Fiducial volume expansion for SK (Brain-storming and not a proposal)

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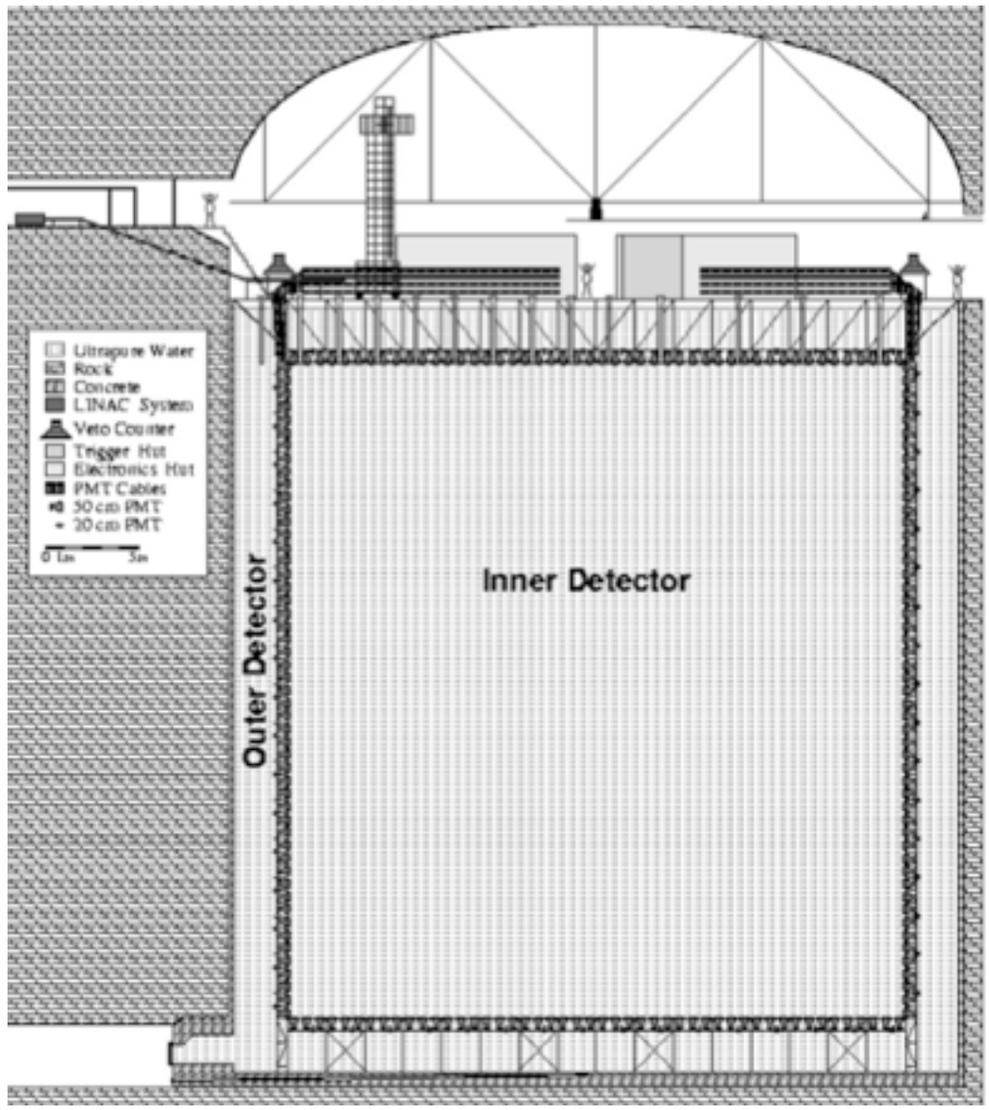
Fiducial volume expansion

- Physics impact of increasing SK fiducial volume:
  - T2K CP sensitivity
  - Proton decays and other physics sensitivities
- Potential to increase the SK fiducial volume:
  - Fiducial is 22.5kton out of the 50kton:
    - fiducial volume could be increased by x1.5-2.0
- How can we increase the fiducial volume?
  - Reducing outer region: 2.55m to 1m?
    - Move the PMT support structure, remove dead space
  - Reducing distance to the inner wall: 2m to 0-1m?
    - Active Veto in the dead space
    - Adding more PMT's to provide better granularity
    - Analysis improvement (FiTQun reconstruction: Wilking's talk)

Reducing the outer volume?

