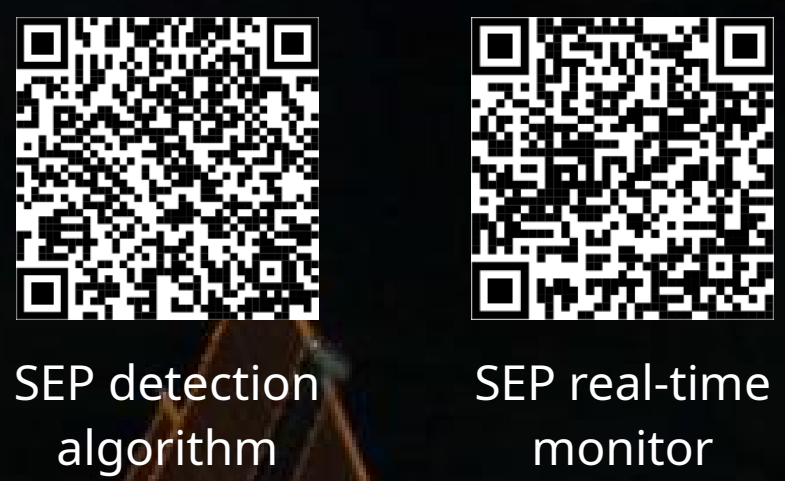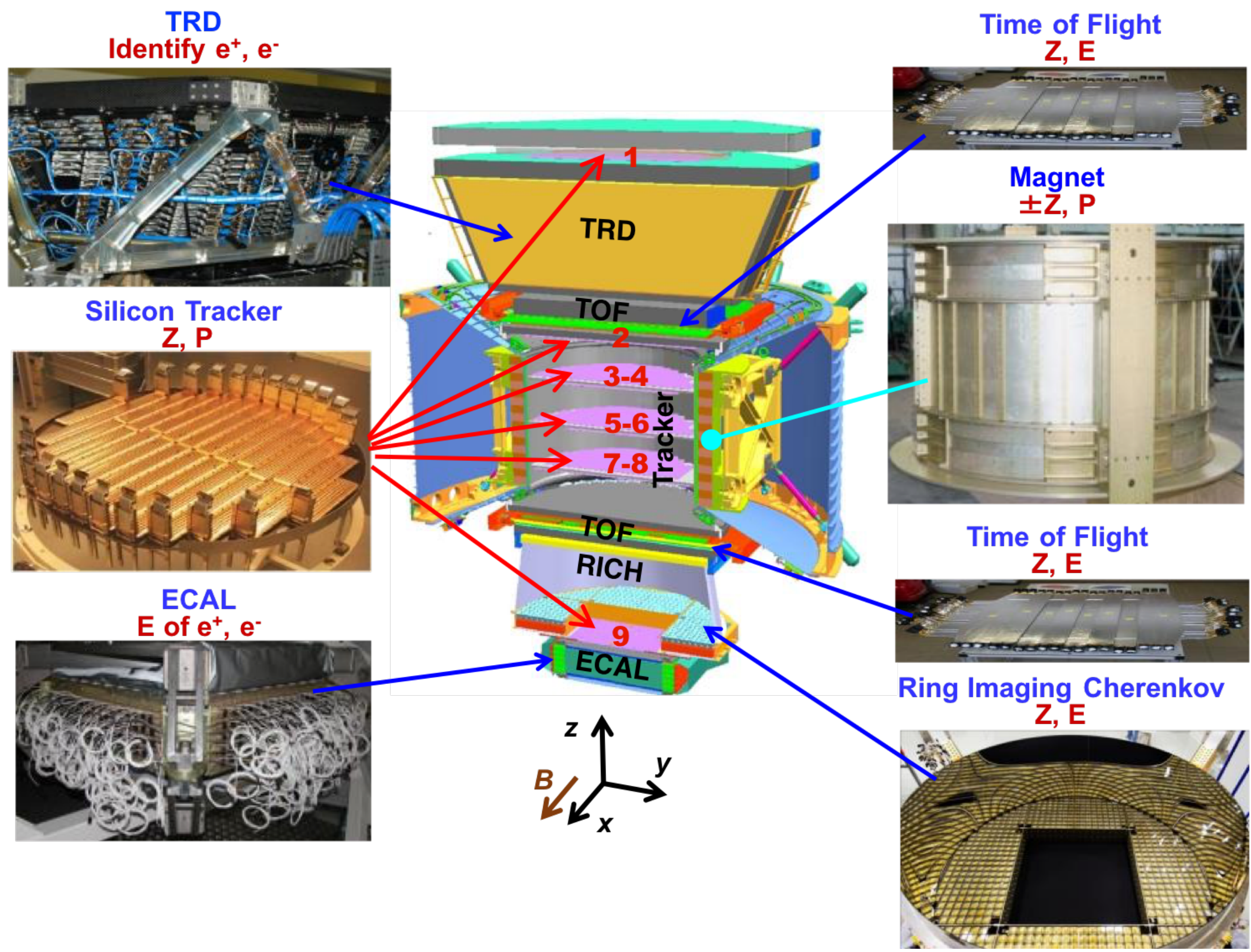# Real-time monitoring of Solar Energetic Particles using Alpha Magnetic Spectrometer on the International Space Station

