

HAMAMATSU

Recent Progress in PMTs

Sept. 25 2007 at LIGHT07 Workshop

**Hamamatsu Photonics
Electron Tube Division**

Contents in this talk

What is Hamamatsu Photonics ?

High QE Bialkali Photocathode

Available Products

(Metal Channel PMTs and others)

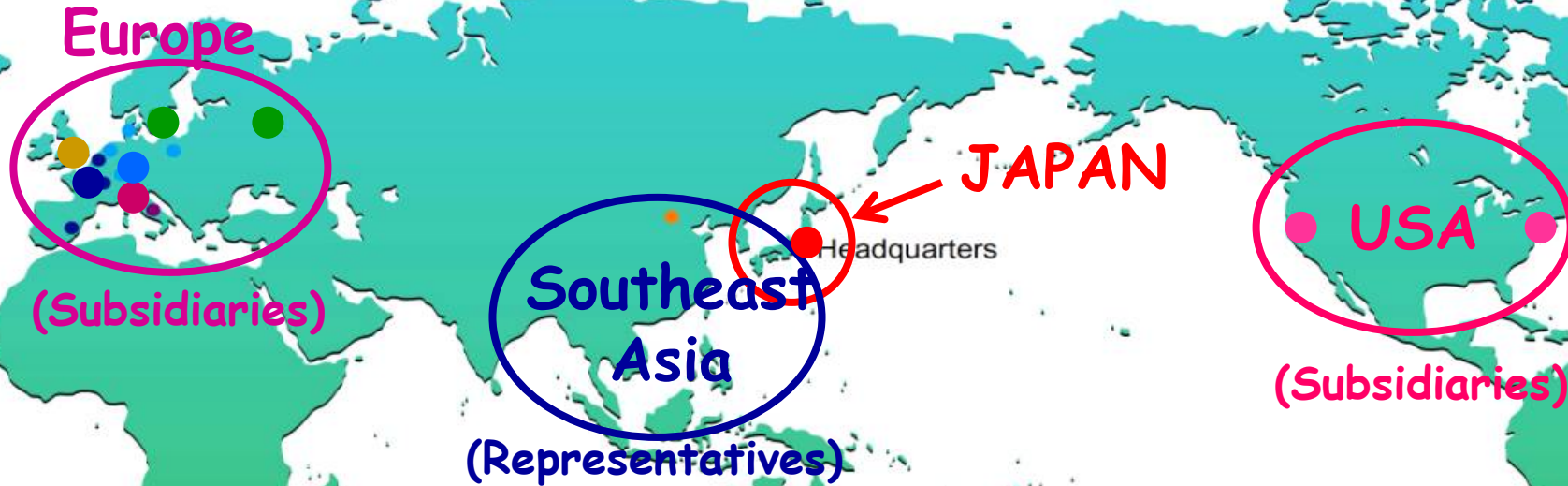
Developmental Products

(Fast PMTs, Large Format PMTs)

Combination with Solid State Devices

HPD(Hybrid Photo Detector)

Hamamatsu Sales Office Map



- HAMAMATSU PHOTONICS DEUTSCHLAND GmbH
 - Main Office
 - Danish Office
 - Netherlands Office
 - Poland Office
- HAMAMATSU PHOTONICS FRANCE S.A.R.L.
 - Main Office
 - Swiss Office
 - Belgian Office
 - Spanish Office
- HAMAMATSU PHOTONICS NORDEN AB
 - Main Office
 - Russian Office
- HAMAMATSU PHOTONICS ITALIA S.R.L.
 - Main Office
 - Rome Office
- HAMAMATSU PHOTONICS UK LIMITED
 - Main Office
 - South Africa Office

- PHOTONICS MANAGEMENT CORP.
 - Main Office
 - Western Office
 - Systems Division, Main Office
 - Systems Division, Sunnyvale Office
- UNIVERSAL SPECTRUM CORPORATION
- PHOTONICS RESEARCH CORP.
- BEIJING HAMAMATSU PHOTON TECHNIQUES INC.

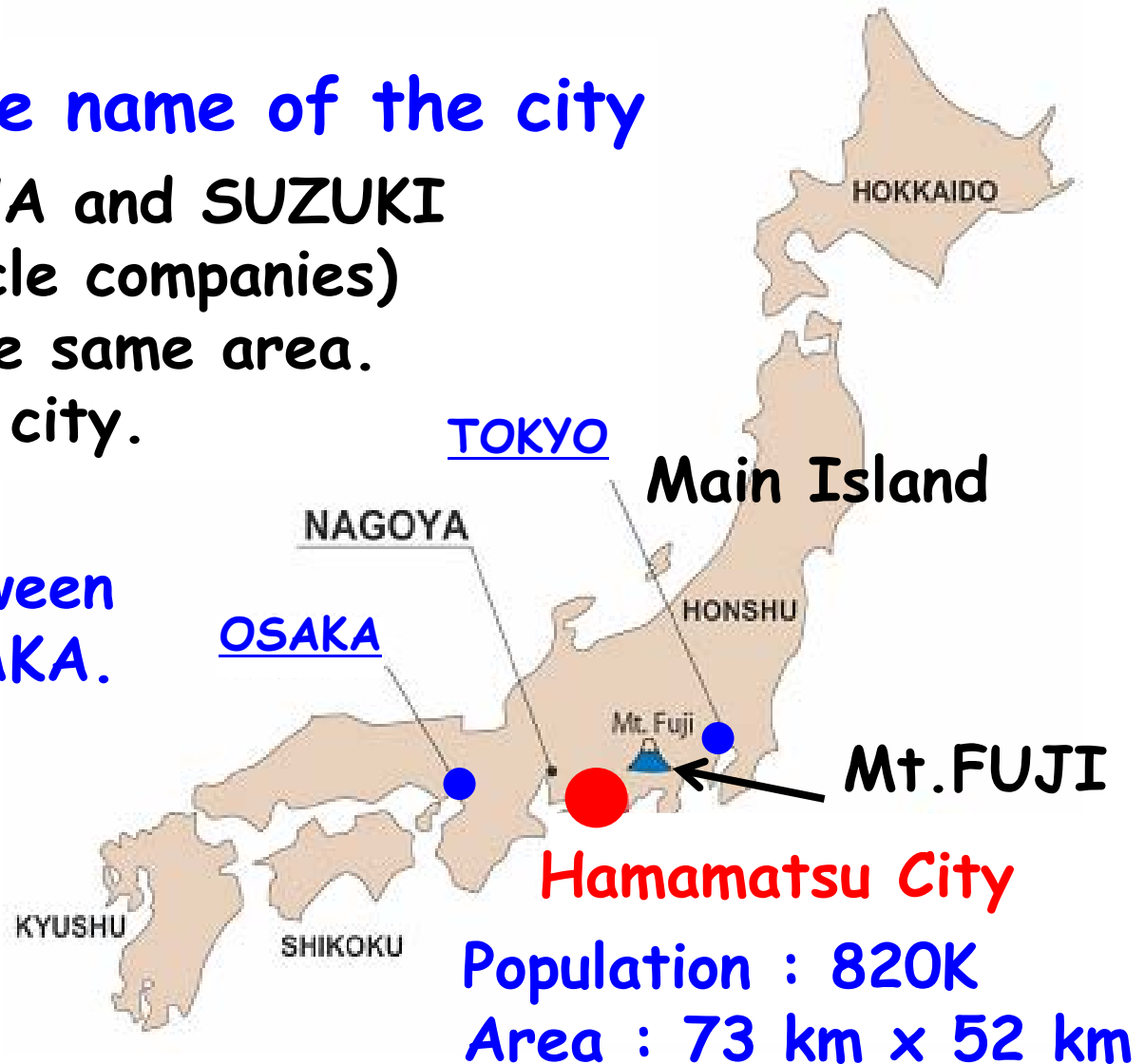
Japanese Standard MAP

Where is Hamamatsu Photonics ?

