Solar Modulation of Cosmic Rays and indirect searches for Dark Matter

Astro@Ts 2019

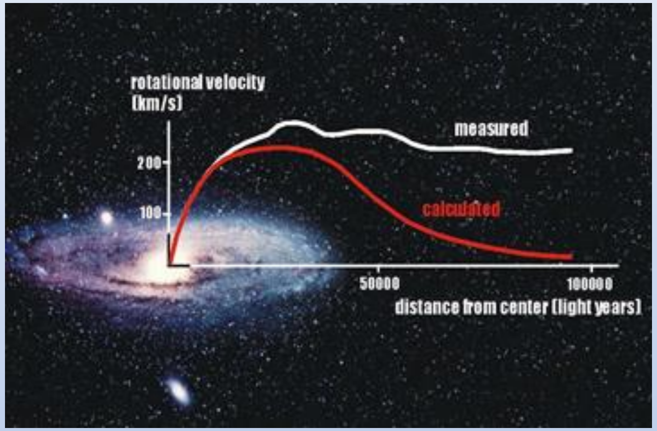
Alex Lenni

Università degli Studi di Trieste
INFN Sezione di Trieste

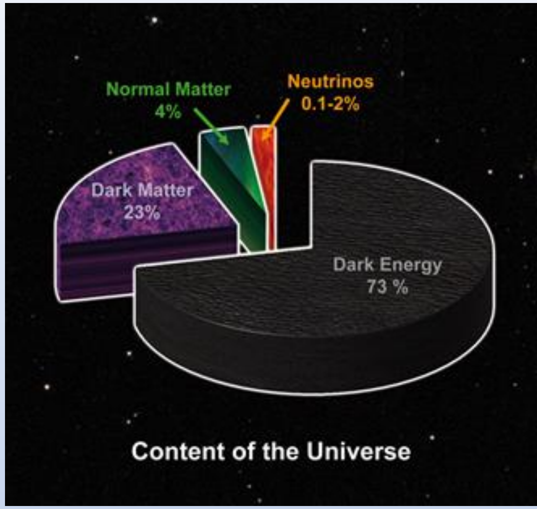
The Dark Matter and its and indirect search

Astrophysical evidences:

Rotation curve of the galaxies:



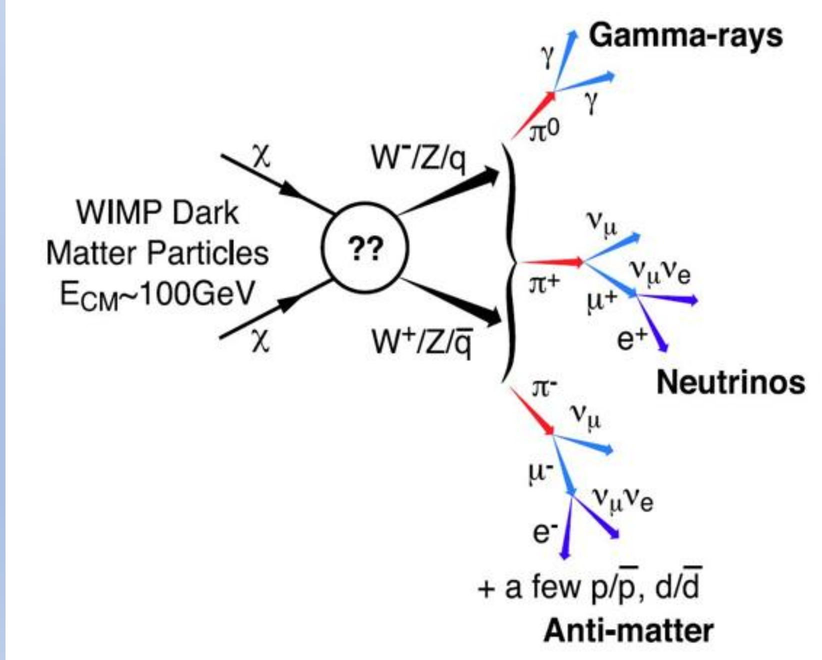
Bullet Cluster:



Indirect search for Dark Matter in astroparticles:

↓

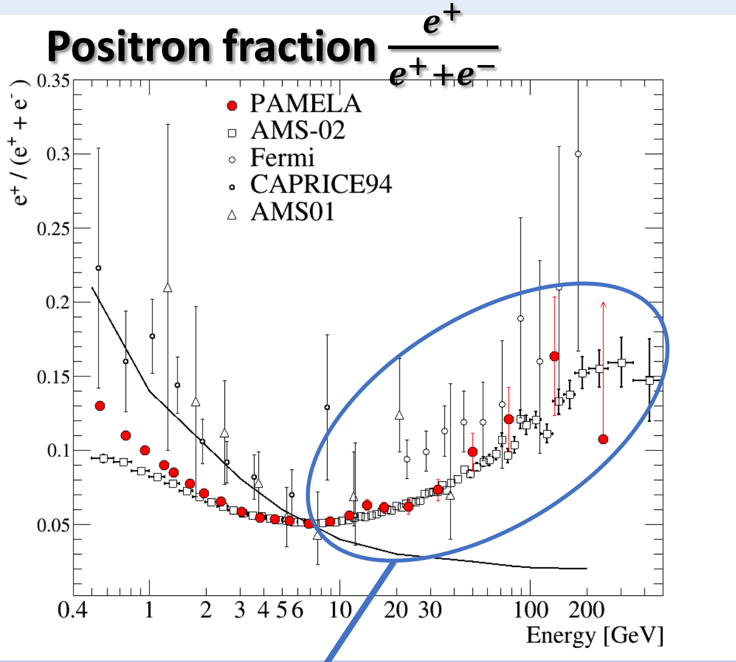
Particles produced by annihilation or decay of Dark Matter Particles



Search for Dark Matter signals in the fluxes of **Cosmic Ray antiparticles**:

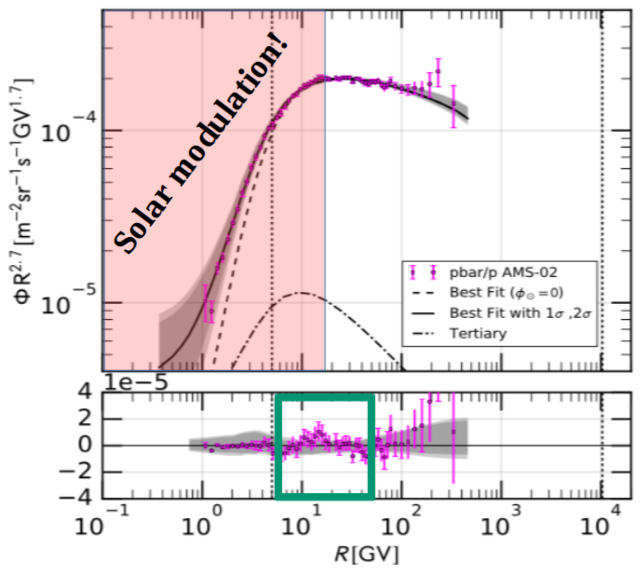
e^{+}, $\overline{p}$, $\overline{d}$, $\overline{He}$

