R&D for
High Energy Astroparticle Physics

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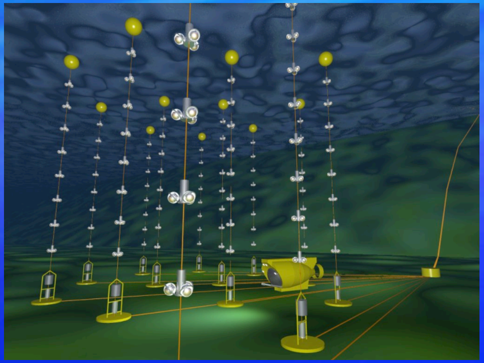
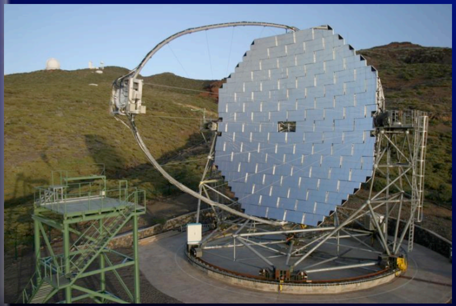
R&D on photon detectors

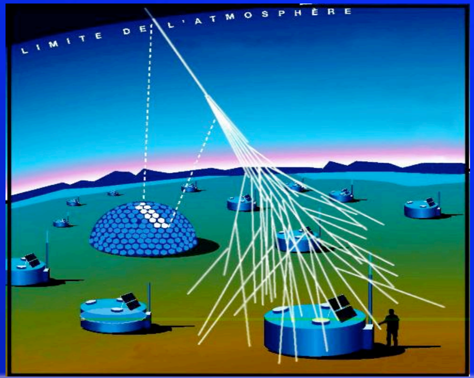
(by M. Teshima)

- Limited flux / rare events ➔ Large area / Large Volume ➔ Transparent Material (Air, Water, ICE) ➔ Photon detectors

- Examples:
  - Ground based Gamma Ray Astronomy
    - Imaging Air Cherenkov Telescopes
  - High Energy Neutrino Astronomy
    - Water / ICE Cherenkov detectors
  - Ultra High Energy Cosmic Rays
    - Water tanks, Scintillation detectors
    - Ground-based air fluorescence detectors







Improvements and developments

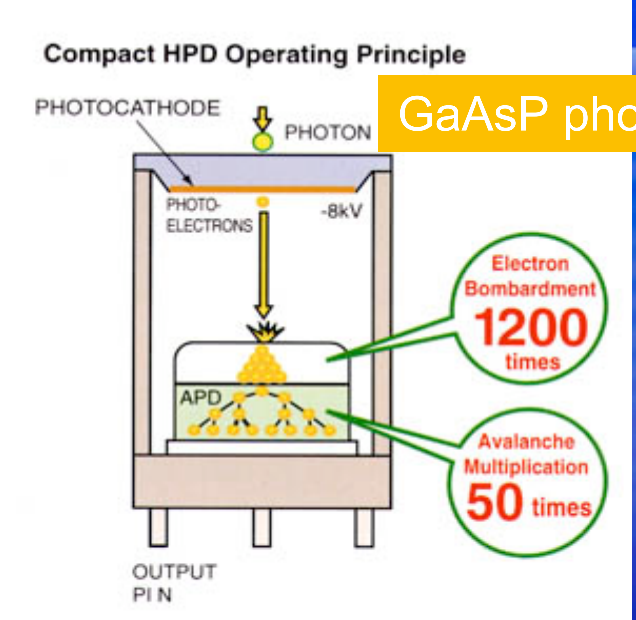
- Higher quantum efficiency / High photo-detection efficiency
  - Lower threshold energy (wider energy range)
  - Equivalent to enlarge telescope
- Very Fast response
  - Better angular / position resolution
  - Better noise reduction
- Pixel detectors and direction sensitive detectors
  - Imaging
  - Better signal to noise ratio
- Associated development
  - Fast, High Integrated Readout Electronics
  - Analogue signal fiber transmission
  - High reflective material
- Service facilities
  - Photodetector measurement/characterization laboratory in EU

