Accelerator neutrino program in Japan

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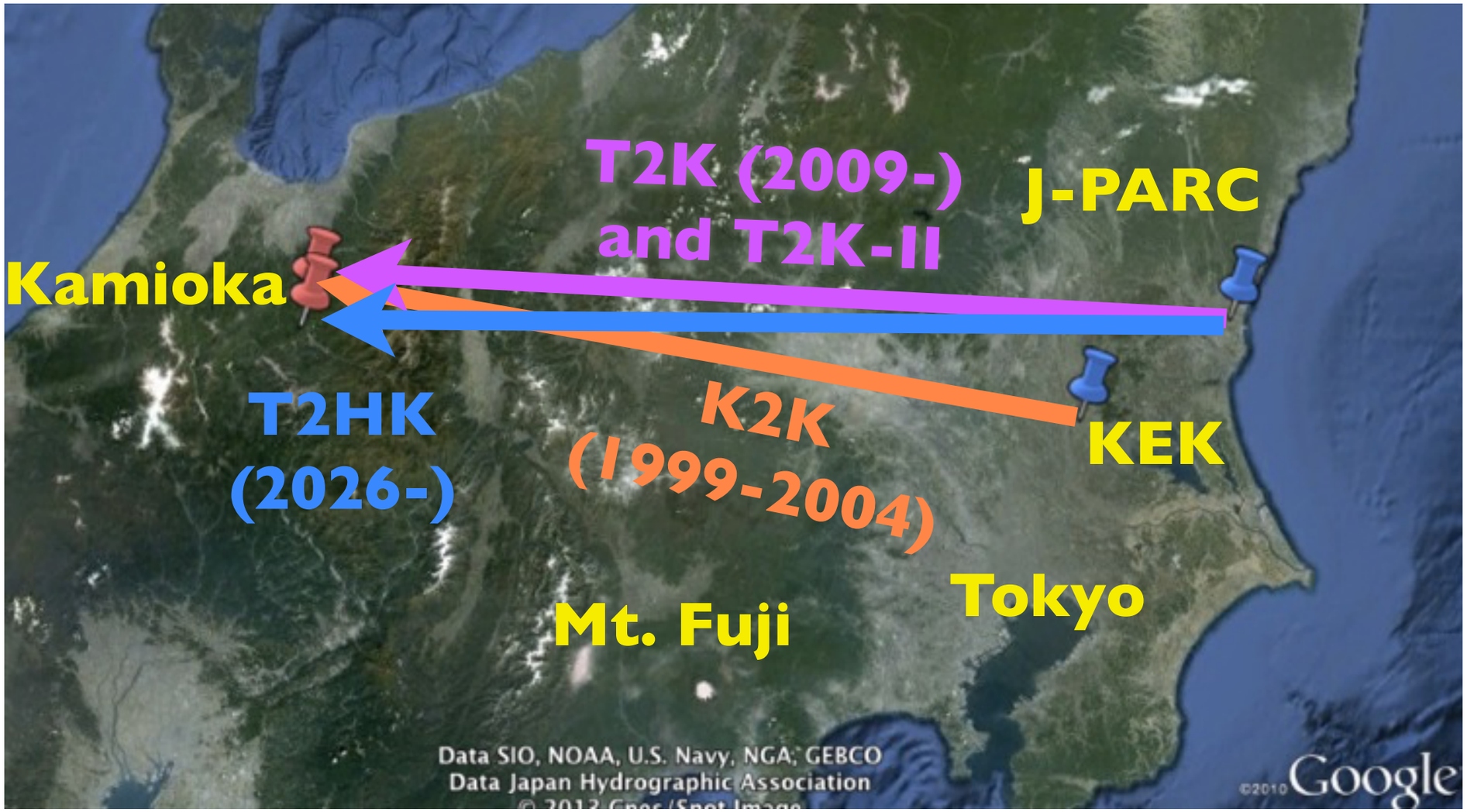
2nd Workshop on Neutrino Near Detectors based on gas TPCs
20-21 March 2017, CERN

Long baseline neutrino experiments in Japan



Starting from K2K
(world's first LBL experiment, confirmed ν osc.),
leading the field for ~20 years!
Currently T2K is running, proposing extension T2K-II
and seamless evolution to Hyper-K

Japan Proton Accelerator Research Complex

3 Accelerators
3(+ 1) User facilities

International User Facility

Hadron Facility

3 GeV synchrotron RCS
(25 Hz, 1MW)

Materials & Life Facility
neutron・muon

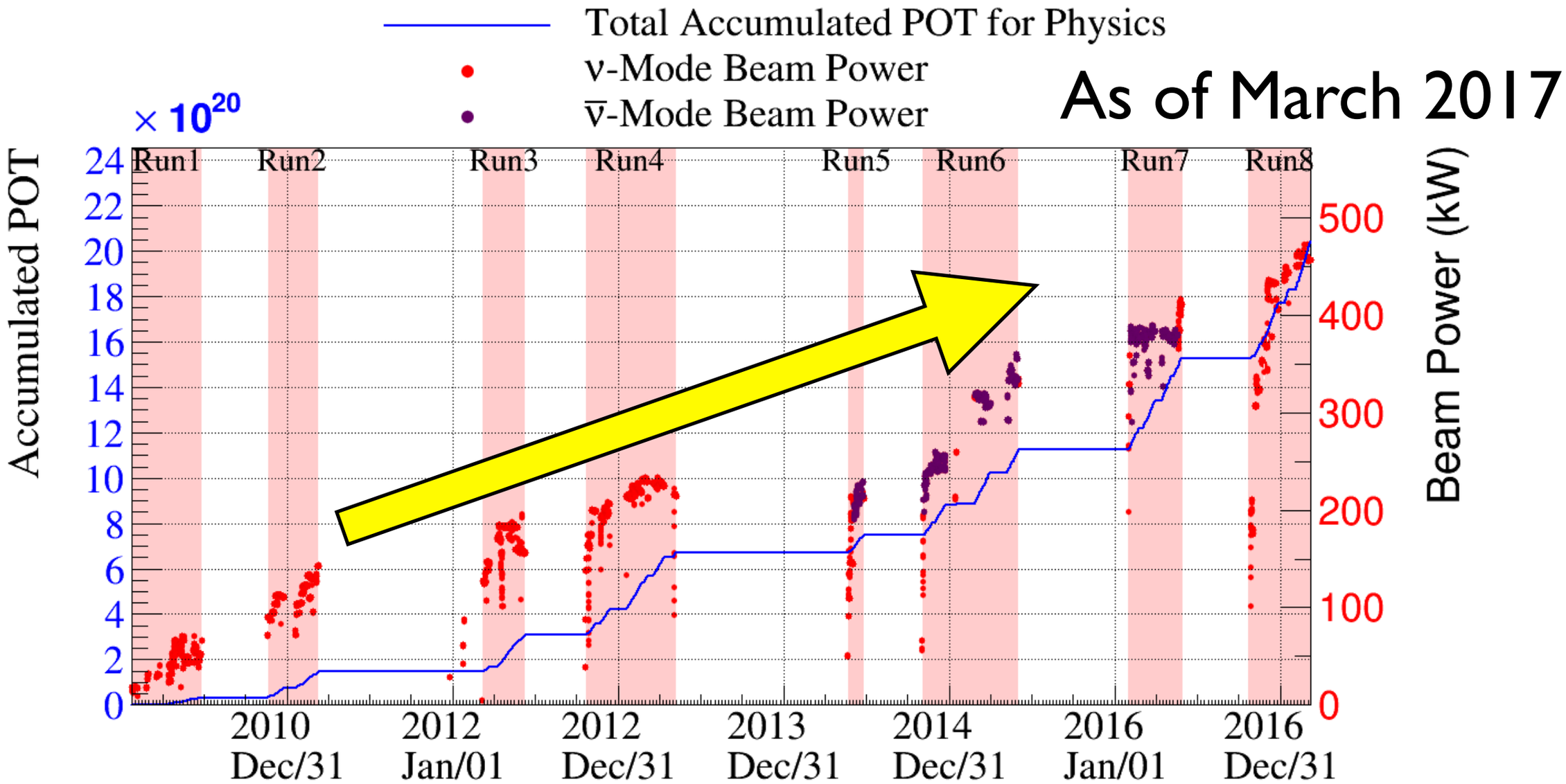
Linac
(400MeV)

