Indirect WIMP detection with neutrinos in Hyper-K

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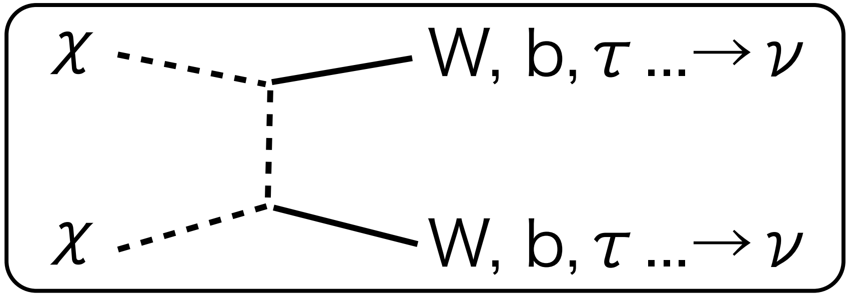
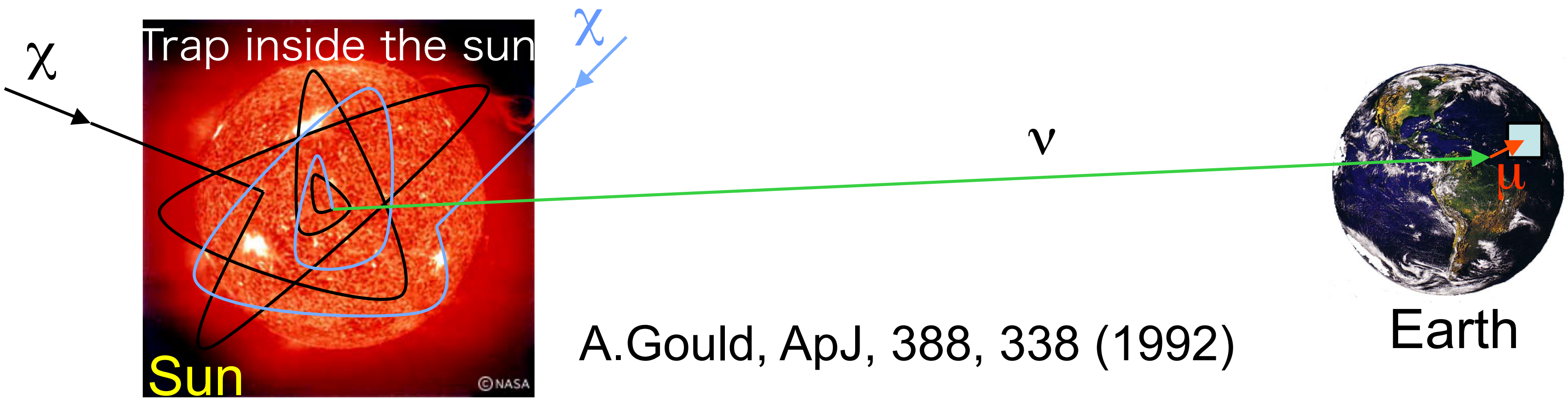
Cosmic Frontier Workshop
SLAC - March 7, 2013

Neutrinos generated by WIMP annihilation



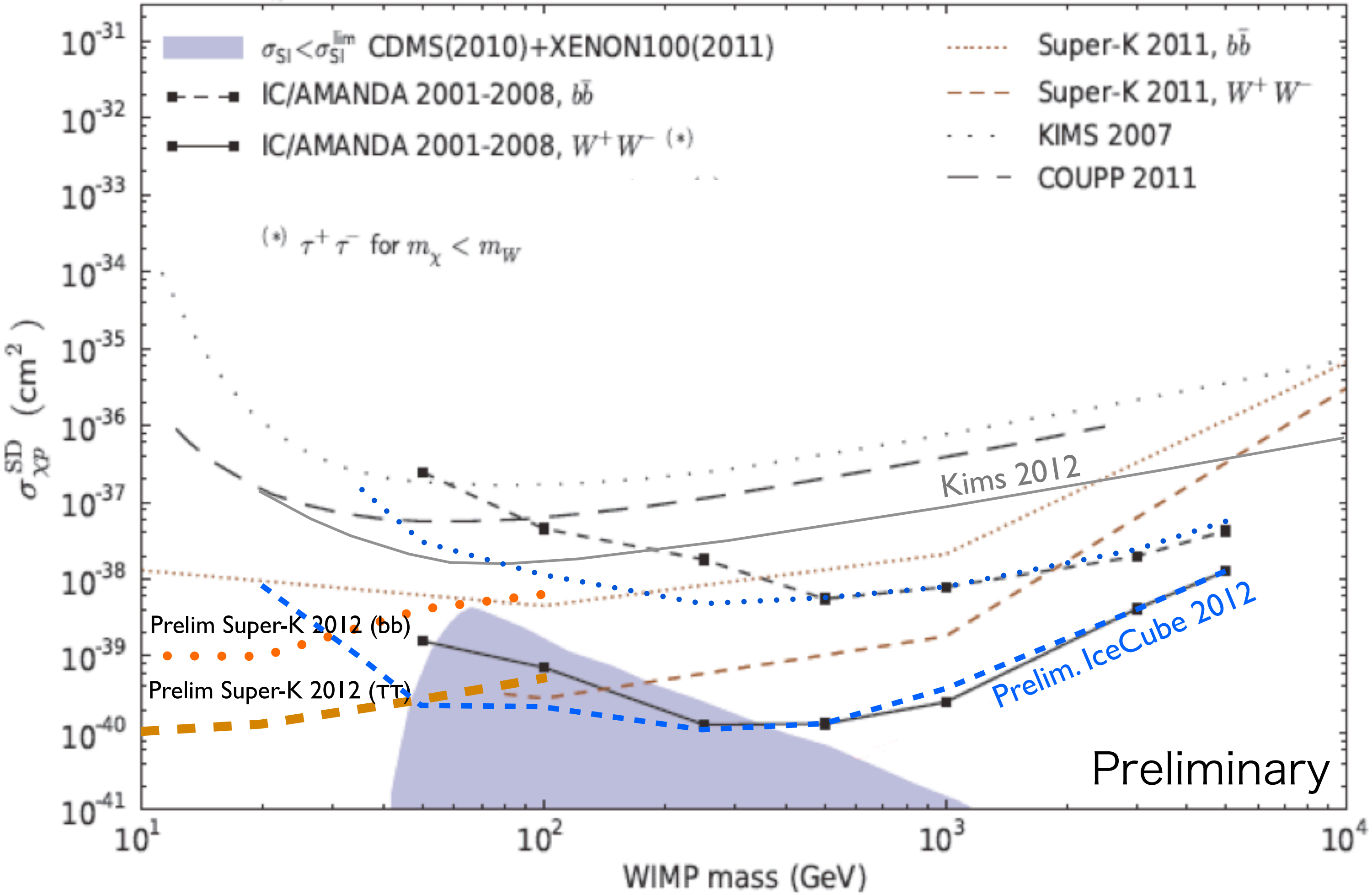
✓ WIMP signal from the Sun



A.Gould, ApJ, 388, 338 (1992)

✓ Annihilation in Galactic Halo, etc..

