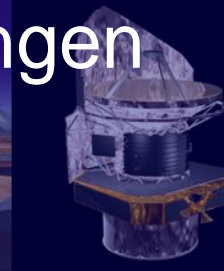
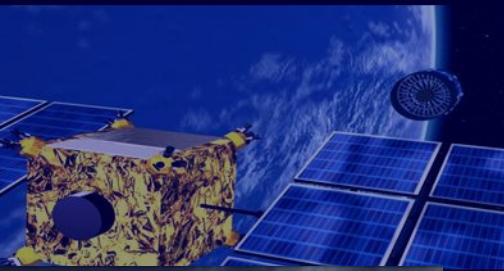


Multifrequenz-Beobachtungen in der Astronomie Wintersemester 2007/8



Themen & Daten

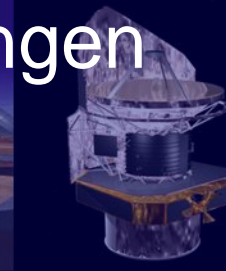
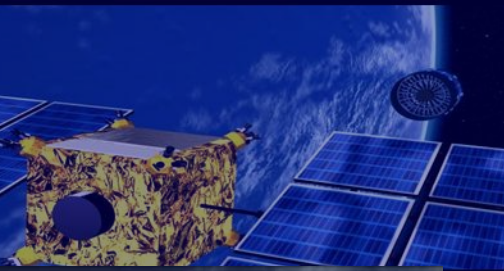
- 19.10.: Überblick
- 02.11.: Erste Ergebnisse der Durchmusterungen
- 16.11.: Hochenergie-Astronomie
- 30.11.: Update: Neue Teleskope
- **14.12.: Dunkles (Materie & Energie)**



- 11.01: Fortsetzung: Dunkles
- 25.01.: Mikrowellenhintergrund
- 08.02.: Virtuelle Observatorien

Multifrequenz-Beobachtungen in der Astronomie

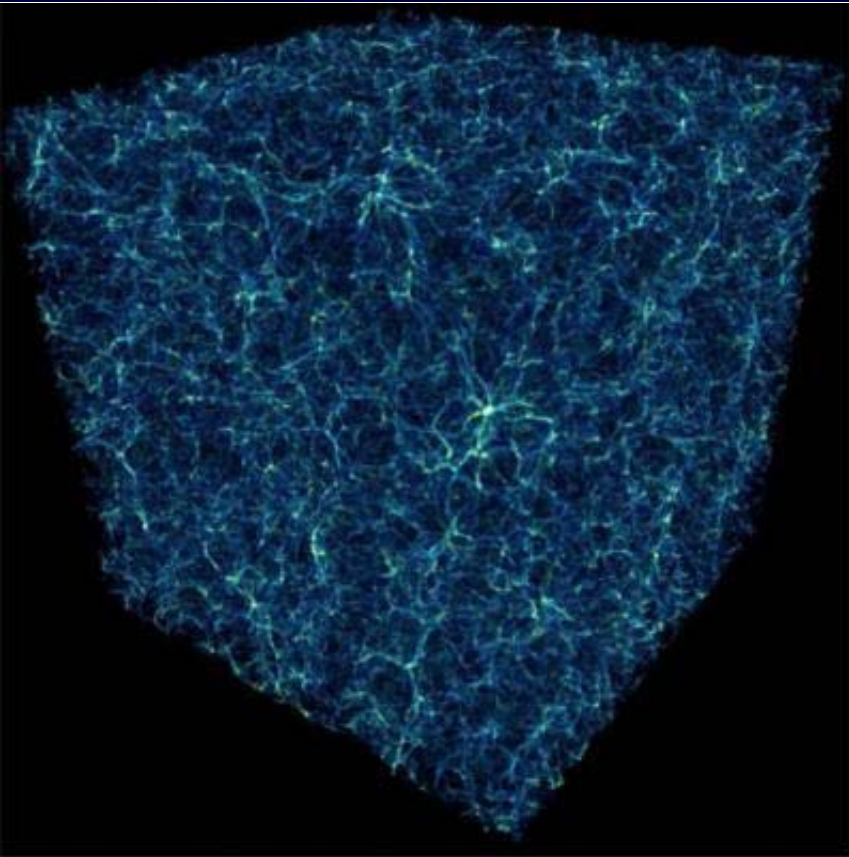
Wintersemester 2007/8




HEUTE

- Neues: Gasverteilung im Weltraum
- Dunkle Materie
- Antimaterie
 - Antimaterie aus den Frühphasen des Kosmos
 - Antimaterie
 - Antimaterie und Dunkle Materie
- Neue Teleskope
 - PAMELA
 - BESS
 - AMS-02
 - GLAST, AGILE, etc.
 - Programm der ESA
 - Auf dem Mond

Supercomputer Simulation des Universums



- Großteil der Gasmasse des Universums ist in einem Netz kosmischer Filamente gefangen, daß sich 100te von Millionen Lichtjahre erstreckt (WHIM: Warm-Hot Intergalactic Medium)
- Ein Jahrzehnt für Computercode (60 Terabytes)
- Um WHIM zu finden: 10m Südpol Teleskop (mm, sub-mm, infrarot) in der Antarktis, 25 m Cornell-Caltech Atacama Teleskop (CCAT), sub-mm



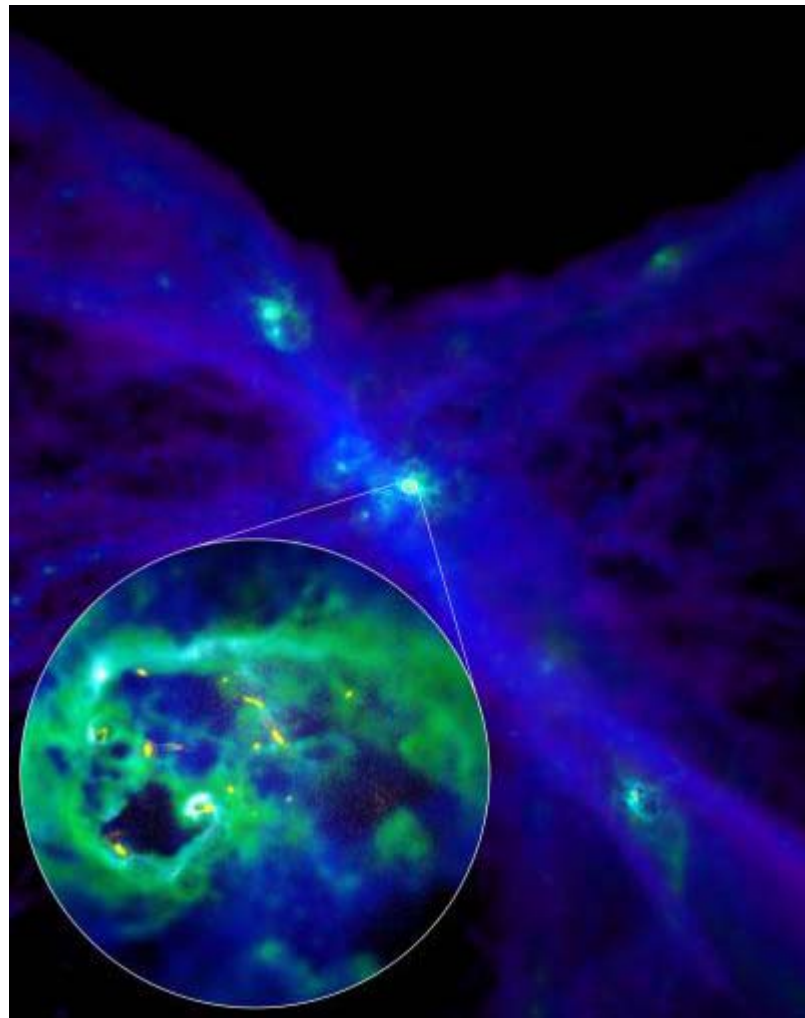
Multifrequenz-Beobachtungen
in der Astronomie, Teil II
Wintersemester 2007/8

„Dunkle Materie“

Cold Dark Matter model: Details

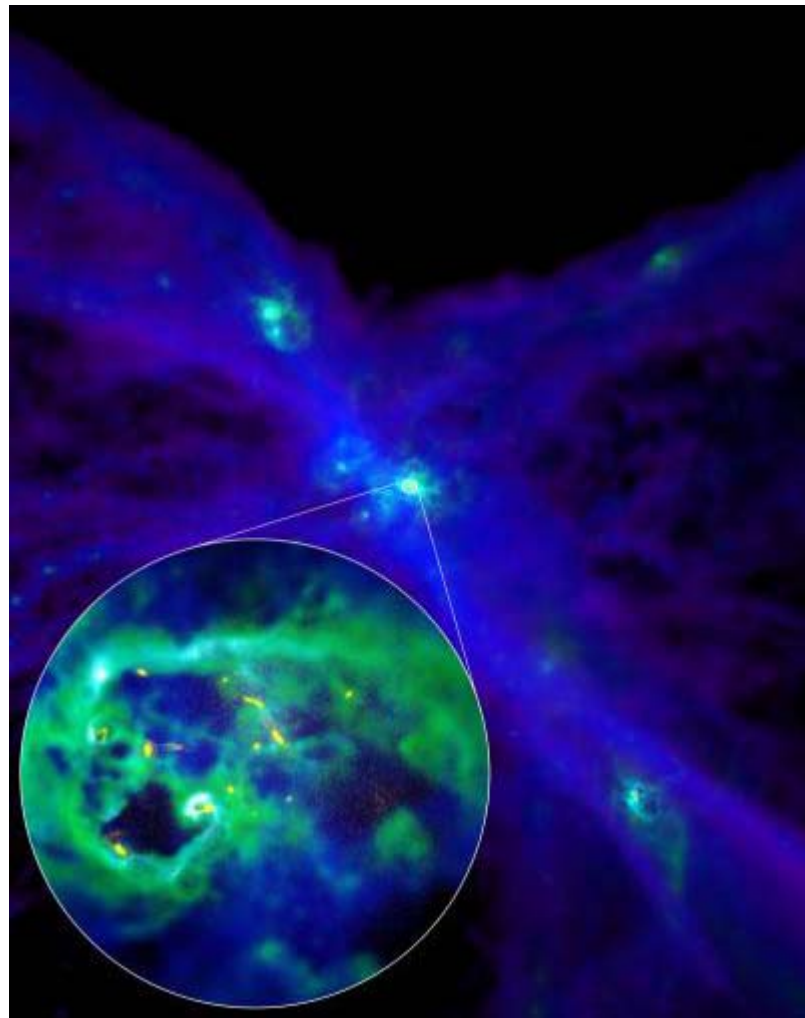
Größe	Betrag	Beschreibung
H_0	$70,9^{+2,4}_{-3,2} \cdot 10^{-6} \frac{\text{km}}{\text{s pc}}$	Hubble-Konstante
Ω_b	$4,44^{+0,42}_{-0,35} \%$	Anteil baryonischer d.h. "normaler" Materie, relativ zur kritischen Dichte
Ω_m	$26,6^{+2,5}_{-4,0} \%$	Gesamtanteil der Materie, d.h. inklusive der dunklen, relativ zur kritischen Dichte
τ	$0,079^{+0,029}_{-0,032}$	Optische Dichte bis zum Zeitalter der Reionisierung
A_s	$0,813^{+0,042}_{-0,052}$	Amplitude der klaren Komponente der ursprünglichen Schwankungen
n_s	$0,948^{+0,015}_{-0,018}$	spektraler Index der klaren Komponente der ursprünglichen Schwankungen

Cold Dark Matter model: Details



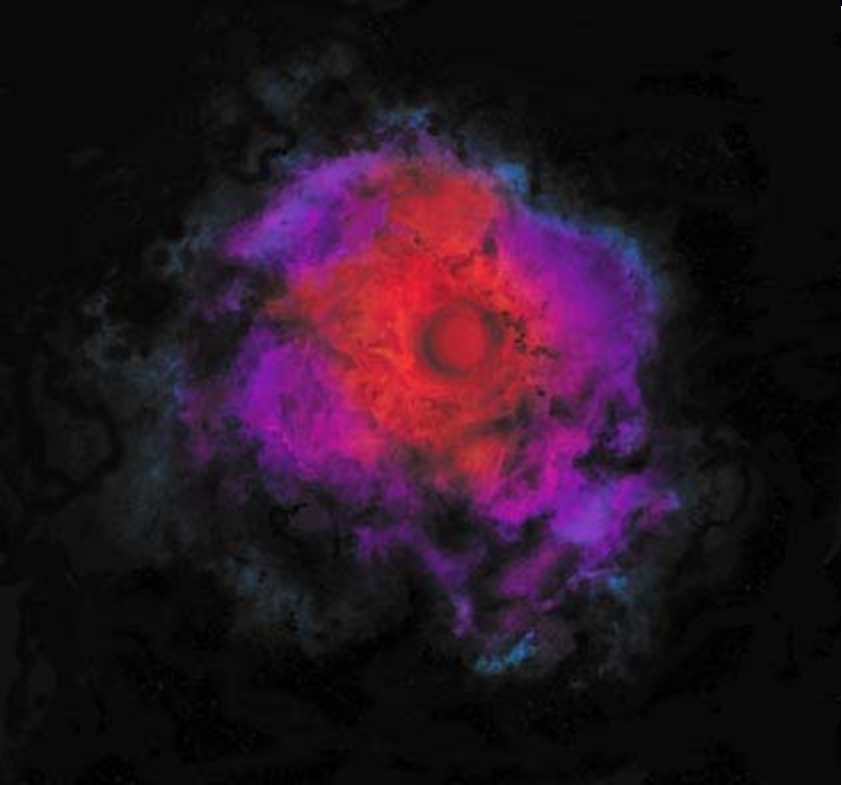
- Mashchenko: Supercomputer Rechnungen berechnet die erste Milliarde Jahre im Leben einer Zwerg-Galaxie
- Gas bei den Berechnungen bisher vernachlässigt
- Gas spielt eine deutlich wichtigere Rolle, als bislang angenommen: beim Explodieren der Sterne schwappt das Gas nach außen und nimmt die Dunkle Materie mit

Cold Dark Matter model: Details



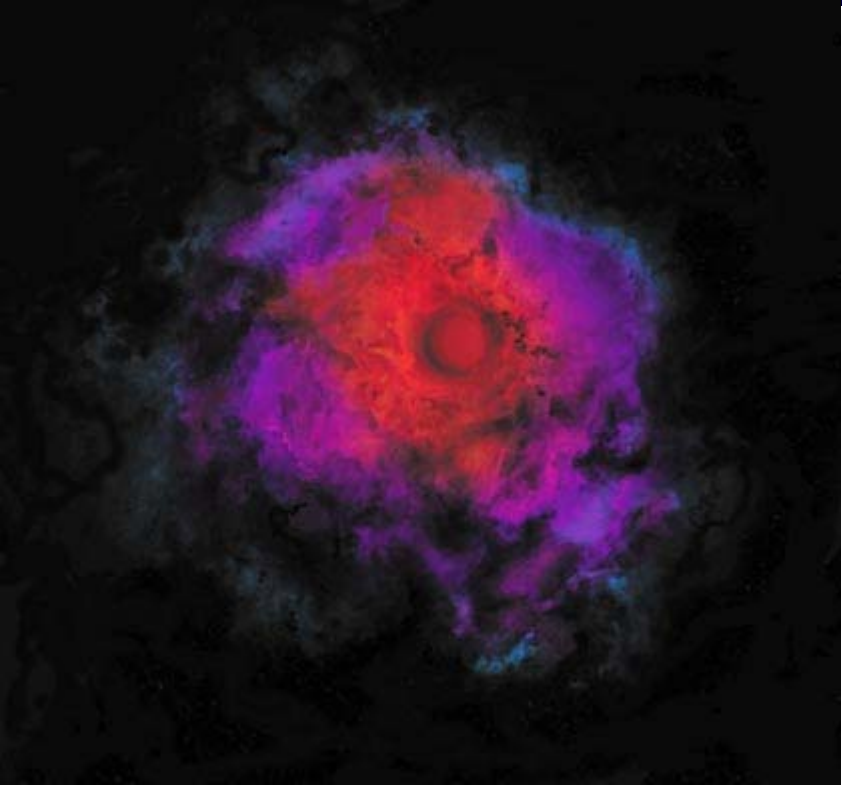
- Mashchenko: Cold Dark Matter Model funktioniert auf den großen Skalen macht aber keine Aussagen über die Zusammensetzung individueller Galaxien
- Geburtsprozess der neuen Galaxien: dichte Wolken aus Sternenstaub wachsen an, explodieren in Supernovae und schieben die interstellaren Gaswolken die wiederum die Dunkle Materie aus dem Innern der Galaxien vertreiben
- Die fehlende Dunkle Materie müsste in den Halos zu finden sein

Erste Sterne: aus Dunkler Materie




- Dunkle Materie könnte für die Entstehung der ersten Sterne vor 13 Milliarden Jahren verantwortlich sein
- Dunkle Sterne: bis zu 200 000 mal größer als die Sonne, unsichtbar; dünne, wabernde Wolke; Dichte: ein Milliardstel der Sonnendichte
- Nicht nur die sichtbare, auch die Dunkle Materie könnte sich in der Frühzeit unseres Universums verklumpt haben: Neutralinos: könnten interagiert und sich dabei ausgelöscht haben (Anihilation); dabei entstehen Elementarteilchen (Neutrinos, Positronen, Antiprotonen), Gammastrahlung und Wärme

Erste Sterne: aus Dunkler Materie

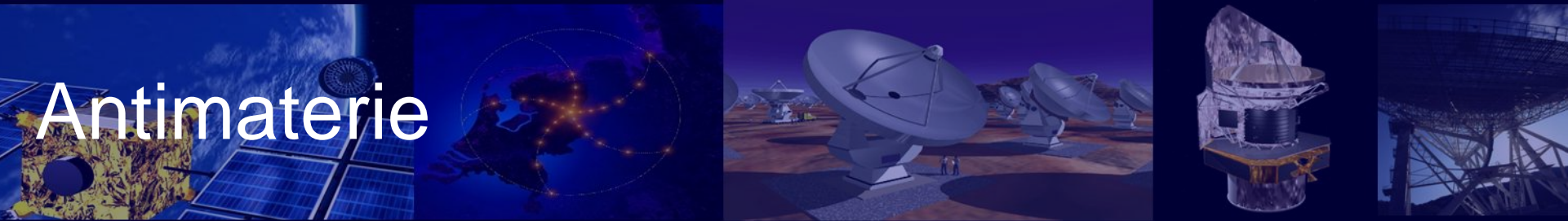


- Hitze soll Wolken aus Wasserstoff und Helium im frühen Universum aufgeblasen haben, daß nicht überall ein Fusionsprozess wie im klassischen Modell der Sternentstehung starten konnte -> stattdessen entstand dort ein Dunkler Stern, angetrieben von der Auslöschung Dunkler Materie in seinem Inneren
- Aber: Neutralinos nicht nachgewiesen (elektr. Neutral, relativ schwer, zw. 50-100 Protonenmassen, müßten in rauen Mengen vorkommen)
- Large Hadron Collider (nächster Sommer) könnte helfen
- Infrarotstrahlung, Gammastrahlung sollte ebenfalls nachweisbar sein

A winter landscape with a snow-covered field, trees, and mountains in the background. The scene is misty and serene, with a winding path leading through the trees. The sky is a pale, hazy blue, suggesting a clear but cold day. The overall atmosphere is quiet and contemplative.

Multifrequenz-Beobachtungen
in der Astronomie, Teil II
Wintersemester 2007/8

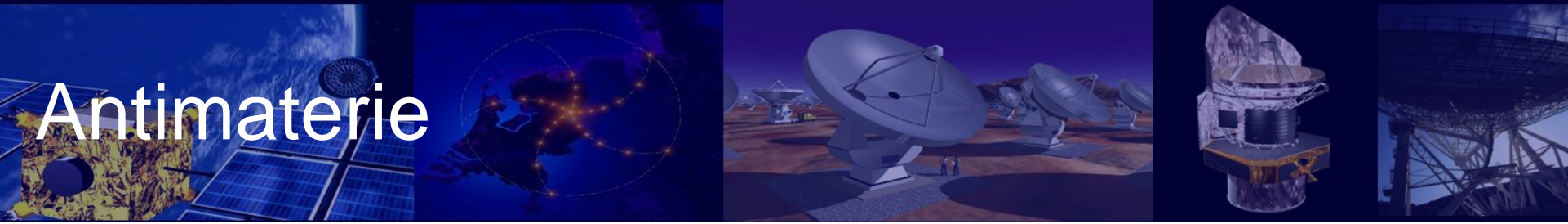
Auf der Suche nach Antimaterie



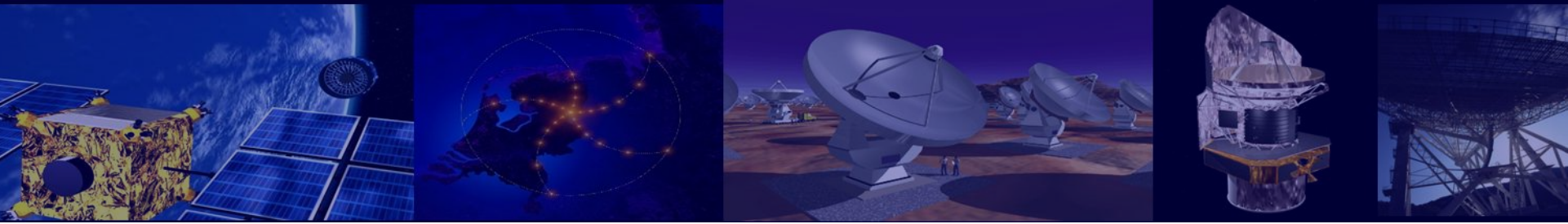
Antimaterie

- Antimaterie: Materie, die aus Antiteilchen aufgebaut ist
- Antiteilchen unterscheiden sich von normalen Teilchen nur im Vorzeichen aller additiven Quantenzahlen (Ladung, Baryonenzahl, Farbladung, schwache Hyperladung); Masse, Spin, Isospin und Lebensdauer sind identisch
- Ganze Atome aus Antimaterie kommen in der Natur – soweit bekannt – nicht vor (im Umkreis von einigen Milliarden Lichtjahren)
- Antimaterie läßt sich in Teilchenbeschleunigern erzeugen
- Durchbruch 1995: W. Oelert am CERN; erzeugten Antiwasserstoff-Atom (aus einem negativ geladenen Antiproton und einem positiv geladenen Positron)
- Kurzlebigkeit: da sofortige Annihilation -> Gammastrahlung; energiereichster Prozess
- Reine Energie wird immer paarweise zu gleichen Mengen in Materie und Antimaterie umgewandelt

Antimaterie



- Im Urknall sollte daher Materie und Antimaterie zu gleichen Mengen entstanden sein und noch heute vorzufinden sein; Ungleichgewicht ist Voraussetzung für die Stabilität unseres Universums; anfängliches gleiches Verhältnis, winziges Ungleichgewicht bewirkte, daß ein Rest an Materie übrigblieb, der unser heutiges Universum ausmacht; Urstrahlung heute noch nachweisbar: kosmische Hintergrundstrahlung
- Die einzig mögliche Speicherform: Antimaterie-Teilchen in einem elektromagnetischen Feld einfangen
- Häufig in der Natur: Erzeugung oder Vernichtung eines Elektron-Positron-Paares, jedes Teilchen hat Ruhemasse von 511 keV
- Existenz von Antimaterie zuerst von Paul Dirac (1928) vorhergesagt, indem er eine speziell relativistische Erweiterung der Quantenmechanik formulierte
- Antimaterie im Kosmos: Gammalinie im Zentrum der Milchstraße, Sagittarius-Region ist 7000-40000 Grad heiß



"We must regard it rather an accident that the Earth and presumably the whole Solar System contains a preponderance of negative electrons and positive protons. It is quite possible that for some of the stars it is the other way about"

Dirac Nobel Speech (1933)



Antimaterie im Universum

- Gibt es im Universum Antimaterie-Welten? Ganze Galaxien aus Antimaterie?
- Sicher ist, Antiteilchen entstehen bei einigen hochenergetischen physikalischen Prozessen im Universum
- Besonders interessant: Teilchen und Antiteilchen der kosmischen Strahlung (in geringem Maße auch Antiteilchen vorhanden)
- Für diese Vorlesung interessant: kann Auskunft über die Natur der „Dunklen Materie“ geben
- Besteht die Dunkle Materie aus WIMPs (Weakly Interacting Massive Particle)? Schwach wechselwirkende massive Teilchen, die nicht elektromagnetisch, sondern nur gravitativ in Erscheinung treten und deshalb nicht mit herkömmlichen Teleskopen beobachtbar sind



Antimaterie im Universum: Dunkle Materie

- WIMPs und AntiWIMPs?
- Dann vernichten sie sich bei einem Aufeinandertreffen mit der Folge eines Sekundärteilchenschauers:
 - Hochenergetische Photonen (Gamma)
 - Protonen und Antiprotonen
 - Elektronen und Positronen
- Könnte gemessen werden mit PAMELA, AMS-02, BESS, GLAST, AGILE, etc.
- Andere Kandidaten für die Dunkle Materie:
 - Neutralino: supersymmetrischer Partner für das Neutrino; Majorana Fermion, die sich gegenseitig im Halo annihilieren, erzeugen Teilchen und Antiteilchen, die nachweisbar sein sollten
 - Axion: wurde aus einer Brechung der Peccei-Quinn-Symmetrie der Lagrangedichte der Quantenchromodynamik als massives Goldstone-Boson abgeleitet, geringe Masse von 10^{-5} eV und ist CDM-Kandidat
- Antiprotonen und Positronen sind keine Indikatoren für Antimaterie im Universum, werden in Kollisionen mit kosmischer Strahlung erzeugt
- Weiterhin gibt es Antiteilchen aus primordialen Schwarzen Löchern in den Frühphasen des Universums

