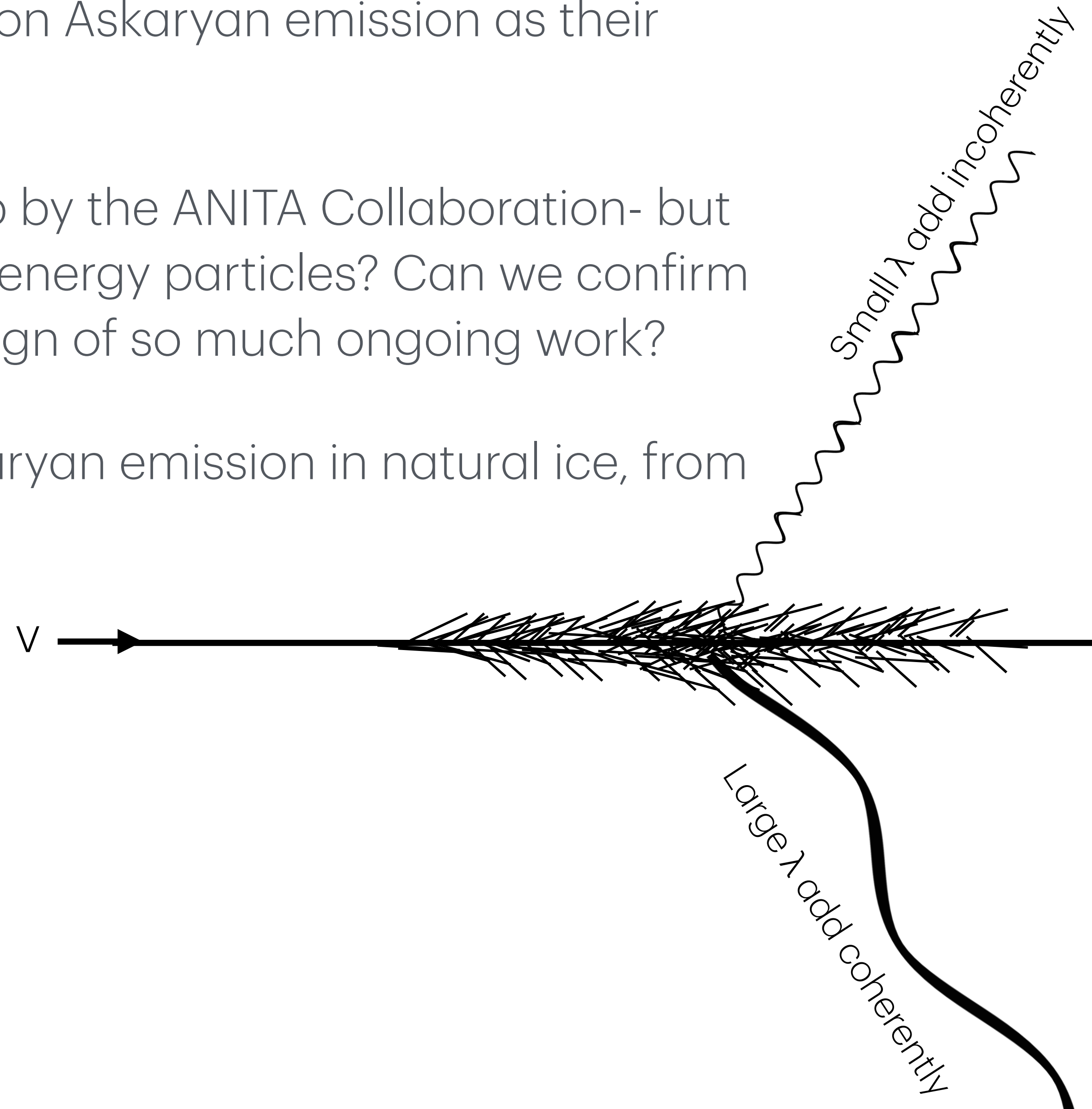
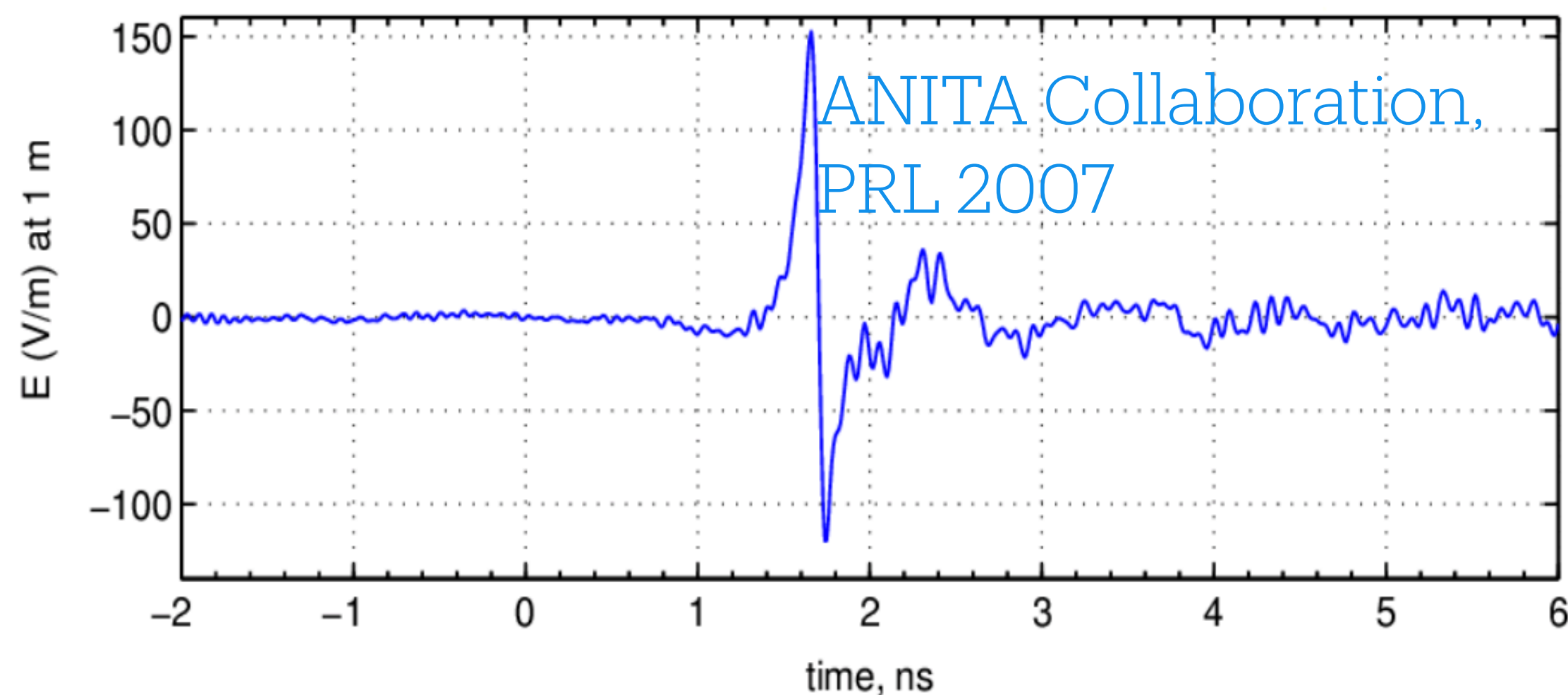


