Comments on the Use of Avalanche Photodiodes in the Electromagnetic Calorimeter of a Tau-Charm Factory

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Introduction

Avalanche photodiodes are relatively new devices, about to be used in a large-scale experiment (CMS) for the first time: 61,200 $PbWO_4$ crystals to read out (earlier proposed for TEXAS and SDC fibre trackers).

High electric field leads to avalanche multiplication following electron-hole pair creation due to absorbed photons.

- Advantages:

– Much recent R&D

– Several manufacturers (EG&G, Hamamatsu, RMD)

– (can be) Radiation hard and able to work in large $\vec{B}$ fields

– Provide gain of $\sim$ 100 easily with bias ~ 400 V

– Very high QE (~ 80 %)

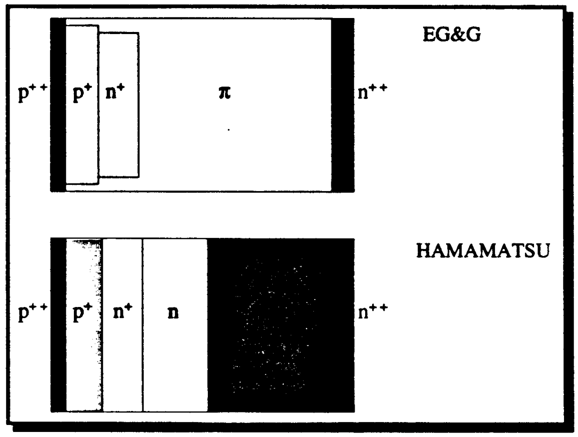
– Small and mechanically robust

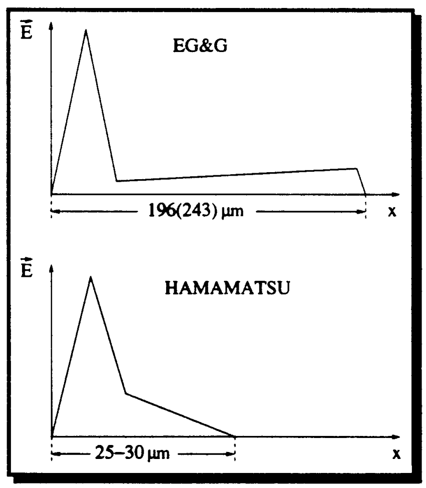
– Fast (low capacitance); Gain $\times$ BW = 100 GHz easy

Introduction

- **Drawbacks:**
  - **Gain is voltage-sensitive ($1/M\ dM/dV \sim$ a few %/V typical)**
  - **Gain is temperature-sensitive ($1/M\ dM/dT \sim 3\%/^{\circ}C$ typical)**
  - **Noisier than PMT's (at least at normal temperatures); fluctations; excess noise factor**
  - **Maximum size $\sim$ 5 mm$\times$ 5 mm (but can use pairs)**
  - **Care needed with "Nuclear counter effect"**

Device Structures





Device Characteristics

Diode	Area [mm^2]	Bias at Gain 50 [V]	I_{bulk} [nA]	C [pF]	Q.E. at 480 nm [%]
BC-16	19.6	183.5	6	140	63
EG&G-15	25	365	9.2	25	78
EG&G-3	25	420	16.2	20	83
S3590-01	100	$40(M = 1)$	0.6	69	65

Table 1: Parameters of APD's and PIN photodiode measured at 20 C before irradiation.

Diode	Bias at Gain 50 [V]	I_{bulk} [μA]	L_{eff} [μm]	Q.E. at 480 nm [%]	neutron fluence [n/cm^2]
BC-16	183.5	13	4.5 ± 0.5	51	2.33×10^{13}
EG&G-15	374	30	9 ± 1	78	2.33×10^{13}
EG&G-3	450	39	11 ± 1	83	2.33×10^{13}
S3590-01	$5(M = 1)$	13	170 ± 10	63	2.17×10^{13}

Table 2: Parameters of APD's and p-i-n photodiode (last line) measured at 20 C after irradiation.

