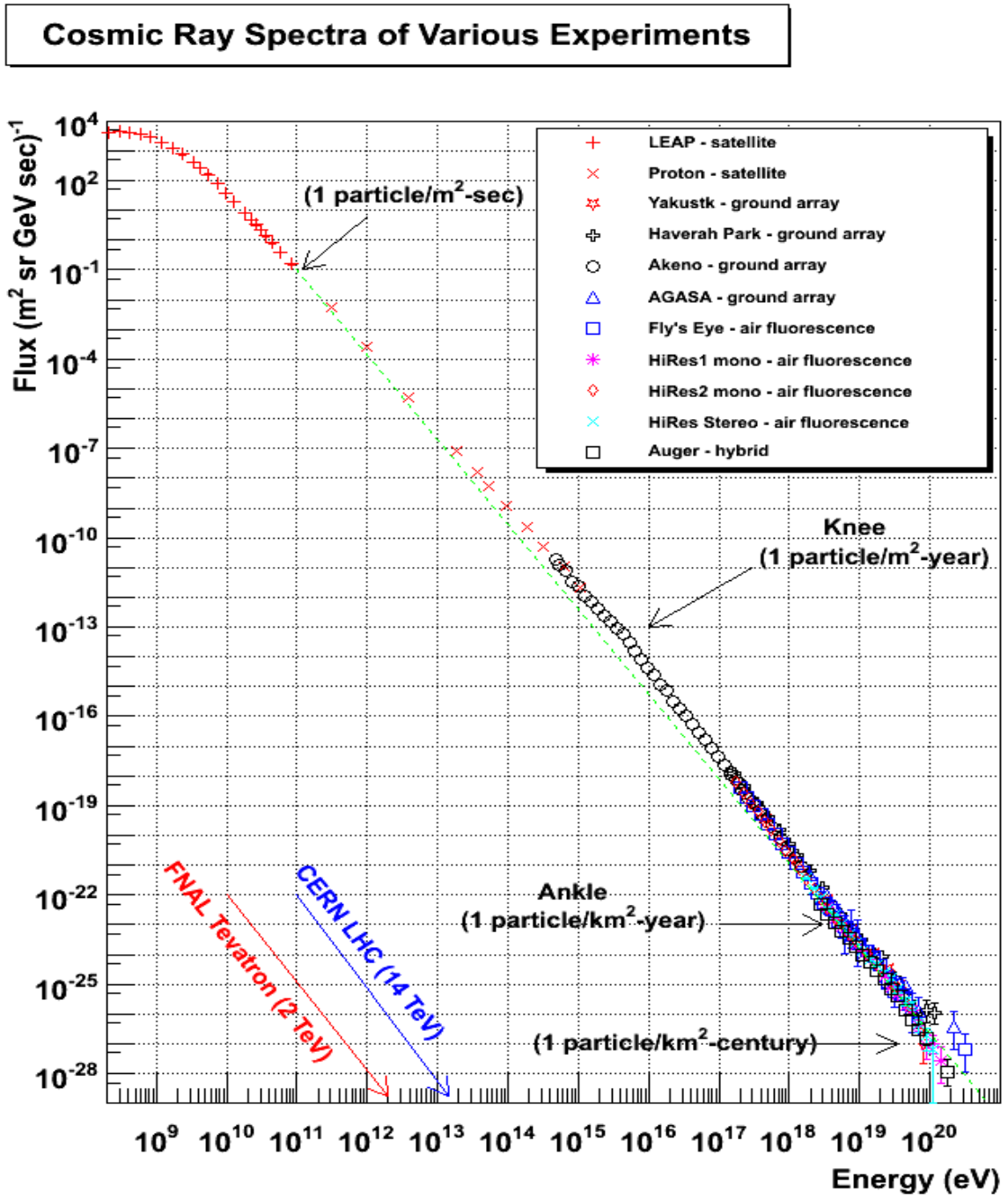