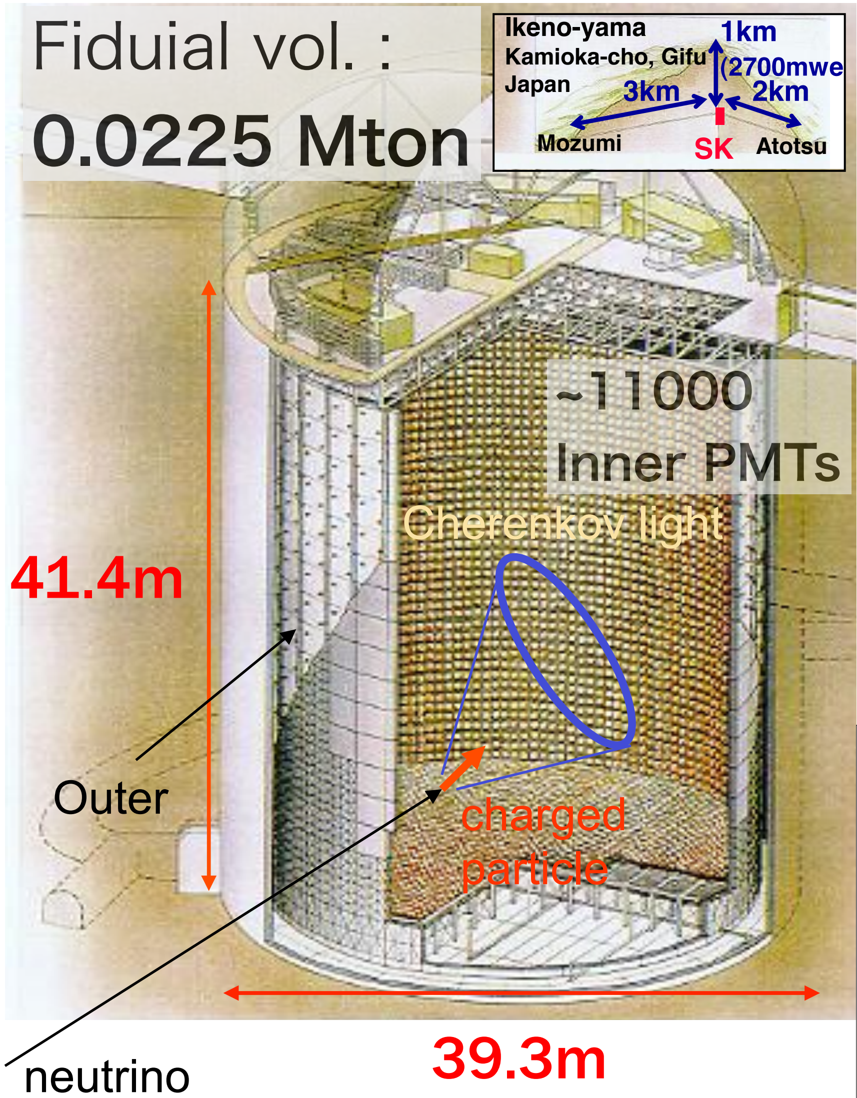
Recent results



T. Tanaka et al. Astrophys. J. 742, 78 (2011)
R. Abbasi et al. Phys. Rev. D 85, 042002 (2012)

Preliminary IceCube/DeepCore Limit IDM 2012 / arXiv:1212.4097
Preliminary Super-K Limit Neutrino 2012 / arXiv:1210.4161

Observation in SuperK



QECC interaction

$$\nu_e + n \rightarrow e^- + p$$

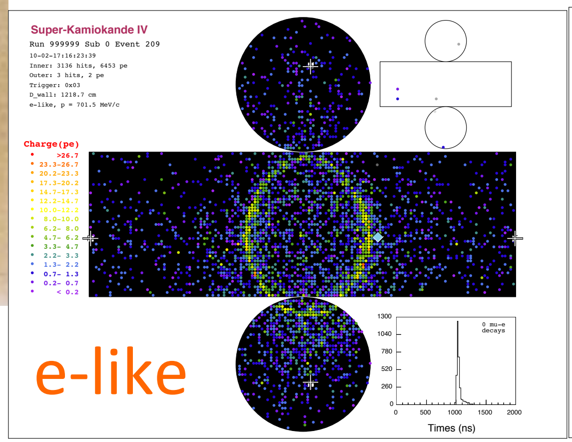
$$\nu_\mu + n \rightarrow \mu^- + p$$

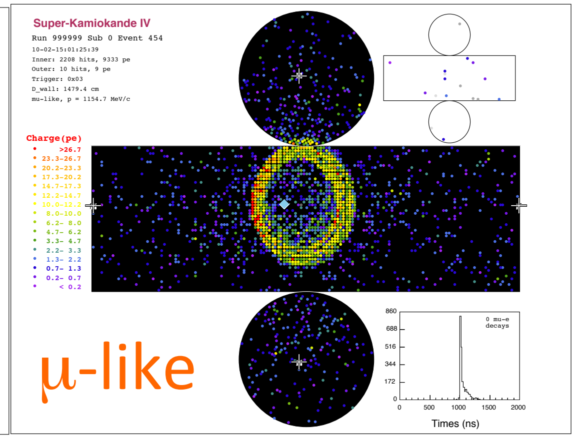
✓ Good Particle ID

✓ Conserve the neutrino direction

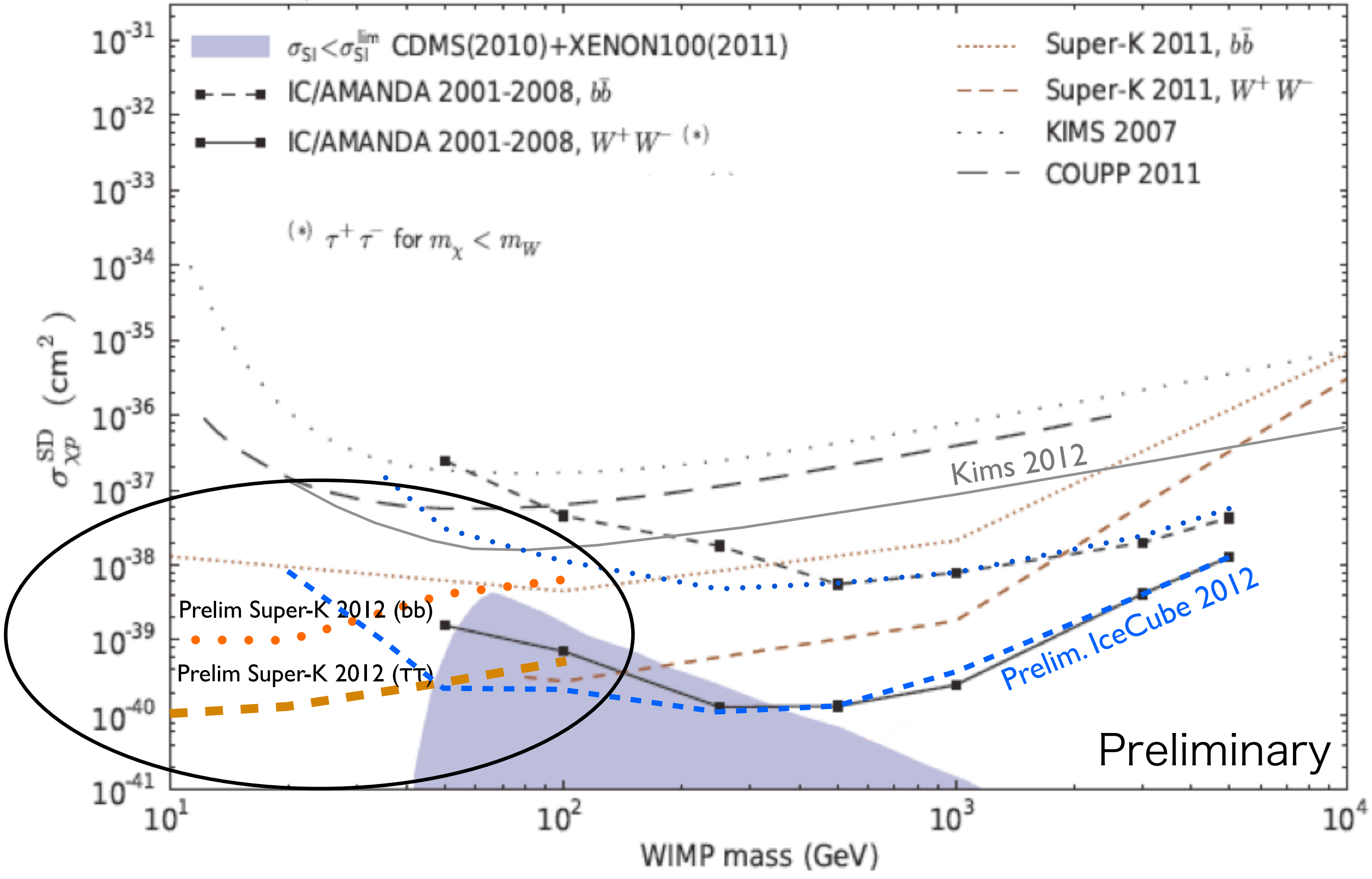
- Important to search for the signal from the Sun

✓ Good energy reconstruction





Recent results



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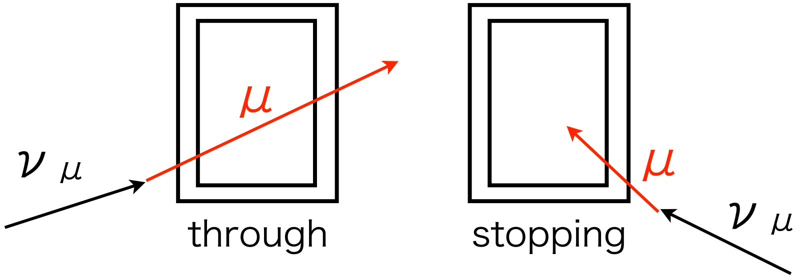
Observation in SuperK

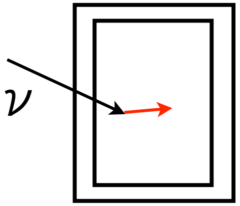
Event category

✓Upward going muons (Upmu)

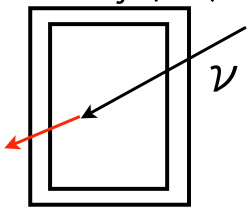


✓Contained events

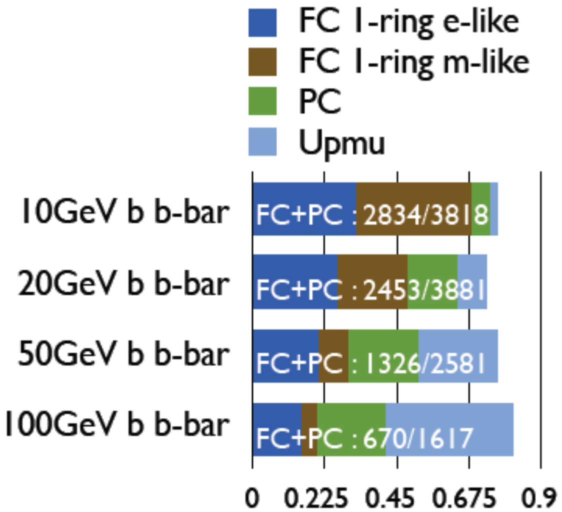
Fully (FC)



