

Origin of the low-energy gamma ray flux of the long-lasting thunderstorm ground enhancements (TGEs)

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Abstracts

To identify the role of the gamma radiation from radon progenies in long-lasting thunderstorm ground enhancement (TGE) flux, the differential energy spectrum is measured with various spectrometers. The measurements demonstrate that radon progeny radiation significantly contributes to the count rate enhancements measured in the winter of 2018-2019 and Spring-Summer 2019 in the energy range below 3 MeV.

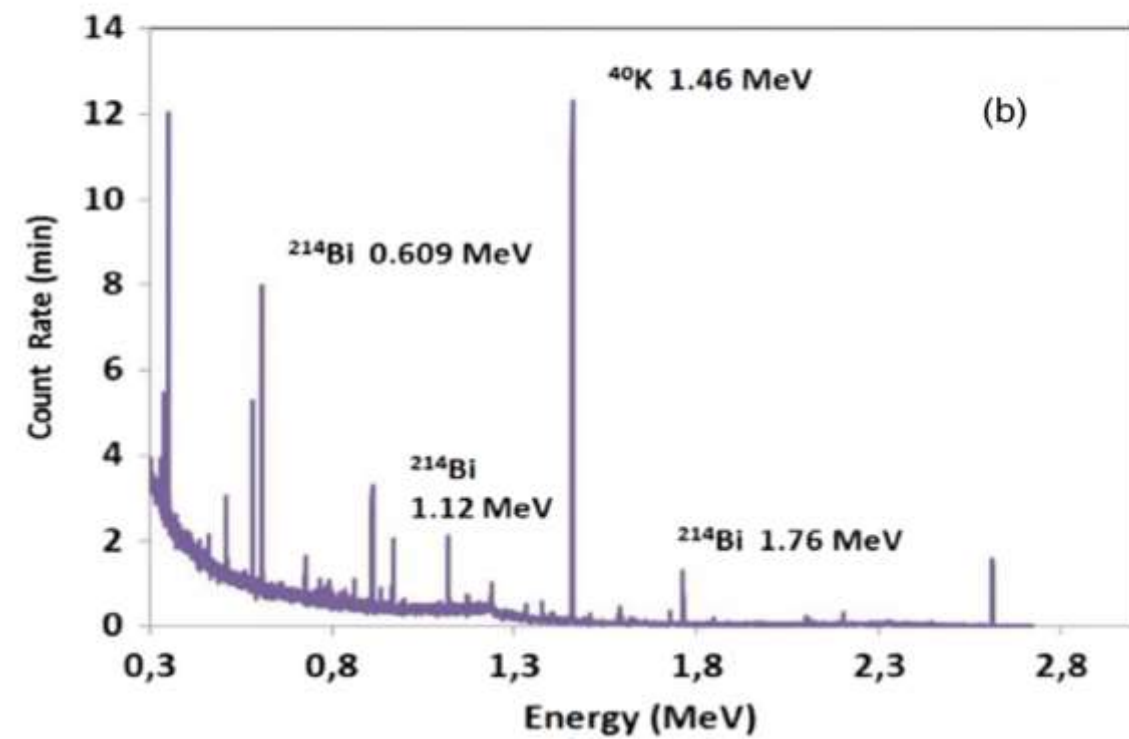
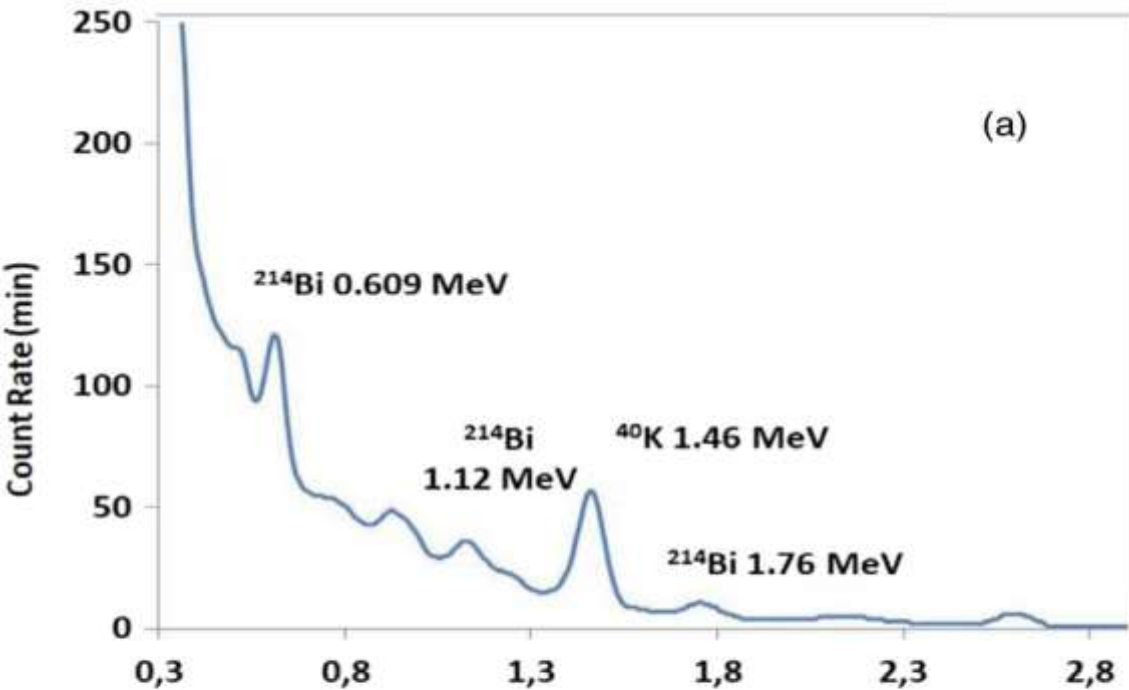
Each TGE observed on Aragats is accompanied by disturbances of the near-surface electric field and, in turn, each disturbance of the electric field lead to the enhancement of Rn chain isotopes concentration near particle detectors located under the roof of experimental hall on Aragats station. Thus, Radon progenies (mostly ^{214}Pb , ^{214}Bi) contribute to count rate in the low-energy domain.

The correlation of Bi isotopes radiation with TGE can be explained by the mobility of the Rn chain isotopes in the near-surface electric field induced by a thundercloud above.

INTRODUCTION



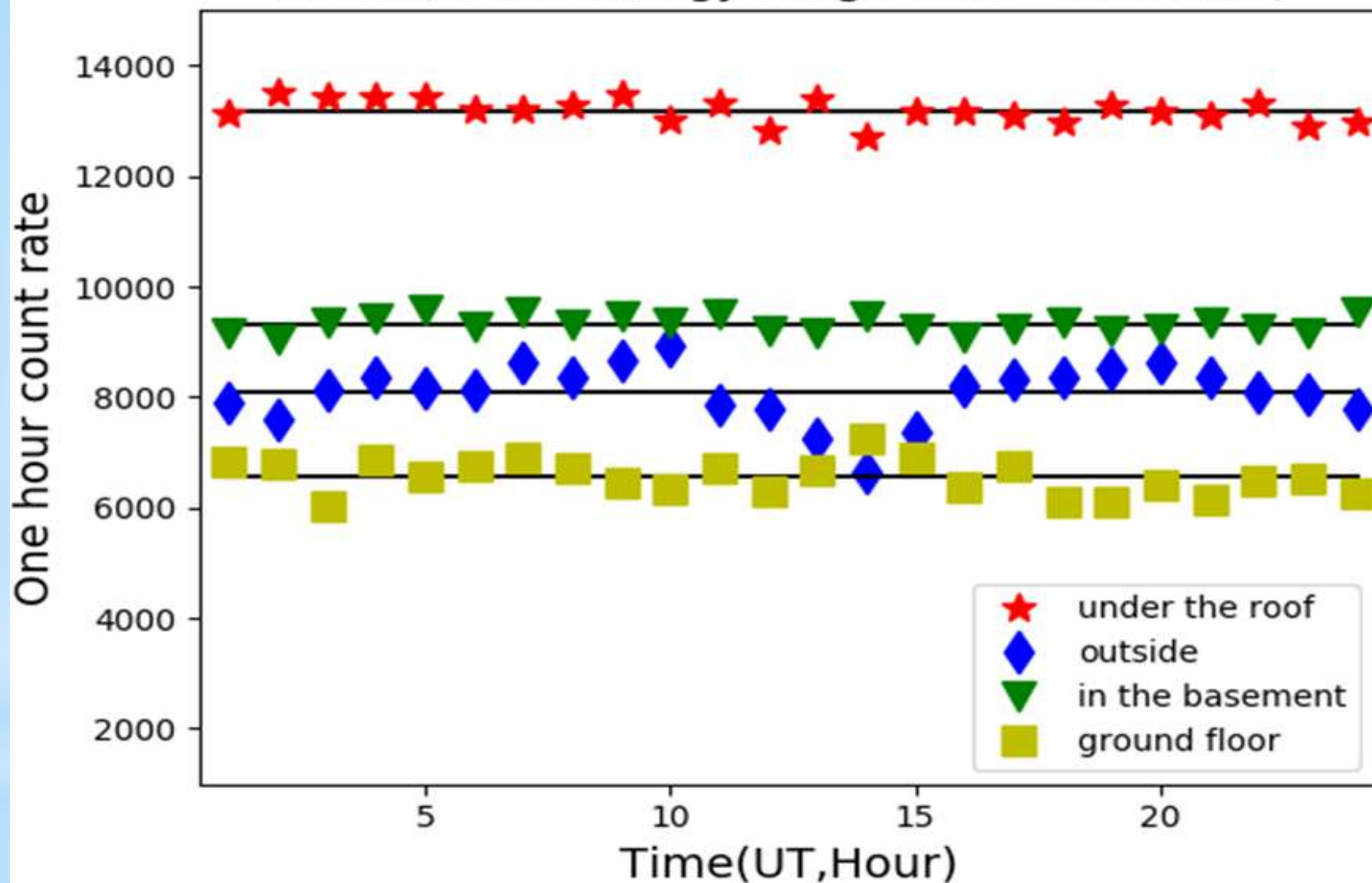
Spectrometer of ORTEC firm[sodium iodide NaI(Tl) crystal, built with 3"×3" inches ,full width at half maximum (FWHM) ~7.7% at 1,46 MeV]



Indoor background gamma ray energy spectrum measured at Aragats and in Yerevan with various spectrometers:

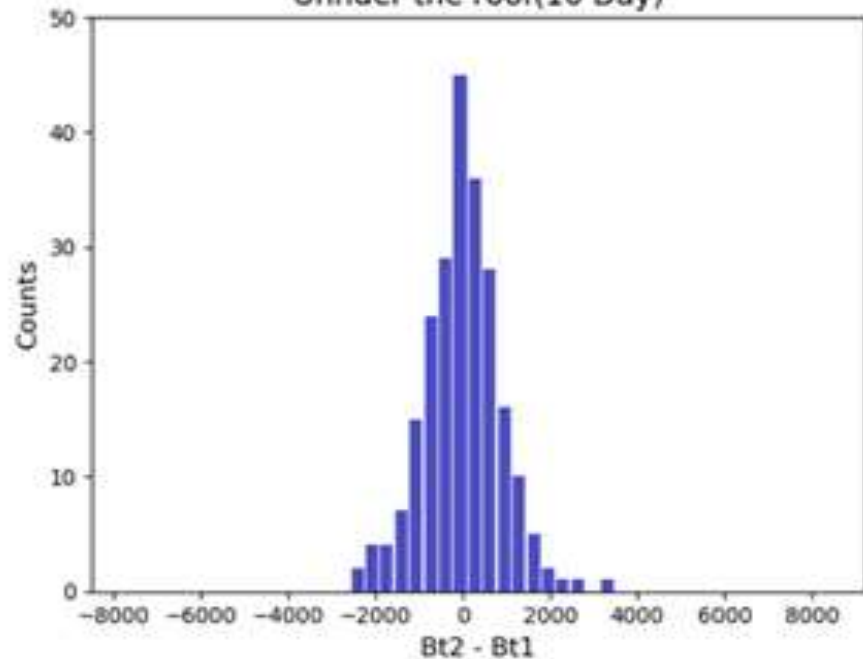
(a) NaI (Tl) and (b) HPGe. The ^{214}Bi spectral line (peak) will be used for the investigation of diurnal variability of radon concentration at Aragats. We also consider the potassium ^{40}K isotope as a stable spectral line used for the calibration of fast varying ^{214}Bi spectral lines.

