

# SOLAR MODULATION OF GALACTIC COSMIC RAY PROTONS ELECTRONS AND POSITRONS OVER THE 23RD SOLAR MINIMUM WITH THE PAMELA EXPERIMENT.

Riccardo Munini

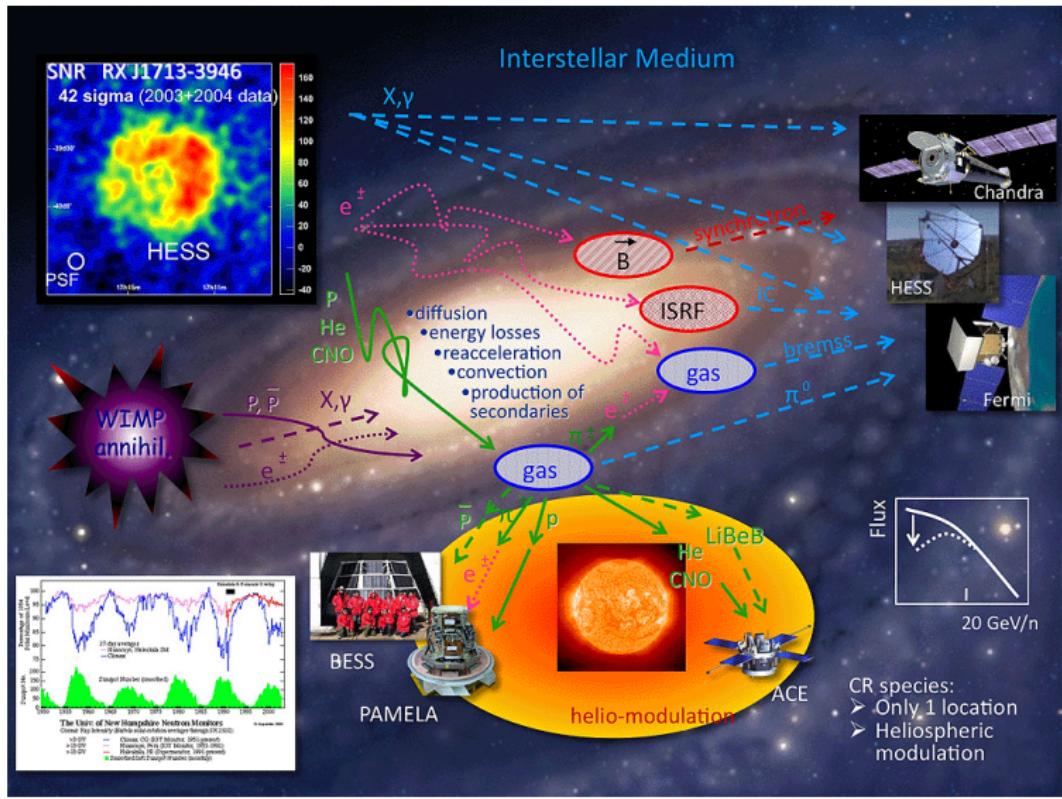
Università degli studi di Trieste - INFN

International Conference on Particle Physics and Astropysics, October  
5 - 10, 2015, Moscow

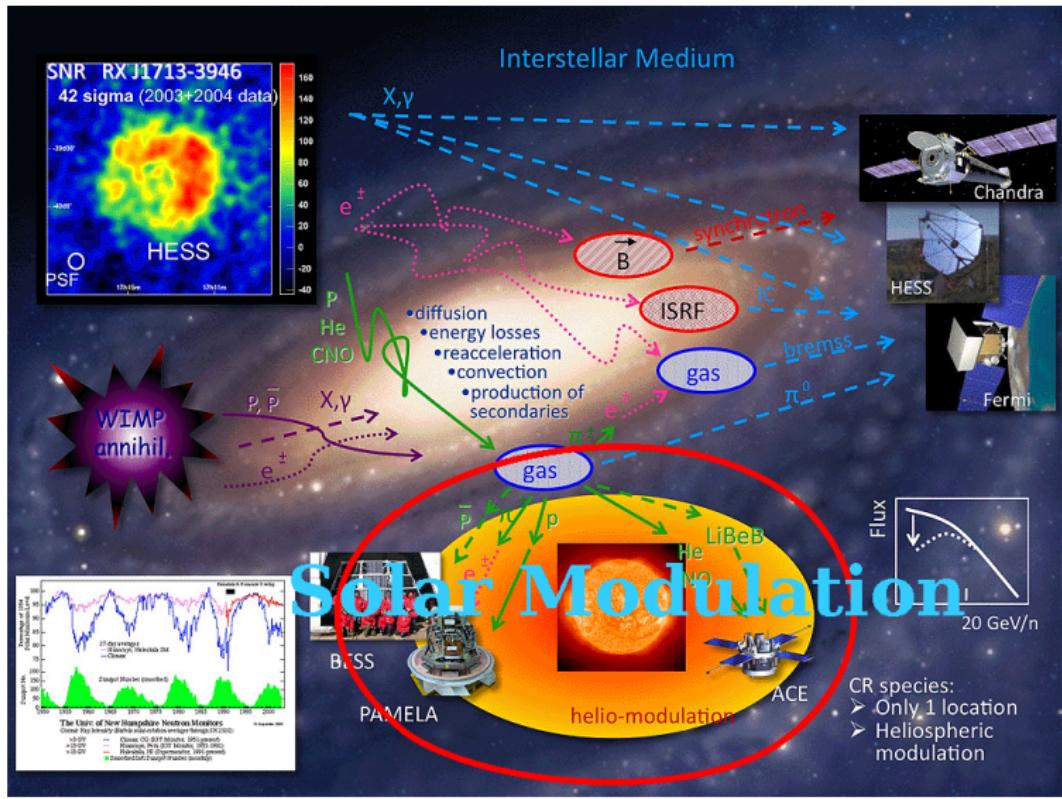


a Payload for Antimatter Matter Exploration  
and Light-nuclei Astrophysics

# COSMIC RAY PROPAGATION



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# CR SOLAR MODULATION WITH PAMELA

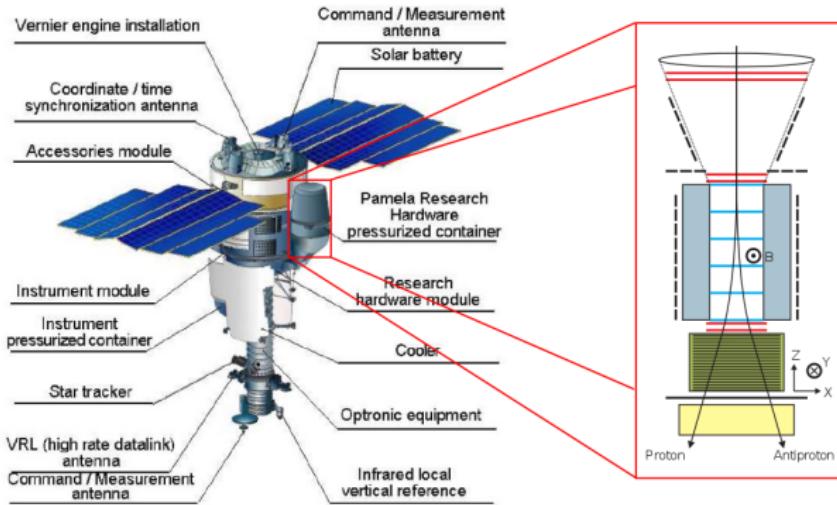
# THE PAMELA INSTRUMENT

## PAMELA

- Launch in June 2006;
- Orbital altitude 350/610 km ;
- More than 50 TB;

