Hyper-Kamiokande project update

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The University of Tokyo, Department of Physics &

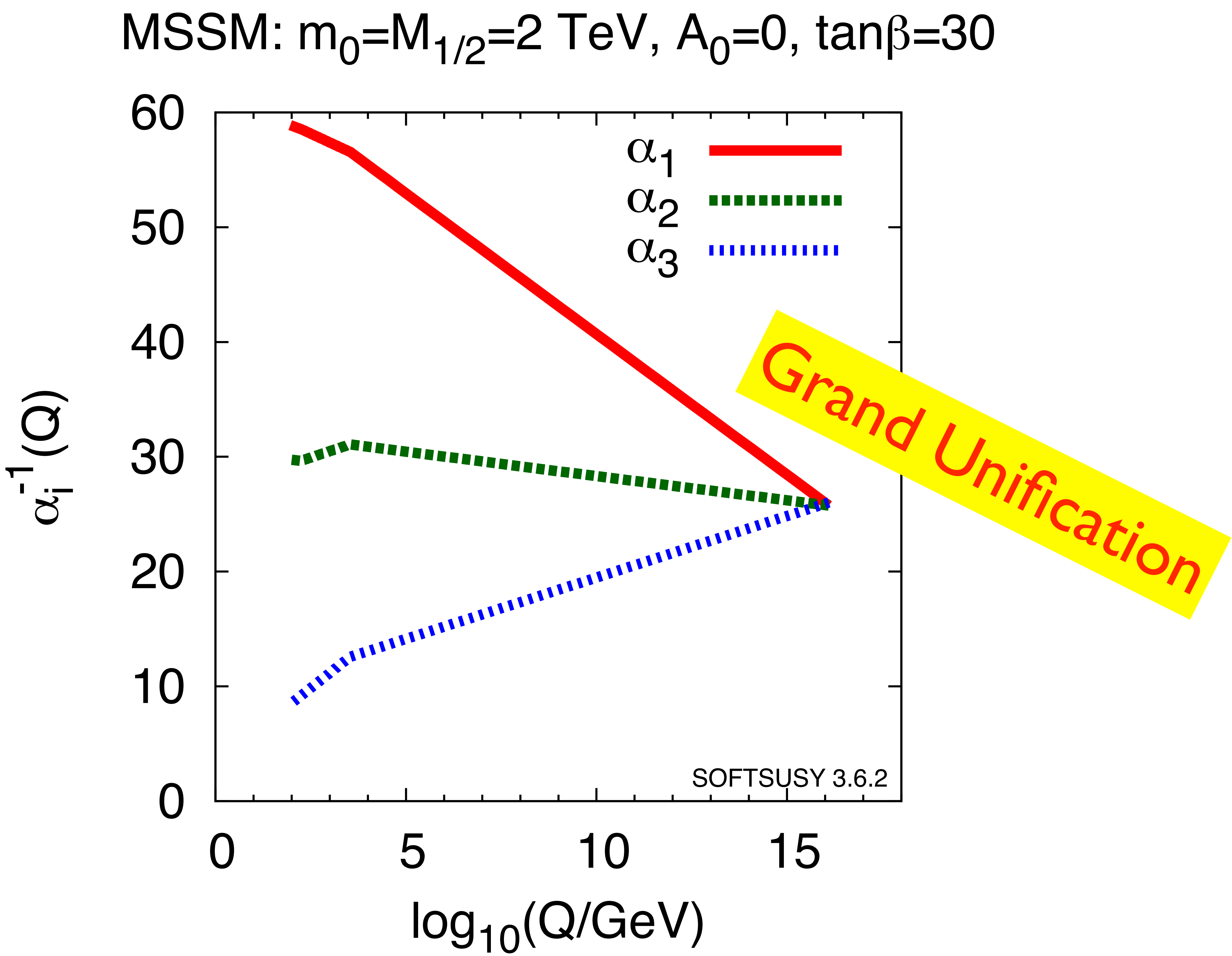
Next-generation Neutrino Science Organization &

Kavli Institute for Physics and Mathematics of Universe

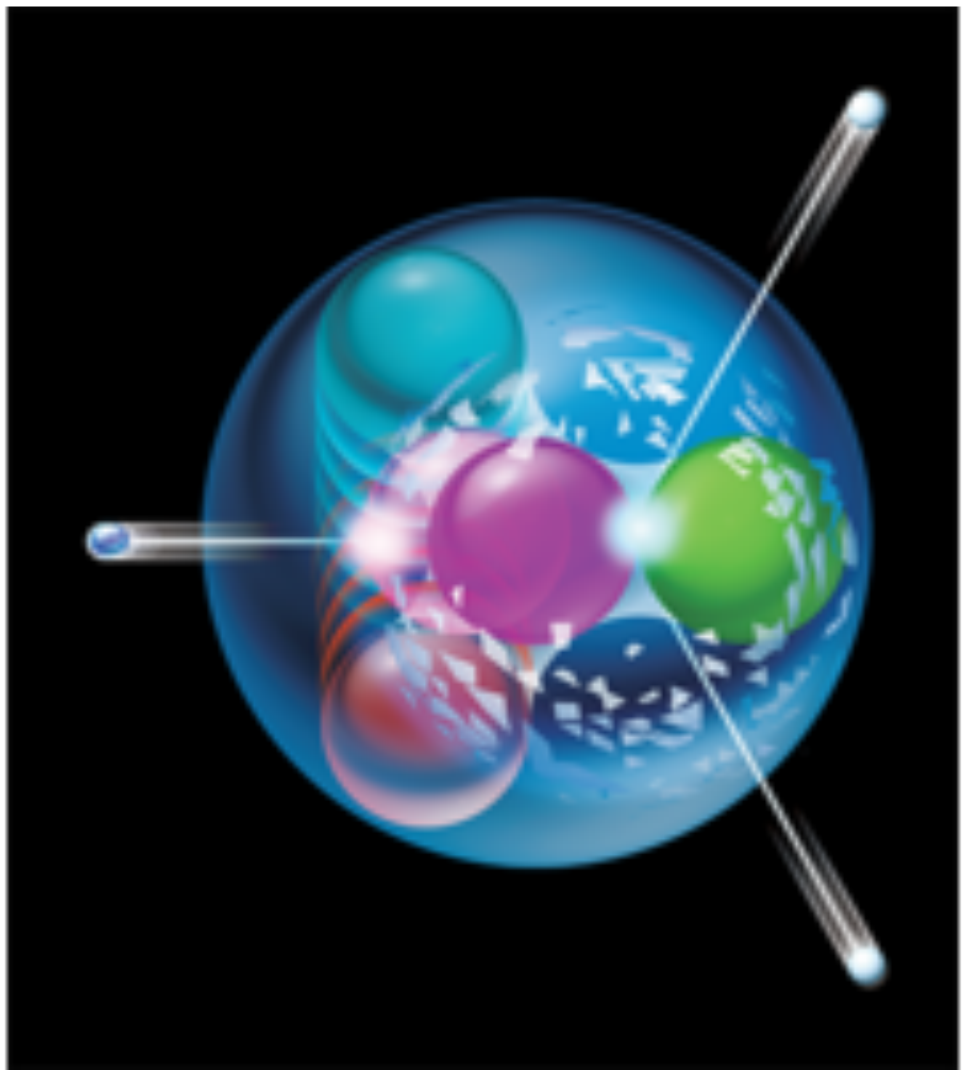
The Future of Particle Physics: A Quest for Guiding Principles

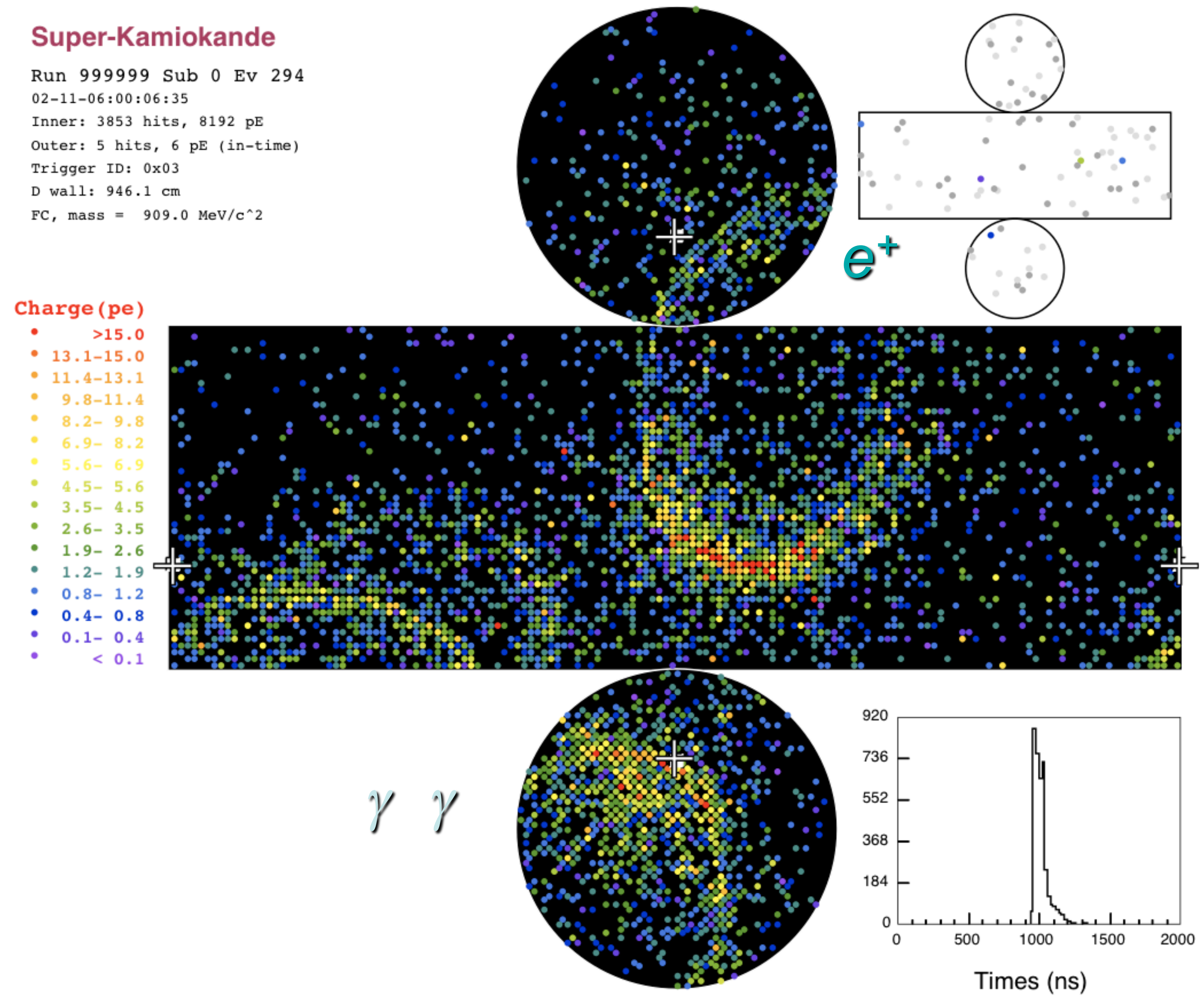
October 1, 2018 Karlsruhe Institute of Technology

One of guiding principles



Direct probe of Grand Unification



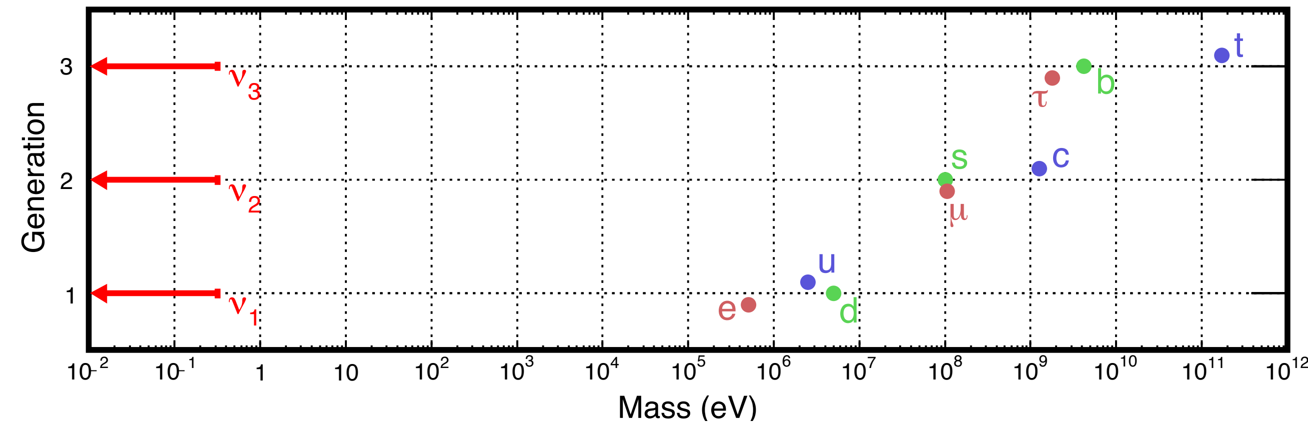


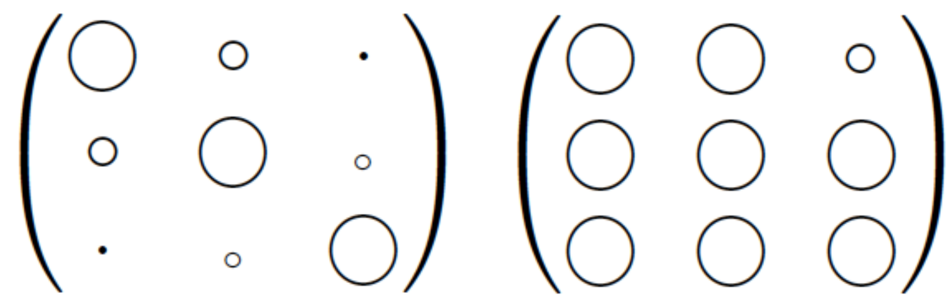
Neutrino oscillation

Evidence for New Physics Beyond SM

Origin of tiny mass

- Majorana mass?
  - Existence of Majorana particle
- Pure Dirac mass?
  - Symmetry to forbid Majorana mass?
  - Origin of tiny Yukawa coupling
- Right handed neutrino must exist:
  even no weak interaction, new kind of particle





