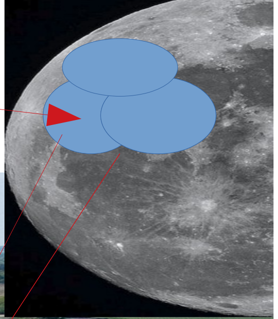
HIGH-ENERGY PHYSICS
RESEARCH CENTRE

P, ν

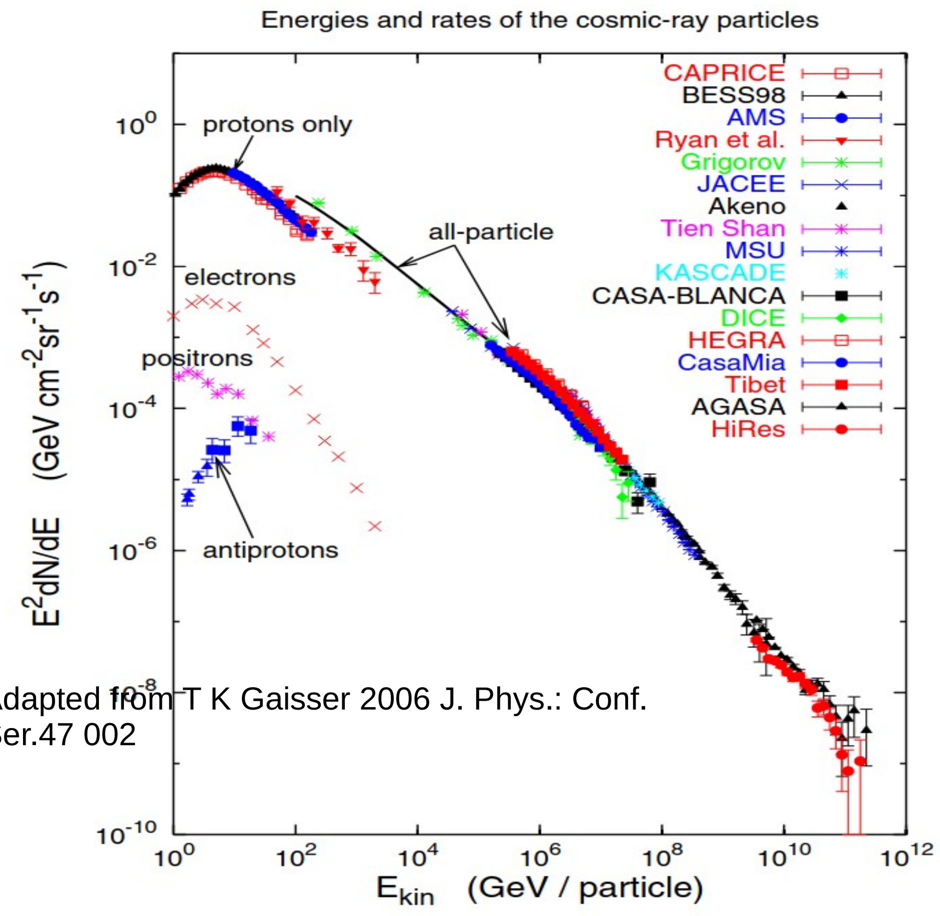


The NuMoon experiment: lunar detection of cosmic rays and neutrinos with LOFAR.

G. K. Krampah, S. Buitink, O. Scholten, B. M. Hare, A. Corstanje, H. Falcke, T. Huege, J. R. H¨orandel, P. Mitra, K. Mulrey, A. Nelles, H. Pandya, J. P. Rachen, T. N. G. Trinho, S. ter Veen, S. Thoudam, T. Winchen

gkrampah@vub.be

Motivation



Adapted from T K Gaisser 2006 J. Phys.: Conf. Ser.47 002

* Cause of cutoff still unclear

* Enough statistics of UHE particles - Lunar Askaryan Technique

* 19 million km^2 area/Larger energy threshold

* Demonstrate detection principle

* show some preliminary results.

Radio Cherenkov Signal

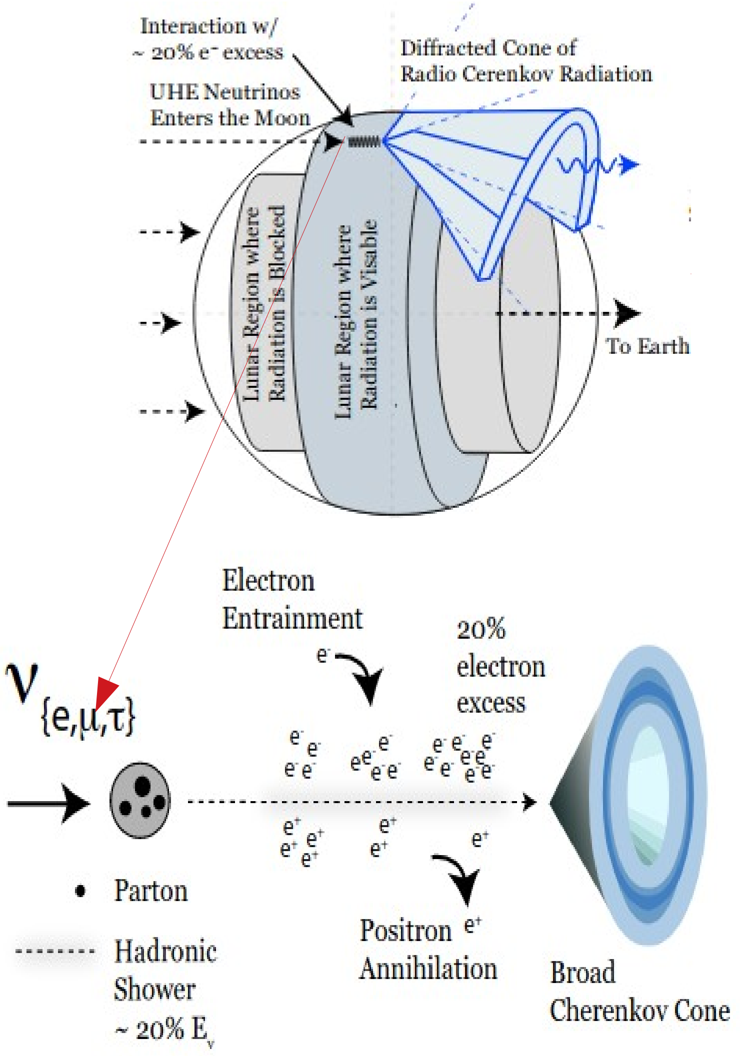
* UHE particles interacts producing showers in the Lunar regolith.

* 20% net charge excess (electrons) from developing showers.

* electrons propagating faster than the phase velocity of light in the regolith produce Cherenkov radiations

* Most radiations are totally internally reflected (especially at higher frequencies)

Adapted from: https://arxiv.org/pdf/0910.5949.pdf



Previous Experiments (Lunar targeted)

* Parkes telescope, Hankins et al (1996)

* Goldstone Lunar UHE Neutrino experiment, Gorham et al. (2001; 2004)

* Beresnyak et al. (2005) Kalyazintelescope

* Buitink et al. (2008), nuMoon with Westerbork Synthesis Radio Telescope

* Jaeger et al., RESUN with VLA

Detection technique

* Observation at frequencies between 110-190MHz with LOFAR HBA radio antannas with 200MHz sampling rate

* Station beams directed towards the Moon are further combined to form smaller tied-array beams (reject RFI)

* Polyphase filter inversion to recover the full the nanosecond resolution.

* De-dispersion

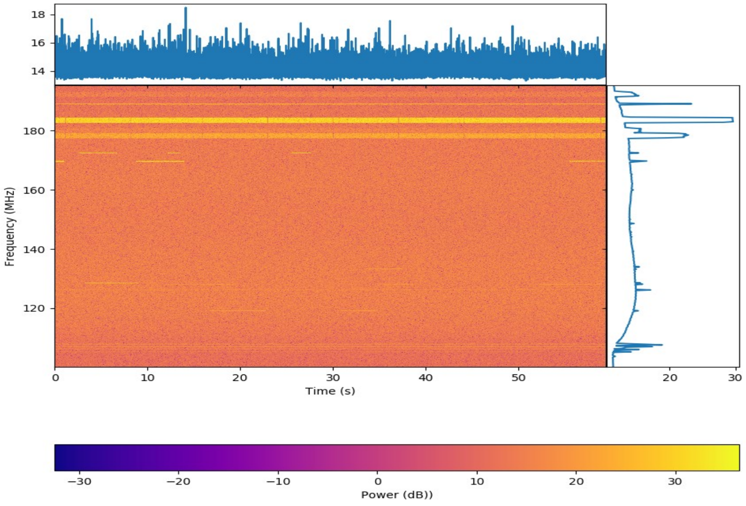
* RFI filtering

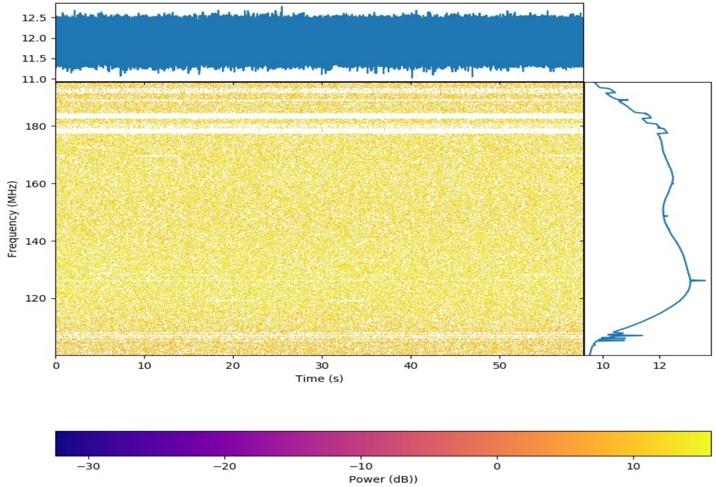
* Pulse search and triggering

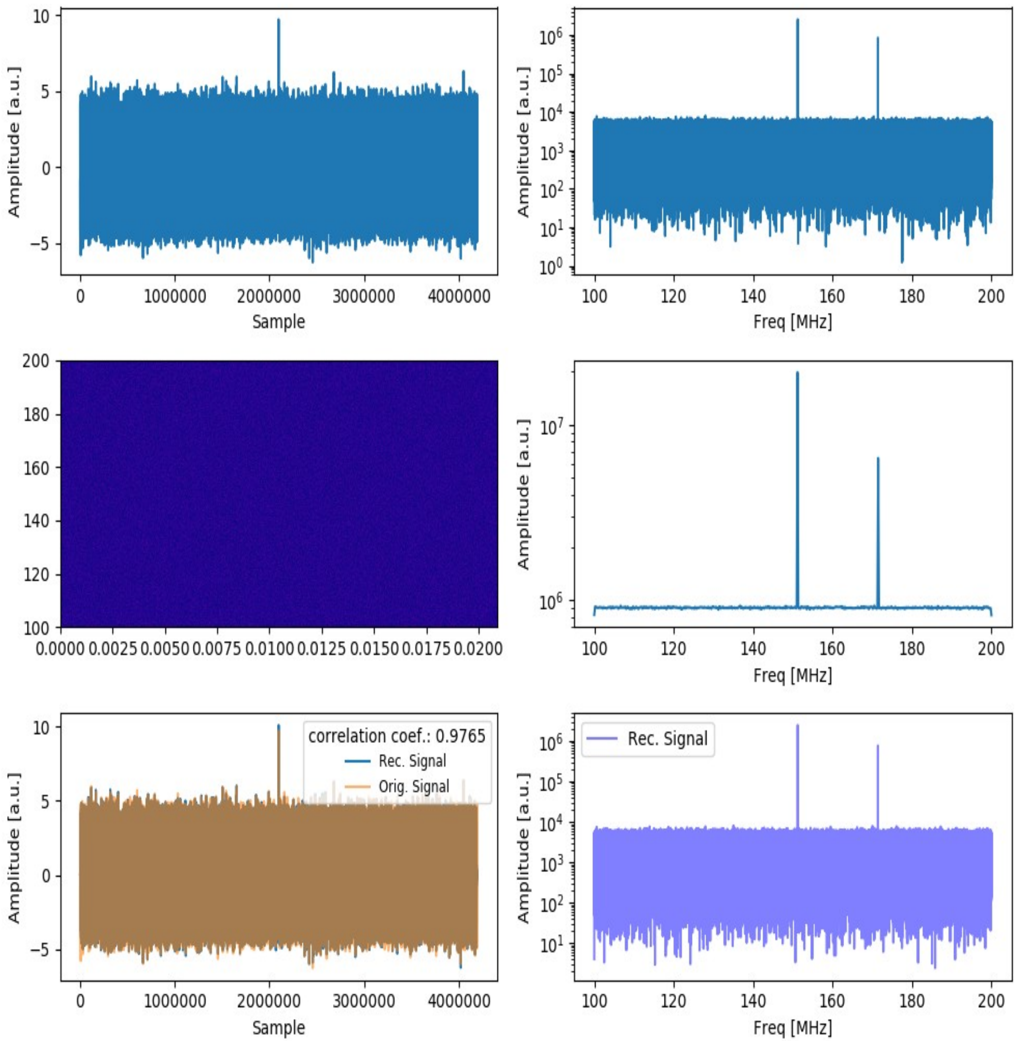
$$P_5 = \frac{\sum_{5samples} P_x}{\langle \sum_{5samples} P_x \rangle} + \frac{\sum_{5samples} P_y}{\langle \sum_{5samples} P_y \rangle}$$

* No selection criteria has been applied in the phase of the work

Station beam data before and after RFI removed

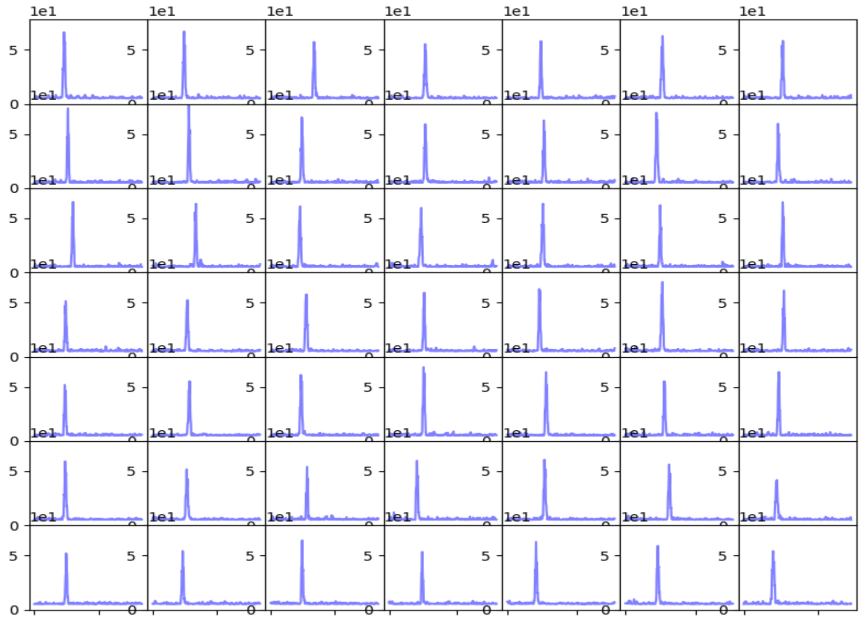




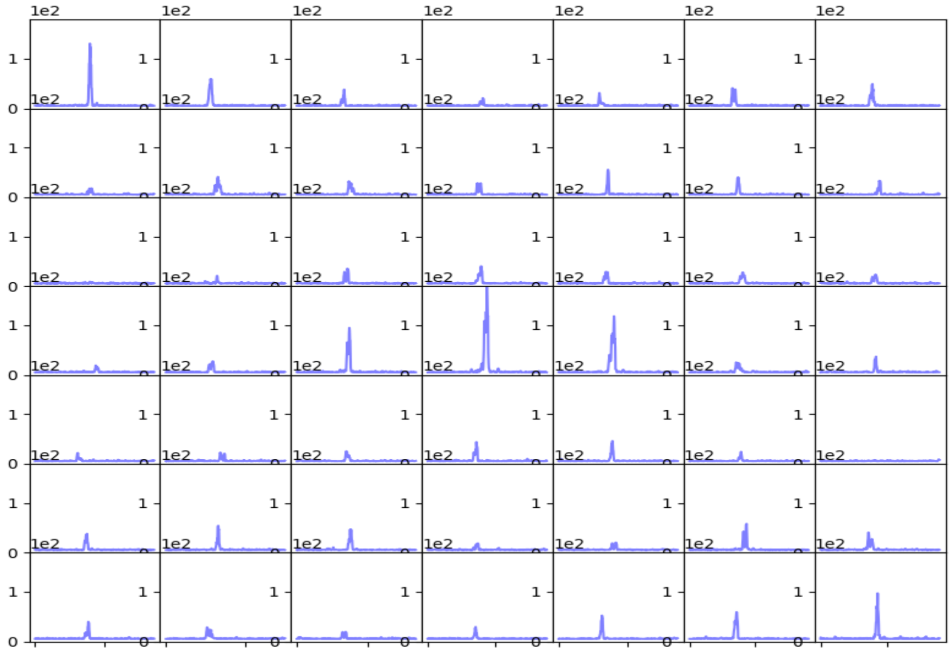


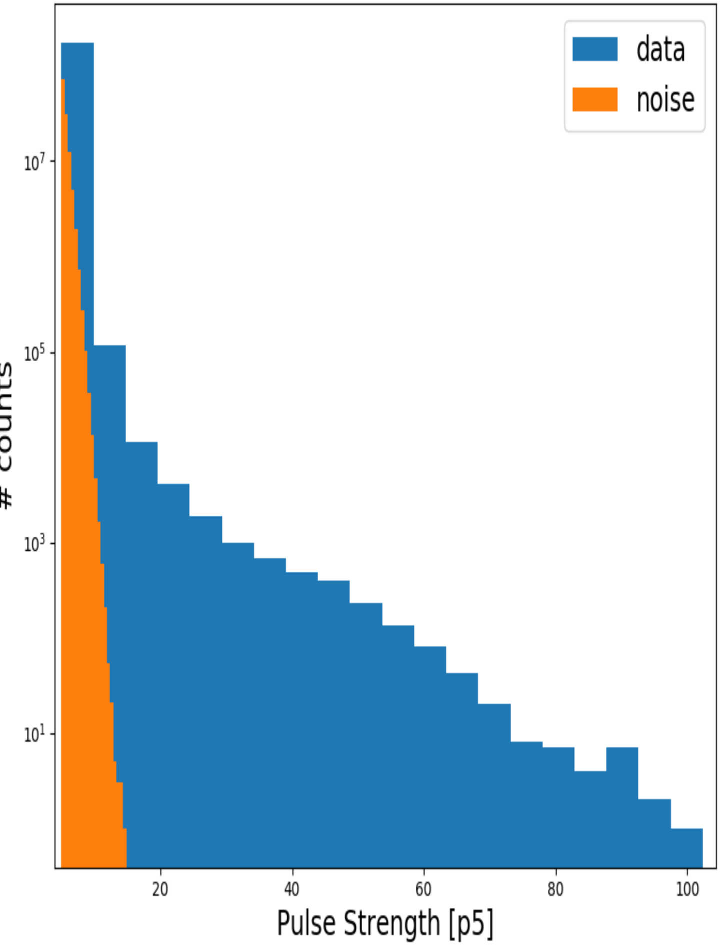
Results

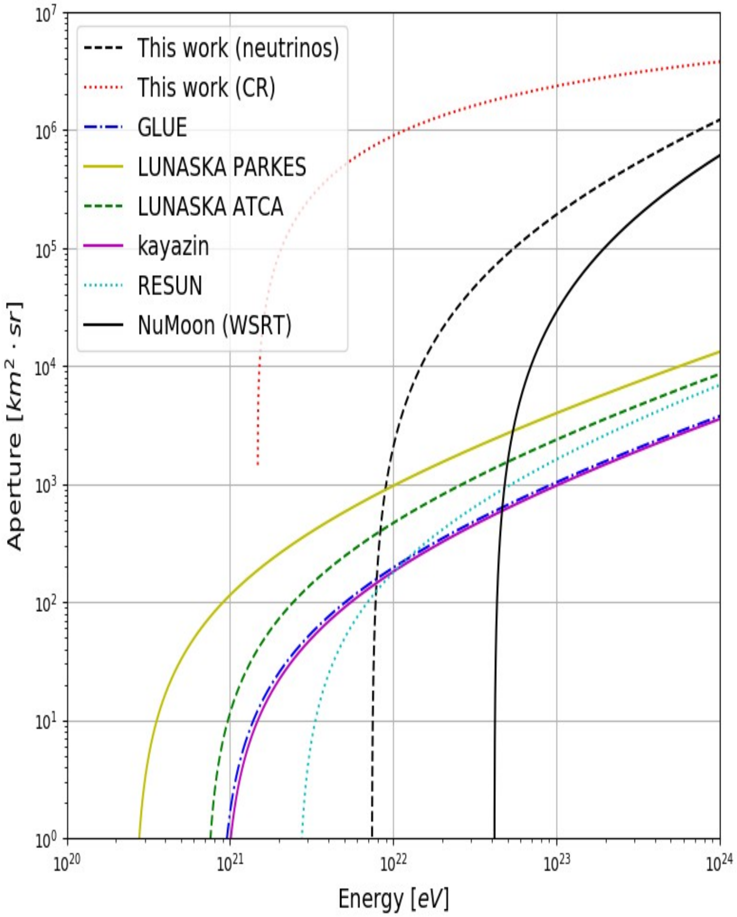
Data (background)



Simulation of signal







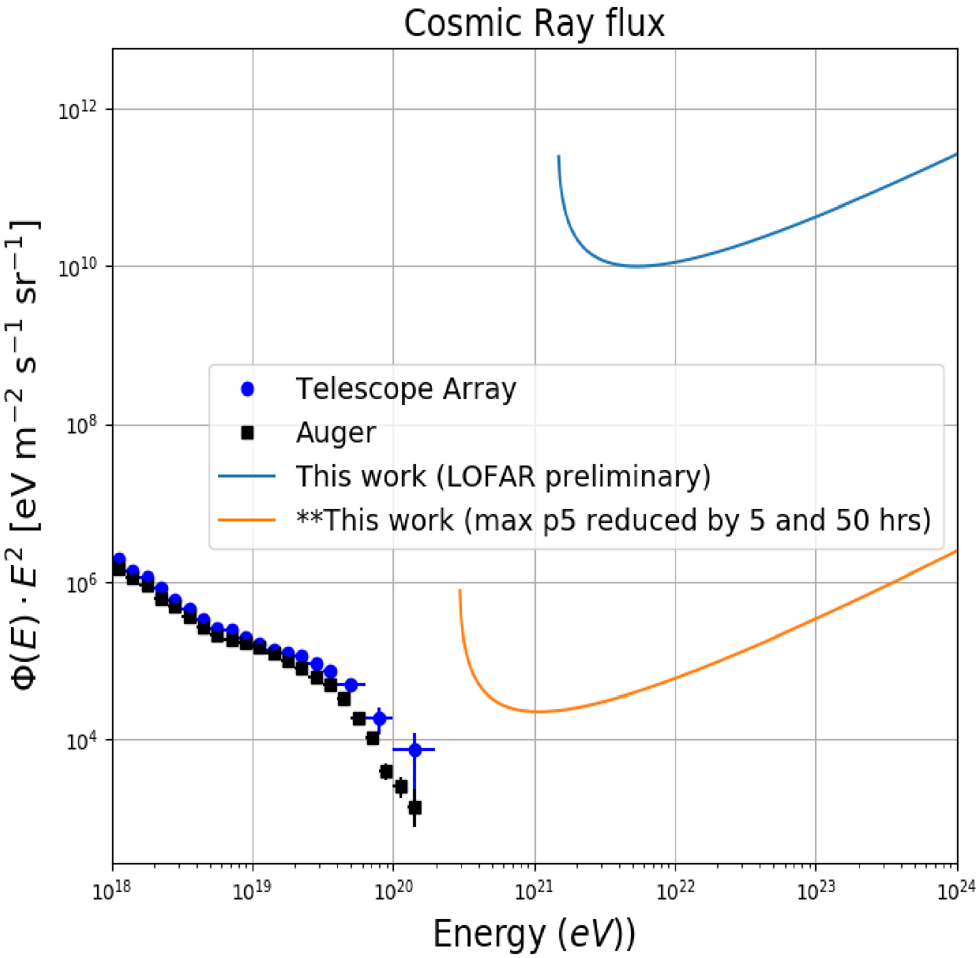
* Some of the strongest pulse were studied

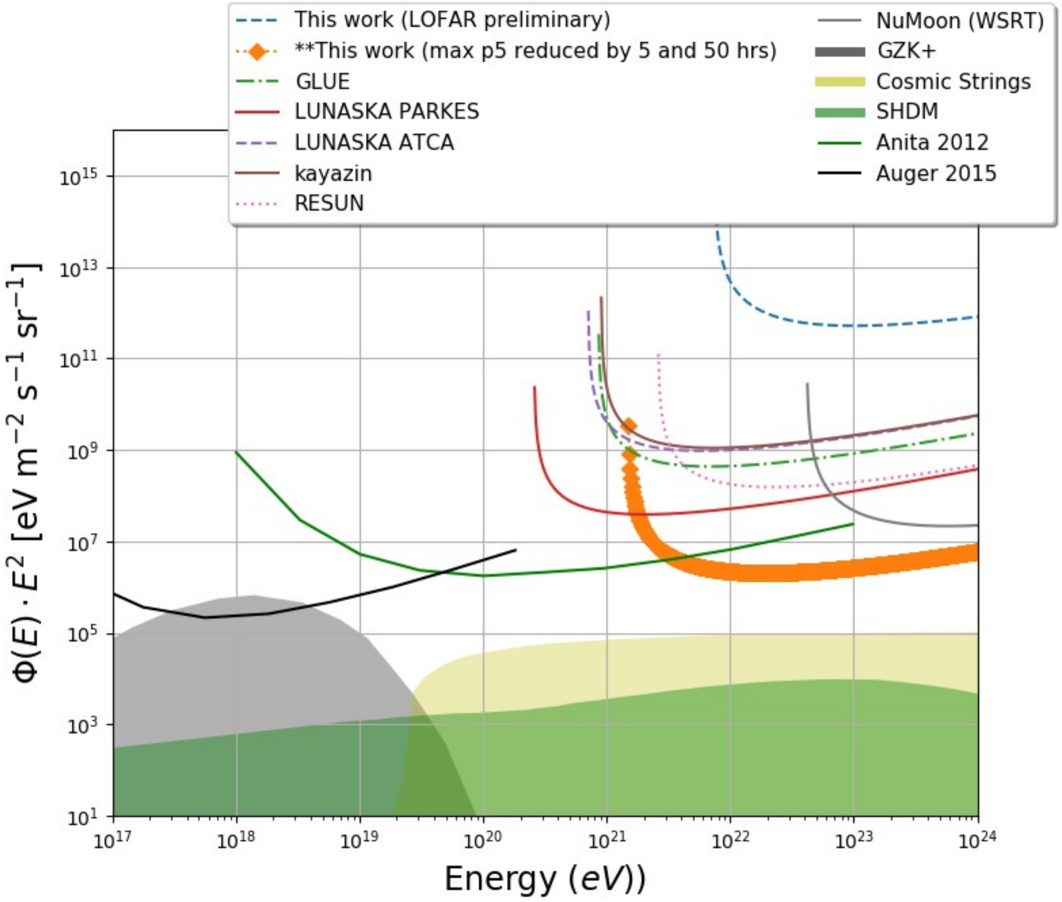
* Exhibit similar x'tics as shown in earlier figure

* This kind of events will be excluded

* No selection criteria applied

* max P5 = 102, which translates to threshold power of 37kJy (0.027 uV/m/MHz)


Cosmic Ray flux
Telescope Array
Auger
This work (LOFAR preliminary)
**This work (max p5 reduced by 5 and 50 hrs)
$\Phi(E)\cdot E^2$ [eV m^{-2} s^{-1} sr^{-1}]
Energy (eV))


This work (LOFAR preliminary)
**This work (max p5 reduced by 5 and 50 hrs)
GLUE
LUNASKA PARKES
LUNASKA ATCA
kayazin
RESUN
NuMoon (WSRT)
GZK+
Cosmic Strings
SHDM
Anita 2012
Auger 2015
$\Phi(E)\cdot E^2$ [eV m^{-2} s^{-1} sr^{-1}]
Energy (eV))

Outlook

* Embark on long hours of real-time observation

* Monte-Carlo simulation of effective aperture