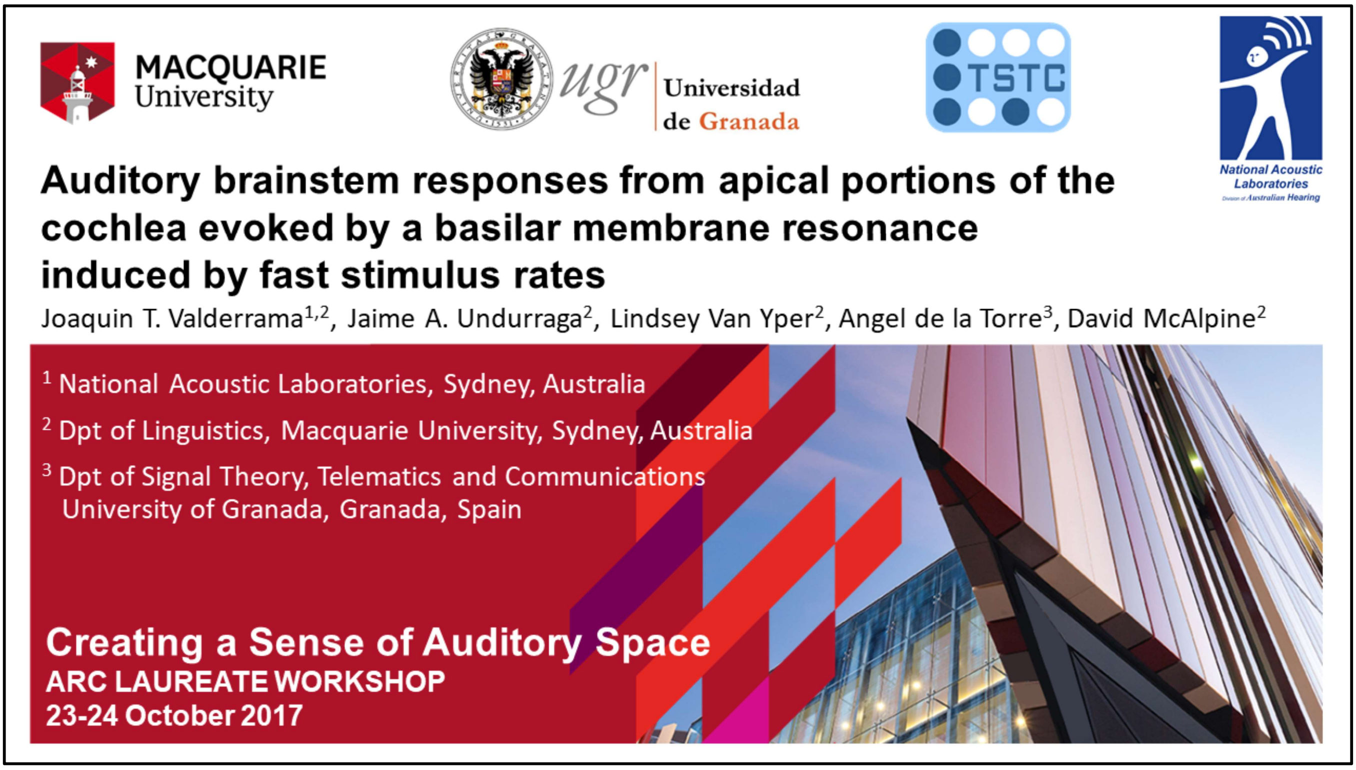


- Hello everybody, thank you David for the invitation to participate in this workshop.

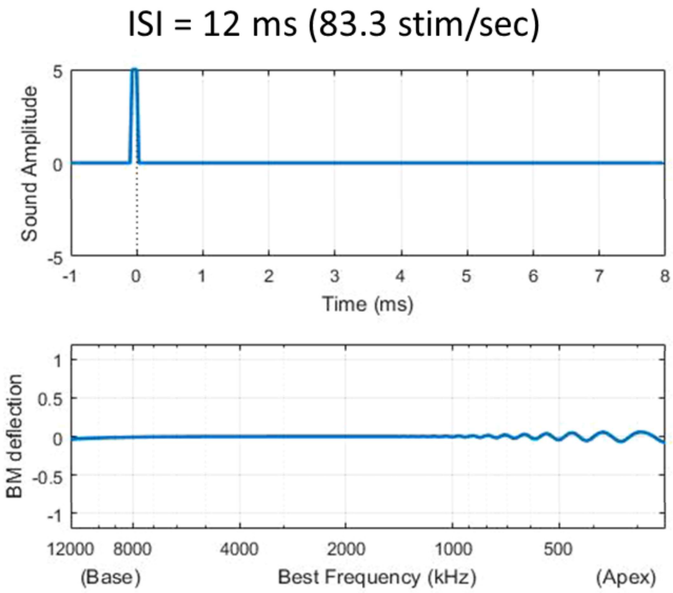
- My name is Joaquin Valderrama, I am with the National Acoustic Laboratories, and I am also an Honorary Research Fellow at Macquarie University.