## MAIN GOALS

- Direct detection of CRs in space;
- Precise measurement of (anti)particles;
- Solar modulation, solar physics;



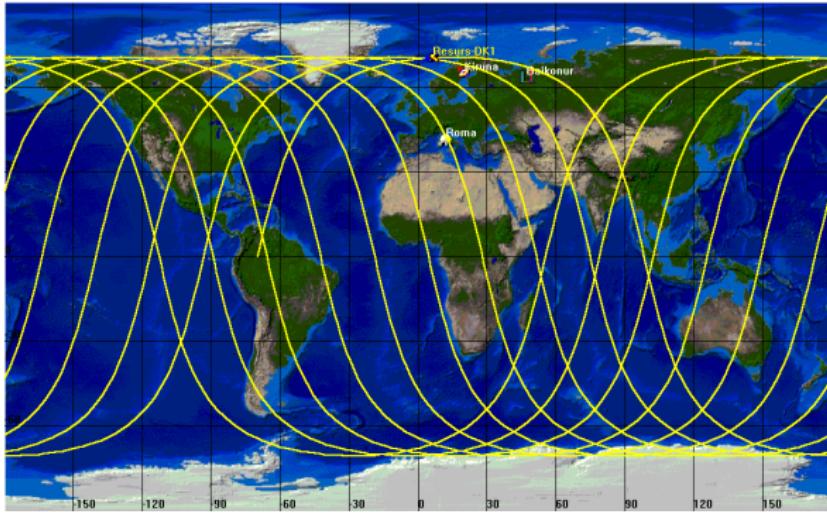
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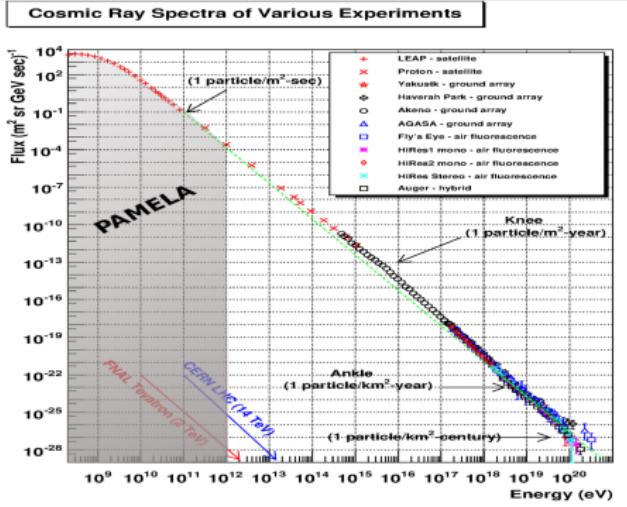
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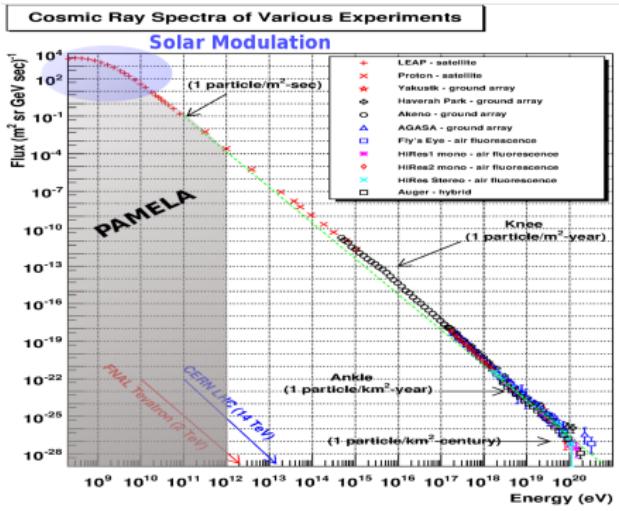
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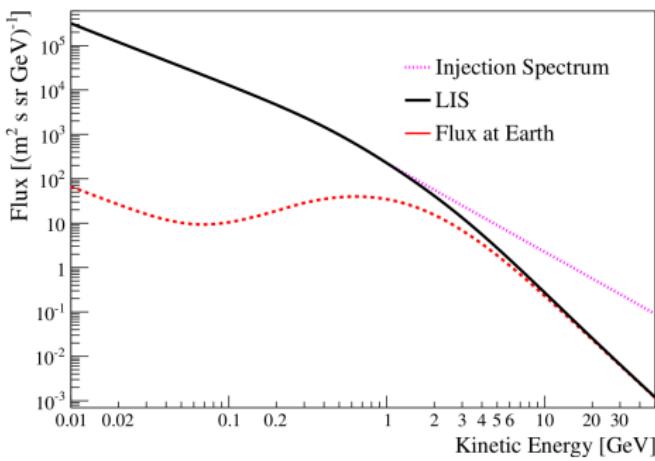
**Below 30 GV CR intensity decreases with respect to the LIS;**

## TIME-DEPENDENT MODULATION

- Sun activity: 11 years cycle;
- Time-dependent CR intensity;

## CHARGE-DEPENDENT MODULATION

- Magnetic field gradients and curvature;
- Oppositely charge particles drift in opposite direction



## SOLAR MODULATION AND PAMELA

- Time-Dependence: long flight duration, 2006 - today, ;
- Composition: hadron lepton separation;
- Low rigidity: 70 MV for  $e^-$ , 400 MV for proton;
- Charge-Dependence: magnetic spectrometer, drift motion ;

