Balloon Experiments in Cosmic ray research and the PAMELA Space Experiment

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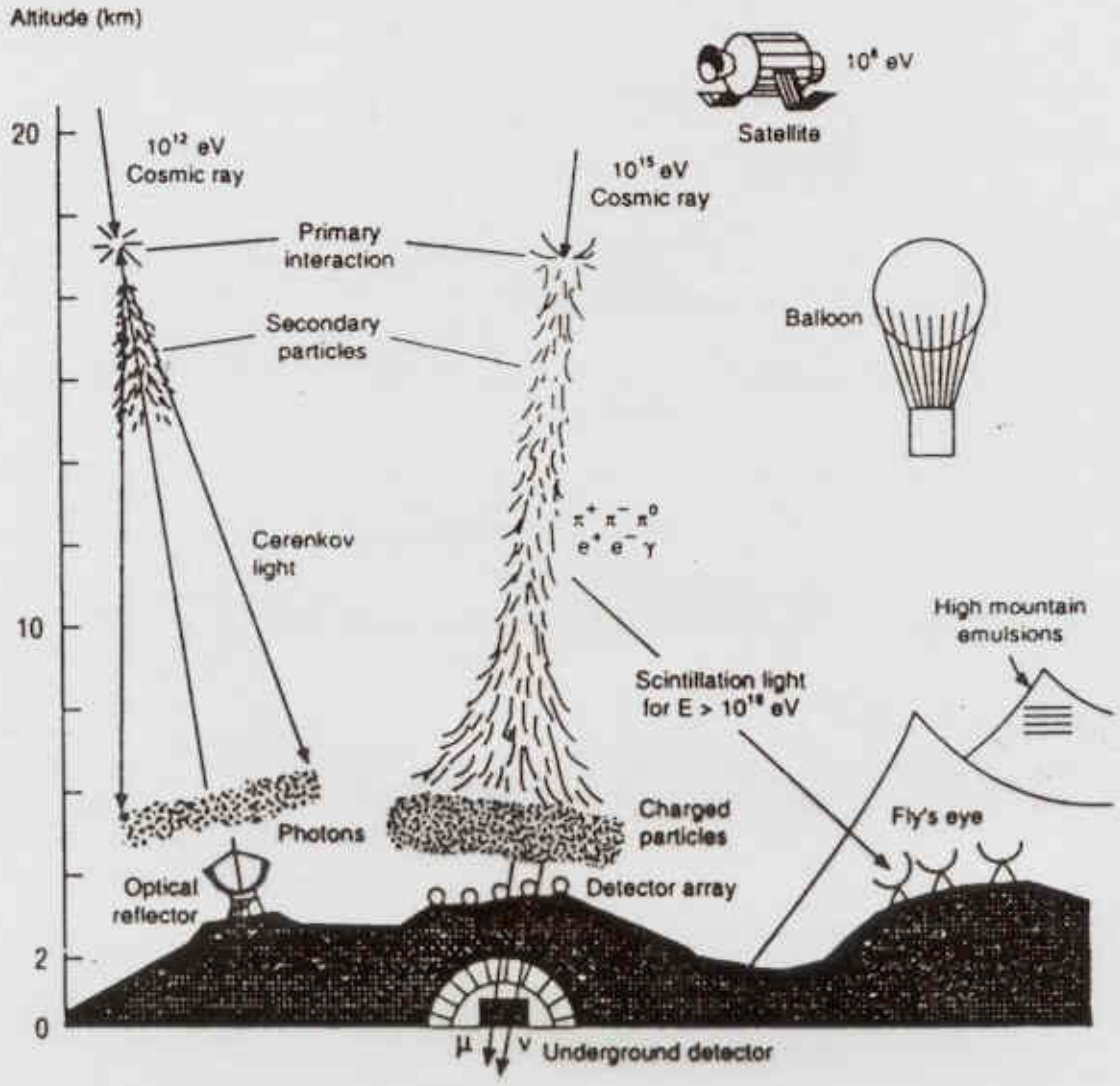
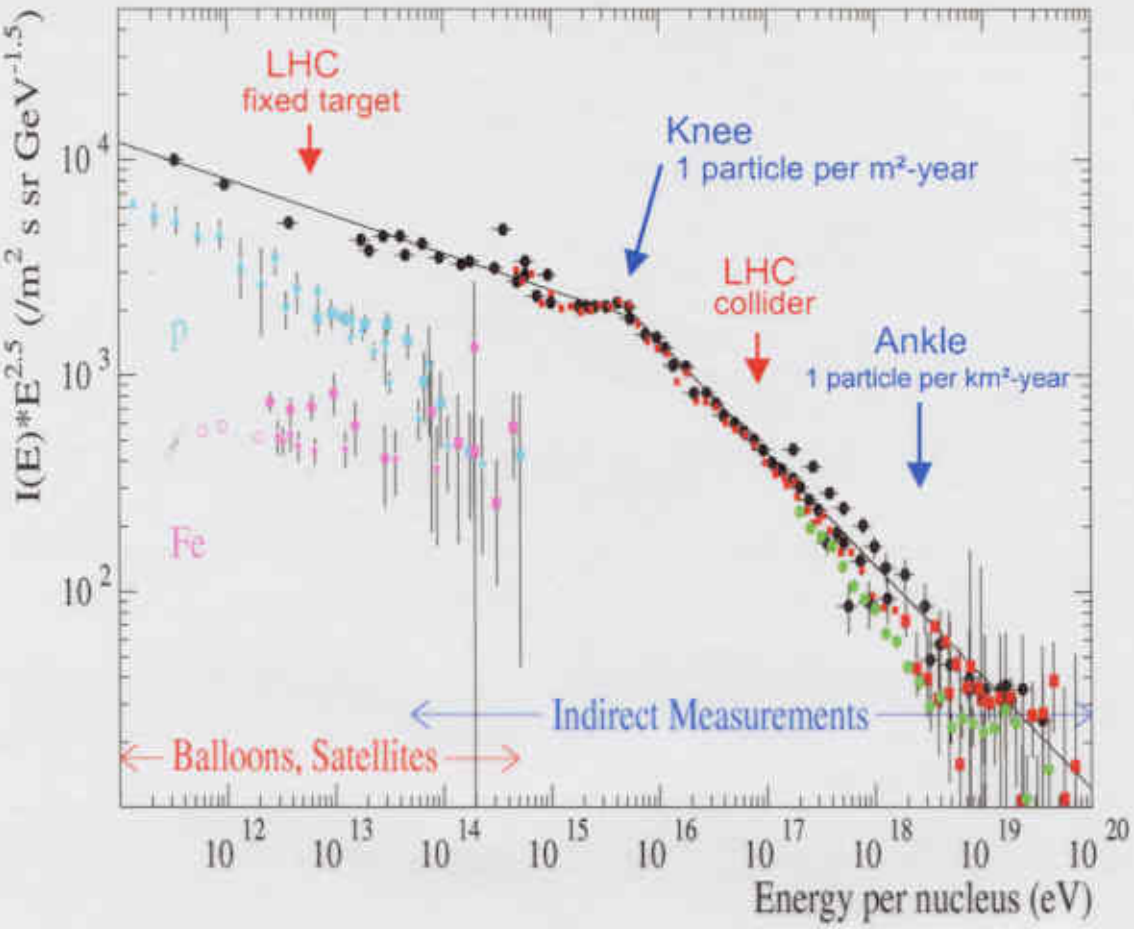
Diversity of the techniques used for cosmic ray detections and measurements



Hadron flux:	1 particle/m²/s	⇔	TeV	10^{12} eV
	1 particle/m²/day	⇔	PeV	10^{15} eV
	1 particle/km²/day	⇔	EeV	10^{18} eV
	1 particle/km²/century	⇔		10^{20} eV

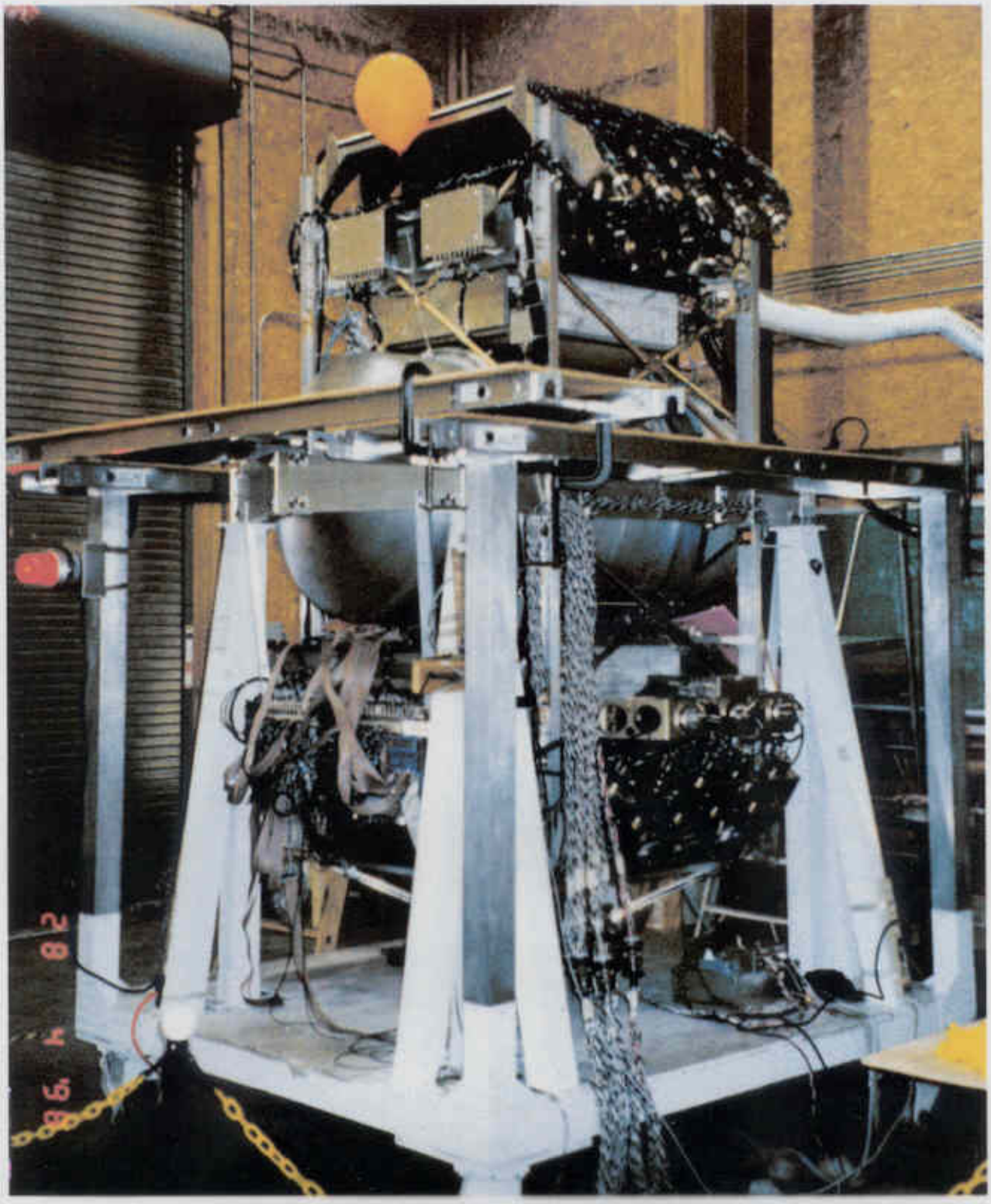
Cosmic Ray Energy Spectrum ($\times E^{2.5}$)



The Currently Existing Balloon Payloads to Measure Cosmic Ray Composition and Spectra

Payload Name	Measured Species	Energy Range	1-day Flights	Long-Duration Flights
		antimatter		
HEAT	e^+/e^-	5 - 50 GeV	1994/95	
	antiprotons	0.2 - 30 GeV	2000	
CAPRICE	atm. μ spectra	0.5 - 50 GeV	2000	
	antiprotons, e^+/e^-			
BESS	antiprotons	0.25 - 3 GeV	1993-1998	2001
		composition		
ISOMAX	Be 10,	0.2 - 3 GeV/n	1998	2001
	$2 \le Z \le 8$ isotopes			
TIGER	$30 \le Z \le 40$ elements	> 0.5 GeV/n	1995	1999
		spectra		
BETS	e^- spectrum	10 - 100 GeV	1997/98	
RICH	H and He spectra	20 - 200 GeV/n	1991/96/97	
JACEE	$1 \le Z \le 26$ spectra	1 - 100 TeV	1979-1987	1987 →
ATIC	p/He-spectra	10 - 10^4 GeV	2000	2002
TRACER	$8 \le Z \le 26$ spectra	< 10 TeV/n	1999	
RUNJOB	$Z \le 26$ spectra	< 100 TeV/n	1995	
BACH	Si, Fe spectra	< 1000TeV/n	1998	