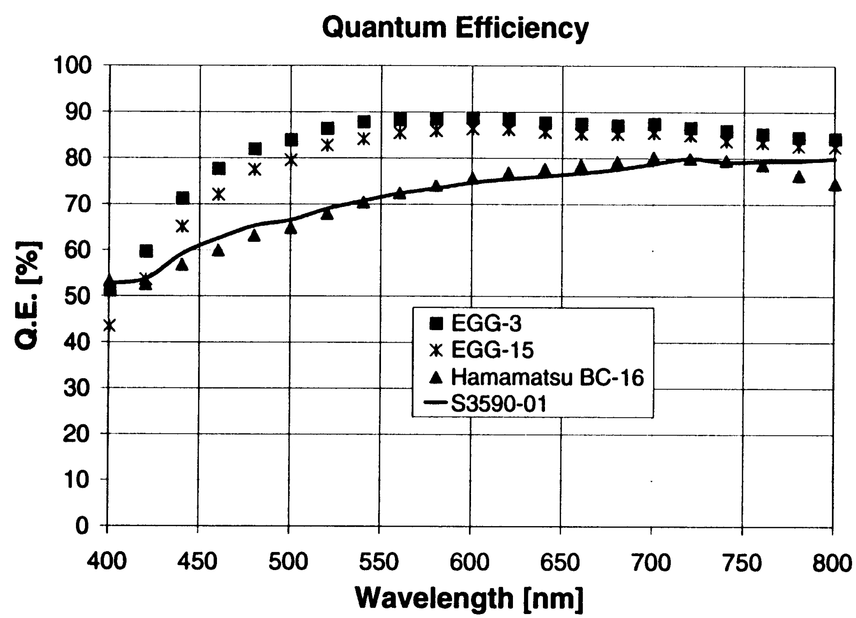


Figure 1: Measured quantum efficiency versus wavelength for APD's and S3590-01 photodiode.

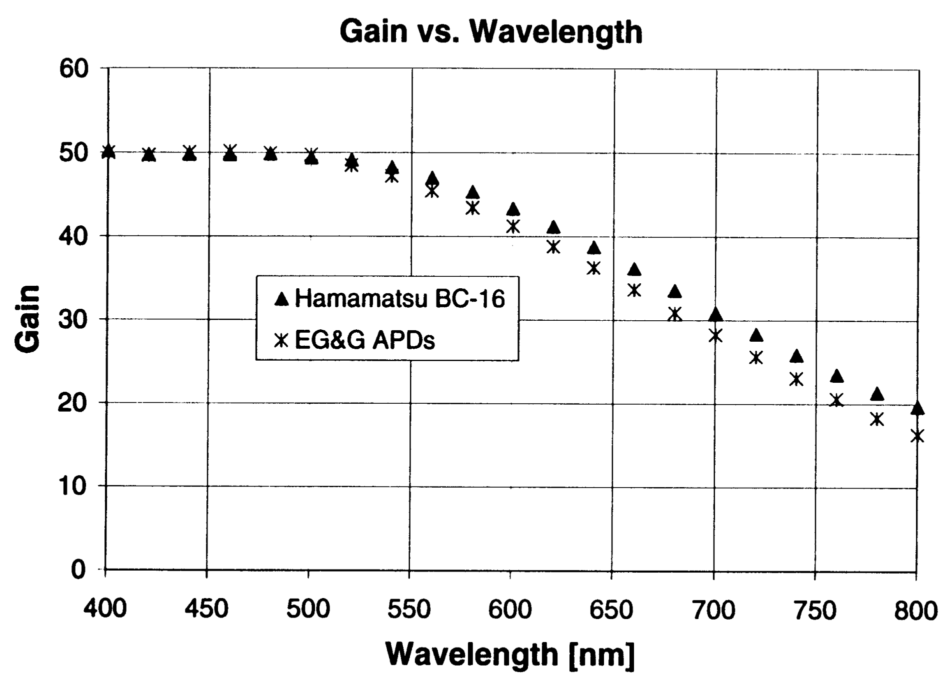


Figure 2: Gain as a function of wavelength for Hamamatsu and EG&G APD's.

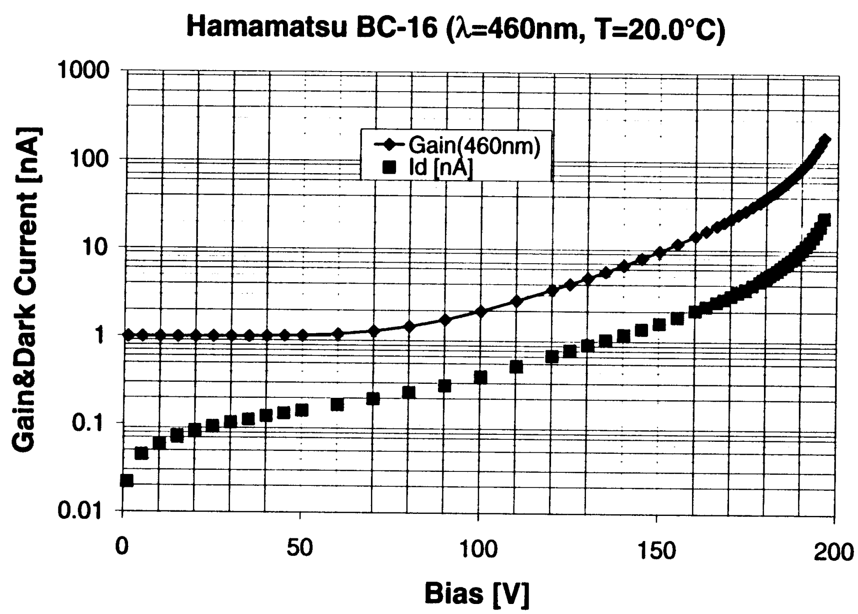


Figure 3: Gain and dark current as functions of bias voltage for Hamamatsu BC-16 APD measured before irradiation.

