Feasibility study for acoustic neutrino detection in ice: The South Pole Acoustic Test Setup

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Outline

- Ultra high energy neutrino detection

- The South Pole Acoustic Test Setup
  - Goals
  - Design

- System status

- Deployment and commissioning

- First results
  - Background Gaussian noise
  - Background transient events
  - Attenuation analysis

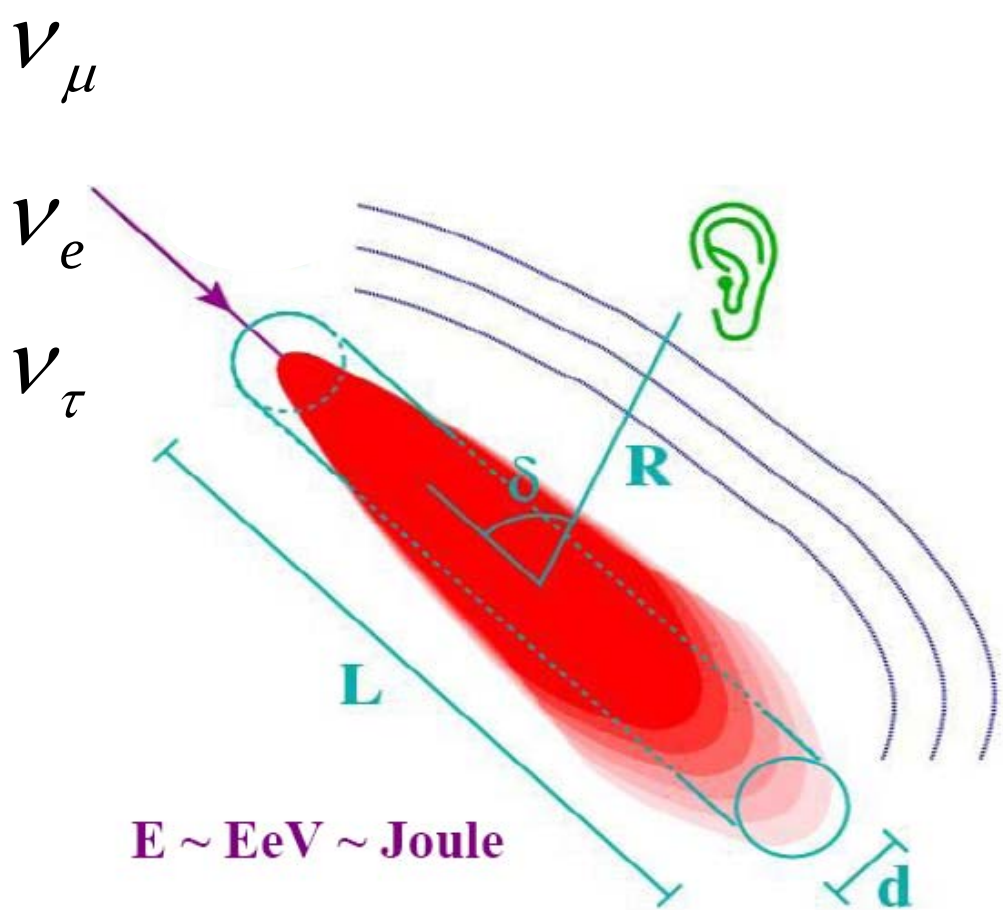
- Conclusion and outlook

Ultra High Energy neutrino detection

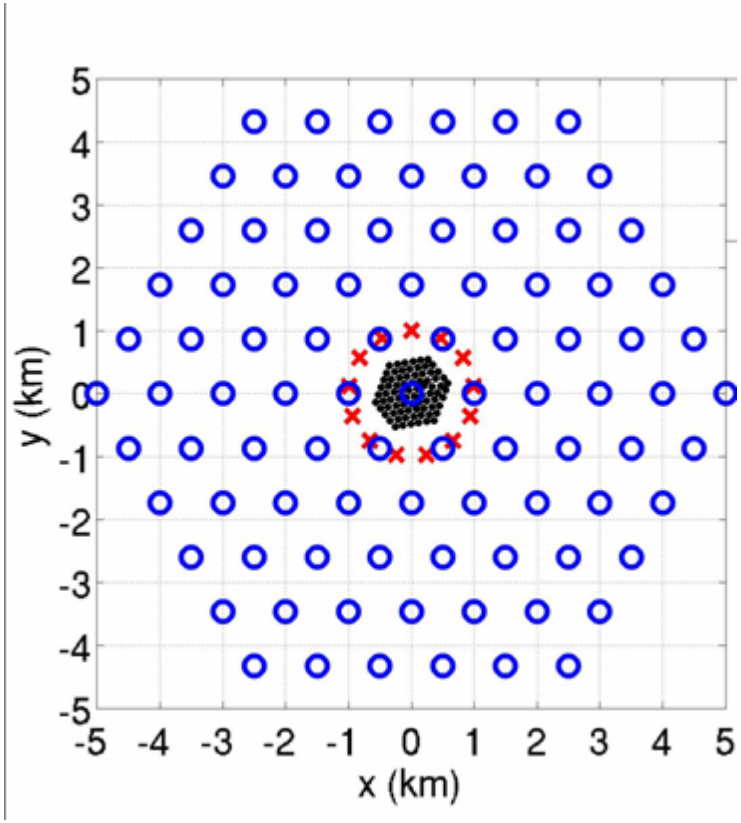
Cascades → ~10 kHz acoustic waves

→ Optical/radio/acoustic hybrid detector of 100km² scale

➔ detect >10 GZK neutrinos each year (astro-ph/0512604)



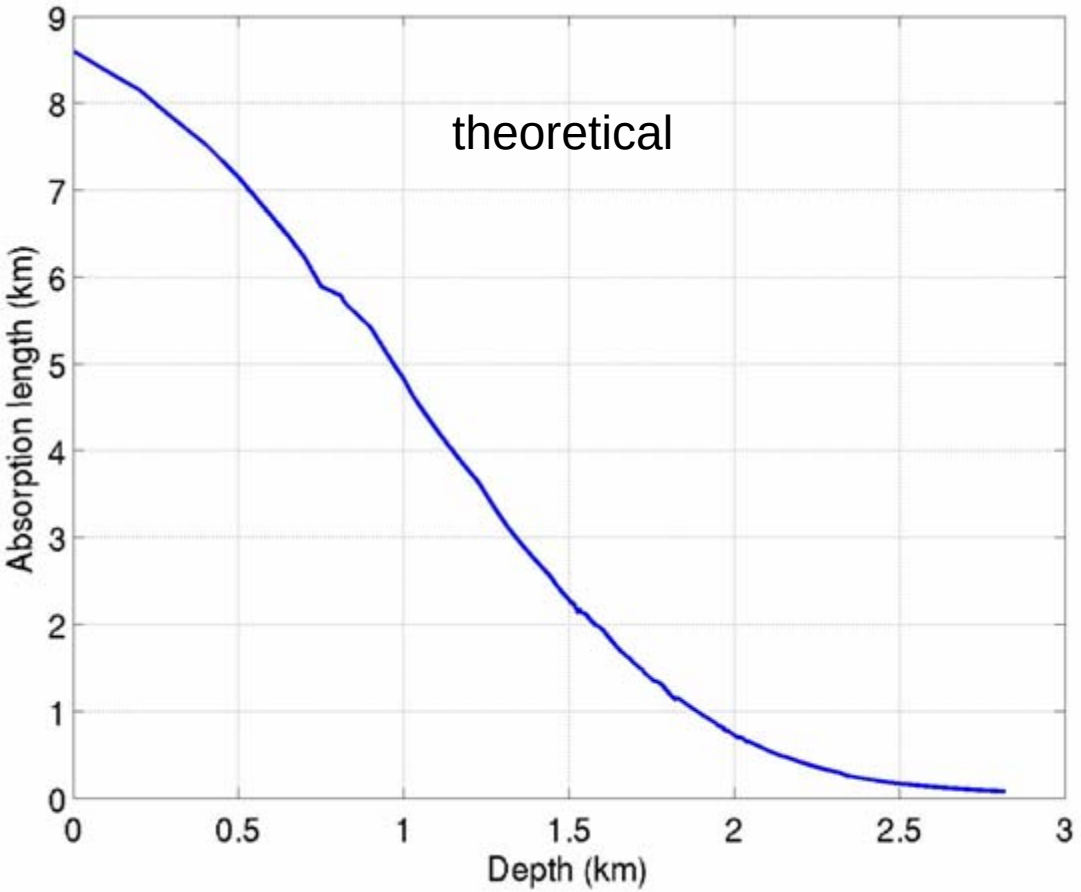
Thermo-acoustic model



The South Pole Acoustic Test Setup

Acoustic waves in the [0,100] kHz range are predicted to travel several km through South Pole ice

Experimental determination of the acoustic properties of Antarctic ice?



- Attenuation length
- Speed of sound
  - refraction
- Background noise level
  - energy threshold
- Transient events

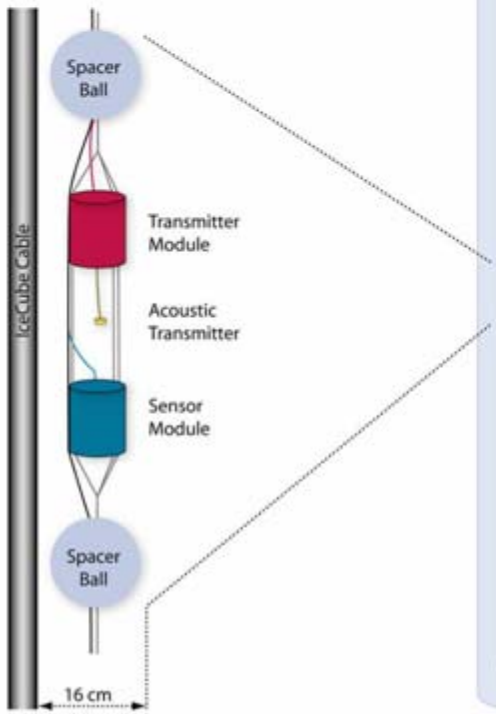
The South Pole Acoustic Test Setup :
deployed in upper 400 meters of the South Pole ice cap

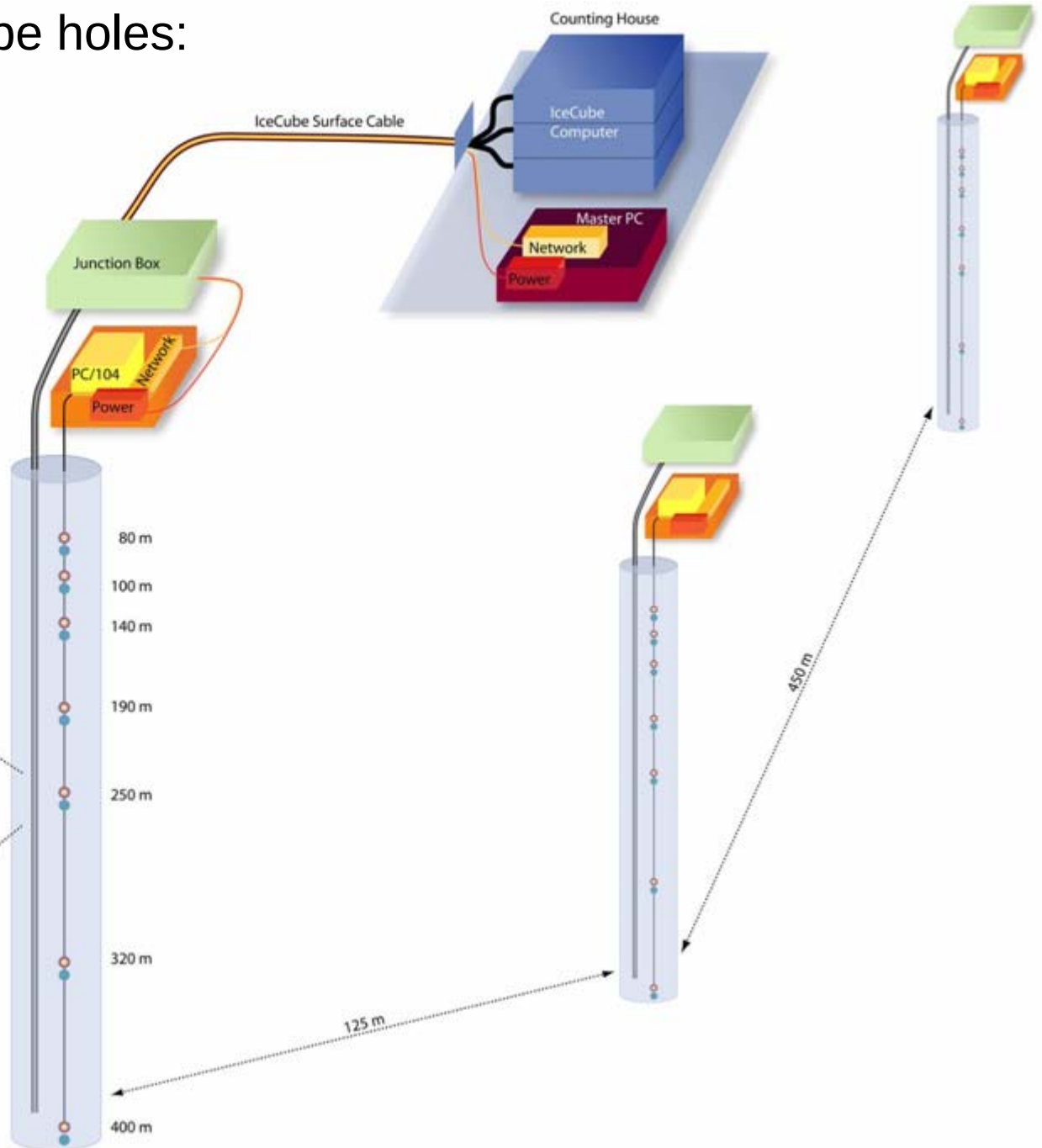
The South Pole Acoustic Test Setup

In upper 400 meter of IceCube holes:

3 strings

- 7 acoustic stages
  - → 1 transmitter
  - → 3 sensor channels

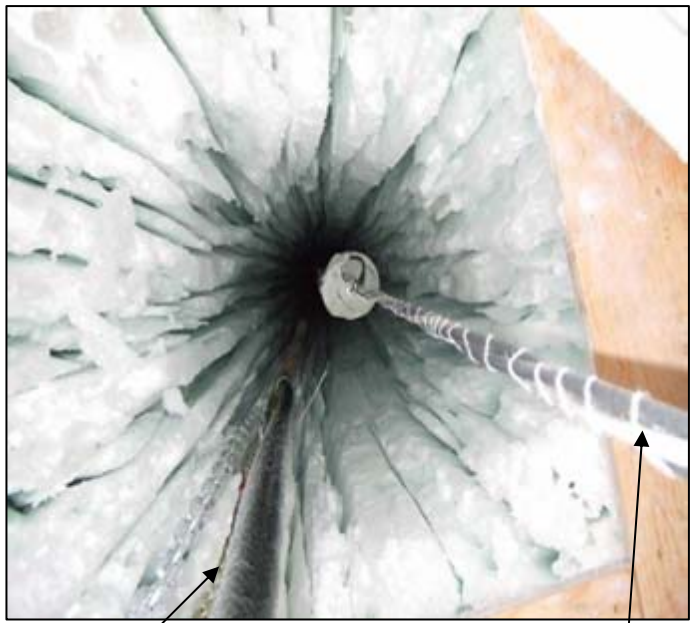




Deployment

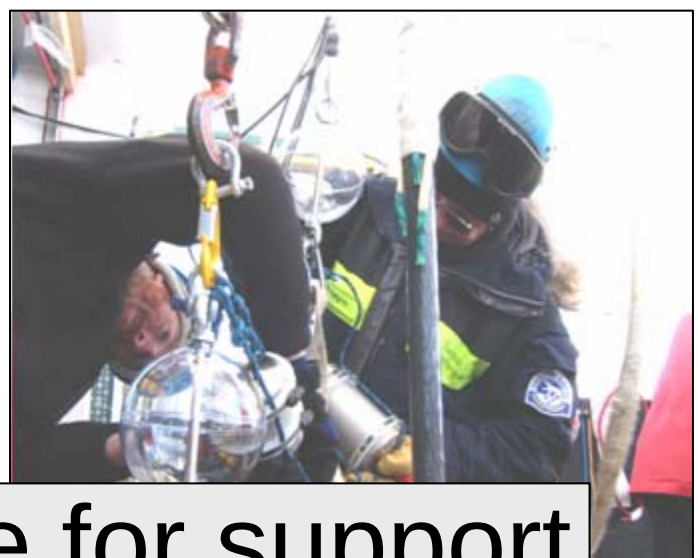
String B (7th) : 01/11/07
String A (8th) : 01/14/07
String C (11th): 01/22/07

- after optical string deployment
- team : ~4 people
- time : 3-4 hours
- monitor pressure readout
  → precision ~2m



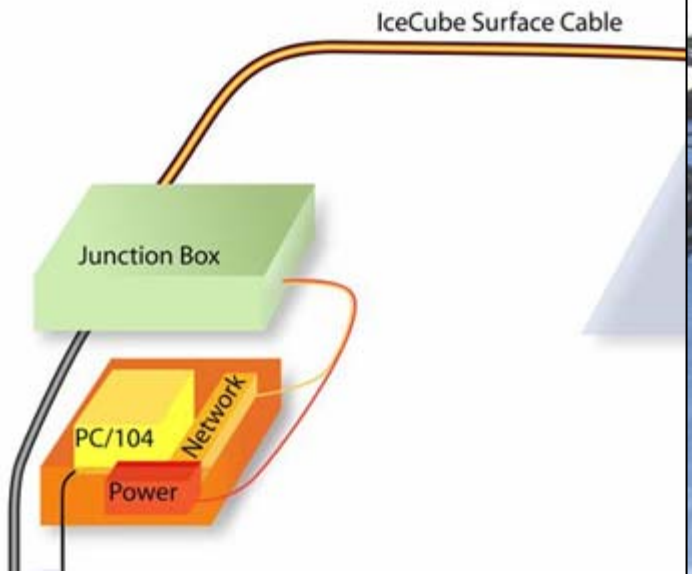
IceCube cable

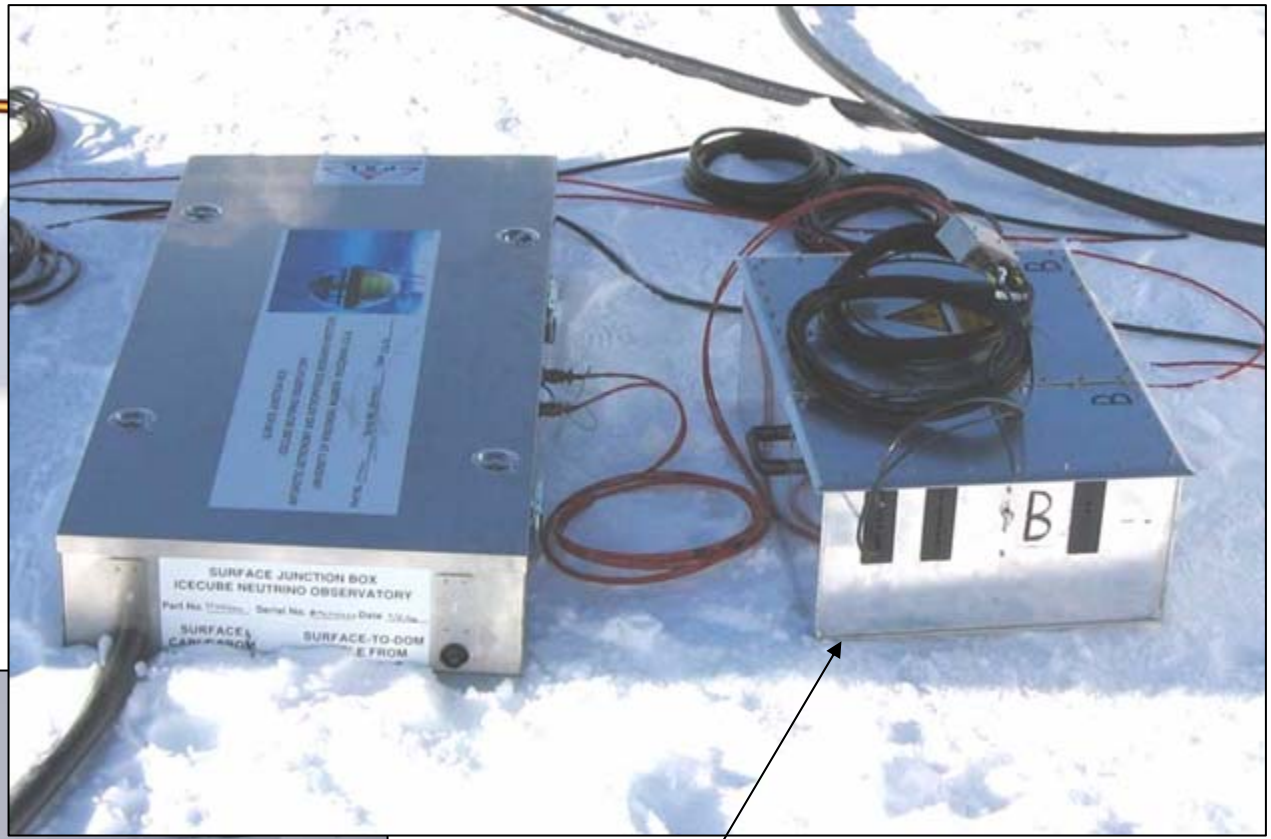
SPATS cable



SPATS thanks IceCube for support

Deployment





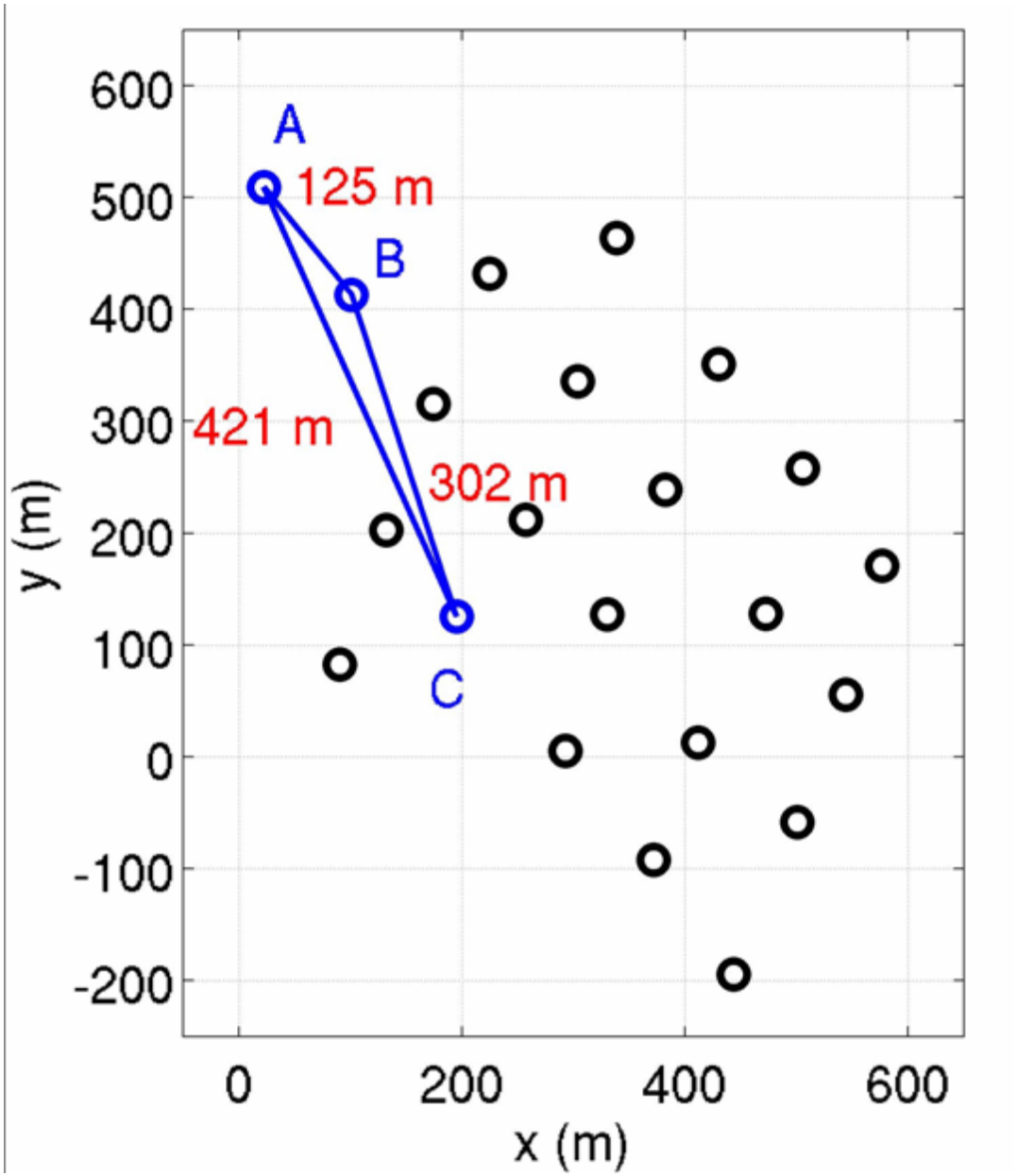
Acoustic junction box:

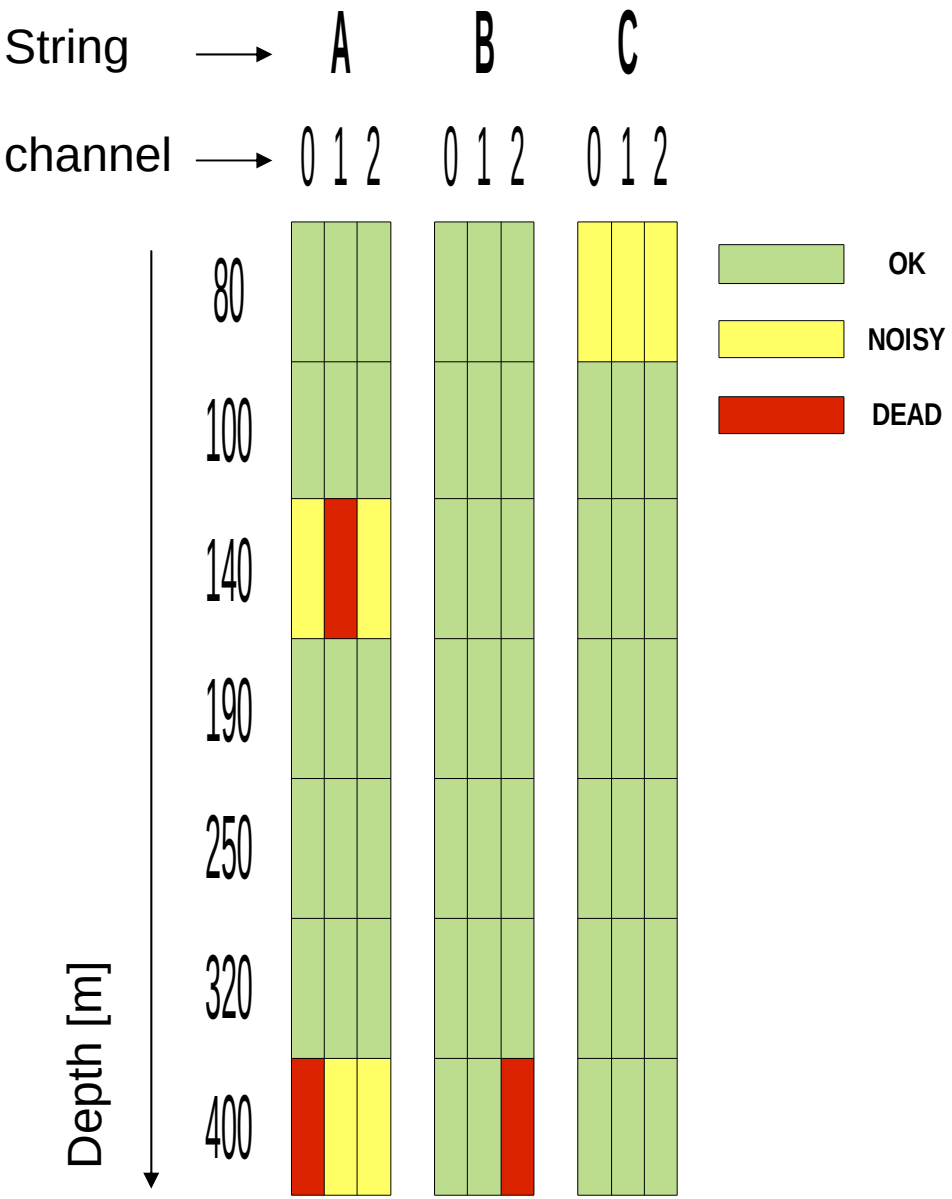
→ 1 for each string each containing a DAQ pc.