Main R&D

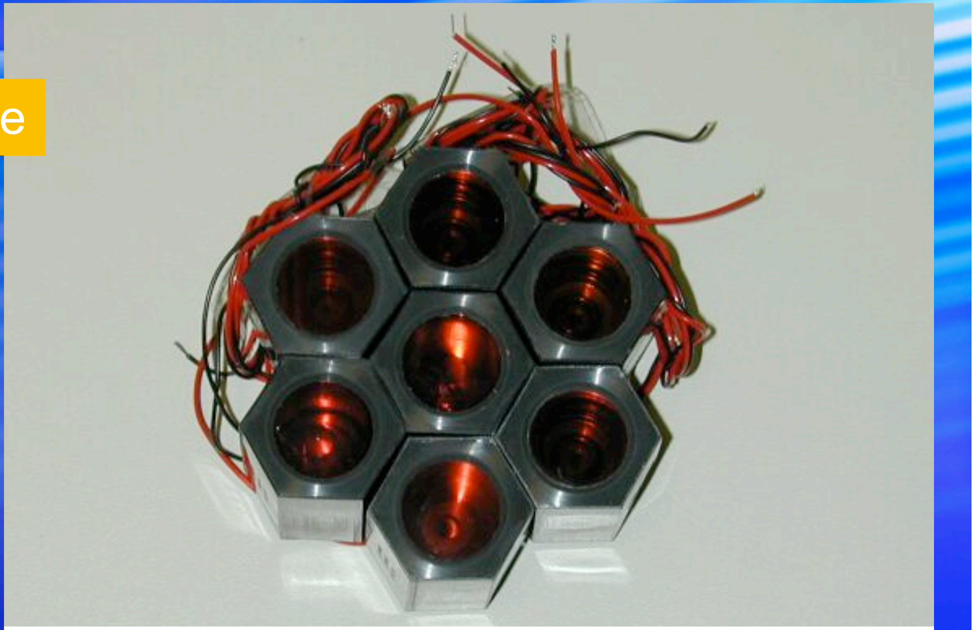
- Vacuum photodetectors
  - HPD development
  - PMT development (higher performance)
  - Large PMT/HPD development
- Si-photodetectors
  - SiPM development (higher performance)
  - SiPM applications (Array of SiPM, cooling module)
  - APDs
- Electronics and Analogue Link
  - Readout Electronics (compact, high integration)
  - Analogue fiber optical signal transmission

