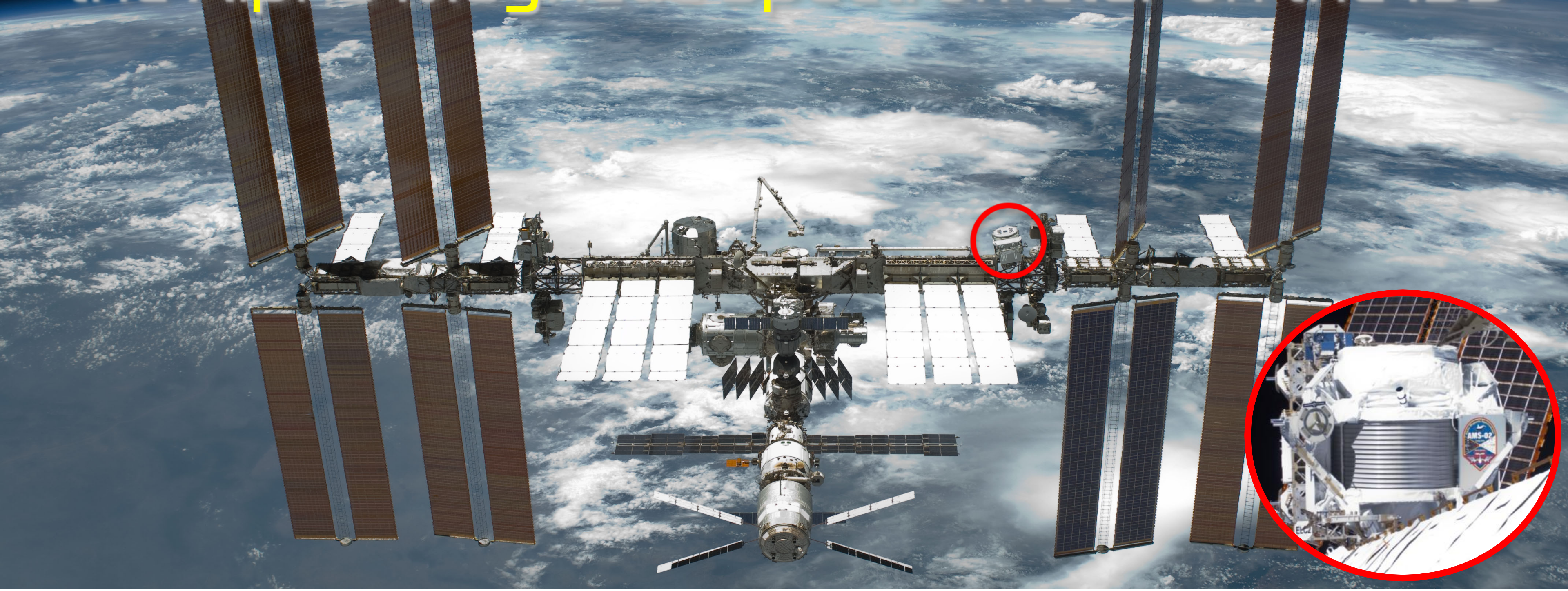
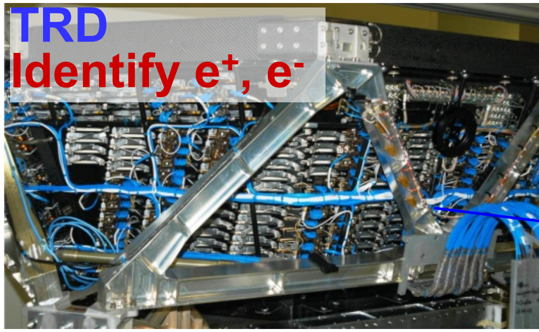
Observation of Complex Time Structures in the Cosmic-Ray Electron and Positron Fluxes by the Alpha Magnetic Spectrometer on the ISS

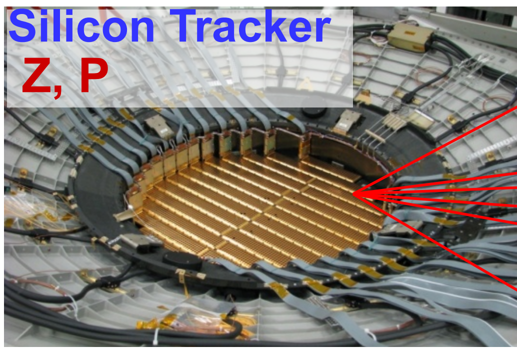


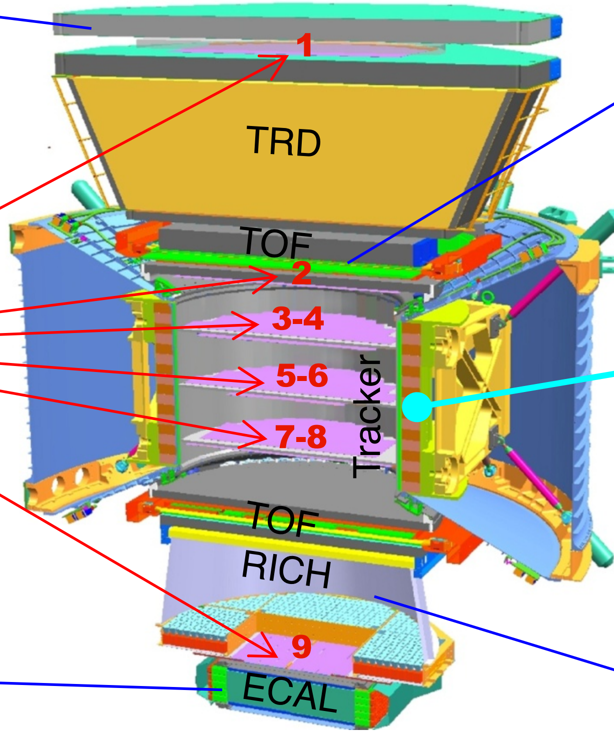
Matteo Duranti
INFN Sez. Perugia
on behalf of the AMS Collaboration

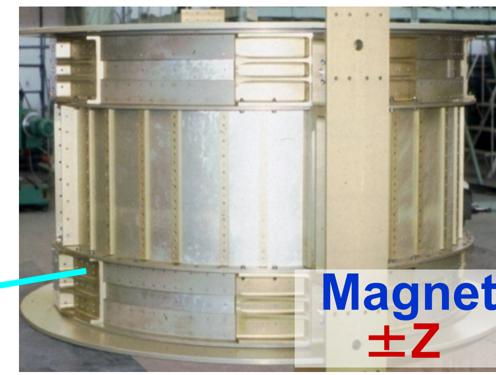
A precision, multipurpose, up to TeV spectrometer

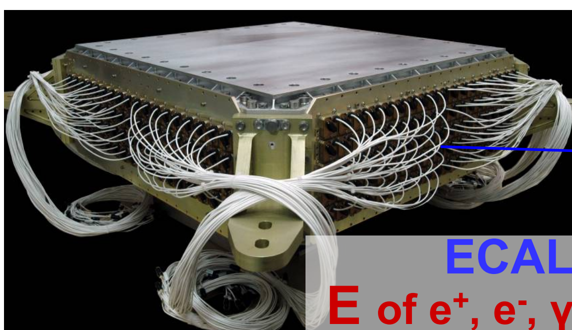


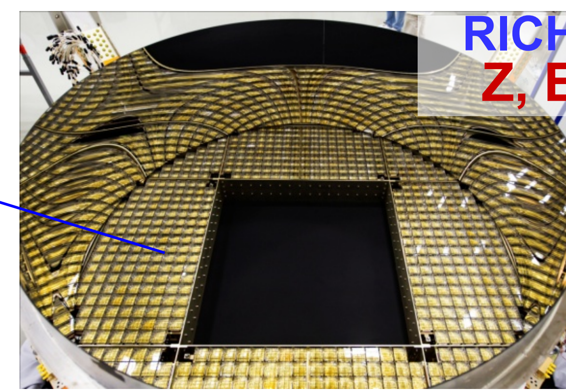
Z, P are measured independently by the Tracker, RICH, TOF and ECAL











