Astroparticle Physics in Hyper-Kamiokande

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EPS-HEP, 8 July 2017

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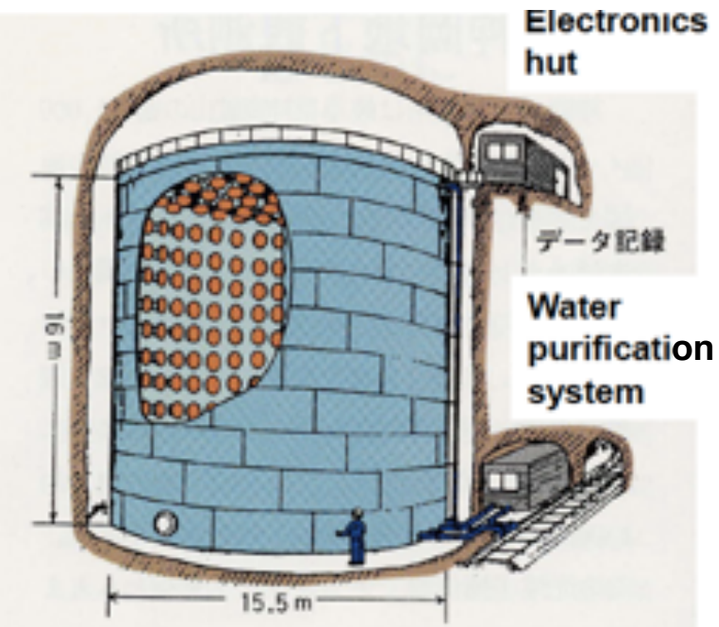
Agenda

- Status of Hyper-K
- Supernova Burst Neutrinos
- Supernova Relic Neutrinos
- Solar Neutrinos
- Dark Matter

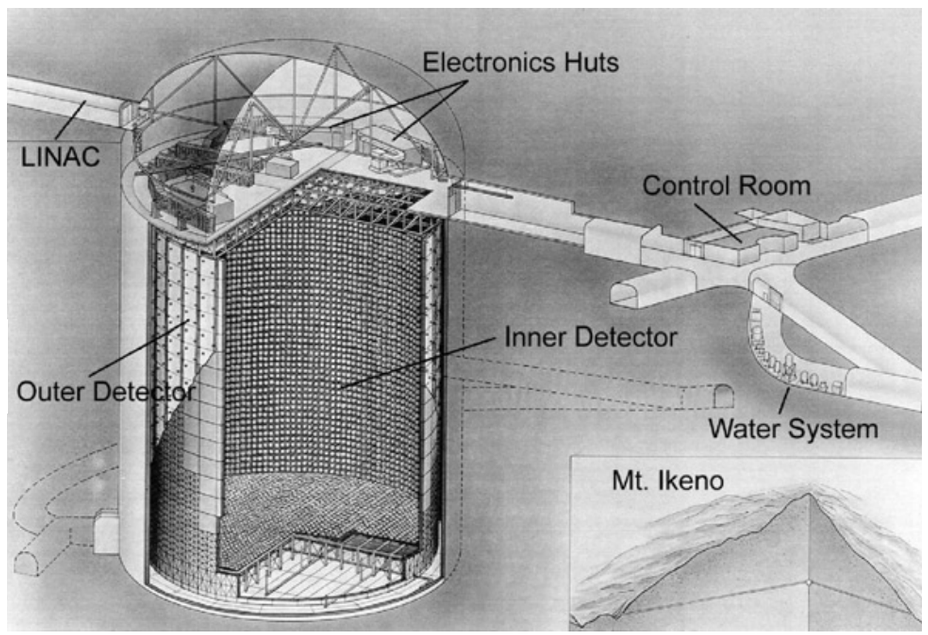
3rd Generation Water Cherenkov Detector

Kamiokande
1983–1996



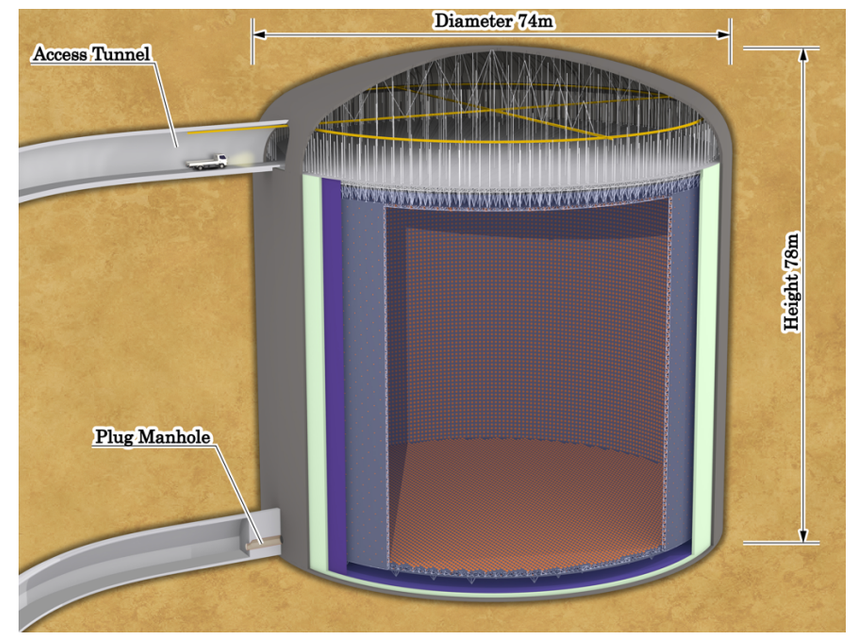

Koshiba, 2002

Super-Kamiokande
1996–today (and beyond)




Kajita, 2015

Hyper-Kamiokande
~2026–???

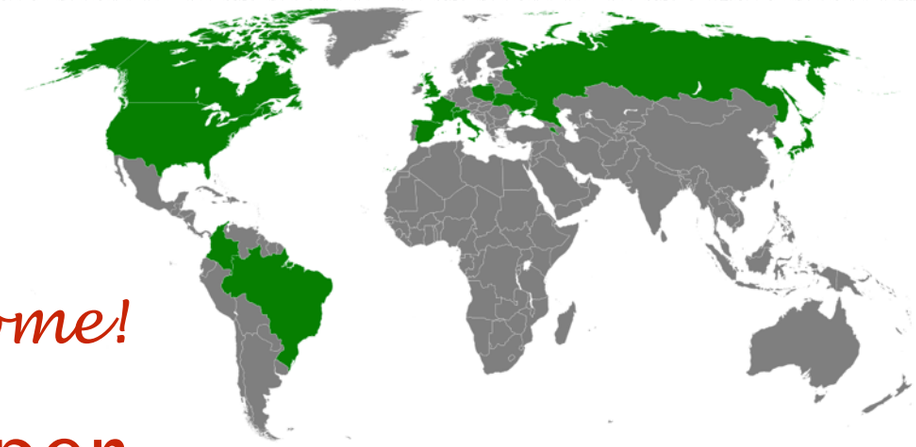



???, 20??

