ELECTRONICS FOR OPTICAL TOTAL ABSORPTION CALORIMETERS

Introduction

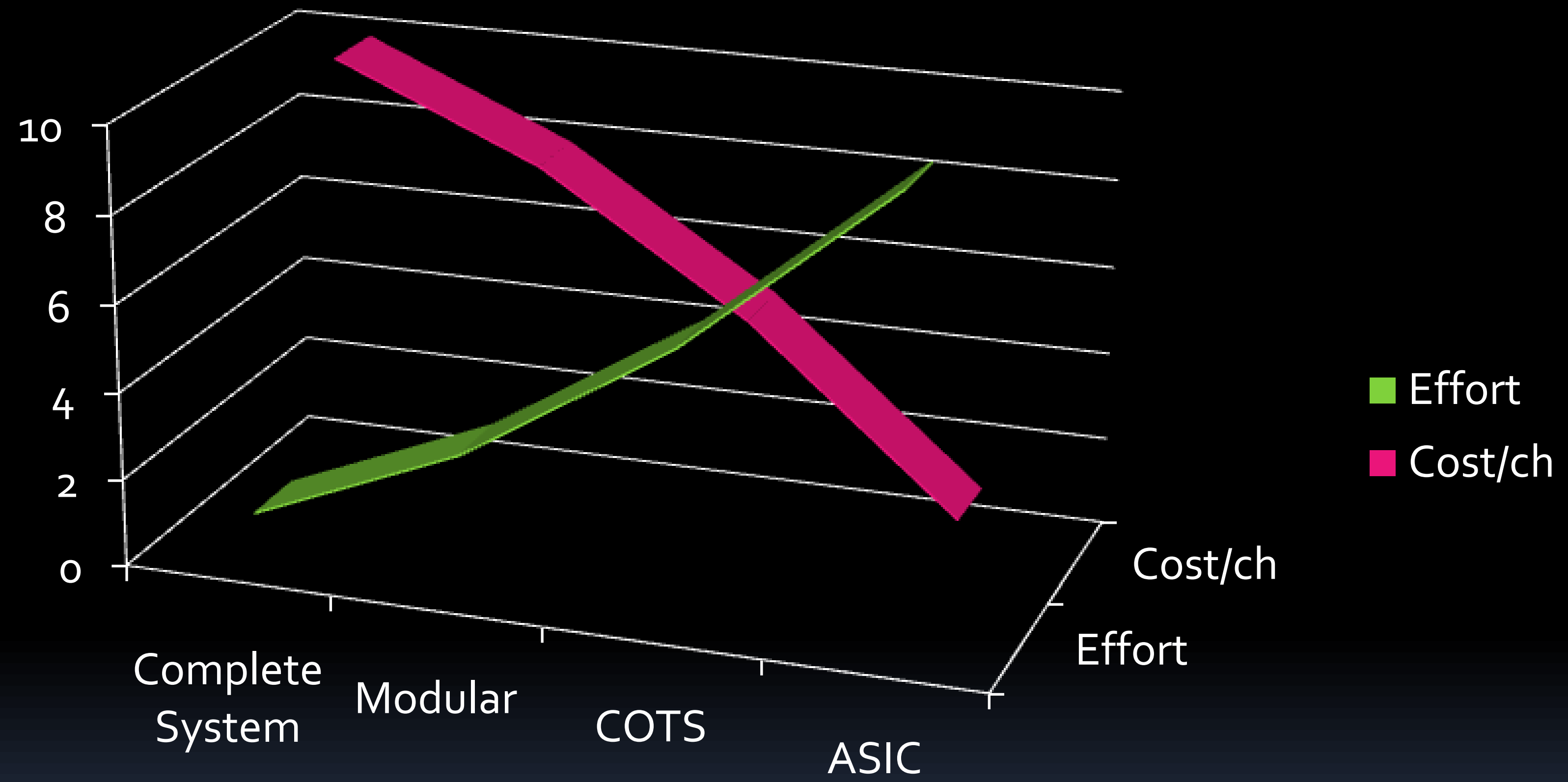
- Electronics are an integral part of any detector development
  - Modular instrumentation for HEP experiments ended at the turn of the century

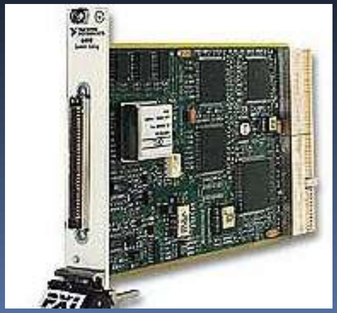
LeCroy Corp: January, 2001. After more than 37 years of manufacturing modular instrumentation for physics, LeCroy announced today that it will be ending production of its CAMAC, VME, NIM and FASTBUS series of modular products

  - That does not mean there are no "general purpose" electronics
  - It does mean you can not apply the JGSFP* strategy

* Just Get Something From PREP

Thinking about electronics





Thinking about electronics

- Electronics for SiPMs, step 1:

  JUST BUY IT

1 to 4 chan:

Shopping list:
Amplifier, LV supply, scope, bias supply, current meter

Design effort:
Almost none (almost because you can still screw up grounding)
Hook them up with Labview

Cost/ch:
a few kilo- $ per chan

Time to implement:
a couple of weeks (once everything in hand)

Toughest challenge:
Getting the reqs approved

The right choice for learning about SiPMs

Thinking about electronics

- Electronics for SiPMs, step 2:

JUST BUILD IT (like TB4)

5 to 50 chan:

Shopping list:
PCBs, components

Design effort:
Analog design, digital design, layout, firmware, software

Cost/ch:
a few hecto-$ per chan

Time to implement:
4 to 6 (wo)man-months (once everything in hand)

Toughest challenge:
Getting the budget code to charge the labor

The right choice for single crystal & cosmic ray studies

Thinking about electronics

- Electronics for SiPMs, step 3:
  THINK ABOUT IT – THEN BUILD IT (quarknet)

50 to 50 000 chan:

Shopping list:
PCBs, components

Design effort:
Analog design, digital design, layout, firmware, software

Understanding the difference between what we want and what we need

Cost/ch:
a few deca-$ per chan

Time to implement:
1 to 4 man-years (depending on #ch), including prototypes

Toughest challenge:
Getting physicists to decide what is REALLY needed

The right choice for small calorimeter with O(100) ch

Thinking about electronics

- Electronics for SiPMs, step 4:
  JUST DESIGN IT FROM SCRATCH

5000+ chan:

Shopping list:
a good ASIC engineer

Design effort:
Understanding the difference between what we want and what we need

Cost/ch:
from a few $/ch to a fraction of a cent/ch

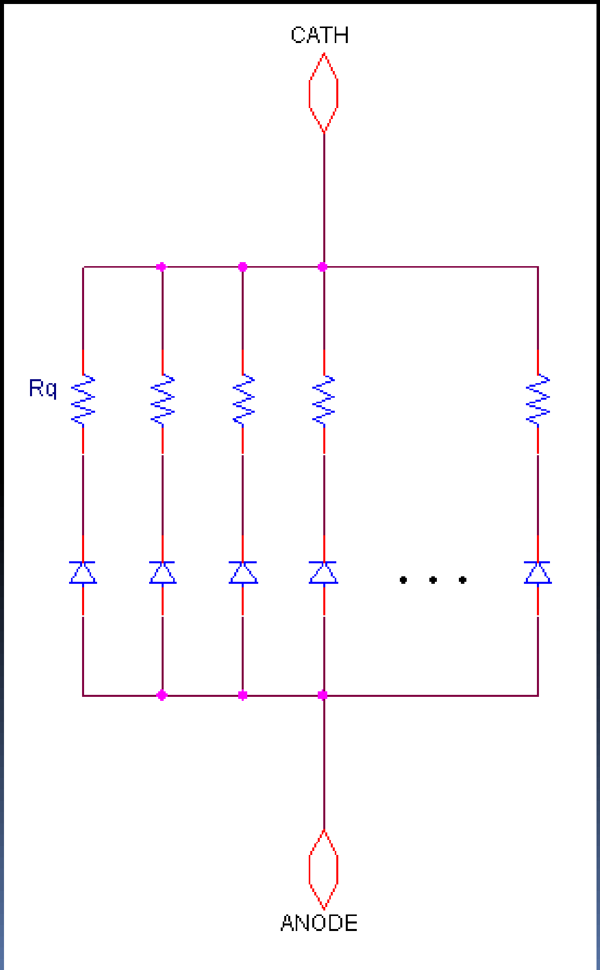
Time to implement:
2 to 4 years for 2 to 4 people