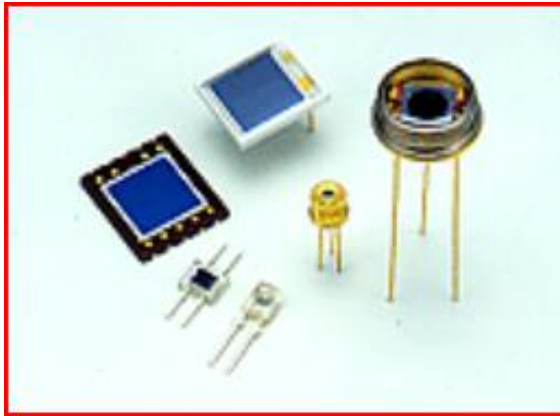
Hamamatsu=the name of the city

HONDA, YAMAHA and SUZUKI
(famous motorcycle companies)
are located in the same area.
It's an industrial city.

It's located between
TOKYO and OSAKA.



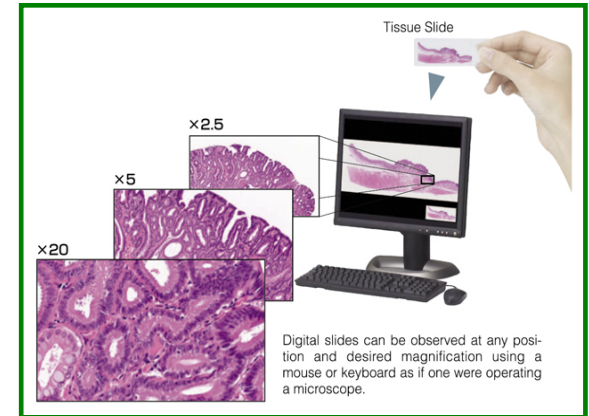
Hamamatsu Photonics K.K.



Solid State Division



Electron Tube Division



Systems Division



Research Laboratories



Laser Group

Established :
Sept 29, 1953
Net Sales : (FY 2006)
Yen 87B (\$750M)
Employees : 4,000
(Group) (As of Jul. 07)

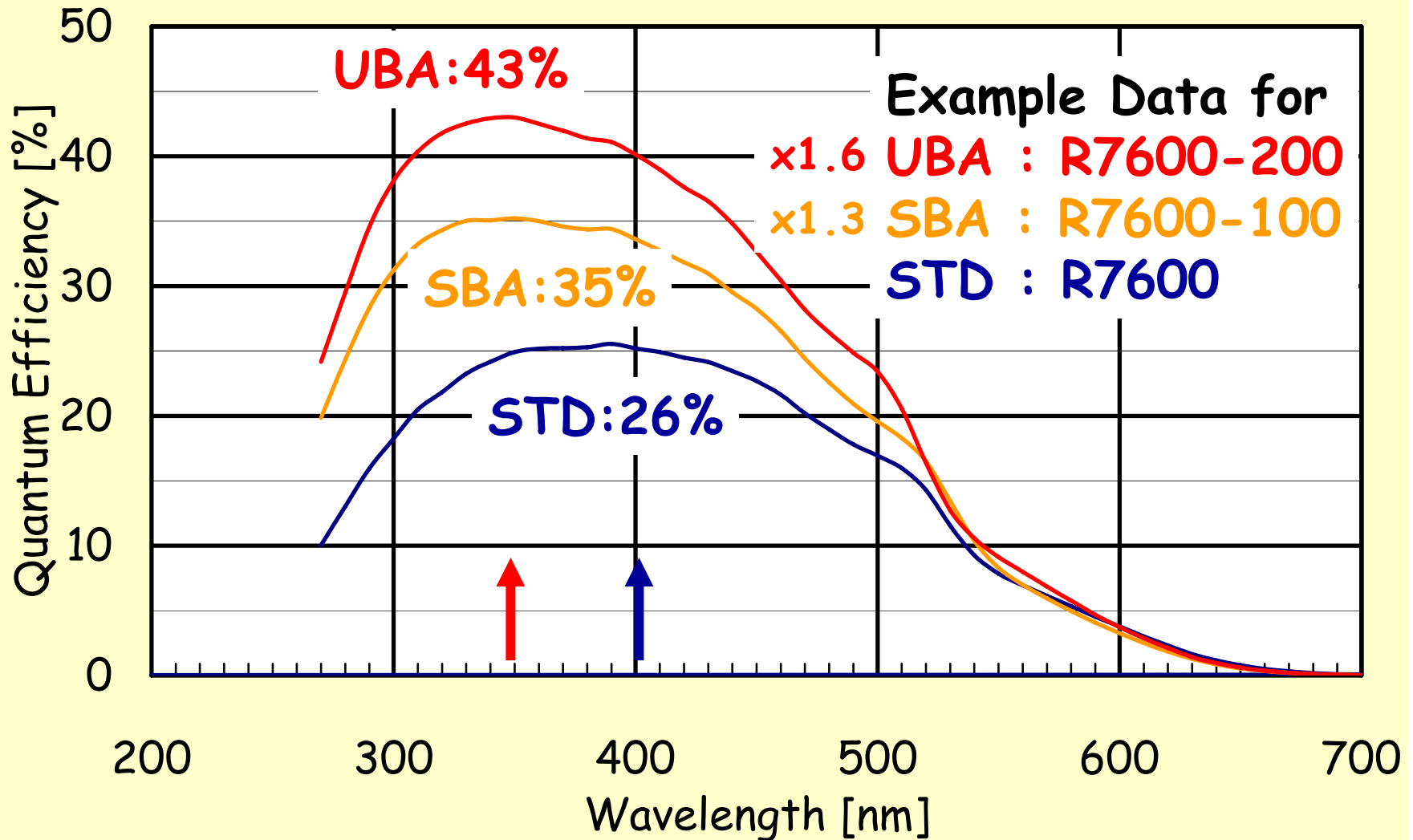
High QE Bialkali Photocathode

Hamamatsu
"Bialkali Climbing Party"
Has Now Reached
"43% QE"!

Announced at IEEE conference in last Oct.
Based on continuous effort for long time

**Ultra Bialkali (UBA)
Super Bialkali (SBA)
Photomultiplier Tube Series**

Bialkali QE Comparison



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"-3" Glass Bulb types

R7600/R8900
1 inch Square
Metal Package



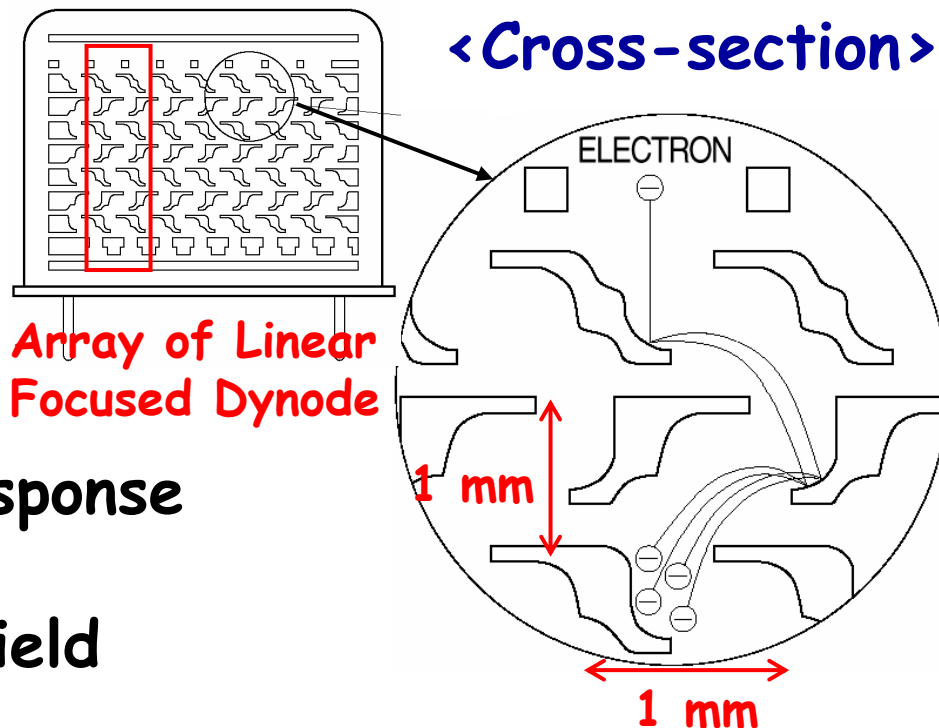
R9880
New TO-8 type
Metal Package



R7600 & R8900 & R9880 (Metal Package PMTs)