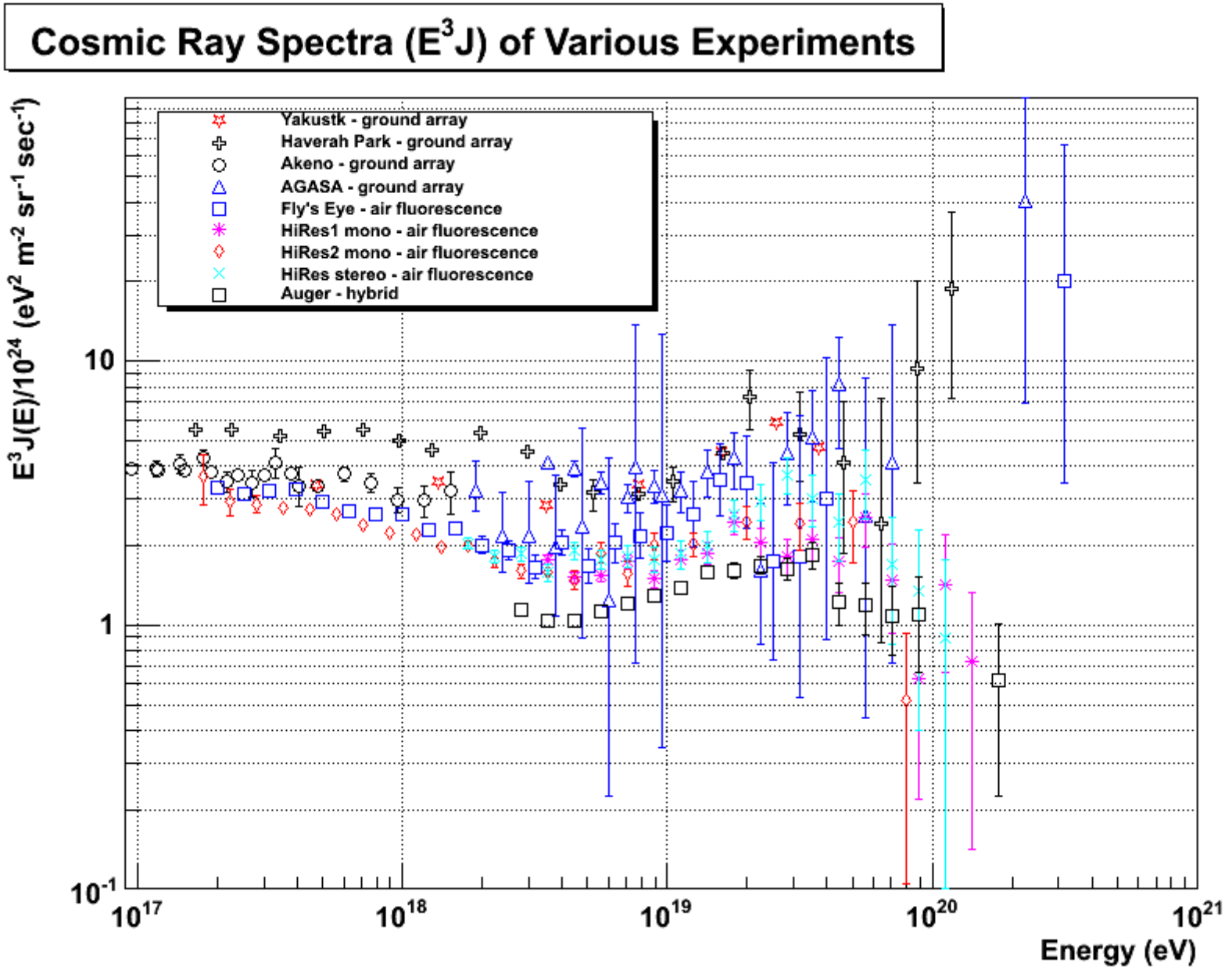
Cosmic Ray Detection with the LWA

