Calculate Light Yield

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Chonbuk National University

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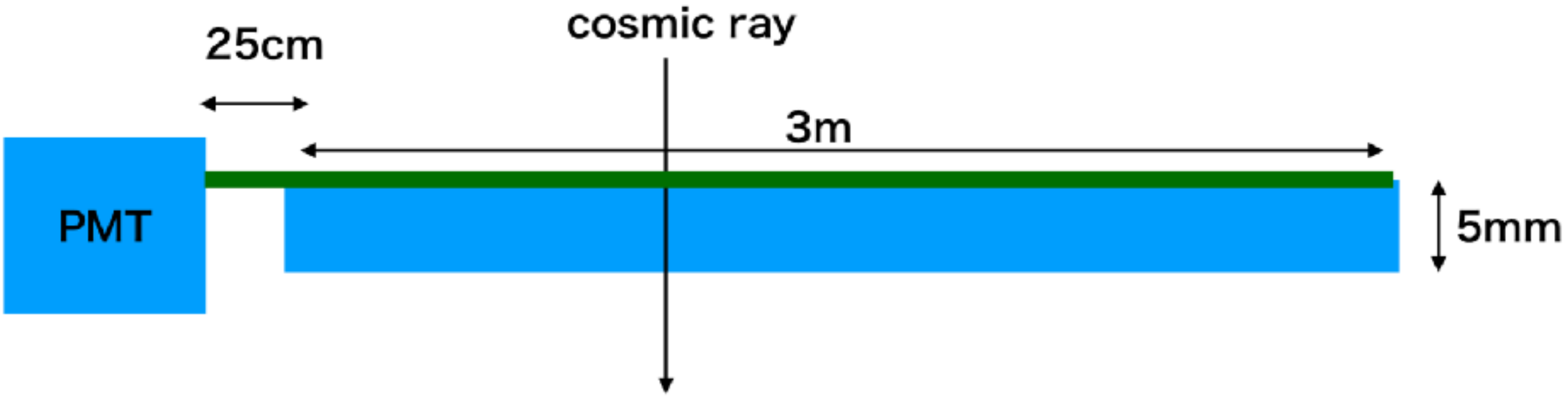


How many photo electrons we will obtain when cosmic ray passing through the 5mm-thick and 3m-long plastic scintillator ?
(6 points (0.5m, 1m, 1.5m, 2m, 2.5m, 3m from the MPT)

Needed input : Light yield of plastic scintillator
Trapping efficiency (1mm diameter WSF)
Absorption wave length of selected WLS Fiber
Attenuation length of the WLS finger
Quantum efficiency of the PMT

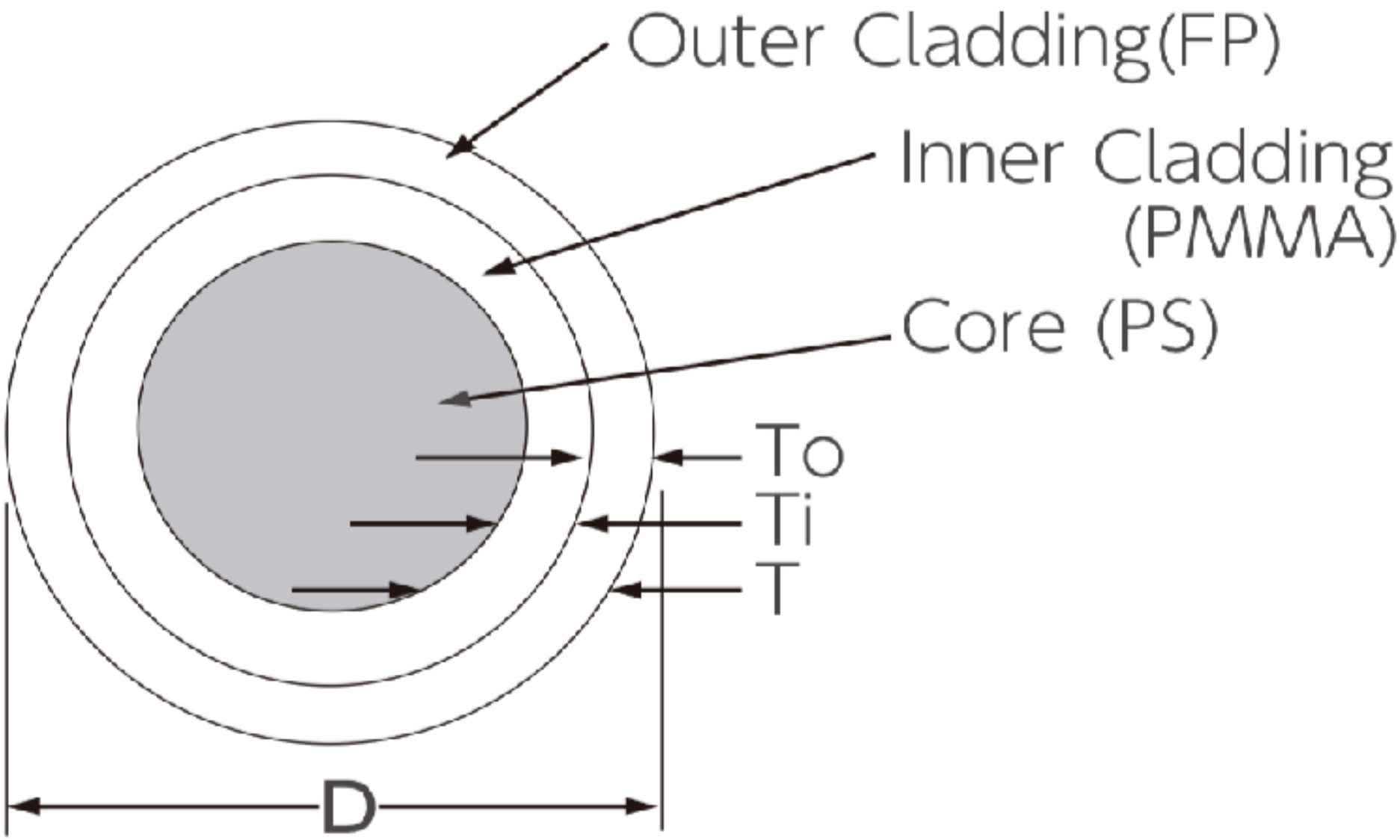
Properties of Plastic Scintillator(EJ-200, Eljen technology)

