Status of A03 Subproject (Neutrinos)

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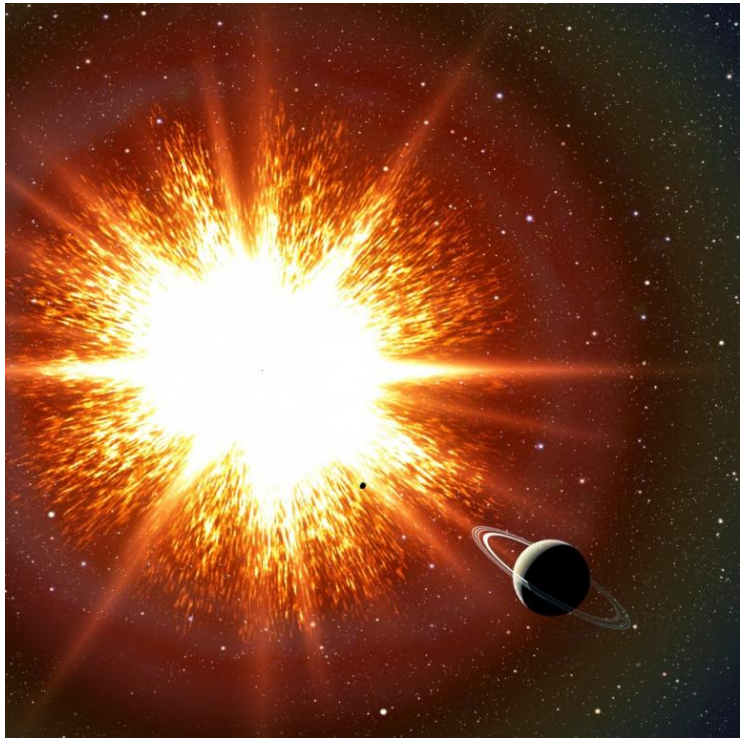
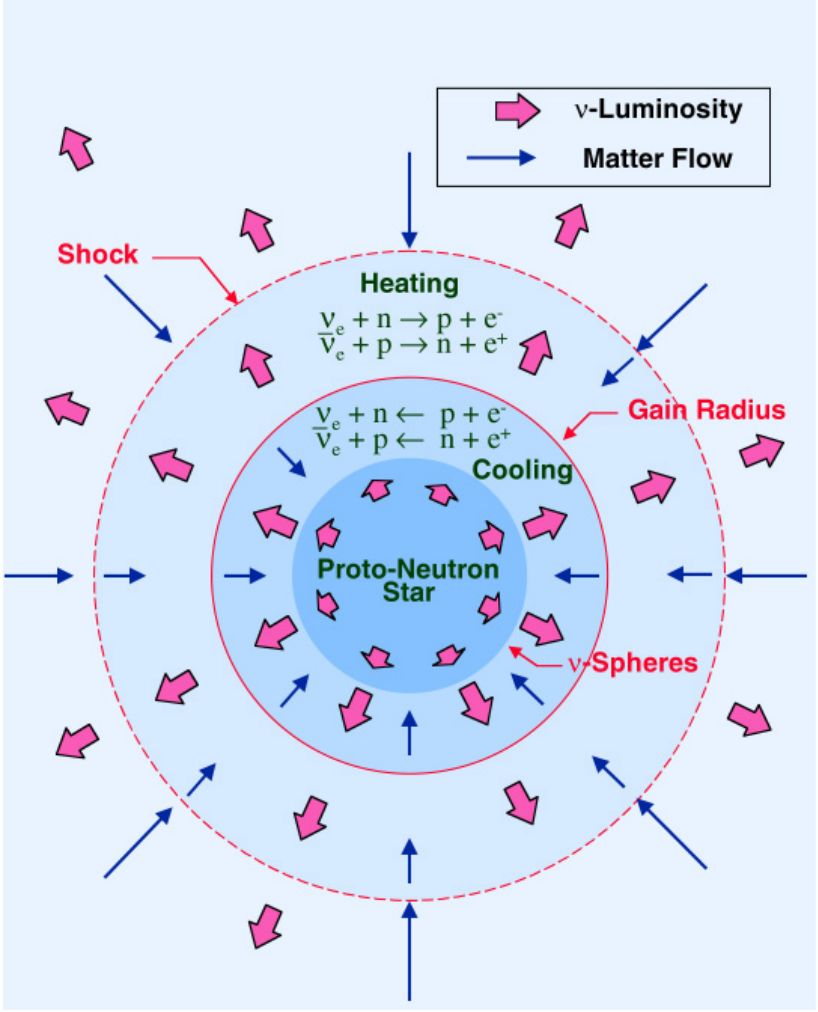
Multi-Messenger Kakenhi 4th Annual Symposium

Kashiwa February 18, 2016

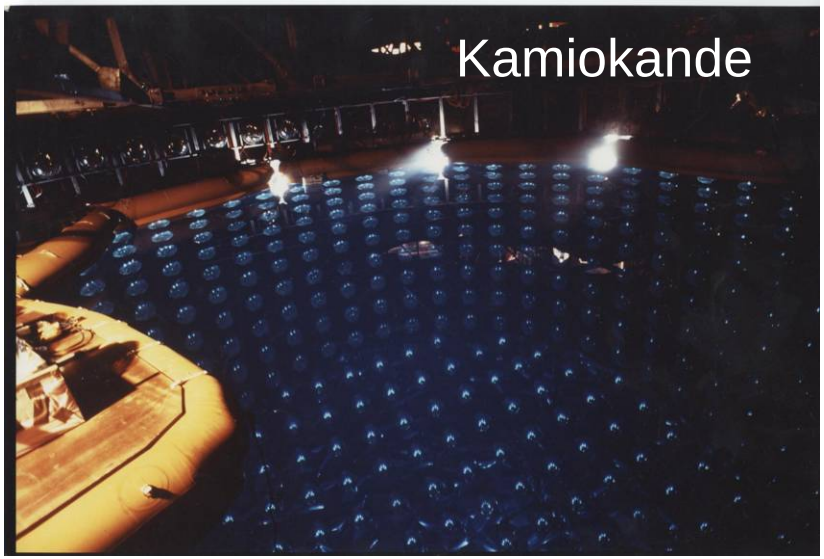
A core-collapse supernova is a nearly perfect “neutrino bomb”.

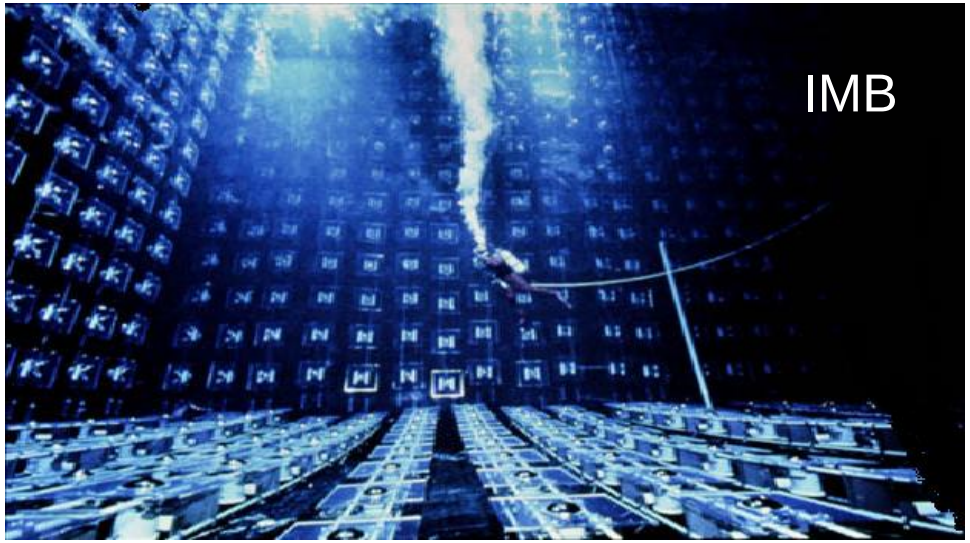
Within ten seconds of collapse it releases >98% of its huge energy (equal to a trillion H-bombs/second since the beginning of the universe) as neutrinos.

