Sensitivity of Aragats Space Environmental Center (ASEC) Particle Detectors to Primary Cosmic Rays

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Ground based detectors register secondary fluxes.

ASEC detectors register

- Low energy charged particles,
- muons with energies >250 MeV,
- high energy muons (>5GeV) and
- Neutrons

Observation of CR variations by ASEC detectors

= >

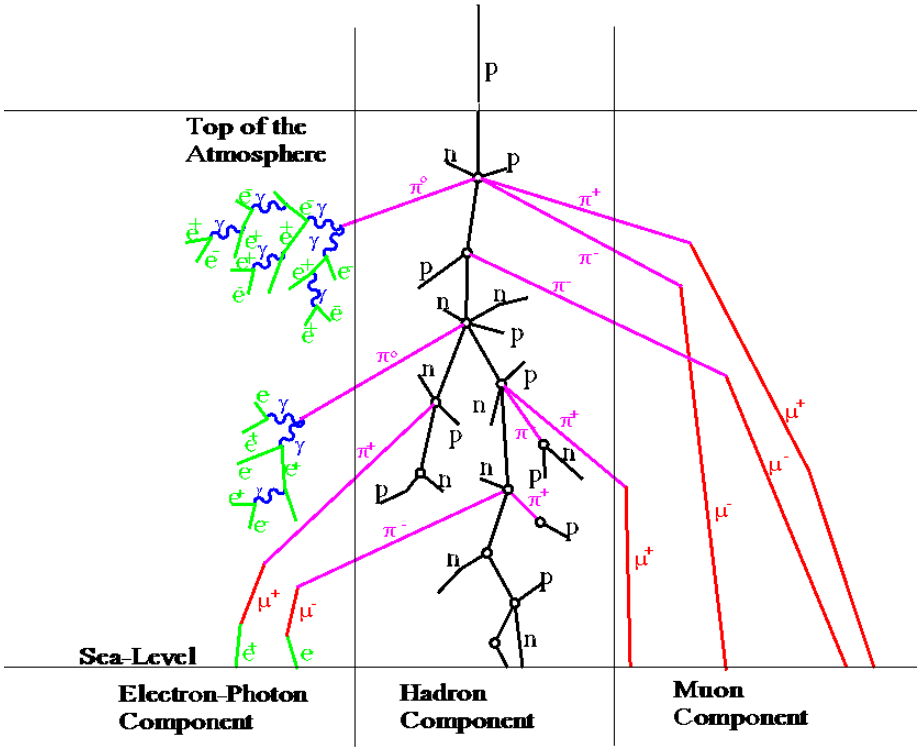
information on the spectrum of primary particles

To evaluate the spectrum of primary particles at the top of the Earth's atmosphere from the measurements of ASEC experiment we need to couple each specified detector to the certain energy range of the primary cosmic ray spectrum

Each specified detector responds to certain energy range of the primary cosmic ray spectrum.

To obtain the relation between detector and energy range of CR spectrum Monte Carlo simulation of the propagation of cosmic rays in the atmosphere was performed.

CORSIKA code (D. Heck et al.) has been used.