Neutrinofacility
(T2K)

30 GeV synchrotron
MR(0.75 MW)

Proton delivery history

As of March 2017



Operated with 470kW, still increasing towards >500kW

Total POT exceeded 2×10^{21} (doubled in ~2 years)

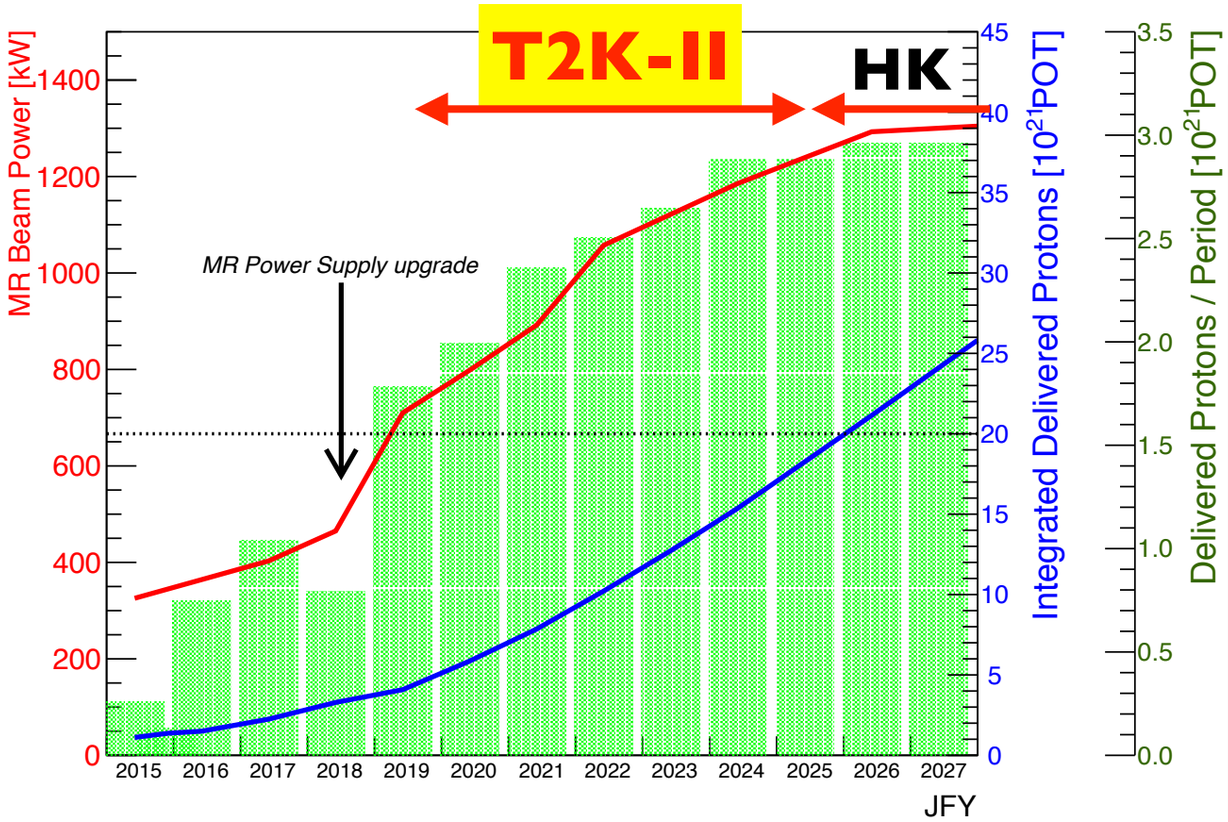
Accumulating ~8×10^{18} POT/day

J-PARC power increase plan

- Reduce repetition cycle from 2.48sec to 1.3sec for >750kW (original design power of J-PARC) by 2019 cf. 470kW achieved with 2.48s cycle
  - Major investment: upgrade of power supply for magnet (ongoing)
- Then, gradual improvement to go 1.3MW+
  - Rep. cycle to 1.16s and ppp to 3.2×10^{14} (original design ppp)
  - Modest investment (RF PS, ..) and continuous effort (beam loss reduction, stability, ..)
- Technical feasibility is demonstrated. No show stopper.

Beam Power (kW)	425 (Achieved)	810	Demonstrated	1326 (Goal for T2K-II)
#p/p(10^{12})	220	220	270	320
#p/b(10^{12})	28	28	34	40
Rep T (s)	2.48	1.3	shots	1.16

J-PARC beam power outlook



KEK Project Implementation Plan Review

- *"J-PARC upgrade for Hyper-K is the highest priority"*

KEK-PIP Advisory Committee Meeting

from Sunday, 22 May 2016 at **08:00** to Monday, 23 May 2016 at **18:00** (Asia/Tokyo)
at **KEK Tsukuba (TBA)**

Description **Advisory Committee Members**

Tatsuya Nakada (Lausanne)
Nigel Smith (SNO lab)
Carlos Wagner (ANL)
Tadafumi Kishimoto（Osaka, RCNP)
Kenneth Hicks (Ohio)
Christine Davies (Glasgow)
Ki-bong Lee (Postech)
Yoshiyuki Amemiya（Tokyo)
Yasuhiro Iwasawa (Dentsudai, UEC)
Jun Akimitsu (Okayama/Hiroshima)
Michael Sullivan (SLAC)
Mei Bai (Juelich)

Project to be prioritized:
- COMET II
- J-PARC upgrade for Hyper Kamiokande
- Hadron Hall Extension
- H-line and g-2/EDM
- LHC and ATLAS
- Super Computer
- RNB

Separate prioritization
- Light Source

Go to day

Sunday, 22 May 2016

09:00 - 09:20 Executive session *20'*
09:20 - 09:35 Welcome address and mandate to the committee *15'*
Speaker: Masanori Yamauchi (KEK)
09:35 - 10:05 KEK Roadmap 2013 *30'*

- Highest priority in KEK Project Implementation Plan (for future budget request from KEK)

Strong commitment from lab!

