Readout Electronics for SiPM Arrays Used for Nuclear Medical Imaging

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- SiPM Readout ASIC
- OpenPET Electronics

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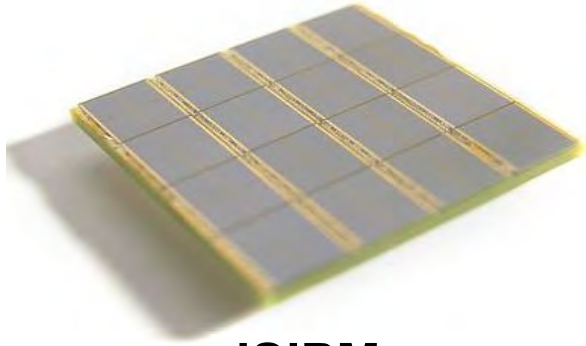
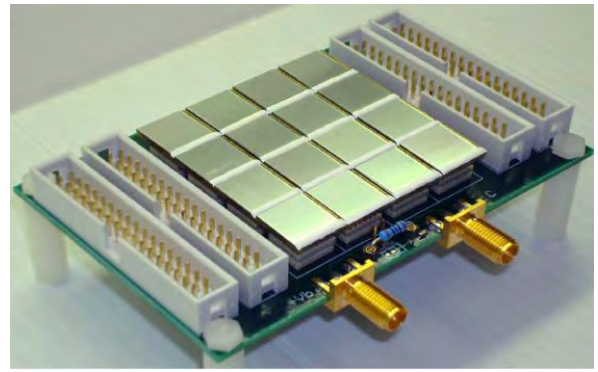
Large Variety of SiPM Arrays Available

Philips



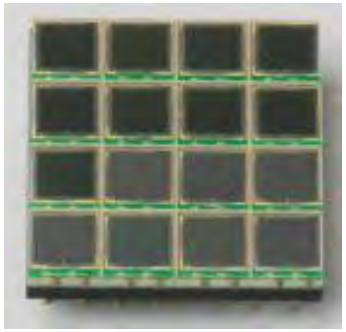
dSiPM

RMD



SSPM

Hamamatsu

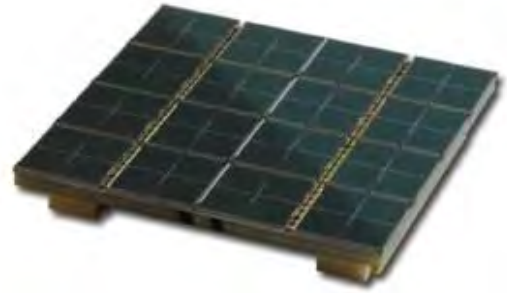


MPPC

SensL

SPM

FBK

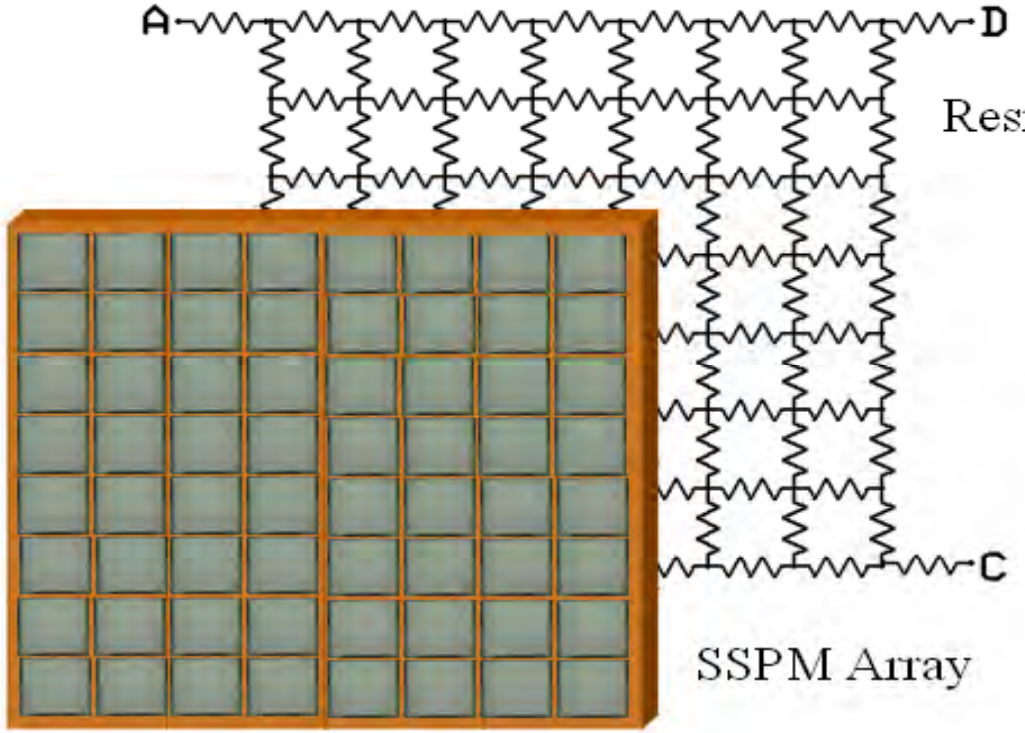


SiPM

- **Very Attractive for PET**
- **Properties Vary (20 pF – 900 pF, ∝Pixel Area)**

Channel Count Reduction Needed for PET!