^{214}Bi (in the energy range 0.56 - 0.66 MeV)

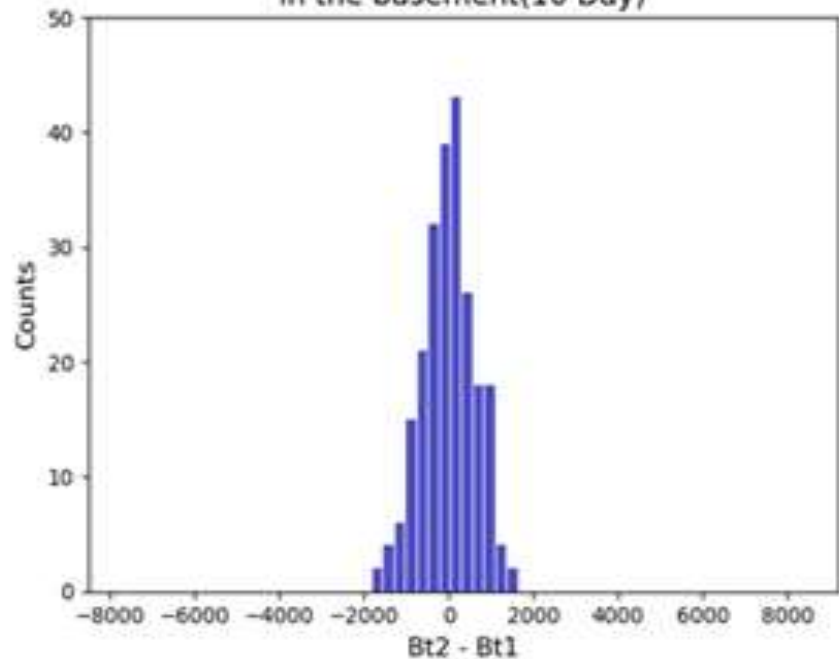


Diurnal variations of the intensity of the 0.609 MeV (^{214}Bi) spectral line measured indoors and in the open air, from measurements performed in December 2018 and January 2019.

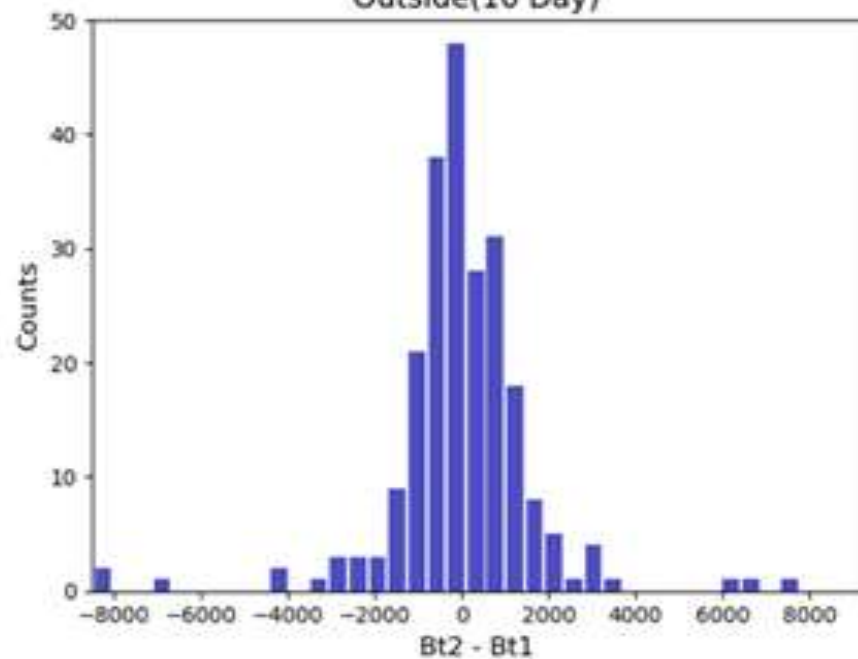
Unnder the roof(10 Day)



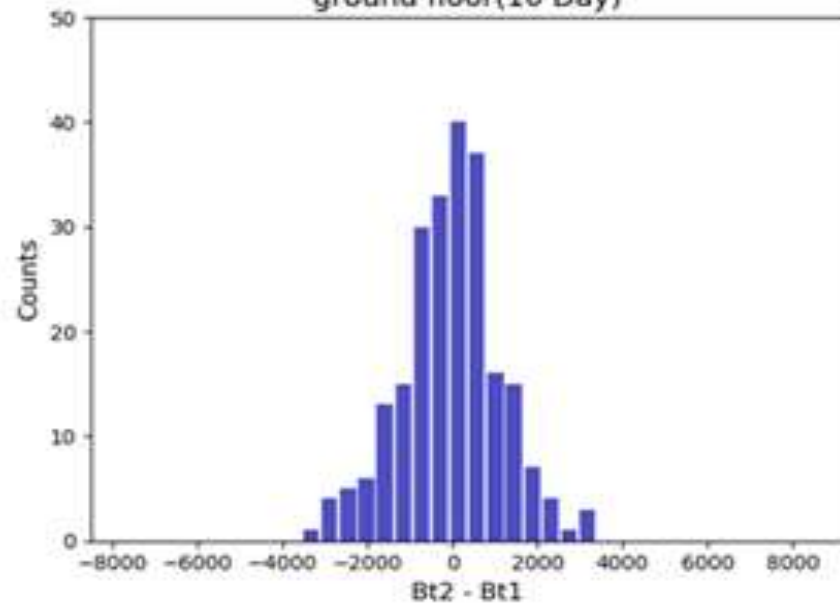
in the basement(10 Day)

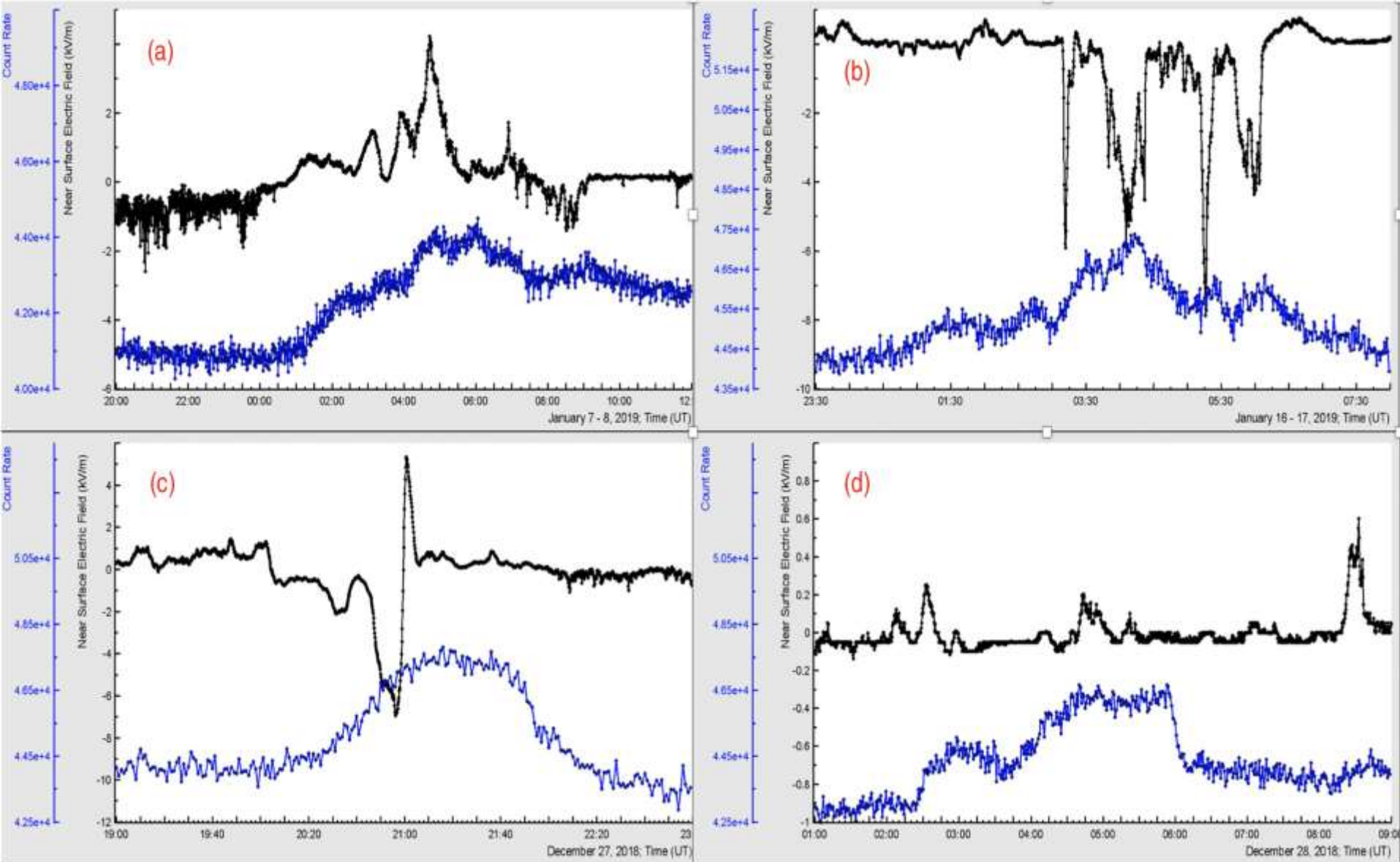


Outside(10 Day)



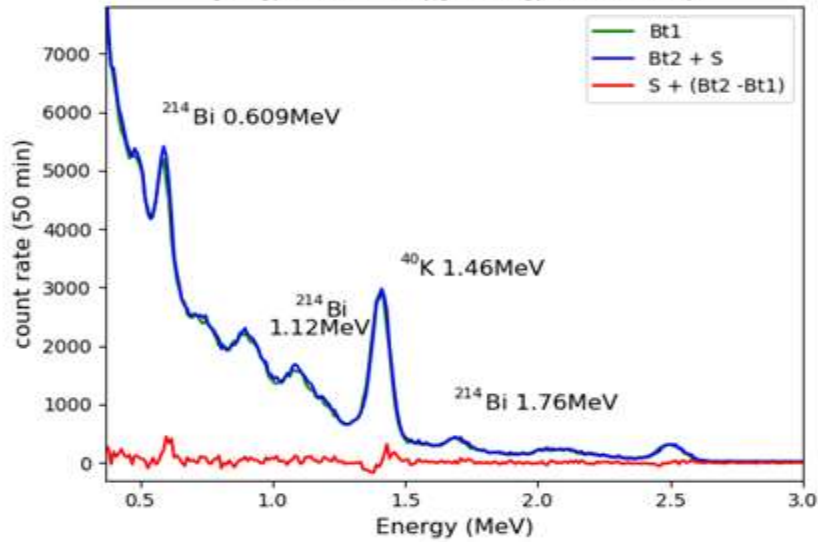
ground floor(10 Day)



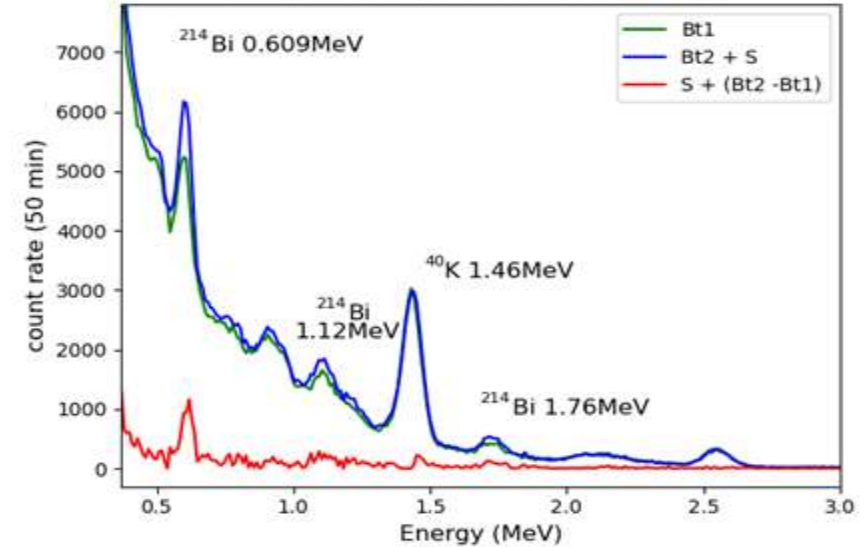


Four observed events of particle flux enhancement in winter 2018/2019. Disturbances of the near-surface electric field (black curves). 1-min time series of count rates of particle flux measured by the first NaI crystal located under the roof of the SKL experimental hall on Aragats (blue curves).

