Detecting extragalactic SNe @ South Pole

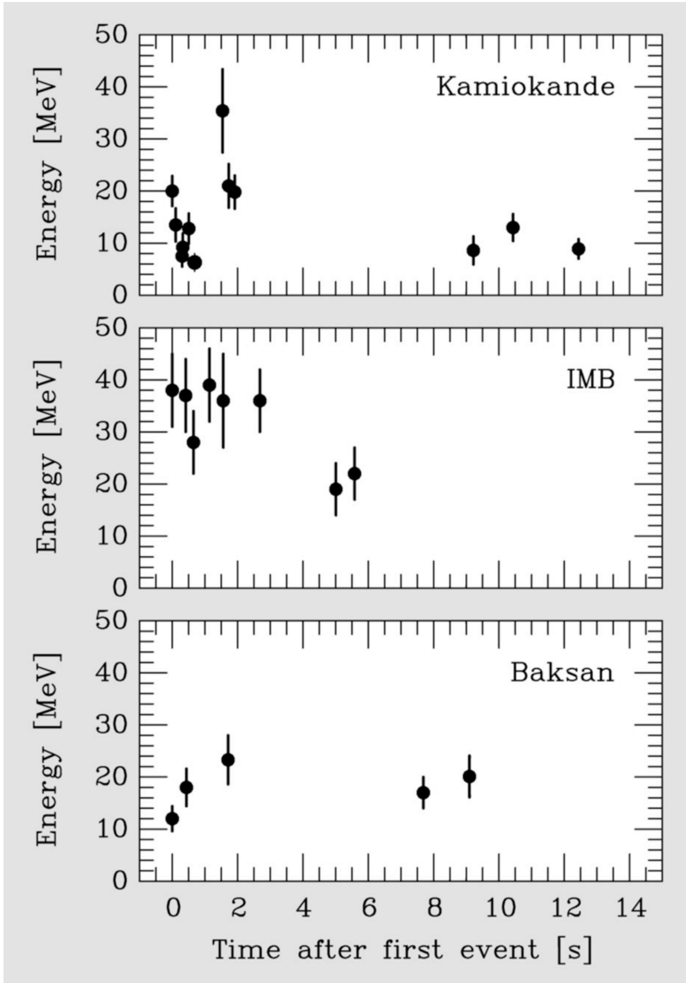
Antactic Science Symposium
27.4.2011

Marek Kowalski, Sebastian Böser,
Nora Linn, Markus Voge

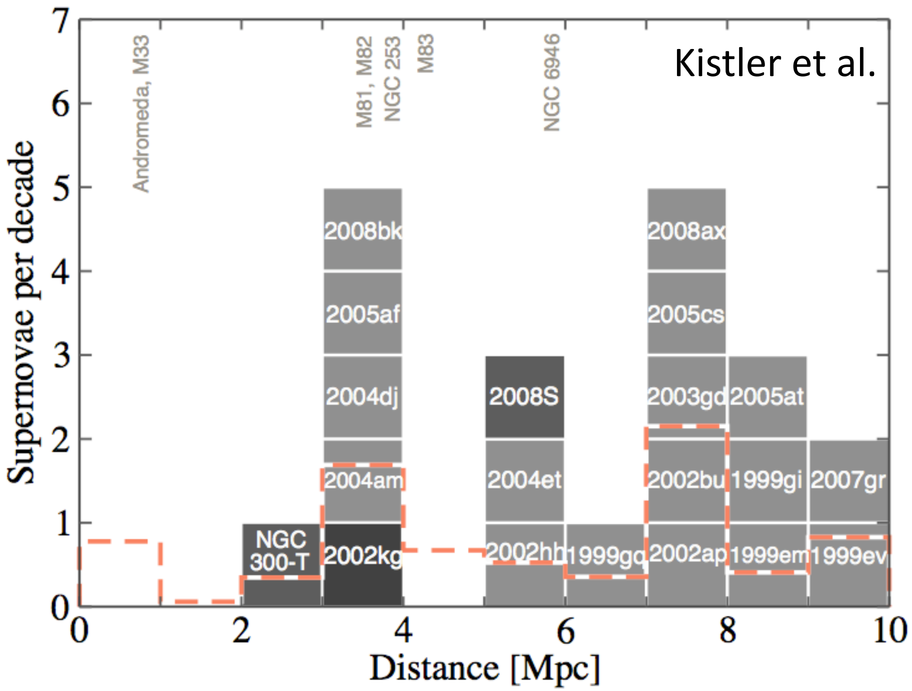
Physikalisches Institut
University Bonn

universitätbonn

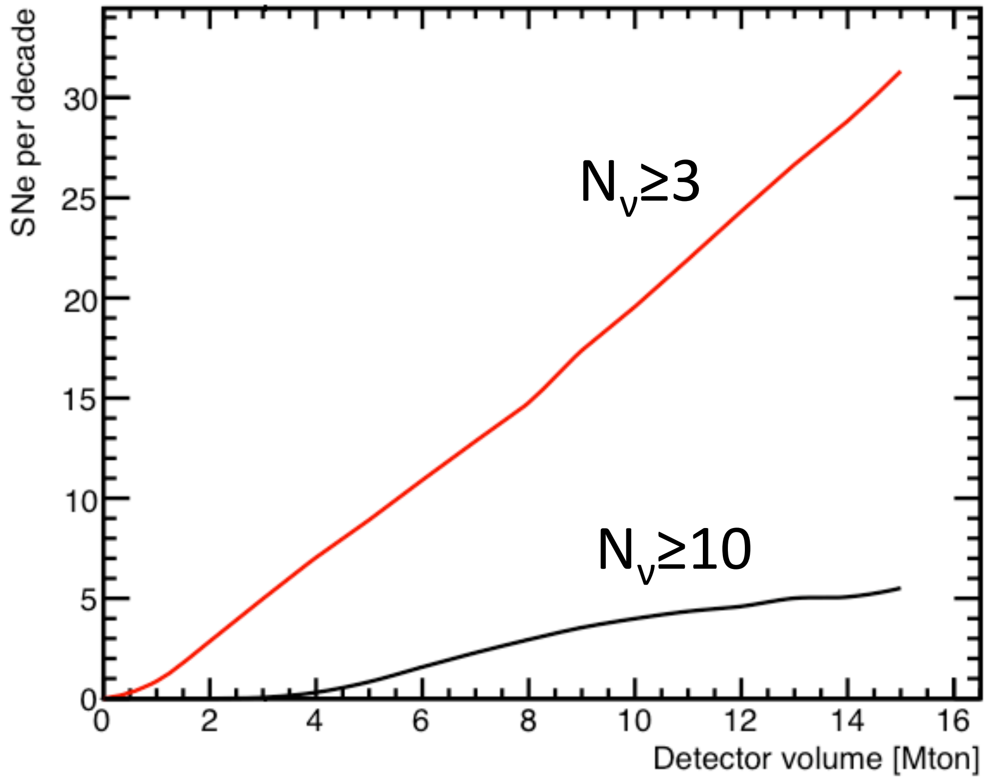
SN 1987A @ 50 kpc distance



Detecting nearby supernovae



2 SNe per yr observed (optically) within 10 Mpc distance



Generic neutrino prediciton (scaling from SN1987A)

