R&D PMT Characterization

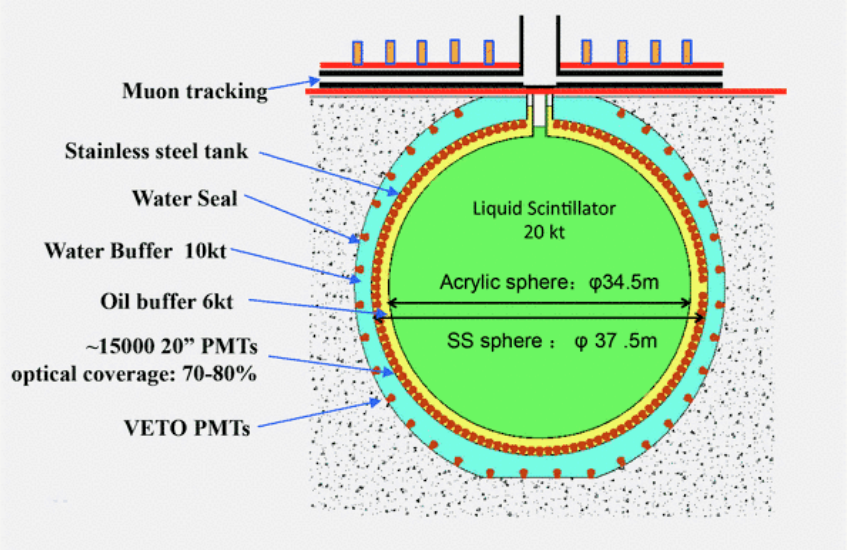
Gran Sasso Summer Institute 2014

STROEM Rickard

TAKACHIO Osamu

Motivation

- R&D for future experiments that need large optical/geometrical coverage and high single photon detection efficiency.
- E.g. this new PMT is planned to be used in JUNO experiment in China.