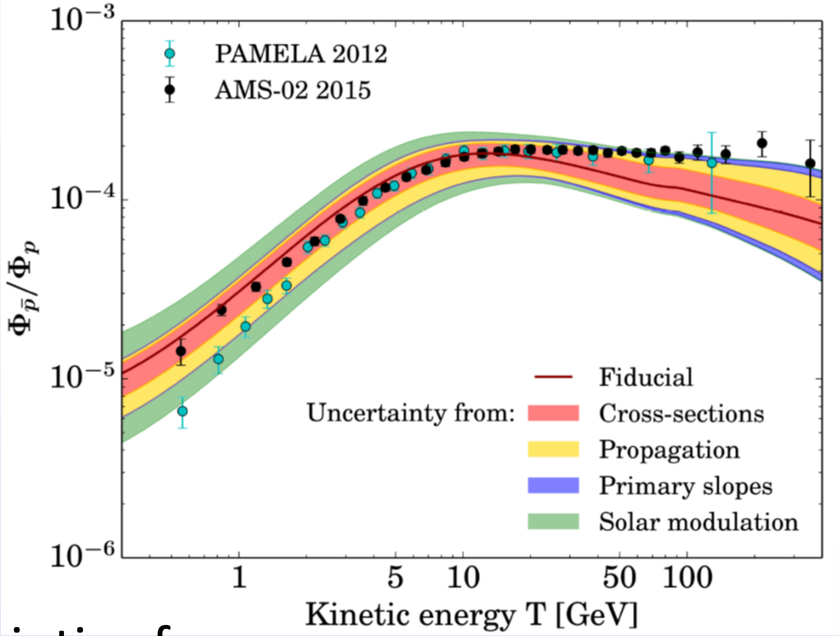
Indirect search of Dark Matter signals in the fluxes of Cosmic Ray Antiparticles



Evidence of **excess of positrons** above 10 GeV from pure secondary production

Antiproton spectrum



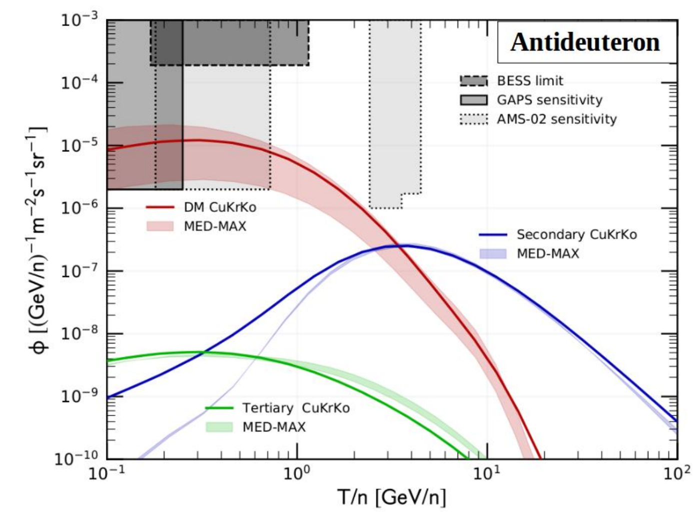


Below few tens of GeVs large uncertainties from modelling the propagation of Cosmic Rays inside the Heliosphere

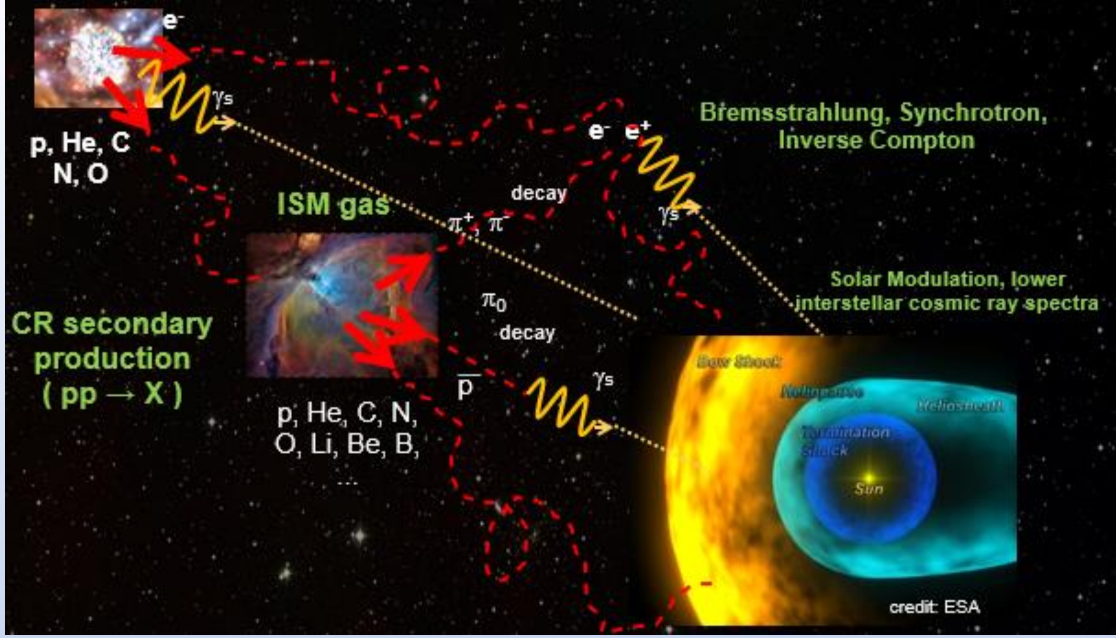
Rare secondary components are very promising channels to detect dark matter

Antideuteron

$$\underbrace{\chi}_{\text{at rest}} + \overbrace{\chi}^{\text{at rest}} \longrightarrow \bar{p}\bar{n} + pn$$



