PIERRE AUGER OBSERVATORY

Acceptance tests for SSD-PMTs as planned in Wuppertal

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Key Specs I (specified in Tender)

2.2 Cathode sensitivity, quantum efficiency:

The photo-cathode sensitivity at a wavelength of 500 nm shall not be less than 120 µA/lm, corresponding to a quantum efficiency of 18%.

2.3 Homogeneity of photo cathode:

The response of the photo-cathode should not vary by more than ± 25 % over its active area.

2.4 Number of stages and gain:

The PMT shall have 8 amplification stages. The standard operation in AugerPrime will use a gain of $5 \cdot 10^4$. The gain of $5 \cdot 10^4$ shall be attained at an average operating voltage of 850 ± 100 V

2.5 Temperature range:

The PMT will allow operation at ambient temperatures from -20 °C up to 50 °C.

2.6 Dark current:

The anode dark current measured at a supply voltage of 1200 V and at a temperature of 25 °C shall be less than 10 nA.

2.7 Linearity:

We require that the tube, when operated at their nominal (recommended) gain, shall have a linear response within better than 5 % over a dynamic range of at least $2 \cdot 10^4$ up to a maximum anode current of 150 mA for a pulse width of 100 ns when operated at a frequency of 100 Hz.

Key Specs II (specified in Tender)

2.8 Rise time:

The pulse rise time at the anode due to fluctuations on the transit time of the electrons shall be less than 5 ns.

2.9 Single photoelectron response:

The manufacturer shall provide information on the typical single photoelectron response of the PMT, if available.

2.10 Requested information (1):

The manufacturer shall provide information on the temperature dependence of all basic parameters of the PMT in the range from –20°C up to +50°C.

2.11 Requested information (2)

The manufacturer shall provide for each PMT the following information:

- photo-cathode sensitivity measured with a filament lamp at 2856 K
- anode luminous sensitivity
- cathode blue sensitivity index
- anode dark current at the gain of $5 \cdot 10^4$
- high voltage needed for a gain of $5 \cdot 10^4$

TECHNICAL INFORMATION

TENTATIVE
Feb. 2018

R9420 SEL

For Pierre Auger Observatory, Fast time response,
38 mm (1.5 inch) Diameter, Bialkali Photocathode, 8-stage, Head-On Type

GENERAL

Parameter		Description / Value	Unit
Spectral Response		300 to 650	nm
Peak Wavelength of Cathode Radiant Sensitivity		420	nm
Window	Material	Borosilicate glass	-
	Shape	Plano concave	-
Photocathode	Material	Bialkali	-
	Minimum Effective Area	ϕ34	mm
Dynode Structure / Number of Stages		Linear Focused / 8	-
Operating Ambient Temperature (with Socket)		-30 to +50	ºC
Storage Temperature (w/o Socket)		-80 to +50	ºC
Suitable Socket		E678-12A	-
Recommended Supply Voltage between Anode and Cathode		1300	V

MAXIMUM RATINGS (Absolute Maximum Values)

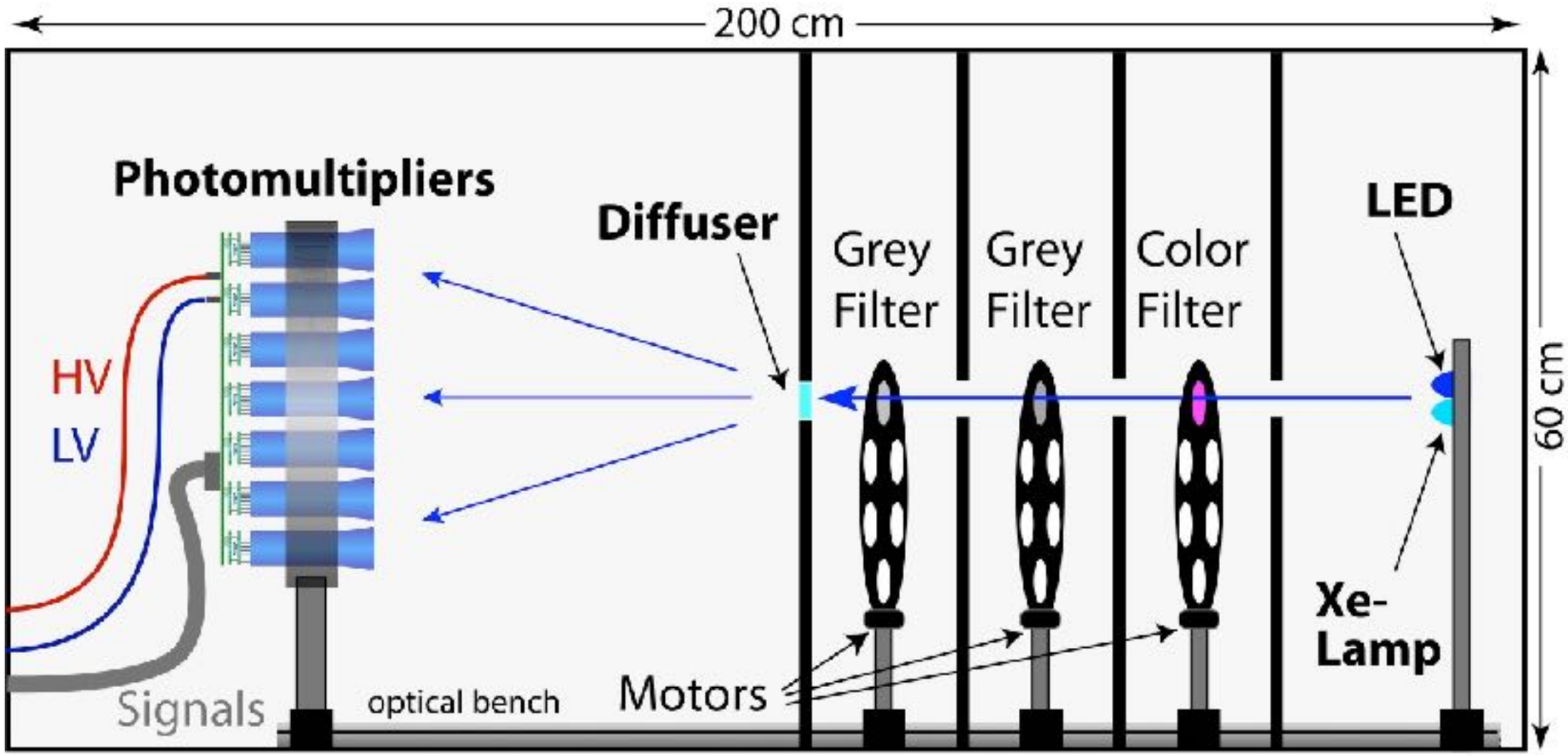
Parameter		Value	Unit
Supply Voltage	Between Anode and Cathode	1500	V
	Between Anode and Last Dynode	350	
Average Anode Current		0.1	mA

