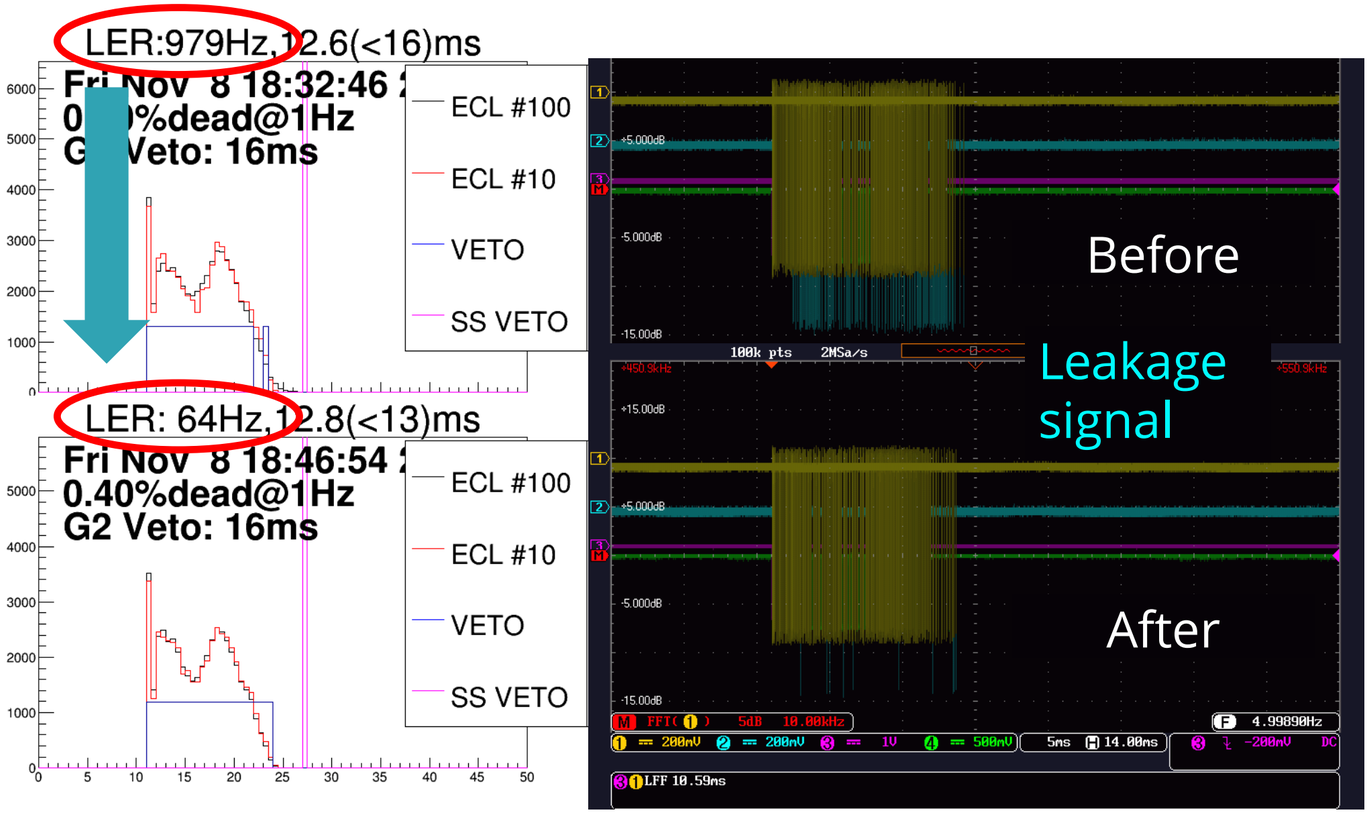
- We will implement upgrades to ensure the stable operation in the next run period

Backup Slides

Injection Veto (H. Bae)

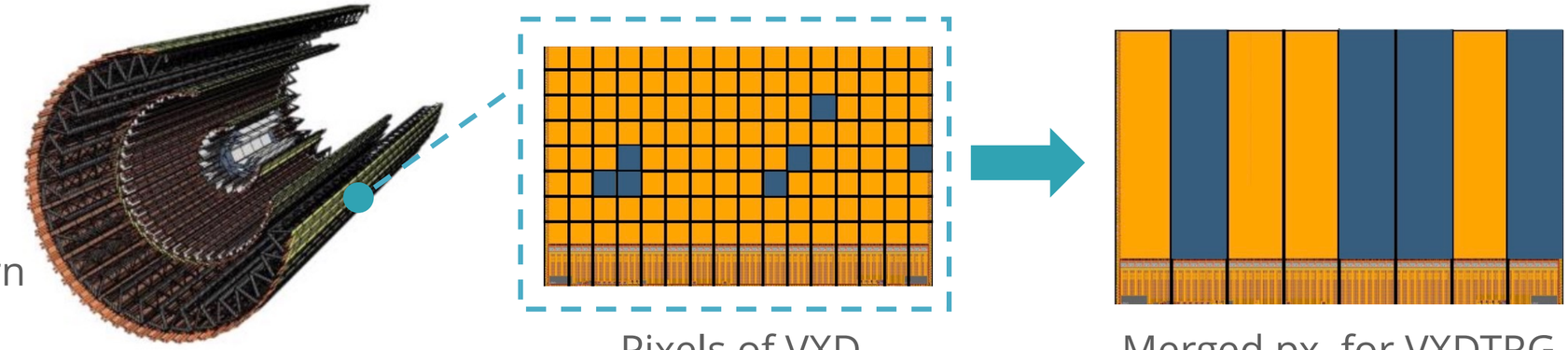
- We enabled the partwise-cut for the number of ECL Trigger Cells (Link @ 49th B2GM)
  - Separate cuts on the number of ECL TC from barrel or end-caps. Enabled from 8th Nov 2024.

- The leakage rate has significantly reduced after enabling the N(TC).