Observation of In-Ice Askaryan Radiation from High Energy Cosmic Rays

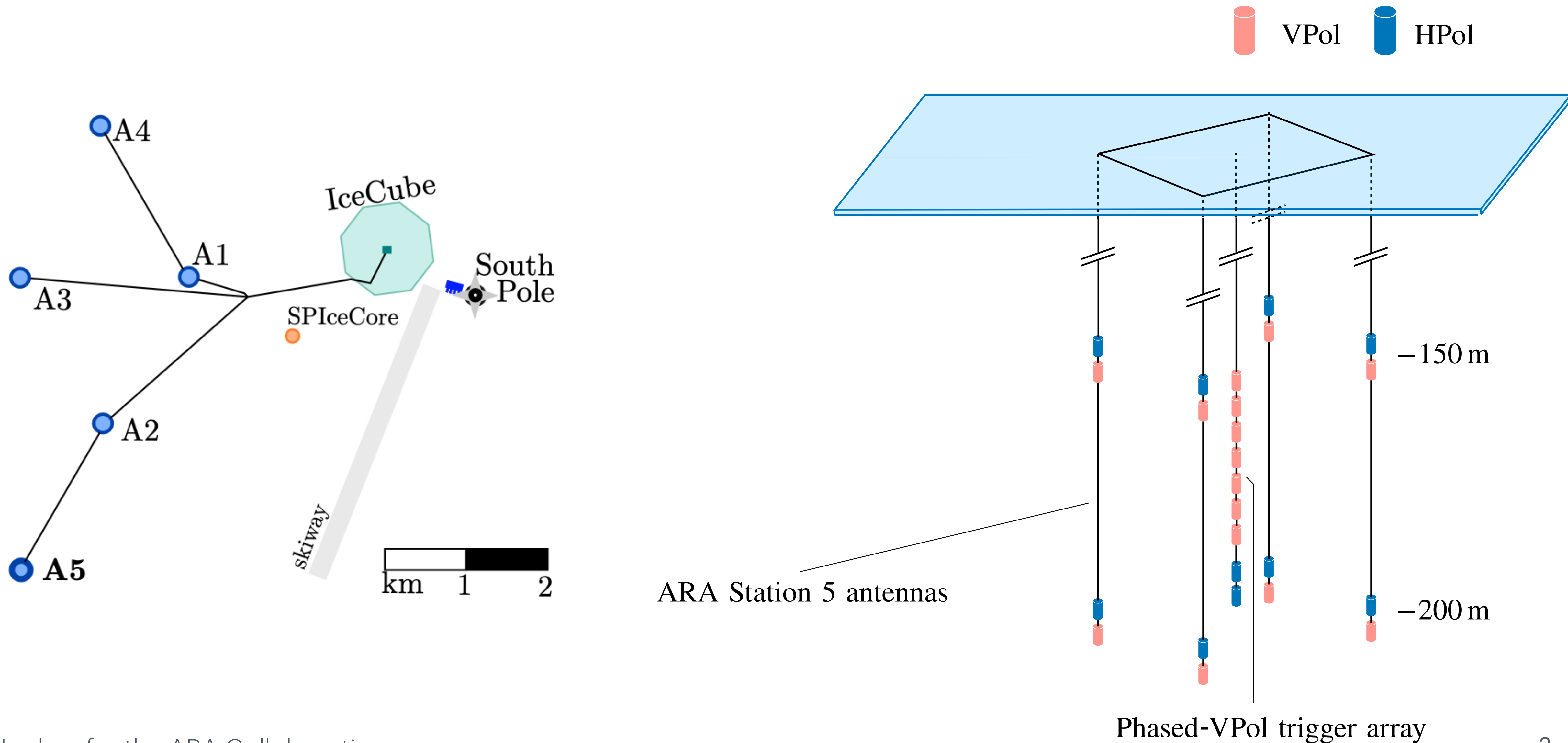
June 9, 2026

The search for Askaryan emission in ice

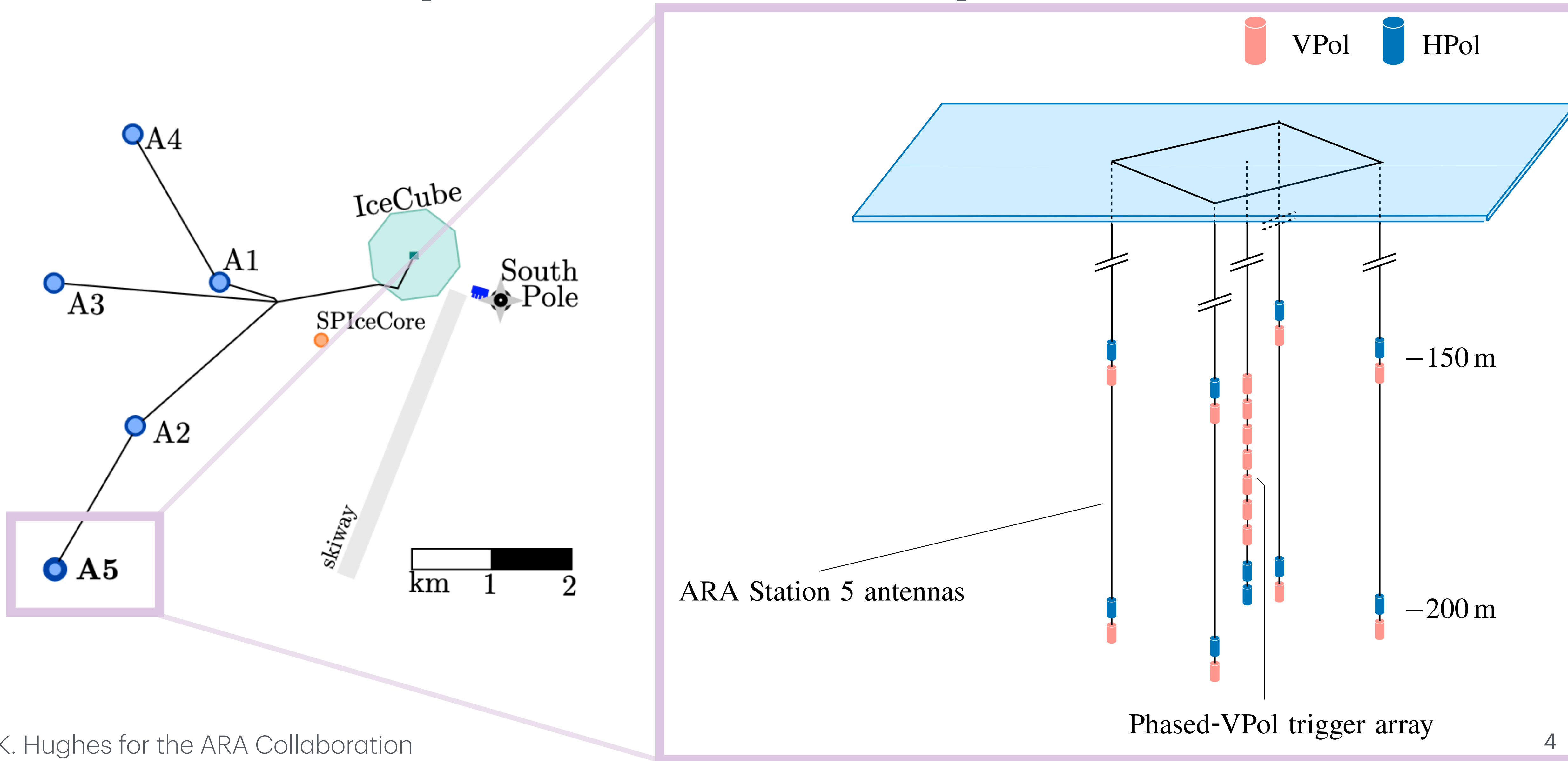
- Many in-ice radio detection experiments rely on Askaryan emission as their primary detection principle
- Successfully detected in 2007 in ice in the lab by the ANITA Collaboration- but what about natural ice with actual ultra high energy particles? Can we confirm the detection principles that underlie the design of so much ongoing work?
- This talk will discuss the first evidence of Askaryan emission in natural ice, from the ARA Collaboration



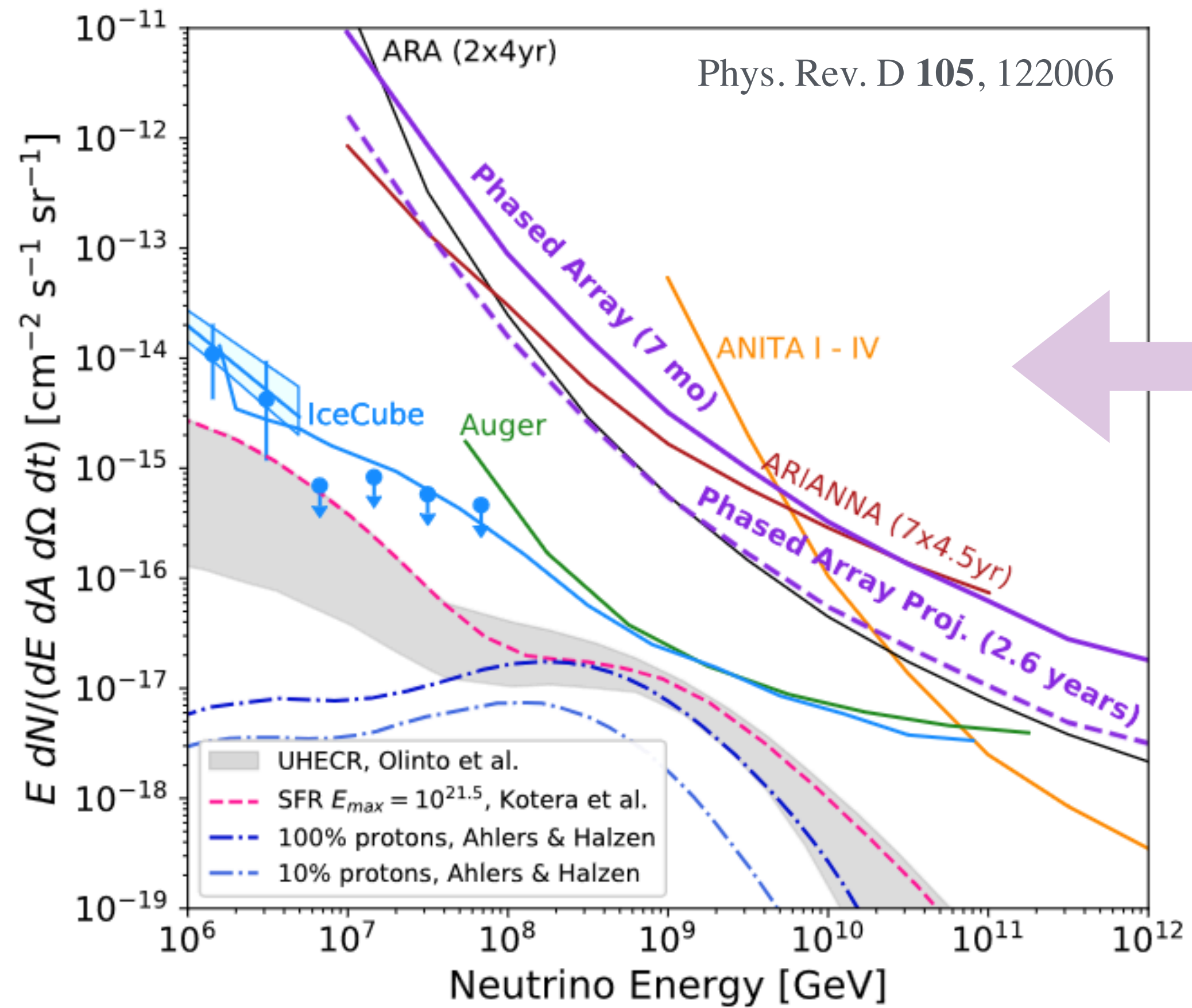
The Askaryan Radio Array (ARA)