PROPERTIES	EJ-200	EJ-204	EJ-208	EJ-212
Light Output (% Anthracene)	64	68	60	65
Scintillation Efficiency (photons/1 MeV e^-)	10,000	10,400	9,200	10,000
Wavelength of Maximum Emission (nm)	425	408	435	423
Light Attenuation Length (cm)	380	160	400	250
Rise Time (ns)	0.9	0.7	1.0	0.9
Decay Time (ns)	2.1	1.8	3.3	2.4
Pulse Width, FWHM (ns)	2.5	2.2	4.2	2.7
No. of H Atoms per cm^3 ($x10^{22}$)	5.17	5.15	5.17	5.17
No. of C Atoms per cm^3 ($x10^{22}$)	4.69	4.68	4.69	4.69
No. of Electrons per cm^3 ($x10^{23}$)	3.33	3.33	3.33	3.33
Density (g/cm^3)	1.023	1.023	1.023	1.023
Polymer Base	Polyvinyltoluene			
Refractive Index	1.58			
Softening Point	75°C			
Vapor Pressure	Vacuum-compatible			
Coefficient of Linear Expansion	7.8×10^{-5} below 67°C			
Light Output vs. Temperature	At 60°C, L.O. = 95% of that at 20°C No change from 20°C to -60°			
Temperature Range	-20°C to 60°C			

Properties of Plastic Wavelength Shifter Fiber(Y11, Kuraray)

		Material	Refractive index	Density (g/cm^3)	No. of atom per cm^3
Core		Polystyrene (PS)	n_D=1.59	1.05	C:4.9×10^{22} H:4.9×10^{22}
Cladding	**for single cladding inner for multi cladding**	Polymethylmethacrylate (PMMA)	n_D=1.49	1.19	C:3.6×10^{22} H:5.7×10^{22} O:1.4×10^{22}
	outer for multi cladding	Fluorinated polymer (FP)	n_D=1.42	1.43	

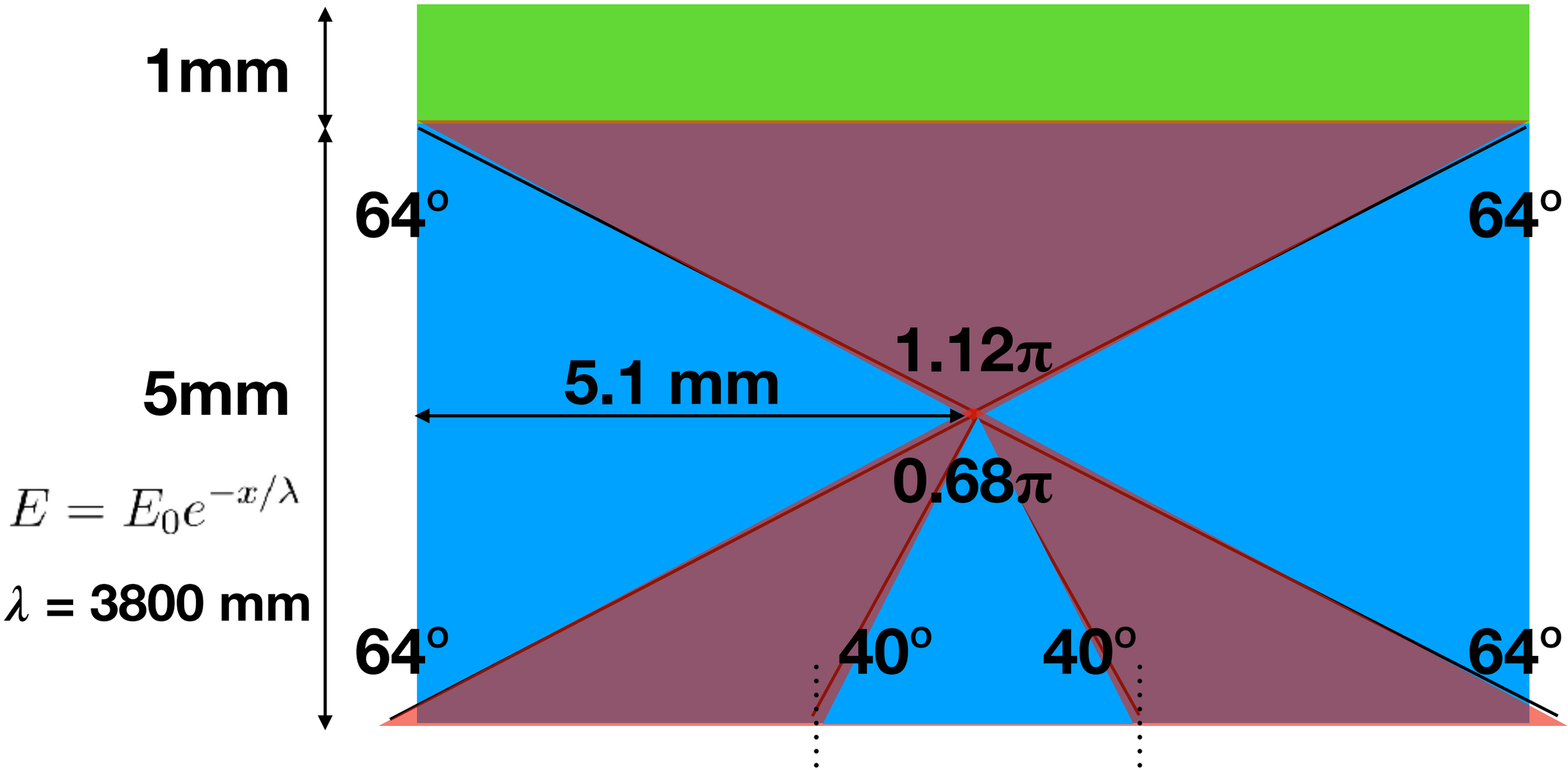
Description	Emission			Absorption Peak[nm]	Att.Leng.[2] [m]	Characteristics
	Color	Spectra	Peak[nm]			
Y-7(100)	green		490	439	>2.8	Blue to Green Shifter
Y-8(100)	green		511	455	>3.0	Blue to Green Shifter
Y-11(200)	green	See the following figure	476	430	>3.5	Blue to Green Shifter (K-27 formulation) Long Attenuation Length and High Light Yield
B-2(200)	blue		437	375	>3.5	UV to Blue shifter
B-3(200)	blue		450	351	>4.0	UV to Blue shifter
O-2(100)	orange		550	535	>1.5	Green to orange shifter
R-3(100)	red		610	577	>2.0	Green to red shifter