Update of VXDTRG (M. Maushart)

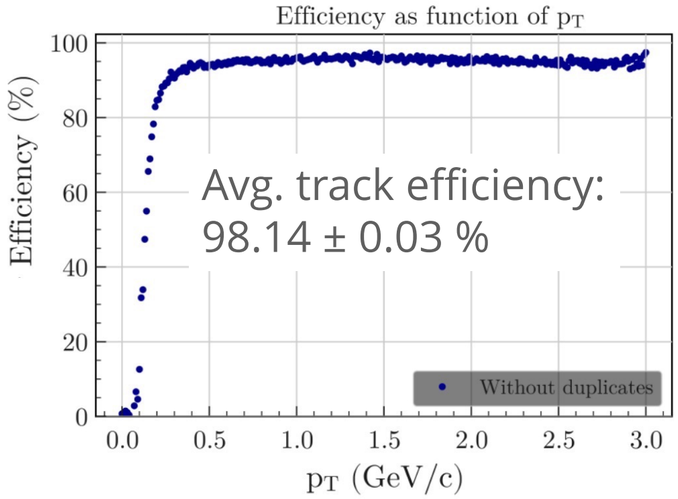
- VXDTRG: Find tracks with LUT and information of OR-combined pixels from VXD
  - Dimension of a sensor:
    18.8 mm x 30.2 mm (8mm)
  - Number of total pixels:
    464 x 896 pixels
  - Merge pixels in a stripe pattern
    for VXDTRG



Pixels of VXD

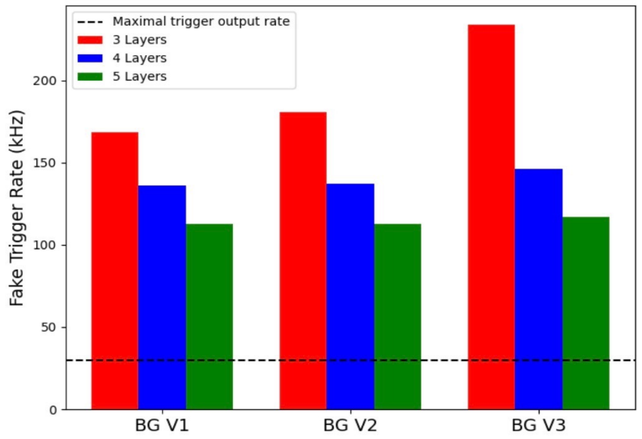
Merged px. for VXDTRG

- We evaluated the fake-track rate and efficiencies w/ various conditions
  - Efficiency study w/ multiple trk. events
  - The tracks can be matched w/ CDCTRG



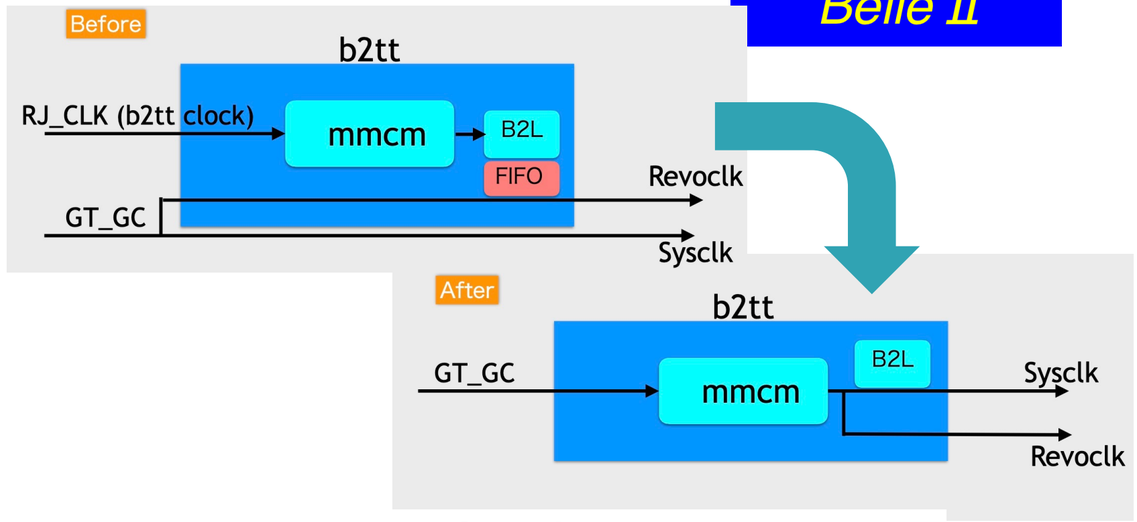
  - About 100-200 kHz single trk. rate is expected

Single trk. trigger rate



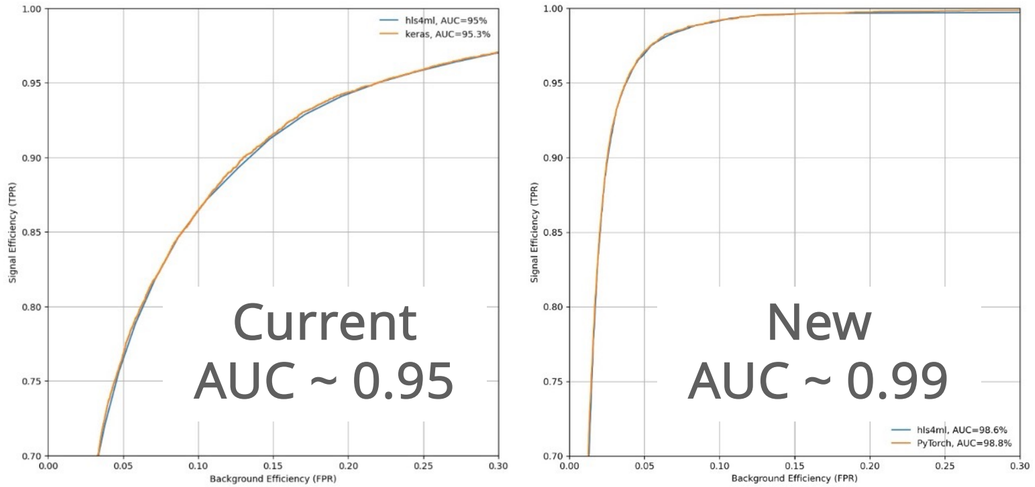
GDL and GRL (H. Nakazawa and D. Misra)

- Status of GDL
  - Clock unification (Slides @ 49th B2GM) improved the stability of GDL 👉 TRG **downtime reduced**!
  - Timing decision module will be updated to provide more accurate L1 timing signals