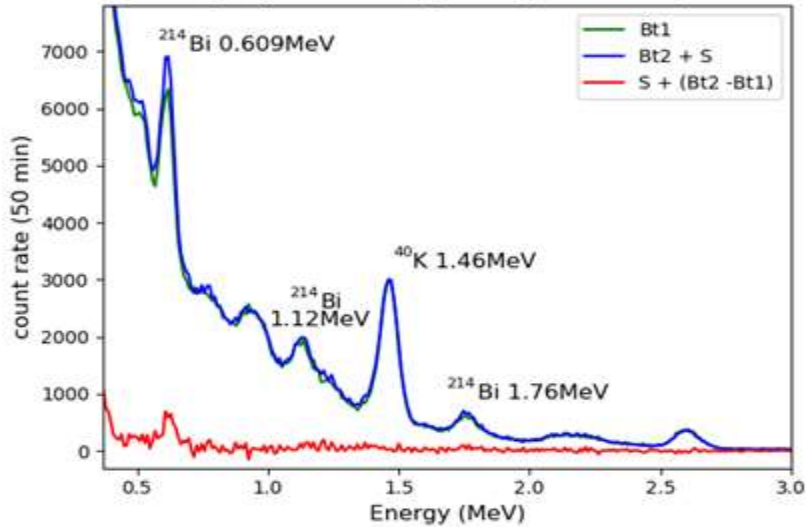
8 January 2019 TGEs
[Bt1](02:20-03:10),[Bt2+S](05:10-06:00)



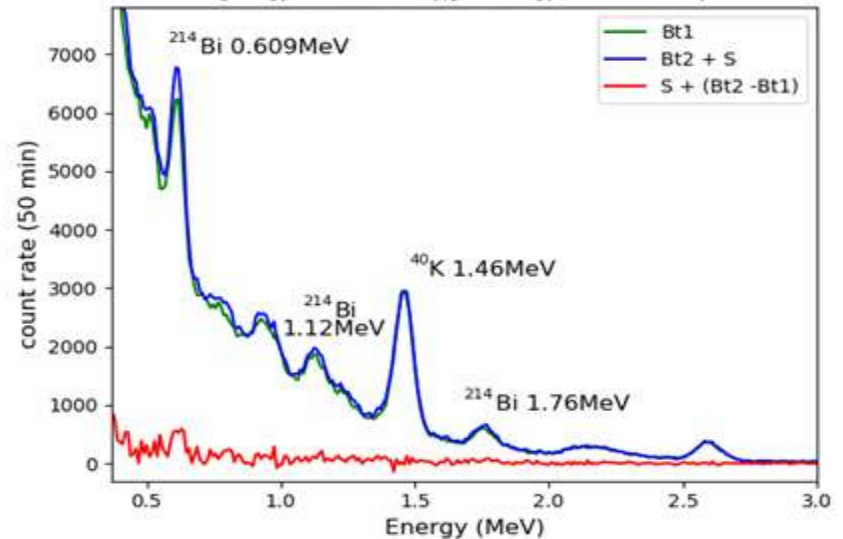
17 January 2019 TGEs
[Bt1](01:40-02:30),[Bt2+S](03:40-04:30)



27 December 2018 TGEs
[Bt1](19:20-20:10),[Bt2+S](21:00-21:50)



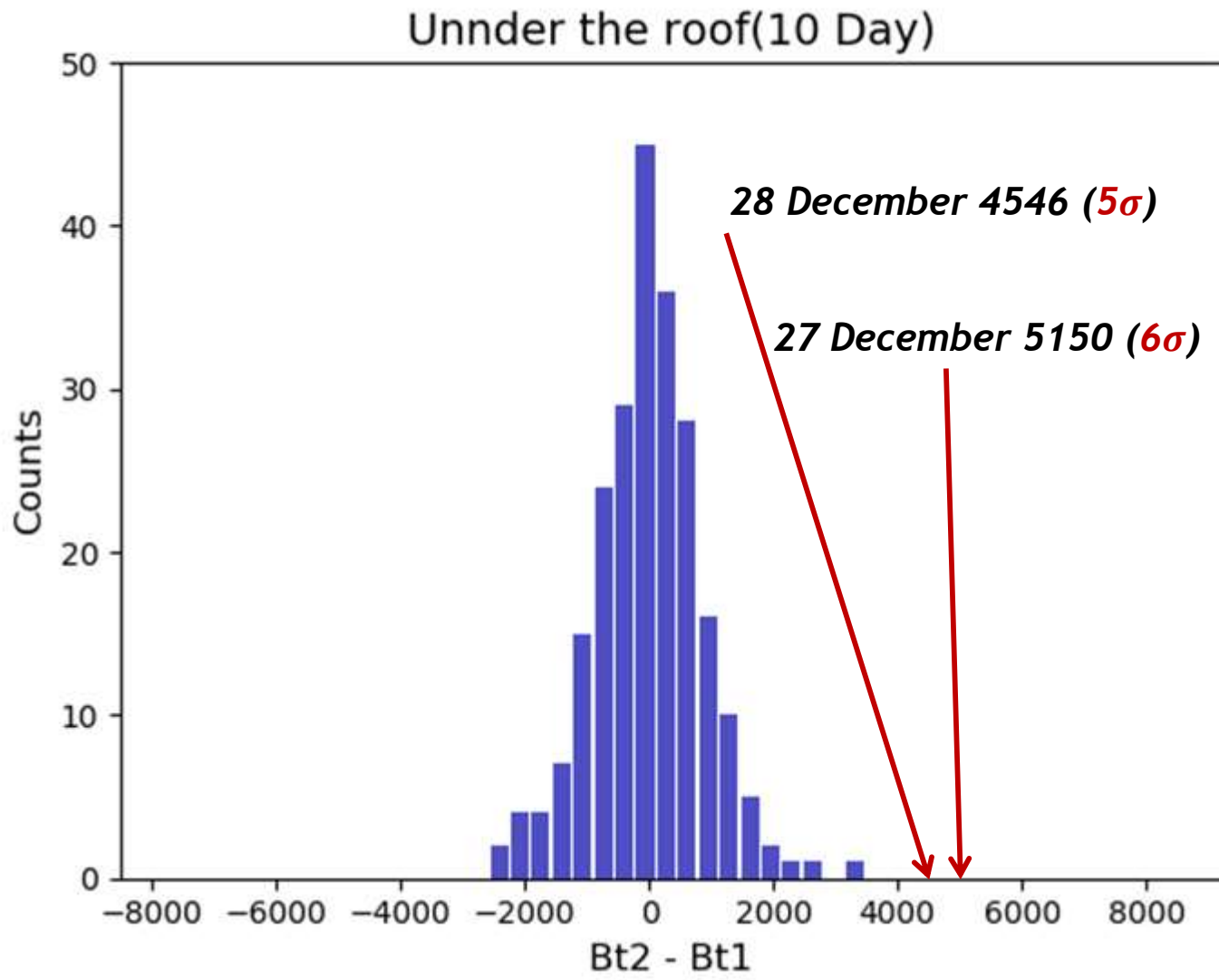
28 December 2018 TGEs
[Bt1](01:20-02:10),[Bt2+S](04:00-04:50)



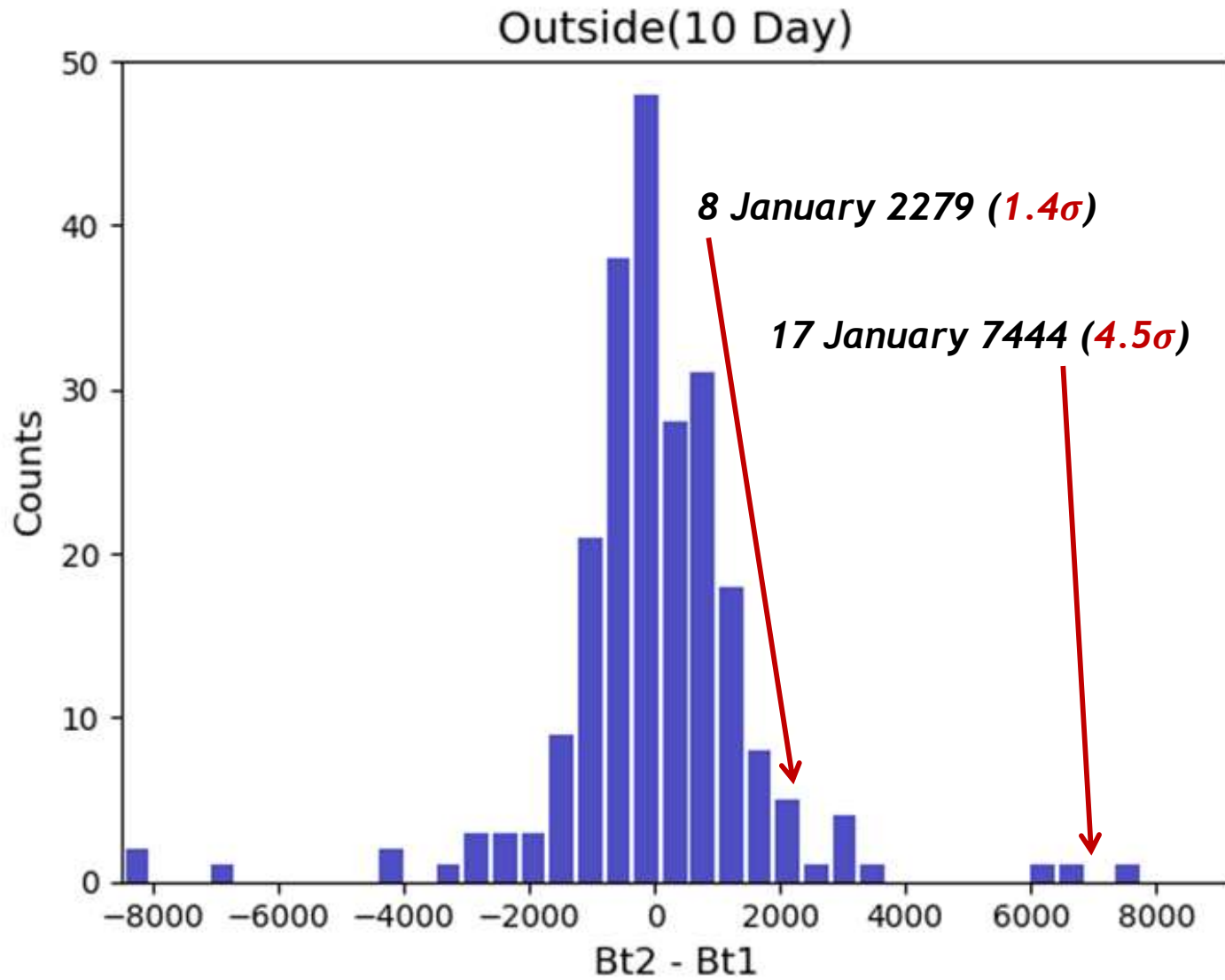
Energy spectra of particle flows recorded at the Aragats research station in the winter months (2018 - 2019) (January 8, January 17, December 27, December 28).

Values of ^{214}Bi (0.609MeV, 1.12MeV, 1.76MeV) energy spectra of particle fluxes recorded at the Aragats research station during the winter months (2018 - 2019).