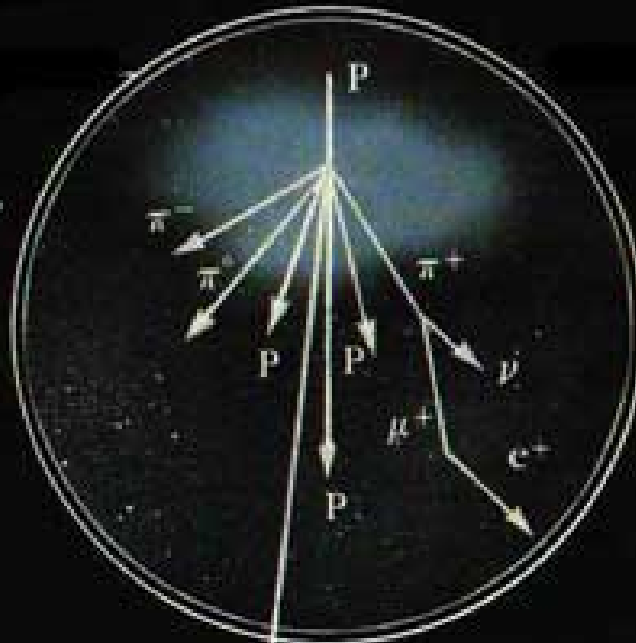
Antimaterie im Universum



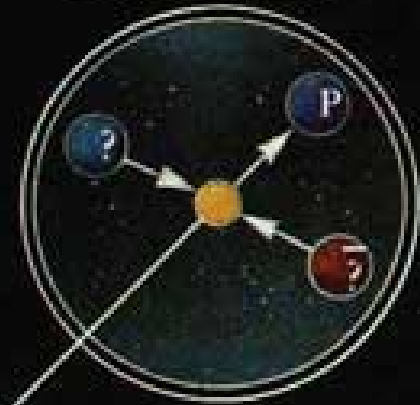
- PAMELA wird Antiprotonen und Positronen nachweisen
- Die Annihilation von Neutralinos (z.Bsp. Higgsinos) könnte eine Größenordnung oberhalb des Flusses sekundärer Antiprotonen liegen -> sollte zweifelsfrei nachweisbar sein; interessanter Bereich: oberhalb von 10 GeV (PAMELA hier sensitiv und Sonne hat geringen Einfluß hier)
- WIMPs könnten zum Positronen-Fluss durch direkte Annihilation in Elektron-Positron beitragen und zum Kontinuums-Positronen durch andere Annihilationen, deutlich sichtbar bei einigen GeV

ANTIMATTER

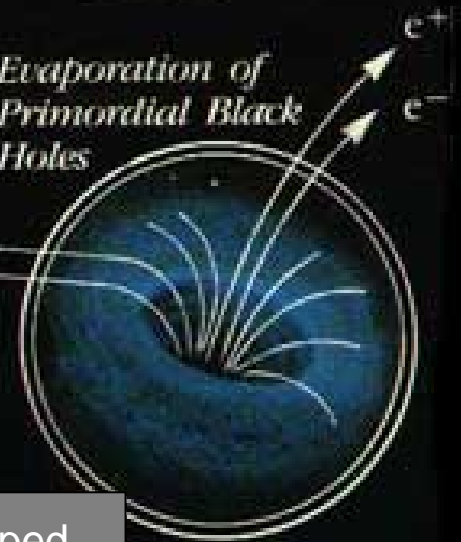
Collisions of High Energy Cosmic Rays With the Interstellar Gas



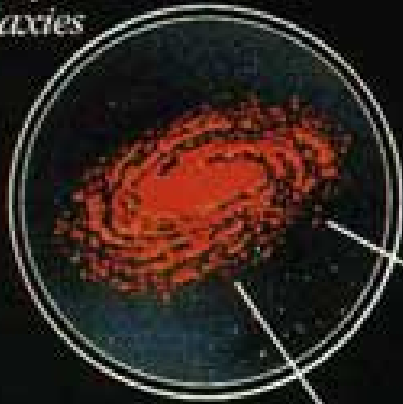
Annihilation of Exotic Particles



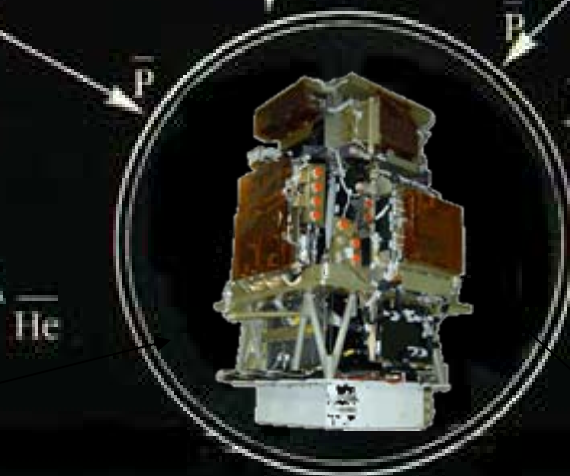
Evaporation of Primordial Black Holes



Cosmic Rays Leaking Out of Antimatter Galaxies



Antimatter Lumps in our Galaxy

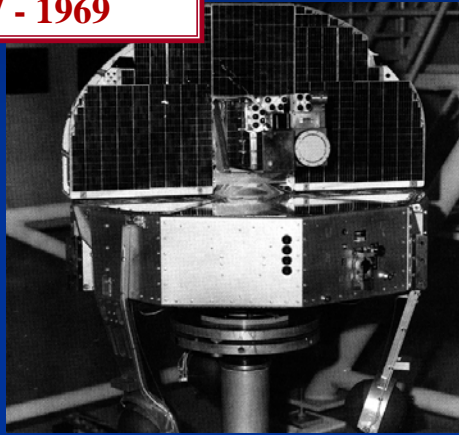


Trapped antiparticles

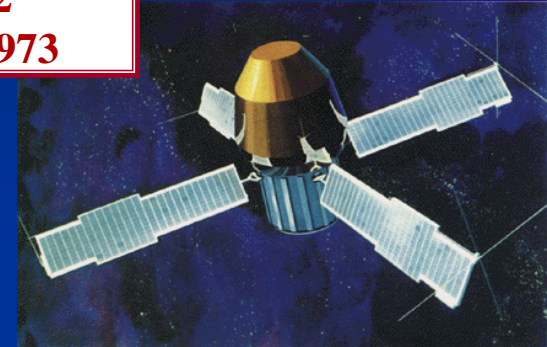
\bar{He}

Gamma Evidence for Cosmic Antimatter?

OSO-3
1967 - 1969



SAS-2
1972 - 1973



COS-B
1975 - 1982



GRO: Comptel and EGRET
1991 - 2000



INTEGRAL/SP1
2002

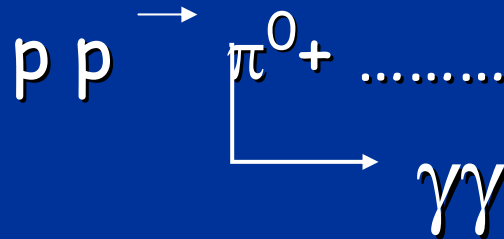


Gamma Evidence for Cosmic Antimatter?

Steigman 1976, De Rujula 1996, Dolgov 2007

- Observation in the 100 MeV gamma range

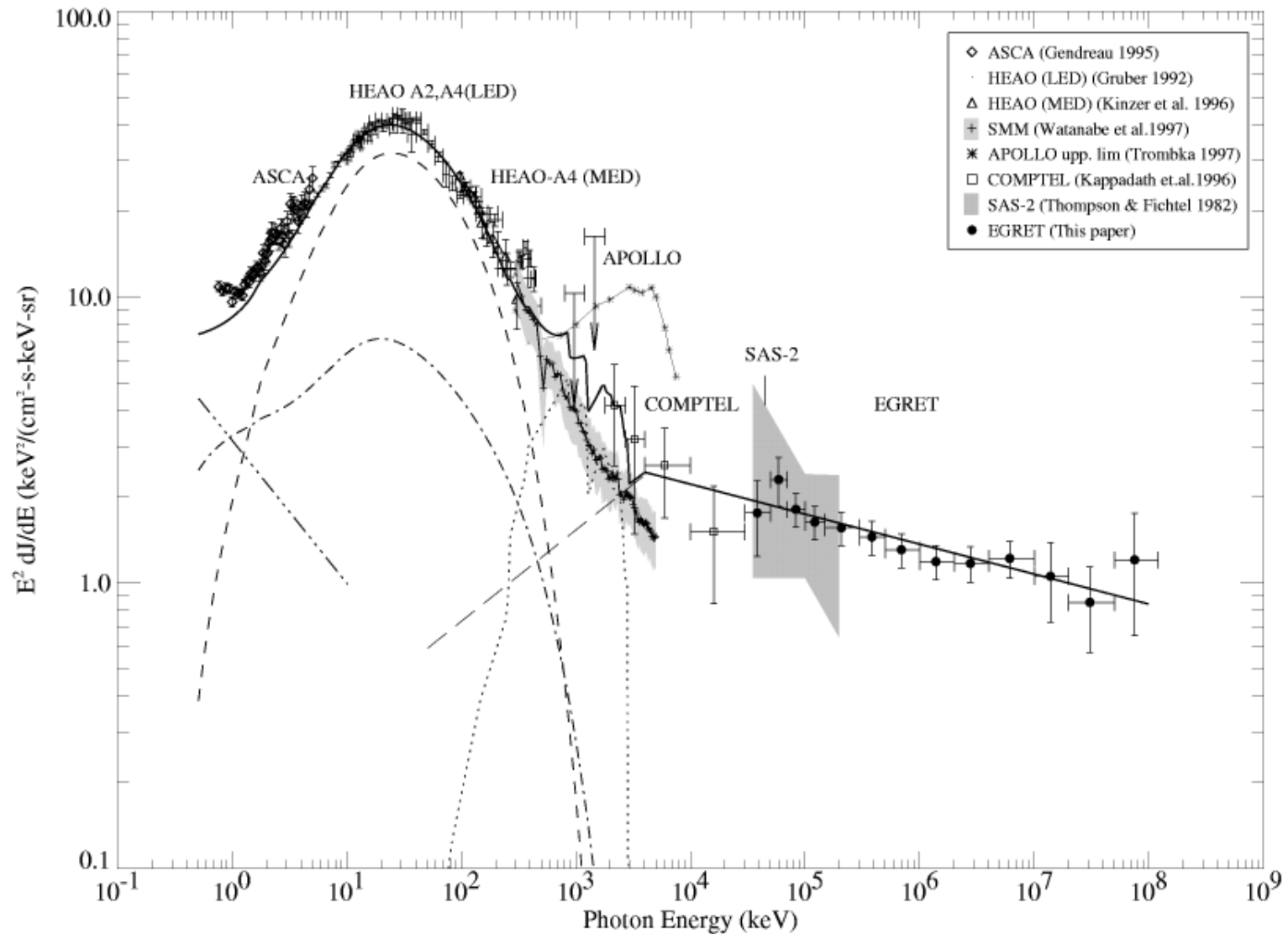
Leading process:



Other processes:



Cosmic Diffuse Gamma Spectrum

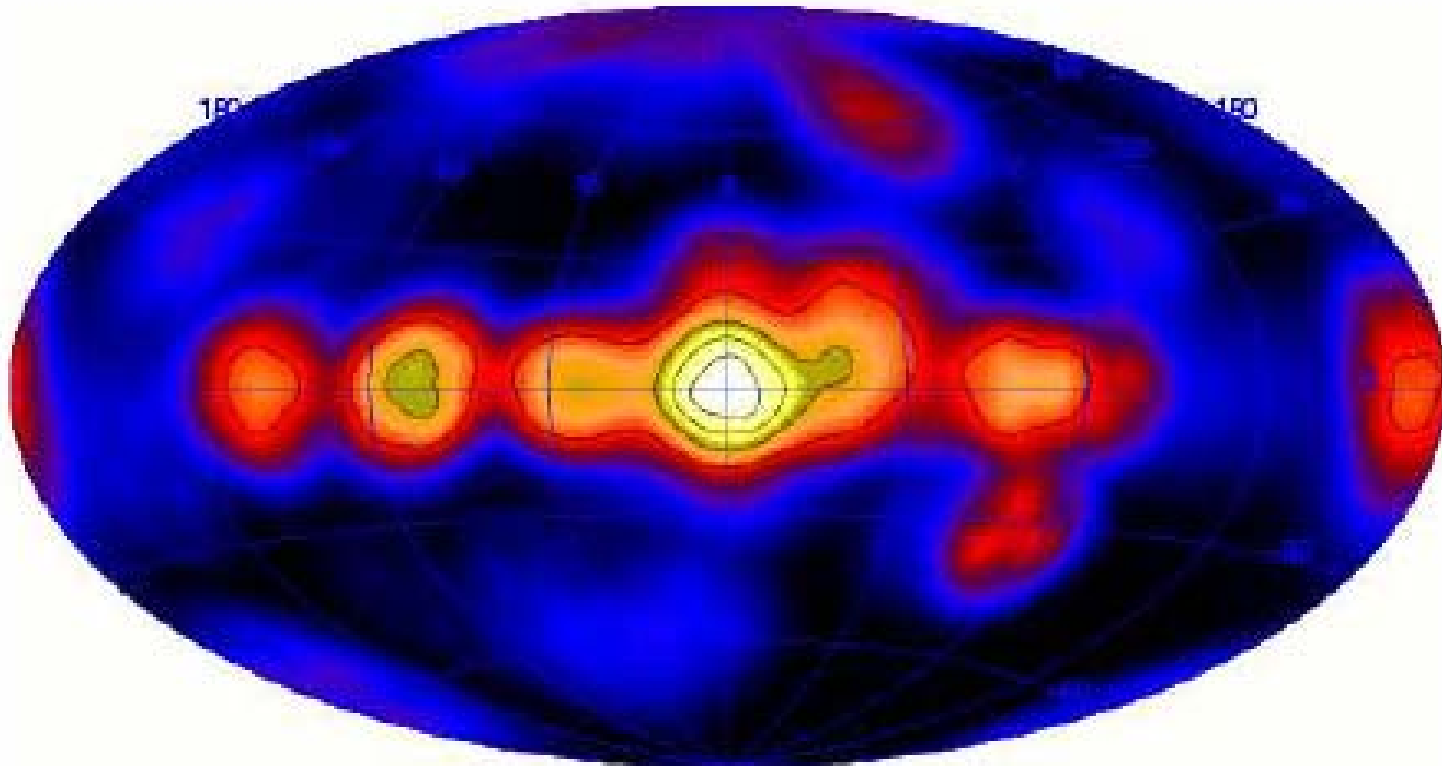


Lumps of Antimatter in our Galaxy?

C. Bambi and A. D. Dolgov, arXiv: astro-ph/0702350 and therein

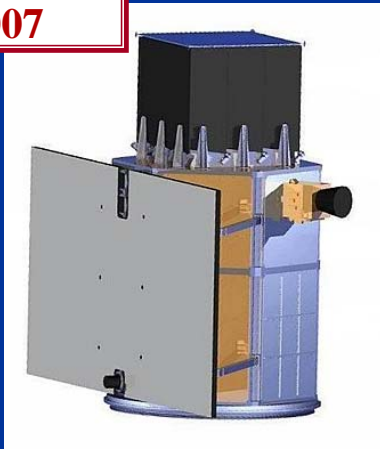
enclosed references

0.511 MeV positron annihilation-Integral/SPI



New Gamma Space Experiments

AGILE
23-04-2007



GLAST
2008



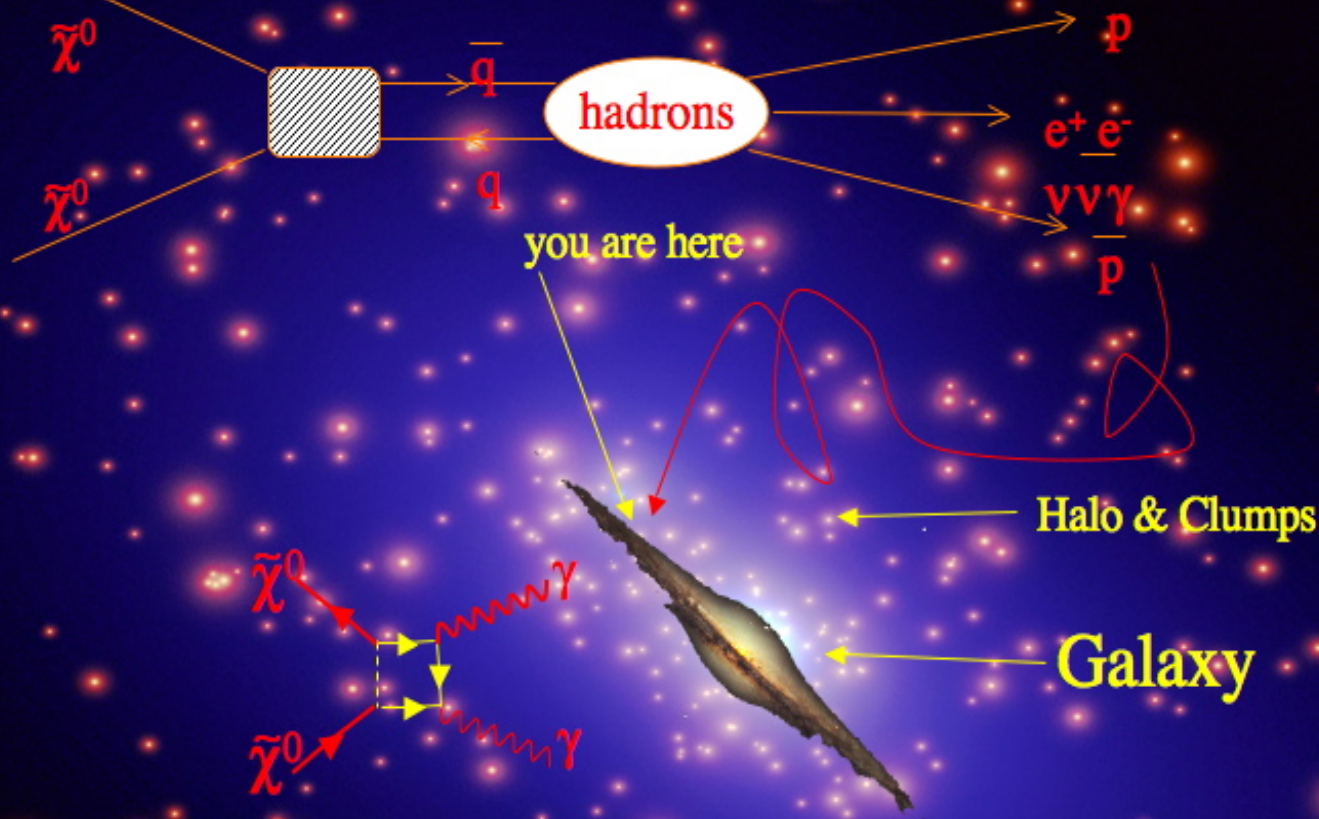
Antimatter Direct research

- **Antimatter** which has escaped as a cosmic ray from a distant antigalaxy

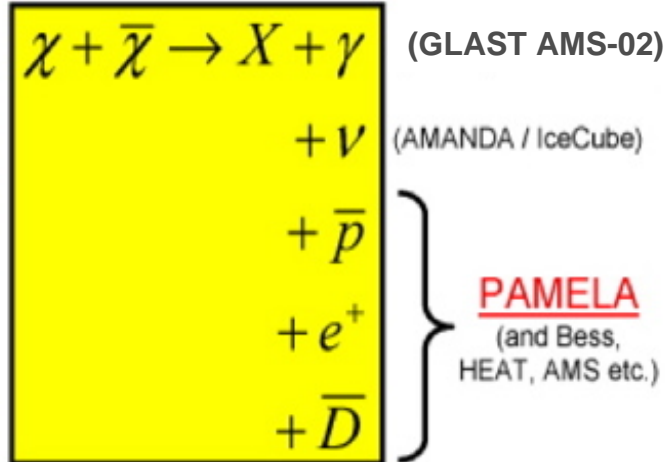
Sreitmatter, R. E., Nuovo Cimento, 19, 835 (1996)

- **Antimatter** from globular clusters of antistars in our Galaxy as antistellar wind or anti-supernovae explosion

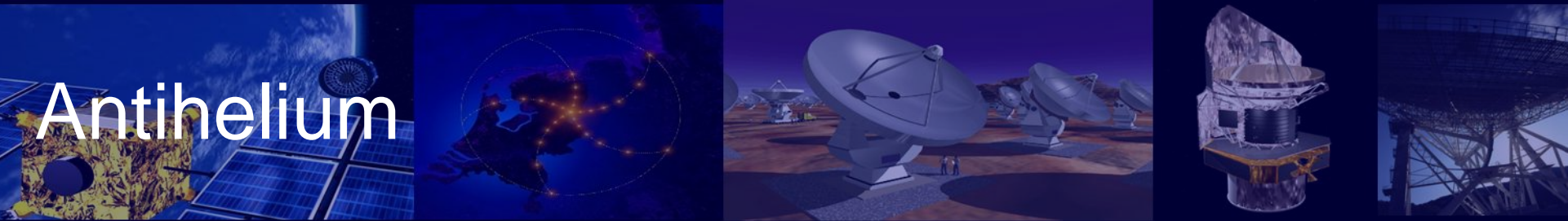
K. M. Belotsky et al., Phys. Atom. Nucl. 63, 233 (2000), astro-ph/9807027



Will distort the antiproton positron and gamma spectra from purely secondary production



Neutralino Annihilations

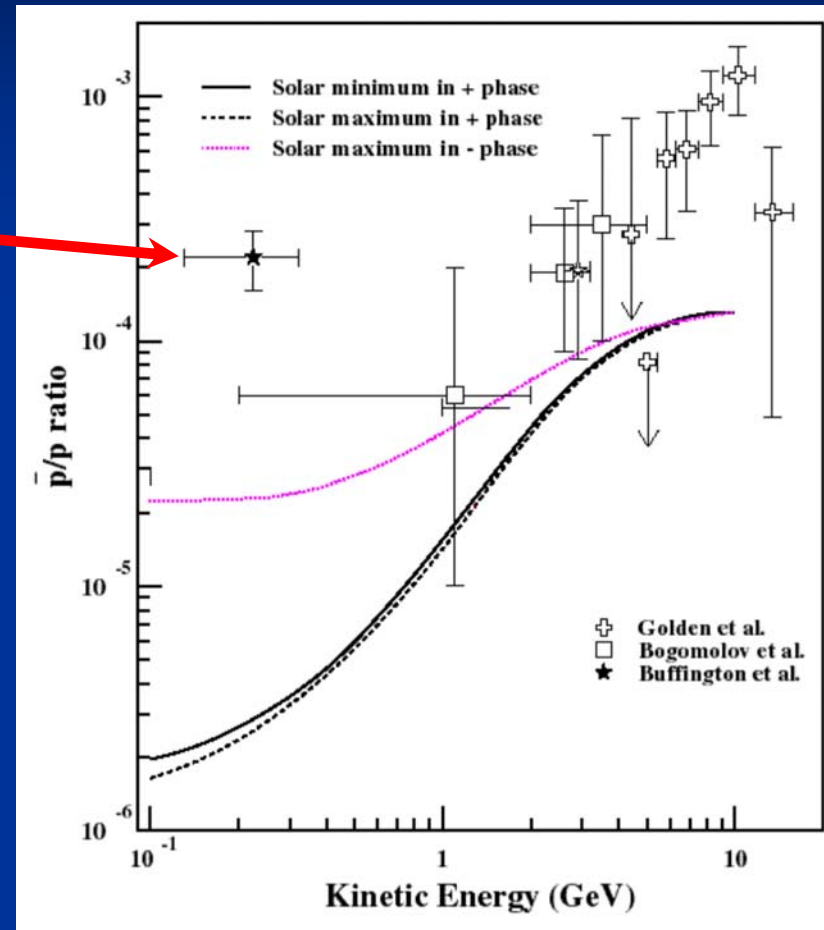


- Positronen, Antiprotonen, Antineutronen, Antideuterium, Antitritium, Antihelium sind bereits im Labor erzeugt worden
- Sollte es Antimaterie aus dem frühen Universum geben, dann ist es am wahrscheinlichsten, daß Antihelium in kosmischer Strahlung nachgewiesen werden kann (zweithäufigstes Element nach Wasserstoff)
- PAMELA wird nach Antimaterie in einem breiten Energiebereich 50 MeV bis einige 100 GeV suchen; Empfindlichkeit für ein Antihelium/Helium Verhältnis besser als 10^{-8}

Antimatter in Cosmic Rays

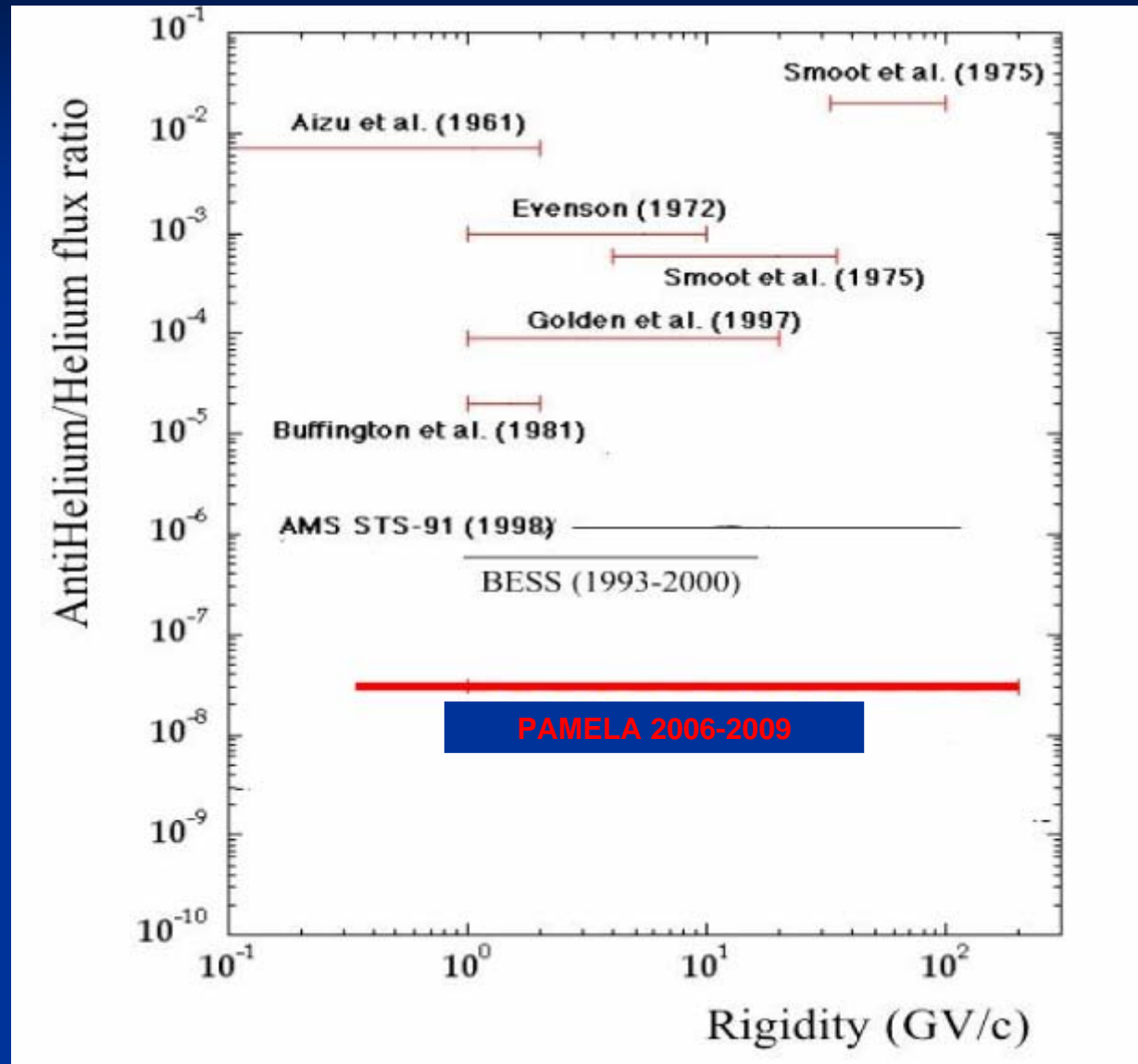
1979: First observation (Golden et al)
1979: Russian PM (Bogomolov et al)
1981: Excess reported (Buffington et al)
1985: **ASTROMAG** Study Started
1987: LEAP, PBAR (upper limits)

1991: **MASS**
1992: **IMAX**
1993: **TS93**, BESS
1994: **CAPRICE94**, **HEAT-e \pm**
1996: Solar minimum
1997: BESS
1998: **CAPRICE98**, **AMS-01**
1999: BESS
2000: **HEAT-pbar**, BESS
2004: BESS Polar I



Before MASS Flight

Extragalactic Cosmic-ray Antimatter Search



What do we need?

