Very low power, High Voltage base for a Photo Multiplier Tube for the KM3NeT deep sea neutrino telescope.

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Outline

- Design requirements for the high voltage circuit board.
- System overview.
- HV generation.
- Diagram.
- Where will these high voltage circuit boards being used.
- Measurement results.
- Prototype of the high voltage circuit board.
- Summary

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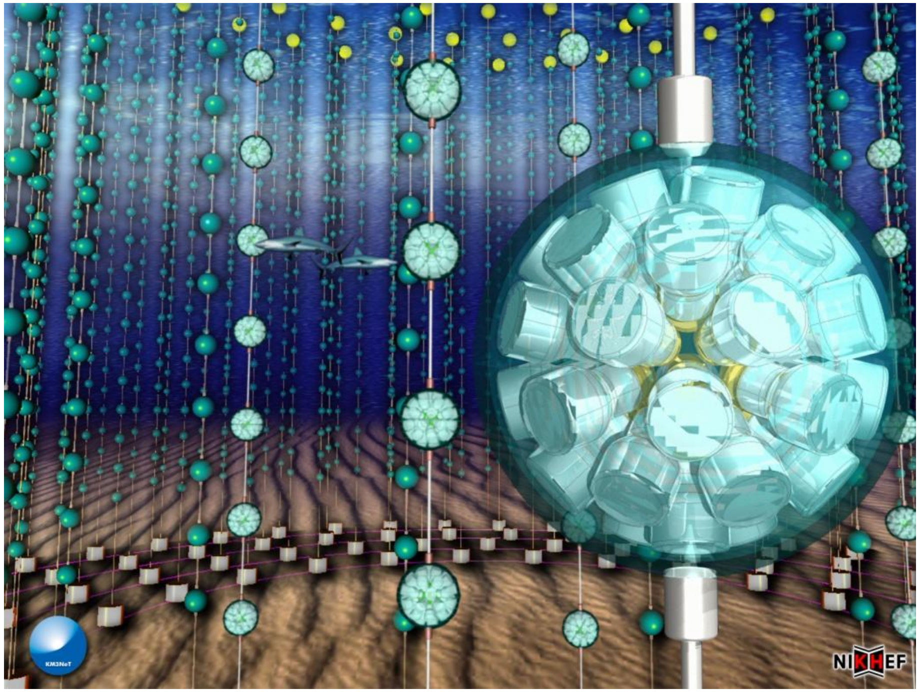
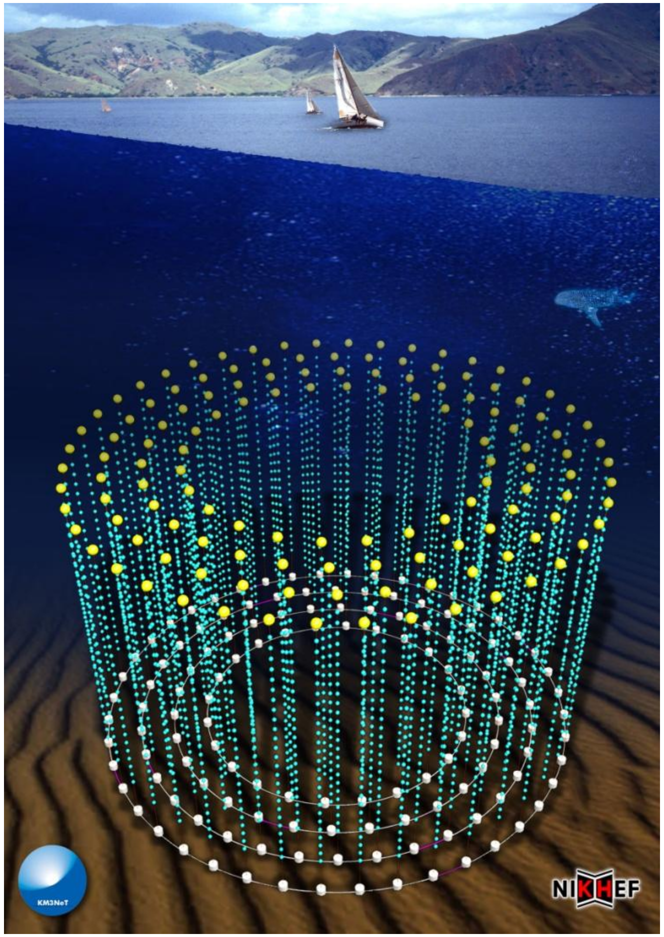
Multi PMT Optical Module system for detection of neutrinos



Location: Seabed of the Mediterranean Sea.
Embracing: several cubic kilometers of seawater, max. 5000 meter depth.
Number of optical modules: 12000
Number of PMT’s: 372000



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What is KM3NeT

•**KM3NeT** is an acronym for cubic kilometre size (**KM3**) **Ne**utrino **T**elescope and will host a neutrino telescope in the form of a water Cherenkov detector with a volume of at least one cubic kilometre.

•KM3NeT will search for neutrinos from distant astrophysical sources like gamma ray bursts, or colliding stars.

•An array of thousands of optical sensors will detect the faint light in the deep sea from charged particles originating from collisions of the neutrinos and the Earth.

•For the detection of this faint light (photons), Photon Multiplier Tubes will be used. 31 PMT's will be housed in a single Optical Module. A total of 300 detection units arranged in a string with 20 optical modules will be deployed.

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Detecting photons caused by neutrinos.

•Photons caused by neutrinos are masked by background photons.

•Background photons come from decay of potassium 40 in the water,
the glass of the sphere and the glass of the PMT itself.

•These photons are detected by the PMT's as single photons.

•Bioluminescence is also a source of photons.

•PMT's will have a their own dark count (caused by thermal electrons)

•Consequently, all PMT's generate random signals.

•Selecting the signals caused by neutrinos in the huge dataflow will be a defiant job.

