The SuperCDMS FPGA Trigger

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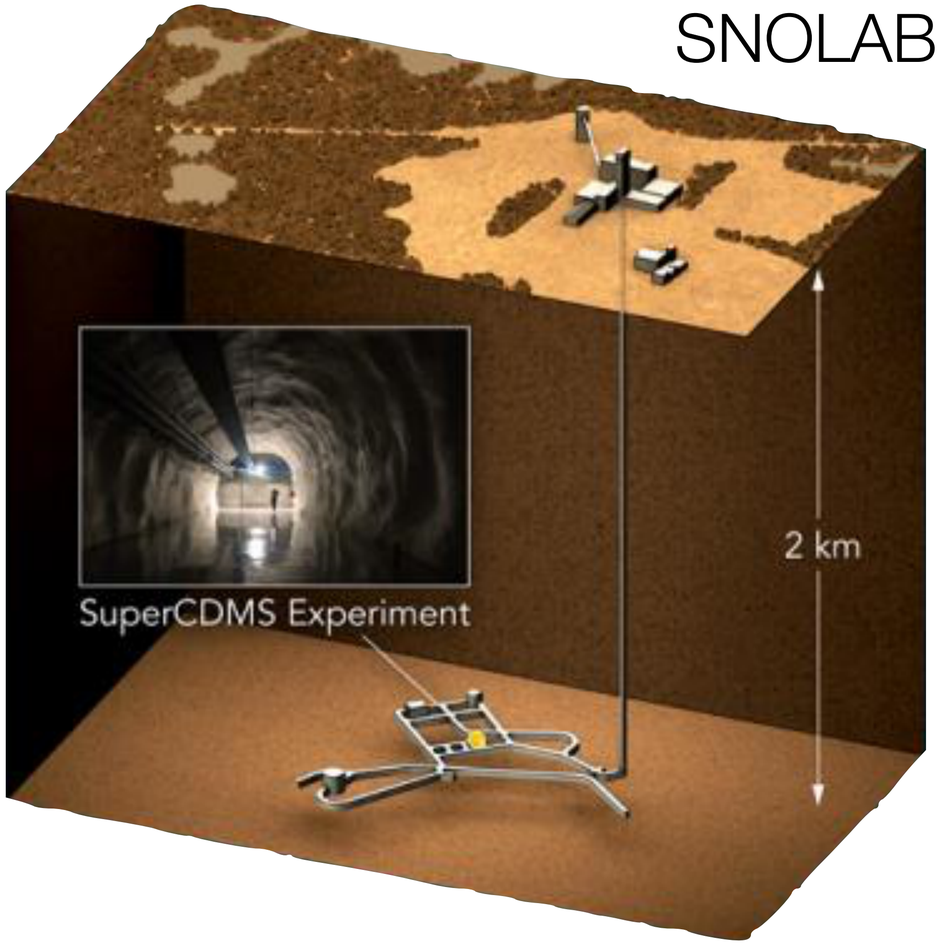
University of Hamburg, Feb 18 ‘20

DFG Deutsche Forschungsgemeinschaft

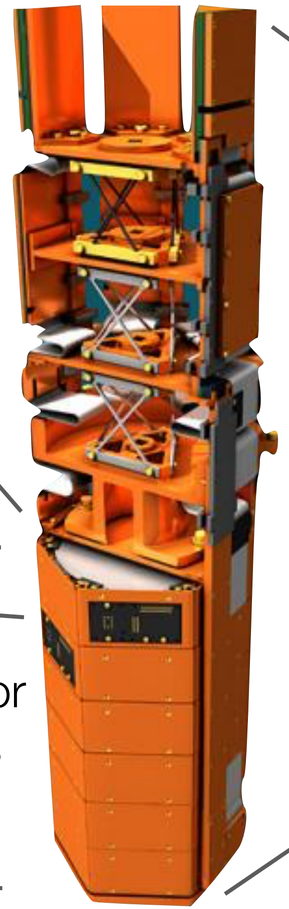
What is SuperCDMS?

Cryogenic **D**ark **M**atter **S**earch



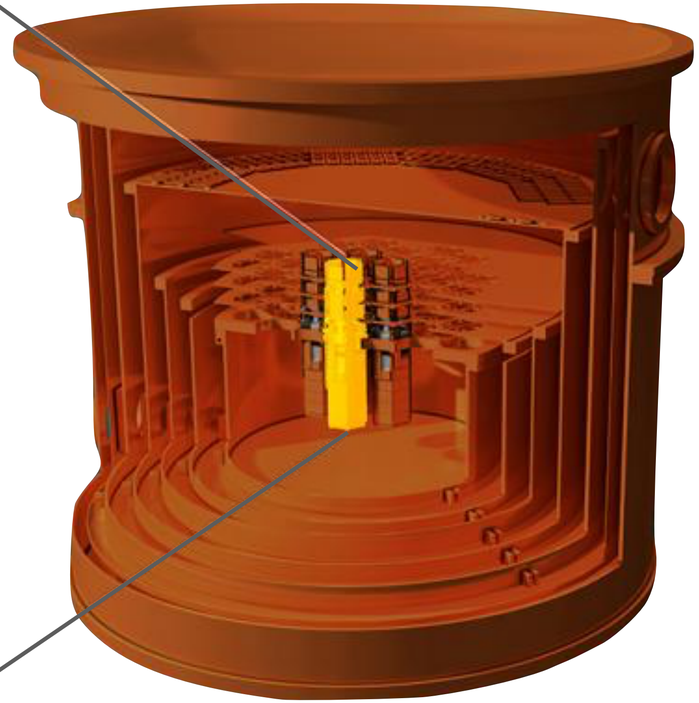
What is SuperCDMS?