- Measurements at higher energies
- Better knowledge of background
- High statistic
- Continuous monitoring of solar modulation

Long Duration Flights

Antimatter Dark Matter Space Missions

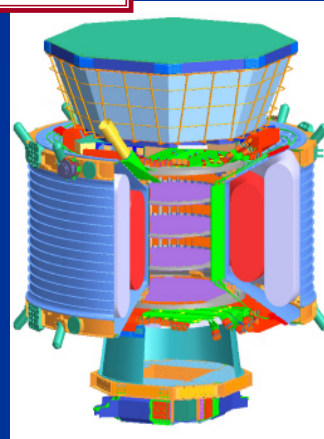
PAMELA
15-06-2006



BESS
2007



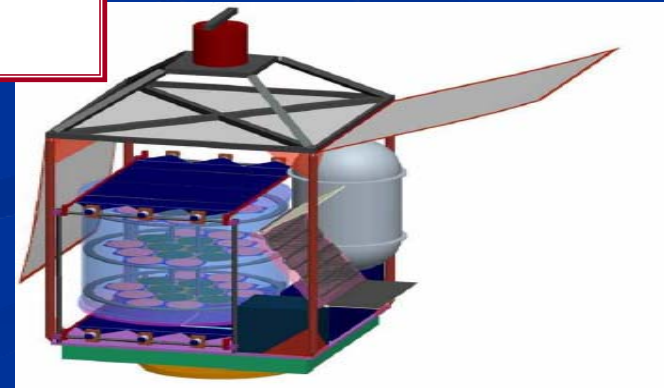
AMS-02
2009



PEBS
2010



GAPS
2013



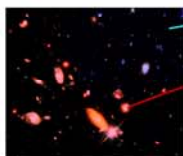
PAMELA and AMS-02: Observatories at 1 AU

TEMPO

SCIENCE FOLDOUT 1

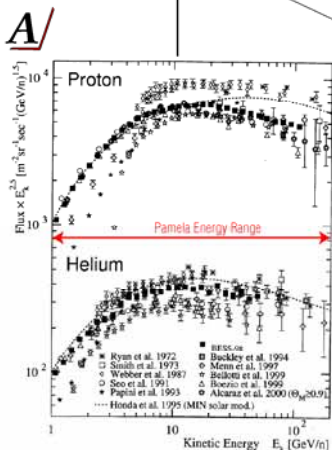
EXOTIC MATTER AND COSMIC RAYS

Extragalactic matter and antimatter domains?



~100 Mpc

Measurements of primary proton and helium spectra and spectra of heavier nuclei



Cosmic Ray Proton and Helium Spectra. PAMELA will measure these fluxes with a precision of 1% for protons and 5% for helium at the highest energy of 200 GeV/n.

Study of acceleration processes; abundances of the elements; measurement of the positron fraction



Antinuclei

Nuclei

Primordial Black Holes



Clumpy Dark Matter

Neutralinos? Other WIMPs?

SOLAR ACTIVITY

Search for dark matter

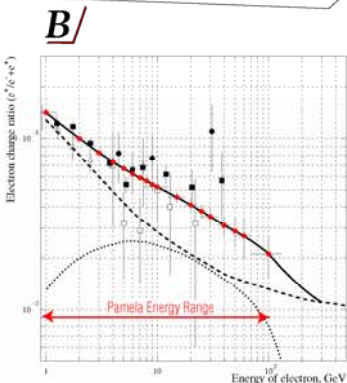
Search for an excess of positron and antiproton flux over the predicted secondary spectra

Precise measurements of antiproton and positron spectra; modeling secondary antiproton and positron spectra

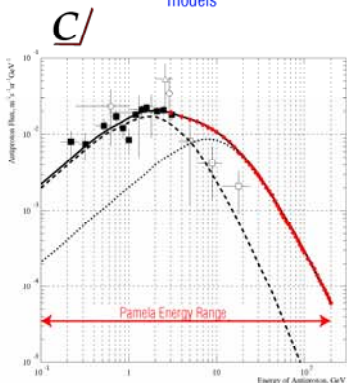
Study of cosmic ray transport models

Fluxes of protons, antiprotons, electrons and positrons measured simultaneously

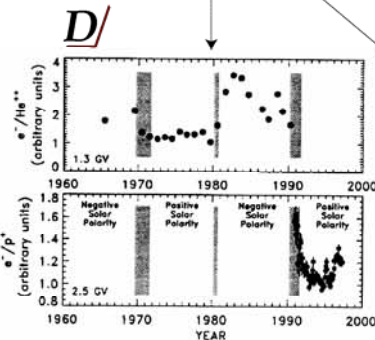
Study of charge-sign dependence of solar modulation



Distortion of the secondary positron fraction (dashed line) due to one possible contribution from neutralino annihilation (dotted line, from Baltz and Edsjo, 1998). Filled circles - TS-93 (Golden et al. 1996), open triangles - CAPRICE-94 (Barbiellini et al. 1996), filled squares - combined HEAT data (Barwick et al. 1997), and open squares - CAPRICE-98 (Boezio et al. 1999). Expected data from PAMELA for one year of operation are shown by red circles.



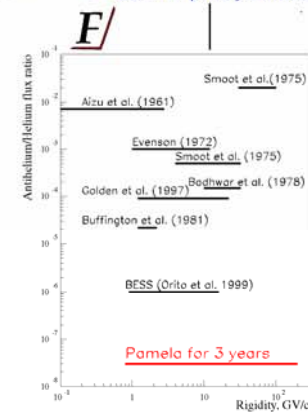
Distortion on the antiproton flux (dashed line) due to one possible contribution from neutralino annihilation (dotted line, from Ullio 1999). Total expected flux is shown by solid line. Filled squares - BESS data (Orto et al. 1999), open squares - MASS-91 (Stochaj et al. 2000), open circles - IMAX (Mitchell et al. 1996), and open triangles - CAPRICE (Boezio et al. 1999). Expected data from PAMELA experiment for 1 year of operation are shown by red circles.



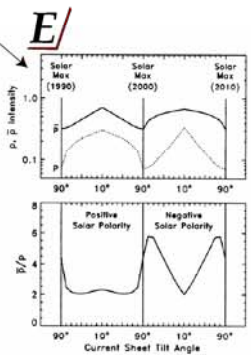
Electron, positron, proton and helium isotope abundance ratios affected by solar modulation in different phases (collected in different experiments, Bieber et al. 1999 and references therein). PAMELA will make all these measurements simultaneously.

Antinuclei

Search for primary antimatter



Current upper limits on the flux of antihelium compared to the sensitivity of PAMELA in 3 years.



Predicted effect of charge-sign dependent solar modulation on the antiproton to proton ratio (Bieber et al. 1999). PAMELA will measure this ratio over the period of expected high variability, testing the model.

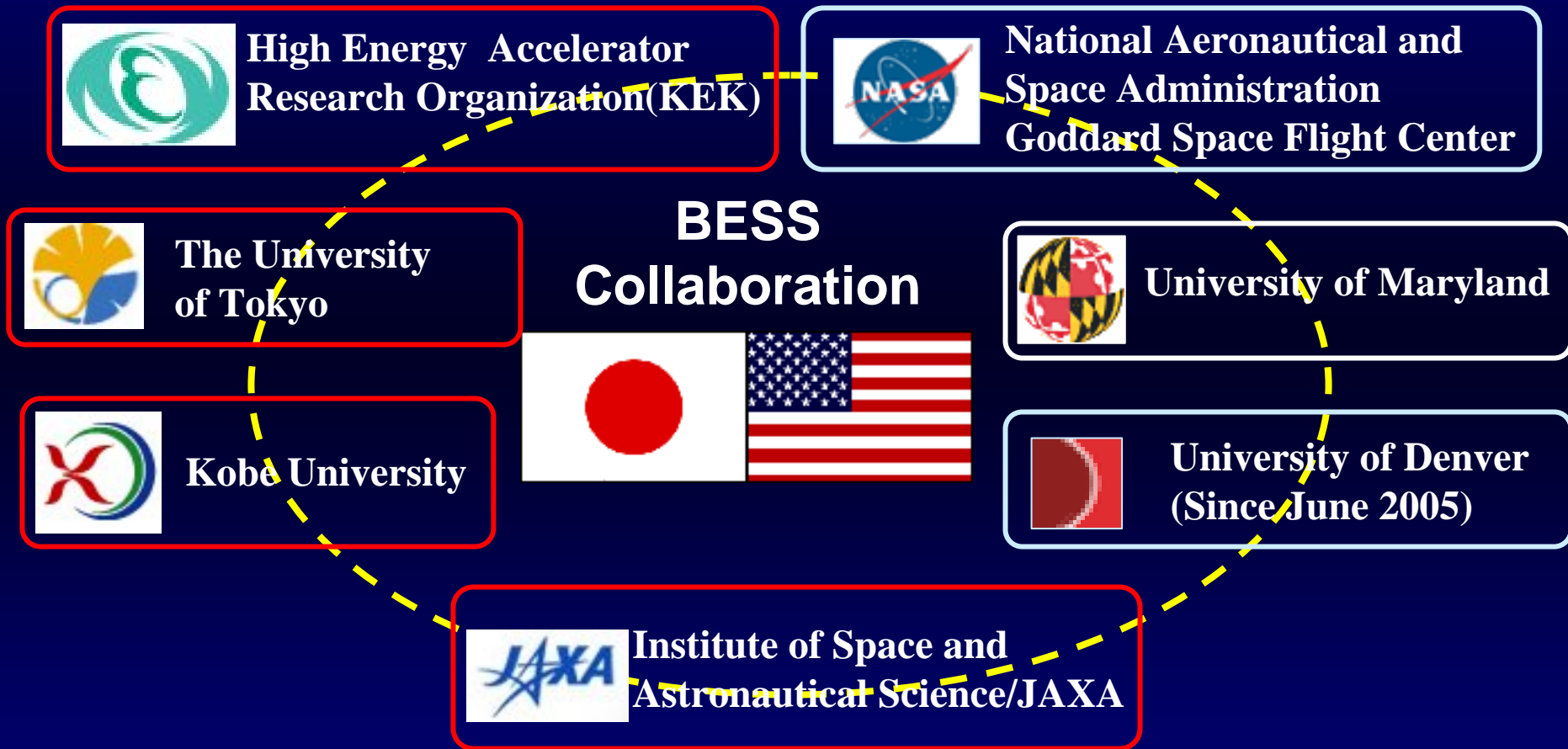
Multifrequenz-Beobachtungen
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BESS

BESS Collaboration

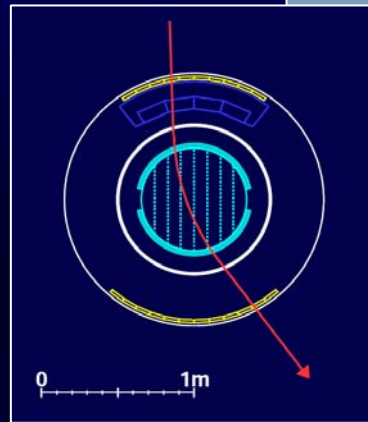
As of April, 2006



Balloon-borne Experiment with a Superconducting Spectrometer

BESS

*Balloon-borne
Experiment with a
Superconducting
Spectrometer*



**Search for
Primordial Antiparticle**

antiproton: Novel primary origins (PBH,DM)

antihelium: Asymmetry of matter/antimatter

Precise Measurement of Cosmic-ray flux:
highly precise measurement at < 1 TeV

BESS Detector

– Rigidity measurement

– SC Solenoid (L=1m, B=1T)

– Min. material (4.7g/cm²)

– Uniform field

– Large acceptance

– Central tracker

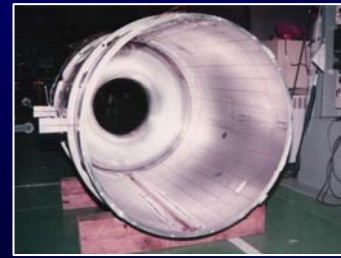
– (Drift chamber

– $\delta \sim 200\mu\text{m}$

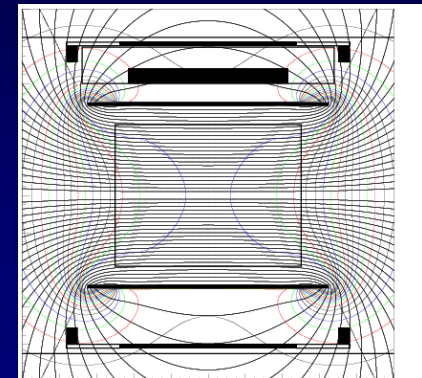
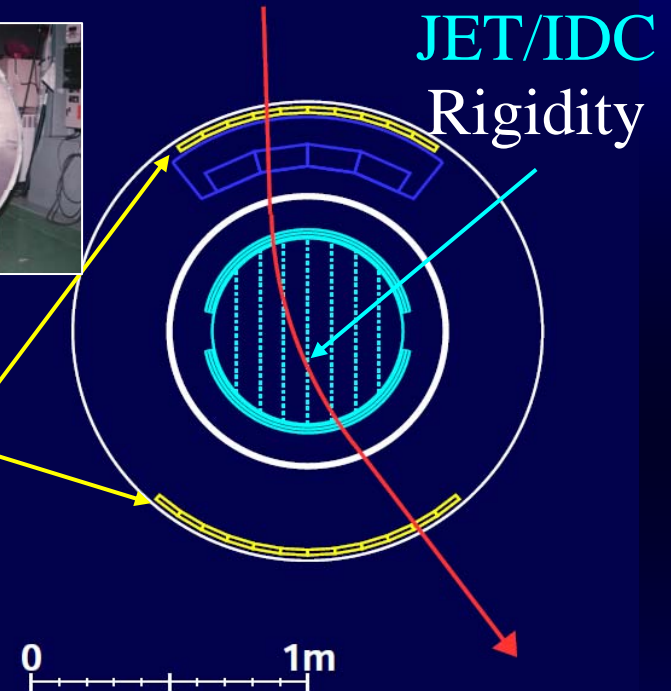
– Z, m measurement

– $R, \beta \rightarrow m = ZeR \sqrt{1/\beta^2 - 1}$

– $dE/dx \rightarrow Z$

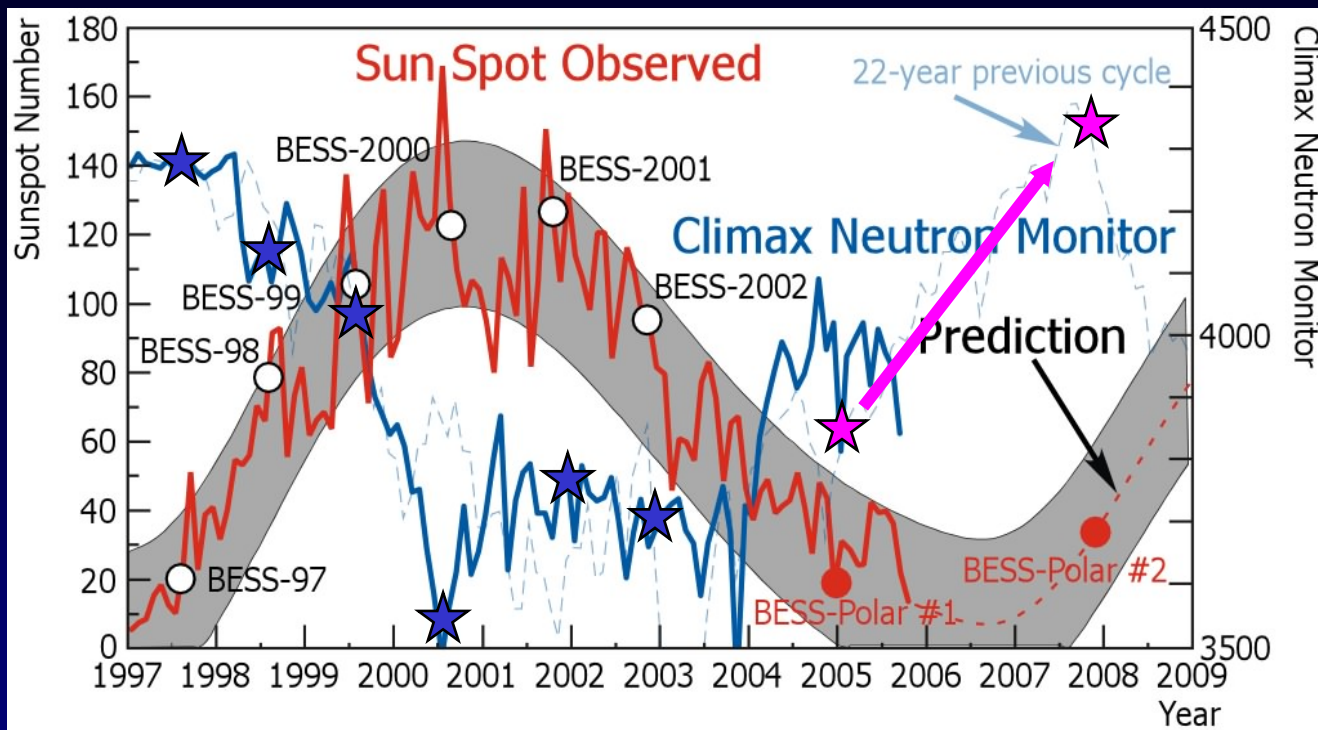


TOF
 $\beta, dE/dx$

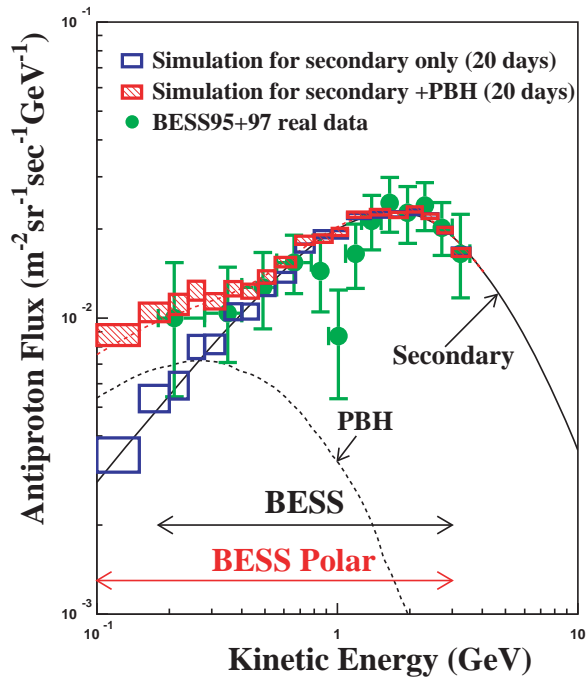


BESS-Polar II December 2007

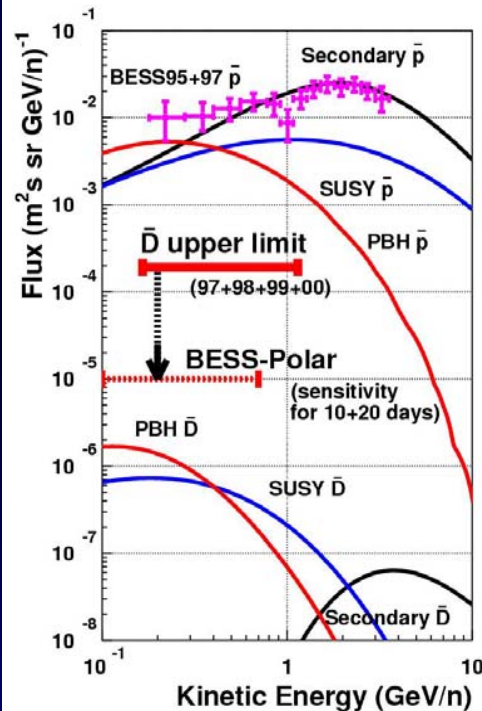
- Long duration flight of **20 days** with two circle around the pole, **4~5 x BESS-Polar I statistics**
- Combined measurements with PAMELA



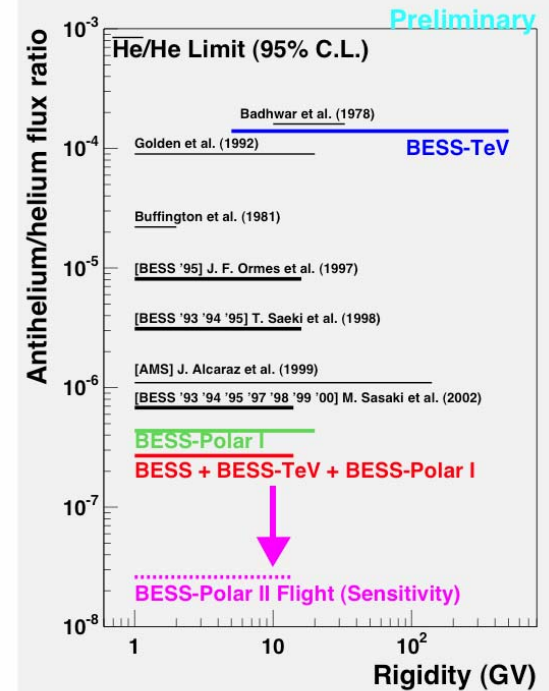
BESS Polar II Observation (Expected)