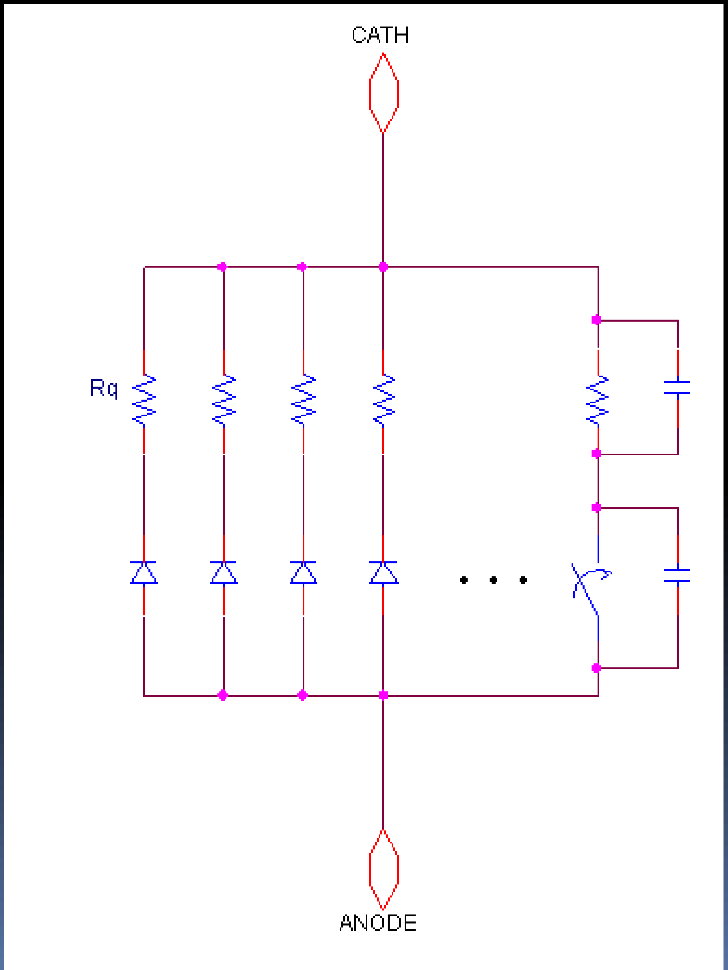
Toughest challenge:
Getting physicists to decide when its good enough

An ASIC is the only way to achieve sufficient performance at reasonable cost

Thinking about SiPMs

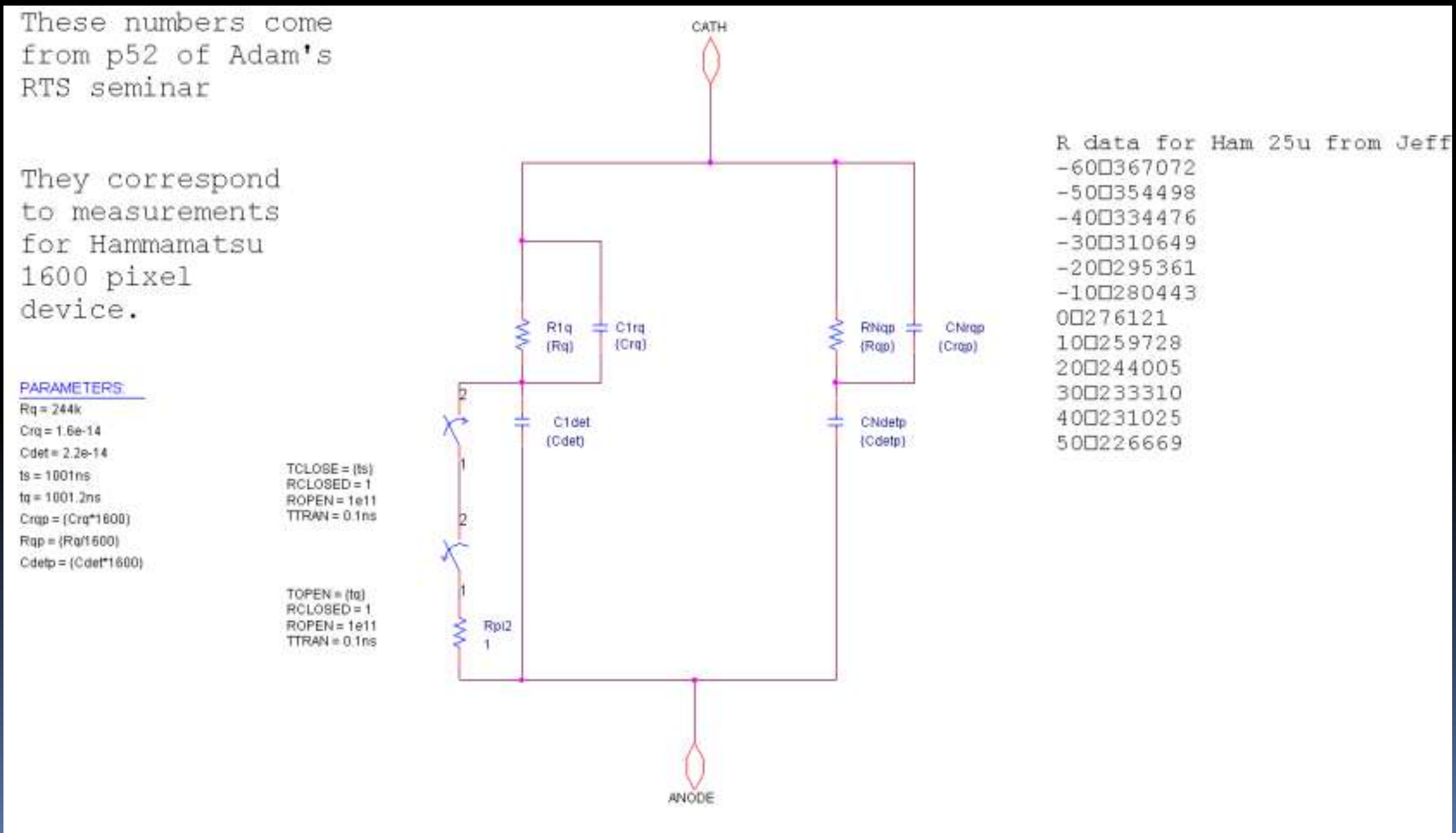
- SiPMs are different: think about the circuit