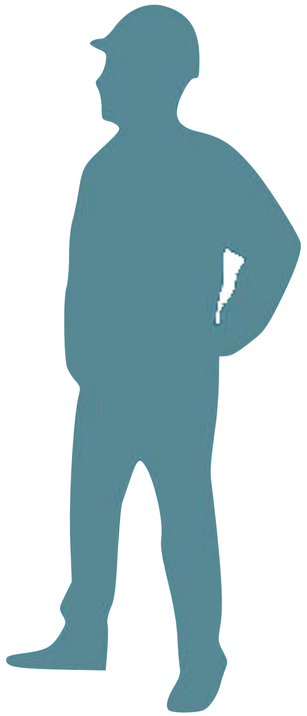
Detector



Detector Packs

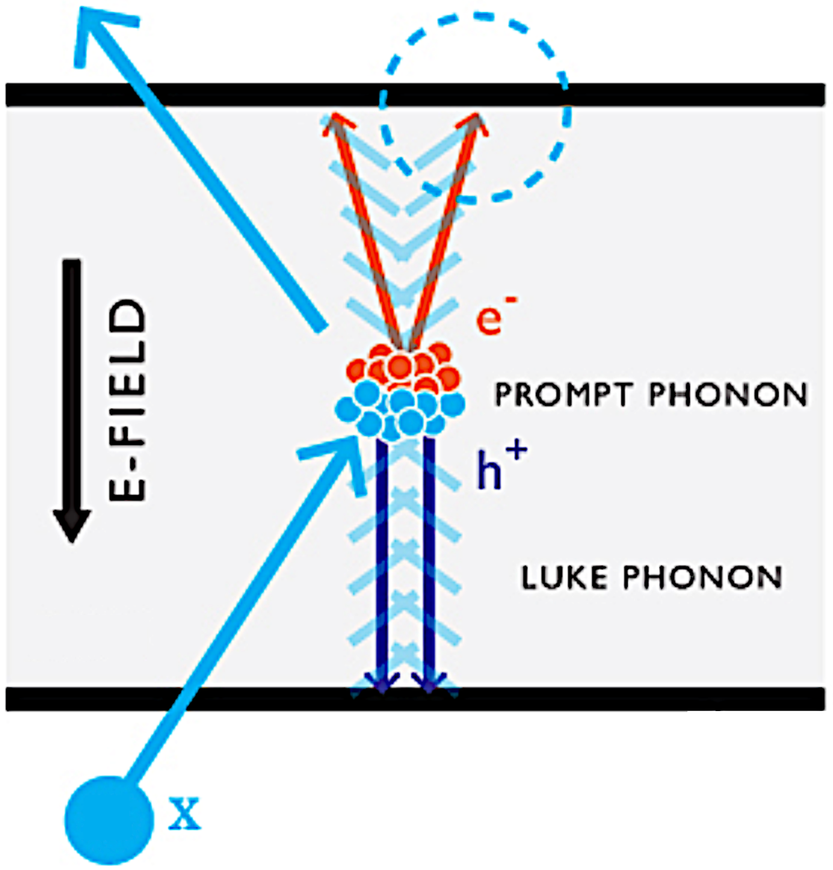
SNOBOX

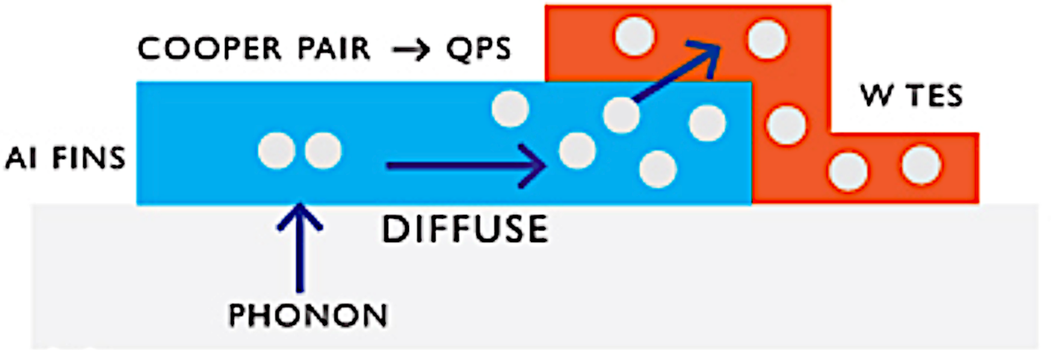


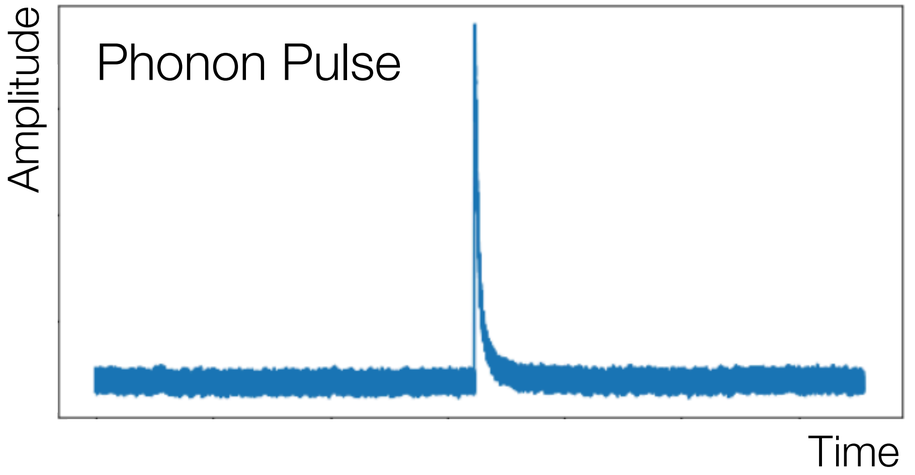


15 mK

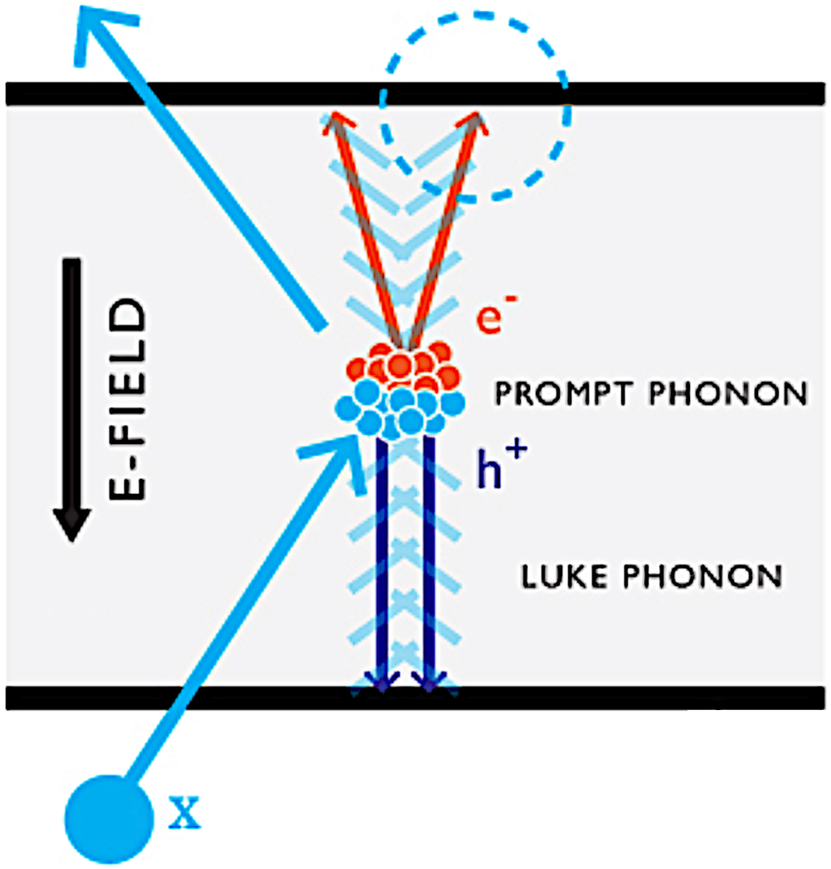
Detection Principle

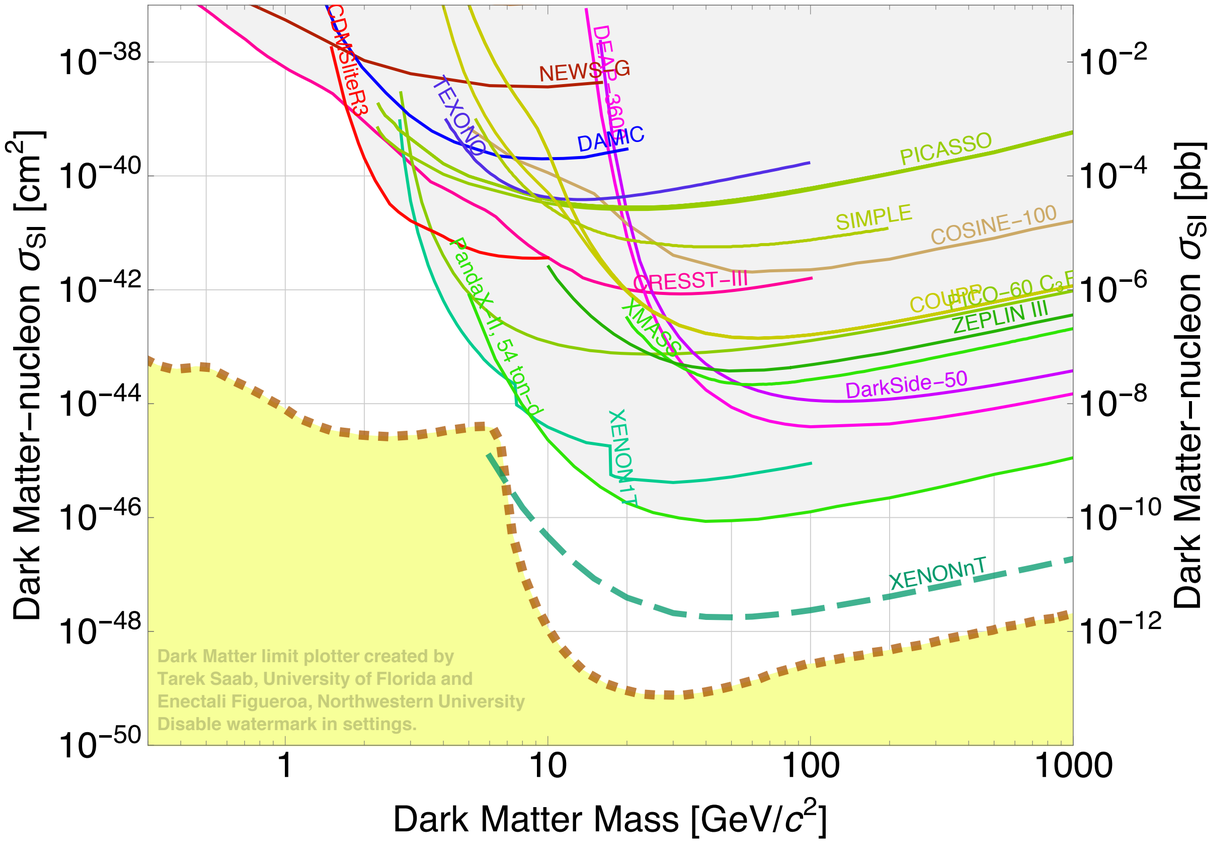






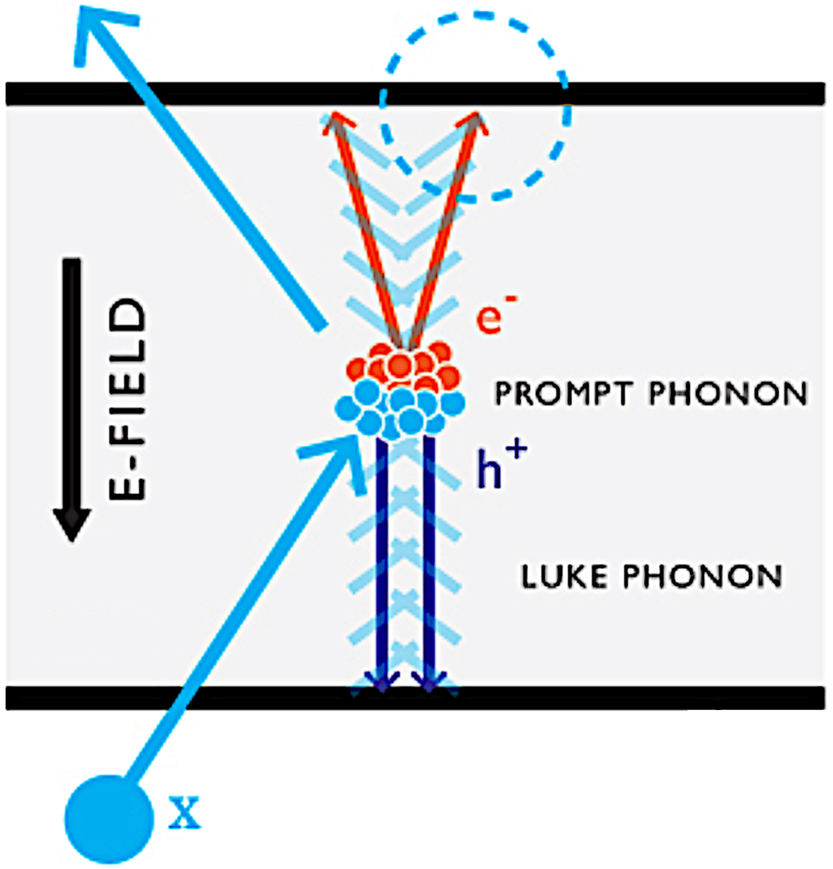
Detection Principle and Sensitivity

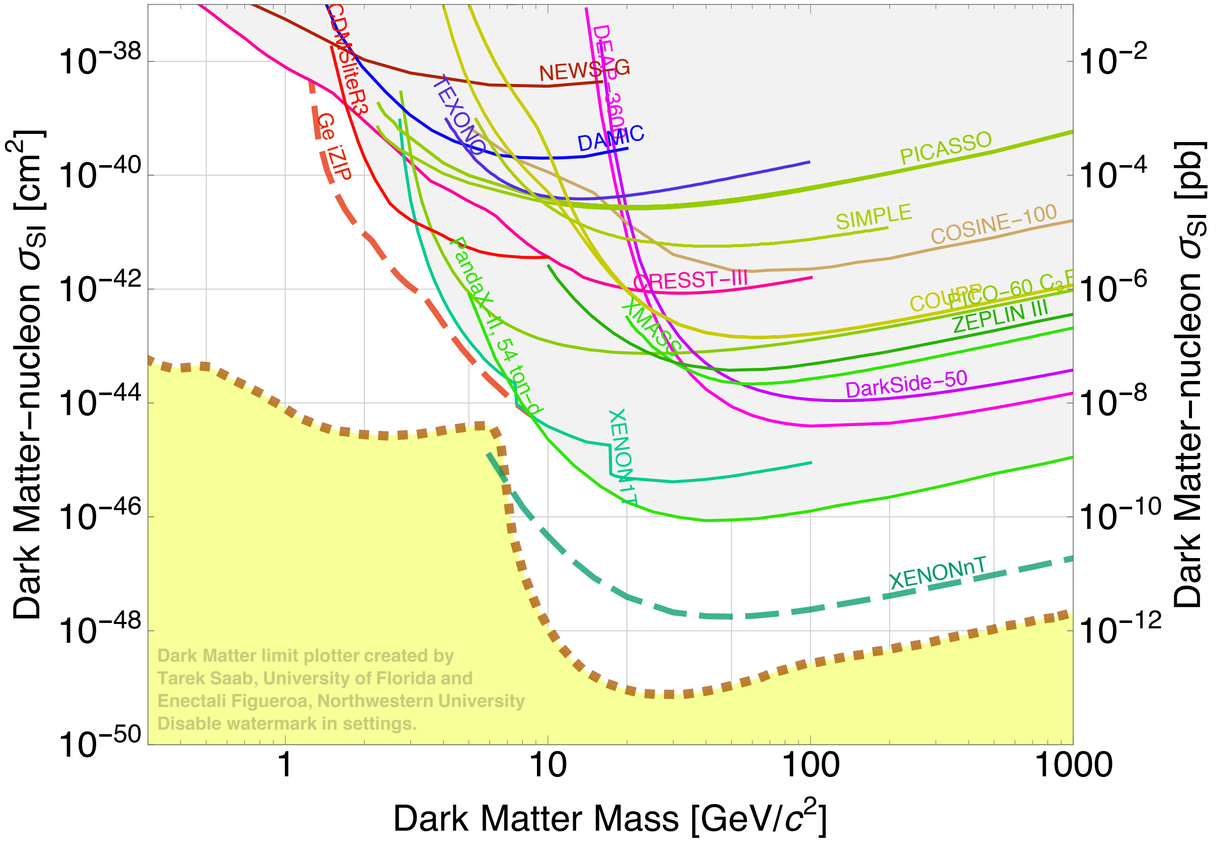




Detection Principle and Sensitivity

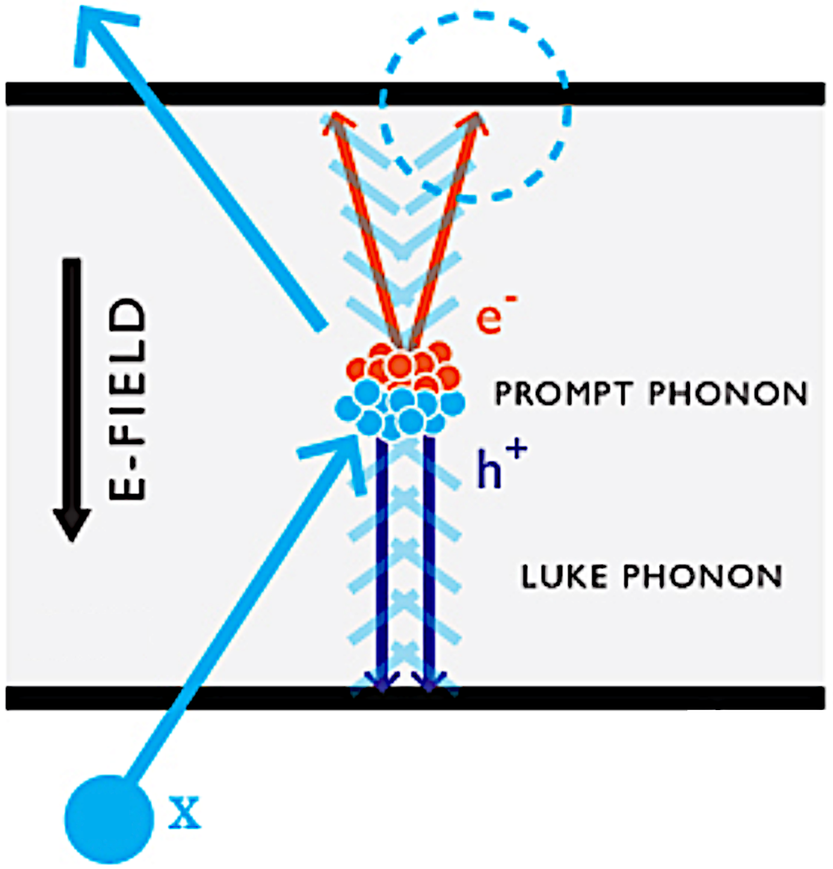
Ge
3V

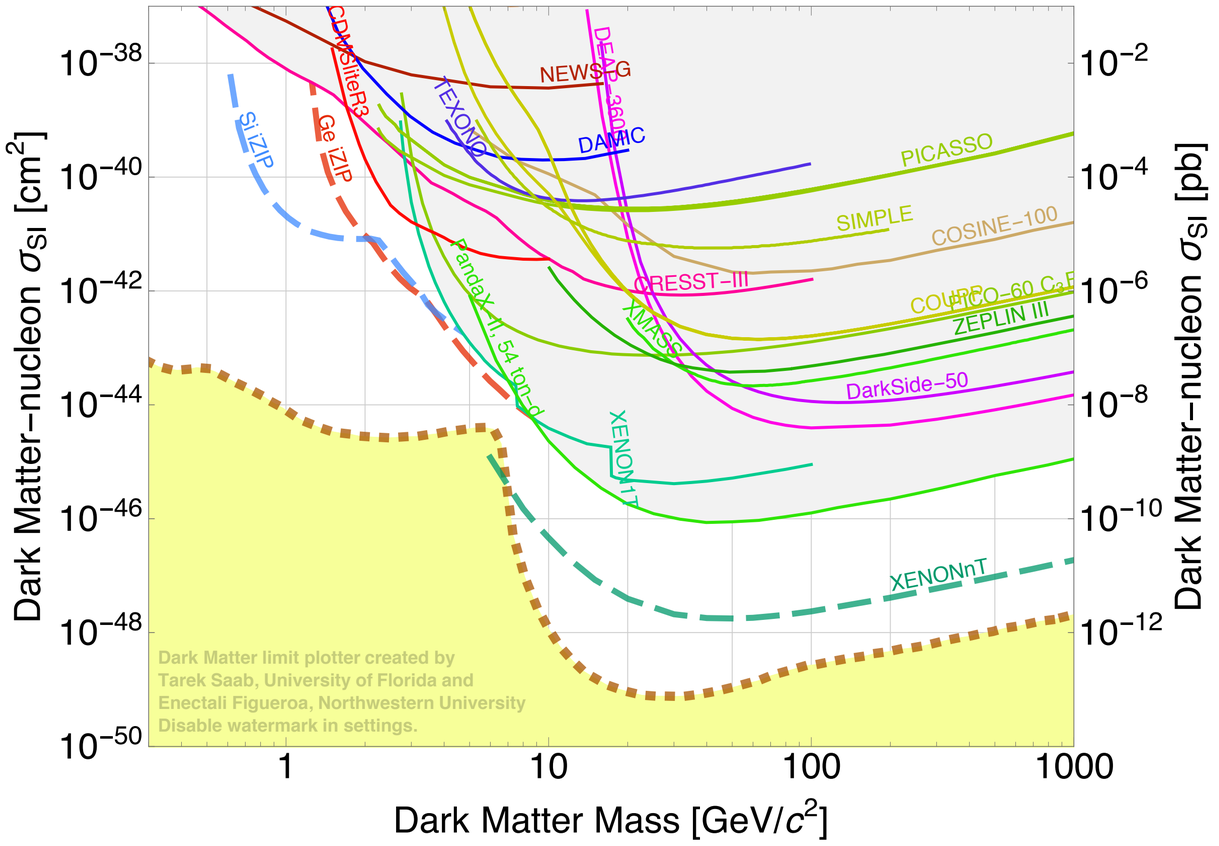