ISOMAX Detector System fully assembled



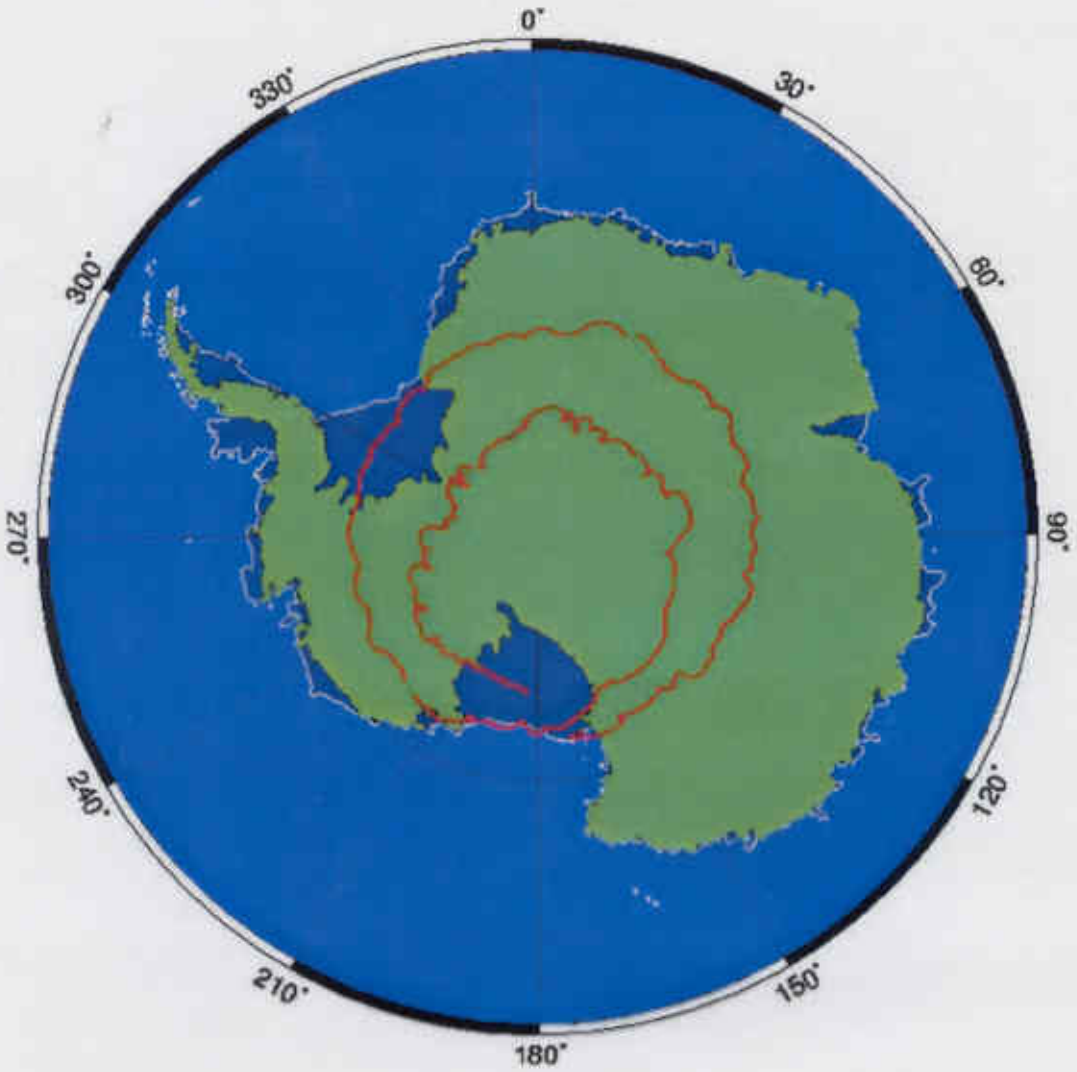
ISOMAX

Flight in August 98

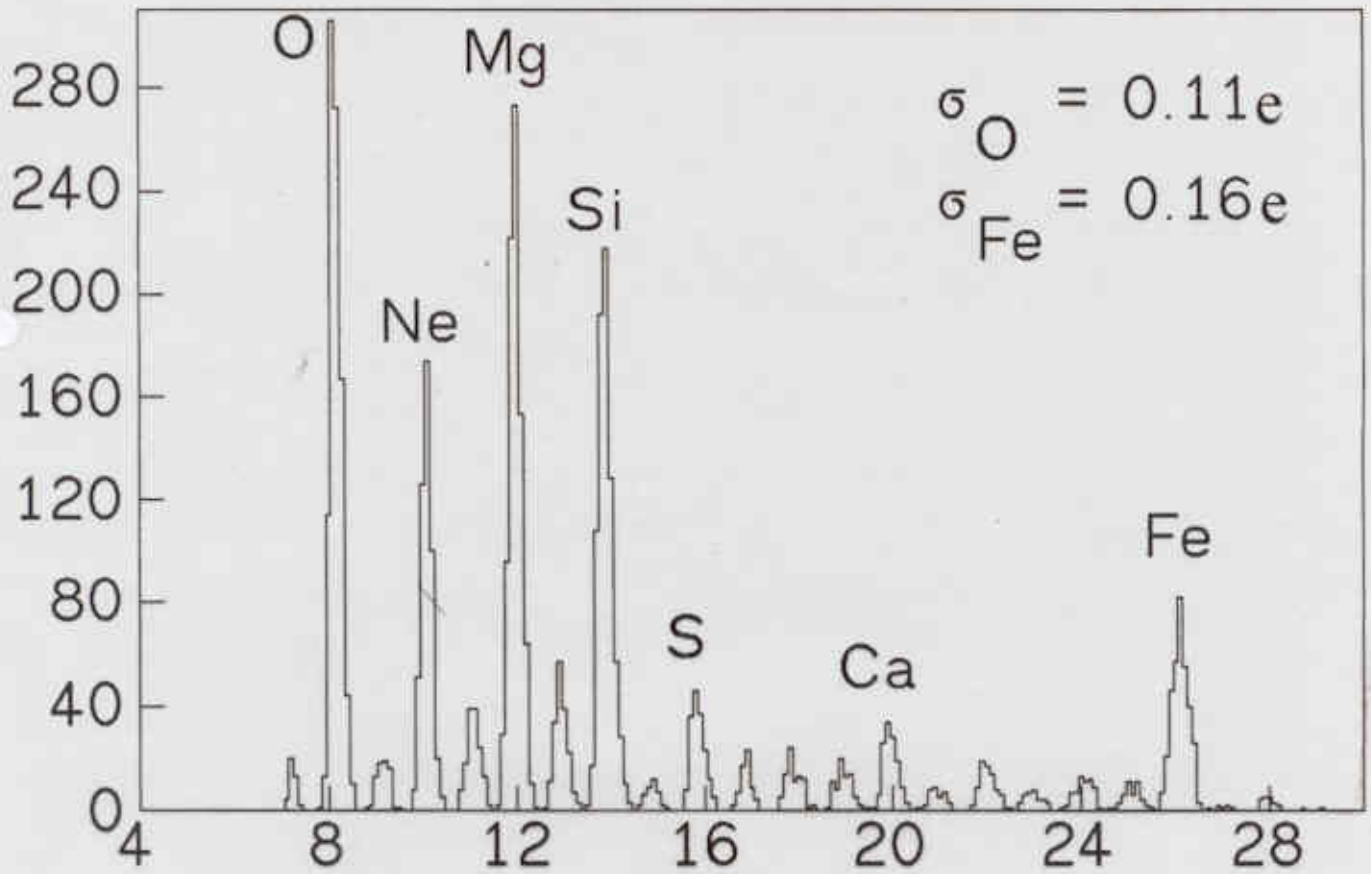
- Launch: 4th. of August 98, 6:55 (CT)
- Flight Time: 32 h 35 min
- Time above 128 kft: 22h 52 min

Flight track of the balloon instrument
TIGER

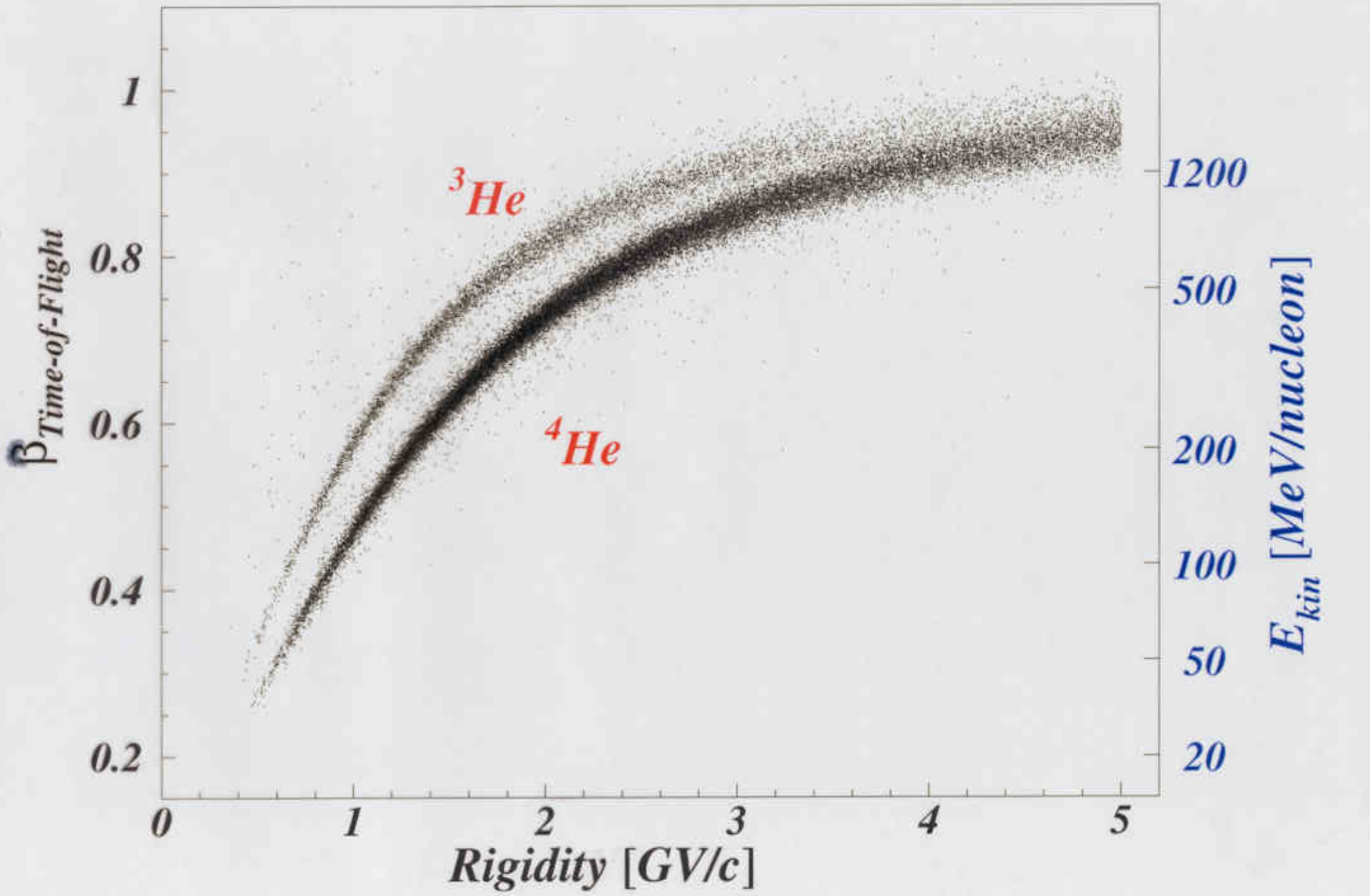
Flight Duration: 31 days
Launched: 21-Dec-2001



Abundance of Cosmic Ray Particles
at 1 GeV/nucleon measured with
the **ALICE**-Experiment

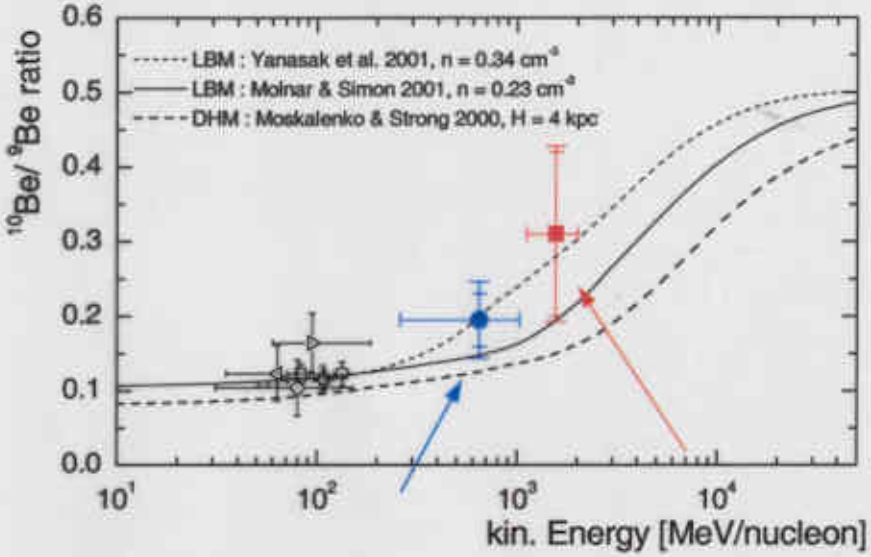


probe of high energy
cosmic matter

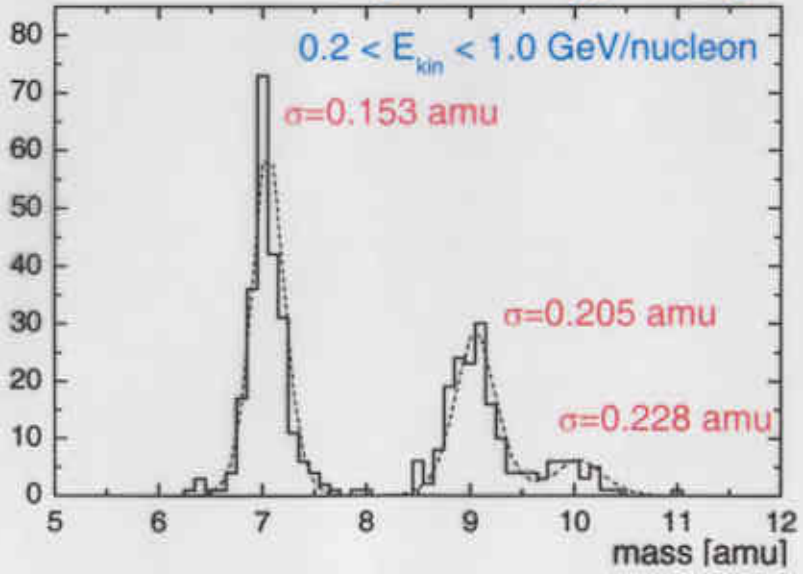

$\beta_{Time\text{-}of\text{-}Flight}$
1
0.8
0.6
0.4
0.2
^3He
^4He
0
1
2
3
4
5
Rigidity [GV/c]
1200
500
200
100
50
20
E_{kin} [MeV/nucleon]