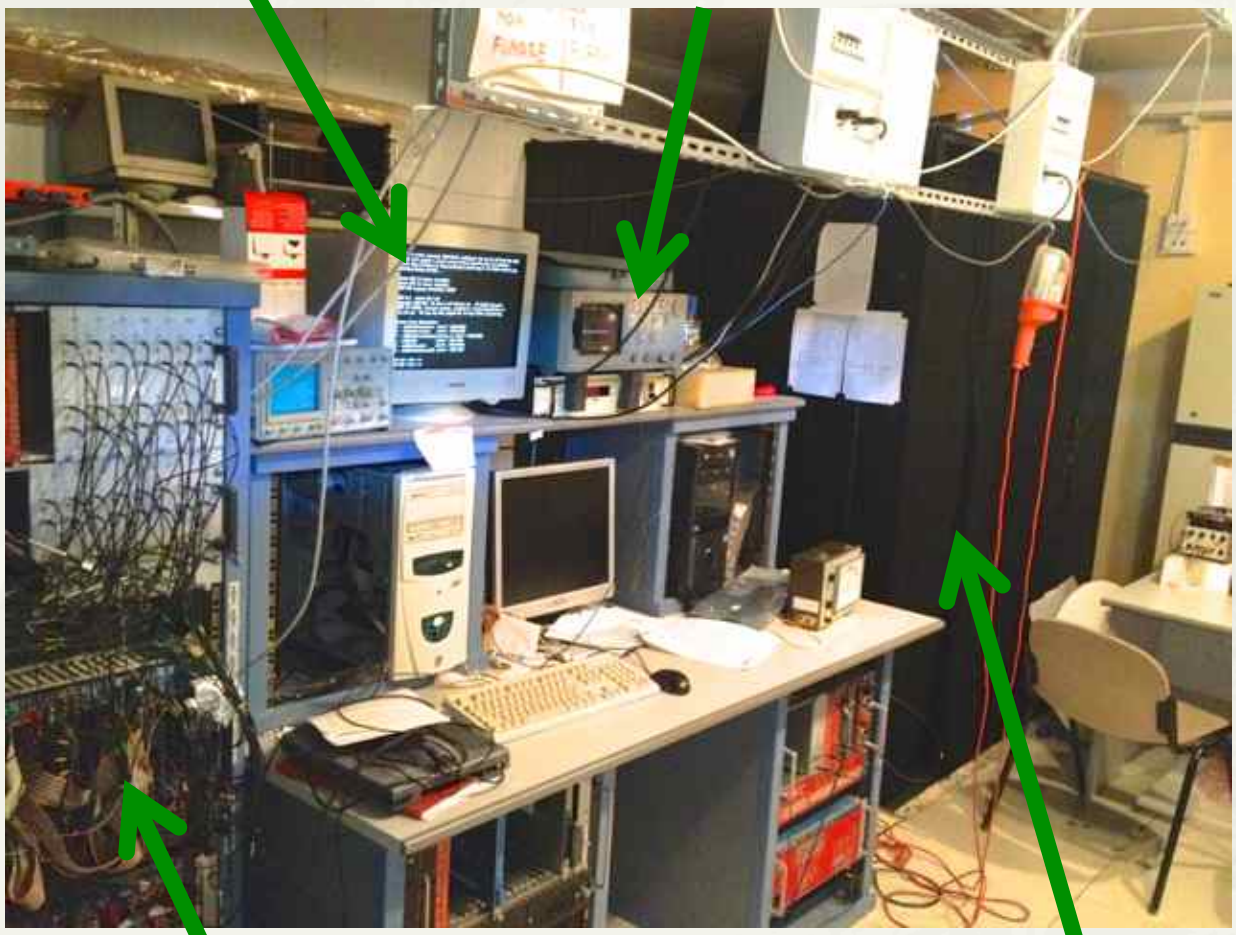


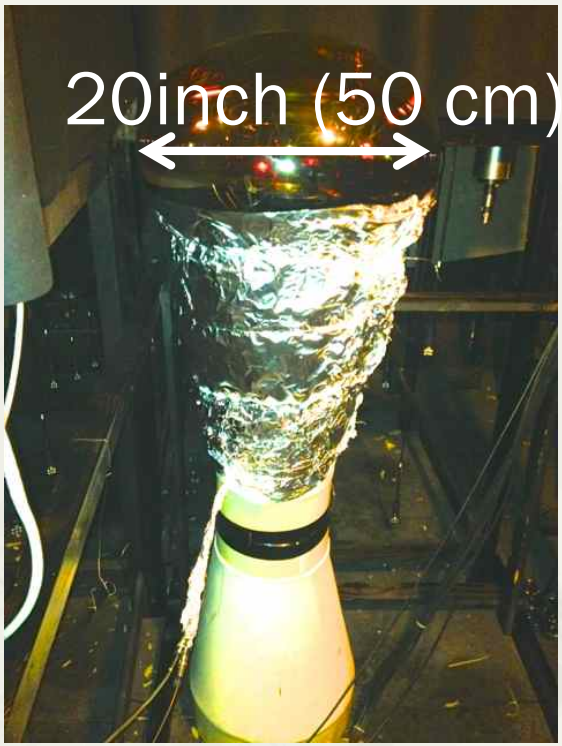
JUNO experiment
- 15,000 20-inch PMTs
- 70-80% optical coverage
- To have sensitivity for the neutrino mass hierarchy they need an energy resolution < 3% at 1 MeV (1,200p.e./MeV) (cmp. to BOREXINO (present state-of-art) 5% (500p.e./MeV)

Goal

- To characterize high Q.E. 20-inch PMT and test its sensitivity to Earth magnetic field (EMF).
- At the test facility built for the BOREXINO experiment at LNGS (incl. dark room)
- The facility is equipped with a system for compensating the Earth's magnetic field.