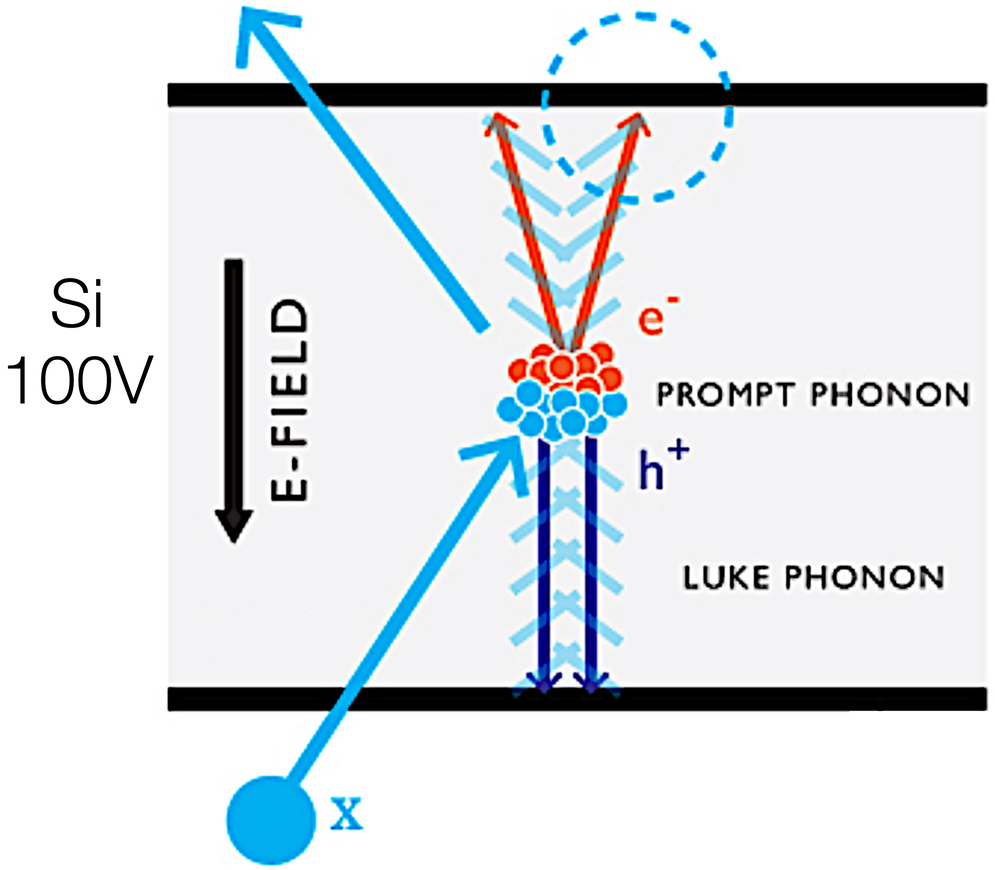
Detection Principle and Sensitivity

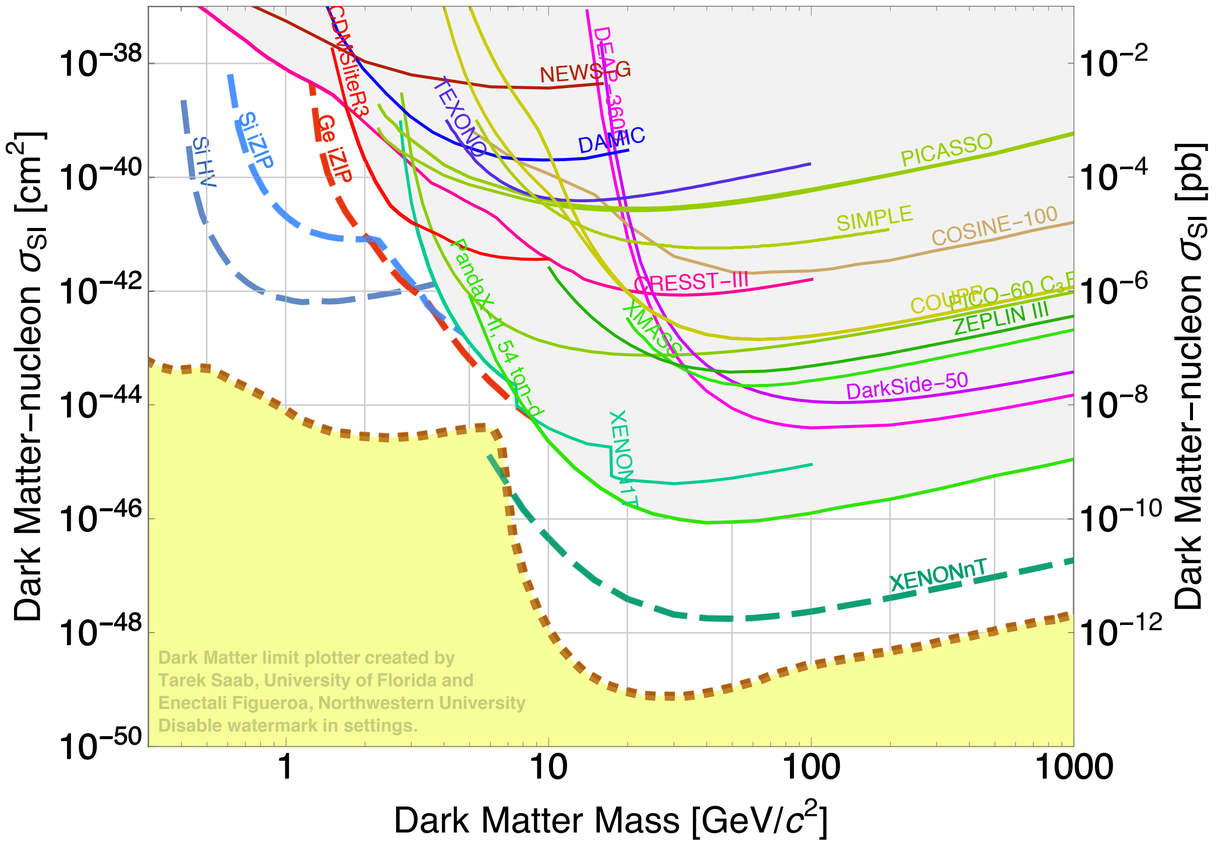
Si
3V



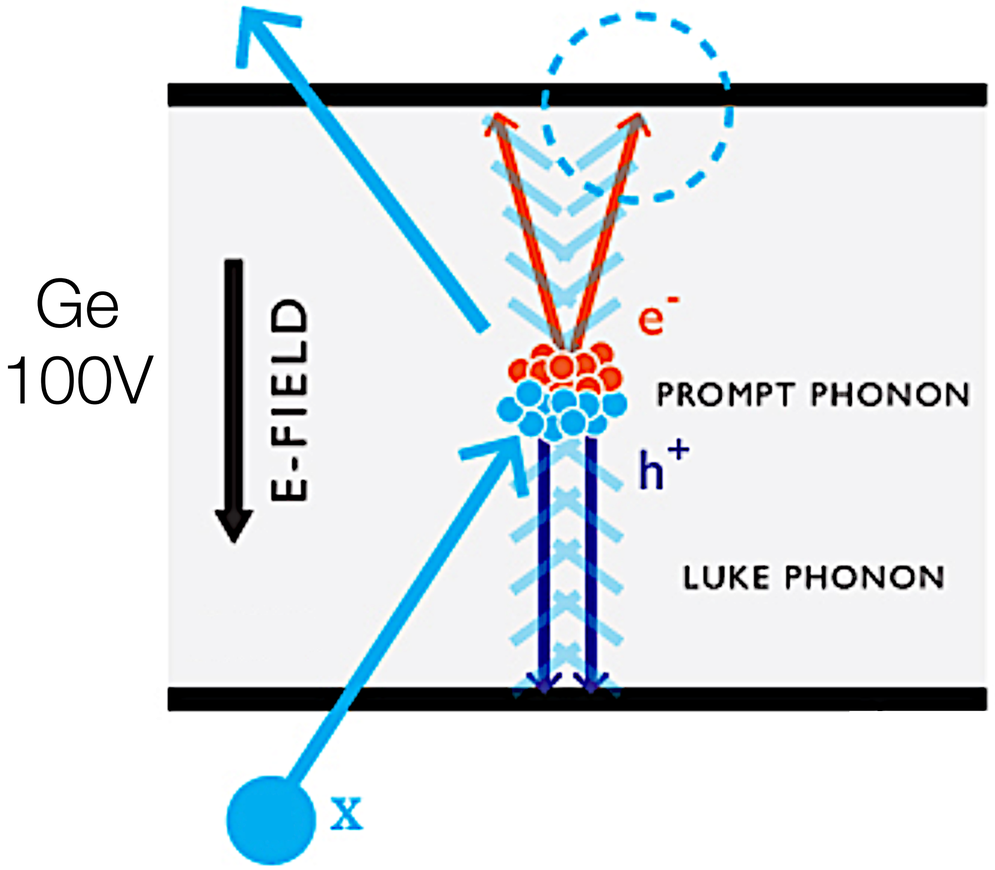


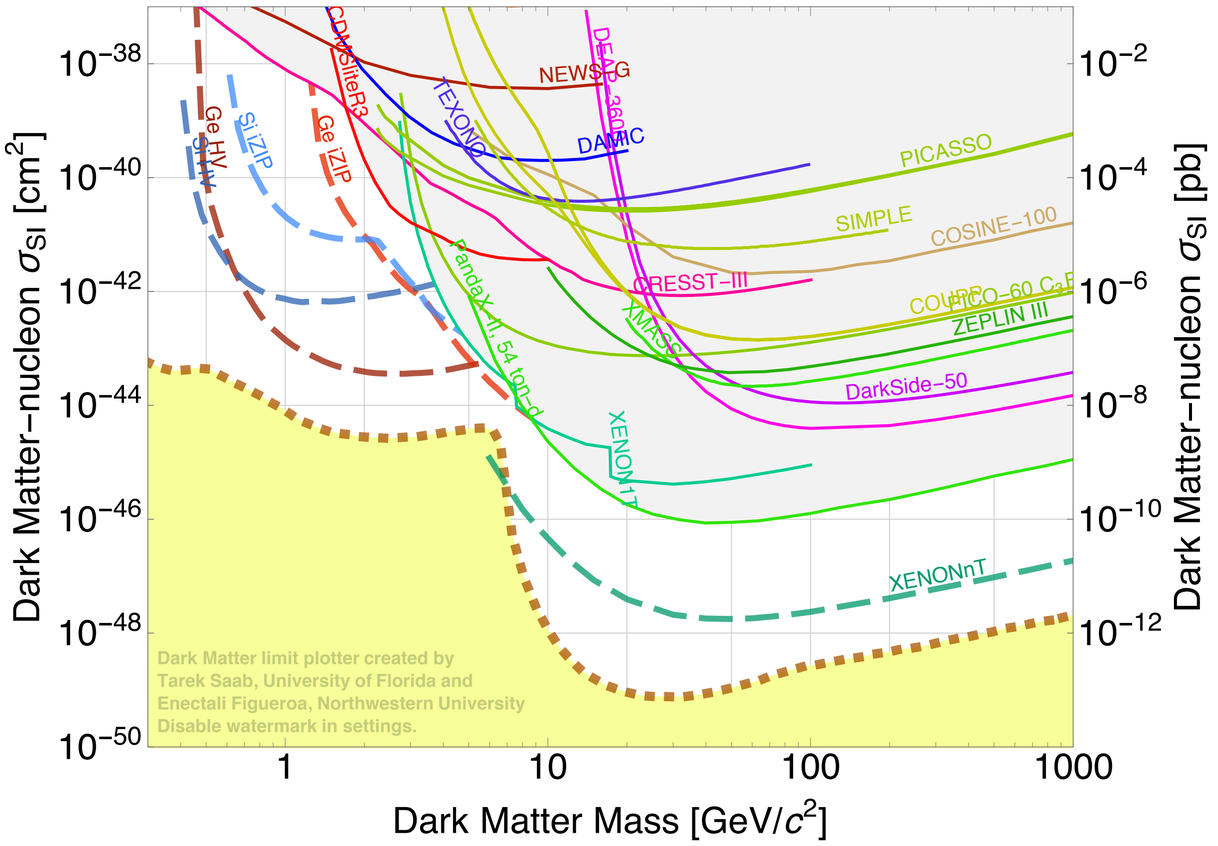
Detection Principle and Sensitivity





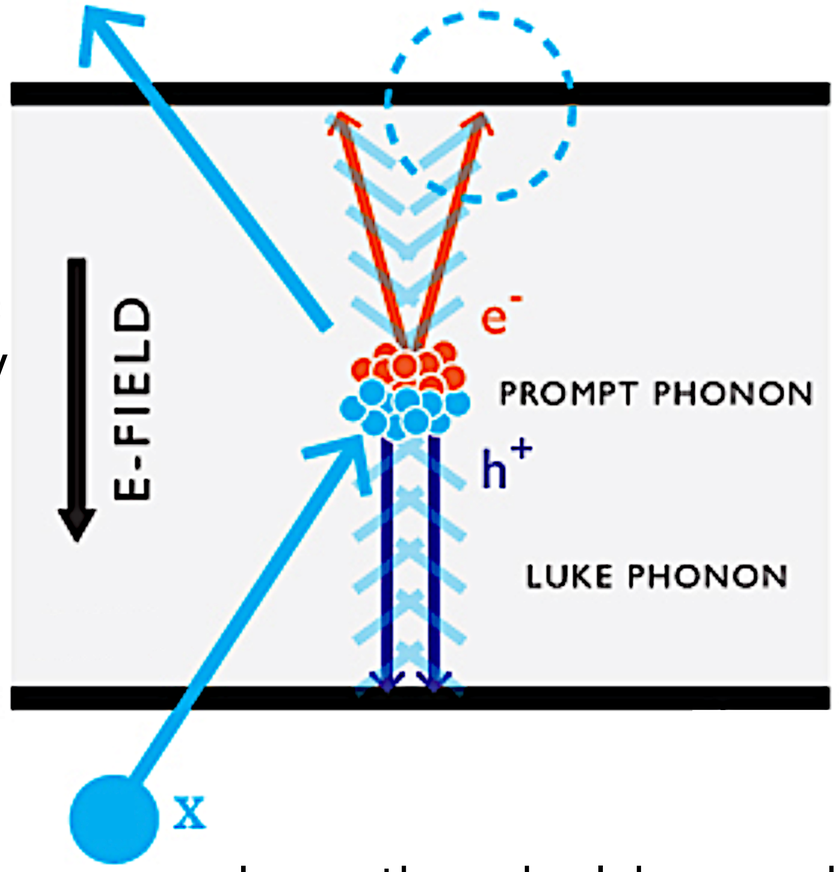
Detection Principle and Sensitivity

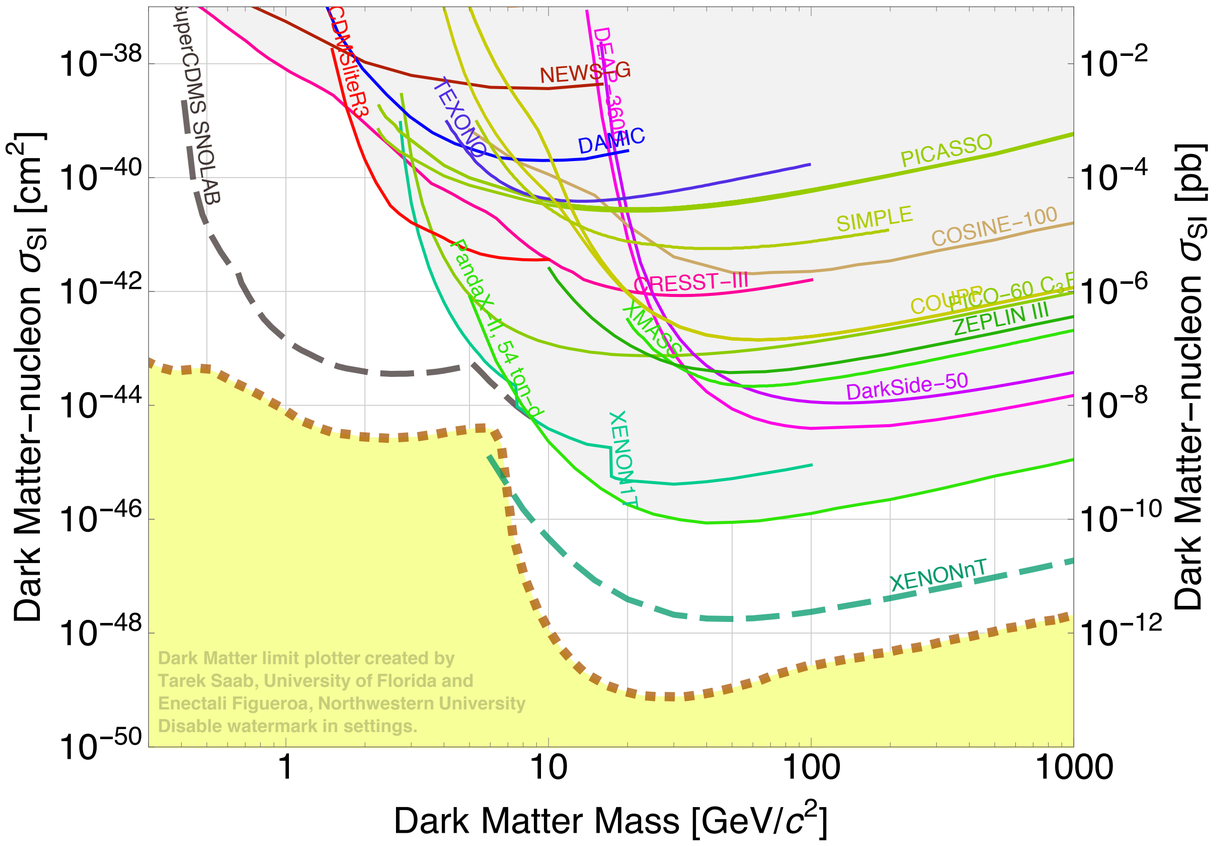




Detection Principle and Sensitivity

Si/Ge
3V/100V

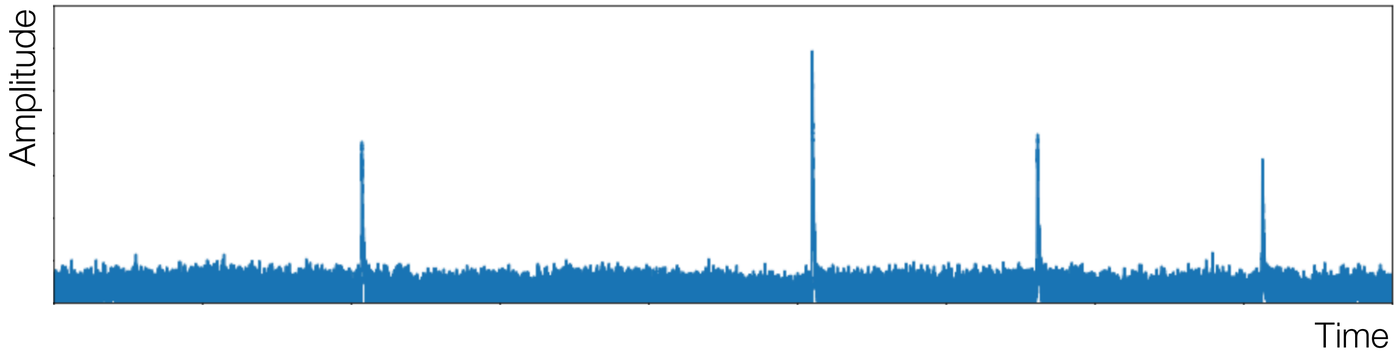




Low threshold experiment requires a good trigger

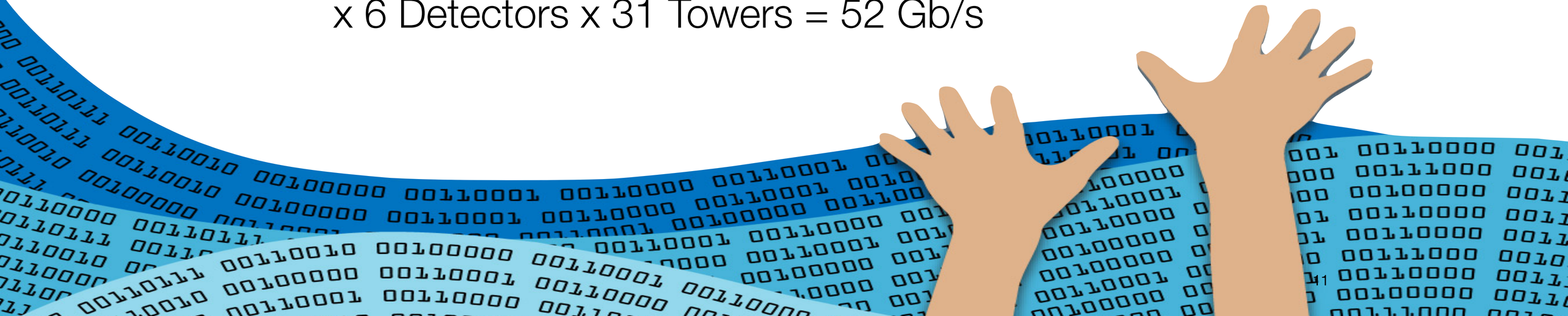
Why does SuperCDMS need a Trigger?