- Dimensions:
  - Fiducial 22.5kton: $29.8m^{\Phi}x32.2m^{h}$
  - Inner 32kton: $33.8m^{\Phi}x36.2m^{h}$
  - Outer 50kton: $39m^{\Phi}x42m^{h}$
- Outer volume reduction:
  - Move Inner wall out by 1.7m
  - Outer detector: ΔR=1m
    - enough to veto cosmic rays
    - activate the dead space
  - Fiducial: 1m from the ID wall
    43kton: $37m^{\Phi}x40m^{h}$

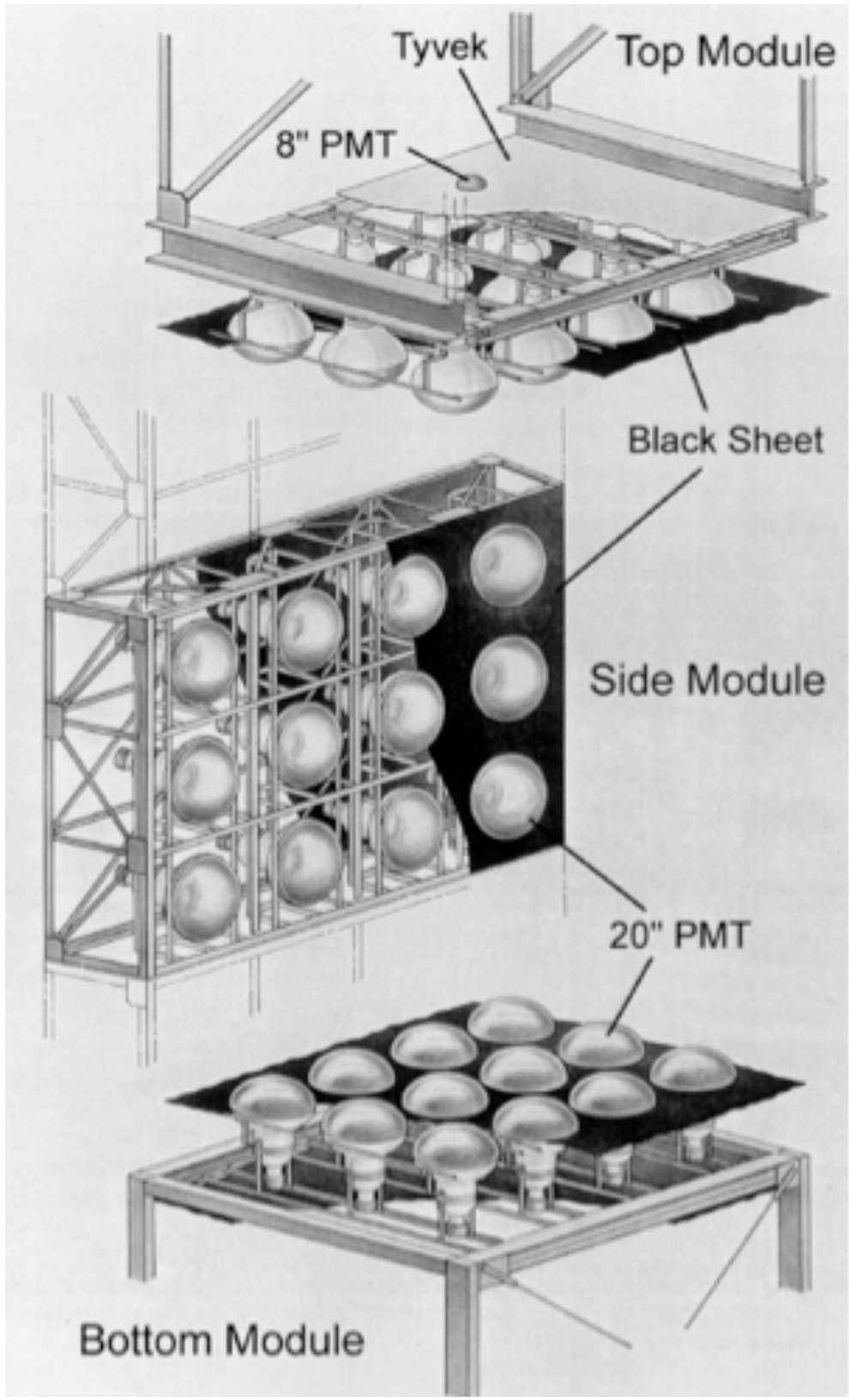


SK PMT support structure

- SK PMT's are supported by super-modules

- Moving the structure outerwards?
  - requires rebuilding the entire structure

- A new structure may be simpler?