CKM MNS

Very different mixing from quarks

- Implications to Grand Unification?
- What is the origin of the generations? *(who ordered that?)*

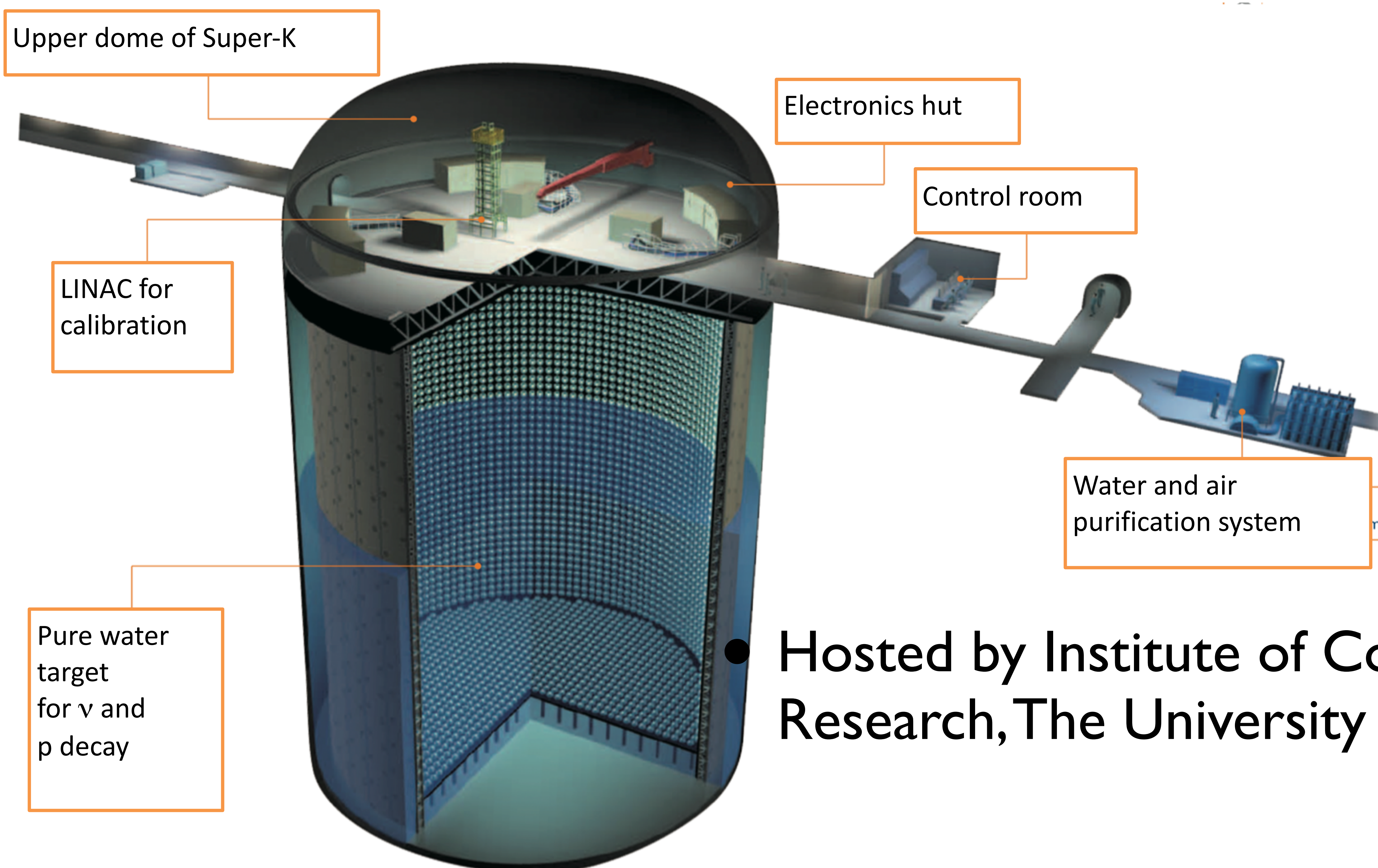
CP violation

- Origin of baryon asymmetry in the Universe

See later talks

Super-Kamiokande

- 50kton (22.5kton fiducial) water Cherenkov detector
- Leading nucleon decay and neutrino physics since 1996



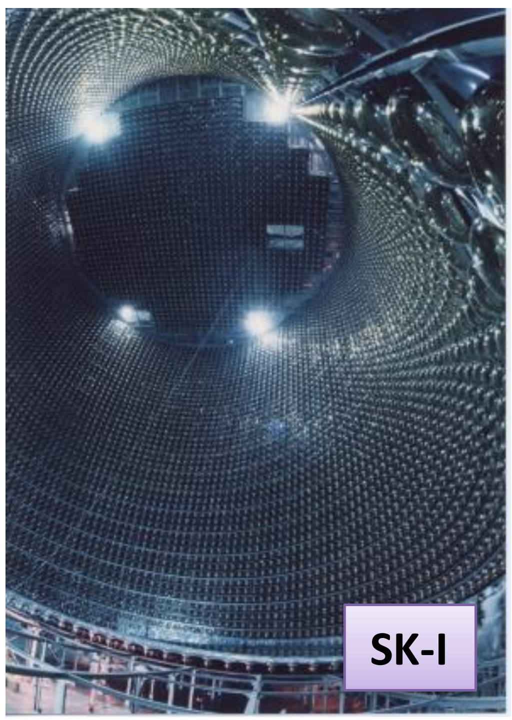
- Hosted by Institute of Cosmic Ray Research, The University of Tokyo

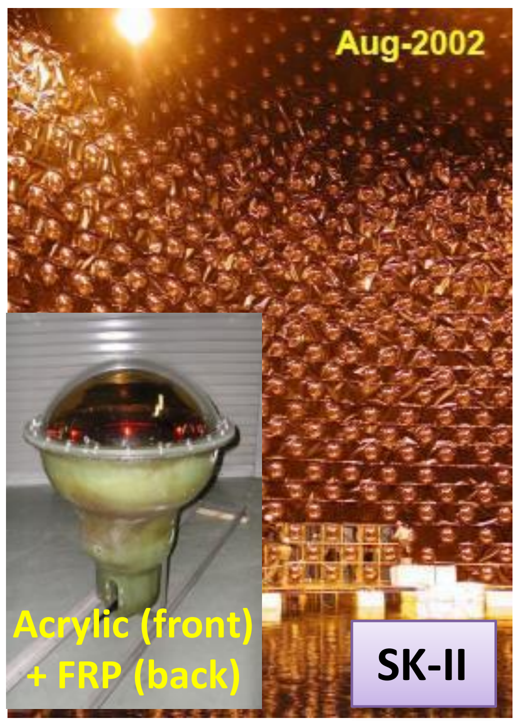
History & Plan of Super-Kamiokande

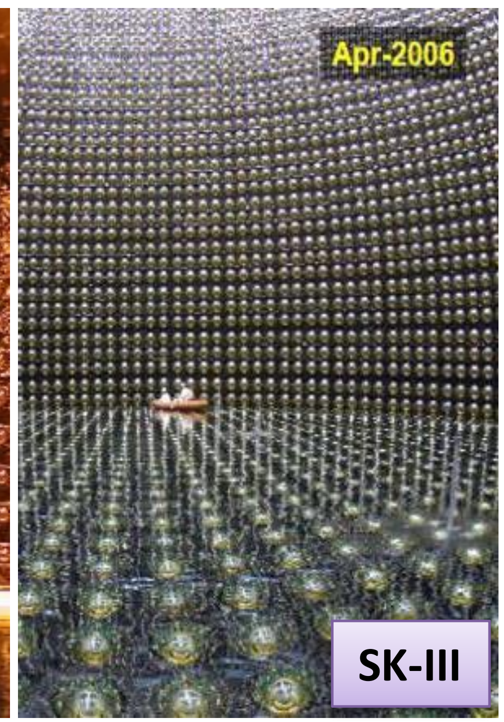
NOW

96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19

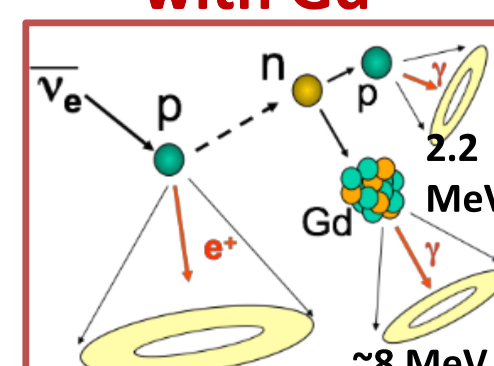
SK-I SK-II SK-III SK-IV Start upgrade for SK-Gd







SK-I	SK-II	SK-III	SK-IV	SK-Gd
11146 ID PMTs (40% coverage)	5182 ID PMTs (19% coverage)	11129 ID PMTs (40% coverage)	Electronics Upgrade	Neutron tagging with Gd
4.5 MeV	6.5 MeV	4.5 MeV	3.5 MeV	
1496 days	791 days	548 days	2860 days	



- Analysis energy threshold (recoil electron kinetic energy)
- Live time for solar neutrino analysis

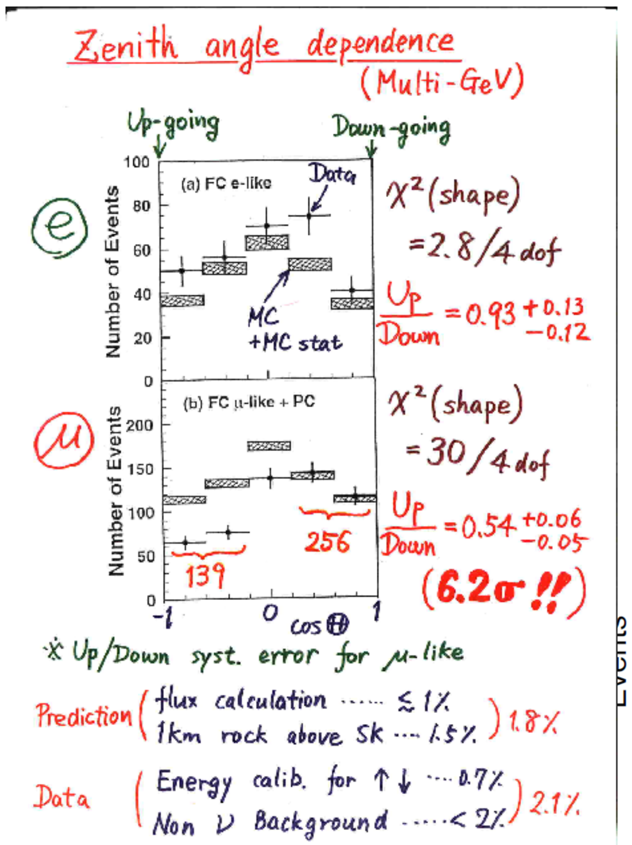
Current total: 5695 days

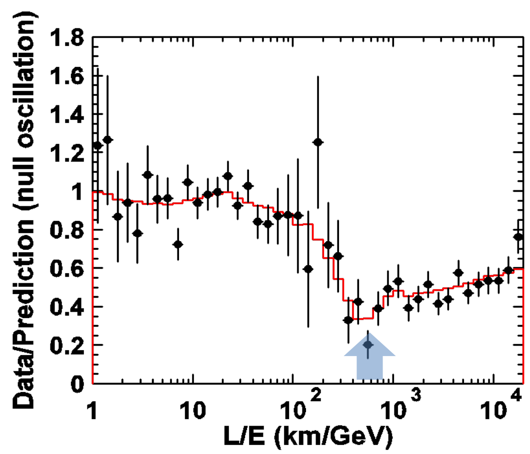
Y.Takeuchi, TMEX2018

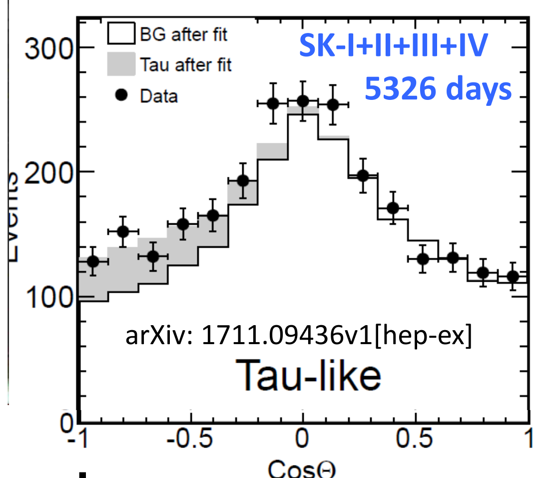
Achievements over >20 years

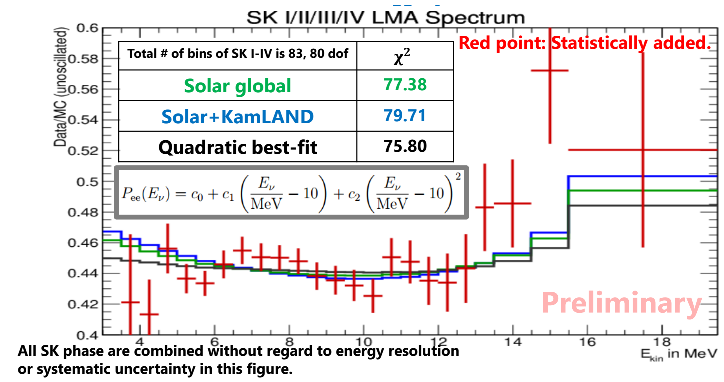
Discovery and measurements of oscillations with atmospheric, solar, and beam neutrinos