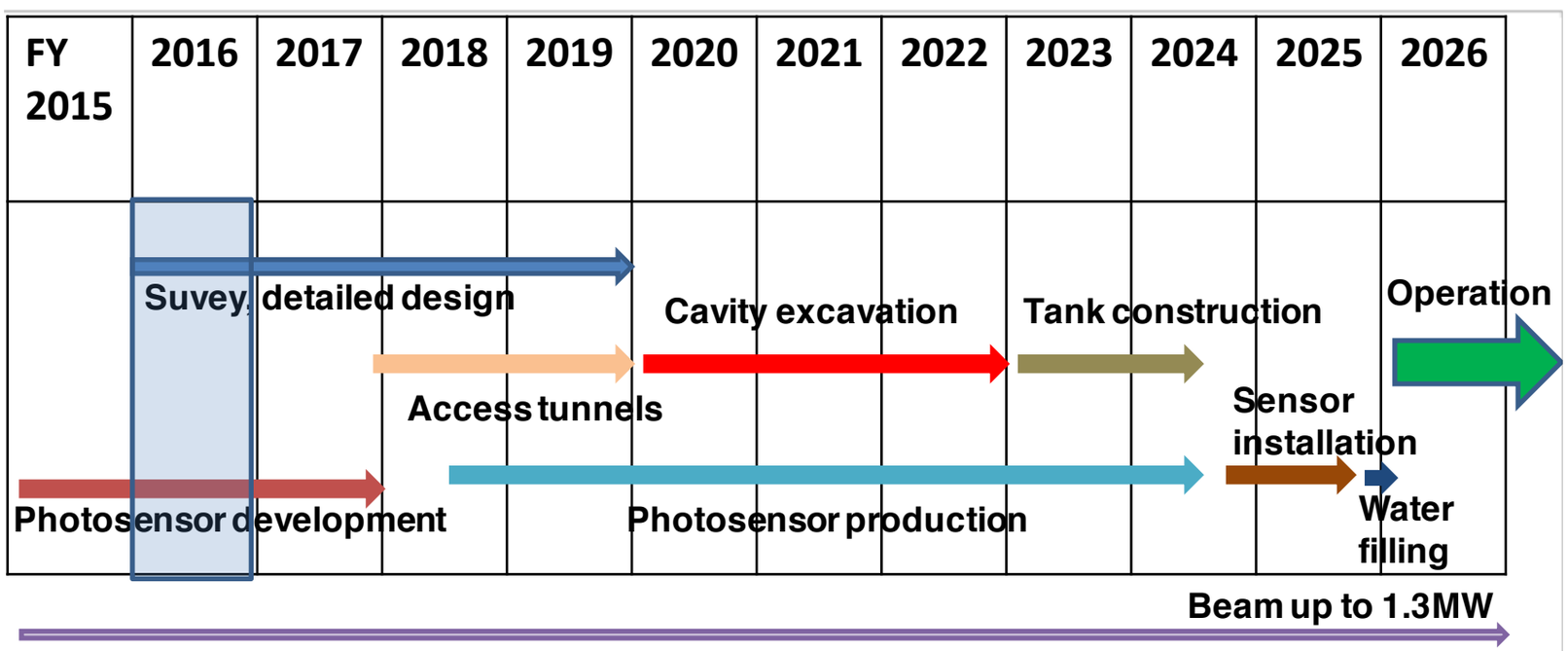
Status of Hyper-K

- Proto-Collaboration formed in 2015
  - now: 300 people in 15 countries

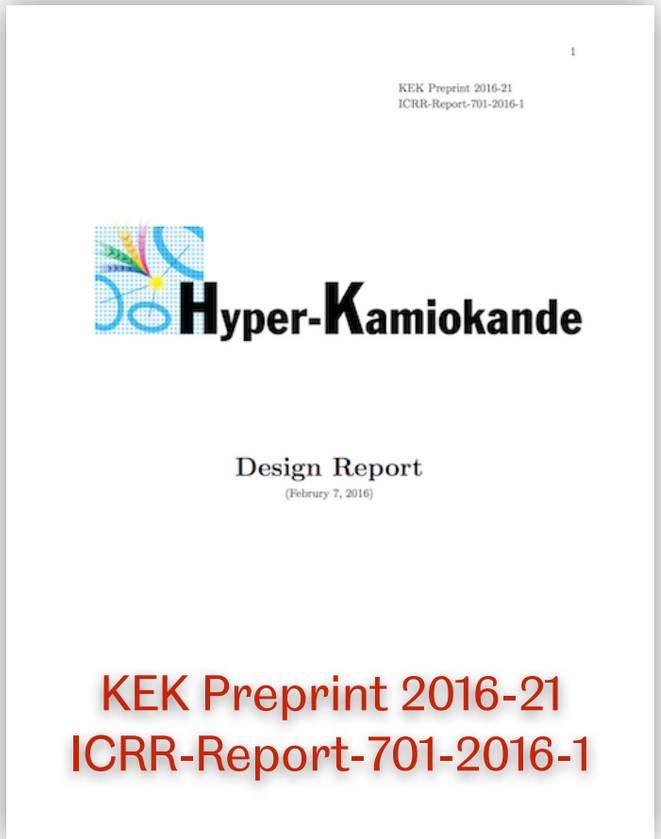
New members welcome!



- published Design Report and White Paper for 2nd tank in Korea in 2016



Timeline for 1st tank (2nd tank up to 6 years later)