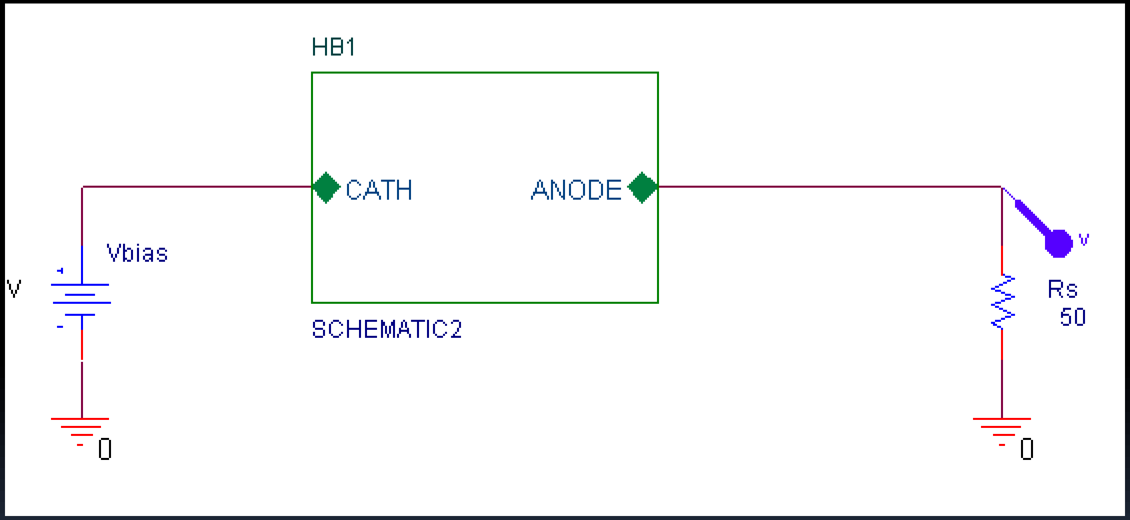
Thinking about SiPMs

- SiPMs are different: think about the circuit



Thinking about SiPMs

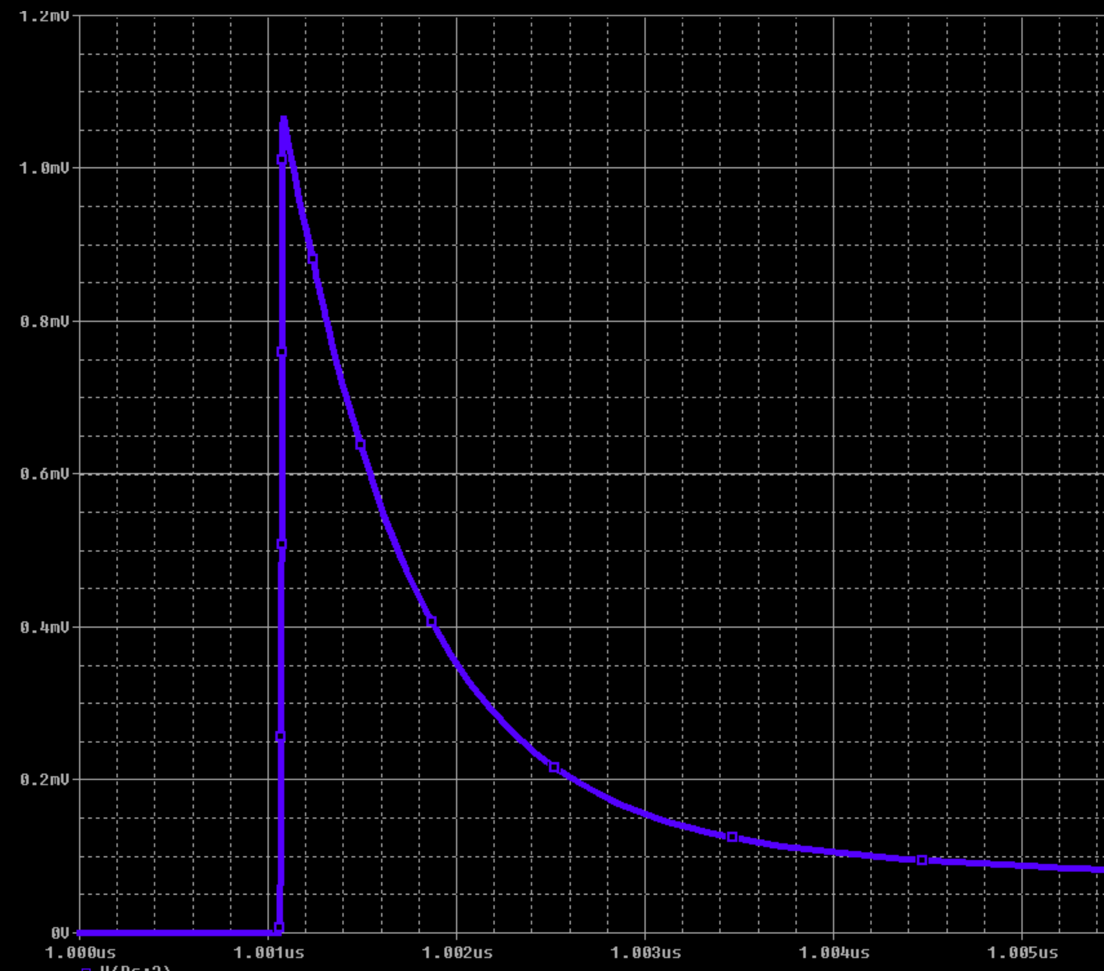
- SiPMs are different: think about the circuit



Thinking about SiPMs

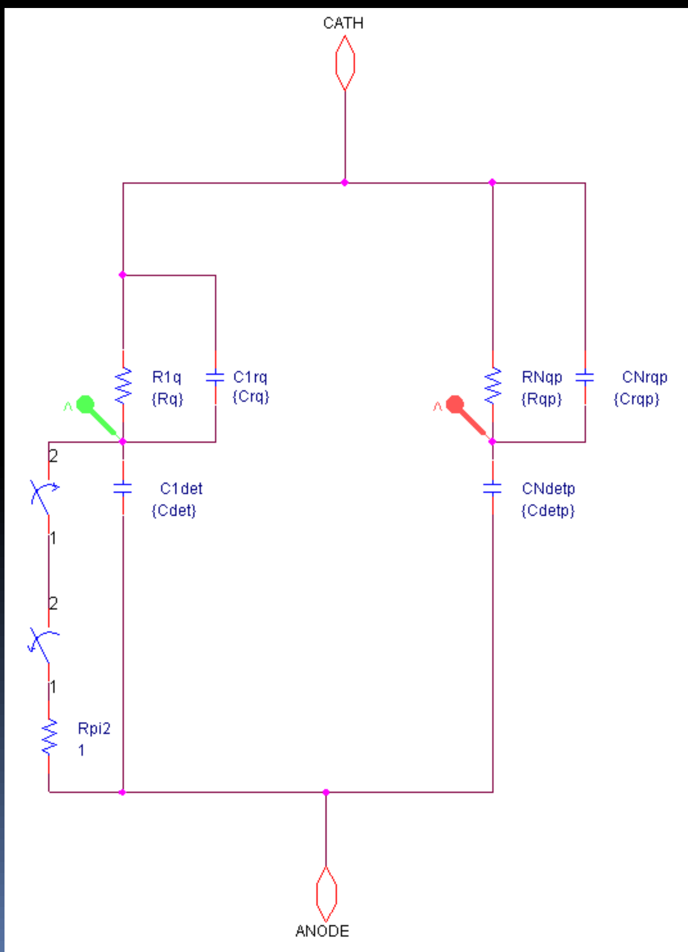
SiPMs are different: let SPICE think about it…

