Data analysis for iRPC BE/TRG Beam Test

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19th.Nov.2023

Outlook

- Introduction of RPC Phase-2 Upgrade Project
- Overview of iRPC Backend Firmware Design
- Introduction of CSP
- Overview of iRPC GIF++ Beam Tests
- Data Analysis
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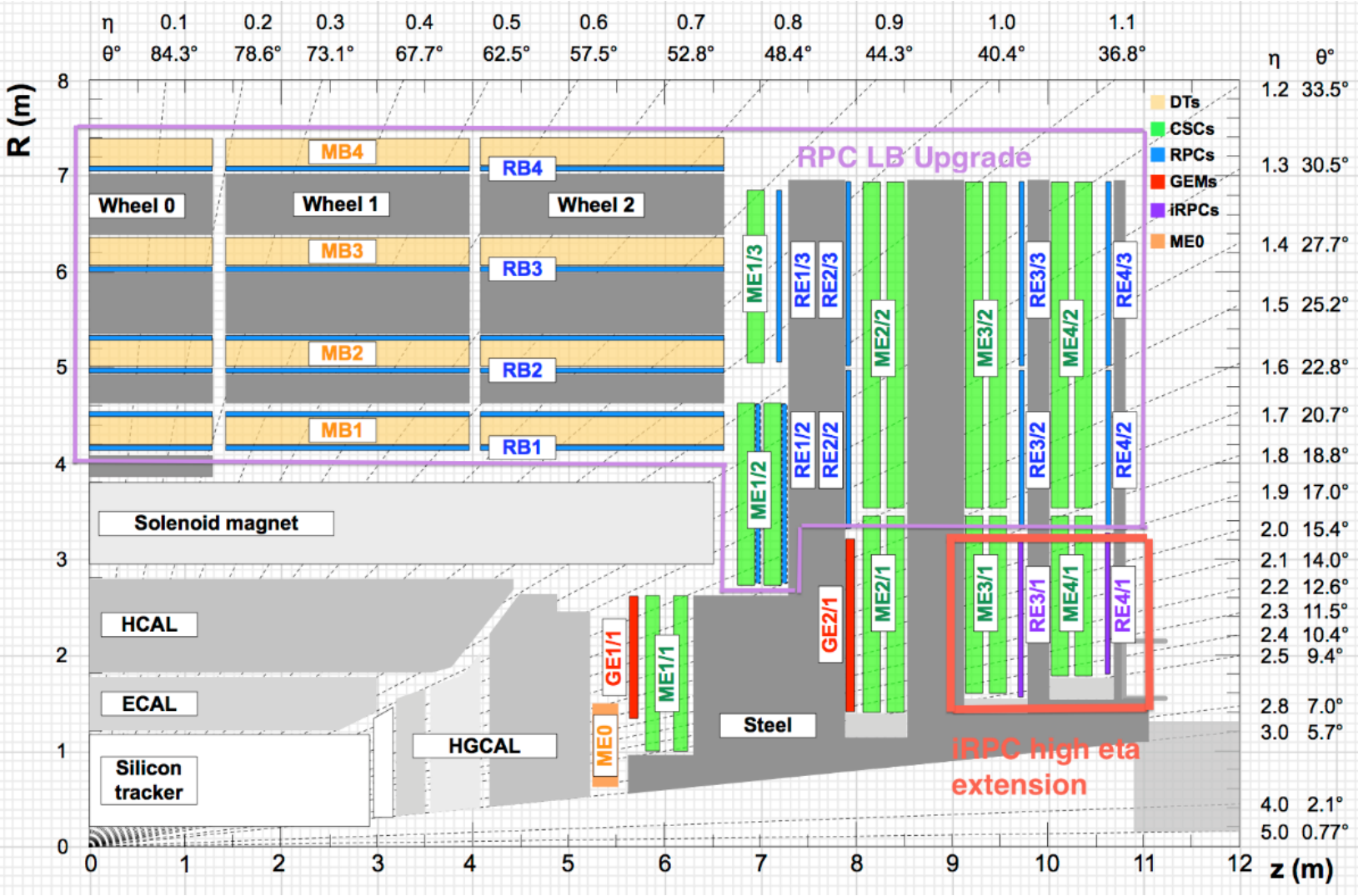
  - Sending Delay
- Summary

