A new Local Interstellar Spectrum for antiproton from PAMELA, BESS and AMS02 data

Solar Modulation and Dark Matter Worshop
14-19 November, IFPU, Trieste

Riccardo Munini
INFN Trieste

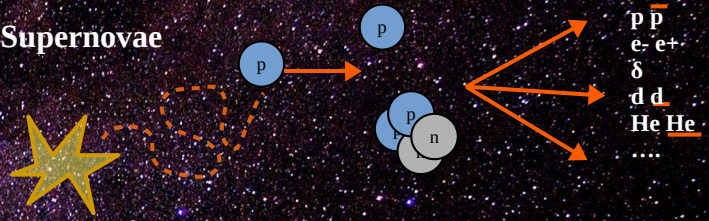
Antiproton in cosmic ray and Dark Matter

Most of the antiproton in Cosmic Rays (CRs) have a secondary origin, produced by the interaction of primary CRs with the interstellar matter.

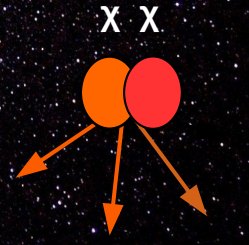
A search for an excess with respect to the secondary component is particularly interesting for Dark Matter indirect measurement since an antiproton component is expected to be produce from the annihilation of Dark Matter candidates of many models.

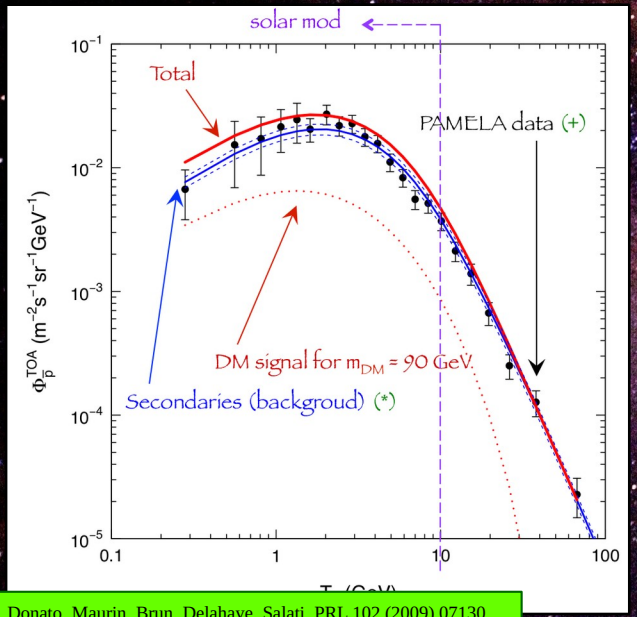
Secondary

Supernovae

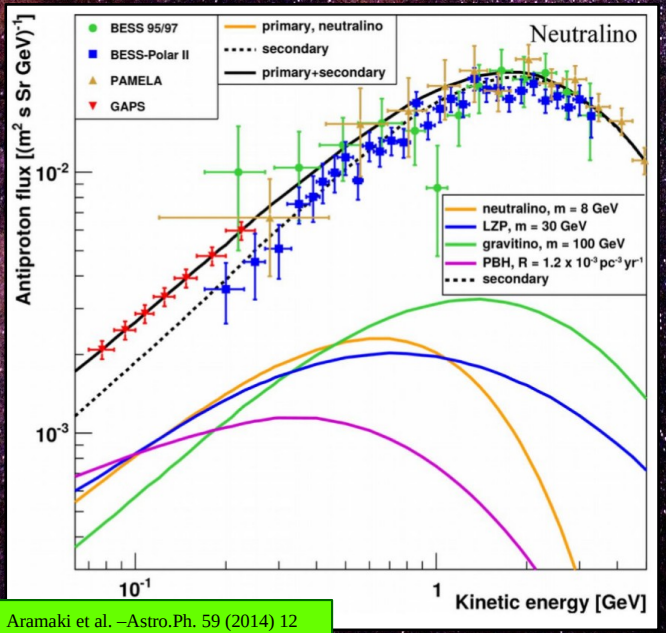


Dark Matter





Donato, Maurin, Brun, Delahaye, Salati, PRL 102 (2009) 07130

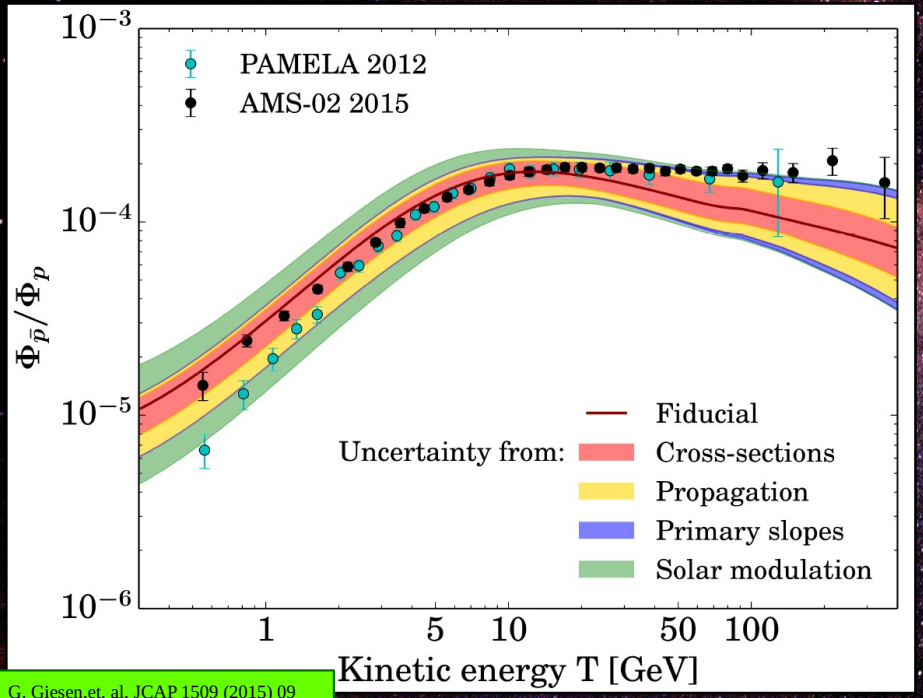


Aramaki et al. –Astro.Ph. 59 (2014) 12

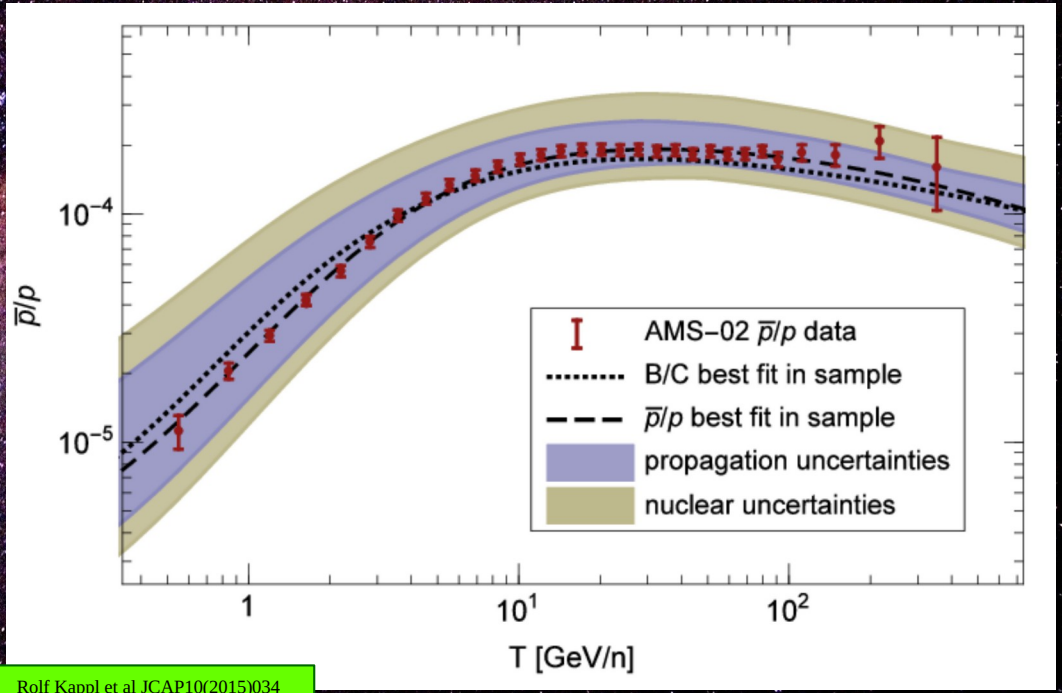
Antiproton in cosmic ray and Dark Matter

Any search for an excess need the secondary antiproton LIS and its uncertainties has to be precisely modeled.

Possible room for high energy antiproton excess for antiprotons has been significantly reduced using improved CRs propagation modelling trough the Galaxy and antiproton production cross section.



G. Giesen,et. al, JCAP 1509 (2015) 09



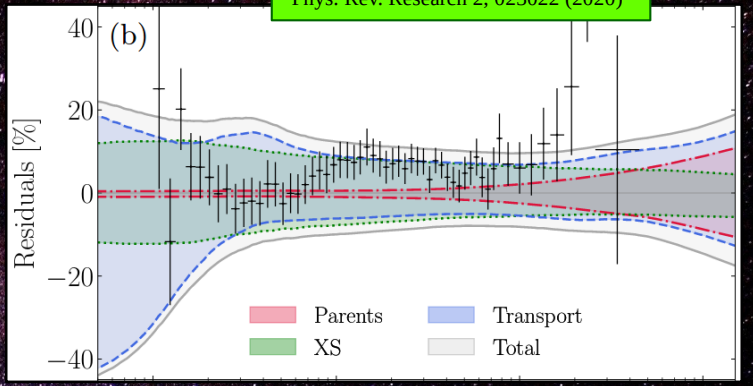
Rolf Kappl et al JCAP10(2015)034

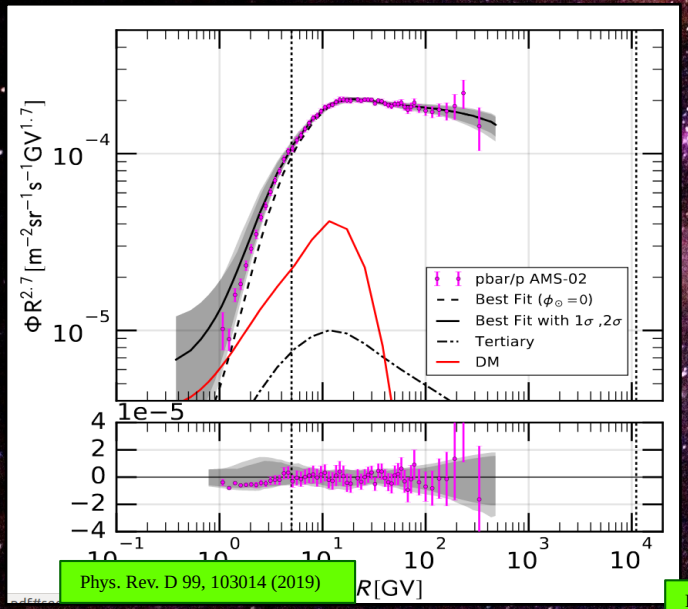
Antiproton in cosmic ray and Dark Matter

Few works claimed a possible excess in the low energy region in the AMS02 antiproton.

