Characterisation of High-QE PMTs

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Schule für Astroteilchenphysik, Obertrubach, 7. - 15. Oktober 2009

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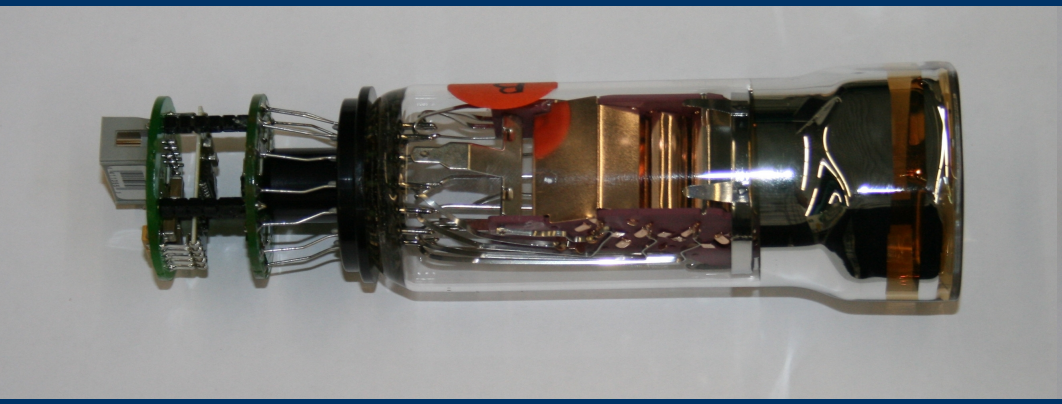
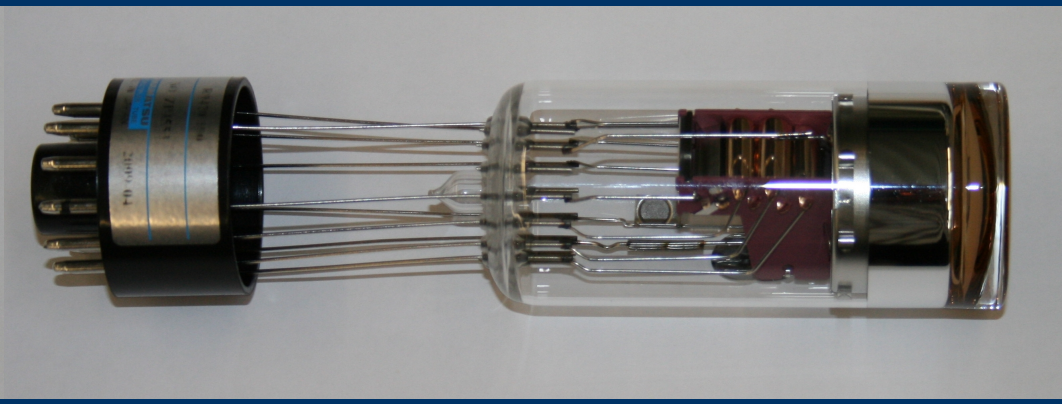
Motivation

- Simulations show improved performance of FD-telescope with high QE-PMTs
- Signal to noise ratio gets better
- Trigger efficiency increases
  - ➔ Telescope can see shower farther away
  - ➔ # of reconstructed showers increases
  - ➔ Energy and X_{max} resolution gets better
- Important to detect faint and fast signals:
  - Low dark current
  - Low afterpulses