~100,000 detector elements in a PET Camera



$$X = \frac{A + B}{A + B + C + D}$$

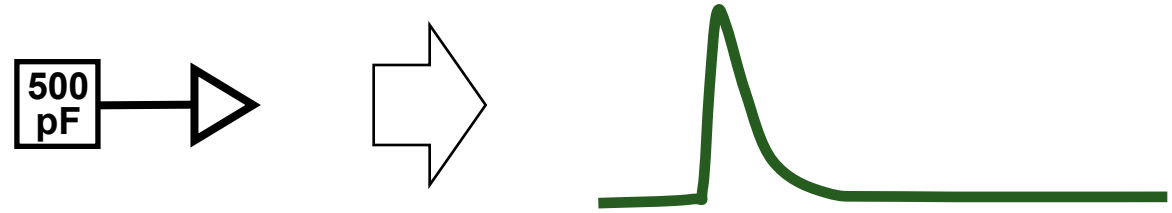
$$Y = \frac{A + D}{A + B + C + D}$$

$$E = A + B + C + D$$

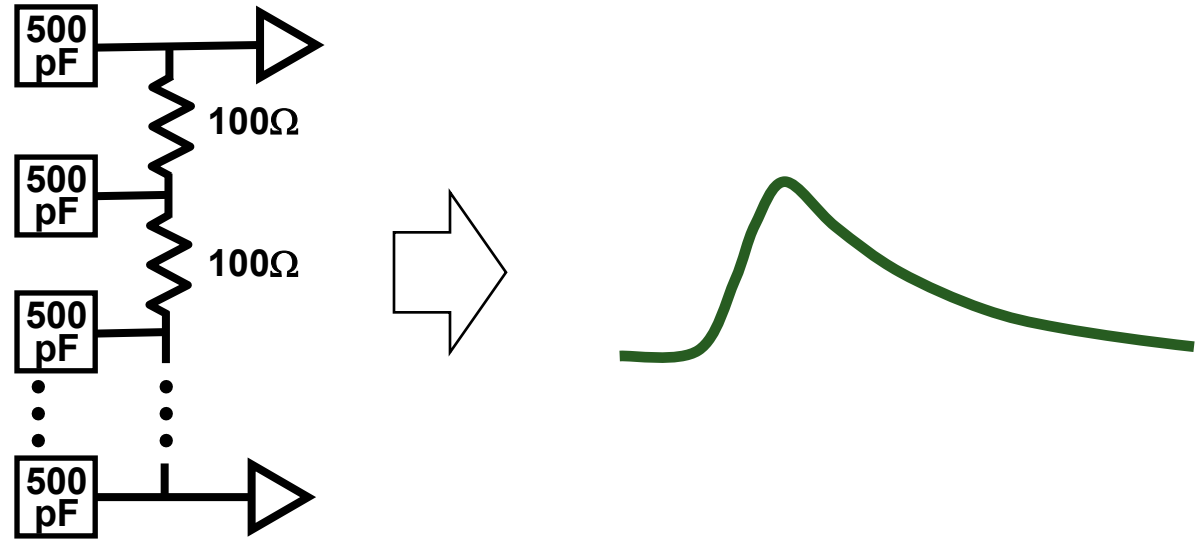
- Current Division ➔ 16-fold Reduction for 8x8 Array
- Standard Technique for PET w/ Multi-Anode PMTs
- Many Commercial PET Cameras Use Similar Readout