ISOtope MAgnet eXperiment

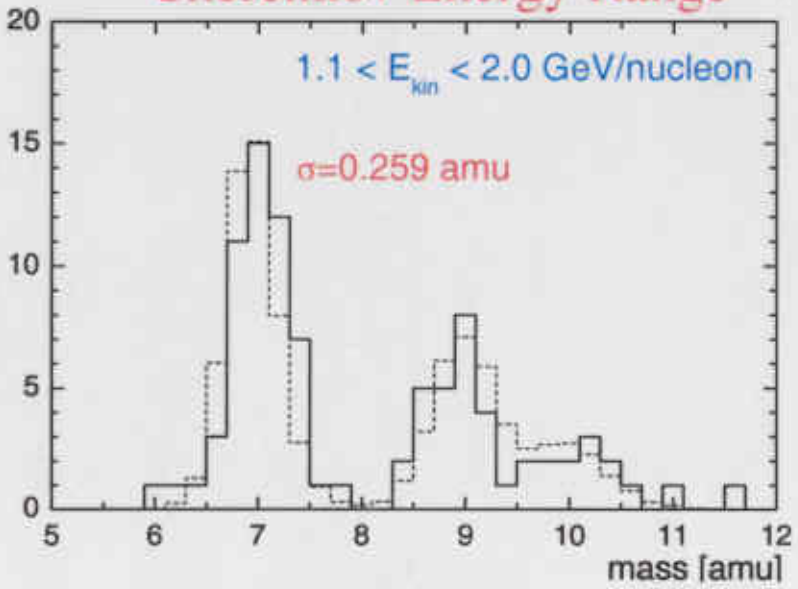
Beryllium Results



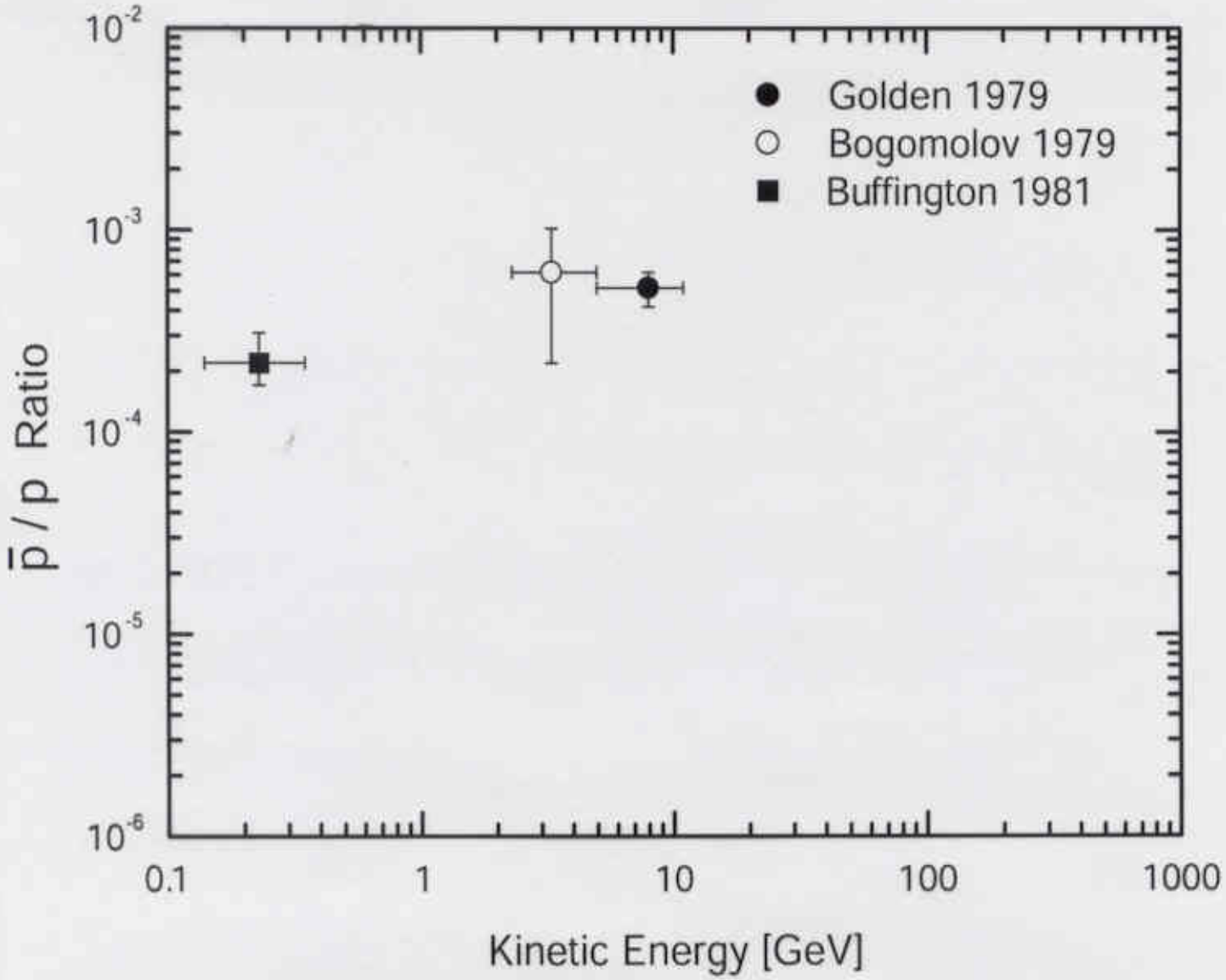
Time-of-Flight Energy Range



Cherenkov Energy Range



early data on $\bar{p}$

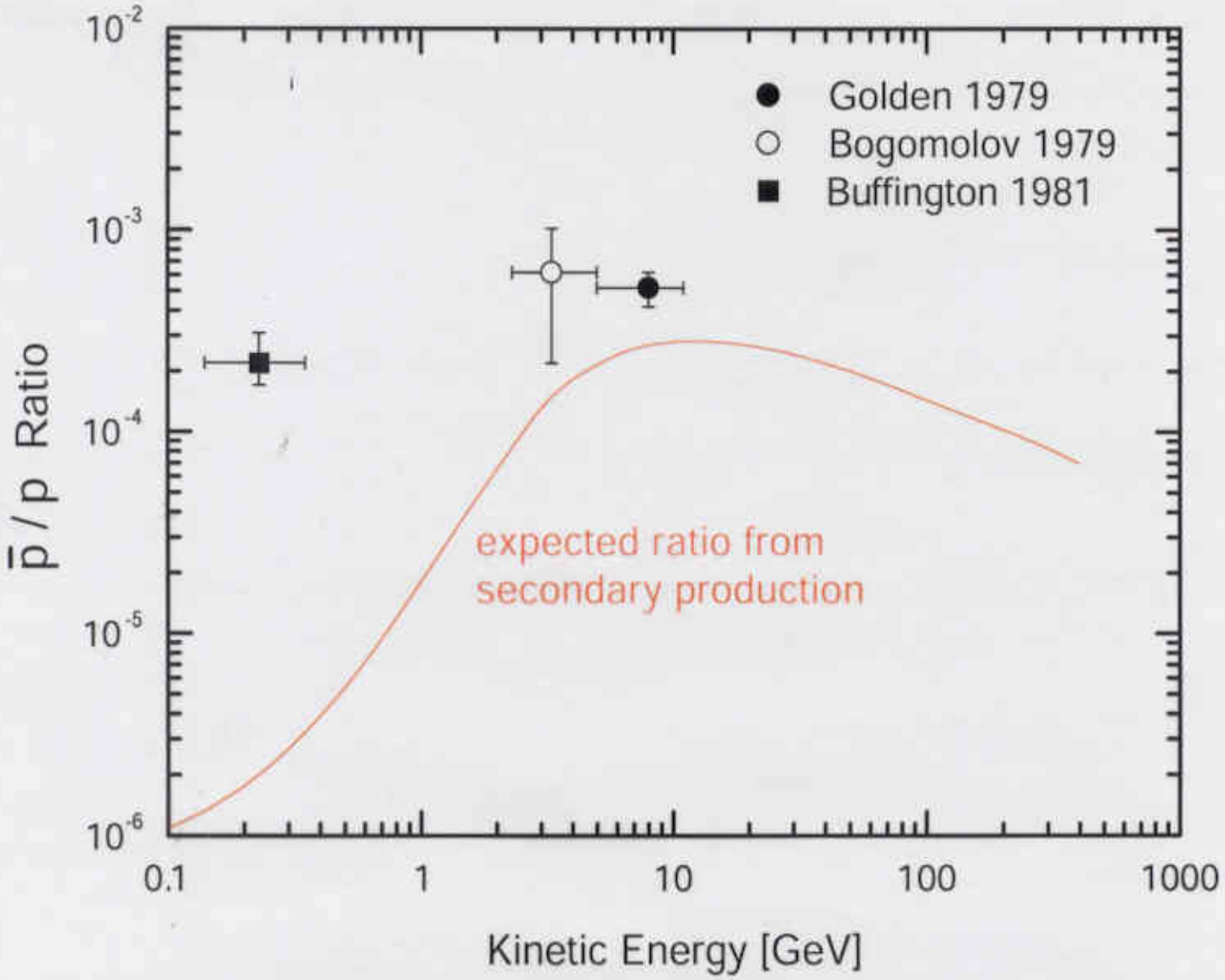


Golden, R. L. et al., 1979, *Phys. Rev. Lett.*, 43, 1196

Bogomolov, E. A. et al., 1979, *16th ICRC*, 1, 330

Buffington, A. et al., 1981, *Astrophys. J.*, 248, 1179

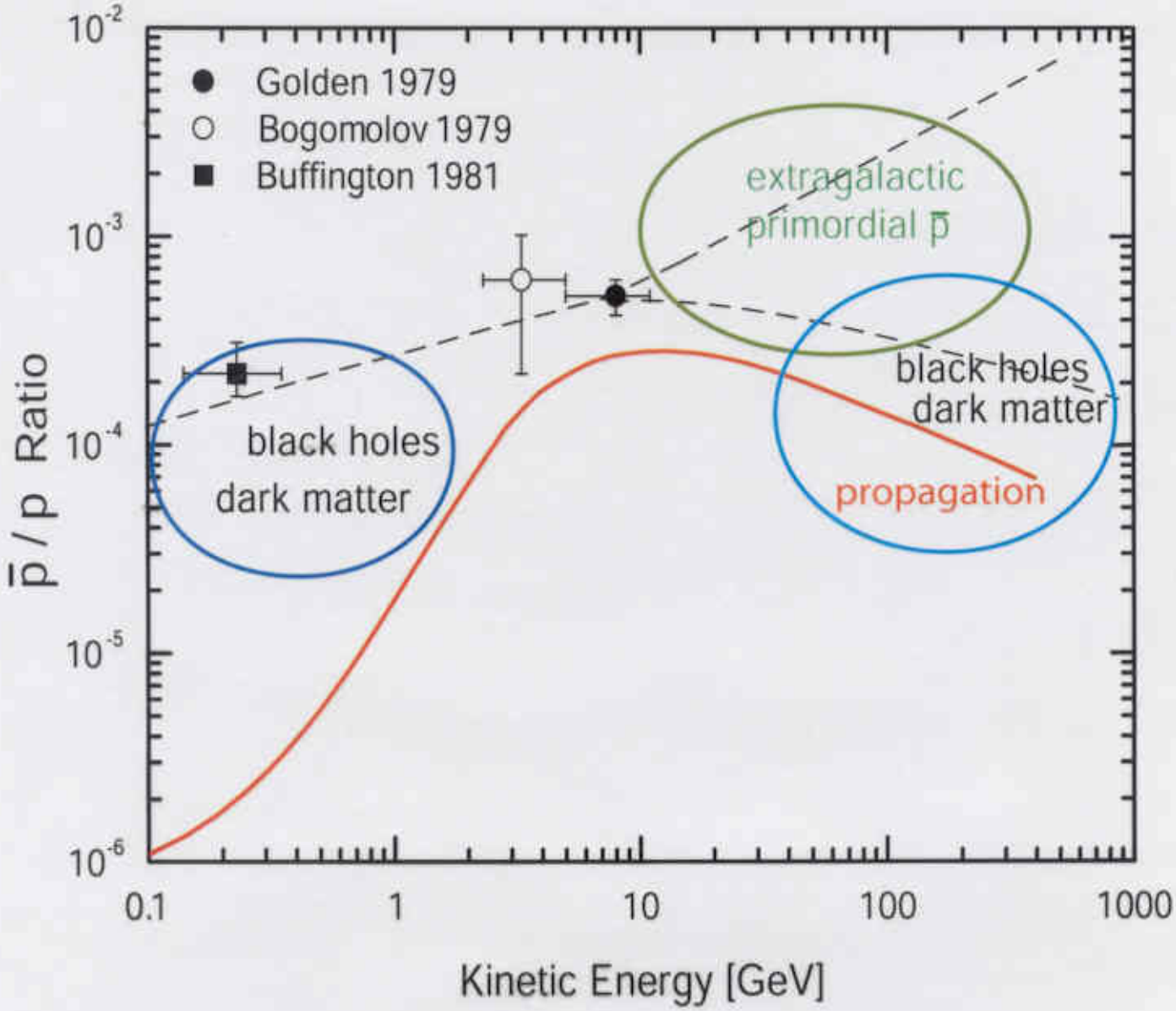
early data on $\bar{p}$



Golden, R. L. et al., 1979, *Phys. Rev. Lett.*, 43, 1196

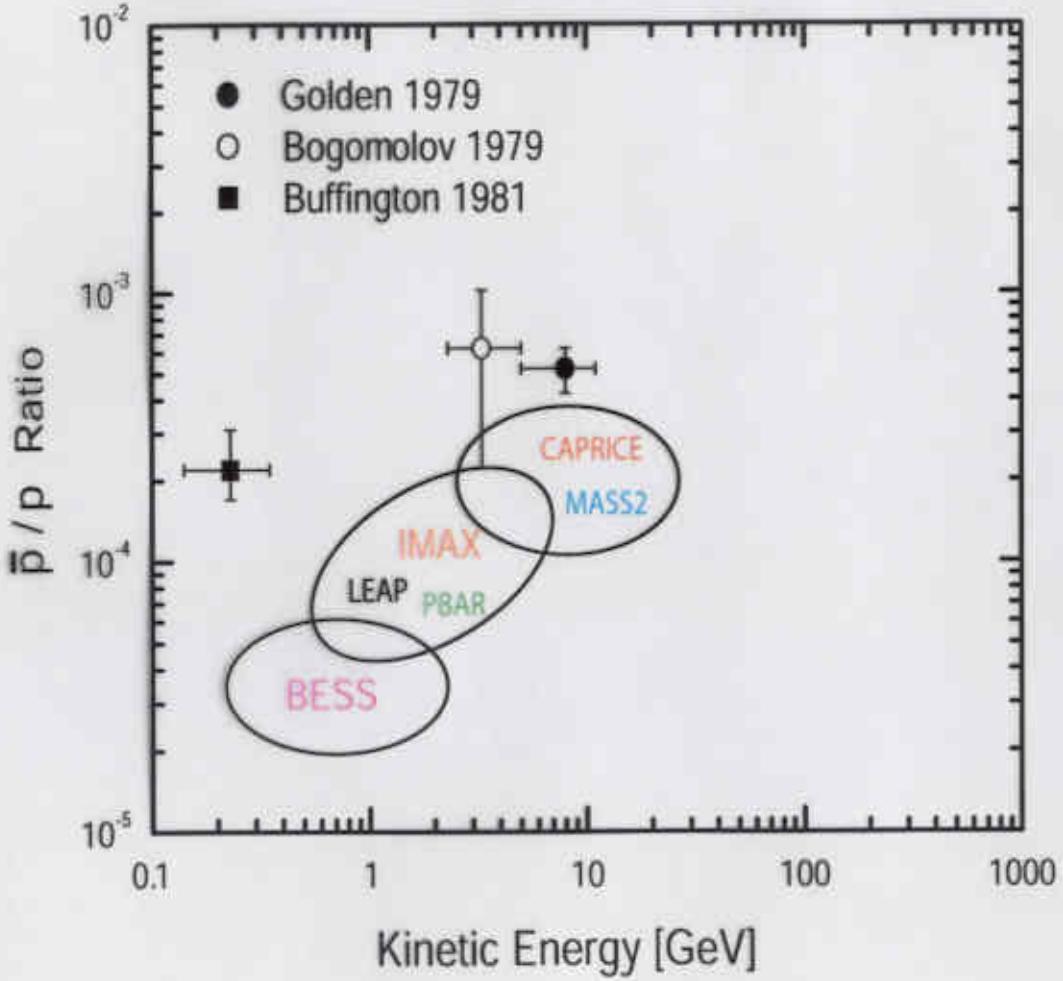
Bogomolov, E. A. et al., 1979, *16th ICRC*, 1, 330