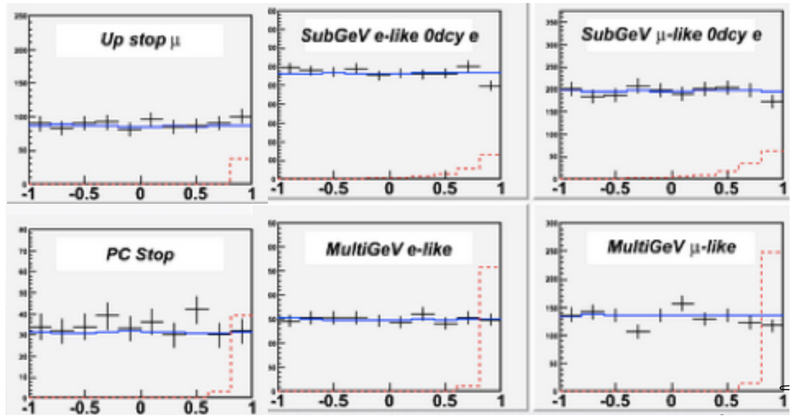
Partially (PC)

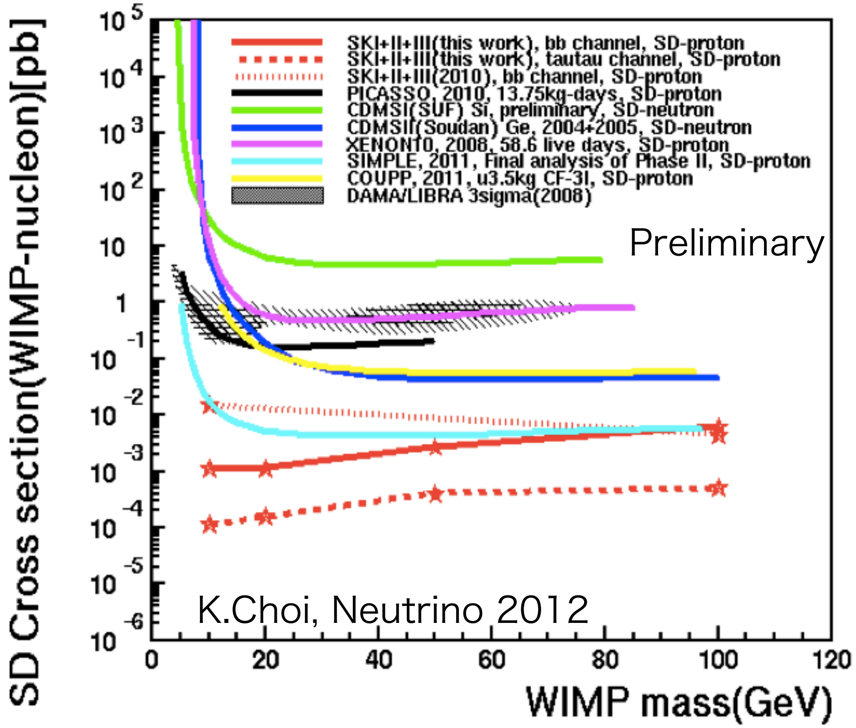


sensitive to low-mass

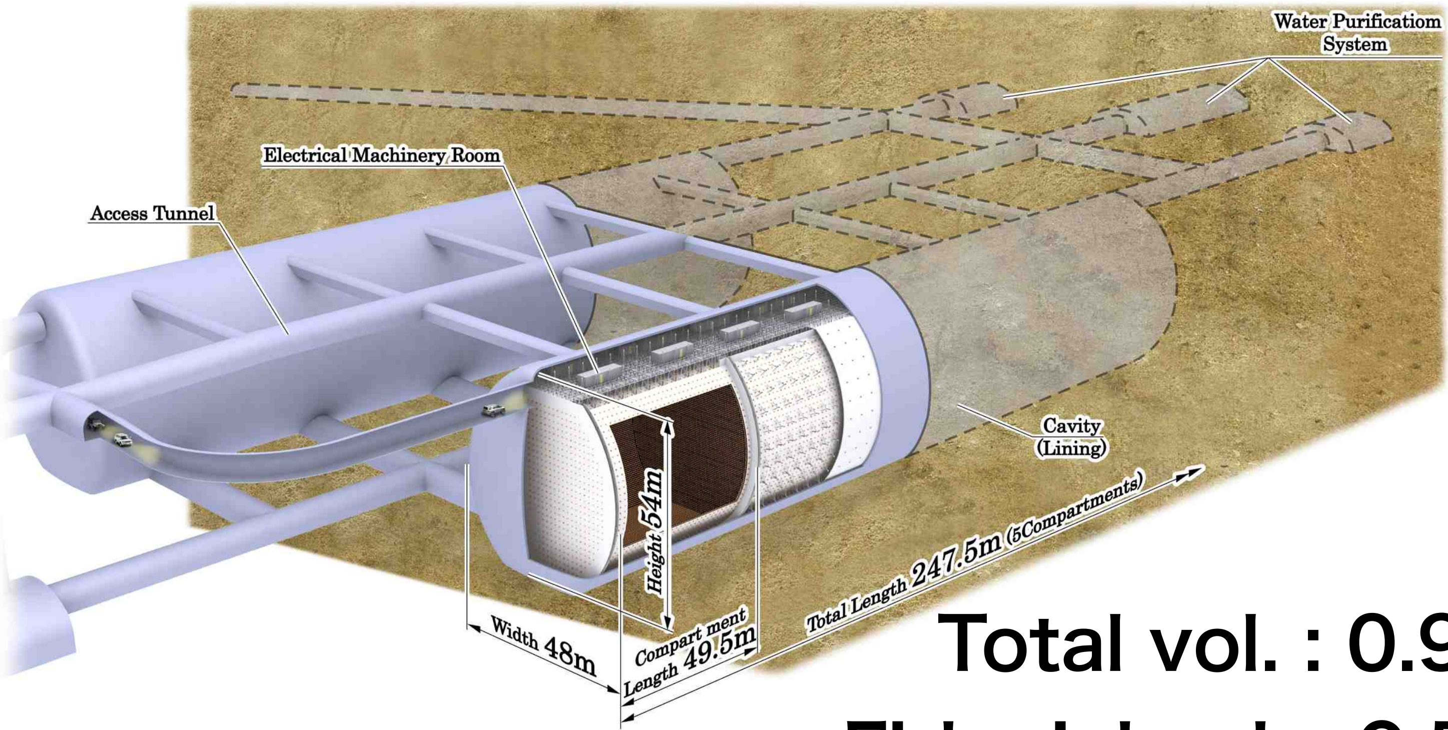


No significant excess from the Sun





Hyper-Kamiokande



LoI : arXiv 1109.3262

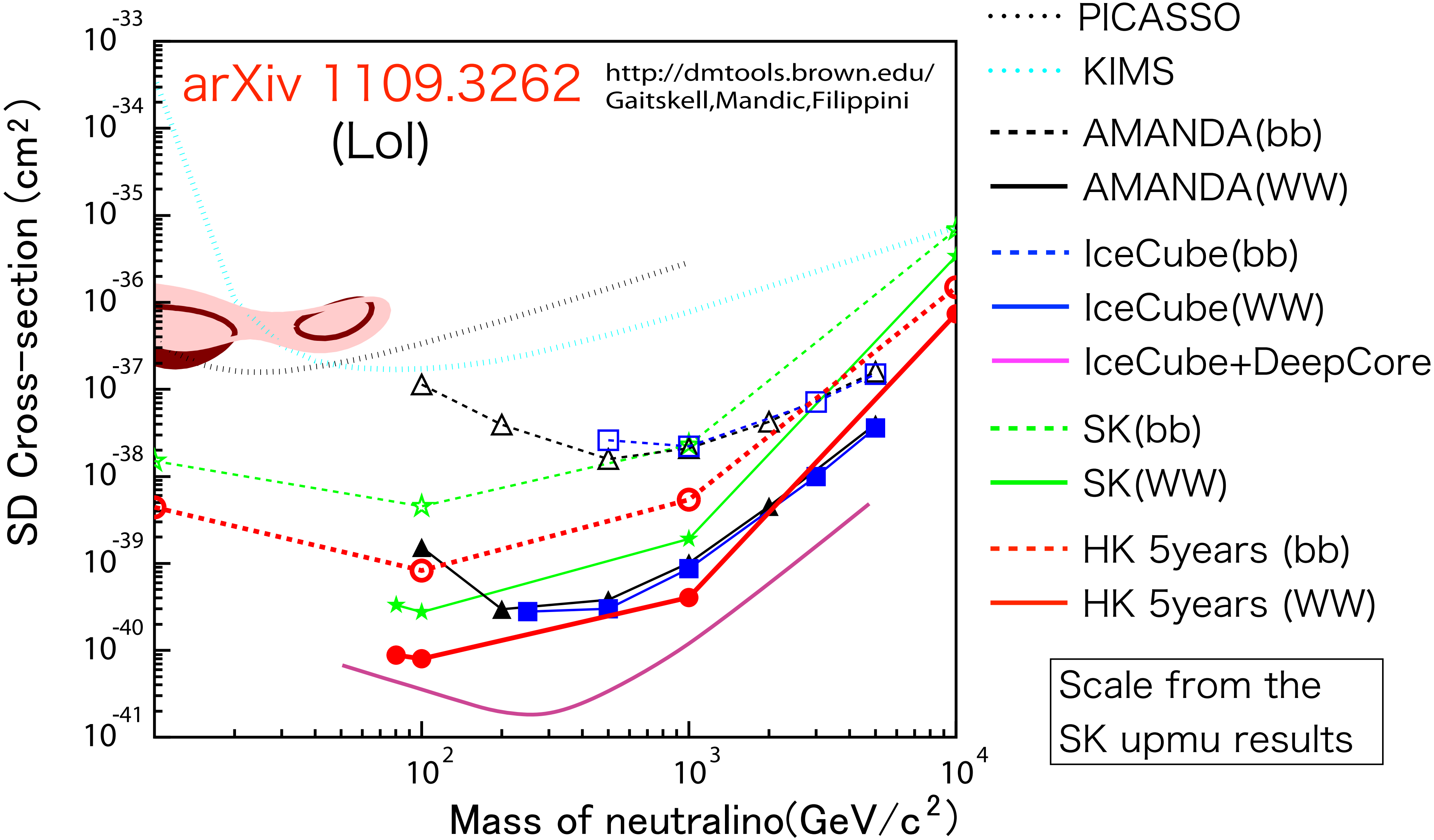
Total vol. : 0.99 Mton

