2009 LCW Paul Rubinov Fermilab

RESULTS AND PLANS FOR SIPM READOUT OF SCINTILLATORS

Executive summary
for people that need a nap

- Muon readout: we are all over it

Detecting Muons with plastic strips

- Statement of the obvious:
  - We have shown ~100% efficiency for MIPs (last year)
  - So this is a question of $$$
- Statement of the problem
  1. Capture light in WLS fiber (scint shape, fiber diameter, fiber placement and coupling)
  2. Transport light to the end of the fiber (atten length)
  3. Couple light from fiber into SiPM (packaging, area)
  4. Readout the SiPM signal (choice of operating point, readout electronics)
- It is not obvious (to me) which of these is the "weakest link" in performance/$

Electronics & Readout

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- I will talk about
  - SiPMs
  - Current status
  - Readout schemes
  - Photo statistics
  - Future developments

SiPM (PPD, MPPC,CPM) is a new photodetector ideally suited to reading WLS fibers

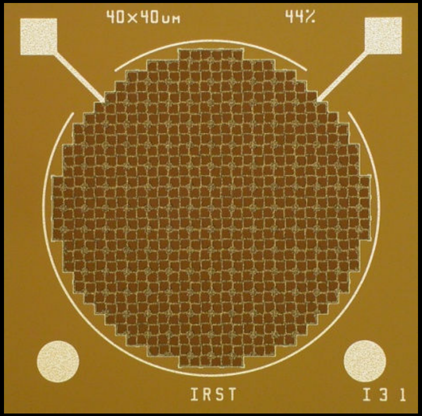
Transistors are not tiny vacuum tubes and

SiPMs are not tiny PMTs

We are working closely with our friends across the pond (INFN Udine)

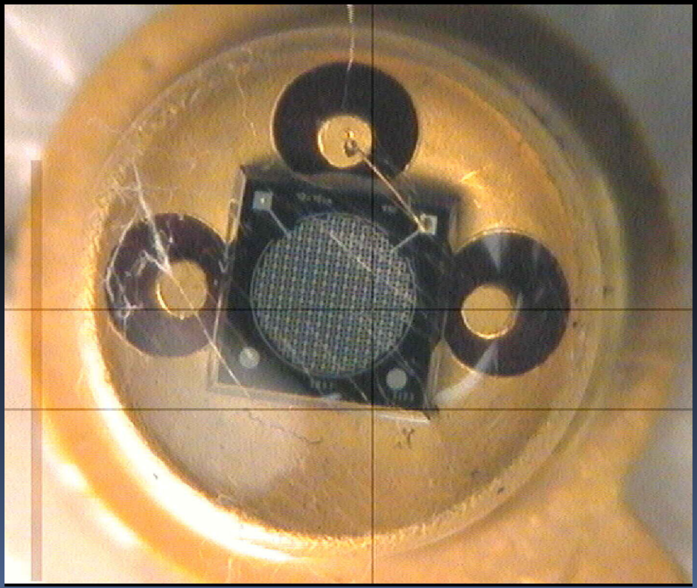
FBK/IRST SiPMs for muon-counter/tailcatcher study at FNAL

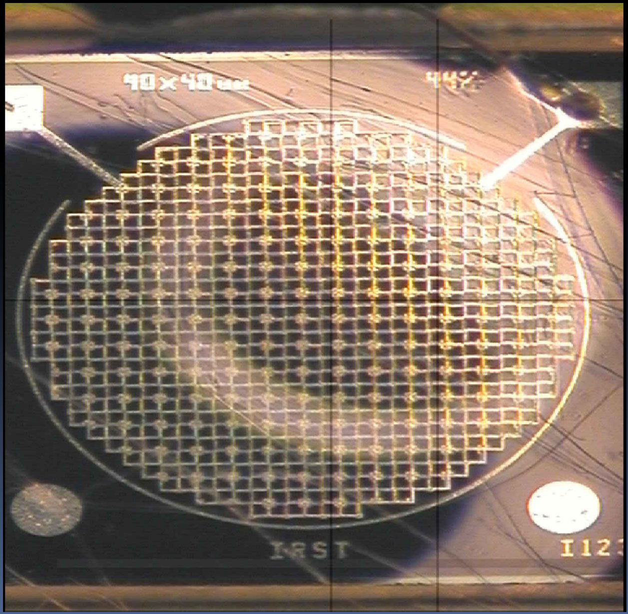
On commission from INFN Udine/Trieste, SiPMs have been produced by FBK-IRST (Trento, Italy) for this application.



Geometry: circular
diameter: 1.2 mm
Microcell: 40 x 40 μm
Improved fill-factor (44%)
Breakdown voltage ~30.5V

They are presently packaged (To18) with photocathode protected by epoxy(glob-top)

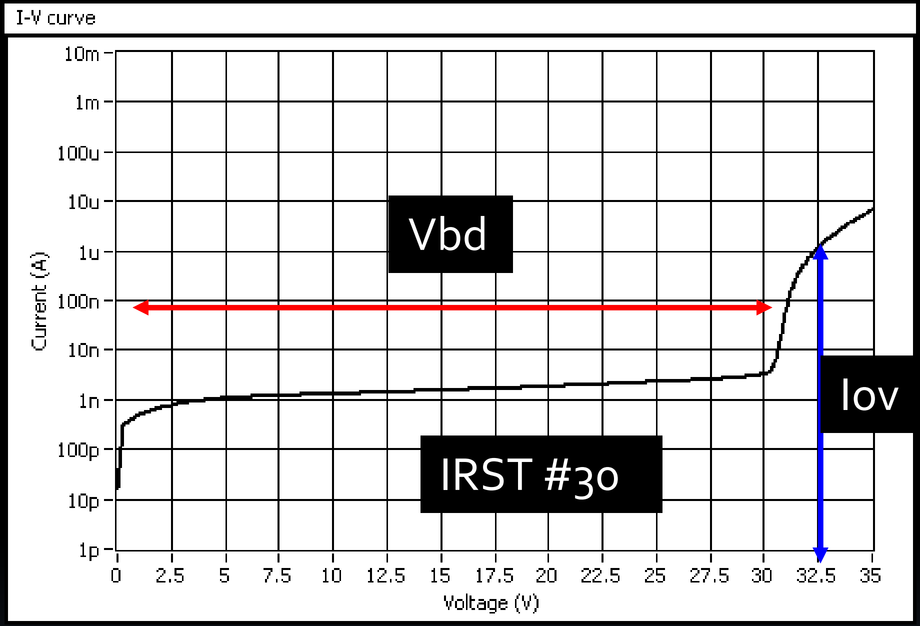




Bench Tests

reveal :

- Low operating voltage (~30V)
- Relatively large operating range (5V)
- very uniform characteristics



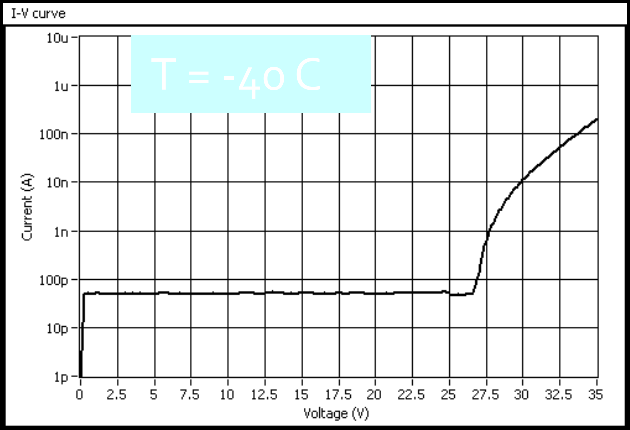
SiPM #	Vbd (V)	Iov (uA)
30	30.4	4.7
31	30.4	3.5
32	30.5	3.2
33	30.6	3.9
34	30.5	3.8
35	30.5	3.7
36	30.6	4.7
37	30.5	5.2
38	30.3	4.6
39	bad	bad
40	30.4	4.3
41	30.6	2.2
42	30.6	1.8
43	30.7	3.5
44	30.7	3.2
45	31.7	4
46	30.3	1.9
47	30.3	2.7
48	30.3	2.8
49	30.4	1.7
50	30.3	4.9

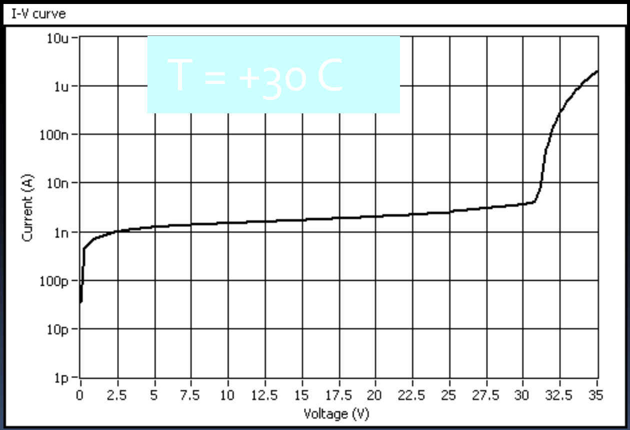
Test beam (fnal: T956)

