The cosmic-ray positron energy spectrum measured by PAMELA

seventh Journal Club

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Università degli Studi di Trieste

1. The PAMELA telescope

What are cosmic rays?

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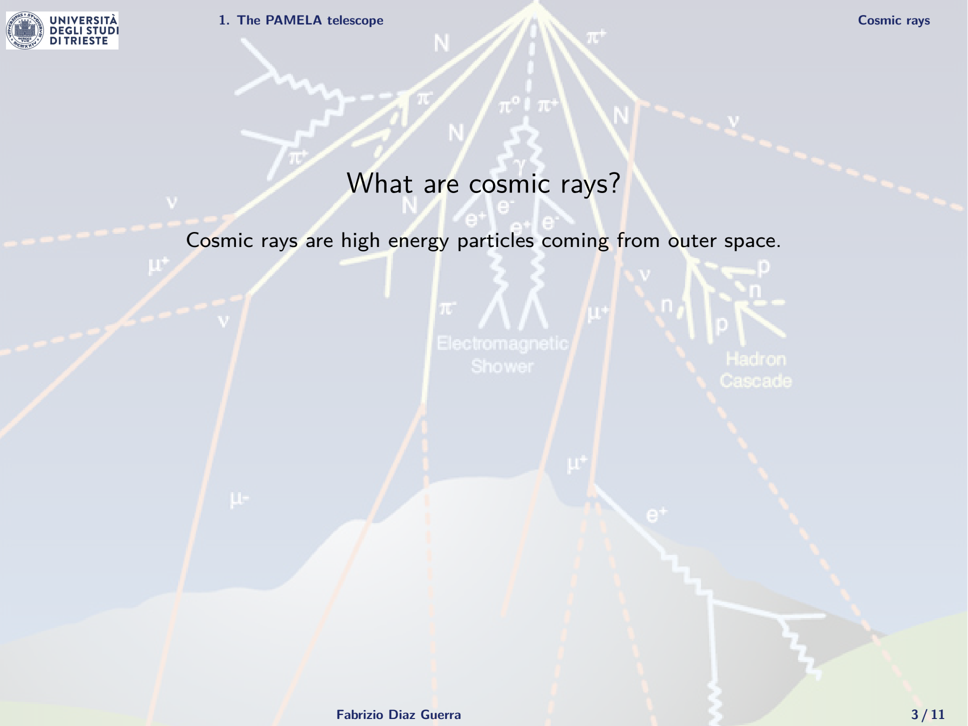
Cosmic rays are high energy particles coming from outer space.



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When these particles (primary cosmic rays) interact with the atmosphere they can generate other type of particles and radiation, known as secundary cosmic rays.

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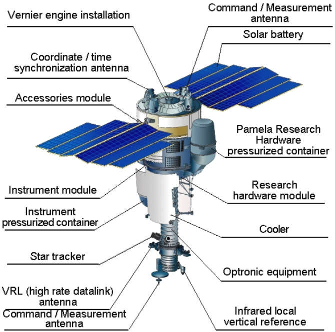
Some components of cosmic rays are:

- naked atomic nuclei
- electrons
- positrons
- antiprotons

What does the PAMELA telescope do?

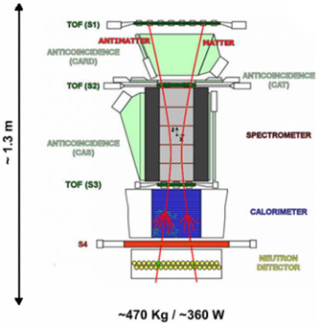
What does the PAMELA telescope do?