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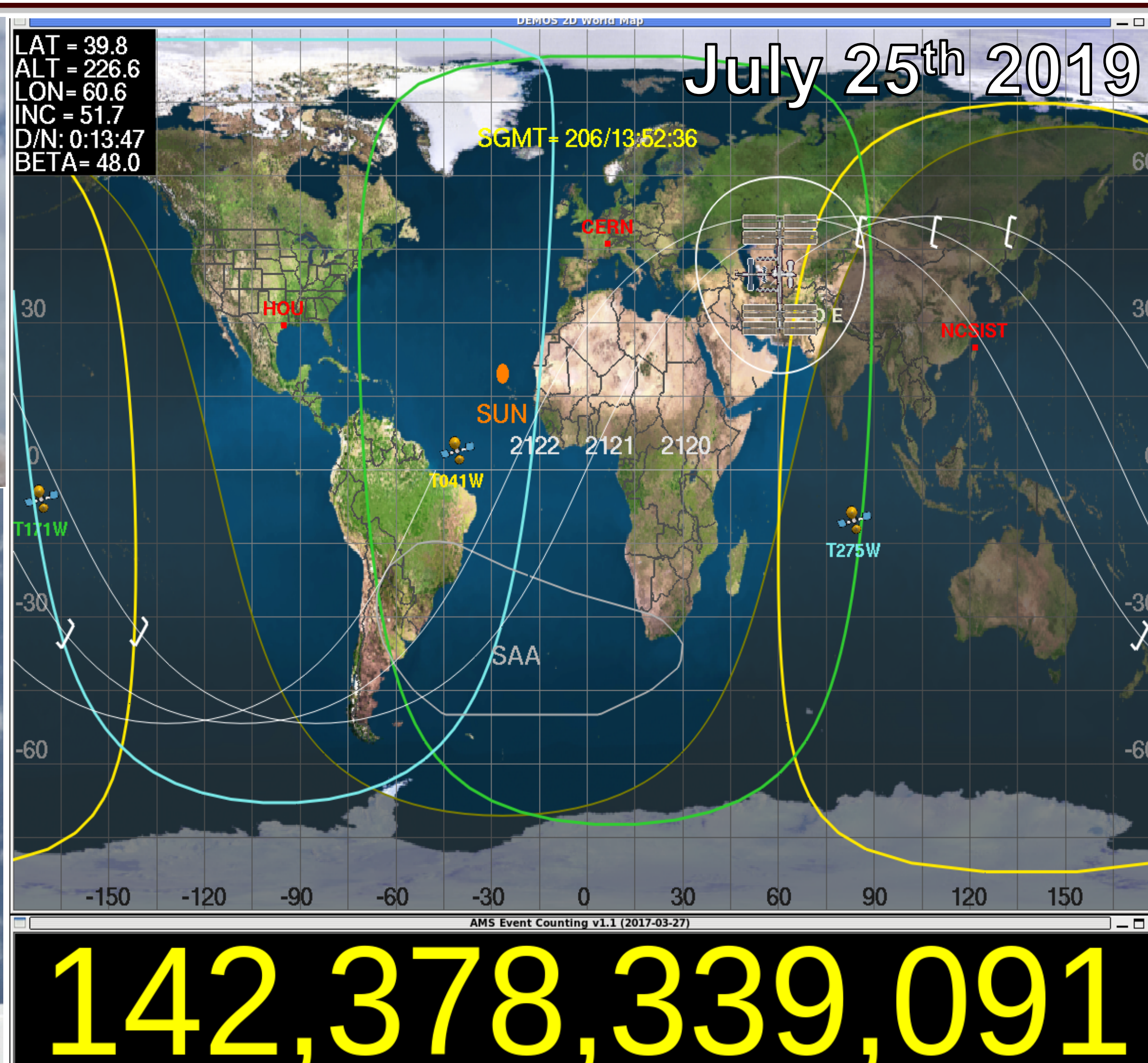

Key requirements

In the e^+, e^- measurement, the key requirements of the detector/experiment are:

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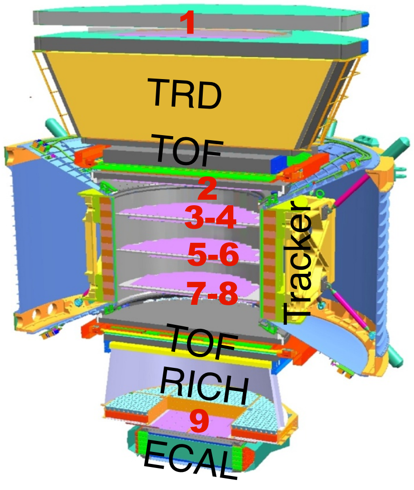
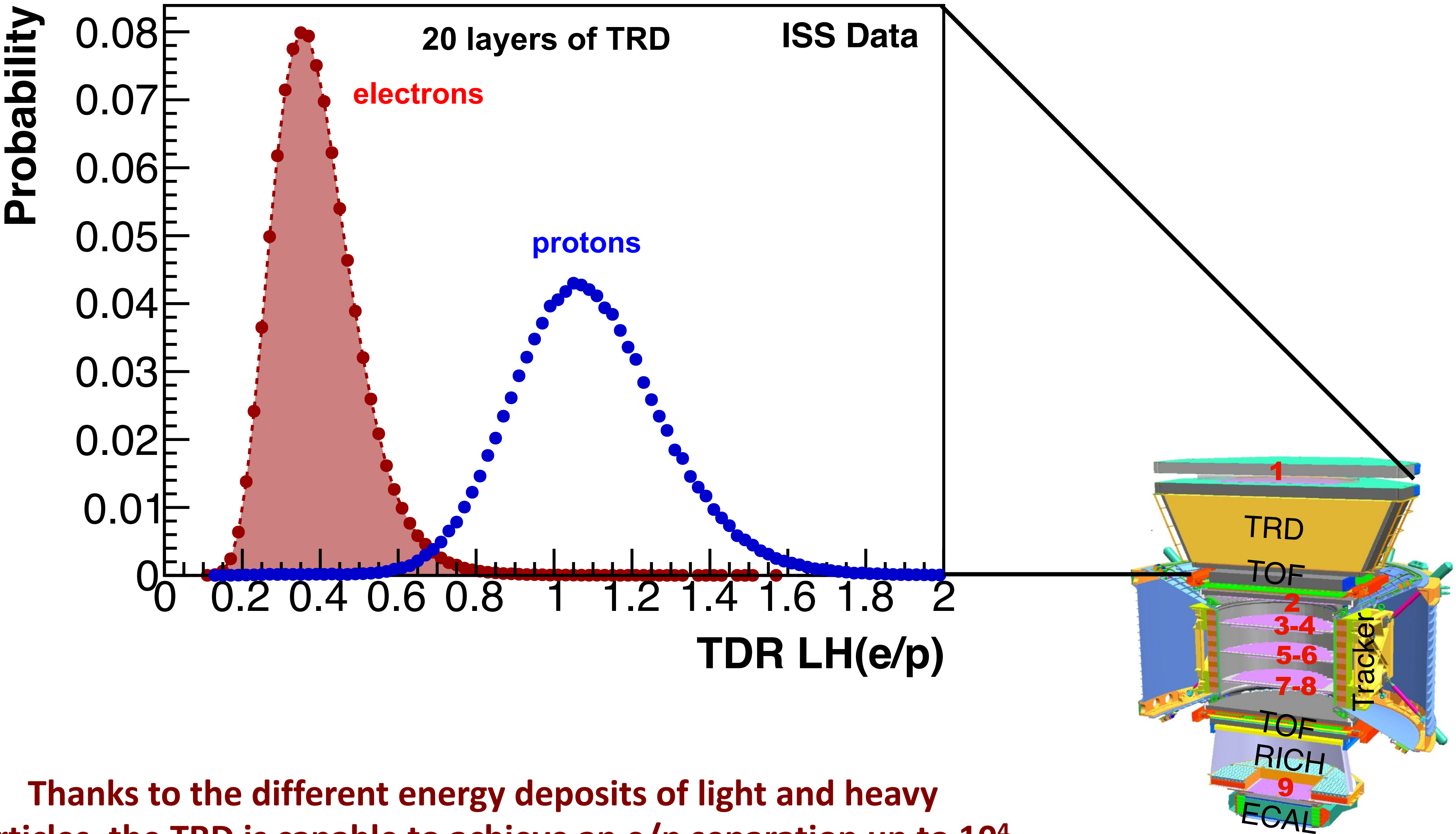
⇨ Redundancy and Complementarity!



