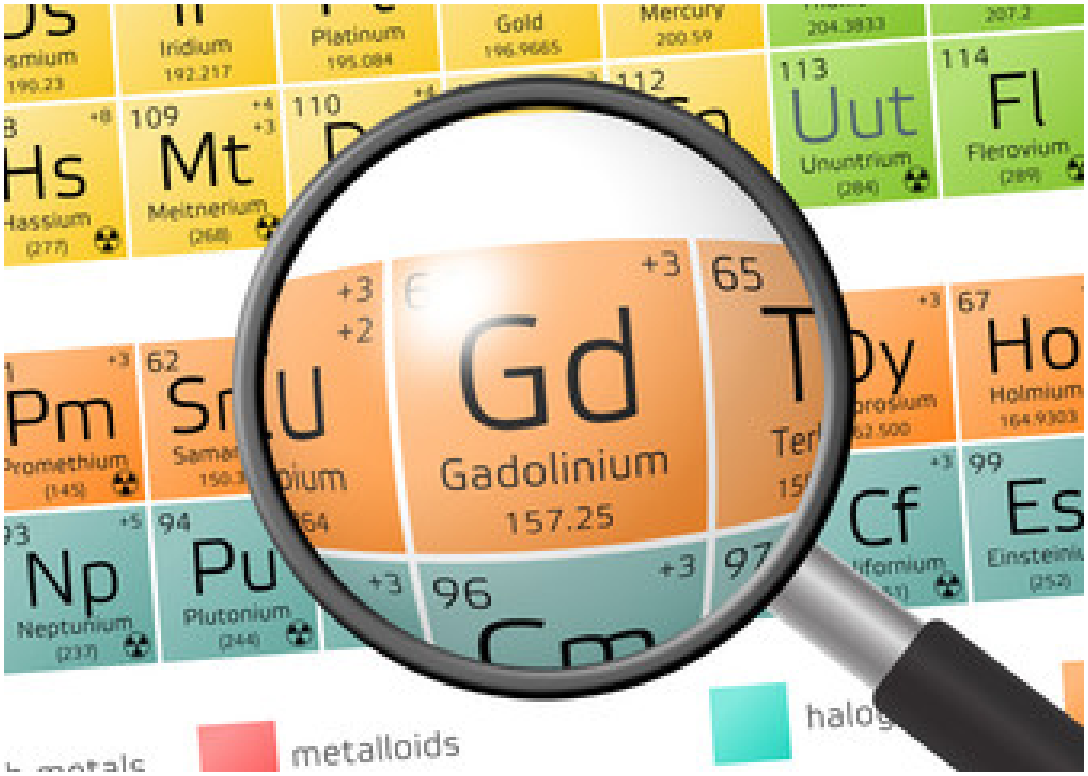
Gadolinium-loading in WC Detectors



Mark Vagins
Kavli IPMU, University of Tokyo

12th Annual Applied Antineutrino Physics Workshop

Liverpool, UK December 1, 2016

I saw this sign in Tokyo's Haneda Airport.

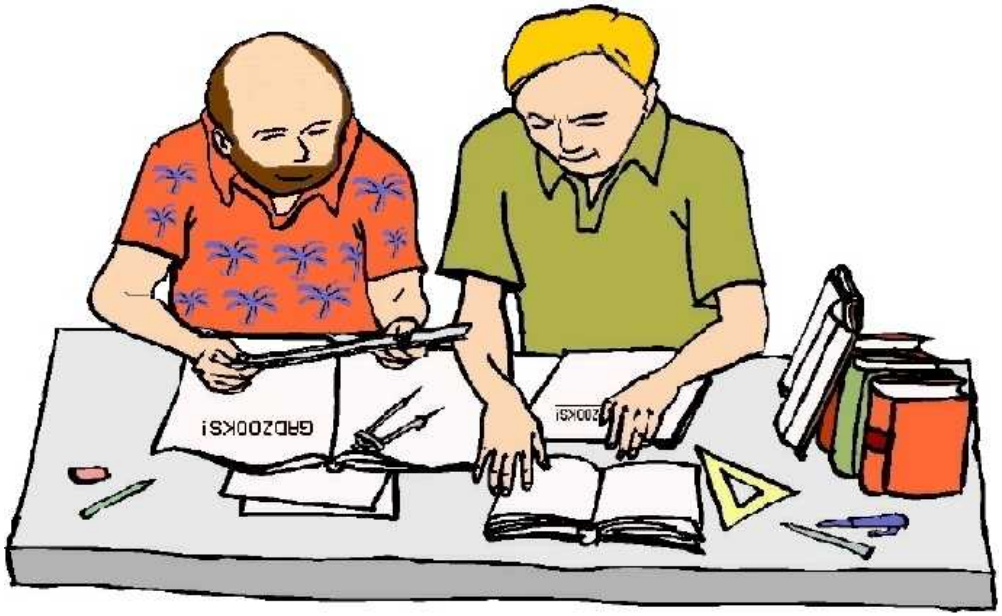

Santa
is
You!
Haneda Christmas Airport

Oh, my…
apparently
it's true:

Santa *is* me!