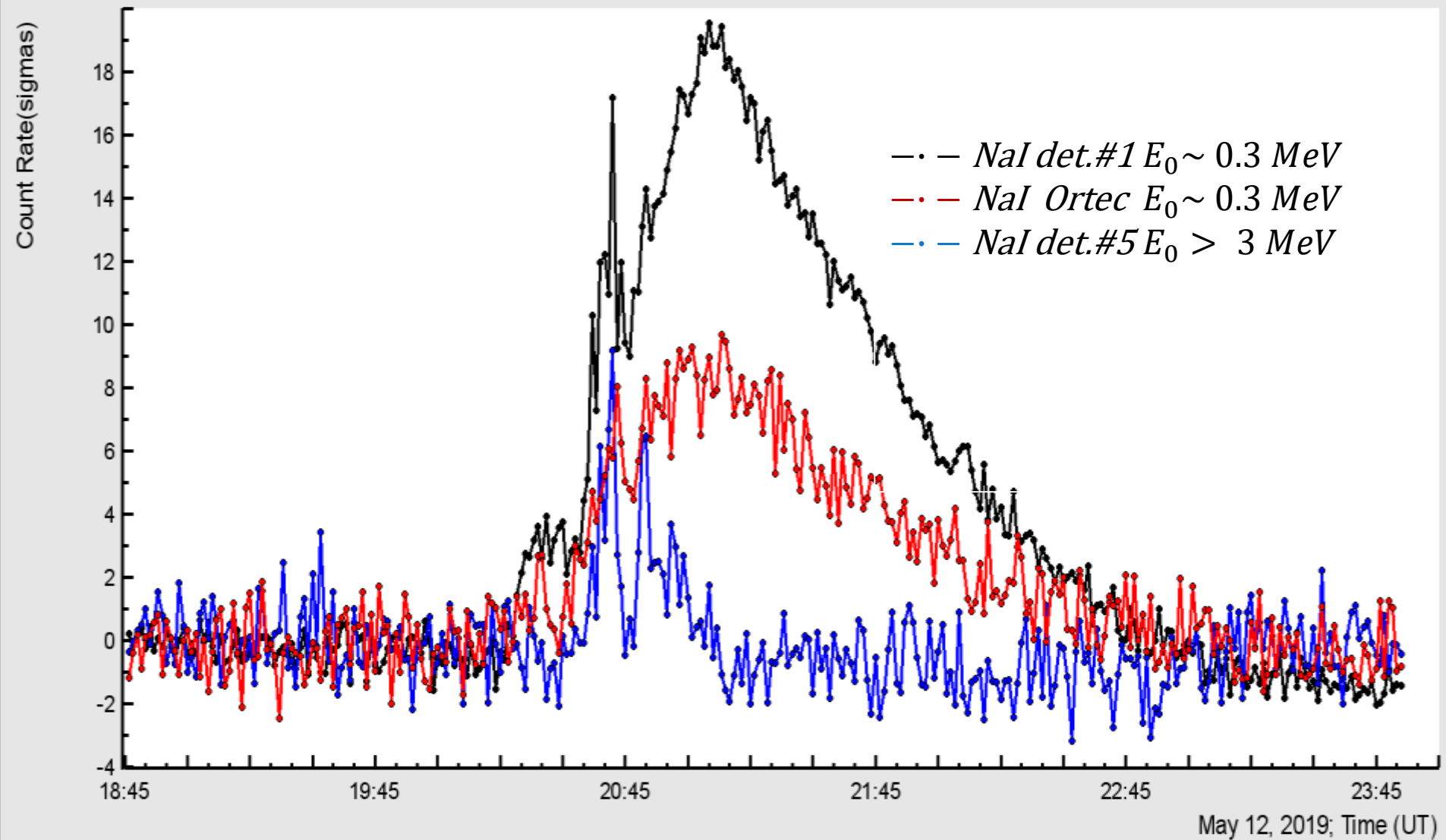
| | Bt1 | S + (Bt2 - Bt1) | 0.36 -0.46 MeV | 0.47 - 0.55 MeV | ^{228}Ac (0.84 - 0.98) | ^{214}Bi (0.56 - 0.66 MeV) | ^{214}Bi (0.7 - 0.83 MeV) | ^{214}Bi (1 - 1.2 MeV) | ^{214}Bi (1.62- 1.9 MeV) | ^{214}Bi (2 - 2.4 MeV) | % |
|-----------------------------|--------|-----------------------|----------------------|--------------------------|---------------------------------------|--|---|--|--|---------------------------------------|-------------|
| December 27th (50min) | 413849 | 18054 | 5643 | 2447 | 328 | 4292 | 746 | 887 | 591 | 10 | 82,8 |
| December 28th (50min) | 406954 | 20073 | 5383 | 2542 | 920 | 3788 | 1613 | 1001 | 534 | 51 | 78,9 |
| January 8th (50min) | 329378 | 7517 | 1926 | 595 | 343 | 1899 | 171 | 485 | 283 | 39 | 76,4 |
| January 17th (50min) | 343685 | 26269 | 7462 | 2505 | 1046 | 6203 | 1549 | 1907 | 832 | 164 | 82,5 |



Reliability of indoor winter flux enhancements (^{214}Bi 0.609 MeV)

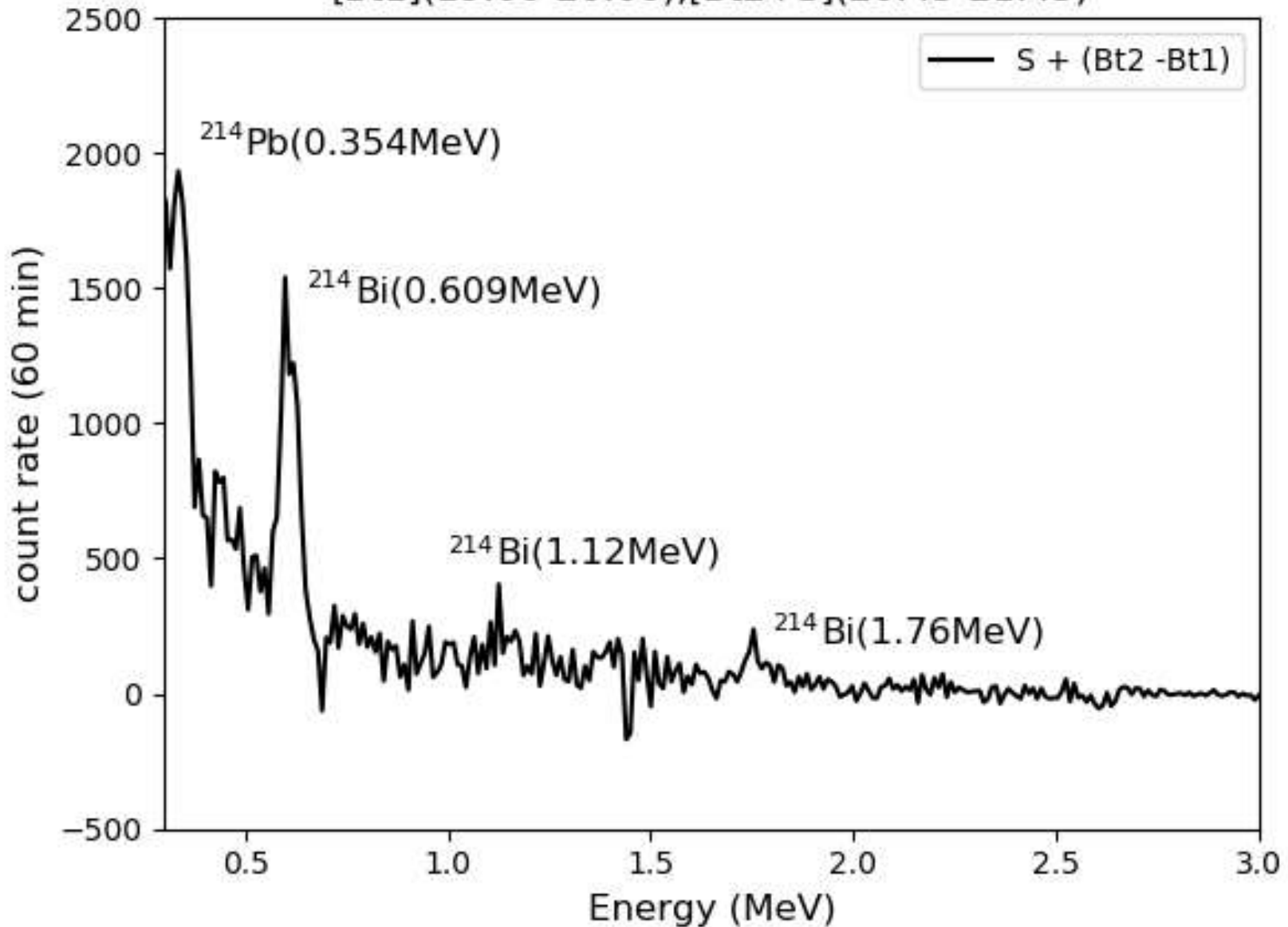


Reliability of outdoor winter flux enhancements (^{214}Bi 0.609MeV)



Observed events of particle flux enhancement in 12 May 2019 . 1-min time series of count rates of particle flux measured by the first NaI (det.#1) crystal located under the roof of the SKL experimental hall on Aragats (black curves), NaI Ortec (red curves), NaI (det.#5, blue curves).

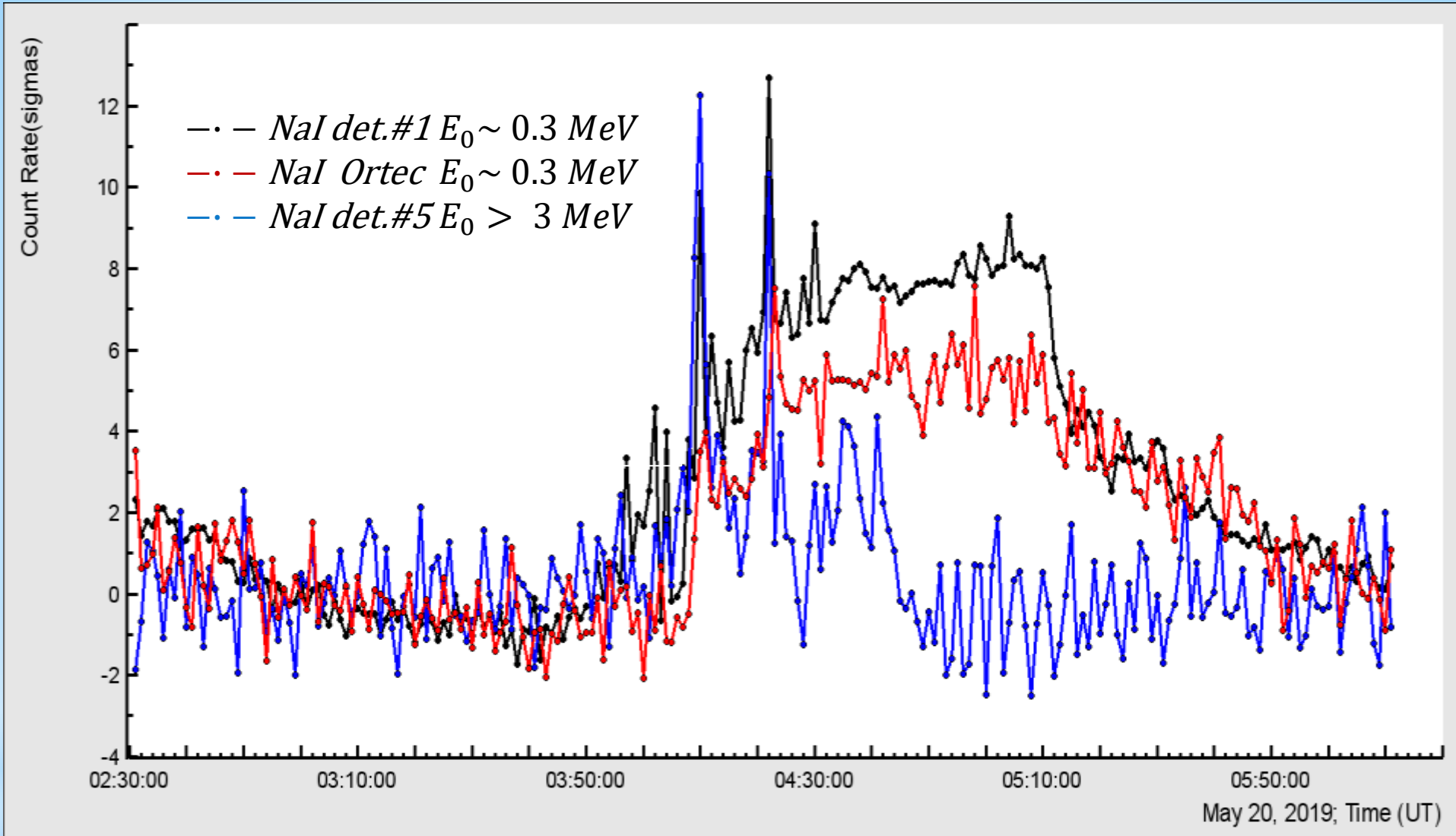
12 May 2019 TGEs
[Bt1](19:00-20:00),[Bt2+S](20:45-21:45)