Test facility

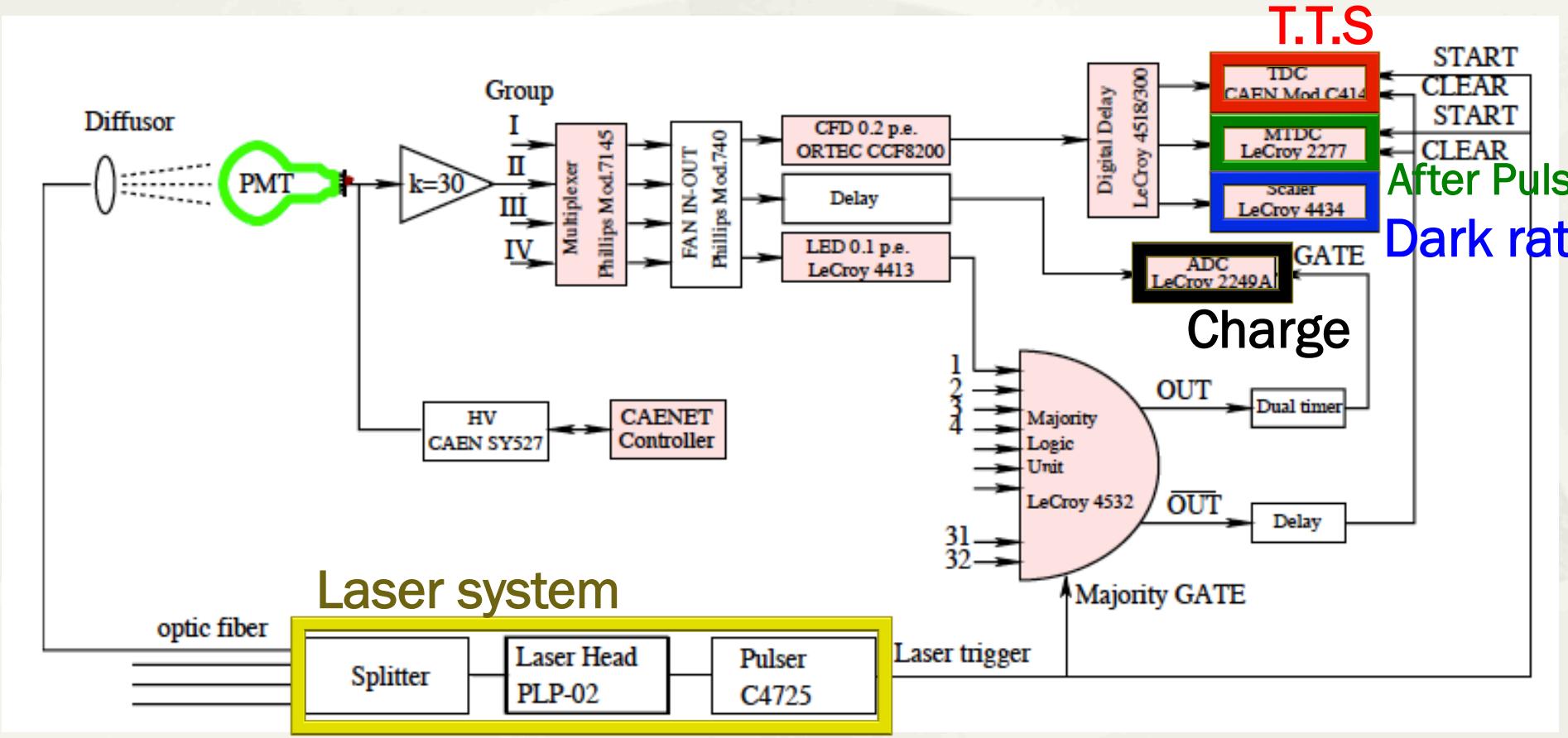




PMT R3600-02 HQE MOD

- Target
  - Type : R3600-02 HQE MOD (HAMAMATSU)
    - High Q.E. equal to 33.4 % according to HAMAMATSU (not a part of these tests)
  - Serial Number : ZP0029
- Characteristics
  - Charge (ADC, Analog-to-Digital Converter)
    - Peak to Valley ratio P/V
    - Relative Variance of 1p.e. v_1
  - Timing (TDC, Time-to-Digital Converter)
    - Transit time T_0, Transit time spread σ_{tt}
  - After Pulse ratio
  - Dark noise
  - Behavior with respect to EMF