- What the LWA can add:
  - Currently, not ideal coverage, BUT
  - The most densely packed radio air shower array
  - =>best tests of modeling of $E(r,\theta)$
    - Cf: LOPES-30 (inverted vee) / CODALEMA (16 Rx) / RASTA (36, proposed, South Pole)
  - Catches:
    - No dedicated trigger
  - Unique combination of an astronomical+astroparticle mission!

Swordy Plot


Cosmic Ray Spectra of Various Experiments
Flux (m² sr GeV sec)⁻¹
Energy (eV)
LEAP - satellite
Proton - satellite
Yakustk - ground array
Haverah Park - ground array
Akeno - ground array
AGASA - ground array
Fly's Eye - air fluorescence
HiRes1 mono - air fluorescence
HiRes2 mono - air fluorescence
HiRes Stereo - air fluorescence
Auger - hybrid
(1 particle/m²-sec)
Knee
(1 particle/m²-year)
Ankle
(1 particle/km²-year)
(1 particle/km²-century)
FNAL Tevatron (2 TeV)
CERN LHC (14 TeV)

CR energy spectrum x E^3/>100 PeV



Science

- Transition from Galactic to extragalactic CR source at 'knee'
- Correlation of CR to SNR (diffuse)
  - Energy resolution limited by modeling uncertainties in RF power, however, should be able to determine slope of CR spectrum

Techniques

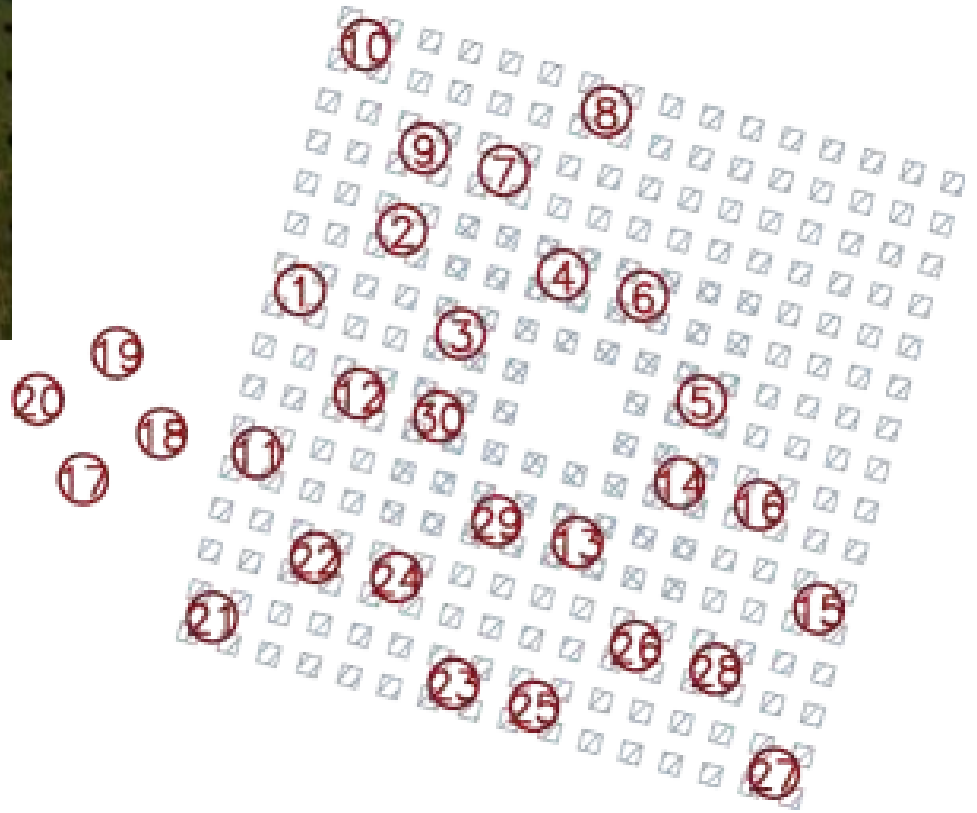
- LOPES (40-80 MHz, σ_θ~1.5^o) , CODALEMA
- MIDAS – microwave bremstrahlung
  - Typically, f>1 GHz
- CRAYDAR – forward scattering of CW through shower 'plasma' (prototype in Longridge, UT)
  - Requires ~20 kW transmitter ~ 50 km away
  - (Obviously impossible in this case)
- All require an event trigger

  Either an RF-only trigger, OR
  - Supplement the LWA array with several ground scintillators; requiring a coincidence can probably lower energy threshold by ~2