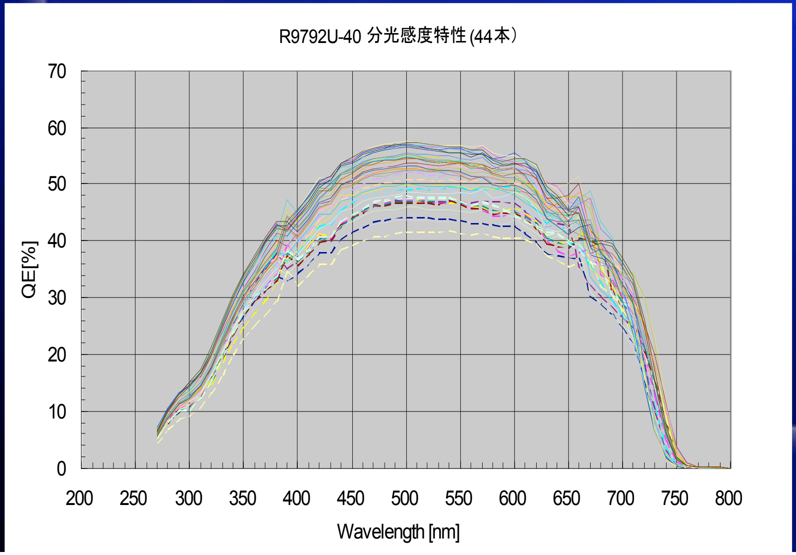
Vacuum detector HPD

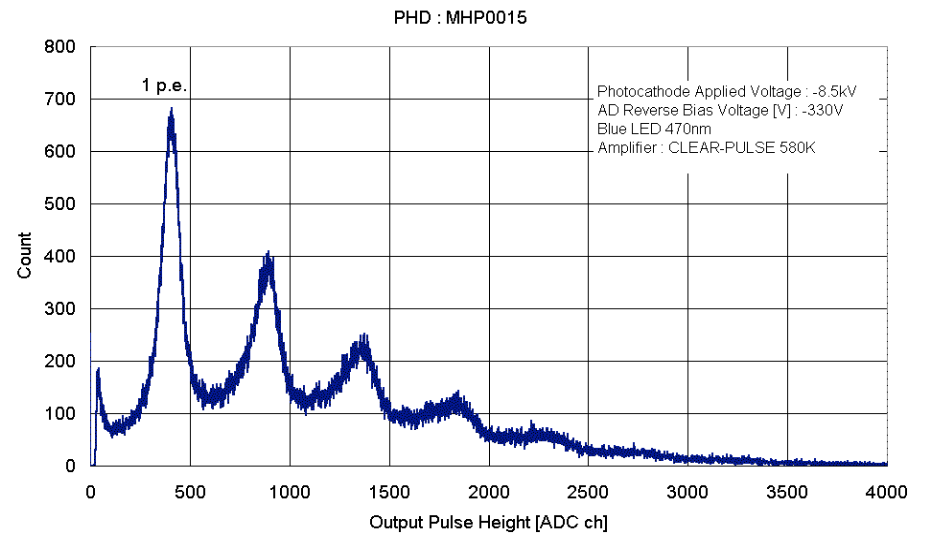
R9792U-40 18mm GaAsP HPD by MPI & Hamamatsu