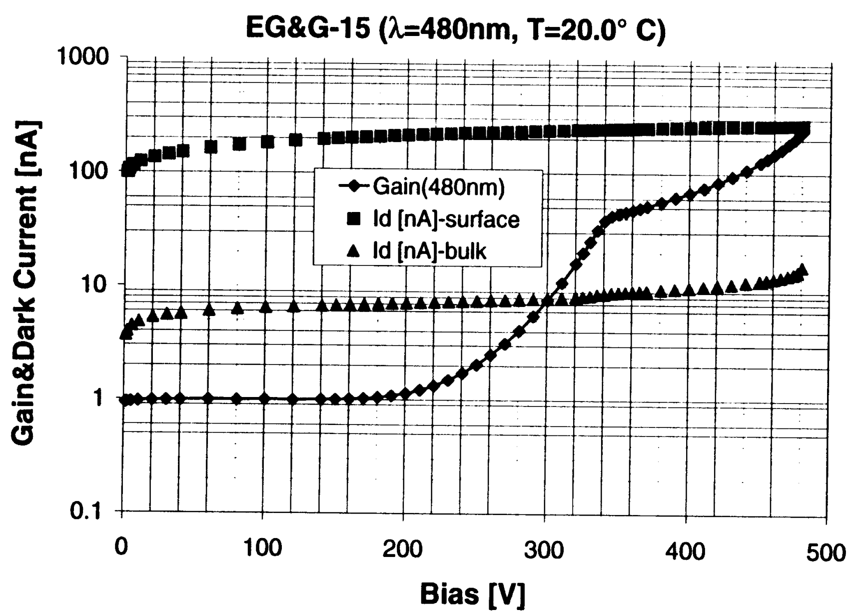


Figure 4: Gain and dark current as function of bias voltage for EG&G-15 APD measured before irradiation.

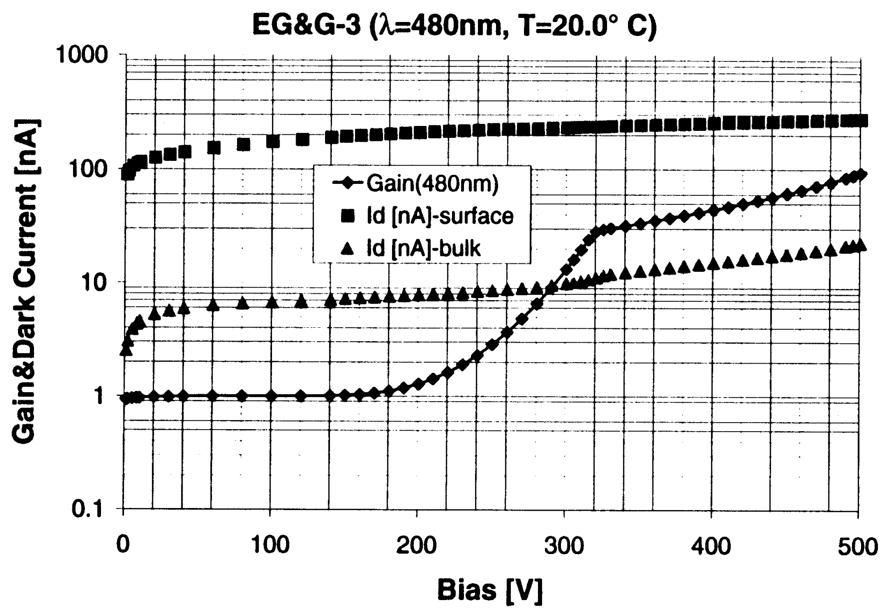


Figure 5: Gain and dark current as function of bias voltage for EG&G-3 APD measured before irradiation.

Conclusions

- **Avalanche photodiodes are potentially attractive readout devices for next generation experiments**
- **They are no longer “exotic” (use in CMS as well as in telecommunications and PET scanners – expect prices to drop)**
- **Detailed studies may be needed, but manufacturers are used to dealing with HEP customers and eager to be involved in R&D**