Hyper-Kamiokande

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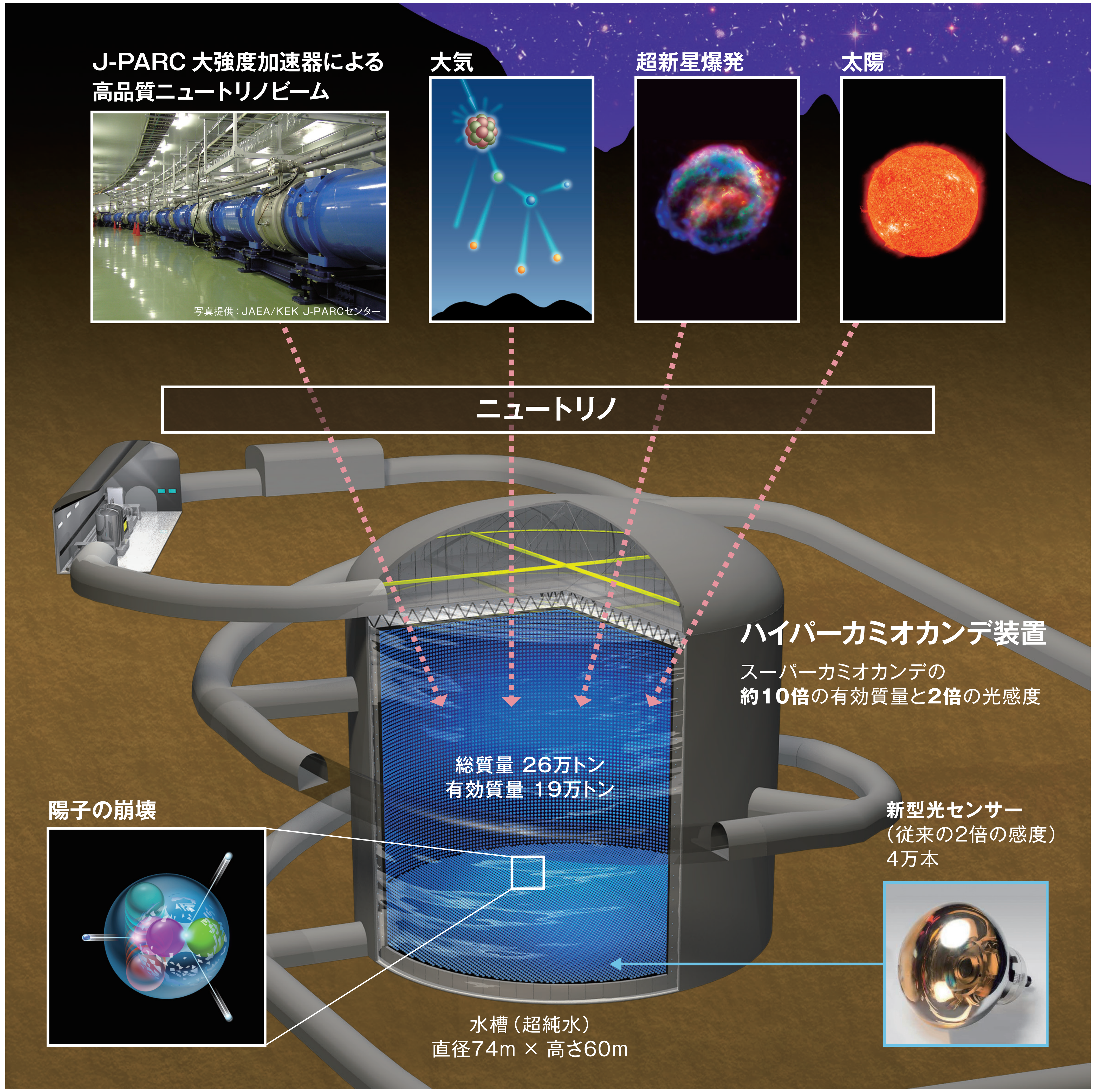
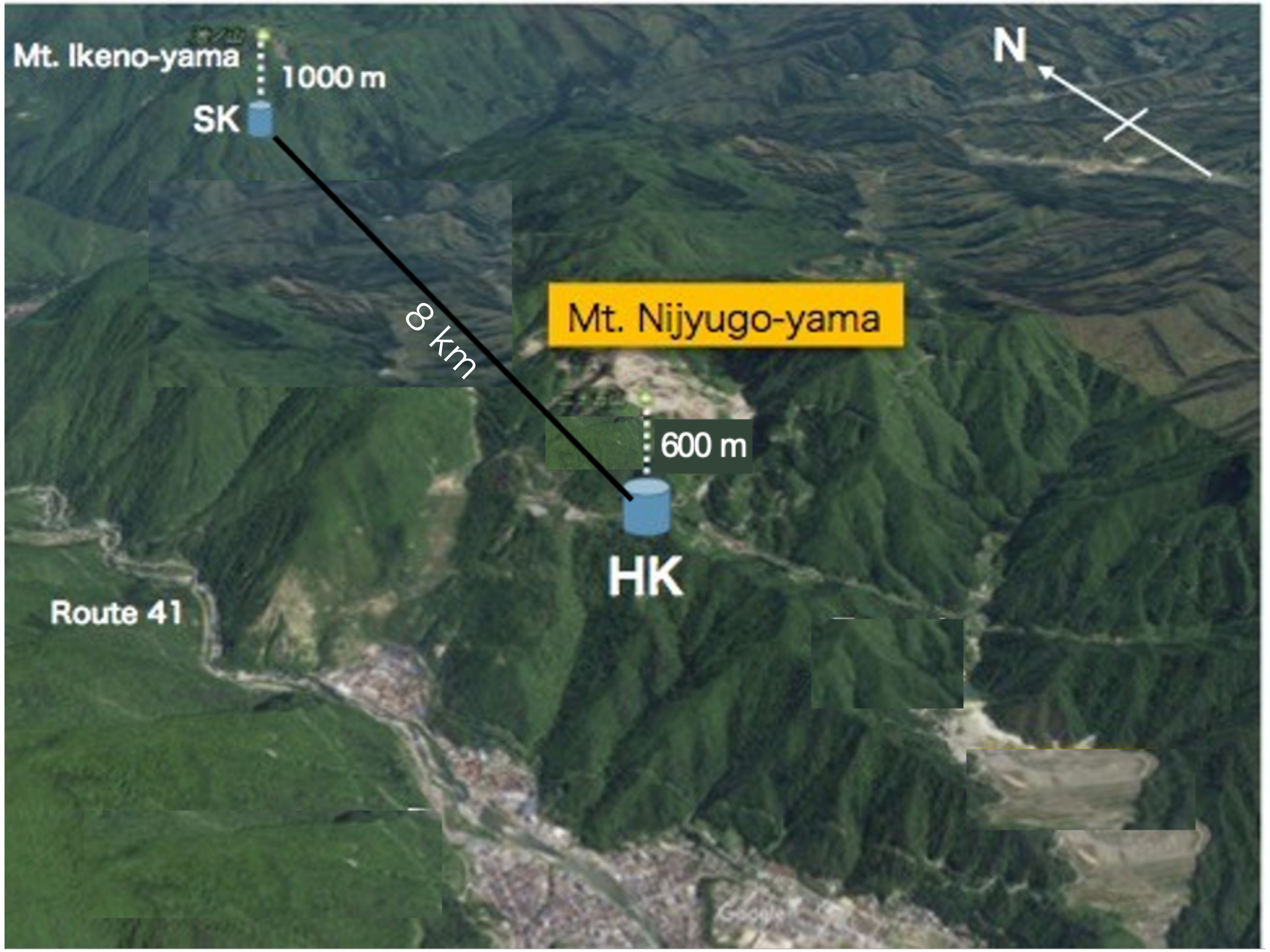
CRC town meeting, 10th of March, 2025

Hyper-Kamiokande

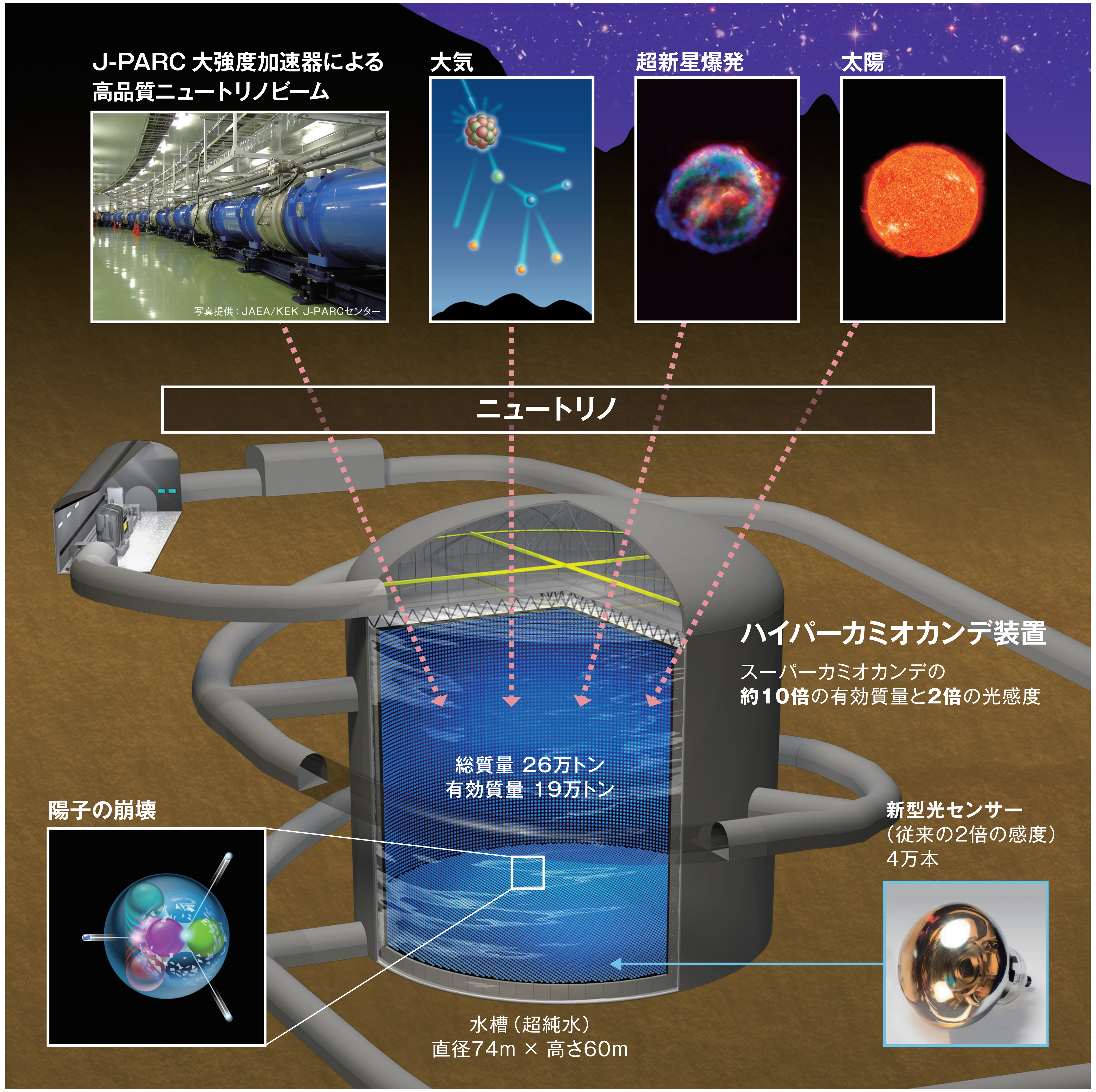
Next generation multi-purpose water Cherenkov detector