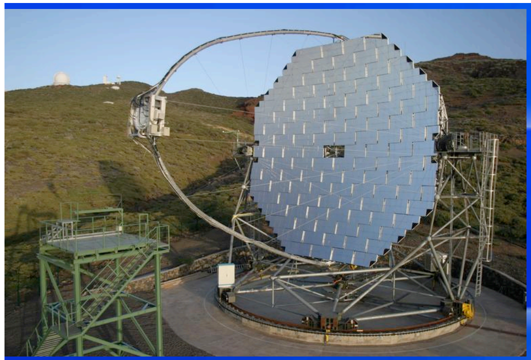


GaAsP photocathode









HPD vs. PMT for M.C. γ Shower

17m telescope becomes equivalent with 24m telescope

HPD

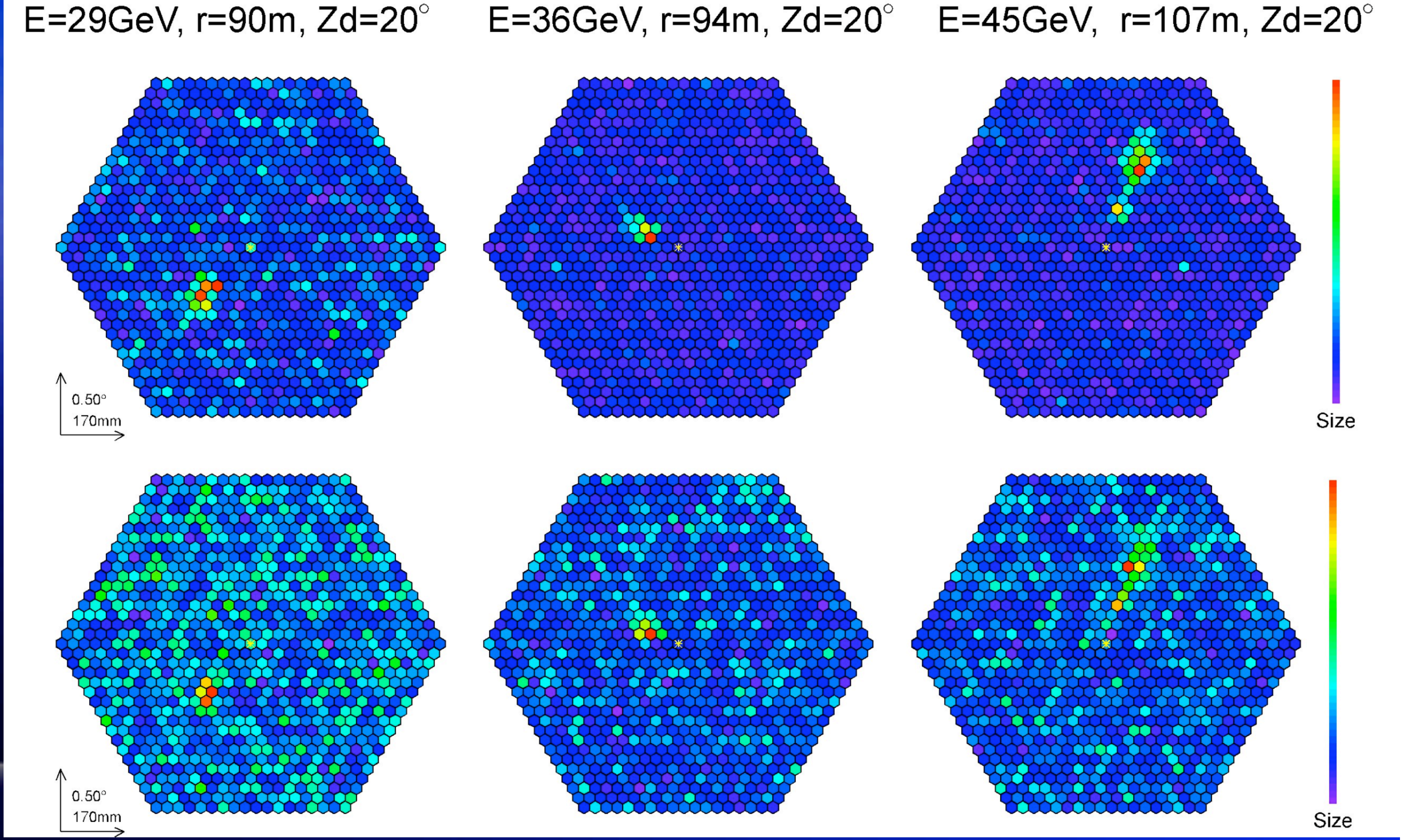
with 10ns gate

(2 Gsamples/s FADC)

