

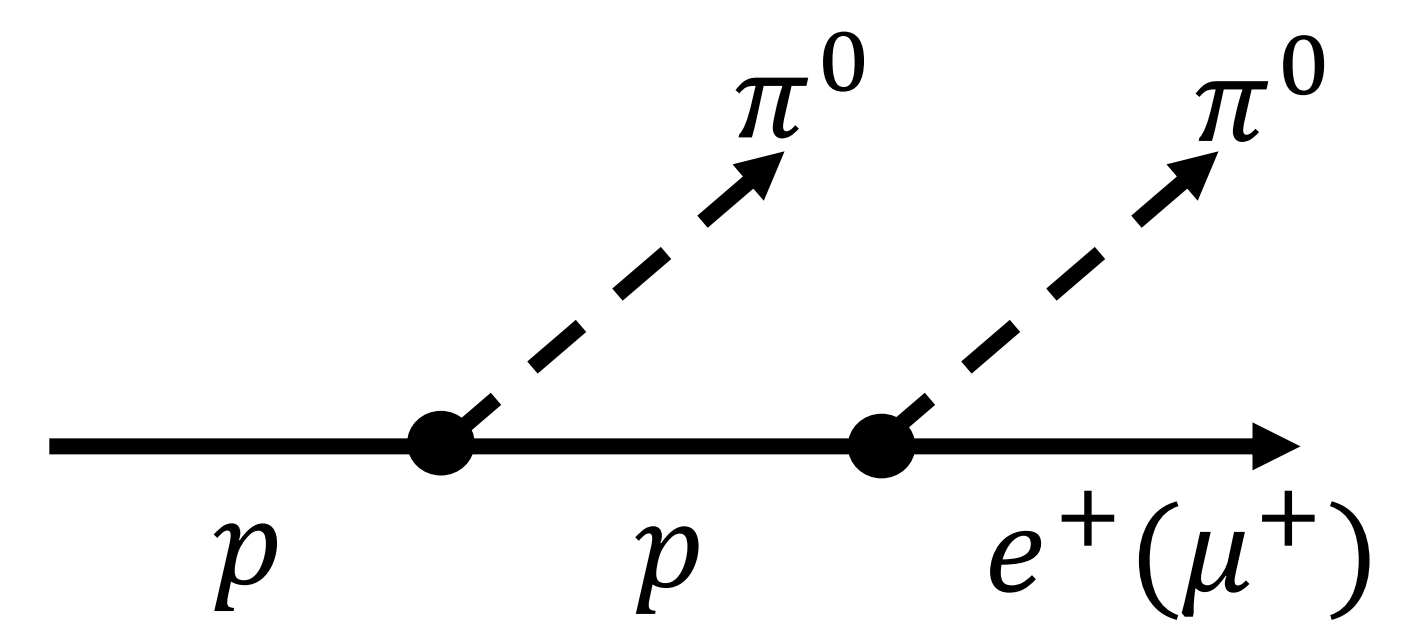
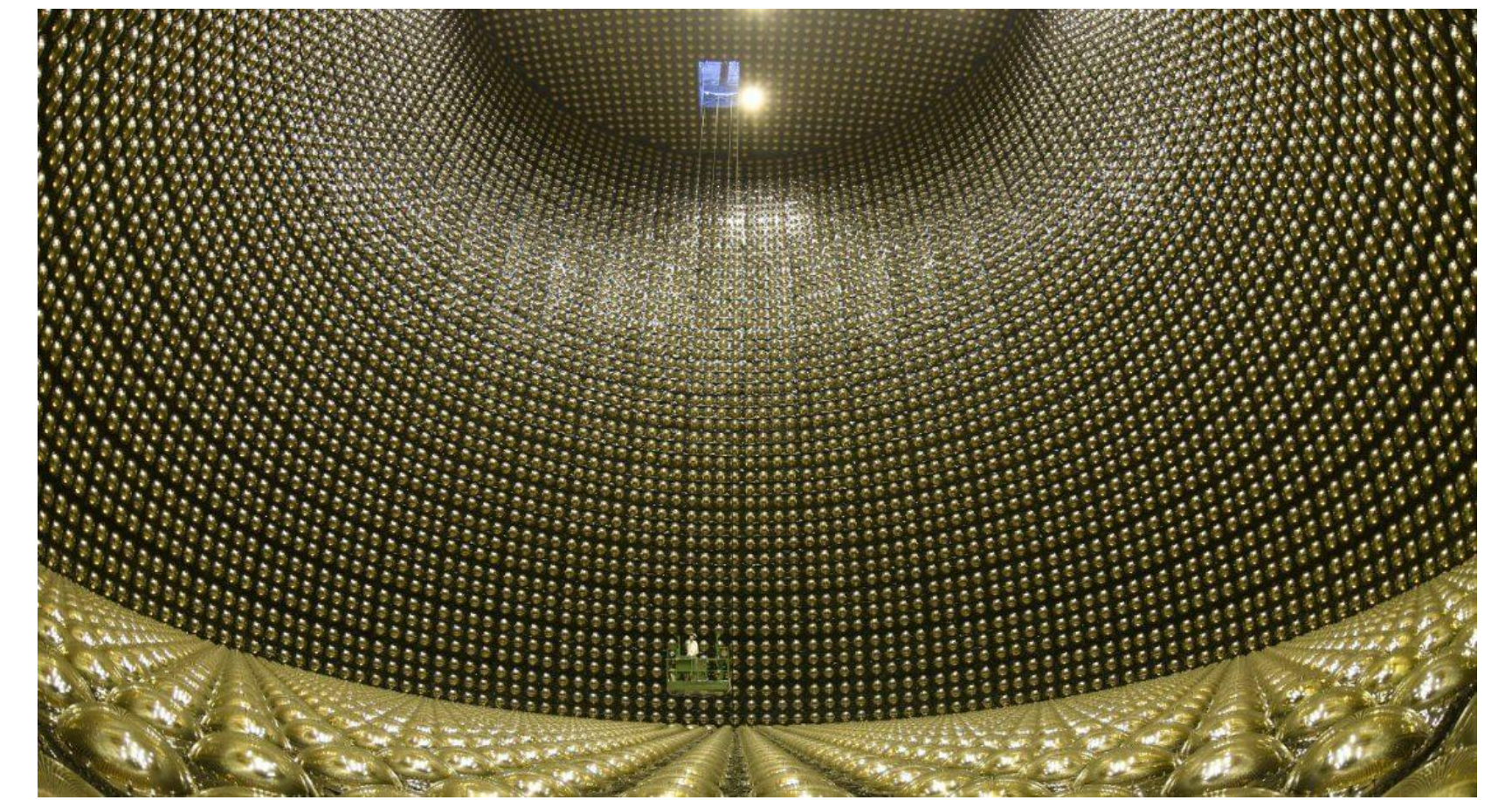
Sensitivity study for proton decay via $p \rightarrow e^+ \pi^0 \pi^0$ and $p \rightarrow \mu^+ \pi^0 \pi^0$ in the Super-Kamiokande Detector