- I am currently working with David's group exploring electrophysiology approaches to understand how the neurons in the brainstem and in the auditory cortex encode the sounds we perceive with our two sensors (ears).

- In this presentation, I will talk about a new stimulation strategy that enhances the brainstem response to low frequency sounds.

- Before starting, please let my acknowledge my colleagues who have also participated in this study. They are Jaime Undurraga, Lindsey Van Yper, Angel de la Torre (from the University of Granada), and David McAlpine.

Click-evoked ABRs – basal portion of the cochlea



Basilar Membrane simulation

- Filter-bank of 300 channels
- Low frequency 250 Hz
- High frequency 12000 Hz
- Gamma-tone filters
- *Jan Schnupp – Auditory Neuroscience* *https://auditoryneuroscience.com/book*

- Auditory brainstem responses are optimally elicited by short duration stimuli, like clicks.

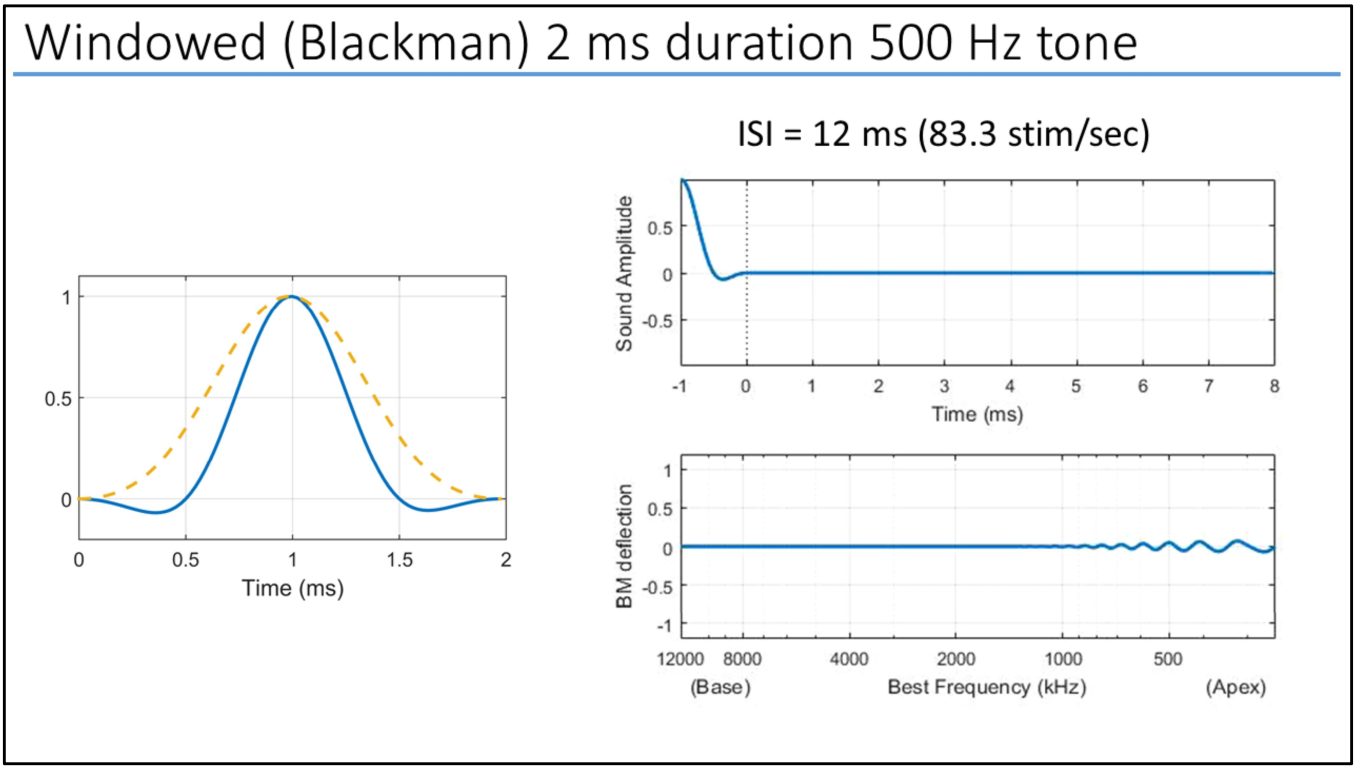
- However, short-duration clicks present most of their energy in high frequency bands, and therefore, activate mostly the basal portion of the cochlea.

- I have created a simulation of the BM deflection to visualize this effect. This simulation was made by considering the BM movement as the result of a filterbank of 300 gamma-tone filters, distributed from 250 Hz to 12 kHz.

- This simulation was implemented using a Matlab script available as supplementary material in the book ‘Auditory Neuroscience’, from Jan Schnupp, great book indeed.

- The top plot in this simulation shows the stimulation pattern, in this case a click presented every 12 ms. The plot at the bottom shows the BM deflection, high-frequencies in the base of the cochlea and low-frequencies in the apex.

- This simulation shows that the maximum deflection of the BM occurs at the high frequencies, and that the sections of the cochlea sensitive to low frequency sounds are activated many milliseconds after the stimulus onset.