Fiducial vol. : 0.56 Mton

Photo-sensors : 99,000 PMTs

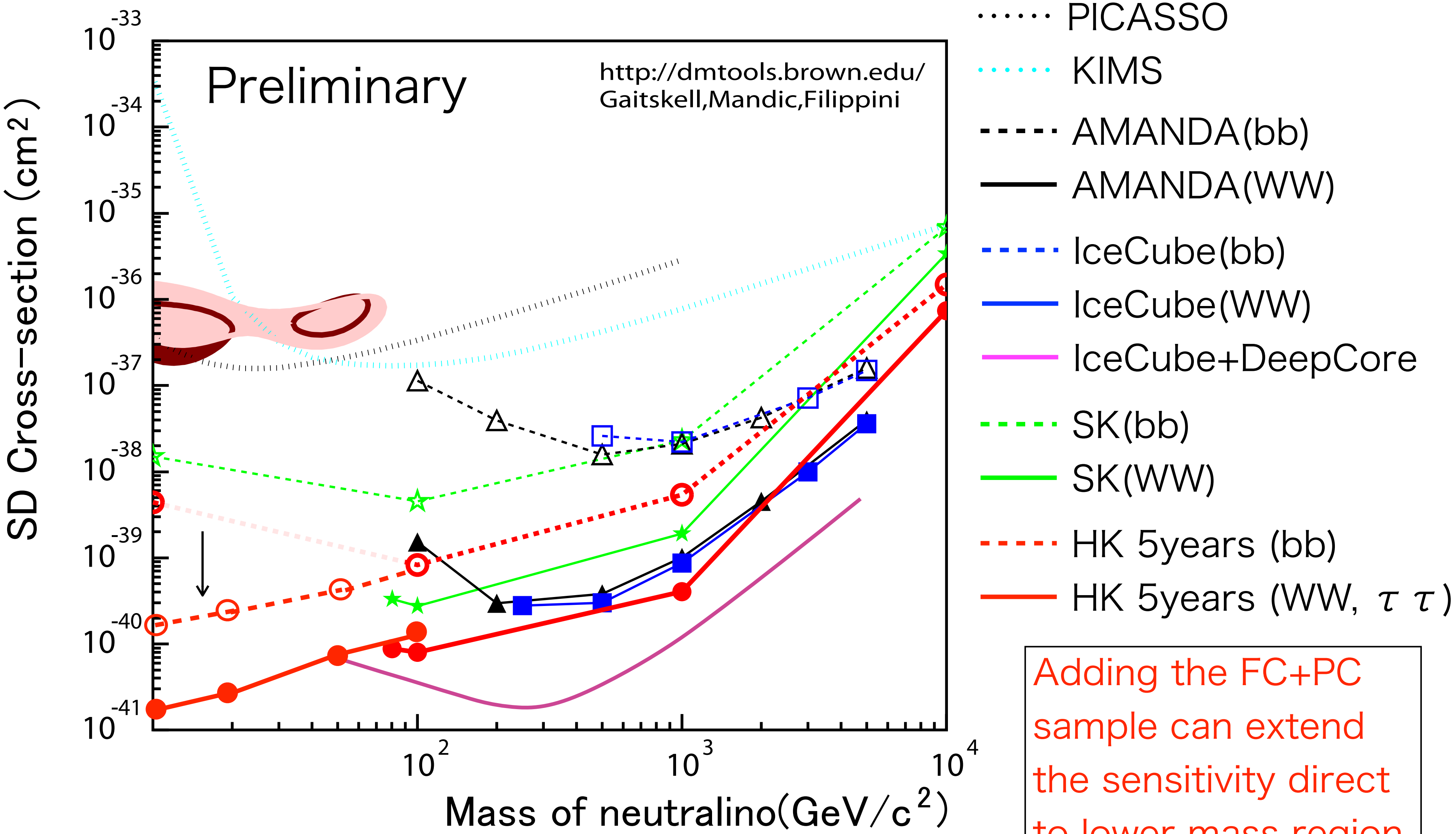
25 times larger than Super-K

Hyper-K sensitivity



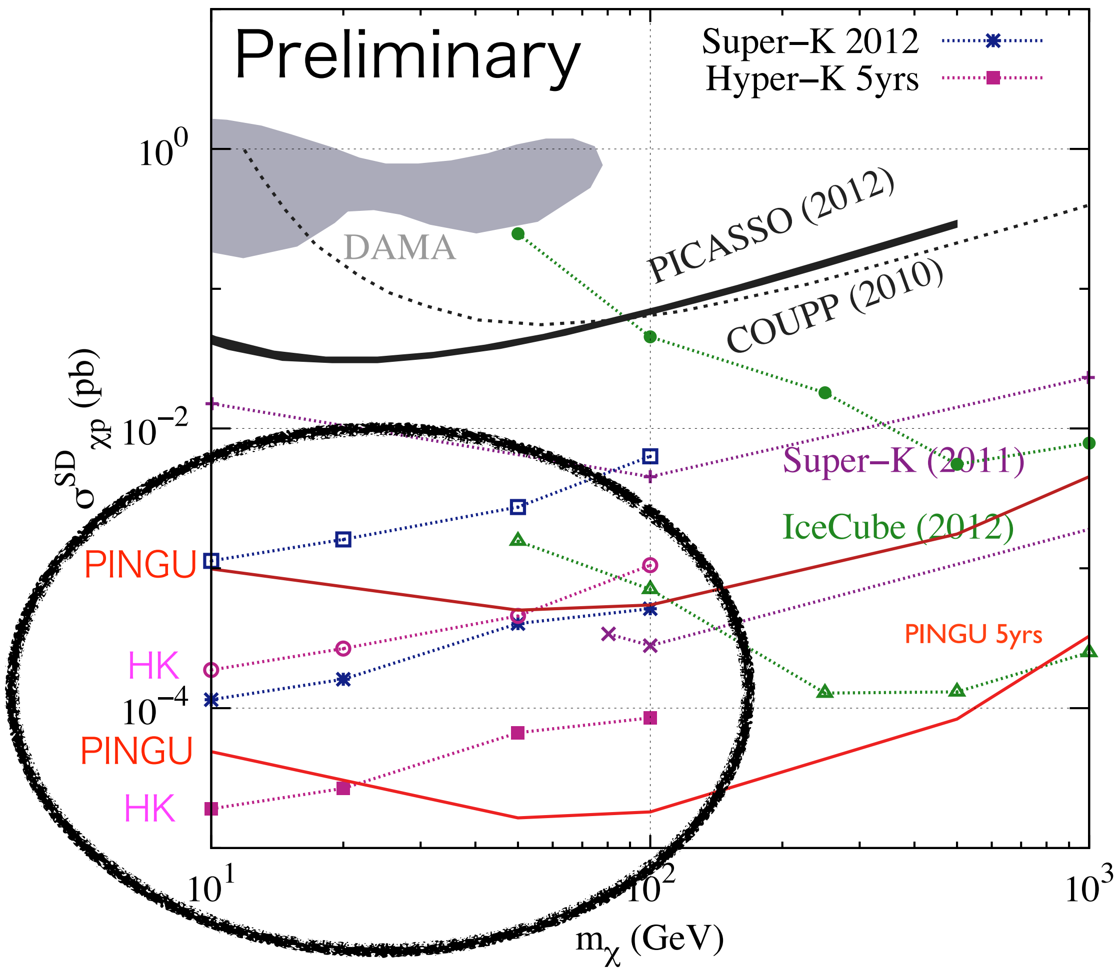
Scale from the SK upmu results

Hyper-K sensitivity



Adding the FC+PC sample can extend the sensitivity direct to lower mass region.