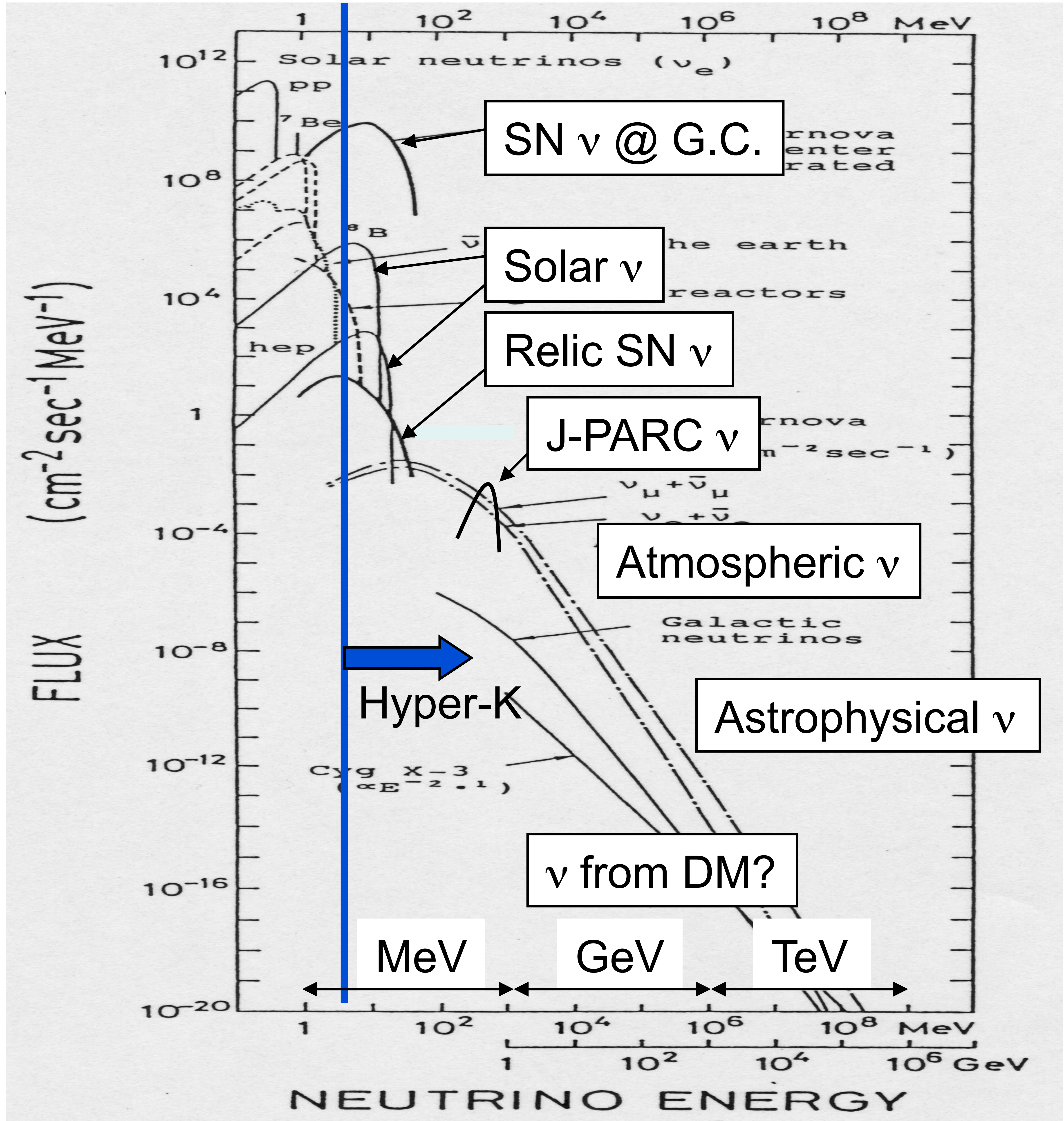




Hyper-Kamiokande

Next generation multi-purpose

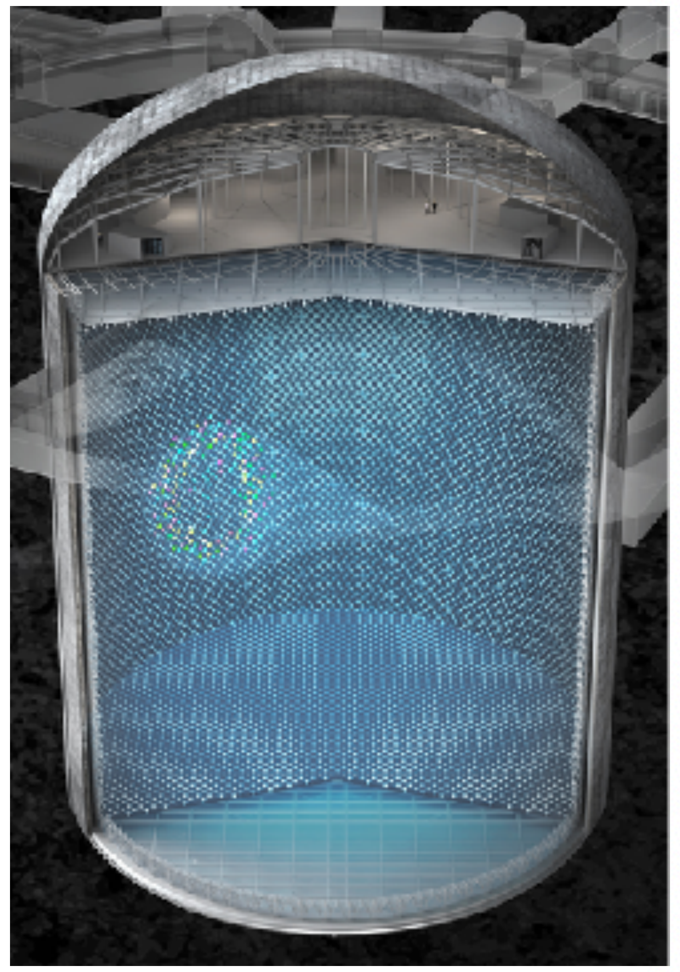


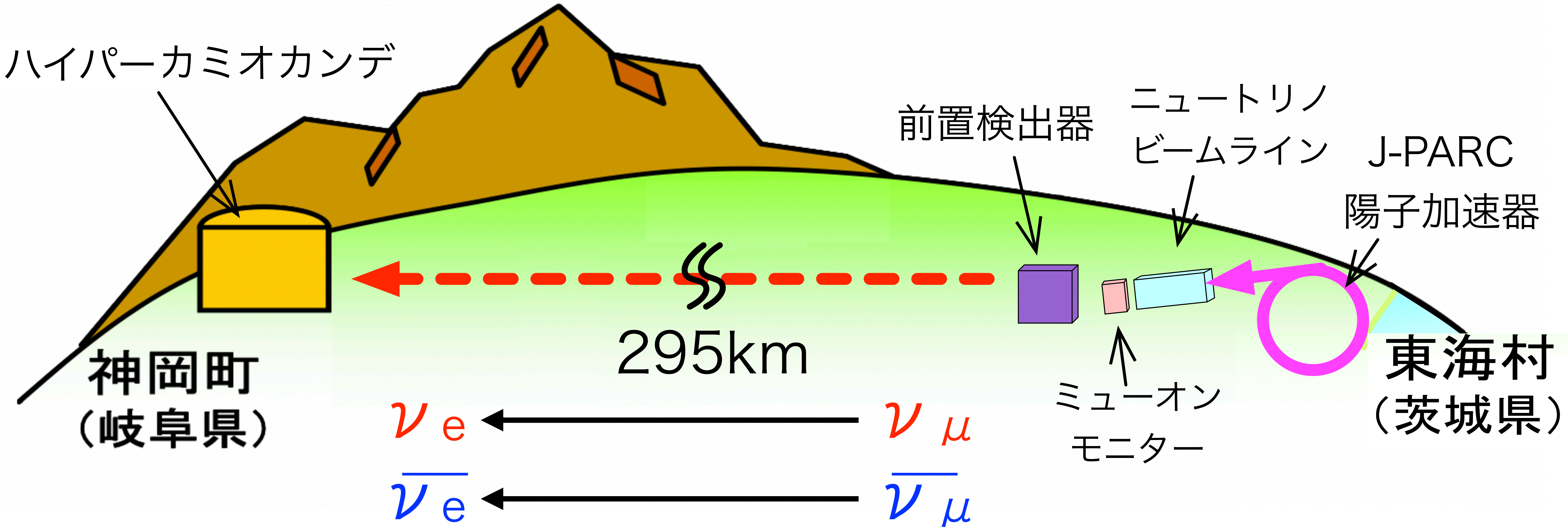


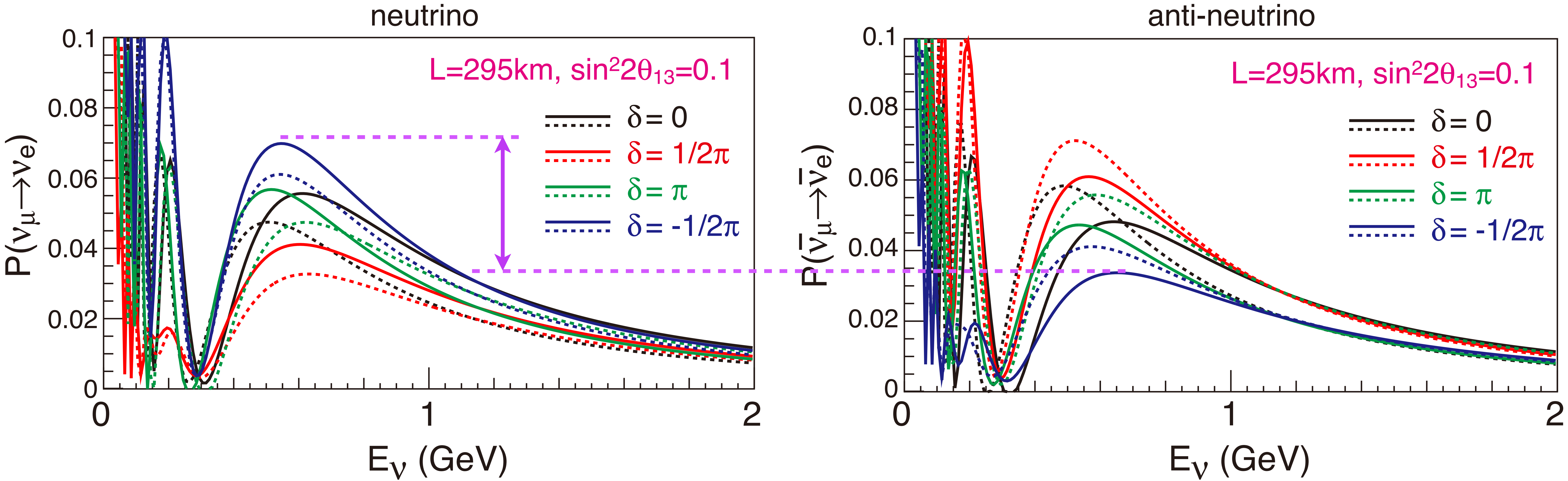
Physics targets

Long baseline neutrino experiment

Search for CP violation in lepton sector



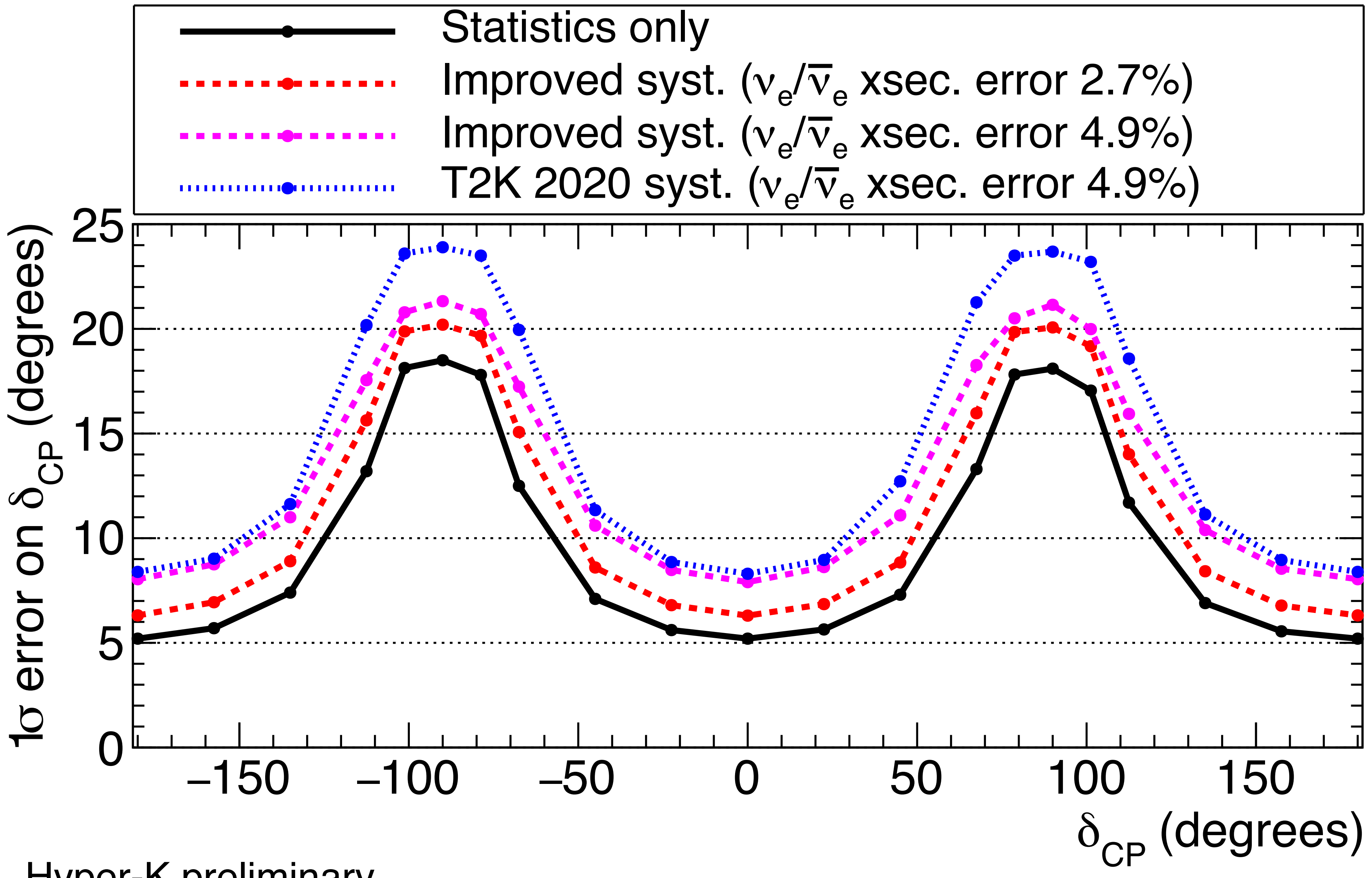




Determination of CP phase

1.3MW x 6 months/y x 10 yrs x 190 kiloton

Precision of CP phase measurement



Hyper-K preliminary

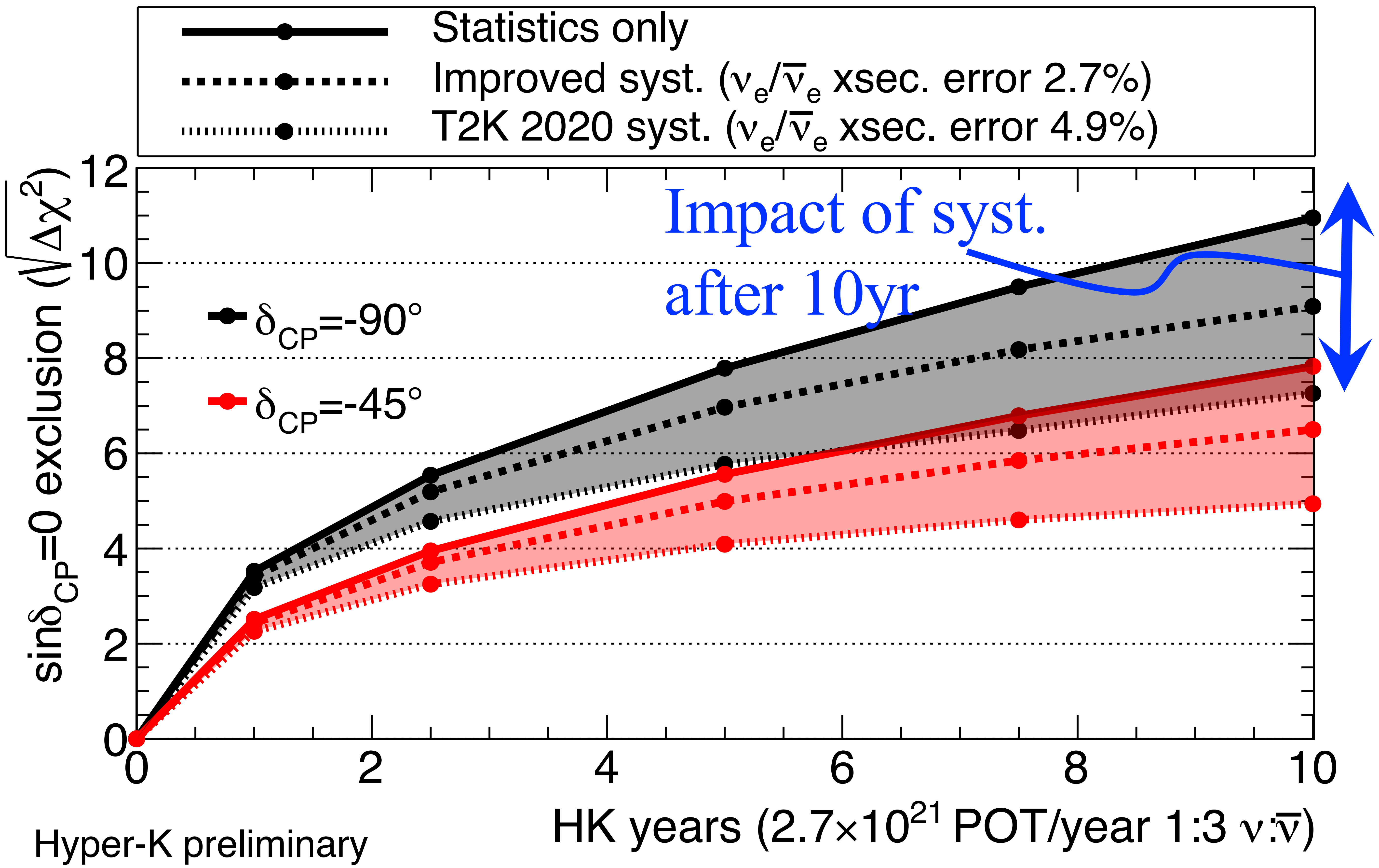
True normal ordering (known), HK 10 Years (2.7×10^{22} POT 1:3 $\nu:\bar{\nu}$)

$\sin^2\theta_{13}=0.0218\pm0.0007$, $\sin^2\theta_{23}=0.528$, $\Delta m^2_{32}=2.509\times10^{-3}\mathrm{eV}^2/c^4$