Like Santa,
I bring good things...
…including lots
of lanthanides for
all the good boys
and girls.

This particular Santa has even gone pro -
performing for a paying audience of
1,317 in a Tokyo stage show!



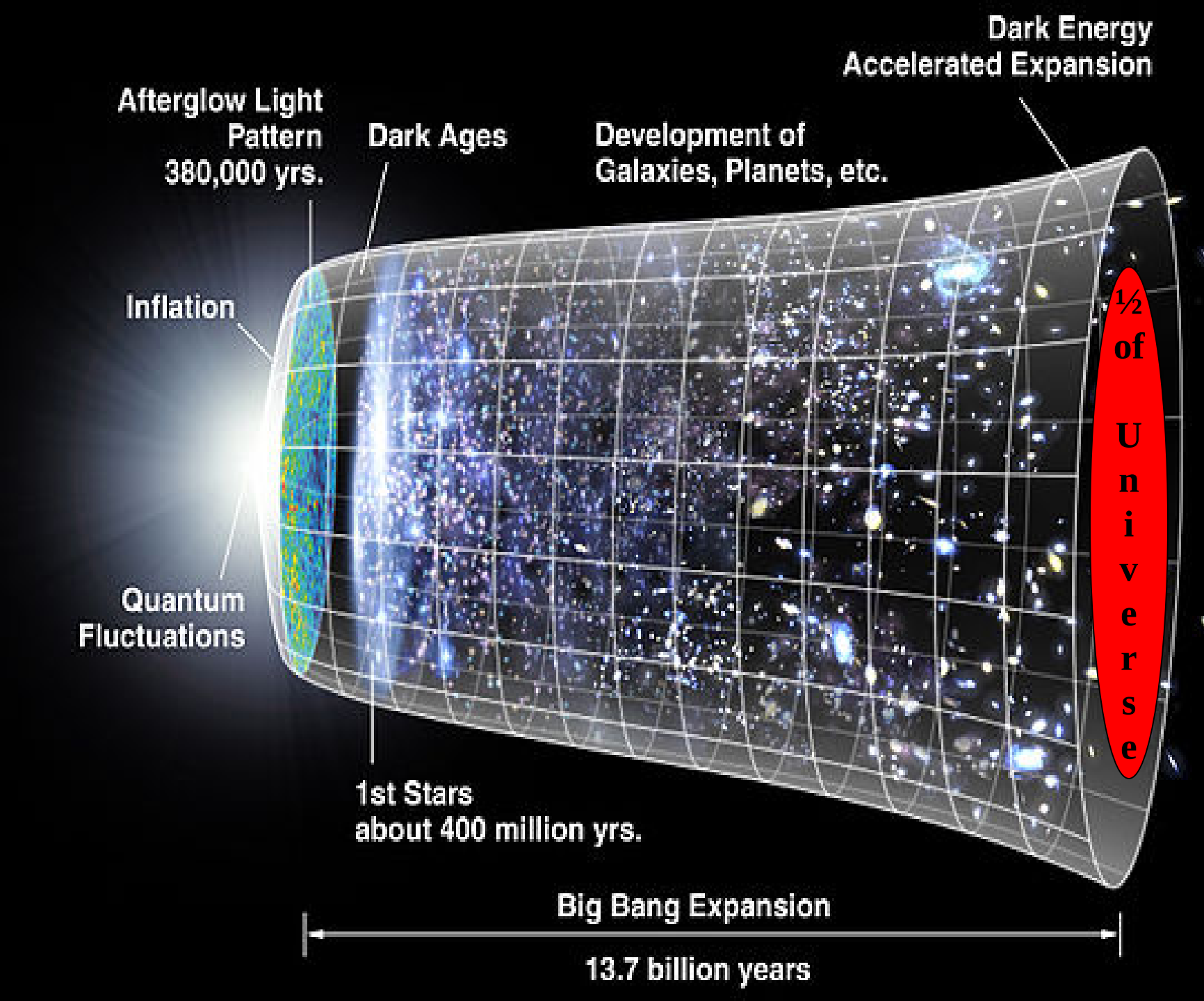
A decade ago theorist John Beacom and I wrote the original GADZOOKS!

(Gadolinium Antineutrino Detector Zealously Outperforming Old Kamiokande, Super!) paper.

It proposed loading big WC detectors, specifically Super-K, with water soluble gadolinium, and evaluated the physics potential and backgrounds of a giant antineutrino detector.