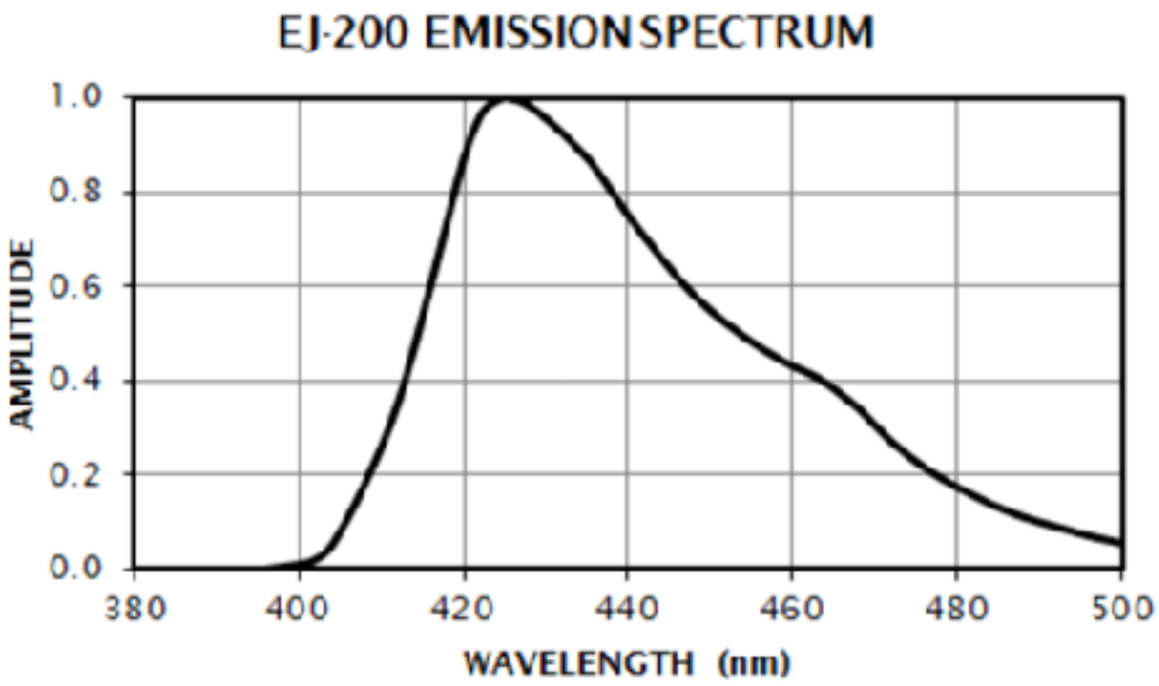
Cladding Thickness[2)] : T=2%(To)+2%(Ti)
=4% of D