Andrea Serpolla

1 Alpha Magnetic Spectrometer 02 (AMS-02)

AMS-02 is a **modern particle physics detector** that measures Cosmic Rays flux and composition **on the ISS since May 2011**.
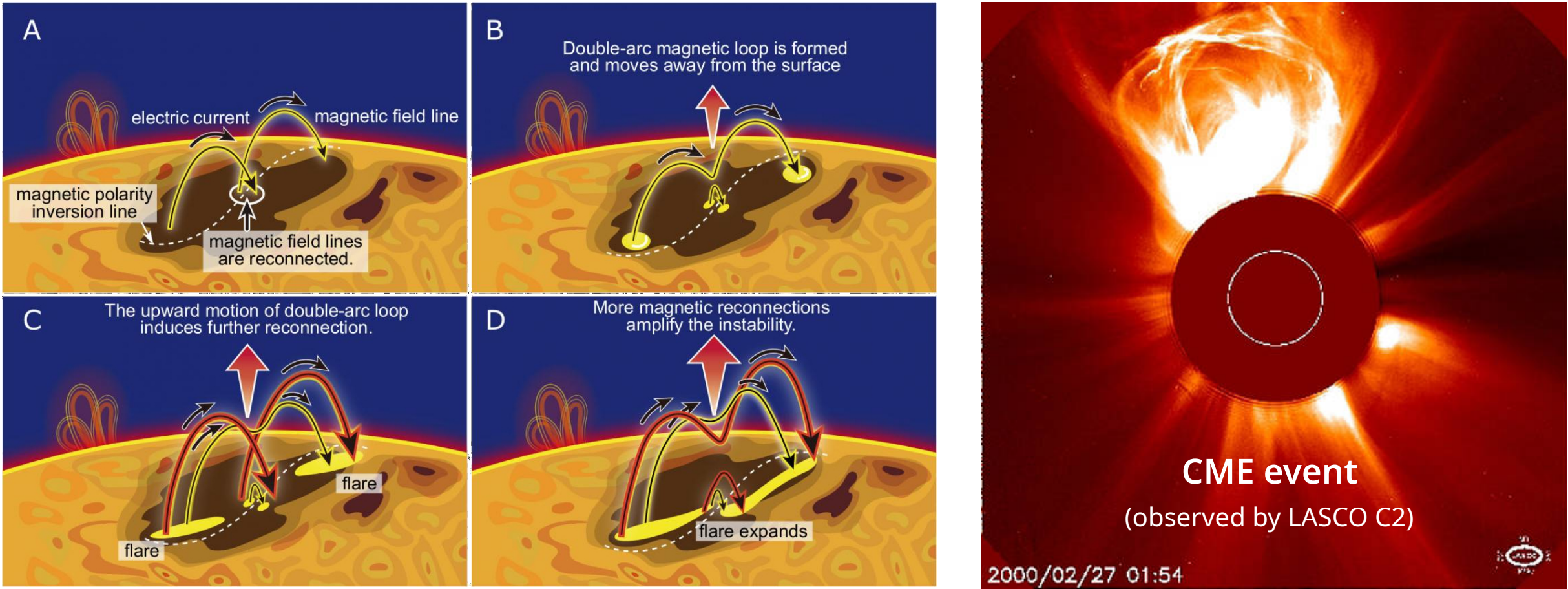
AMS **trigger rates** can be used **to detect SEP** in real-time.