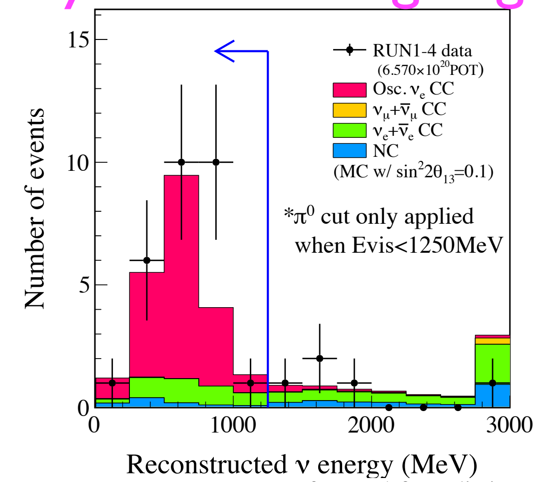
Crucial contributions for discovery of all mixing angles

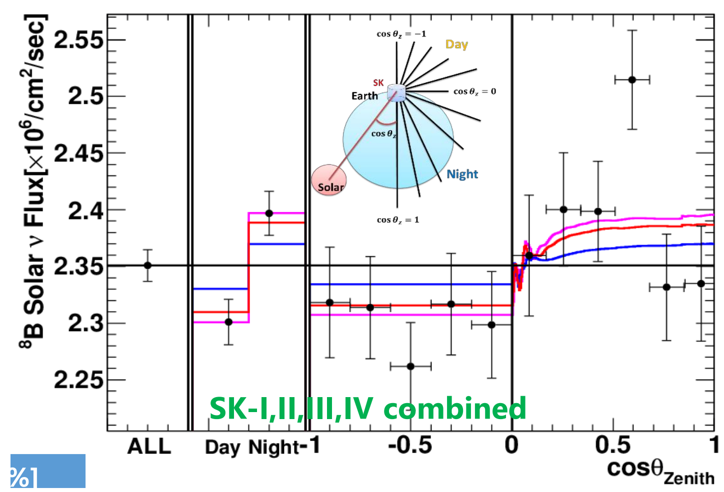


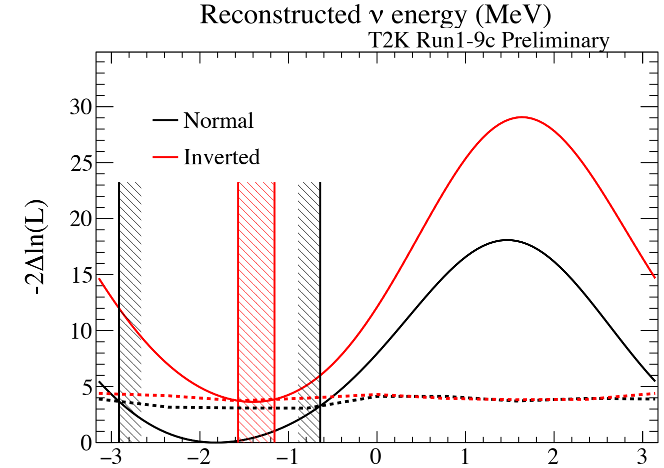






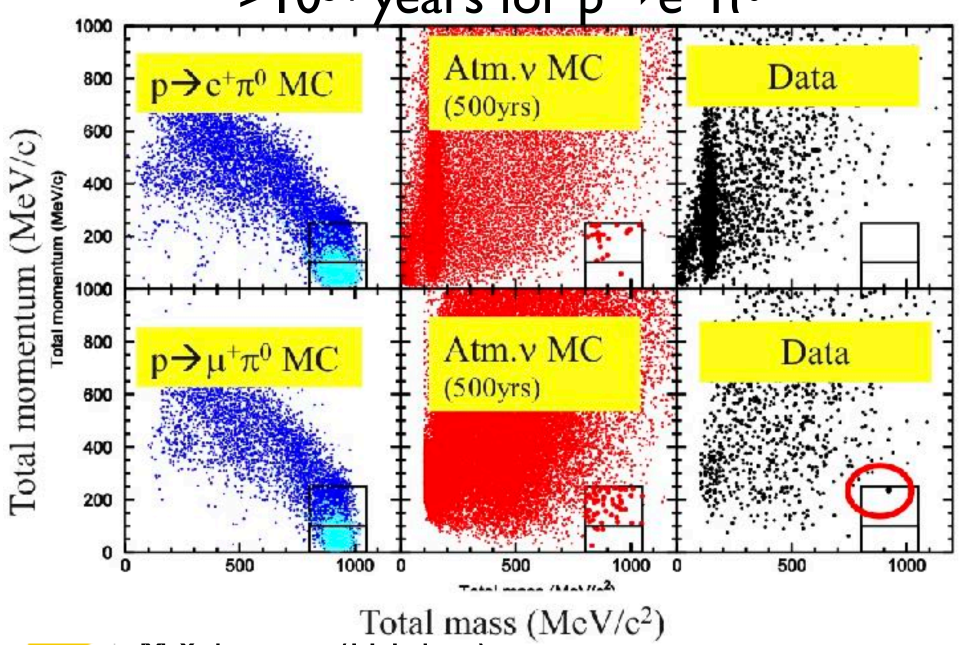




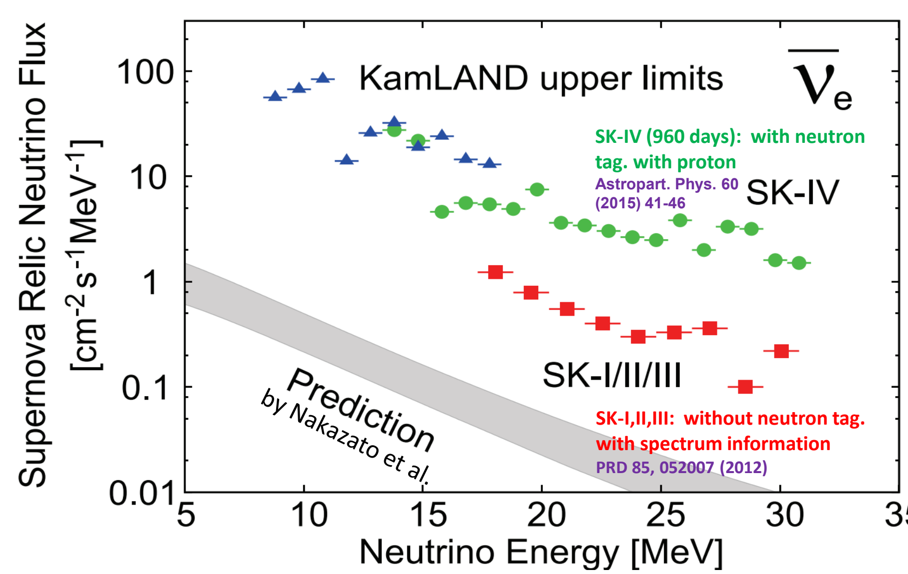


Searches for nucleon decays

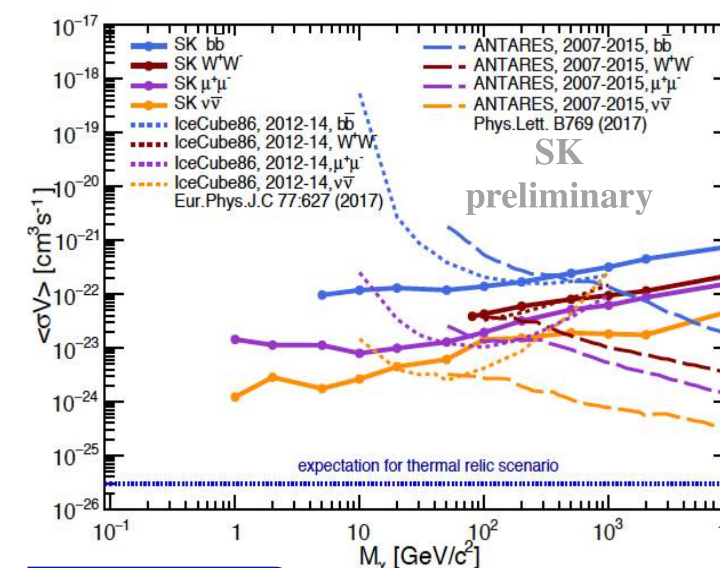
>10^{34} years for $p\rightarrow e^+\pi^0$



Relic SN ν search

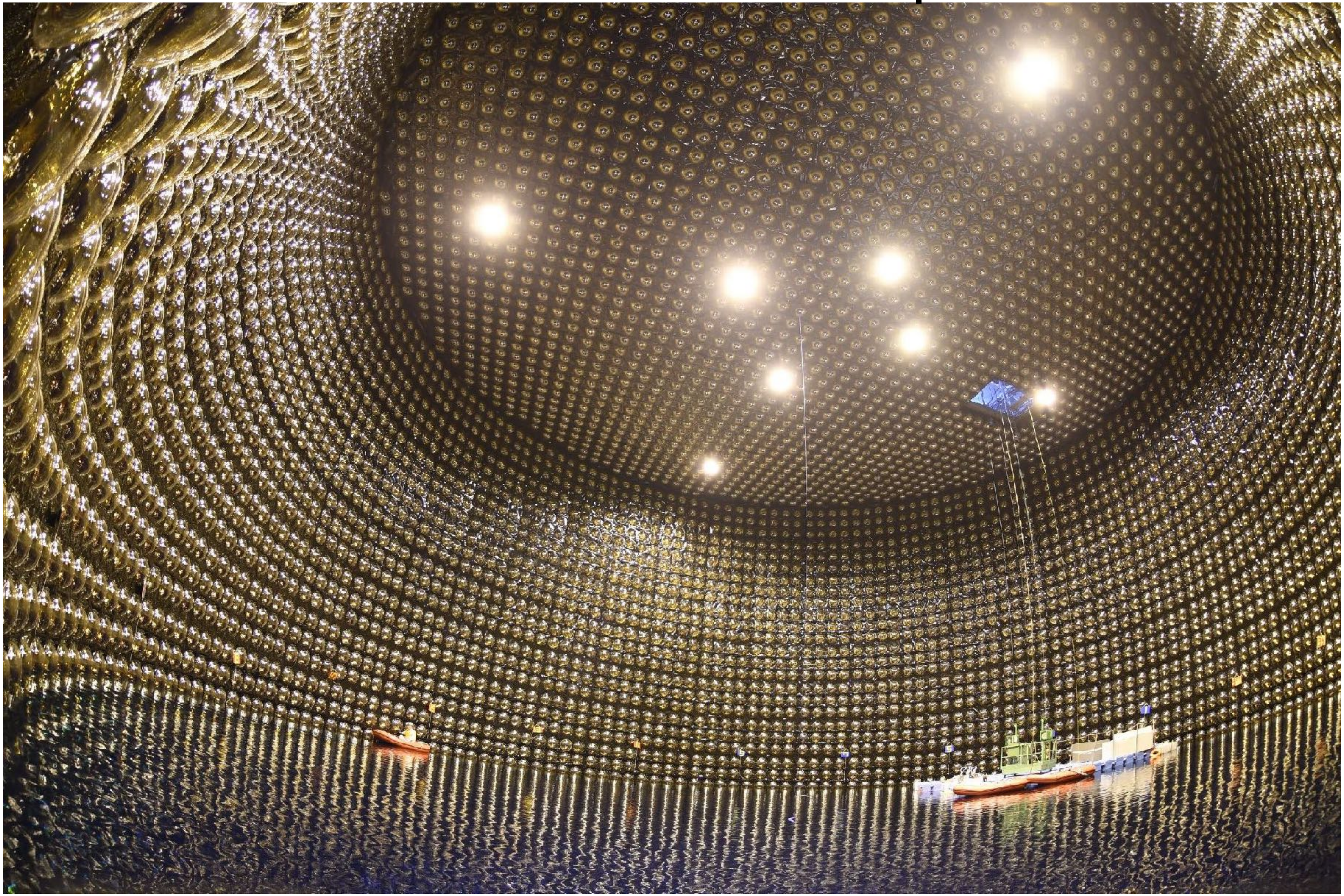


Indirect DM searches



Super-K refurbishment work in 2018

Preparation for SK-Gd



Will be back online by the end of 2018

Super-K refurbishment work in 2018

Preparation for SK-Gd

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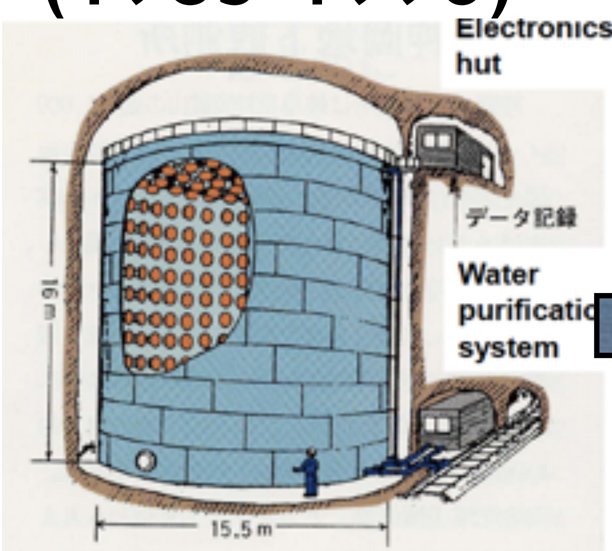
Another principle: *Three Generations*

