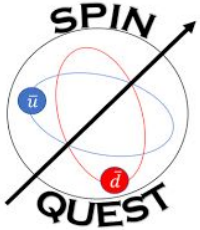
Displaced dimuon trigger and hodoscopes status

DarkQuest Collaboration meeting
Oct-20th-2023
Zijie Wan



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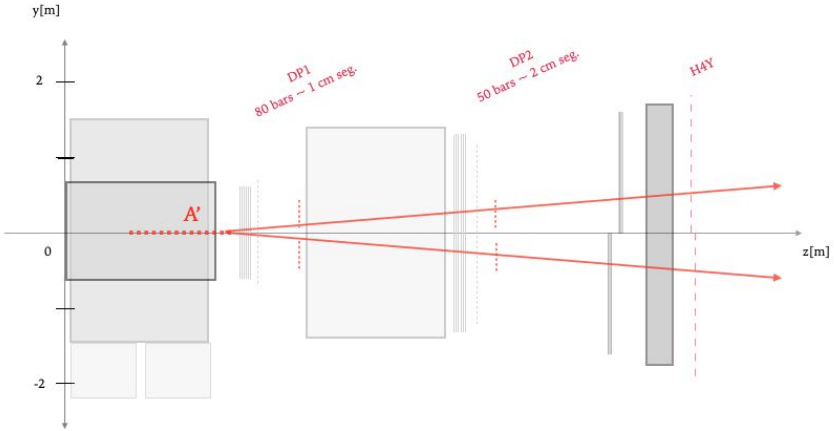
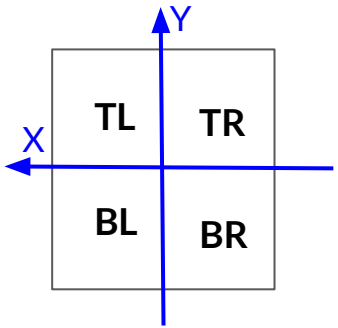
Displaced dimuon trigger algorithm





- Applying two dark photon fiber hodoscopes to improve the trigger efficiency on displaced signals.
- Trigger fires if hits are in the same quadrant for DP1, DP2, and H4Y detector.
- Z-vertex reconstruction can be made based on the hit positions on DP1 & DP2.

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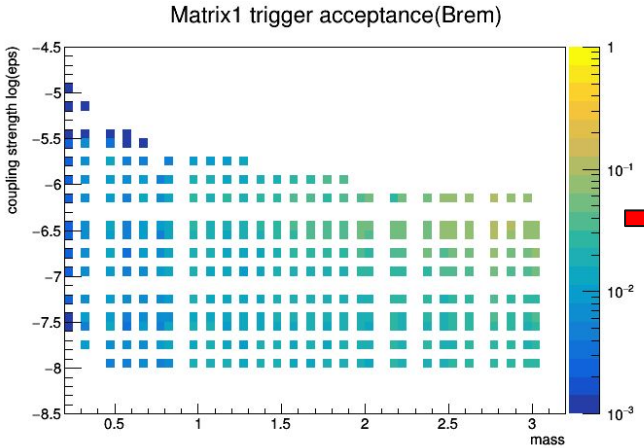
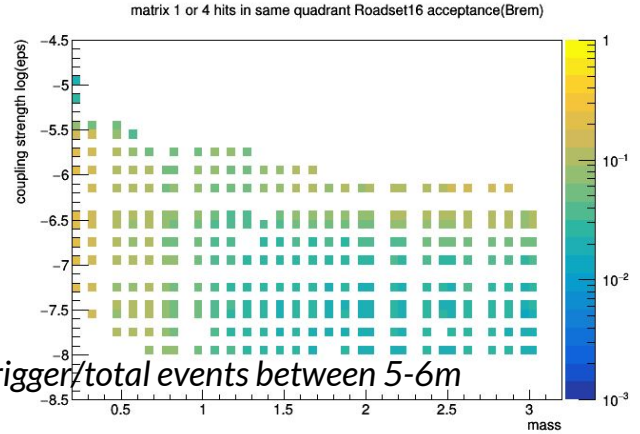
Specific road & background rejection



Trigger eff improvement

Bremsstrahlung channel



eff = events # pass the fpga trigger/total events between 5-6m

- Specific trigger road is defined by 4 coincidence fiber hodoscope hits in the same quadrant: (dp1_hit_elmID1, dp1_hit_elmID2, dp2_hit_elmID1, dp2_hit_elmID2)
- Rule out all of the road hitted by ~140k NIM3 triggered events in 2017 experimental data.
- Choose 4096 most frequent hitted roads for each quadrant by signal files.