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on behalf of the Super-Kamiokande Collaboration



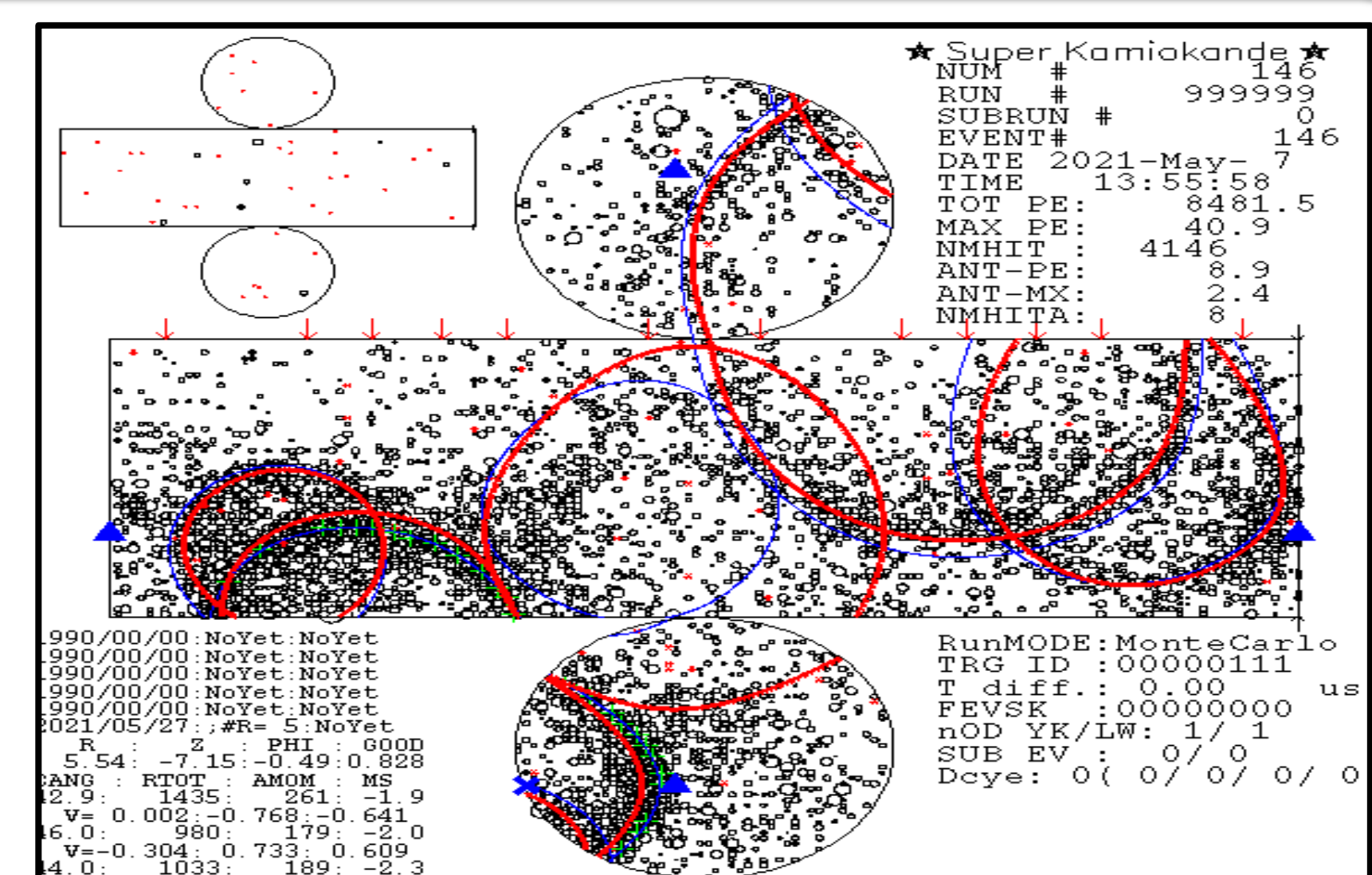
Introduction

- Nucleon decay search is an important physic topic to test GUT
- Super-Kamiokande (SK) have been searching for various nucleon decays
 - World largest water Cherenkov Detector
 - About 11k 20-inch PMTs are installed on the wall
- One of the three-body decay modes of proton, charged lepton and two pion decay mode can be considered in a model-independent manners
 - search for $p \rightarrow e^+ \pi^0 \pi^0$ and $p \rightarrow \mu^+ \pi^0 \pi^0$
 - expected decay rate is $0.24 \sim 1.4$ in comparison with $p \rightarrow e^+ \pi^0$ [M.B. Wise, R. Blankenbecler, and L. F. Abbott., Phys. Rev. D 23.7 (1981): 1591]
- First search for nucleon decaying directly to a lepton and multiple pions in SK



