ARENA 2008 Conference Summary (Acoustic)

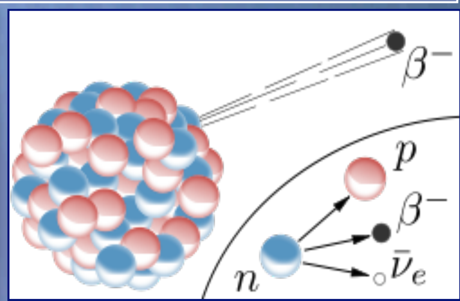
Lee Thompson
University of Sheffield

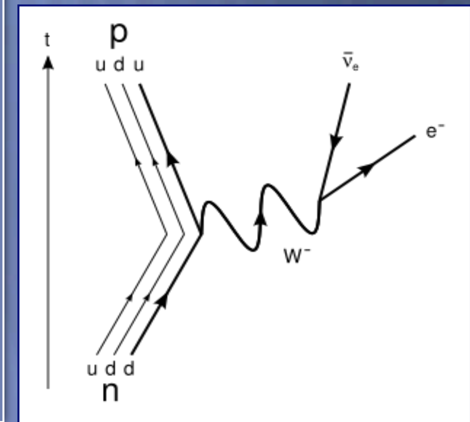
Universita di Roma - "La Sapienza"
June 27th 2008

“I ragazzi di Via Panisperna”

Edoardo Amaldi, Emilio Segrè, Franco Rasetti, Ettore Majorana, Enrico Fermi, Bruno Pontecorvo

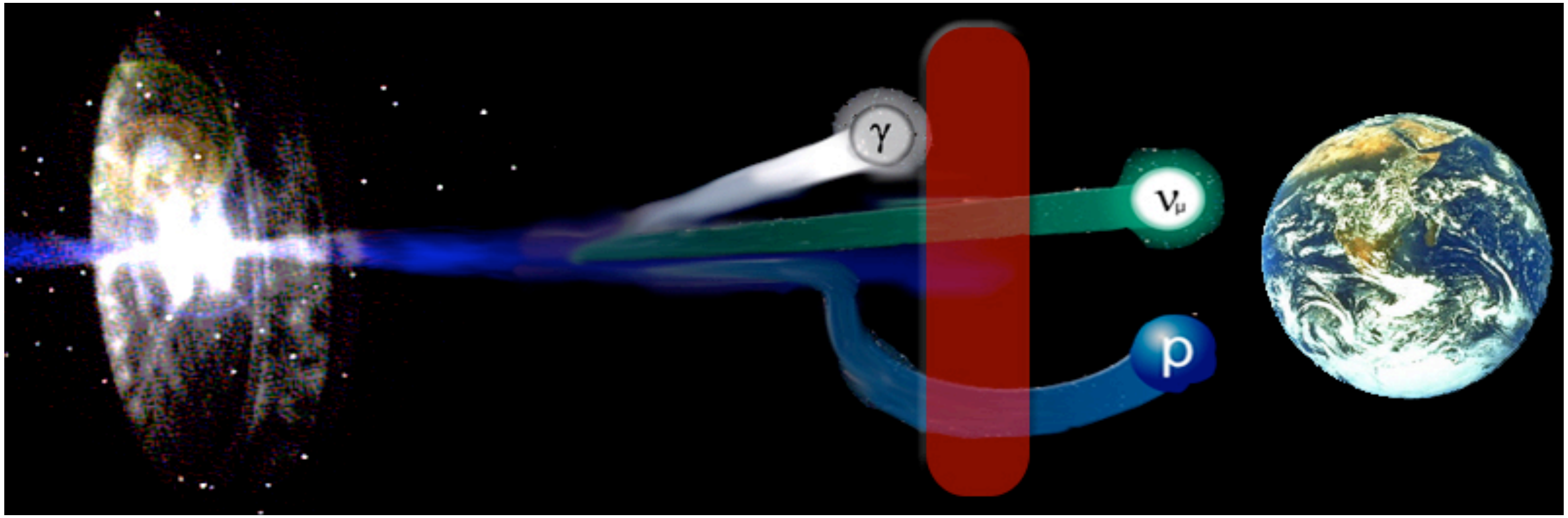
- Fermi: 1939 Nobel Prize for Physics: "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons"
- Segrè: 1959 Nobel Prize for Physics: discovery of the anti-proton





- *“There are many categories of scientists, people of second and third rank, who do their best, but do not go very far. There are also people of first class, who make great discoveries, fundamental for the development of science. But then there are the geniuses, like Galilei and Newton. Well, Ettore Majorana was one of them …”* (Enrico Fermi on Ettore Majorana)

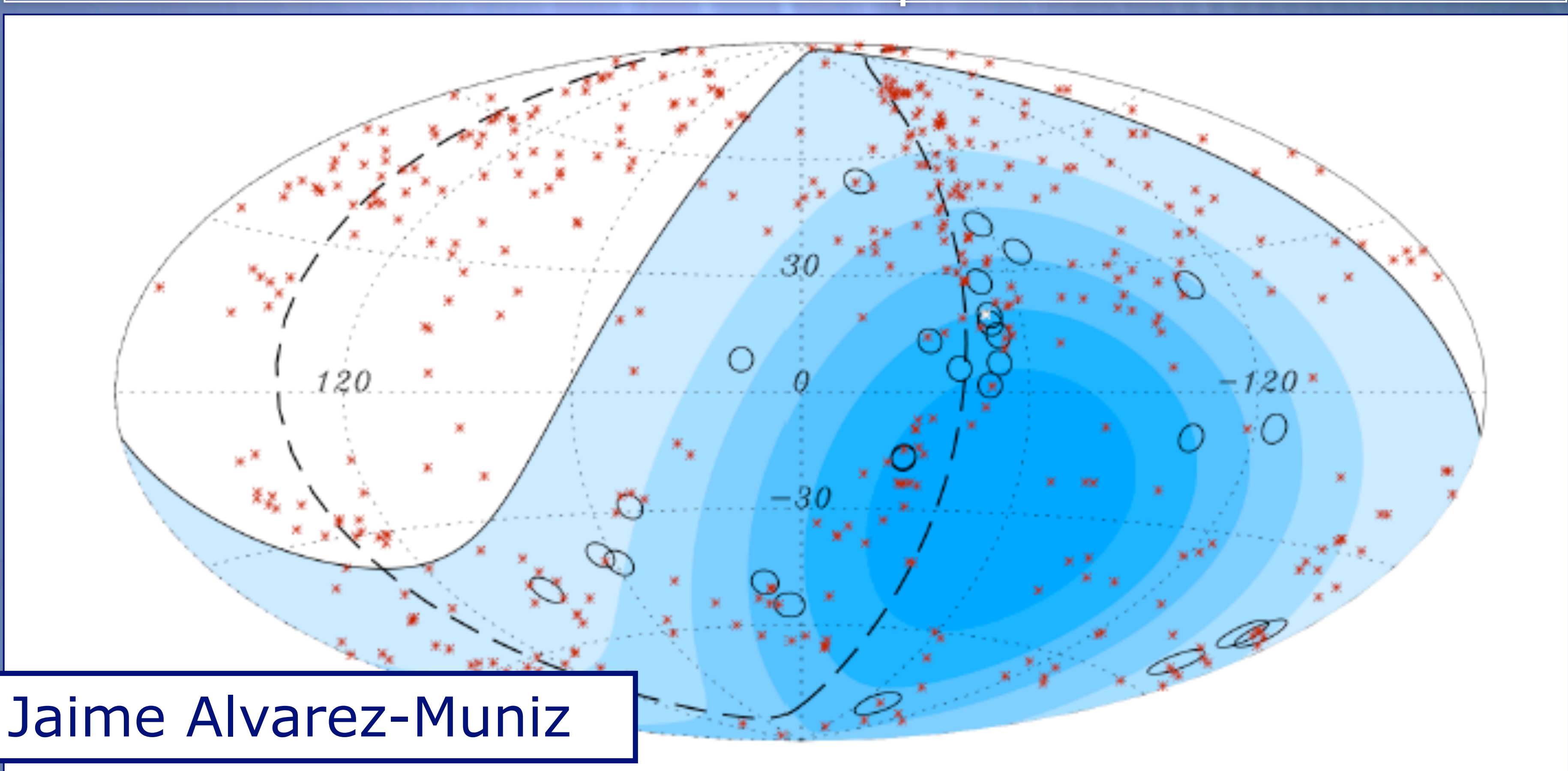
Why look for neutrinos?



- Neutrinos open up a "new window on the Universe"
  - *Photons are absorbed in interactions with the interstellar medium (PeV γ-ray - microwave bkgd, TeV γ -ray - IR/optical bkgd)*
  - Charged particles may be deviated in (extra-)galactic magnetic fields - loss of information on astrophysical source
- *Neutrinos form a powerful probe of the Universe even at large redshifts*

AUGER and AGN

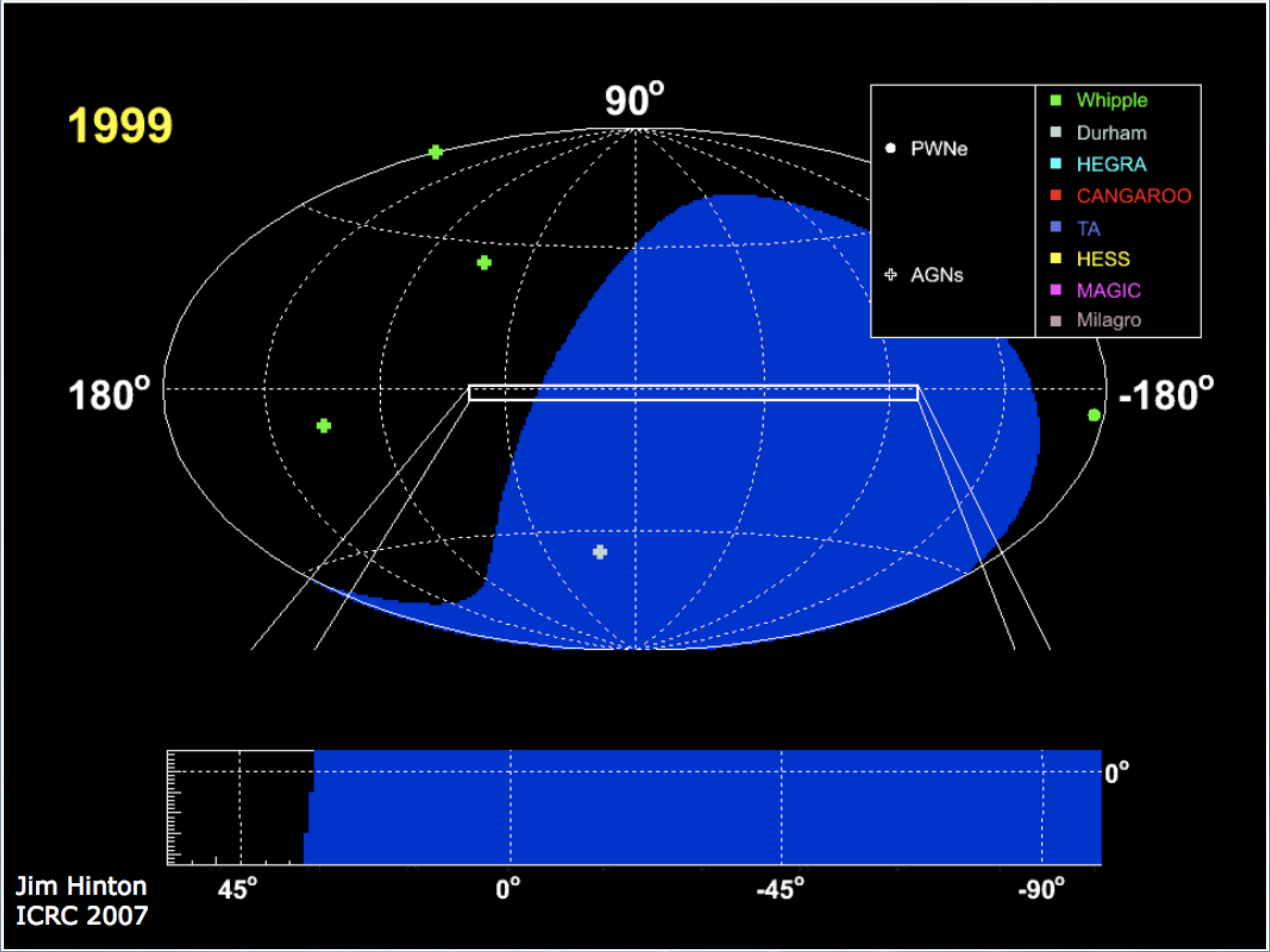
- 2007 AUGER Science paper correlates 20 out of 27 UHE events with known AGN positions



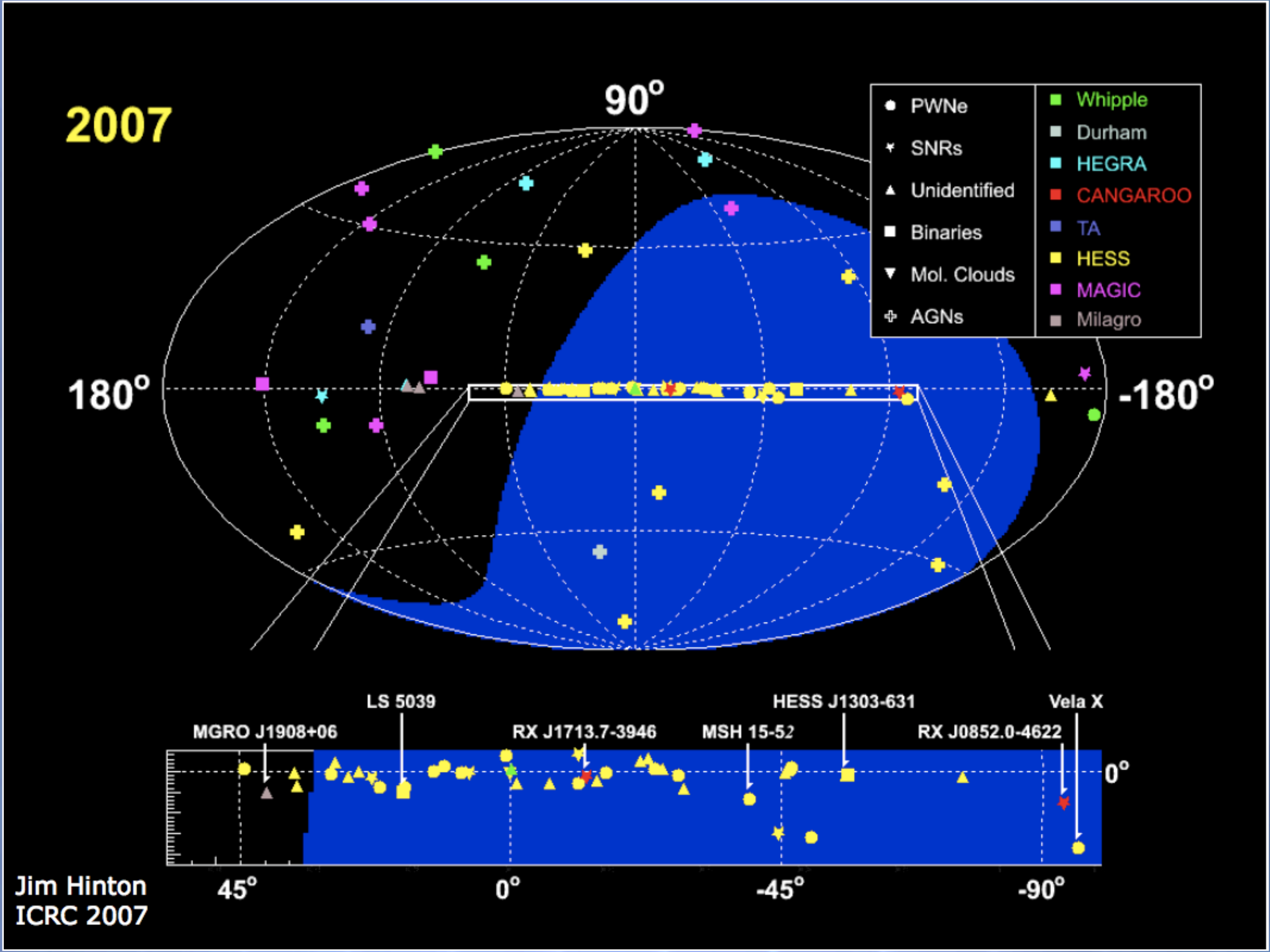
Jaime Alvarez-Muniz

- Note: no assertion here that AGN are the source of UHECR

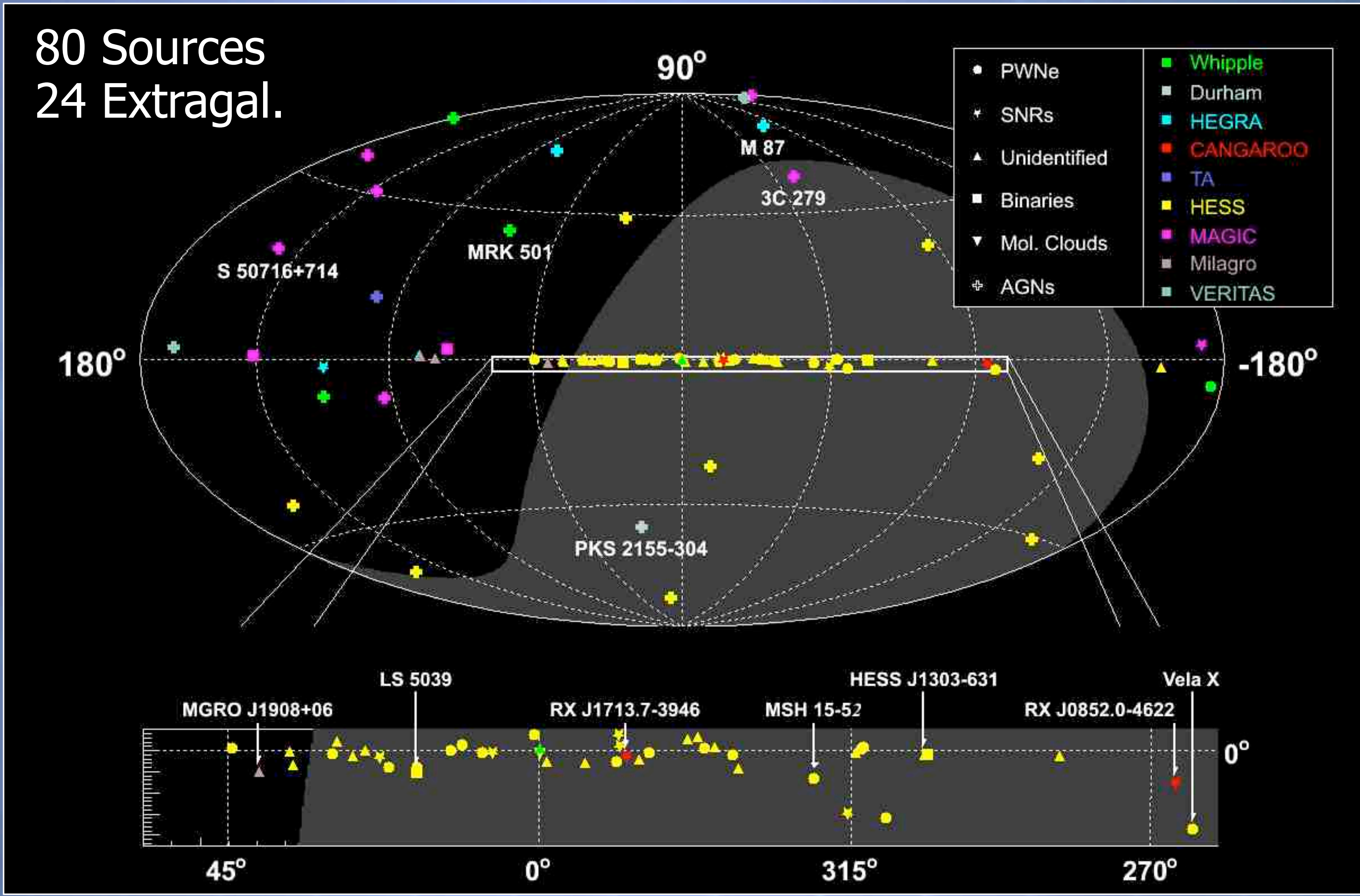
High energy γ ray sources '99



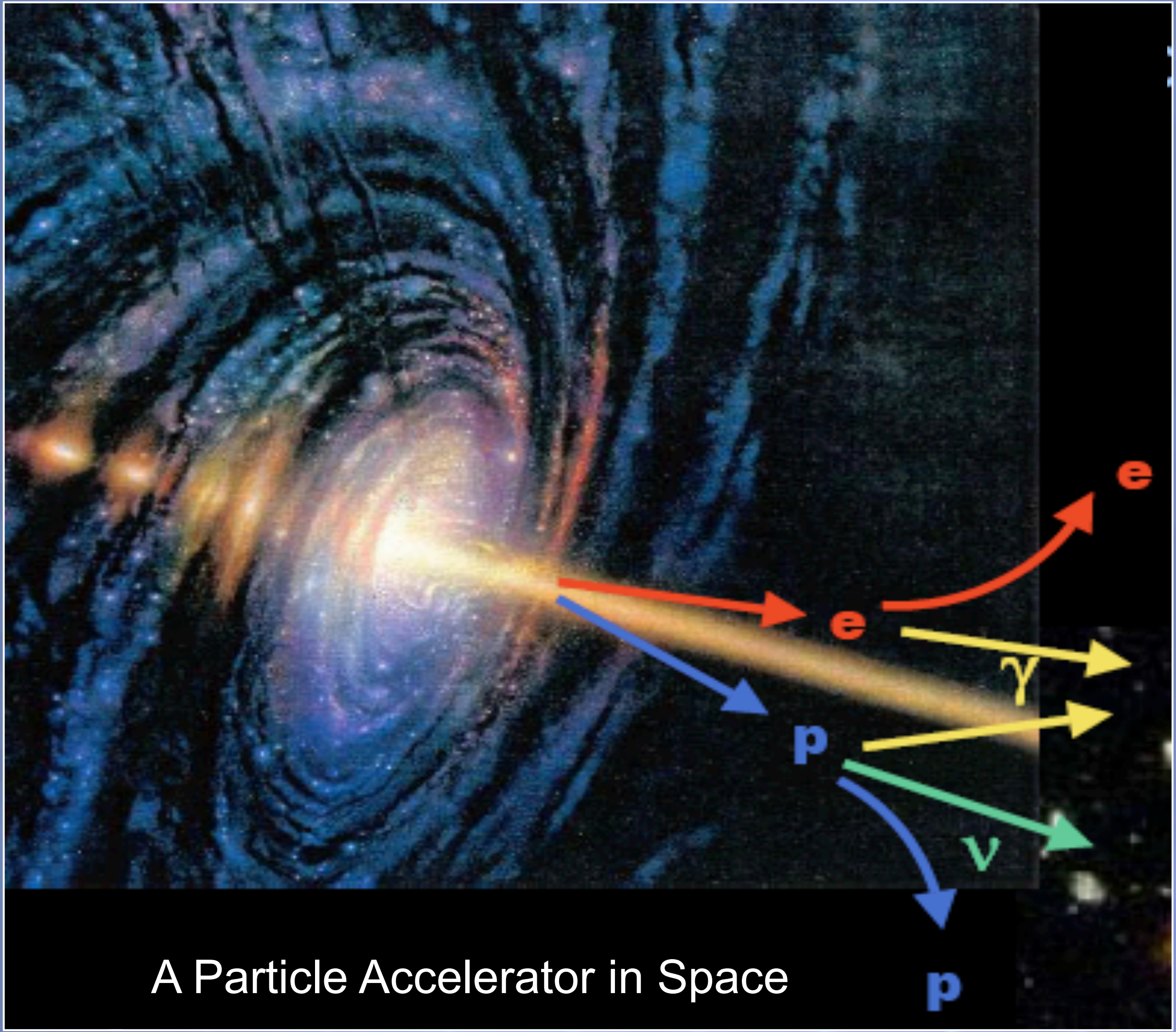
High energy γ ray sources '07



HE γ-ray sources 2008



High energy γ ray sources '07



71 sources:

- 7 SNR
- 18 PWN
- 21 Un.Gal.
- 2 Diffuse
- 4 Binary
- 19 AGN
- 3 in Gal. plane have <u>no</u> counterparts

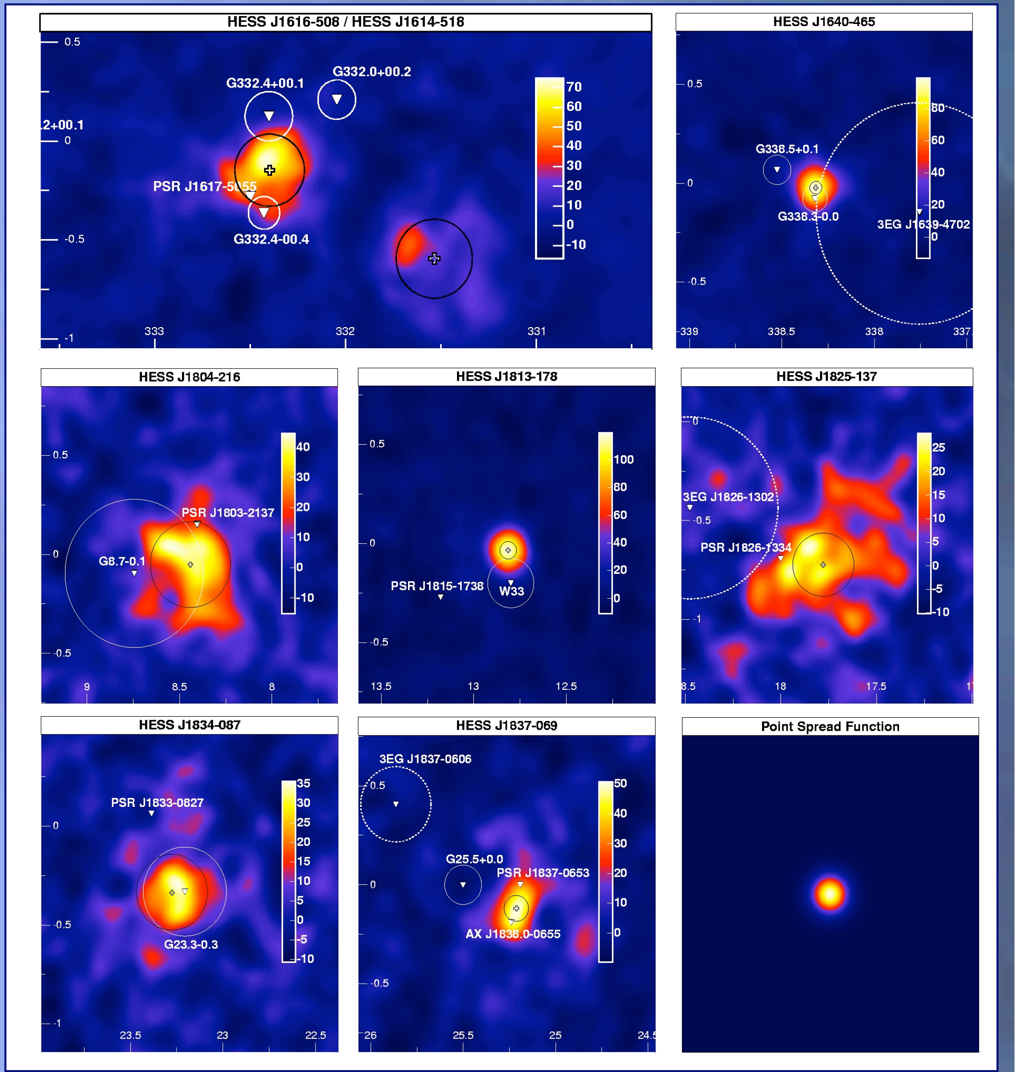
- Each of these sources is a high energy cosmic accelerator of primary electrons or nuclei

HESS Unidentified Sources

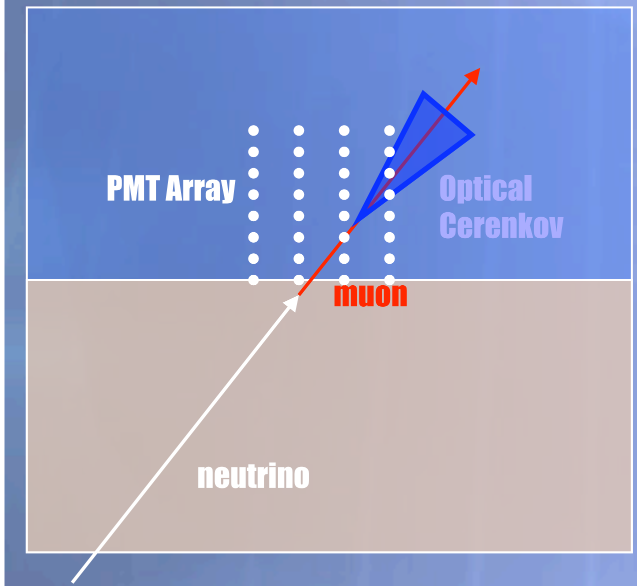
Dark accelerators?