Resistor Array Degrades Timing

Single
SiPM Pixel

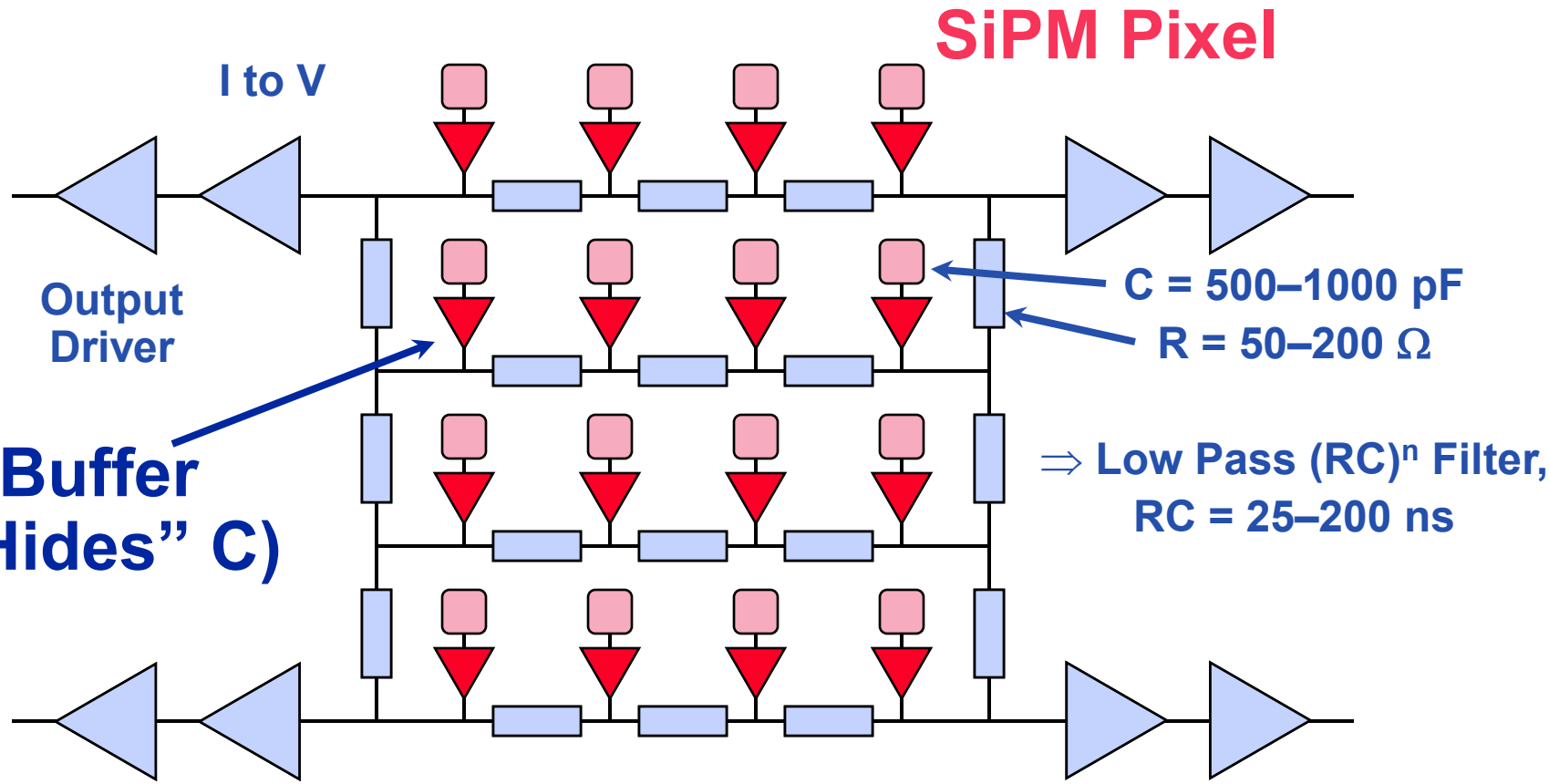


Array of
SiPM Pixels



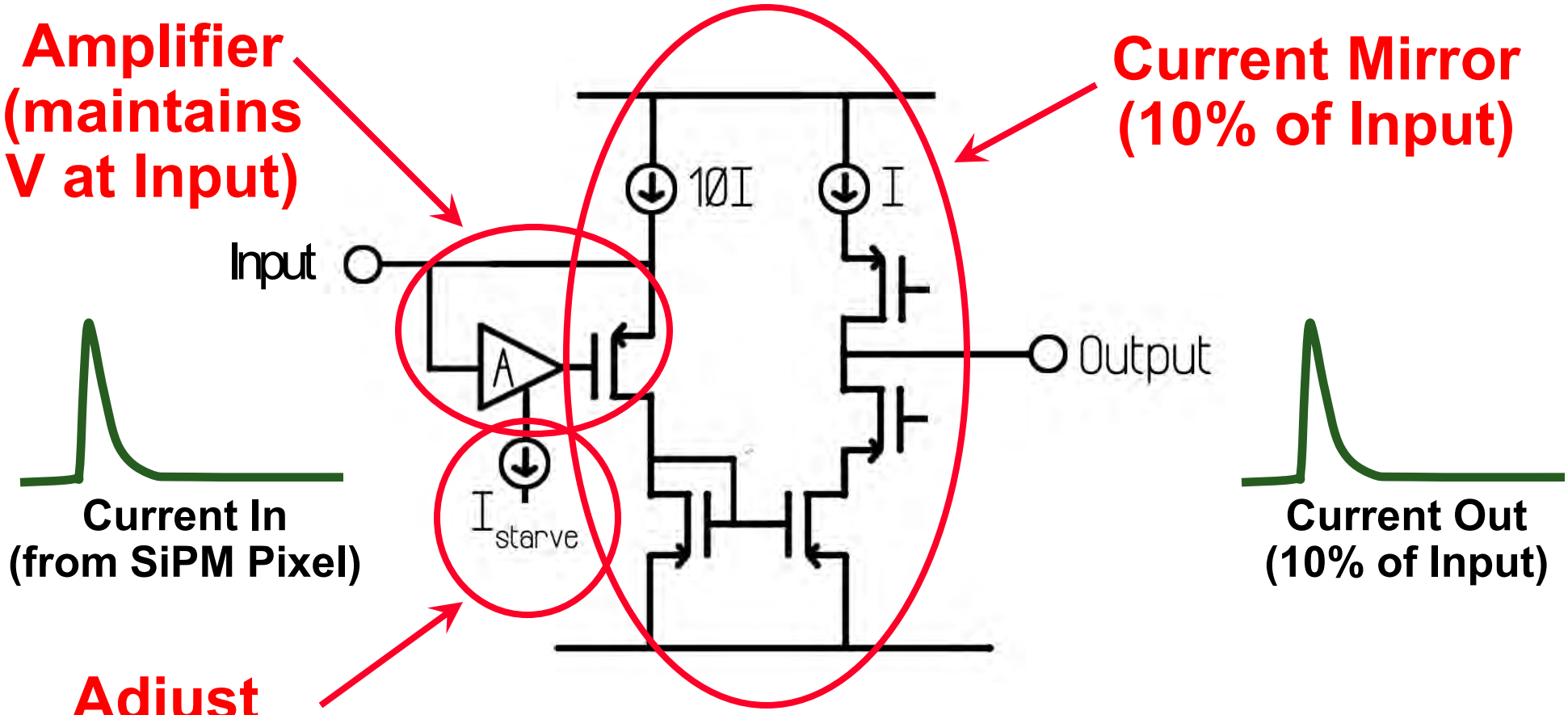
Multi-Pole RC Filter

ASIC Block Diagram



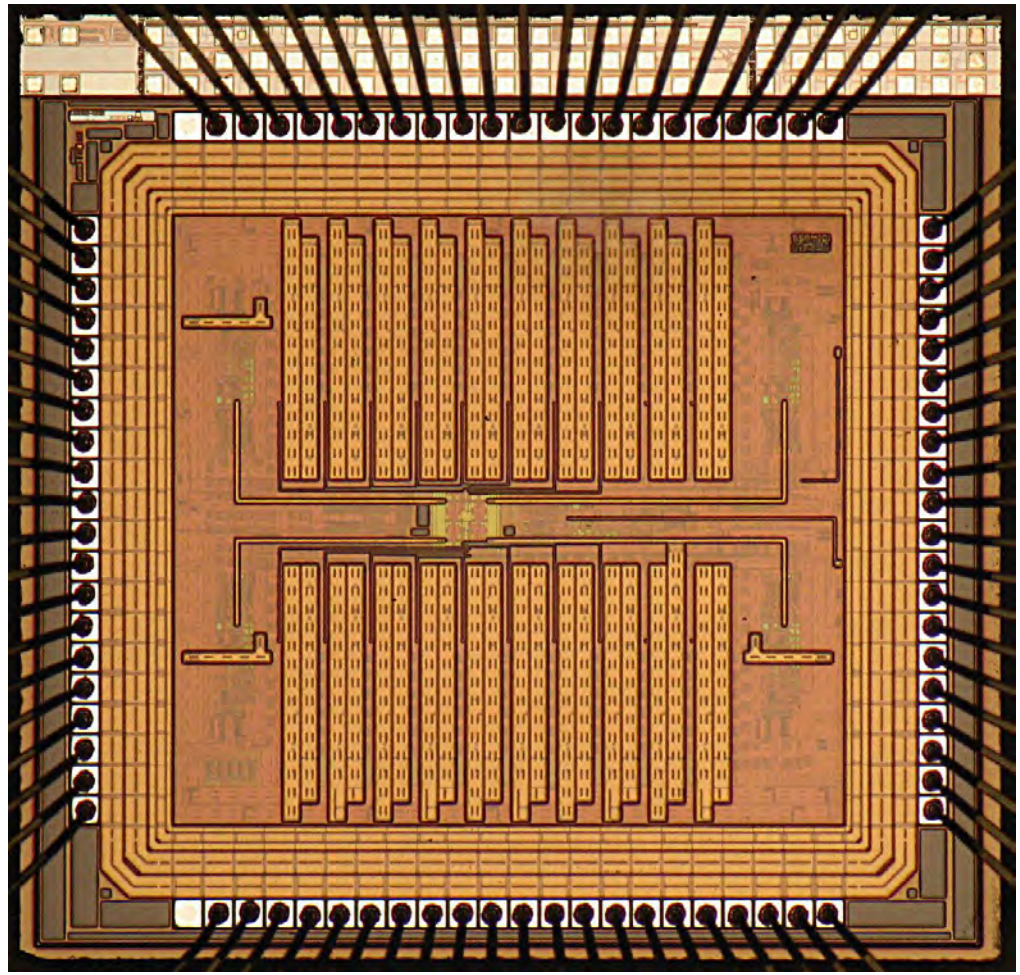
- Insert Buffer Between SiPM & Resistor Array
- Restores Timing Properties

Current-Current Converter



2 ns Rise Time

Photograph of 16-Input Prototype
(Photo Required for *All* ASIC Presentations)