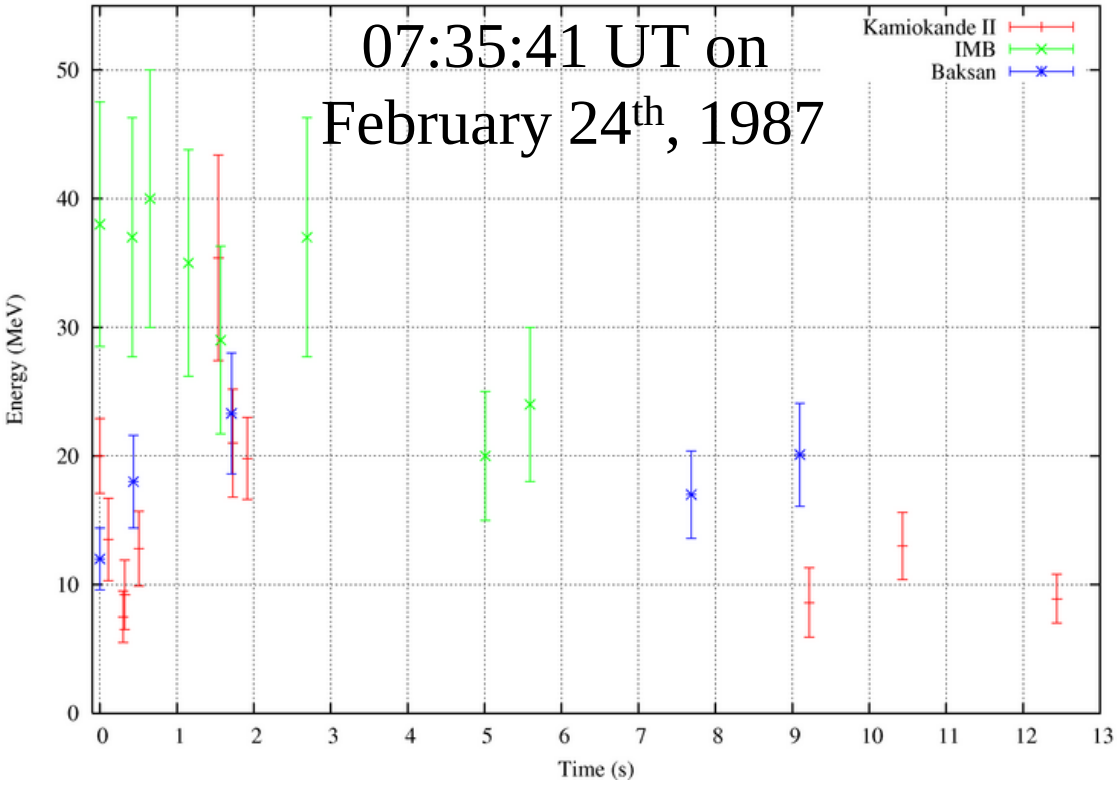


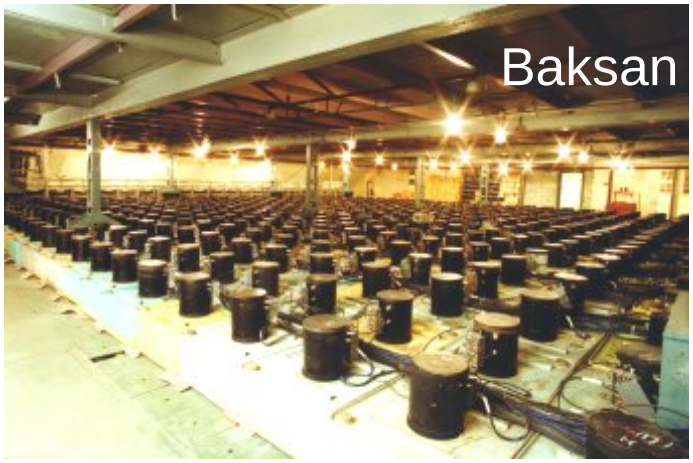


Neutrinos, along with gravitational waves, provide the only possible windows into core collapses’ inner dynamics.