CHARACTERISTICS (at 25 ºC)

Parameter		Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856K)	120	-	-	µA/lm
Cathode Blue Sensitivity Index (Cs 5-58)		9.0	11.0	-	-
Cathode Radiant Sensitivity (at 400 nm)		-	88	-	mA/W
Quantum Efficiency (at 500 nm) (Guaranteed)		18	-	-	%
Anode Sensitivity	Luminous (2856K)	-	50	-	A/lm
Ebbv (Nominal Voltage)	Gain $5x10^4$	750		950	V
	Gain $7x10^5$	-	1250	-	V
Ebbi (Dark Current at Ebbv)*	Gain $5x10^4$	-	3.0	10	nA
	Gain $7x10^5$	-	6.0	-	nA
Anode Output Rise Time at Ebbv (for Gain $5x10^4$) (Guaranteed)		-	-	5.0	ns
Pulse Linearity at Ebbv(for Gain $7x10^5$) (±5% deviation) ** (Guaranteed)		150	-	-	mA
Cathode Uniformity in effective area (at 500 nm) (Guaranteed)		-25	-	25	%

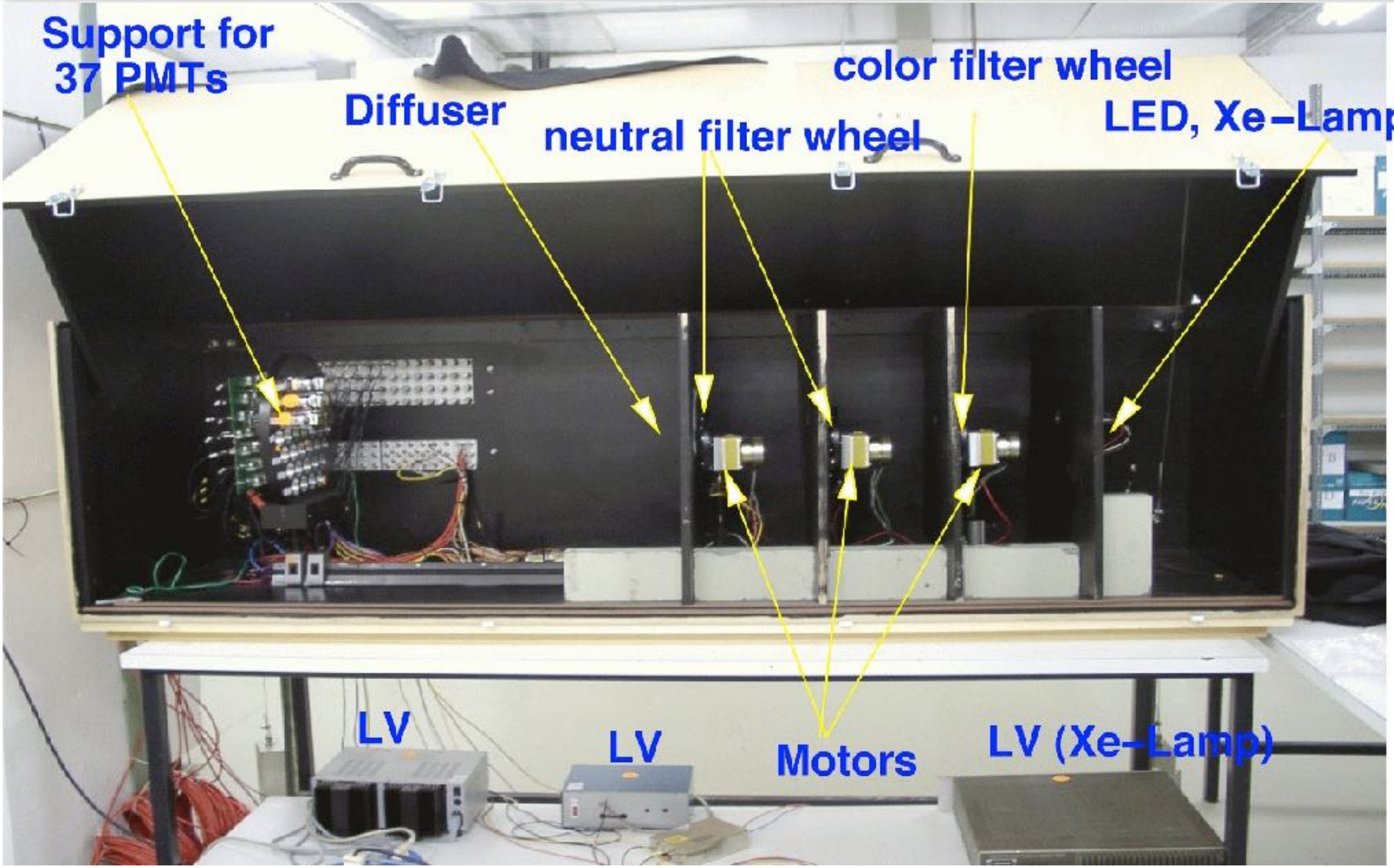
NOTE: Anode characteristics are measured with the special voltage distribution ratio (Tapered ratio) and supply voltage shown next page.
NOTE*: Measured after 30min storage in the darkbox.
NOTE**: Detailed conditions are described on the next page.