Assume: Continuous readout with up to 2.5 MHz sampling frequency

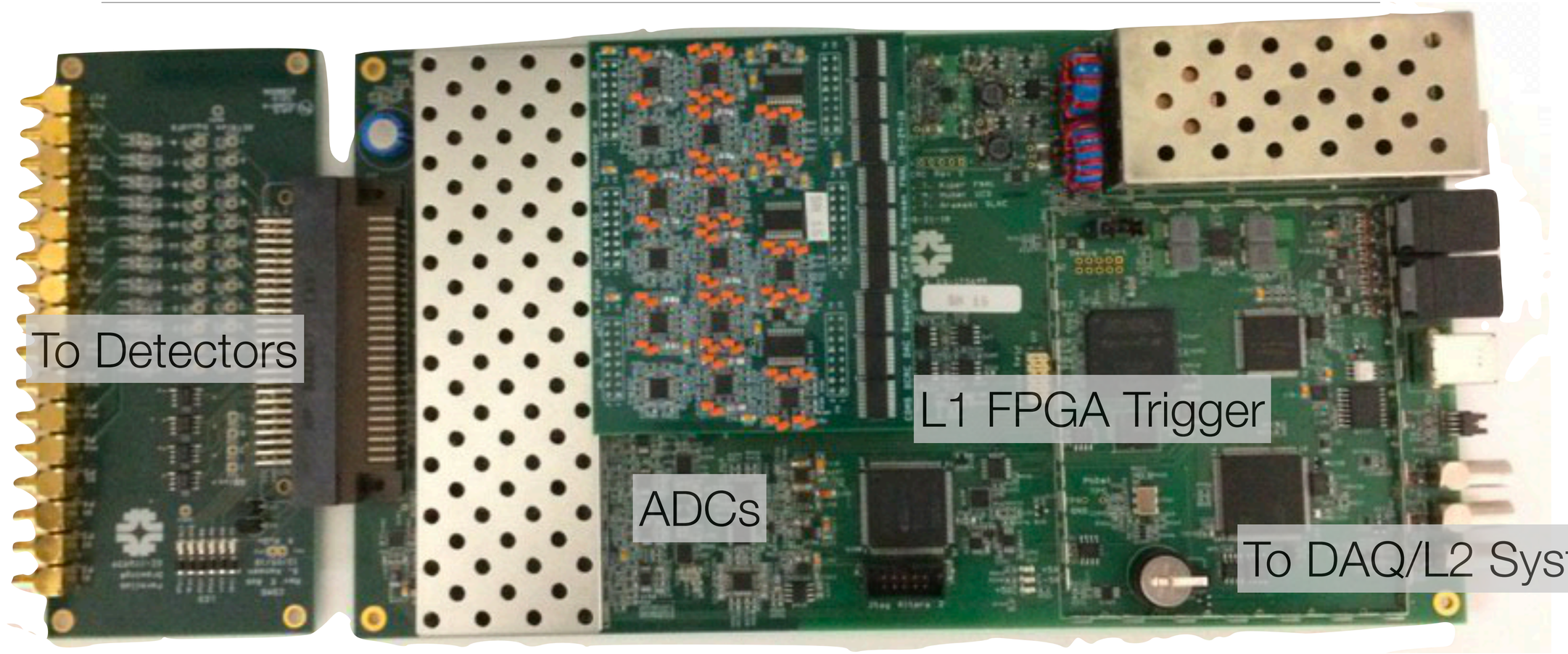


280 Mb/s per detector

x 6 Detectors x 31 Towers = 52 Gb/s



Detector Readout and Control Cards



The L1 FPGA Trigger

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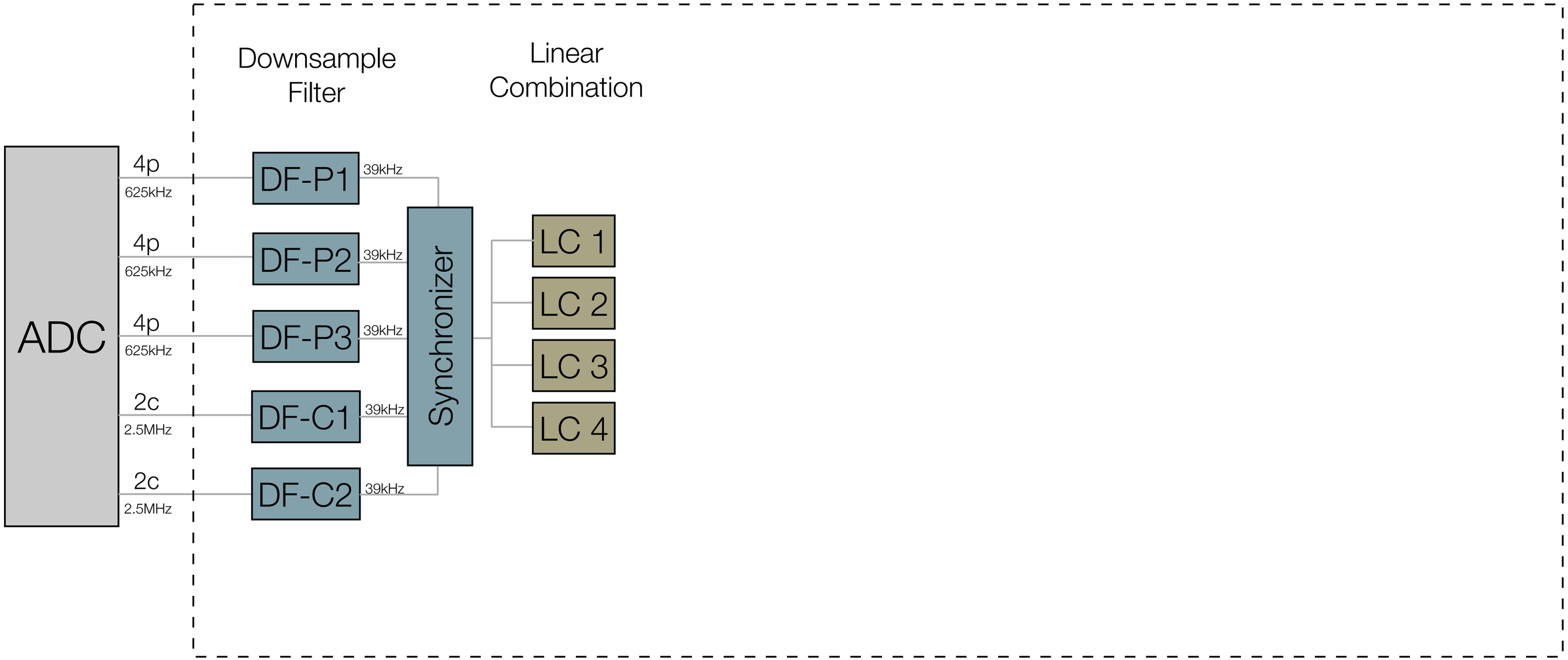
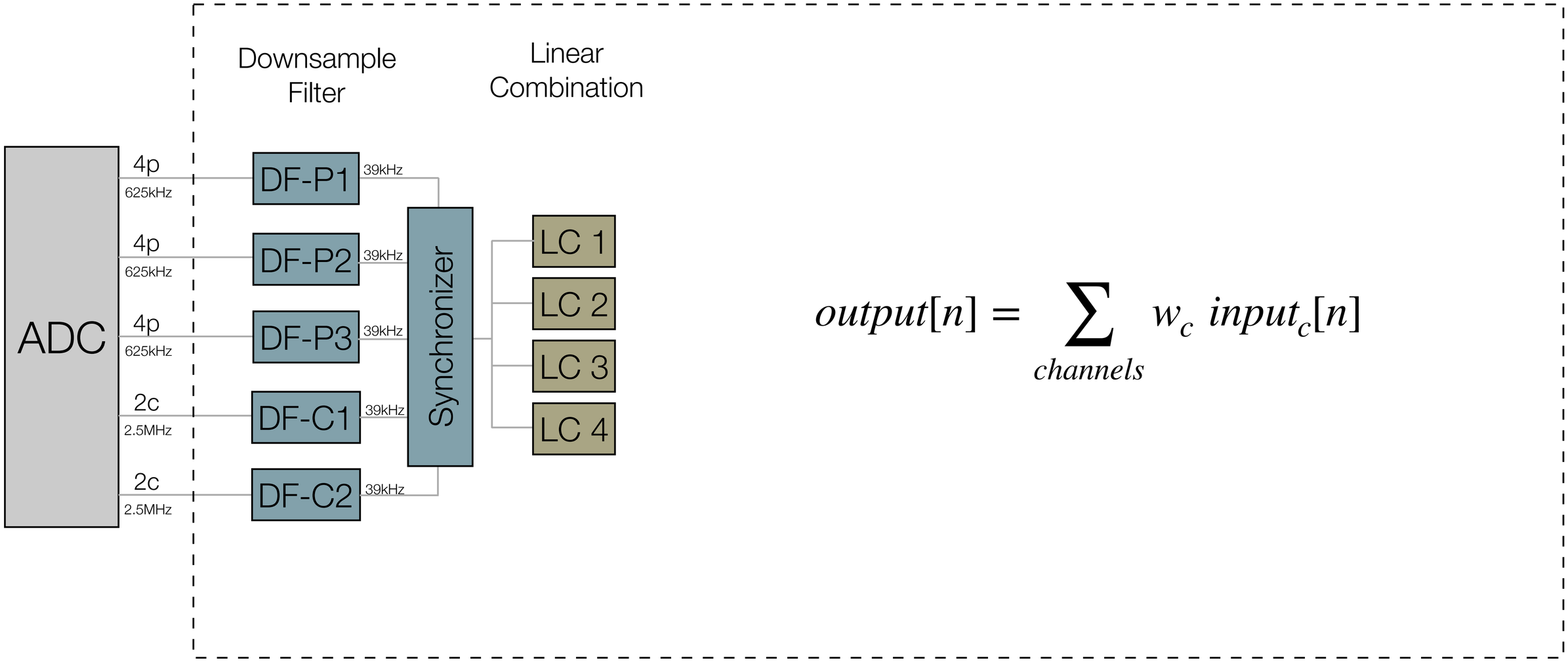
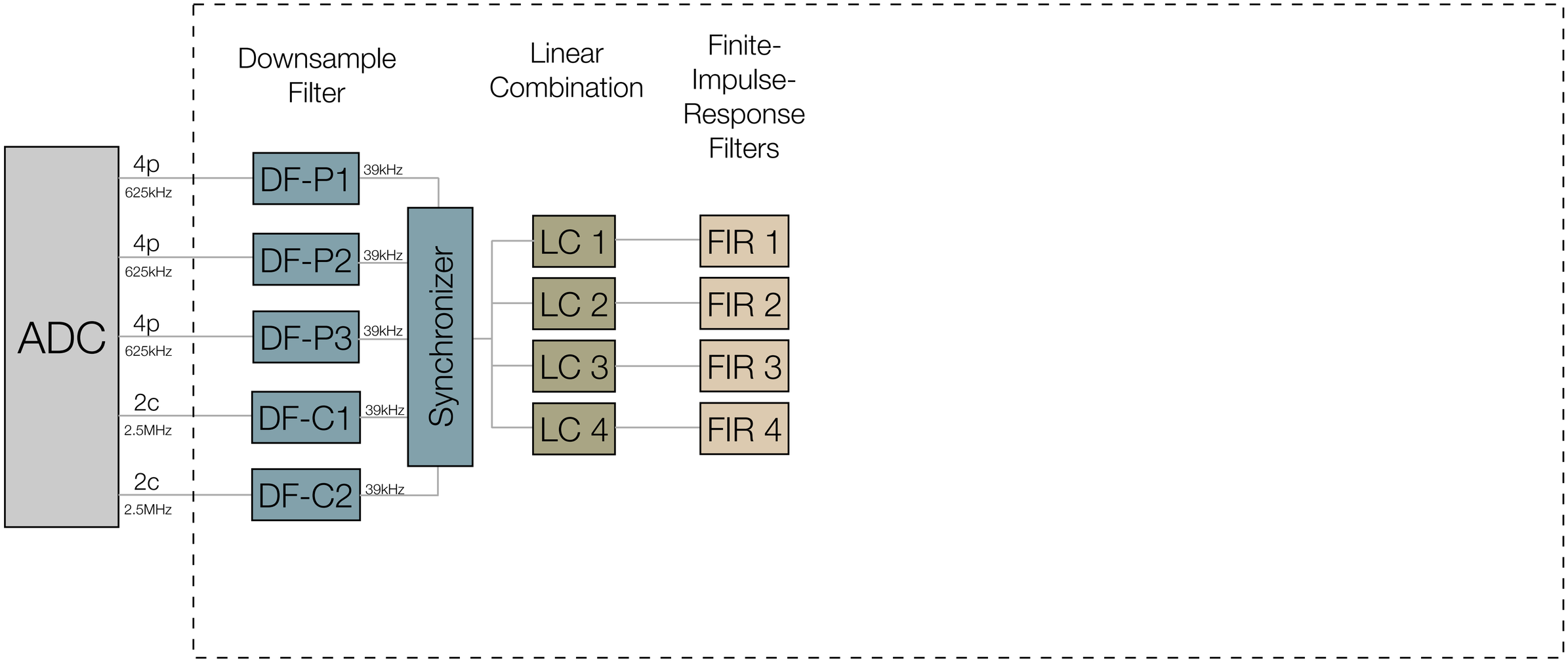