Introduction of RPC Phase-2 Upgrade Project

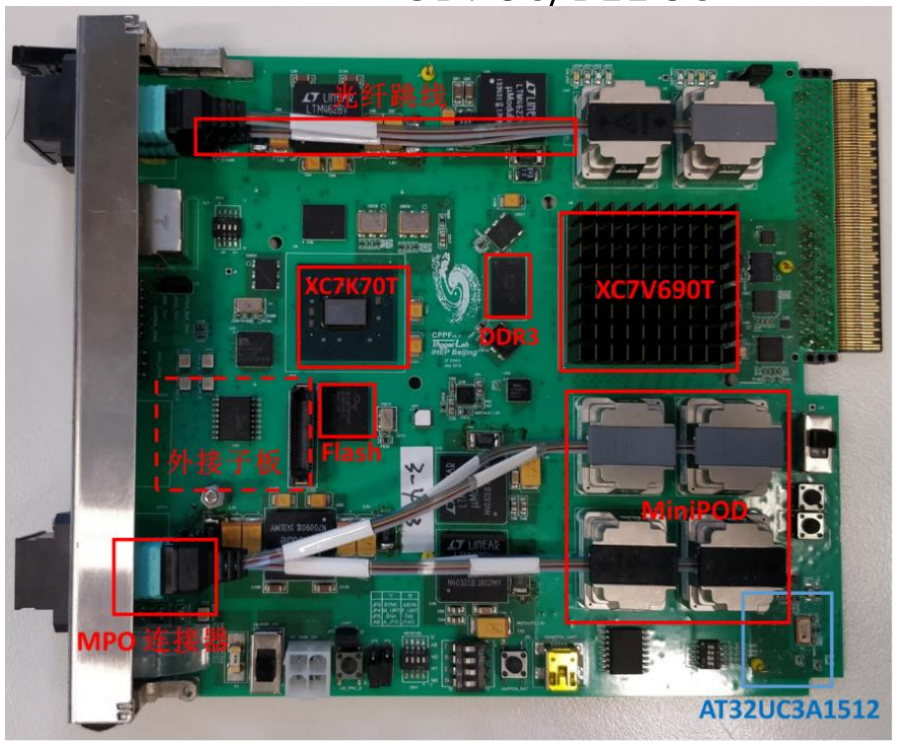


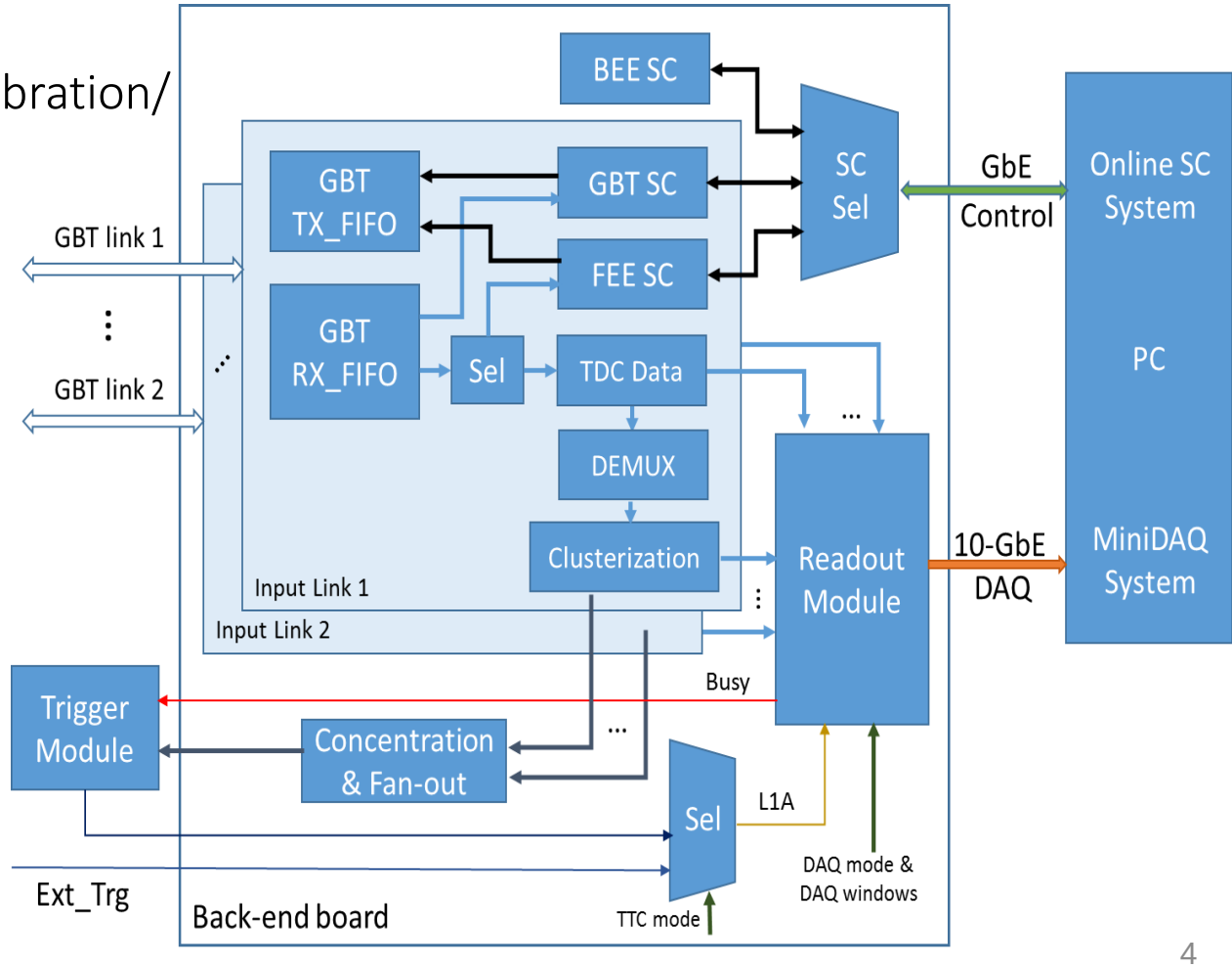
- New electronics for legacy detector
  - Upgrade of Link System to improve timing resolution for existing RPC ($|\eta| < 1.9$)
- New detector: improved RPC (iRPC)
  - Extend the RPC coverage up to $|\eta| = 2.4$ to increase redundancy in high eta region in stations 3 and 4

Overview of iRPC Backend Firmware Design

Backend Firmware Design

- GBT protocol: Hit and control information
- Trigger pre-process : Demux and cluster finding
- DAQ: multi-link integration
- Fast/Slow control: Timing reference- BC0 / Delay calibration/ GBT SC/BEE SC