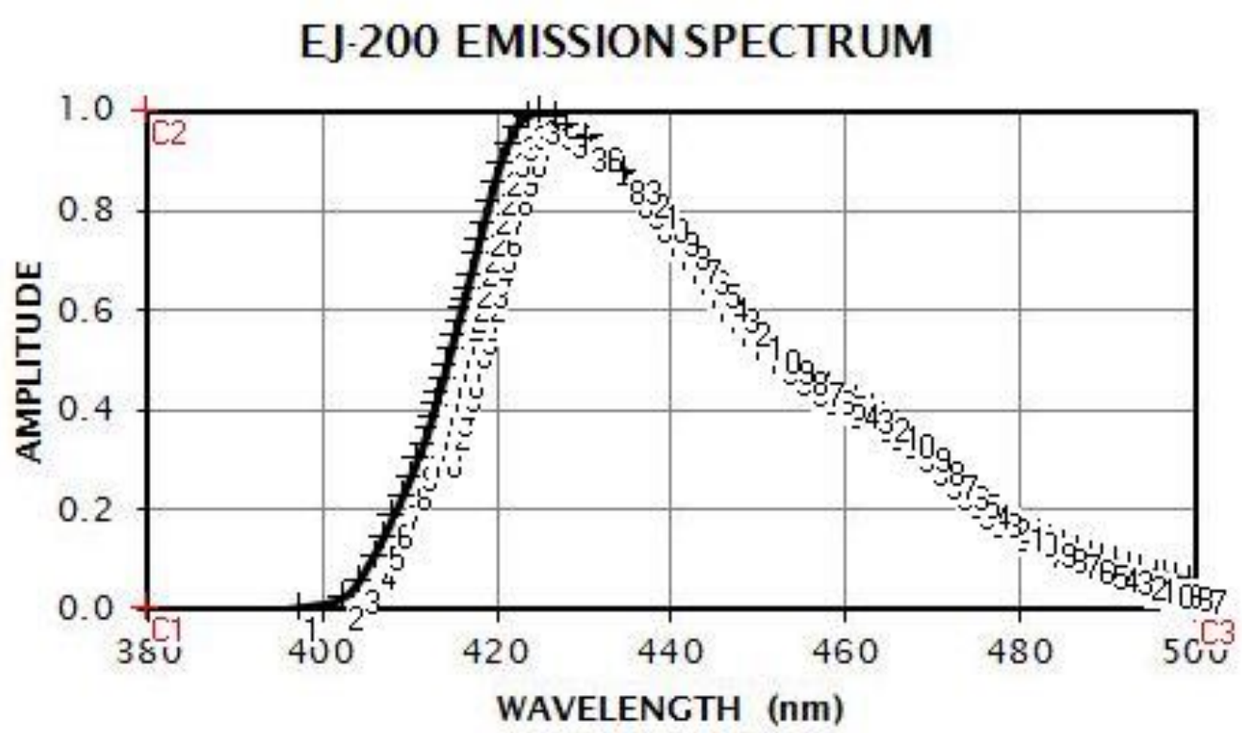
Numerical Aperture : NA=0.72

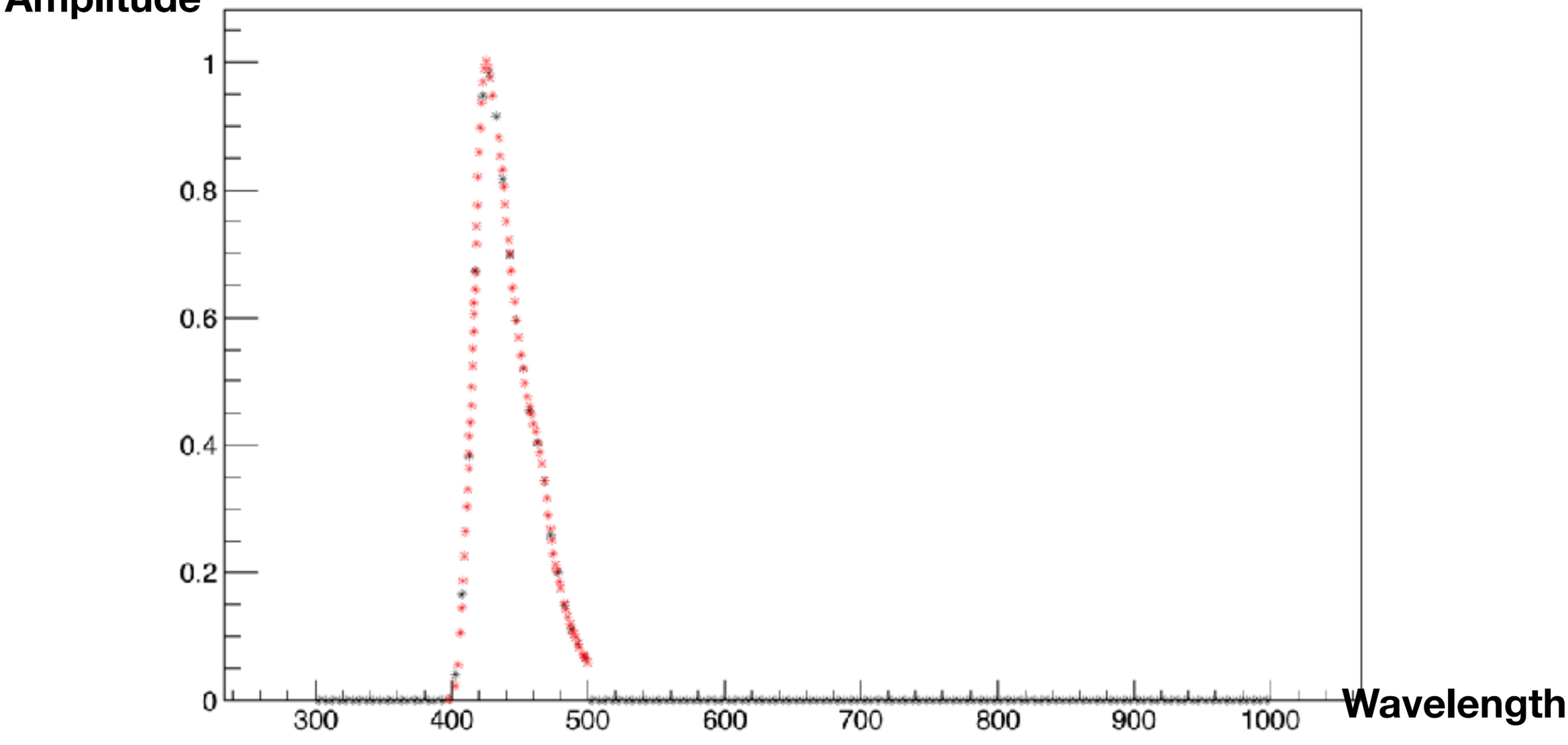
Trapping Efficiency : 5.4%



$$\frac{1.80\pi}{4\pi} = \frac{4500 photons}{10000 photons}$$

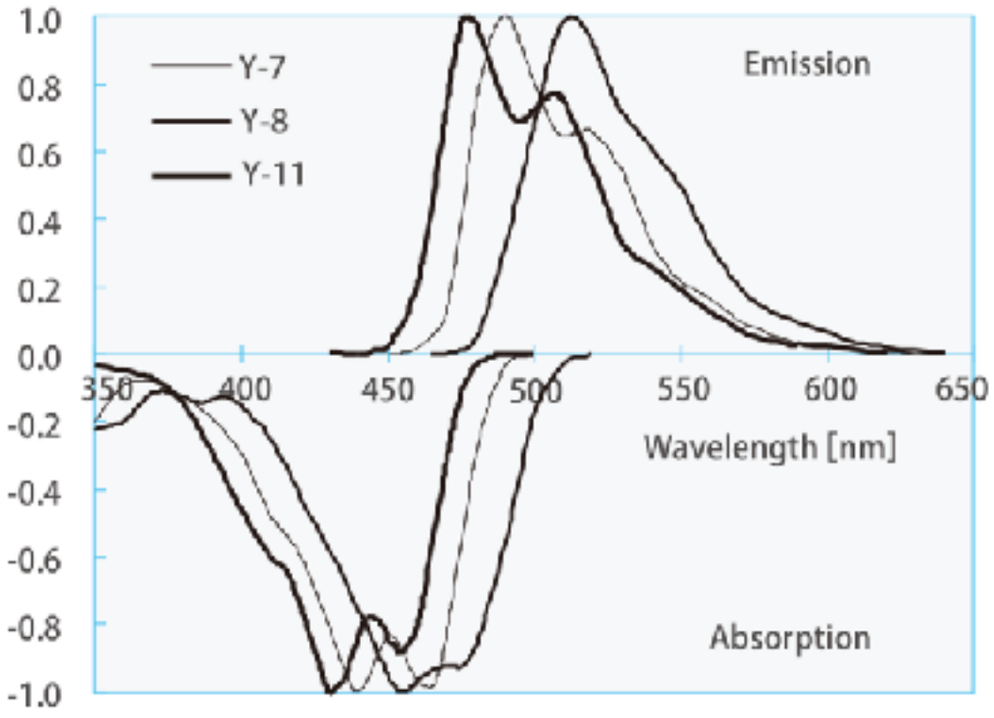