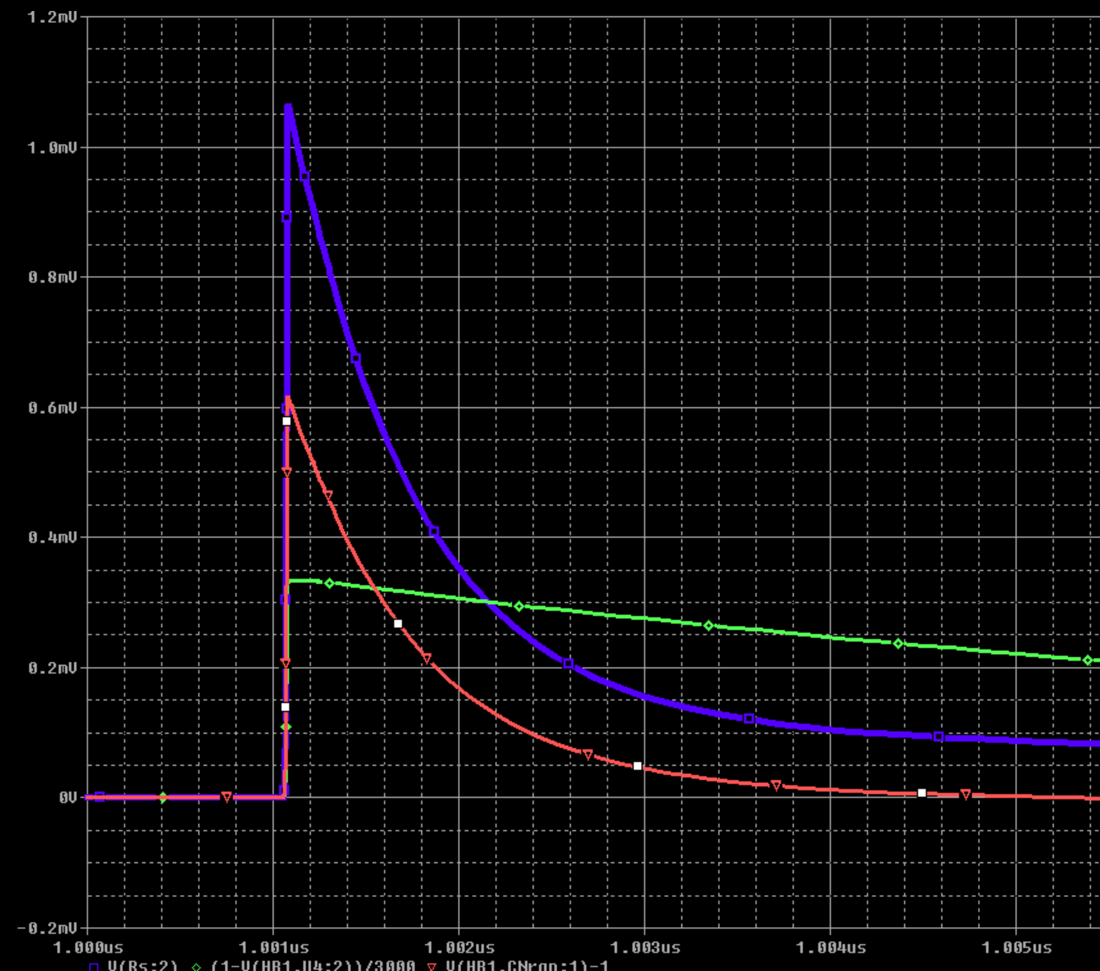
SiPMs
ARE NOT
little PMTs



Thinking about SiPMs

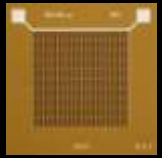
- This is not an exp, it has 2 components





Thinking about SiPMs

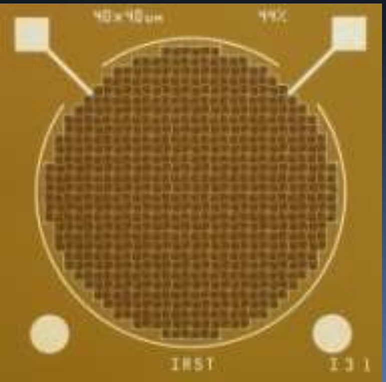
- Thinks get more complicated:
  different SiPMs are different! (Rq, Cdet, etc.)



1x1mm

fill factor:

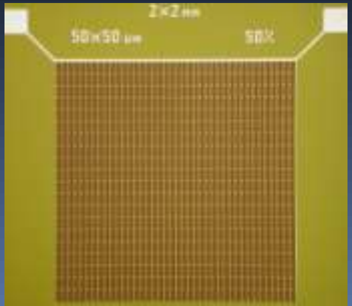
40μx40μ => 44%
50μx50μ => 50%
100μx100μ => 76%;