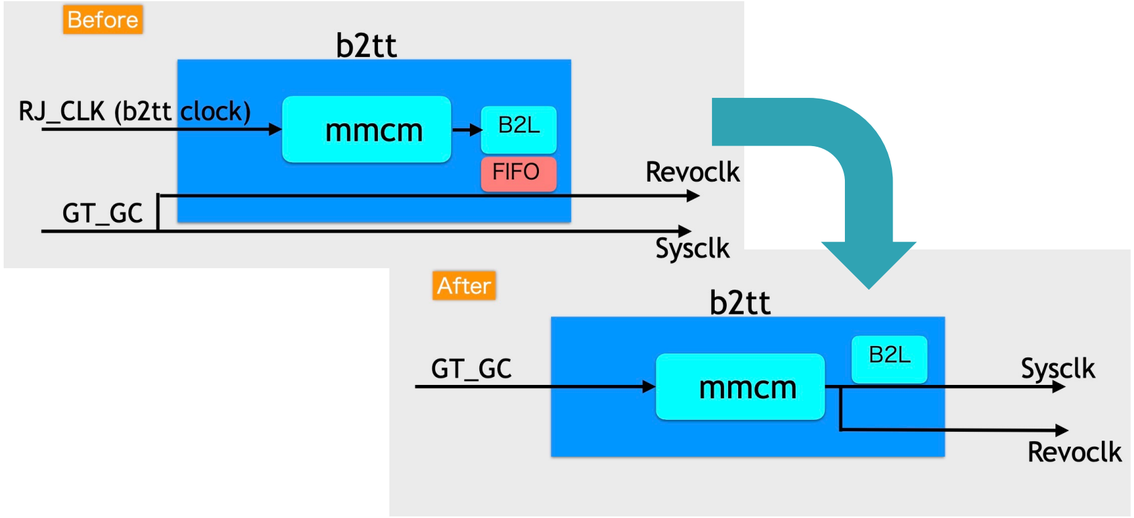
- Tau trigger in GRL: Improving the performance of neural network
  - Adopting another method for quantization
  - Improved AUC from 0.95 to 0.99!

ROC Curves for the tau trigger



GDL and Infrastructures (H. Nakazawa)

- Status of GDL
  - Clock unification (Slides @ 49th B2GM) improved the stability of GDL 👉 TRG **downtime reduced**!
  - Timing decision module will be updated to provide more accurate L1 timing signals



- VME boards and OS of the “btrgsrv” servers
  - New VME boards: OS for VMECPU and VME drivers are ready.
  - We planned updating the OS version of trigger DAQ servers

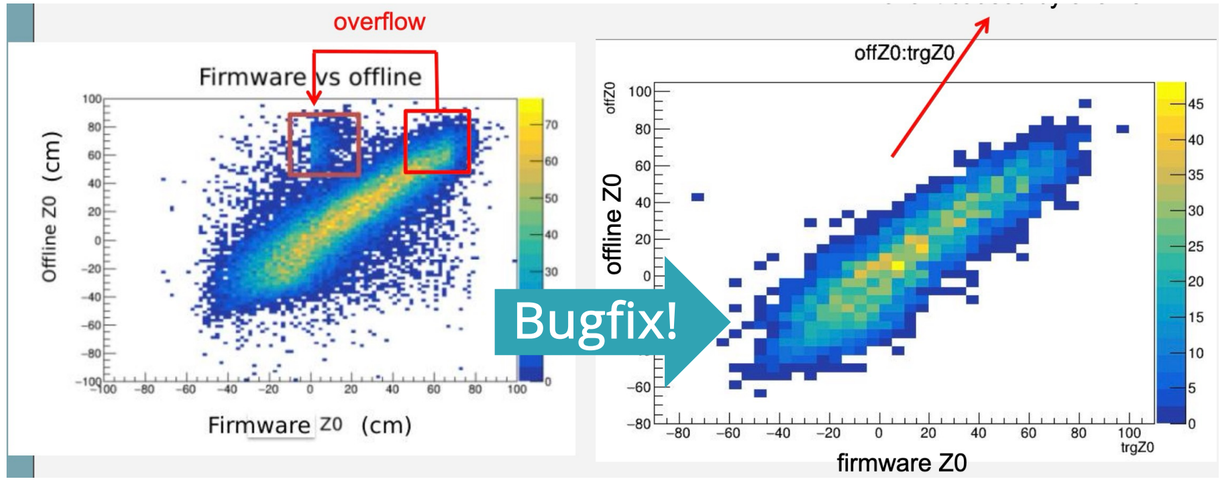
	Old OS	New OS
btrgsrv0, 1	SL6	Rocky8
btrgsrv2, 3	SL7	Rocky8 or 9
btrgctr0, 1	SL6	Rocky8

CDCTRG: Update of 3D Trigger (Z. Xu and C. Kiesling)

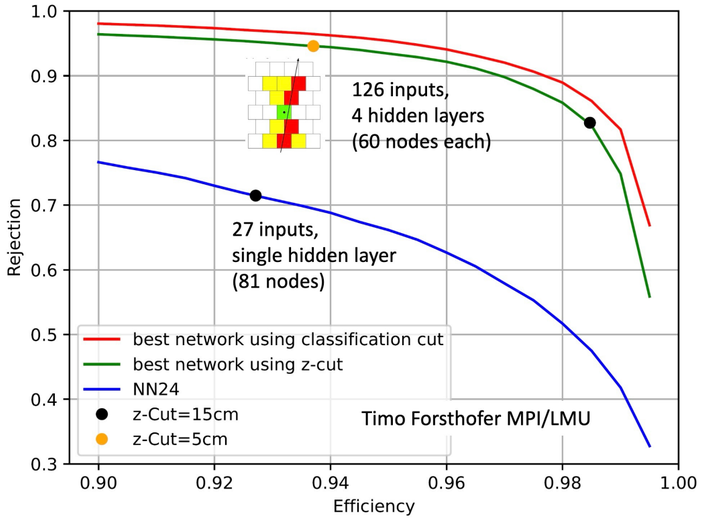
- The bugfix of the DNN firmware: A bug of z_0 value in the DNN firmware fixed
  - Studies to improve the z_0 resolution from the DNN 3D trigger is ongoing

- Plan: 3D-Hough Tracking (3DHDNN)
  - Extension of the 2D Hough transformation to 3D using deep neural networks
  - Improved z_0 resolution and less bckg. tracks

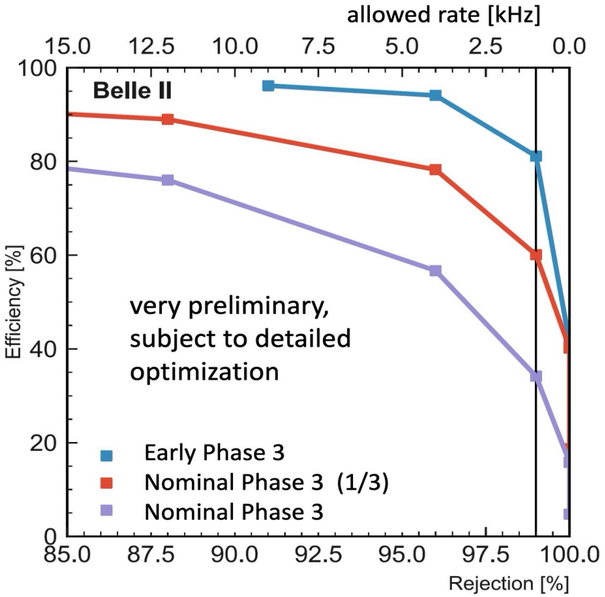
- Plan: Displaced Vertex Triggers (DVT)
  - Triggering long-lived particles with extended track segments and many Hough trans.
  - Basic algorithms are ready, and further studies are ongoing



