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Latest progress in PMT development

VLVnT11 in October, 2011

Hamamatsu Photonics K.K.

Electron Tube Division

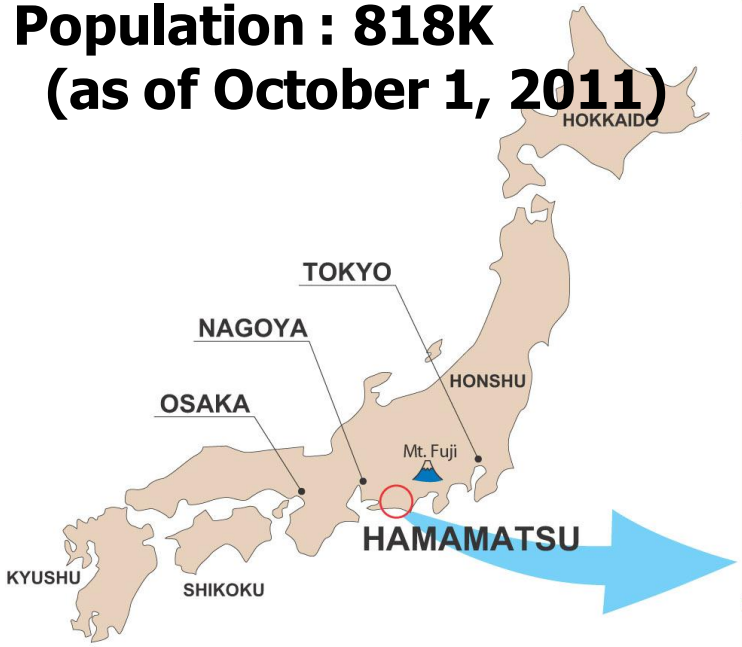
Yuji Hotta

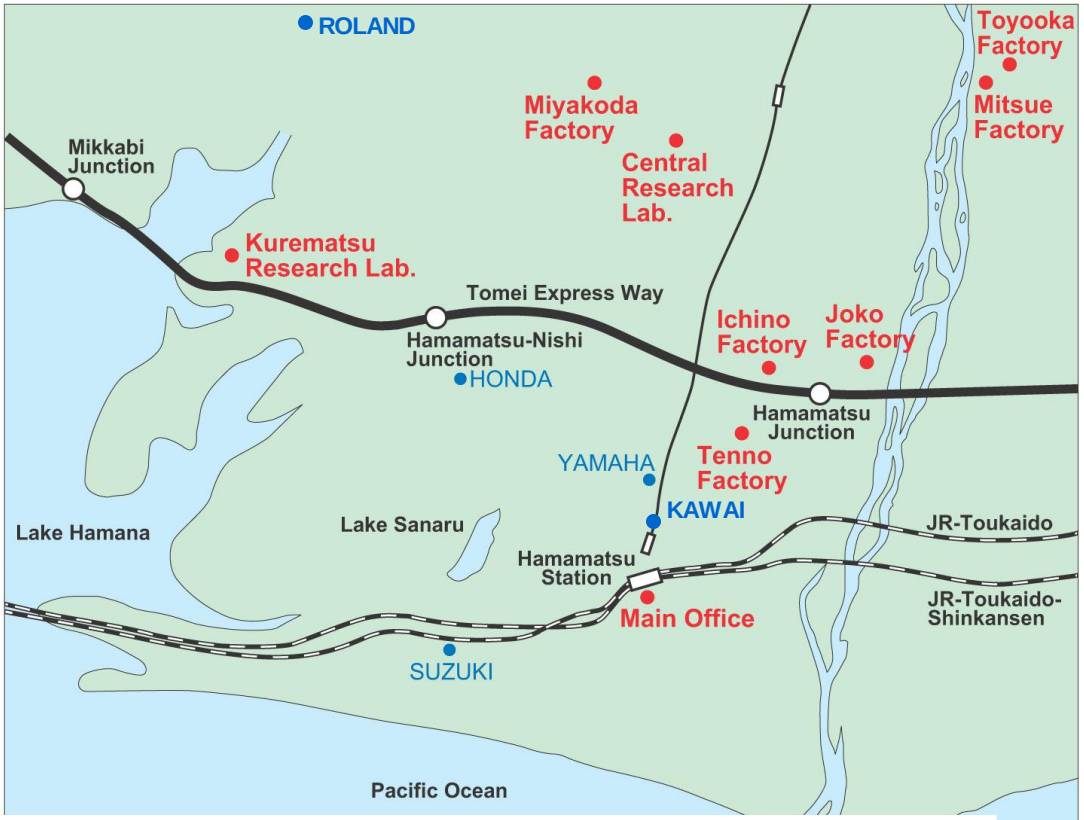
Contents

1. Profile of Hamamatsu

Where we are located

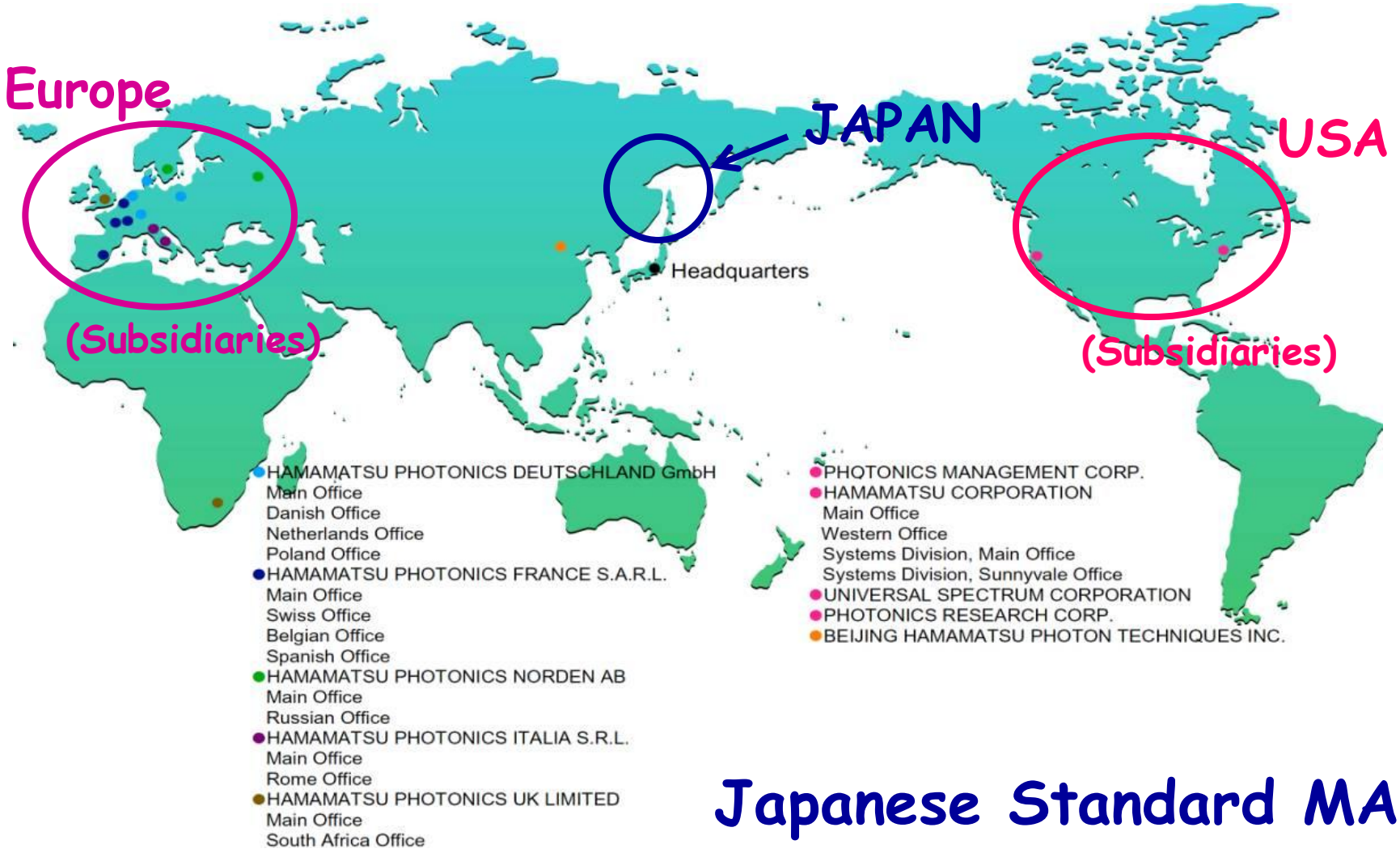
Population : 818K
(as of October 1, 2011)





Hamamatsu is a name of a city.
HONDA, YAMAHA and SUZUKI
(famous motor cycle companies) are located in the same area.

Global Network of Hamamatsu



Japanese Standard MAP

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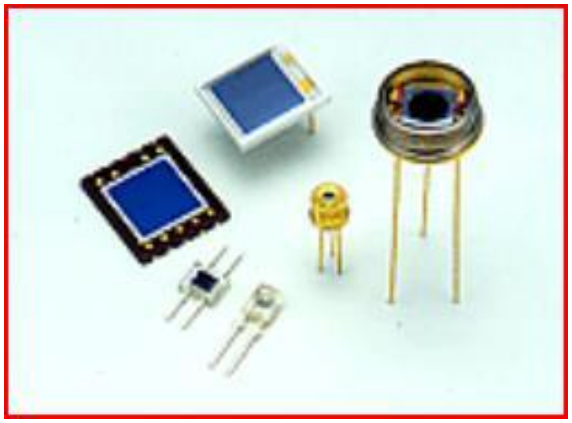
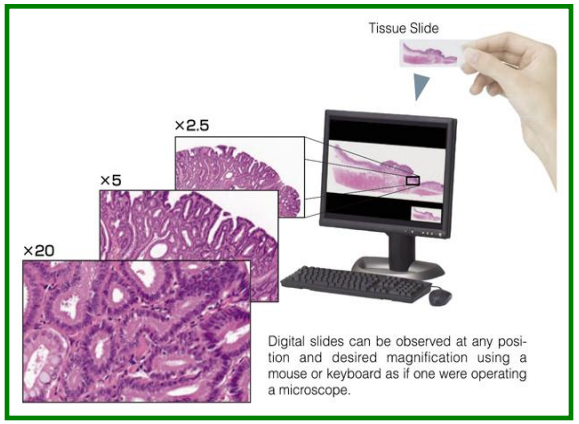
Hamamatsu Photonics K.K.



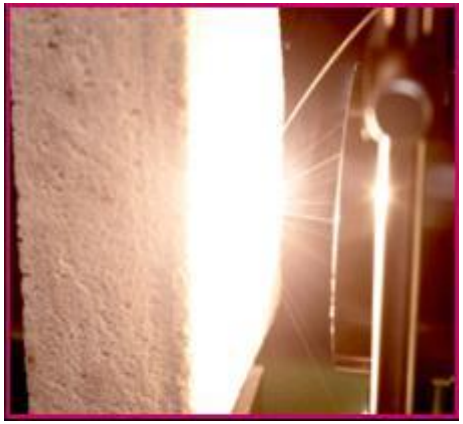
Solid Sate Division

Electron Tube Division



Systems Division

Central Research Lab



Laser Group

Established : Sept 29, 1953
Employees : 4,167 (Group)
(As of Jun 2011)
Net Sales : \91B (€830M)
(FY2010)

2. 3 inch PMT Development for KM3NeT

Requirements for KM3NeT

Quantum Efficiency at 404 nm : 32% min.

Inhomogenity of cathode response : 10% max.

Supply Voltage : 1400 V max.

Gain : 5E+06

Dark count rate at 15 degree C : 3 kHz max.

Transit Time Spread : 2 ns max. (sigma) => 4.7 ns max. (FWHM)

Peak to valley ratio : 3.0 min.

Length : 105 mm max.

Effective area : 72 mm diameter min.