1sigma error on δcp

~20 degree at δcp = $1/2\pi$

~7 degree at δcp = 0



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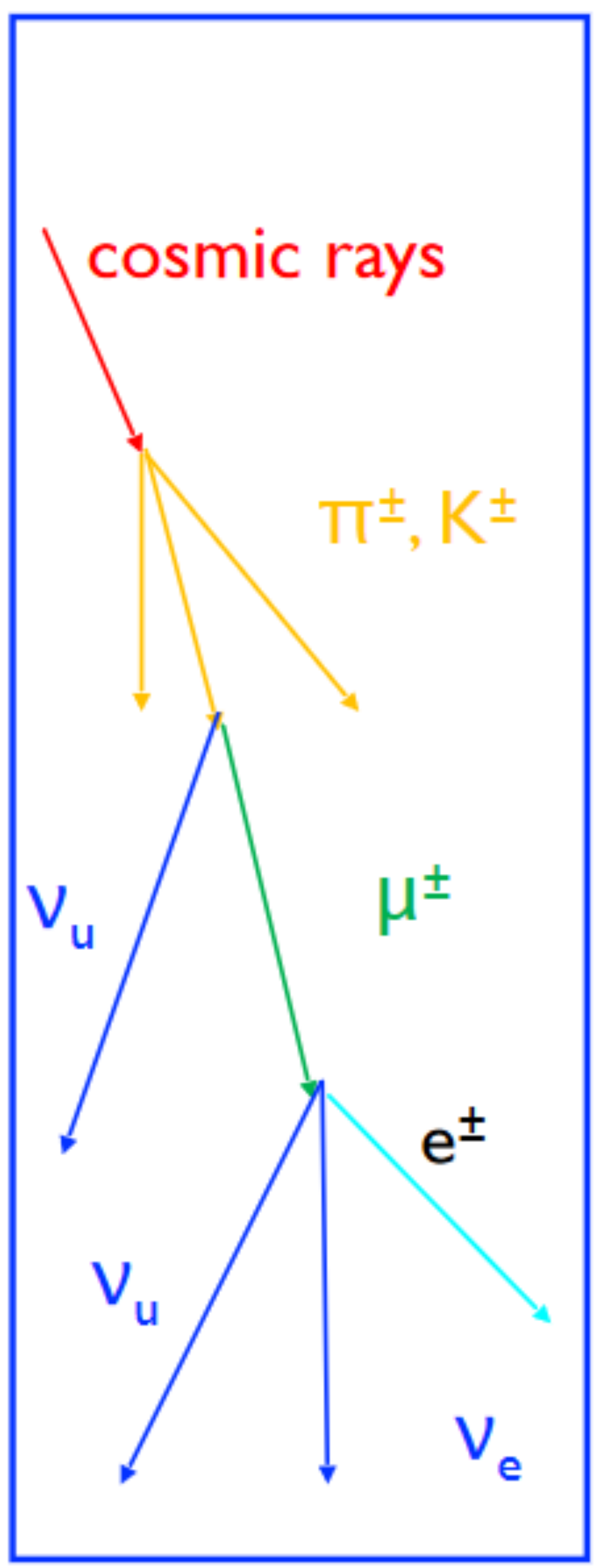
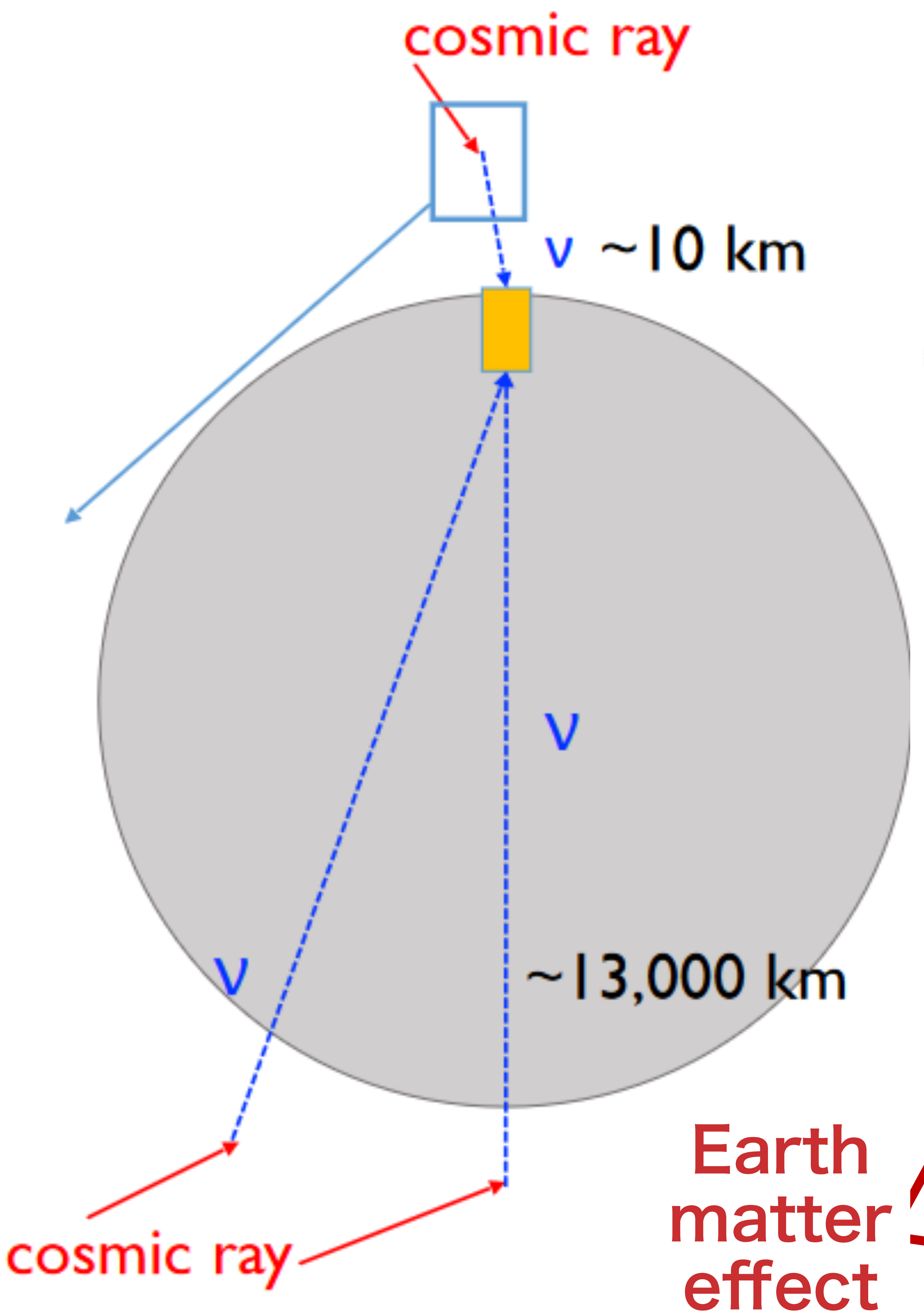
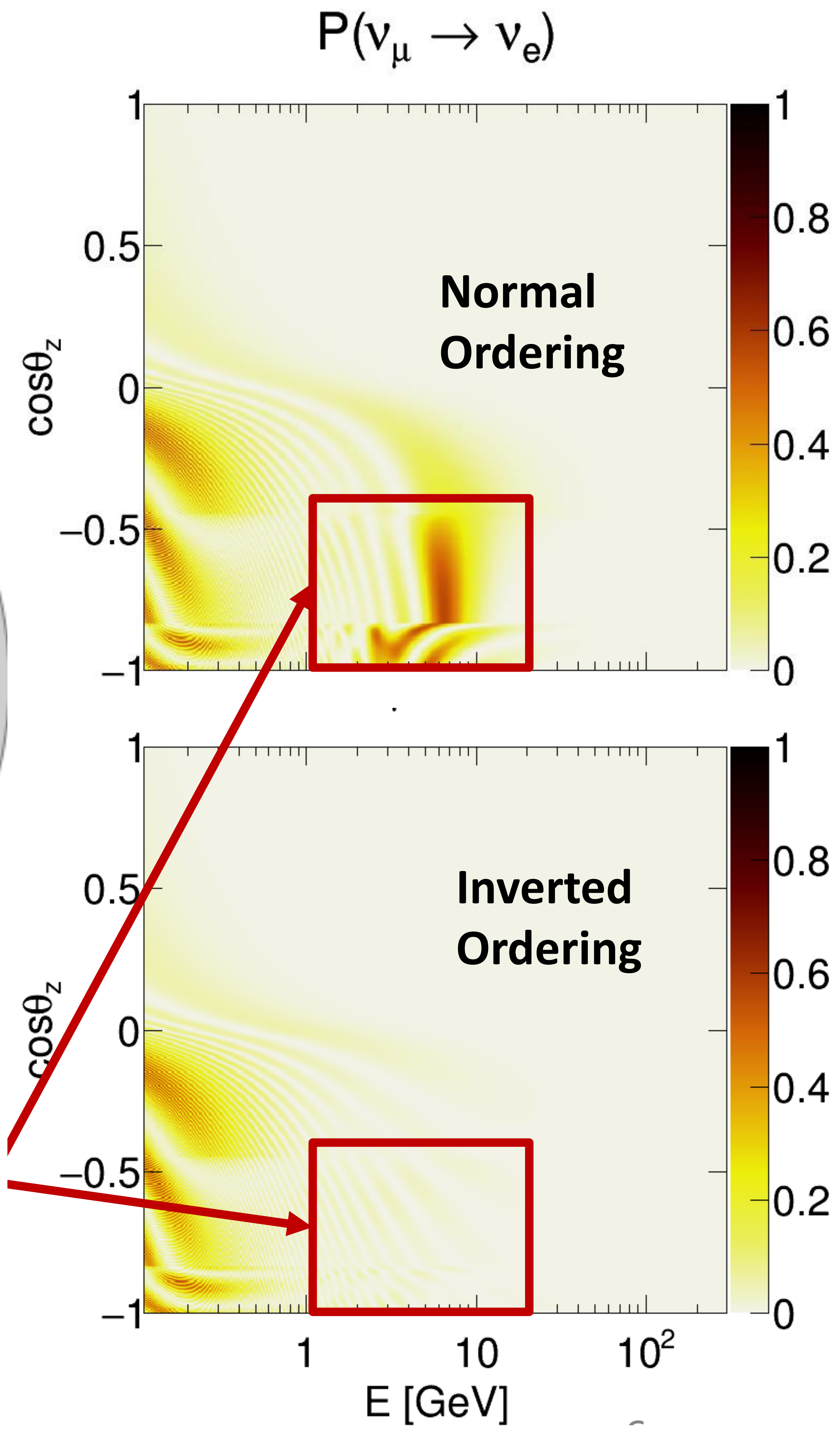
Atmospheric neutrino

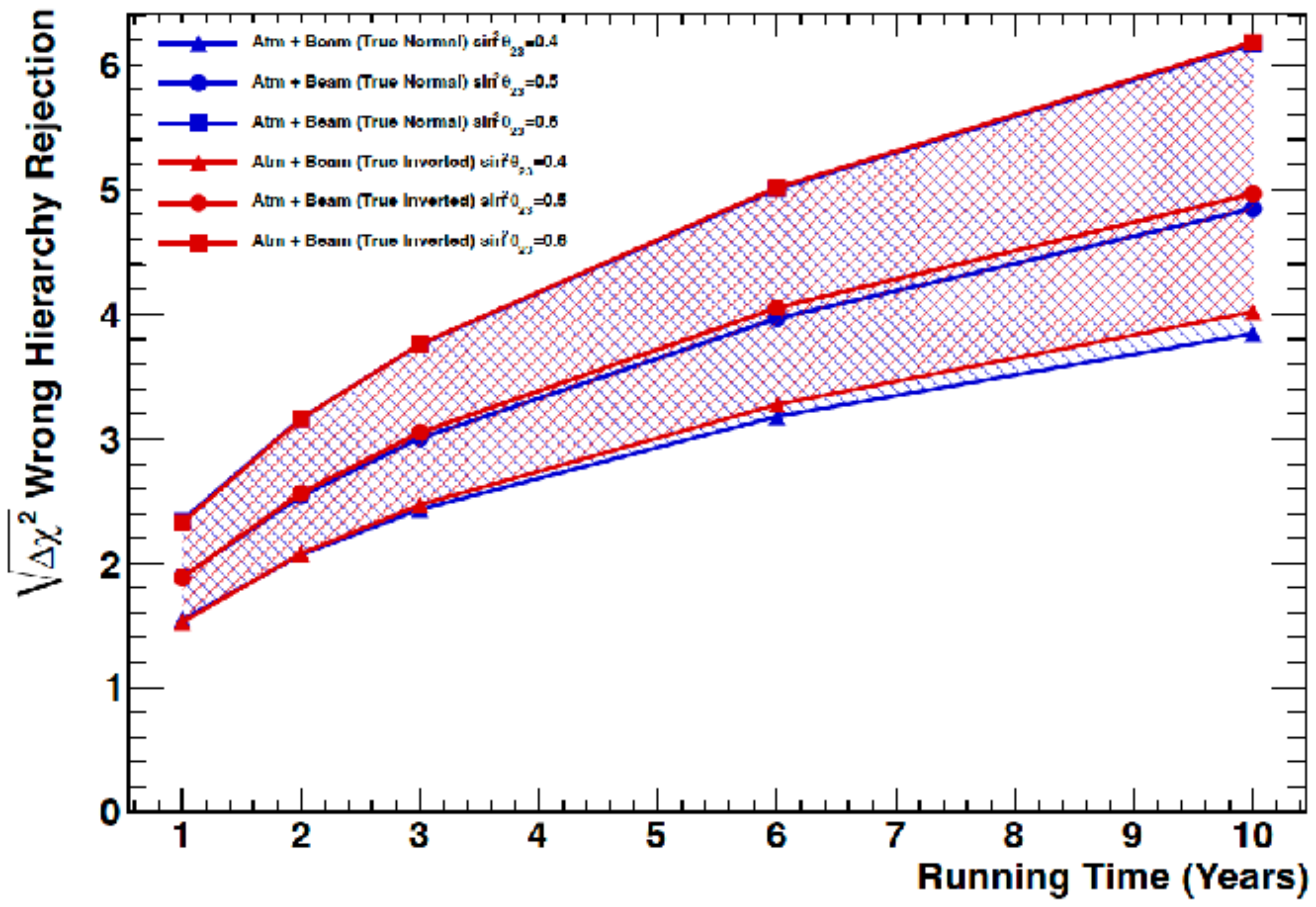
Neutrino oscillation parameter determination, especially, mass ordering





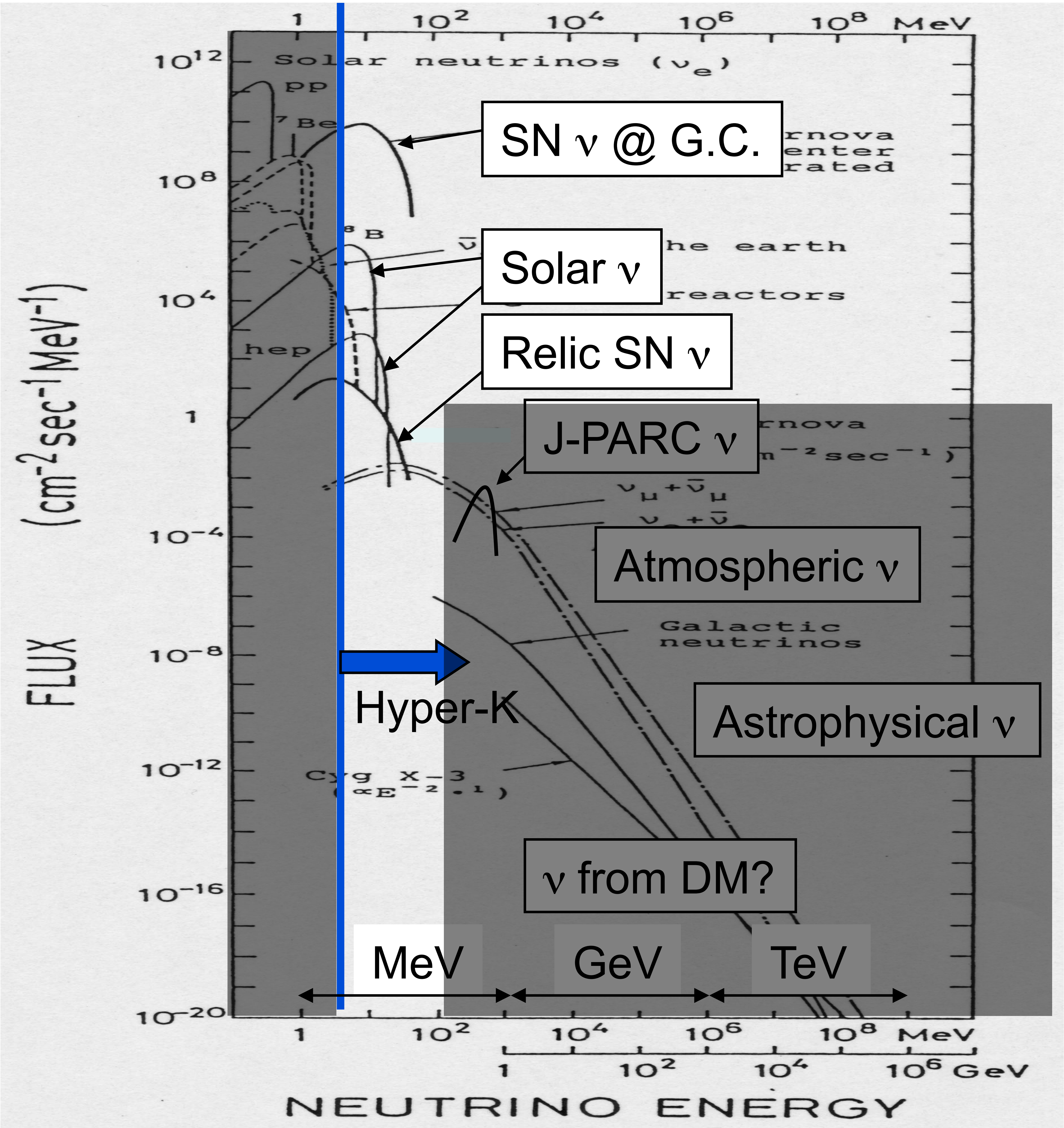
Sub-GeV to more than 10 TeV neutrino energy.





Determination possible by ~5 years

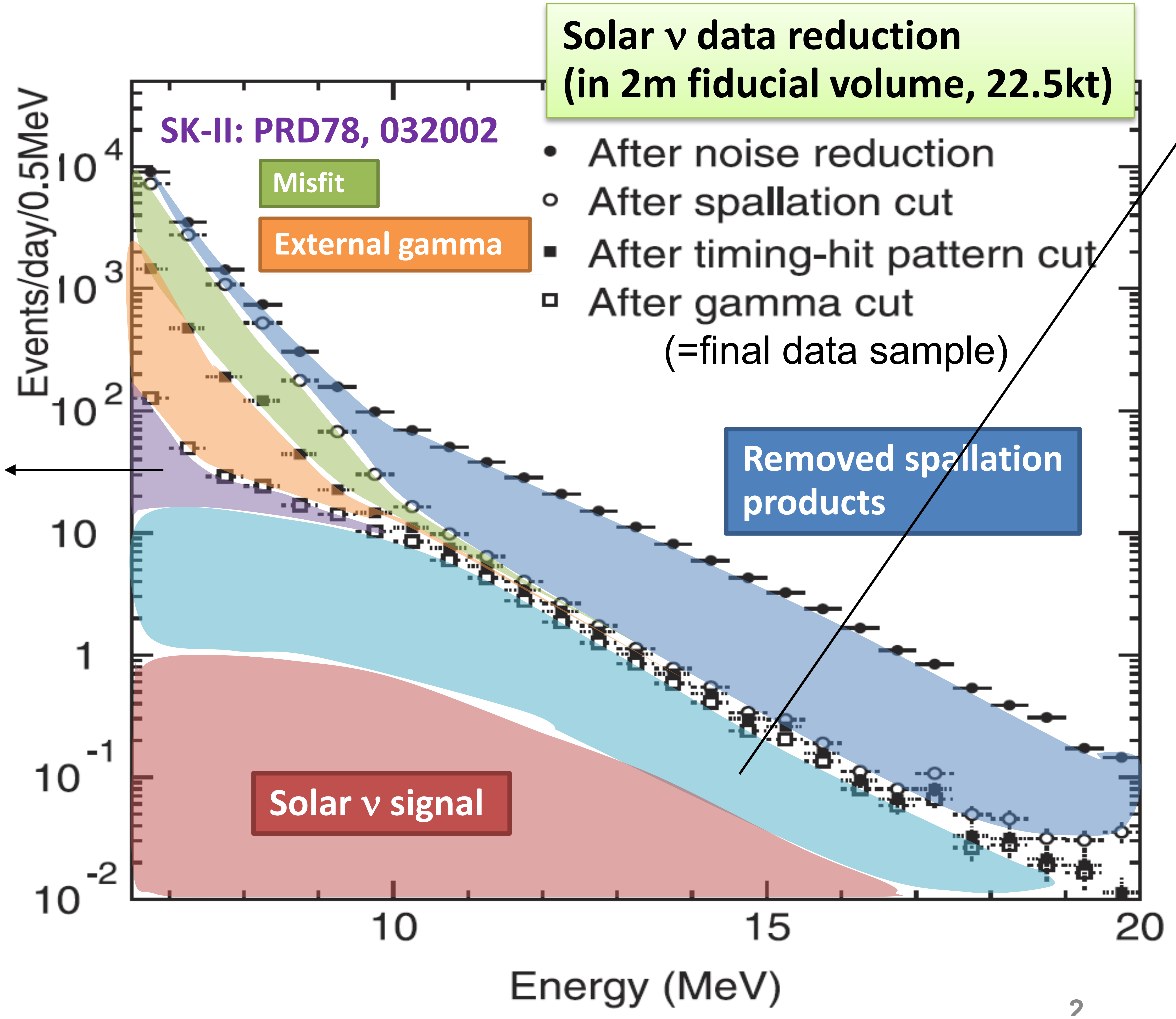
Astronomical neutrino search



Challenges in neutrino research below 100MeV

- Understanding backgrounds and their efficient reduction.
  - Muon spallation
  - Radioactive purity such as Radon
- Precise detector calibration (vertex, energy, direction)

