

Status of the **Gadolinium** project for Super-Kamiokande

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for SK Collaboration

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on High Energy Physics

Melbourne Convention and
Exhibition Centre



The facility

Search for Supernova Relic Neutrino

Throughout the history of the Universe, supernovae have exploded and have released 99% of their energy as neutrinos.

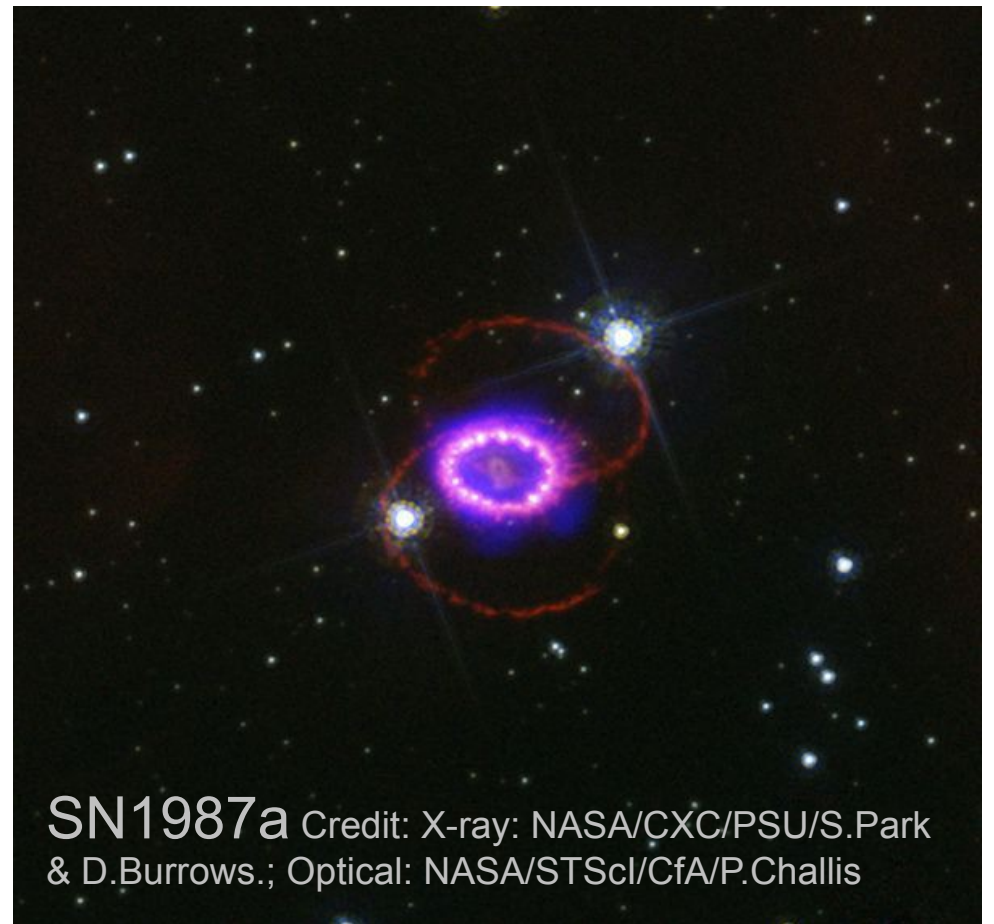
The neutrinos from the past universe, **S**upernova **R**elic **N**eutrinos, still exist and wait for our discovery.

Several experiments searched for the SRN and set the upper limit on its flux.

SNO, KamLAND, Borexino...

and

Super-Kamiokande.



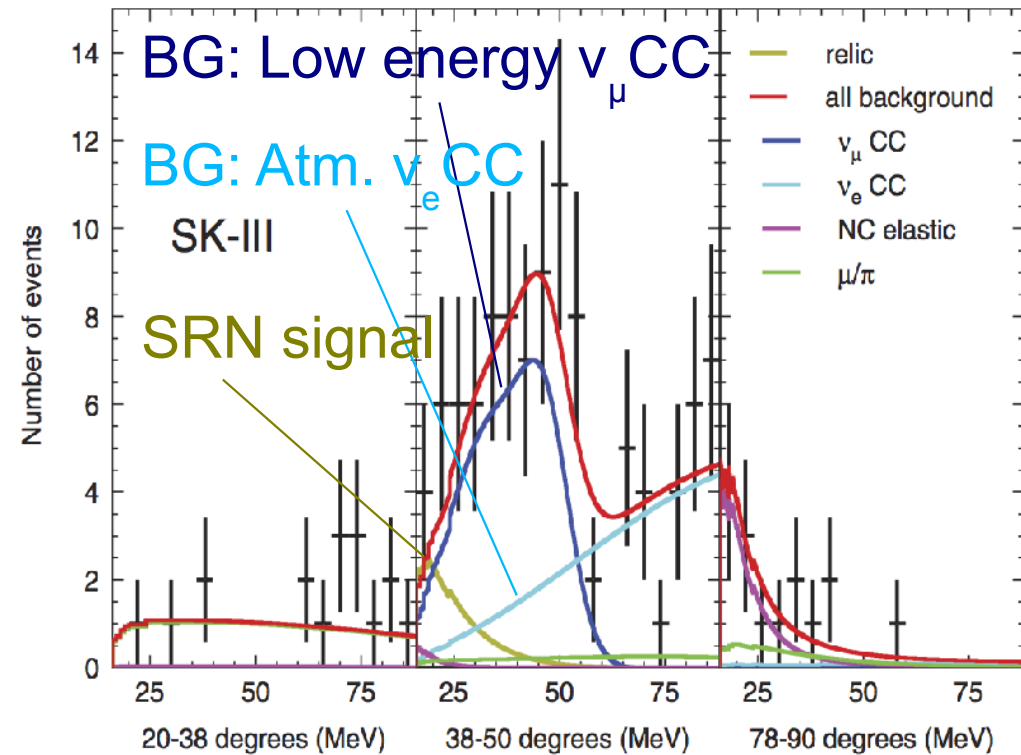
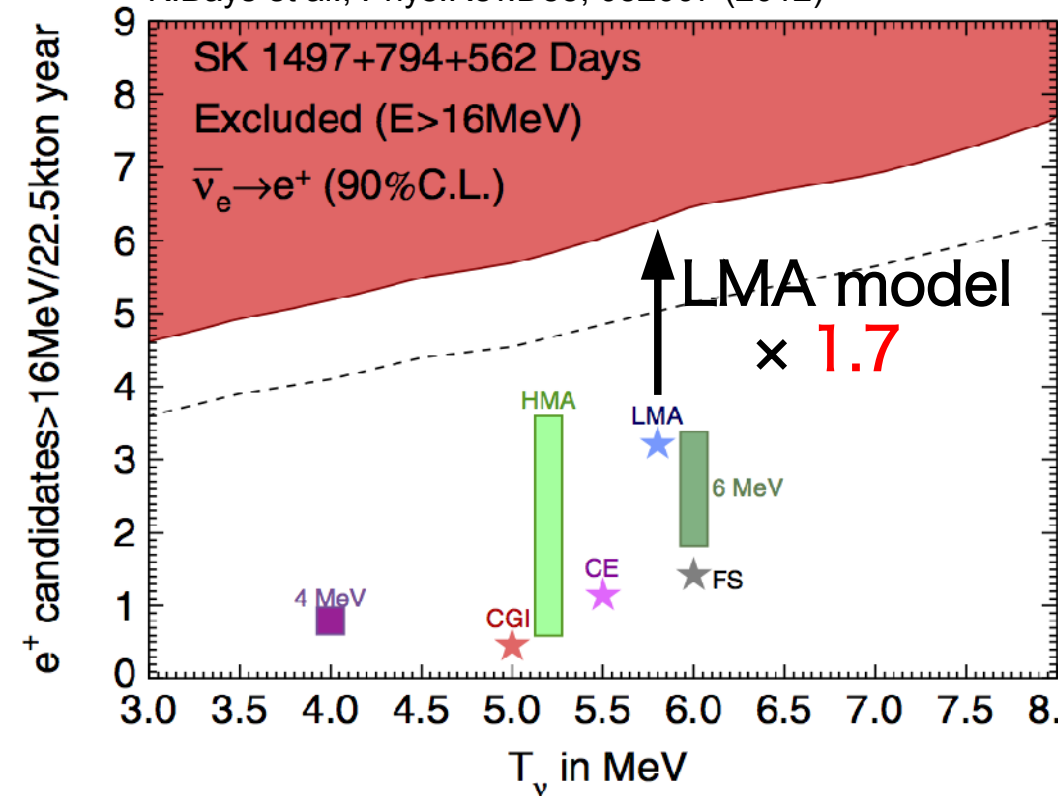
SRN Search with Super-Kamiokande