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

(280 citations → one every 16 days for twelve years)



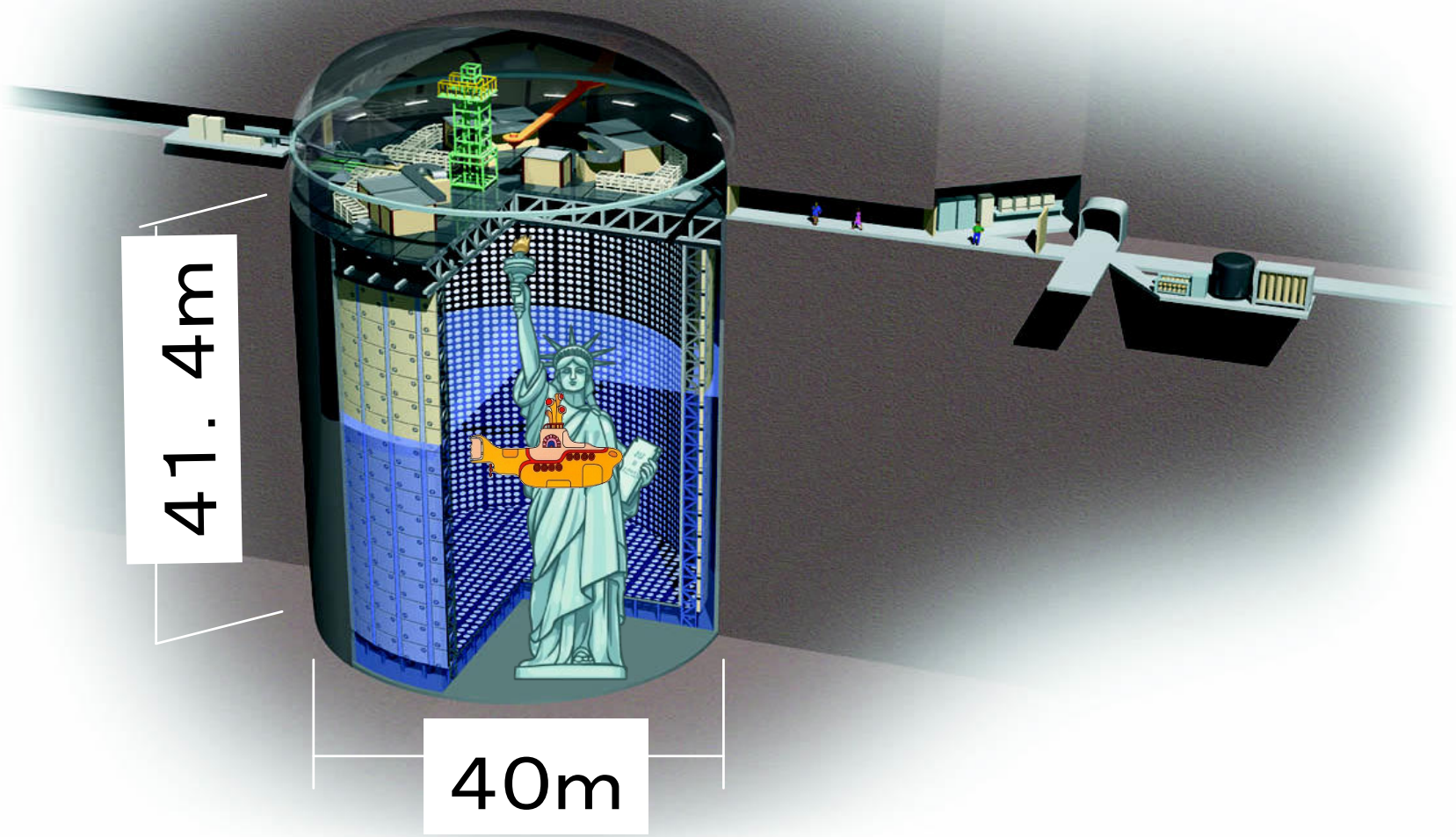
Adding Gd will expand Super-K's supernova sensitivity!

