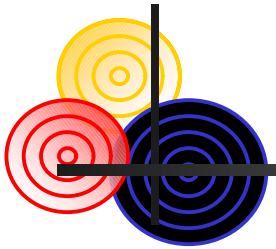


Hyper-Kamiokande project

Kamioka Observatory Masato Shiozawa
For JHF-Kamioka ν working group

- Introduction
- Hyper-K project
  - Detector
  - Physics
- Summary

Next generation proton decay detector

Super-K has not found nucleon decays in 3.5 years data

- τ /B($p \rightarrow e^+ \pi^0$) > 5.0 × 10^{33} years (90% CL)
- τ /B($p \rightarrow \nu K^+$) > 1.6 × 10^{33} years (90% CL)

Predicted lifetime of nucleon

- 4 fermion interactions

$$\Gamma = \frac{g^4 m_p^4}{M_X^4} \quad : \quad \tau(p \rightarrow e^+ \pi^0) = 10^{35 \pm 1} \text{ years}$$

- 2 fermion – 2 sfermion interactions (SUSY models)

$$\Gamma = \frac{h^4 m_p^4}{M_{Hx}^2 M_X^2} \quad : \quad \tau(p \rightarrow K^+ \bar{\nu}) = 10^{29\text{-}35} \text{ years}$$

One or two order of extension of Super-Kamiokande would reveal new physics!!!

Hyper-K as a far detector of 2nd JHF ν

Same baseline with Super-K (295km)

Enable higher statistics physics (22.5 kton → ~1000 kton)

- improved sensitivity for θ_{13} measurement
- CP phase measurement in lepton sector
- test of the unitarity triangle