Energy spectra of particle flows recorded at the Aragats 12 May 2019

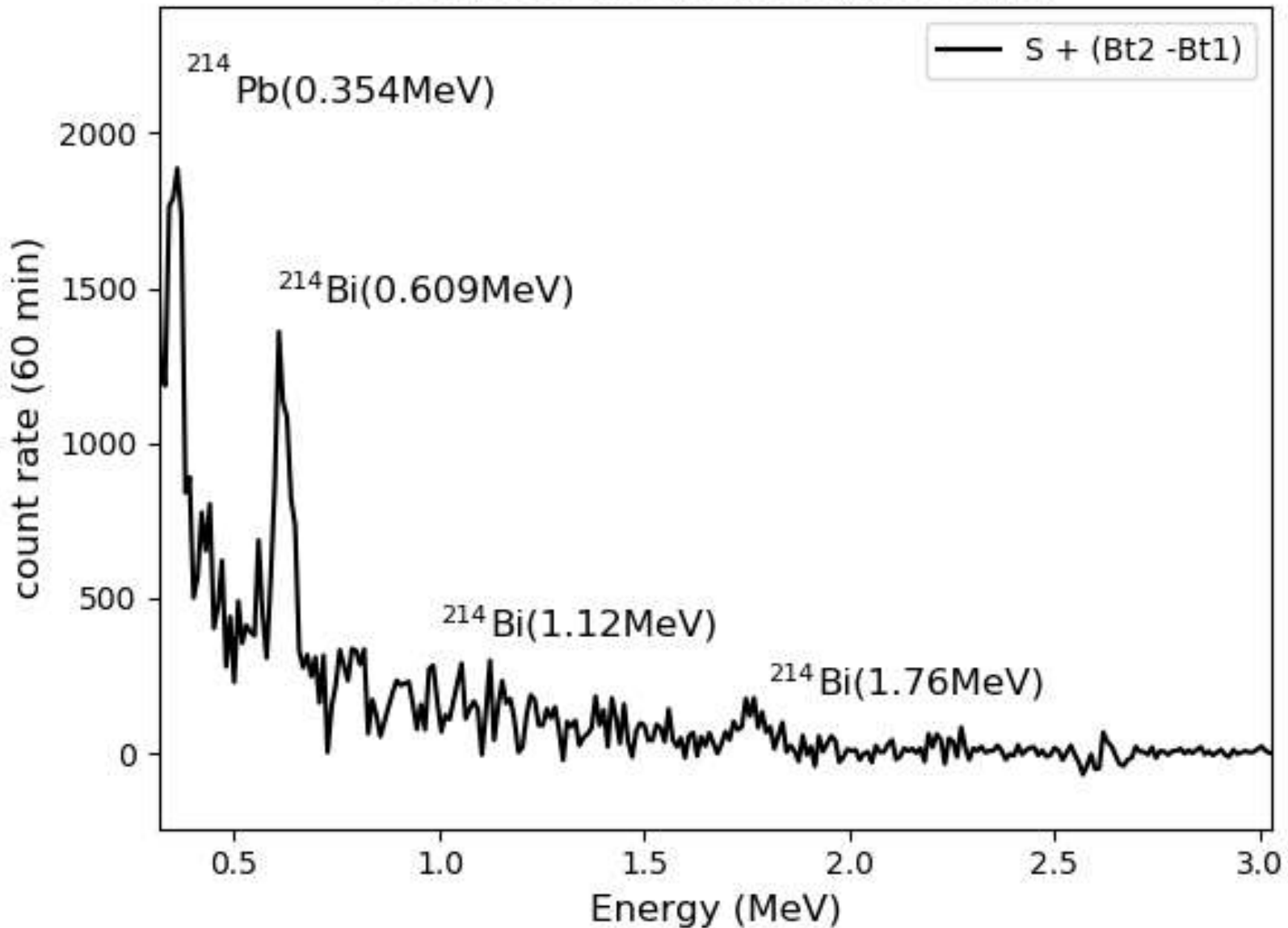
Values of ^{214}Pb (0.354 MeV) and ^{214}Bi (0.609MeV, 1.12MeV, 1.76MeV, 2,2MeV) energy spectra of particle fluxes recorded at the Aragats 12 May 2019

| 12 May | Sum 0,3 - 3 MeV | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|--------|-----------------------|--------------------|--------------------|-------------------|-----------------------|----------------|------------------|----------------|
| Count | 42827 | 16840 | 9094 | 2257 | 1436 | 2104 | 1189 | 304 |
| % | | 39,32 | 21,23 | 5,27 | 3,35 | 4,91 | 2,78 | 0,71 |



Observed events of particle flux enhancement in 20 May 2019 . 1-min time series of count rates of particle flux measured by the first NaI (det.#1) crystal located under the roof of the SKL experimental hall on Aragats (black curves), NaI Ortec (red curves), NaI (det.#5, blue curves).

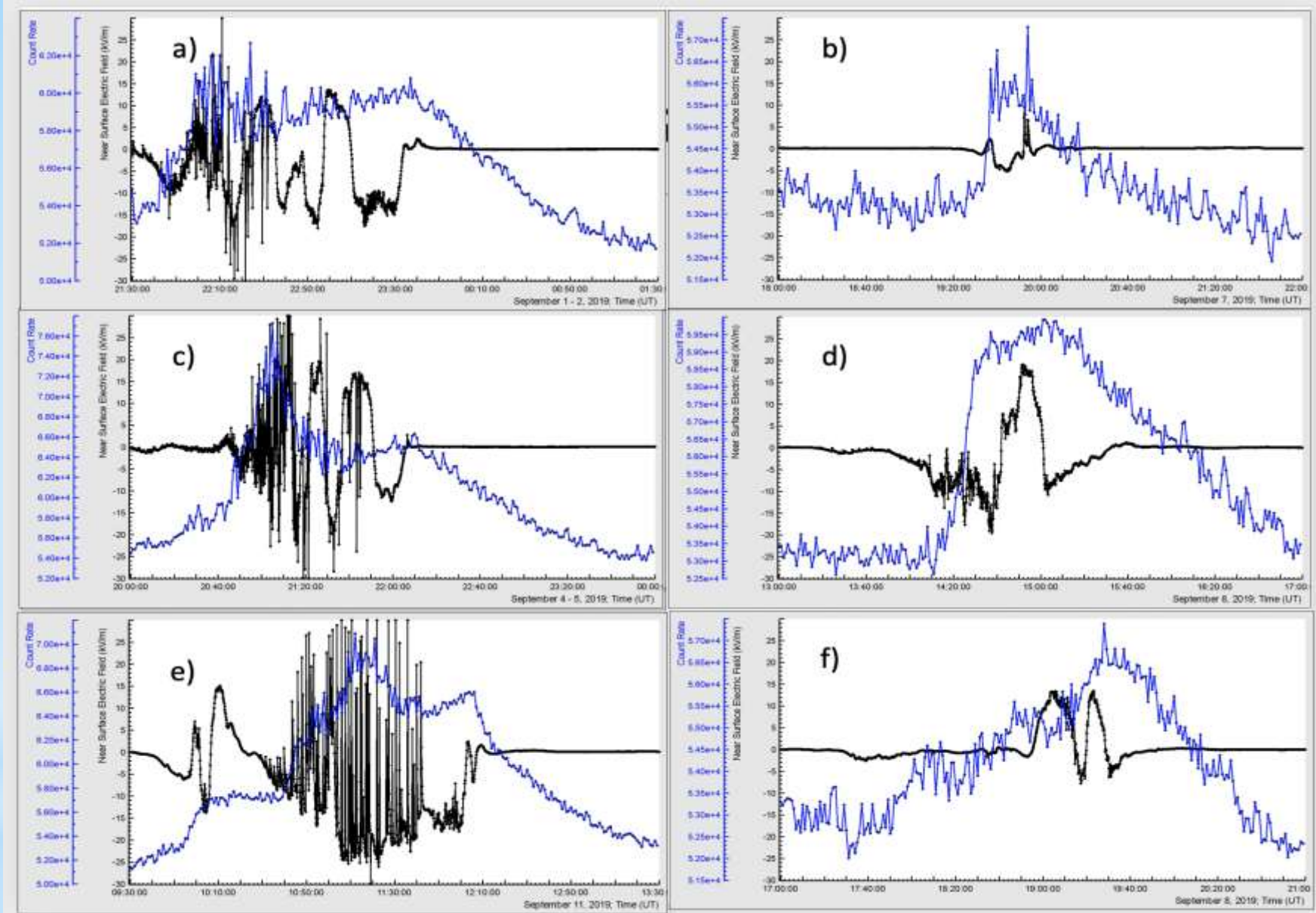
20 May 2019 TGEs
[Bt1](3:00-4:00),[Bt2+S](4:10-5:10)



Energy spectra of particle flows recorded at the Aragats 20 May 2019

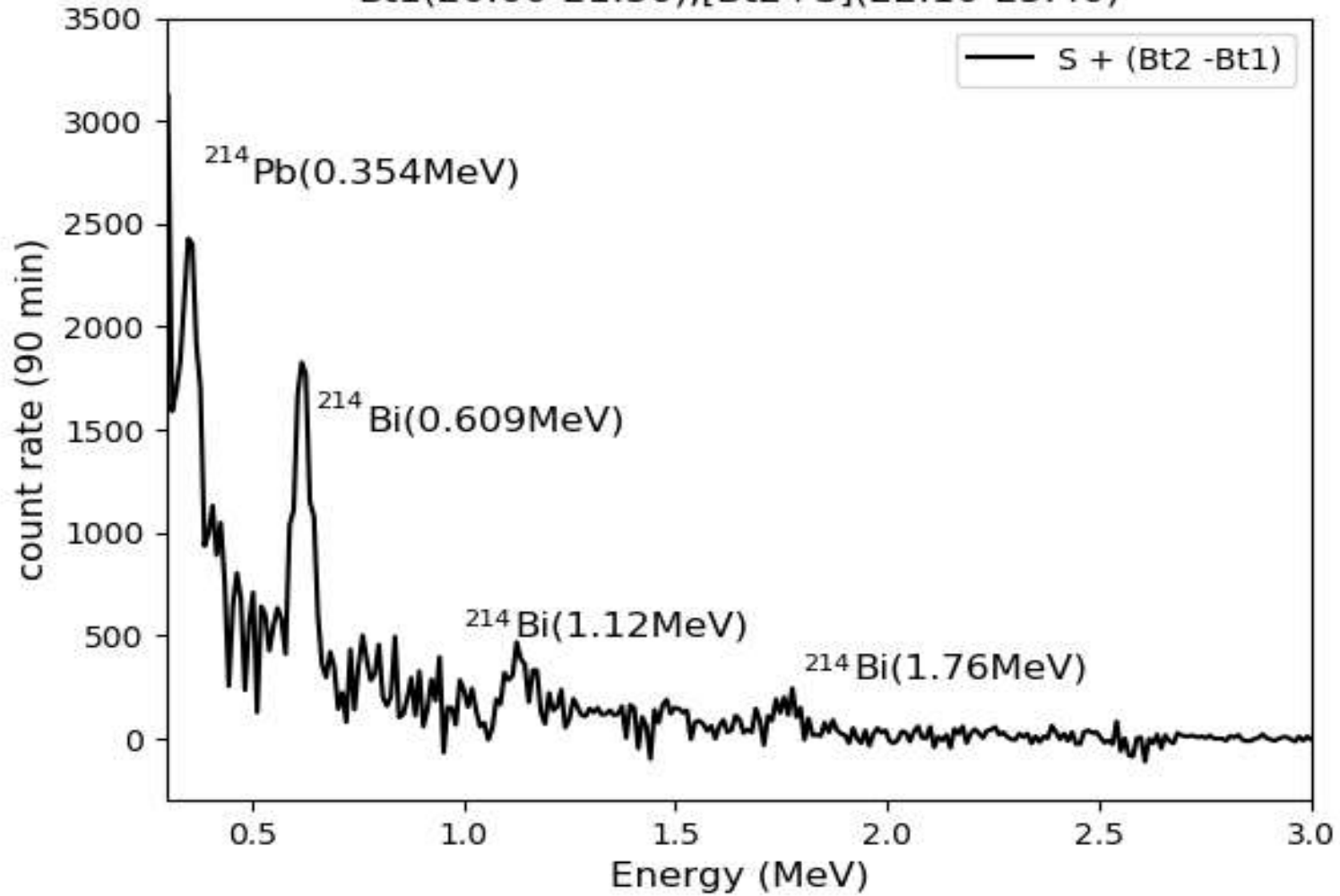
Values of ^{214}Pb (0.354 MeV) and ^{214}Bi (0.609MeV, 1.12MeV, 1.76MeV, 2,2MeV) energy spectra of particle fluxes recorded at the Aragats 20 May 2019

| 20 May | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|--------|-------------------------|--------------------|--------------------|-------------------|--------------------|----------------|------------------|----------------|
| Count | 41840 | 14175 | 8336 | 2747 | 1768 | 1646 | 1118 | 208 |
| % | | 33,88 | 19,92 | 6,57 | 4,23 | 3,93 | 2,67 | 0,50 |