Super-Kamiokande

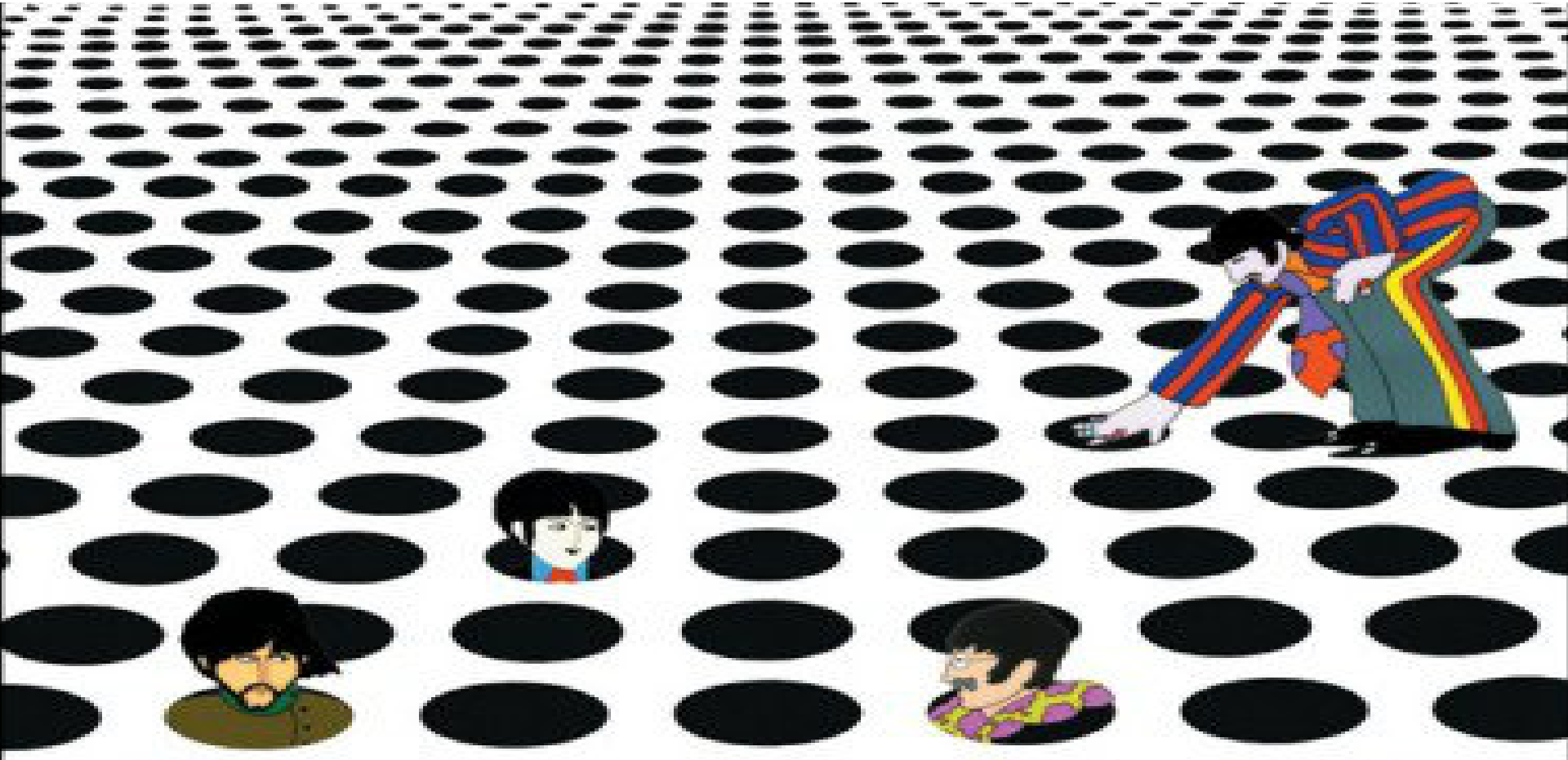
50,000 tons ultra-pure water

22,500 tons fiducial volume

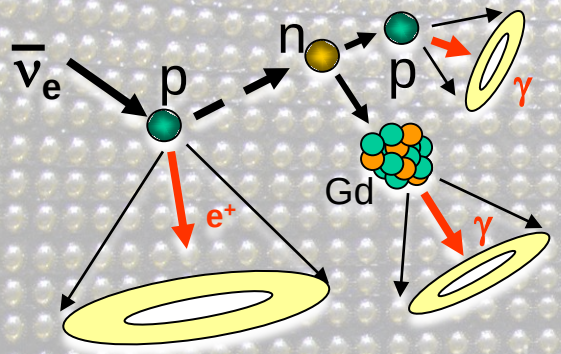
1 km overburden = 2,700 m.w.e.



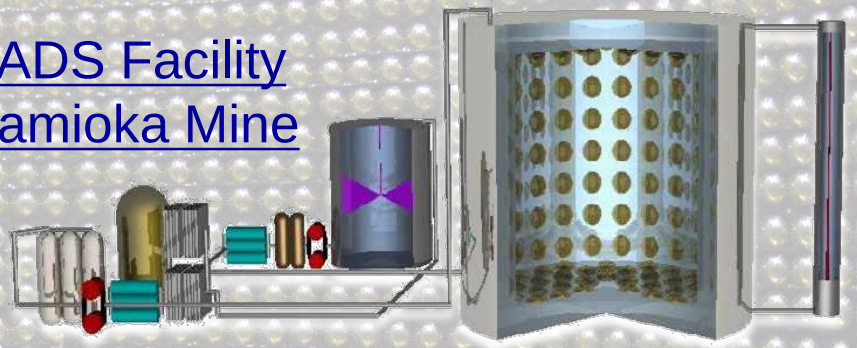
Now, why does this look so familiar?



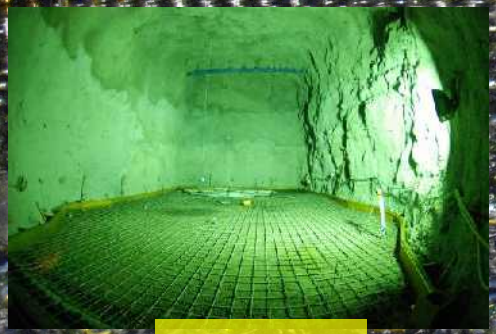
Adding **water soluble gadolinium** to **Super-K** will greatly enhance its ability to detect **supernova neutrinos** (and help with many other physics topics like **proton decay**). **EGADS** is a dedicated gadolinium demonstrator which includes a working 200 ton scale model of SK.