The instrument produces a **fast trigger (FT)** and a **level 1 trigger (LV1)**; only the latter is used for scientific data acquisition.

AMS makes use of a custom monitoring interface, the **AMS monitoring interface (AMI)**, where all data is stored.

2 Solar Energetic Particles (SEP)

SEP events can last for hours or days, releasing in space **mostly protons** with energies **from ~ 10 keV up to several GeV**.

Reconnections of solar magnetic field lines and **coronal mass ejections** originate respectively *impulsive* and *long-duration* events.

3 Action of the geomagnetic field

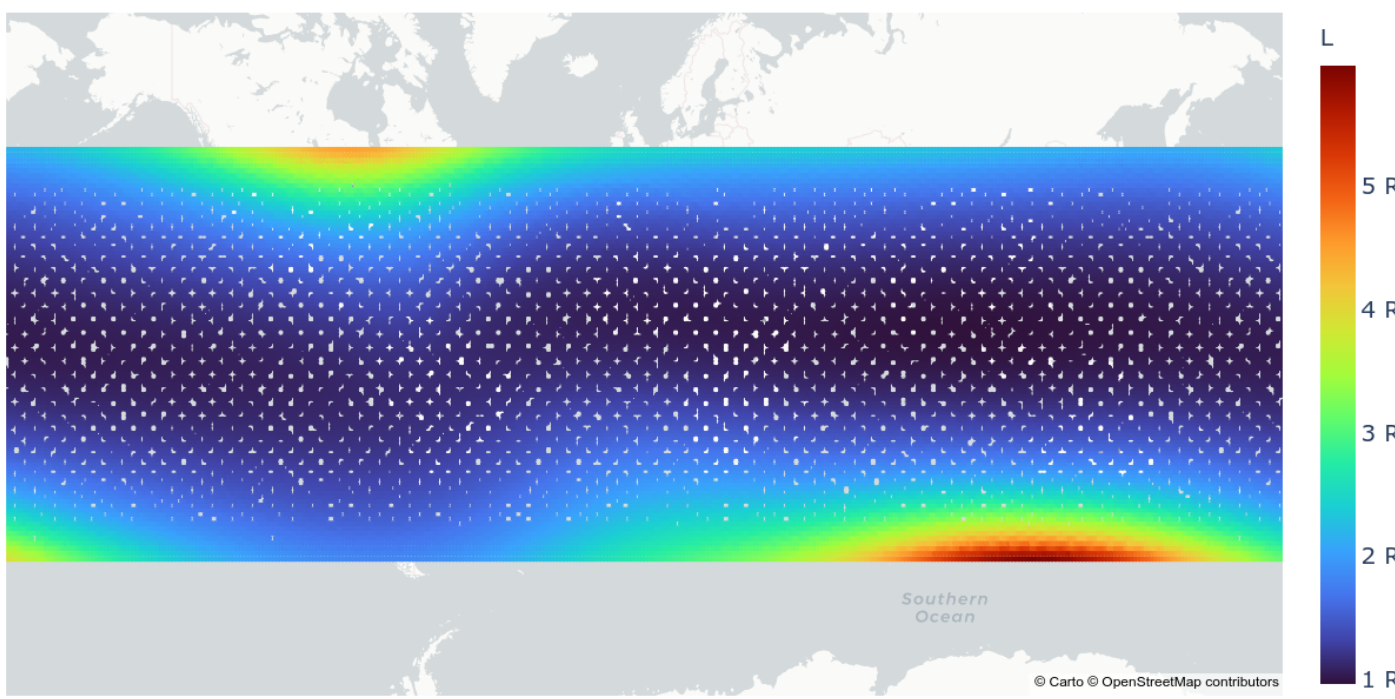The **rigidity** of a particle in a magnetic field is defined as

