Desired FrontEndElectronic for PANDA TOP-DISC DIRC

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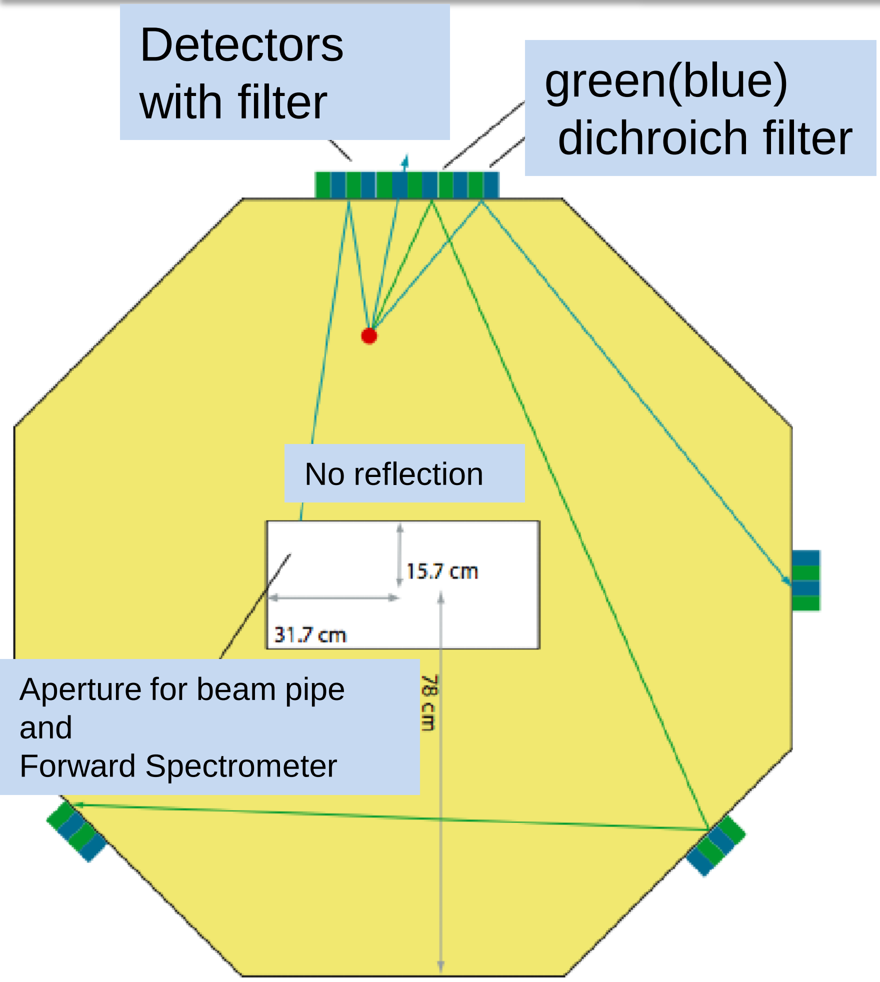
on behalf of AG. Düren

Workshop on Fast Cherenkov Detectors, DIRC Design
May 11-13 2009 Gießen

1. Design options in discussions, anticipated Rates
2. Candidate Detectors
3. Desired Electronics chain
4. Conclusions

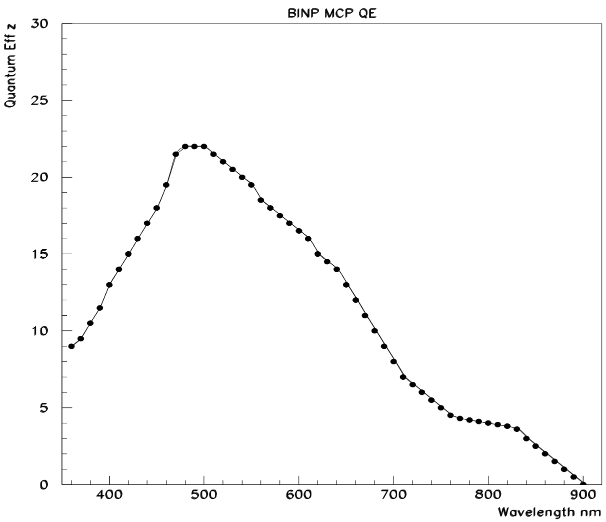
Design Options currently in discussions



- In current PANDAROOT modelling we assume 960 Channel of MCP-PMT‘s mounted on the rim of the DISK
- for FEE and DAQ let assume that DIRC has 1024 channels to be digitized/readout
- anticipated tracks per event on DISC are Beam energy/model dependent on average are 1-2(2GeV – 15 GeV Beam)
- anticipated Cherenkov photons per track might reach 20-30 (thickness,flatness,roughness,geometry,glue, number of pieces,detector acceptance,Eff...)
- anticipated Event rate at PANDA is in order of 2(HighResolution mode)-20(HighLuminosity mode) Mhz , and if we multiply these numbers we conclude that our FEE should be as fast as possible

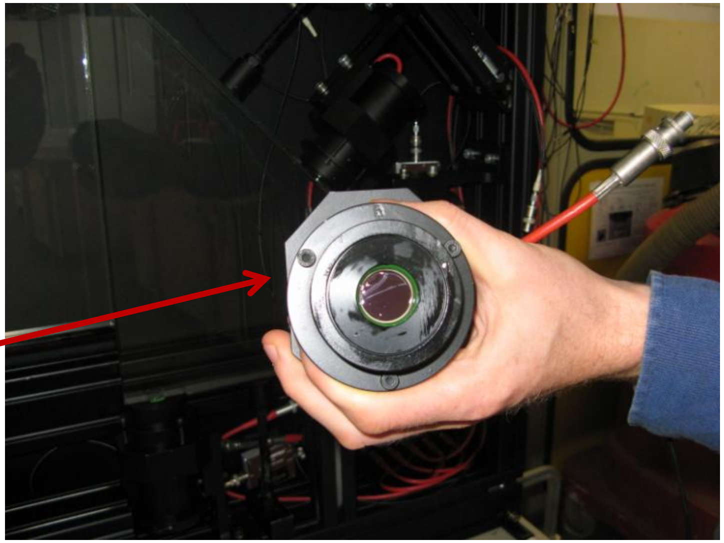
Candidate Detectors...Nr1 MCP_PMT

- so far we have only one type, BINP one



QE(30%max)

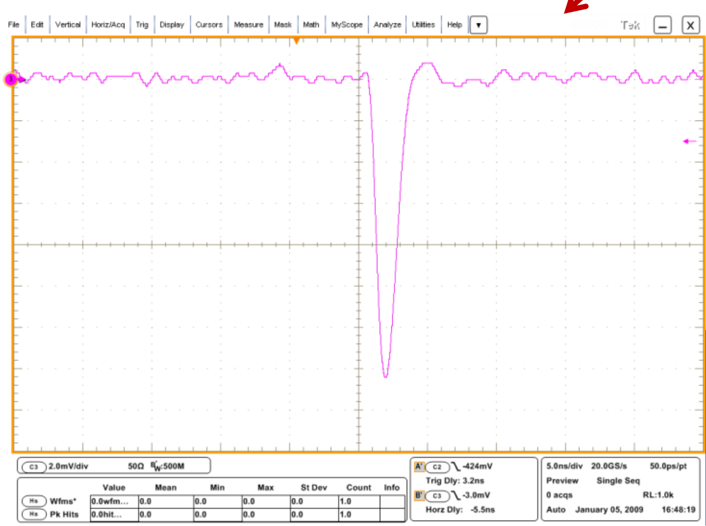
18mm, with HV and mount



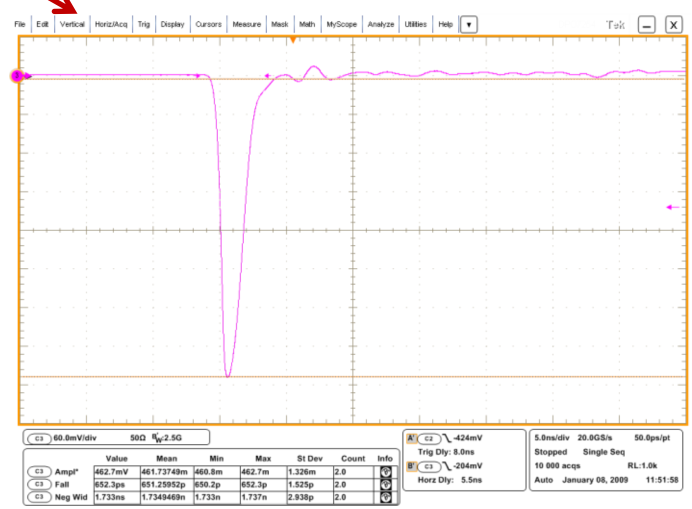
- ➢ We have accumulated some experience with these type of MCP‘s during Test Beam
- ➢ the best resolution so far we got is ~90psec(cosmics in Lab)
- ➢ there is always „shoulders“ on signal shape, which might be explained by Cathode MCP Distanse
- ➢ there is a hope that BINP might produce them in quadratic form, enhancing GeomEff
- ➢ the lifetime and radiation hardness are still behind what PANDA requires

Candidate Detectors…Nr1 MCP_PMT

- The signal shapes before and after amplifier(ORTEC,VT120)



5-7mV Amp
<1ns Risetime
4-5ns fullwidth

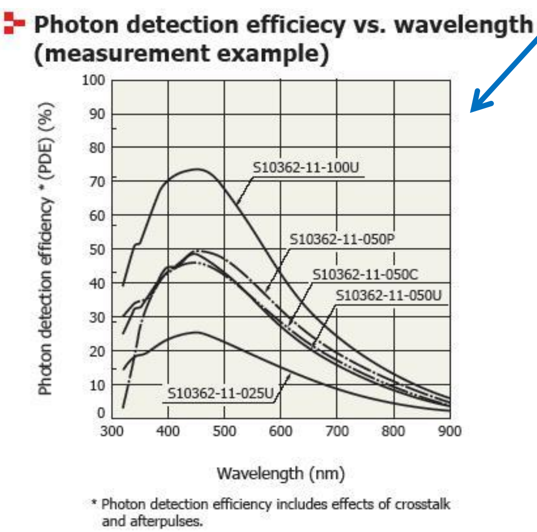


- ➢ after amplification the signal could travel a few tens meters till CFD(ORTEC 935)
- ➢ but that is not Desirable, we can catch a lot of noise in between
- ➢ if we have enough strong signal can we miss the Preamplifier In our chain??? assuming the CFD is placed immediately close to the Detector