PMTs

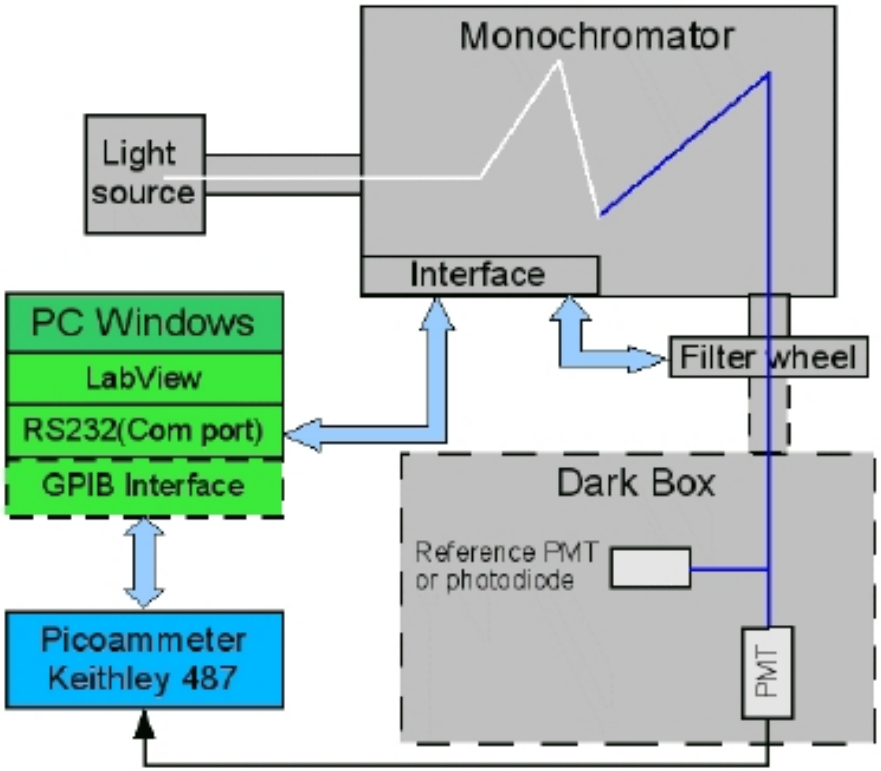




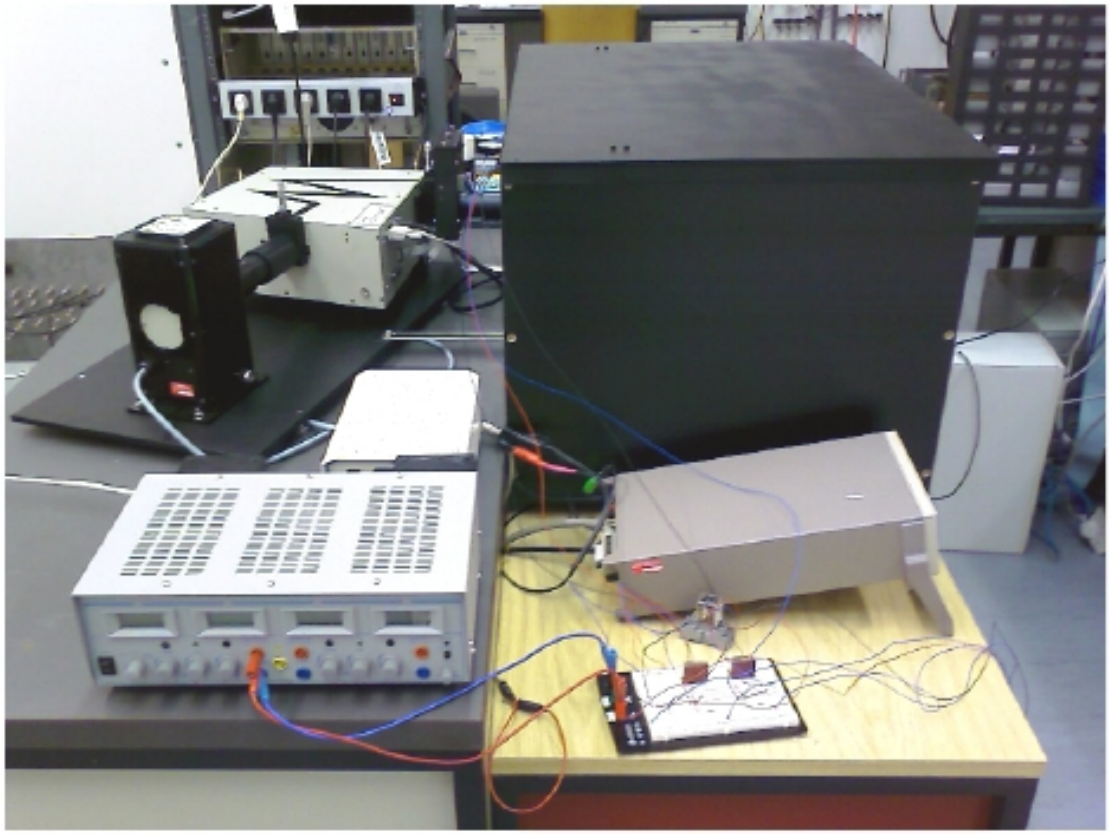
		Photonis XP3062	Hamamatsu R9420-100
Faceplate		hexagonal	round
Photocathode		bialkalie	Super-bialkali
Window		lime glass	borosilicate
Dynode Structure/Stage		linear focused/8	linear focused/8
Gain		$2.6*10^5$	$3.7*10^5$
Supply Voltage [V]	typ.	1100	1300
	max.	1300	1500
Dark current [nA]	typ.	1	10
	max.	20	100
Cathode Radiant Sensitivity [mA/W]		90	110
$Q.E._{\text{at Peak Wavelenght}}$		27%	35%
Rise Time [ns]		3	1.6