} discussed in other talk

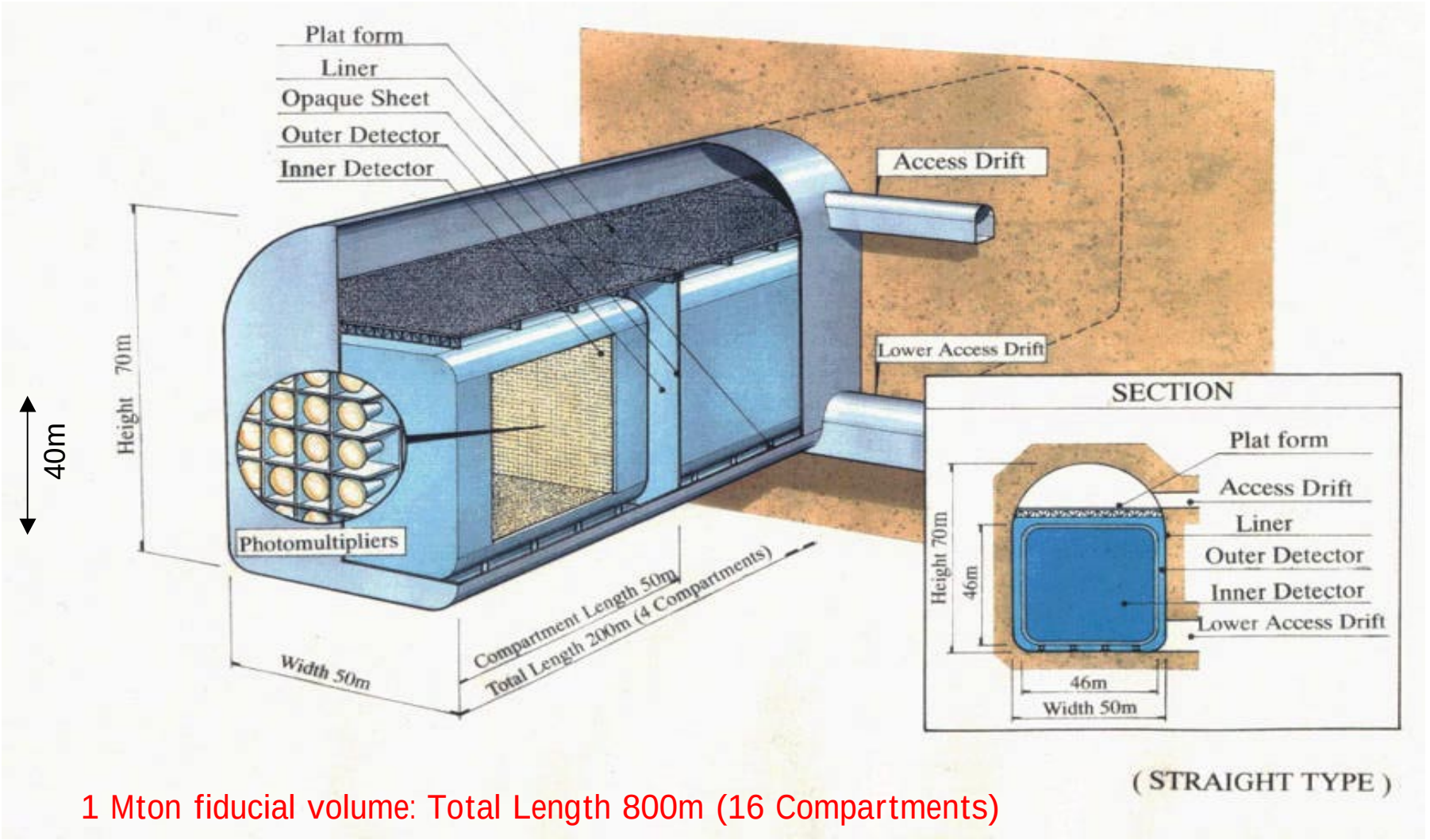
Detector requirement

- good e/π^0 separation capability at low energy
- No magnetic field is needed

Possible Design of Hyper-Kamiokande

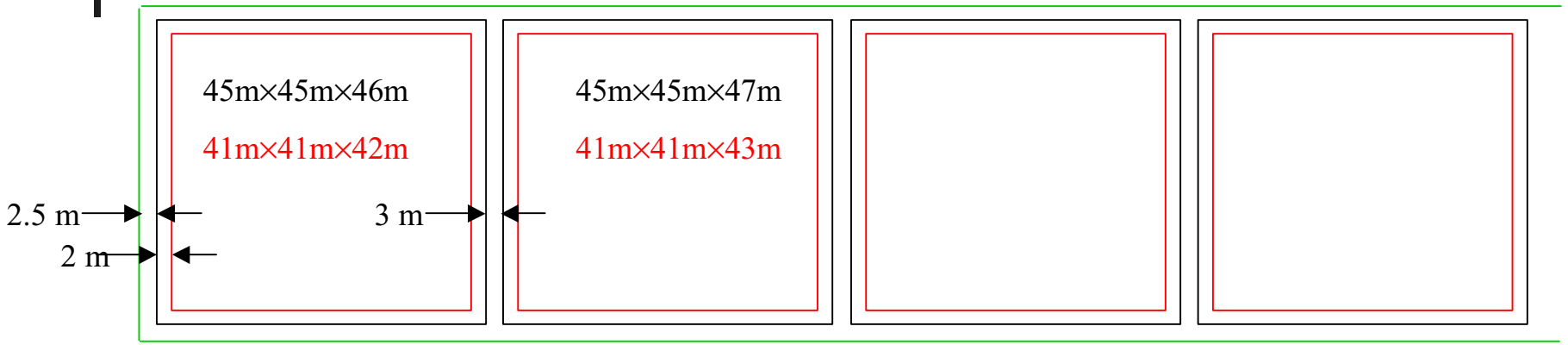
Super-K

40m



1 Mton fiducial volume: Total Length 800m (16 Compartments)

Possible Design of Hyper-Kamiokande (2)



- PMT Wall

$45\text{m} \times 45\text{m} \times 2\ \text{planes} \times 16\ \text{modules} = 64{,}800\ \text{m}^2$

$45\text{m} \times 46\text{m} \times 4\ \text{planes} \times 4\ \text{modules} = 33{,}120\ \text{m}^2$

$45\text{m} \times 47\text{m} \times 4\ \text{planes} \times 12\ \text{modules} = 101{,}520\ \text{m}^2$

Total $199{,}440\ \text{m}^2$

$\Rightarrow \sim 200{,}000$ PMTs if 1 PMT/m^2

- Fiducial Volume

$41\text{m} \times 41\text{m} \times 42\text{m} \times 4\ \text{modules} = 282{,}408\ \text{m}^3$

$41\text{m} \times 41\text{m} \times 43\text{m} \times 12\ \text{modules} = 867{,}396\ \text{m}^3$