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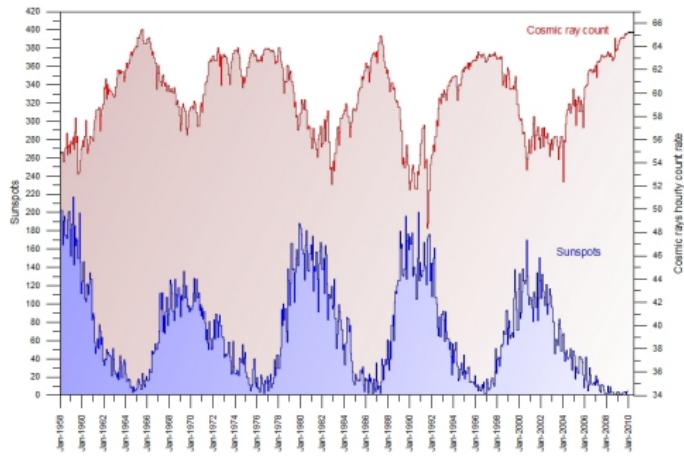
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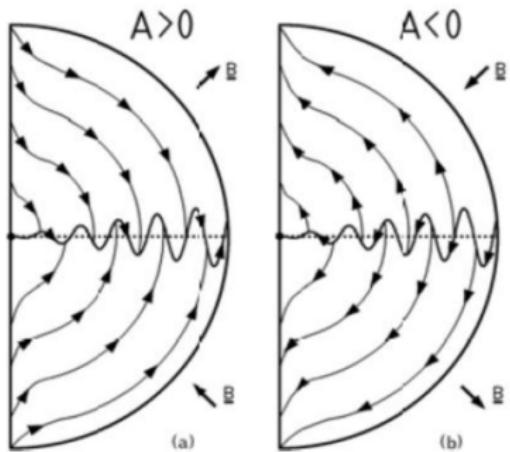
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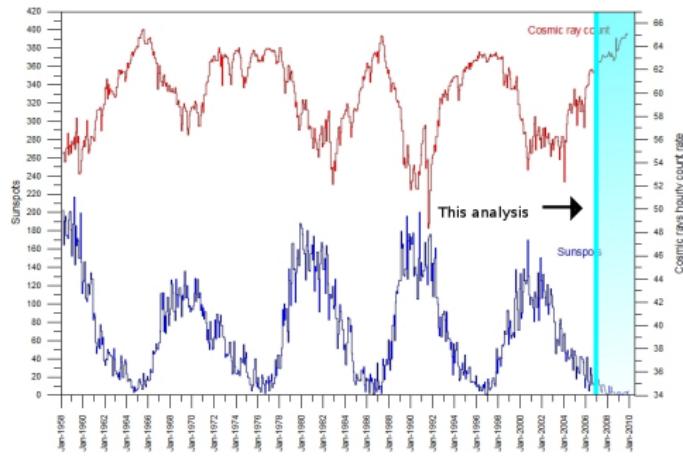
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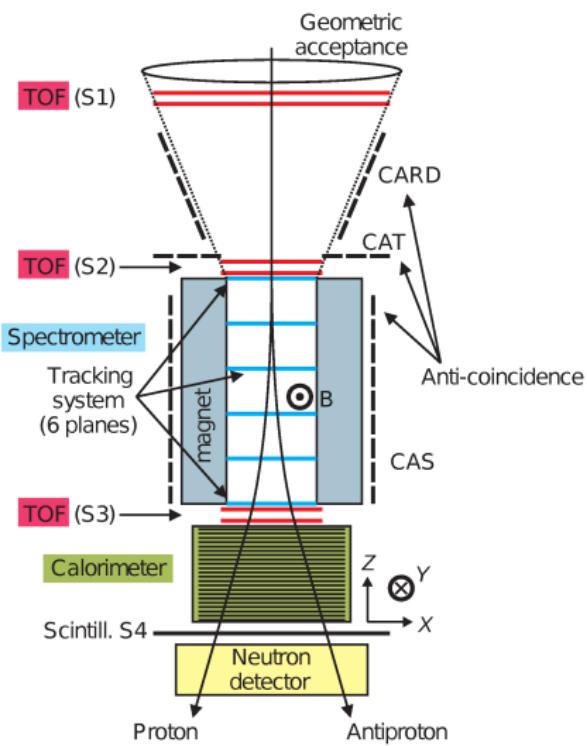
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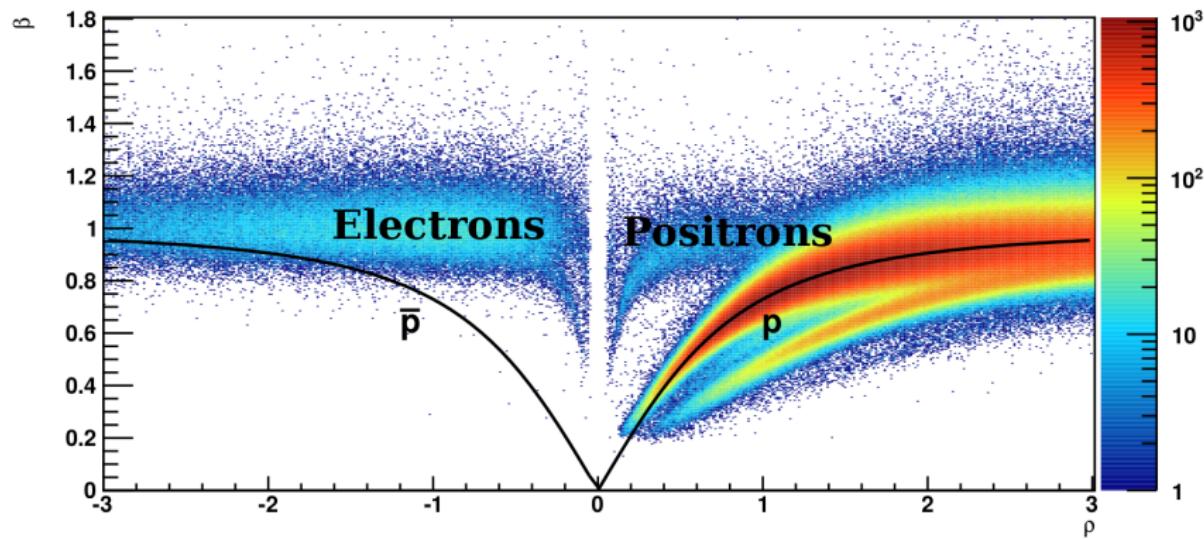
## SUBDETECTORS

- **Tracking system:** six plane of silicon detector inside a magnetic cavity;
- **Time of Flight (ToF):** 24 bars of plastic scintillator disposed on six plane, S11, S12, S21, S22, S31, S32;
- **Anticoincidence (CAS, CARD e CAT):** nine plane of plastic scintillator around the apparatus;
- **Calorimeter:** 44 planes of Si detector interleaved with 22 tungsten planes;
- **Neutron detector:** 36 proportional counter filled with  $^3\text{He}$ .



# PARTICLE SELECTIONS

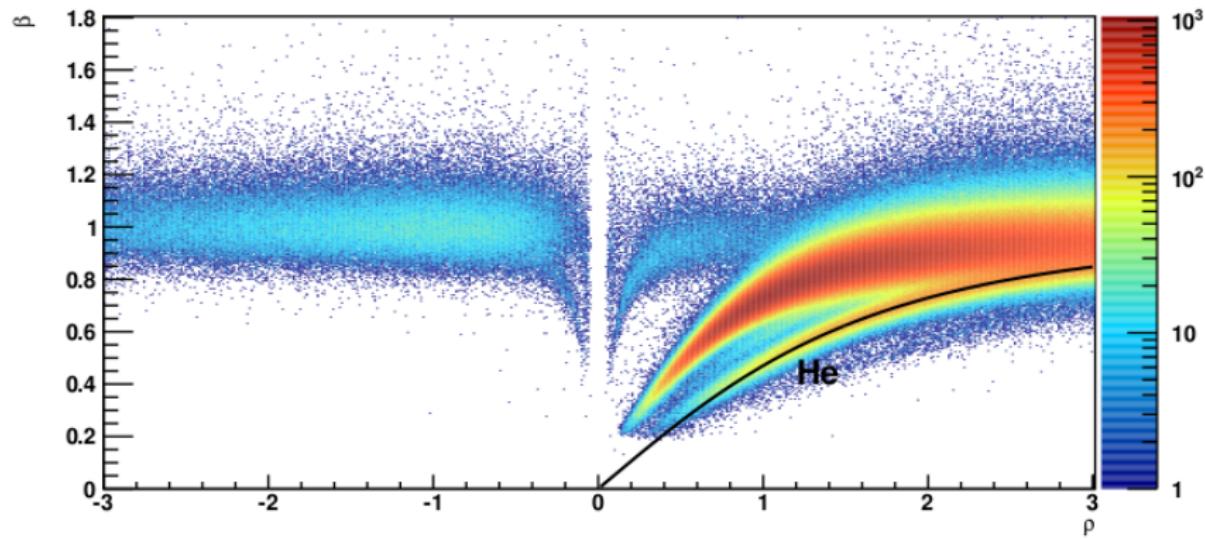
# BACKGROUND SOURCES



## Primary sources:

- $p/e^+ \sim 10^3$  at 1 GV  $\rightarrow 10^4$  at 100 GV;
- $He/e^+ \sim 10^2$  at 100 GV  $\rightarrow 10^3$  at 100 GV;