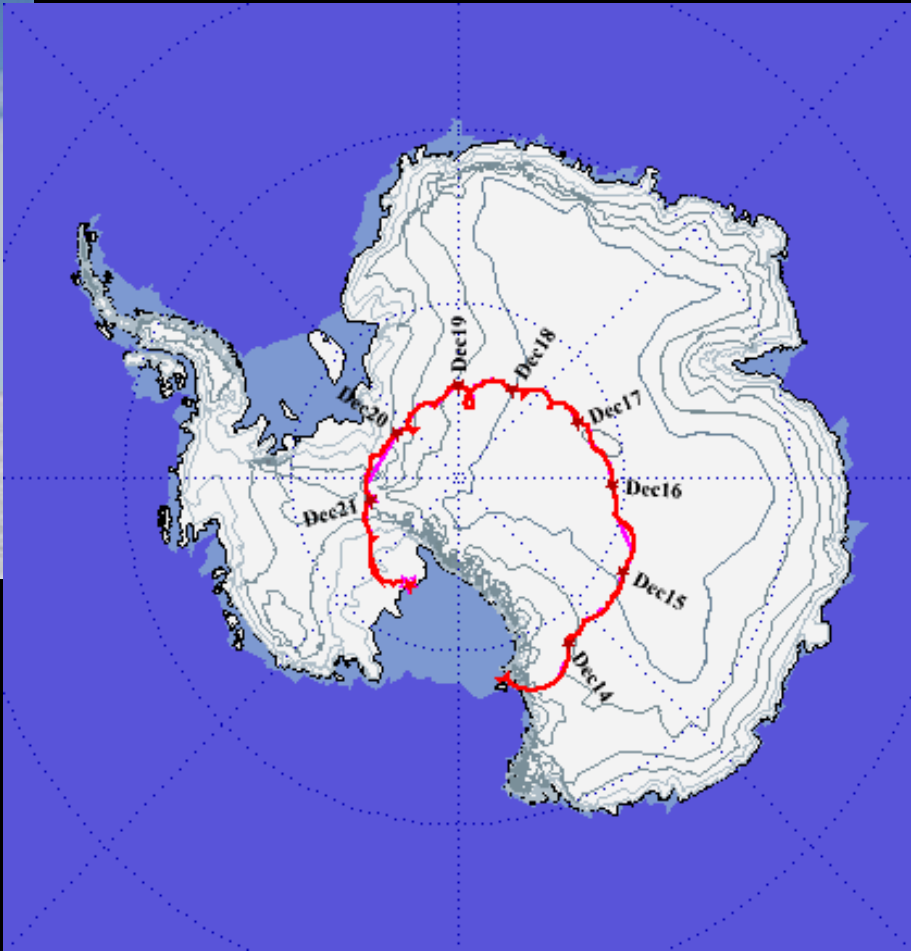
Antiproton Spectrum



Search for Antideuteron and AntiHelium
(Search for PBH)

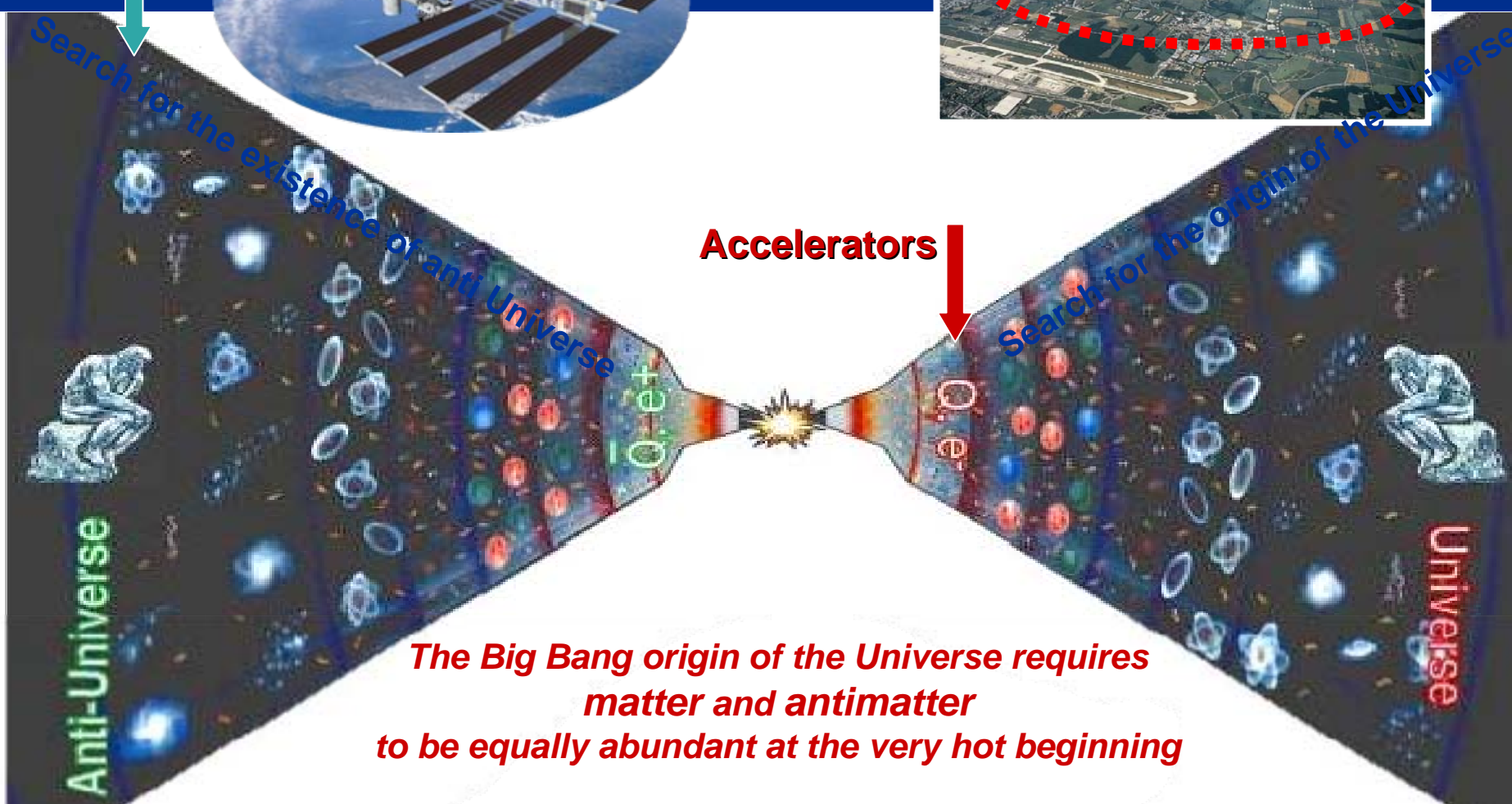


BESS



Search for the existence of Antimatter in the Universe

**PAMELA AMS
in Space**



The Big Bang origin of the Universe requires matter and antimatter to be equally abundant at the very hot beginning

Pamela and AMS-02

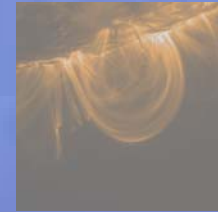
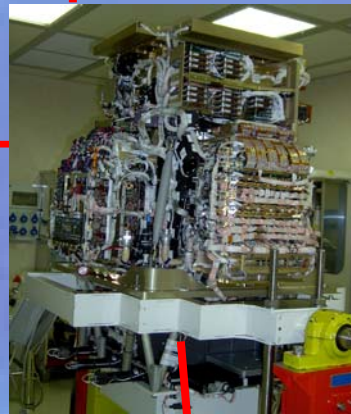
Space Observatories at 1AU

Exotic matter : Antimatter Solar Energetic particles

PBH Dark Matter

Galactic cosmic rays

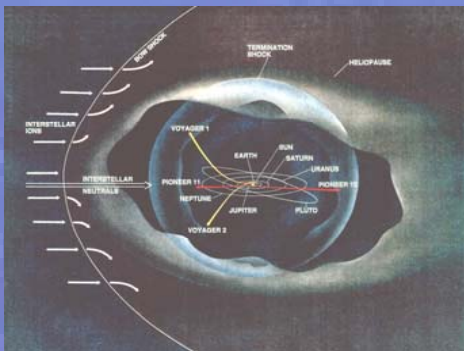
Jovian electrons



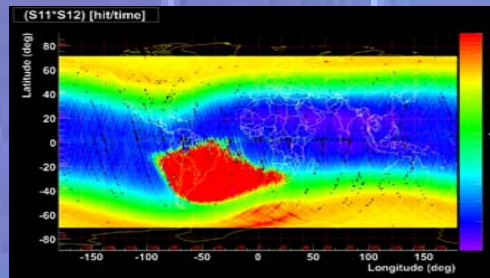
Solar Modulation



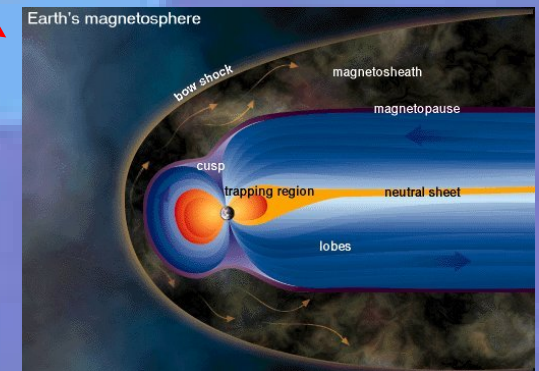
*Anomalous Nuclei
Nearby e⁻ Sources*




*R. B., SAA, Albedo,
secondary particle*



Magnetospheric physics



A winter landscape with snow-covered fields, trees, and mountains in the background. The scene is misty and serene, with a large tree in the foreground on the right and a winding path in the middle ground.

Multifrequenz-Beobachtungen
in der Astronomie, Teil II
Wintersemester 2007/8

**Update: Neue Teleskope
PAMELA**

PAMELA Collaboration

Italy:



Bari



Florence



Frascati



Naples



Rome



Trieste



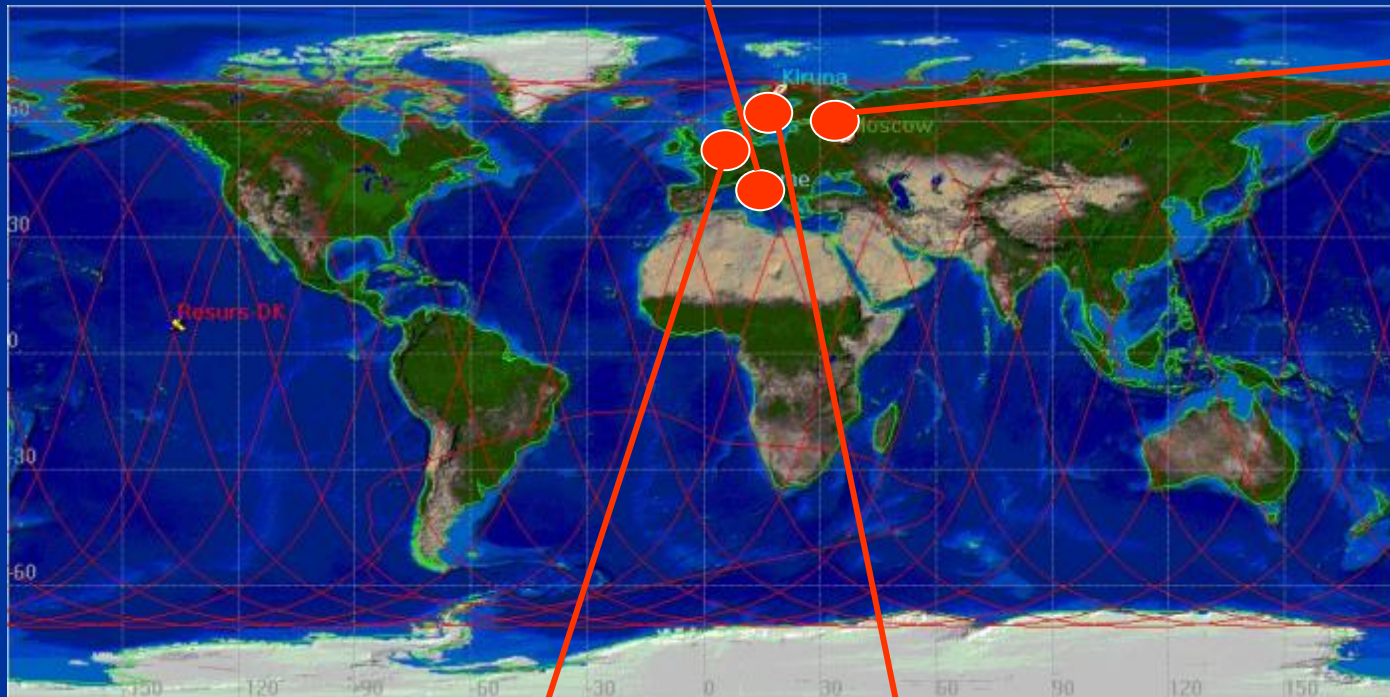
CNR, Florence

Russia:



Moscow

St. Petersburg



Germany:



Siegen

Sweden:



KTH, Stockholm

Pamela's scientific objectives

- ✓ Study antiparticles in cosmic rays
- ✓ Search for antimatter
- ✓ **Search for dark matter**
- ✓ Study cosmic-ray propagation
- ✓ Study solar physics and solar modulation
- ✓ Study the electron spectrum (local sources)

PAMELA nominal capabilities

	<u>energy range</u>	<u>particles in 3 years</u>
■ Antiprotons	80 MeV - 190 GeV	$\sim 10^4$
■ Positrons	50 MeV – 270 GeV	$\sim 10^5$
■ Electrons	up to 400 GeV	$\sim 10^6$
■ Protons	up to 700 GeV	$\sim 10^8$
■ Electrons+positrons	up to 2 TeV (from calorimeter)	
■ Light Nuclei	up to 200 GeV/n He/Be/C:	$\sim 10^{7/4/5}$
■ AntiNuclei search	sensitivity of 3×10^{-8} in antiHe/He	

PAMELA in Space

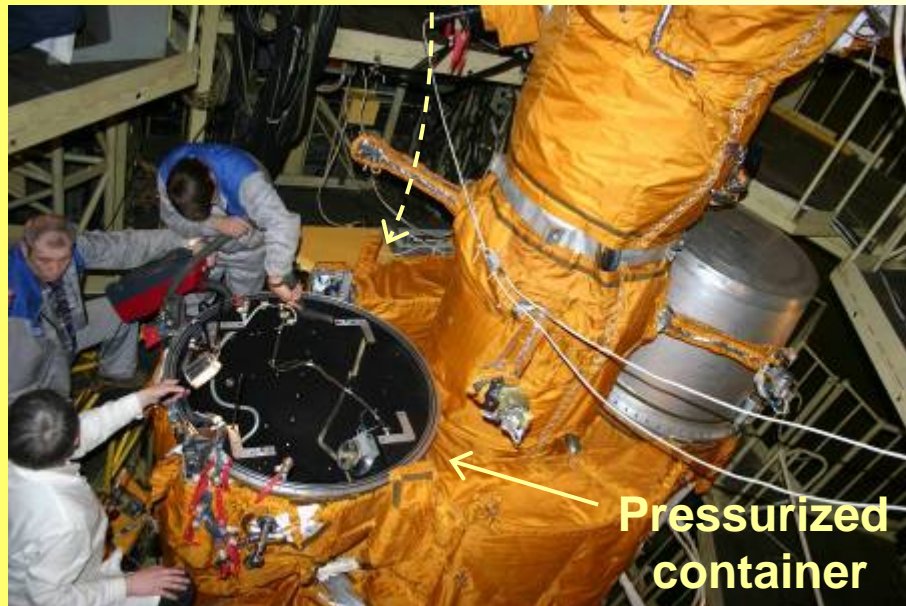
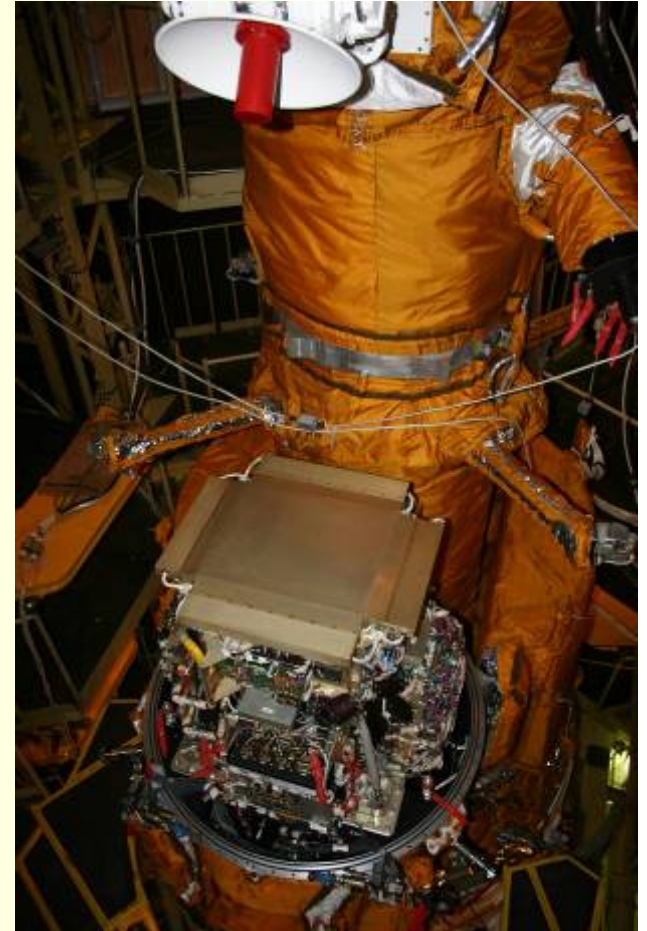
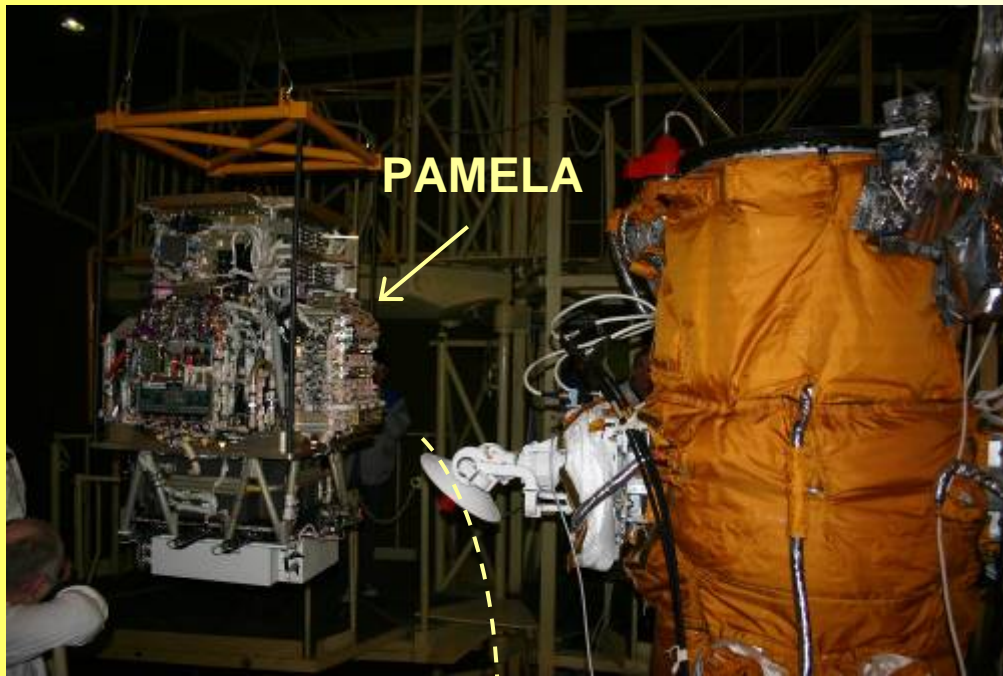


- On June 15th 2006 at 08:00 UTC the RESURS DK-1 satellite housing the PAMELA apparatus was successfully launched in space from the Russian cosmodrome of Baikonur.
- PAMELA was switched on for the first time on June 21st.
- In the following days PAMELA was on for

PAMELA flight

- Detectors operated as expected after launch
- Tested different trigger and hardware configurations
- As of August 30, 2007 PAMELA has collected data for about 30 million seconds corresponding to more than 340 days (8100 hours) of continuous data taking (life time $\sim 70\%$)
- The amount of data collected is ~ 5.8 TB, corresponding to more than 700 million events

March 2006 @Baykonur
Integration with satellite



The PAMELA apparatus



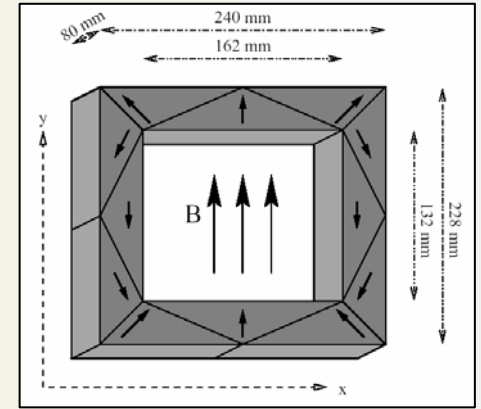
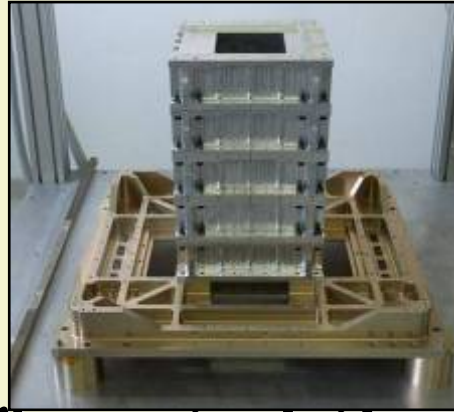
$$\frac{\bar{p}}{p} \sim O(10^{-4})$$

$$\frac{e^+}{e^-} \sim O(0.1)$$

$$\frac{p}{e^-} \sim O(200)$$

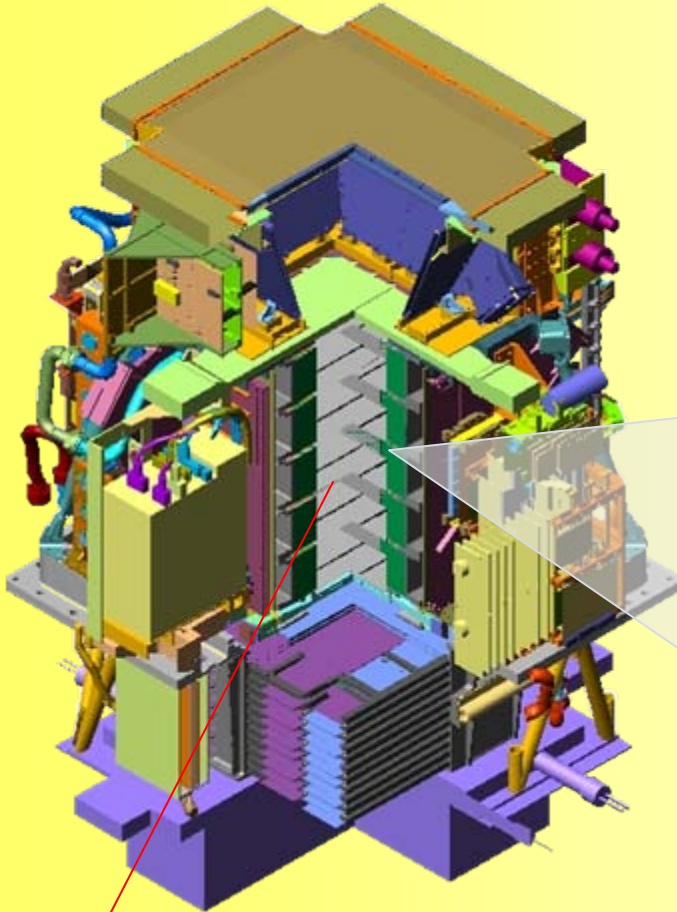
Mass ~450 kg Power ~360 W Geometrical Factor ~20.5 cm²sr

The magnet



Characteristics:

- 5 modules of permanent magnet (Nd-B-Fe alloy) in aluminum mechanics
- Cavity dimensions 162x132x445 cm³
→ GF 21.5 cm²sr
- Magnetic shields
- 5mm-step field-map
- B=0.43 T (average along axis), B=0.48 T (@center)



SPECTROMETER

The tracking system

Main tasks:

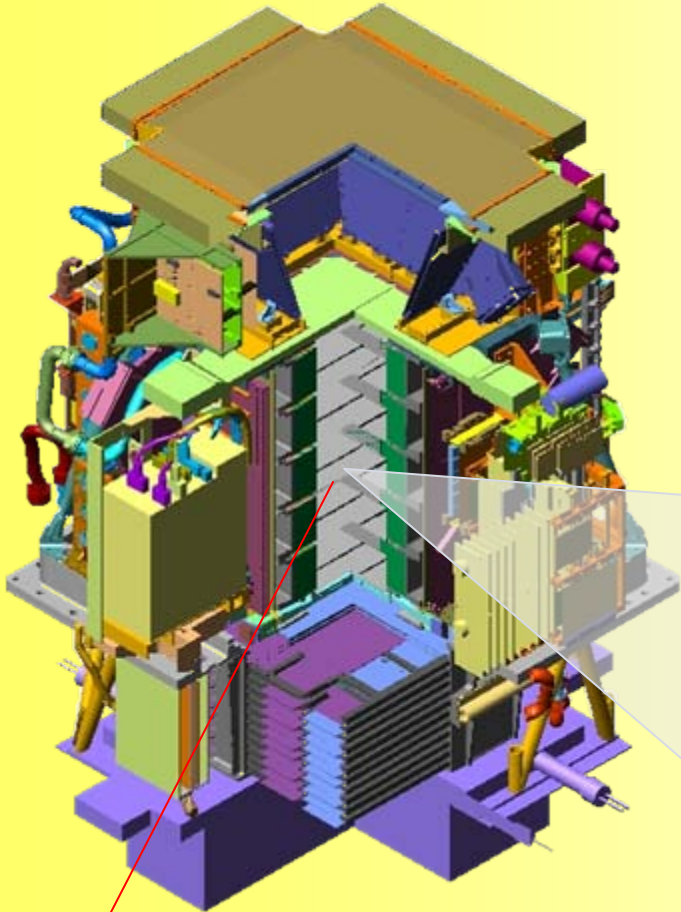
- Rigidity measurement
- Sign of electric charge
- dE/dx

Characteristics:

- 6 planes double-side (x&y view) microstrip Si sensors
- 36864 channels
- Dynamic range 10 MIP

Performances:

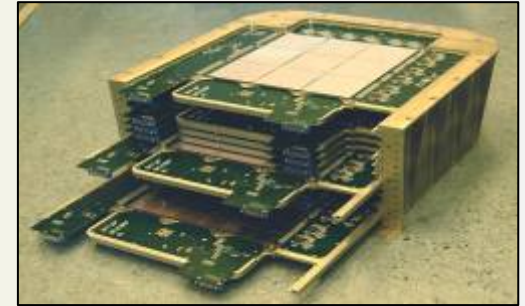
- Spatial resolution: 3-4 μ m
- MDR $\sim 1TV/c$ (from test beam data)



SPECTROMETER



The electromagnetic calorimeter



Main tasks:

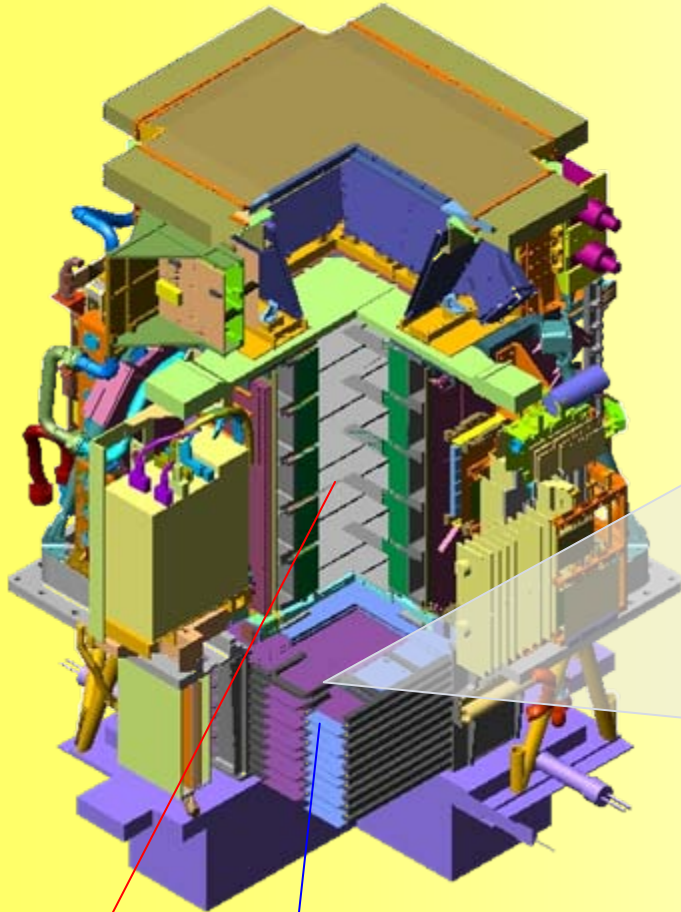
- e/h discrimination
- e^{+/-} energy measurement

Characteristics:

- 44 Si layers (X/Y) +22 W planes
- 16.3 X₀ / 0.6 λ₀
- 4224 channels
- Dynamic range 1400 mip
- Self-trigger mode (> 300 GeV GF~600 cm² sr)

Performances:

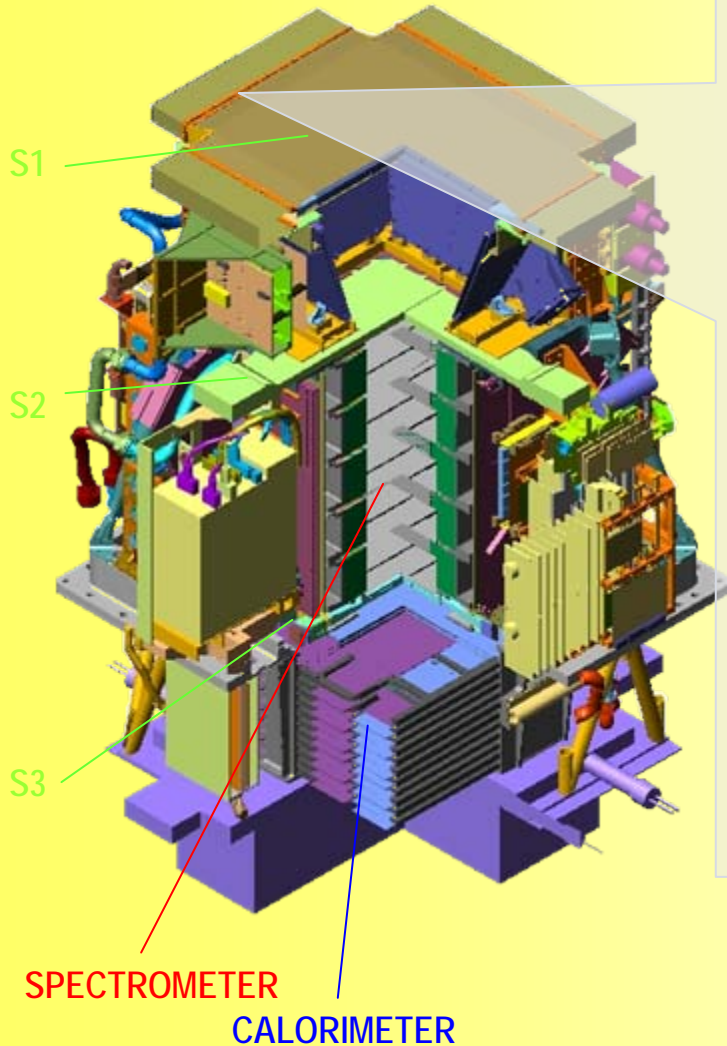
- p-bar and e⁺ selection efficiency ~ 90%
- p rejection factor >10⁵
- e⁻ rejection factor > 10⁴
- Energy resolution ~5% @200GeV



SPECTROMETER

CALORIMETER

The time-of-flight system



Main tasks:

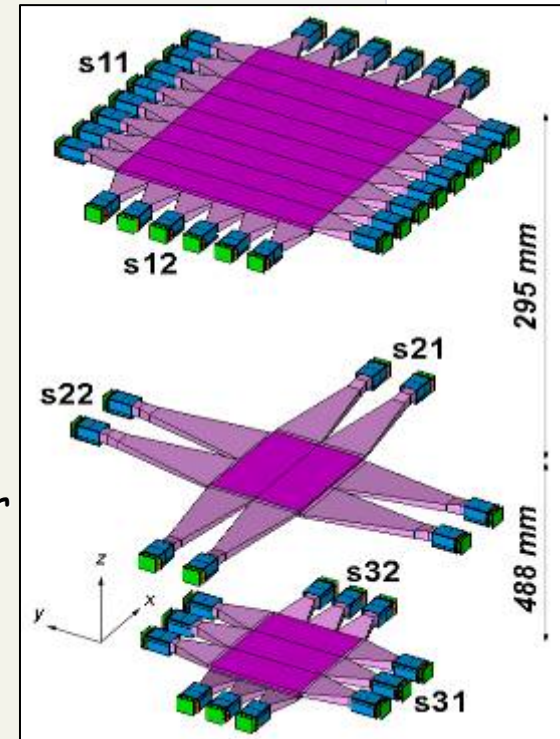
- First-level trigger
- Albedo rejection
- dE/dx
- Particle identification (<1 GeV/c)

Characteristics:

- 3 double-layer scintillator paddles
- X/Y segmentation
- Total: 48 Channels

Performances:

- $\sigma(\text{paddle}) \sim 110\text{ps}$
- $\sigma(\text{TOF}) \sim 330\text{ps}$ (for MIPs)



The anticounter shields

Main tasks:

- Rejection of events with particles interacting with the apparatus (off-line and second-level trigger)

Characteristics:

- scintillator paddles 10mm thick
- 4 up (CARD), 1 top (CAT), 4 side (CAS)

Performances:

- Efficiency > 99.9%



CARD

S1

CAT

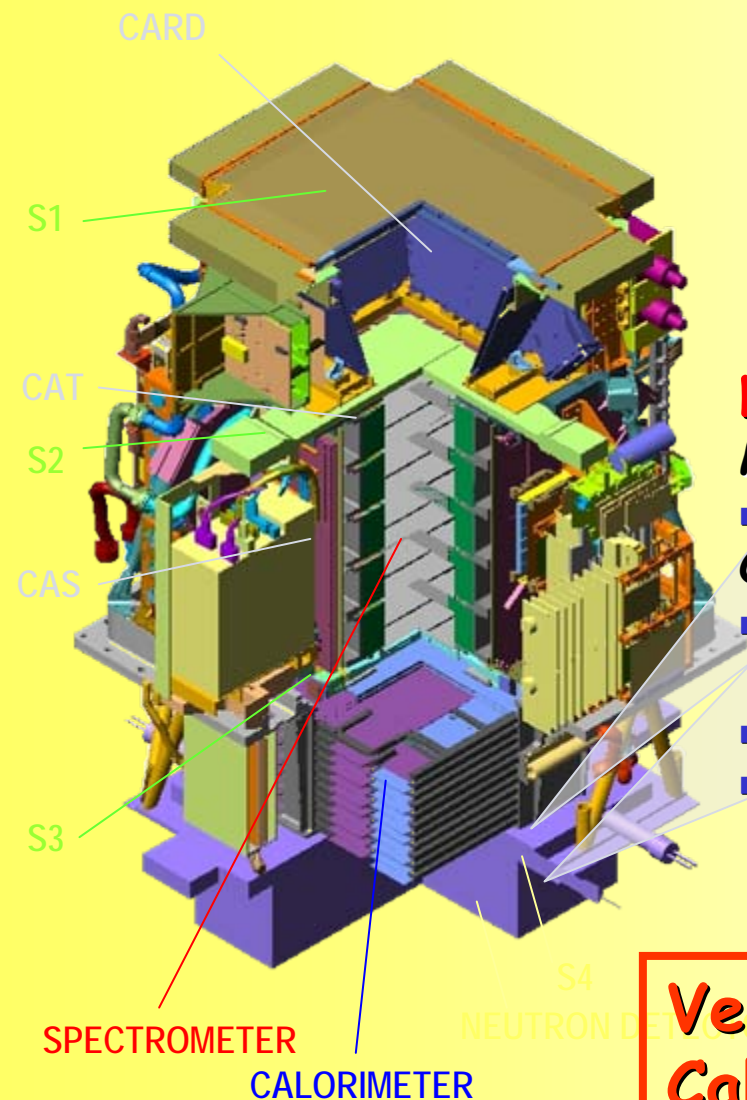
S2

CAS

S3

SPECTROMETER

CALORIMETER



Shower-tail catcher (S4)

Main tasks:

- ND trigger

Characteristics:

- 1 scintillator paddle
10mm thick



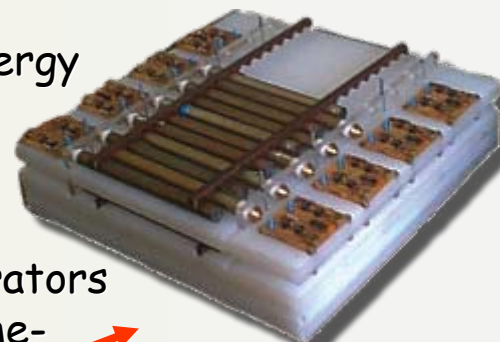
Neutron detector

Main tasks:

- e/h discrimination @high-energy

Characteristics:

- 36 ^3He counters:
 $^3\text{He}(n,p)\text{T} \rightarrow E_p=780 \text{ keV}$
- 9 cm thick polyethylene moderators
- n collected within 200 μs time-window



Very important to help the Calorimeter in the particle separation

DAQ and data link with earth



Data transmission

- Collected data stored in PAMELA mass-memory (2GB)
- Download (PAMELA → satellite)
7-8 per day → 14-16 GB
- Downlink (satellite → ground)
2-3 sessions per day
- Error rate $<10^{-9}$

Main downlink station:
Research Centre for Earth
operative monitoring "NtsOMZ"
(Moscow, Russia)

Spare downlink station:
Khanty-Mansiysk West Siberia

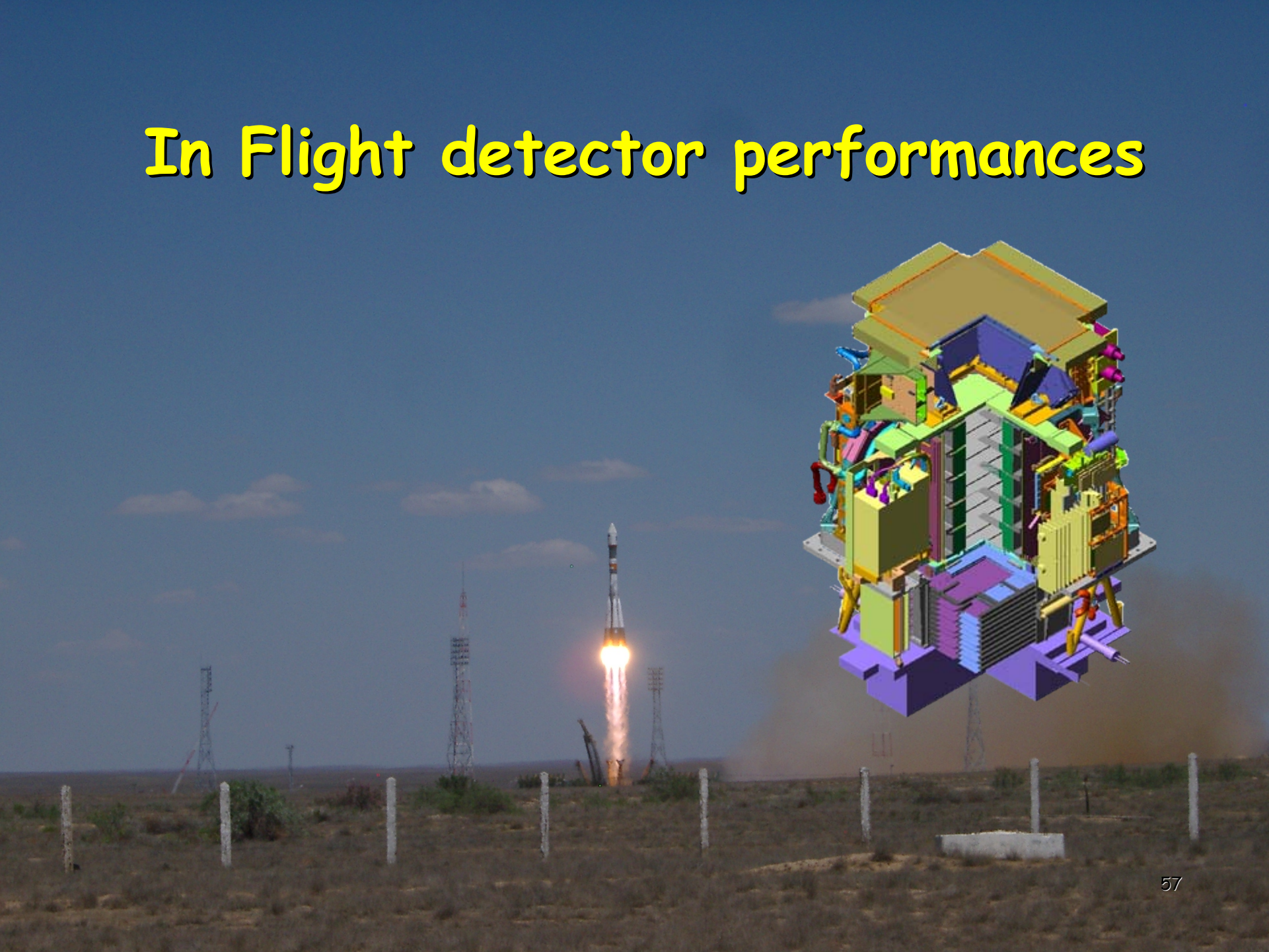
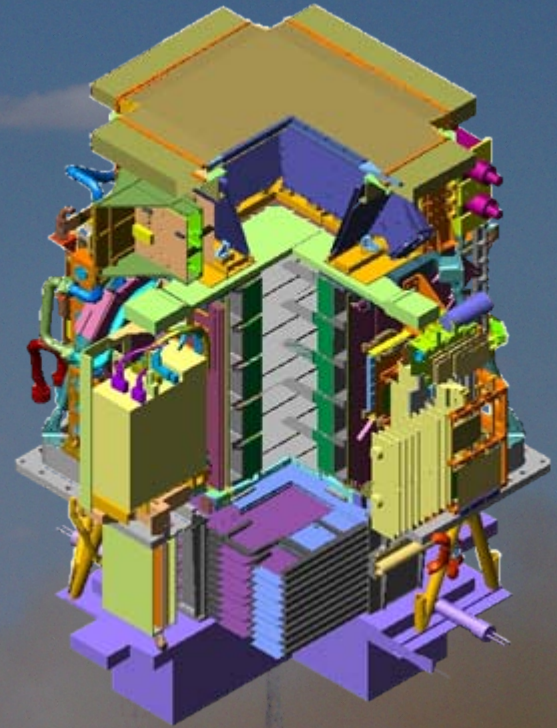


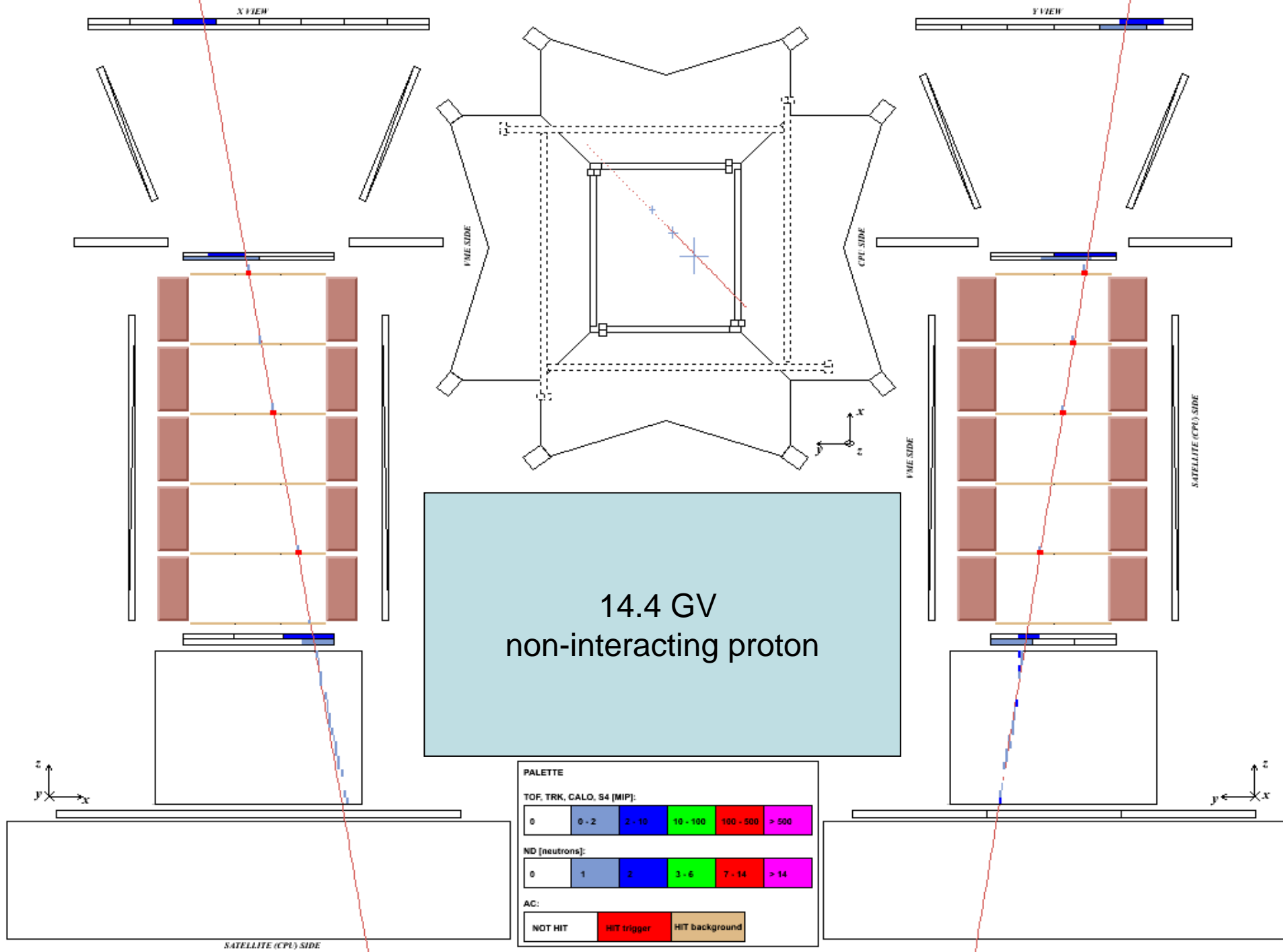
Remote control

- Macrocommands: commands to PAMELA cpu
 - System configuration (hundreds of modifiable parameters):
 - Calibration (ascending node)
 - Download to satellite mass memory
 - ...
 - Telecommands: hardware lines to handle power modules
- Extremely flexible system, designed to be easily adapted to space (unknown) conditions.