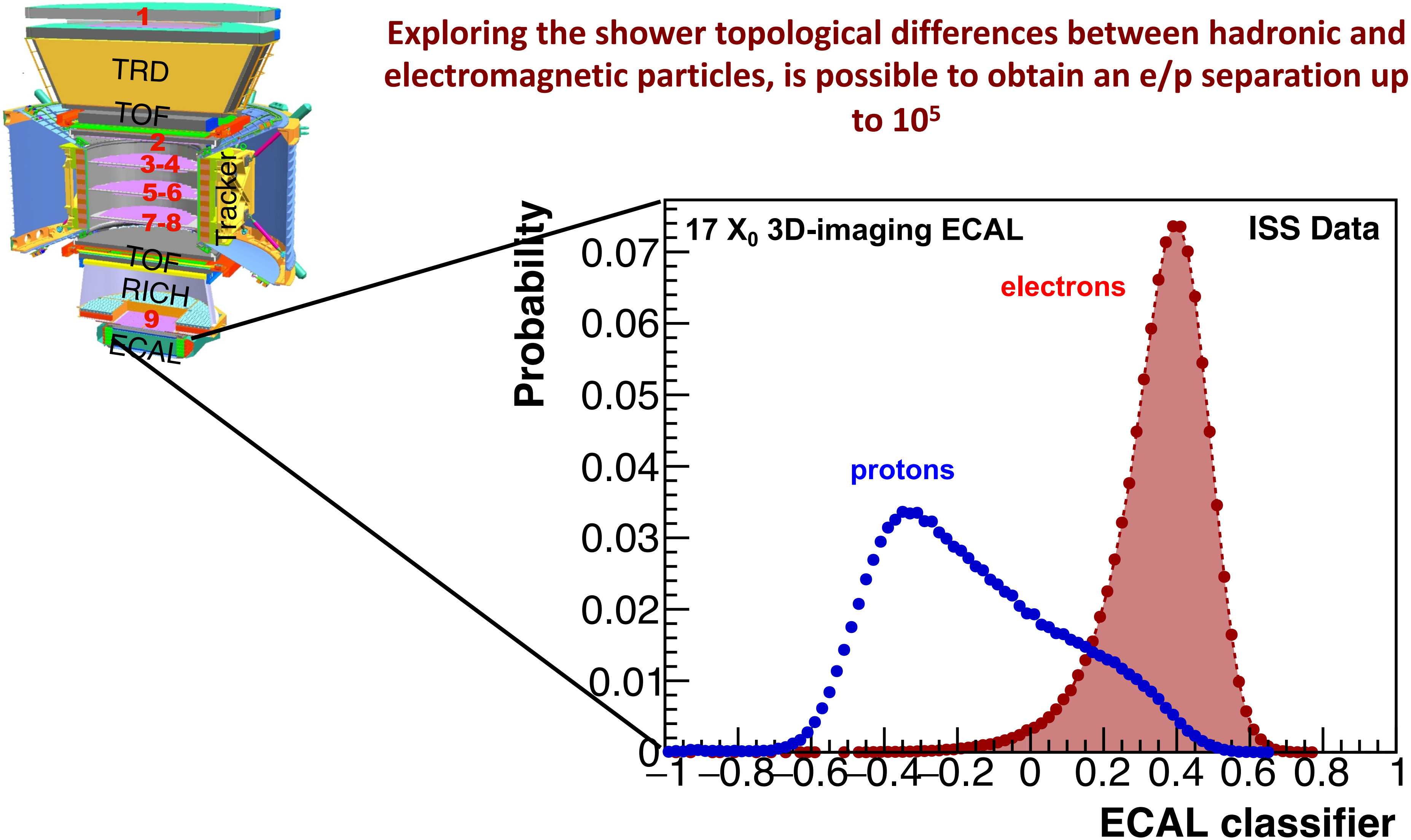
e/p separation: TRD



Thanks to the different energy deposits of light and heavy particles, the TRD is capable to achieve an e/p separation up to 10^4

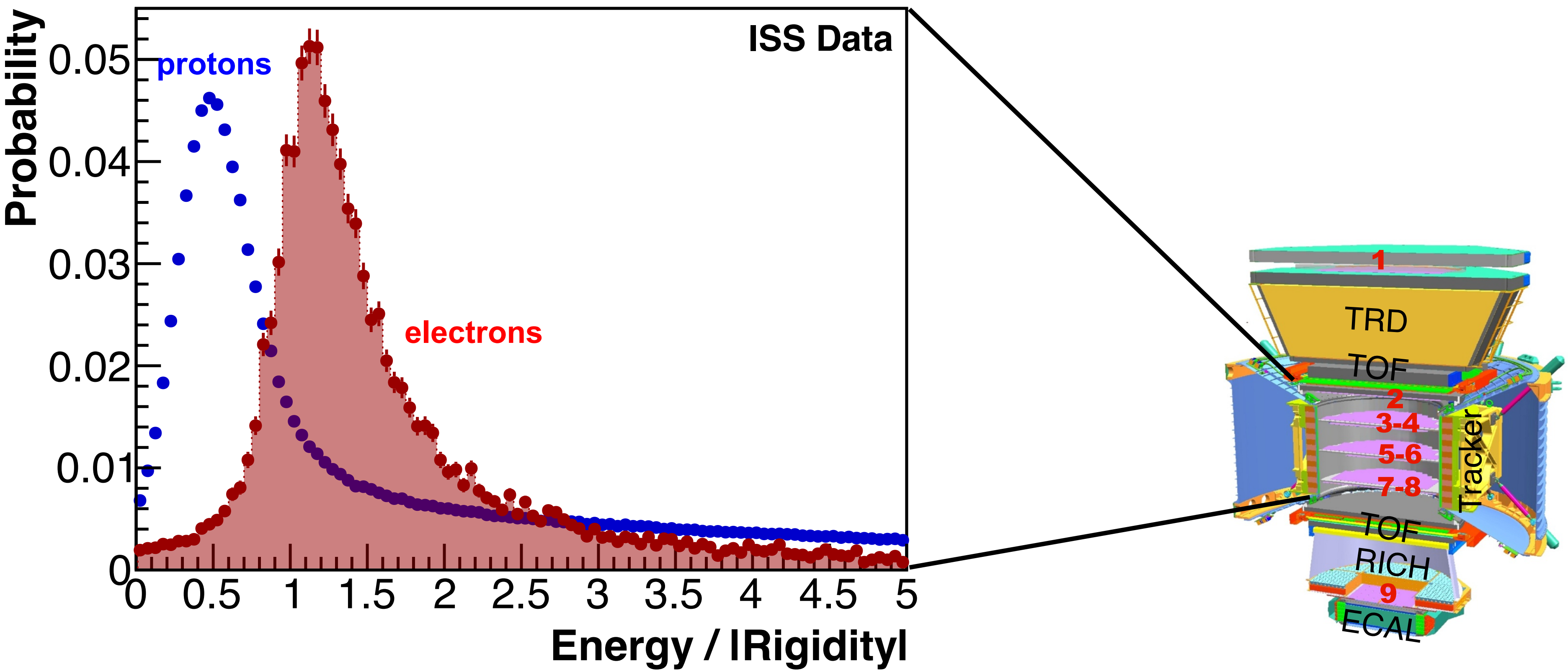
e/p separation: ECAL

Exploring the shower topological differences between hadronic and electromagnetic particles, is possible to obtain an e/p separation up to 10^5