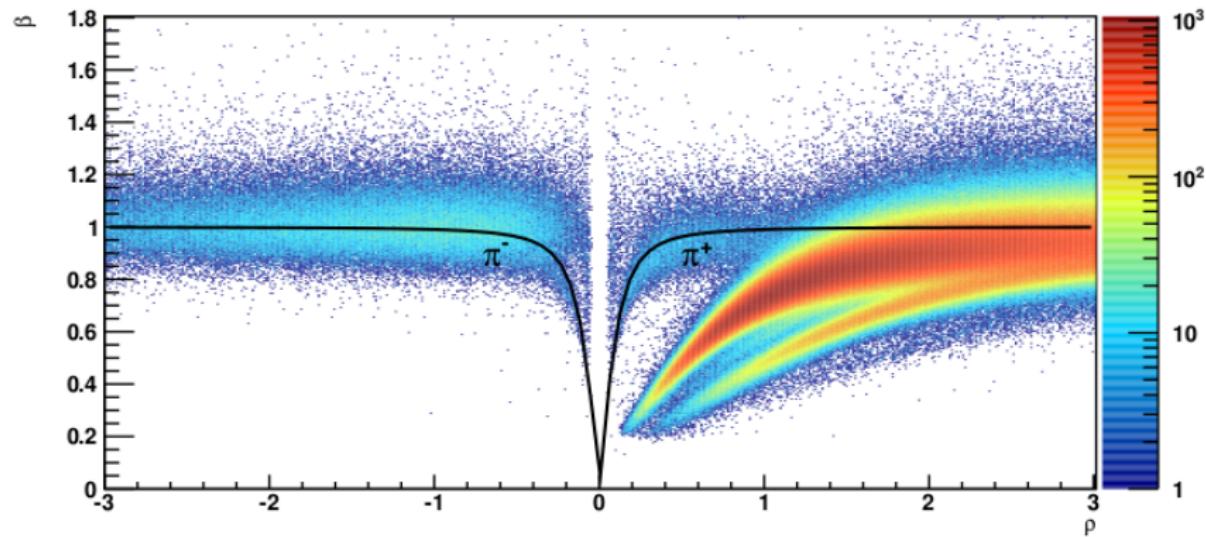
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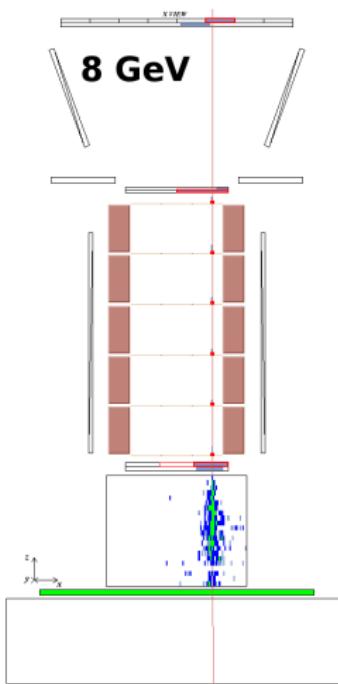


## Secondary sources:

- $\pi^+/\text{e}^+ \sim 1$  at 100 MV  $\rightarrow 10^{-1}$  at 1 GV;