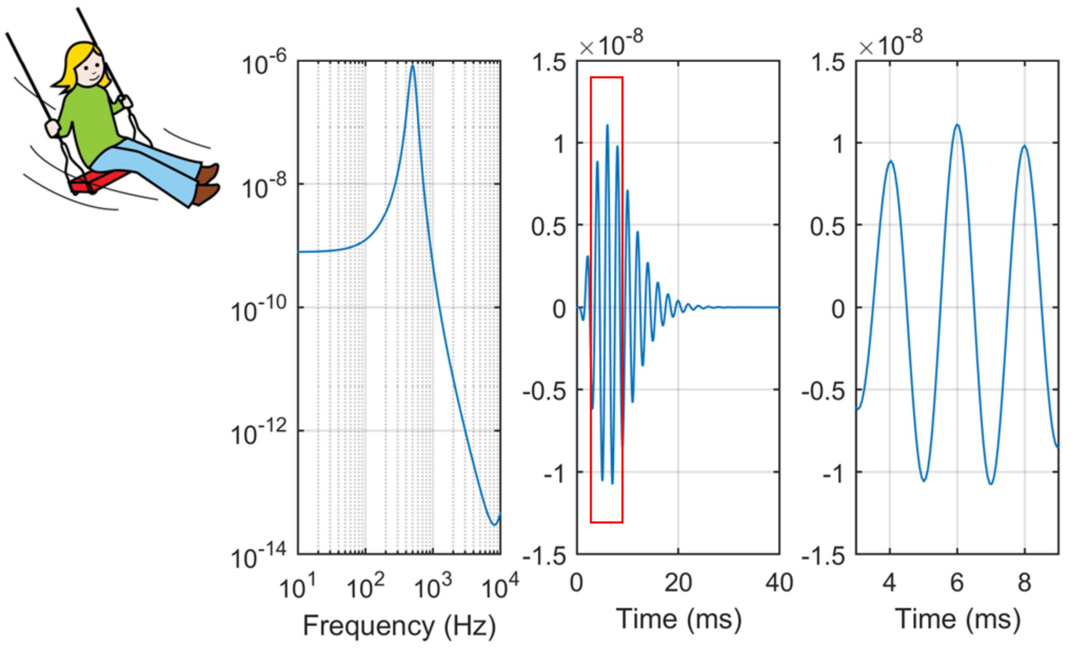


- We can modify the features of the stimulus to activate specific portions of the cochlea.

- For example, this figure shows a 1 period of a 500 Hz tone, windowed with a Blackman window (yellow line). Note that this stimulus has a significantly larger duration than clicks (2 ms vs 0.1 ms), but also, 2 ms is the shortest duration of a stimulus with energy in the 500 Hz frequency band.

- When this stimulus is used, the simulation shows that (a) a large range of frequencies in the apical portion of the cochlea are activated [i.e. this stimulus has a low frequency specificity], and (b) the BM magnitude deflection is not very pronounced.

Use the ringing property of the cochlea filter (500 Hz)



- The stimulation strategy proposed in this work is based on the ringing property of the cochlear filters.

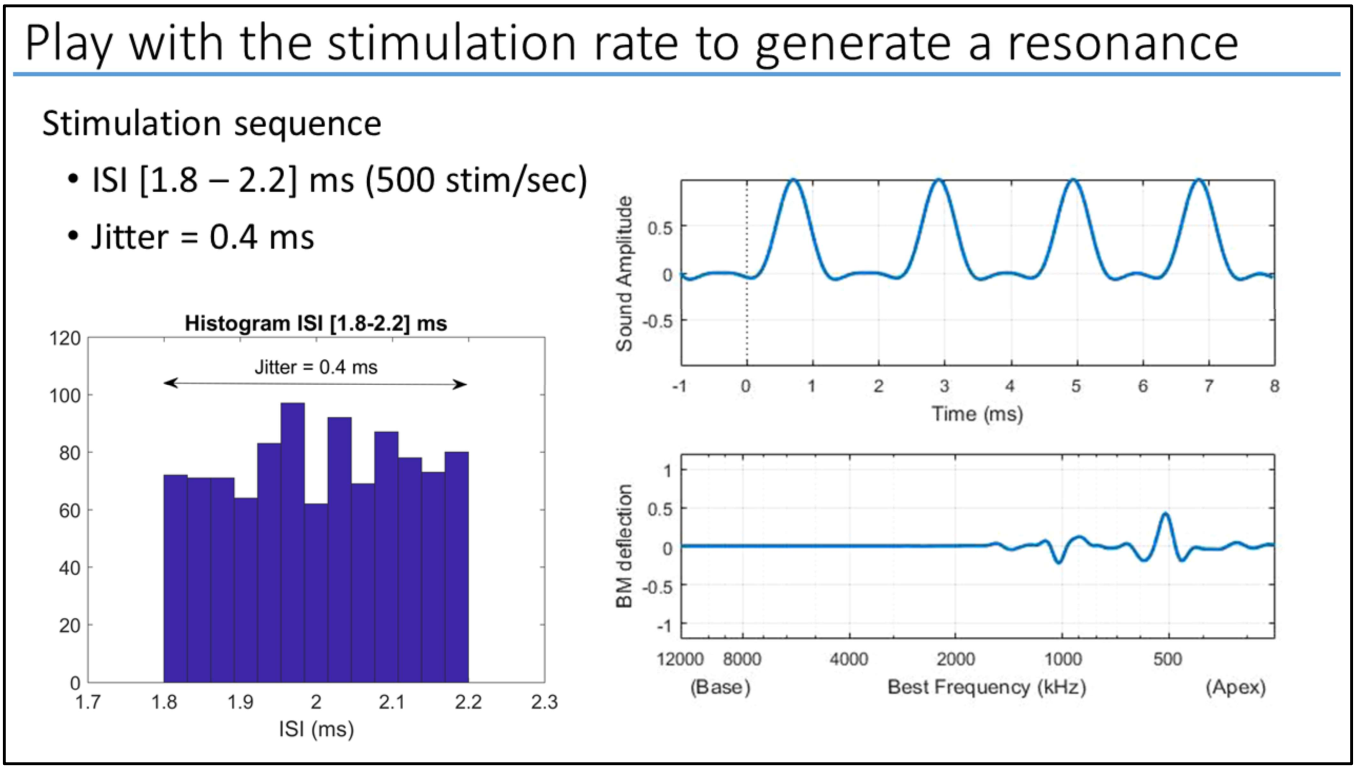
- The figure on the left shows the frequency response of a Gamma-Tone filter with characteristic frequency of 500 Hz, and the figure on the middle the impulsive response of the same filter. The figure on the right shows a detail of the section with maximum BM deflection.