CORSIKA options

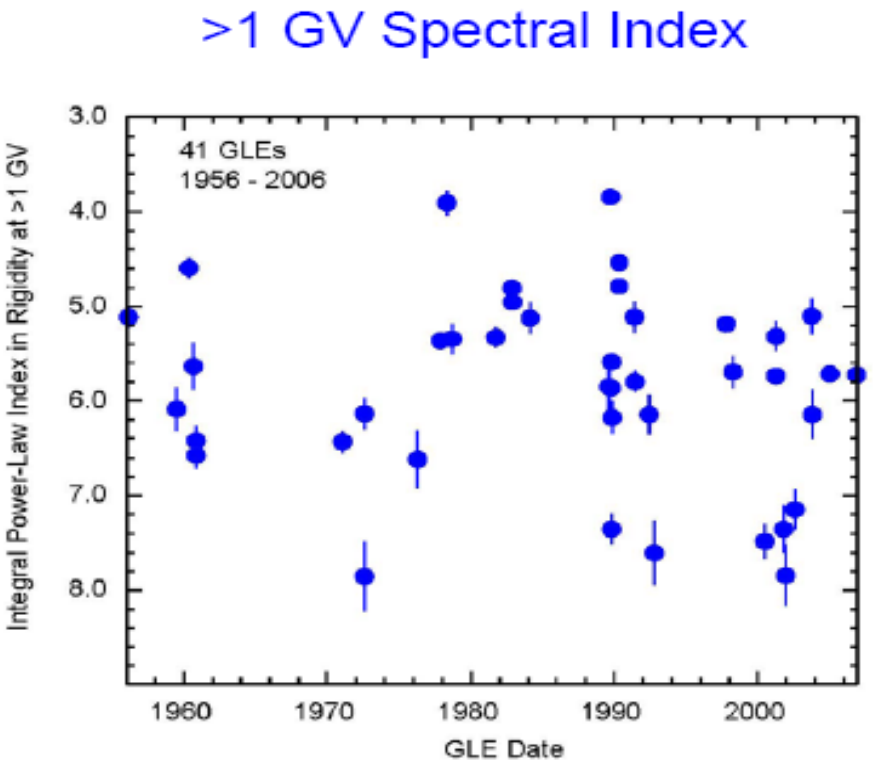
- primary cosmic ray particles: p.
- primary energies: 7.06 GeV < E_o <350 GeV
- zenith angles $0<\theta<70°$.
- low energy thresholds for secondary particles:
  - for hadrons: 50 MeV.
  - for muons : 10 MeV
  - for electromagnetic particles: 3MeV
- high energy (Eo>80 GeV) hadronic interaction model: QGSJET01
- low energy model: GHEISHA2002 and FLUKA2006
- observation level: Aragats – 3200m above sea level
  Nor-Amberd –2000m above sea level
  Yerevan – 1000m above sea level

Number of showers simulated: 300000 for each simulation.

Primary spectra in power-law form: $dN/dEo \sim Eo^{-\gamma}$

γ=2.7 (GCR), γ= 4, 5, 6 (SCR)

Survey of GLE Parameters, 1956-2006



Proton Spectra in Ground-Level Enhanced (GLE) Solar Particle Events

Allan J. Tylka& William F. Dietrich

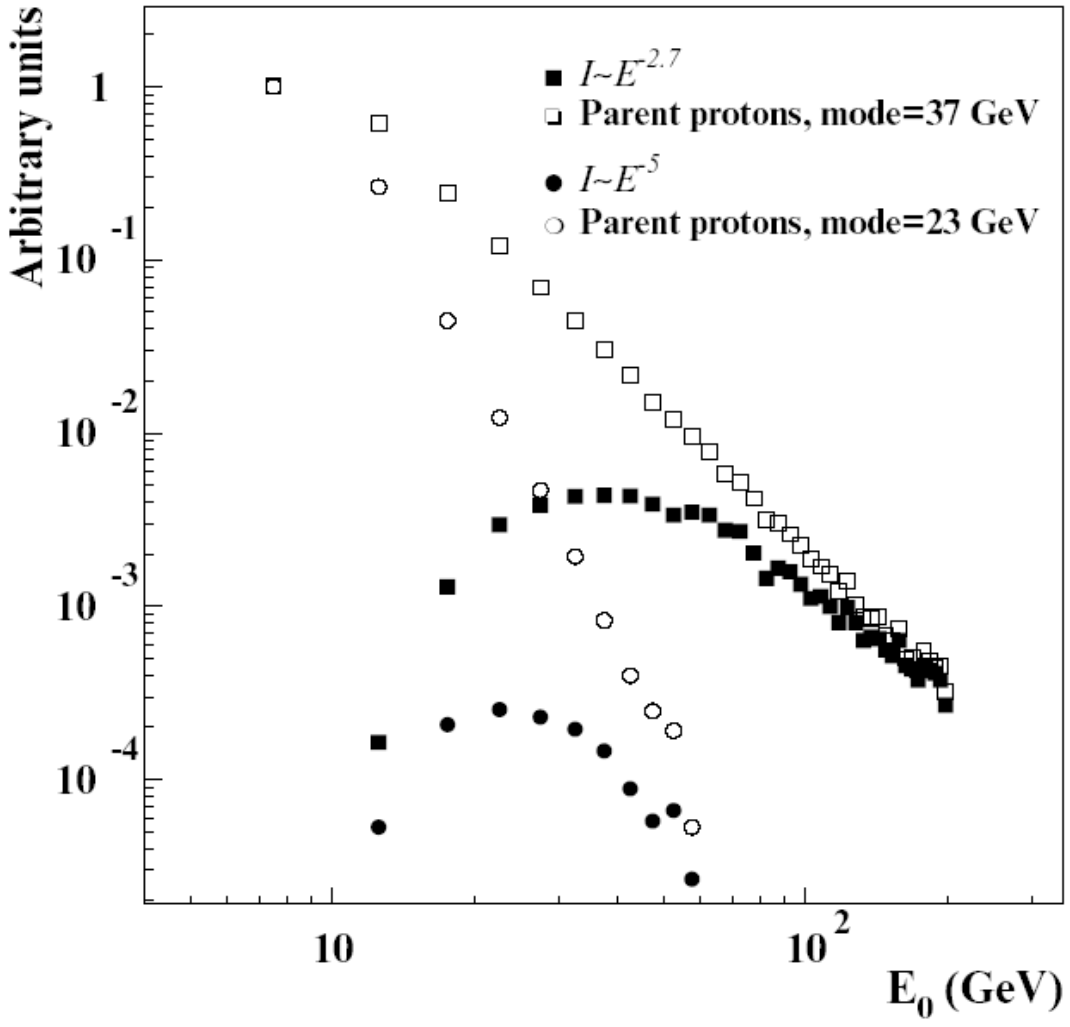
Not all primary particles give secondaries on the level of observation.

