

# T2K experience with scintillator/MPPC detectors

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for T2K-ND280 photo-sensor group  
and KEK Detector Technology Project

# Outline

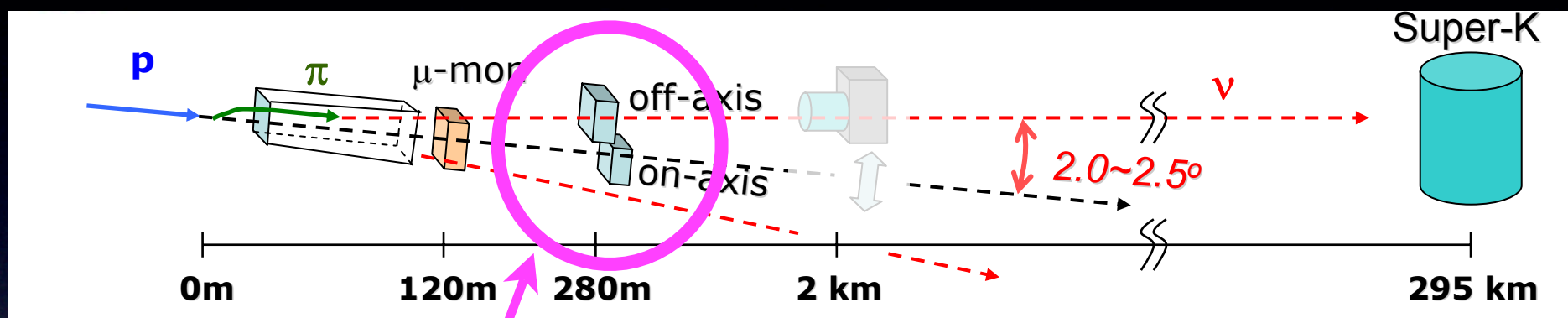
- Introduction: T2K and near detectors
- MPPC (Multi-Pixel Photon Counter)
  - Principle
  - Performance
- Ongoing R&D
- Summary

# T2K experiment



- Search for  $\nu_{\mu} \rightarrow \nu_e$  oscillation
- Precise measurement of  $\nu_{\mu}$  oscillation
- CP violation in lepton sector (2nd stage)

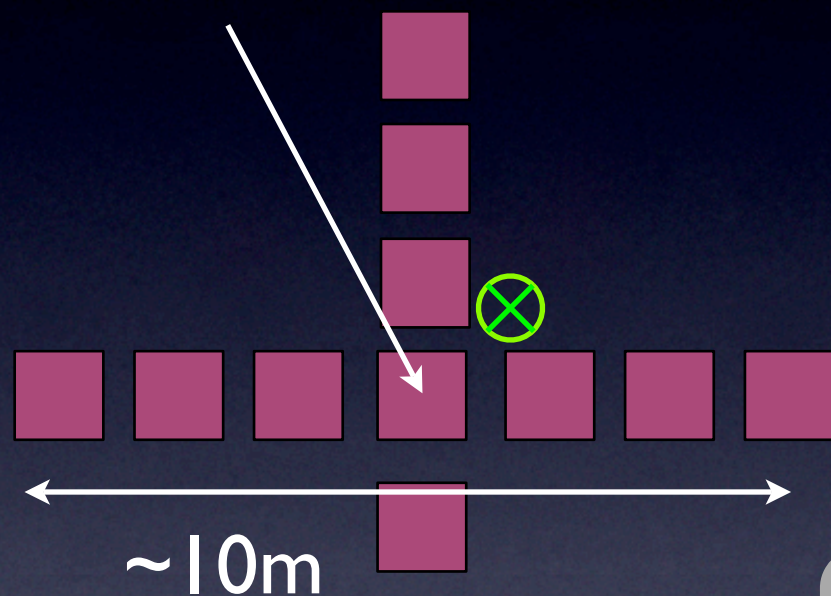
# Exp. layout



- Near detector complex to characterize neutrino beam before oscillation
  - ‘on-axis’ to confirm beam direction
  - ‘off-axis’ to measure flux, energy spectrum, cross-section, etc.