- This figure shows that after the stimulus is presented, the 500 Hz filter rings during more than 20 ms with a period of 2 ms, and that the maximum deflection occurs at about 6 ms after the stimulus onset.

- Taking this into account, our stimulus paradigm aims to present a stimulus every-time the BM fluctuates in order to generate a resonance.

- A similar analogy would be a swing, in which a small force in the correct moment can keep a swing oscillating.

- In our case, if we want to generate a resonance in the 500 Hz filter, then we would have to present stimuli every 2 ms. This is illustrated in the next slide.



- This figure shows the BM deflection to a stimulus sequence consisting of same stimulus defined before presented with an ISI that varied randomly according to a uniform probability distribution between 1.8 and 2.2 ms, i.e with an average ISI of 2 ms, equivalently to 500 stimuli per second.

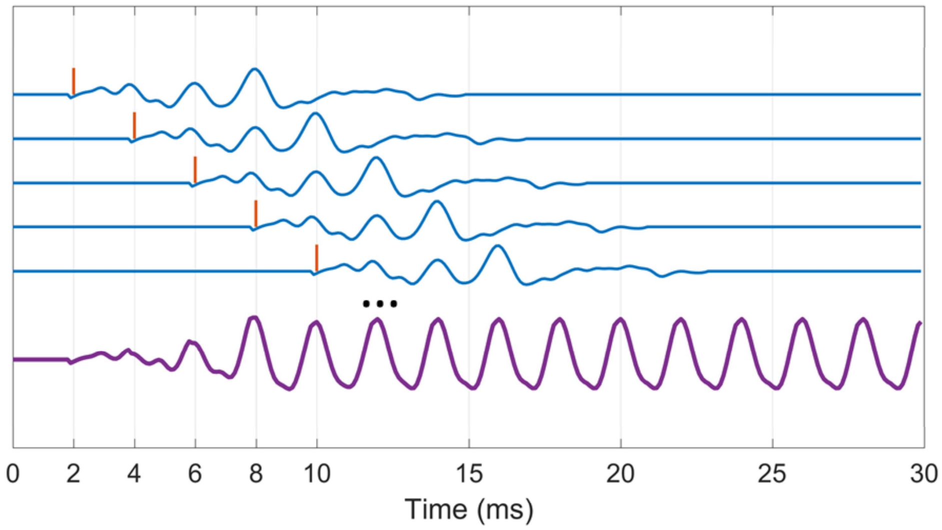
- The jitter measures the grade of dispersion of the ISI, which in this sequence is the 0.4 ms.

- This figure shows that this stimulus paradigm generates a BM deflection resonance at 500 Hz and its harmonic frequencies.

- This resonance improves the frequency specificity and increases the magnitude of the deflection.

- However, presenting stimuli at a rate of 500 stimuli per second poses one important challenge.

Overlapping responses – Deconvolution by IRSA



- Valderrama *et al*. (2014) Auditory brainstem and middle latency responses recorded at fast rates with randomized stimulation. Journal of the Acoustical Society of America 136, 3233-3248.
- Valderrama *et al*. (2016) Selective processing of auditory evoked responses with iterative-randomized stimulation and averaging: A strategy for evaluating the time-invariant assumption. Hearing Research 333, 66-76.

- This figure illustrates the problem of overlapping responses.

- Red vertical bars show the instants in which the stimuli are presented, i.e. every 2 ms. The blue signals are the ABRs evoked by each of these stimuli.