- 'Significant fluxes of VHE γ-rays without accompanying x-ray and radio emission suggest absence of relativistic electrons and the presence of energetic nucleons'
- Aharonian et al. astro-ph/0510397

- **Completely hidden (neutrino only) sources?**
  - Young SN shell
  - Thorne-Zytkow stars
  - Cocooned massive black hole
  - AGN with standing shock
  - pre AGN
- Berezinsky, Dokuchaev astro-ph/0002274



HE Neutrino Detection Methods



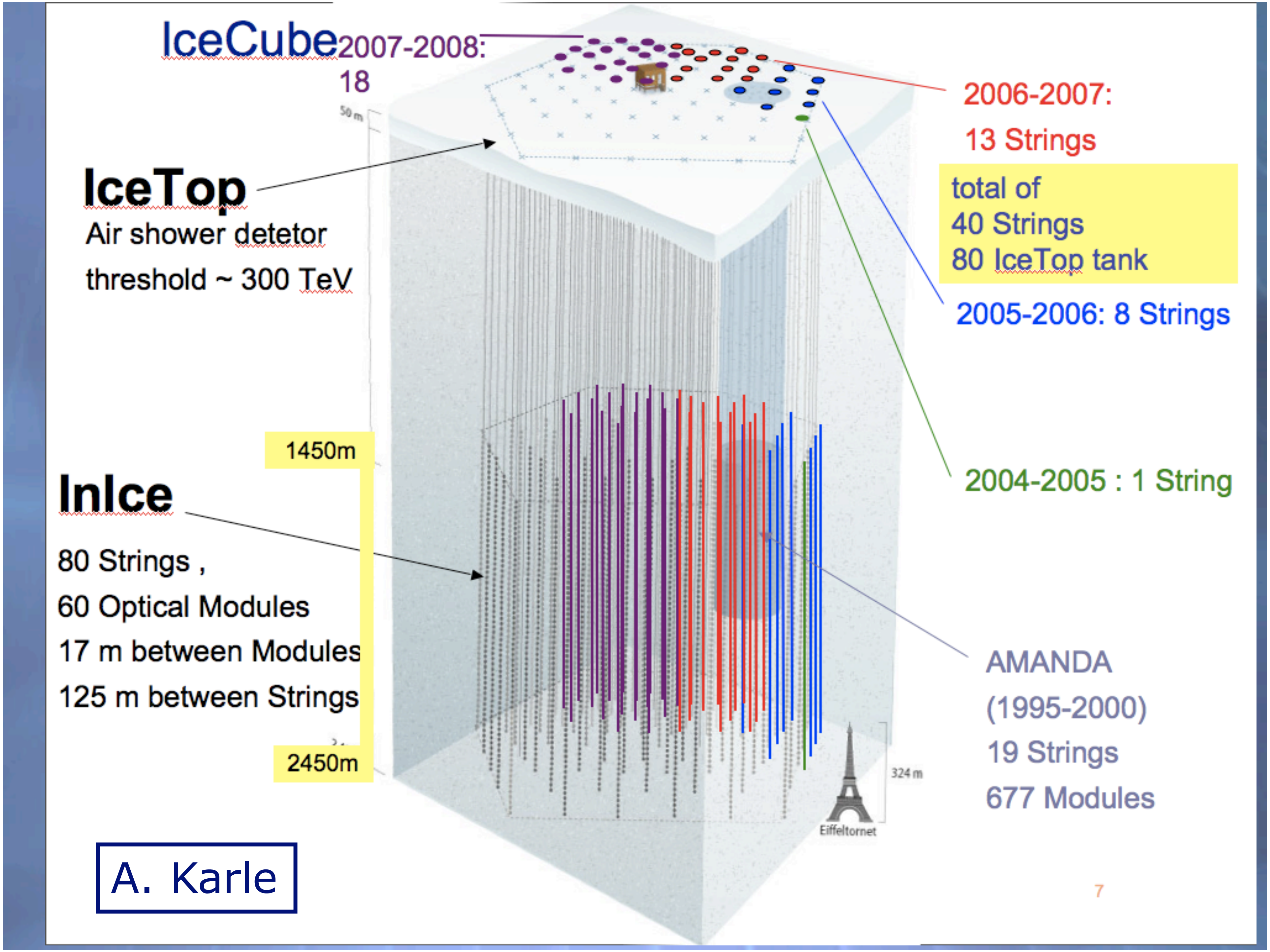
Optical Cerenkov

Works well in water, ice

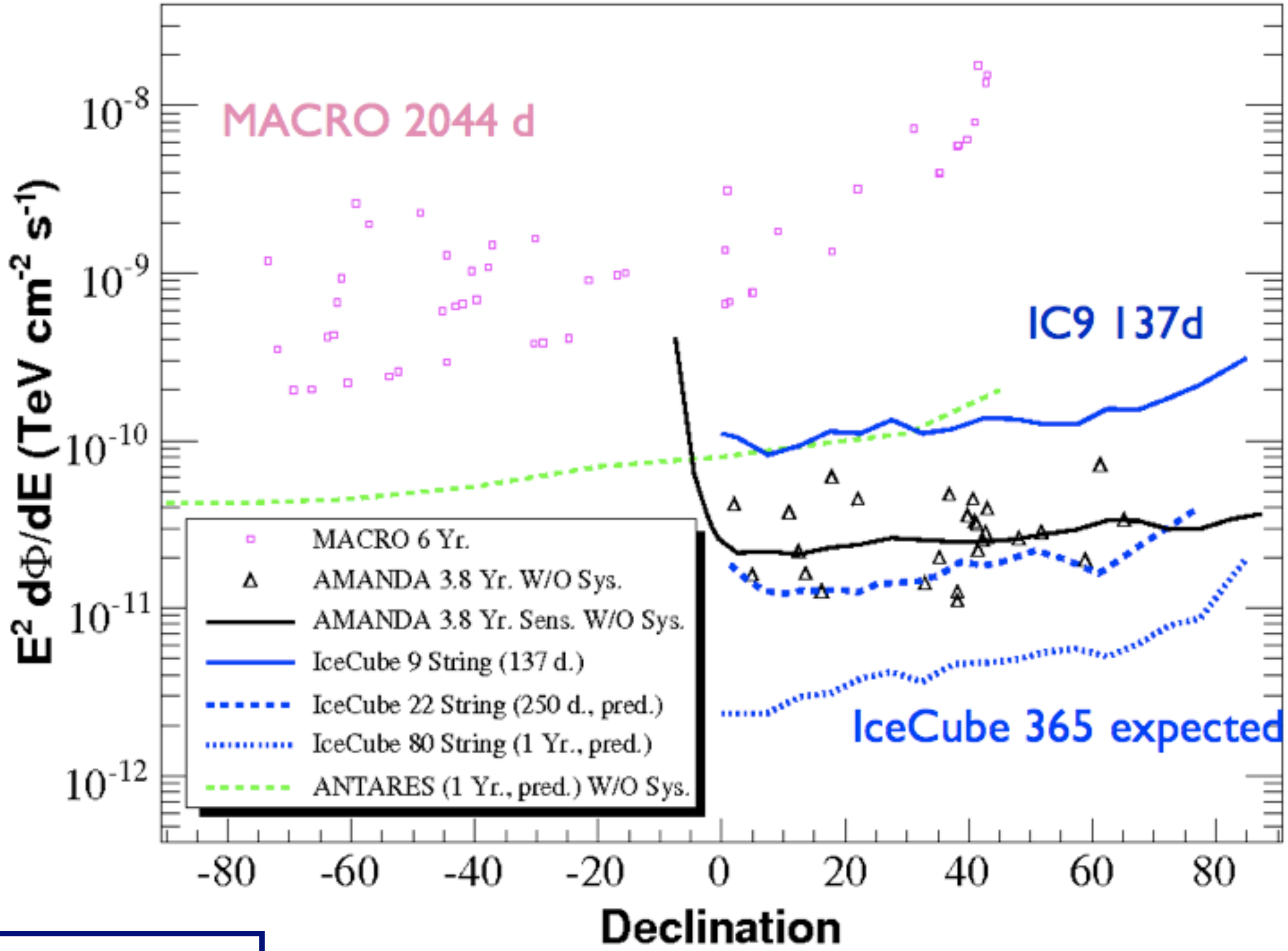
Attenuation lengths of order 50m to 100m

Most advanced technique

!! Infrastructure !!


IceCube
2007-2008:
18
50 m
IceTop
Air shower detetor
threshold ~ 300 TeV
2006-2007:
13 Strings
total of
40 Strings
80 IceTop tank
2005-2006: 8 Strings
2004-2005 : 1 String
1450m
InIce
80 Strings ,
60 Optical Modules
17 m between Modules
125 m between Strings
2450m
AMANDA
(1995-2000)
19 Strings
677 Modules
324 m
Eiffeltornet
A. Karle

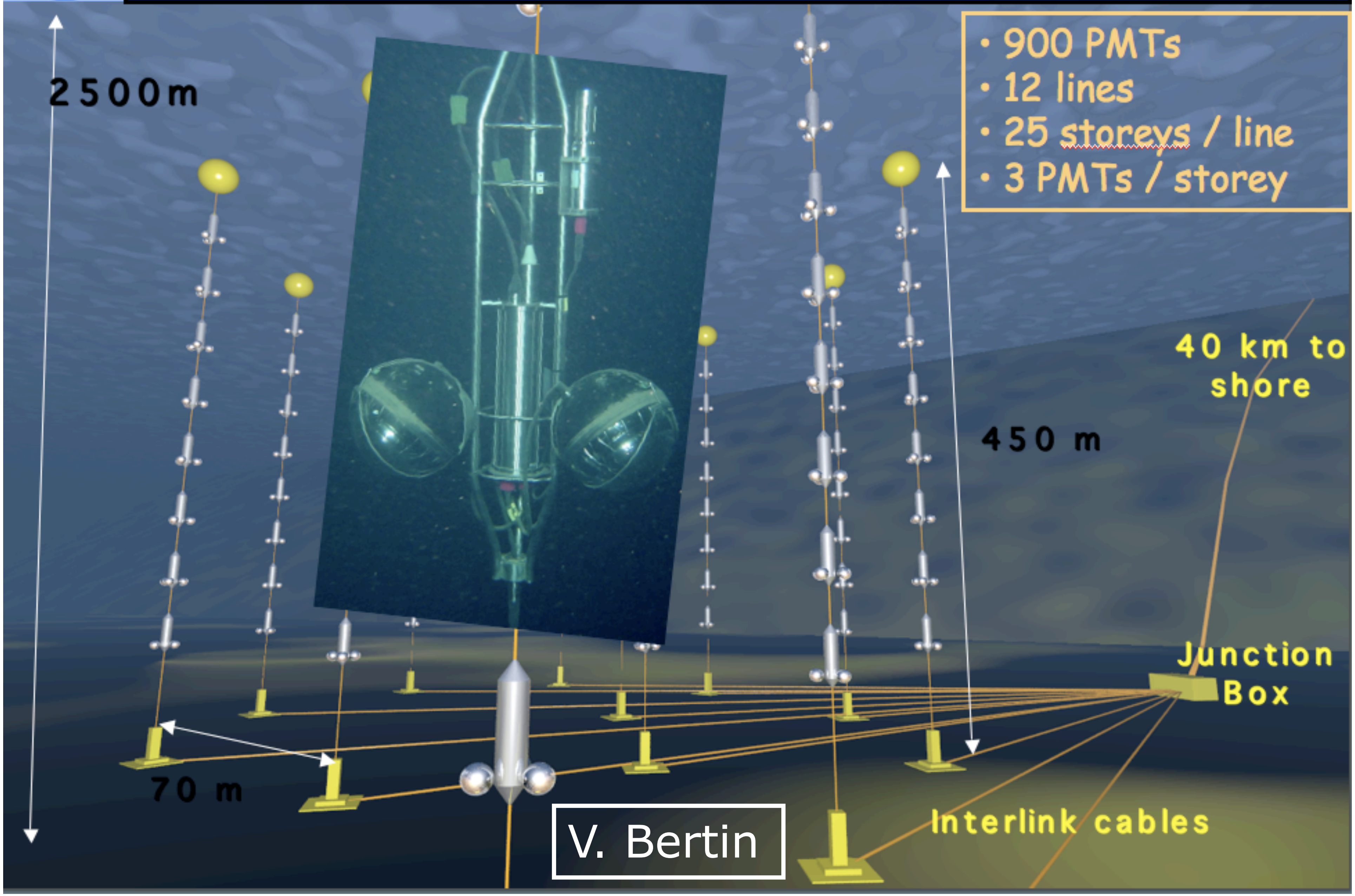
Flux limits and sensitivities



A. Karle

AMANDA-5yrs: astro-ph/0611063
IceCube:stro-ph/030519

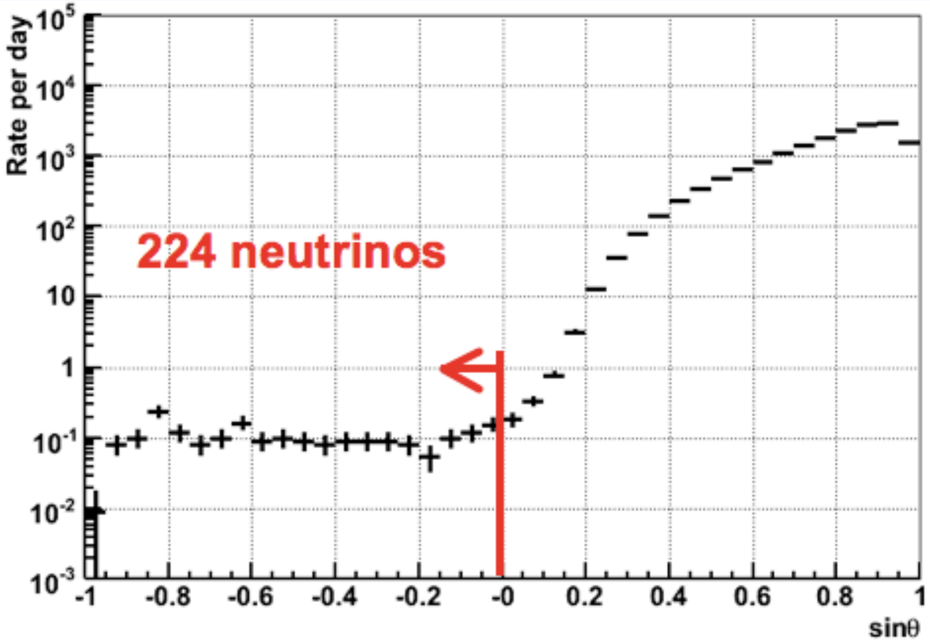
The ANTARES detector



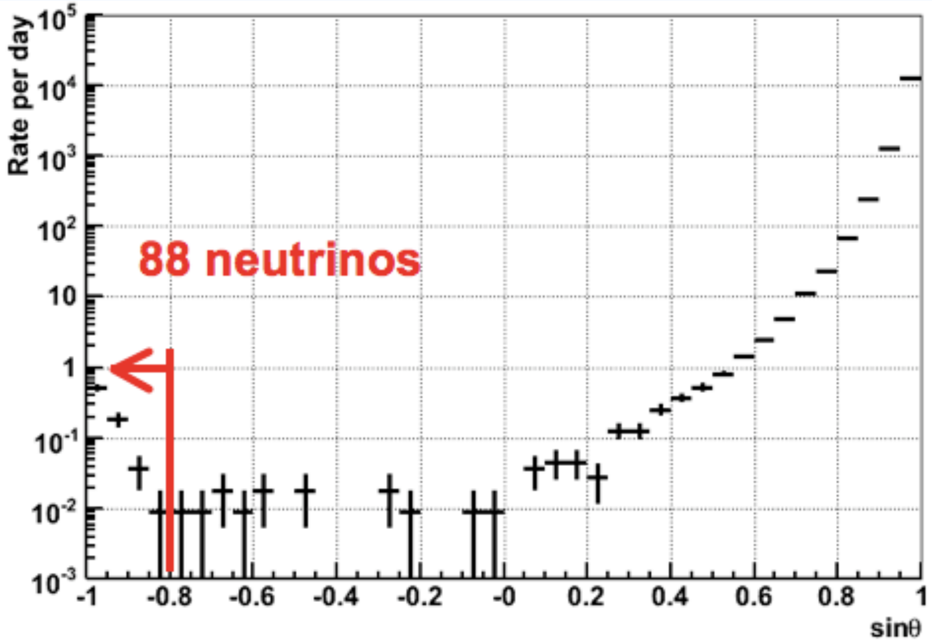
Reconstructed events with 10 line data

Data: Dec 2007 – May 2008 : 109 active days

Multi line fit

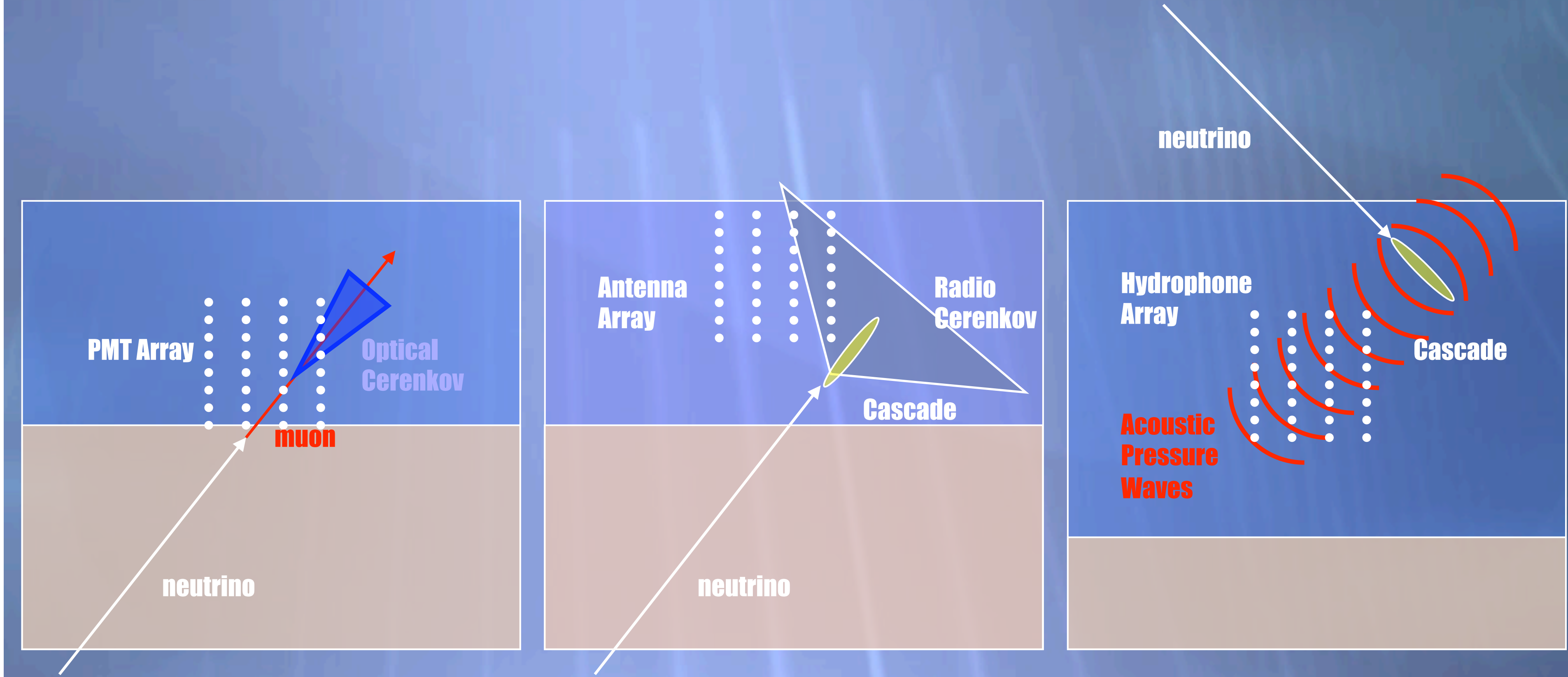


Single line fit



V. Bertin

HE Neutrino Detection Methods



Optical Cerenkov

Works well in water, ice

Attenuation lengths of order 50m to 100m (blue light)

Most advanced technique

Radio Cerenkov

Long (order km) attenuation lengths in ice and salt

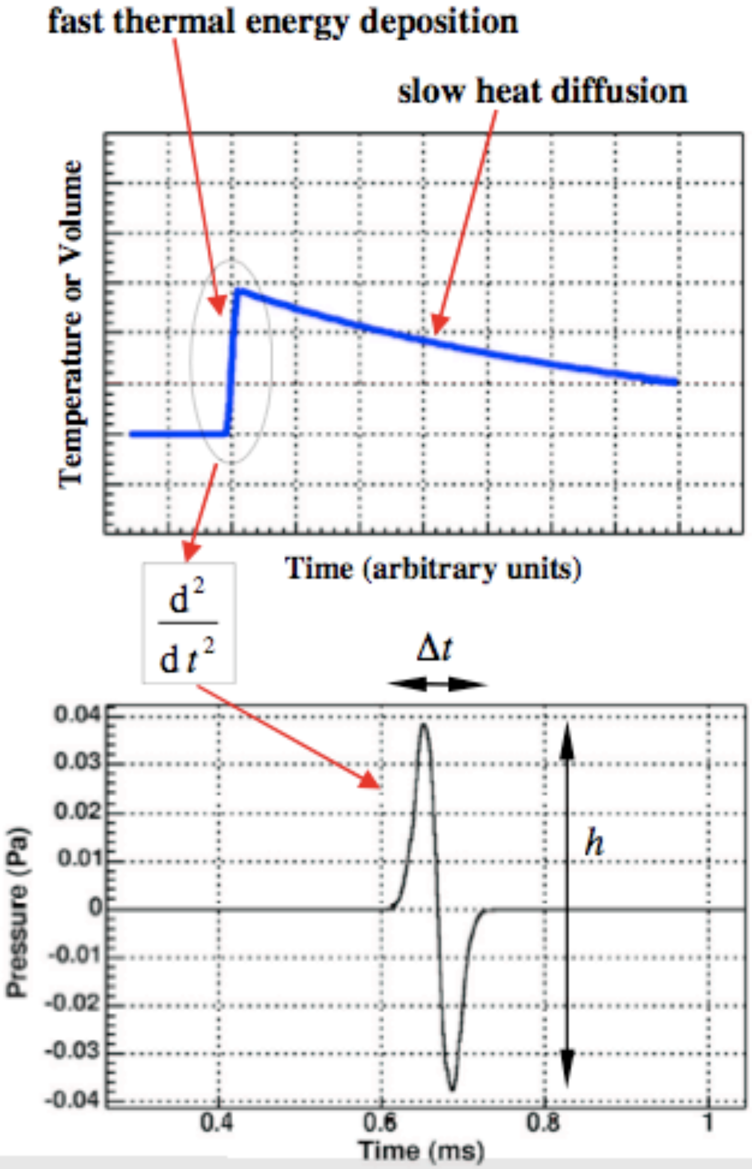
See Andreas Haungs' summary talk

Acoustic Detection

Very long attenuation lengths in water (order 10km), ice and salt

Huge effective volumes may be possible

Acoustic Detection Principle



shower thermal energy density

$$p(\vec{r},t) = \int_V \rho_E(\vec{r}\,')\, G(\vec{r}-\vec{r}\,',t)\, d^3\vec{r}\,'$$

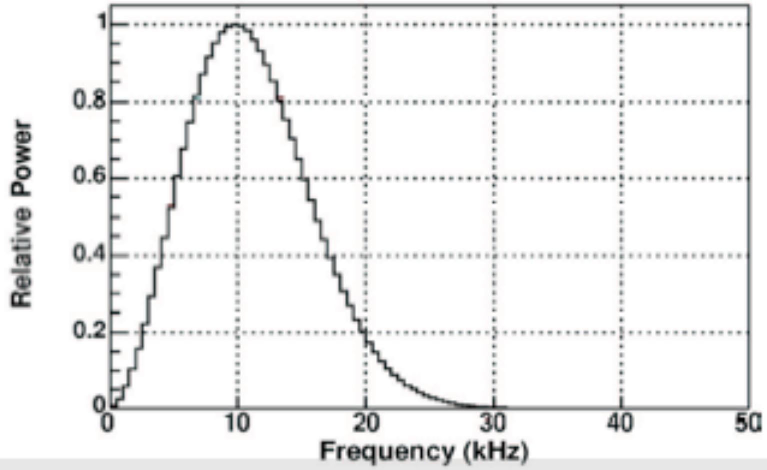
pulse due to a point source

$h \propto \beta/C_p$, where :

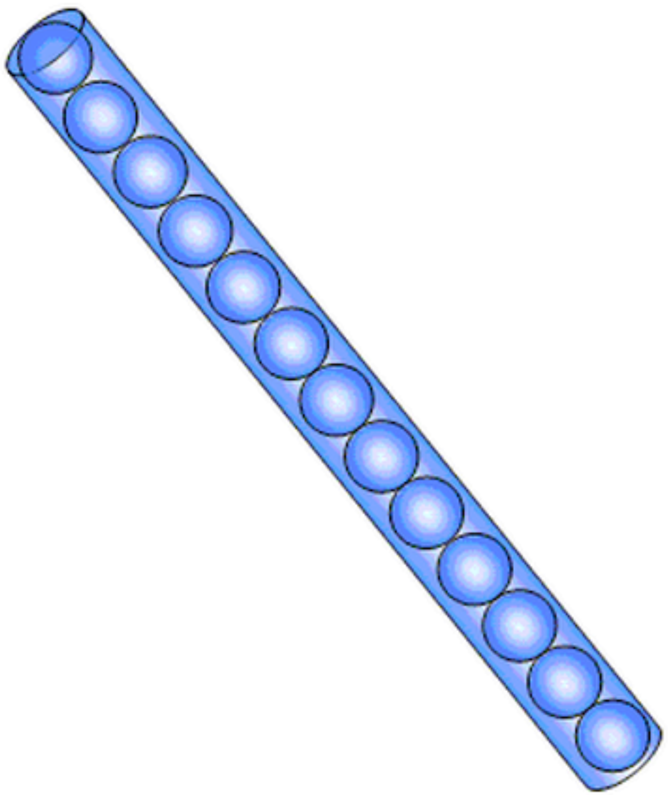
β = coefficient of thermal expansivity [$O(10^{-4})$ K^{-1} for water]

C_p = specific heat capacity [water : 3.8×10^3 $Jkg^{-1}K^{-1}$]

$\Delta t \propto$ transverse shower size



Acoustic Detection Features



- Typical cylindrical volume over which the hadronic energy is deposited is ~20m long by a few centimetres wide (95% of energy at 10^{20}eV)
- *The energy deposition is instantaneous with respect to the signal propagation*
- Hence the acoustic signal propagates in a narrow "pancake" perpendicular to the shower direction in analogy with light diffraction through a slit

Acoustic detection projects

"Around the World in *almost* 80 ~~Days~~ *slides*"


Deutschland
England
Olympiastadion
München
1 : 5
01.SEP.
2001
DIE BUNDESLIGA

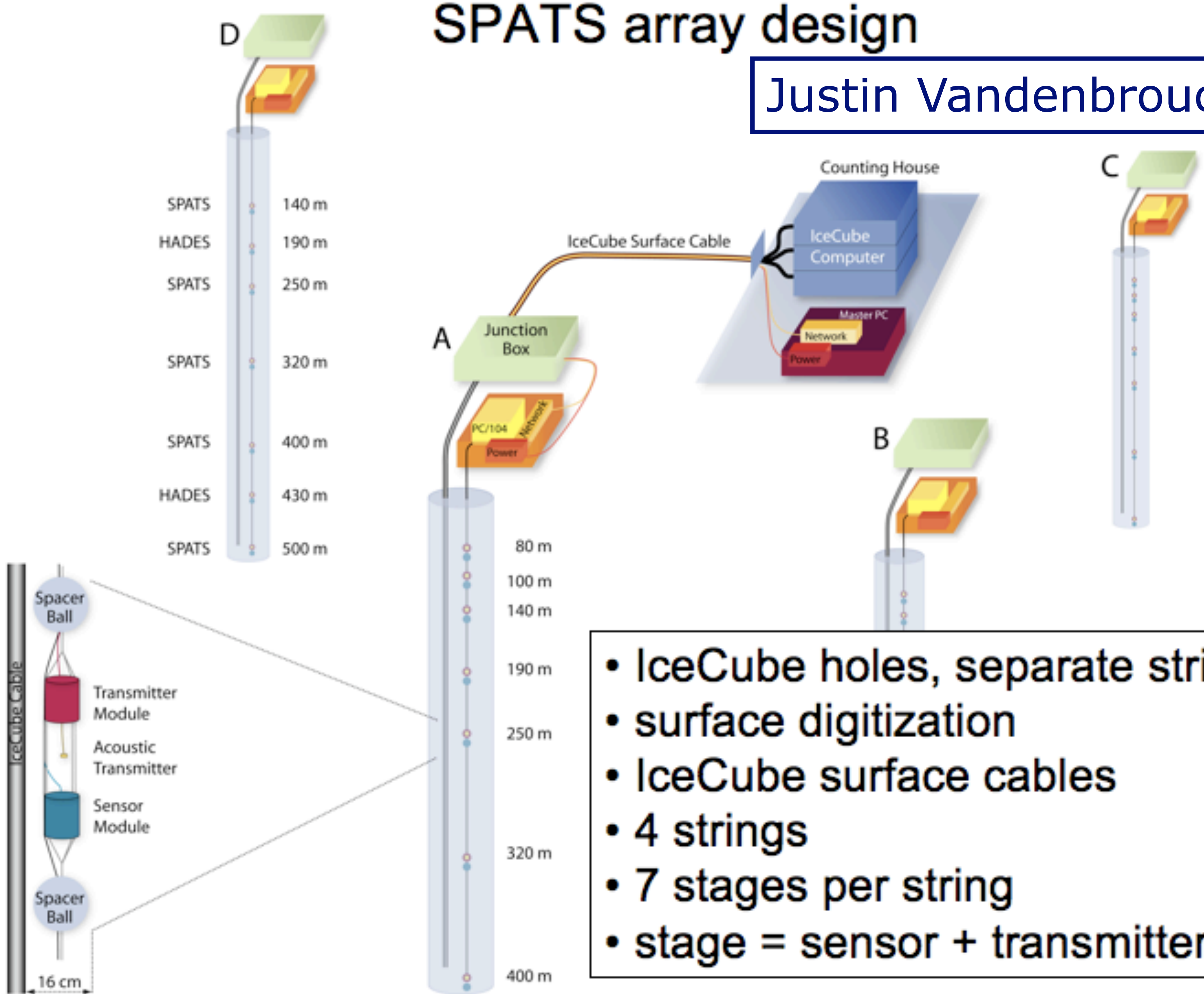
SPATS (ICECUBE)

Po

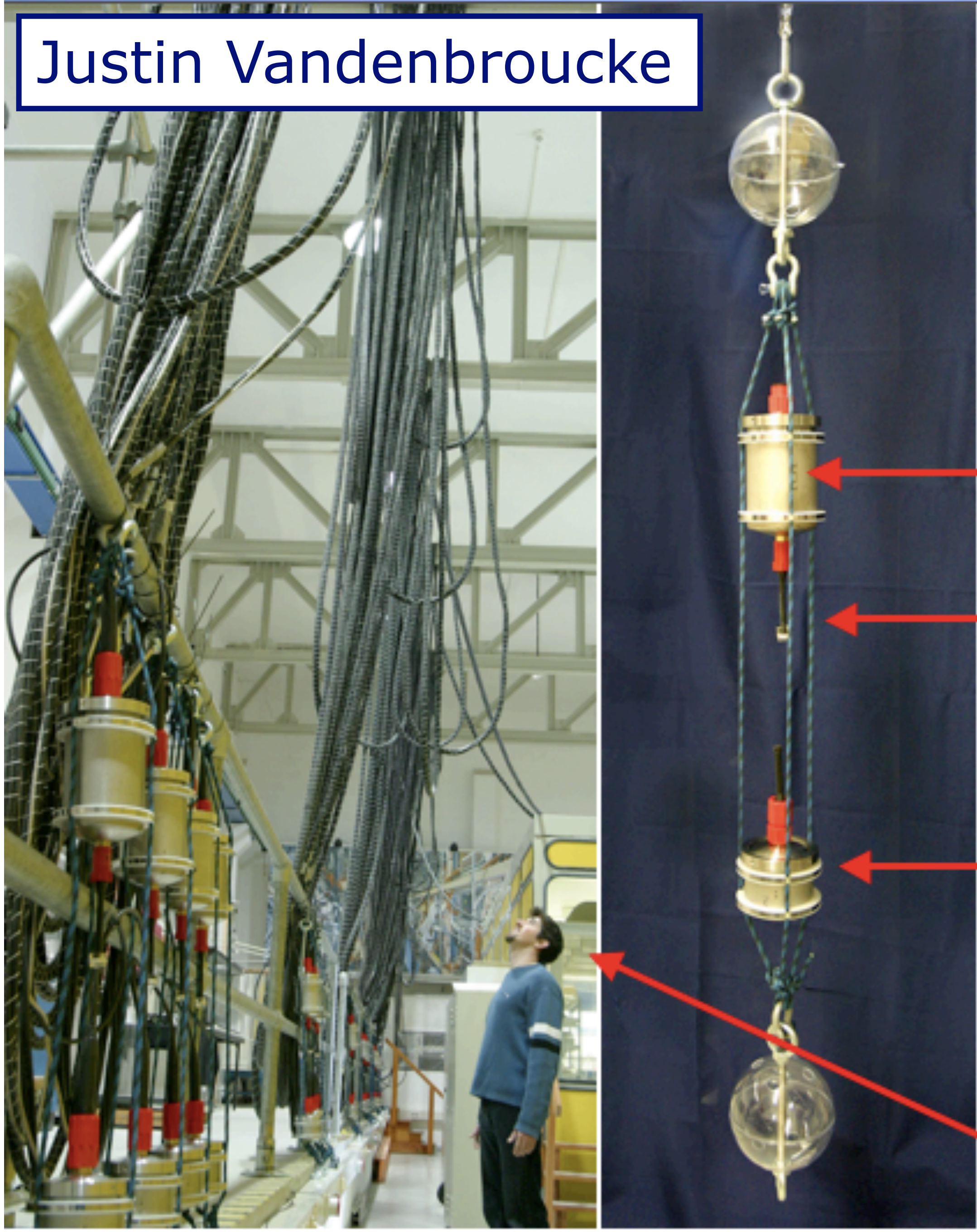
ourtesy

SPATS array design

Justin Vandenbroucke



- IceCube holes, separate strings
- surface digitization
- IceCube surface cables
- 4 strings
- 7 stages per string
- stage = sensor + transmitter