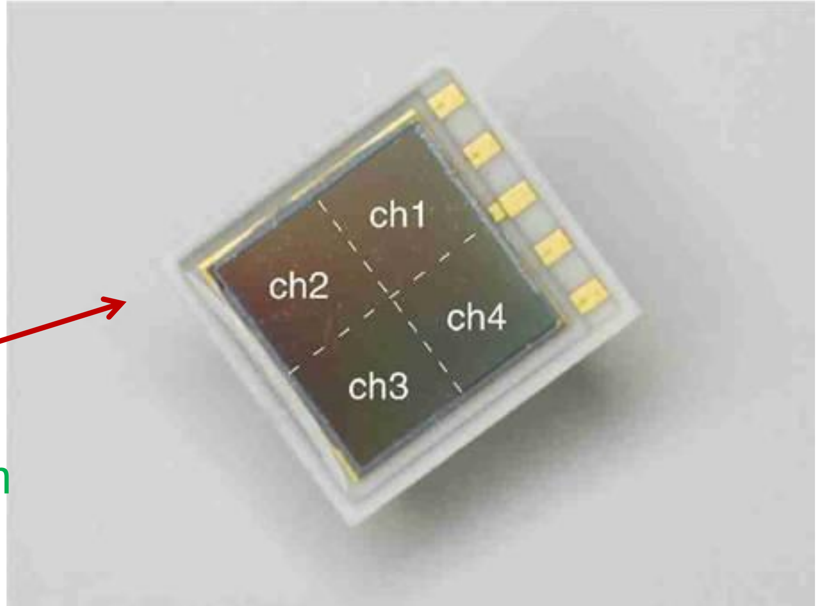
Candidate Detectors…Nr2 SiPMT=APD=MPPC

- so far we have only two type, Russian(from CALICE) and Hamamatsu

QE according Hamamatsu



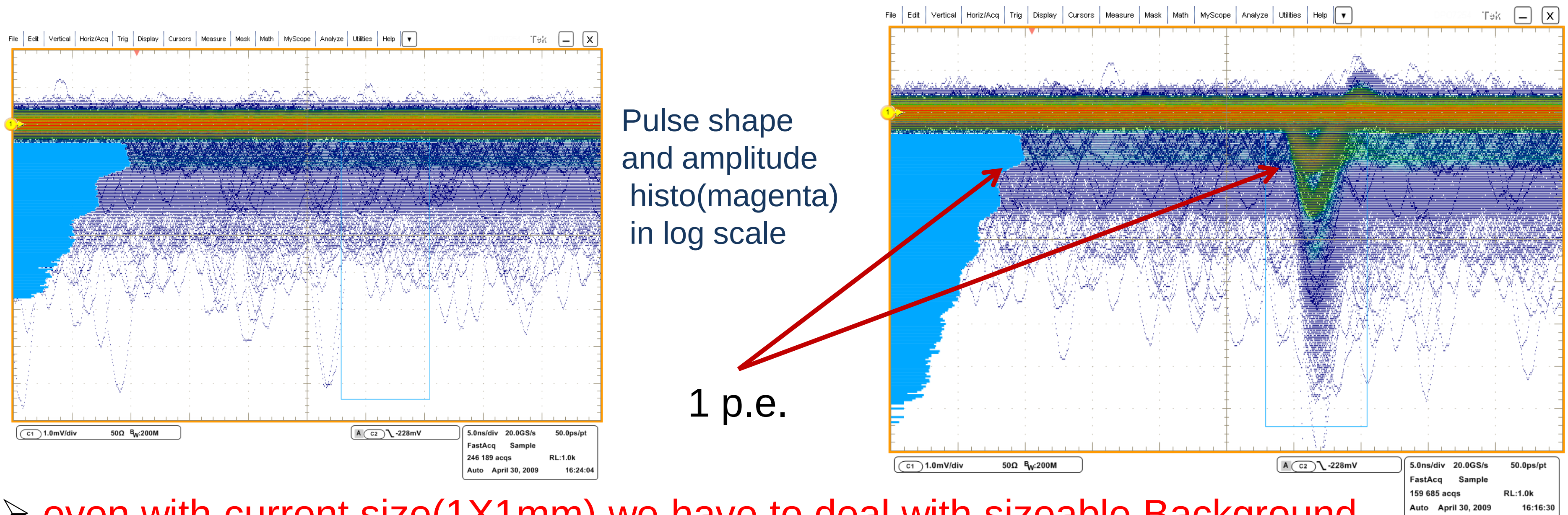
1ch has 3X3mm size



- ➢ Warning the right side plot with 70% PDE was too OPTIMISTIC
- ➢ There is a report(A. Ronzhin TIPP09) that one can achieve ~50psec time resolution with such a detectors
- ➢ the right side configuration might create a hope that we can cover more than mmXmm sizes, but the we have to fight against Background, cooling???, see next page

Candidate Detectors...Nr2
Signals

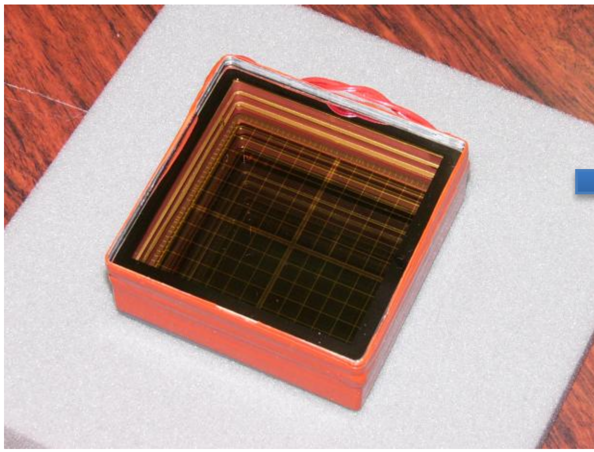
- Our first view of Russian APD WO Laser light(left), WITH Laser light(Right,409nm,73ps) in 1mVX5ns Tektronix bins

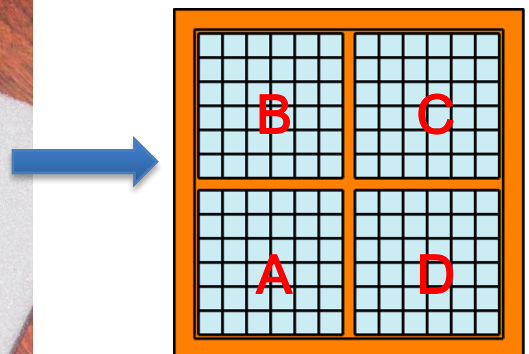


- ➢ even with current size(1X1mm) we have to deal with sizeable Background
- ➢ A way to overcame , maybe to use „Light Collectors“ (see S. Korpar presentations) or to cool them (see M. Düren presentation for Gießen test on Hamamatsu C10751-03 module)

Candidate Detectors…Nr3 Multi-Channel Hybrid Avalanche Photo-Detector (HAPD)

- Hamamatsu Photonics

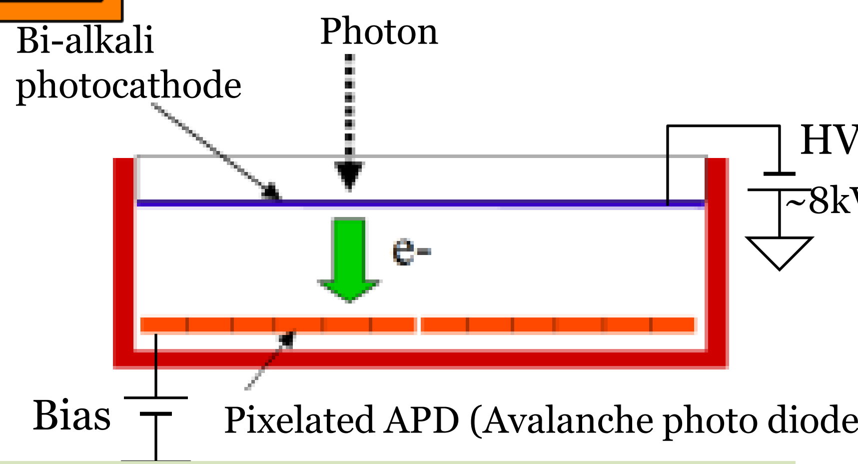




4 avalanche diodes (ADs) are accommodated in one detector

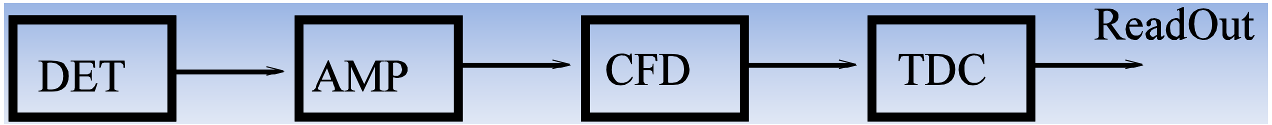
QE ~ 25%

Package	72x72 [mm^2]
# of pixels	144 (36x4chips)
Pixel size	5x5 [mm^2]
Effective area	67 %



There is ongoing R&D for Diamond PMT's and they are going to be Candidate Nr4, but the soon we decide about the detector the time to devote on FEE will benefit from that

TOP DIRC possible FEE chain..currently on test stand in LAB



- DET MCP-PMT from BINP, Hamamatsu MPPC
- AMP ORTEC VT120,9327
- CFD ORTEC 934,935
- TDC CAEN V1290, with HPTDC Chip
- Readout Via Struck SIS3100 Optolink from VME
  ALL are connected through a few m(total) LEMO cables,NO ASIC yet

TOP DIRC possible FEE ASIC As an example see COMPASS one

Already working chain COMPASS, source H. Fischer talk at TIPP09

Optical fibre to CATCH

Trigger rate up to 100kHz

DREISAM card (TDC-F1)

