Update on Time Resolution Improvement of Single Scintillator Tile for PANDA Barrel TOF

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PANDA Collaboration Meeting

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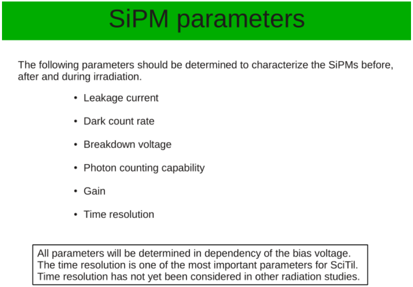
Outline

Impact of Radiation on SiPM performance

- NIEL hypothese: Radiation damage is proportional to non ionising energy loss. Normalisation to 1 MeV neutron.
- Expected dose over 10 years of PANDA lifetime: $\phi_{eq} \approx 9 \cdot 10^{10}$ n_{eq}/cm^2.
- Summary of radiation studies:
  - Dark count rate increases linearly with dose.
  - Dark current increases, loss of photon counting ability.
  - V. A. Kaplin simulates radiation damage: time resolution deteriorates $\approx 30 - 60\%$.
- open issues: Dependency of radiation damage on time resolution depending on: recovery time, size, type of SiPM.

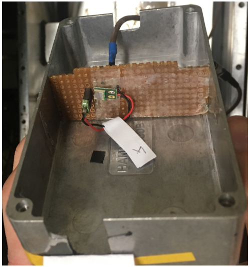


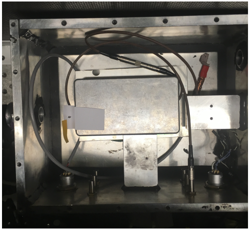
Lukas Gruber: Radiation damage studies of SiPMs for the SciTil detector of PANDA

Analysis of measurement before radiation is ongoing, not final results. Joint work with JLU Gießen.

Setup

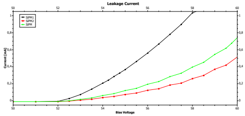
- 6 MPPC tested: 3x S13360-75PE (75μm), S13360-3025PE (25μm), S10931-025P, ASD-SiPM 35-P-50.
- Pulsed laser light, 100 kHz.
- Diffuser distributes light homogeneous over the SiPM.
- Set laser light to $\approx$ 1 photon/event.
- SiPM signal amplified, LeCroy Oscilloscope 735Zi with 40 Gs/s for data acquiring.
- Room temperature.
- For each SiPM 3 Measurements:
    - I/V curve.
    - Pulse height spectrum.
    - Single photon time resolution.

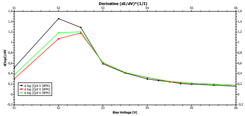


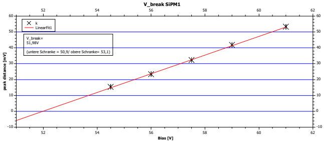


Measurement

- Leakage current → I/V curve.
- Breakdown voltage → d log(I)/d V.

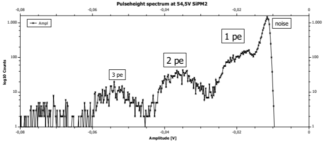


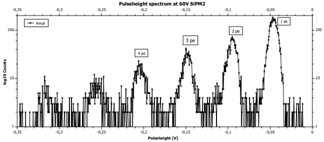




Pulse height Spectrum for different Bias Voltage

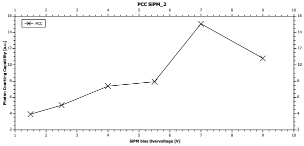
- Gain
- Photon counting capability → separation of single photon peaks.
- Breakdown voltage → extrapolate to separation of single photon peaks = 0.

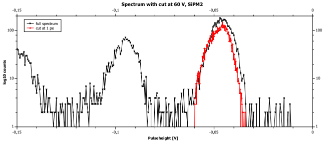


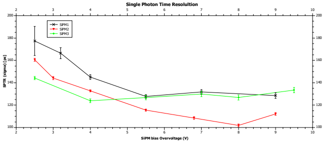


Single Photon Time Resolution

- Set threshold to 1 p.e. $\rightarrow$ Single Photon Time Resolution.
- Use laser signal for time reference.
- Take time difference of laser signal and SiPM.
- Measurement dependent on over-voltage.







Single Scintillator Tile improvement

- SciTil Design: 87 x 29.4 x 5 mm^3, 4 SiPM on each end.
- Study on the Scintillator Material (EJ 228, EJ 232, EJ 232.Q.05).
  - Signal Rise time $\longrightarrow$ affects time resolution.
  - Light output affects detector performance.
- Study impact of Scintillator thickness (3, 4, 5, 6 mm).
  - Small Scintillator thickness $\longrightarrow$ less photons produced.
  - Find optimum in material budget vs. time resolution.
- Study effect of polishing.
- Order of different samples to test.

PROPERTIES	EJ-232	EJ-232Q (% Benzophenone)				
		0.5	1.0	2.0	3.0	5.0
Light Output (% Anthracene)	55	19	11	5	4	3
Scintillation Efficiency (photons/1 MeV e⁻)	8,400	2,900	1,700	770	610	460
Wavelength of Maximum Emission (nm)	370	370	370	370	370	370
Rise Time (ps)	350	110	105	100	100	100
Decay Time (ps)	1600	700	700	700	700	700
Pulse Width, FWHM (ps)	1300	360	290	260	240	220

PROPERTIES	EJ-228	EJ-230
Light Output (% Anthracene)	67	64
Scintillation Efficiency (photons/1 MeV e⁻)	10,200	9,700
Wavelength of Maximum Emission (nm)	391	391
Light Attenuation Length (cm)	–	120
Rise Time (ns)	0.5	0.5
Decay Time (ns)	1.4	1.5
Pulse Width, FWHM (ns)	1.2	1.3

Barrel time-of-flight (TOF) detector for the $\bar{P}$ANDA experiment at FAIR

K. Suzuki [1], D. Steinschaden [1], S. Zimmermann [1 2],
N. Kratochwil [1], L. Gruber [3], C. Schwarz [4], H. Orth [4],
L. Schmitt [5], K. Gtzen [4], K. Brinkmann [2], A. Lehmann [6],
M. Bhm [6], K. Dutta [7], K. Kalita [7], M. Chirita [1]

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- How to calculate time resolution.
- Temperature of Detector, cooling.
- How to fix SiPM to SciTil.
- Why not using smaller single tiles.

Interesting talks

- PANDA:
  - Roman Dzygadlo, Cherenkov Group: *The Barrel DIRC Detector for the PANDA Experiment at FAIR*.
  - Mustafa Schmidt: *Particle Identification with Disc DIRC at PANDA*
- MEG II:
  - Gianantonio Pezzullo, calorimeter group: *Design, status and perspective of the Mu2e crystal calorimeter*
  - Ivano Sarra, calorimeter group: *The Mu2e calorimeter SiPMs*
  - Mitsutaka Nakao: *Results from Pilot Run for MEG II Positron Timing Counter*

Conclusion

- Start working on radiation hardness performance test.
- Expect $\approx 30\%$ worse time resolution after radiation dose due to increase of dark count rate.
- Order of new prototypes for laboratory test and beam time.
- SciTil detector represented at TIPP2017 (Beijing).