ν beamline for >MW

M.Friend(KEK), NEUTRINO2016

High Power J-PARC Secondary Beamline

J-PARC secondary beamline infrastructure (shielding, decay volume, hadron absorber) were all designed for 3–4 MW

Component	Limiting Factor	Current Acceptable Value	Upgraded Acceptable Value
Target	Thermal Shock	3.3×10^{14} ppp	3.3×10^{14} ppp
	Cooling Capacity	0.75 MW	>1.5 MW
Horn	Conductor Cooling	2 MW	2 MW
	Stripline Cooling	0.54 MW	>1.25 MW
	Hydrogen Production	1 MW	>1 MW
	Operation	2.48 s & 250 kA	1 s & 320 kA
He Vessel	Thermal Stress	4 MW	4 MW
	Cooling Capacity	0.75 MW	>1.5 MW
Decay Volume	Thermal Stress	4 MW	4 MW
	Cooling Capacity	0.75 MW	>1.5 MW
Beam Dump	Thermal Stress	3 MW	3 MW
	Cooling Capacity	0.75 MW	>1.5 MW
Radiation	Radioactive Air Disposal	1 MW	>1 MW
	Radioactive Water	0.5 MW	0.75→1.3 or 2 MW

24 / 31

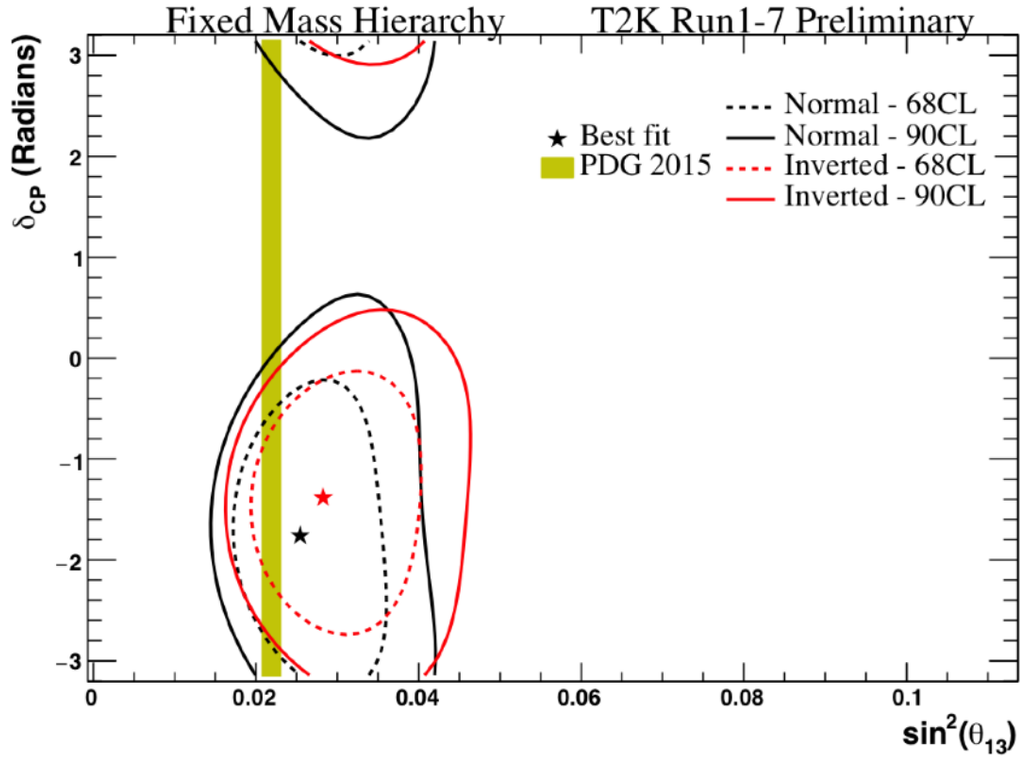
Target designed for 3.3×10^{14}ppp, infrastructure for >3MW

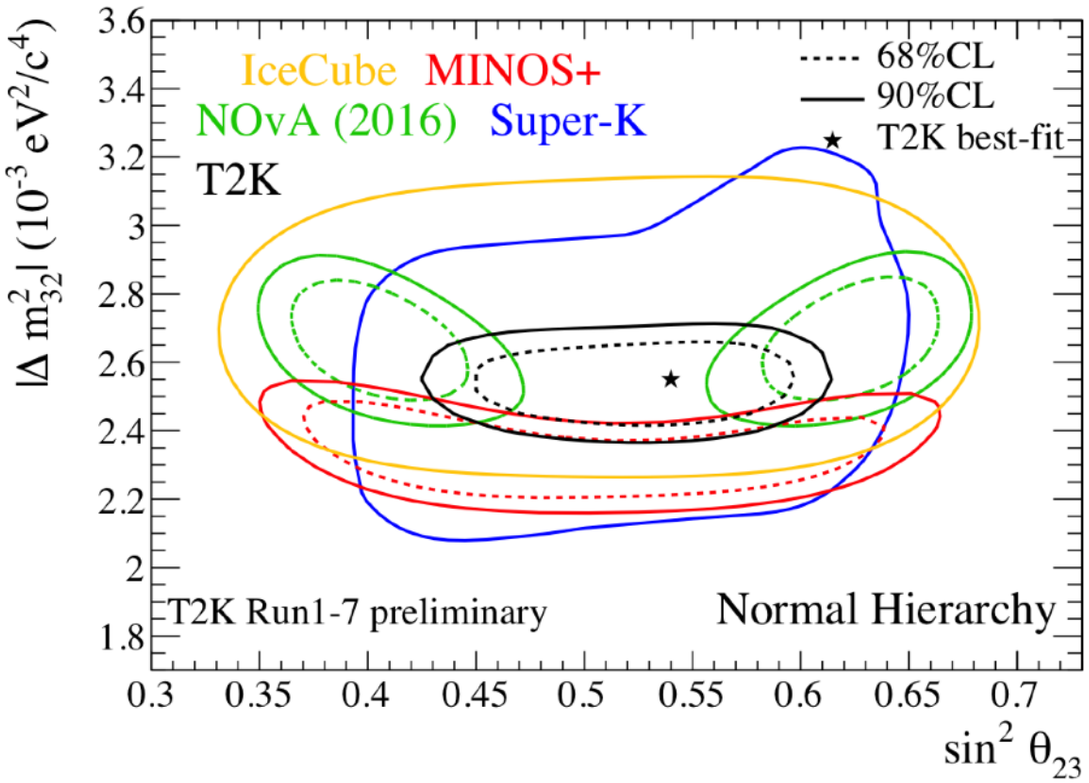
→ <u>no large R&D or construction necessary</u>

