Prototype string for a km3 Baikal neutrino telescope

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for the Baikal Collaboration

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Collaboration

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- DESY-Zeuthen, Zeuthen, Germany.
- Joint Institute for Nuclear Research, Dubna, Russia.
- Nizhny Novgorod State Technical University, Russia.
- St.Petersburg State Marine University, Russia.
- Kurchatov Institute, Moscow, Russia.

Outline

1. Introduction
   Objectives of prototype string installation

2. Prototype string design

3. Prototype string as a part of NT200+,
   modernization of NT200+ data acquisition system

4. Preparative works (2007)
   - prototype of a FADC based system
   - new optical module
   - PM selection for the km3 prototype string

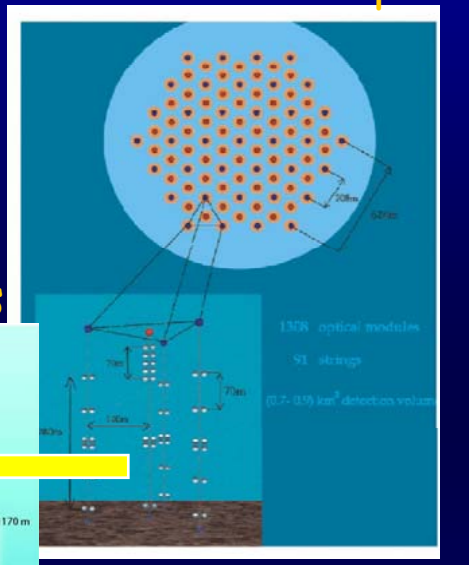
Summary

Introduction

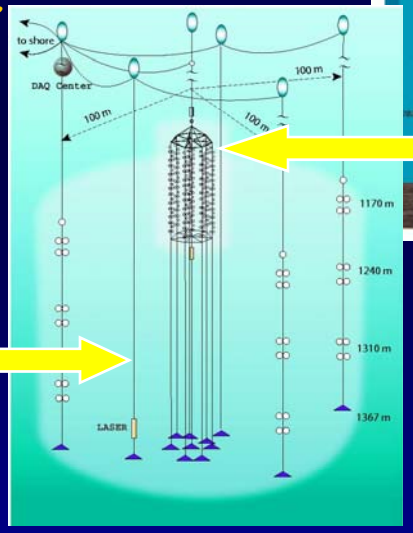
Installation of a "new technology" prototype string as a part of NT200+ (spring 2008)

- Investigations and in-situ tests of basic knots of future detector: optical modules, DAQ system, new cable communications.
- Studies of basic DAQ/Triggering approach for the km3-detector.
- Confrontation of classical TDC/ADC approach with FADC readout.

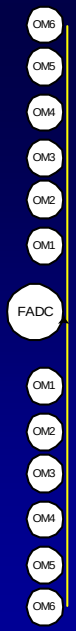
Project of km3 Baiakl Neutrino Telescope