ROC Curve of 3DHDNN



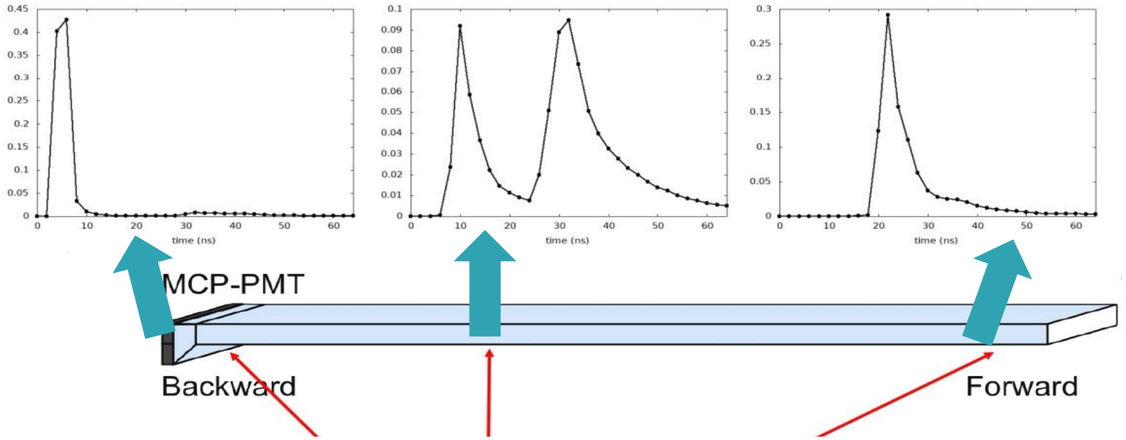
ROC Curve of DVT



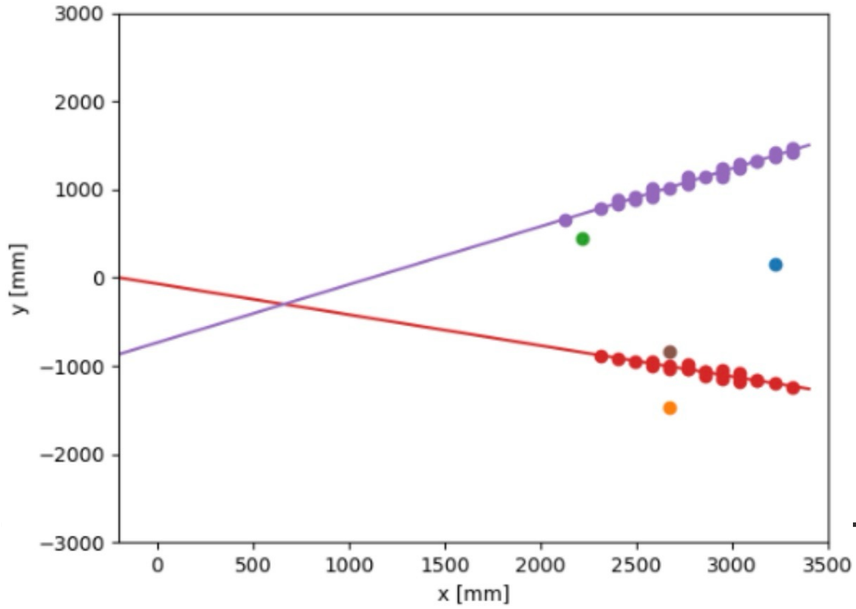
Summary from TOPTRG and KLMTRG

- TOPTRG (K. Arai and V. Savinov):
  Improving t_0 performance
  - Likelihoods for TOPTRG t_0 determination: MC-generated (Current) → Real data (New)
  - Basic methodology and tools are ready: We make the likelihoods by using the TOP digits of extrapolated tracks from inner detectors

PDFs for TOP hits by indicent $\vec{x}$



- KLMTRG (R. Peschke):
  Update of Simulation and firmware
  - A bug in the KLMTRG simulation is addressed
  - Overflow in a component of KLMTRG is confirmed: update will be made



List of Slides

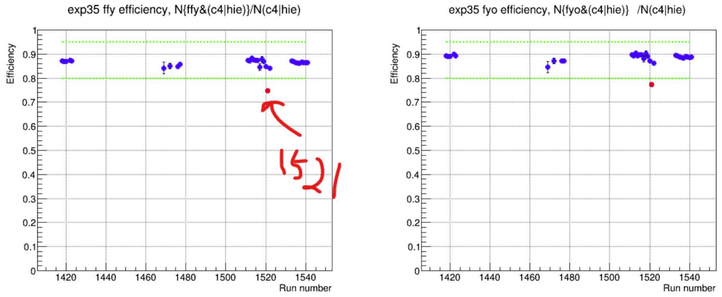
- C. Liu's B2GM TRG parallel: https://indico.belle2.org/event/13863/contributions/88469/attachments/32835/48460/TRG_Efficiency_on_DQM_Mirabelle.pdf
- J. Yuan's TRG Weekly meeting: https://indico.belle2.org/event/13858/contributions/86608/attachments/32094/48092/DataFlag_Dec2024.pdf
- M. Neu's B2GM TRG Parallel: https://indico.belle2.org/event/13864/contributions/88484/attachments/32972/48690/2025_02_24_B2GM_Marc_Neu(2).pdf

List of runs with trigger related problems

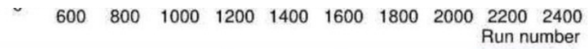
C. Liu's Slide

Run number	Quality flag	Problem
911,912	BAD	ECL detector issue, hadron/Bhabha etc. is out of limit
1317	RECOVERABLE	Efficiency of f is low
1521	RECOVERABLE	Injection BG is very high
1836	BAD	KLM efficiency is low due to KLM detector issue
1971-1976	RECOVERABLE	CDCTRG short track efficiency is low due to bad MGR
2273-2274	BAD	BKLMTRG efficiency is low (Reason is not understood yet)
2321	BAD	Strange hadron/Bhabha (Probably it is not TRG issue)
2564	RECOVERABLE	hadronb2, mumu2trk, hadron are out of limits
2566	RECOVERABLE	hadronb2 is out of limit
2581	RECOVERABLE	lml10 is out of limit
2654	RECOVERABLE	mu_b2b, cdcklm1 and cdcklm2 are out of limits
2772	RECOVERABLE	lml12 is out of limit
2833,2835,2840,2876,2903	RECOVERABLE	hadronb2 is out of limit

➢ Flag the exp35run1521 as RECOVERABLE. Injection BG was very high at that time.



