SWx: Flight Operations & Research Perspective

Matthias M. Meier

Radiation Biology, Institute of Aerospace Medicine, DLR

Outline

- Introduction
- Case Study (GLE 65, 29 October 2003)
- Lessons learnt
- Mitigation
- Summary

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Space Weather Impacts on Aviation

- Ionospheric effects (communications, navigation)
- Ionising Radiation (biological effects, avionics)
- Ground infrastructure (power supply, airports, ATM, etc.)

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Background Information: Radiation Protection in Aviation

- Characterization of radiation field by dose quantities (D, E, H*(10), dD/dt, dE/dt, dH*(10)/dt, etc.)
- Radiation field in dependence on GCR and solar cycle is well understood
- Radiation protection and dose limits regulated by EU law
- Dose quantities can be assessed by measurement or calculation
- Several models for additional SWx contributions (GLEs)

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Background: October 2003

TV reported on SPEs and gave rise to public awareness all over the world.

Due to the public pressure some airlines even operated their flights at lower altitudes between 29. and 31. October.

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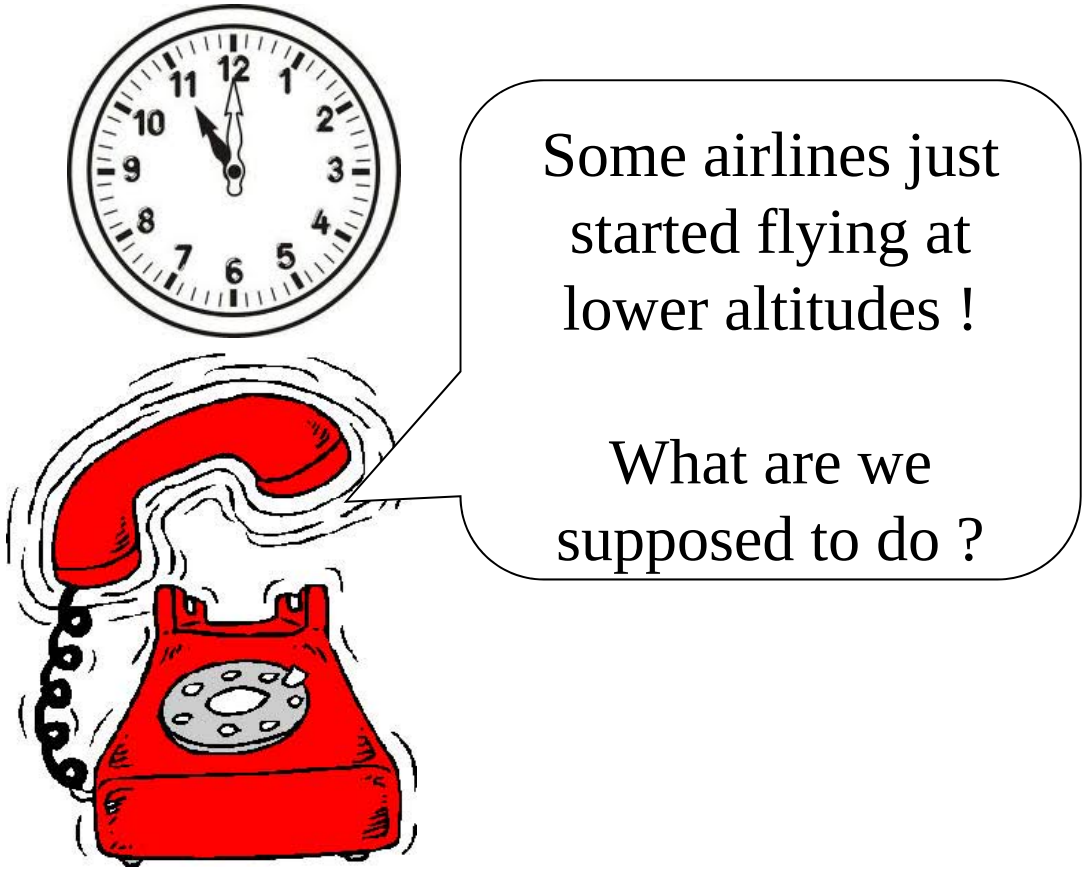
GLE 65: 28./29. October 2003