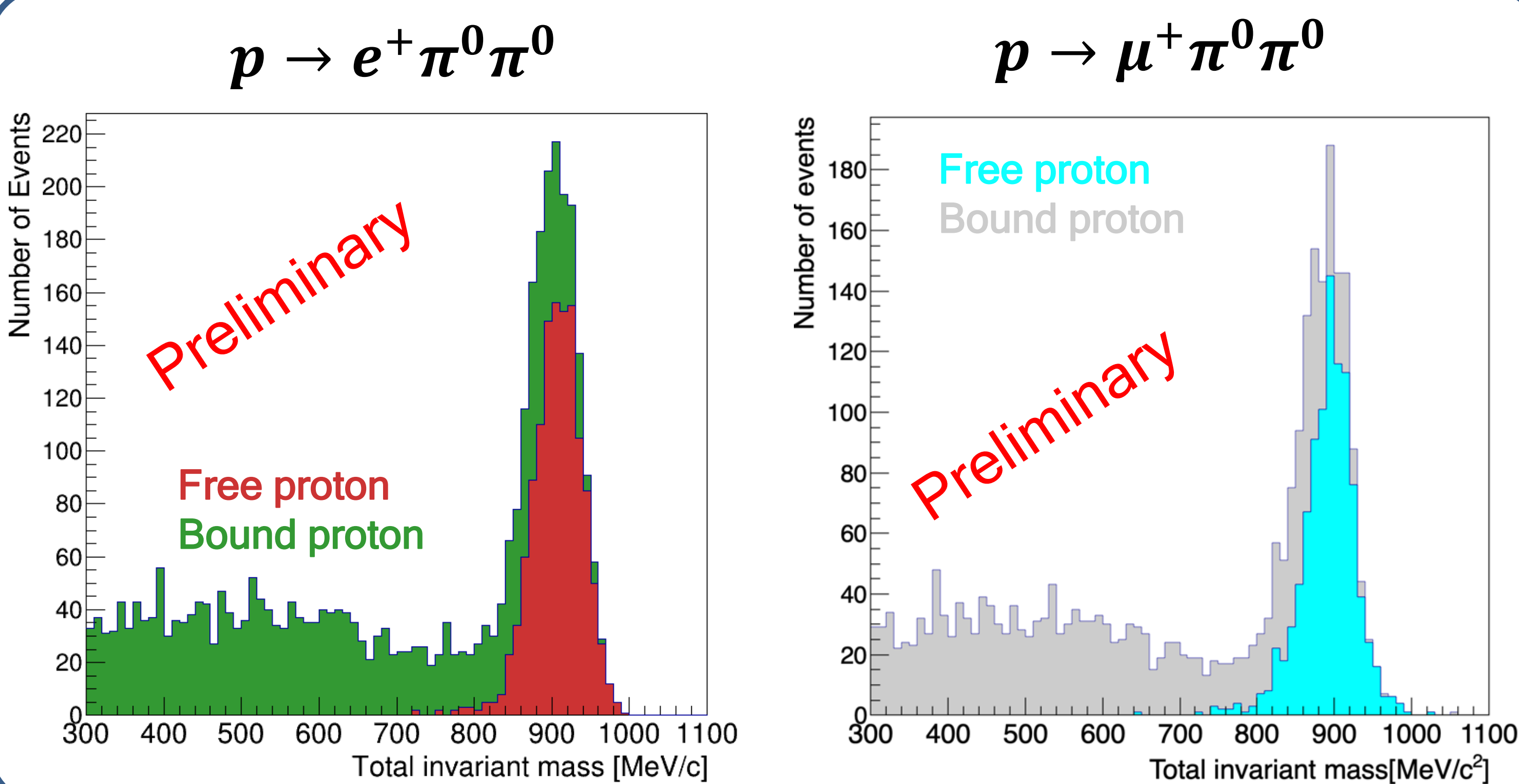
Event Selection

- SK detector can successfully reconstruct all the final particles
- Atmospheric neutrino interacts with water and generates charged particles
 - Selection criteria effectively rejects the atmospheric neutrino background events
- Optimize selection criteria for each $p \rightarrow e^+ \pi^0 \pi^0$ and $p \rightarrow \mu^+ \pi^0 \pi^0$ mode