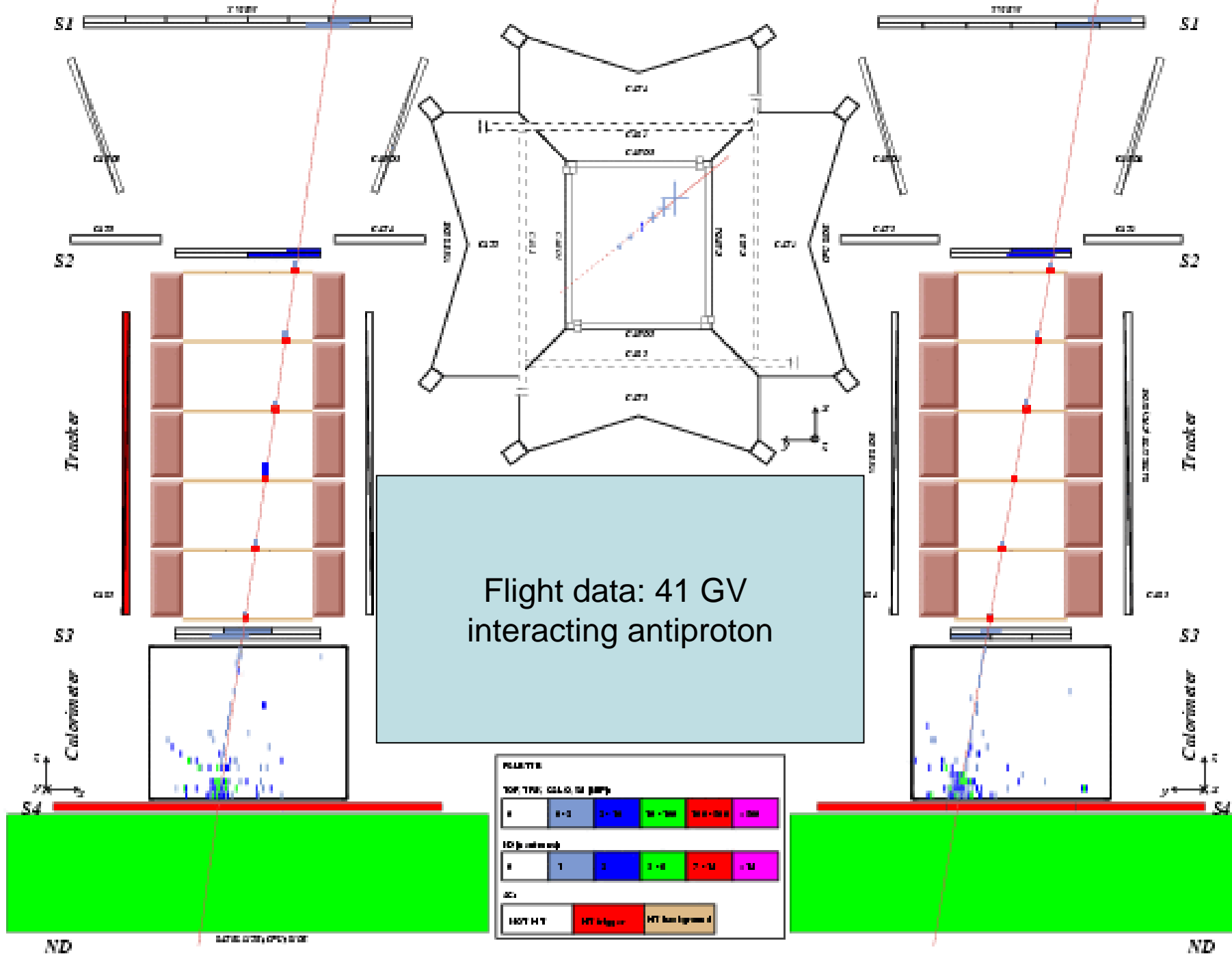


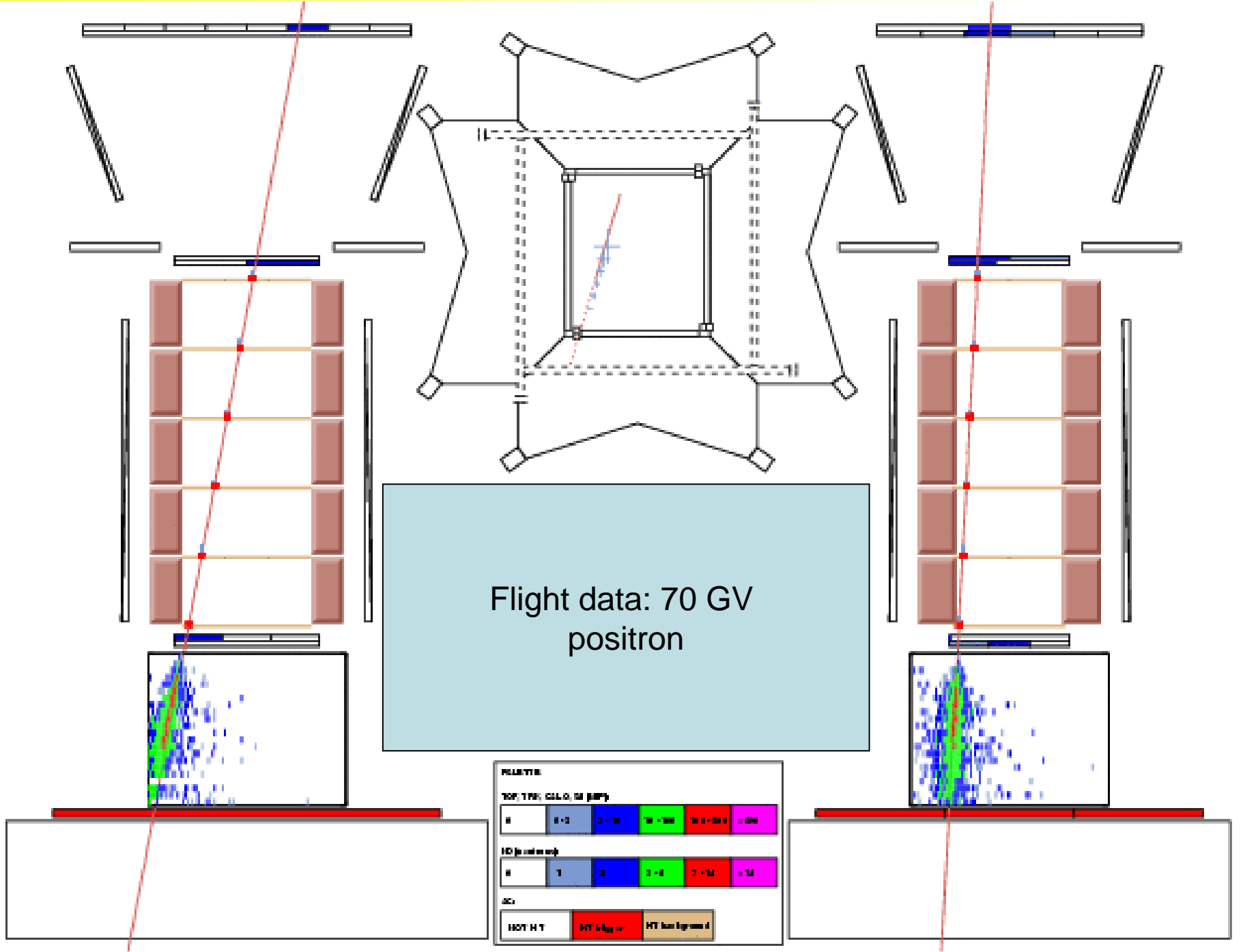
In Flight detector performances

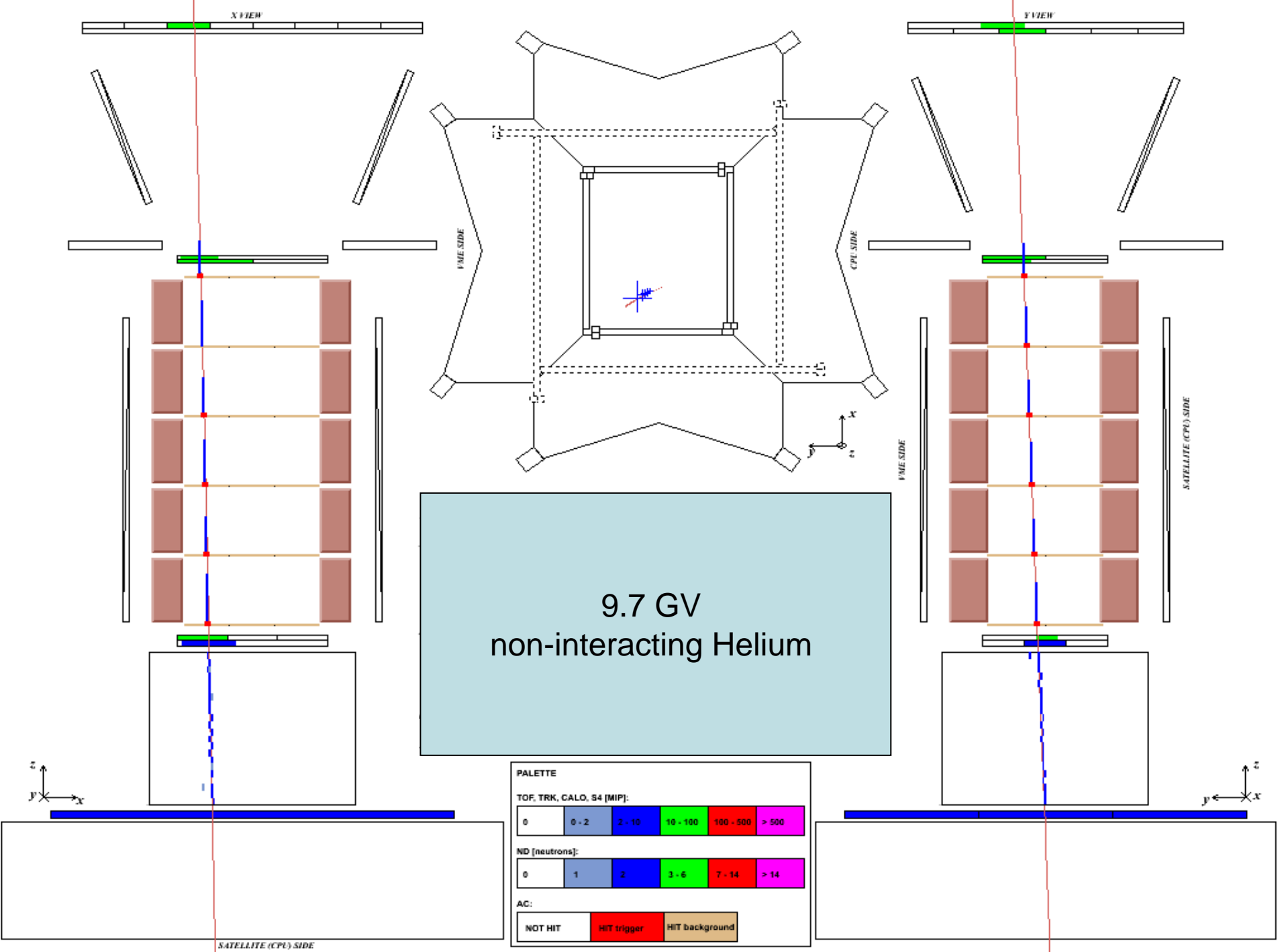


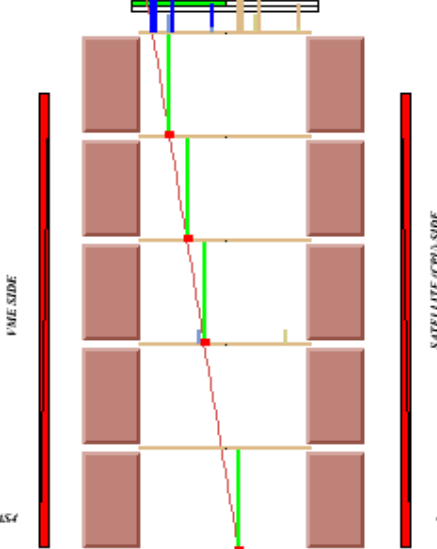
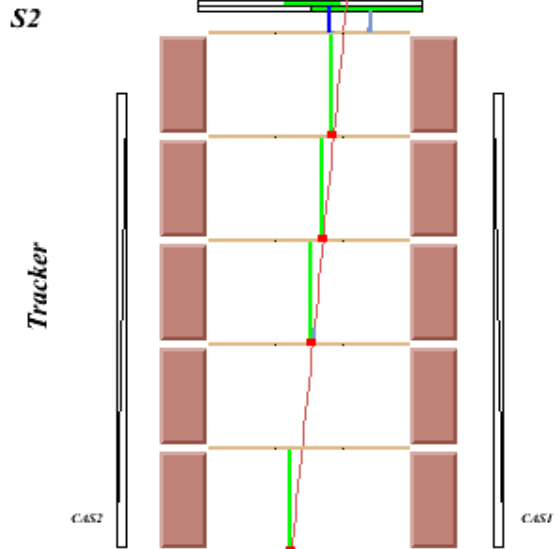
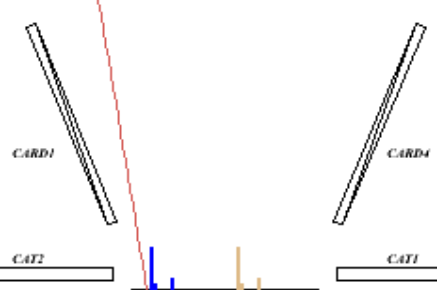
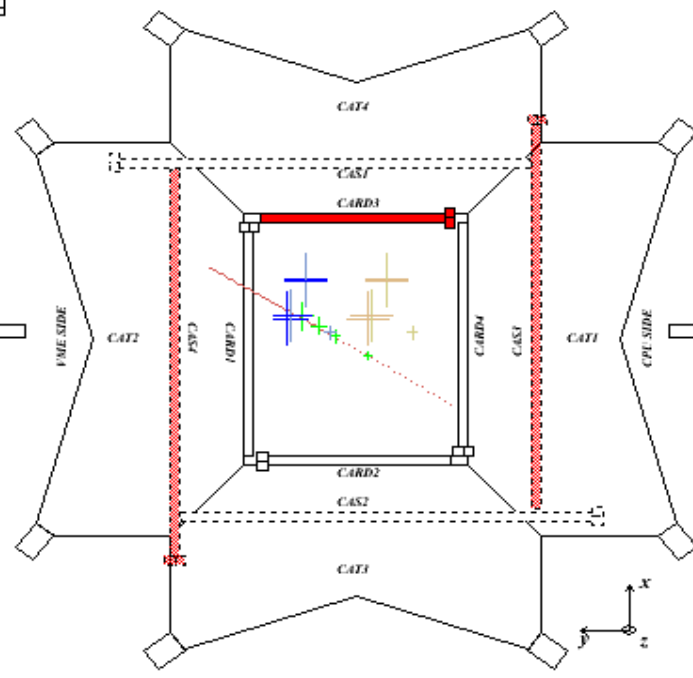
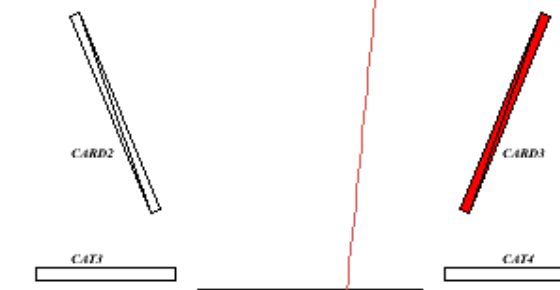
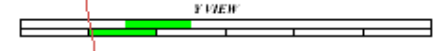
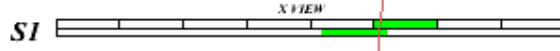


Flight data: 41 GV
interacting antiproton

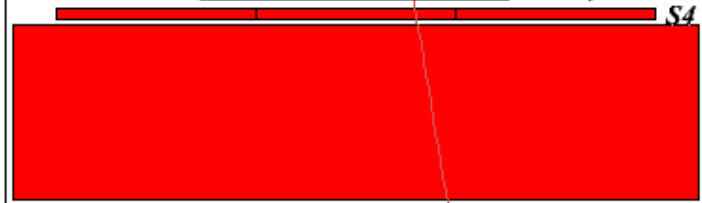
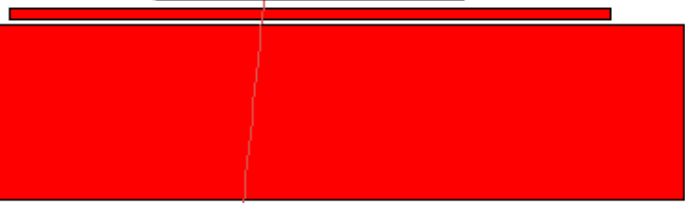
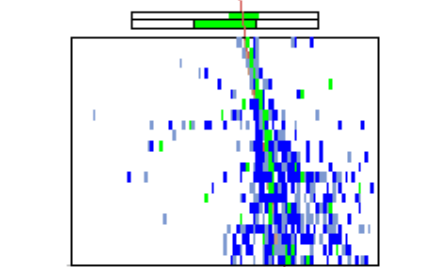
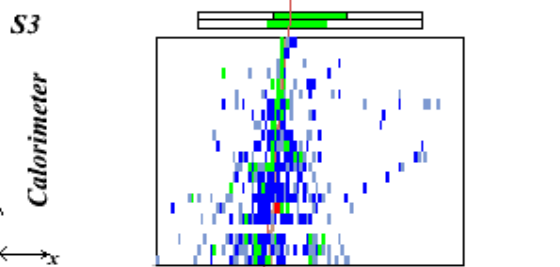








14.7 GV
Interacting nucleus
(Z~8)



PALETTE

TOF, TRK, CALO, S4 [MIP]:

0	0 - 2	2 - 10	10 - 100	100 - 500	> 500
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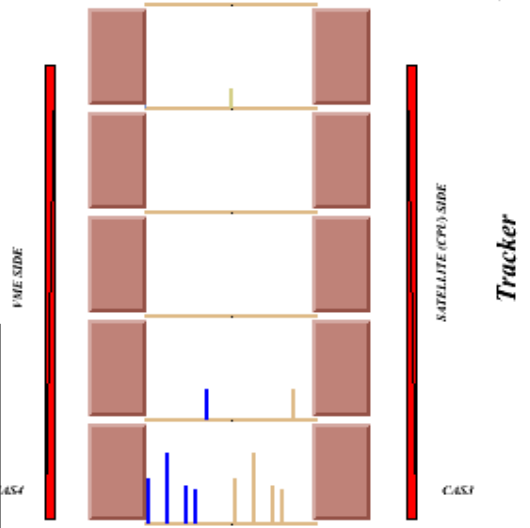
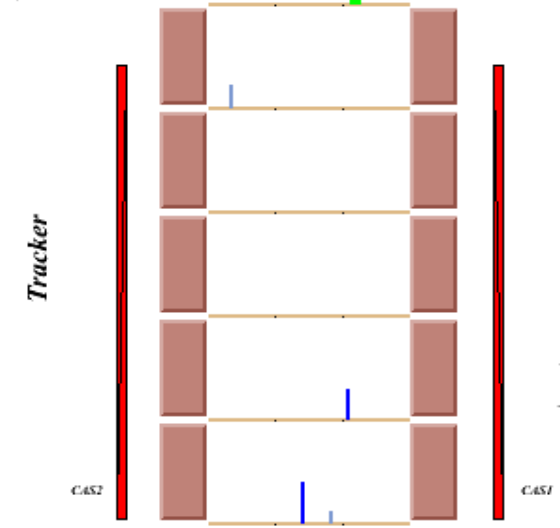
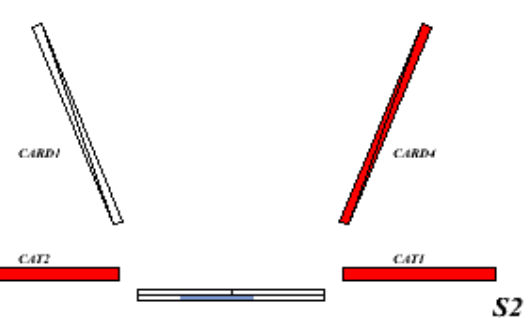
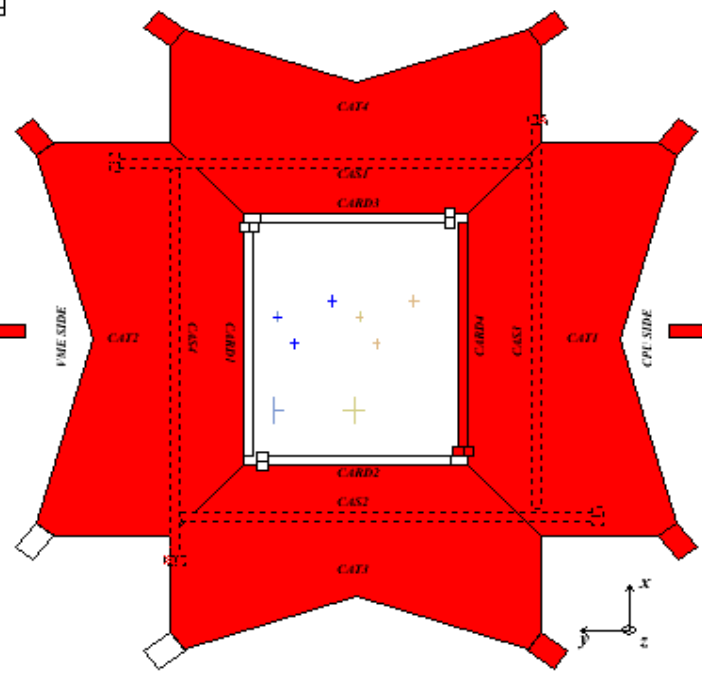
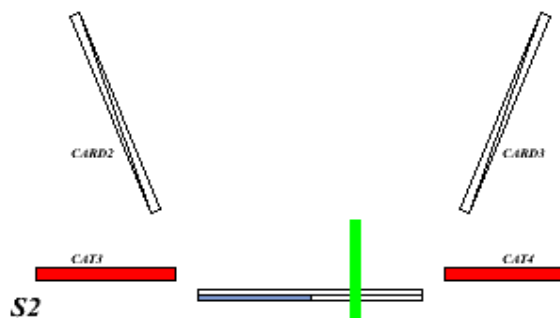
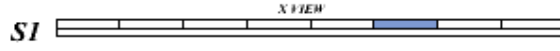
ND [neutrons]:

0	1	2	3 - 6	7 - 14	> 14
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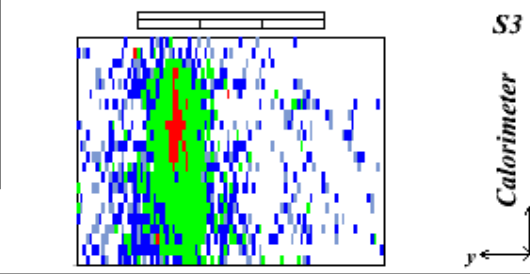
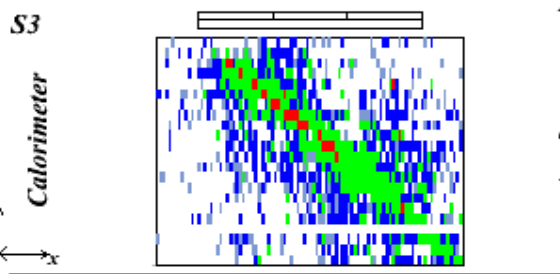
AC:

NOT HIT	HIT trigger	HIT background
---------	-------------	----------------

SATELLITE (CPU) SIDE



calorimeter self-trigger
(m.p. proton)



PALETTE

TOF, TRK, CALO, S4 [MIP]:

0	0 - 2	2 - 10	10 - 100	100 - 500	> 500
---	-------	--------	----------	-----------	-------

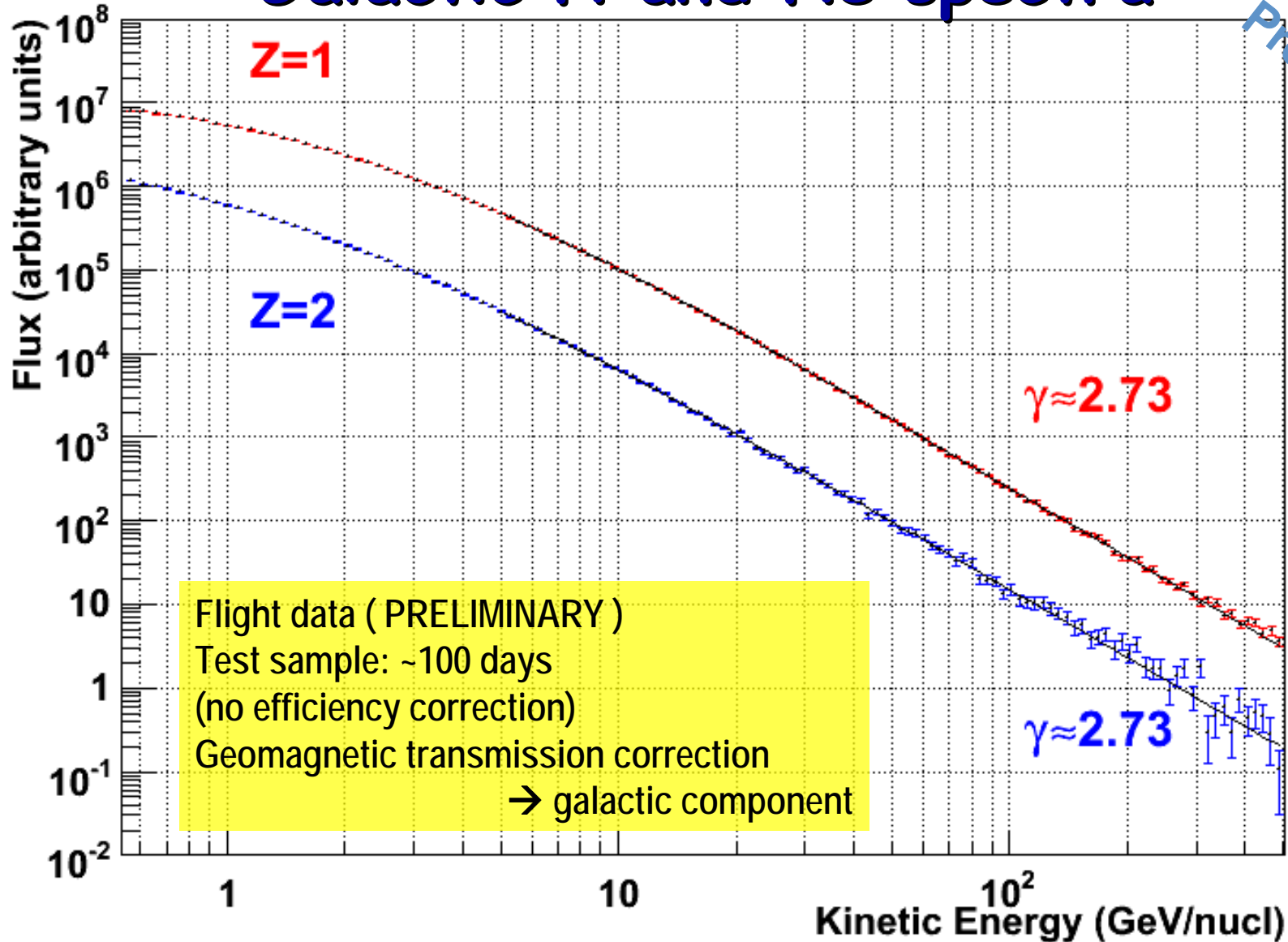
ND [neutrons]:

0	1	2	3 - 6	7 - 14	> 14
---	---	---	-------	--------	------

AC:

NOT HIT	HIT trigger	HIT background
---------	-------------	----------------

Galactic H and He spectra



Preliminary !!!

Flight data (PRELIMINARY)
Test sample: ~100 days
(no efficiency correction)
Geomagnetic transmission correction
→ galactic component

Pamela vs Dark Matter

Indirect Search!!!!



Cosmic-ray Antimatter from Dark Matter annihilation

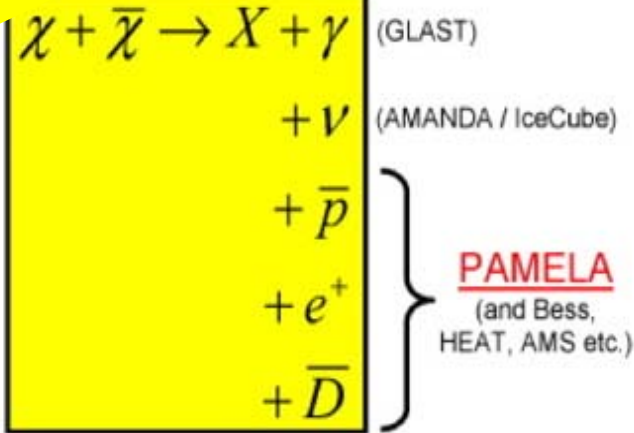
A plausible dark matter candidate is neutralino (χ), the lightest SUSY particle.

Annihilation of relic χ gravitationally confined in the galactic halo

→ Distortion of antiproton spectrum

- $\chi + \bar{\chi} \rightarrow e^+, \dots$
- direct antiproton peak $E_{e^+} \sim M_{\chi}/2$
- other processes \Rightarrow positron continuum $E_{e^+} \sim M_{\chi}/20$

PAMELA will try to indirectly look for Dark Matter by precisely measuring the antiproton and positron spectra!!!



What we can learn from existing data?

Situation is not clear:

- Big statistical uncertainties
- Big systematic uncertainties (poorly known propagation models used during 90s)
- Many different experiments each covering a small energy range
- Different modulation effects (different places, different years)

Pamela really has a good chance to look for Dark Matter!!!! (thanks also to the improved models...)