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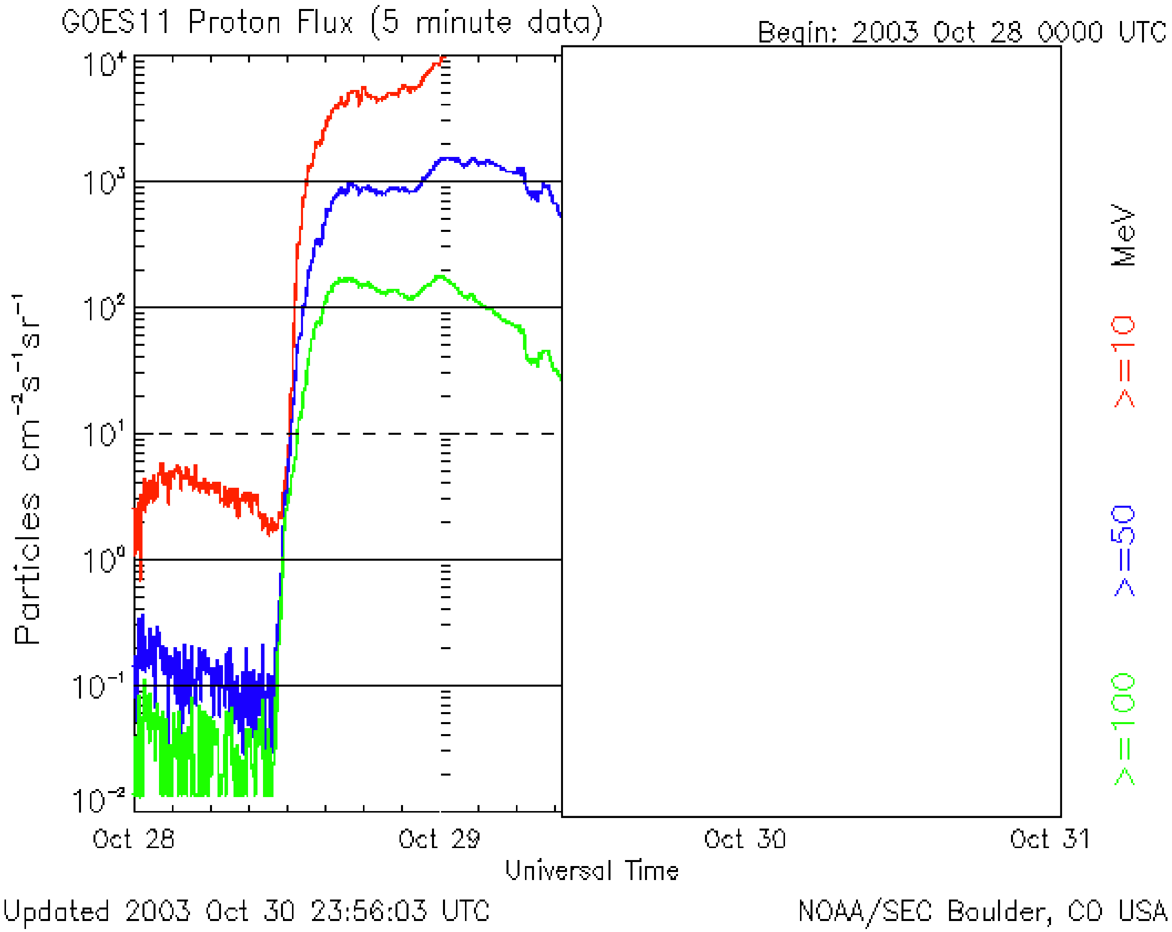

NOAA Space Weather Scale for Solar Radiation Storms

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Solar Radiation Storms			Flux level of >= 10 MeV particles (ions)*	Number of events when flux level was met (number of storm days**)
S5	Extreme	**Biological:** unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); high radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 100 chest x-rays) is possible. **Satellite operations:** satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. **Other systems:** complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S4	Severe	**Biological:** unavoidable radiation hazard to astronauts on EVA; elevated radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 10 chest x-rays) is possible. **Satellite operations:** may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. **Other systems:** blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S3	Strong	**Biological:** radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in commercial jets at high latitudes may receive low-level radiation exposure (approximately 1 chest x-ray). **Satellite operations:** single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. **Other systems:** degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S2	Moderate	**Biological:** none. **Satellite operations:** infrequent single-event upsets possible. **Other systems:** small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S1	Minor	**Biological:** none. **Satellite operations:** none. **Other systems:** minor impacts on HF radio in the polar regions.	10	50 per cycle

* Flux levels are 5 minute averages. Flux in particles·s^{-1}·$ster^{-1}$·cm^{-2}. Based on this measure, but other physical measures are also considered.
** These events can last more than one day.