Solar Modulation of Cosmic Rays

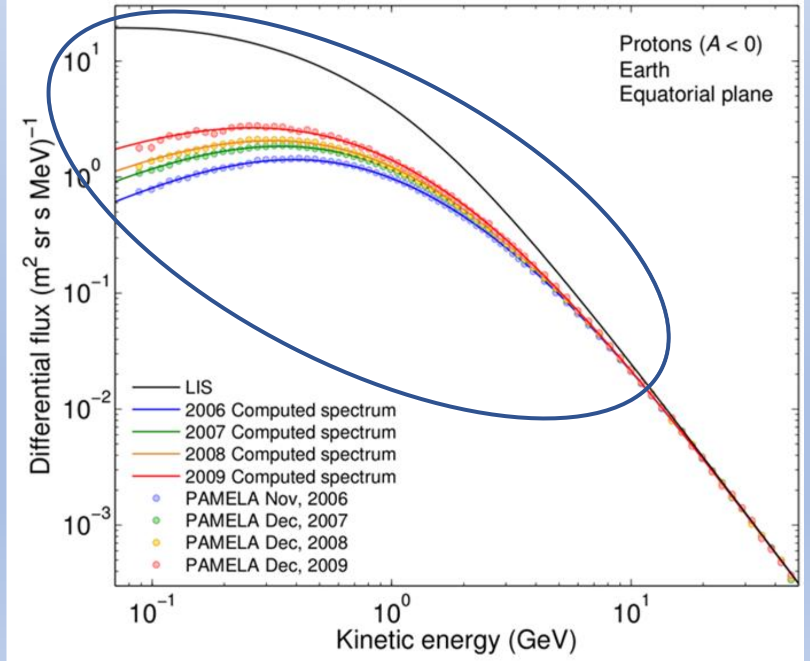


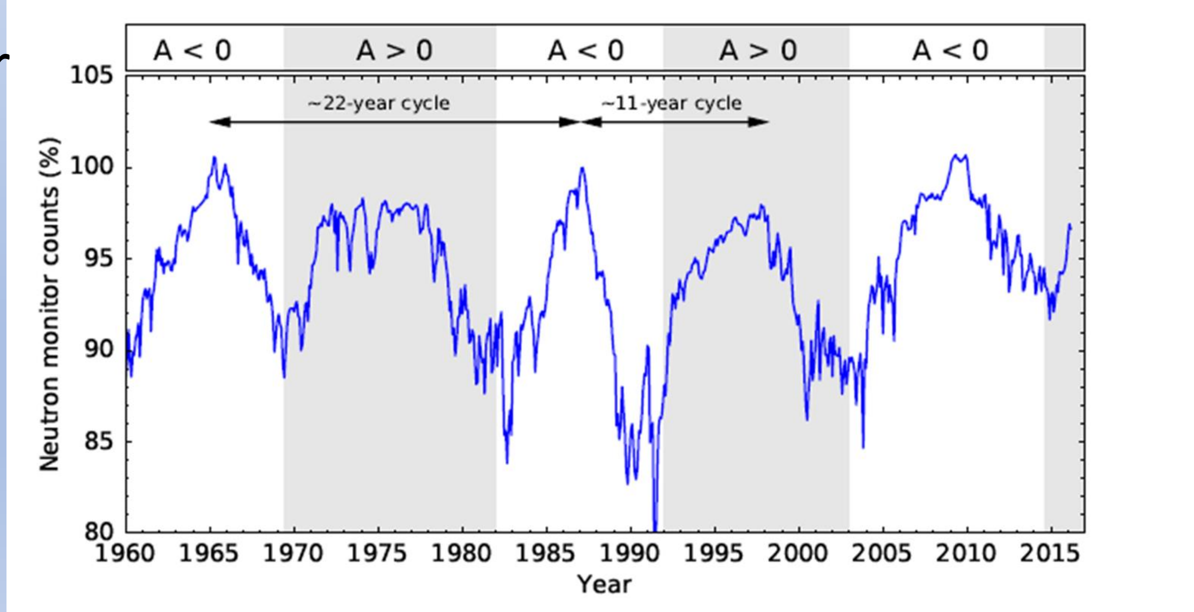
Interaction of Cosmic Rays with Heliosperic Magnetic Field freezed in the Solar Wind

Solar Modulation

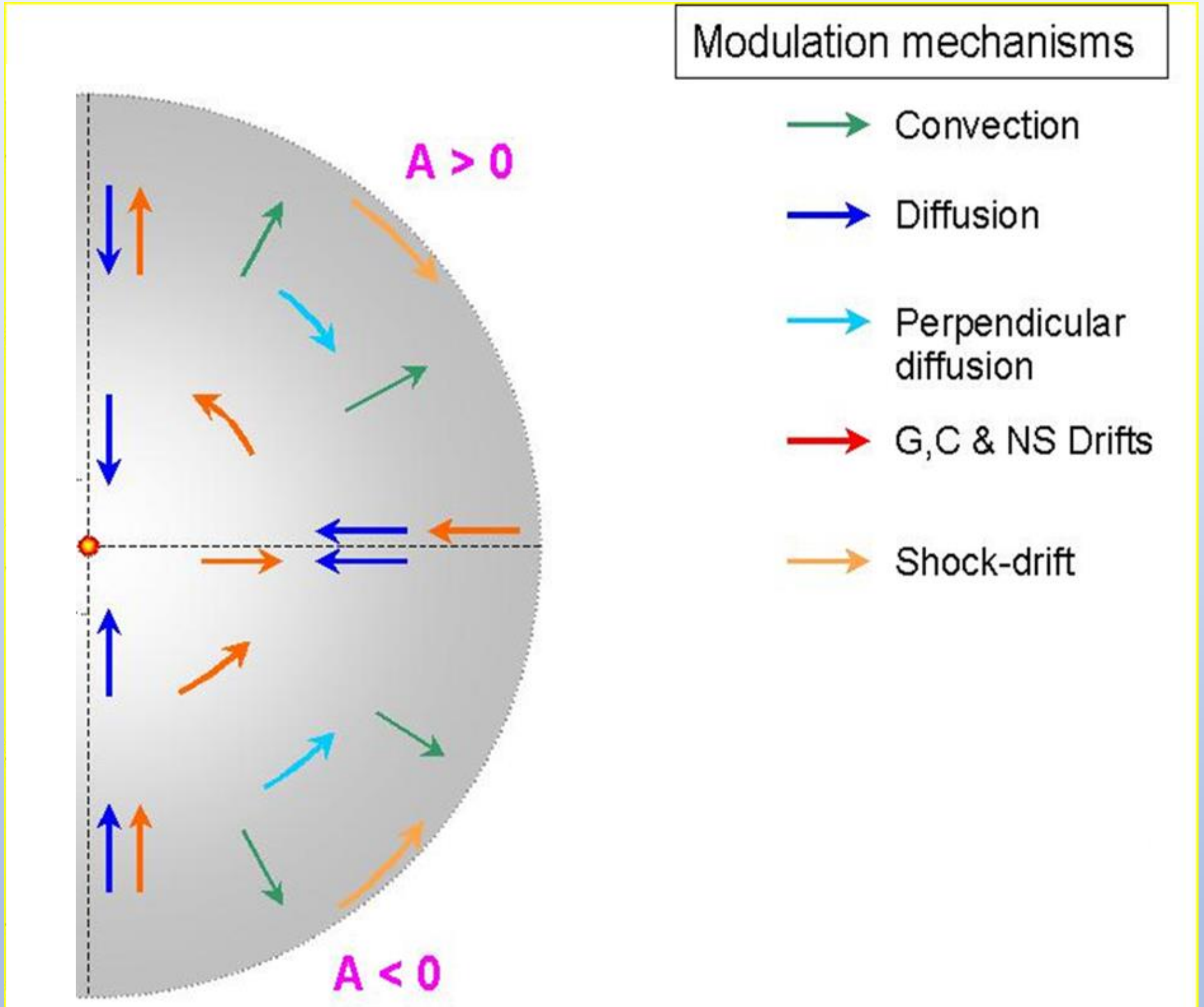
Decrease of energy spectrum below few tens GeVs