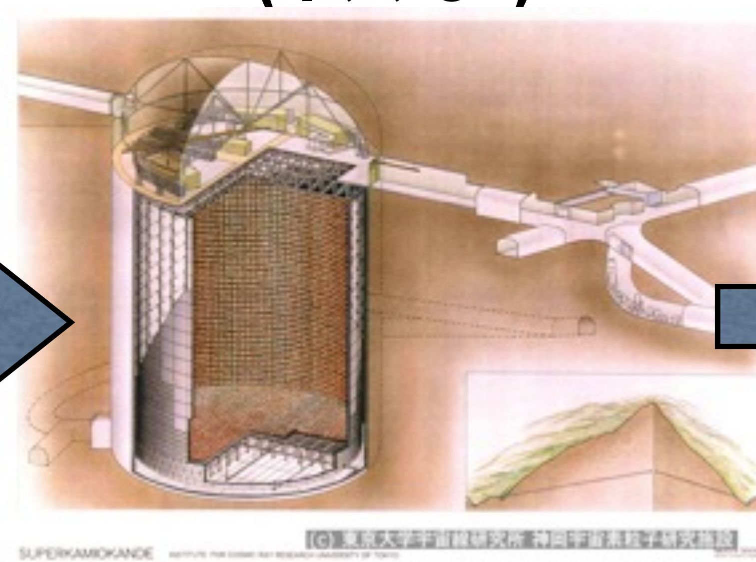
Kamioka"NDE"

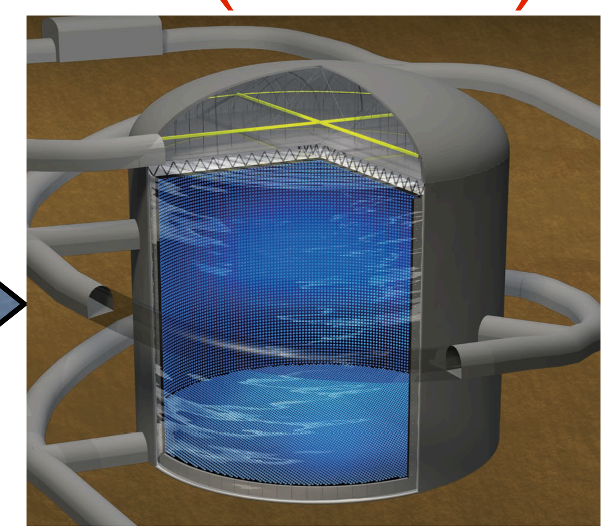
Nucleon Decay Experiment

Neutrino Detection Experiment

Kamiokande (1983-1996)	Super-Kamiokande (1996-)	Hyper-Kamiokande (~2027-)



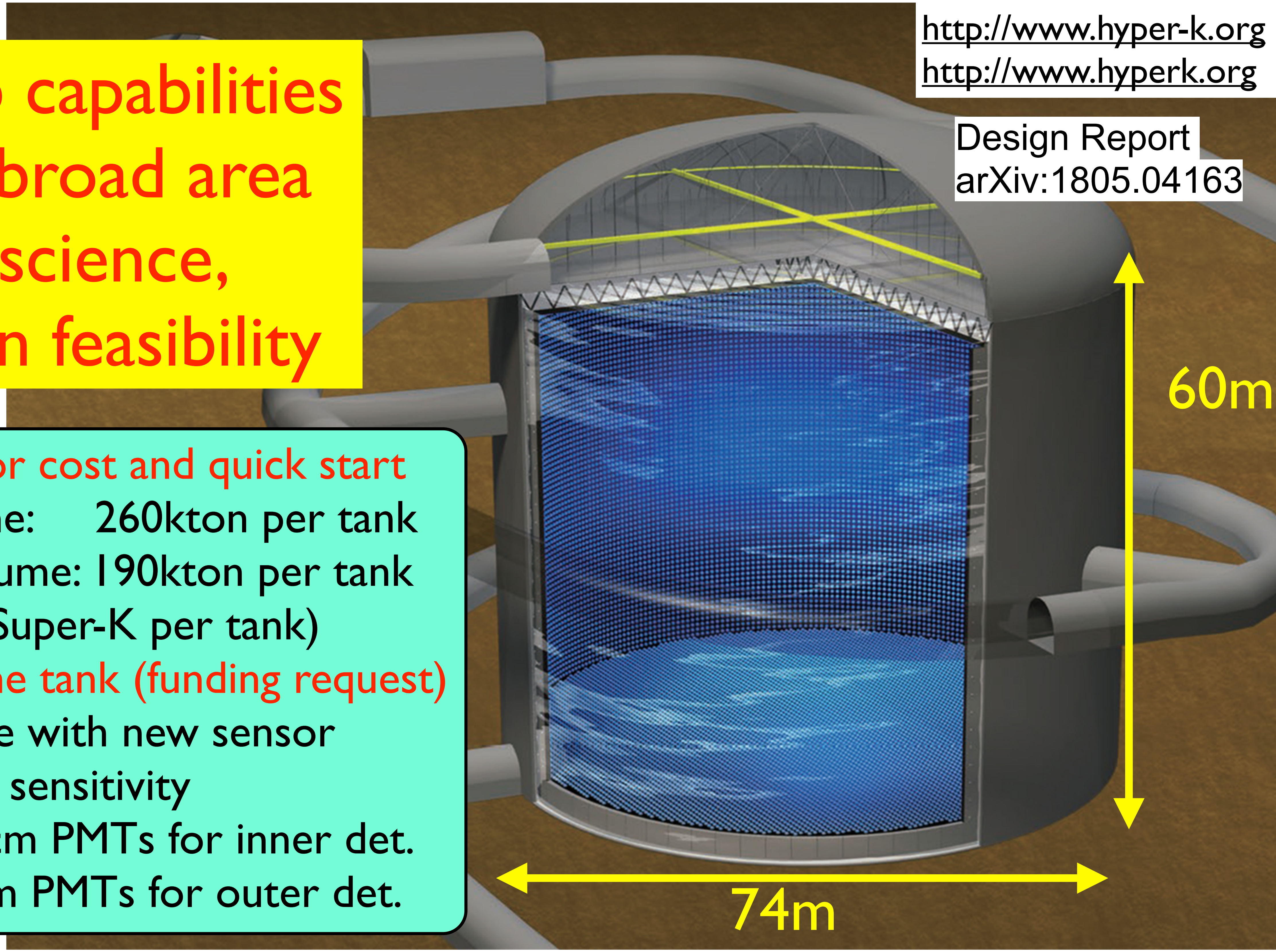




3kton	50k(22.5k)ton	260k(190k)ton
20% coverage with 50cm PMT	40% coverage with 50cm PMT	40% coverage with high-QE 50cm PMT

The Hyper-Kamiokande detector

superb capabilities for a broad area of science, proven feasibility



Optimized for cost and quick start

Total volume: 260kton per tank
Fiducial volume: 190kton per tank
(~×10 of Super-K per tank)

Start with one tank (funding request)

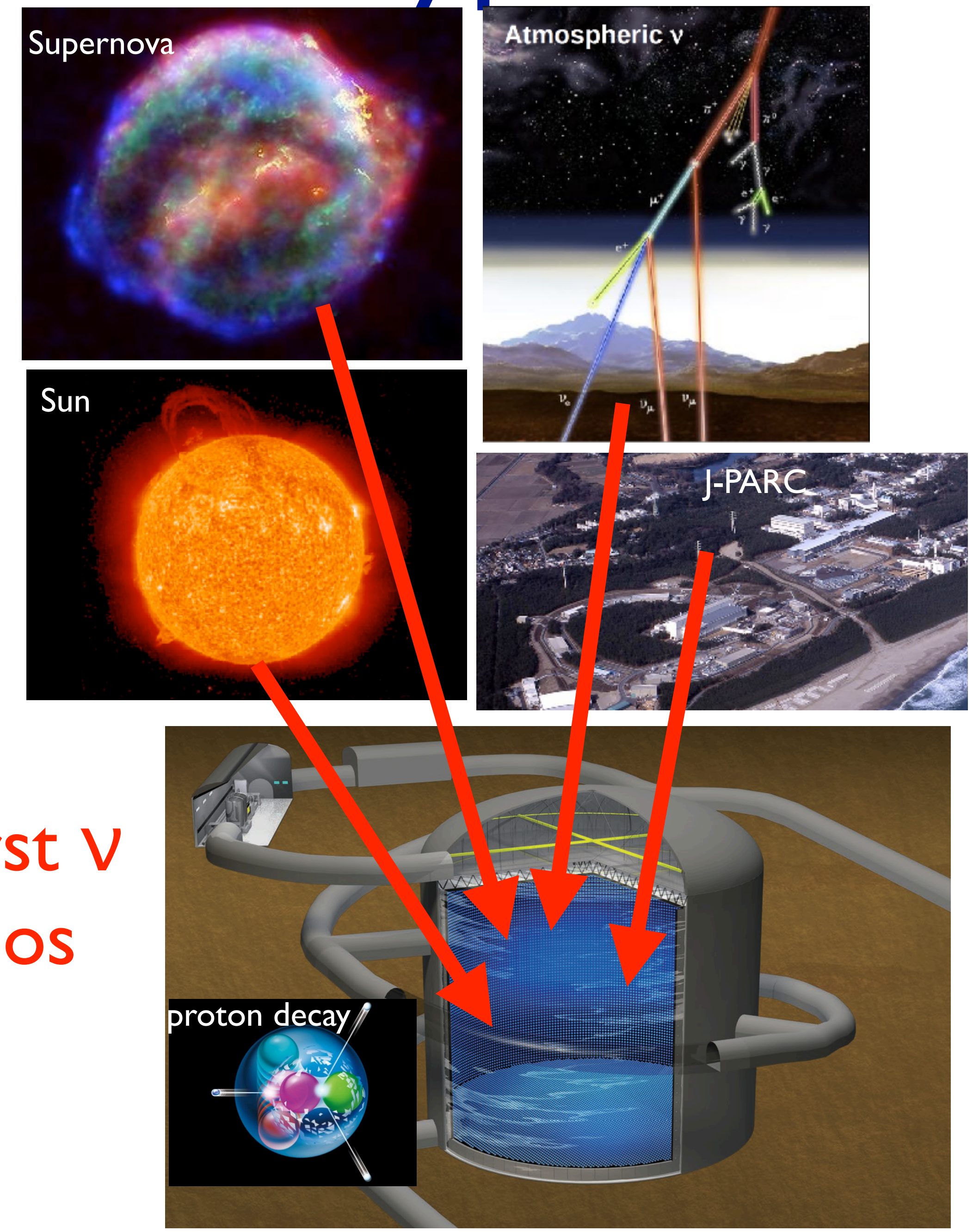
40% coverage with new sensor
×2 photon sensitivity
~40,000 50cm PMTs for inner det.
~6,700 20cm PMTs for outer det.