EGADS Facility
in Kamioka Mine



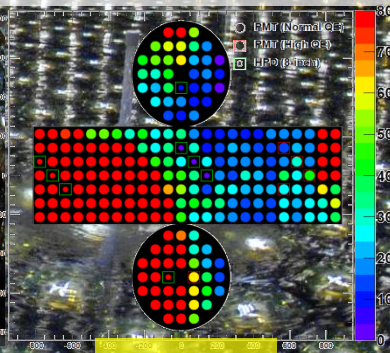
Beacom and Vagins, *Phys. Rev. Lett.*, 93:171101, 2004 [280 citations]



12/2009

11/2011

8/2013

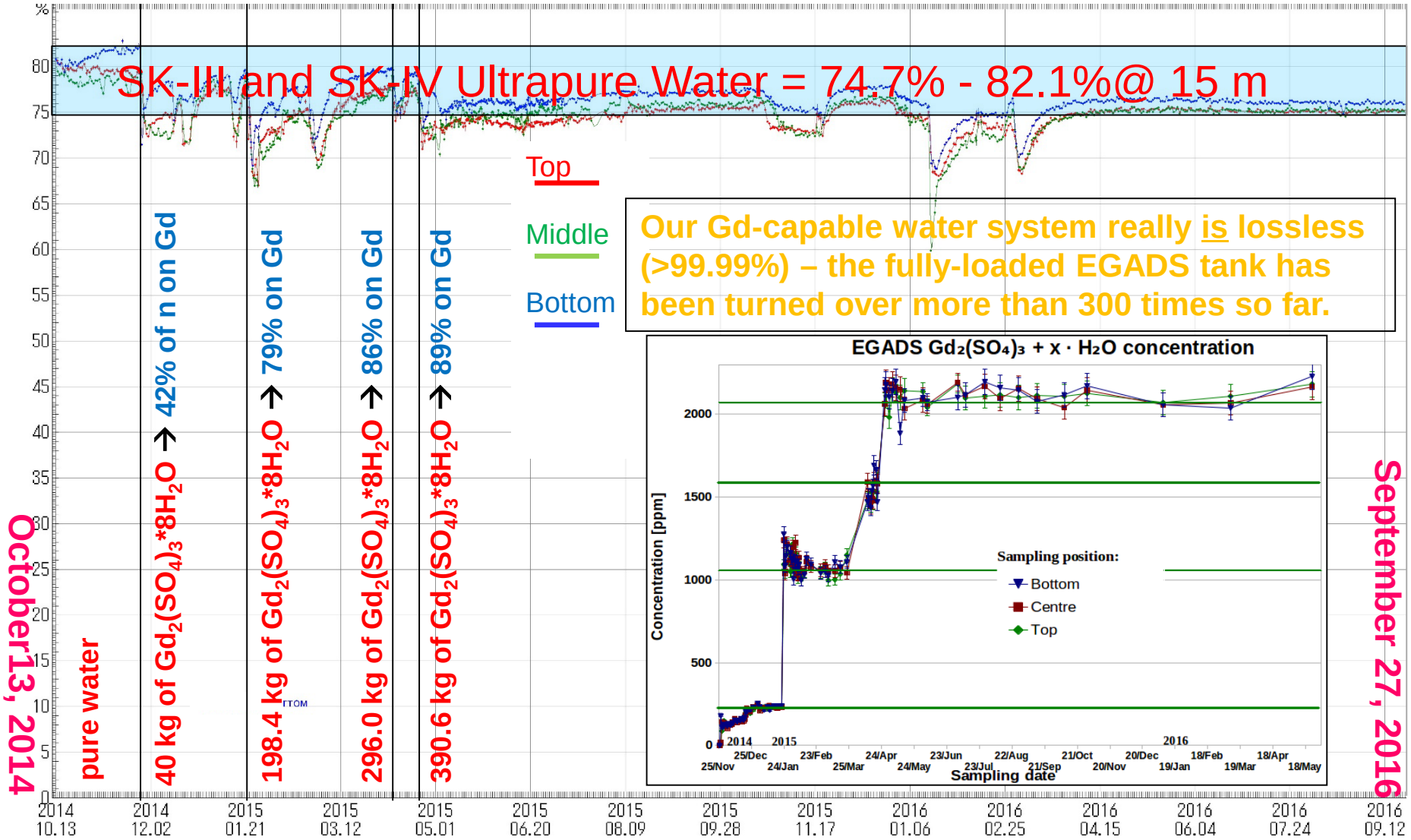


6/2015

Since April 2015, the EGADS detector has been fully loaded (0.2%) with gadolinium sulfate, and functioning perfectly.


Main 200-ton Water Tank with
227 50-cm PMT's + 13 HK tubes
(PMT's installed in summer of 2013)
15-ton Gadolinium
Pre-treatment
Mixing Tank
Selective Water+Gd
Filtration System
11/2011

Light @ 15 meters in the 200-ton EGADS tank



As was discussed in the original GADZOOKS! paper, as well as in the 280 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.