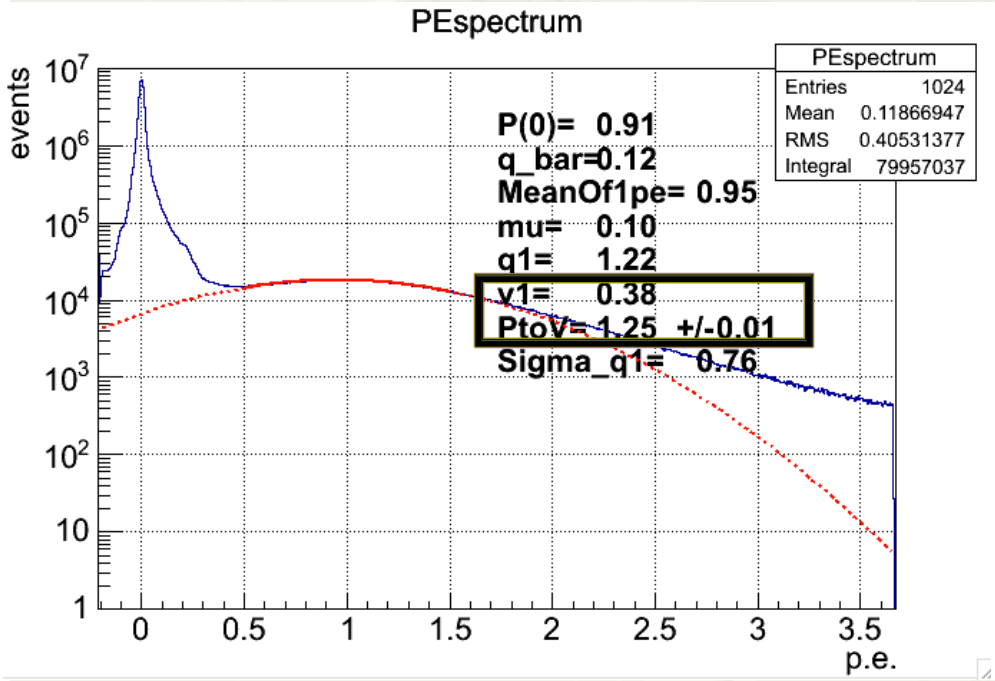
Block scheme



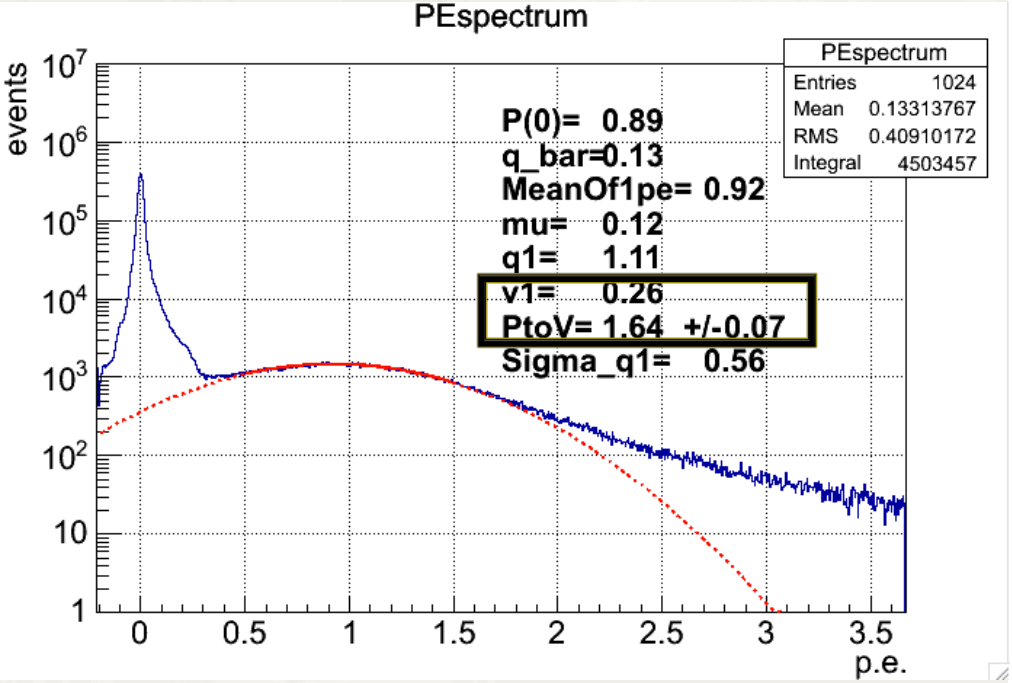
A. Brigatti et al. Nuclear Instruments and Methods in Physics Research A 537 (2005) 521-536

