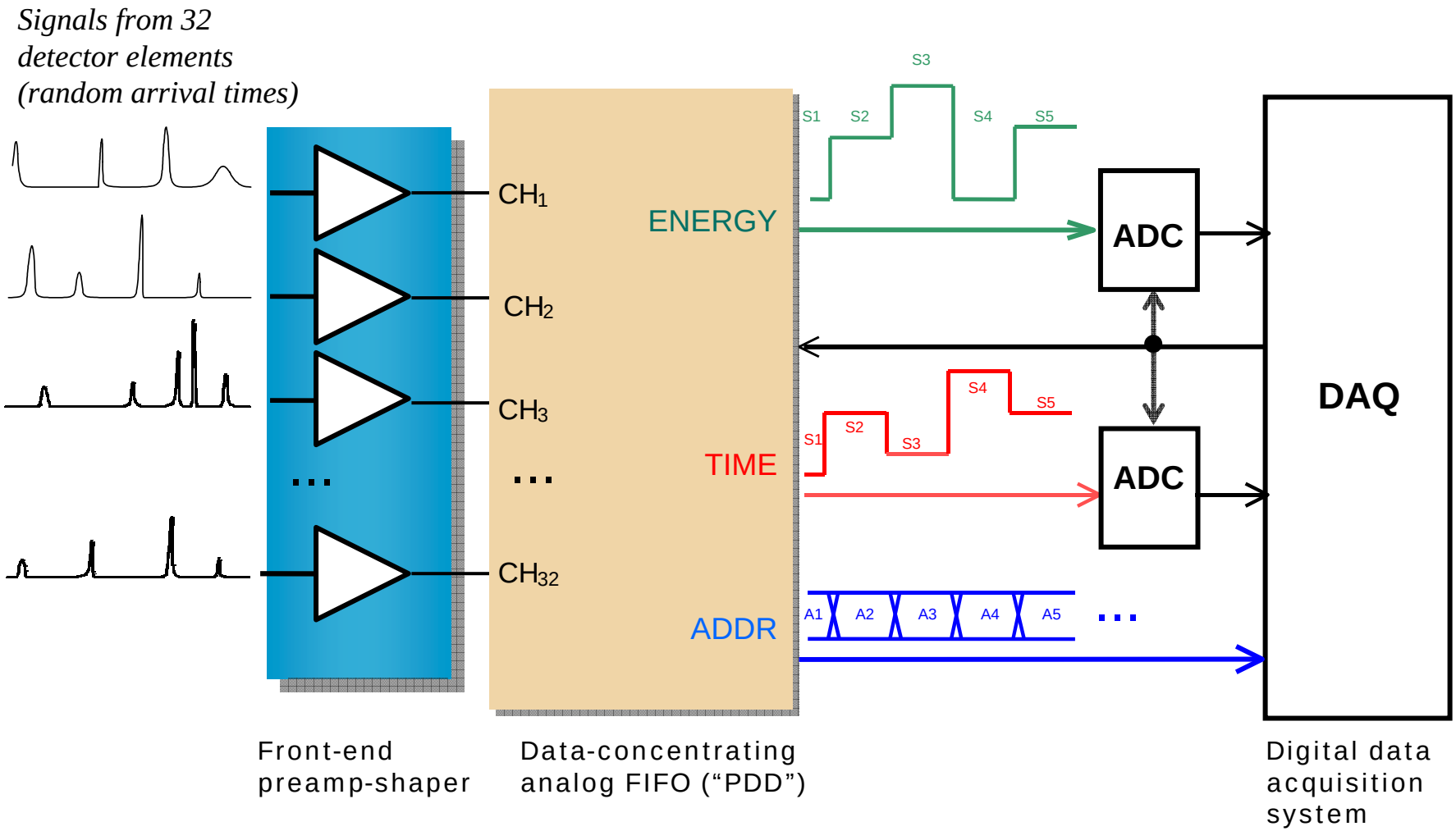
Design Examples:

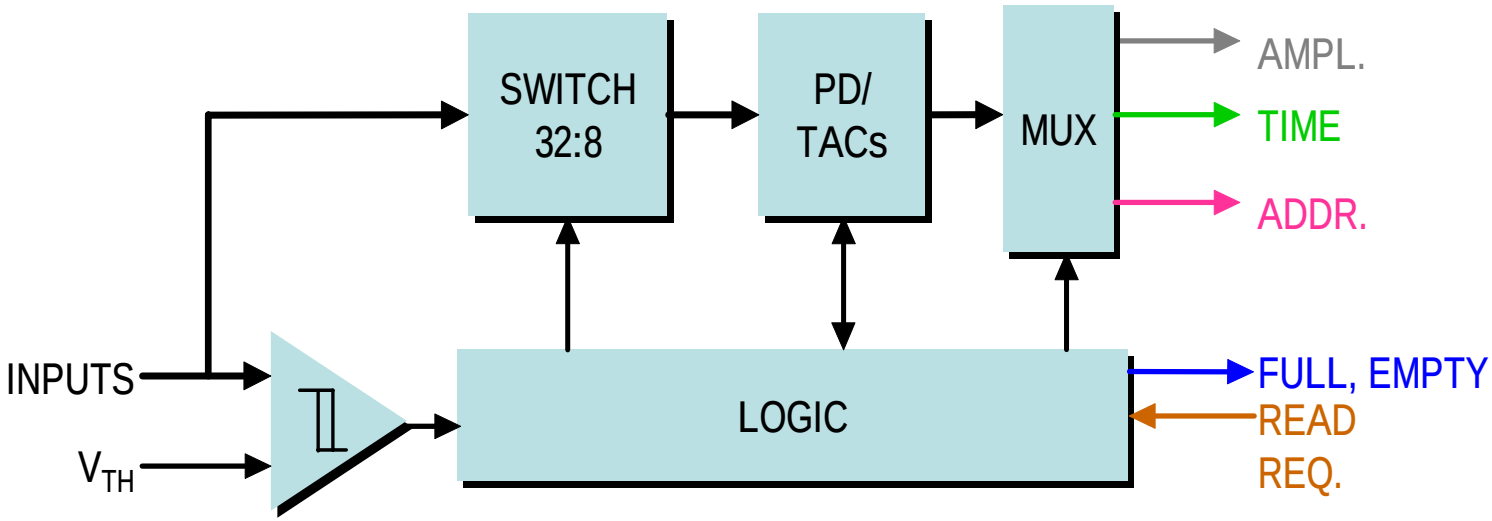
1. Multichannel pulse measurement with analog data concentration and derandomization