15 yrs ago: FD-PMT Qualification

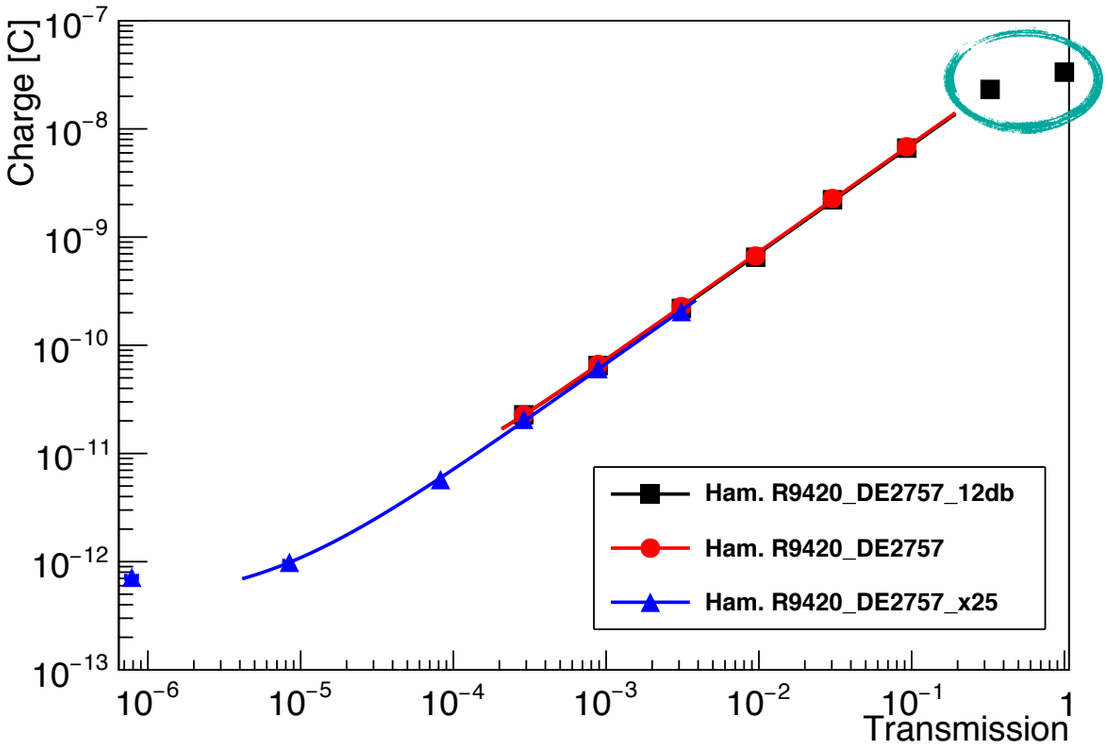


Measuring gain, linearity, dark current, after pulsing, wavelength dependence, etc.
(up to 1000 PMTs per week)

PMT Qualification



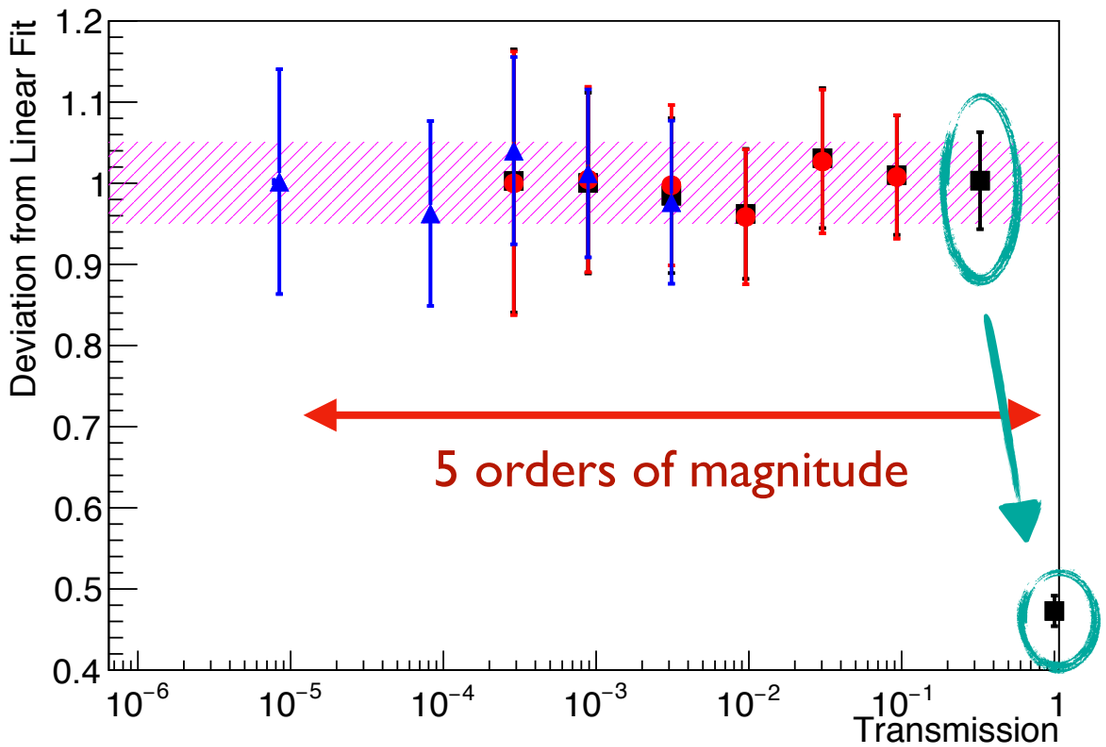
Recent Linearity Tests using Filters



Covering this enormous dynamic range with a single signal cable was not possible in a single run.