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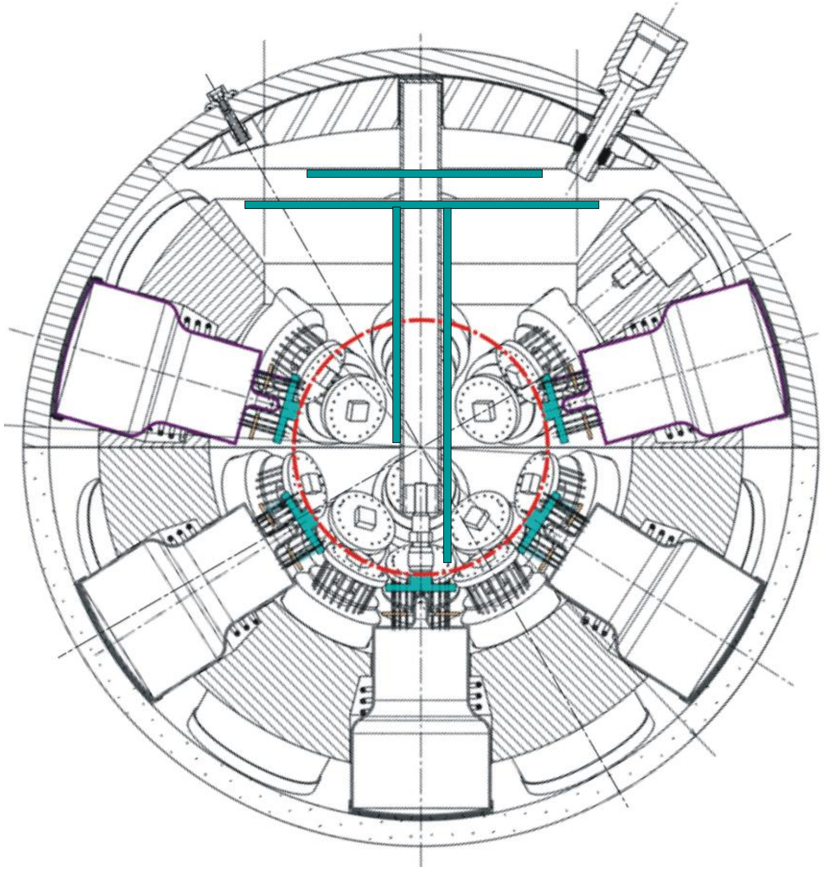
Optical Module



Vitrovex sphere 17 inch

12 PMT's in the upper half of the optical module
19 PMT's in the lower half of the optical module

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Design requirements for the high voltage circuit

Every PMT must give the same output signal as it is hit by a single photon.
The gain of a PMT depends on the level of the supplied high voltage.

The HV for each PMT needs to be individually adjustable.
Consequently **each PMT gets its own HV circuit board**.

Limited space in the OM available.
Only in the centre of the sphere is room for the electronics.
Consequently **limited board space**.

Heat dissipation must be kept to a minimum.
No active cooling in the sphere available. The produced heat has to be transferred through the glass to the seawater
Consequently **low dissipation**.

Good design rules imply also low ripple and low RFI generation.

Be aware, if the circuitry dissipates e.g. 0.5 W more,180 kW extra has to be transported over 100 km from shore to the detector.

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PMT global specifications

The detector will be designed for a lifetime of 15 years.
The lifetime of a PMT depends on the maximum amount of charge the anode can supply.
Because of this property a low gain PMT has been chosen.
A low gain PMT means a dedicated pre amplifier.

Cathode characteristics

Radiant blue sensitivity at	470 nm > 130 mA/W
QE at	470 nm > 20%
Non homogeneity of cathode response	target +/- 10%, +/- 20% acceptable

Characteristics with voltage divider

Maximum supply voltage	1400 V
Maximum Gain	$5 * 10^6$

External electro static coating to the cathode

Anode characteristics

Dark count	< 500Hz at 15 °C, > 0.3 pe threshold
Pulse rise time	< 3 ns
Duration at half height	5 ns FWHM at single photon
Transit time spread	< 2 ns sigma
Peak to valley ration	3, typical 2

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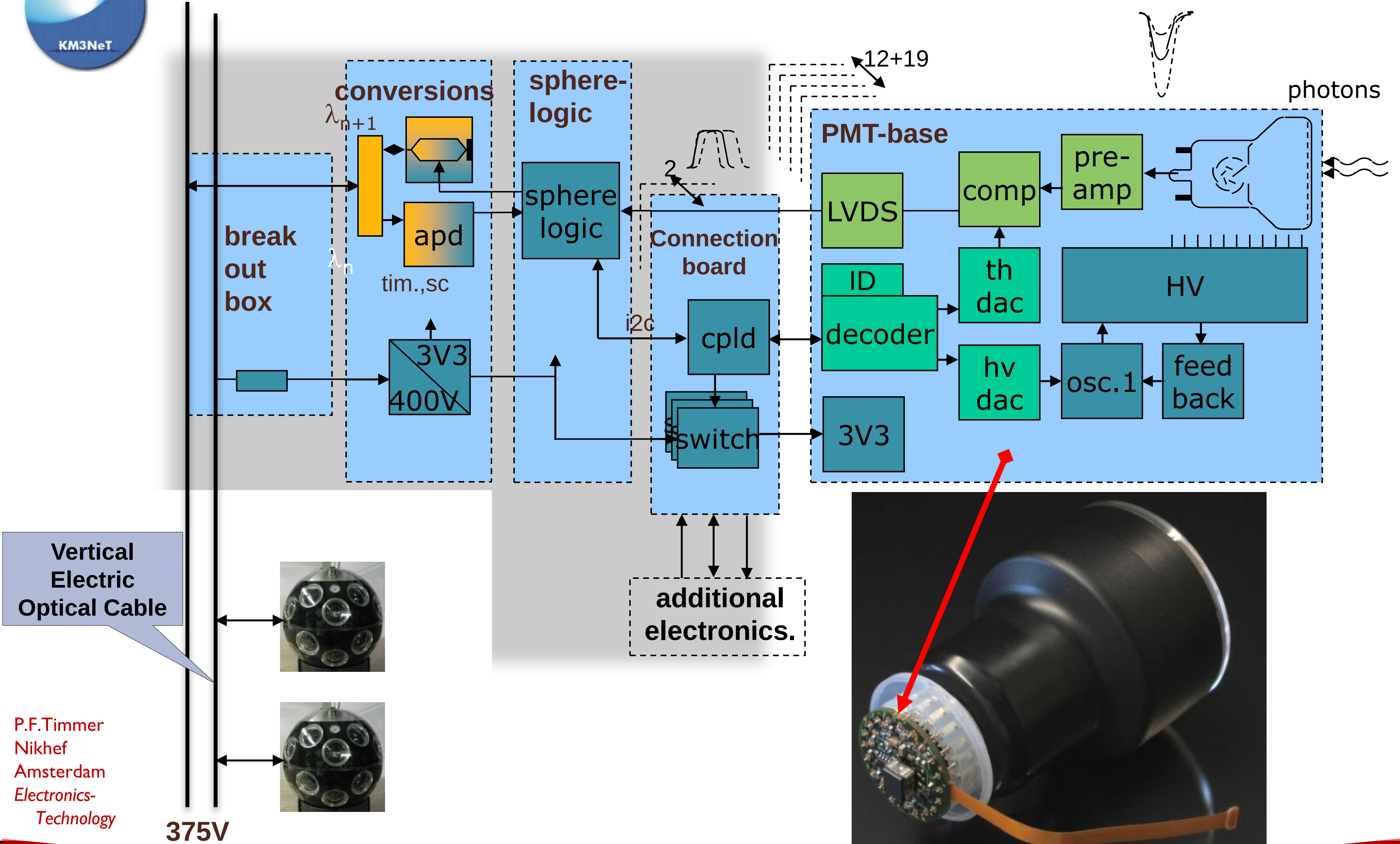
Electrical/Optical Diagram of the Optical Module