→ buried under ~1.5m snow at -50 °C

→ survived several power outages

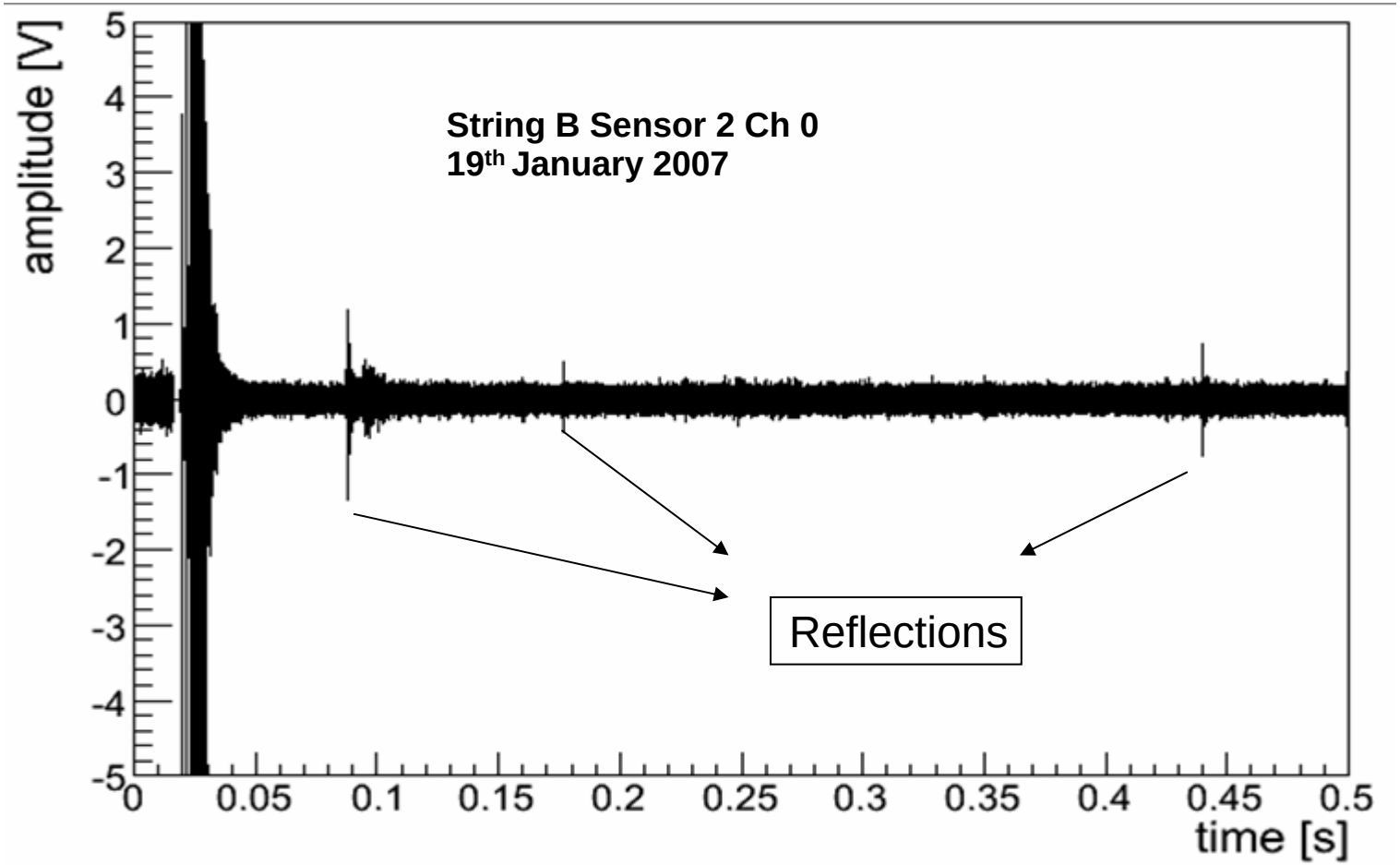
System Status : current layout





Commissioning

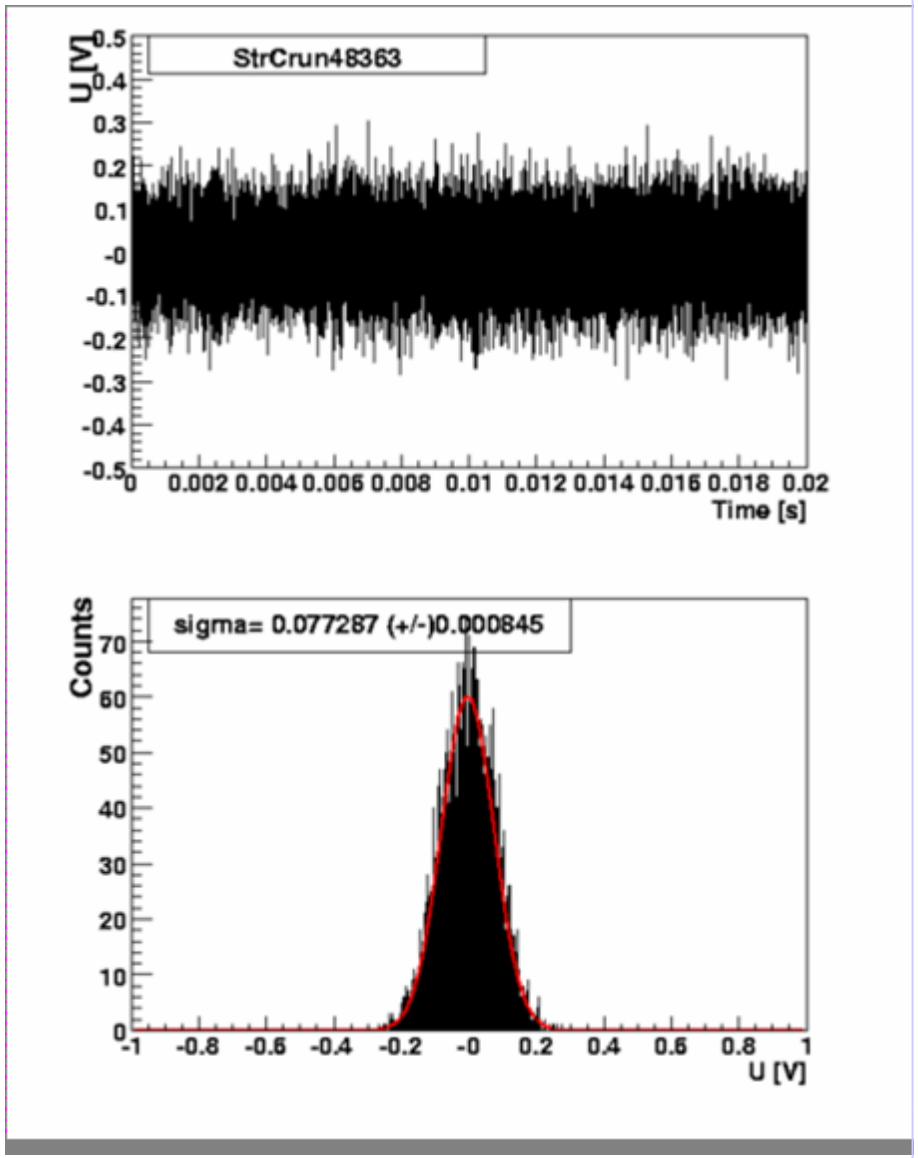
Commissioning runs while stages were still in water:



→ Strings were commissioned within 24 hrs after deployment
→ All stages responded
→ Intra-string events were observed
→ Reflections on water-ice interface

Results

Background noise: Gaussian noise level



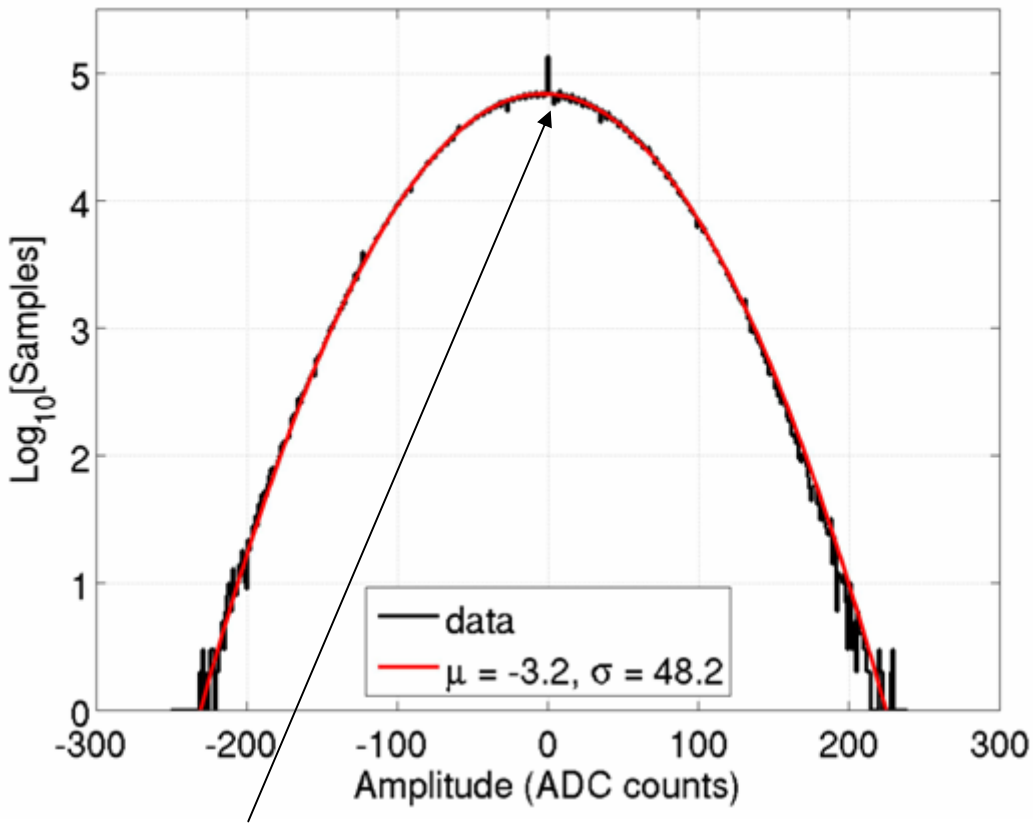
Waveform observations:

→ noise is very Gaussian

→ stable on all time-scales

- noise in sea is very dependent on sea-state, wildlife and human activity

→ noise is higher than in lake-test

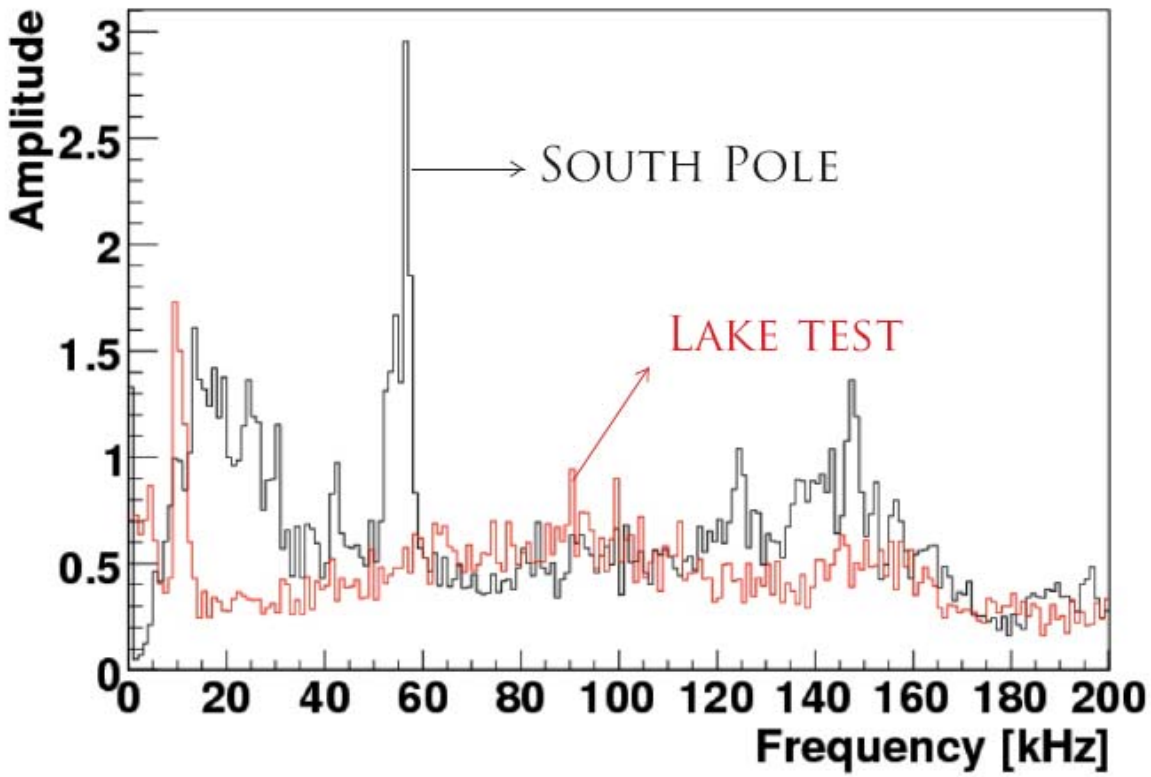


Excess of zeros due to ADC-glitch

Preliminary Results

Background noise: Gaussian noise level: overview

Spectrum example:
Stage 21, channel C
Lake test → **in water at 4 °C, 42 m under ice-surface**
South Pole → **in ice at -50 °C, 400 m deep**



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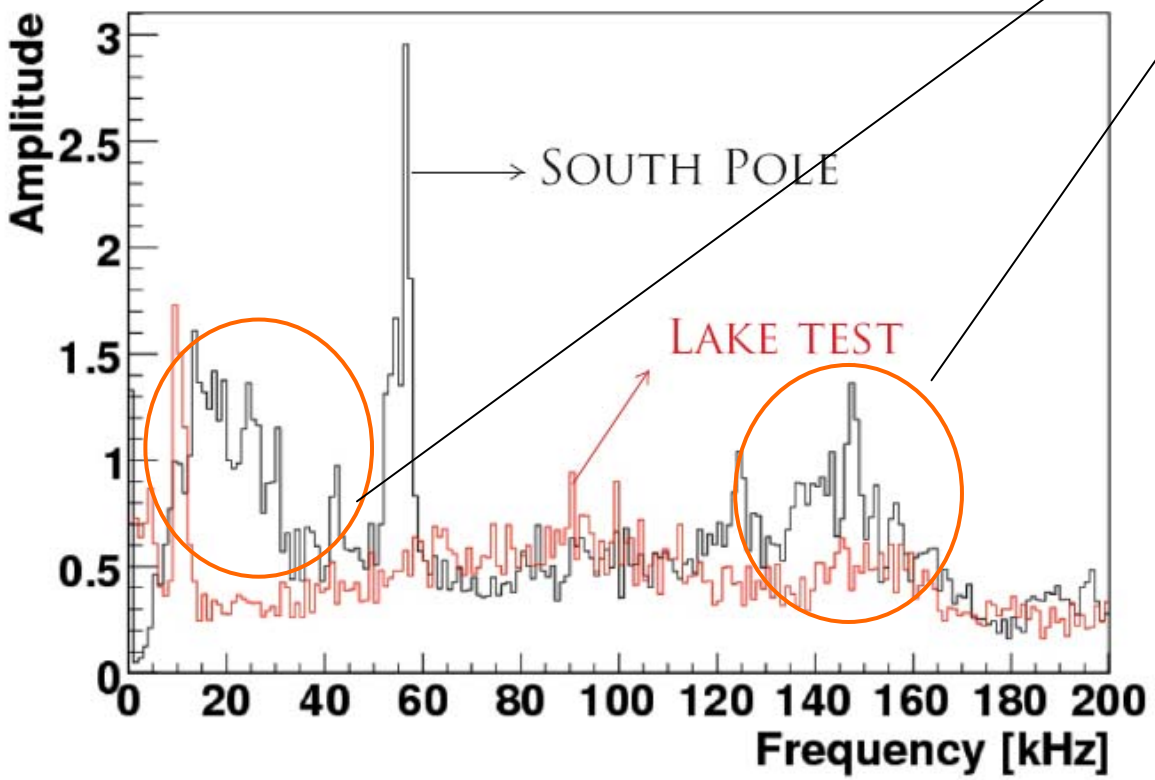

