The readout electronics for the Hybrid Avalanche Photon Detector

A. Seljak[1,2], H.Ikeda[5], S.Iwata[4], S.Korpar[6,1], P.Križan[7,1],
R. Pestotnik[1], S.Nishida[3], T. Sumiyoshi[4]

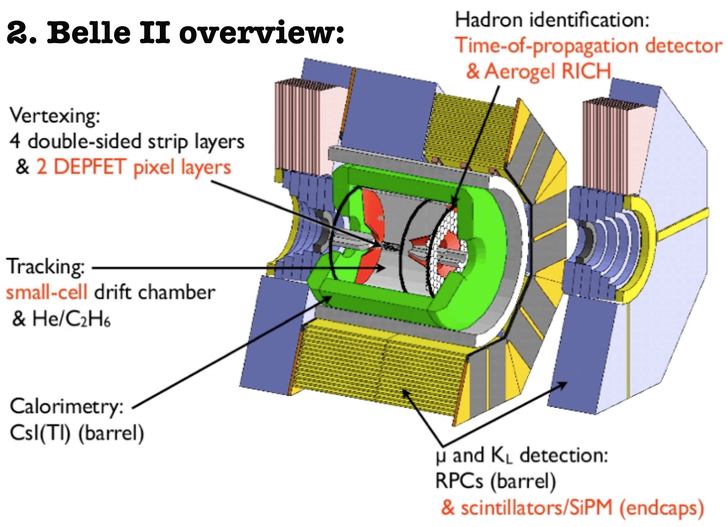
[1] Jožef Stefan Institute, Ljubljana, Slovenia, [2] Cosylab d.d. Ljubljana, [3] KEK High energy accelerator research, Tsukuba Japan
[4] TMU Tokyo Metropolitan University, Japan, [5] Japan Aerospace Exploration Agency, Saganihara city Japan,
[6]Faculty of Chemistry and Chemical Engineering, University of Maribor, [7]Faculty of Mathematics and Physics, University of Ljubljana

1. Motivation:

Belle II experiment: study of rare B and D meson decays

The Belle II detector at the Super KEKB asymmetric e^+ e^- collider (start of operation 2015), will use an proximity focusing ring imaging Cherenkov detector with aerogel radiator as particle identification device in the forward endcap region. It will allow efficient separation of kaons from pions (4σ) in the wide range of particle momenta up to 4Gev/c.

2. Belle II overview:

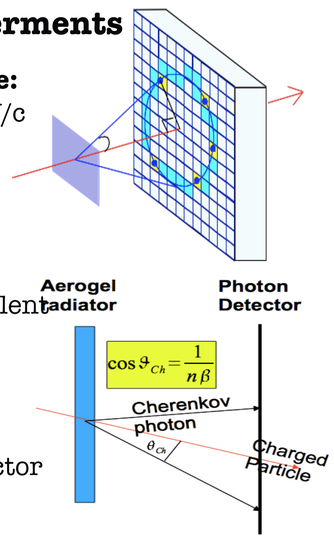


3. Belle II ARICH - requierments

Difference in Cherenokov angle:
- $\Theta(\pi) - \Theta(K)$ = 23 mrad for 4GeV/c n=1.05
- very reduced available space
- low power

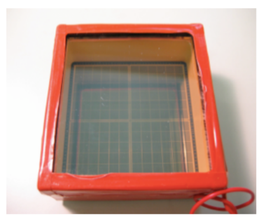
Environment:
- 1.5 T field
- 10 ^{11} neutrons of 1 MeV equivalent per year per cm^2

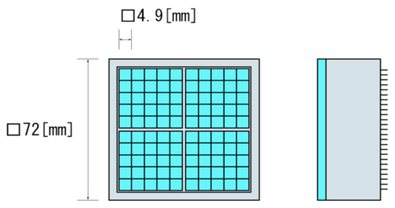
Elements of ARICH:
- Aerogel radiator
- Expansion Volume (20cm)
- Position sensitive photon detector

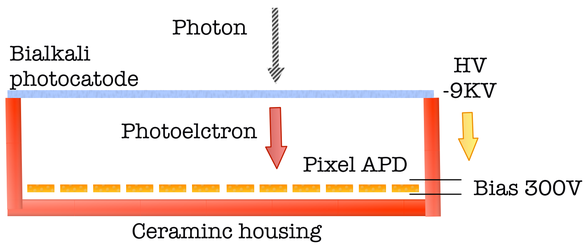


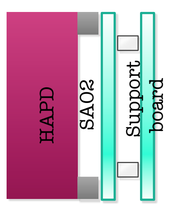
4.Photon sensor:

Hybrid avalanche photon detector (HAPD)
Developed with Hamamatsu Photonics.
144 channels, 4 APD chips (36ch/chip).
Pad size 5mm×5mm
Total area: 72mm×72mm.
Effective area 64mm×64mm (65%).
Bi-alkali photochatode 25% peak quantum efficiency
Bombardment gain factor 10^3
Avalanche gain in APD about 10
Total gain~10^4