Well proven, scalable technique

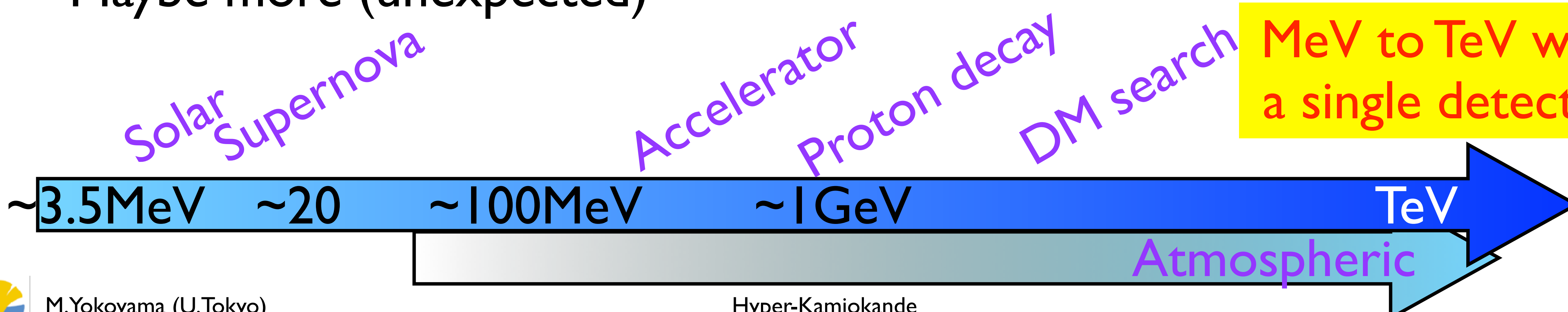
- Feasibility of ~Mton size detector confirmed with various studies over past decade
  - >20 years of experience with Super-Kamiokande
- Yet many challenges to realize full capabilities

Broad science program with Hyper-K

- **Neutrino oscillation physics**
  - Comprehensive study with beam and atmospheric neutrinos
- Search for **nucleon decay**
  - Possible discovery with ~×10 better sensitivity than Super-K
- **Neutrino astrophysics**
  - Precision measurements of solar ν
  - High statistics measurements of SN burst ν
  - Detection and study of relic SN neutrinos
- Geophysics (neutrino oscillography of interior of the Earth)
- Maybe more (unexpected)

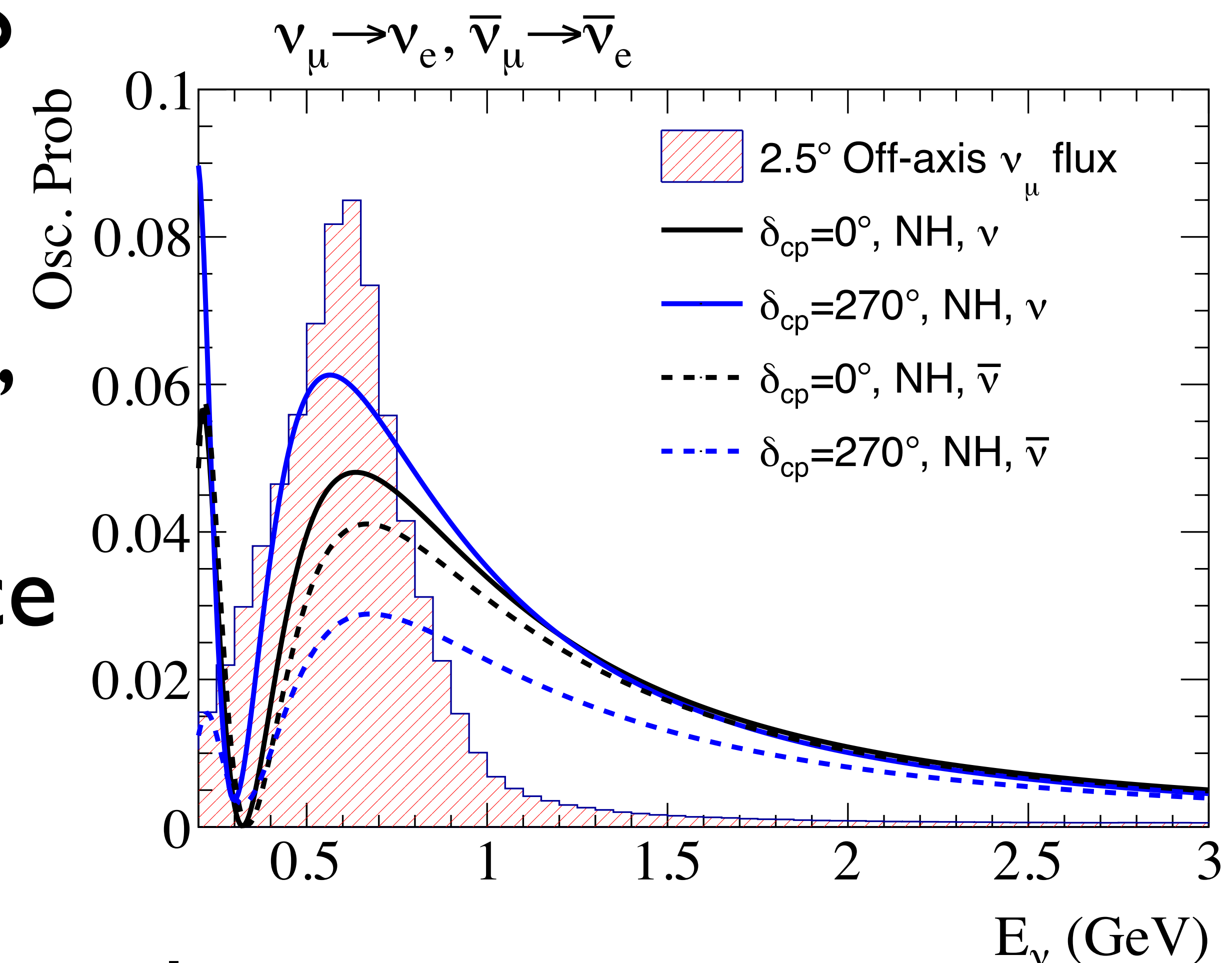


MeV to TeV with a single detector



Measuring CP violation in lepton sector

- CPV effect in standard MNS framework ~±27% max
  (at the first oscillation maximum)
- For a definite measurement, need O(1000) events for each of ν_e and $\bar{\nu}_e$ appearance
  - cf. current T2K data:
    89 ν_e and 7 $\bar{\nu}_e$



- Control of systematics is crucial
  - Huge effort by T2K has been improving our ability
    - Neutrino beam, interaction, and detector
    - Currently 6-7% for 1 ring $\nu_e/\bar{\nu}_e$
    - Improvement with T2K directly applicable to HK

Neutrino beam from J-PARC

The same beamline used for T2K
well understood

30GeV, 485kW in 2018

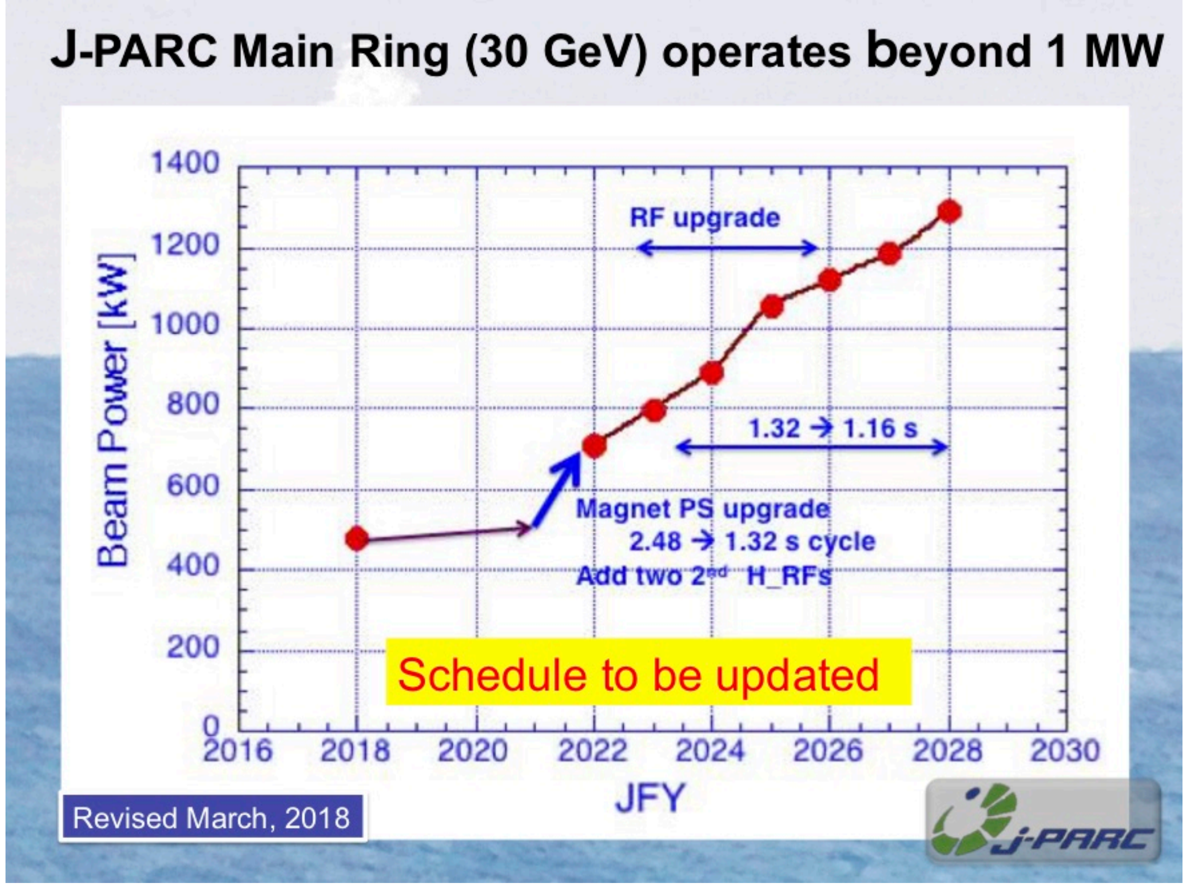
2.5×10^{14} protons/pulse (world record)

Beam Power (kW)	485 (Achieved)	(940)	1,300 (Goal for T2K-II)
#p/p(10^{12})	250	250	320
Rep T (s)	2.48	1.28	1.16

+25%

Funding started

-10%



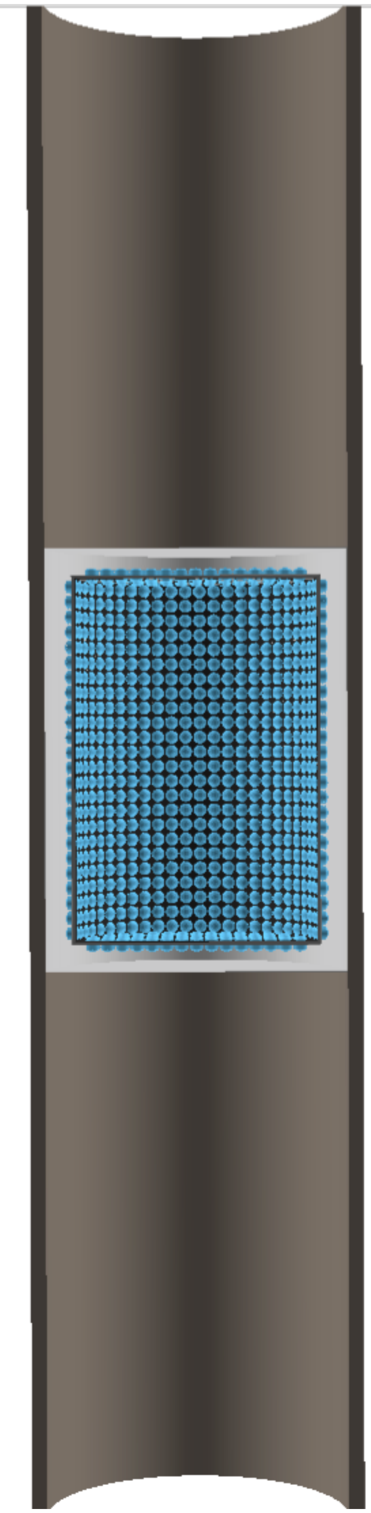
- Reduce rep. cycle with new power supplies
- Then, gradual improvements for >1.3MW

Upgrade of J-PARC for Hyper-K is the <u>highest priority</u> in KEK Project Implementation Plan

Near Detectors

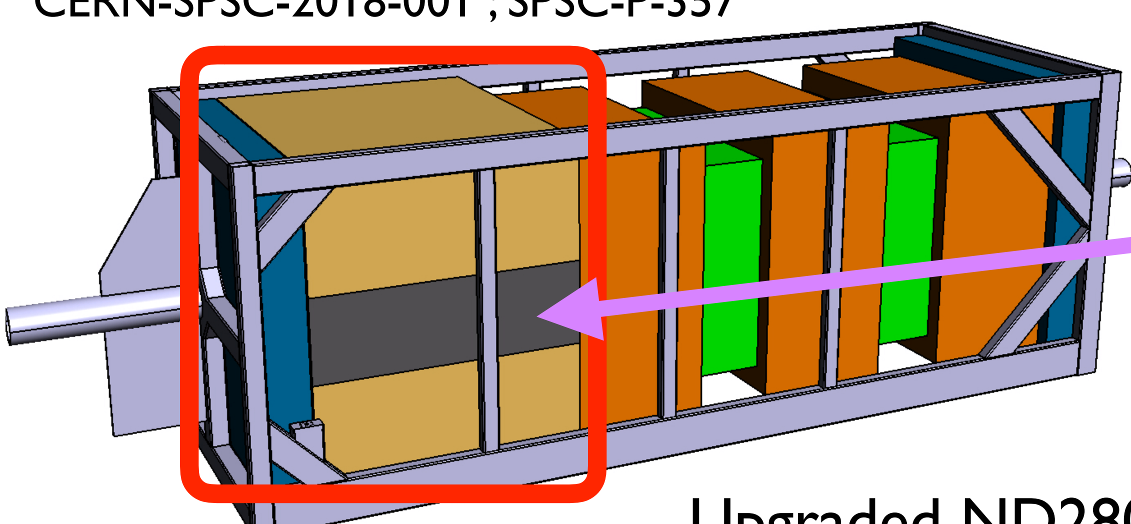
- Based on experience in T2K, with new ideas
- Upgraded ND280 off-axis detectors
  - Upgrade proceeding for T2K-II, installation in 2021
  - International effort including CERN
- Intermediate Water Cherenkov Detector at 1-2km from target also planned
  - Off-axis spanning, with Gd loading