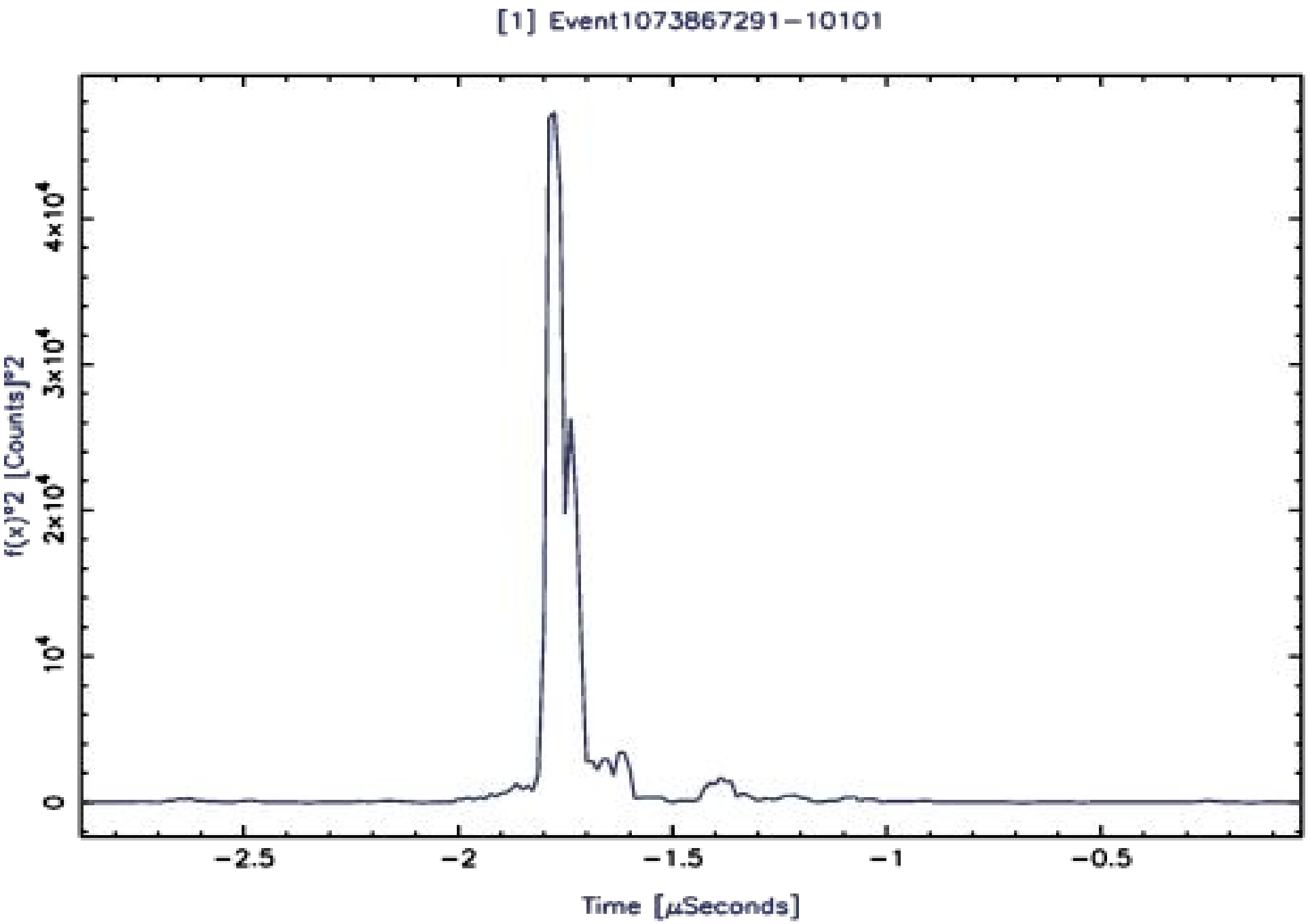
Geosynchroton mechanism

1) Developing shower in atmosphere generates ~10% e-/e+ charge excess
2) Geosynchrotron radiation give signal with wavelength weighted to (macroscopic) charge separation scale