EJ-200 EMISSION SPECTRUM
AMPLITUDE
1.0
0.8
0.6
0.4
0.2
0.0
380
400
420
440
460
480
500
WAVELENGTH (nm)

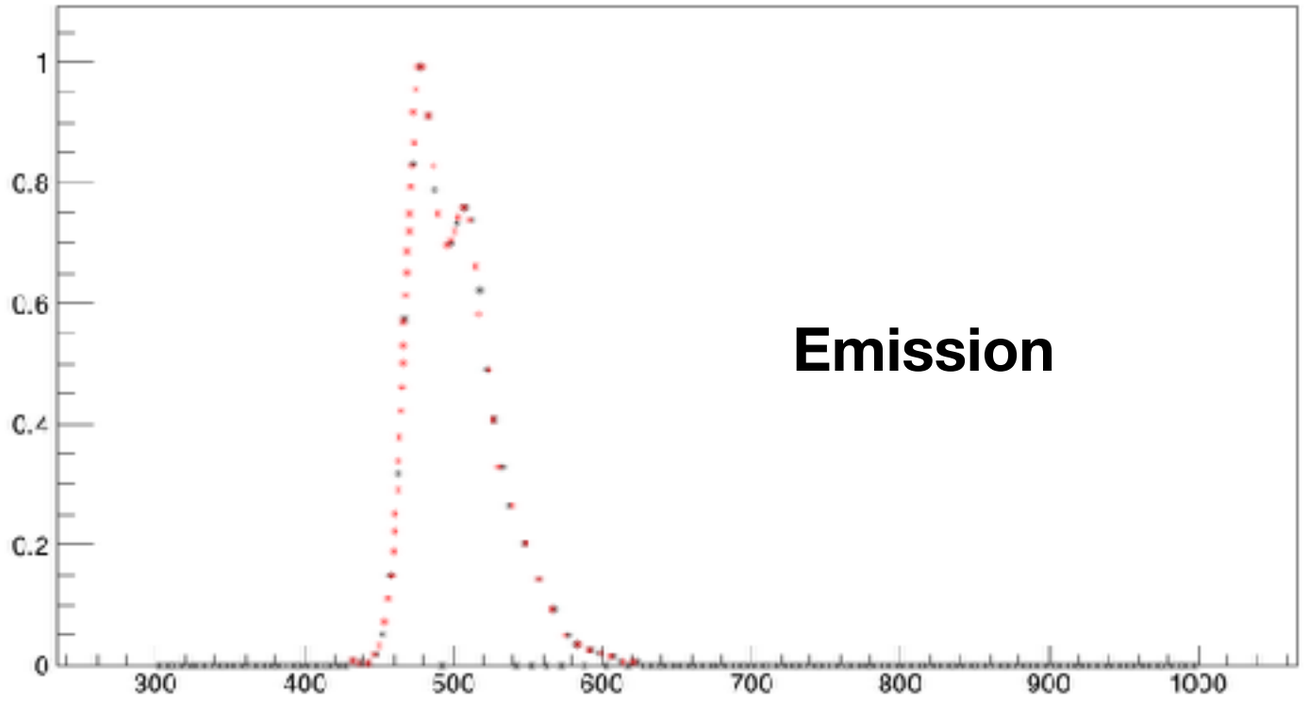

EJ-200 EMISSION SPECTRUM
AMPLITUDE
1.0
0.8
0.6
0.4
0.2
0.0
C2
C1
C3
380
400
420
440
460
480
500
WAVELENGTH (nm)