10 Mton ⇒ ≥ 2 SNe/yr!

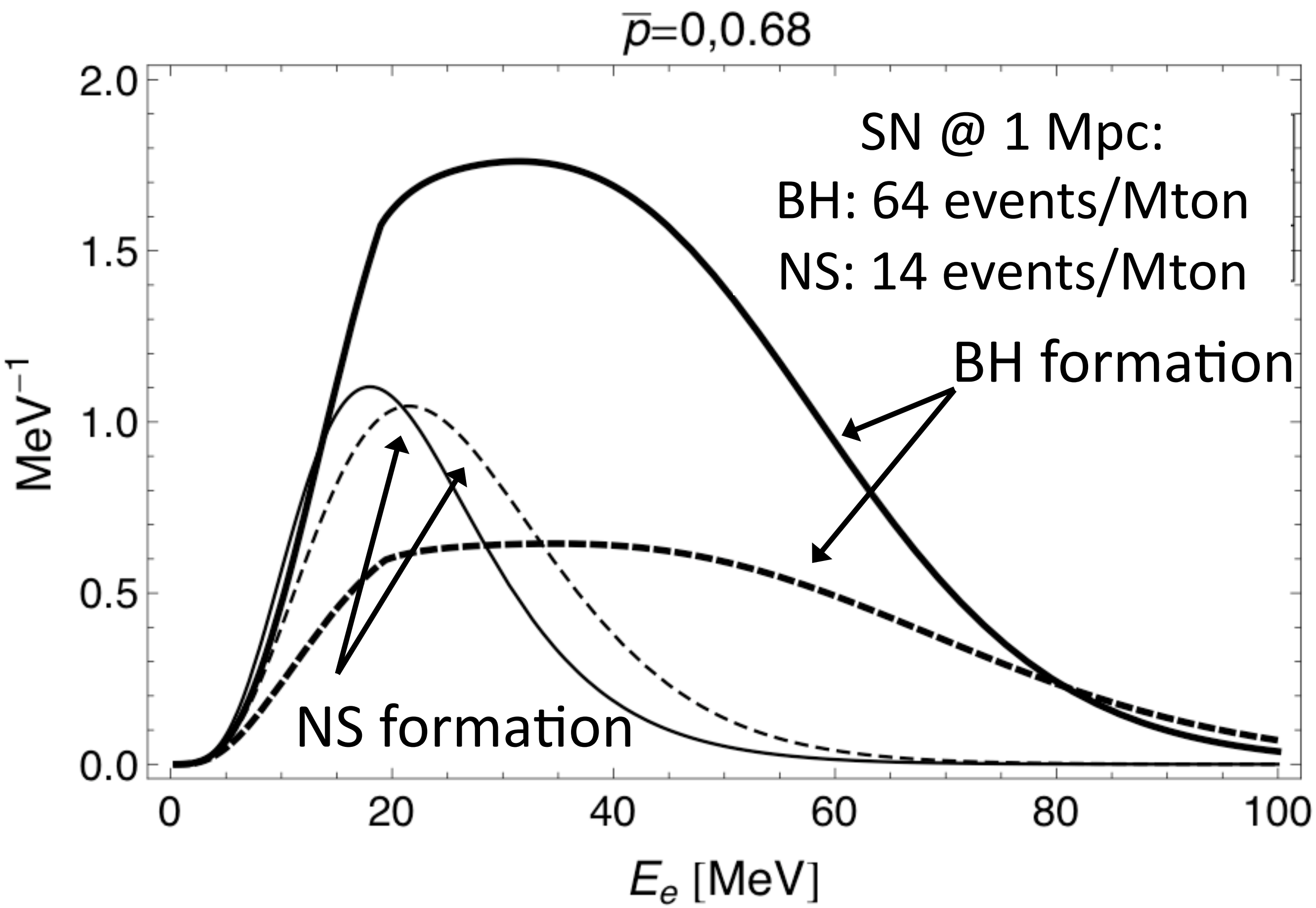
SN Science (1): Astrophysics

- 99% of energy released in neutrinos, hence direct probe of core collapse!
- Creation of a black hole can be identified by missing star (or rapid cut-off of neutrino light curve).
- Rate of SNe: Dust obscured SNe can be ideally identified by neutrinos.
- Distance of nearby SNe sufficiently small for posteriour identication of progenitor stars.
- Early triggers for optical and X-ray follow-up to catch very early phase.

SN Science (1): Astrophysics

- 99% of energy released in neutrinos, hence direct probe of core collapse!
- Creation of a black hole can be identified by missing star (or rapid cut-off of neutrino light curve).
- Rate of SNe: Dust obscured SNe can be ideally identified by neutrinos.
- Distance of nearby SNe sufficiently small for posteriour identication of progenitor stars.
- Early triggers for optical and X-ray follow-up to catch very early phase.

Gravitational Collapse: Black Hole vs Neutron Star



Yang, Lunardi, arXiv:1103.4628v1

SN Science (2): Particle Physics & Multi-Messenger

- Neutrino mass: going out to 10 Mpc provides mass sensitivity to ~0.2 eV.
- Neutrino-mass hierarchy & QCD phase transition possibly observable.
- Gravitational detectors: Coincident search is 3000 times more significant than GW detectors alone.

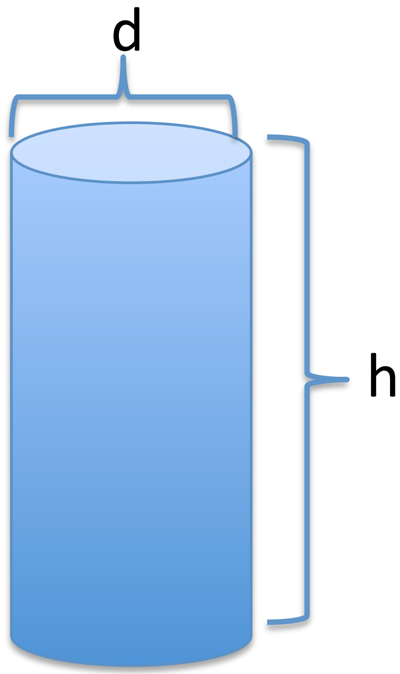
Detector consideration

3000 photons for 15 MeV neutrino

⇒ dense instrumentation needed

Unit sensor:
Cylinder of 1 cm width and 1 m height
which is 100 % efficient on (π d x h) surface
(≈ 1.7 DOMs or 1.25 HQE DOMs per m depth);
Noiserate of 500 Hz per module