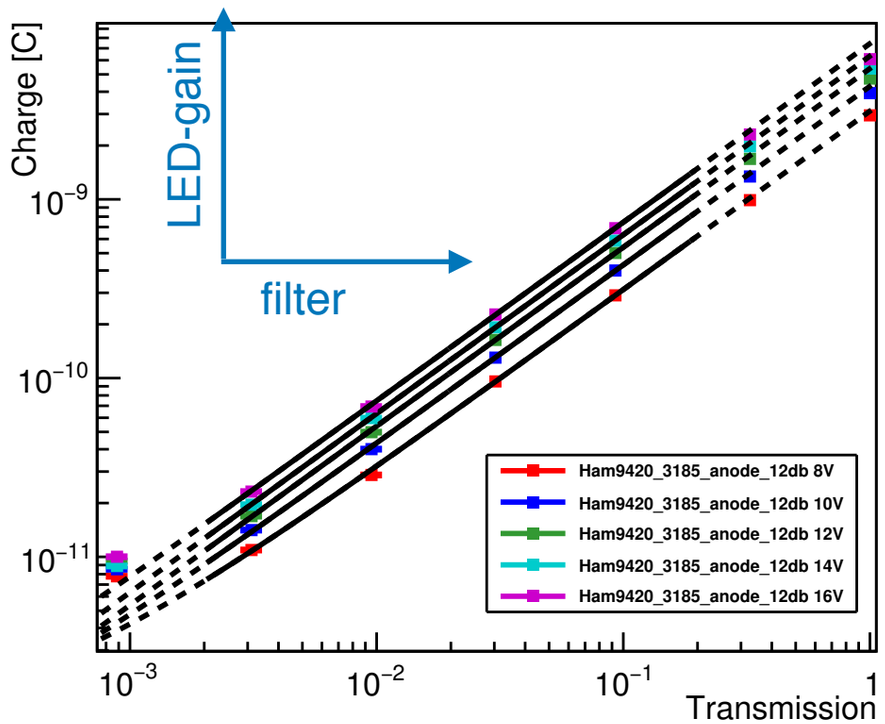
Measuring the large pulses in 12 bit 100 MHz ADCs required a 12 dB attenuator at ADC input

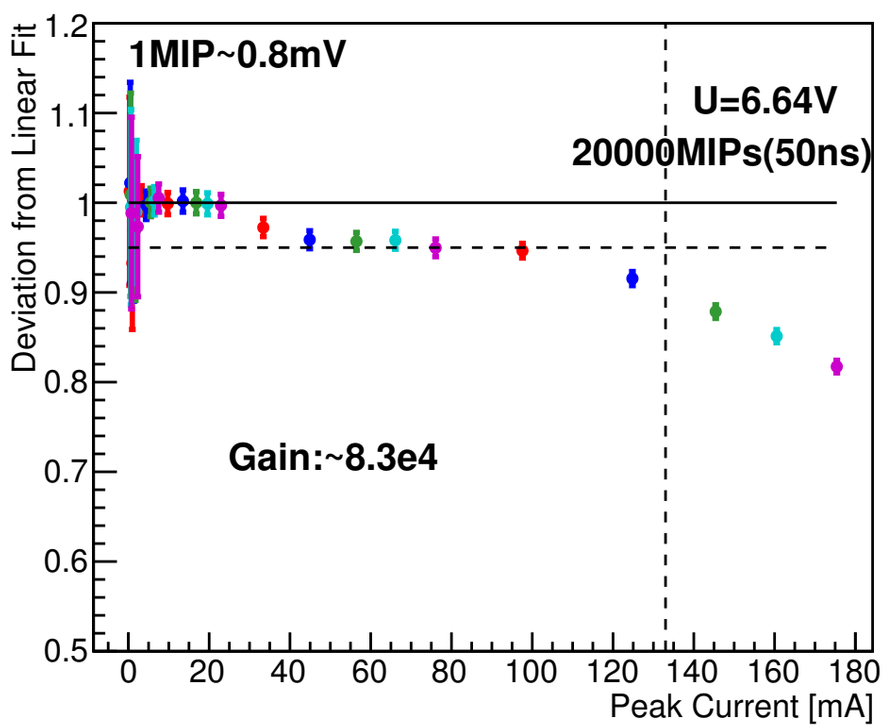
Measuring the sub-mV pulses required an amplifier of gain 25 at ADC input

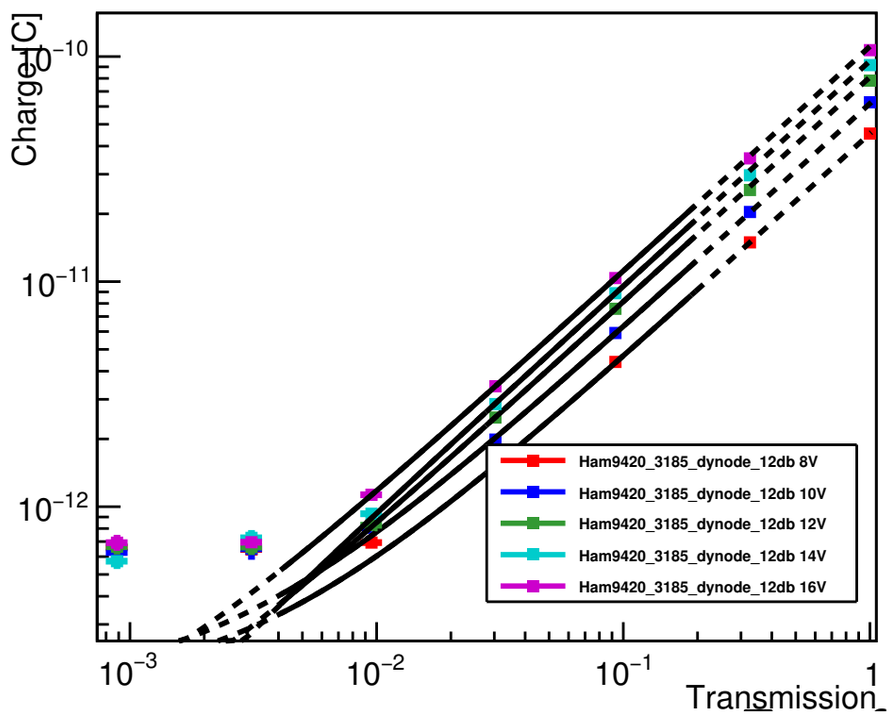


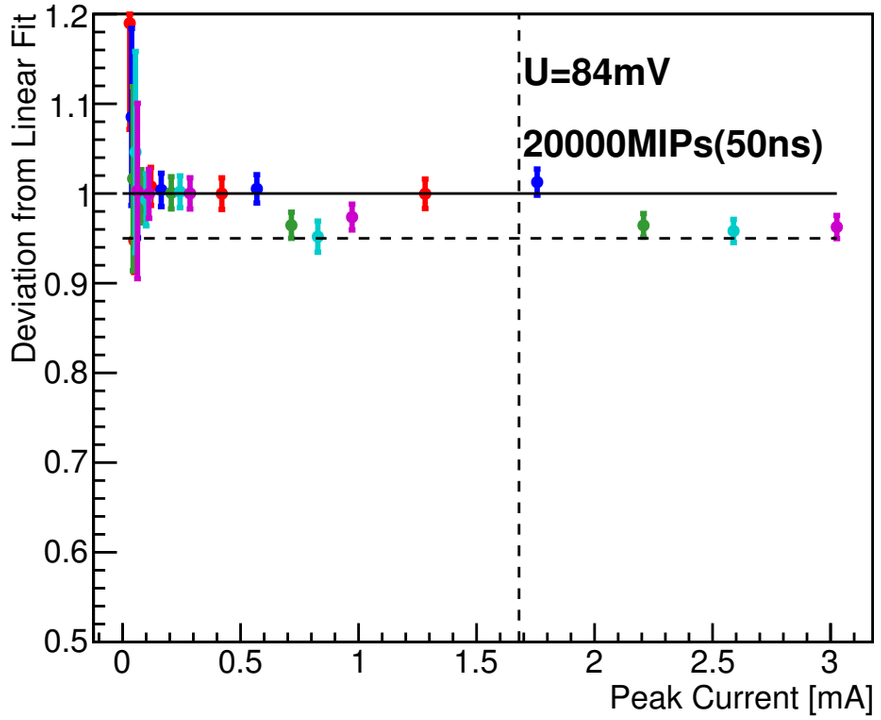
Moreover, want more data points in saturation region
→ adopt the „2 LED idea“ by using a single LED of variable intensity combined with finer set of attenuation filters to allow smaller steps in saturation region

Filters combined with variable LED-intensity









S. Querchfeld, Analysis Meeting, Paris 06/2017

New test setup used for MAPMTs & QE-Measurements

Cover box lifted

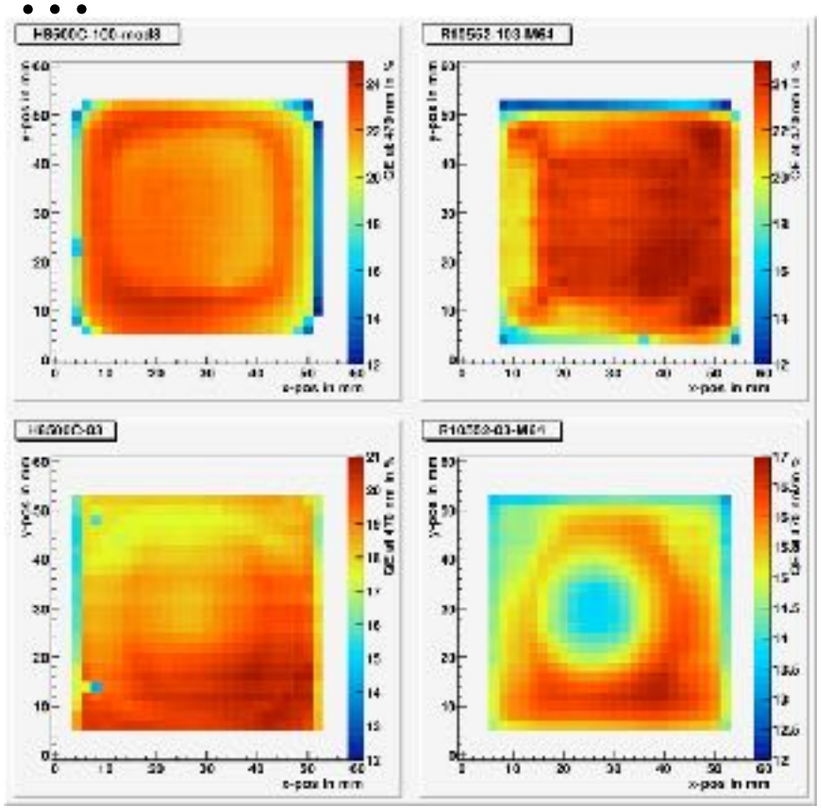
have just finished acceptance tests
of 1100 MAPMTs, each with 64 channels

Box closed

New test setup used for MAPMTs & QE-Measurements

Test parameters for 1100 MAPMTs:

- cathode homogeneity
- gain of each pixel
- single photon response
- dark current / noise
- …

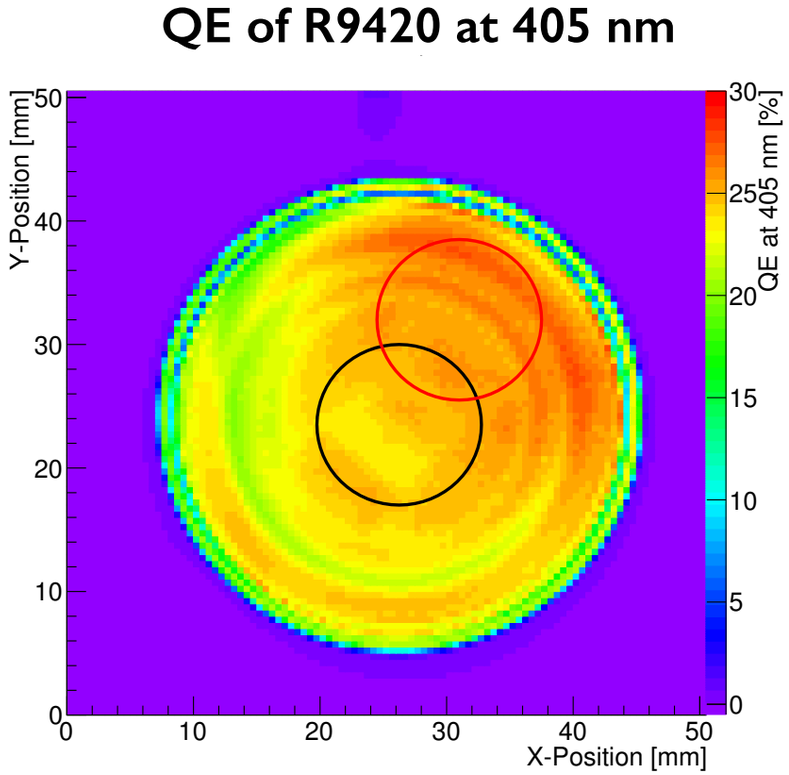


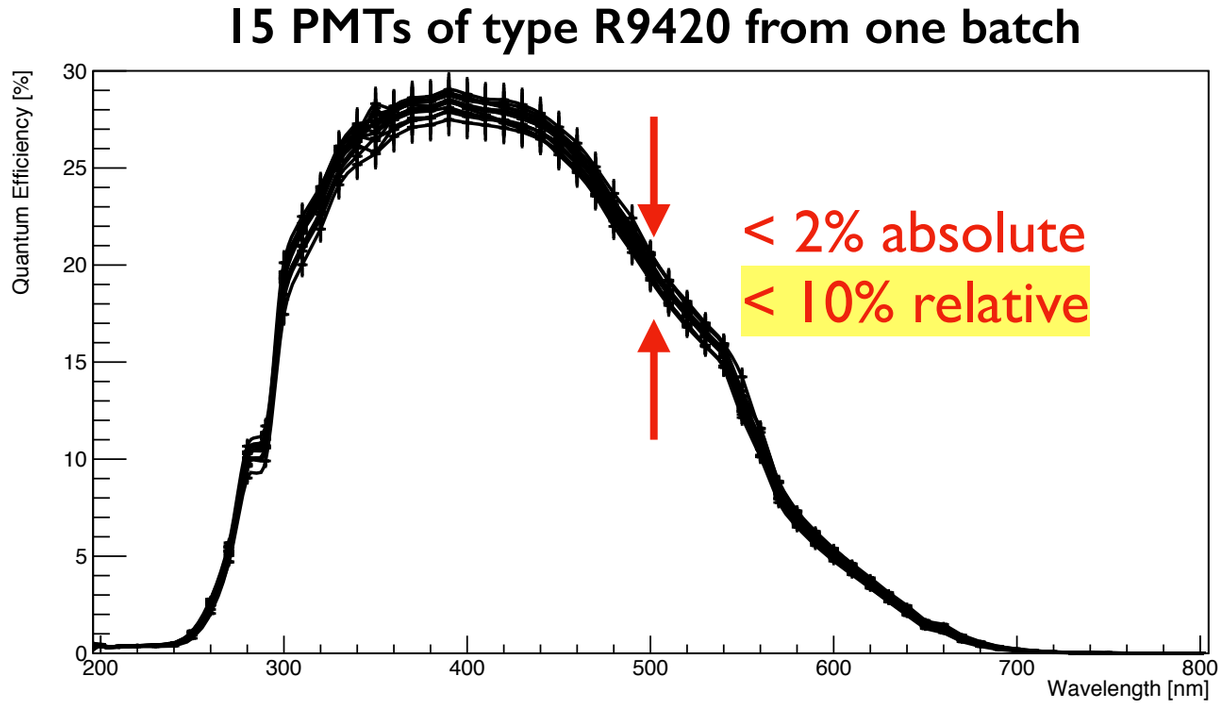
examples of
2d Quantum Eff.
at 470 nm

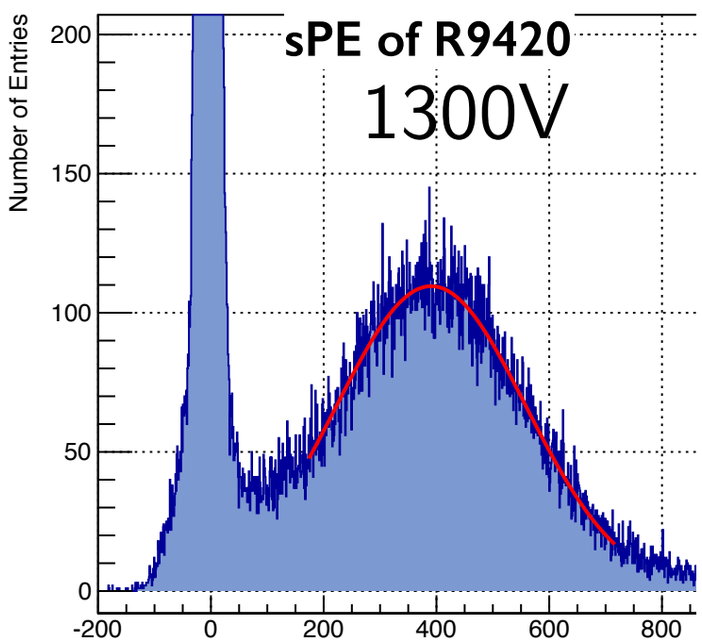
Test procedure very much automised (EPICS), including archiving results in a mySQL database