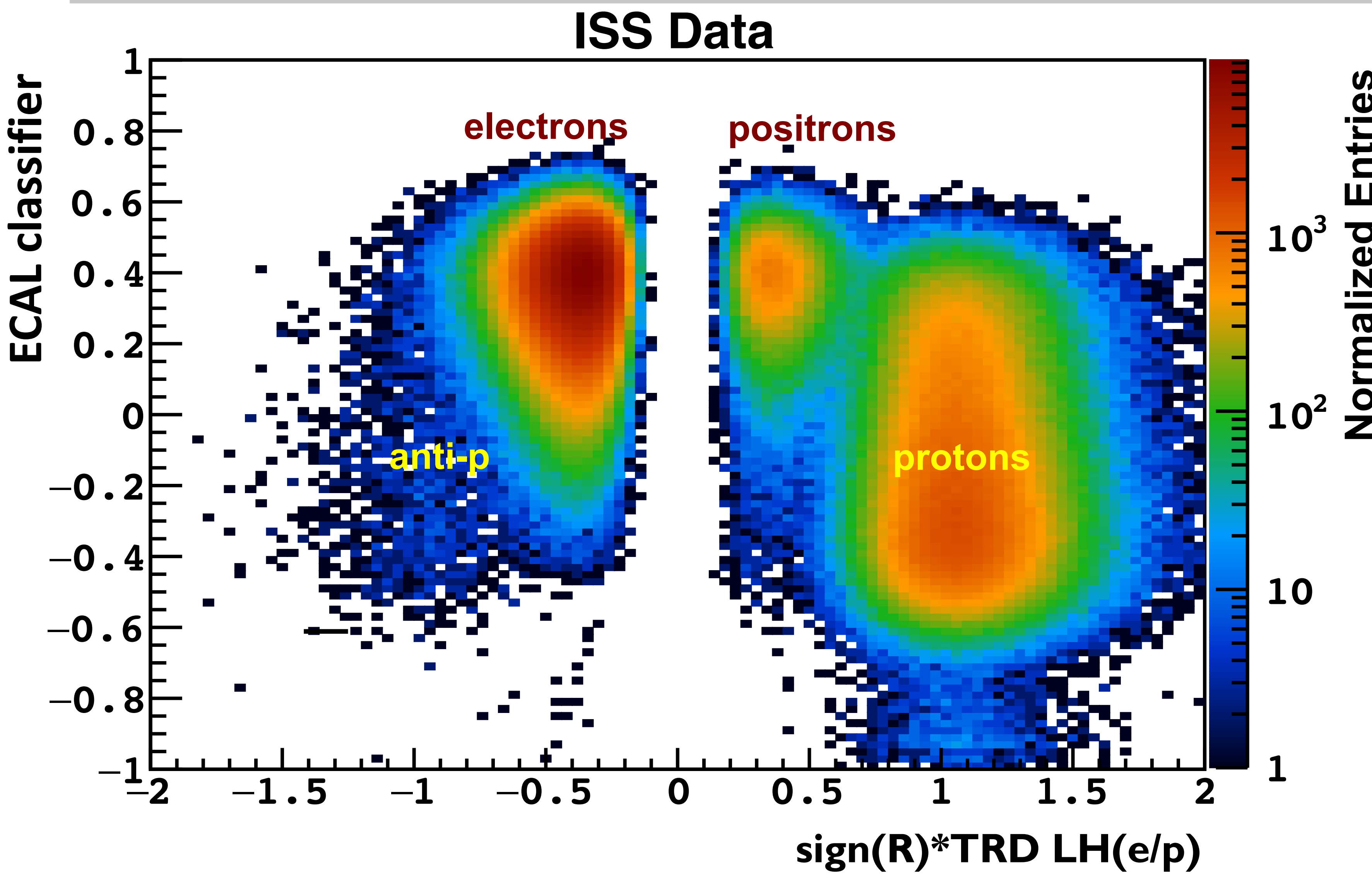


e/p separation: Tracker+ECAL

Comparing the Energy measurement by the ECAL to the Rigidity one by the Tracker is possible to discriminate electromagnetic and hadronic particles. Given the natural abundances of p^+, p^-, e^- and e^+, even a selection only based on the <u>sign of the Rigidity</u> is possible to obtain quite pure sample of p^+ and e^-

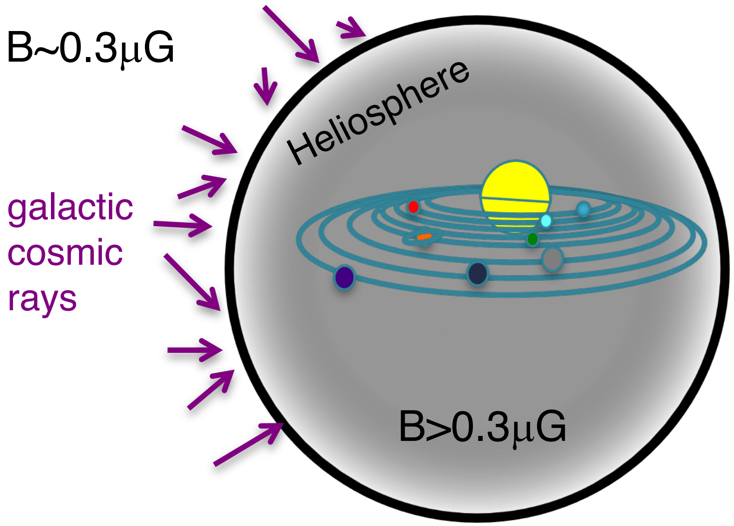


e/p separation: redundancy and complementarity



Solar modulation and e^+,e^-

Solar modulation of Cosmic Rays

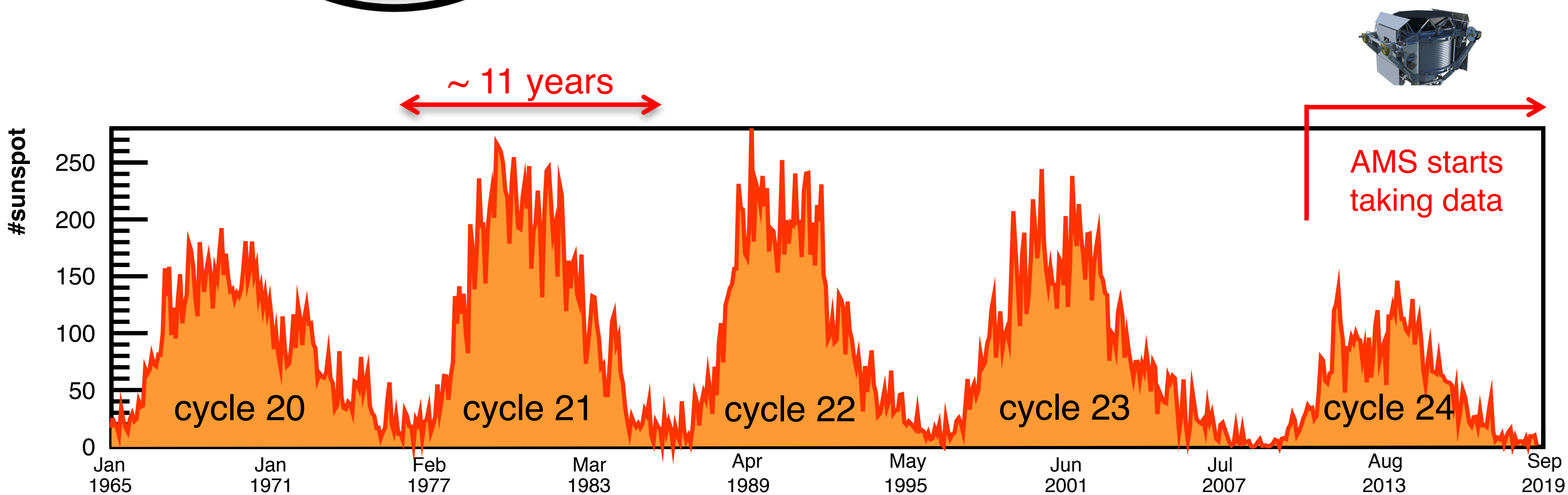


1. Large time scale effects (~years):

- *change on intensity* of CRs
- *charge-sign* dependence:
  - at maximum: diffusive motion
  - at minimum: magnetic drift + diffusive motion

2. Small time scale effects (~days)

Forbush decrease & Solar Energetic Particles (SEP)