IWCD



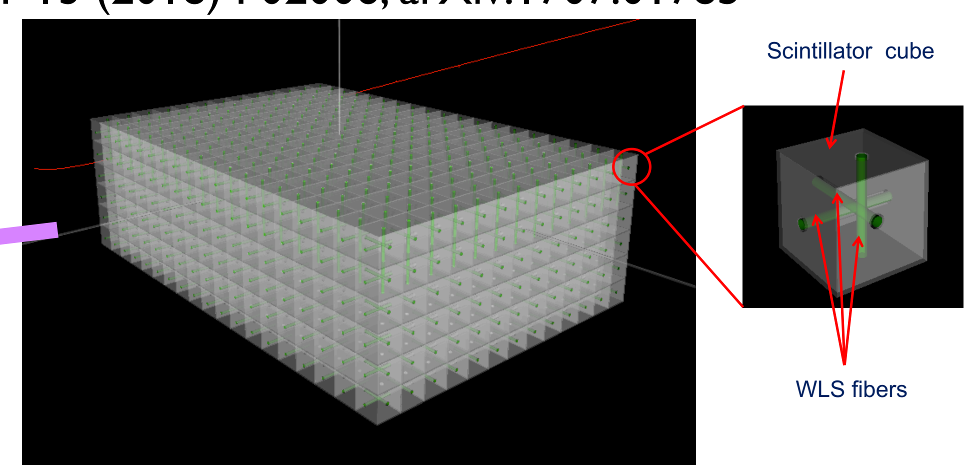
arXiv:1412.3086
arXiv:1606.08114

CERN-SPSC-2018-001 ; SPSC-P-357



Upgraded ND280

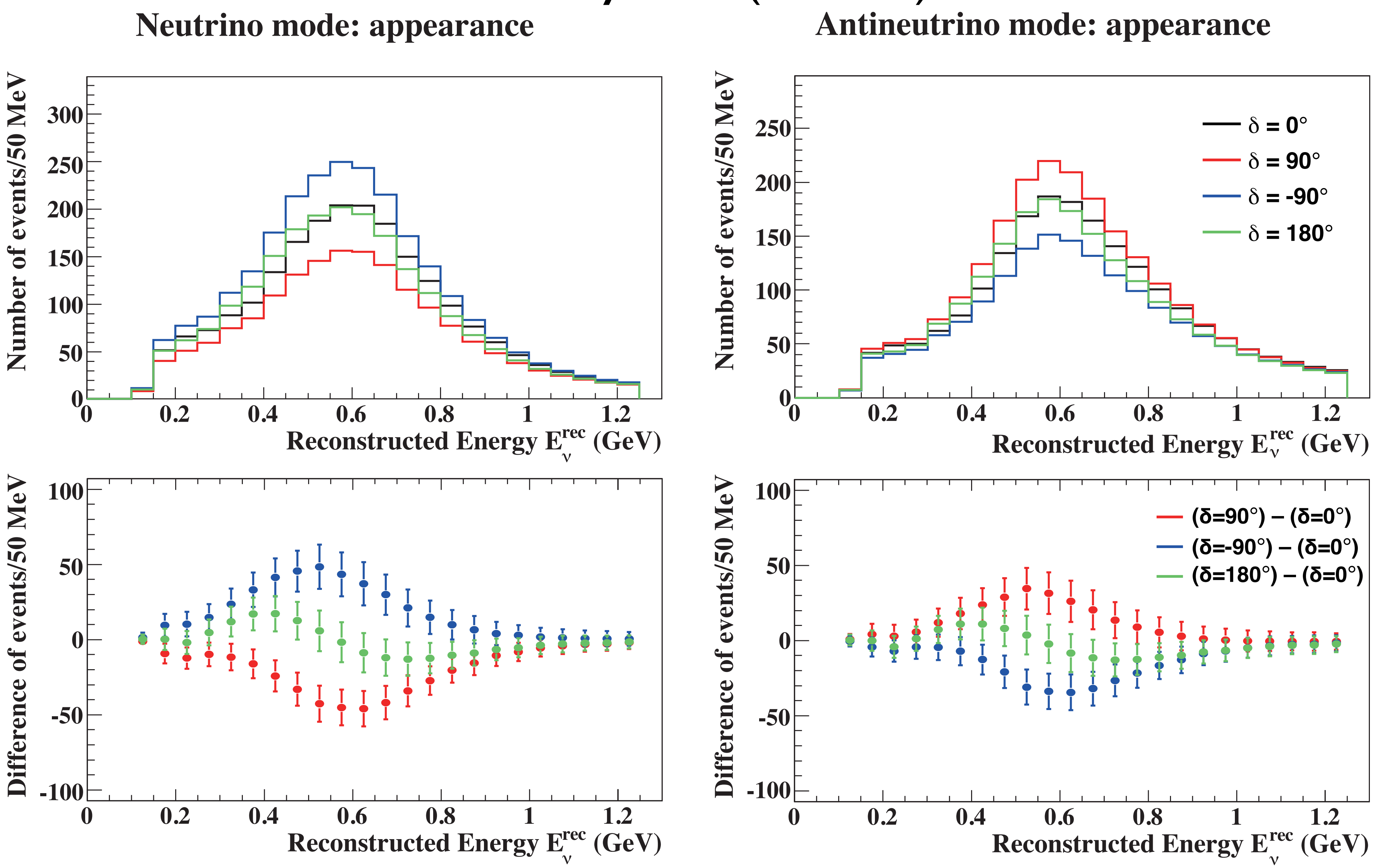
JINST 13 (2018) P02006, arXiv:1707.01785



SuperFGD target detector

Expected events at HK

For 1.3MW×10years (10^8sec), $\nu:\bar{\nu}$=1.3

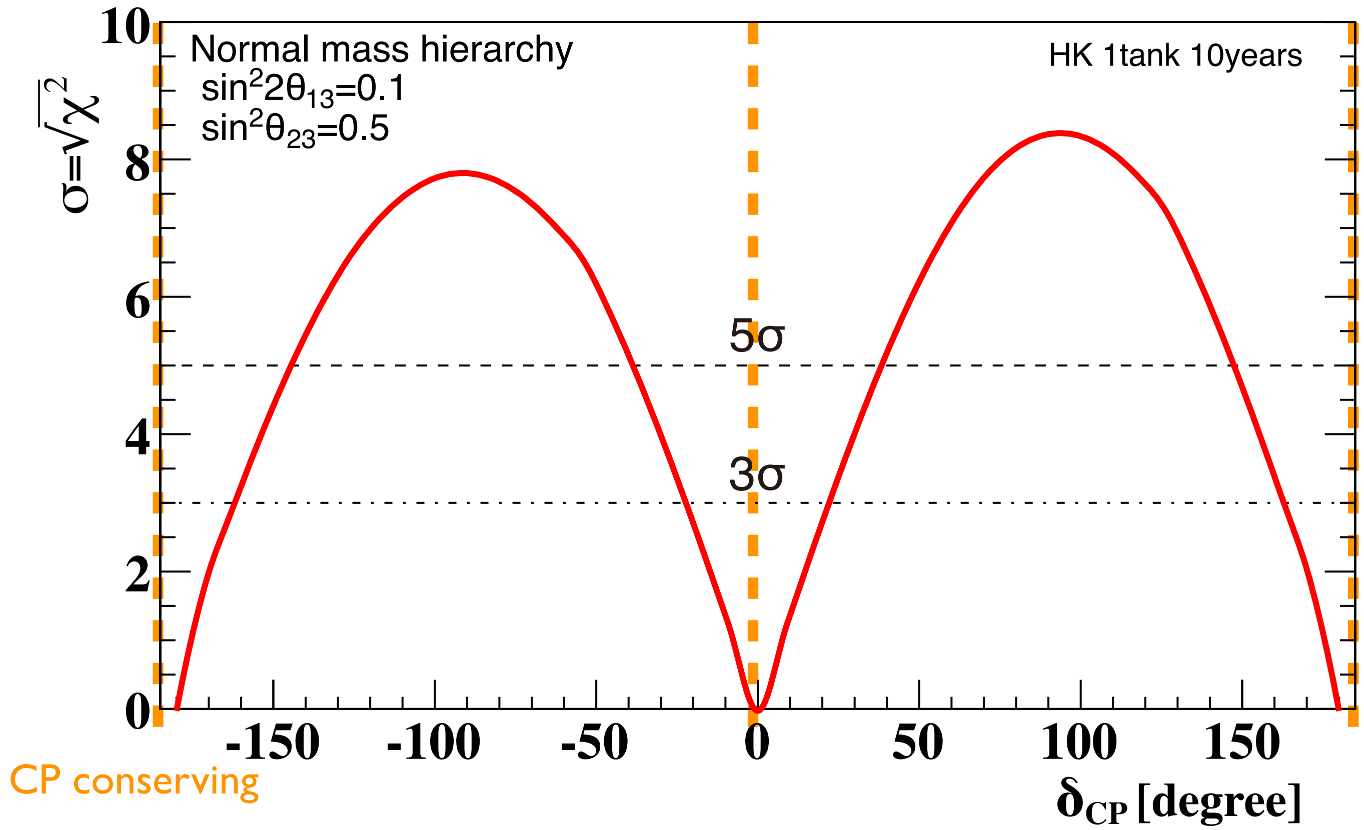


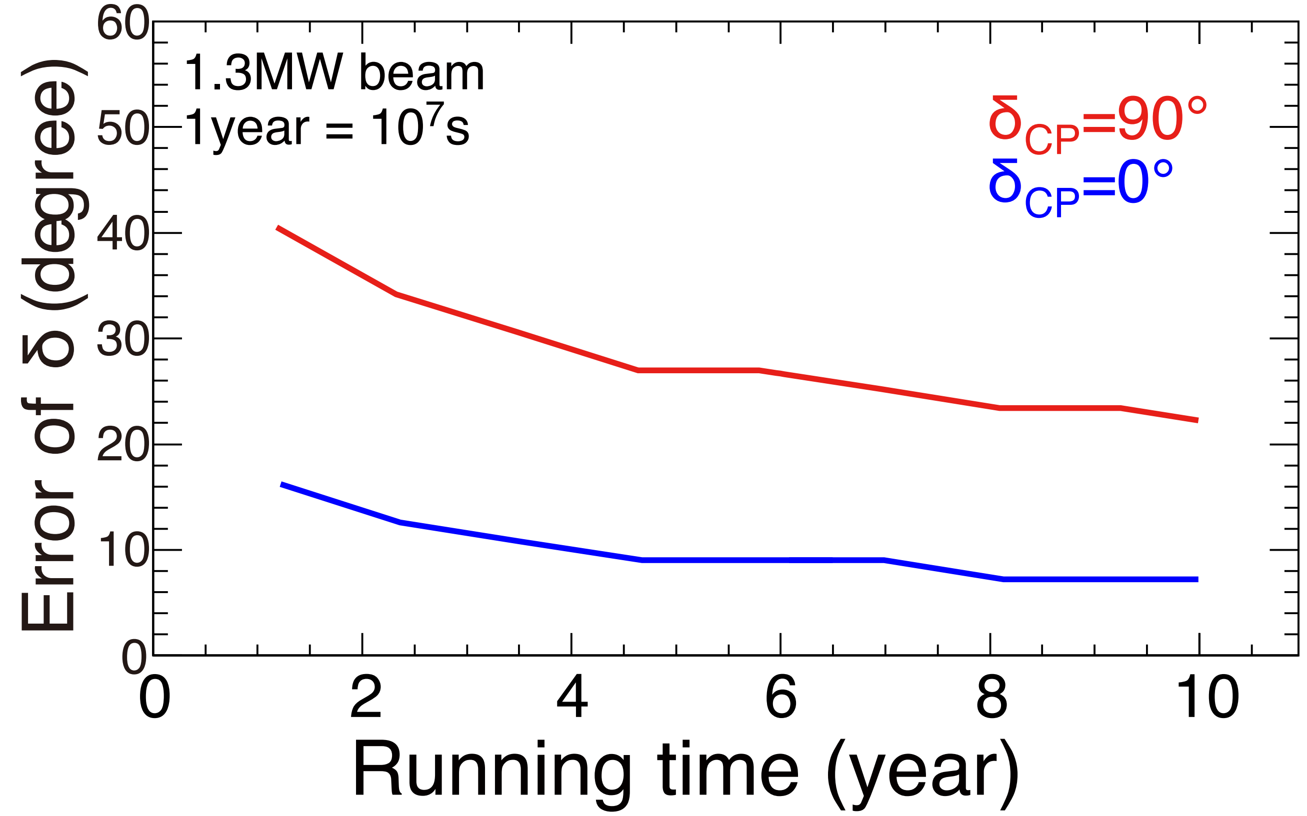
for δ=0	Signal ($\nu_\mu \to \nu_e$ CC)	Wrong sign appearance	$\nu_\mu/\bar{\nu}_\mu$ CC	beam $\nu_e/\bar{\nu}_e$ contamination	NC
ν beam	1,643	15	7	259	134
$\bar{\nu}$ beam	1,183	206	4	317	196

Sensitivity to CP violation

- Exclusion of $\sin\delta_{CP}=0$
  - ~8σ(6σ) for δ=±90° (±45°)
  - >3σ(>5σ) significance for ~76%(58%) of δ_{CP} space
- δ_{CP} resolution:
  - 22° for δ_{CP}=±90°
  - 7° for δ_{CP}=0°or 180°