The L1 FPGA Trigger

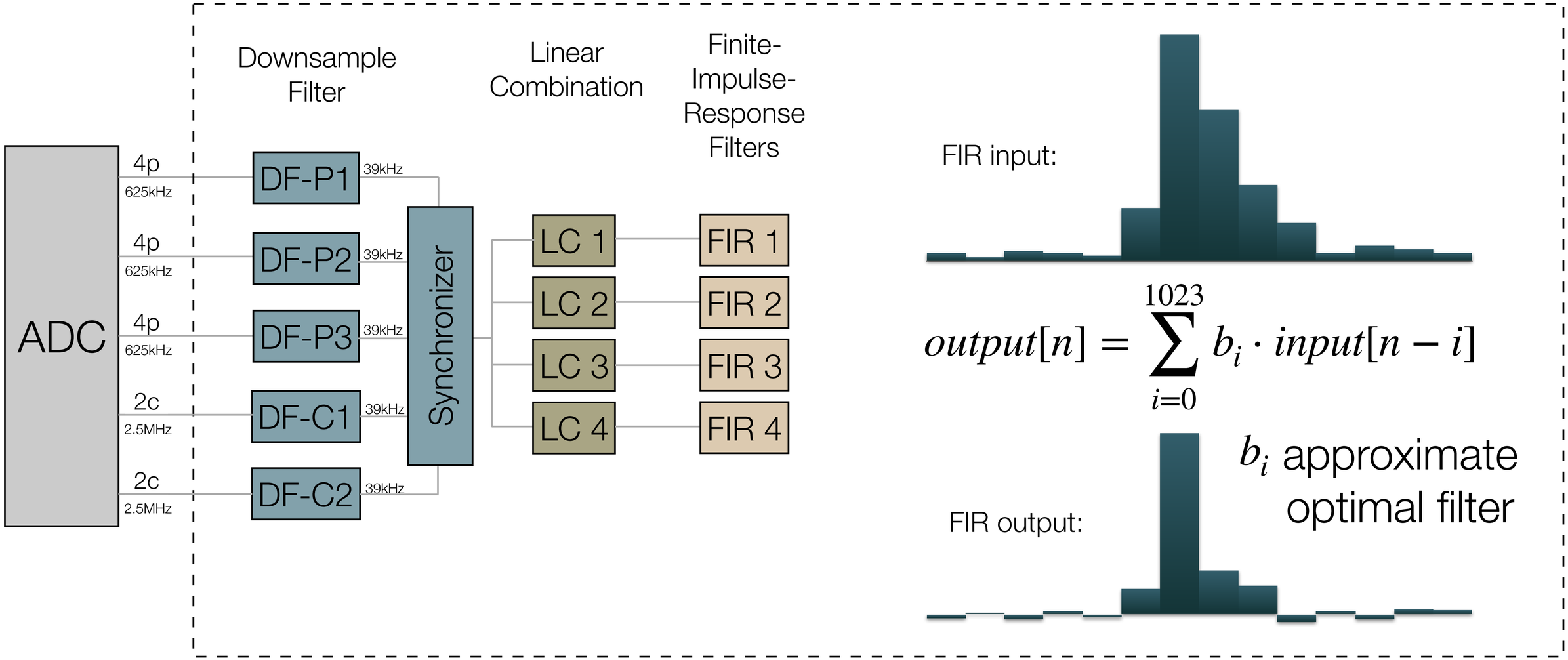


$$output[n] = \sum_{channels} w_c \; input_c[n]$$

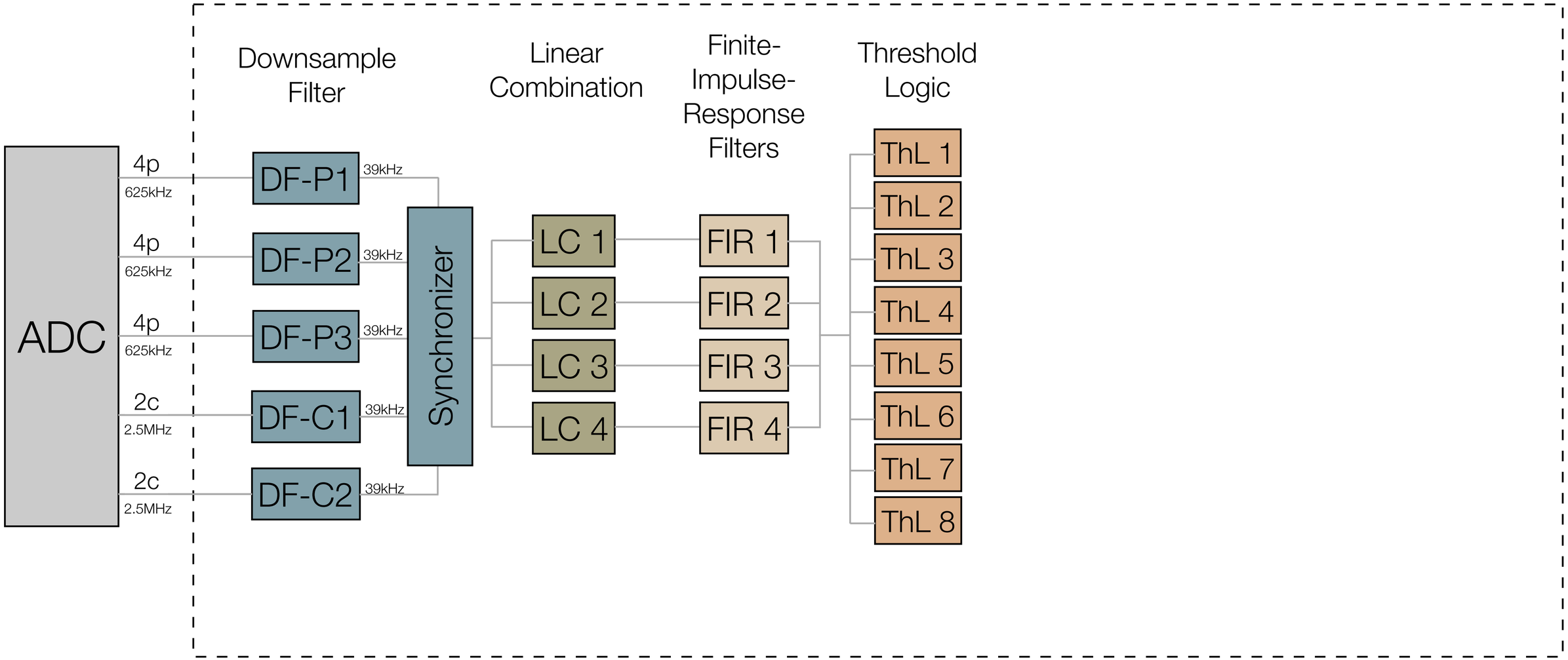
The L1 FPGA Trigger



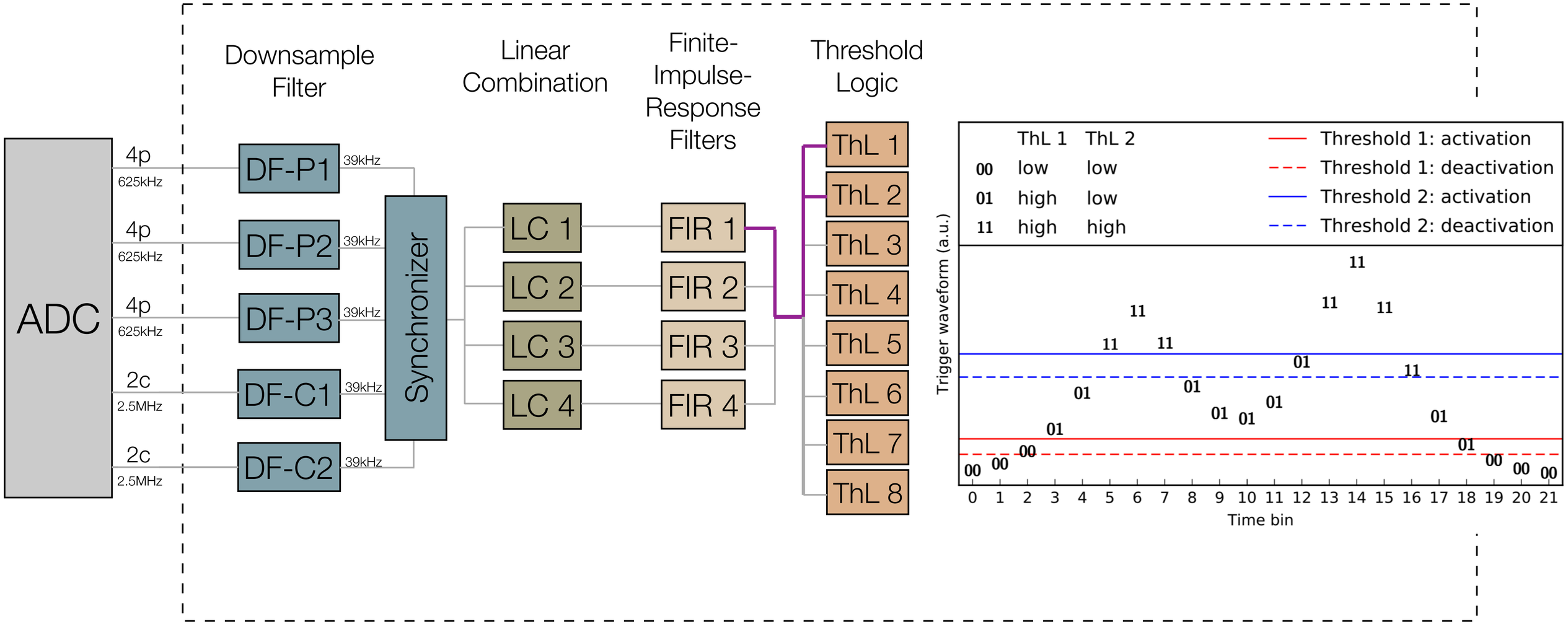
The L1 FPGA Trigger



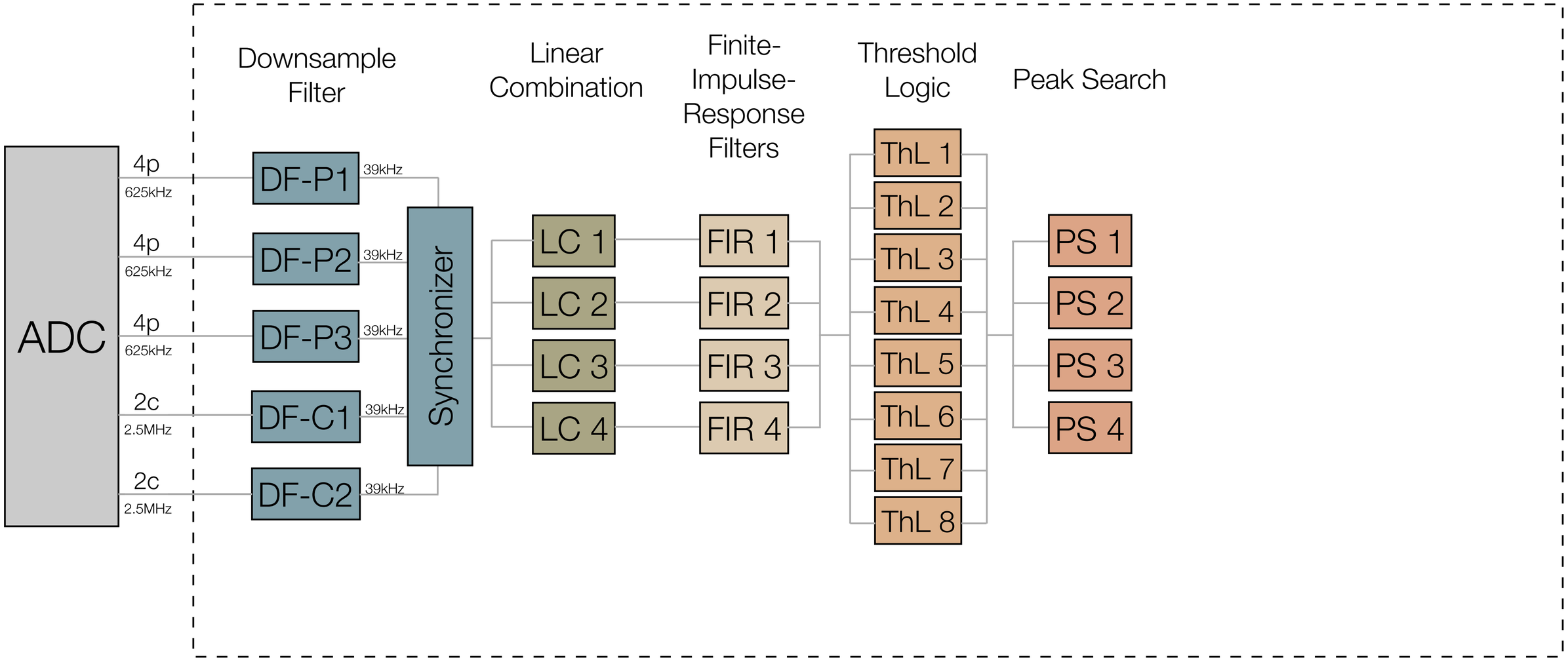
The L1 FPGA Trigger



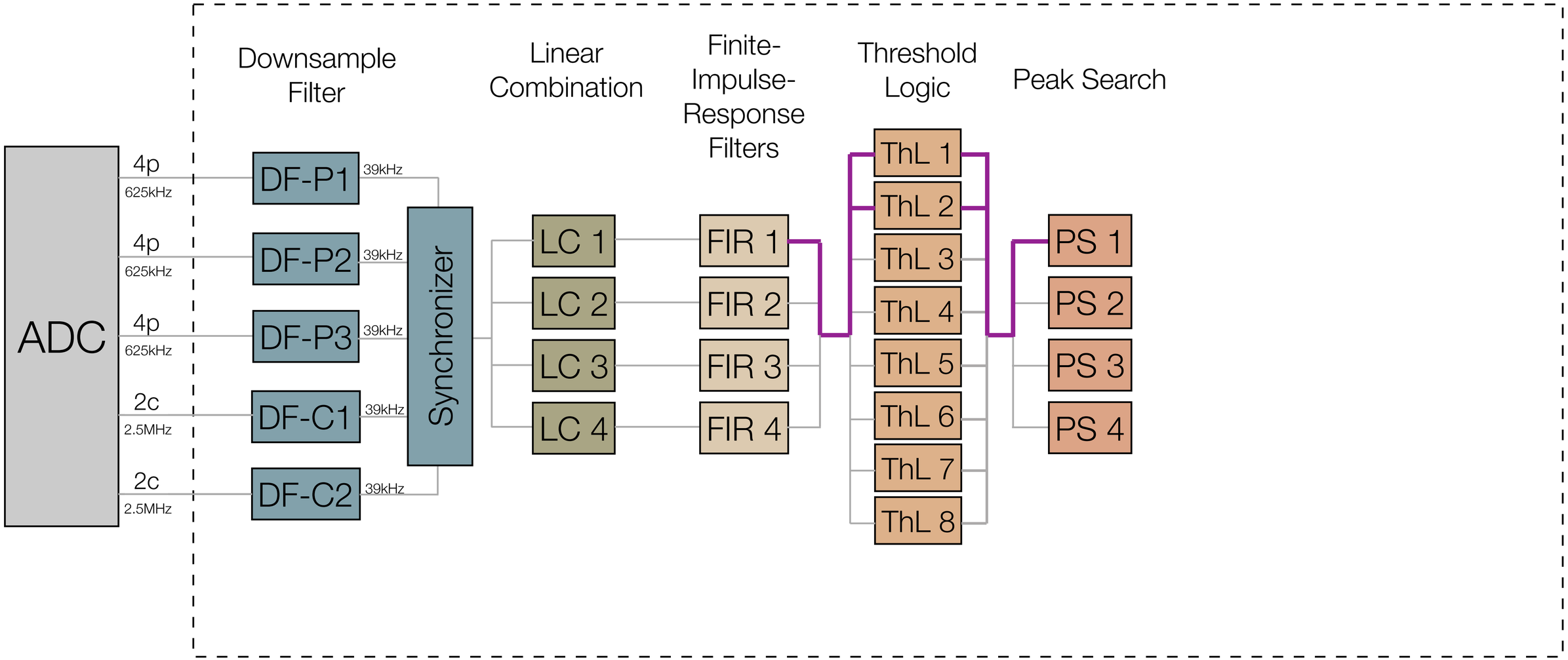
The L1 FPGA Trigger



The L1 FPGA Trigger



The L1 FPGA Trigger



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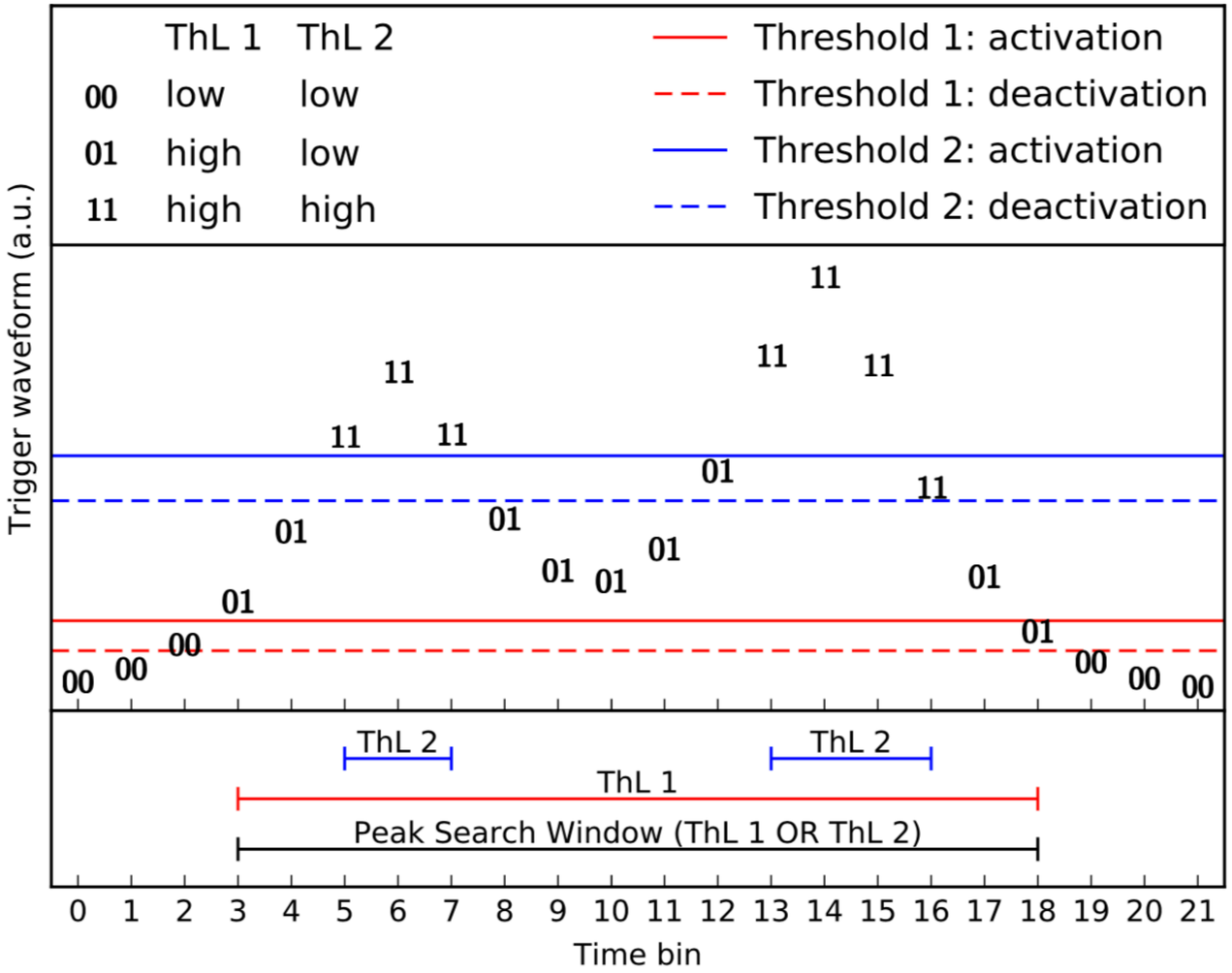