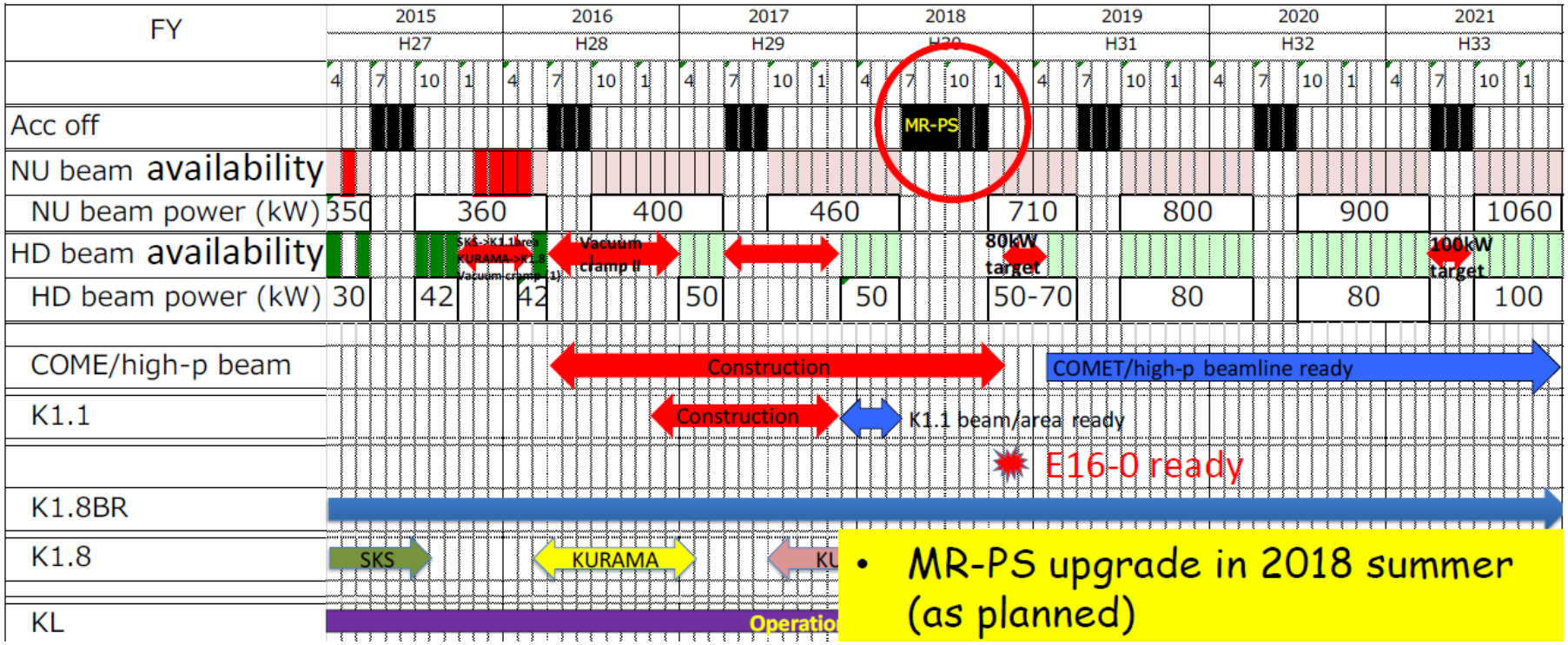
The actual schedule of the project including refurbishment of the tank and Gd-loading time will be determined soon taking into account the T2K schedule.