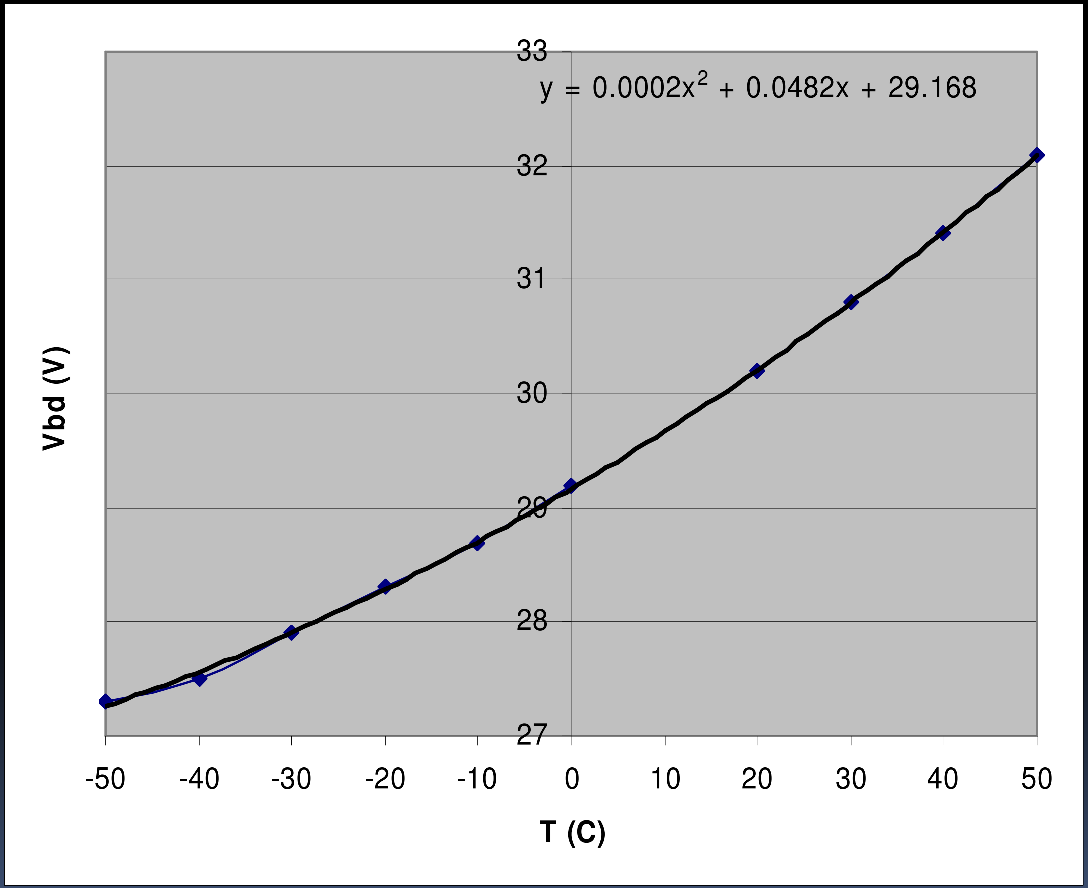
~20 p.e./mip from T956 extrude scint. bar read out by wls fiber.

Detailed characterization, under controlled climactic conditions reveal:

- A low , well-behaved break-down voltage V_{BD} varying with temperature as illustrated below