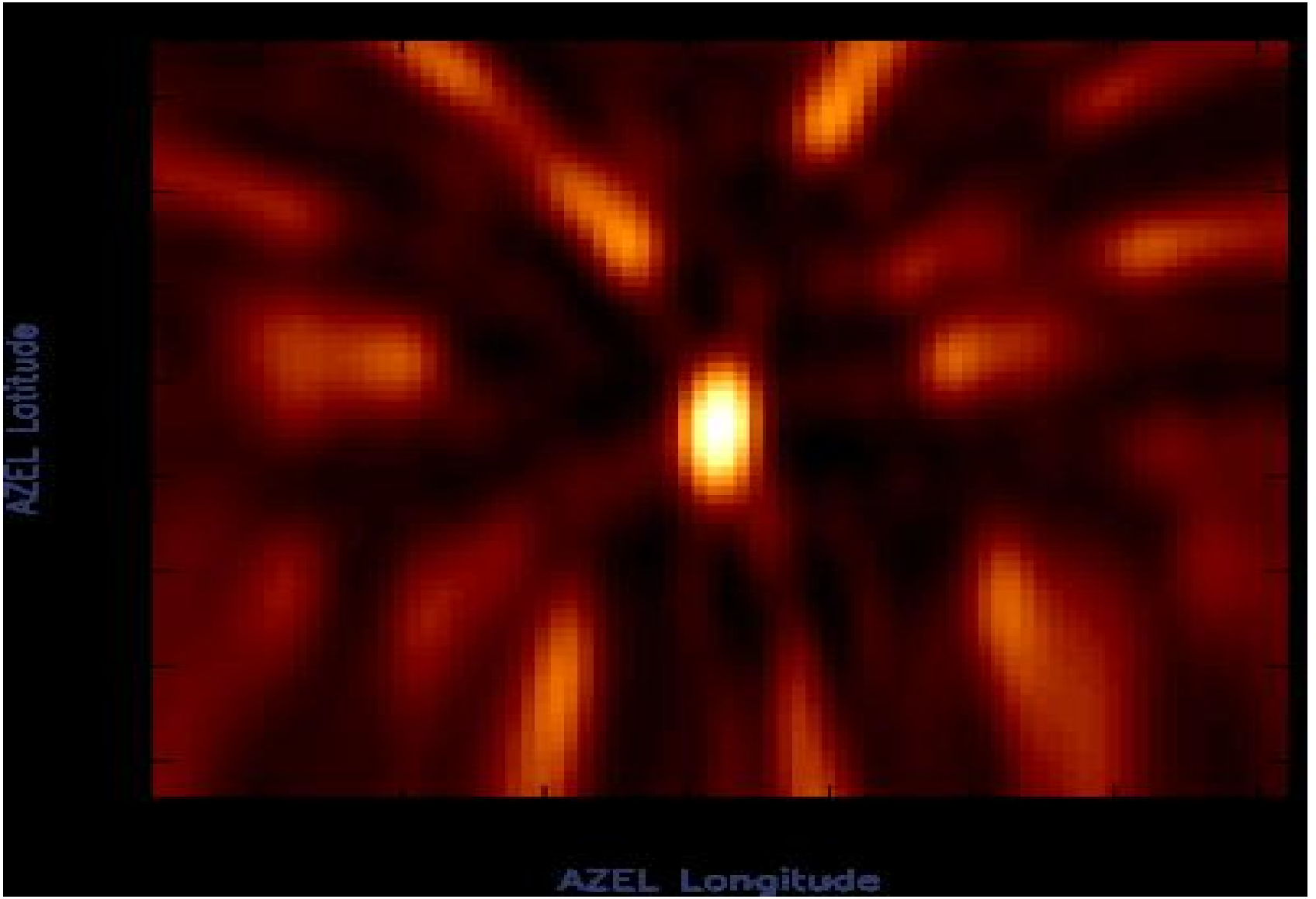
LOPES-36 in KASCADE



Signal Time Profile



Solar Flare interferogram (~5º resolution)



CODALEMA

- 7000 m^2 collection area

(144 log-periodics, filtered to 40-70 MHz)

4-fold coincidence: 0.7 evt/10 minutes

Good events: 0.3 evt/day, 2.5^o resolution

Threshold~50 PeV (PeV 10^{15} eV)