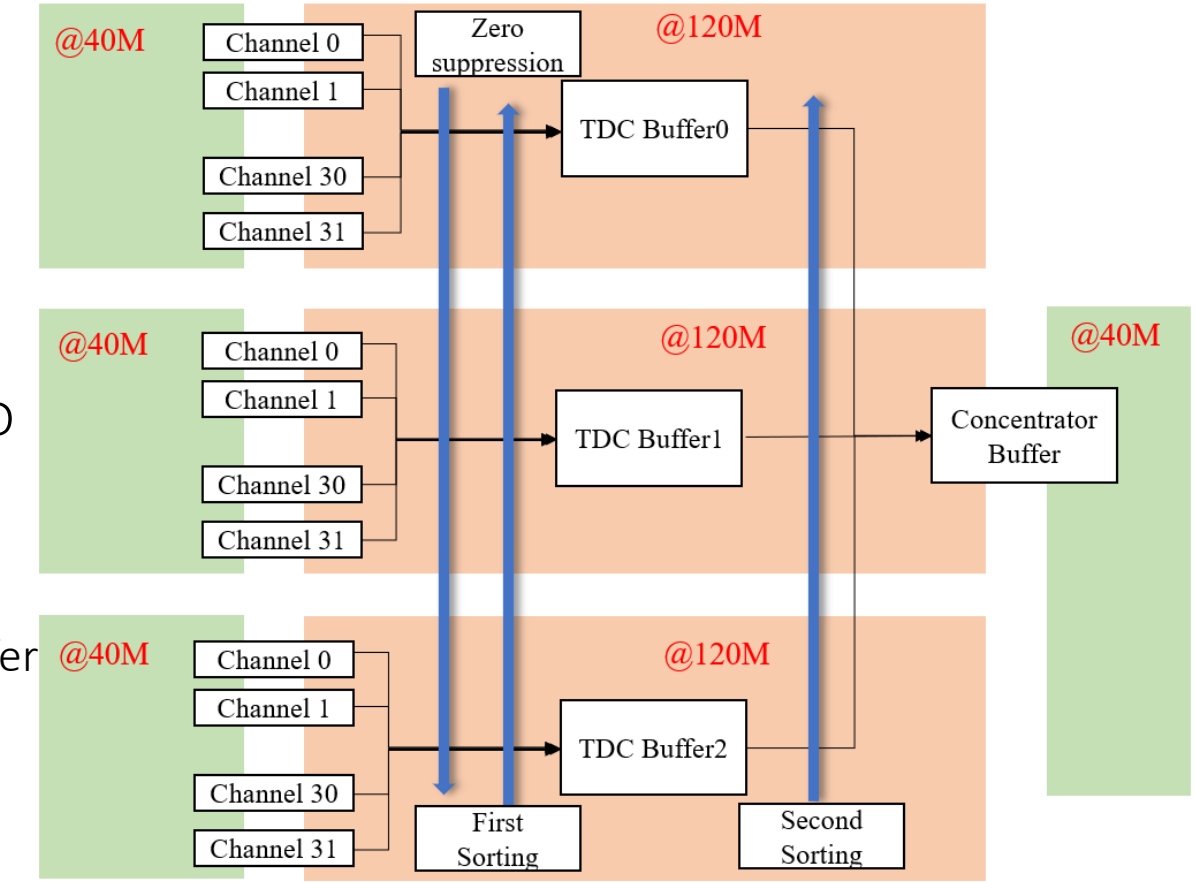


Introduction of CSP

- Based on data analysis results of cosmic test in 904, we find FEB sending mechanism is not suitable
- **Previous FEB sending mechanism**:
  - Data with smaller FPGA ID and channel ID have the higher priority to be transmitted
  - Data with bigger channel ID will be delayed transmitted
- Disadvantages:
  - Need bigger DAQ receive windows and more firmware source
  - Lost good hits information in high gamma background
- We proposed a new sending mechanism: CSP(Check- sort- Push)
  - More detailed information about CSP: https://indico.cern.ch/event/967463/contributions/4071622/attachments/2126016/3579438/RPC_electronic_meeting_20201020.pdf

Introduction of CSP

- What is CSP(Check-Sort-Push)?
  - Data with earlier generation time will have higher priority to be transmitted which is the fundamental difference with previous FEB sending mechanism
  - Check
    - Data with generation time(in BX) and channel ID
    - Sequential readout with digitizing clock
  - Sort
    - First sorting by generation time before moved to buffer
    - Second sorting by generation time in the merge module before moved to concentrator buffer
  - Push
    - Sending frame per BX



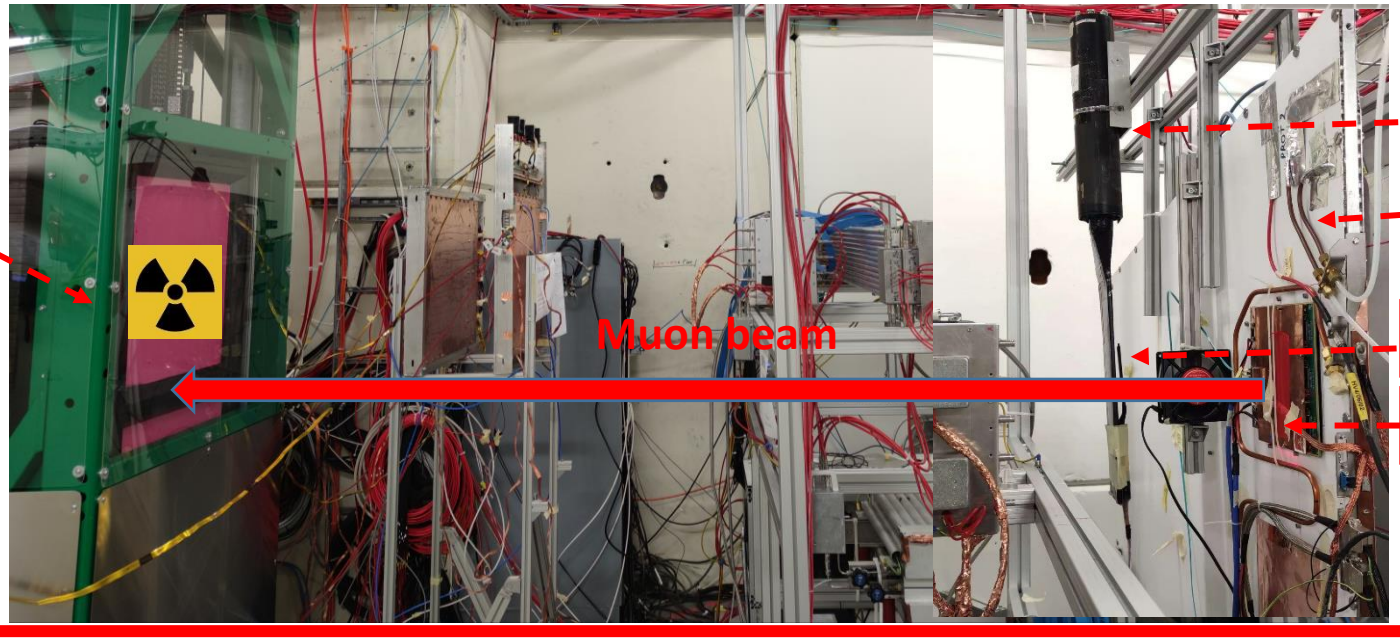
Overview of iRPC GIF++ Beam Tests

Three GIF++ beam test (2022.10 – 2023.10)

- Verify the function of iRPC system under different gamma background
- Verify the timing reference alignment function of backend firmware
  - More detailed information about this in **2023 CMS China**: https://indico.ihep.ac.cn/event/19532/contributions/135837/attachments/69837/83991/iRPC%20BETRG%20Beam%20tests%20in%20GIF.pdf
- Study the system efficiency/sending delay with/without CSP