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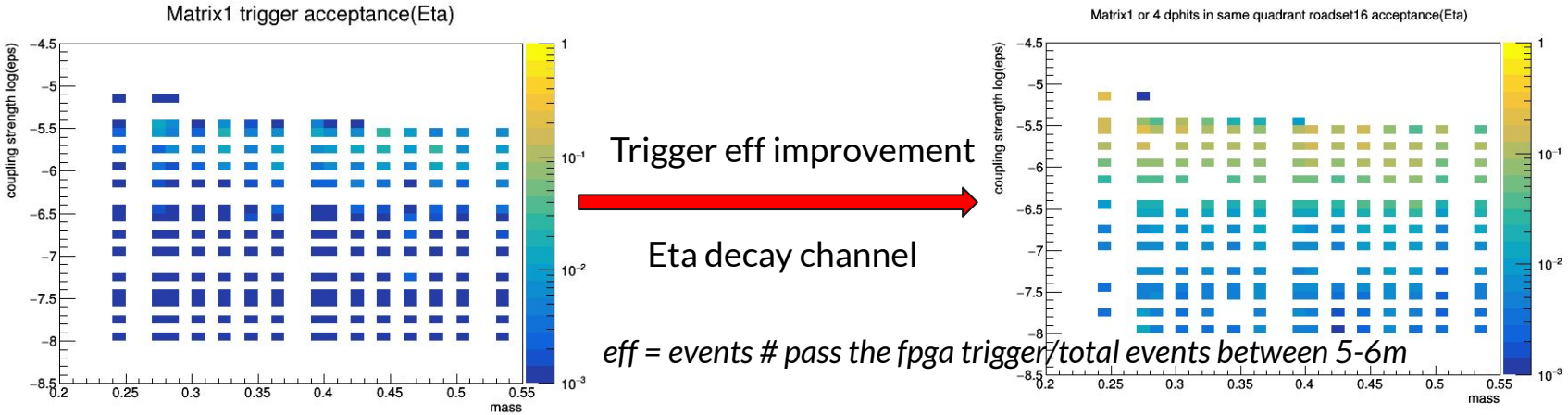
Specific road & background rejection



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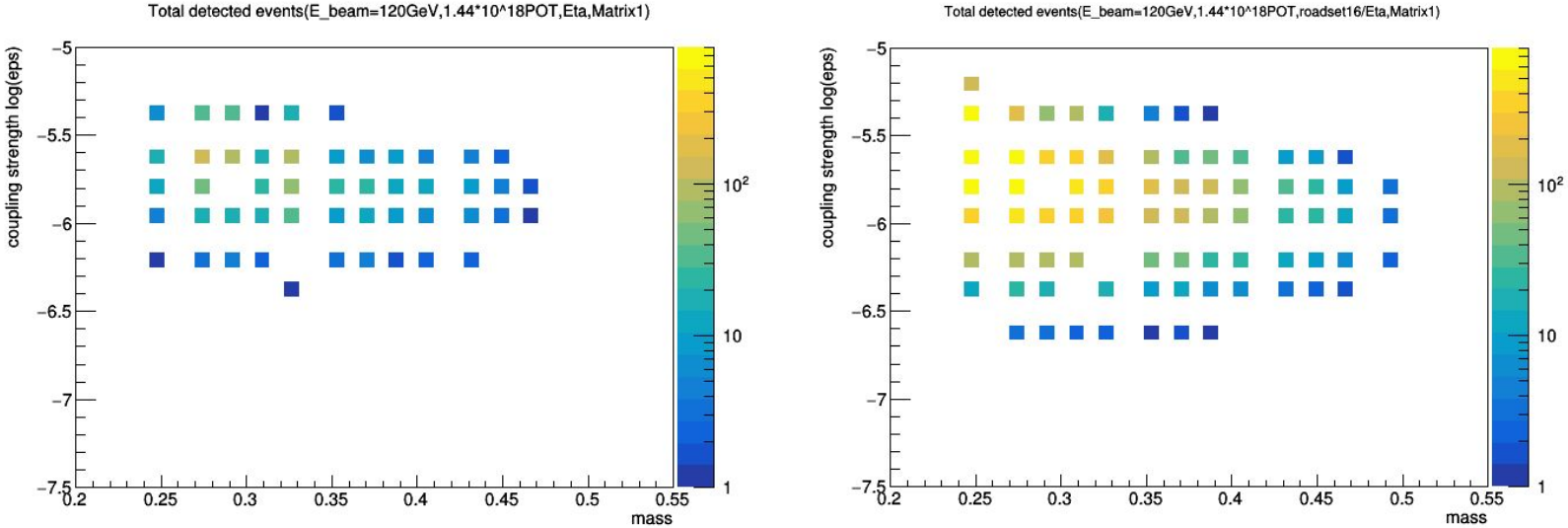
Total Expected events

Knowing the trigger efficiency, we can calculate the total number of Aprime Events that can be detected. *N = cross section(eps^2) * L(POT) * decay_prob(5-6m) * acc(trigger)*



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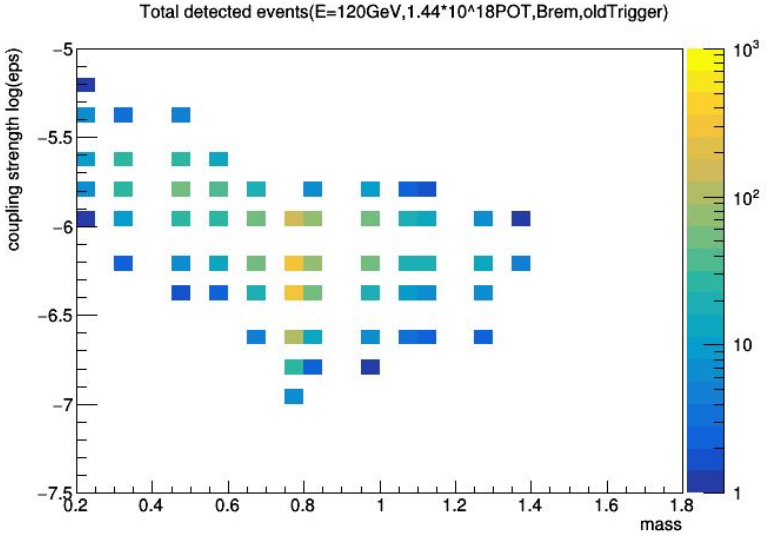

