Detecting extragalactic SNe @ South Pole

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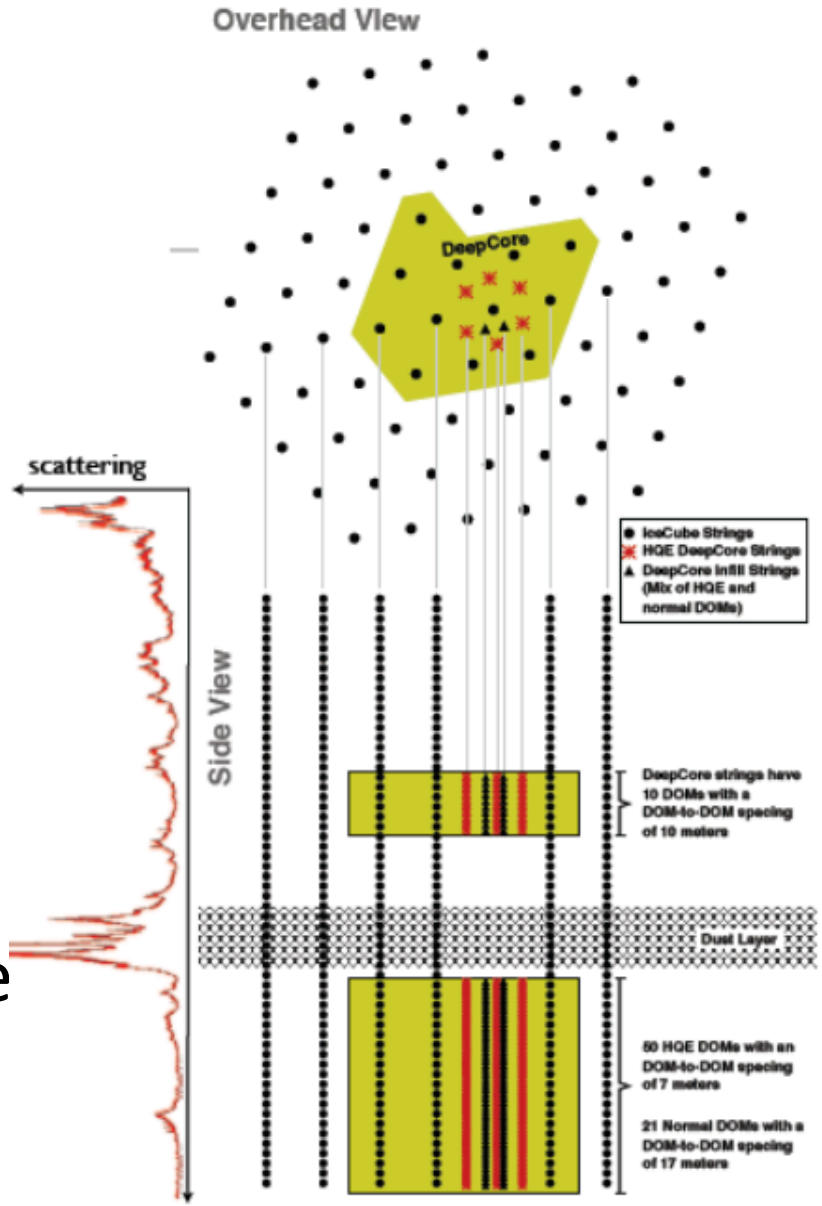
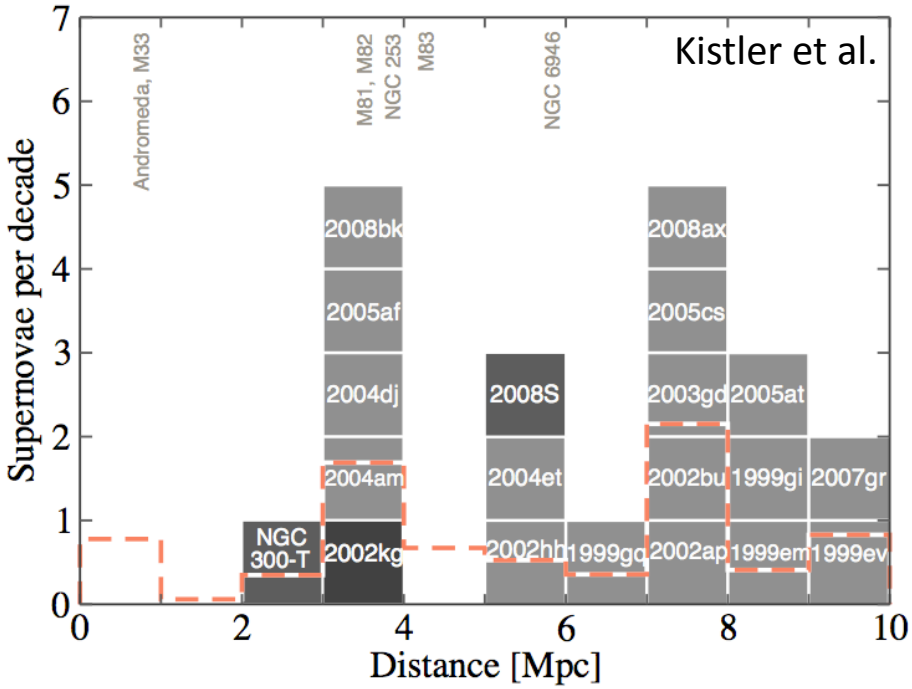
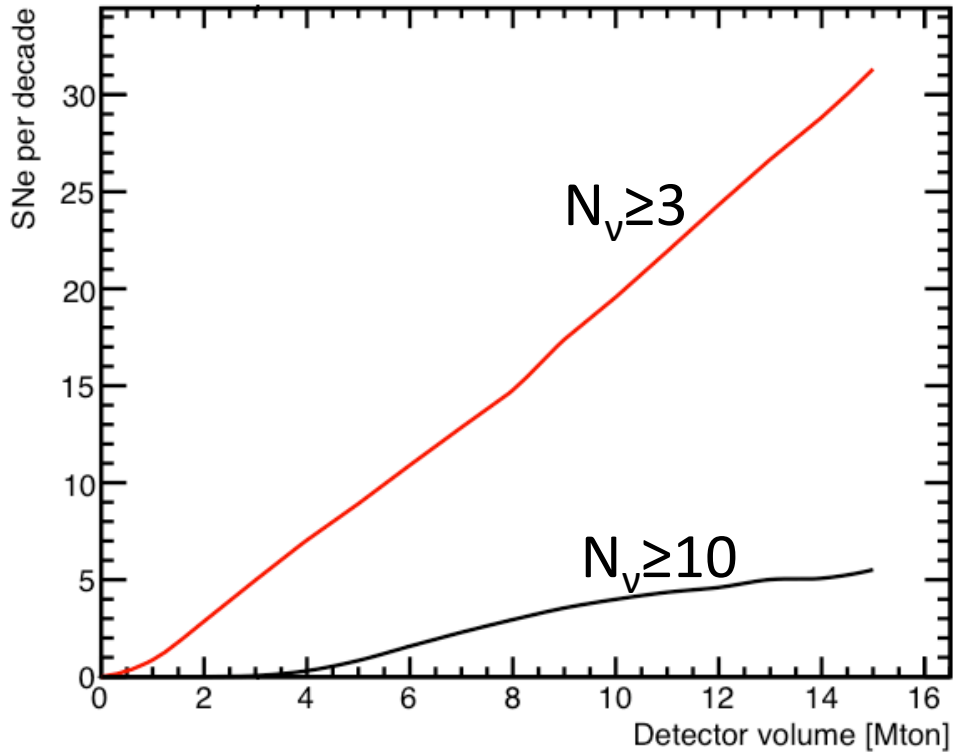
Why South Pole