Up to 10MHz rate per channel, 100ps resolution Deadtime free TDC

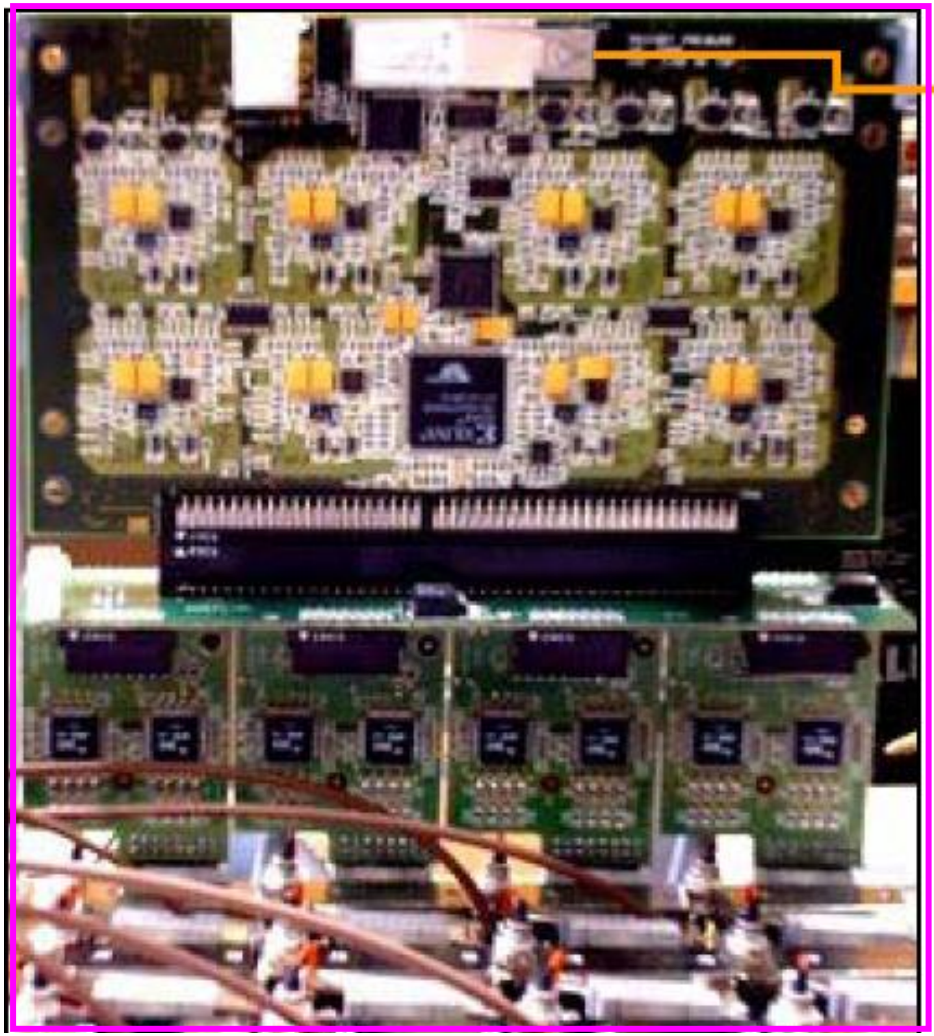
MAD4 discriminators

Up to 1MHz channel, wil get upgrade till 5

MAPMTs

Can accept rates up to 5MHz

TOP DIRC possible FEE ASIC
On basis of this one dream about modernised one like



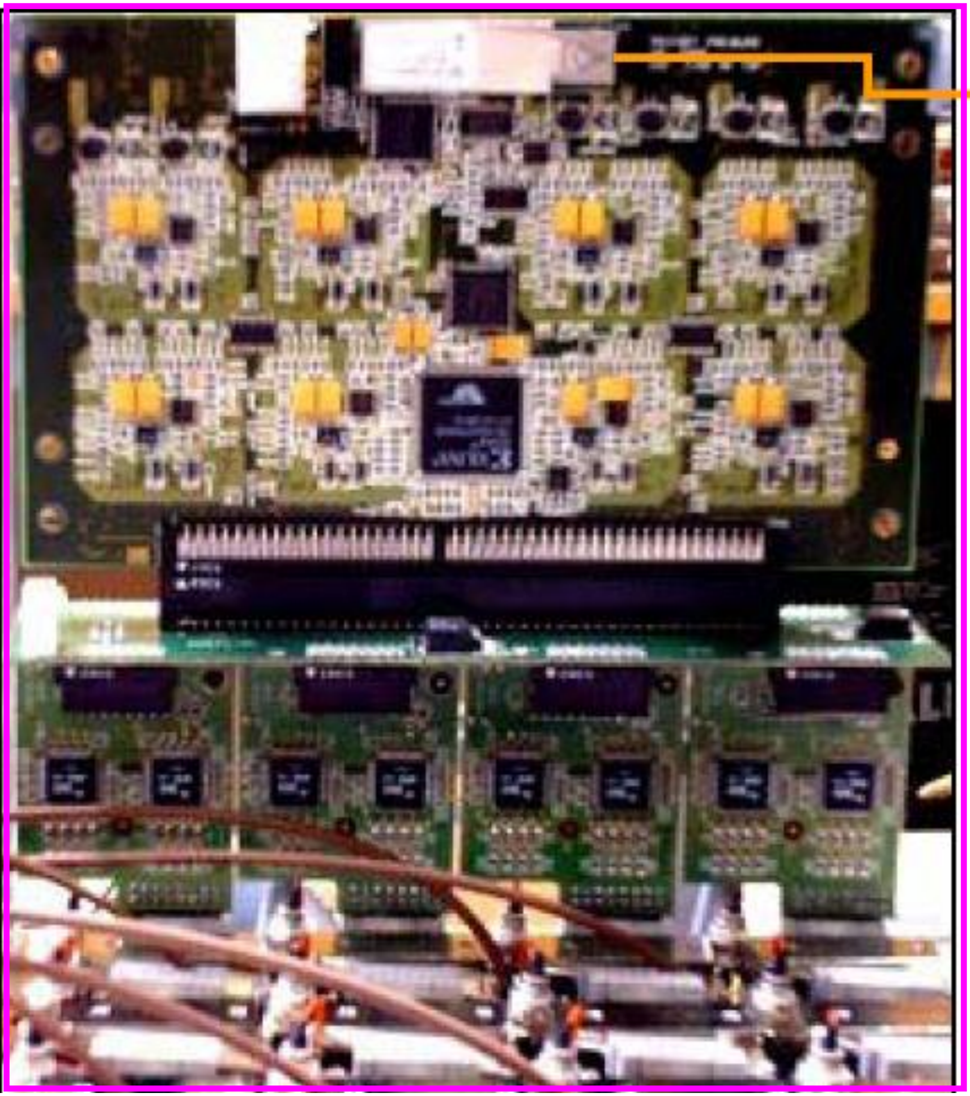
Optical fibre to CATCH

CERN HPTDC TDC(25ps) or
GSI GET4(25ps) or
ACAM M-Mode(10ps) bin size

MAD4 discriminators

MAPMTs

TOP DIRC possible FEE ASIC On basis of this one dream about modernised one like



Optical fibre to CATCH

CERN HPTDC TDC(25ps) or
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ACAM M-Mode(10ps) bin size

NINO or
ORTEC or
Hamamatsu developed

MAPMTs

TOP DIRC possible FEE ASIC
On basis of this one
dream about modernised one like

Optical fibre to CATCH

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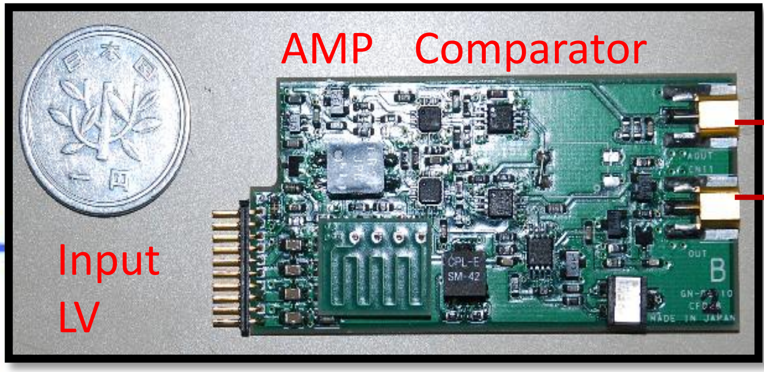


to TDC

to ADC

MAPMTs

TOP DIRC possible FEE ASIC

dream about modernised one like

TOP ASIC

Optical fibre to PANDA DAQ

CERN HPTDC TDC(25ps) or
GSI GET4(25ps) or
ACAM M-Mode(10ps) bin size

NINO or
ORTEC or
Hamamatsu developed

MCP or
APD or
HAPD or Diamond PMT??

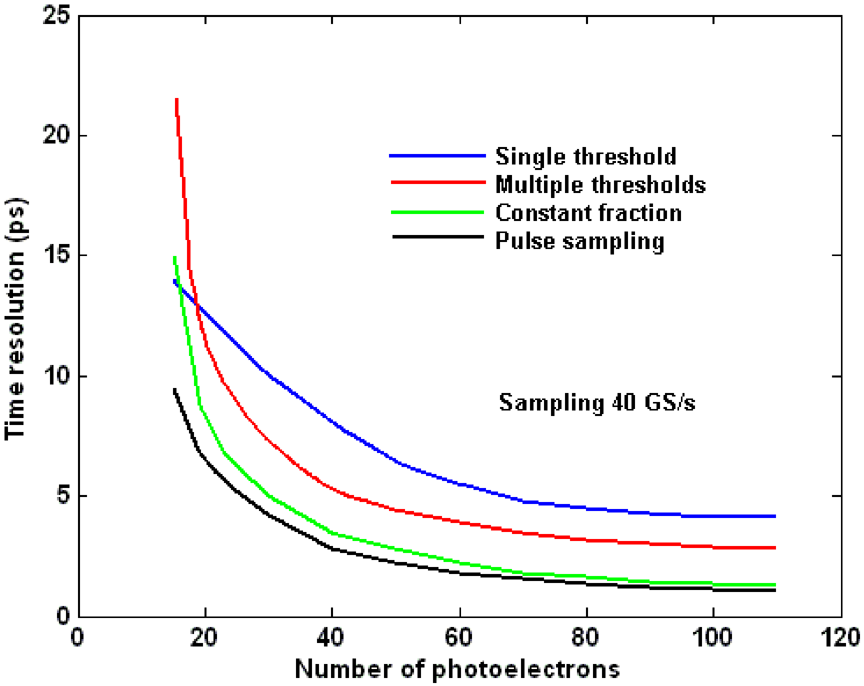
All this seems feasible,
but there is a second path of development

BLAB

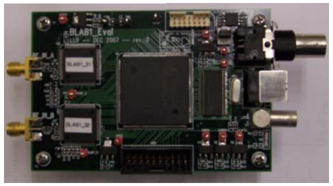
Buffered Large Analog Bandwidth

High Speed Digitization

- Simulation efforts at U.Chicago indicate that pulse shape digitization at 40 Gs/s would equal or improve on Constant Fraction Discriminator's
- During laser and beam tests, we have built up a library of pulse shapes from the MCP/PMT's using 20 Gs/s to compare with simulation
- Goal is to develop custom digitizer in parallel with the efforts to grow micropore structures on a large scale.
- Working with Gary Varner/Hawaii (Blab chip) and Stefan Ritt/PSI (DRS chip) to study fast digitizers:



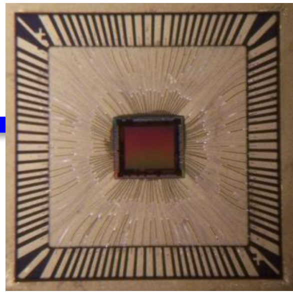
DRS4 6GS/s Waveform Digitizing Chip – S. Ritt PSI



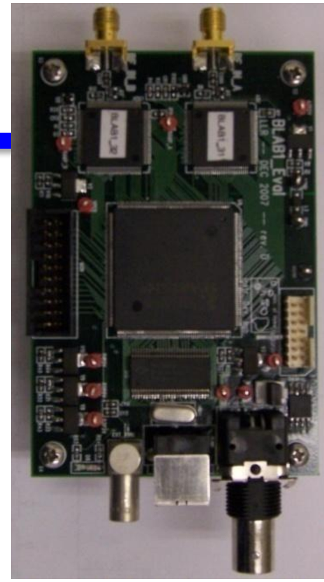
BLAB1 2 Gs/s Waveform Digitizing Chip – G. Varner Hawaii

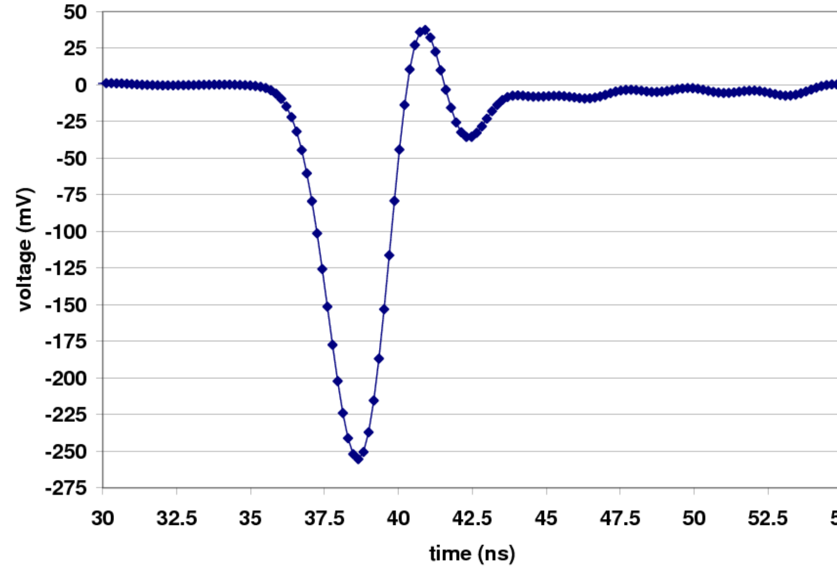
SOURCE
E. Ramberg/Fast Timing at Fermilab Test Beam/TIPP09

BLAB1 ASIC studies

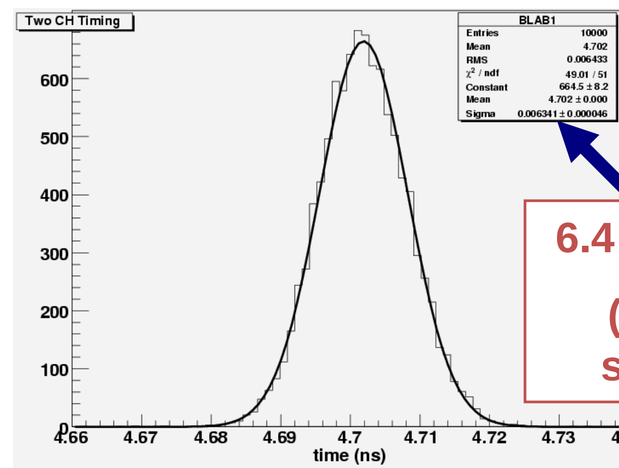


BLAB1 -- NIM **A591** (2008) 534





- Comparable performance to best CFD + HPTDC
- MUCH lower power, no need for huge cable plant!
- Using full samples significantly reduces the impact of noise
- Photodetector limited



6.4 ps RMS

(4.5ps single)

Being published in NIM, arXiv:0805.2225

Conclusions

Many Thanks

Especially to ALL People from whom

I stole Transparencies!!