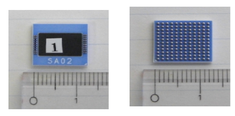






Mounting HAPD-Electronics

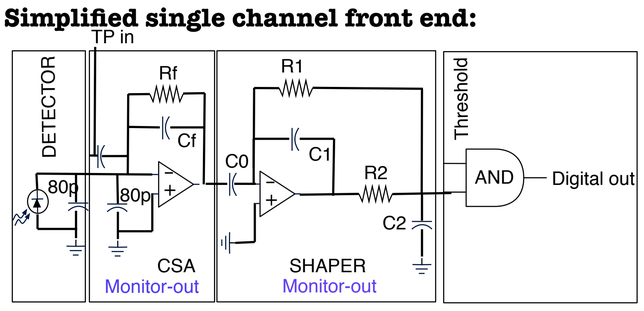
5. Asic digitizer - SA02



Process: TSMC CMOS 0.35 μm
Production at MOSIS - Japan
36 ch/chip
Std. Input Signal: 60000 e$^-$
Target Noise Level: 1200 e$^-$ @ 80pF (HAPD)
Chip size = 6.5mm × 3mm
Power consumption: 3.7 mW/ch
Variable gain: 20-70 mV/fC
Shaping time: 250-1000 ns
Offset adjustment: ±300mV (8bit: 5mV step)
Leading edge discrimination

LTCC - Low Temperature Co-fired Ceramic Package size 13x13mm

Simplified single channel front end:



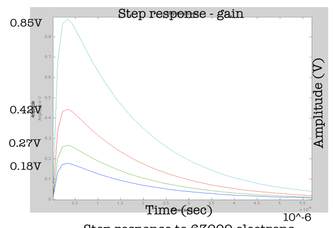
6. Asic Front End simulation:

A numerical model of simplified front end circuitry is presented using a transfer function (TF) in Laplace domain (s Laplace operator):

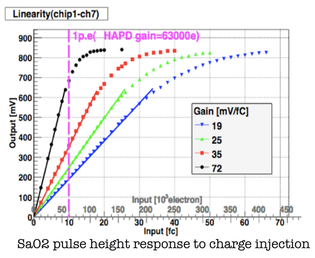
$CSA = -R_f/(1 + sR_fC_f)$

$SHAPER(s) = sC_0R_1/(2sC_2R_2+1)^2$

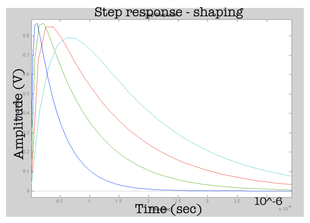
TF(s) =CSA(s)*SHAPER(s)



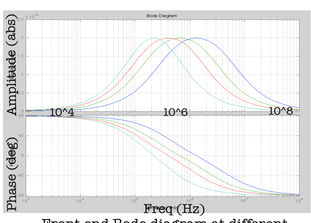
Step response to 63000 electrons with different gain settings



SA02 pulse height response to charge injection

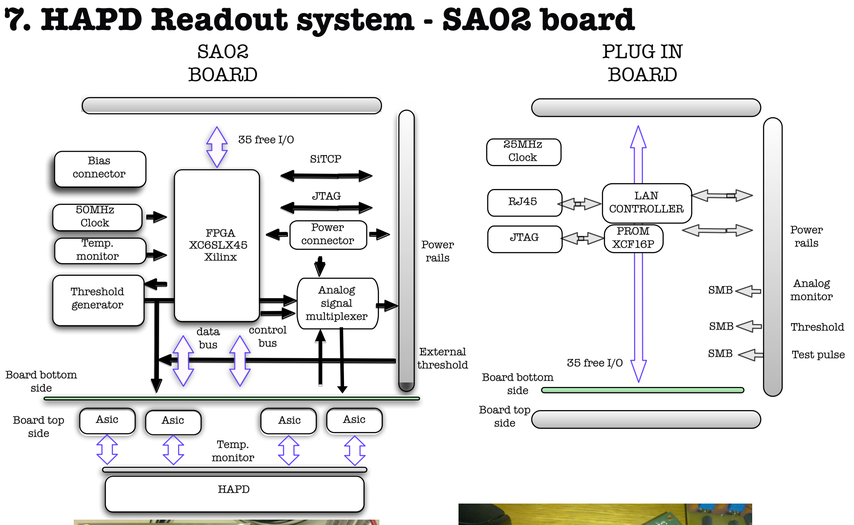


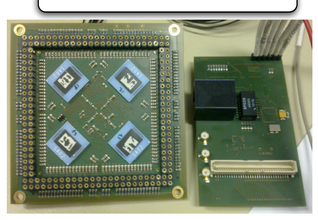
Step response to 63Kelectrons with fixed gain and different shaping constants