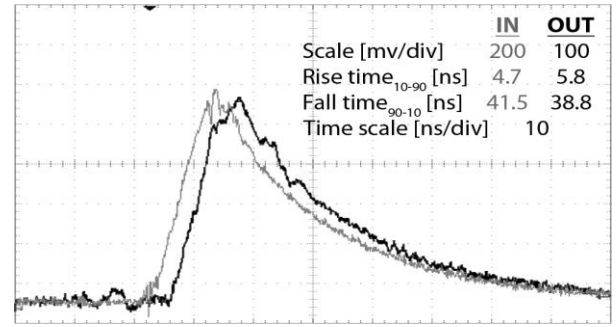
AMS 0.35 µm
TSMC CMOS,
high voltage

Chip Dimensions:
2.5 mm x 2.5 mm

64-Input Version Just Back from Foundry…

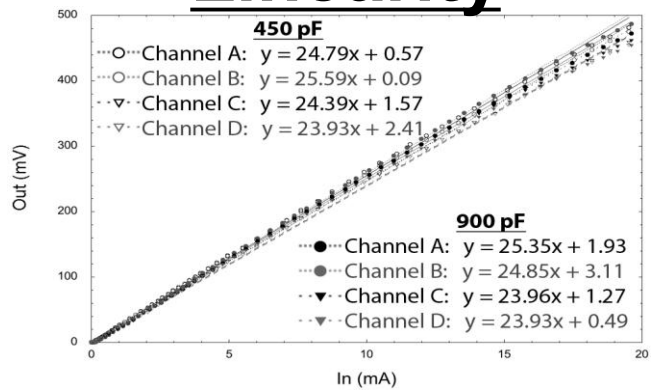
Performance Tests (16-Channel) w/ Pulser

Input vs. Output

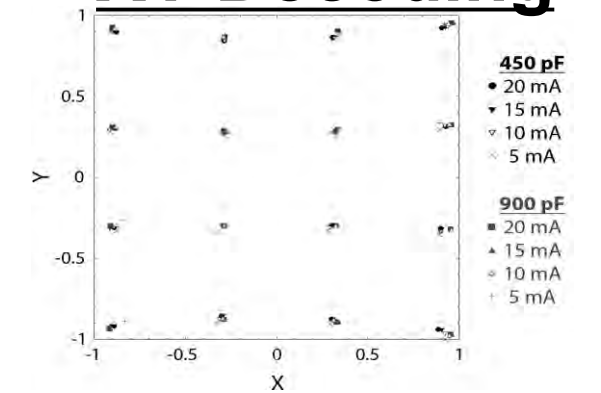


Input Rise Time: 4.7 ns
Output Rise Time: 5.8 ns

Linearity

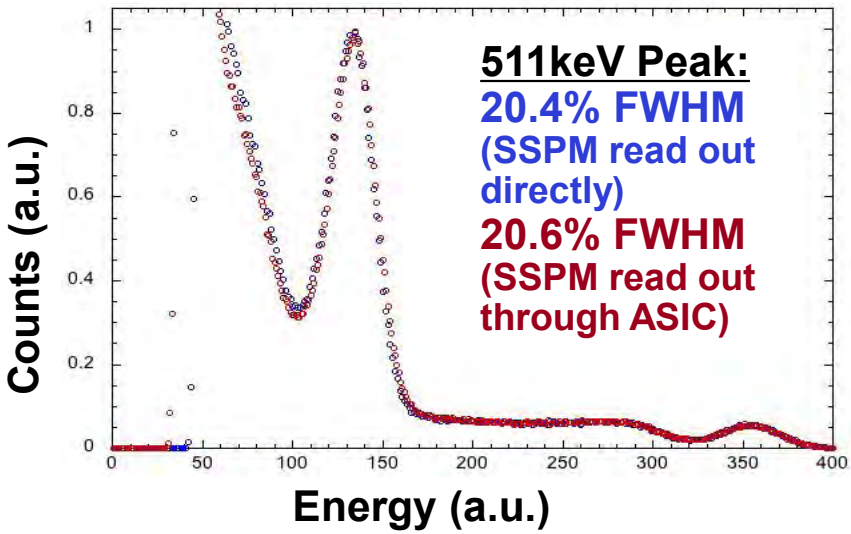


XY Decoding

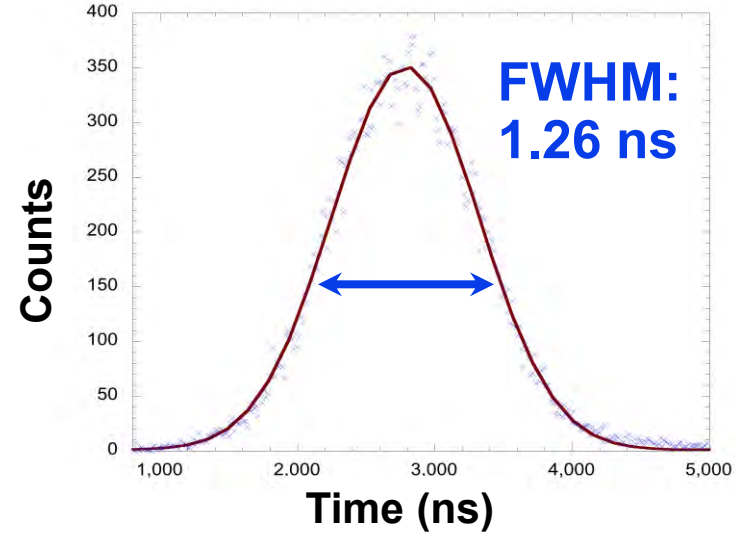


Performance Tests (16 Channel) w/ LSO Array

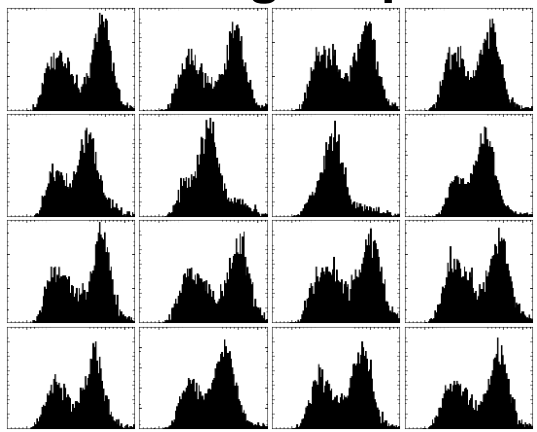
Pulse Height Spectrum



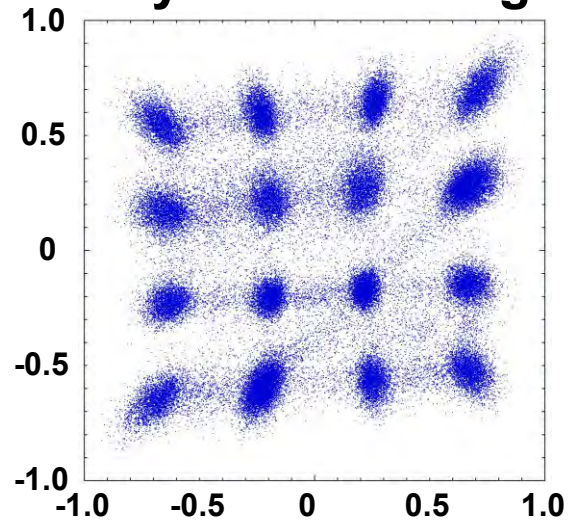
Coincidence Timing



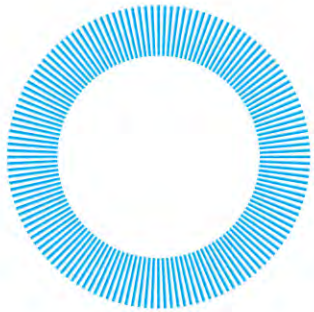
Pulse Height Spectra



Crystal Decoding



It Works!!!