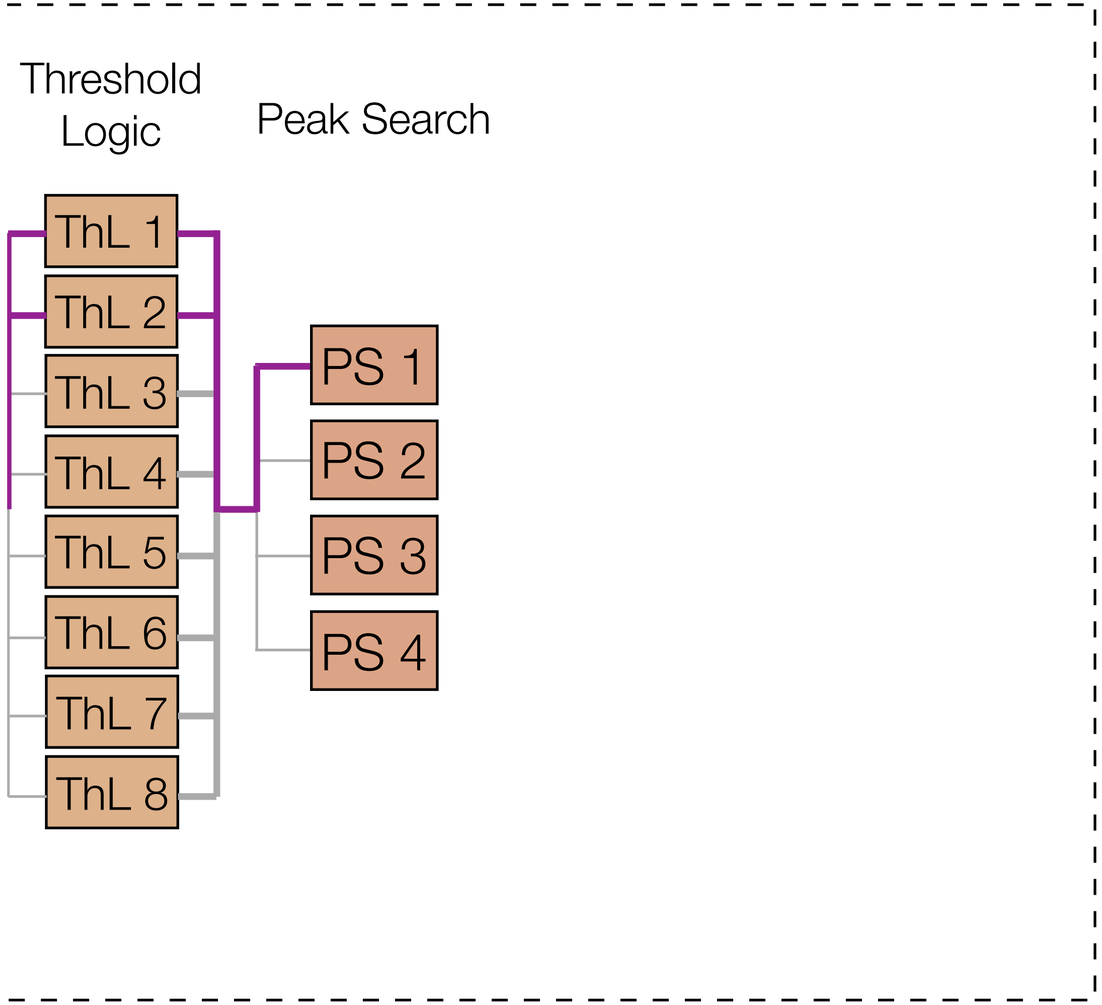

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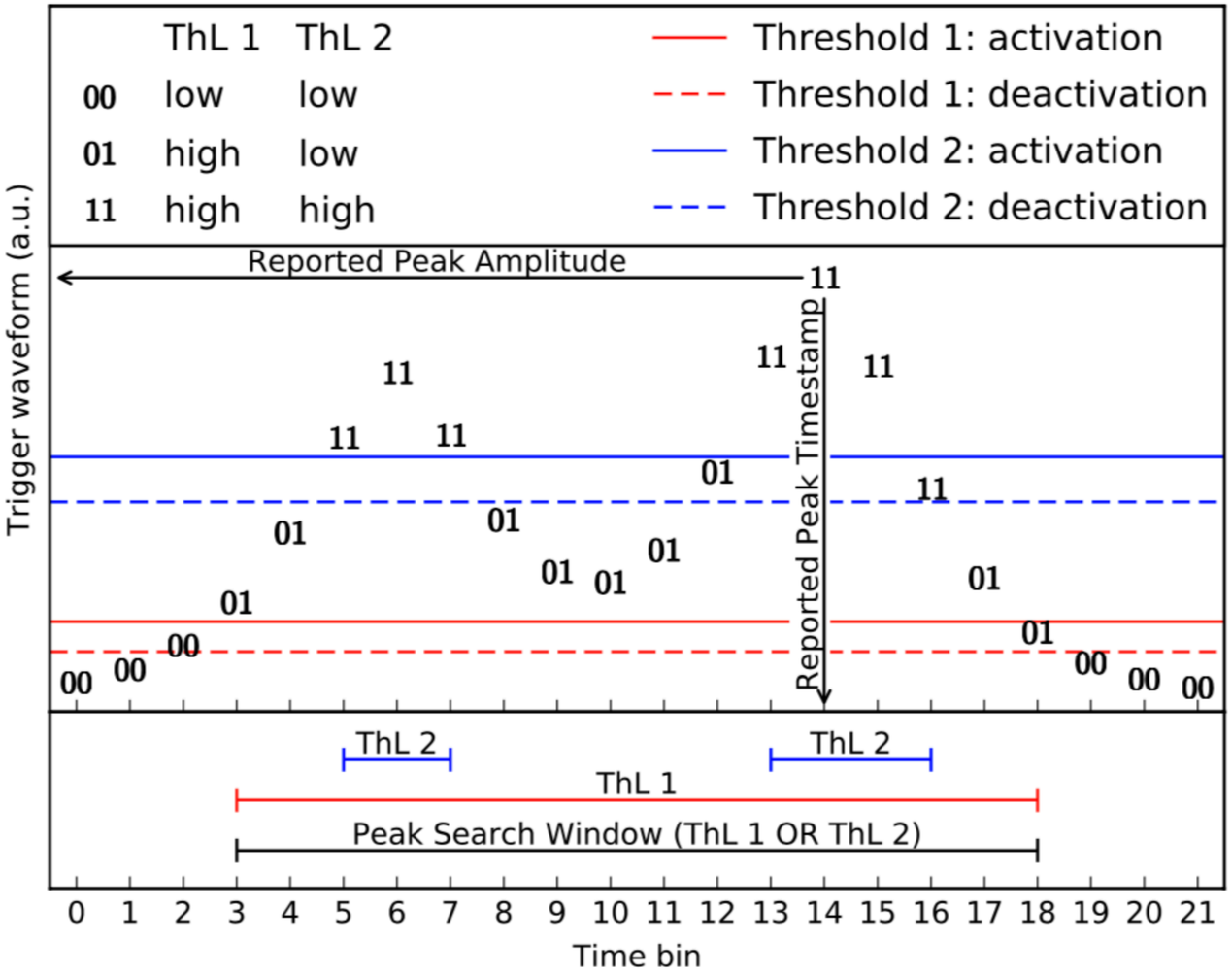
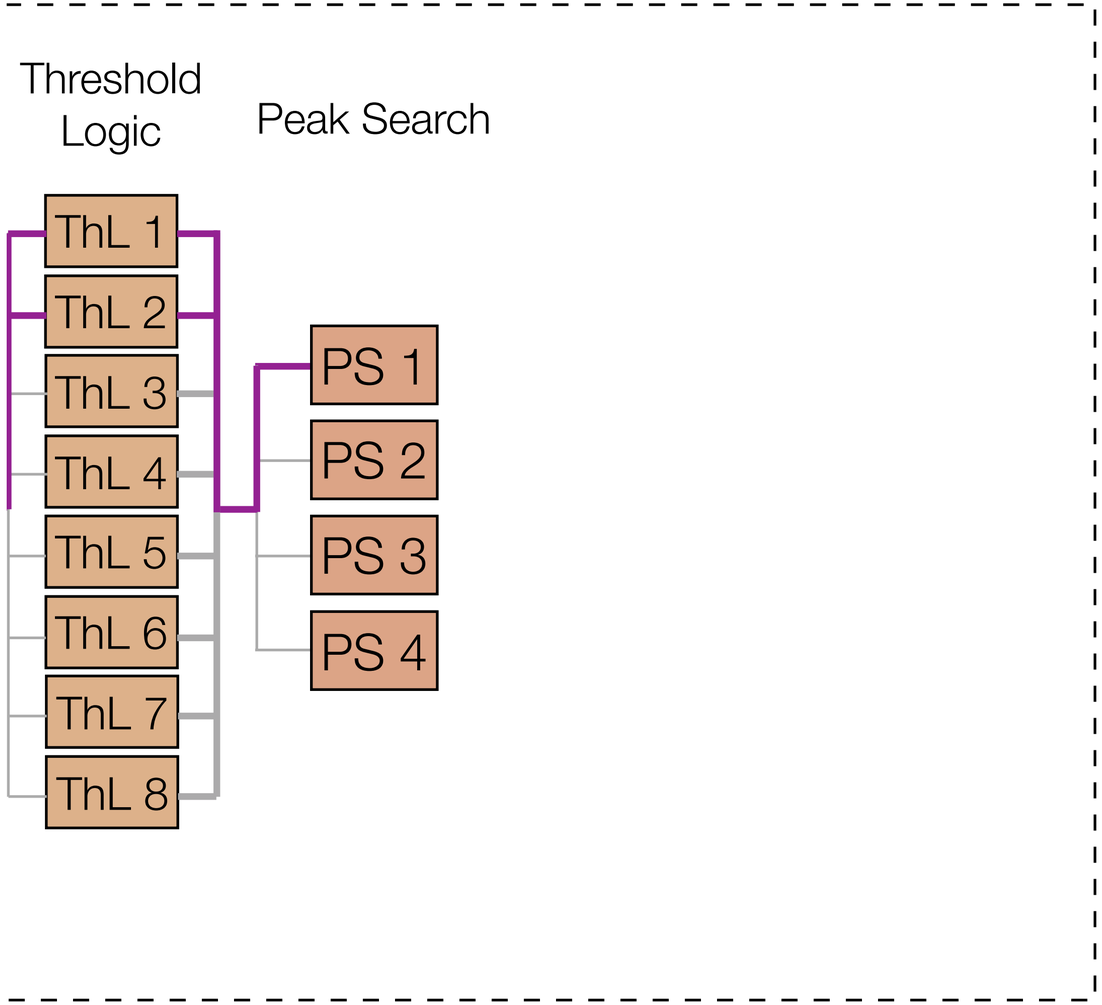
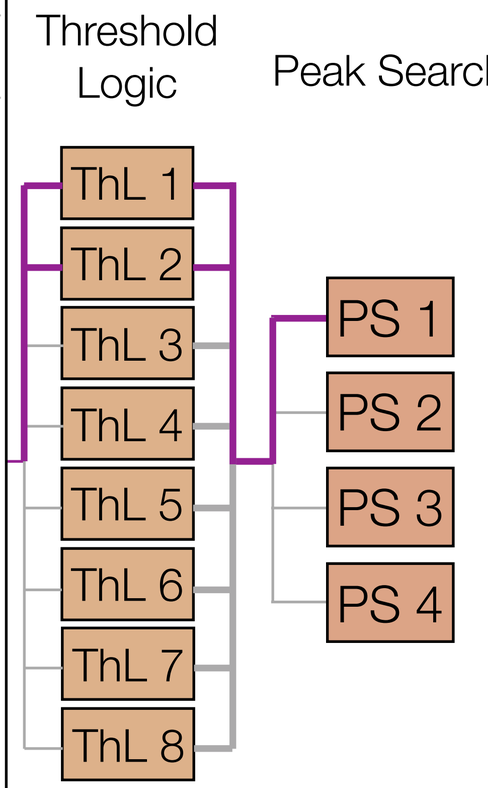




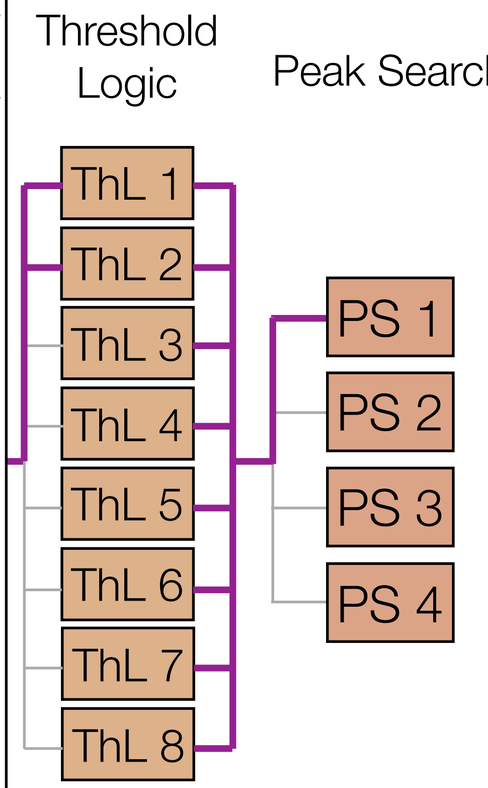
The L1 FPGA Trigger

	ThL Selectors	0	0	1	1	1	2	2	3	
Time bin	Trigger Waveform 0	ThL 1	ThL 2	ThL 3	ThL 4	ThL 5	ThL 6	ThL 7	ThL 8	Peak Search Window
0	10	0	0	1	0	0	0	1	1	0
1	14	0	0	1	0	0	0	1	1	0
2	22	0	0	0	0	0	0	1	1	0
3	36	1	0	0	0	0	0	1	1	1
4	70	1	0	0	0	0	0	1	1	1
5	91	1	1	0	0	0	0	1	1	1
6	113	1	1	0	0	0	0	1	1	1
7	92	1	1	0	0	0	0	0	1	1
8	64	1	0	0	0	0	0	0	1	1
9	47	1	0	0	0	0	0	0	1	1
10	43	1	0	0	0	0	0	0	1	1
11	54	1	0	0	0	1	0	0	1	1
12	80	1	0	0	0	1	1	0	1	1
13	118	1	1	0	0	1	1	0	1	1
14 (peak)	145	1	1	0	0	1	1	0	0	1
15	115	1	1	0	0	1	1	0	1	1
16	74	1	1	0	0	1	1	0	1	1
17	45	1	0	0	0	0	1	0	1	1
18	26	1	0	0	0	0	1	0	1	1
19	16	0	0	0	0	0	1	0	1	0
20	11	0	0	1	0	0	1	0	1	0
21	8	0	0	1	0	0	1	0	1	0
At-peak trigger word		1	1	0	0	1	1	0	0	
During-window trigger word		1	1	0	0	1	1	1	1	



The L1 FPGA Trigger

	ThL Selectors	0	0	1	1	1	2	2	3	
Time bin	Trigger Waveform 0	ThL 1	ThL 2	ThL 3	ThL 4	ThL 5	ThL 6	ThL 7	ThL 8	Peak Search Window
0	10	0	0	1	0	0	0	1	1	0
1	14	0	0	1	0	0	0	1	1	0
2	22	0	0	0	0	0	0	1	1	0
3	36	1	0	0	0	0	0	1	1	1
4	70	1	0	0	0	0	0	1	1	1
5	91	1	1	0	0	0	0	1	1	1
6	113	1	1	0	0	0	0	1	1	1
7	92	1	1	0	0	0	0	0	1	1
8	64	1	0	0	0	0	0	0	1	1
9	47	1	0	0	0	0	0	0	1	1
10	43	1	0	0	0	0	0	0	1	1
11	54	1	0	0	0	1	0	0	1	1
12	80	1	0	0	0	1	1	0	1	1
13	118	1	1	0	0	1	1	0	1	1
14 (peak)	145	1	1	0	0	1	1	0	0	1
15	115	1	1	0	0	1	1	0	1	1
16	74	1	1	0	0	1	1	0	1	1
17	45	1	0	0	0	0	1	0	1	1
18	26	1	0	0	0	0	1	0	1	1
19	16	0	0	0	0	0	1	0	1	0
20	11	0	0	1	0	0	1	0	1	0
21	8	0	0	1	0	0	1	0	1	0
At-peak trigger word		1	1	0	0	1	1	0	0	
During-window trigger word		1	1	0	0	1	1	1	1	



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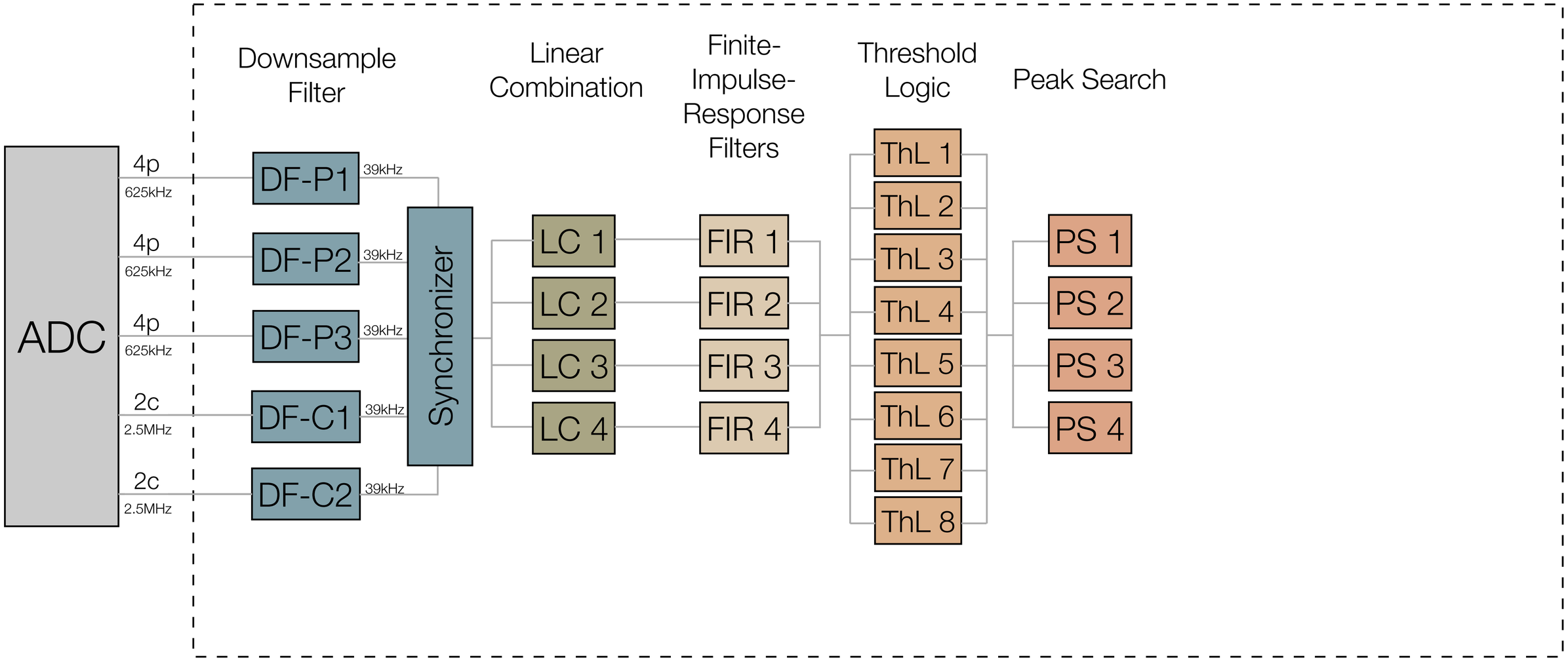

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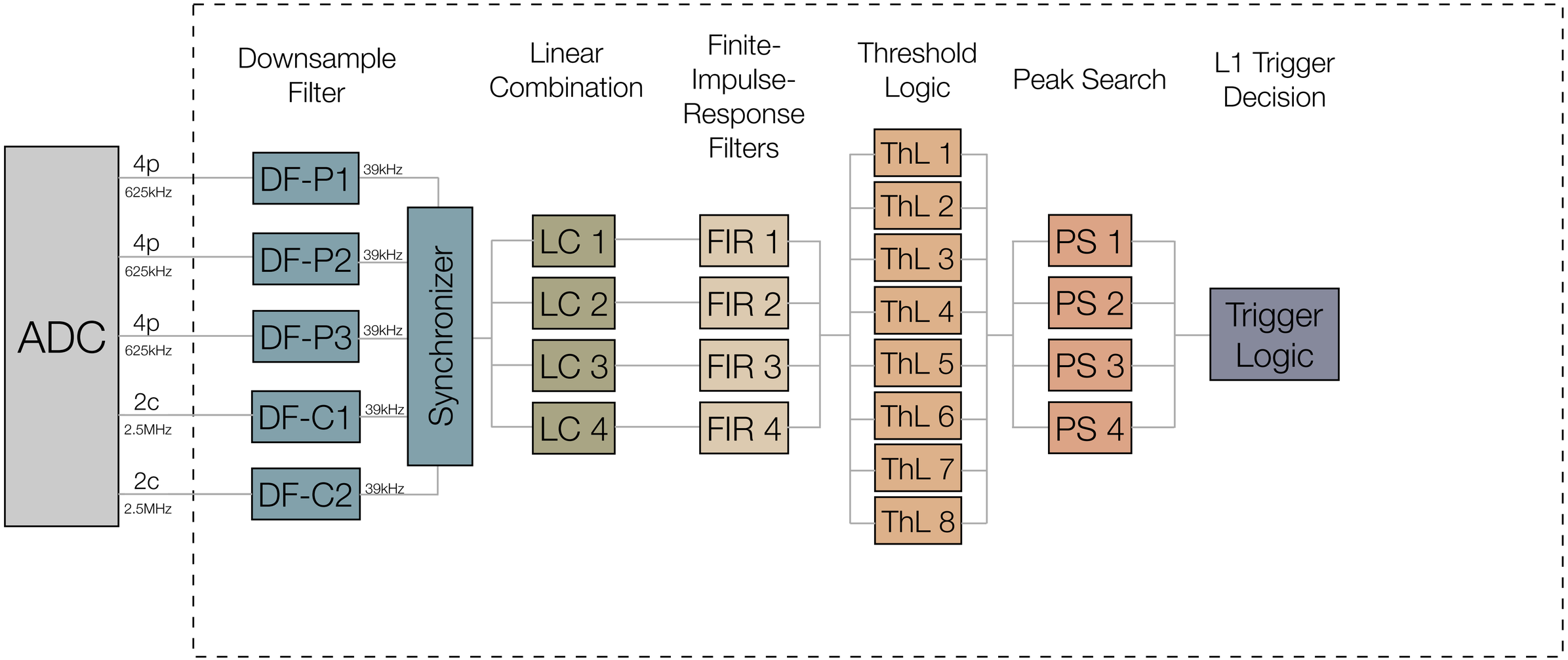