Overview of iRPC GIF++ Beam Tests

GIF++ System Setup

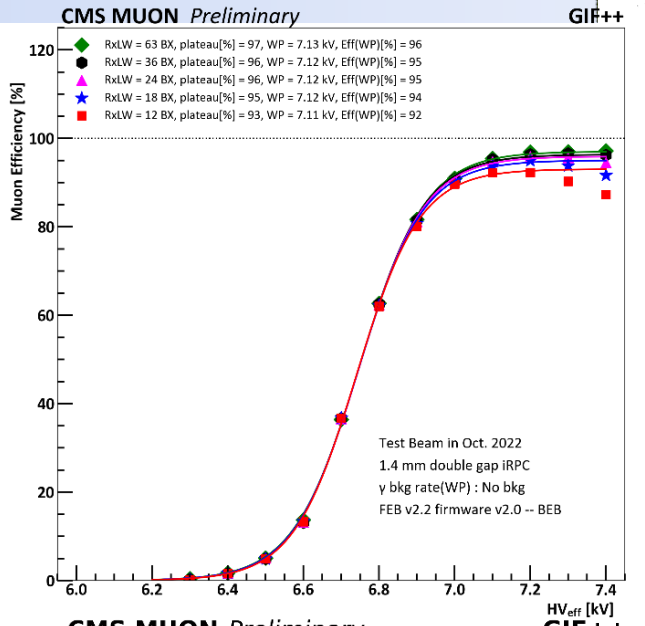


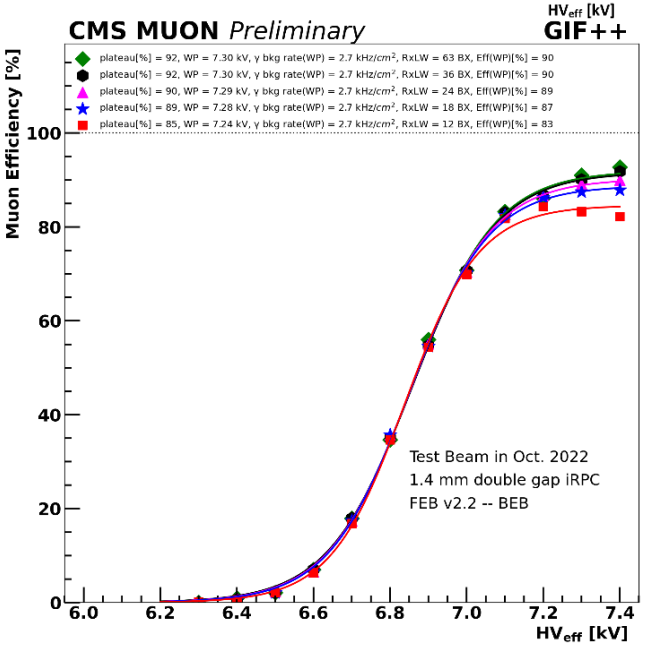
Data Analysis – Efficiency

- **Purposes:**
  - Verify the function of iRPC system under high gamma background
  - Study the system efficiency without CSP
- **Data source :** Beam data in GIF++ in Oct.2022
- **Definition:**
  - Efficiency = good event number/ total event number
  - Good event: At least one hit whose position in the scintillator area in one event
- **Methods:**
  - Reconstruct: hit position based on both-ended timestamps and propagation speed in the strip
  - Check: good event selection based on scintillator area
  - Repeat: calculate efficiency in different high voltage
  - Fit: S curve

Data Analysis – Efficiency

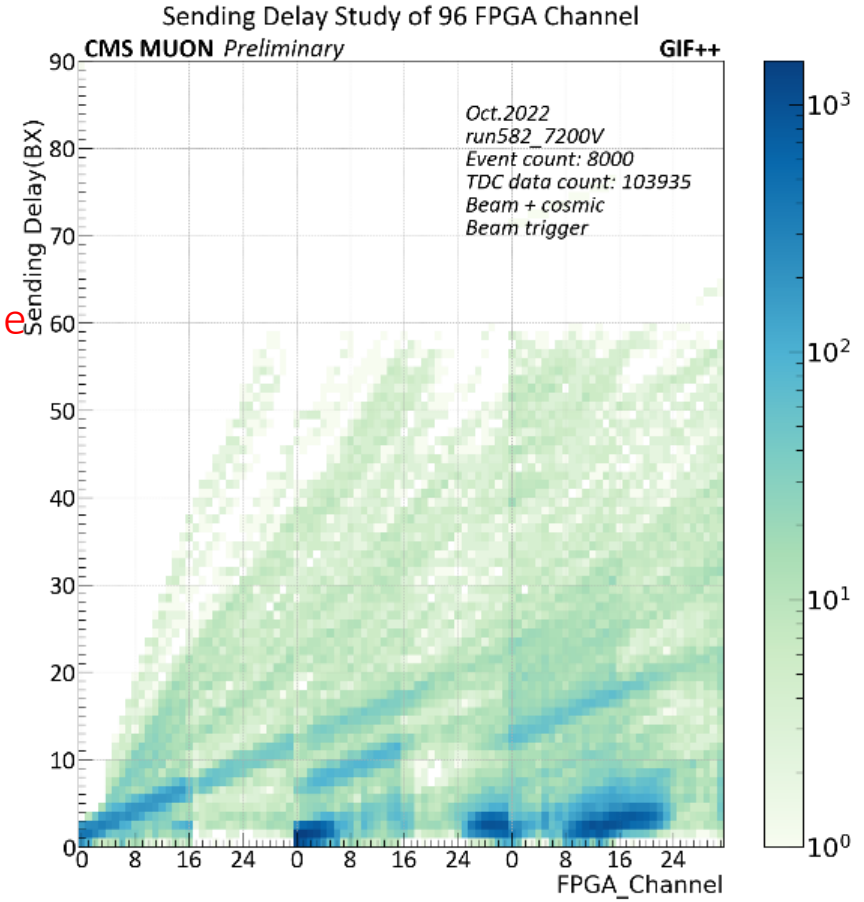
- **Results:**
  - The backend works normally under different gamma background
  - The efficiency of RxLW (Receive Latency Window) 12 BX under different gamma background rate is low without CSP
- The low efficiency of RxLW 12BX means that some good hits are delayed by more than 12 BX
- **Further Verification :** Study the sending delay