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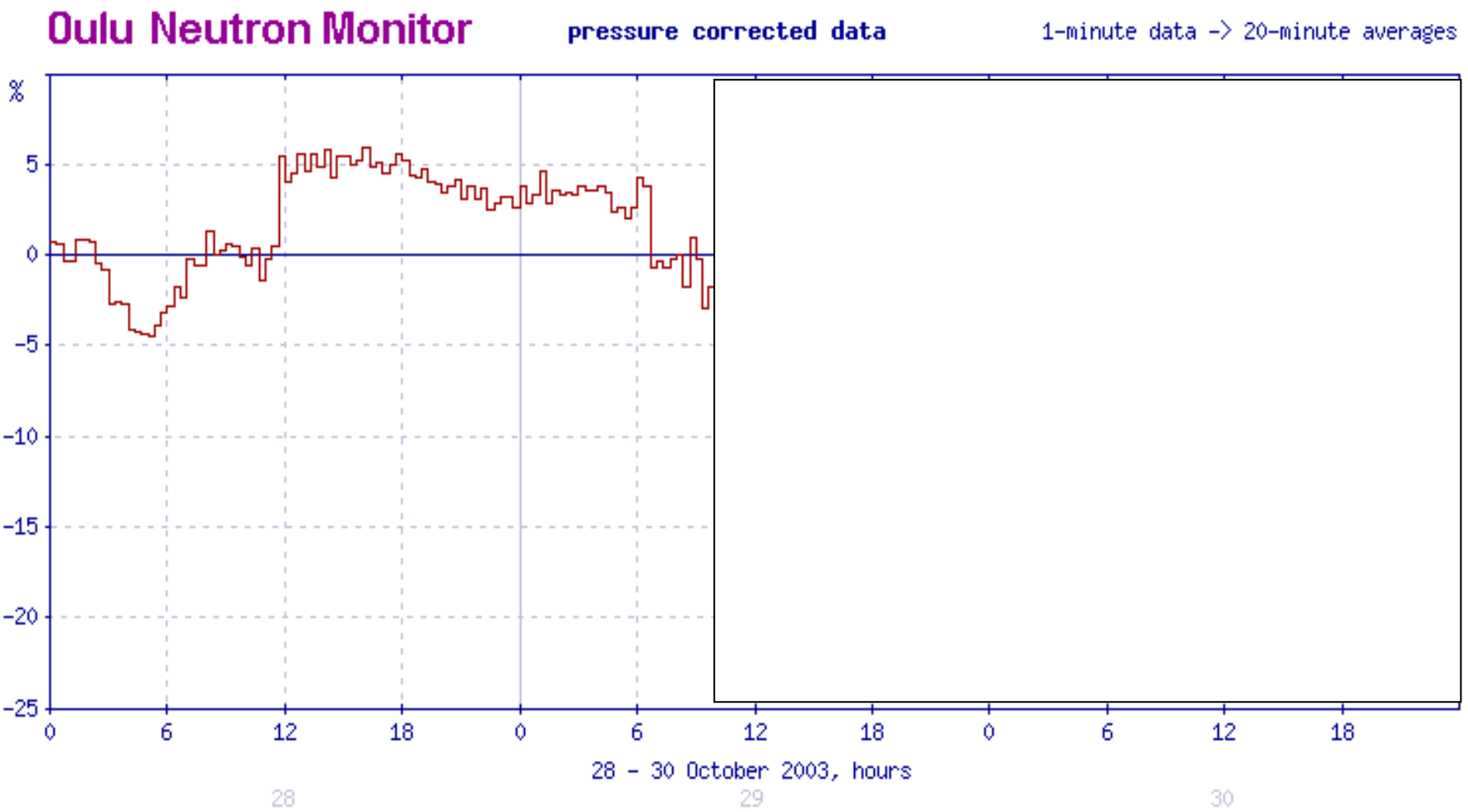