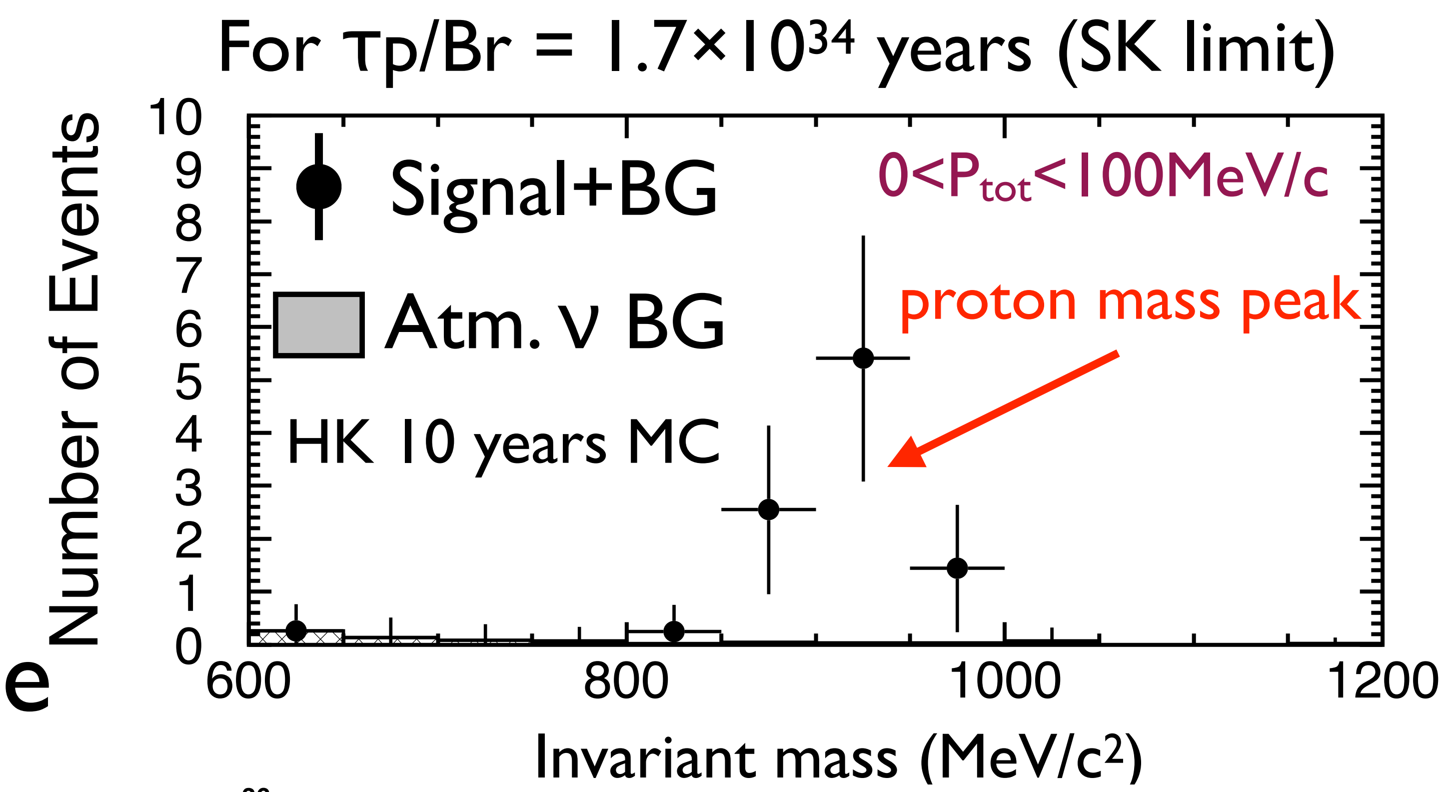
Enhanced further by combination with atmospheric ν

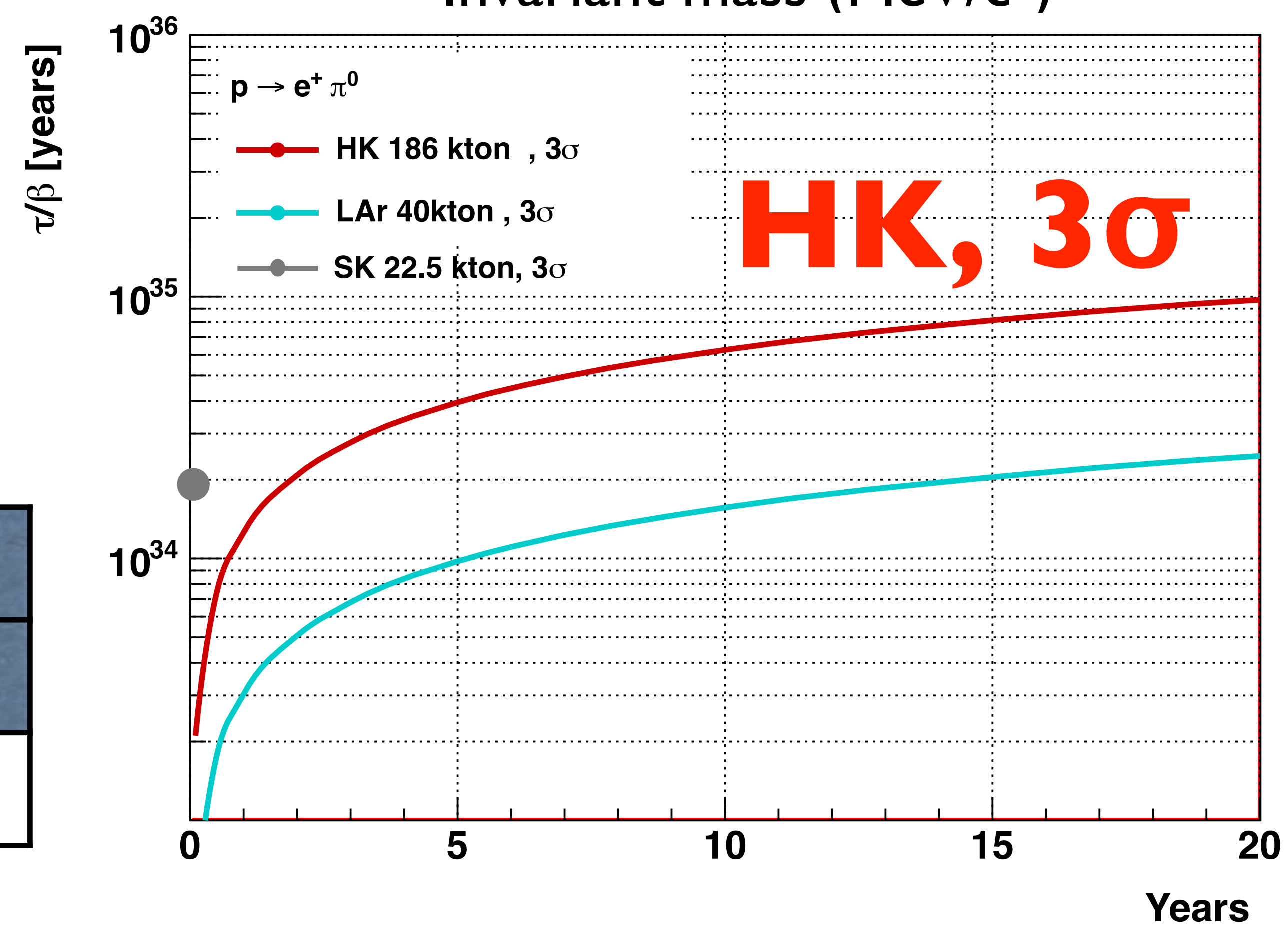




$p \rightarrow e^+\pi^0$ discovery potential

- BG free search possible (0.06 BG/Mton · year)
  - Free proton (^1H) – no nuclear effect
  - Well proven performance and understood BG
- Discovery potential extends to 10^{35} years





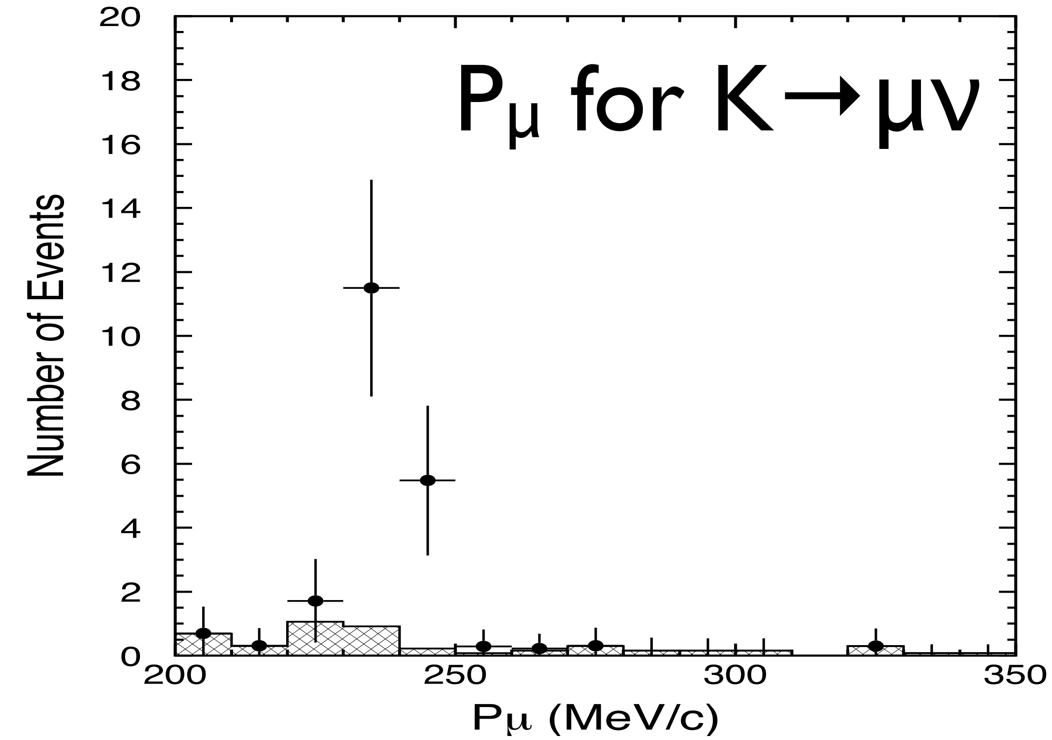
p_{tot}<100MeV/c		100<p_{tot}<250MeV/c	
Signal eff. (%)	BG (/Mt · yr)	Signal eff. (%)	Signal eff. (%)
18.7	0.06	19.4	0.62

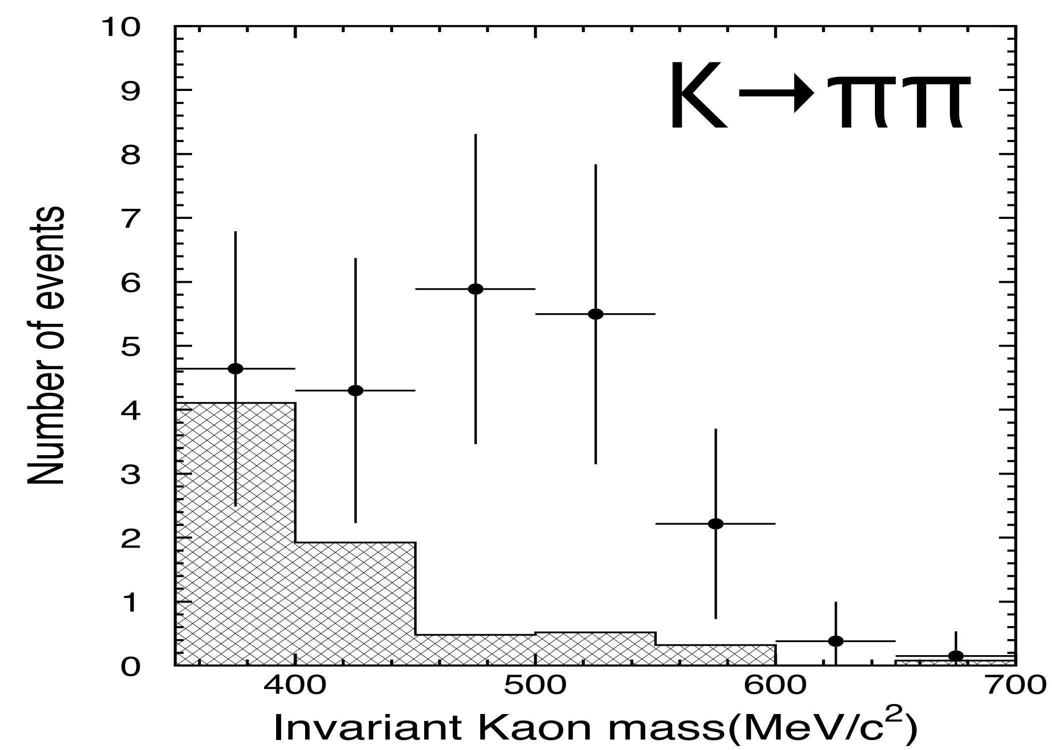
$p \rightarrow \bar{\nu} K$ discovery potential