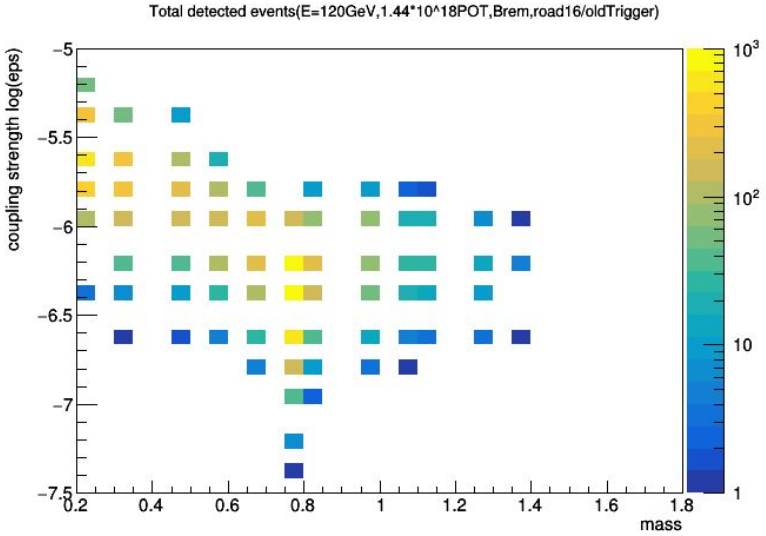

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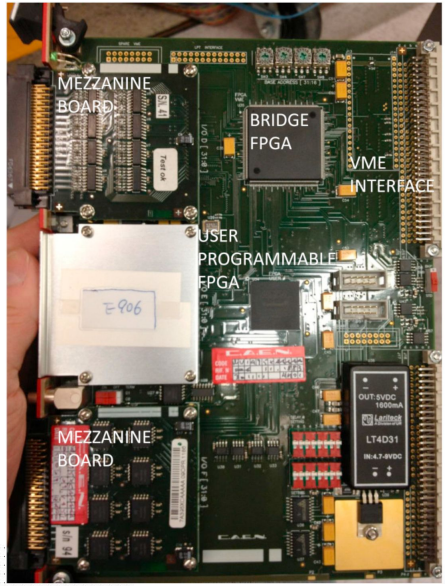
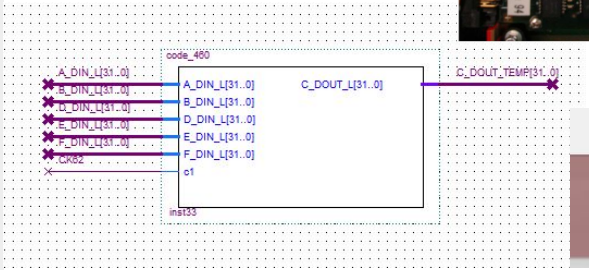
FPGA firmware realization

- Edit the FPGA firmware using Interl Quatus.
- Start from the level 1 trigger firmware (nim_460) from SpinQuest FPGA trigger group.
- Customize the “trigger-road” in coincidence logic block—code_460.vhd.



Fitter Summary

Fitter Status	Successful - Mon Jun 12 18:42:34 2023
Quartus II Version	11.0 Build 208 07/03/2011 SP 1 SJ Web Edition
Revision Name	SeaQuestTrig1
Top-level Entity Name	SeaQuestTrig1
Family	Cyclone
Device	EP1C20F400C6
Timing Models	Final
Total logic elements	18,962 / 20,060 (95 %)
Total pins	275 / 301 (91 %)
Total virtual pins	0
Total memory bits	192,512 / 294,912 (65 %)
Total PLLs	1 / 2 (50 %)