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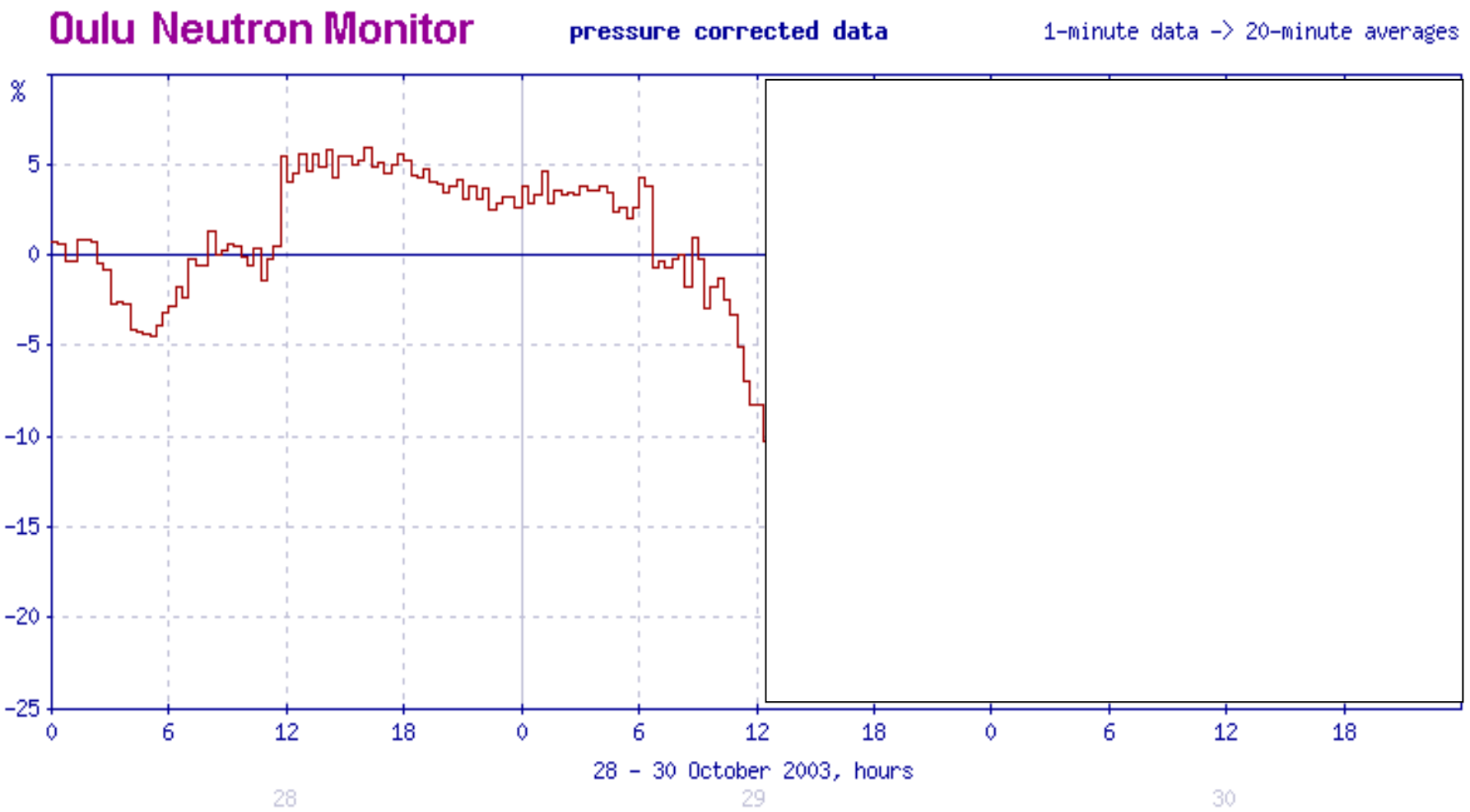

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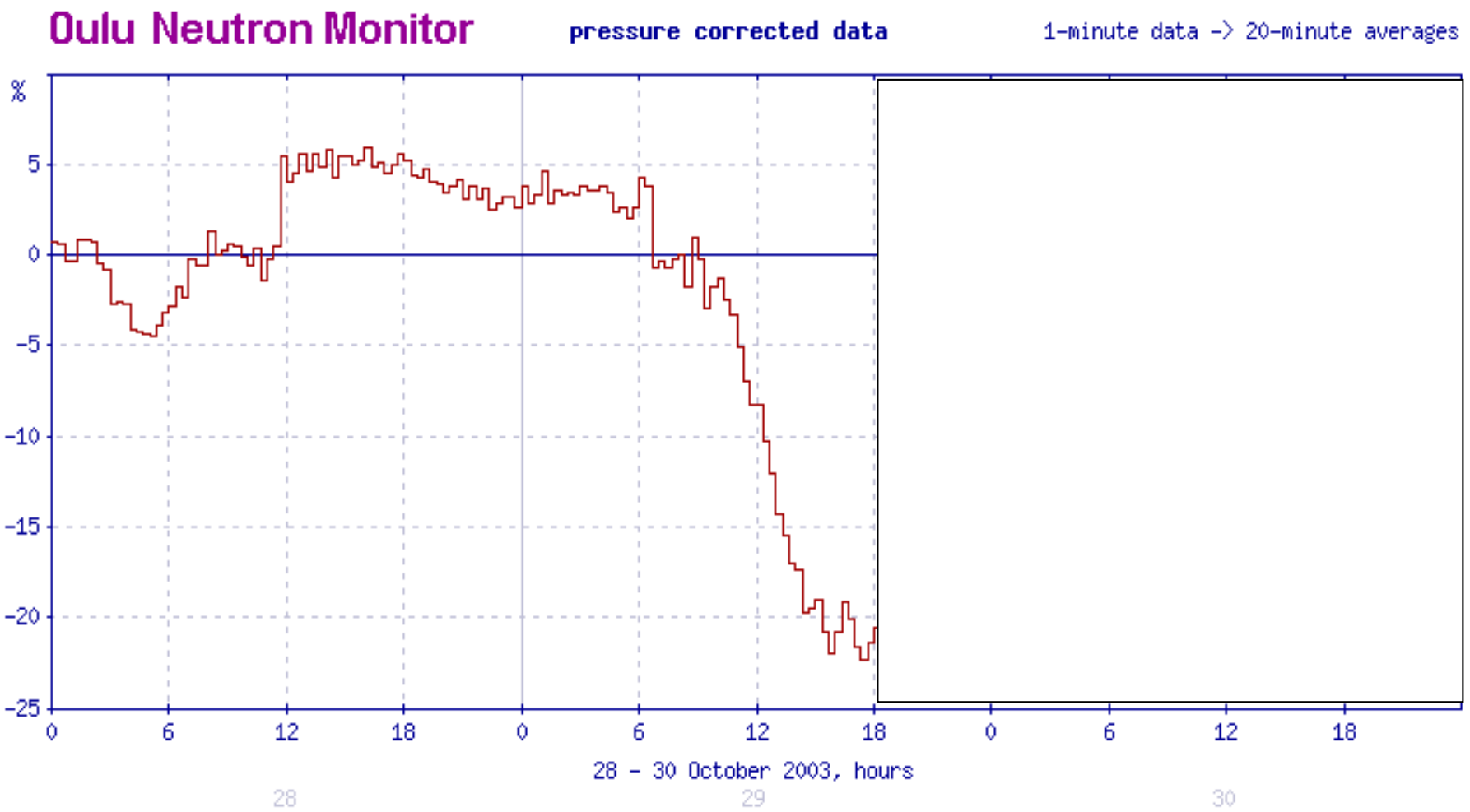