# ELECTRONS AND PROTONS

● Electron

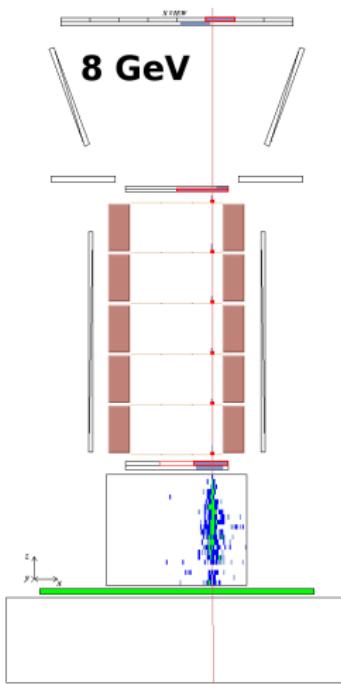


● Proton

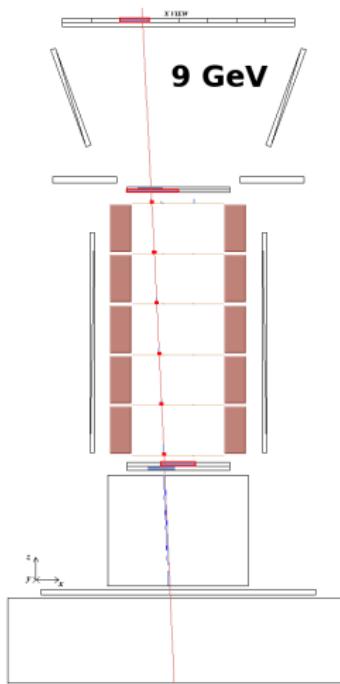
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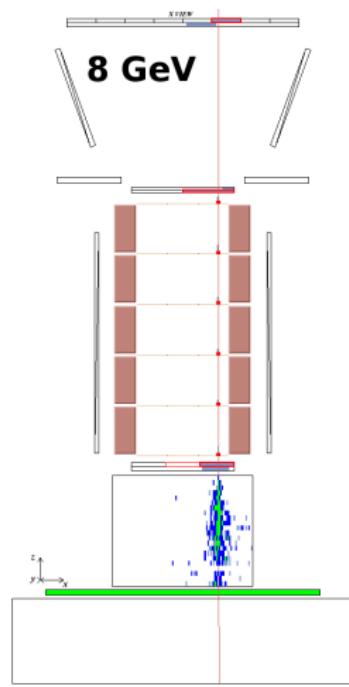
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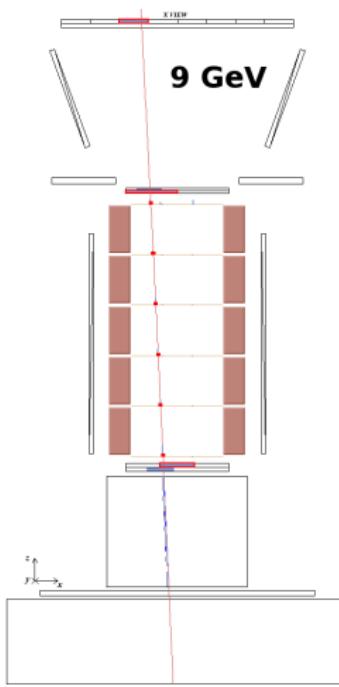
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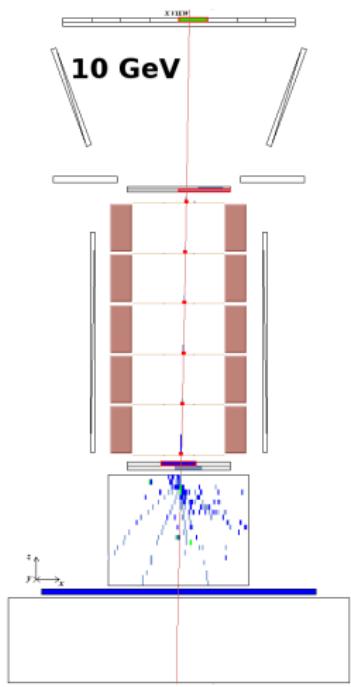
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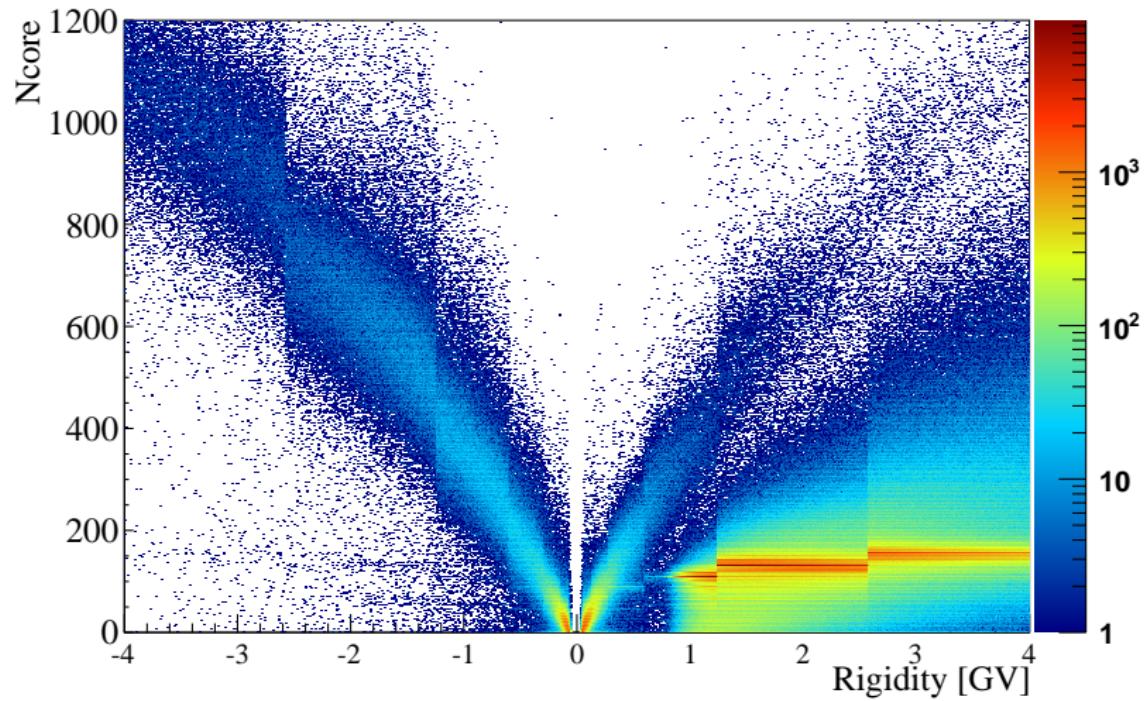
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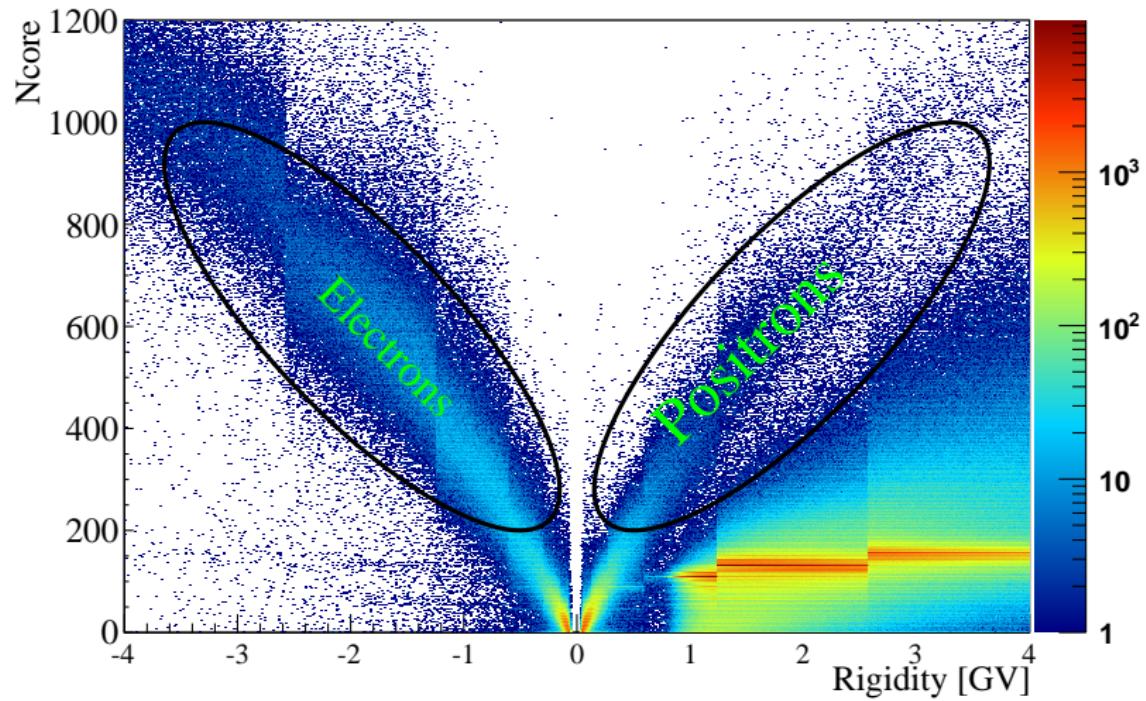
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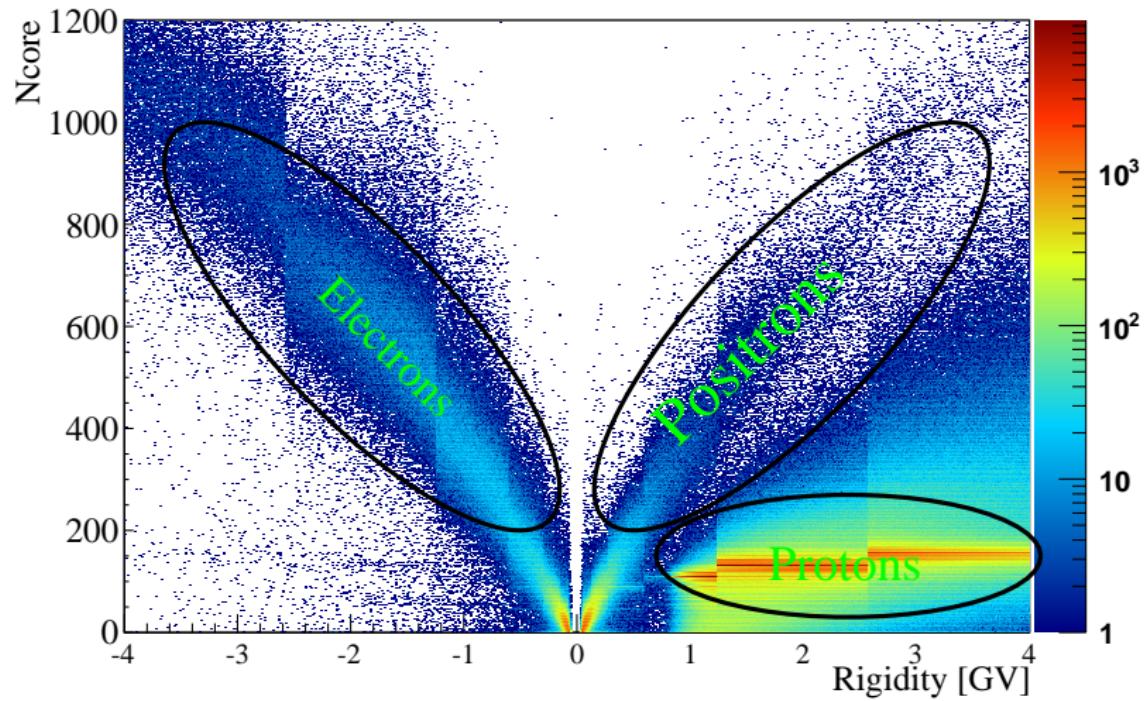
## CALORIMETER SELECTION