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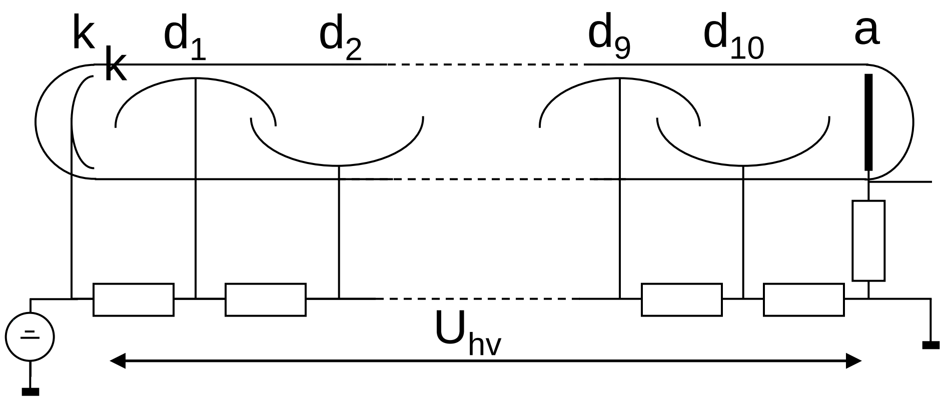
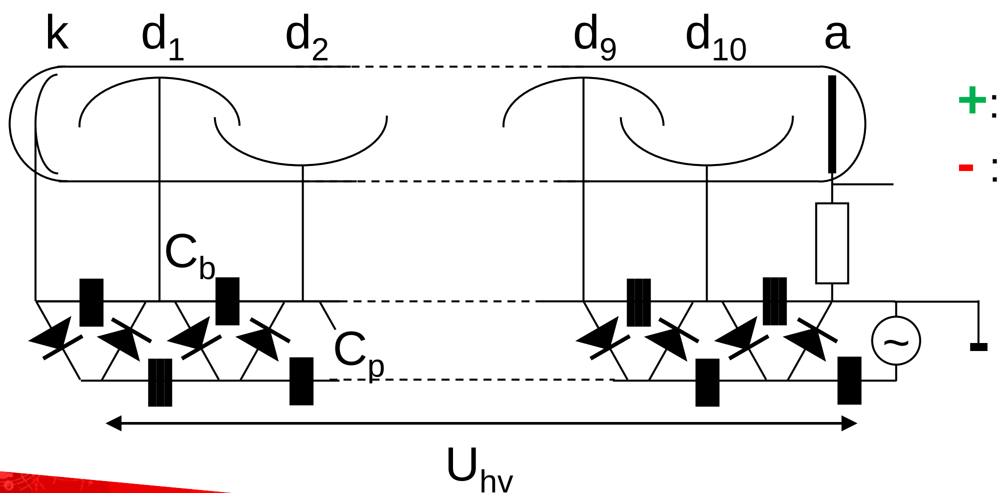
HV generation 1

Resistor Base



- 'High' power dissipation
- Temperature Sensitive output voltage
- Bigger volume then CW base
- DC current 10 times anode current