- IceCube „lab“ has been completed – significant (positive) experience with deployment & operation
- Very clear, pure & stable detection medium
- Cost-effective option for Megaton instrumented volume with 10 MeV threshold



Detecting nearby supernovae





Generic neutrino prediciton
(scaling from SN1987A)

10 Mton ⇒ ≥ 2 SNe/yr!

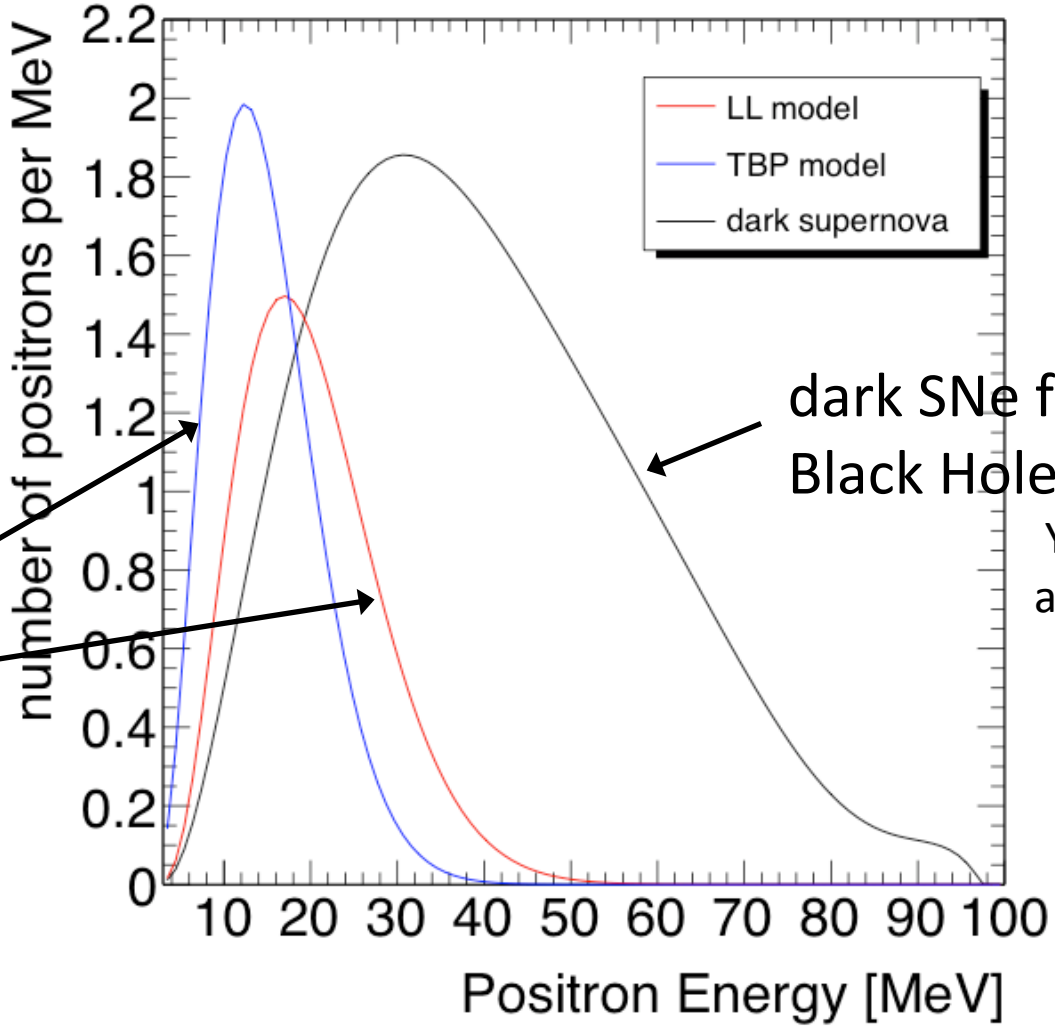
SN Science with neutrinos

- Directly probe of core collapse, e.g. black hole vs neutron star
- Rate of SNe (e.g. no dust obscuration)
- Neutrino-mass hierarchy & QCD phase transition.
- Early triggers for follow-up to catch very early phase.
- Gravitational detectors: Coincident search ~3000 times more significant.