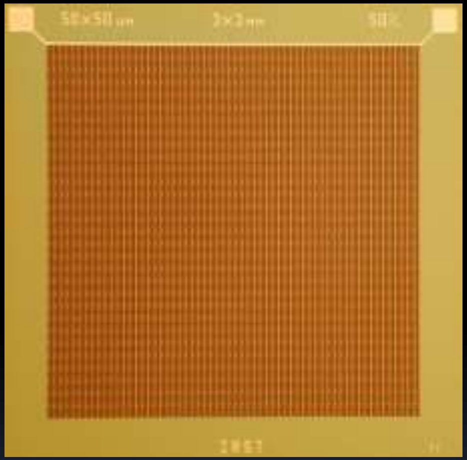


Circular Array 1.2mm dia.
~ 650 pixels 40 x 40 μ^2

Giovanni Pauletta

2x2mm

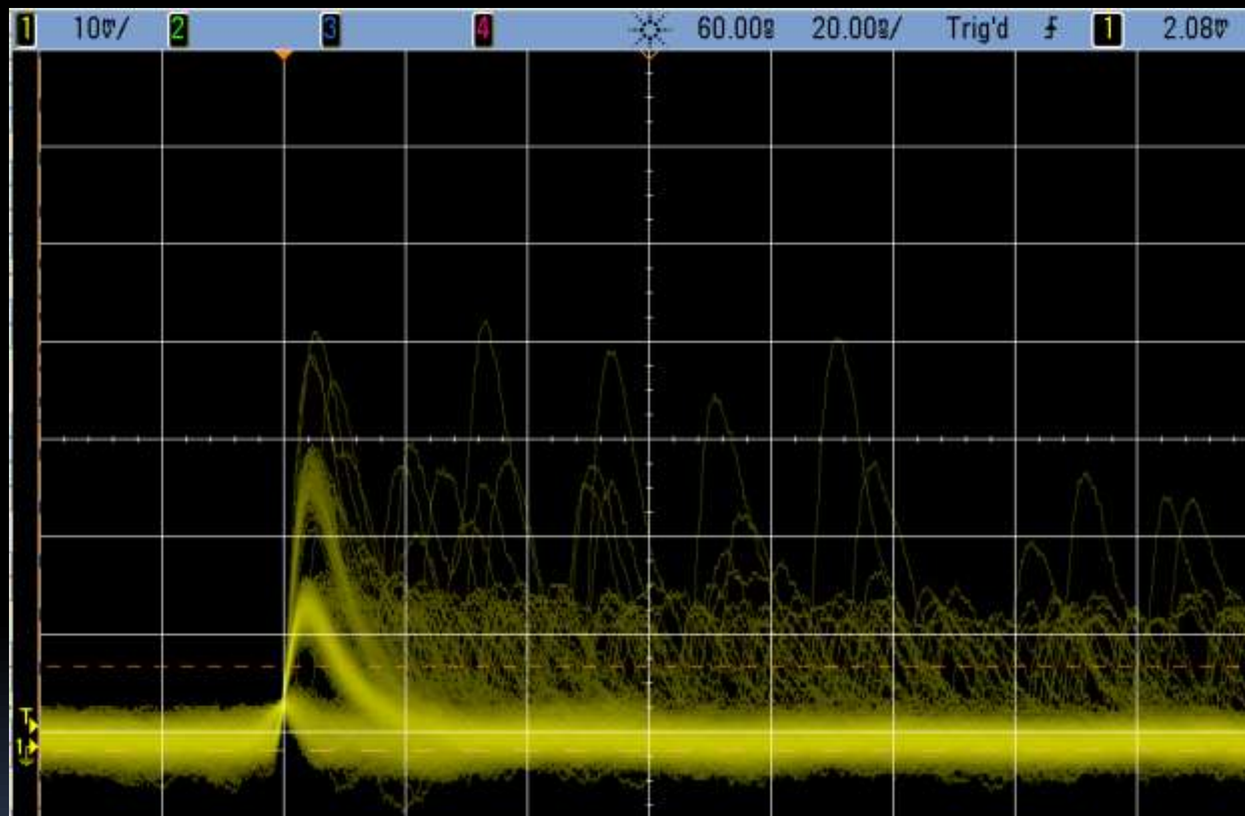




3x3mm

Electronics for SiPMs

- Step 1 : Scope



- MPPC-11-050C#37 at 71.1deg F operating at 69.81 (recommended V is 70.02 at 25C)
- Current reading is 0.044uA
- 1pe is about 13.25mV

Electronics for SiPMs

- Step 2 : build our own, but generic
- Enable applications that would not otherwise be possible
- Aim to support test beam
- Provide support
- Appropriate for studies with single crystals
- They also work for PMTs

But… more on that later

Electronics for SiPMs: Step2

- Best available commercial components without heroic efforts and reasonable $
  (~1ns resolution, ~400 pe range)
- Integrated with SiPM specific features
  (bias generator, current readback, temp sensor)
- Optimized for 4-48 ch count (dozen(s) SiPMs)
- Flexible: using 50 ohm input, generic daughter board connection to support faster readout/more memory
- Large FPGA to allow DSP features

A bit more about TB4

50ohm inputs
12bit ADC, so large dynamic range, 212MSPS, up to4k samples/ch
~100MHz bandwidth, noise ~30uV RMS
Up to 16ch per MB
Bipolar, so ped is around 8100 (half scale)
Setup over USB, readout over 100mbit Ethernet