Possible procedure

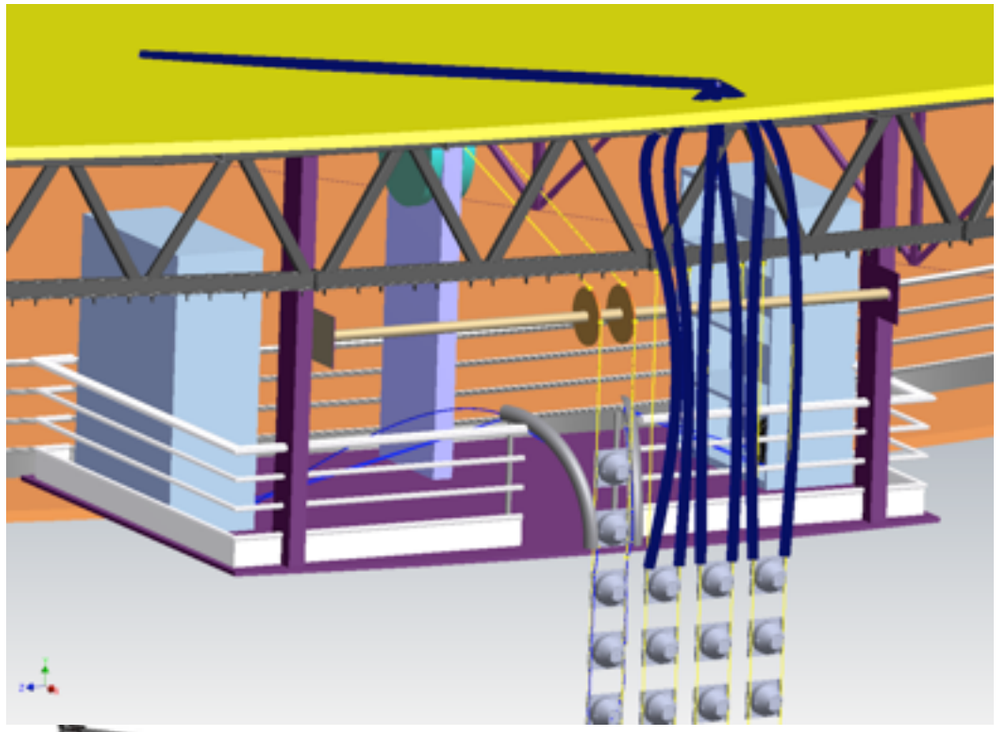
- Nakahata-san provided an idea on the scale of the project:
- Procedure:
  - Remove the bottom PMT's (cut cables) and the support frame.
  - Bring down each column of side PMT frame and disassemble to super-modules.
  - Weld a new side frme support at the top, and bring up the side frame.
  - Connect all the cables, or draw new cables.
  - Assemble the bottom frame and PMT's
- Time and Resources:
  - 1-2 years of (re)construction and costs $10-20M
  - ~30 contractors/day and 30 scientists/day
  - For replacing the FRP cover, each PMT has to be brought out and assemble: 2-3 people can do 10 PMT's/day

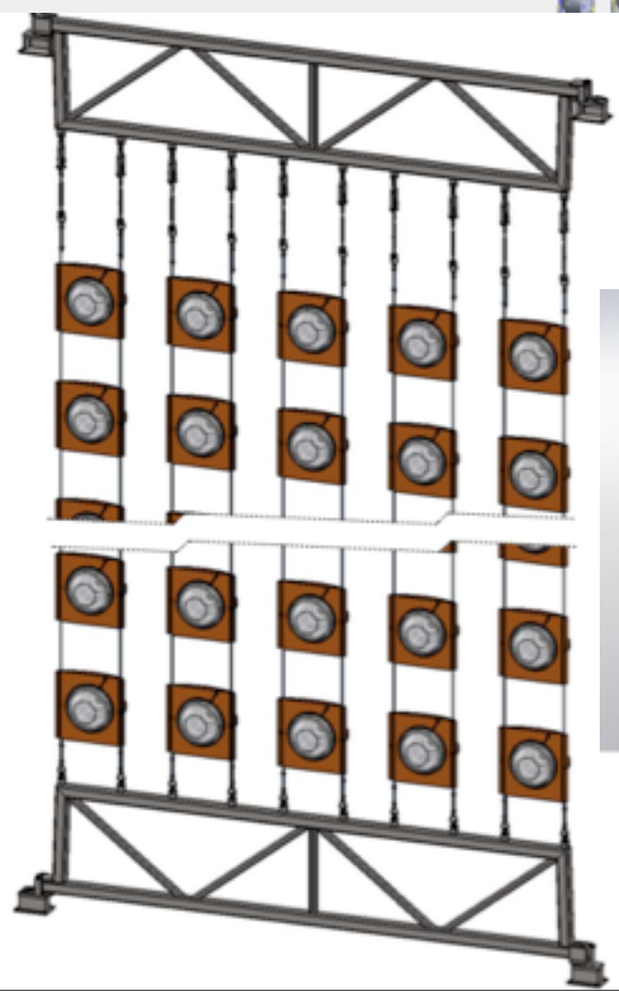
PMT support like LBNE-WC?