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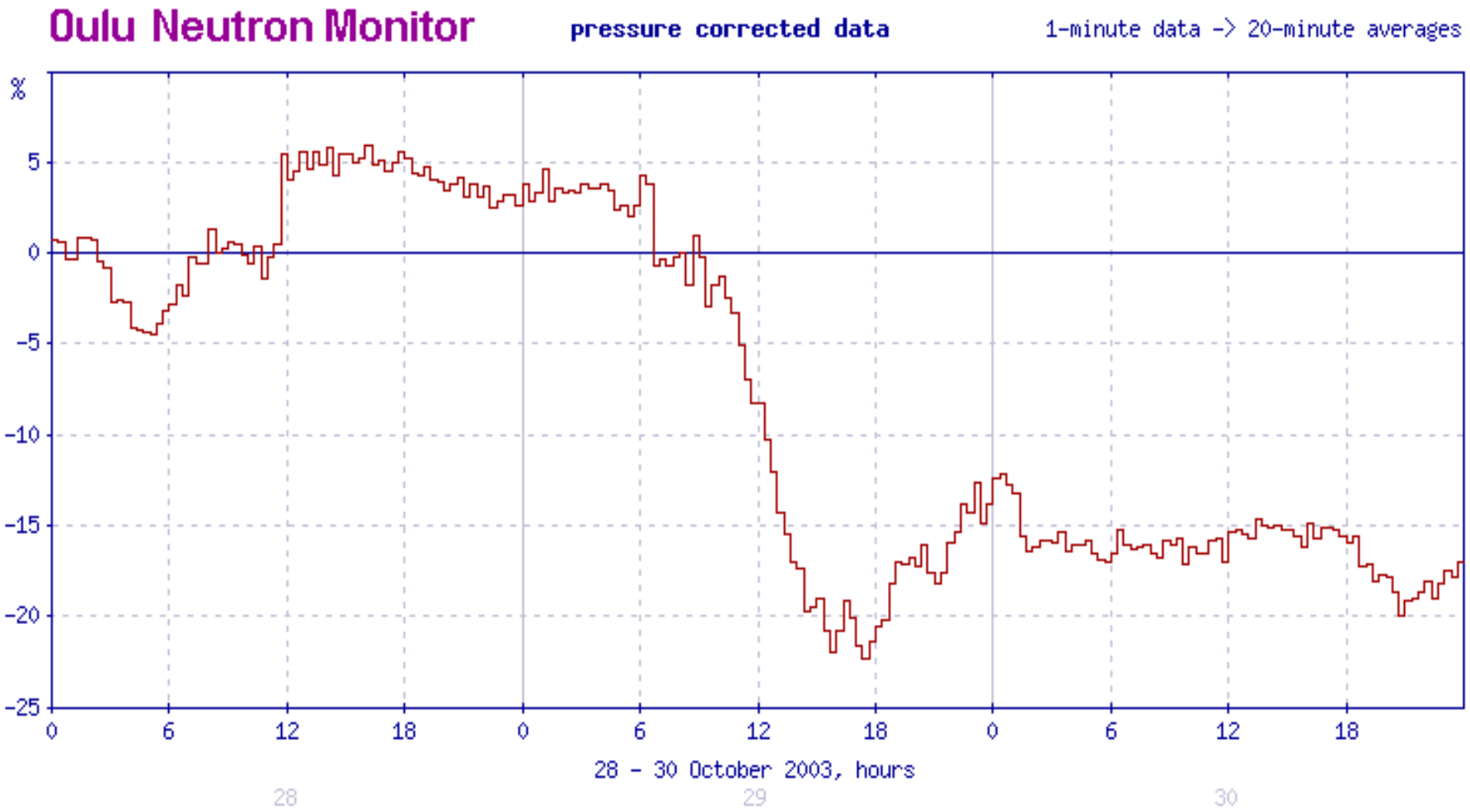