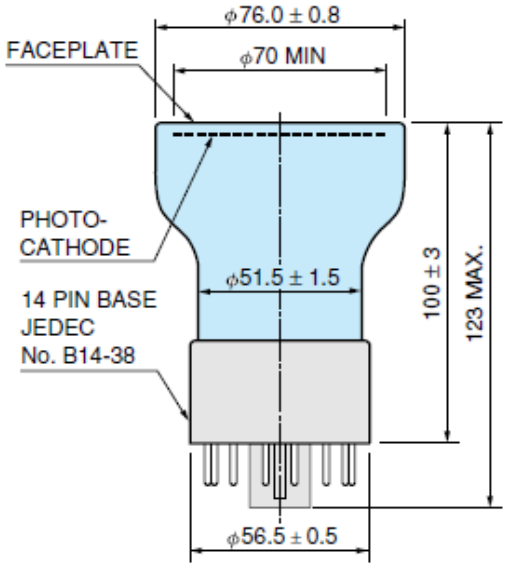
Convex input window : 198 mm radius

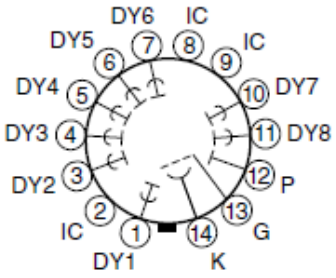
Price : Cheap

Production capability : High

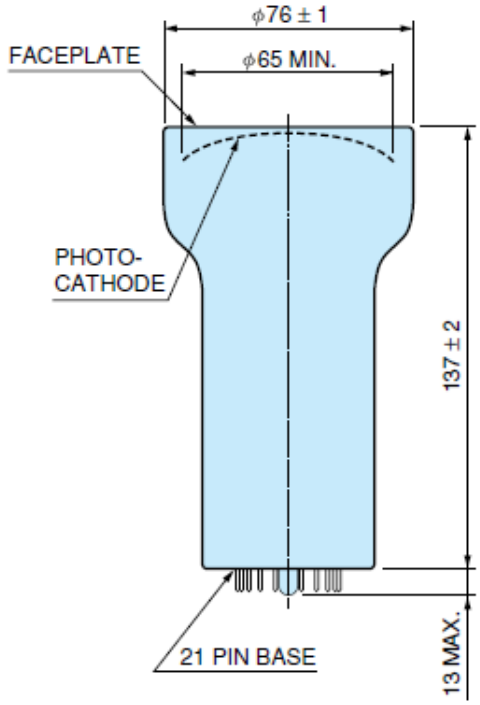
Hamamatsu 3 inch PMTs

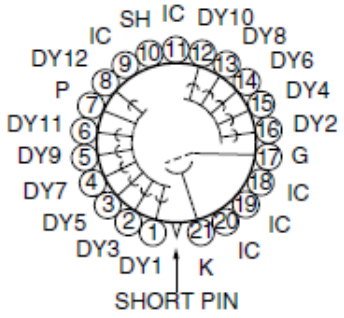
R6233





R6091





Hamamatsu 3 inch PMTs

Parameter	Requirement	R6233	R6091
QE	32% min at 4	30% typ. k	26% typ. at peak
Gain	5 x 10^6	2.7 x 10^5 typ.	5 x 10^6 typ.
TTS (FWHM)	4.7 ns max.	12.2 ns typ.	2 ns typ.
Effective area (Diameter)	72 mm min.	70 mm min.	65 mm min.
Length	105 mm	+/- 1 mm	137 mm +/- 2mm
Price	Cheap	Cheap	Not Cheap
Mass Production	Possible	Possible	Not Possible

Need to improve!

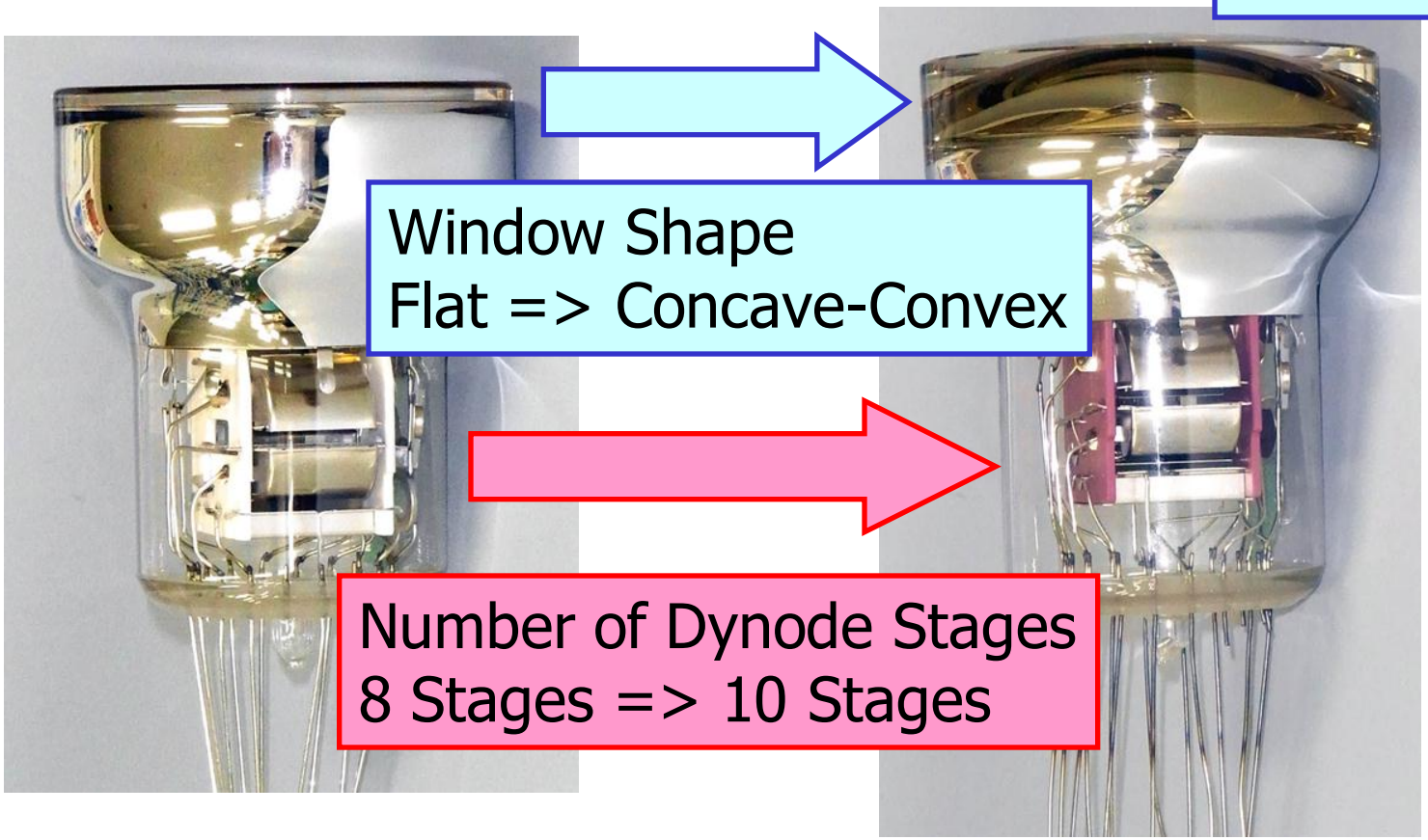
Important!

3 inch PMT Development

R6233-01 (Standard)

R6233-01 M

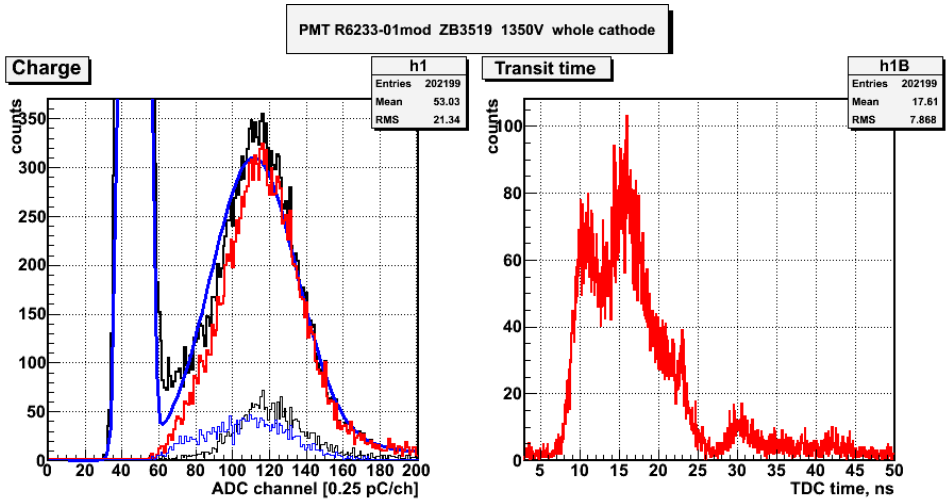
Outer : R198



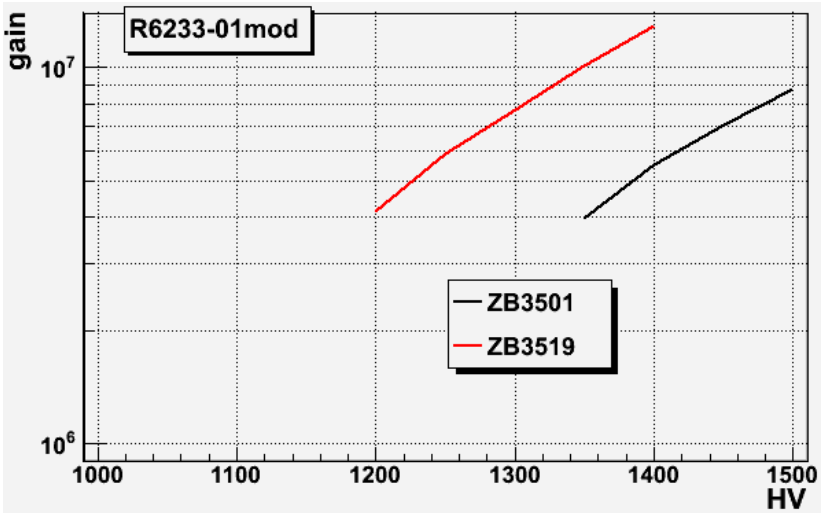
Window Shape
Flat => Concave-Convex

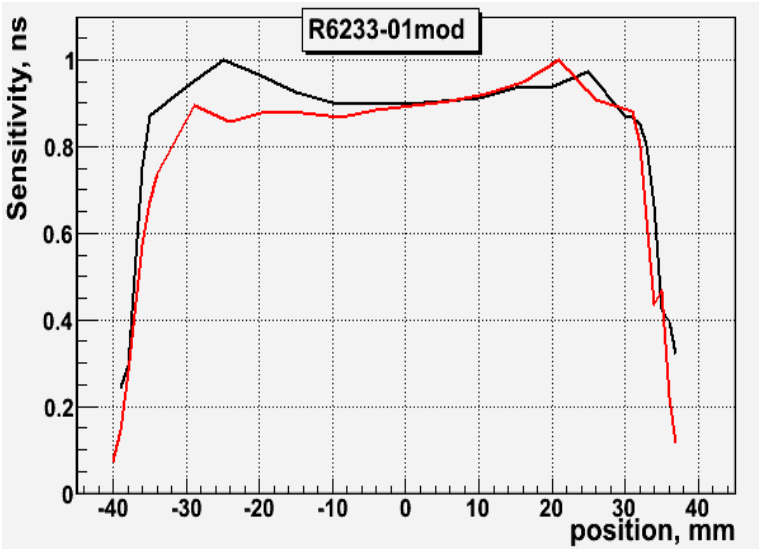
Number of Dynode Stages
8 Stages => 10 Stages

R6233-01 MOD Test Result



TTS => slow





Gain => low

Effective area => small

New 3 inch PMT Development

TTS => fast

Gain => high

Effective area => large

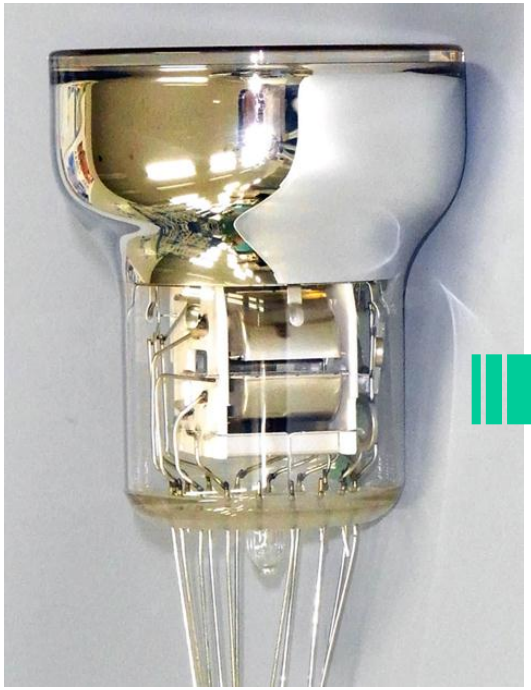
Electrodes need to be changed.

Shape of Glass bulb needs to be changed.

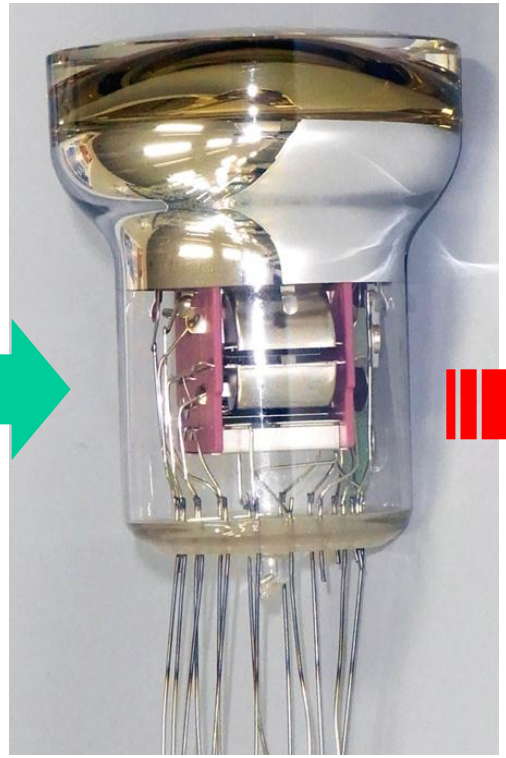
PMT has to be cheap
and has to be suitable for mass production.