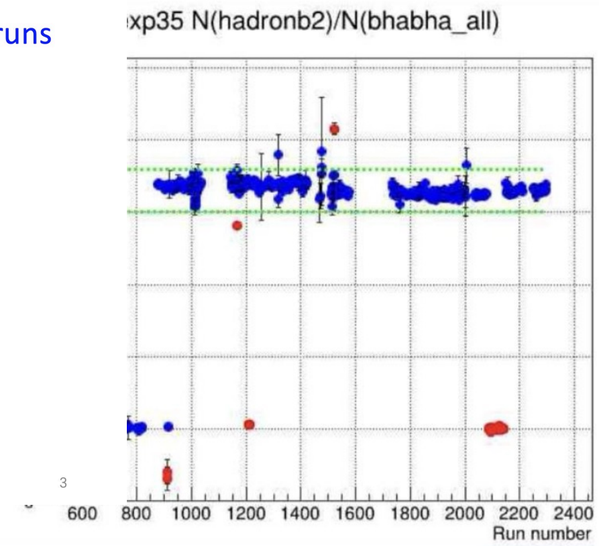
➢ Flag exp35run1836-1836 as BAD. KLM efficiency was low due to KLM detector issue.



ctor issue, hadron/Bhabha etc. is out of limit.

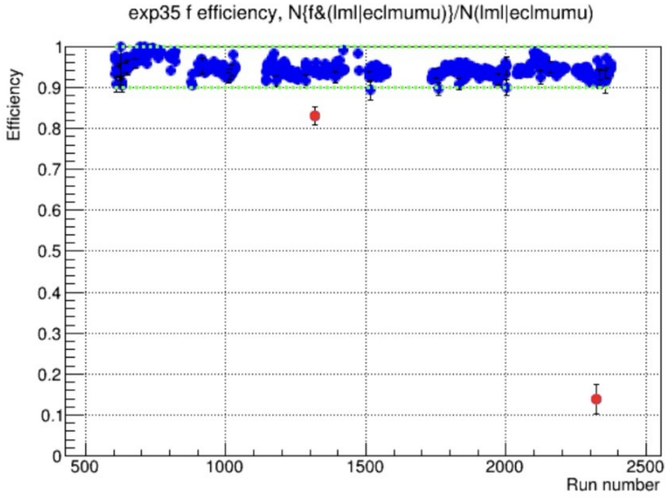
J. Yuan's Slide

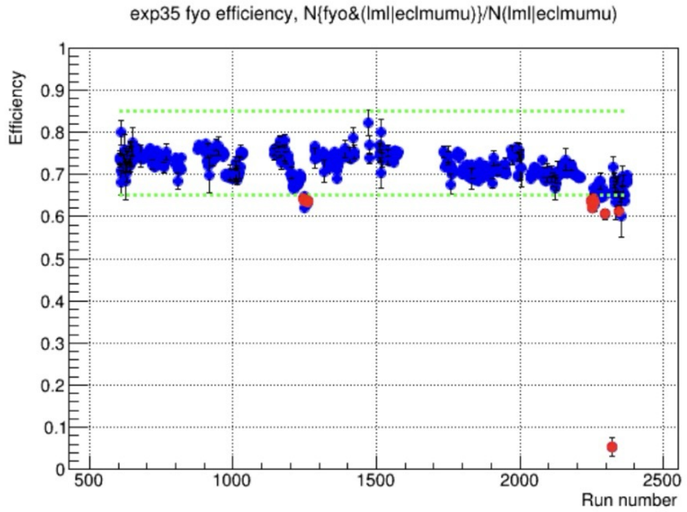
Bad runs



Bad runs

➢ Efficiency of f in run1317 is low as below. Strangely, another bit (like fyo) is fine. Pre-scale of f is very large, so Koga-san thinks the data can be used for analysis. Flag the exp35run1317 as RECOVERABLE. (it is short, 3minutes run.)

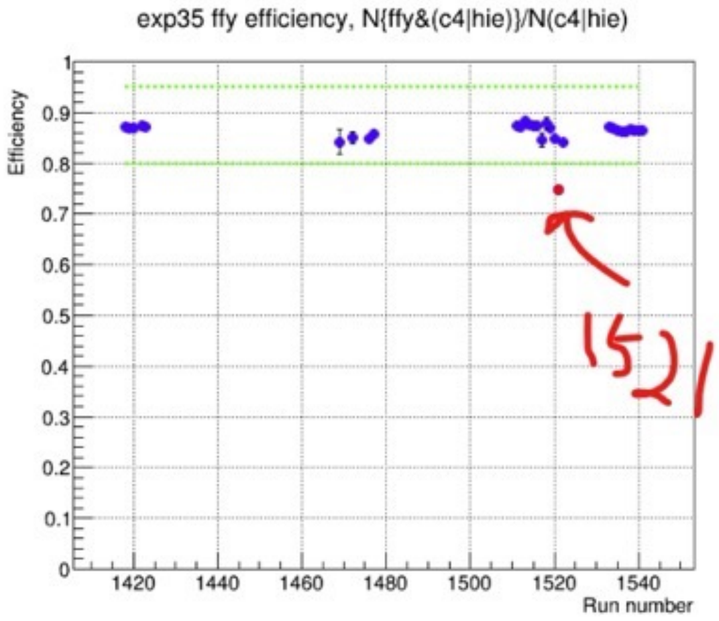


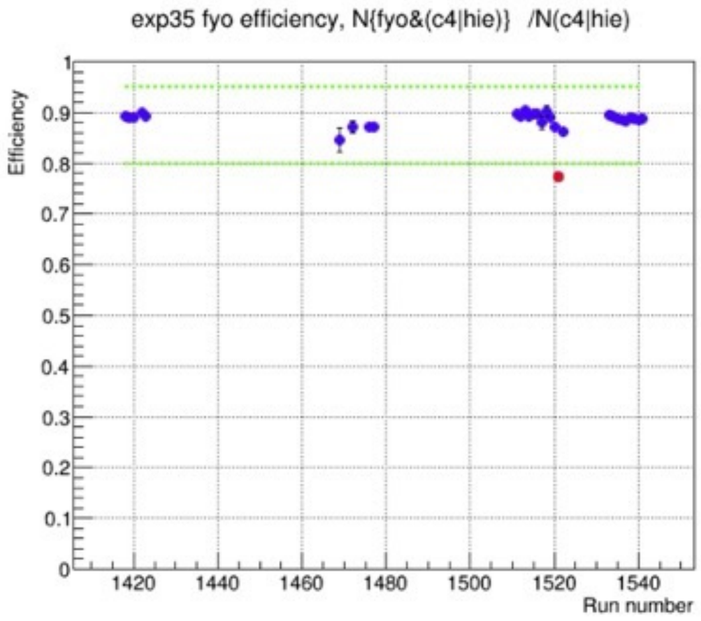


J. Yuan's Slide

Bad runs

- Flag the exp35run1521 as RECOVERABLE. Injection BG was very high at that time.