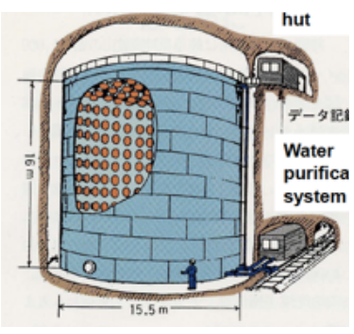


KEK Preprint 2016-21
ICRR-Report-701-2016-1

http://hyperk.org/?p=215

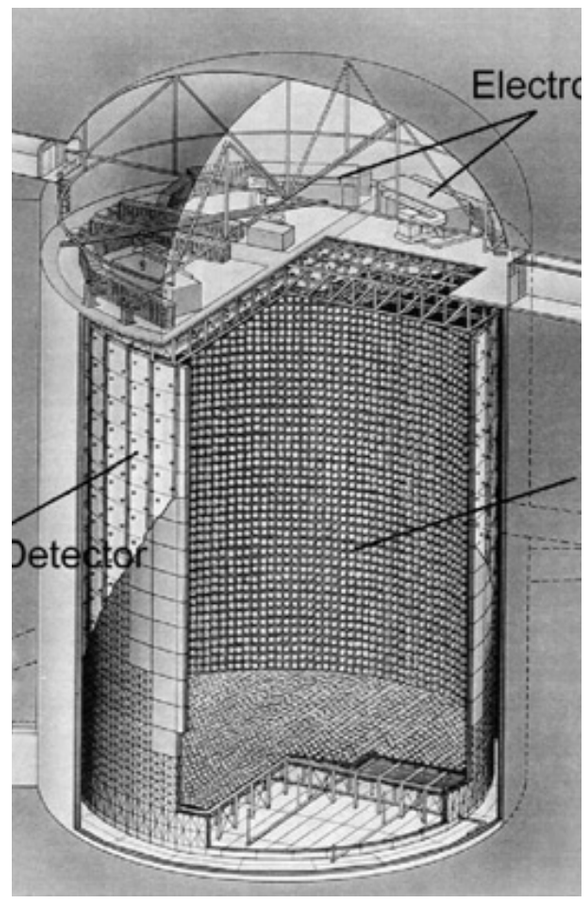
3rd Generation Water Cherenkov Detector

Kamiokande
1983–1996



3 kton

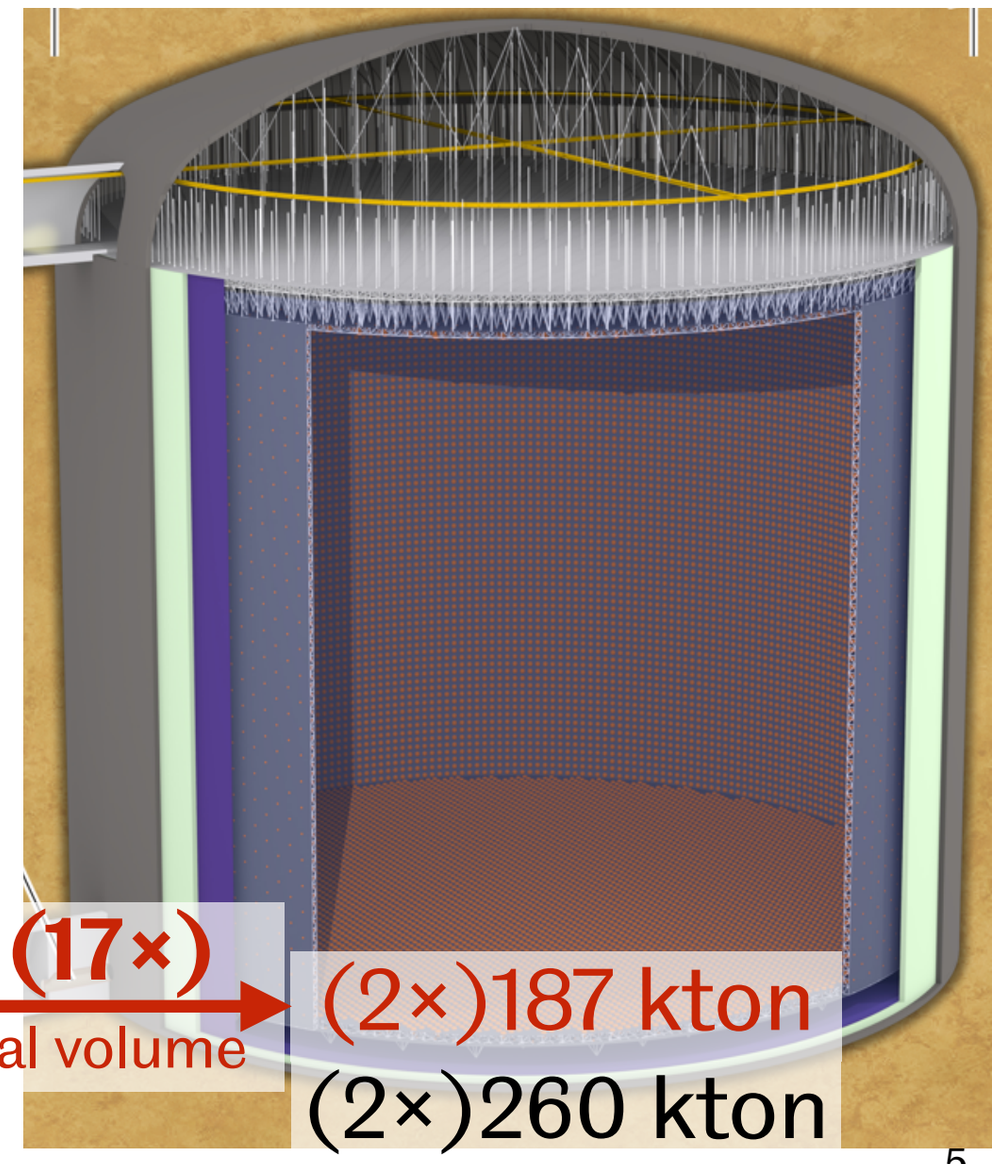
Super-Kamiokande
1996–today (and beyond)



22.5 kton → 8× (17×) fiducial volume → (2×)187 kton

50 kton

Hyper-Kamiokande
~2026–???



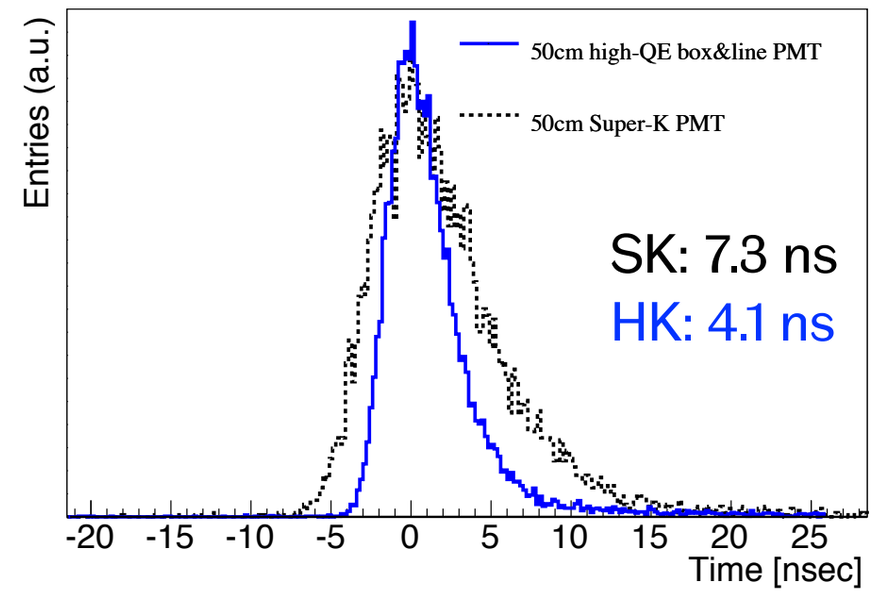
(2×)260 kton

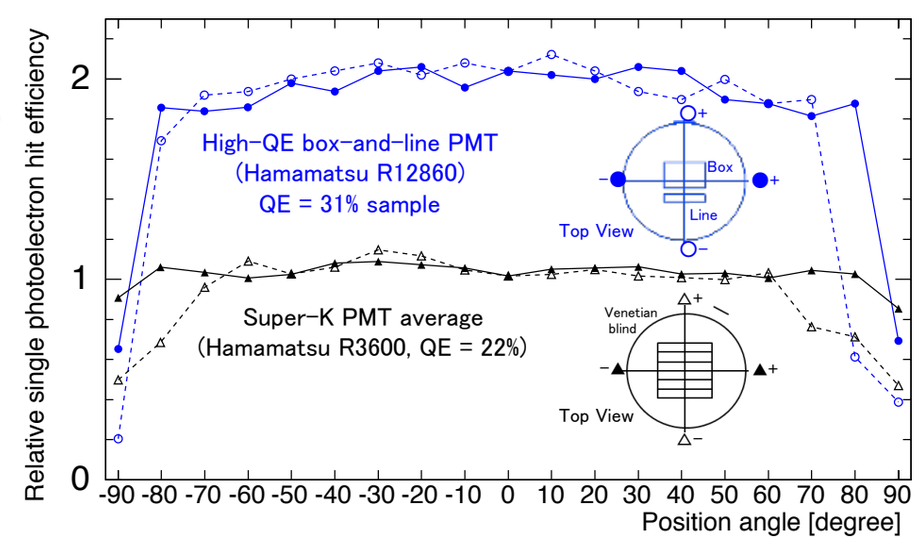
Changes for Low-E Physics

- lower overburden ➔ higher μ flux (e.g. solar: 2.7× spallation background compared to SK)
  - 2nd tank in Korea with SK-like overburden

- new PMTs with 2× timing resolution and 2× photon detection efficiency
  - **better energy/vertex reconstruction ➔** lower bkgd & enhanced physics capabilities
  - **lower energy threshold**
  - R&D is still ongoing
    (e.g. mPMTs – MoU with KM3NeT)