3 inch PMT Development

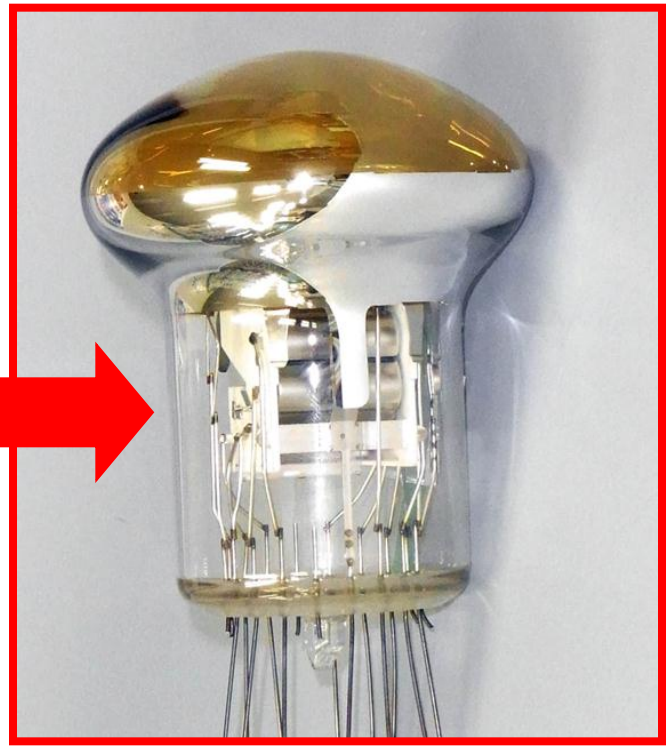
R6233-01 (Standard)



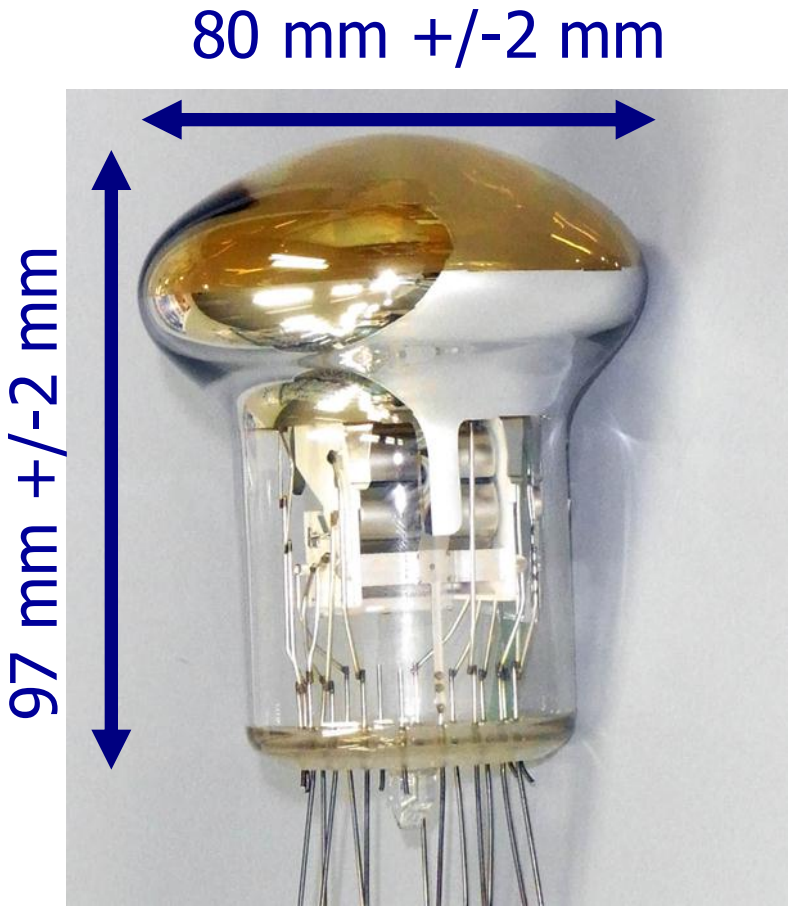
R6233-01 MOD



R12199 (New!)



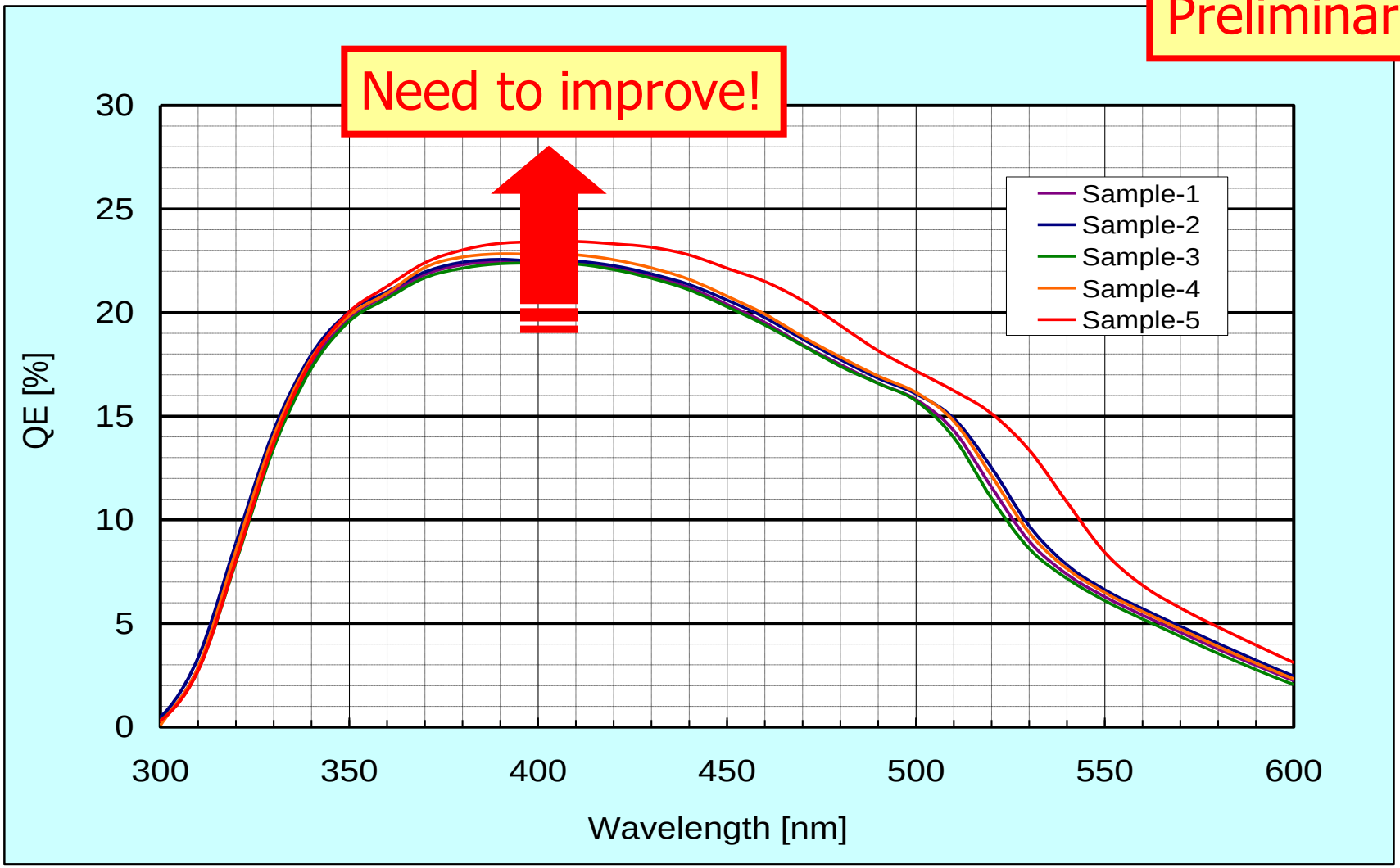
New 3 inch PMT Development



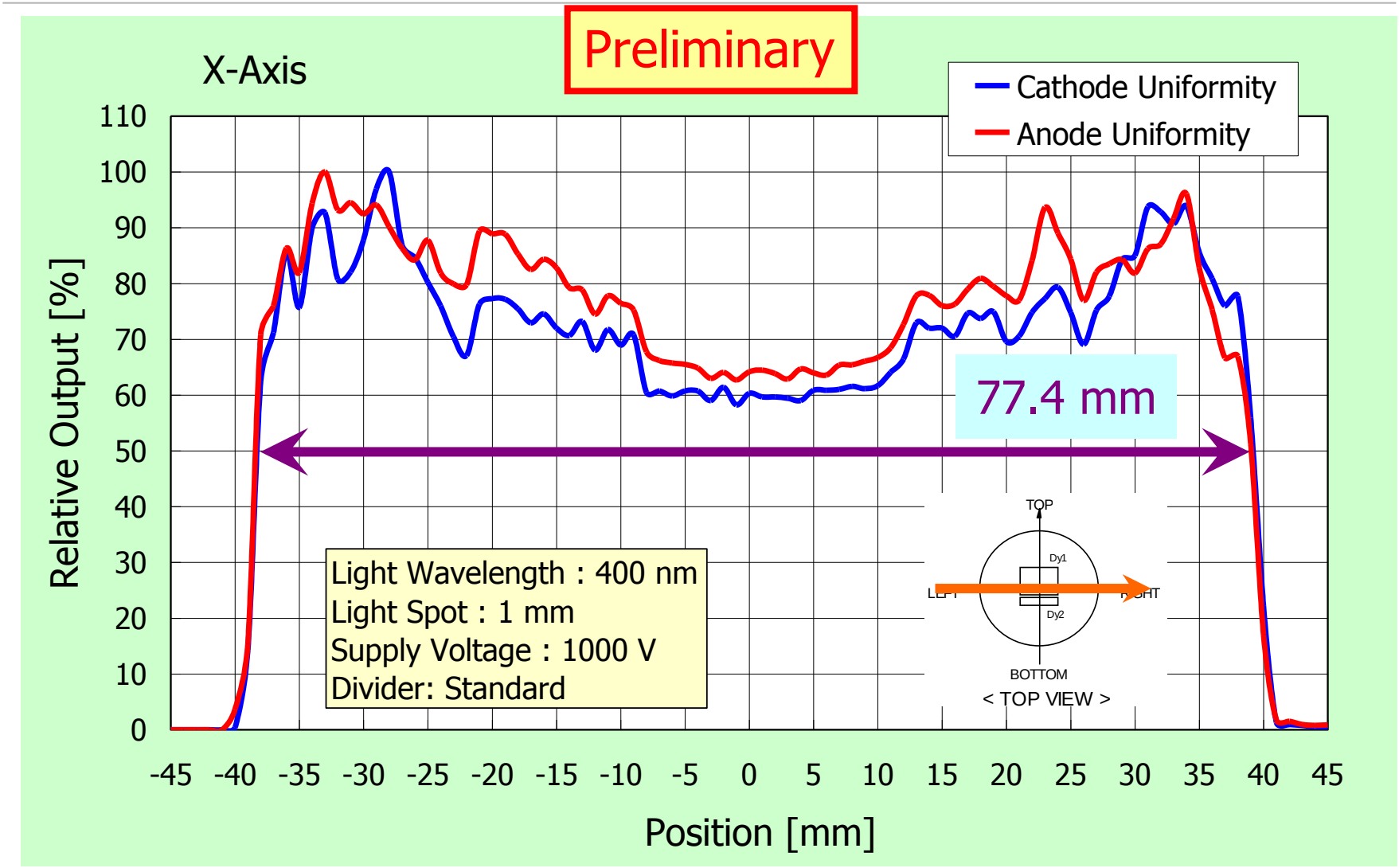
Type Number : R12199
Window Shape : Concave-Convex
Window Material : Borosilicate Glass
Photocathode Material : Bialkali
Number of Dynode Stages : 10
Outer Diameter : 80 mm
Length : 97 mm