...

SN 1987A

Gravitational Collapse: Black Hole vs Neutron Star



NS formation:
TBP-Model
LL-Model

dark SNe from
Black Hole formation

Yang, Lunardi,
arXiv:1103.4628v1

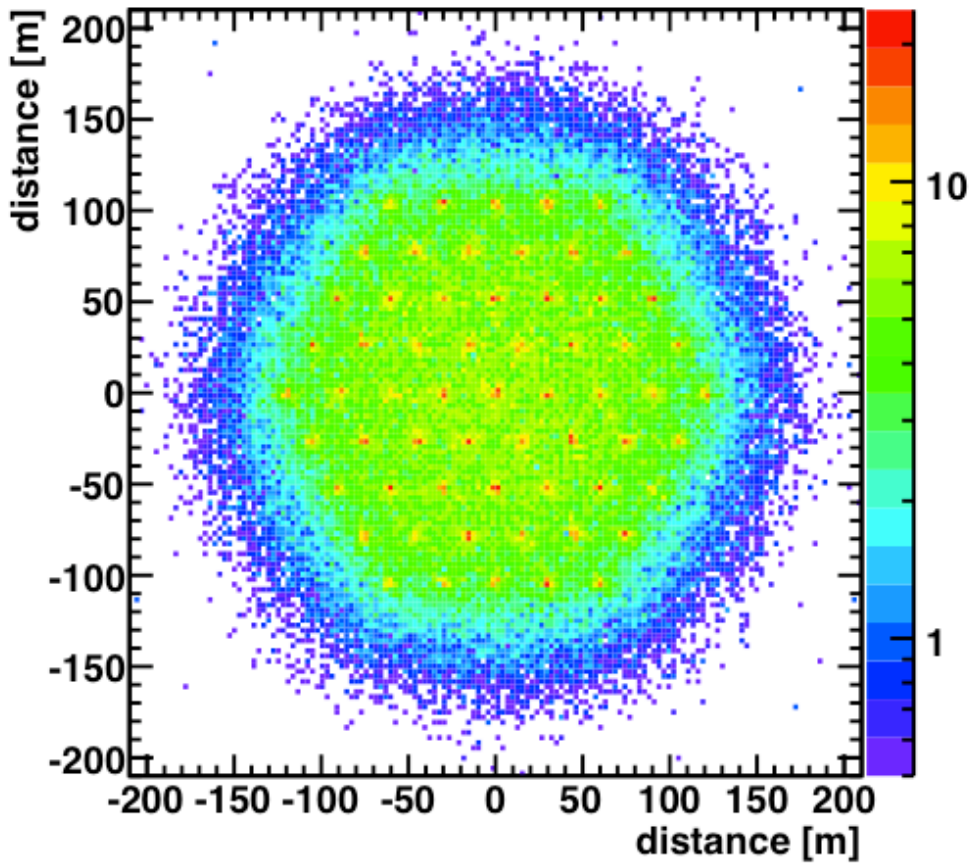
Detector consideration

3000 photons for 15 MeV neutrino

⇒ very dense instrumentation needed

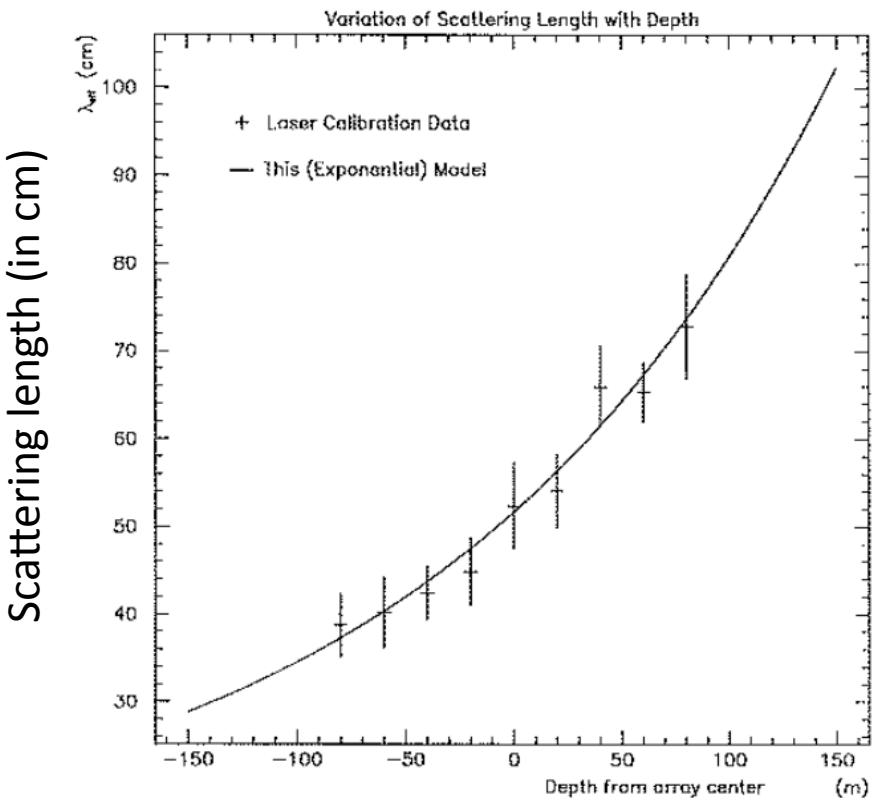
Simulation using IceCube softare:

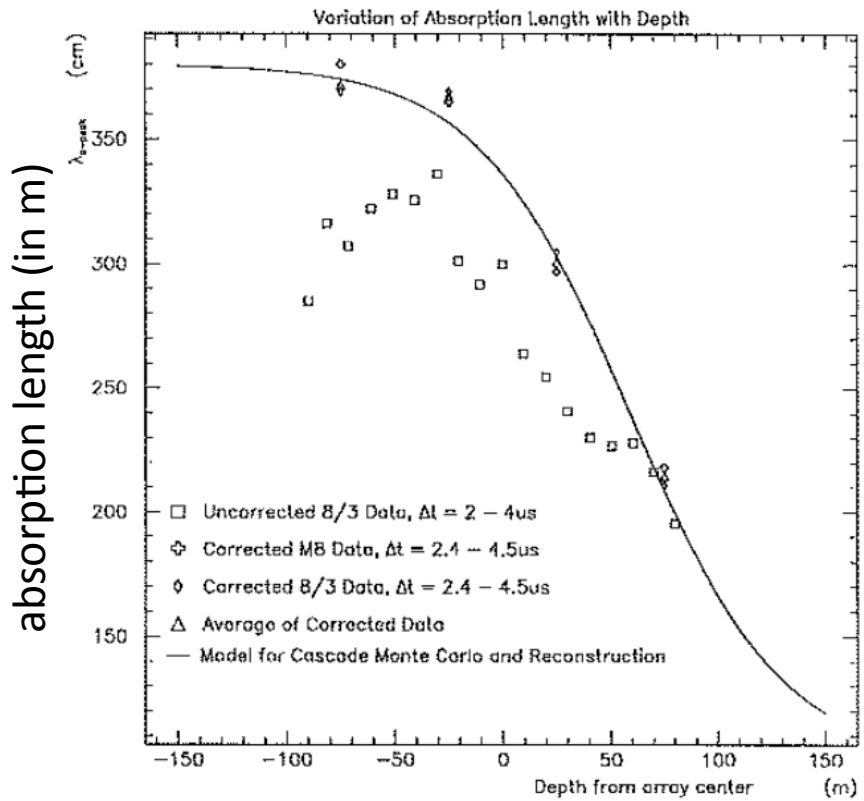
- 2200 – 2500 m depth
- 61 strings
- variable string spacing
- Variable number of sensors (23000 – 91000 HQE 10‘‘ PMTs)
- ν-events: $N_{hits} \geq 5$



Shallow ice?

- In the early nineties, 4 AMANDA (A) strings where deployed between 800-1000 m





R. Perrata, PhD thesis

Depth

Depth

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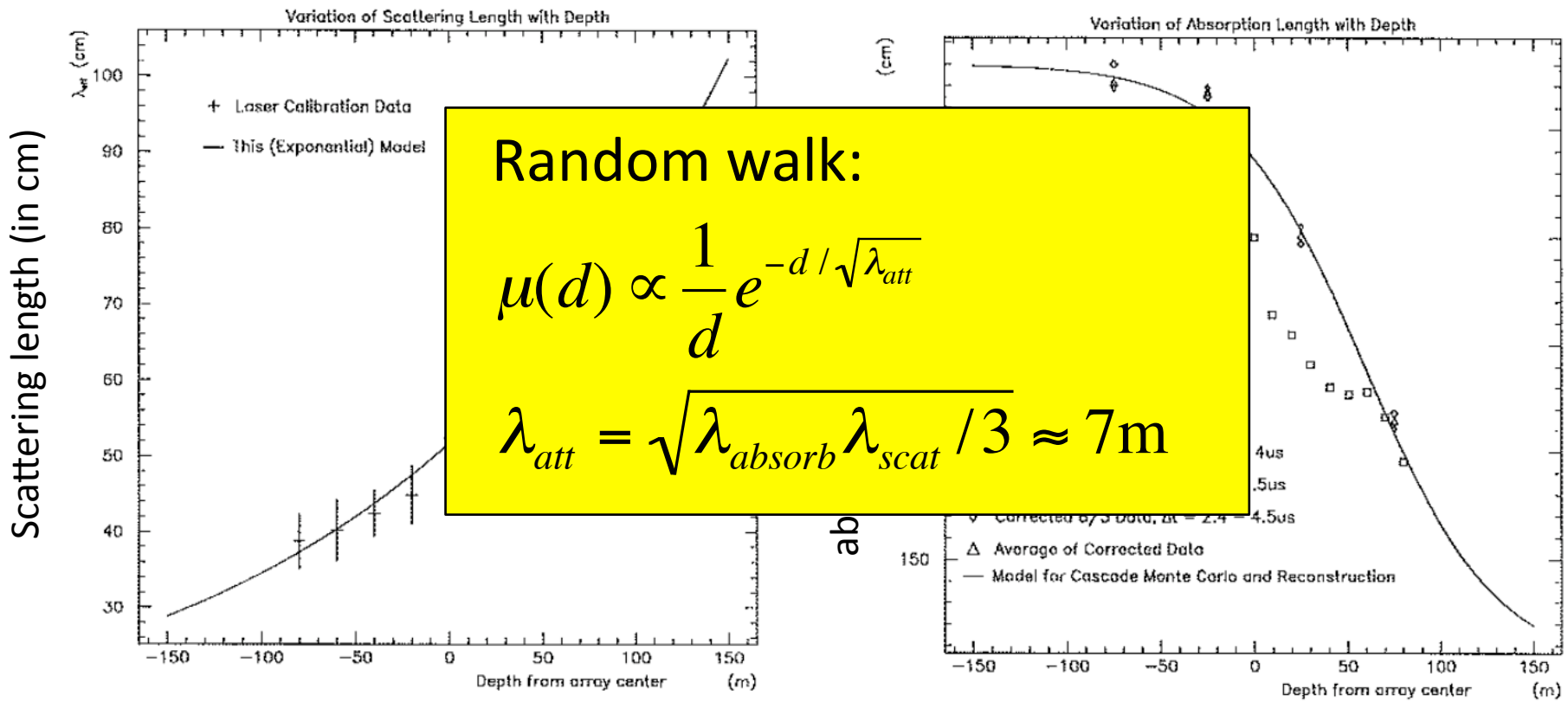