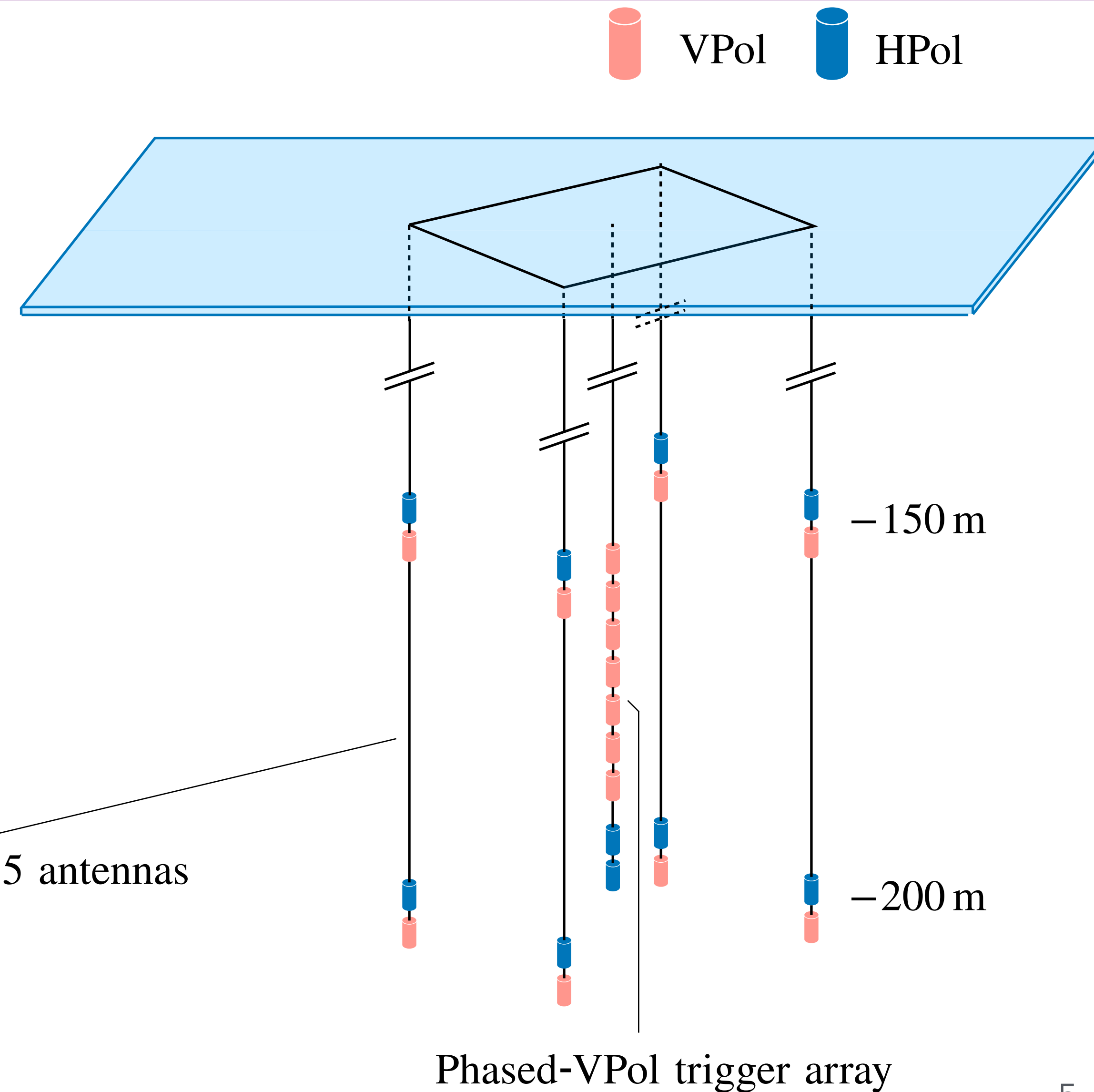
The Askaryan Radio Array (ARA)



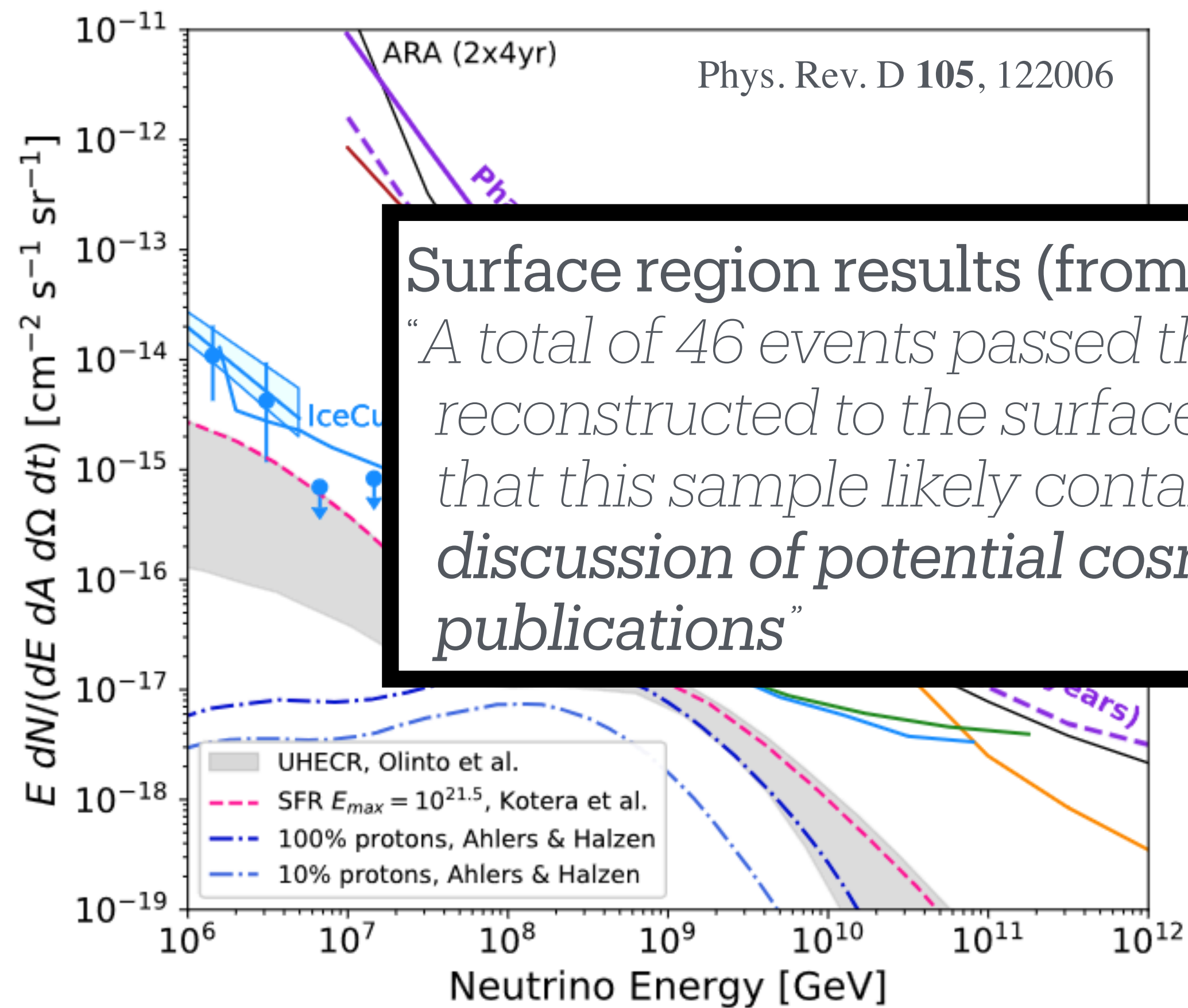
Previous ARA Results



ARA Station 5 antennas



Previous ARA Results



Surface region results (from Phys. Rev. D 105, 122006):

*“A total of 46 events passed the cuts... 36 were uniformly distributed in time, reconstructed to the surface well, and were generally impulsive, suggesting that this sample likely contains cosmic ray candidates... **More study and discussion of potential cosmic ray candidates will be done in future publications**”*