$$R = pc/q = B\rho$$

Within the geomagnetic field, a **rigidity cutoff R_C** can be defined as the **minimum rigidity value measurable**.

The **McIlwain's L-parameter** is related to R_C as
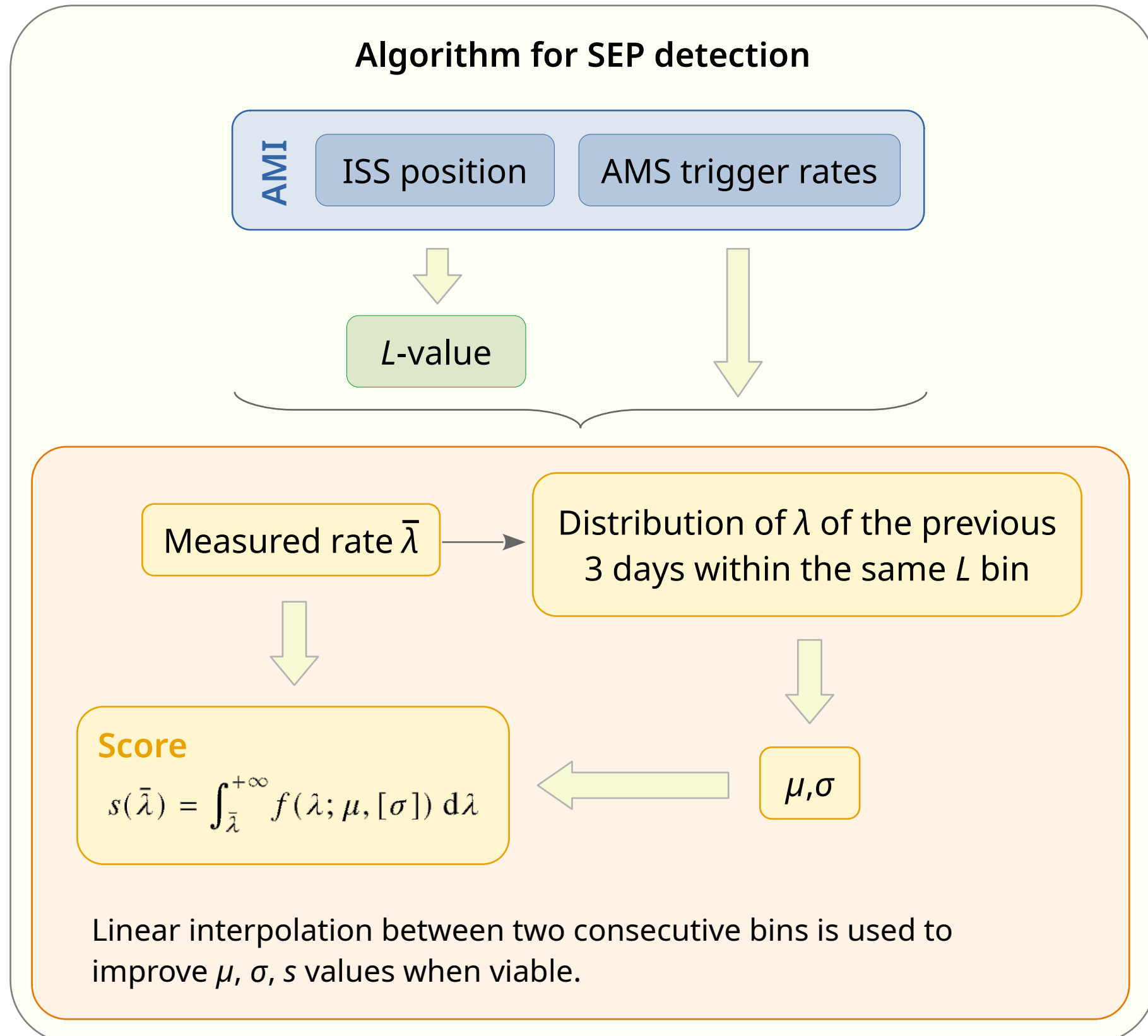
$$\frac{L}{R_{\text{Earth}}} = \sqrt{\frac{k}{R_C}}$$