PaMeLa a Payload for Antimatter Matter Exploration and Light–nuclei Astrophysics

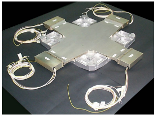


Abstract

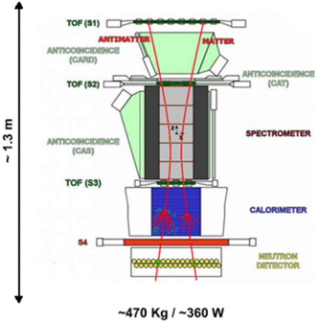
Precision measurements of the positron component in the cosmic radiation provide important information about the propagation of cosmic rays and the nature of particle sources in our Galaxy. The satellite-borne experiment PAMELA has been used to make a new measurement of the cosmic-ray positron flux and fraction that extends previously published measurements up to 300 GeV in kinetic energy. The combined measurements of the cosmic-ray positron energy spectrum and fraction provide a unique tool to constrain interpretation models. During the recent solar minimum activity period from July 2006 to December 2009 approximately 24500 positrons were observed. The results cannot be easily reconciled with purely secondary production and additional sources of either astrophysical or exotic origin may be required.


TOF (S1)
ANTIMATTER
MATTER
ANTICOINCIDENCE (CARD)
ANTICOINCIDENCE (CAT)
TOF (S2)
SPECTROMETER
ANTICOINCIDENCE (CAS)
~ 1.3 m
TOF (S3)
CALORIMETER
S4
NEUTRON DETECTOR
~470 Kg / ~360 W

ToF scintillators



- S1,S2,S3 double layer
- plastic scintillator (8mm)
- ToF resolution $\sim$ 300 ps
- lepton-hadron separation $<$ 1 Gev/c



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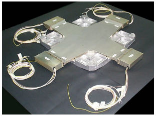

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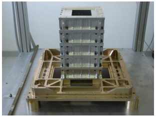
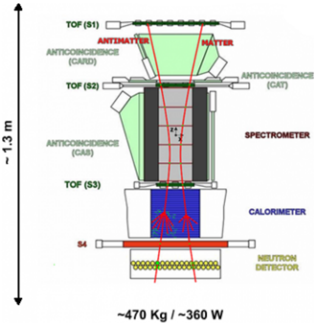
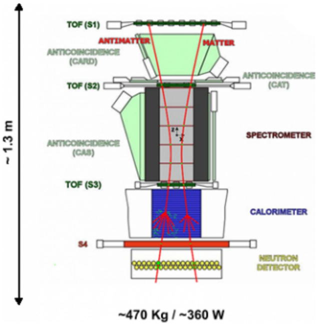


- permanent magnet .43 T
- 21.5 cm^2 sr
- 6 planes double-sided silicon strip
- 3 μm resolution in bendings
- MDR $\sim$ 600GV





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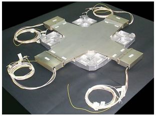

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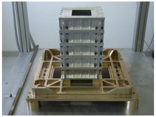

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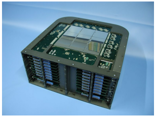
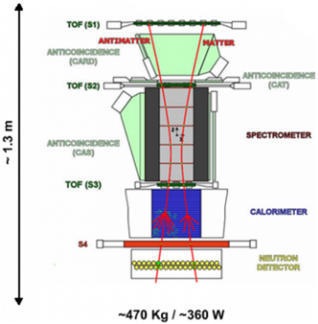
calorimeter



- 44 Si x/Si y planes
- dE/E $\sim$ 5%
- self trigger $>$ 300GeV/600 cm^2 sr



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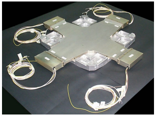

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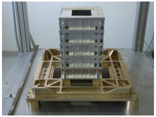

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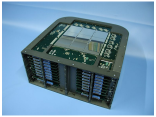

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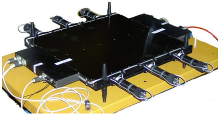
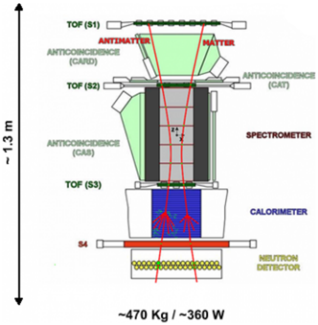
bottom scintillator



- 1cm x 48x48 cm scintillator
- 6 photomultipliers
- triggers the neutron detector



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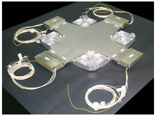