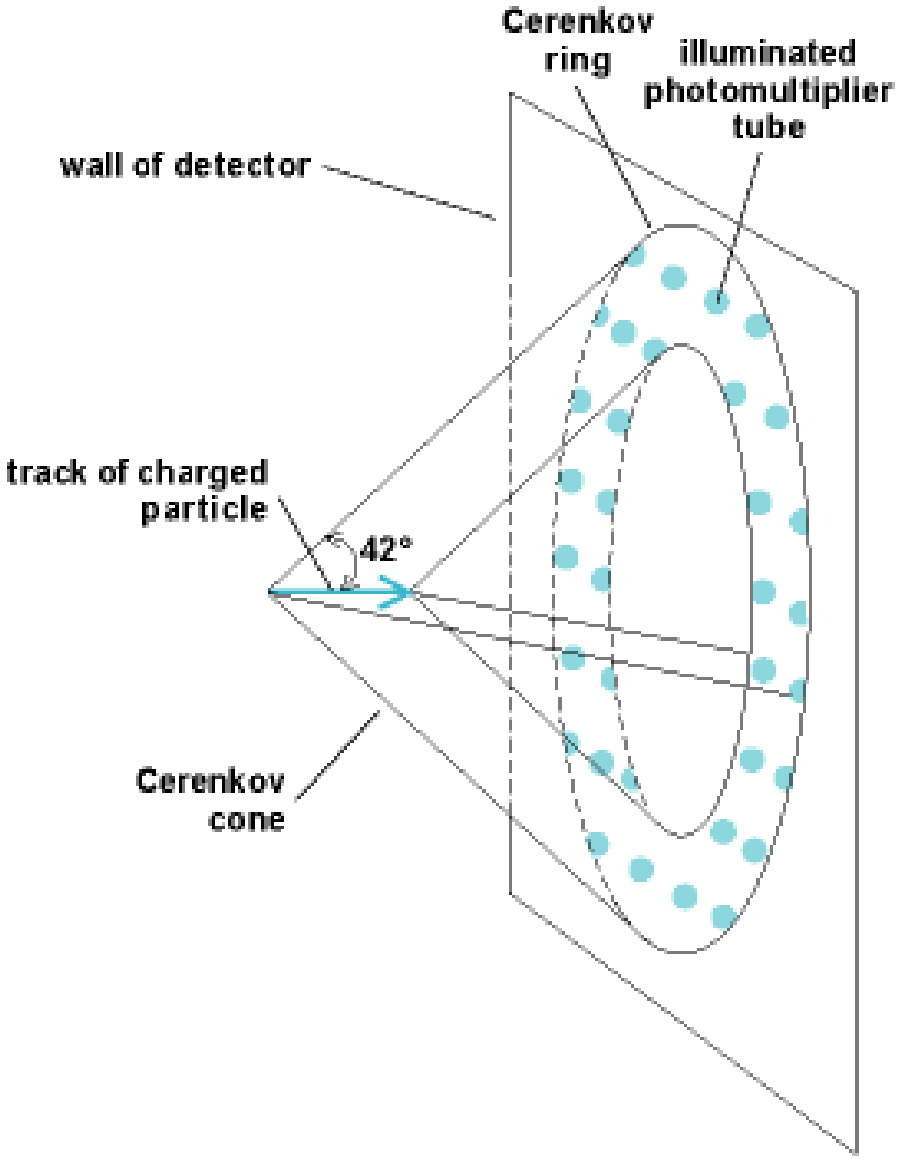


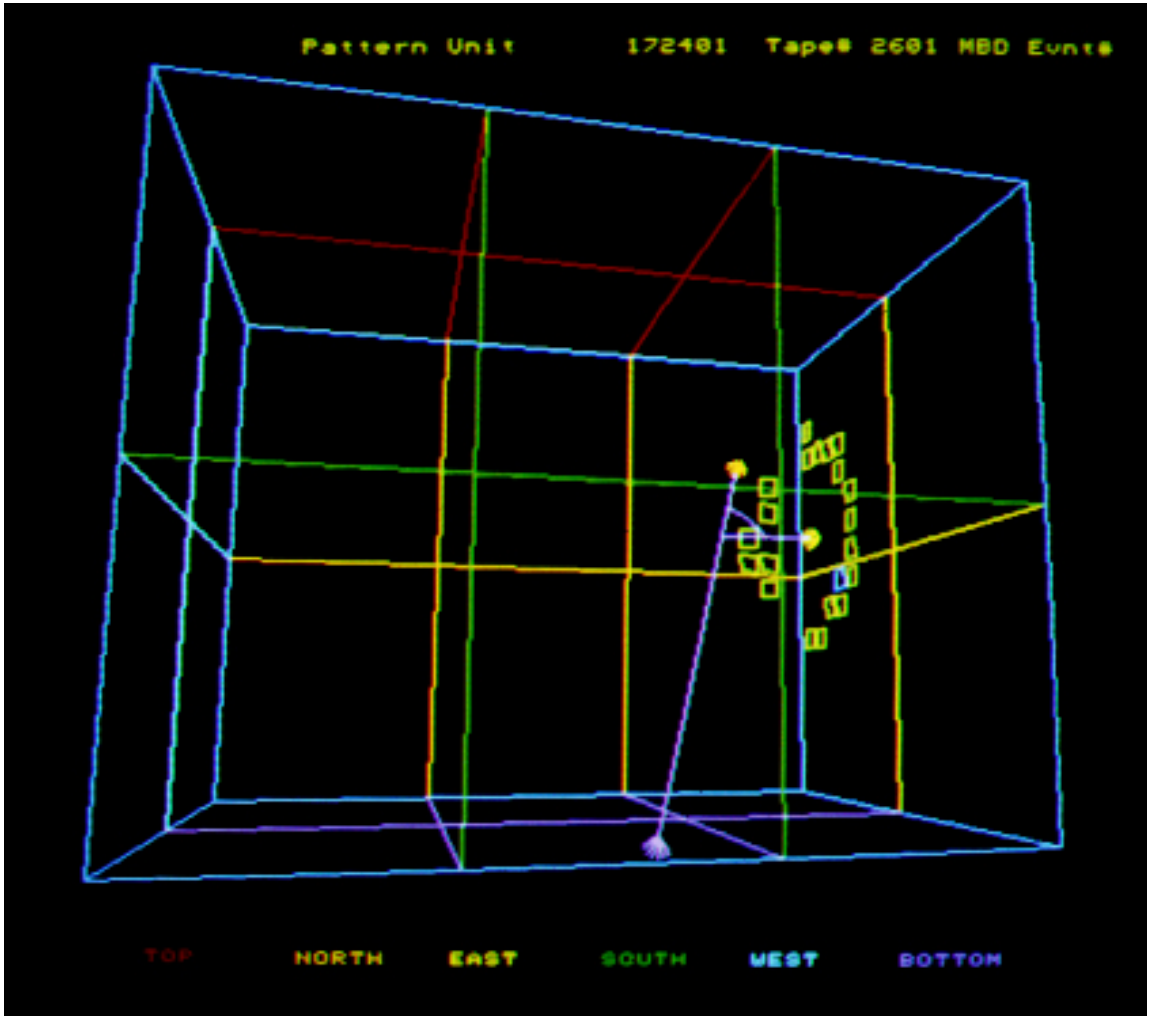


One paper every 10 days… for 29 years!

Ring-Imaging Water Cherenkov Detector

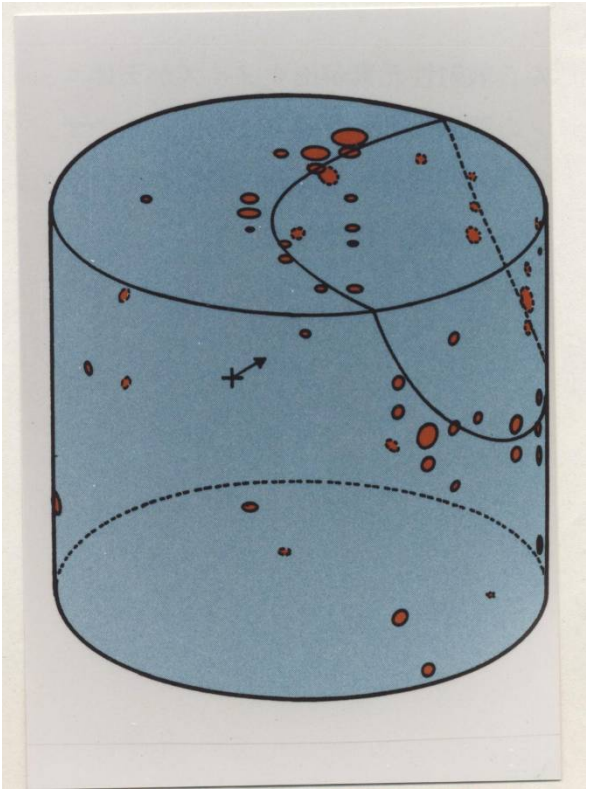
Relativistic charged particles traveling through water make rings of light on the inner wall of the detector. The rings are then imaged by photomultiplier tubes.