SPATS in-ice hardware

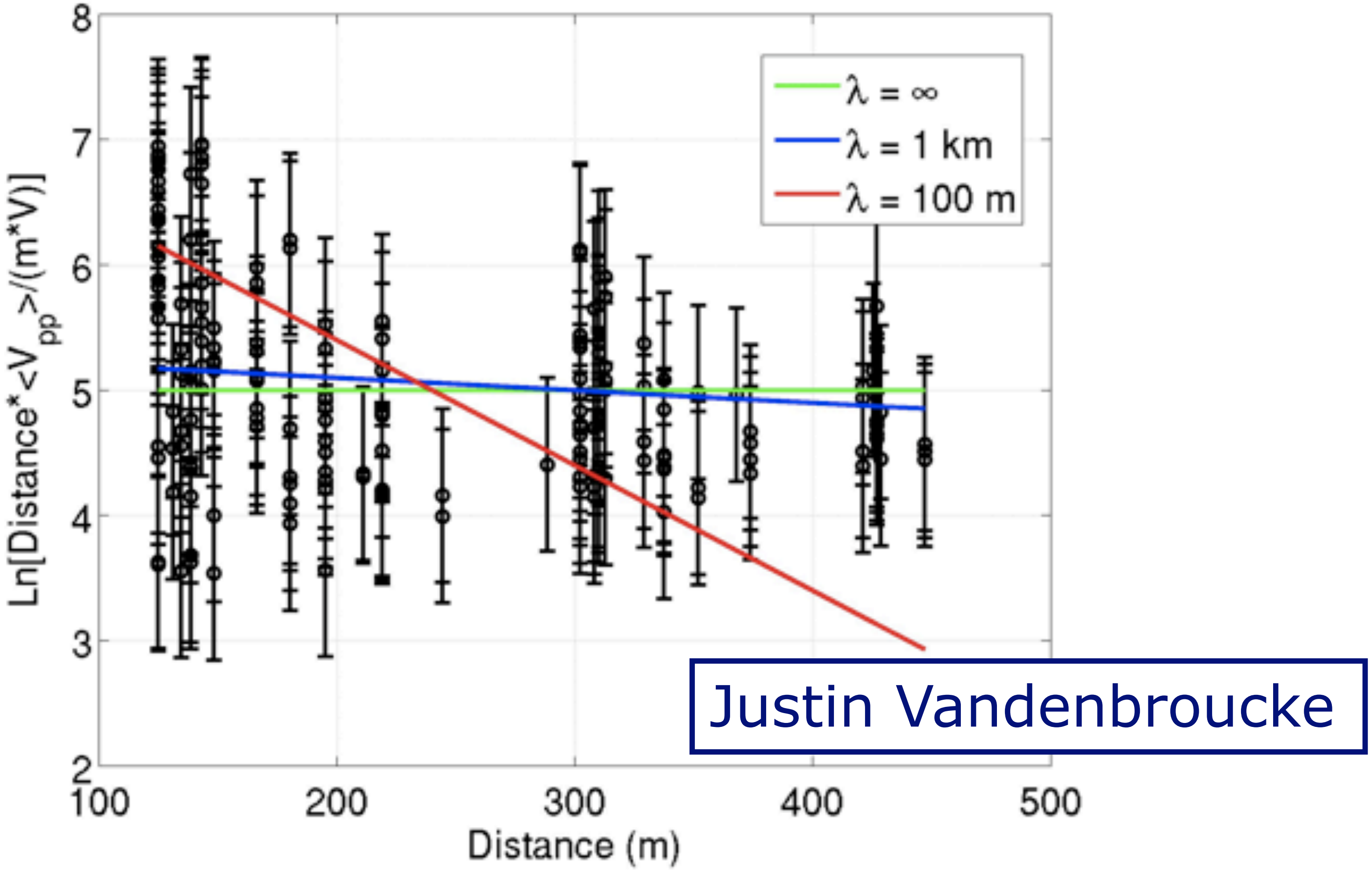
transmitter module
(electronics)

transmitter piezo-ceramic

sensor module
3 piezo-ceramics inside
for full azimuthal coverage

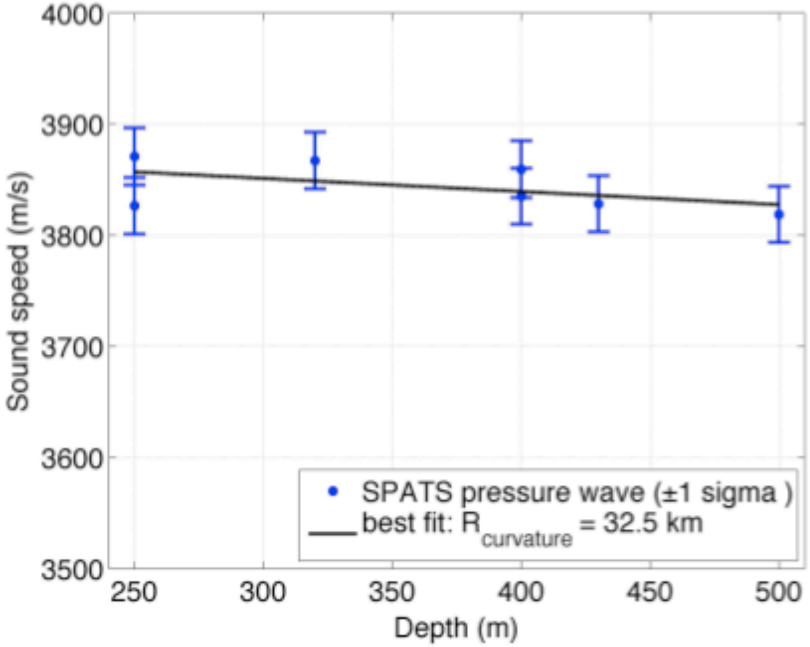
Sebastian

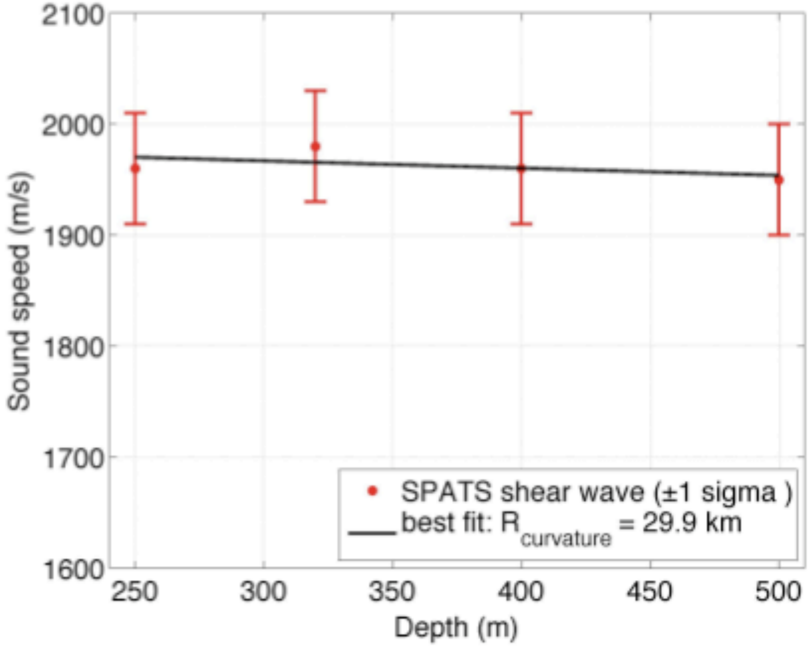
Attenuation analysis (1) inter-string data: Ln(amplitude*distance) vs. distance



- 3 string data; some data points buried in noise
- significant improvements in run optimization underway: retrieve missing points
- 4 string analysis in progress

$v_{pressure}$ and v_{shear} constant [250m,500m]





- consistent with no refraction, best fit gives slight refraction:

  $\Rightarrow$ **R_{curv} = 32.5km (P) and 29.9km (S)**

Freija Descamps

For a 32.5 km radius:

100 m path deflects 0.154 m, 3 km path deflects 138 m

1 km path deflects 15.4 m $\sim$ acoustic pancake width

Conclusions and outlook

SPATS pressure and shear waves

- SPATS pinger data: precise timing achieved
- Shear waves have been detected in SPATS emitters and pinger data.

Sound speed results

- Both P and S wave speeds have been mapped vs. depth in firn and bulk

  First measurement of P speed in bulk ice
  First measurement of S speed in both firn and bulk ice
- Refraction is consistent with 0 between 250 and 500m depth.

Outlook

Freija Descamps

- Precision can be improved:

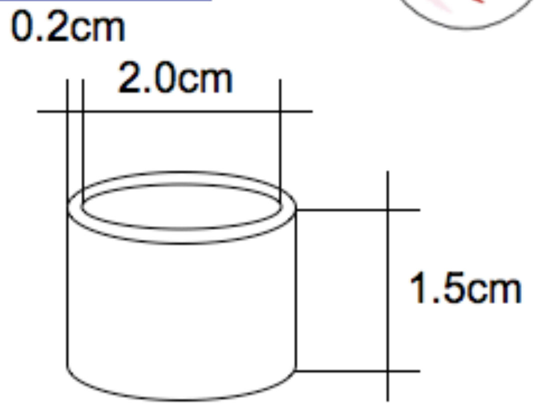
  Clock drift correction
  Larger baselines
- New pinger-runs with larger baselines 2008/2009 polar season

Development of HADES

Ring piezo:

- HADES A
- Pz-26 (hard PZT)

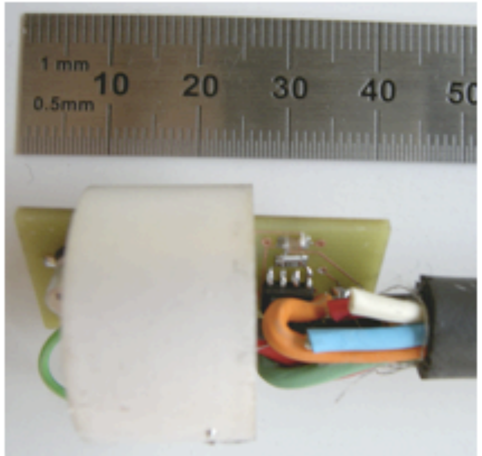
- HADES B
- Pz-27 (soft PZT)

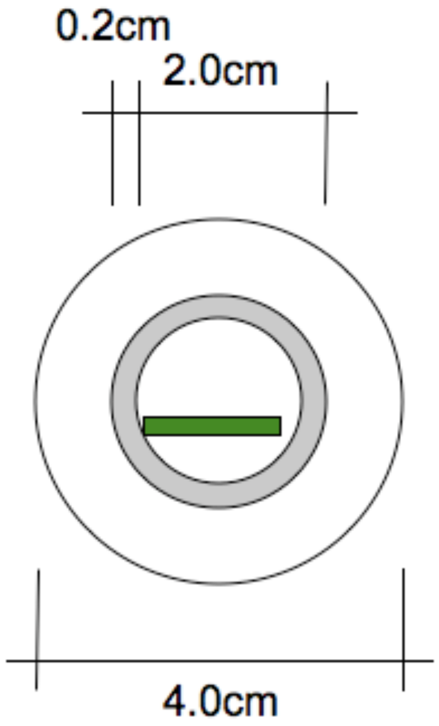


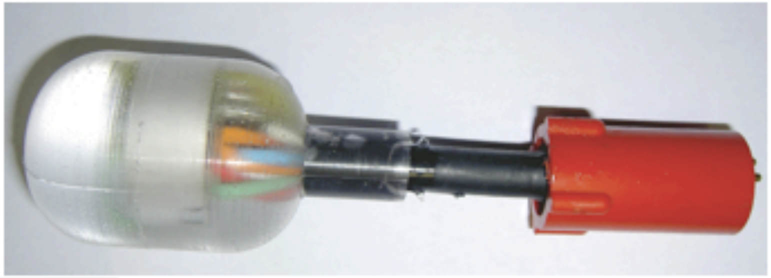
Benjamin Semburg

Amplifier:

- 2 stage amplification
- Type : Ti TL072
- Differential signal



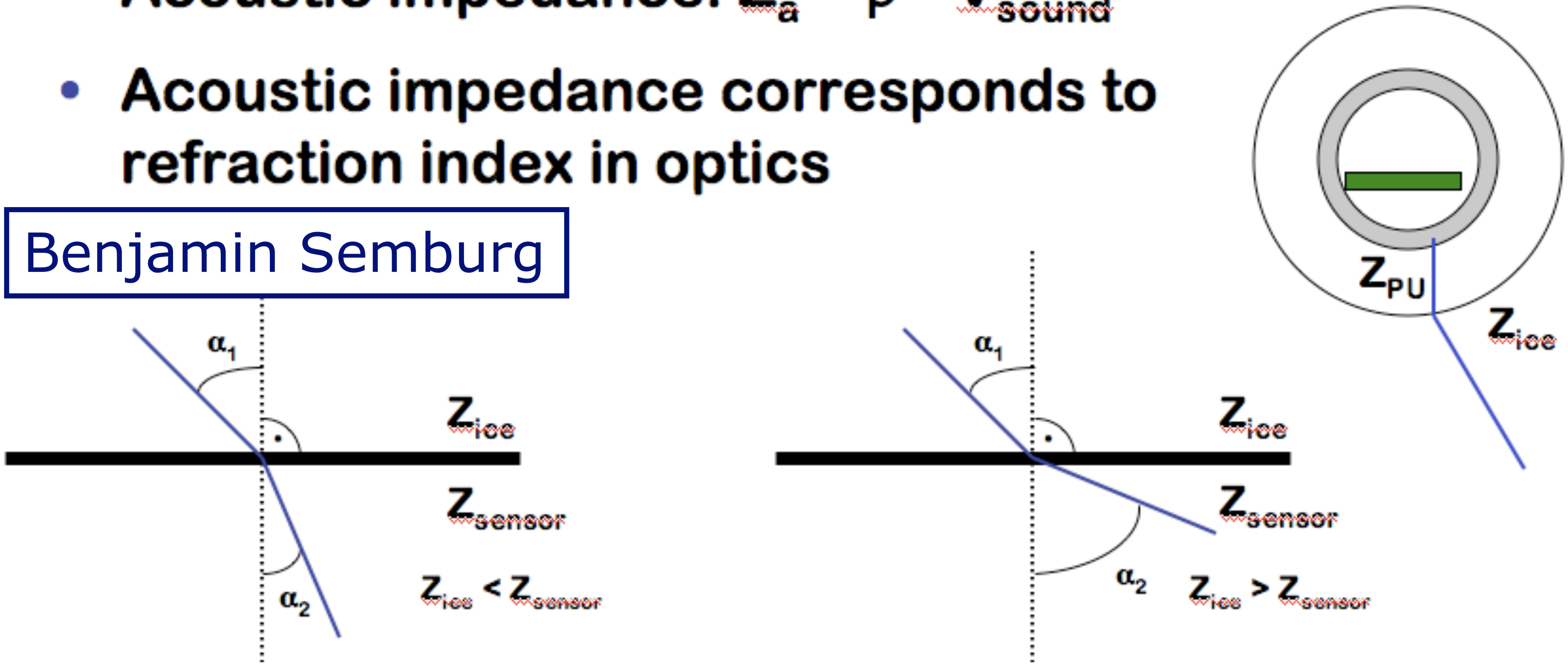




Acoustic impedance matching

- Acoustic impedance: $Z_a = \rho * V_{sound}$
- Acoustic impedance corresponds to refraction index in optics

Benjamin Semburg



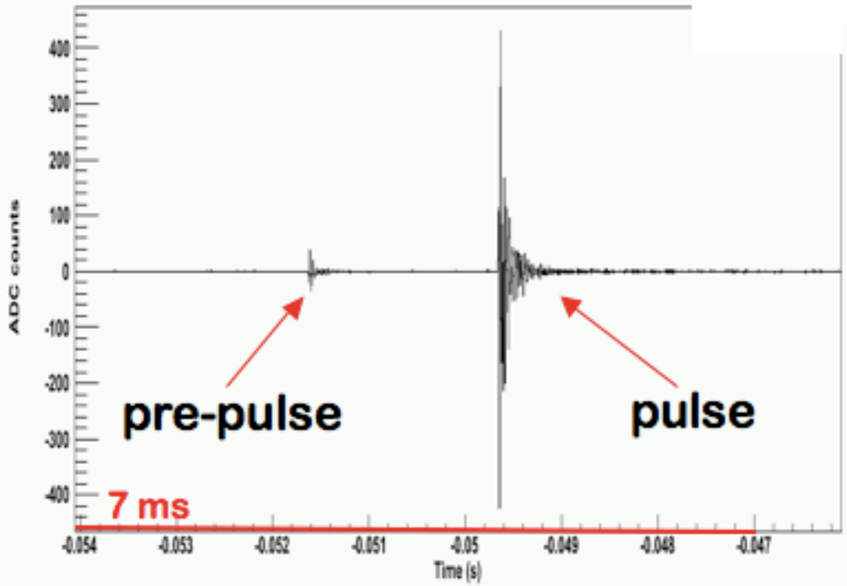
- Match impedance of ice and resin to maximize signal transmission

First cry: intra-stage pulses

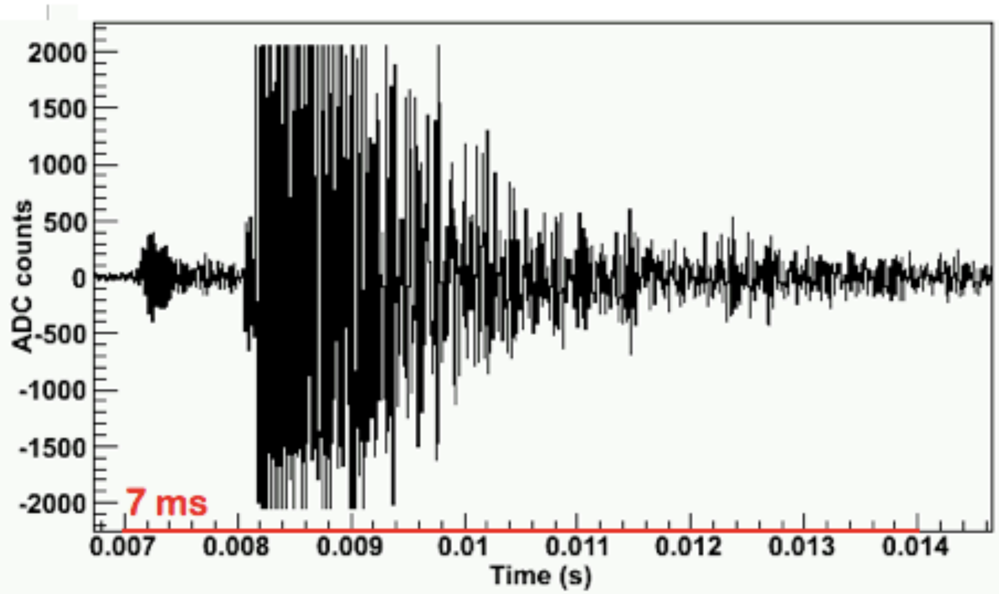
- Sent intra-stage pulses
  - ➢ Only possible at stages with HADES sensors, because all other stages (with SPATS sensors) are in saturation

Benjamin Semburg

HADES B L6 (depth: 430 m)

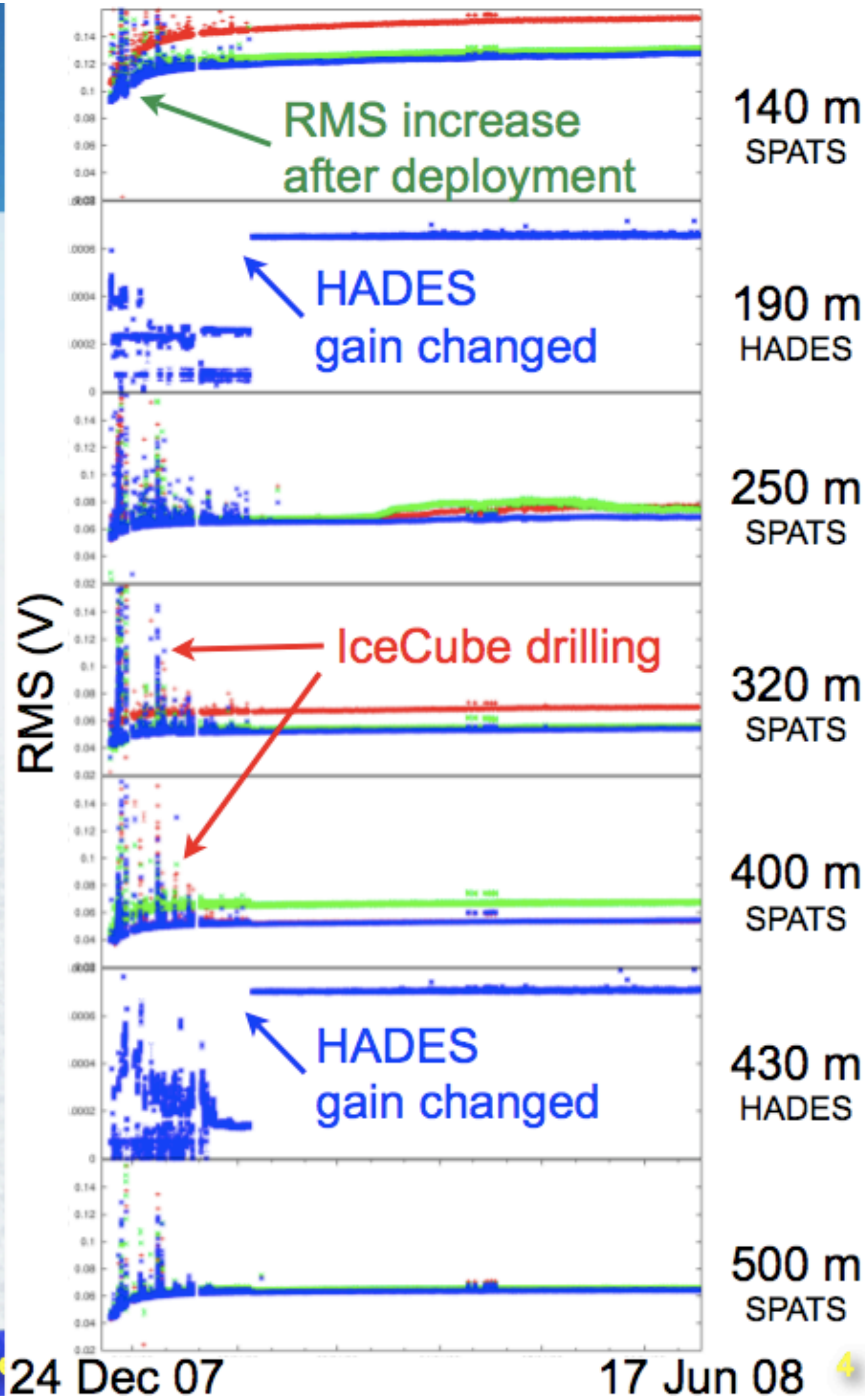


SPATS sensor L5 (depth: 400 m)



Temporal evolution

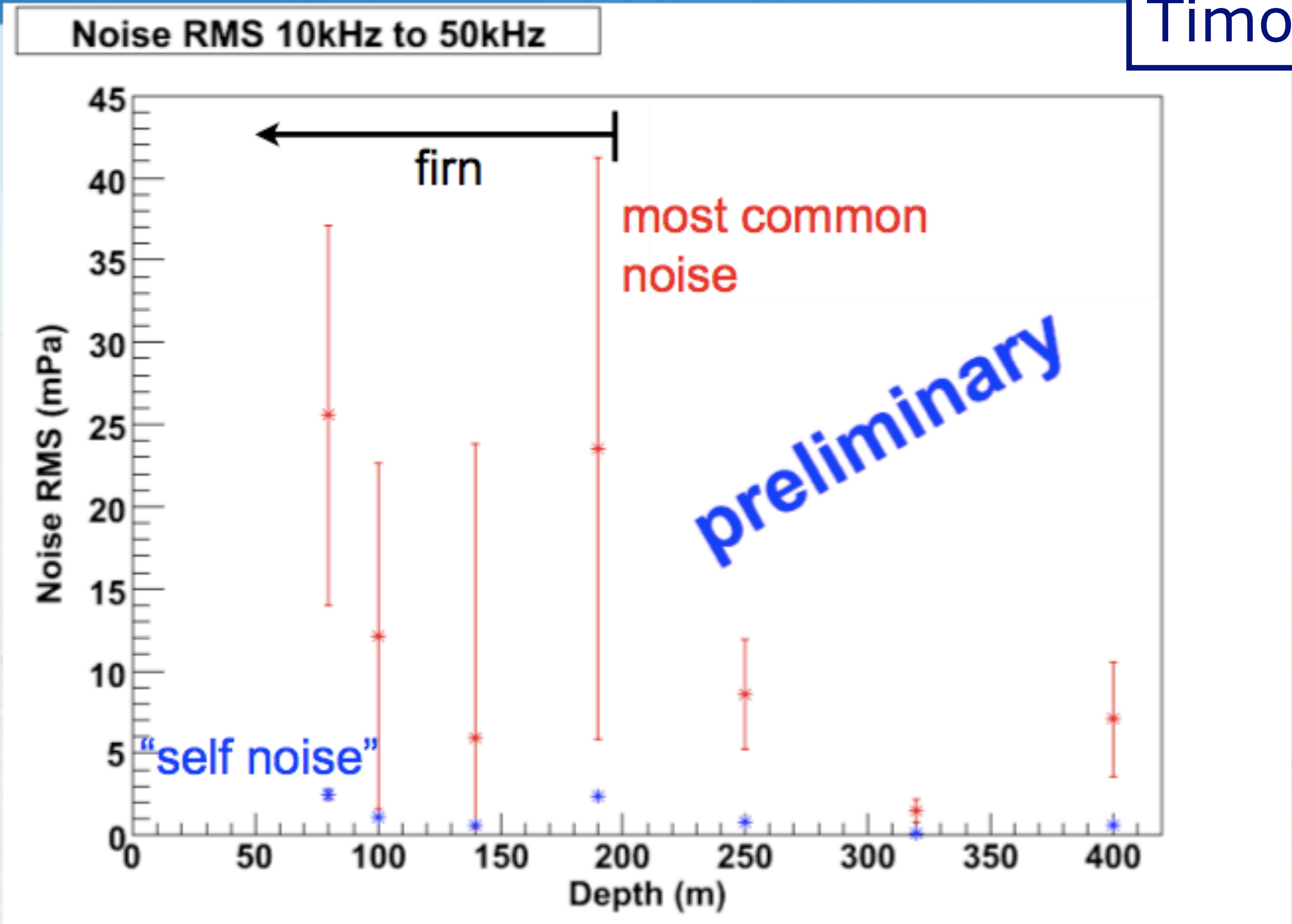
- String D: deployed 24 Dec 2007
- RMS very stable over time
  - large peaks correlated with IceCube drilling
- RMS increases during freeze-in
  - better coupling to bulk ice
  - increased sensitivity at low temperatures



Timo Karg

Noise depth profile

Timo Karg



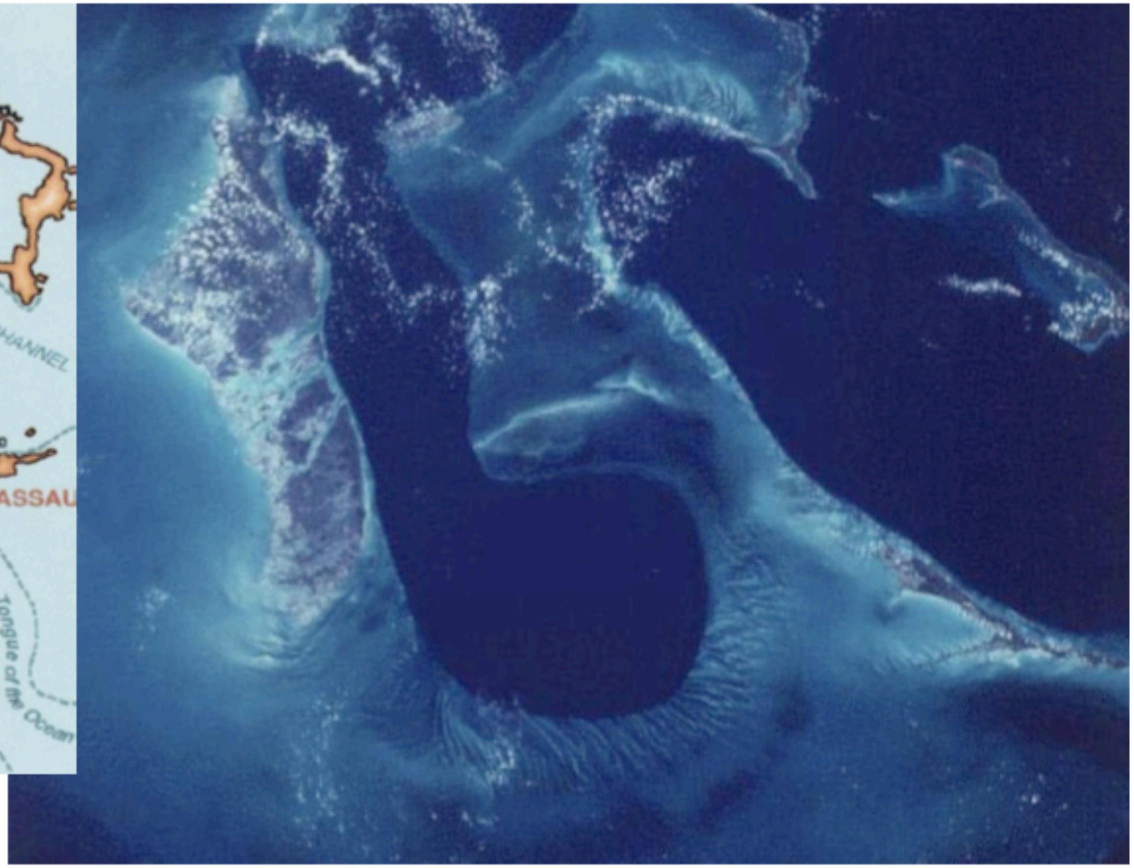
- Assumption: Pole sensitivity = 1.4 Lab sensitivity
- Error bars only represent sensor to sensor variations
- Noise consistent between different strings

SAUND


NORTH
PACIFIC
OCEAN
UNITED
STATES
NORTH ATLANTIC
OCEAN
Tropic of Cancer
Gulf of
Mexico
MEXICO
THE BAHAMAS
CUBA
DOMINICAN
REPUBLIC
HAITI
BELIZE
HONDURAS
GUATEMALA
EL SALVADOR
NICARAGUA
Caribbean
Sea
TRINIDAD
and TOBAGO
COSTA
RICA
PANAMA
VENEZUELA
GUYANA
SURINAME
French Guiana
(FR.)
COLOMBIA
Equator
GALAPAGOS ISLANDS
(ECUADOR)
ECUADOR
PERU
BRAZIL

