TRIUMF

NuPRISM Electronics

Thomas Lindner, Fabrice Retiere,
Carl Rethmeier | TRIUMF

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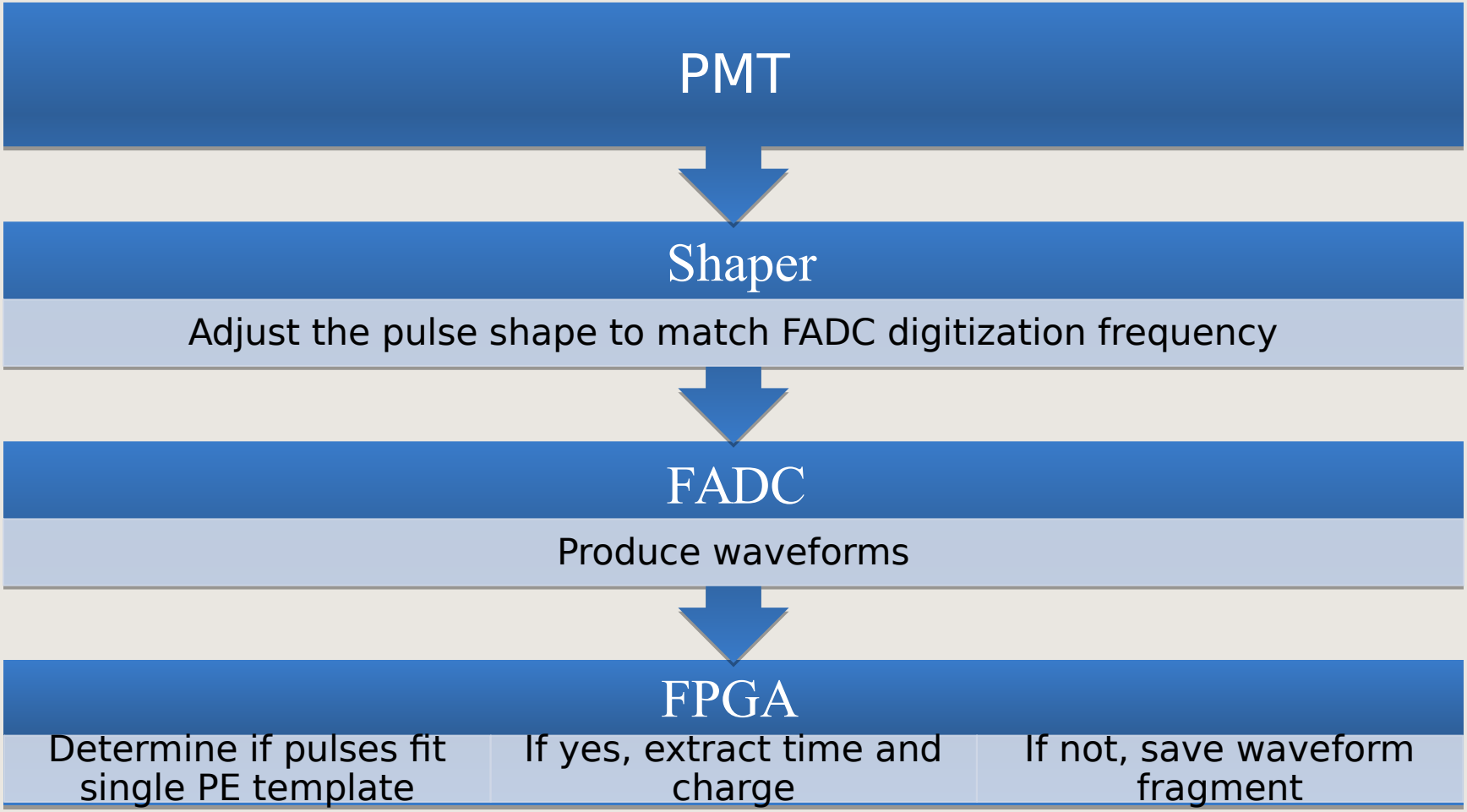
Overview

- Current work on FADC digitization.
- Medium term electronics plans.
- 3” PMTs option: thoughts on cost.

