Large area photon detectors in large-scale neutrino physics experiments: single large area PMT and multi small PMTs

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More than 40 years ago beginning of works on deep underwater high energy neutrino telescope projects (DUMAND and Baikal) inspired development of new photon detectors: large area photomultipliers (PMTs), multi small PMT optical modules, small PMTs equipped with wavelength shifting plates and rods and even small area solid state photon detectors for such kind application

Now days we witness rebirth of the multi small PMT approach and it started to compete quite successfully with a single large area photon detector approach . The latter have been reigning supreme for almost half century. But recent developments of astroparticle physics experiments demonstrated good competiveness of the "multi small PMTs" idea. Several projects of astroparticle physics experiments may serve as good examples, Km3NET project and coming JUNO experiment among them.

Large area photomultipliers are basic detecting elements of contemporary large-scale neutrino experiments

They are used in overwhelming majority of large-scale neutrino experiments

In some experiments – more than 10k PMTs

IceCUBE

Tunka/TAIGA

JUNO

Pierre Auger

LBNT

LHAASO

Super-Kamiokande

Antares

Hyper-Kamiokande

Daya Bay

Double Chooz

IMB

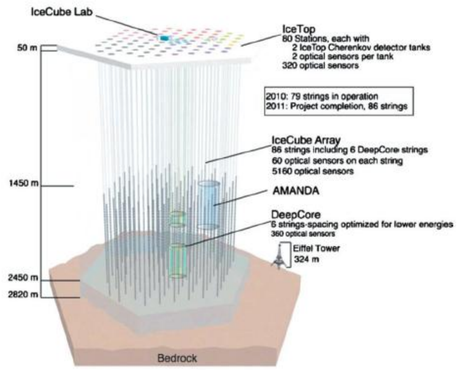
RENO

HAWC

GVD

10-inch (25 cm) PMTs

Experiment IceCUBE, 5160 10" PMTs



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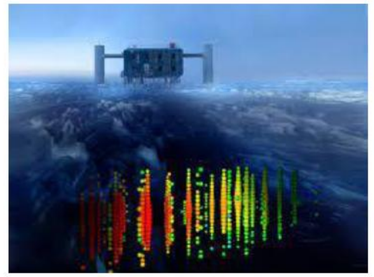
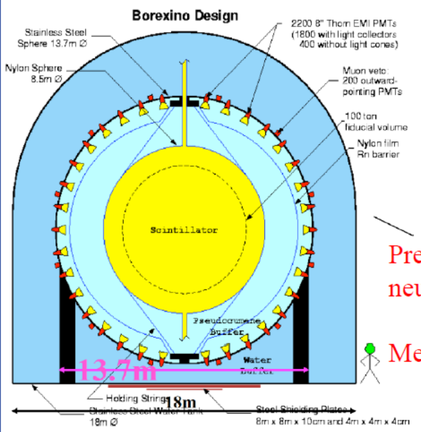


Starting neutrino astronomy!!!

8-inch (20 cm) PMTs

Experiment Borexino, ~2200 8" PMTs



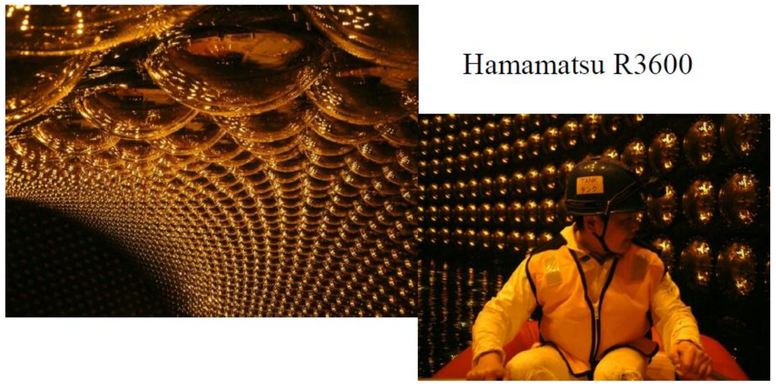
Electron Tubes ETL9351B

Precision measurements of solar neutrino fluxes;

Measurements of geoneutrino flux

20-inch (50 cm) PMTs

Experiment Super-Kamiokande, >11100 20" PMTs



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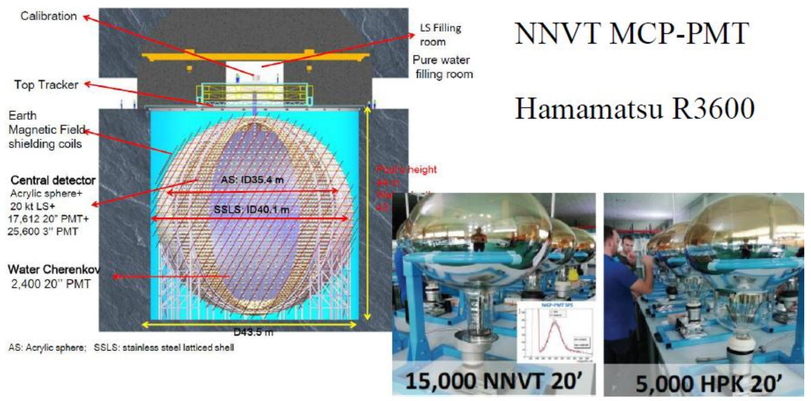
Discovery of neutrino oscillation!!!

20-inch (50 cm) PMTs

Experiment JUNO, ~20k 20" PMTs



NNVT MCP-PMT

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Measurement neutrino mass hierarchy

Conclusion

Large area photon detectors play a key role in running and planning large-scale experiments in astroparticle physics, in neutrino physics in particular.