with $k \sim 16$ GV.
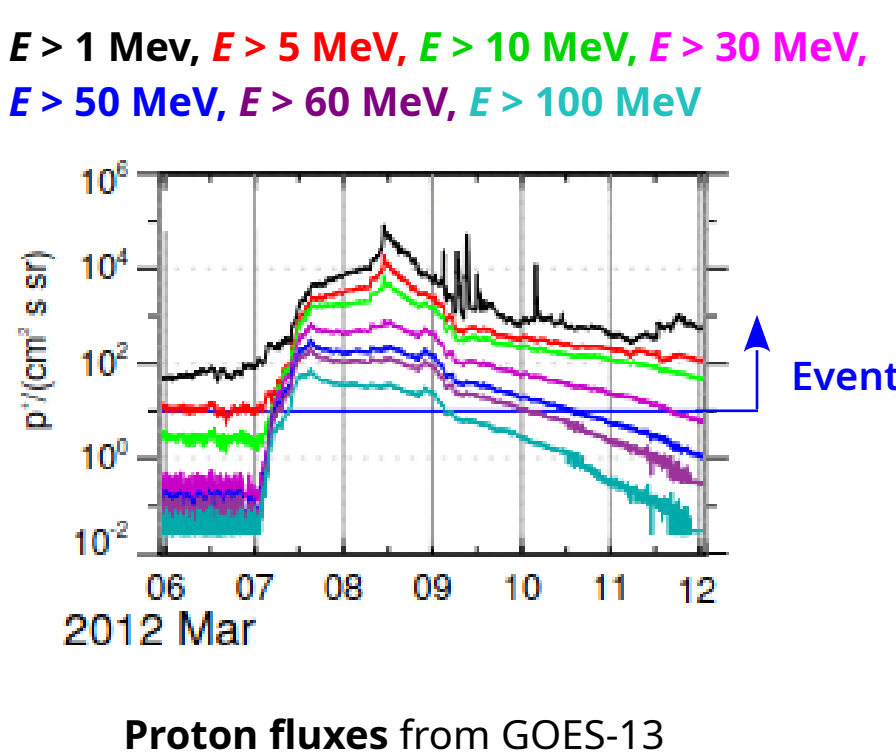