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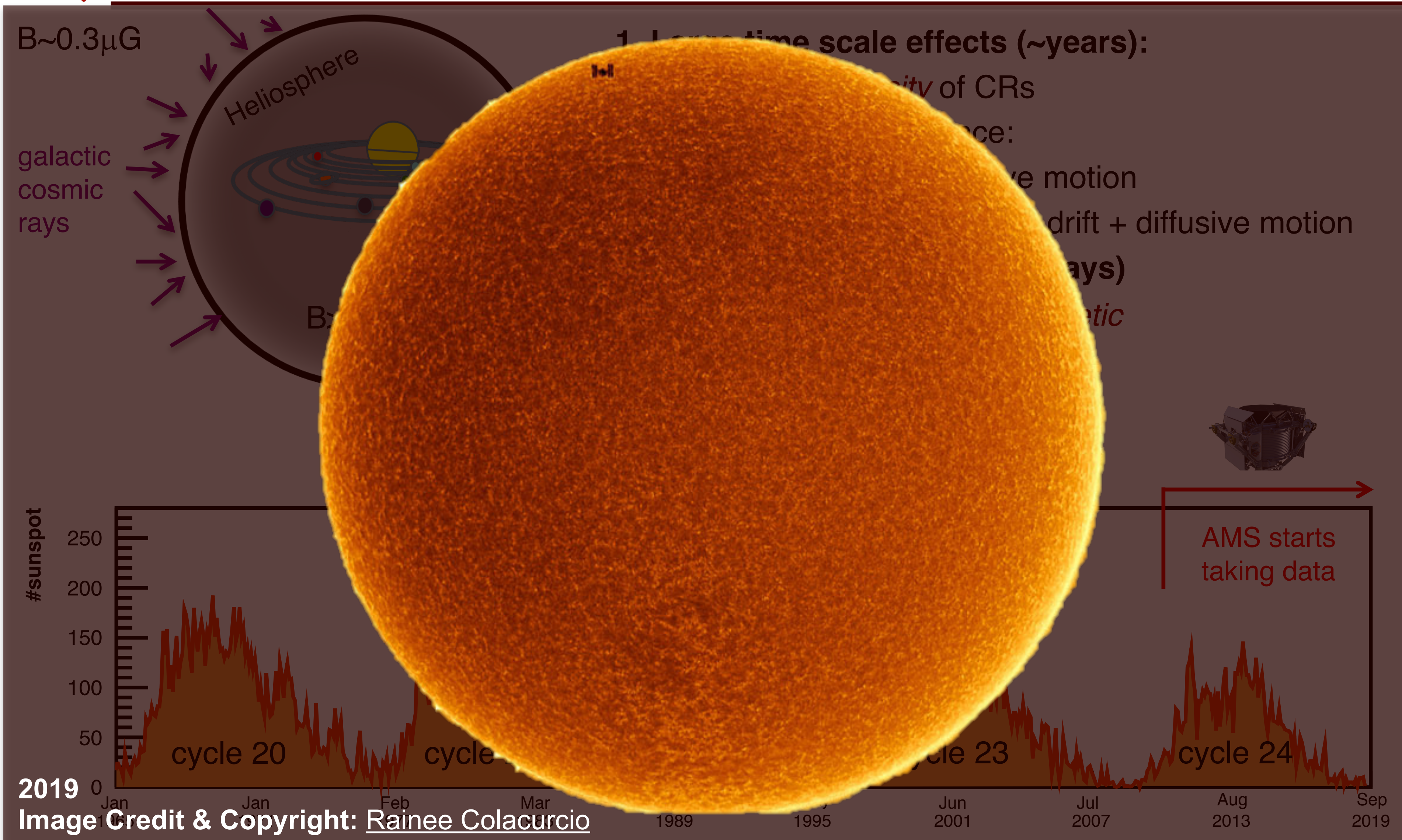


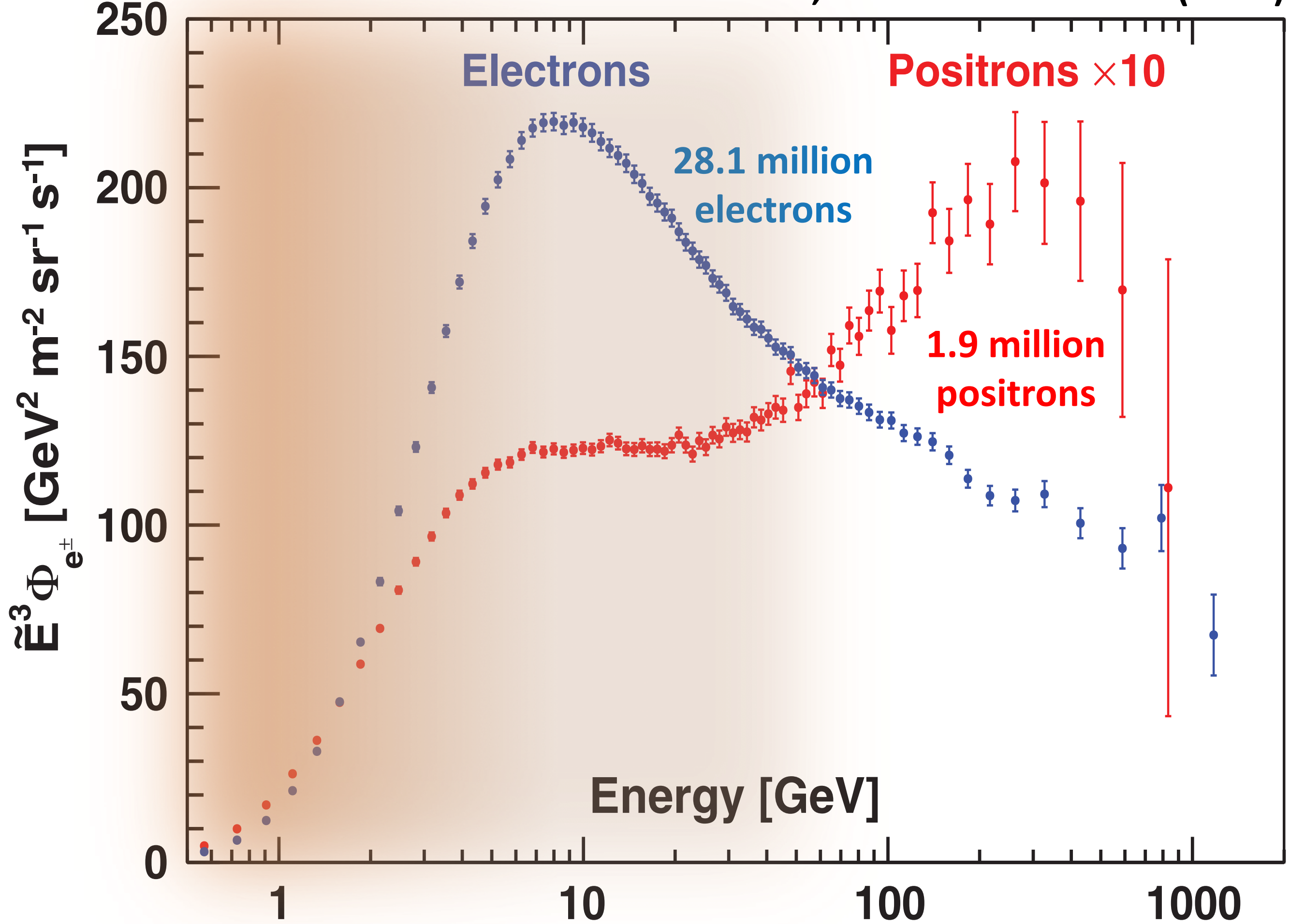
Solar modulation of Cosmic Rays

At low energies the flux behavior is strongly dependent on the local environment.

The effect of the solar wind and of the solar magnetic field is modifying the observed spectra with respect to the Local InterStellar ones

<u>For a perfect knowledge and understanding of the LIS spectra a detailed and predictive model of the sola modulation is needed</u>

PRL 122, 101101 and 041102 (2019)



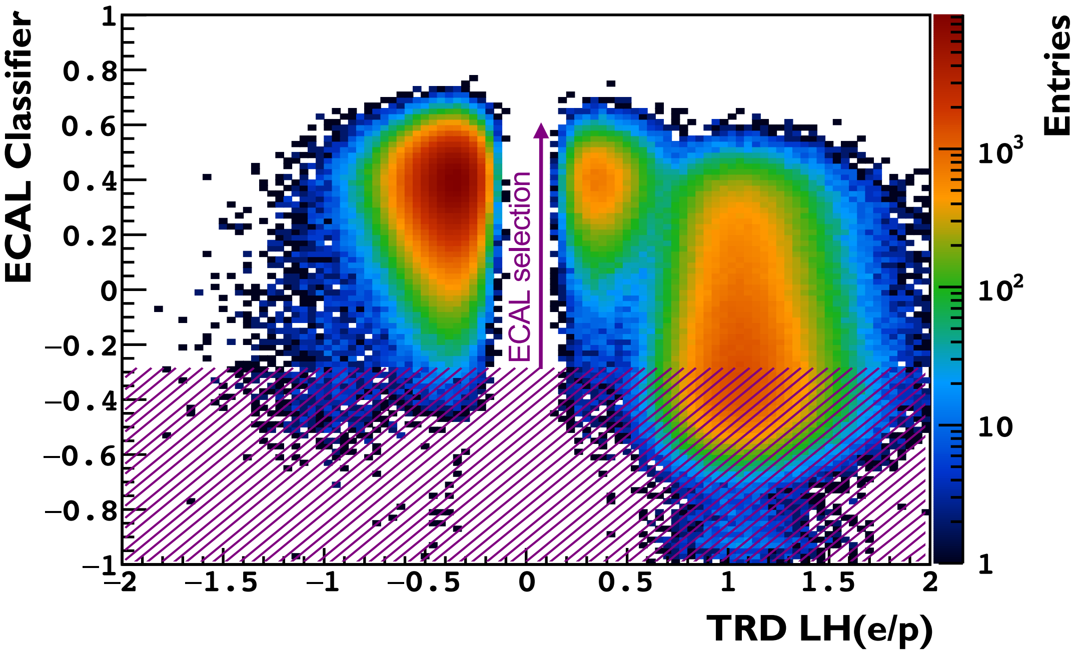
* e^+ and e^- up to TeV presented in next talk by W.Xu