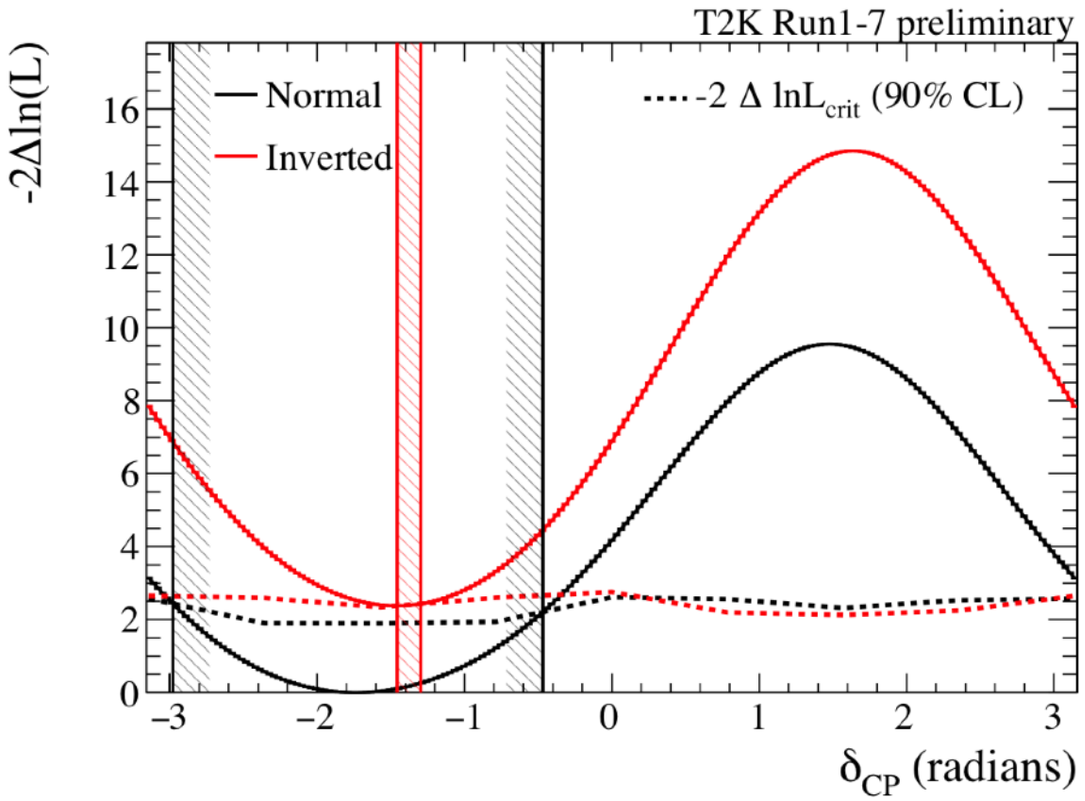
Cooling/radiation handling facilities need upgrades

Current T2K results

- Providing exciting results!
  - leptonic CP, θ_{23}, and mass hierarchy..
  - Neutrino data ~doubled before summer 2017
- Great opportunities with measured θ_{13}
  - More physics with more data!