Total $1{,}149{,}804\ \text{m}^3$

R&D Items for Hyper-K

- Cavity design and assessment
  - Rock stress analysis
  - Cost analysis, optimization
- Simulation studies for
  - Proton decay
    - e^+p^0:
    - $K^+\nu$:
  - Neutrino oscillation experiment

How to improve S/N
Optimize photocathode coverage

- Study neutrino background ⟵ K2K 1kton water Cherenkov

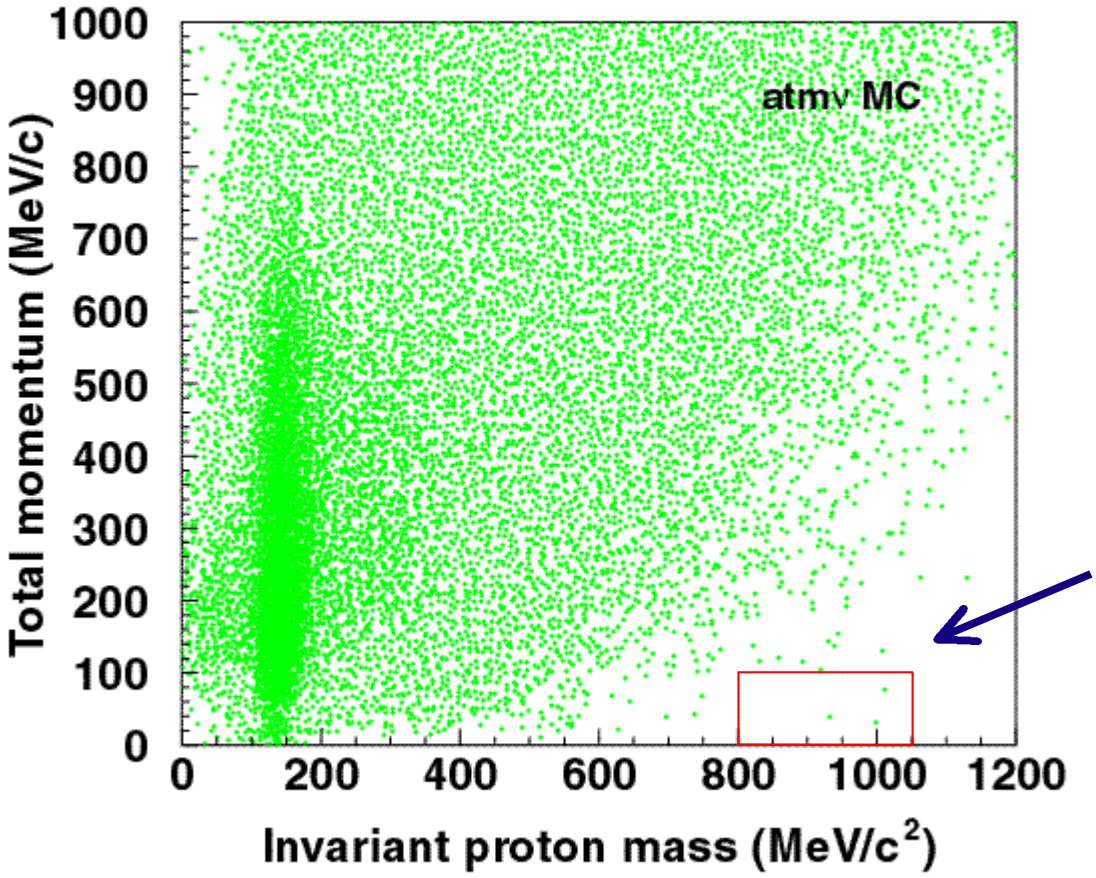
- Development of new photodetectors
  - PMT: High QE, Low cost, Flat & thin.....
  - Other technique

Multi-Purpose detector

- Proton decay searches
- Consider a huge water Cherenkov detector to have a sensitivity to $p \rightarrow K^{+}\nu$ through detection of a 6 MeV prompt gamma.
- Then, threshold will be low enough to observe
  - Supernova neutrinos
  - Solar neutrinos with very high statistics
- It will be a far detector for a JHF-Kamioka long baseline neutrino oscillation experiment.
  - Enhance the sensitivity to the θ_{13} measurement
  - If lucky, measure CP violation
- Also It could be a far detector for a neutrino factory.
  - Magnetic fields are needed to measure the muon charge.