Photo Electron Spectrum

Without magnetic compensation

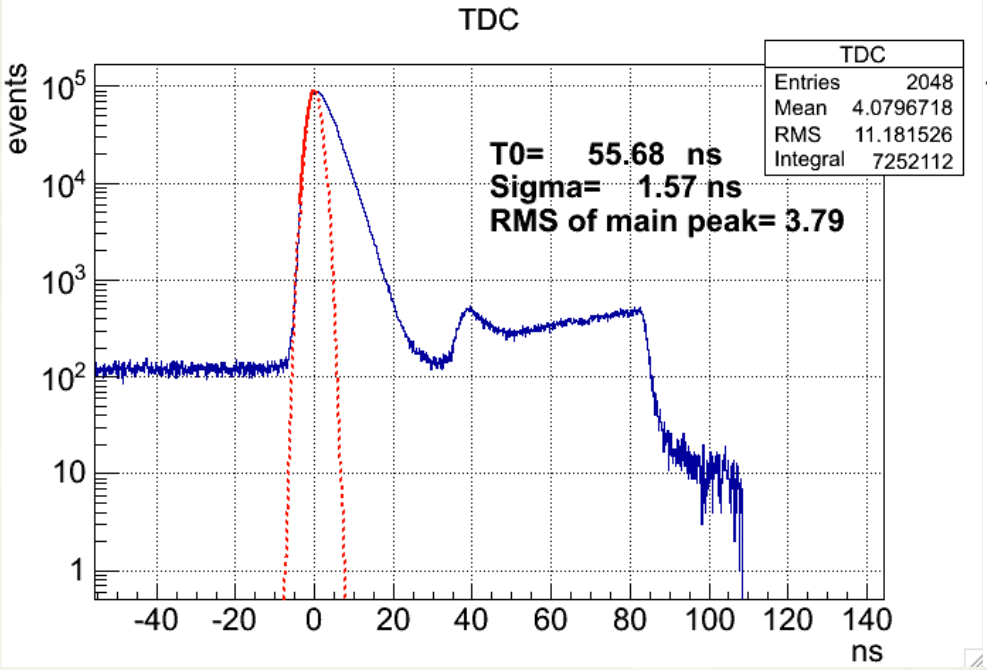


With magnetic compensation

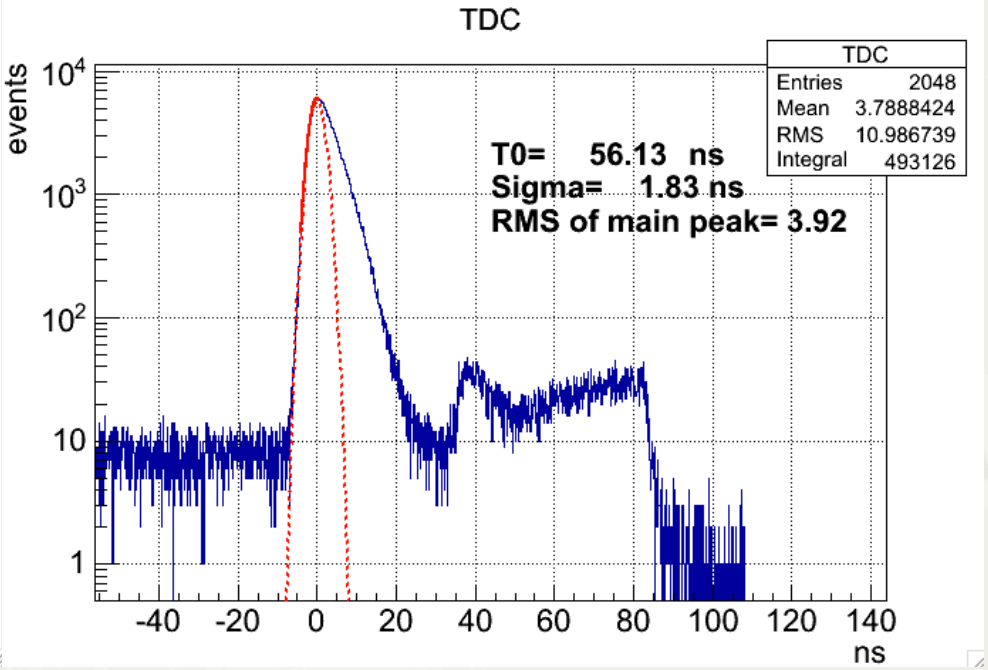


Transit Time Spread

Without magnetic compensation



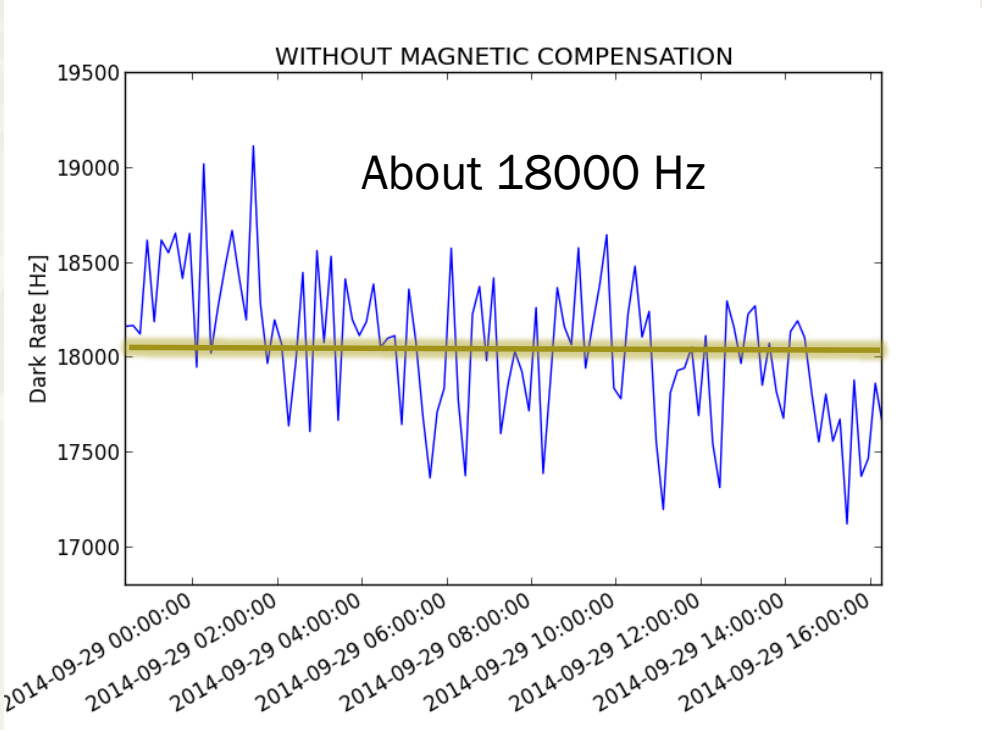
With magnetic compensation