ARA Station 5 antennas

Phased-VPol trigger array

VPol HPol

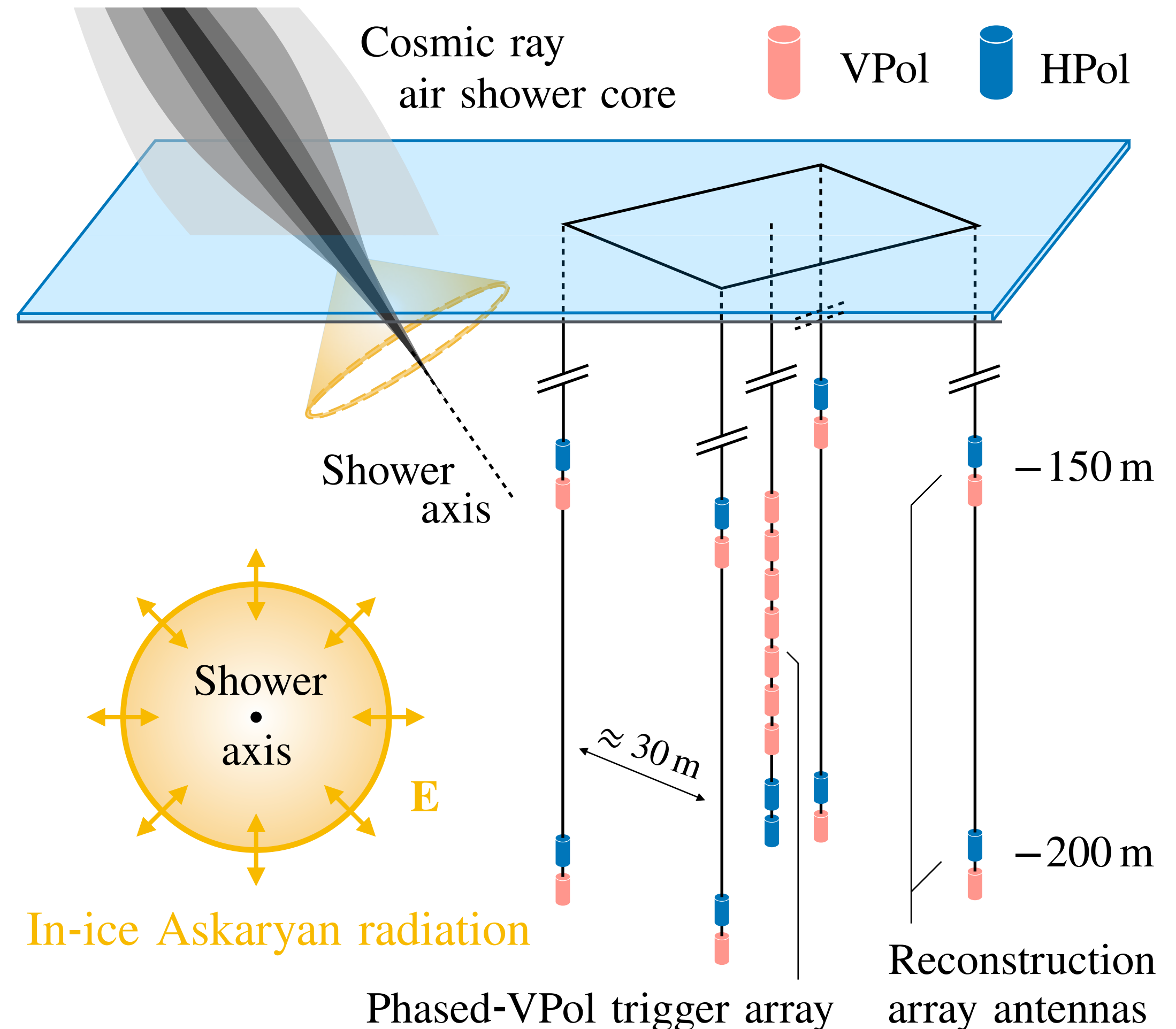
150 m

200 m

Expected Askaryan signal characteristics

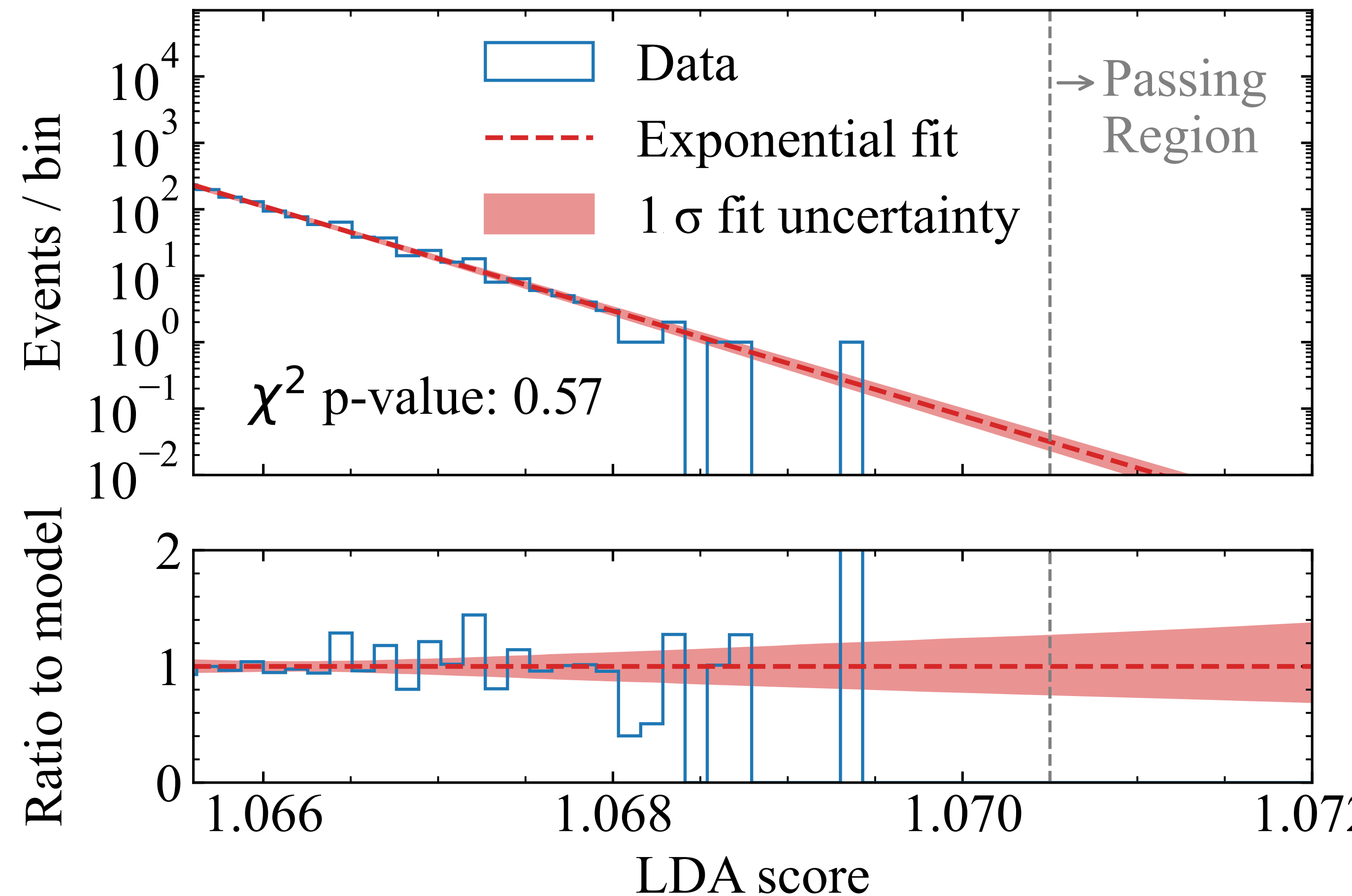
If we were to see such a signal in ARA from cosmic ray interactions, what would we expect?

- Impulsive signal
- Isolated in time
- Uniform in arrival direction
- Rate matches expectations from simulation
- Distinct from other backgrounds (geomagnetic, thermal, anthropogenic)



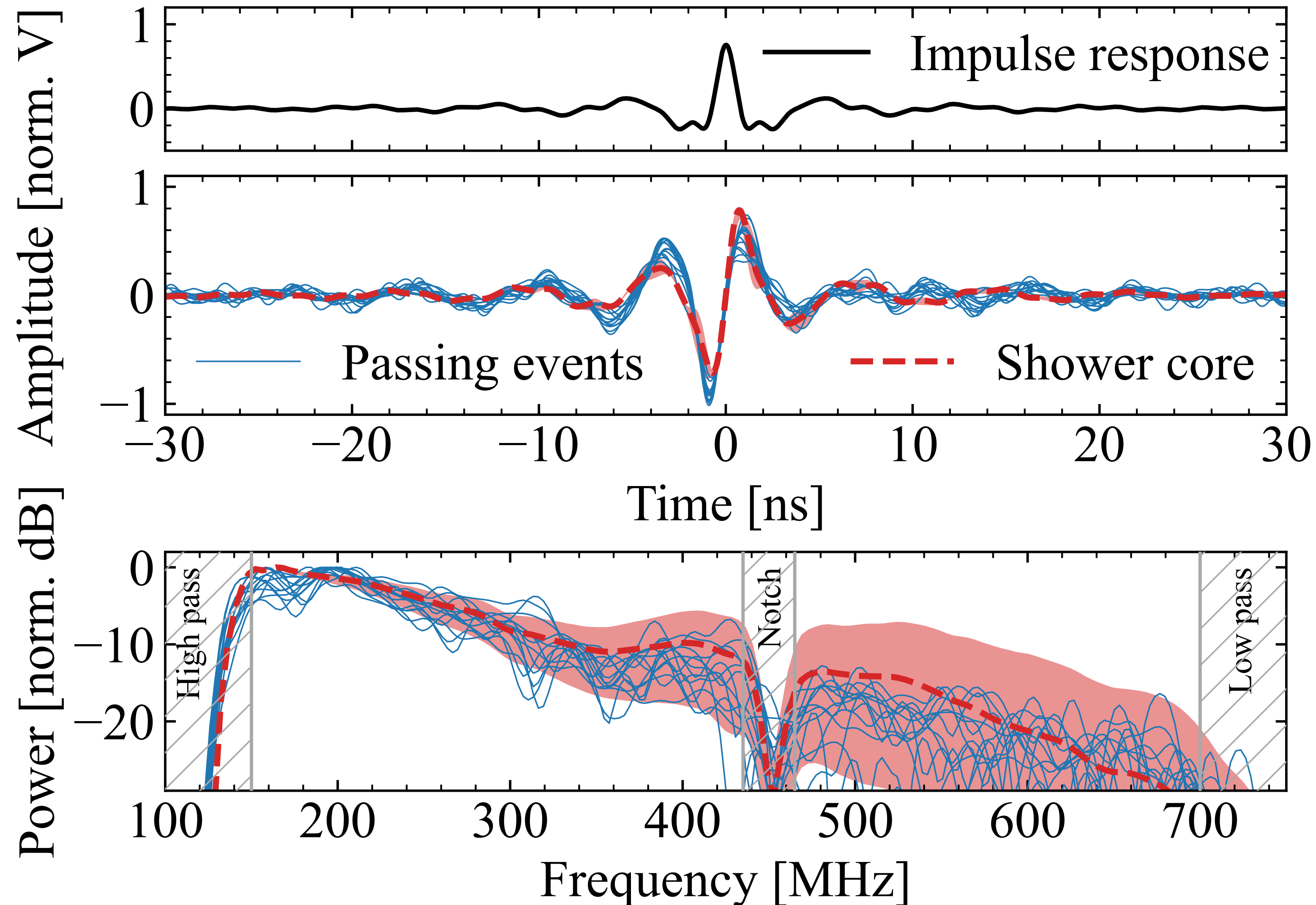
Estimating our background

- It's important to emphasize: this was not an independent blinded analysis
- Instead, we are calculate a postunblinding background estimate:
 - Thermal backgrounds: $0.14^{+0.05}_{-0.03}$
 - Distant near-horizon sources:
 0.15 ± 0.04 (stat.) $^{+0.07}_{-0.03}$ (syst.)
 - On-surface sources within 250 m of the detector: 0.12 (95 % F.C. upper limit)