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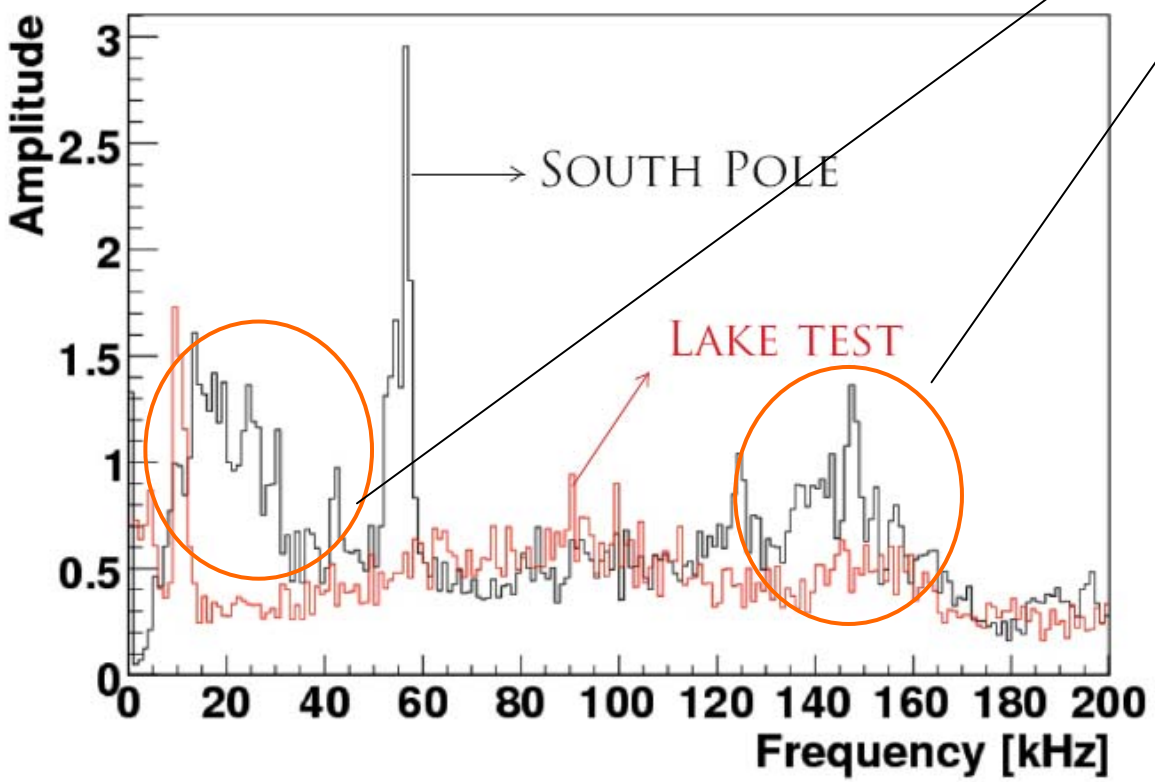

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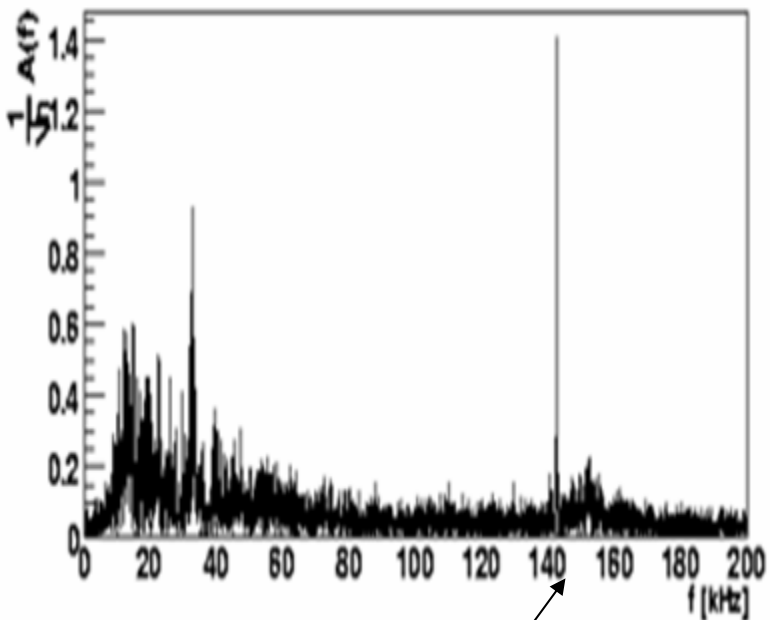

Test in Ghent lab in ice showed same feature...

Preliminary Results

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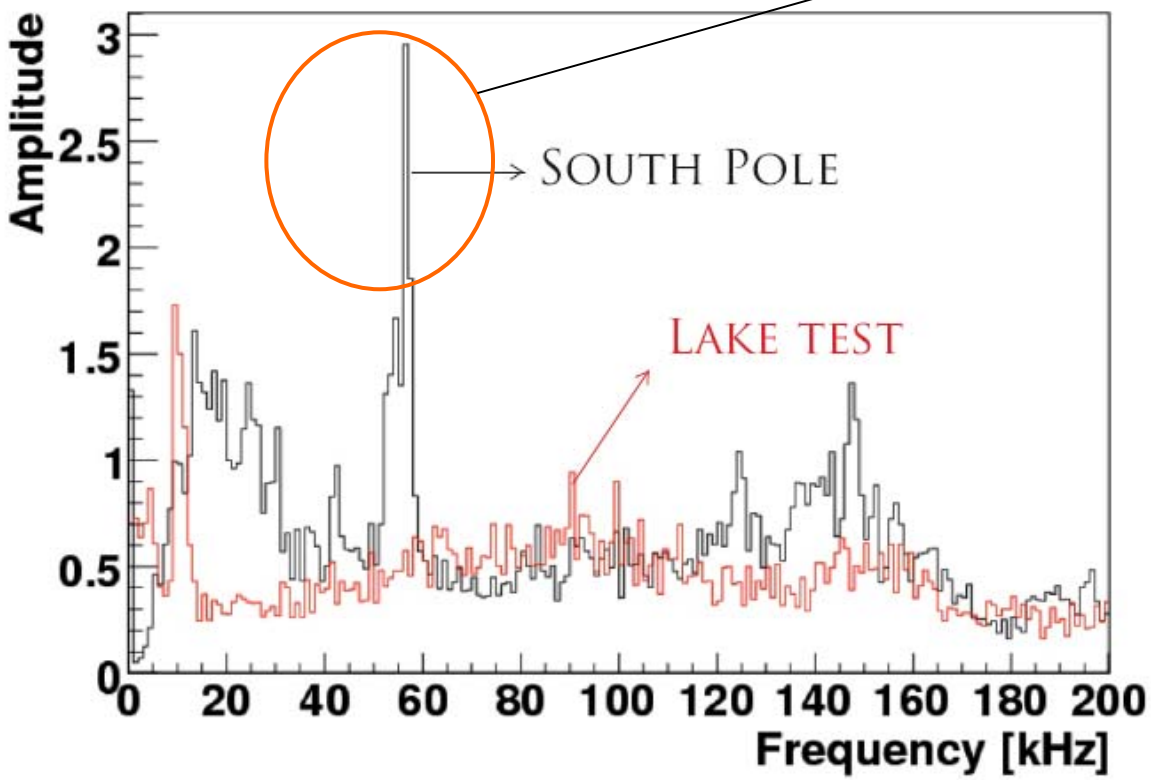

Believed to be EMI
-but cables are shielded!
-not from out own system?

→ during shutdown of IceCube and Amanda

Preliminary Results

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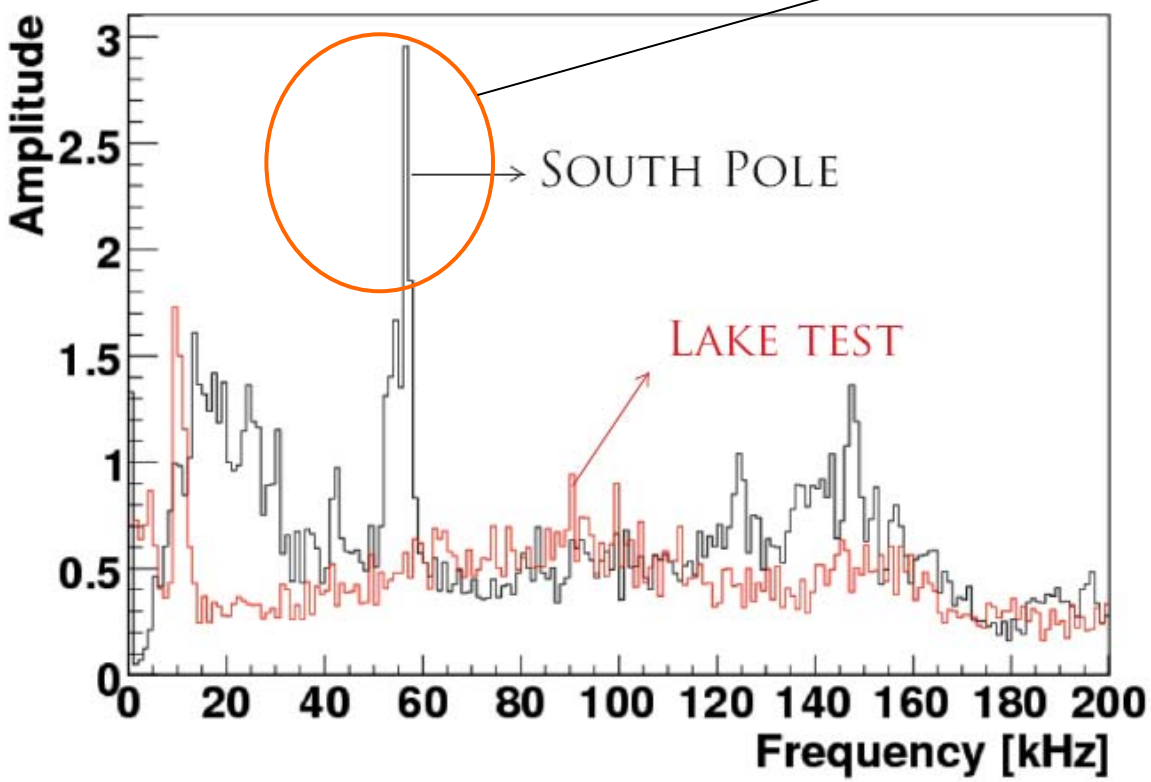

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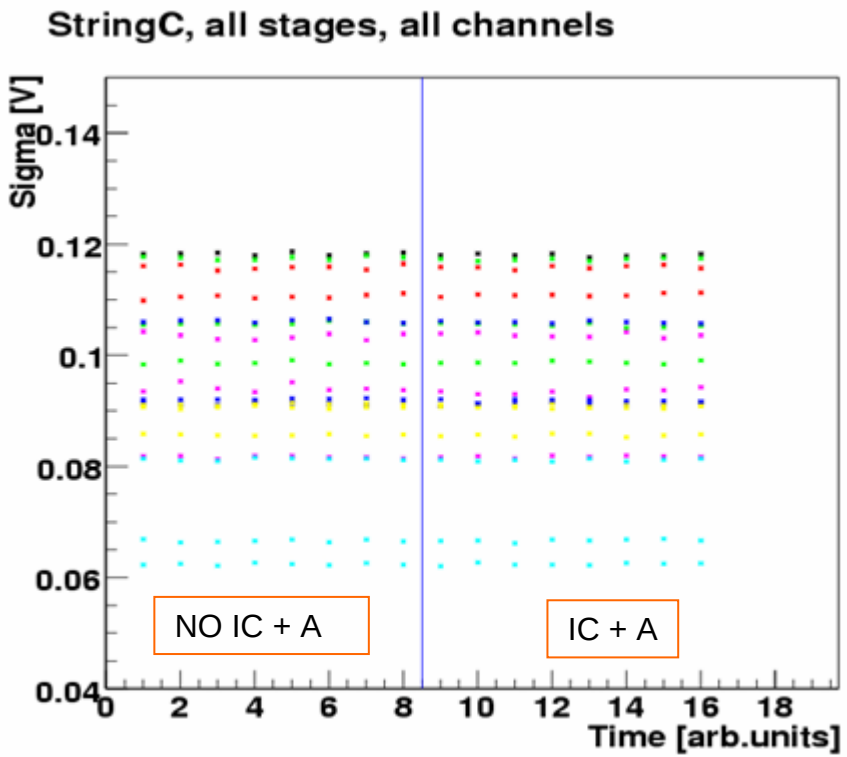
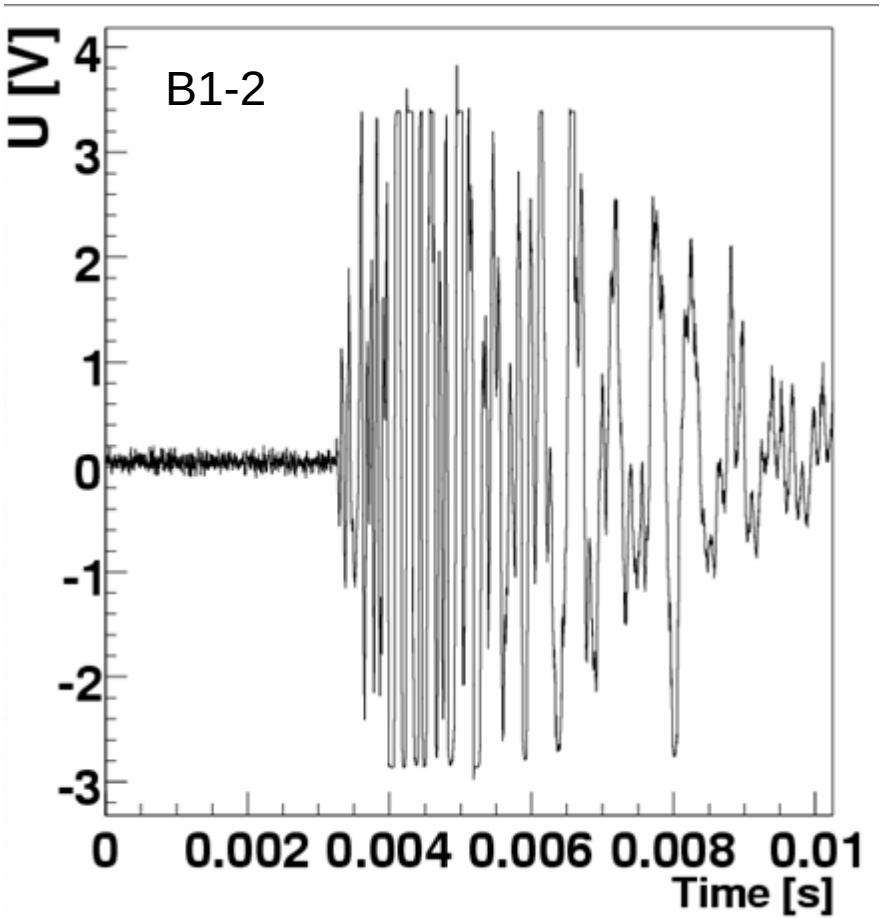


→ **No effect!**

Results

Background noise: Transients

➔ Order of magnitude ~1/minute
➔ Source : unknown (cracking ice, refreezing, ...)