# On-axis detector

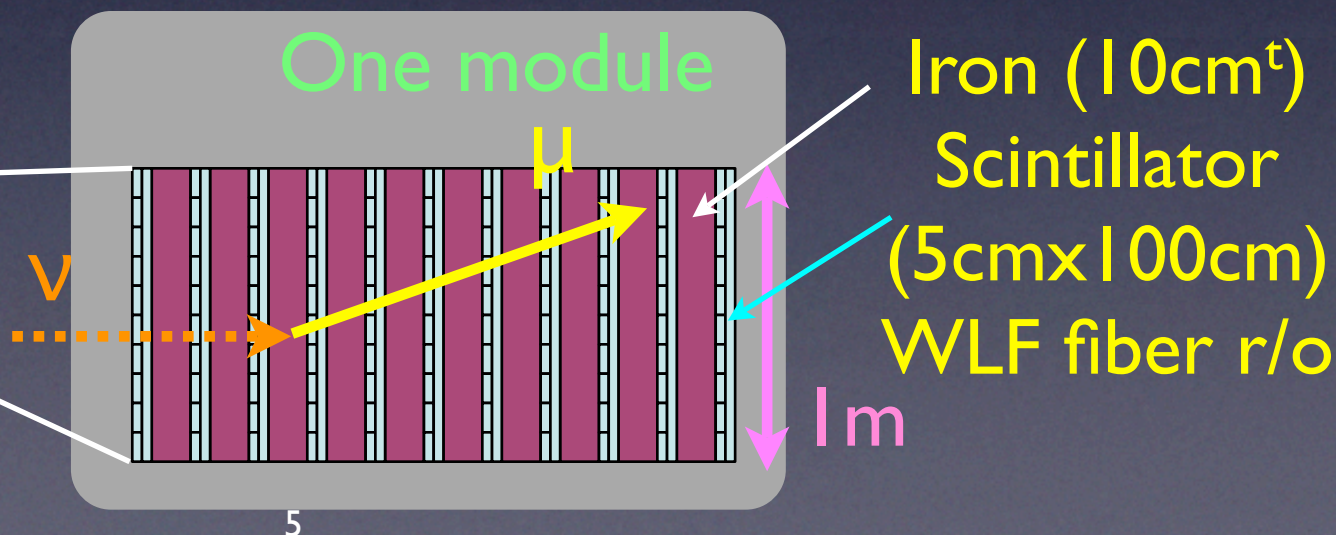
$\nu$  beam center



~10m

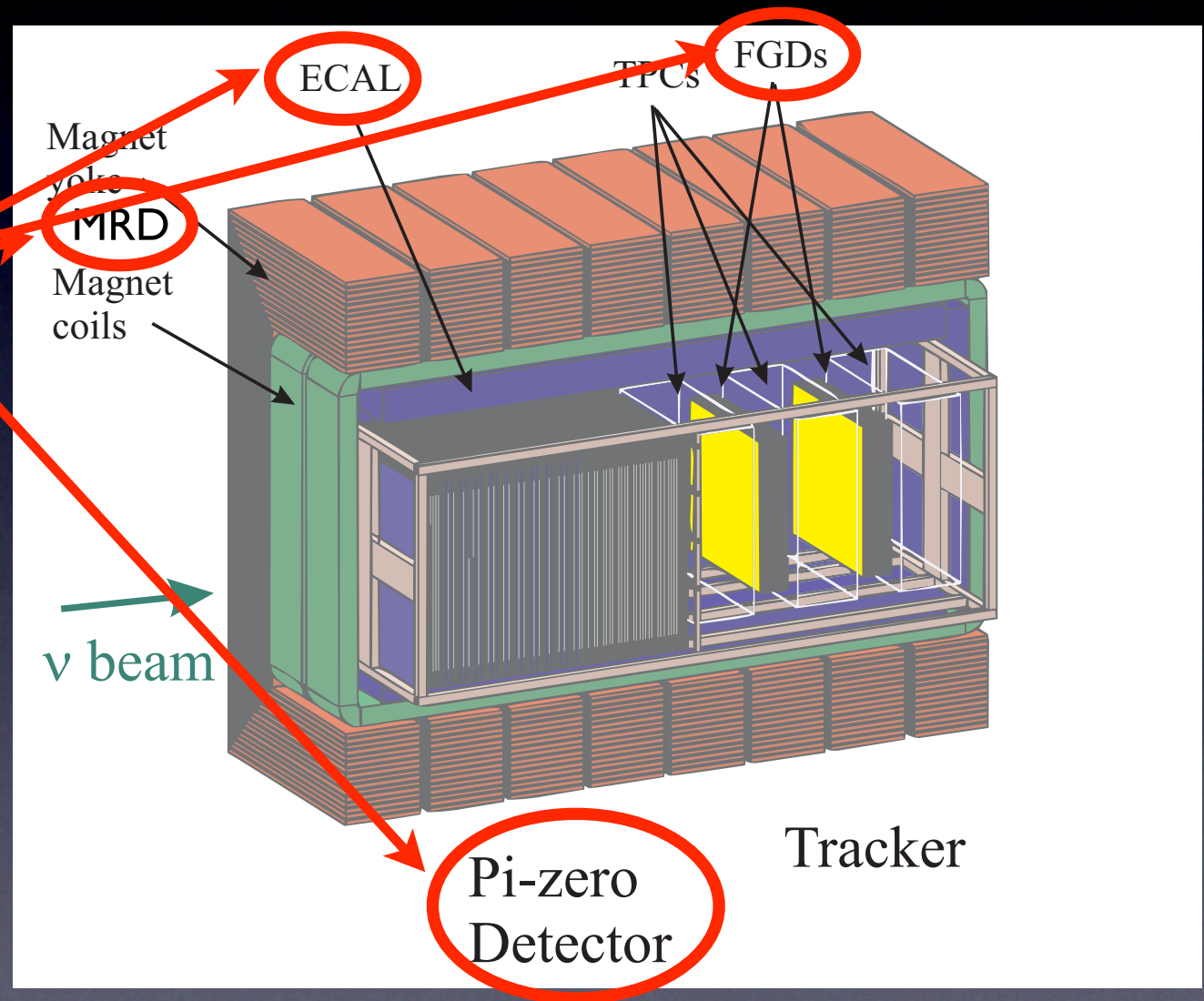
Event rate  
~0.5/spill/ton @  
design intensity  
at center

- Array of iron-scintillator stack
- Measure neutrino beam profile by detecting muons from  $\nu_\mu$  interaction in iron
- Cover wide area ( $\pm 5\text{m}$ ), large target mass ( $\sim 100$  ton total)



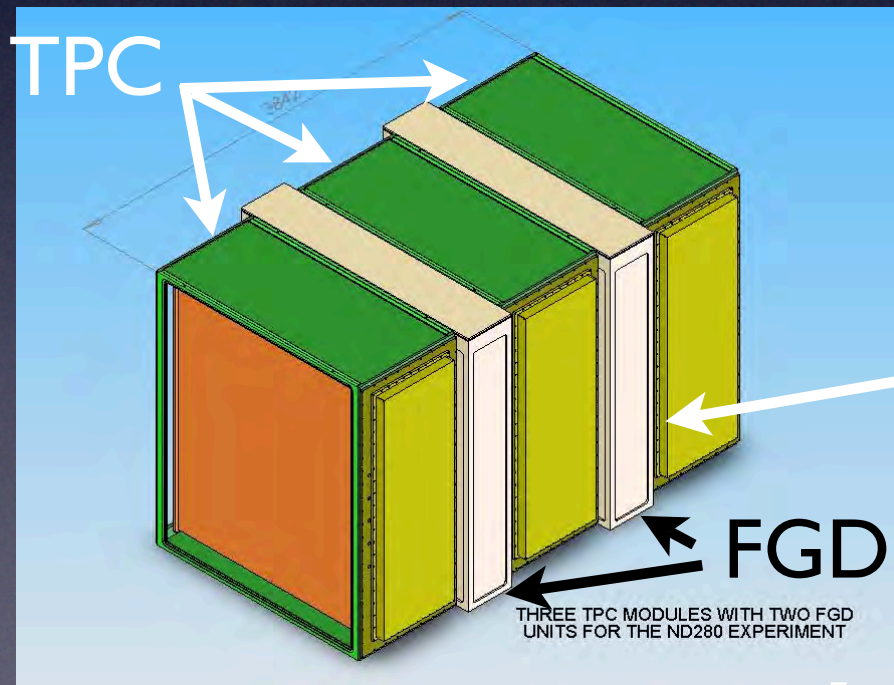
# Off-axis detectors

- Many active components based on scintillator + WLS fiber
- Inside 0.2T magnetic field by UAI magnet