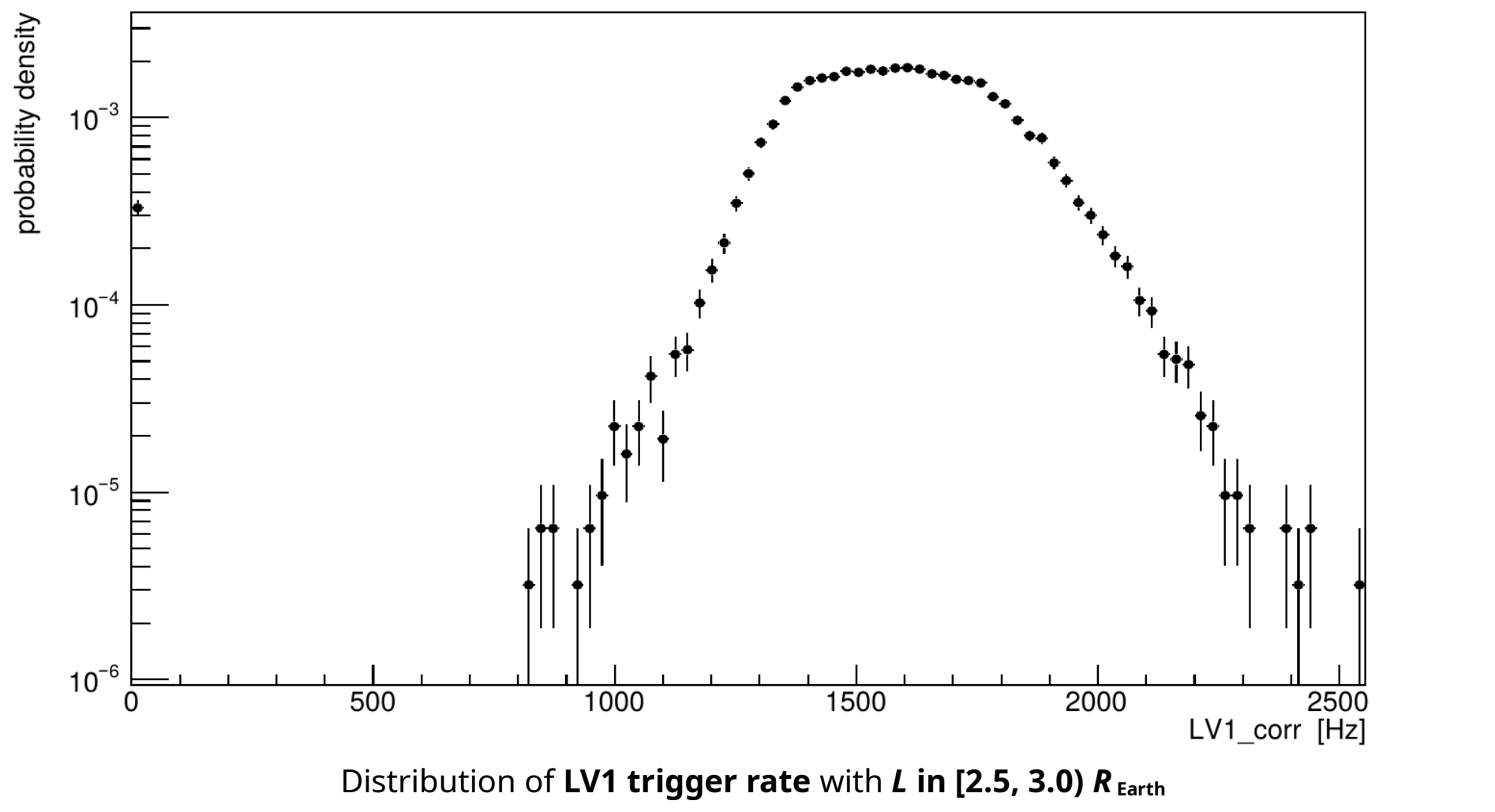