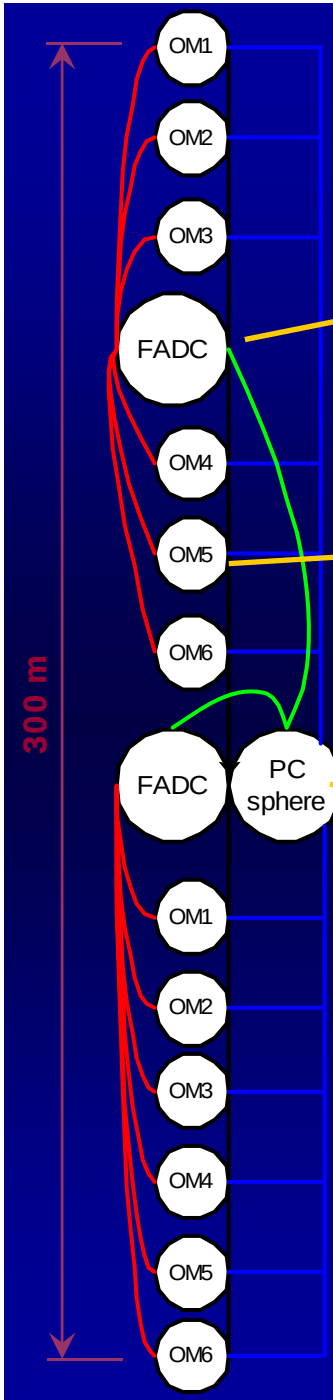
NT200+ current status

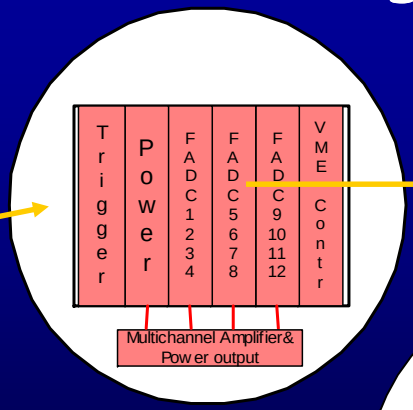


Prototype string

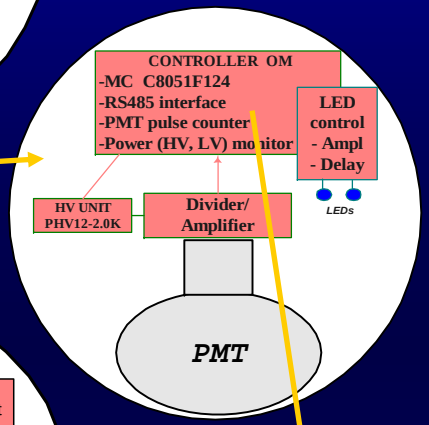


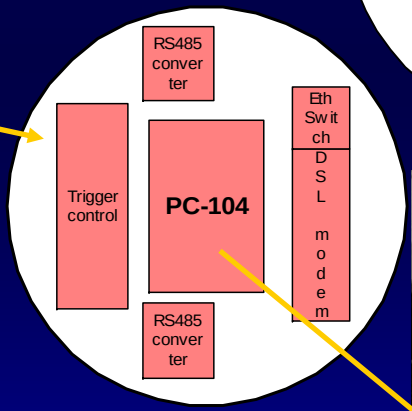
Design of Prototype string

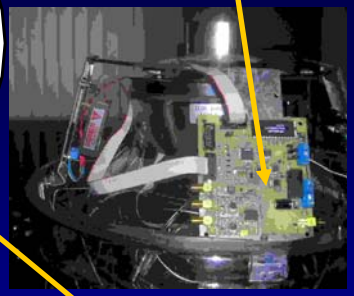




FADC unit is operating now in Tunka detector (astro-ph/0511229)