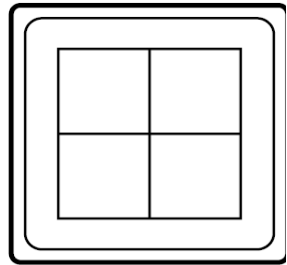
Metal Channel Dynodes
Micro processing technology



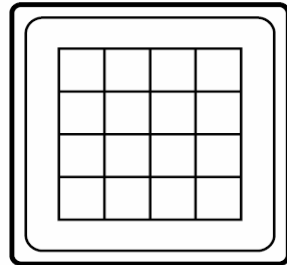
Features

Compact, Fast Time Response
Position Sensitive
Immunity to magnetic field

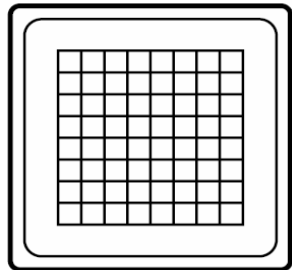
R7600 & R8900 Various Anode Types



4 channels
M4 (2x2)

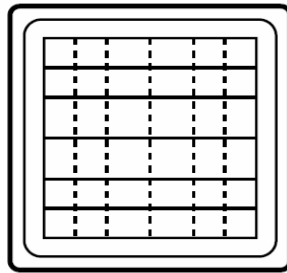


16 channels
M16 (4x4)



64 channels
M64 (8x8)

Y
↑



→ X
Cross-Plate
C12 (6+6)

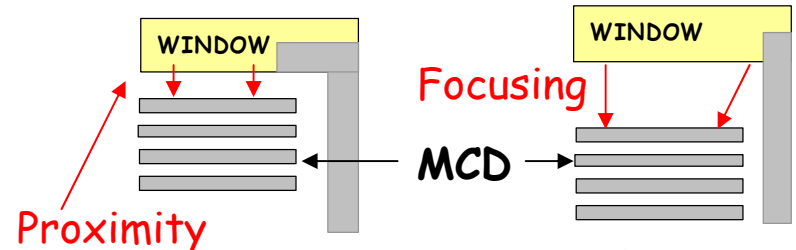
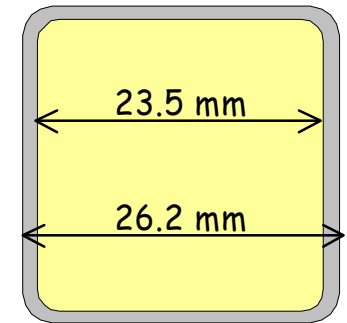
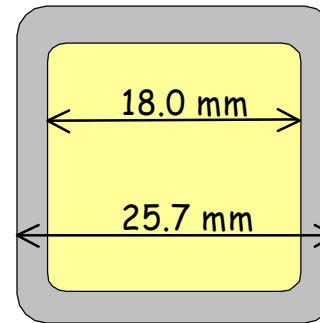
(R7600-M64 only)

(R8900-C12 only)

Difference of R7600 & R8900

R7600

R8900

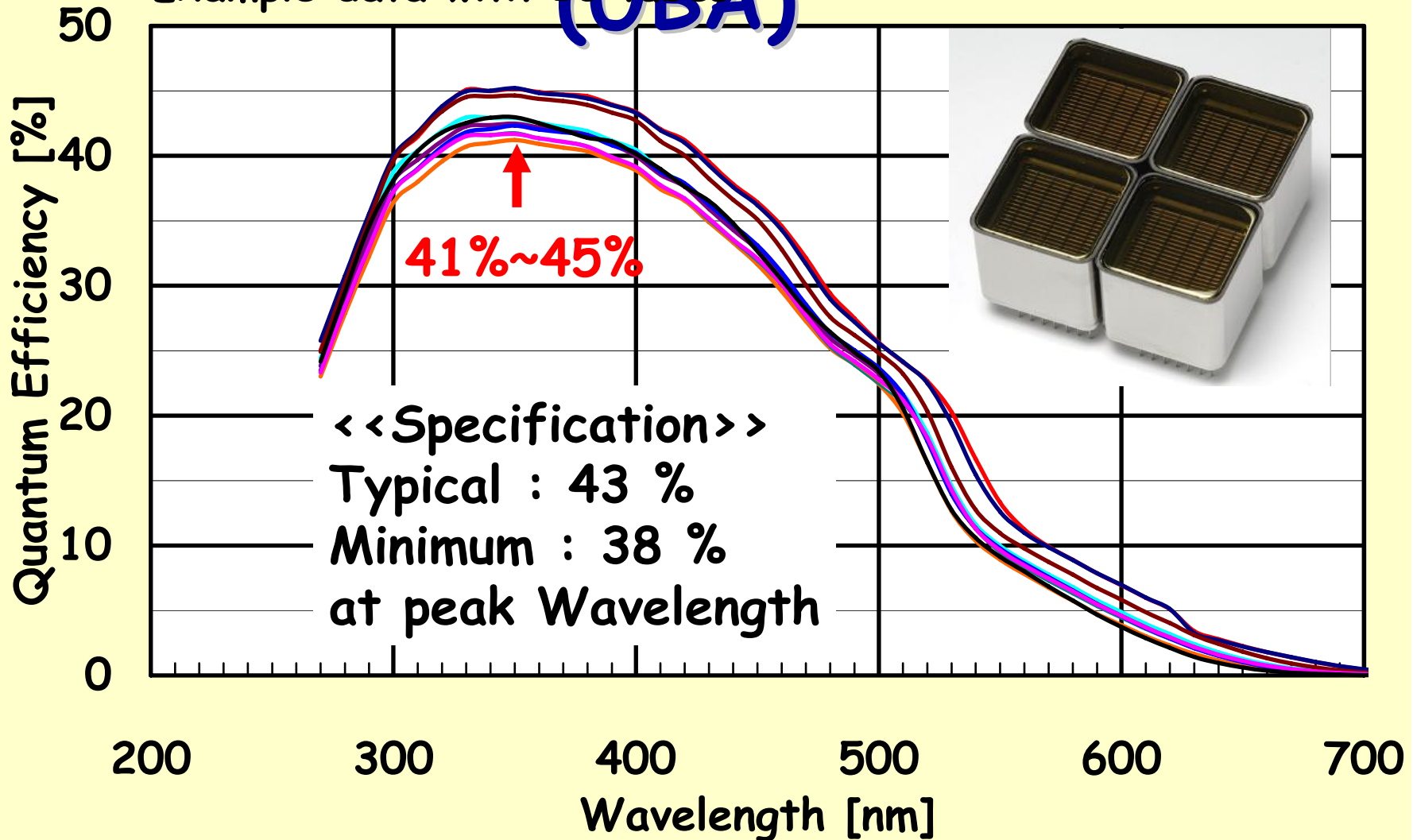


Multi-anode
Fiber Coupling

Imaging
RICH

Latest Data of R7600-200

Example data with 10 tubes
(UBA)



Conventional PMTs with SBA



R6231-100
(2 inch)

R6233-100
(3 inch)