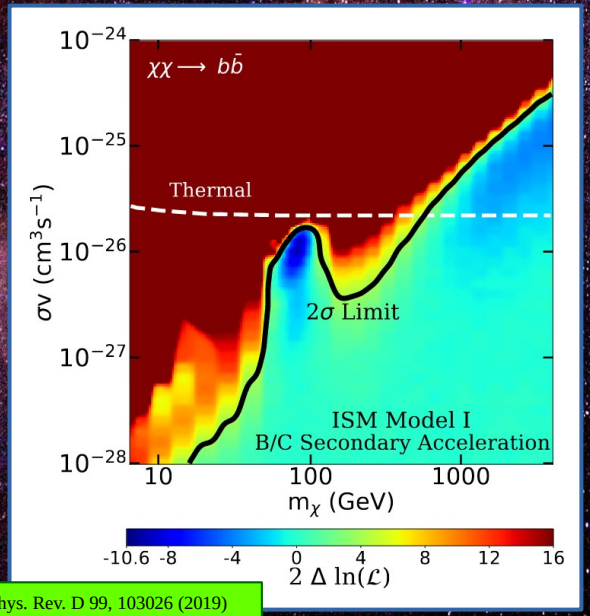
Further analysis reduce the significance of the excess if all the systematics uncertainties and their possible correlation are taken into account.

Phys. Rev. Research 2, 023022 (2020)

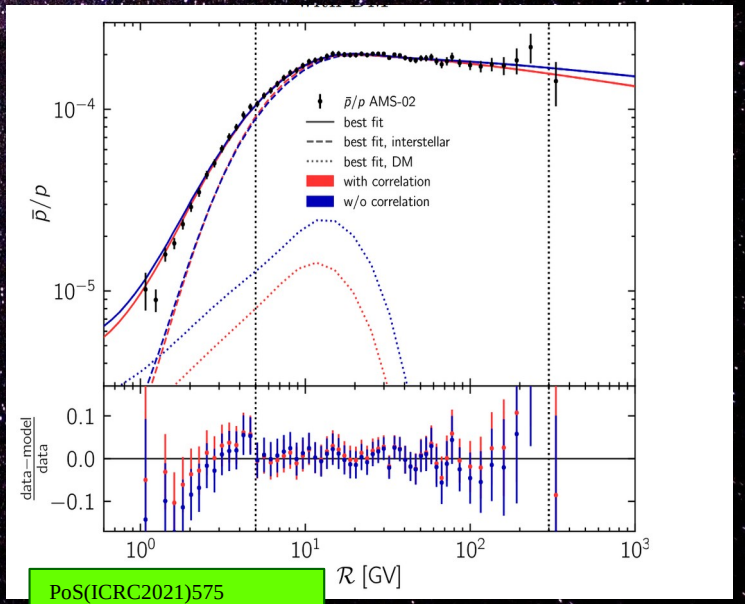




Phys. Rev. D 99, 103014 (2019)



Phys. Rev. D 99, 103026 (2019)



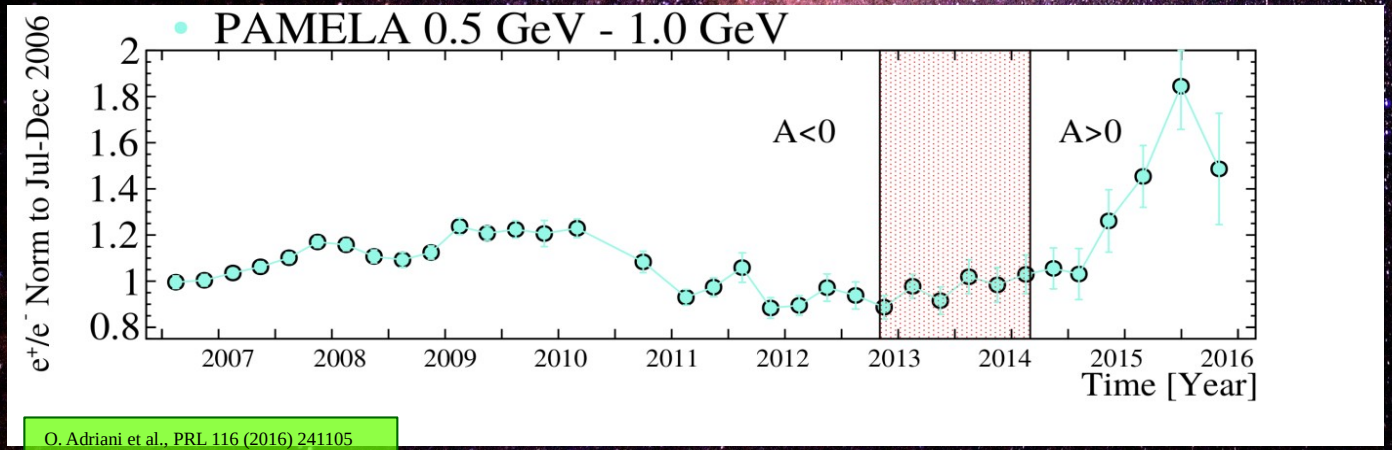
PoS(ICRC2021)575

Galactic Cosmic Rays propagation in the Heliosphere

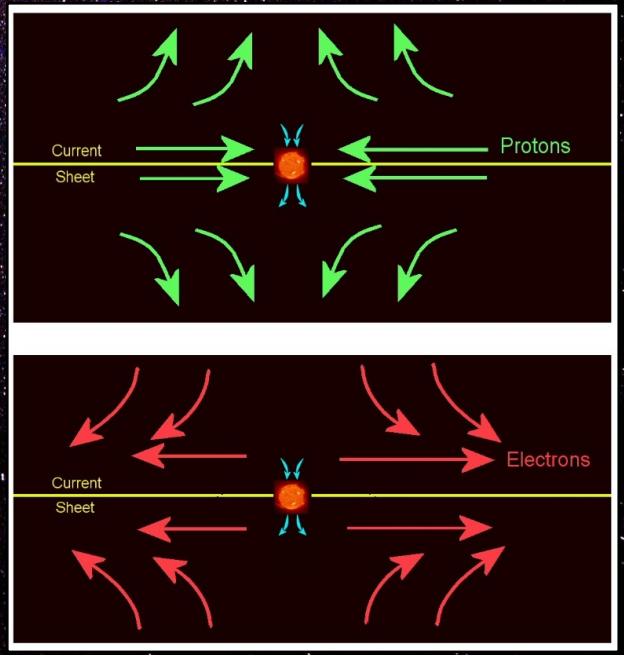
The expected signal from DM is expected to be a small fraction of the secondary component, thus precise modelling of the backgroud and its uncertainties is essential.

Below few tens of GeV the propagation of CRs is affected by the Heliosphere. This reduce the intensity with respect the Local Interstellar Spectrum. This represent also one of the major source of uncertainies at low energy.

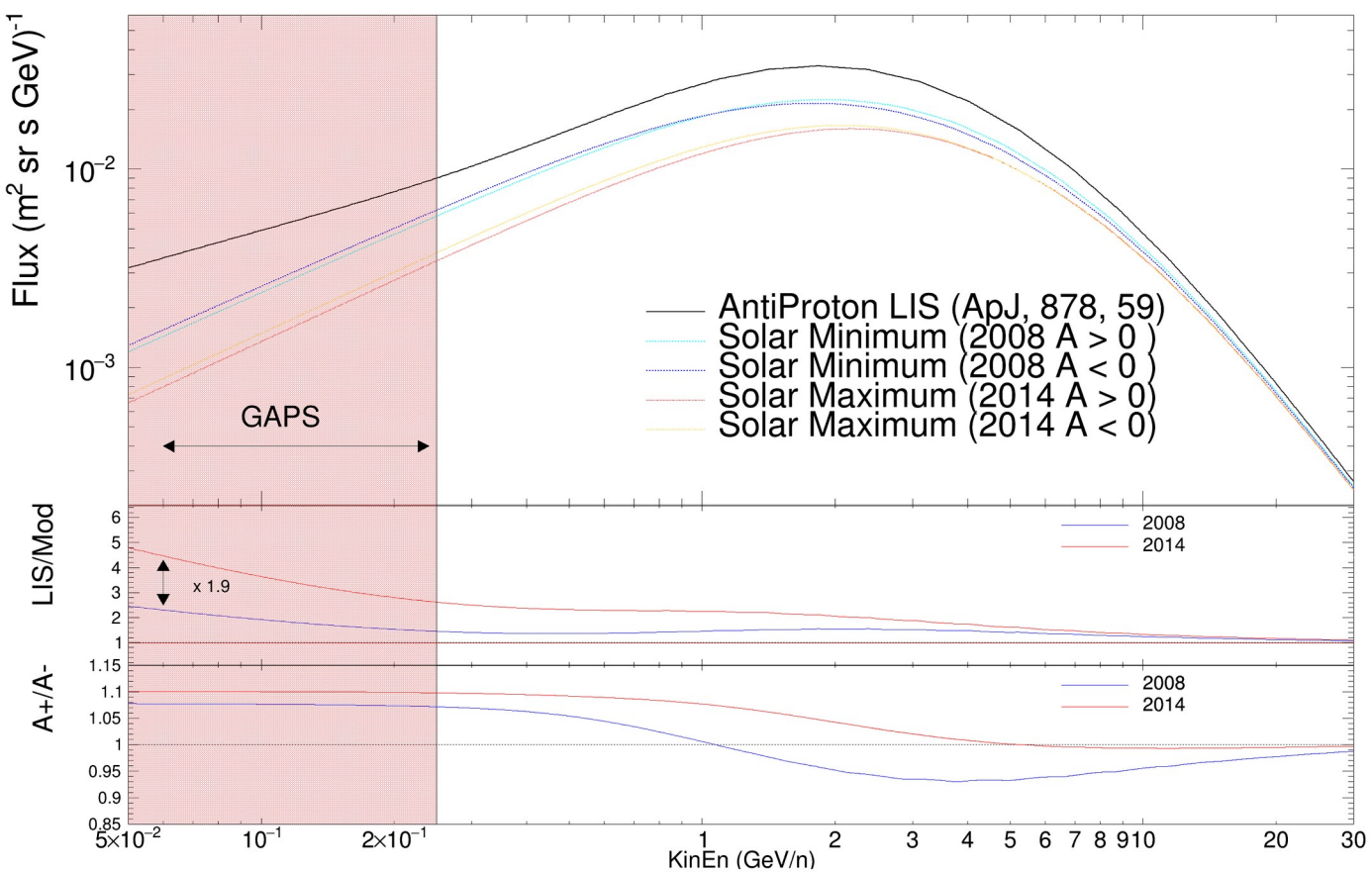
In order to search for an excess a model of the seocondary antiproton LIS is needed along with a reliable model for CRs propagation through the Heliosphere. In particular the charge sign dependence is relevant.