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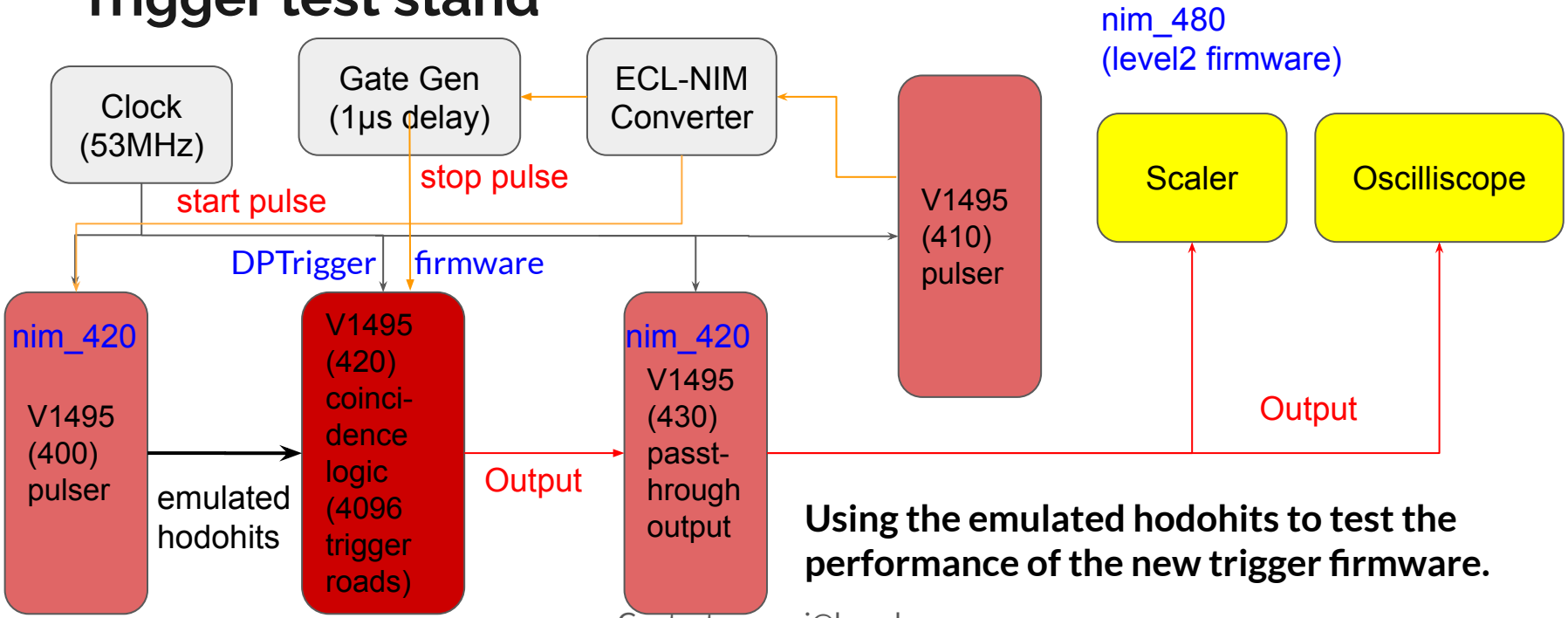
Trigger test stand



Using the emulated hodohits to test the performance of the new trigger firmware.

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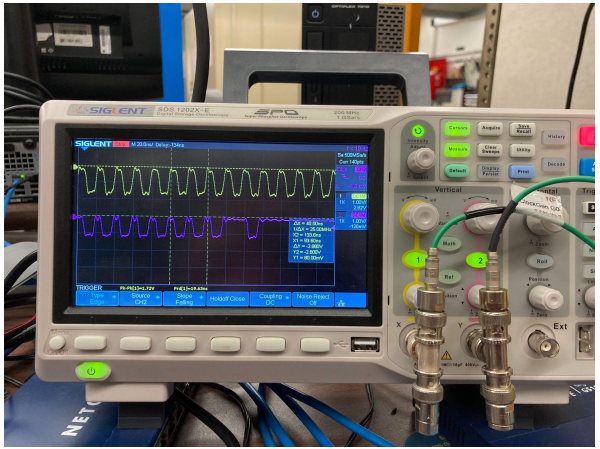
road_3881.txt

```
0002,0100,1100,0000,0000,0000
0002,0100,1100,0000,0000,0000
0000,0000,0000,0000,0000,0000
0000,0000,0000,0000,0000,0000
```

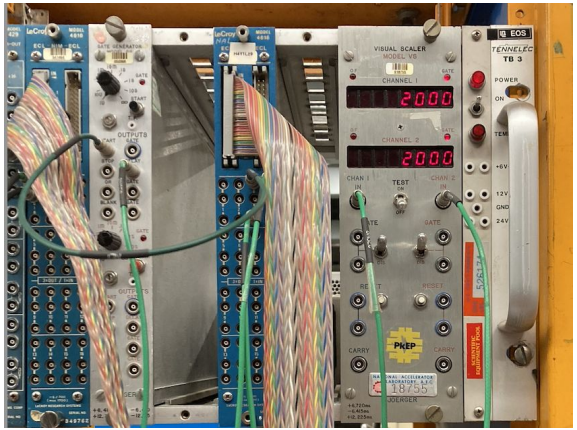
Trigger test stand output

- Preset pulse patterns can emulated the trigger roads from signal or background events.
- Check the trigger file both on the scope (single pattern test) and the visual scaler (full road test).



9 signal roads +
1 background road
in one pattern file

Ch1:Start signal
(number of pattern files loaded)
Ch2: FPGA Coincidence output



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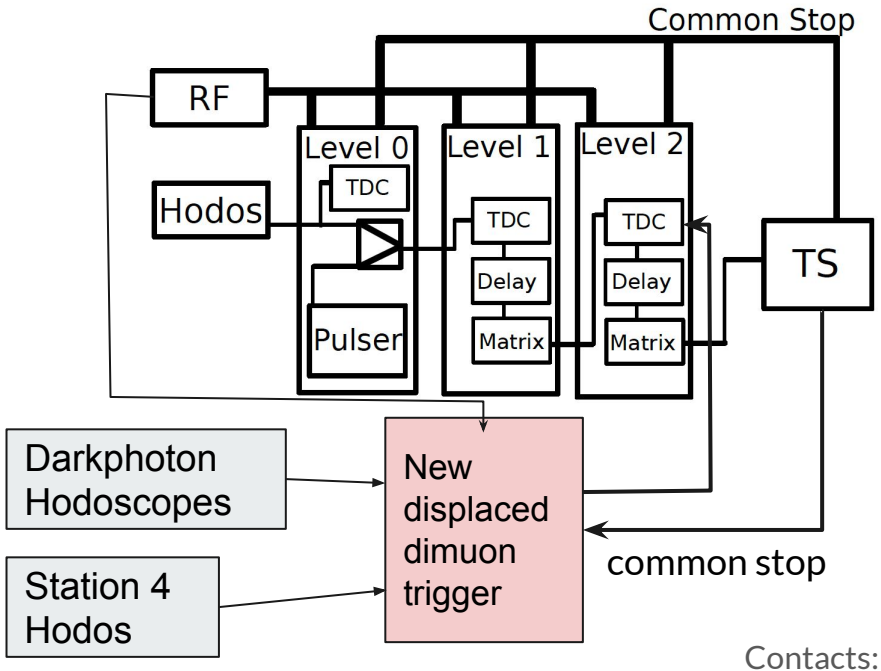
New DP trigger integration