Hyper-K sensitivity



- Scale of achieved Super-K results (FC+PC+upmu) to Hyper-K.
- Hyper-K is sensitive to the interesting WIMP mass region suggested by the direct search experiments.
- Hyper-K compares favorable to other indirect searches for WIMP masses below ~20-50 GeV.

arXiv 1210.4161 by C.Rott

New detection channel

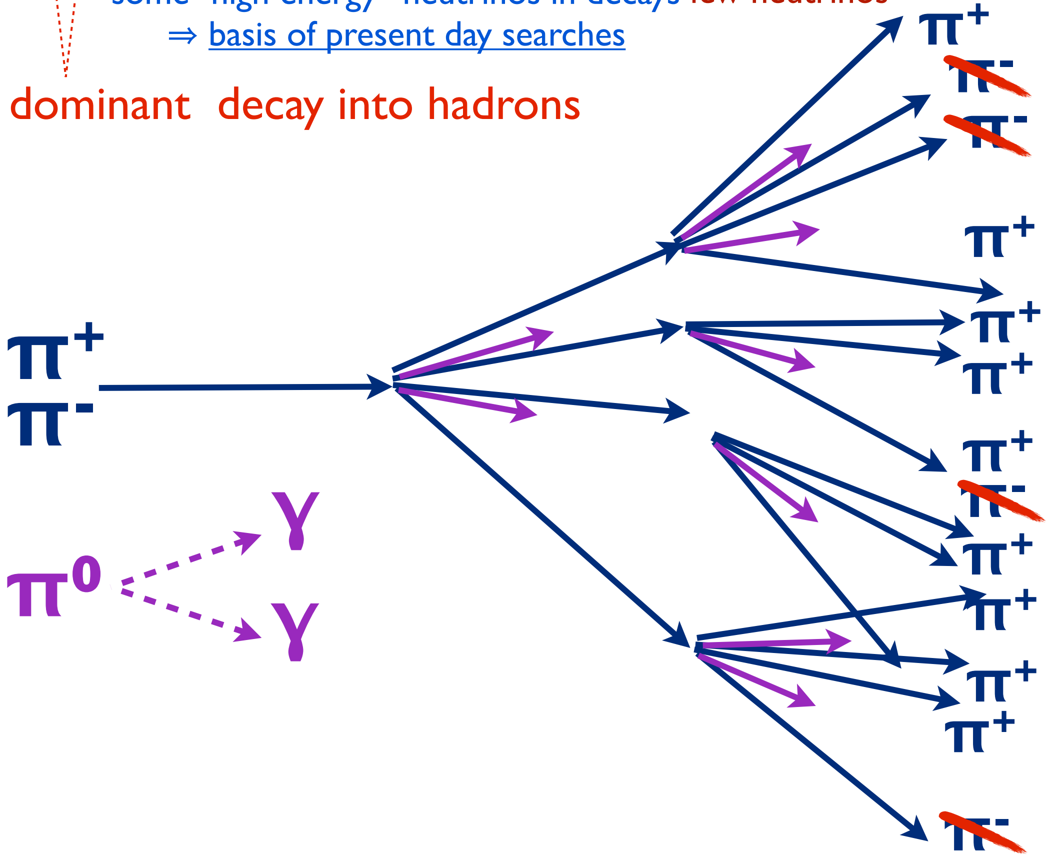
Possible annihilation channels:

qq,gg,cc,ss,bb,tt,W^+W^-, ZZ, $\tau^+\tau^-$,$\mu^+\mu^-$, νν, e^+e^-,γγ

some "high energy" neutrinos in decays few neutrinos

⇒ basis of present day searches

dominant decay into hadrons

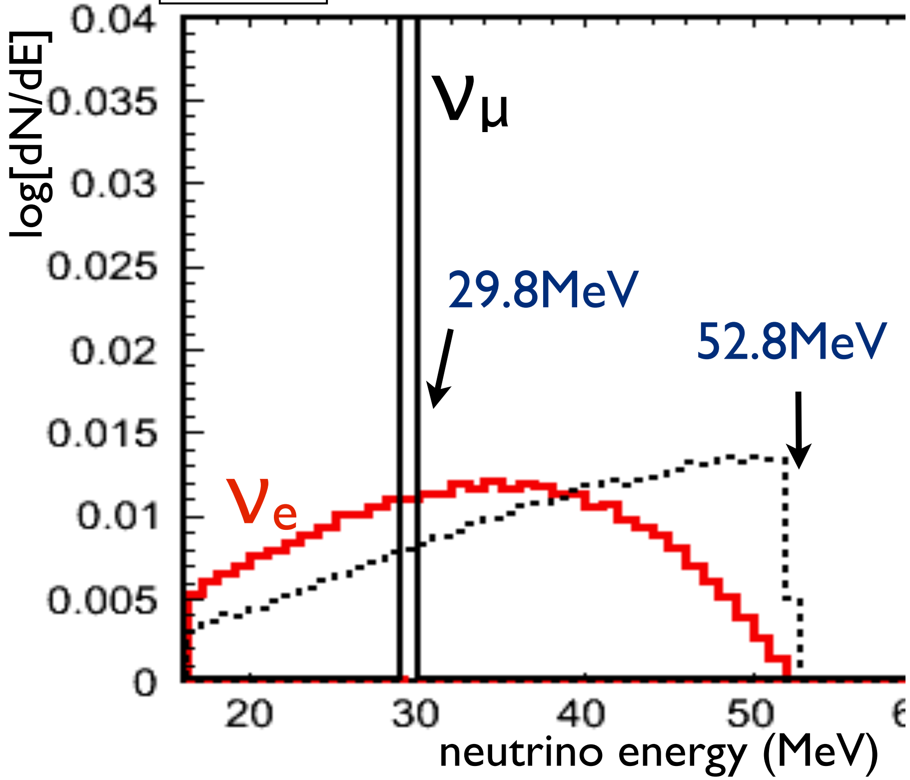


Charged pions at rest producing neutrinos up to E=52.8MeV

Decay At Rest

$$\pi^+ \to \mu^+ \nu_\mu$$

$$\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$$



K. Bays {Super-K Collaboration}
Phys.Rev. D85 (2012) 052007

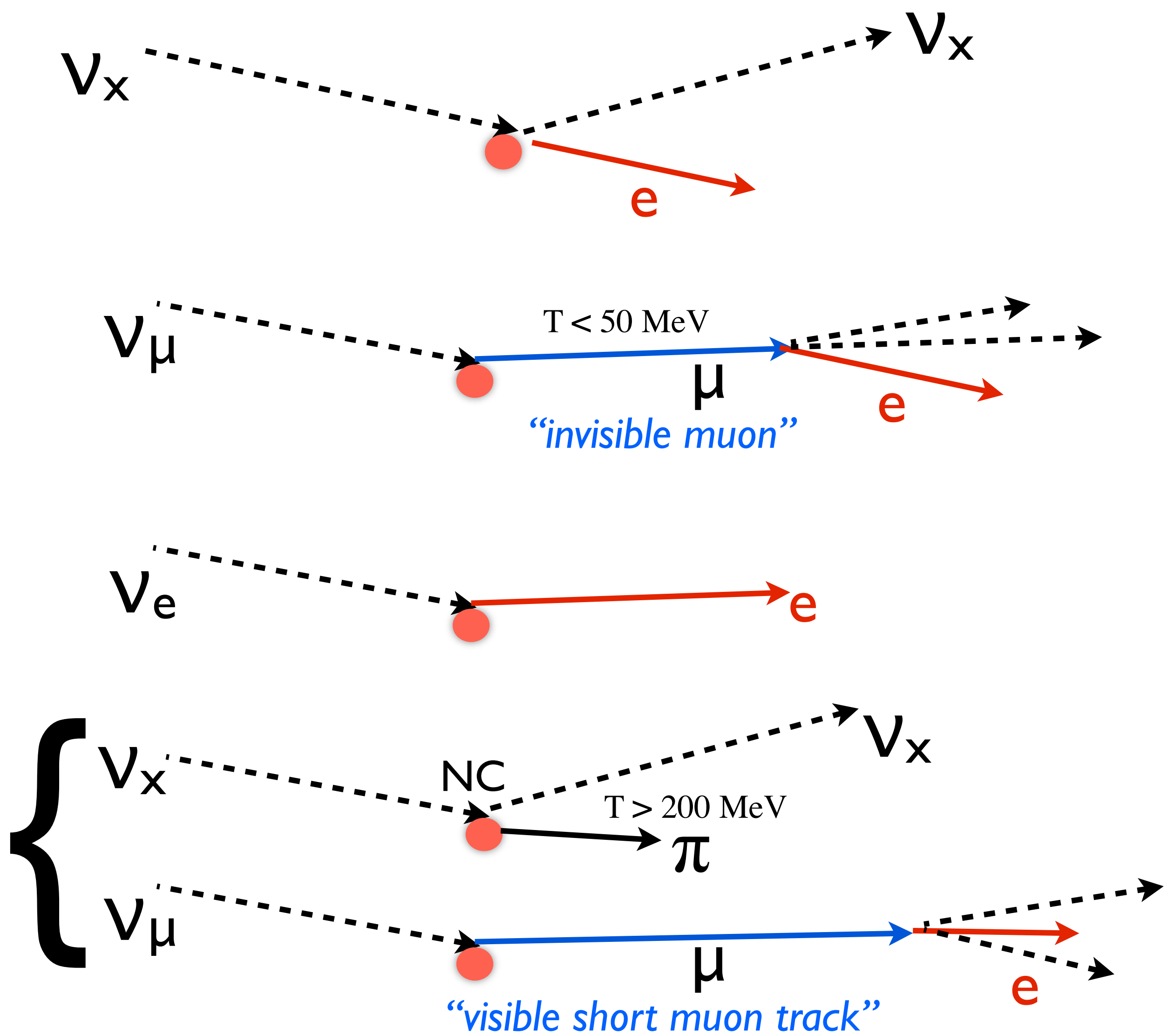
Backgrounds

NC Elastic
"reactor + solar"