Secondary production of Antiparticles

- $pp \rightarrow ppp\bar{p}$ is the main antiproton source
- In order to look for Dark Matter with good sensitivity we need to precisely know the secondary produced $p\bar{p}$ spectrum
- Propagation equation for CR in our Galaxy should be solved
- Many very precise and fine tunable models exists in literature now (big effort in the last few years!!!!)
- Lionetto/Morselli/Zdravkovic model used as example in the next slides

Propagation Equation for Cosmic Rays in the Milky Way

$$\frac{\partial \psi(\mathbf{r}, p, t)}{\partial t} = q(\mathbf{r}, p) + \nabla \cdot (D_{xx} \nabla \psi - \mathbf{V} \psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi - \frac{\partial}{\partial p} \left[\dot{p} \psi - \frac{p}{3} (\nabla \cdot \mathbf{V}) \psi \right] - \frac{1}{\tau_f} \psi - \frac{1}{\tau_r} \psi$$

convection velocity field that corresponds to galactic wind and it has a cylindrical symmetry, as the geometry of the galaxy. It's z-component is the only one different from zero and increases linearly with the distance from the galactic plane

diffusion coefficient is function of rigidity

loss term: fragmentation

loss term: radioactive decay

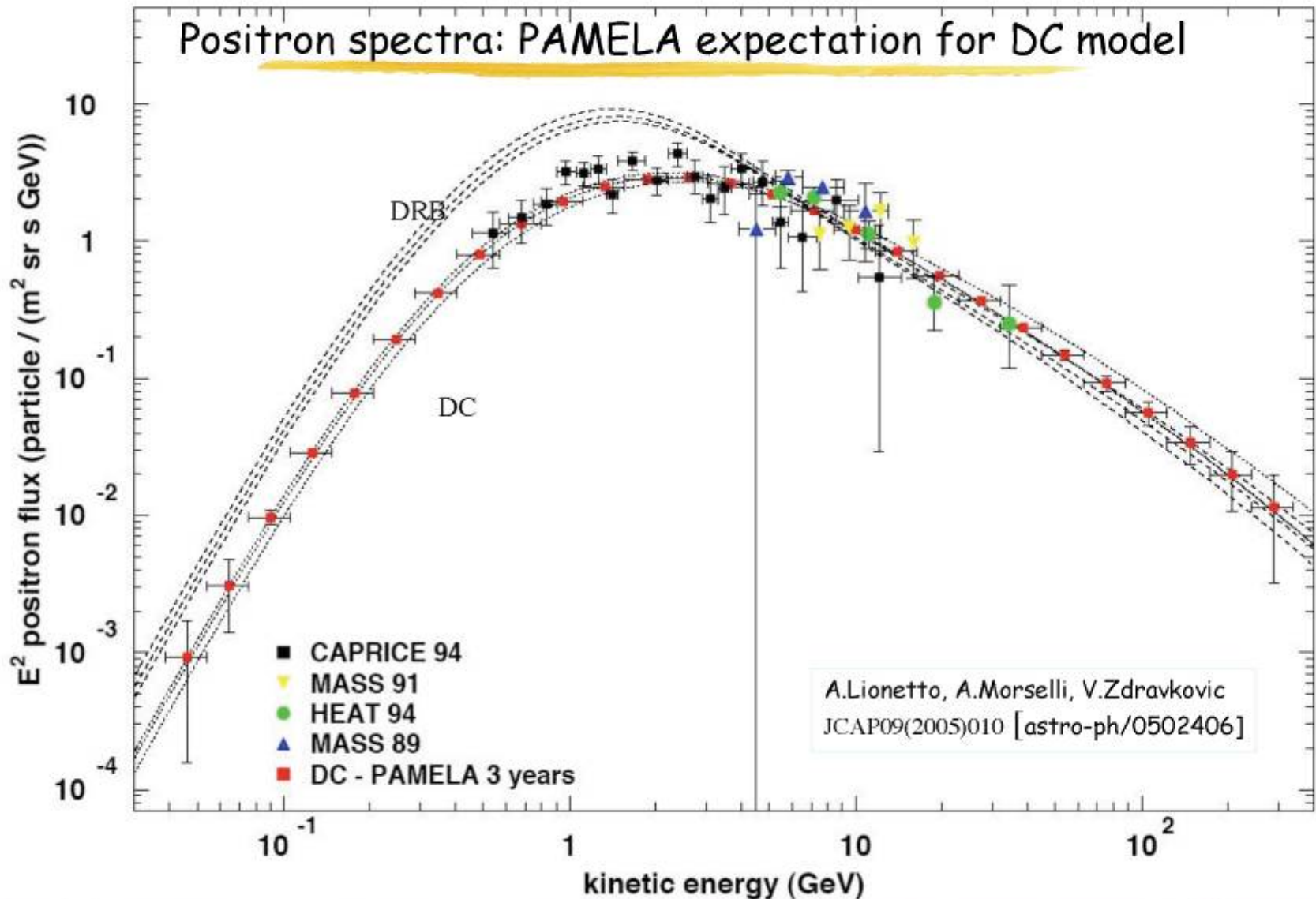
diffusion coefficient in the impulse space, quasi-linear MHD:

$$D_{pp}(D_{xx}, v_A)$$

- Inputs and Cross Checks for the Models:**
- Secondary/primary (B/C, Be/C, Li/C etc.)
 - Absolute fluxes of p, e⁻, He
 - Nuclear Cross Sections

Pamela can also help to improve the models!

Expected e^+ spectrum from secondary origin

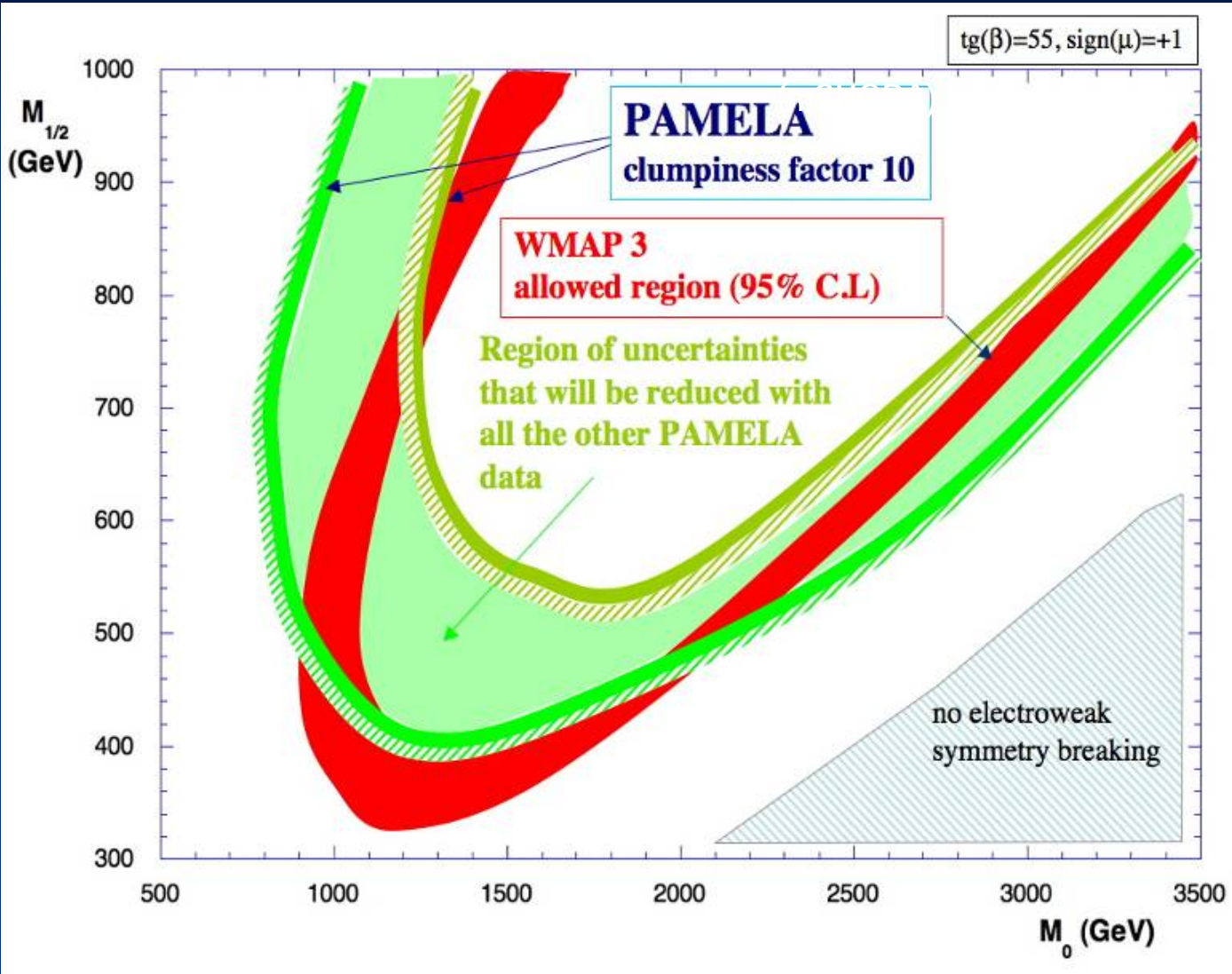


What we can expect from Dark Matter?

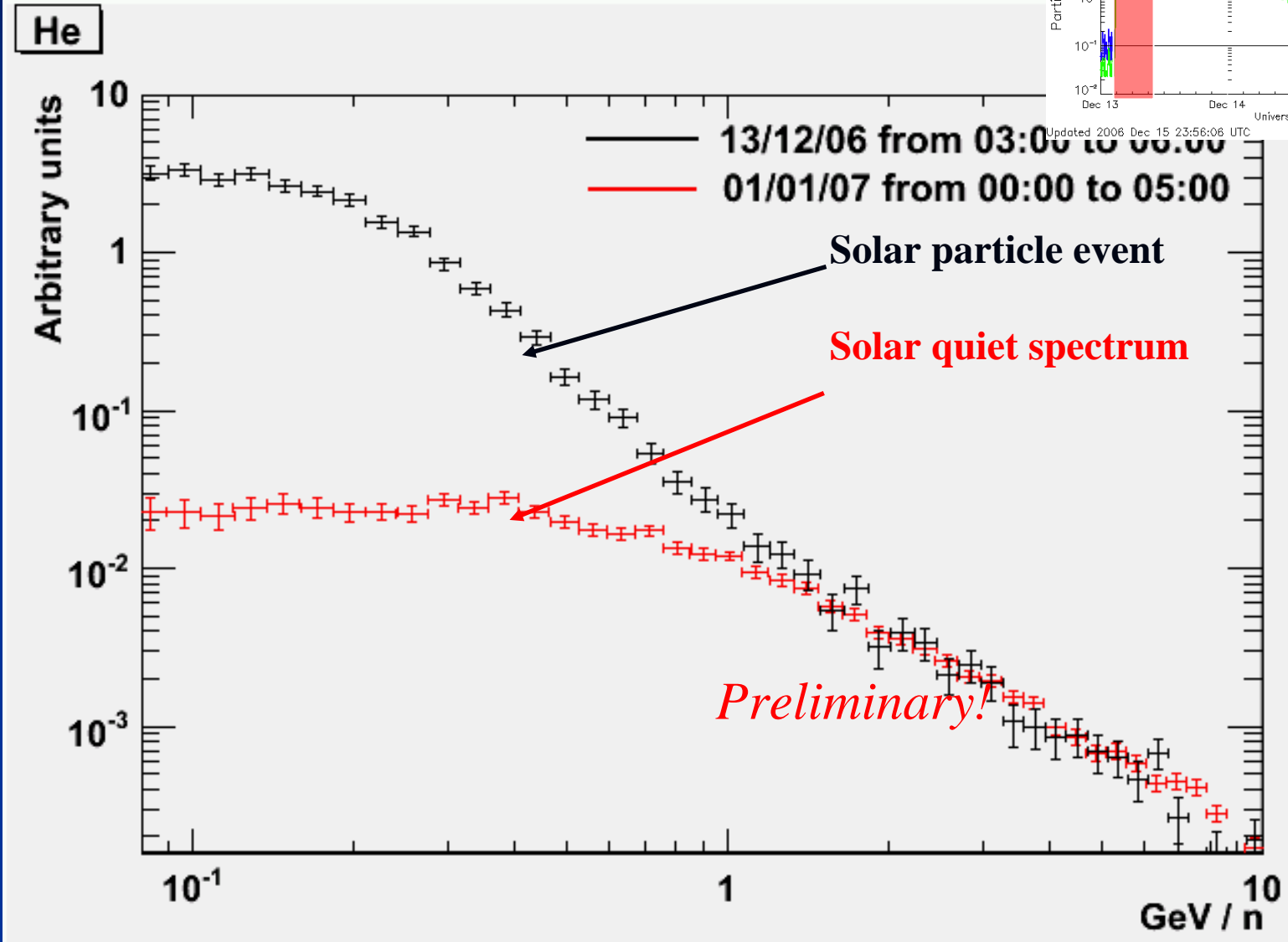
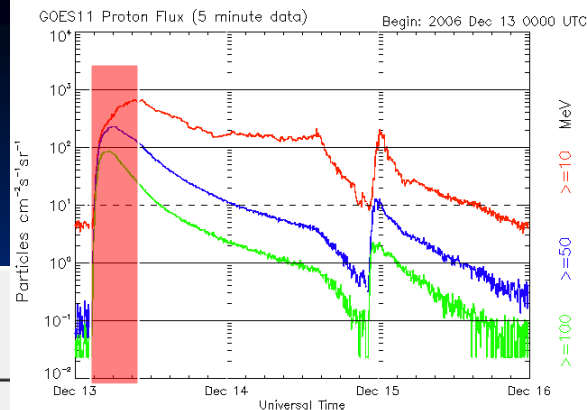
- Antiparticles secondary spectra will be distorted by the Dark Matter annihilation induced antiparticles
- The effect heavily depends on the characteristics of the Dark Matter composing particles!
- Effect more evident in the high energy part of the spectra
- Detailed analysis exists to understand which part of the SUSY parameter space is accessible to Pamela data


Antiprotons

(Lionetto, Morselli & Zdravkovic 2005)



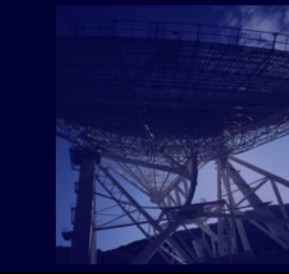
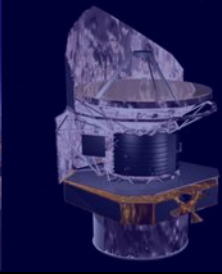
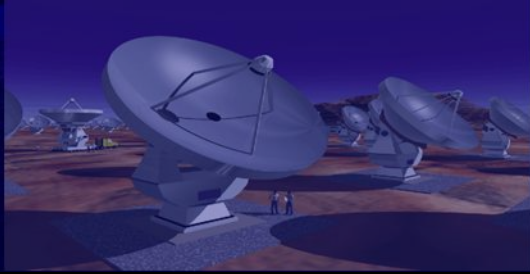
13 december 2006 solar impulsive event

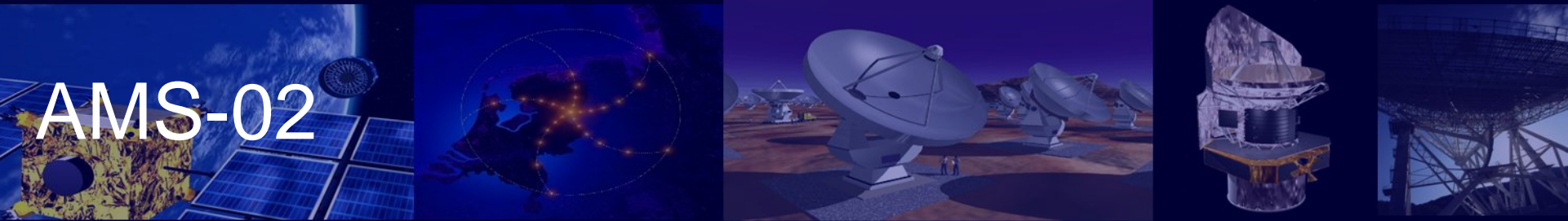




Multifrequenz-Beobachtungen
in der Astronomie, Teil II
Wintersemester 2007/8

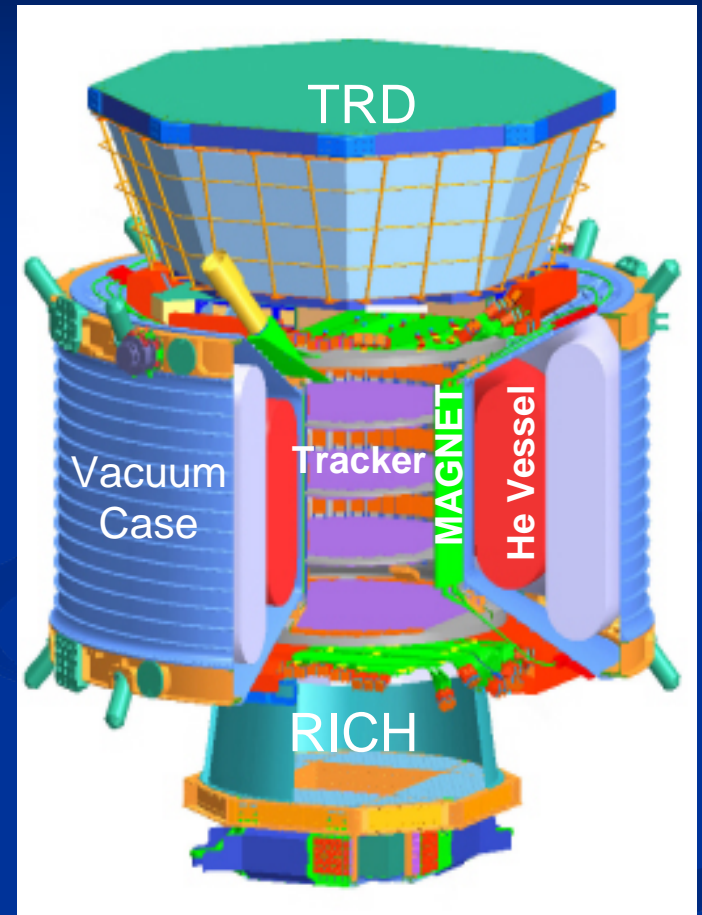
AMS-02





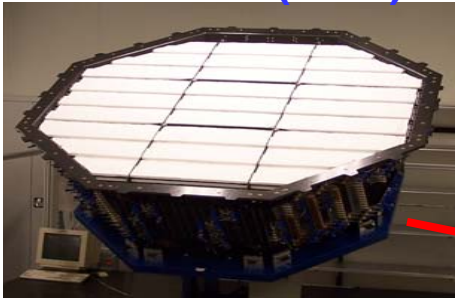
- Alpha-Magnet-Spektrometer: soll ab 2009 für einen Zeitraum von 3 Jahren auf der Internationalen Raumstation die Zusammensetzung der kosmischen Höhenstrahlung messen
- Durch Absturz des Space Shuttles Columbia (2003) hat sich ursprgl. Starttermin verschoben
- Suche nach Antimaterie (Relikt aus dem Urknall)
- Propagationsmechanismen von geladenen Teilchen in der Milchstraße besser verstehen -> Annihilationsprodukte von Dunkler Materie mit höherer Genauigkeit suchen zu können
- Im Rahmen von supersymmetrischen Modellen oder von Kaluza-Klein-Theorien werden Anomalien in den Energiespektren von Positronen, Antiprotonen und Photonen vorhergesagt, die mit AMS-02 möglicherweise nachgewiesen werden können sollten

AMS-02 on ISS In Orbit 2009



The Completed AMS Detector on ISS

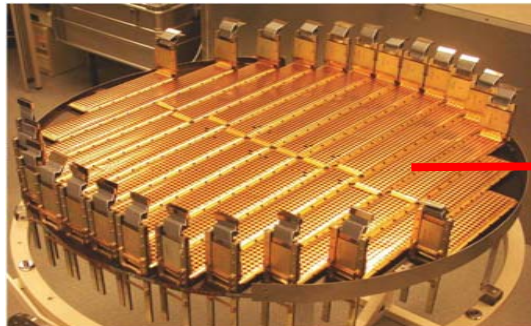
Transition Radiation Detector (TRD)



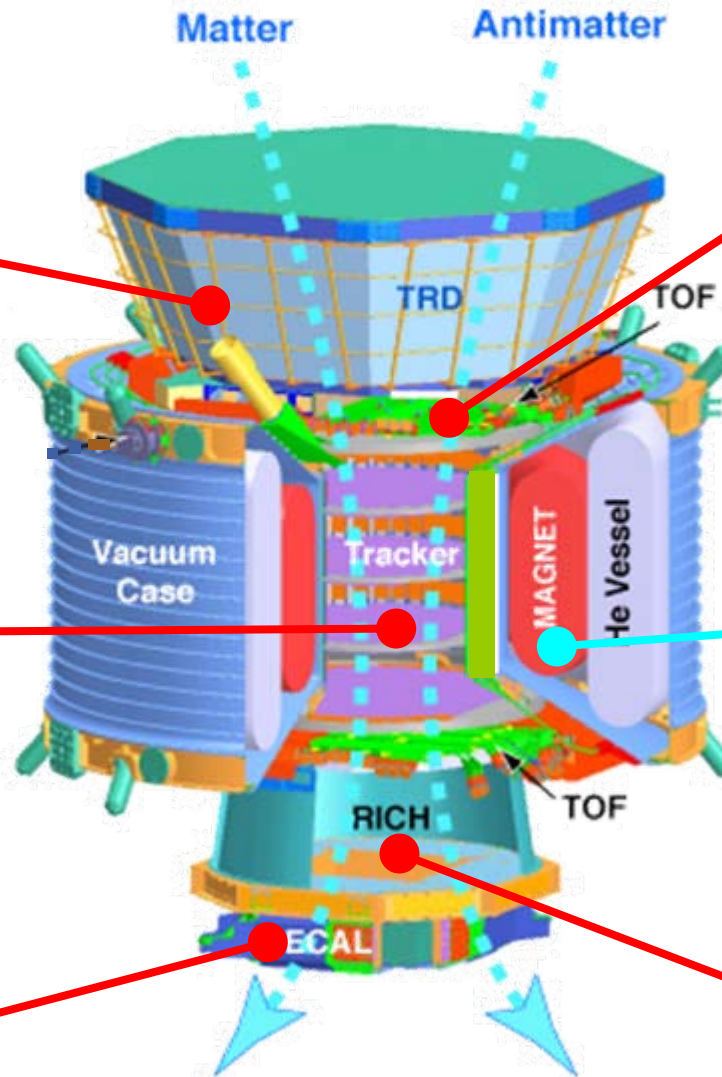
Time of Flight Detector (TOF)



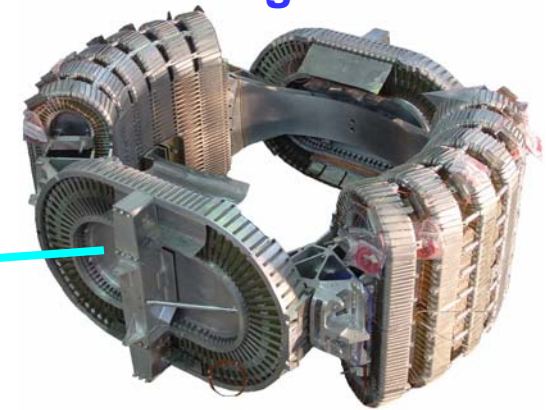
Silicon Tracker



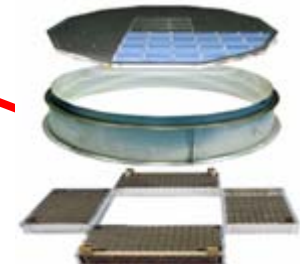
Electromagnetic Calorimeter (ECAL)



Magnet



Ring Image Cerenkov Counter (RICH)



Size: 3m x 3m x 3m
Weight: 7 tons

The Completed AMS Detector on ISS

Transition Radiation
Detector (TRD)

Detektiert Masse

Matter

Antimatter

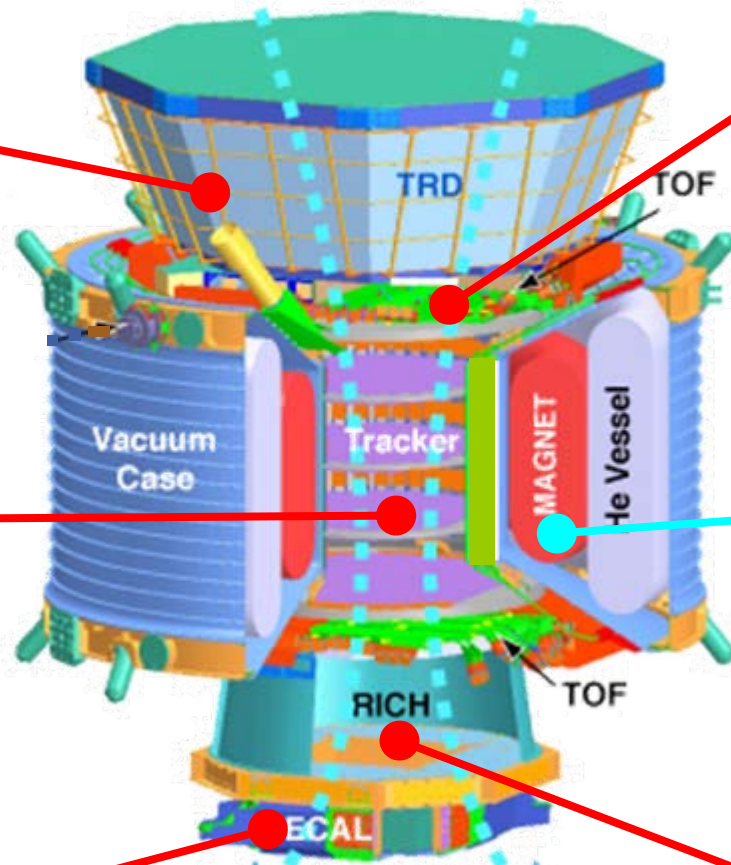
Time of Flight
Detector (TOF)