- This figure shows that presenting stimuli with an ISI of 2 ms leads to responses being overlapped by adjacent responses, obtaining a steady-state or quasi-steady-state signal at the electrodes.

- However, obtaining the transient ABR is key to analyse the contribution from different neural generators.

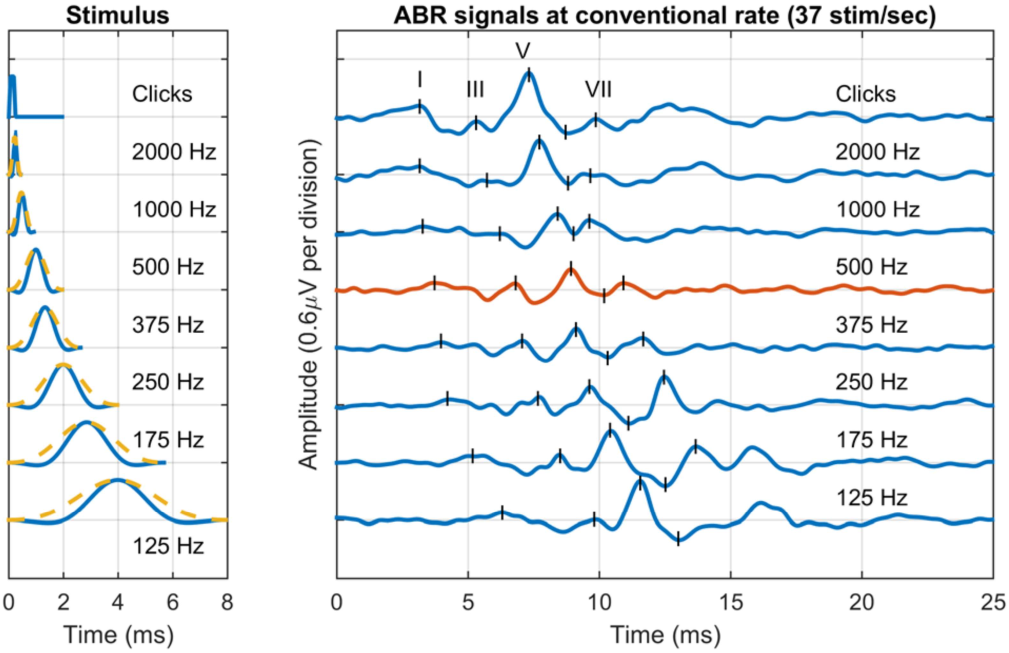
- It is necessary to deconvolve, i.e. to disentangle the overlapping responses.

- In this study we have used a deconvolution technique named iterative-randomized stimulation and averaging, which is able to estimate the transient from the convolved signals through an iterative process in the time domain.

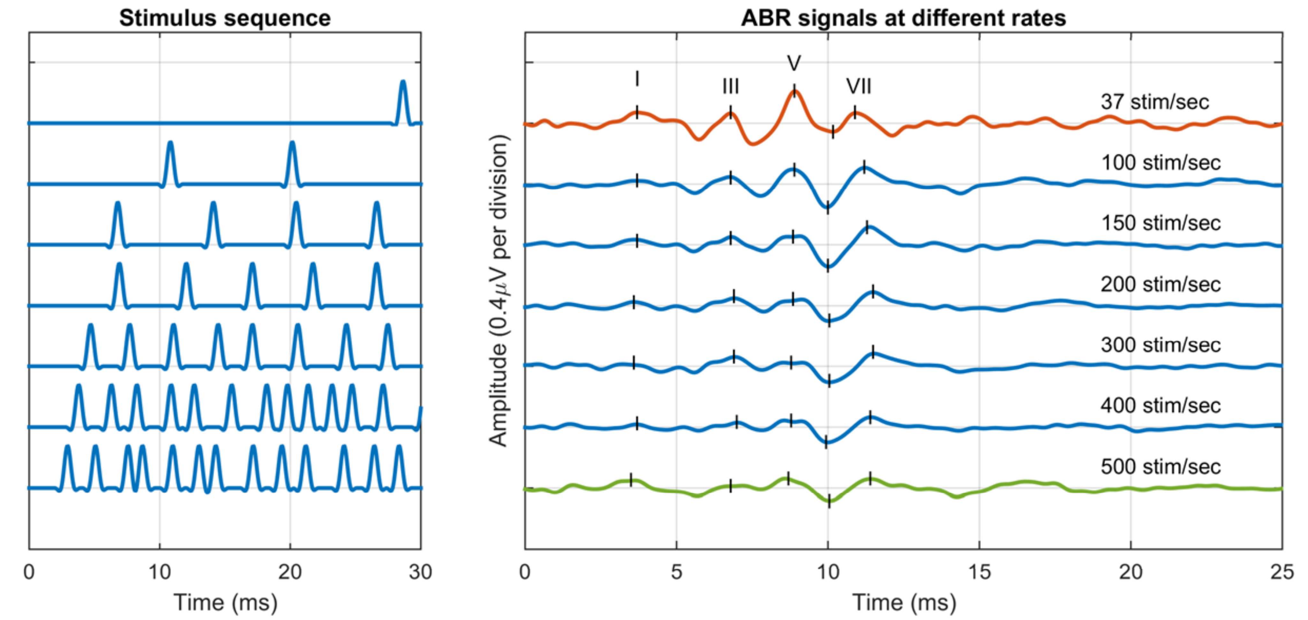
- I will not review the maths of the IRSA algorithm in this presentation because it is already described with sufficient detail in a couple of papers.