Postcards #4,5

SAUND and AUTEC

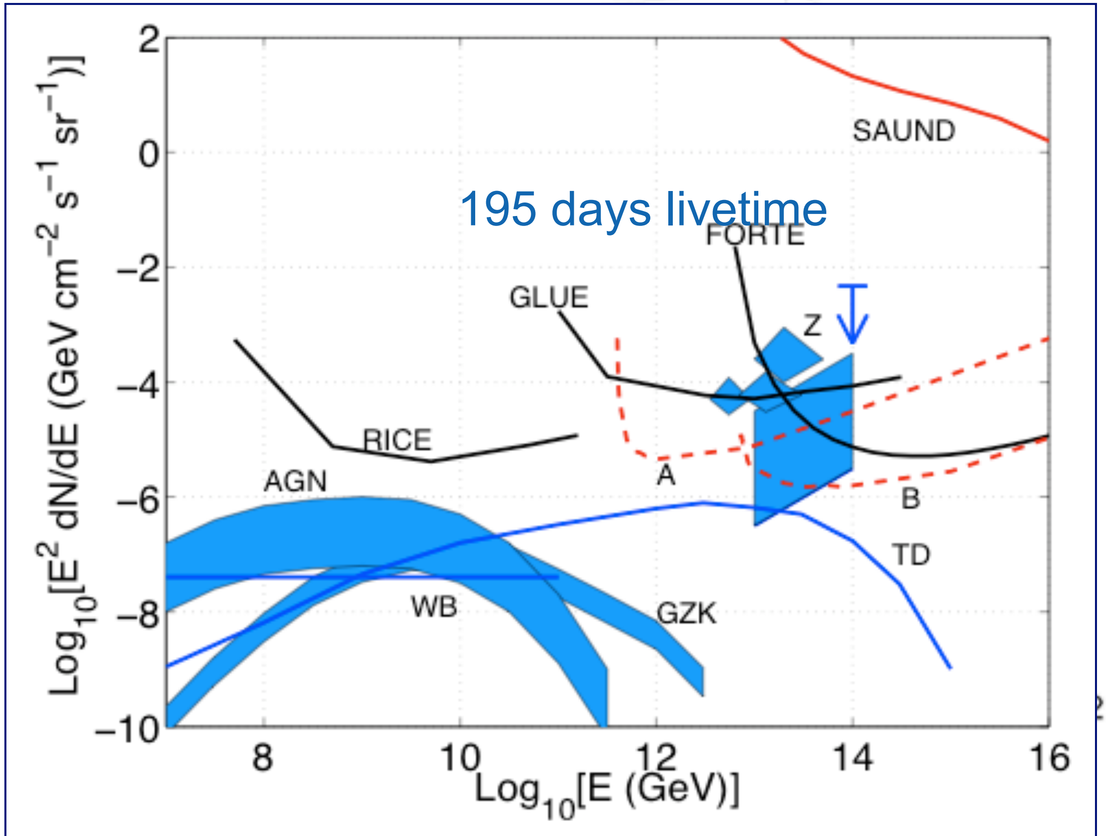


Naoko Kurahashi

History of SAUND

SAUND II based on....
Feasibility and Sensitivity Study
N.G. Lehtinen et al., Astroparticle Physics 17 (2002) 279-292
SAUND I Experiment
J. Vandenbroucke et al., Astrophysical Journal 621 (2005) 301-312

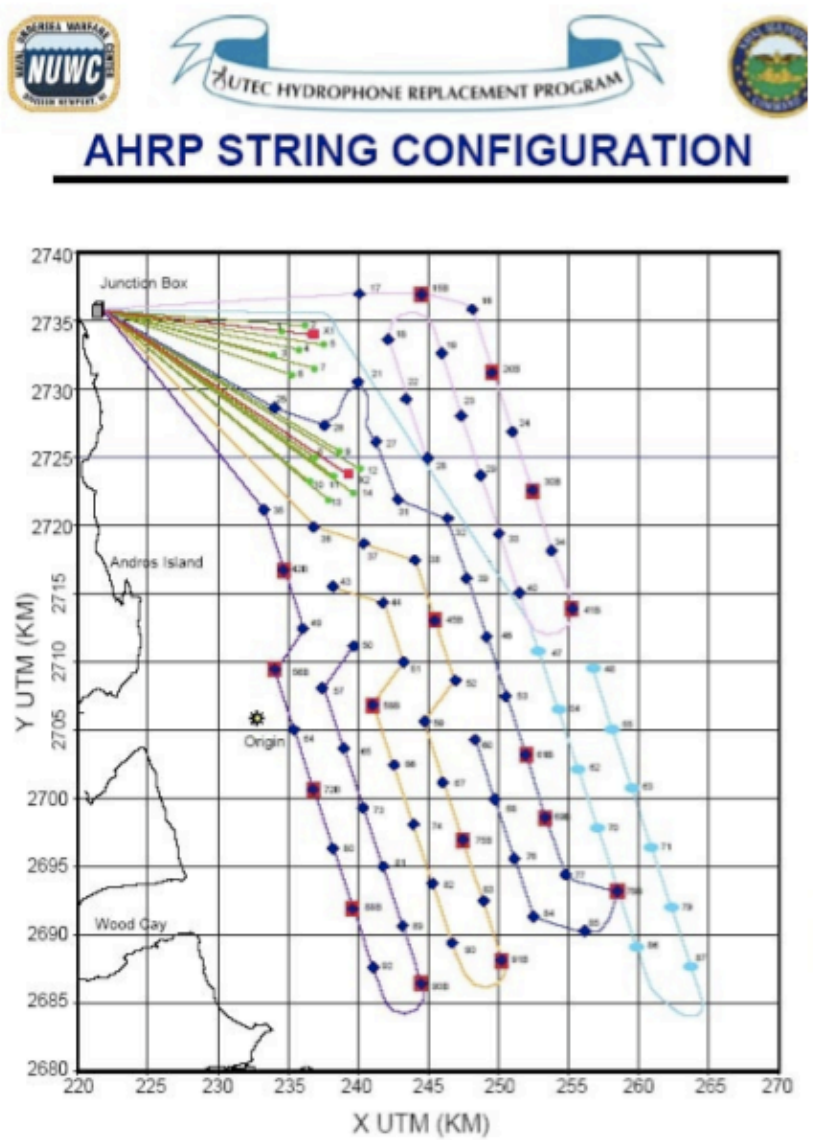
7 hydrophones were used at the same site but with different hydrophones and cables



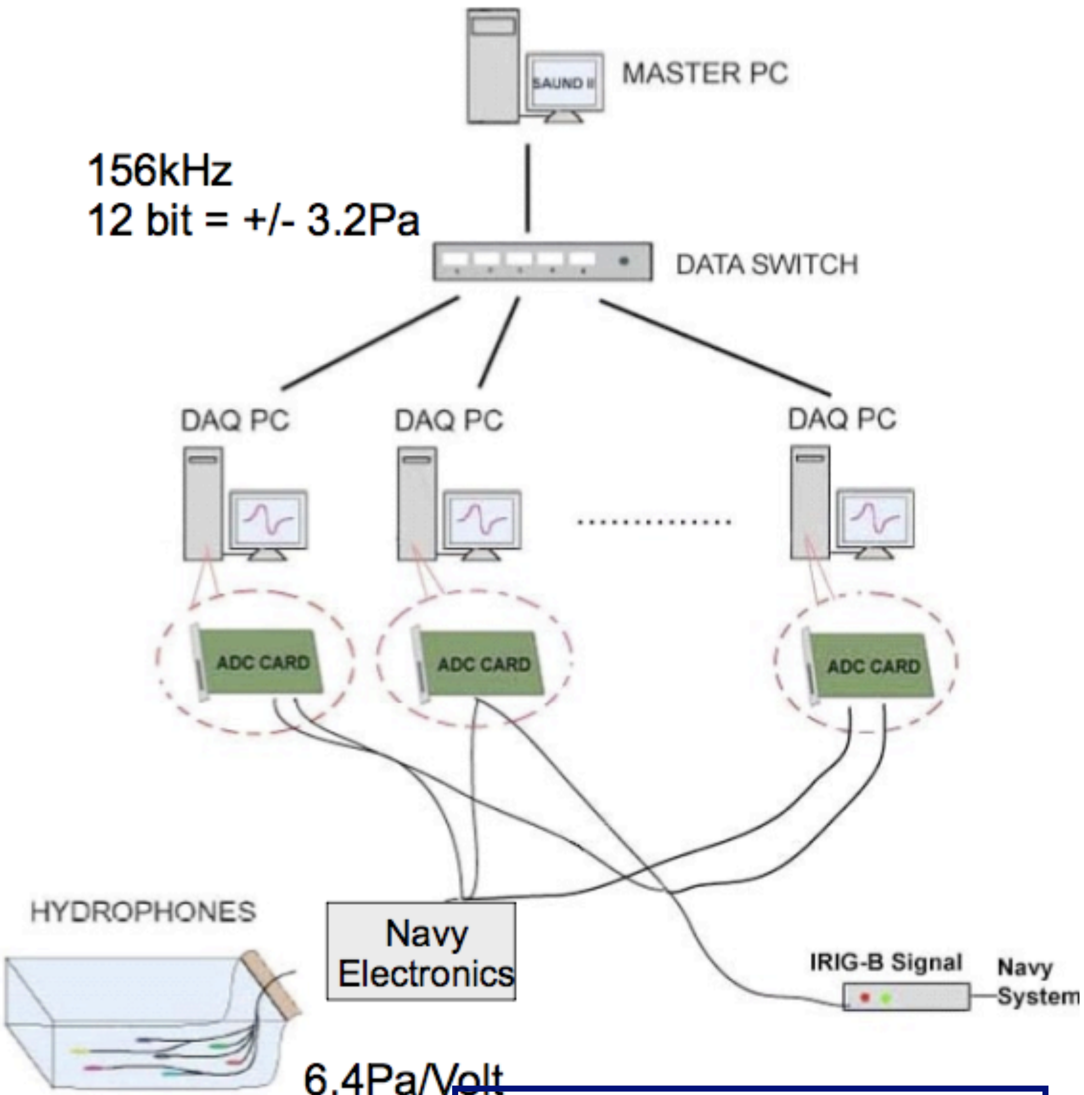
Naoko Kurahashi

SAUND II Schematics

49 Uni-directional Hydrophone readout
20 x 50 km array



156kHz
12 bit = +/- 3.2Pa



6.4Pa/Volt

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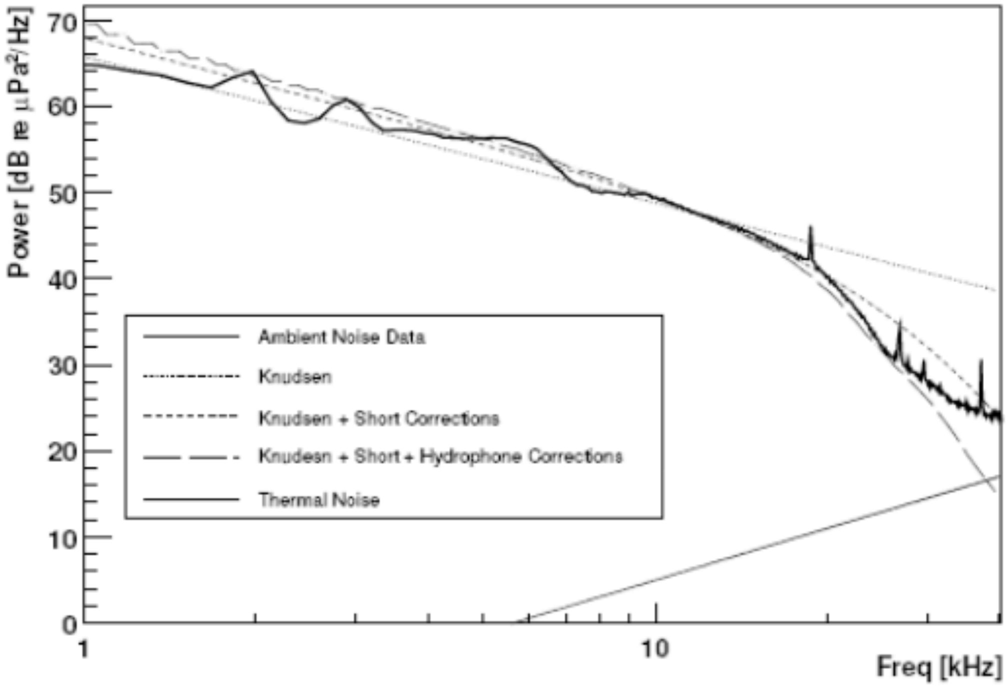
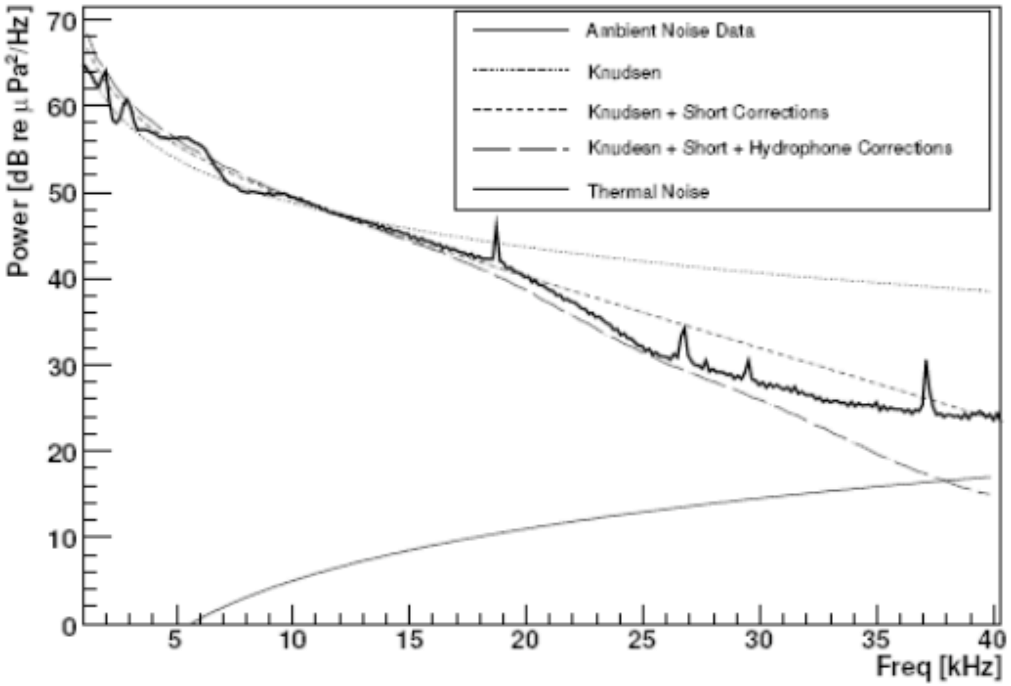




Results

$$J_0(a,h) = 2\pi J_\infty \int_0^{\pi/-} \cos^{n-1}\theta e^{-ah\sec\theta} g(\theta,f)\sin\theta d\theta$$

Introduce new term
g is the response function of the hydrophone
- not perfectly omnidirectional
- freq response not perferctly flat

Naoko Kurahashi

Kurahashi and Gratta
arXiv:0712.1833v1 [physics.ao-ph]
Submitted to JASA, Dec 2007

ACORNE

Ocean
NORWAY
Oslo
Baltic Sea
Helsinki
Tallinn
ESTONIA
Stockholm
North Sea
U. K.
Glasgow
Edinburgh
DENMARK
Goteborg
IRELAND
Belfast
Riga
LATVIA
Dublin
Sunderland
Copenhagen
Limerick
Leeds
LITHUANIA
Liverpool
Manchester
Vilnius
Cork
Waterford
Leicester
Birmingham
Gdansk
The Hague
Amsterdam
Hamburg
London
NETHERLANDS
Berlin
POLAND
BELARUS
Rotterdam
Warsaw
Brussels
GERMANY
Poznan
Leipzig
Lubin
Lodz
BELGIUM
Bonn
Luxembourg
LUX.
Frankfurt
Wroclaw Breslau
Paris
Prague
Krakow
Nuernberg
Karlsruhe
CZECH
Ostrava
Lviv
Nantes
Strasbourg
Stuttgart
Brno
Muenchen
SLOVAKIA
Rhine
Vienna
Zurich
Bratislava
Bern
FRANCE
MOLDOVA
SWITZERLAND
AUSTRIA
Budapest
Bordeaux
Chisinau
Geneva
HUNGARY
Lyon
SLOVENIA
Cluj
ROMANIA
Milano
Ljubljana
Bayonne
Timisoara
Zagreb
Porto
Turin
Venezia
CROATIA
Belgrade
PORTUGAL
Valladolid
Toulouse
Monaco
Genova
Bologna
BOSNIA and HERZ.
Sarajevo
SPAIN
Danube
Marseille
Firenze
Sofia
Lisbon
Madrid
YUGOSLAVIA
BULGARIA
Barcelona
Skopje
Valencia
Rome
ITALY
Tirane
MACEDONIA
Cordoba
ALBANIA
Napoli
Thessaloniki
Sevilla
GREECE
Gibraltar
Agrinion
Algiers
Palermo
Rabat
Tunis
Athens
Casablanca
Valletta
MALTA
MOROCCO

Rona hydrophone array

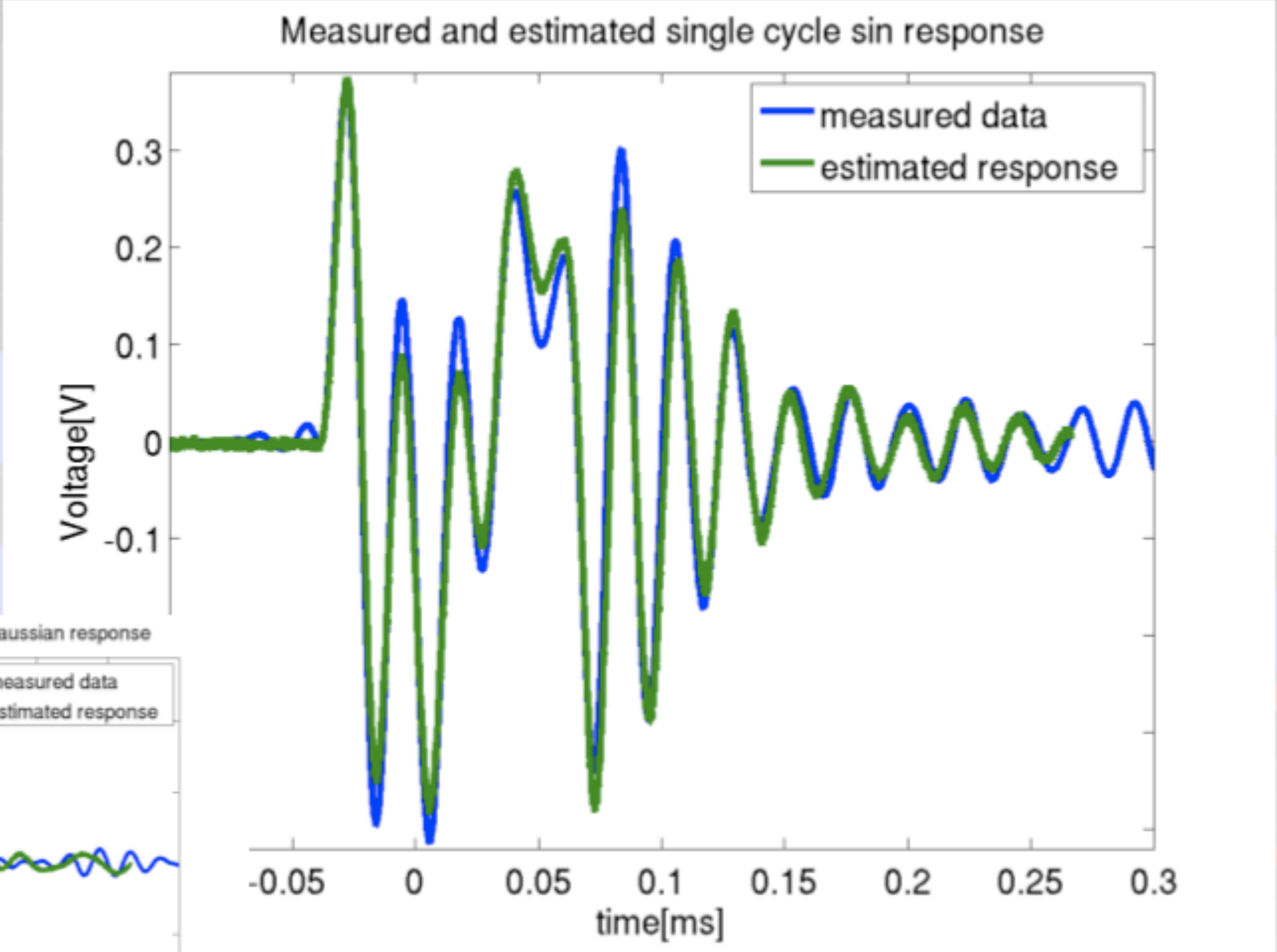
Omar Veledar

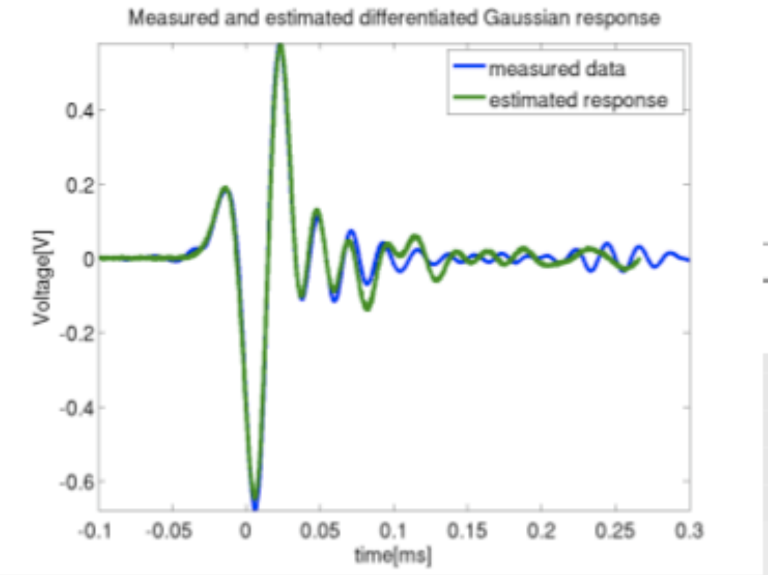
- North-West Scotland (ranging hydrophones)
- Good test bed for future deep sea experiments

- Existing infrastructure √
- Wideband hydrophones √
- Omnidirectionality √
- Unfiltered data √
- All data to shore √
- Control over DAQ √
- No remote access X

Technique verification

Omar Veledar

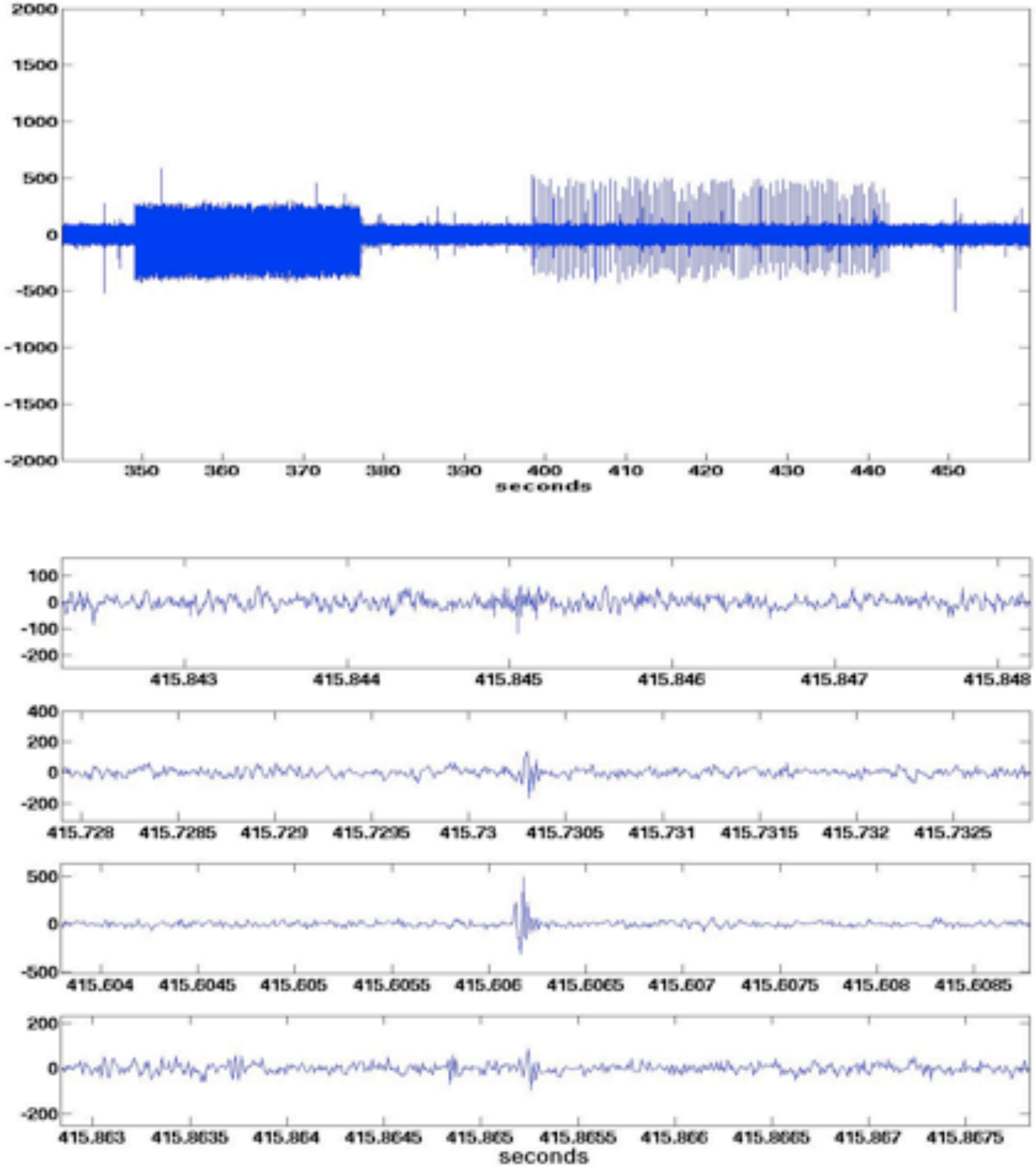




Postcards #6,7,8

- N
- N e!

Picking Out the Pulses



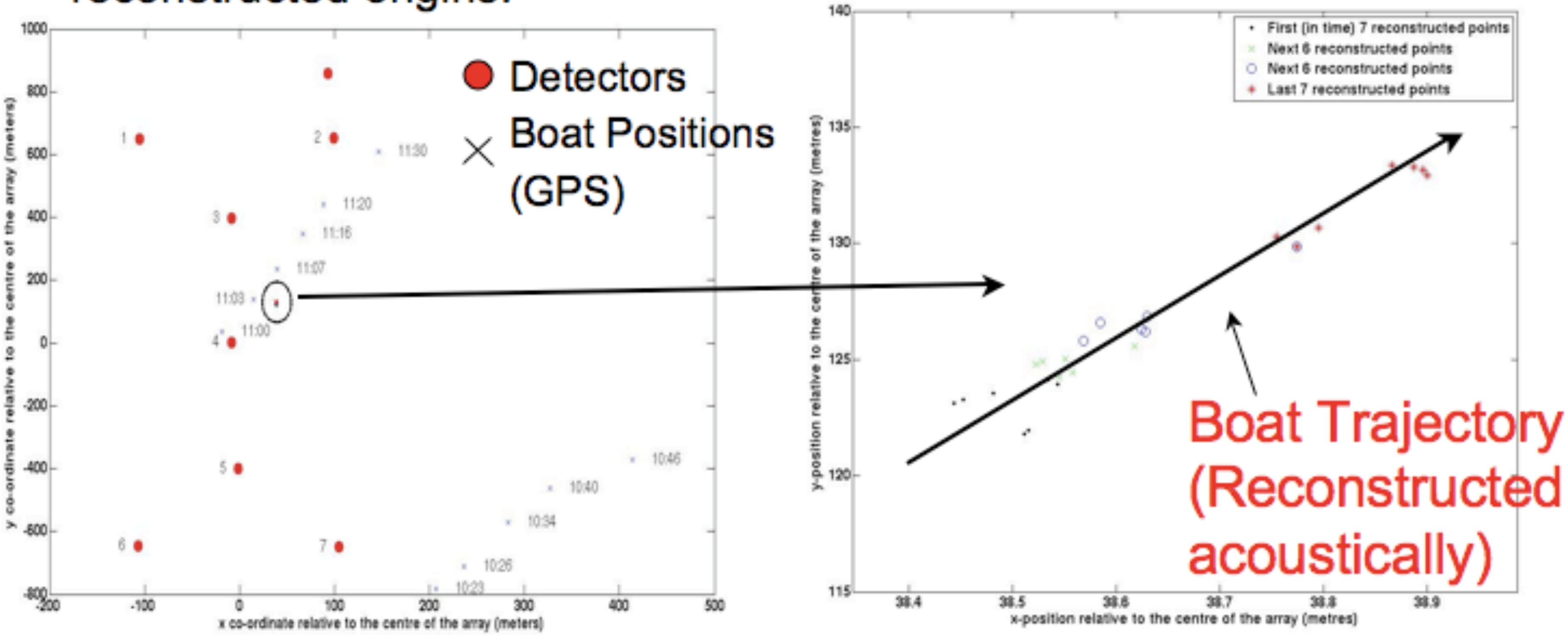
- The top plot shows raw data where 2 periods of pulse injection can be seen
- The bottom plot shows a close up of one of these pulses on the 4 nearest detectors
- Reconstructed 25% of events

Simon Bevan

Boat Reconstruction

- Using the known detector positions and the time of arrival of the pulse on each hydrophone, each detected pulses' origin (if detected on > 4 detected) could be calculated.
- The boat, and drift, was successfully reconstructed
- Plots show the detector positions, the boat positions, and the reconstructed origins.