If we have at least one secondary particle of specified flux (charged particles, muons with energies >250 MeV, high energy muons (E>5GeV) or neutrons) => energy spectra of parent protons are constructed for each case.

Detection efficiency of primary particles

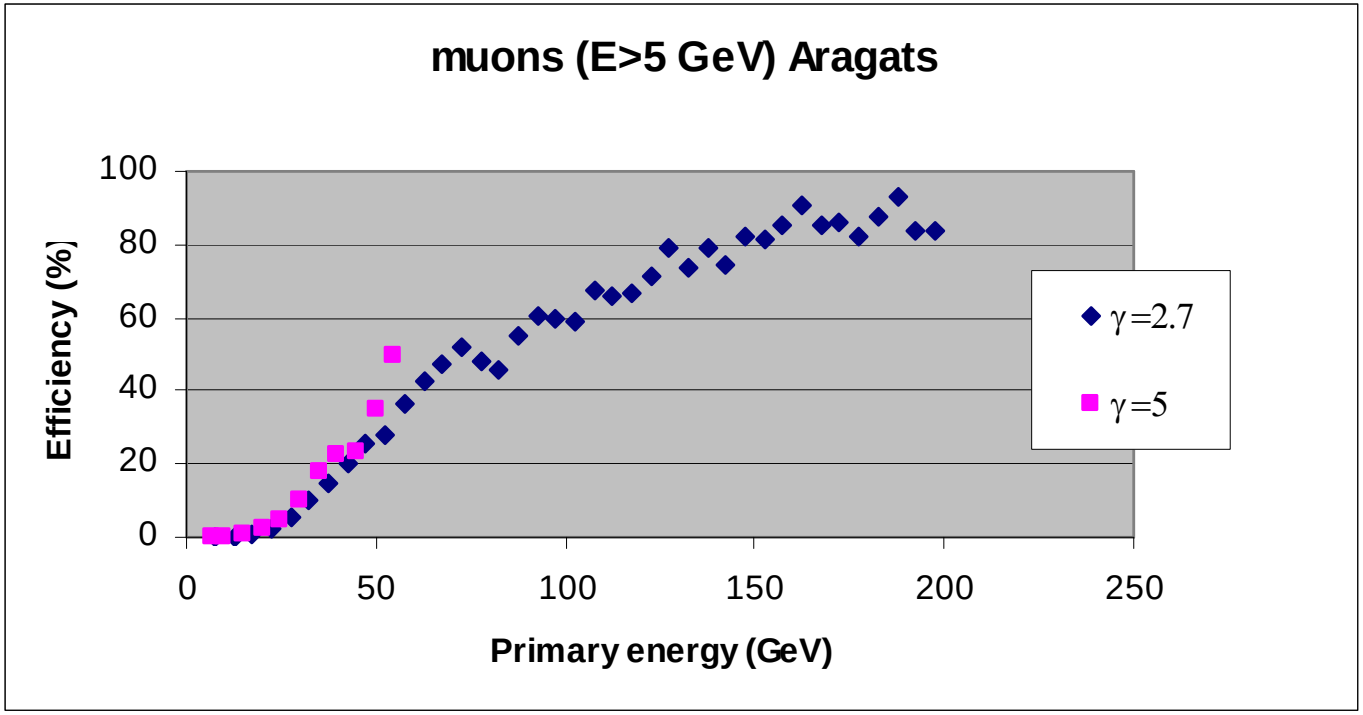
$$\text{eff} = \text{Nev}\ (\geq 1\ \text{sec. part})/\text{Nev}$$