Backgrounds for $p \rightarrow e^+ \pi^0$ search

Tight momentum cut to reduce BG



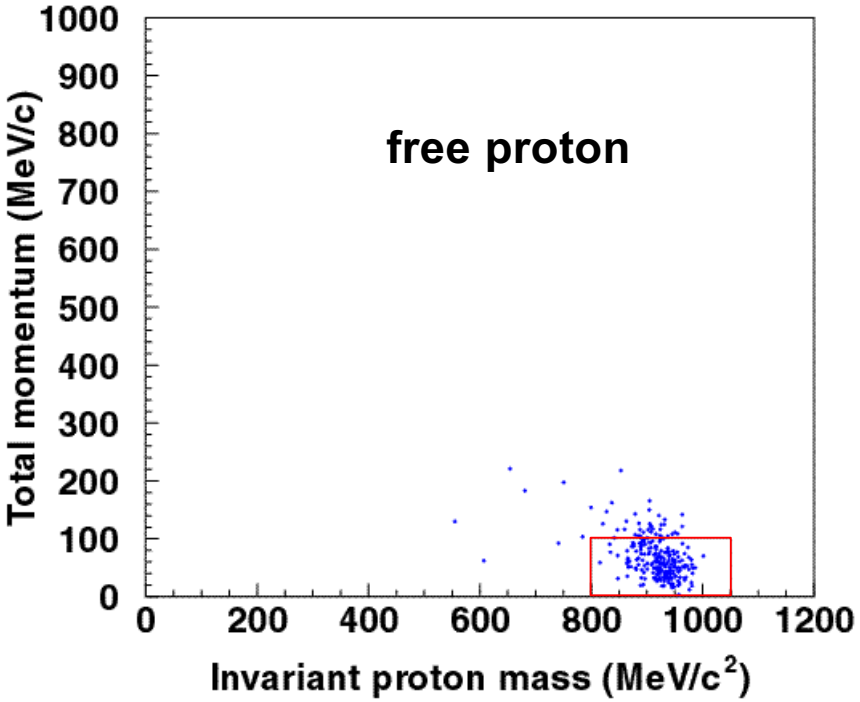
- P_{tot} < 250 MeV/c
- P_{tot} < 100 MeV/c

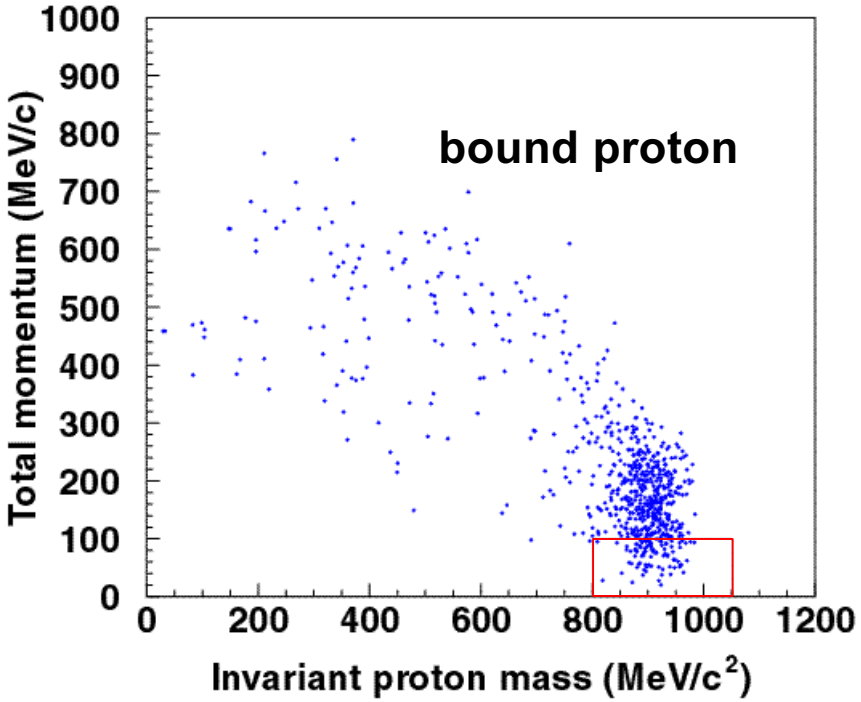
BG events in signal box
3 events/20 Mton· yr