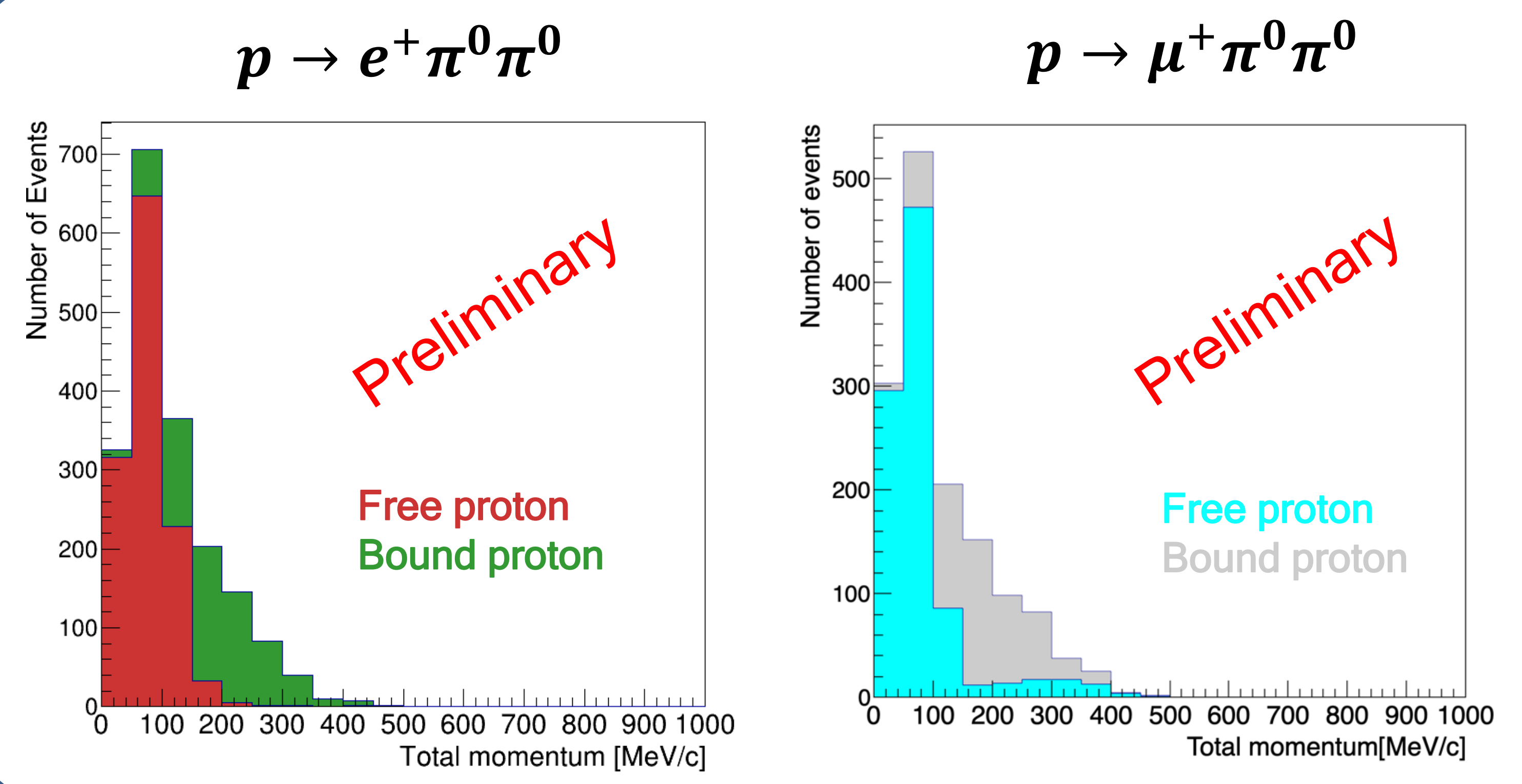


A sample event display of $p \rightarrow e^+ \pi^0 \pi^0$

Total invariant mass



Total momentum



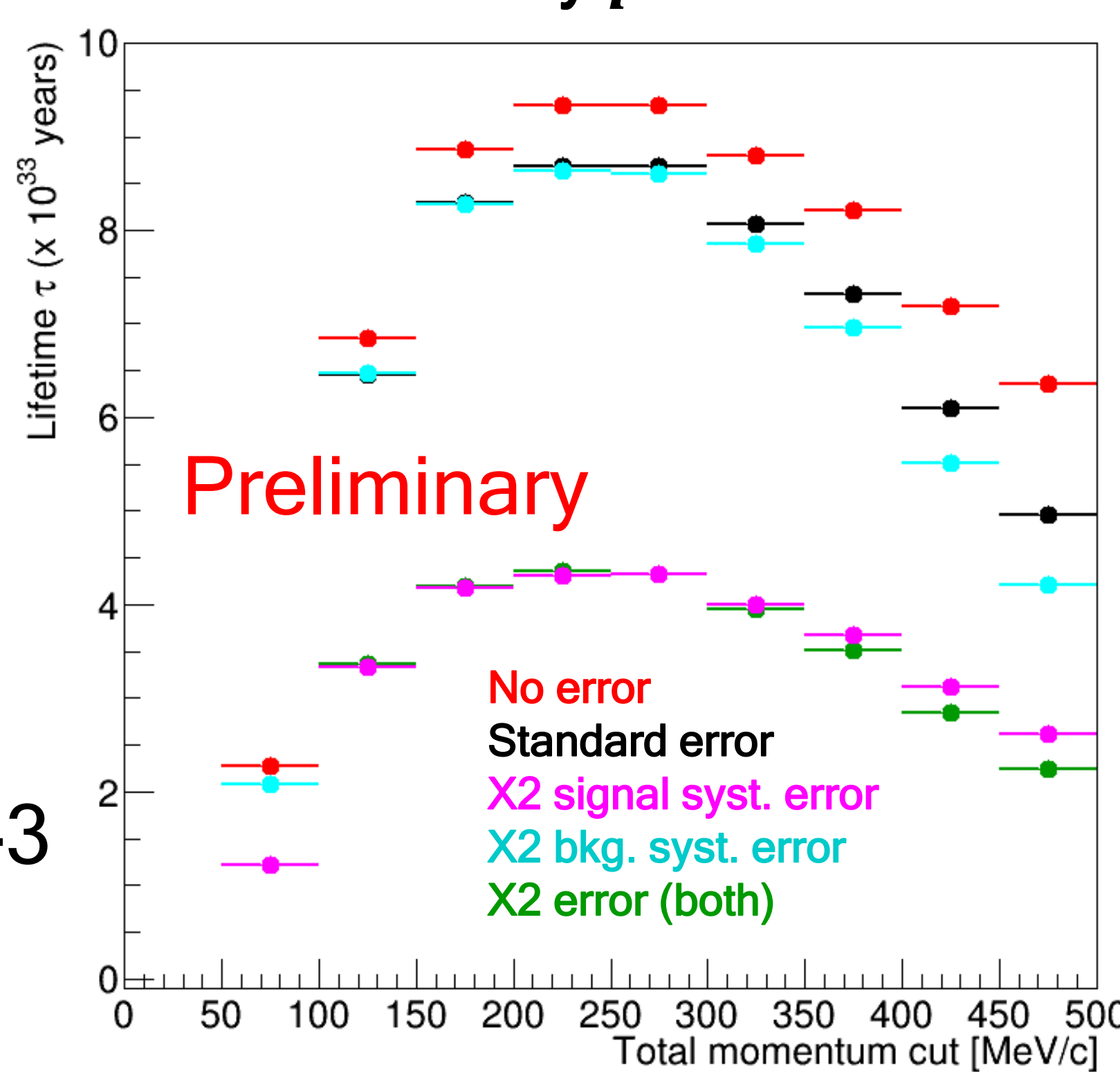
Results

- We obtained sensitivity by simulation study
 - Assumed same systematic error for $p \rightarrow e^+ \pi^0$ and $p \rightarrow \mu^+ \pi^0$ [Takenaka, A., et al., Phys. Rev. D 102.11 (2020): 112011]
- Expected sensitivities are