Reminder of FADC Digitization



Advantages/Disadvantage of FADC Digitization for nuPRISM

- NuPRISM will have high rate of pile-up, many interactions per spill, as well as multiple michel electrons.
  - FADC digitization should give lots of well separated information on all events.
- Still hoping to use same electronics for HK and nuPRISM (synergy between projects); so much of the current work is more HK focused.

- Main challenge: achieving the desired timing resolution and dynamic range.

Current Test Setups at TRIUMF

Signal

- PMT + shaper
  - R9875P with TTS<0.3ns but very fast pulse
  - Shaping using DEAP signal conditioning board. Not optimized for timing resolution
- Arbitrary waveform generator
  - Allow changing pulse shape, and amplitude

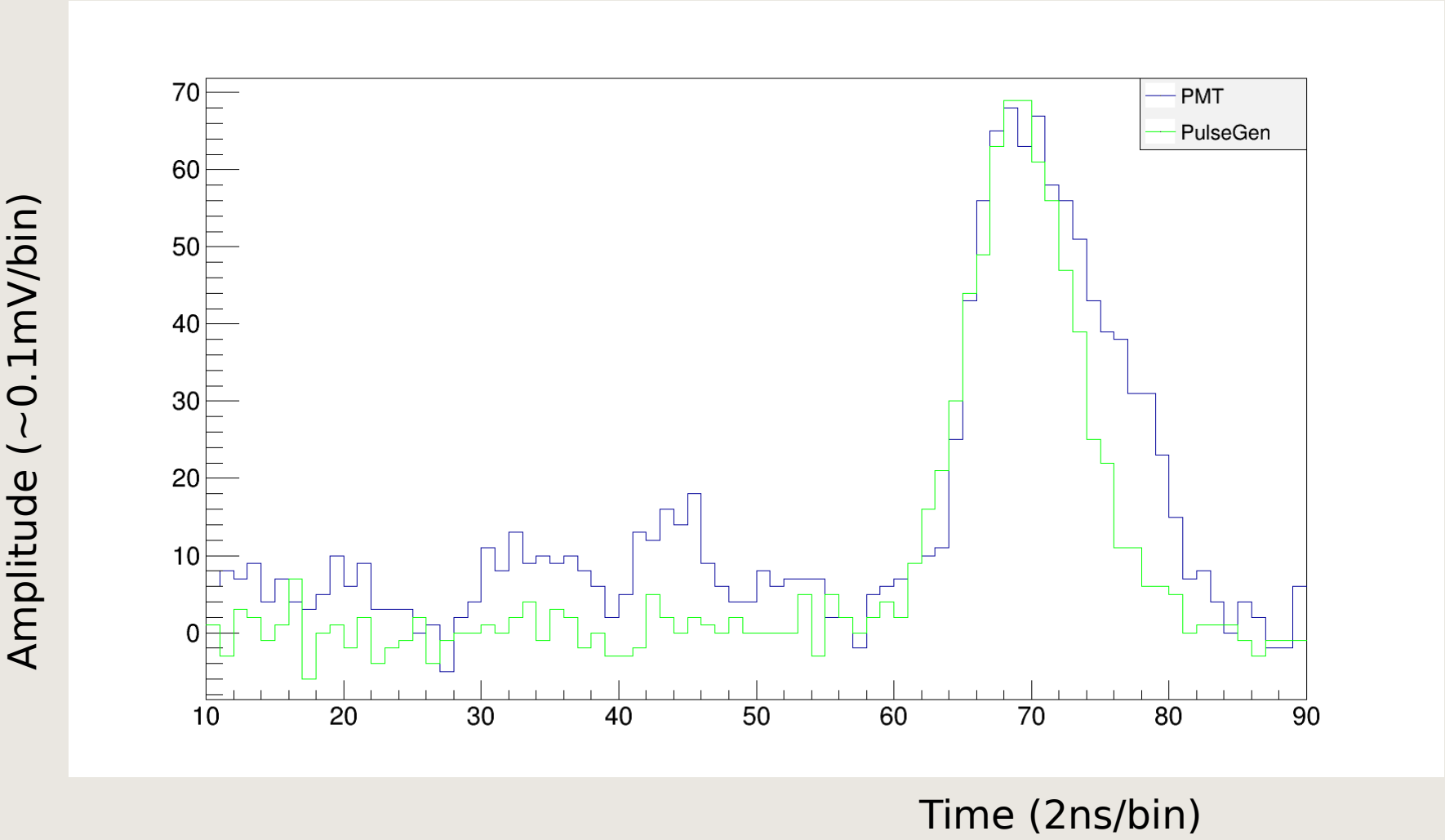
Digitizers

- 500MHZ, 14bits, CAEN V1730
- 250MHz, 12bits, CAEN V1720
- 100MHz, TRIUMF custom FADC for GRIFFIN experiment