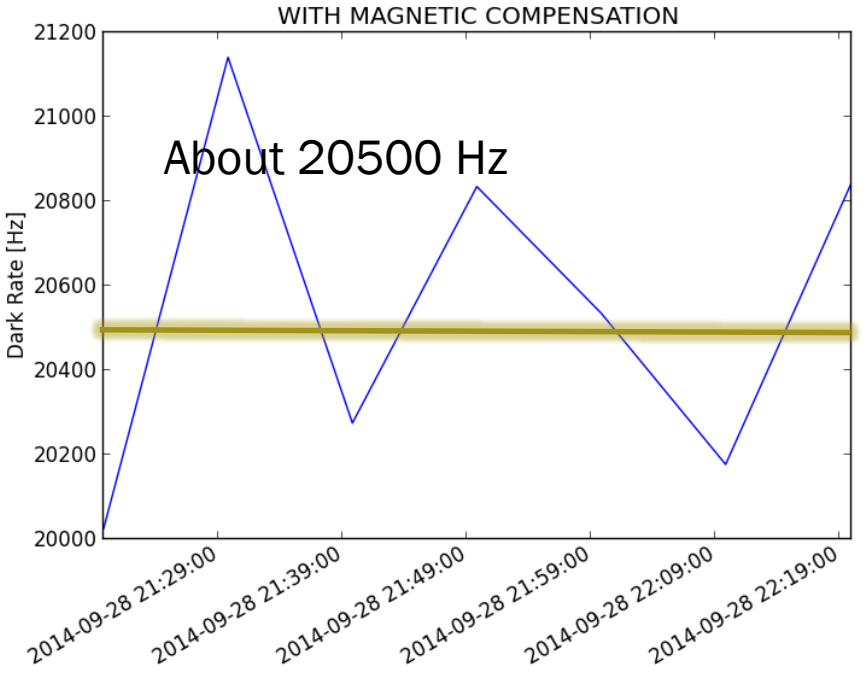
Dark Rate

- Specification value (HAMAMATSU) : 19800 Hz (operated at 1900 V)
- Dark rate measured with laser on : gives contribution of about 3300 Hz
- Operated at 1789 V
- Conclusion : Acceptable and lower than the reference value by HAMAMATSU