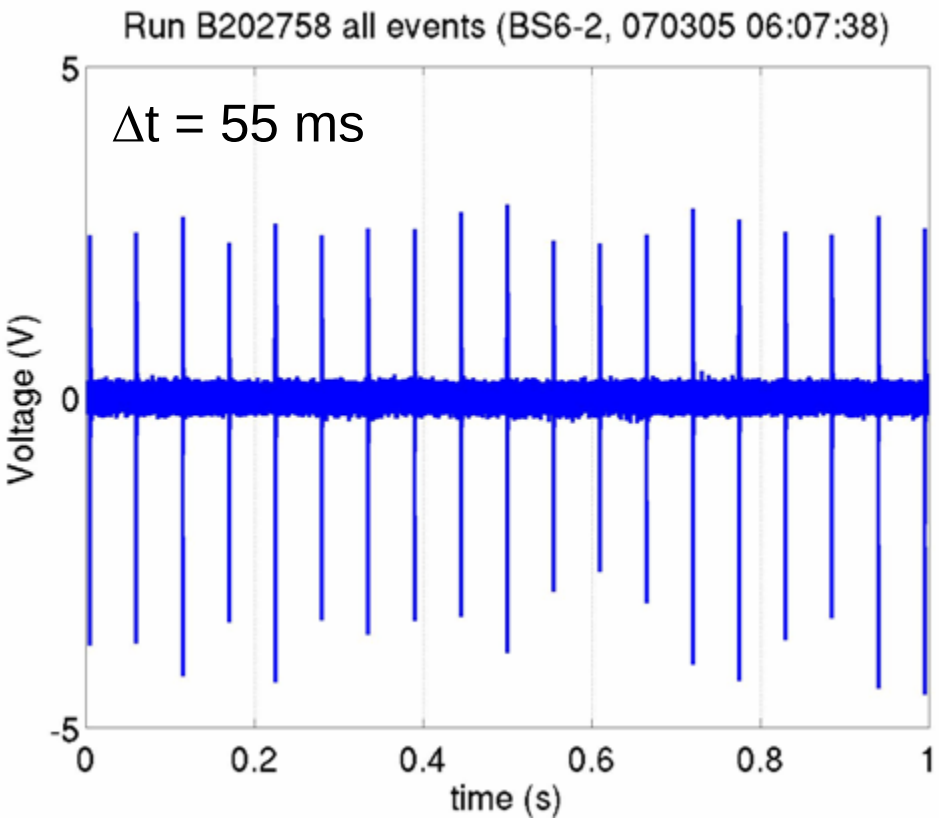


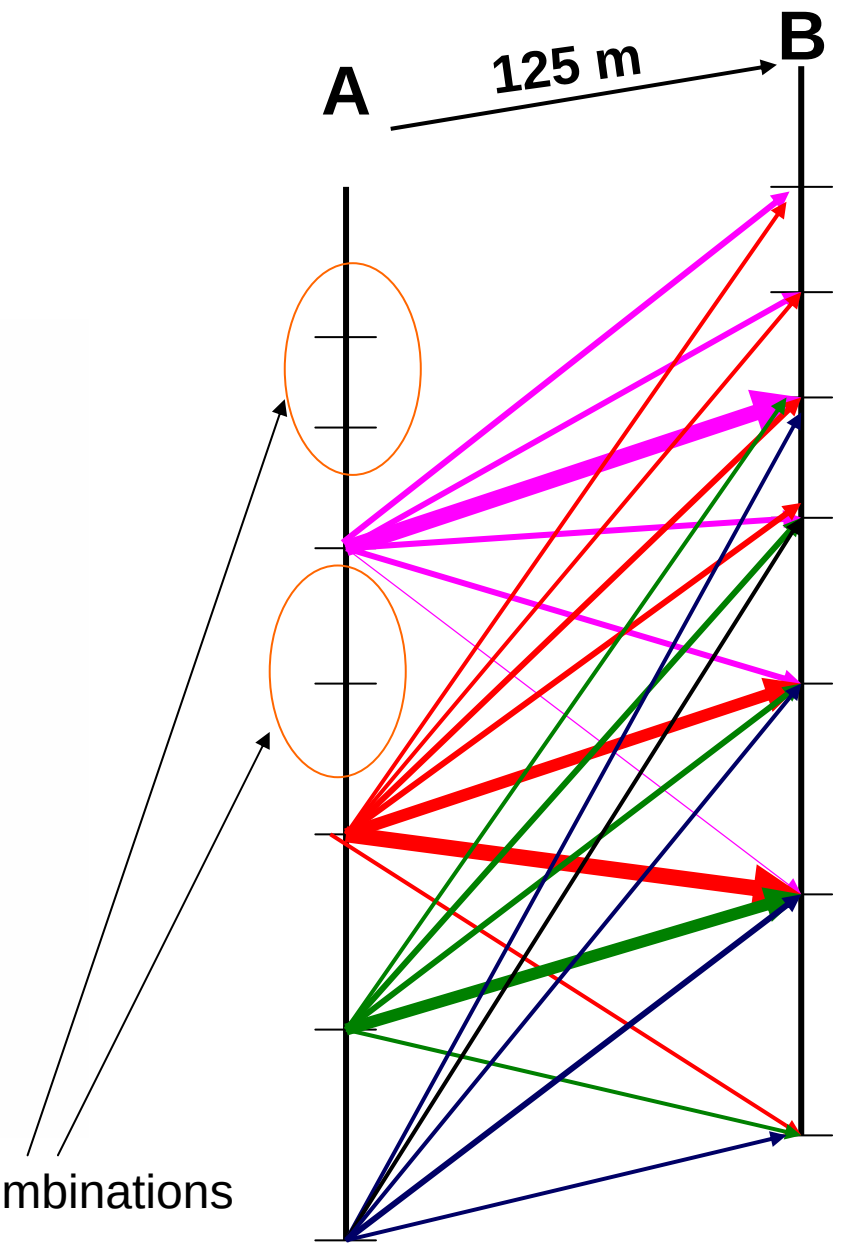
Results

Attenuation length

For attenuation length :
- record inter-string transmitter pulses
- signals are x10 lower than expected

19 pulses from A6 to B6



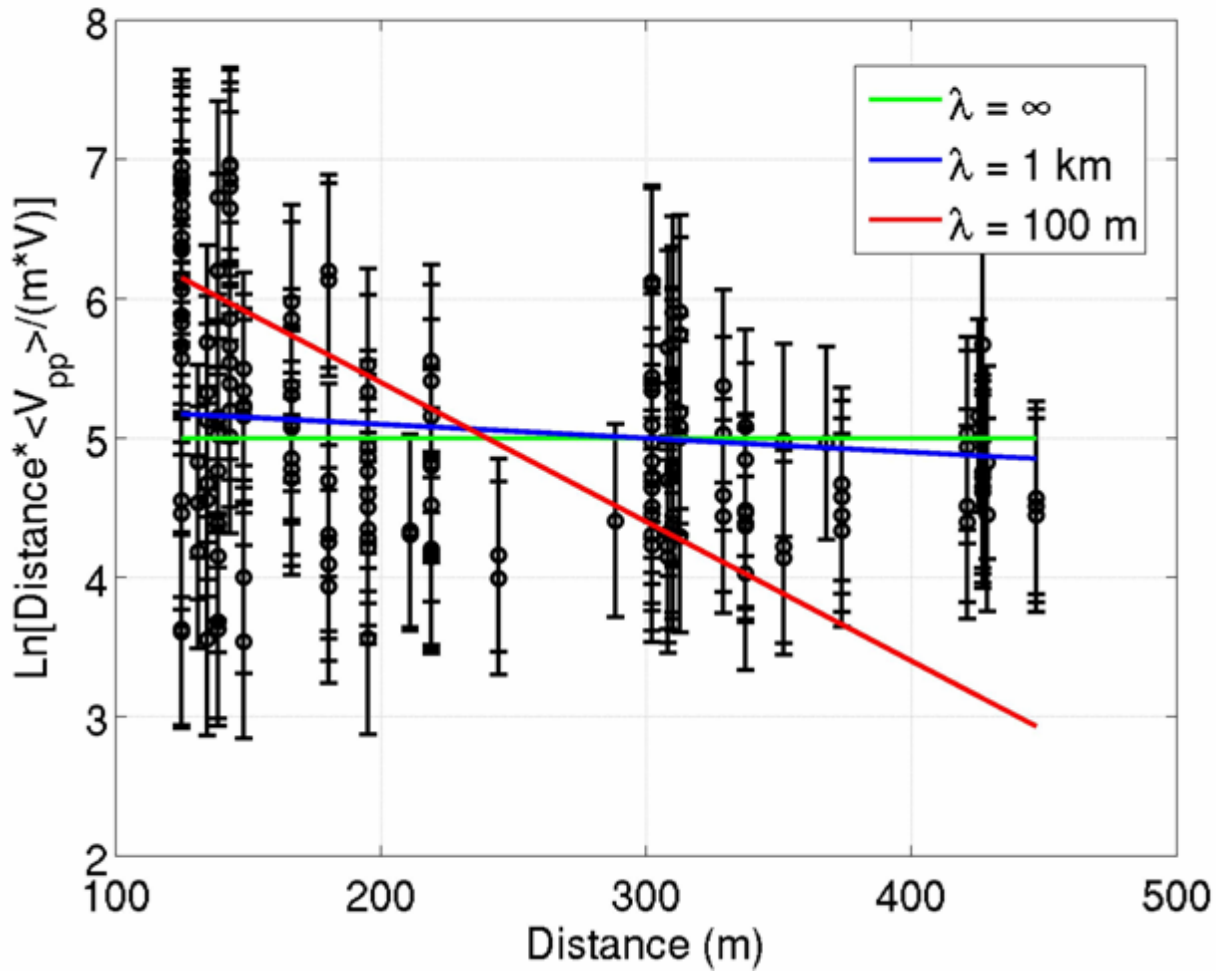


Missing combinations

Results

Attenuation length

Log(amplitude*distance) vs. distance



→ **Many missing combinations due to noise floor or saturation**
Data does not allow attenuation fit yet!

Outlook

Conclusions

➔ **SPATS is in good shape**
➔ **Preliminary results**

NOISE:

- Gaussian background noise is low and stable.
- rate of transient events is low
- spectrum shows interesting features
- not shown: interesting noise vs. time trends

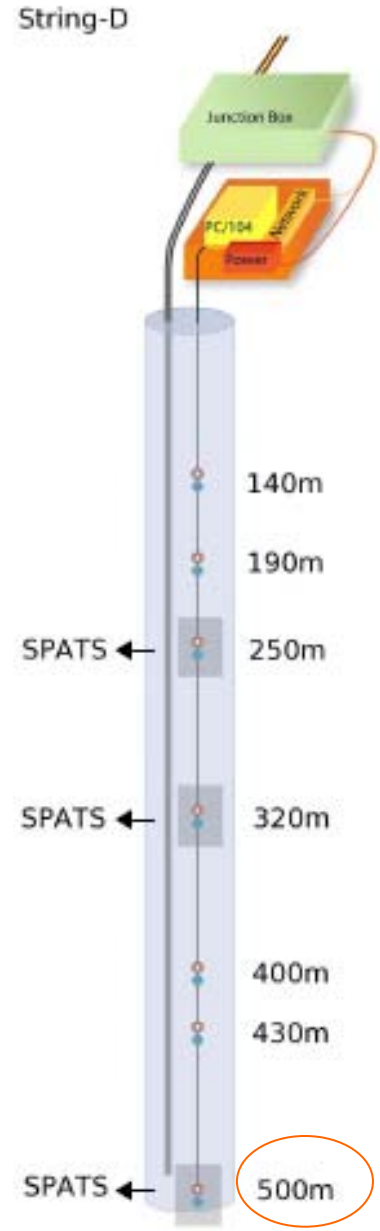
ATTENUATION LENGTH:

- data does not allow fit yet
- implementation of new techniques → more (T,S) combinations
- improved data and analysis under way

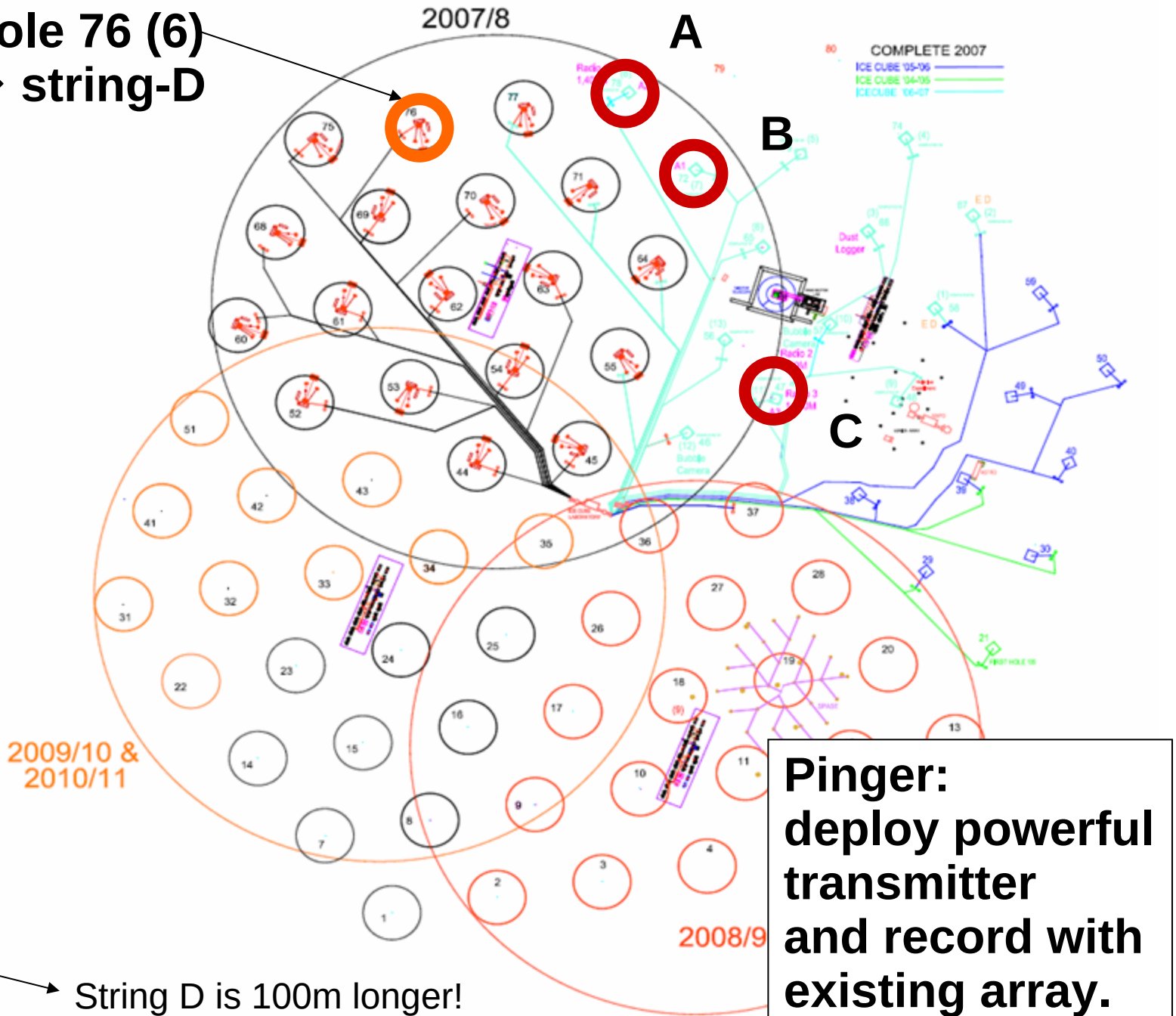
Outlook

- More analysis and results to come (speed of sound, refraction, …)
- 4th string to be deployed in 2007/2008 season

Outlook: String-D and pinger project



Hole 76 (6)
→ string-D



String D is 100m longer!