Possible realization at the end of the talk



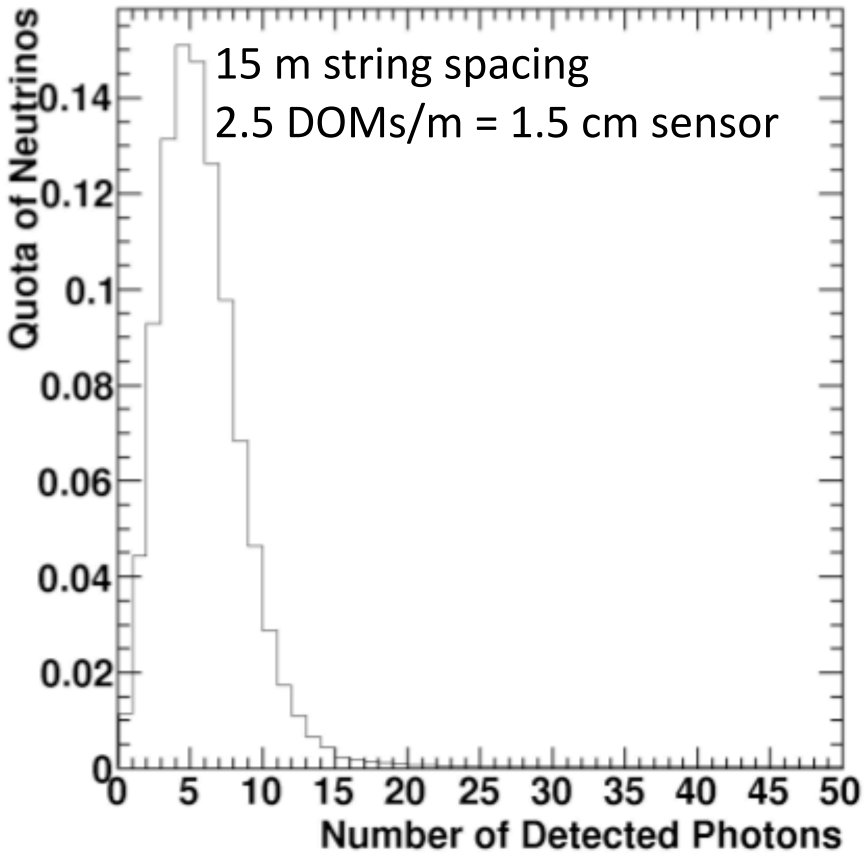
Detector consideration

3000 photons for 15 MeV neutrino

⇒ very dense instrumentation needed

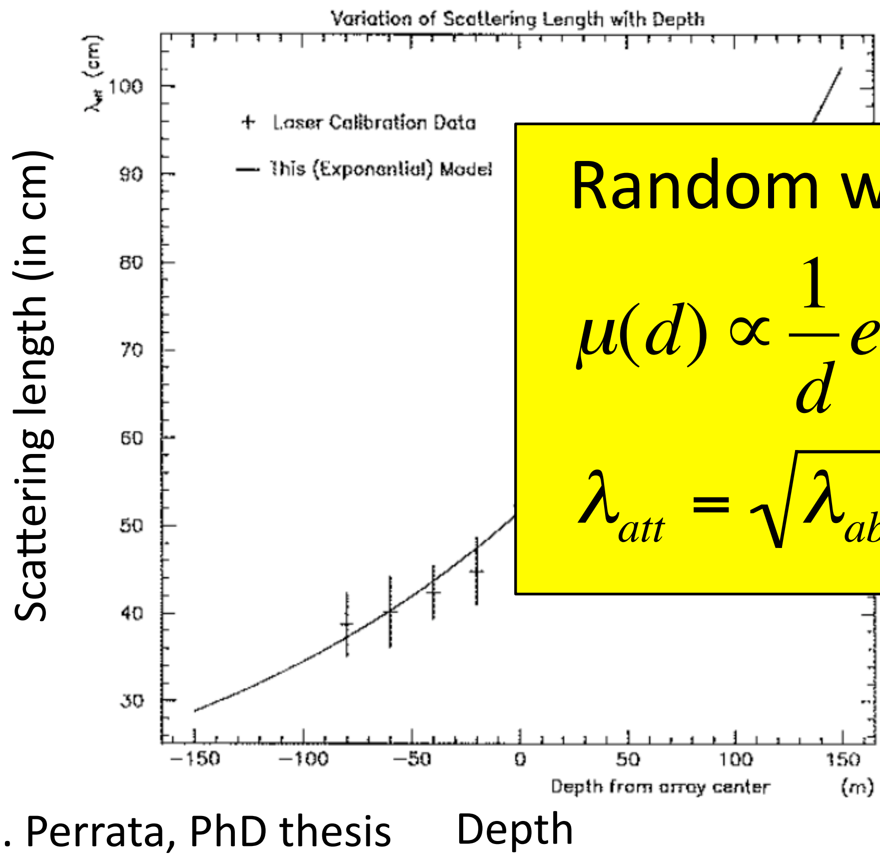
Simulation (deep ice):

- standard DOMs
- 2200 – 2500 m depth
- 20 MeV e^+
- 61 strings
- variable string/DOM spacing



What about the shallow ice?

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

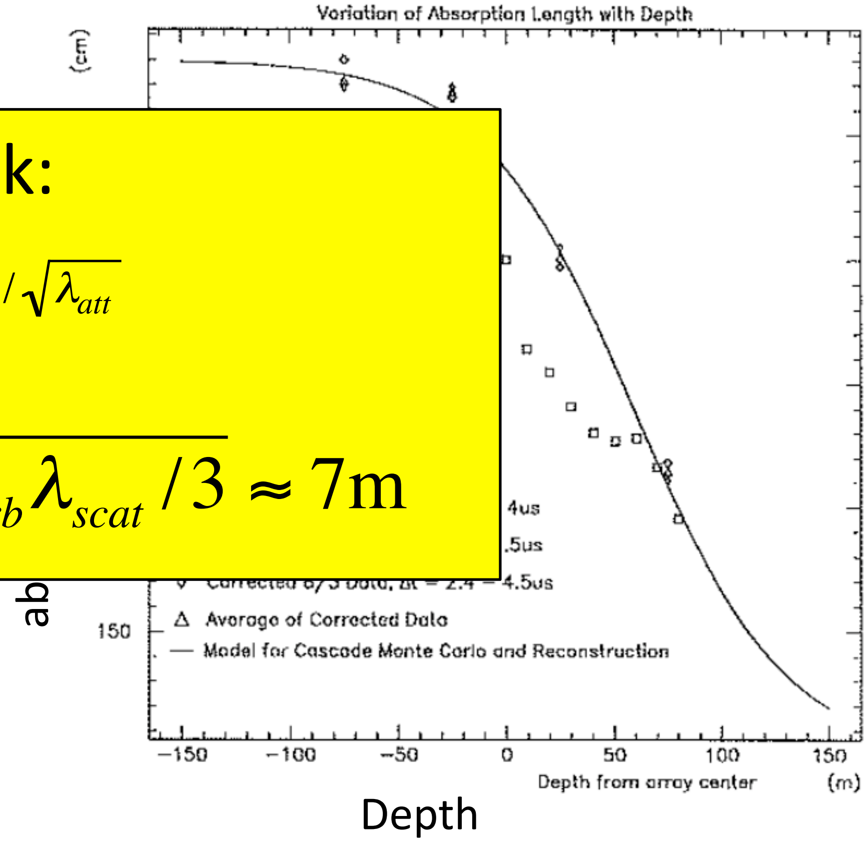


R. Perrata, PhD thesis

Random walk:

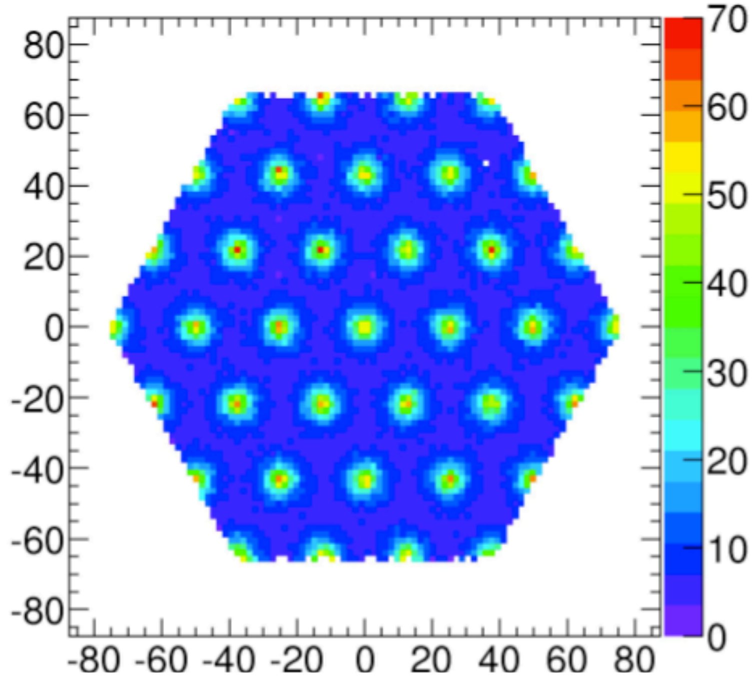
$$\mu(d) \propto \frac{1}{d} e^{-d/\sqrt{\lambda_{att}}}$$