Buffington, A. et al., 1981, *Astrophys. J.*, 248, 1179

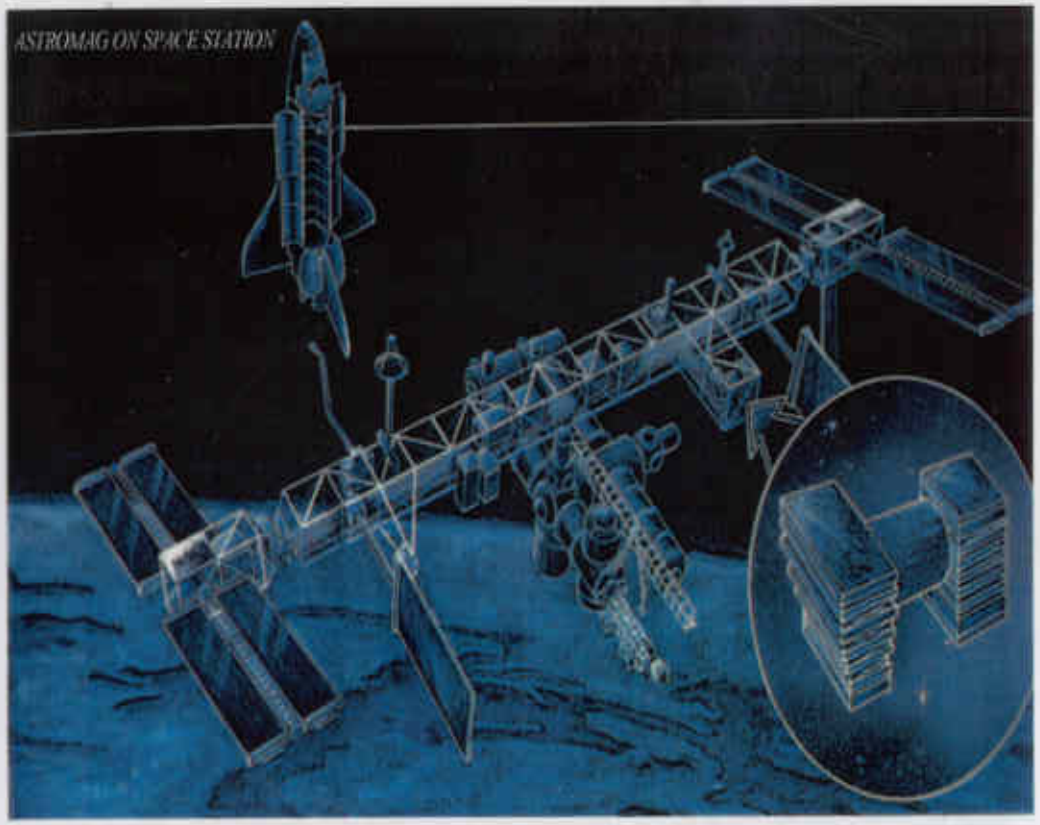

Golden 1979
Bogomolov 1979
Buffington 1981
extragalactic
primordial p̄
black holes
dark matter
black holes
dark matter
propagation
p̄ / p Ratio
Kinetic Energy [GeV]
10^-2
10^-3
10^-4
10^-5
10^-6
0.1
1
10
100
1000

Program for antimatter search in the 80's

Balloon activities

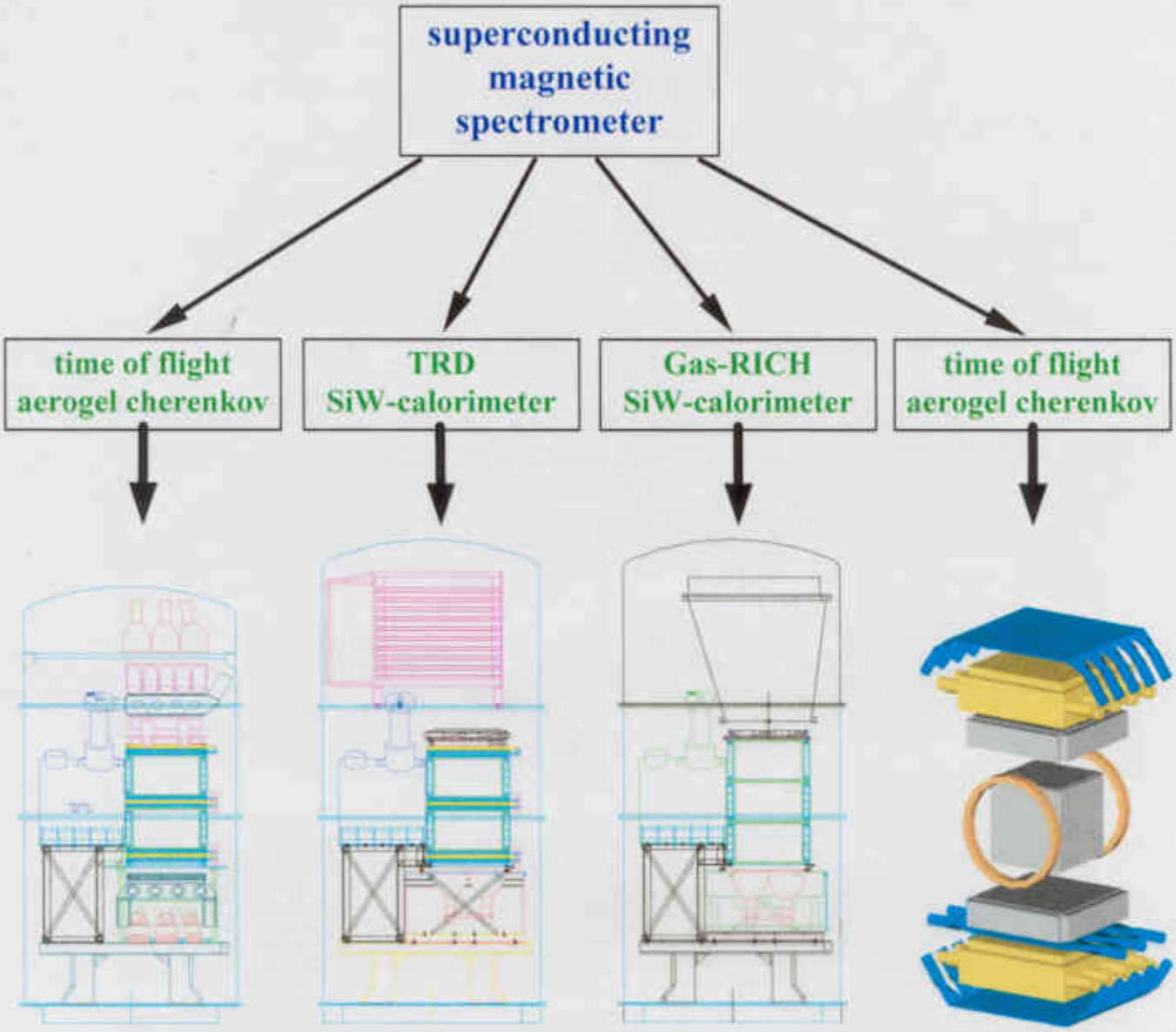


Space activities



Astromag

Detector arrangements and scientific goals of previous and current balloon experiments with participation of the University of Siegen



IMAX (1992)

$\bar{p}$ (0.2 - 3.2 GeV)

$^3He/^4He$ (0.2 - 3.6 GeV/n)

TS93 (1993)

e^+ (5 - 60 GeV)

CAPRICE (1998)

$\bar{p}$ (4 - 50 GeV)

e^+ (4 - 50 GeV)

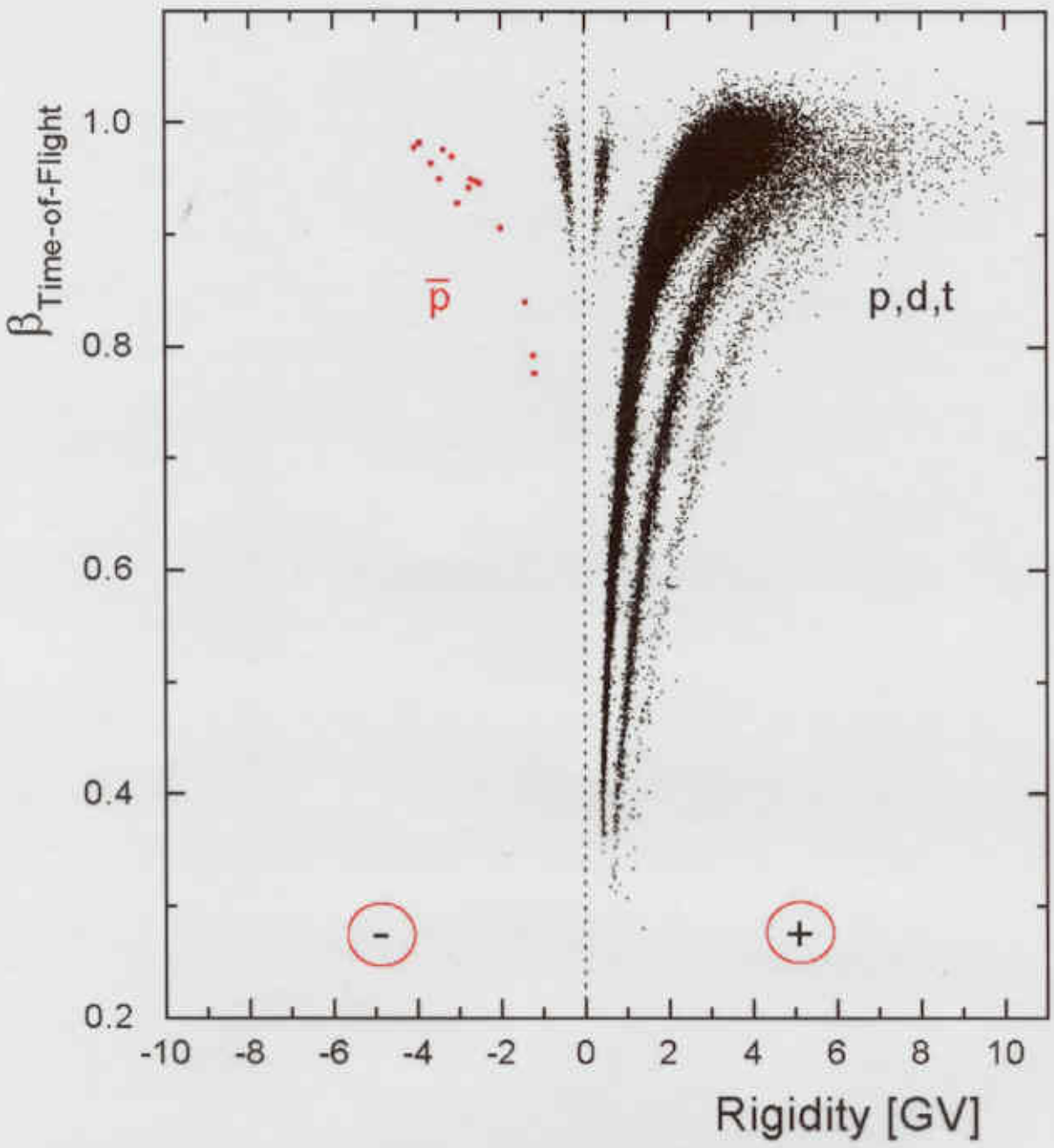
ISOMAX (1998)