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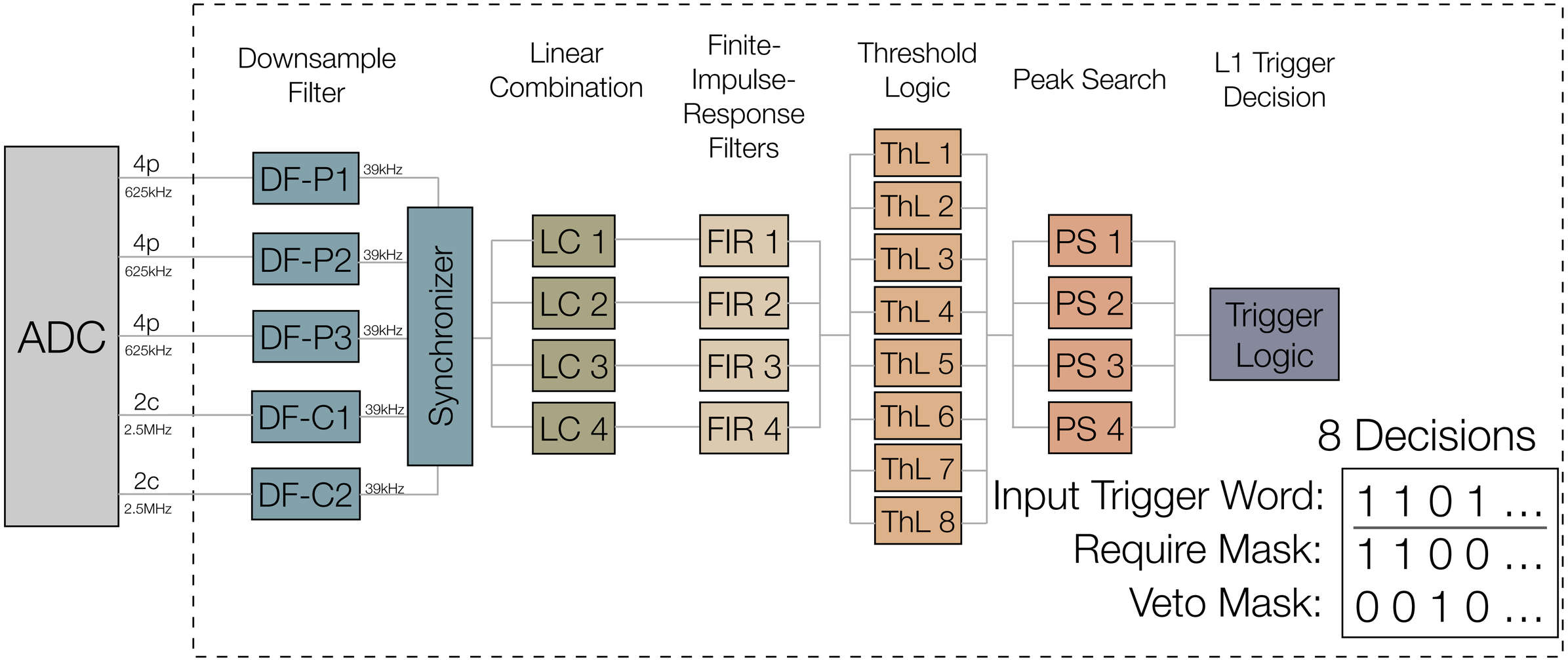

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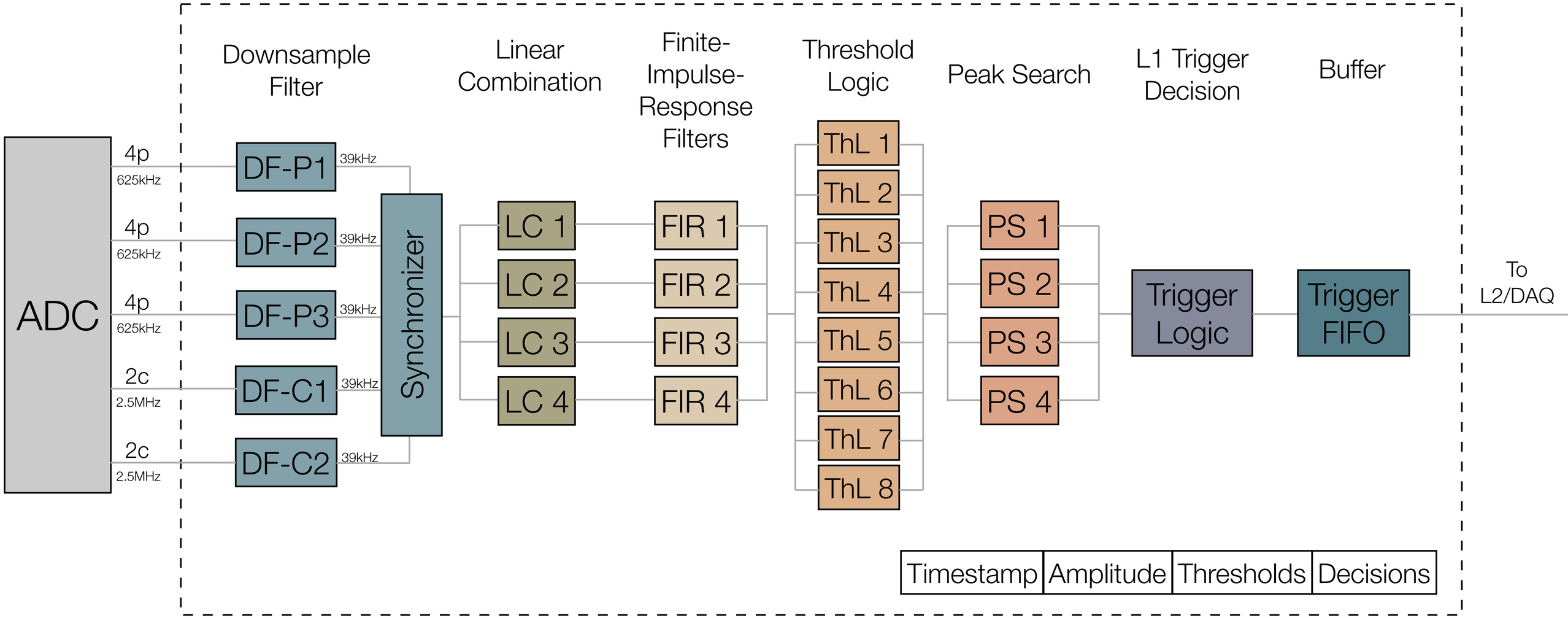
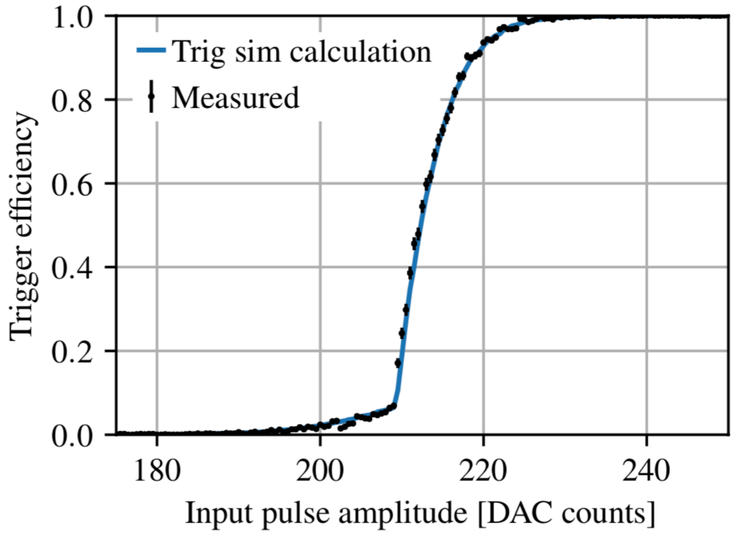
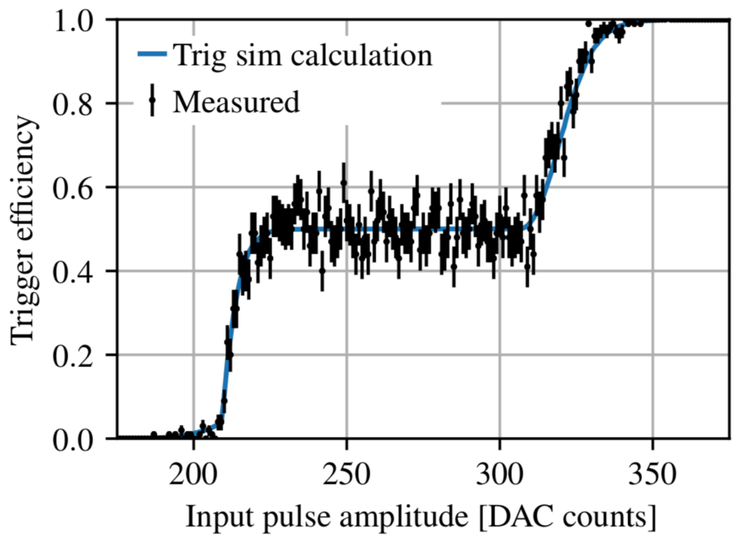


Trigger Performance

Single threshold



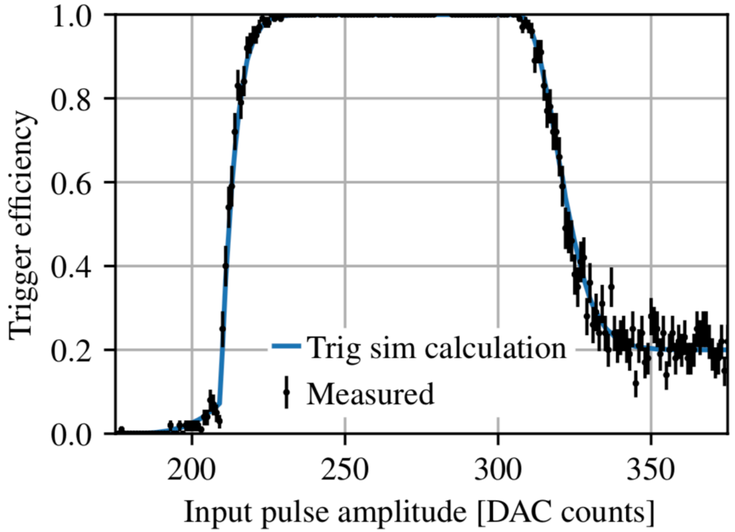


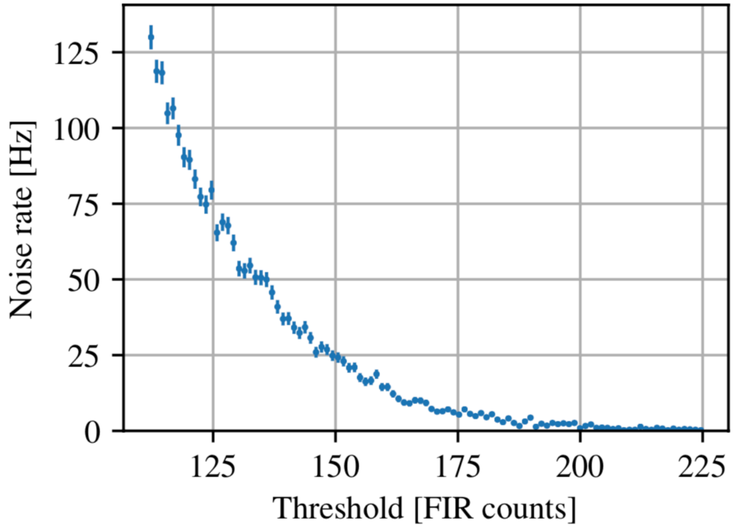
Low threshold
50% prescaled

High threshold
Unprescaled

Low threshold
unprescaled

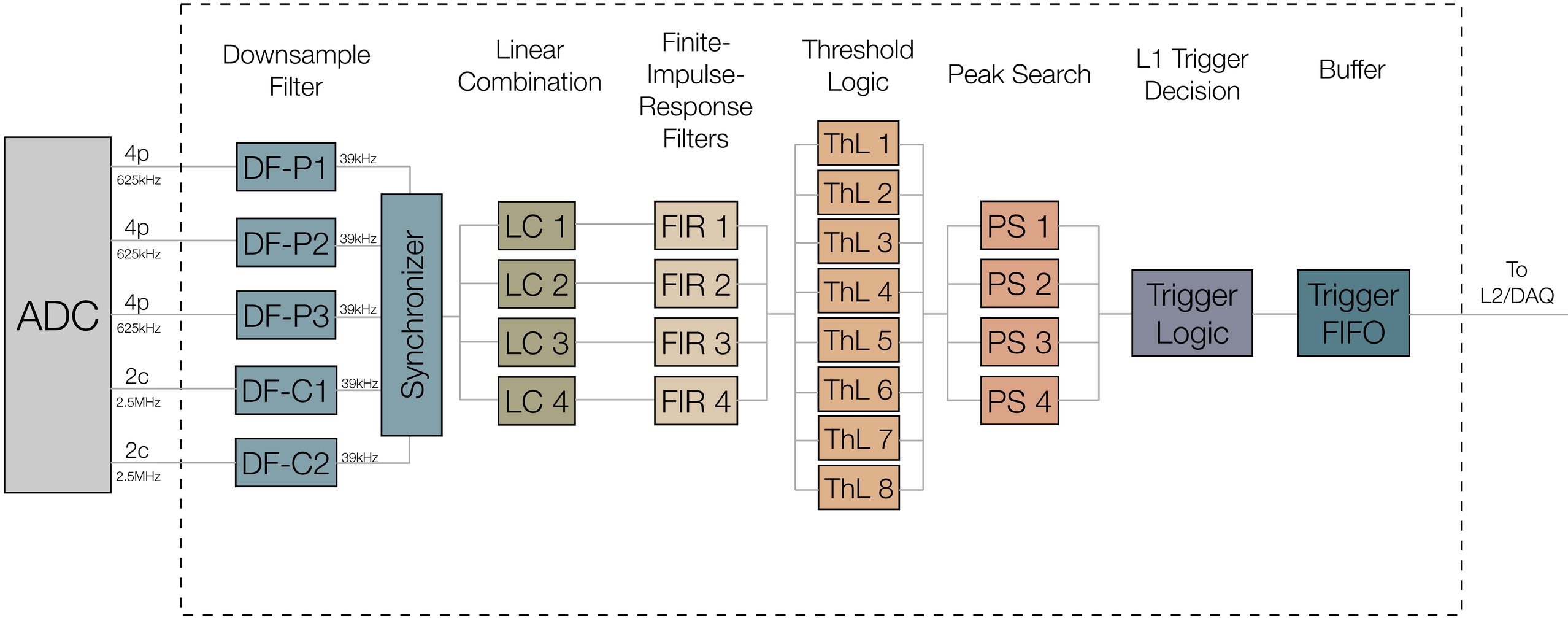
High threshold
vetoed



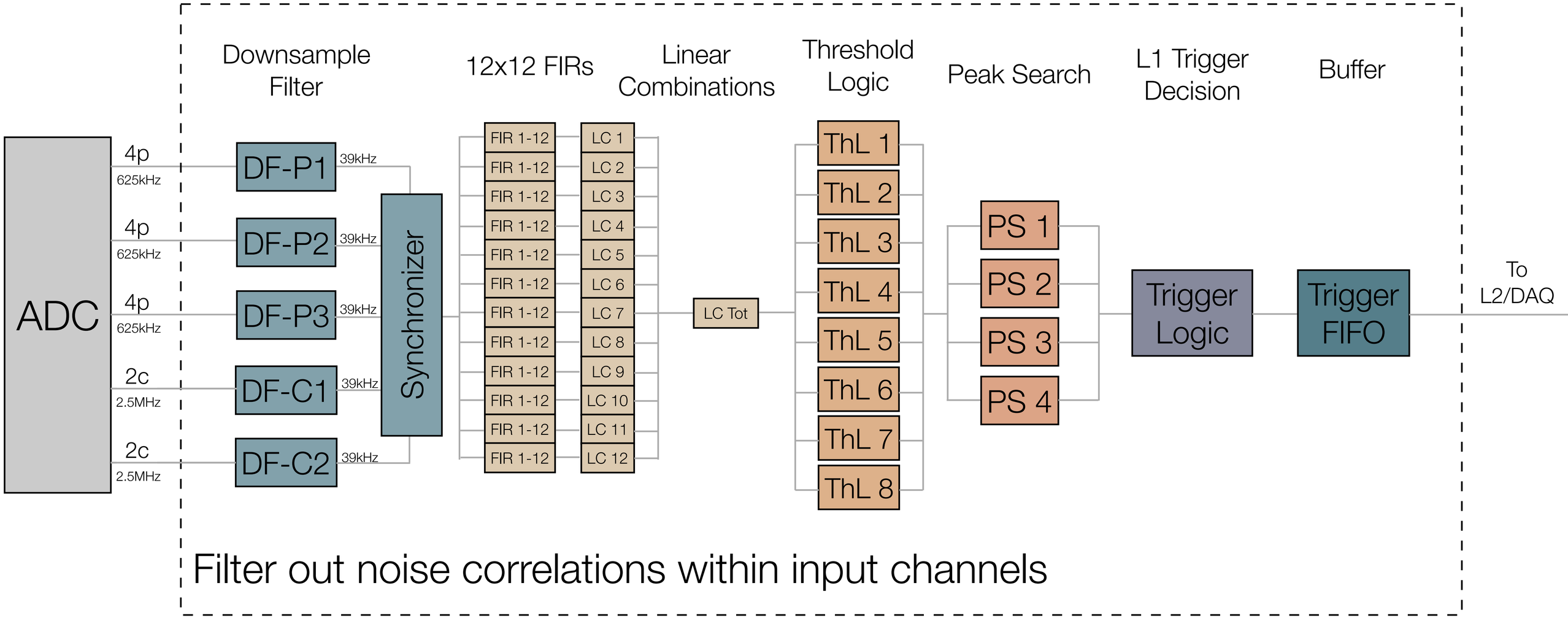


Noise dependence

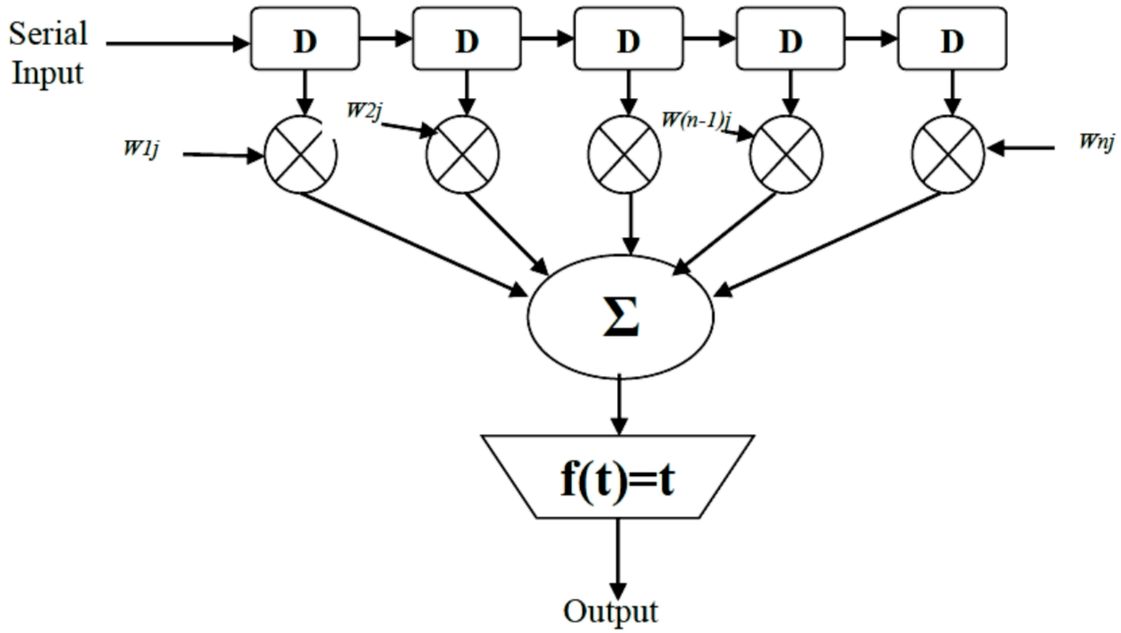
Future Improvement: NxM Correlated Optimal Filter