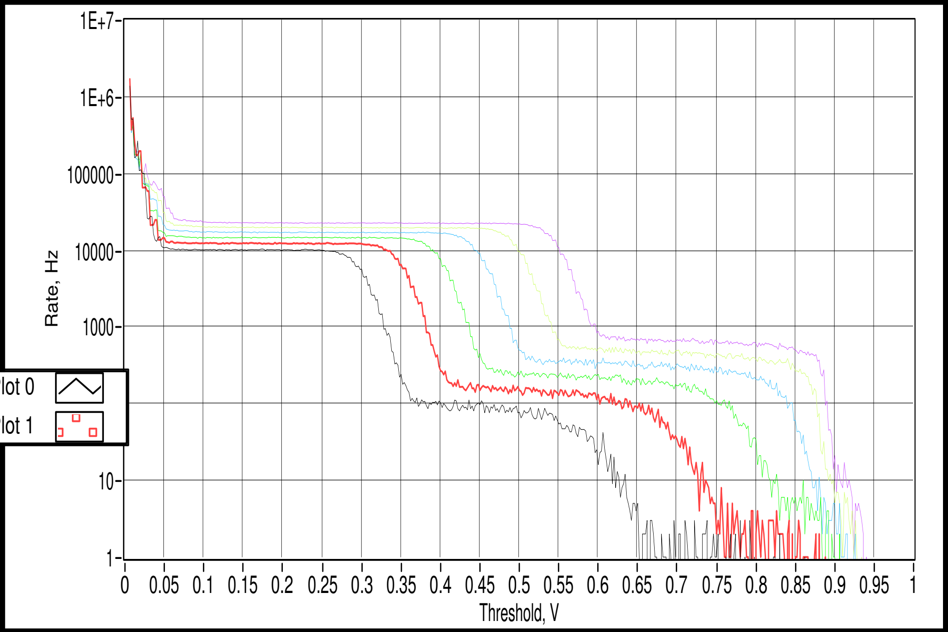


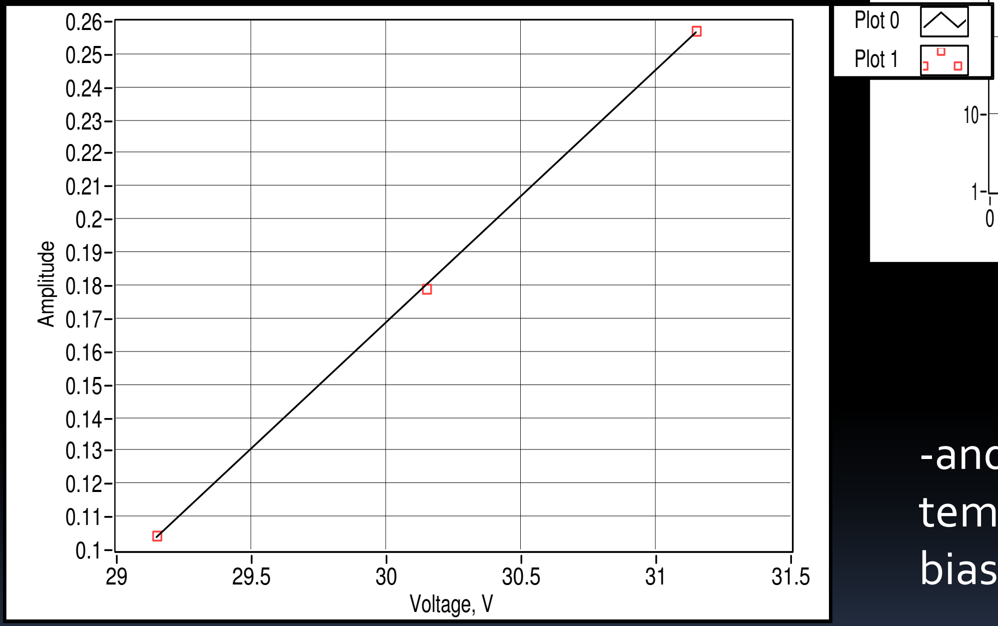




-- a dark count ranging between

~10⁴ Hz at low temperatures and
~10⁶ Hz at at ambient temperatures

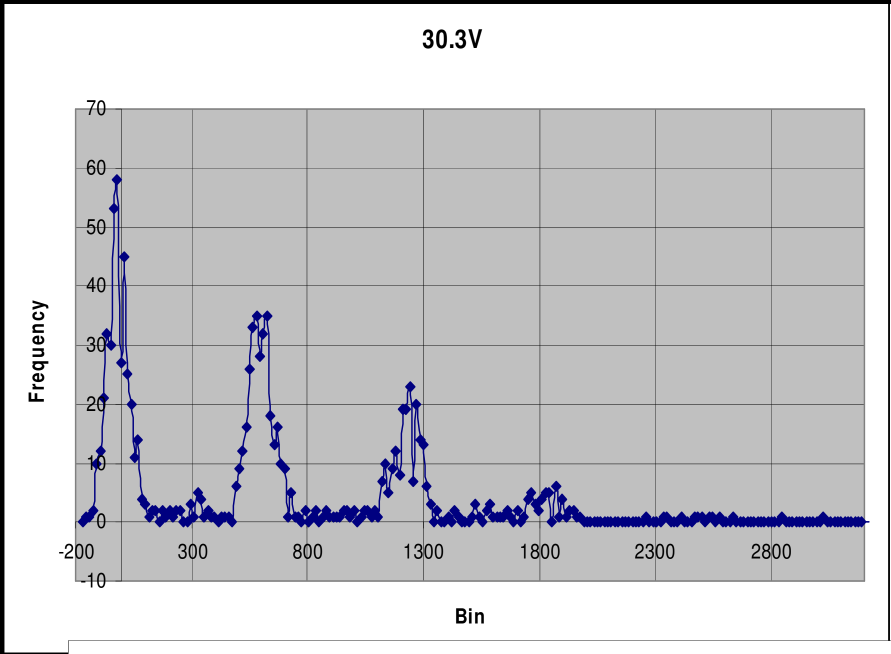


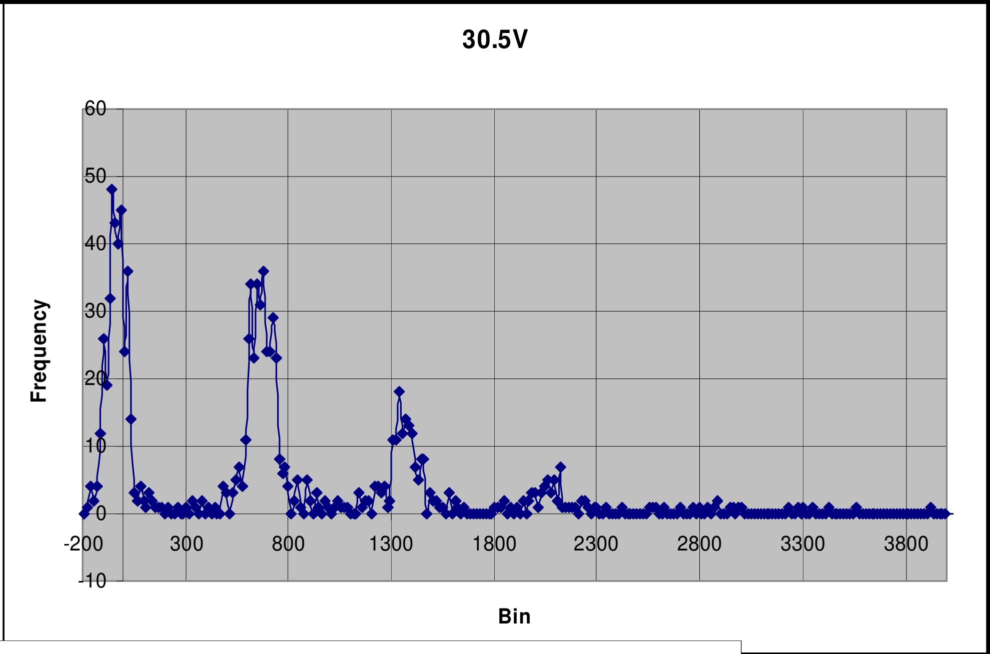


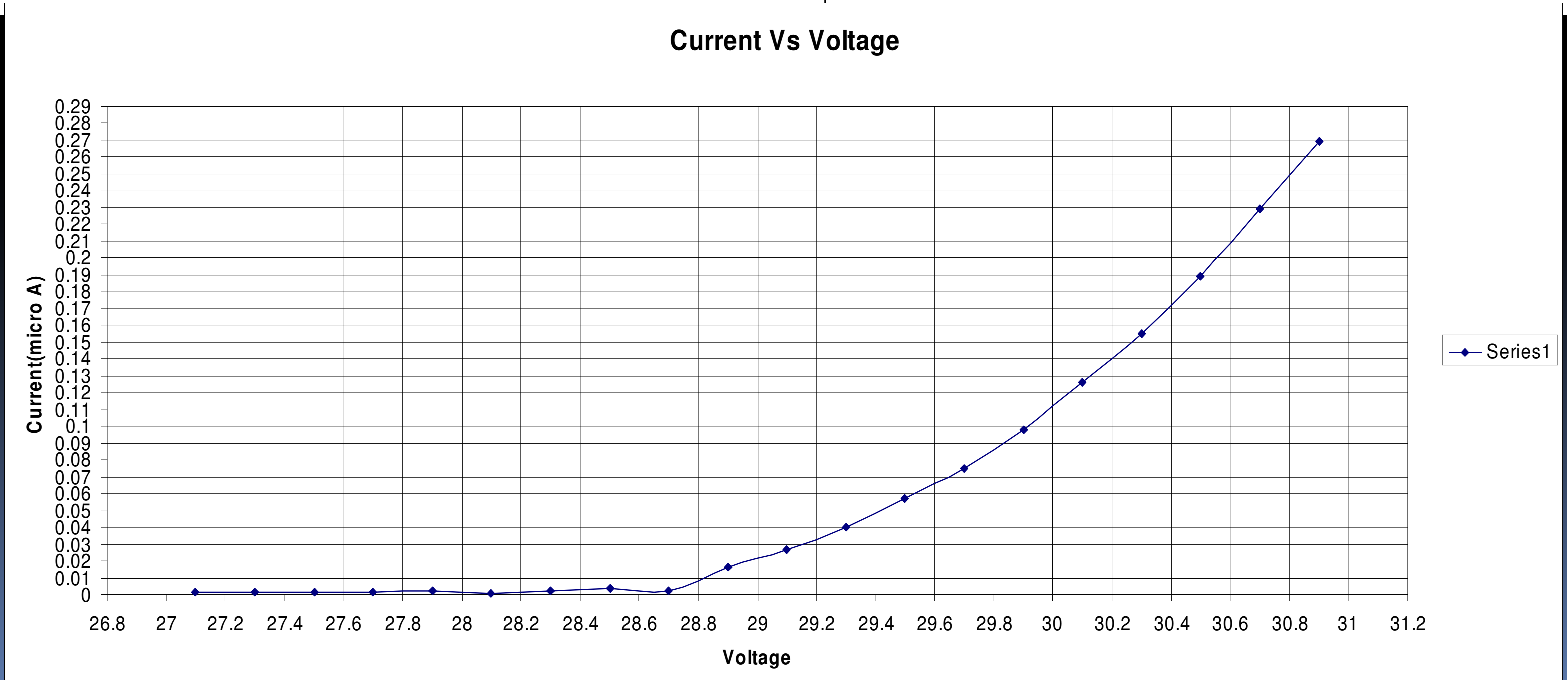
-and a gain of ~ 10⁶ at ambient temperatures which varies linearly with bias voltage

The effects of γ and neutron radiation have also been studied and, as expected are not of concern at the larger radii occupied by the neutron counters

SenSL devices (1mm x 1mm)







SiPM

- We have tested SiPMs from
  IRST/FBK
  Hamamatsu
  Started looking at SenSL devices
  Quick look at sensors from Zacotek

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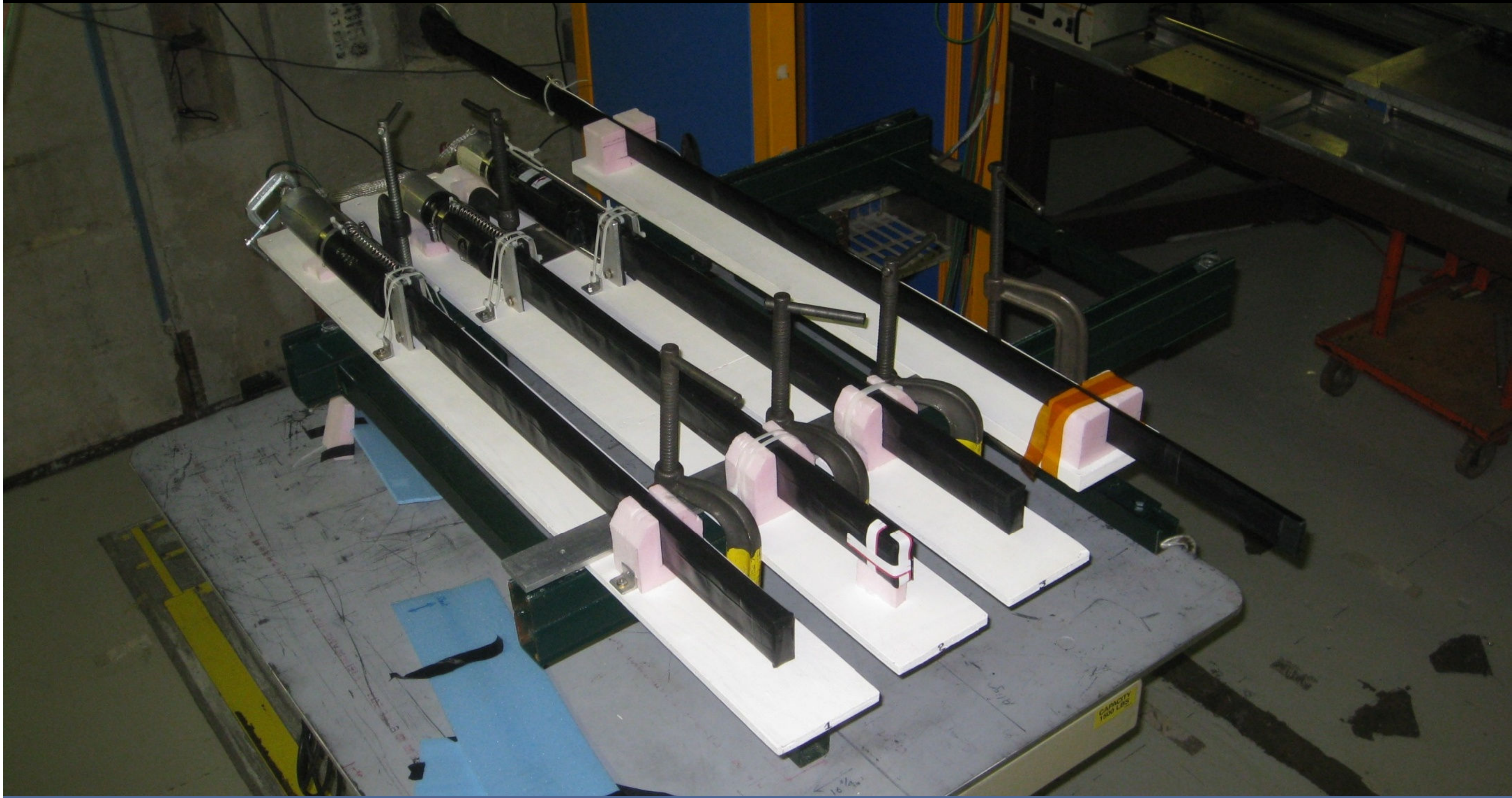
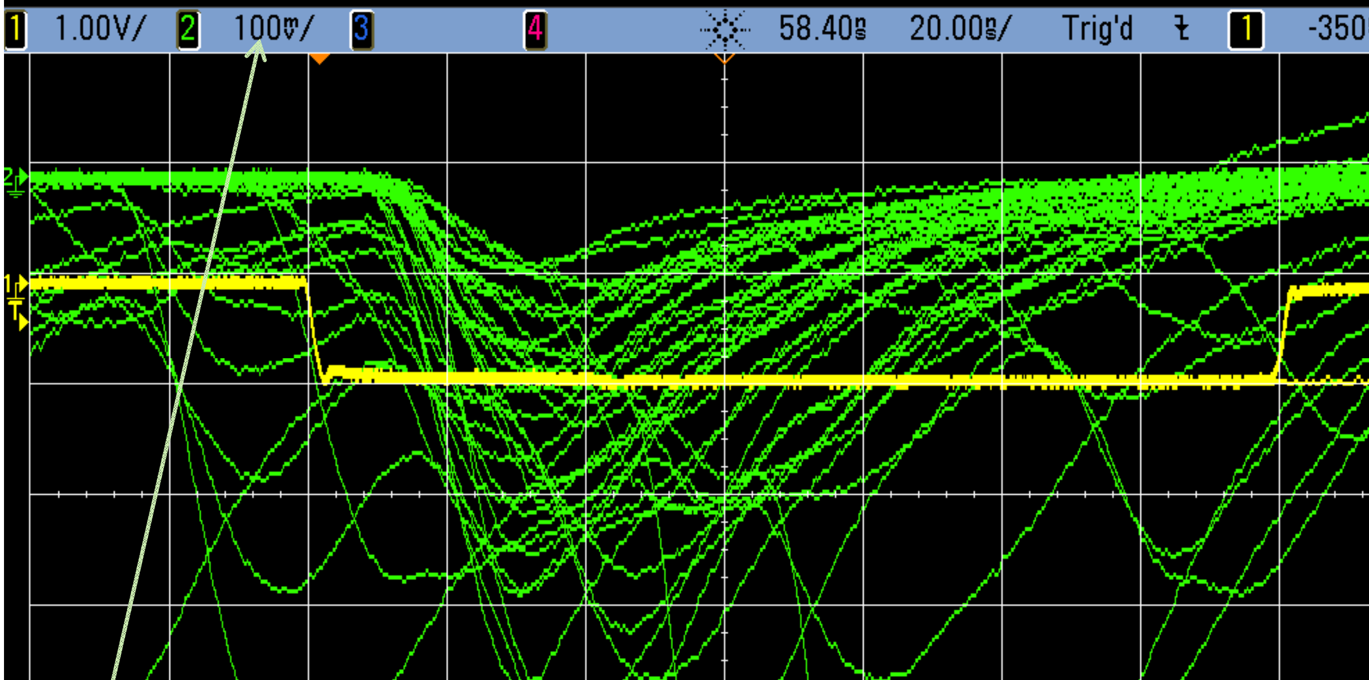
We have tested them in TB