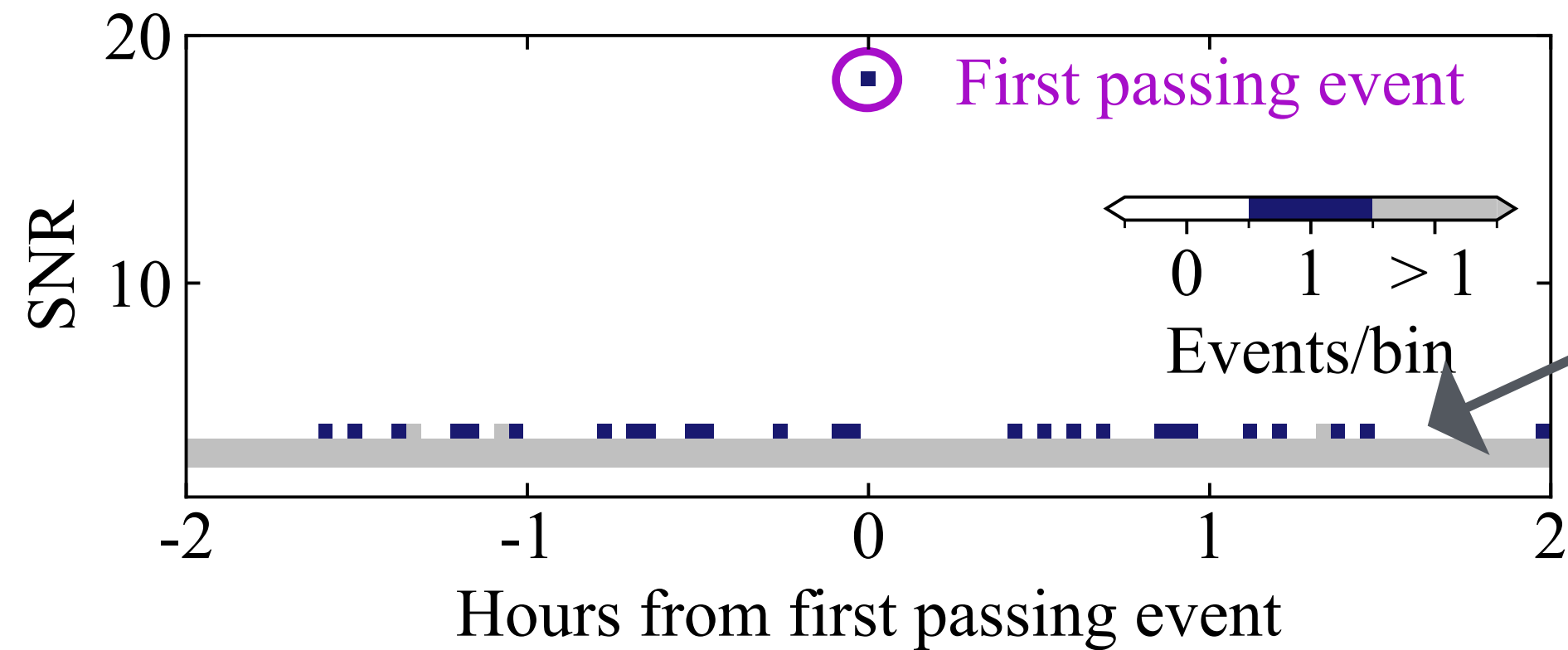


Are the events impulsive?

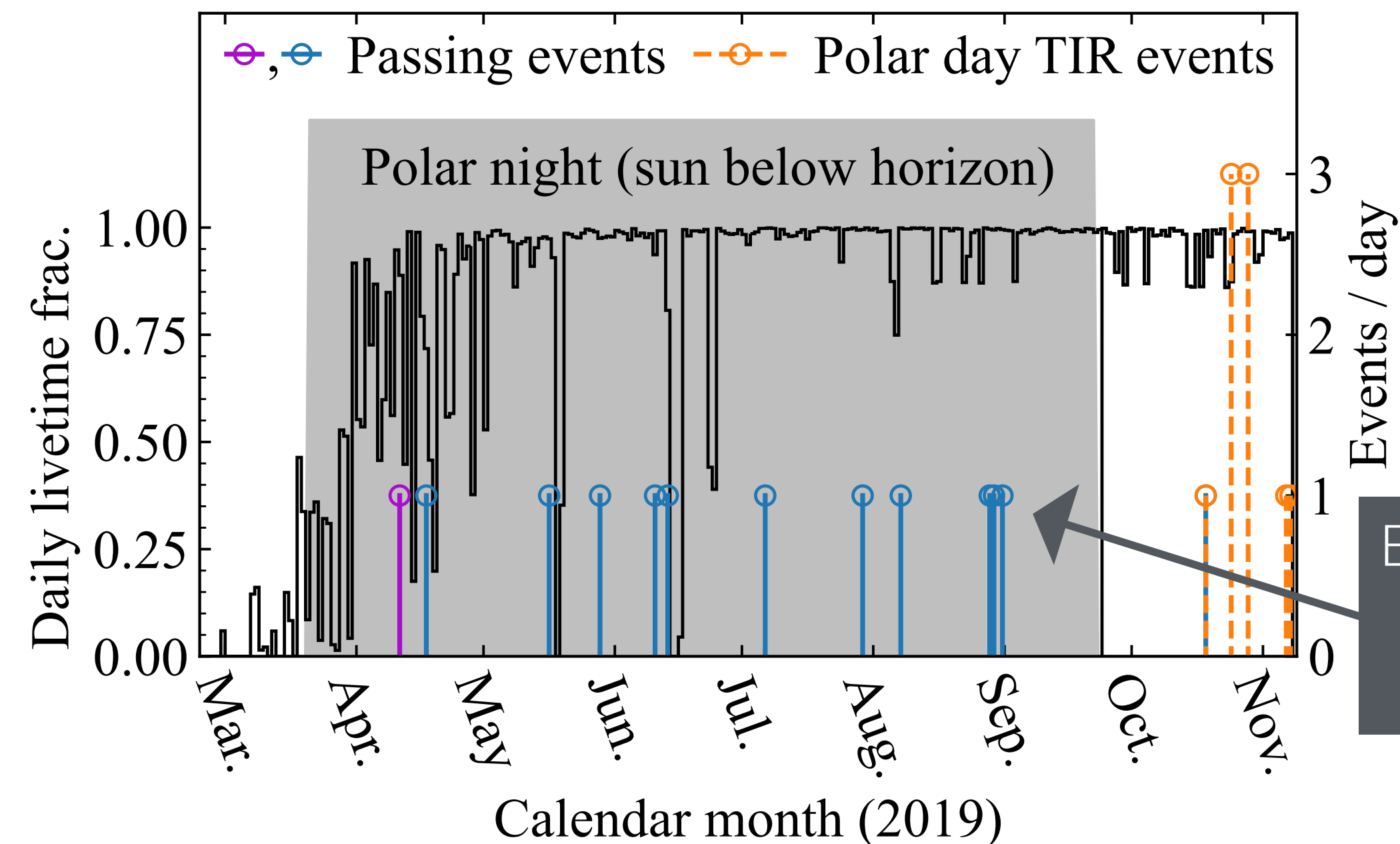
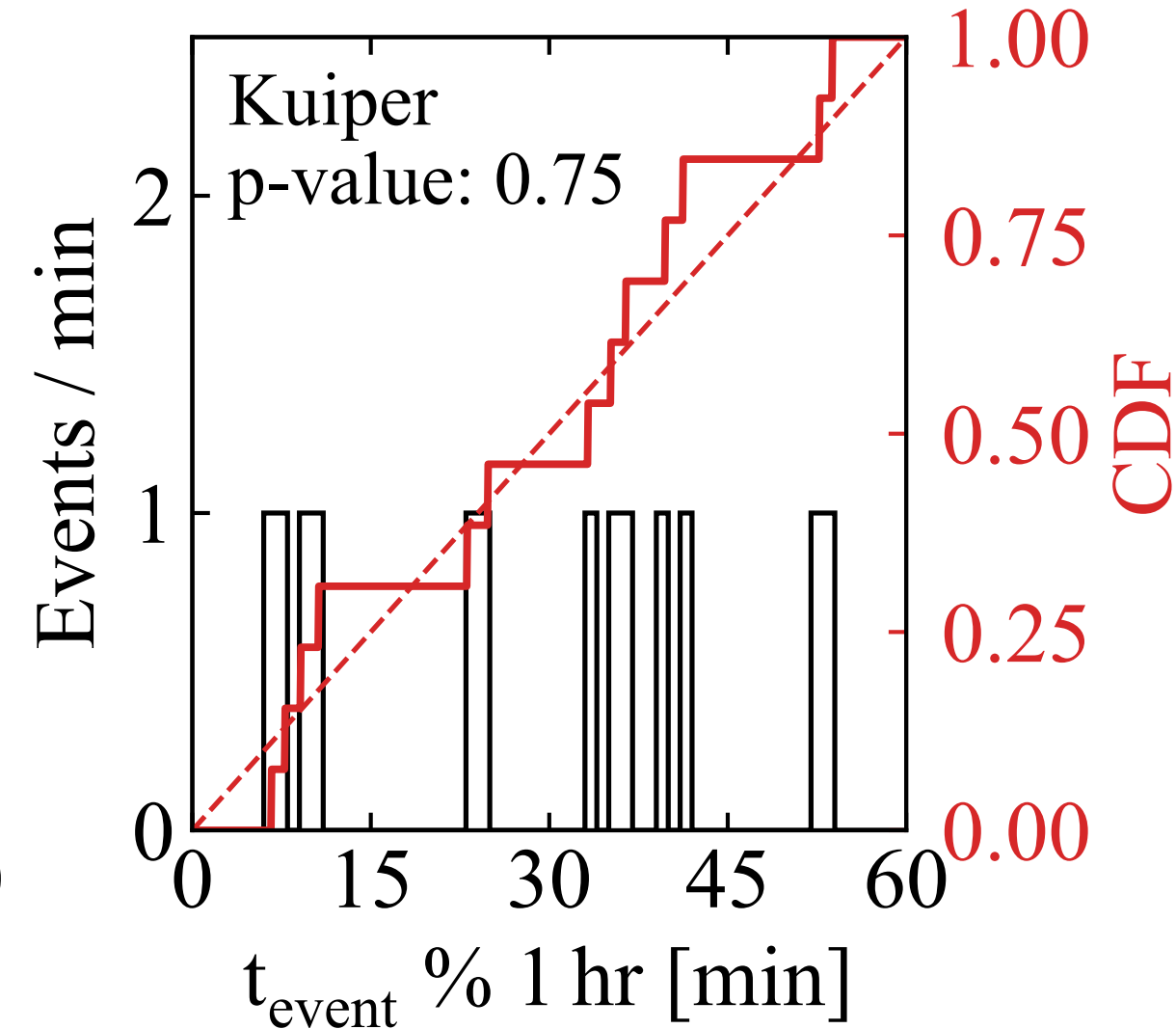
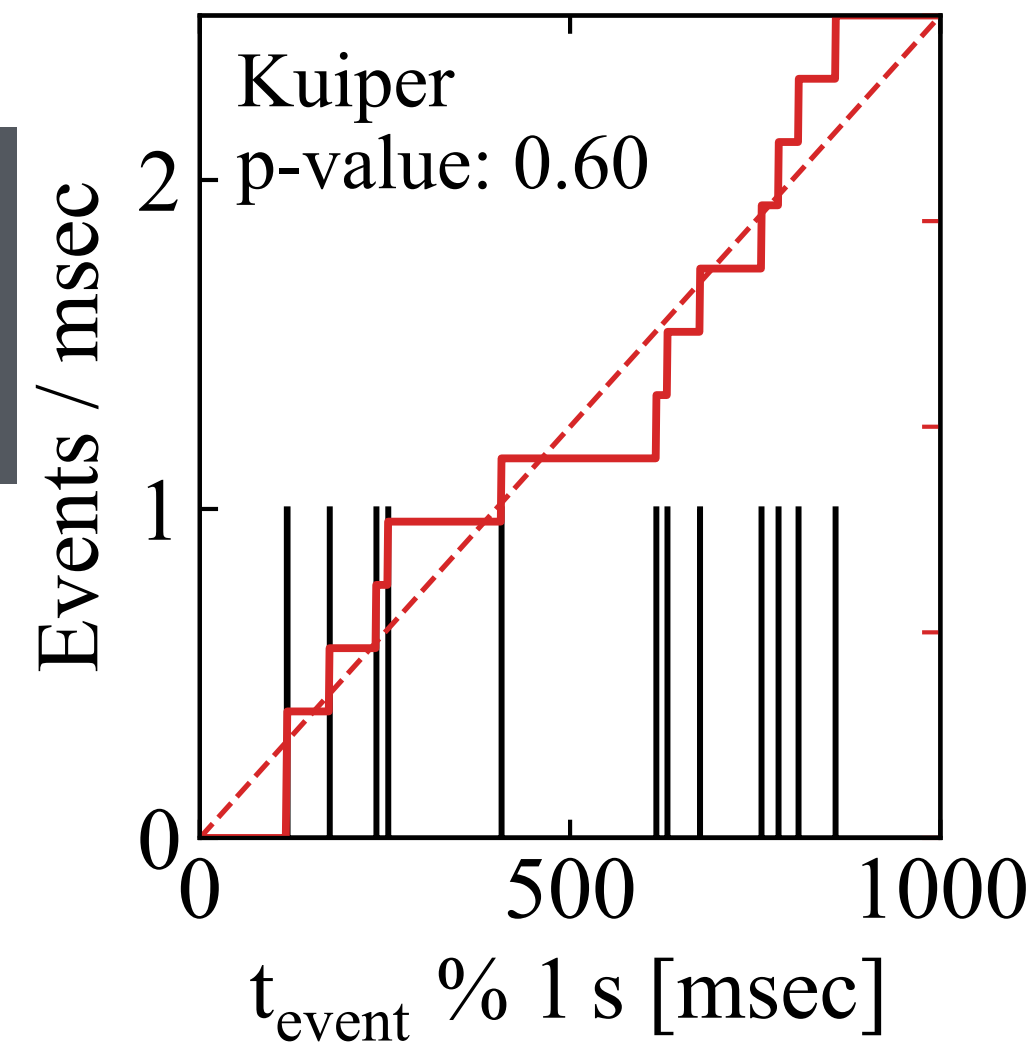
- Yes! And they match predicted signal shape from simulation
- Simulation uses CORSIKA 8 (for particle cascade) and Eisvogel (for radio emission and propagation)
- See D. Baack's talk for more on CORSIKA 8!
- Event rate is separately estimated using Monte Carlo approach in Coleman et. al. (2025) as $8\text{-}34\text{ yr}^{-1}$