It seems that the FEE we need to

build the TOP DIRC exist already

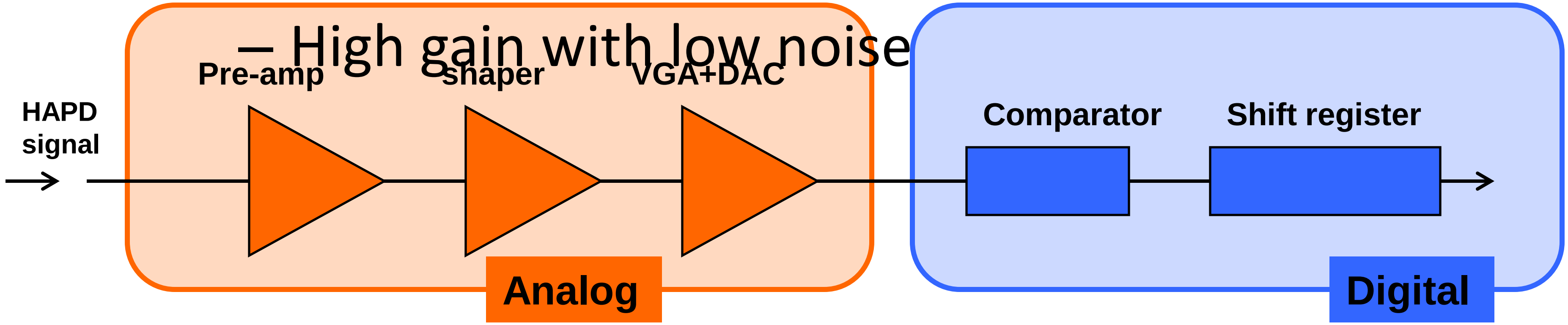
...unfortunately as a single pieces

But the feasibility to get it build is high enough

BACKUP

HAPD Front-end Electronics

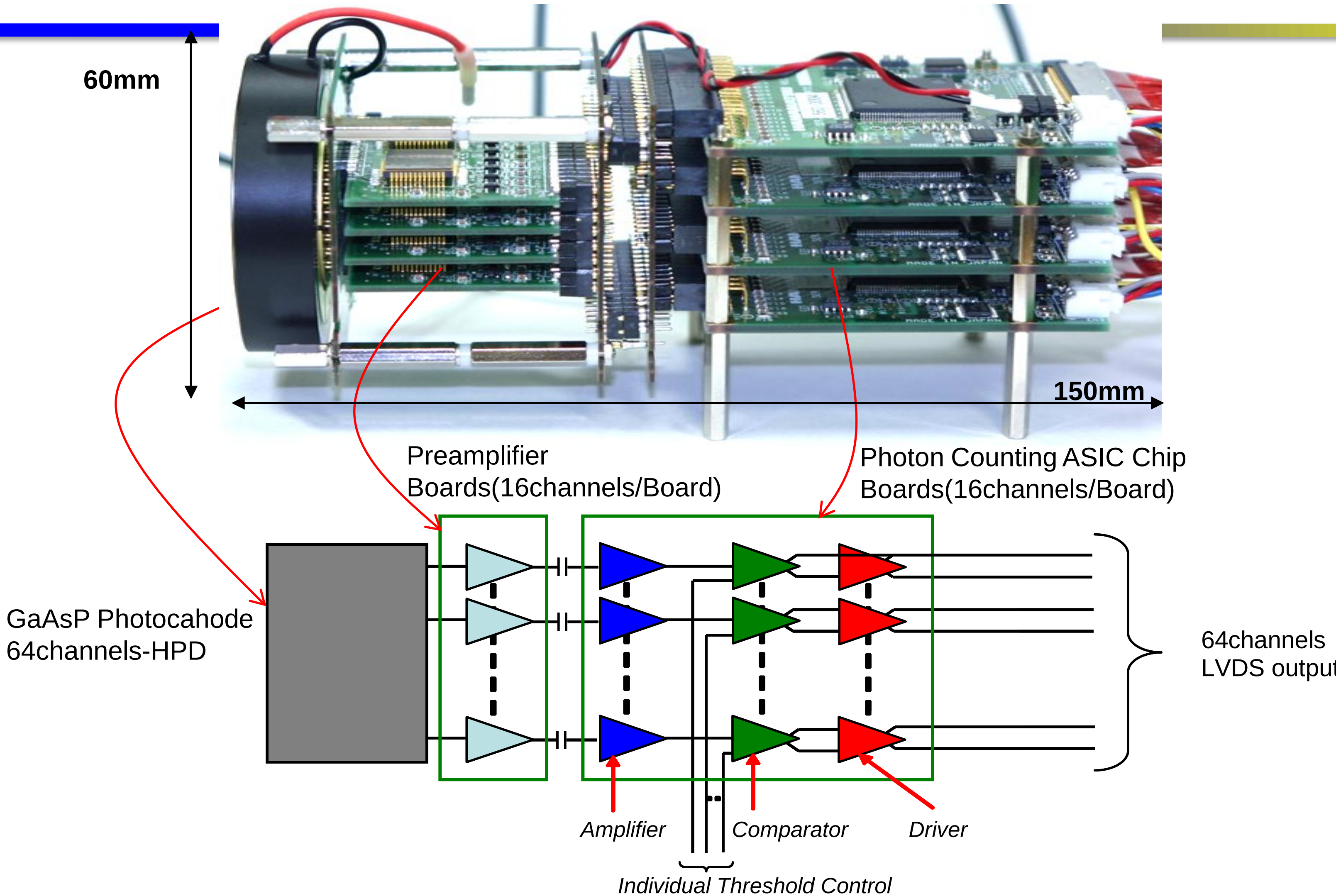
- Custom-made ASIC has been developed for HAPD read out.
  - Manage ~100K channels
  - High gain with low noise



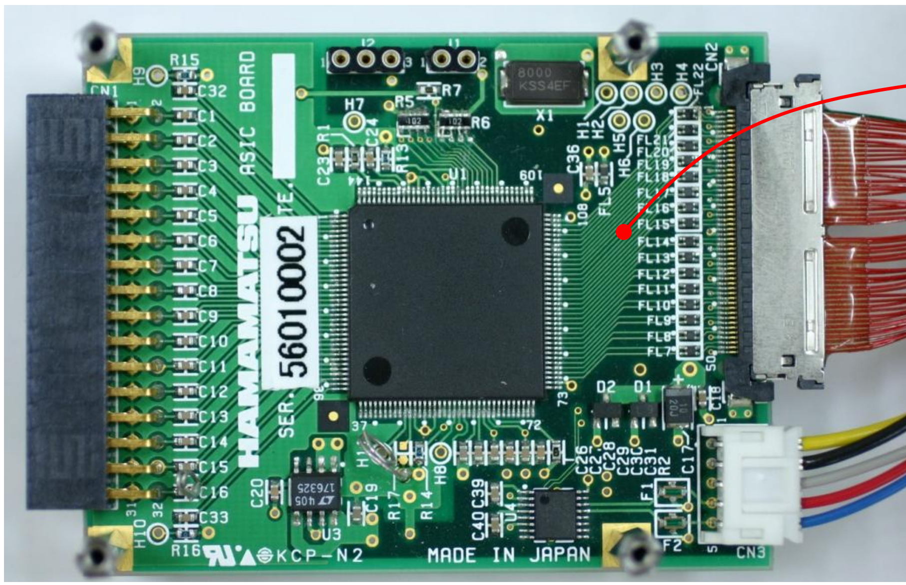
- 18 channels/ASIC chip
- Shaping time 0.3~2.0μsec
- Variable gain 1.25~20
- Channel-by-channel offset adjustment (+/-200mV)

See poster: S.Nishida "Development of the readout ASIC for the 144ch HAPD for Aerogel RICH" (ID:64)

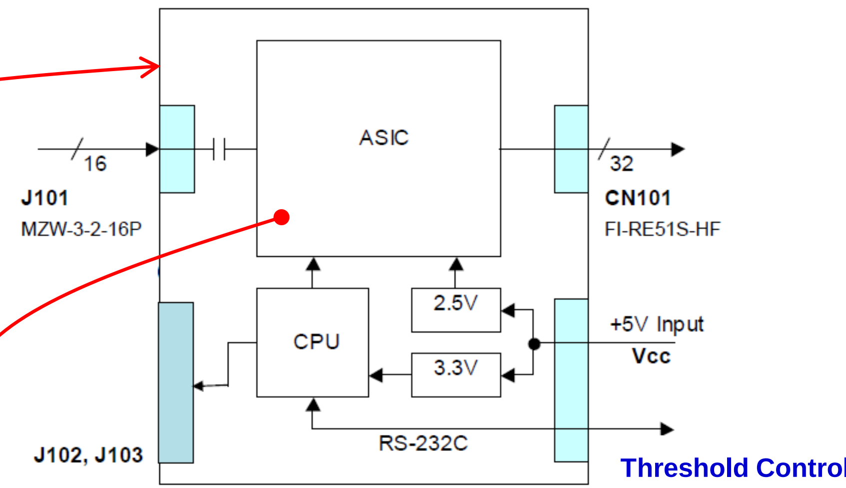
Prototype Module



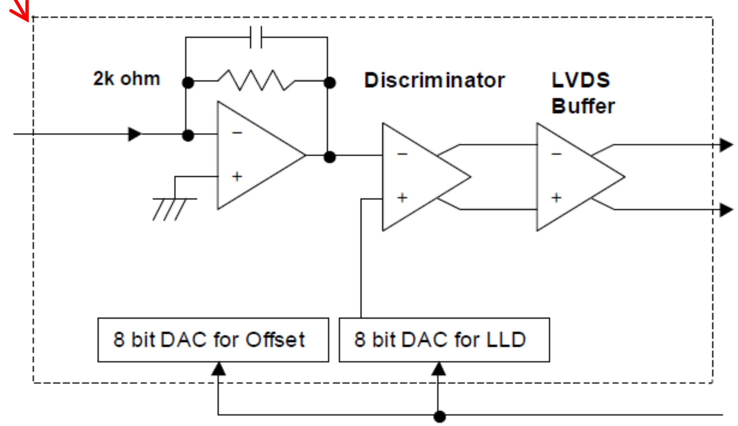
Photon Counting Electronics: P.C. ASIC Board by Hamamatsu



Board Block Diagram



Chip Structure(1/16 channels)



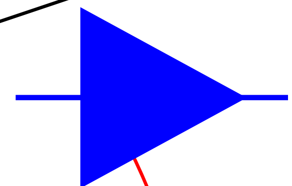
Designed for Multi-Anode PMTs. Provides 16channels and accepts direct connection with PMTs.

Maximum count rate: >100MHz

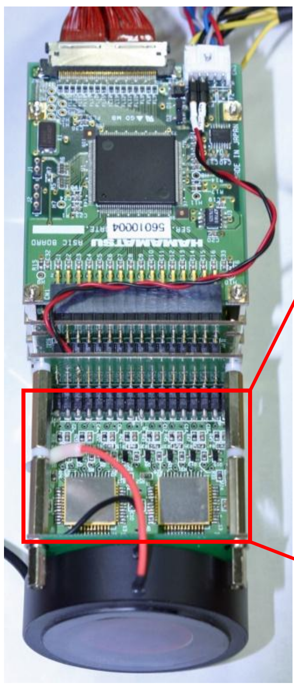
Preamplifier Array ASIC Chip

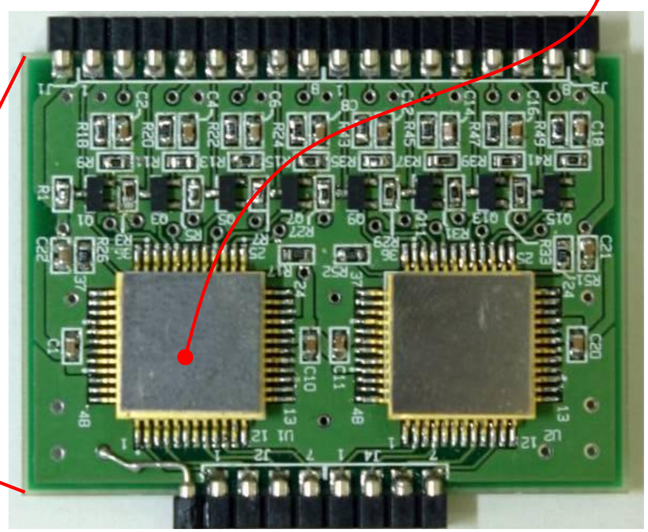
Amplifier is required to amplify HPD signal to the acceptable input level of the PC ASIC