K.Bays et al., Phys.Rev.D85, 052007 (2012)

Single positron tag analysis :

*SRN Flux < $1.7 \times$ LMA Flux (90%CL), for $E_e > 16\text{MeV}$

K.Bays et al., Phys.Rev.D85, 052007 (2012)



Current analysis is limited by systematic error, not statistic.
Further background reduction is necessary for SRN discovery.

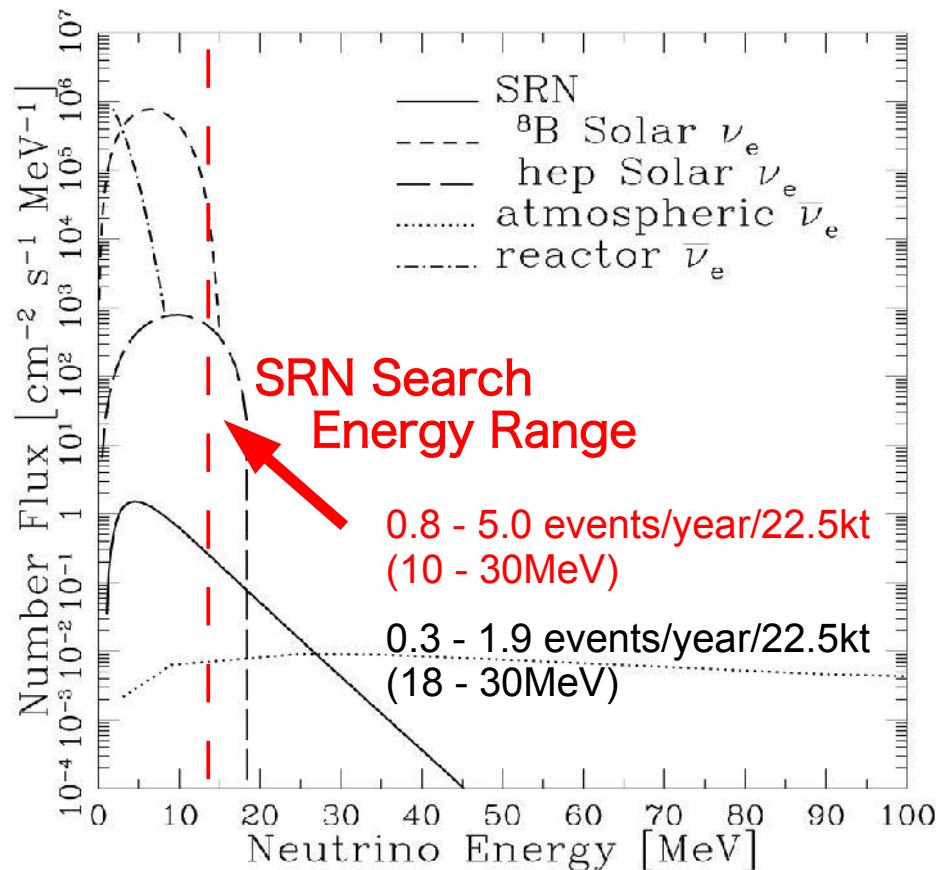
Super-Kamiokande + Gadolinium

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

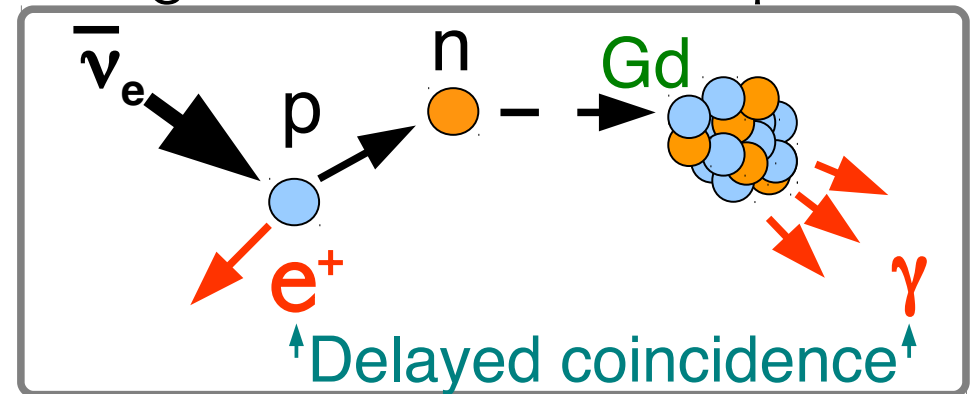
0.2% Gadolinium sulfate in SK would reduce the background significantly by positron + neutron tagging.

- Signal efficiency : 90%

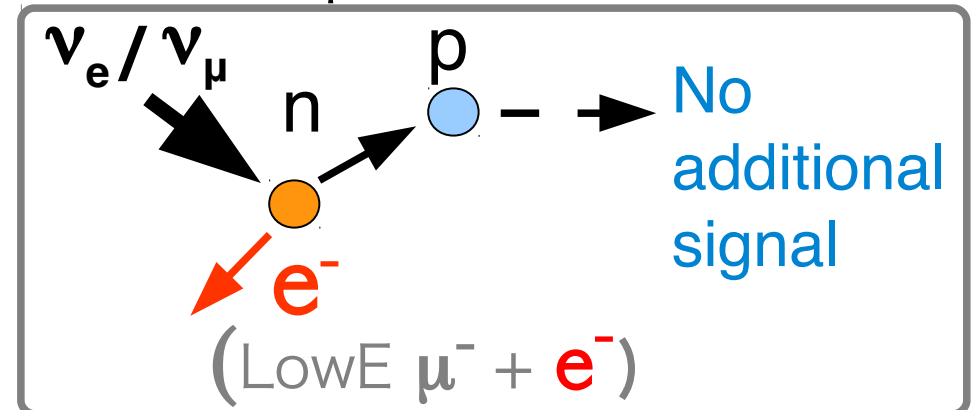
- Background reduction : 2×10^{-4} Watanabe et. al, Astroparticle Physics Vol31 Issue 4, 2009



SRN signal, Reactor, Atmospheric



Solar, Atmospheric



Evaluating Gadolinium's Action on Detector Systems “EGADS”

Motivation : To prove that the principle works.

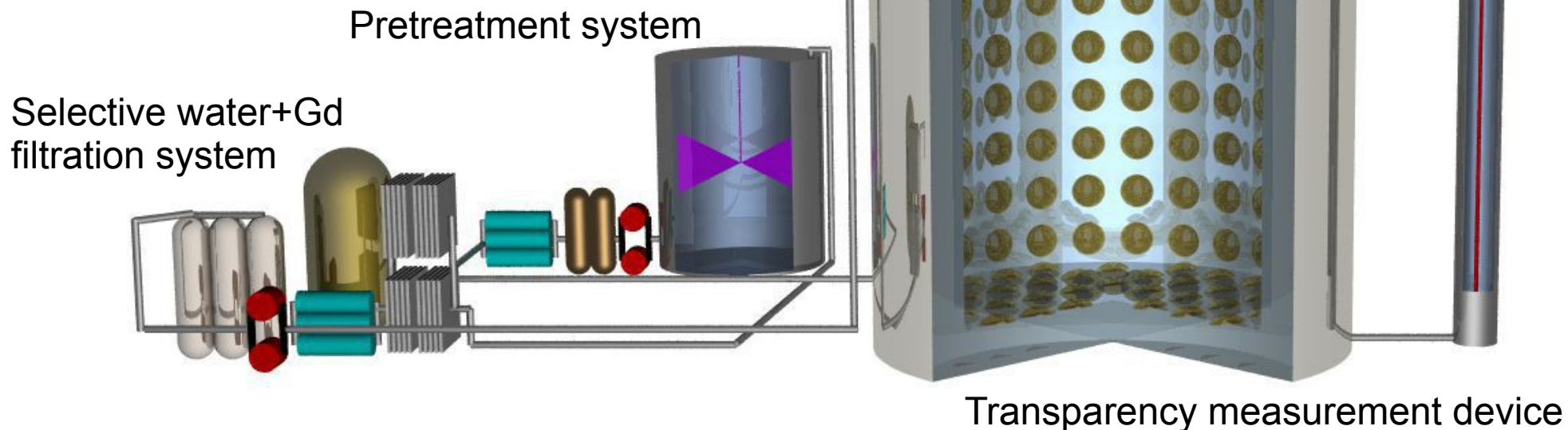
- How to add/remove Gd
- Water purification
- Water transparency
- Effects on materials
- Neutron background
- Detection efficiency

Under study

To be studied

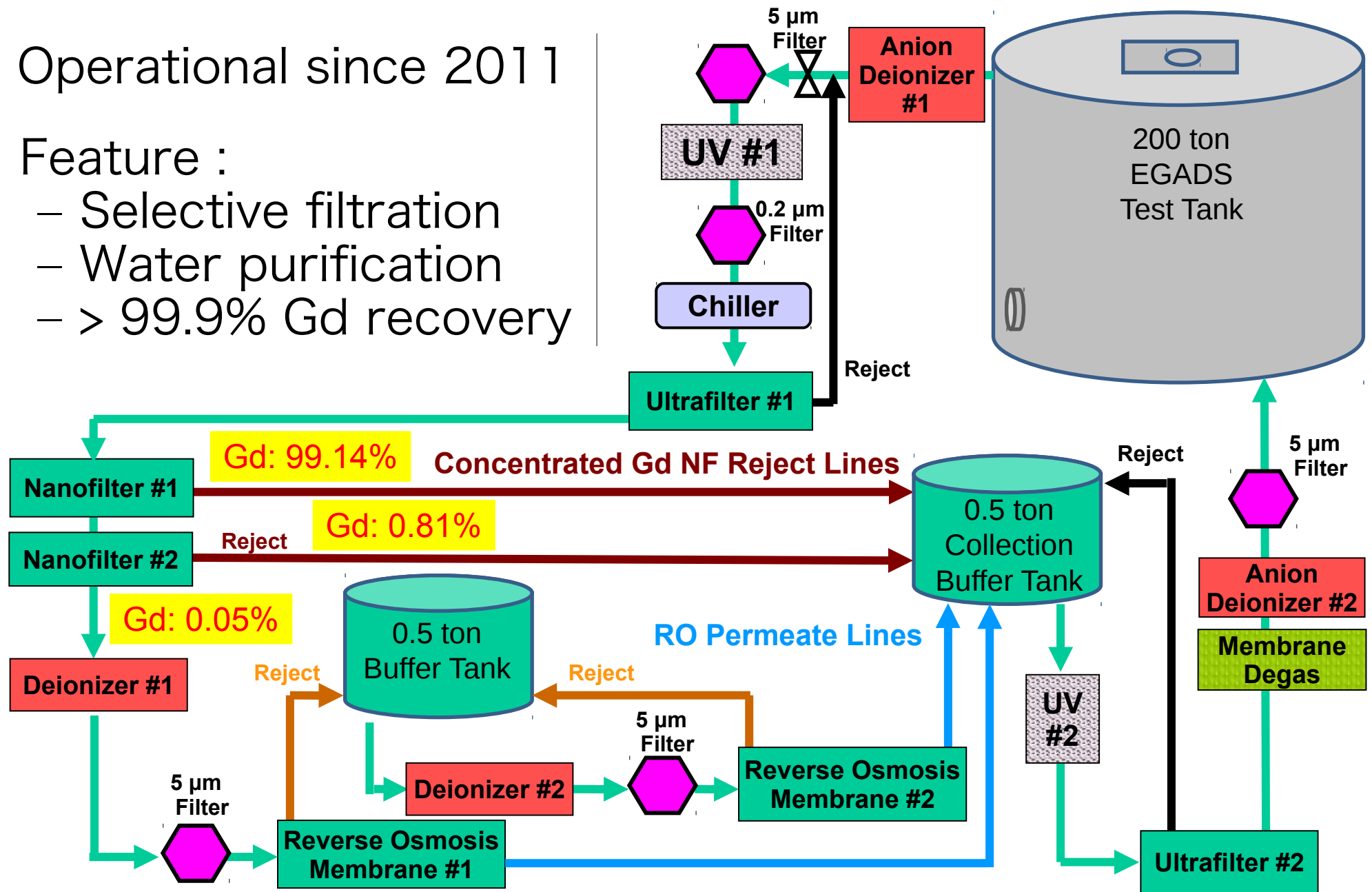
200 ton water tank + 240 “20 PMT

Overview :

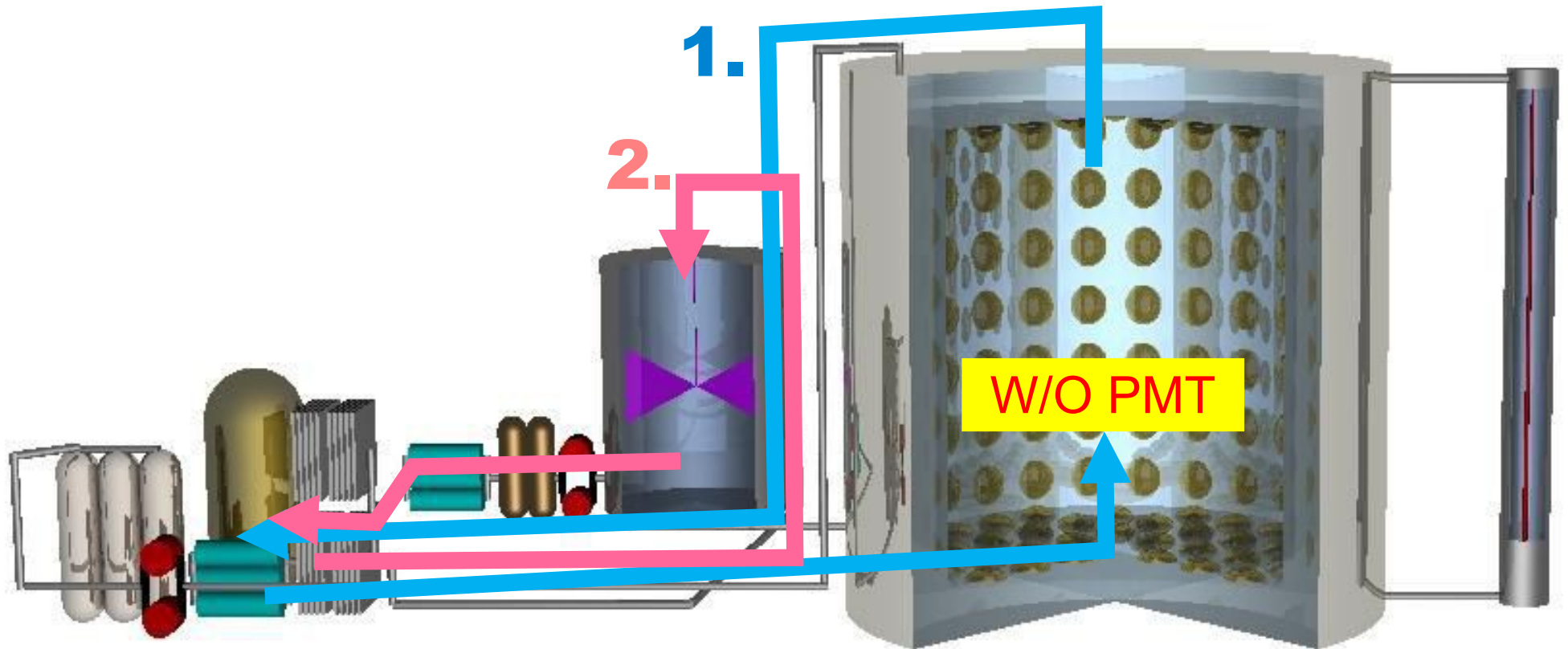


EGADS Water Circulation System

- Operational since 2011
- Feature :
 - Selective filtration
 - Water purification
 - > 99.9% Gd recovery



Water Circulation Tests



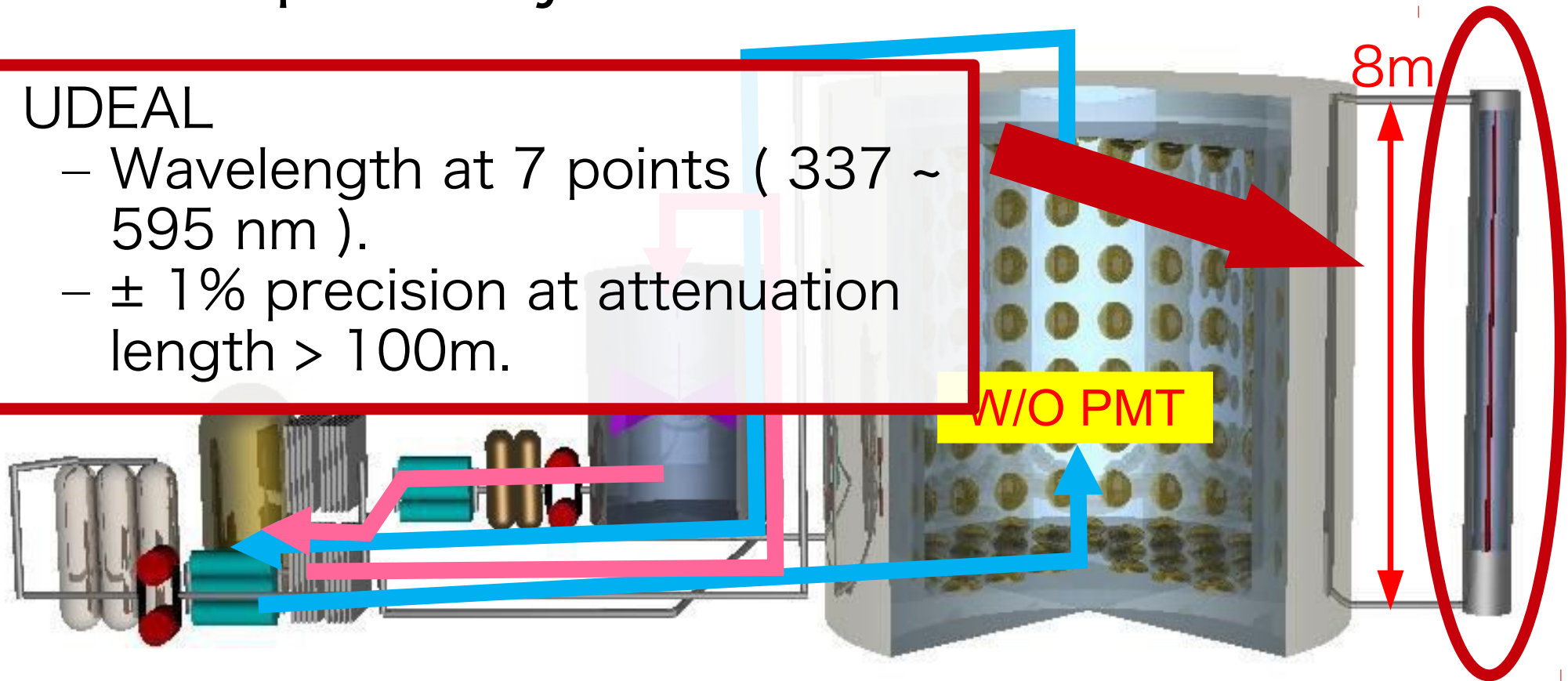
1. March – June, 2011
Pure water circulation through 200t tank.

2. Aug. 2011 ~ Present
Gd-loaded water circulation through 15t tank.
→ Circulation and water transparency measurement

Transparency Measurement Devices

UDEAL

- Wavelength at 7 points (337 ~ 595 nm).
- $\pm 1\%$ precision at attenuation length $> 100\text{m}$.

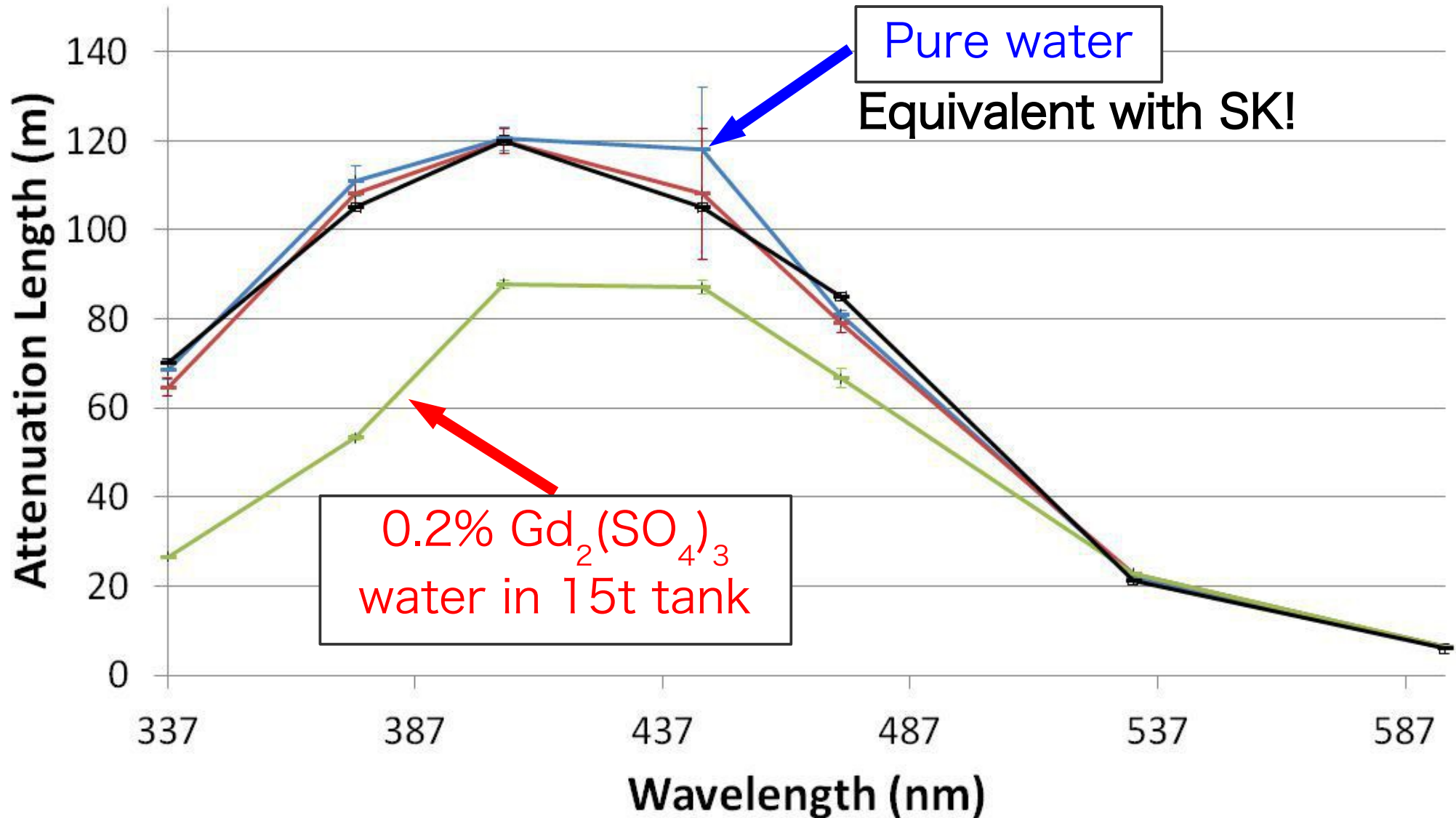


Water transparency measured by UDEAL, device built in house which can give precisely measured attenuation length over 100 meters.

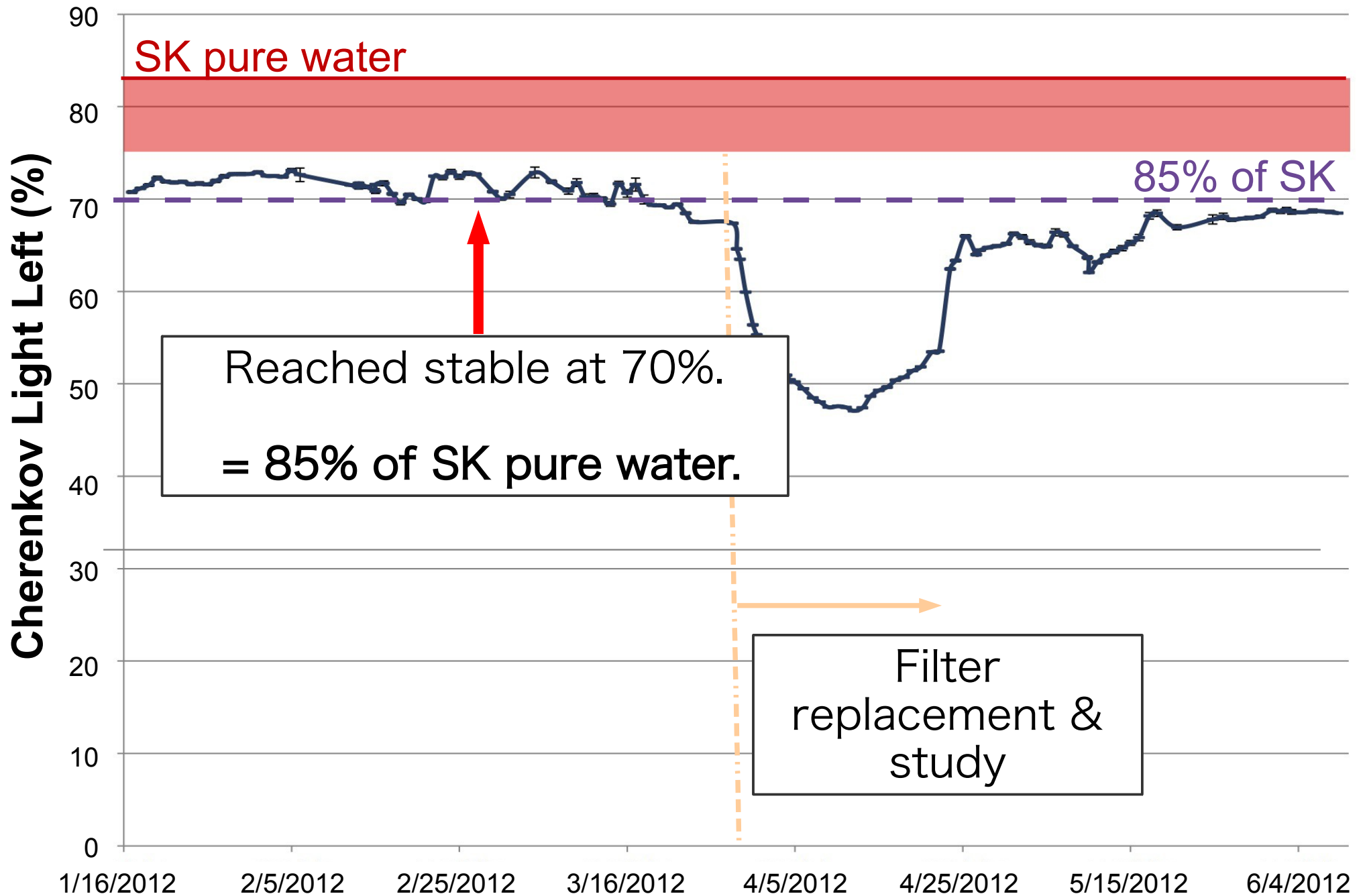
Spectrophotometer is also used for the spectrum and the absorption peaks. ($< 337 \text{ nm}$)

Measured water transparency with Gd

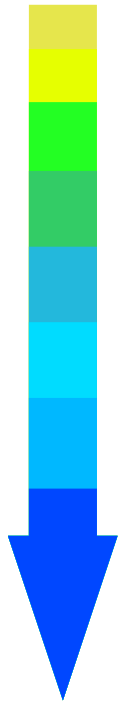
— Pure Water in 200 Ton Tank — Pure Water in 15 m³ Tank
— Gd Water on Feb. 1st — SK Water



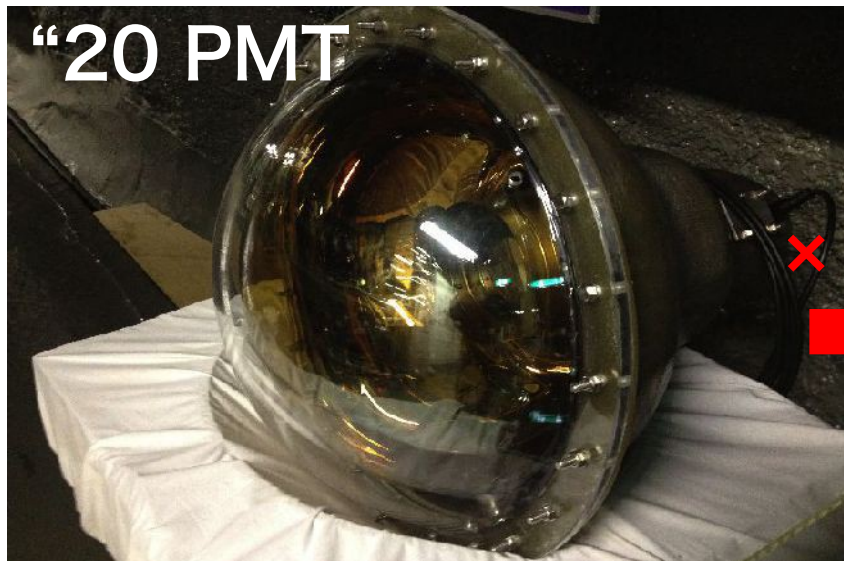
Cherenkov light left at 15m in Gd water



Status and Future Plan



- ~ '11 200t tank and circulation system are ready.
- '12 Gd-loaded water circulation with 15t tank.
- < Here
- Gd-loaded water circulation with 200t tank.
- 240 PMTs installation into 200t tank.
- Gd-loaded water circulation with 200t tank and PMT.
- Detection efficiency measurement with n source.



× 240



Summary and Discussion

Adding 0.2% **Gadolinium** sulfate to SK, anti-neutrino inverse beta decay can be identified.

- **S**upernova **R**elic **N**eutrino can be discovered.
 - Background reduction
 - Lower energy limit
 - 0.8 – 5.0 events/year/22.5kt (10 – 30 MeV)

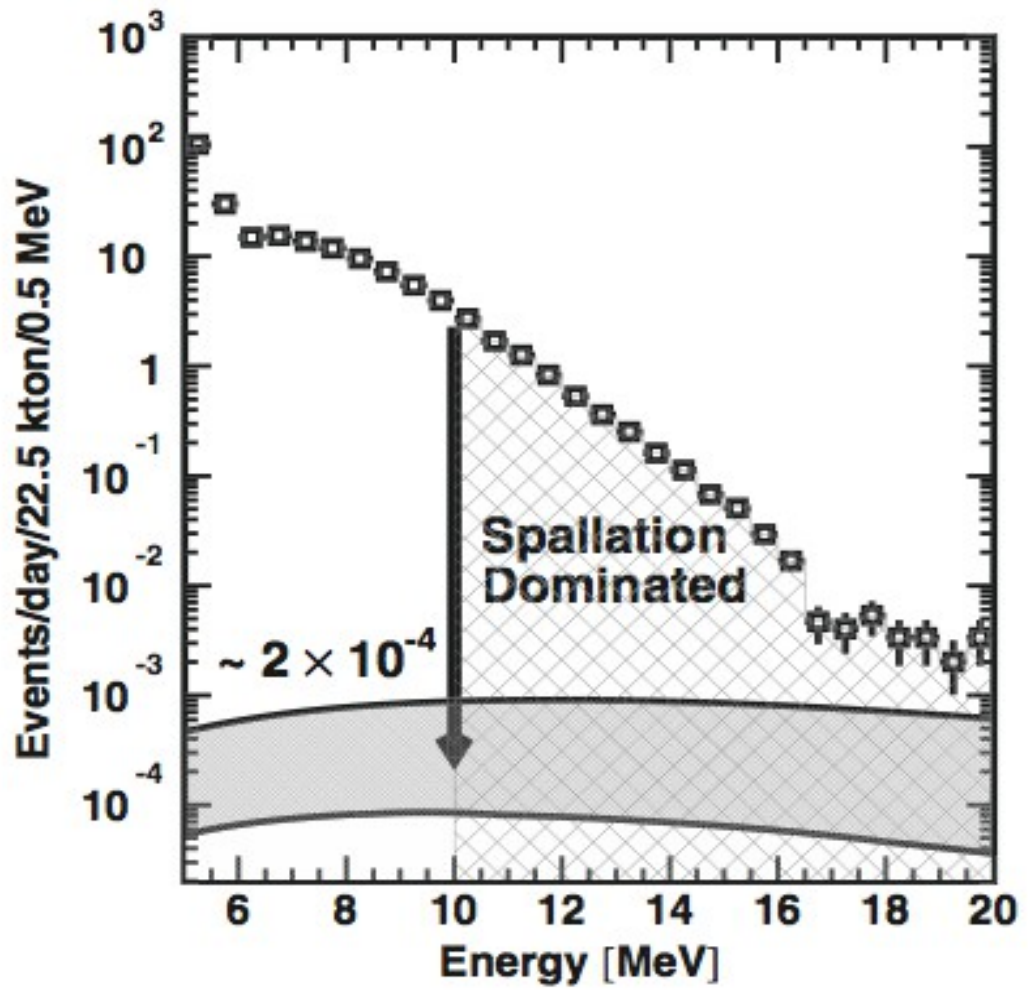
EGADS, the R&D project, is ongoing.

- Water circulation system has been in operation since 2011 in the Kamioka mine.
- Transparency of Gd-loaded water is still under study.

To do

- Gd-loaded water circulation with 200t tank
- Detection efficiency measurement with 200t tank and 240 PMTs

Appendix



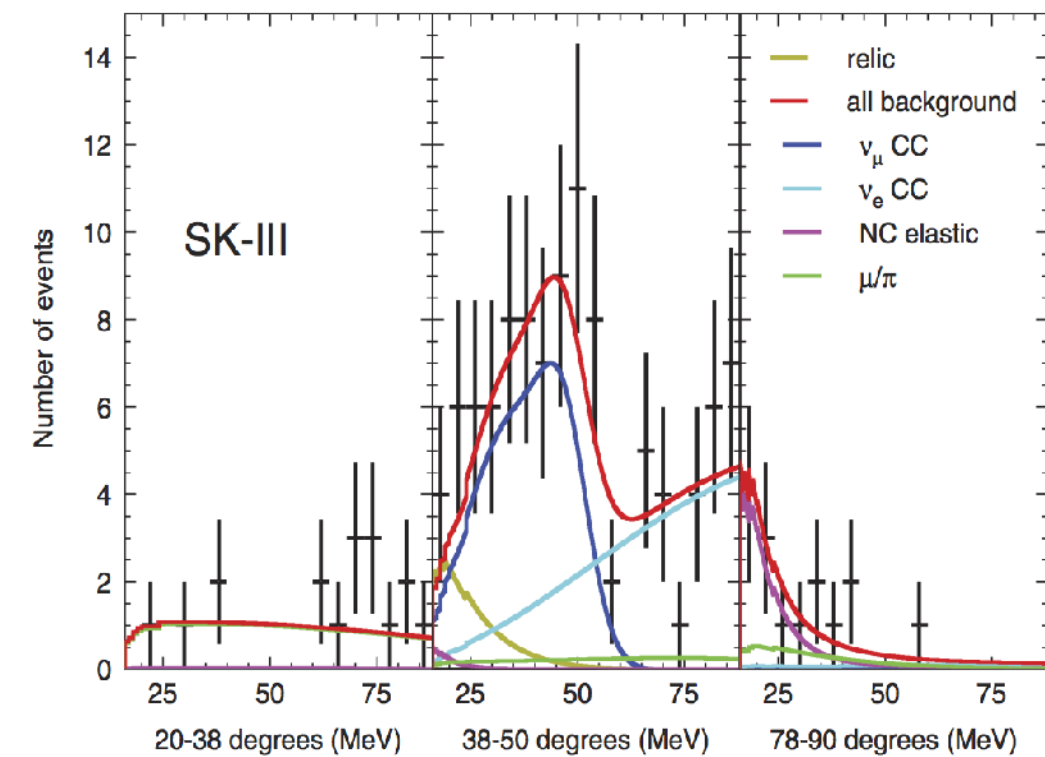
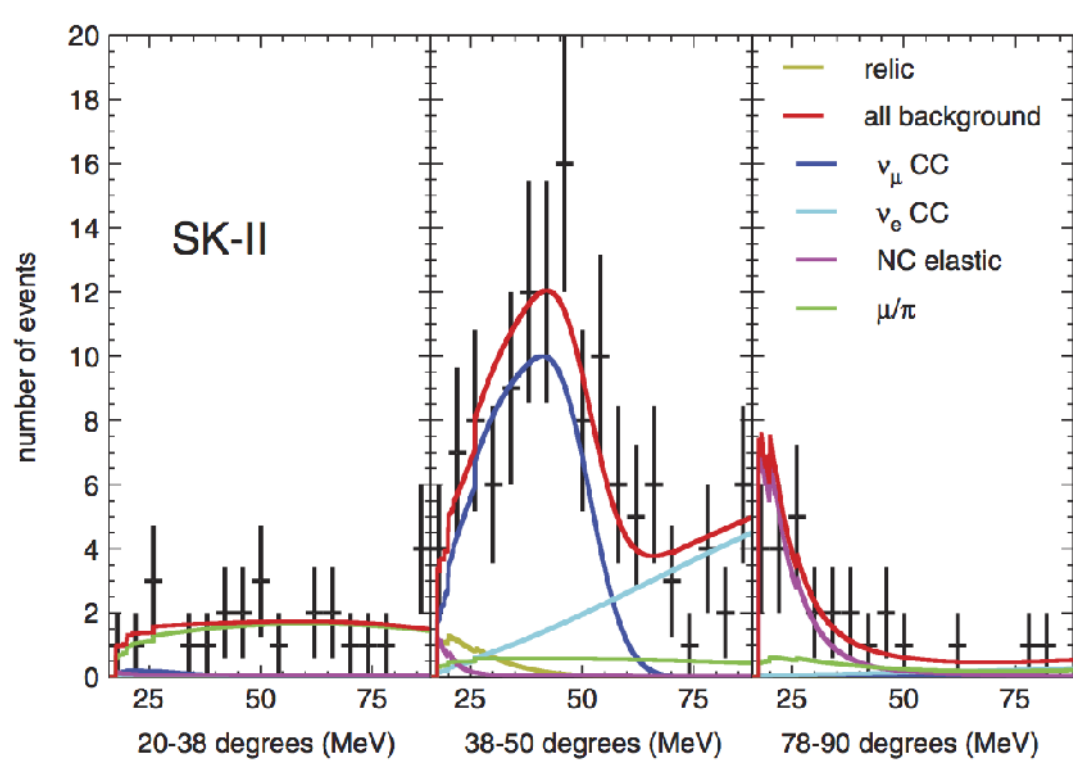
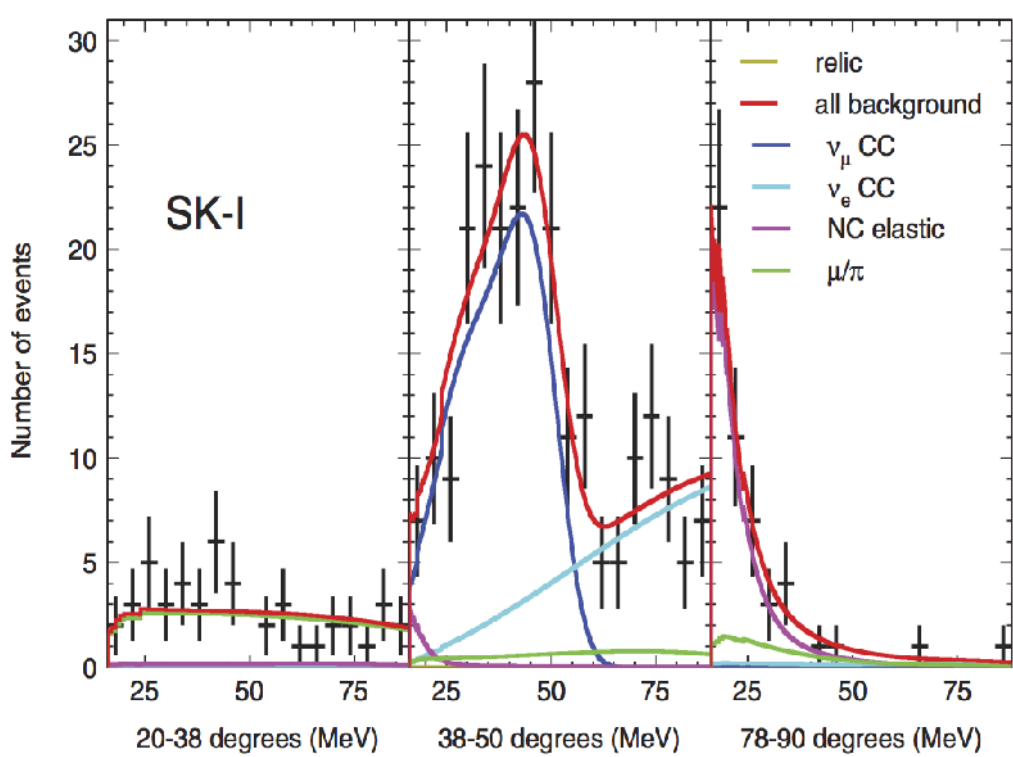


TABLE V. 90% C.L. flux limit ($\bar{\nu}$ cm⁻² s⁻¹), $E_\nu > 17.3$ MeV.

Model	SK-I	SK-II	SK-III	All	Predicted
Gas infall (97)	<2.1	<7.5	<7.8	<2.8	0.3
Chemical (97)	<2.2	<7.2	<7.8	<2.8	0.6
Heavy metal (00)	<2.2	<7.4	<7.8	<2.8	<1.8
LMA (03)	<2.5	<7.7	<8.0	<2.9	1.7
Failed SN (09)	<2.4	<8.0	<8.4	<3.0	0.7
6 MeV (09)	<2.7	<7.4	<8.7	<3.1	1.5

K.Bays et al., Phys.Rev.D85, 052007 (2012)

Introduction -SRN-

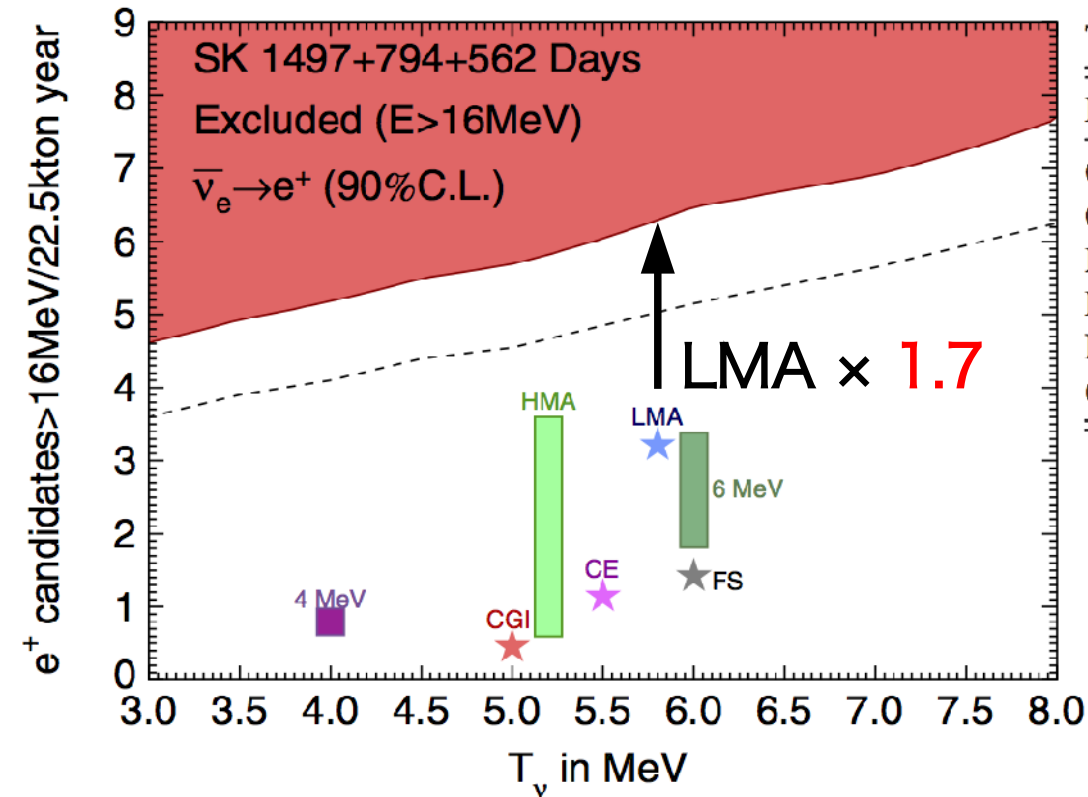
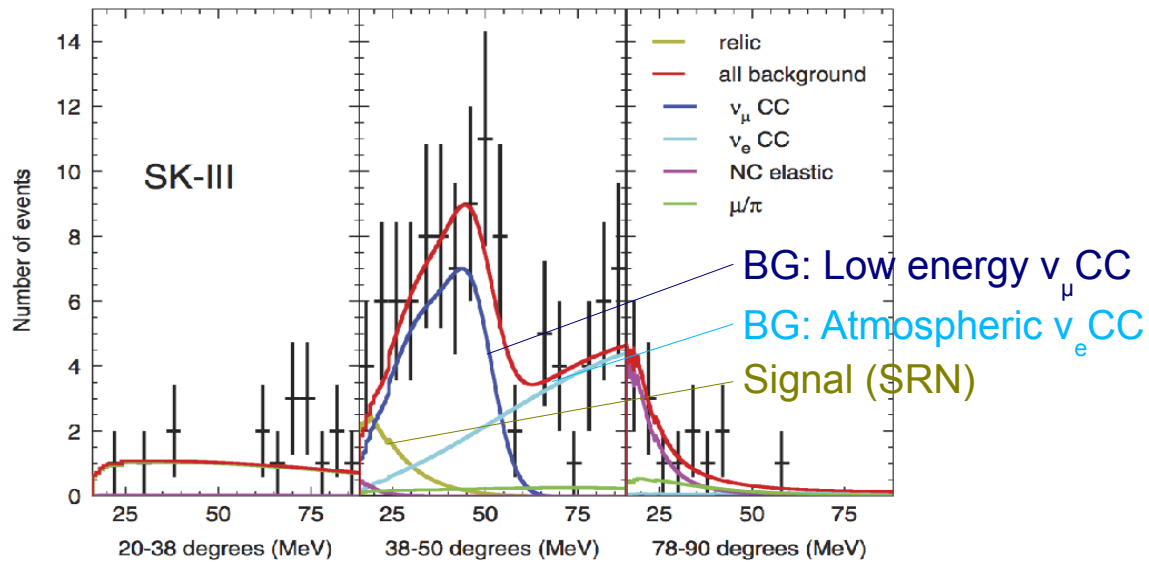


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Introduction -Background-



Main background for SRN search is :

- Decay electron from low energy atmospheric ν_μ CC
- Atmospheric ν_e CC