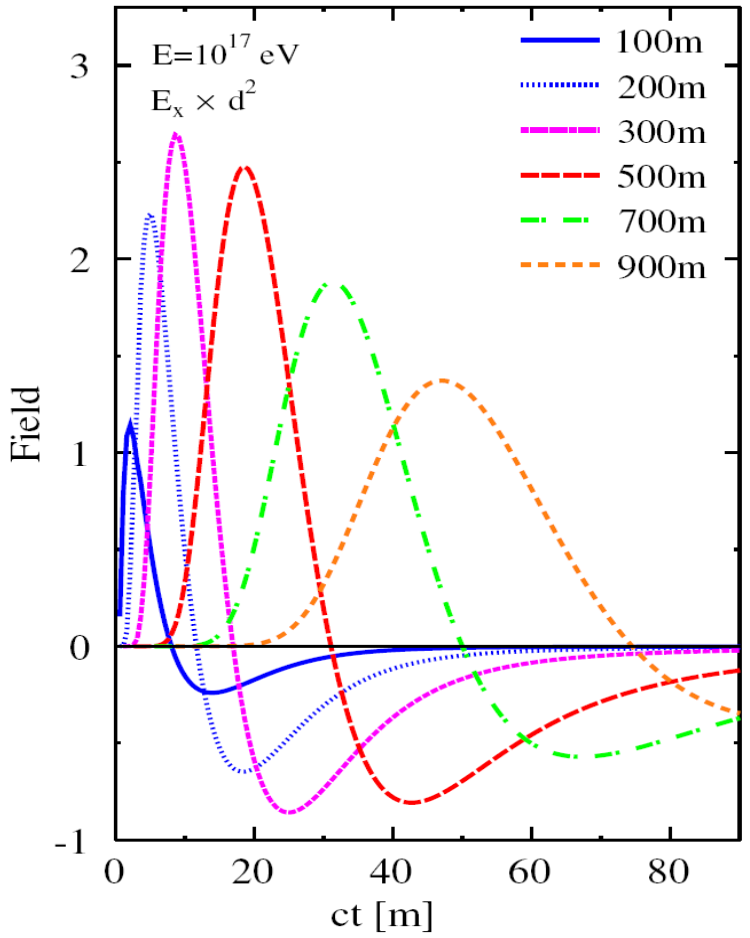
Calibration (claimed) on solar flares

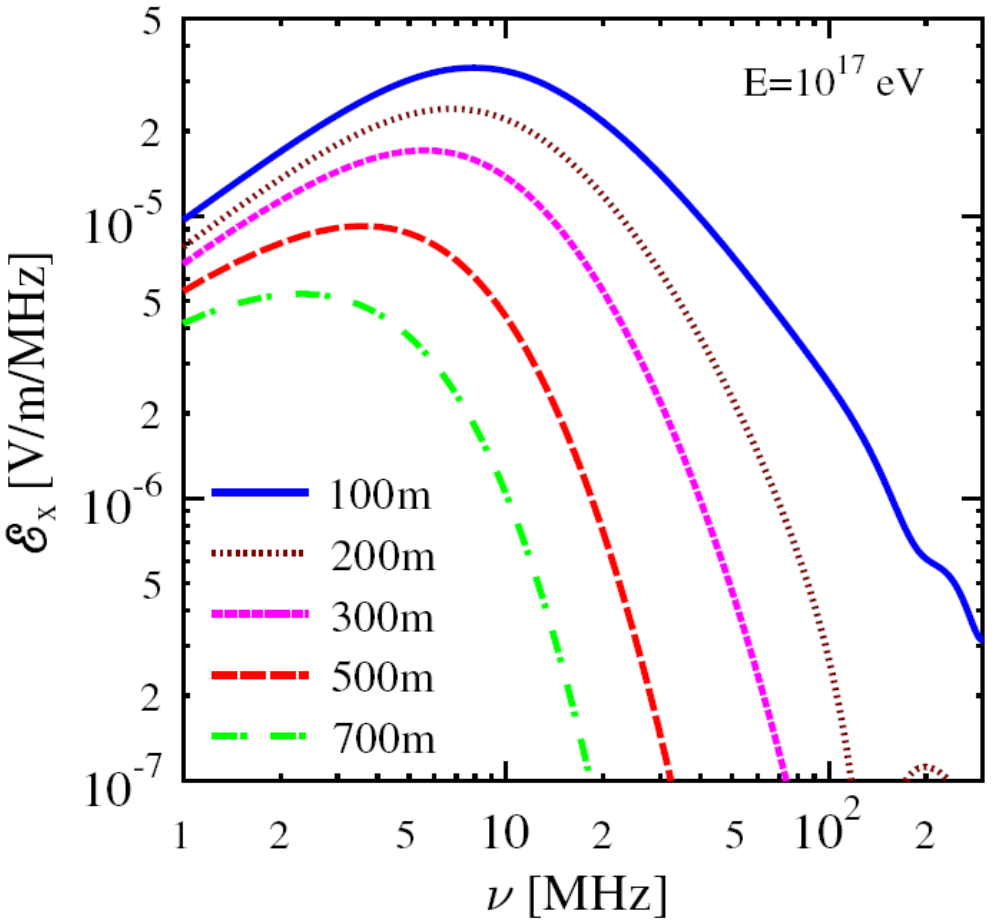
Current simulations

- Agreement of REAS3 at ~15% level for vertical showers
- Agreement for highly inclined showers (>50^{o}) somewhat worse.
  - Dense packing of LWA can be very useful in this case.