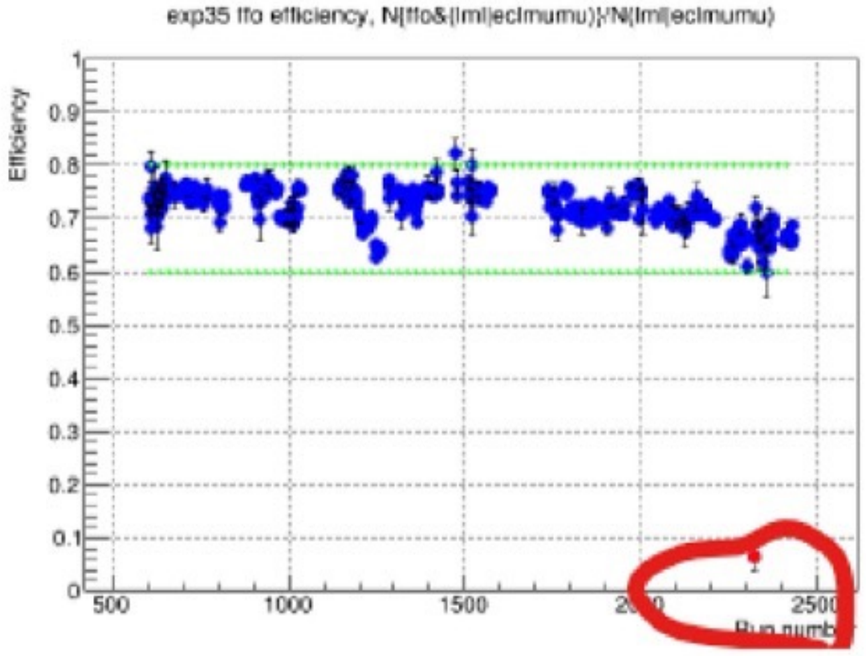
- Flag exp35run1836-1836 as BAD. KLM efficiency was low due to KLM detector issue.

J. Yuan's Slide

- Flag exp35run1971-1976 as RECOVERABLE. CDCTRG short track efficiency was low due to bad MGR.
- Flag exp35run2273-2274 as BAD. BKLMTRG efficiency was low. Reason is not understood yet.

Bad runs

- Flag exp35run2321 as BAD. Strange hadron/Bhabha. (Probably it is not TRG issue.)



- Flag exp35run2528~2529 as BAD. Low KLMTRG efficiency.

Trigger rate status in 2024c

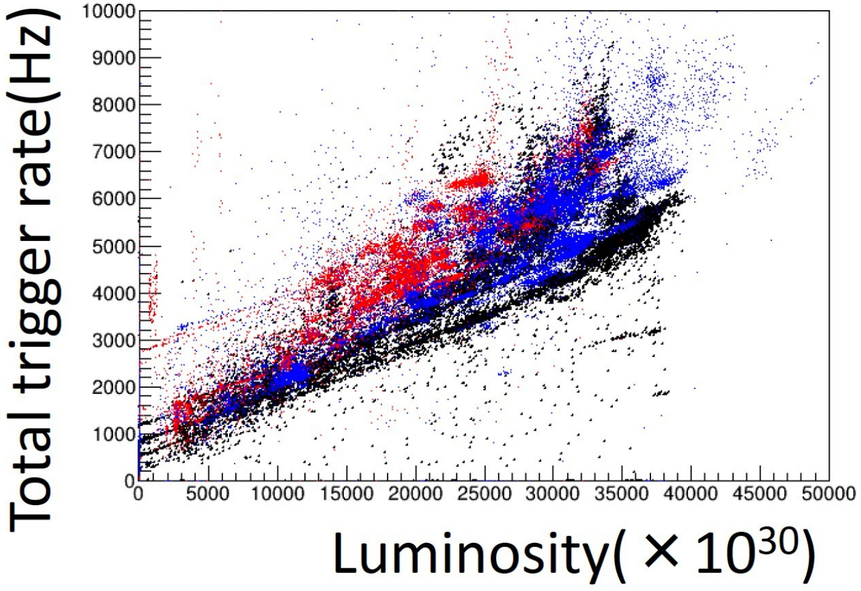
T. Koga's Slide

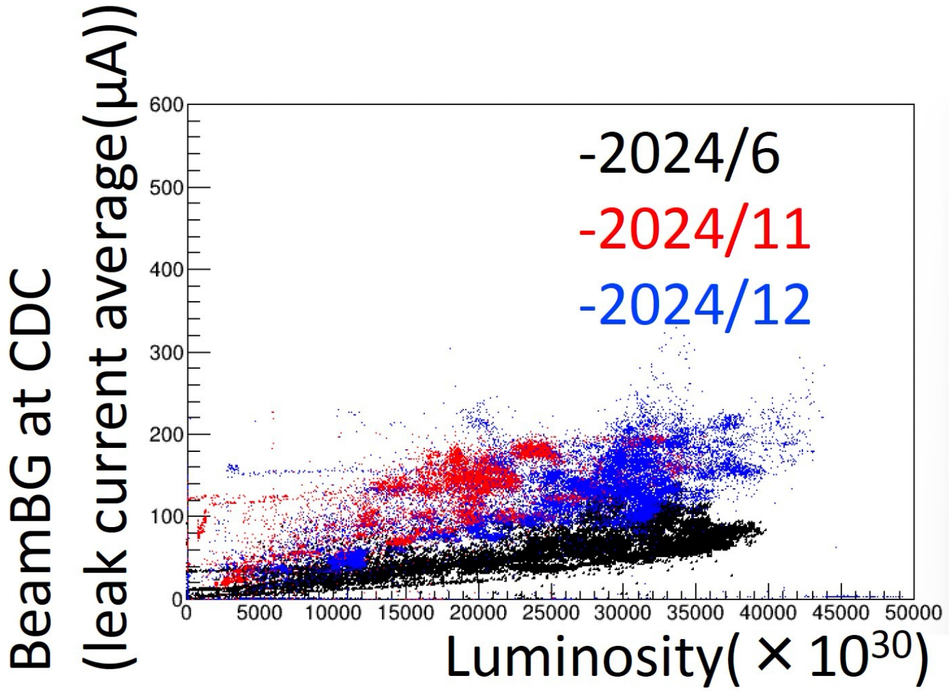
-Trigger rate in 2024c was 1~1.5 times larger than 2024ab

-Beam background in 2024c was 1.5~4times larger than 2024ab

-Trigger rate in 2024c was ~8kHz at maximum.