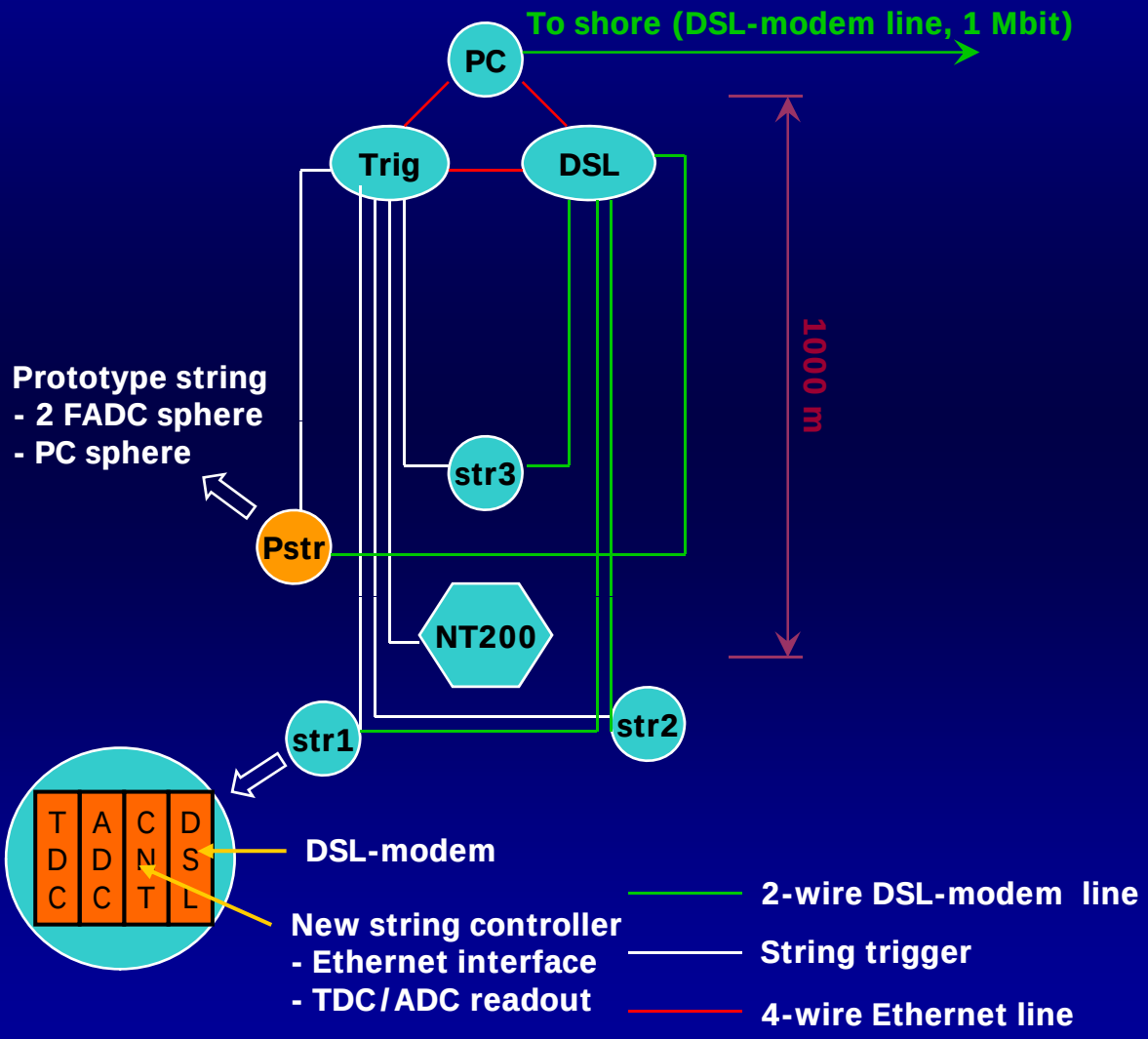
PMT pulses & Power 12 V Control line

Data (Ethernet), Trigger

Basic features

- String lengths ~300 m
- String contains 12…16 OM
- Optical modules contains only PM and control electronics
- 12 bit 200 MHz FADC readout is designed as multi channel separate unit.
- Half-string FADC controllers with ethernet-interface connected to string PC unit
- String PC connected by string DSL-modem to central PC unit

Prototype string as a part of NT200+
Modernization of data acquisition system during expedition 2007



Basic goal of DAQ modernization is increase of the uw-data rate:
- Transmission FADC data;
- Trigger algorithm optimization