- build on experiences of SK-Gd



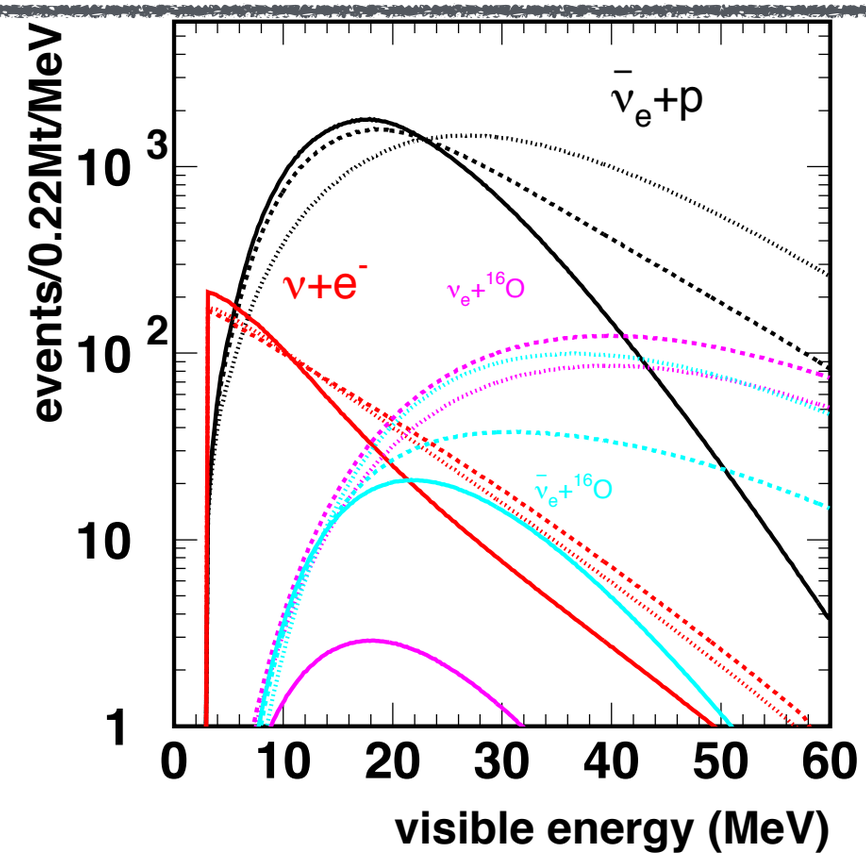


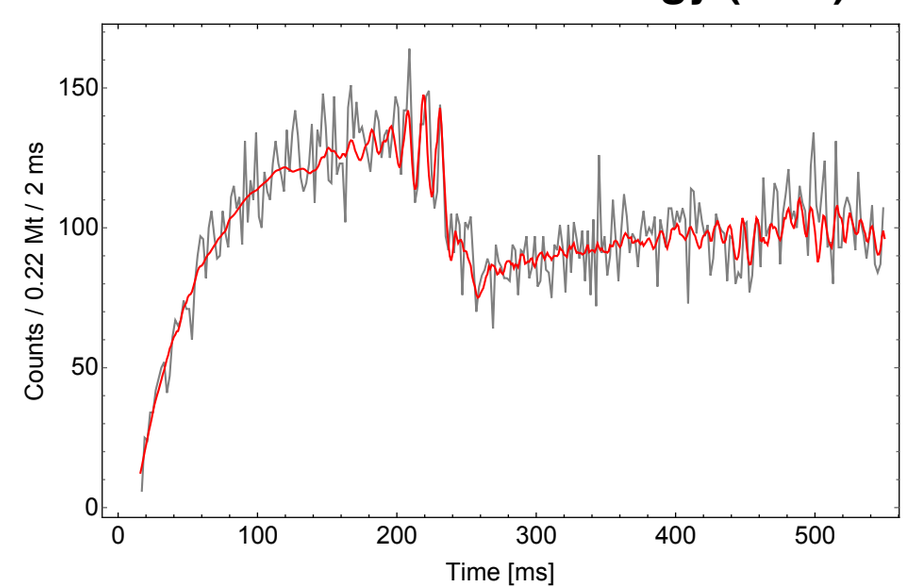
50cm PMT
Hamamatsu R12860

Supernova ν Burst

- at 10 kpc: **50 k – 80 k events** per tank (hierarchy-dependent) **in ~10 s**
- precise event-by-event **time & energy** information
- **directionality**: ~1° (via νe-scattering)
- most sensitive to $\overline{\nu}_e$ (~90% inverse beta decay on H)

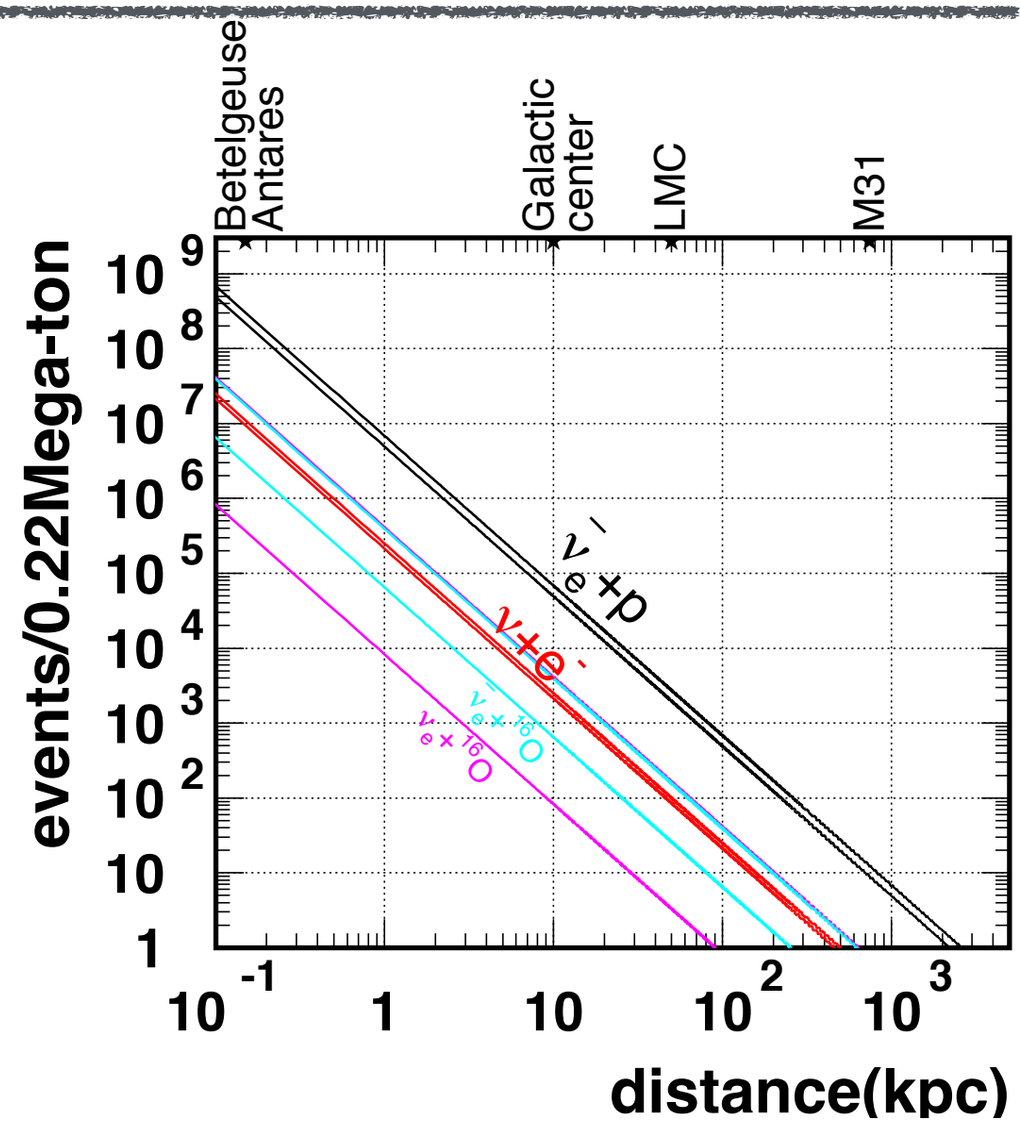
➔ detailed information on SN explosion mechanism (e.g. Standing Accretion Shock Instability – SASI)