- K is below Ch. threshold, identified by daughter particles (established by SK)
  - Monochromatic muon ($K \rightarrow \mu\nu$)
  - $K \rightarrow \pi^+\pi^0$
- Enhanced sensitivity thanks to improved photosensors (photon efficiency and timing)
- Discovery reach $>3\times10^{34}$ years

	Prompt γ		$\pi^+\pi^0$	
	Eff(%)	BG (/Mtyr)	Eff(%)	BG (/Mtyr)
HK	12.7	0.9	10.8	0.7
SK 4	8.5	1.0	9.0	0.9

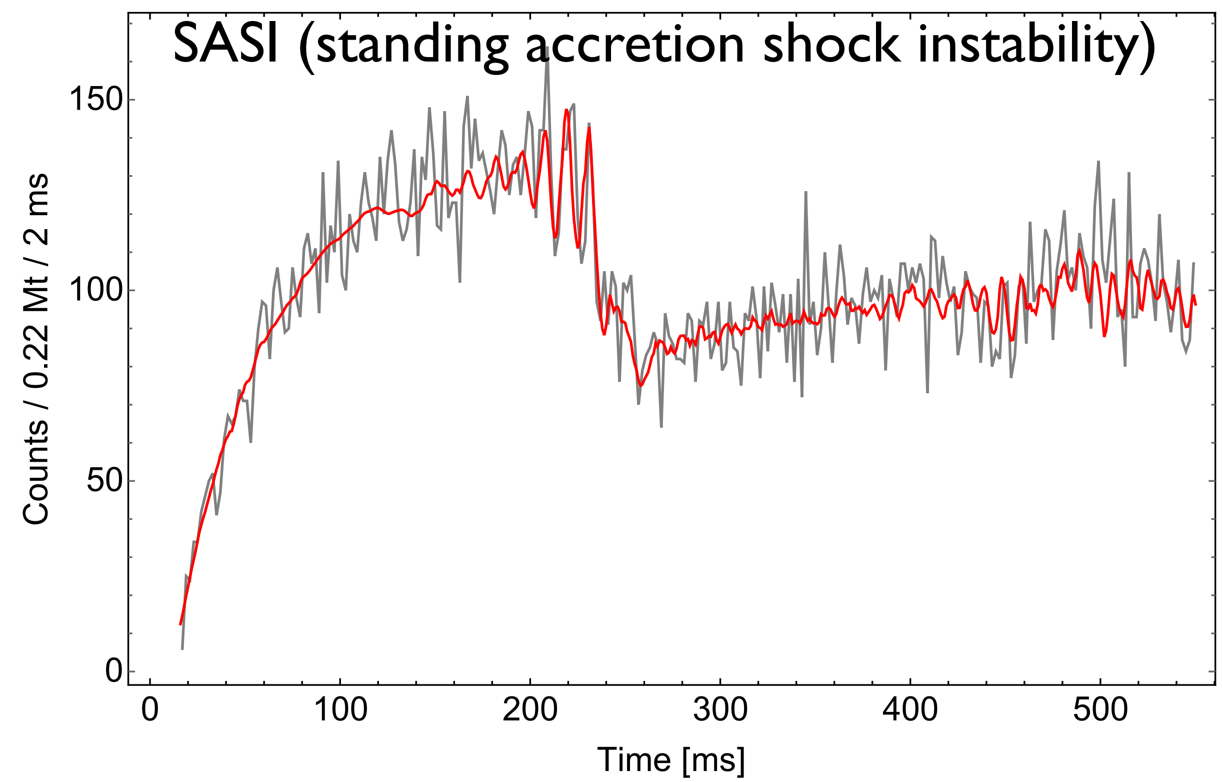
For $\tau p/Br = 6.6\times10^{33}$ years

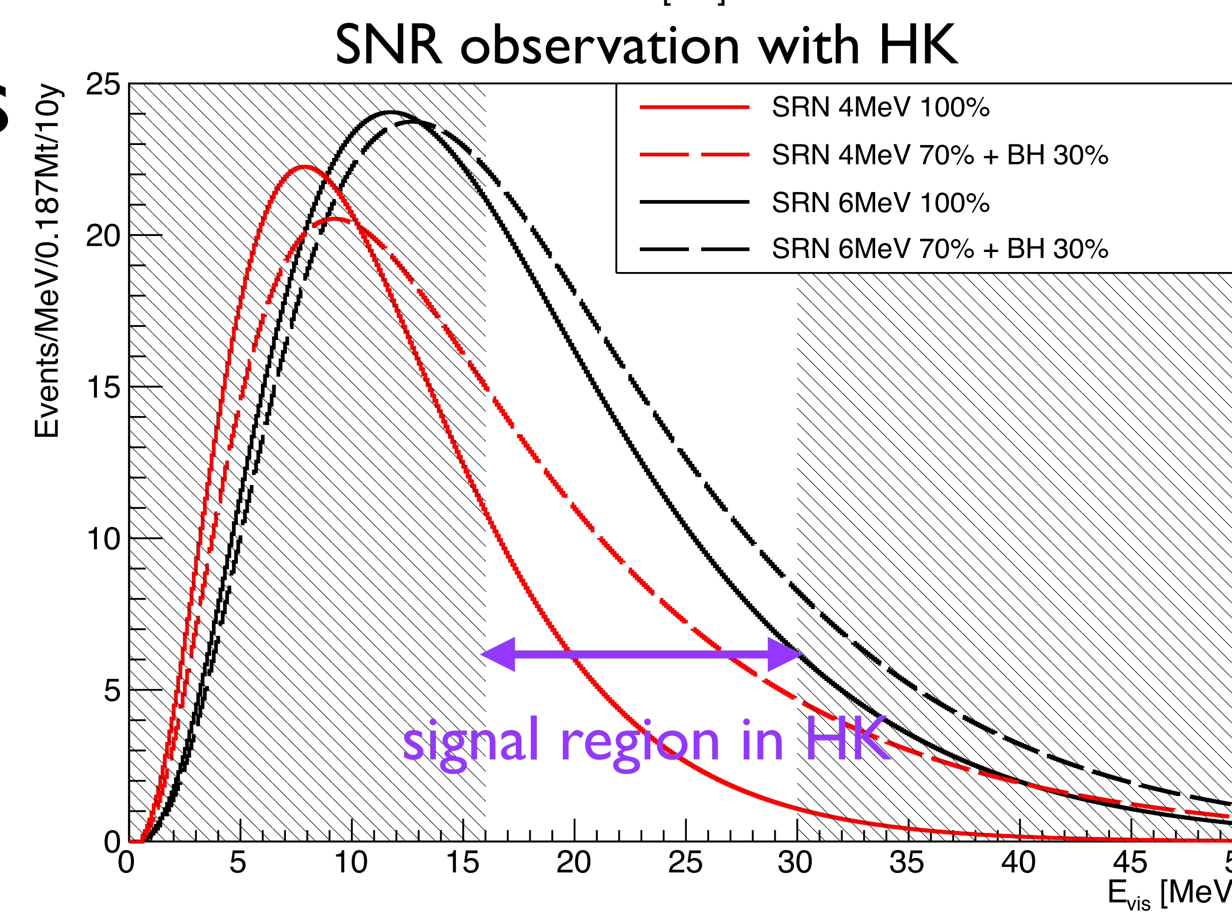




Astrophysics with HK

- Supernova burst neutrinos
  - 50-80k events /SN @10kpc
  - Precise time/energy profile
  - SN models, SASI (standing accretion shock instability), neutronization, …
  - Multi-messenger astrophysics
- Supernova relic neutrinos
  - Measurement of spectrum
  - Study history of star formation / black hole formation





Organization

- International Hyper-K proto-collaboration
  - 15 countries, 73 institutes, ~300 members, ~75% non-Japan
  - International project leaders, steering members, WG conveners
- 2 host institutes: UTokyo/ICRR and KEK/IPNS
  - Working under MoU for cooperation on HK
  - International HK Advisory Committee under directors
  - UTokyo launched a institute for HK construction: Next-generation Neutrino Science Organization (NNSO)

Collaboration meeting, Sep. 2018

Proto-Collaboraion Inauguration and ICRR-IPNS MoU

NNSO Inauguration Ceremony

Towards construction

- MEXT (funding agency) lists Hyper-Kamiokande on its Roadmap2017
- UTokyo has been making all efforts to get funded with strong leadership of the president Gonokami
  - Hyper-K is requested to MEXT as a top priority project
- Seed funding has been allocated within MEXT budget request for JFY2019
  - Seed fundings in the past projects usually led to full funding in the following year, as it was the case for the Super-Kamiokande project

Then, …

Statement by UTokyo President

On September 12, 2018

東京大学
THE UNIVERSITY OF TOKYO

The University of Tokyo

Hongo, Bunkyo-ku, Tokyo 113-8654, Japan

September 12th, 2018

Concerning the Start of Hyper-Kamiokande

Seed funding towards the construction of the next-generation water Cherenkov detector Hyper-Kamiokande has been allocated by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) within its budget request for the 2019 fiscal year. Seed fundings in the past projects usually lead to full funding in the following year, as it was the case for the Super-Kamiokande project.

The University of Tokyo pledges to ensure construction of the Hyper-Kamiokande detector commences as scheduled in April 2020. The University of Tokyo has made this decision in recognition of both the project's importance and value both nationally and internationally.

The neutrino research that lead to Nobel prizes for Special University Professor Emeritus Koshiba and Distinguished University Professor Kajita has entered a new era. The international community has demonstrated the need for Hyper-Kamiokande. The considerable expertise and achievements of the University of Tokyo and Japan, and unique and invaluable contributions from national and international collaborators will ensure the project will make significant contributions to the intellectual progress of the world.

Makoto Gonokami

Makoto Gonokami
President, The University of Tokyo

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PARTICLE PHYSICS NEWS AND RESOURCES

A communication resource from the **world's particle physics laboratories.**

Hyper-Kamiokande Experiment to Begin Construction in April 2020

19 September 2018 - Kavli Institute for the Physics and Mathematics of the Universe

Last week at the 7th Hyper-Kamiokande proto-collaboration meeting, a statement was issued by the University of Tokyo recognizing the significant scientific discoveries which the planned Hyper-Kamiokande experiment would enable.

It states that, based on these exciting prospects, the University of Tokyo will ensure that construction of the experiment will begin in 2020. Hyper-Kamiokande now moves from planning to a real experiment.

The Hyper-Kamiokande proto-collaboration welcomes this exciting endorsement of the project and the boost it will give to increasing even further the international contributions and participation in the experiment. Introducing the statement, Professor Takaaki Kajita, Director of the Institute for Cosmic Ray Research at the University of Tokyo and 2015 Nobel Laureate in Physics, pointed out that the Japanese funding agency MEXT has included seed funding for Hyper-Kamiokande in its JFY 2019 budget request. He illustrated with many examples that it is standard in Japan for large projects to begin with a year of seed funding, and said that in any case the University of Tokyo commitment meant that Hyper-Kamiokande construction will begin in April 2020.

The Hyper-Kamiokande Proto-Collaboration will now work to finalize designs, and is very open to more international partners to join in this far-reaching new experiment.

Links:

University of Tokyo statement regarding the Hyper-Kamiokande experiment

Related Links:

Hyper-Kamiokande official website

DATE ISSUED:

September 19th, 2018

SOURCE:

Kavli Institute for the Physics and Mathematics of the Universe

CONTENT:

Press Release

CONTACT:

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University of Tokyo
E-mail: press@ipmu.jp
Tel: 04-7136-5980

http://www.nnso.u-tokyo.ac.jp/news/20180912-e.html

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Hyper-Kamiokande Experiment to Begin Construction in April 2020

The Hyper-Kamiokande proto-collaboration welcomes this exciting endorsement of the project and the boost it will give to increasing even further the international contributions and participation in the experiment. Introducing the statement, Professor Takaaki Kajita, Director of the Institute for Cosmic Ray Research at the University of Tokyo and 2015 Nobel Laureate in Physics, pointed out that the Japanese funding agency MEXT has included seed funding for Hyper-Kamiokande in its JFY 2019 budget request. He illustrated with many examples that it is standard in Japan for large projects to begin with a year of seed funding, and said that in any case the University of Tokyo commitment meant that Hyper-Kamiokande construction will begin in April 2020.

The Hyper-Kamiokande Proto-Collaboration will now work to finalize designs, and is very open to more international partners to join in this far-reaching new experiment.

Links:

University of Tokyo statement regarding the Hyper-Kamiokande experiment

Related Links:

Hyper-Kamiokande official website

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Press Release

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http://www.nnso.u-tokyo.ac.jp/news/20180912-e.html

Opportunities for collaboration

- Japanese funding request includes facility (cavern, tank, infrastructure..), beam upgrade, and half of inner detector photosensor described in the Design Report
- Many areas of significant contributions possible to enhance the science capabilities of Hyper-K
  - Photosensors for more (and detailed) information, especially for low energy events
  - Background suppression instrumentation and techniques (neutron tagging, radiopurity control, ..)
  - Accelerator, beamline, and near detectors for better sensitivities to lepton CP asymmetry
  - ....

Conclusions

- Hyper-Kamiokande is the next generation water Chrenkov detector with tremendous science capability
  - Based on the monumental achievements of Kamiokande and Super-Kamiokande
  - Proton decay (>10^{35} years), neutrino oscillation, and neutrino astrophysics
- Project boosting with the recent statement by UTokyo President, start of construction in April 2020
  - International contributions can significantly enhance the project
- Another path to the Quest for Guiding Principles!