Decay electron
"atm. muon neutrinos"

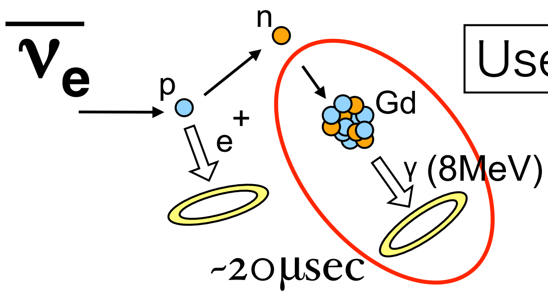
ν_e CC
"atm. electron neutrinos"

μ/π
"μ/π production from atm. neutrinos"



Gadolinium in water

- Decay electron events are the dominant background
- Identifying neutrinos of the inverse beta decay reaction can provide a way to discriminate against this background

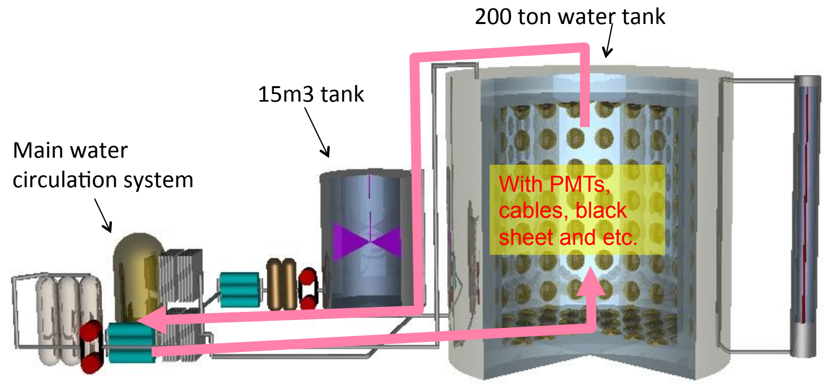


Use a delayed coincidence signal

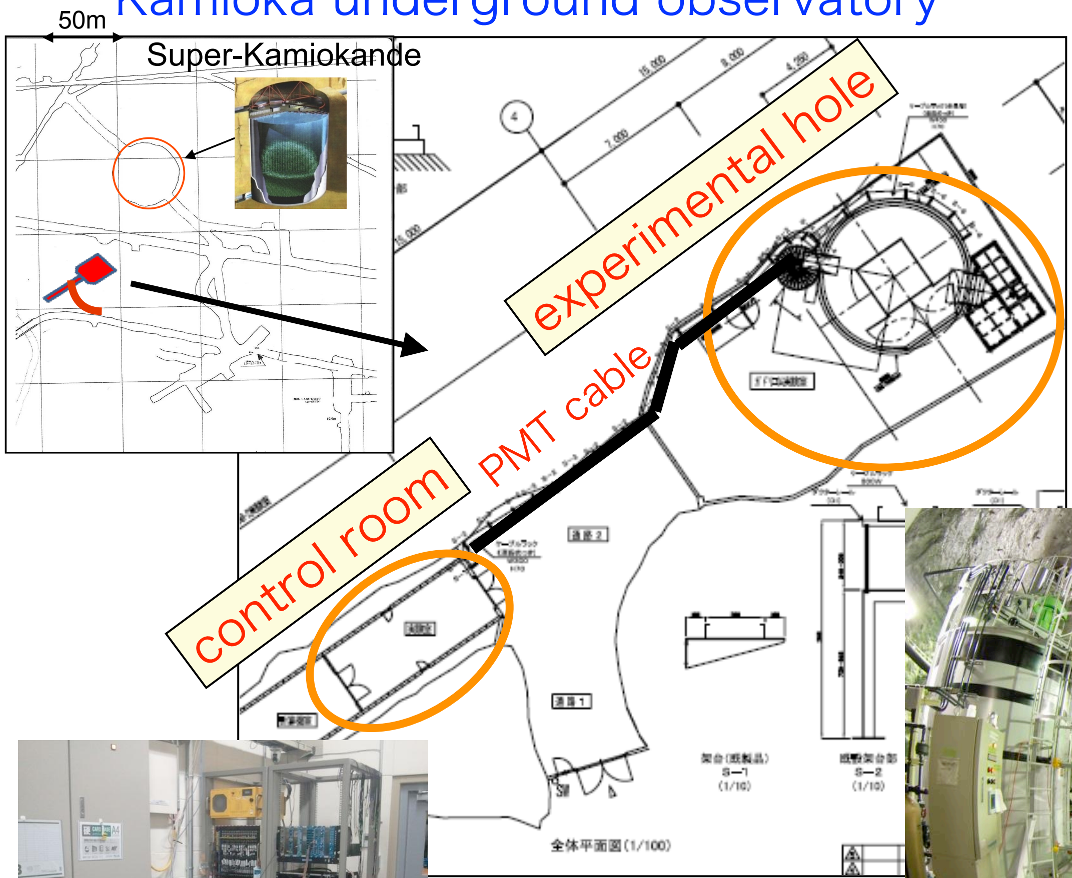
- Proposal : add Gd to Super-K for SuperNova relic neutrino search. (Beacom & Vagins : Phys.Rev,Lett. 93(2004)171101)
  - 0.2% Gd solution would yield >90% neutron captured.

EGADS

Evaluating Gadolinium's Action on Detector Systems

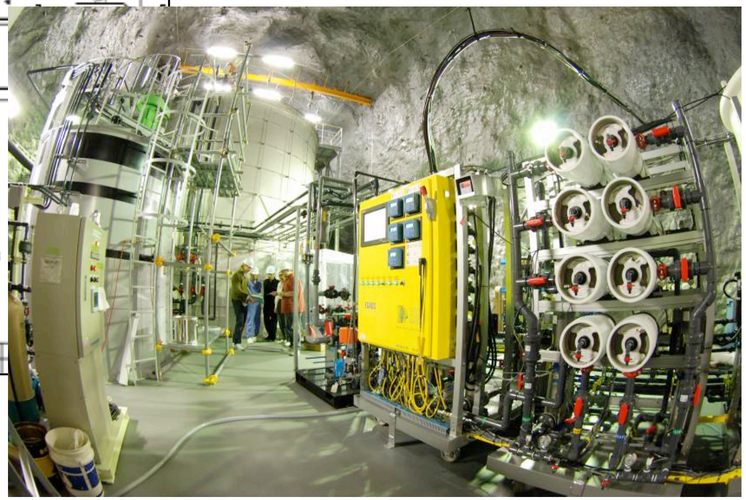


Kamioka underground observatory



R&D for Gd in SuperK (GADZOOKS!)