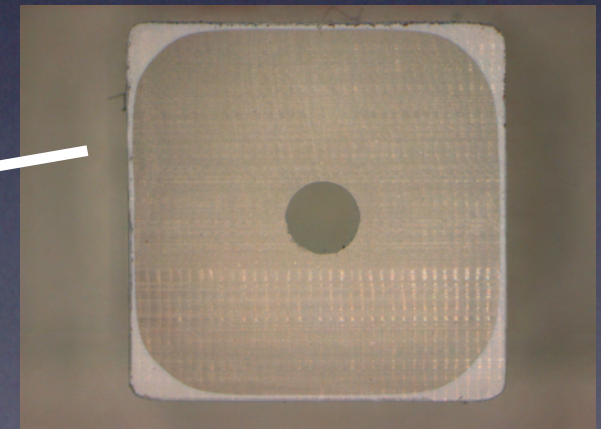


# Fine Grain Detector (FGD)

- (Fully) active target for  $\nu$  interaction
- $1 \times 1 \text{ cm}^2 \times \sim 2 \text{ m}$  length
- X-Y alternating layers, 30cm in beam direction
- $\sim 10,000$  channels in total



Scintillator in Canada

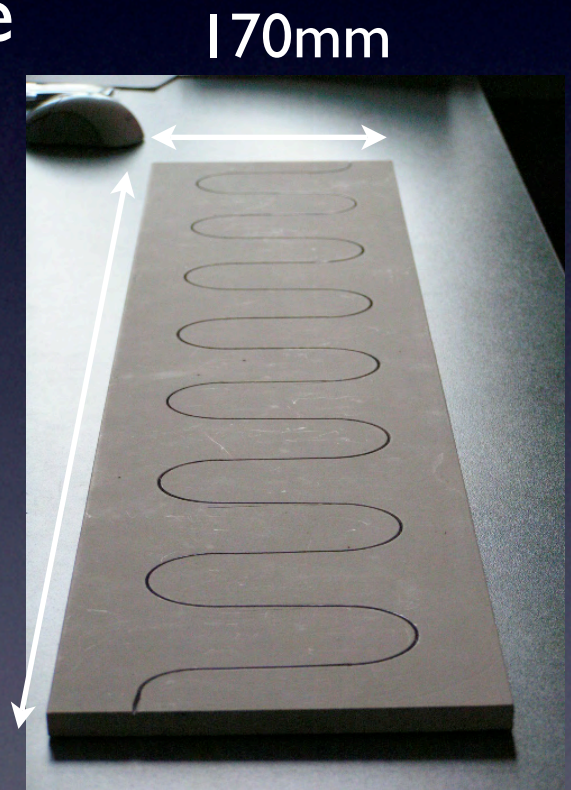
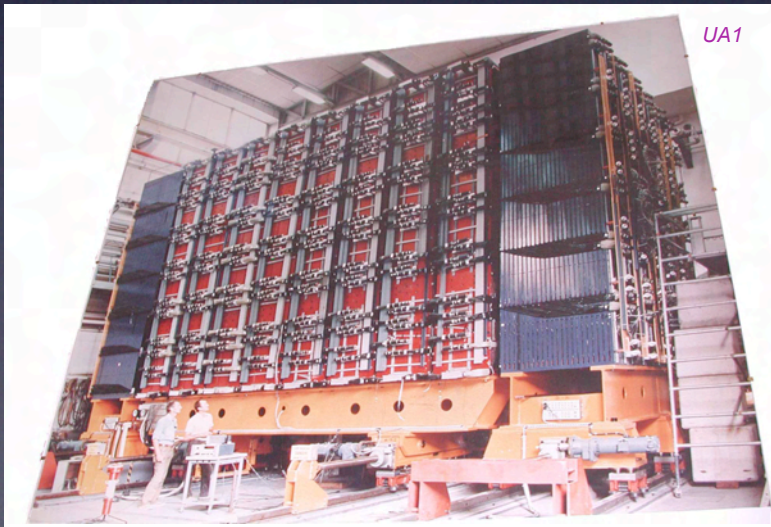


# Side MRD

- Instrument gaps in UAI magnet yoke
  - Measure muons w/ large angle
- Large area: “S-shaped” groove

arXiv:physics/0606037

UAI detector



Prototype in Russia



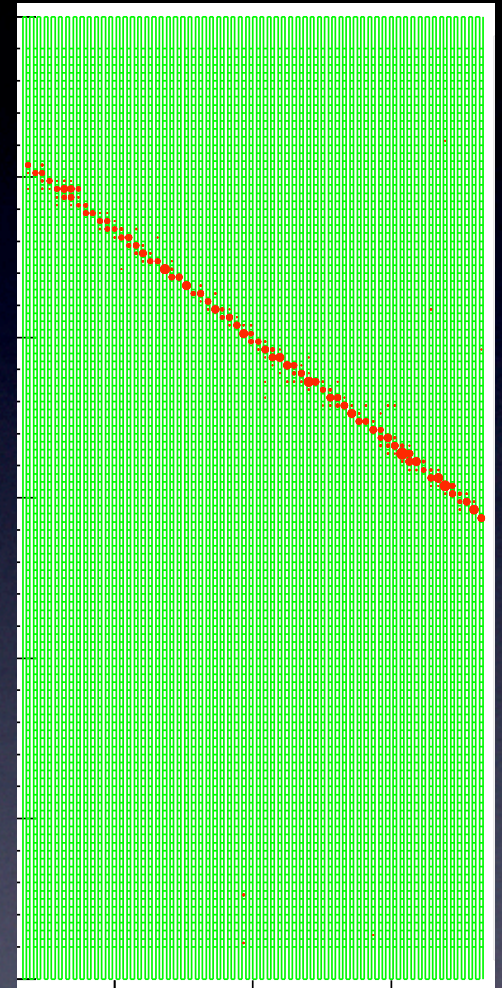
# Pre-T2K detector: K2K-SciBar

- Constructed for K2K
- Fully active detector with scintillator/  
WLS fiber/MA-PMT
- ~15,000  $1.3 \times 2.5 \times 300 \text{cm}^3$   
scintillators
- Hamamatsu 64-ch MAPMT (x224)
- ~3m WLS fiber (Kuraray Y11)
- 10~20p.e./MIP/cm
- Now moved to FNAL for new  
experiment (E-954/SciBooNE)