-Lower than DAQ limit (~20kHz)

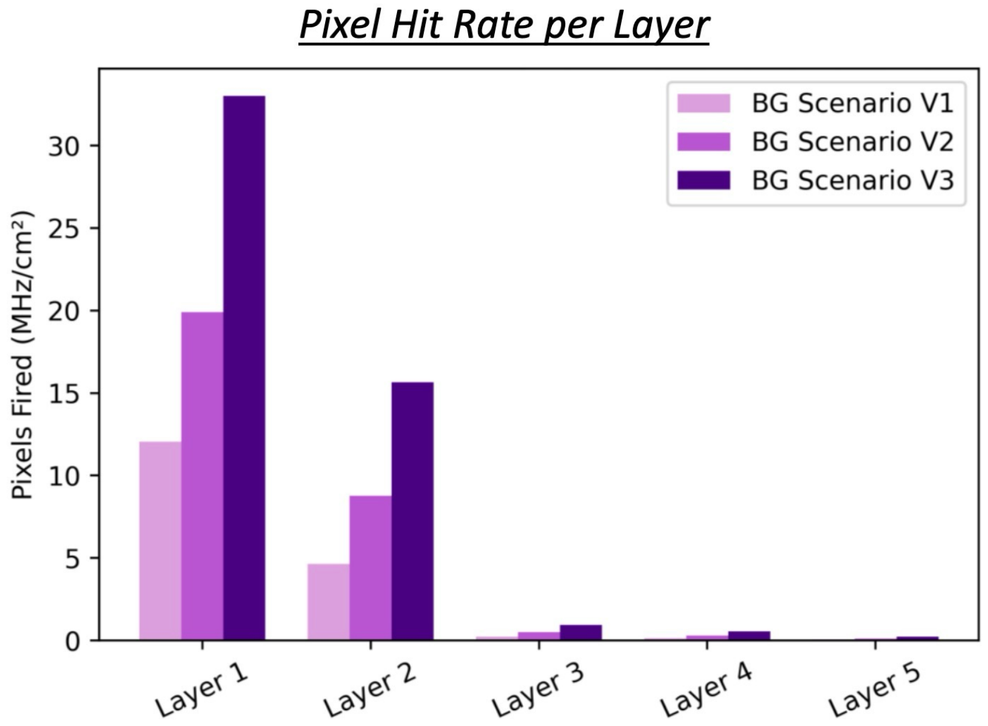




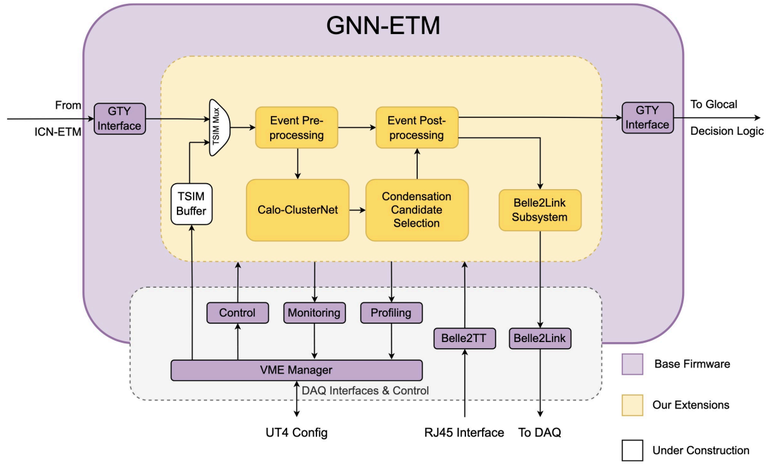
M. Maushart's Slide

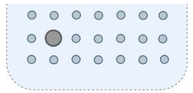
XVI.Background Scenarios

- 3 BG Scenarios considered at $\mathcal{L} = 6.0 \times 10^{35}\ cm^{-2}s^{-1}$ in CDR :
  - V1/V2/V3 : Optimistic/ Intermediate/ Conservative