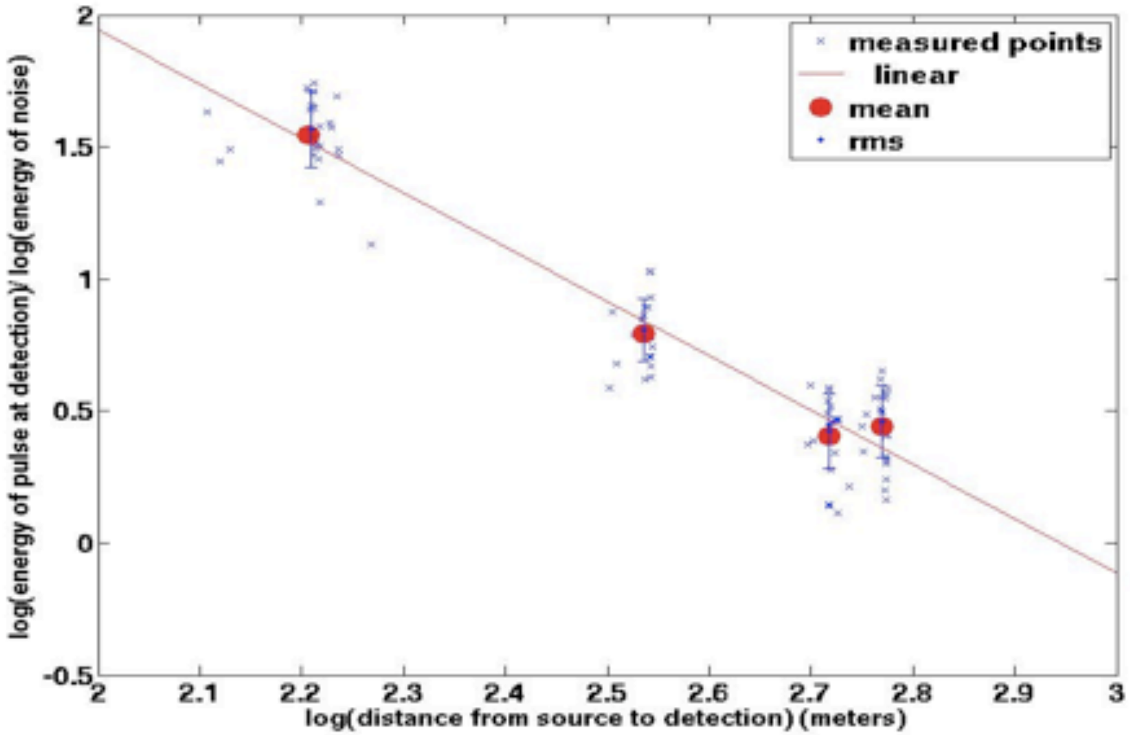
Simon Bevan



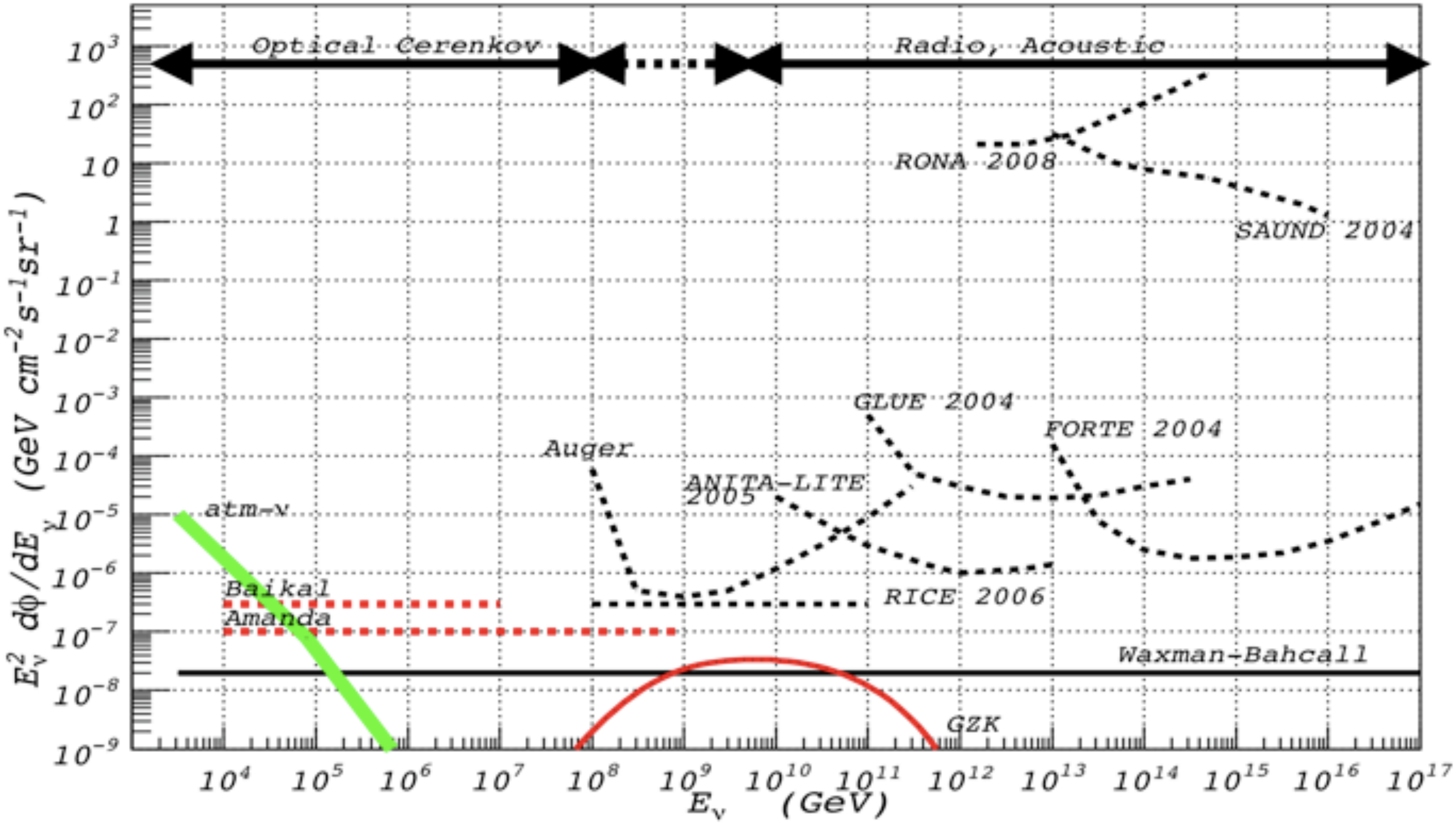
Energy Dissipation

- Another test was to see if the energy of the reconstructed pulses fell as $1/r^2$.
- Again, this proved successful with the slope of the line being -2.1 ± 0.23.

Simon Bevan



Rona Limit

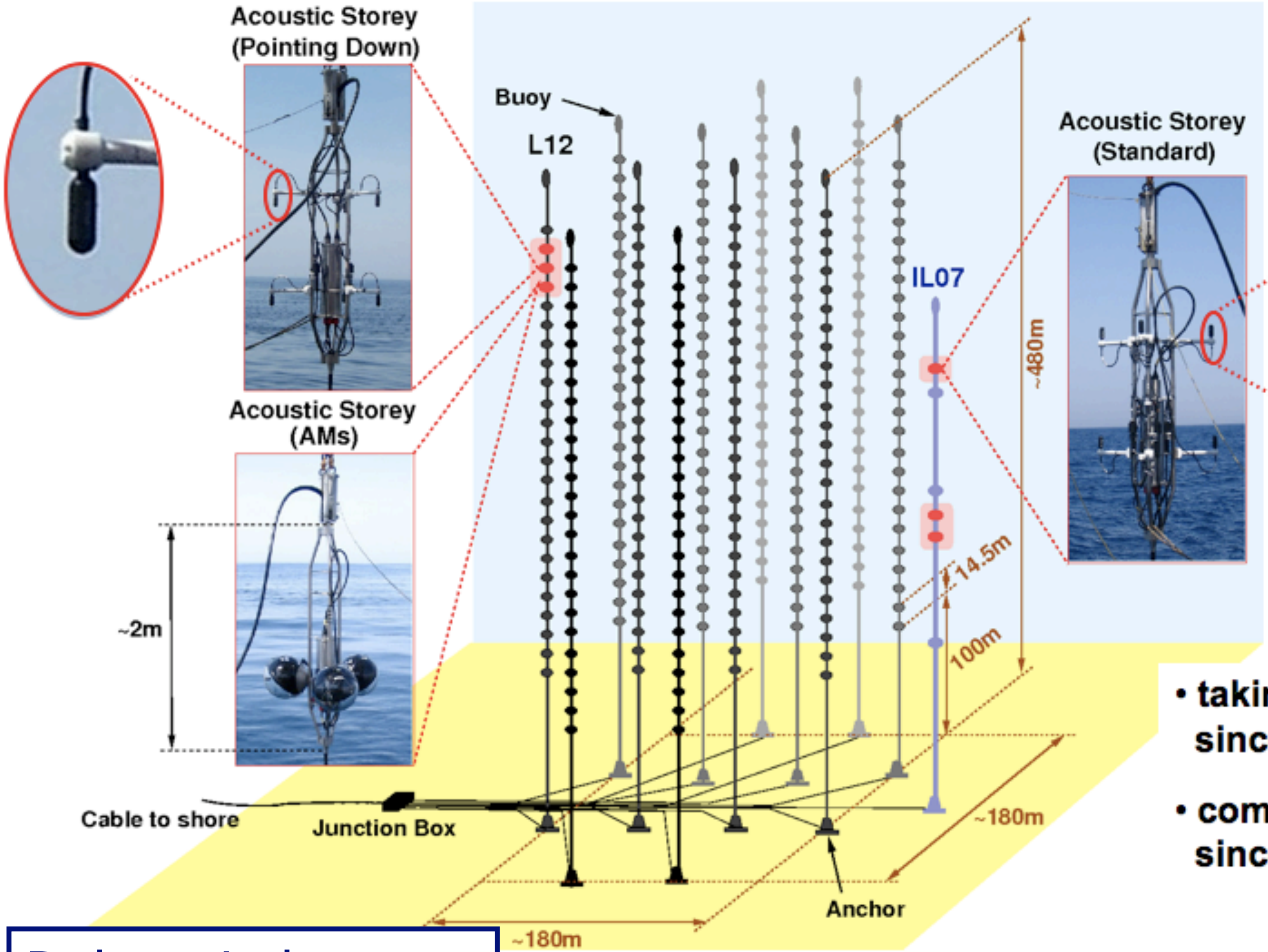


Simon Bevan

AMADEUS (ANTARES)

Postcard #9

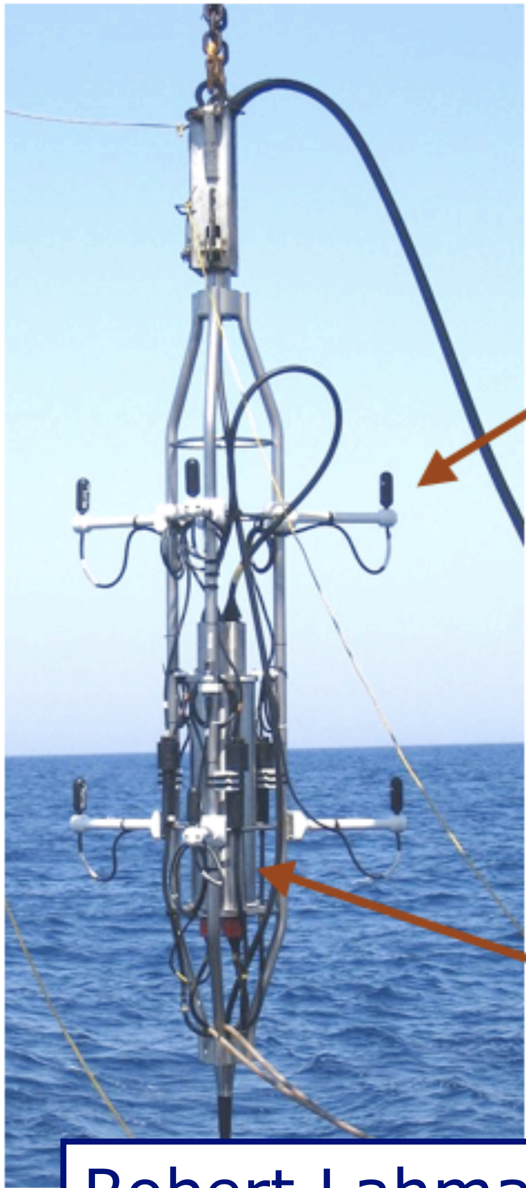
The AMADEUS System



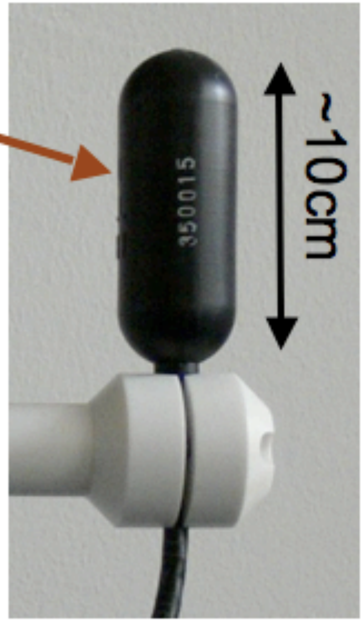
- taking data since 5-Dec-2007
- completely installed since 30-May-2008

Robert Lahmann

Setup of Acoustic Storey with Hydrophones



Hydrophone:
Piezo sensor
with pre-amplifier
and band pass
filter in PU
coating



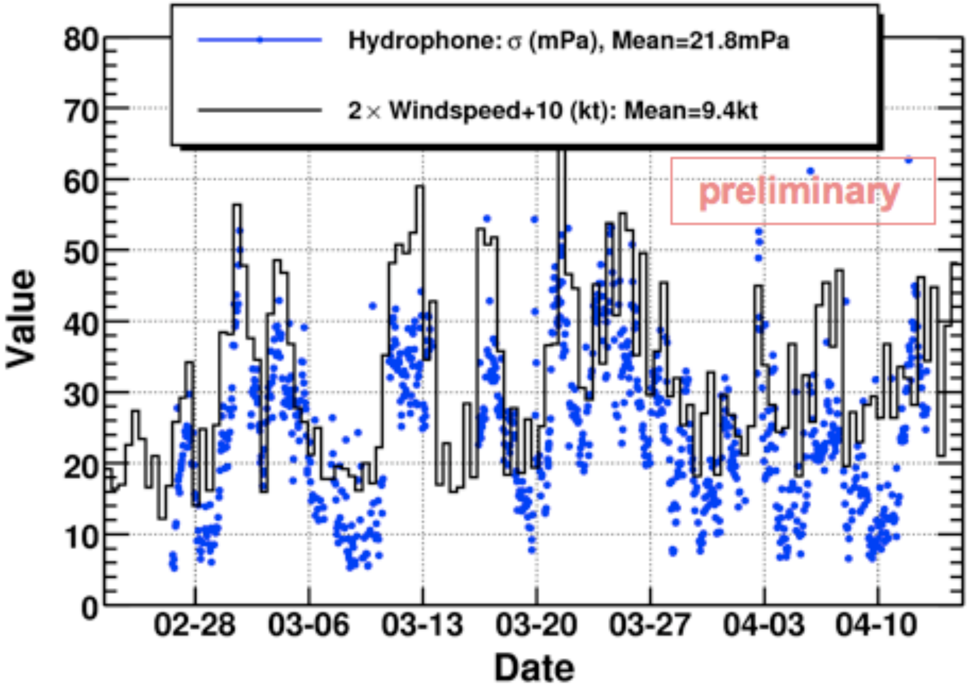
Titanium cylinder
with electronics

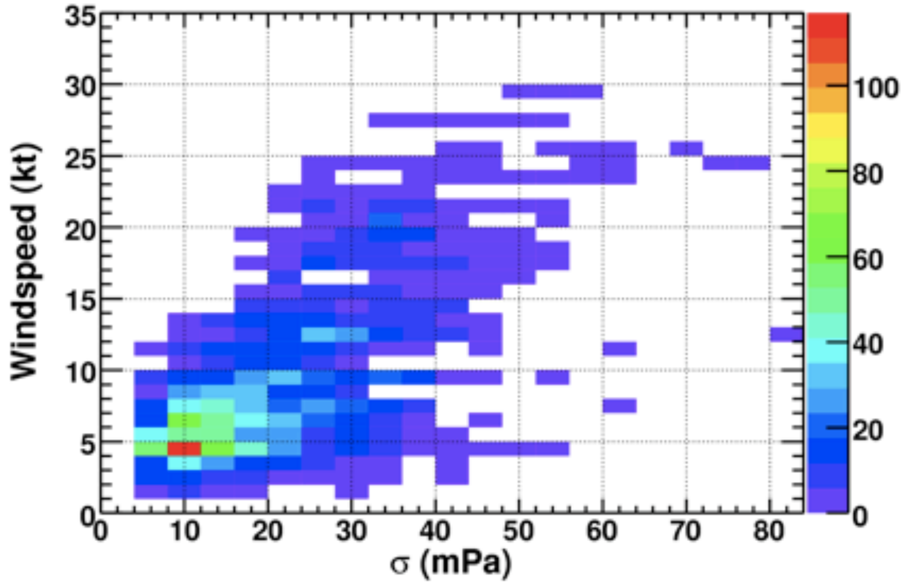
3 custom designed
Acoustic ADC boards

Robert Lahmann

Correlation with Weather Conditions

Hydrophone noise integrated from 1 to 50 kHz





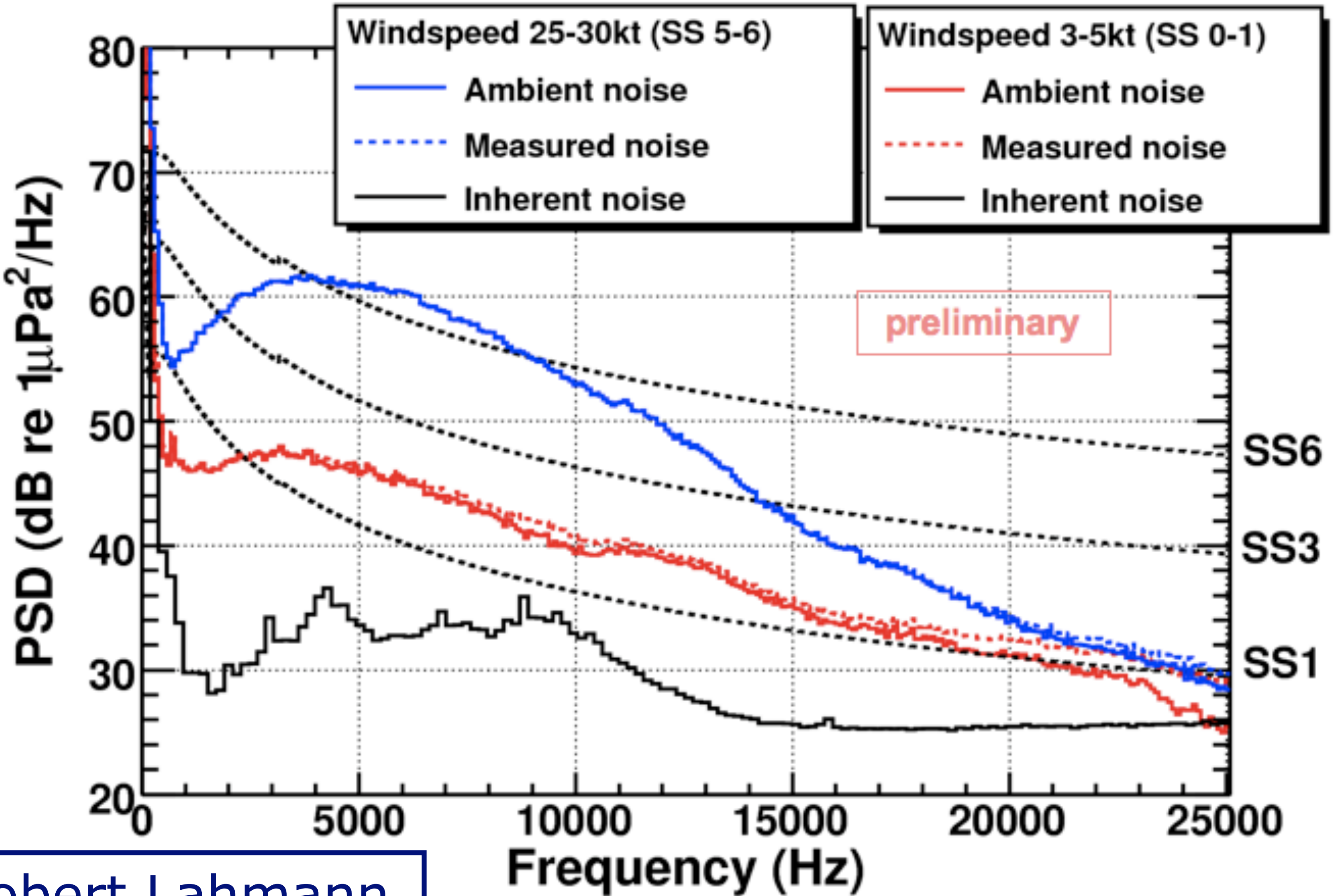
Weather conditions measured at Hyères airport, about 30km north of ANTARES site

- Correlation coefficient ~ 80%
- Deep-sea noise dominated by sea surface agitation

Robert Lahmann

Noise distribution in dependence of wind speed

Exemplary 10s-slices from one month period of previous slide

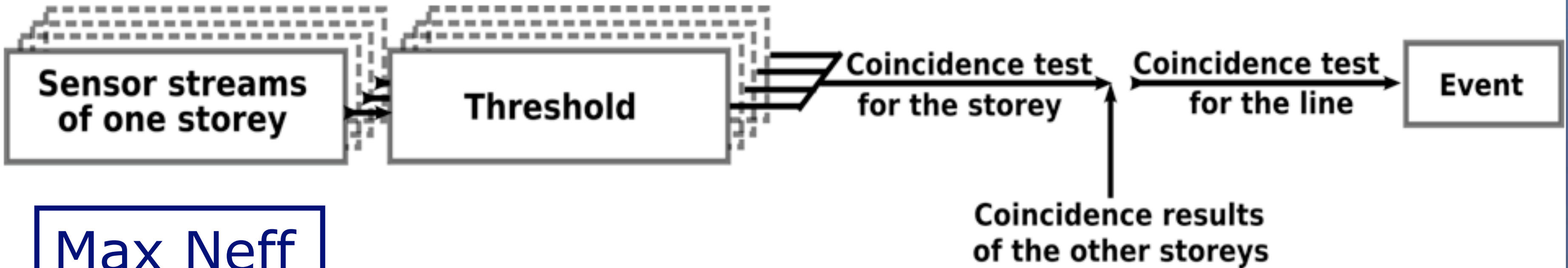


Robert Lahmann

AMADEUS Online Trigger and Filtering Methods

Coincidence Method

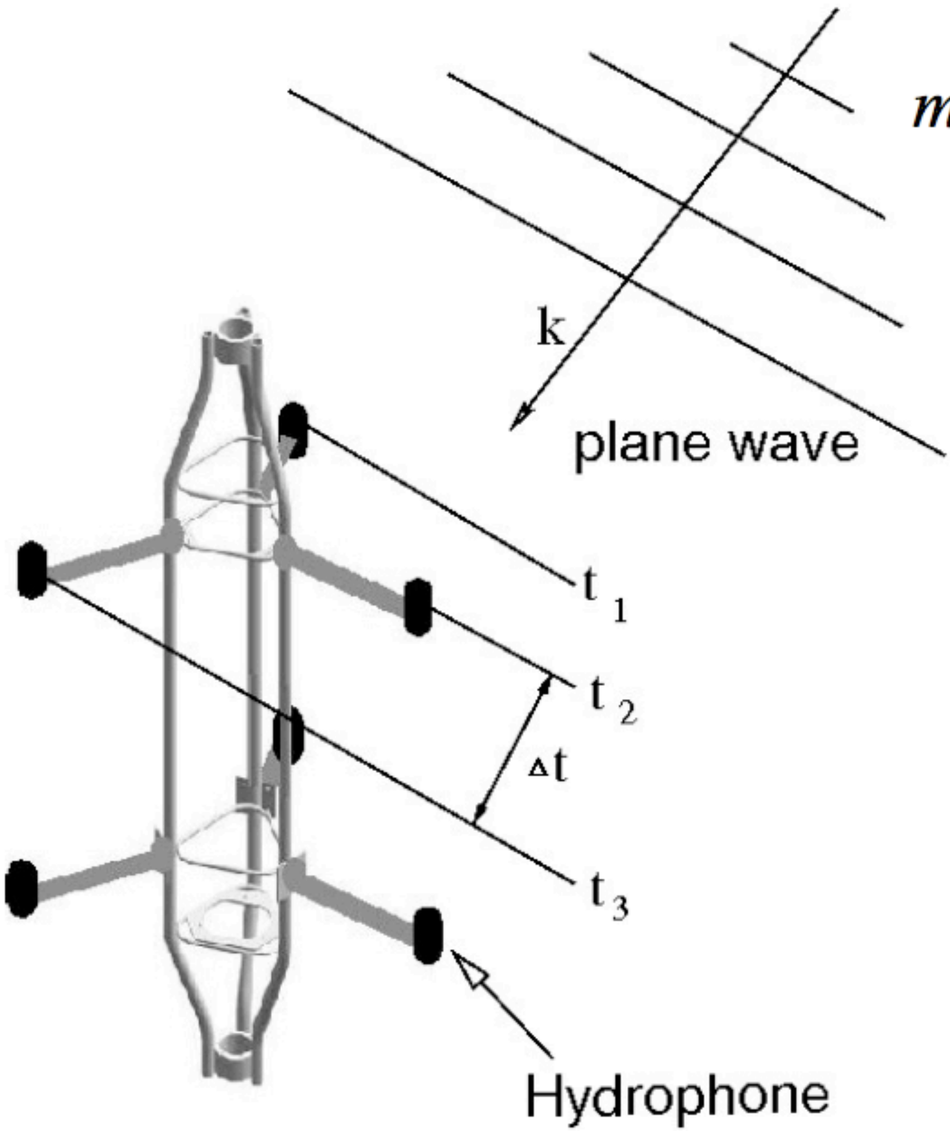
- Coincidence tests after each filter
- Time window of 0.104 s
- Tests on different levels
    - For the sensors of one storey
    - Between the storeys of one of the lines



Max Neff

Beamforming

Carsten Richardt



$$max(b(\vec{k},t)=\sum^{N} p_n(t-\Delta t_n(\vec{k})))$$

$$b(\vec{k},t)=Beamforming\ output$$

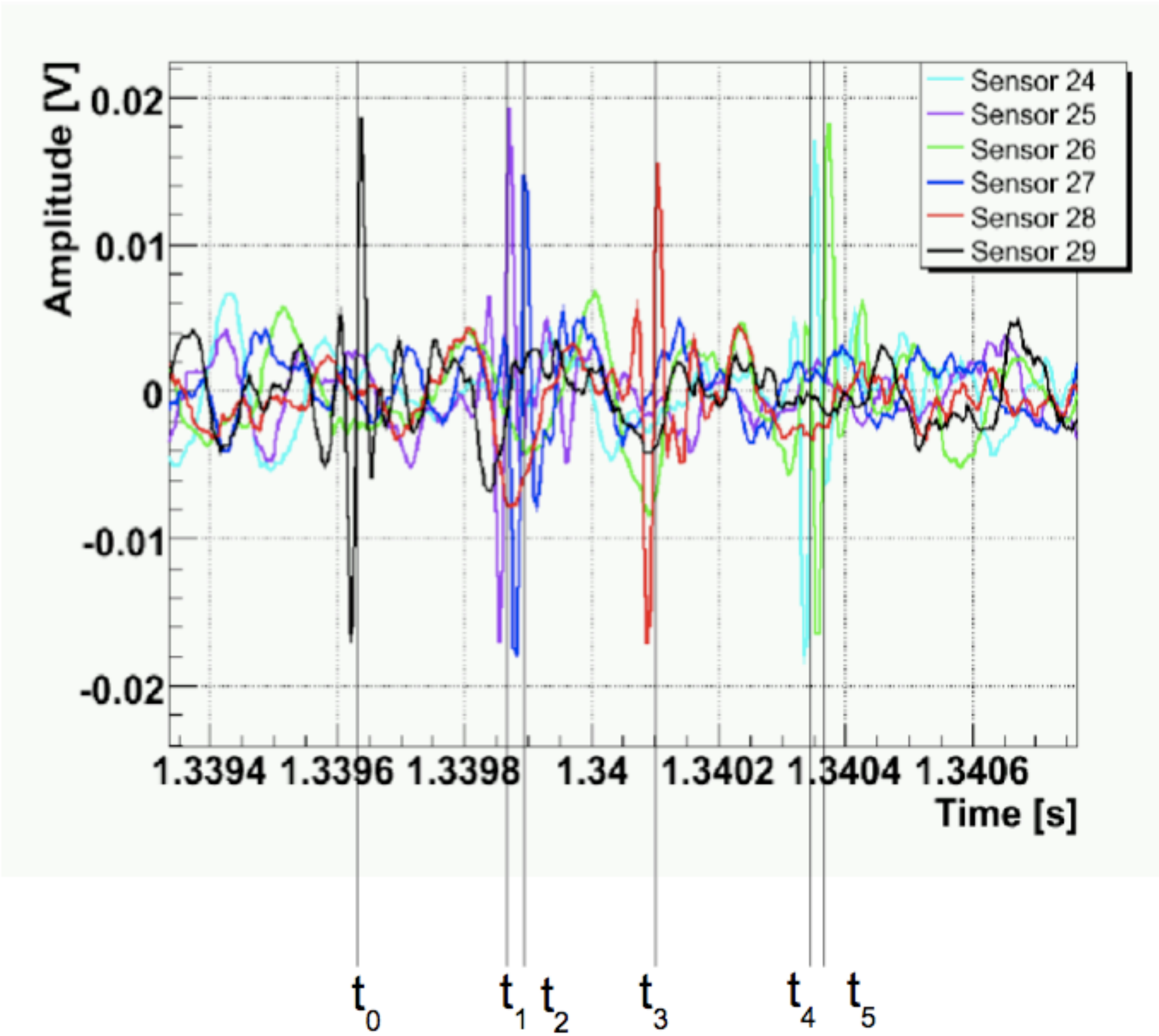
$$p(t)=Signal\ amplitude$$

$$\Delta t=delay\ time\ (lookup\ table)$$

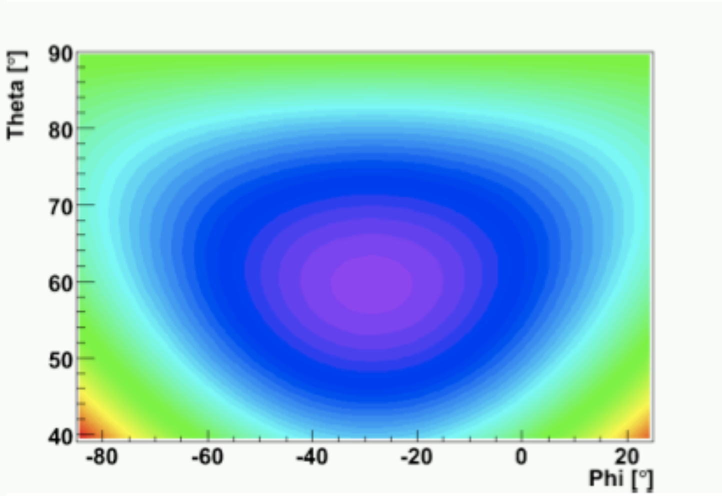
Orientation given by compass

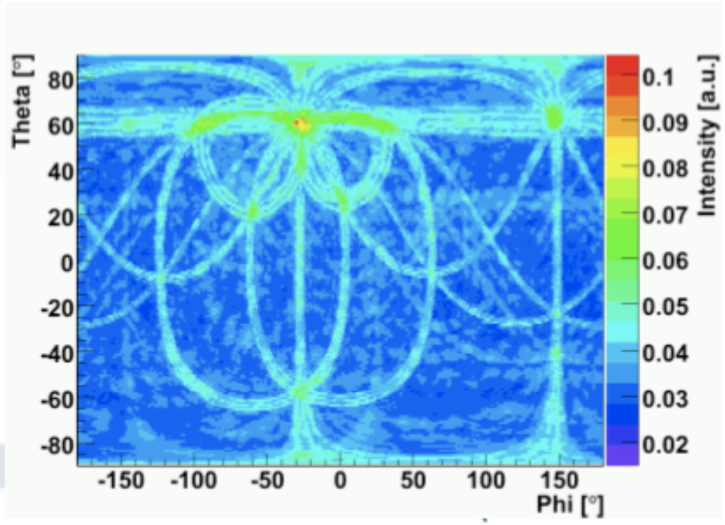
Time difference method

Carsten Richardt



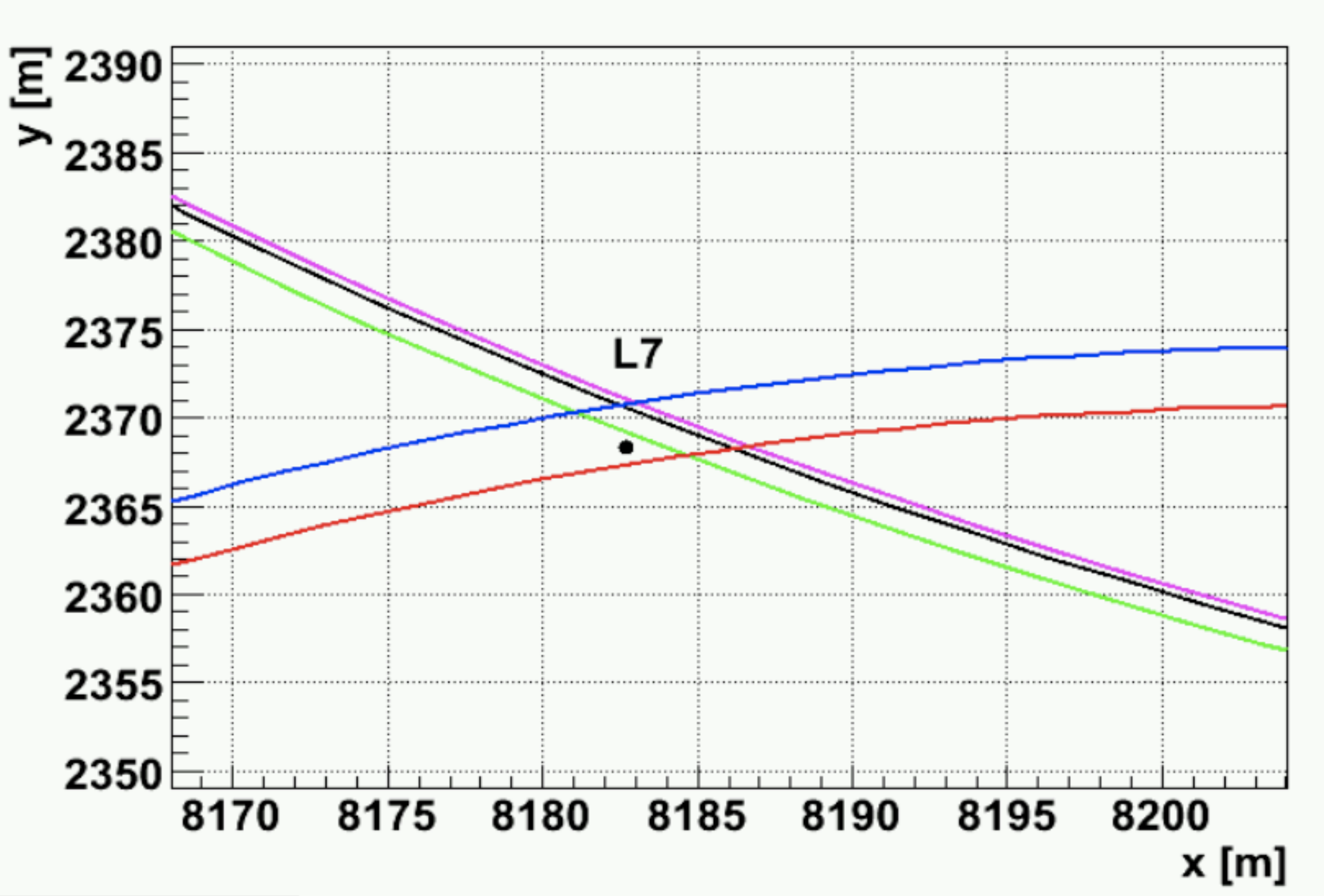
$$min\left(\sum_i (t_{i_M} - t_{i_E}(\theta, \phi))^2\right)$$