2. Readout ASIC for miniaturized PET tomograph

1. Multichannel pulse measurement with analog data concentration



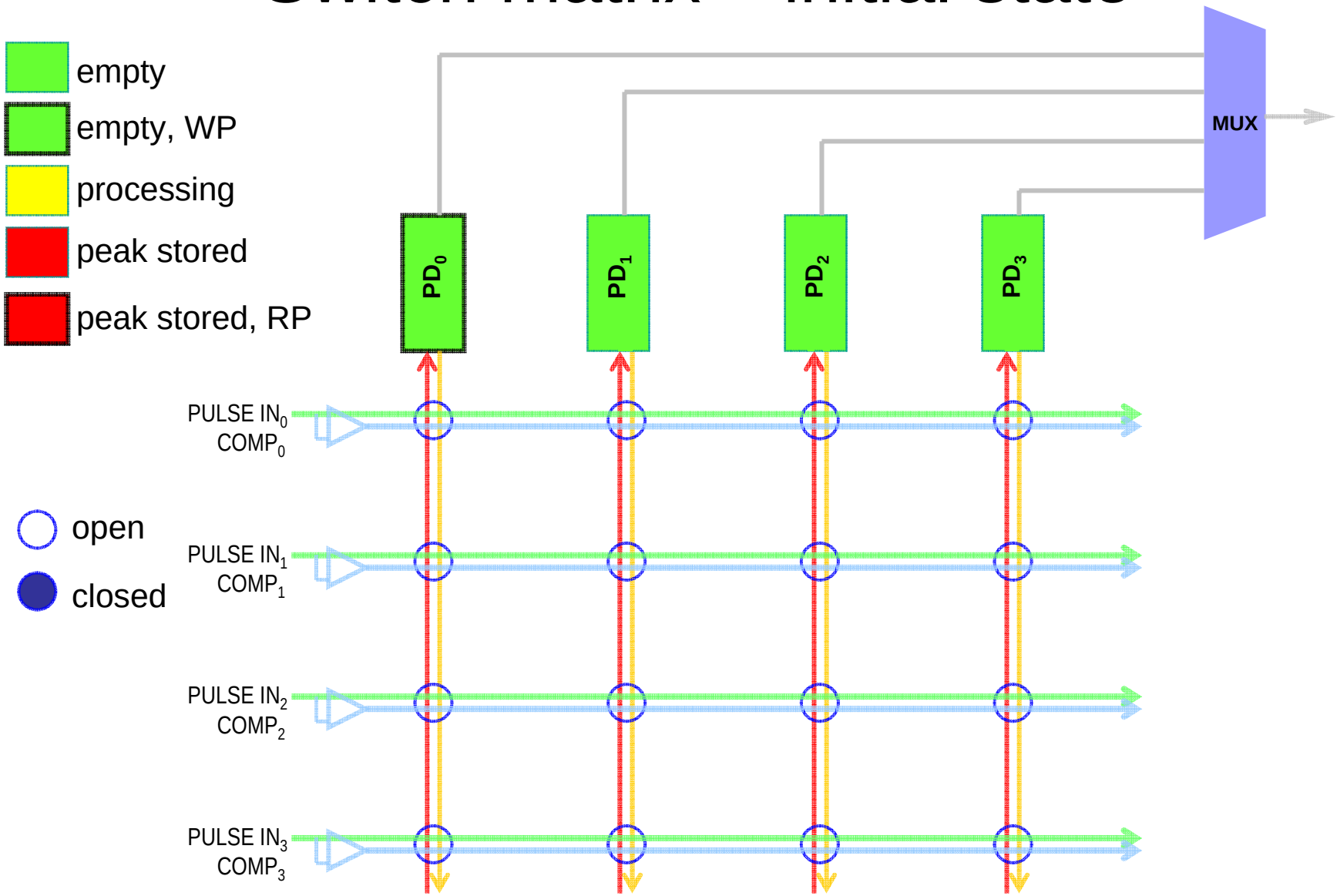
PDD ASIC Block Diagram



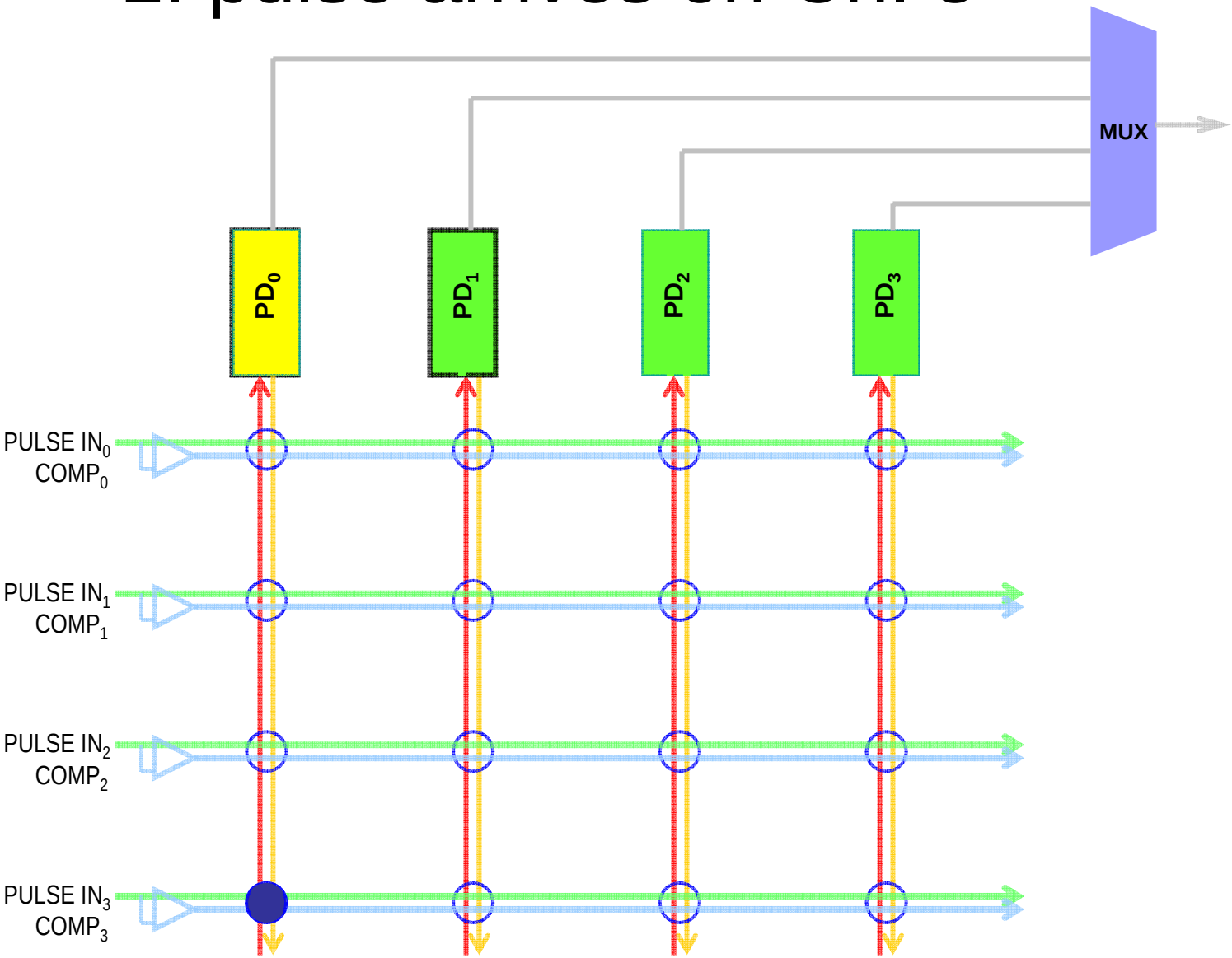
- ***Self-triggered and self-sparsifying***
- ***Simultaneous amplitude, time, and address measurement for 32 input channels***
- ***Set of 8 peak detectors act as derandomizing analog memory***
- ***Rate capability improvement over present architectures***
- ***High absolute accuracy (0.2%) and linearity (0.05%), timing accuracy (5 ns)***
- ***Accepts pulses down to 30 ns peaking time, 1.6 MHz rate per channel***
- ***Low power (3 mW per channel)***

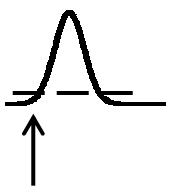
P. O'Connor, G. De Geronimo, A. Kandasamy, *Amplitude and time measurement ASIC with analog derandomization: first results*, IEEE Trans. Nucl. Sci. 50(4), pp. 892-897 (Aug. 2003).