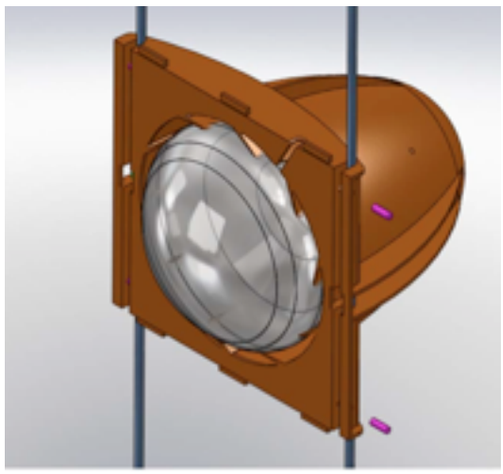
- LBNE design considers PMT loading by strings

- The dead space is minimized

- Potential to add more PMT's and replace FRP cover (source of low energy background)

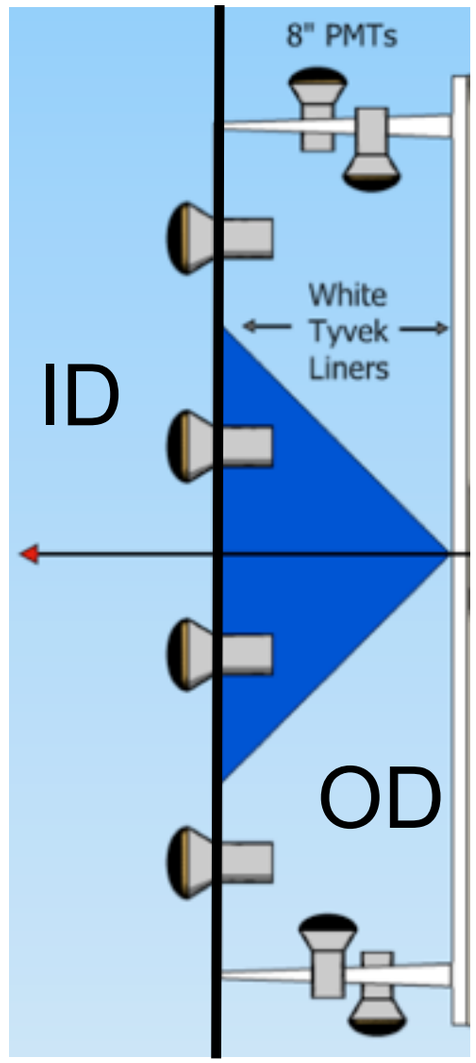






Keep OD / expand fiducial

- Expand fiducial without changing the OD:
  - Instrument the 55cm dead space between ID&OD
    - Scintillator panel on the ID wall?
    - Veto PMT's and Tivek in the dead space:
      Veto photons etc. leaking into dead space
      Use as much 32kton ID as possible