~0.15 events/Mton· yr

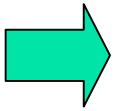
Analysis for discovery of $p \rightarrow e^+ \pi^0$

Tight momentum cut
⇒ target is mainly free protons
efficiency=17.4%, 0.15BG/Mtyr



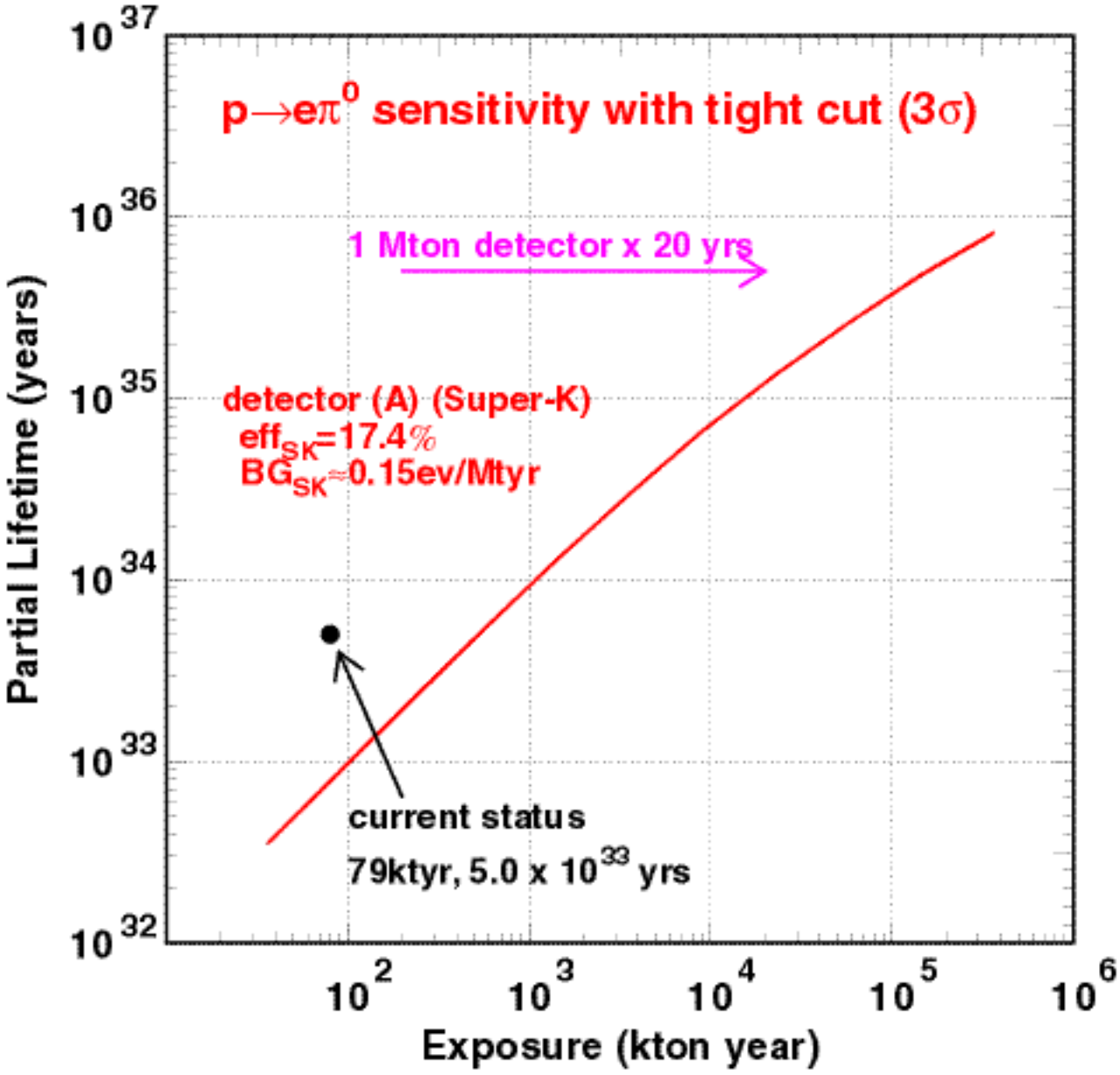


No Fermi momentum
No binding energy
No nuclear effect



Small systematic uncertainty of efficiency
High detection efficiency
Perfectly known proton mass and momentum