Position Reconstruction (Zoom)

Carsten Richardt



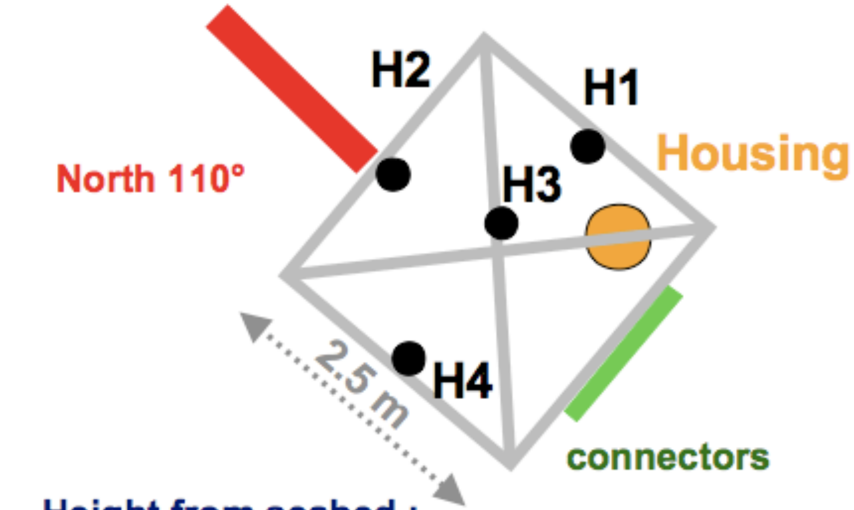
ONDE (NEMO)

Ocean
North Sea
Baltic Sea
NORWAY
Oslo
Stockholm
Helsinki
Tallinn
ESTONIA
Riga
LATVIA
LITHUANIA
Vilnius
Minsk
BELARUS
U. K.
Glasgow
Edinburgh
Belfast
IRELAND
Dublin
Limerick
Cork
Waterford
Liverpool
Sunderland
Leeds
Manchester
Leicester
Birmingham
London
DENMARK
Goteborg
Copenhagen
The Hague
Amsterdam
NETHERLANDS
Rotterdam
Hamburg
Gdansk
Berlin
POLAND
Warsaw
Poznan
Lodz
Lubin
Leipzig
Brussels
BELGIUM
Bonn
GERMANY
Luxembourg
LUX.
Frankfurt
Wroclaw Breslau
Krakow
Lviv
Paris
Karlsruhe
Nuernberg
Prague
CZECH
Ostrava
Brno
Nantes
Strasbourg
Stuttgart
Muenchen
Vienna
Bratislava
SLOVAKIA
Zurich
Bern
SWITZERLAND
Geneva
AUSTRIA
Budapest
HUNGARY
MOLDOVA
Chisinau
FRANCE
Bordeaux
Lyon
Milano
SLOVENIA
Ljubljana
Cluj
ROMANIA
Timisoara
Bayonne
Turin
Venezia
Zagreb
CROATIA
Belgrade
Porto
PORTUGAL
Valladolid
Toulouse
Monaco
Genova
Bologna
BOSNIA and HERZ.
Sarajevo
Danube
SPAIN
Marseille
Firenze
Sofia
BULGARIA
Lisbon
Madrid
Barcelona
YUGOSLAVIA
Valencia
Rome
ITALY
Tirane
Skopje
MACEDONIA
Cordoba
Napoli
ALBANIA
Thessaloniki
Sevilla
GREECE
Gibraltar
Agrinion
Palermo
Algiers
Rabat
Tunis
Athens
Casablanca
MALTA
MOROCCO

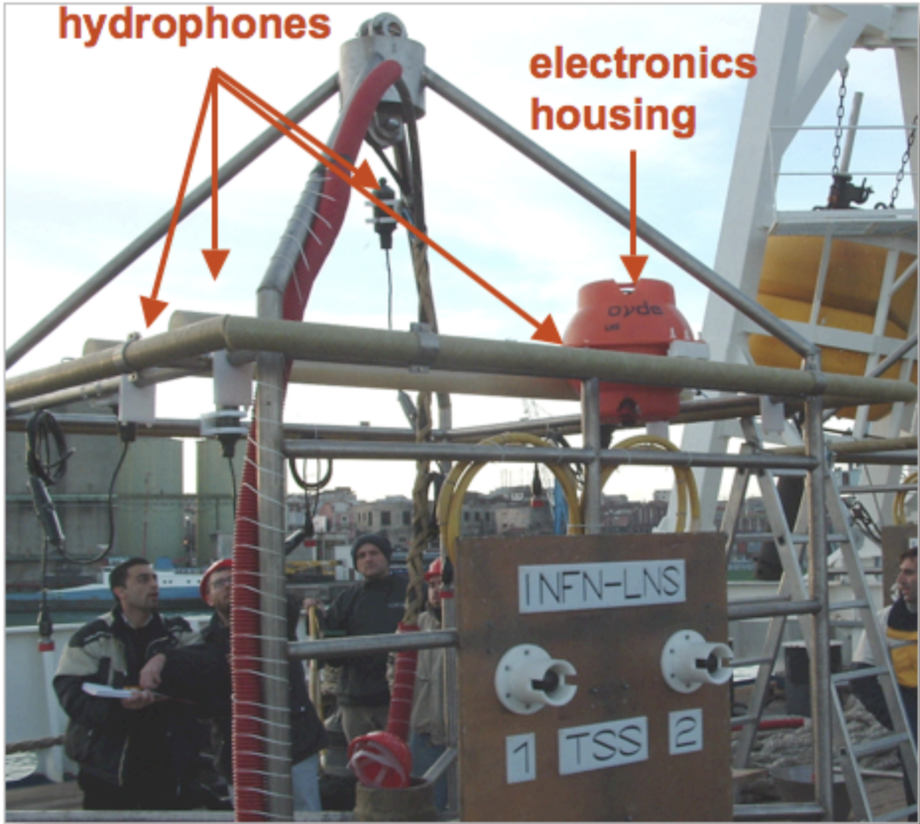
Postcard #10

4 hydrophones (10 Hz-40 kHz bandwidth) synchronized.
Acoustic signal digitization (24bit@96 kHz) at 2000m depth.
Data transmission on optical fibers over 28 km.
On-line monitoring and data recording on shore. Recording 5' every hour.
Data taking from Jan. 2005 to Nov. 2006 (NEMO Phase 1 deployed).

Giorgio Riccobene

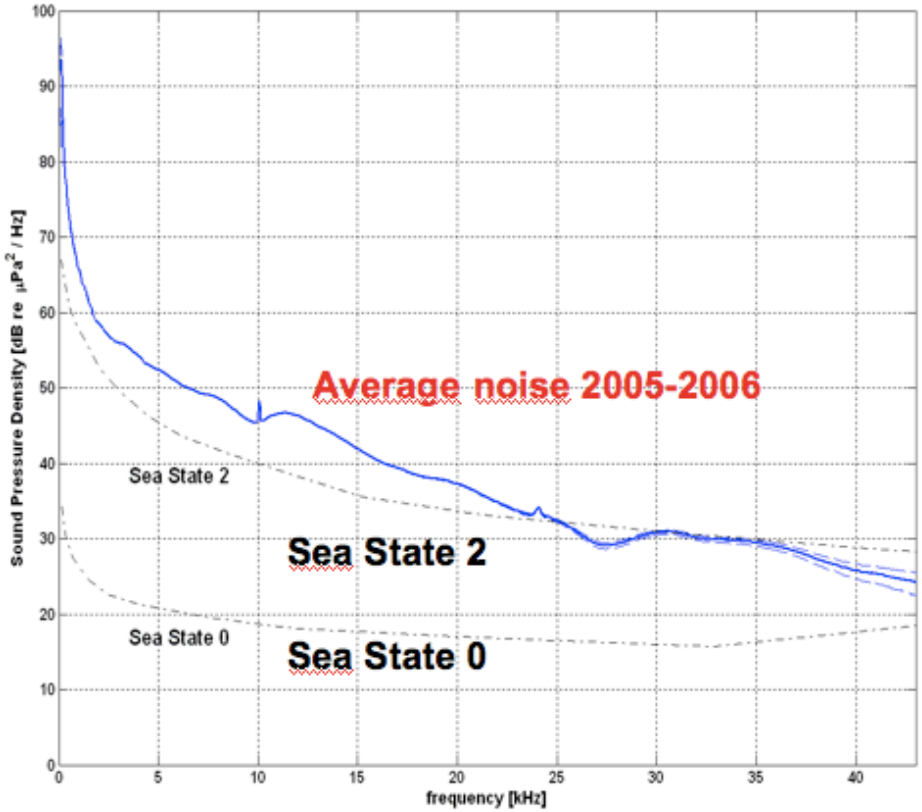


Height from seabed :
H1, H2, H4: ~ 2.6 m   H3: ~ 3.2 m



In collaboration with Uni-Pavia CIBRA

Giorgio Riccobene

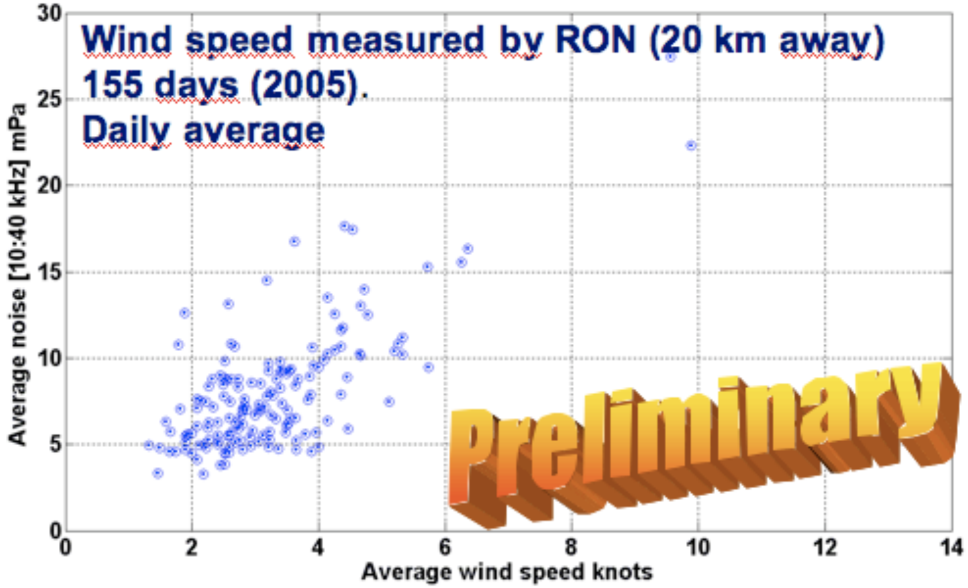


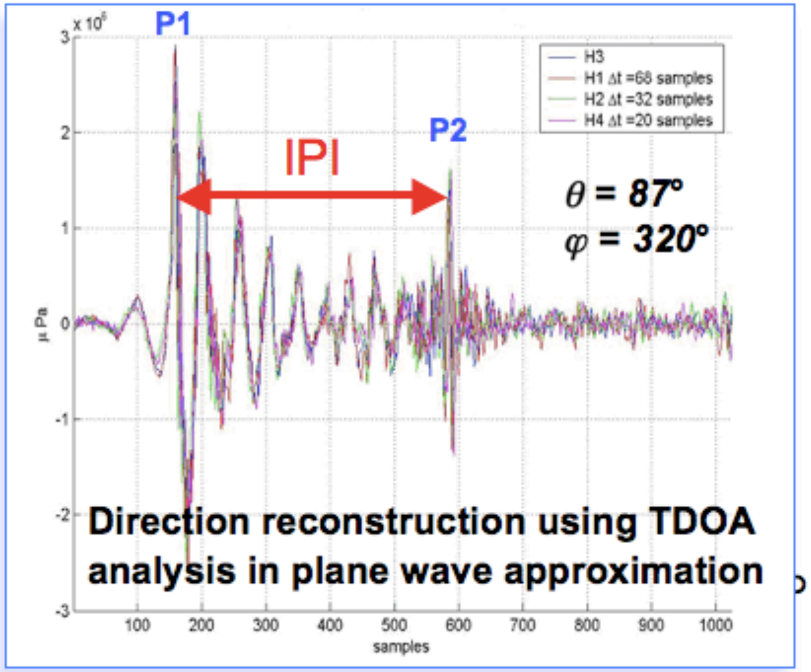
The average SPD is close to SS2, with increase at low frequency probably due to diffuse anthropogenic noise.
Peaks are due to pingers and shipping instrumentations continuosly present in the area.

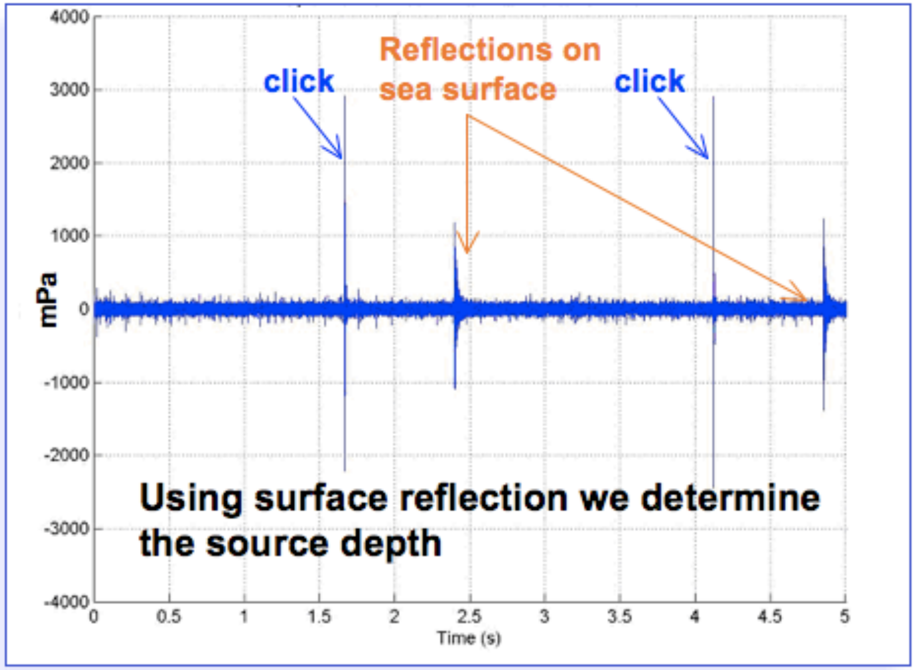
Giorgio Riccobene

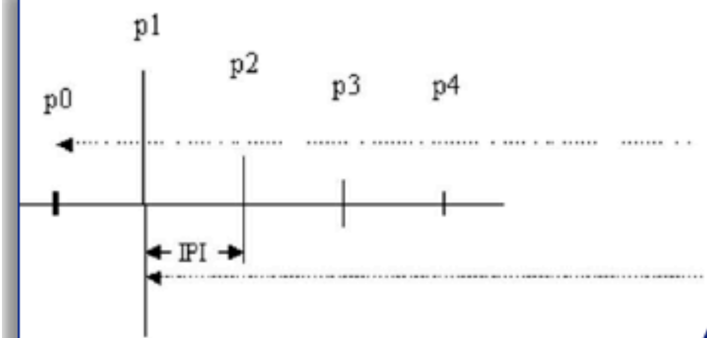
$$A_p(f_1,f_2) = \left[\int_{f_1}^{f_2} PSD\cdot(f)df\right]^{\frac{1}{2}}$$

The average noise in the [20:43] kHz band is $5.4 \pm 2.2_{stat} \pm 0.3_{syst}$ mPa

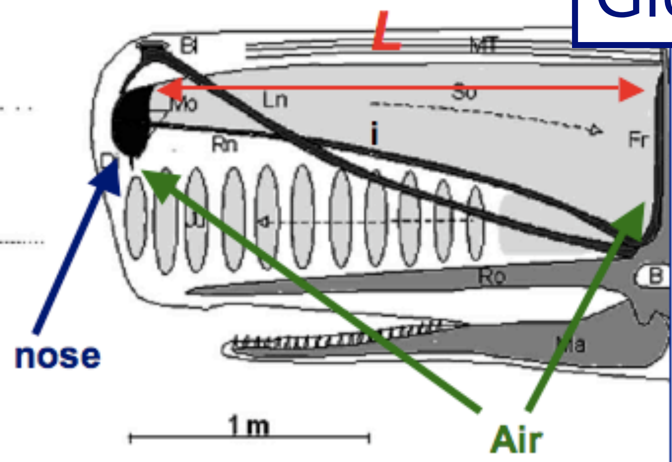








$$IPI = \frac{2L}{c_s}$$



Giorgio Riccobene

Depth = 560 ± 5 m

L = 3.41 ± 0.05 m
Size = 9.72 - 10.50 m

Young male or female

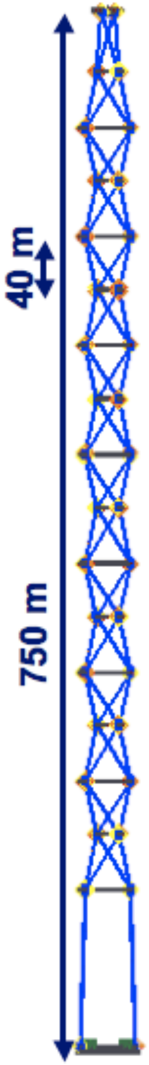
NEMO Phase II: Installation and operation of a "full scale" tower in Capo Passero Site
16 floors, 64 Optical Modules, 750 m total height

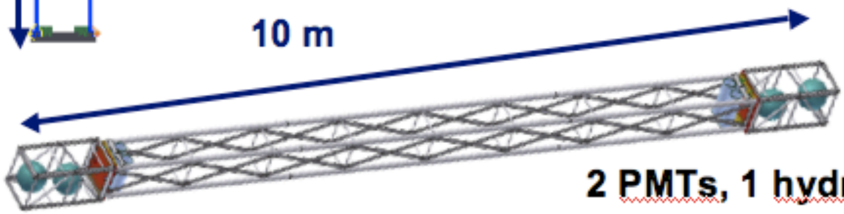
Same electronics and DAQ and DAT as NEMO Phase I:
All detectors data synchronised and phased (about 1 nsec)

32 hydrophones used mainly for Acoustic Positioning and also for Acoustic Physics/Biology

- → Reduce costs and improve reliability of the tower acoustic positioning system
- → O(1km) long antenna for feasibility studies on acoustic detection
- → Optical and acoustic data in the same data stream with the same timing
- → Interdisciplinary
- → Environment and Detector acoustic monitoring

Hydrophones (SMID-NURC)	30 (-207 dB re 1V/uPa) + 4 (-201 dB re 1V/uPa) – tested at 3500 m
Preamp (SMID-NURC)	32 dB gain, 0.8 nV/sqrt(Hz) input noise
ADC-board	24 bits, 192 kHz sampling (2 hydros = 1 OM payload), 3 dB gain
FCM	Optical Transmission to shore + GPS Time info





2 PMTs, 1 hydrophone

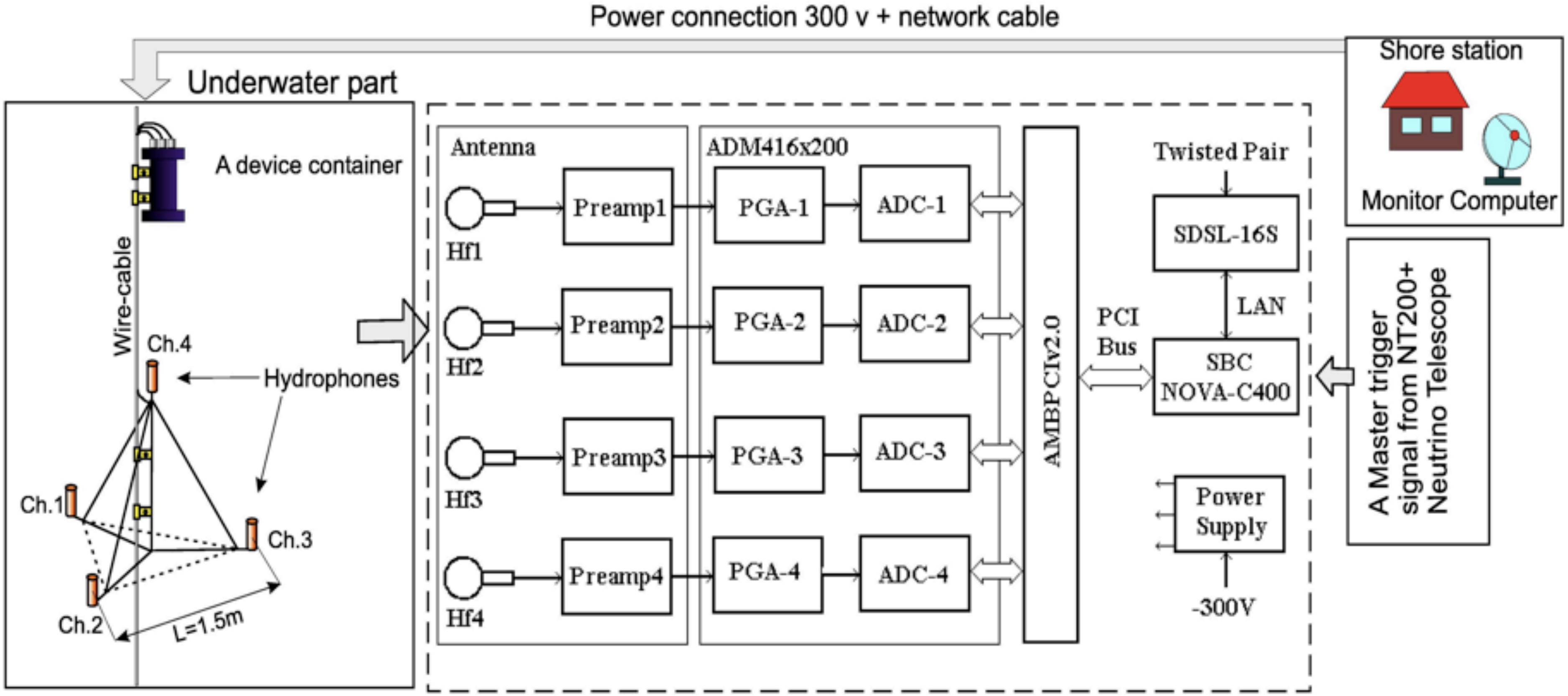
Giorgio Riccobene

Lake Baikal

Arctic Ocean
Norwegian Sea
North Sea
Norway
Sweden
Baltic Sea
Finland
St. Petersburg
Pskov
Moscow
Urals
RUSSIA
SIBERIA
Sea of China
Black Sea
Yekaterinburg
Irkutsk
Lake Baikal
Turkey
Kazakhstan
Caspian Sea
Mongolia
Iran
China
Afghanistan

Postcards #11,12

Schematic view of prototype device

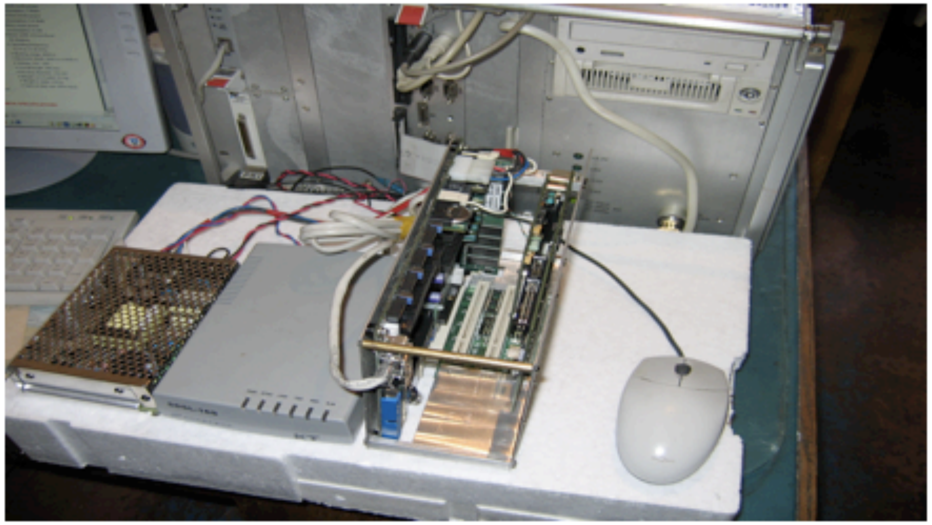


Nikolai Budnev

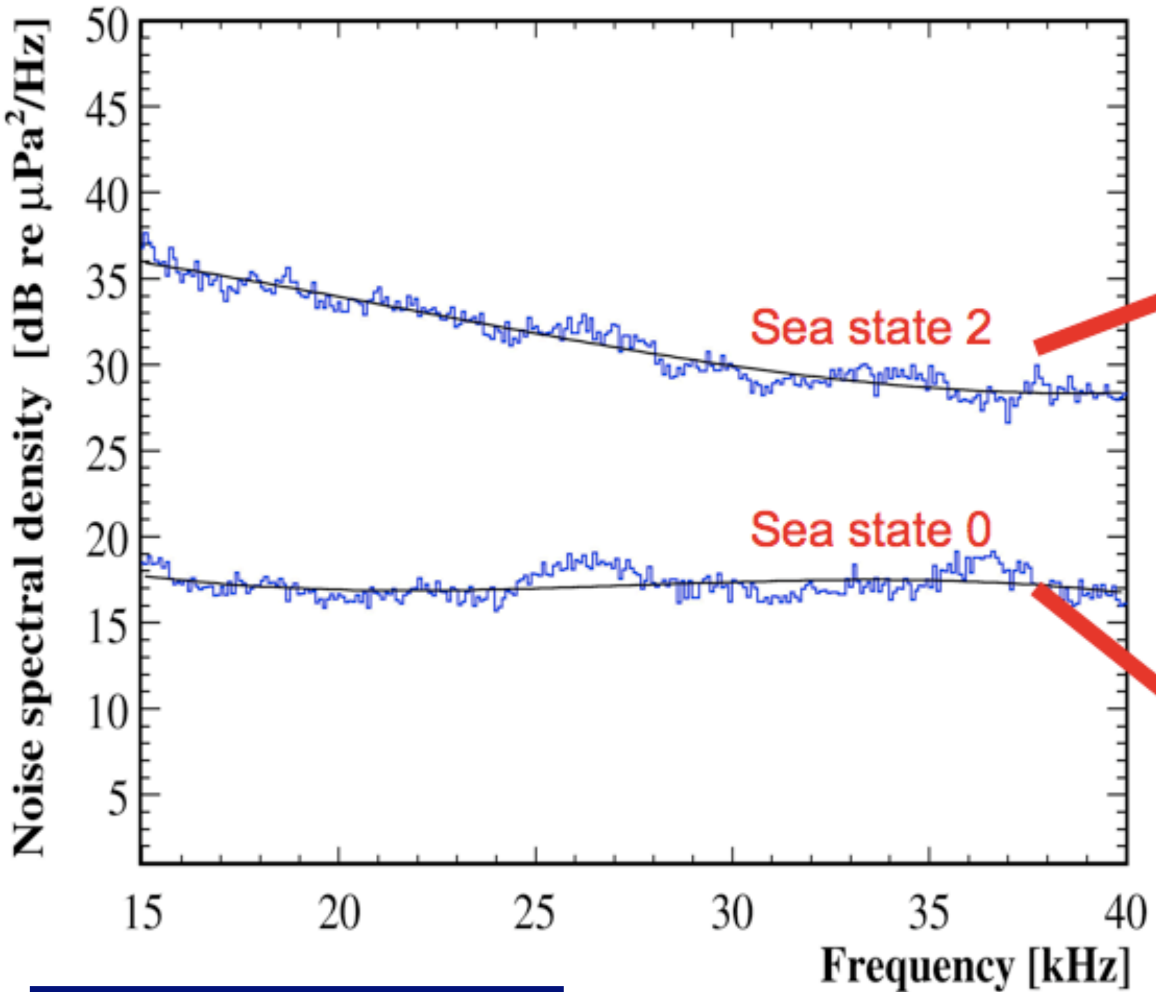
Antenna and electronic components

Nikolai Budnev

- Tetrahedral antenna 1.5m
- 4 hydrophones H2020C
- 4-ch, 195kHz, 16-bit ADC AD7722
- One-plate computer NOVA-C400
- 2 Mbit DSL modem