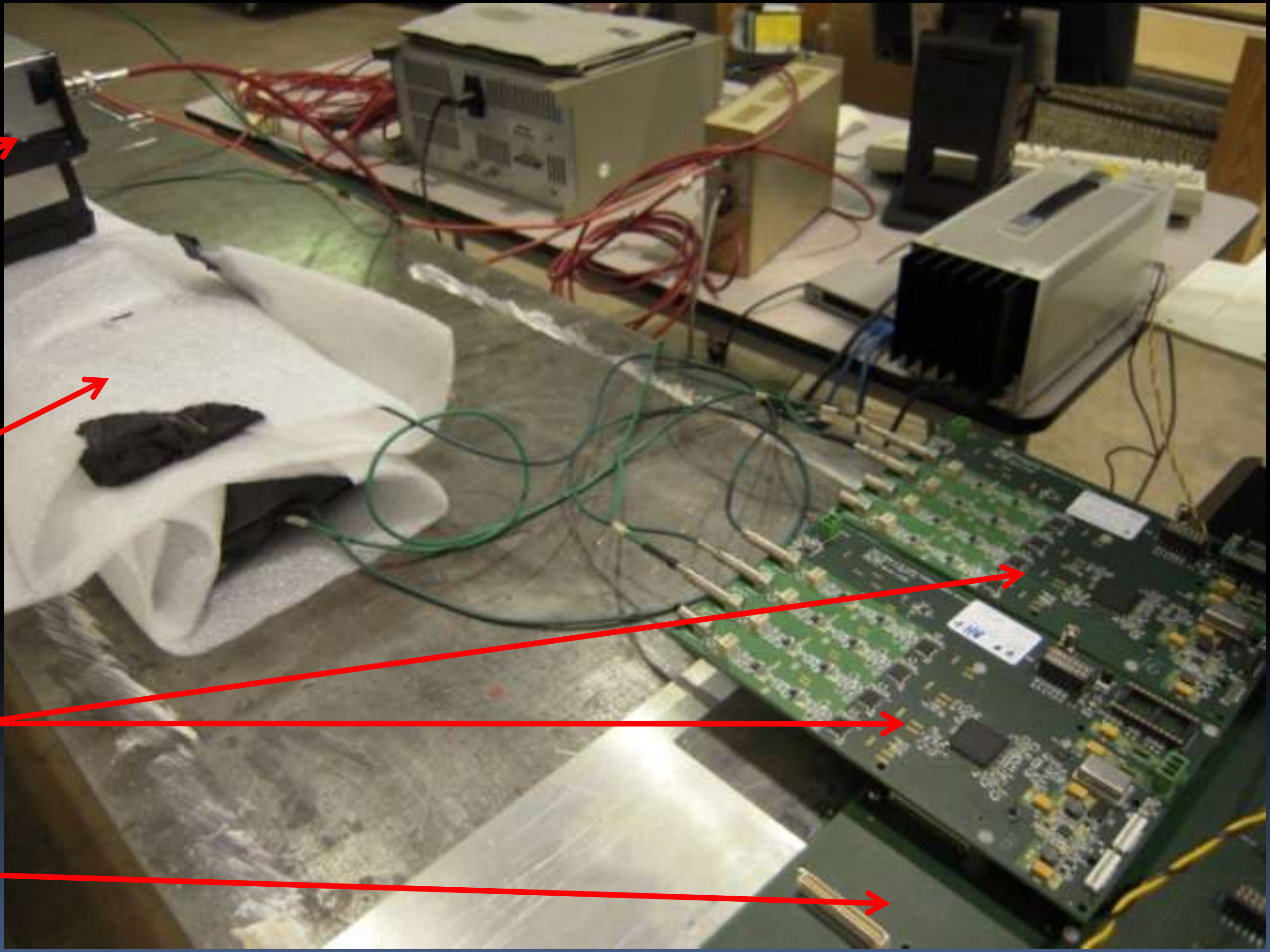
Test Beam 4 channel electronics:TB4

Cosmic Ray Trigger Counters

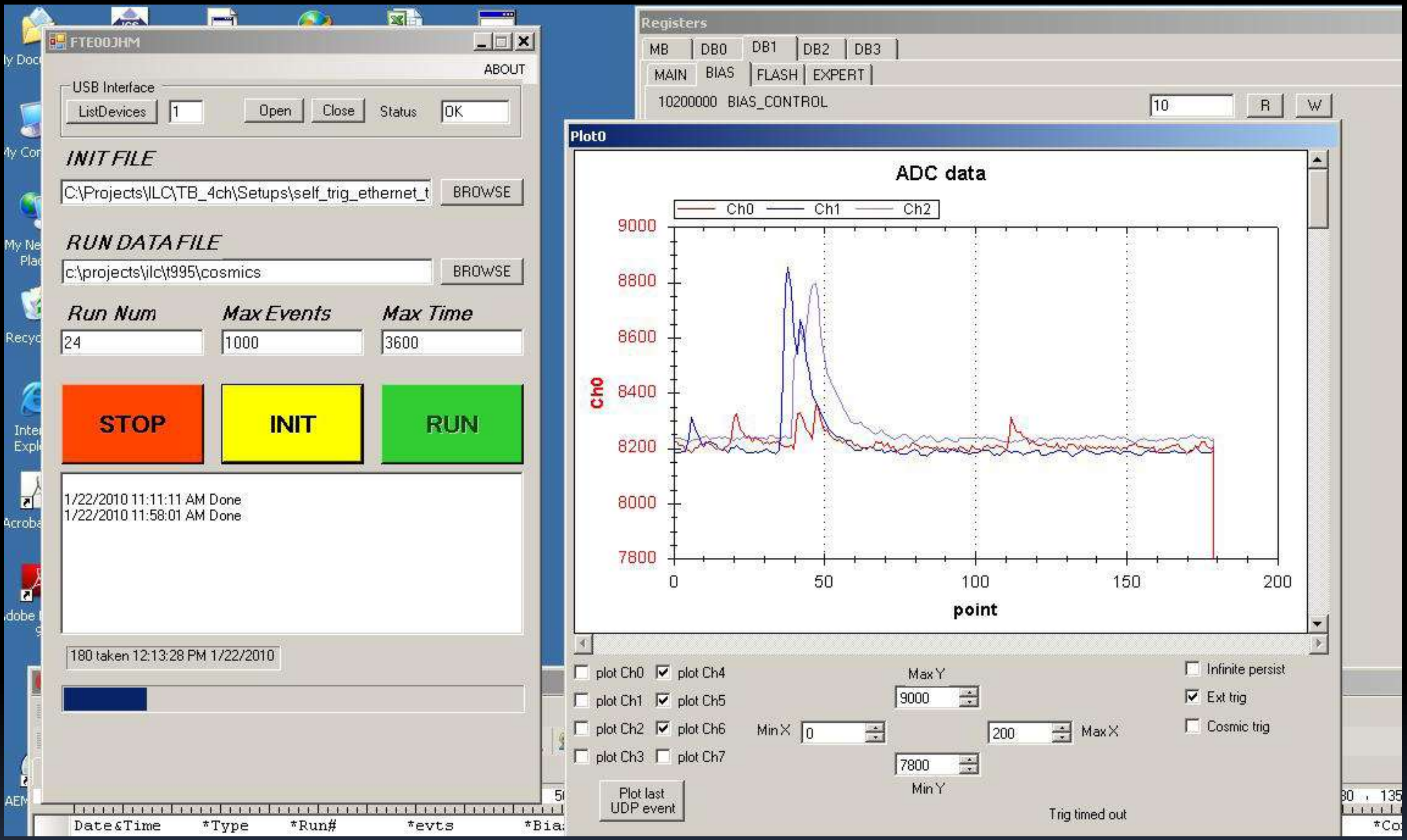
Strip Scintillators

TB4 Daughter Boards

TB4 Mother Board

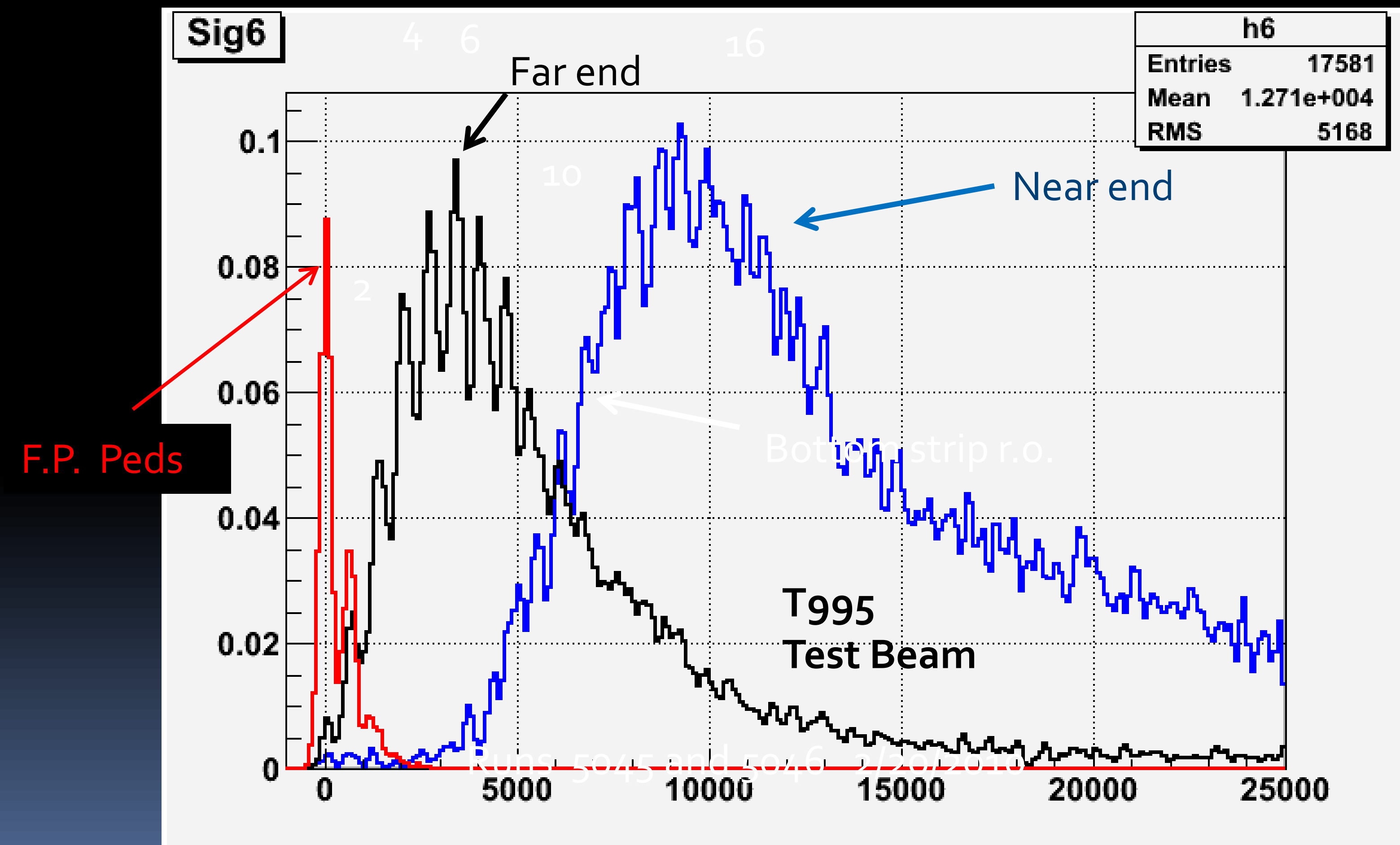


TB4 Set-up at D0: Cosmic Rays



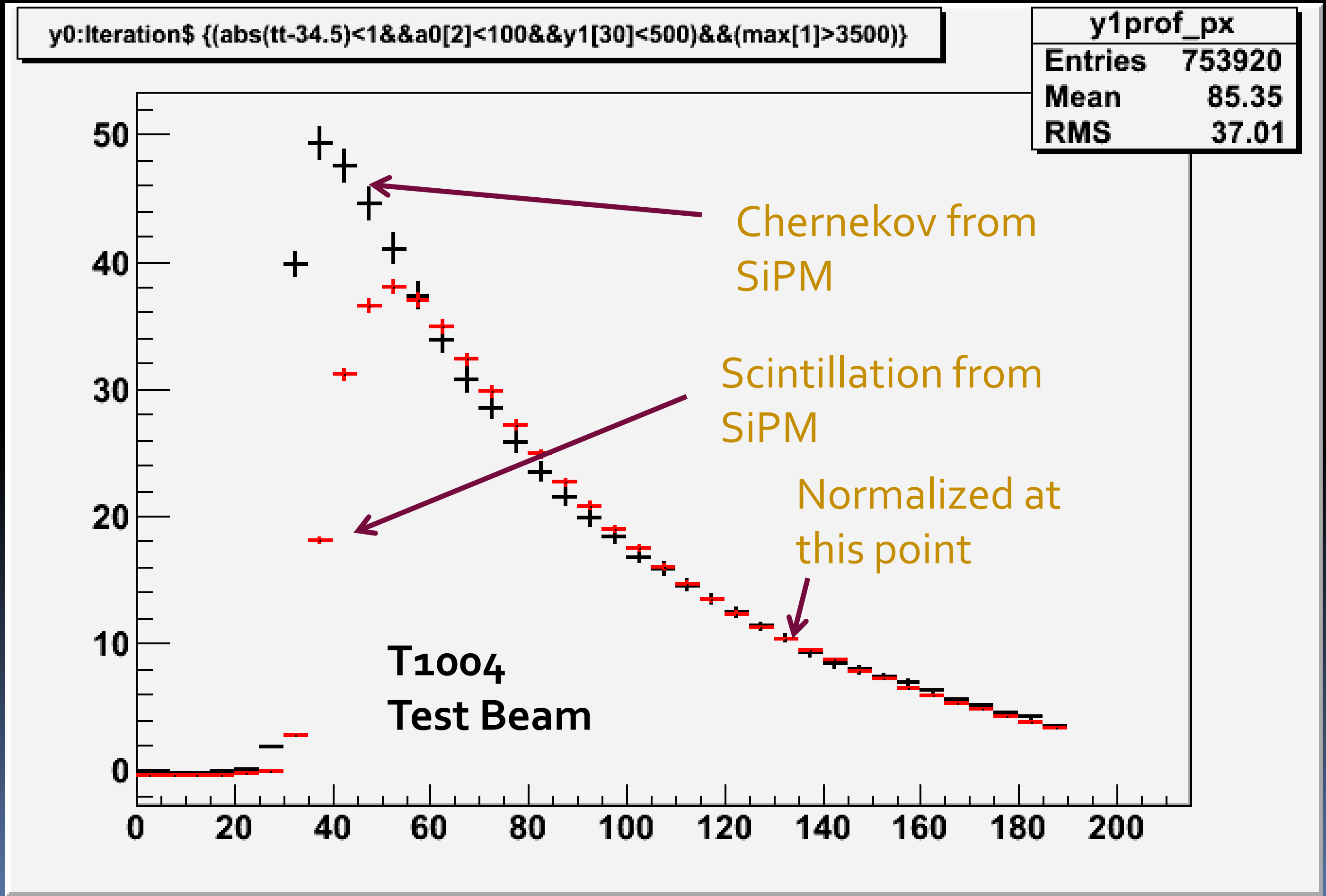
180 digitizations * 4.708ns = 847ns . **Small pulses and Large pulses!**

Muon detector (7m MINOS extrusion) read both ends with 1.2mm SiPM and TB4 electronics



Electronics for SiPM

- TB4 also works for dual readout calorimetry (single 5x5c, crystal in 4GeV beam



Electronics for Bigger Calorimeter

- Step 3 ? : detector specific electronics
  - Precision calorimetry is a challenge
    1. Dynamic Range
    2. Linearity
    3. Calibration
- Next step is still COTS (no ASICs) but much more application specific

  Probably different electronics for PMTs and SiPMs
- More specific = lower cost/ch but more effort
  - Optimize for O(100) ch

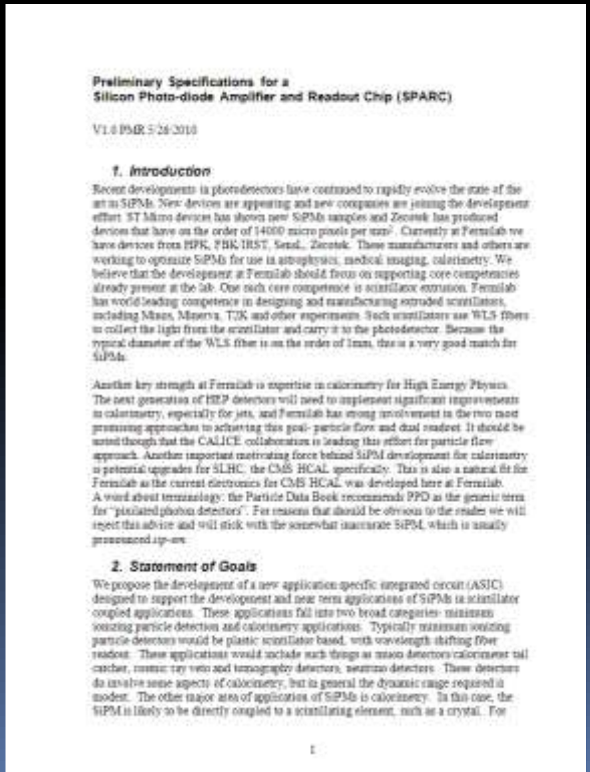