- Ok, enough theory, let's see some data. I have prepared 3 experiments to show the benefits of this resonance with real responses.

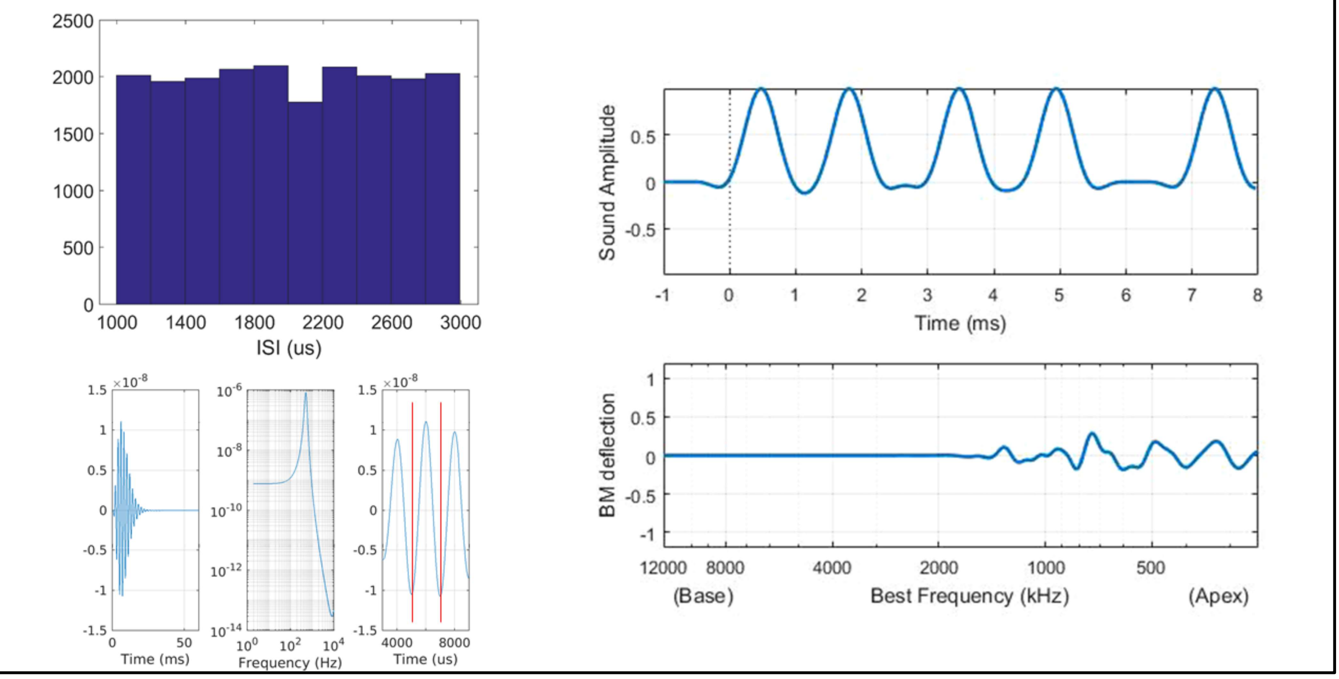
Effect of stimulus [Conventional rate, 20K stim]



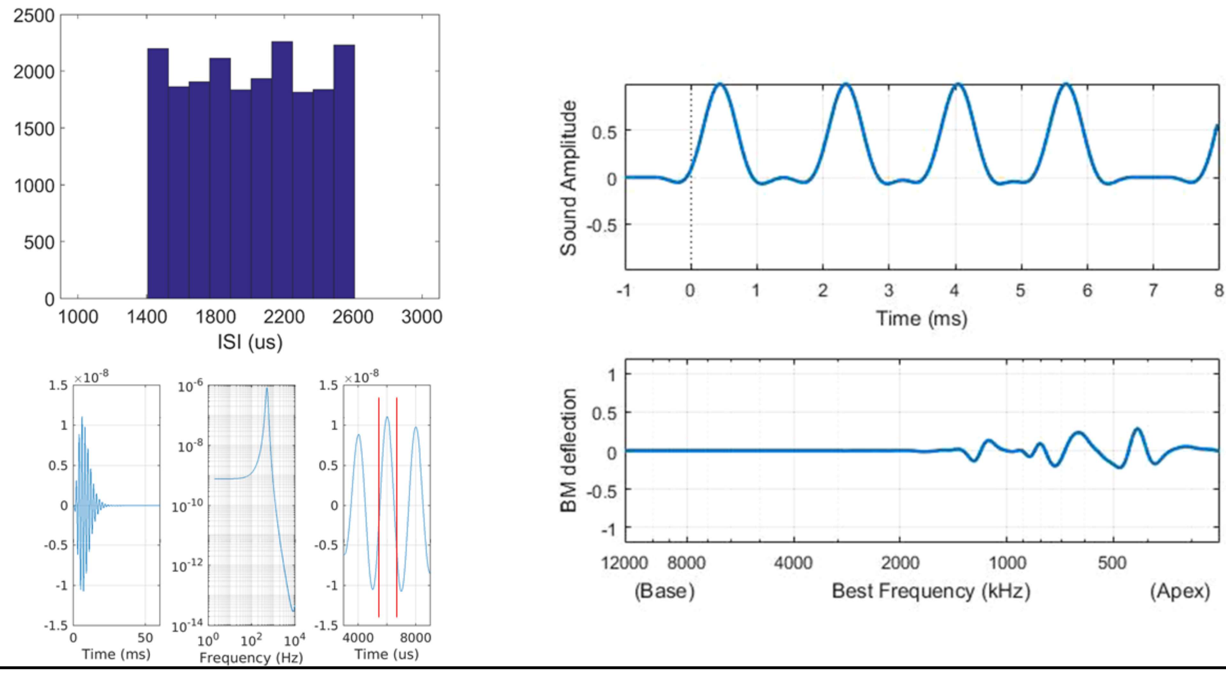
Effect of rate [Jitter = 2 ms, 100K stim]