Amplitude
1
0.8
0.6
0.4
0.2
0
300
400
500
600
700
800
900
1000
Wavelength

Absorption and Emission Spectra

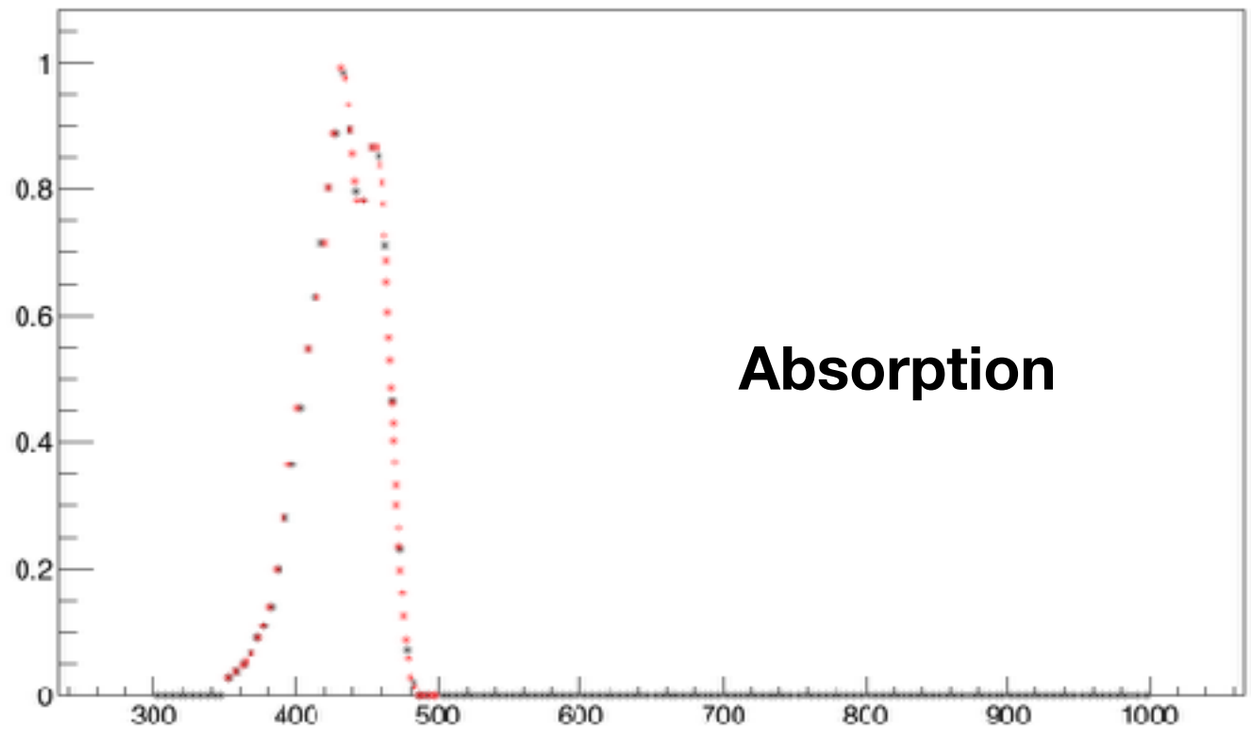
Y-7, Y-8, Y-11





Emission

Intensity



Absorption

3305 photons

Wavelength[nm]