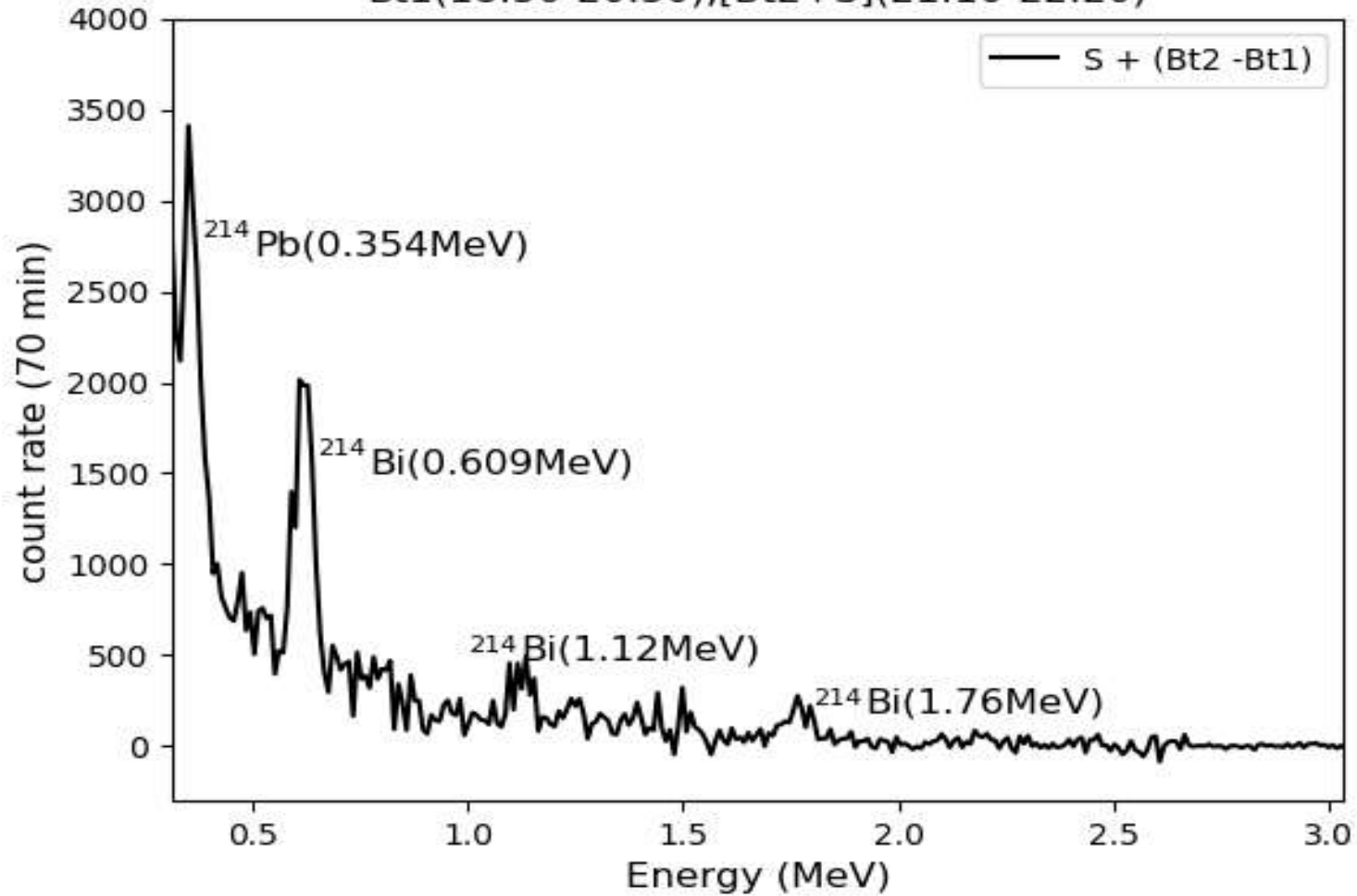
Six observed events of particle flux enhancement in September 2019. Disturbances of the near-surface electric field (black curves). 1-min time series of count rates of particle flux measured by the first NaI crystal located under the roof of the SKL experimental hall on Aragats (blue curves).

01 September 2019
 Bt1(20:00-21:30),[Bt2+S](22:10-23:40)

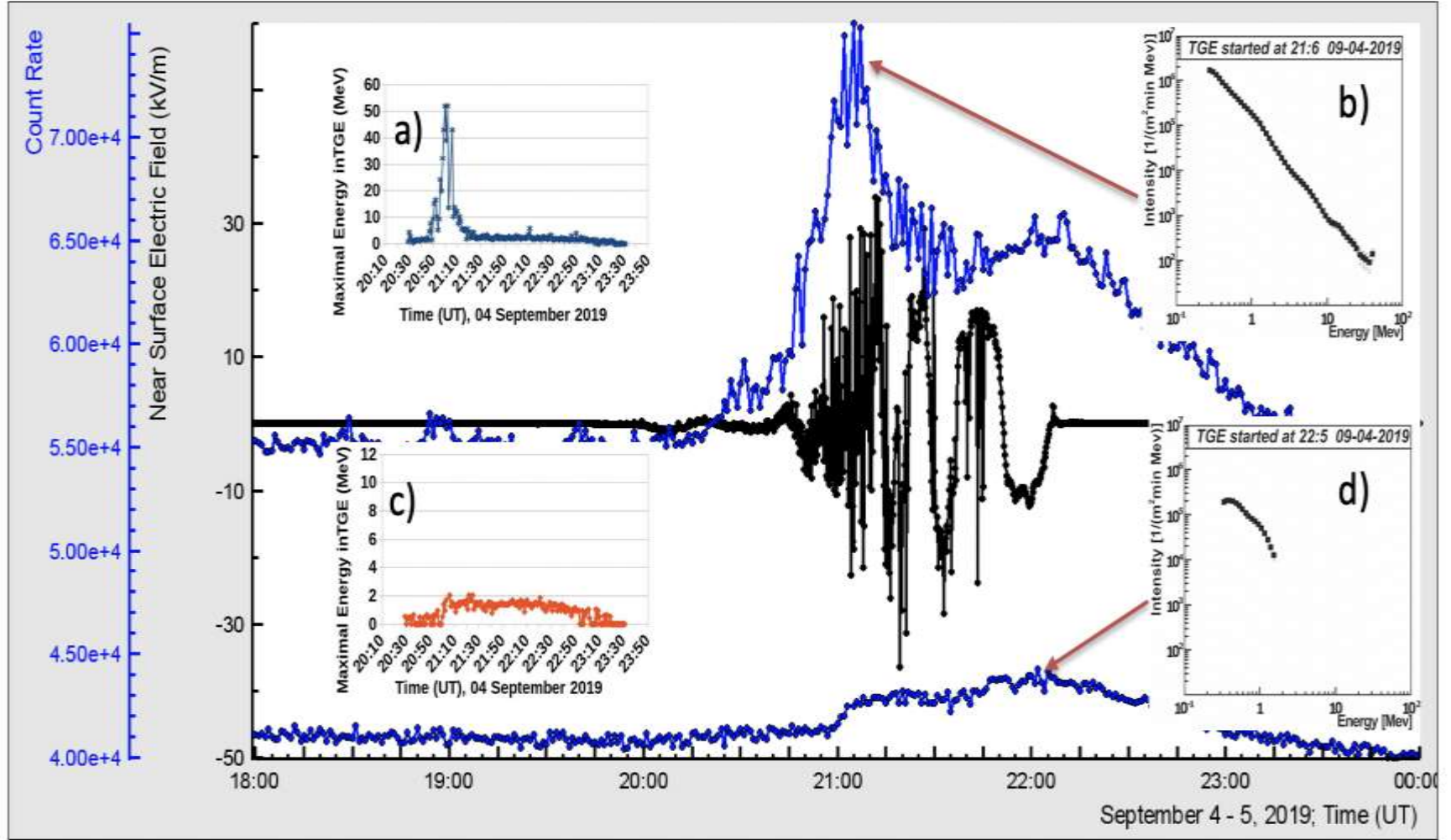


| 01 September | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|--------------|-------------------|-----------------|-----------------|----------------|-----------------|-------------|---------------|-------------|
| Count | 58718 | 20732 | 11585 | 3369 | 2648 | 3326 | 895 | 166 |
| % | | 35.31 | 19.73 | 5.74 | 4.51 | 5.66 | 1.52 | 0.28 |

04 September 2019
 Bt1(18:50-20:30),[Bt2+S](21:10-22:20)



| 04 September | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|--------------|-------------------|-----------------|-----------------|----------------|-----------------|-------------|---------------|-------------|
| Count | 70713 | 27114 | 13564 | 4453 | 2452 | 3157 | 1441 | 221 |
| % | | 38.34 | 19.18 | 6.30 | 3.47 | 4.46 | 2.02 | 0.31 |