openPET

- **Nuclear Medicine Research Community Needs "Industrial-Strength" Electronics**
- **Needs Can Be Met By Single, *Flexible* Design!**

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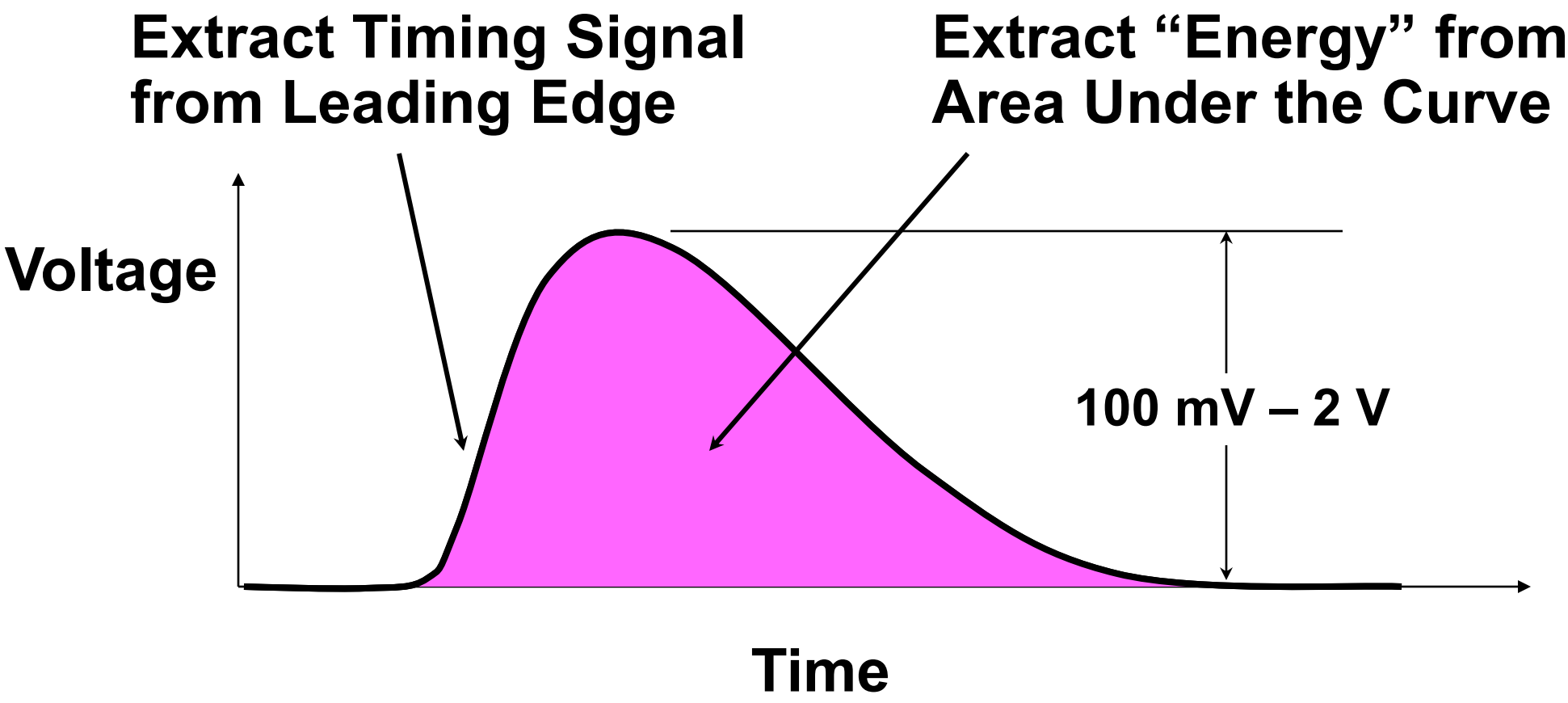
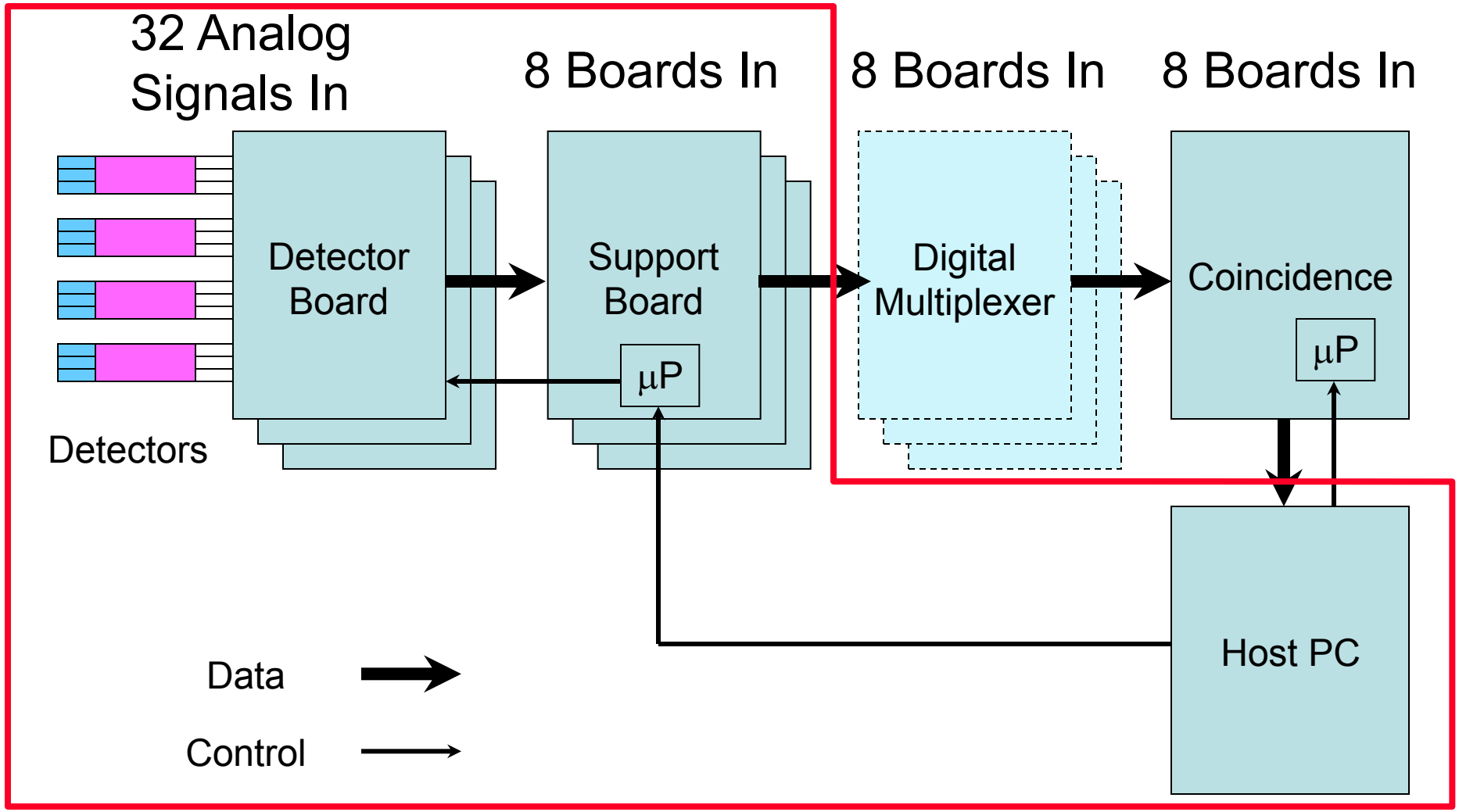
All Detector Outputs Look the Same