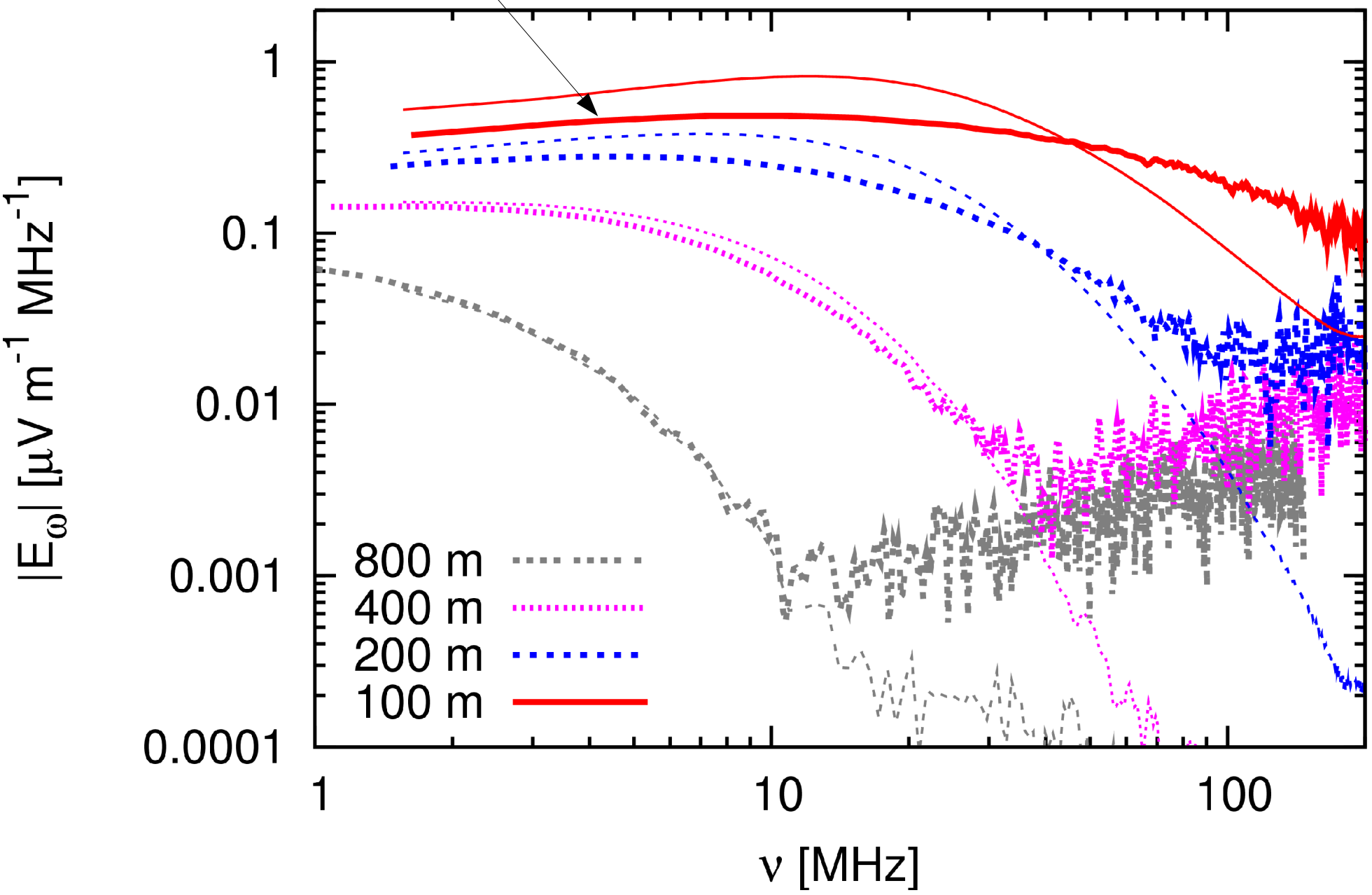
2008: The MGMR model

- Kahn & Lerche: parameterized air shower model
- macroscopic description in the time-domain
  - relates pulse features to longitudinal shower evolution
  - time-derivative of air shower evolution=>bipolar pulses