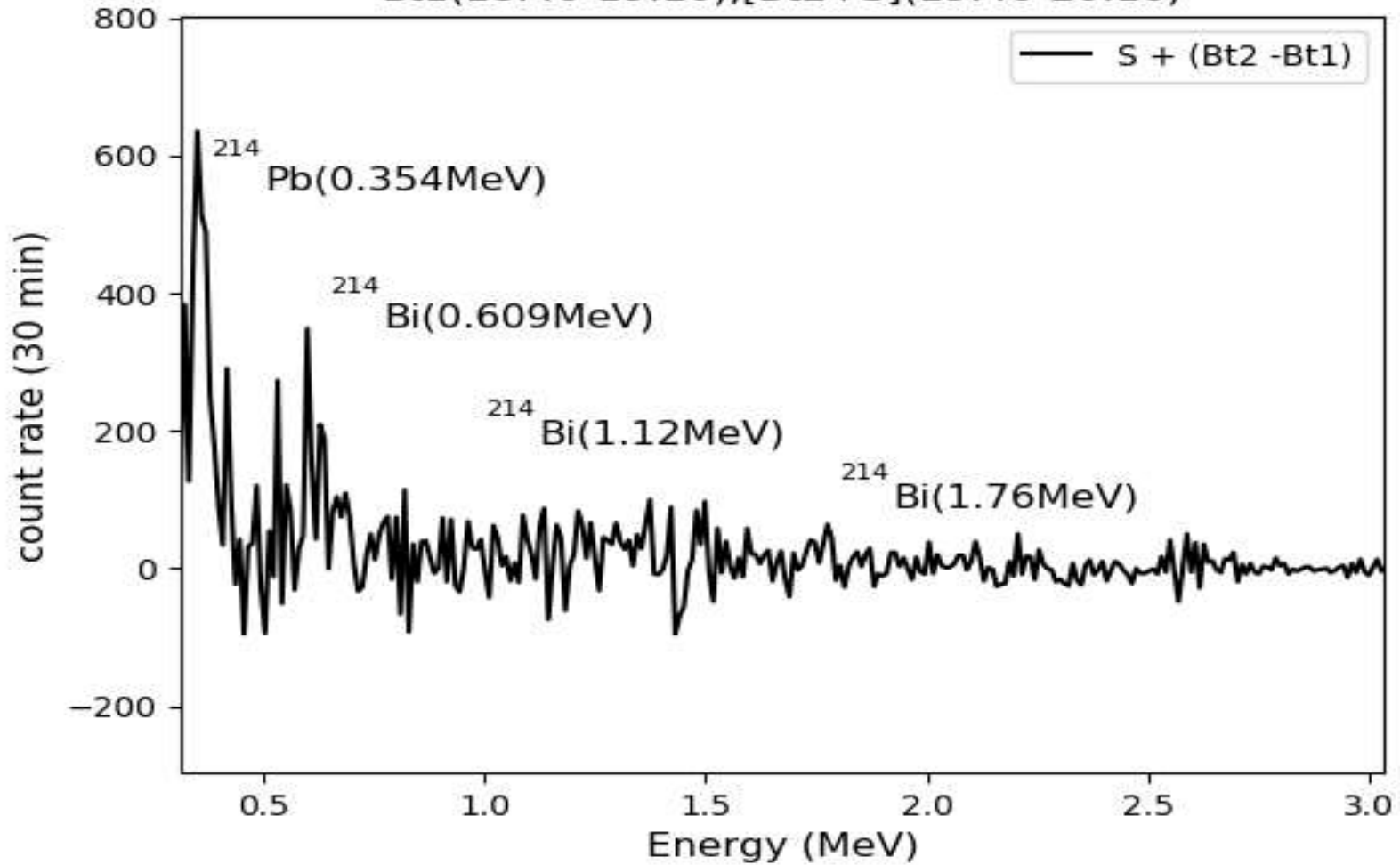


a),b) NaI det.#1



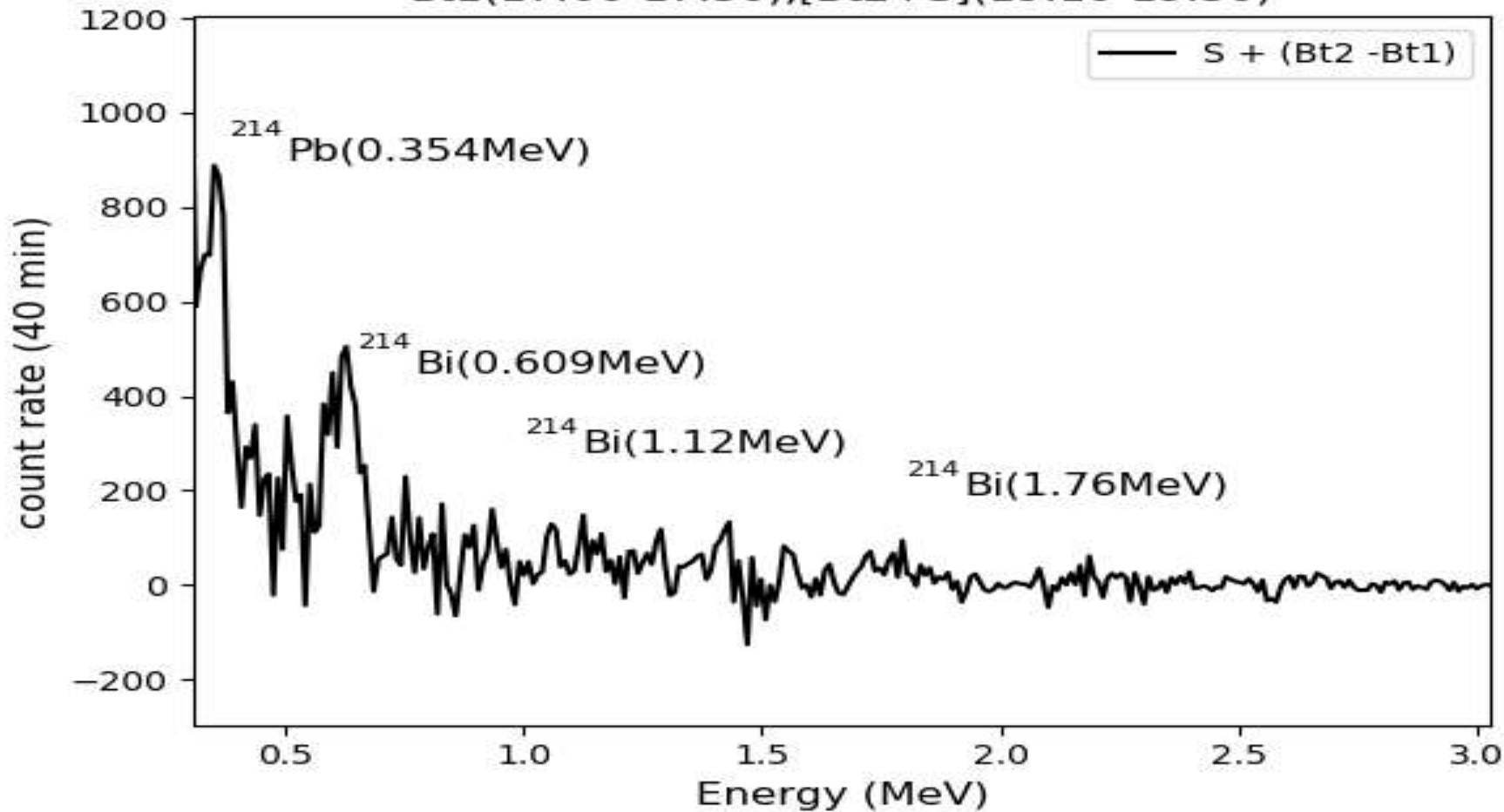
c) d) NaI det.#4

07 September 2019
 Bt1(18:40-19:10),[Bt2+S](19:40-20:10)



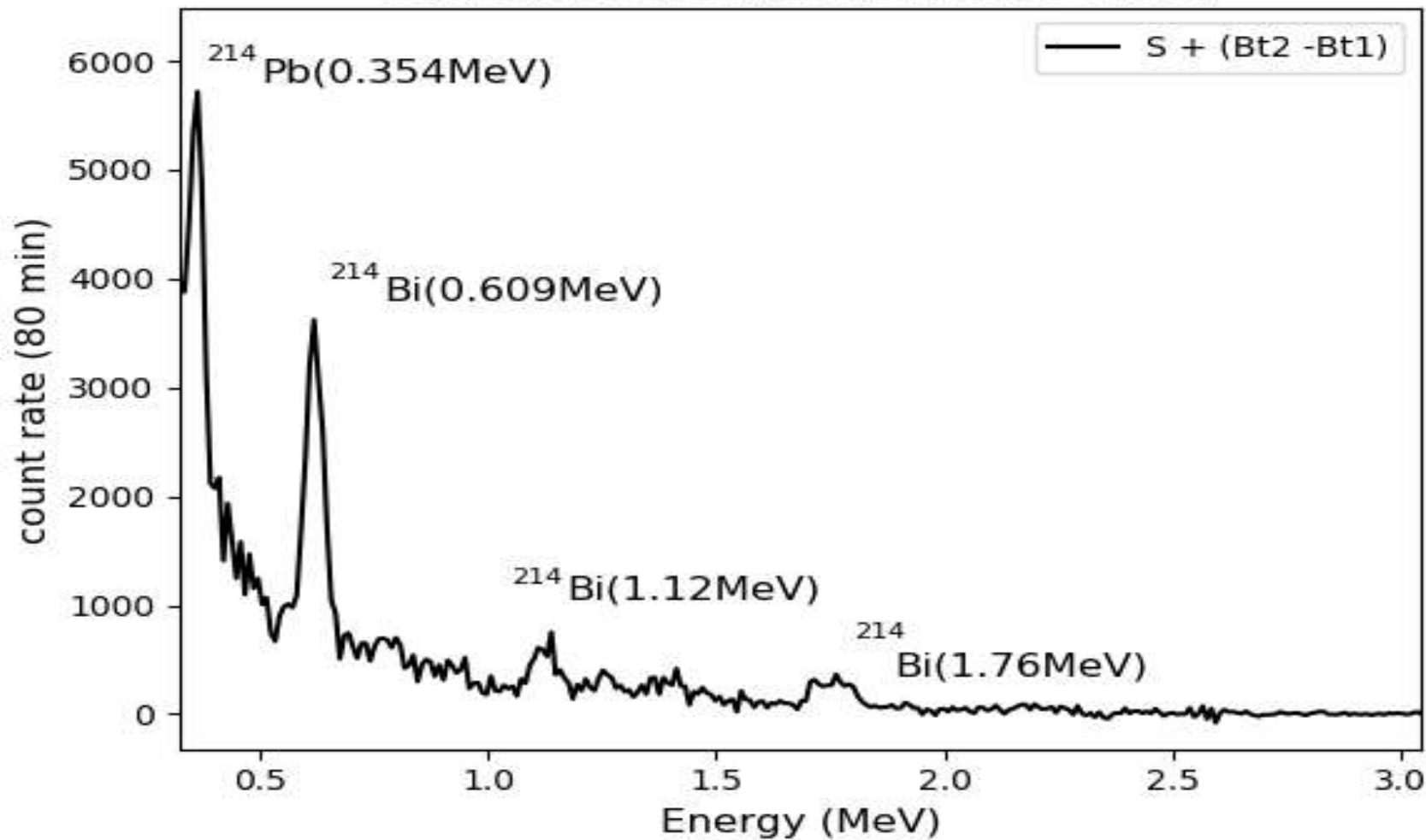
| 07 September | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|--------------|-------------------|-----------------|-----------------|----------------|-----------------|-------------|---------------|-------------|
| Count | 7781 | 3649 | 1191 | 288 | 156 | 251 | 109 | 16 |
| % | | 46.90 | 15.31 | 3.70 | 2.00 | 3.23 | 1.40 | 0.21 |