- We did a quick run in 2008 (parasitic with Minerva)



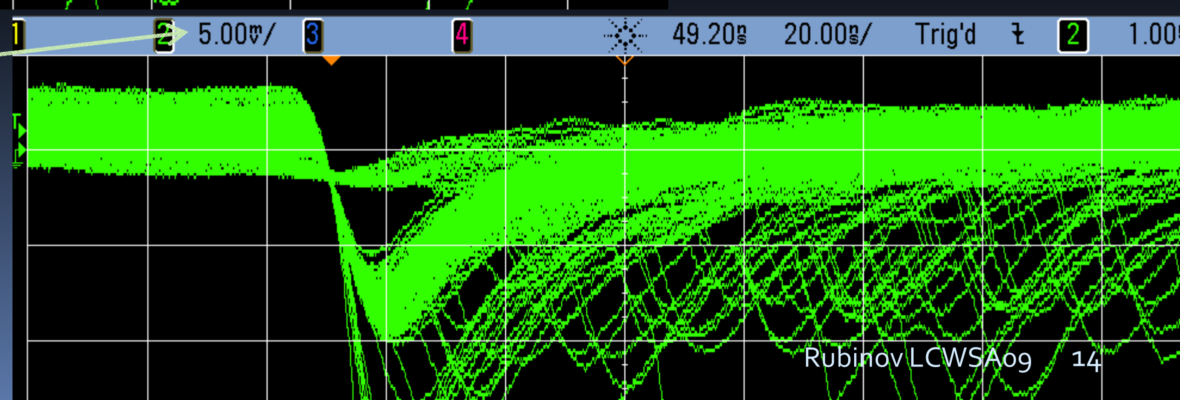
From testbeam

- ~100% Efficient (~1m from SiPM, middle of strip)
- A few hundred traces from 1 spill



Noise

Don't miss the scale change!



Results from TB Fall 08

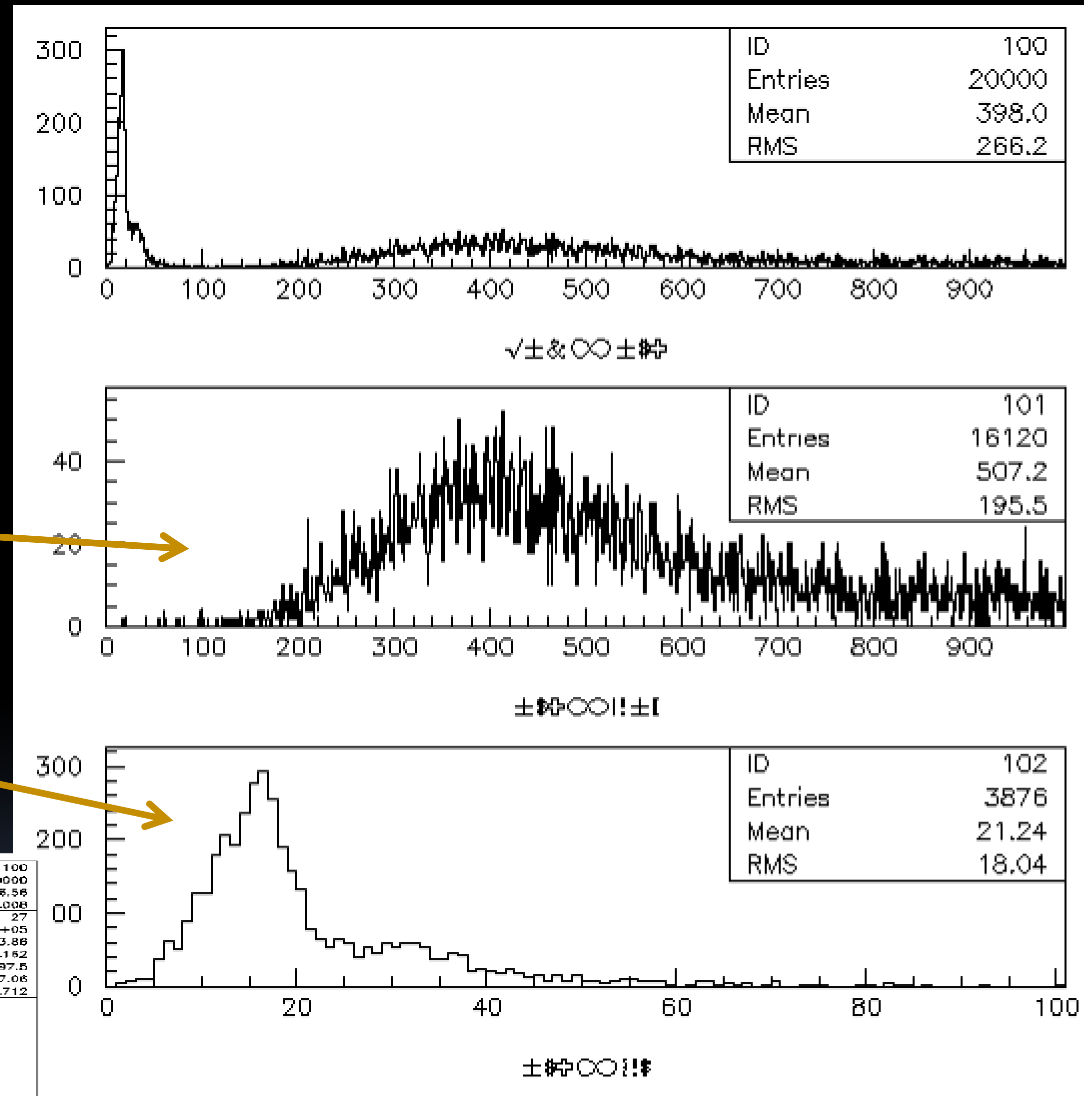
- This is our typical plots

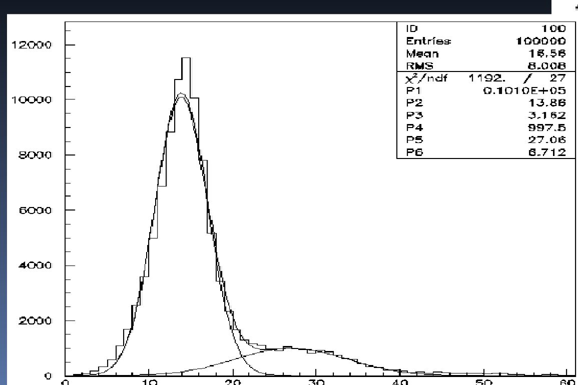
Our strategy is:

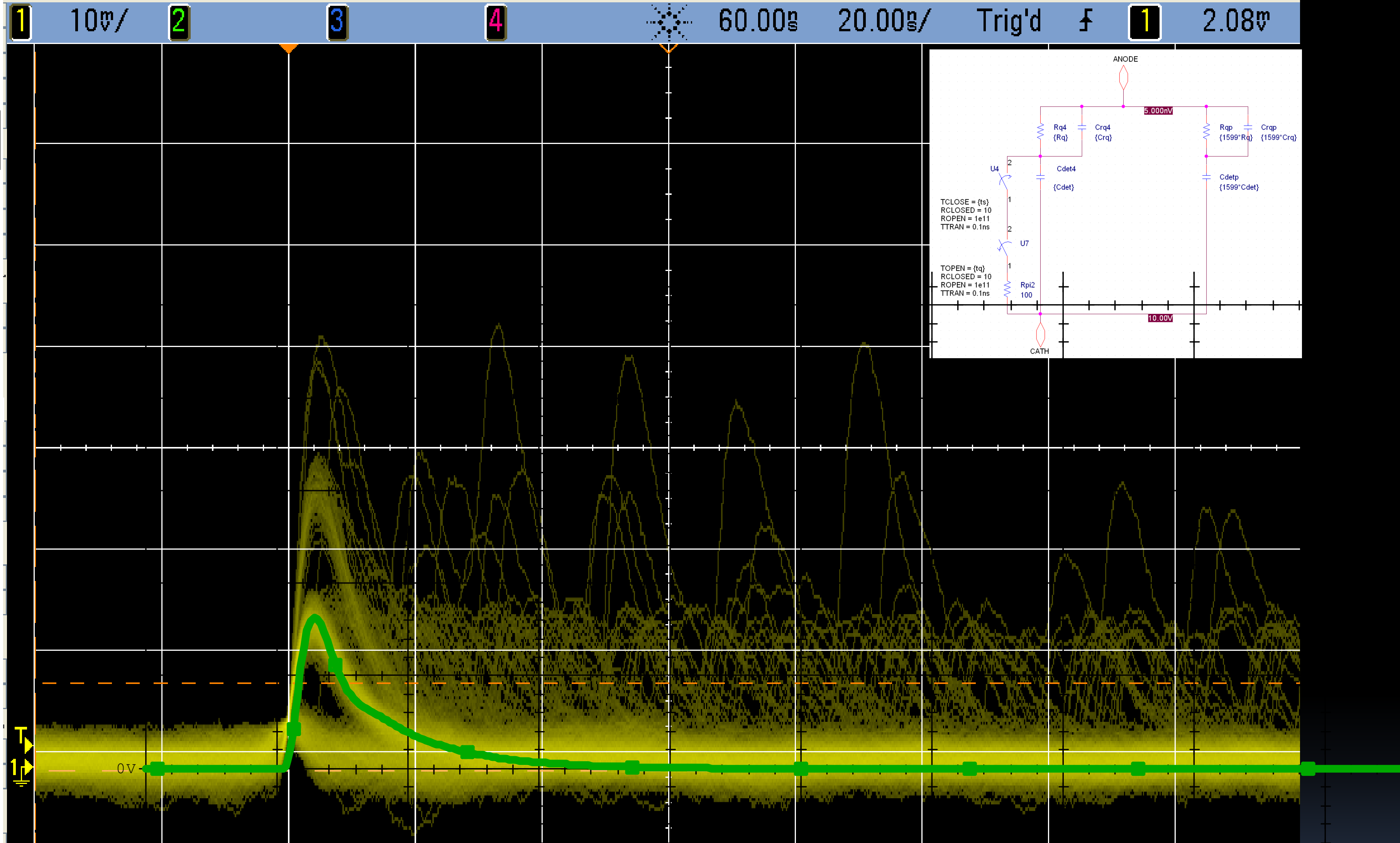
Take data with loose trigger to enable us to see pedestal