Time dependence of the fluxes as a function of the solar activity phase





Mechanisms of solar modulation effect on Cosmic Rays

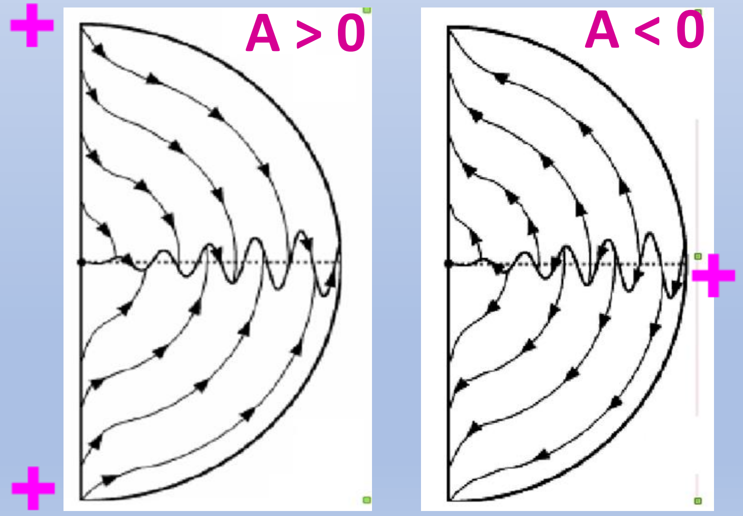


Parker's equation:

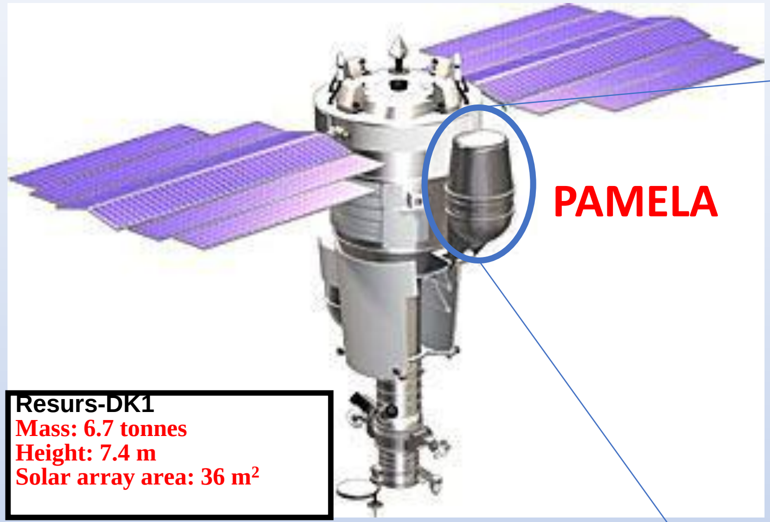
$$\frac{\partial f}{\partial t} = -(\mathbf{V} + < \mathbf{v}_d >)\cdot\nabla f + \nabla\cdot(\mathbf{K}_s\cdot\nabla f) + \frac{1}{3}(\nabla\cdot\mathbf{V})\frac{\partial f}{\partial \ln \rho} + Q(\mathbf{x}, p, t)$$

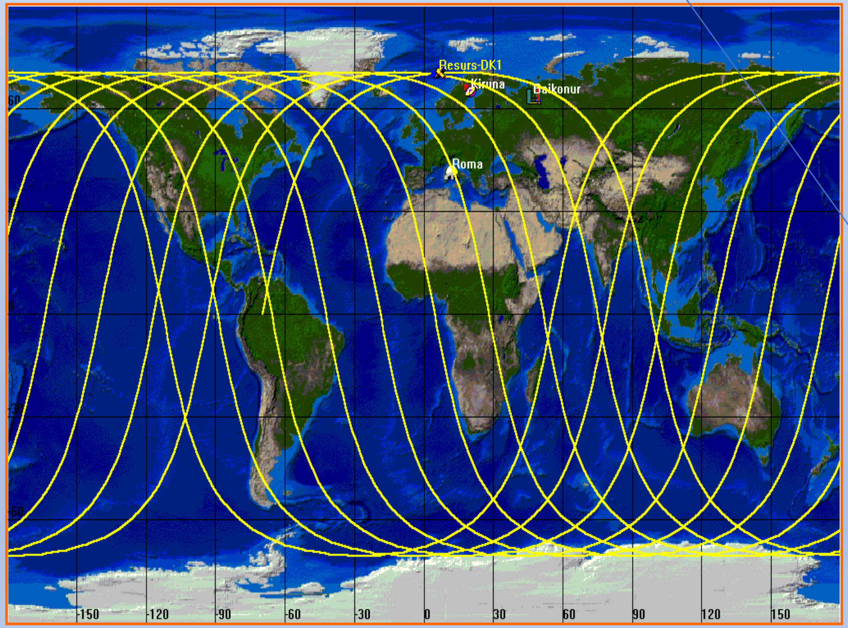
Sophisticated numerical models are able to model the Local Interstellar Spectrum (LIS) of a nuclear species of Cosmic Rays

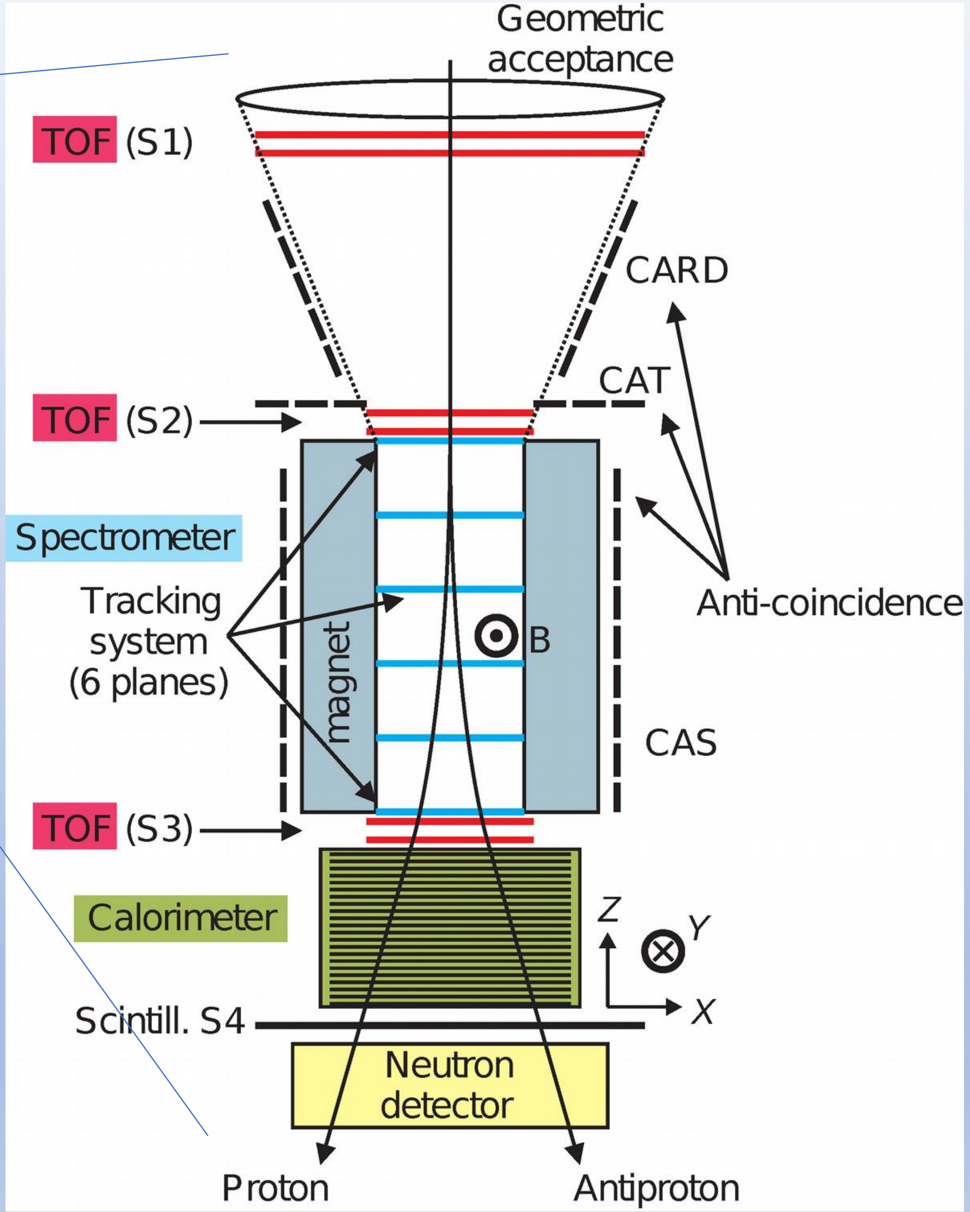
Take into account the charge sign effect resulting from drift motions