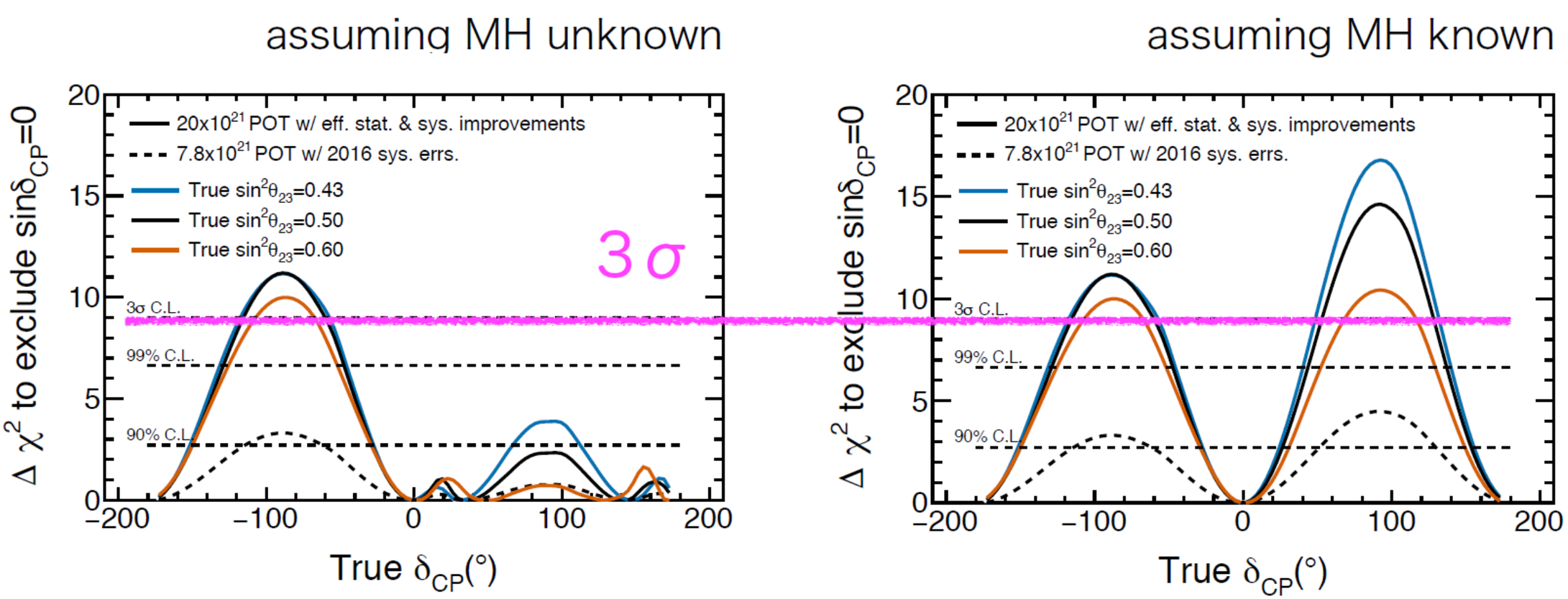






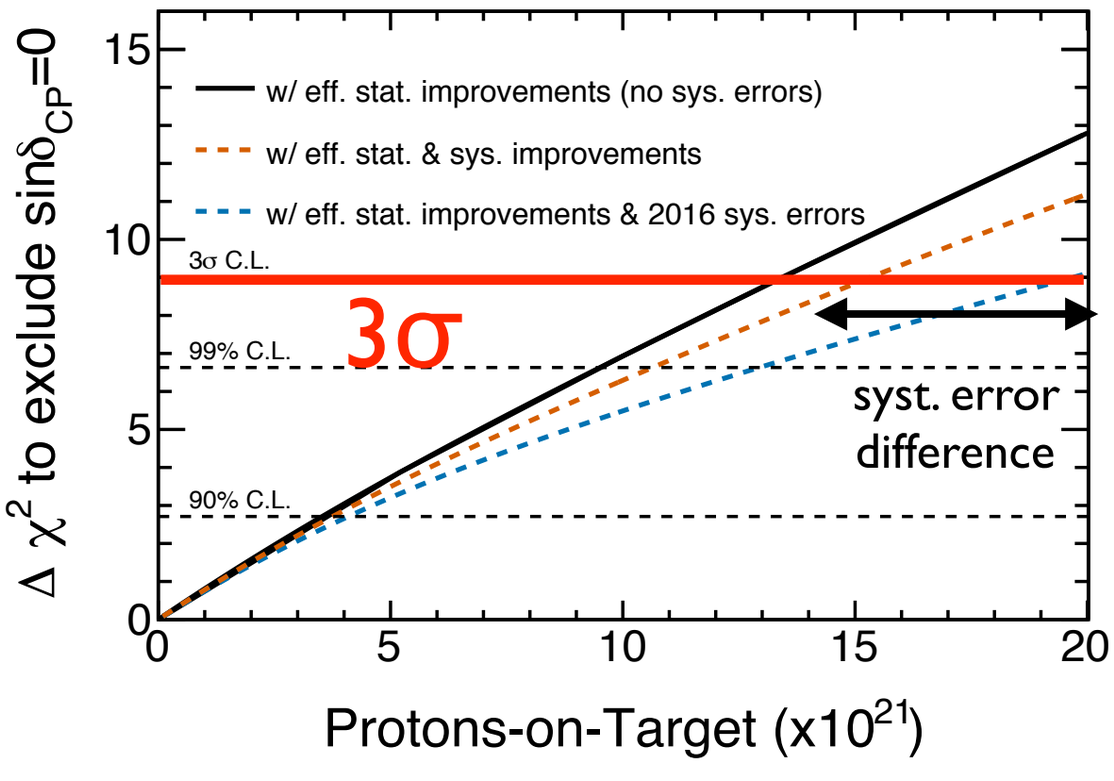
T2K Phase II (T2K-II)

- Original T2K program is 7.8×10^{21} POT
  - Will be achieved in the middle of power increase
- T2K-II extension proposal (arXiv:1609.04111)
  - Accumulate 2×10^{22}POT by ~2026 (start of HK)
  - 3σ CPV sensitivity for favorable parameters

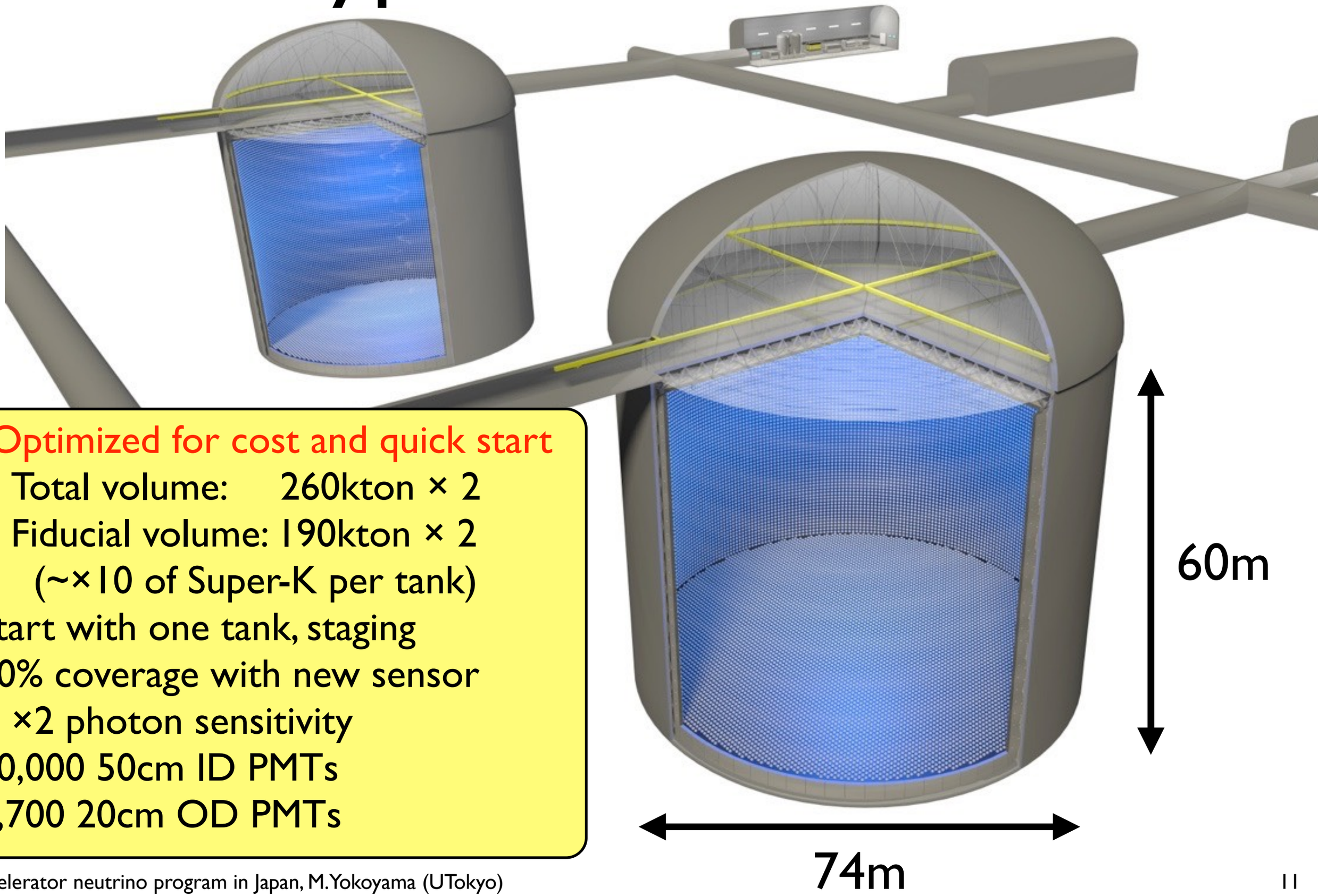


T2K-II goals

- ~400 events expected for νe appearance signal
  - Analysis improvement to increase statistical significance
  - Goal of systematics: 4% in total for number of ν_e
  - ND measurement is a key!
- Stage-1 status given by PAC recommendation.
- Technical Design (including beamline) in 2017 to request for Stage-2 approval.