Output Signal Level 64ch HPD



Acceptable Input Signal Level of the Photon Counting ASIC





Fabricated 8 amplifiers/chip

Process: NEC Bipolar 0.5μm

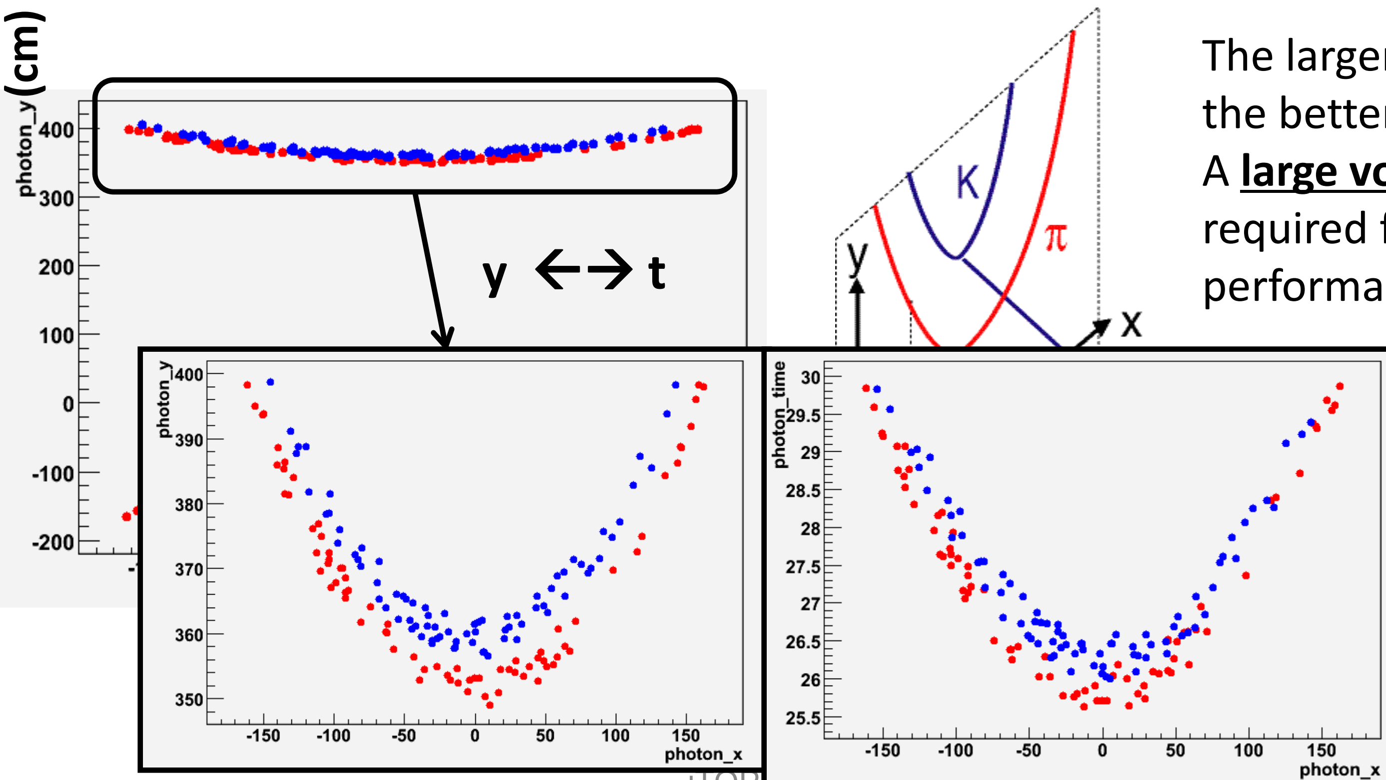
BW: ~20MHz

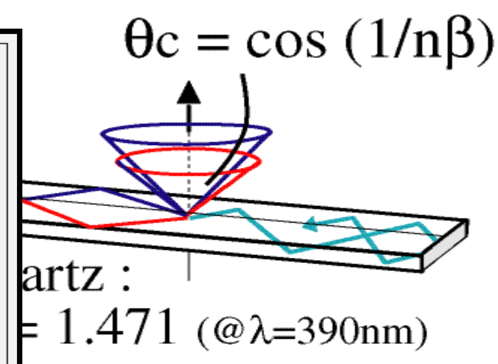
Power Consumption: ~80mW/chip (8channels)

Detection of Internally Reflected Cerenkov Light (DIRC)

- Charged particles of same momentum but different mass (e.g., K§ and ¼§) emit Cerenkov light at different angles.
- Detect the emitted photons in 2+ dimensions (x,y,t)

The larger the expansion region, the better the x-y image...
A **large volume (>1m)** may be required for acceptable performance.

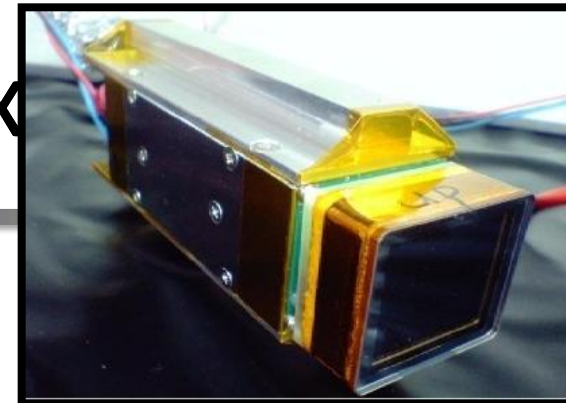




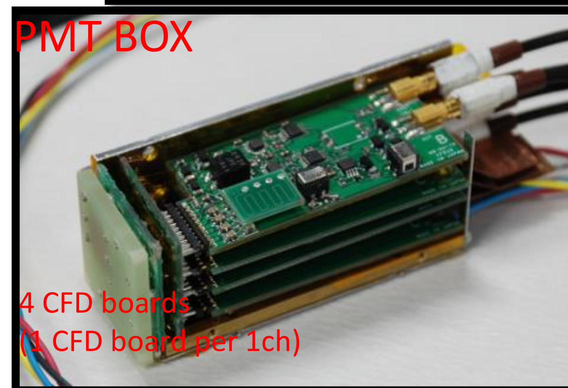
(2 m) expansion

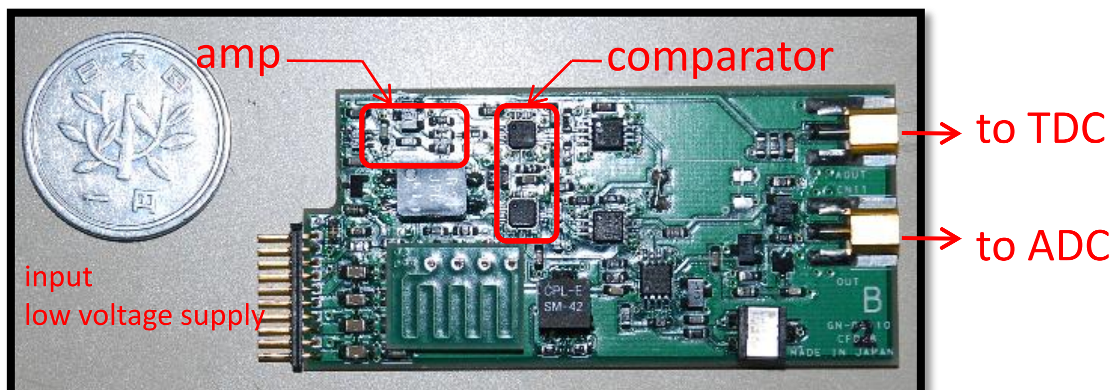
volume, 2 GeV K/¼

CFD and PMT box



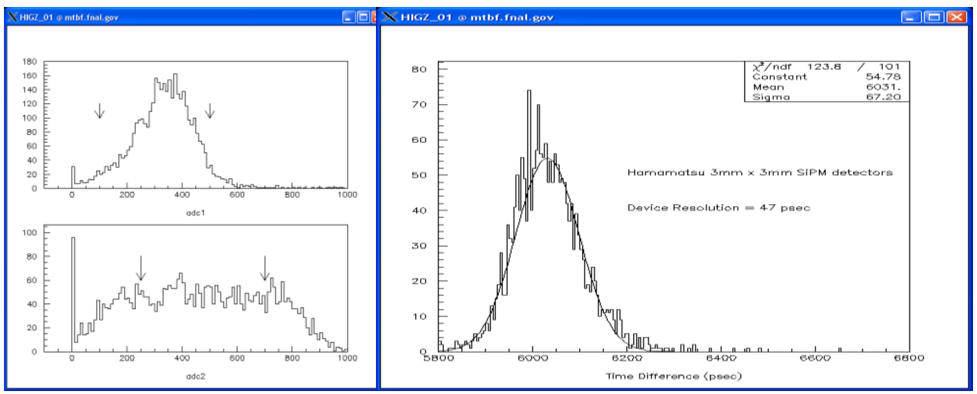
- HV divider + AMP + Discriminator
- Smaller size
  - $29mm^{W} \rightarrow 28mm^{W}$
- Prototype
  - Fast AMP (MMIC, 1GHz, x20)
  - Fast comparator (180ps propagation)
  - CFD with pattern delay
- Performance
  - Test pulse
    - ~5ps resolution
  - MCP-PMT
    - σ<40ps
    - Working well

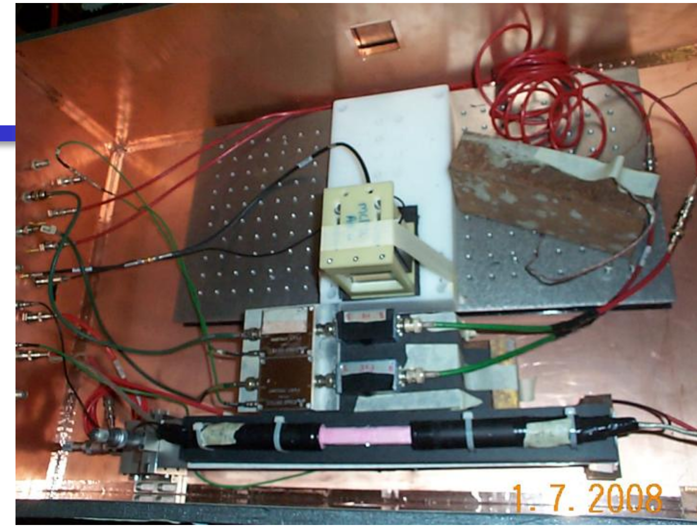


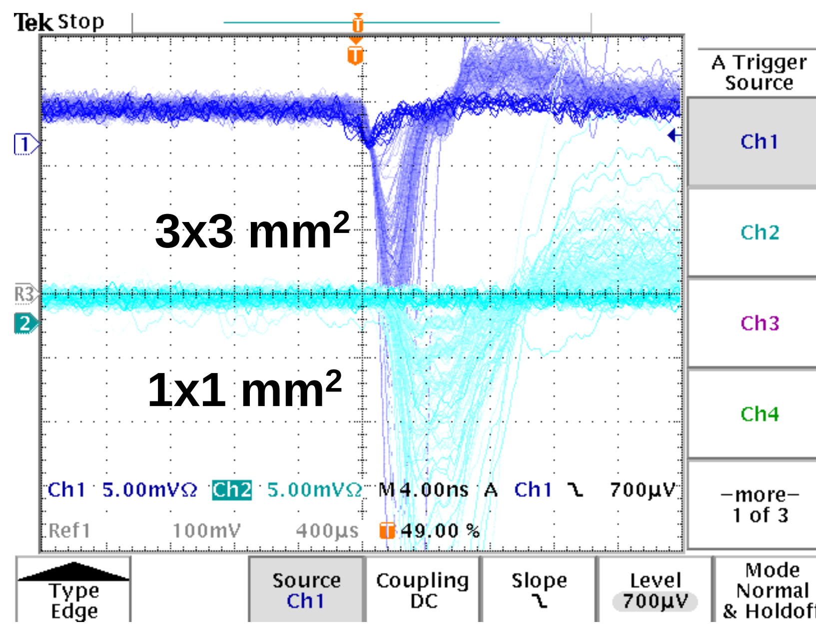


SiPM Results

- SiPM = “Silicon PMT”, which is a multi-pixel Geiger mode silicon device for photon counting
- SiPM’s used is Hamamatsu MPPC 3 x 3 mm^2 with 6 x 6 x 16 mm^3 poly radiator





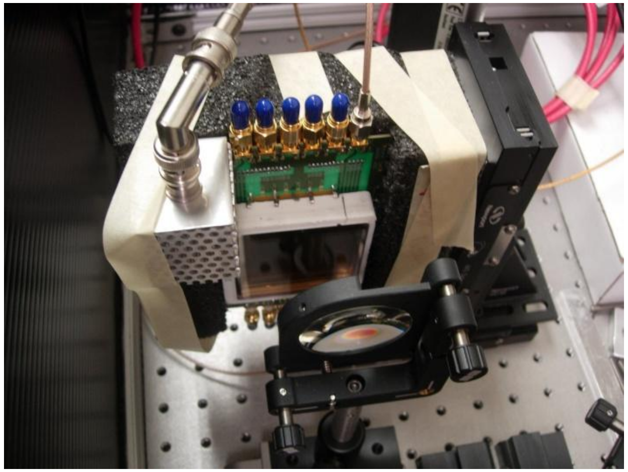


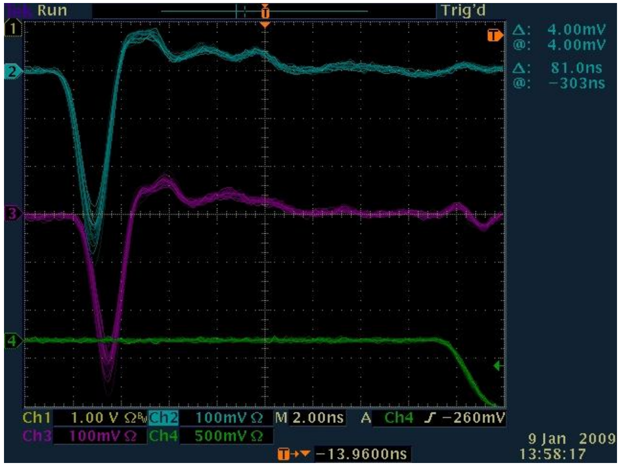
- Obtained 48 ps timing resolution per device, even with poor light collection on one device.