Lifetime sensitivity with tight cut

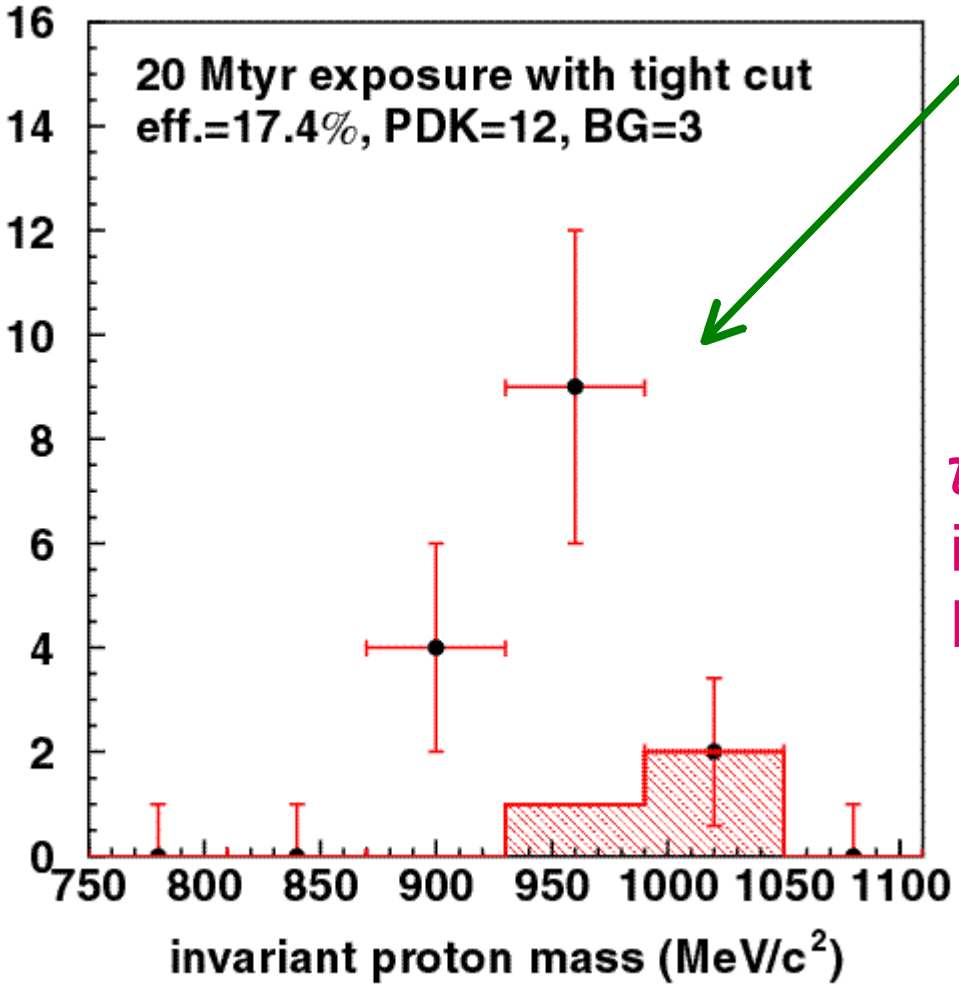


With 3σ (99.73%) level

- 1Mton ×20 years → ～1×10^{35} years lifetime

How the signal looks like

$\tau_p / B(p \rightarrow e^+ \pi^0) = 1 \times 10^{35}$ years



Proton mass peak can be observed !