The PAMELA experiment



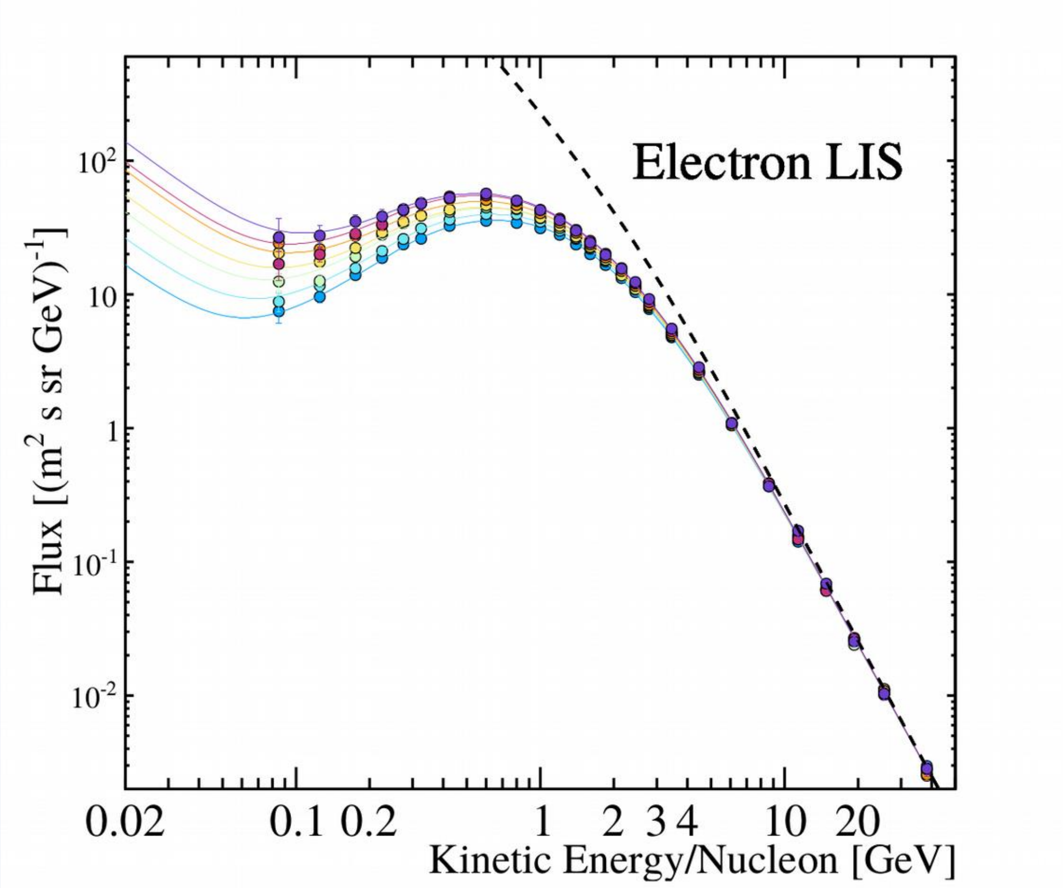




PAMELA strengths:

- **Semi-polar orbit** allows to measure particles where the Stoermer cutoff is lower.
- **Magnetic spectrometer** and ToF system allow to establish the charge sign of the particles
- **Electromagnetic calorimeter** to discriminate protons from electrons
- **About 10 years of data taking** allows to study Cosmic Rays during a whole solar cycle

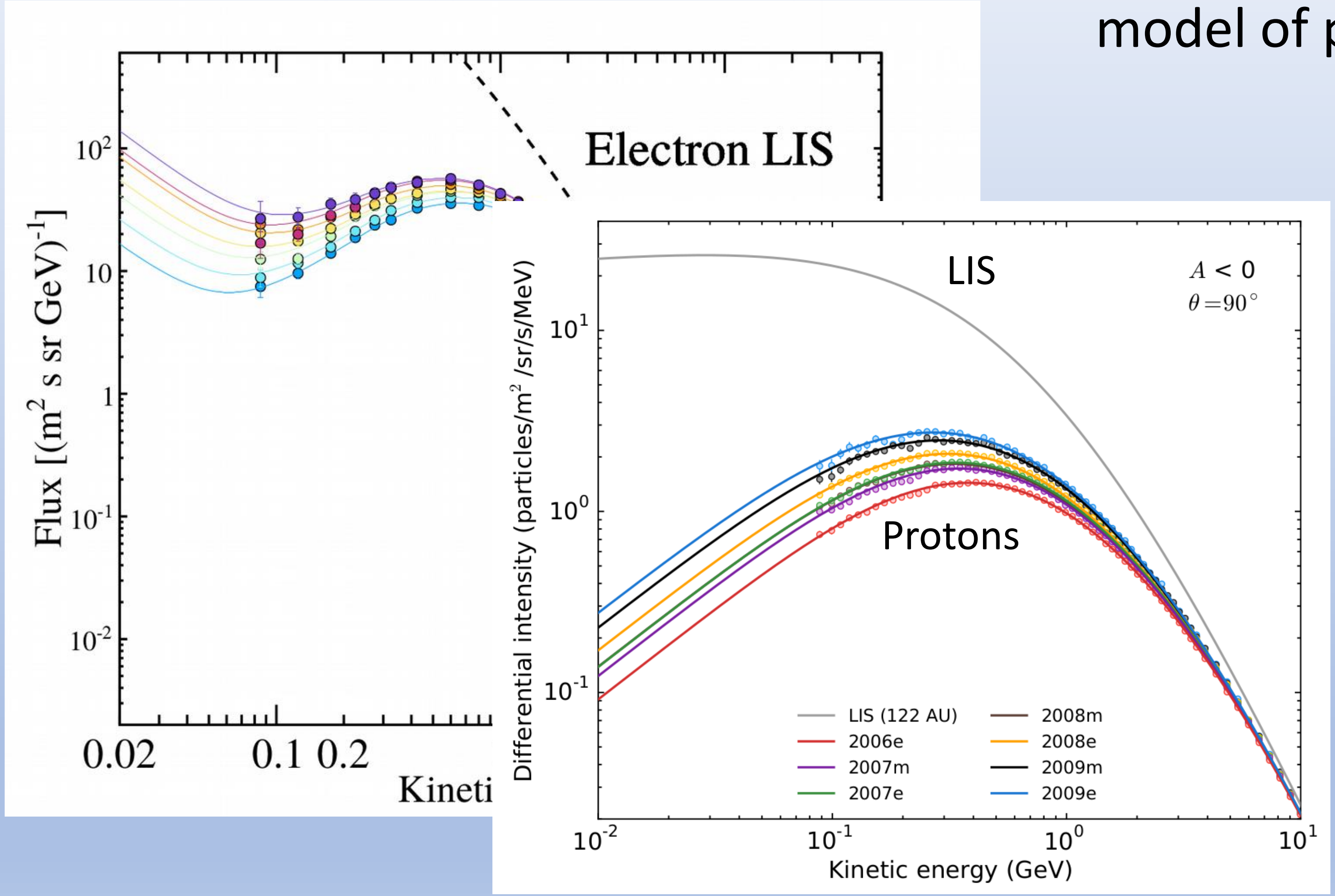
PAMELA results about the solar modulation effects