Quantum efficiency (QE)

$$QE_{PMT}(\lambda) = QE_{Ref}(\lambda) \cdot \frac{|I_{PMT}| - |\bar{I}_{ped,PMT}|}{|I_{Ref}| - |\bar{I}_{ped,Ref}|}$$



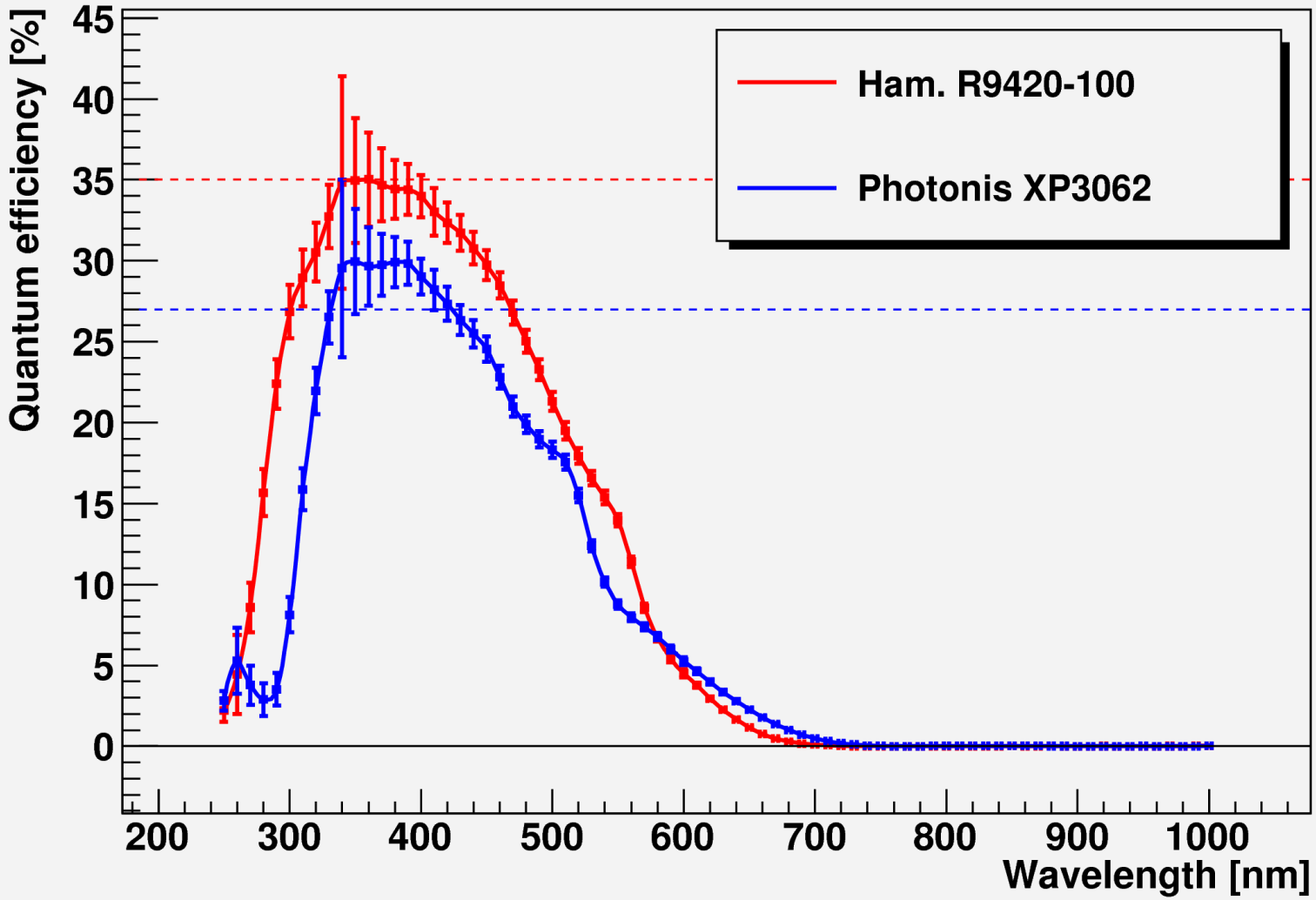
(a) schematisch



(b) Foto

by Björn Herold

Quantum efficiency

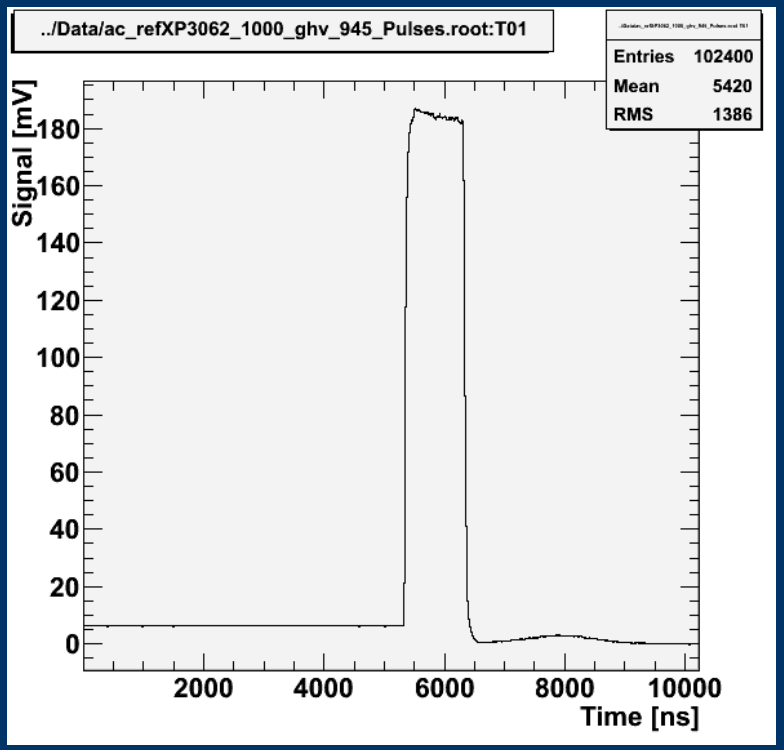


Dark current