Cockroft Walton base



+: Low power dissipation then RB

- : Fixed voltage ratio

no DC current

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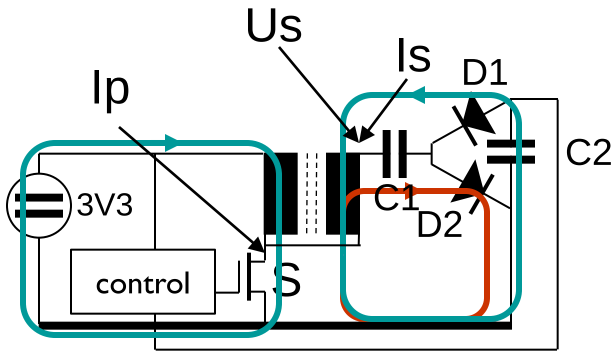
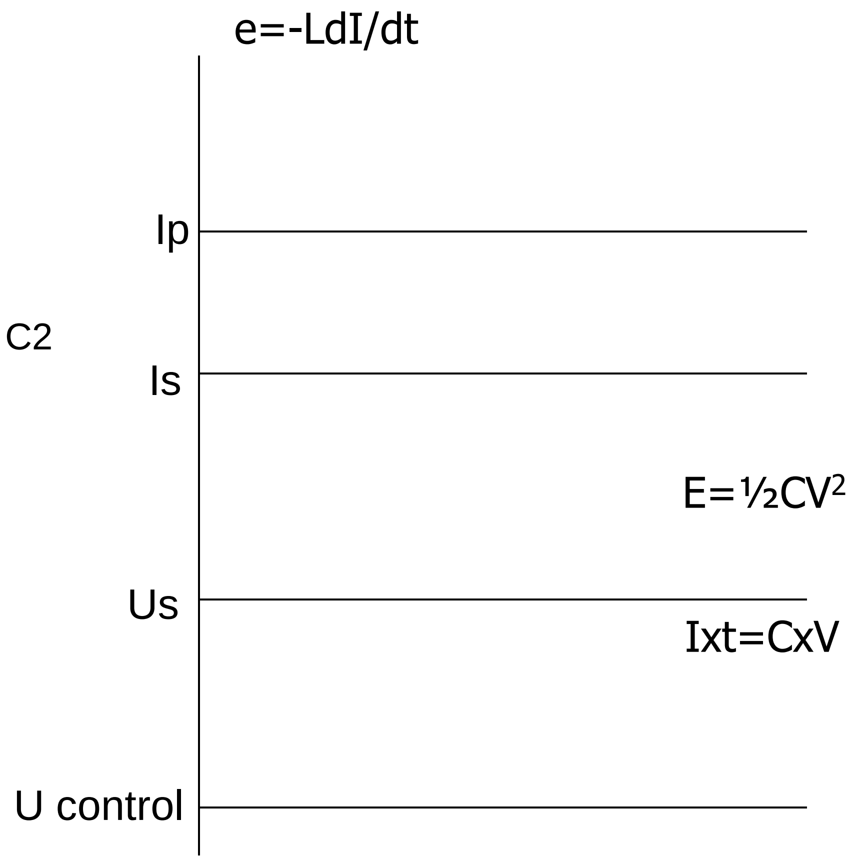
HV generation 2

Fly back principle





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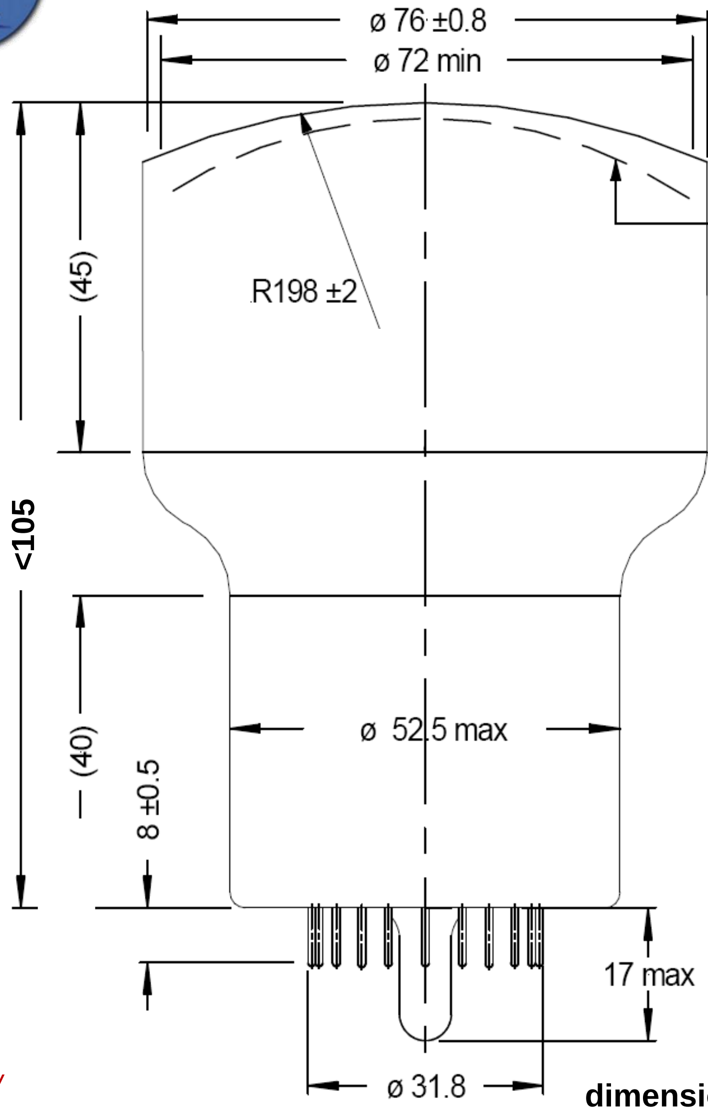
PMT proposed form factor



cathode voltage -800 - -1400 V

Voltage dividing ratio
(between Cathode and Anode Photonis XP53B20)

K DA G D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 A
0.15 1 1.5 2 1 1 1 1 1 1 1 1 1
(total: 13.65)