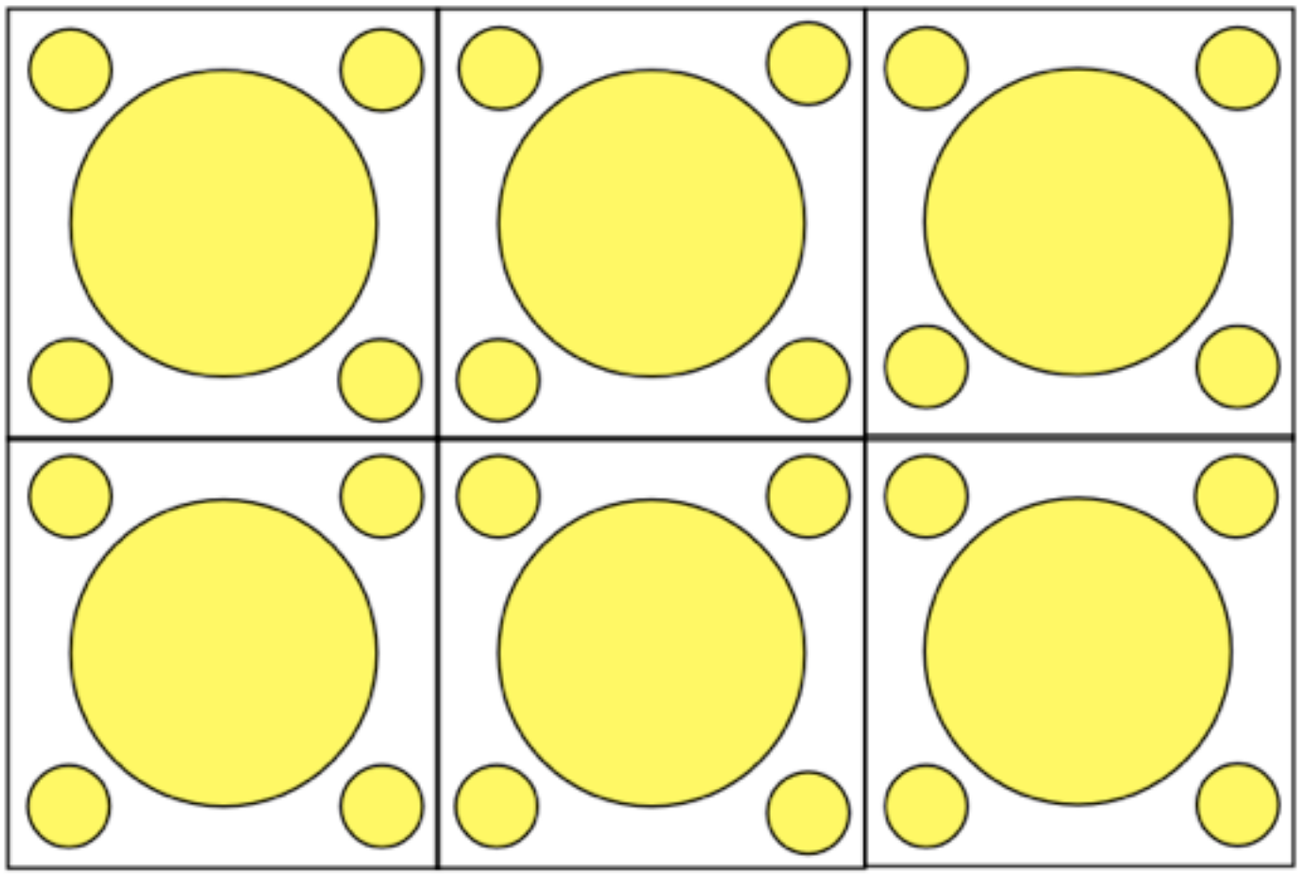


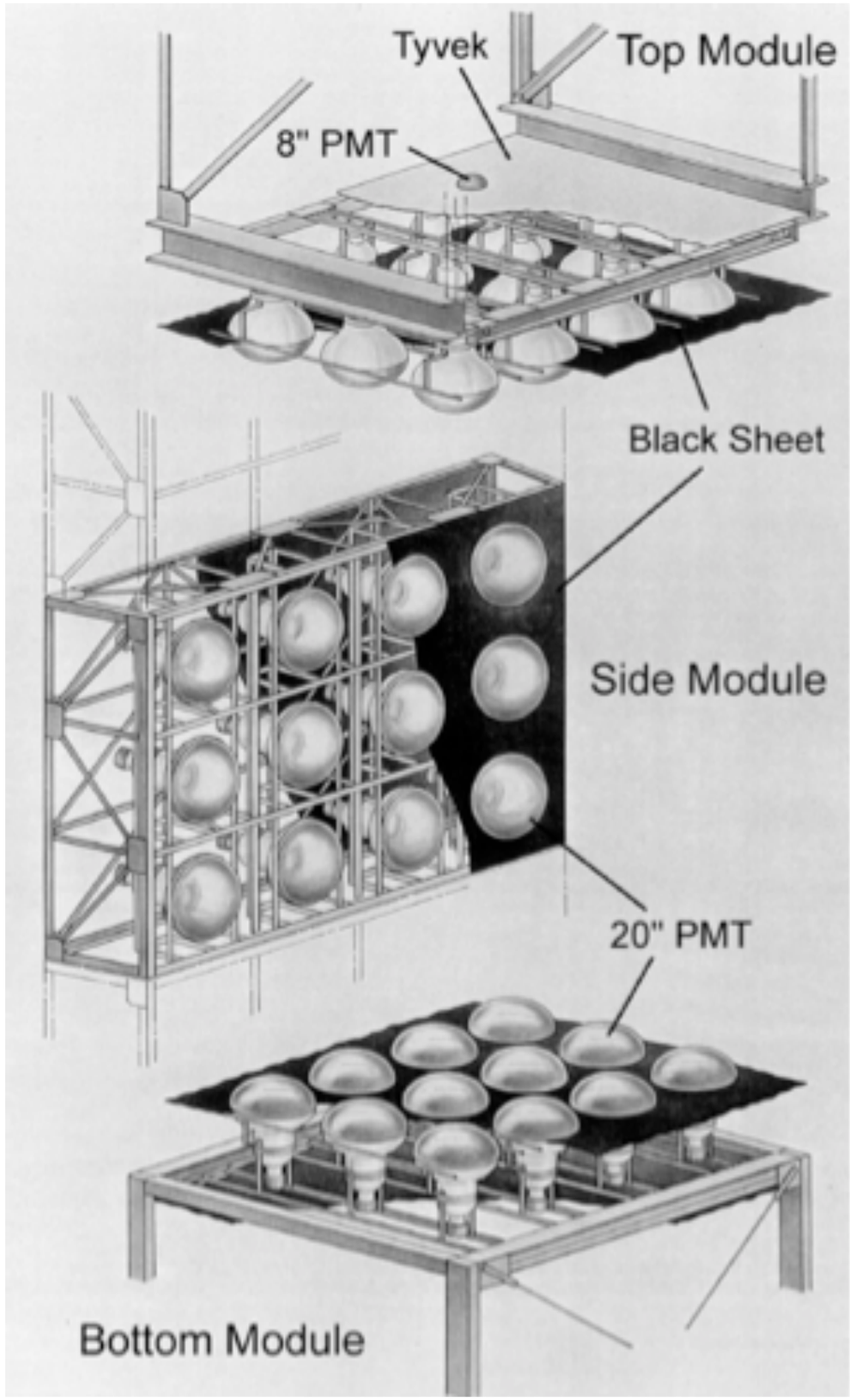
- Introduce more ID PMT's
  - Finer granularity:
    Better event reconstion near the wall
  - Better photon detection efficiency and timing

SK supermodule