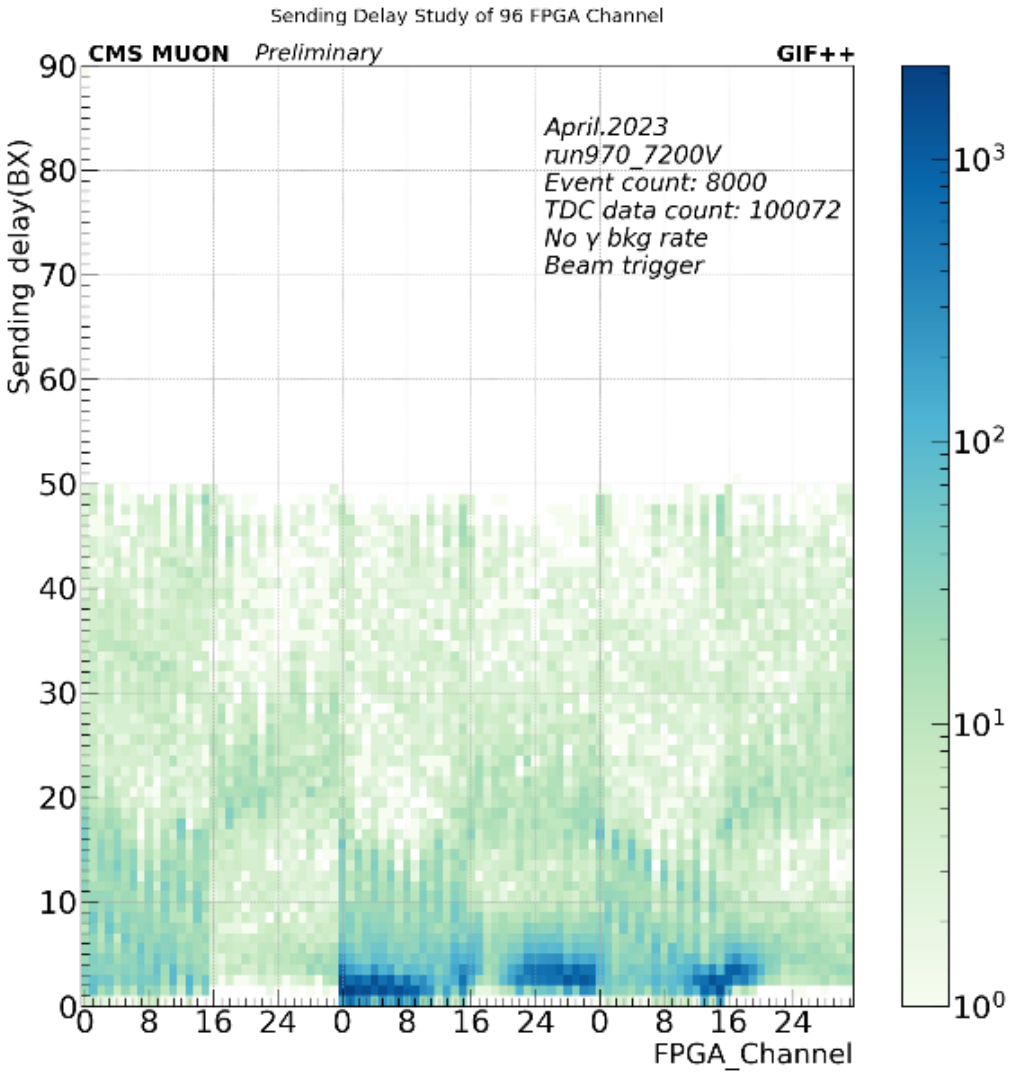
Data Analysis – Sending Delay

- **Purposes:**
  - Verify the relationship between Channel ID and sending delay
  - Study the distribution of tdc data sending delay
- **Data source :** Beam data in GIF++ in Oct.2022
- **Definition:**
  - Sending delay(BX): The difference of tdc data sending time and generation time
- **Methods:**
  - Check for the channel number and sending delay value of every tdc data
  - Repeat and get all sending delay value from 8000 events
- **Results:**
  - FEB data sending mechanism is verified
  - Data with smaller FPGA ID and channel ID have the higher priority to be transmitted without CSP



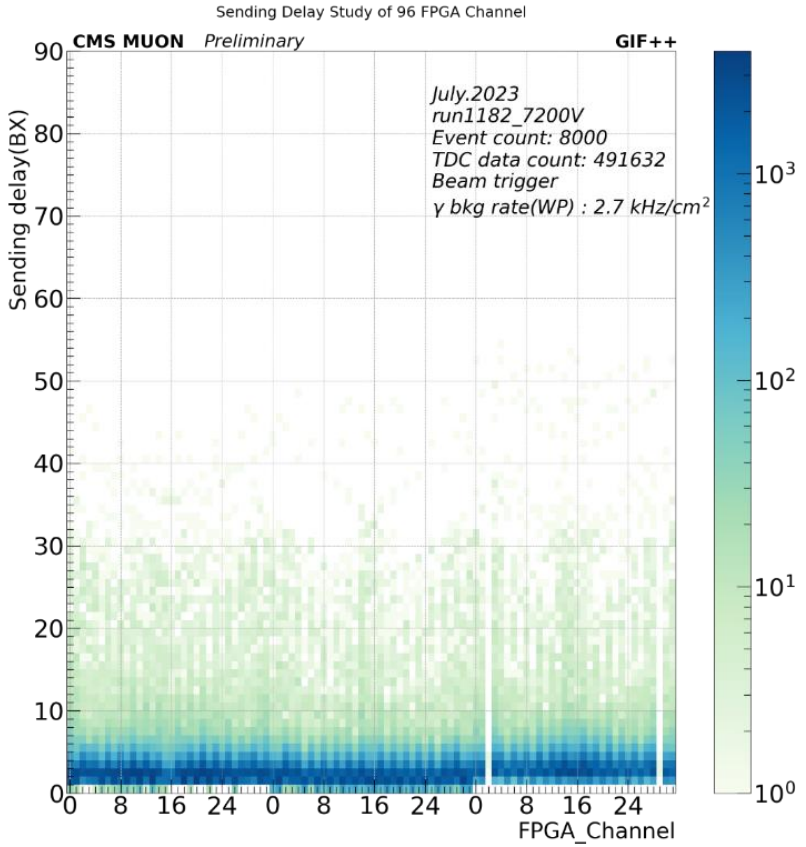
Data Analysis – Sending Delay

- For GIF++ test in April.2023, FEB firmware have developed the preliminary CSP mechanism which only have the first sorting
- The max sending delay is smaller than before
- However, the max sending delay is still bigger than desired effect
- Finding there are lots of single-ended TDC data in some events