- The new displaced dimuon trigger will run parallel with the current trigger system.
- The output for this new trigger will go to level 2 trigger, combine with main trigger and then go to the trigger supervisor.
- We won't use much trigger band width as the new trigger algorithm has already made the trigger rate to be very low.

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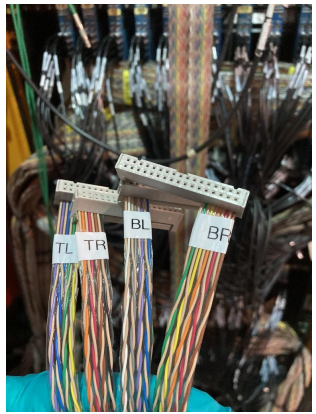
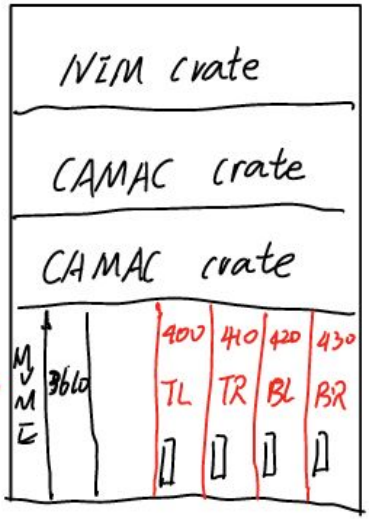
New DP trigger integration

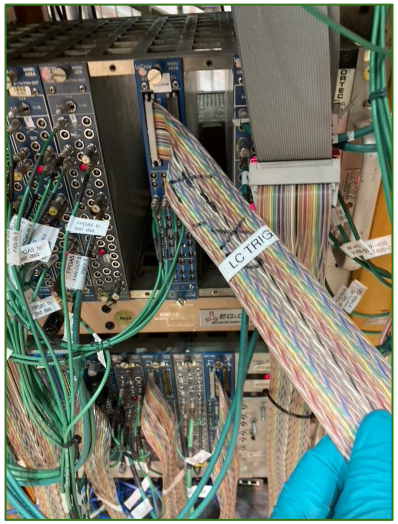


VME crate

DP Trigger crate

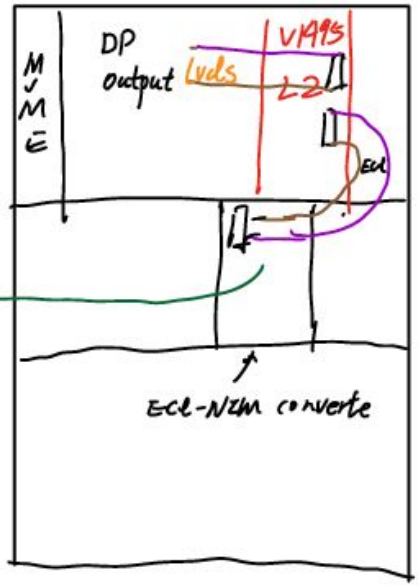
DP1 rack





NIM output send out to counting room for monitor

Main FPGA trigger rack



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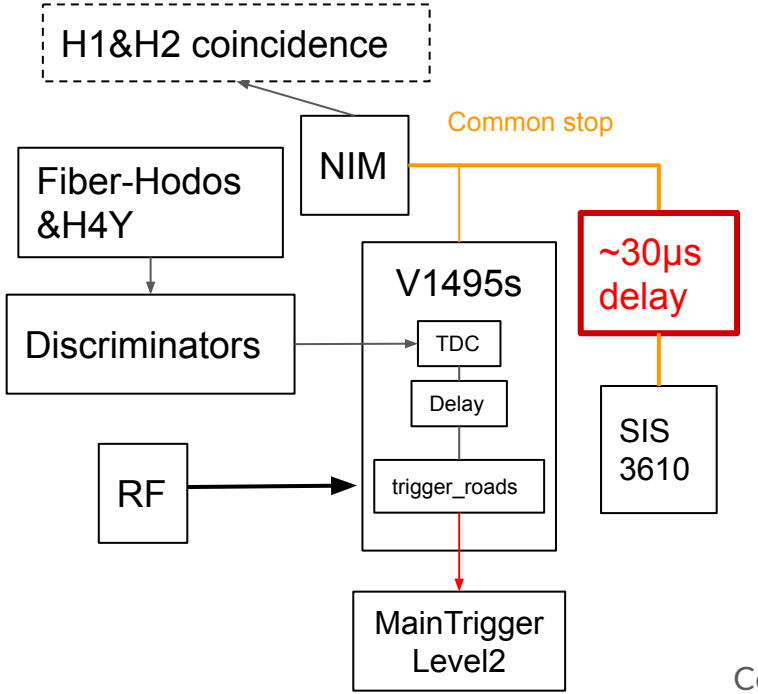
New DP DAQ for time alignment of trigger input



- In order to process the coincidence logic inside the V1495 FPGA firmware. Need to align the time for each input channels.
- Main DAQ did not record the TDC time for V1495 trigger board for darkphoton triggers. Have to build a seperate DP DAQ.
- This new DAQ record the TDC time of input hits to the V1495 FPGA boards for each channel and adjust the TDC time delay for each channels.