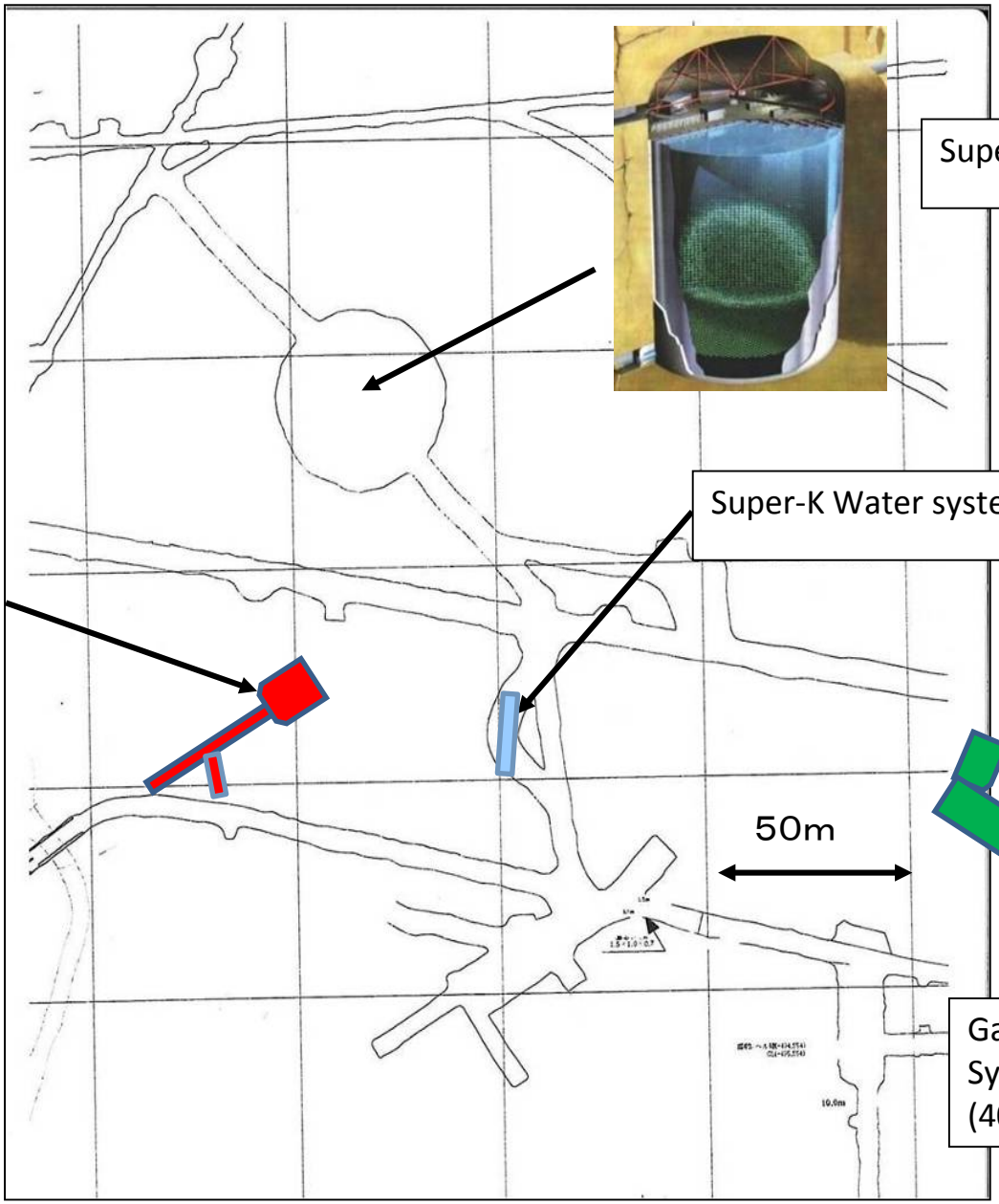
T2K/SK "SK-Gd" joint Statement

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.

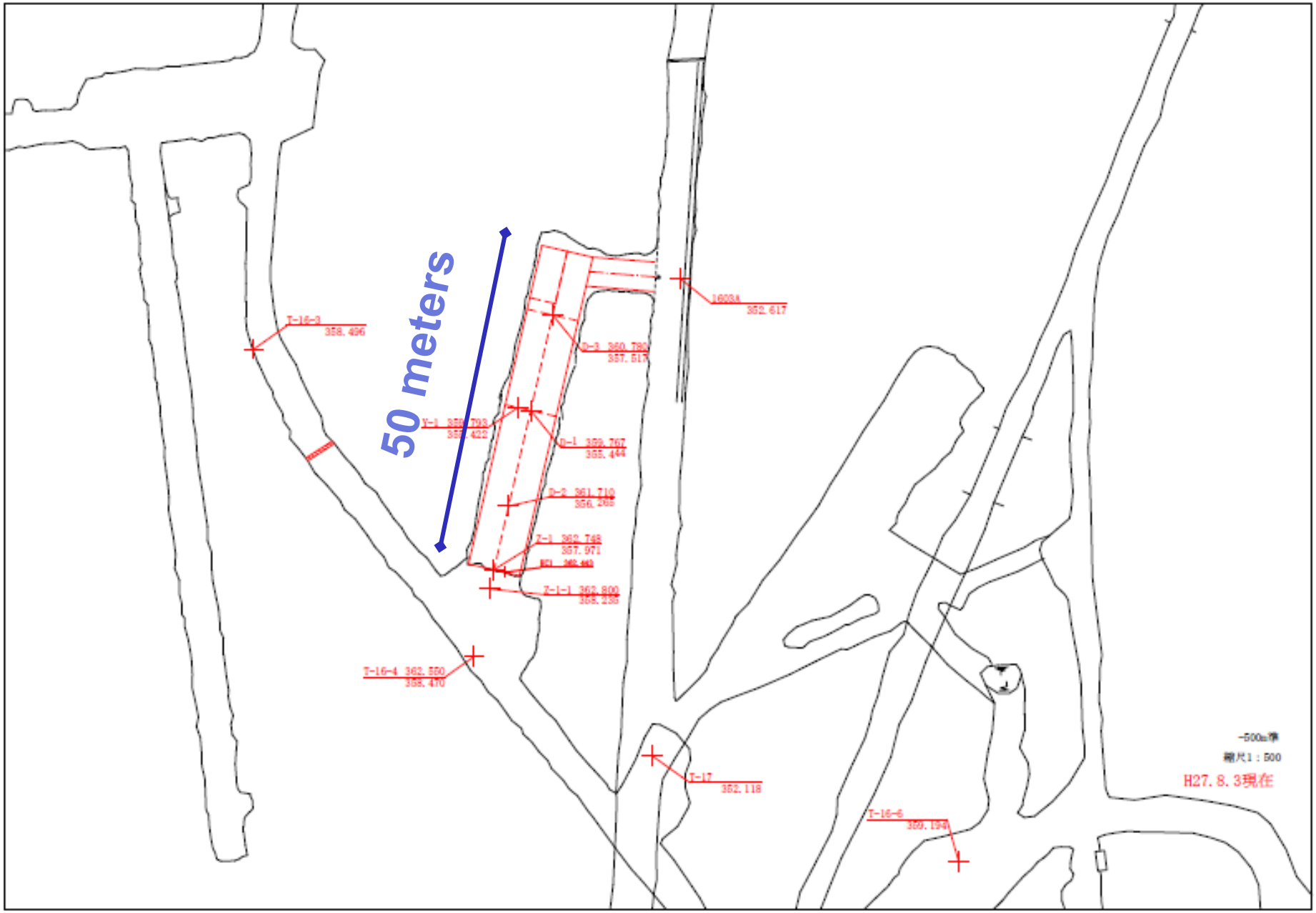
T2K and SK will jointly develop a protocol to make the decision about when to trigger the SK-Gd project, taking into account the needs of both experiments, including preparation for the refurbishment of the SK tank and readiness of the SK-Gd project, and the T2K schedule including the J-PARC MR power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