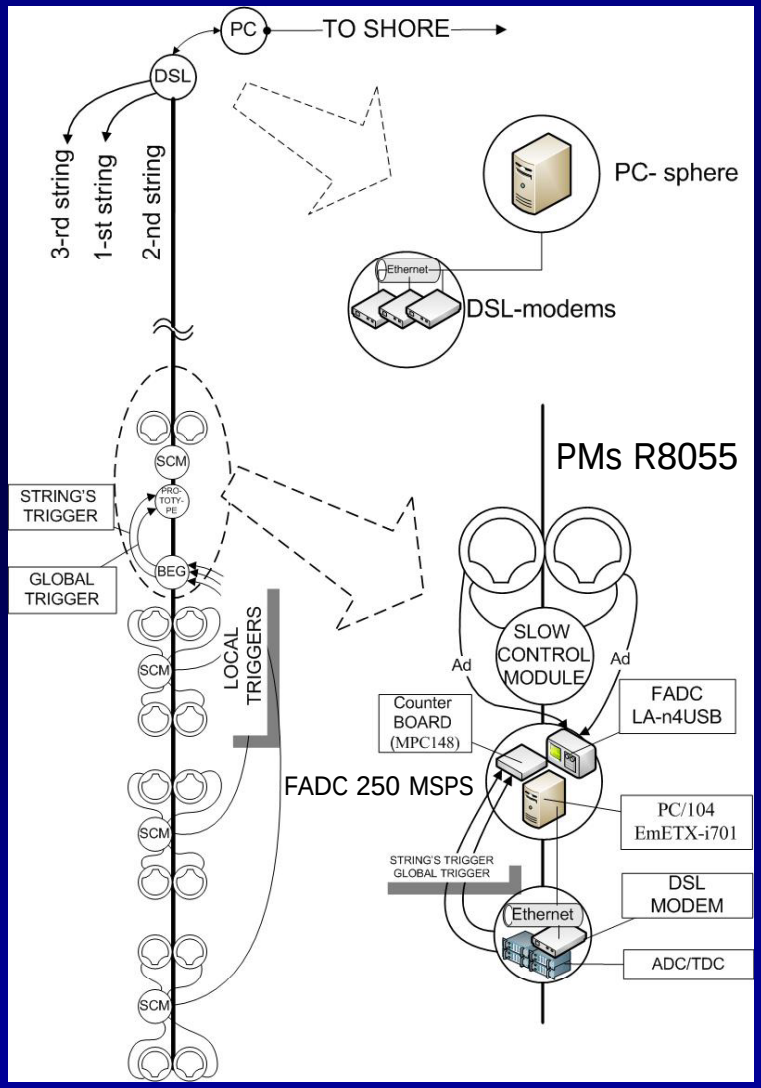
2005: data/control TCP/IP connection between the shore station and central uw-PCs.

2007: TCP/IP communication between uw-PCs and string controller.

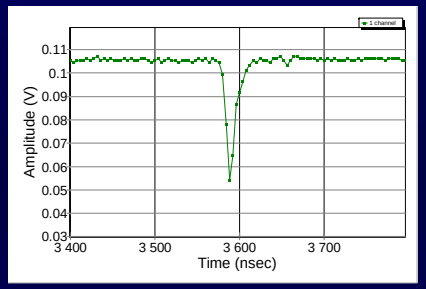
Time synchronization: measuring of each string trigger time with 2 ns precision).

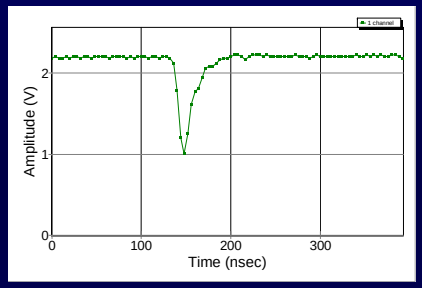
Prototype of FADC based system

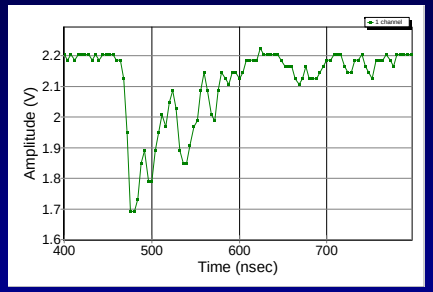
2-channel FADC prototype was installed during expedition 2007



Purposes:
- optimal sampling time window
- dynamic range
- obtainable pulse parameter precision
-algorithms for online data handling





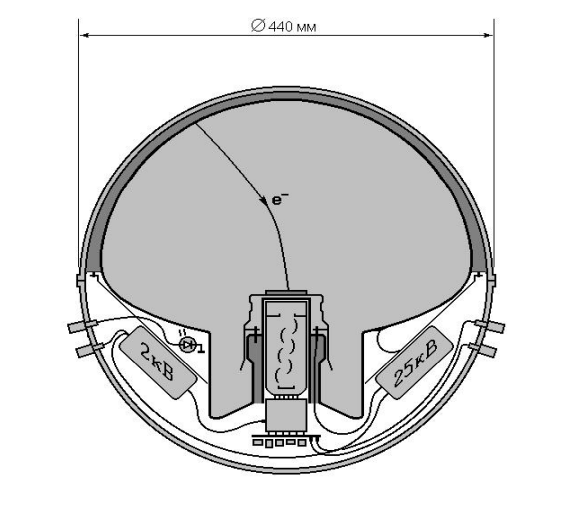


Examples of FADC pulses for different classes of events:

1. One p.e. noise hit
2. A muon trigger (multi-p.e.)
3. Backward illumination by a calibration laser

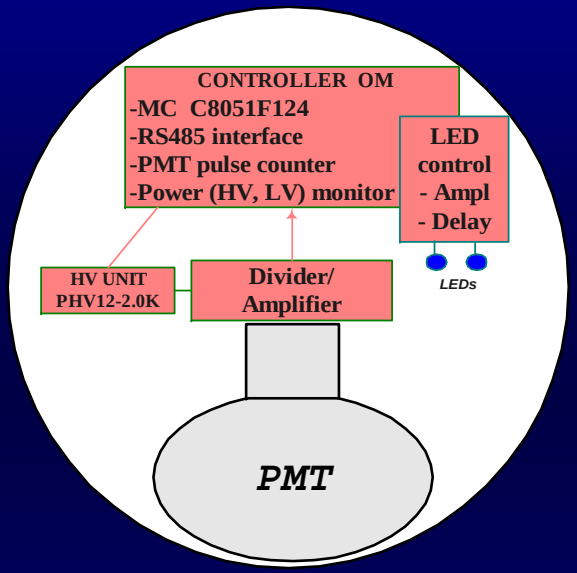
New optical module (OM)

OM NT200+



1. Hybrid photodetector Quasar-370: ~80…100 ns FWHM
2. Outer control system
3. 25 kV Quasar power supply
4. 1-LED calibration

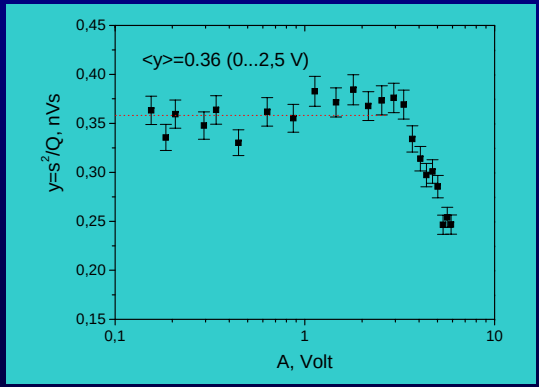
NEW OM designed for km3 Baikal telescope



1. New PMT: R8055, XP1807, … : ~20 ns FWHM
2. Control and monitoring system inside OM: HV value, power supply, PMT noise rate, temperature.
3. 2-LED calibration system for operation with FADC: LED amplitude and pulse delay control: dynamic range >10^8, delay range 0…1000 ns (+/- 1 ns).

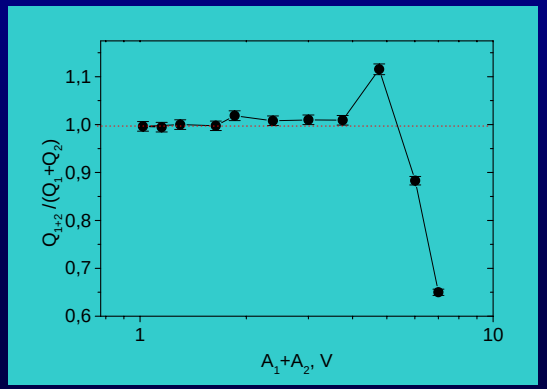
PM parameter monitoring with new OM control system

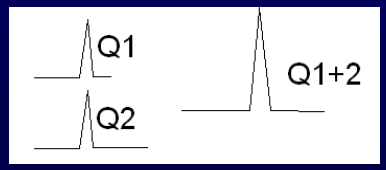
PM monitoring with one LED



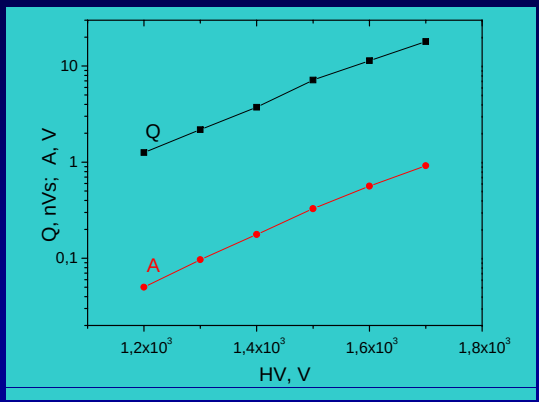
σ^2/Q dependence on pulse amplitude (s^2/Q ~ Gain_of_PM)