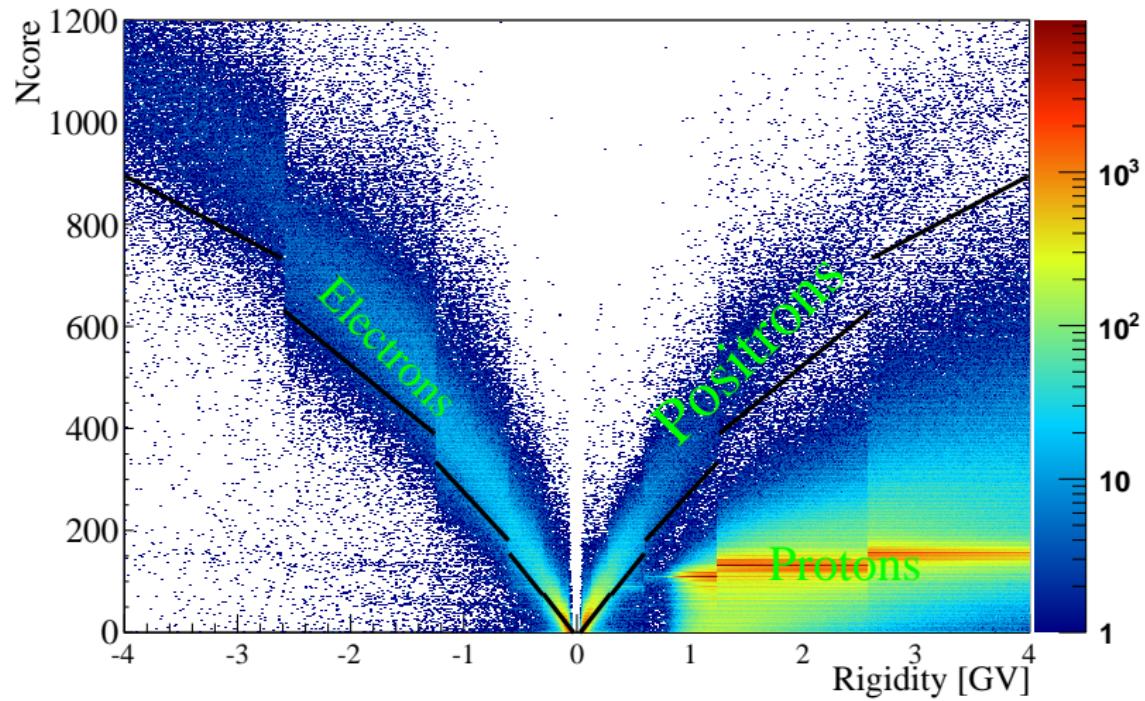
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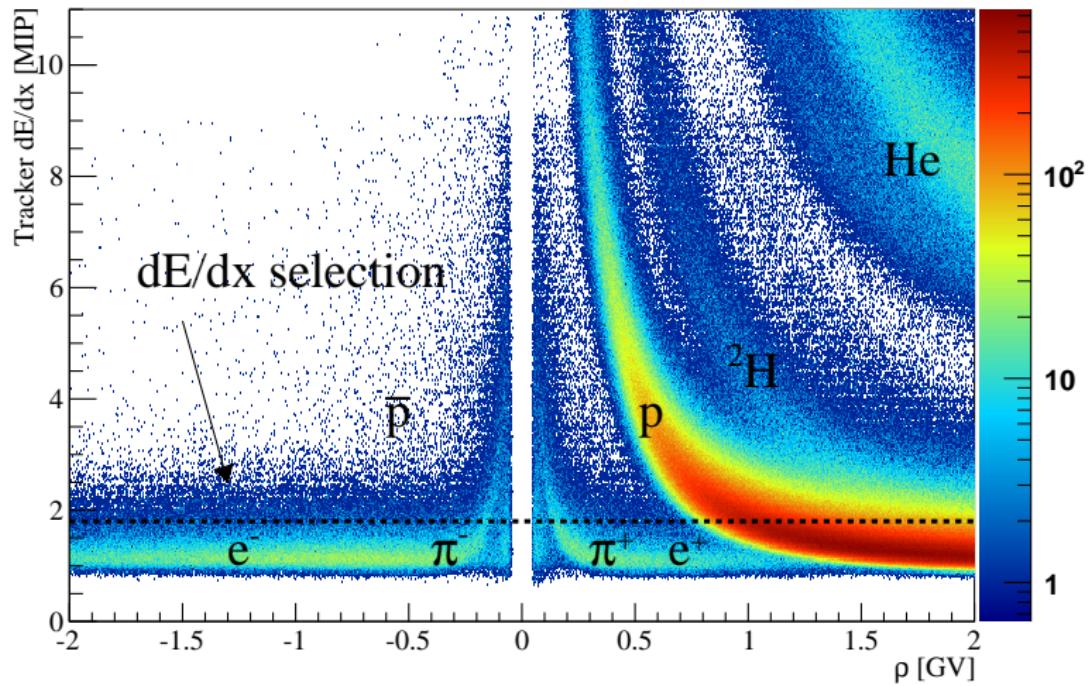
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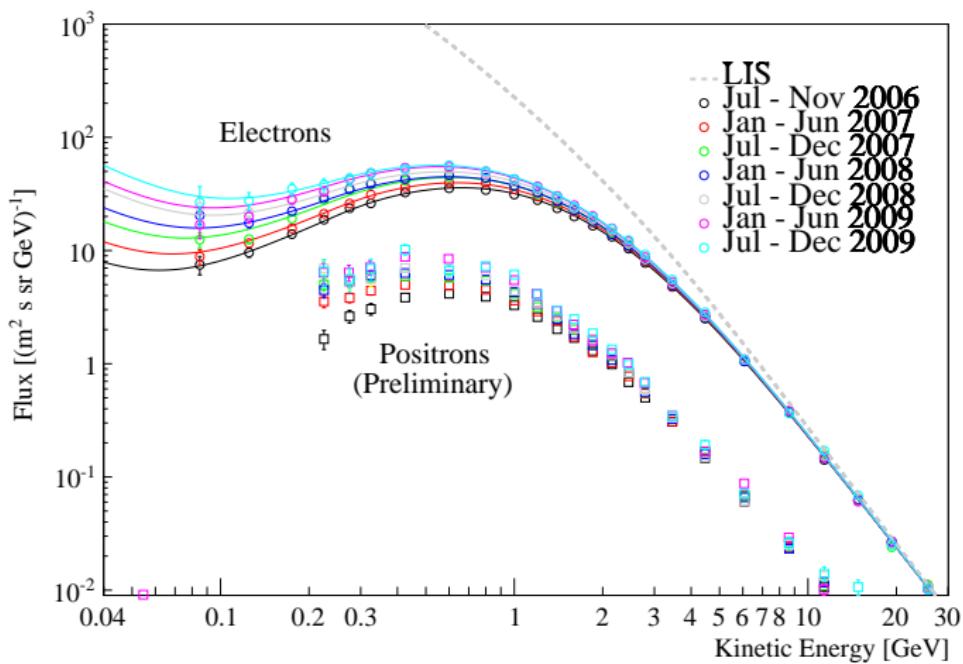