light isotopes

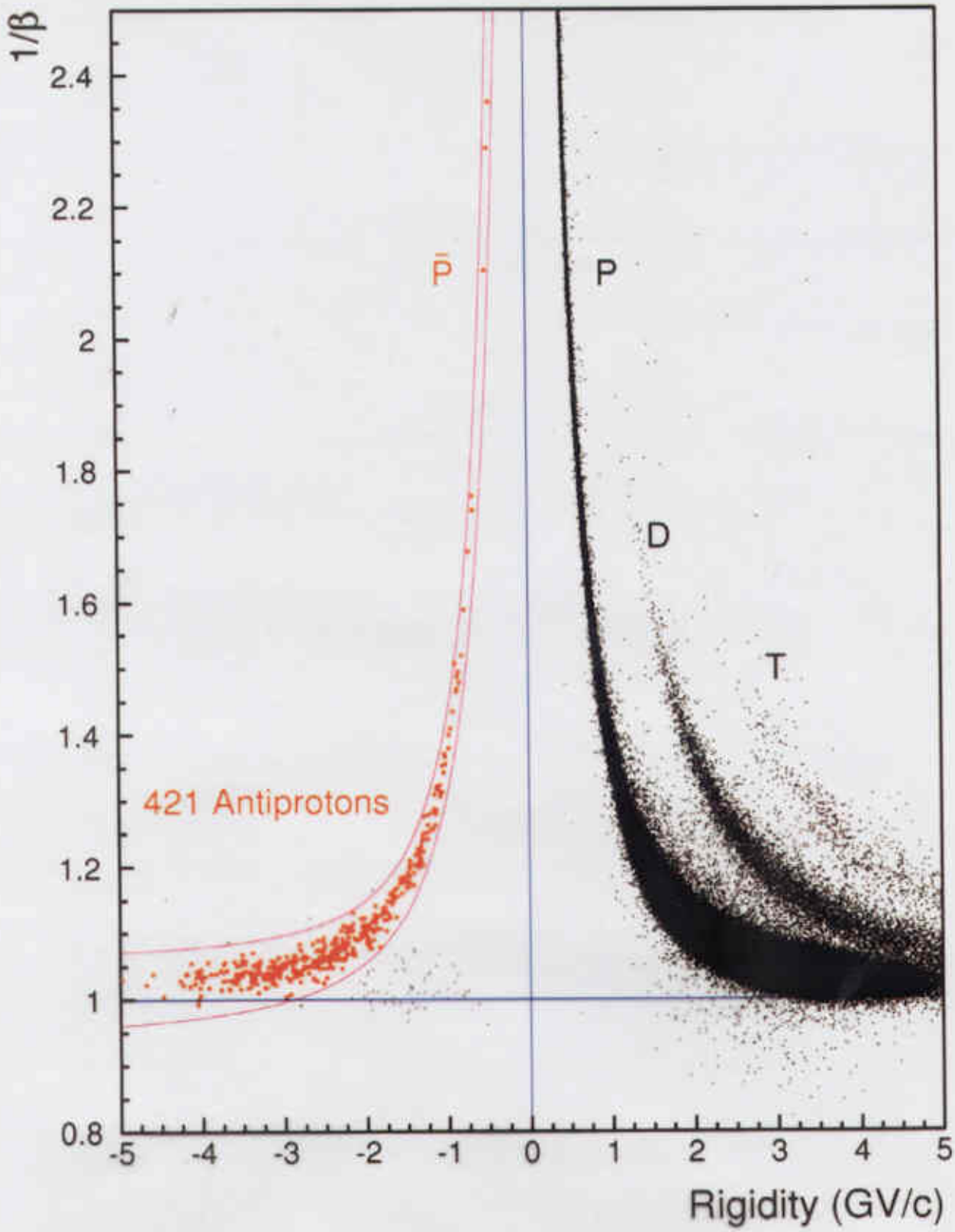
^{10}Be (0.2 - 4 GeV/n)

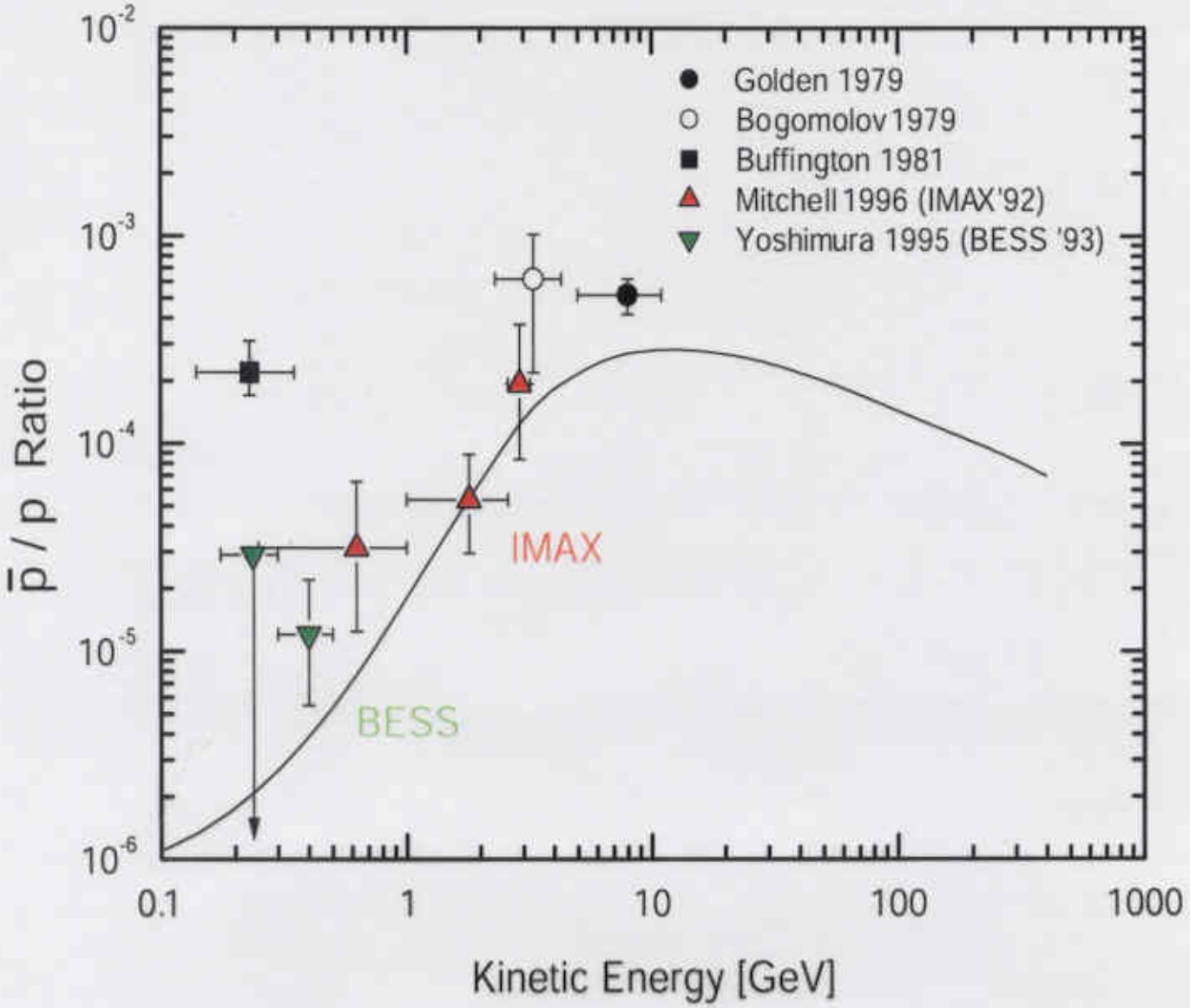
The first measurement of mass-identified cosmic ray antiprotons performed with the IMAX instrument

1992

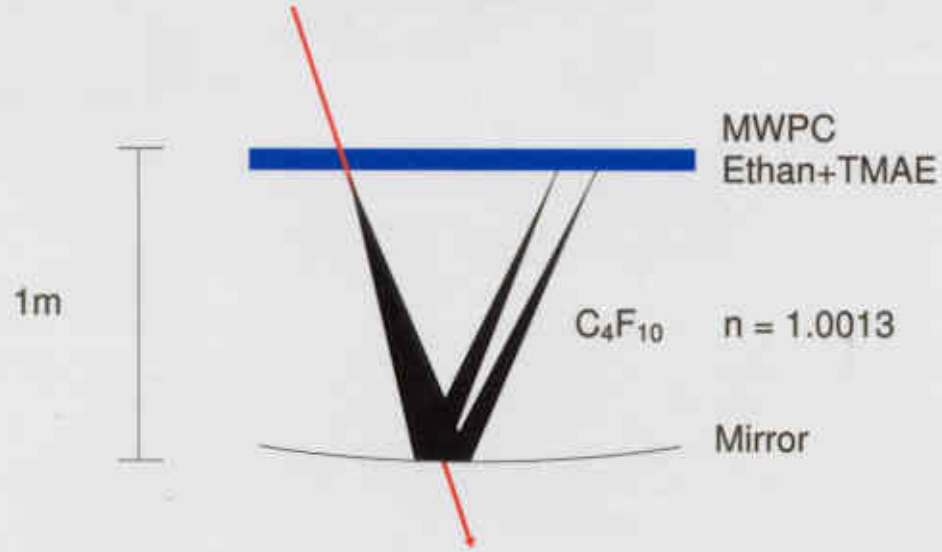


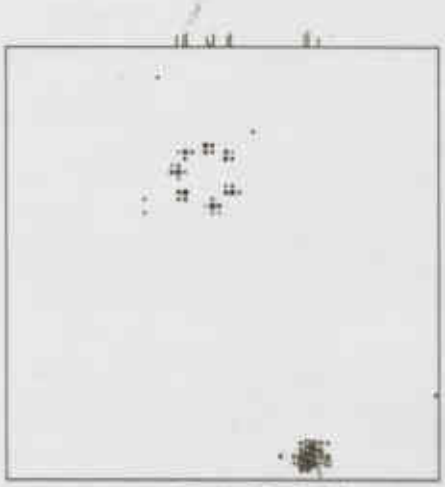
Measurements with the BESS-Experiment



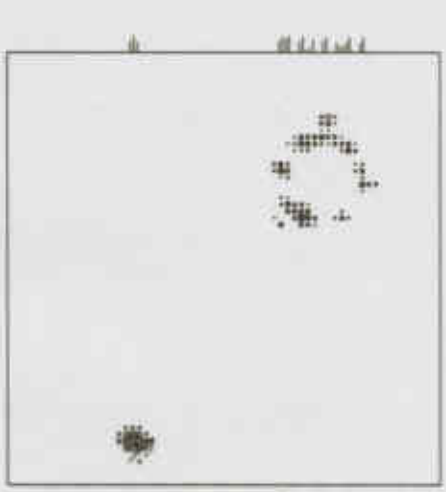

Golden 1979
Bogomolov 1979
Buffington 1981
Mitchell 1996 (IMAX'92)
Yoshimura 1995 (BESS '93)
IMAX
BESS
$\bar{p}/p$ Ratio
Kinetic Energy [GeV]
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.1
1
10
100
1000