Data analysis

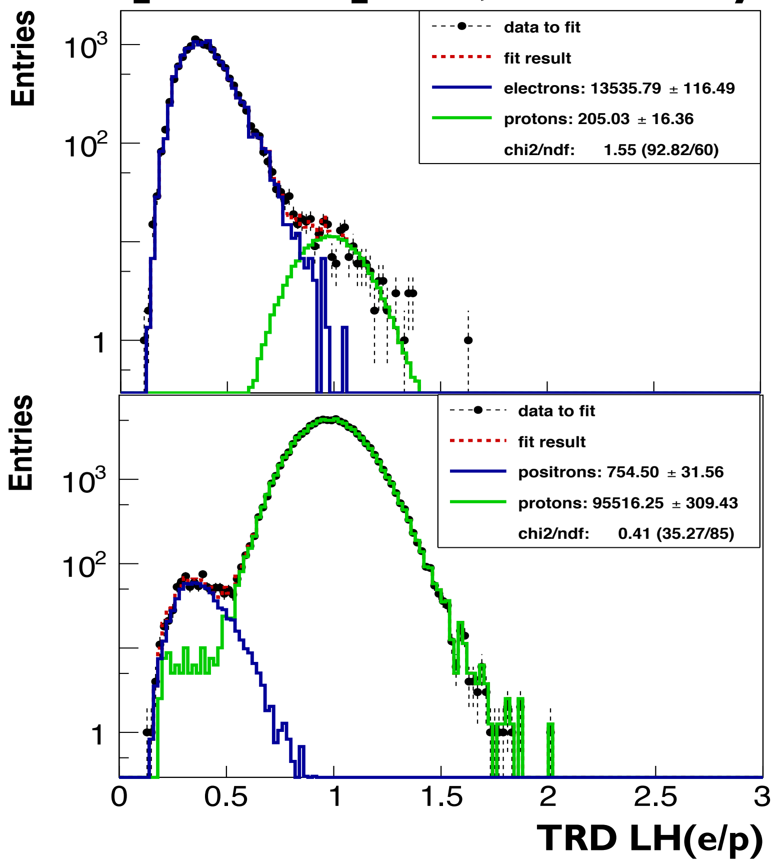
Template fit to measure the number of electrons/positrons

Data driven background subtraction

Reference spectra for the signal and the background are fitted to data as a function of the TRD LH(e/p) once a ~ 100% efficiency cut is applied on the ECAL classifier



E=[4.12-4.54] GeV, Δt = 27 days



The template fit is performed with reference spectra extracted from data, for each 27 days time period independently

The flux measurement

$$\Phi^i(E, E+\Delta E) = \frac{N^i_{obs}(E, E+\Delta E)}{A^i_{eff}\ \Delta T^i\ \varepsilon_{trig}(E)\ \Delta E}$$

Φ = Absolute differential flux ($m^{-2}\ sr^{-1}\ GeV^{-1}$)

N_{obs} = Number of observed events

ΔT = Exposure time (s)

27 days (79 intervals, in May 2011-May2017)

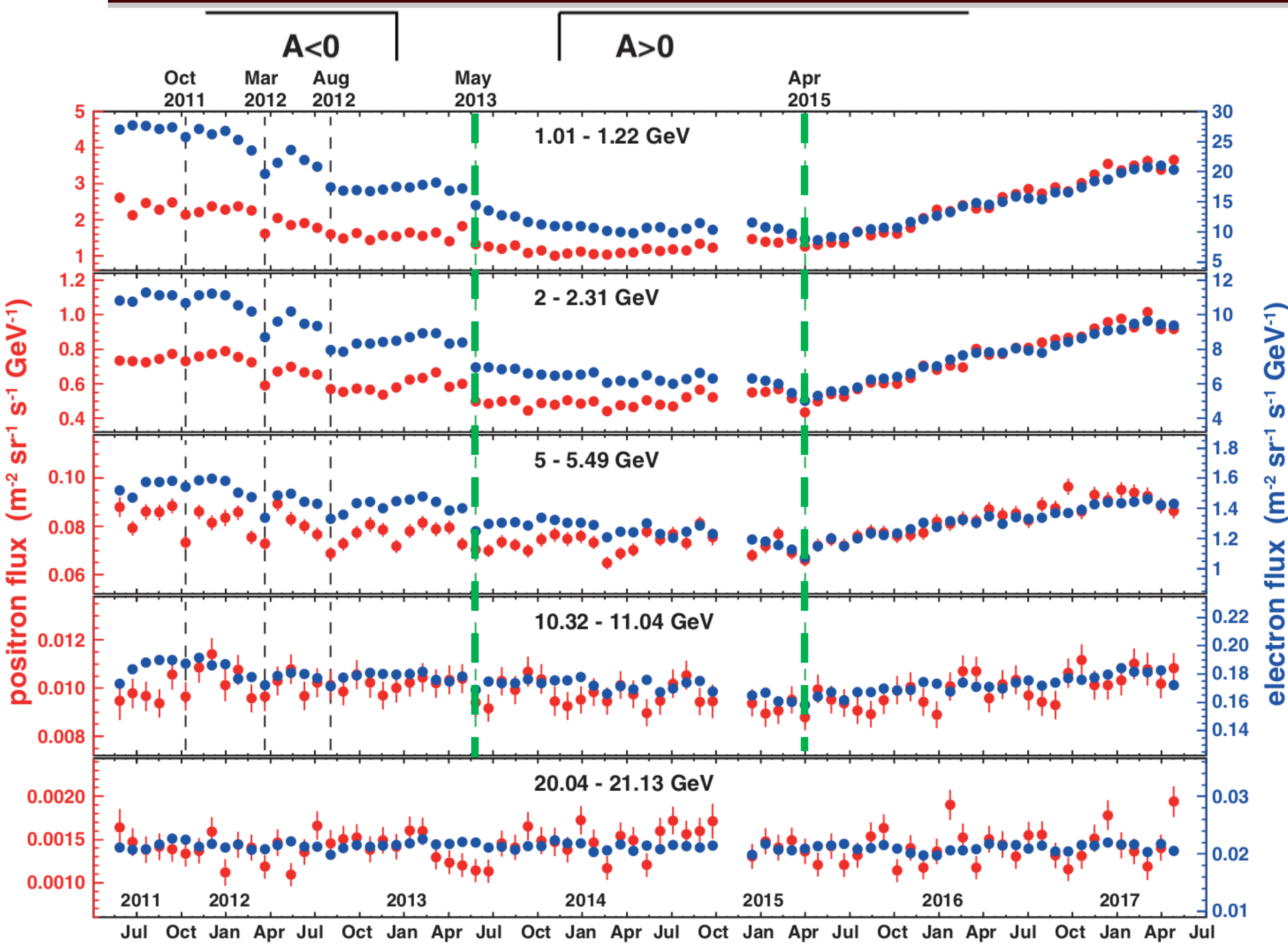
A_{eff} = Effective acceptance ($m^2 sr$)

ε_{trig} = Trigger efficiency

If the control of N_{obs} (i.e. rejection of the background) is important for the flux measurement, the control of the detector acceptance (geometrical one + efficiencies), $A_{eff}\varepsilon_{trig}$, and <u>its stability in time</u>, is important at the same level

Results

Electron and Positron fluxes vs Time – PRL 121, 051101 (2018)