Switch matrix – initial state

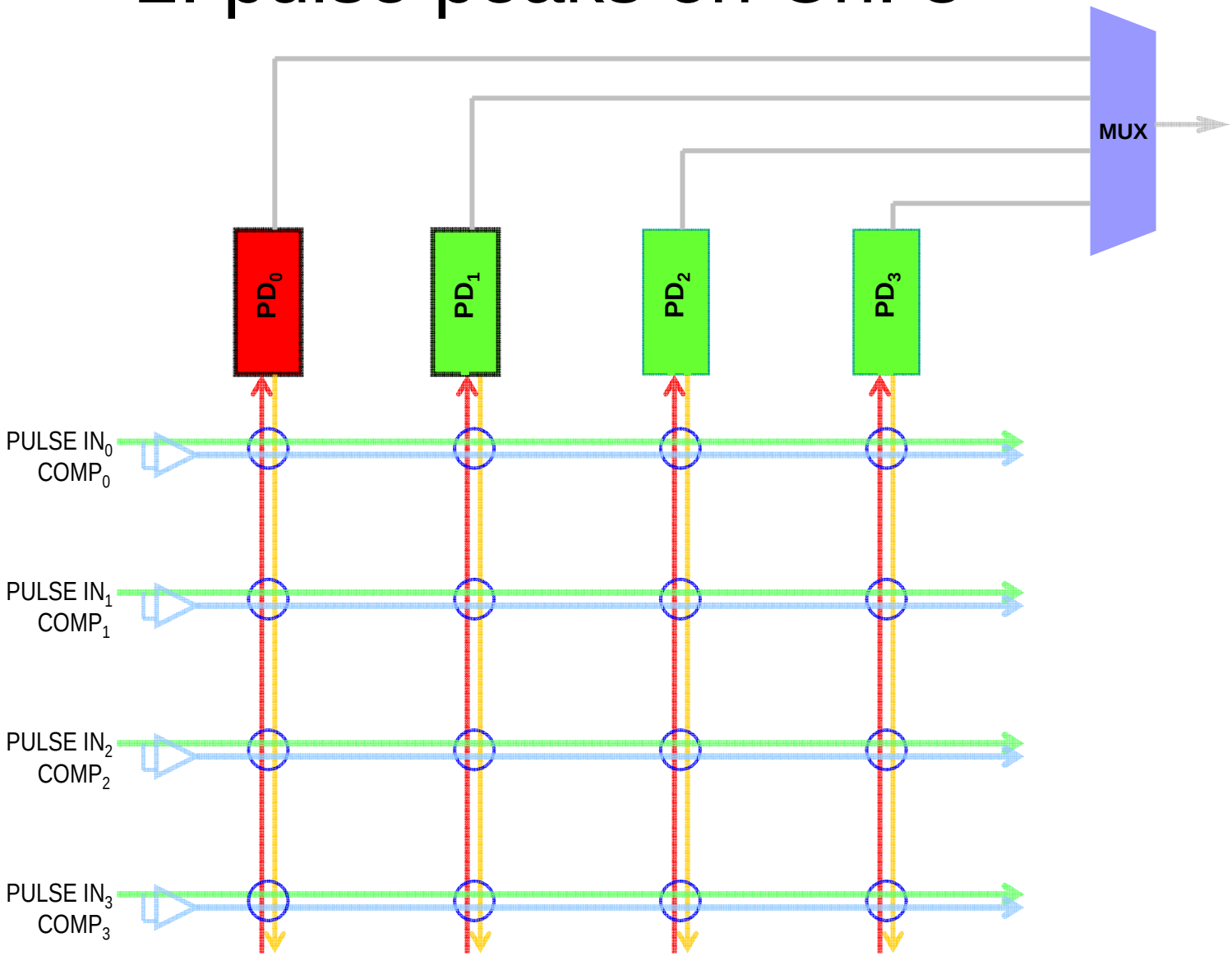


1. pulse arrives on Ch. 3

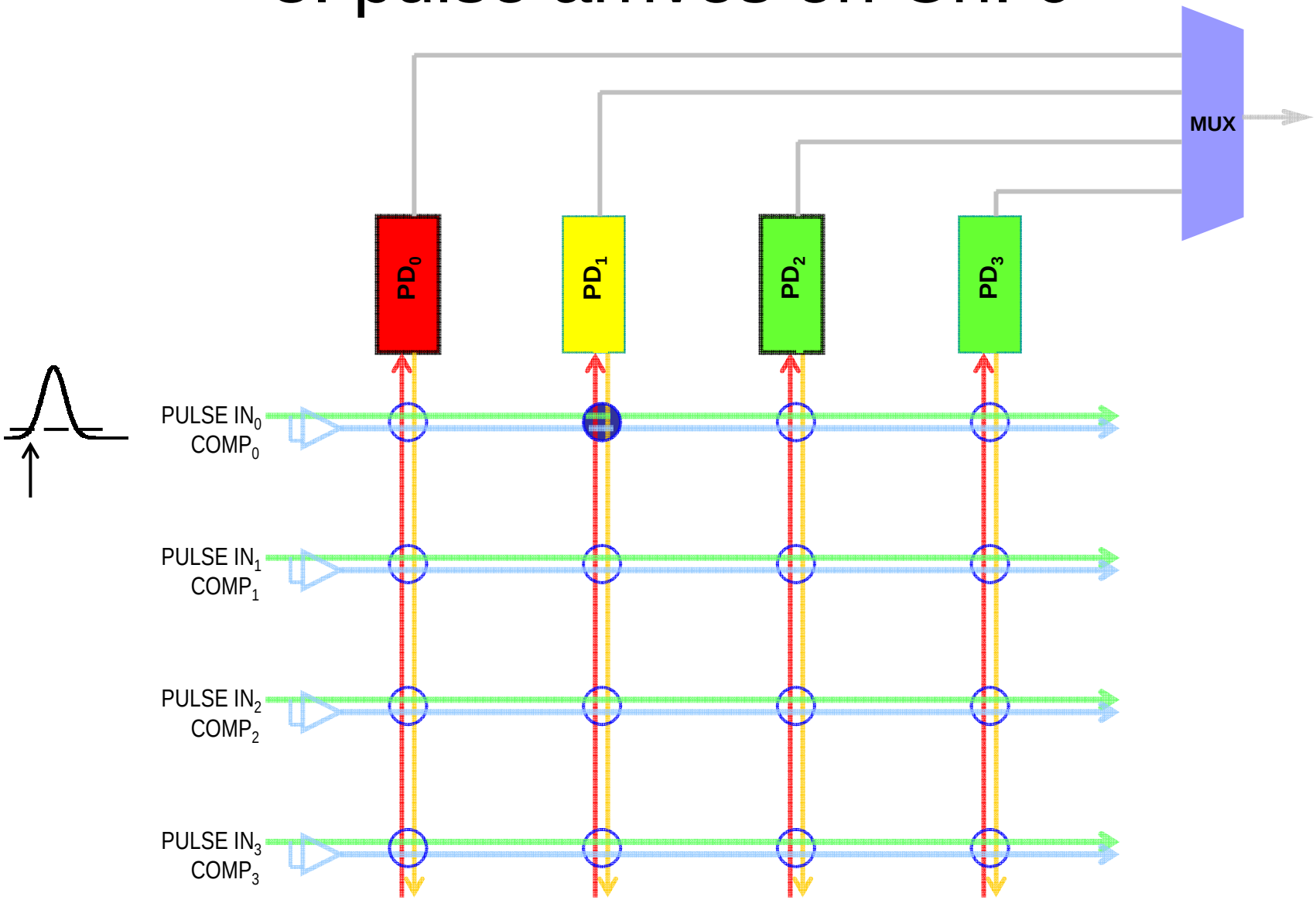




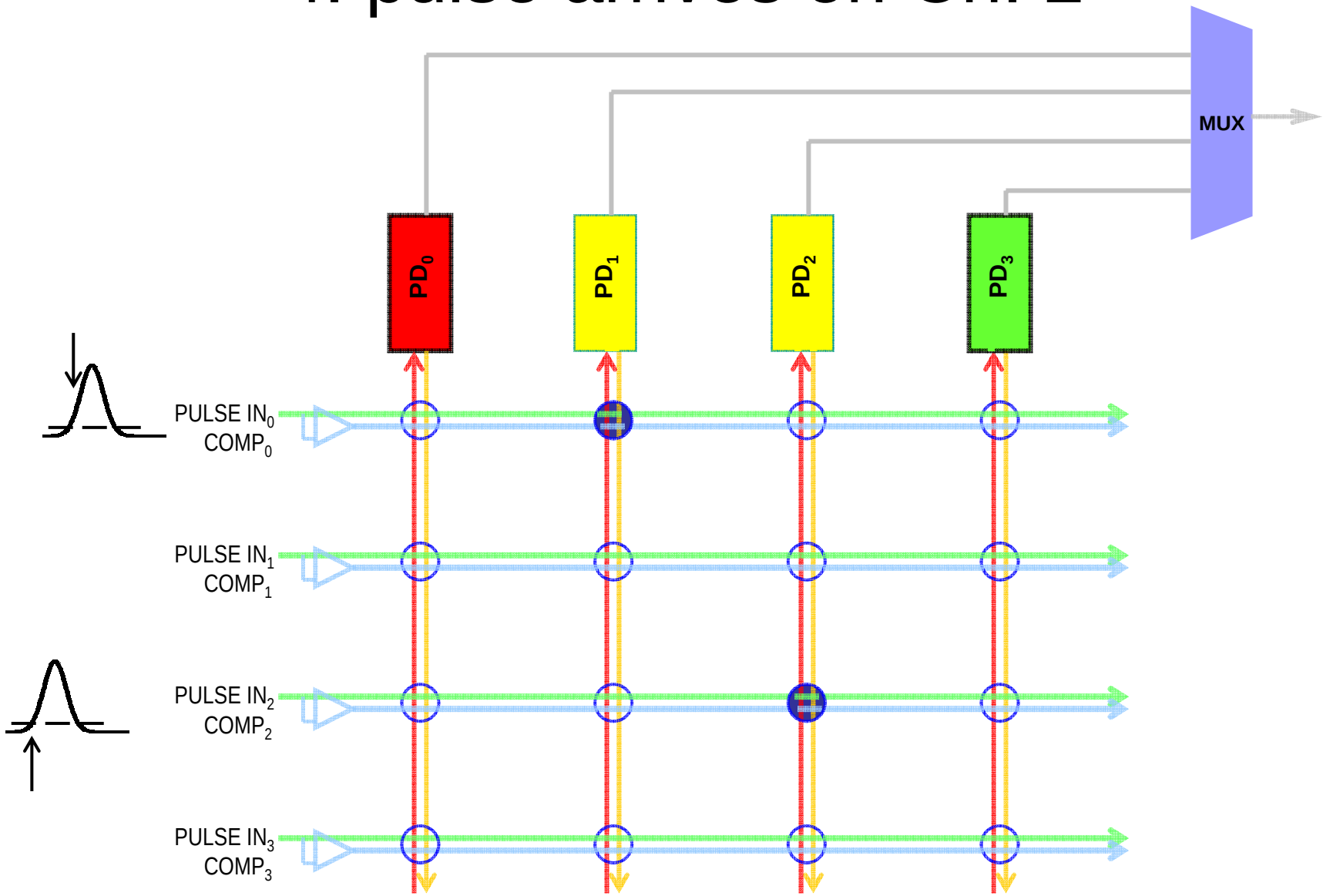
2. pulse peaks on Ch. 3



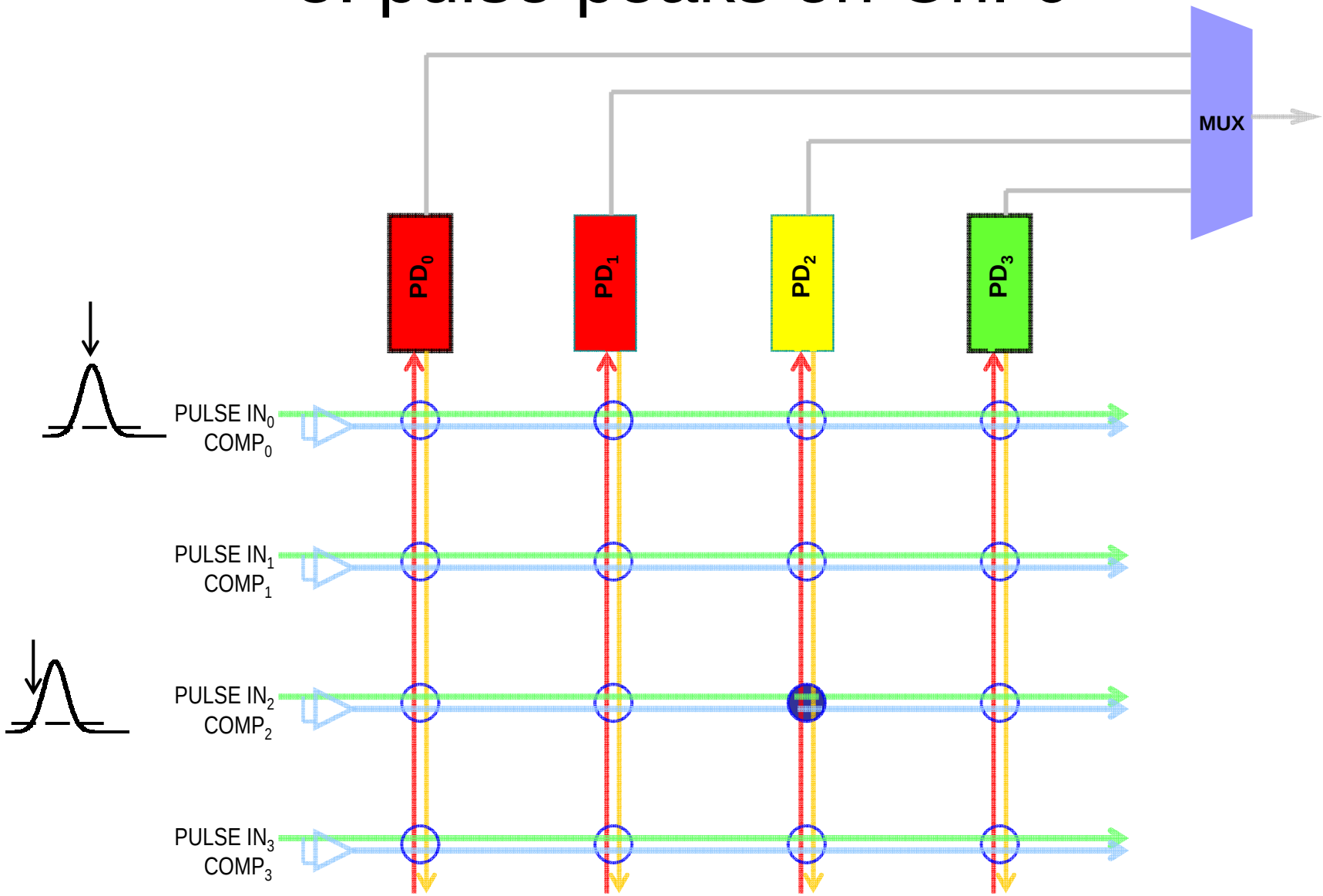
3. pulse arrives on Ch. 0



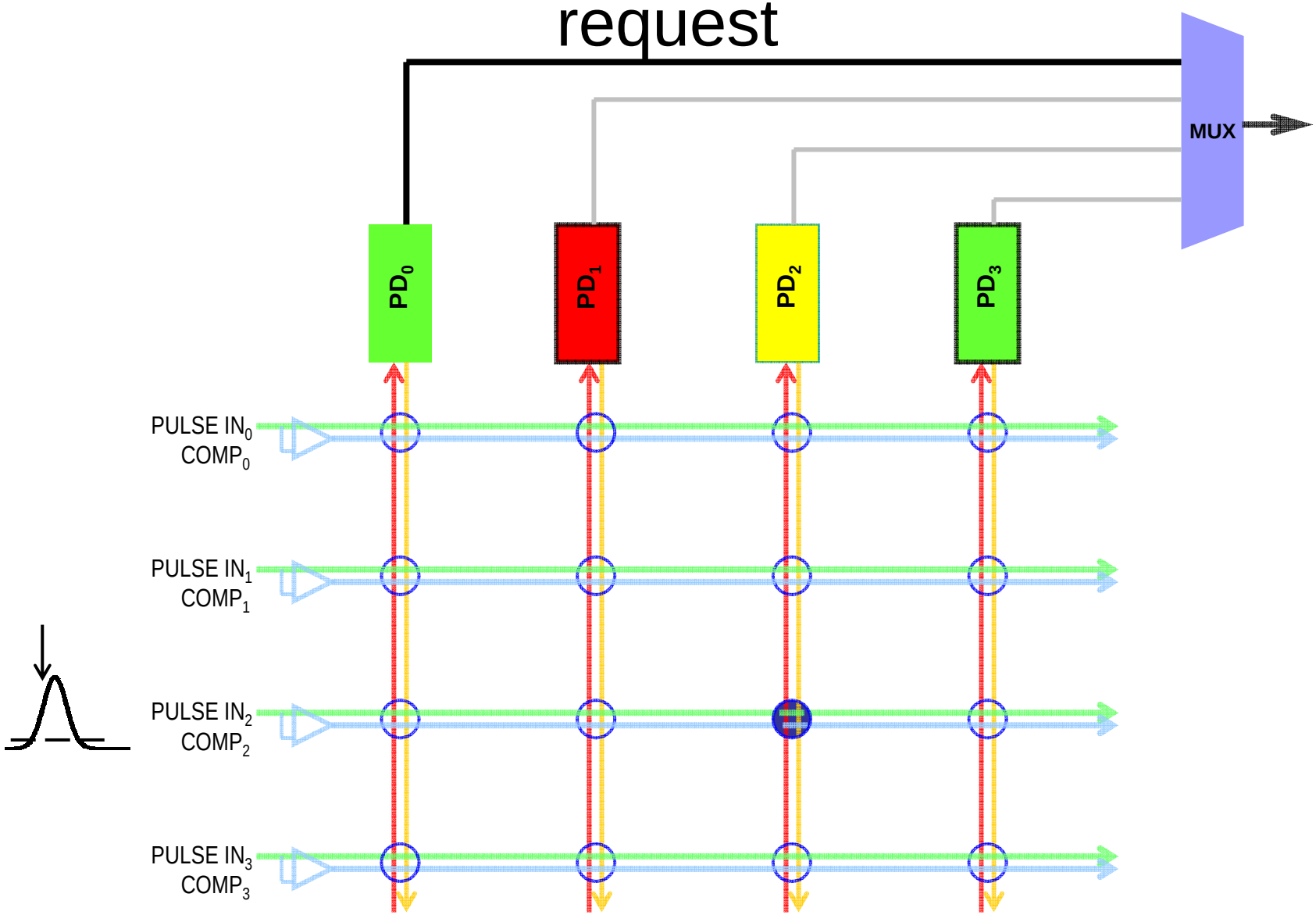
4. pulse arrives on Ch. 2



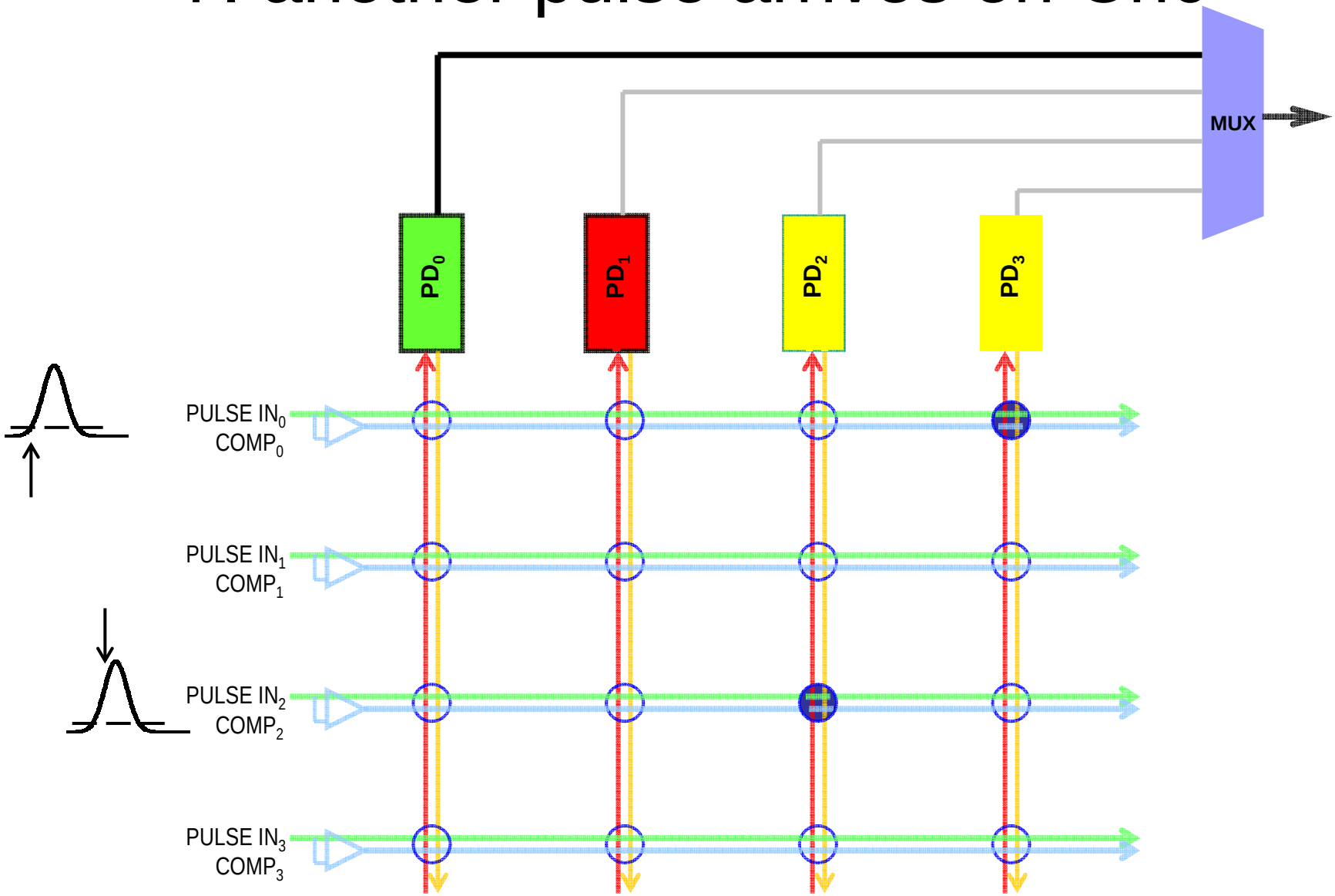