Filling the gap with small PMT's?

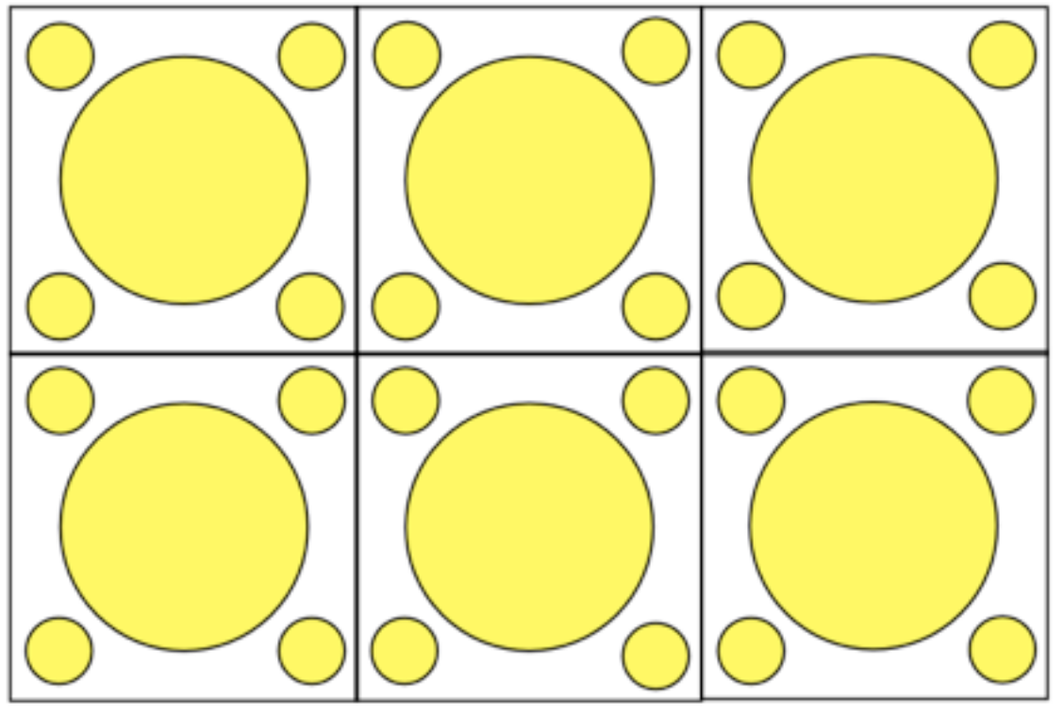
- Four 5"PMT's per 20" PMT
  - Equivalent to 10" PMT area
  - high QE (x2 better efficiency)
  - Better timing, granularity
  - Space may be very tight