## CHARGE SELECTION



# TIME DEPENDENT FLUXES

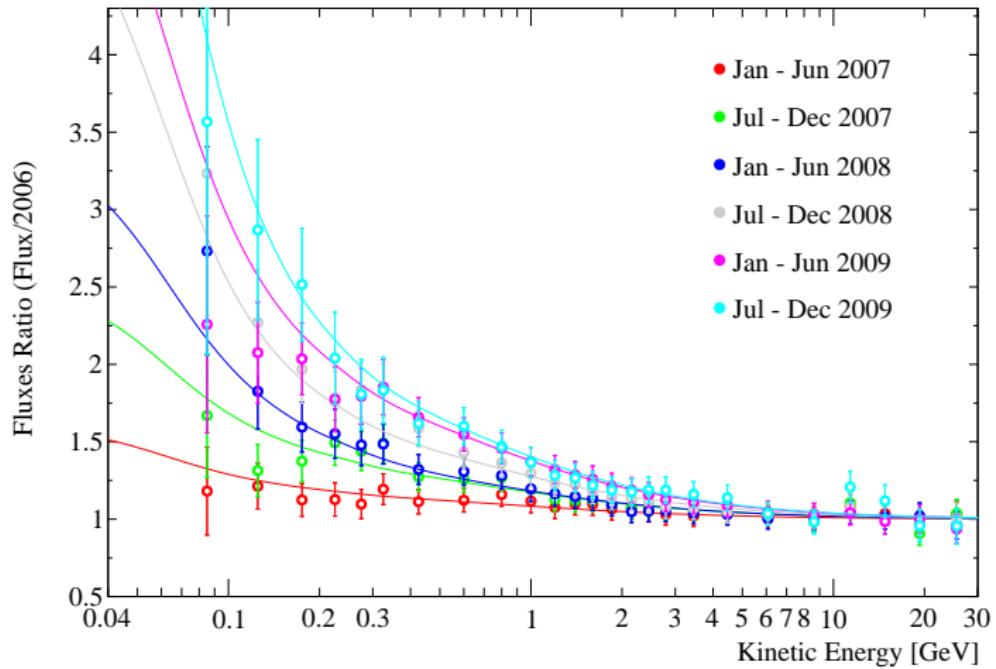
# ELECTRON AND POSITRON SPECTRA



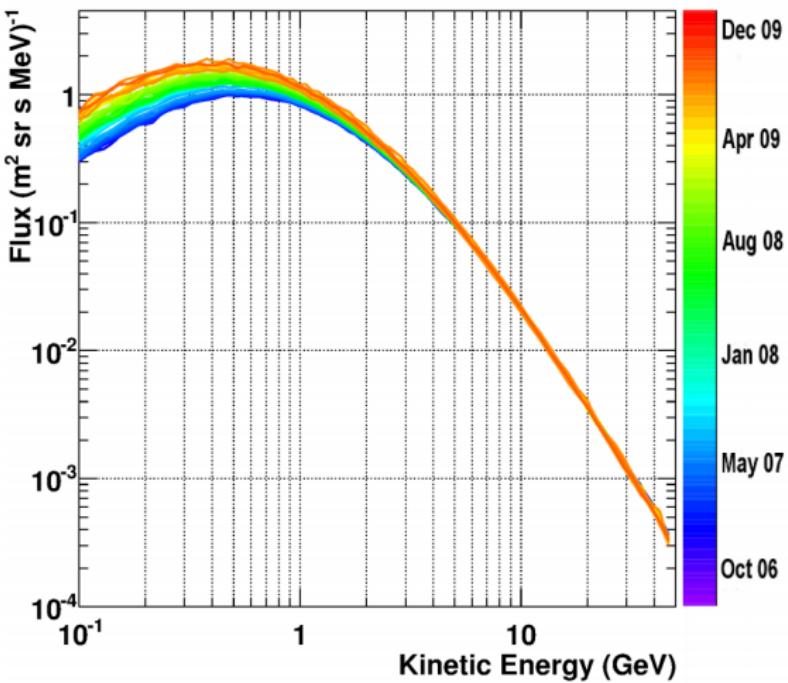
Apj - 0004-637X-810-2-142

*Time Dependence of the  $e^-$  Flux Measured by PAMELA during the July 2006–December 2009 Solar Minimum.  
O. Adriani et. al.*

## ELECTRON RATIO



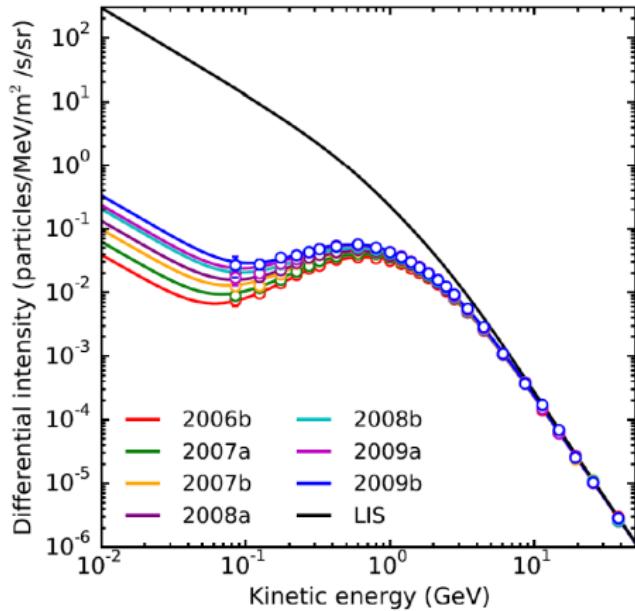
## PROTON SPECTRA



arXiv:1301.4108

*Time dependence of the proton flux measured by PAMELA during the July 2006 - December 2009 solar minimum.  
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# MODELING RESULTS

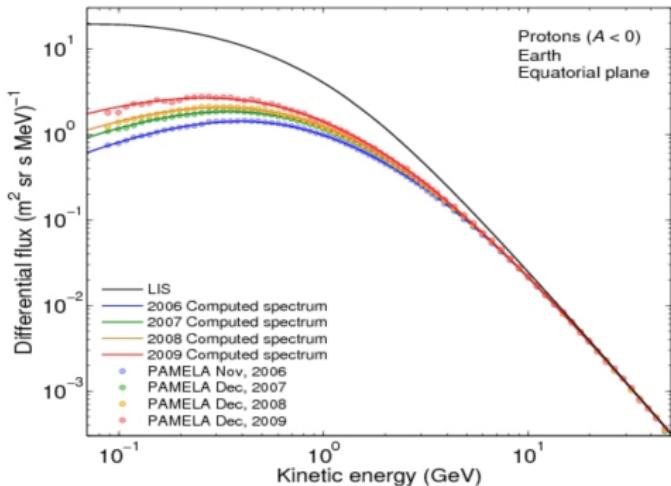


## RESULTS

- 3D numerical solution of Parker equation.
- Input parameter: LIS, tilt angle, HMF;
- Low energy  $e^-$  diffusion dominated;
- Low energy proton, adiabatic energy losses;