Use other counters to select MIPs

Extract 1pe peak from pedestal







- We can model the SiPM/amplifier (model from talks by C. Piemonte and others)
- Where available, I use parameters measured by Adam Para and co.
- Where not available, I guess and fiddle

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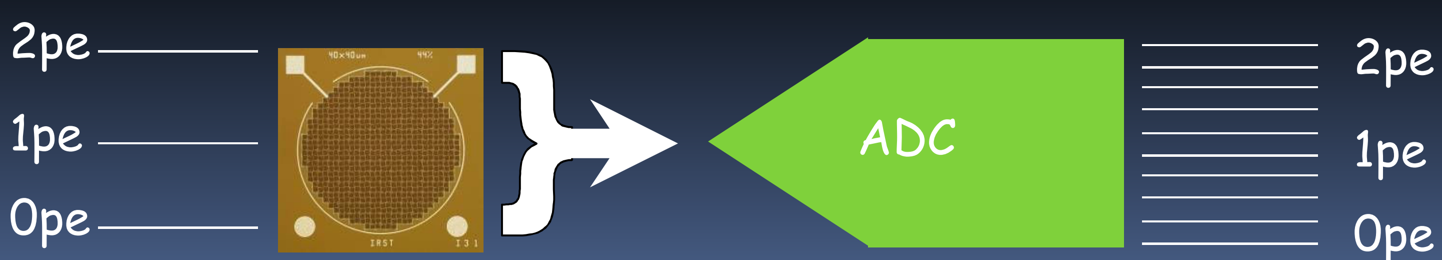
Readout of the SiPM

- I am deeply inspired by the attitude of the inventors of the SiPM
  - SiPM is an inherently digital device
  - We digitize the signal from the SiPM
  - So why do we have an analog step in between?!?
    - Because we want to get started!

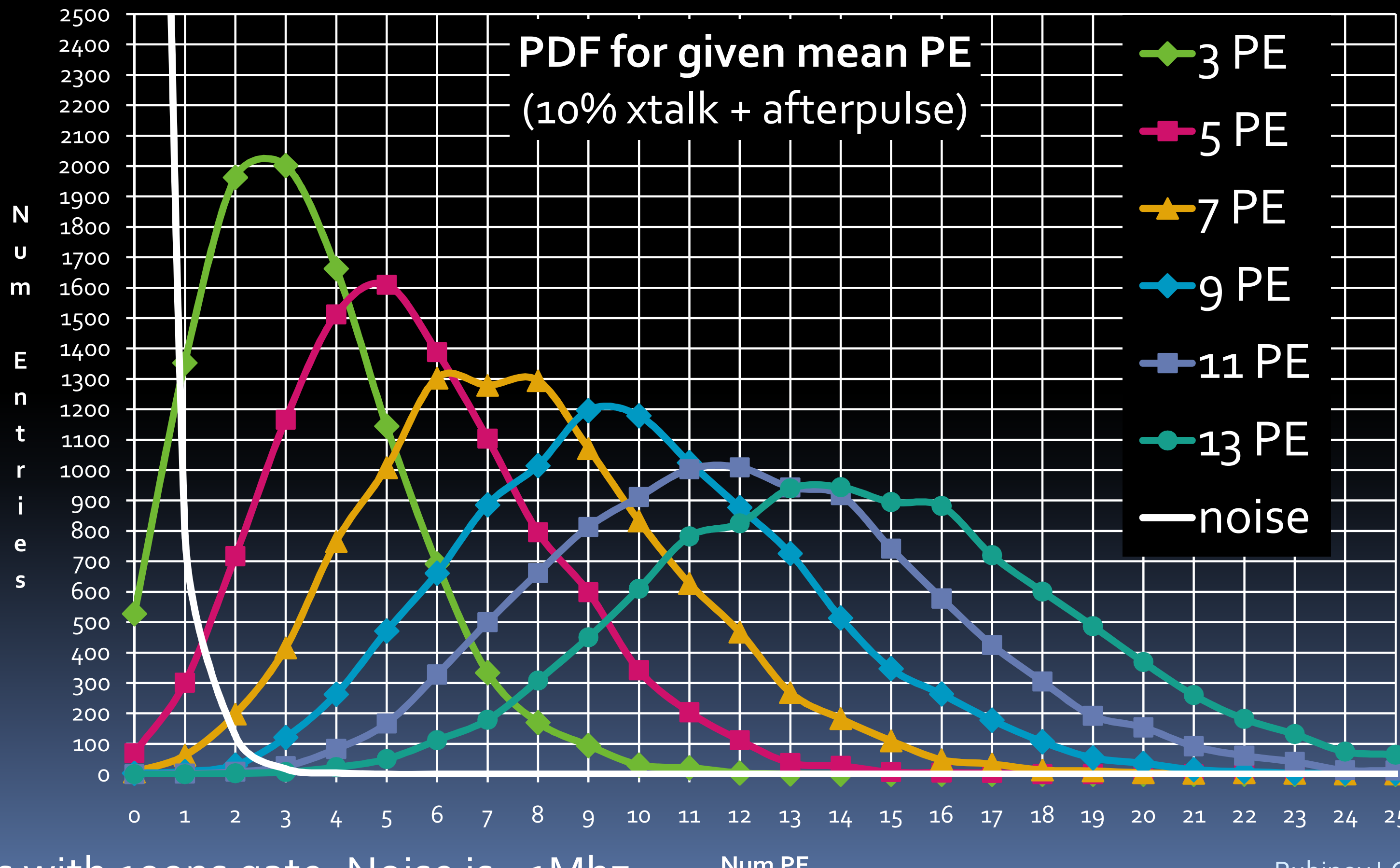


We want to get started

- 08: support applications with ~10 ch, learn about pulse shape, needs for amplifiers
- 09: support applications with ~50 ch, simplify support (no separate HV, current meters)
- 11: support applications with ~500 ch
  - But this is driven by calorimetry, not muon
  - This will require ASIC
    we are starting preliminary design now

Photon Statistics

- This is the ultimate limit for noise/efficiency
- No honest readout system will recover pe's that were not delivered to the photo detector



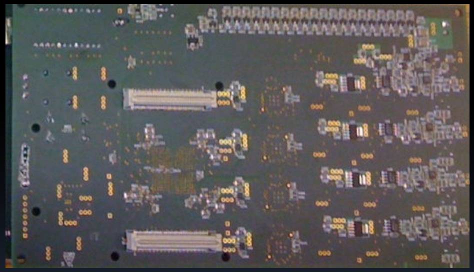
This is with 100ns gate. Noise is ~1Mhz

New since LCW08

- Our plan for readout was (and is)
  - Fall 08: just an amplifier in a NIM bin using 50ohm cables
  - Spring 09: Integrate amp, ADC, bias on one board
  - Fall 10?: SiPM readout ASIC

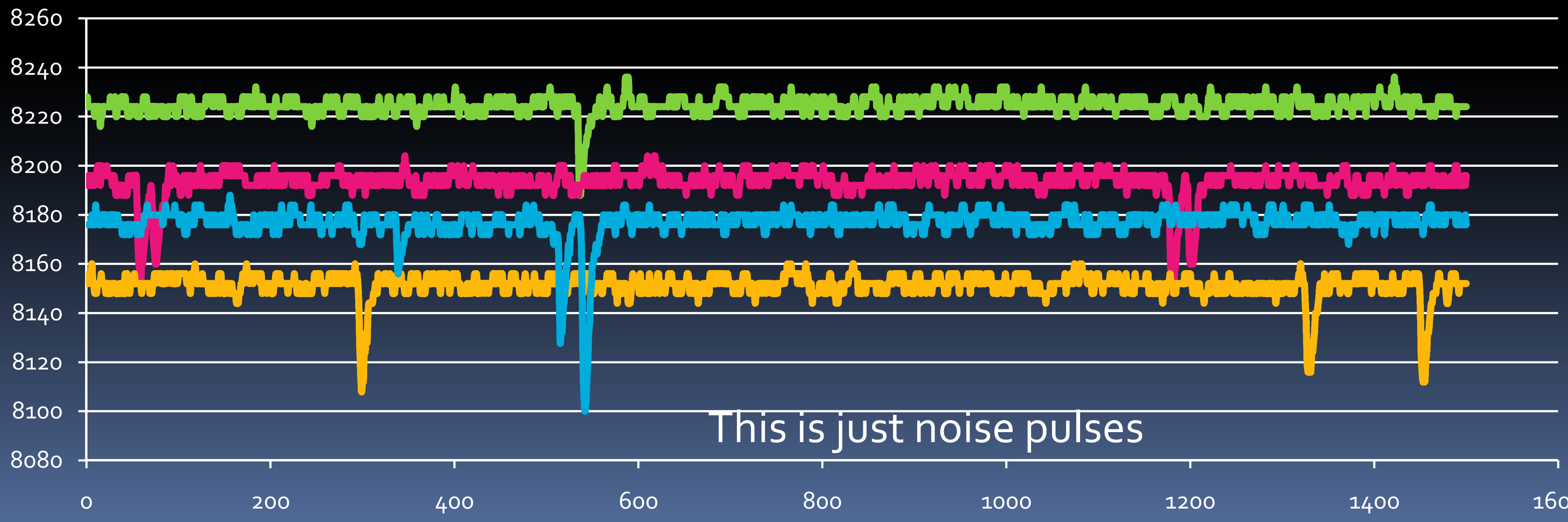
- New electronics ready to go for TB
  - A board that strikes a good balance of high performance and reasonable cost to support SiPM studies
  - self sufficient, simple to use and flexible
  - reuse known working designs whenever possible.