O. Adriani et al., PRL 116 (2016) 241105



Antiproton solar modulation and sign charge dependence

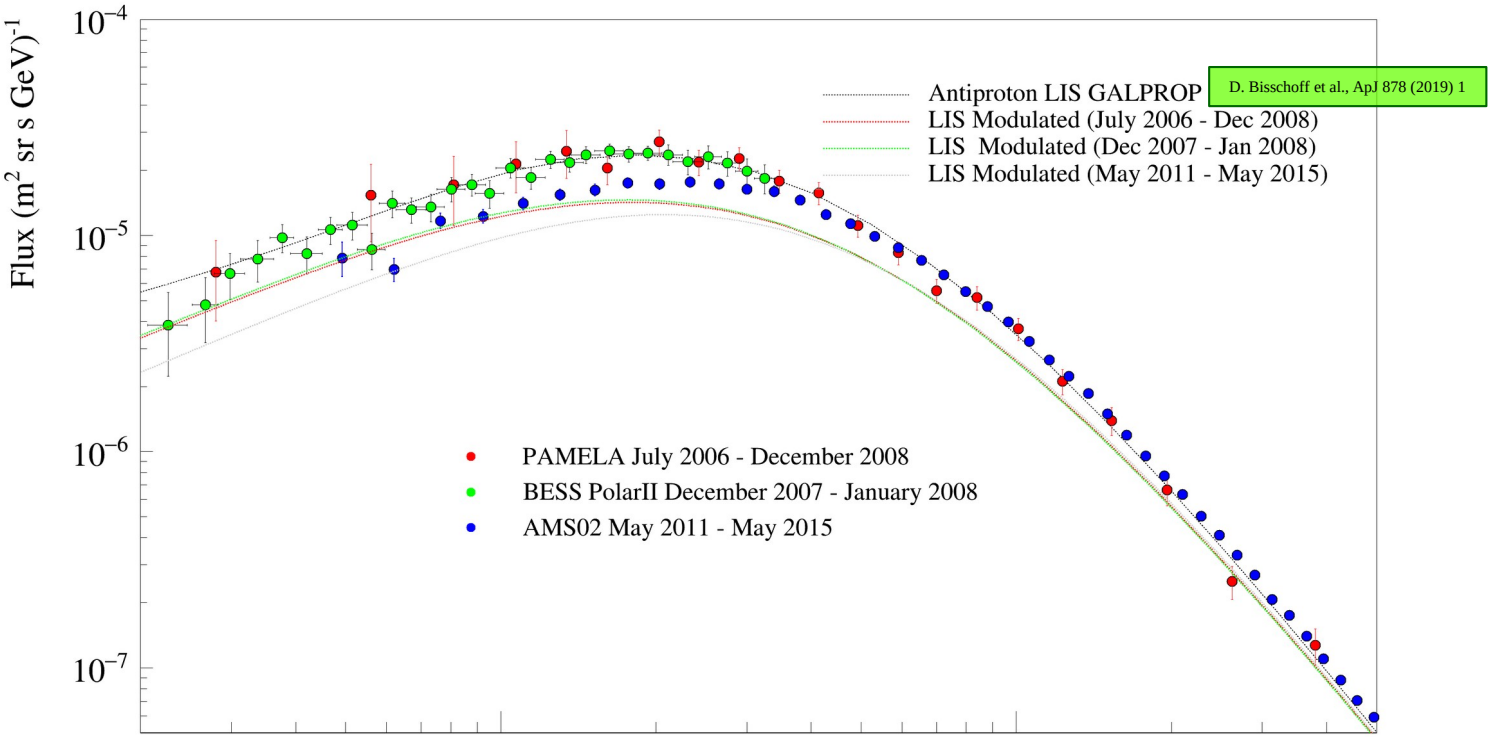


The effect of the charge sign dependece is of the order of 5-10% up to 10 GeV/n.

If a model like the force field approximation tuned on the proton spectra is used a systematics of 5-10% is introduced.

Modulation model need to take into account for all the mechanism in order to study antimatter.

An antiproton LIS able to reproduce the experimental data

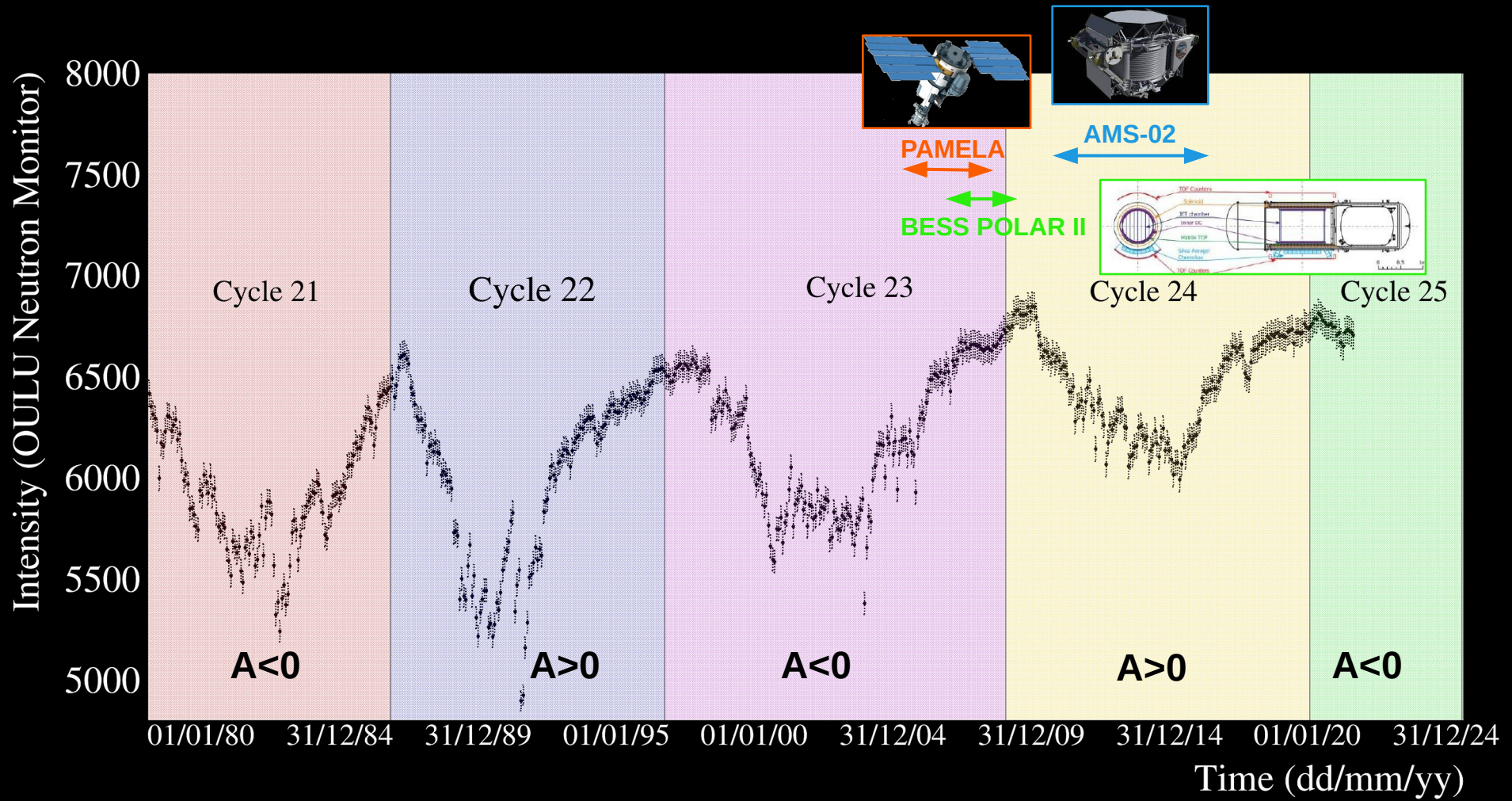


Final Goal

Estimate the best antiproton LIS and its uncertainties due to the solar modulation and the experimental data.

PAMELA, BESS PolarII and AMS02 antiproton data will be used to fine tune the antiproton Local Interstellar Spectrum obtained with GALPROP in order to reproduce, when modulated with a 3D numerical model tuned on the proton spectra, the measured antiproton spectra.

Antiproton data set from PAMELA, BESS PolarII and AMS-02



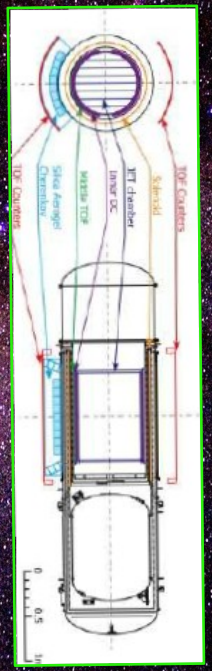
PAMELA , BESS Polar II and AMS-02

PAMELA

July 2006 – March 2016
Time of Flight + Magnetic spectrometer + Calorimeter
50 MeV – 1 TeV
e^+, e^-, p, He, He3, He4, D, H

AMS-02

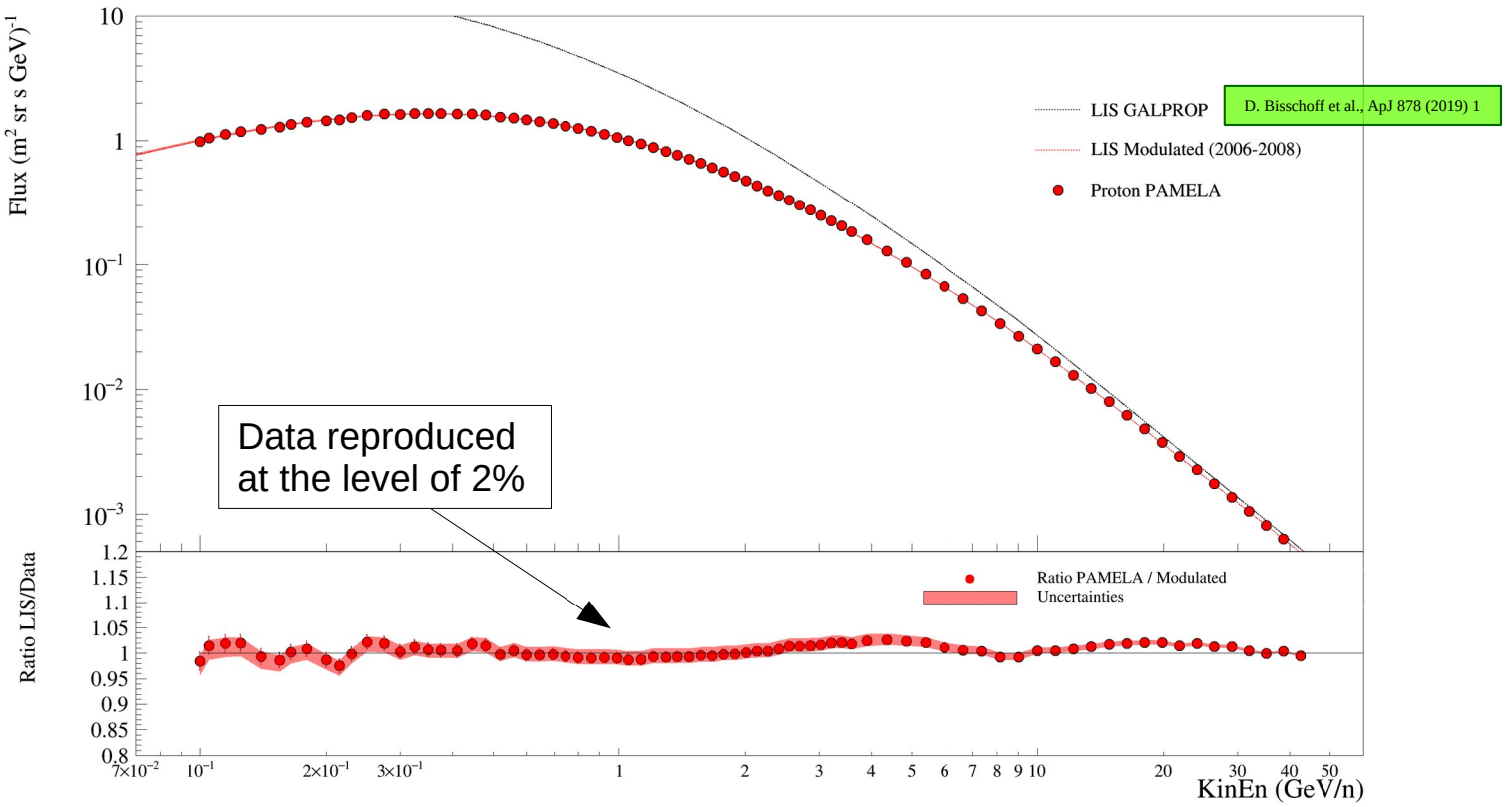
May 2011 – Today
Time of Flight + Magnetic spectrometer + Calorimeter + TRD + Cherenkov
500 MeV – 3 TeV
e^+, e^-, p, p, He, He3, He4, D, C, O