The CAPRICE Gas RICH Detector

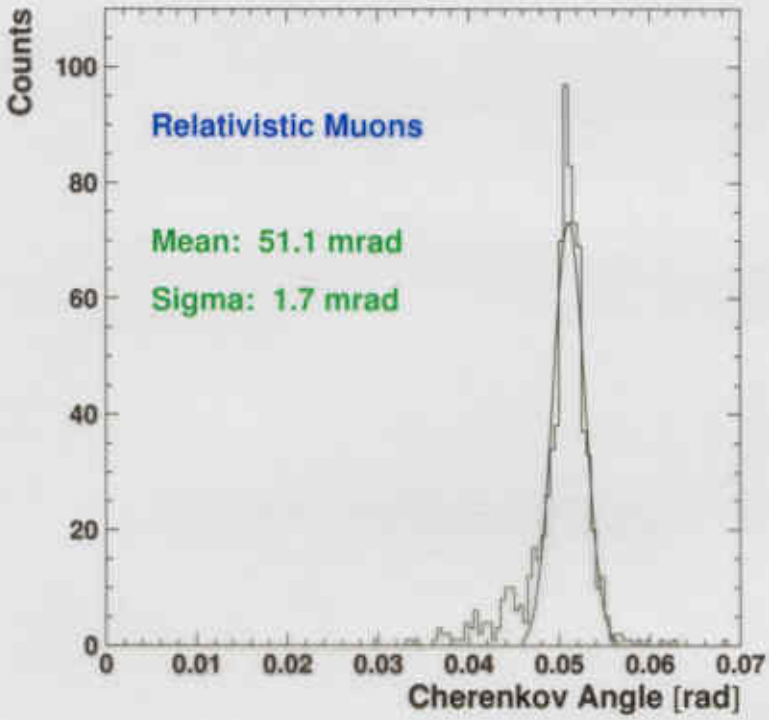


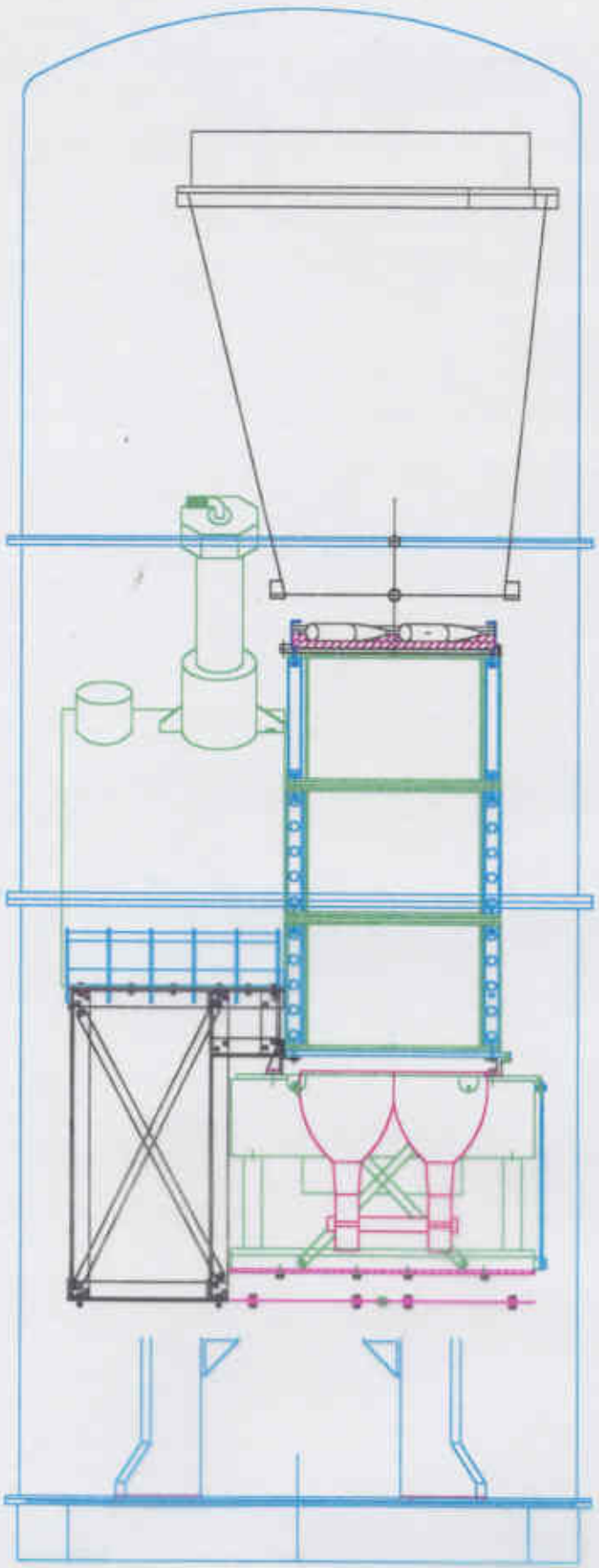


p_μ = 2.8 GeV/c



p_μ = 12.2 GeV/c





Gas RICH

β

Magnetspektrometer

R

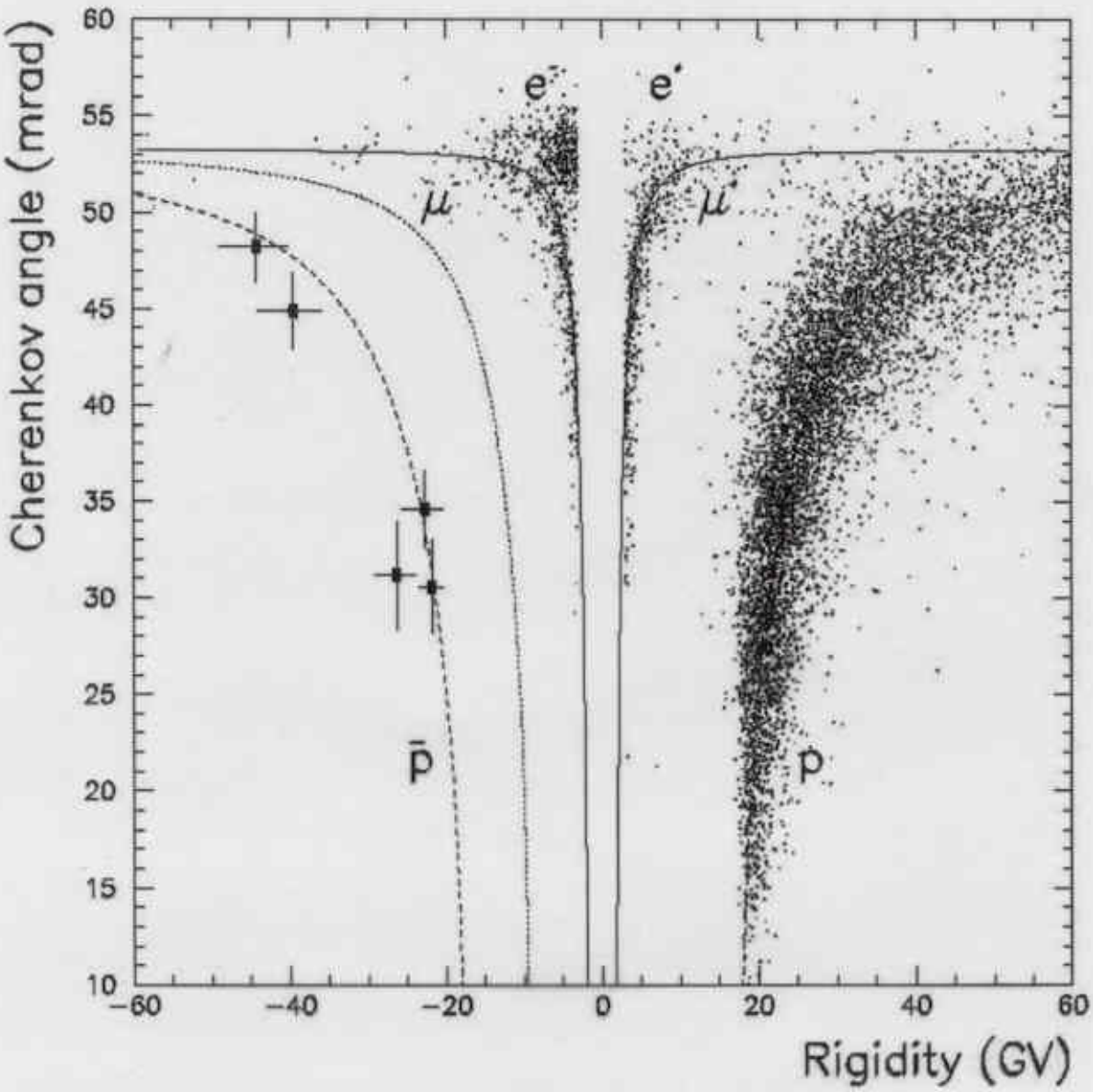
Flugzeitmessung

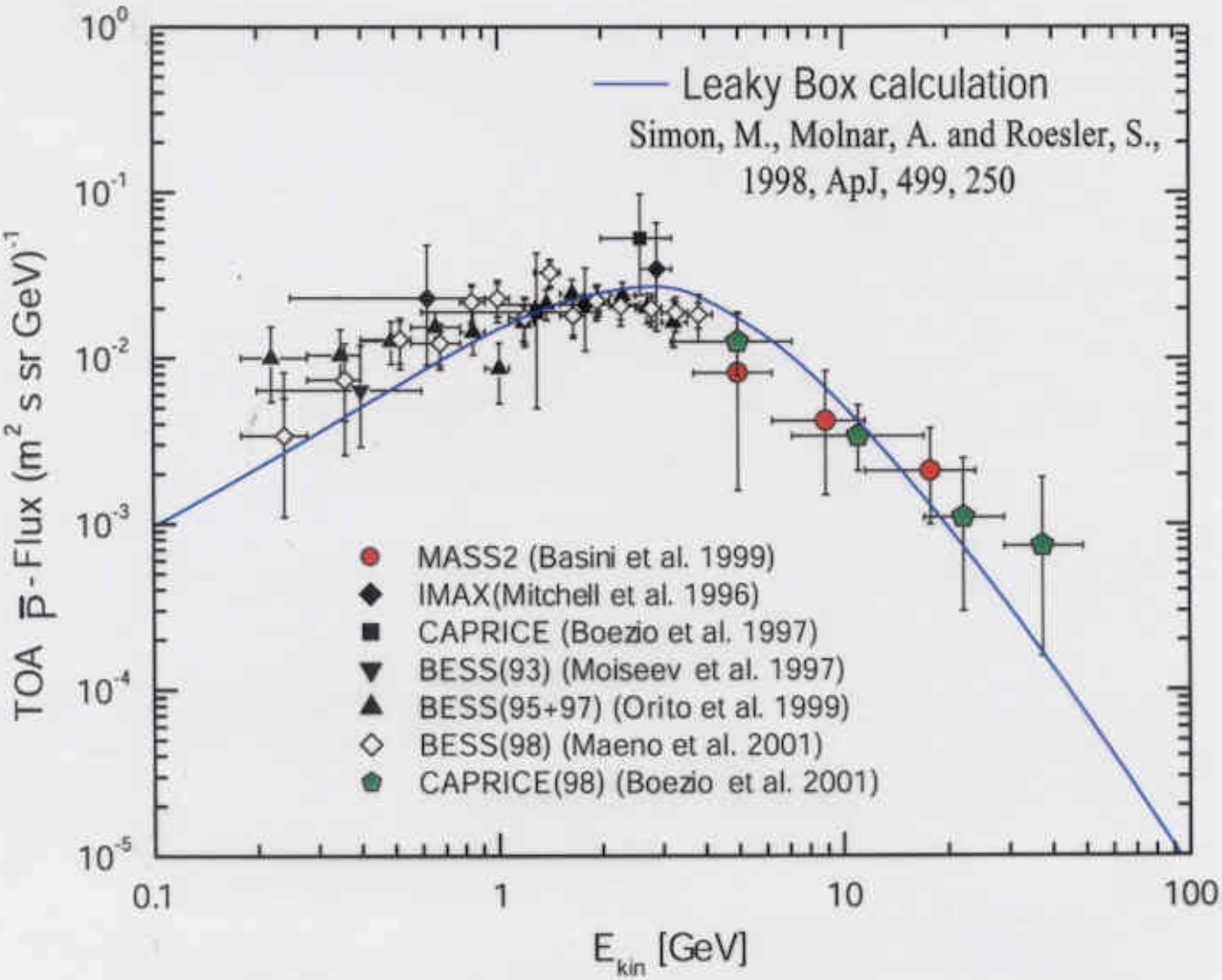
β, Z, Richtung

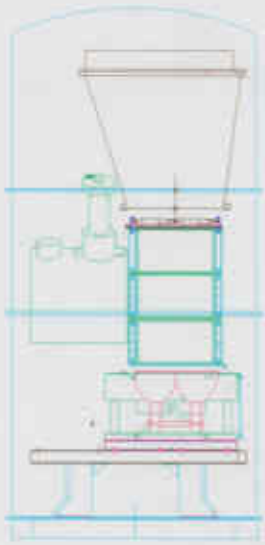
Kalorimeter

e.m. Schauer

CAPRICE


Cherenkov angle (mrad)
Rigidity (GV)
e⁻
e⁺
μ⁻
μ⁺
p̄
p
60
55
50
45
40
35
30
25
20
15
10
−60
−40
−20
0
20
40
60


Leaky Box calculation
Simon, M., Molnar, A. and Roesler, S.,
1998, ApJ, 499, 250
MASS2 (Basini et al. 1999)
IMAX(Mitchell et al. 1996)
CAPRICE (Boezio et al. 1997)
BESS(93) (Moiseev et al. 1997)
BESS(95+97) (Orito et al. 1999)
BESS(98) (Maeno et al. 2001)
CAPRICE(98) (Boezio et al. 2001)
TOA p̄-Flux (m² s sr GeV)⁻¹
E_kin [GeV]
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
0.1
1
10
100