Secondary high energy muons (E >5 GeV)



Most probable energy **for GCR - 37 GeV, for SCR - 23 GeV** due the steeper primary cosmic ray spectrum of SCR

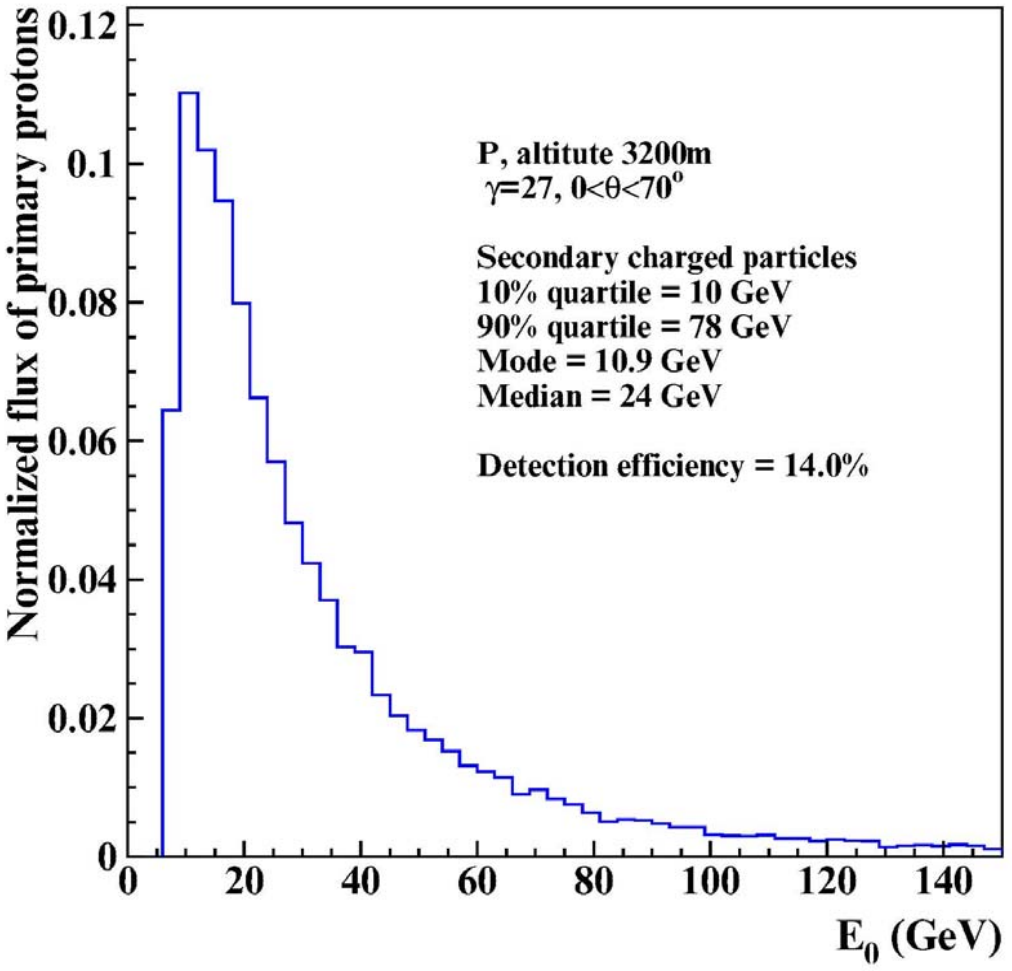
Primary protons detection efficiency

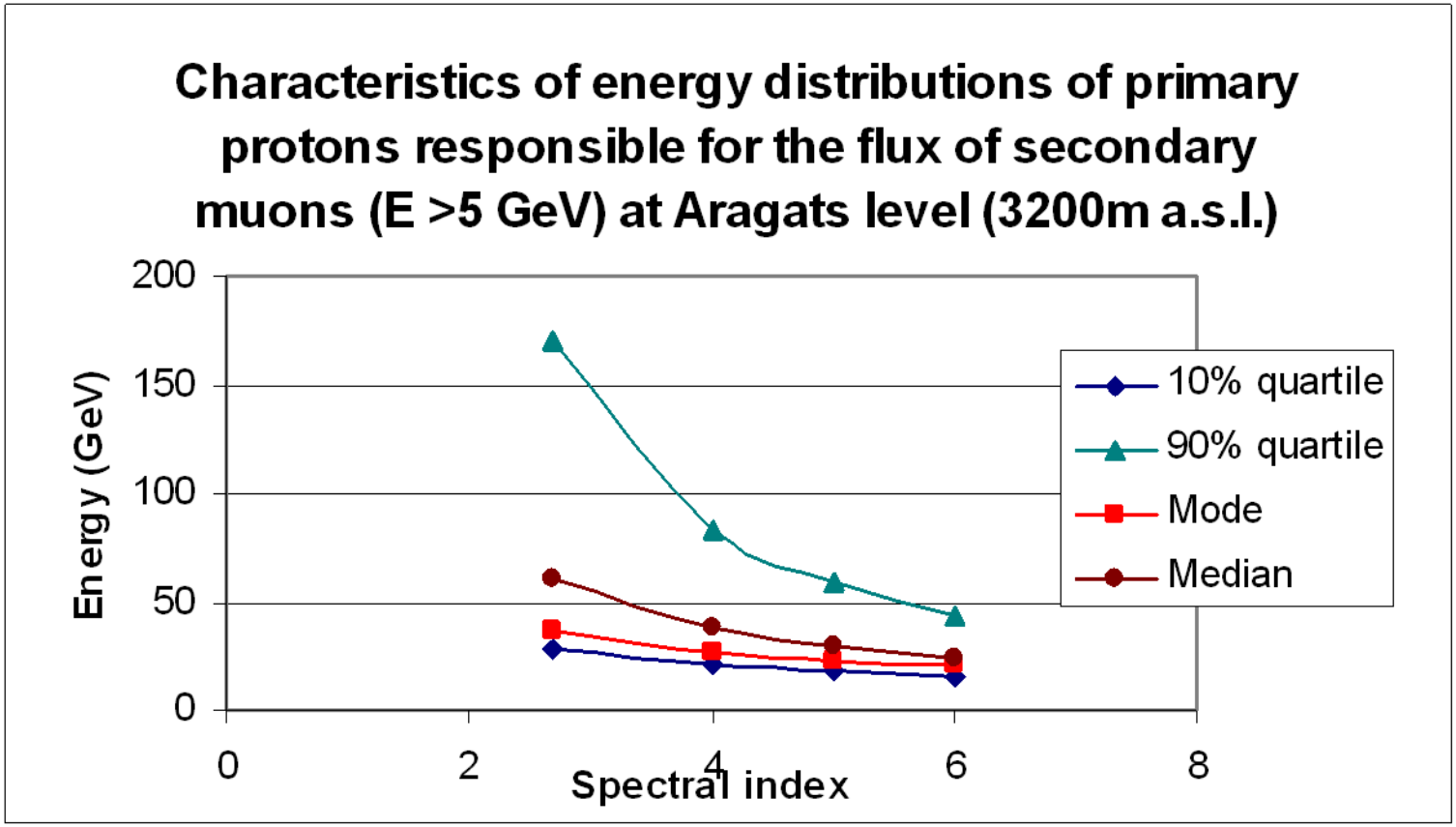


0-80 GeV - GHEISHA; 80 – 250 GeV - QGSJET01

Characteristics of distributions of parent protons:

- 10%-quartile
- 90% quartile
- Median
- Mode




Characteristics of energy distributions of primary protons responsible for the flux of secondary muons (E >5 GeV) at Aragats level (3200m a.s.l.)
Energy (GeV)
200
150
100
50
0
0
2
4
6
8
Spectral index
10% quartile
90% quartile
Mode
Median

Why mode?