- 200 ton tank with 232 PMTs
- Establish purification method

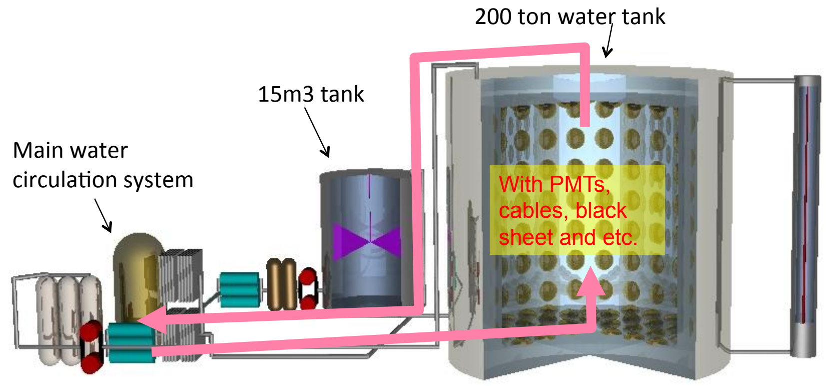


Electronics and computer

Start data taking in this Summer

EGADS

Evaluating Gadolinium's Action on Detector Systems



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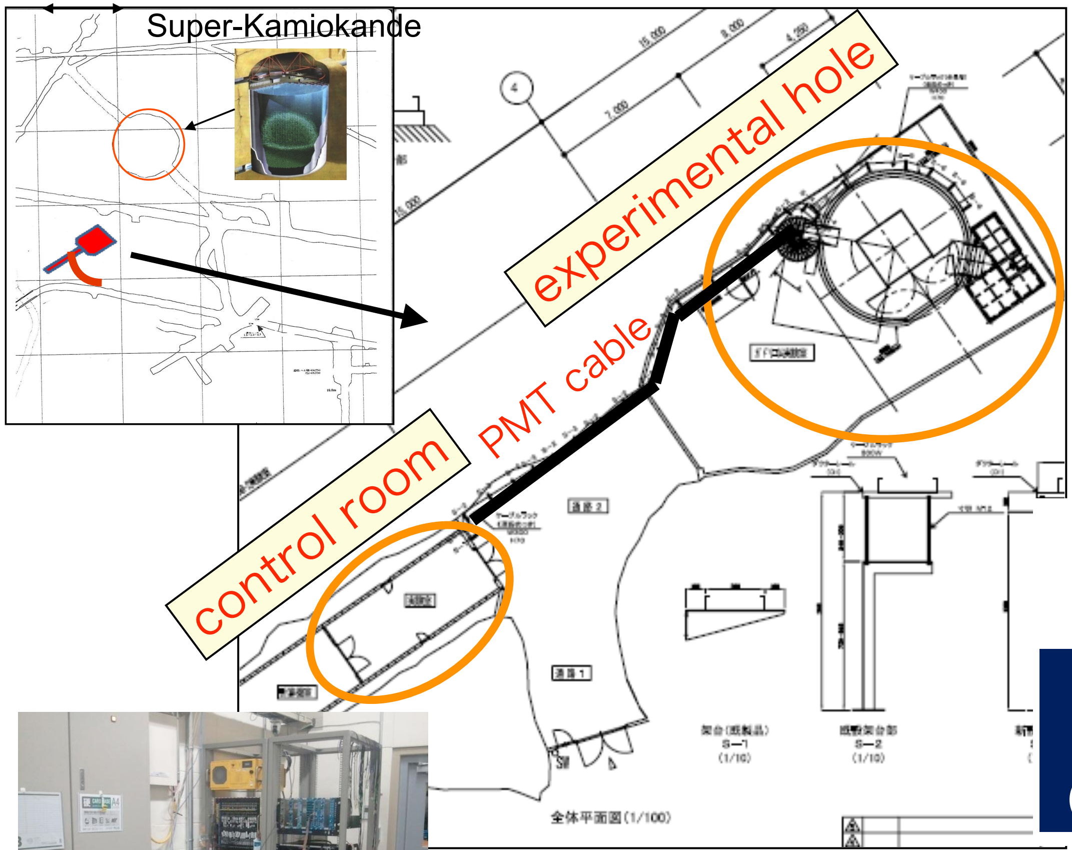
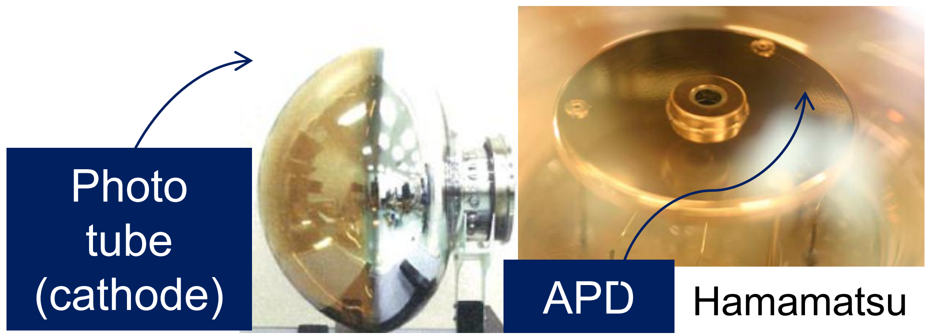


R&D for Hyper-K (Gd option)