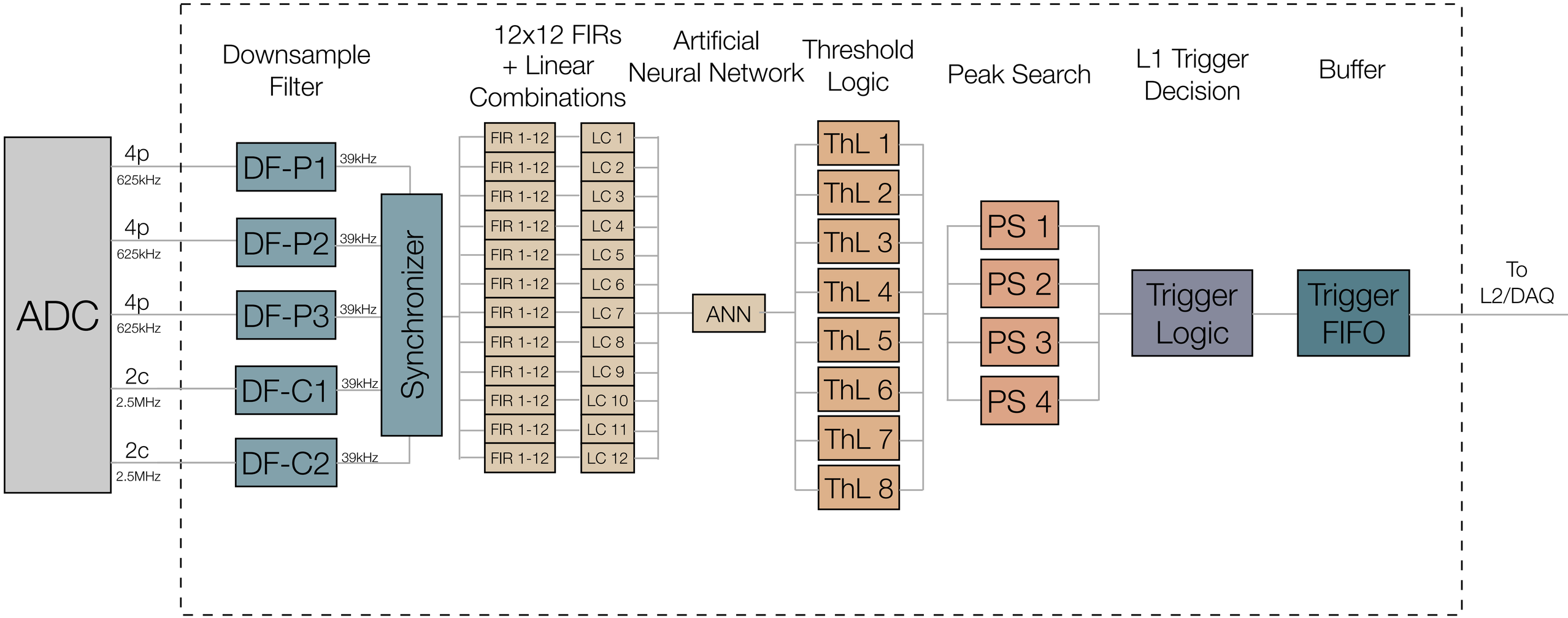
Future Improvement: NxM Correlated Optimal Filter



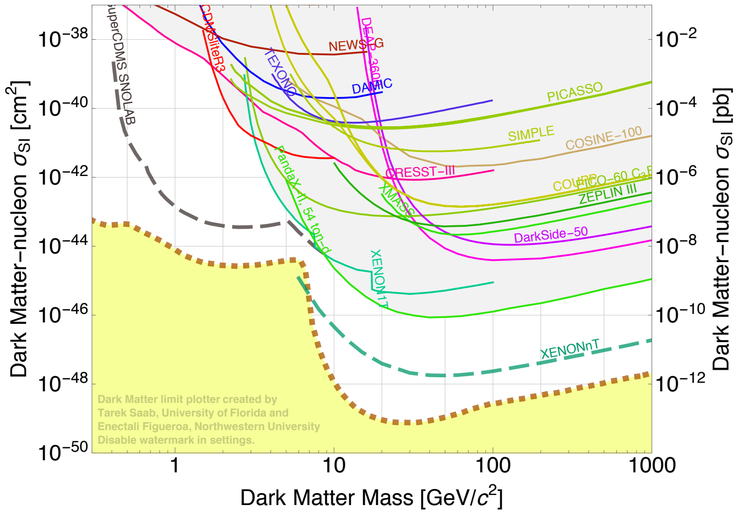
Future Improvement: Machine Learning on FPGA

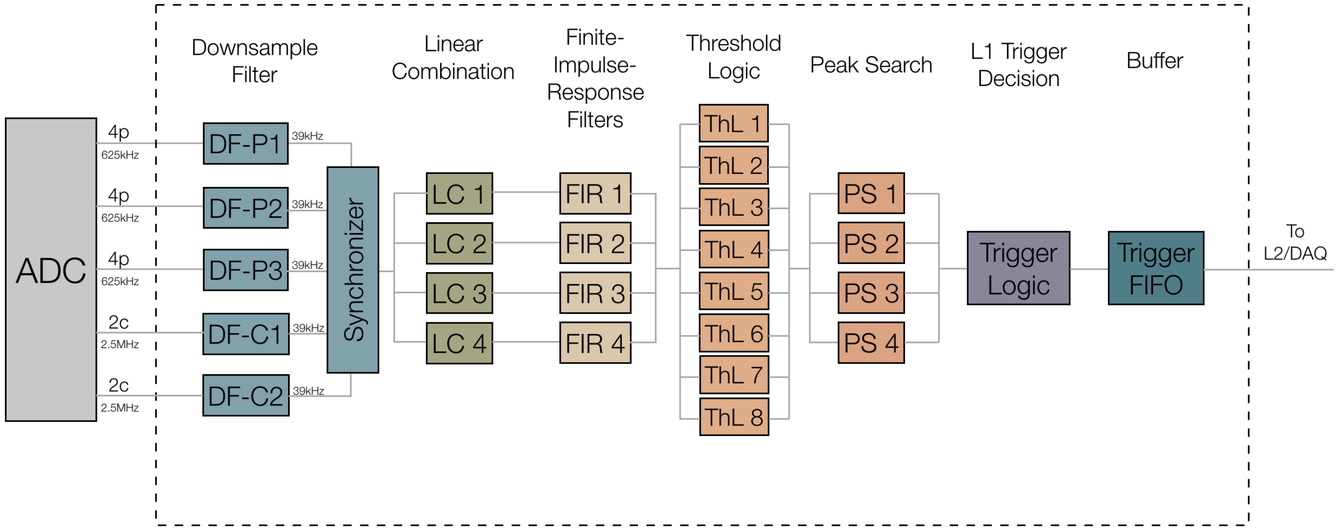


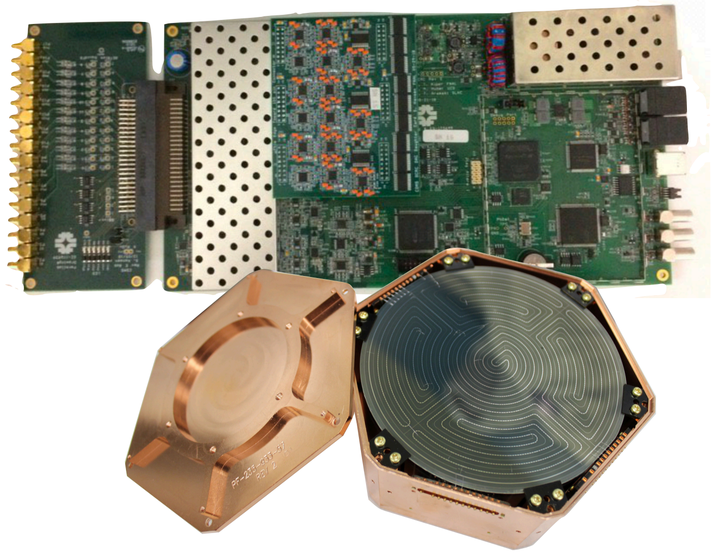
Future Improvement: Machine Learning on FPGA



Thanks for your attention!







Two cross-disciplinary open positions:

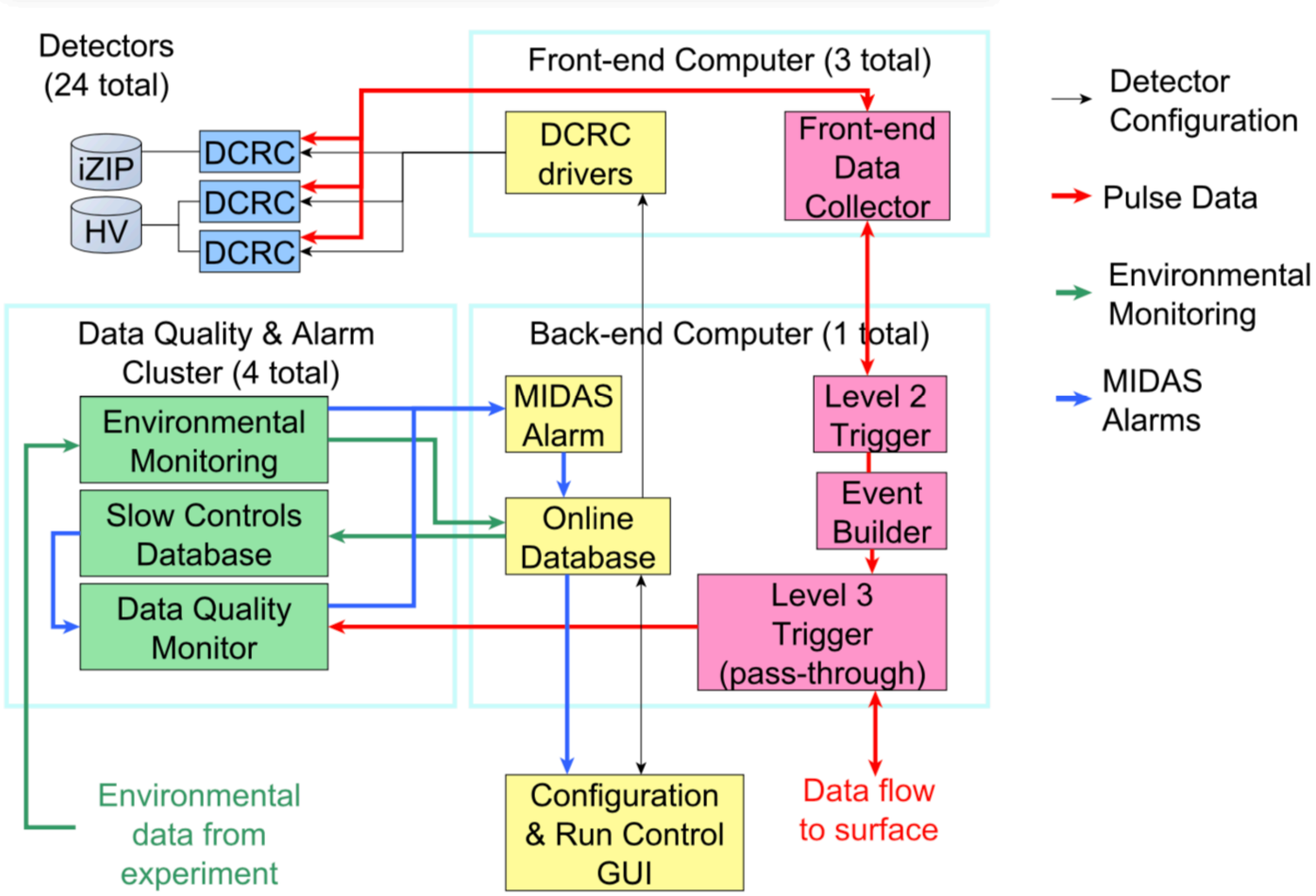
SuperCDMS (Postdoc):

https://www.uni-hamburg.de/uhh/stellenangebote/wissenschaftliches-personal/exzellenzcluster-quantum-universe-qu1/29-02-20-19-en.pdf

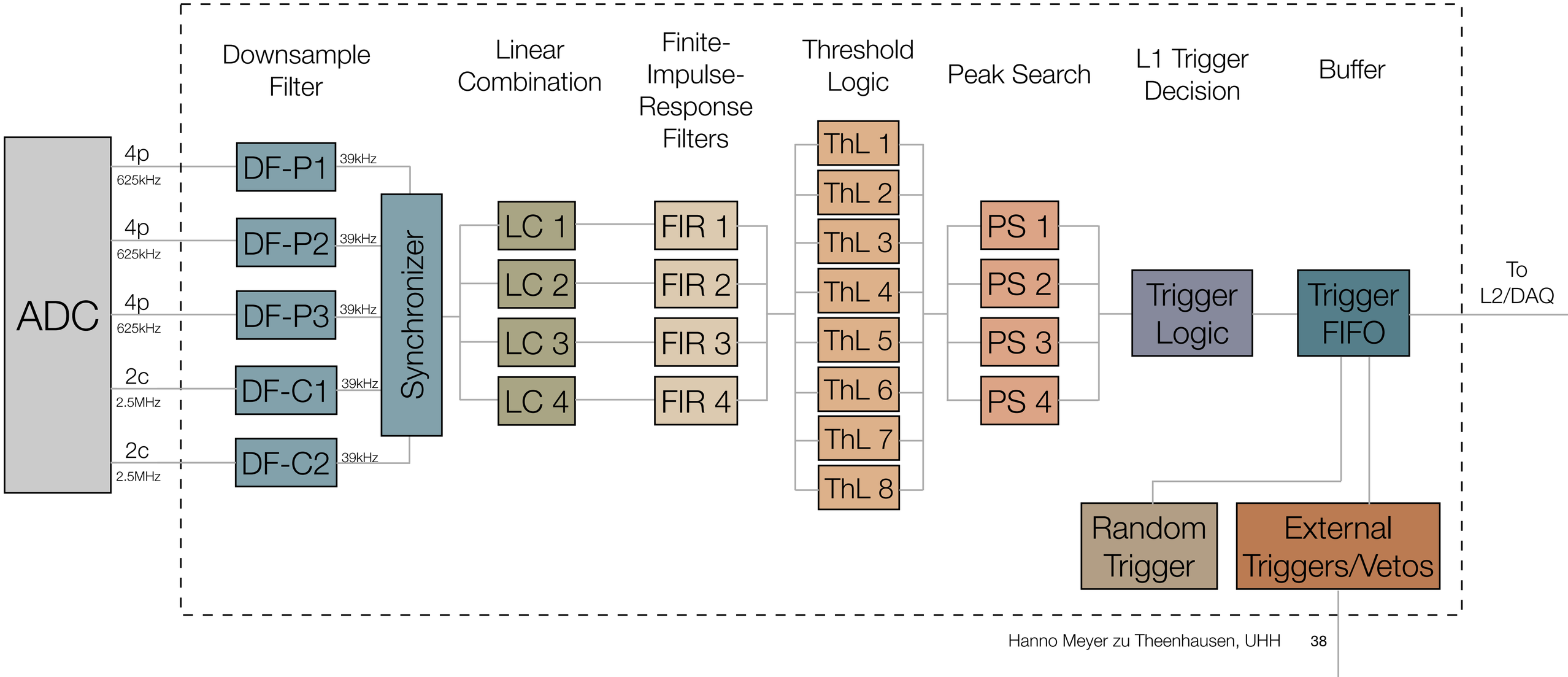
Belle II (PhD):

http://www.desy.de/career/job_offers/index_eng.html?joboffer=99930

Backup: The SuperCDMS DAQ System



Backup: Randoms and External Triggers/Vetos



Backup: Signal Vs Background Trace