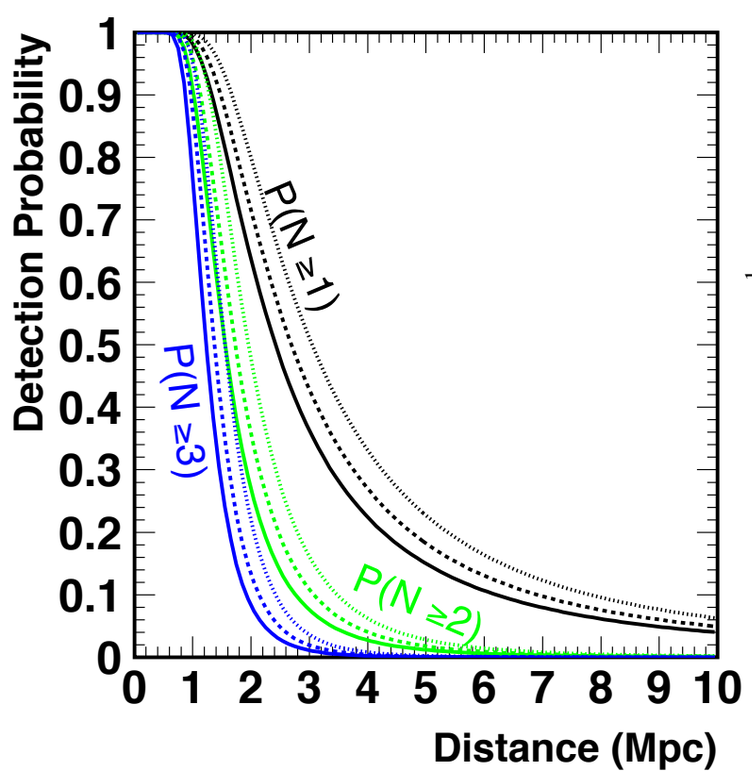


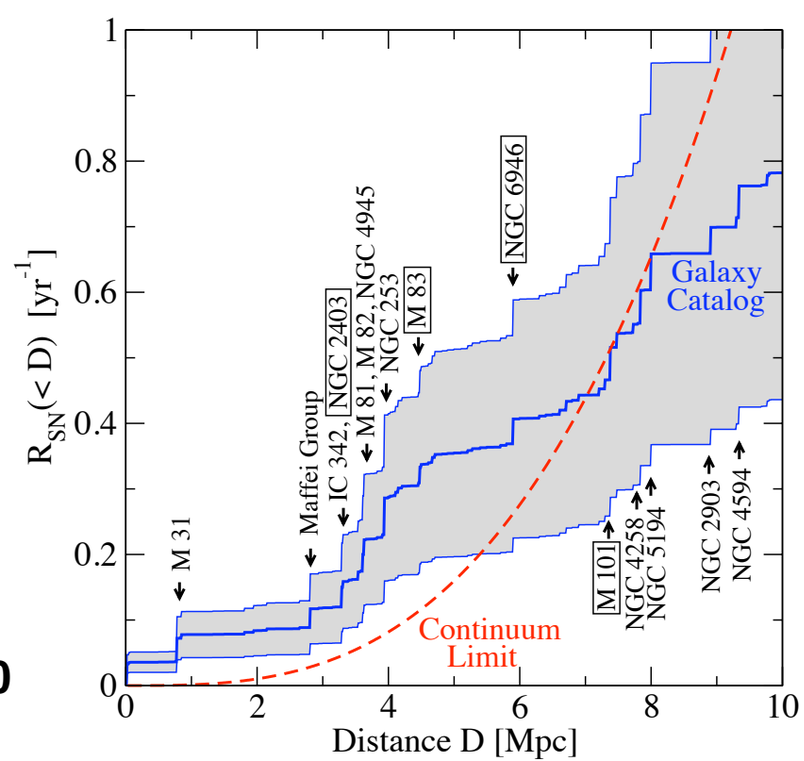


SN in Nearby Galaxy

- 2100–3150 events in LMC (SN1987a-like)
- 9–13 events in Andromeda
- ≥1 event out to few Mpc