Electronics for Calorimeter

- Step 4 : designed for a specific calorimeter
  - For a “real” calorimeter: O(5000) chan
  - System aspects: power, cooling, control, readout
  - ASICs required
    - ASICS take a long time to develop
      (critical to have experience!)
    - Need to start prototypes so they can participate in small calorimeter (O(100) = MOSIS MPW)
    - System design: calorimeter AND electronics

SPARC

- ASIC in progress!
  - Basic idea is QIE on steroids

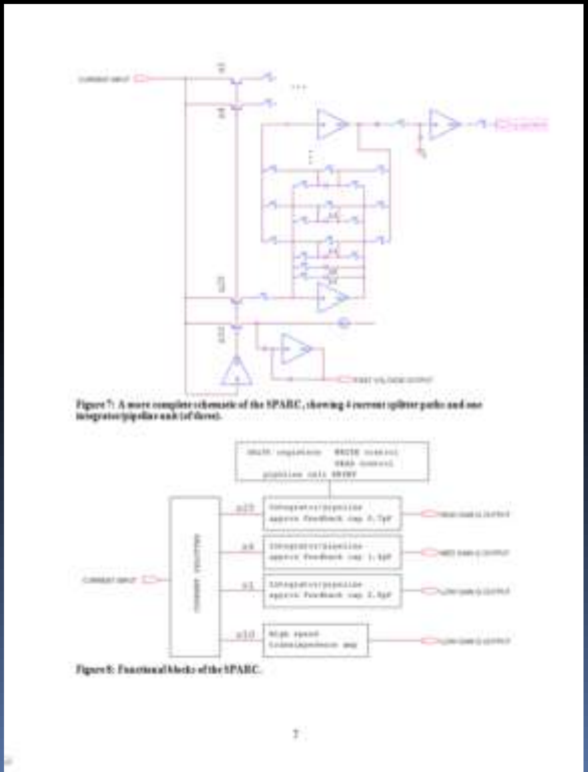
    16bit+ dynamic range, 1ns timing, 0.2pe noise


Preliminary Specifications for a Silicon Photo-diode Amplifier and Readout Chip (SPARC)

V1.0 PMR 5/26/2010

1. Introduction

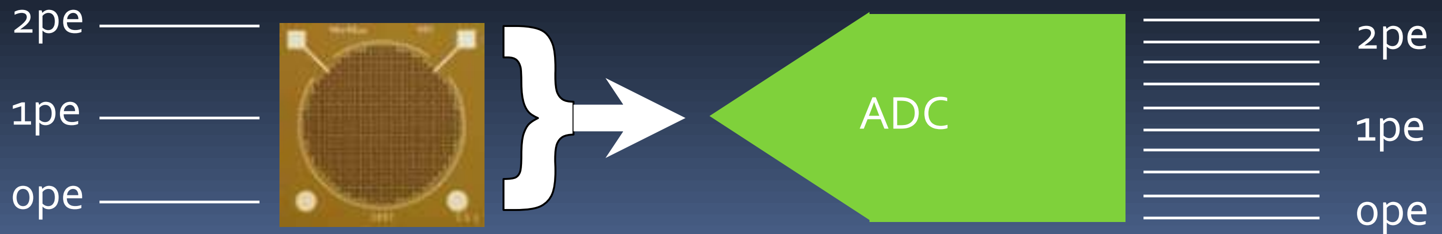
2. Statement of Goals



The Future

- I have seen the future of SiPM readout
  - Readout electronics will be integrated into the SiPM!

  because
  - SiPM is an inherently digital device
  - We ALWAYS convert the signal from the SiPM to digital
  - So why do we have an analog step in between?!?