PAMELA results used to calibrate a 3D numerical model of propagation in the Heliosphere

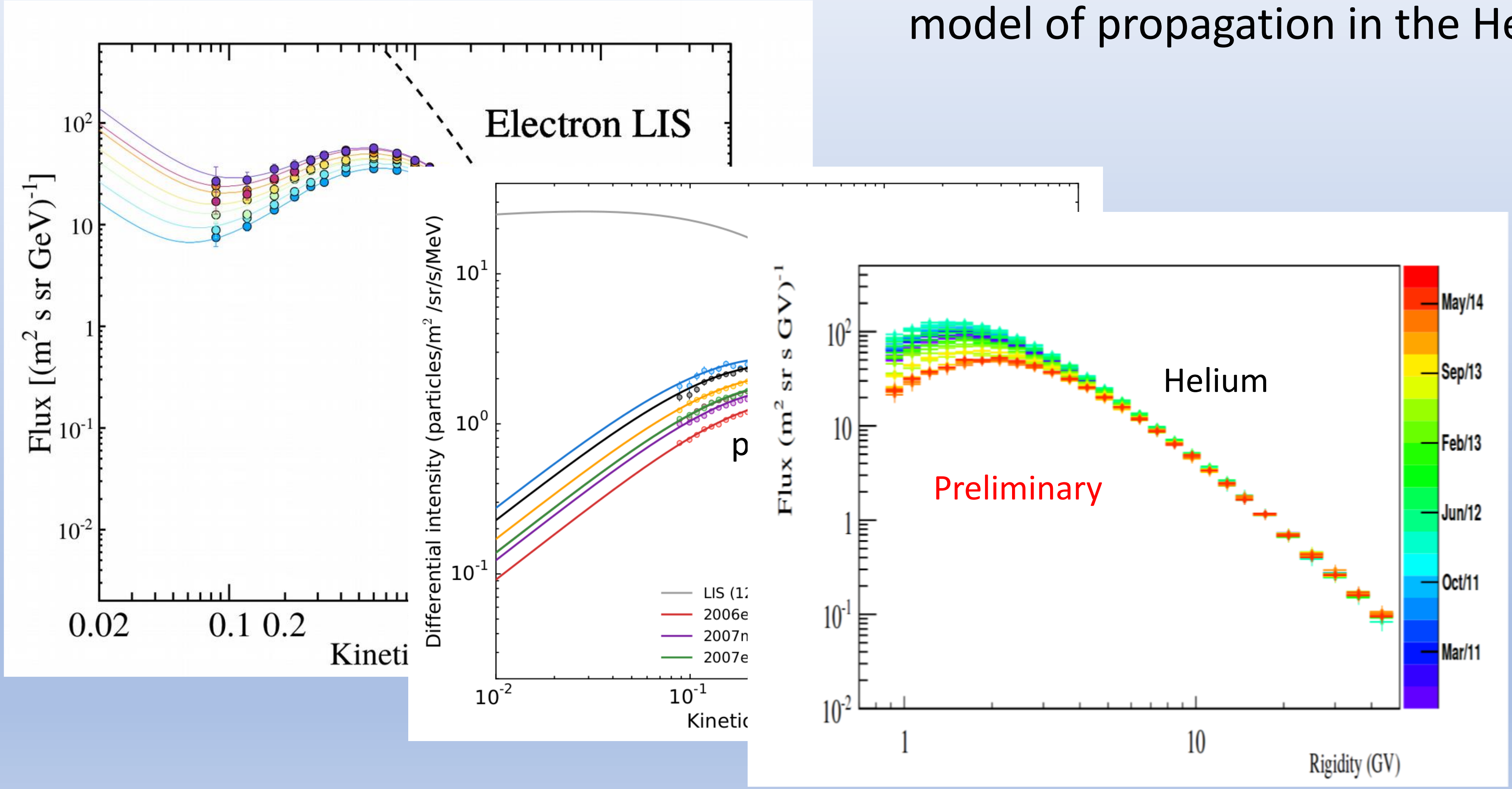
PAMELA results about the solar modulation effects

PAMELA results used to calibrate a 3D numerical model of propagation in the Heliosphere



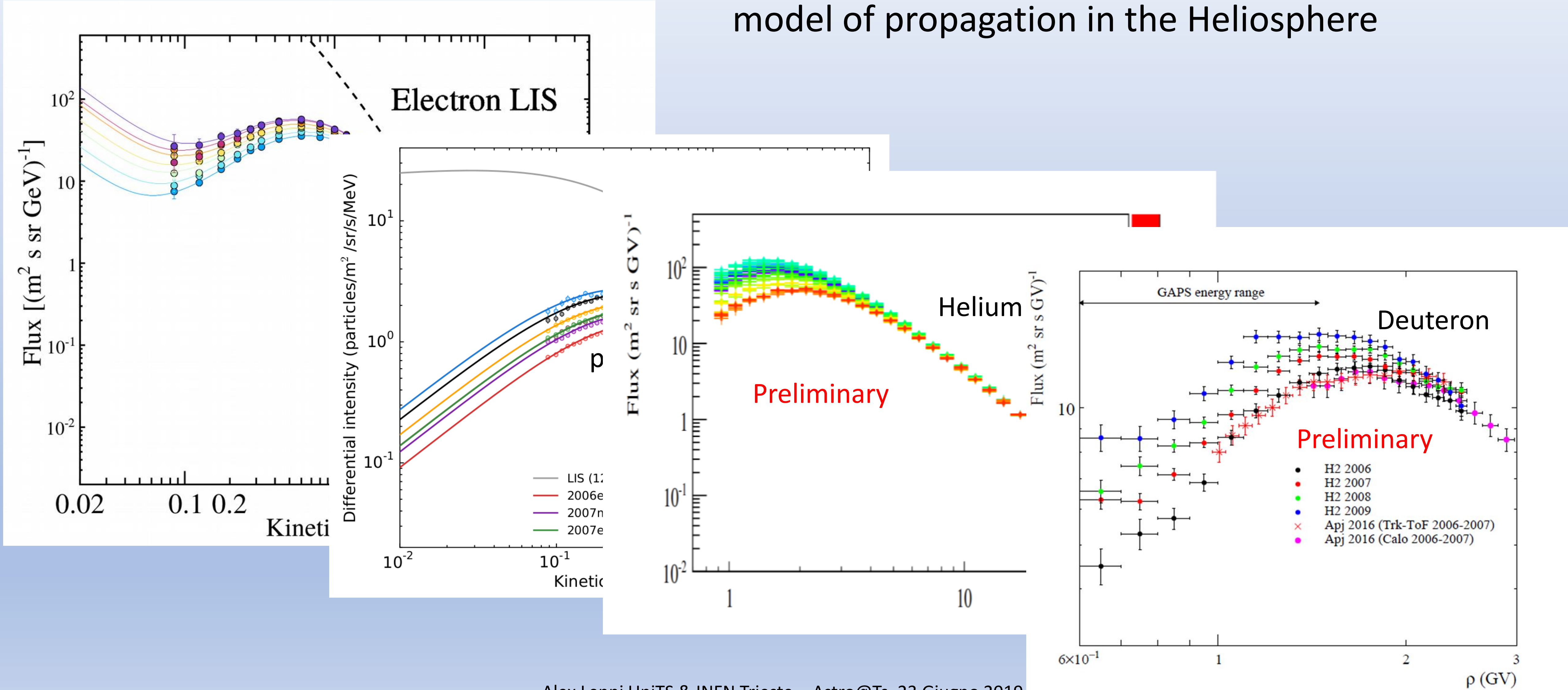
PAMELA results about the solar modulation effects