R12199 Quantum Efficiency

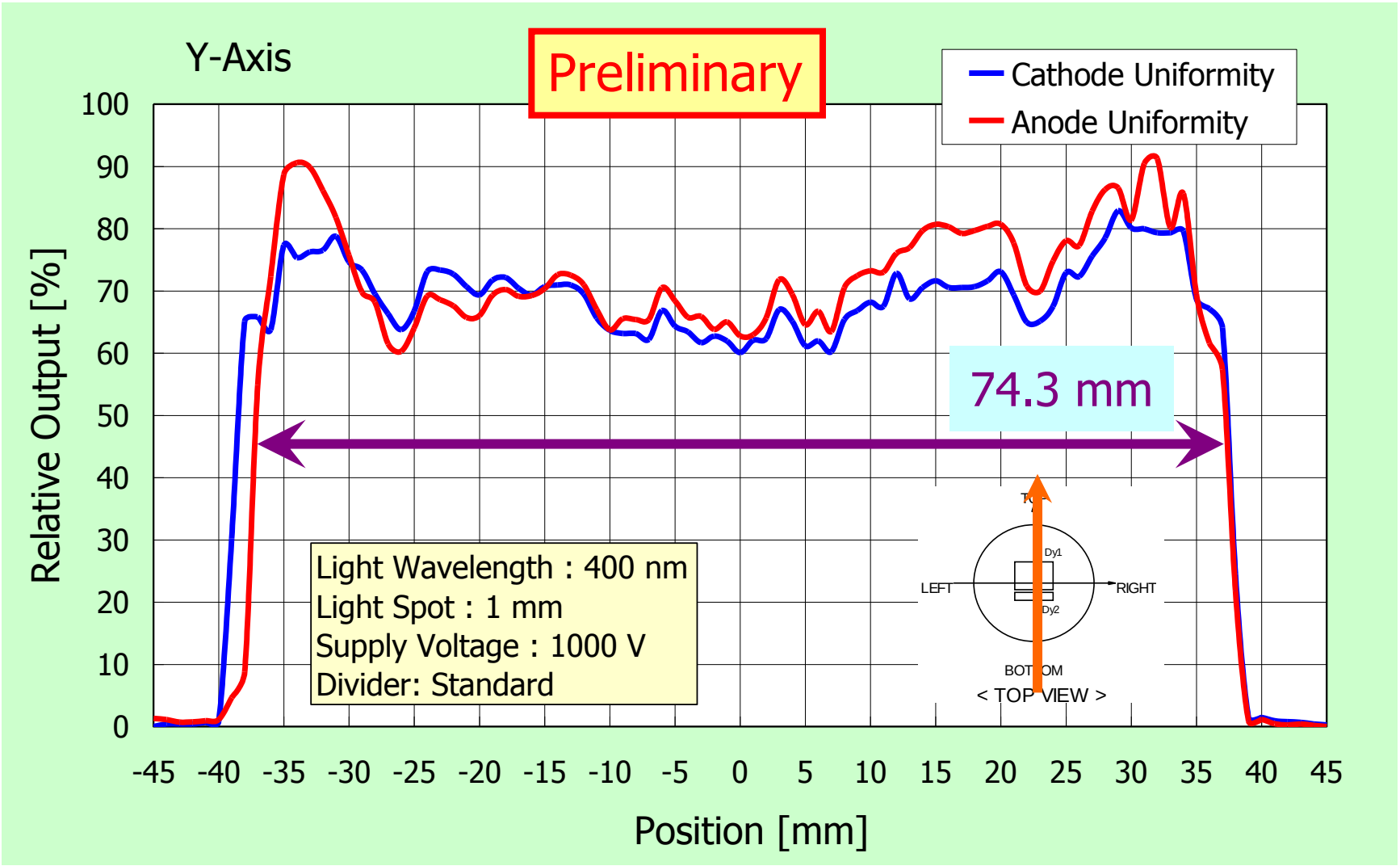
Preliminary



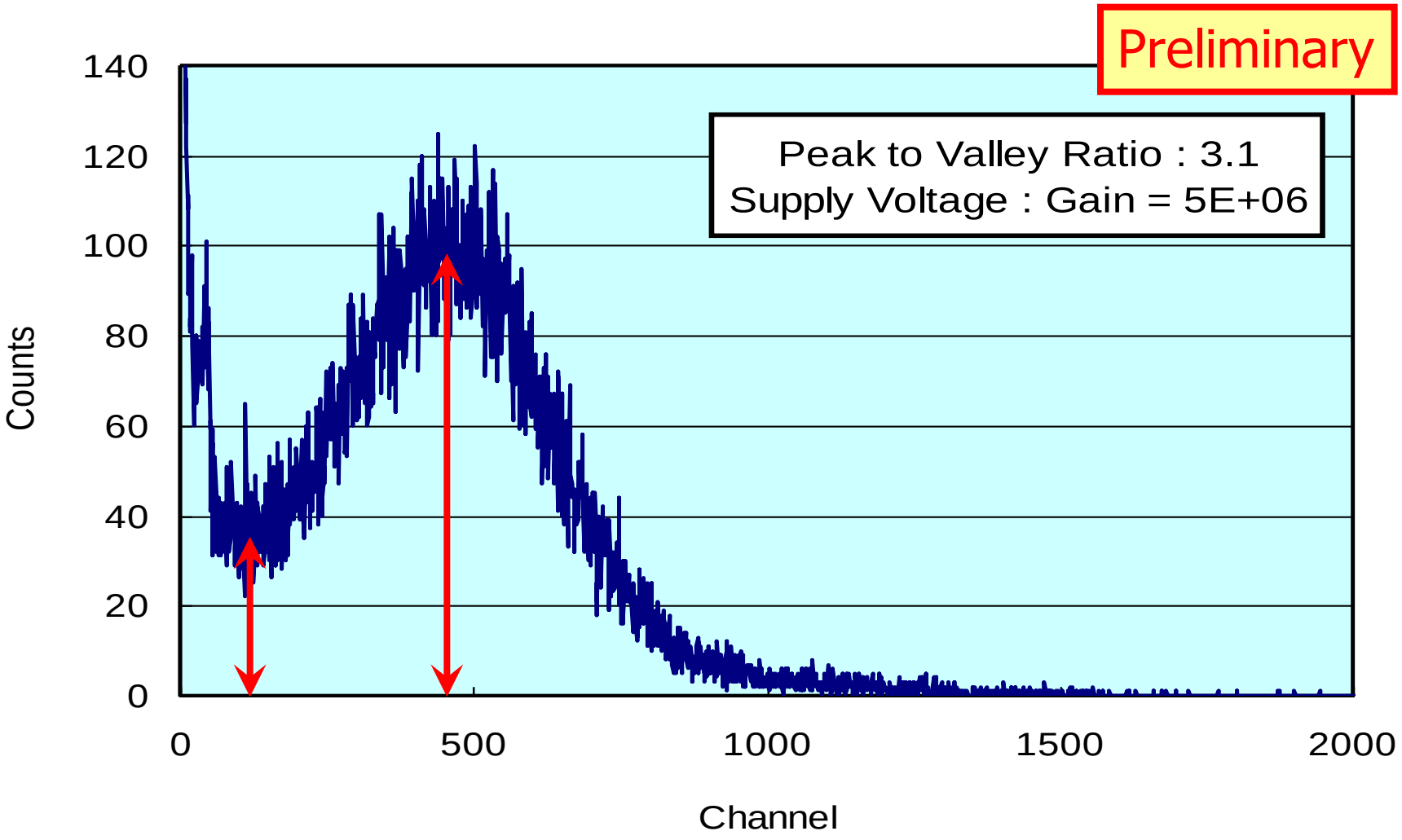
R12199 Uniformity (X-Axis)



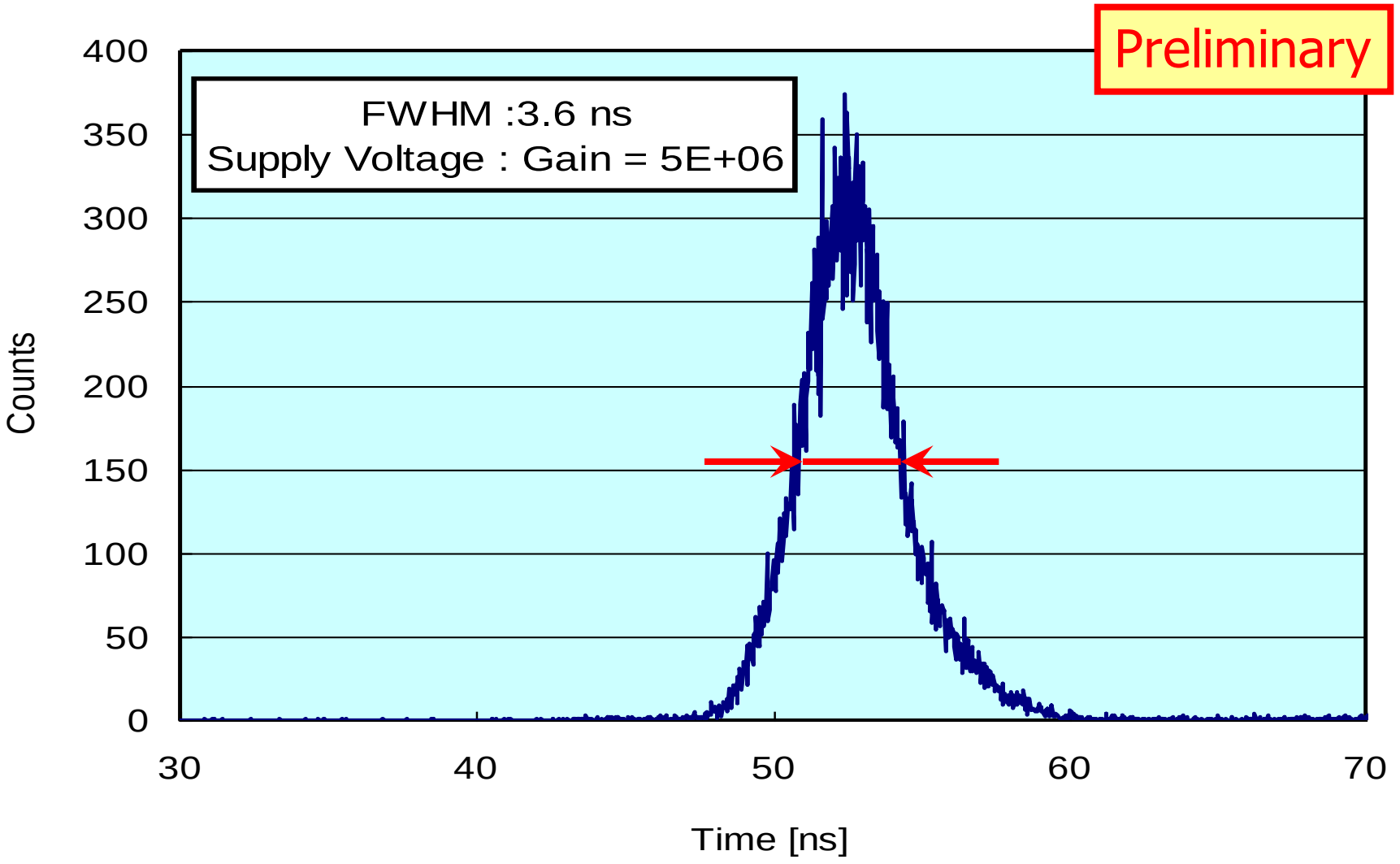
R12199 Uniformity (Y-Axis)