PM monitoring with two LED

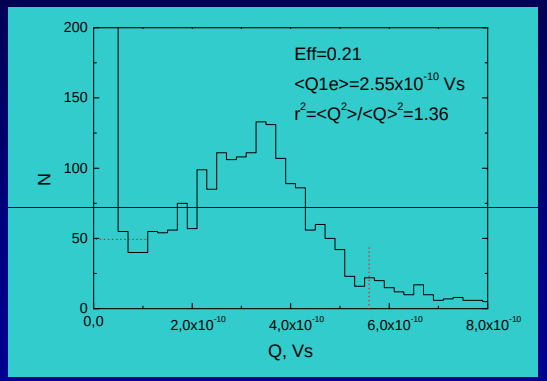


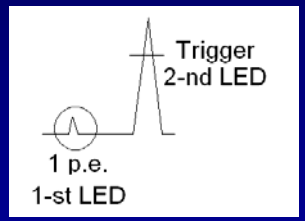


PM linearity test with 2 LEDs (1% precision)



Pulse area and amplitude dependence's on HV value





Single electron PM spectrum

PM selection for the km3 prototype string

Basic criteria of PM selection is its effective sensitivity to Cherenkov light: fraction of registered photons per photon flux unit.
(Photocathode area × Quantum efficiency × Collection efficiency)