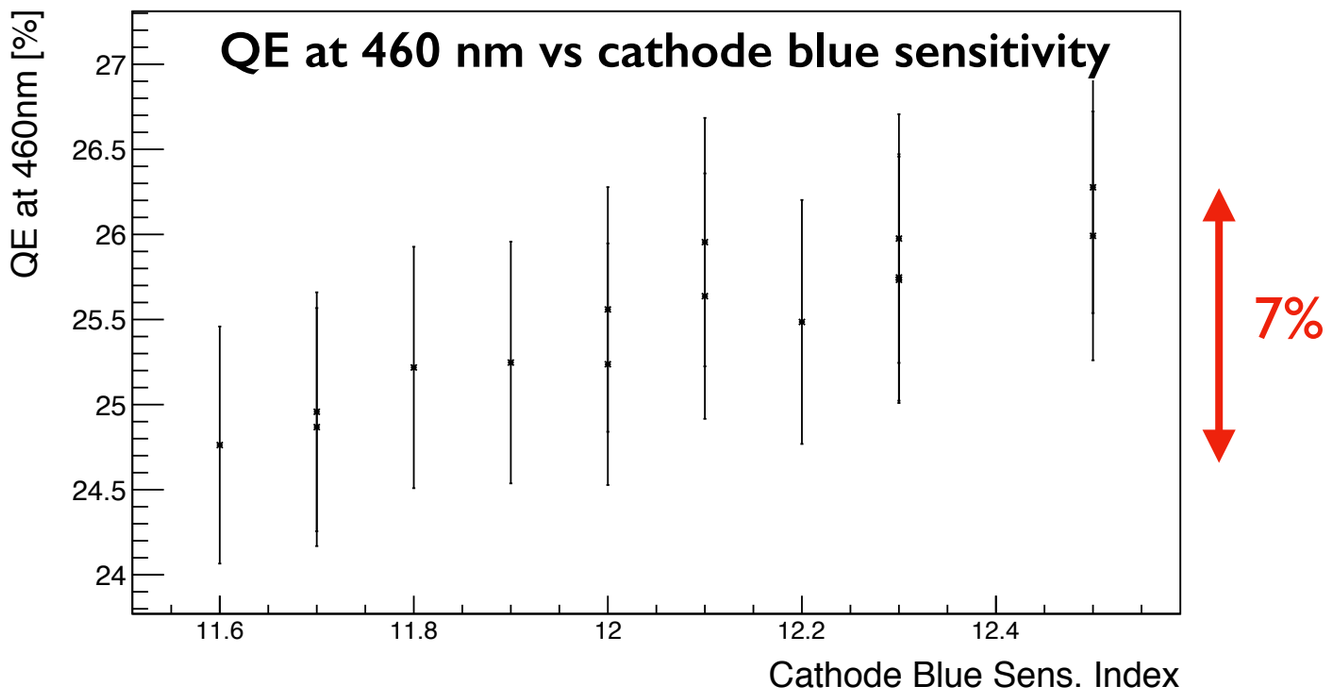
New test setup used for MAPMTs & QE-Measurements