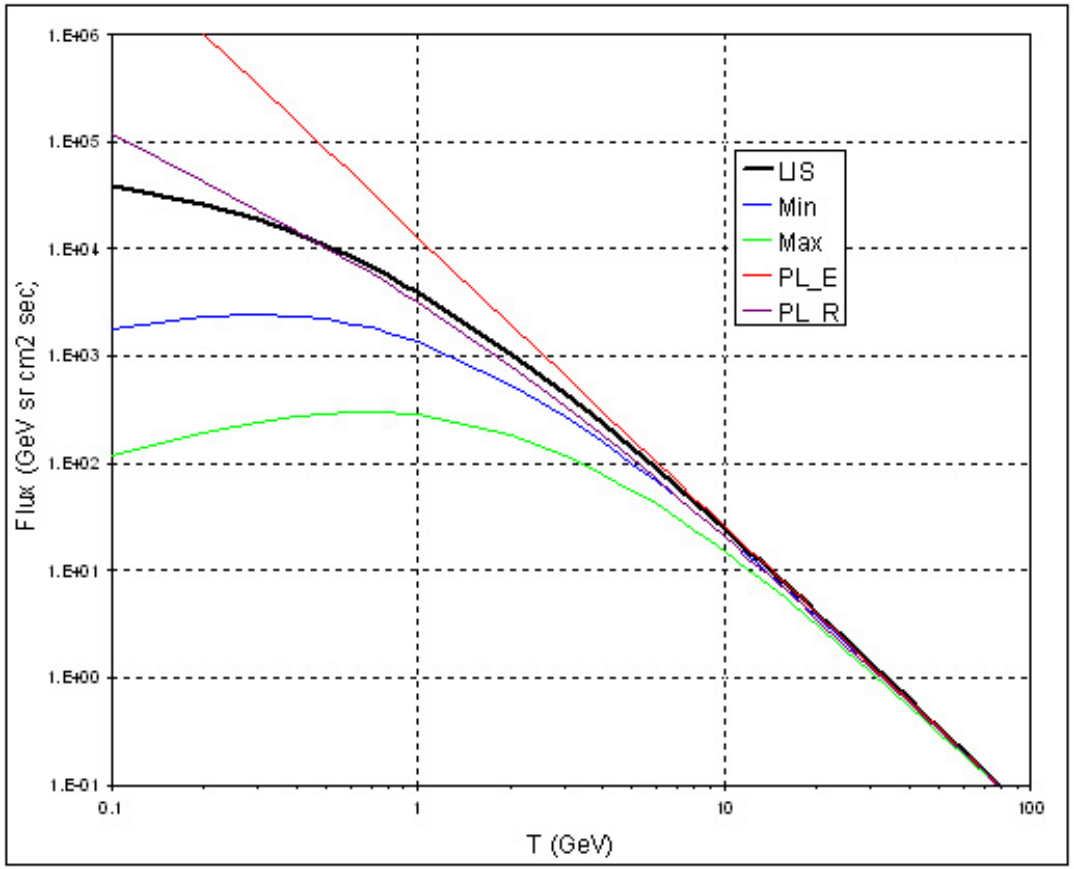
- Maximal probability;
- Stable against change of model (both strong interaction and primary spectra);
- Robust against random fluctuations;
- Robust against occasional very large energies;

The spectrum of GCR depends on solar activity

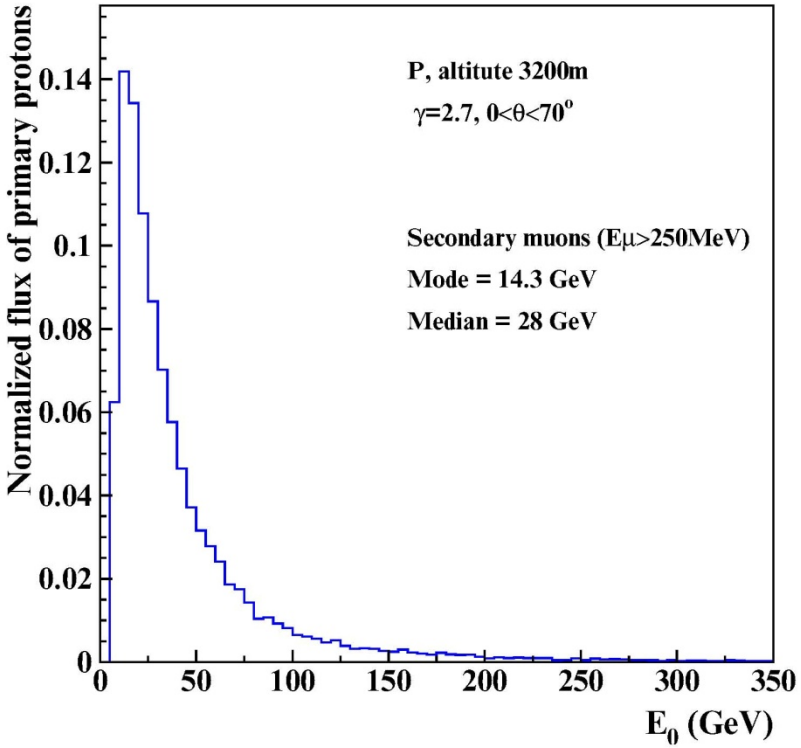
To take into account solar modulation we represented primary spectrum by two power law spectra