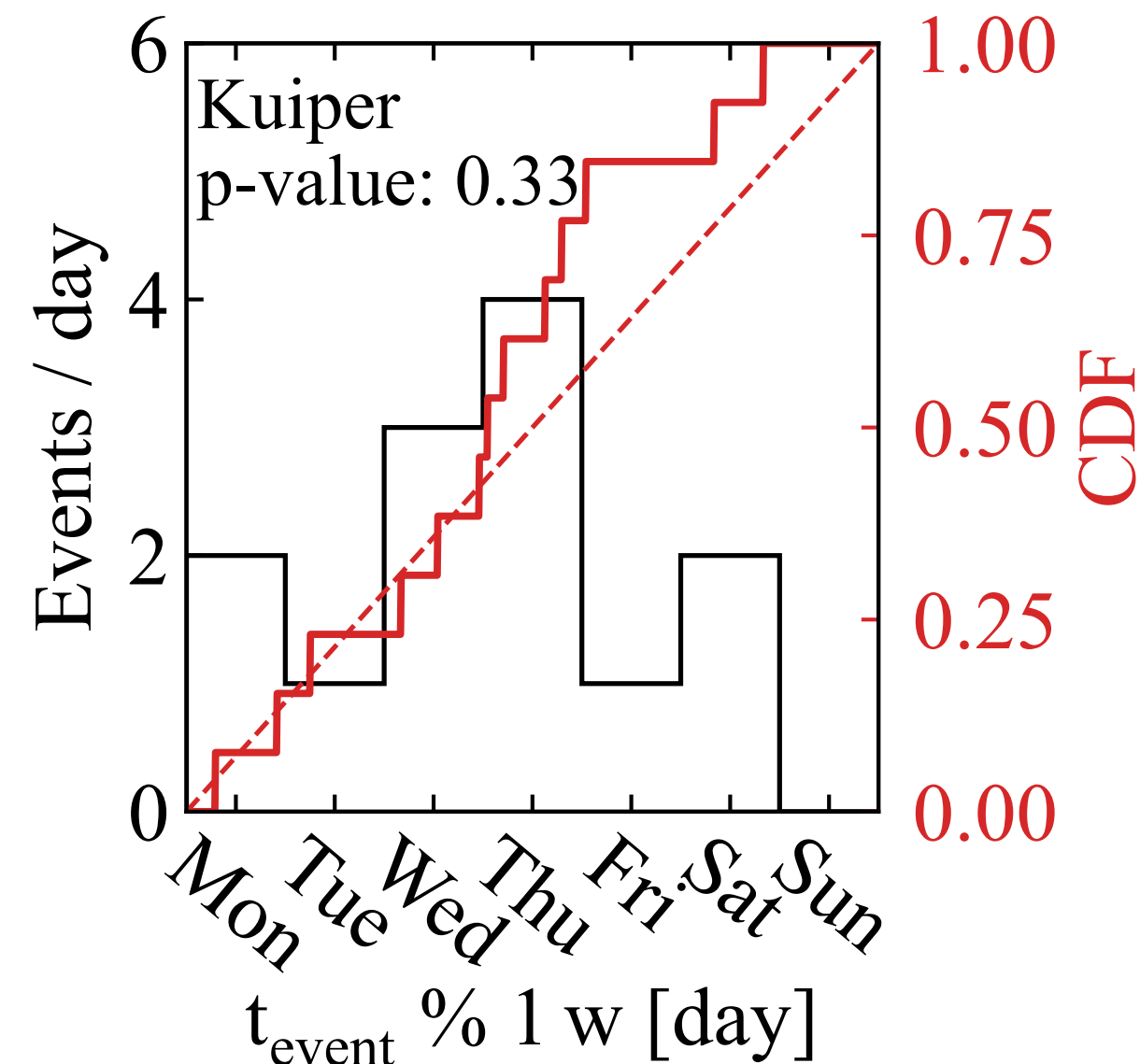
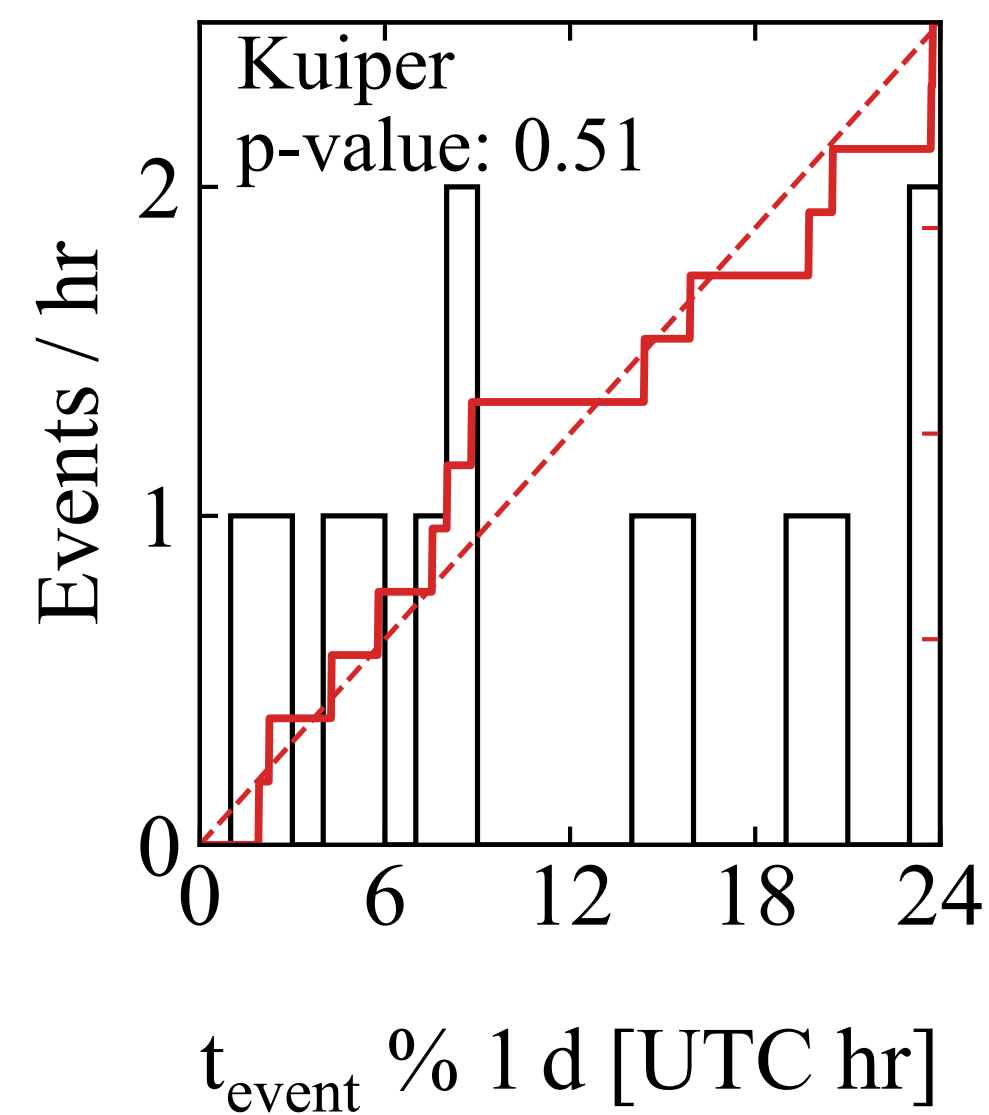
Are the events isolated in time?