J-PARC Schedule




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

New gadolinium water system hall (“Hall G”);
September 10st, 2015

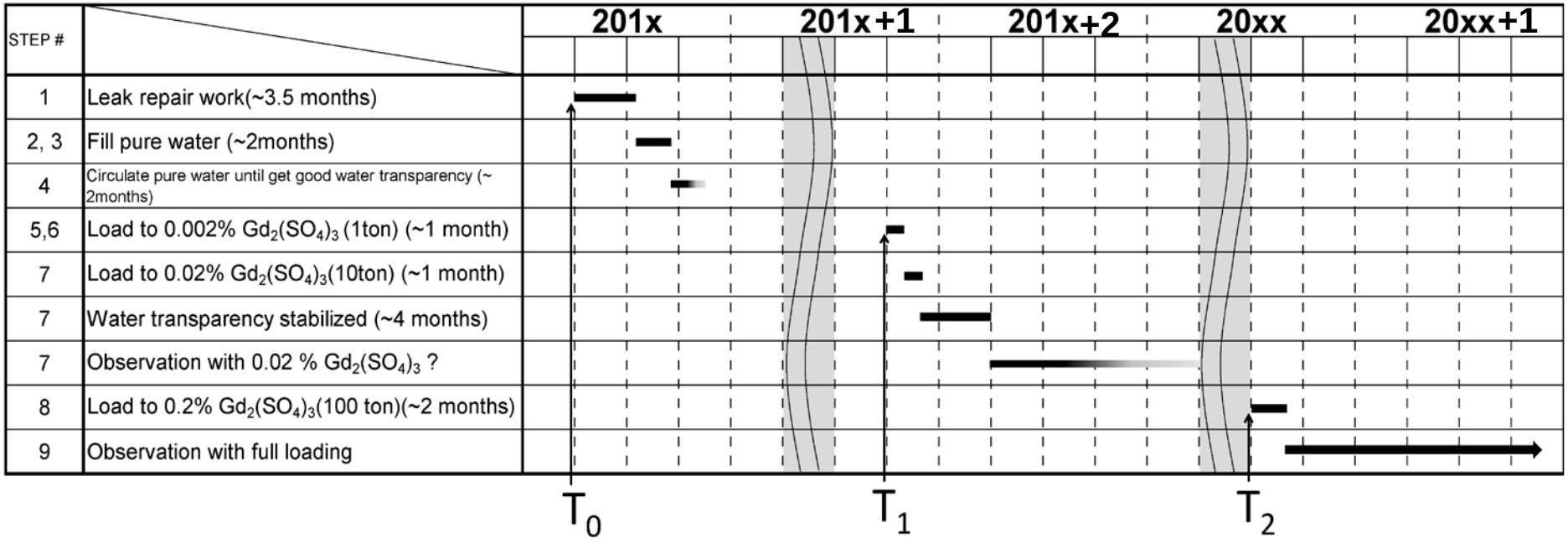
Hall G ready for occupancy;
April 22nd, 2016

Hall G being filled with equipment for the gadolinium loading of Super-Kamiokande; November 10th, 2016

Hall G being filled with equipment for the gadolinium loading of Super-Kamiokande; November 10th, 2016

Timeline

Preliminary, but x=8 is highly likely



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%)

→ Since April 2015, EGADS has been fully loaded with the target goal of 0.2% (390.6 kg) of $Gd_2(SO_4)_3$.

→ The EGADS water systems are working perfectly, keeping the fully Gd-loaded 200-ton tank water transparency well within the SK-III/IV pure water range without any measureable loss of water or gadolinium after over a year and a half of operation.

→ As a result of this and other studies over the past decade, both the Super-K and T2K Collaborations have formally approved the plan to add Gd to Super-K.

→ EGADS's proven, Gd-capable water systems are now being scaled up for use in Super-Kamiokande. A large new underground space ("Hall G") has been prepared and is being rapidly filled with equipment in anticipation of the Gd loading of Super-K.

→ Based on the success of Super-K's R&D program, various new water Cherenkov detectors around the world are also actively pursuing enrichment with gadolinium (see the next few talks).

In conclusion (Liverpool version):

The Gd-in-water technique has gone from nowhere, man, to being something real, and soon we will be gazing at neutrinos from across the universe!

We are planning to begin the in-tank work in 2018.