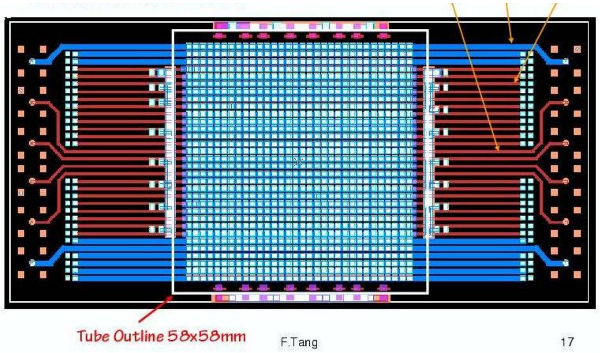
See Anatoly Ronzhin poster showing detailed calibration results for MPPC timing

Transmission line readout of MCP/PMT's

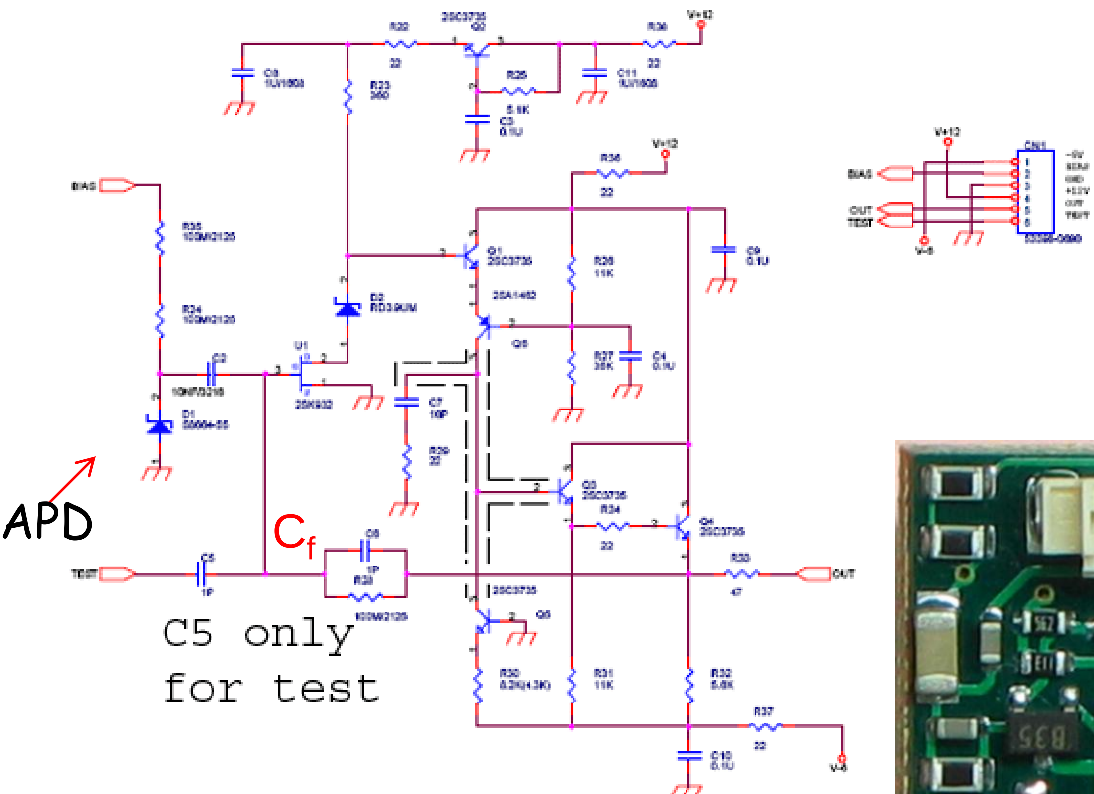
- Read out both ends => gives both position and time
- Cover large areas with much reduced channel account (does not scale with area)
- Transmission speed agrees exactly with simulation
- Signal is not degraded over lengths even larger than 70 mm, according to simulation.

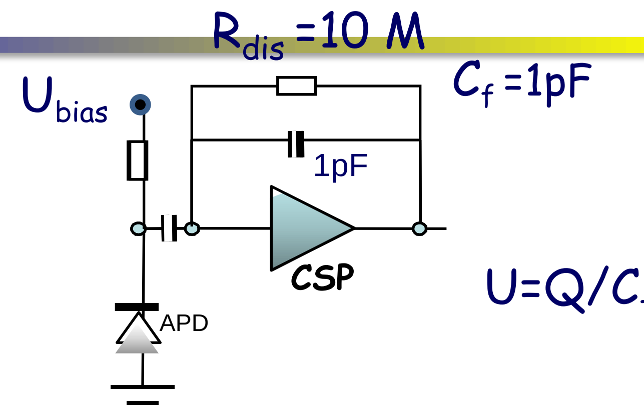






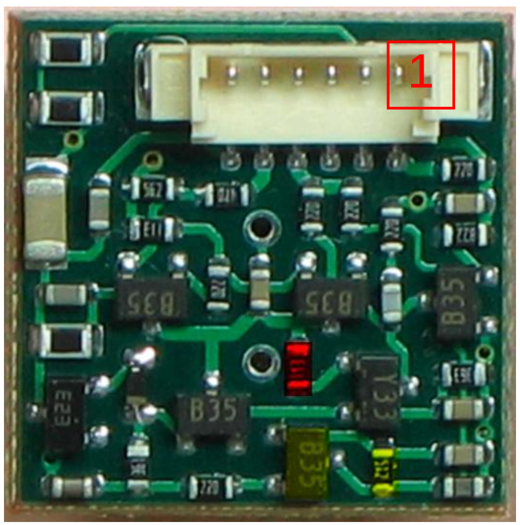
Charge Sensitive Preamplifier (CSP)





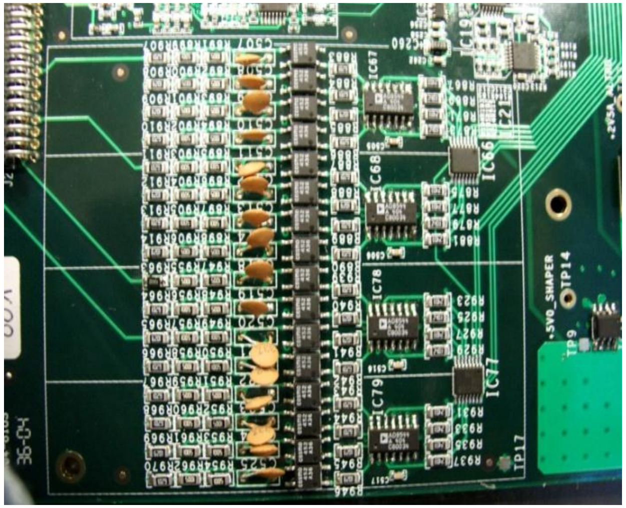
Voltage/charge gain:
U_Q = 1mV / fC

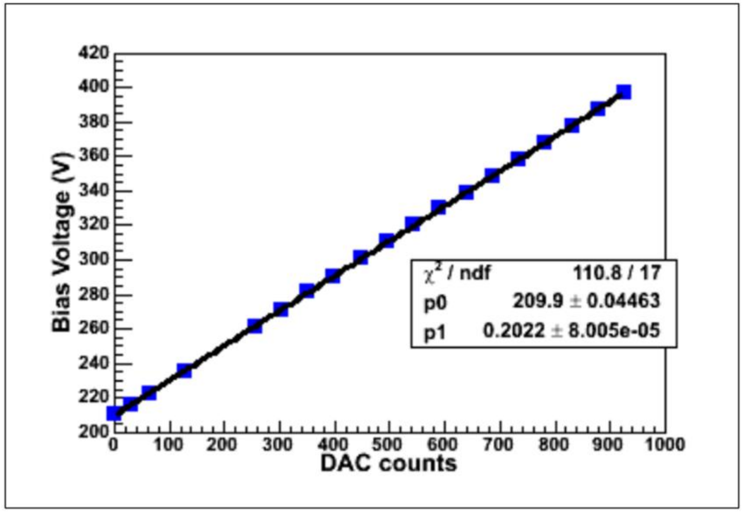
- U_{CSP}/E= 26.7 μV/MeV at M_{APD}=50 and -25°C
- Intrinsic ENC noise of 520e



HV Bias controller

32 HV Bias controllers for APD bias 210-410 V
10 bit range programmable via DCS





- Registers of 10 bit range with a bias voltage increment 0.20V/bit in the range of 210-400V
- With typical voltage coefficient of 3.3%/V at gain 50, the APD gain variation can be limited to ~0.66%

Trigger Region Unit

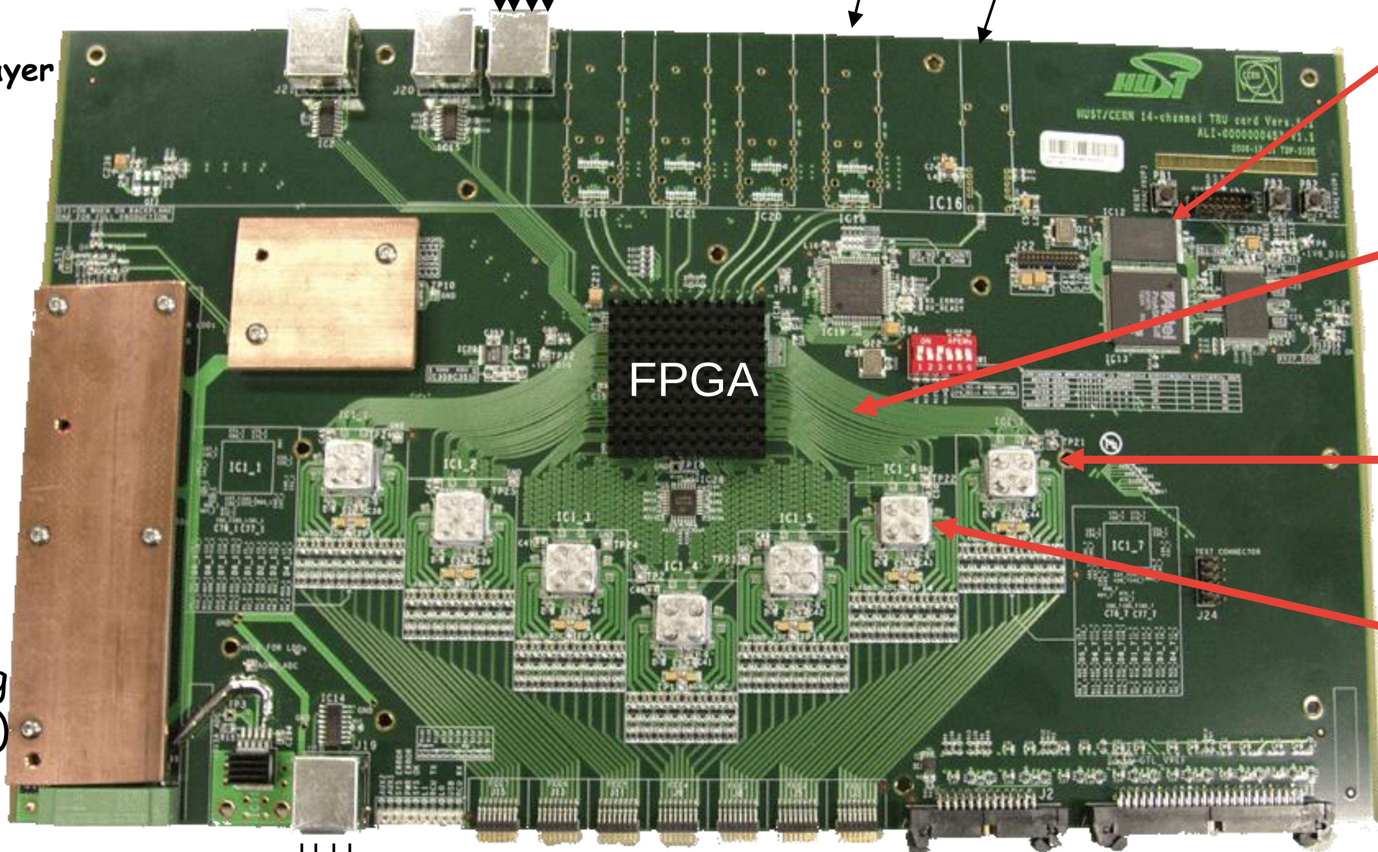
112 FastOR signals converted ->12 bit ADC & processed within 300 ns in FPGA