- 200 ton tank with 8 HPDs
- Establish purification method

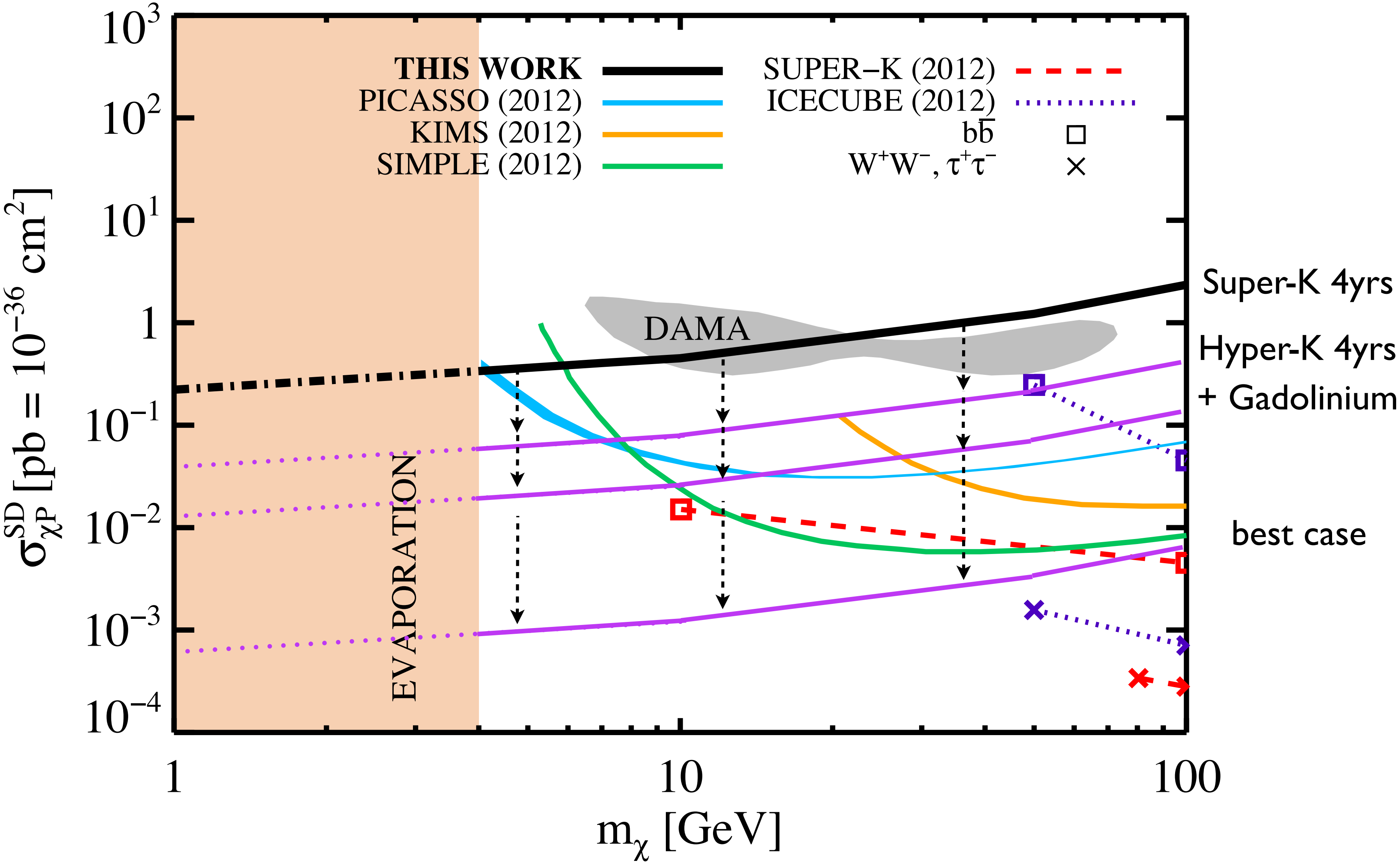


M.Yokoyama, this afternoon session

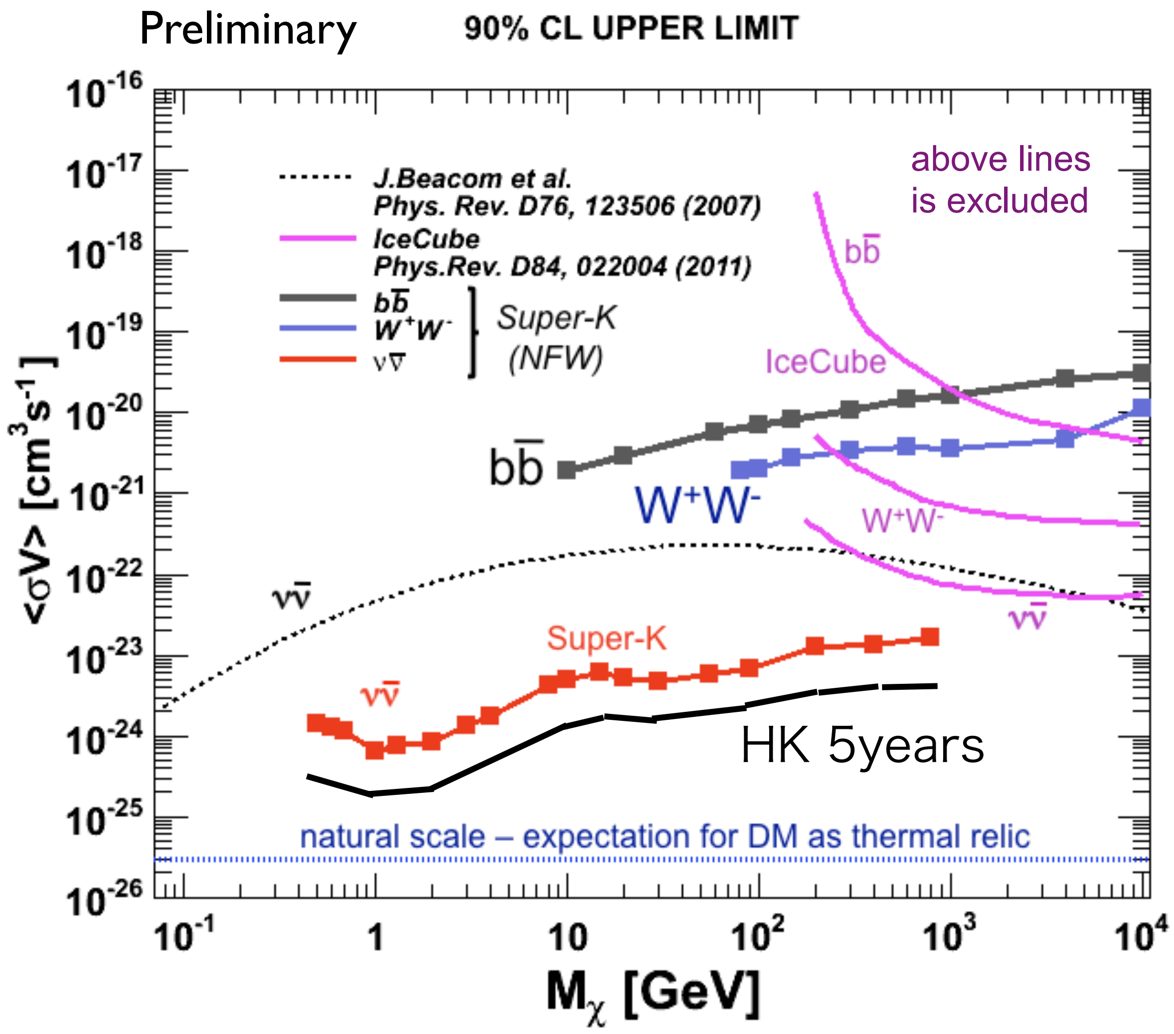
Electronics and computer

Start data taking in this Summer

Hyper-K sensitivity



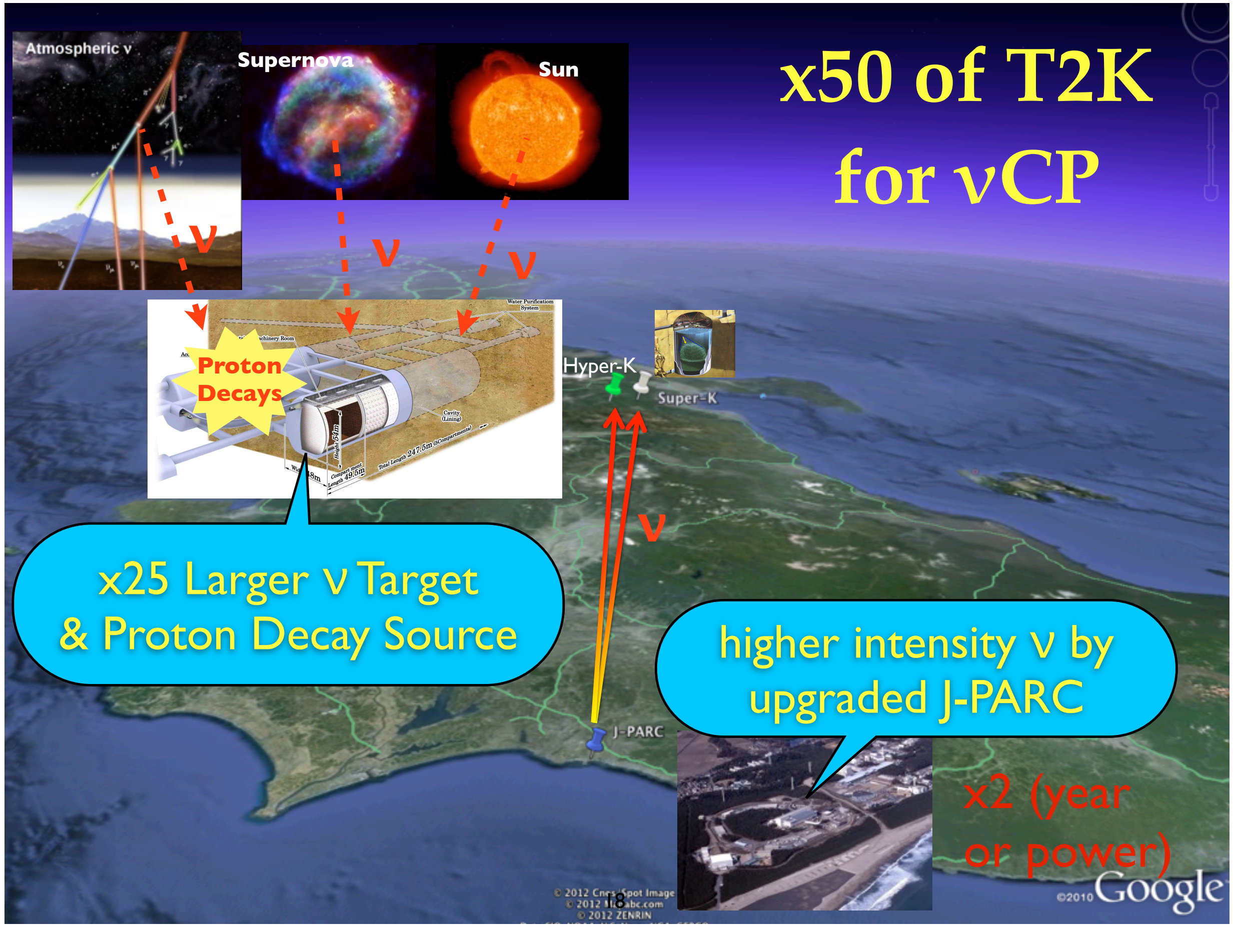
Galactic search



Hyper-Kamiokande

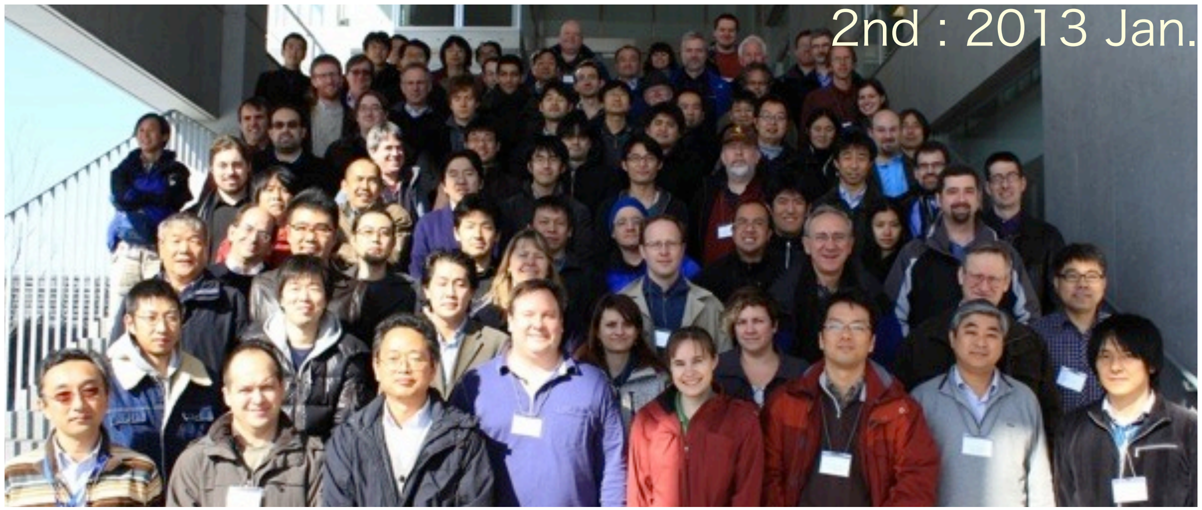
multi-purpose detector

LoI : arXiv 1109.3202



International HK meeting

http://indico.ipmu.jp/indico/conferenceTimeTable.py?confId=7



http://indico.ipmu.jp/indico/conferenceTimeTable.py?confId=10

Start up an international working group (~100 researchers)

< List of R&D >

- Physics potential
- Cavity and Tank
- Water system
- Photo-sensor development
- DAQ and electronics
- software
- calibration

etc.

Conclusion

- Water Cherenkov detector has a unique potential for indirect WIMP search.
  - Established by Super-K.
  - Good flavor tagging, energy and direction reconstruction.
- Hyper-K will be most important to cover the WIMP mass region less than 50GeV.
- New low-energy neutrinos from the Sun could offer unique prospects for Hyper-K.