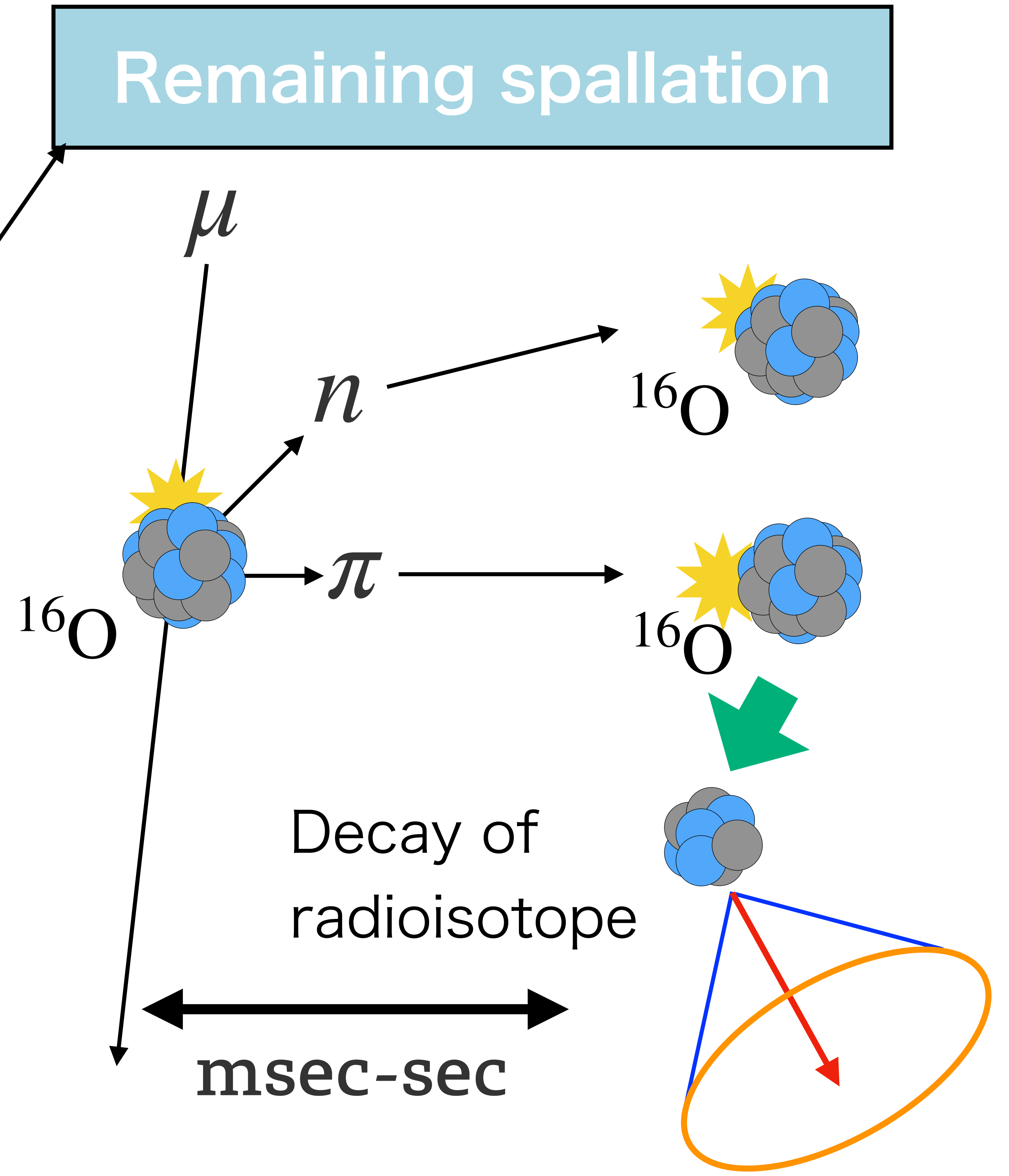
Fight against background



Radon in water, External gamma, etc.

Key issue

- Cleanness
- Water control

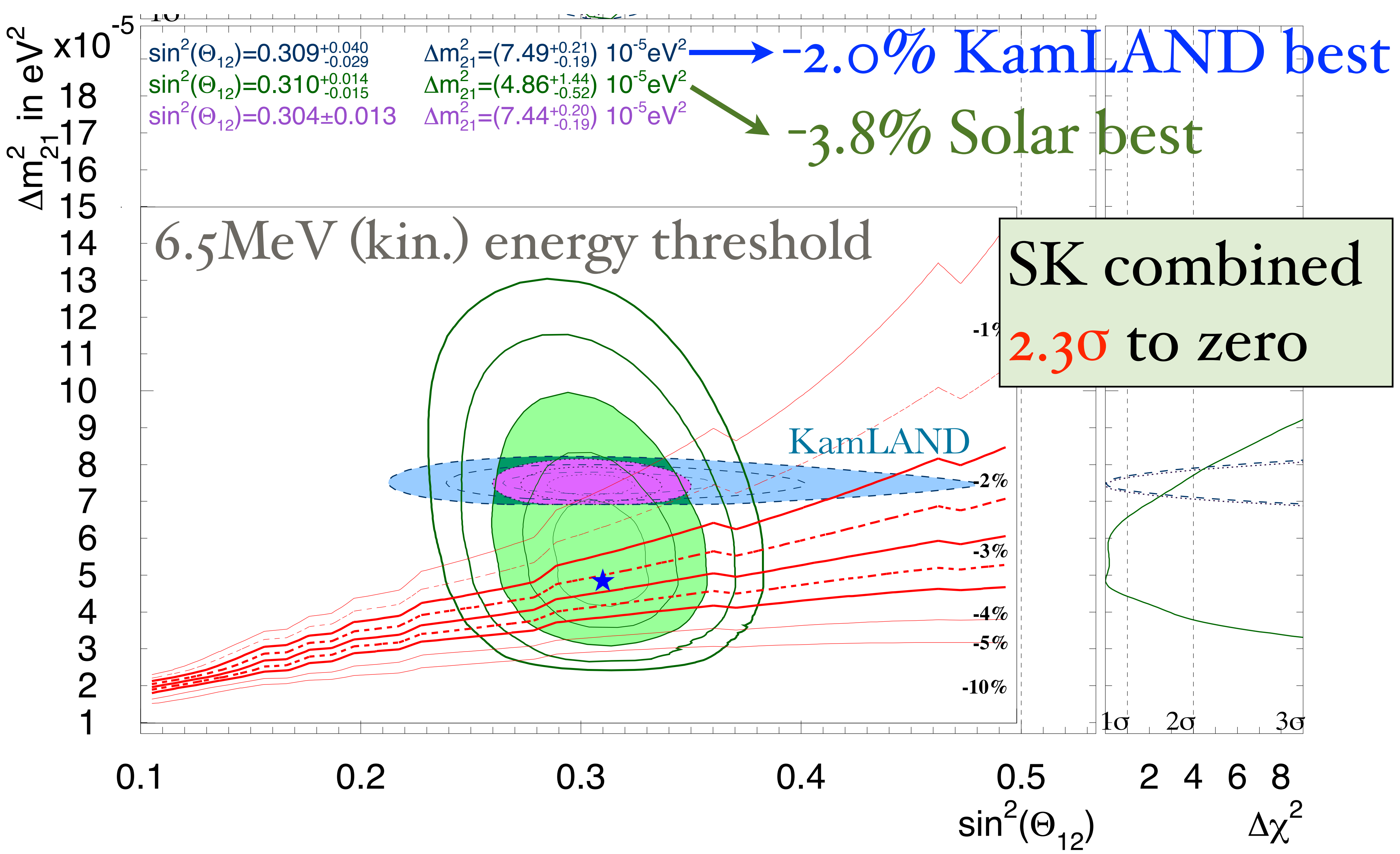


Muon flux is 5 times and the area is 4 times larger than Super-K site. (~40Hz in HK)

Solar neutrino

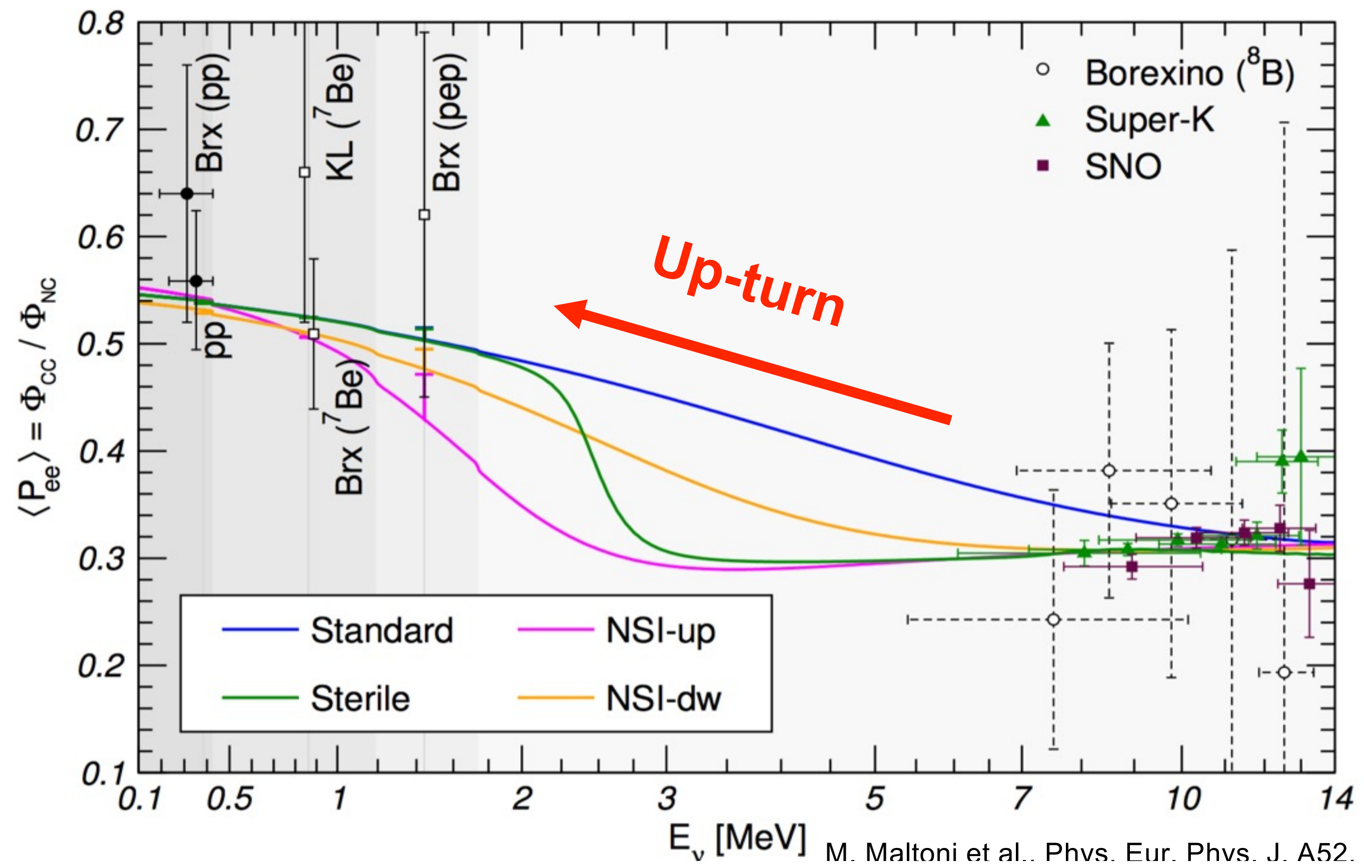
Neutrino oscillation studies

Day-Night flux asymmetry

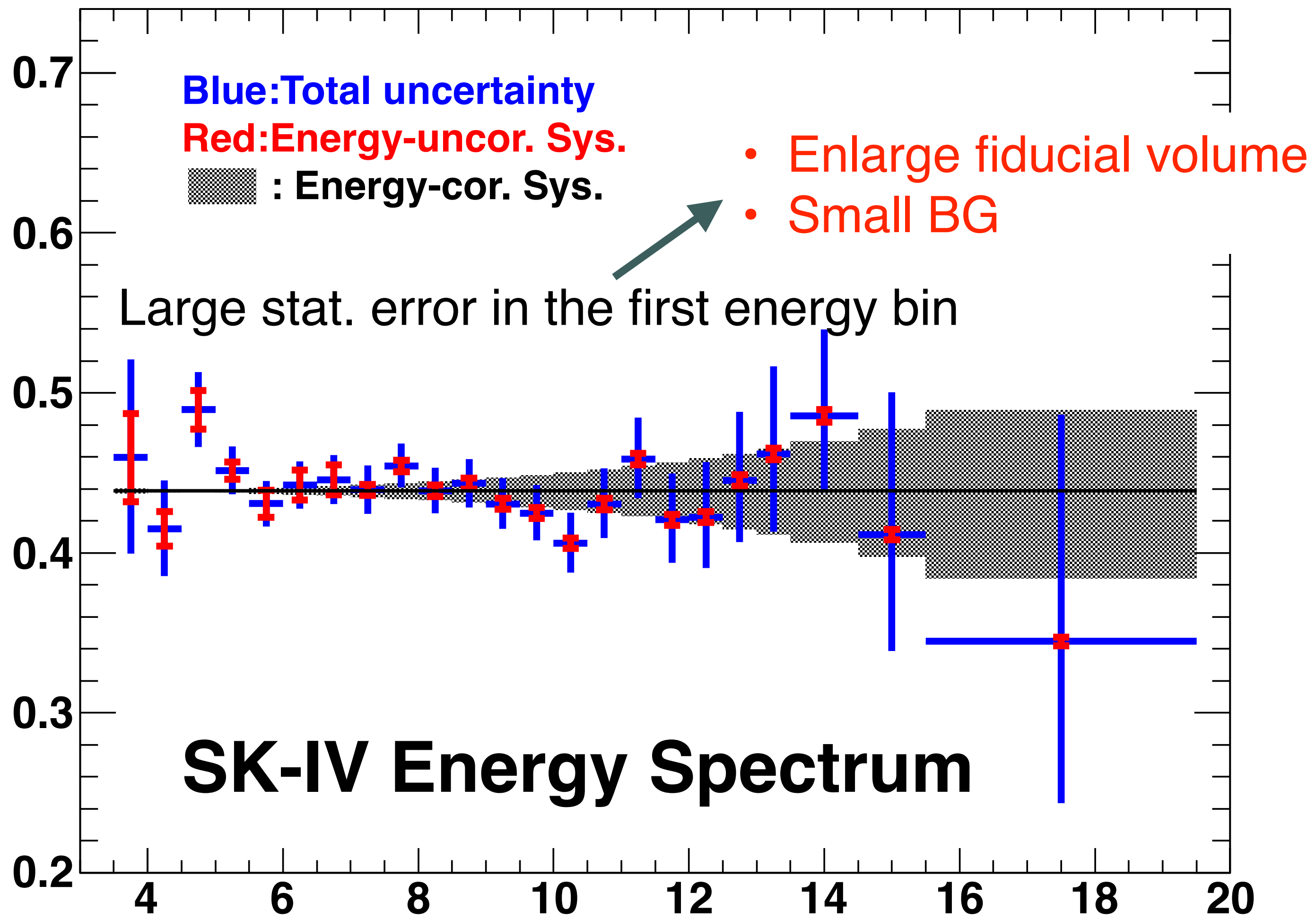


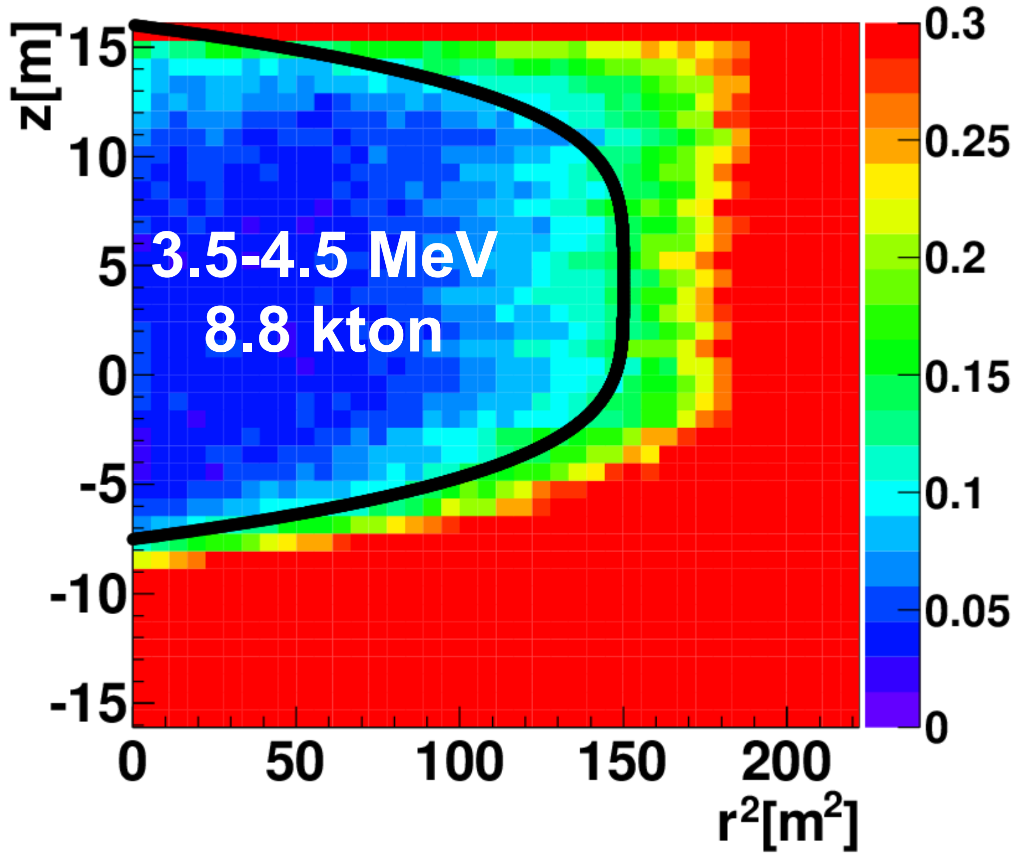
- Reduce spallation BG
- Control water condition
  → well understand the BG shape
  → modeling of position dependence

