SiPM Research in Germany Status and Future Perspectives

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4th Detector Workshop of the Helmholtz Alliance Wednesday, March 16th, 2011 DESY, Hamburg

Ongoing Activities

DESY

Collaborations:

Aachen CMS, T2K, Medical Application, Fiber-Tracker [for PEBS] CMS, CALICE, Medical Application [PET] Dortmund Fiber-Tracker Gießen Panda, ATLAS [Cherenkov, AFP] CALICE, Medical Application [PET] Heidelberg Munich CALICE, SiPM Coupling, SiPM Design CALICE Wuppertal

> CMS: Aachen, DESY CALICE: DESY, Heidelberg, Munich, Wuppertal Medical Application: DESY, Heidelberg Fiber Tracker: Aachen, Dortmund

Analog HCAL: 1 m³ Prototype Steel/Scintillator sampling structure

approx. 8000 Channels Light detection with SiPMs

Calibration/Monitoring using MIPs and integrated LED system

Stable test beam operation since 2006















Tungsten HCAL [for CLIC, √s ≈ 3 TeV] Active AHCAL layers with SiPM readout 30 plates of 1 cm thick tungsten as absorber



T3B Tungsten Timing Test Beam [16 channels]

Goal:

Measure time structure of signals within hadronic showers

Small number of scintillator cells read out with high time resolution

via directly coupled blue sensitive SiPMs [layer at 3λ to avoid large signals] [use of fast USB Oscilloscope]

Time resolution: 800 ps





Outer Hadron Calorimeter

Measures leakage for high energy particles Presently: Scintillation light collected and guided to hybrid photo detector (HPD)



2012: HO 2015: Barrel + Endcap







CMS Large Scale Application of SiPMs Aachen, DESY Muon Track Fast Tag (MTT) for CMS 10 GeV µ-MTT sector Φ Scintillating Tile Option: MB1 Tkl MTT Sector MB1 area 10 tiles; 25 x 25 cm² each 25 cm Readout with SiPMs Х Solenoid 4 MTT sector n Muon tag signals send to (Track) Trigger 6 2.76 Muon Aachen: Study SiPM readout options Muon Trigger: Combine signals [Collaboration with CMS HO work] from MTT and Tracker Layer (TkL) Research work: Simulation of light transport and SiPM coupling ... Simulation studies also in ... Aachen, DESY, Heidelberg, Munich ... Tile [direct + indirect]



Large Scale Application of SiPMs A Fiber Tracker for Cosmic Ray Physics

High resolution fibre tracker [Beischer et al., arXiv:1011.0226v1] Scintillating fibers with $\emptyset = 0.25$ mm read out by special linear SiPM arrays

Prototype test beam measurements yield: 50 µm spacial resolution ...

[Dortmund: Irradiation Tests]











Large Scale Application of SiPMs A Fiber Tracker for Cosmic Ray Physics



Panda & AFP Giessen, Munich

Timing Measurements with SiPMs SiPMs for Panda and AFP

Requirements:

Very good time resolution [PANDA: $\sigma \approx 40$ ps for single photons; TOP meas.] [AFP: $\sigma \approx 20$ ps for multiple photons; coincidence meas.] Low dark count rate Long life time Operation in magnetic field [Panda, B $\approx 2T$] Radiation hardness

Gießen:

Study ToF and ToP determination with SiPMs ...

Munich:

Uniformity studies ...









SiPMs for Medical Application Positron Emission Tomography



DESY, Heidelberg



Electronic Development for SiPM High Gain vs. Fast Response

HEP Calorimetry

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KLauS: Charge Readout Chip [Kanäle für Ladungsauslese von SiPMs]

AMS 350nm CMOS technology SPI interface; tunable bias DAC High signal/noise ratio [>10, 40 fC signal charge]; Fast trigger available [pixel signal jitter < 1ns]; Large dynamic range up to 150pC

Klaus 2.0: Power pulsing; first SPS measured ... [To be part of SPIROC III]

[S. Callier et. al, IEEE NSS/MIC, 2009; 0.1109/NSSMIC.2009.5401891]

STIC: SiPM Timing Chip

[Fast Discrimination for ToF]

STiC 1.0: AMS 350 nm CMOS , 4 channels; Leading edge & Constant fraction trigger; Tunable bias DAC ~ 1 V; power < 10mW/ch Pixel jitter ~ 300 ps, time of flight capability

STiC 2.0: UMC 180 nm [in preparation] Differential design to explore timing limits ... Simulation: single pixel time resolution ~ 100 ps. [EndoToFPET-US project: STiC 2.0 + TDC ...]

W. Shen et. al, IEEE NSS/MIC, 2009; 10.1109/NSSMIC.2009.5401693





Teaching Students A Test-box for Future SiPM Researchers

SiPM key properties can be studied ...

Measurements w/o light:

Thermal noise rate (dark rate) Cross-talk I-V curve

Measurements with light:

Single photoelectron peak spectrum for gain determination Voltage and temperature dependence of the break-down voltage Linearity and saturation effects Waveform analysis

Data analysis performed with the ROOT ...





Concluding Remarks

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SiPM research is certainly "en Vogue" ... Many R&D activities by German institutions ...

Activities within Alliance (partially) combined in VSL ...

[Virtual SiPM Lab]

Knowledge exchange valuable ...

e.g. increase combined efforts concerning ...

Simulation of light transport and SiPM response ... SiPM characterization measurements ... Scintillator/SiPM coupling Readout electronics ... Industry contacts ...