PAMELA results used to calibrate a 3D numerical model of propagation in the Heliosphere



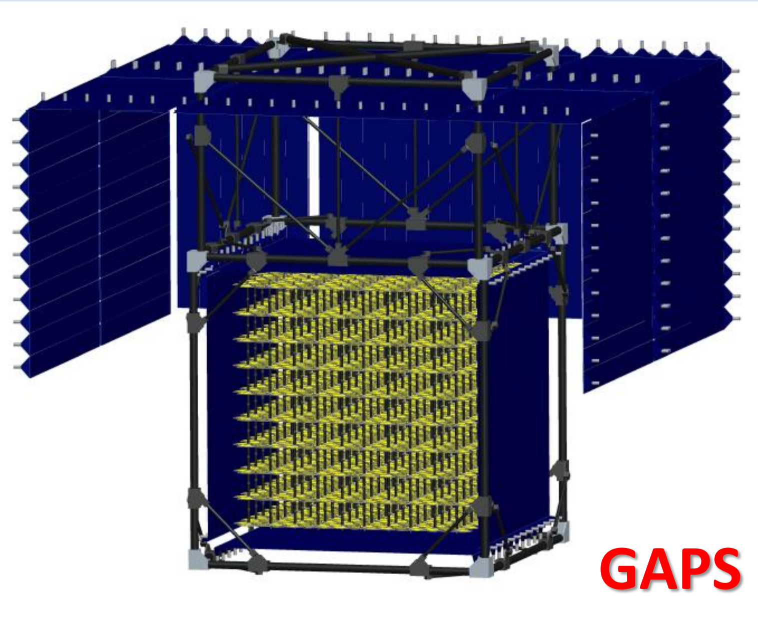
PAMELA results about the solar modulation effects

PAMELA results used to calibrate a 3D numerical model of propagation in the Heliosphere

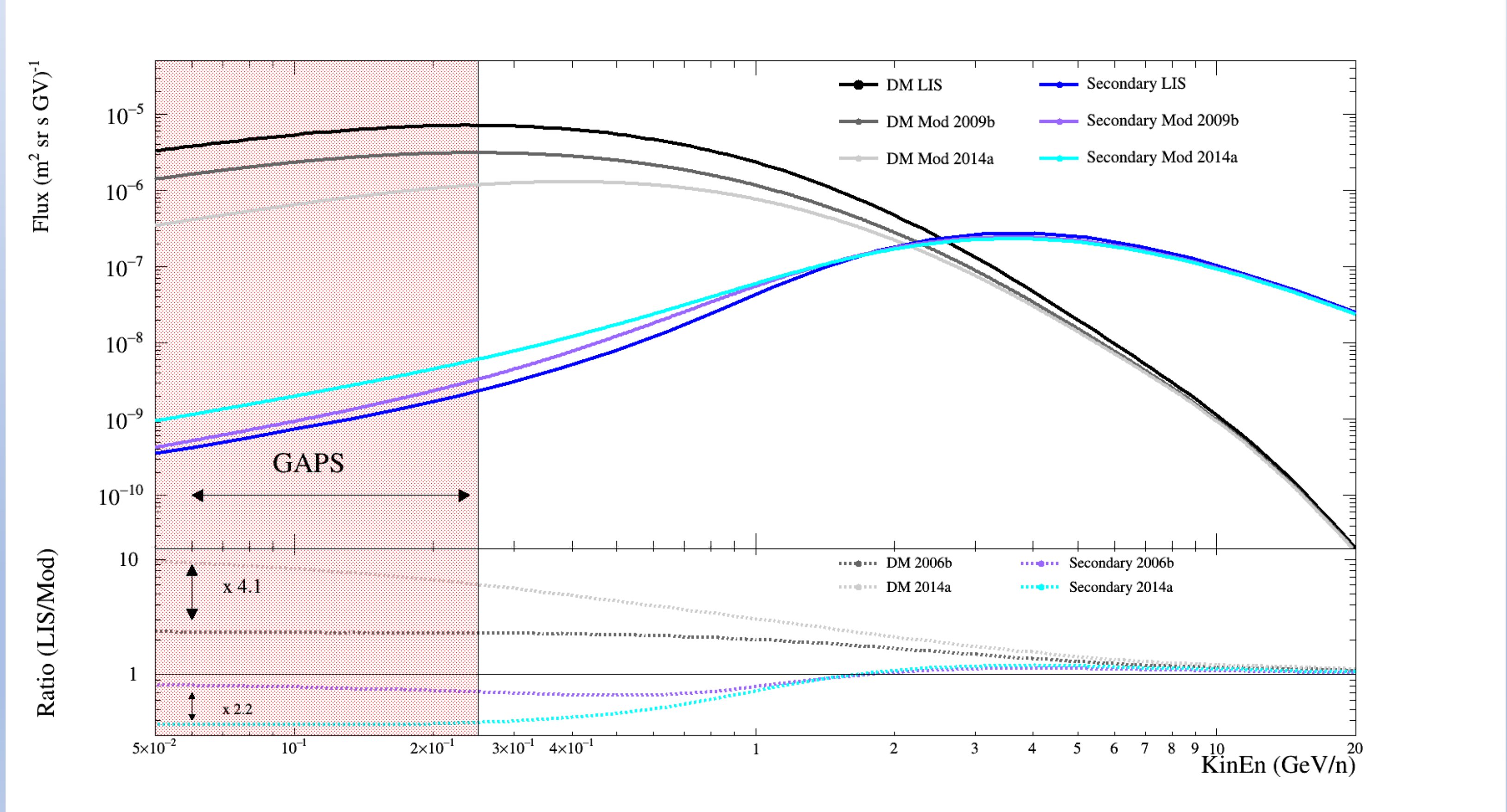


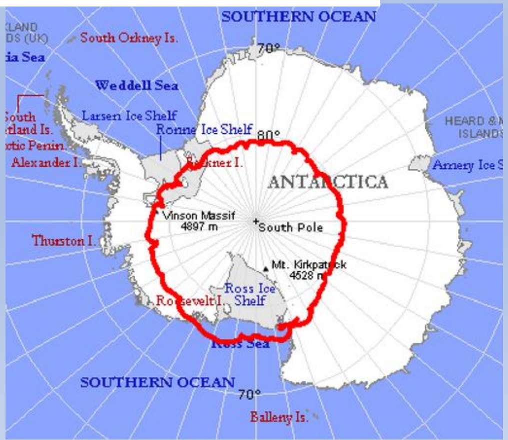
The future: GAPS

The GAPS experiment is going to measure the antiproton and antideuteron components in the cosmic radiation between 50 and 250 MeV/n, an energy range where solar modulation is important.