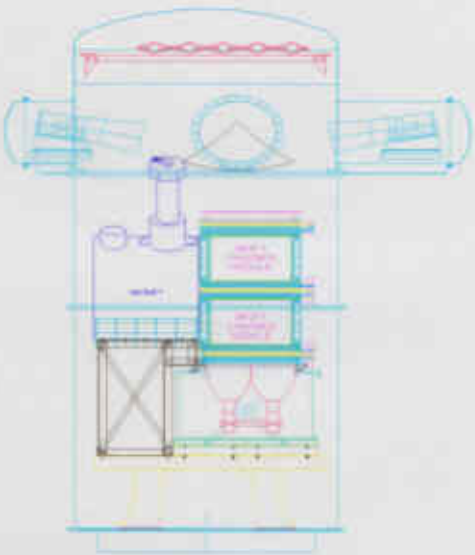
CAPRICE

ISOMAX

PAMELA

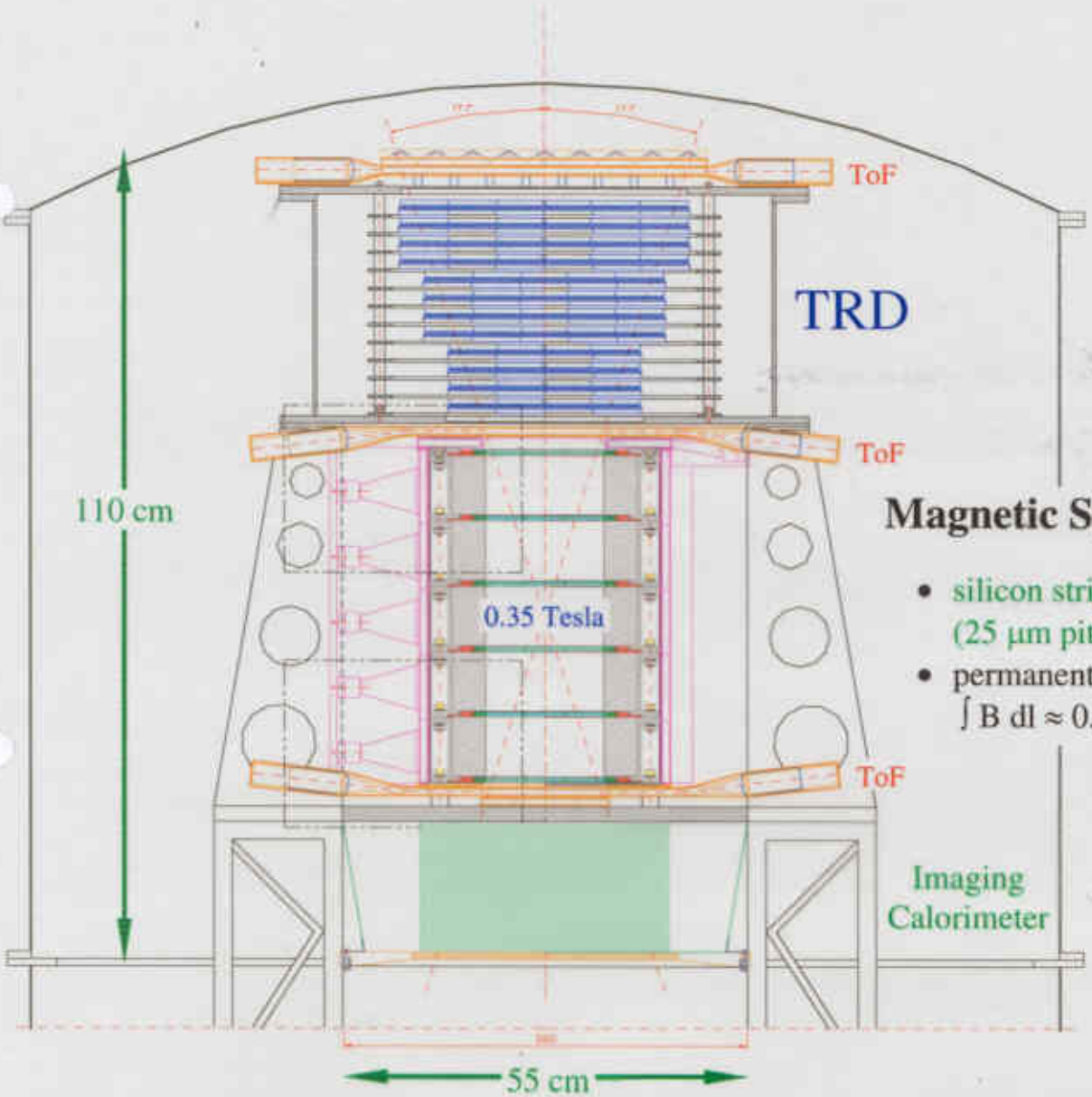
IMAX

MASS2



The **PAMELA** - Experiment

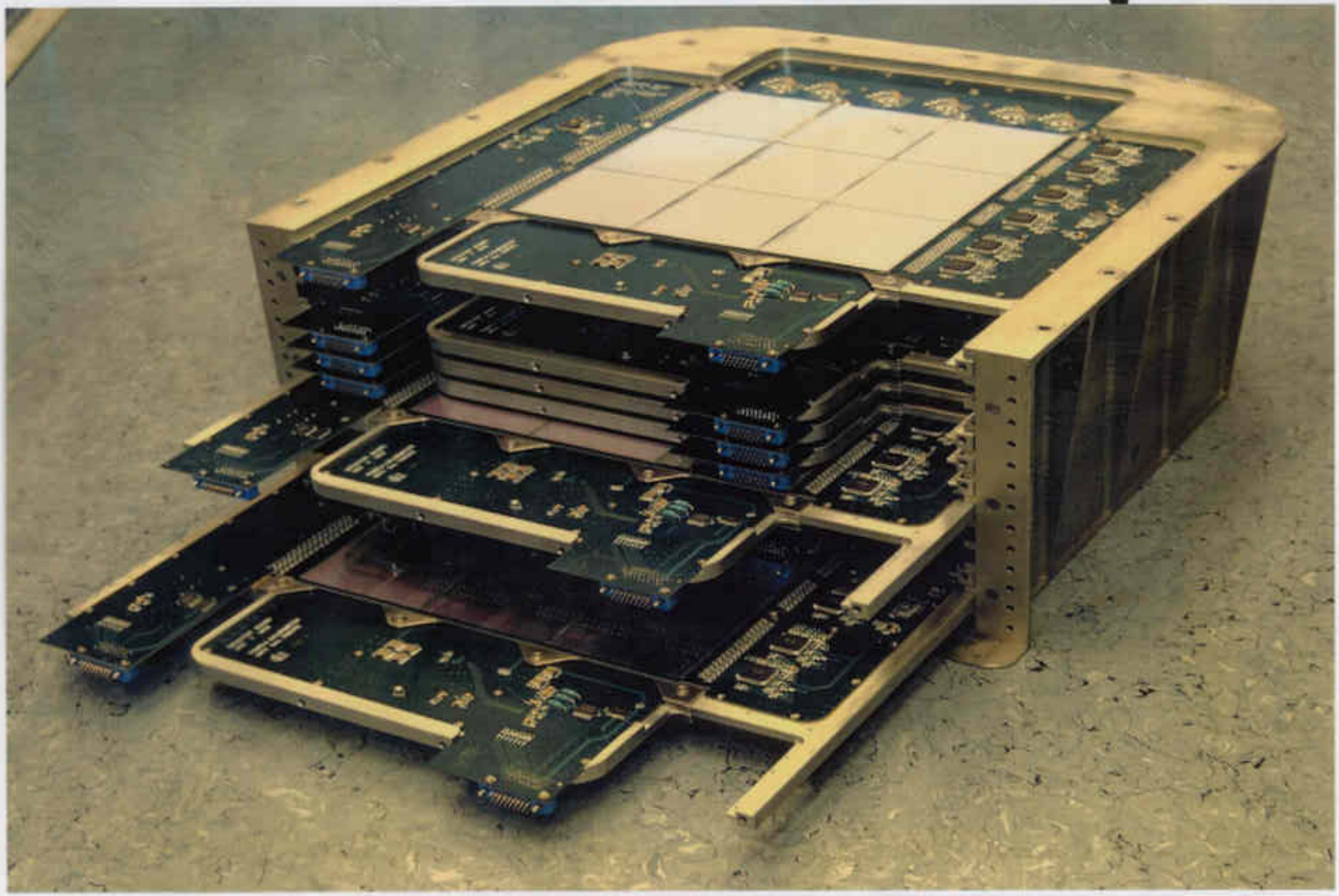
Geometry factor	:	21 cm^2 sr
Mass	:	400 kg
Power	:	< 300 W



Magnetic Spectrometer

- silicon strip tracker (25 μm pitch)
- permanent magnet $\int B\,dl \approx 0.16$ Tm

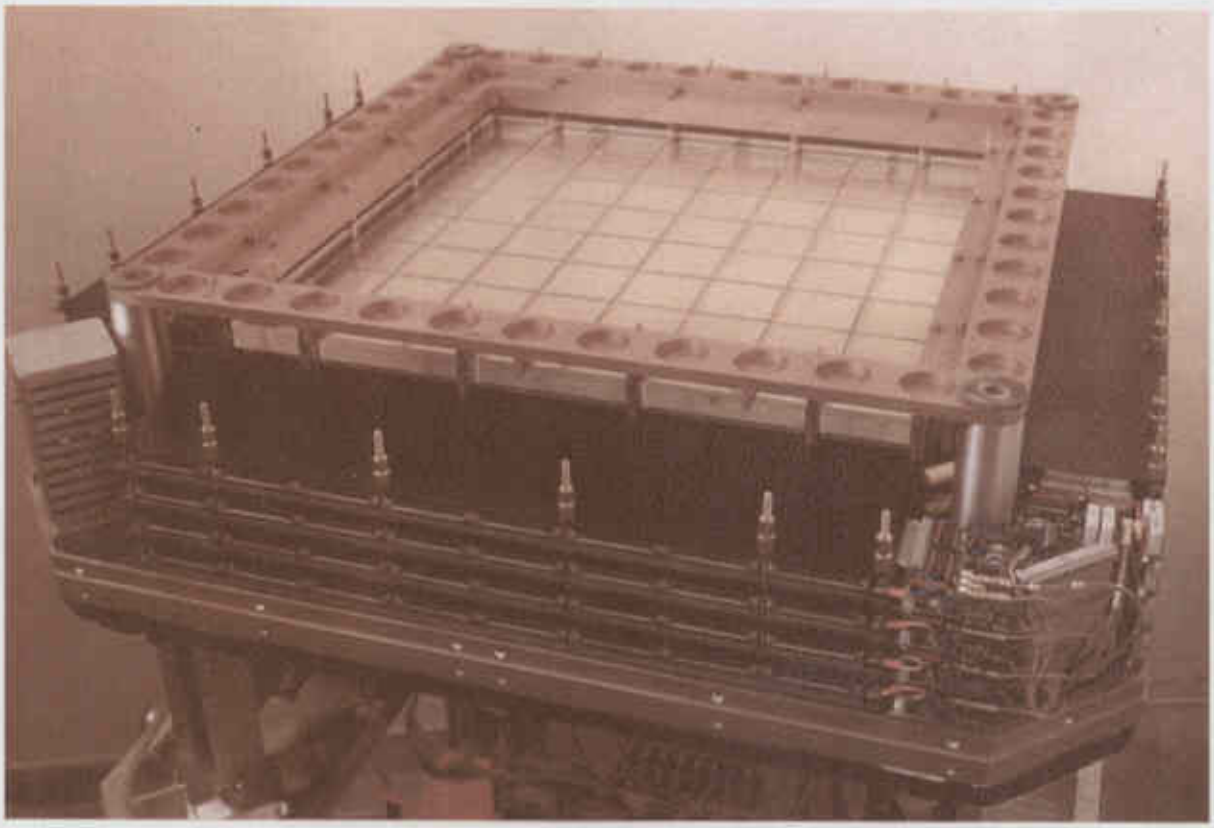
INFN Trieste

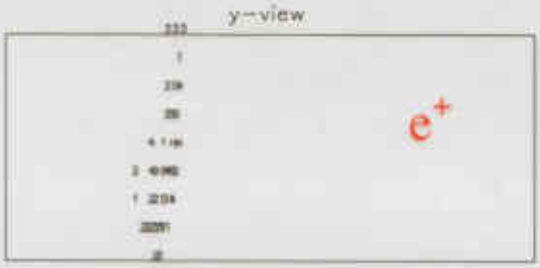


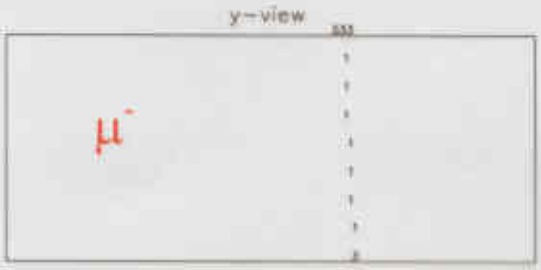
Imaging Calorimeter of CAPRICE

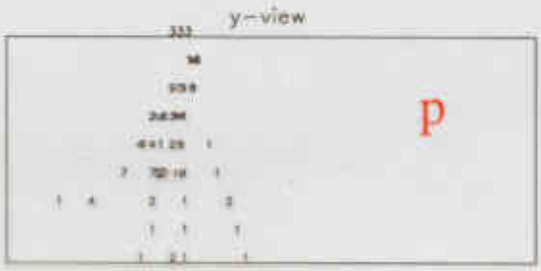
8 layers of silicon detectors
7 layers of tungsten

$\Rightarrow$ 7.2 radiation length
0.33 interaction length





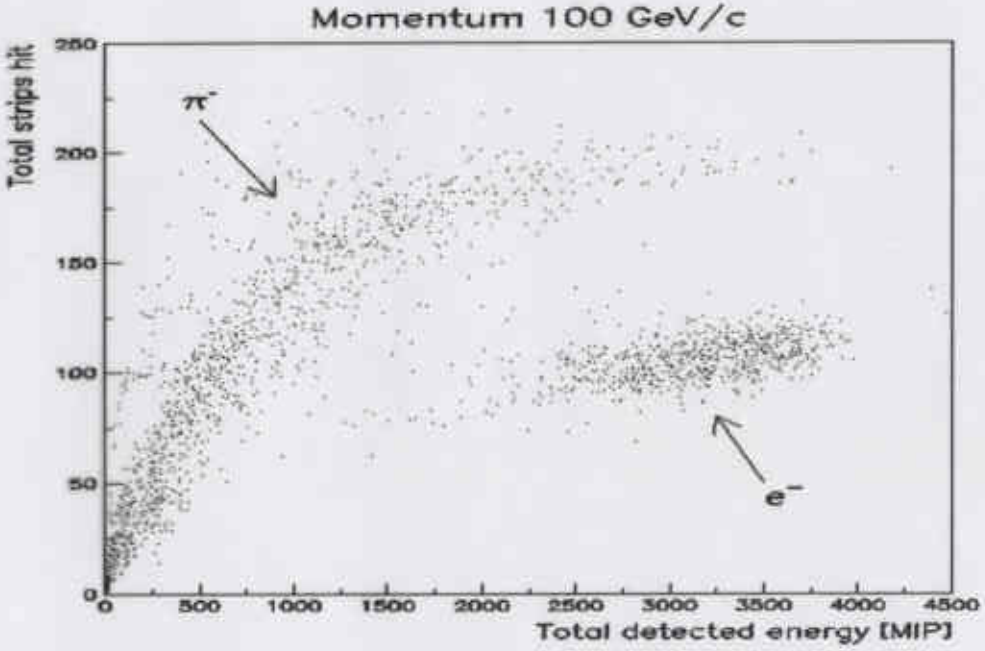




INFN Trieste

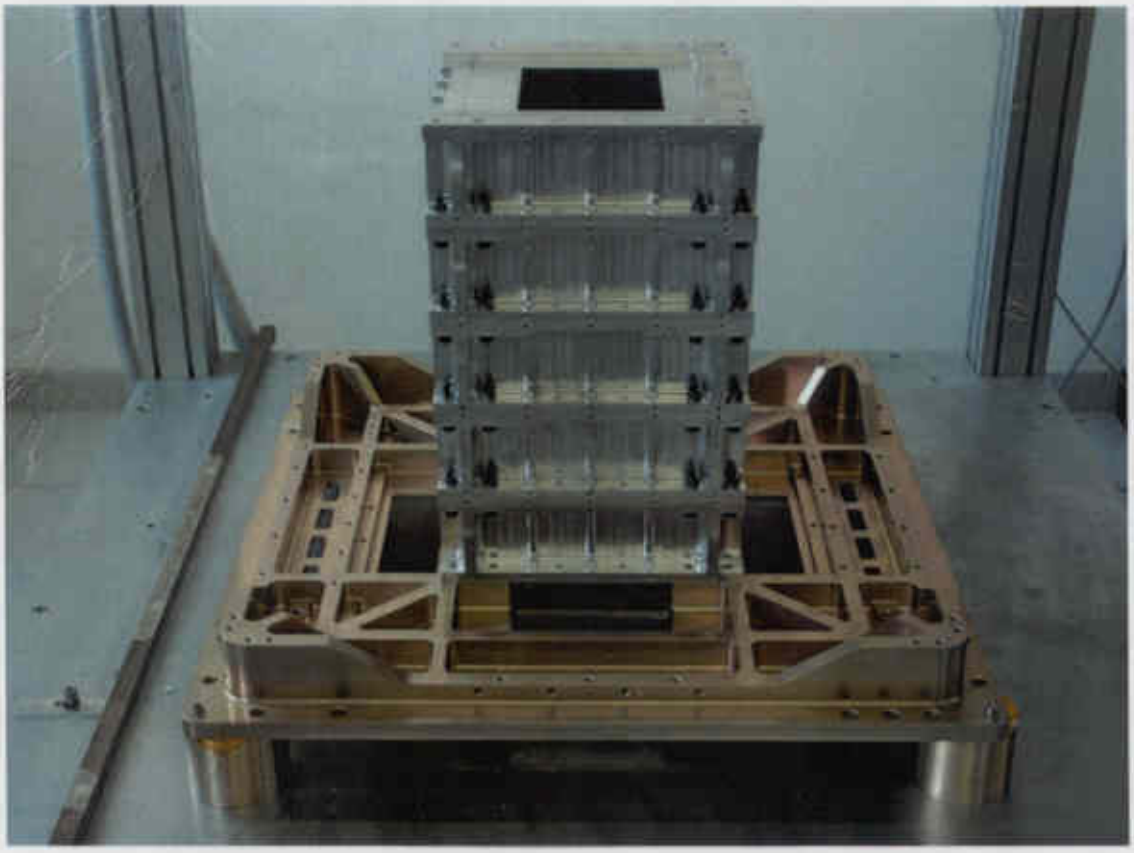
PAMELA CALORIMETER - July 2000 Test Beam CERN SPS

(5 Si views mounted out of 44)