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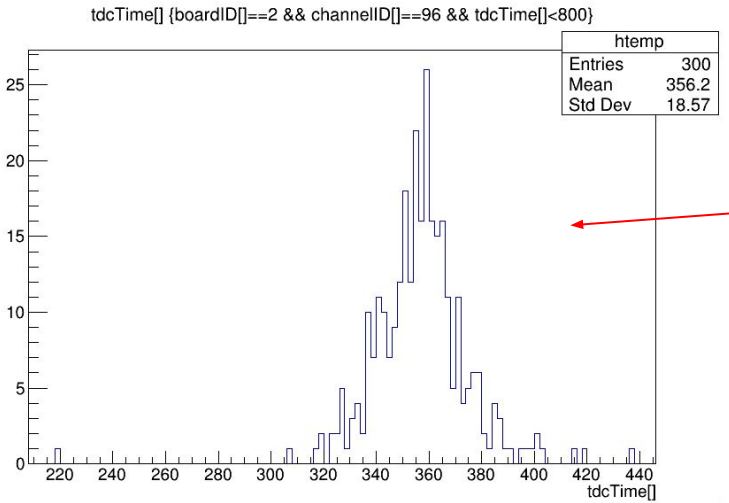
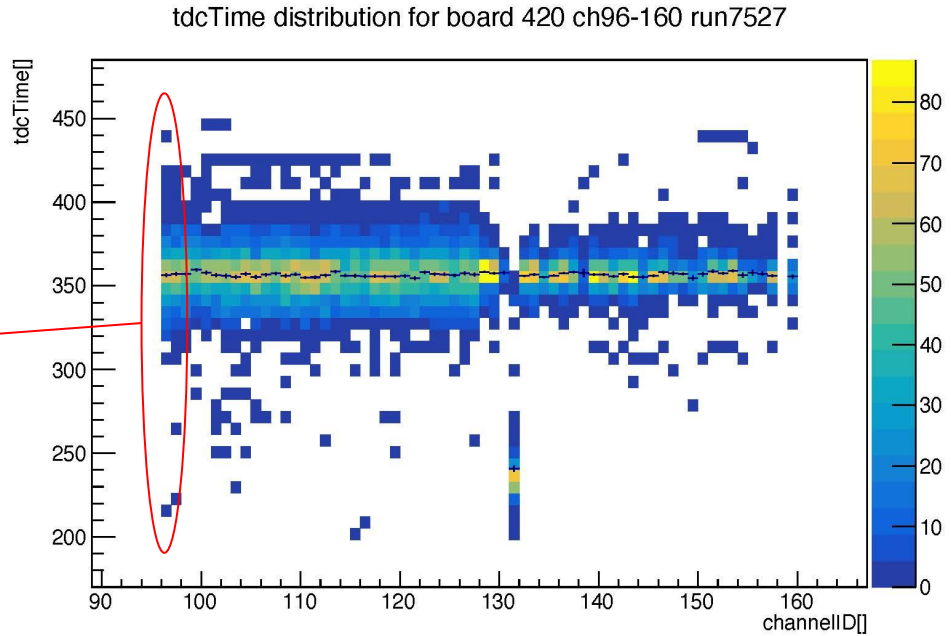
New DP DAQ for time alignment of trigger input

Take the cosmic run:





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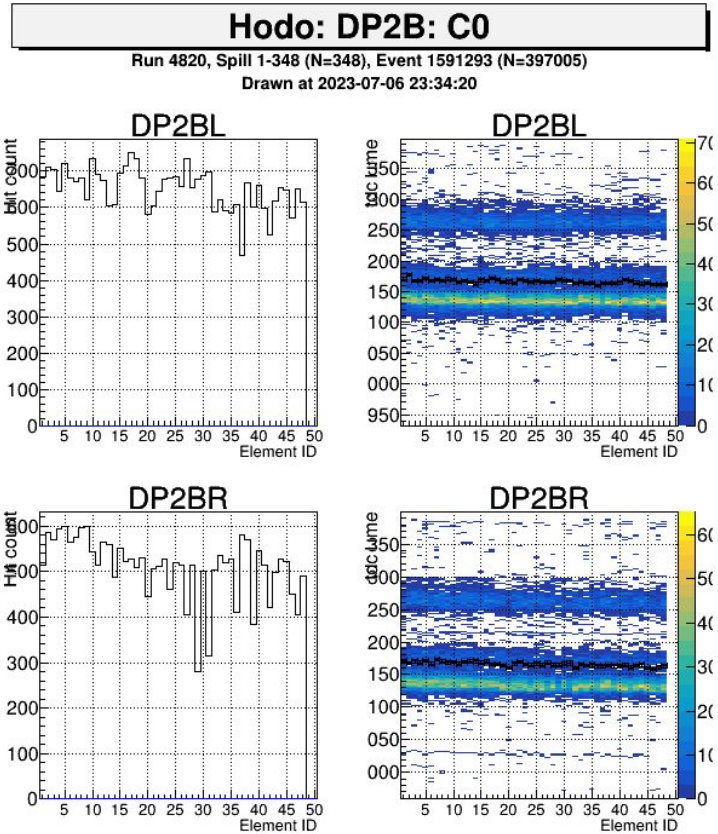
Fiber hodoscope status

- Most channel works fine based on the online monitor.
- Several bad channels can be identified:

  Noisy:
  DP1BL_CH31, DP1BR_CH16, DP1BR_CH41
  Dead:
  DP1TL_CH56,DP1BL_CH52, DP1BR_CH5, DP1BR_CH77,78,79,80

- Some low-eff channels can be optimized through the bias voltage scan.