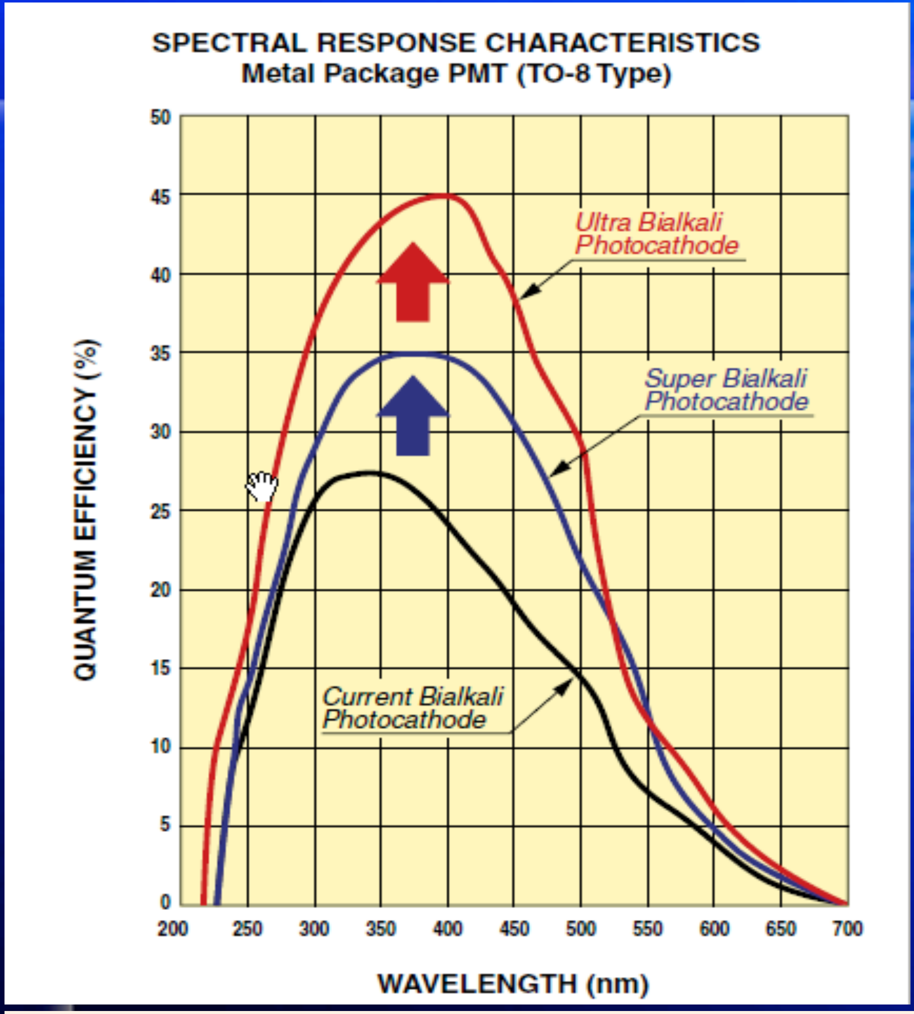
PMT

with 20ns gate

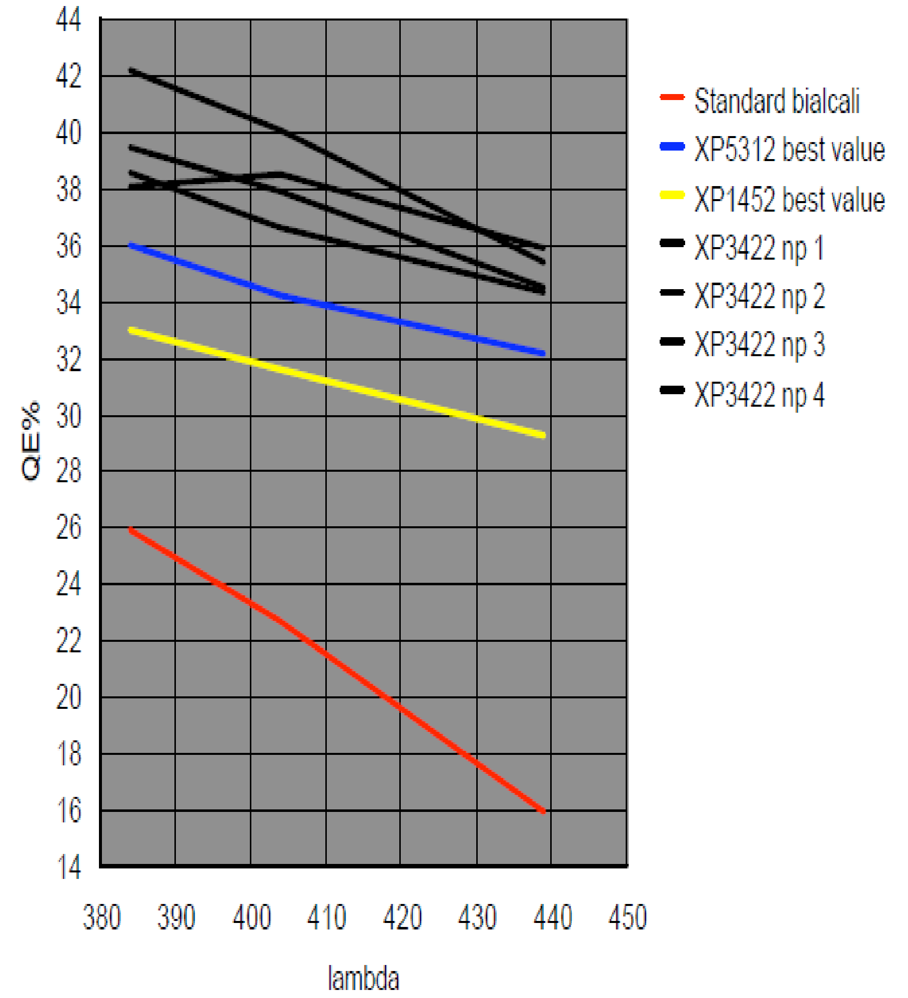
(300Msamples/s FADC)