Data Analysis – Sending Delay

- After discussion, we try to use the new function of FEB firmware – Pair filtering and remove single based preliminary CSP
- In GIF++ test in July.2023, **the results are following**:
  - The sending delay of data is mainly smaller than 30 BX even in high gamma background with preliminary CSP
- Now the FEB firmware only develops the first sorting, the sending delay will be further smaller after second sorting developed as expected. And we will further discuss the corresponding implement with FEB team
- Further study will continue to focus on sending delay and efficiency with complete CSP



Summary

- iRPC backend electronics features are complete
  - GBT links、Trigger pre-process、DAQ、Fast/Slow control
- Three GIF++ tests have been done. iRPC system runs stably, and the BEE functions are stable and reliable under high gama background
- The efficiency of RxLW 12 BX under different gamma background rate is low because of previous FEB sending priority
- Based on preliminary CSP, the sending delay is smaller than before, but did not achieve the desired effect
- Preliminary CSP obviously reduced the data sending delay by removing single function
- Further study will continue to focus on sending delay and efficiency with complete CSP

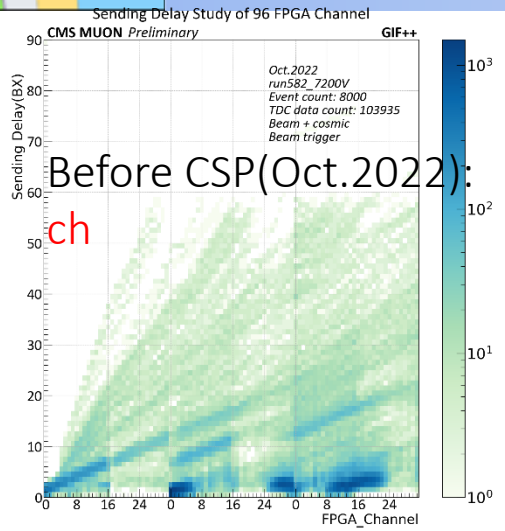
Thanks!

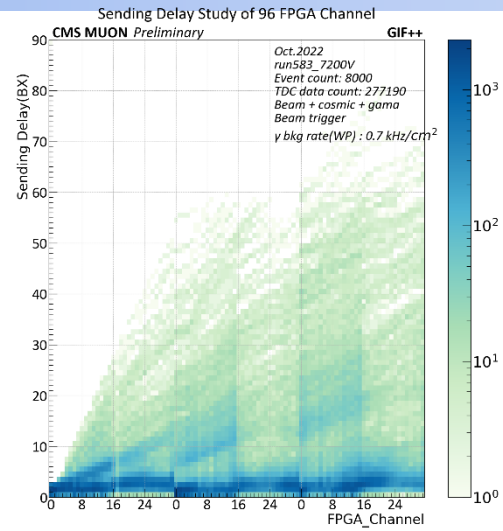
Backup

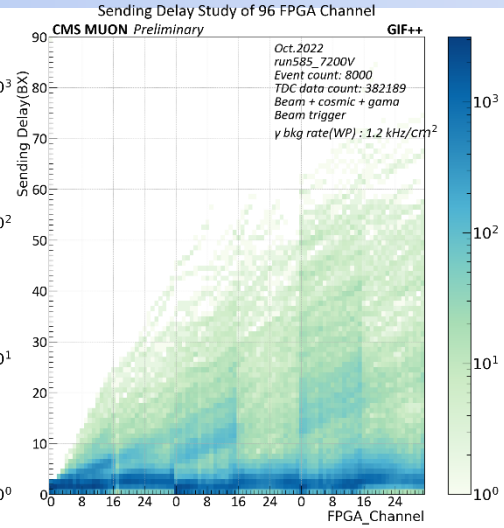
Sending Delay Study

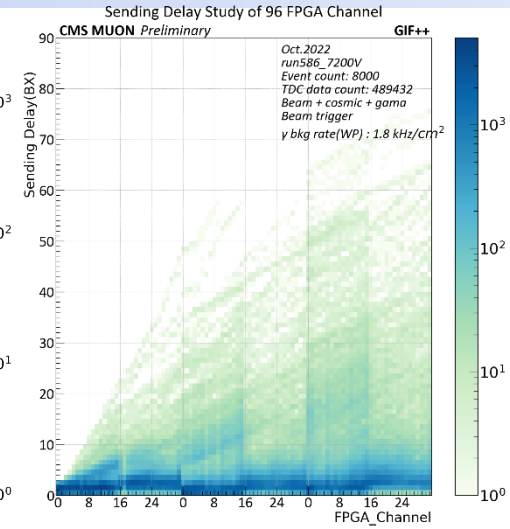
Before CSP(Oct.2022):