number	EJ200 Emission Particle	Y11 Aborption Intensity	Emission Particle * Absorption Intensity	number of partice (50cm)	number of particle(300cm)	Quantum Efficiency	number of particle * Q.E(50cm)	number of particle * Q.E(300cm)
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0.0293381	0	0	0	0	0	0
11	0	0.0389765	0	0	0	0	0	0
12	0	0.0510383	0	0	0	0	0	0
13	0	0.0660205	0	0	0	0	0	0
14	0	0.0923646	0	0	0	0	0	0
15	0	0.1118619	0	0	0	0	0	0
16	0	0.141164	0	0	0	0	0	0
17	0	0.1998219	0	0	0	0	0	0
18	0	0.2829689	0	0	0	0	0	0
19	0.4088117	0.366176	0.1496970330592	0	0	0	0	0
20	20.170463	0.454245	9.162331985435	0	0	0	0	0
21	84.746421	0.5471429	46.368402550509	0	0	0	0	0
22	195.74539	0.6302379	123.386163526281	0	0	25.445699	0	0
23	343.43035	0.713405	245.00492884175	0	0	0	0	0
24	483.84884	0.801549	387.82855385316	0	0	24.756599	0	0
25	501.49517	0.889674	446.16721387458	0	0	24.4228	0	0
26	466.57118	0.982609	458.45702085644	0.127702	0.0613951	0	0	0
27	416.92593	0.8941633	372.808203942969	0.0526078	0.0252921	24.078699	1.2667330670324	0.6090059213979
28	358.35687	0.7960125	285.684522990875	0.0512195	0.0246249	23.085699	1.1824379699305	0.5684807207352
29	304.32529	0.7811499	237.724451000871	0.2722	0.130865	0	0	0
30	265.19467	0.8642809	229.202688062803	0.788698	0.379182	0	0	0
31	231.68127	0.851888	197.366493878776	2.26685	1.08983	21.4904	48.57950224	23.355492832
32	208.57659	0.7095595	146.578381912105	4.81815	2.31642	20.763999	100.04406178185	48.09814256356
33	175.86234	0.4839509	91.586851410106	8.69055	4.17815	0	0	0
34	132.52063	0.2319976	30.744494614614	12.6211	6.06782	19.057899	240.5316490689	115.63990071018
35	102.25403	0.0742651	7.593805758358	15.0512	7.24095	0	0	0
36	75.287231	0.0226686	1.7067528778746	13.8021	6.63561	17.4342	240.62857182	115.688551862
37	58.720142	0.0004322	0.0245144453724	11.9512	5.74579	16.8211	201.03233032	96.650506169
38	45.609275	0.0002575	0.0117443883125	0	0	16.4132	0	0
39	34.278137	0.0001011	0.0034655196507	10.6174	5.10454	16.0053	169.93467222	81.699594062
40	0	0	0	11.0971	5.33514	0	0	0
41	0	0	0	11.5027	5.53017	14.385899	165.4778306873	79.55702006963
42	0	0	0	11.2059	5.38742	13.5719	152.08287844	73.118986756
43	0	0	0	9.42884	4.5331	12.954999	122.15061277115	58.7263059669
44	0	0	0	7.42947	3.57186	0	0	0
45	0	0	0	6.17105	2.96685	11.3048	69.76248604	33.53964588
46	0	0	0	4.98635	2.39728	10.485199	52.28287203365	25.13595785872
47	0	0	0	4.02233	1.93381	9.0444068	36.379568803844	17.490184313808
48	0	0	0	0	0	8.1407899	0	0
49	0	0	0	3.05832	1.47035	7.6500001	23.396148305832	11.248177647035
50	0	0	0	0	0	6.8451499	0	0
51	0	0	0	2.1683	1.04245	6.3846149	13.84376048767	6.655641892505
52	0	0	0	0	0	5.7686702	0	0
53	0	0	0	1.42837	0.685757	5.2686649	7.522212813413	3.6116523218293
54	0	0	0	0	0	4.8589102	0	0
55	0	0	0	0.7583	0.364567	3.7681167	2.85736289361	1.3737310009689
56	0	0	0	0.534266	0.256858	3.4347798	1.8350860646268	0.8822506606684
57	0	0	0	0	0	2.9545867	0	0
58	0	0	0	0.384355	0.184788	2.8333301	1.0121335805855	0.4866025358586
59	0	0	0	0.269429	0.149293	2.12909	0.8597521882	0.2171891996

$$E = E_0 e^{-x/\lambda}$$

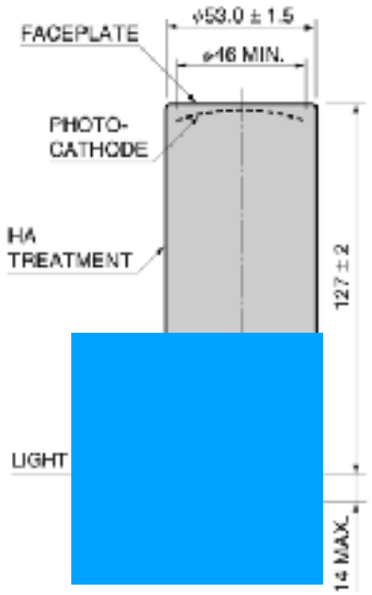
λ = 350 cm

Trapping Efficiency : 5.4%

x	50cm	100cm	150cm	200cm	250cm	300cm
Attenuatiion Length 고려	2904	2483	2153	1866	1617	1402
Trapping Efficiency 고려	156	134	116	100	87	75