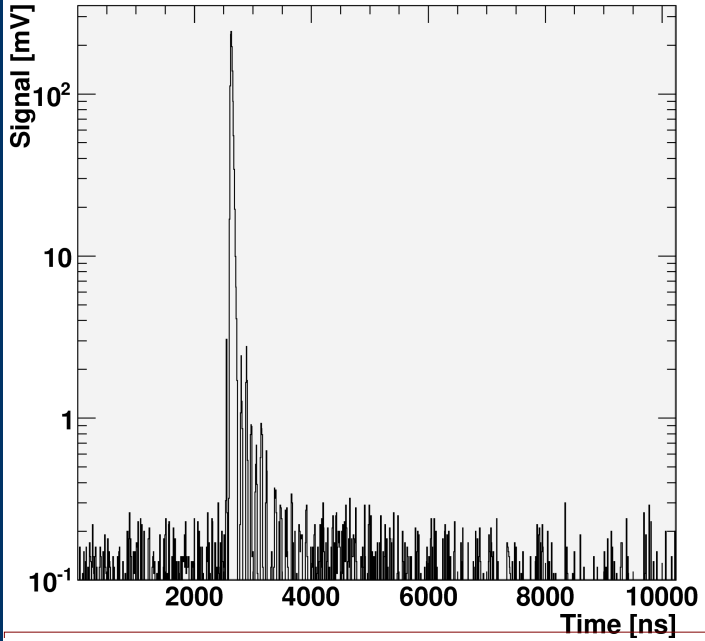
- Anode current at total darkness
- Current measured with picoampermeter
- Measurement in anode grounded mode
- Recently illuminated PMTs have to stay several hours in darkness

		Photonis XP3062	Ham. 9420-100	
			ZP525	ZP4553
Dark current [nA]	typ.	1	10	10
at Working Point	max.	10	100	100
	measured	<1	<3	<1