The future

- I never said I was the ONLY one…
- SiPM is not a tiny PMT but it is a very simple ASIC

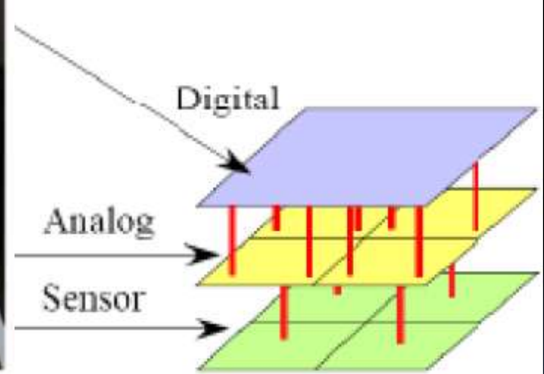
Next step for SiPMs is ROC+Sensor unit

Oct 8, 2009 Philips announces breakthrough in fully digital light detection technology
Eindhoven, the Netherlands - Royal Philips Electronics today announced that its scientists have developed a highly innovative digital silicon photomultiplier technology that will allow faster and more accurate photon (the basic quantum unit of light) counting in a wide range of applications where ultra-low light levels need to be measured.

There is more future yet…

Grzegorz Deptuch
on behalf of the FERMILAB ASIC design group
Raymond Yarema, Grzegorz Deptuch, Jim Hoff, Farah Khalid, Marcel Trimpl, Alpana Shenai, Tom Zimmerman

Hey! I know these people!



Fermilab position in 3D-IC

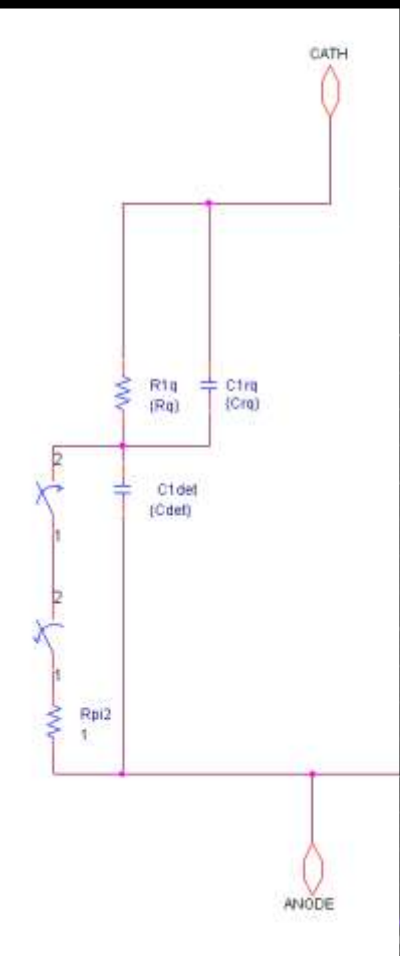
Fermilab began exploring the technologies for 3D circuits in 2006.

Fermilab is leading an Int'l Consortium (15 members) on 3D-IC for scientific applications, mainly HEP

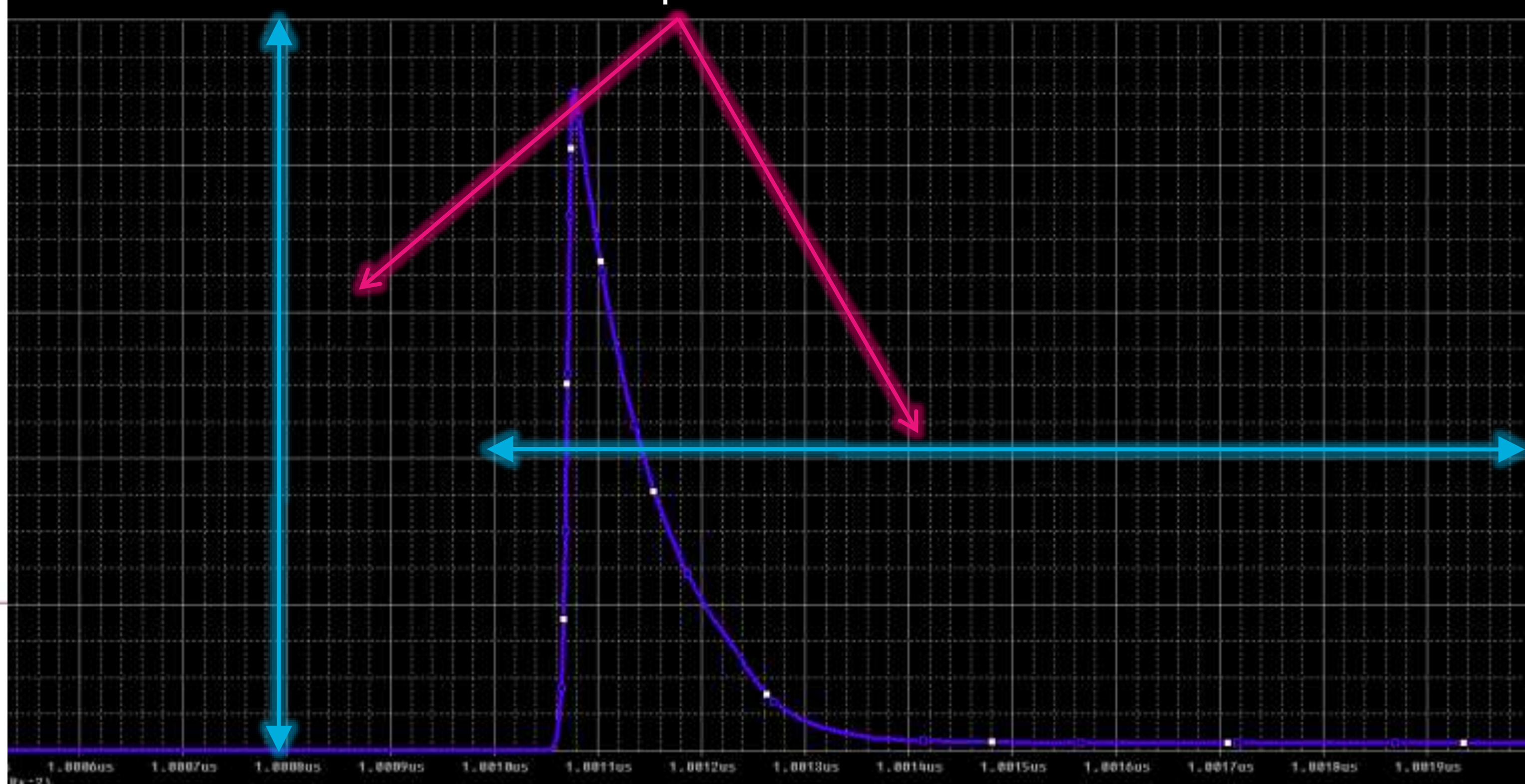
3-d for SiPMs?

- Oh yes. You don't need an amplifier.

  Lets see what happens if we just have 1 pixel



1000 x bigger amplitude
10 x faster pulse



Conclusion

- We have a clear road map for electronics to support dual readout calorimetry
- Our efforts can scale to match the scale of R&D

BUT

We are in a unique position to move on 3-d SiPMs

- Modern detectors can not afford to put off thinking about electronics. Must be supported at a proportionate level