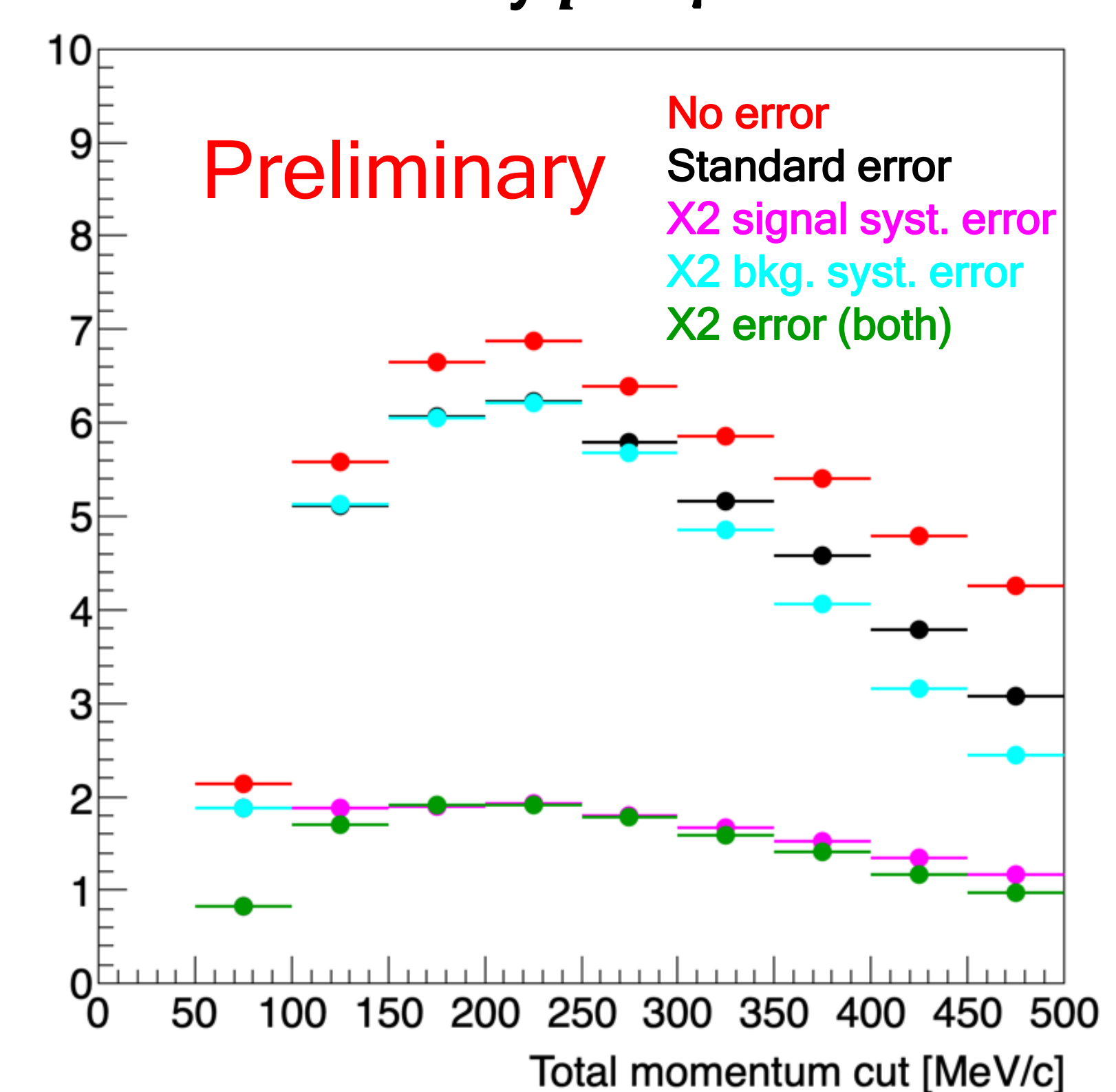
$$p \rightarrow e^+ \pi^0 \pi^0 = 4 \sim 9 \times 10^{33} \text{ years}$$

$$p \rightarrow \mu^+ \pi^0 \pi^0 = 2 \sim 7 \times 10^{33} \text{ years}$$
- Sensitivity depends on the signal systematic error
- It is expected to extend the lifetime limit of the IMB-3 result by about $10 \sim 60$ times [McGrew, C., et al. Phys. Rev. D 59.5 (1999): 052004]

Sensitivity $p \rightarrow e^+ \pi^0 \pi^0$



Sensitivity $p \rightarrow \mu^+ \pi^0 \pi^0$



Summary

- The first study of proton decay directly into a lepton and two pion in SK
- We obtained the sensitivity of $p \rightarrow e^+ \pi^0 \pi^0$ and $p \rightarrow \mu^+ \pi^0 \pi^0$ by simulation study
- We plan to analyze the SK1-5 data in near future