Science Case Session

- **Goals**: Define scientific goals that can be funded
  - for the large-scale prototype: in 5-10 years
  - for longer term

- **Sensitivity to aim for Phase 1: Discovery phase.**
  Reach a sensitivity between 10^-9 - 10^-8 GeV/sr/s/cm^2

- **Guaranteed or non-guaranteed flux:**
  - the only guaranteed flux is the cosmogenic flux. But this can be very low.
  - if we want to guarantee its detection, we need to go down to 10^-11
  - the astrophysical fluxes are not guaranteed but we can use models to benchmark the expected fluxes, in a bottom-up approach. It is like a Waxman-Bahcall flux.
  - we can extrapolate from the IC fluxes, which gives a guideline.
  - rather sell the previous examples of non-guaranteed detection: GW and PeV neutrinos

- **Angular resolution?**
  Sub-degree angular resolution comes for free with radio in air anyway.
  We can definitely sell it. Even if we detect few neutrinos, our strength is to be able to point the source.

- **FoV?**
  Maybe we don't need FoV if we want to just be a discovery instrument.
  But instantaneous FoV is a potentially "cheap" way to gain aperture. So should not be sacrificed.

- **UHECR science case?**
  - We should not optimize the detector to incorporate UHECR science
  - Little science gain today to expect from detecting more UHECR.
  - Also the composition seems to be the major measurement to refine, and it will be difficult to do with radio alone.
  - UHECRs don't come for free. It will cost something - sensitivity, complexity, money...

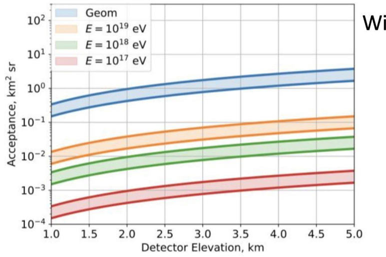
TODO:

—> forecasts using his pipeline developed for Gen2-Radio, that implement existing UHE neutrino production models. To be run with detector parameters that come out from this workshop. (Rafa, Mauricio, Valentin D., Kumiko)
—> event rate calculation to assess the importance of going to low E.

Effective area

Perfect case scenario: What would be the effective area of assuming a detector with 100% detection efficiency for neutrino-induced showers?
Blue curve BEACON study (2004.12718, Figure 2) does not take into account exit probability

- at low energy we pay the cost of the energy losses, small exit probability for taus
- at high energy we pay the cost of late decay after tau exits Earth



Wissel e

Figure 2. Order of magnitude estimates for the acceptance of a single high elevation station. The band shows the maximum geometric acceptance based on Eqn 3.5, assuming a factor of 1/3 to accoun an expected 120° field of view. The acceptance at three neutrino energies $\mathcal{E}_\nu$ is estimated from peak values of Ref. [40]. The width of each band illustrates the impact of the maximum view angle over whic detector can trigger $\theta_{\rm cut}$, assuming a range of $[1.0°, 1.5°]$.

How to normalize / assess merits of different techniques?
GRAND probably not ready to reach 10^-9 within 5 years, given the large area it would require.
DANTON & Marmots

TODO:

- Maximum aperture of any tau detector: calculate the geometric area available; include the tau exit probabilities; also include the decay length in the calculation (Austin, Valentin N., Steph, Olivier, Aurelien)
- How much do you really gain in event rate by going to lower energies given that you are limited by the exit probabilities?
- How difficult is it to lower the detection threshold with beam-forming? Easier than building many detectors?
- Simulation study to study a design for a hybrid detector? DANTON down to tau decay… to be plugged in RDSim (Washington Carvalho)?
- Study a potential background of atmospheric tau neutrinos (from high-energy air showers)

RFI Mitigation Session

- Need to discern narrow-band and impulsive RFI.
- Cannot escape RFI entirely (satellites, airplanes, …), also sites might degrade with time.
- Tolerating some RFI might give access to more practical sites with more infrastructure.
- Narrow-band RFI needs to be dealt with before triggering (notch filters). It must not drive any detector component into non-linearity, which would cause intermodulation (include bandpass filters already on the LNAs). ADCs must not be driven into saturation.
- Narrow-band RFI can actually be a useful diagnostic (check if detector is working, antenna alignment, possibly time synchronization, …).
- Impulsive RFI is mostly a problem for triggering, hopefully can be dealt with both on FLT and SLT level (-> see NUTRIG project). At analysis level extremely good suppression must be reached for both transient RFI and cosmic rays.
- Below 40 MHz definitely during active sun phases the ionosphere reflects and far-away transmitters and thunderstorms become visible, both seen in OVRO-LWA and AERA, and also GP13.