No indication of other events with high SNR within ~hours



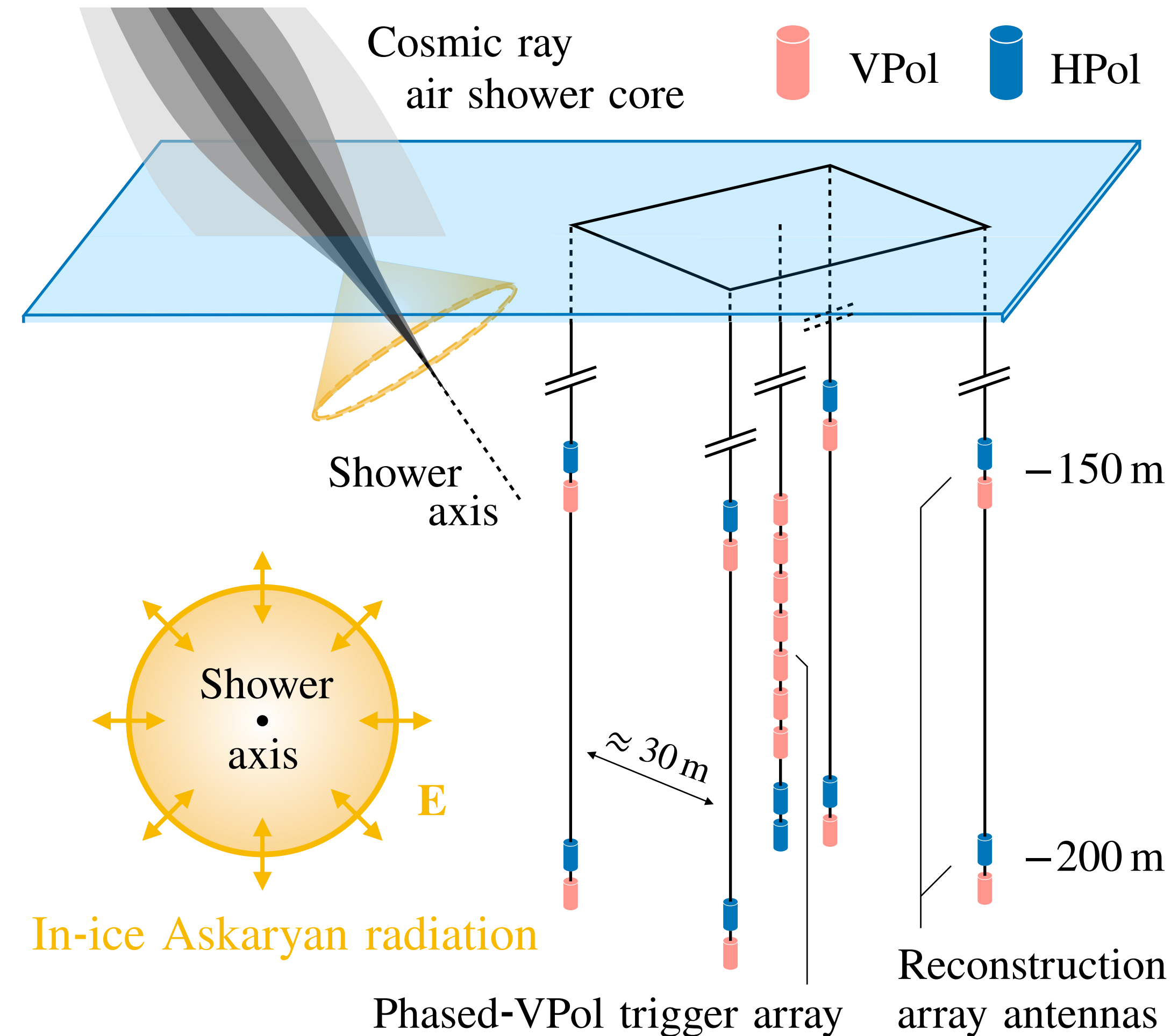
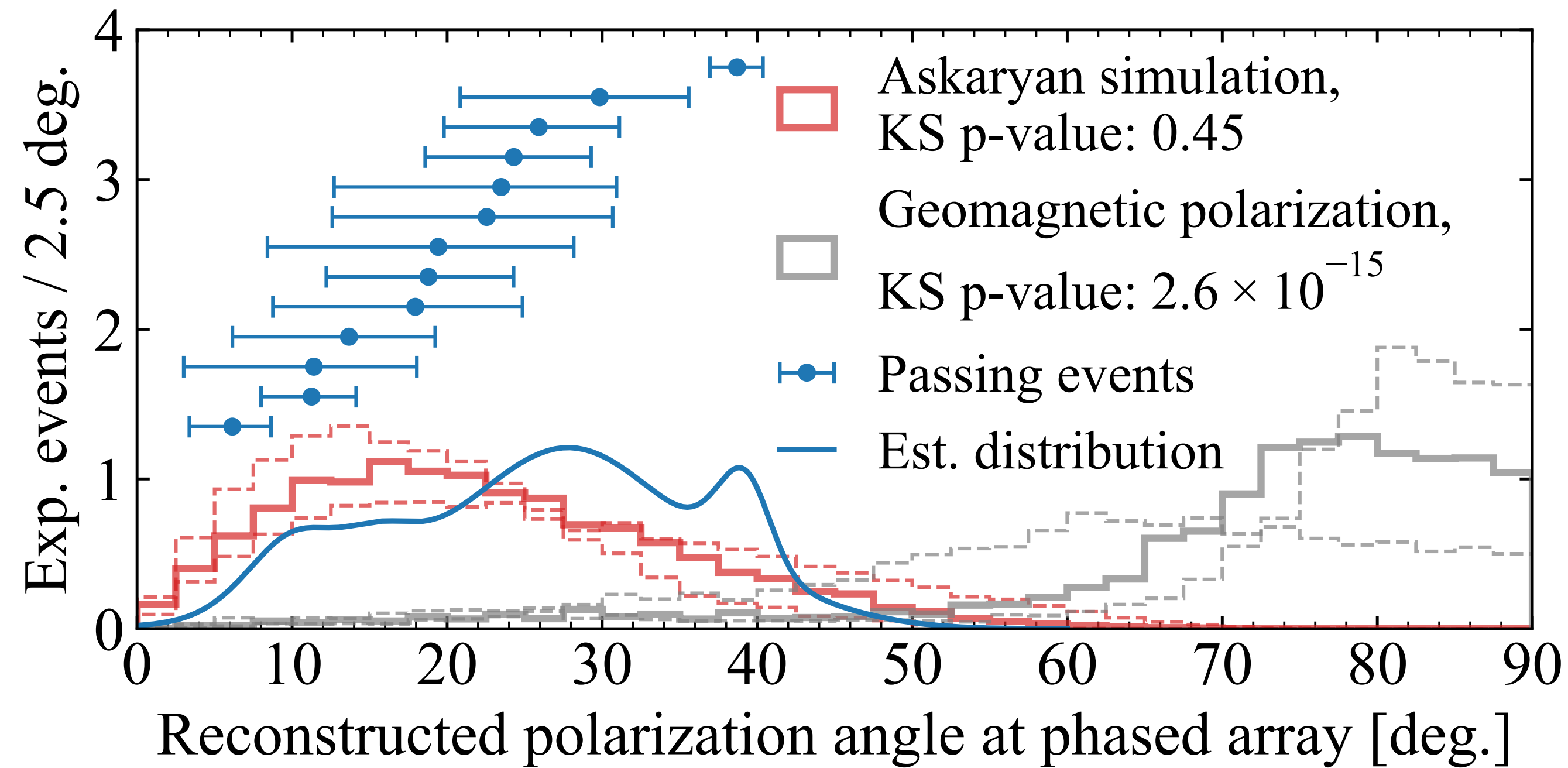
Events are spaced out over the calendar year



No periodicity identified

Are the events distinct from other backgrounds?