Pinger:
deploy powerful transmitter and record with existing array.

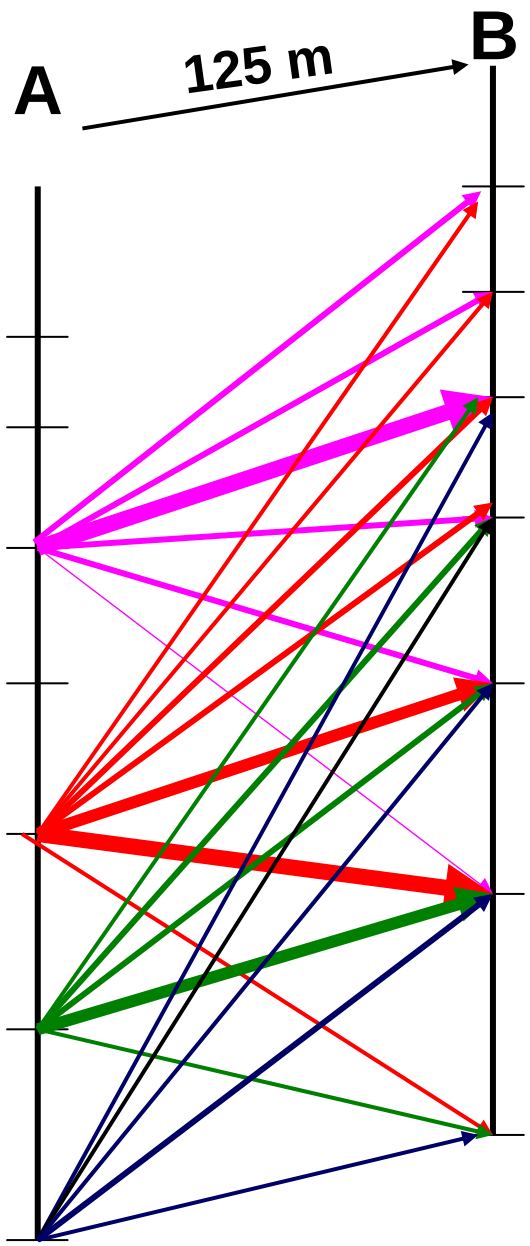
SOUND OF SPATS TRANSMITTERS IN ICE @ 18Hz (10x slower) :

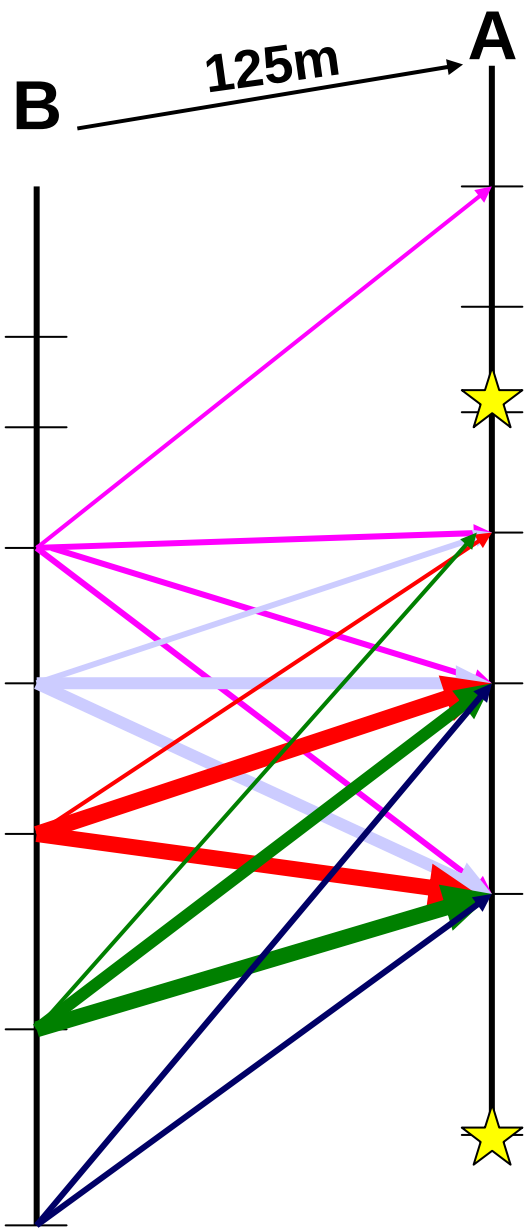
THANK YOU... QUESTIONS?