BESS PolarII

Devember 2007 – January 2008
Time of Flight + Magnetic spectrometer + Calorimeter
10 MeV – 100 GeV
e^+, e^-, p, He, He3, He4, D, H

Calibrate the solar modulation on protons: PAMELA

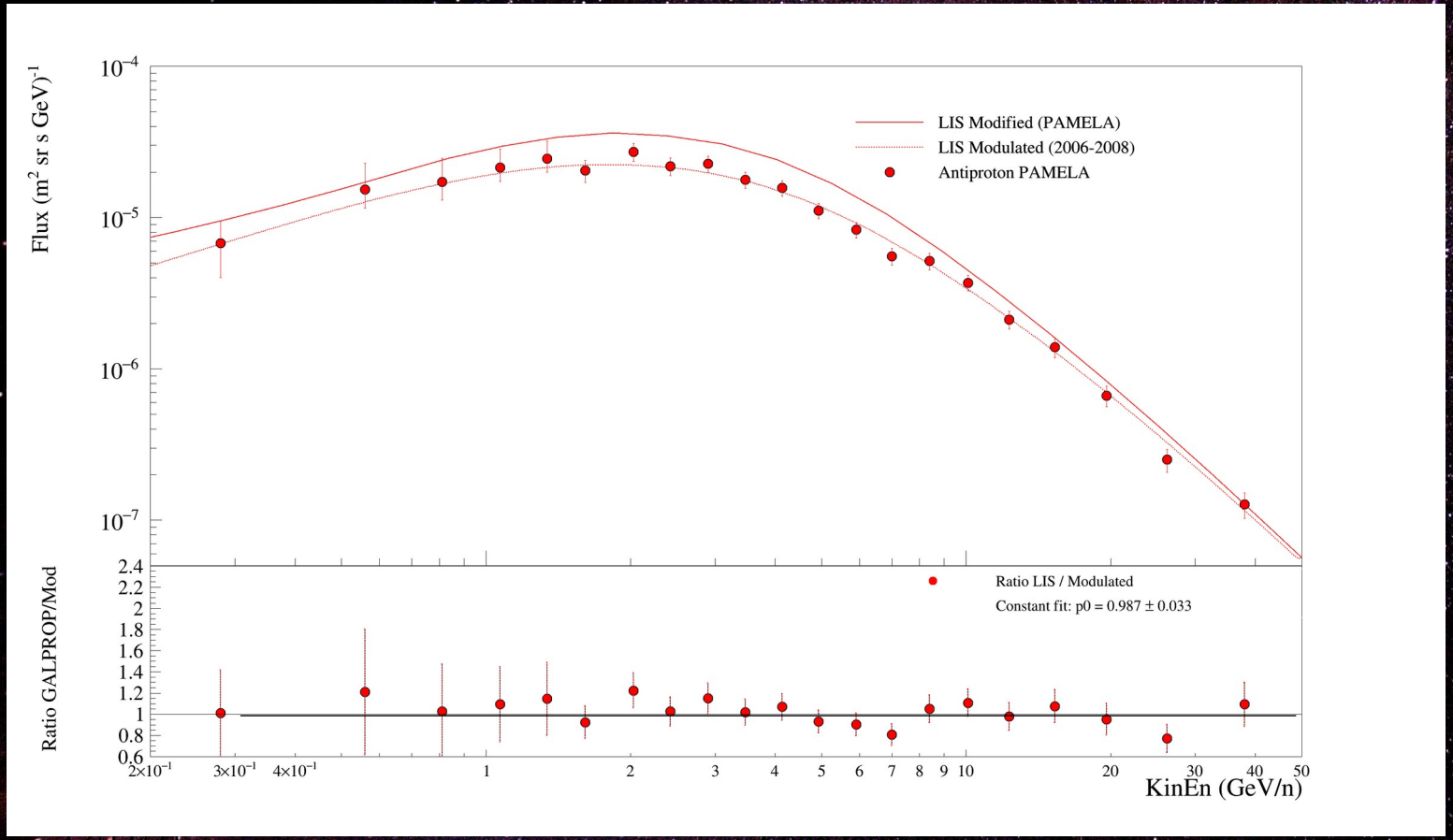


The published PAMELA proton data were averaged over the period July 2006 and December 2008.

The diffusion coefficients of the 3D numerical model were tuned in order to reproduce the PAMELA data (chi2 minimization).

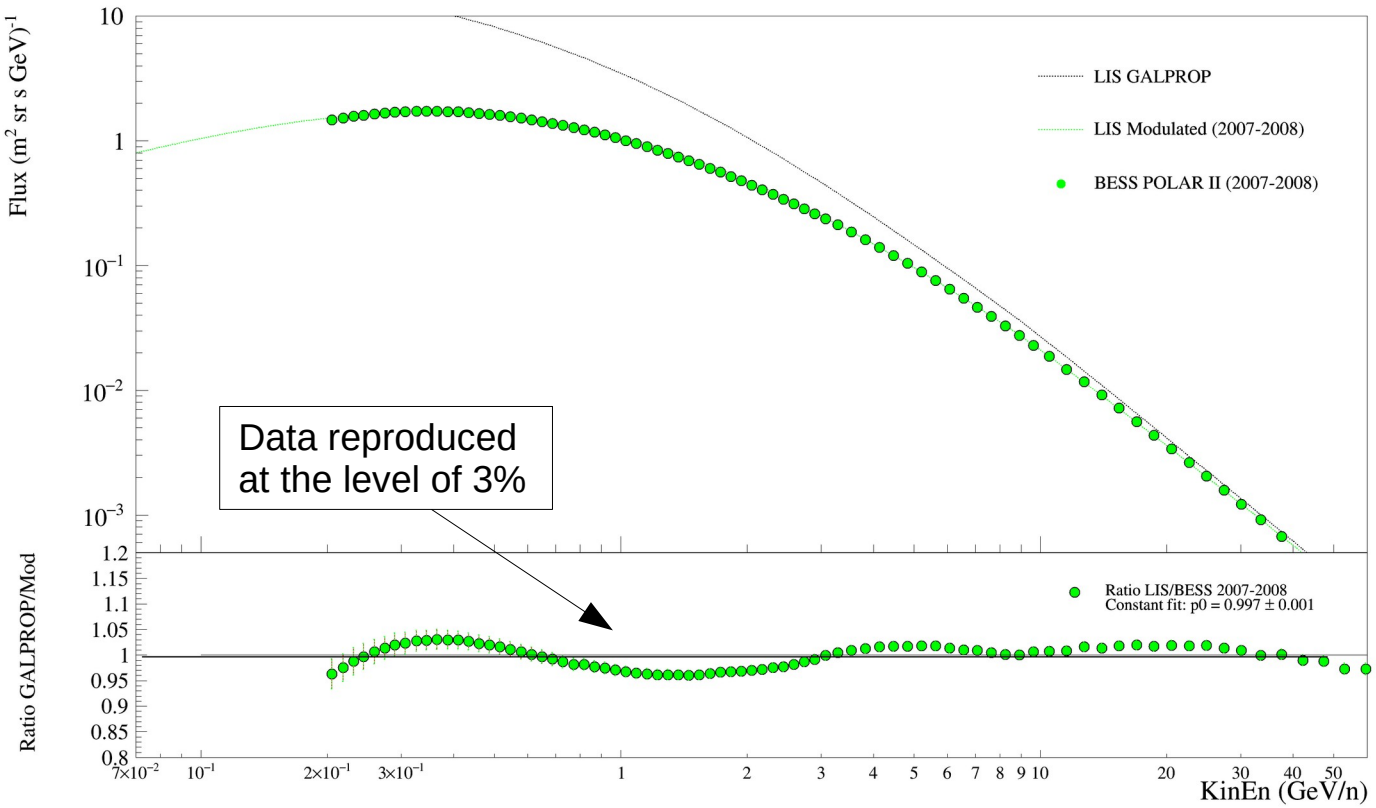
The shaded area represent an estimated systematics which take into account for the experimental uncertainties.

The Antiproton LIS from PAMELA data



The GALPROP antiproton LIS has been modified in order to reproduce the experimental data when modulated with the parameters calibrated on the protons (opposite polarity of the HMF).