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Commisioning w/ the beam

- Use the DP DAQ to align the FPGA input time for darkphoton trigger.
- Take the bias voltage scan to optimize the hodoscope efficiency for each channel.
- Adjust the trigger roadset to avoid the “hot” road, restrict the trigger rate to under its limit. (5kHz for the whole experiment, ~100 Hz for dark photon trigger)

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On shift during the SpinQuest Run

- Monitor the behavior for the darkphoton trigger system:
  - trigger rate
  - hodoscope efficiency
- Input channel time alignment once a week. ~1 hour every time.
- Update the trigger firmware based on the data taken.
  - Come up w/ the new trigger road set based on the data reconstruction and simulation.
  - Update the v1495 FPGA firmware and compile w/ Intel Quatuas.
  - Test the new firmware in the test stand.
  - Flash the firmware to the DP trigger boards, monitor its rate.

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Summary

- New displaced dimuon trigger system is fully prepared for the beam.
  - Displaced the dimuon trigger algorithm improve the trigger efficiency for the long lived dark photon.
  - Customized FPGA firmware is tested in the trigger test stand.
  - Newly set DP DAQ do input channels time alignment for new trigger system.
  - Integrate the new trigger output to current trigger system.
- Clear the tasks and workflow for final beam comissioning and shift work during data taking period.
  - Optimize the trigger roadset under the beam condition.
  - Conduct the bias voltage scan and adjust the discriminator threshold to maximize the hodoscope efficiency.

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Backups

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Trigger road for 4 dp hits in same quadrant

Road Format: (a,b,c,d) where
a: the first dp1 hits element id in a certain quadrant
b: the second dp1 hits element id in a certain quadrant
c: the first dp2 hits element id in a certain quadrant
d: the second dp2 hits element id in a certain quadrant
all these 4 hits are required to be in the same quadrant

Road selection:

Based on several signal files:

- choose 12 signal simulation files,
  mass=[0.25,0.45,0.75,1.05]
  eps=[-6,-6.4,-7]
  115,762 events in total
- choose all of the trigger roads has at least 3 hits.
  Approximately 150-200 road in each quadrant.

- Road examples:

Quadrant	Trigger-Road	nhits
TL	(1,1,3,3)	15
TL	(1,2,3,5)	25
TL	(1,3,3,7)	28
TR	(1,1,3,4)	34
TR	(1,1,4,4)	57

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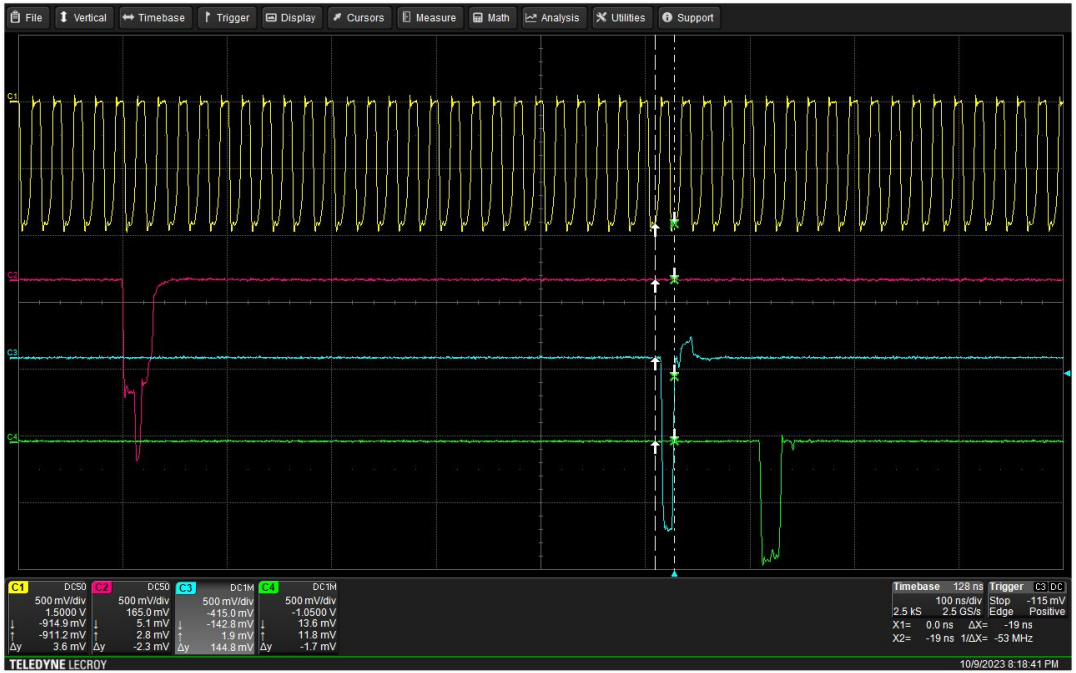
Trigger teststand output