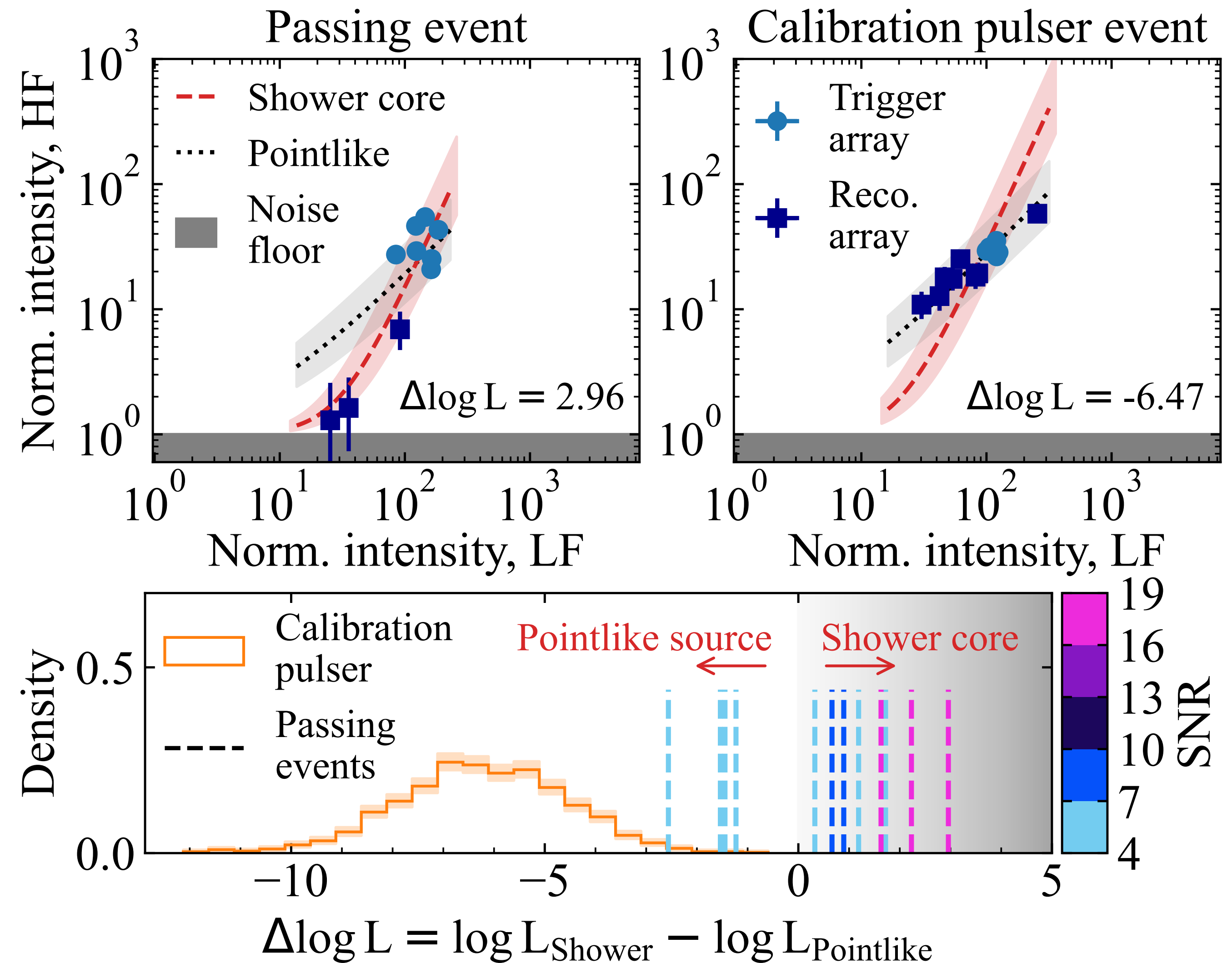
Polarization estimate is quite distinct from expected geomagnetic signals



We expect Askaryan emission to mostly manifest as vertically polarized emission

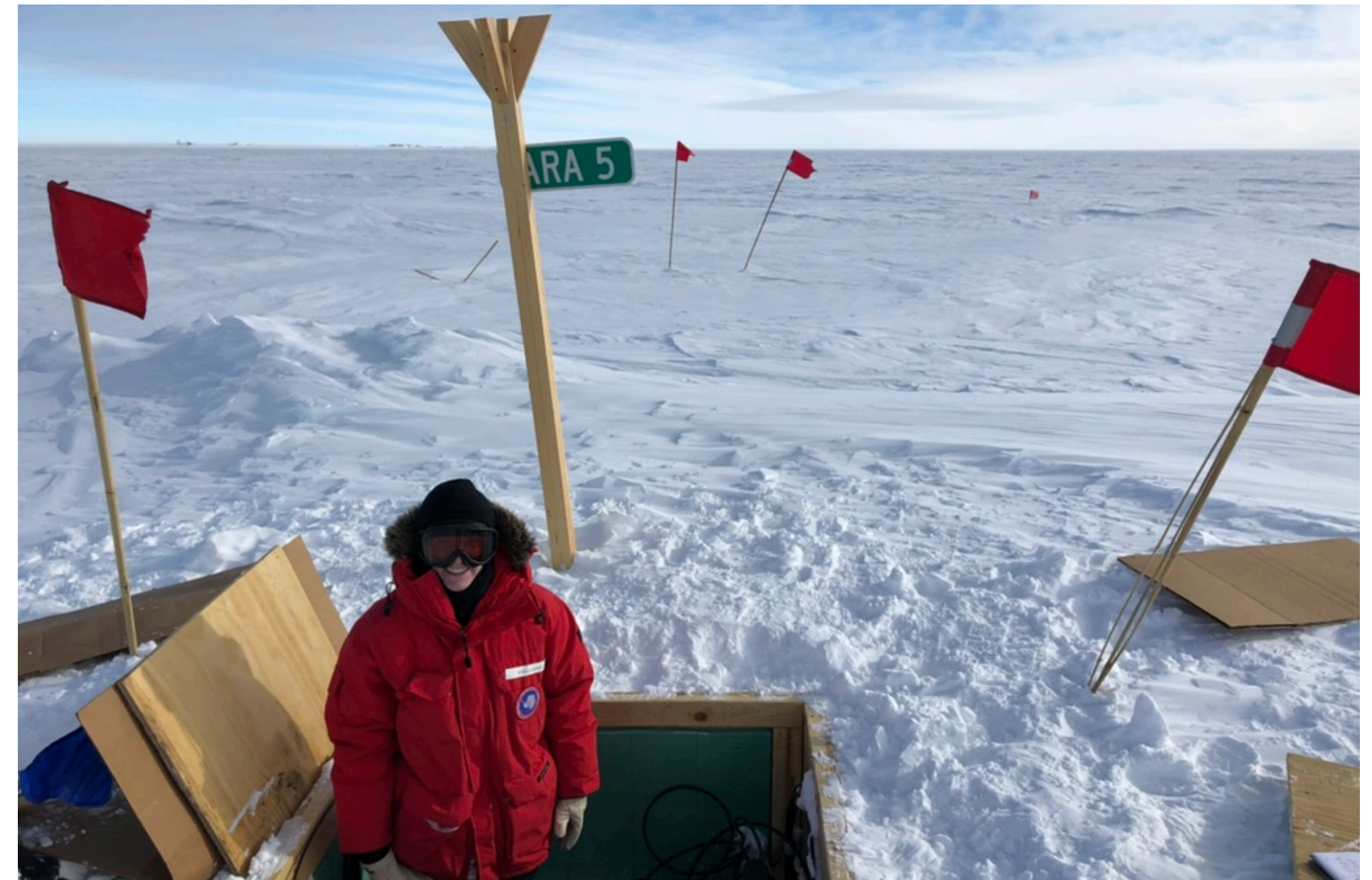
Comparing our signals to other impulsive sources

- We expect Askaryan signals to be beamed: frequency content will change as Cherenkov view angle changes
- With distributed antennas like ARA, this may be possible to detect
- One measure of this: compare high frequency and low frequency power on multiple channels
- Non-askaryan pulses: expect frequency content ratio to stay the same
- Askaryan pulses: expect frequency content to vary across the array



Conclusion and outlook

- 13 events observed by ARA instrument in 208 days of data - a 5.1σ deviation from the expected background
- Events are consistent with expected Askaryan signal
- Further study warranted:
 - We expect hundreds of events in full ARA dataset which is in the process of being unblinded!
 - What else can we learn about the cosmic rays themselves? (See Cosmin's talk!)



Backup

What about direction reconstruction?