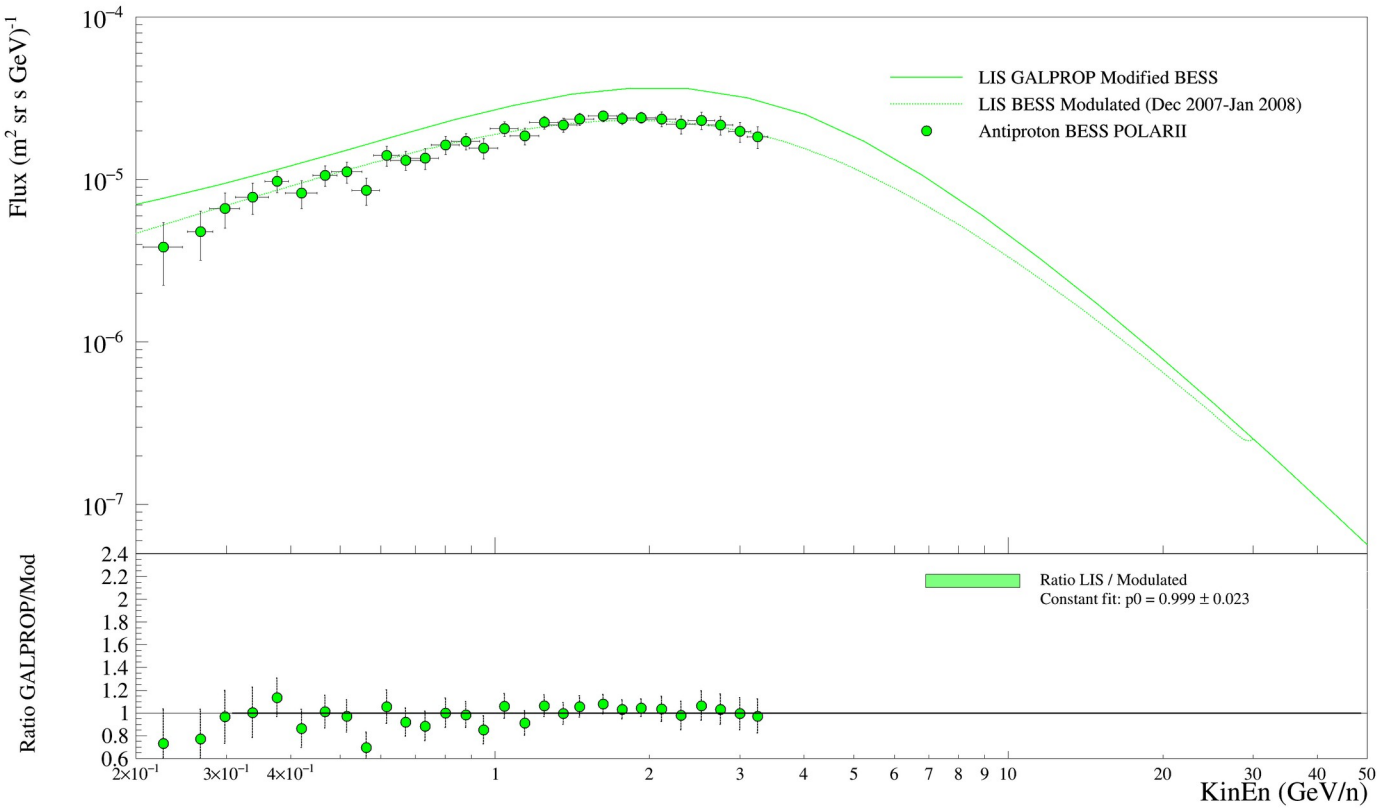
Calibrate the solar modulation on protons: BESS



The published BESS polar II data refers to the period from December 2007 to January 2008.

The diffusion coefficients of 3D numerical model were tuned in order to reproduce the experimental data.

The Antiproton LIS from BESS Polar II data

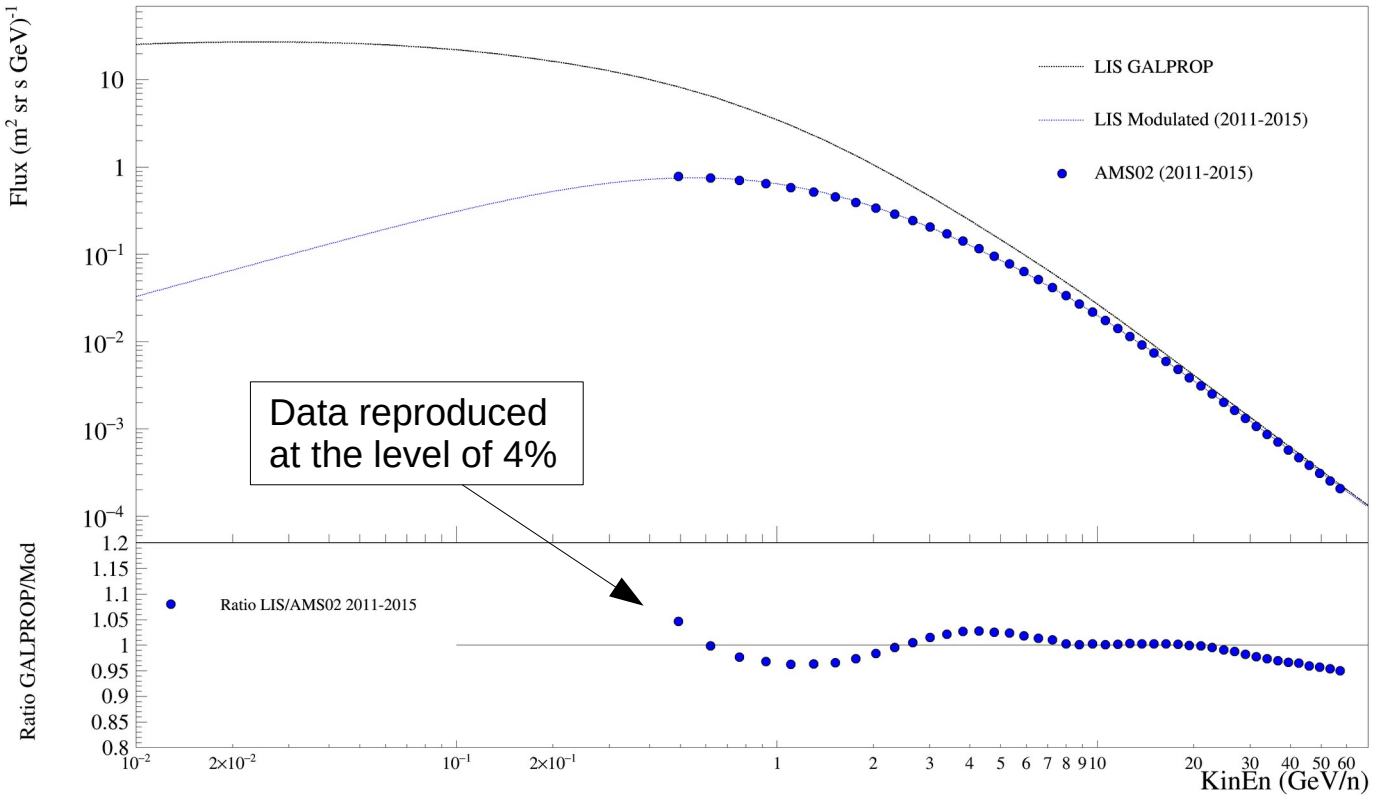


The GALPROP antiproton LIS was smoothly modified in order to reproduce, once modulated, the BESS Polar II data .

Below 2 GeV the BESS Polar II antiproton data has lower statistical with respect to PAMELA uncertainties which reflects in a smaller systematics for the LIS.

Since experimental data extend just up to 3 GeV above this energy the LIS cannot be re-defined.

Calibrate the solar modulation on protons: AMS-02

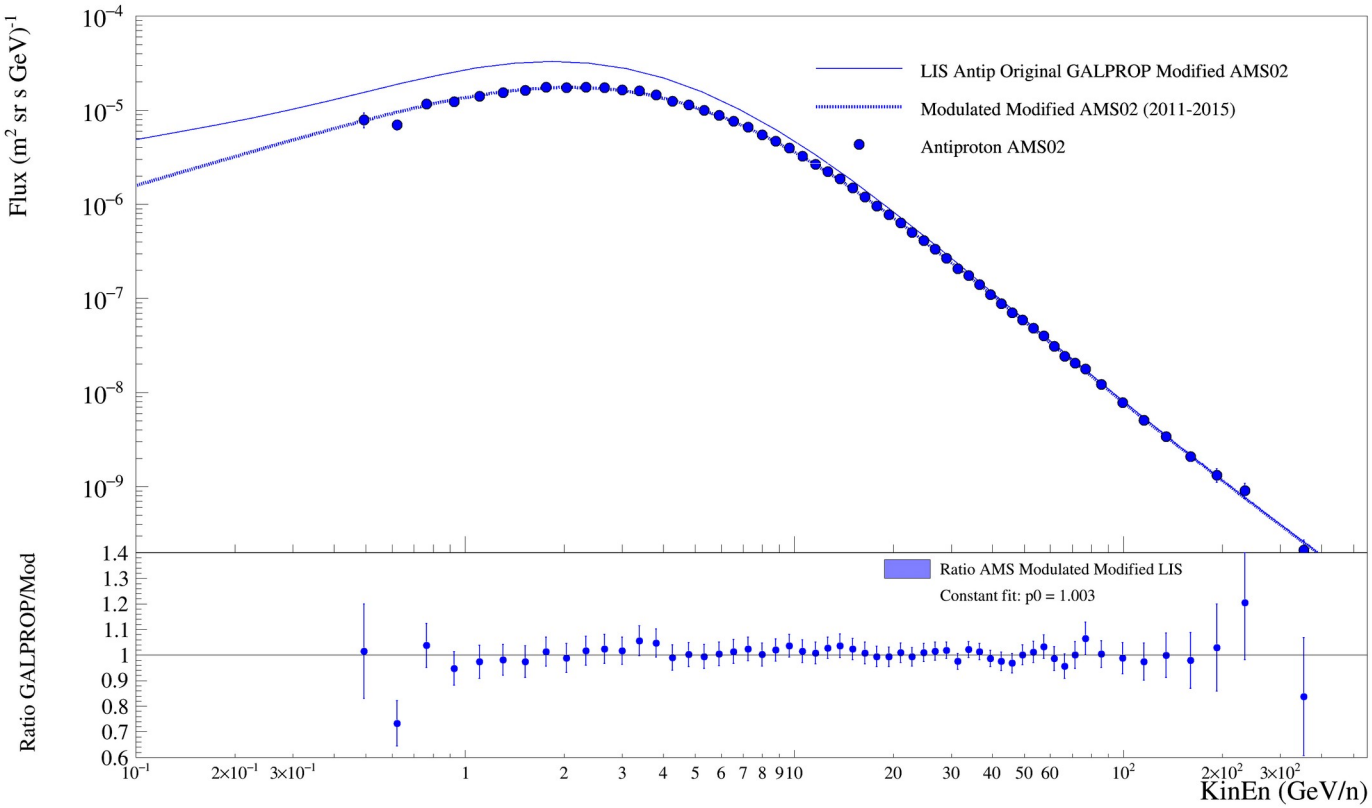


AMS-02 antiproton data extend over 4 years in a period of maxium solar activity and a polarity reversal of the HMF. Is more challenging to reproduce the appropriate solar activity conditions.

AMS-02 proton data were split into two dataset one for each HMF polarity and they were modulated separately.

Then the average spectra was considered.