R12199 Pulse Height Distribution

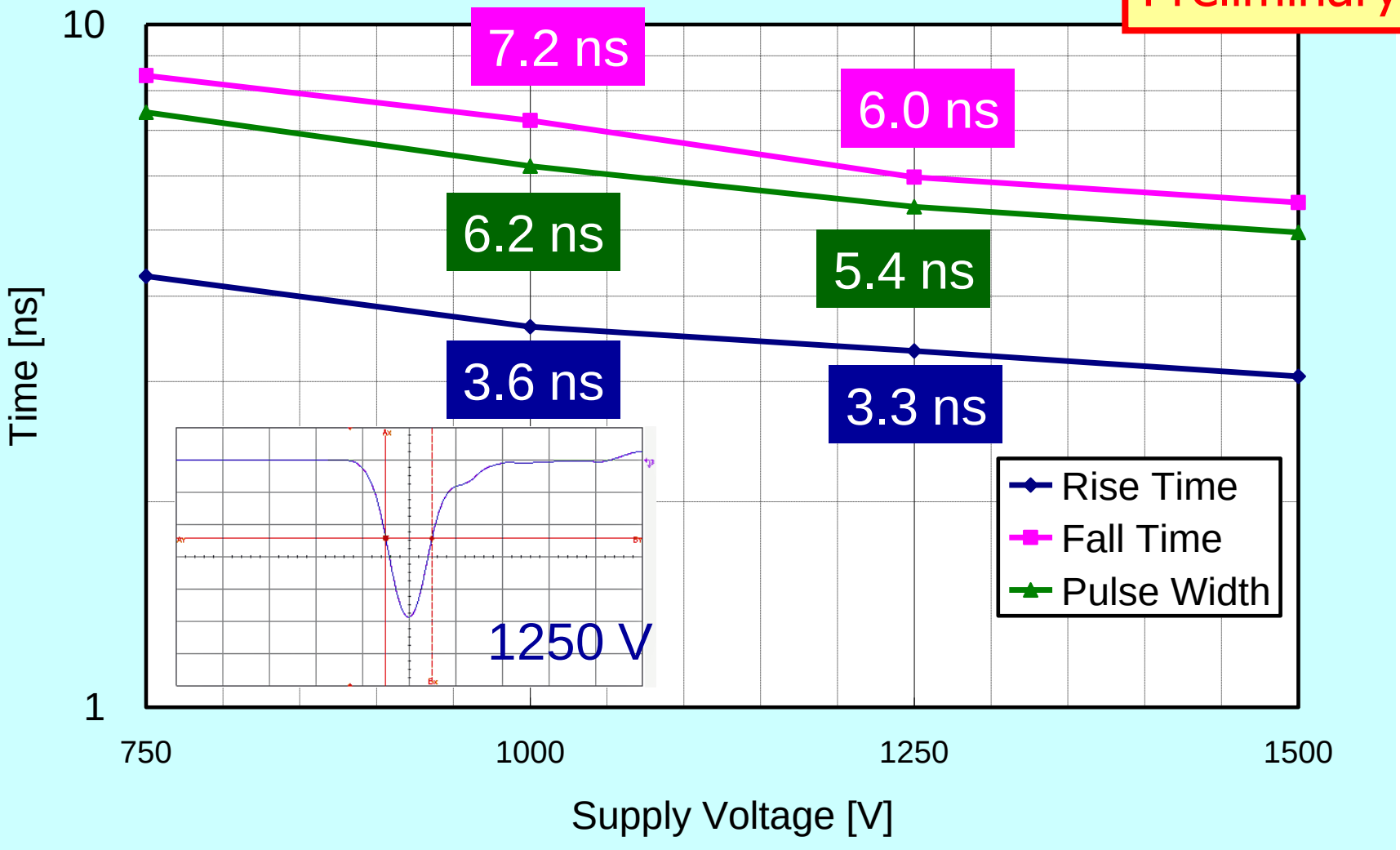


R12199 Transit Time Spread



R12199 Time Response

Preliminary



R12199 Characteristics

Preliminary

Parameter	Requirement	R12199
QE	32% min. at 404 nm	22 - 23% at peak
Gain	5×10^6	$2 - 5 \times 10^6$
TTS (FWHM)	4.7 ns max.	3.5 – 4.5 ns
Effective area (Diameter)	72 mm min.	74 mm.
P/V ratio	3 min.	3
Dark Count	3000 max.	To be measured
Length	105 mm max.	97 mm +/- 1 mm
Price	Cheap	Cheap
Mass Production	Possible	Possible

R12199 Development

-We are now trying to find optimal production condition for R12199 (New 3 inch PMT).

- Samples will be available soon.

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Tentative Delivery Schedule

Production and Delivery Plan of 3-inch PMT for KM3NeT

Date: Apr.27.2011

	1st Year												2nd Year				3rd Year				4th Year				5th Year				6th Year				7th Year			
	1	2	3	4	5	6	7	8	9	10	11	12	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Delivery					1,000/M				2,000/M				4,200/M				4,200/M				4,200/M				4,200/M				4,200/M				4,200/M			
Subtotal:									12,000				50,400				50,400				50,400				50,400				50,400				50,400			
Total:																																	314,400			

Materials	Production (Employment of New Workers -> Training -> Skill up																																			
									Additional Equipment-1 (Welding Machine, Activation Bench)																													
													Additional Equipment-2 (Evaporation, DC Measurement Setup)																										

3. Development of 12 inch PMT

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Large Format PMT Lineup

We have 13" Between 10" and 20".
It has Metal Flange (special part).
Limited production rate & higher cost !!

It's necessary to have a similar size of PMT with conventional structure for less cost and mass-production.
=> 12-inch PMT was developed !!

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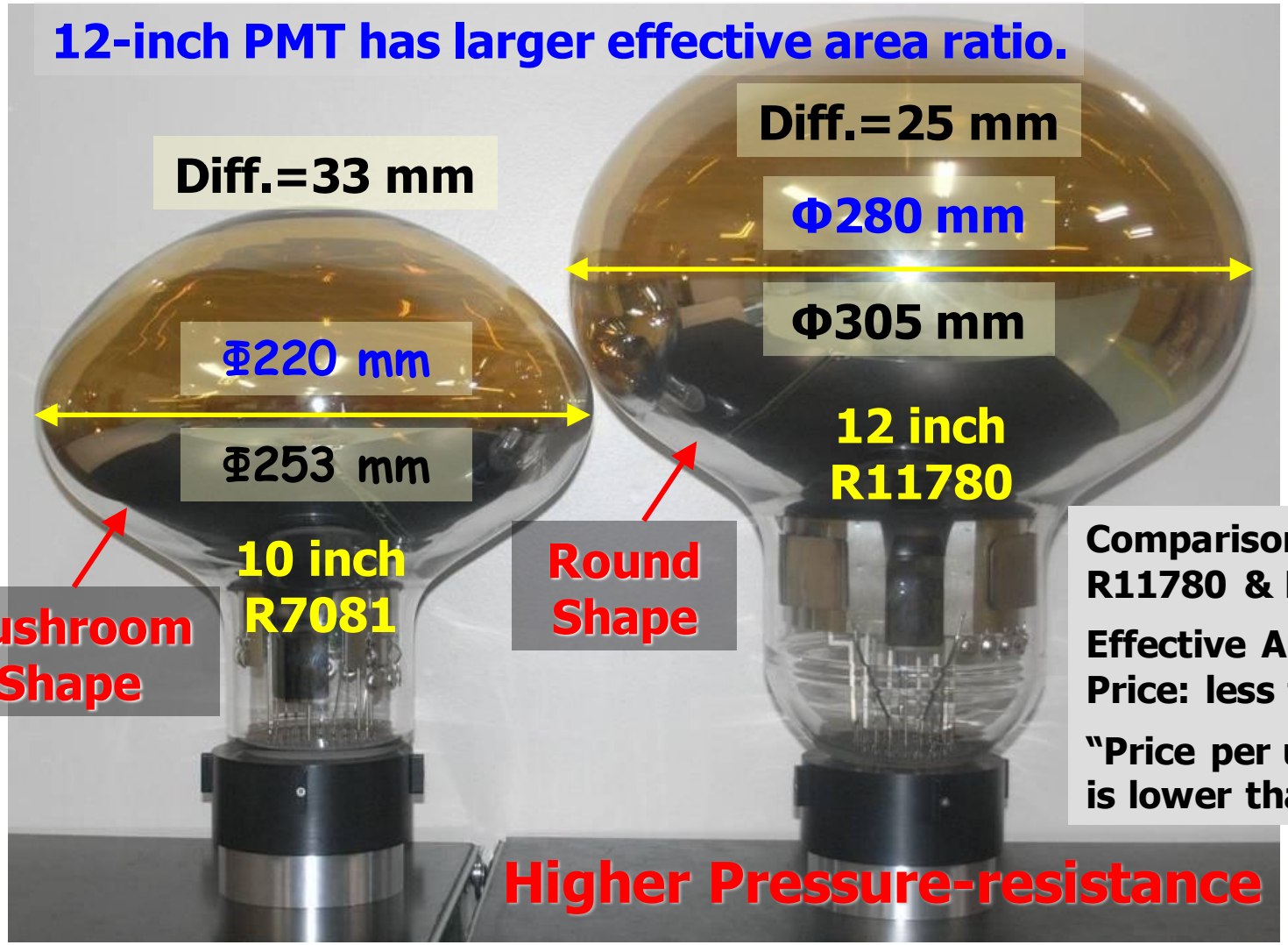
Comparison of Dimension between 10-inch and 12-inch PMT



Comparison between R11780 & R7081

Effective Area: 1.62
Price: less than 1.5

"Price per unit area" is lower than R7081.

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Comparison of Characteristics

Items	R11780 12-inch PMT	R7081 10-inch PMT
Diameter	305 mm	253 mm
Effective Area	280 mm min.	220 mm min.
Effective Area Ratio	84.3%	74.6%
Tube Length	385 mm	300 mm
Dynodes	LF/10-stage	LF/10-stage
GAIN	1.0E+07 at2000V	1.0E+07 at 1500V
T.T.S. (FWHM)	2.7 ns	2.9（3.4） ns
P/V Ratio	3.0	2.5（2.8）
Dark Counts	10,000 cps	7,000 cps

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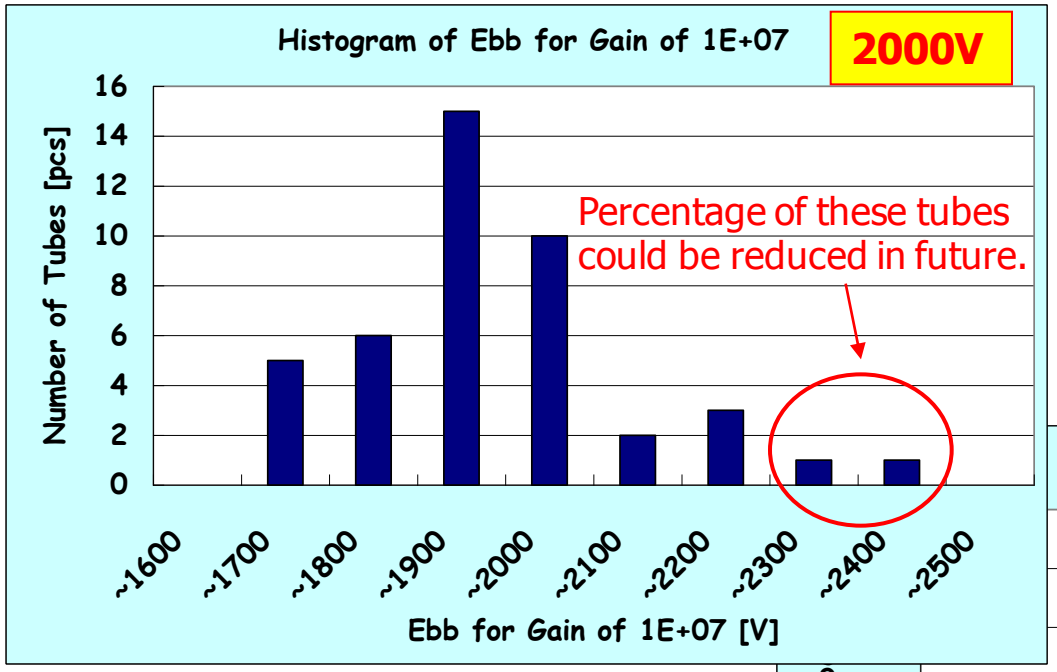
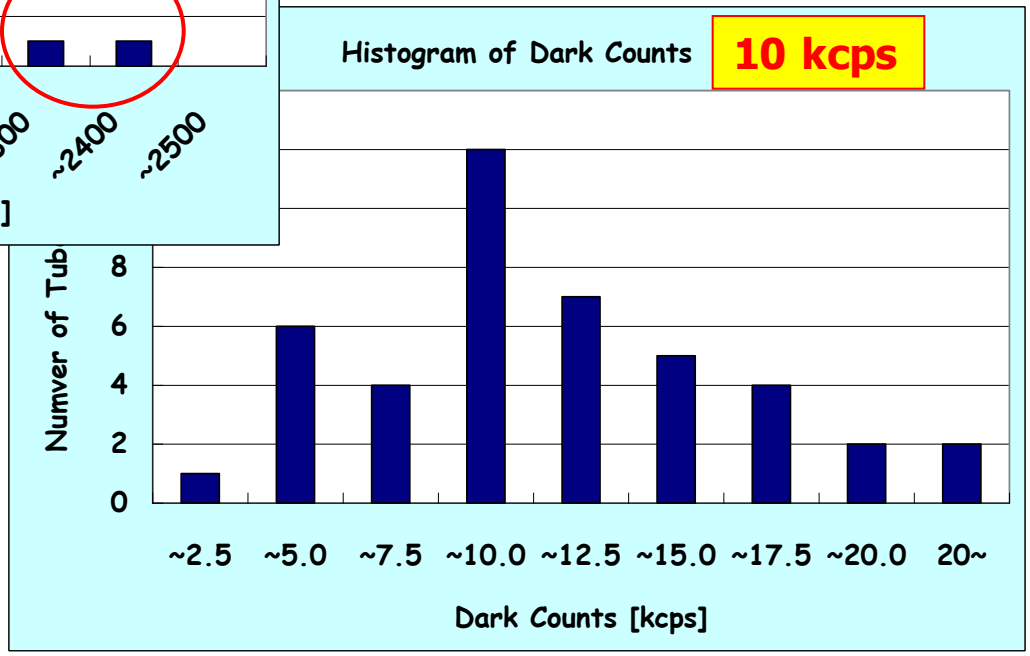
R11780 Ebb & Dark Counts