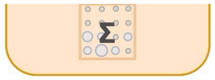


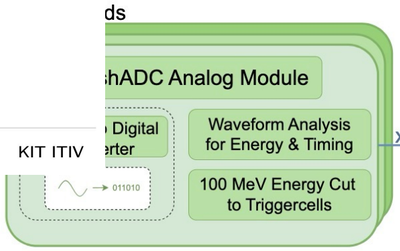
The GNN-ETM





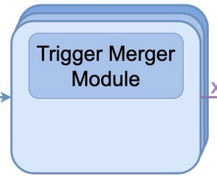
L1 Trigger Input
Full ECL





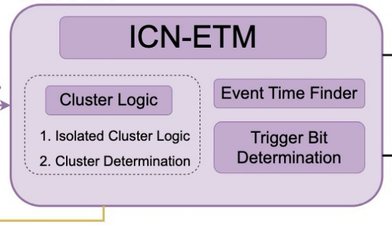
x 52

x 7 Boards

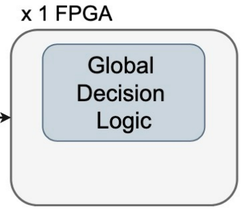


x 7

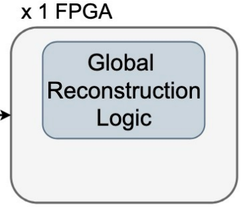
x 1 FPGA



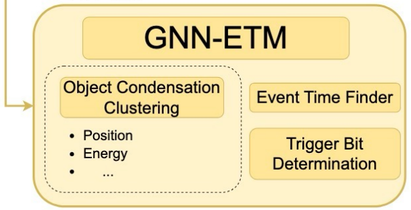
x 1 FPGA



x 1 FPGA



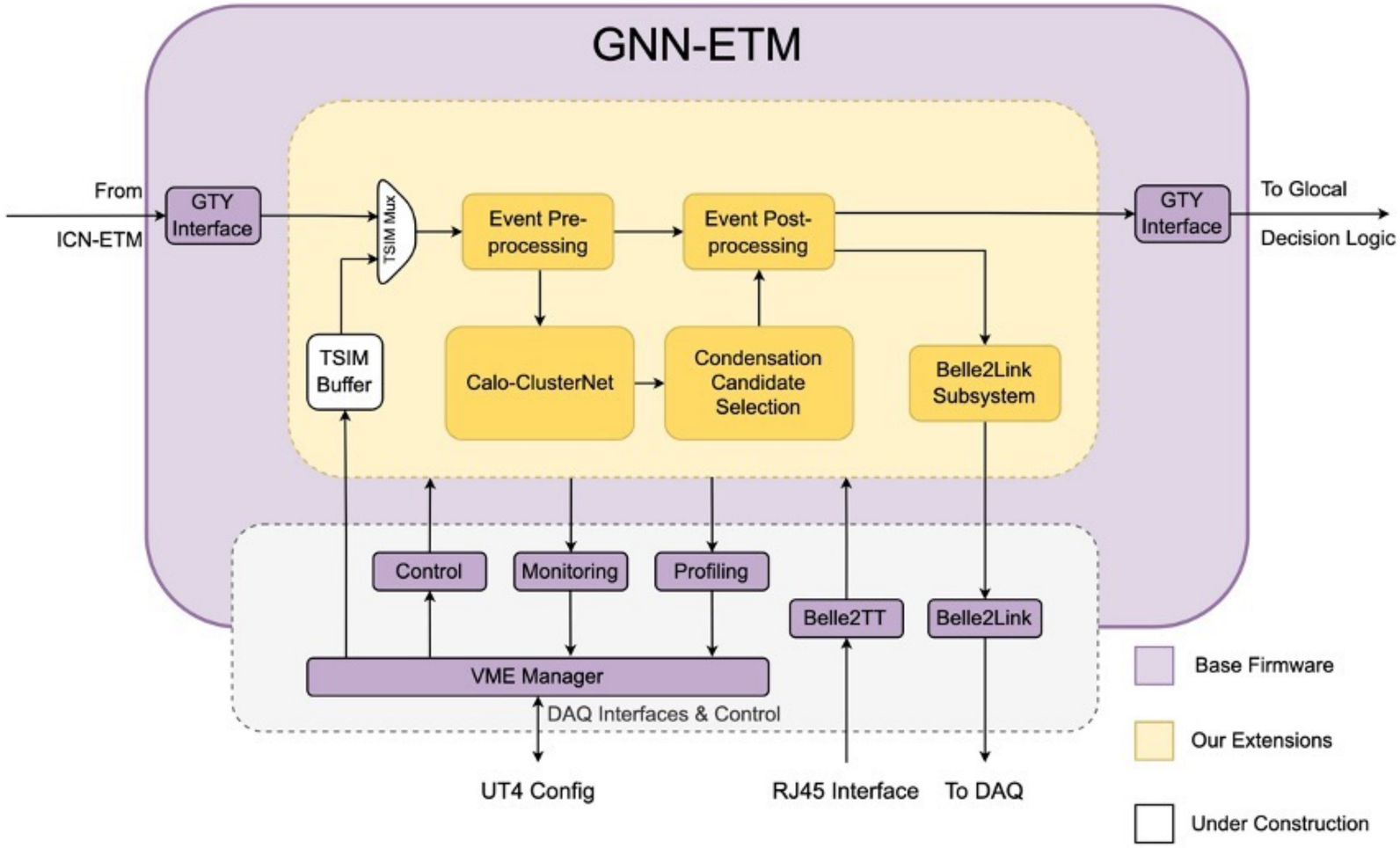
x 1 FPGA



M. Neu's Slide

The GNN-ETM

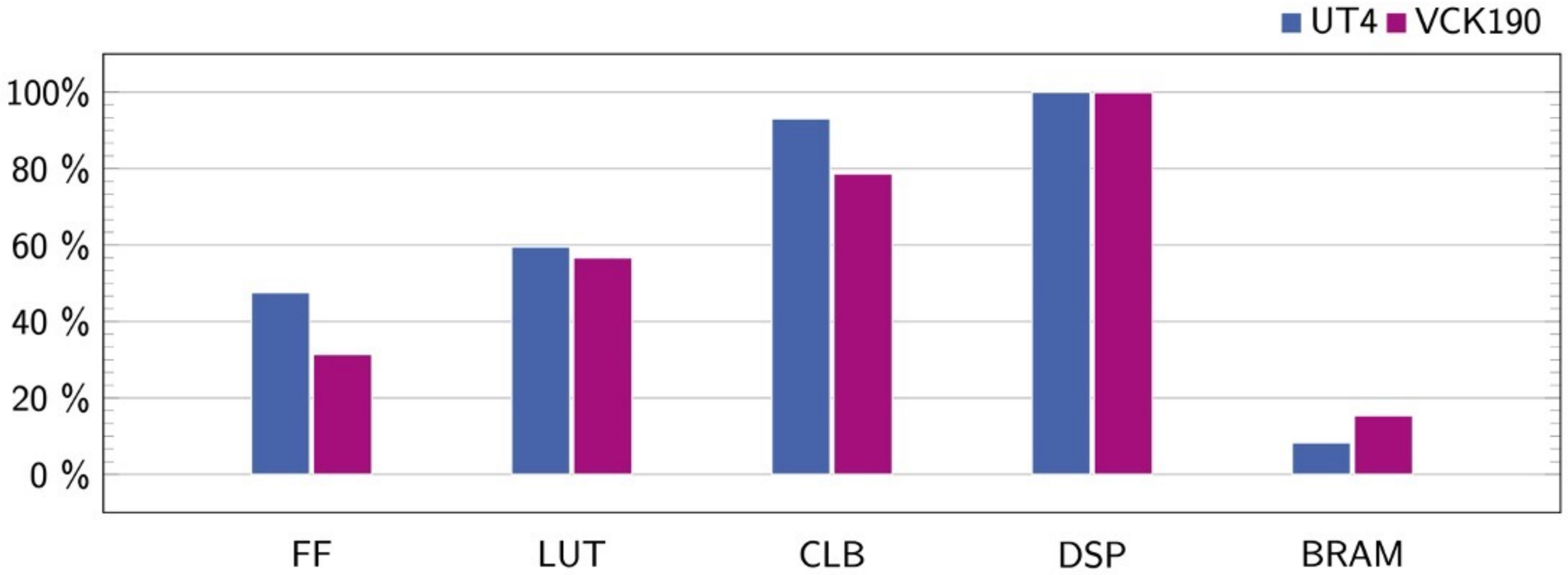
M. Neu's Slide



VCK190 Implementation

M. Neu's Slide

- I have implemented the CaloClusterNet on the AMD VCK190.
- No utilization of AI-Engines.
- The implementations required around 3 h.



Control-Level Behavioral Simulation M. Neu's Slide

- We identify test cases for various operation conditions: Writing registers, link instabilities, transmission of B2Link packets.
- I have written test cases in CoCoTb using Python. QuestaSim 2023.4 for all simulations.
- In the future, solved bugs will receive a specific test case which covers the issue.