Properties of Photomultiplier Tube

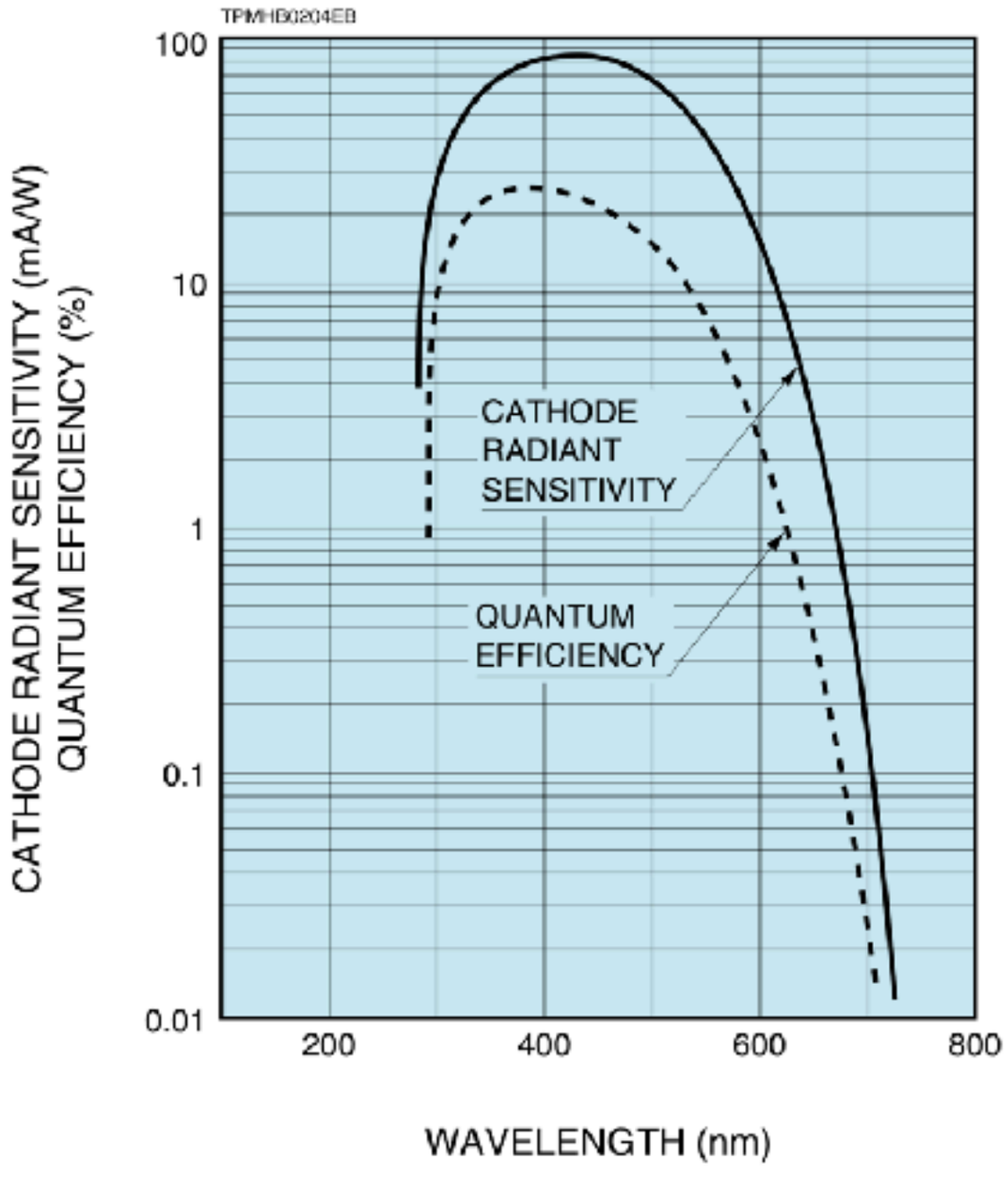
Hamamatsu R329-02

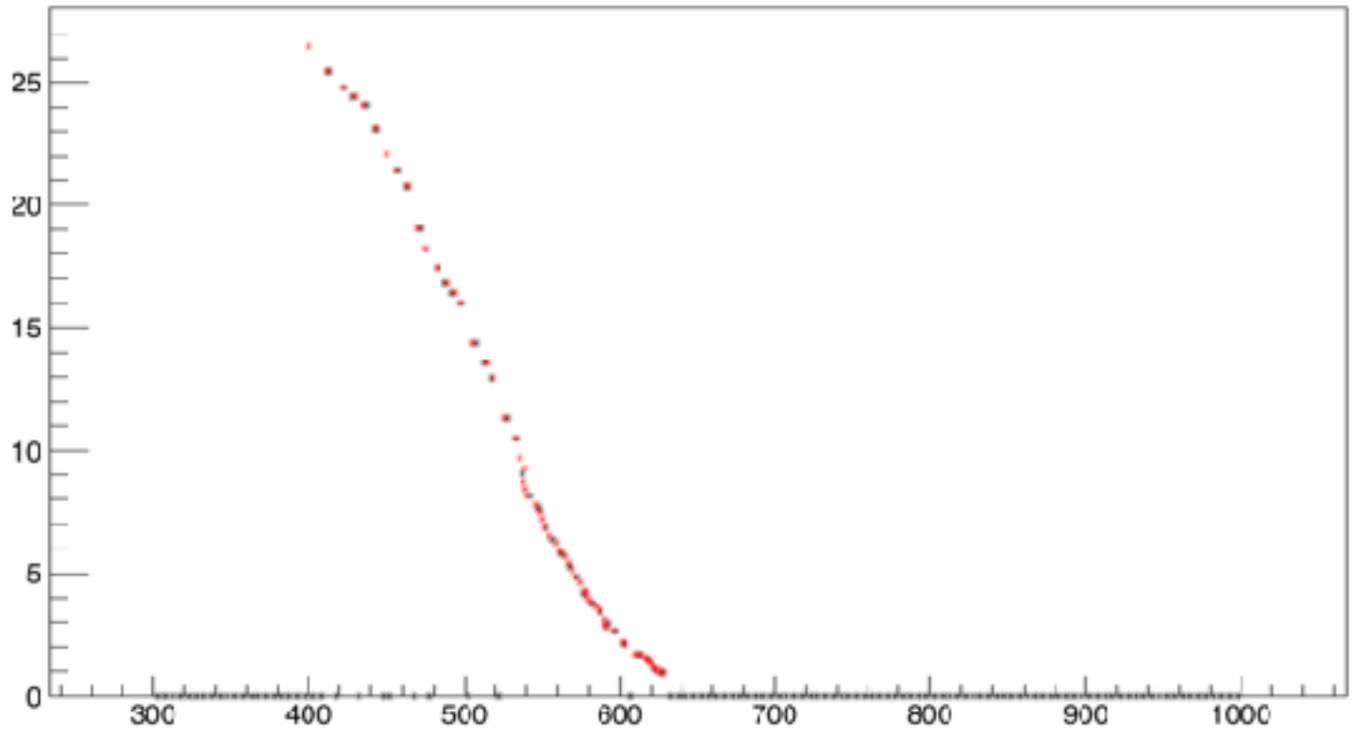


Parameter		Description / Value	Unit
Spectral response		300 to 650	nm
Wavelength of maximum response		420	nm
Photocathode	Material	Bialkali	—
	Minimum effective area	φ46	mm
Window material		Borosilicate glass	—
Dynode	Structure	Linear focused	—
	Number of stages	12	—
Operating ambient temperature		-30 to +50	°C
Storage temperature		-30 to +50	°C
Base		21-pin glass base	—
Suitable socket		E678-21C (supplied)	—

Quantum Efficiency

$$Q.E. = \frac{\text{Number of Photoelectrons}}{\text{Number of incidentphotons}}$$





Result

x	**50cm**	**300cm**
Number of photoelectron	16	7