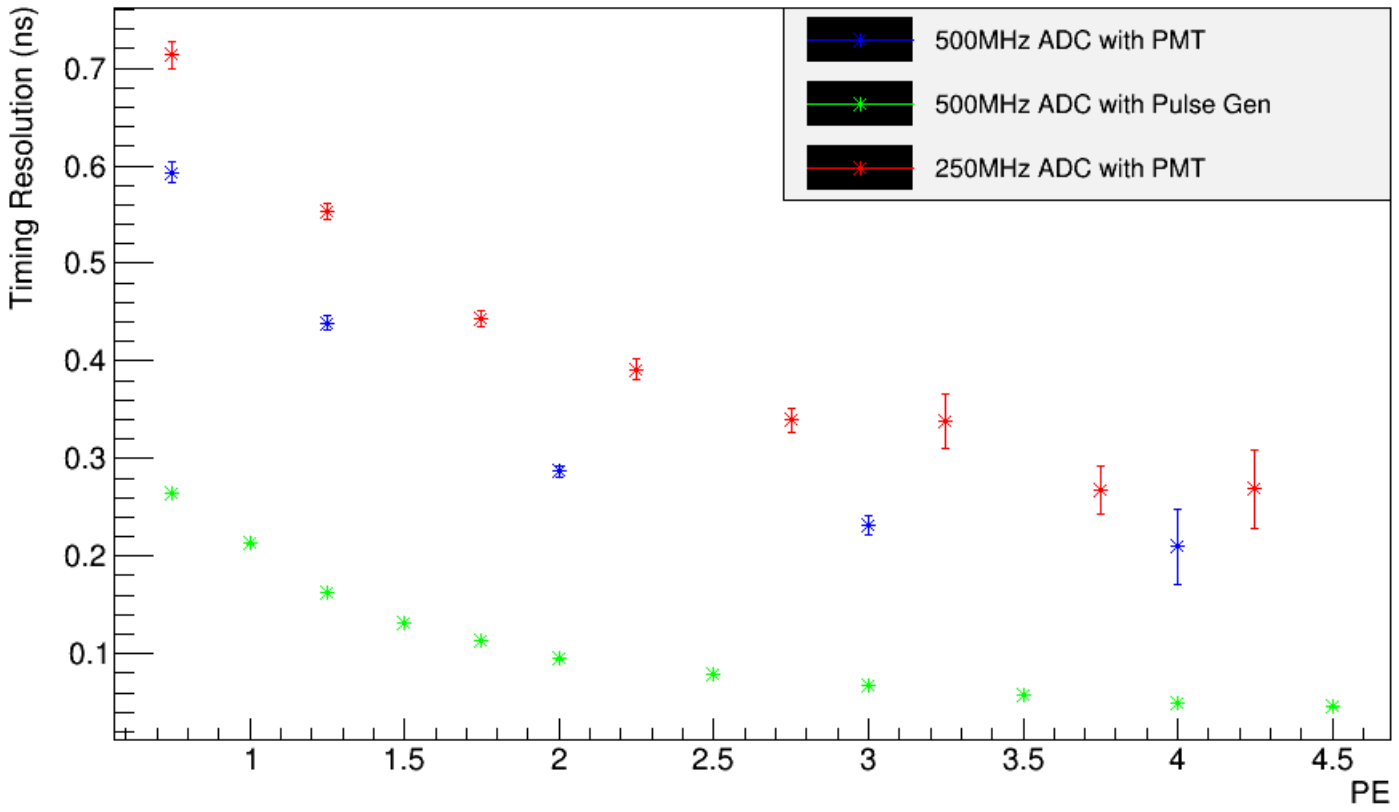
Pulse analysis offline analysis for now

- Test CAEN digital CFD later this year

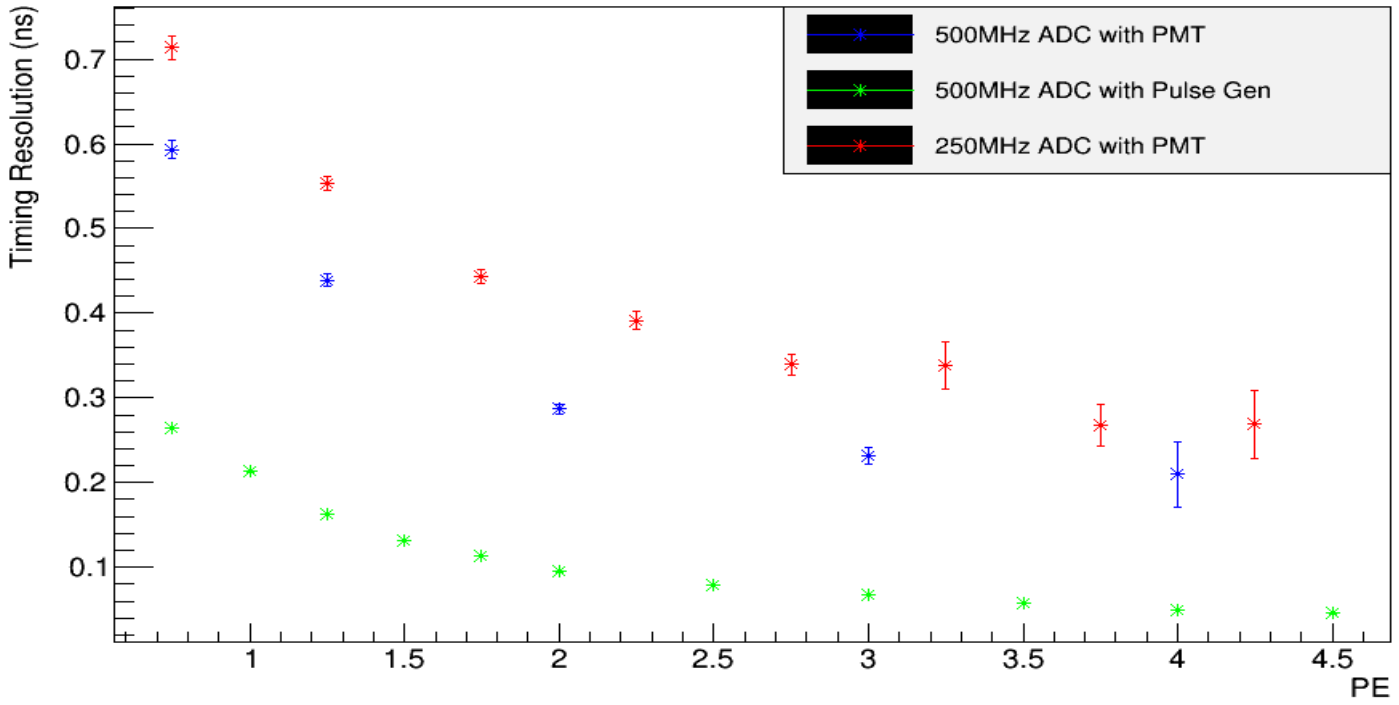
Arbitrary Waveform Generator



Timing Resolution vs #PE



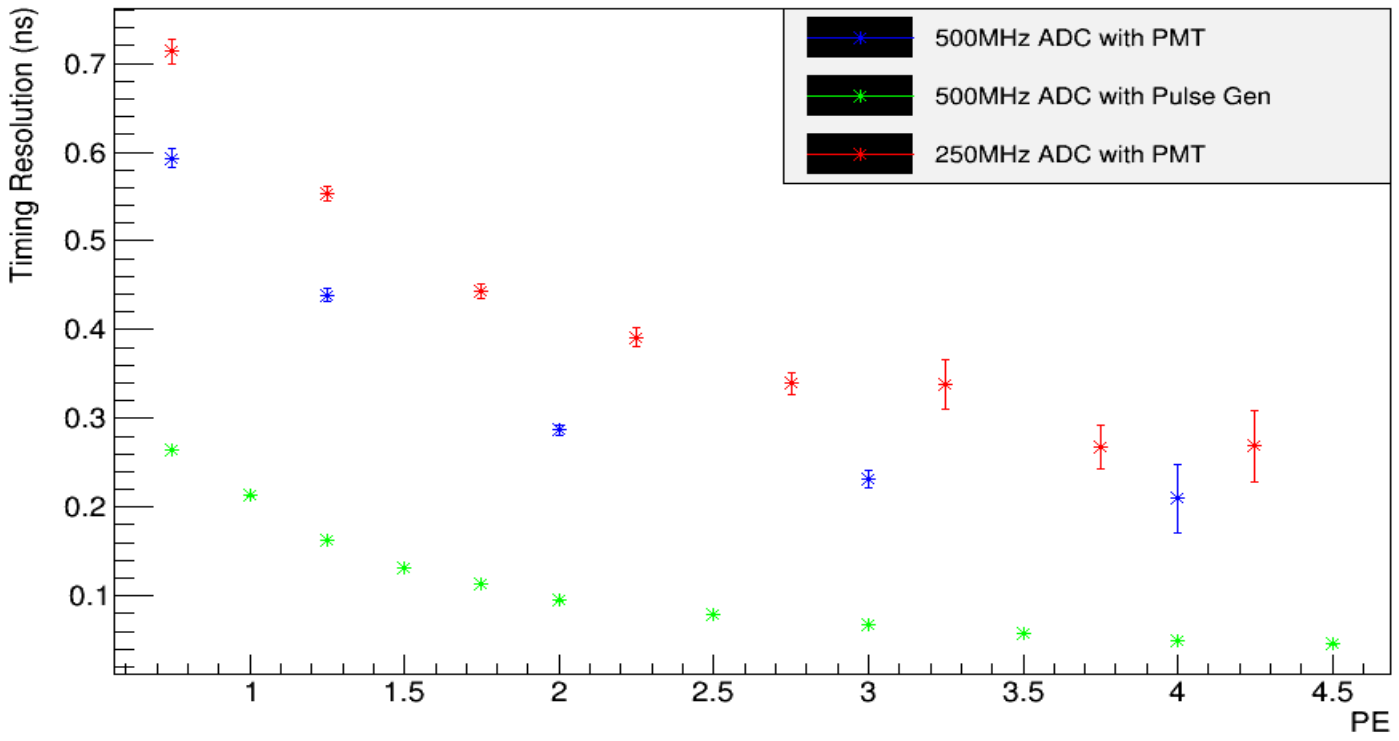
Timing Resolution vs #PE



In principle the 500MHz ADC results with PMT and pulse generator should have similar timing resolution. But:

- Fitting method was different for pulse generator test
- The PMT has an intrinsic TTS on order ~0.2-0.3ns

Timing Resolution vs #PE



- We are in the right ball-park for the needed timing resolution.
- But need to understand better which type of PMTs we are using; what is Transit Time Spread for 8" PMT?
  - Marcin found that it is probably ~1ns.

Short/Medium Term Plans (Mostly just HK electronics work)

- Continue the set of tests of timing resolution for various combinations of digitizer and shaping.
  - More comparing to Marcin's simulation results (next talk)
- Will get another 250MHz digitizer from PINGU in a couple months for testing. Might be a good baseline design for our own 250MHz digitizer.
  - PINGU::Perry's idea 'compressor' might help with our dynamic range problems.

Short/Medium Term Plans (Mostly just HK electronics work) [2]

- Have agreement to build a FADC digitizer mezzanine card for HK prototype in 2015/2016.
- We are considered either making the digitizer mezzanine ourselves or asking CAEN to make it for us.
- This tests should also help us refine the cost estimates for FADC digitization (as well as confirming the physics performance)

Discussion of 3” PMTs

- Mike suggested that we investigate the KM3NET claim that multiple 3” PMTs is more cost effective than 8” PMTs for nuPRISM.
- Clearly one major concern is then the electronics; if we just scale up our previous electronics budget (~$1million) by factor of 5-7, then electronics is starting to become a major cost driver.
- What are options for reduced per channel cost?