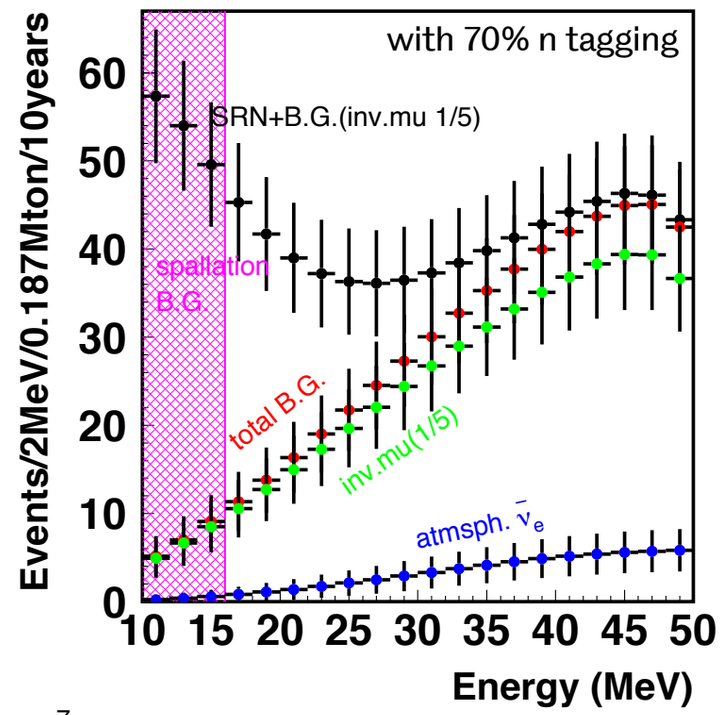


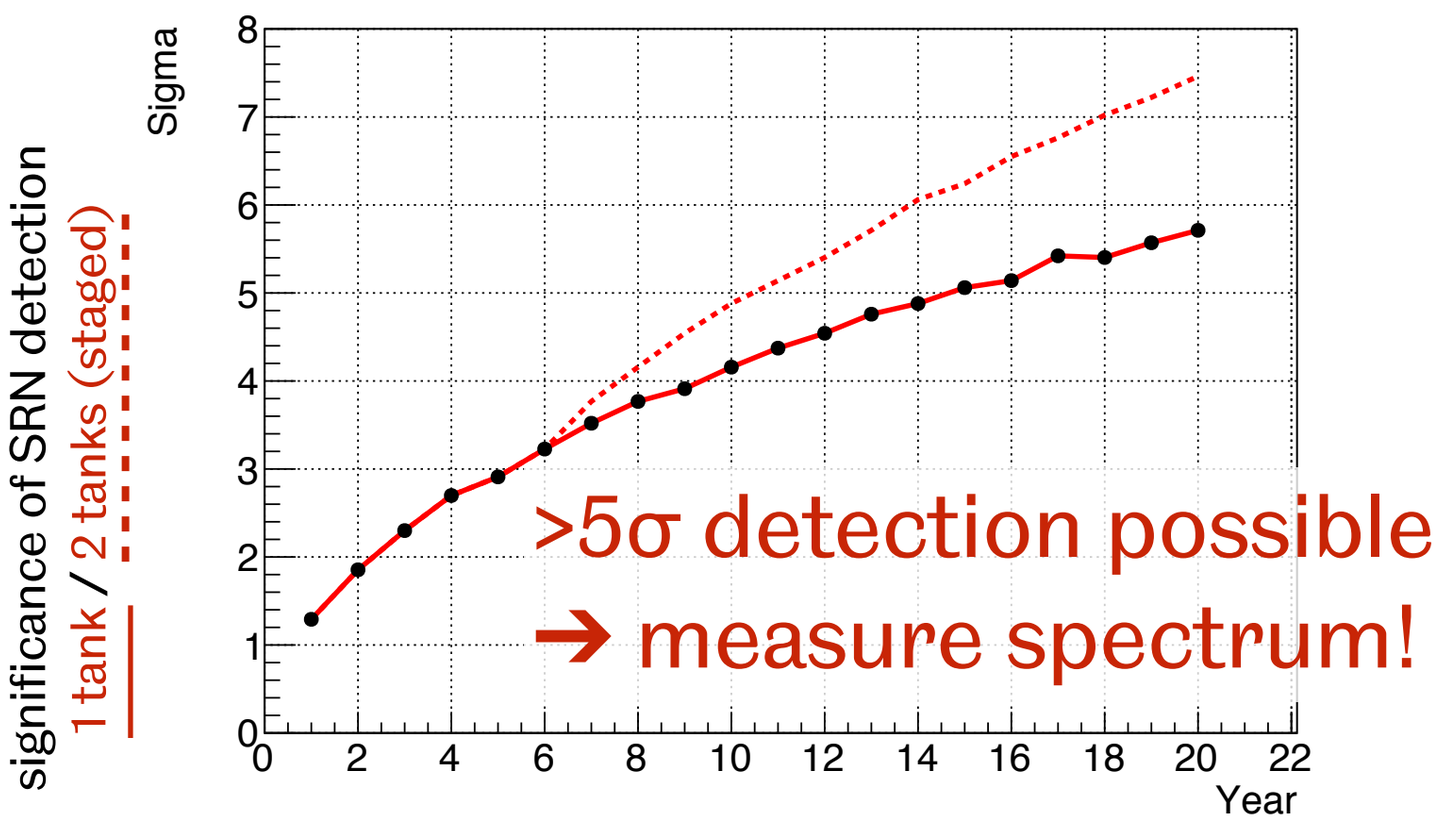


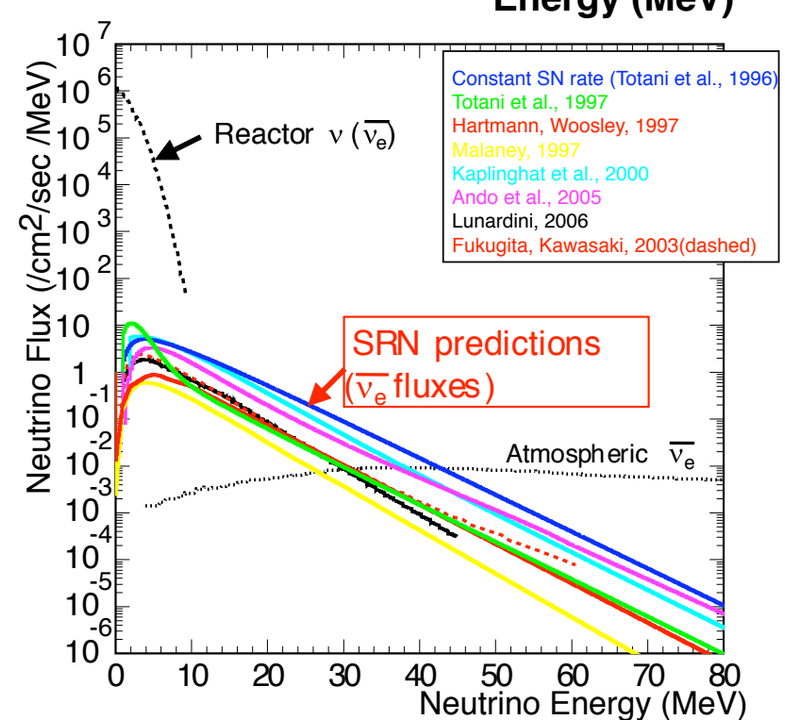
→ important test for SN simulations

Supernova Relic Neutrinos

- ν from all SN integrated over the history of the universe
  - encode history of star formation
  - information on dim SNe & black hole formation



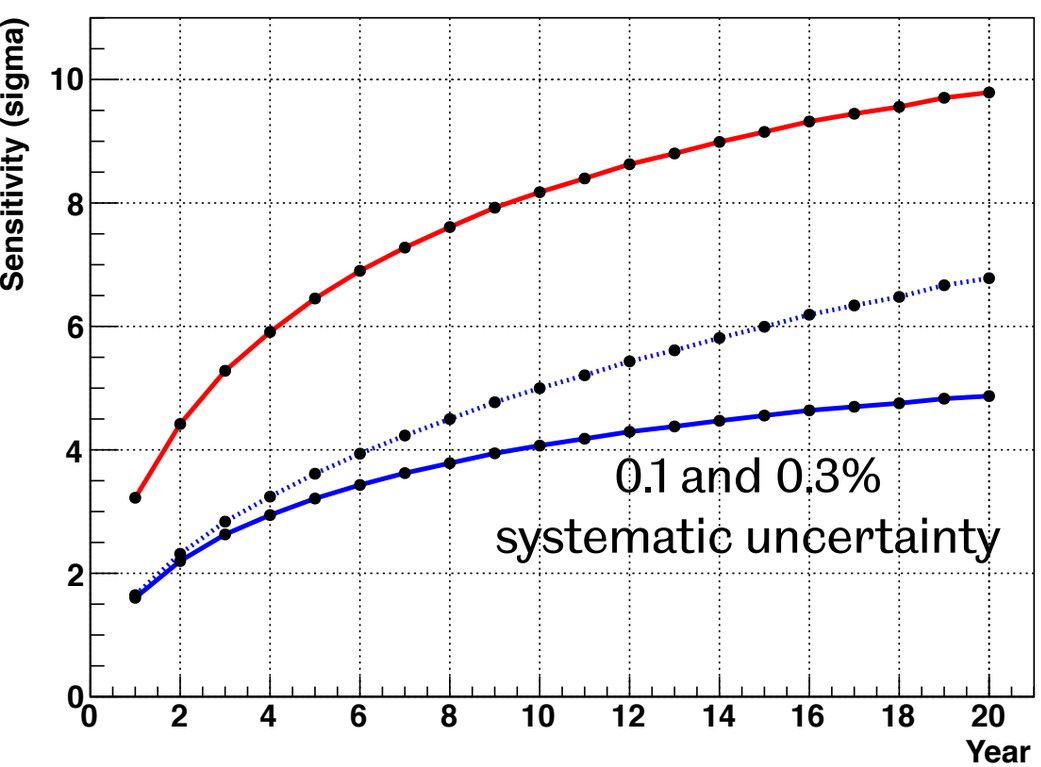


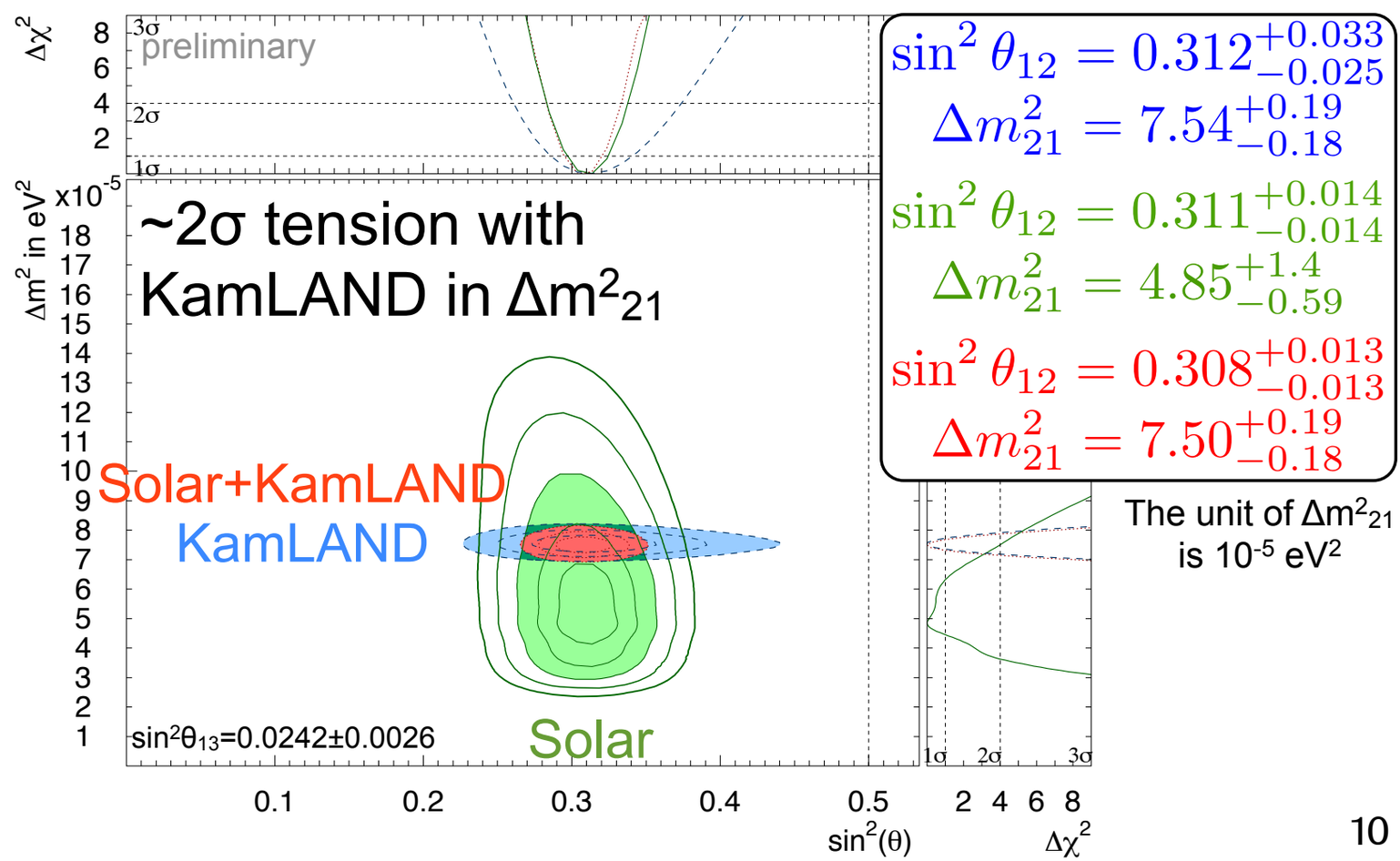


Solar Neutrinos

- Day/Night asymmetry (Earth matter effect)
- 5σ observation in ~3 years
- distinguish solar (ν_e) & reactor ($\overline{\nu}_e$) values of Δm^2_{21}