Without magnetic compensation



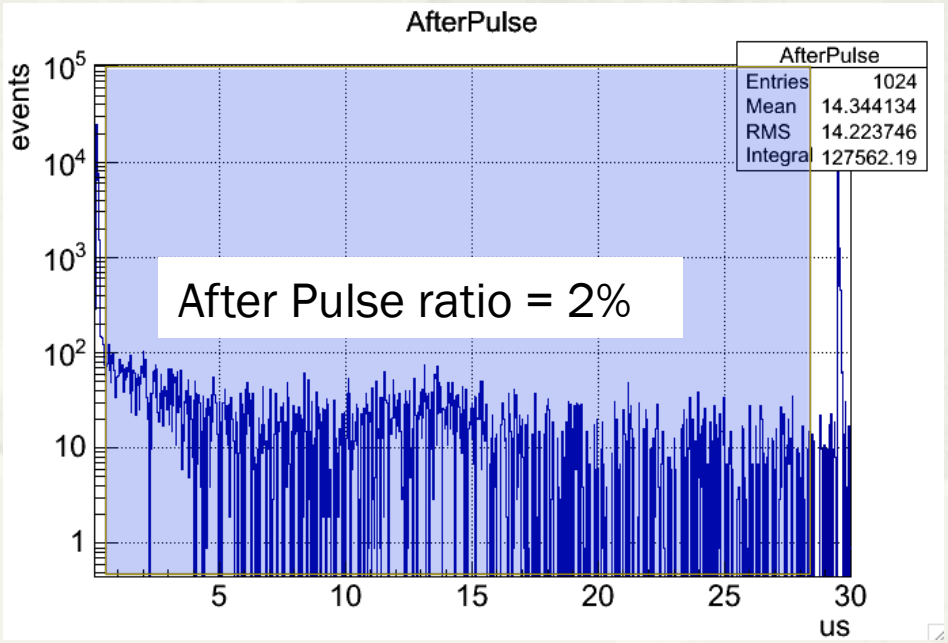
With magnetic compensation



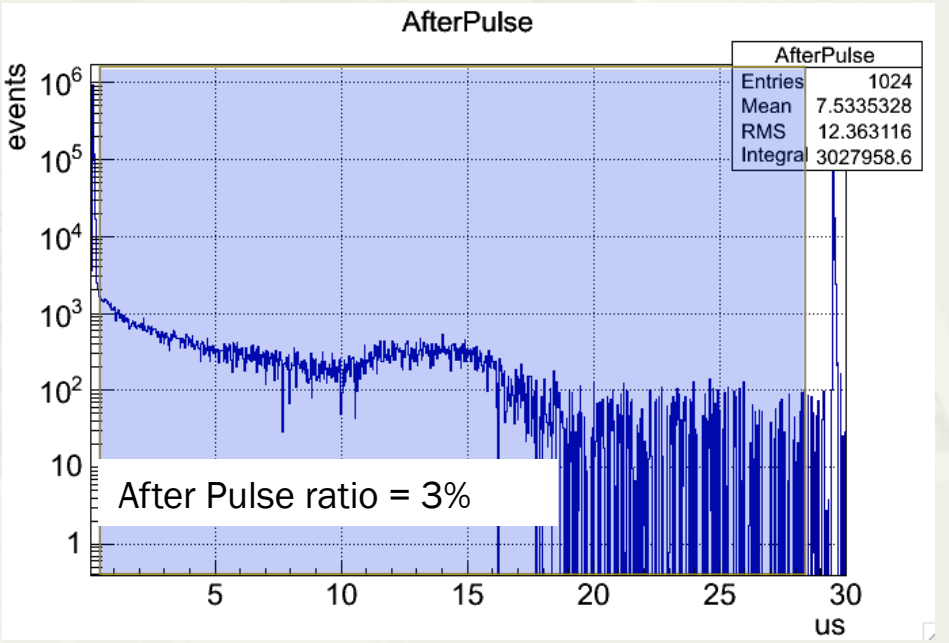
After Pulses

After Pulse ratio ≡ $N_{(400ns<t<28us)}/N_{single\ trigger}$

Without magnetic compensation



With magnetic compensation



Result

Test	P/V	mu	q1	σ_{q1}	1peMean	v1	T.T.S(ns)	RMS(ns)	After Pulses
Non comp	1.25	0.12	1.03	0.64	0.95	0.38	1.57	3.79	3%
comp	1.64	0.14	0.93	0.47	0.92	0.26	1.83	3.92	2%
Non comp 90°	1.45	0.13	1.09	0.72	1.01	0.43	2.47	3.94	2%
comp 90°	1.55	0.14	0.94	0.48	0.92	0.26	1.84	3.91	3%

Reference	Type	Serial number	P/V	RMS*(ns)
HAMAMATSU	20-inch	ZP0029	1.48	6.200

Results – Cmp. to BOREXINO

Test	P/V	mu	q1	σ_{q1}	1peMean	v1	T.T.S(ns)	RMS(ns)	After Pulses
Non comp	1.25	0.12	1.03	0.64	0.95	0.38	1.57	3.79	3%
comp	1.64	0.14	0.93	0.47	0.92	0.26	1.83	3.92	2%
Non comp 90°	1.45	0.13	1.09	0.72	1.01	0.43	2.47	3.94	2%
comp 90°	1.55	0.14	0.94	0.48	0.92	0.26	1.84	3.91	3%

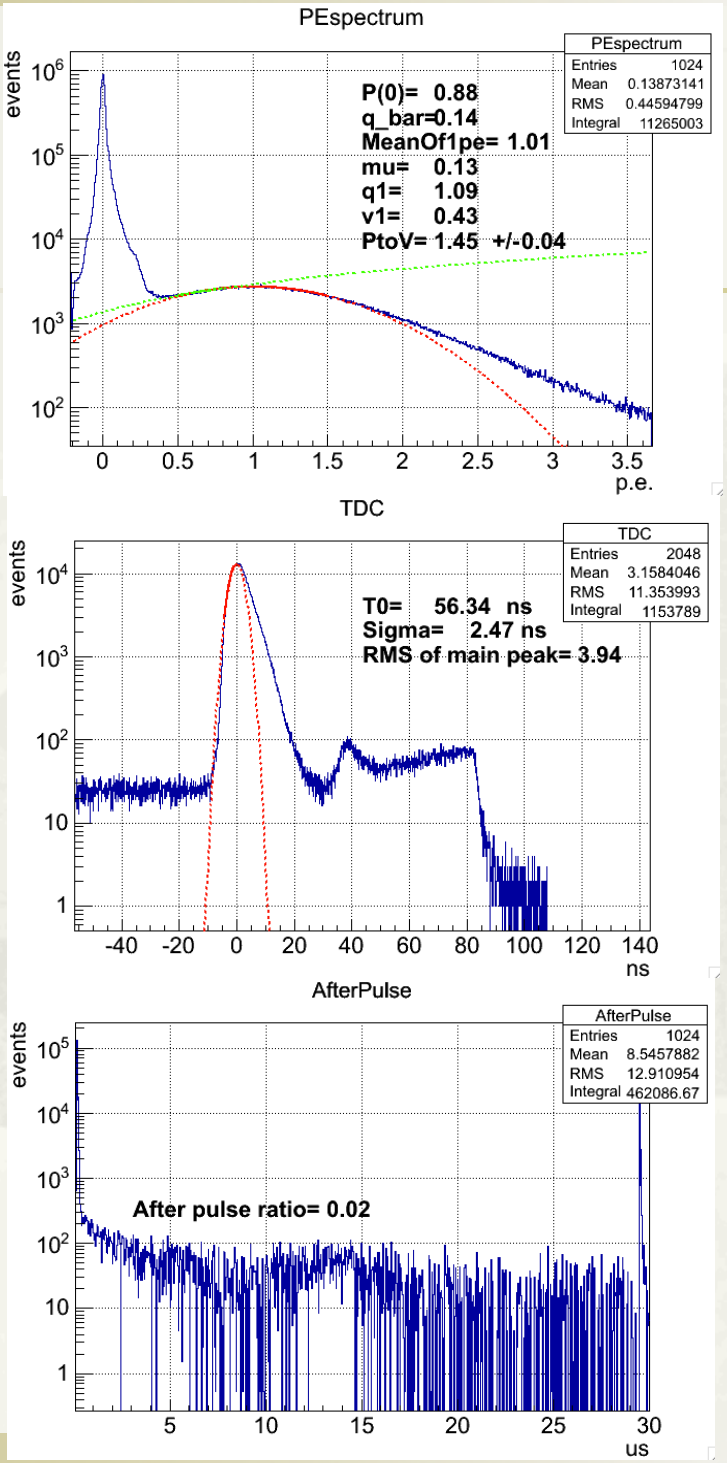
Reference	Type	Serial number	P/V	mu	q1	σ_{q1}	v1	T.T.S (ns)	RMS*(ns)	After Pulses
BOREXINO	8-inch	Average	[1.35-2.27]	0.059	1.00	0.58	0.34	1.17	8.14	5%