4x LVDS to TOR / STU

Optional MGT Gigabit fibers for debug line
Optional Vo Multiplicity input for EMCal

FPGA reconfiguration Logic (Actel)

12 layer PCB



112 x serial Data to FPGA 240 MHz DDR

112 x ADC 12 bit@40 MHz

1 octal ADC =1 Watt

LDO Power Cooling (30 W)

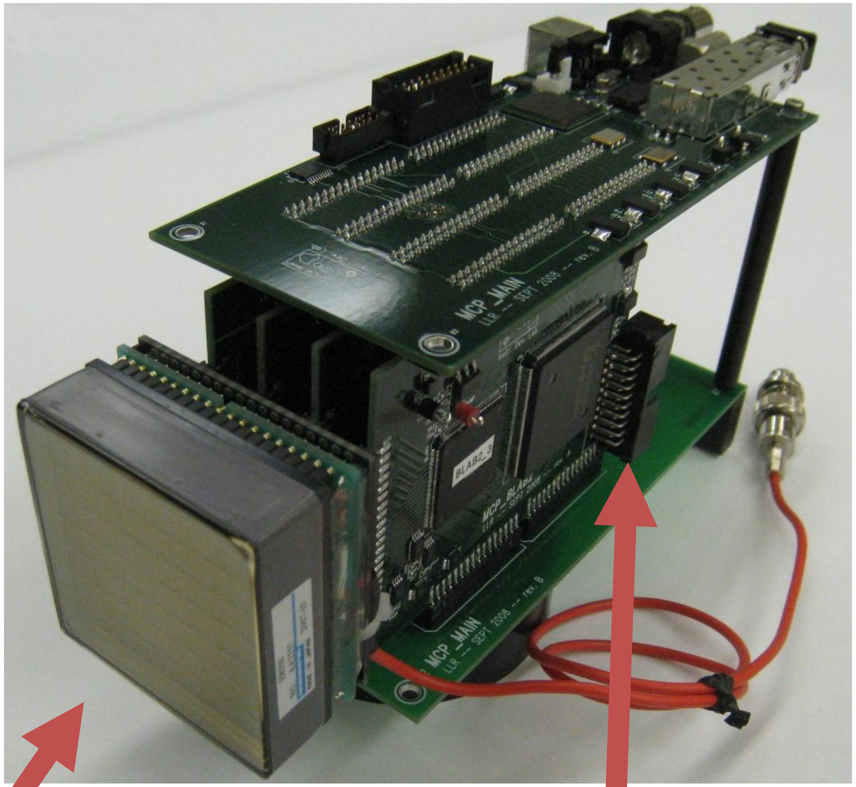
Local Level-0
3 x level-1

112 analogue inputs (Fast OR from FEE)

RCU readout bus

H8500 MCP-PMT Readout

- Integrated photodetector packaging
- Close to the sensor to reduce pickup noise
- Developing techniques for package electronics and PMTs together

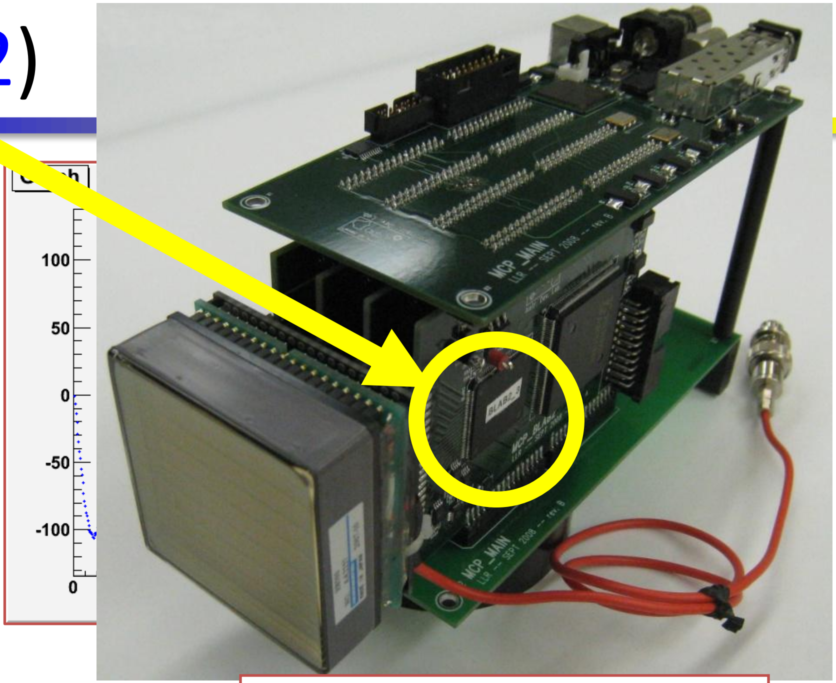


Hamamatsu H8500

Custom Hawaii Electronics

2nd Generation Buffered Large Analog Bandwidth (BLAB2)

- Custom Waveform Sampler ASIC
- Tuned to 2.5 GS/s for HI-TIDE
- 1.25 μs deep analog buffering
- ~300 MHz input bandwidth
- 16x sensor channels with on-chip amplifiers
- Plus, 1x (no gain) calibration channel for timing.



30 MHz Sine wave

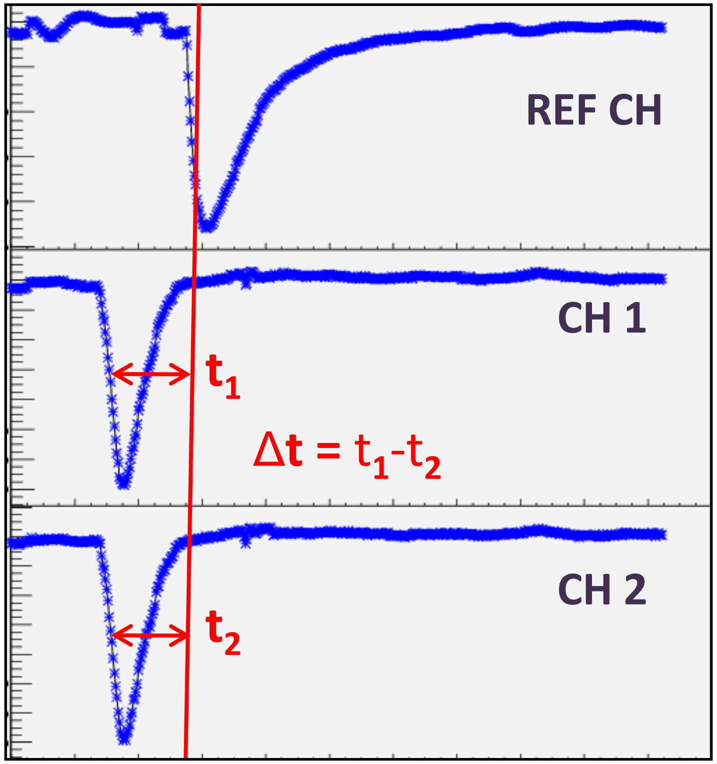
mV

ns

Timing Algorithm

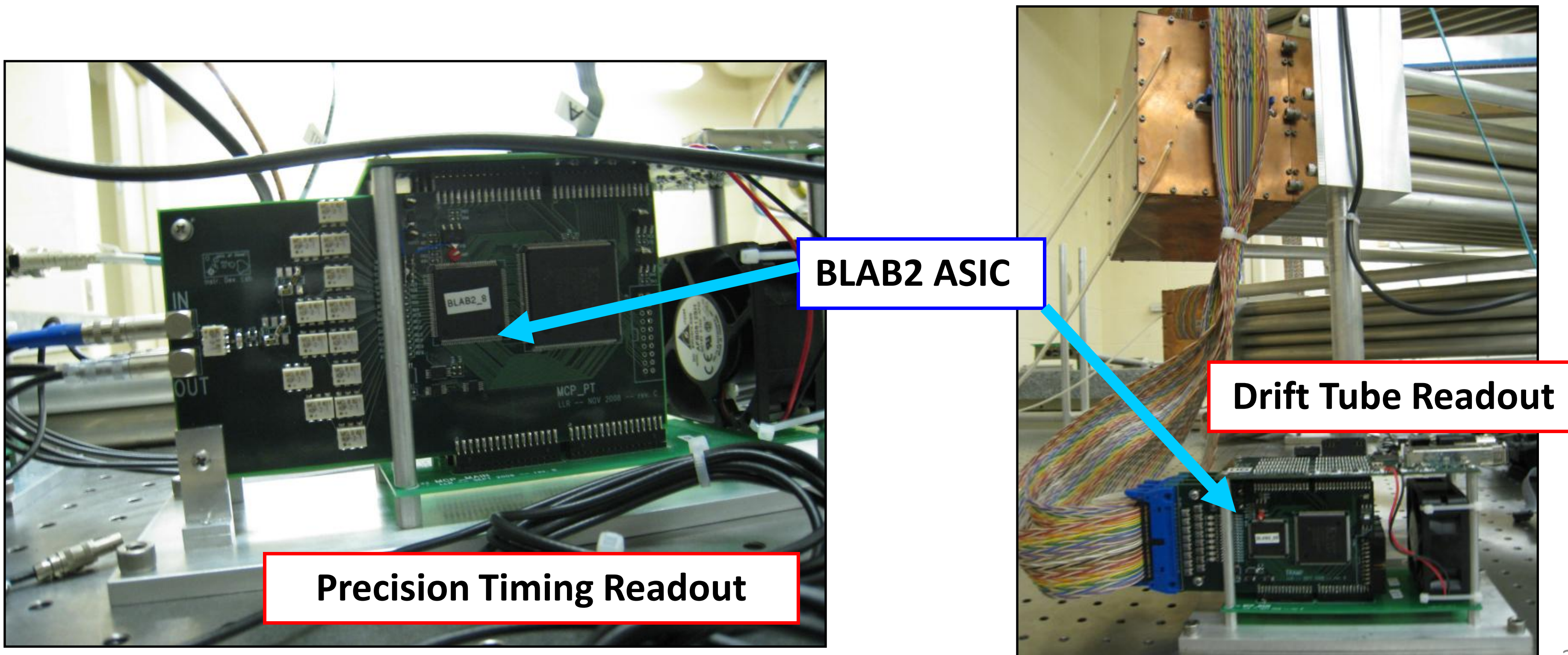
$$(f \star g)[n] \stackrel{\mathrm{def}}{=} \sum_{m=-\infty}^{\infty} f^*[m]\, g[n+m]$$

- Discrete cross-correlation of sensor channels with the reference channel
- Relate the timing of all channels with the common generated reference pulse
- Algorithm done in software