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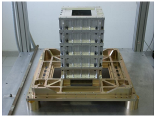

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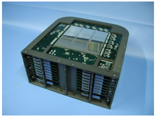

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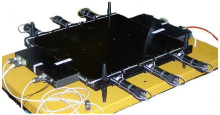

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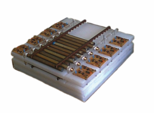
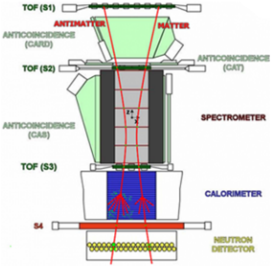
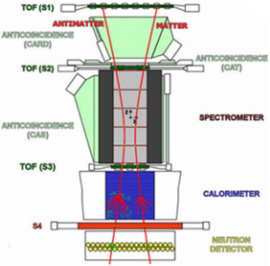


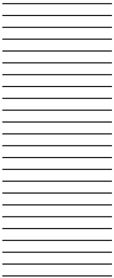
- 36 ^{3}He counters two layers
- ^{3}He(n,p)T
- 9 cm polyethilene moderator

2. Data and results



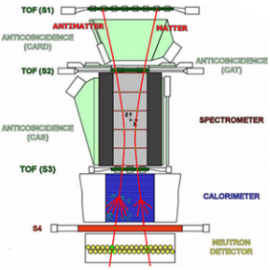
PAMELA
model

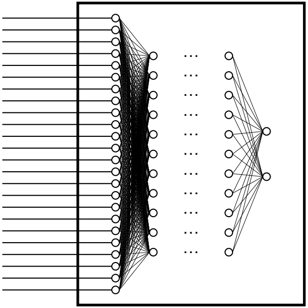




PAMELA model

24 variables





PAMELA model

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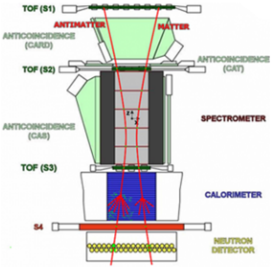
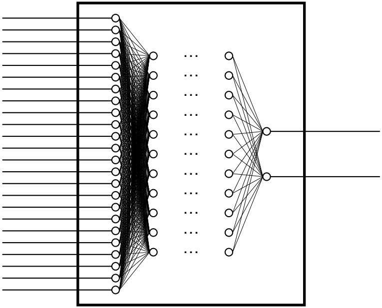
multilayer perceptron





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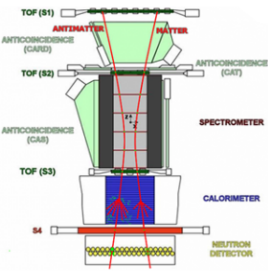
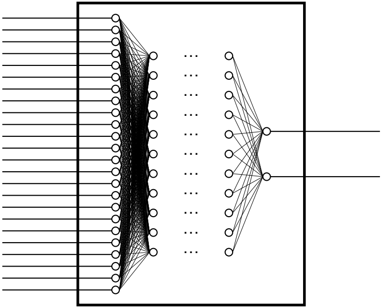
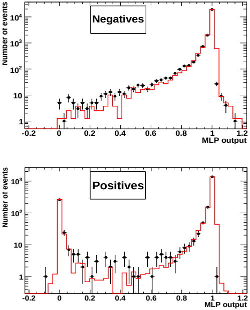
discrimination







PAMELA model

24 variables

multilayer perceptron

discrimination

output distribution

TABLE I: Summary of positron results. The lower limit is that for a 90% confidence level. For the flux the first and second errors represent the statistical (68% confidence level) and systematic uncertainties, respectively.