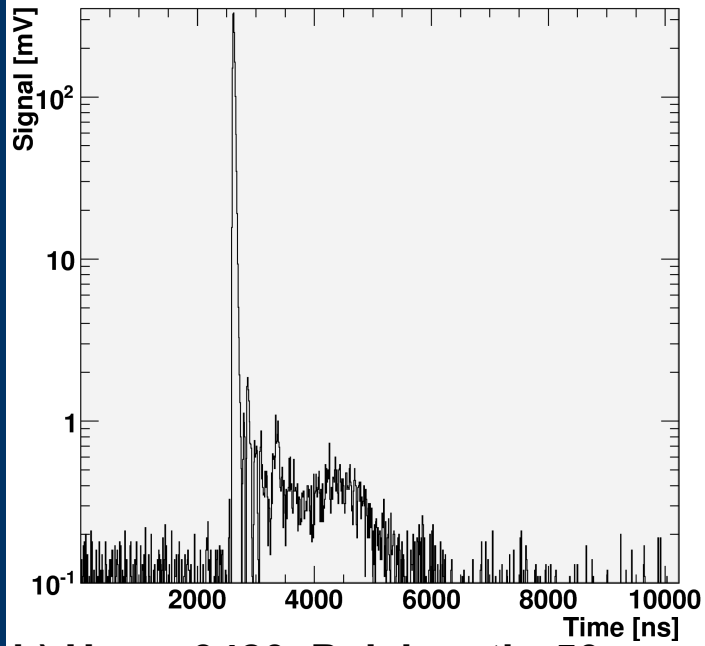
Afterpulse



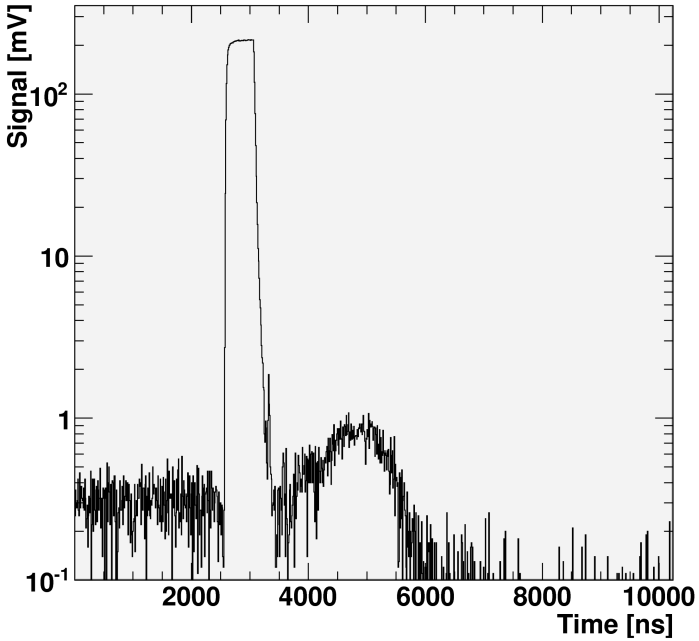
- Occur due to luminous reactions & ionisation of residual gases
- Transit time:
  - Luminous reactions: after 20-100ns
  - Ionisation of gases: few 100ns to several µs
- Stochastic process → average over 100 pulses
- Calculation: Ratio of charge (integral) of afterpulse and signal
- Result:
  - Phot. XP3062: ~1%
  - Ham. 9420-100: ~4%



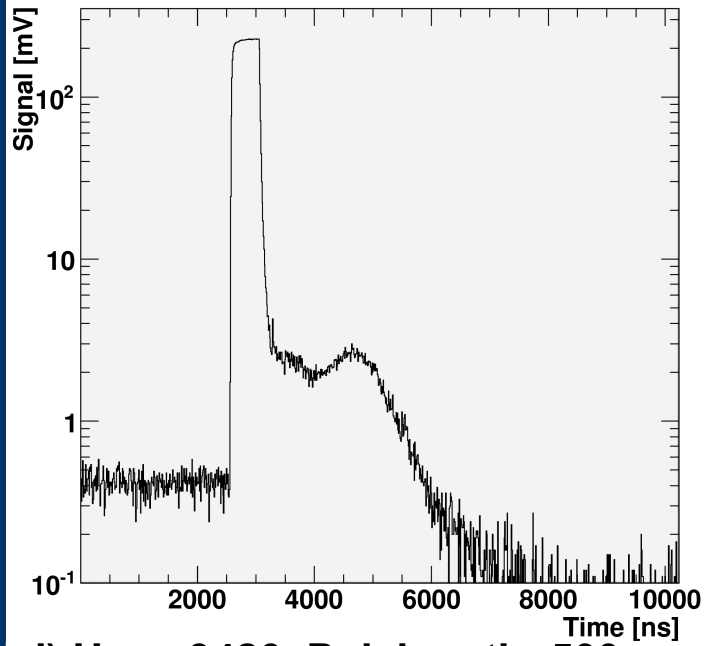
a) Phot. XP3062. Pulslength: 50 ns



b) Ham. 9420. Pulslength: 50 ns



c) Phot. XP3062. Pulslength: 500 ns



d) Ham. 9420. Pulslength: 500 ns

Outlook

- Effects of Earth's magnetic field
  - Angle dependence
  - Shielding with Mu-metal
- Photocathode uniformity
- Temperature dependence

Outlook

		Hamamatsu R8900U-100
Faceplate		square
Photocathode		Super-bialkali
Window		Borosilicate
Dynode Structure/Stage		Metal channel/10
Gain		$1*10^6$
Supply Voltage [V]	typ.	800
	max.	900
Dark current [nA]	typ.	2
	max.	20
Cathode Radiant Sensitivity [mA/W]		110
Q.E.$_{\text{at Peak Wavelenght}}$		35%
Rise Time [ns]		1.8

Back up

Pierre Auger North (planned)

- About 20.000 km² area (South 3.000 km²)
- ~ 4000 SD-Tanks (South 1600)
- FD-Telescopes
  - 39 “Eyes” in 5 Stations