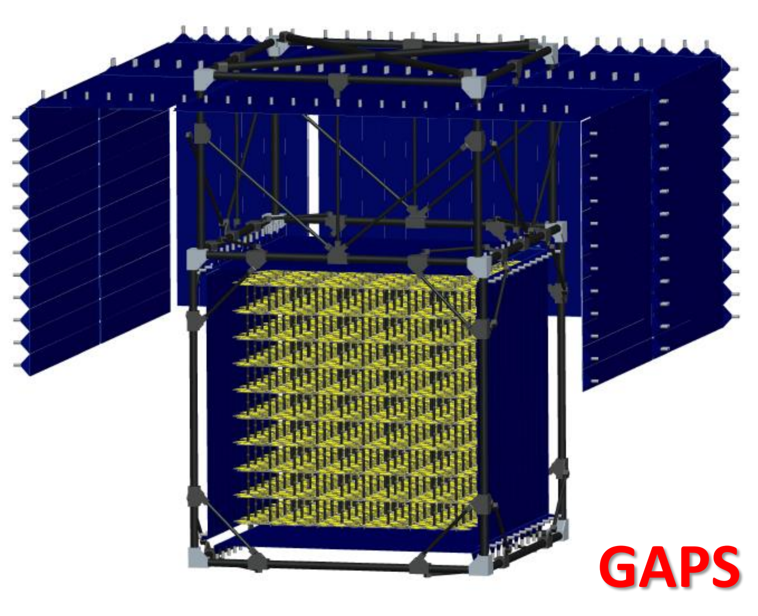
First flight in Antarctica is scheduled for the austral summer 2021 - 2022



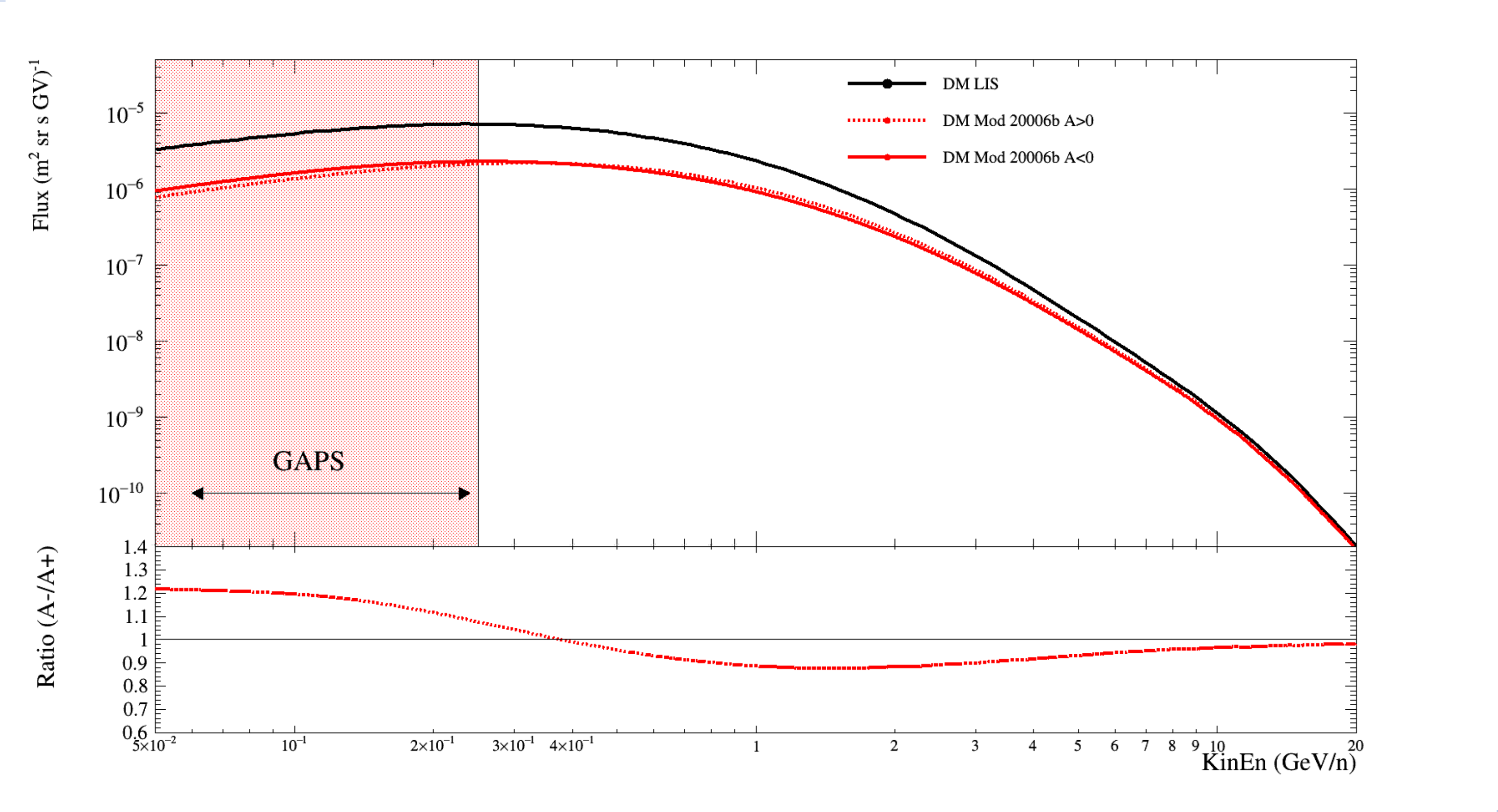


The future: GAPS

The GAPS experiment is going to measure the antiproton and antideuteron components in the cosmic radiation between 50 and 250 MeV/n, an energy range where solar modulation is important.



First flight in Antarctica is scheduled for the austral summer 2021 - 2022



Conclusions:

- The uncertainties on the modelling of solar modulations are the main limitation for a detailed analysis of the CR low energy spectra measured inside the Heliosphere
- A 3D state of art model which solves numerically the transport equation of Cosmic Rays in the Heliosphere has been calibrated using the PAMELA data.
- This model will be applied in future Dark Matter experiments like GAPS which will search for antiprotons and antideuterons from Dark Matter annihilation.