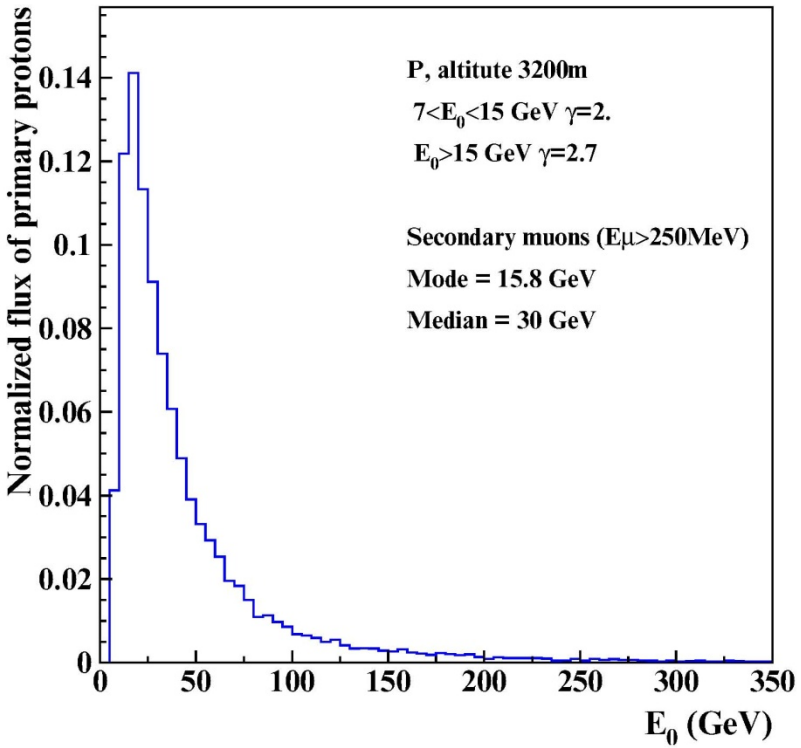
γ=2 for 7GeV<Eo<15GeV

γ=2.7 for Eo>15GeV

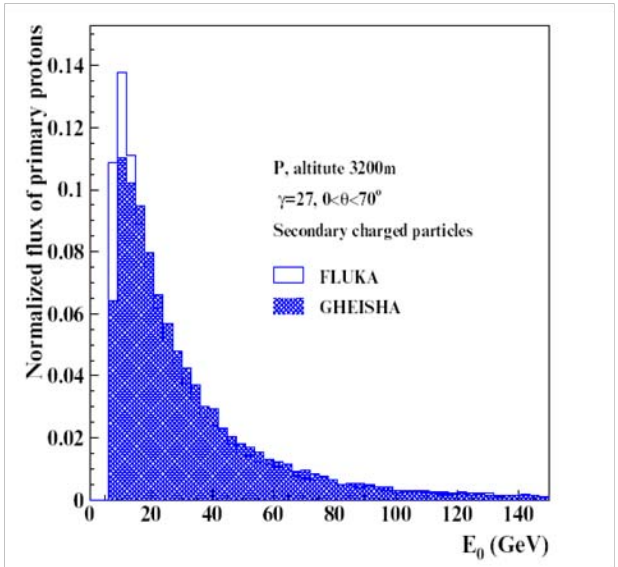


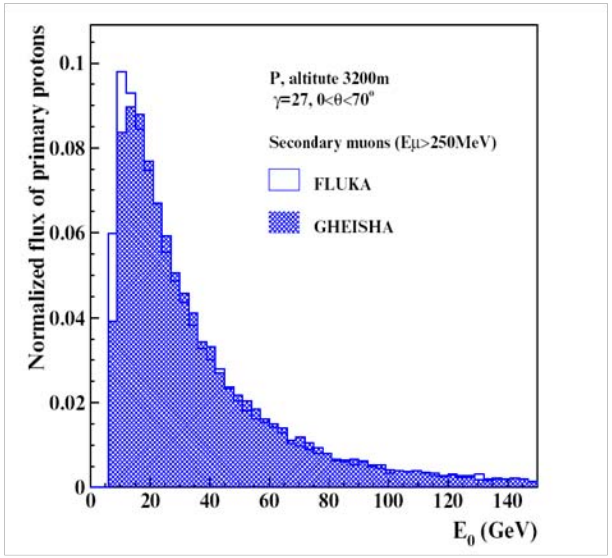
Muons (E>250 MeV)