High Q.E. PMT materials



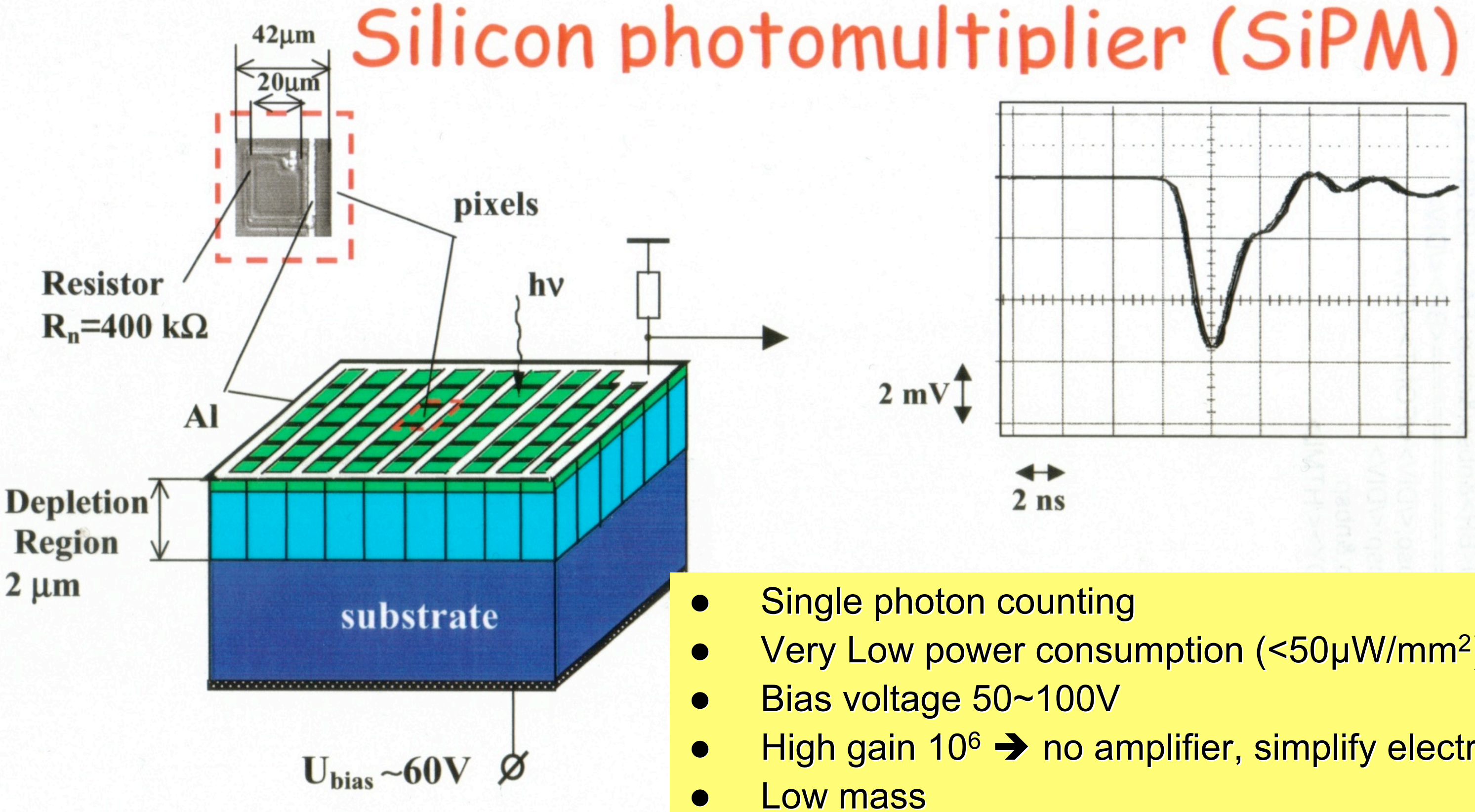
SPECTRAL RESPONSE CHARACTERISTICS
Metal Package PMT (TO-8 Type)



Photocathode	QE at peak wavelength		Type Availability
	Min.	Typ.	
Ultra Bialkali (UBA)	38 %	43 %	Metal Package PMT (TO-8 Type, □28 mm Type PMT)
Super Bialkali (SBA)	32 %	35 %	Metal Package PMT (TO-8 Type, □28 mm Type PMT) φ28 mm to φ76 mm Head-on PMT (Glass Bulb Type)

R&D on SiPM

Silicon photomultiplier (SiPM)



- Single photon counting
- Very Low power consumption (<50µW/mm^2) ➔ <50 W/m^2
- Bias voltage 50~100V
- High gain 10^6 ➔ no amplifier, simplify electronics
- Low mass
- Long life time

- Potentially High photon detection efficiency

For further details see:
«Advanced study of SiPM»
http://www.slac.stanford.edu/pubs/icfa/fall01.html

Courtesy of Prof.Dolgoshein

R&D on atmospheric monitoring

by J. Ridky

- Better quality of atmospheric monitoring to make full use of new technology in order to obtain high quality & precision data
- Main problem: processes in the troposphere are not coupled to what we can observe on the ground
- Build a local weather model -it will be an ad hoc model, the more reasonable input the better results....after some maturing of the model (it takes time!)
- Control aerosols

Monitoring and tools

- Necessity to monitor:
  - Attenuation - Rayleigh, Mie scattering
  - Cloud coverage
  - Atmospheric profile - vertical density distribution
  - Air glow
  - Lightning
- Available tools:
  - Local weather stations
  - Meteorological probes - balloons
  - Star monitors
  - Lidars - single w.l., Raman
  - Aerosol probes, laser shots
  - Light sources - HAM
  - Satellite measurements