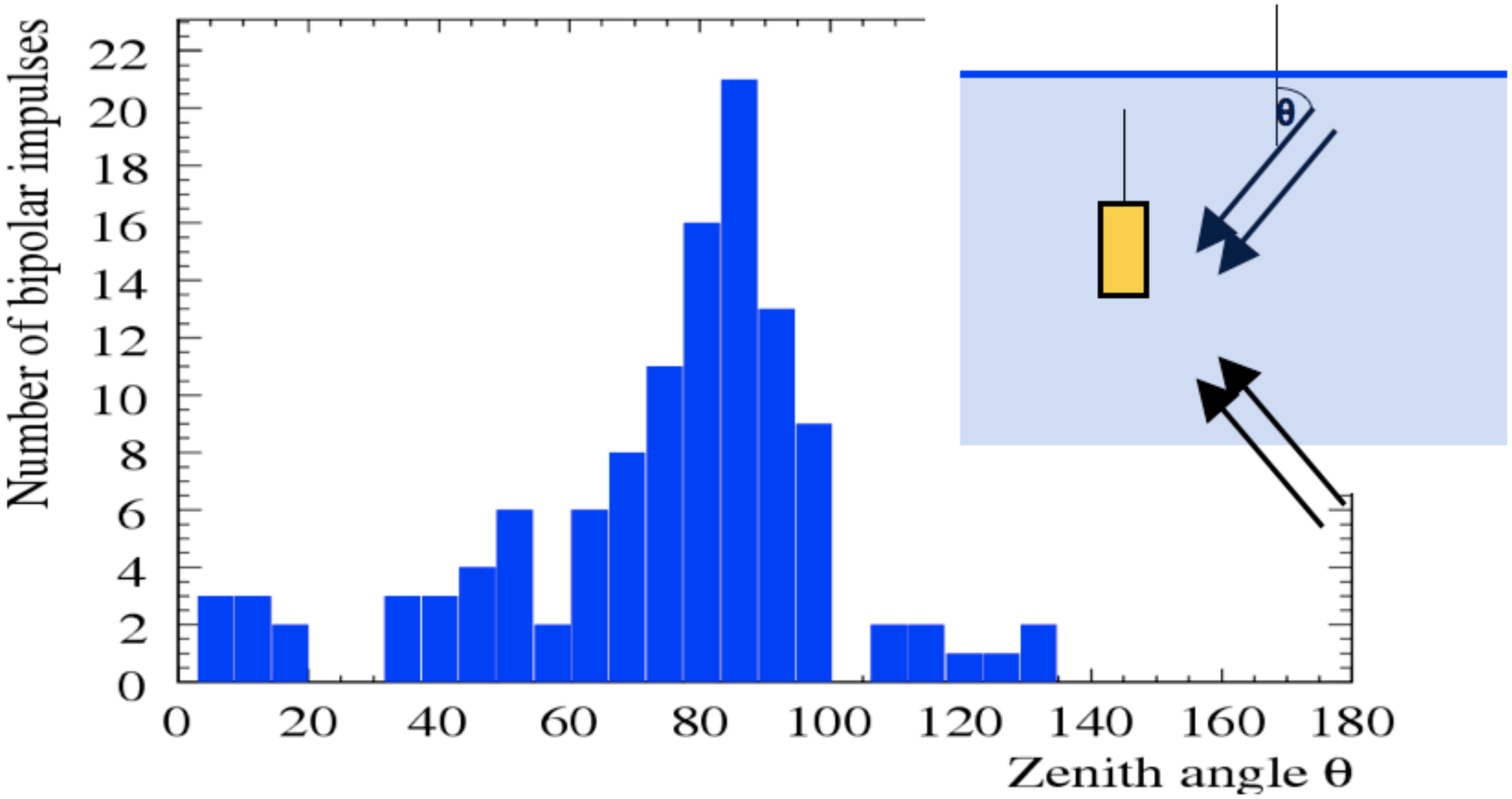
Lake Baikal noise spectral density



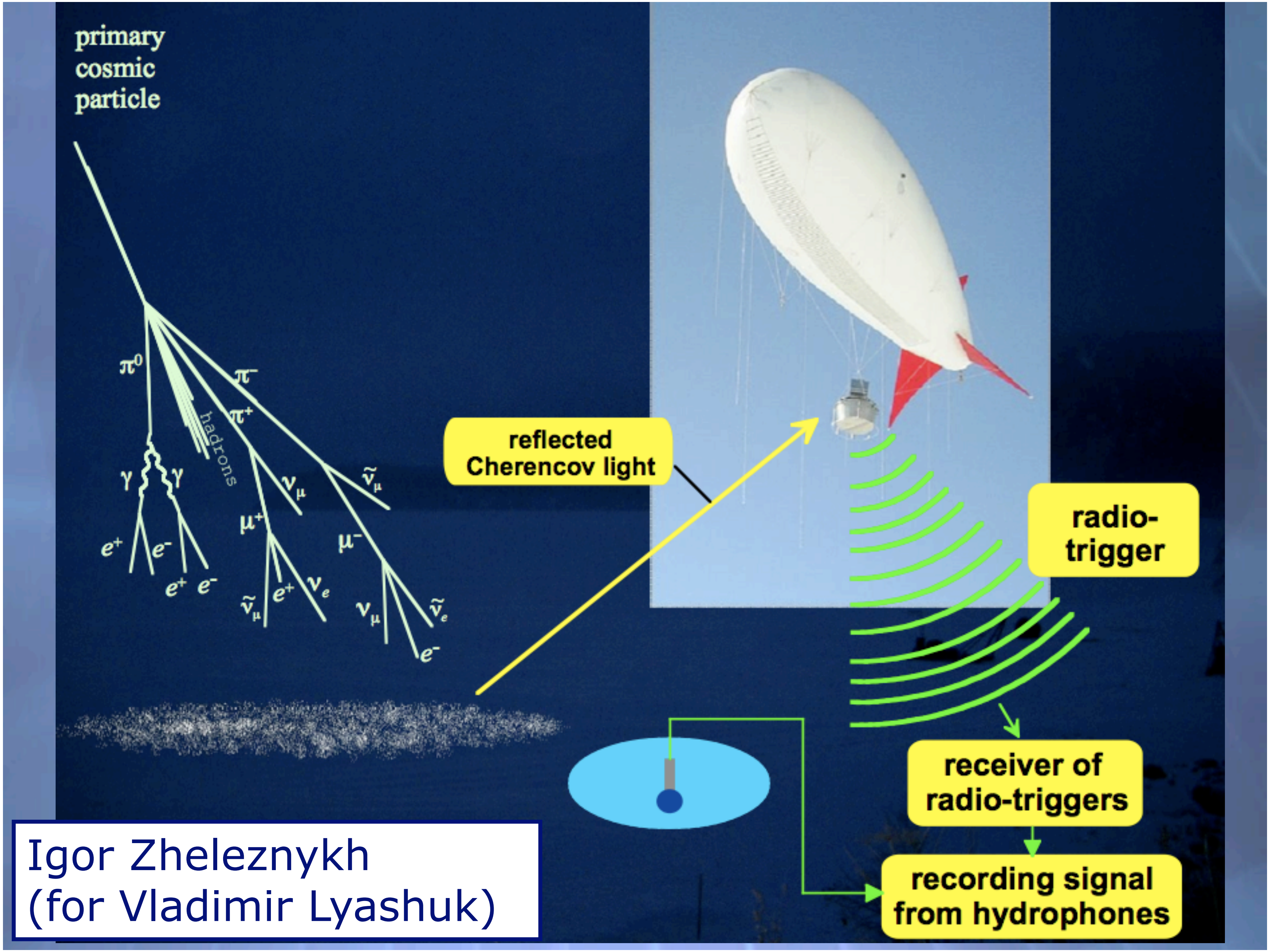
Nikolai Budnev

Angle distribution of detected bipolar pulses

Nikolai Budnev



Downward going pulses	Upward going pulses



Igor Zheleznykh
(for Vladimir Lyashuk)

Igor Zheleznykh
(for Vladimir Lyashuk)

SPHERE-2 installation

109 small photomultipliers are fixed in the focus of 1.5 m mirror (which look down - to the ice); the pulse profiles are registrated during 12.8 ms with 25 ns sampling; the angle of vision is ~ 1 steradian; the installation is operated by means Wi-Fi connection. Test launch of the SPHERE installation was realized in March, 2008 in Baikal.

Aerostats

Aerostat AZ-55

Aerostat APA-1

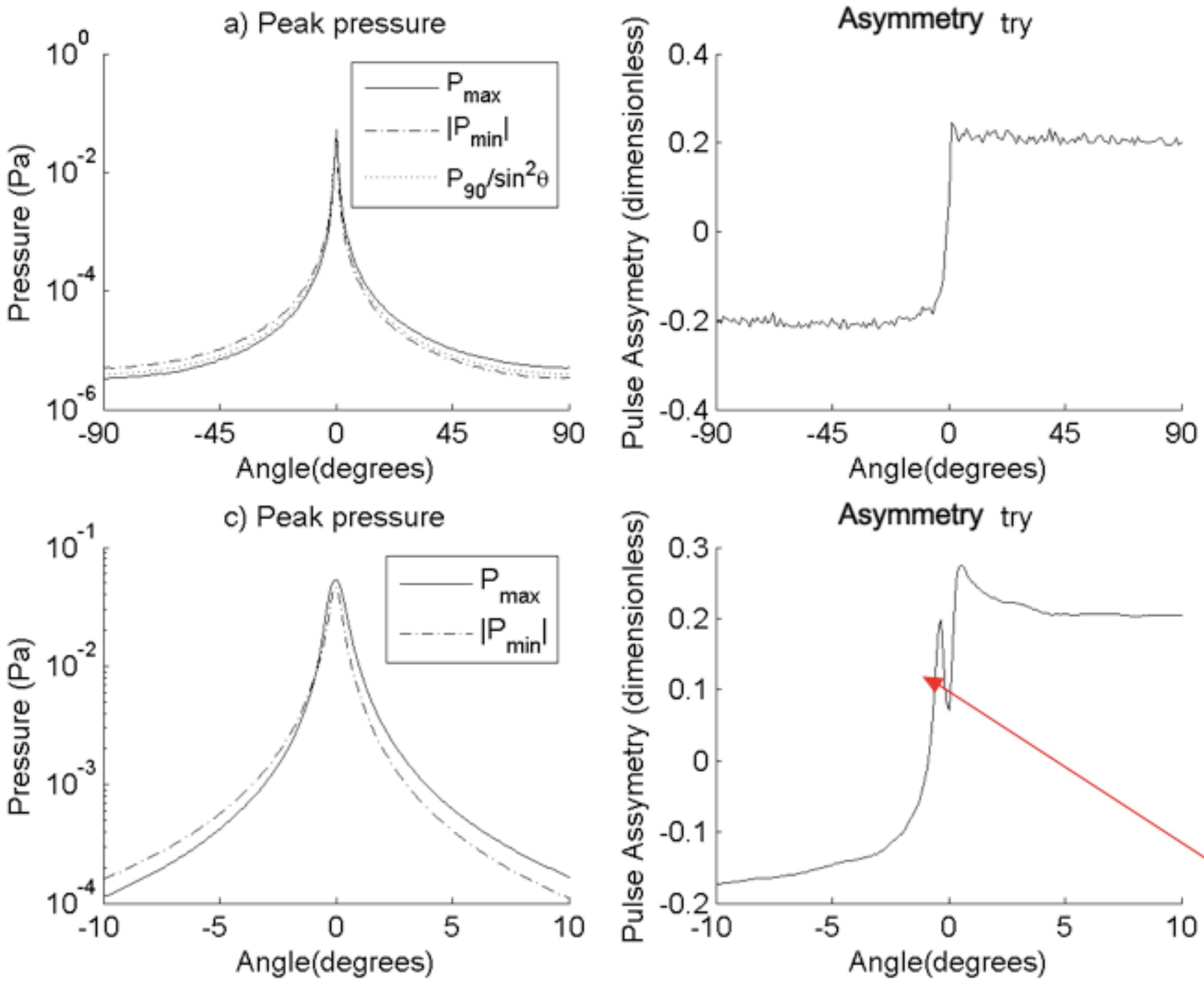
Igor Zheleznykh
(for Vladimir Lyashuk)

Other presentations

- Other detection media
- Alternative acoustic sensors
- Calibration and parametrization techniques
- Acoustic integrals
- Software methods
- Acoustic detection in proton beams
- Sensitivity calculations

Pulse as a Function of Angle for CORSIKA Showers Seawater

Sean Danaher

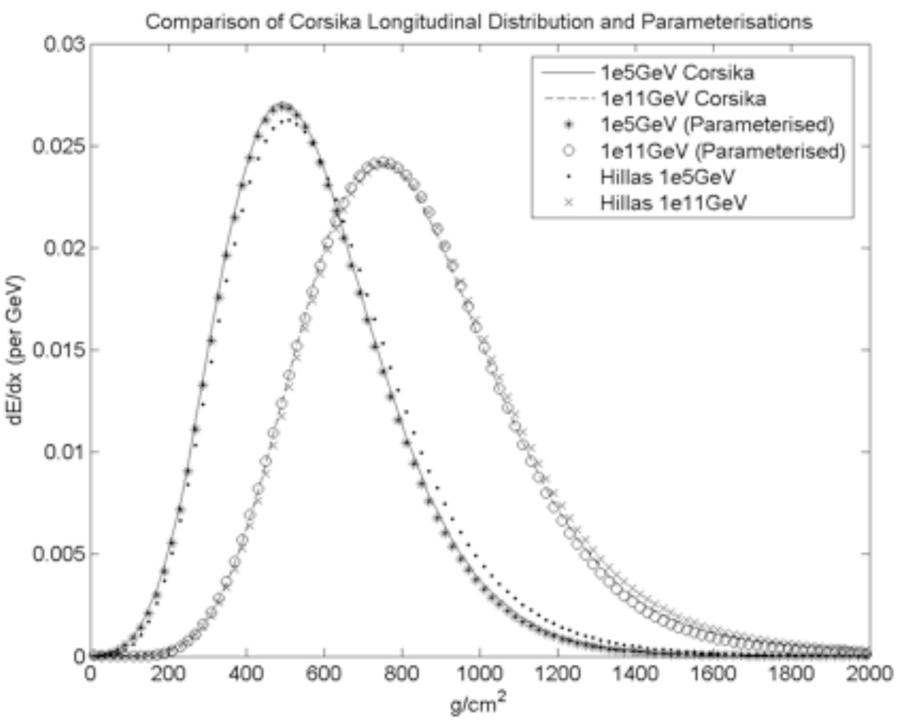


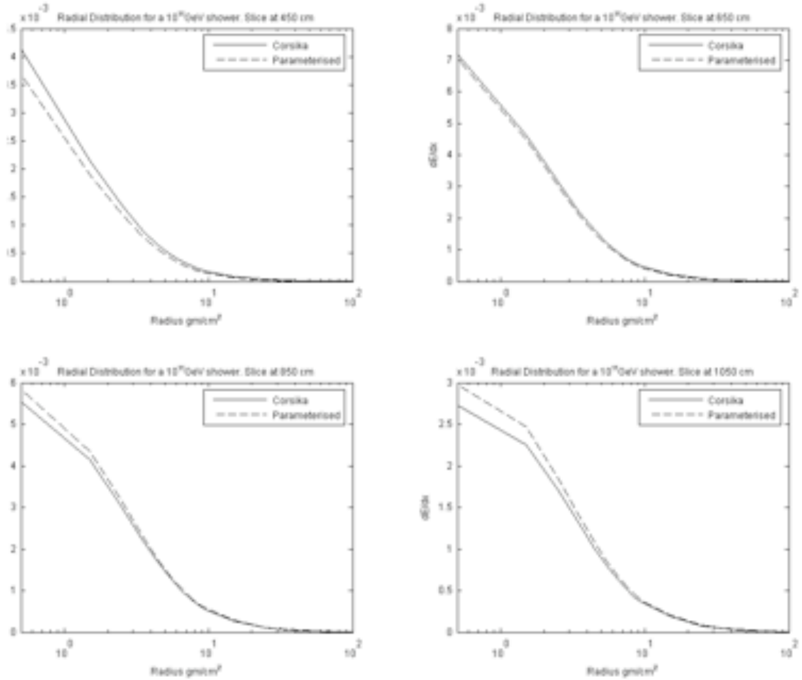
Outside a few degrees the pulse shape remains the same but gets longer in time as $\sin\theta$ and shorter in amplitude as $1/\sin^2\theta$

Outside a few degrees the asymmetry is constant; dictated by the longitudinal distribution. This flips for +/- angles

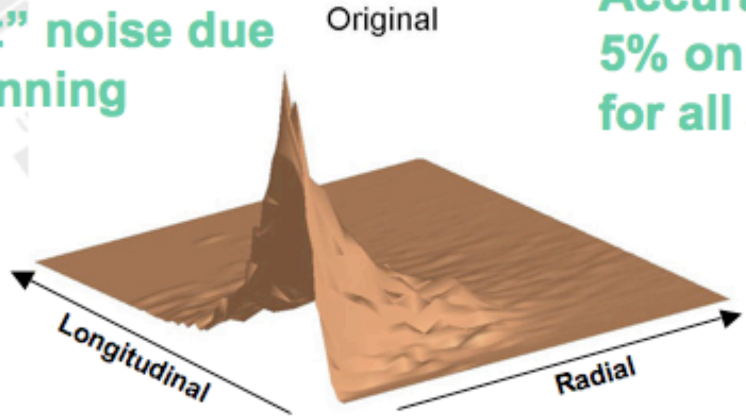
What is happening here?

Fits Showers well



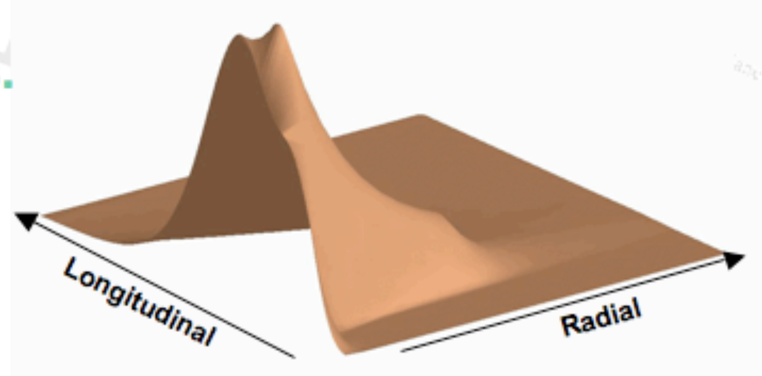


Original shows "shot" noise due to thinning



Accuracy within 5% on average for all showers.

Sean Danaher



Acoustic Source Location

Spherical Interpolation Method

$$R_i \stackrel{\Delta}{=} \|r_i\| = \sqrt{x_i^2 + y_i^2 + z_i^2}, i = 1,\dots,N \qquad R_s \stackrel{\Delta}{=} \|r_s\| = \sqrt{x_s^2 + y_s^2 + z_s^2}.$$

$$D_i \stackrel{\Delta}{=} \|r_i - r_s\| = \sqrt{(x_i - x_s)^2 + (y_i - y_s)^2 + (z_i - z_s)^2}.$$

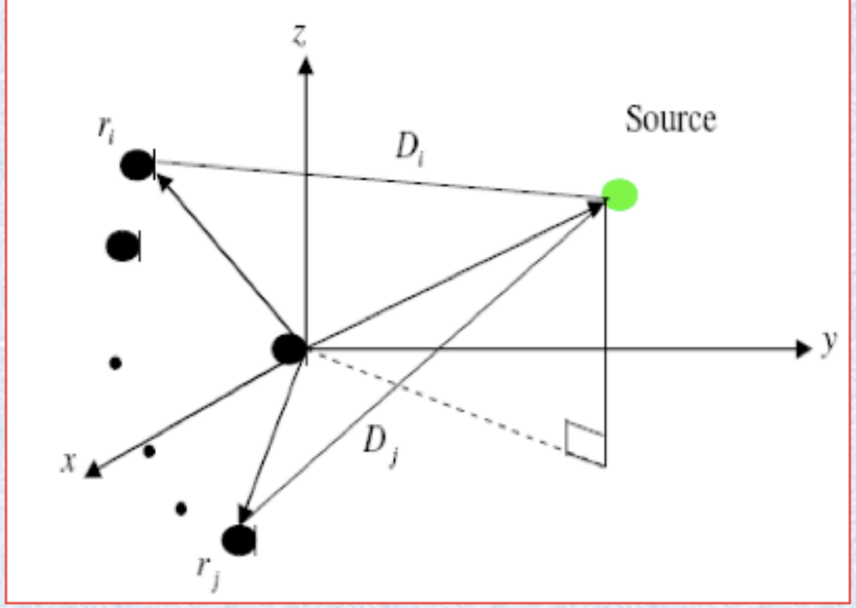
The spherical LS error is defined as:

$$e_{sp,i}(r_s) \stackrel{\Delta}{=} \frac{1}{2}\left(\hat{D}_i^2 - D_i^2\right)$$
$$= r_i^T r_s + d_{i0} R_s - \frac{1}{2}\left(R_i^2 - d_{i0}^2\right), \quad i = 1,\dots,N.$$

$$e_{sp}(r_s) = A\theta - b,$$

Matrix Form

$$J_{sp} = e_{sp}^T e_{sp} = [A\theta - b]^T [A\theta - b]$$



$$r_s = S^*(b - R_s d),$$

Leat Square Solution

↓

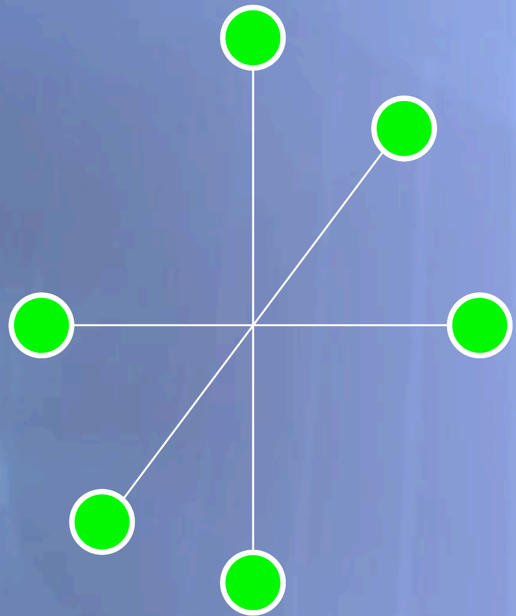
Range estimation

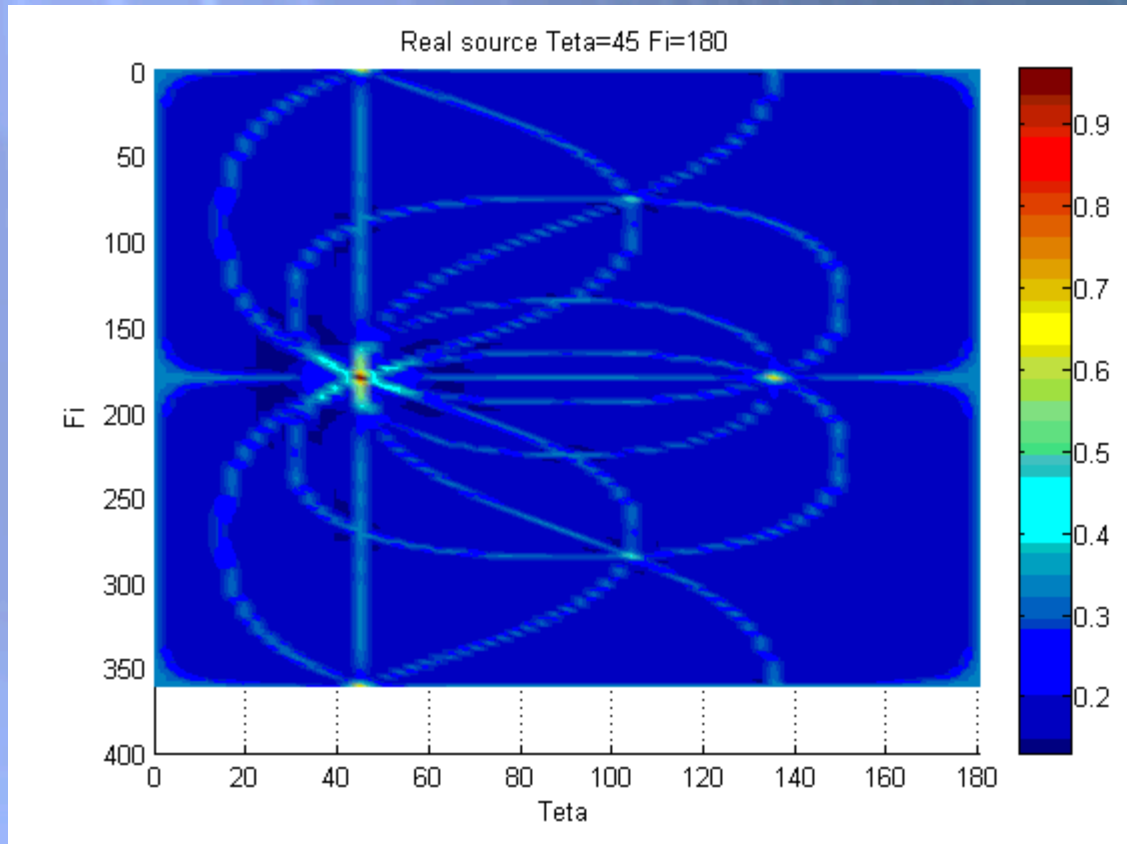
↓

Re-estimation of position

Bachir Bouhadef

Beamforming





Francesco Simeone

Other considerations.

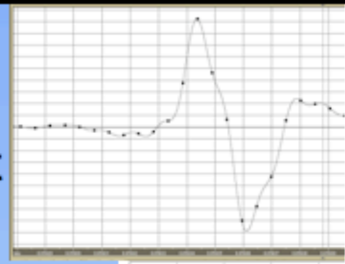
Timing and positioning systems

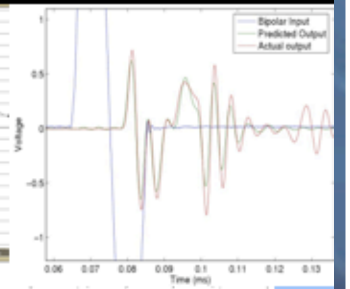
Miguel Ardid

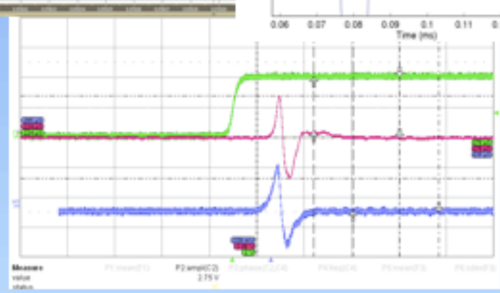
- **For a good determination of coincidences and reconstruction of the source, it is essential a time synchronisation of the sensors and to know their positions:**
- **Timing system:**
  - A **μs accuracy** is enough
  - Compared to the ns level for optical based telescopes, **it seems not a big deal**. Electronic clock can be enough. **However**:
    - Considering the **size of the telescope**, it is not straightforward to think that all the hydrophones will be connected and synchronised with respect to a master clock
    - In **case of independent clusters** of sensors, the timing synchronisation can become **not trivial** at all.
- **Positioning system:**
  - For undersea telescopes, the sea currents will result on drifts of the hydrophones positions not anchored directly to the sea floor. A system to monitor their positions (within cm accuracy) is needed.
    - Of course, a Long Baseline **Acoustic system** can be used. It would be convenient that the acoustic calibration system will **give the position** at the same time that providing the tool for the **sensitivity and response** of the sensors of the telescope
    - WARNING: Be sure that the **system** is **redundant enough** in order to decouple all the effects. Independent cross-checks are welcomed

In situ Calibration. Transmitters and Techniques
Acoustic transducers and arrays

- **The easiest way to produce the neutrino signal is by means of acoustic transducers:**
  - The ‘neutrino’ bipolar signal obtained with different groups using different modelling techniques for feeding signal:
    - ACORNE (circuit modelling, see O. Veledar talk)
    - Erlangen (two times integrated signal)
    - Valencia (Inverse filter equalisation)

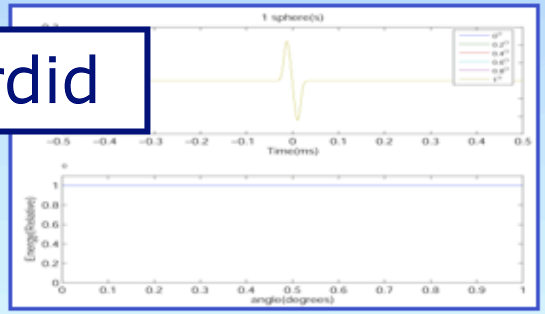


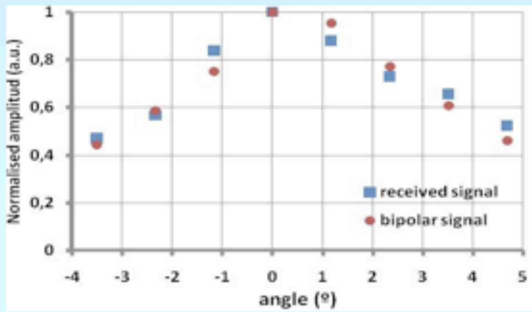




- **However, there is still the difficult aspect of the ‘pancake’ directivity**
  - Different approaches have been tried:
    - ACORNE: Phased linear omnidirectional array (under development)
      - OK: Simple and direct idea
      - NOT GOOD: Long array (difficult design and operation), problems with side lobes?
    - Valencia: Acoustic parametric sources (under study and development, see M. Bou talk)
      - NOT GOOD: Non-linear effect, not simple
      - OK: more compact design, no side lobes