TB4



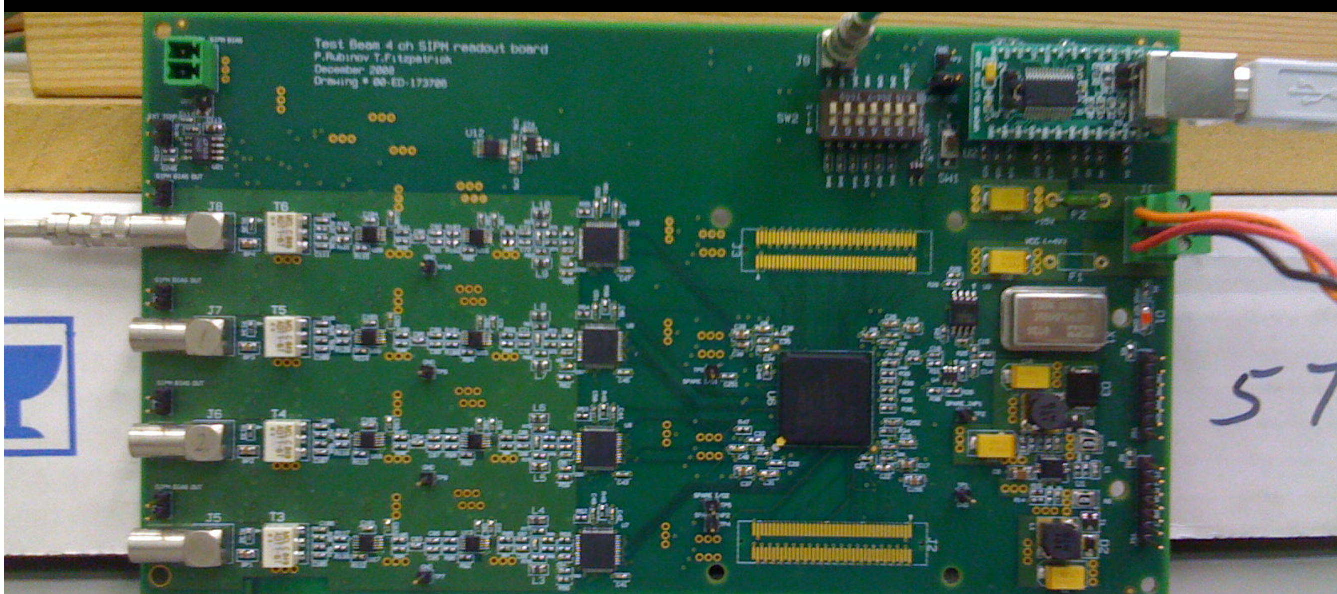
TB4 key features

- 4ch of HS ADC (10 or 12 bit, 210 or 250 MSPS)
- Largish FPGA (with 4kpts memory/ch)
- USB interface, High Speed io
- On board bias generation for SiPMs (and current meas)



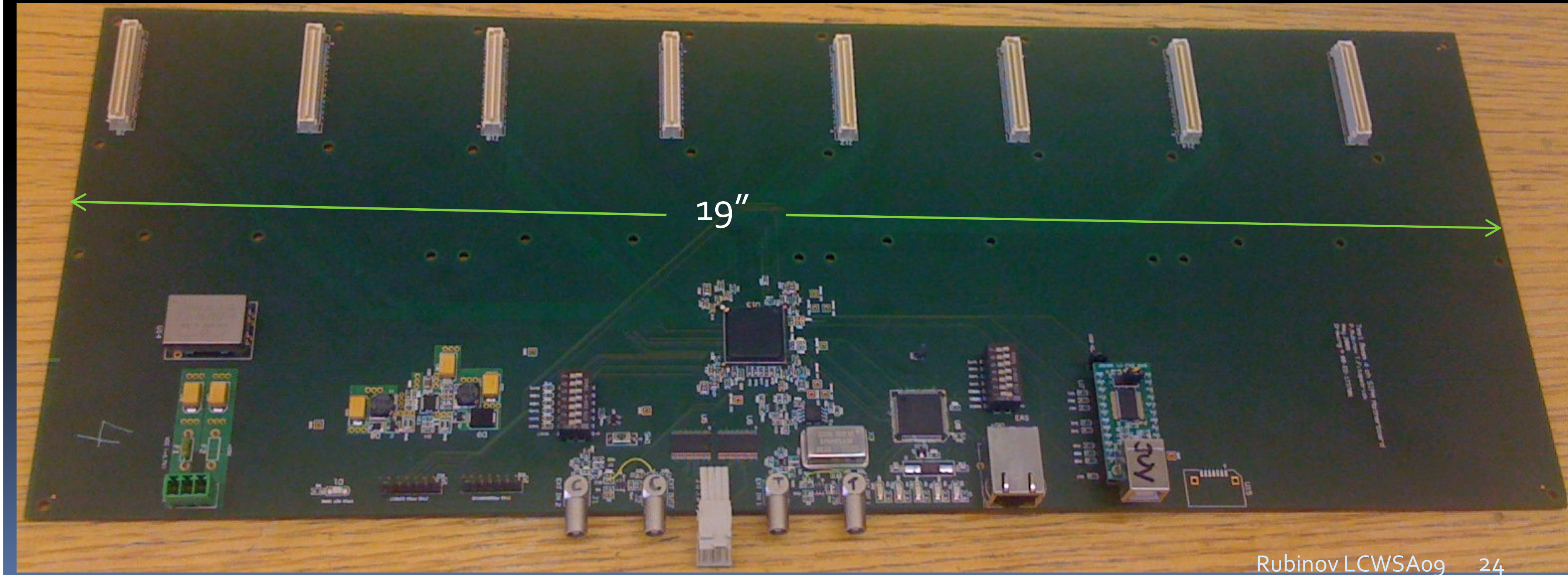
Emphasis on simple

- Plug in 5V power
- Plug in SiPM into an end of a 50 ohm cable
- Plug the other end of the cable into the TB4 board
- Plug in the USB connector into your computer
- Start the software, and press the RUN button



TB4 continued

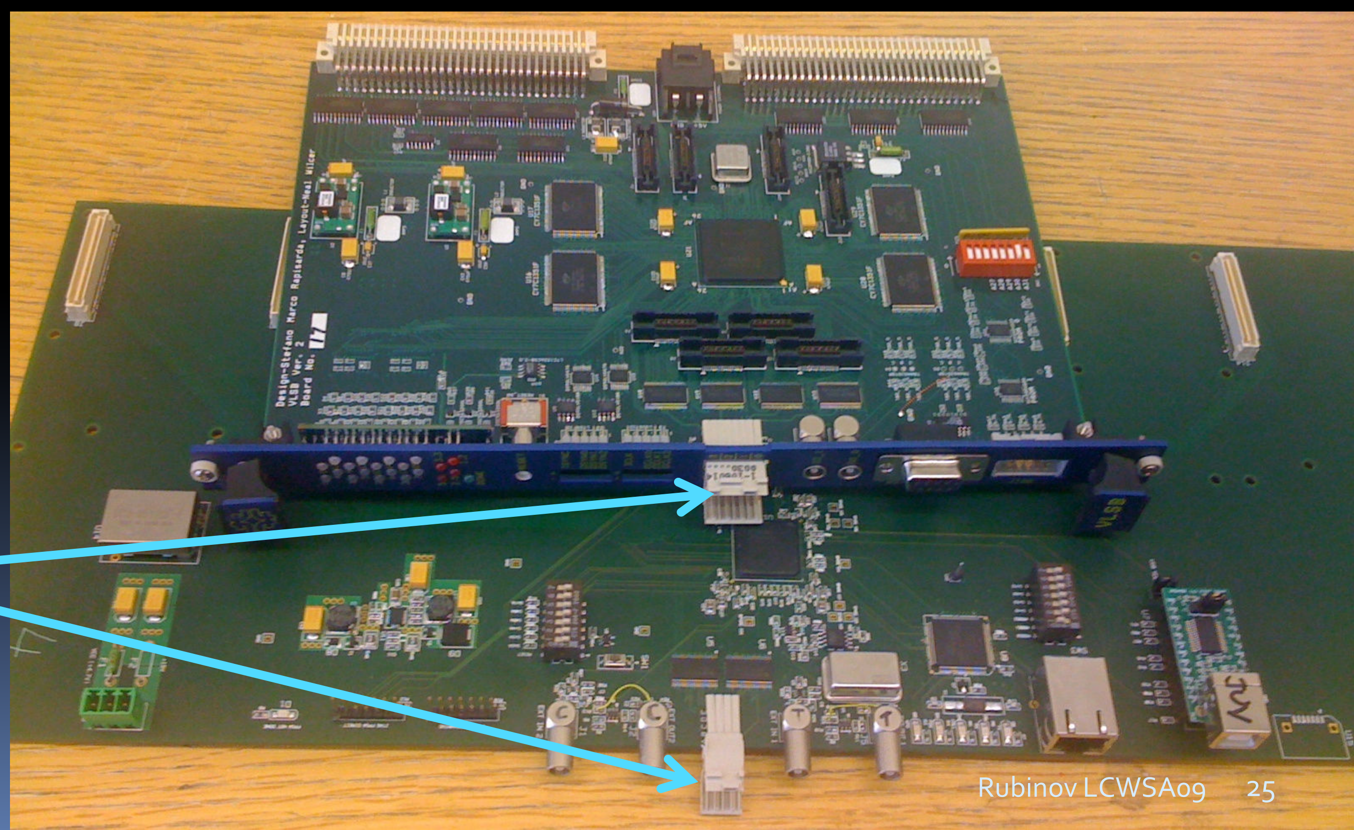
- For slightly larger applications, like test beam
  - 4x TB4 combined on 1 motherboard
  - Mother board provides:
    - Ethernet interface, USB interface, triggering, clocking



TB4 continued

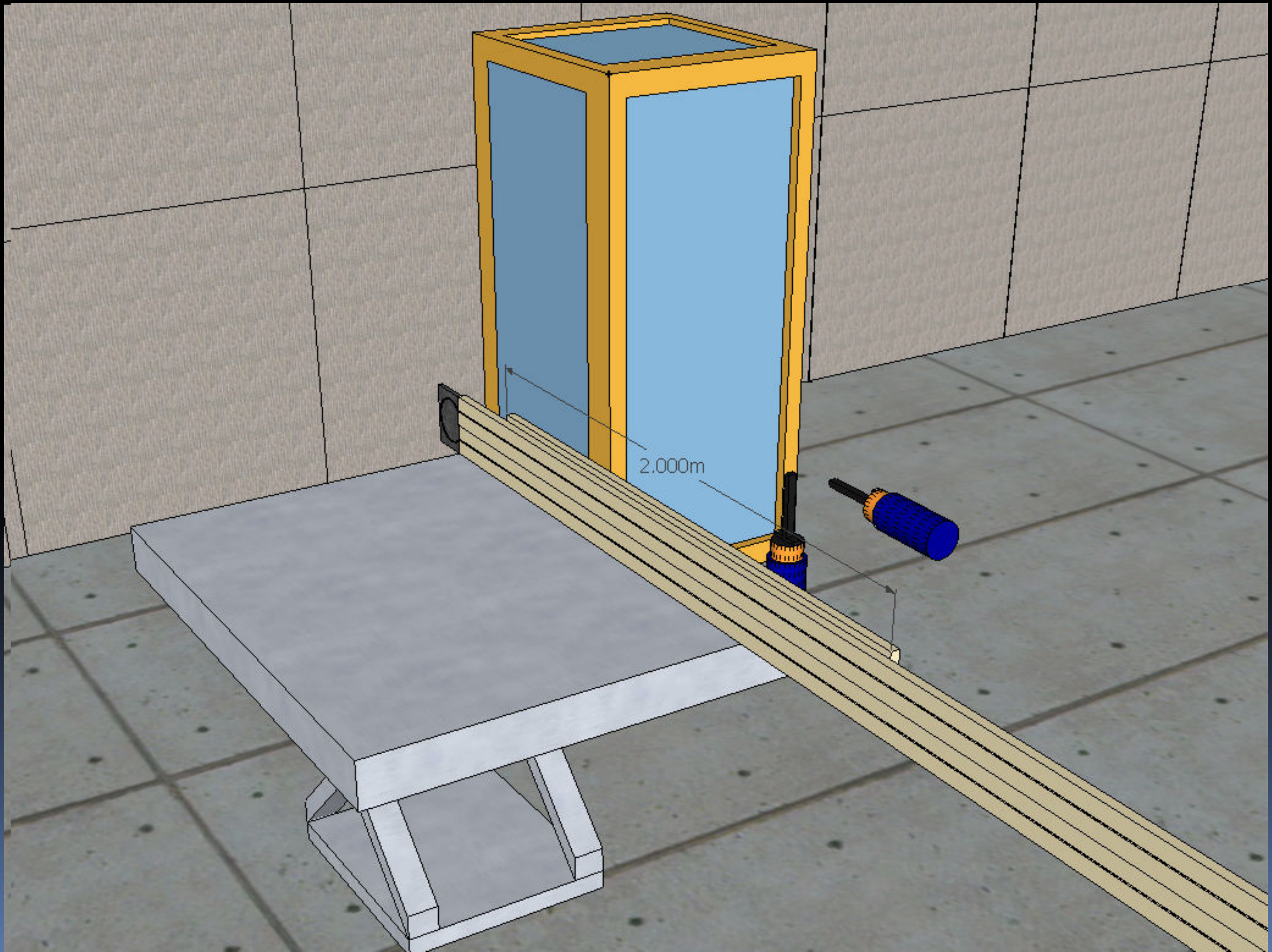
- For fast readout: LVDS links (2 x 1 Gbps) go to a VME module (1 module has 4 links) with sufficient memory (512KB) to act as a buffer for better throughput

LVDS links run from MB to VLSB (old Dzero module left over from AFE2 project)



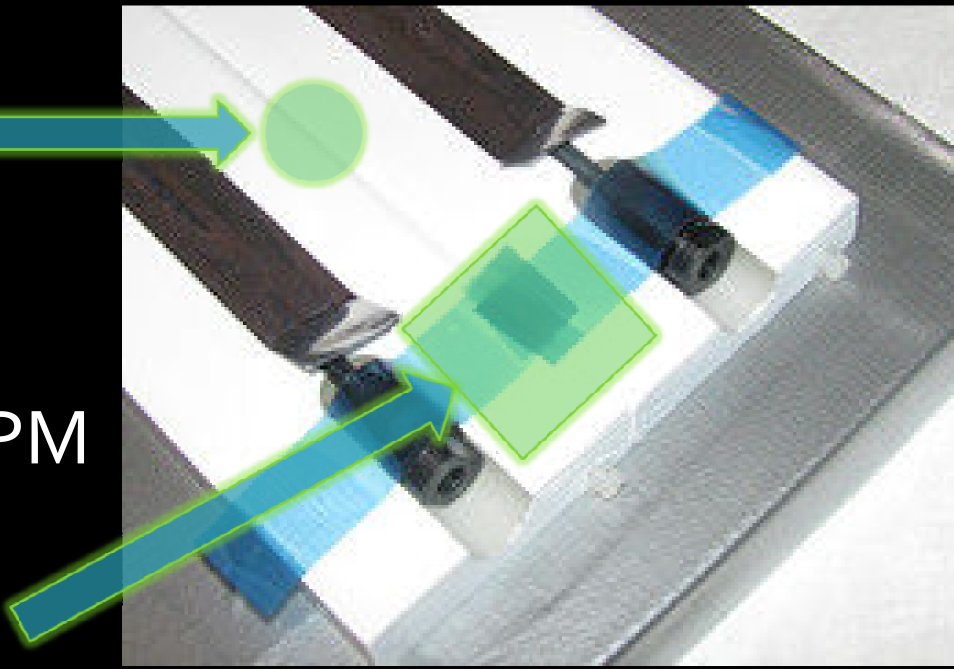
Next up: Test Beam

- Sketch of the TB 2008 setup



Key question to address

- Losses in the crack between adjacent strips
- Losses in scint behind SiPM
- Two sided/one sided readout
- Attenuation
- SiPM/fiber coupling



Future work

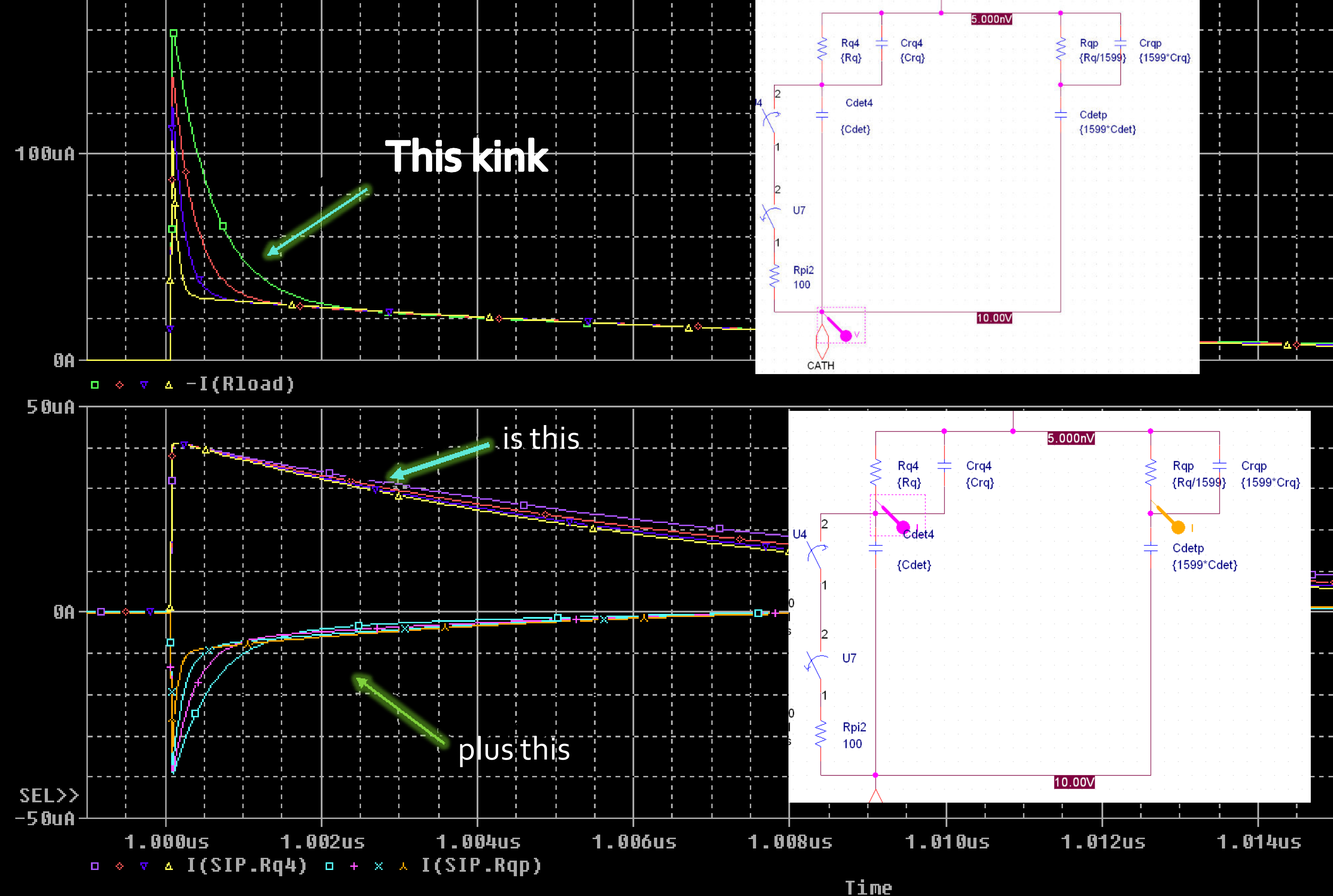
- We are looking forward to taking the next step on readout – SiPM specific ASIC on scale of 1yr
- Refine our cost model
- Identify and address cost drivers/key issues
- Aim to write a NIM paper on the results