# Pre-T2K detector: K2K-SciBar

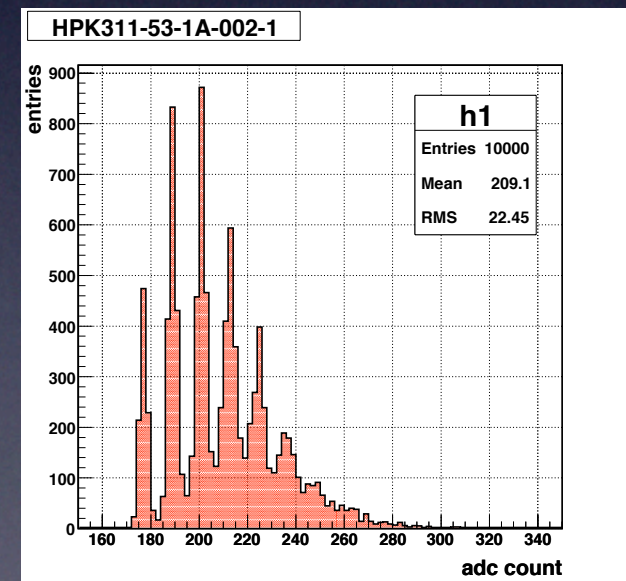
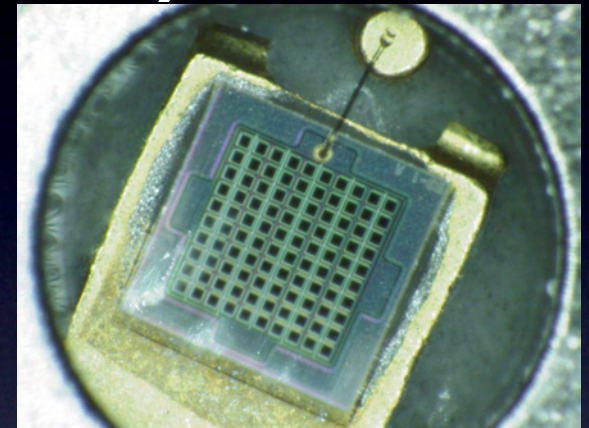
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Cosmic ray observed w/  
SciBar @ CDF hall  
(Mar. 2007)

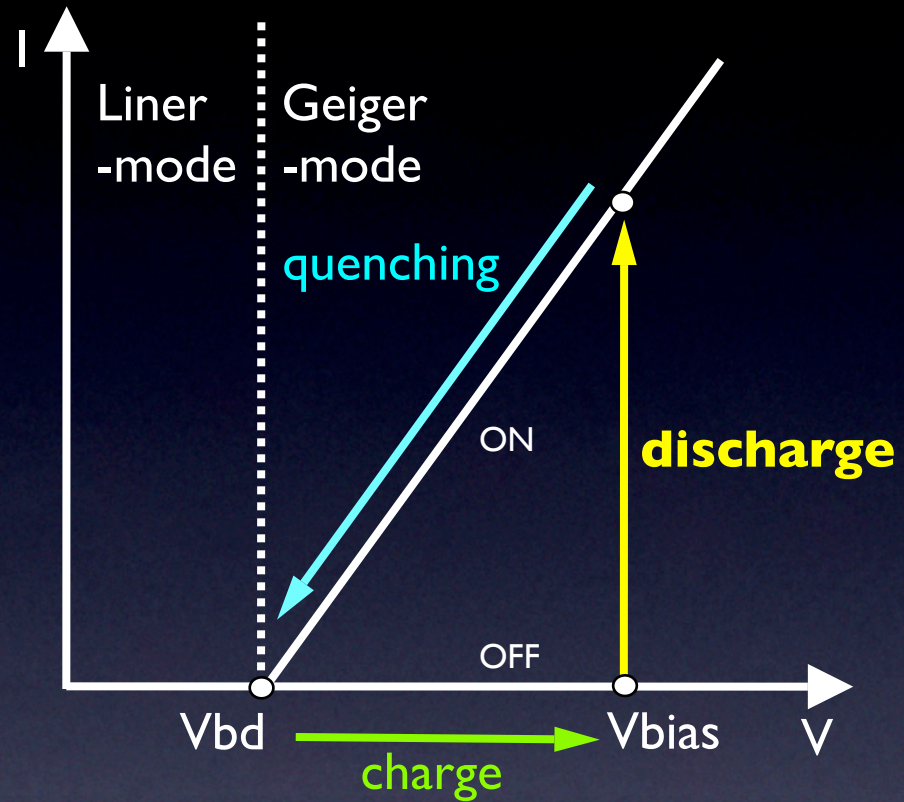
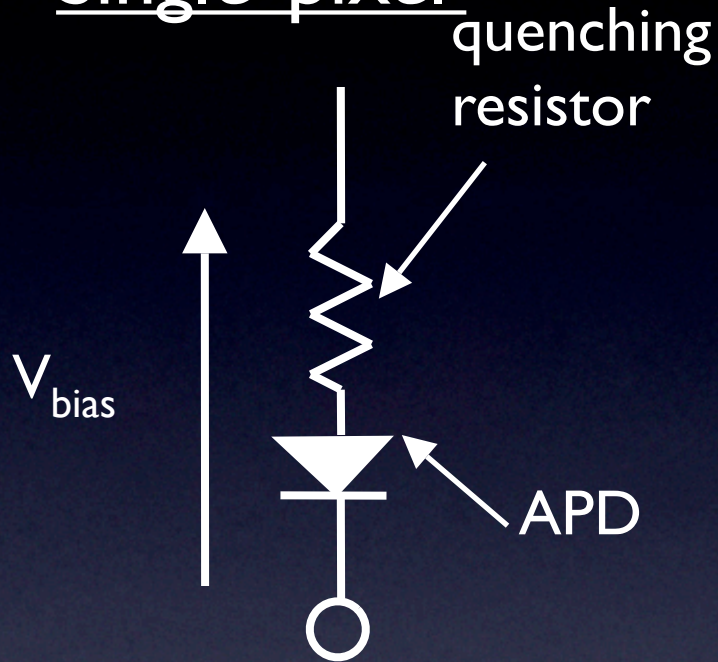
# Multi-Pixel Photon Counter (MPPC)

- Product of Hamamatsu Photonics
  - “silicon PM” family
- Characteristics:
  - Gain  $\sim 10^6$  w/ 70~80V
  - Noise  $\sim O(100\text{kHz})$  @room temp
  - Photon eff.  $>\sim \text{PMT} \times 2$
  - Insensitive to B-field
  - Compact

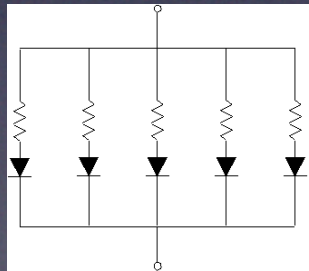


# MPPC principle

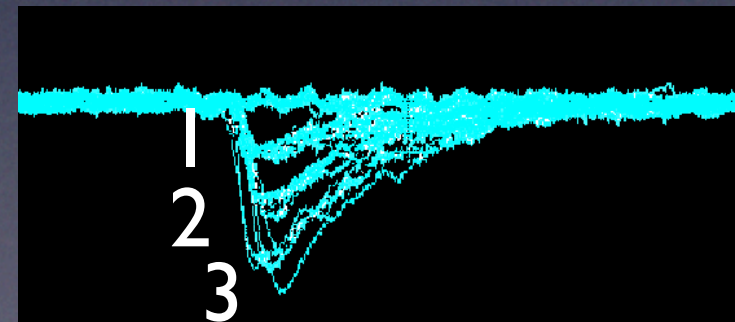
## Single 'pixel'



## Sum from all the pixel

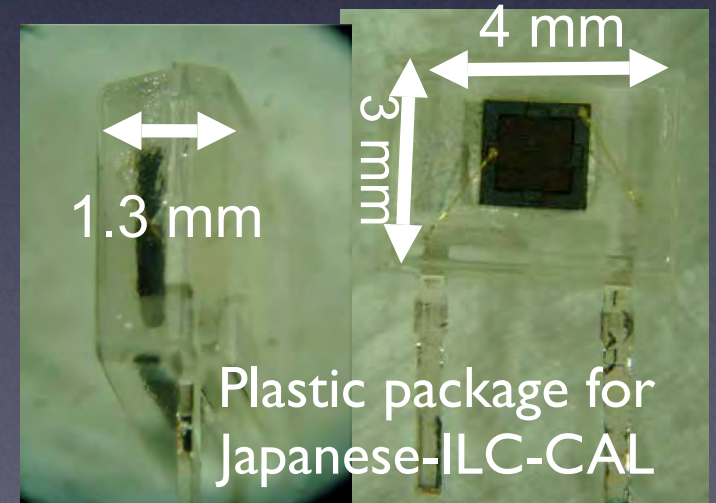


Signal proportional to number of 'fired' pixels



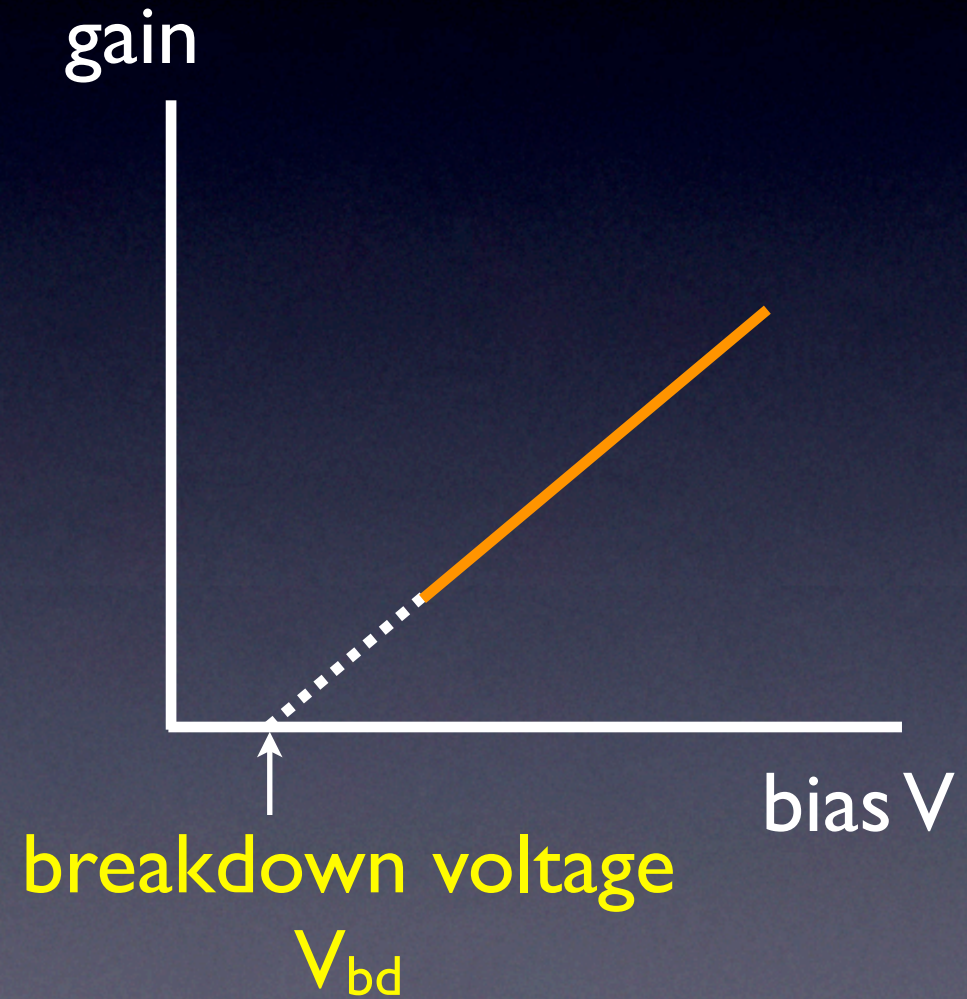
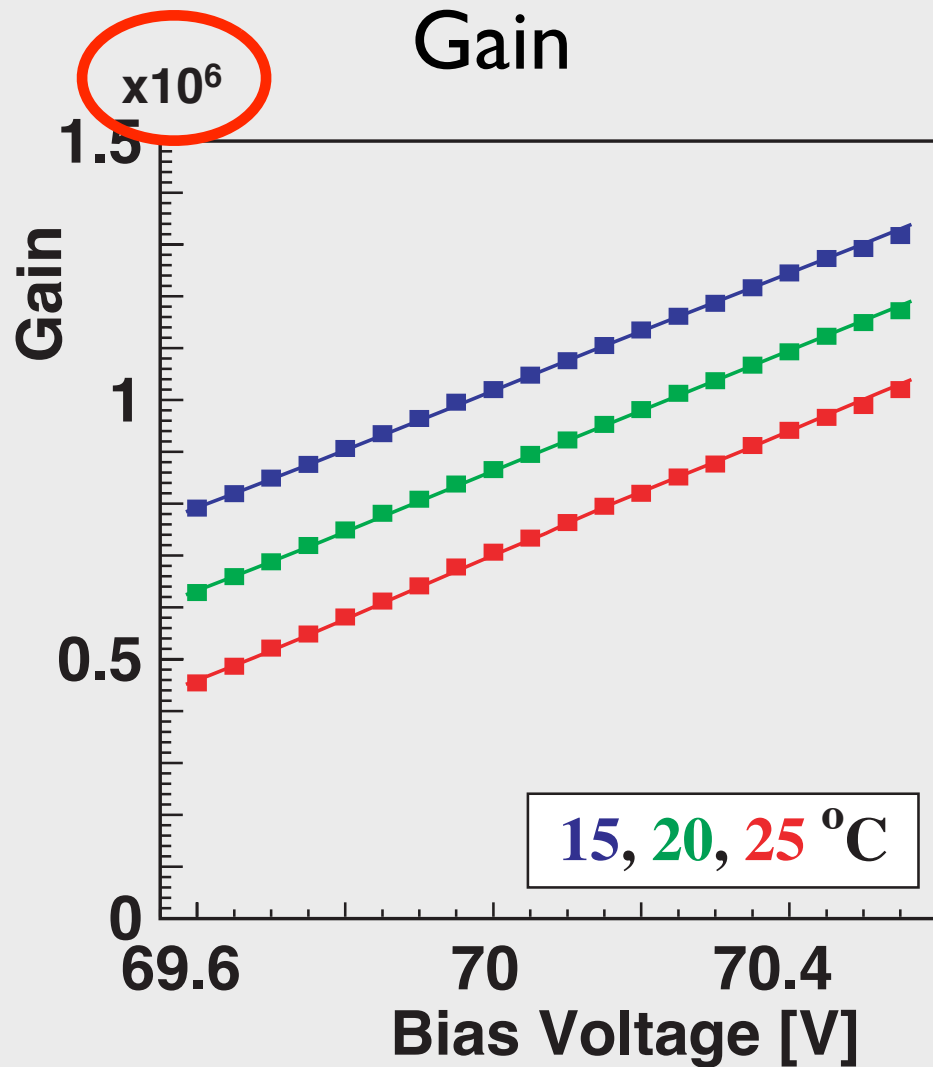
# Current MPPC lineup

- Active area size:  $1 \times 1 \text{ mm}^2$   
(larger size device under development)
- Pixel pitch: 100, 50, 25  $\mu\text{m}$   
Number of pixels/device: 100, 400, 1600
- Package: can or ceramic  
other package needs negotiation  
(and possibly additional cost)

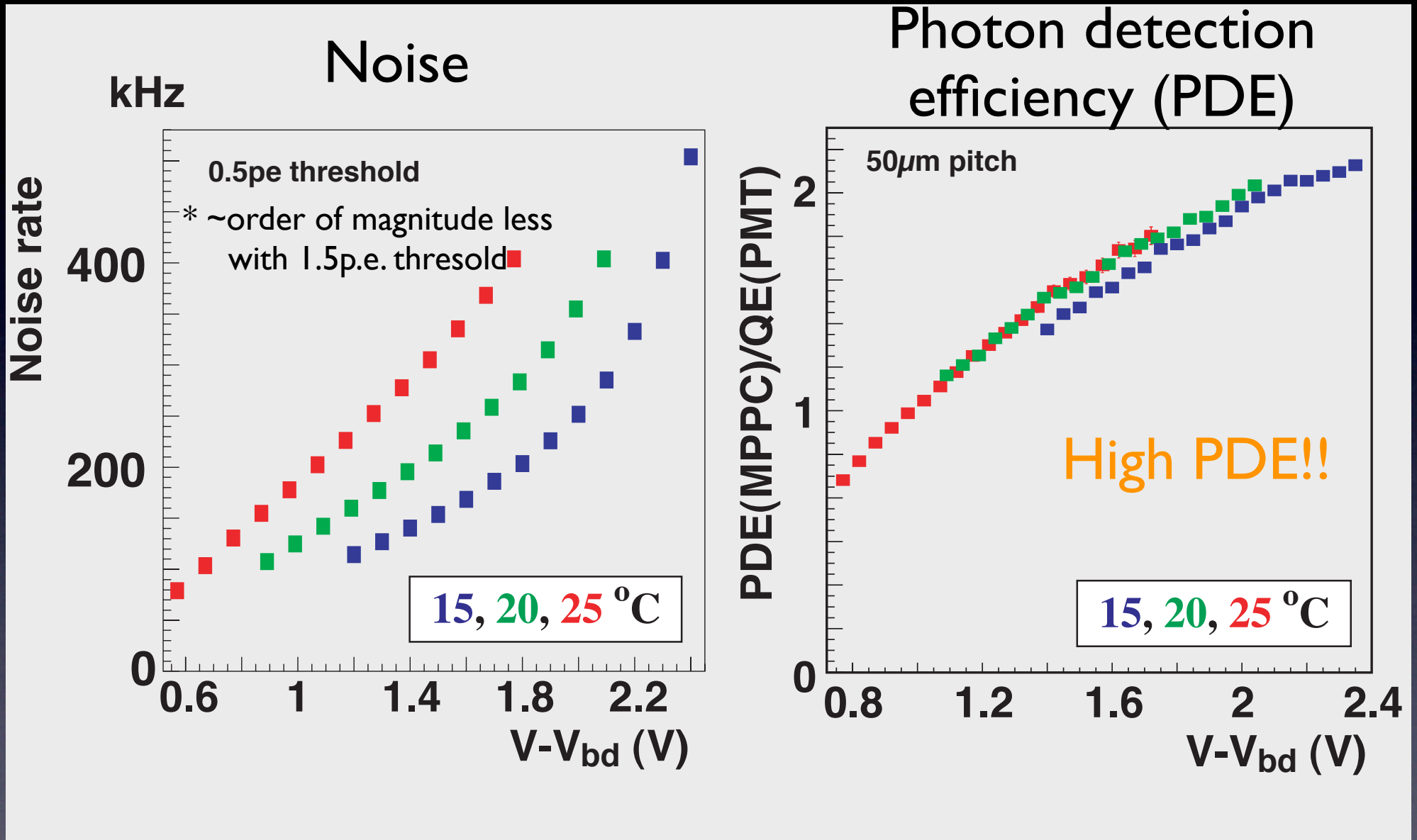


400 pixel  
(50um pitch)

# MPPC performance



400 pixel  
(50 $\mu$ m pitch)

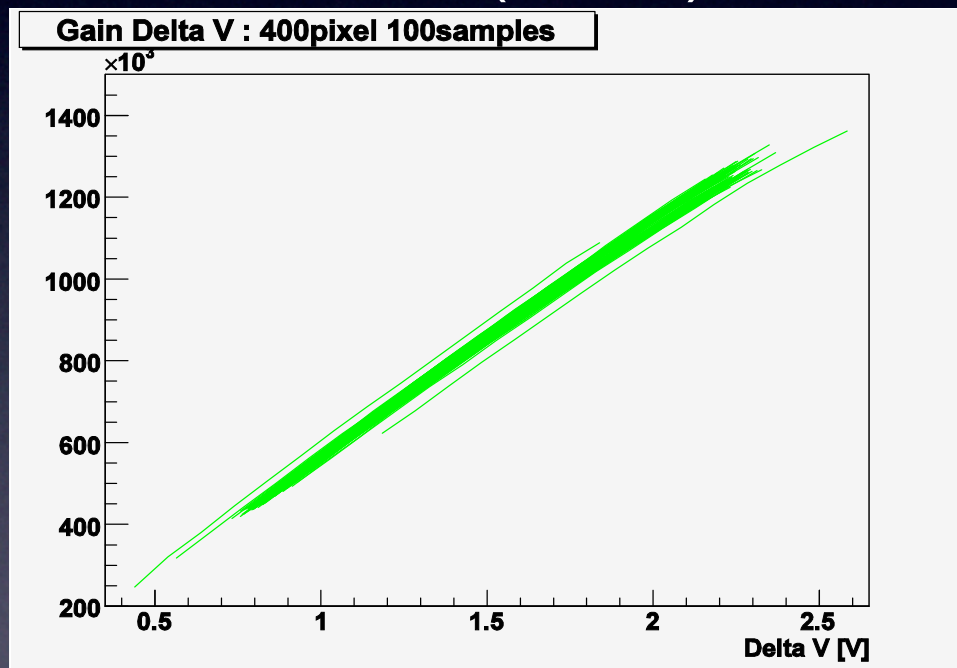


PMT: H8643,  
Green light from WLS (YII)