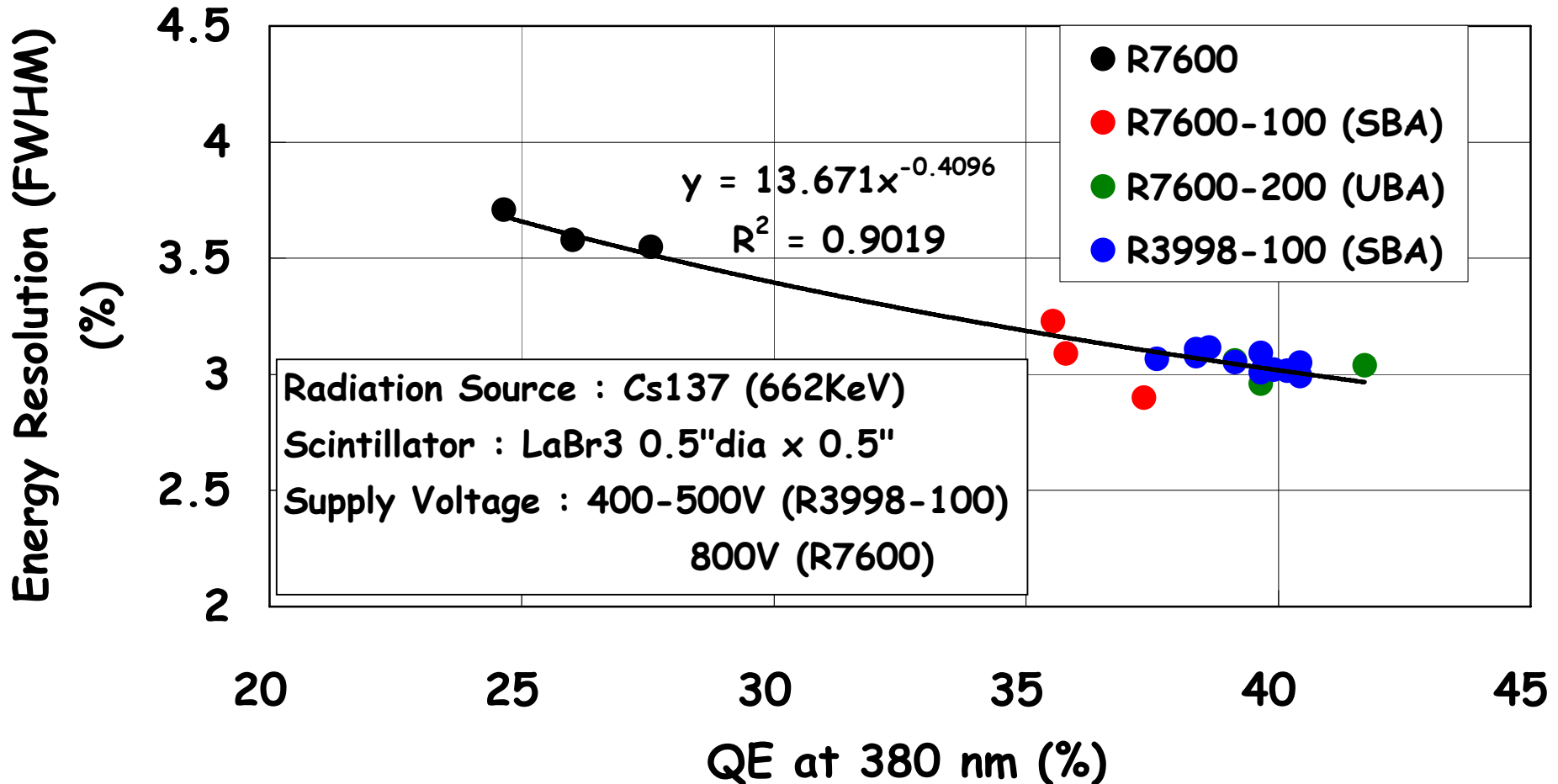
R3998-100
(1-1/8 inch)

Applications:
Radiation detection
Gamma Camera
Radiation Probe

For Better
Energy Resolution

Energy Resolution vs. QE

QE at 380 nm vs Energy Resolution (LaBr3 + Cs137)



Developmental Products for High QE

Fast Time Response PMTs
for HEP experiments & PET

Large Format PMTs
for Neutrino experiments

Flat Panel PMTs
for Medical Applications

Fast Time Response PMTs

For Faster Timing Resolution

R9779 (2")

TTS: 250 ps
Rise: 1.8 ns
at 1500V

R9800 (1")

TTS: 270 ps
Rise: 1.0 ns
at 1300V

R9420 (1.5")

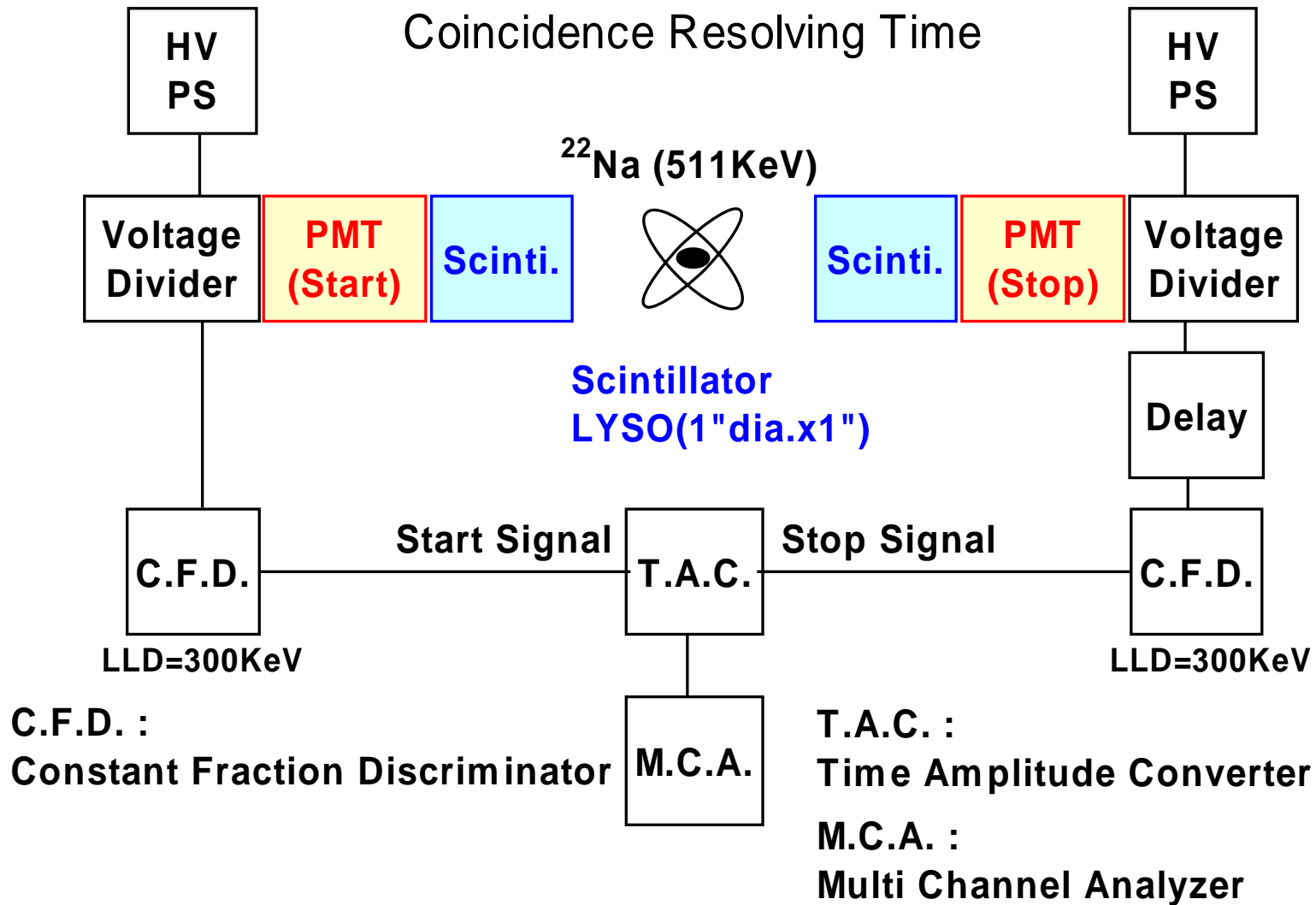
TTS: 550 ps
Rise: 1.6 ns
at 1300V

< Concept >
Simple Structure
For Low Cost and
Mass Production

**Applications:
TOF-PET and
HEP Experiments**

Test Setup for CRT

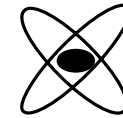
CRT: (Timing Resolution)
Coincidence Resolving Time