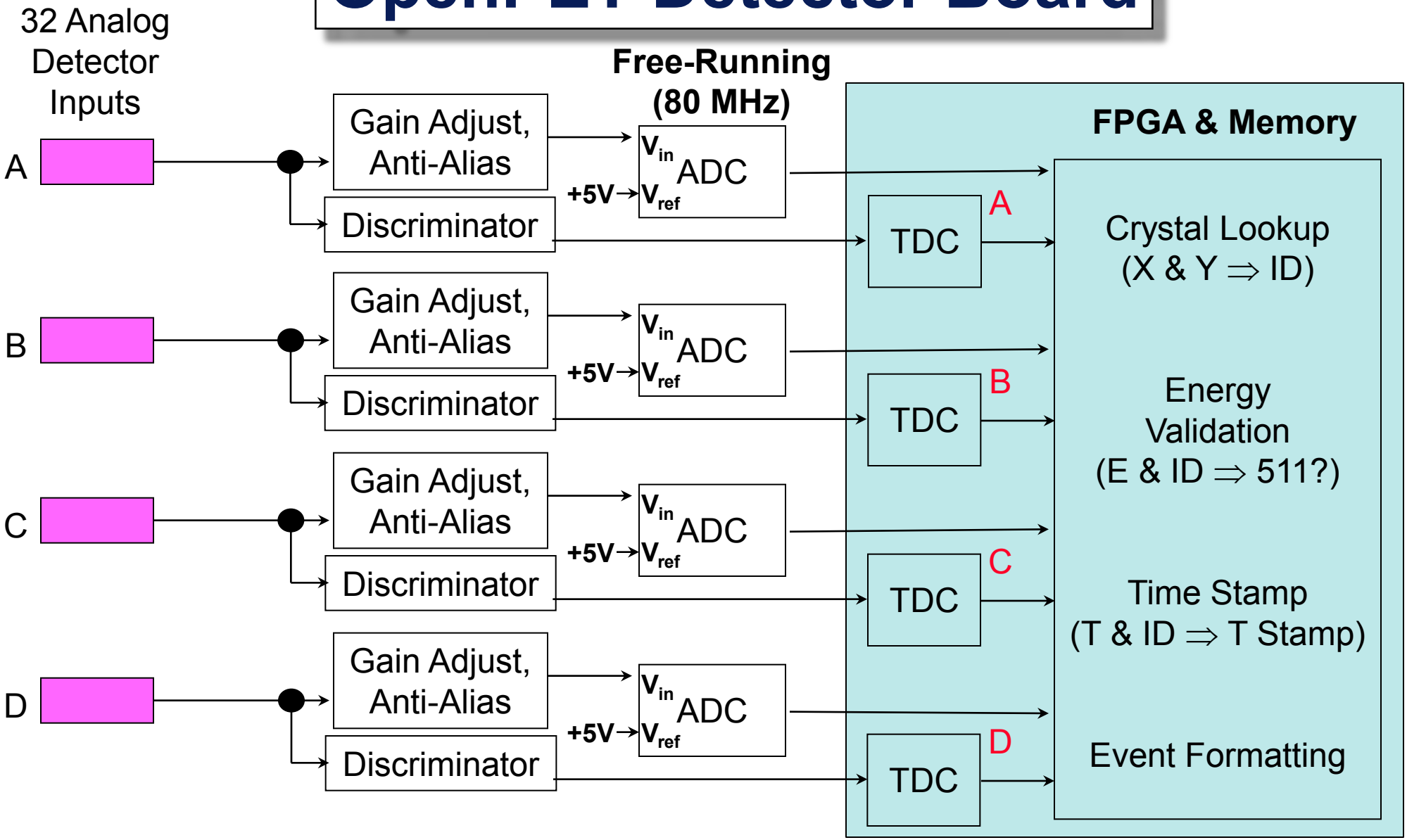
- *Tremendous* Variation in How Outputs Are Combined
  ⇒ Digitize, Then Combine Outputs in Firmware

OpenPET System Architecture



- **Supports 512 Block Detectors (4096 With Multiplexers)**
- **SB + 8 DBs Makes Nice Test Stand (64 Block Detectors)**

OpenPET Detector Board



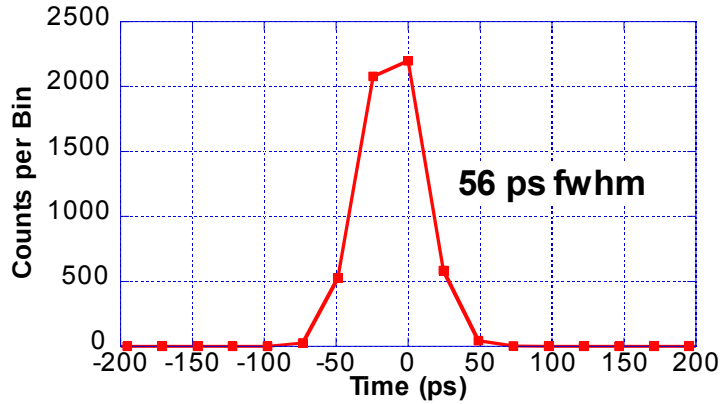
All Inputs Have Individual ADC, LE Discriminator, & TDC