Hyper-Kamiokande



Optimized for cost and quick start

Total volume: 260kton × 2

Fiducial volume: 190kton × 2

(~×10 of Super-K per tank)

Start with one tank, staging

40% coverage with new sensor

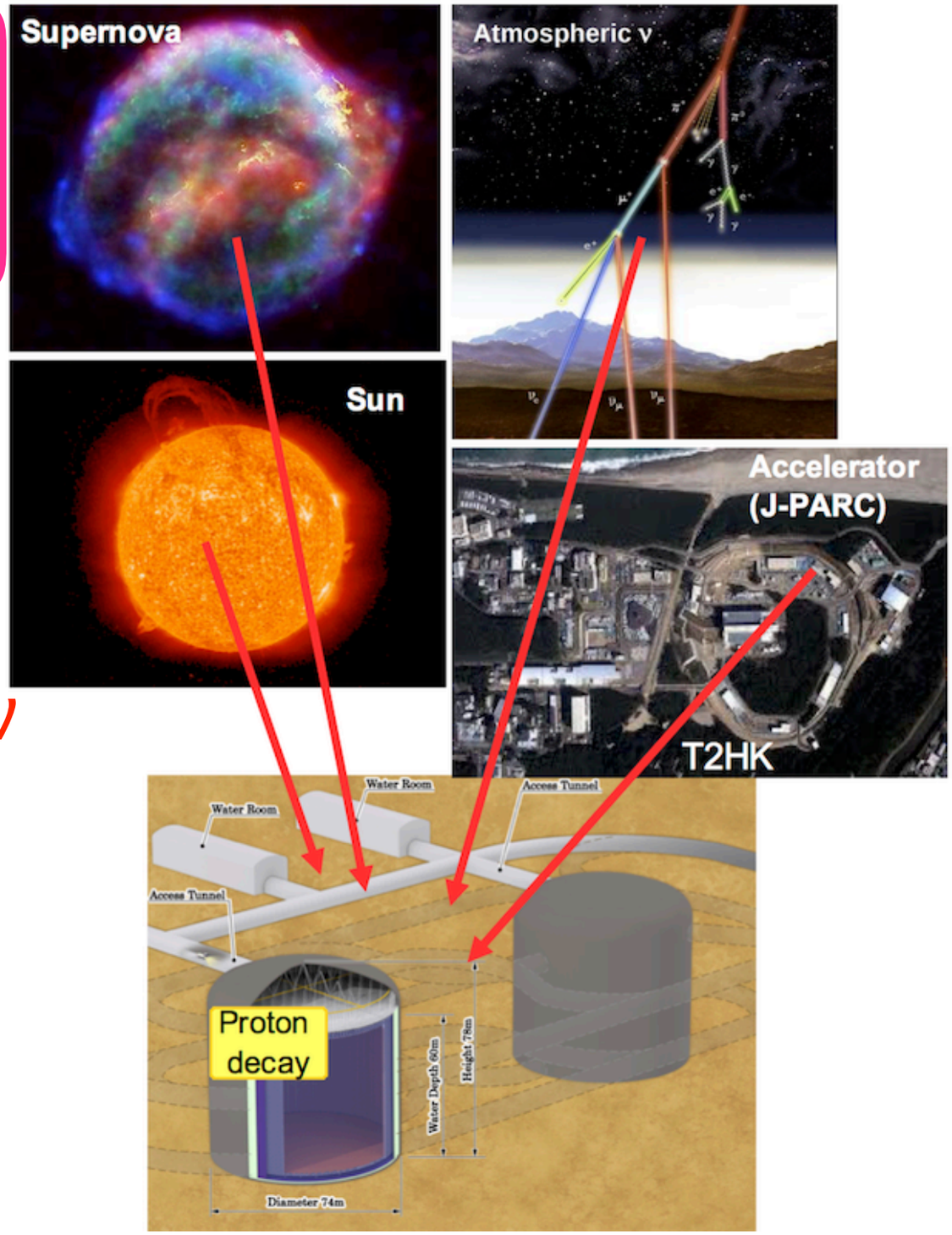
×2 photon sensitivity

40,000 50cm ID PMTs

6,700 20cm OD PMTs

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 (neutrinography of interior of the Earth)
- Maybe more (unexpected)



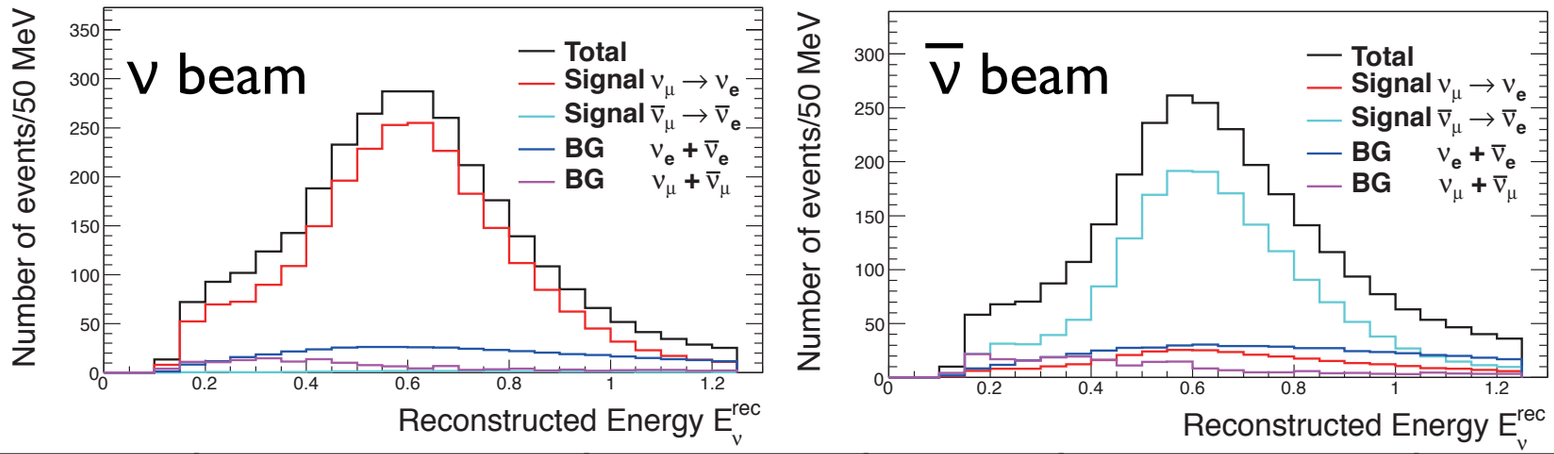
Extend highly successful program of Super-K