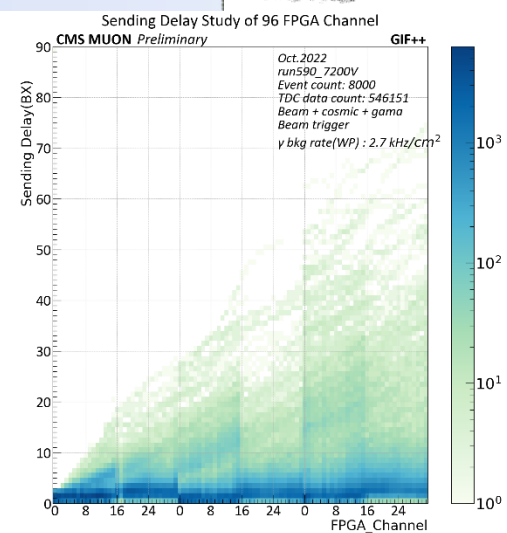
ch





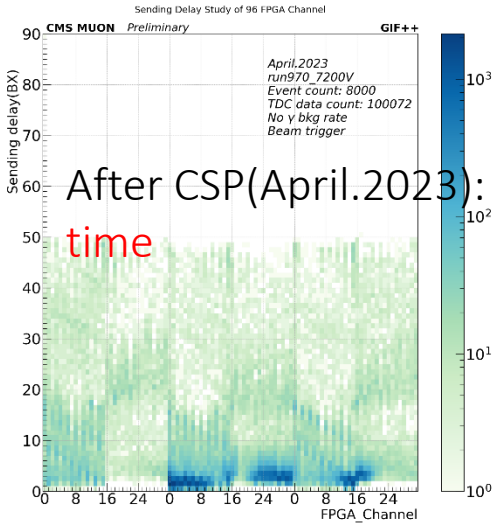


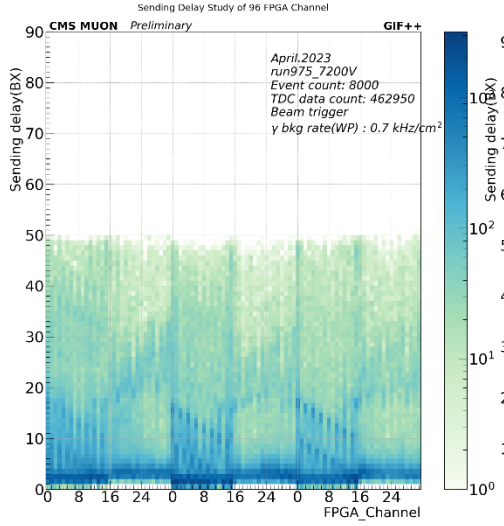


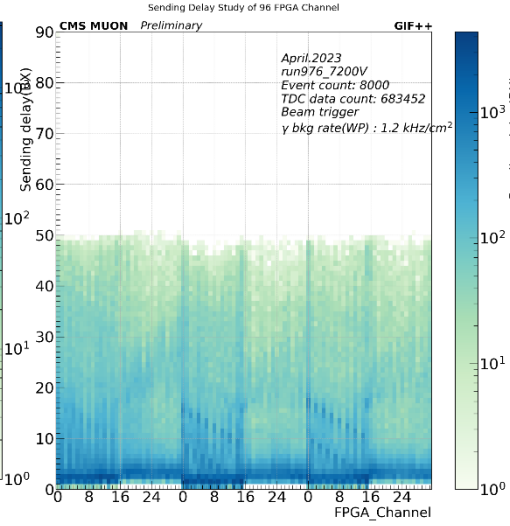


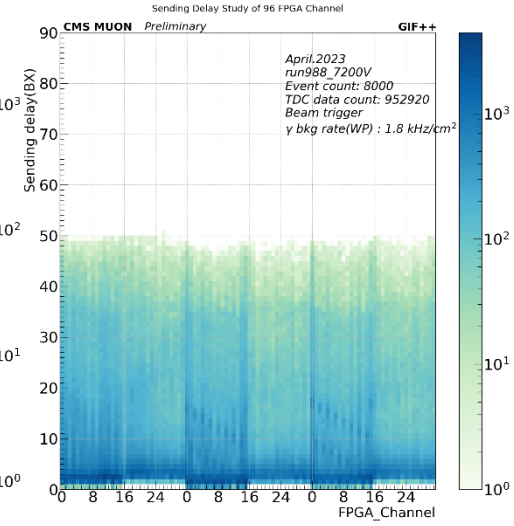
After CSP(April.2023):

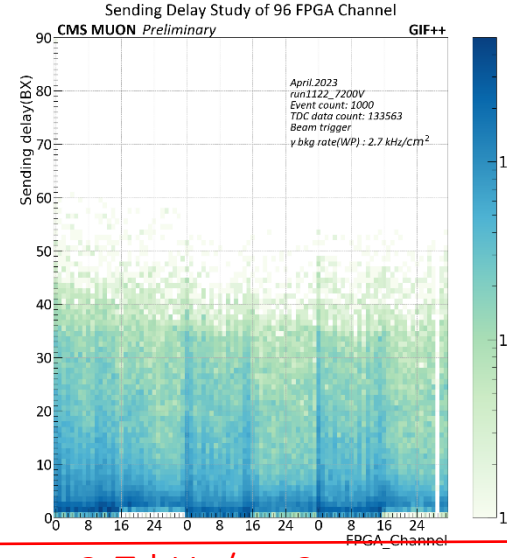
time











No gamma

0.7 kHz/cm2 gamma

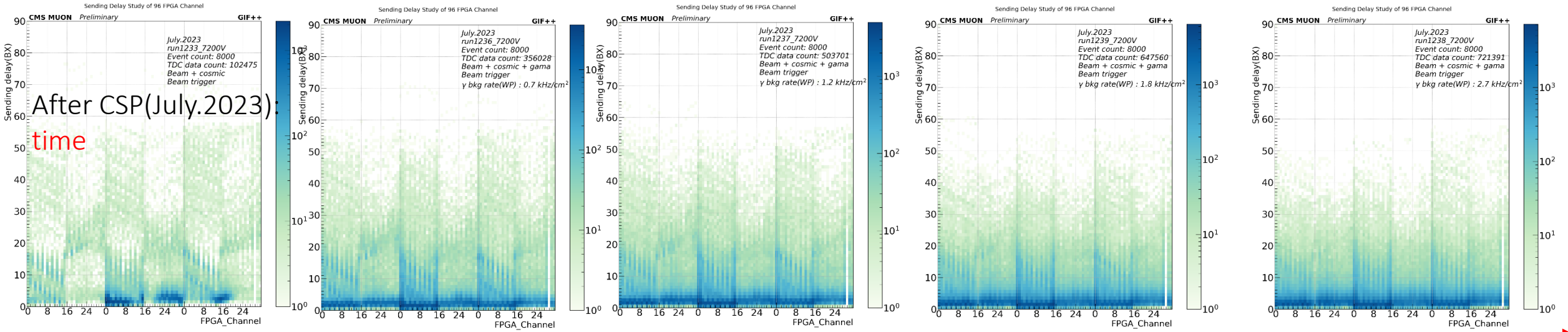
1.2 kHz/cm2 gamma

1.8 kHz/cm2 gamma

2.7 kHz/cm2 gamma

Gamma Rate

Sending Delay Study



After CSP(July.2023):

time

No gamma | 0.7 kHz/cm2 gamma | 1.2 kHz/cm2 gamma | 1.8 kHz/cm2 gamma | 2.7 kHz/cm2 gamma