Random walk:

$$\mu(d) \propto \frac{1}{d} e^{-d/\sqrt{\lambda_{att}}}$$

$$\lambda_{att} = \sqrt{\lambda_{absorb}\lambda_{scat}/3} \approx 7\mathrm{m}$$

Scattering length (in cm)

R. Perrata, PhD thesis

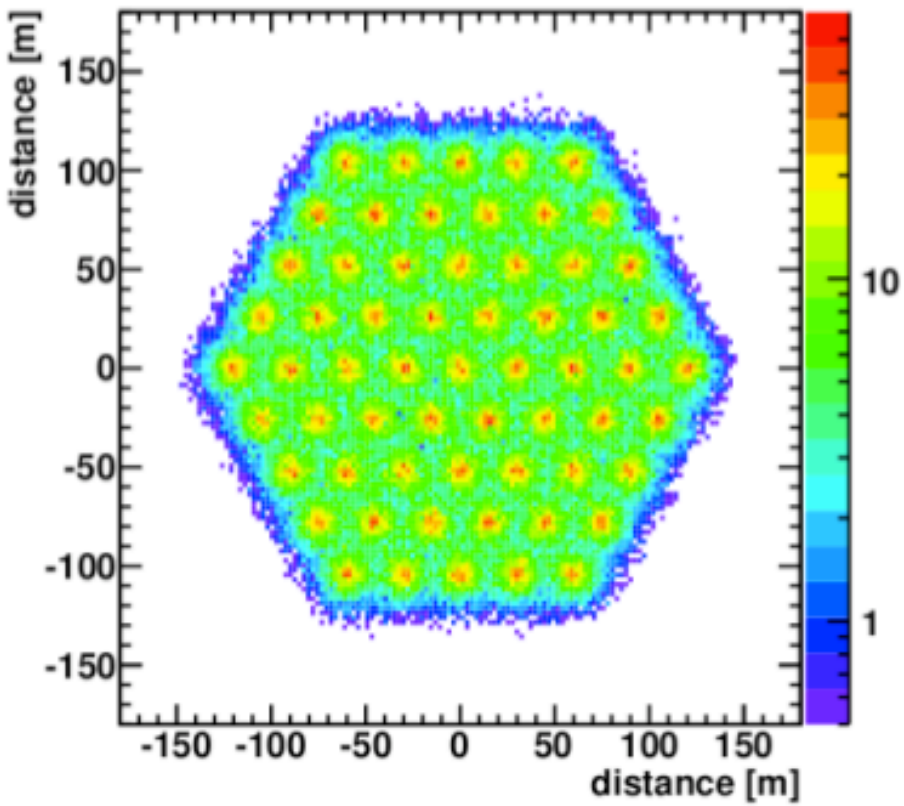
Depth

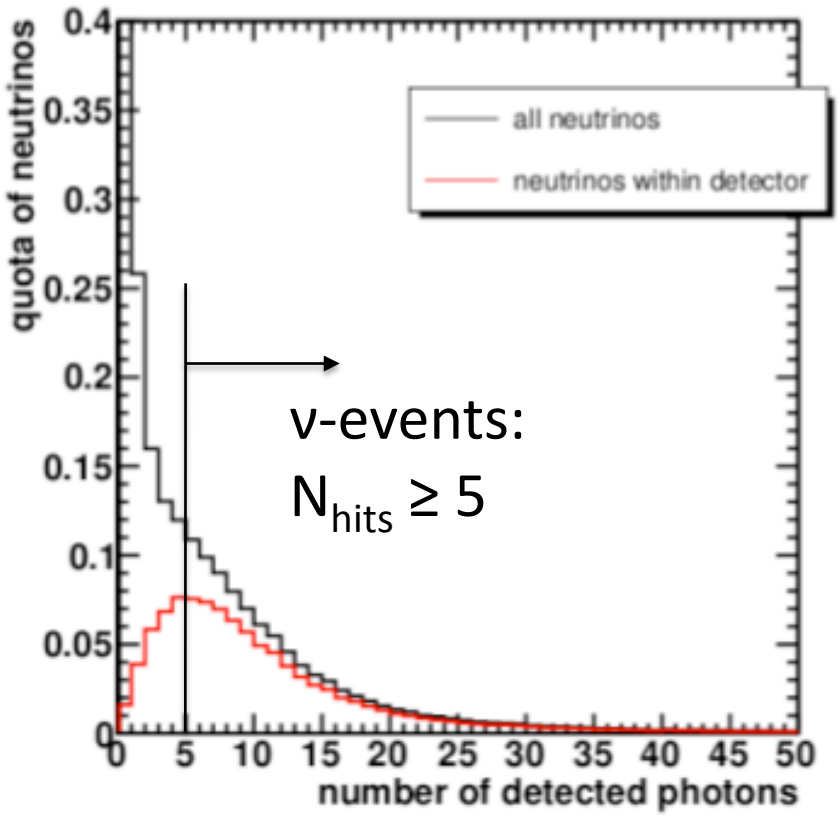
Depth

Detector simulation (shallow ice)