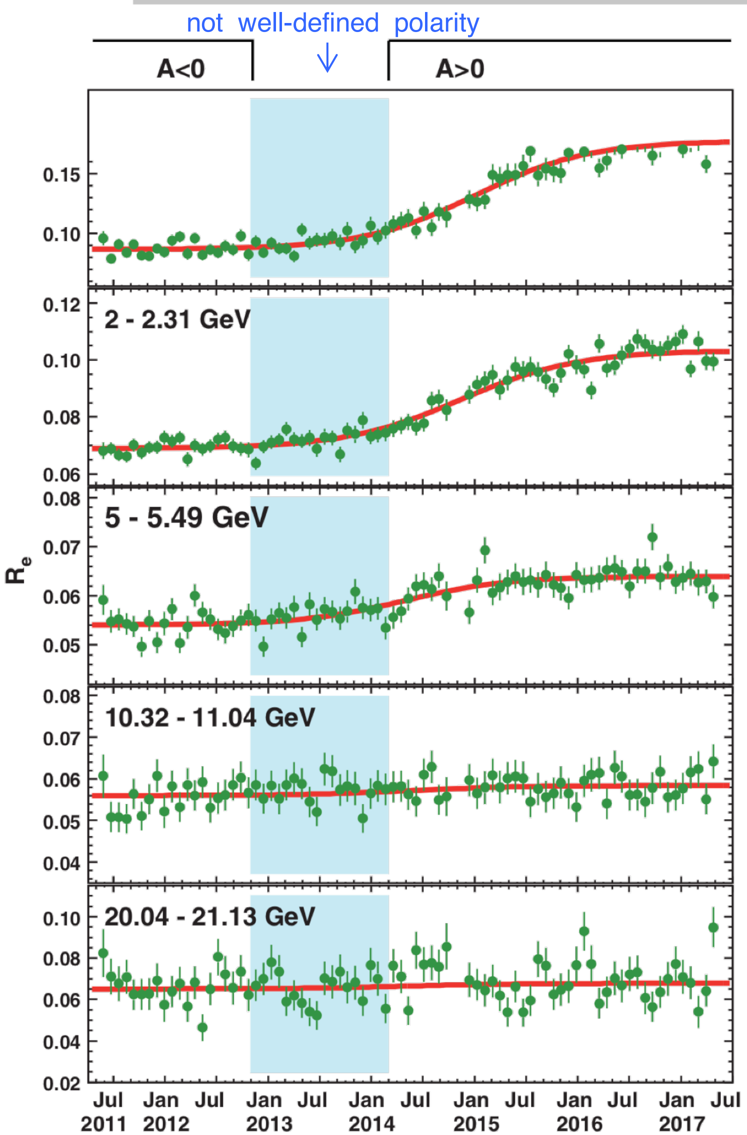


Long-term:

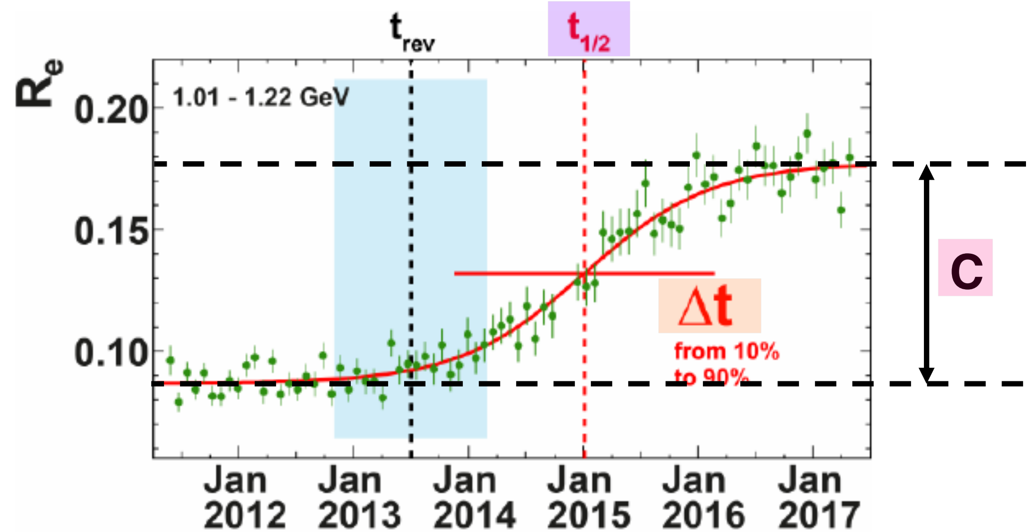
- both positrons and electrons show the same trend (decrease and then increase
- the end of the decrease phase, for the two fluxes, clearly happens at different times (green dashed vertical lines)

Short-term: prominent and distinct time structures visible in both the positron spectrum and the electron spectrum and at different energies (black dashed vertical lines)

Positron/Electrons ratio vs Time – PRL 121, 051101 (2018)



The 3871 independent $\mathbf{R_e}$ measurements as a function of energy and time can be described well with a logistic function



amplitude of the transition

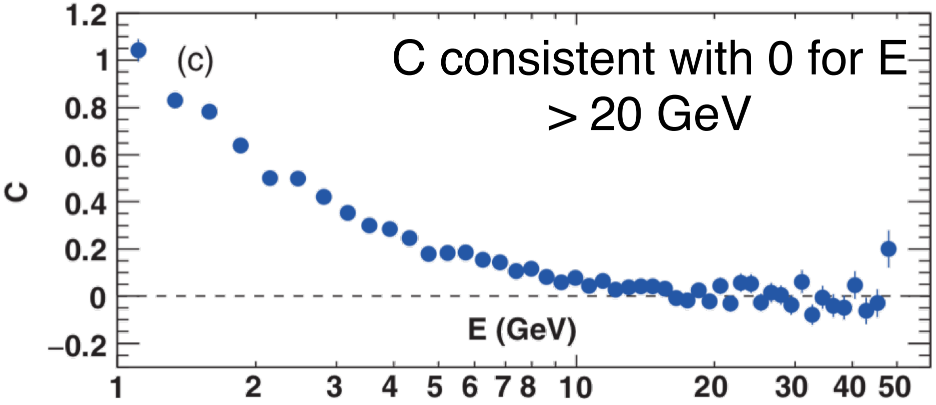
midpoint of the transition

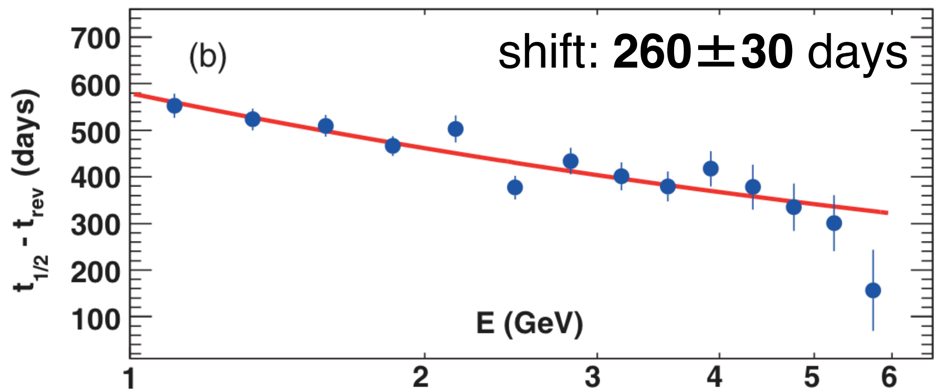
$$R_e(t,E) = R_0(E)\left[1+\frac{C(E)}{\exp\left(-\frac{t-t_{1/2}(E)}{\Delta t(E)/\Delta_{80}}\right)+1}\right]$$

duration of the transition

Positron/Electrons ratio vs Time – PRL 121, 051101 (2018)

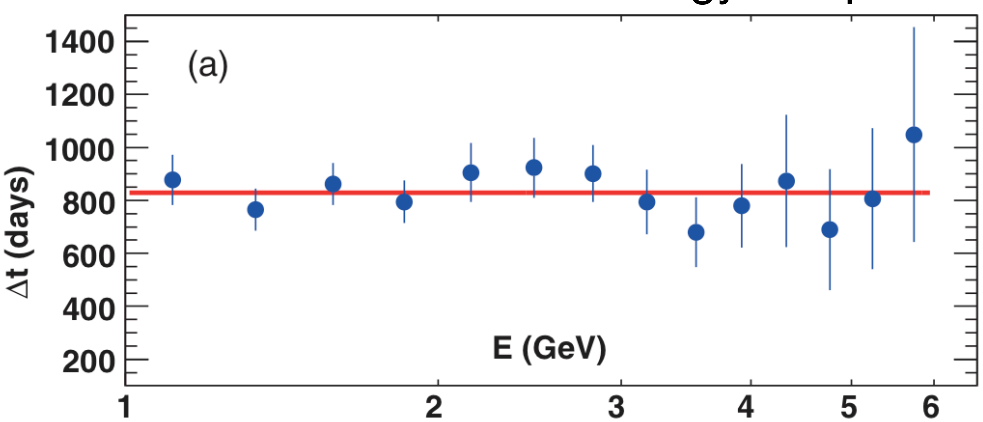
The amplitude (**C**) and the midpoint (**$t_{1/2}$**) of transition are energy dependent:





* t_{rev}=01/July/2013, time of the solar magnetic field reversal

The duration of transition is energy independent:



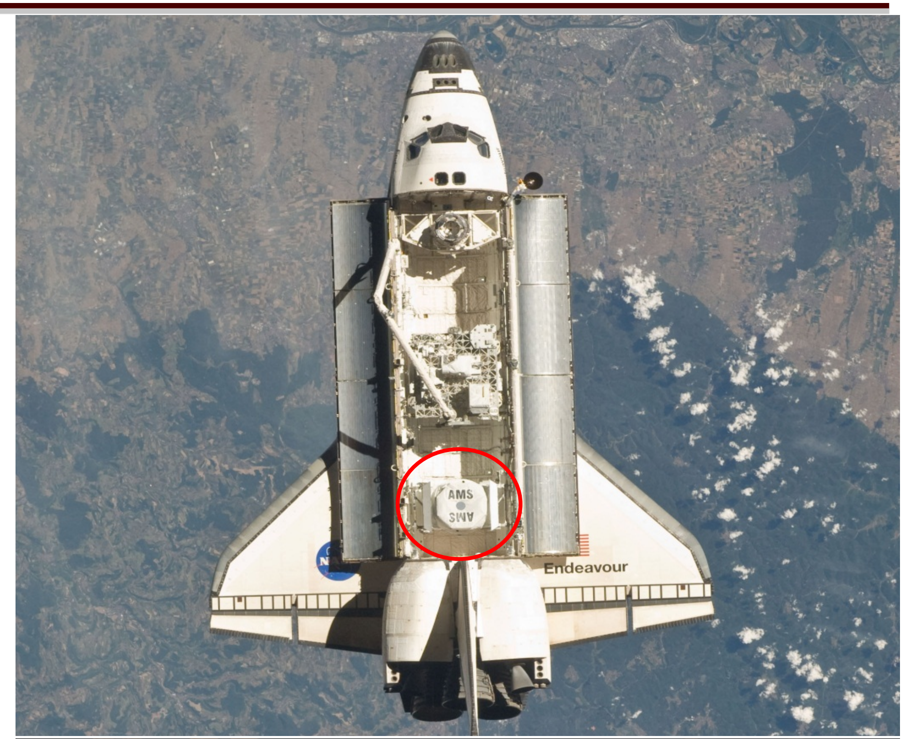
The ratio exhibits a smooth transition over **830±30** days from one value to another

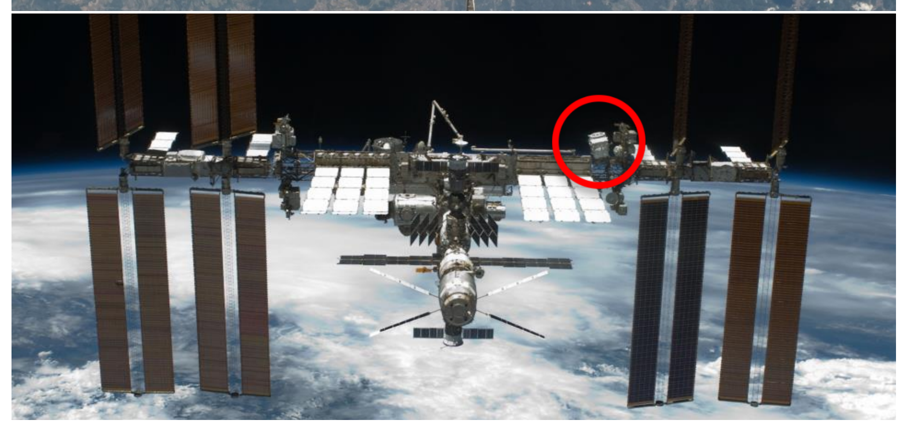
Conclusion

- The redundancy and complementarity of AMS-02 and its large acceptance and long exposure time permitted an unprecedented measurement of the e^+ and e^- fluxes as function of time

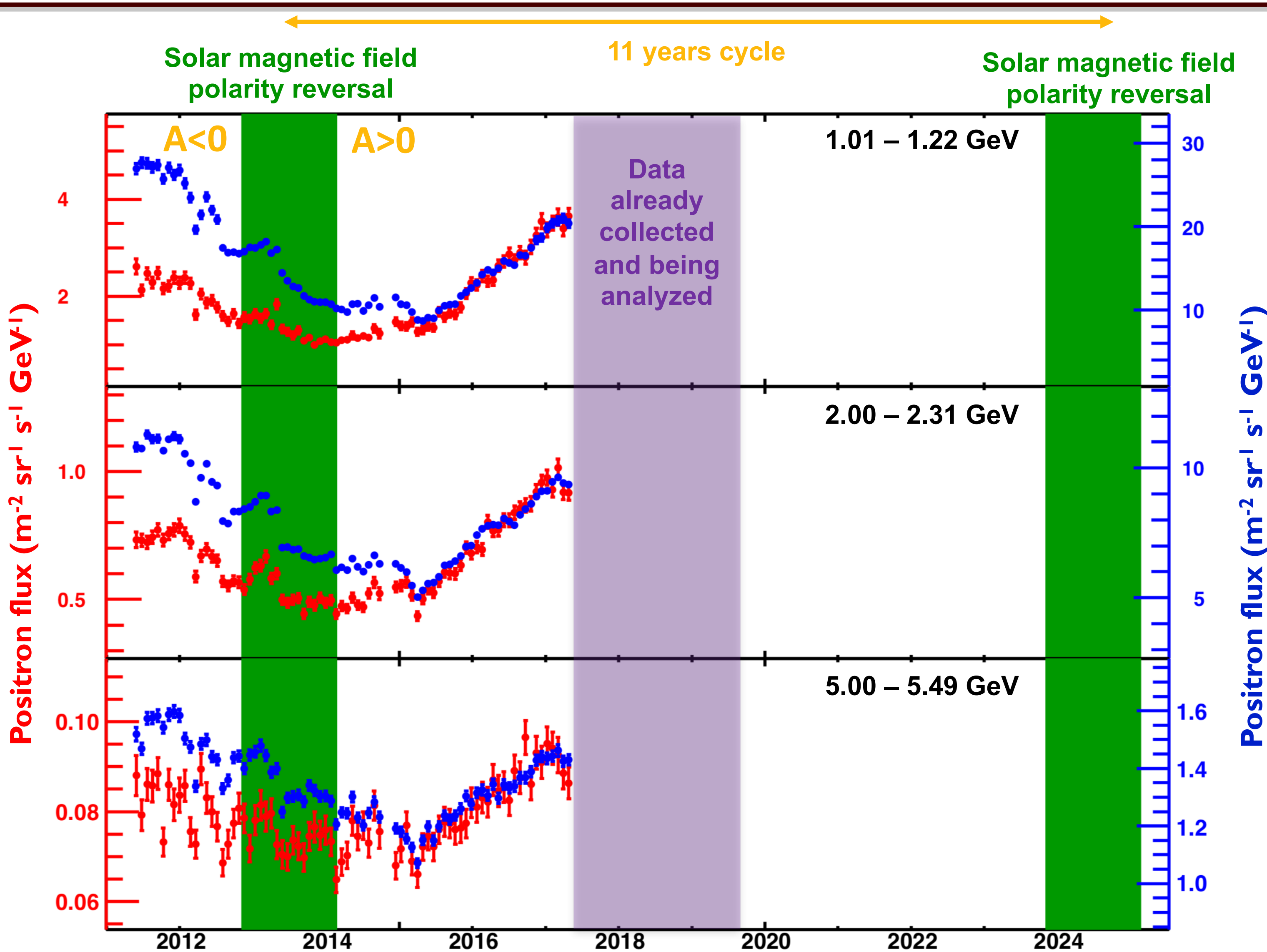
- For the first time, the charge-sign dependent modulation has been investigated in detail by leptons alone

- The high granularity and the large range of the time measurement permitted a detailed investigation of both the short-term and long-term characteristic structures of the fluxes





More to come!



11 years cycle
Solar magnetic field polarity reversal
Solar magnetic field polarity reversal
A<0
A>0
Data already collected and being analyzed
1.01 – 1.22 GeV
2.00 – 2.31 GeV
5.00 – 5.49 GeV
Positron flux (m^{-2} sr^{-1} s^{-1} GeV^{-1})
Positron flux (m^{-2} sr^{-1} s^{-1} GeV^{-1})
4
2
1.0
0.5
0.10
0.08
0.06
30
20
10
10
5
1.6
1.4
1.2
1.0
2012
2014
2016
2018
2020
2022
2024


Stay tuned!
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JAXA
STS Crew Wake
AMS Lead
AMS Tracker
STS-134
Chips Ahoy!