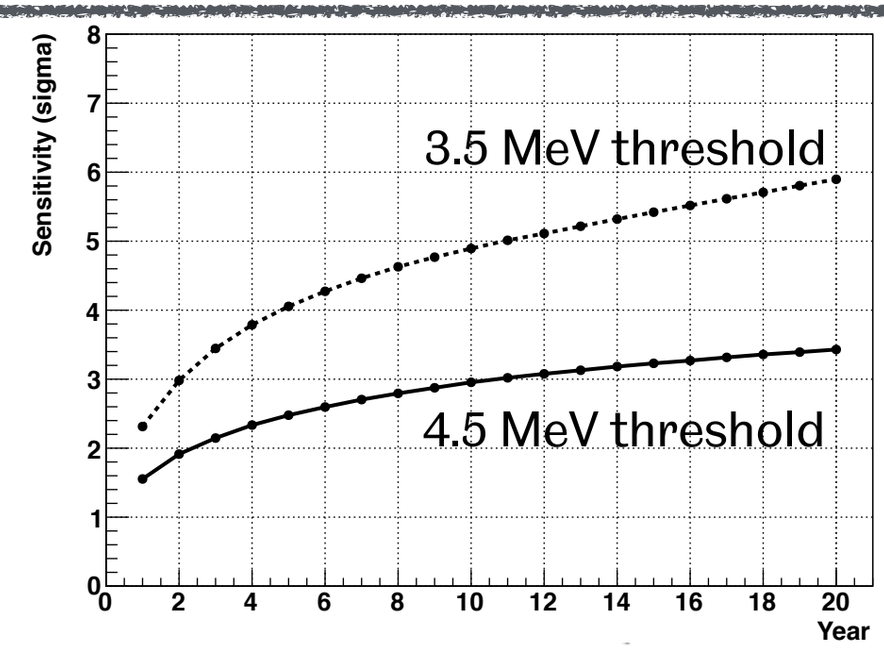
  ➔ CPT violation?

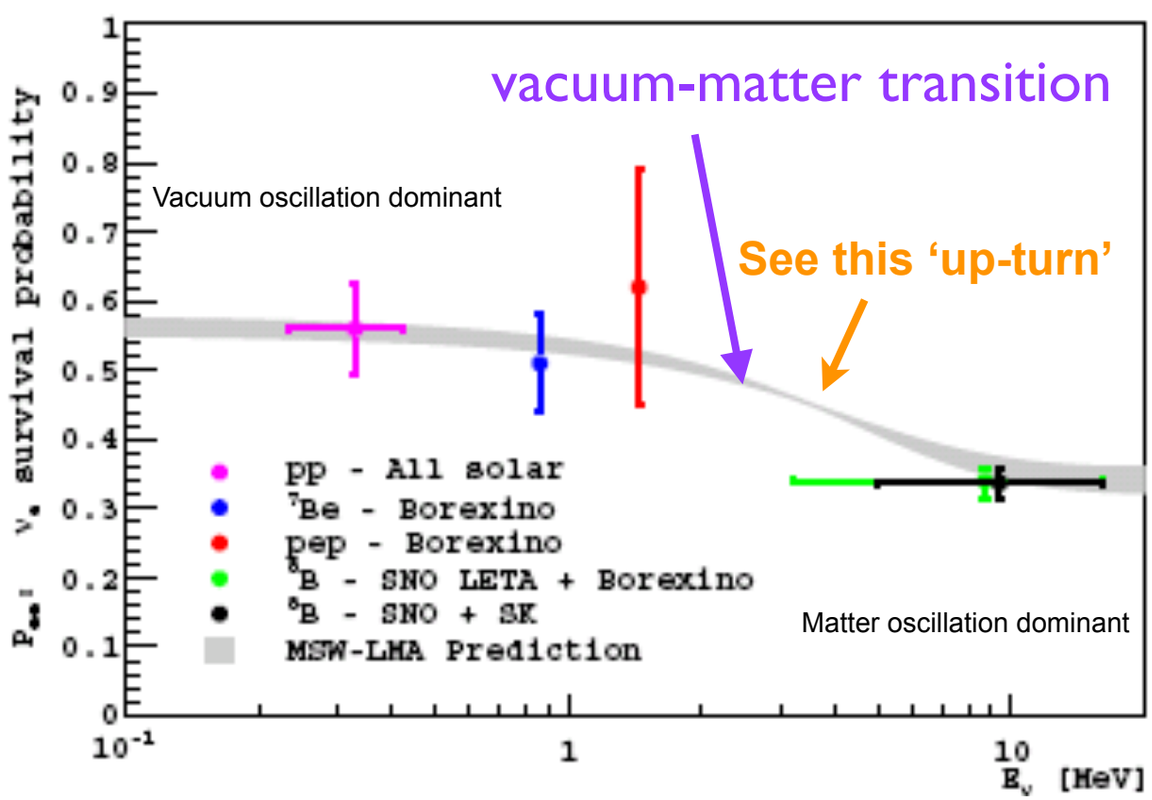




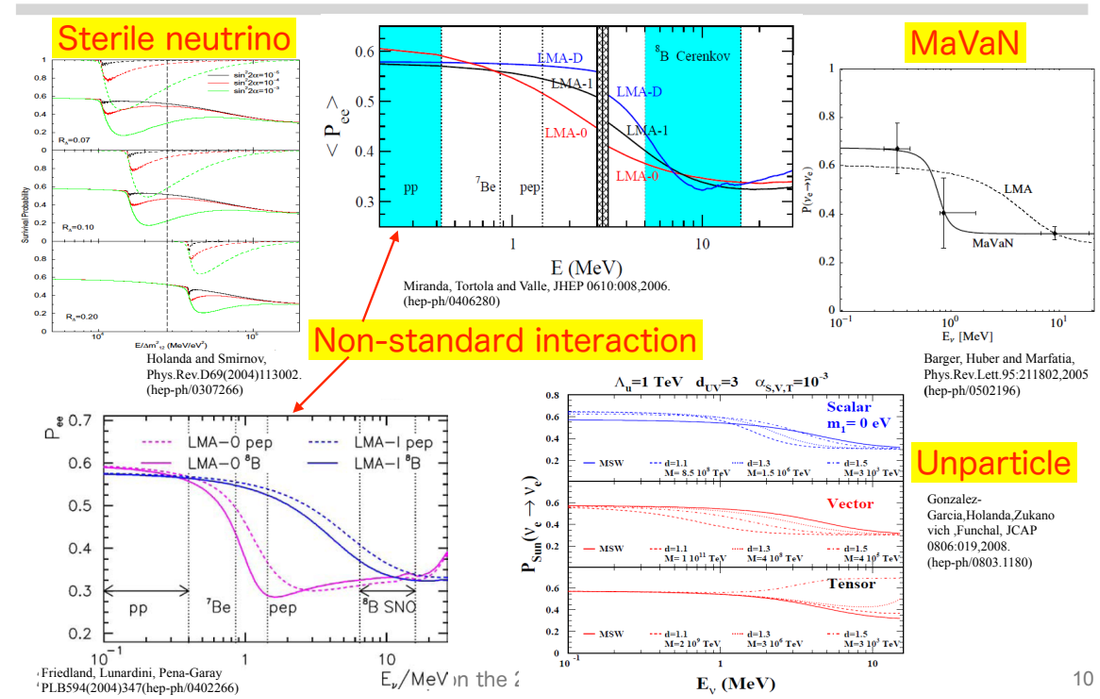
Solar Neutrinos

- transition between vacuum and matter oscillations occurs at ~5 MeV
- 3–5σ observation in 10 years