Flugzeiten,
Geschwindigkeiten
Ausleseelektronik
auslösen

Magnet

Silicon Tracker

Durchgang geladener
Teilchen wird mit
Einzelpunktauflösung
Von 0.01 mm
vermessen



Zentrales Element,
Impuls, Ladungs-
vorzeichen

Electromagnetic
Calorimeter (ECAL)

Masse-
bestimmung

Ring Image Cerenkov
Counter (RICH)

Masse-
bestimmung

Size: 3m x 3m x 3m
Weight: 7 tons

AMS-02 goals and capabilities

Cosmic rays spectra and chemical composition up to 1 TeV

Search for Antimatter in Space

Search for Dark Matter

Gamma Rays



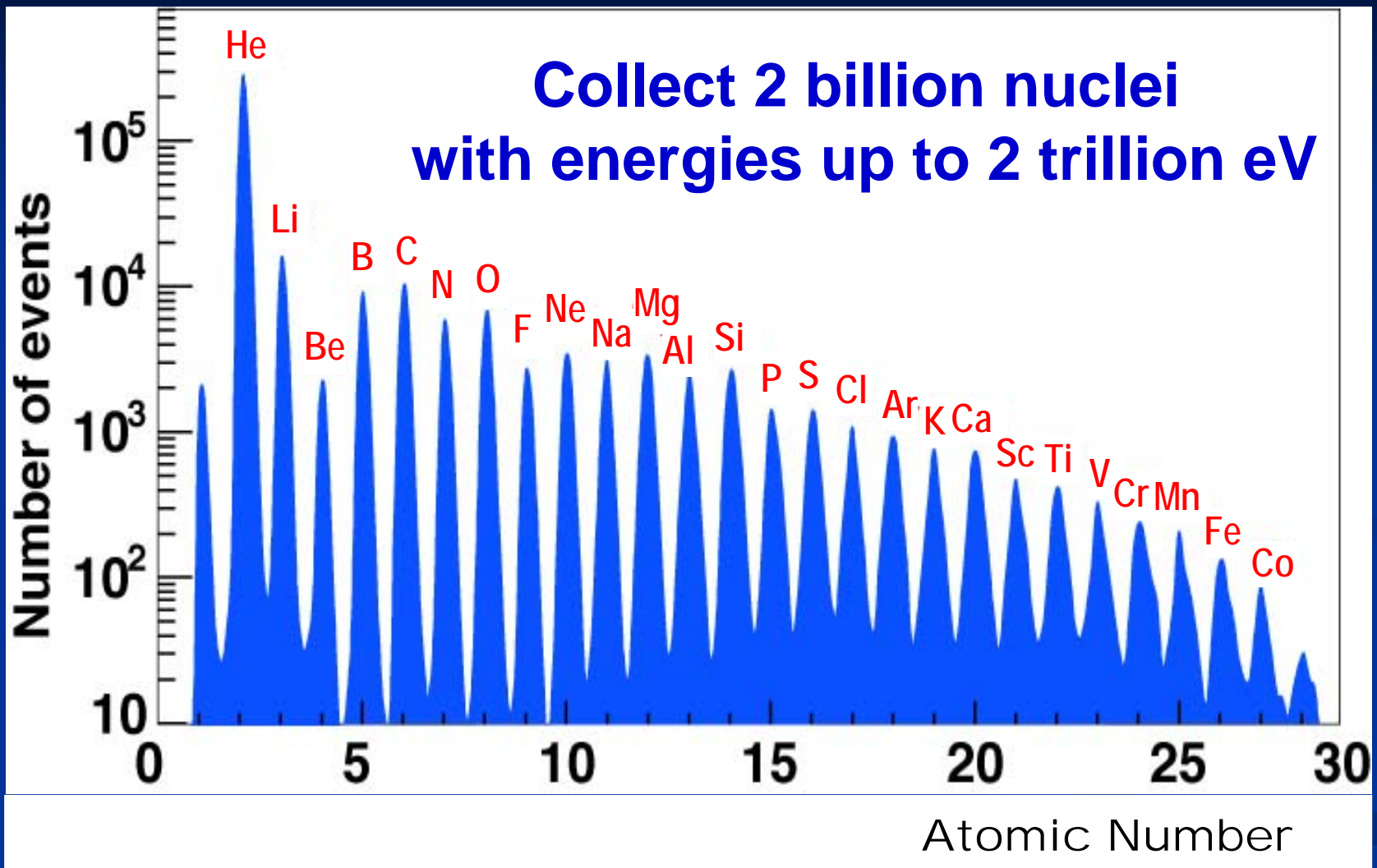
AMS will identify and measure the fluxes for:

- p for $E < 1$ TeV with unprecedented precision
- e^+ for $E < 300$ GeV and e^- for $E < 1$ TeV (unprecedented precision)
- Light Isotopes for $E < 10$ GeV/n
- Individual elements up to $Z = 26$ for $E < 1$ TeV/n

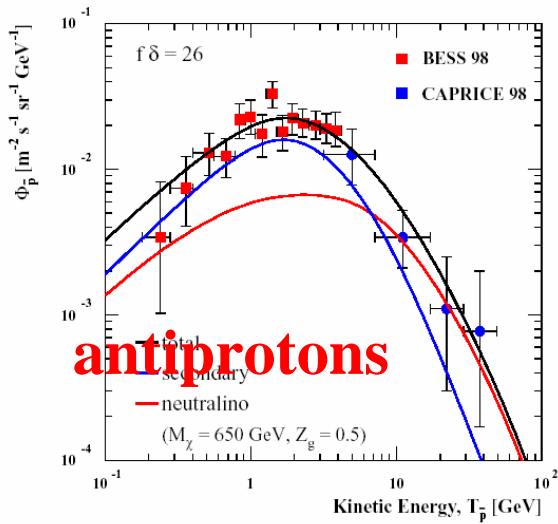
Absolute fluxes and spectrum shapes of protons and helium are important for calculation of atmospheric neutrino fluxes

Composition and spectra are important to constraint propagation, confinement, ISM density

Direct search for antimatter: AMS on ISS

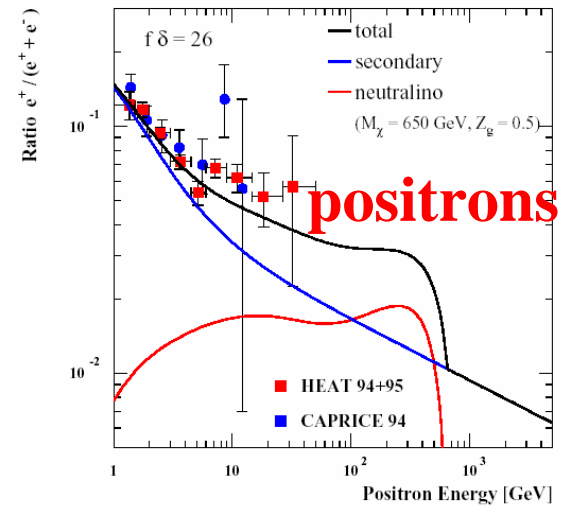


Sensitivity of AMS: If no antimatter is found => there is no antimatter to the edge of the observable universe (~ 1000 Mpc).



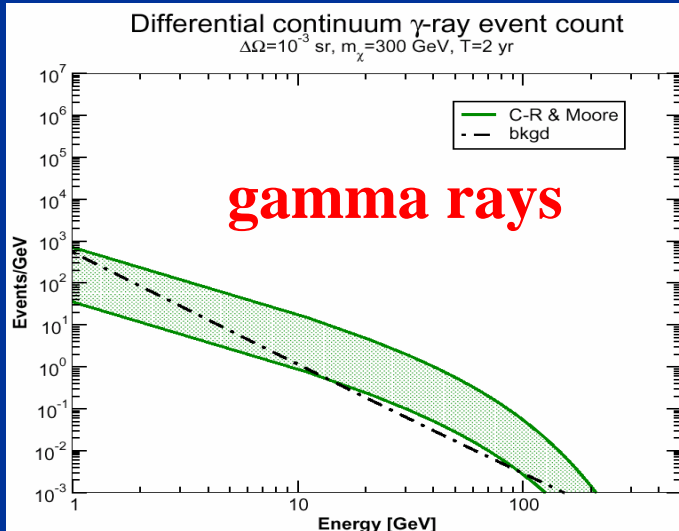
antiprotons

Unique Feature Of AMS

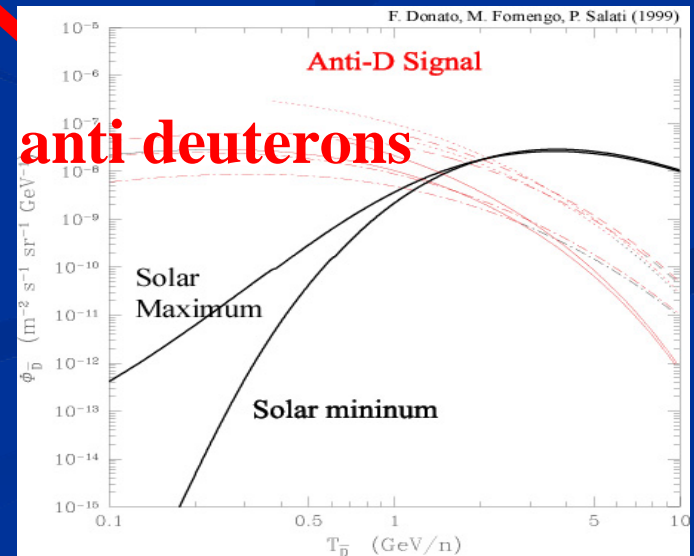


positrons

Combining searches in different channels could give (much) higher sensitivity to SUSY DM signals



gamma rays



anti deuterons

Multifrequenz-Beobachtungen in der Astronomie, Teil II

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GLAST

NASA's Shuttle and Rocket Missions

A variety of vehicles, launch sites on both U.S. coasts, shifting dates and times... the NASA Launch Schedule is easy to decipher by checking out our [Launch Schedule 101](#) that explains how it all works!

Updated -- Dec. 12, 2007 - 1:30 p.m. EST

Legend: + Targeted For | * No Earlier Than (Tentative) | ** To Be Determined

2008 Launches

Date: May 29 *

Mission: [GLAST](#)

Launch Vehicle: [United Launch Alliance Delta II](#)

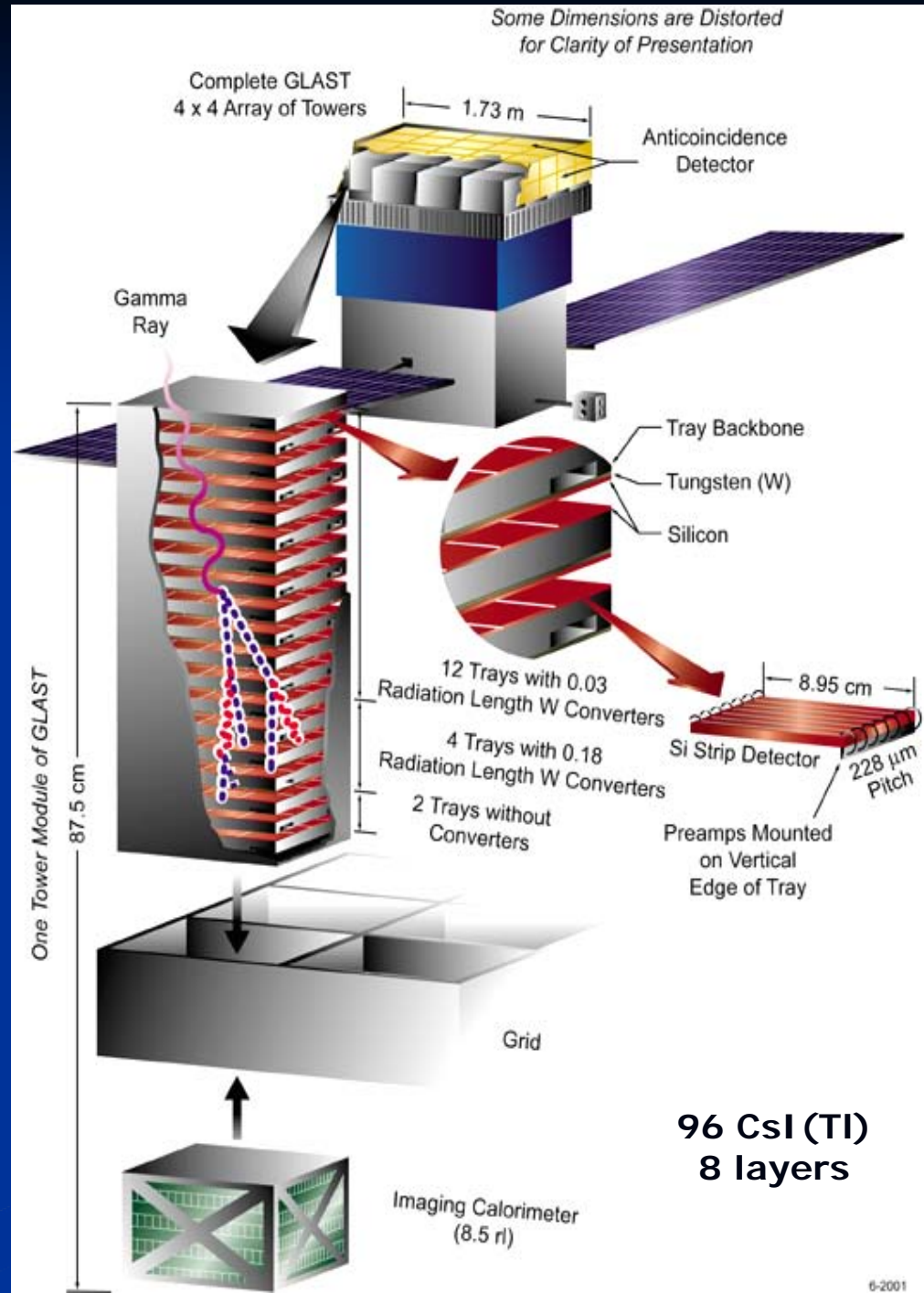
Launch Site: [Cape Canaveral Air Force Station](#) - Launch Complex 17 - Pad 17-B

Description: An heir to its successful predecessor -- the Compton Gamma Ray Observatory -- the Gamma-ray Large Area Space Telescope will have the ability to detect gamma rays in a range of energies from thousands to hundreds of billions of times more energetic than the light visible to the human eye. Radiation of such magnitude can only be generated under the most extreme conditions, thus GLAST will focus on studying the most energetic objects and phenomena in the universe.

GLAST

Gamma-Ray Large Area Space Telescope

3000 kg, 650 W
1.8 m x 1.8 m x 1 m
20 MeV – 300 GeV



Multifrequenz-Beobachtungen in der Astronomie, Teil II

Wintersemester 2007/8



AGILE

AGILE

the most compact instrument for high-energy astrophysics

It combines for the first time a **gamma-ray imager (30 MeV- 30 GeV)** with a **hard X-ray imager (18-60 keV)** with large FOVs (1-2.5 sr) and optimal angular resolution



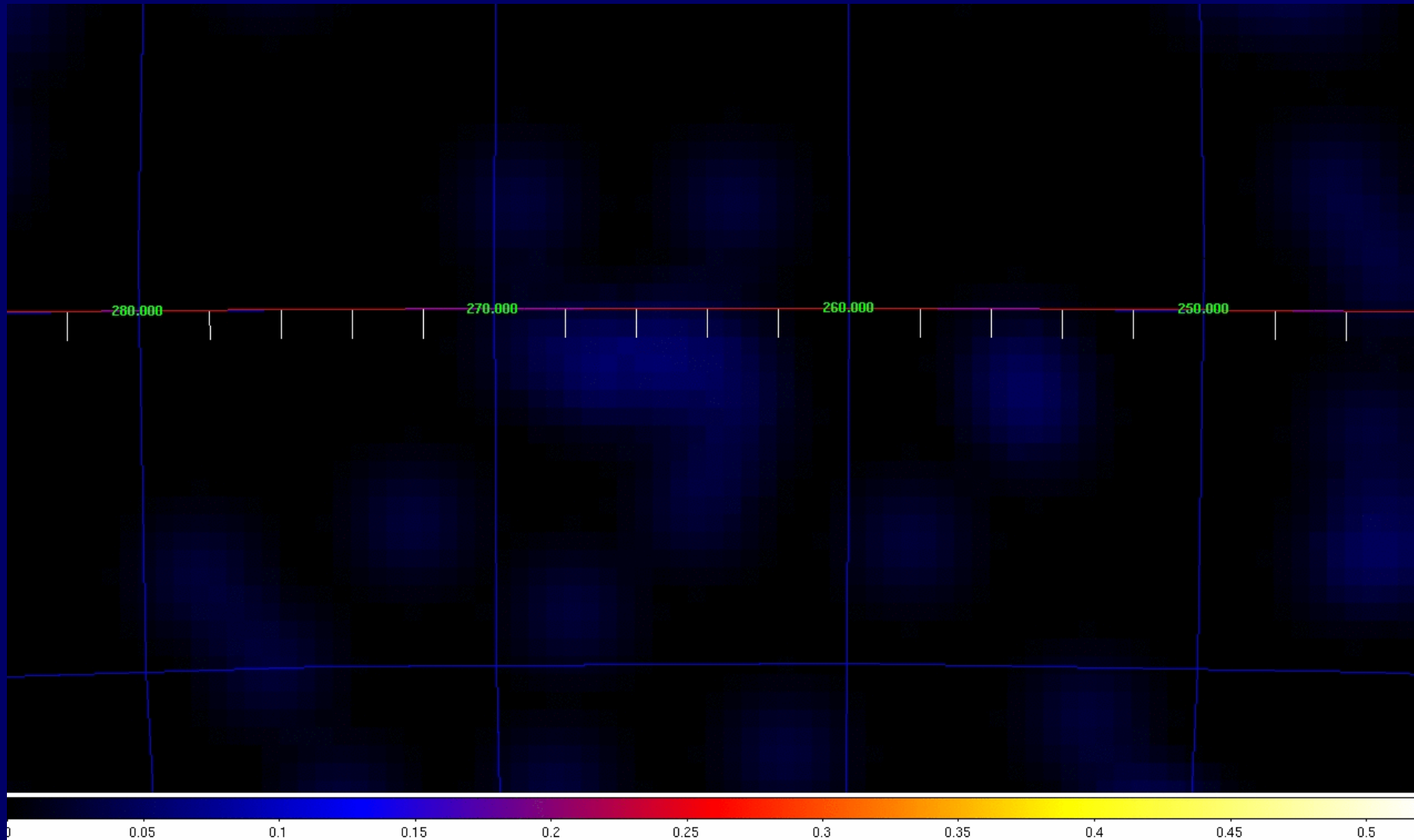
AGILE in orbit

April 23, 2007

**ISRO Sriharikota base,
PSLV-C8**

AGILE gamma-ray detection of the Vela PSR

12 orbits data accumulation of the **Vela PSR region**



Exploring the Basic Laws of Physics from Space

Satellites and ISS



■ PAMELA	15/06/2006	Resurs DK1
■ AGILE	23/04/2007	MITA
■ GLAST	03/2008	Satellite
■ AMS	2009	ISS
■ NUCLEON	2010	ISS
■ TUS / Klypve	2010	Sat./ISS
■ MONICA	2011	Satellite
■ JEM-EUSO	??	ISS
■ CALET	??	ISS
■ OWL	??	Satellite
■ ACCESS	??	ISS

Balloon Experiments

- ACTIC
- ATIC
- BESS
- CREAM
- CROSS
- GAPS
- PEBS

- PPB
- PPP-BETS
- RUNJOB
- TIGER
- TRACER



Fluxes of Cosmic Rays

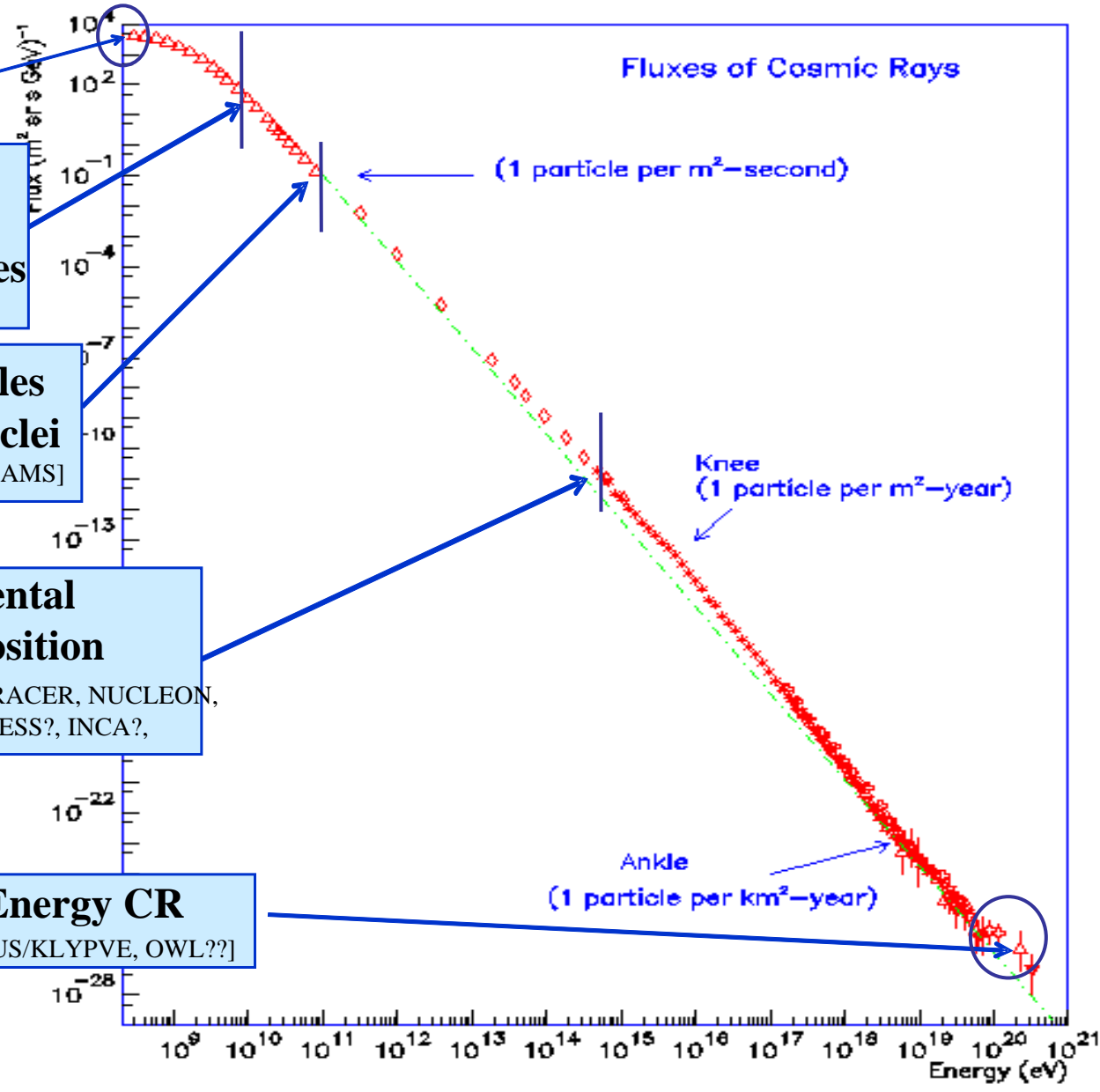
High Z
[ENTICE, ECCO]

Light Elements And Isotopes
[ACE]

Antiparticles and Antinuclei
[BESS, PAMELA, AMS]

Elemental Composition
[CREAM, ATIC, TRACER, NUCLEON, CALET, ACCESS?, INCA?,

Extreme Energy CR
[AUGER, EUSO, TUS/KLYPVE, OWL??]

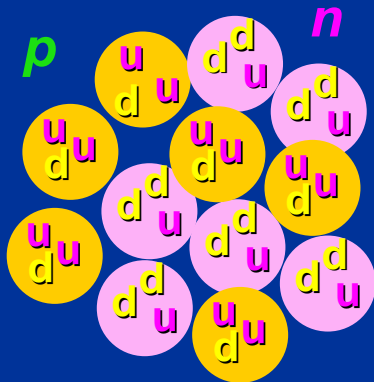


Search for New Matter in the Universe:

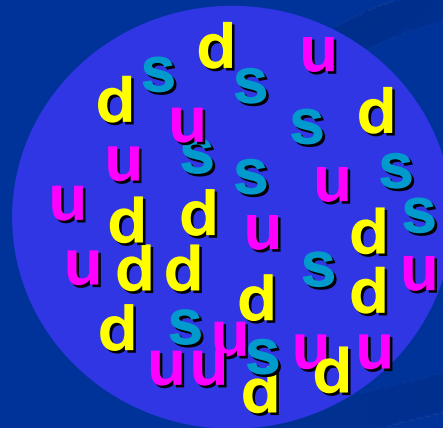
An example is the search for “strangelets”.

*There are six types of Quarks found in accelerators.
All matter on Earth is made out of only two types of quarks.
“Strangelets” are new types of matter composed of three types of quarks which should exist in the cosmos.*

Carbon Nucleus



Strangelet



- i. A stable, single “super nucleon” with three types of quarks
- ii. “Neutron” stars may be one big strangelet

AMS will provide a definitive search for this new type of matter.

MOON BASE

For expanding our knowledge to the extreme Universe at higher energies the Moon based CR observations must be part of the future programs

Zero generation experiments:

Install on the Moon the experiments planned for satellites or ISS, and that

are long time in stand by because too massive and difficult to be operated

In LEO:

Examples:

1. ECCO for very high Z (supernovae rate counting) [small changes]
2. Rare elements, radioactive isotopes [new, ISOMAX-like magnetic spectrometer]

