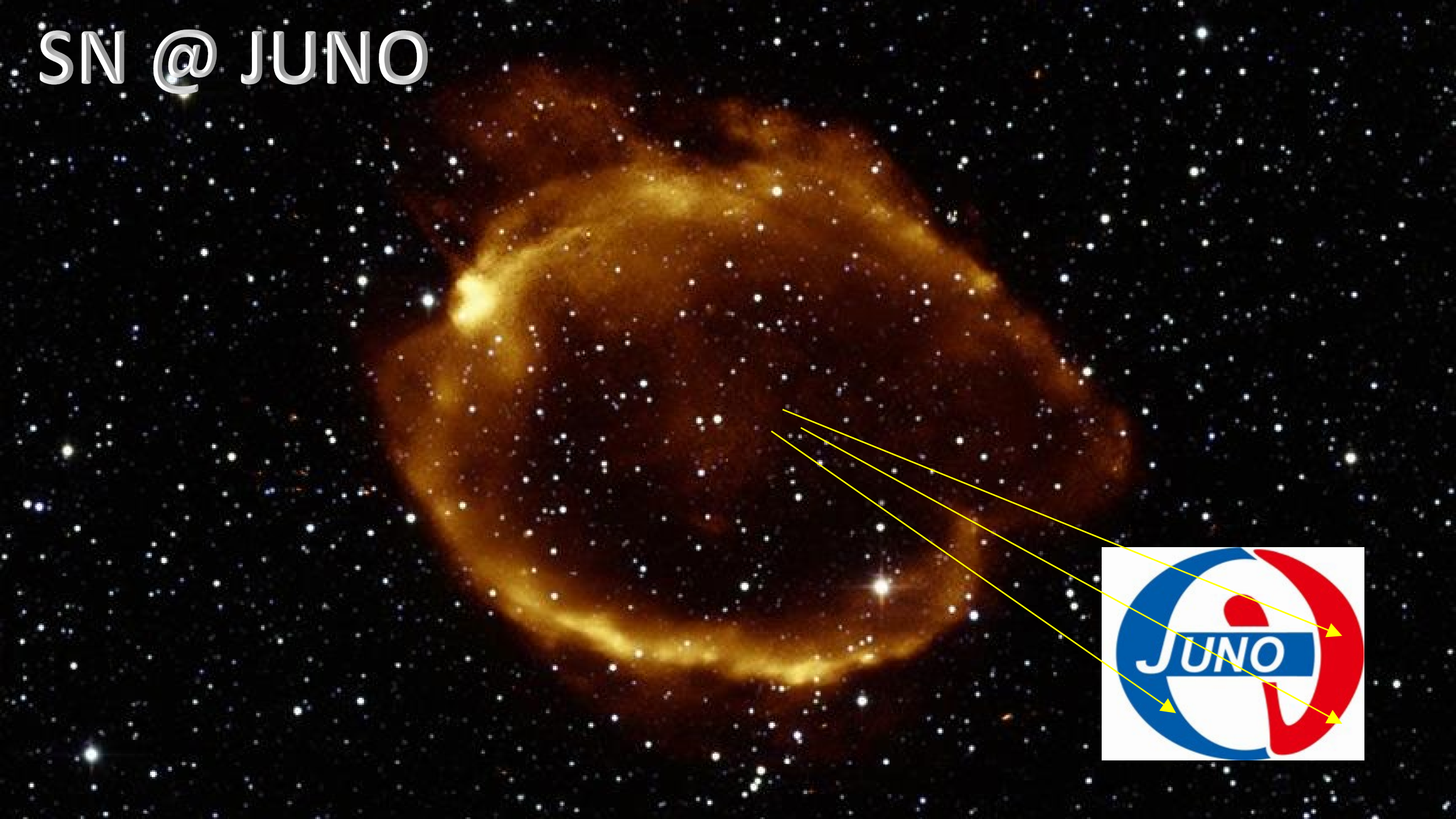
SN @ JUNO

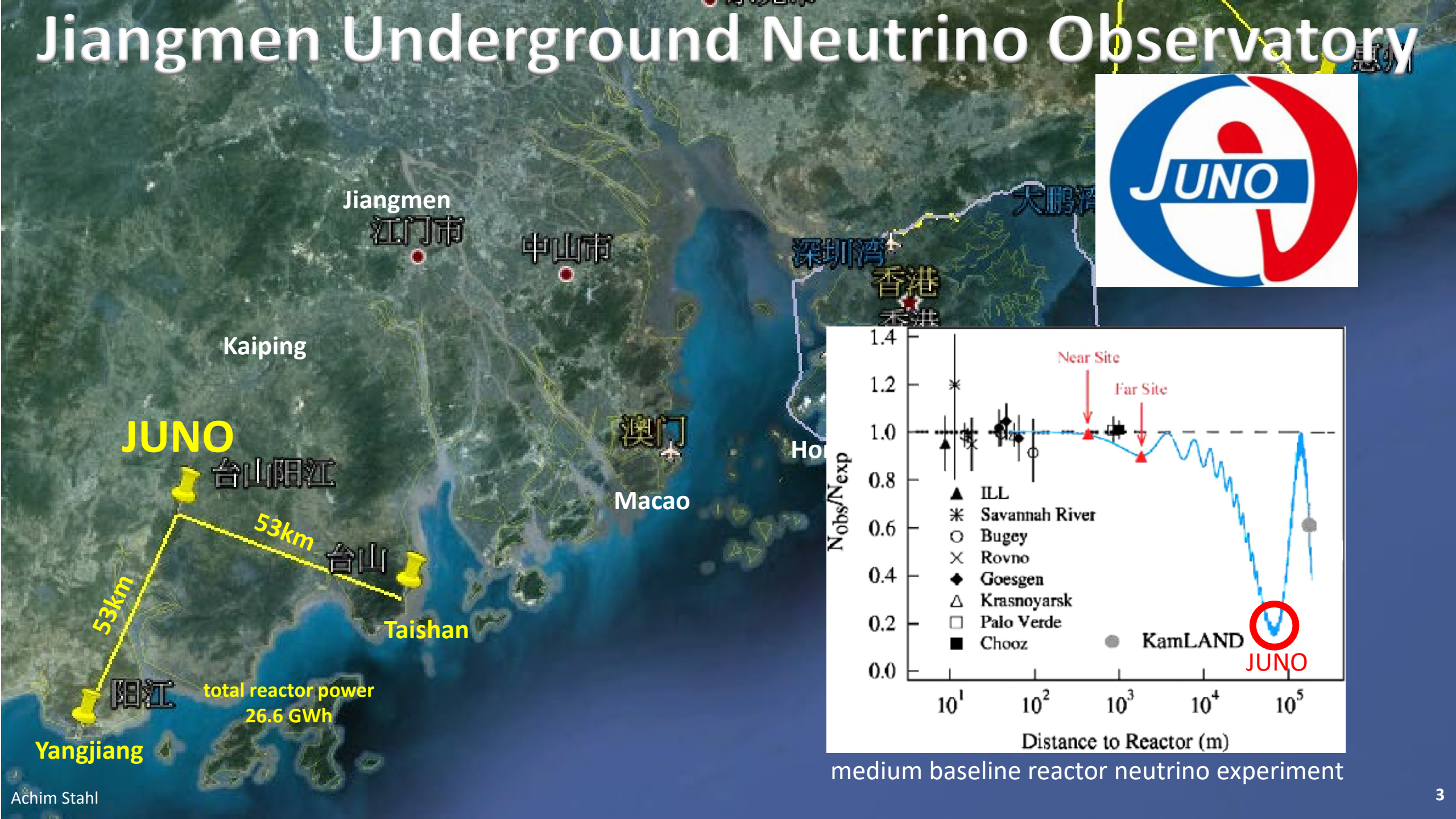
Achim Stahl,
SNνD2023, L'Aquila
on behalf of the JUNO collaboration

Physics Institute III
RWTH AACHEN UNIVERSITY

SN @ JUNO



Jiangmen Underground Neutrino Observatory

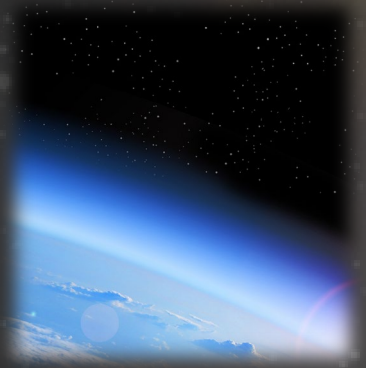
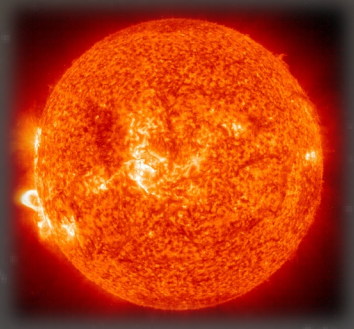


medium baseline reactor neutrino experiment

Jiangmen Underground Neutrino Observatory

a versatile neutrino project

neutrino properties

reactor	atmospheric	solar	supernova	geo
				
~ 60 / day	several / day	^{8}B: 50 / day CNO: 1000/day ^{7}Be: 10000 / day	~5000 @ 10 kpc diffuse: few/year	~ 400 / year

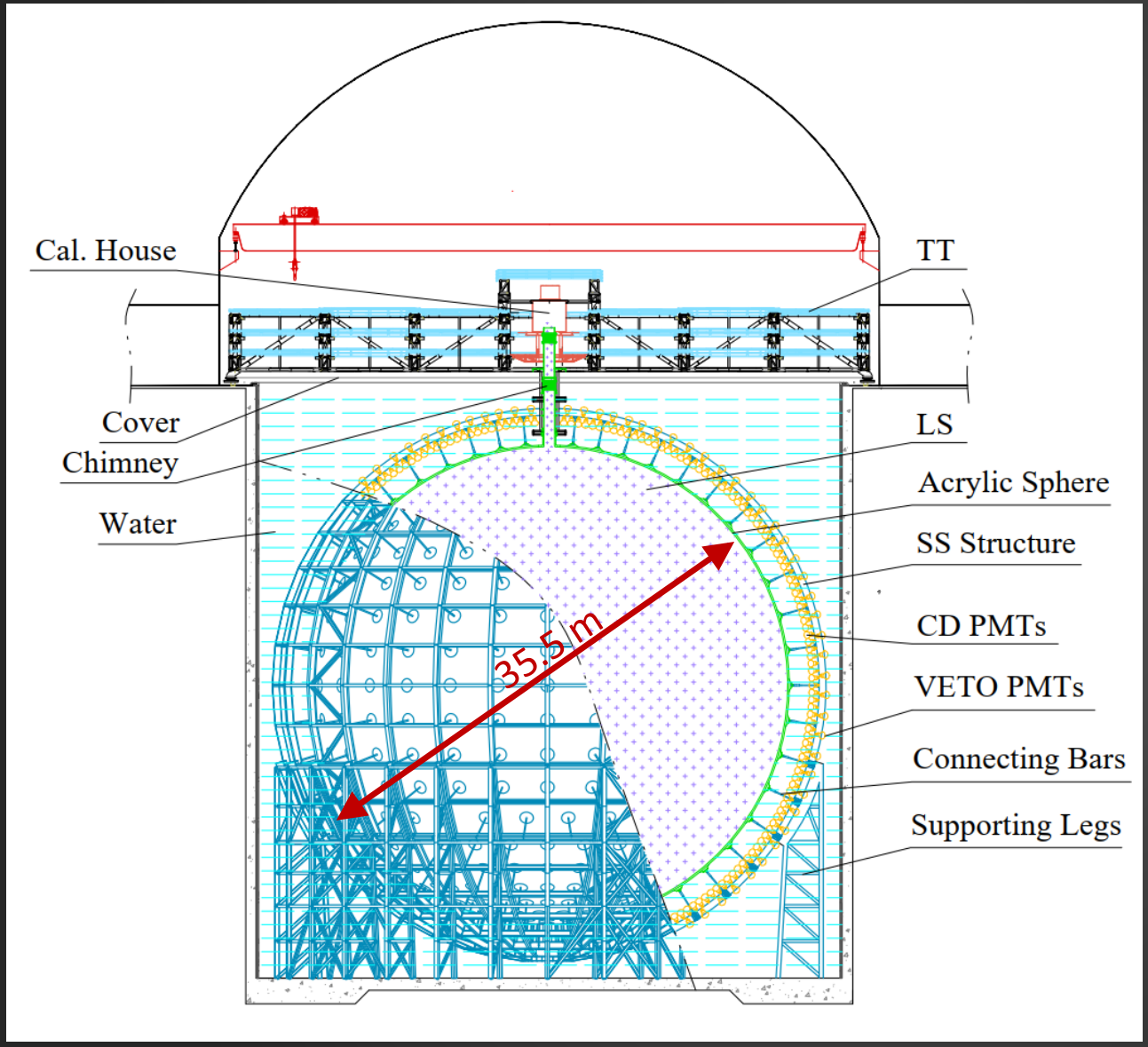
neutrinos as probes

\+ NEW PHYSICS

proton decay
sterile neutrinos
dark matter annihilation
neutrino magnetic moment

PPNP 123 (2022) 103927
J. Phys. G 43 (2016) 030401

JUNO Detector



20 kt liquid scintillator in acrylic sphere
Veto: water-Čerenkov Top-Tracker

17600 20“ PMTs

25600 3“ PMTs
total coverage: 78%

Detector comparison

	Daya Bay	KamLand	JUNO	SuperK	DUNE
target mass	20 t	1 kt	20 kt	25 … 30 kt	40 kt
energy resolution	$7.5\ \%/\sqrt{E}$	$6\ \%/\sqrt{E}$	$3.0\ \%/\sqrt{E}$	14.2 % @ 10 MeV	~10 % @ 10 MeV
energy calibration	~ 1.5 %	2 %	< 1 %	~ 1 %	?
optical coverage	12 %	34 %	78 %	40 %	-
light yield	160 p.e./MeV	500 p.e./MeV	1345 p.e./MeV	-	-

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large target mass
excellent energy resolution
very low detection threshold

The Observatory

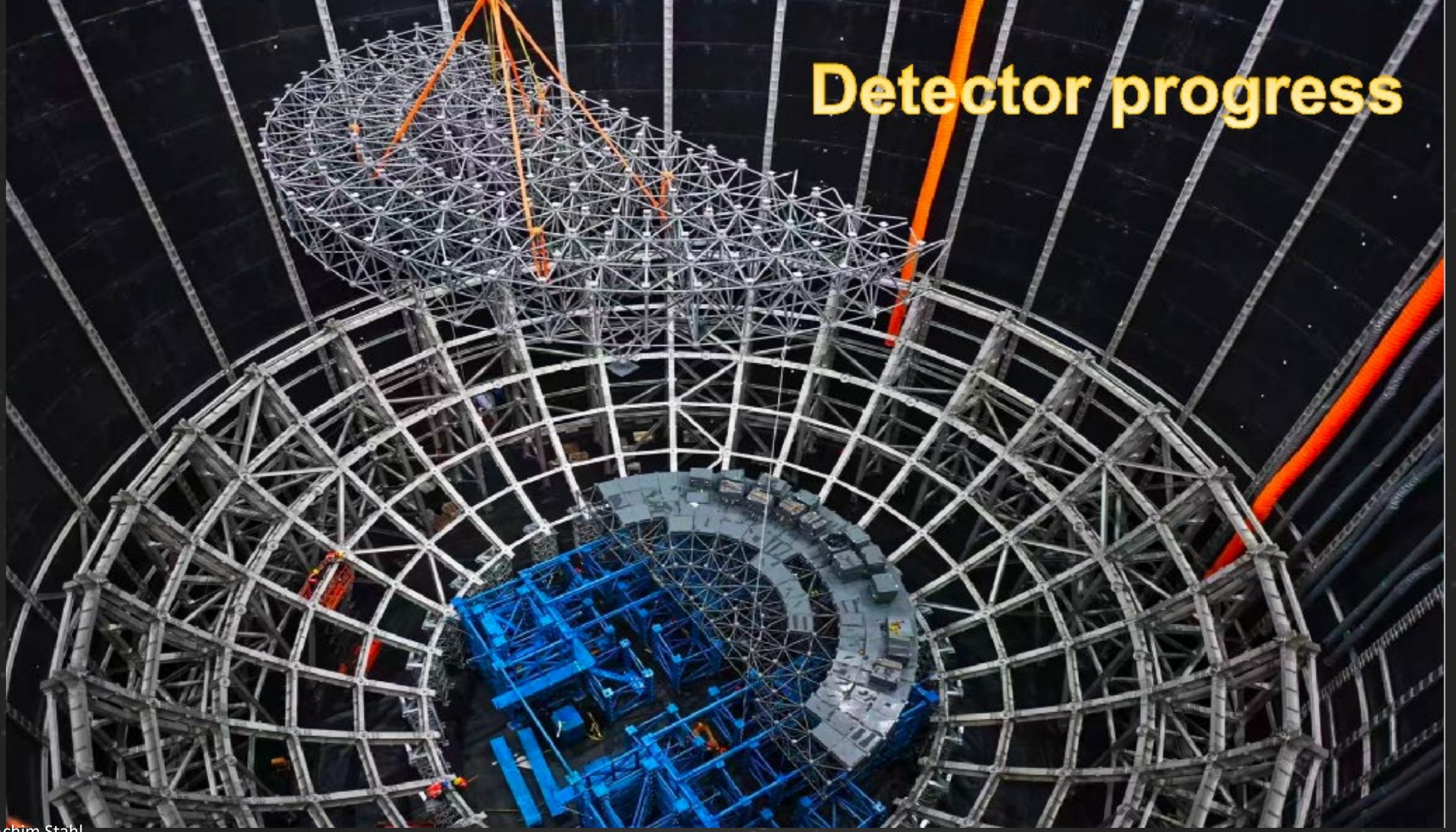
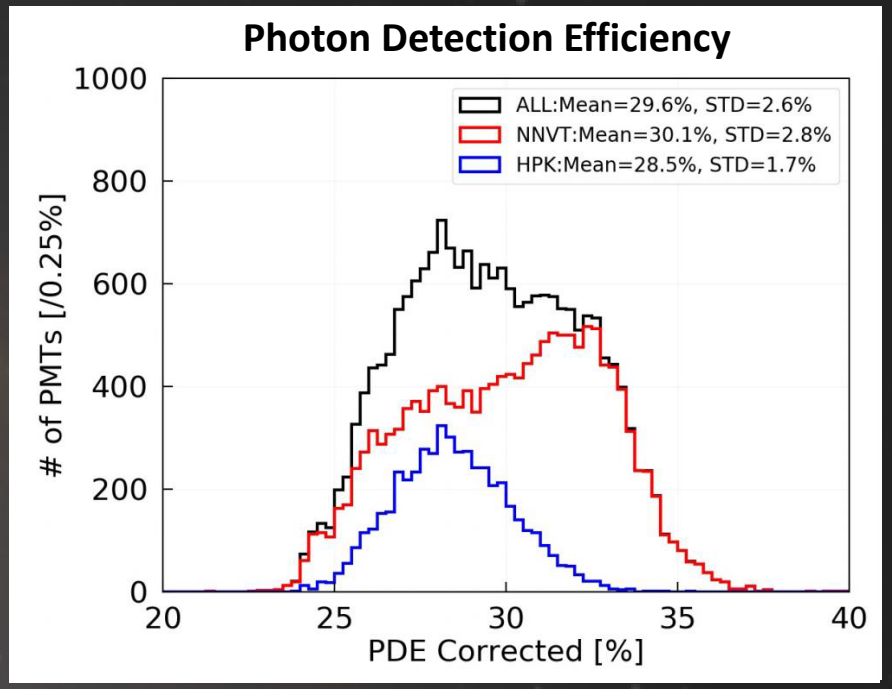

Detector progress

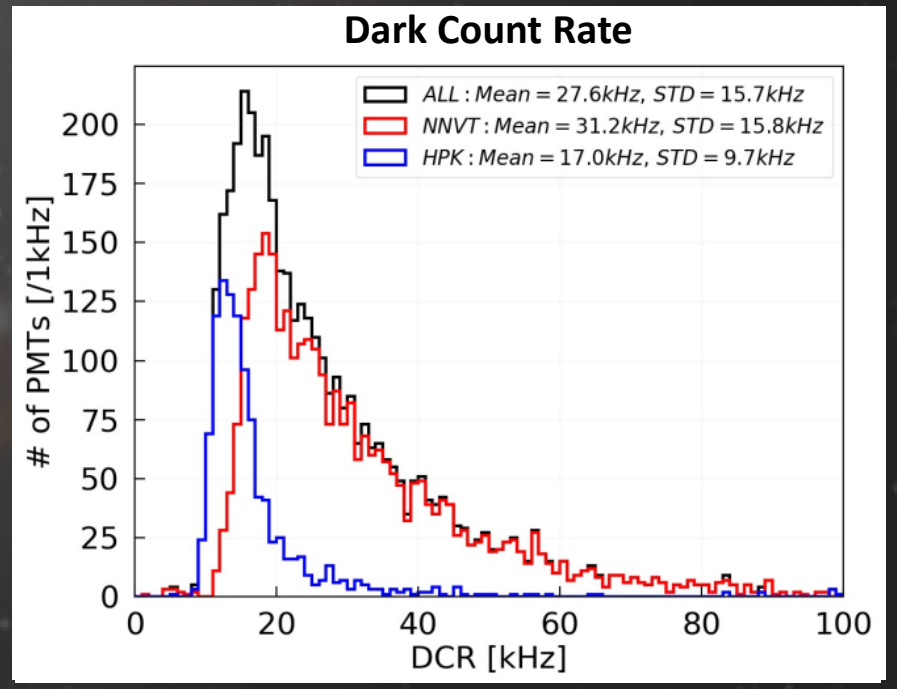
Photo Multipliere Tubes

20“ tubes: 17612 (CD) + 2400 (Veto)

3“ tubes: 25600

all PMTs tested





Status of the Detector

Stainless steel structure

- 30 longitudinal & 23 latitudinal layers
- 590 connecting rods
- 6000 m^2 HDPE covering the WP surface

completed

Acrylic sphere

- Inner radius: (35.40 ± 0.04) m
- Thickness: (12.4 ± 0.4) cm
- Radiopurity: U/Th/K < 1 ppt

assembly started in June ’22
(8 out of 23 rings installed)

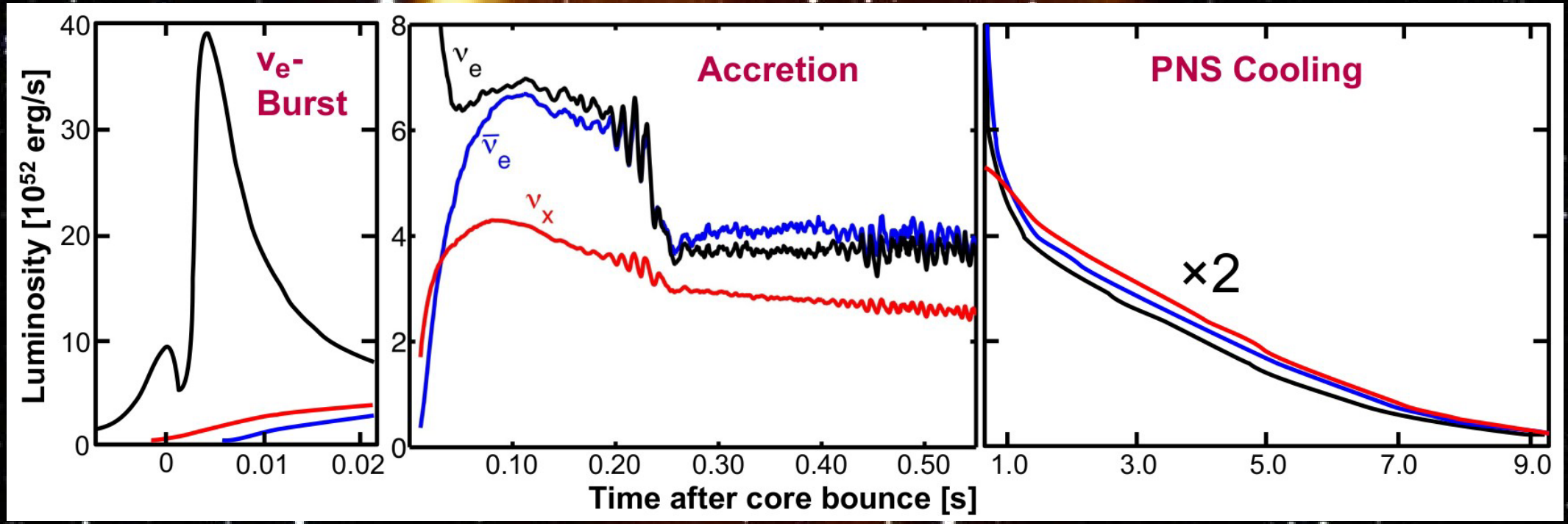
PMTs

- Large PMTs 3300 / 17600
- Small PMTs 2200 / 25600
- A few modules operational

Installation started

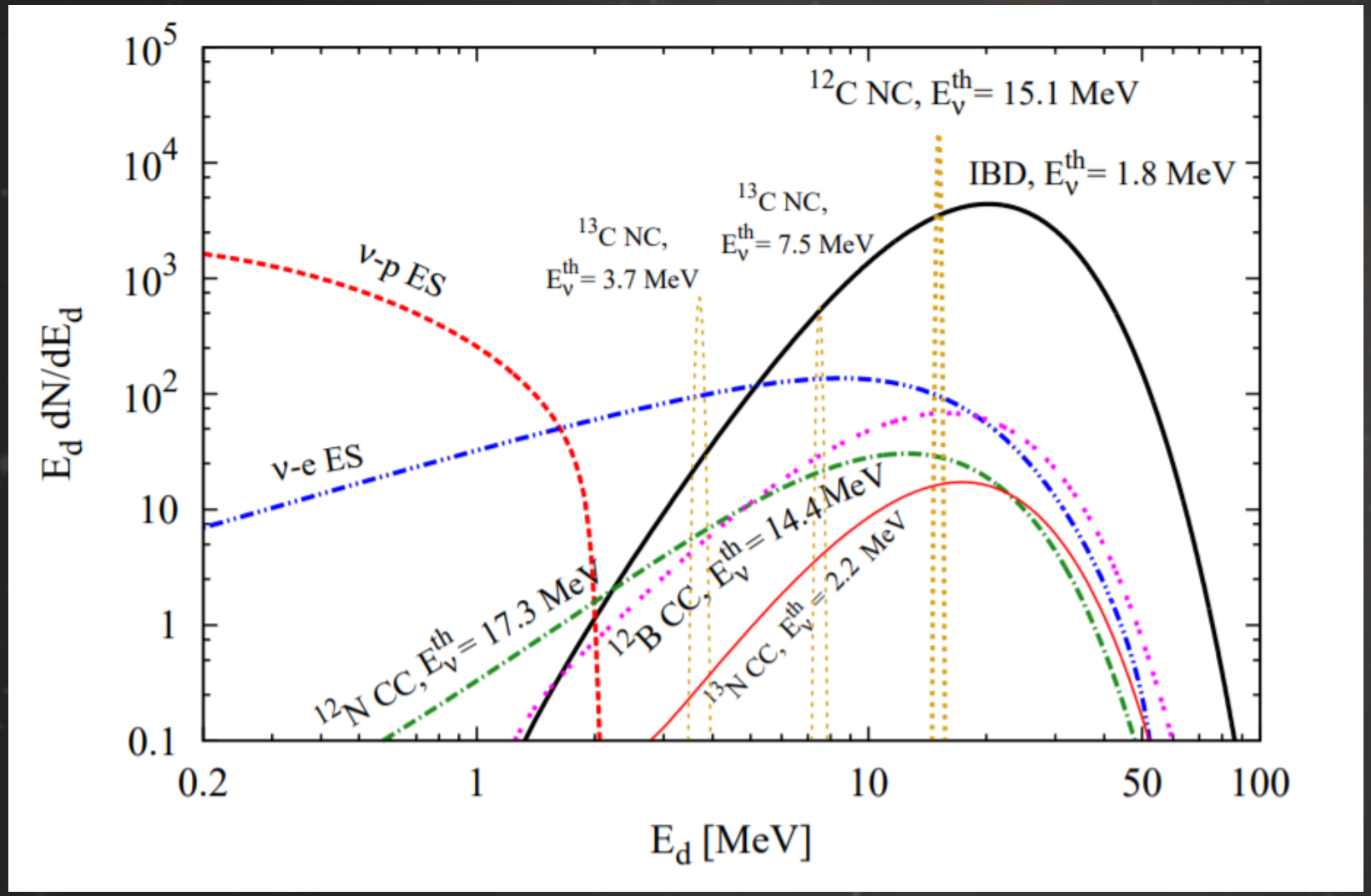
Direct CCSN Observation @ JUNO

Direct CCSN Observation @ JUNO



Detection Channels

CCSN @ 10 kpc



Inverse **B**eta-**D**ecay 5000 ev.

$\bar{\nu}_e + p \rightarrow e^+ + n$

p-**E**lastic **S**cattering 2000 ev.

$\nu + p \rightarrow \nu + p$

e-**E**lastic **S**cattering 300 ev.

$\nu + e^- \rightarrow \nu + e^-$

Neutral Current 300 ev.

$\nu + {}^{12/13}C \rightarrow \nu + {}^{12/13}C^*$

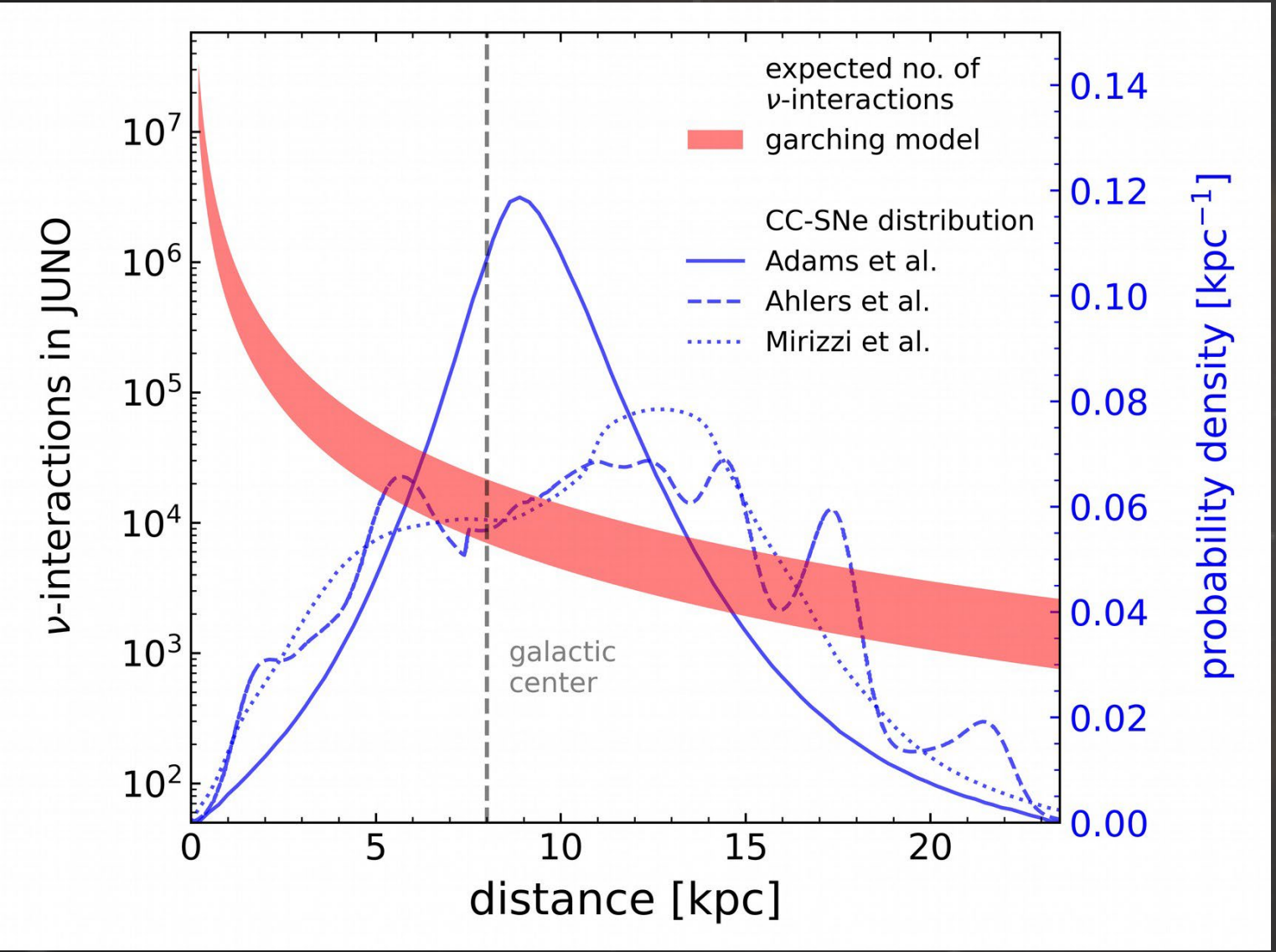
Charged Current 100 ev.

$\nu_e + {}^{12}C \rightarrow e^- + {}^{12}\mathrm{N}$

Charged Current 100 ev.

$\bar{\nu}_e + {}^{12}C \rightarrow e^+ + {}^{12}\mathrm{B}$

Event Rates



galactic center:

$\sim 10^4$ events in 10 s → okay

close CCSN

rates up to MHz!

issue with transmission rate

- temp. storage near the PMTs
- send only charge/time of pulses

SN Alert System

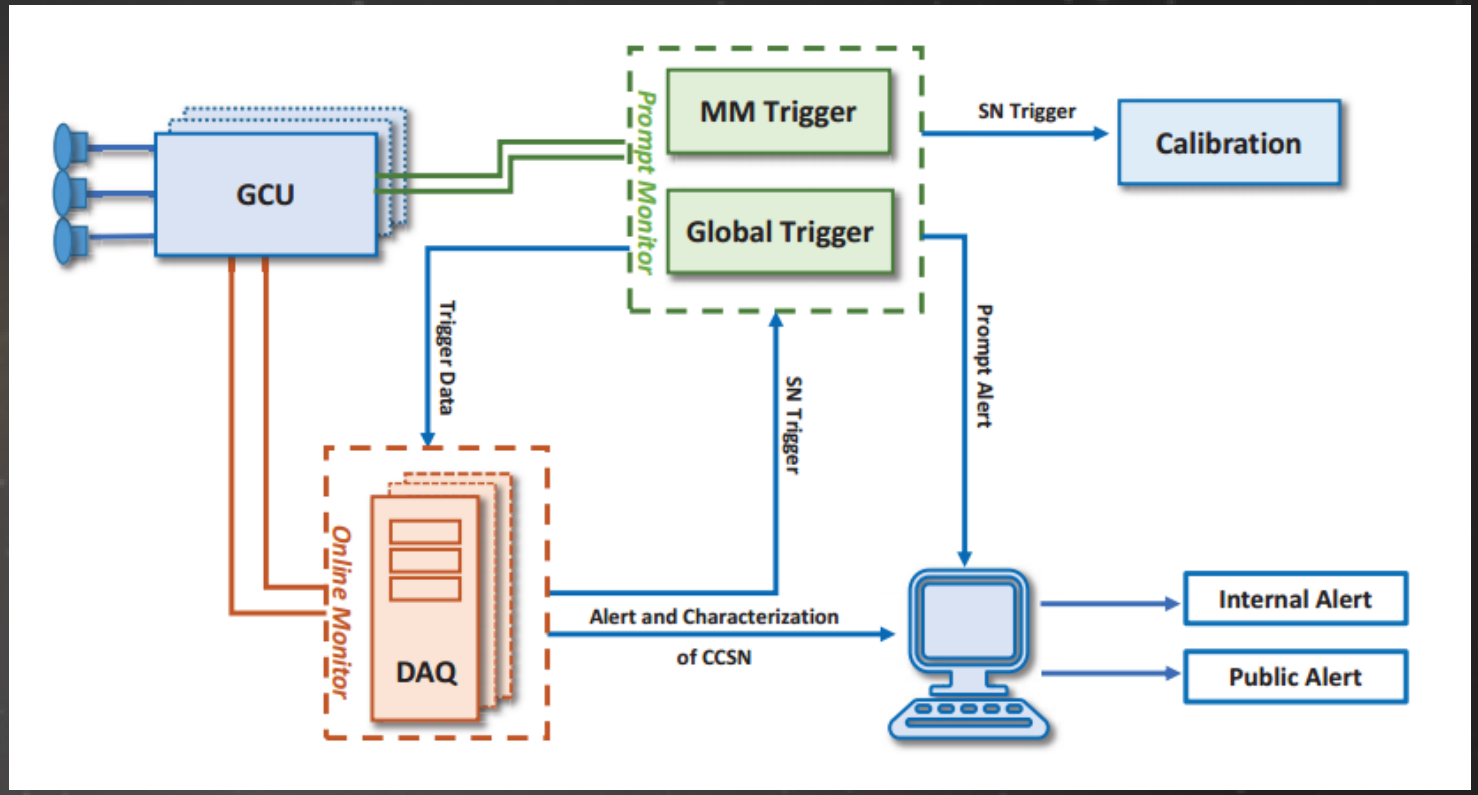
- monitor trigger/event rates
- scan for sudden increases of rates

Prompt (trigger) monitor

- global trigger
- multimessenger trigger

Online (DAQ) monitor

- fast reconstruction of events



global trigger: low threshold (200 keV), low background, full readout of waveforms

multimessenger trigger: even lower threshold (20 keV), more background, limited readout (charge & time of pulses)

CCSN Alerts: Prompt Monitor

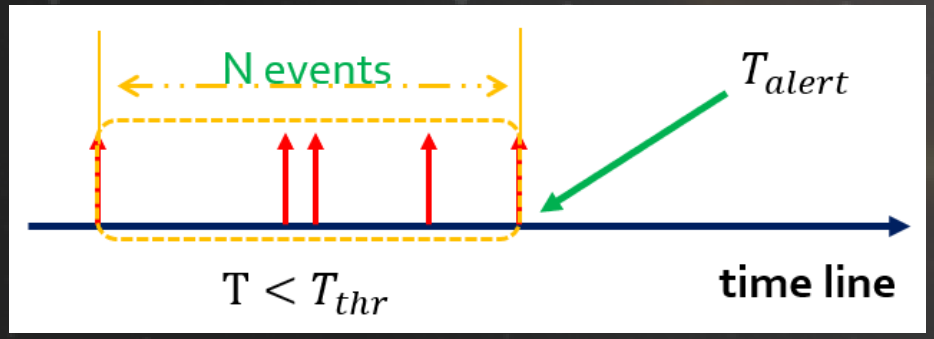
Online monitor from global trigger

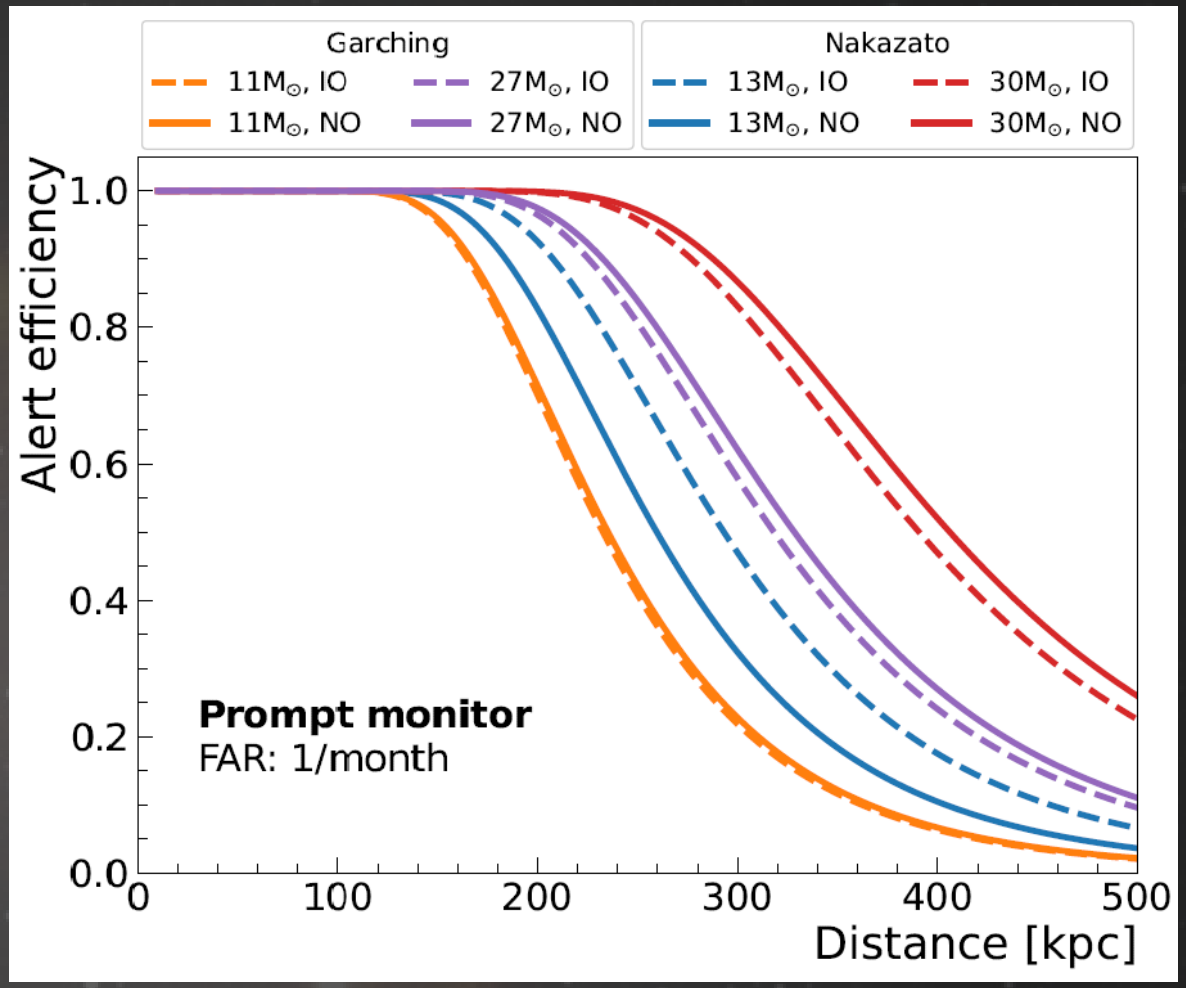
Select events 8 … 40 MeV

(based on # fired PMTs)

Muon-Veto

Monitor the rate





Alert time: 10 … 30 ms @ 10 kpc

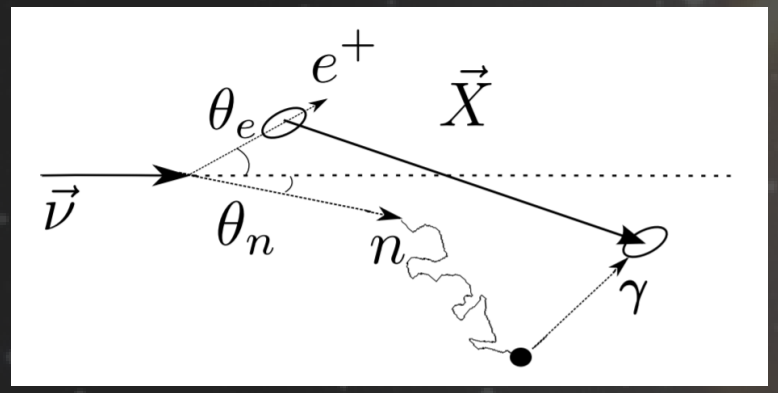
CCSN Pointing

IBD events

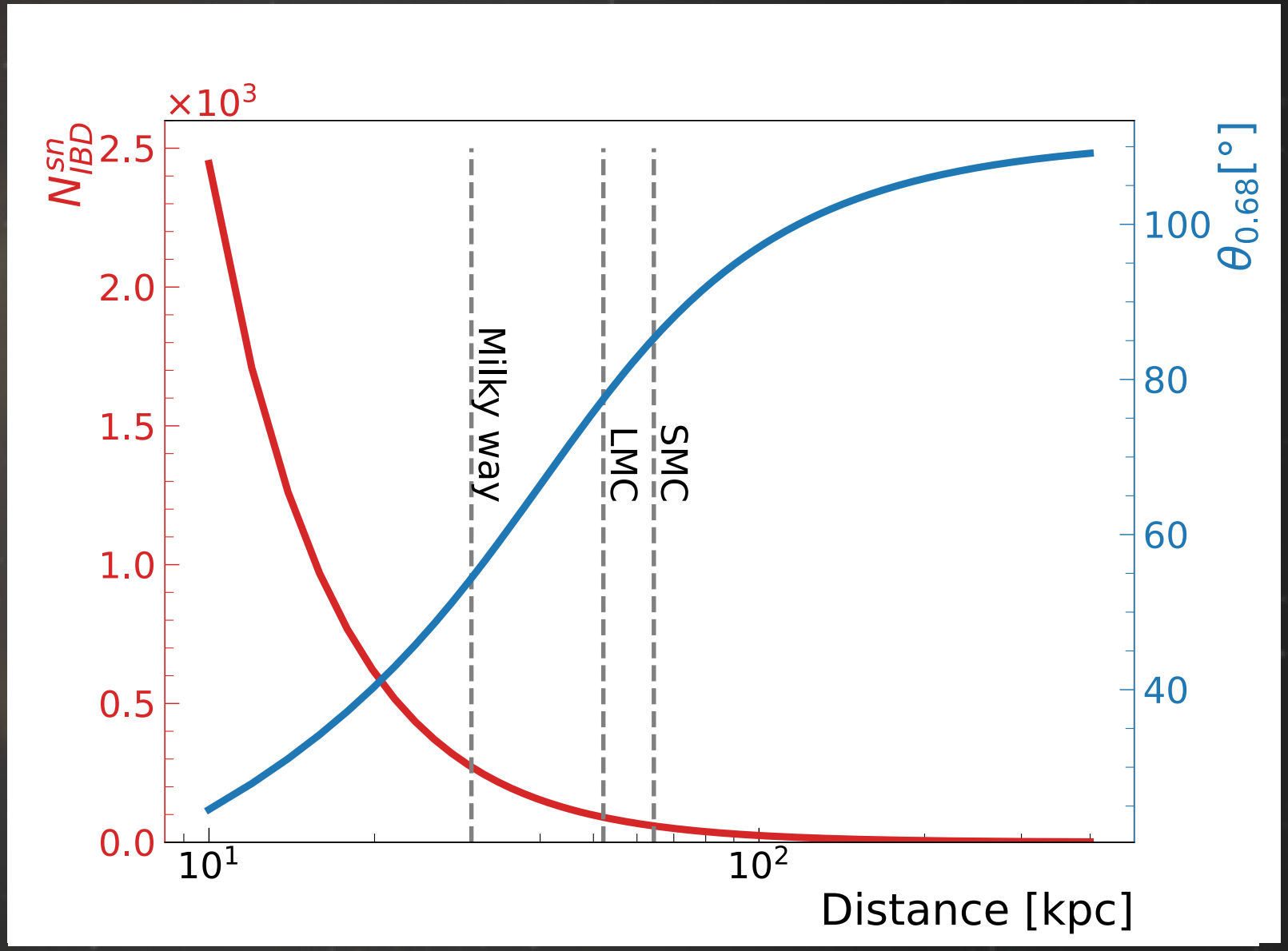
$(\bar{\nu}_e + p \rightarrow e^+ + n)$

displacement of

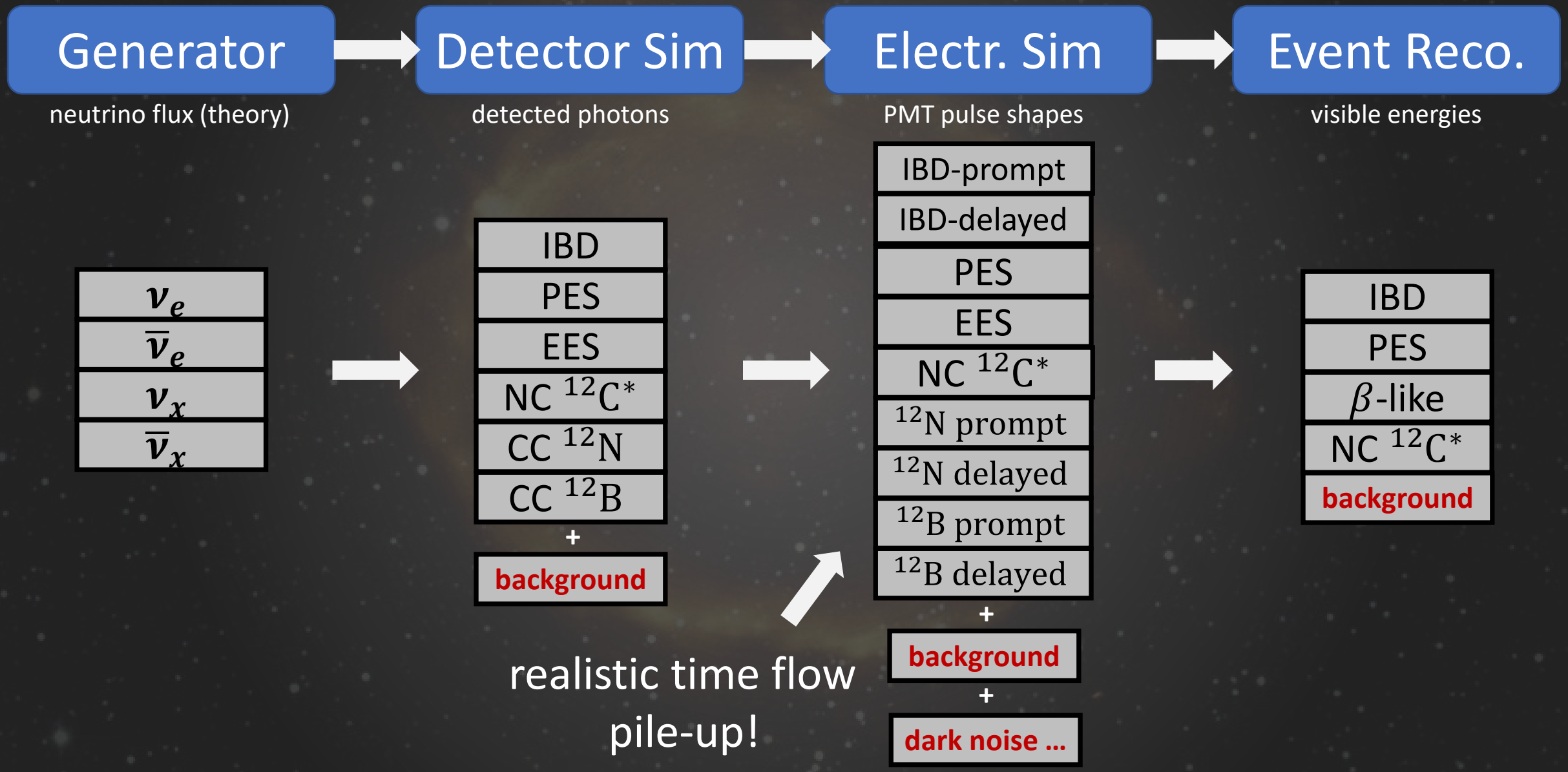
prompt – delayed events



$$\vec{d}_\nu = \frac{1}{N}\sum_i \vec{X}_i$$

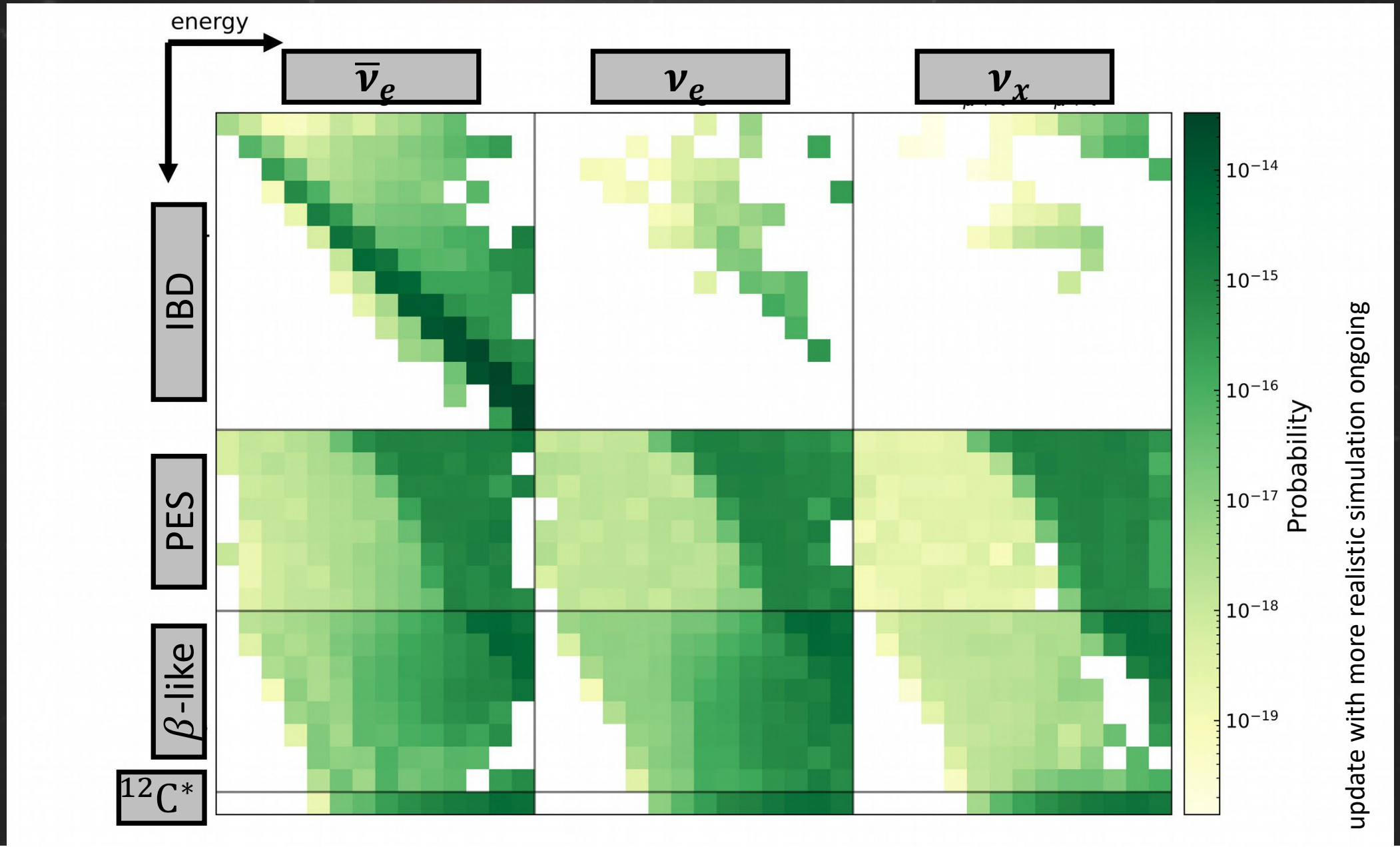


Monte Carlos Simulation



Unfolding: energy & flavour

Phys. Rev. D 99, 123009 (2019)



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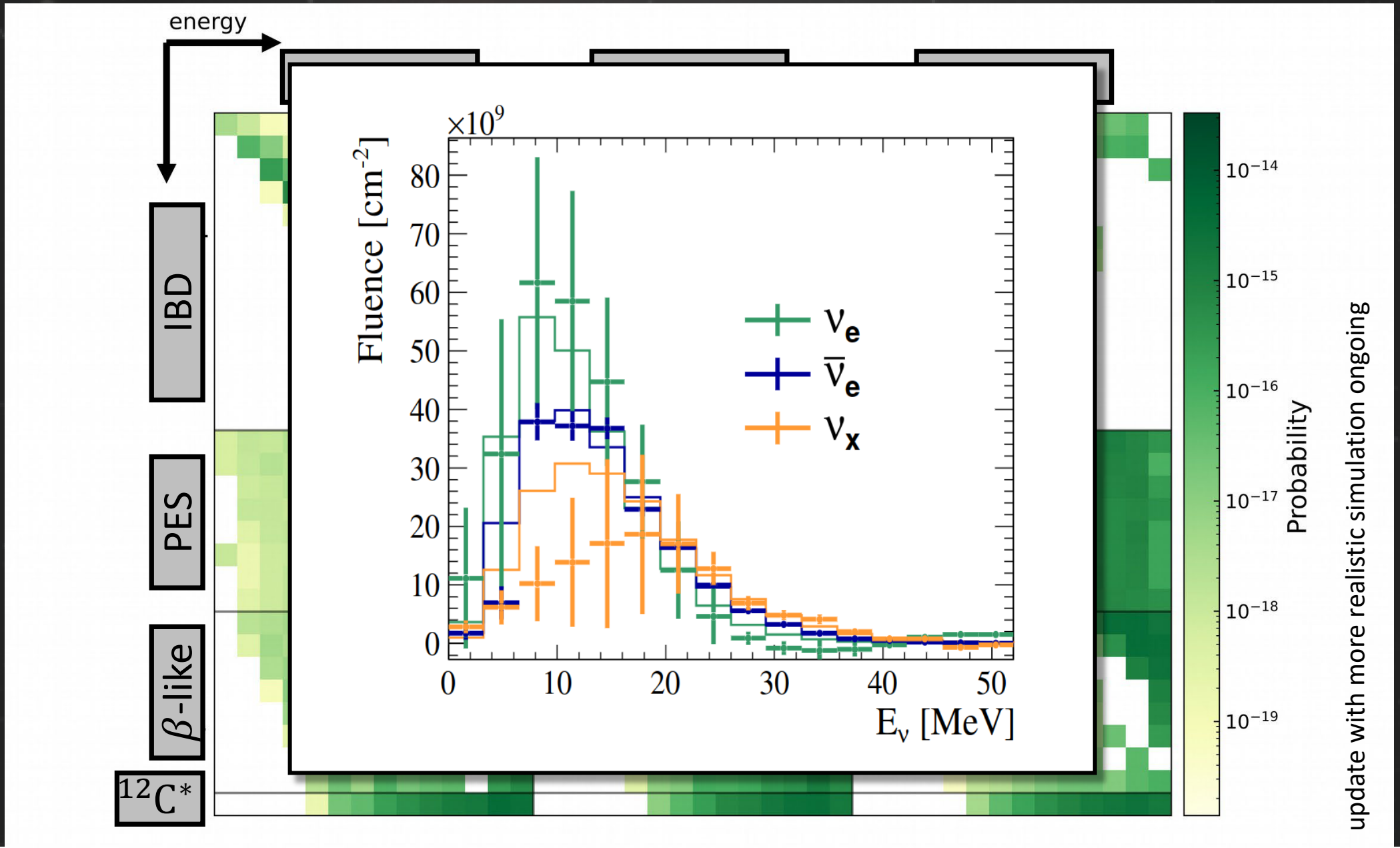

Diffuse SN Neutrino Background

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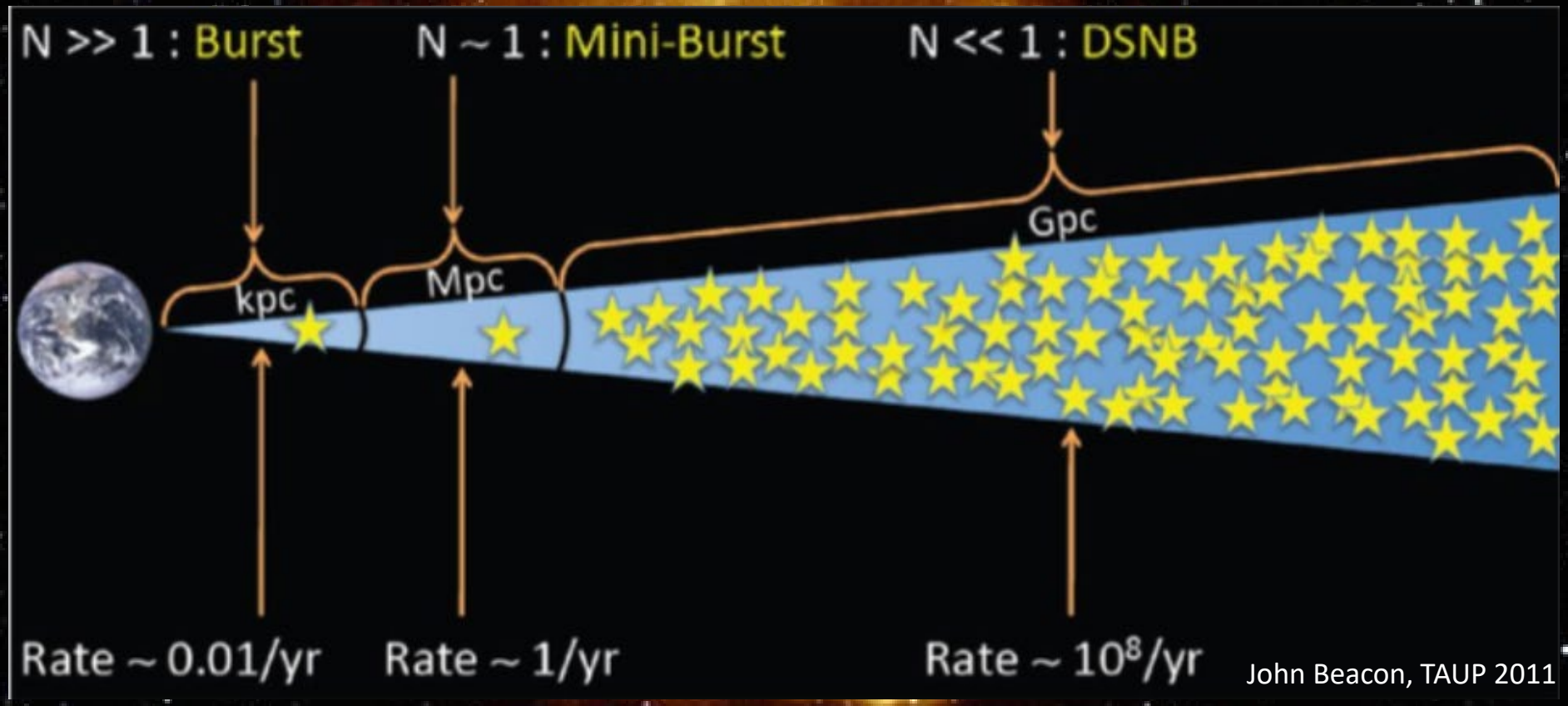


John Beacon, TAUP 2011

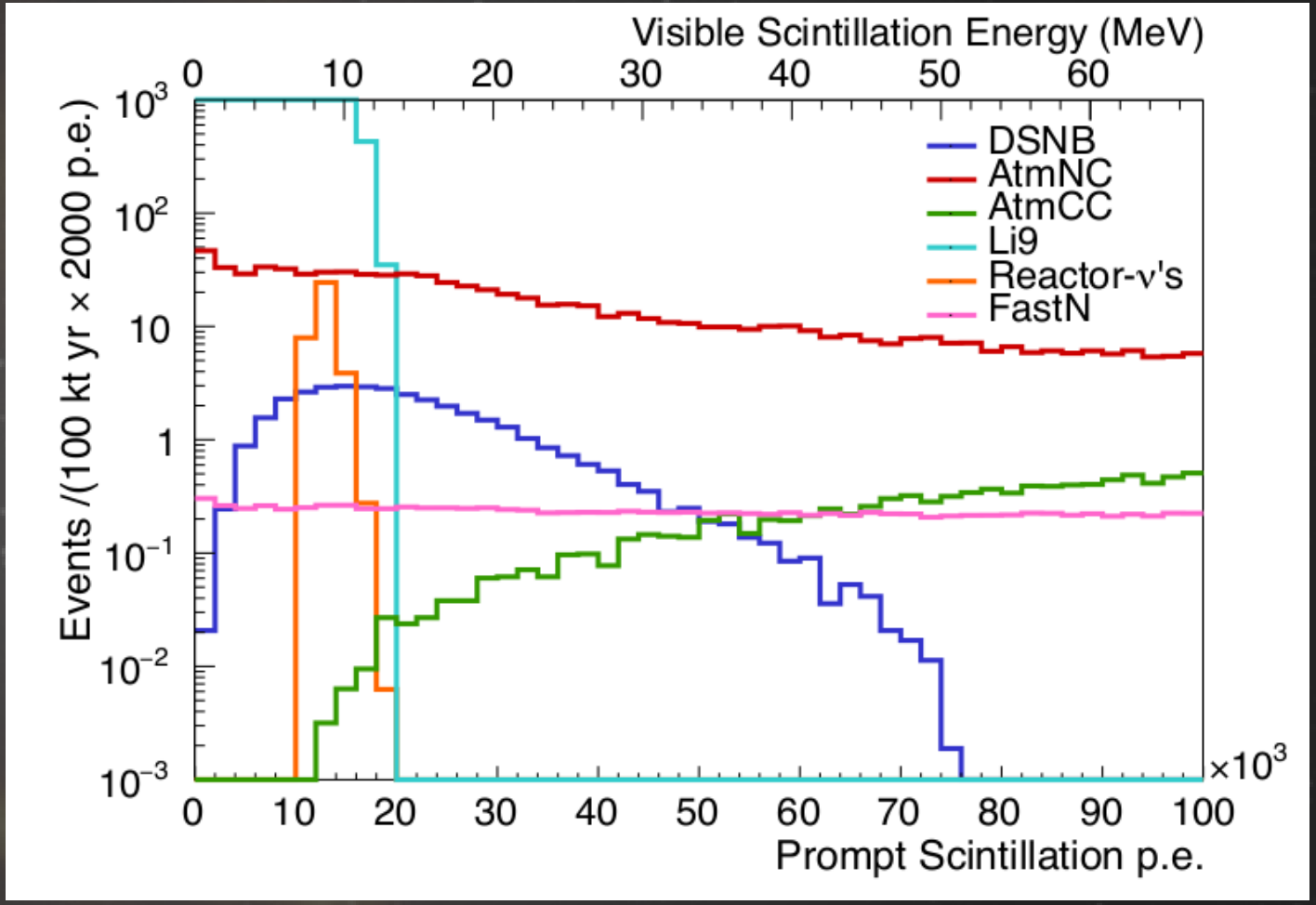
The Challenge

JCAP 10 (2022) 033

main background

- NC-atmospheric
  i.e. $\nu_x + {}^{12}\mathrm{C} \rightarrow \nu_x + n + {}^{11}\mathrm{C}$
  pulse shape discrimination
  triple coincidence

IBD events: $\bar{\nu}_e + p \rightarrow e^+ + n$



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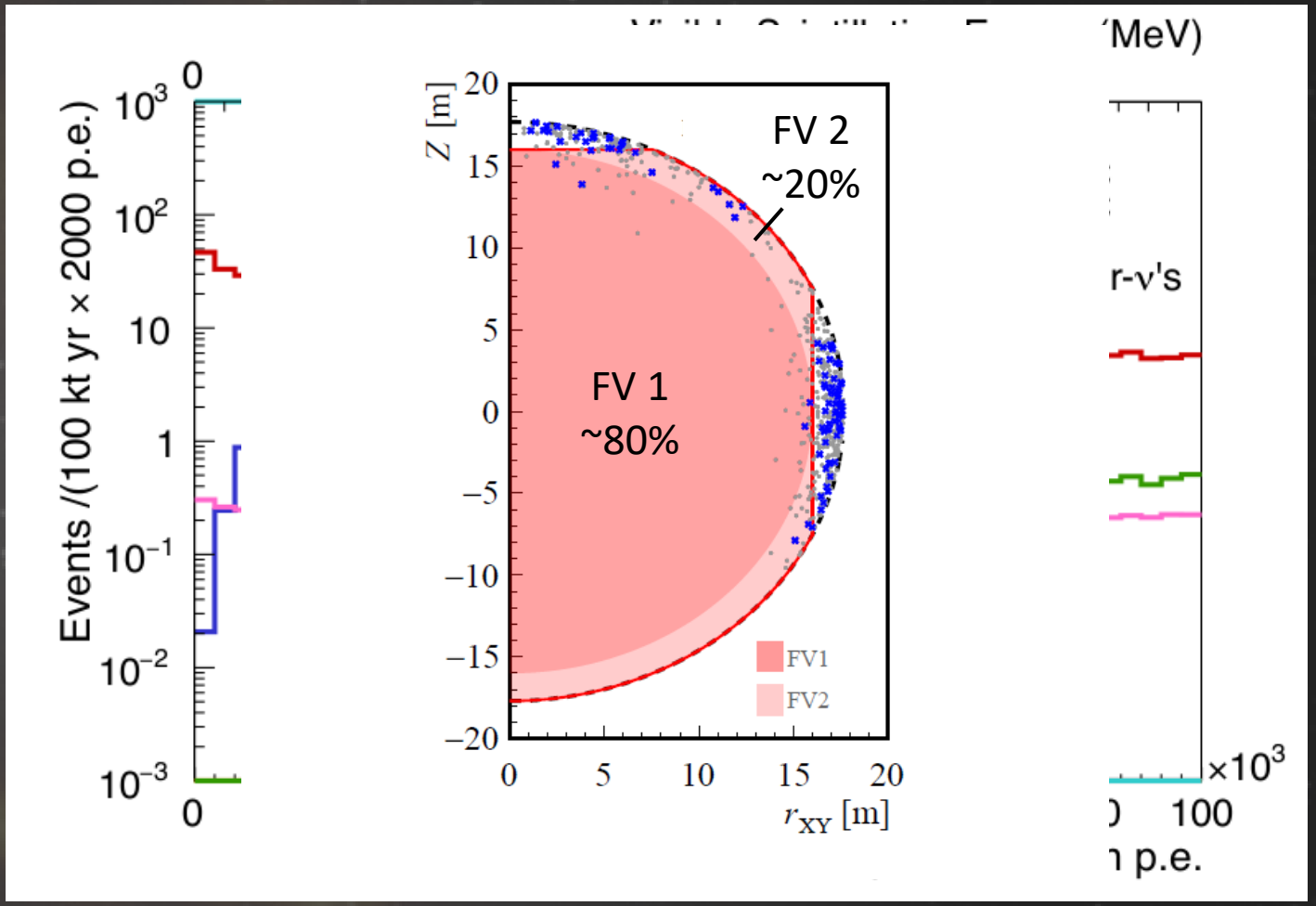

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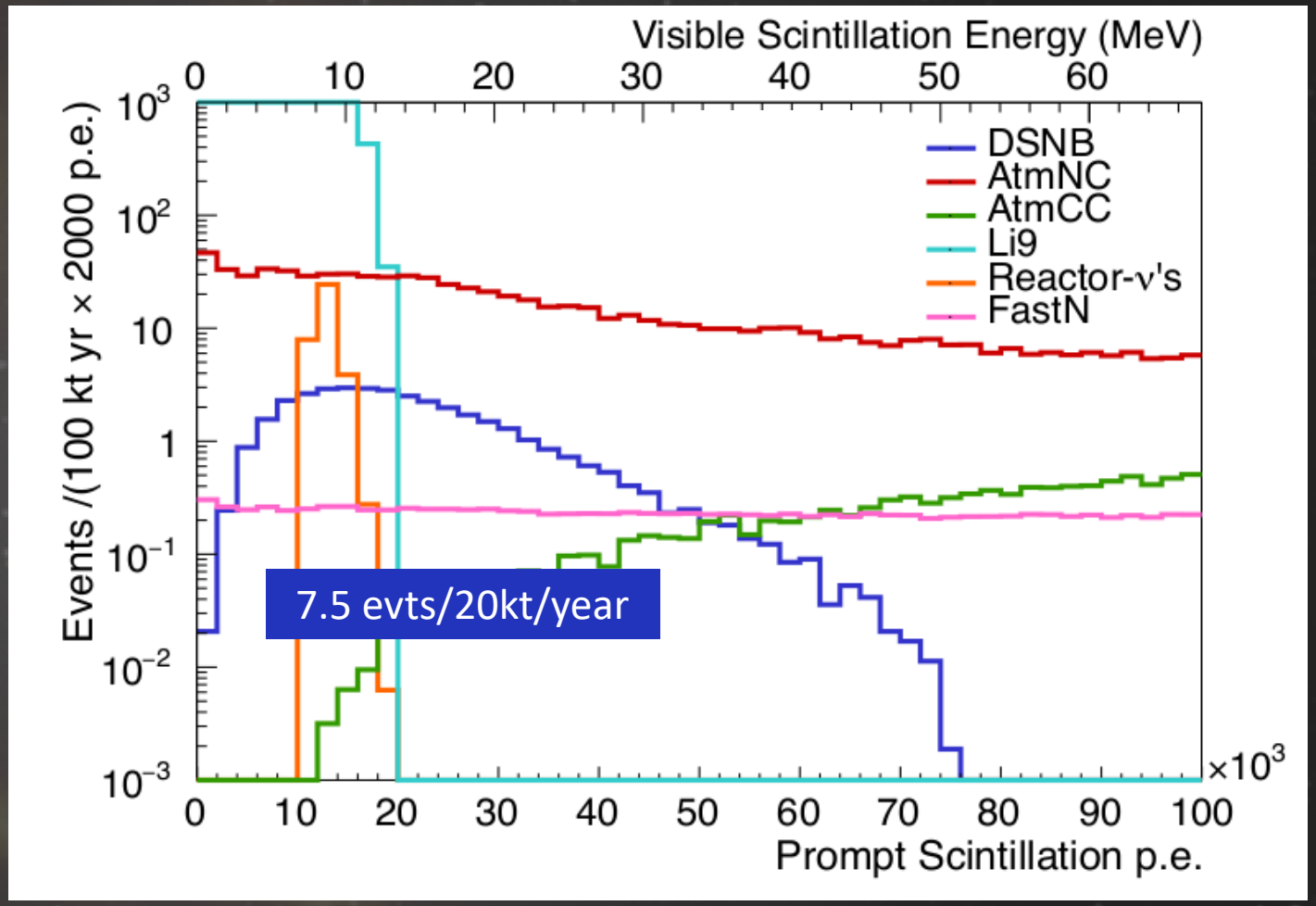
  fiducial volume cut
  energy cut ($E_\nu < 35$ MeV)

other background

- reactor neutrinos
- cosmogenic isotopes (${}^{7}\mathrm{Li}$)
  muon veto & energy cut
  ($E_\nu > 12$ MeV)

IBD events: $\bar{\nu}_e + p \rightarrow e^+ + n$



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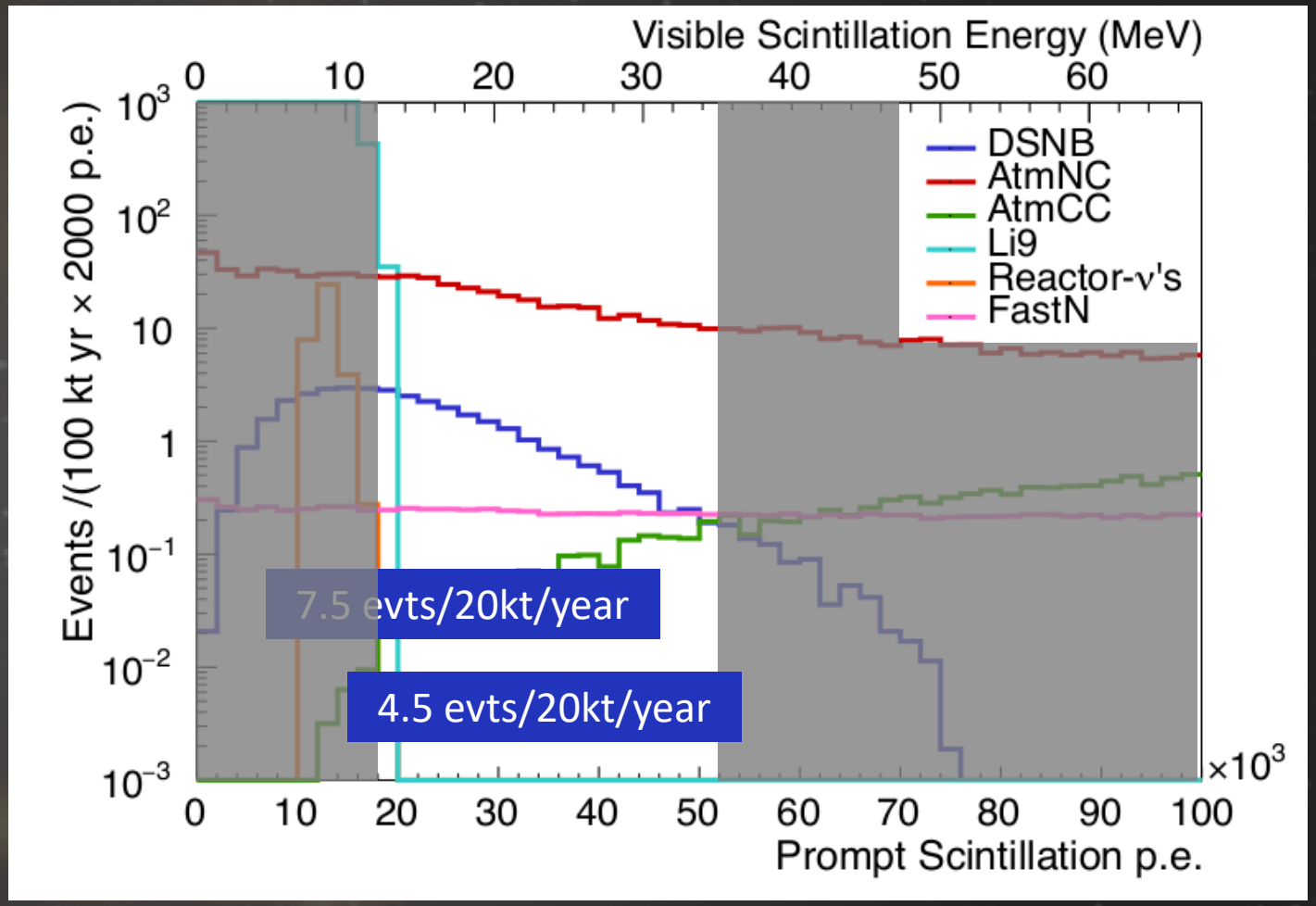
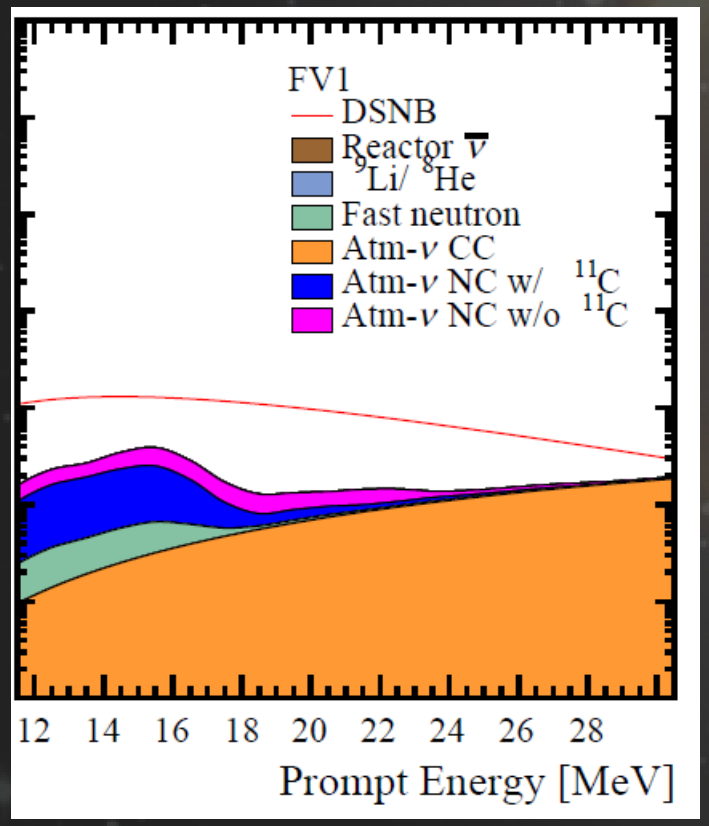
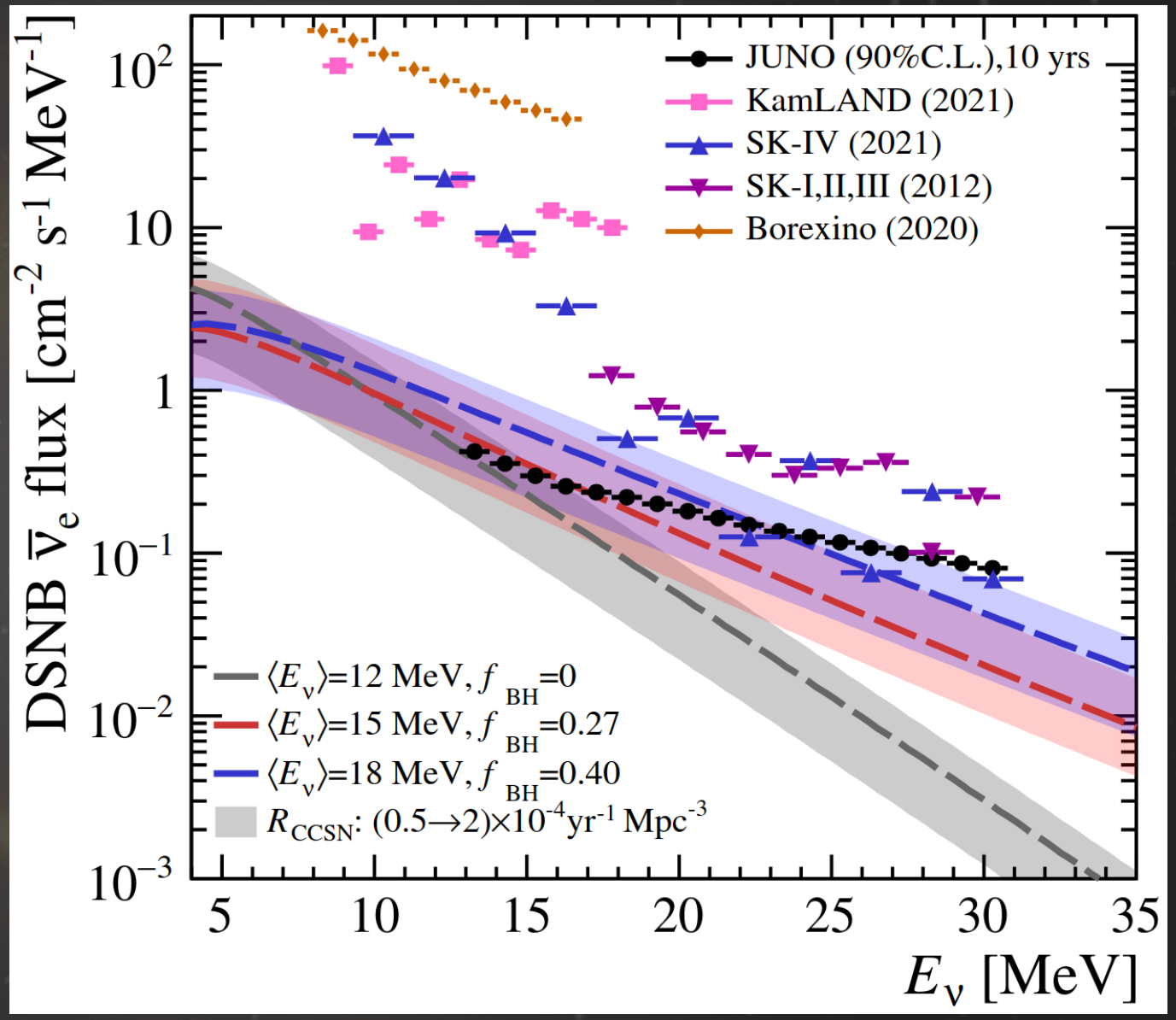
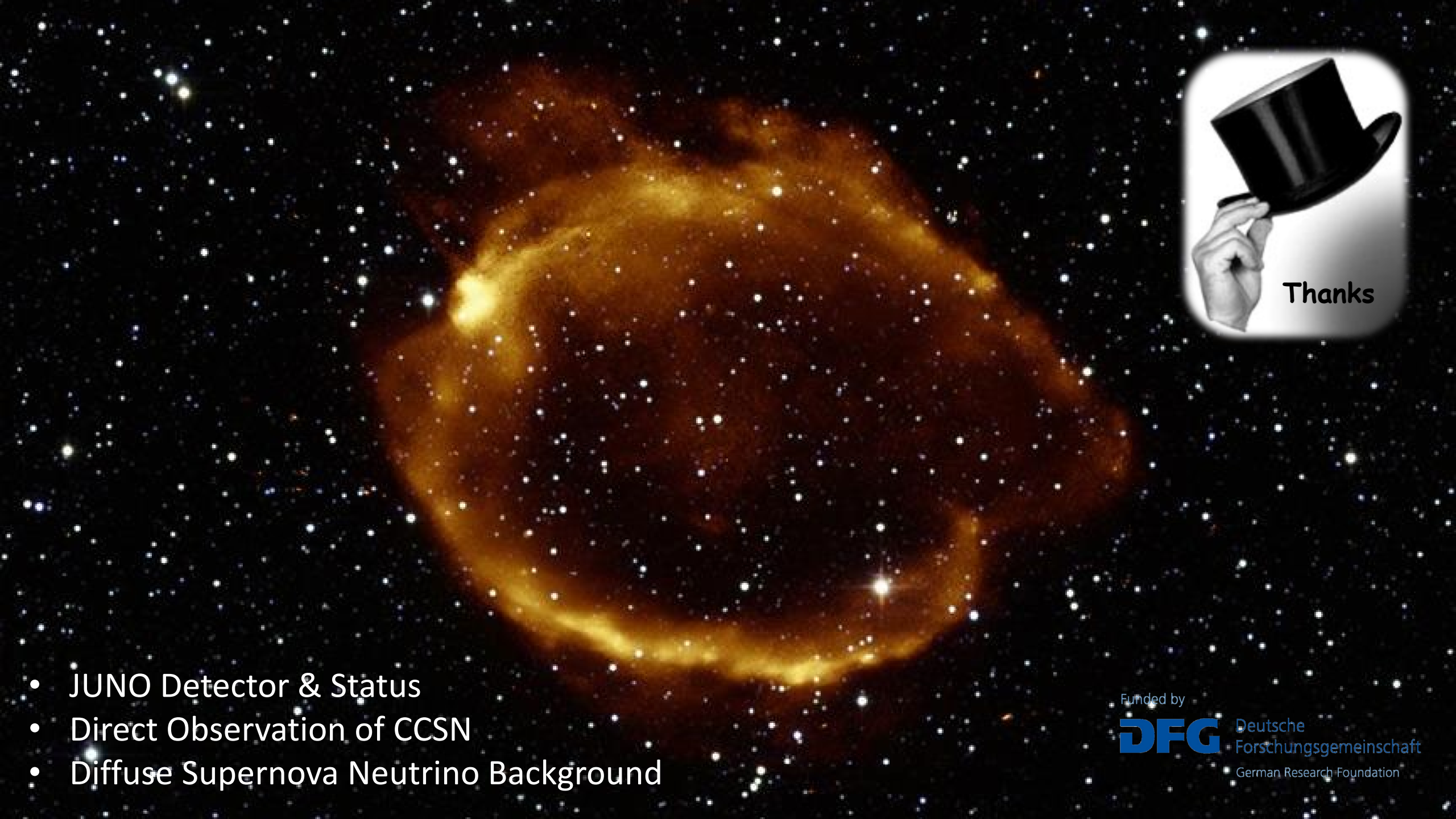


The Expectation

signal: 4 … 7 evts/year
efficiency ~ 75%
background ~ 5 evts/year







- JUNO Detector & Status
- Direct Observation of CCSN
- Diffuse Supernova Neutrino Background

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DFG Deutsche Forschungsgemeinschaft
German Research Foundation