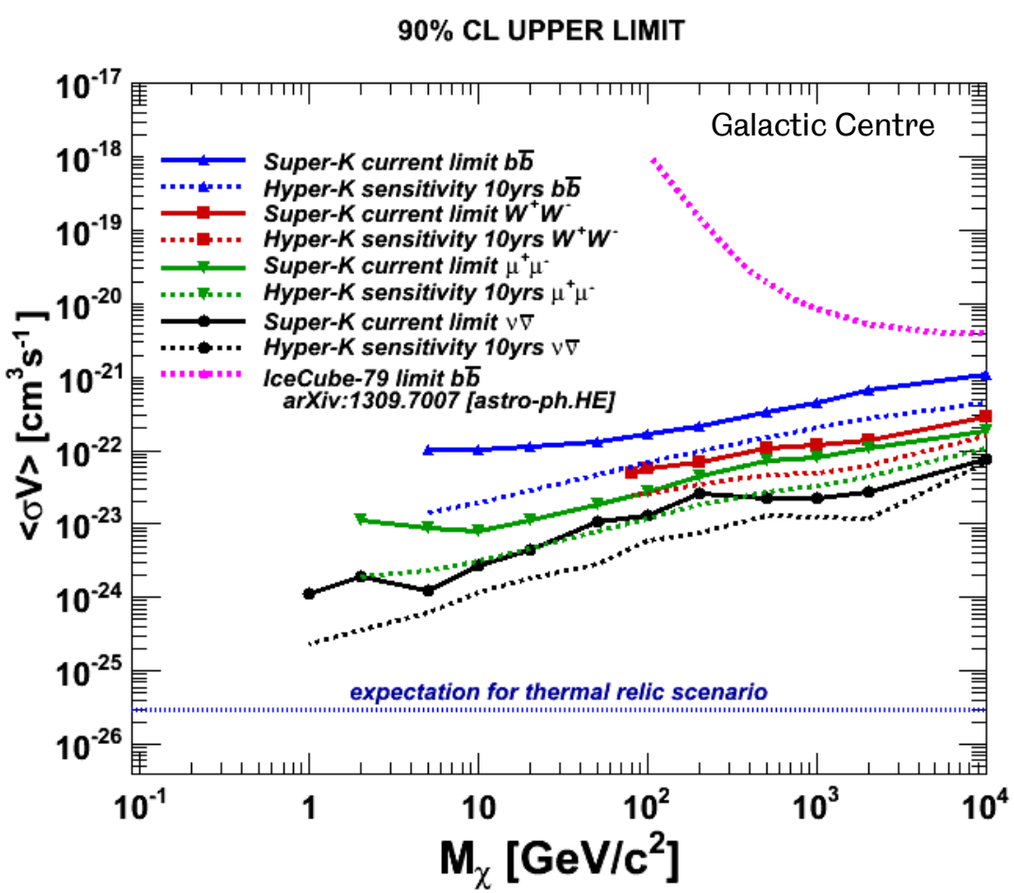


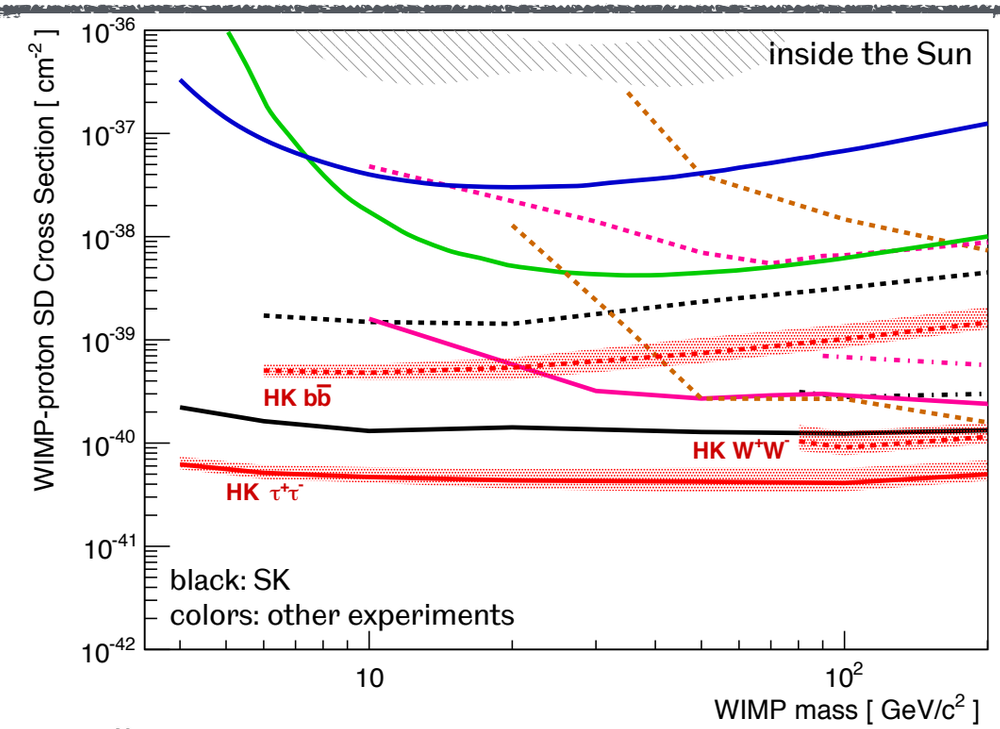
Various non-standard models

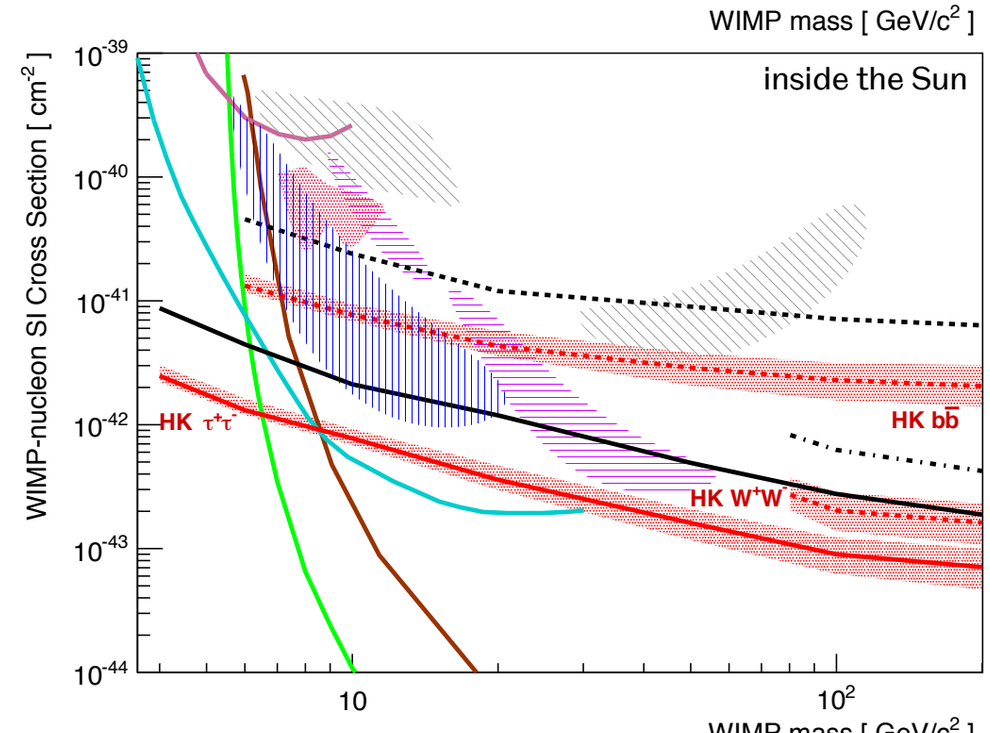


Dark Matter

- indirect detection via annihilation/decay to ν
- very good sensitivity at low WIMP masses (≤100 GeV)







Other Measurements

- detect solar *Hep* neutrinos ($^3\mathrm{He} + \mathrm{p} \rightarrow {}^4\mathrm{He} + \mathrm{e}^+ + \nu_e$)
- short-time variations in solar neutrino flux
- solar flares
- gamma ray bursts
- newborn pulsar winds
- *etc.*

... and non-astrophysics:

- determine δ_{CP} and mass hierarchy with beam and atmospheric neutrinos
- proton decay searches
- *etc.*

Summary

- Hyper-K is the next step in the very successful Japan-based neutrino research programme.

- 8× (17×) fiducial volume & high-efficiency PMTs improve low-E astrophysics:
  - galactic SN: ~10^5 events, detailed info on explosion mechanism
  - 5σ observation of supernova relic neutrinos (SRN) & first measurement of SRN spectrum
  - solar neutrinos (day/night asymmetry & spectrum upturn, *Hep* neutrinos, time variation)
  - indirect dark matter searches
  - *etc.*