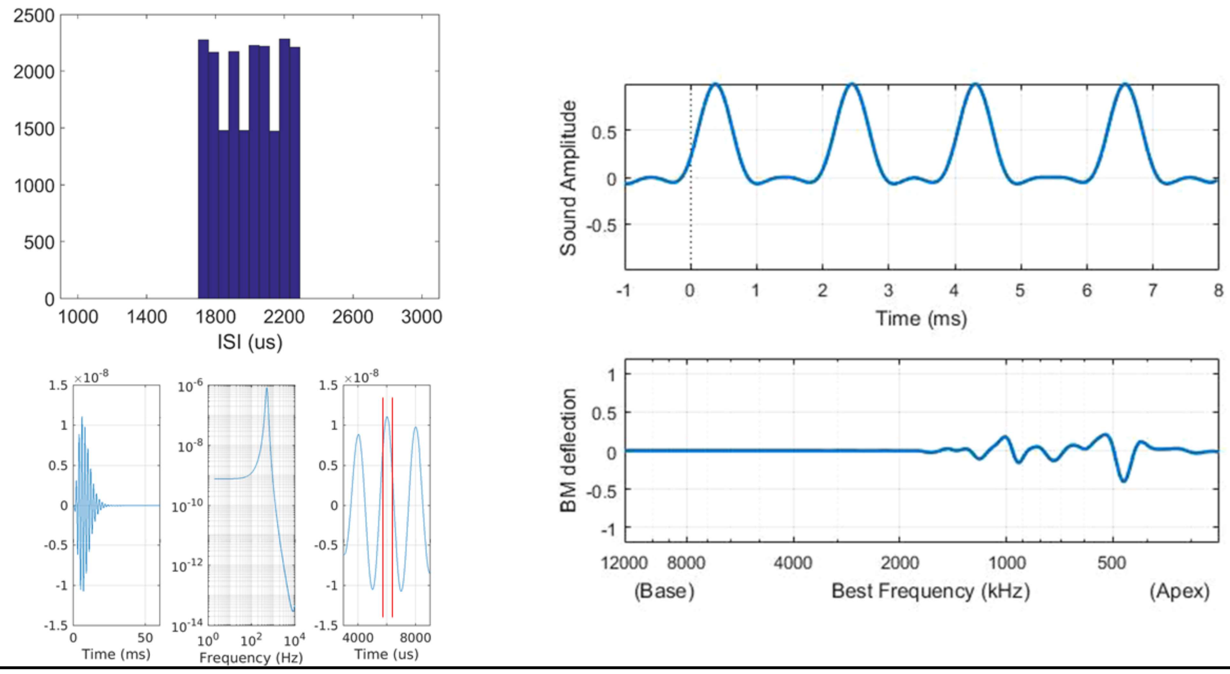
ABRs at 500 stim/sec [Jitter = 2000 μs]