Ebb for Gain of 1E+07
Average: 1890 V
STDEV: 157 V
Min.: 1660 V
Max.: 2320 V

Samples: 43 tubes



Dark Counts at Ebb (1E+07)
Average: 10.6 kcps
STDEV: 5.6 kcps
Min.: 2.0 kcps
Max.: 30.5 kcps

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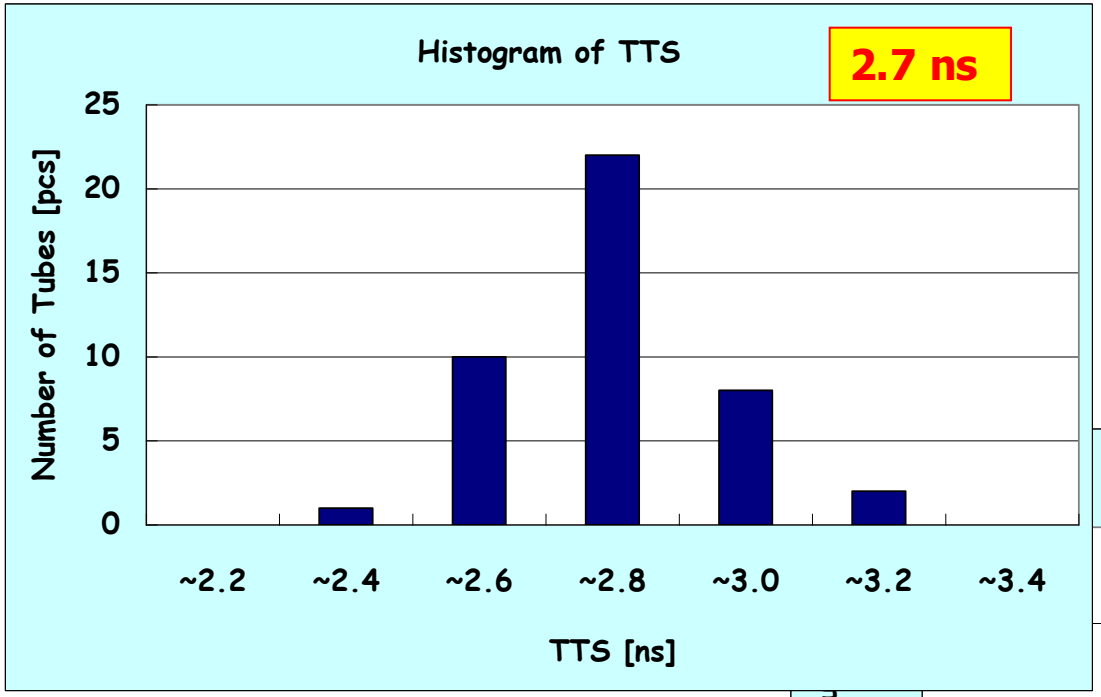
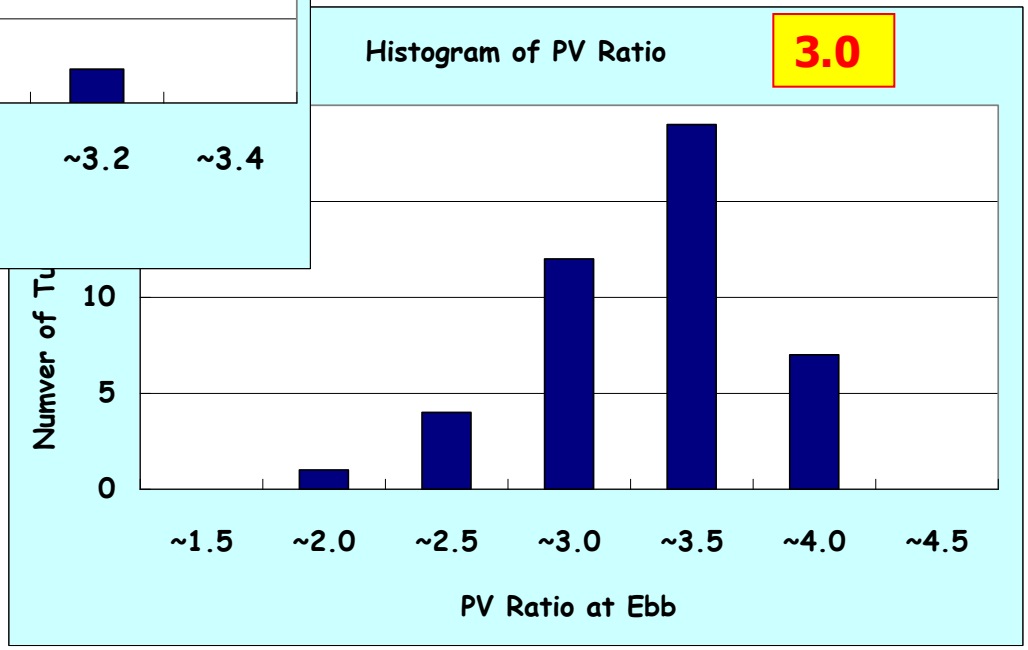
R11780 TTS & PV Ratio



TTS at Ebb (1E+07)
Average: 2.70 ns
STDEV: 0.16 ns
Min.: 2.35 ns
Max.: 3.13 ns

Samples: 43 tubes



PV Ratio at Ebb (1E+07)
Average: 3.00
STDEV: 0.48
Min.: 1.70
Max.: 3.90

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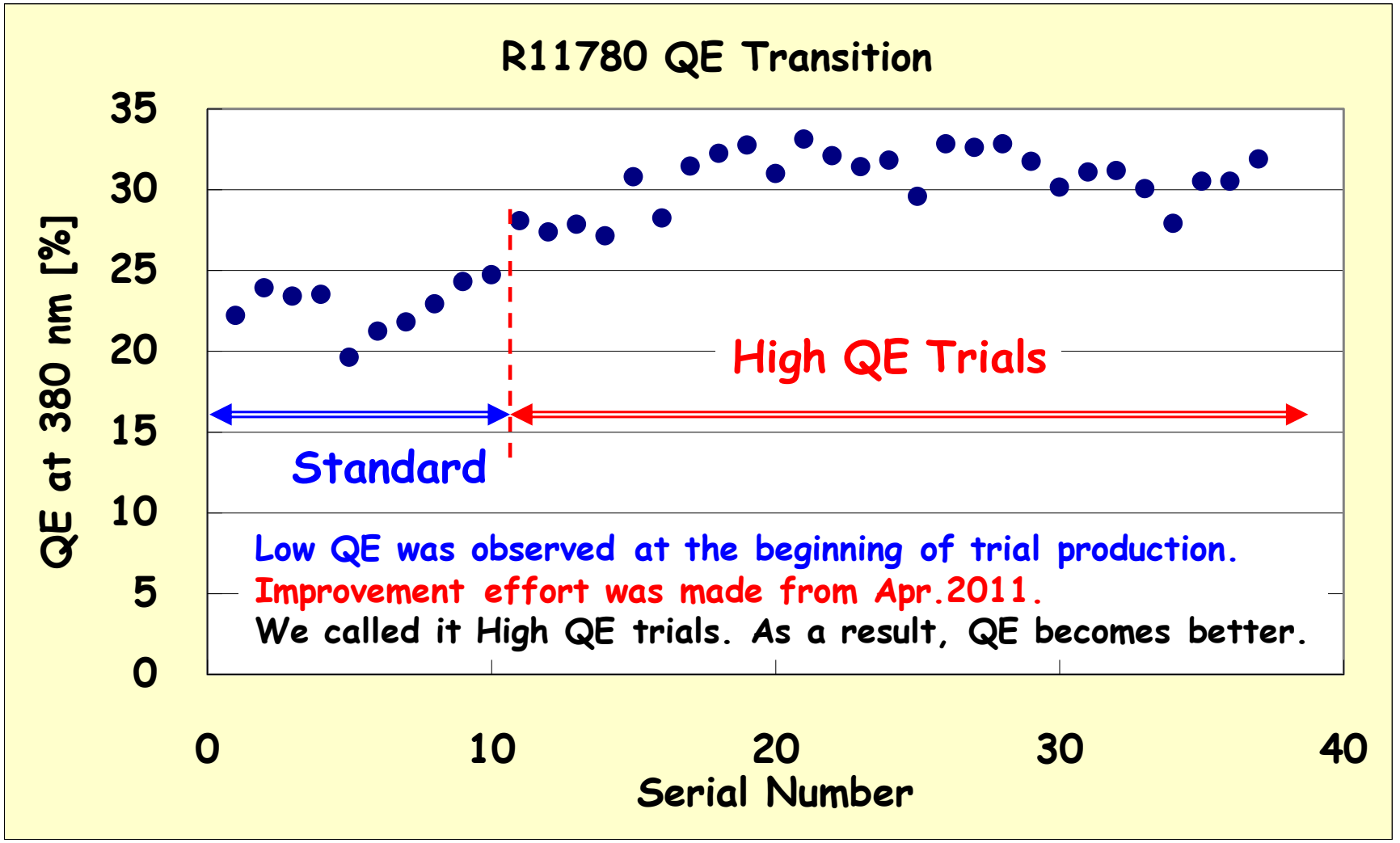
R11780 QE Improvement



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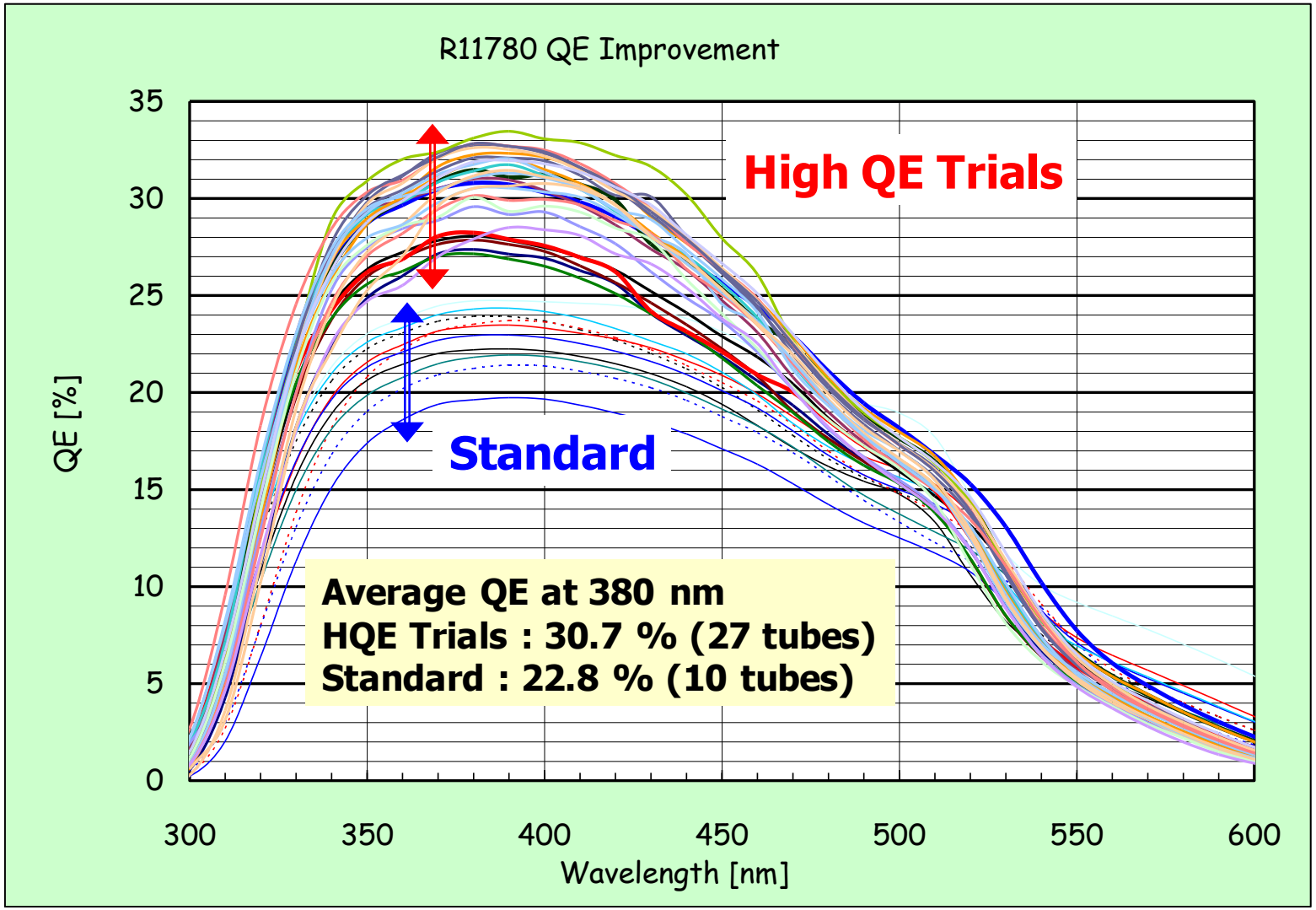
R11780 QE CURVES



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R11780 Further Improvement

QE has to be improved further.