CH1: RF clock
CH2: start pulse (t=0)
CH3: Trigger output (500ns later)
CH4: stop pulse (600ns later)

dump the TDC memory for
board 420:
~500ns time before stop signal
it receives pattern inputs



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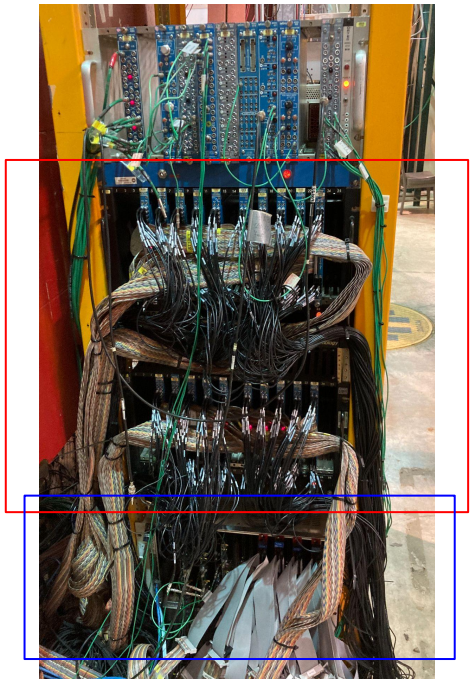
DP Trigger ROC inside NM4



Discriminators
for dp1

darkphoton trigger
VME crate

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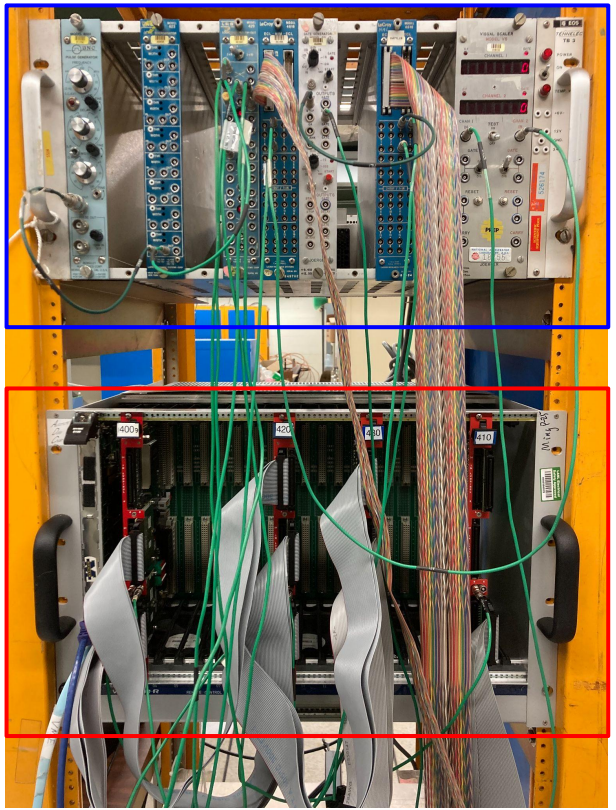
Trigger Teststand in Counting room

Support modules:
a) Function generator —> set RF clock
b) Conversions
c) Scaler —> Read output
d) Oscilloscope(not shown in the graph)

Trigger VME:
a)2xV1495 —> pulser generator
(emulate hodo hits)
b)1xV1495 —> coincidence logic
(trigger roads)
c)1xV1495 —> Trigger supervior
(common stop, output)



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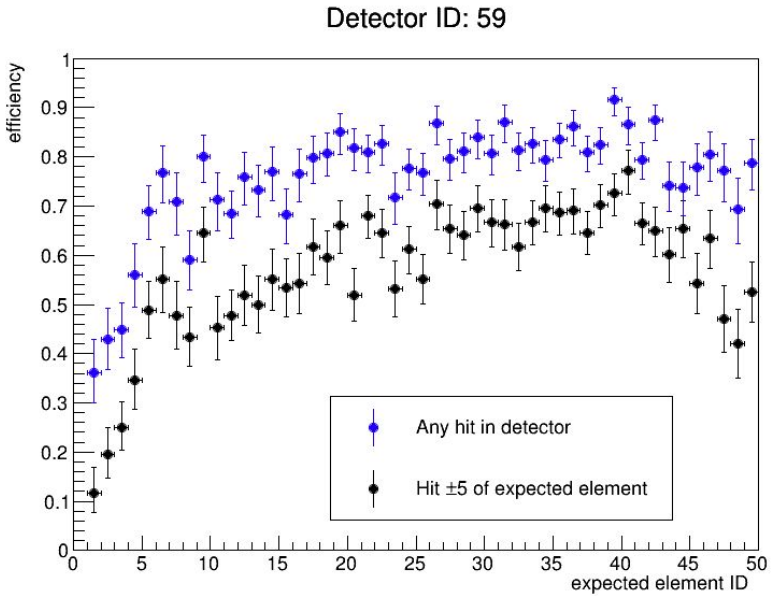
Hodo eff measurement

- Run the tracking using the hits from other hodoscopes and drift chambers. https://github.com/E1039-Collaboration/e1039-analysis/blob/master/RecoDev/RecoE1039Data.C
- Check whether there is the fiber hodoscopes hits in the expected position.
- Large angle of cosmic muon and low rate making this measurement hard without proton beam delivery



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