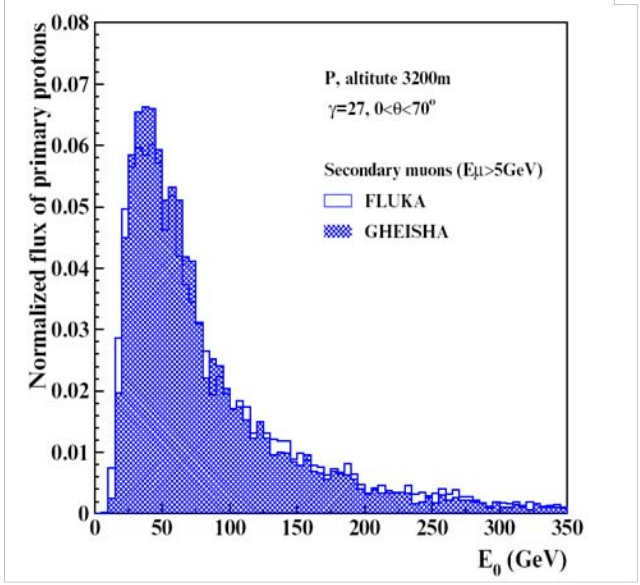


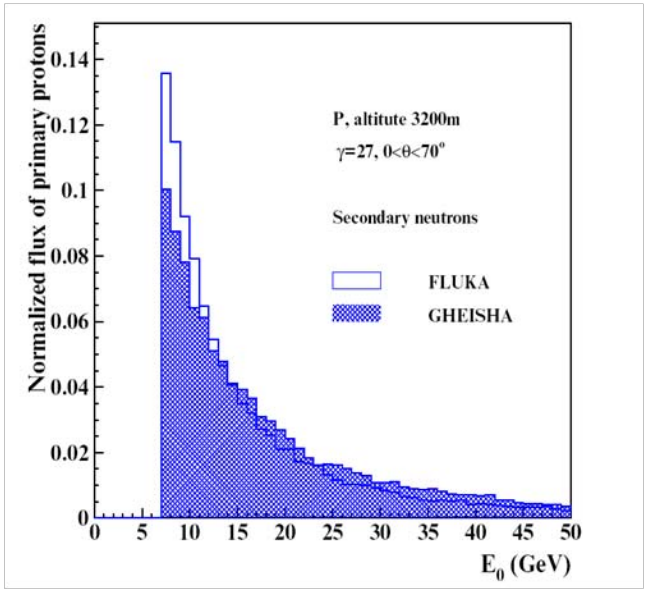


Comparison of two codes: FLUKA and GHEISHA









Characteristics of energy distributions of primary protons originated the flux of secondary muons (E >5 GeV) at Aragats level (3200m a.s.l.)

	GHEISHA	FLUKA
10% quartile	**28 GeV**	**26.5 GeV**
90% quartile	**170 GeV**	**183 GeV**
Mode	**37 GeV**	**37.7 GeV**
Median	**61 GeV**	**63 GeV**

To evaluate variability in simulation runs, we performed three independent runs.

Characteristics of energy distributions of primary protons (γ=2.7) originated secondary charged particles flux

	sample 1	sample 2	sample 3	mean
10% quartile	10 GeV	10 GeV	10.1 GeV	10.03±0.06 GeV
90% quartile	78 GeV	75.4 GeV	74.4 GeV	75.93±1.86 GeV
Mode	10.9 GeV	10.8 GeV	11.2 GeV	10.98±0.21 GeV
Median	24 GeV	23.6 GeV	23.6 GeV	23.73±0.23 GeV

Conclusion

Based on the detailed analysis of distributions obtained for different observation levels (Aragats, Nor-Amberd and Yerevan), two low energy models (GHEISHA and FLUKA) and different spectral indexes of initial energy (γ=2.7,4,5,6) one can conclude, that

the range of most probable energy of primary protons originated secondary fluxes is:

Secondary flux	**GCR (γ=2.7)**	**SCR (γ=4,5,6)**
charged particles	10.9 - 14.6 GeV	7.4 – 11.2 GeV
muons (E>250 MeV)	14.3 –18.4 GeV	7.6 –11.6 GeV
muons (E>5 GeV)	37 – 41.2 GeV	21.2 – 31.9 GeV
neutrons	7.1 GeV	7.1 GeV
Horizontal muons (E>5 GeV)	42 GeV	