R7081-HQE select : QE = 32 % min. at 380nm
R11780-HQE Trials: QE = 30.7 % ave. at 380nm

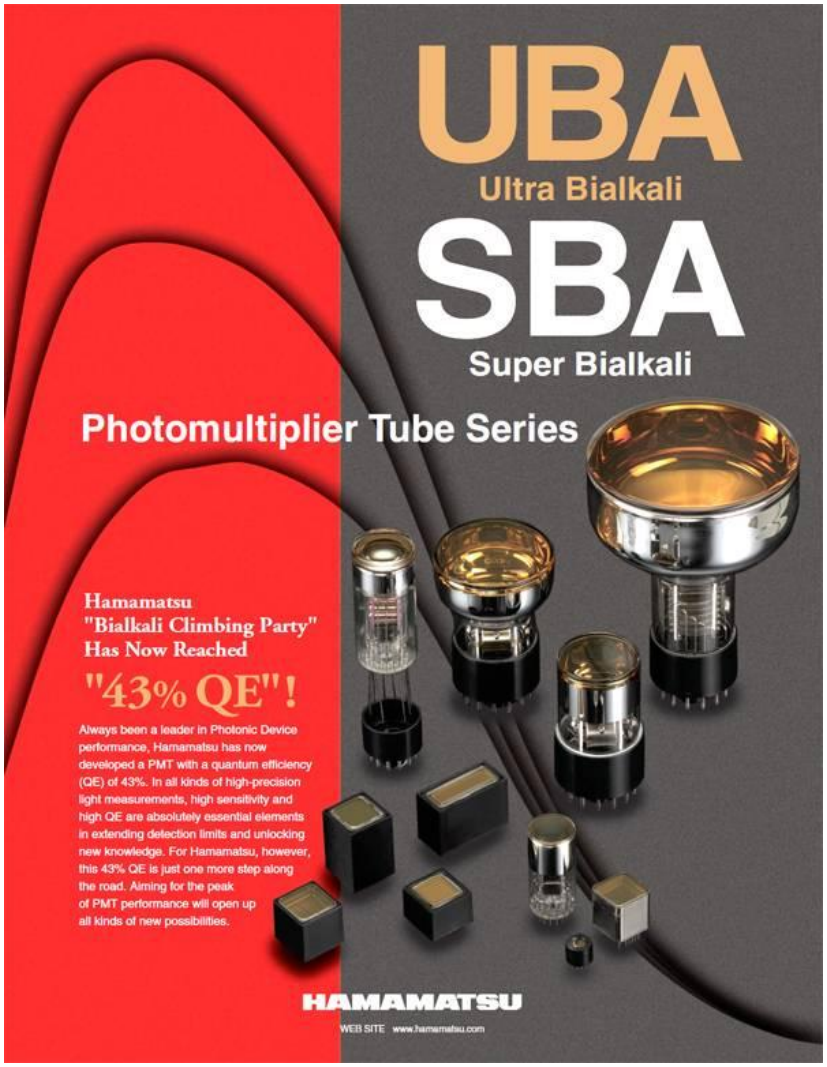
After Pulse is larger than our expectation.

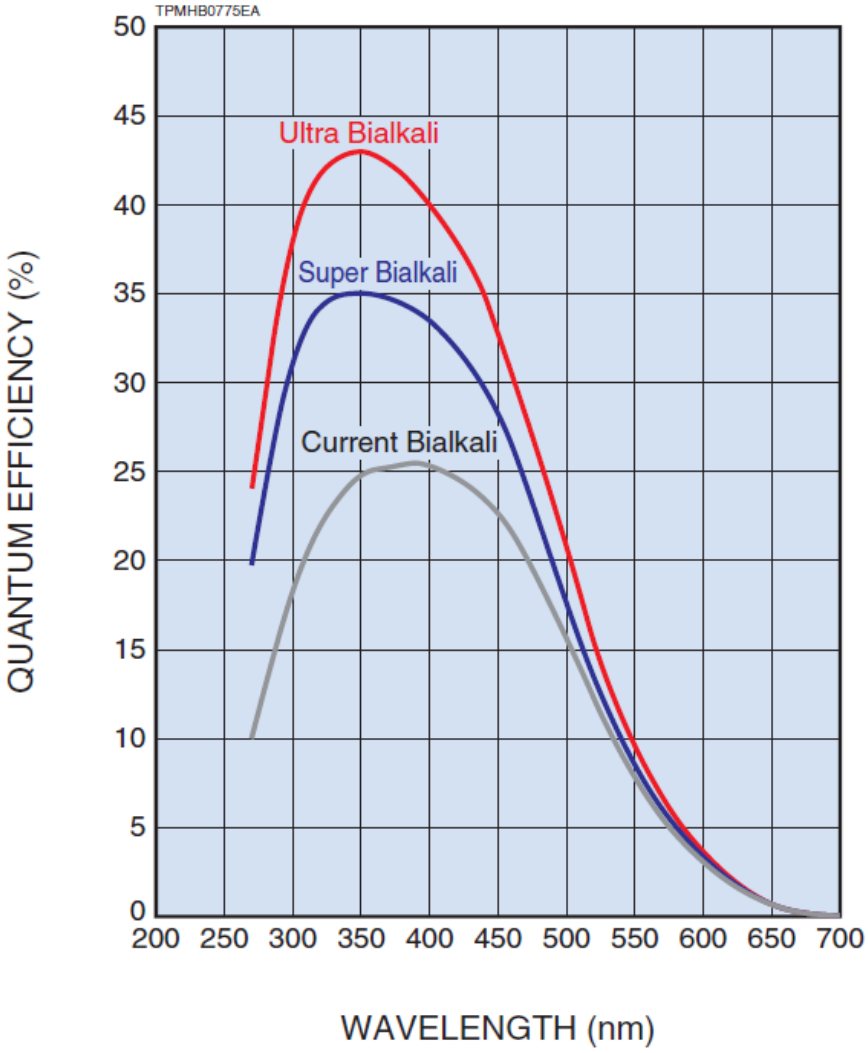
R11780 standard : 10% (0.1~16u sec)
R11780-HQE Trials : 15% (0.1~16u sec)
R7081: 2% (0.1~16u sec)

Those characteristics can be improved with suitable production conditioning, especially in the activation process.

www.hamamatsu.com

High QE Bialkali Photocathode



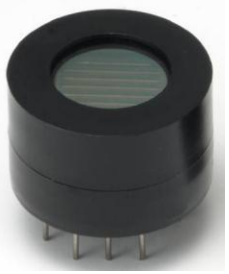


Definition of SBA/UBA

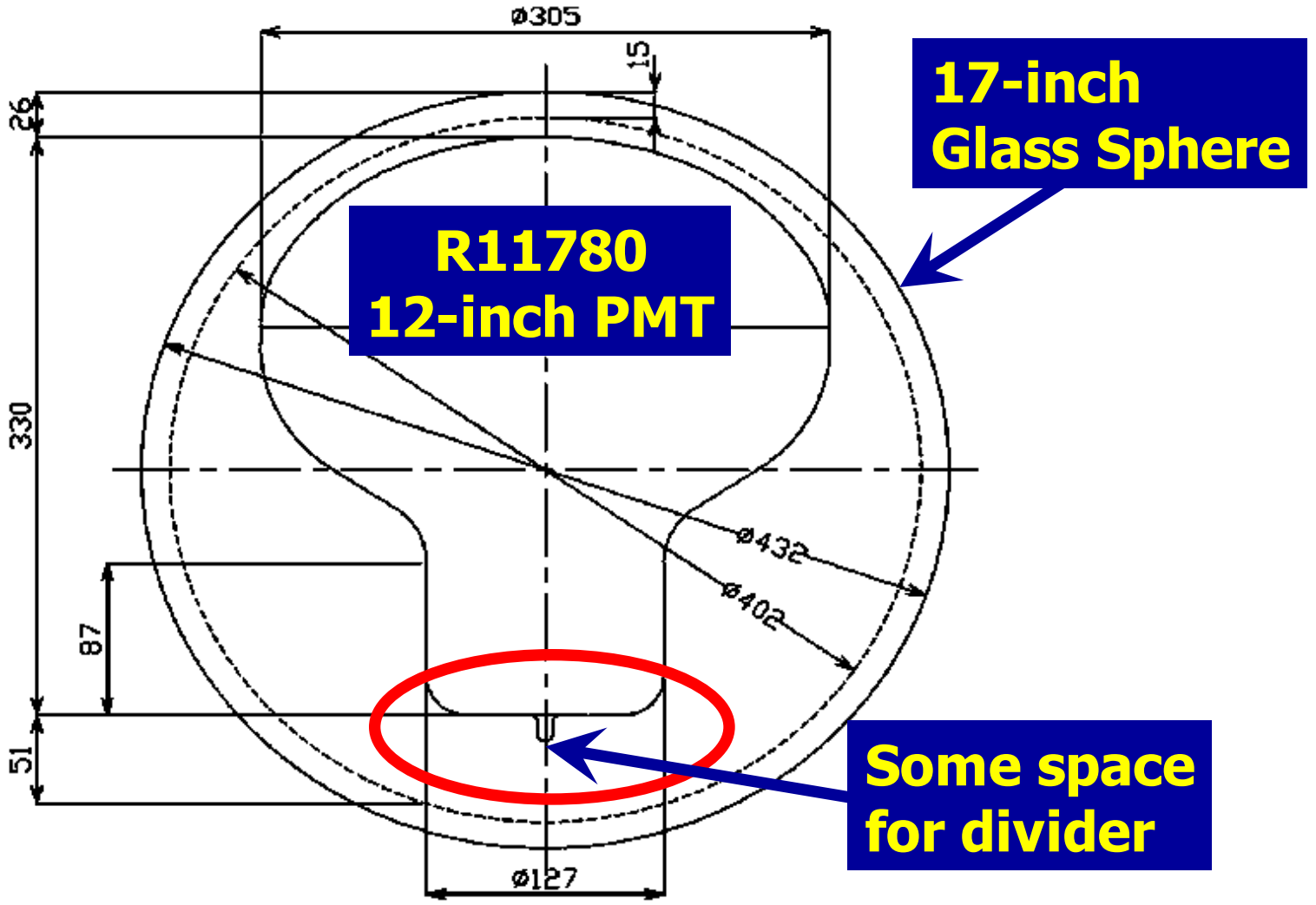
Photocathode (suffix)	QE at peak wavelength		Available Products
	Min.	Typ.	
Ultra Bialkali "UBA" (-200)	38%	43%	R7600/R8900 (Metal Package PMT)
Super Bialkali "SBA" (-100/-110)	32%	35%	R7600/R8900/R9880 (Metal Package PMT) 1-1/8"-5"Glass Bulb types