Spectrum up-turn

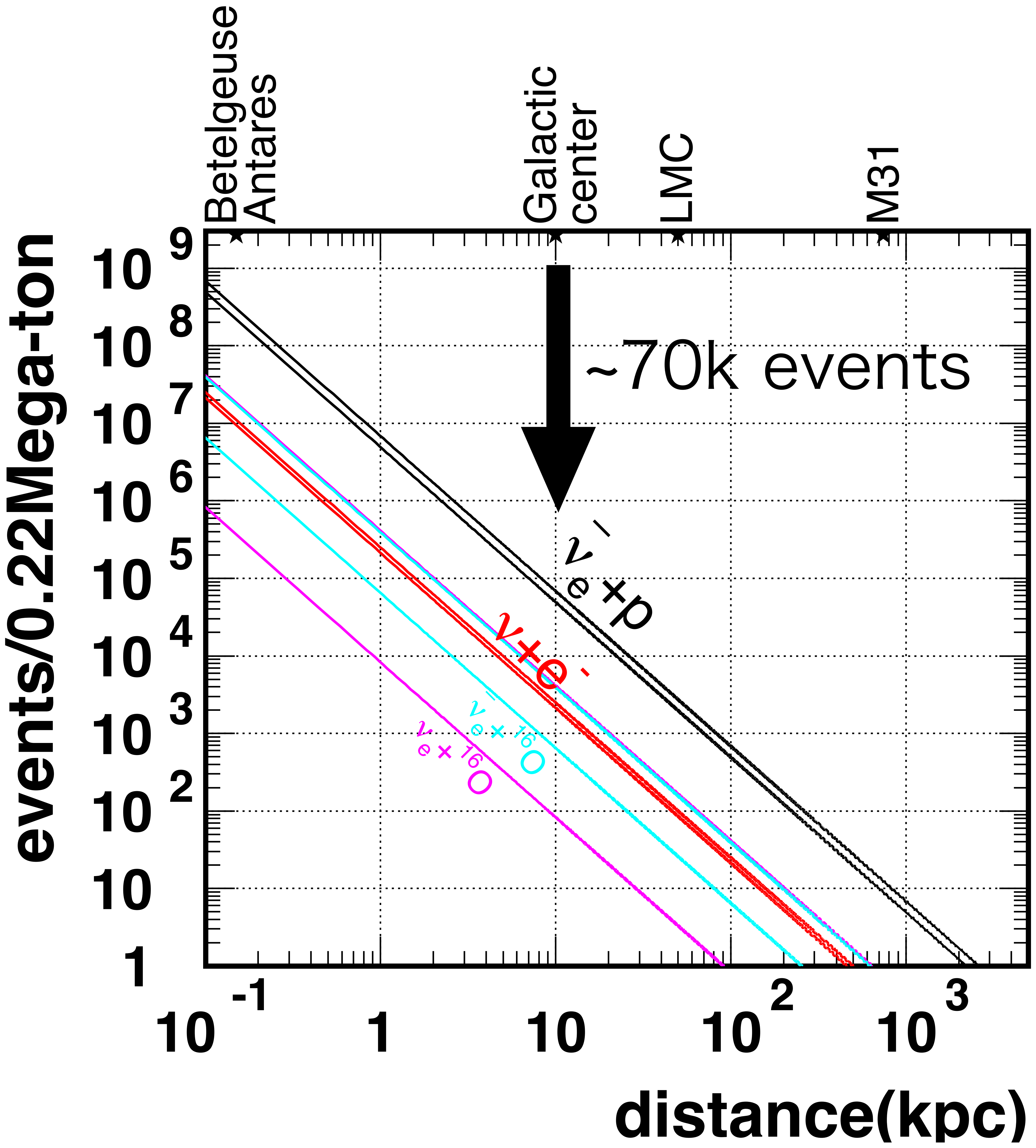


- Lowering threshold with low BG.
  → low Rn water
- Energy scale error
  → detector calibration

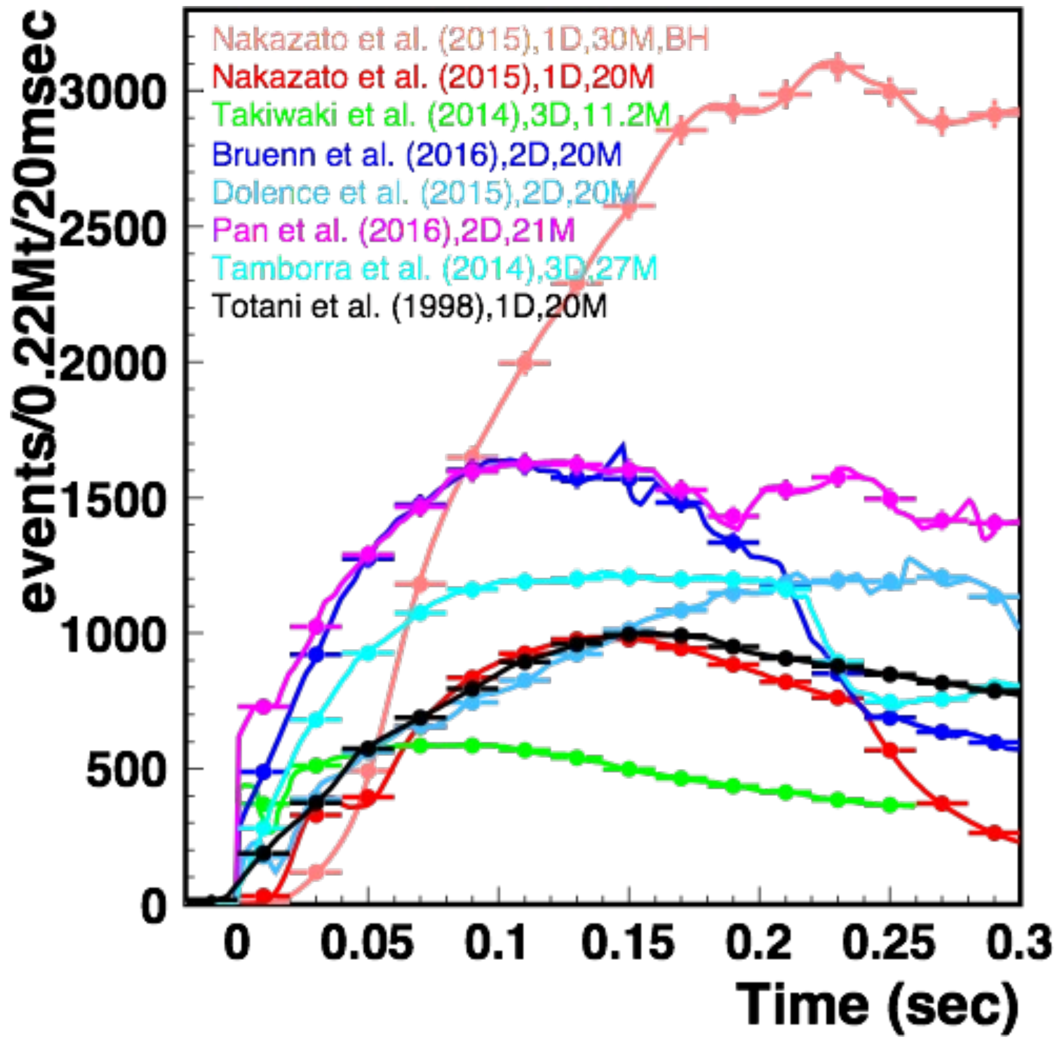


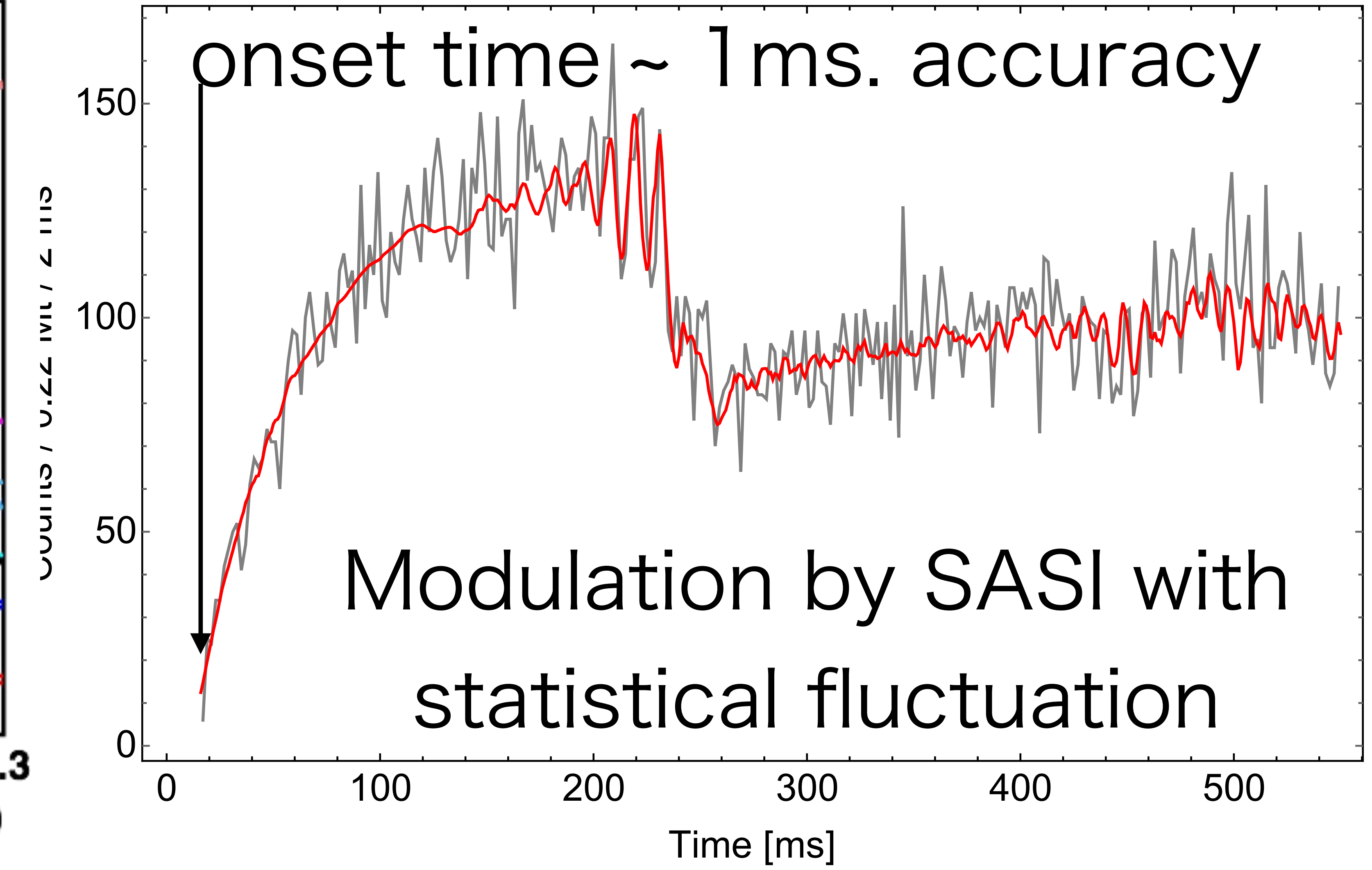


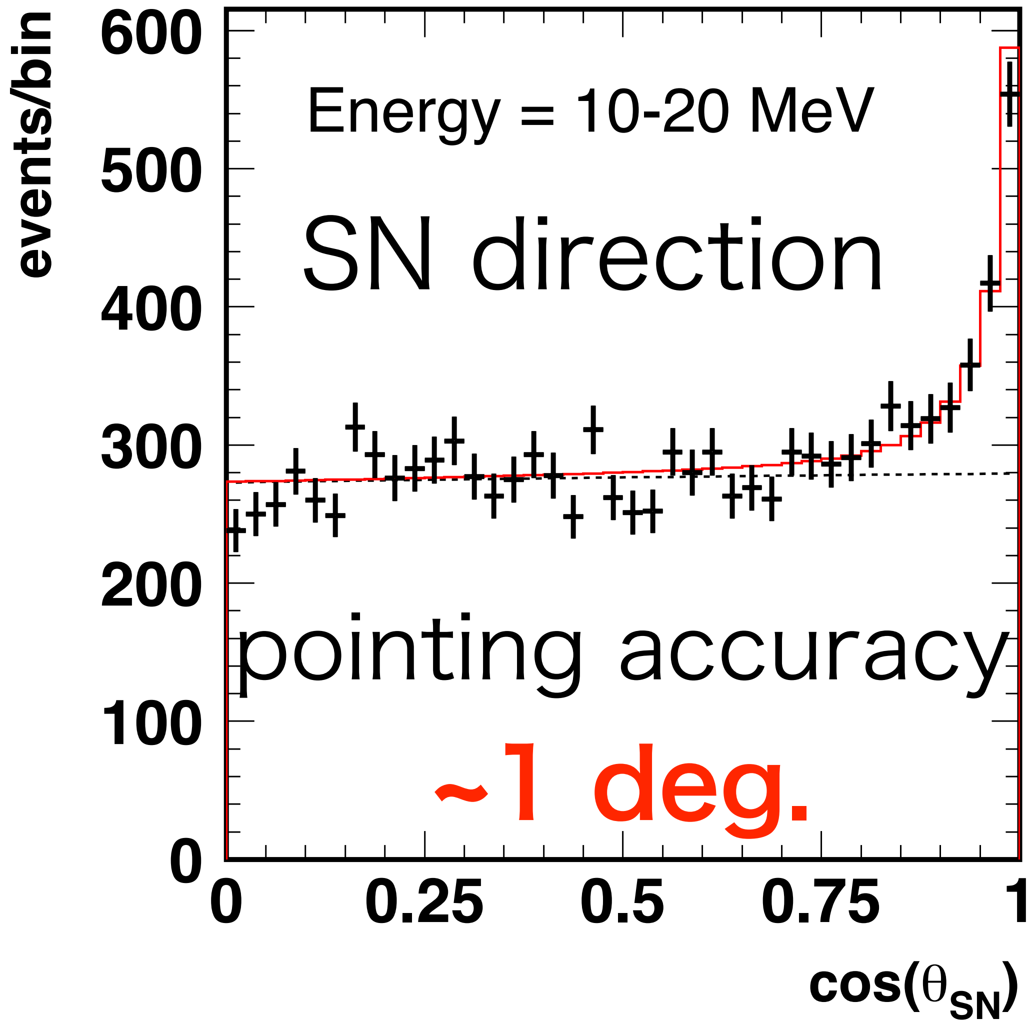
Supernova neutrino (burst)

