Study of MRS photodiodes for T2K experiment

Yury Kudenko

E. Akhromeev, G. Bondarenko^{*)}, V. Golovin^{*)}, E. Gushin, A. Izmailov, M. Khabibullin, A. Khotjantsev, B. Lubsandorzhiev, O. Mineev, Yu. Musienko, A. Shaikhiev, N. Yershov

INR, Moscow *) CPTA, Moscow

> *T2K detectors MRS photodiodes parameters tests 400 pixel MPPC's SMRD detectors with MRS APD's*

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ND280m





Scintillator detectors with WLS fibers

- Individual fiber readout FGD, POD, Ecal, SMRD, INGRID: ~ 60000 readout channels
- Limited space for photosensors
- Magnetic field

T2K decision in 2004: ND280m baseline photosensor -Multi-pixel Geiger mode avalanche photodiode

Photosensors for T2K

(2004 - 2005)

MPPC (Hamamatsu, Japan) 100/400 pixels



MRS APD (CPTA, Moscow) 556 pixels



T2K requirements:

pixels Active area Gain Minimum PDE **Bias voltage** Dark rate Pulse width Life time, stability very good

≥ 400 1.0-1.2 mm² ~10⁶ 12% 25-70 V ≤ 1MHz (th = 0.5 p.e.) ≤ **50 ns**

Structure of MRS APD



About 300 MRS APD's were tested in total

PDE

Photon detection efficiency (PDE) = $QE \times \varepsilon_{pixel} \times \varepsilon_{Geiger}$



Dark rate vs threshold



Th = 0.5 p.e. \rightarrow dark rate ~ 1MHz Cross talk <10%

Dark rate vs threshold

MPPC (400pixels) 6 devices





Parameters vs V_{bias}

MPPC

MRS APD 42V



MPPC-10 t=23.0-23.4 C; MPPC-2 t=25.5-25.9 C

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Operating voltage

MRS APD

MPPC



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Temperature dependence

MRS APD: 42V, 23V, 30V



Temperature dependence

MPPC (400 pixels)



Recovery time



T2K readout

Readout electronics for POD, ECAL, SMRD, INGRID TRIP-t ASIC





Pulse shape: MRS APD



Pulse shape: MPPC

MPPC 400 pixels $V_{\text{bias}} = 69.85 \text{ V}$



LED spectra

M. Raymond, Imperial





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Long term stability/Life time



For 3 years ~300 MRS APDs have been tested (~220 MRS-42V(1710); 40 MRS-23V, 30V and others) 14 (13 MRS-42V and 1 of an old type) APDs died at INR

10 400 pixel MPPC's were tested for about 2 months, 1 - for 0.5 year ALL are alive and show stable parameters

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SMRD counters

UA1/NOMAD magnet will be instrumented with scintillator counters → SMRD

SMRD comprises of about 2000 counters \rightarrow 4000 photosensors

Detection of high energy muons from ν interactions Cosmic trigger for TPC calibration

Physics requirements: Detection efficiency ~100% Dark rate <1MHz (<100 kHz for cosmic trigger)

Baseline design:

- Extruded scintillator (Vladimir, Russia)
 - ~ 90 x 17 x 0.7 cm³
- Chemical reflector
- One fiber KURARAY Y11, double clad, \emptyset 1 mm, S-bent, length ~2.5 m
- 3 mm deep groove
- Both end readout

Inner Detectors

μ



Spatial resolution



Beam test with 1.4 GeV/c pions
MRS APD 42V
well separated p.e. peaks
light yield15 p.e.
1.5 - 2.0 ns
spatial resolutiontiming (σ_t) 1.5 - 2.0 ns
99%

SMRD with MPPC

S-counter 7mm, cosmic muons, Photosensors: two MPPC's



 V_{bias} =69.8V \rightarrow I.y. = 22.9 pixels

$$V_{\text{bias}} = 70.0 \rightarrow \text{I.y.} = 31.8 \text{ pixels}$$

Parameters of MRS APD's and MPPC's

(room temperature)

	MRS APD (23V/30V)	MPPC
# pixels	556	400
PDE, %	25-32	30-33
Dark rate (th=0.5pe) MHz	1.0	0.3
Cross talk, %	<10	<20
Gain	(0.3-0.5)x10 ⁶	0.8x10 ⁶
Pulse shape	long tale	<50 ns
Single p.e.	+-	ОК
Recovery time	a few μs	≤ 20 ns
Temperature dependence:		
Signal	-(2-3)%/deg	-(6-8)%/deg
Dark rate	60 kHz/deg	(10-12) kHz/deg

Conclusion

Remarkable progress in GM APD's for last 2 years

MPPC: almost met the T2K requirements

MRS APD: problem with pulse shape/gain long recovery time (?)

Lifetime, long term stability should be extensively studied

T2K/ND280 will be the first large experiment/detector which will use Geiger mode APD's as photosensors