IMB
(in USA)

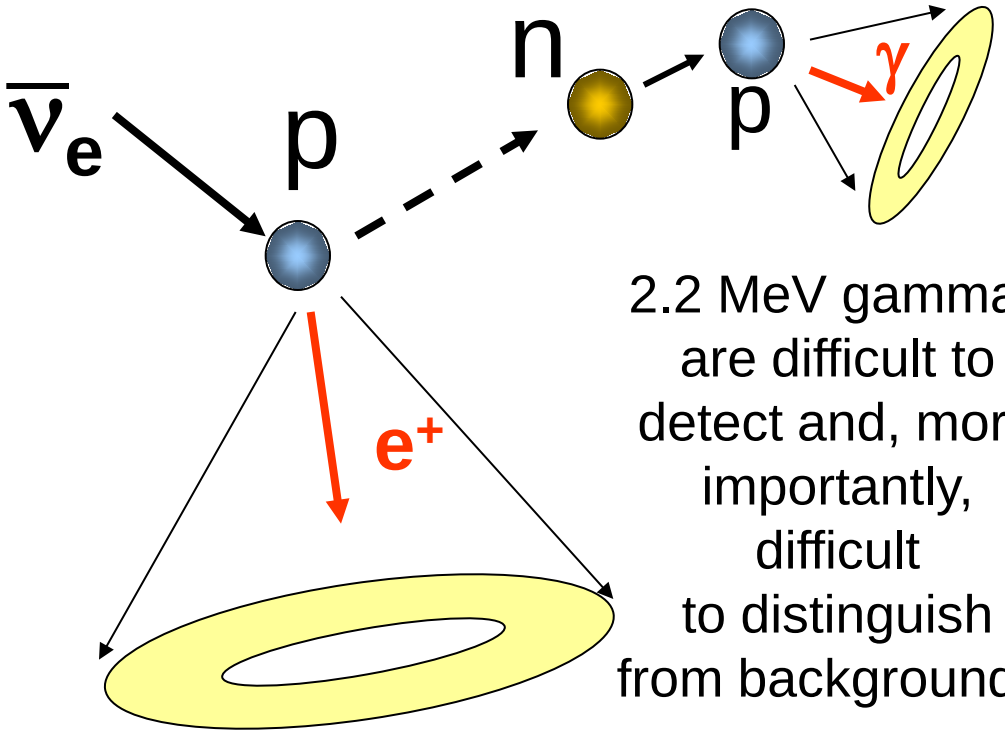
Kamiokande
(in Japan)



Event Displays of Actual Neutrinos from SN1987A

Inverse Beta Decay

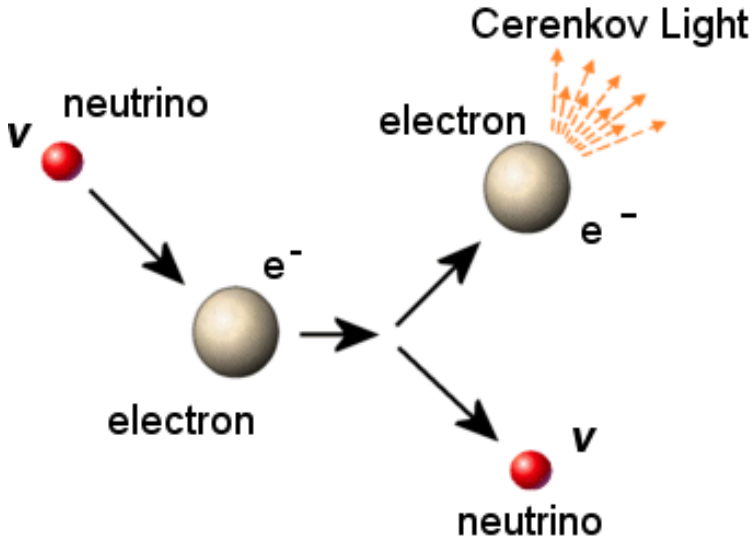
(~80% of events →dominant, but challenging to uniquely identify)

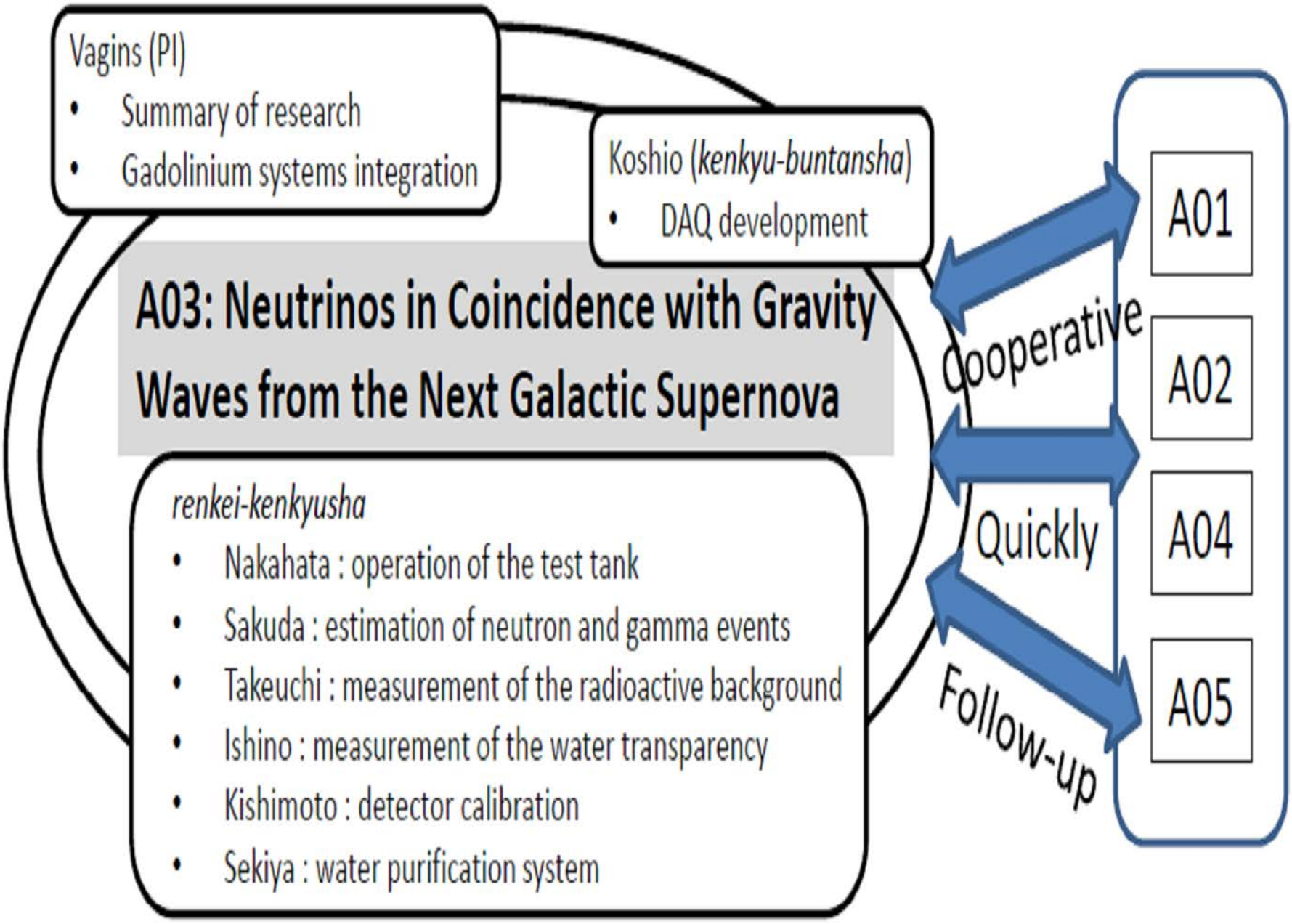


2.2 MeV gammas are difficult to detect and, more importantly, difficult to distinguish from backgrounds.

Elastic Scattering

(~3% → directional)