Quasar-370
D ≈ 14.6″
Quantum efficiency ≈ 0.15

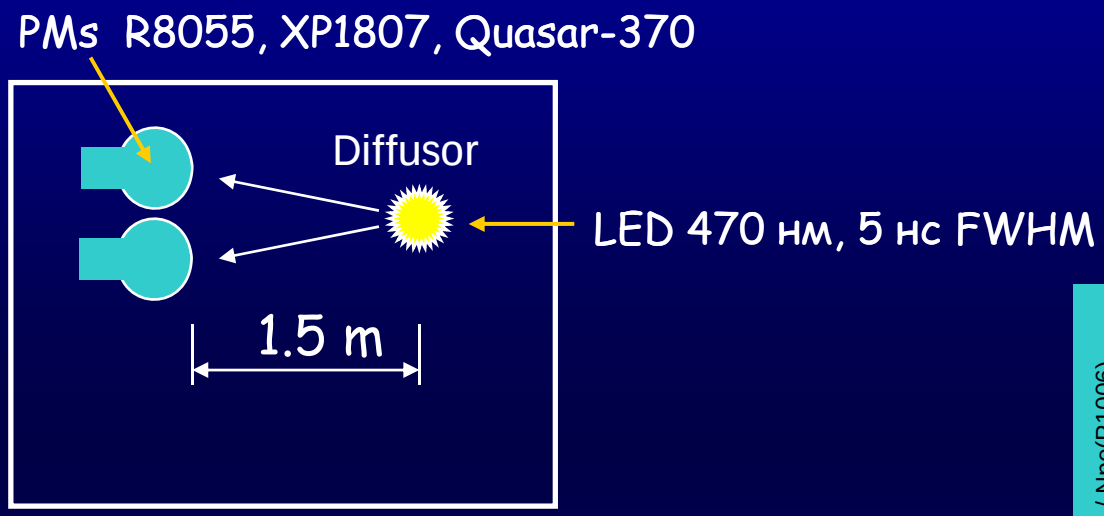
?≈

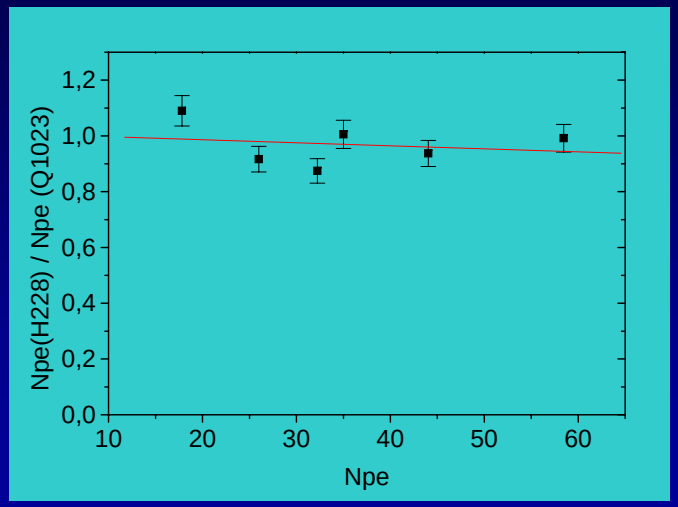
Hamamatsu R8055
D ≈ 13″
Quantum efficiency ≈ 0.20