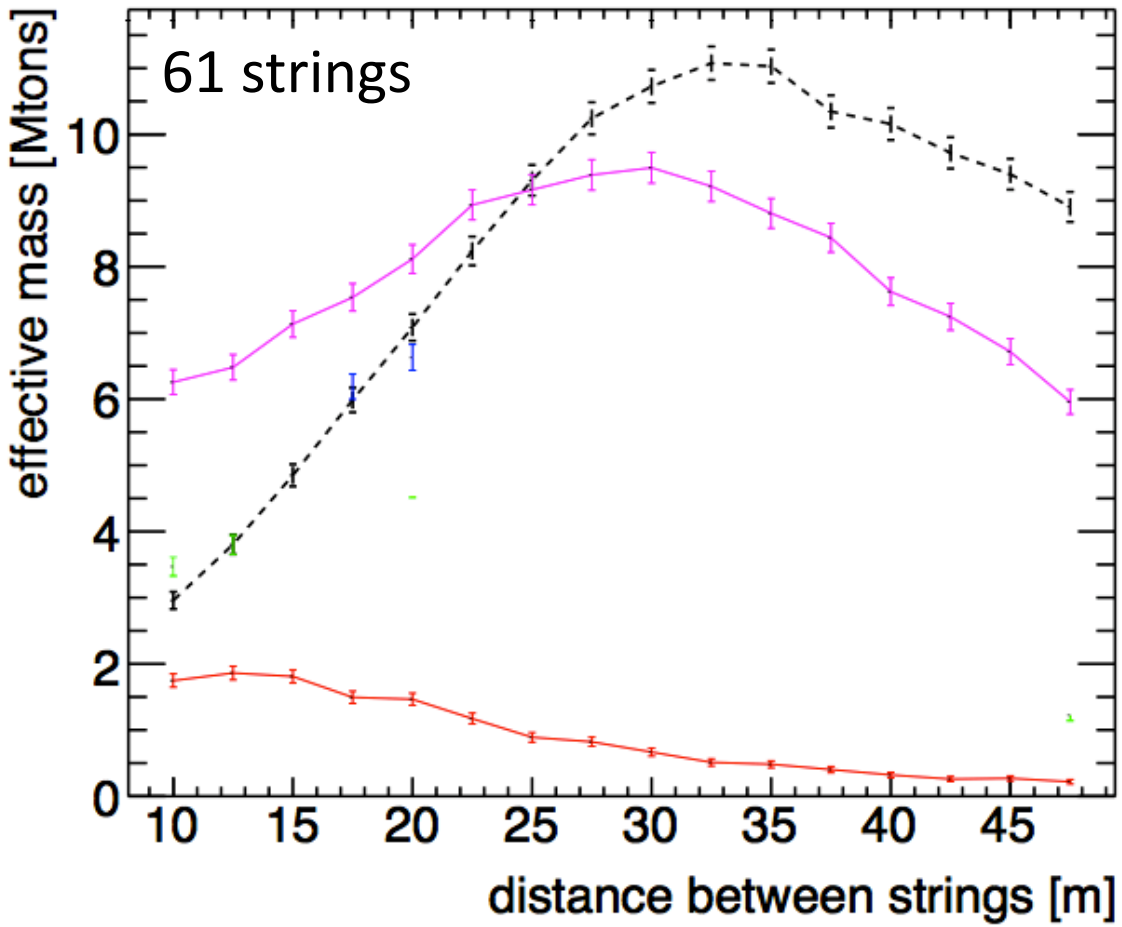
Special simulation:

- 61 strings
- 300 m long strings
- 23000 10‘‘ HQE-PMTs





Effective volume for SN neutrinos as a function of string spacing for $N_{hits} \geq 5$