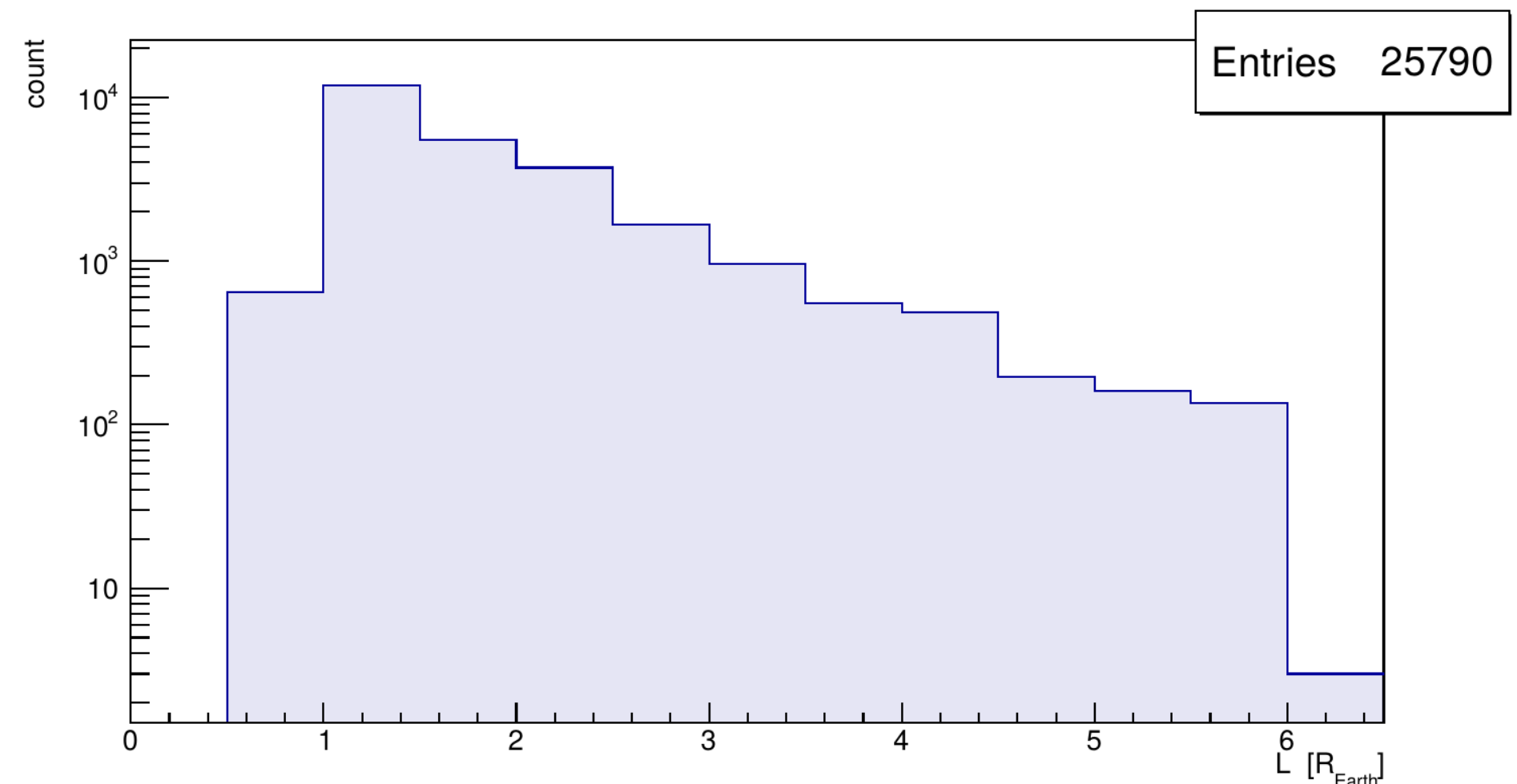