Rigidity at the spectrometer GV/c	Mean Kinetic Energy at top of payload GeV	Observed number of events e^+	Rescaled Flux at top of payload $(\mathrm{GeV^{-1}s^{-1}sr^{-1}m^{-2}})\times10^{-3}$	$\frac{e^+}{(e^+ + e^-)}$ at top of payload
1.5 - 1.8	1.64	4644	$1762 \pm 24 \pm 111$	0.0777 ± 0.0011
1.8 - 2.1	1.94	3356	$1262 \pm 21 \pm 80$	0.0711 ± 0.0012
2.1 - 2.7	2.38	2809	$808 \pm 11 \pm 51$	0.0653 ± 0.0009
2.7 - 3.5	3.06	3755	$411 \pm 6 \pm 26$	0.0586 ± 0.0010
3.5 - 4.2	3.83	3951	$226 \pm 5 \pm 15$	0.0545 ± 0.0013
4.2 - 5	4.57	1520	$137 \pm 3 \pm 9$	0.0535 ± 0.0014
5 - 6	5.46	1124	$79.9 \pm 2.2 \pm 5.0$	0.0523 ± 0.0015
6 - 8	6.88	712	$38.4 \pm 1.0 \pm 2.6$	0.0504 ± 0.0014
8 - 10	8.9	920	$17.1 \pm 0.6 \pm 1.2$	0.0520 ± 0.0019
10 - 13	11.3	491	$8.4 \pm 0.3 \pm 0.6$	0.0557 ± 0.0023
13 - 15	13.9	448	$4.82 \pm 0.27 \pm 0.40$	0.063 ± 0.004
15 - 20	17.2	307	$2.30 \pm 0.13 \pm 0.18$	0.061 ± 0.004
20 - 28	23	195	$0.92 \pm 0.07 \pm 0.08$	0.062 ± 0.005
28 - 42	33.1	114	$0.32 \pm 0.03 \pm 0.03$	0.073 ± 0.007
42 - 65	50.2	68	$0.109 \pm 0.013 \pm 0.012$	0.099 ± 0.013
65 - 100	77.5	33	$0.034 \pm 0.006 \pm 0.005$	0.121 ± 0.022
100 - 200	135	25	$0.0118 \pm 0.0026 \pm 0.0024$	0.163 ± 0.040
200 - 300			> 0.00091	> 0.107

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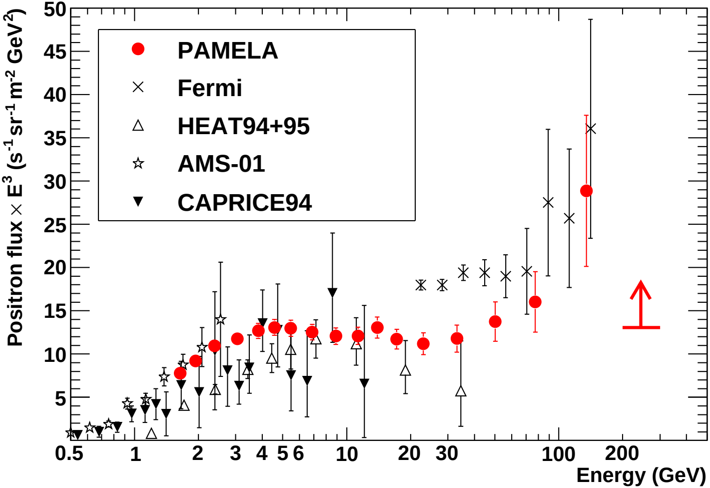