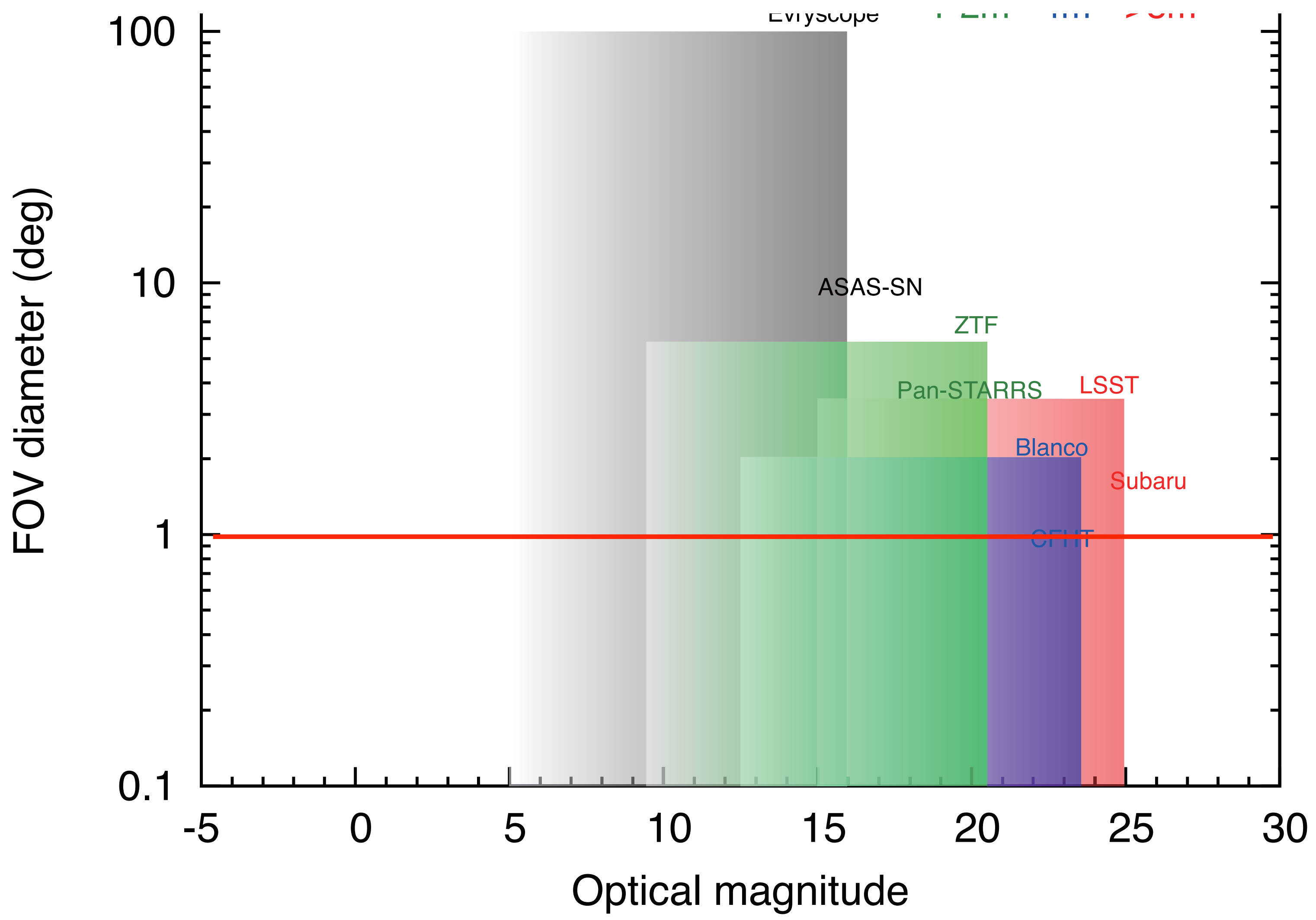


Galactic center (@10kpc)



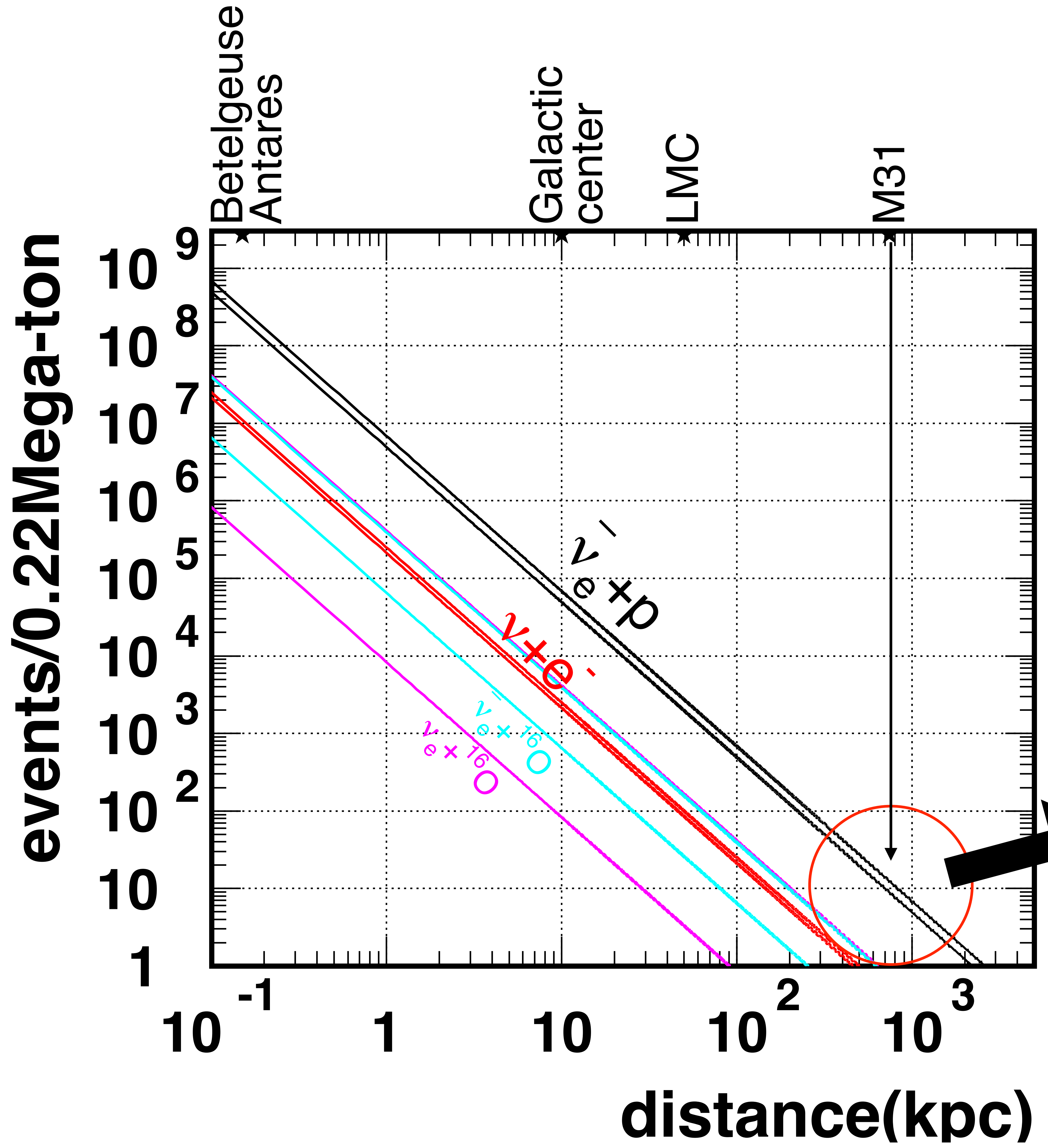




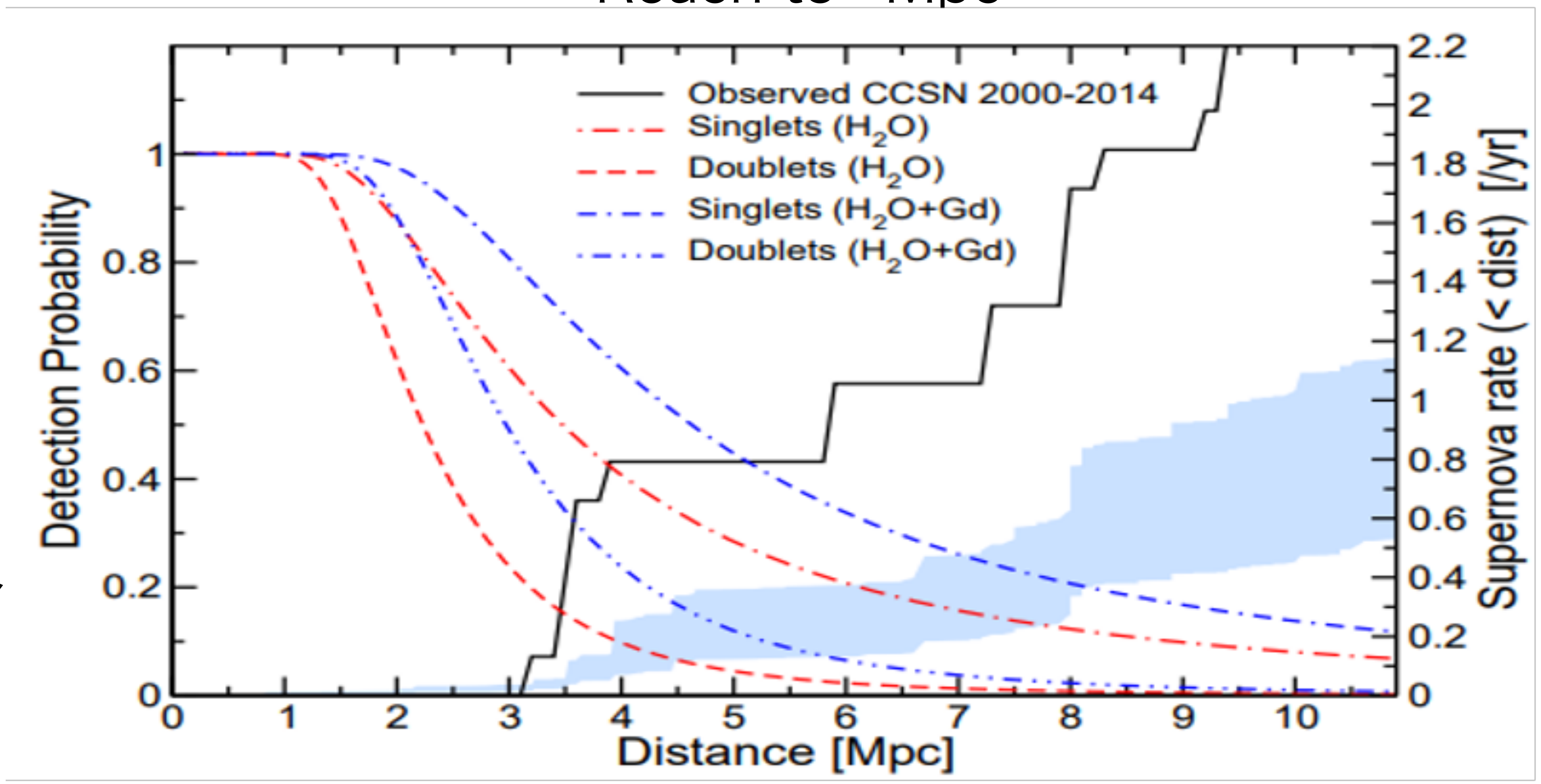


Continuous operation, Success of DAQ at high rate

Supernova neutrino (burst)



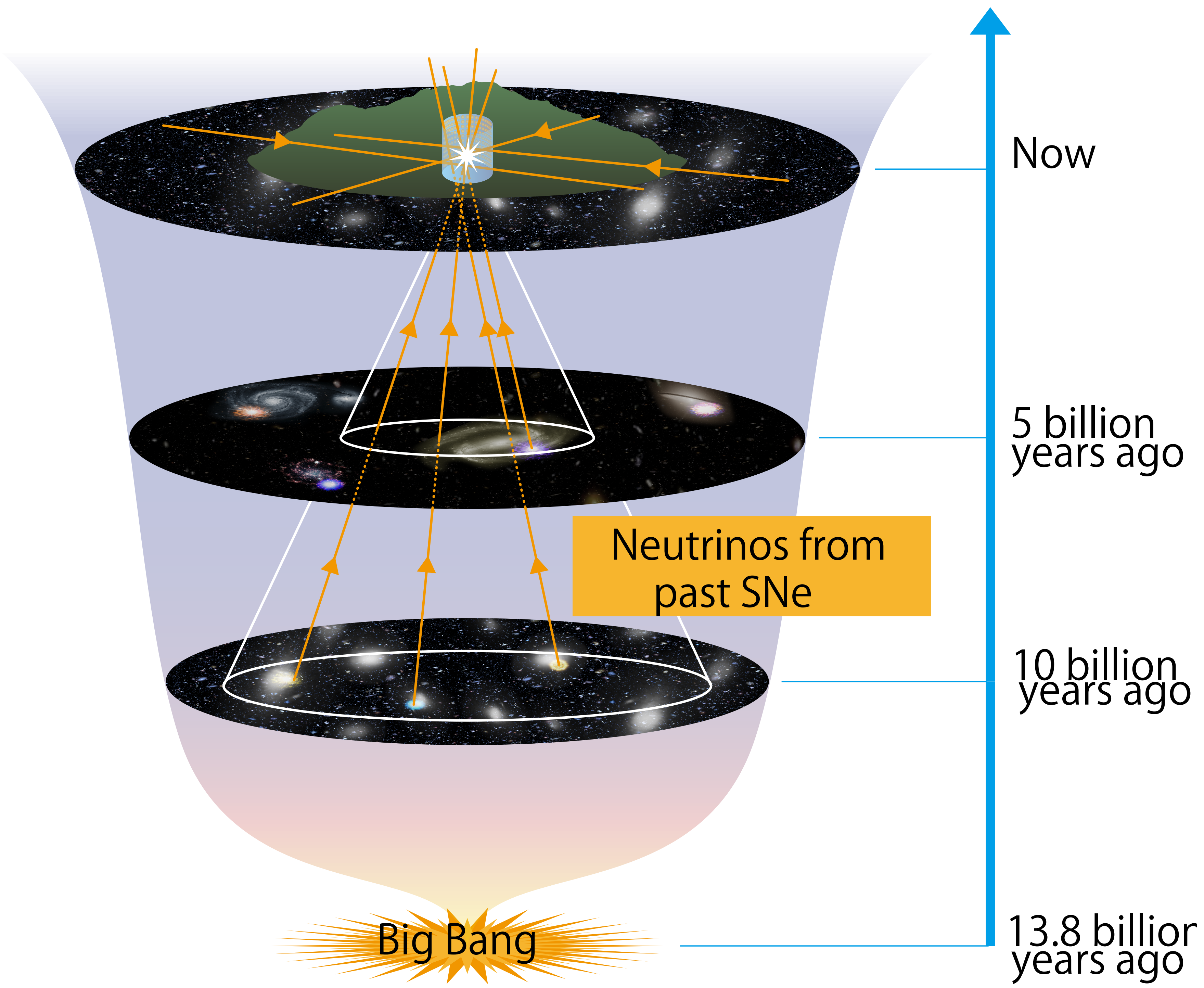
Reach to ~Mpc

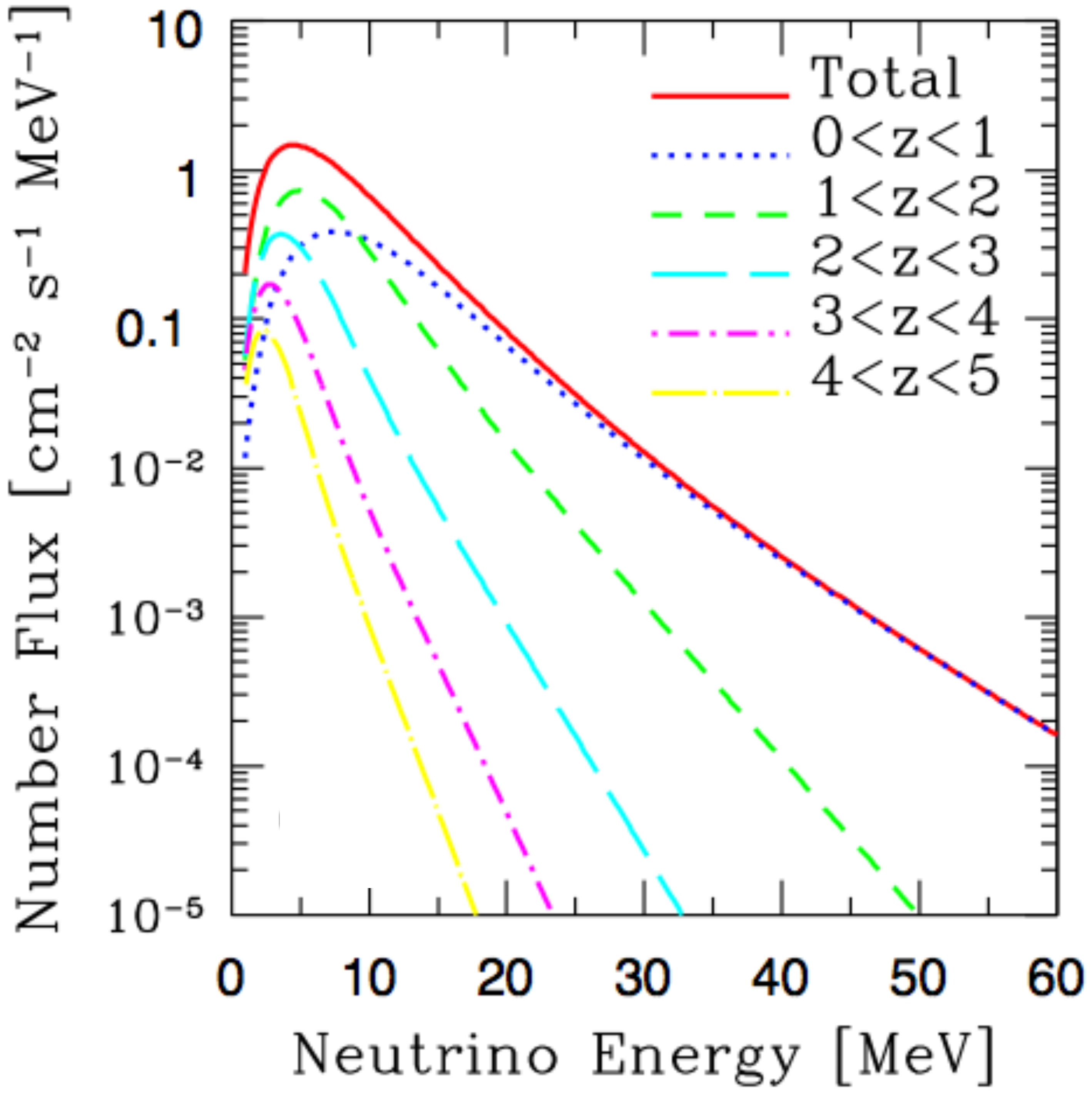


Continuous operation, BG free

Supernova neutrino (diffuse)