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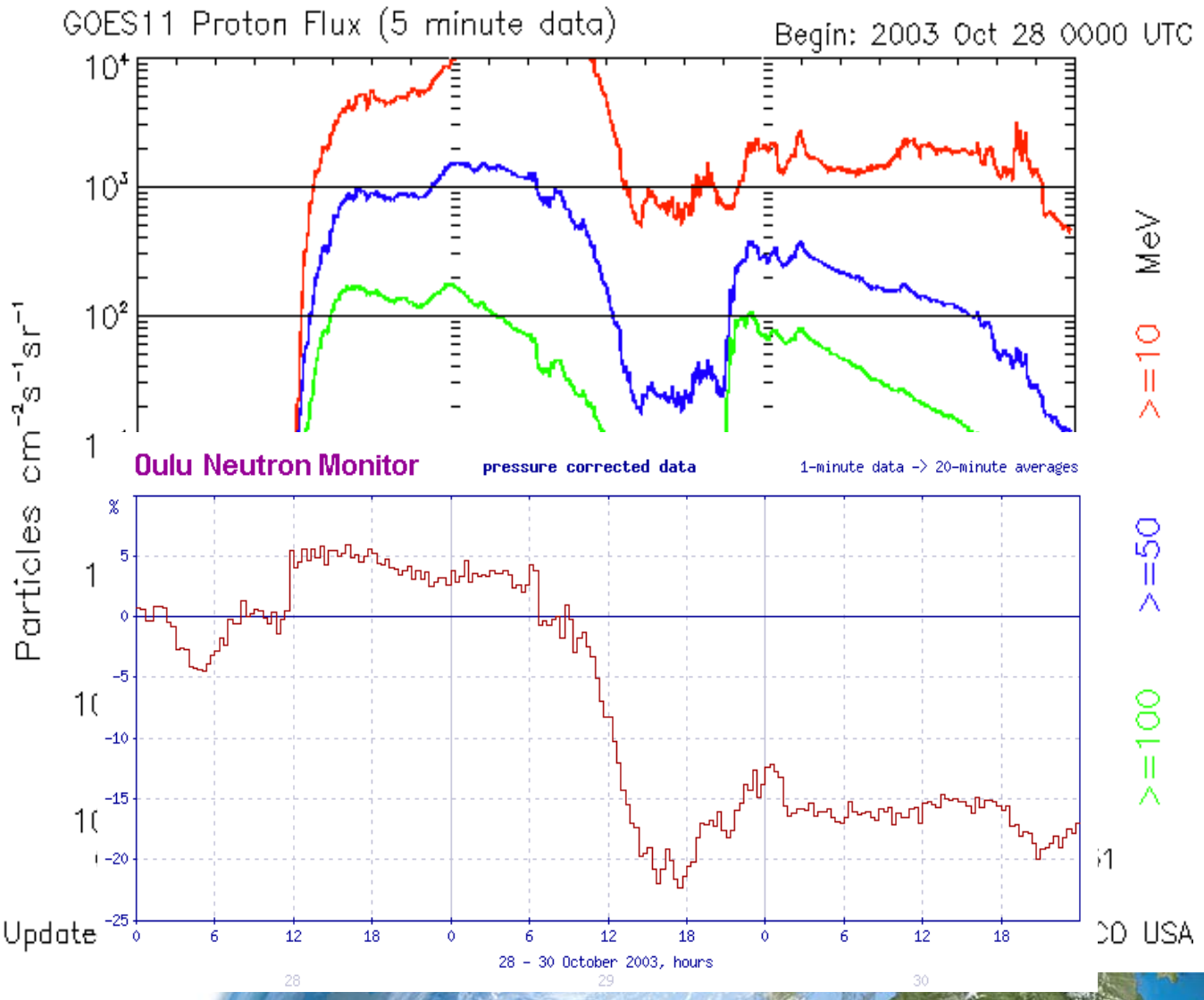
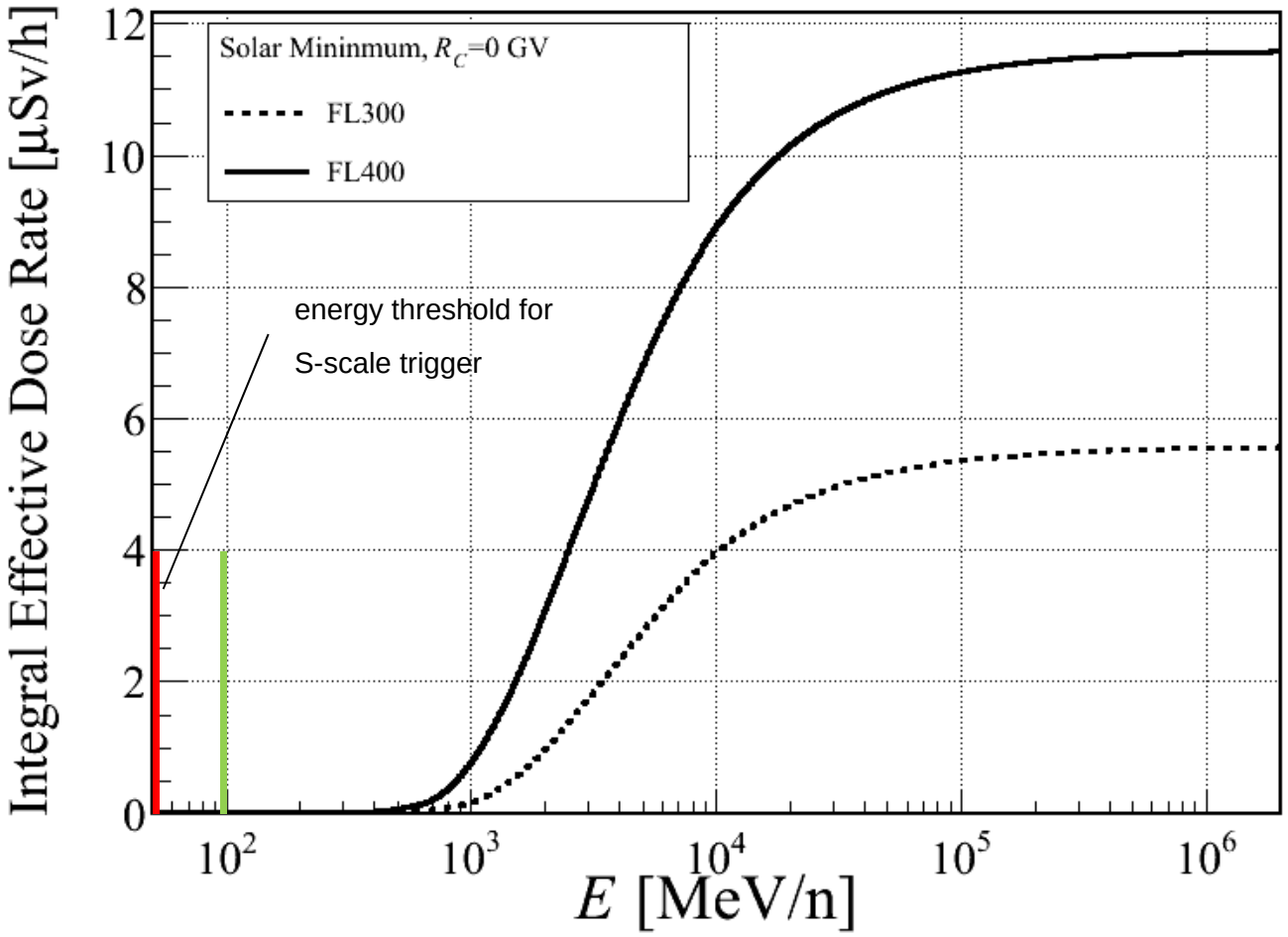