Expected events

1.3MW, 10×10^{7}sec, $\nu:\bar{\nu}$=1.3

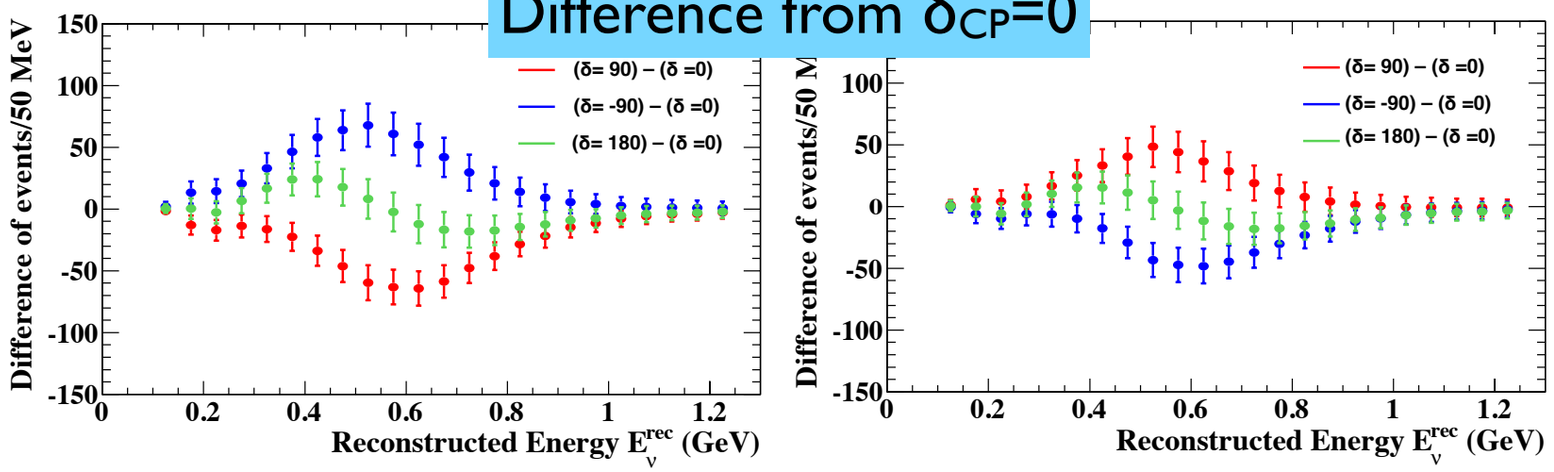
ν_e candidates

Using fiTQun for π^0 rejection



for δ=0	Signal (νμ→νe CC)	Wrong sign appearance	$\nu_\mu/\bar{\nu}_\mu$ CC	beam $\nu e/\bar{\nu} e$ contamination	NC
ν beam	2,300	21	10	362	188
$\bar{\nu}$ beam	1,656	289	6	444	274

Difference from δ_{CP}=0



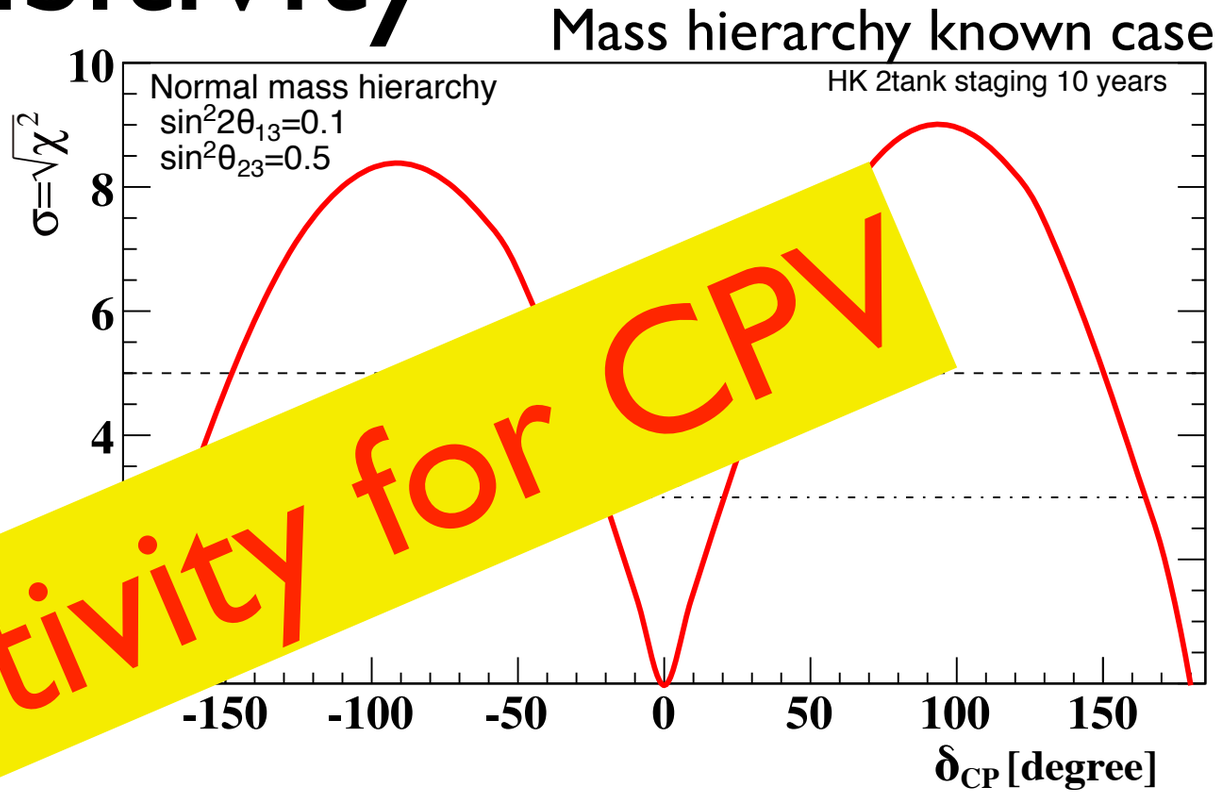
δ=0 and 180° can be distinguished using shape information