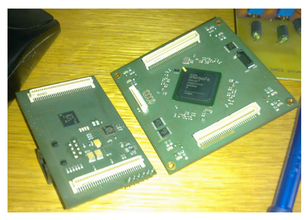


Front end Bode diagram at different shaping times

7. HAPD Readout system - SA02 board

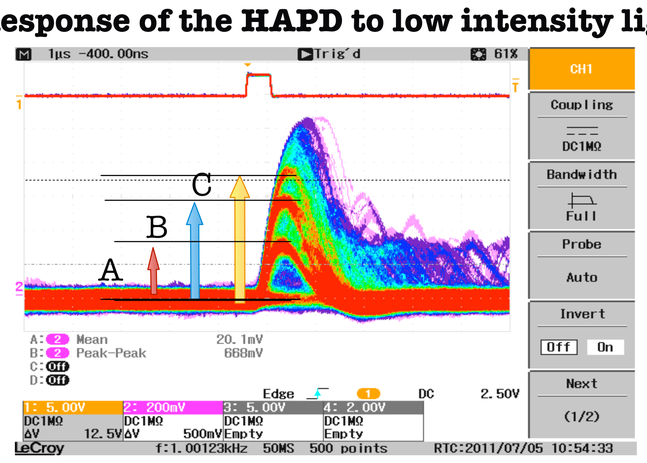


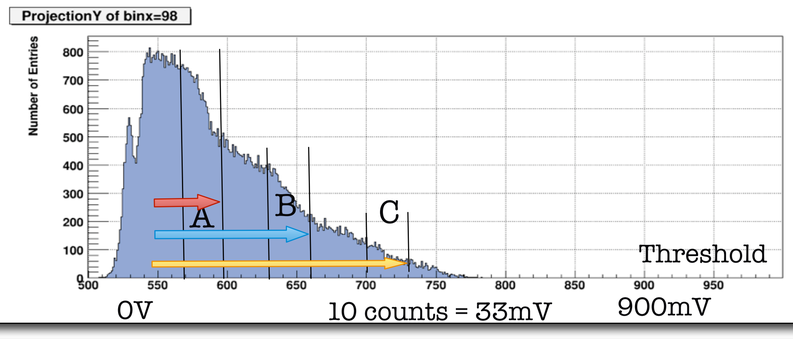


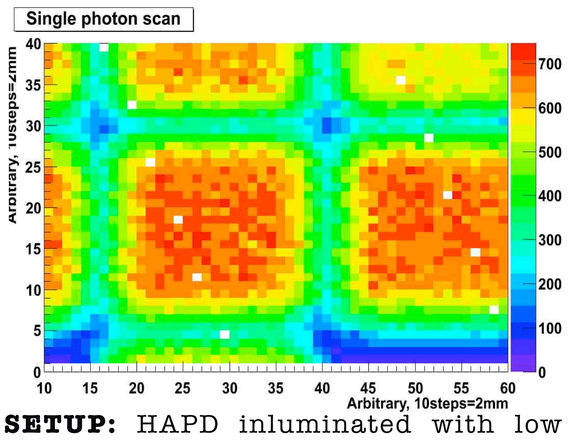


Plug in board is used for laboratory tests and debugging.

8. Response of the HAPD to low intensity light.

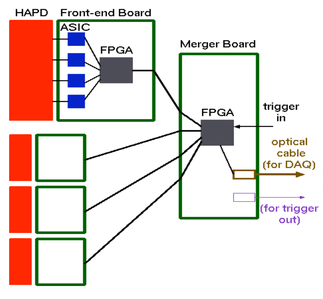






SETUP: HAPD inluminated with low intensity LED trigged light in light tight box.
Left top image shows monitor signal after shaper circuitry. A,B,C represent single,double and triple photon events respectively.
Left bottom image is threshold scan of the same channel.
Right top image made using led diode set to emmit mostly single photons. Partial HAPD 2D scan.

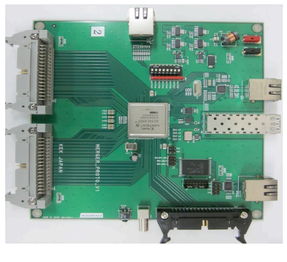
9. Belle II readout system

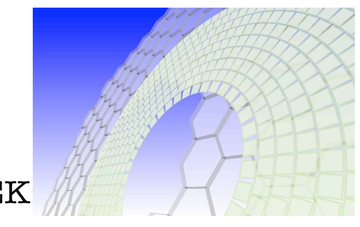


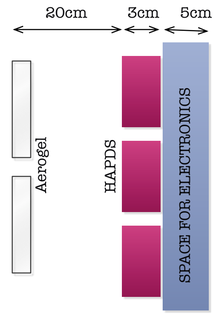
The Belle II ARICH detector will have 456 HAPDs.

- Available space is limited (4-5 cm)

Merger board:(functional prototype)developed at KEK
- Intended to merge signals from four SA02 boards
- Communication over fiber optic cable using Belle2Link
- JTAG, firmware loading functionality
- Trigger distribution
- data buffer to keep history of events.
- Different data compression methods under study.







10. Summary

The SA02 readout board was tested on test bench using single photons.

SA02V2 readout board (redesigned) includes patches from presented design. The newly developped system was tested in Speptember 2011 using Pion beam in SPS ring at CERN. Preliminary results show good operation.

We plan to verify the SA02 readout board under neutron exposure in order to verify its radiation tolerance. Next is to merge the SA02 readouts with the merger board and to verify the Belle2link communication over fiber optic link.

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