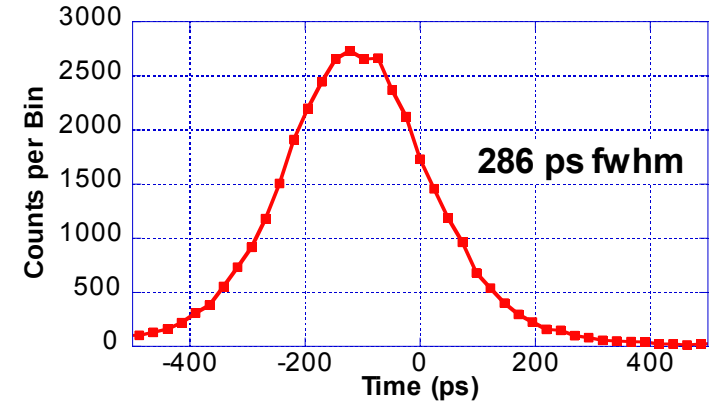
Timing Resolution

Test Pulse

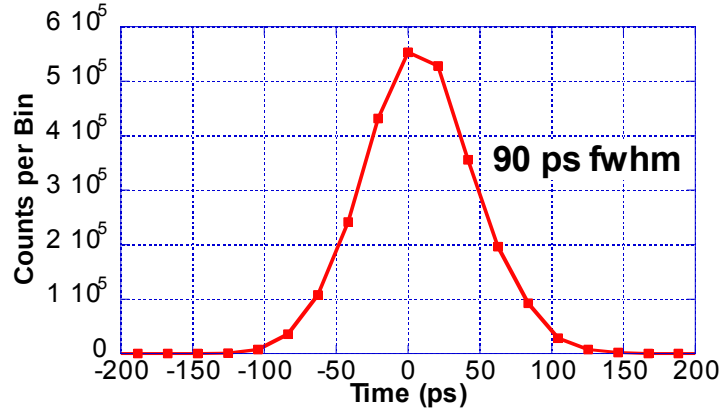
TOF Module Pair

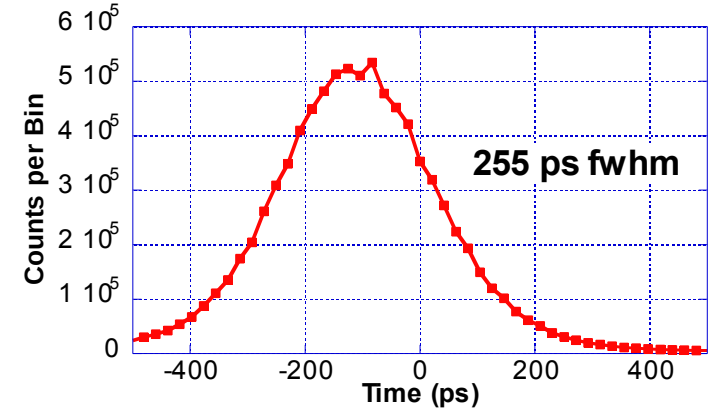
HPTDC (CERN)





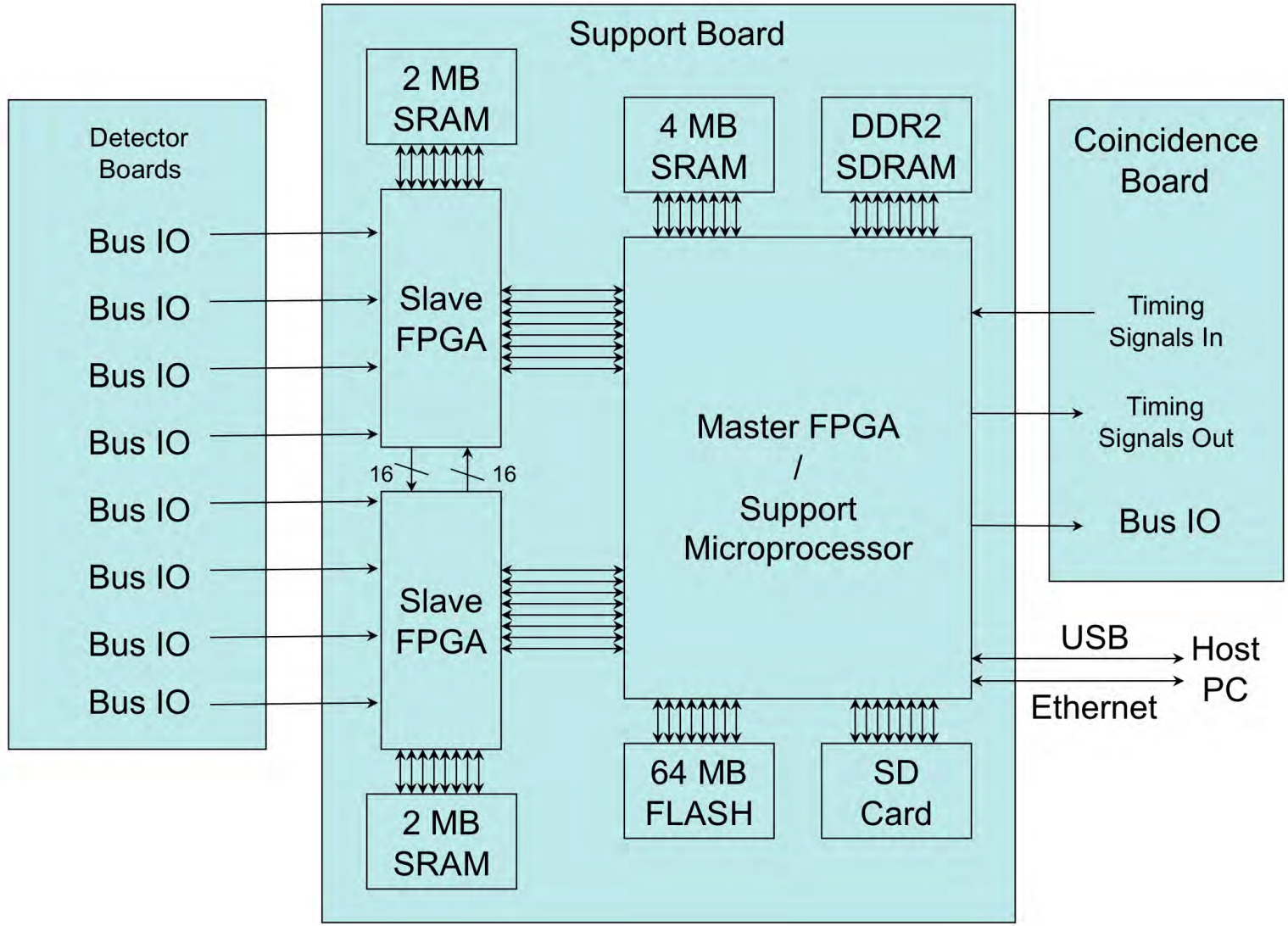
FPGA





- 32 Channel TDC in Cyclone II FPGA
- Performance Good Enough for Time-of-Flight PET