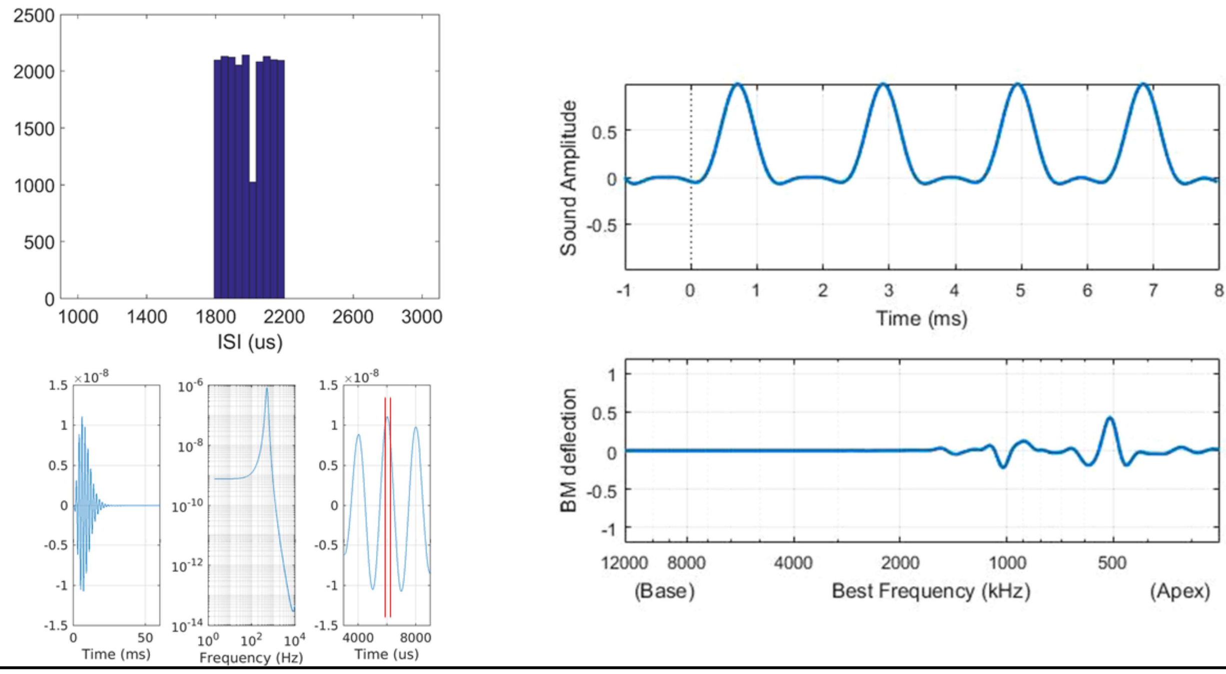
ABRs at 500 stim/sec [Jitter = 1200 µs]



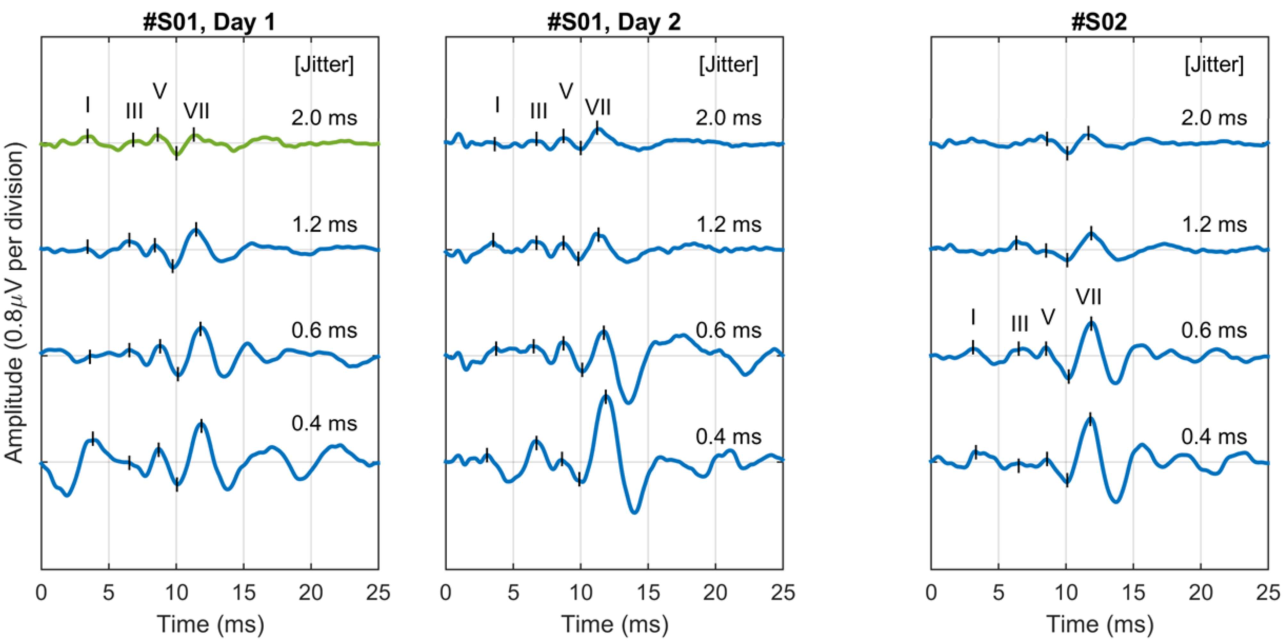
ABRs at 500 stim/sec [Jitter = 600 μs]



ABRs at 500 stim/sec [Jitter = 400 µs]



ABRs obtained at different jitters



Take-home message

1. We can take advantage of the resonance properties of the cochlear filters to enhance the brainstem response elicited by selective apical portions of the cochlea

2. Wave VII [medial geniculated body] seems to be playing an important role.

3. Future work
   - ✓ Any other ideas are welcomed