Miguel Ardid

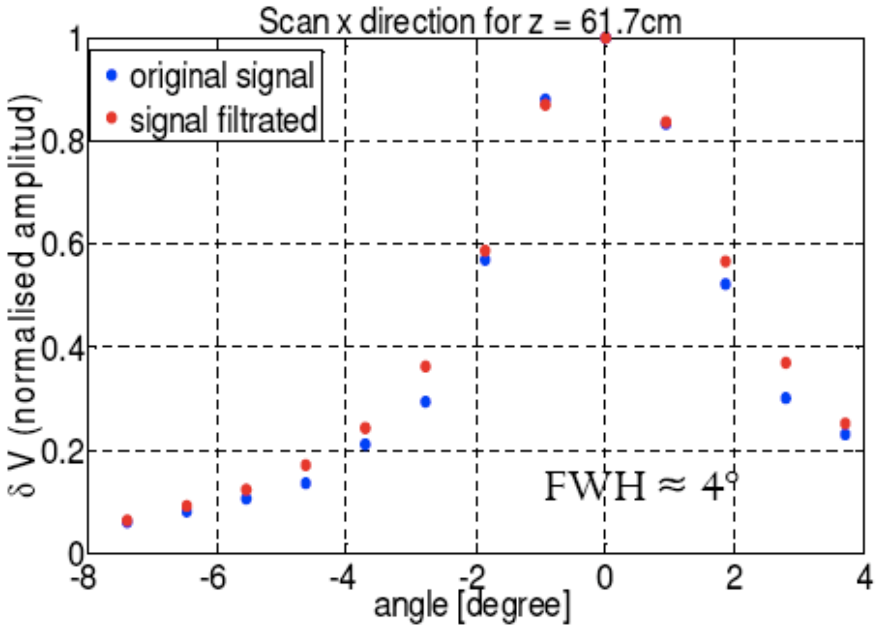


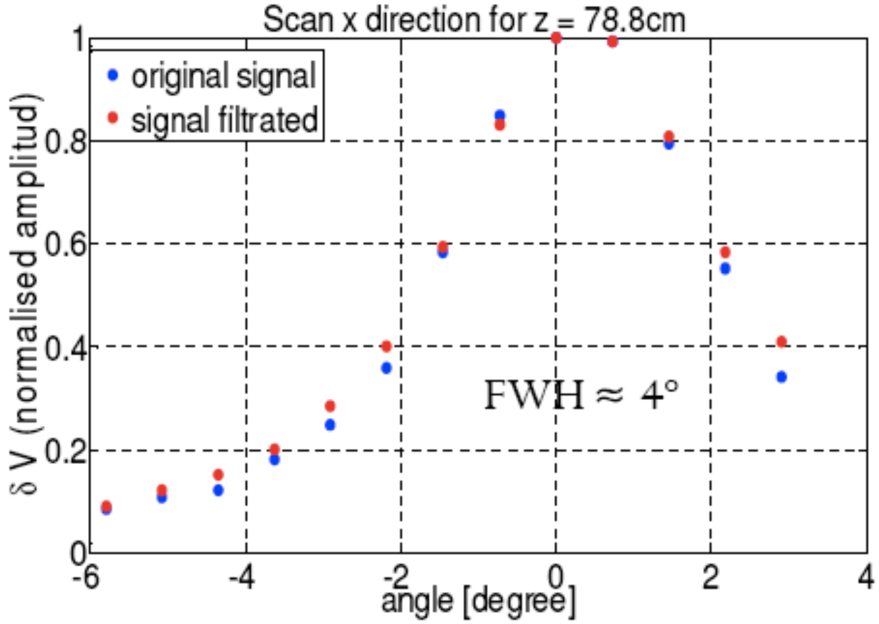


Studies in IGIC – UPV(Results)

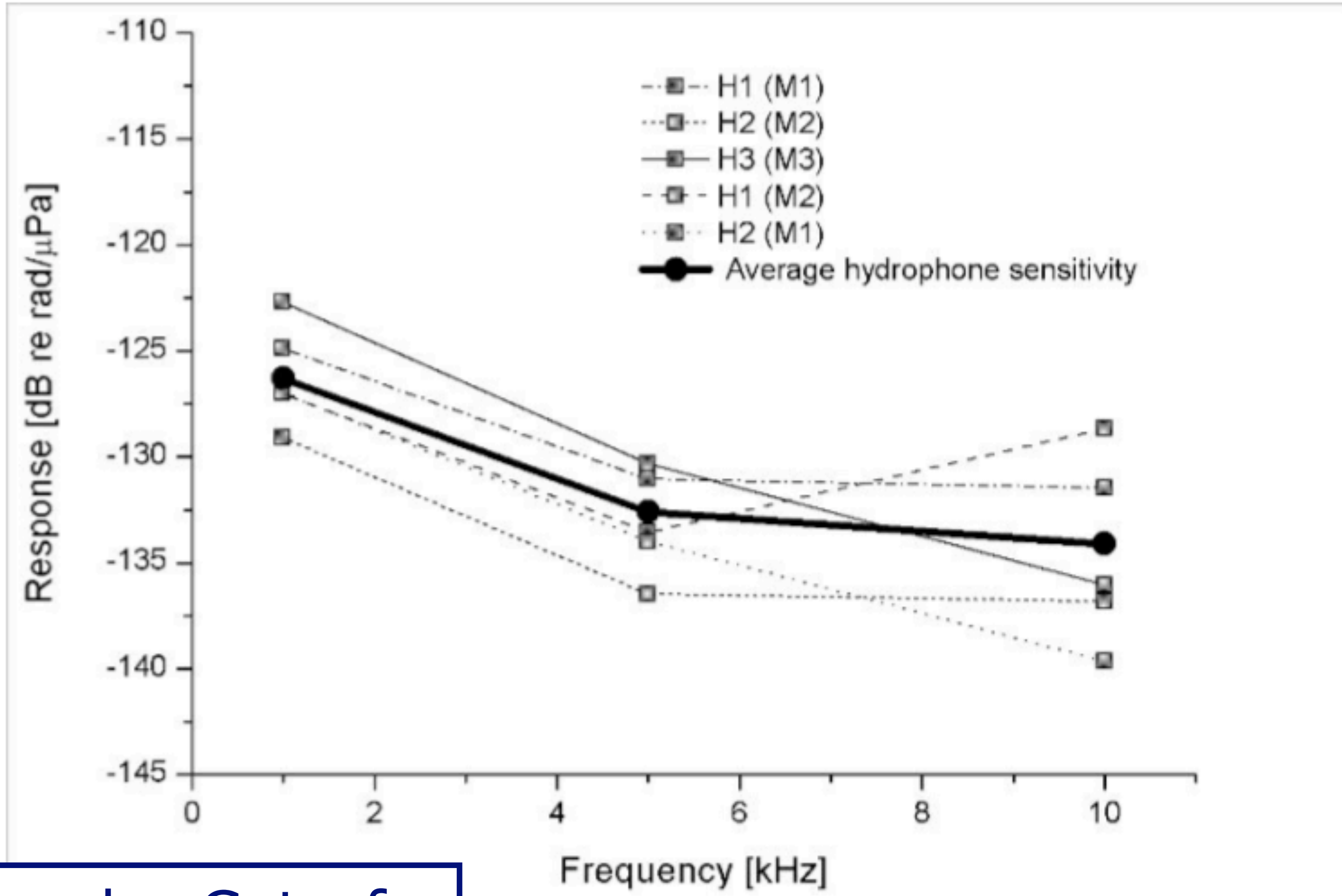
Manuel Bou-Cabo

- 2MHz Transducer.





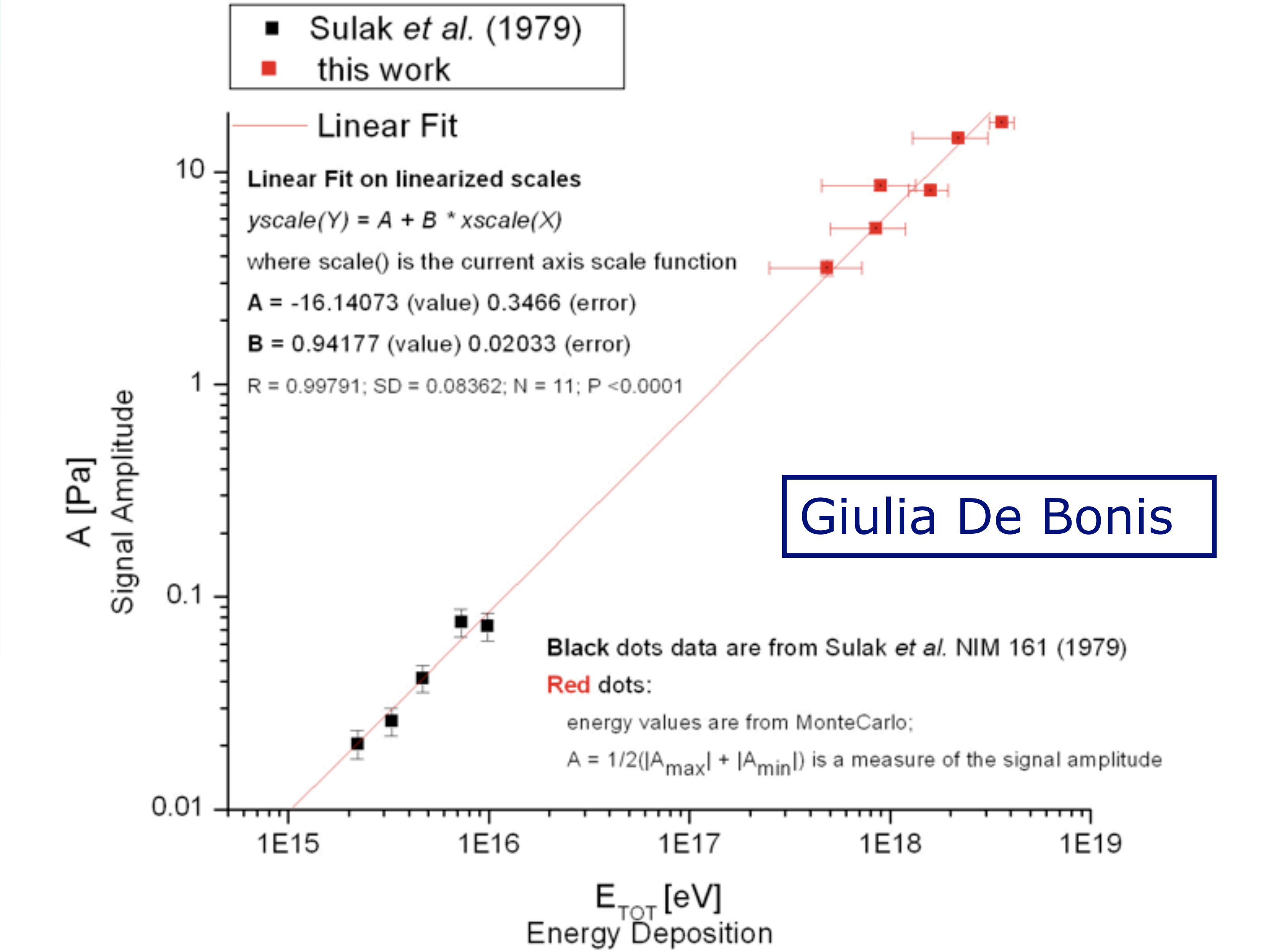
Results for xscan , dv means difference of maximum and minimum value of voltage.



Alessandro Cotrufo

Hydrophone sensitivity in $dB\, re\, rad/\mu Pa$ at different positions calculated using the calibration

Comparing with Sulak Data → FIT



Finding GAMMA

An estimate of the Gruneisen coefficient can be extracted combining experimental data and results from simulation.

The estimate suffers of the same limits already discussed, i.e. **strong indetermination of environmental parameters and geometry**, that reflects mainly on large errors in the energy values.

A good results is, therefore, if the value obtained is compatible, as it is, with a range of expected gamma-values.

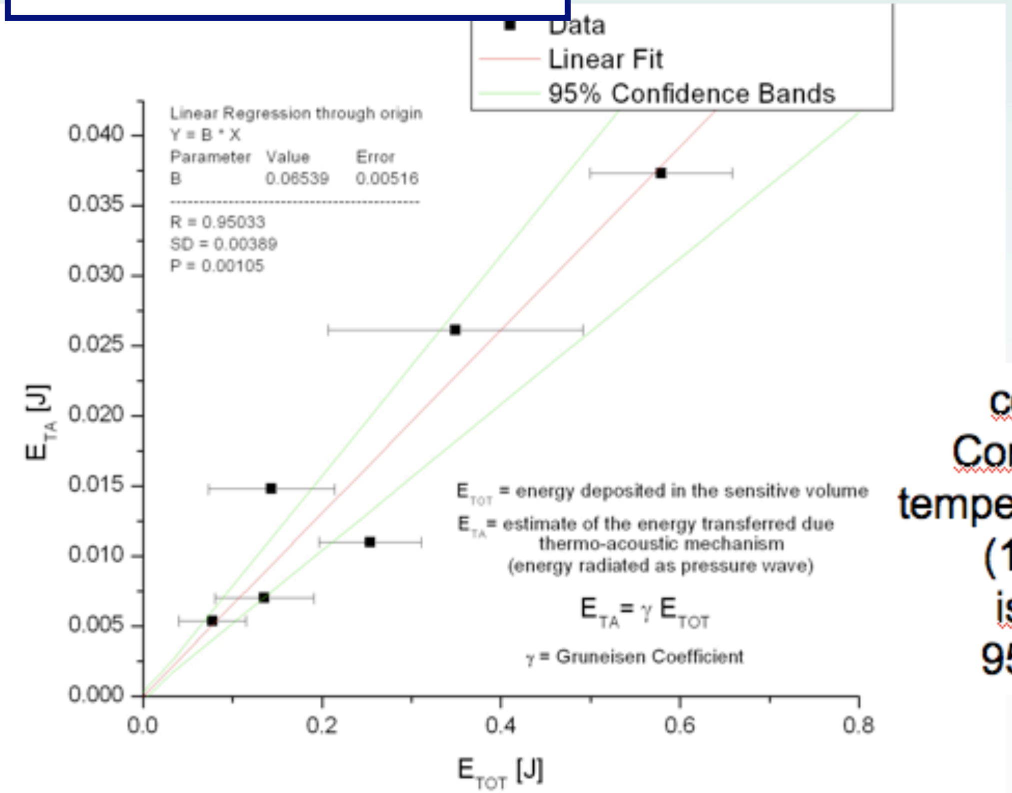
Giulia De Bonis

[Technical details in short]

The idea is to assume the Poisson formula

$$p(\vec{r},t) = \frac{1}{4\pi}\frac{\beta \cdot c_S^2}{C_p}\frac{\partial}{\partial R}\int_{S_{\vec{r}}^R}\frac{q(\vec{r}\,')}{R}d\sigma$$

for the experimental pulse and "go back", thus integrate over R and compute the surface integral (assuming an average value on an average sphere) to get an extimate of the amount of energy radiated as pressure wave, i.e converted via the thermo-acoustic mechianism



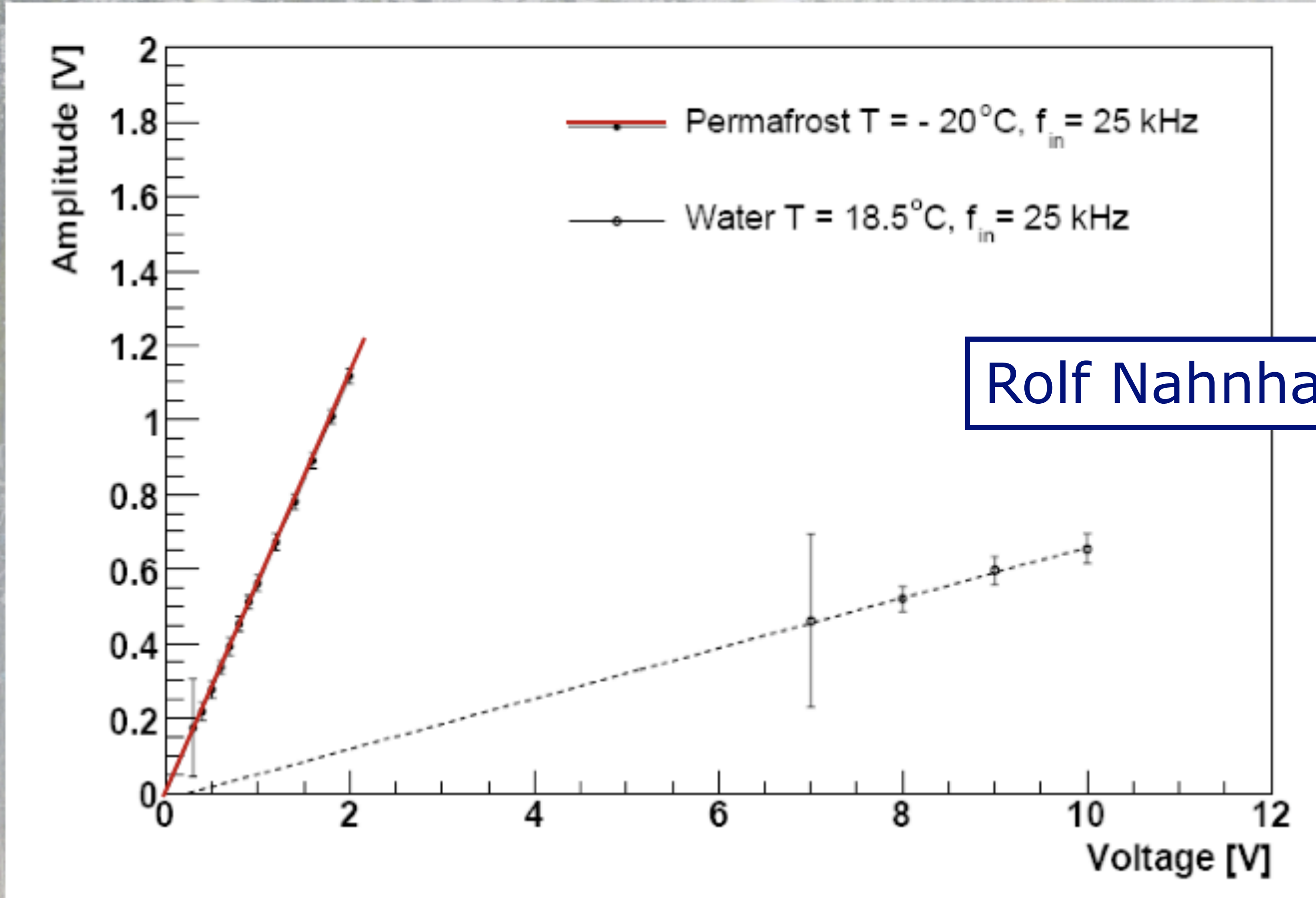
γ=0.6539

↓

T=12.65°

considering the Confidence Bands, temperature in the range (10.75°, 14.65°) is allowed with 95% confidence

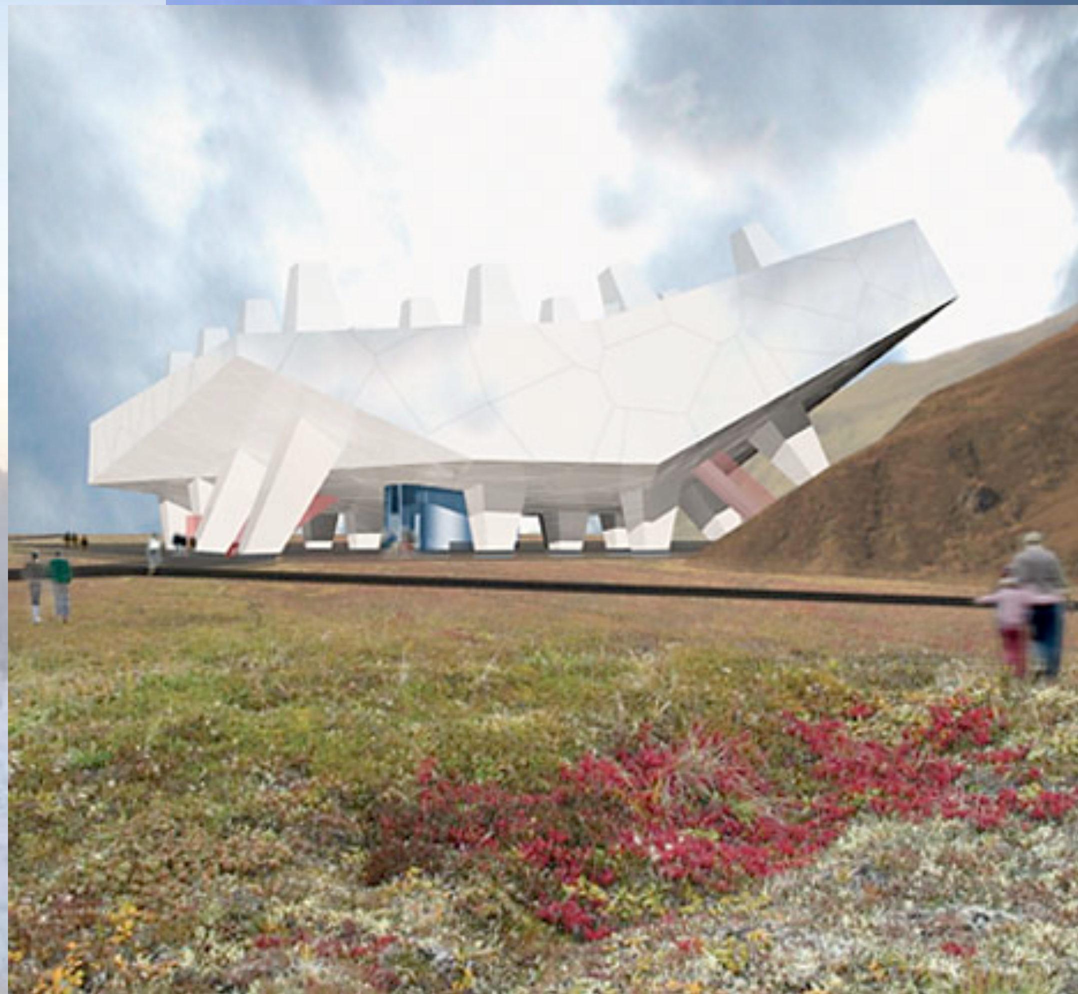
Signal Amplitude



Rolf Nahnhauer

amplitude in permafrost about 10 times larger than in water at 25 kHz

Postcards #13,14

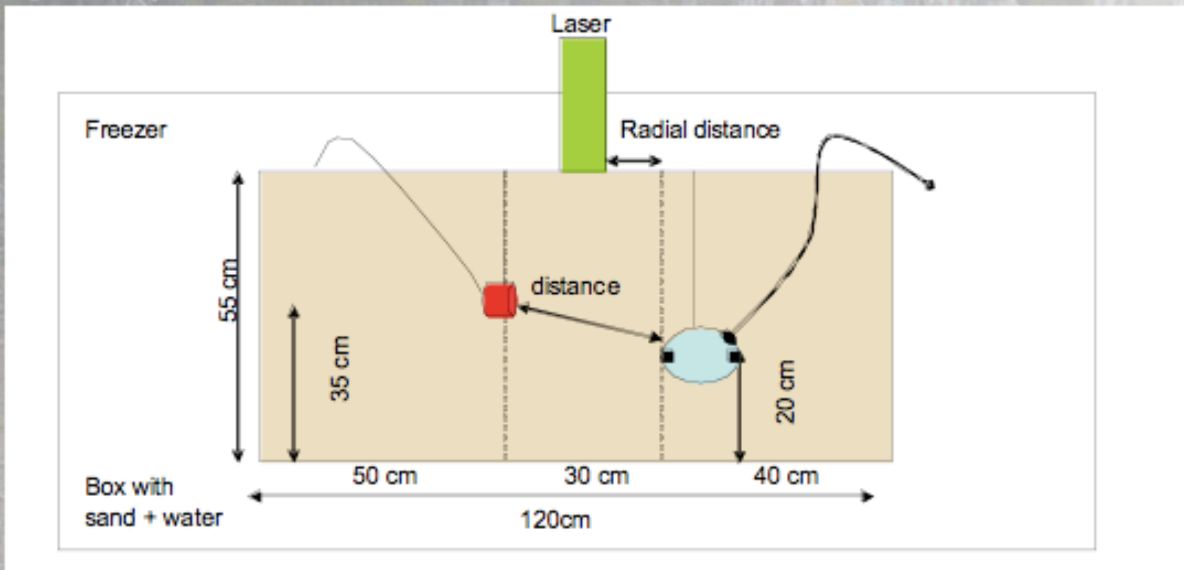


Artificial Permafrost

No clear picture for evolves from available papers

→ Study „artificial“ permafrost in laboratory

Rolf Nahnhauer



Sand-water mixture

Grain size ≤ 1mm

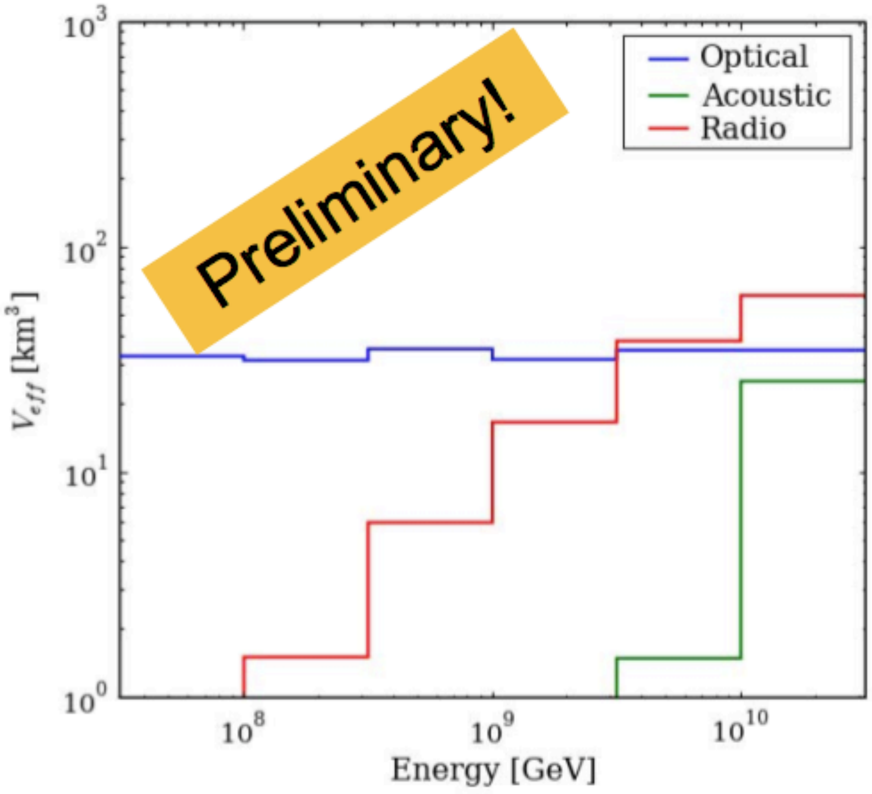
T = -5 to -30 °C

Measured density:

$\rho = 2\ g/cm^3$

Delia Tosi

Effective volumes



- Effective volume does not include ν_τ events
- Expected increase:
  - 1.2 for the optical channel
  - 1.3 for the radio and the acoustic channels

Event rates

Delia Tosi

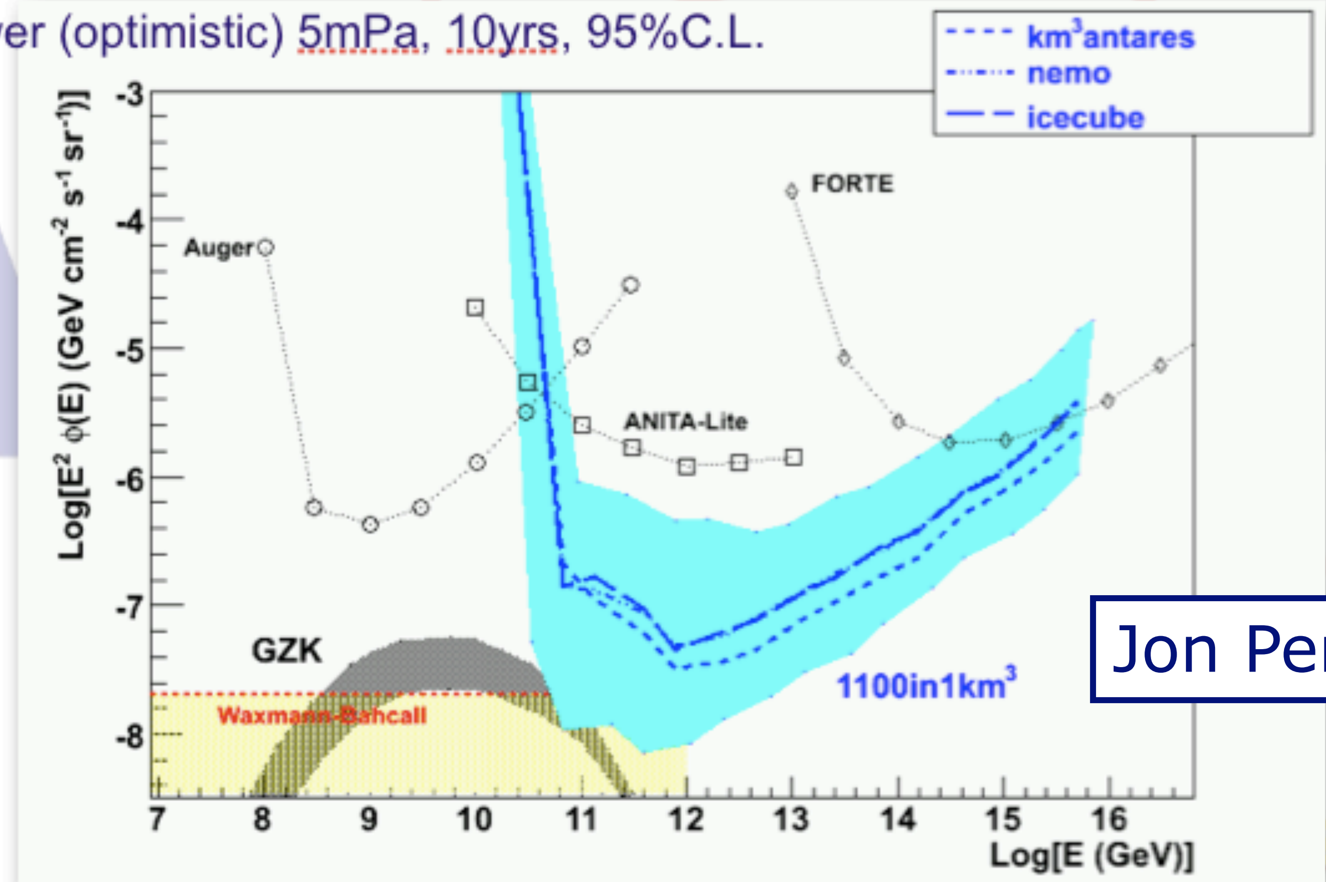
- Event rates assuming the ESS GZK flux model ($\Omega_\Lambda = 0.7$)
  [R. Engel, D. Seckel and T. Stanev Phys. Rev. D 64, 093010 (2001)]
- ν_τ contribution not included
- IceCube results higher than in the previous simulation, but:
  - Geometry of the ring is different
  - New software
  - One additional channel: $\nu_e + \nu_\mu$ (+ showers) vs ν_μ only
  - Trigger level is weaker: 8 hits in 5 μs vs 5 in 2.5 μs

Detection option	GZK events/year*)
IceCube	2.39
Optical	3.99
Radio	1.68
Acoustic	0.43
Optical+Radio	0.098
Optical+Acoustic	0.043
Radio+Acoustic	0.089
Opt.+Rad.+Acou.	0.012
TOTAL	5.568

Preliminary!

In context of real infrastructures

- Create km^3 geometries based on Antares, Nemo and IceCube @ 15mPa, 5yr, 95%C.L.
- Bounded region 1100 randomly distributed hydros in $1km^3$:
  - upper (pessimistic) 35mPa, 1yr, 95%C.L.
  - lower (optimistic) 5mPa, 10yrs, 95%C.L.



Jon Perkin

the sensitivity of km^3 arrays

2008...

Conclusions I

- Recent results from HESS/AUGER make it an exciting time for HE astroparticle physics
- *ARENA 2008 is the 4th acoustic (3rd joint with radio) meeting since the Stanford meeting in September 2003*
- Since then enormous progress has been made in many areas
- *The concept of the hybrid detector is a very powerful one, e.g. AUGER*
- Exciting times ahead

List of acoustic talks at ARENA 2010

- First 2 years of data from AMADEUS
- New limit from SAUND II
- First measurement of attenuation length in ice using SPATS
- First results from Lake Baikal acoustic string
- NEMO-2 acoustic positioning sensors as neutrino detectors
- Comparison of Line array deployments (linear vs. parametric)
- … etc.

A vote of thanks …

- To Tonino, Giulia, Francesco and the rest of the Local Organising Team