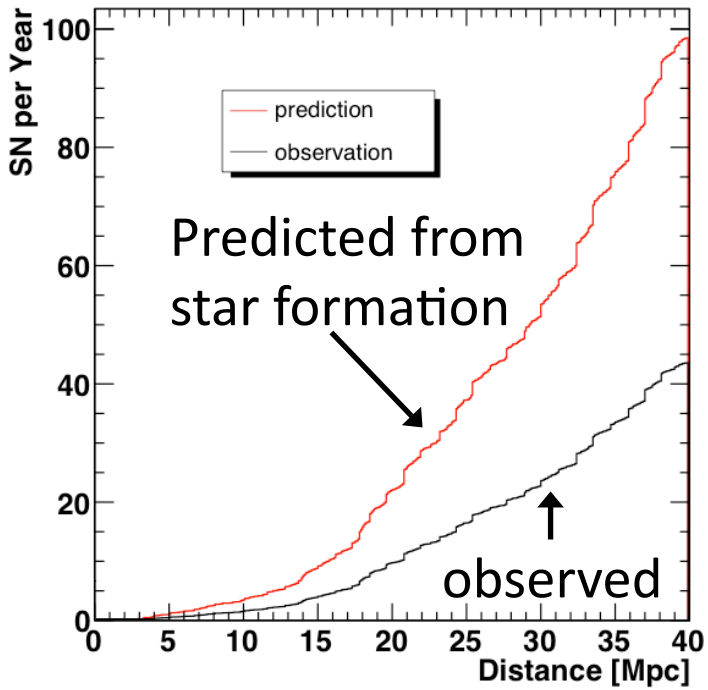
shallow &
22875 sensors

deep &
91500 sensors

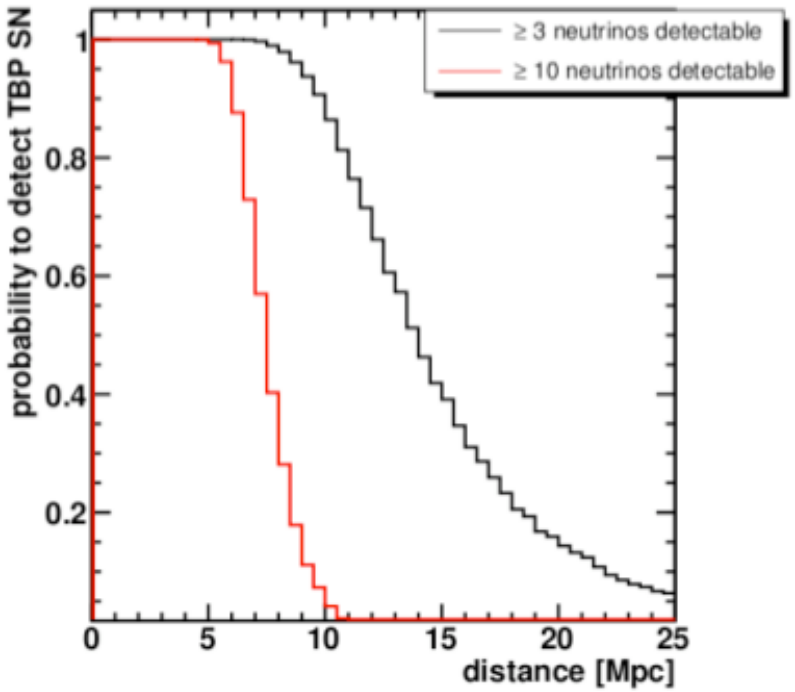
deep &
22875 sensors

Supernova Detection rate

Supernova Rate



Detection probability



SNe detections per year for diffuse ice with $N_\nu \geq 3$ assuming observed SN rate:

Rate based on star formation: ~10 yr^{-1}

	$N_\nu \geq 3$	$N_\nu \geq 10$
TBP model	3.2	0.5
Dark SNe (0.1 of all)	1.4	0.15

PINGU - Phased IceCube Next Generation Upgrade

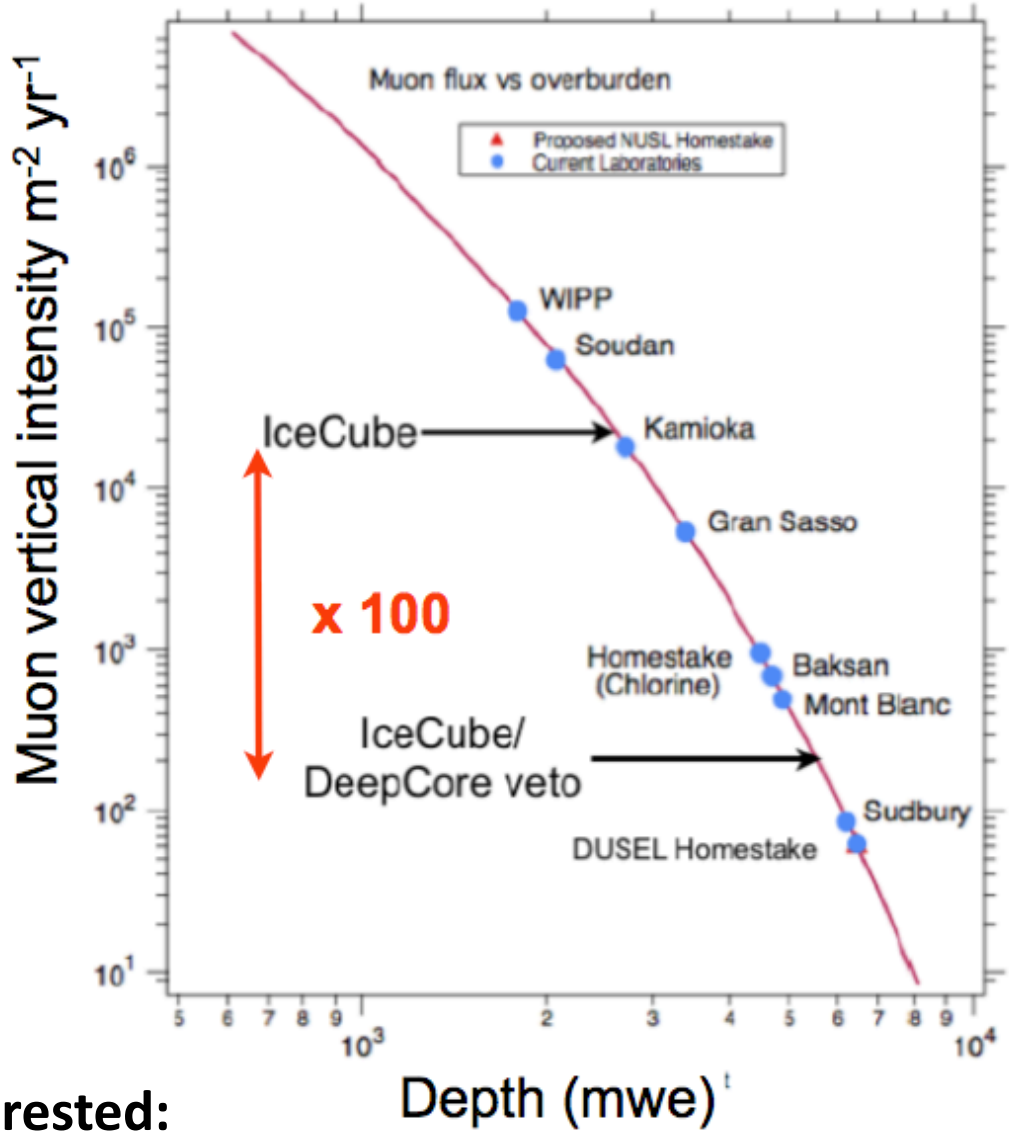
Utilizing existing infrastructure & experience for a large, low energy neutrino-detector

First stage ("PINGU-I")

- ~20 extra strings for E_{thresh}~1 GeV
- WIMP search, ν-oscillation,...
- test bed for new technologies

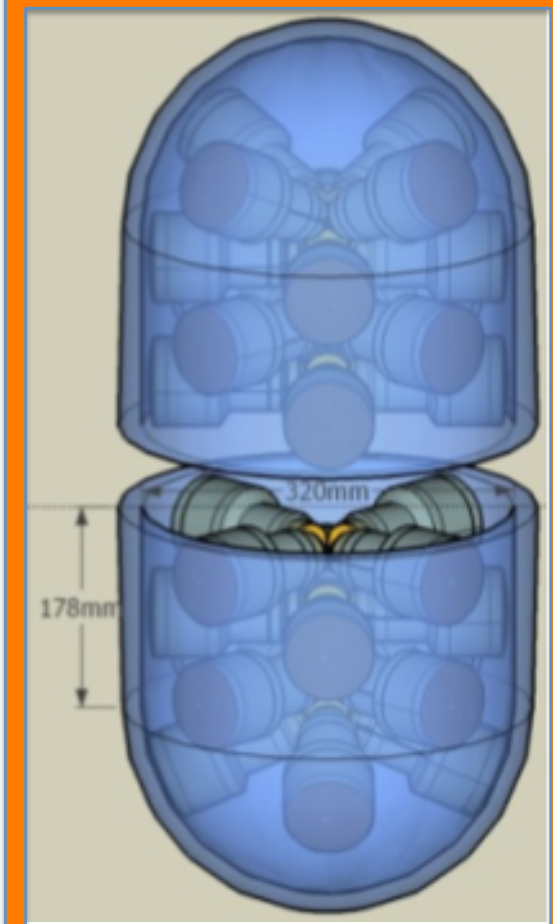
Second stage ("PINGU-II")

- New photon detection technology, E_{thresh}~ 10 MeV
- Costs comparable to IceCube
- supernovae, proton decay,...

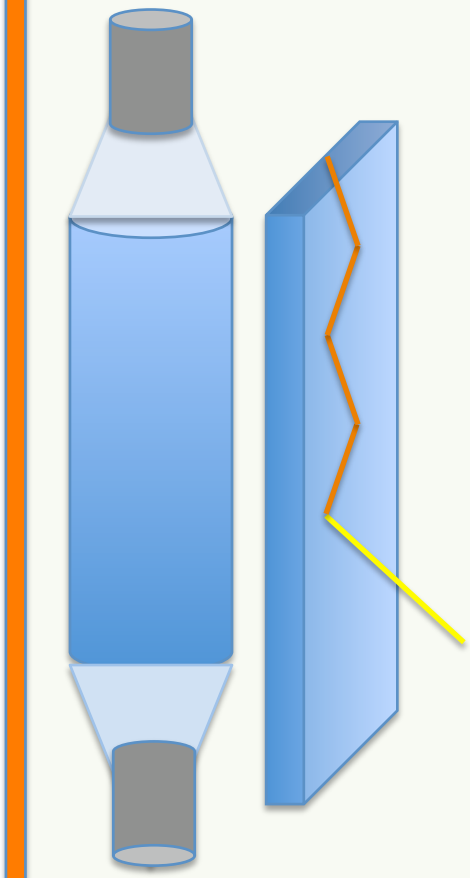


Proto-Collaboration forming, if interested:
http://www.mailman.srv.ualberta.ca/mailman/listinfo/beyonddc

R&D for larger/cheaper photo-sensors

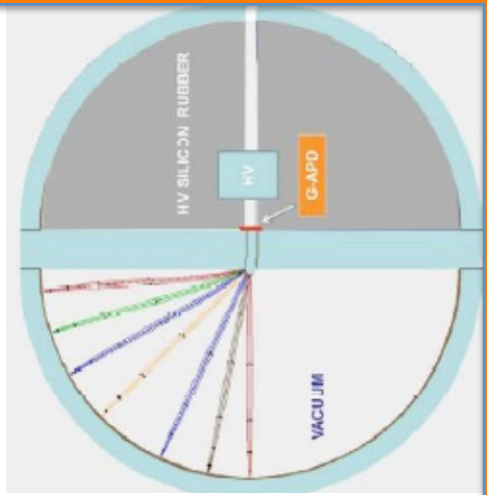


KM3Net-like design
P. Kooijman et al.



WLS as light catchers?

IceCube DOMs



Abalone PMTs,
Ferenec et al.

Conclusion

- IceCube/DeepCore provides a unique „lab“ infrastructure to exploit physics at lower energies
- 8 (10) Mtons for SN neutrinos for 61 deep (shallow) strings with 9 (2) 10^4 IceCube-DOMs
- R&D for larger/cheaper photo sensors ongoing
- 3-10 SNe yr^{-1} → A novel perspective for astronomy and fundamental physics!

PINGU proto-collaboration – if interested sign mailing list:
http://www.mailman.srv.ualberta.ca/mailman/listinfo/beyonddc