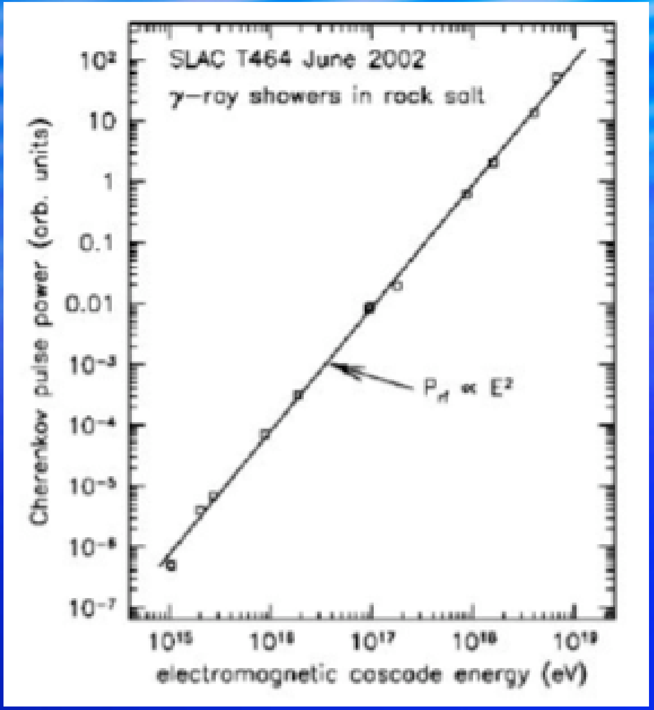
Curent situation

	whether stations	balloon probes	star monitor	lidars - single w.l.	Raman lidar	aerosol monitor	satellite data
AUGER	✔	✔	✔	✔	✓	✔	✓
H.E.S.S.	✔	✔	✔	✔	✓	✔*	
MAGIC	✔			✔	✓		
R&D EUSO				✓	✓		✓

R&D on radiodetection

by A. Van den Berg

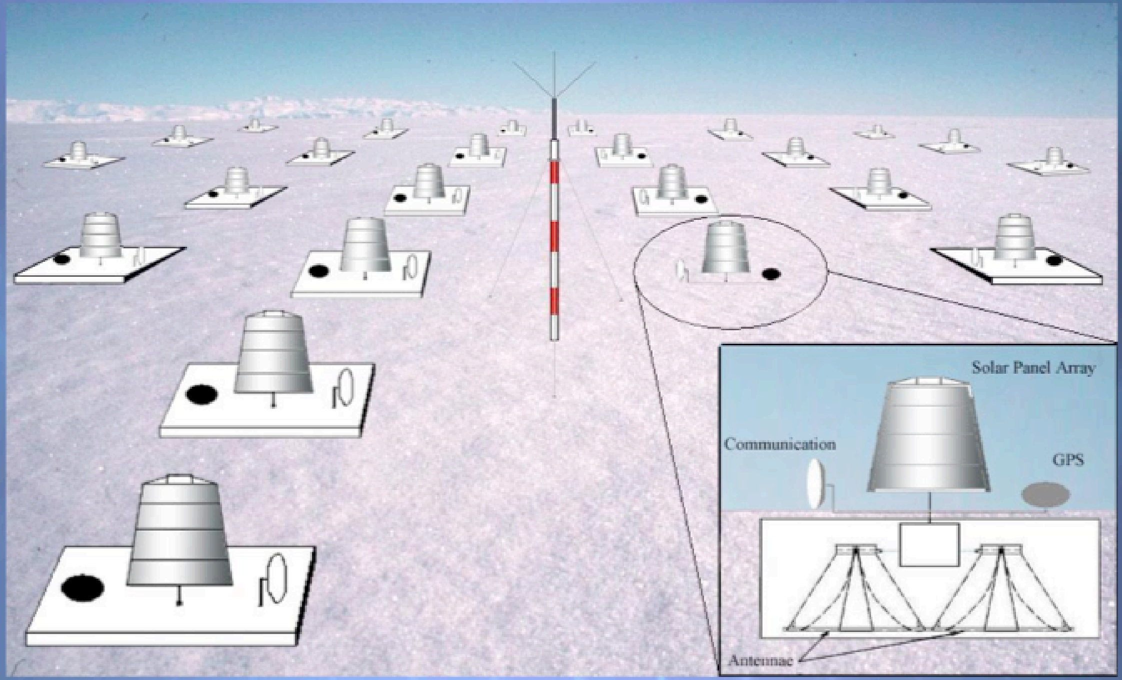
- Long attenuation length in atmosphere and dielectric solids
- Coherence if shower front < wave length
- Polarization measurement provides extra information (magnetic field strength and direction)
- Directional technique (main stream)
  - Cherenkov radiation (Askaryan effect)
  - Geo-synchrotron radiation
- Omni-directional technique (few activities)
  - Radar
  - Molecular Bremsstrahlung