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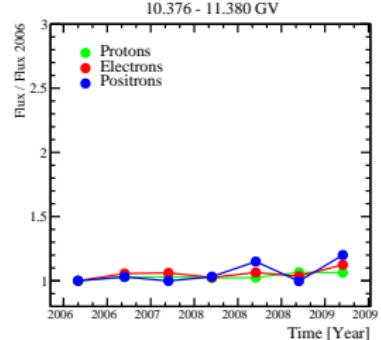
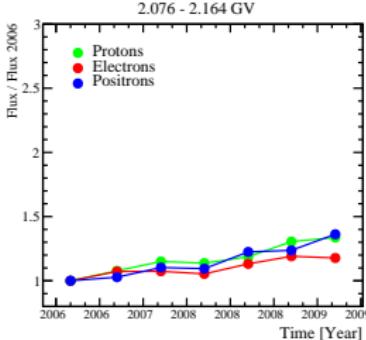
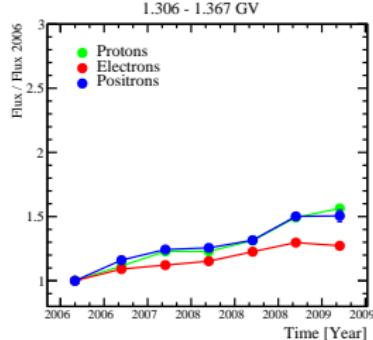
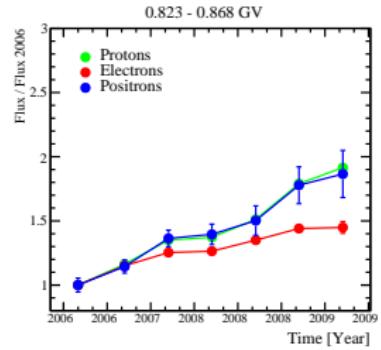
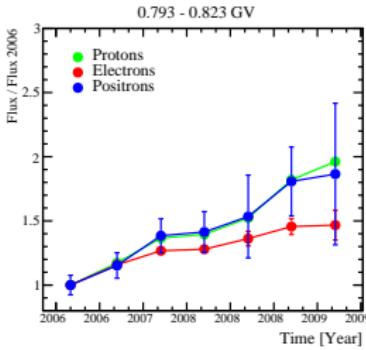
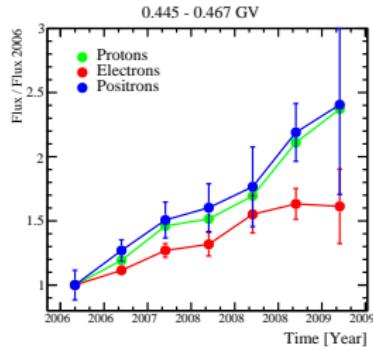
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# CHARGE-SIGN MODULATION

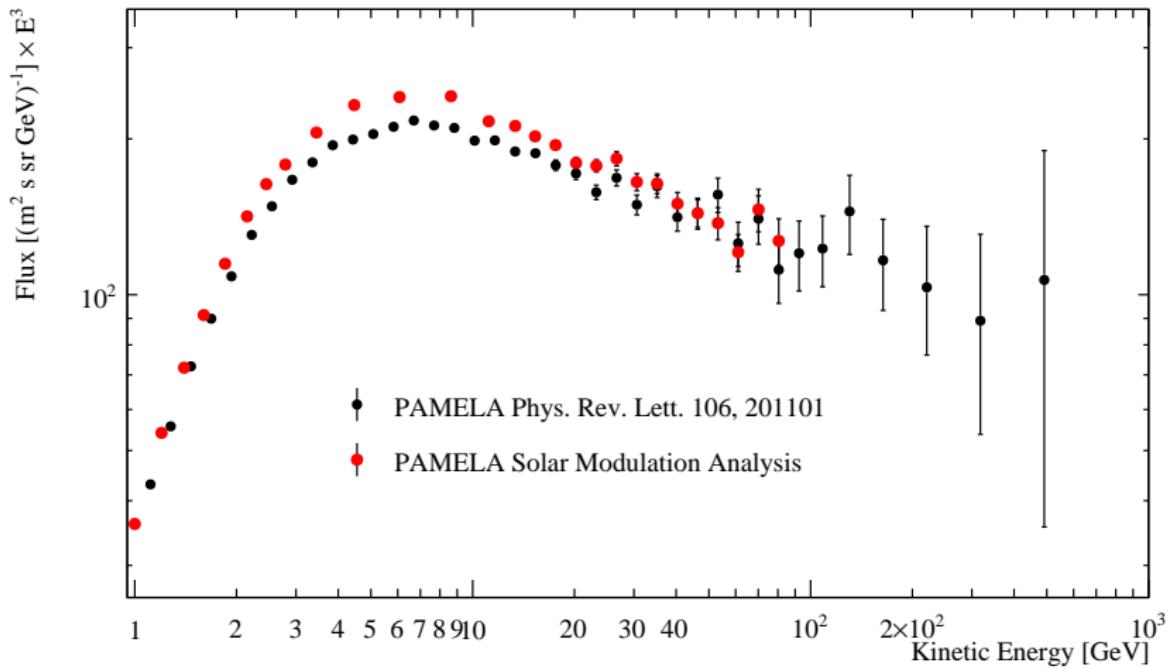


# CONCLUSIONS

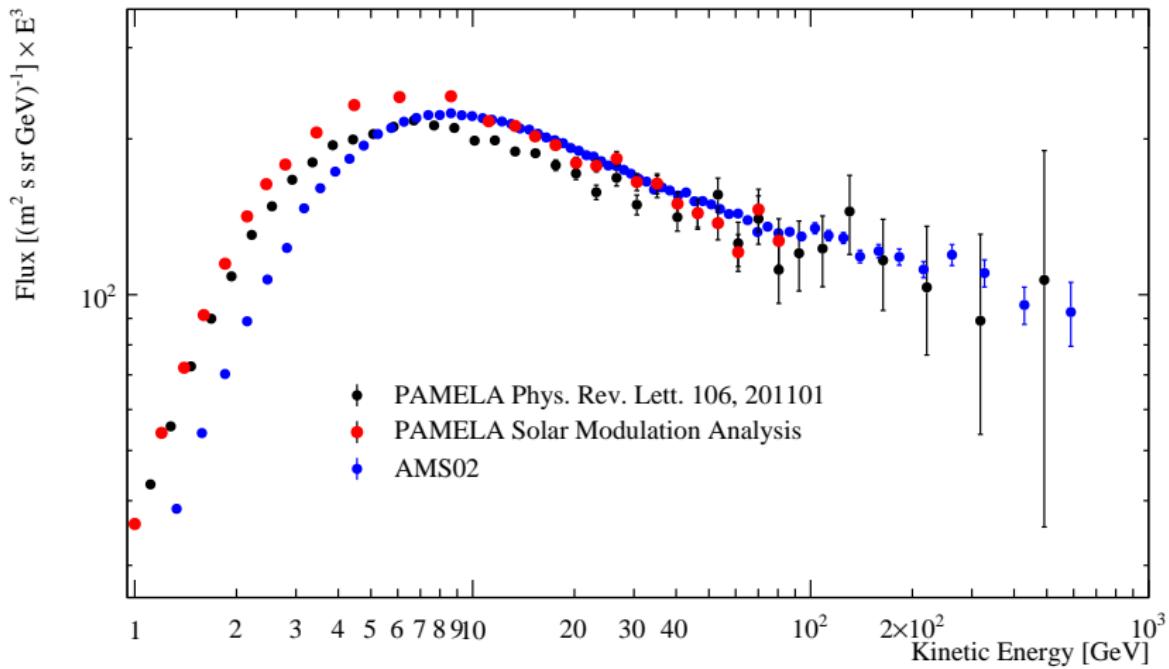
- PAMELA long flight duration allows precise measurement of the time-dependent CR fluxes;
- Time-dependent electron, positron and proton galactic CR electron during the 23th solar minimum were presented;
- PAMELA results allows to test the theoretical model and to derive propagation parameter (diffusion coefficient).
- Charge-sign dependence were observed.



# ELECTRON SPECTRUM



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