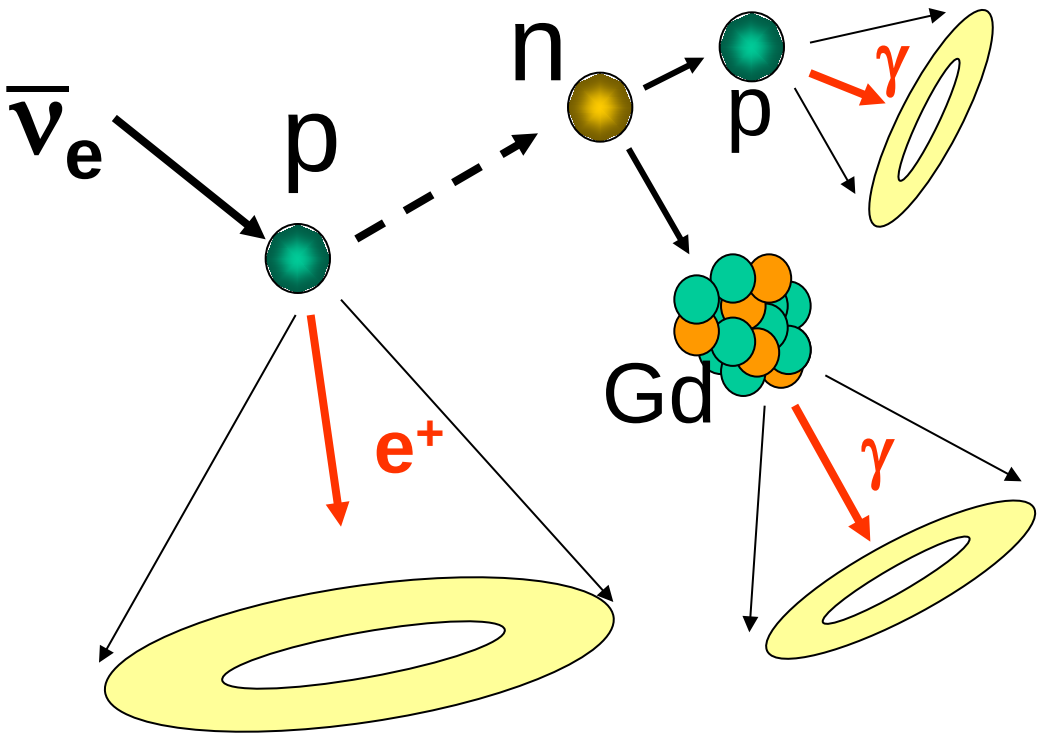

Vagins (PI)
• Summary of research
• Gadolinium systems integration
Koshio (*kenkyu-buntansha*)
• DAQ development
A03: Neutrinos in Coincidence with Gravity Waves from the Next Galactic Supernova
renkei-kenkyusha
• Nakahata : operation of the test tank
• Sakuda : estimation of neutron and gamma events
• Takeuchi : measurement of the radioactive background
• Ishino : measurement of the water transparency
• Kishimoto : detector calibration
• Sekiya : water purification system
Cooperative
Quickly
Follow-up
A01
A02
A04
A05

- Special features of SN neutrinos and GW's
  - Provide image of core collapse itself (identical t=0)
  - Only supernova messengers which travel without attenuation to Earth (dust does not affect signal)
  - Full-galaxy coverage

- What is required for maximum SN ν information?
  - Full sensitivity to very nearby explosions (close gap in Super-Kamiokande's galactic SN ν coverage)
  - Deconvolution of neutrino flavors via neutron tags
  - Ultrafast alert generation to aid other observations

["GADZOOKS!", Beacom and Vagins, *Phys. Rev. Lett.*, **93**:171101, 2004]

Inverse Beta Decay with 0.1% Gadolinium



Possibility 1: 10% or less

$n+p \rightarrow d + \gamma$

2.2 MeV γ-ray

Possibility 2: 90% or more

$n+Gd \rightarrow$ ~8MeV γ

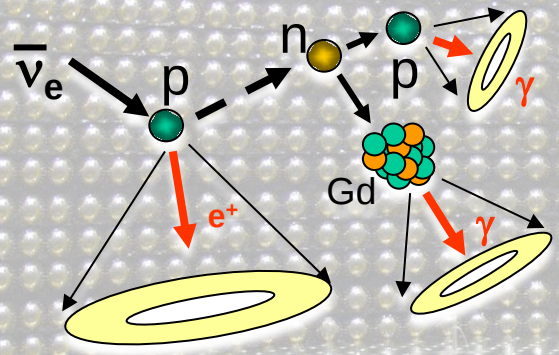
ΔT = ~30 μsec

$\overline{\nu}_e$ can be positively identified by delayed coincidence.

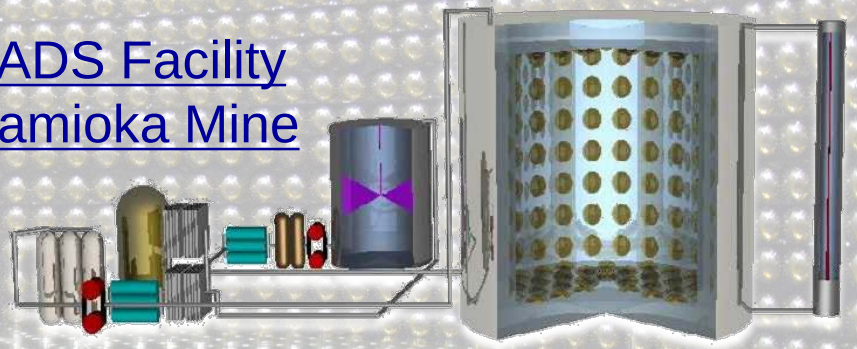
Even a single coincident pair + GW → Supernova!

EGADS/Super-K

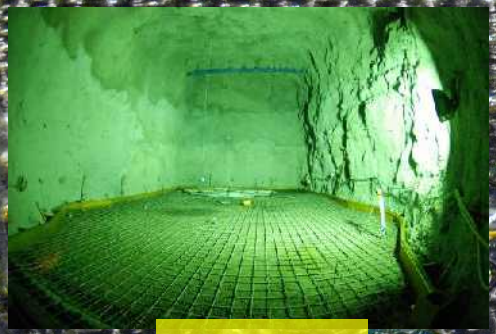
Adding **water soluble gadolinium** to **Super-K** will greatly enhance its ability to detect **supernova neutrinos** (and help with many other physics topics like **proton decay**). **EGADS** is a dedicated gadolinium demonstrator which includes a working 200 ton scale model of SK.



