Updates from the OVRO-LWA Commissioning a Full-Duty-Cycle Radio-Only Cosmic Ray Detector

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We aim to make new, independent cosmic ray composition estimates across the energies where the cosmic ray flux transitions from Galactic to extragalactic sources, using a cosmic ray radio air-shower detector currently under development as part of an NSF-funded upgrade to the Owens Valley Radio Observatory Long Wavelength Array (OVRO-LWA). This detector will use radio signals alone to trigger data readout, distinguish cosmic ray air-showers from a background of radio frequency interference (RFI), and reconstruct shower energy and column depth of shower maximum (X_{max}). Radio-only detection and analysis will reduce the dependence on uncertainties in hadronic models and avoid selection effects from surface scintillators.

The Owens Valley Radio Observatory Long Wavelength Array (OVRO-LWA, see Figure 1) in sparsely-populated Eastern California is currently upgrading from 255 dual-polarization dipole antennas to 352 dual-polarization antennas and all new digital signal processing electronics, pursuing science goals that include studying exoplanet magnetospheres, solar and stellar flares, the cosmic dawn epoch, and cosmic ray air-showers. The array layout (Figure 2) consists of a dense 200-meter-diameter core array surrounded by a sparse array out to a maximum antenna separation of 2.4 km. Galactic noise will dominate the antennas' sensitivity limits at 12–85 MHz.

A previous experiment demonstrated radio-only cosmic ray observations with the OVRO-LWA prior to the upgrade by detecting 8 cosmic rays during 40 hours of special-purpose use of the array. The upgraded array will search for cosmic rays with nearly full duty cycle, using the new electronics simultaneously with the other science. After completing the upgrade, we expect to detect 2000 cosmic rays per year in the energy range 100-1000 PeV, with an X_{max} precision better than 20 g/cm^2 for ideal events.

Cosmic ray trigger decisions and RFI rejection must occur on the 11 field programmable gate array (FPGA) chips that perform the first stages of digital signal processing. When a trigger condition occurs, the FPGAs read out 20 μs at 5 ns time resolution, from the entire array. The beamed nature of cosmic ray footprints allows the use of distant antennas to veto triggers in a first stage of RFI rejection on the FPGAs. True cosmic rays will be identified by their polarization signature and beamed radio footprint after transmitting the candidate data from FGPAs to CPUs, following the technique previously prototyped. This conference contribution focuses on the FPGA firmware as well as overviewing the rest of the system.

Figure 1: OVRO-LWA antennas (Photo: Gordon Wiltsie). The Owens Valley Radio Observatory lies between two mountain ranges in the sparsely populated region of Eastern California. The OVRO-LWA antennas' bandpass will be Galactic-noise-dominated from 12-85 MHz.

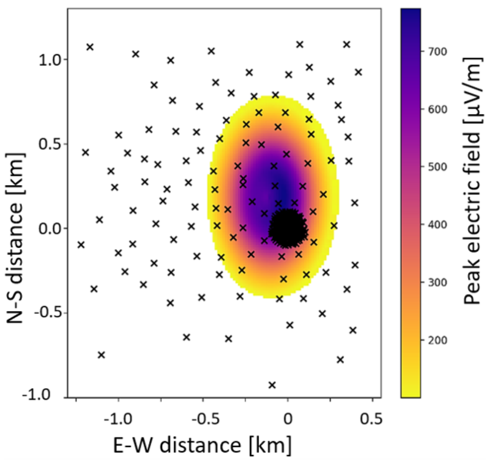

Figure 2: OVRO-LWA antenna positions (X's), overlaid with an air-shower simulation (color) for a 100 PeV proton from the North inclined 50° with $X_{max} = 695$ g/cm^2. OVRO-LWA expects thousands of 100 PeV to 1 EeV cosmic rays per year with a radio-only trigger running full-time alongside other astronomy applications.