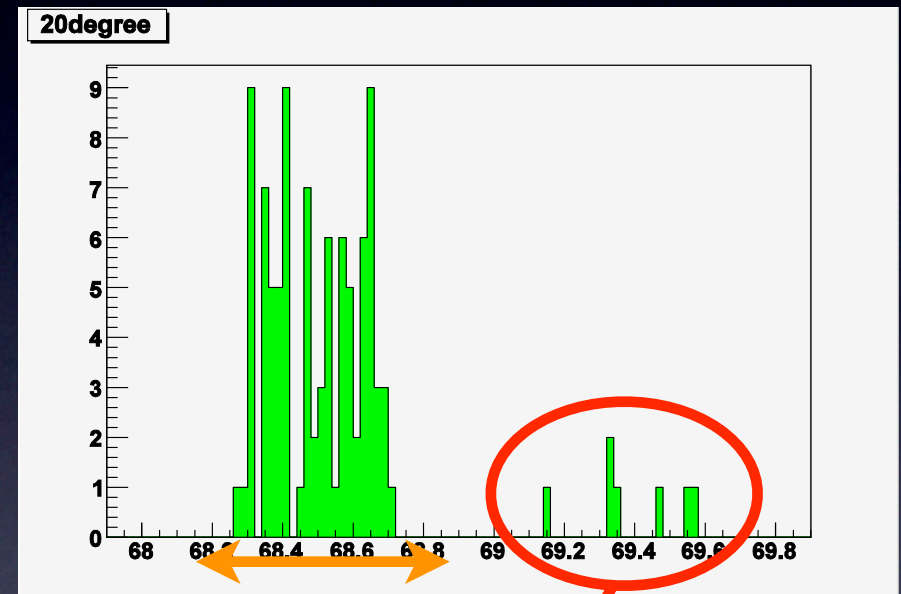
# Mass-sample test

400 pixel, 100 samples

Gain vs.  $(V - V_{bd})$



$V_{bd}$



0.4V

Consistent with  
test sheet from Hamamatsu



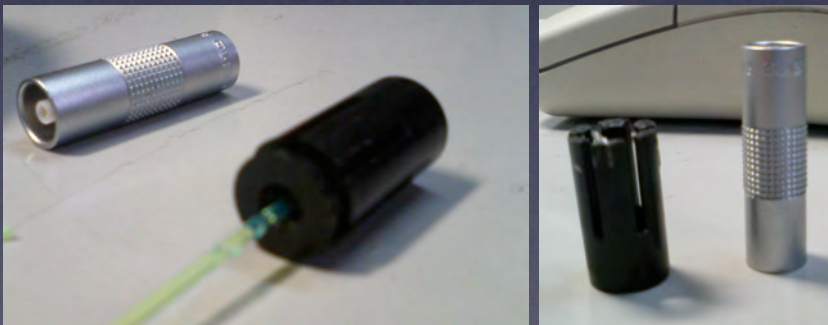
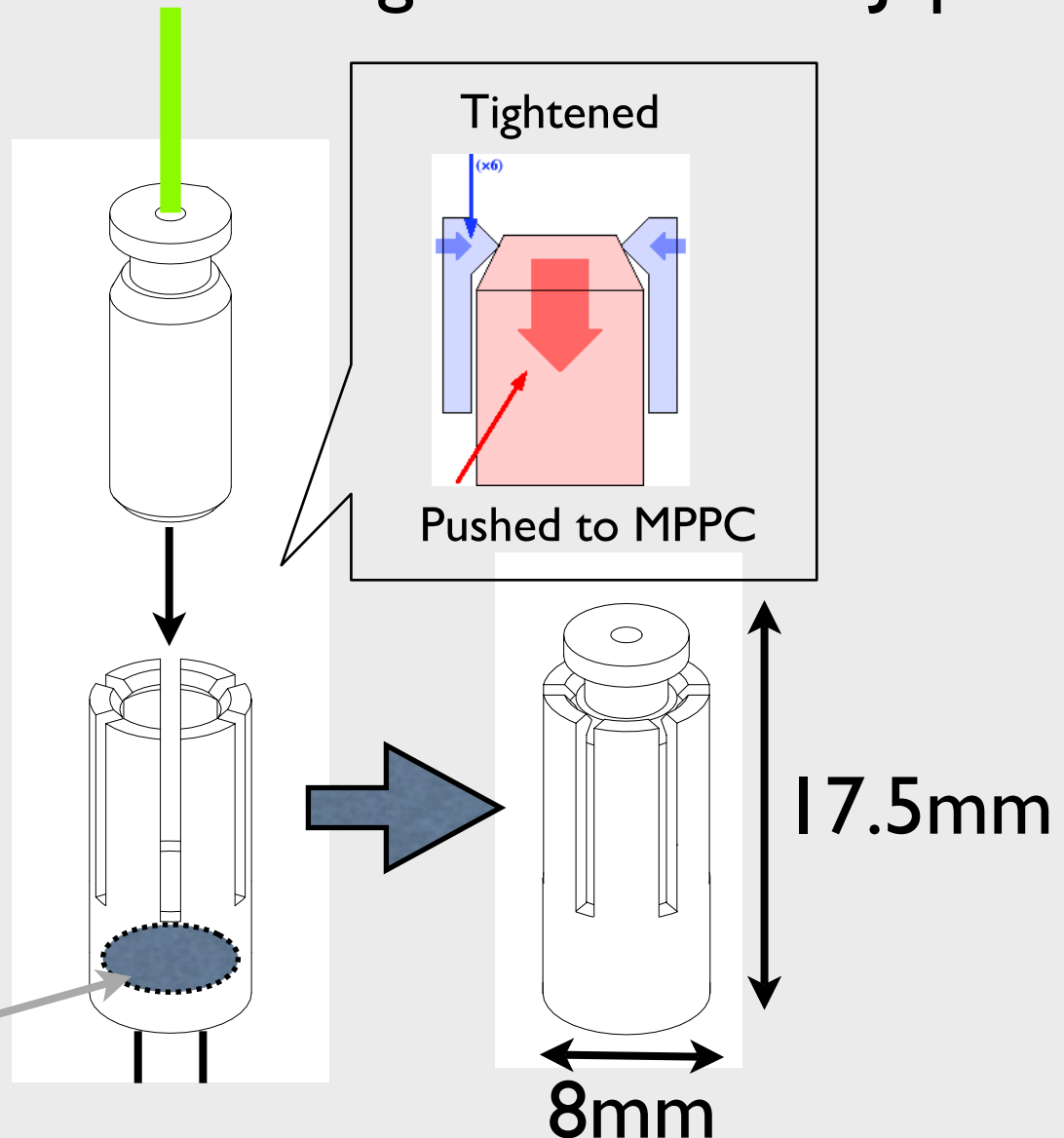
# Needs for T2K

- Total number of devices: ~60,000
  - MRS-APD by CPTA will be also used for some of sub-det. (contribution from Russian collaborators)
- PDE > MA-PMT (used in K2K/SciBooNE)
- Number of pixel: ~500 (~100 for on-axis)
- Basic performance OK 😊 with current MPPC (although continuing improvement)
  - Active area:  $1.2 \times 1.2 \text{mm}^2$  to match 1.0mm dia. fiber (under development)
  - Cross-talk/after-pulse reduction

# Optical coupler

- Easy to handle
- Simple structure
- Compact (FGD has 1cm segmentation)
- Test sample just arrived

One of designs worked in Japan



MPPC

# Works in progress

- Absolute PDE measurement
- Timing resolution
- Radiation hardness (gamma, proton, neutron)
  
- Aging effect
- Test with prototype scintillator
- .....
- Mass-production of MPPC for T2K (~50,000) will start this year!

Sounds interesting?

# International Workshop on new photon-detectors

## PD07

June 27–29, 2007 @ Kobe University, JAPAN

<http://www-conf.kek.jp/PD07/>

Deadline of abstract submission: April 30, 2007

### Main Topics

- Geiger-mode multi-pixel photon device
- Hybrid-PMT
- APD
- MCP-PMT
- New type of photon-sensors
- Applications of photon-sensors to High Energy Physics, Nuclear Physics, Cosmic-Ray Physics, Astronomy, Cosmology and Medical Science



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Detector Technology Project, IPNS, KEK  
Faculty of Science, Kobe University



Supported by JSPS Grant-in-Aid for Creative Scientific Research, "Research and Development of a Novel Detector System for the International Linear Collider", and MEXT Grant-in-Aid for Scientific Research on Priority Areas, "New Development of Flavor Physics"



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Particle Physics, Cosmic-Ray Physics,  
Cosmic-Ray Physics, Astronomy,  
Cosmology and Medical Science

- MPPC is one of photo-sensors to be used in T2K-ND scintillator detectors
- Performance satisfies our requirement
- Preparation ongoing for start in Apr, 2009
- If you are interested, come to PD07 workshop in Kobe (June 27-29, 2007).

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(in English)
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