PCB = 38 mmØ

dimensions in mm

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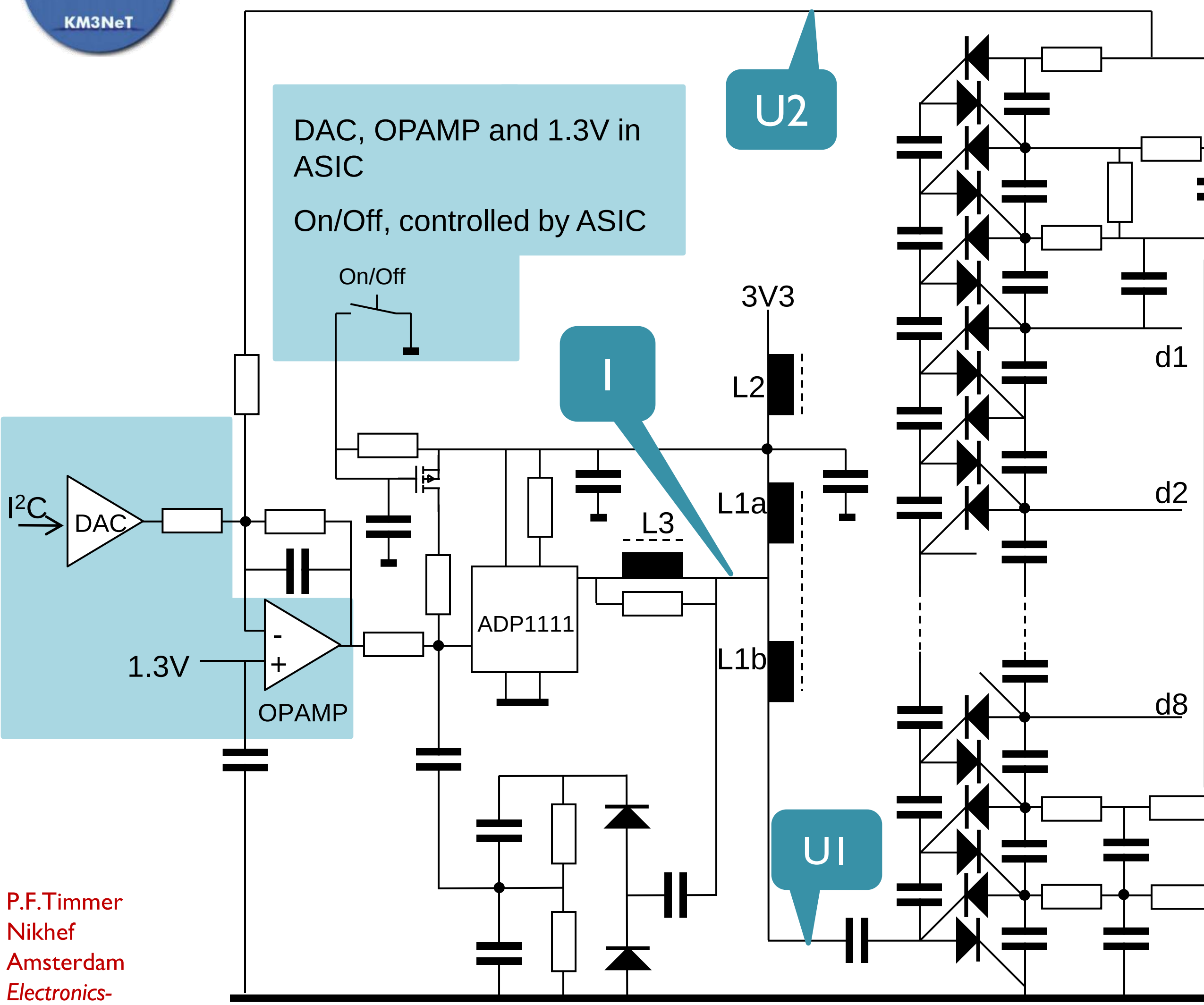
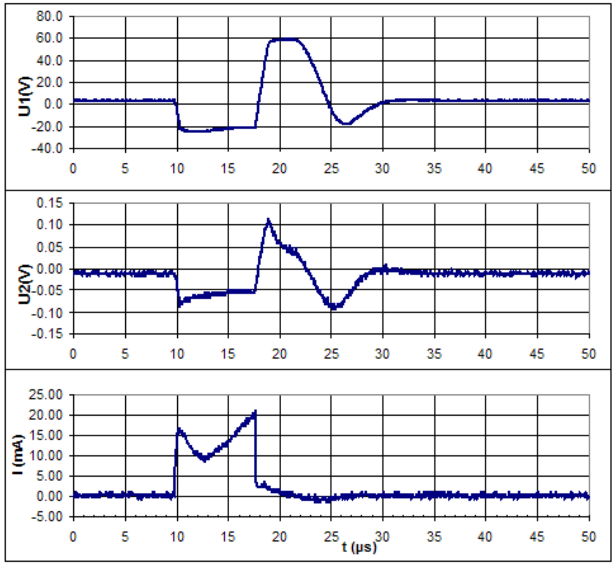
Diagram



Component choices,
-Transformer core
-Diode switching characteristics
-Control IC
-ASIC, low dissipation, less space



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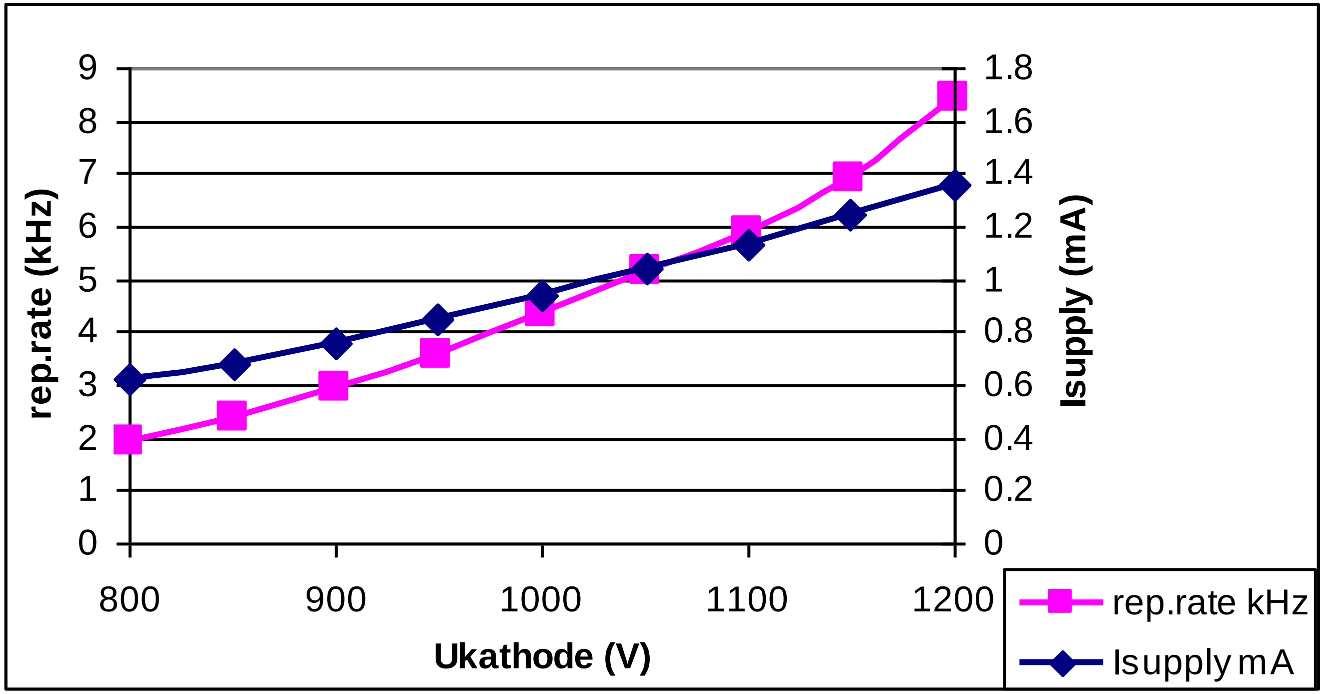
HV versus frequency and Isupply