What energy is relevant (Simulation with PANDOCA)?



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Lessons learnt

- Significant increase in dose rates -> strong GLE (not GLE 65)
- Operational satellite data -> different scenario (lower energy)
- No operational ground based monitor available (up to now)
- No appropriate SWx scales & no coordinated action plan
- Incomplete information + public pressure = inappropriate reaction

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Mitigation

In order to mitigate radiation exposure in case of GLEs, we could

- delay a flight (avoidance, temporal profile)
- increase atmospheric shielding (altitude, coordinated)
- increase geomagnetic shielding (reroute a flight, if possible)

- assess the dose & inform correspondingly (crew, public, etc.)

Prerequisites for Mitigation Measures

☹ Slow event (temporal profile)

😐 Fast detection of a warning situation

☺ Operational procedures

Temporal profile of GLEs

Threshold:

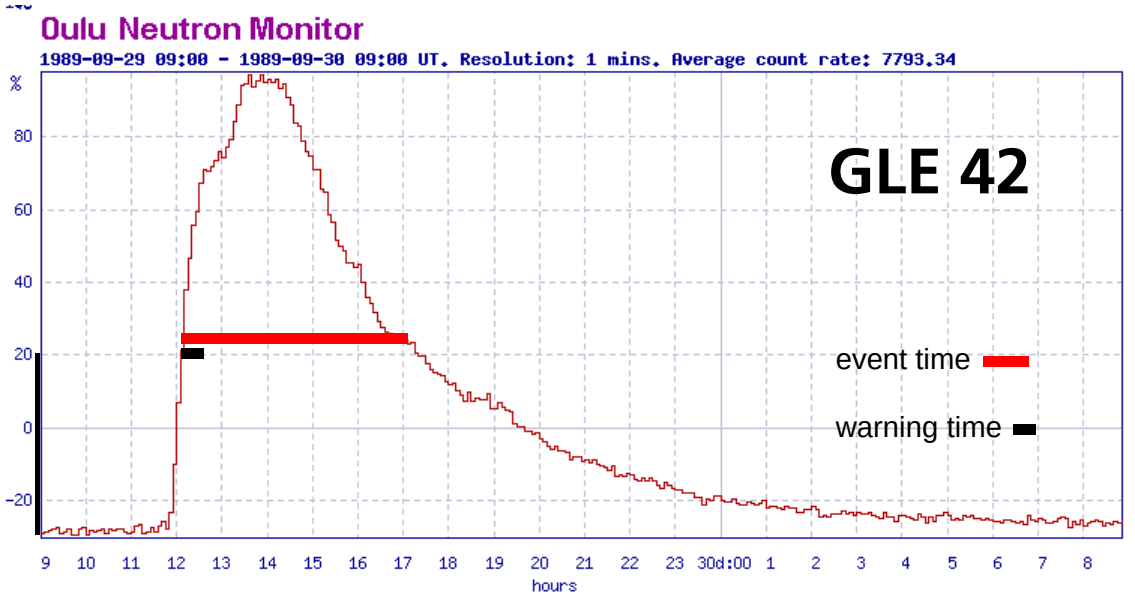
50% increase

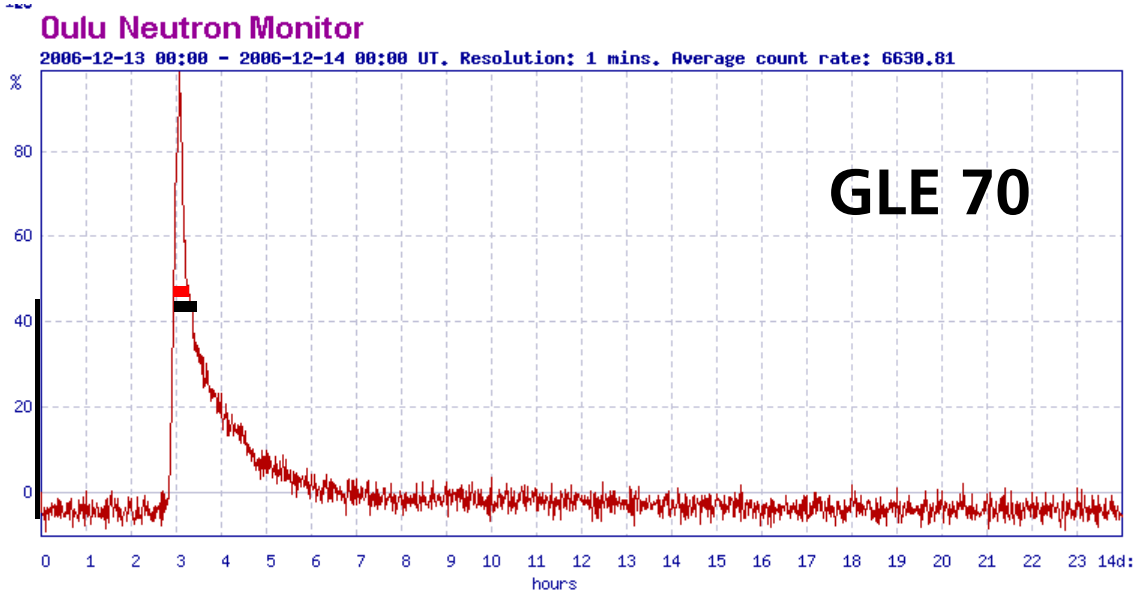
Warning time:

approx. 30 min

Mitigation:

$t_{event} > t_{warn}$





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Summary

- In the EU aircrew members are legally treated as radiation workers.
- Solar Particle Events (SPEs) can cause temporary increases in radiation exposure at aviation altitudes as a function of the corresponding energy spectrum.
- SPEs with a significant high energy component are still **unpredictable !!!**
- Mitigation measures are in principle possible under certain circumstances and have to be based on nowcasts.
- International coordination in case of a significant Solar Particle Event (SPE) is highly recommended.

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Discussion

‘Io e te, sotto lo stesso cielo
Insieme, unite, unite, Europe.’

Toto Cutugno

(Winner of the Eurovision Song Contest in 1990)

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