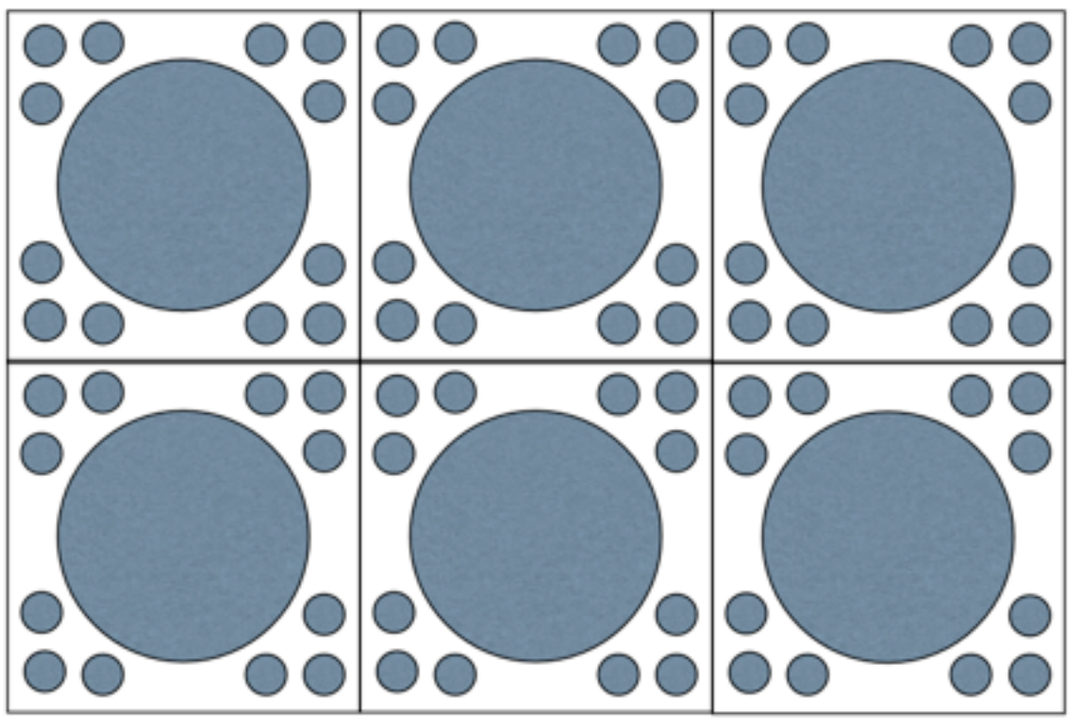


Small PMT's

- 5" High QE
  - R877-100
  - SuperBialkali

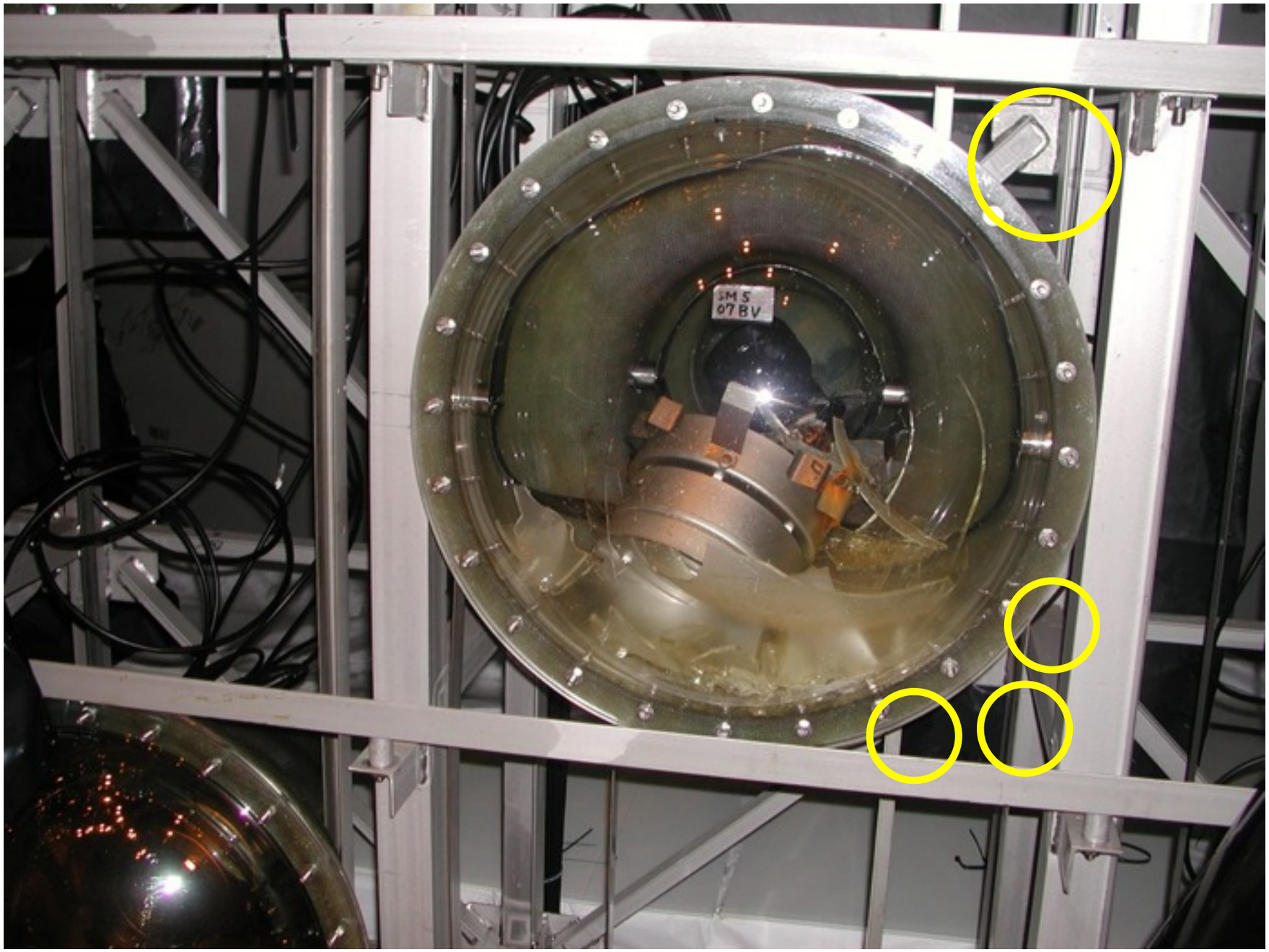


- 3" (80mm)
  - R12199-02
  - Cost effective mass-produced
  - Developed for Km3net



Space is very tight

- Space is very tight due to the support frame and the PMT cover



Benefit of additional PMT's

- Additional PMT would improve
  - Fiducial volume: better reconstion near the wall
    - Important for CP measurement
  - Multi-ring reconstruction:
    - multi-GeV atmospheric ν_e for mass hierarchy
    - Reduce π^0 background in T2K CP study
- Neutron tagging with better timing/light yield:
  2.2MeV $np \rightarrow d\gamma$ detection (improve beyond n tag by Gd)
  - Reduce wrong sign background in T2K CP study
  - Anti-ν tag for CP in subGeV atmospheric ν
- Better light yield and timing for low energy events:
  - 6MeV γ tagging in $p \rightarrow K\nu$ decay
  - Improvement for solar and supernova neutrino studies

Summary

- Potential expansion of the fiducial volume
  - Potential to increase the fiducial volume by x1.5-2.0
    - Very significant impact equivalent to beam intensity and run time
- Reducing OD thickness
  - Reducing the dead space and OD (2.55m) down to 1m?
    - Similar to the designs for HyperK and LBNE-water
  - Very large effort
    - 60 people/day for 1-2 years and $10-20M
- Adding more PMT's on dead space and ID
  - Use the 32kton ID fiducial as much as possible (for CP)
    - Finer granularity for reconstruction near the ID wall
    - Veto photons and other particles leaking into the dead region
  - additional benefits
    - Improved neutron tagging, ring counting, and lowE detection: e.g. improved multi-ring detection for mass hierarchy