Neutrino detection

- Several neutrino detectors have already taken data (RICE, ANITA,GLUE…)
- New projects

ARIANNA Array



Antarctic Ross Ice shelf ANtenna Neutrino Array

Cosmic air shower detection

- Intense R&D activity
  - Set ups
    - LOPES @ Karlsruhe, DE
    - CODALEMA @ Nançay, FR
    - LOIS @ Växjö, SE
    - Tests on the Auger site (Malargue)
  - Theory
    - Analytical
    - Monte-Carlo

Required R&D

- Optimize antenna: dipole (thin, fat, log-periodic, inverted dual-V), tripole
- Self-trigger, data handling and transfer
- Power budget
- Atmospheric conditions
- Simulations on energy estimation and particle identification

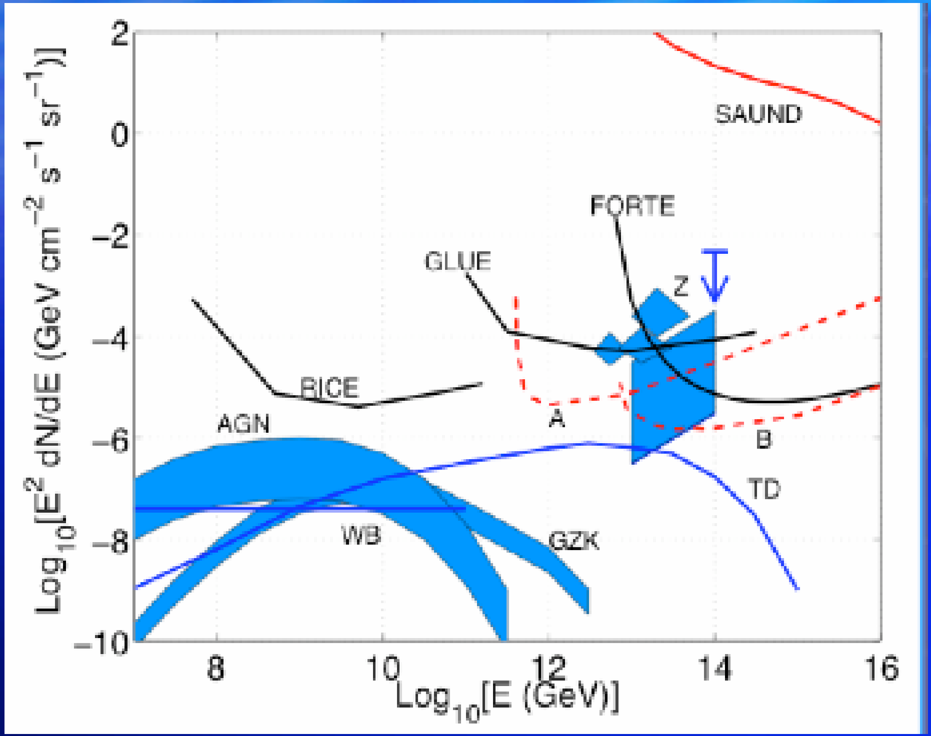
R&D on acoustic detection

by L. Thompson

- Interesting for high energy neutrino telescopes: hybrid detection

Existing experiment: Sound *Stanford based venture using the AUTEC array, naval hydrophones in the Bahamas*

First limit paper published based on 195 days reading out 7 hydrophones *astro--ph/0406105ph/0406105*



R&D challenges

- Sensor development
  - *Requires a good theoretical model of piezo and the coupling*
- Sensor calibration
  - Calibration by using a large water volume (78m x 10m x 5m) 10m x 5m) *a fully calibrated reference hydrophone and* a broadband transmitter
- Simulations and sensitivity calculations

Computing challenges in HEAP experiments

- Data transfer from isolated locations
- Storage of data and in particular large amount of monitoring data
- Fast simulations