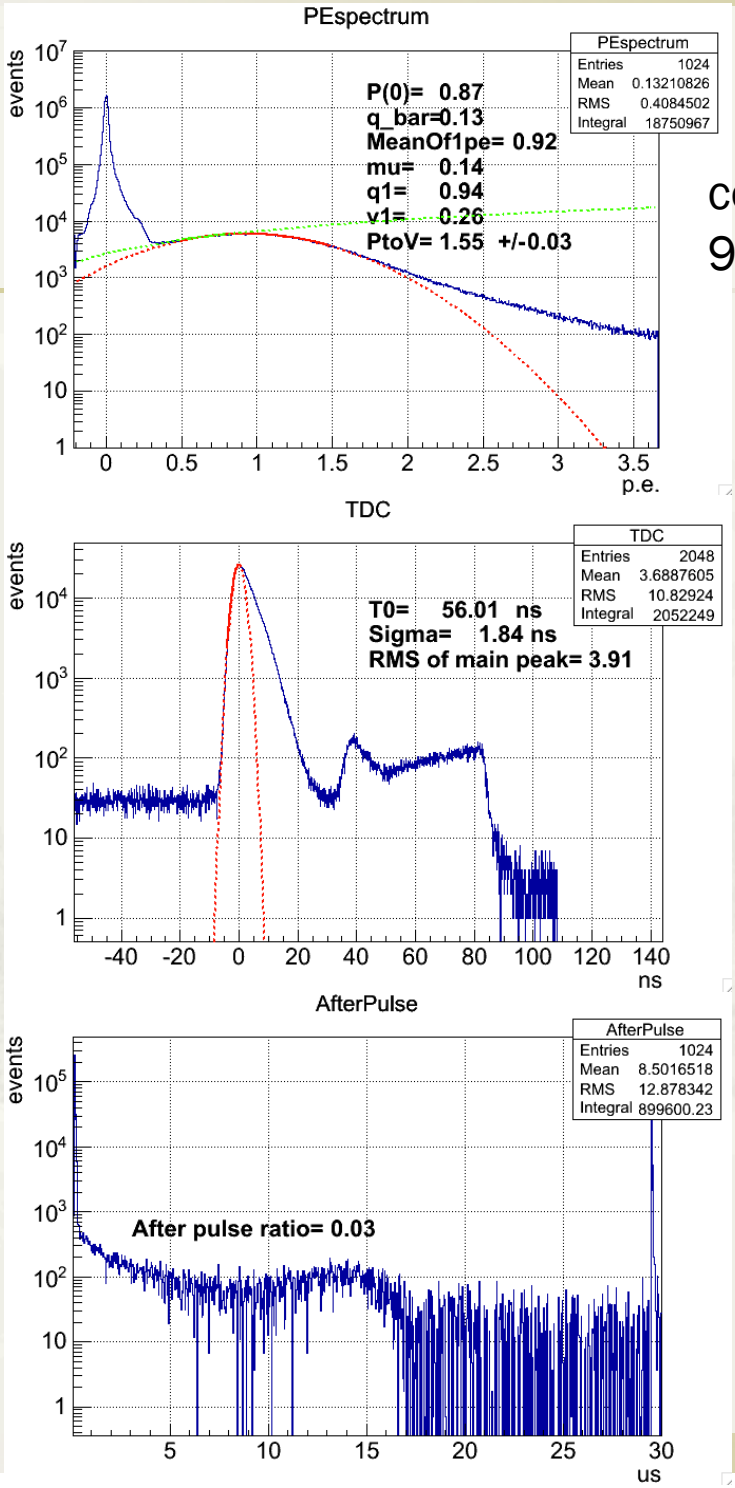
Summary

- Dark rate is at an acceptable level and somewhat lower than measured by HAMAMATSU.
- After pulse fraction is 2-3% for all tests (BOREXINO PMT has about 5% on average)
- Our tests show that the PMT is sensitive to the presence and direction of the E.M.F. Hence JUNO will have to compensate. Current plan is to use mu-metal shields (built-in) and huge Helmholtz coils.

Back up

No_comp_
90deg





comp_
90deg