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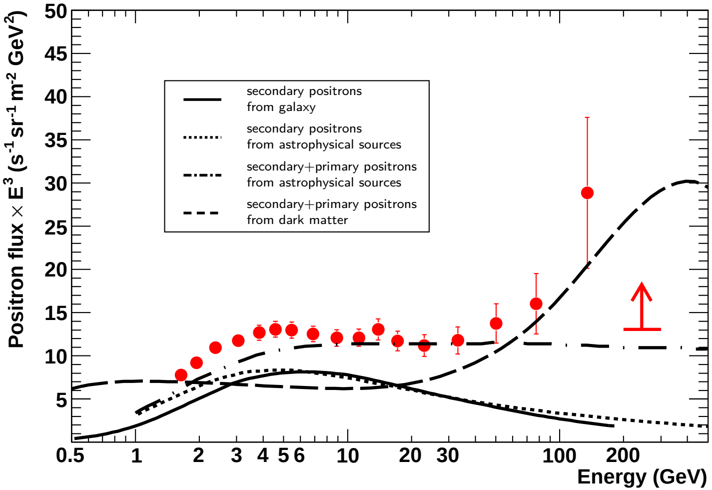
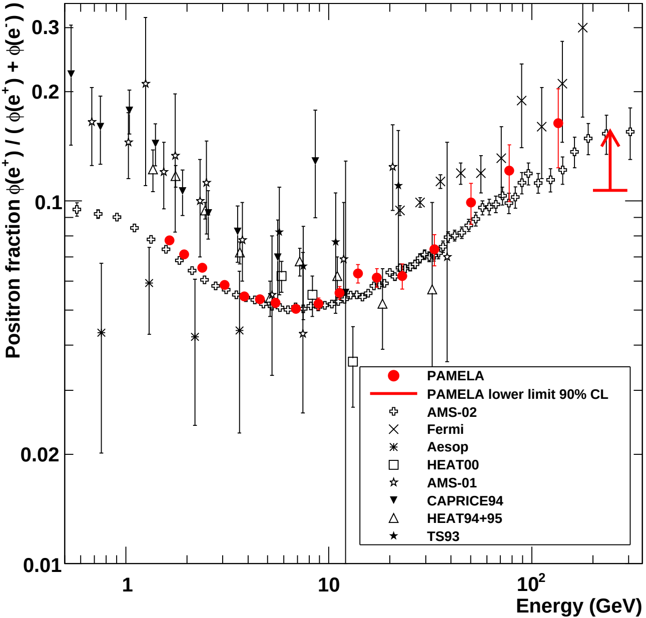
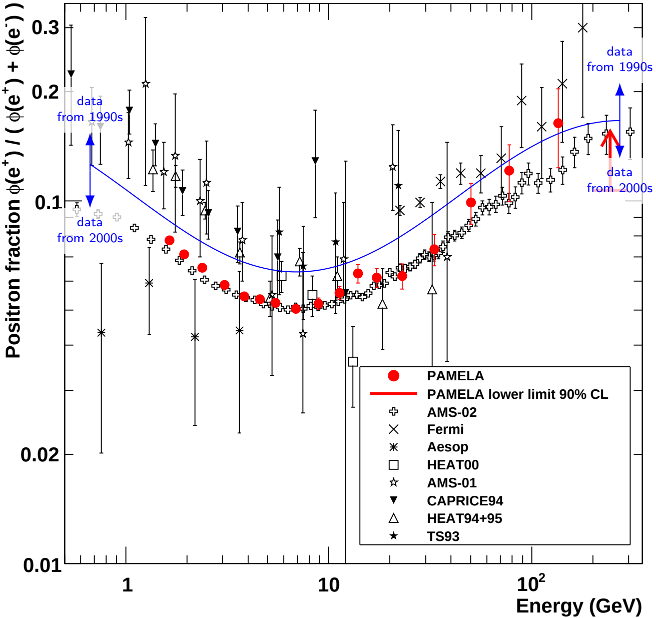

secondary positrons
from galaxy
secondary positrons
from astrophysical sources
secondary+primary positrons
from astrophysical sources
secondary+primary positrons
from dark matter
Positron flux × E^3 (s^{-1} sr^{-1} m^{-2} GeV^2)
Energy (GeV)
50
45
40
35
30
25
20
15
10
5
0.5
1
2
3
4
5
6
10
20
30
100
200


Positron fraction φ(e+) / (φ(e+) + φ(e-))
0.3
0.2
0.1
0.02
0.01
1
10
10^2
Energy (GeV)
PAMELA
PAMELA lower limit 90% CL
AMS-02
Fermi
Aesop
HEAT00
AMS-01
CAPRICE94
HEAT94+95
TS93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0.3
0.2
0.1
0.02
0.01
1
10
10^2
Energy (GeV)
data from 1990s
data from 2000s
data from 1990s
data from 2000s
PAMELA
PAMELA lower limit 90% CL
AMS-02
Fermi
Aesop
HEAT00
AMS-01
CAPRICE94
HEAT94+95
TS93