  Conceptual Design of a Scintillator-based LC Muon/tail catcher System

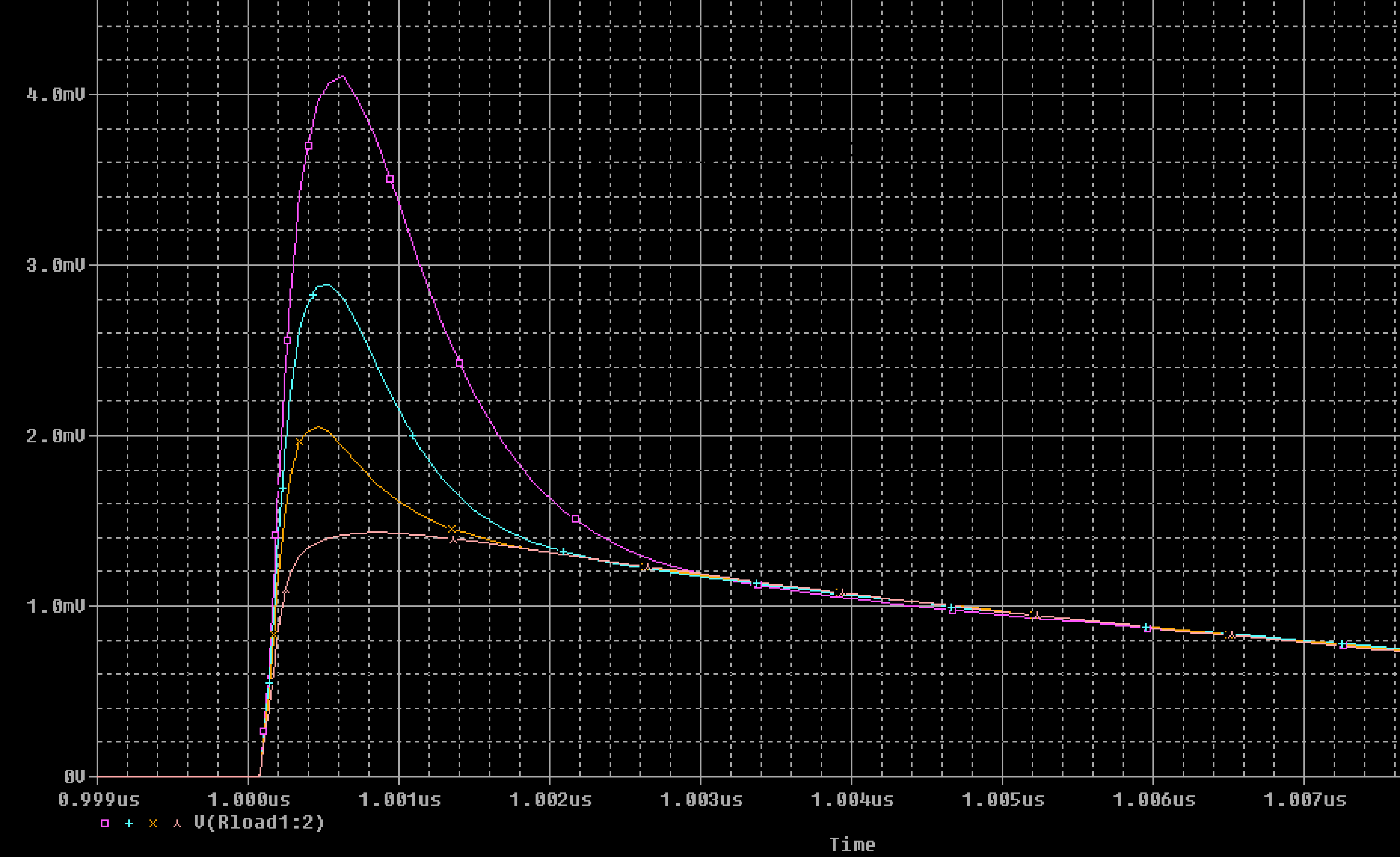
Conclusion

- Muon readout is not that scary-IF you fill its candy bag once per year

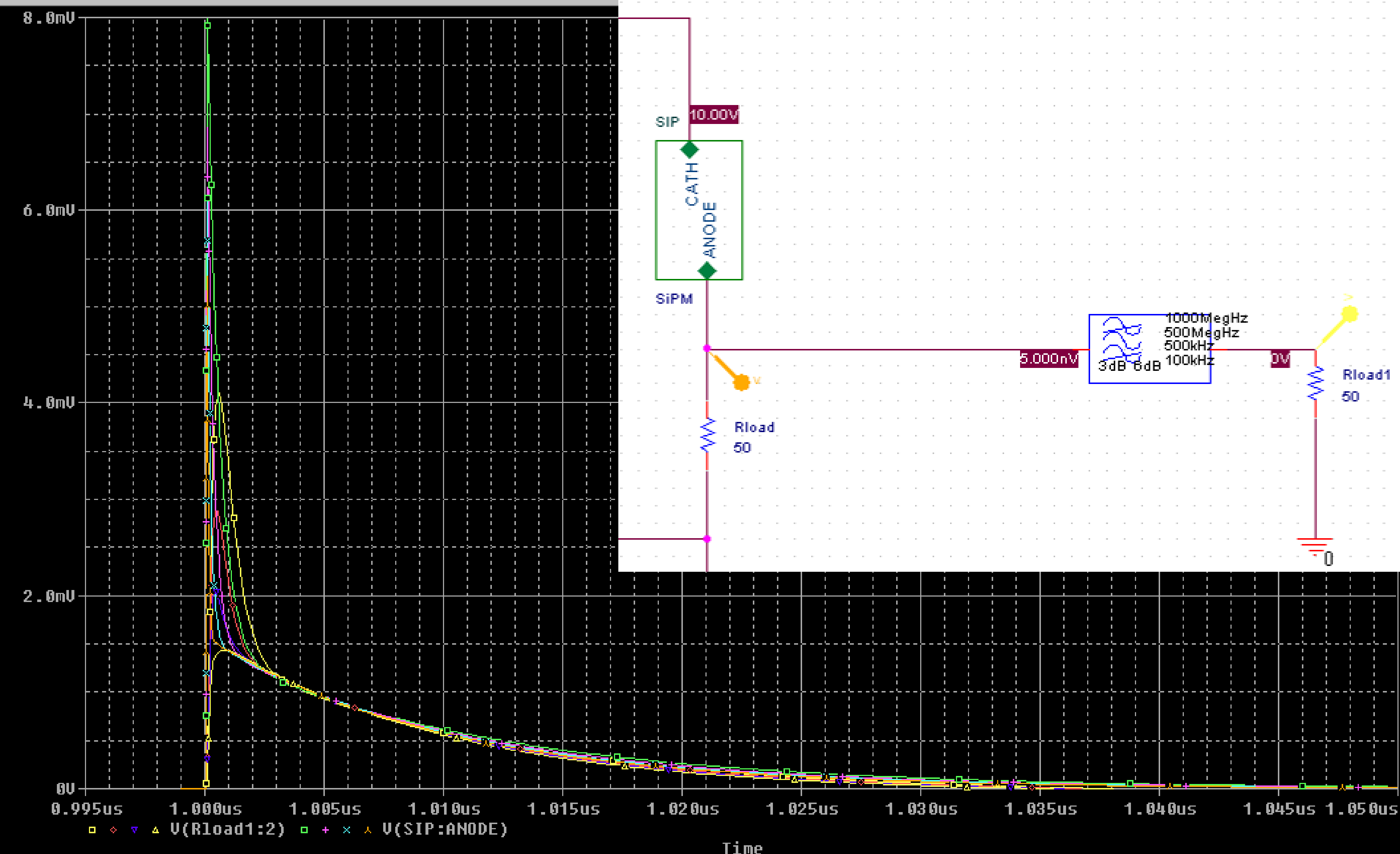
- END OF TALK



There are 4 values of Crq from 1 to 10 fF. So Crq is important for "spike" but not "tail"

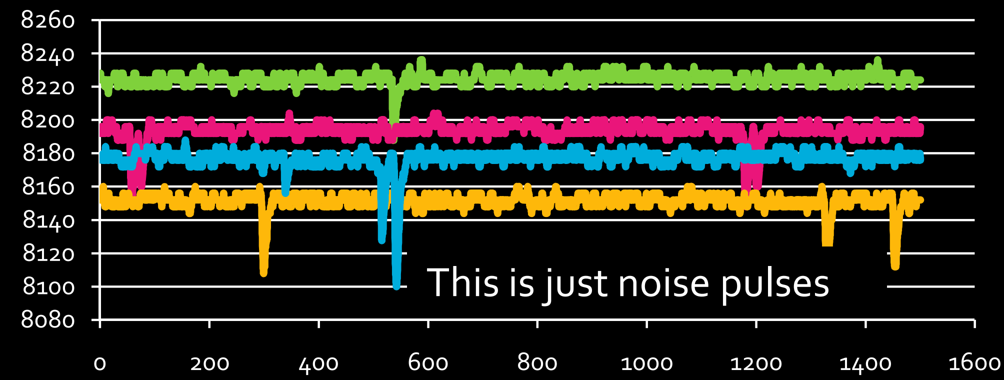


- The shape of the spike depends critically on the shaping function of the amplifier – you can also get “ripples”



- I think it makes sense to "integrate" this spike away before digitizing waveform

TB4 key features



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