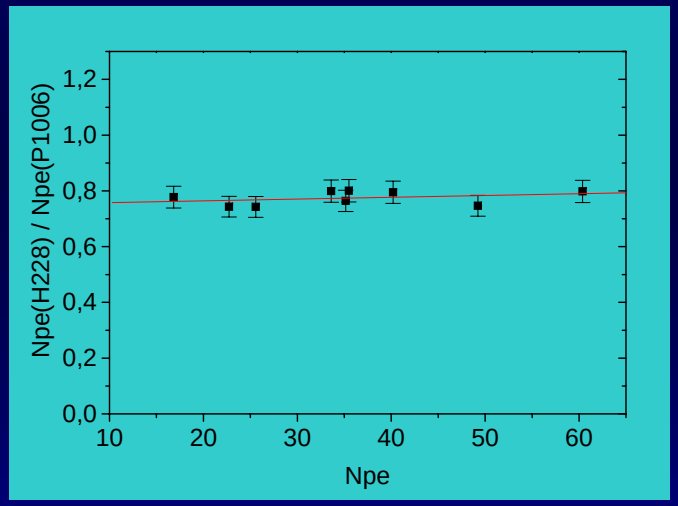
?≈

Photonis XP1807
D ≈ 12″
Quantum efficiency ≈ 0.24

PM selection : Laboratory tests





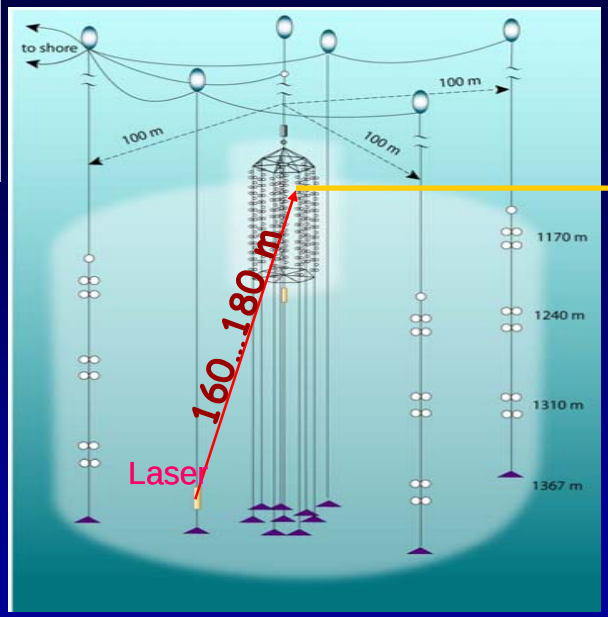


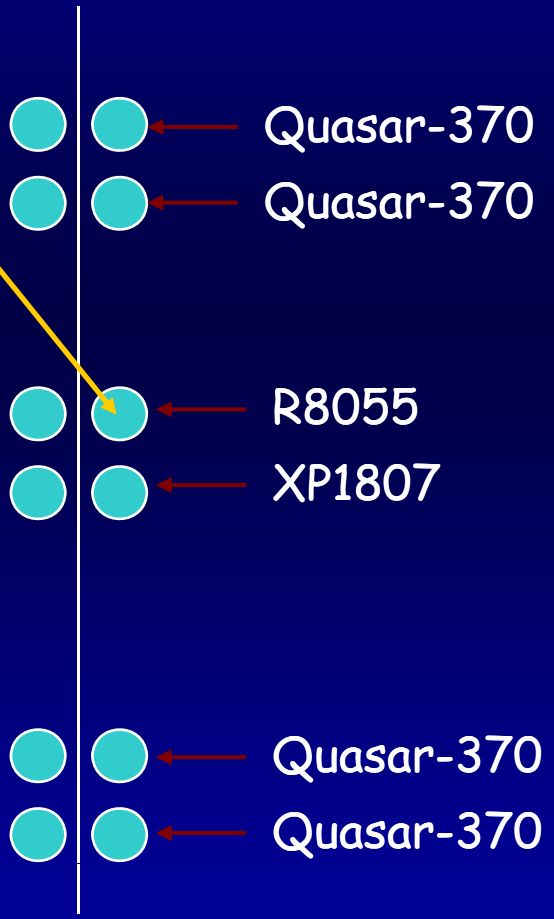
Examples of relative sensitivities measurements for Quasar-370, R8055, and XP1807

PM selection: Underwater tests

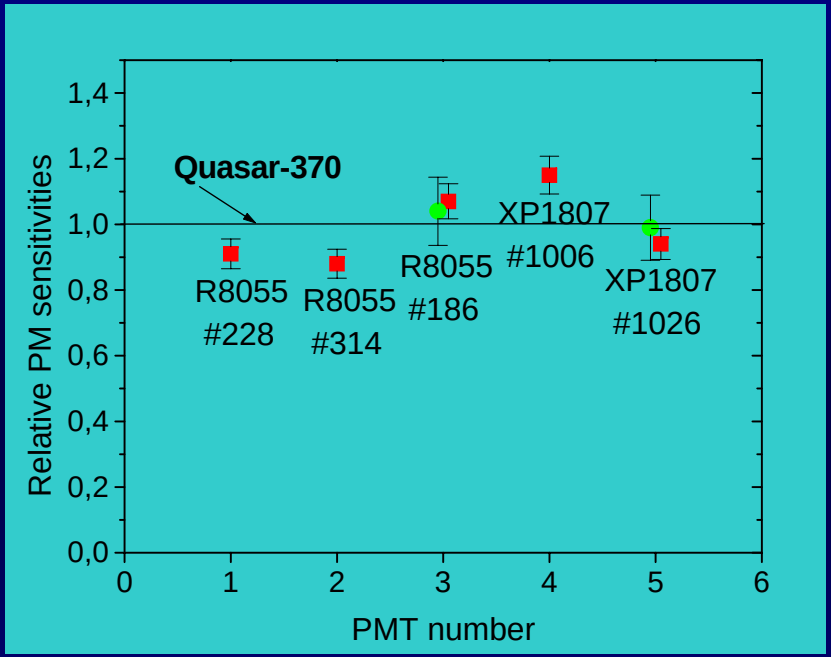
4 PM R8055 (Hamamatsu)
и 2 XP1807 (Photonis)
were installed to NT200+
detector (April 2007).

4 PM: central telescope
NT 200;
2 PM R8055: outer string,
FADC prototype.





Ratio of effective sensitivities of large area PMs (preliminary results)



Smaller size (R8055, XP1807) tends to be compensated by larger photocathode sensitivities.

Ratio of effective sensitivity of large area PMs R8055/13" and XP1807/12" to Quasar-370/14.6". Laboratory (squares), in-situ (dots).

Summary

1. For the planned km3-detector in lake Baikal, R&D-activities have been started.
2. The existing NT200+ allows to verify all key elements and design principles of km3-detector.
3. Modernization of NT200+ DAQ system allowed to install a prototype FADC PM readout at spring 2007.
4. Six large area hemispherical PM (2 Photonis XP1807 and 4 Hamamatsu R8055) have been integrated into NT200+ to facilitate the optimal PM choice.
5. A full scale "new technology" prototype string will be installed in spring 2008 as a part NT200+.