BACKUP SLIDES

Preliminary Results

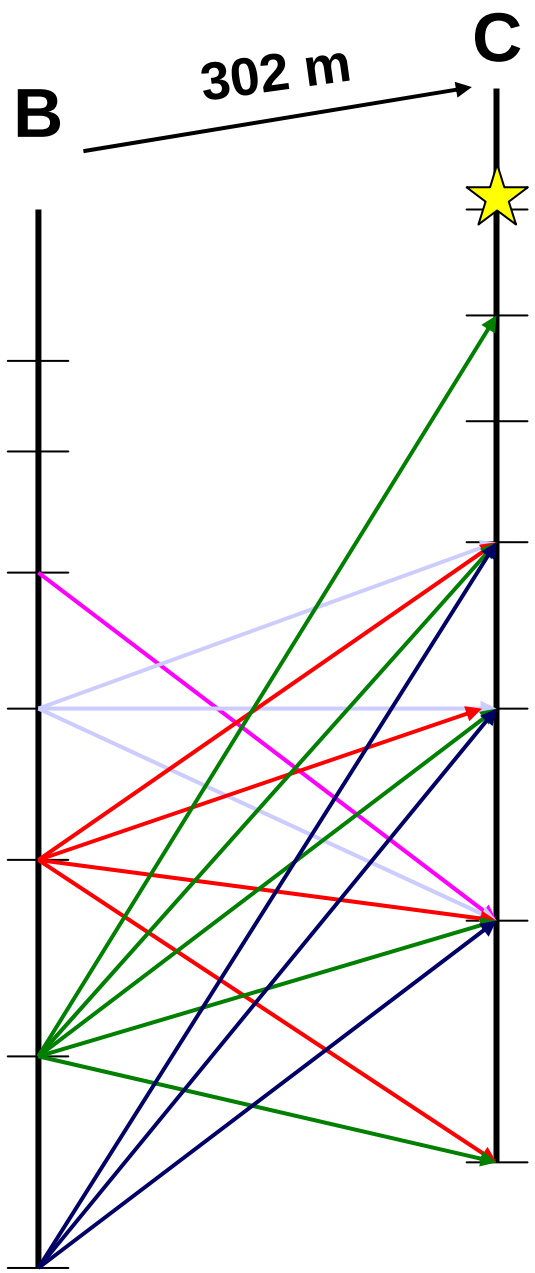
Shortest baseline

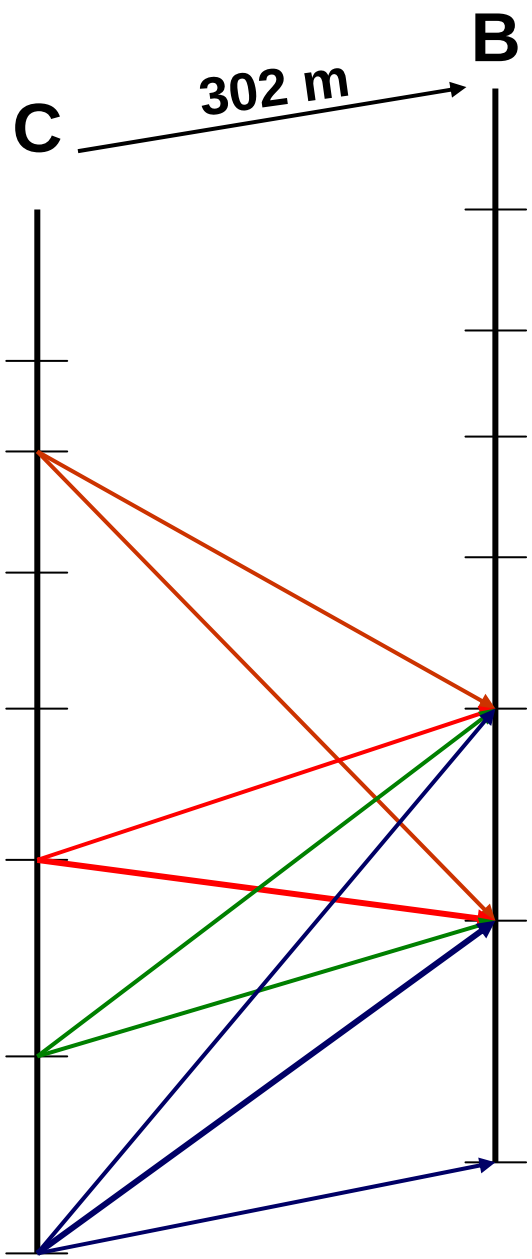




Preliminary Results

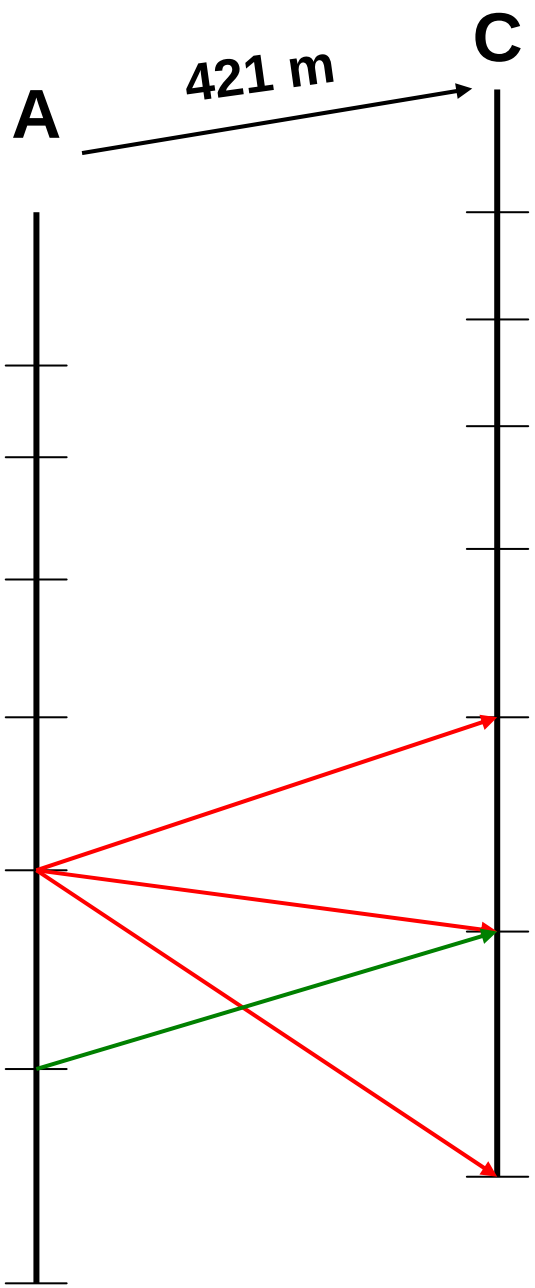
Intermediate baseline

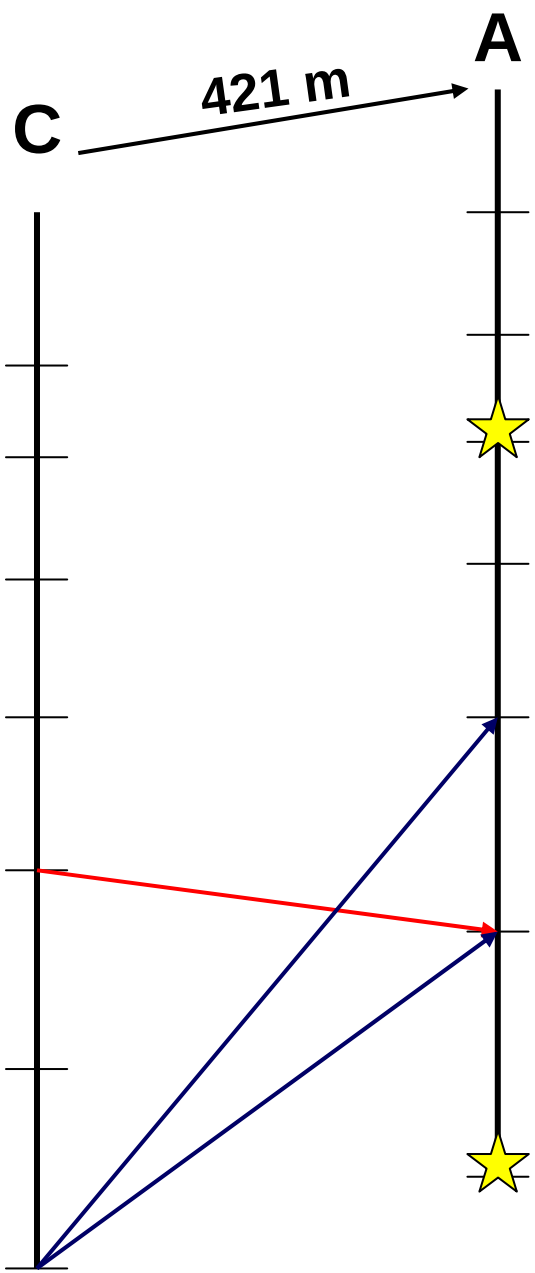




Preliminary Results

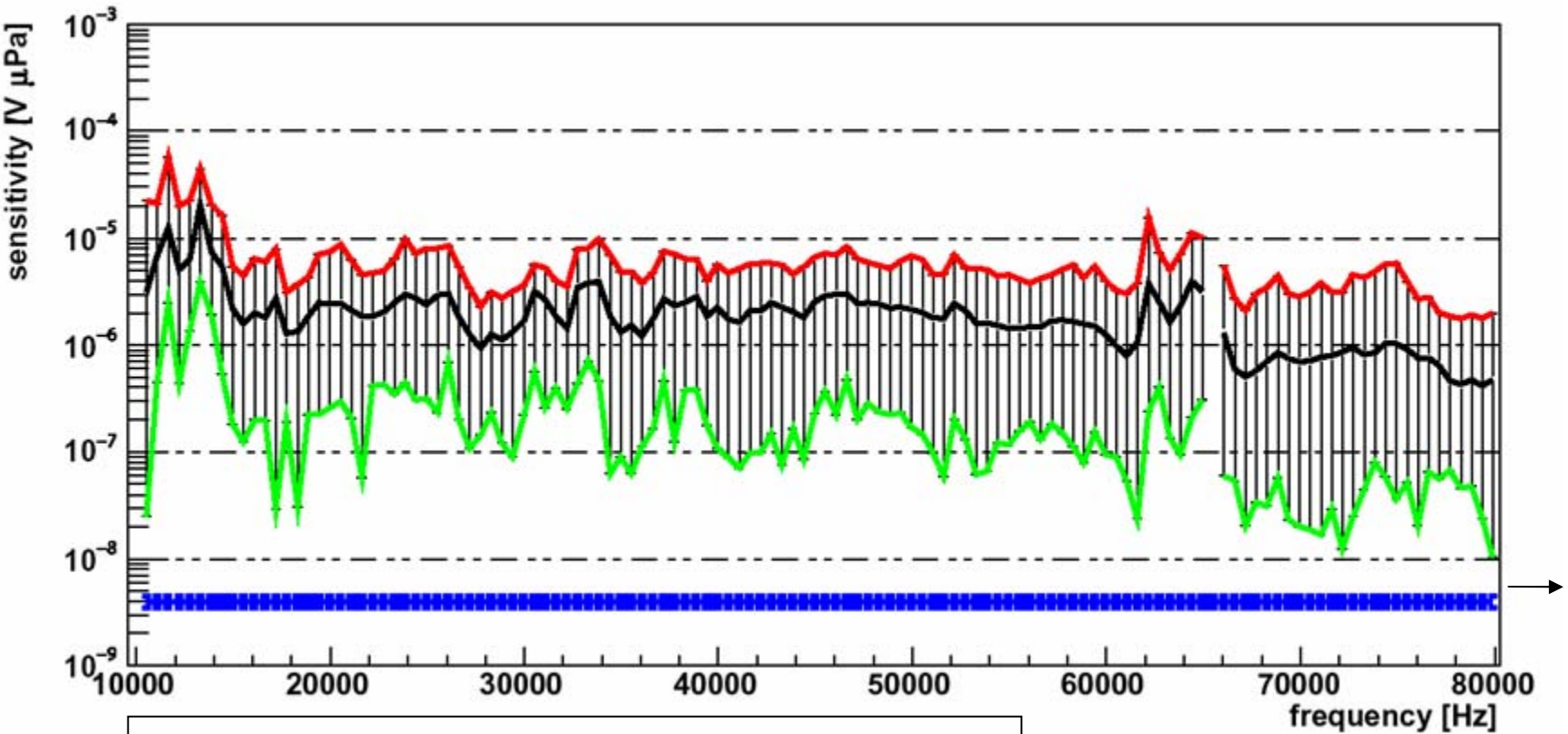
Longest baseline





Results: overview for all sensors

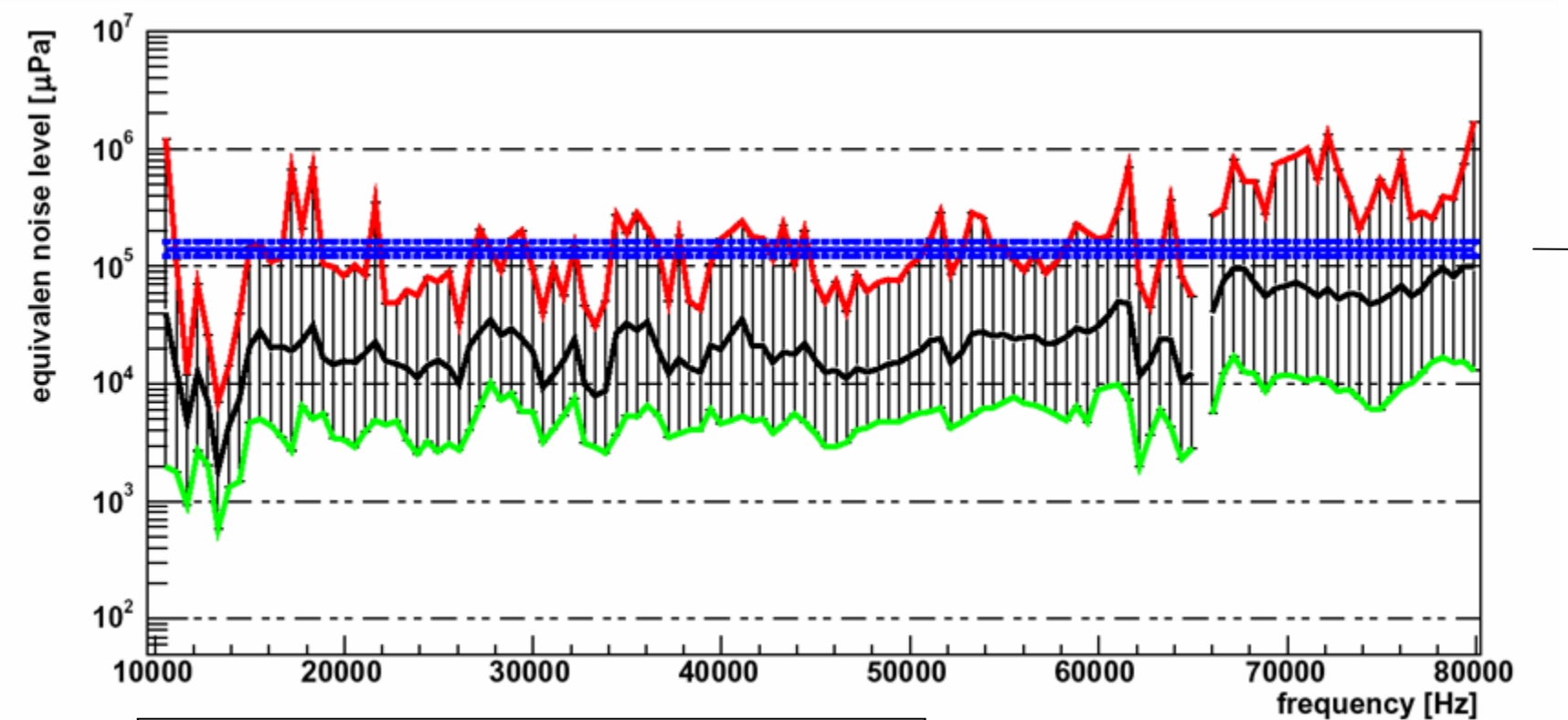
I) Absolute sensitivity range for all sensors [dB re V/mPa]



Effective detection threshold
- Not determined by sensitivity
- Most important is signal to noise

Results: overview for all sensors

II) Equivalent noise level [mPa] for each sensor module and all channels

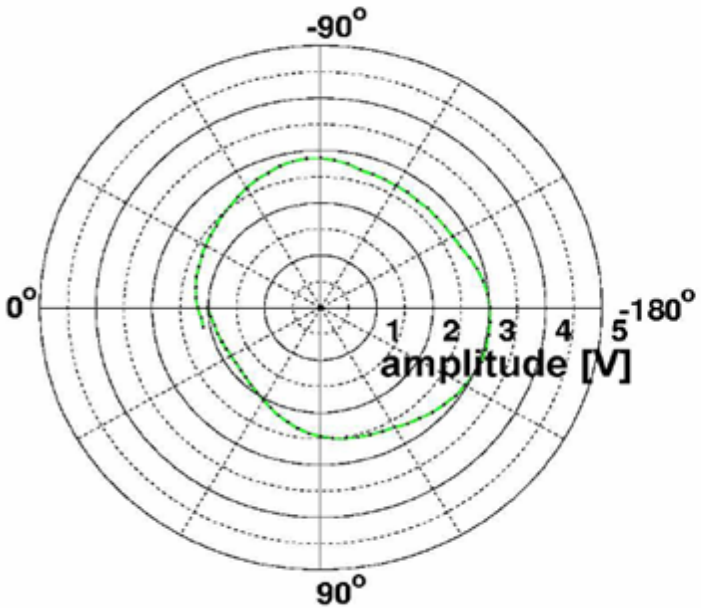


Equivalent self noise level
- Different for each sensor
- For most modules < 30mPa
- Hydrophone: 150mPa