EGADS Facility
in Kamioka Mine



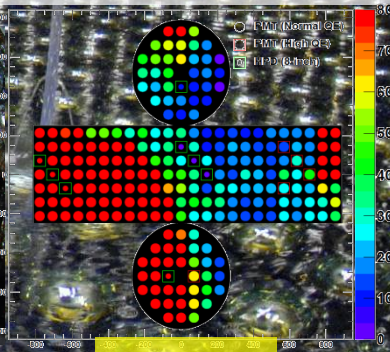
Beacom and Vagins, *Phys. Rev. Lett.*, 93:171101, 2004 [246 citations]



12/2009

11/2011

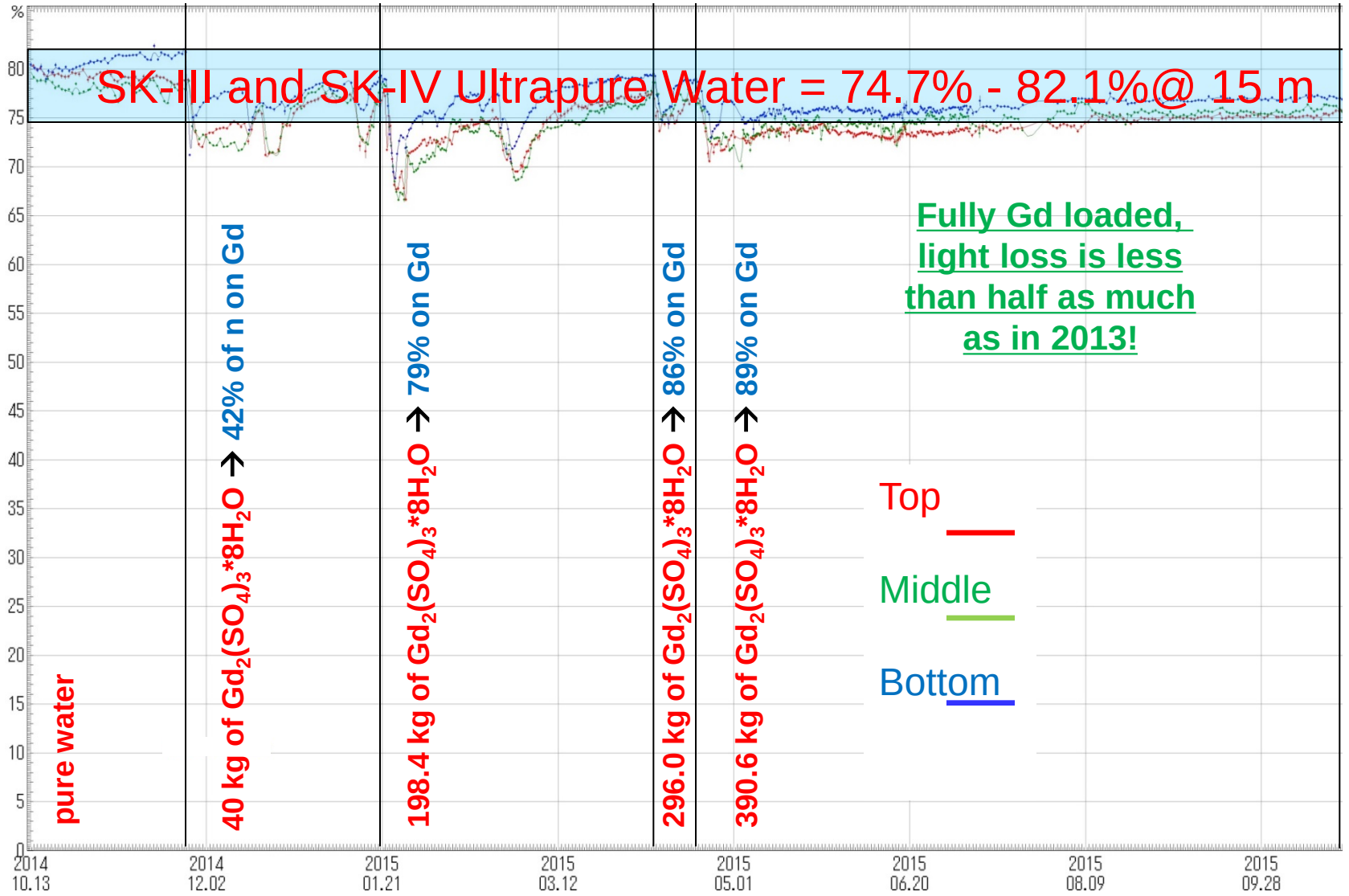
8/2013



6/2015

As of April 2015, the EGADS detector has been fully loaded (0.2%) with gadolinium sulfate, and functioning perfectly. The R&D phase of gadolinium loading is now coming to a close.

Light @ 15 meters in the 200-ton tank (Gd water, PMT's)



Oct. 13, 2014

May 1, 2015

Oct. 21, 2015

As was discussed in the original GADZOOKS! paper, as well as in the 246 papers to date which have cited it, the physics benefits provided to water Cherenkov detectors by dissolved gadolinium are numerous and compelling.

After years of testing and study
– culminating in these powerful EGADS results –
no technical showstoppers have been encountered. Therefore:

On June 27, 2015, the Super-Kamiokande collaboration approved the SuperK-Gd project which will enhance anti-neutrino detectability by dissolving gadolinium to the Super-K water.

The actual schedule of the project including refurbishment of the tank and Gd-loading time will be determined soon taking into account the T2K schedule.

T2K/SK "SK-Gd" joint Statement

On June 27, 2015, the Super-Kamiokande collaboration approved the SK-Gd project which will enhance neutrino detectability by dissolving gadolinium in the Super-K water.

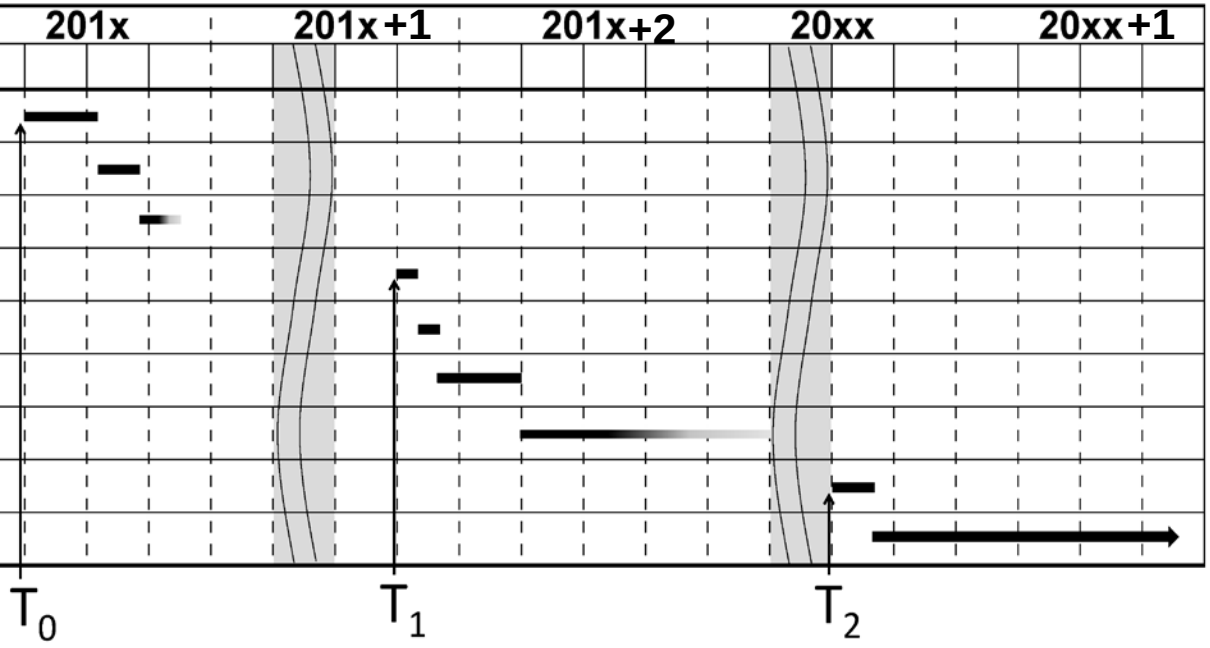
T2K and SK will jointly develop a protocol to make the decision about when to trigger the SK-Gd project, taking into account the needs of both experiments, including preparation for the refurbishment of the SK tank and readiness of the SK-Gd project, and the T2K schedule including the J-PARC MR power upgrade. Given the currently anticipated schedules, the expected time of the refurbishment is 2018.

[T. Nakaya @ January 2016 T2K Collaboration meeting]

Timeline

Preliminary

STEP #	
1	Leak repair work(~3.5 months)
2, 3	Fill pure water (~2months)
4	Circulate pure water until get good water transparency (~ 2months)
5,6	Load to 0.002% $Gd_2(SO_4)_3$ (1ton) (~1 month)
7	Load to 0.02% $Gd_2(SO_4)_3$(10ton) (~1 month)
7	Water transparency stabilized (~4 months)
7	Observation with 0.02 % $Gd_2(SO_4)_3$?
8	Load to 0.2% $Gd_2(SO_4)_3$(100 ton)(~2 months)
9	Observation with full loading



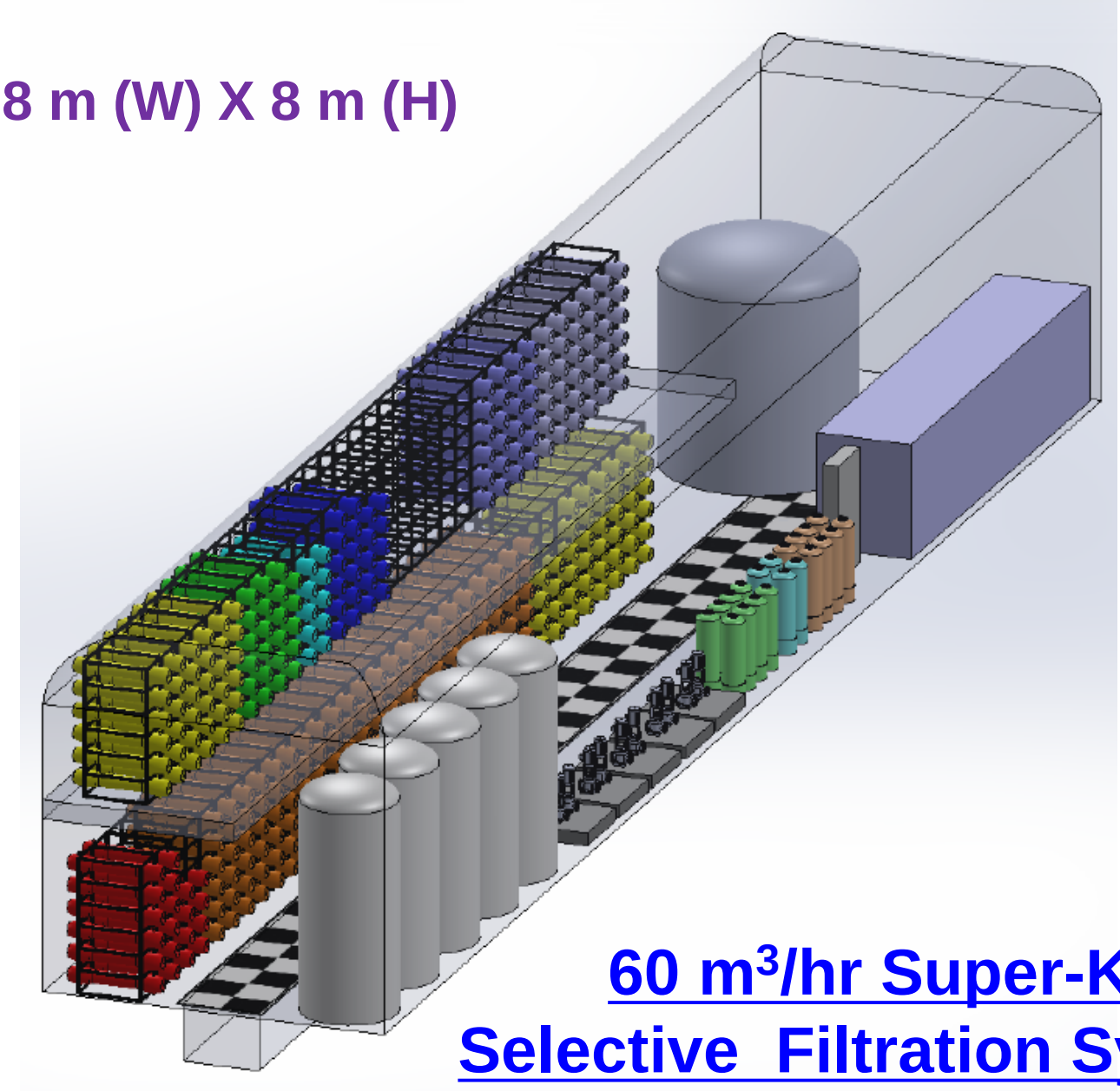
T_0 = Start refurbishment of SK detector

T_1 = Add first gadolinium sulfate (0.000% -> 0.002% → 0.020%)

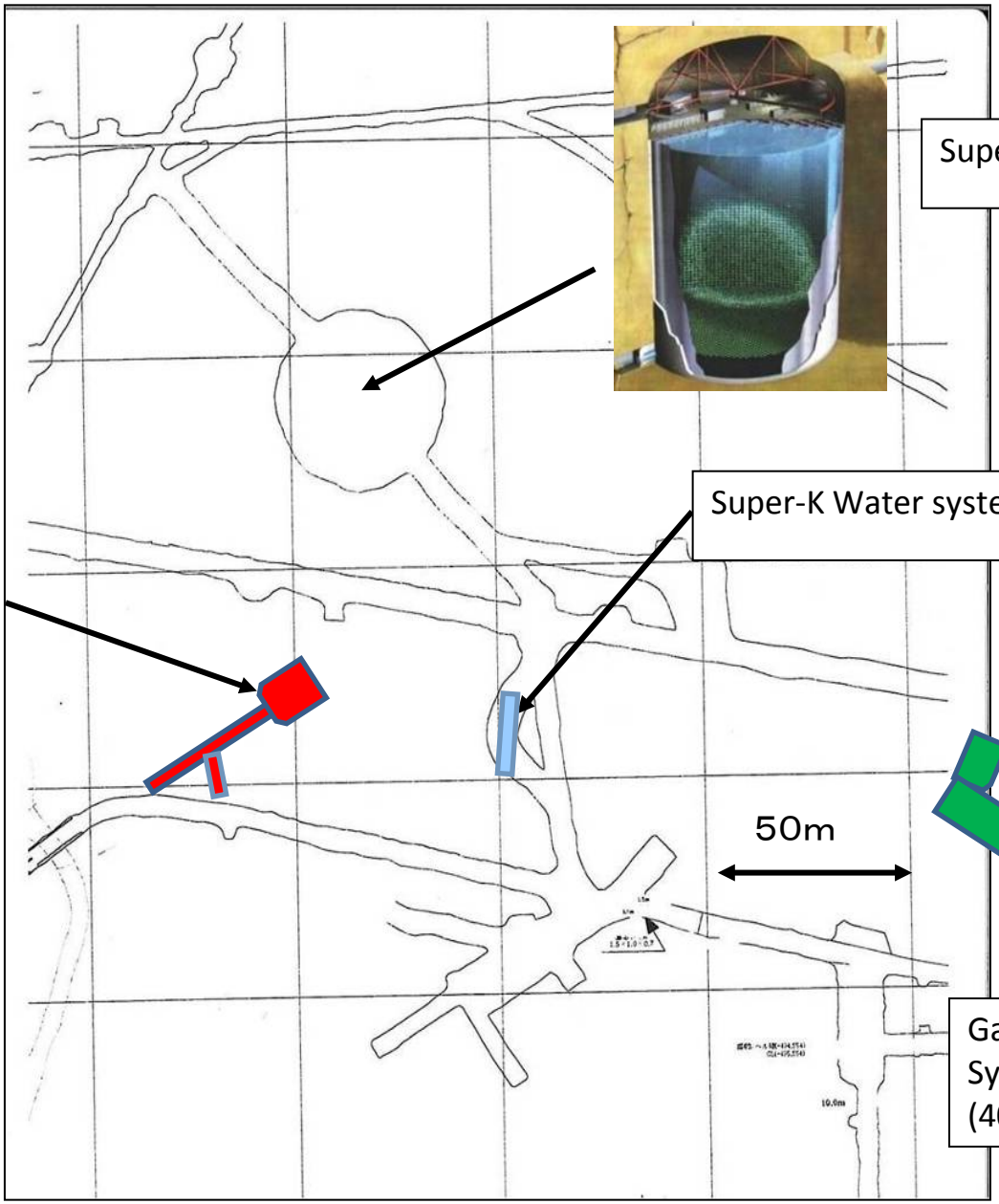
T_2 = Full loading of gadolinium sulfate (0.20%)