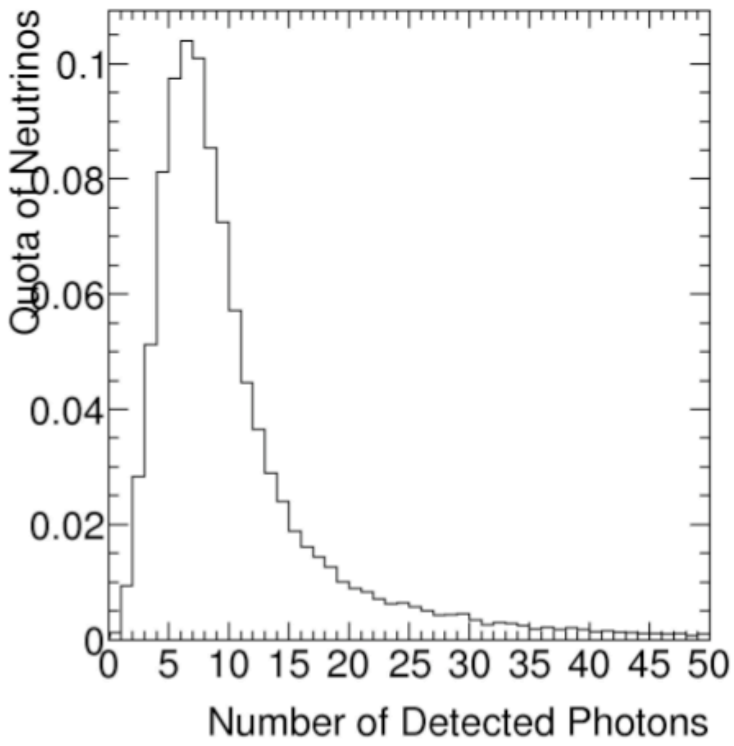
$$\lambda_{att} = \sqrt{\lambda_{absorb}\lambda_{scat}/3} \approx 7\mathrm{m}$$



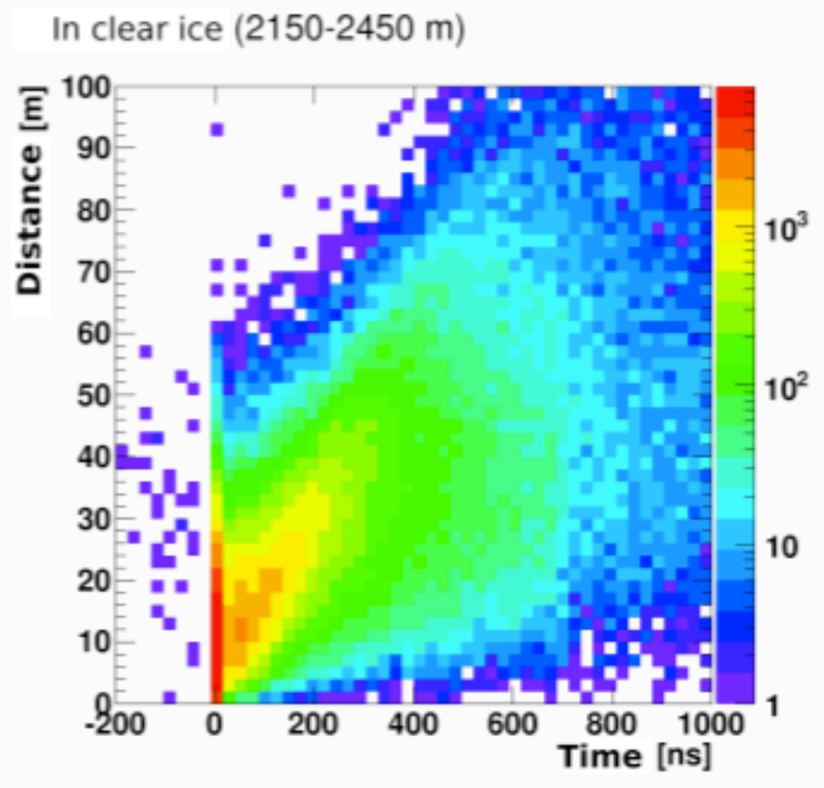
Detector simulation (shallow ice)

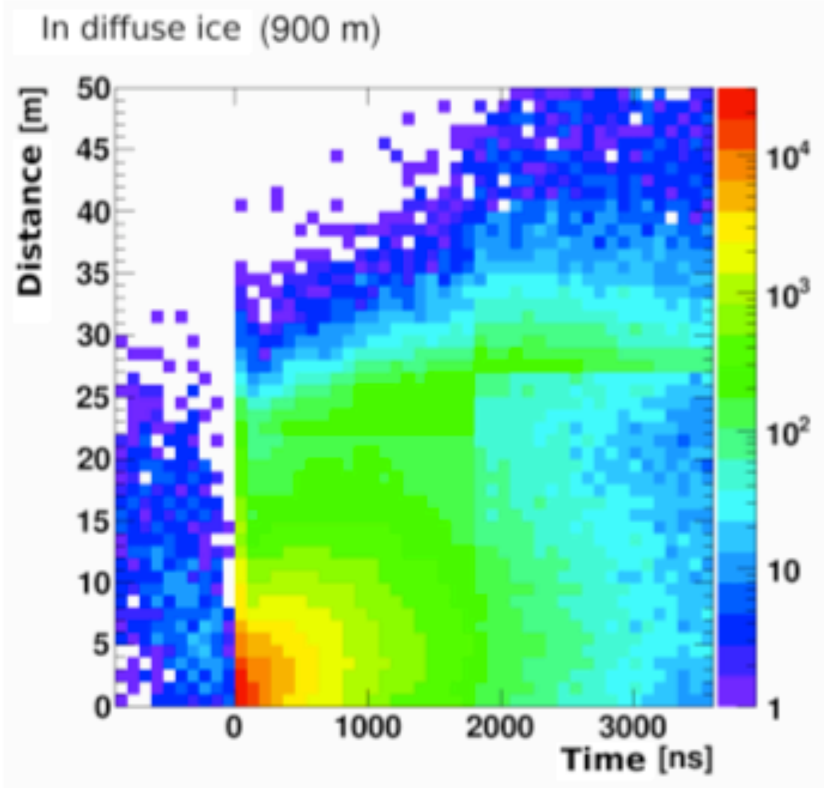
- Toy simulation based on ice at 900 m depth
- 300 m long strings
- 3000 photons per event
- 0.01m^2 effecitve sensor area per m





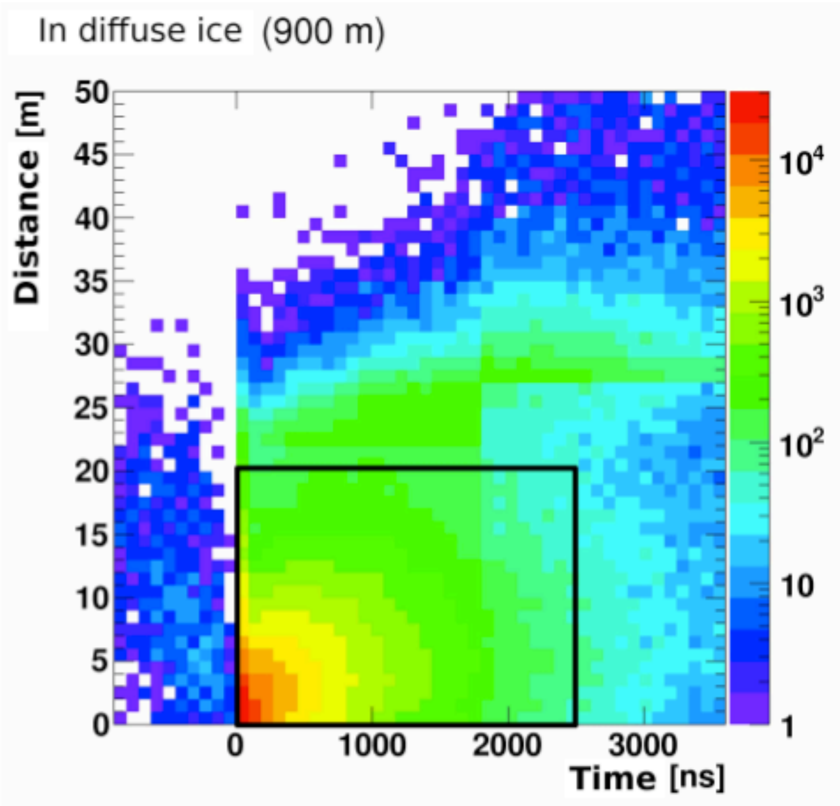
Trigger: pre-selection of photons





Radial distance vs. time difference from first guess reconstructed vertex

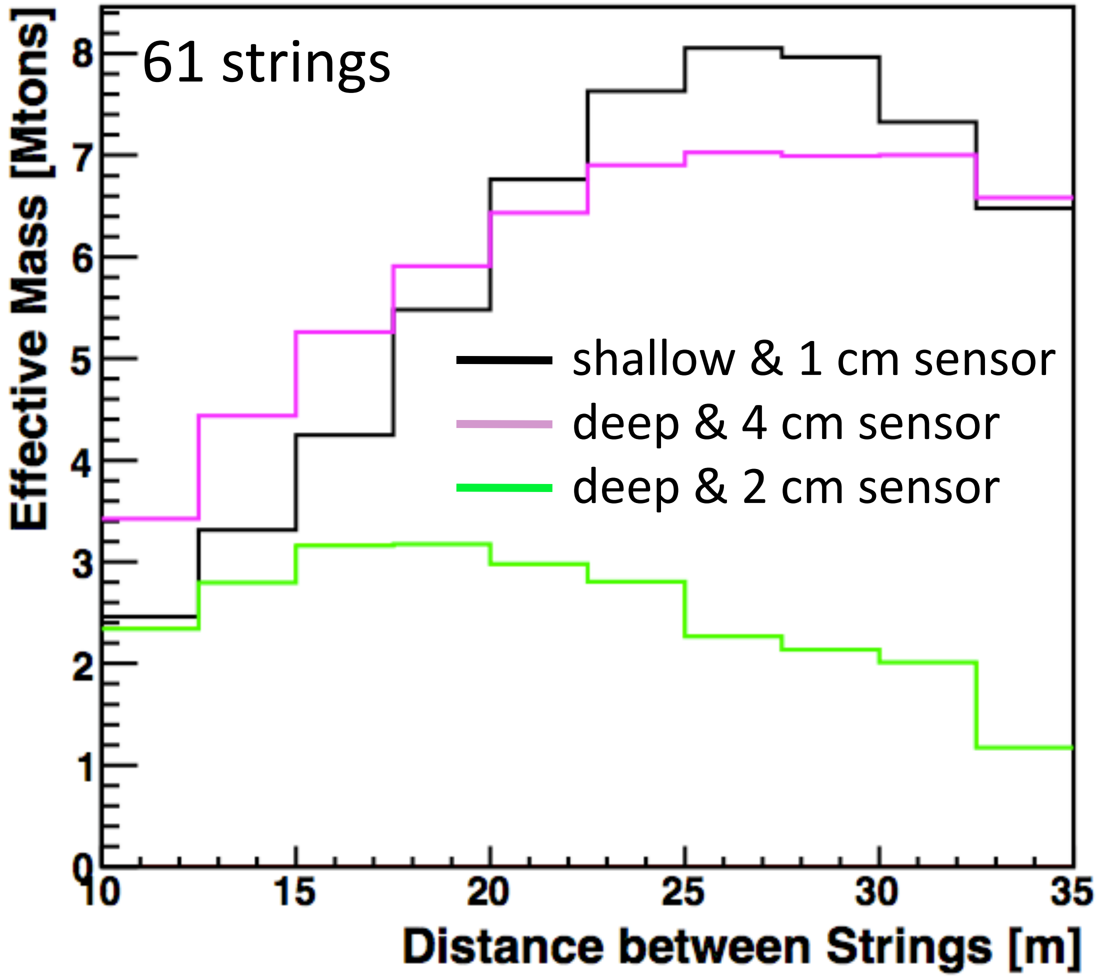
Fake vs Signal „events“: $N_{hits} \geq 5$ (shallow ice)



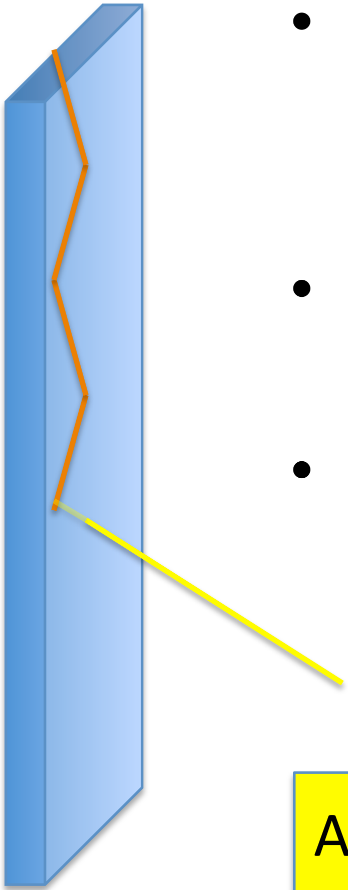
- Simple cut to reject background
- Time window 2500 ns, Radius 20 m
- Trigger efficiency: 79% $\Rightarrow$ Effective mass on trigger level: 6 Mtons
- Background trigger rate: 1.5 mHz (Noise assumed: 500 Hz per meter)

Assumption: muon back ground can be seperated by brightness cut

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

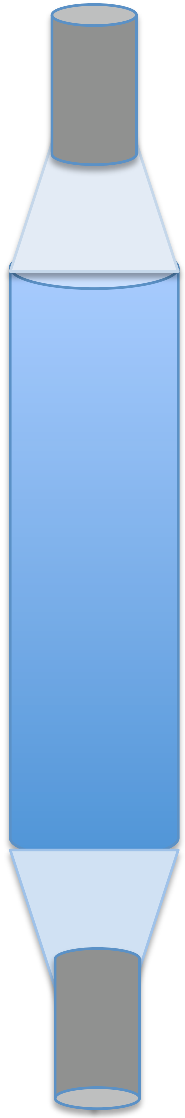


R&D for cheap photo-sensors



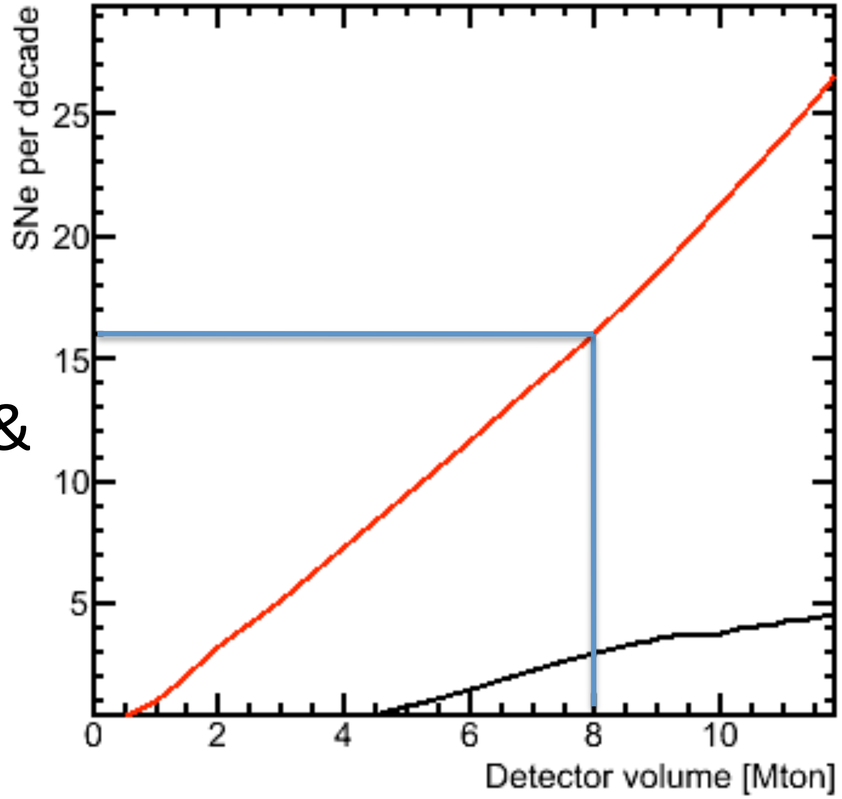
- Idea: Use of plastic wavelenght shifters to capture photons and read them out with (small) PMTs at the bottom/top.
- Simulation indicate up to 40% capture efficiency (depending on geometry)
- Interest in Erlangen (G. Anton) and Stanford (G. Gratta). R&D effort in Bonn started.

Alternatives: Albalone PMTs (Ferenc et al.), Micro Channel Plate Sensors (FNAL,...)



Summary

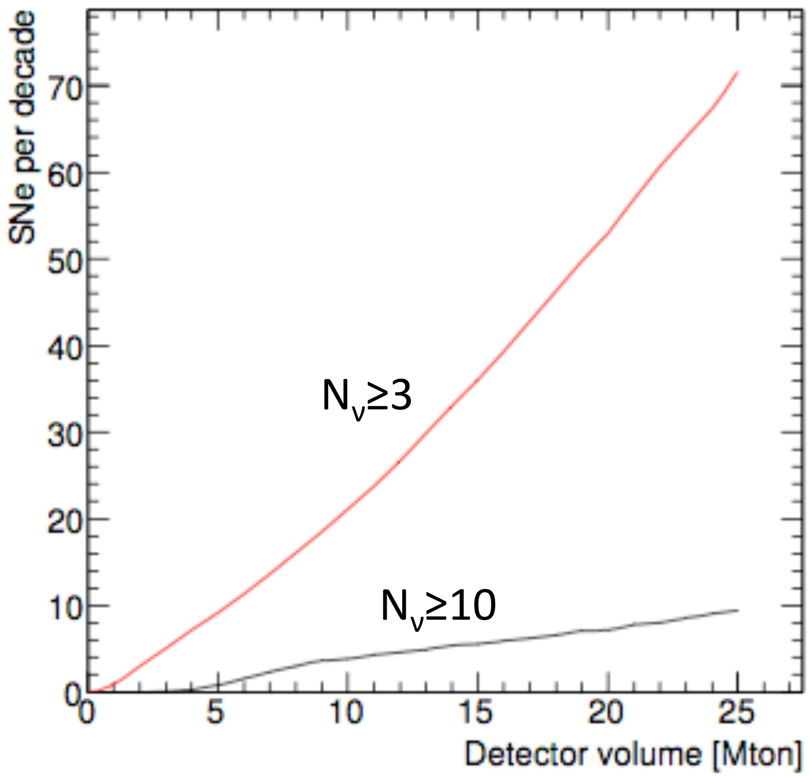
- 8 Mtons for 61 shallow/deep strings with 2/8 10^4 DOMs
- 1.5-2 SN per yr is a lower limit
- R&D for more photo sensor area & low noise rate needed
- Things still to explore: diffuse flux

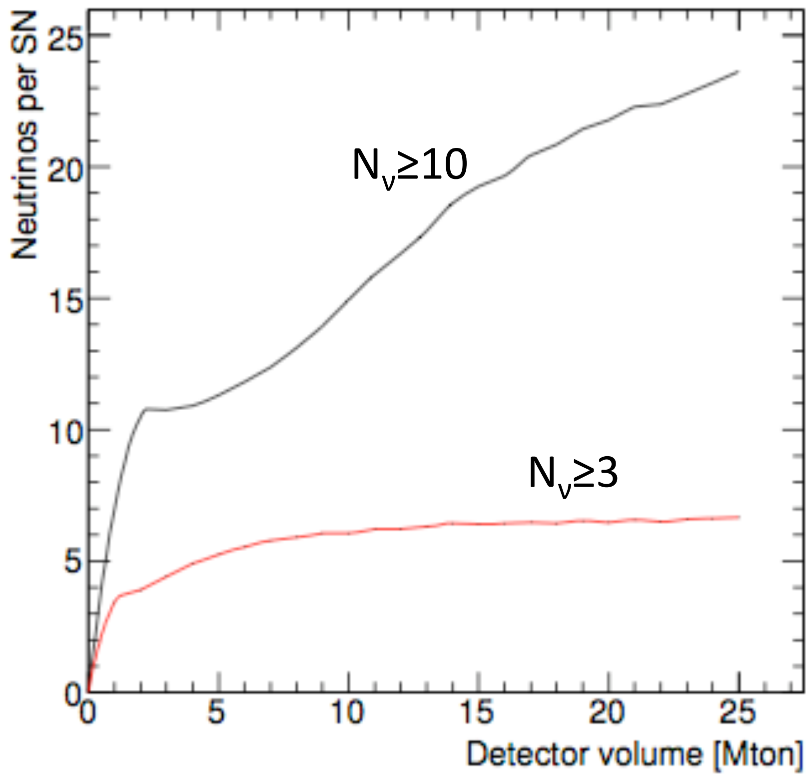


Back Up

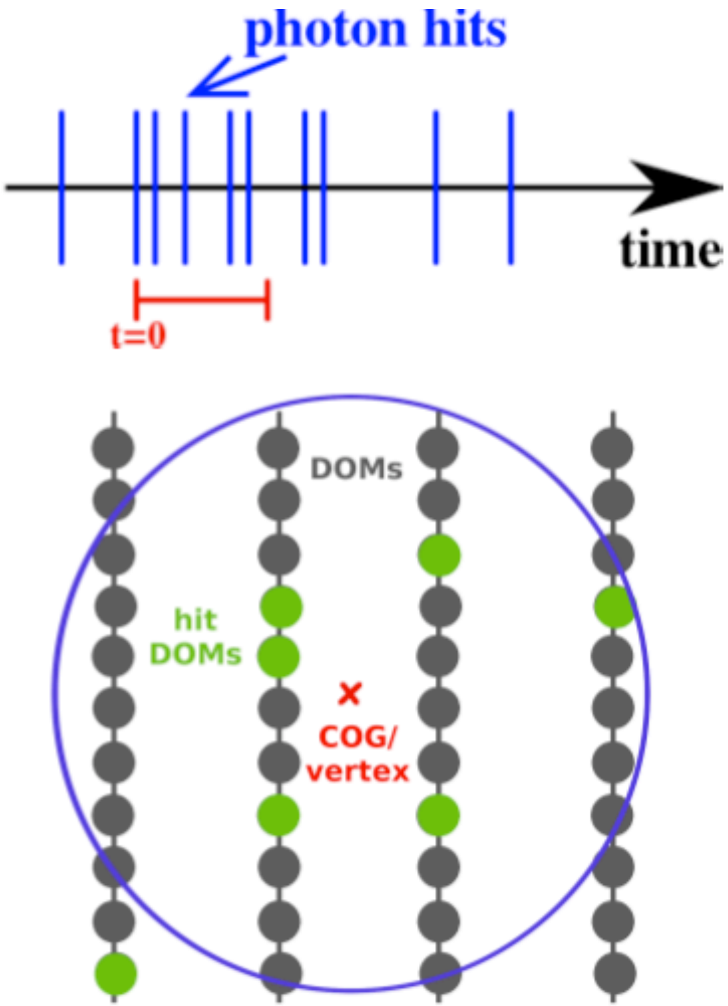
Detecting nearby supernovae

$$N_\nu \approx 20 \times (D/\mathrm{Mpc})^{-2} \times (V/\mathrm{Mton})$$

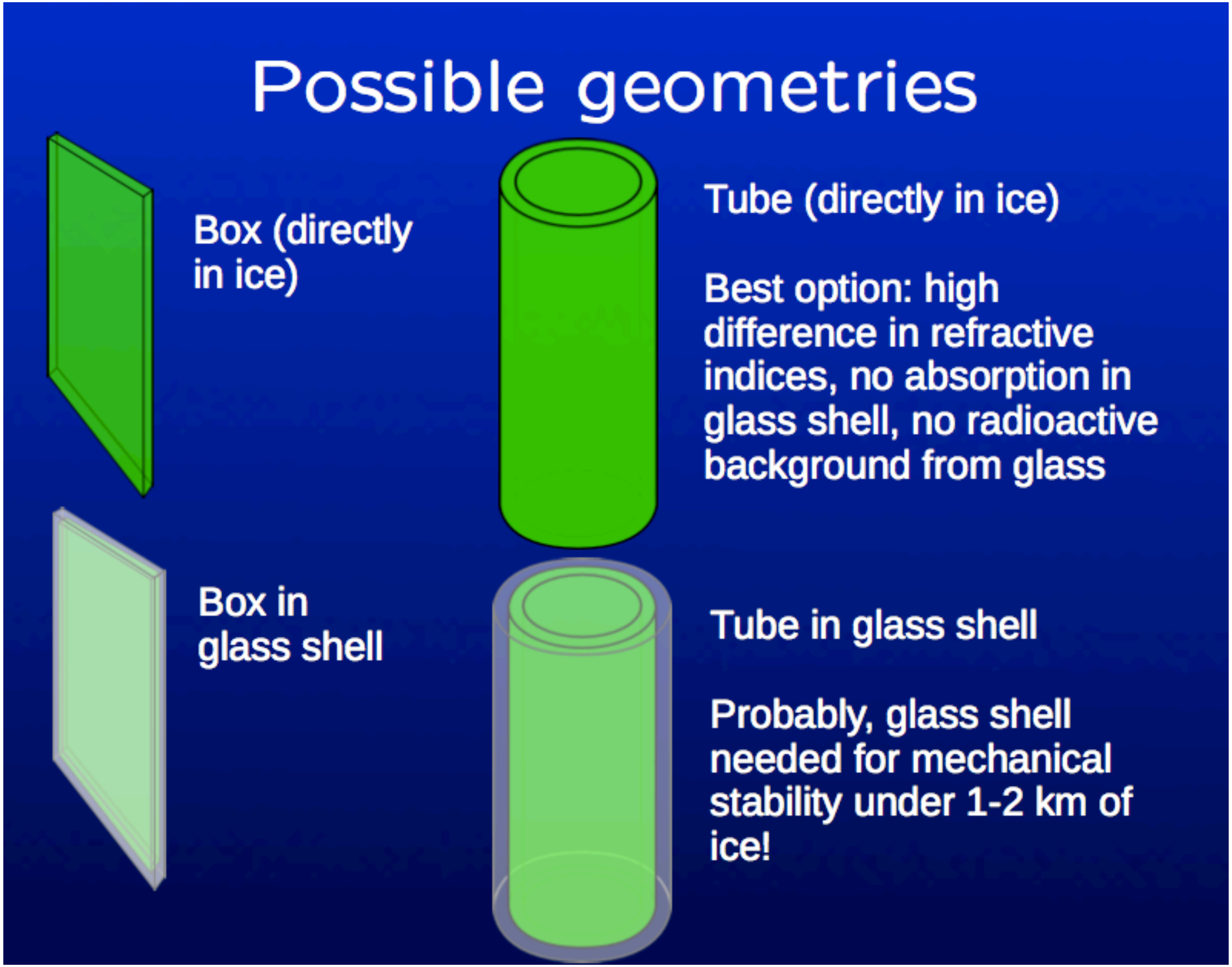




Event Filtering / First guess reconstruction



- Find time window with most module hits (minimum 5)
- Calculate center of gravity (COG) of the hits
  $\Rightarrow$ "vertex"
- Read out all hits of time window within certain radius from COG



Markus Voge, BDC workshop, Amsterdam 2011

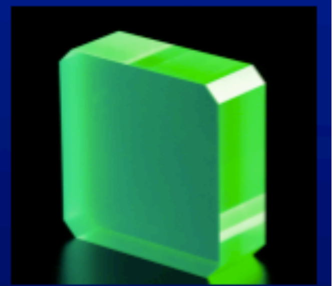
Available materials

- St. Gobain (formerly Bicron):
  - BC-480: 330 nm → 425 nm
  - BC-482A: 420 nm → 500 nm
  - BC-484: 380 nm → 435 nm

http://prod.detectors.saint-gobain.com/

- Eljen Technology:
  - EJ-280: 420 nm → 500 nm

http://www.eljentechnology.com/



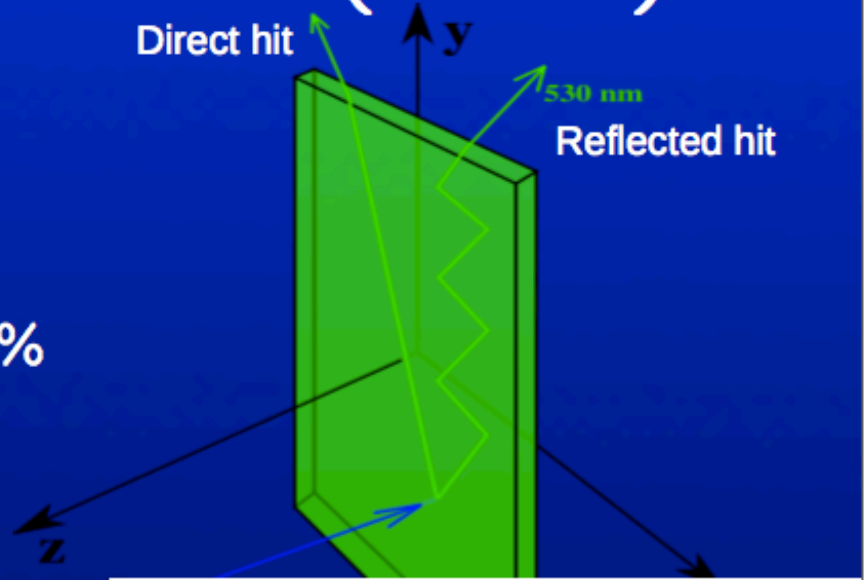
- Evonik Industries?

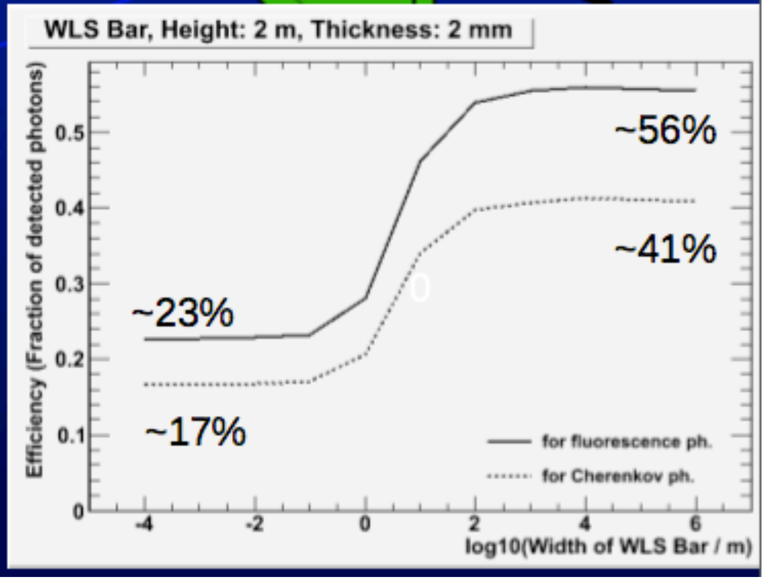
http://www.plexiglas-shop.com/

Markus Voge, BDC workshop, Amsterdam 2011

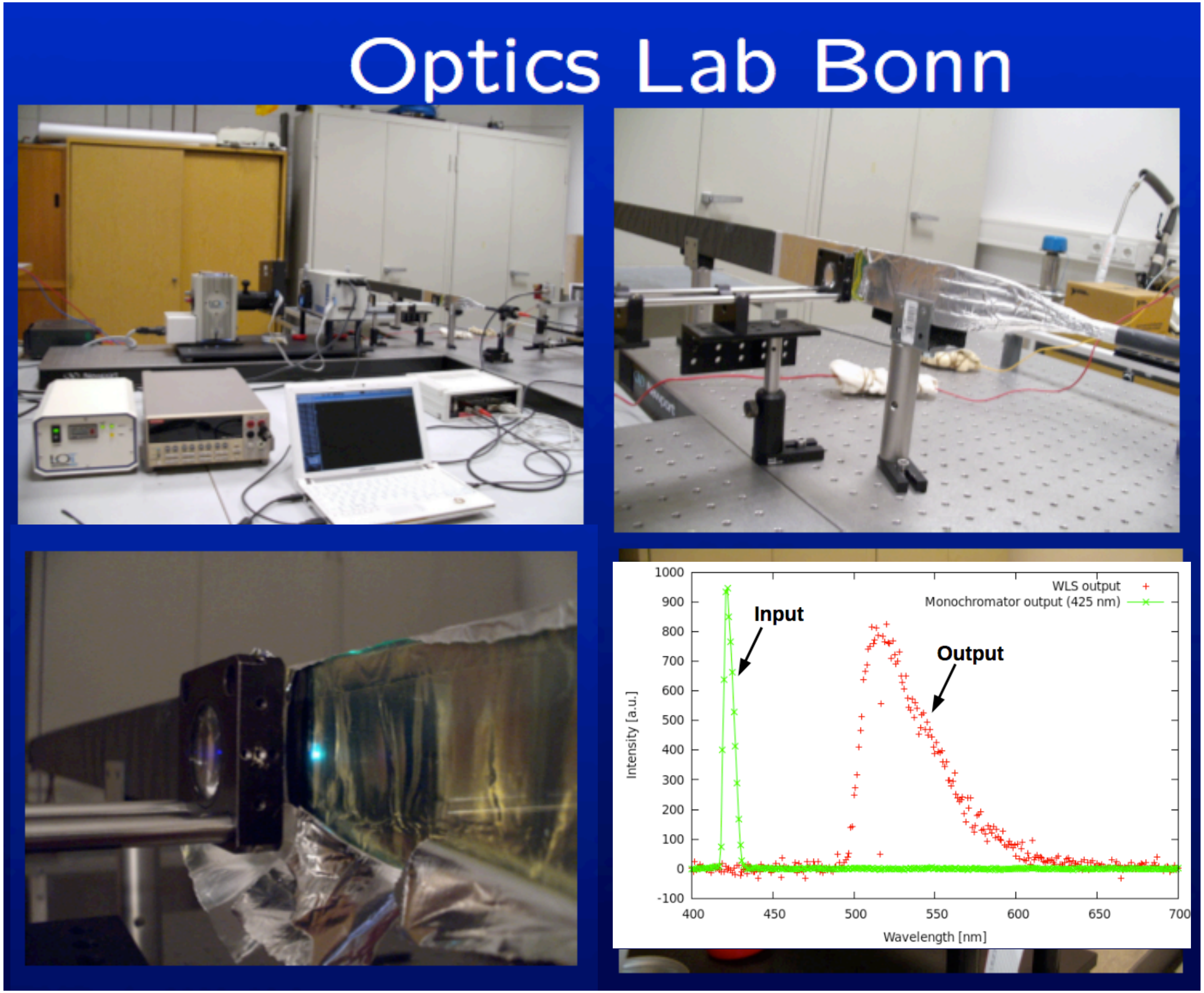
Wavelength Shifters (WLS)

- Wavelength-dependent absorption
- Isotropic re-emission of fluorescence photon with ~86% efficiency (otherwise, energy goes to phonons)
- Fraction $\Delta\Omega/4\pi$ of photons reaching readout surface depends on geometry and material
- Tubular geometry (like infinitely wide box): **significant fraction (~20-40%)** reaches readout surface





Markus Voge, BDC workshop, Amsterdam 2011



Markus Voge, BDC workshop, Amsterdam 2011