Power and frequency

2 - 9 kHz at 800 - 1200 V

0.6 - 1.4 mA_{3v3} at 800 - 1200 V (0.66mW-4.6mW)

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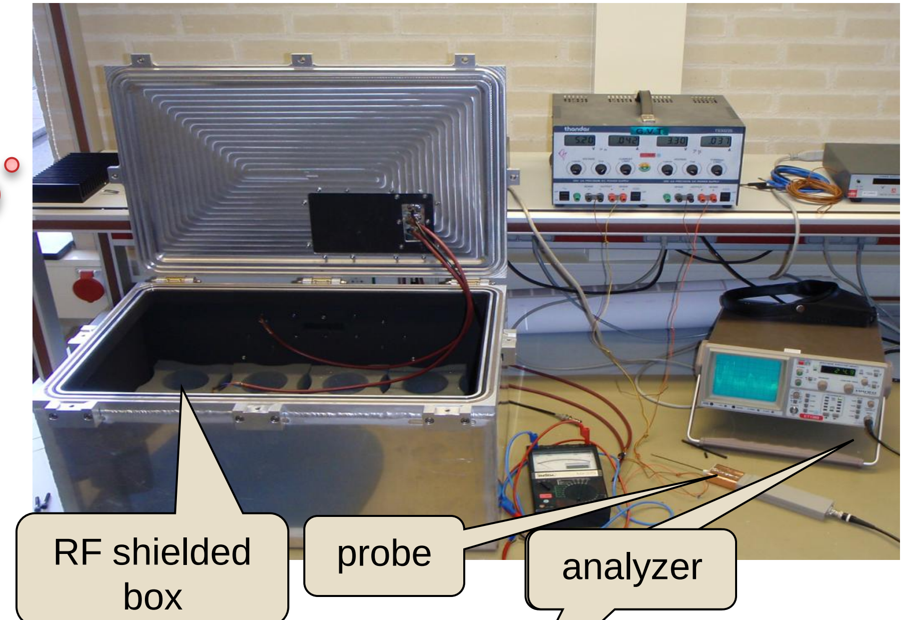
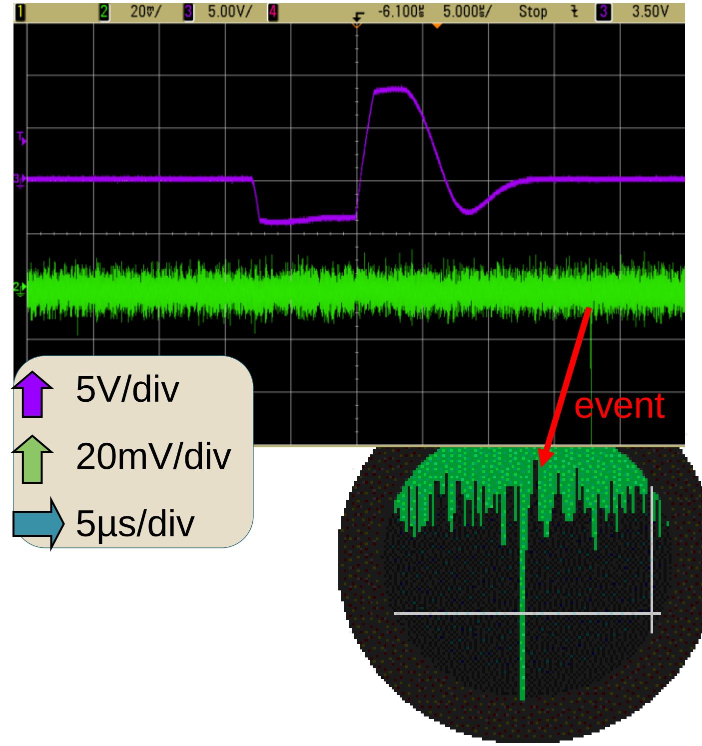
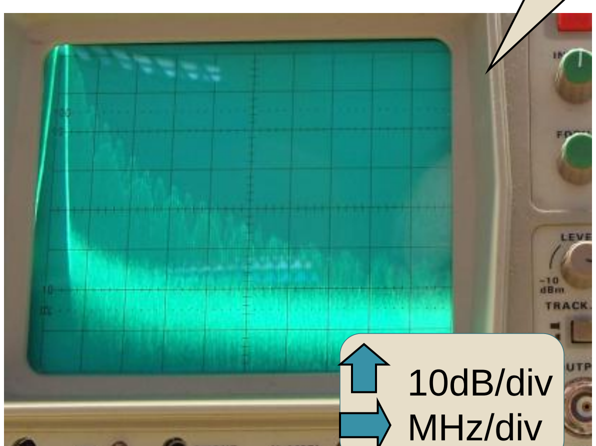
EMC