Electronics Cost

- Hayato-san original estimate of cost for HK components.
- Works out to $433/channel or $1.3 million for 3000 nuPRISM channels.

Extremely rough estimate of the costs

Electronics part		
	ADC/TDC	~ 480k / board (20k * 24 channels)
	Network	~ 50k / board
	Control block	~ 50k / board
LV/HV		
	power supply	~ 240k / board (10k * 24 channels)
Connectors		~ 120k / board (5k * 24 channels)
Case		~ 100k / board
Total		~1040k / board
		(for 100k channels, ~ 4.3×10^9)

Cost reduction for 3” PMTs option

- Digitization options
  - Need better estimates for true cost for FADC option. Might be less than $200 estimated. Will have better idea after tests in next half year.
  - Can also consider the TDC/QTC or custom ASIC solutions. Might be cheaper, though need to investigate.
    Also a QTC with 1 us dead-time really wouldn't work for pile-up.
  - Let's assume we can get this down to $100/channel?

Extremely rough estimate of the costs

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ADC/TDC	~ 480k / board	(20k * 24 channels)
Network	~ 50k / board	
Control block	~ 50k / board	$100/ch
LV/HV		
power supply	~ 240k / board	(10k * 24 channels)
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Total	~1040k / board	
	(for 100k channels, ~ 4.3 x 10^9)	

Cost reduction for 3” PMTs option

- LH/HV power.
  Marcin thought that we could probably do some sort of HV supply for the PMT for quite a bit cheaper.
  - Group had previously made Geiger PS for ~$15/ch.
- Connectors/Case
  Probably could get grad students to just epoxy together cheap boxes; can probably do that for less than $2000 per case.
  - Also, think about the option of out-of-water electronics. Save on case, but more cost for cables.

Extremely rough estimate of the costs

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ADC/TDC	~ 480k / board (20k * 24 channels)	
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  - So a reduced electronics budget might be $180/ch. So still $3.6 million for 20,000 PMTs.

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3” PMT – Timing Resolution

- Different question: the 3” PMT would presumably have better timing resolution than a 8” PMT.
- So we would want better electronics if we want to fully take advantage of the faster PMTs.
- How much does this matter?
- Would be good to have some guidance from simulation about how beneficial it would be to have fast PMT + fast digitization.

Gadolinium electronics

- Gadolinium a serious option?
- Capture time for neutron on gadolinium has 20 us time. (?)
- So if we use a triggered system for nuPRISM electronics, then would want to stay active for 50-100us.
- This might make it difficult to use some electronics options. For instance, might be difficult to find Switched Capacitor Array with 100us depth and very fast sampling.
  - But I guess that is what they are using for ANNIE; should ask what solution they use.

Conclusion

- We are continuing to make progress on testing timing resolution of FADC option. Can get around 0.3-0.5ns for SPE, but still need to work on understanding these results fully.
- We have plans for producing a couple different digitizer boards in coming years. In addition to checking physics performance, this will also give us a better estimates on cost.
- Considered the 3” PMT option. It will be difficult to not have electronics be a cost driver in this case; need to consider different digitization options; also understand better physics requirements for 3”.

Backup

Nominal HK Electronics Requirements

- Timing resolution $\sigma \leq 0.5$ns for 1 photo-electron
- Noise ≤0.1PE
- Dynamic range
  - 1,000 PE over 1ms
    - What is it over 50ns, 250?
  - Maintain PMT linearity, i.e. use low gain?
- Power dissipation ~1W/channel
- Readout scheme
  - Dark noise dominated ~5kHz/PMT
    - Only send time (~TDC) and charge (~QDC) for single PE
    - Could send more data for >1PE pulses
  - Trigger less front end. Send information to backend for all pulses
    - Data suppression occur in backend
  - Daisy-chained in-water front end boards
    - Need fail-safe communication system
- Desirable features:
  - Deadtime-less
  - Ability to identify and time stamp every photo-electrons