R7600/R8900
1 inch Square
Metal Package

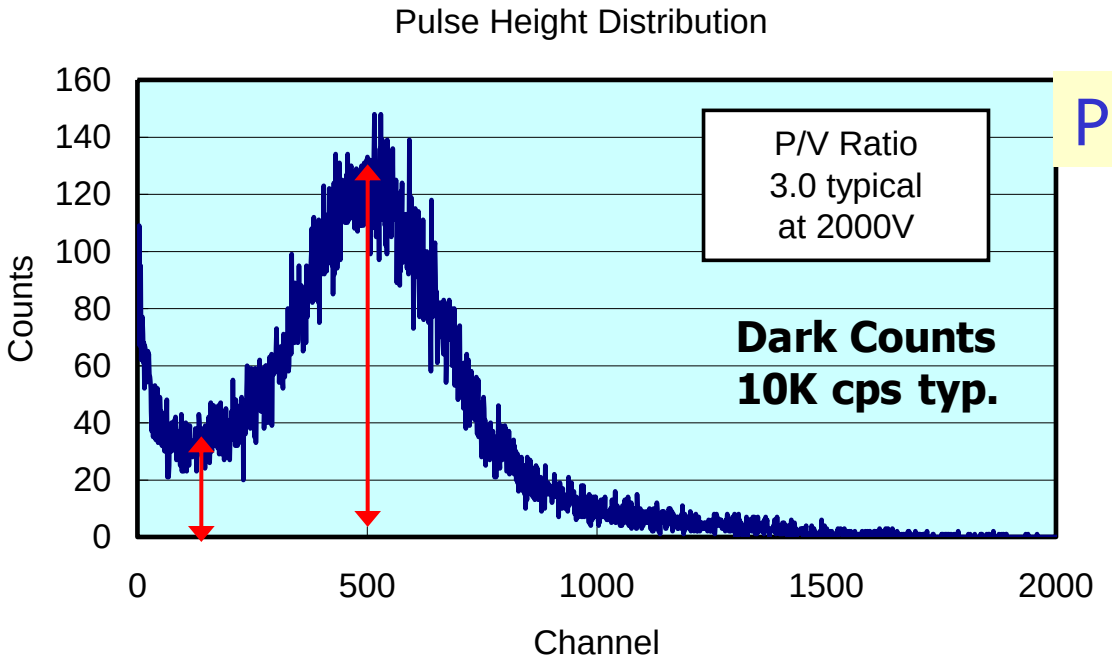
R9880
New TO-8 type
Metal Package



R11780 with 17″ Glass Sphere

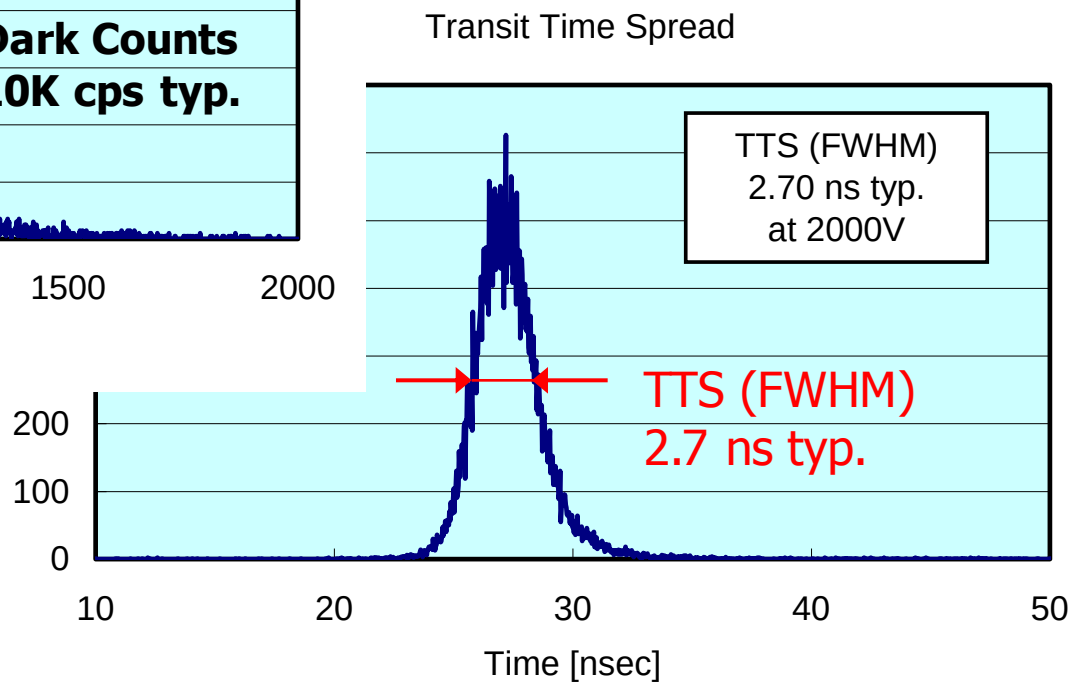


R11780 PHD and TTS

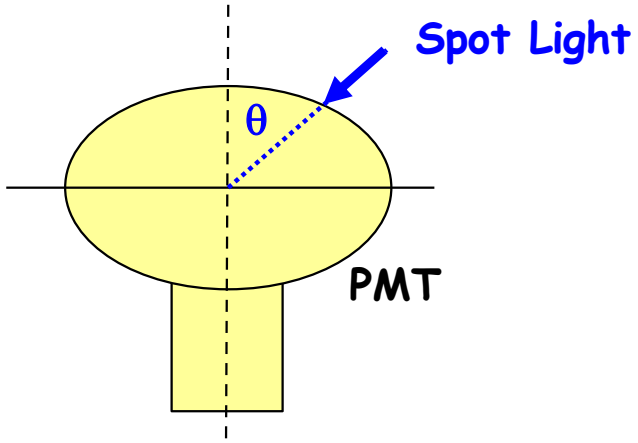


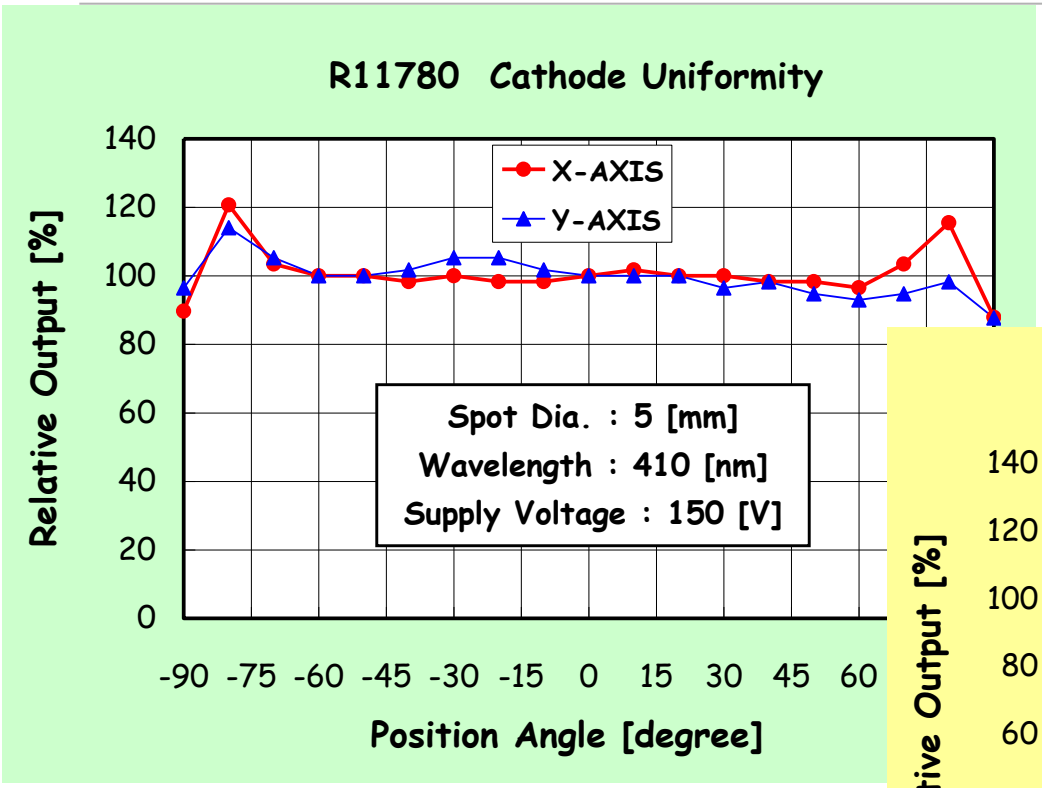
P/V ratio
3.0 typ.

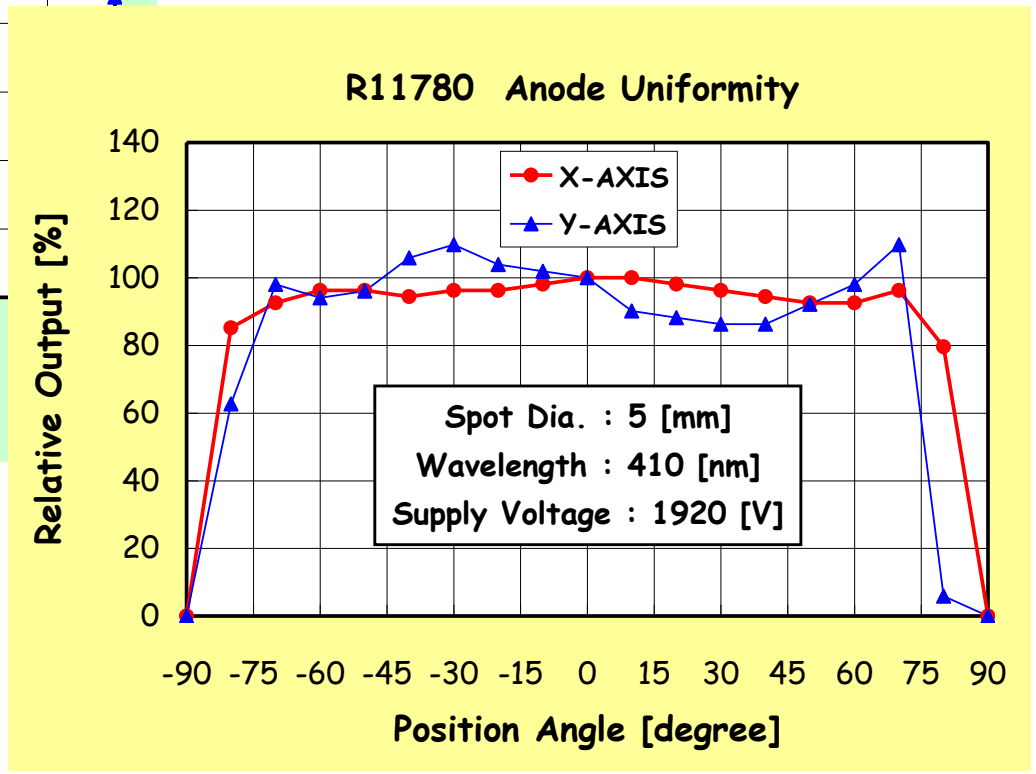
Prime features of R11780



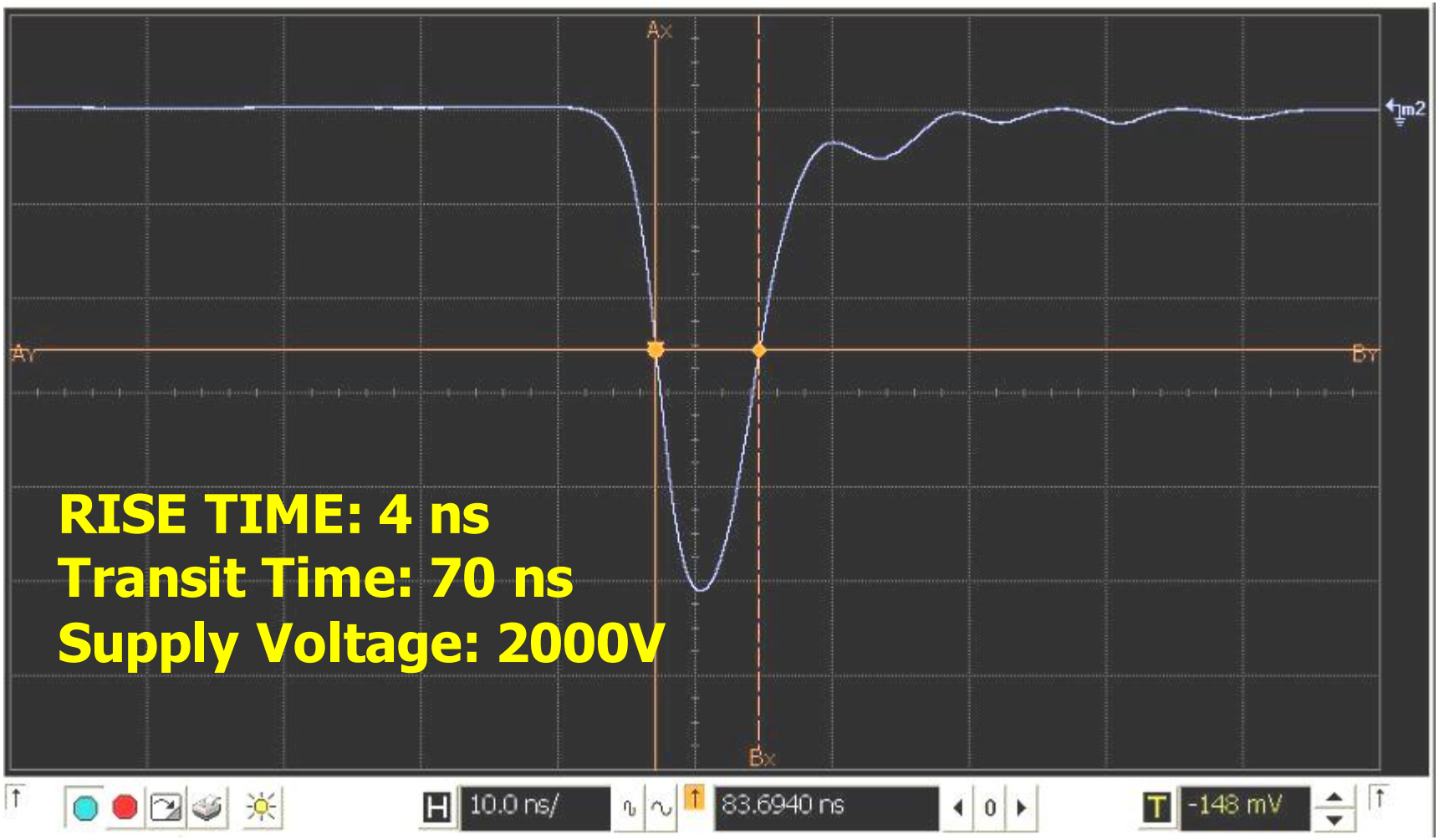
R11780 Uniformity







R11780 Waveform (Rise Time)



R11780 Gain vs Voltage