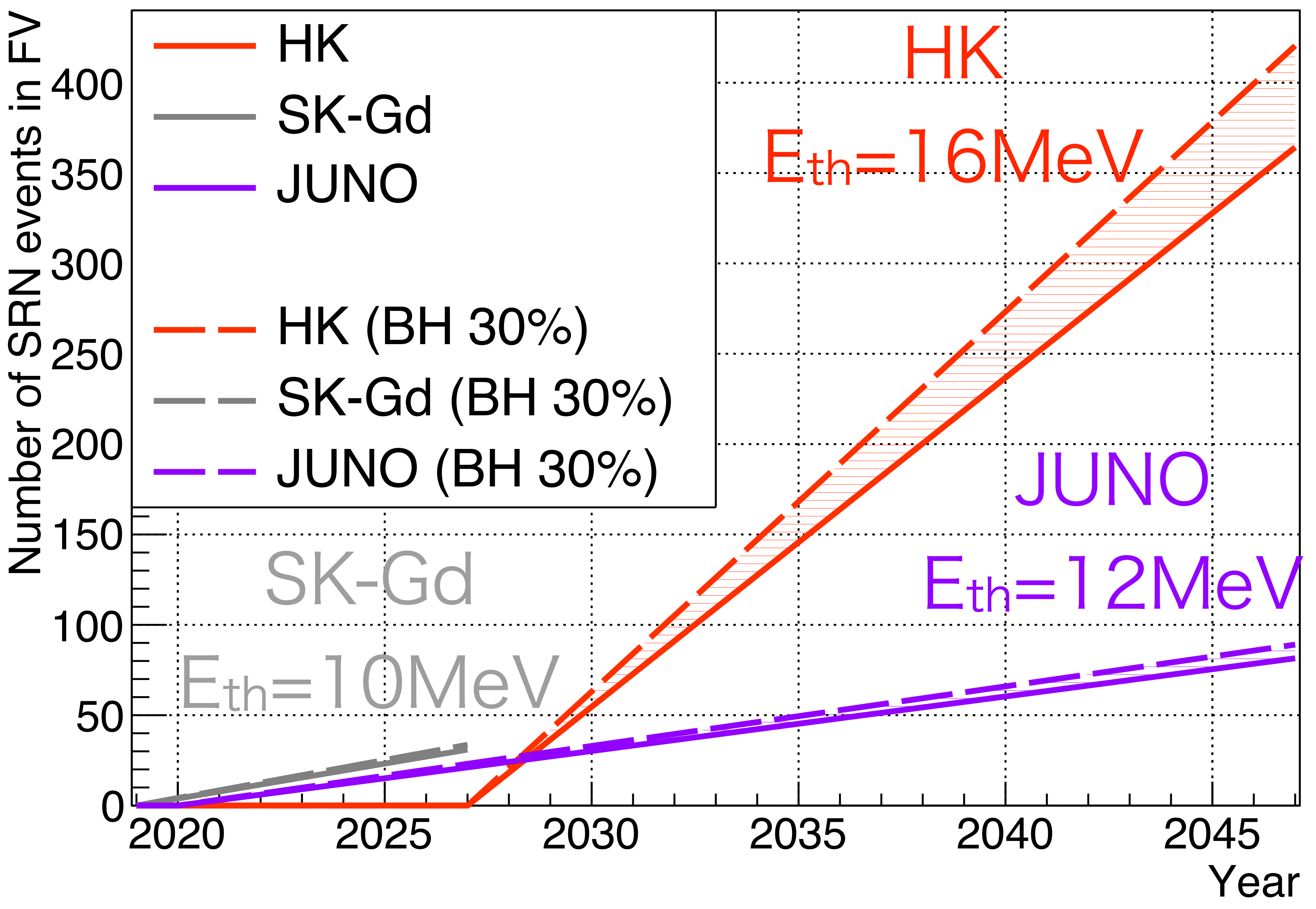
Neutrinos emitted from past supernovae ~O(10^{18})





S. Ando and K. Sato, New J. Phys. 6, 170 (2004)

Number of expected signals



ΛCDM, cosmic expansion

$$\Phi_{\mathrm{DSNB}}(E) \propto \int \boxed{R_{\mathrm{SN}}(z)} \boxed{\frac{dF_{\bar{\nu}}(E,z)}{dE}} \boxed{\left|\frac{dt}{dz}\right|} dz$$

SN rate

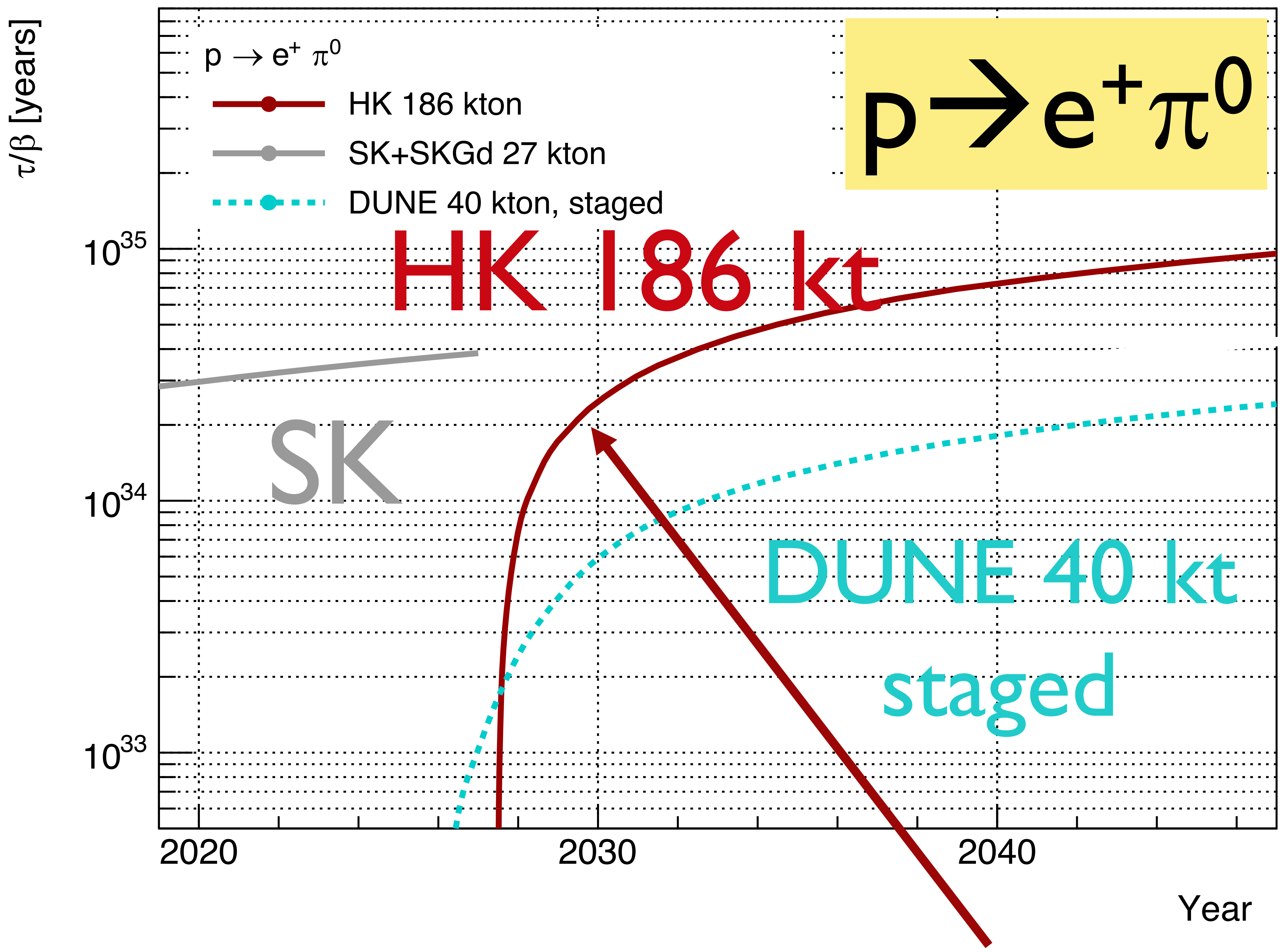
SN ν emission

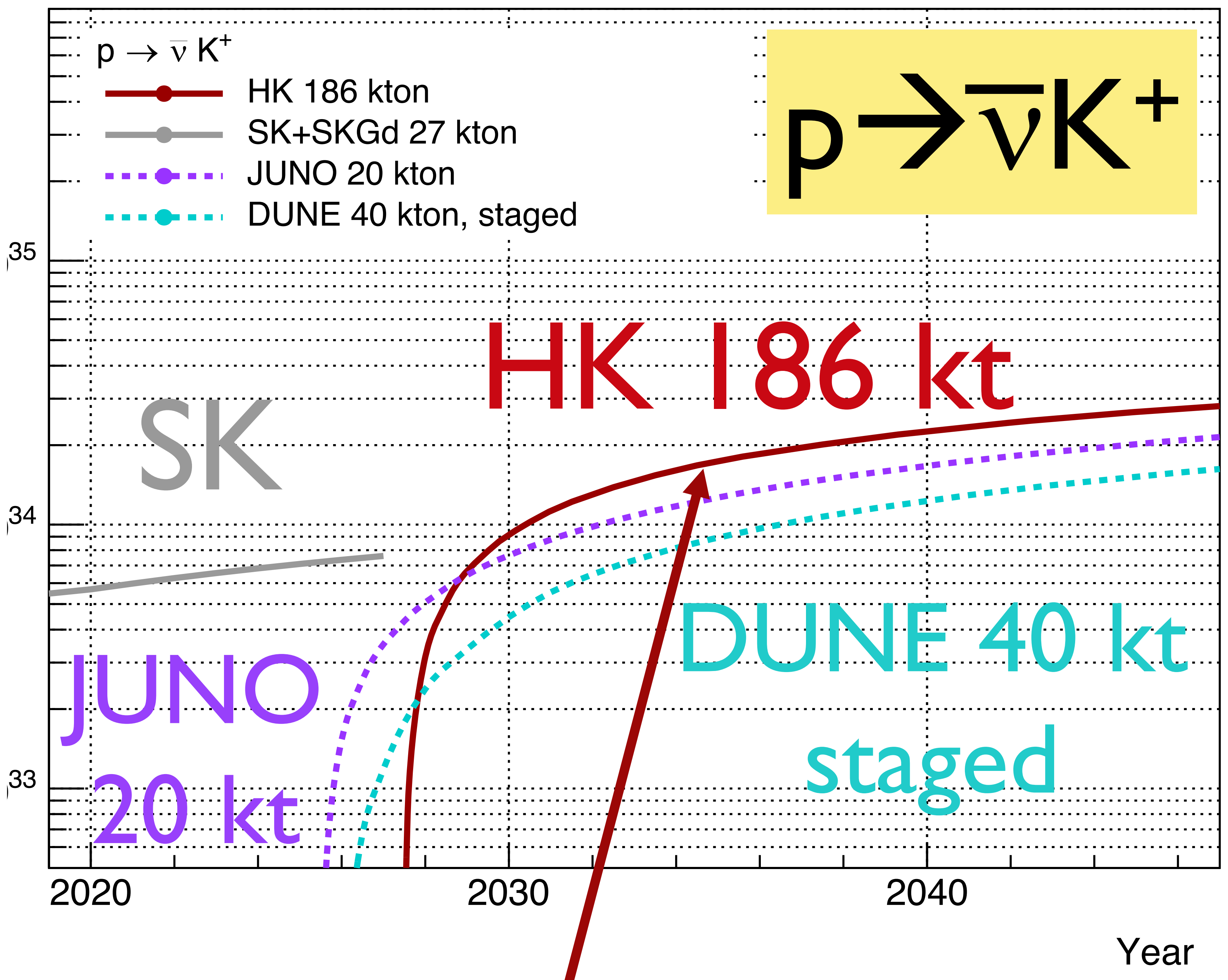
Background reduction is the key

- **Optimization of spallation cut**
  → Energy threshold?
- **Neutron tagging with 2.2MeV γ**

Proton decay

Fiducial volume is 8 times larger than Super-K





3 sigma discovery potential

HK 10 years sensitivity:

~ 6 x 10^{34} years

~ 2 x 10^{34} years

Detector construction

Time line

2025 Construction of Tank Liner

2026 Installation of PMTs and Electronics

2027 Operation starts

Excavation

Complete in 2025

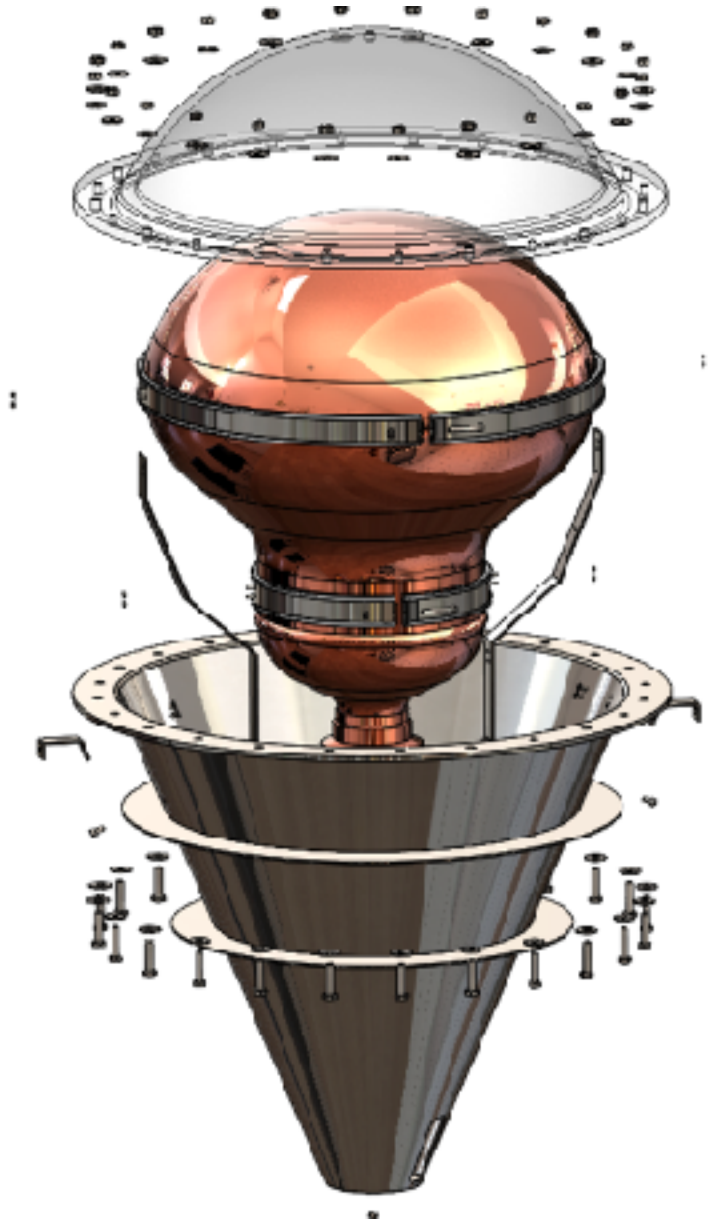
Tank construction

Mock up test for the support structure

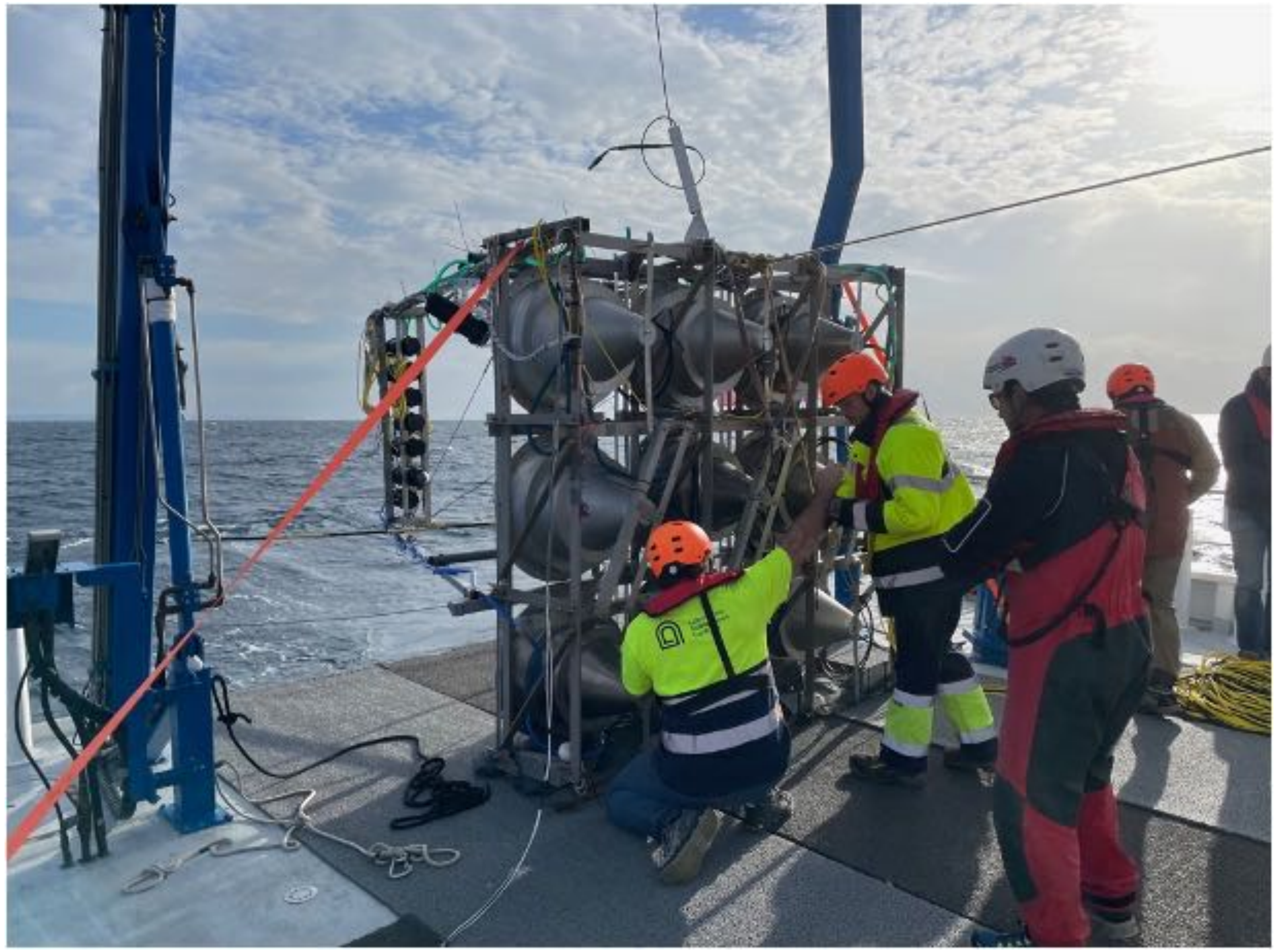
20 inch PMT

- Purchased ~13000 PMTs so far.
- Screening test is on going for the confirmation that the quality does not depend on the production period.
- Total 20,500 PMTs will be available by Sep. 2026.
- Long term measurement is underway to calculate the failure rate of PMTs, with 100PMTs in operation for six months.

Cover for 20 inch PMT

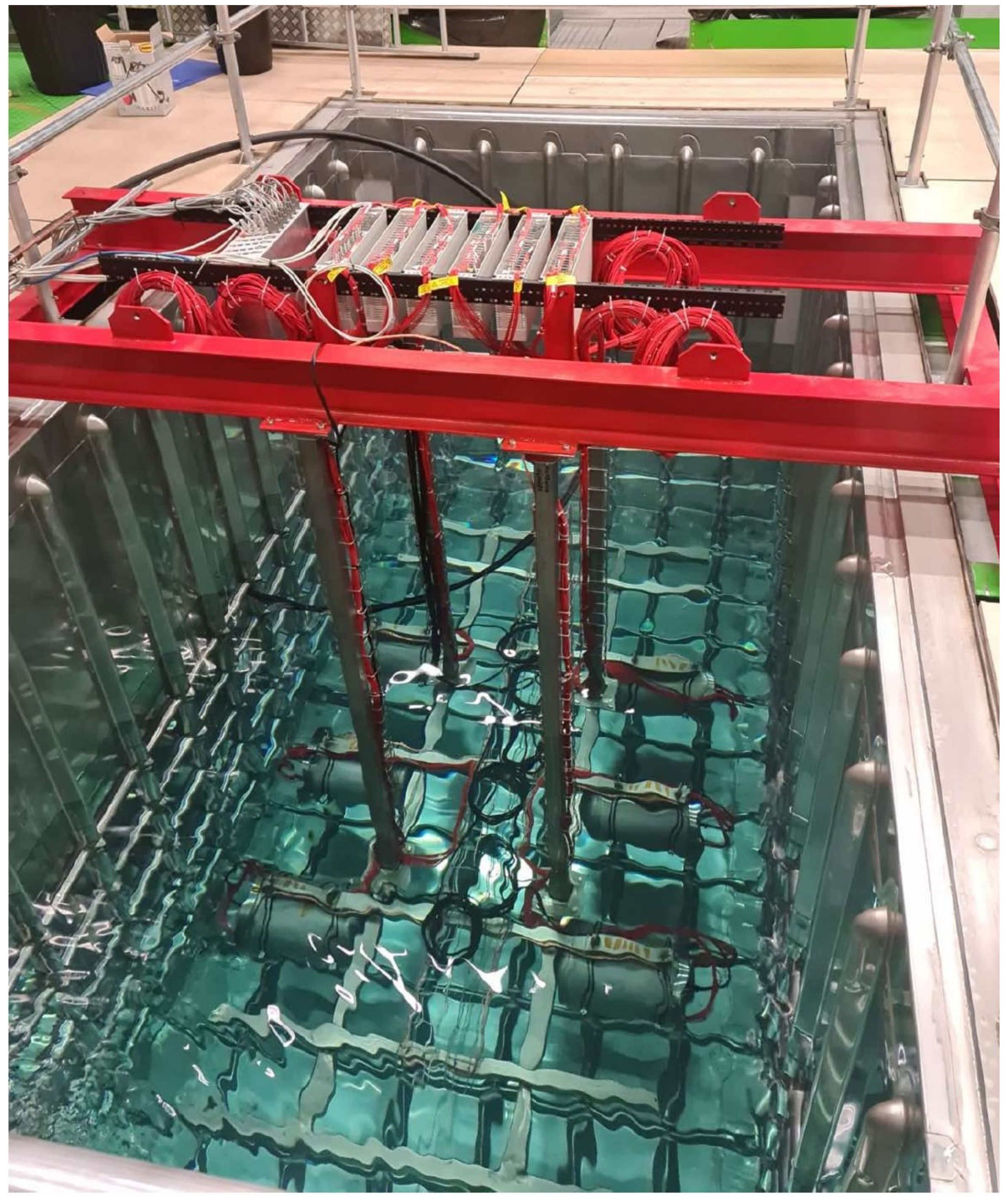


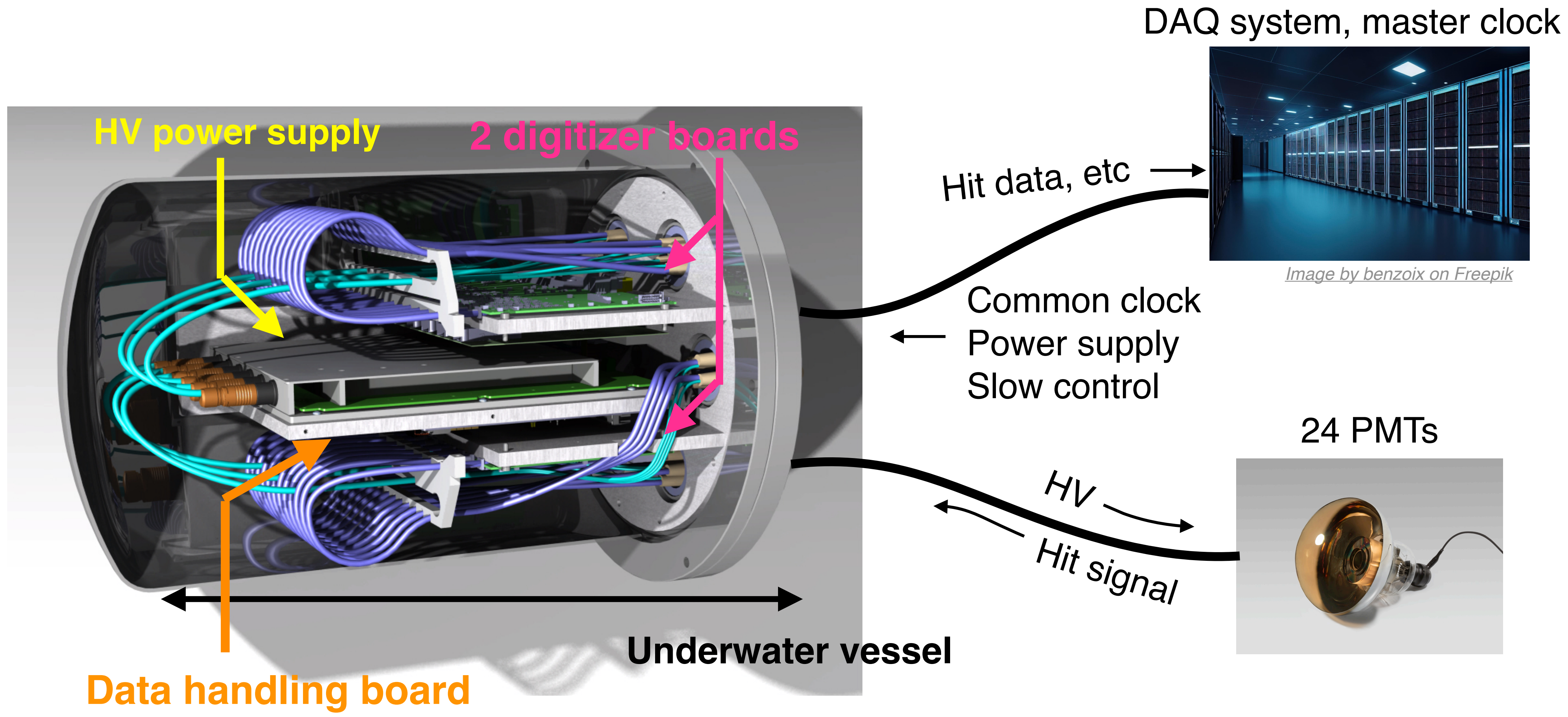
- If a PMT is damaged, chain implosion could lead to the loss of most of the PMTs. The cover prevents chain implosion.
- Developed in cooperation with Japan and Spain.
- Demonstrated capability to prevent chain implosion in this January.
- Production will start within this year.
- PMT and cover assembly workflow will also be established in cooperation with Japan and Spain.

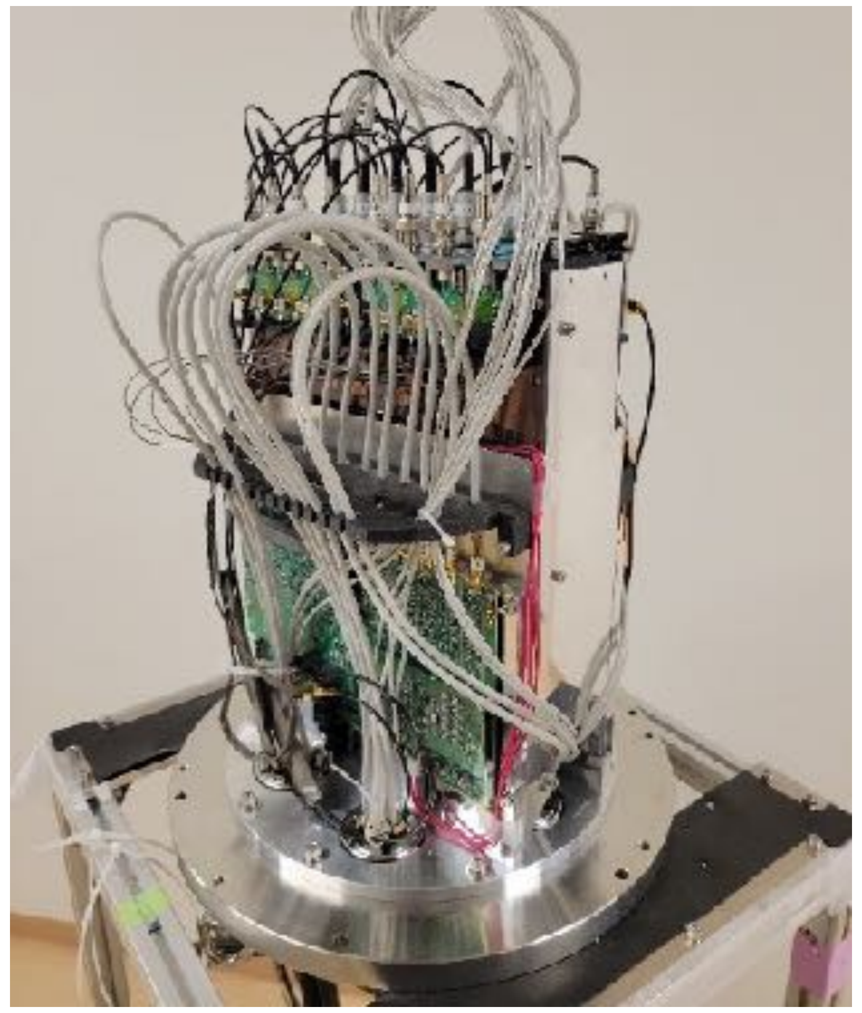


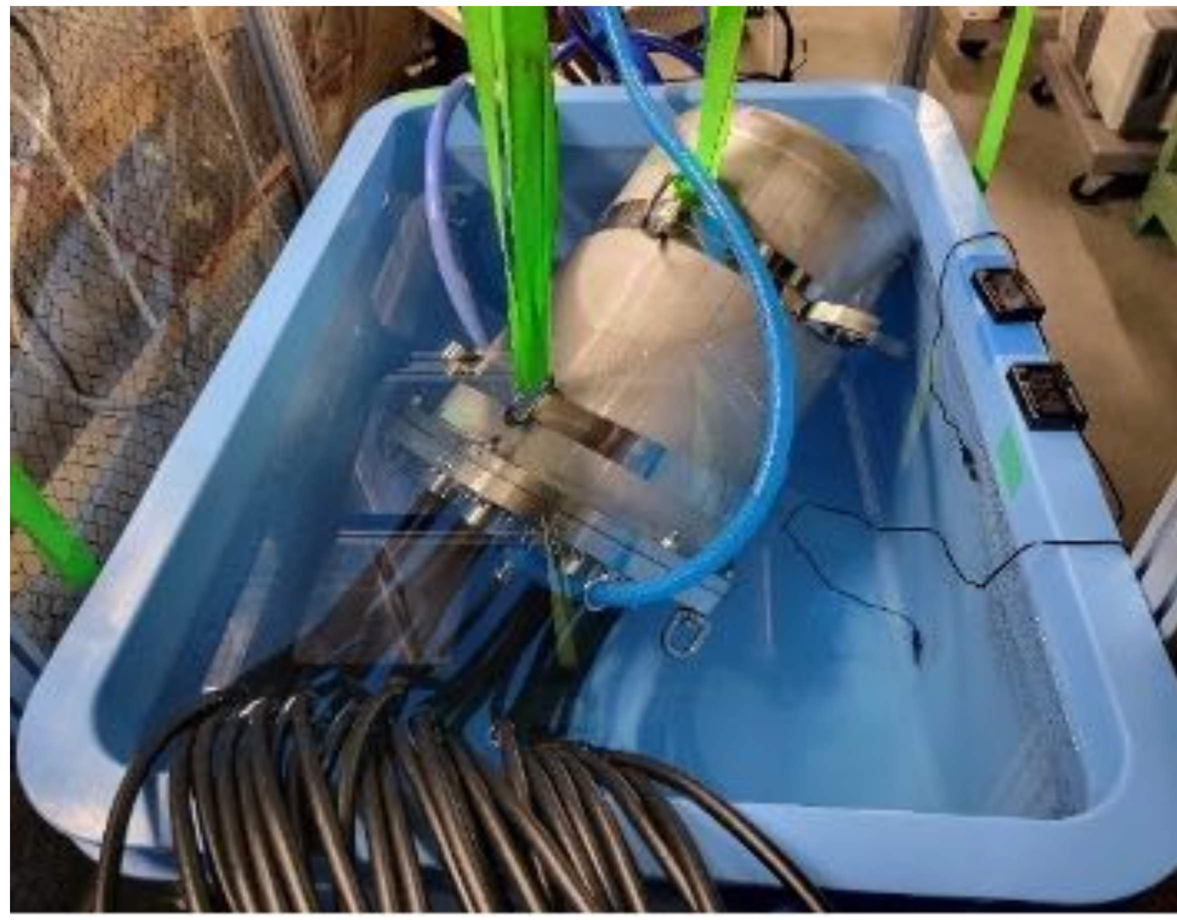
Electronics

- Front-end electronics placed in underwater vessel.
- Development shared among 8 countries.
- Working on a system test in/out of the water.
- Design will be finalized within this fiscal year.









Hyper-K

Summary

- Hyper-Kamiokande is a next generation of multi-purpose water Cherenkov detector and will play a central role in particle and astro physics.
  - Neutrino oscillation : CP violation in lepton sector by long baseline neutrino experiment, mass ordering by atmospheric neutrinos, precise validation of MSW effect by solar neutrinos, and so on.
  - Neutrino astronomy : Supernova neutrinos; from explosion in nearby galaxy, from explosions around Mpc, and diffuse neutrinos from past explosions.
  - Nucleon decay, indirect dark matter, etc.
- Construction is currently underway. We are making our best efforts to start operation.

Stay tuned!