Test setup also has also been used for AugerPrime purposes

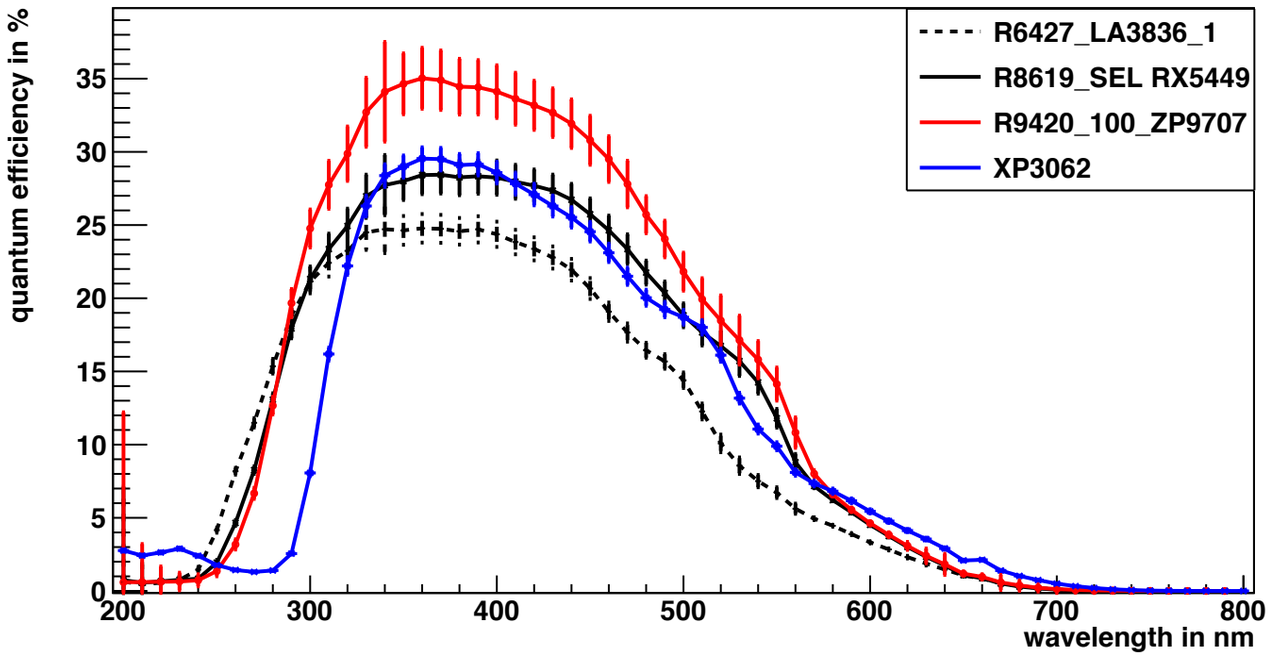


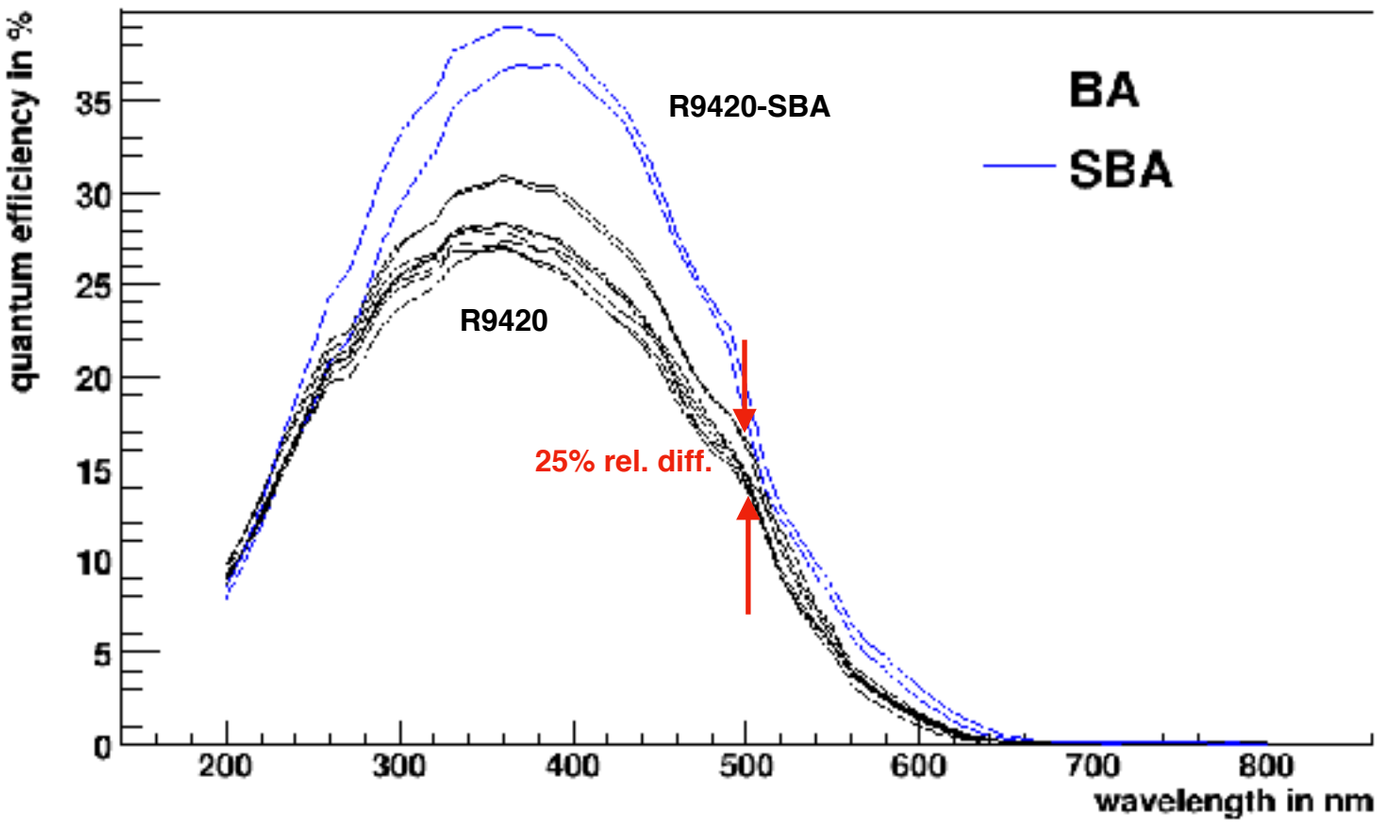






Some other QE-examples





AugerPrime Testbox being constructed

Keeping principles, enlarging box to 200 x 70 x 70 cm^3 to allow **simultaneous testing ca. 15 PMTs** plus a reference PMT.
All PMTs will mounted in the full SSD scheme →

- Need PMT Al-tubes for this

- We also need at least another group contributing to the production of the 1200 PVC tubes

Planned Acceptance Tests

Measure for each PMT:

- gain (relative to reference PMTs)
- gain vs HV
- linearity at 1300 V to verify 150 mA
  single LED operated at different pulse heights up to factor of three
  will be combined with several attenuation filters mounted on filter wheel
  (checking single photoelectron peak would require recabling at ADC)
- could measure spe → abs. gain and relative QE of each tube
- shall we repeat linearity at 800 V ??
  need to see how long it takes
- after-pulsing (will be part of data anyway)
- dark current ?
  (could be combined with sep measurement)
- …?

→ store all key data in mysql database

Time Schedule & Costs

- 80 PMTs being ordered now (for preproduction)
  delivery 8 weeks after ordering (244 € per unit, 25 k€ total)
  shipment to Wuppertal
  Alberto: MinCyT
- 100 ISEG bases being ordered now (for preproduction)
  delivery 12 weeks after ordering (8.4 k€)
  soldering of bases to PMTs by ISEG (4 € / unit)
  KHK: BMBF via Ahuekna
- Simplified tendering with Hamamatsu and Electron Tubes
  1200 - 1800 additional units (293 k€ - ...) **Alberto: 210 k€ from MinCyT**
  ca. 80-90 k€ still uncovered !
- Ordering PMTs: Can we send them to Europe for soldering the bases and doing the tests ?
  This is the largest uncertainty we have… !
  … no need to construct a test box, if acceptance tests done in Malargüe
- Ordering 1200-1800 ISEG bases (100 k€ - ...)
  KHK: 100 k€ BMBF via Ahuekna