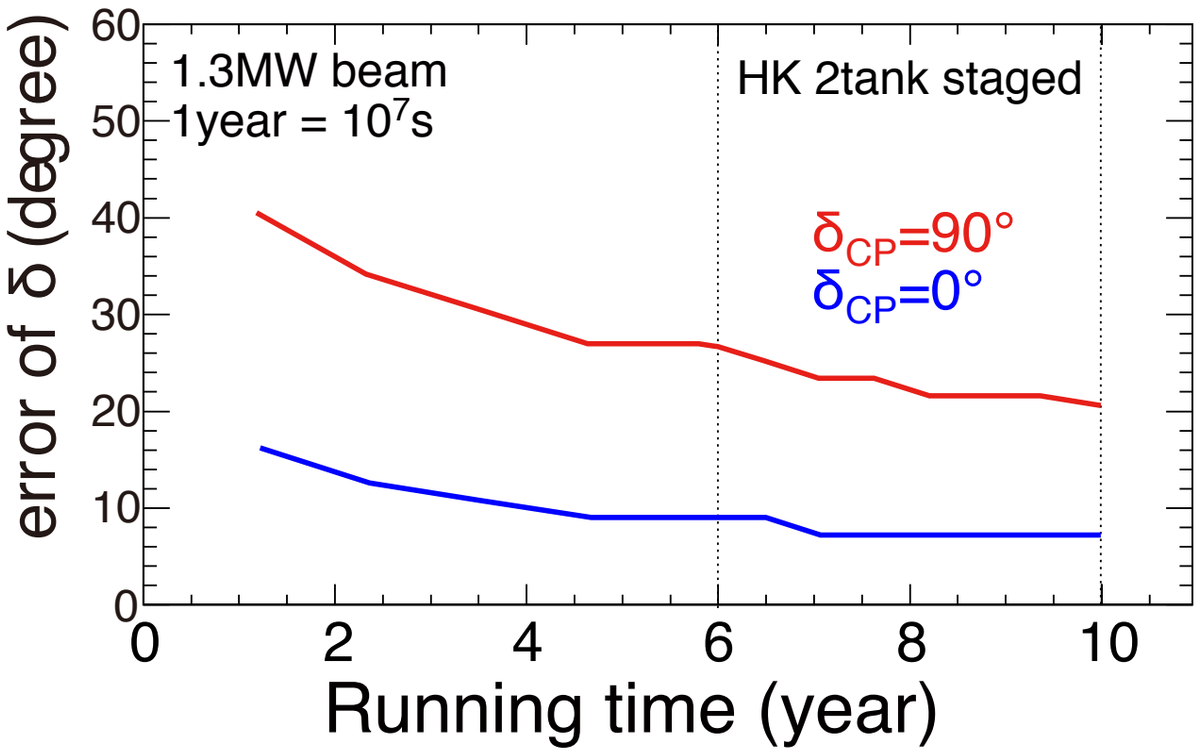
CPV sensitivity

- Exclusion of $\sin\delta_{CP}=0$
  - >8σ(6σ) for δ=-90°(-45°)
  - ~80% coverage of δ parameter space with >3σ
- From discovery to
  δ_{CP} measure
  - ~7° ossible

Excellent sensitivity for CPV

sinδ=0 exclusion		error	
>3σ	>5σ	δ=0°	δ=90°
78%	62%	7.2°	21°



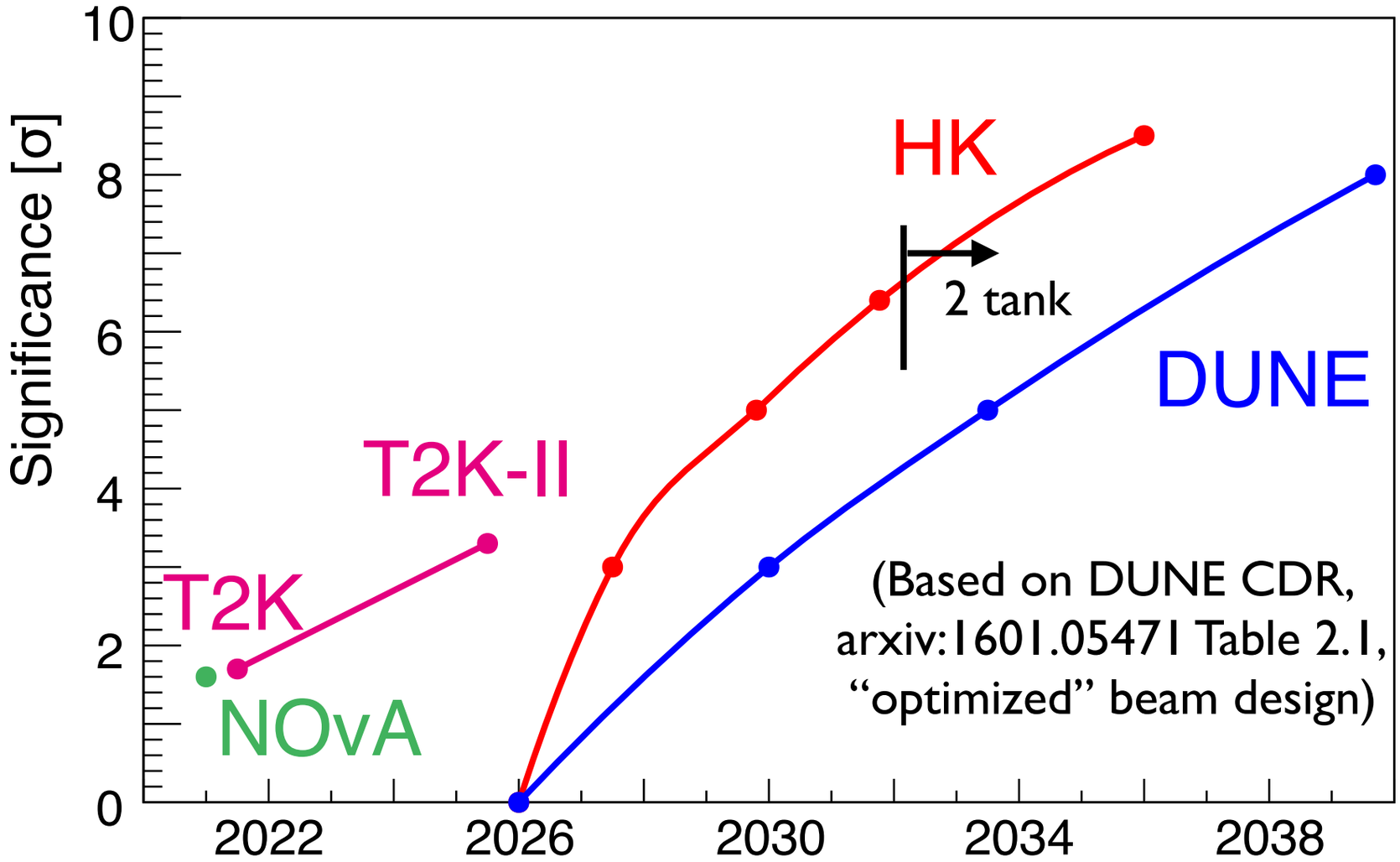


Status of Hyper-K

- Proposal of the Hyper-K project is under review by several council, managements and committees in Japan.
  - Science Council of Japan "Master Plan" for large scale projects: selected as one of 28 priority projects (Feb.2017)
  - MEXT (funding agency) will make "Roadmap" in mid 2017 with SCJ report as one of input
- Working closely with labs and communities
  - KEK-PIP 1st priority: J-PARC upgrade for HK
  - ICRR future project committee formed to evaluate HK as the next main project of lab after KAGRA (GW telescope)
  - MoU of IPNS/KEK and ICRR/UTokyo for HK promotion, International Advisory Committee formed under Directors
- Budget request for detector construction in preparation. Discussion with University of Tokyo (host of Super-K) ongoing

Towards leptonic CP asymmetry

CPV significance for δ=-90°, normal hierarchy



Seamless program of Japan-based experiments

~3σ indication with T2K→T2K-II,

>5σ discovery and measurement with HK

Note: "exact" comparison sometimes difficult due to different assumptions

Summary

- Long baseline neutrino experiment is one of central pieces of Japanese HEP program
  - Planed upgrade of J-PARC to 1.3M+ propriety of KEK
  - Hyper-K is moving forward
- Seamless continuation of projects
  - T2K → T2K-II → HK
  - Investment in current program directly affects future
- With more statistics and precision, *control of systematic uncertainties* is a key for best physics output
  - Near Detectors will play crucial role..
    → That's why we're here now!