RFI -20 dB @ 150 kHz-10 MHz

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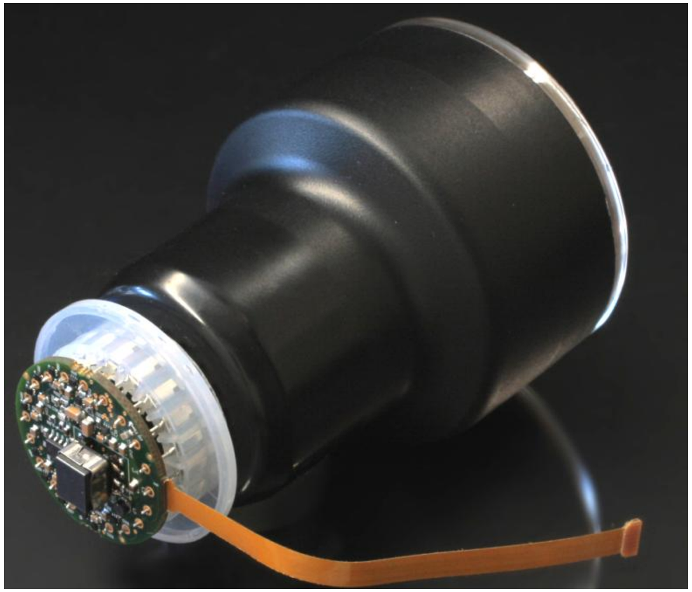
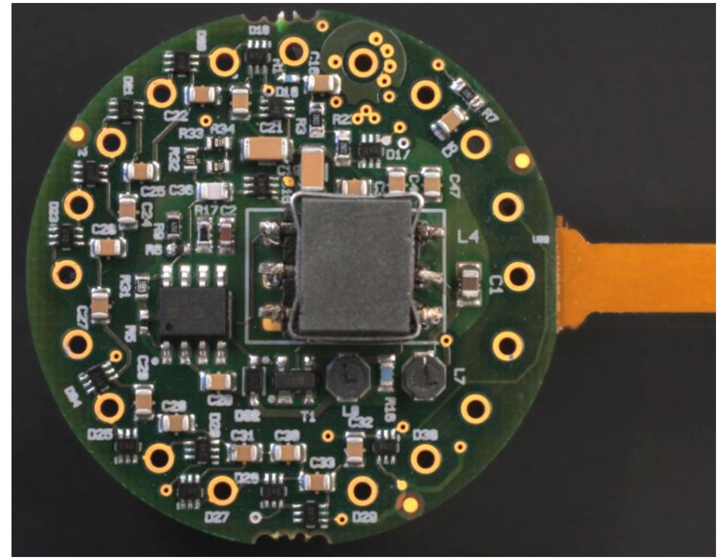
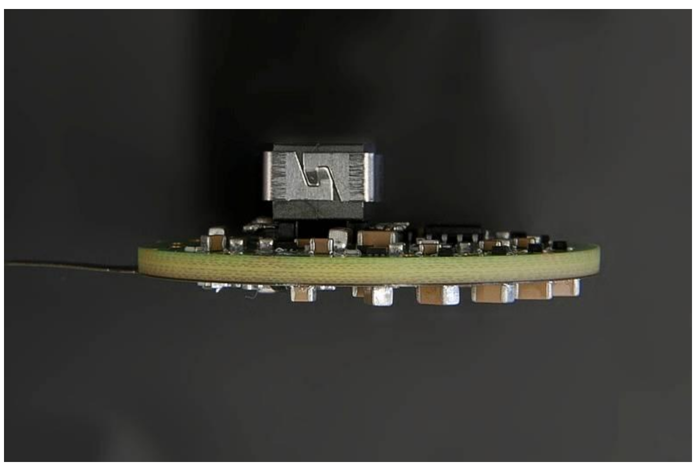
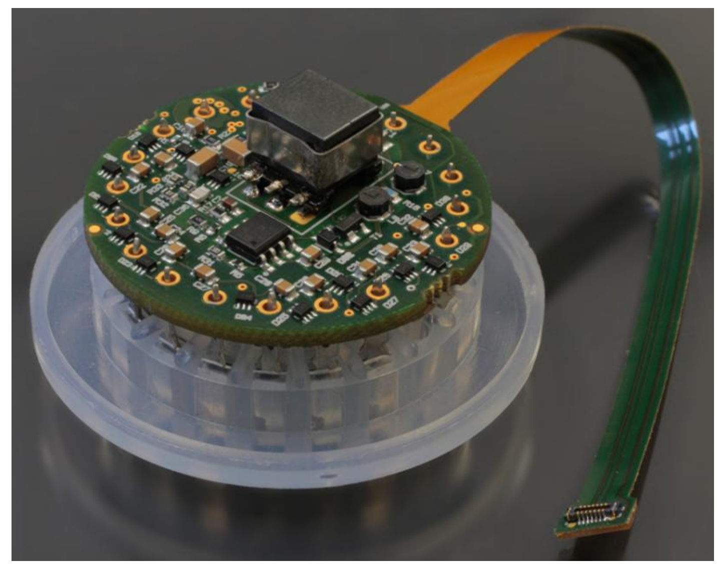
PMT and HV circuit