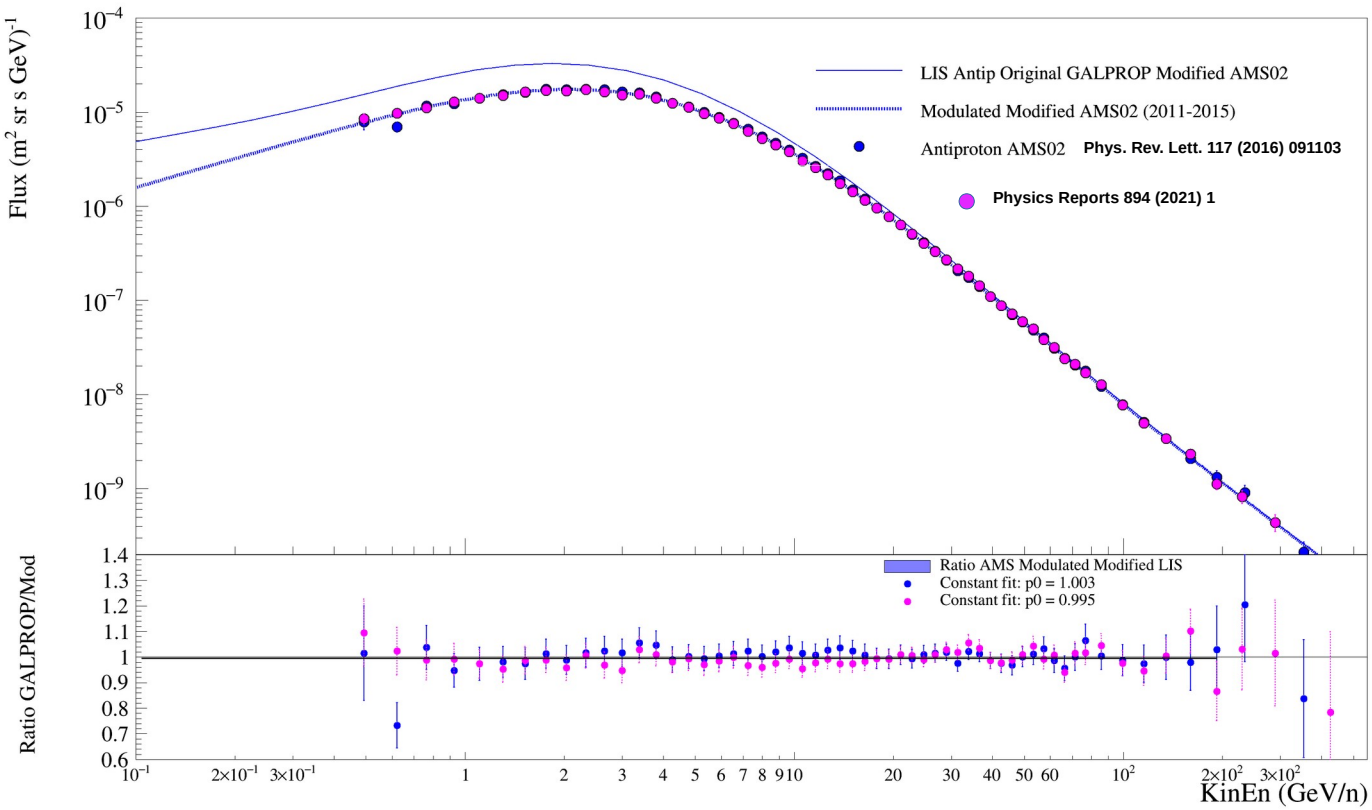
The Antiproton LIS from AMS02 data



The GALPROP antiproton LIS was smoothly modified in order to reproduce, once modulated, the AMS-02 data .

The associated uncertainties are much lower with respect to the PAMELA and BESS Polar II derived LIS due to the higher statistics.

The Antiproton LIS from AMS02 data



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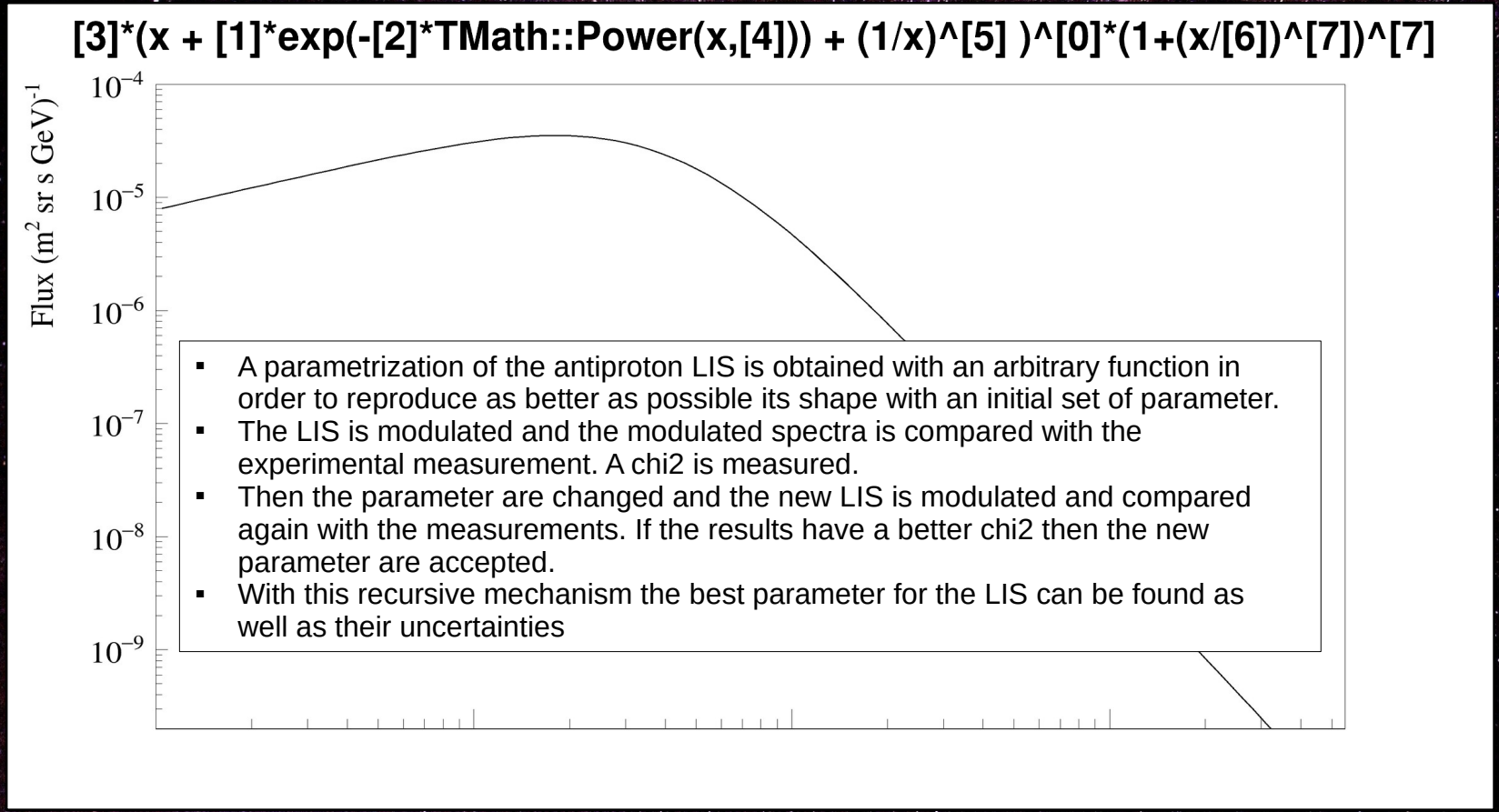
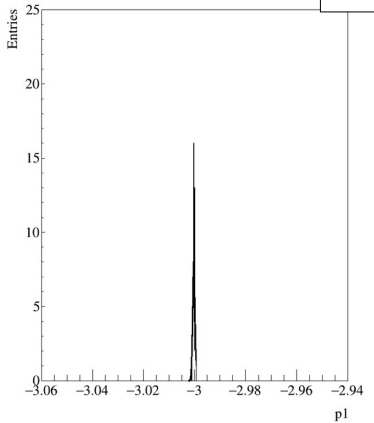
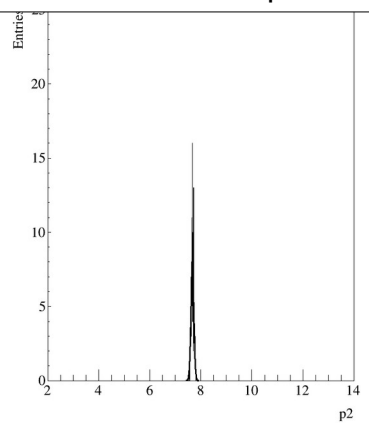
Estimating the uncertainties with Markov chain

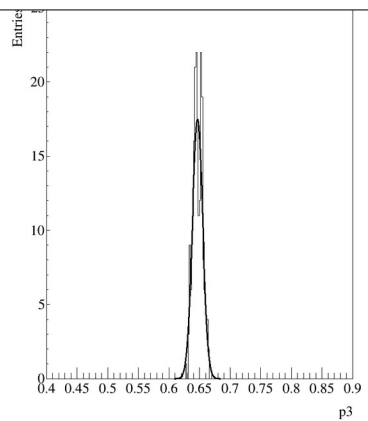


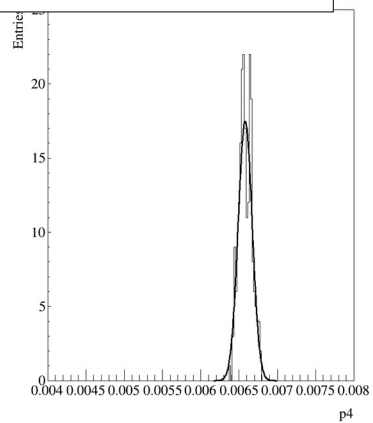
Estimating the uncertainties with Markov chain

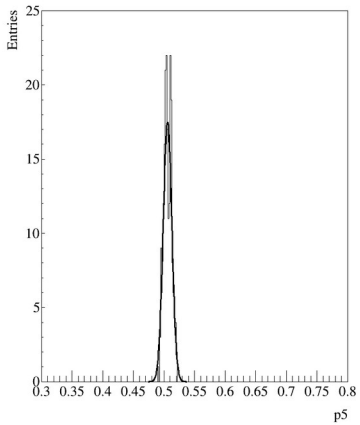
- Parameters distribution for the LIS parametrization
- Gaussian fit to each parameter in order to estimate the sigma

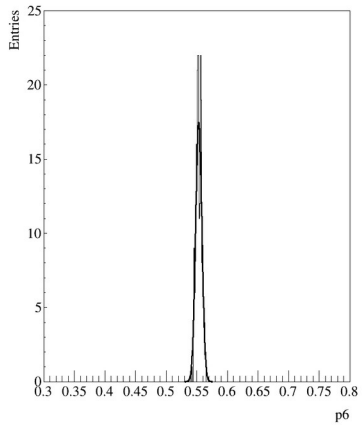


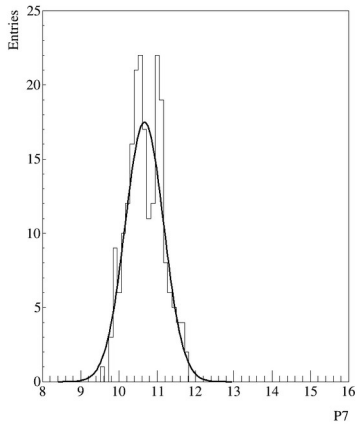


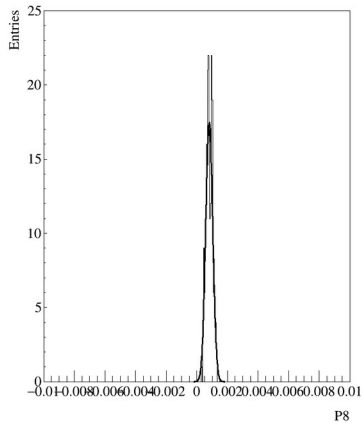




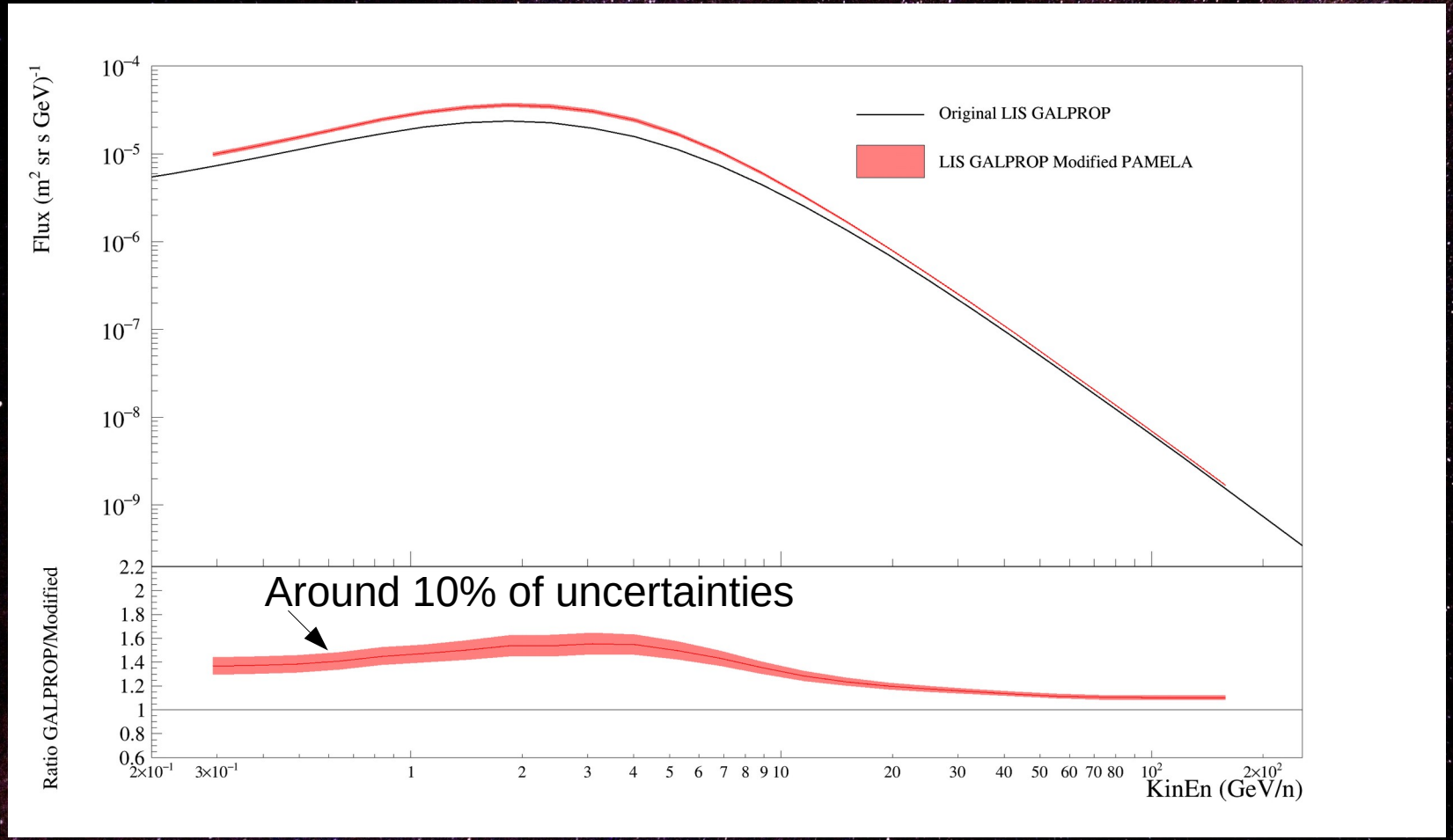








Estimating the uncertainties with Markov chain



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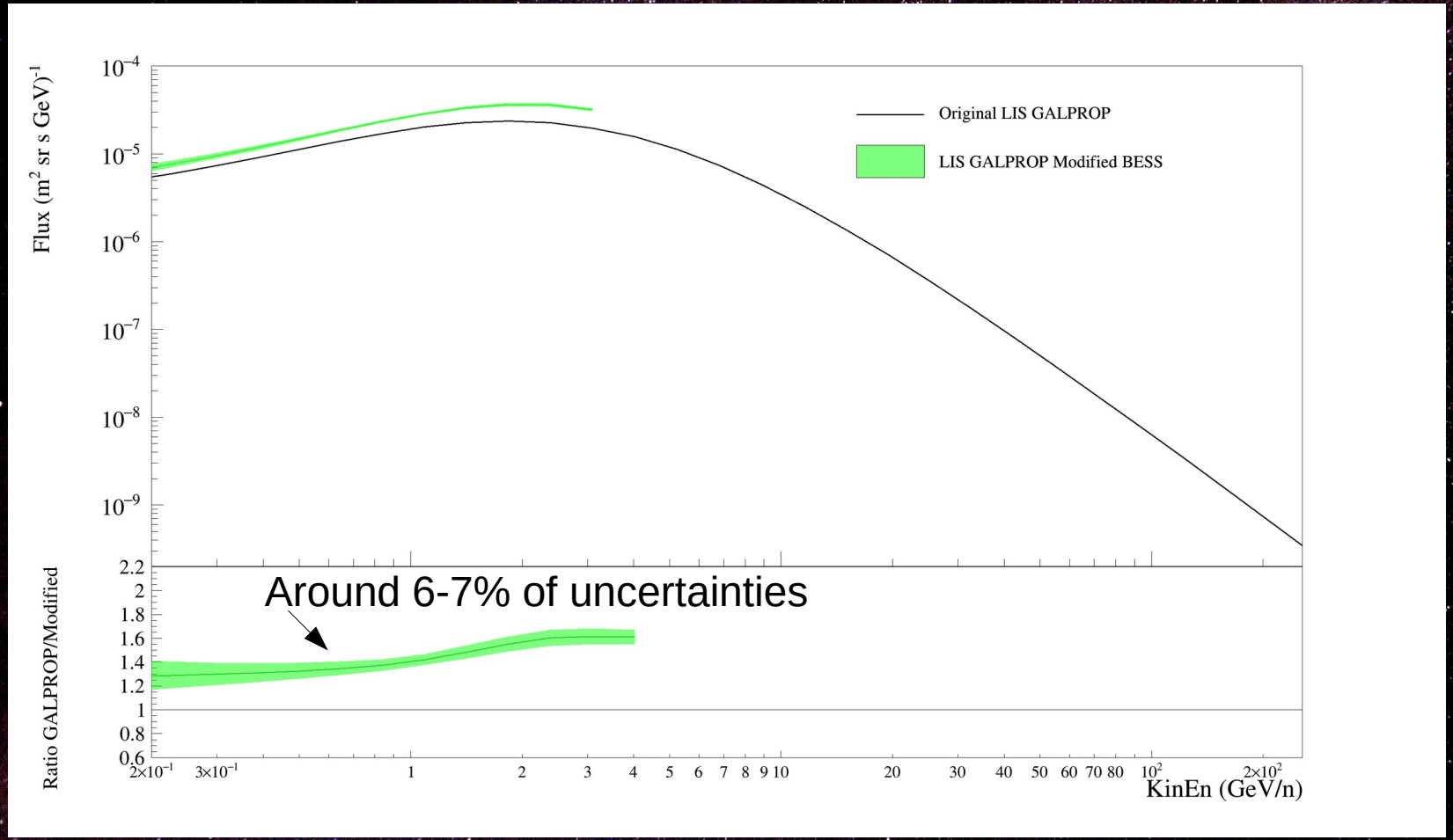

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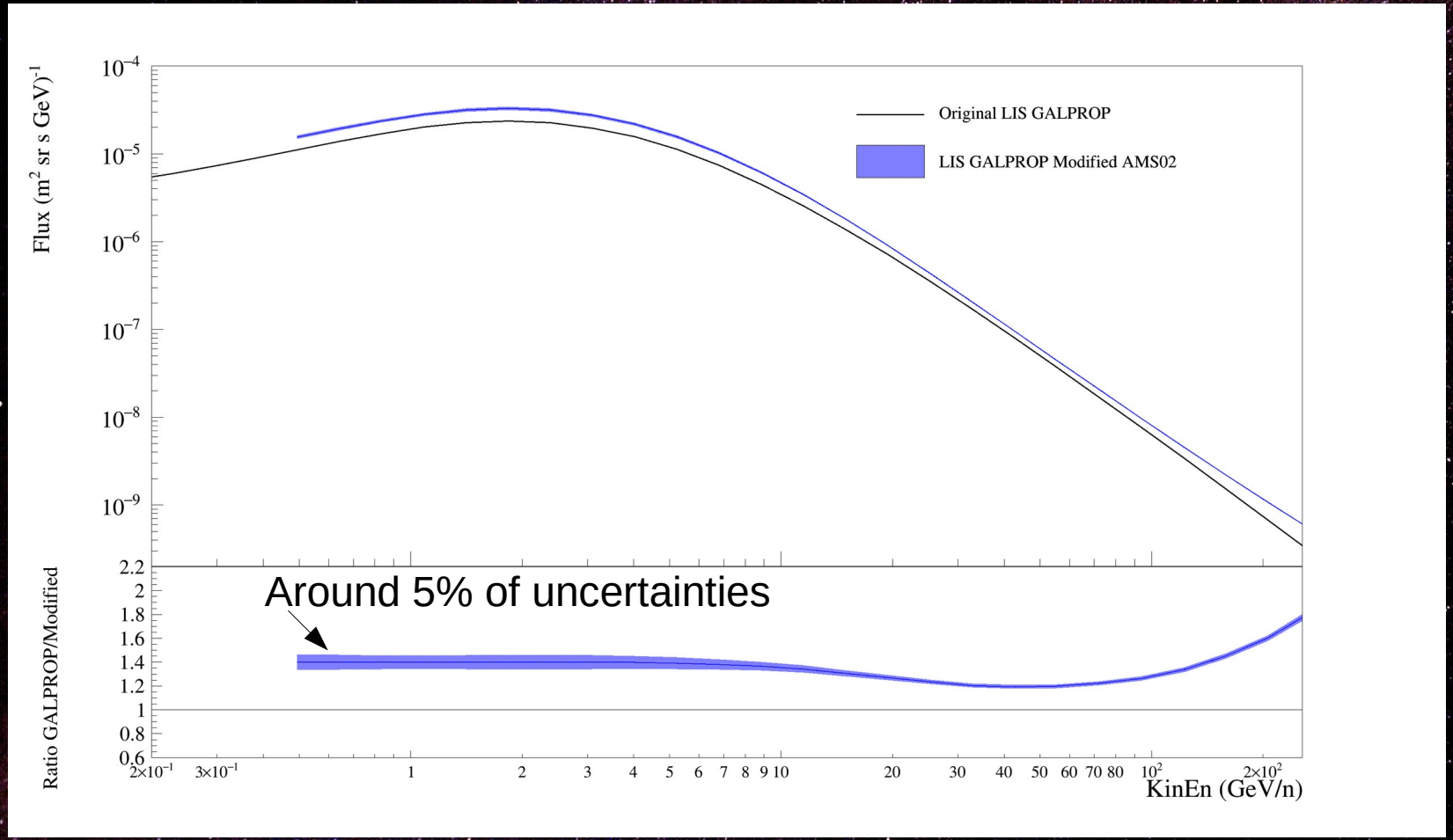

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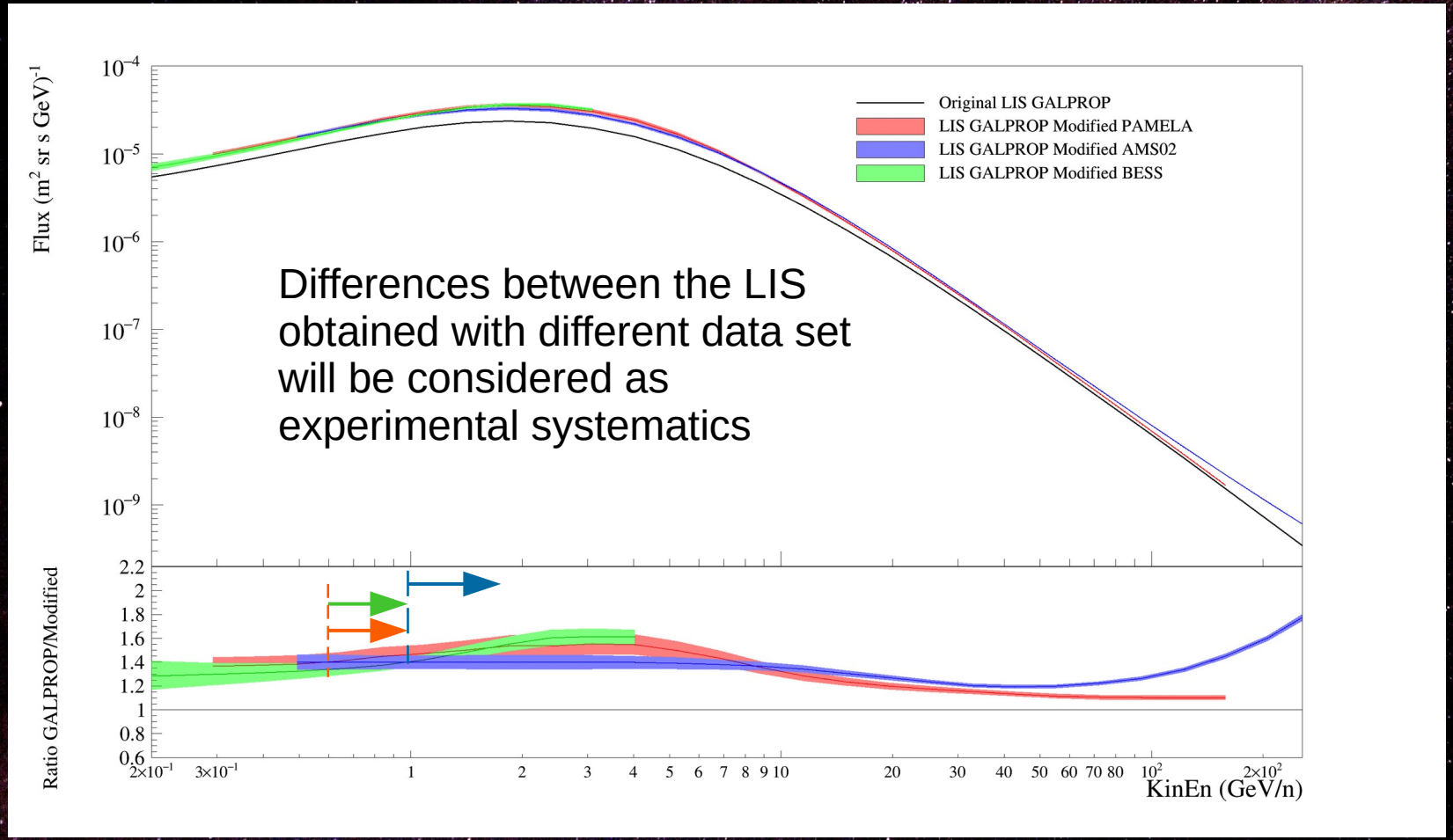

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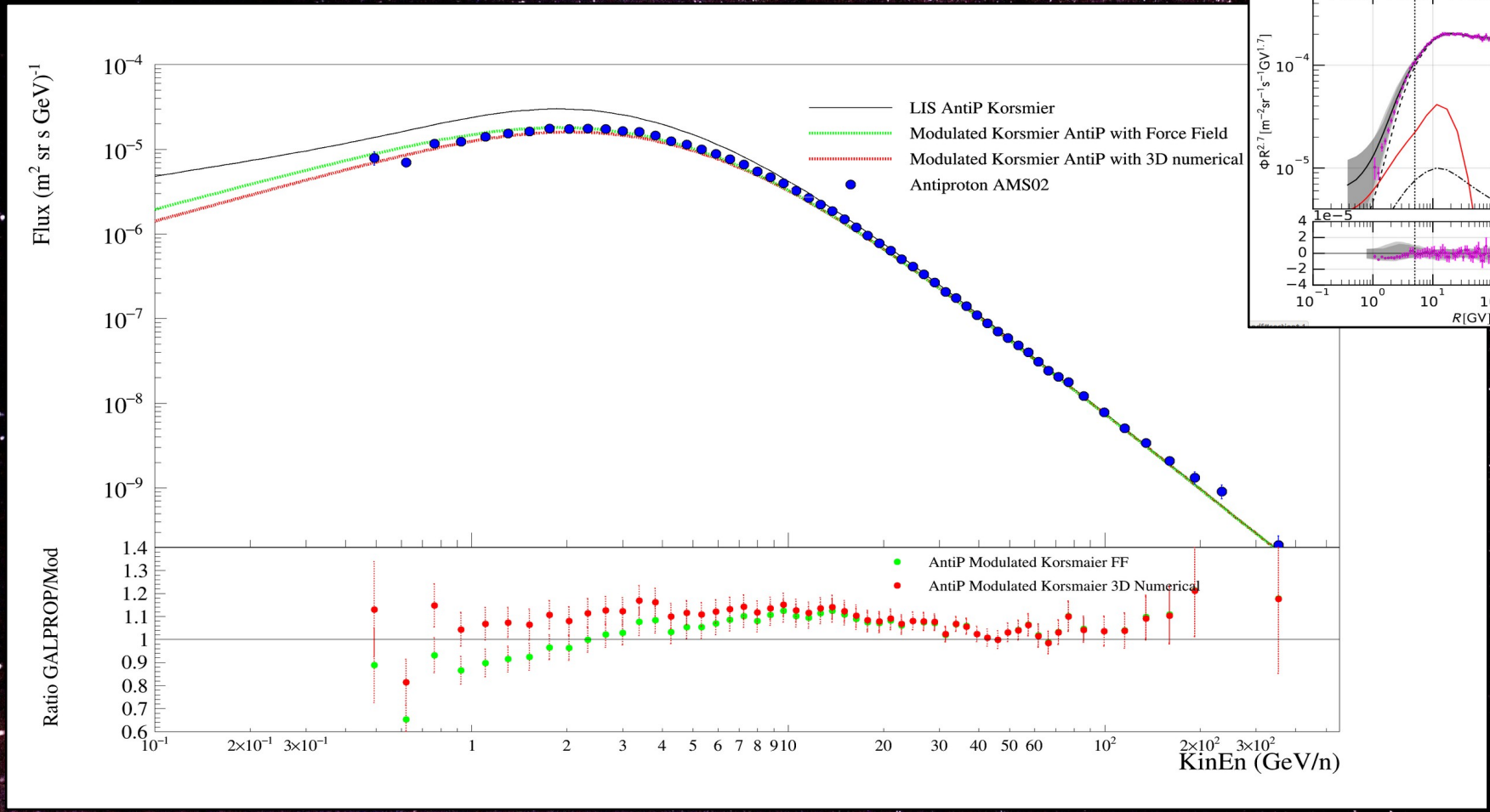

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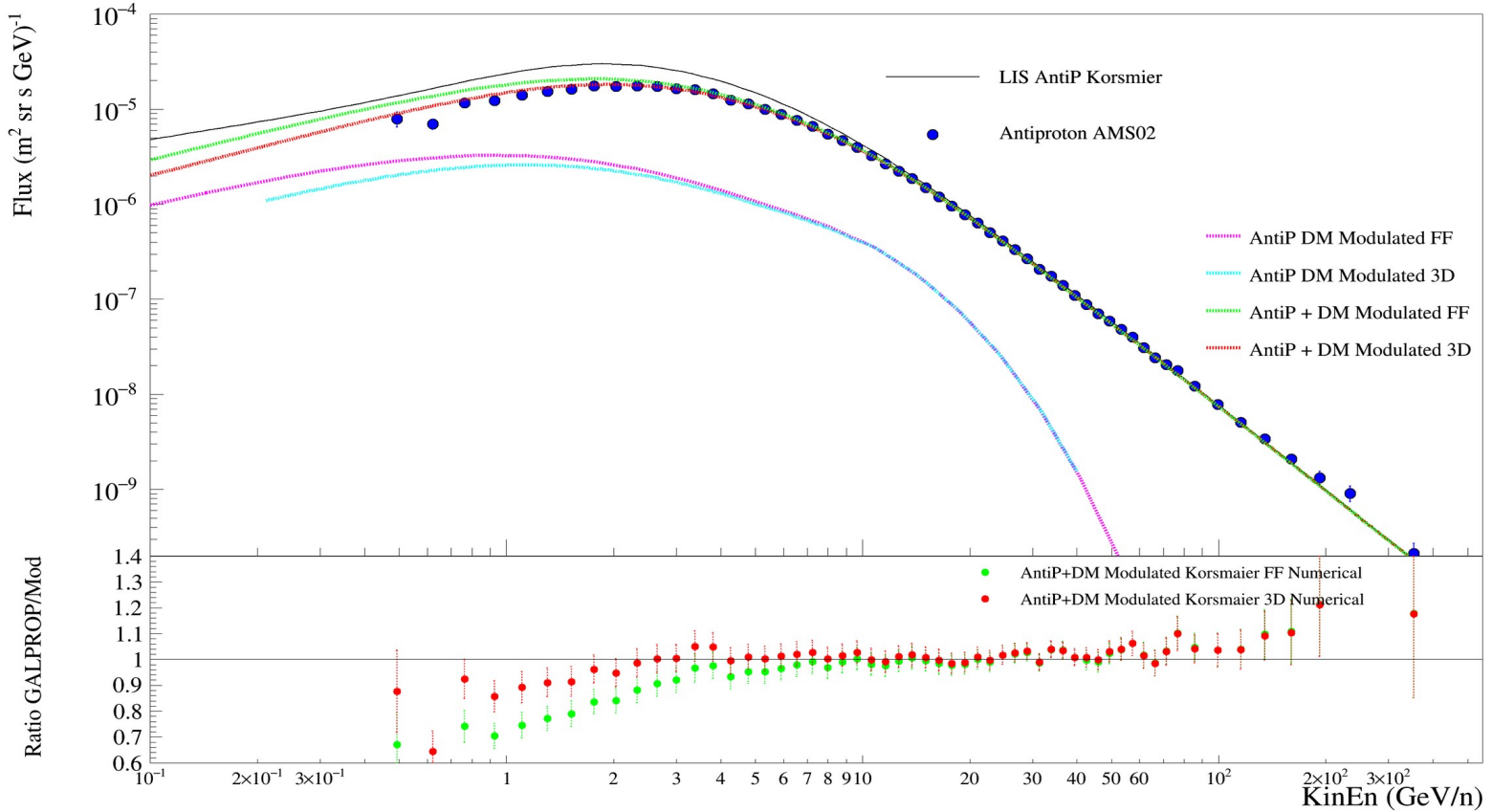

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