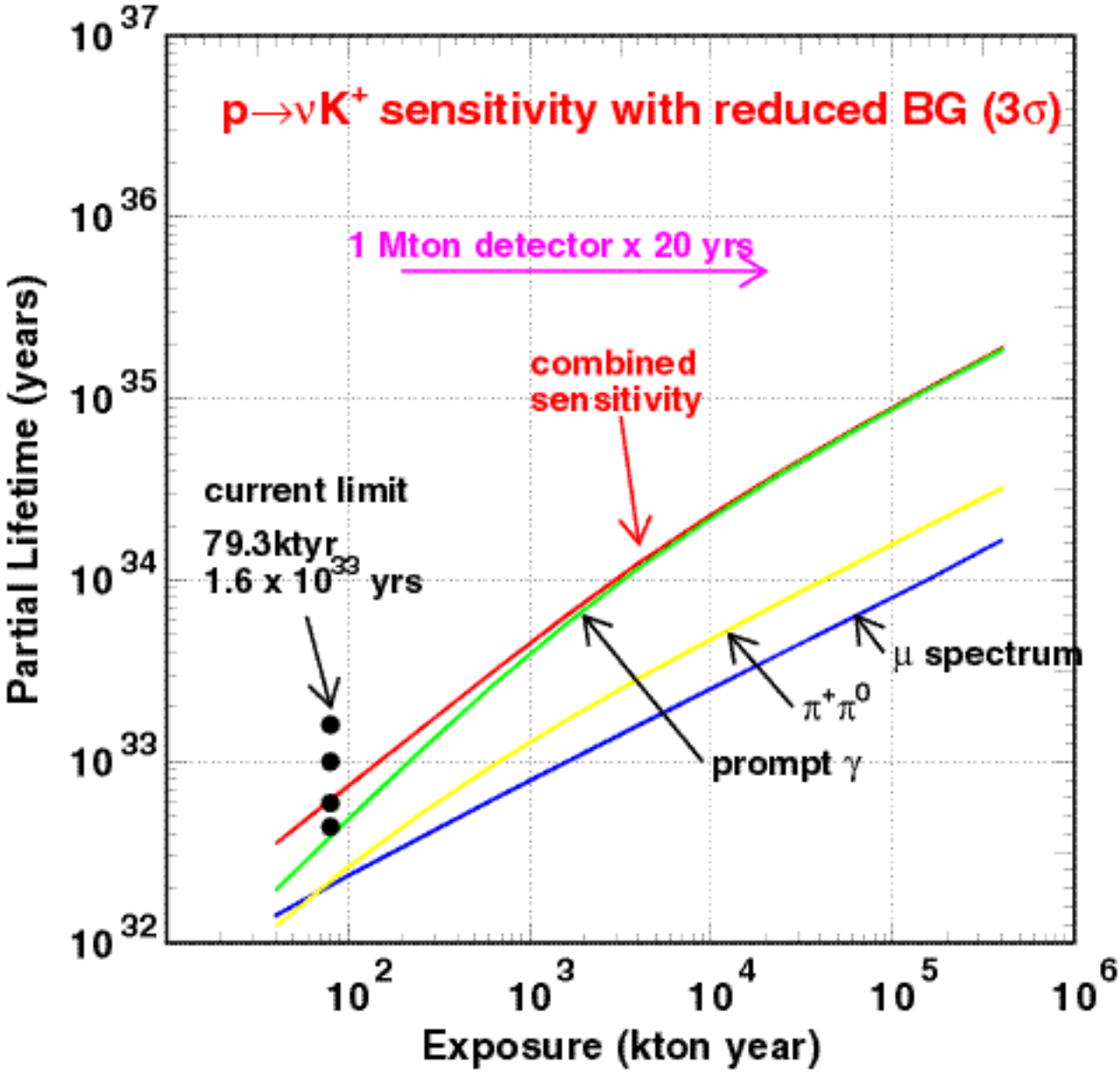
S/N = 4 for 1×10^{35} years

↓

S/N = 1 for 4×10^{35} years

$\tau_p / B(p \rightarrow e^+ \pi^0)$ = several $\times 10^{35}$ yrs is reachable by a large water Cherenkov detector

Lifetime sensitivity with reduced BG



Prompt γ tagging is essential

With 3σ (99.73%) level

- 1Mton ×20 years → ~3×10^{34} years lifetime

Summary

- Hyper-Kamiokande project
  - $\tau_p/B(p \rightarrow e^+ \pi^0) \sim 1 \times 10^{35}$ years (3σ CL with 20Mtyr)
  - $\tau_p/B(p \rightarrow \nu K^+) \sim 3 \times 10^{34}$ years (3σ CL with 20Mtyr)
  - Supernova
  - other physics
- Huge far detector for 2nd phase JHF ν beam
  - Θ_{13} measurement
  - CP phase measurement
  - test of lepton unitarity triangle