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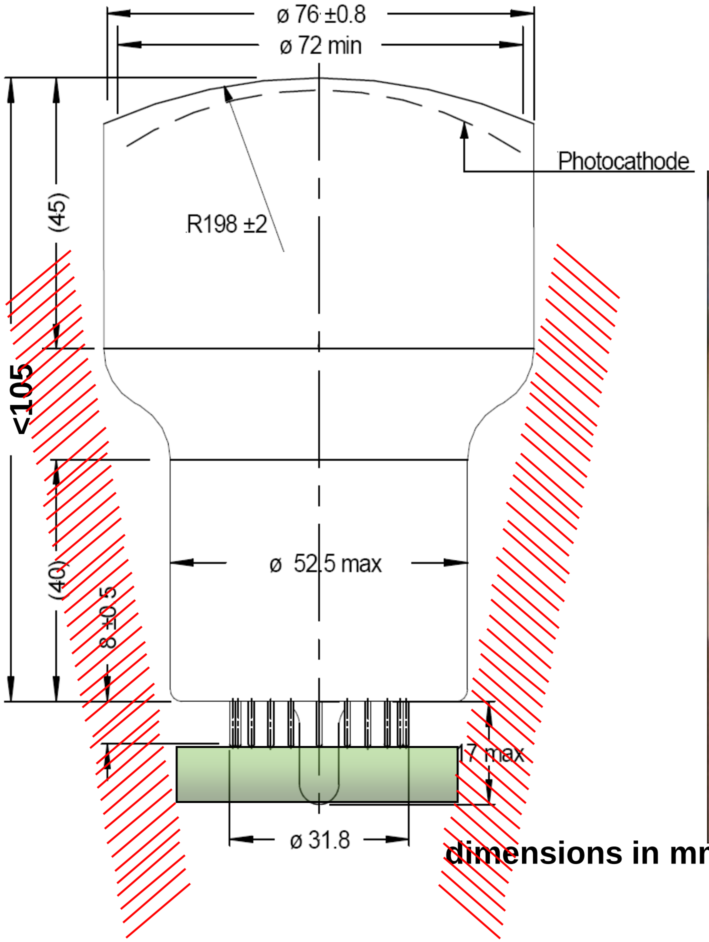
Form factor mostly dictated by PMT



dimensions in mm

PCB space

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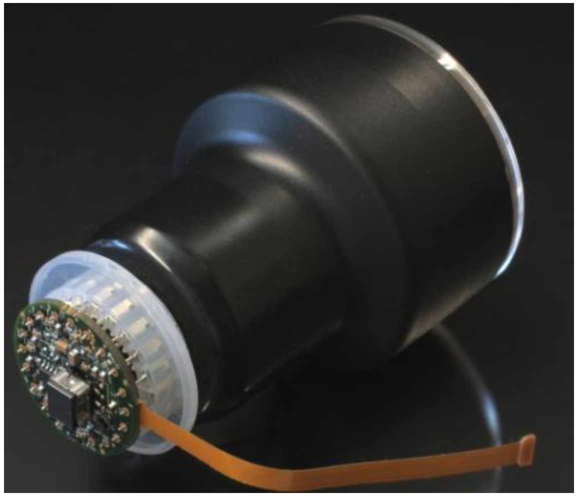
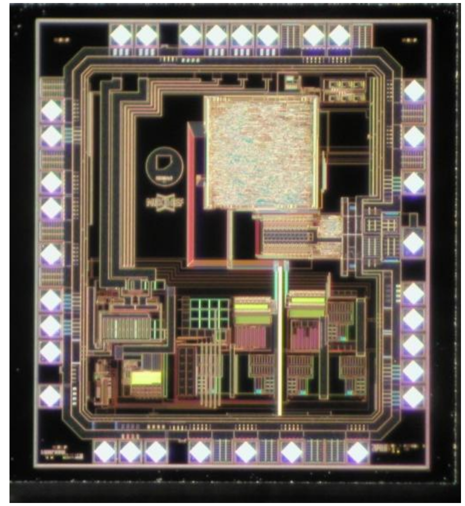
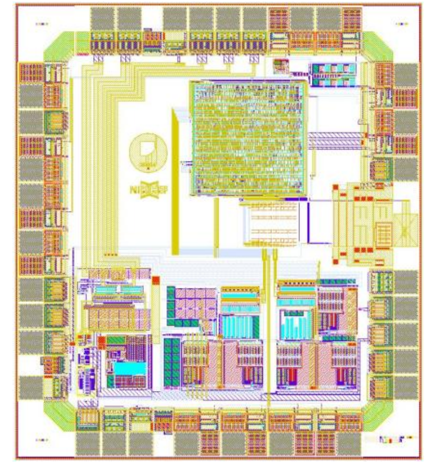
PMT base







V_{ripple} 706 mV_{1056} 8.5 < T(°C) < 22.1
V_{ripple} 0.07% 8.5 < T(°C) < 22.1
V_{ripple} < 150 mV/dynode
Voltage stabilization 0.95% on 38% input variation
Supply voltage 2V5 < 3V3 < 4V0
Power .6 - 1.4 mA_{3v3} at 800 - 1400 V < **4.5 mW**
dV/dt < 75 mV/µs, RFI -20 dB @ 150 kHz-10 MHz
cathode voltage -800 - -1400 V
Voltage divider (between D1 – D10 and A for Photonis XP53B20)

K	DA	G	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	A
0.15	1	1.5	2	1	1	1	1	1	1	1	1	1	

(total: 13.65)
PCB = 38 mmØ

Time resolution	2 ns
Two-hit time separation	25 ns
Threshold DAC	8 bits
HV DAC	8 bits
PROM (ID)	20 bits
Communication I^2C	
Supply voltage	3V0 < 3V3 < 3V6
Power consumption	20 mW
Technology	350 nm CMOS
Silicon area	1.6 mm x 1.8 mm

Presentation given by Deepak Gajanana
A Front End ASIC for the read out of the PMT in the KM3NeT Detector

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Summary

HV circuit, designed for a 10 dynodes PMT after the requirements

- ✓ **Adjustable HV**
  cathode voltage -800 - -1400 V
- ✓ **Small footprint**
  PCB = 38 mmØ
- ✓ **Low power**
  Vinput 3.3V
  0.6 - 1.4 mA_{3v3} at 800 - 1200 V < **4.5 mW**
  (commercial available 50 mW)
- ✓ **Low ripple**
  706 mV_{1056} 8.5 < T(°C) < 22.1
  0.07% 8.5 < T(°C) < 22.1
  Vripple < 150 mV/dynode
- ✓ **Low RFI**
  RFI -20 dB @ 150 kHz-10 MHz

Thank you

Amplifier

With a prototype of the dedicated amplifier 80 fC was successfully detected. (PMT gain $0.5*10^6$)
No influence of the switching cycle of the HV converter was seen.

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