OpenPET Support Board

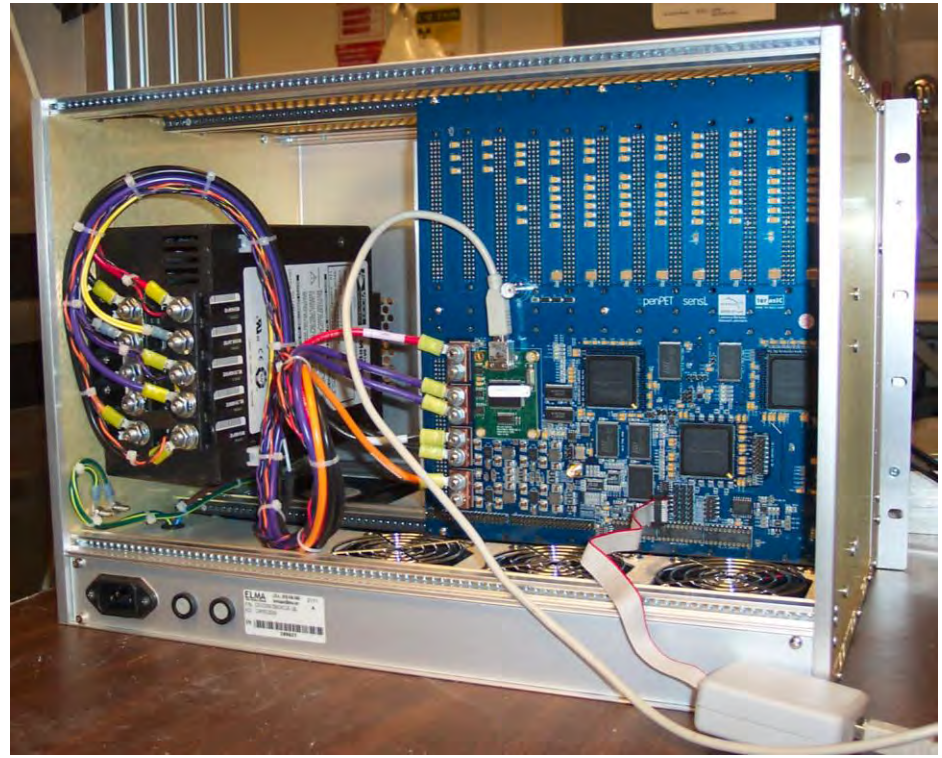


Resembles a PC Motherboard…

Support Board Designed, Built, & Tested

Front View

Back View



Slot 1–8: Detector Boards
Slot 9: Coincidence Board Interface
Slot 10: PC Interface (USB, Ethernet, SD Card, Detector Bias, 20 LEDs)
Slot 11: User Digital I/O (2 RS-232, 48 Digital I/O, External Clock In)
Slot 12: Debugging (JTAG, 4 Logic Analyzer Connectors, 30 LEDs)

VME Form Factor to Reduce Cost

openPET Vision

Open Source

- Hardware, Firmware, and Software
- Schematics, Gerbers, BOM,…

Active User Community

- Share Software and Expertise
- Module, Calibration, DAQ, Display,…

Hardware Readily Available

- Support Boards Available Now
- Detector Boards Available Spring 2012

http://OpenPET.LBL.gov

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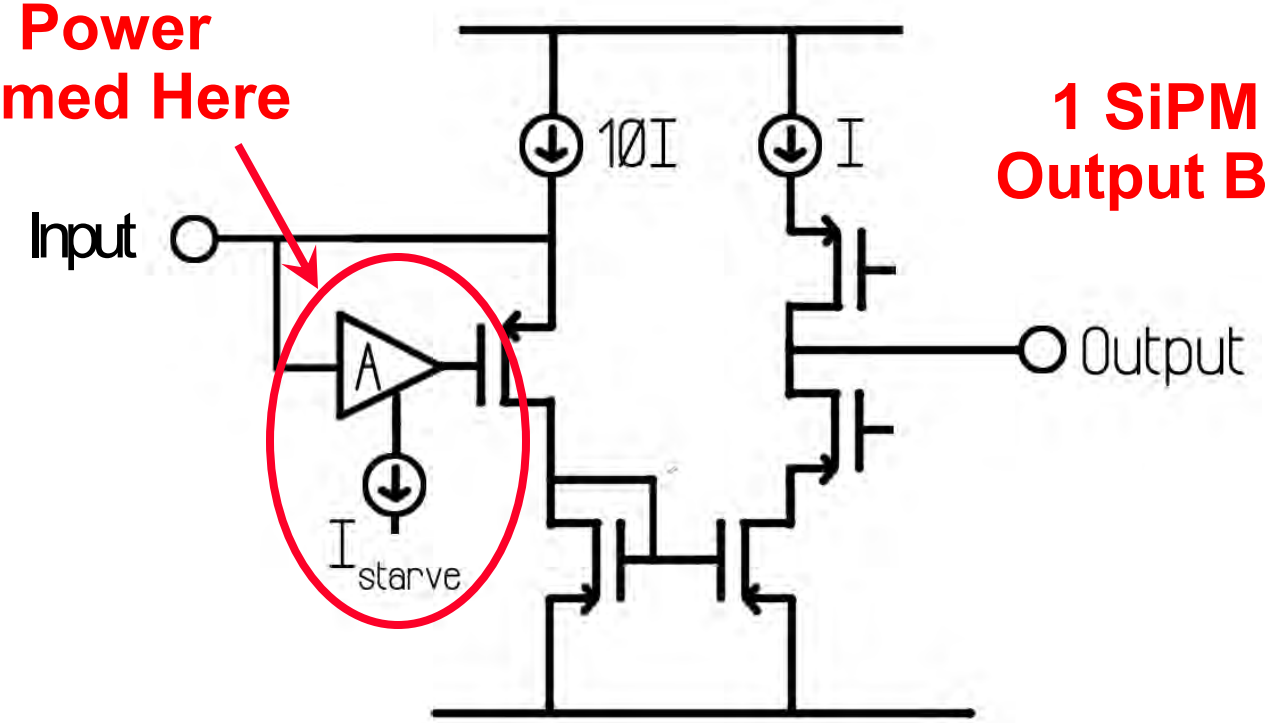
ASIC Achilles Heel: Power Consumption

~All Power Consumed Here



1 SiPM Pixel = 12 mW
Output Buffers = 120 mW

- Amplifier power proportional to pixel capacitance (& bandwidth)
  - Pixel capacitance proportional to area

➔ Power / area is constant (75 mW / cm^2 ➔ 500 W / PET camera)

How Can We Reduce Power / Area?

Conclusions

SiPM Readout ASIC Front-End Electronics

- Current Division → 16x Lower Channel Count
- 16 Channel Prototype Fabricated & Tested
- 64 Channel ASIC Recently Received
- 75 mW / cm^2

OpenPET Back-End Electronics

- "Open Source" Electronics for Nuc. Med.
- Programmable – Extensive Use of FPGAs
- Support Boards Available Now
- Detector Boards Available Spring 2012