256-pixel SiPM based Imaging Camera and Its Status

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Overview of Talk:

• Cherenkov technique
• SiPM sensor
• Imaging Camera Electronics
• SW scheme
• Camera prototypes – 16 pixel/64 pixel
• 256 pixel Camera status
Cherenkov technique for Gamma ray study

- Faint
  - 1Tev Gamma -ray (10 photons/m²)
    > Big Dishes
- Fast light lasts for few ns
  > Fast sensor and Electronics
- Peaks at Blue @350nm
  > PMTs/SiPM

TACTIC at Mount Abu, Rajastan

HAGAR at Hanle, 4300m
Features

- 13x13mm – 4x4 array, 74% Fill Factor
- Sub-pixel: 3584 micro-cells of 50 μm pitch
- Low voltage (Vop=53V Typ.) operation
- High gain: $10^5$ to $10^6$
- Operating temp -20 to +60°C
- Spectral Response 270 to 900nm Peak at 450
- PDE 40% at 450nm
- Dark count typ 0.5Mcps at 25°C
- Cross talk 3%
- Temp coeff of BD voltage is 52mV/C
• BDV variation of 10% seen, **Independent Pixel Bias control** needed
• SiPM temp coeff varies by 2.56% across SiPMs, We need **independent temperature coeffs for gain compensation.**
Individual SiPM Calibration constants used for Camera operation

Gain = 581679.75xOV + 552125.38

VBD = 52.209xT + 50.958

OV = BiasV - BDV

Vary the BiasV proportional to BDV to maintain OV constant.
Imaging Camera and DAQ

**System Components:**
- Imaging Camera Electronics in focal plane of telescope
- Light Concentrator
- Hamamatsu G-APD S13361 4x4 array
- Processing, digitizing & data recording
- Back end Electronics 233x420x220mm
- Ethernet link to control room for control & data transfer
- Back end Module (233x20x220mm)
- Signal conditioning, Bias control & monitoring
- PCM
- Front end Electronics 360x360x280+24 mm
- RG-178
- CDM-16no
- DCM-1no
- CTM-1no.

**Graphical Elements:**
- Networked Servers in the Control Room

**Additional Information:**
- Date: 18/12/2020
- Event: DAEHEP2020
- Presenter: Suresh S Upadhya, TIFR
Camera Specifications

• **Specifications:**
  - Operating condition at Mount Abu and Hanle
    - Hanle 4300m altitude with temperature range of -30°C to 40°C
  - Field of View of 5.0°X5.0° with pixel resolution of 0.3°
  - SiPM as pixel sensor to increase the observation duty cycle
  - Pixel dynamic range of 1500 pe
  - Recording of pulse profile @1GSPS
  - Trigger rate up to few hundred with 3 or 4 near neighbour pixels as trigger criteria
  - In-situ gain Calibration of pixel
Camera Front-end status - PCM

LC Assembly

Pixel Cluster Module (PCM)

4 Pixel Pre-Amplifier

G-APD PCB

LV PS

8 ch. Bias Card

8 Cards inside a PCM (9x9x28cm)

Single sub-pixel pair enabled

2x(3x3mm)

Typical Dark Pulses

All sub-pixel pairs enabled

13x13mm
SPE spectrum of Pixels (13x13mm SiPM)@ 3V OV in a PCM
Camera Back-end Status

Connection flow of Back-end Modules

CDM-1    CDM-2    CDM-3    CDM-16

Data serial links

CSPI link

CSL, Pre-triggers

CTM

DCM: Cluster Digitizer Module
DCM: Data Concentrator Module
CTM: Control and Trigger Module

100 Mbps

1Gbps Ethernet links
Camera - Software Scheme

FE: Bias Control & Monitoring
- PCM-0
  - BIAS card 0 & 1 (µC-Firmware)
- PCM-15
  - BIAS card 30 & 31 (µC-Firmware)
  - Camera Bias Server in Raspberry-Pi

BE: Data Acquisition, Control & Monitoring
- CDM 0 (NIOS firmware)
- CDM 1 (NIOS firmware)
- CDM 15 (NIOS firmware)
  - CTM
    - Camera Control & Monitoring firmware
  - DCM
    - Event Data Server

Network switch (1Gbps /10Gbps)

Camera

Control Room

PC-1
- Data Base Server
- Data Base GUI

PC-2
- Bias Control
- FE Monitoring Data Acquisition

PC-3
- Main Console
- BE Monitoring Data Acquisition

PC-4
- Event DC-A
- Event DC-B
- Event Builder

NAS Storage system
( Configuration Database, Monitoring files, Event files, Log files )

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Network of Servers in Control room to Configure, control and monitor the Camera

Configuration Data base

FE control parameters Data base
Network of Servers in Control room to Configure, control and monitor the Camera

FE Monitoring

Main Console & BE monitoring
16-Pixel prototype under lab evaluation

LC assembly

PCM

BE : CDM, DCM, CTM

SW: Bias control and Monitoring, DCs, Event builder
DDB channels systematic noise and correction result

Before correction: sigma of 13mV

After correction: sigma of 1mV

Figure 4: The DC (0V) signal sampled at 1 GSPS before and after (red color) offset correction. Spike at 1-2 ns in the first DR3/DDB channel. This spike is present only in the first event data.
Pixel HG chl pulses of a DDB for pulsed light flash
After baseline correction from off pulse region
64-Pixel prototype - Status

Front End

• Modules are ready and tested independently
• FE integration is tested for its stability and performance
• Whole prototype integration test need to be carried out

Back-end

Camera prototype
Bias card and SiPM temperature Monitoring in room temperature

Bias card T over 3min samples

GAPD T over 3min samples
OV maintained for 8 channels in room T with compensation applied

OV variation of less than 0.5% is seen with 0.5C correction step
Status and Future plans

• 16 pixel prototype is under lab test for integration performance evaluation and long term stability
• 64 pixel prototype Hardware is ready for Lab test
• The LC testing and production of LC assembly is under progress
• SW development and integration test is under progress
• The conceptual design for mechanical housing for the Camera is under progress
• The production of front end modules for whole camera is under plan
• Immediate plan is to do performance evaluation of 64 pixel prototype in the field ie in the TACTIC telescope at Mount Abu

......THANK YOU.....