Antennas focused towards the horizon

- How relevant are ground effects?
  - Ground absorption can be very relevant if signals propagate within 1 deg of horizon (cf. AERA beacon). May be relevant even within 2-3 deg below/above horizon for air showers.
  - Given that the emergence angle of taus is only a few degrees (depending on energy), this may be very relevant.
  - Initial GRAND simulations indicate that it may not be relevant, and also for a Beacon-like scenario on mountains the relevance is not clear (better than ground-based arrays).

  → Needs to be studied in more detail.

- Suppression of Galactic noise (several 1000 to 10000K below 100 MHz)
  - Some suppression (maybe up to a factor 4 in an ideal case, factor 2 in energy threshold), may be achieved by choosing locations and observation times where the Galactic center is not visible.
  - A directional antenna mostly observing ground would reduce dominant noise source to 300K temperature of the ground. Reflected Galactic noise could matter, though.
  - Are antennas of high enough directionality available at the low frequencies? Gigantic LPDAs?
  - A tradeoff to be investigated: use narrow-band antennas easier to have a high gain (Yagi-Uda antennas can get 15 dB gain): have 2-3 narrow low-frequency bands + possibly a broad band antenna for higher frequencies (high means Galactic noise not worse than ground temperature)

Phased versus unphased arrays

- Advantages of phased arrays:
  - Lower thresholds, push to lower energies, deeper sensitivity
  - Directional masking of RFI
  - Potential of narrow or wide beams dependent on your spacing
  - Can build a high gain array digitally with arbitrary number of beams to cover full FOV desired
  - Tune the direction (provided your antenna gain is sufficient in the direction you want to look)
    - Trades/studies to consider:
      - Spacing between antennas and loss of cohrence
      - Demonstrate SNR gain with data (has been done with ARA, likely can do with OVRO-LWA and BEACON)
- Advantages of unphased arrays:
  - NuTrig idea: build image of Cherenkov ring in the trigger from a distributed array
  - Build a large aperture with cheap antennas.
- There are also novel triggers: neural nets, RFi rejection with outriggers that can be incorporated with both
- There is probably a tradeoff between multiple phased stations seeing the same patch of sky (small instantaneous field of view at high sensitivity) or phased stations seeing independent patches of the sky (larger instantaneous field of view at lower sensitivity); probably former is better without knowledge about source population (same dilemma was for FRB detection, depends on cosmological evolution of sources), although the tradeoff is probably relatively mild, no strong preference for one or the other (there are always more fainter than strong sources); from a practical point of view the former is probably easier in terms of deployment, because you will have a more localized setup [see also next slide]

Phased arrays and Science Case

- Multimessenger astronomy — form deep beams in a certain direction that can be turned on and off; narrow beams that are pointed very much in specific directions — sub-degree FOVs
    - Is it better to go deeper? Should we have more overlap to allow for deeper views. Larger overlap between neighboring stations so you can combine beams
    - Phased array stations that can be all pointed in the same direction
    - Seeing this teased out a bit with the point source sensitivity calculations from A. Zeolla
    - Kumiko is really interested in: Mode that increases dramatically the sensitivity in a small, narrow direction. Wants to be able to do impulsive neutrino astronomy
- Trades to consider:
    - You can improve your sensitivity / effective area by pointing multiple phased array stations to the same source
    - This would not allow you to lower your SNR threshold any more than you already did by phasing at each station
    - FOV of each station matters: since we are ultimately limited by the FOV of a given station (determined largely by the exit probabilities)
    - Trade is whether its better to see a large patch with a certain instantaneous effective area or a small beam with an even deeper effective area (and how would you tile the beams that you could still have)