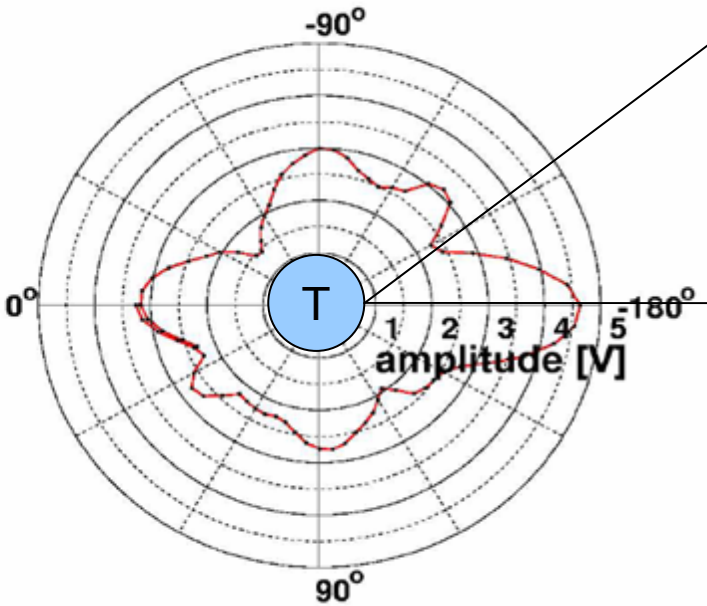
Preliminary Results

Attenuation length: results

azimuthal



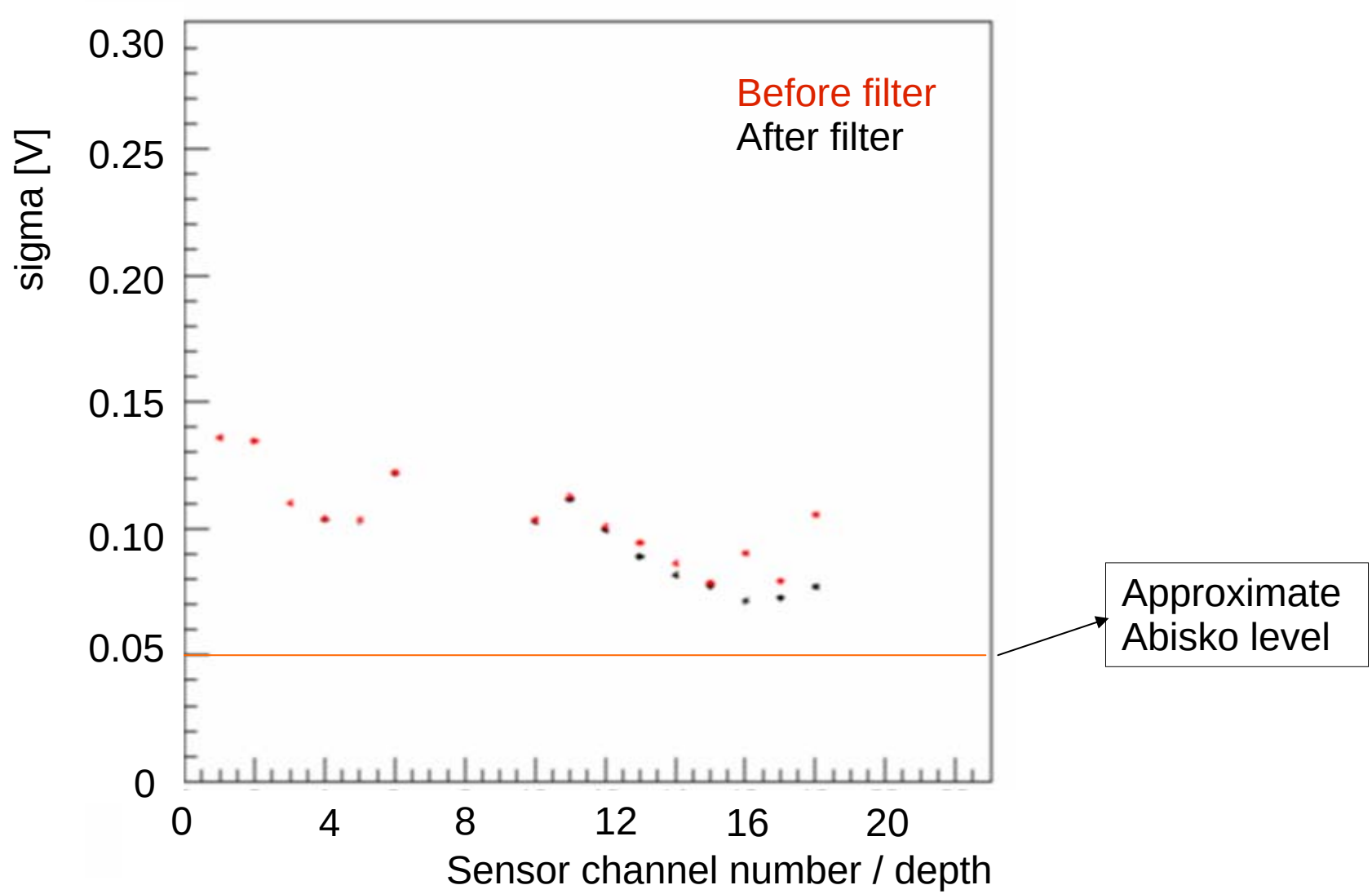
polar



Preliminary Results

Background noise

STRING A

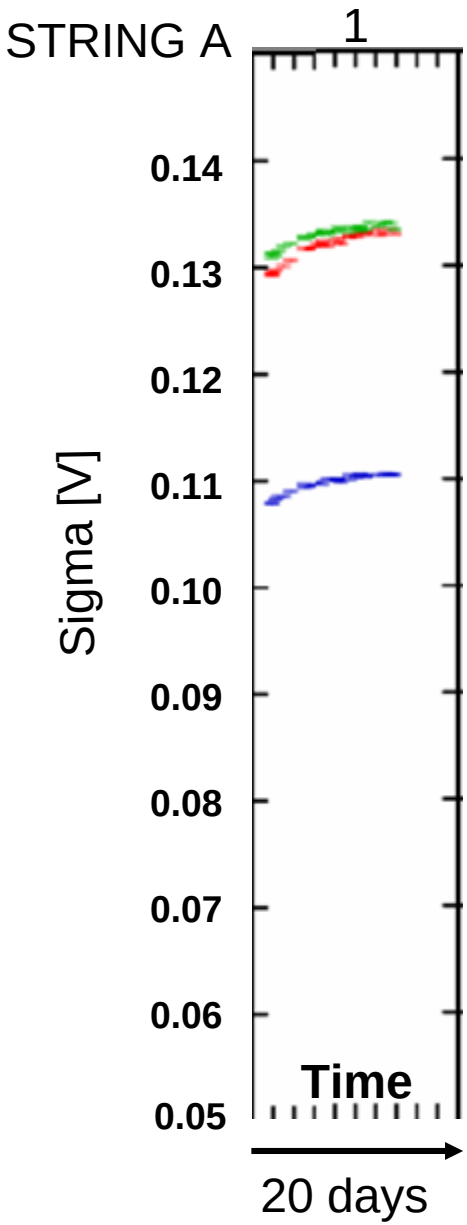


➔ **Filtering does not have a big effect**

➔ **Downward trend as we go deeper in the ice?**

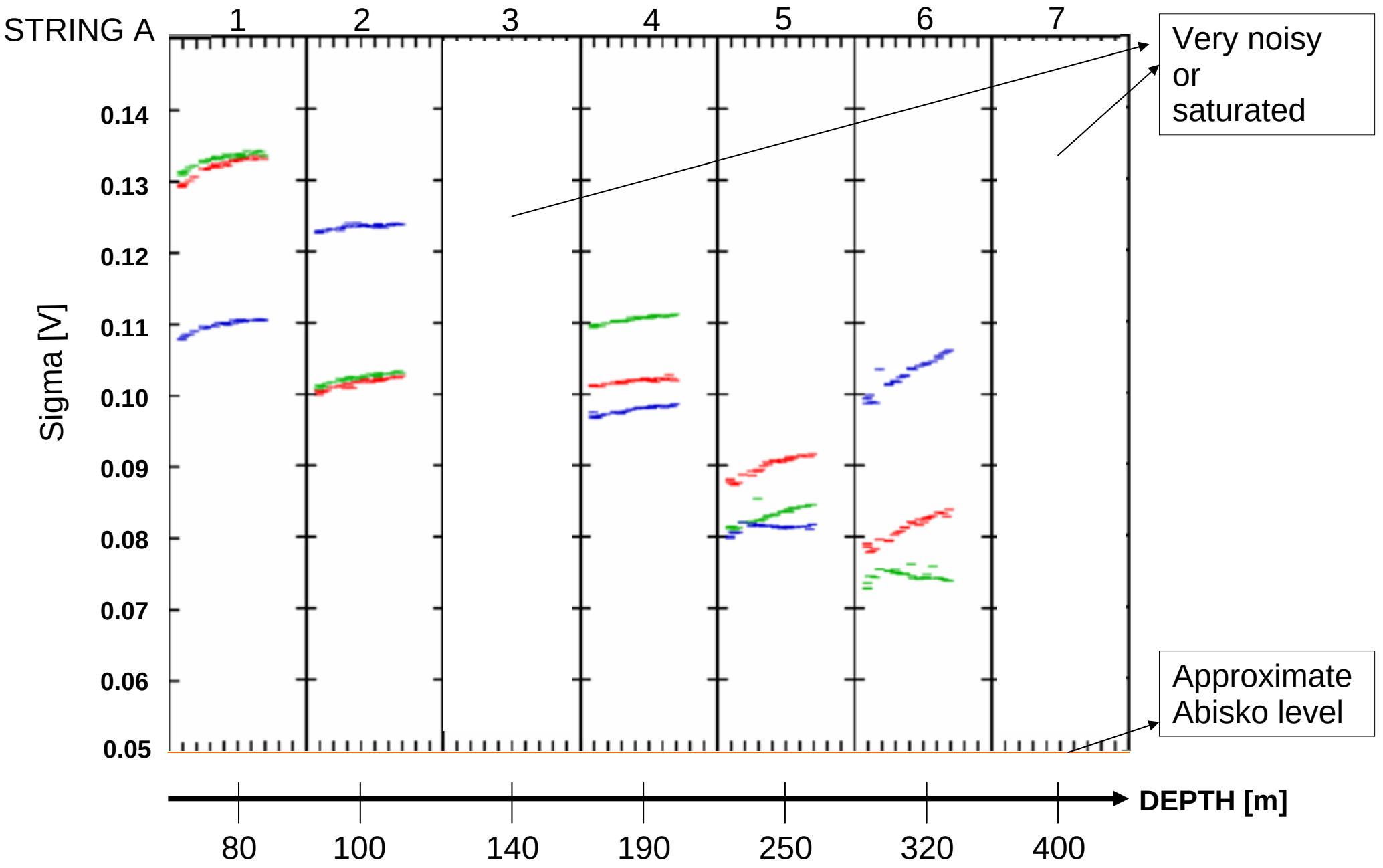
Preliminary Results

Background noise: evolution in time

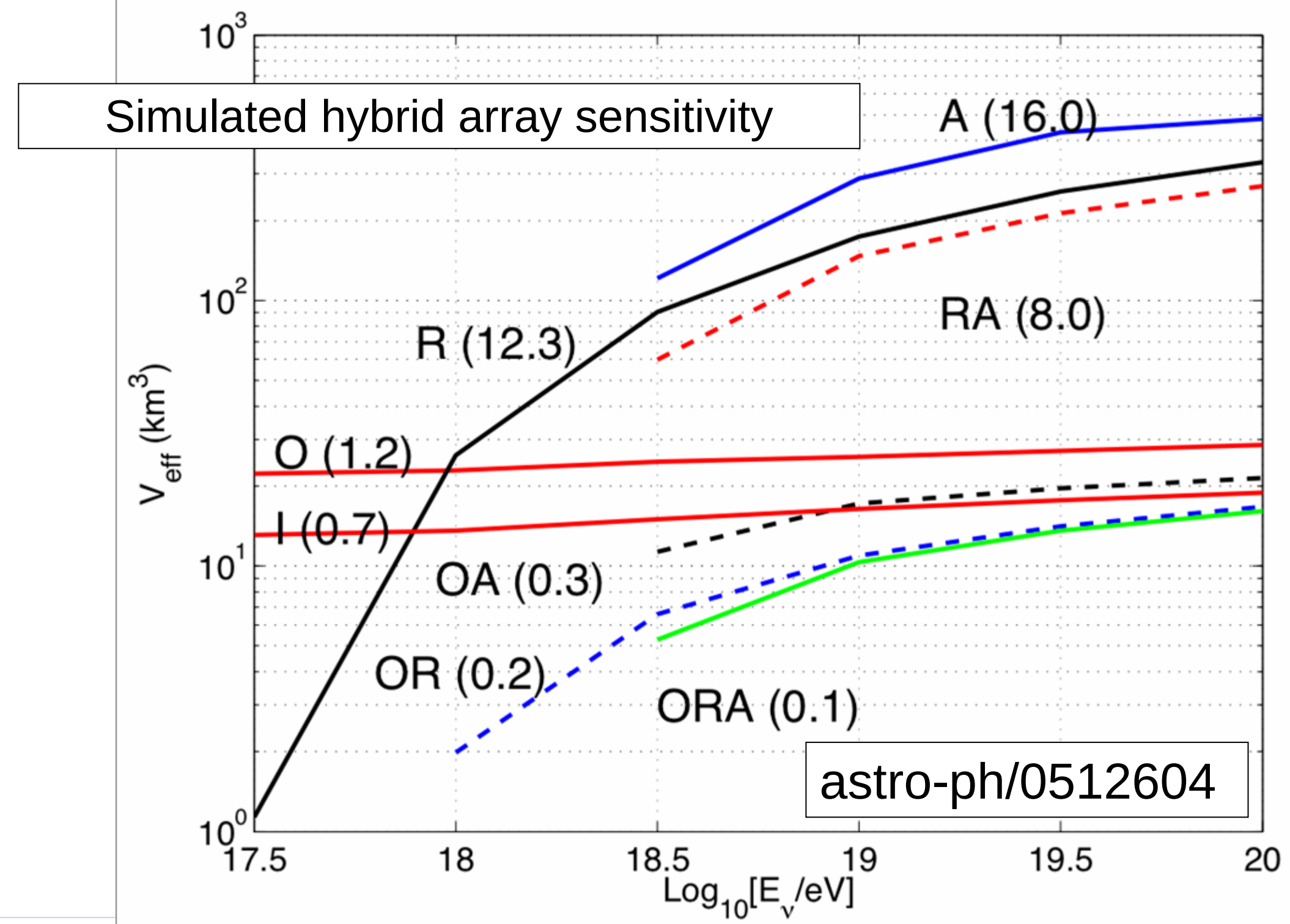


Preliminary Results

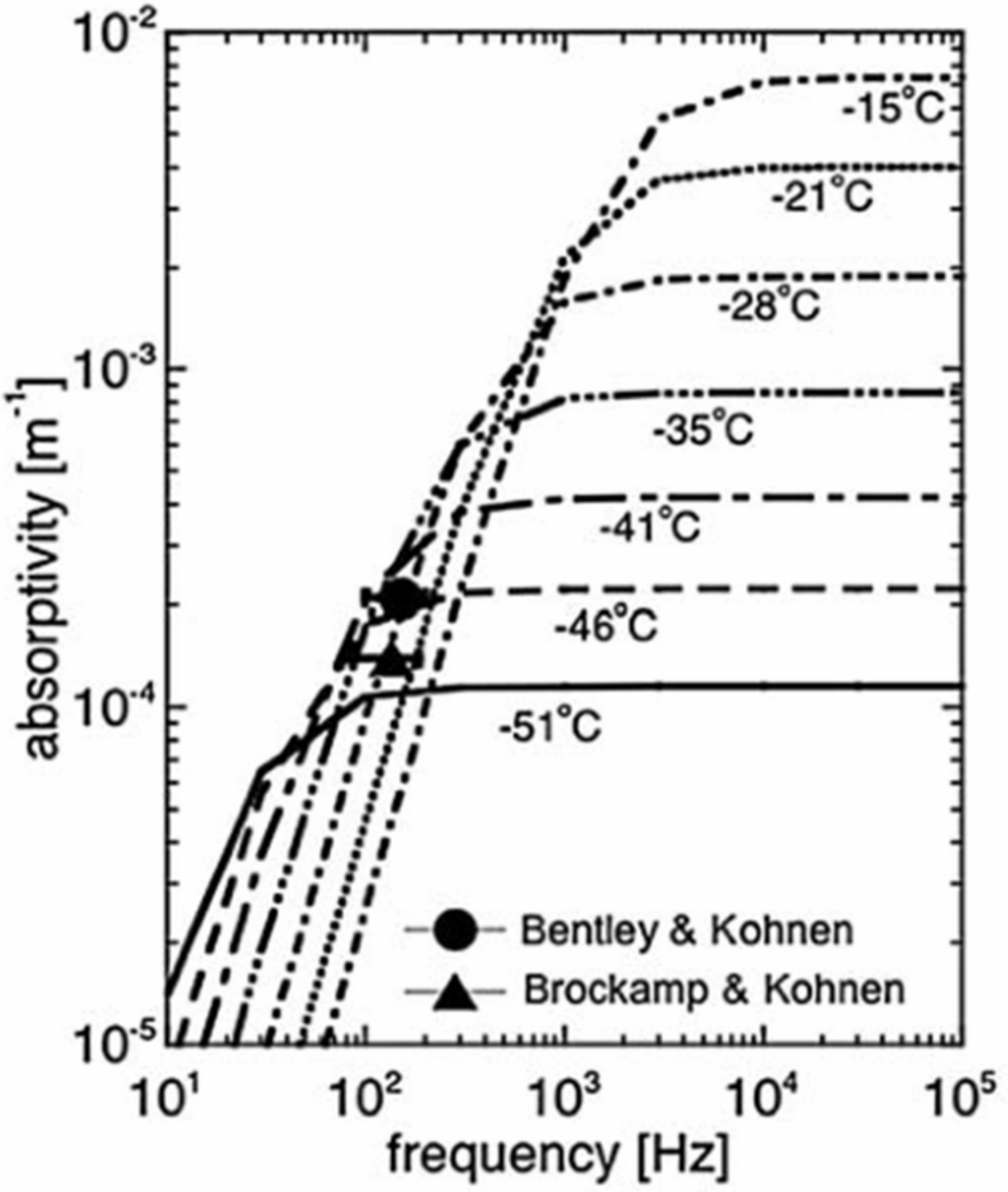
Background noise: evolution in time and space



Simulated hybrid array sensitivity



Theoretical attenuation vs. frequency (P. B. Price 2006)



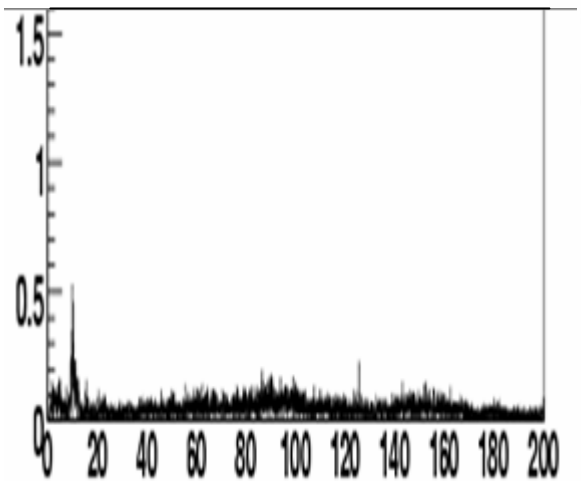
Results

Background noise: Gaussian noise level: overview

Previous tests:

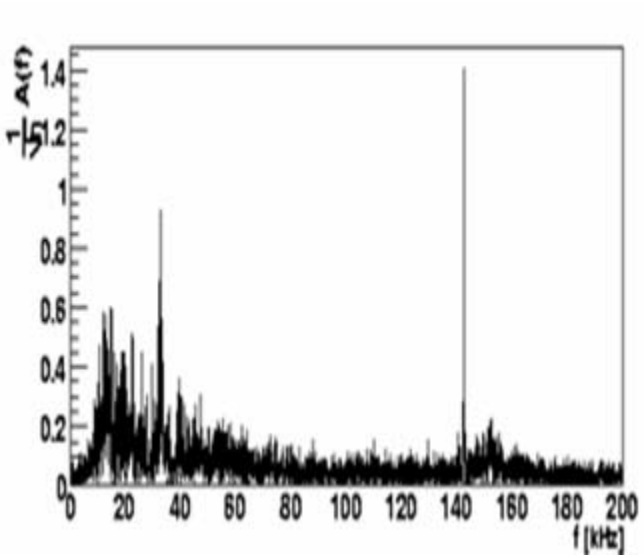
WATER

Abisko lake test:



ICE

Ghent freezer test:



AIR

SP pre-deployment test: