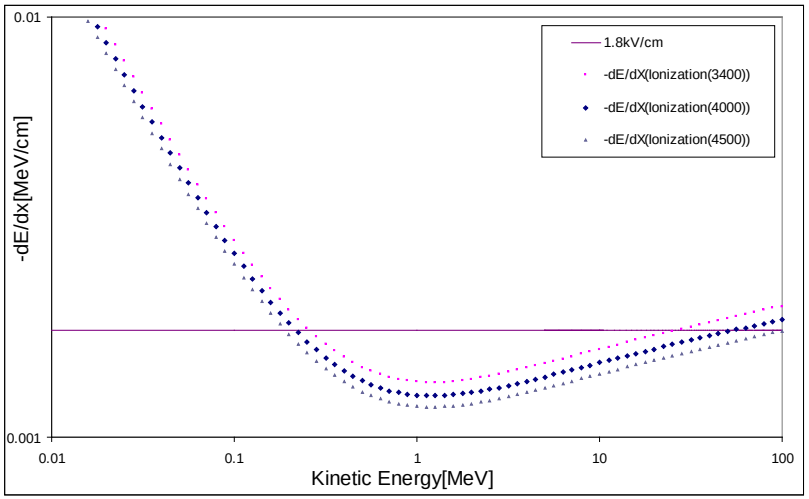
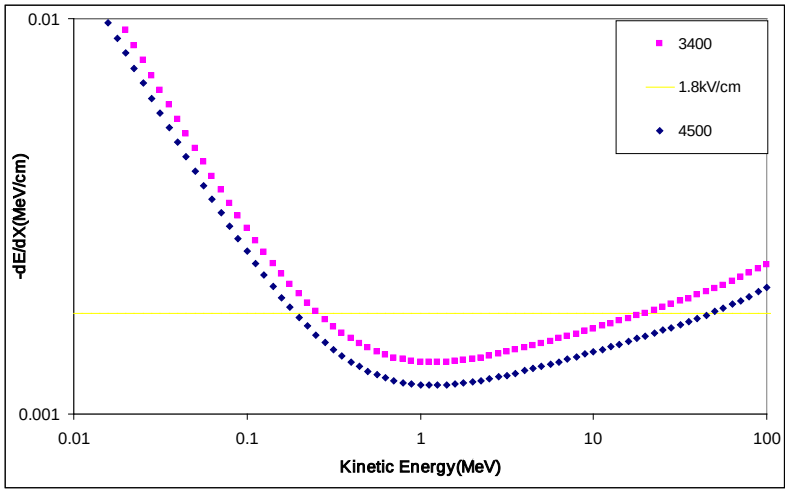
Production of gamma rays in the thunderstorm electric fields with strength below the run-away threshold due to MOS effect (MOdification of secondary cosmic ray Spectra).

L.Vanyan, A.Chilingaryan
Yerevan Physics Institute

Electron energy losses by ionization(left) + bremsstrahlung (right), compared with energy gained by an electric field

with the strength 1.8kV/cm electric field





E_{min} = 2.14kV/c increases taking into account elastic scattering of electrons - E_t = 2.84 kV/cm

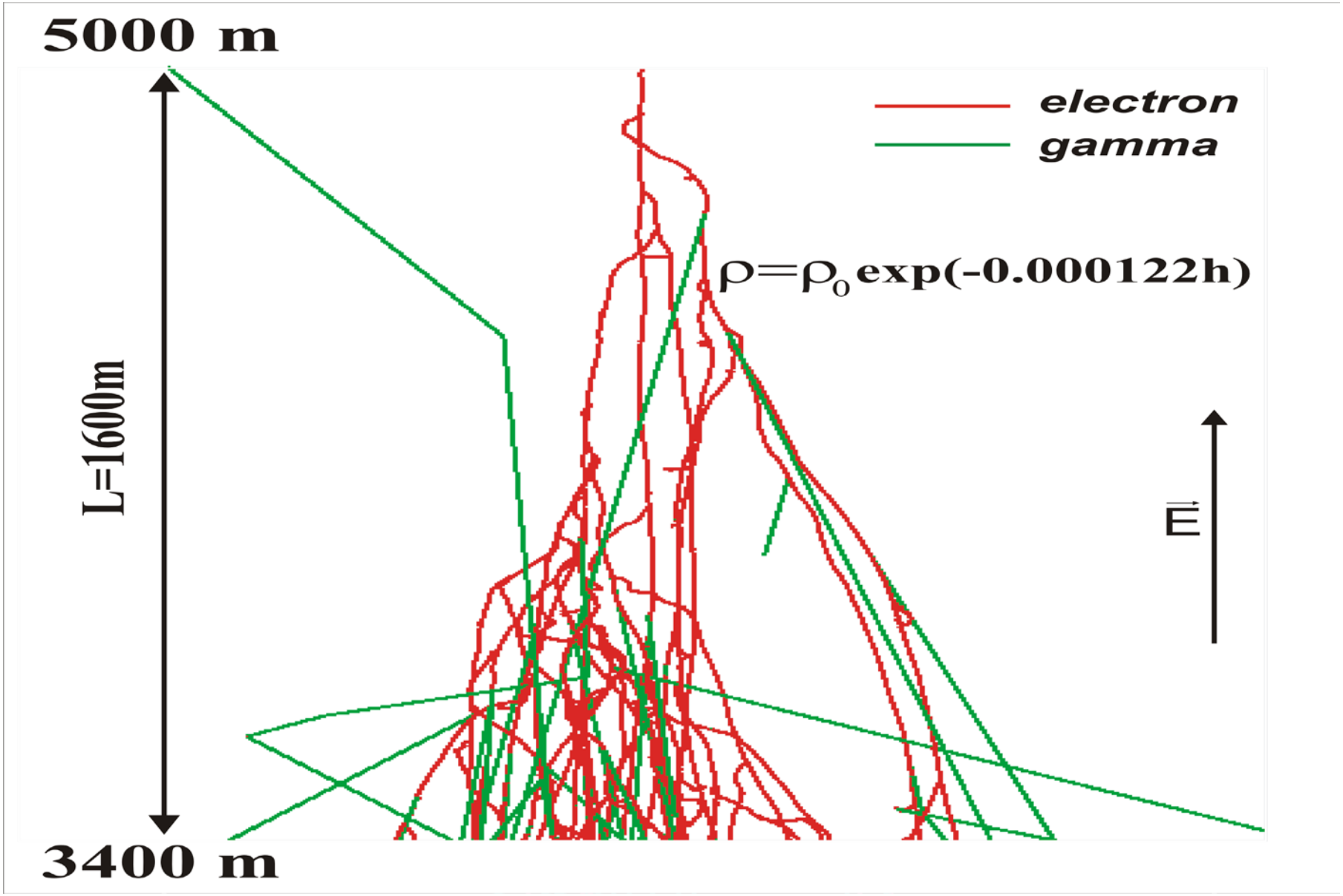
GEANT4 simulation parameters

- Electric fields with the strengths 1.7,1.8,1.9, 2kV/cm. Also 1.5kV/cm to consider MOS (MOdification of Spectra).
- Air density dependence on altitude - $\rho=\rho_0 exp\{-0.000122h\}$
- Electric field elongation – from 5000m to 3350m asl
- For electrons and positrons – ionization, bremsstrahlung, multiple scattering;
- For gamma rays – Compton scattering, conversion, photoelectric effect, photonuclear reaction.
- Seed electrons – secondary cosmic ray electron energy spectrum

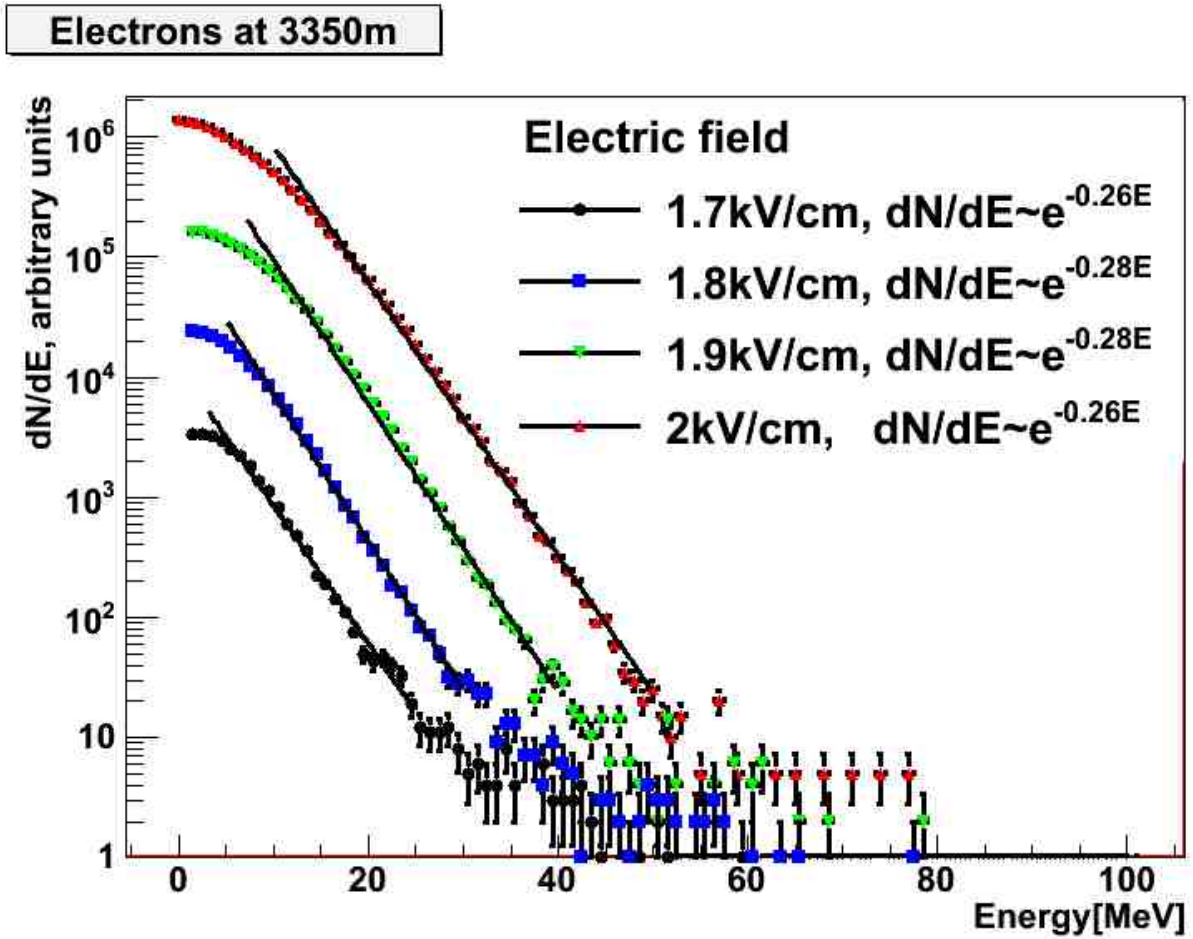
$$dN/dE \sim E^{-1,13} (1\text{-}100MeV)$$

$$dN/dE \sim E^{-2,2} (100\text{-}300MeV)$$

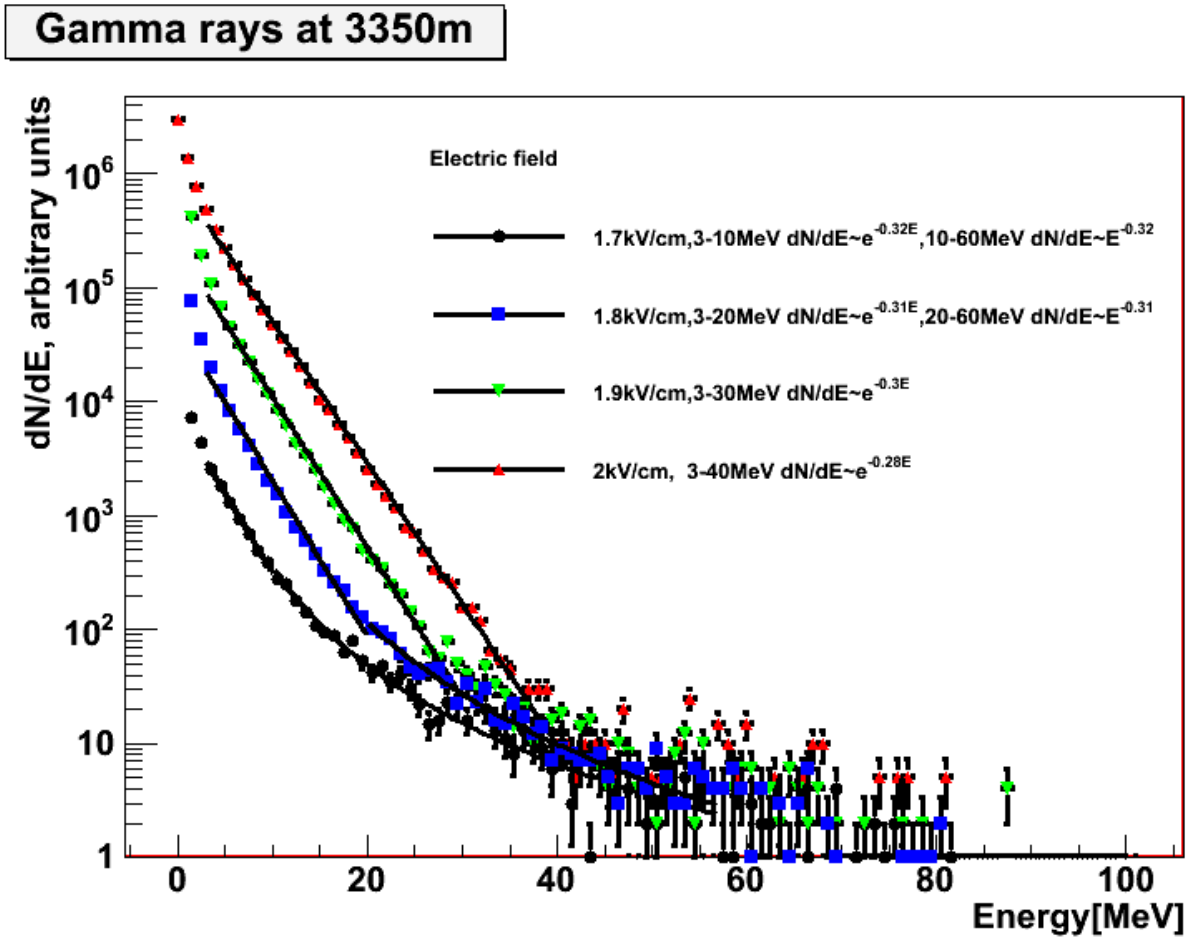
Runaway Relativistic Electron Avalanches(RREA), visualised by GEANT4



Differential energy spectra of electrons derived from simulations in different electric fields Seed electrons with energies 1-100MeV

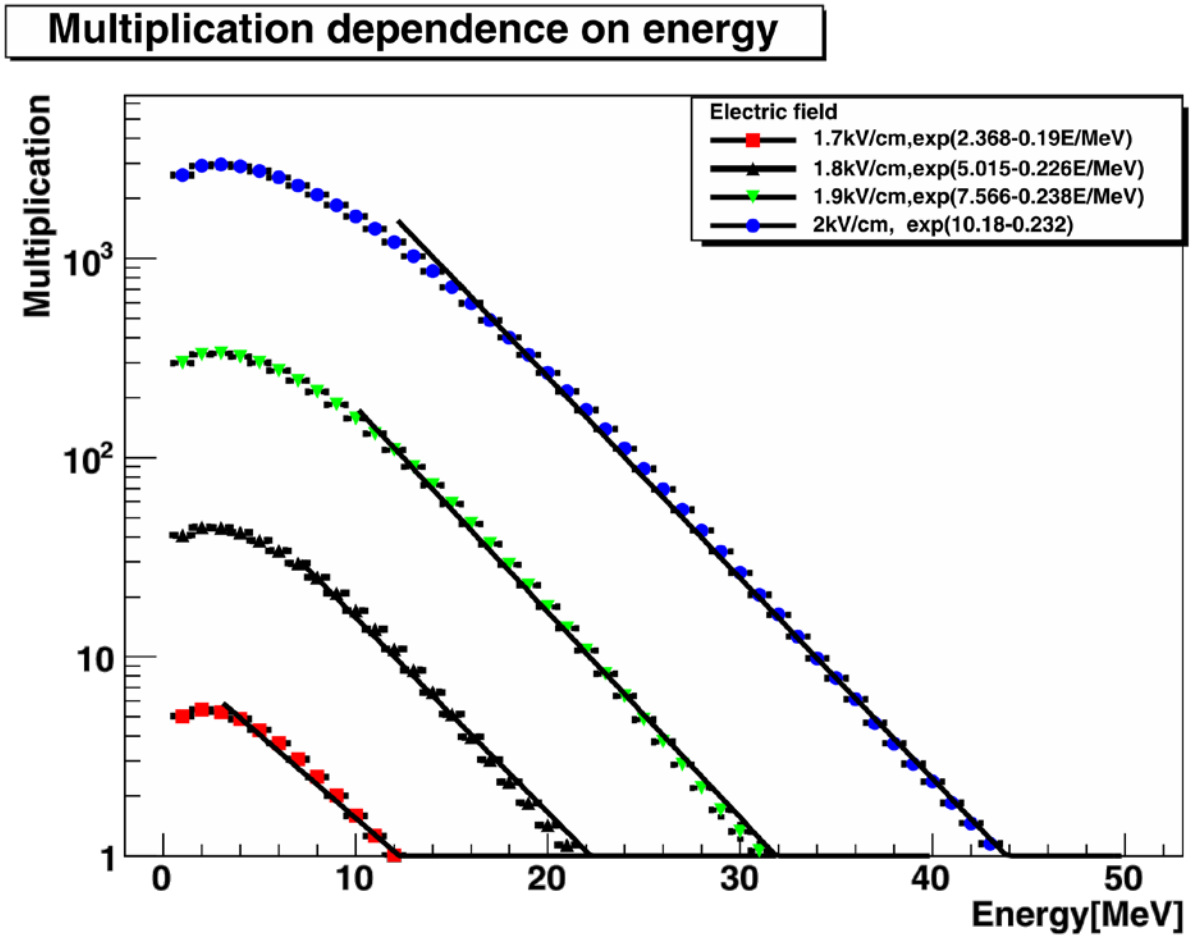


Differential spectra of gamma rays derived from simulations in different electric fields: seed electrons with energies 1-100MeV



Dependence on energy of MR(Multiplication rates)

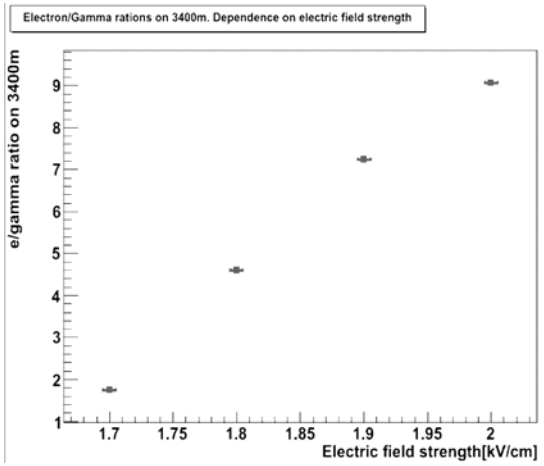
MR(ξ,E) = I3350(ξ,E)/I5000(ξ); E = 1.7-2kV/cm



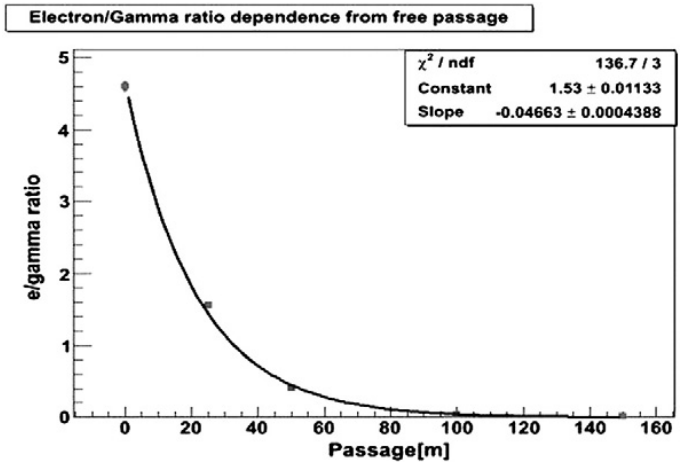
$$MR_{12MeV}^{1.7kV/cm} \approx MR_{21MeV}^{1.8kV/cm} \approx MR_{31MeV}^{1.9kV/cm} \approx MR_{43MeV}^{2kV/cm} \approx 1$$

Proportion of electrons in the detected flux (e-/γ ration)

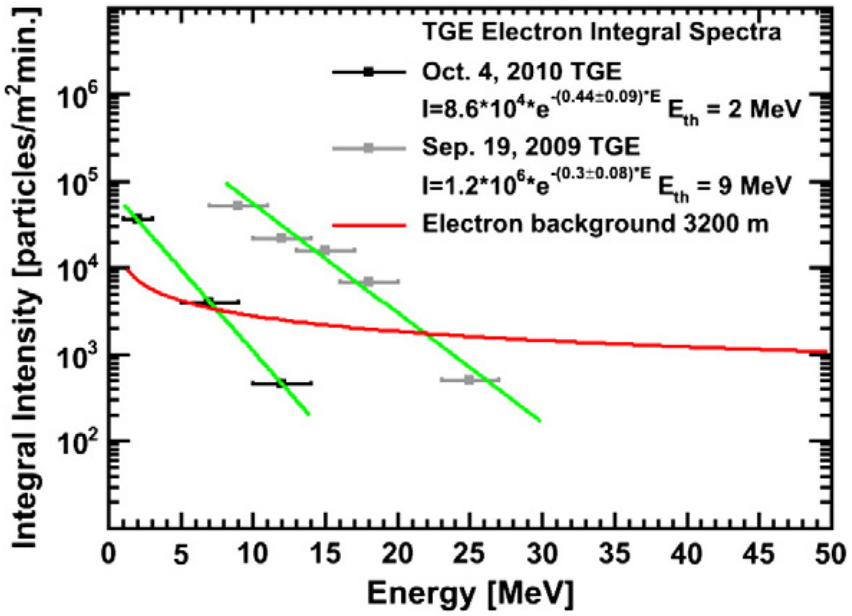
- Electron/ (gamma ray) ratios at 3350m.: Dependence on electric field strength (E>7MeV)

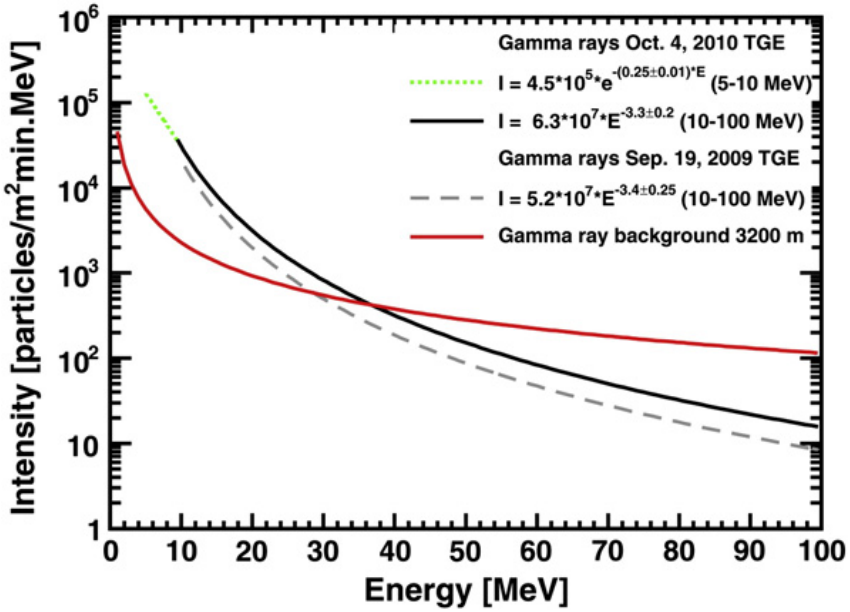


- Dependence of the electron/gamma ray ratio on the free passage after quitting the electric field region (Electric field strength-1.8kV/cm)

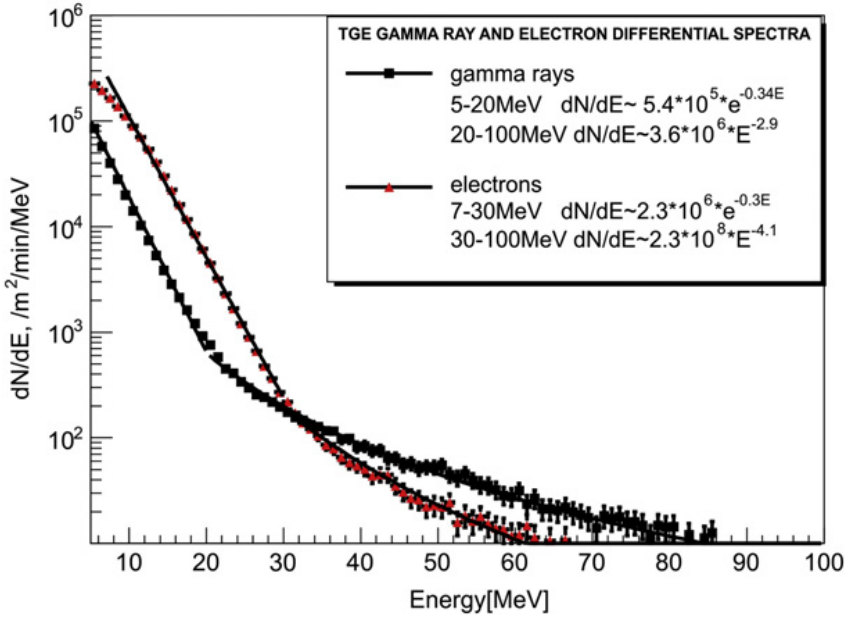


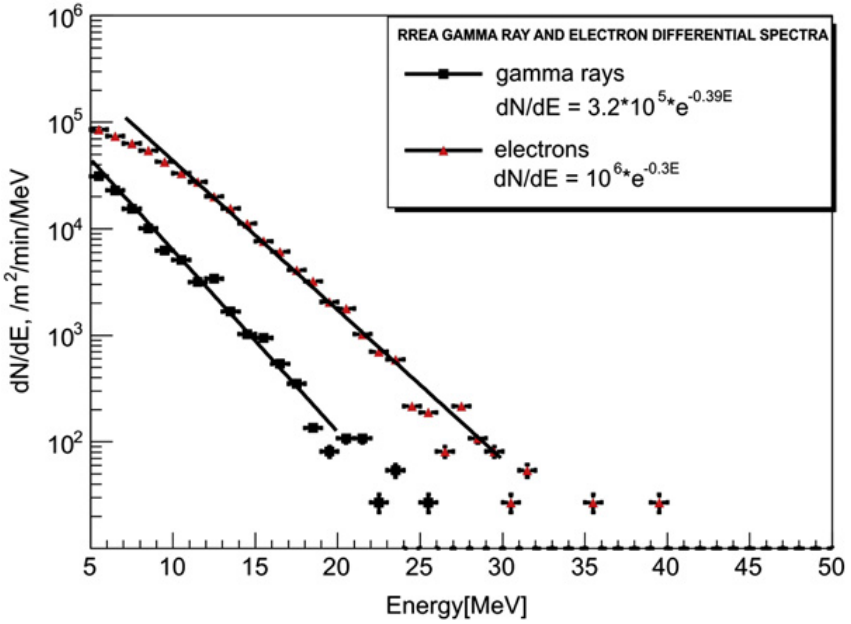
Characteristics of two largest TGEs





TGE gamma ray and electron spectra(left) and RREA gamma ray and electron spectra (right)

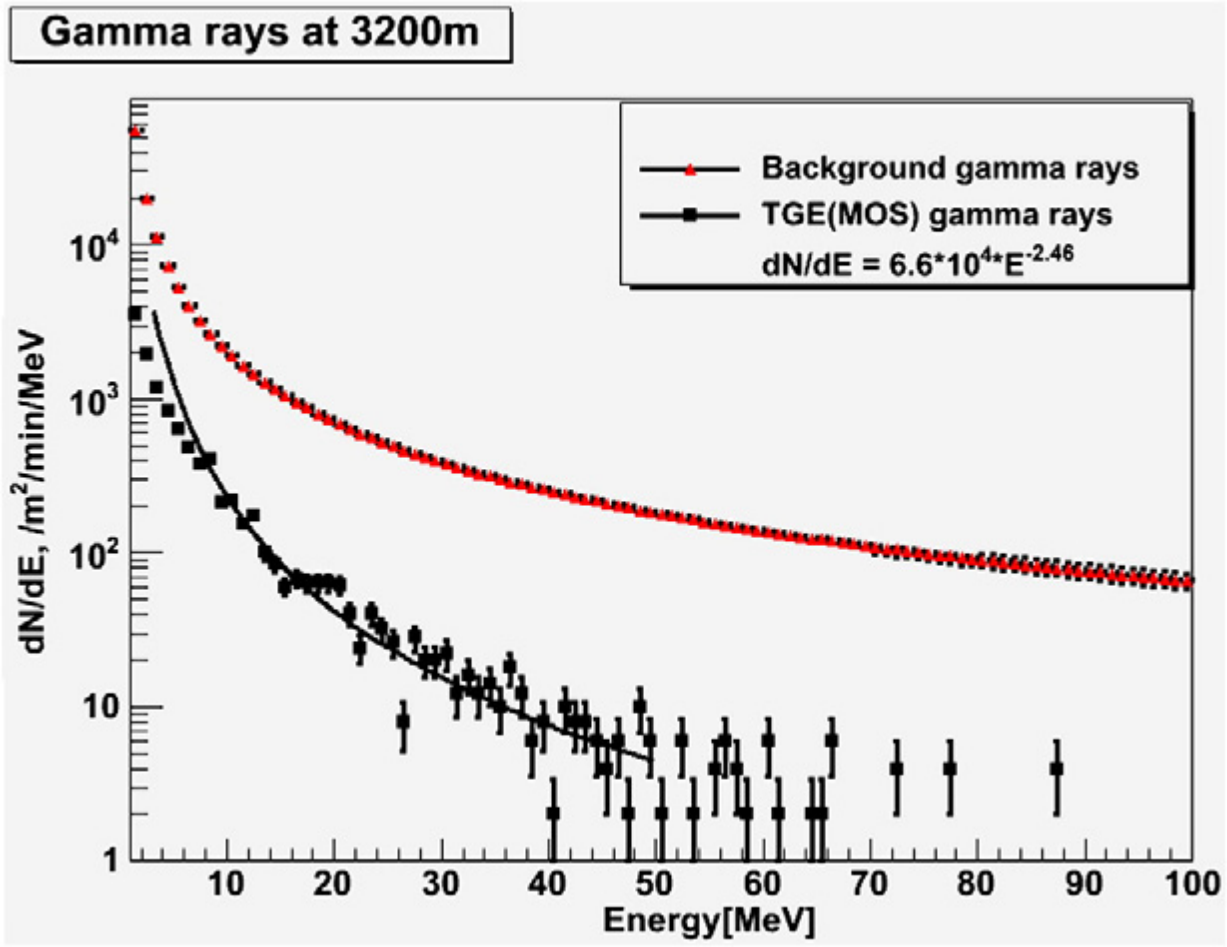




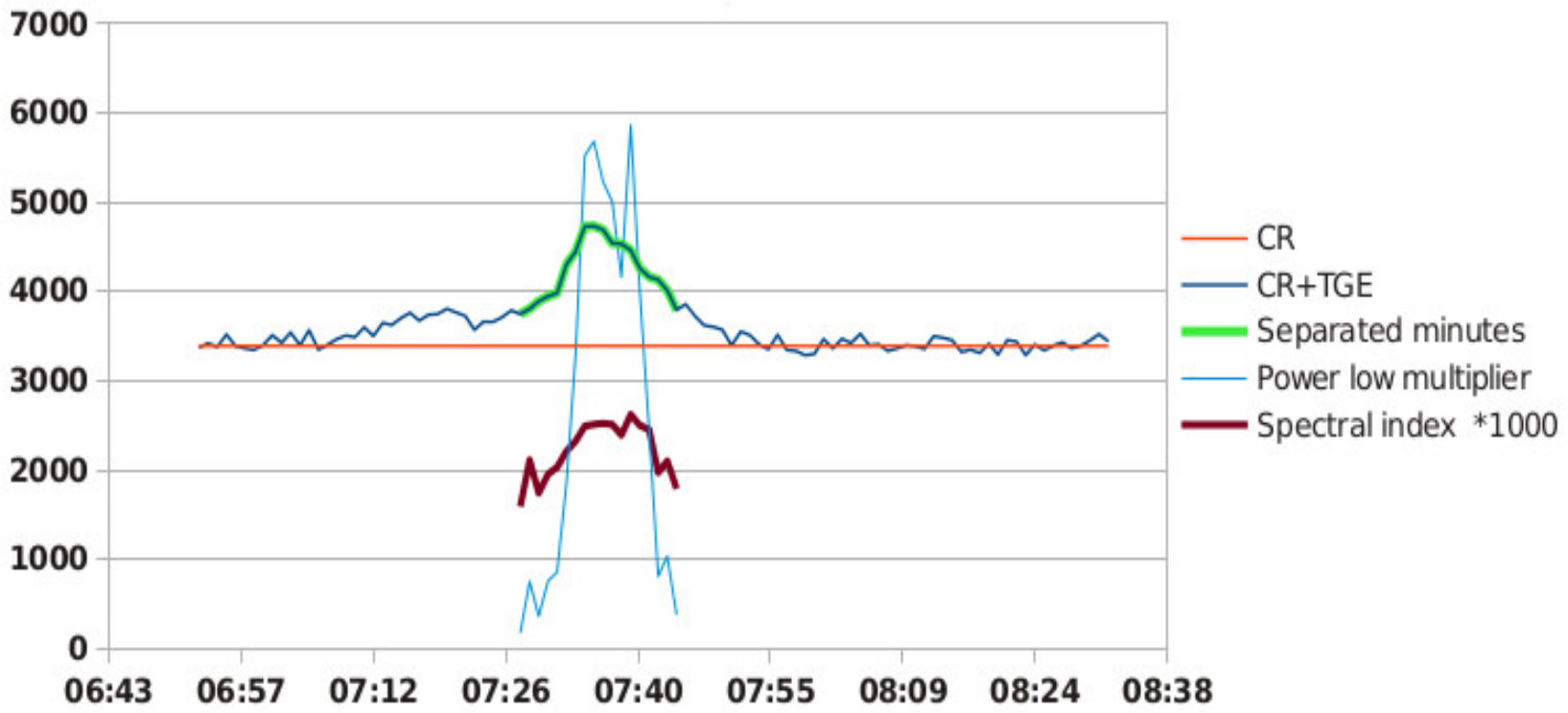
electrons I(1MeV) = $5.6*10^6$ /min/m^2

Gamma rays I(1MeV) = $1.134*10^6$ /min/m^2

Comparison of background gamma ray spectrum with the surplus gamma ray spectrum generated by electrons accelerated in the field of strength 1.5 kV/cm below the critical field for the RREA initiation; the background cosmic ray gamma ray flux and TGE gamma ray flux are calculated at 3200m altitude after exiting from the uniform electrical field at 3350maltitude

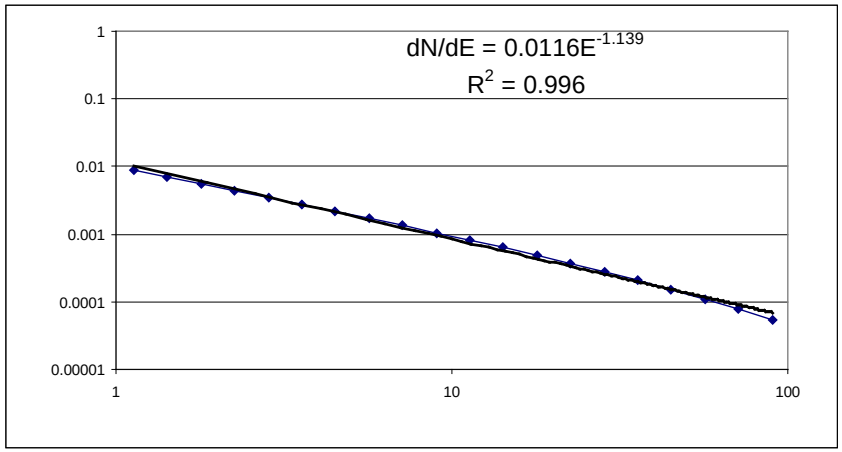


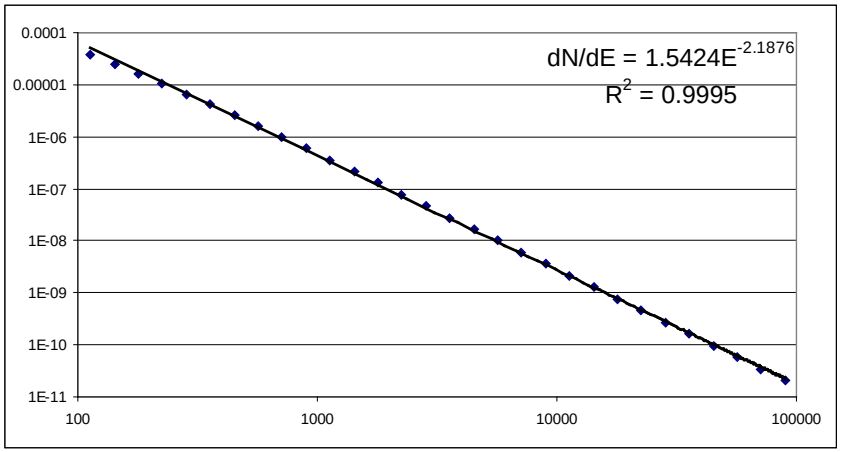
Time series of TGE of 19.06.2013.. Differential energy spectra of gamma rays measured for each separate minute. Power low indexes (*1000) and multiplier (*1/100) are shown.



message by Hovsepyan Gagik

Differential energy spectrum of secondary cosmic ray electrons at 5000m altitude. Energy intervals - 1-100MeV(left) and 100MeV-100GeV(right). Is the reason of spectral index variations in the differences between Secondary Cosmic Ray electron spectra in the different energetic intervals? With the increasing of fields the investment of te second interval increases.





Conclusion

We suggest two component model of TGE generation

- TGE initiation via RREA process. When the atmospheric electric field strength exceeds the critical value and we observe multiplication of seed electrons and large (100%) increases of gamma rays
- Initiation via spectrum modification, when the strength of an electric field doesn't exceed the critical value. However, the electrons gain "additional path length": The probability of high energy bremmstrahlung increases. The same effect we observe also in cases of bigger than critical electric fields for high energy electrons