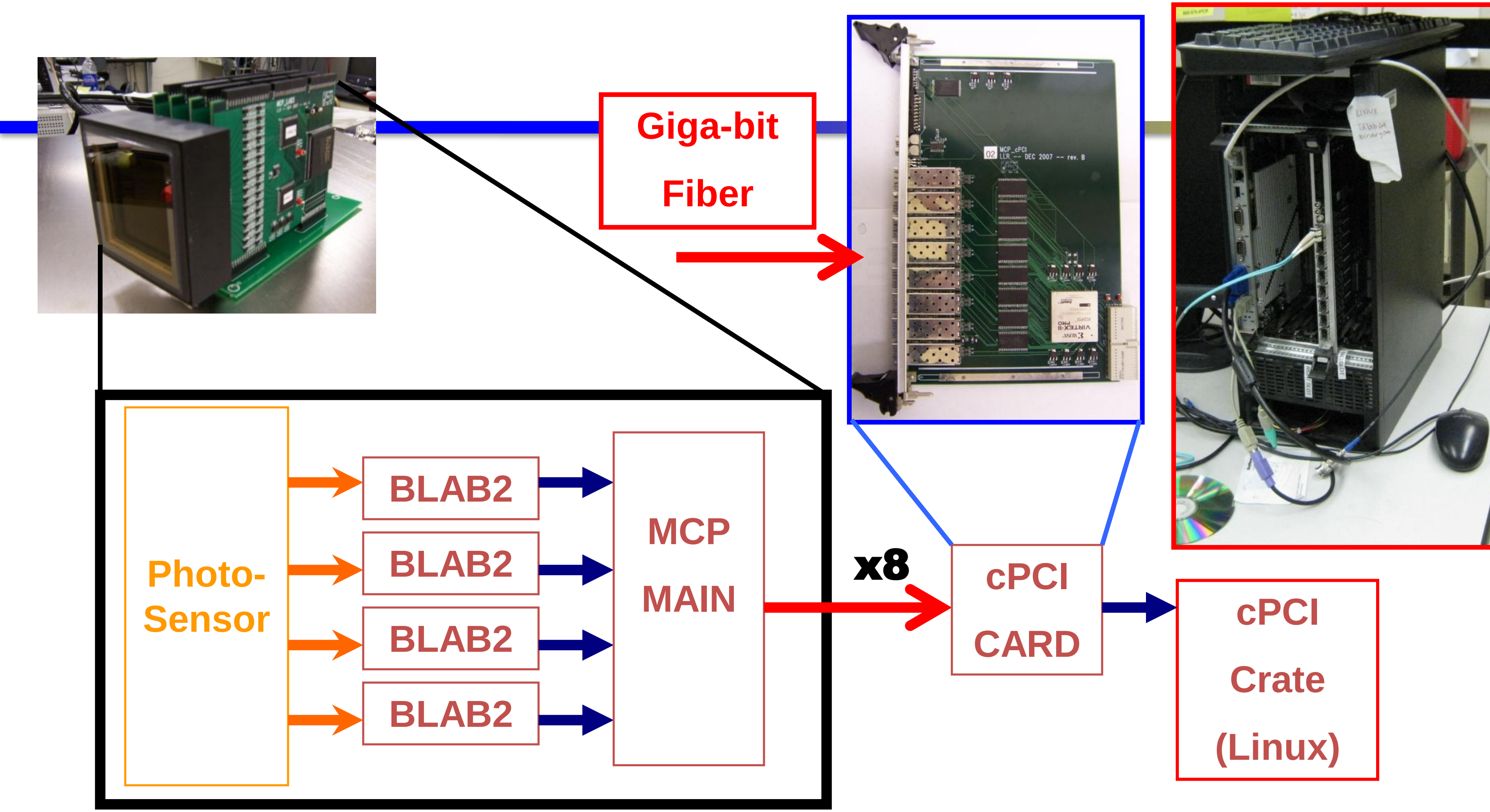


BLAB2 flexibility

- Extremely flexible readout solution:
  - Variable sampling speed, depth.
  - Being tested at HI-TIDE with drift tubes, PMTs, and MCP_PMT.



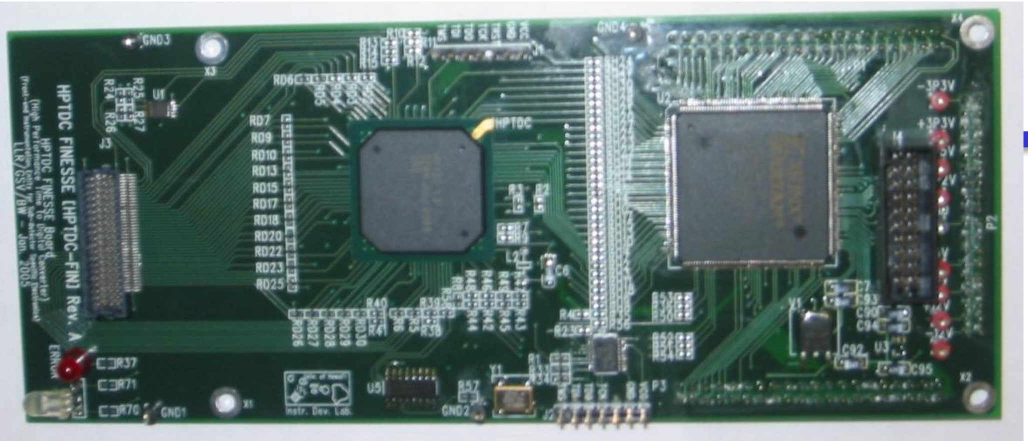
Readout System Components

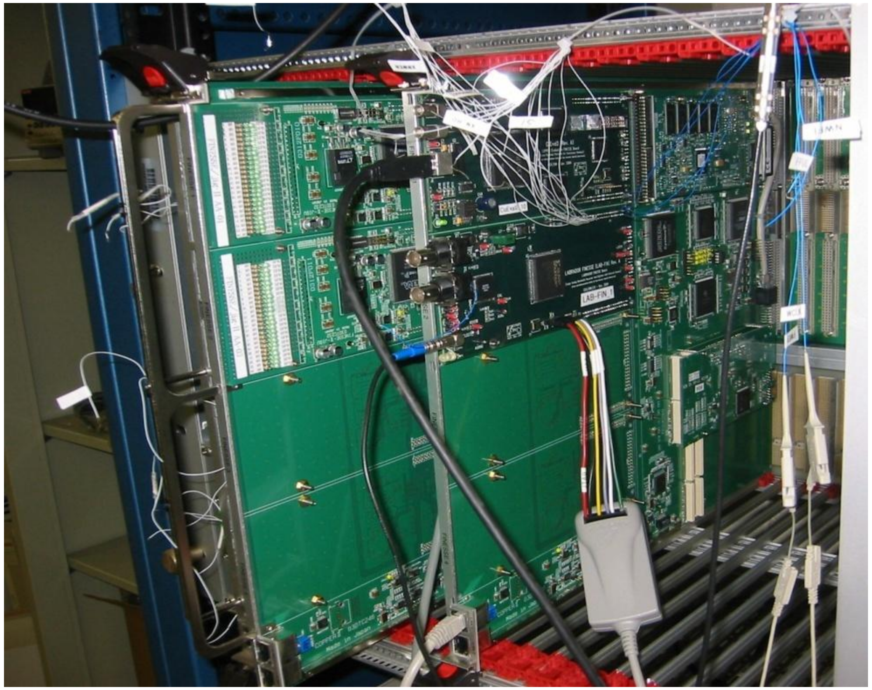


- Up to 8x64 channels per cPCI card
- Very portable DAQ
- Up to 3,584 channels/cPCI crate

Very cost effective, probably ATCA used in actual SuperB (?)

Fast Feature Extraction





Assume:
100kHz singles per pixel

150kHz trigger rate at SUPERB
200ns trigger window (2% occup.)
Each 64-chan PMT has ~200k hits/s
Each hit = 32 samples * 12bits = 384bits
➔~77Mbits/s
(link is 2.5Gb/s ~ x10 margin)
[perhaps 2x PMT/link]

<u>BlackFin DSP</u>

- Pedestal subtract
- Feature extract → T, Q
(tentatively allow up to 8x hits in 200ns)
- Time = 2Bytes, Q = 2Bytes

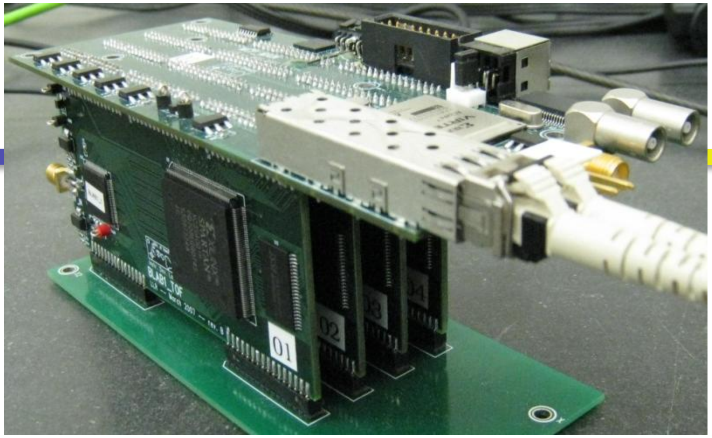
1k PMT * 1.28 hit typ * 4By =
5.12kB/event
Estimate 1.5us/hit processing time,
To be evaluated

Highly Integrated Readout

- **Buffered LABRADOR**

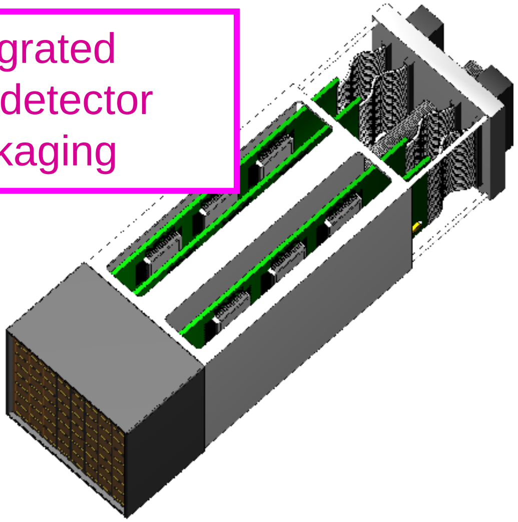
TABLE II: *BLAB2 ASIC Specifications.*

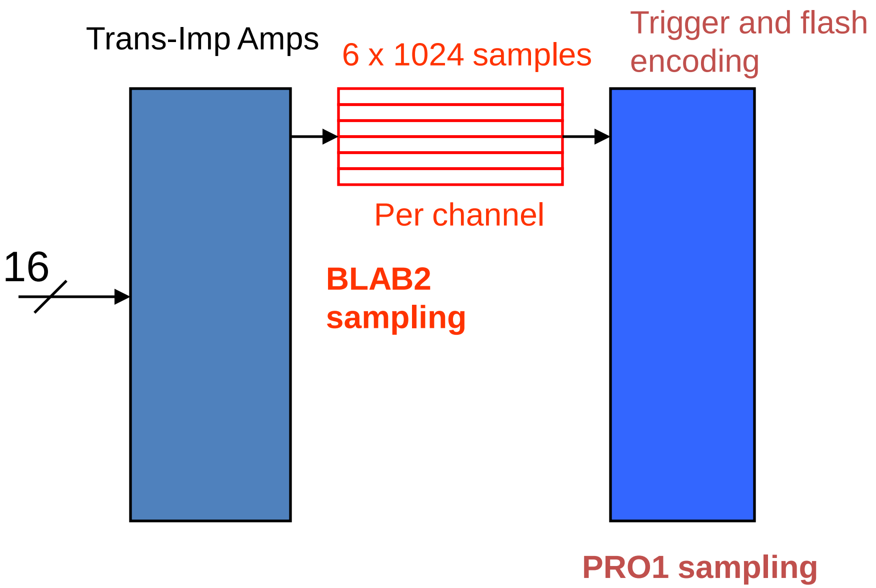
Item	*Value*
Photodetector Input Channels	16
Linear sampling arrays/channel	~~2~~ → 6
Storage cells/linear array	~~512~~ → 1024
Sampling speed (Giga-samples/s)	2.0 - 10.0
Outputs (Wilkinson)	32



BLAB2 ASIC

Integrated Photodetector packaging





HPK H-8500 Readout basis for this next step