New Super-K gadolinium water system

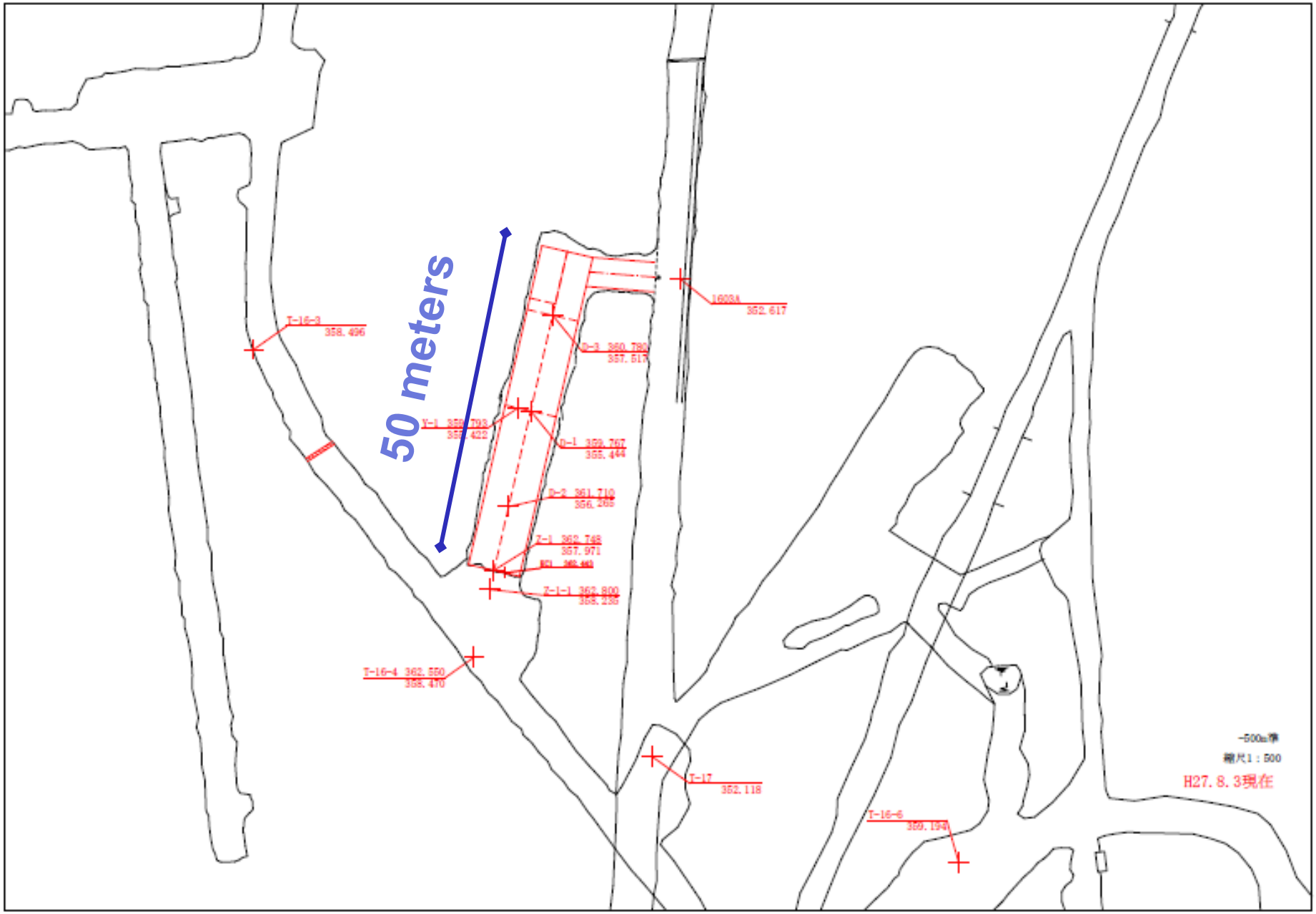
30 m (L) X 8 m (W) X 8 m (H)



60 m^3/hr Super-K Selective Filtration System


Super-Kamiokande
Super-K Water system
EGADS Hall
(2500 m3)
50m
Gadolinium Water
System Hall
(4000 m3)

New SK gadolinium water system hall (“Hall G”)

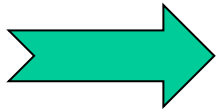


New gadolinium water system hall (“Hall G”);
September 10st, 2015 [photo by M. Nakahata]

New gadolinium water system hall (“Hall G”);
September 10st, 2015 [photo by M. Nakahata]

So, we should have gadolinium in SK before the end of the decade. What's going on with EGADS now?

Evaluating	**E**mploying
Gadolinium's	**G**adolinium to
Action on	**A**utonomously
Detector	**D**etect
Systems	**S**upernovas



This multimessenger kakenhi is supporting the conversion (via upgraded electronics, realtime event reconstruction, etc) of EGADS from an R&D facility into the world's most advanced water-based supernova neutrino detector. What is learned will then be applied to the Gd-loaded Super-K.

[See the next talk by Lluis Marti]


~90,000 ν events
@ Betelgeuse
~40 ν events
@ G.C.
Our target: send out
announcement
within ***one second***
of the SN neutrino
burst's arrival in EGADS!

An EGADS timeline:

2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017

R&D Project Approved

Hall E Excavation

Build 200-ton Tank

Install Water Systems

15-/200-t Pure Water Runs

15-ton Tank Gd Runs

200-ton Tank Pure Water Run w/o PMTs

200-ton Tank Gd Run w/o PMTs

200-ton Tank PMT Installation

200-ton Tank Pure Water Calibration Run

200-ton Tank Gd Data-taking Run

Cleanup and Pure Water Certification Run

Continuous Supernova Running With Gd

Fully Automated Instant Supernova Alert Capability

While we prepare Super-Kamiokande to be loaded with gadolinium, EGADS is already fully loaded and taking data continuously, waiting for the next galactic supernova.

This year we plan to fully automate EGADS's event reconstruction and alert system. When the next MW star explodes, we will let you know without *any* delay!