5. pulse peaks on Ch. 0



6. PD_0 read out in response to external read request

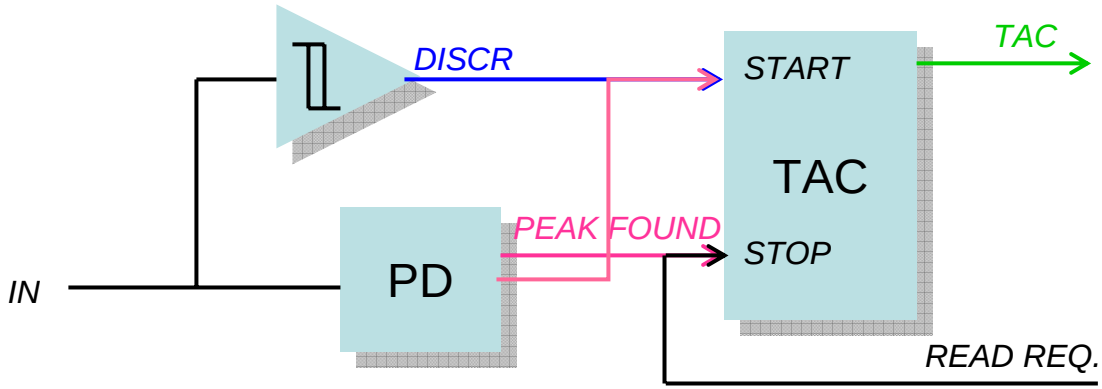


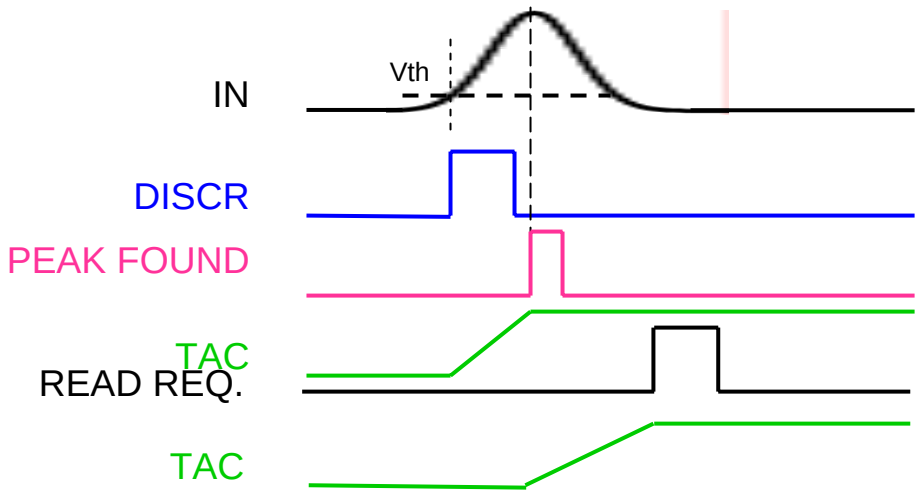
7. another pulse arrives on Ch0



Quad-mode Time-to-Amplitude Converter

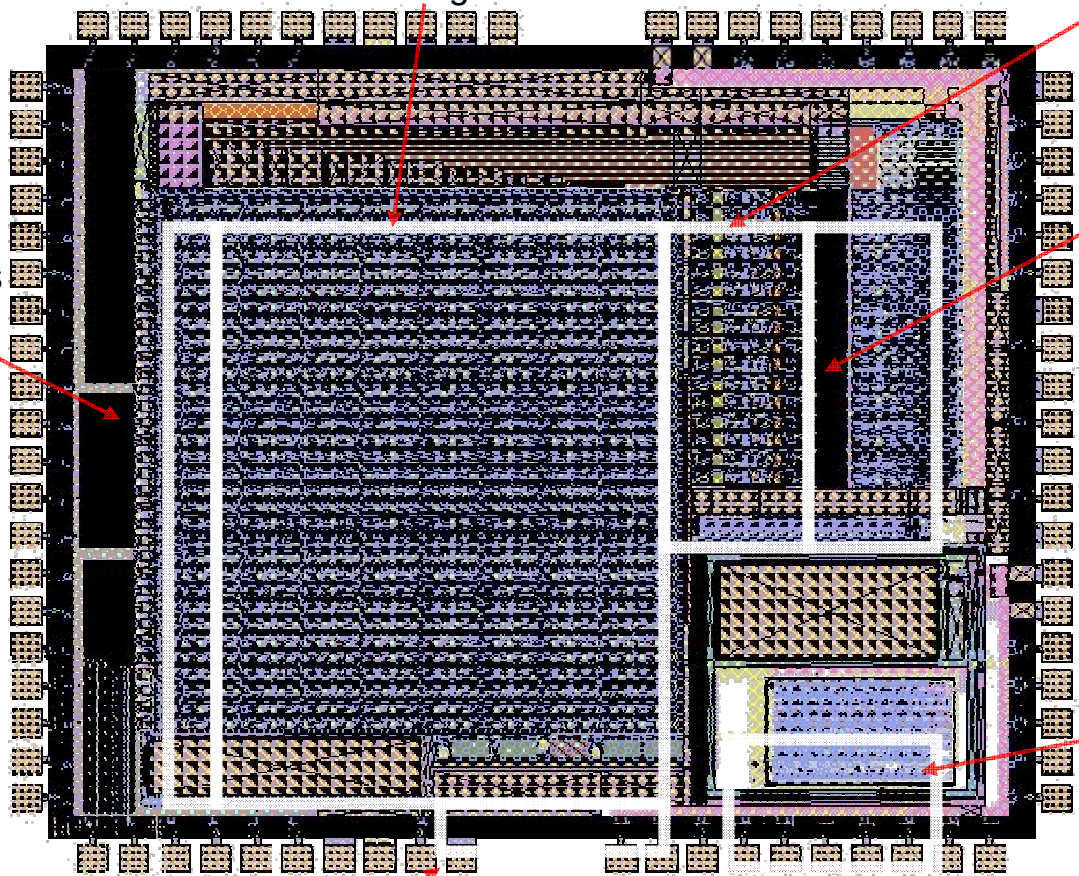
MODE 1
MODE 2





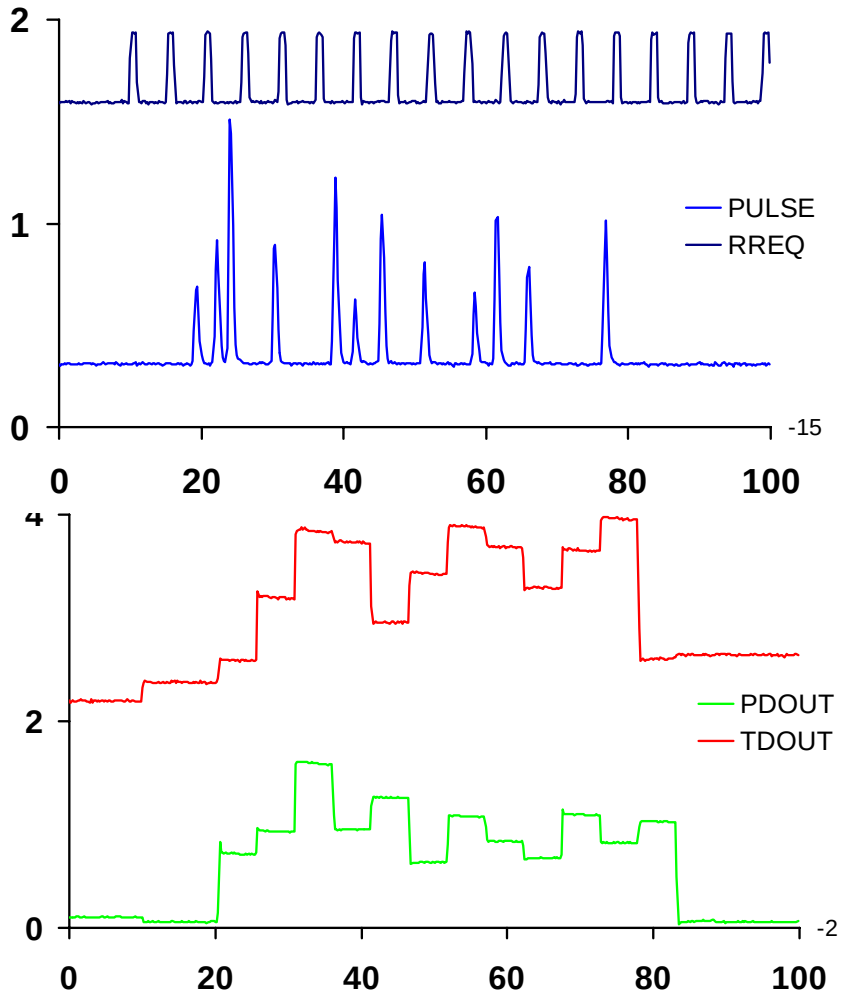
1. risetime
2. peak-RR
3. TOT
4. lead-RR

PDD layout



size : 3.6 x 3.2 mm²
technology: 0.35µm CMOS DP4M

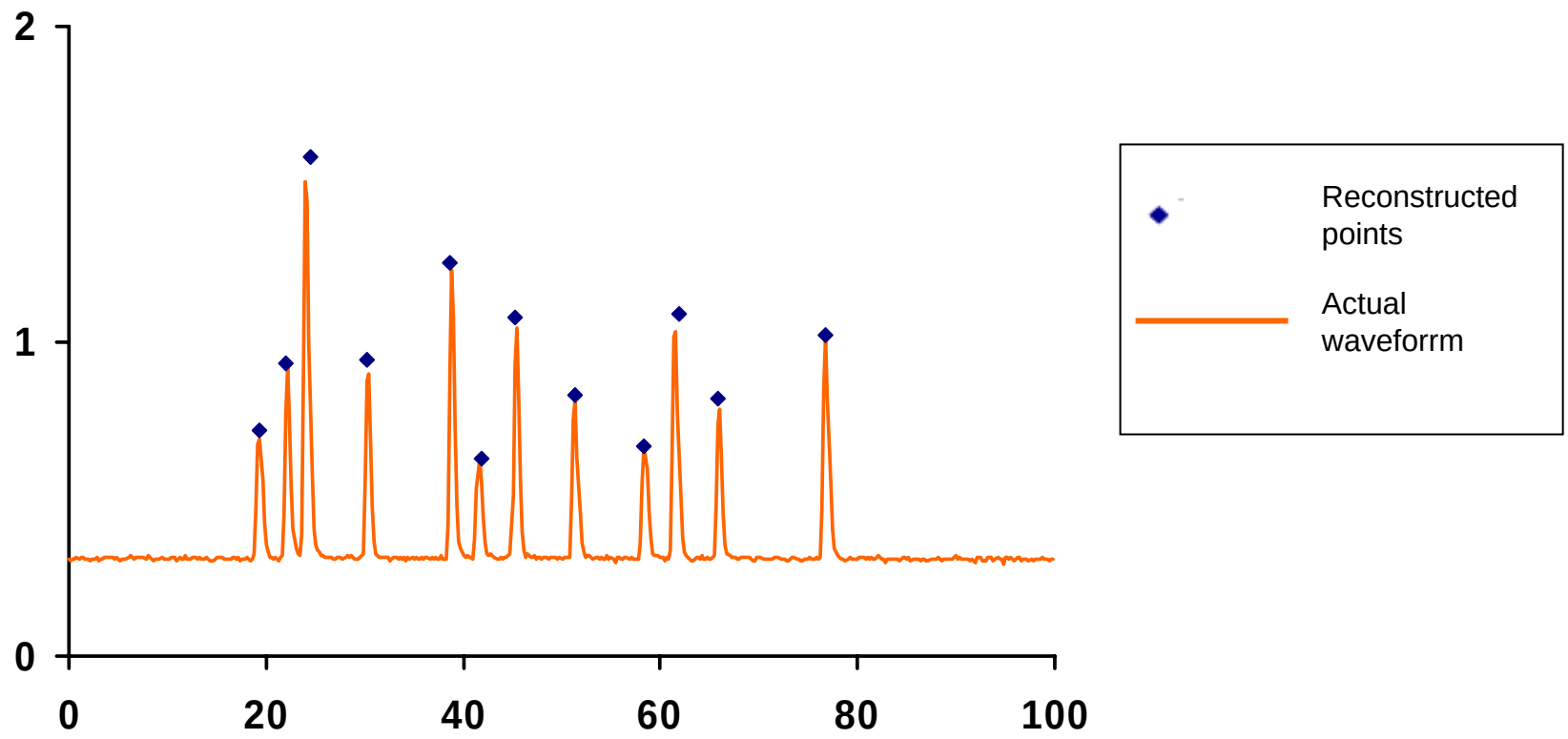
Reconstruction of peak height and time



ASIC Inputs

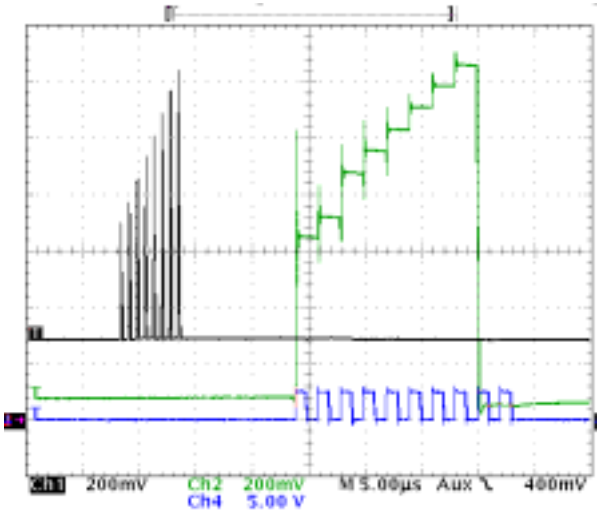
ASIC Outputs

Reconstruction of peak height and time



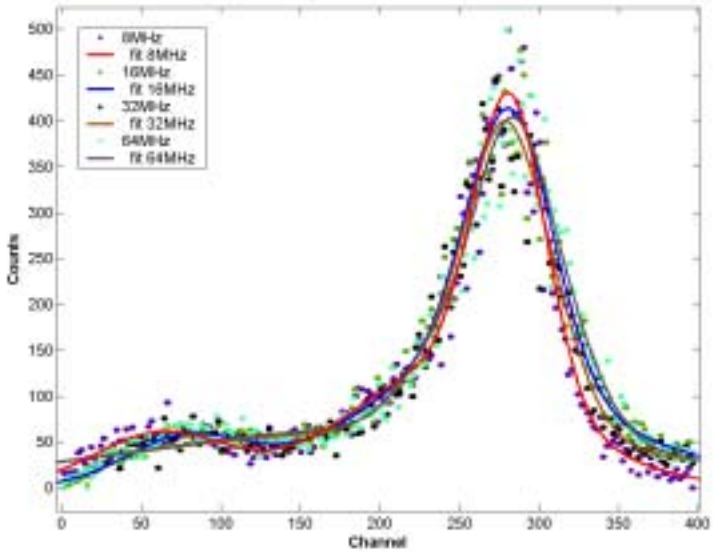
High rate capability

Fast pulses, high rate



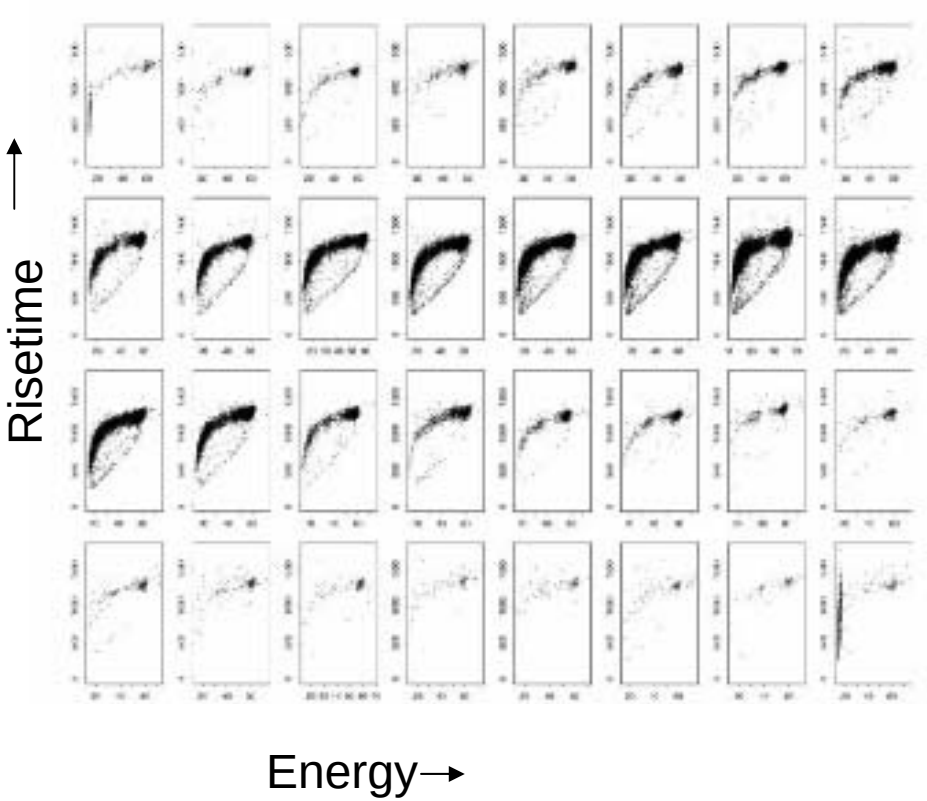
Black – pulse input
Blue – Read Request
Green – PD output

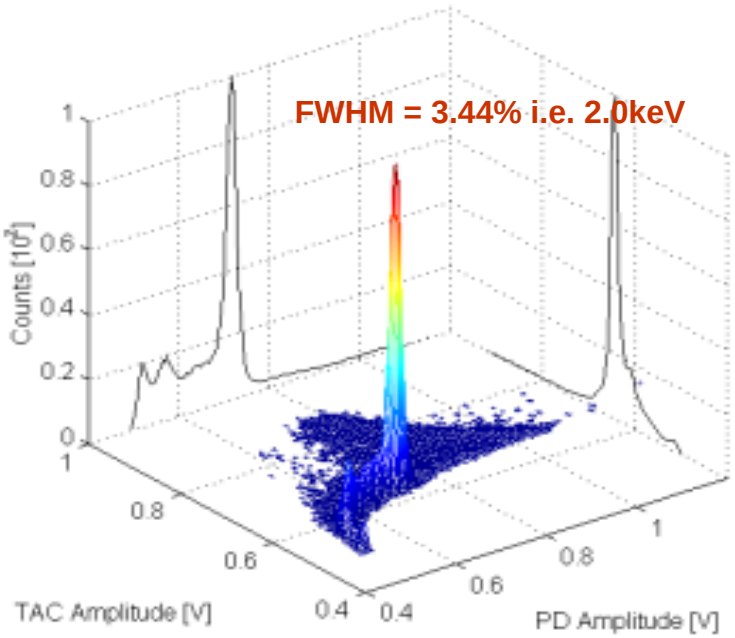
- Input pulses:
  - 30 ns peaking time
  - 1.6 MHz rate
- Readout rate 500 kHz



- 32 CZT sensors, 7x3x7mm^3
- ^{241}Am source, overall rate ~ 8MHz
- Shaper peaking time 600ns
- Rate of read request varied from 8 MHz to 64 MHz
- No peak shift or FWHM degradation seen
- Settling time of output mux ~ 10ns

Biparametric spectra



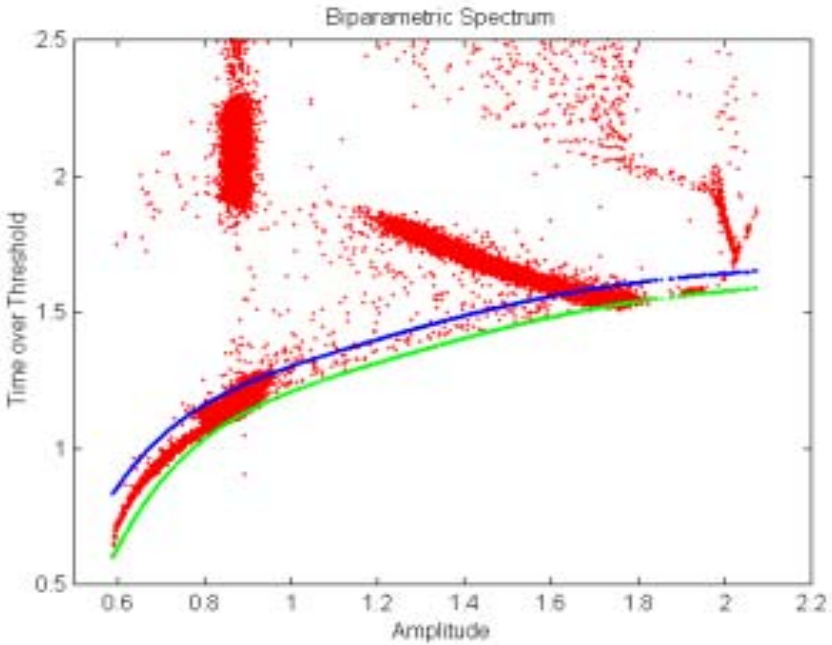


- **Detector: eV Products CZT Pixellated Linear Array of 32 elements 16x3x3 mm³ biased at 900V**
- **Source: 2 x 8mCi ^{241}Am**
- **FE: t_p = 400ns, gain=200mV/fC**
- **Event Rate: 4.5MCounts/s overall, 210kCounts/s on the single pixel**

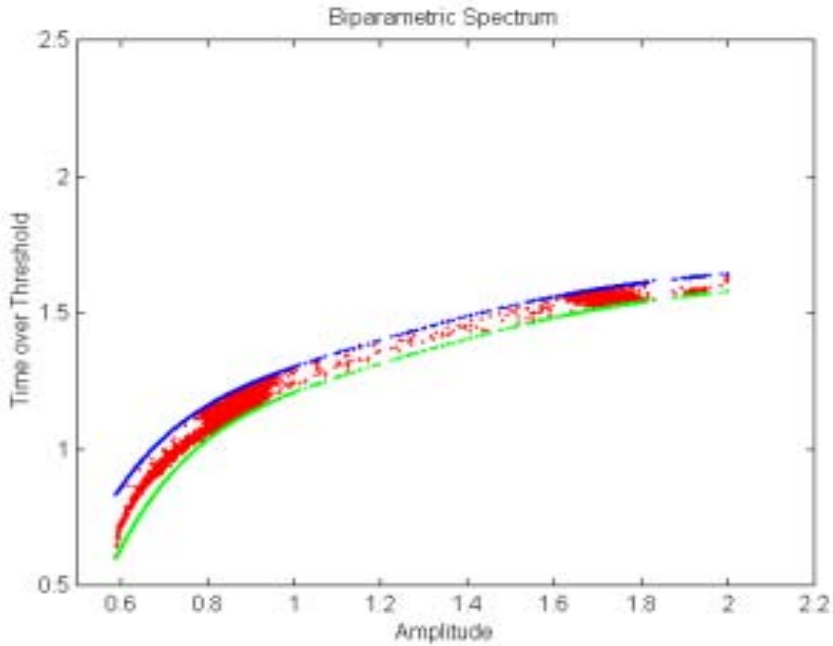
Time-Over-Threshold Measurement for pile-up rejection

Experiment Setup

- Array of 1mm x 1mm silicon diodes, built on a fully-depleted 400um high-resistivity wafer and cooled at ~ -54 ˚C
- 8keV X-ray monochromatic collimated 10umx10um beam from NSLS focused on the center of one pixel
- FE with 2us peaking time

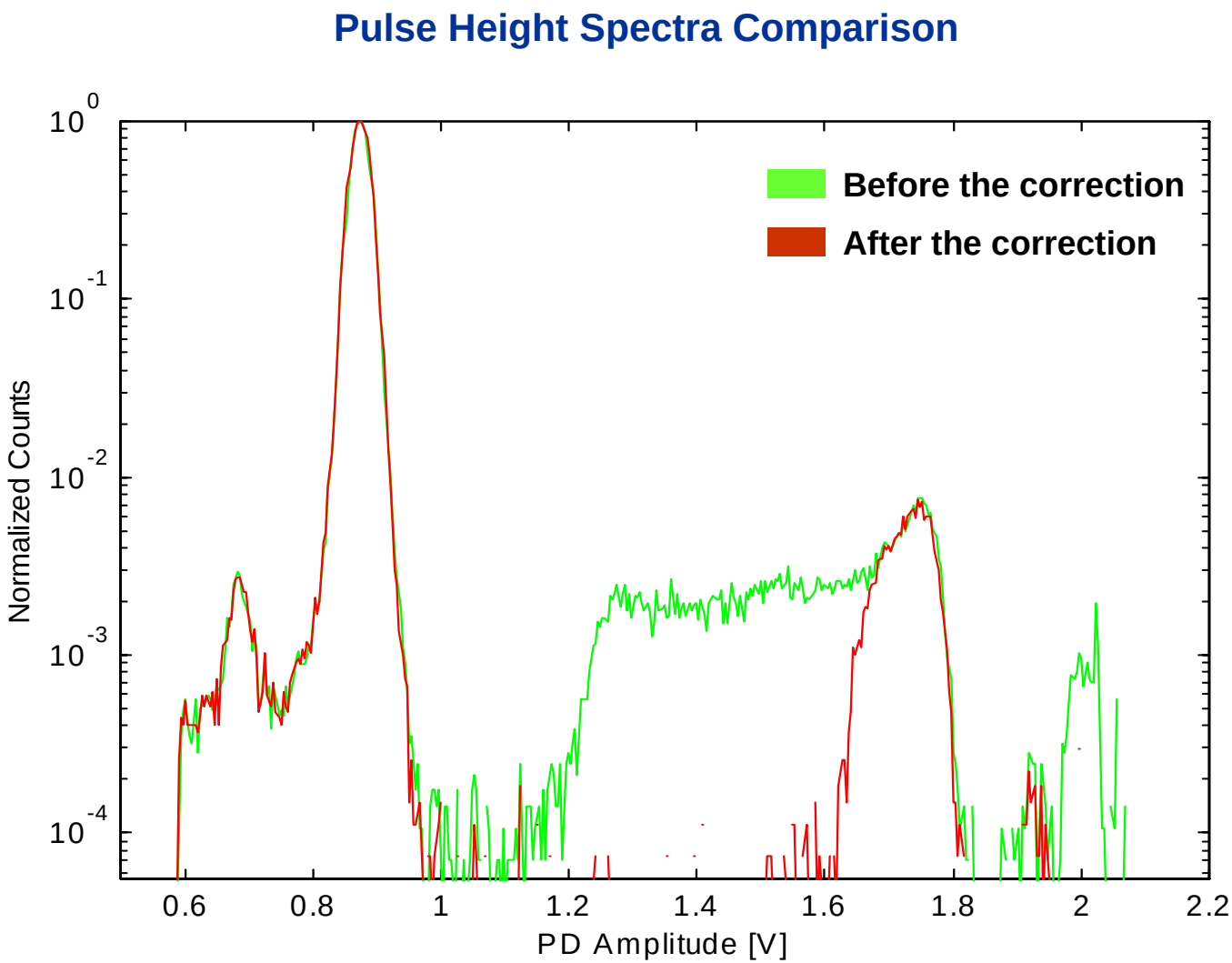


Before The Correction

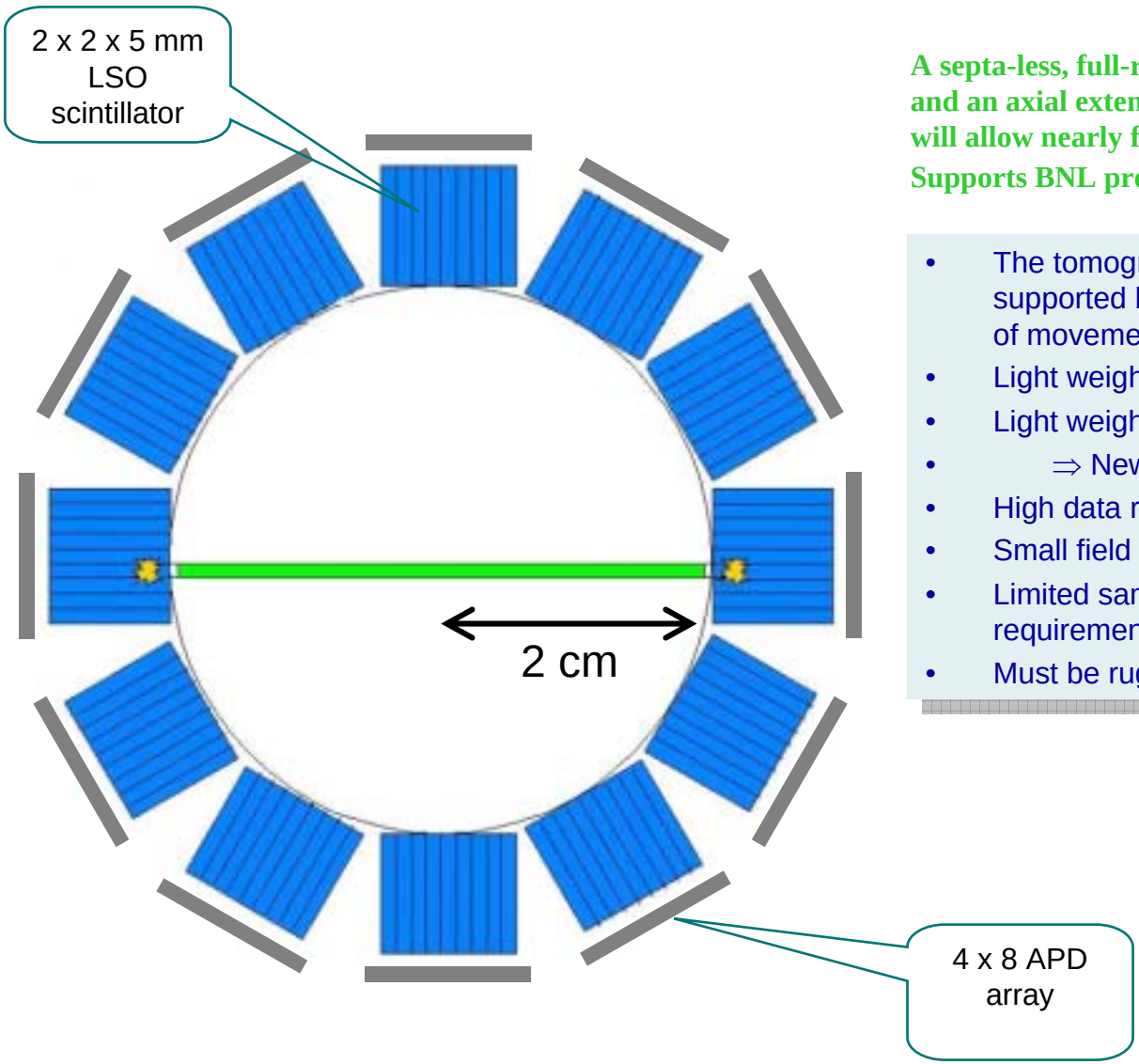


After The Correction

Time-Over-Threshold Measurement for pile-up rejection



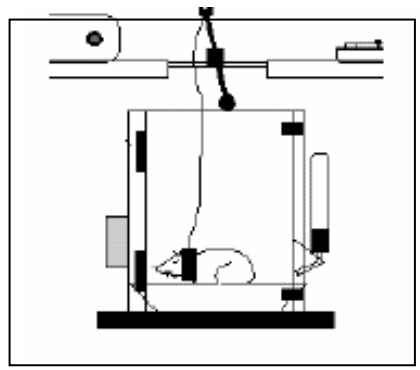
2. RatCAP – Rat Conscious Animal PET



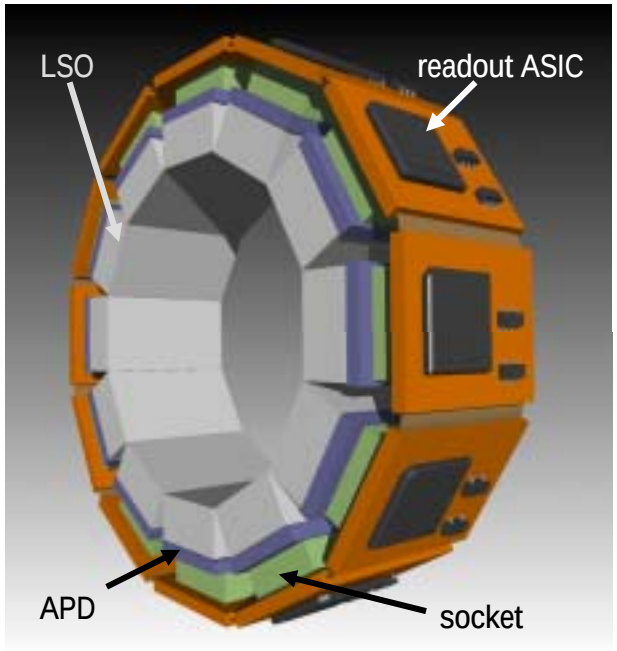
A septa-less, full-ring tomograph with a diameter of 4 cm and an axial extent of 2 cm, suspended by a tether, which will allow nearly free movement of the awake animal.

Supports BNL program in addiction research.

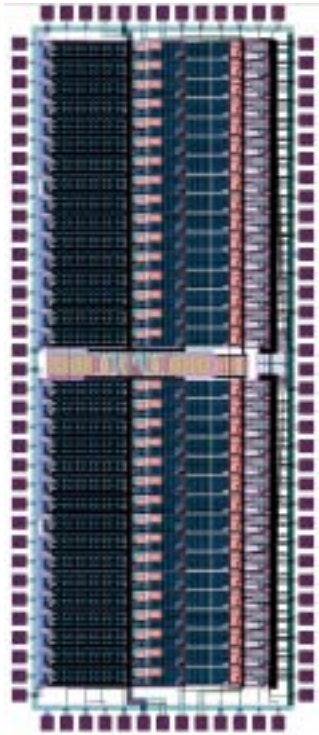
- The tomograph ring must be light enough to be supported by the rat and allow reasonable freedom of movement
- Light weight detectors (~ 150 g total weight)
- Light weight electronics with low power dissipation
- ⇒ New custom ASIC
- High data rates and large singles background
- Small field of view and large parallax effects
- Limited sampling due to space and weight requirements
- Must be rugged enough withstand activity of the rat



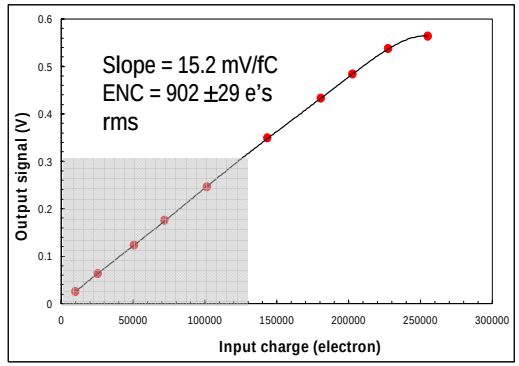
Electronics for a mobile, miniature animal PET tomograph



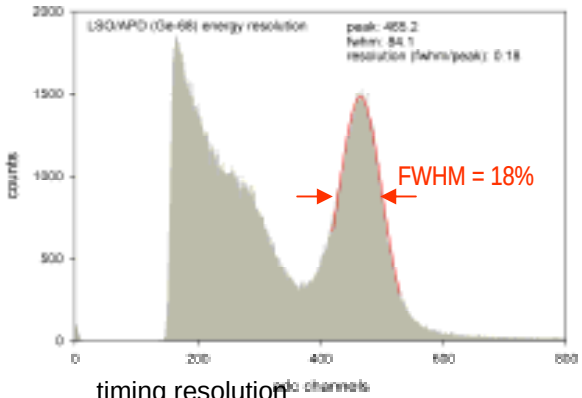
- 0.18 μm CMOS
- 1.5 mW/channel
- 32 channel ASIC
- Preamplifier + shaper + timing discriminator
- address encoding
- serialized output



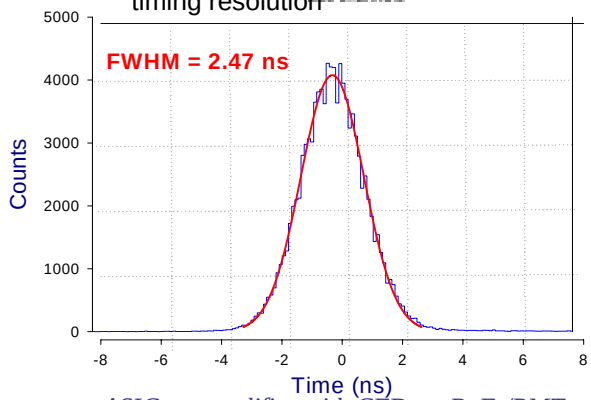
linearity



energy resolution



timing resolution



ASIC preamplifier with CFD vs. BaF_2/PMT

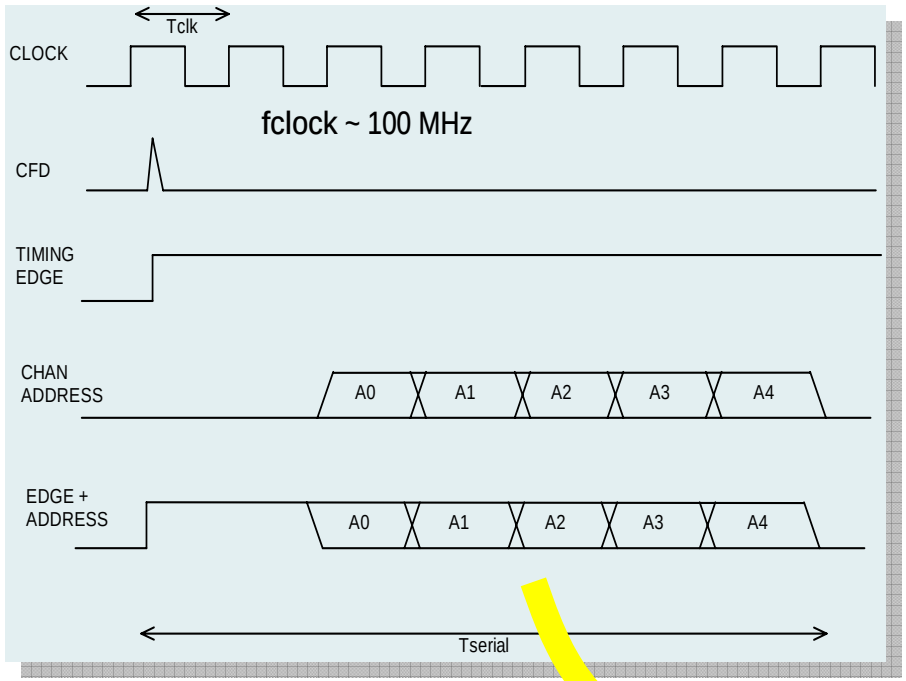
Mockup of the portable ring on the head of a rat

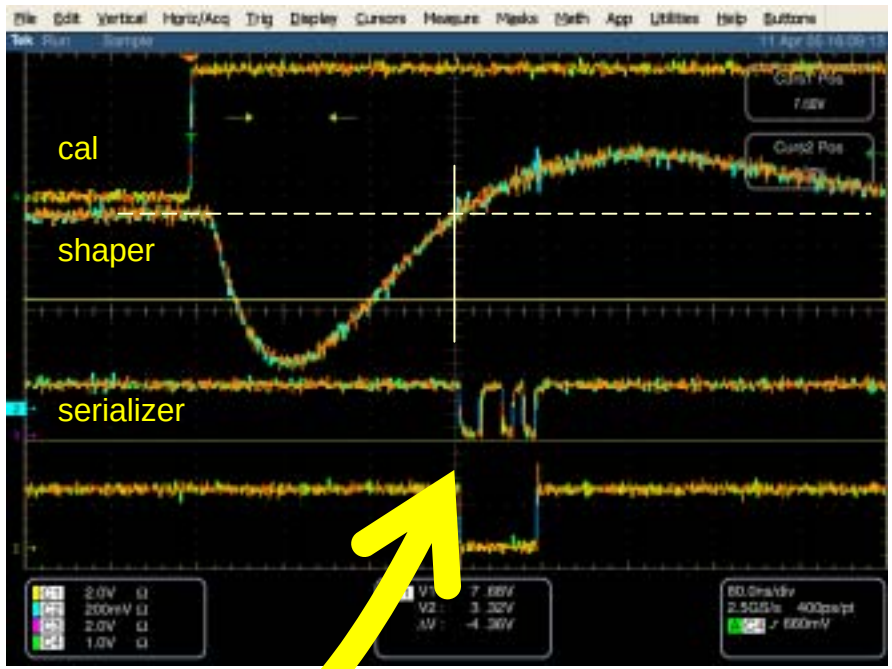
LSO scintillator

APD array

RatCAP ASIC address serializer

- 384 channels on ring make it impossible to bring all signals off detector.
- Analog pulse height information is not saved, lower level discriminator only.
- Discriminator pulse is encoded to give 5 bit address
- Leading edge of encoded serial pulse train gives time information

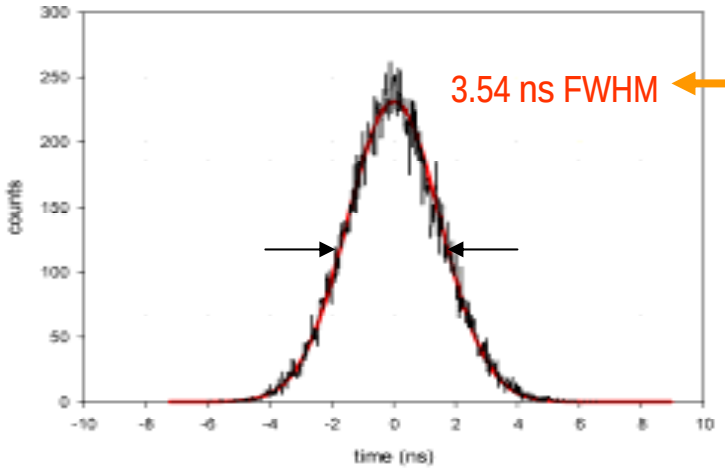




J.-F. Pratte et al., *Front End Electronics for the RatCAP mobile animal PET scanner*, IEEE Trans. Nucl. Sci. 51(4), pp. 1318-1323 (Aug. 2004).

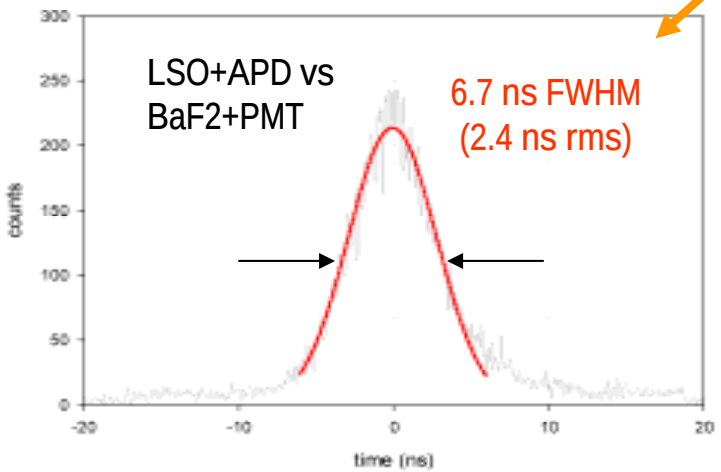
ASIC Performance - Timing Resolution

Preamp/Shaper + ZCD

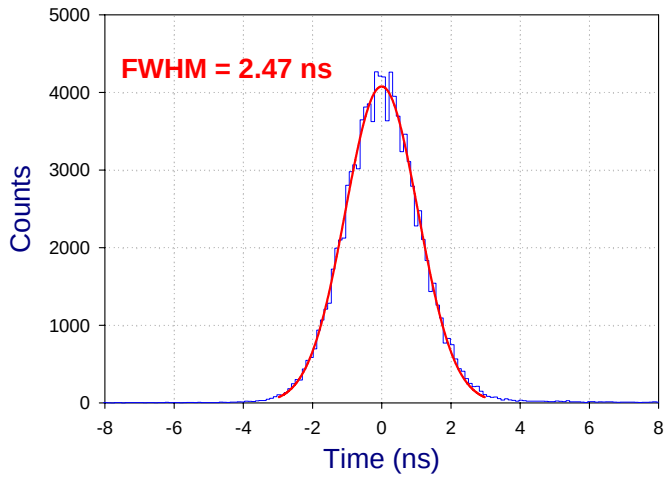


Electronic Timing Resolution
at 511 keV equivalent energy

Coupled to LSO/APD with 511 keV γ's
timed against a BaF_2 scintillator w/PMT

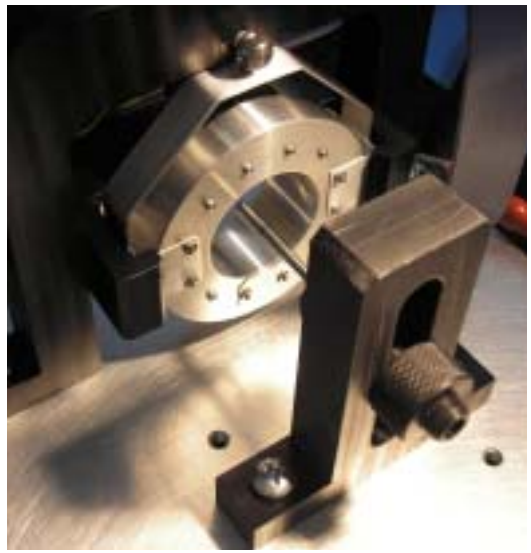


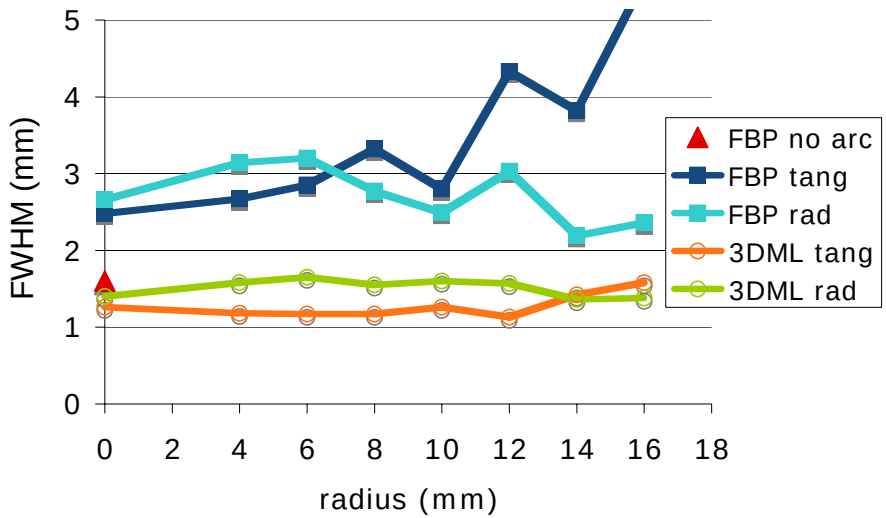
Same with CFD



Spatial Resolution

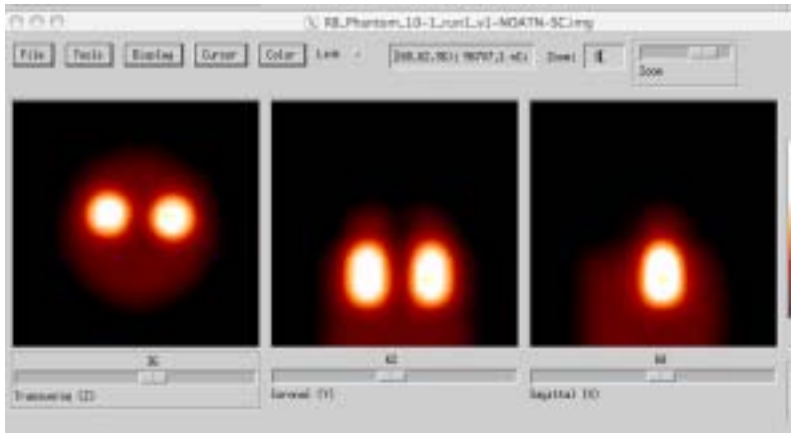
- ^{68}Ge point source
  - ~1 mm dia.
  - r = 0-16 mm
- 2D FBP
  - sinogram arc correction by linear resampling
  - ramp filter
- 3D Monte Carlo MLEM
  - 50 iterations
- Note:
  - arc correction parameters to be optimized
  - point source size NOT deconvolved

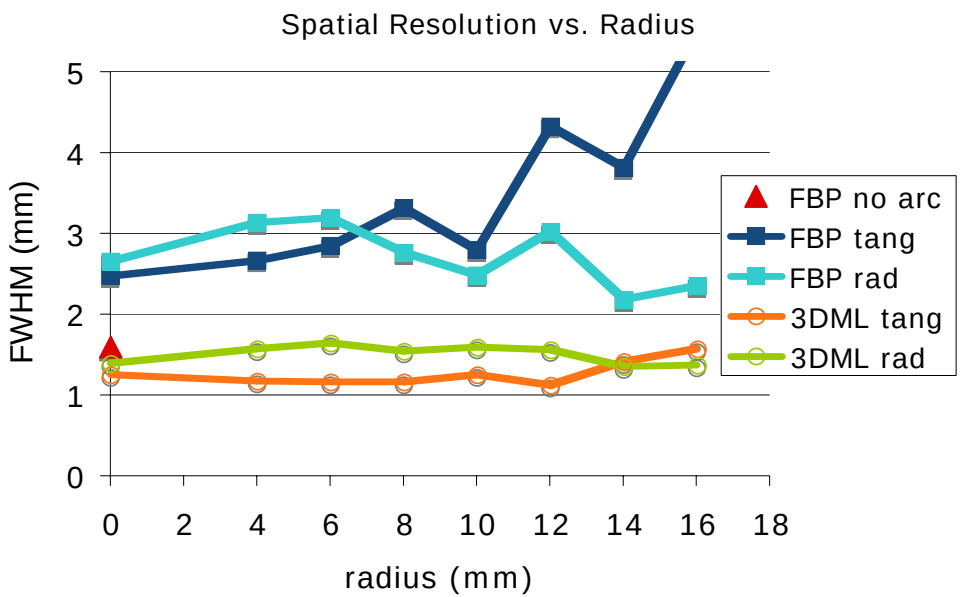




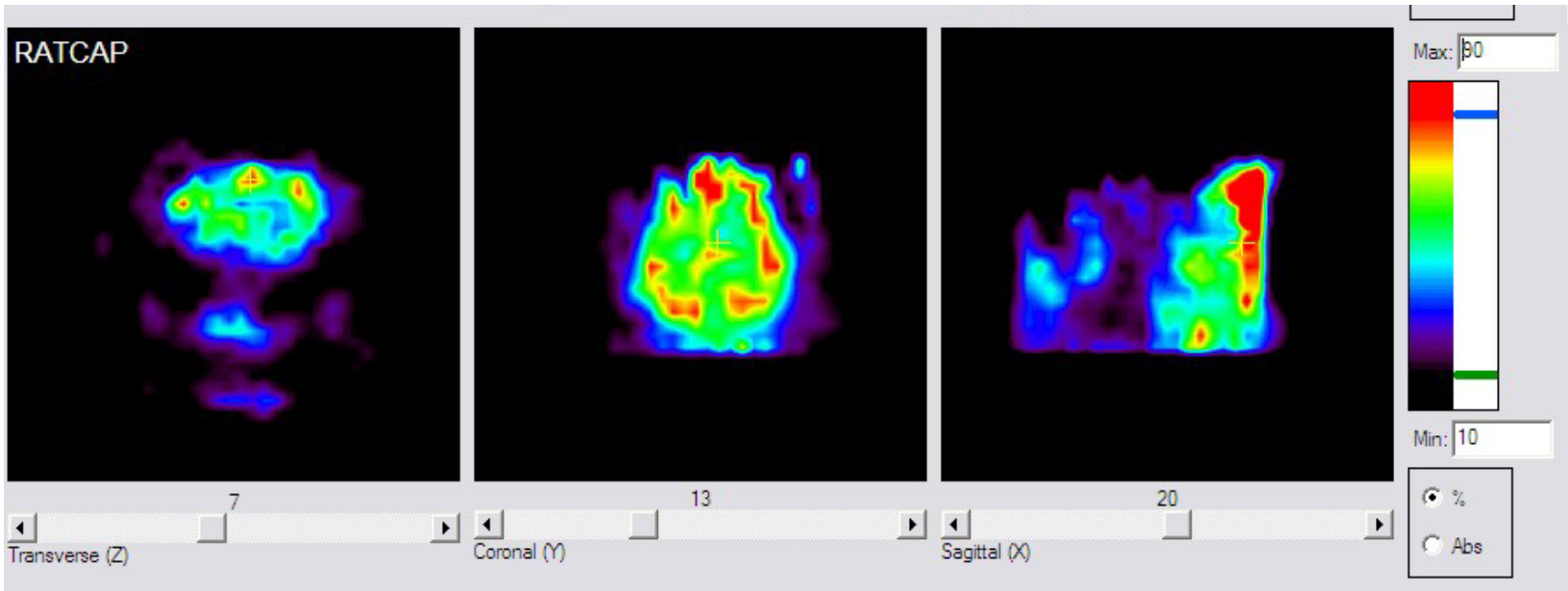
First Phantom Data

- Rat striatum phantom
  - 3.4:1 ratio
  - RatCAP
    - MLEM
    - 25 iterations
    - post-smoothing with 2 mm FWHM Gaussian

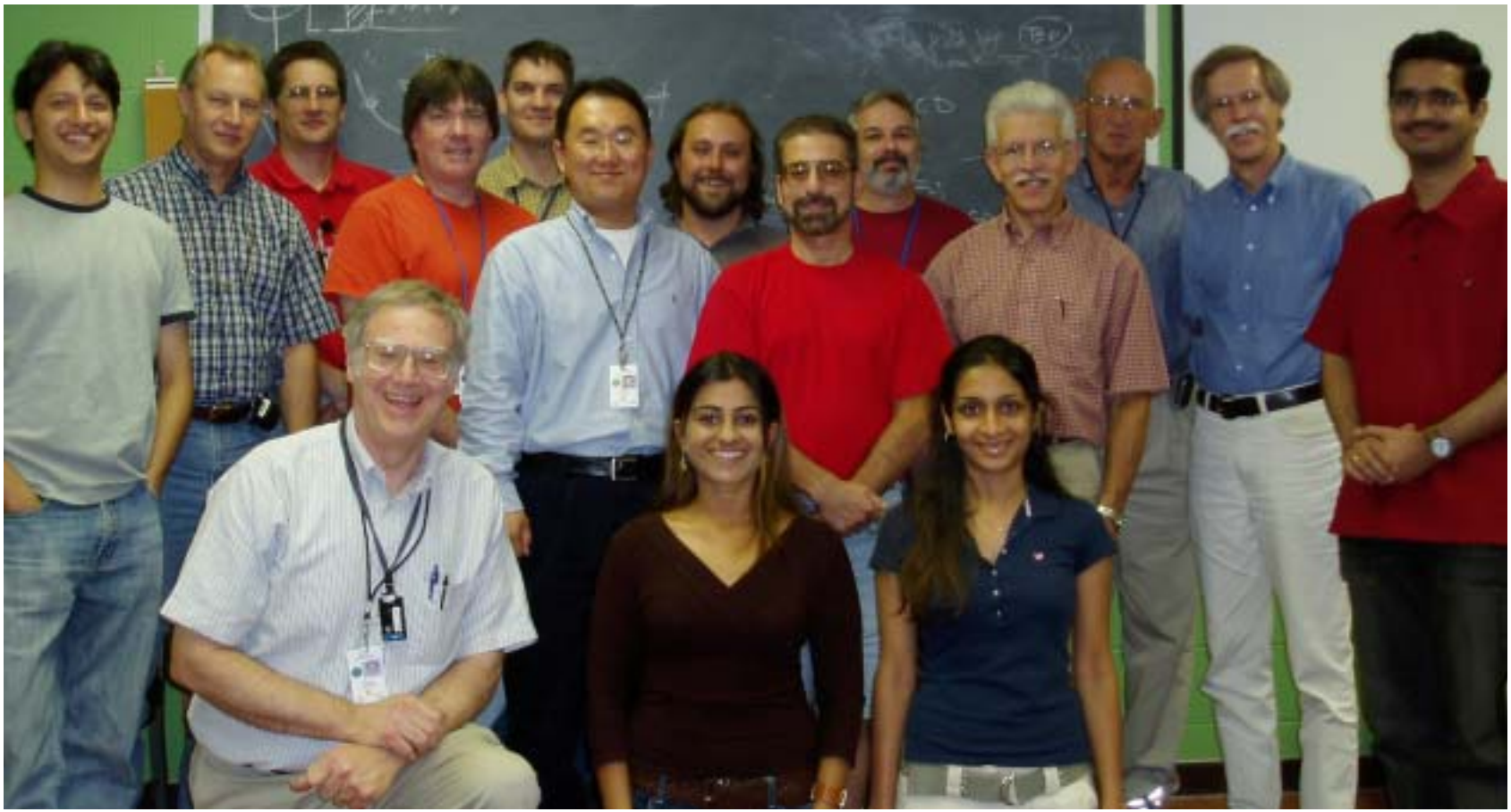




First conscious rat brain image



Thanks!



BNL RatCAP team