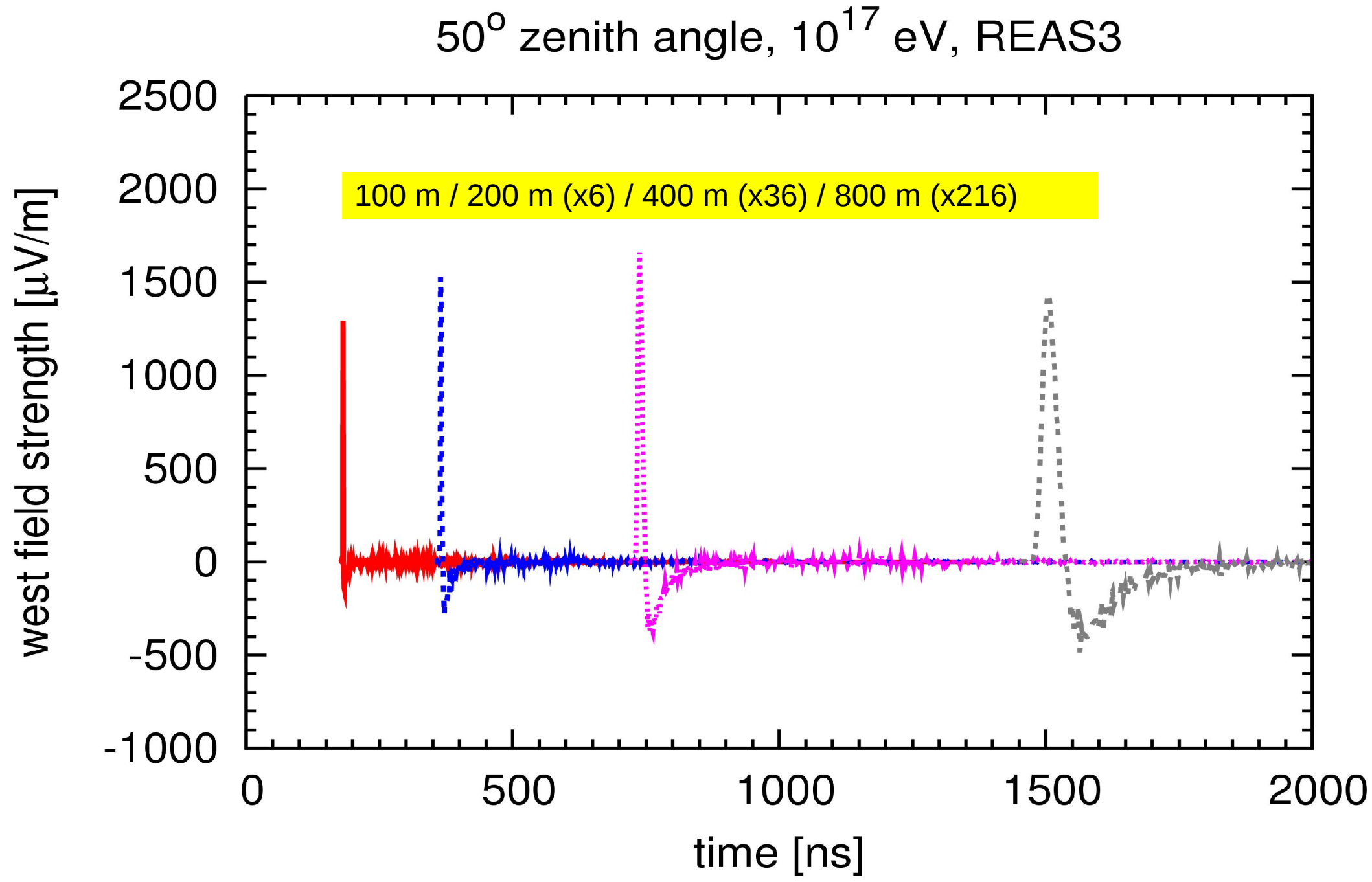




REAS3: particle-level calculation



Signal Strength (cf: bkgnd=thermal~10 uV, + galaxy)



Summary

- With existing array, LWA is competitive with other existing installations
- But need an external trigger line.
  - Minimal price: 250K personnel to rework trigger (JPL)
    - +25K coincidence hardware + computing
    - If add scintillators:
      - 50K for scintillators + photomultiplier tubes for readout + cables
- Full LWA would be a world-class instrument that would map geosynchrotron radio signal with unprecedented precision.