08 September 2019
 Bt1(17:00-17:50),[Bt2+S](19:10-19:50)

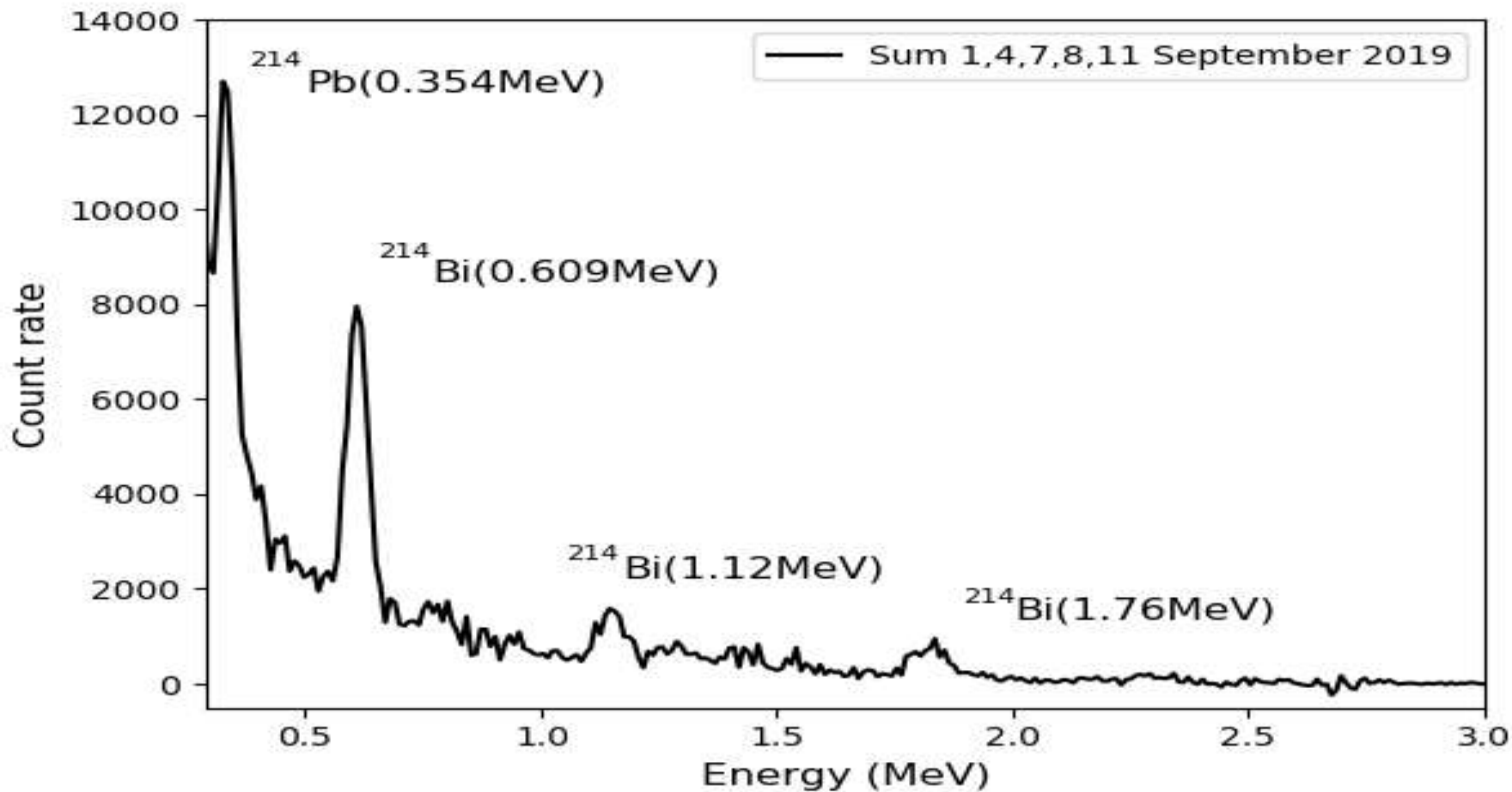


| | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|-------|----------------------|--------------------|--------------------|-------------------|--------------------|----------------|------------------|----------------|
| Count | 18318 | 7430 | 3847 | 980 | 523 | 700 | 384 | 21 |
| % | | 40,56 | 21,00 | 5,35 | 2,86 | 3,82 | 2,10 | 0,11 |

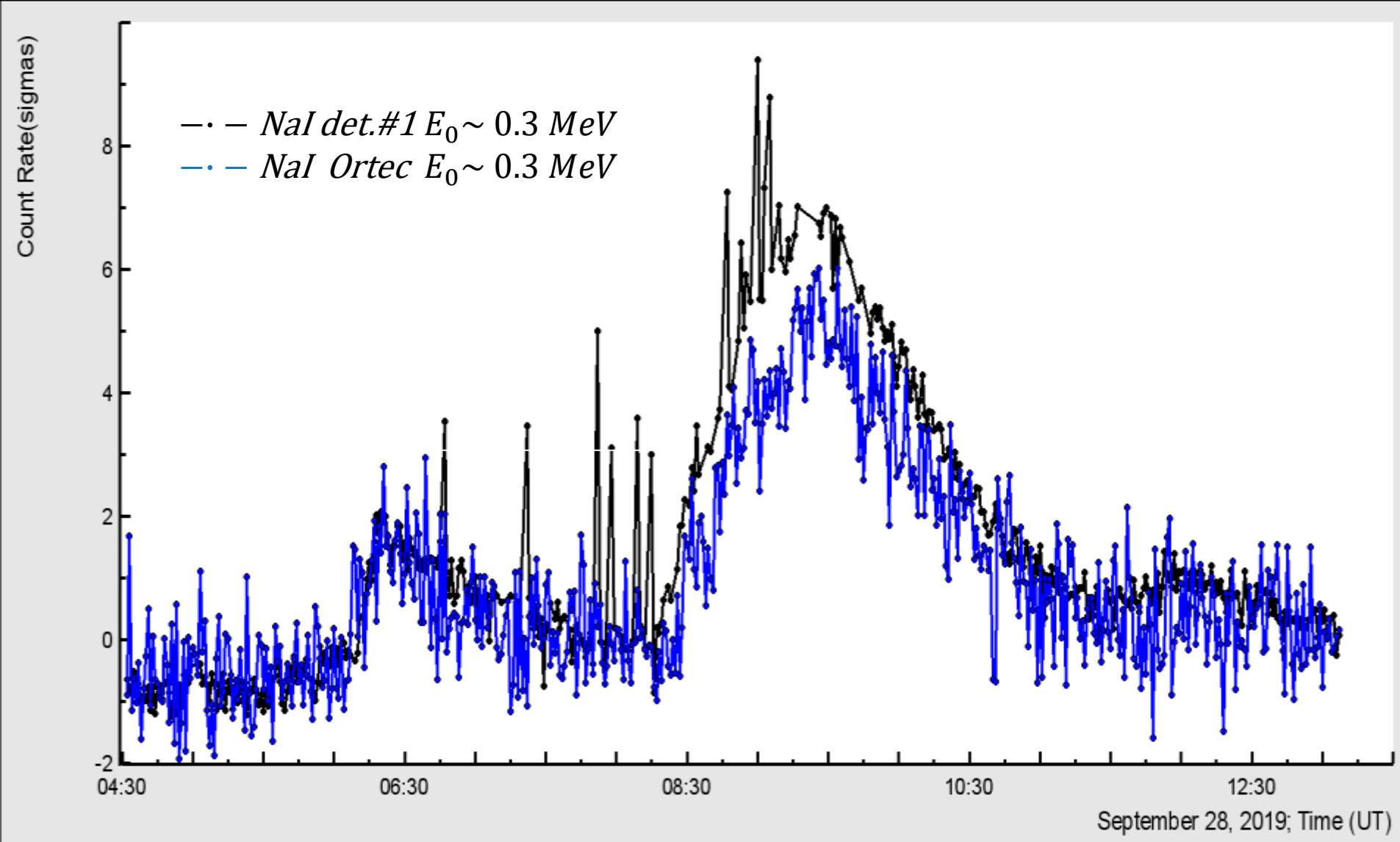
11 September 2019
 Bt1(08:20-09:30),[Bt2+S](10:50-12:10)



| | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|-------|-------------------------|--------------------|--------------------|-------------------|-----------------------|----------------|------------------|----------------|
| Count | 120536 | 42434 | 22332 | 8597 | 5441 | 4969 | 1834 | 663 |
| % | | 35,20 | 18,53 | 7,13 | 4,51 | 4,12 | 1,52 | 0,55 |

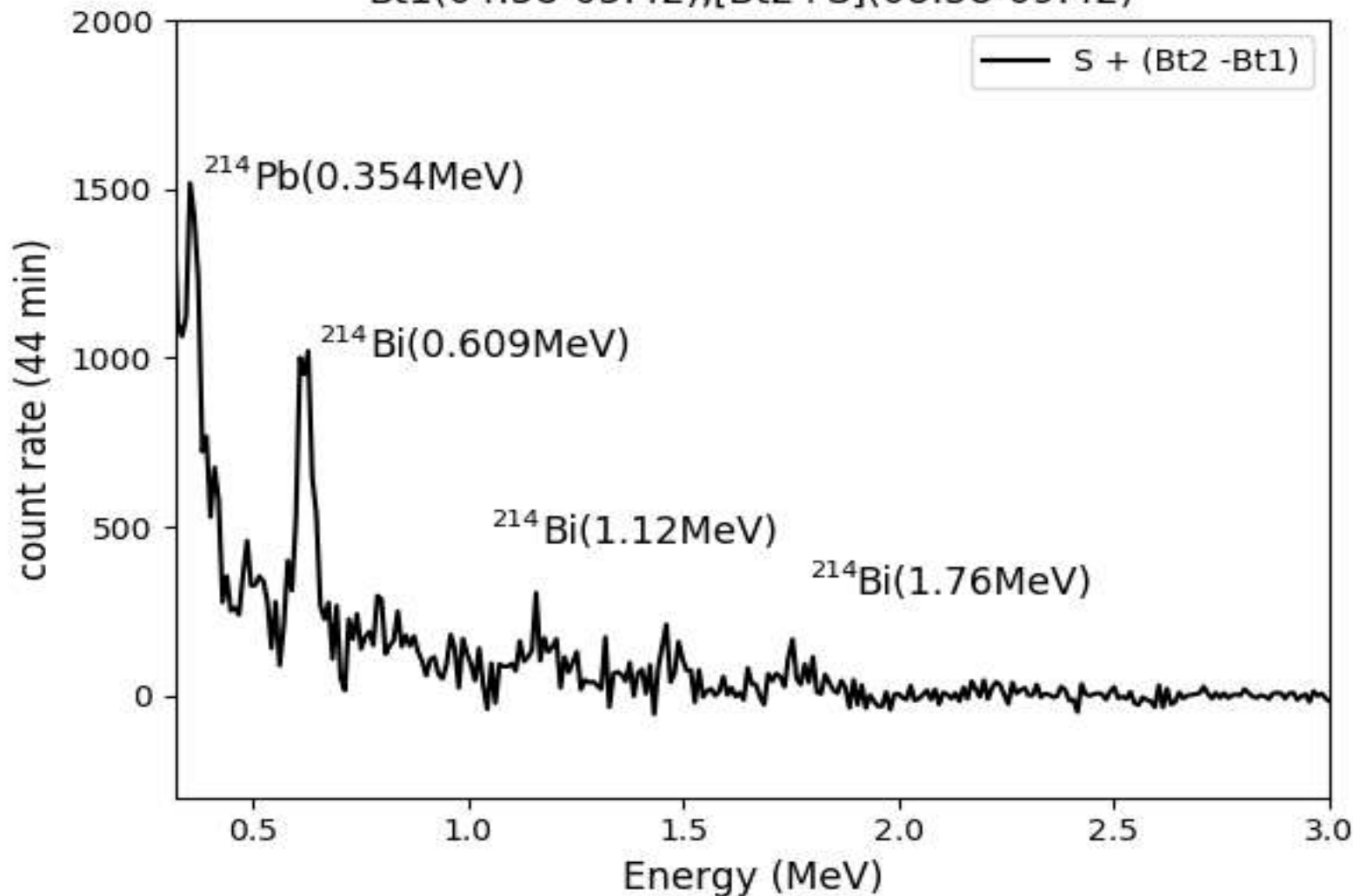


| | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|-------|----------------------|--------------------|--------------------|-------------------|-----------------------|----------------|------------------|----------------|
| Count | 276066 | 104253 | 52380 | 15918 | 12003 | 12576 | 2539 | 1635 |
| % | | 37,76 | 18,97 | 5,77 | 4,35 | 4,56 | 0,92 | 0,59 |



Observed events of particle flux enhancement in 28 September 2019 . 1-min time series of count rates of particle flux measured by the first NaI (det.#1) crystal located under the roof of the SKL experimental hall on Aragats (black curves), NaI Ortec (blue curves).

28 September 2019
 Bt1(04:58-05:42),[Bt2+S](08:58-09:42)



| | Sum (0,3 - 3 MeV) | 0,33 - 0,38 MeV | 0,47 - 0,55 MeV | 0,56 - 0,66 MeV | 0,7 - 0,83 MeV | 0,84 - 0,98 MeV | 1 - 1,2 MeV | 1,6 - 1,9 MeV | 2 - 2,4 MeV |
|-------|-------------------------|--------------------|--------------------|--------------------|-------------------|-----------------------|----------------|------------------|----------------|
| Count | 32631 | 12686 | 3550 | 5965 | 2392 | 2048 | 1164 | 209 | 112 |
| % | | 38,88 | 10,88 | 18,28 | 7,33 | 6,28 | 3,57 | 0,64 | 0,34 |

Conclusions

-Low energy (300keV to 3MeV) analysis give us that particle fluxes during TGEs are connected to radiation from Rn-222 progenies.

-Enhancements of particle fluxes, at the beginning of events, are well correlated with electric fluctuations, but these continue on even after said electric field fluctuations.

Thank you for attention