L-values crossed by ISS orbits in 1 month

4 SEP detection

Algorithm for SEP detection

AMI → ISS position, AMS trigger rates

→ L-value

Measured rate $\bar{\lambda}$ ← Distribution of λ of the previous 3 days within the same L bin → μ, σ

Score
$$s(\bar{\lambda}) = \int_{\bar{\lambda}}^{+\infty} f(\lambda; \mu, [\sigma]) \, d\lambda$$

Linear interpolation between two consecutive bins is used to improve μ, σ, s values when viable.

AMS activity increases with the **L-value**, which is used to separate different **nominal conditions**.

Trigger rates are **normally or Poissonianly distributed**.

Intense **SEP events** produce increments in AMS trigger rates, that lower the **score towards 0**.

L bins statistics for 3 days of ISS positions

Distribution of **LV1 trigger rate** with L in [2.5, 3.0) R_{Earth}

$E > 1$ Mev, $E > 5$ MeV, $E > 10$ MeV, $E > 30$ MeV, $E > 50$ MeV, $E > 60$ MeV, $E > 100$ MeV

A **SEP event** took place at the beginning of **March 2012**:
- CME *Halo /07 0036*;
- flare *X5.7/3B*.

Proton fluxes from GOES-13

Score time-series of **LV1 trigger rate** during a **SEP event** (March 2012). Cuts have been applied on L-value, geomagnetic field intensity, AMS zenith angle and on age of ISS position and orientation data to reject background. Cuts are listed in detail in the next panel as members of the alert conditions.

5 SEP real-time monitoring

Two sources of delays affect data storage in AMI database:
- **AMI feeder** stores data every **1 minute**;
- **ISS can lose connection** with the ground for **20–30 minutes**.

The real-time monitoring implements a **series of fillers** that use **different delays** for their **requests to AMI**; fillers with a **higher delay overwrite** data processed previously by fillers with a **lower delay**.

Data requests efficiency **with different delays** (delay of 1h used as reference)

Monitor data

Delays used by the **fillers of the real-time monitor** for their **requests to AMI**.

ALERT CONDITIONS

score $\leq 10^{-6}$
geomagnetic field intensity ≥ 25 µT
AMS zenith angle $\leq 15°$
age of ISS position ≤ 10 s
age of ISS flight orientation ≤ 1 min
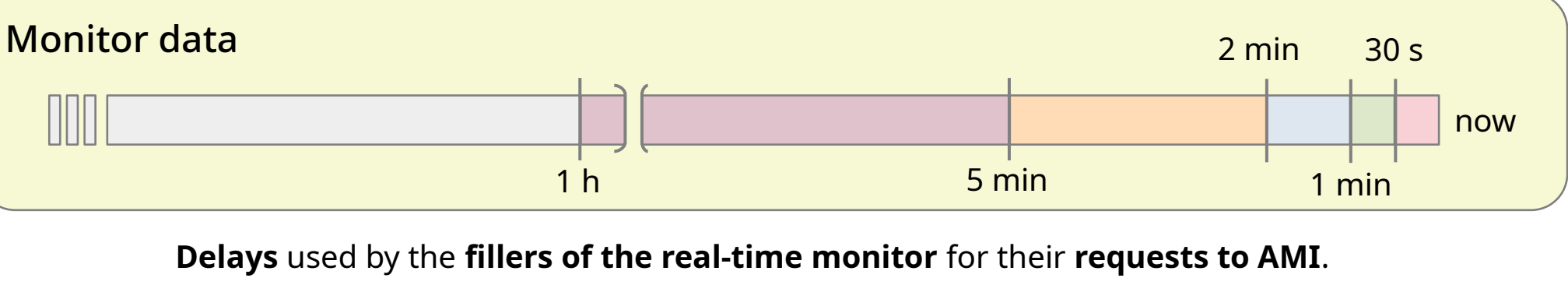
Geomagnetic field intensity is used to **exclude data collected in the South-Atlantic Anomaly (SAA)**.

ISS flight orientation (i.e. yaw, pitch and roll angles), retrievable on AMI, is used **to calculate AMS zenith**.

AMS zenith is used to **reject** the detection of **particles trapped along the geomagnetic field lines**.

Ages of ISS position and orientation measurements are used to **exclude data** with an **outdated information**.

Alerts are **evaluated every 10 s**, on **data between 70–60 s ago**.