Relation between Timing and QE

< Basic Equations >

Pt-1



Pt-2

$$CRT = \text{root}[(Pt-1)^2 + (Pt-2)^2]$$

$$Pt-1 = \text{root}[(St-1)^2 + (Pm-1)^2]$$

$$= \text{root}[(St-1)^2 + \left(\frac{TTS}{\text{root}[Npe]} \right)^2]$$

Pt : Timing with combination of St and Pm

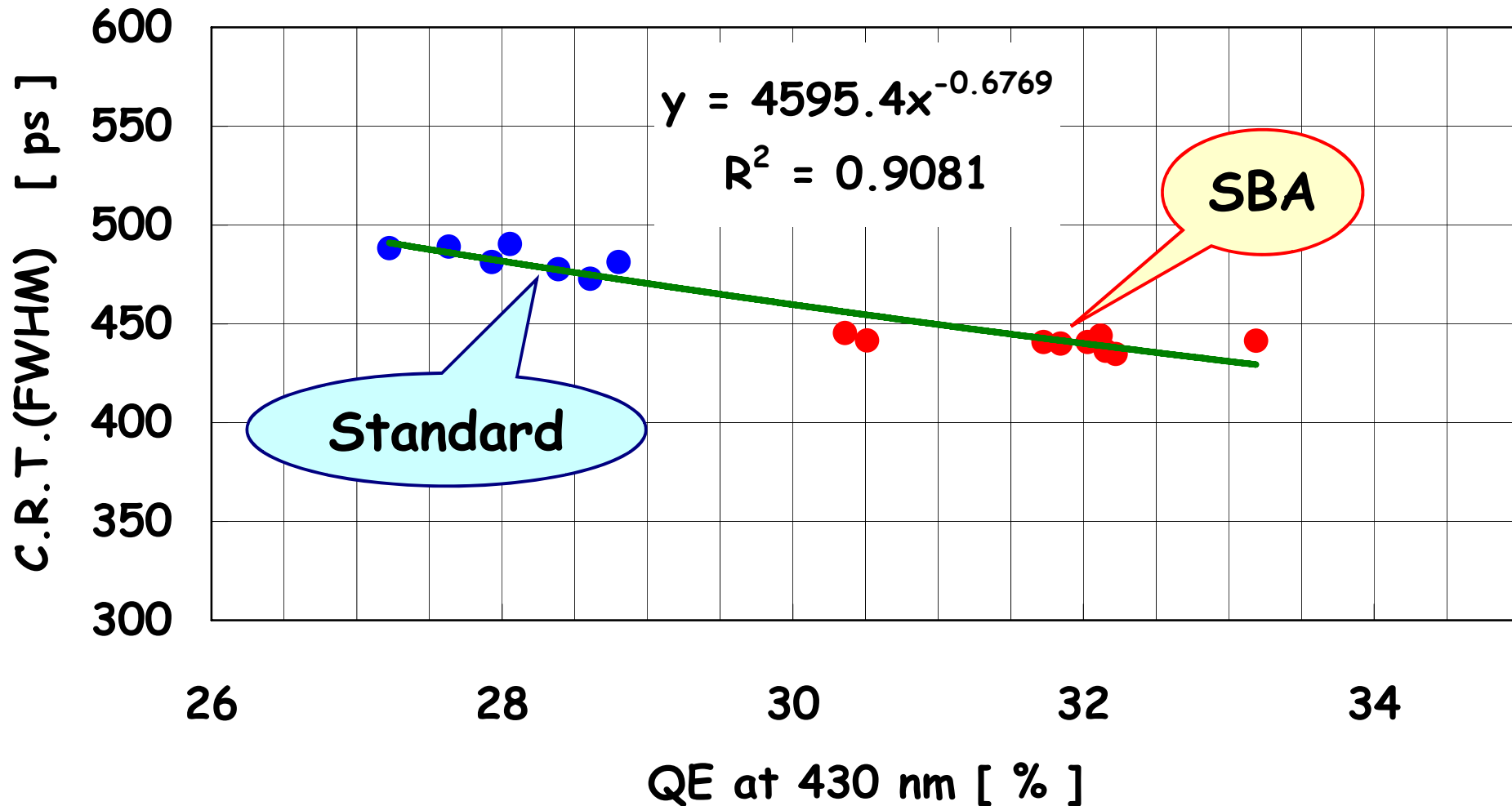
St : Timing of a Scintillator

Pm : Timing of a PMT

Npe : Number of photoelectrons (which depends on QE)

CRT vs. QE (an Example)

Correlation between C.R.T. and QE at 430 nm



Large Format PMTs

For Better Detection Efficiency

20 inch

13 inch PMT is very low profile despite its diameter.

13 inch

8 inch

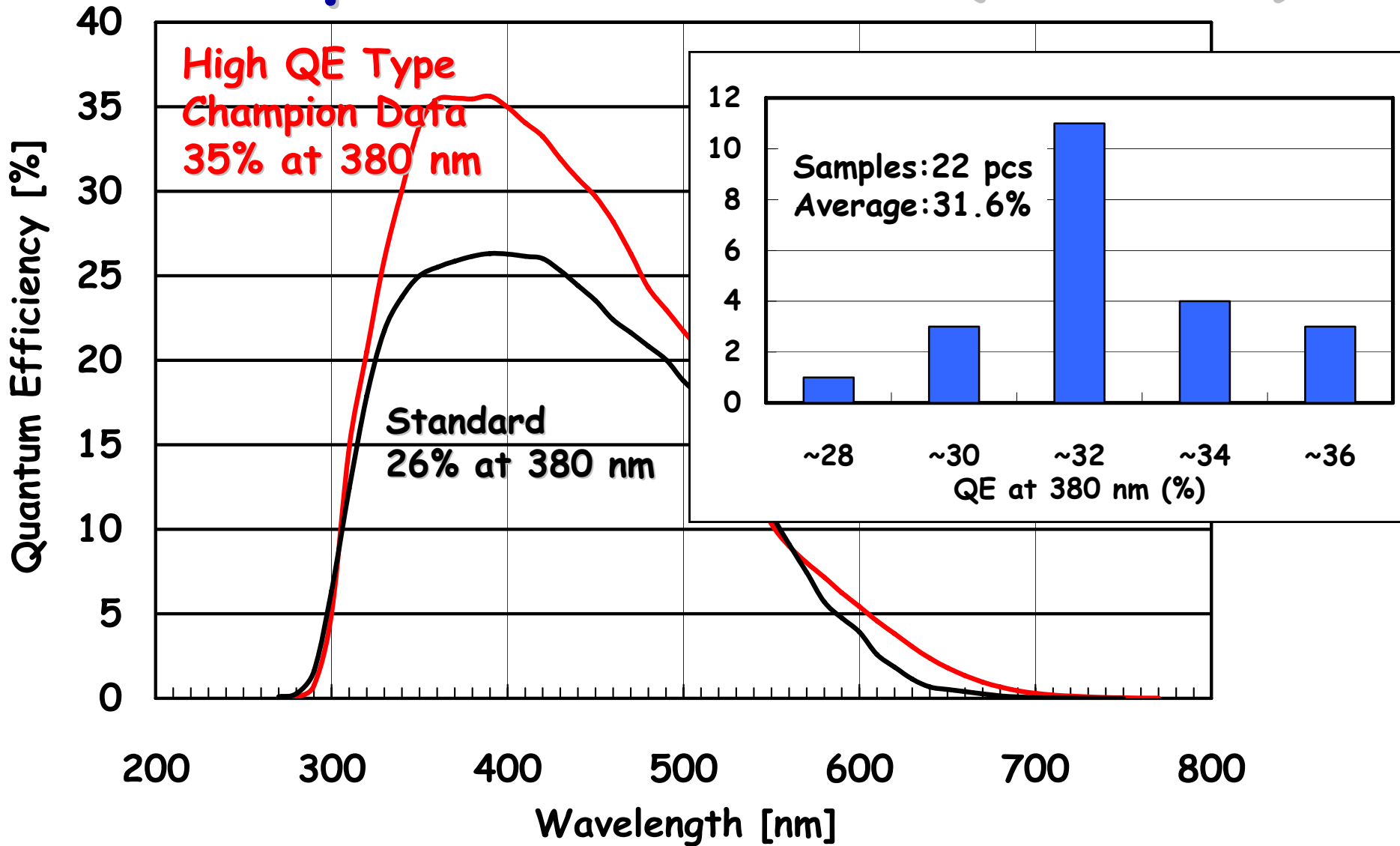
10 inch



Trial for High QE

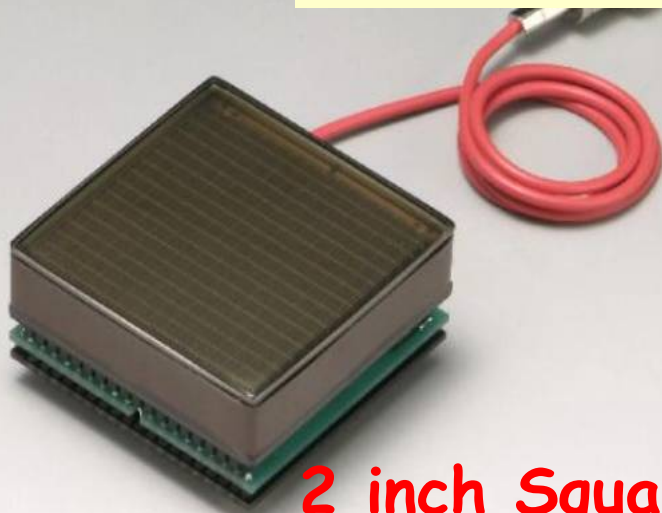
**Applications:
Neutrino Experiment**

Example data R7081 (10 inch)

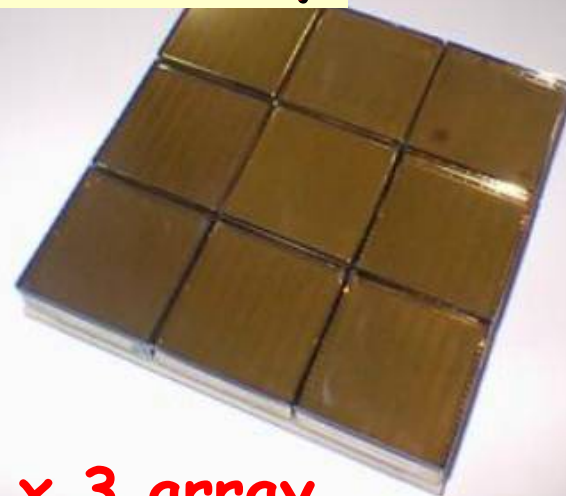


Flat Panel PMTs

For Better Image Quality



2 inch Square



3 x 3 array

Channels Pixel Size

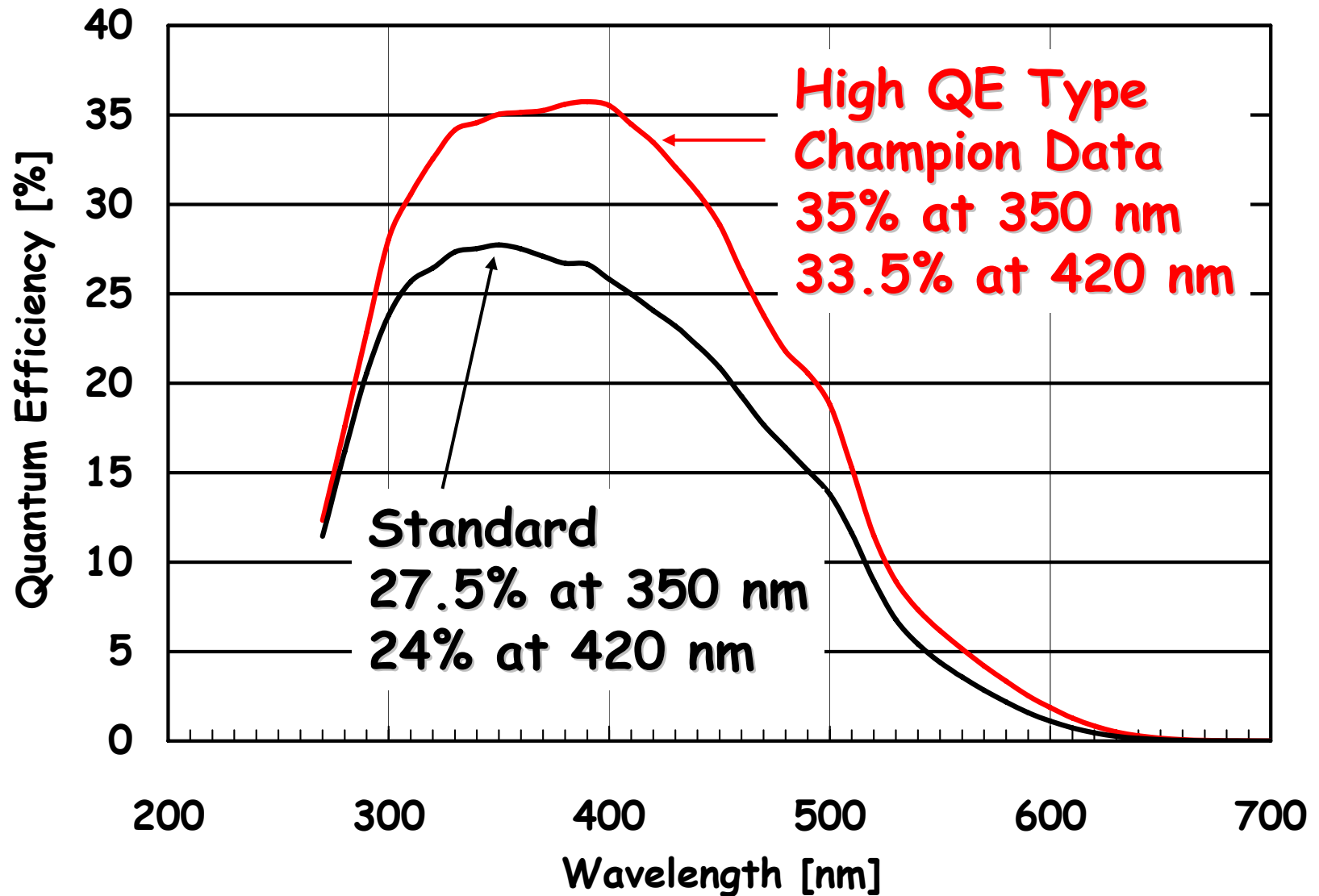
H8500 64 ch (8x8) 6x6 mm

H9500 256 ch (16x16) 3x3 mm

**Applications:
Radiation Imaging
HEP Experiments**

High Packing Ratio (89% effective area ratio)

Example data for H8500



High Speed HPD

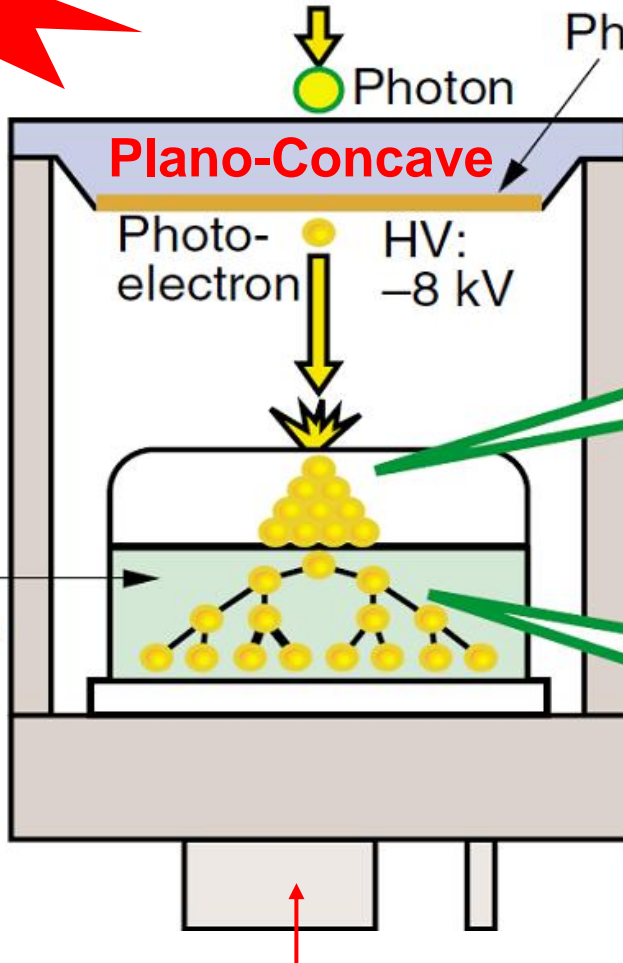
R10467U

NEW

Diameter:
33 mm
Length:
34 mm

AD
(Avalanche Diode)

Small AD



SMA Connector

Bialkali
(8 mm in dia.)

Electron
Bombardment
Gain

×1600

at 8KV

Avalanche
Gain

×130

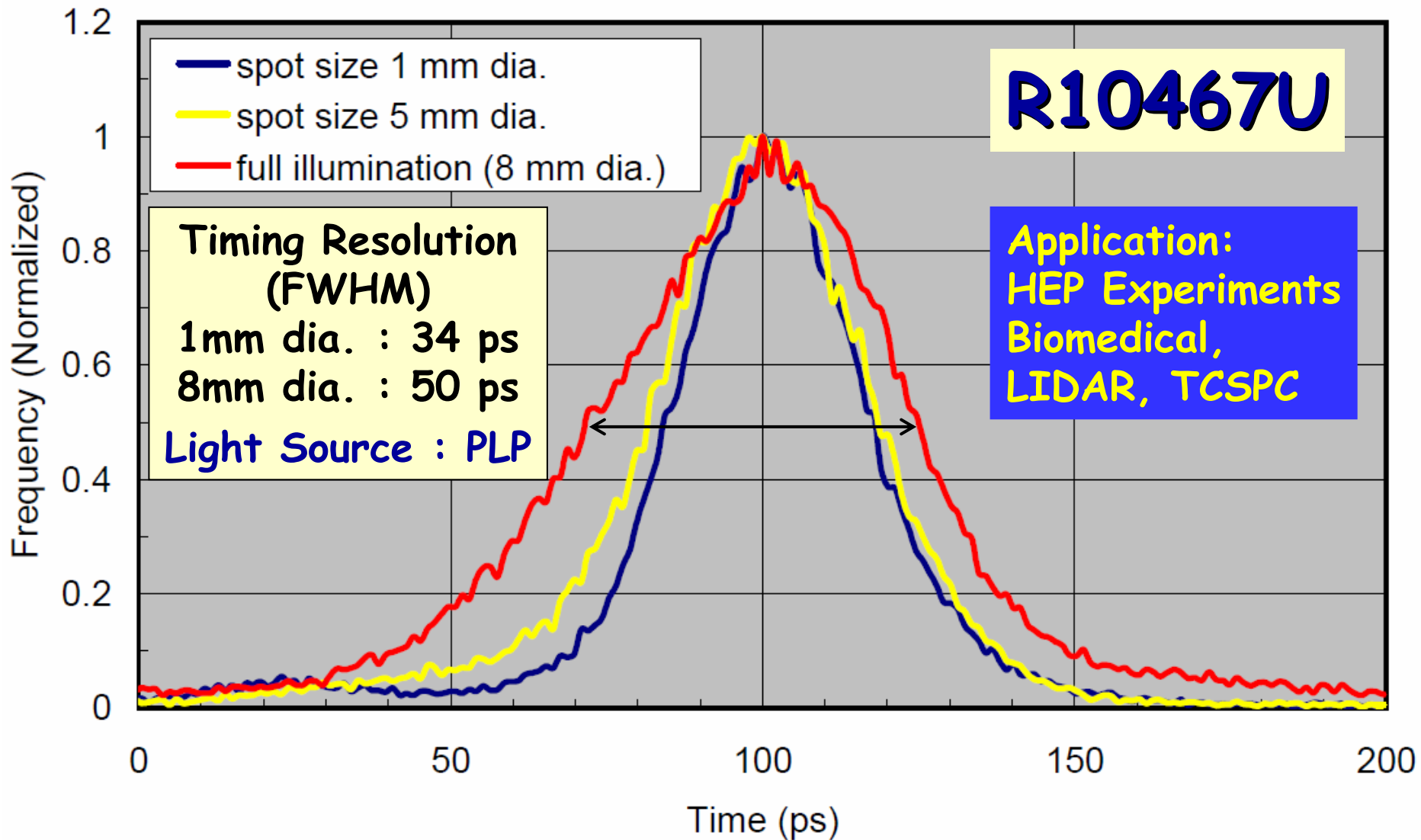
at 400V

Total Gain
200,000

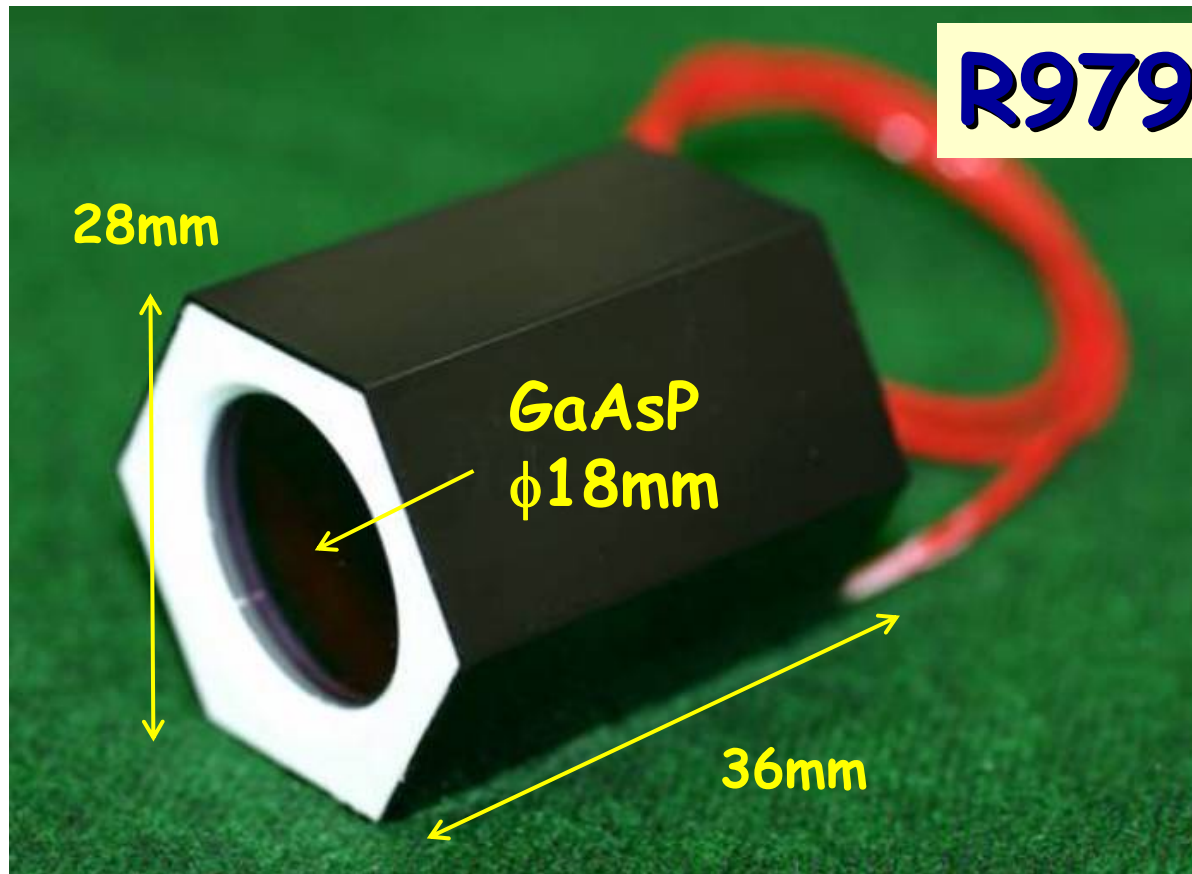
<Collaboration>
KEK (HEP Lab in

Japan)

Timing Resolution with Single p.e.



$\phi 18\text{mm}$ -GaAsP HPD



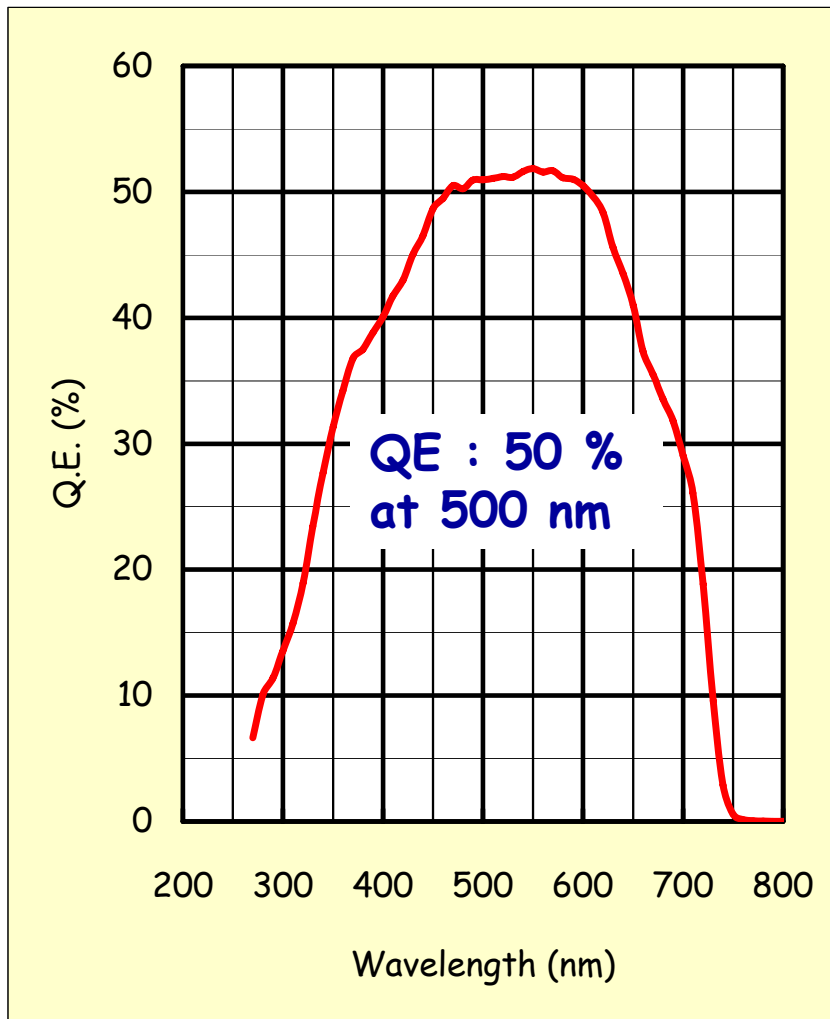
R9792U-40

**<Collaboration>
MPI Muenchen (MAGIC)**

Characteristics of MAGIC HPD

GaAsP Photocathode

R9792U-40

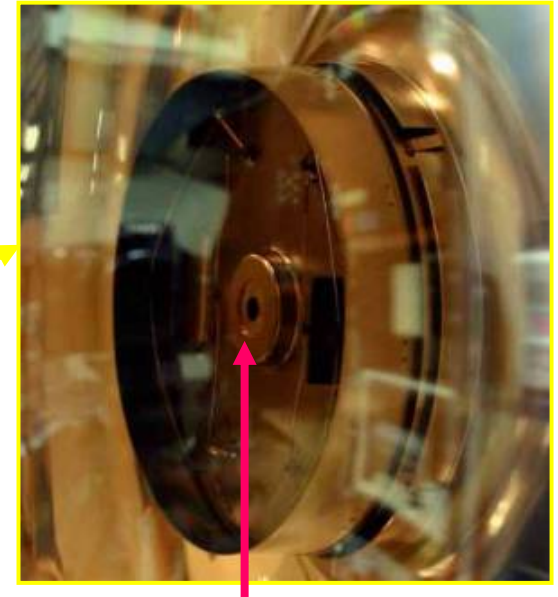
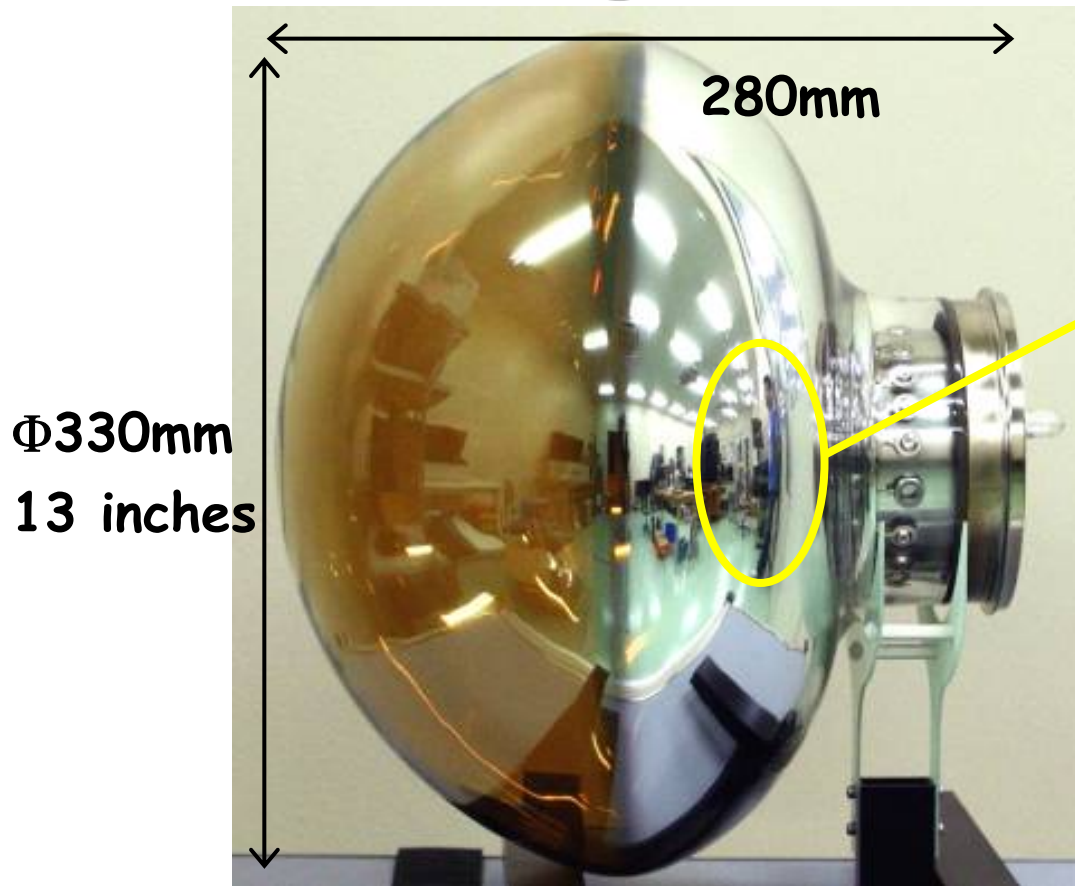


GaAsP with $\phi 18\text{mm}$
 Q.E. at 500 nm : 50 %

Total Gain : ~60,000
 EB Gain (at 8KV):
 ~1,500
 AD Gain (at 400V):
 ~40

AD was modified for
 Long Life Operation
 Fast Time Response

Large Format HPD



Total Gain : 2×10^5
TTS(FWHM) : 440 ps

<Collaboration>

Tokyo Univ. and JST (JAPAN SCIENCE
AND TECHNOLOGY AGENCY)

Development will be
finished by Mar.2009

Summary

PMTs are getting improved.

- High QE Bialkali photocathode is ready for some products
- Unique shapes are offered with MCD (MCD: Metal Channel Dynode)

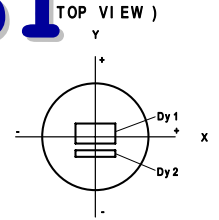
HPDs are getting matured.

- High Speed HPD / ϕ 18mm-GaAsP HPD
- Large Format HPD (13 inch)

Thank you for your attention !!

Any Questions ?

Cathode Uniformity of R7081



R7081 (SBA)

R7081 (BA)