Example

FROM SAME PETIROC

the last fired ch

Time unit: ns

CH:	0	1	2	3	4	5	6	7	8	9	10	11
HR:	88567.5	88567.7	88567.7	88567.8	88567.8	88567.6	88567.7	88567.7	88567.7	88567.6	88567.5	88566.4
LR:	0	0	0	0	0	0	0	0	0	0	0	0
CH:	12	13	14	15	16	17	18	19	20	21	22	23
HR:	88567.5	88566.0	88566.0	88565.8	0	0	0	0	0	0	0	0
LR:	0	0	0	0	0	0	0	0	0	0	0	0
CH:	24	25	26	27	28	29	30	31	32	33	34	35
HR:	0	0	0	0	0	0	0	0	0	0	0	0
LR:	0	0	0	0	0	0	0	0	0	0	0	0
CH:	36	37	38	39	40	41	42	43	44	45	46	47
HR:	0	0	0	0	0	0	0	0	0	0	0	0
LR:	0	0	0	0	0	0	0	0	0	0	0	0

the first fired ch

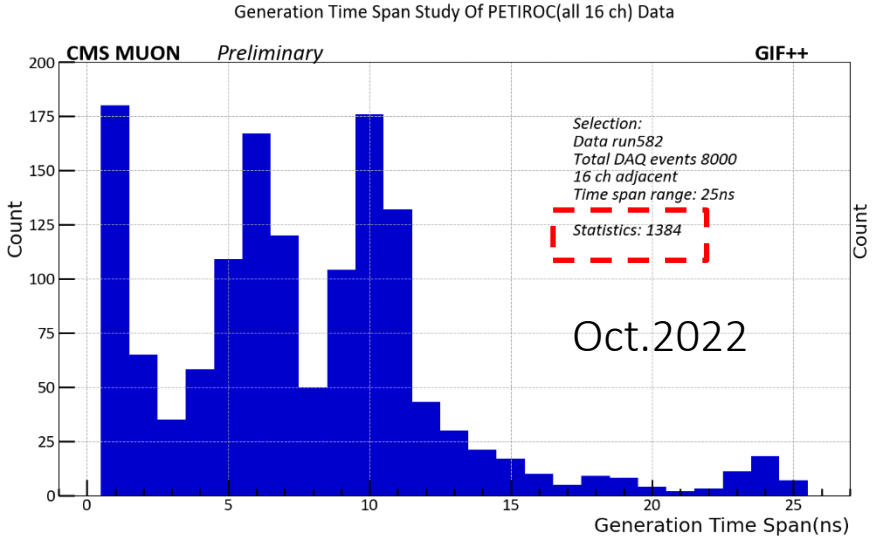
- Only HR(high radius) channels have signal, the other side(LR: Low radius) has nothing from the same Petiroc
- Generation time span(ns) = 88567.8 – 88565.8 = 2.0 ns
- Petiroc: ASIC reads the strips and digitizes incoming signal, producing trigger signals to the FPGAs. Every Petiroc is responsible for 16 channel from only HR/LR

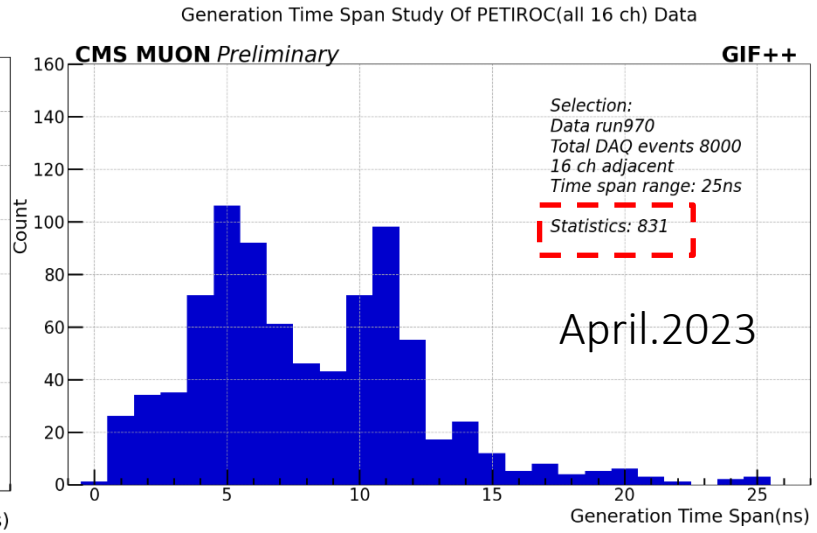
Data Analysis – Petiroc Cross Talk

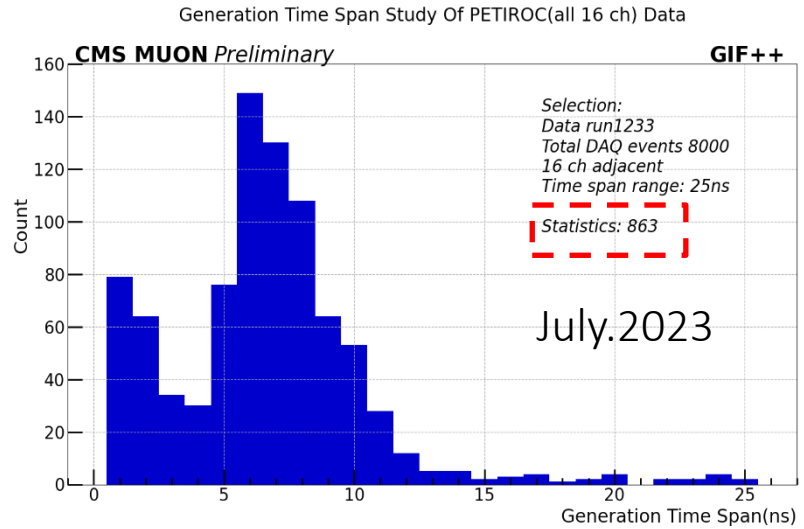
- From single-ended TDC events, we tried to study further so-called “crosstalk” event for channel all fired phenomenon with 3 GIF++ tests data
- **Data source & configuration :**
  - Beam(without gamma) data in GIF++
  - Time: Oct.2022/April.2023/July.2023
- **Definition:**
  - Generation time span: Difference of the timestamps from the first fired channel and the last fired channel
- **Methods:**
  - Check number of petirocs with all fired channels(16 ch) from 8000 events
  - Calculate the generation time span of 16 fired ch and get the distribution

Data Analysis – Petiroc Cross Talk

- Results :







	Rate of Event with "Cross talk" (Events with Cross talk/8000)
Oct.2022	6.8%
April.2023	4.6%
July.2023	5.2%

- The generation time span of 16 fired channel mainly ranges from 1 to 15 ns
- Conclusion: "Crosstalk" could be defined as 16 fired channels within 15ns
- Rate of event with Petiroc "cross talk" is estimated as listed in the left table
- Lead to bigger sending delay because of events with so much single-ended TDC data