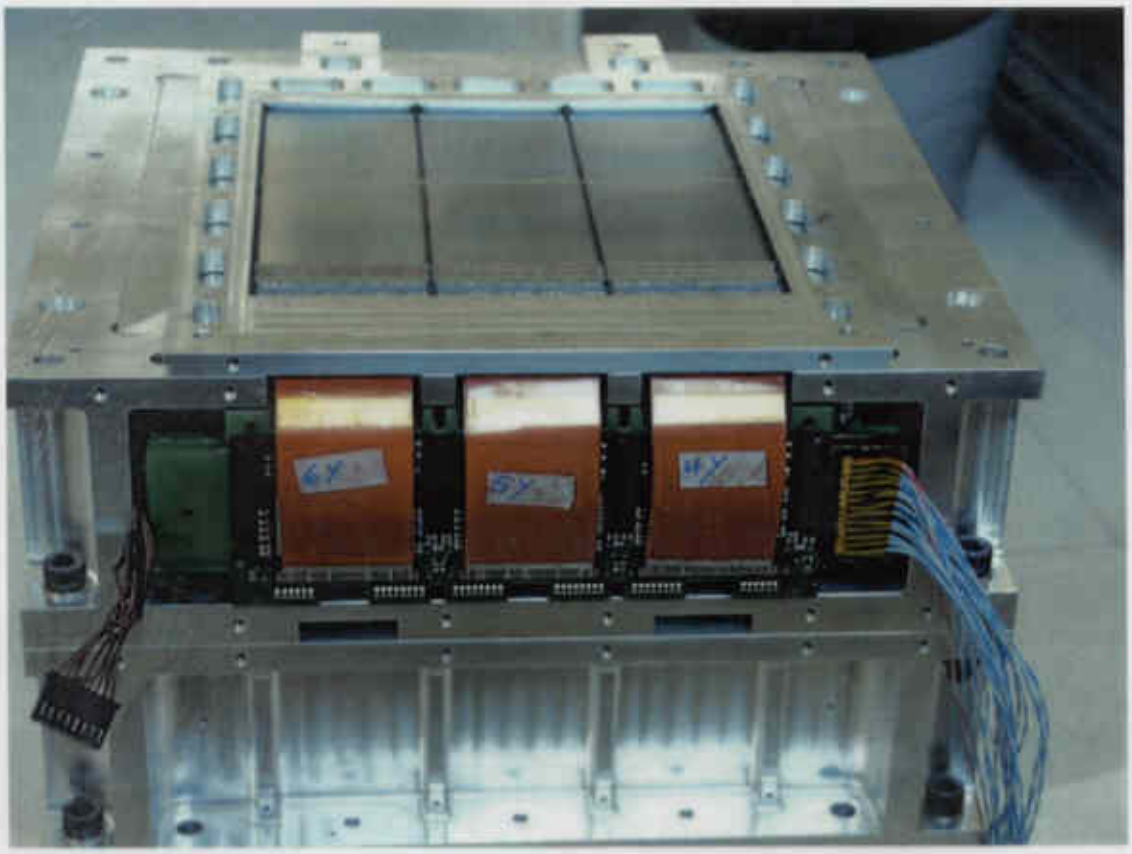


PAMELA

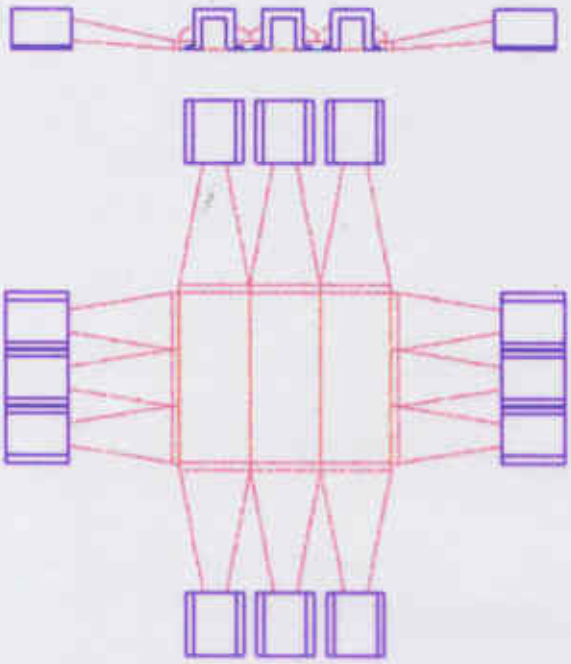
Permanent Magnet

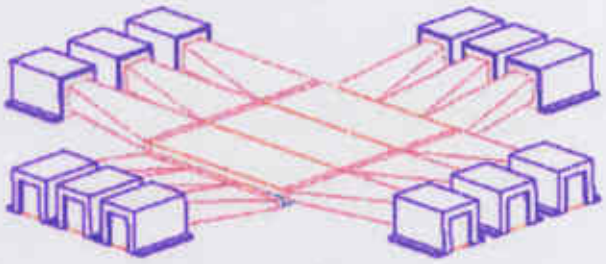


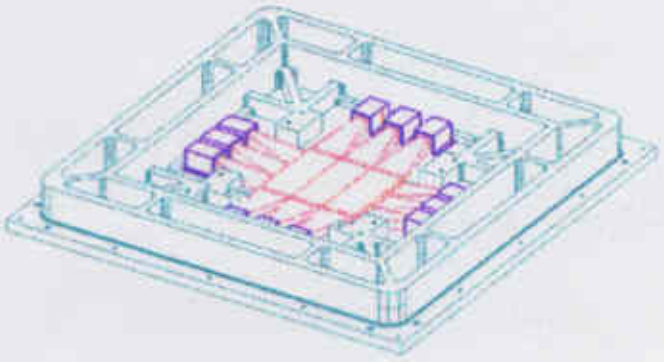
Silicon Tracker Plate

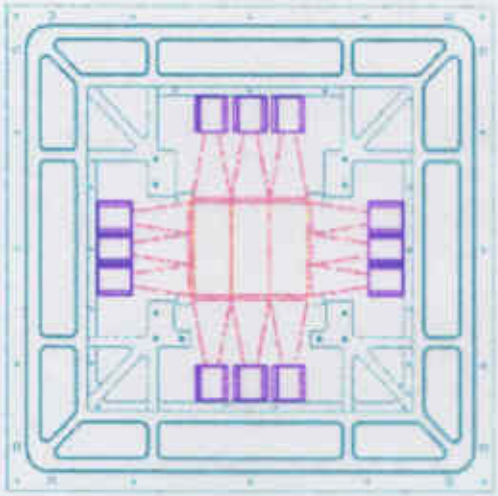


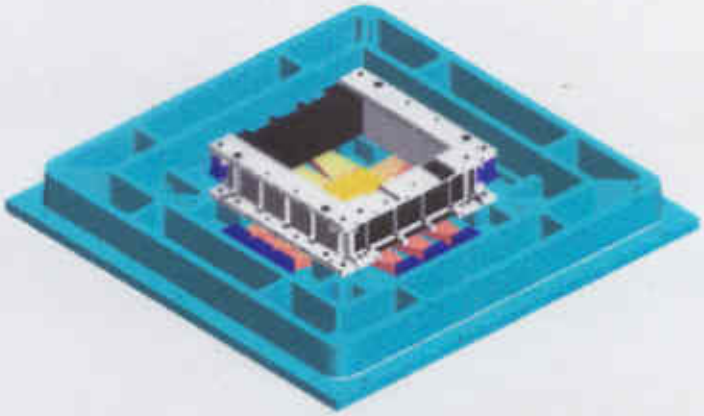
- Bottom (S3) two layers16.8 cm x 13.6 cm x 0.64 cm.
  - S31 - three 13.6 cm x 5.6 cm strips.
  - S32 - three 16.8 cm x 4.5 cm strips.
  - Strips individually light-tight.
  - Supported in Pamela base plate.











Pamela Subdetectors

INFN Trieste

TRD

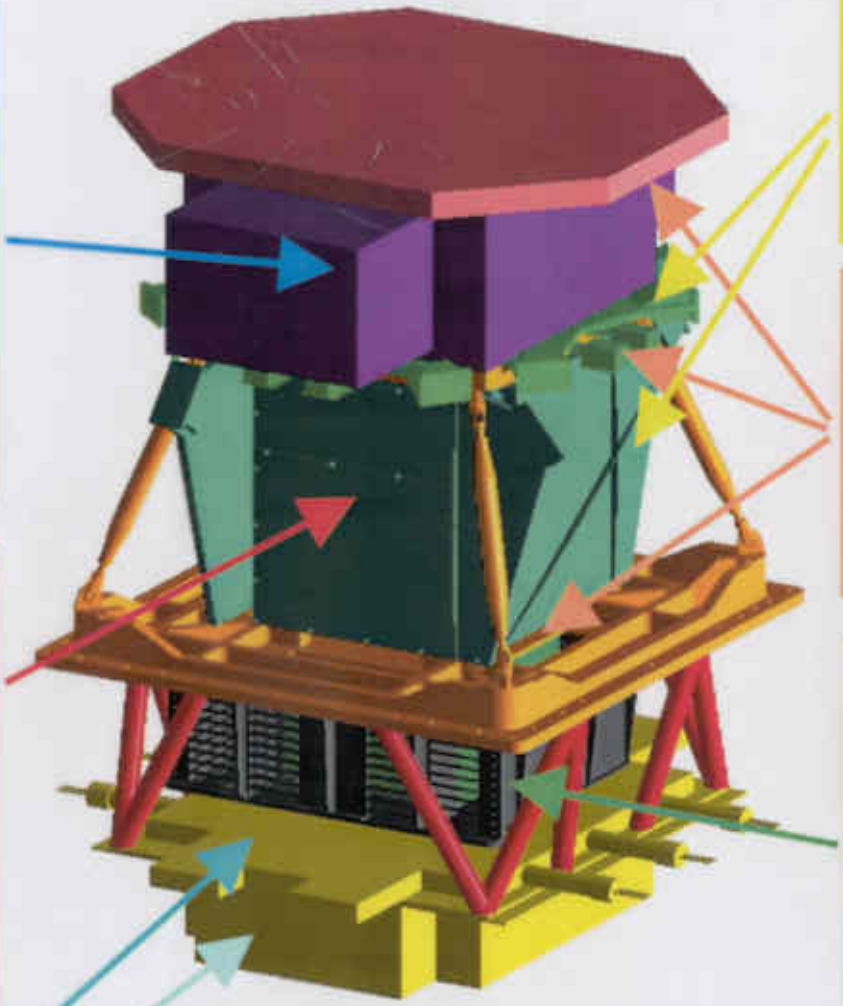
- Threshold device. Signal from $e^{\pm}$, no signal from p, π
- 9 planes of Xe/Co_2 filled straws (4mm diameter). Interspersed with carbon fibre radiators ⇒ crude tracking.
- Aim: 10^2 separation e -vs- p (above 1GeV/c). NB: 10^6 with calorimeter.

Si Tracker + magnet

- Measures rigidity
- 5 Nd-B-Fe magnet segments (0.4T)
- 6 planes of 300μm thick Si detectors
- ~3μm resolution in bending view demonstrated, ie: MDR = 740GV/c

Bottom scintillator (S4)

Neutron counter



[Acceptance ~21 cm^2sr]

Anticoincidence system

- Defines acceptance for tracker
- Plastic scintillator + PMT
- Binary read-out

Time-of-flight

- Gives L1 trigger / detects albedos / particle identification (up to 1GeV/c) / dE/dx
- Plastic scintillator + PMT
- Timing resolution = 100ps

Si-W Calorimeter

- Measures energies of $e^{\pm}$. $\Delta E/E = 15\% / E^{1/2}$.
- Si -X / W / Si -Y structure.
- 44 Si / 22 W ⇒ $16X_0$ / $0.6\lambda_0$
- Imaging: EM - vs- hadronic discrimination. Reconstruct long. and transverse shower profile.

CERN Test Results of the PAMELA TRD

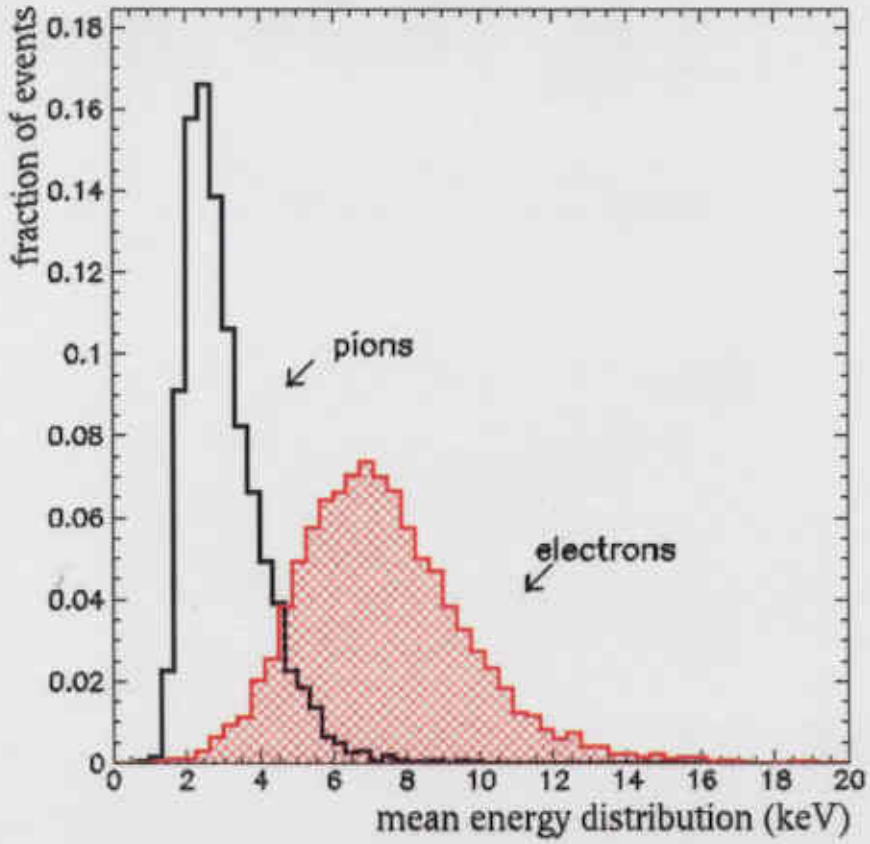
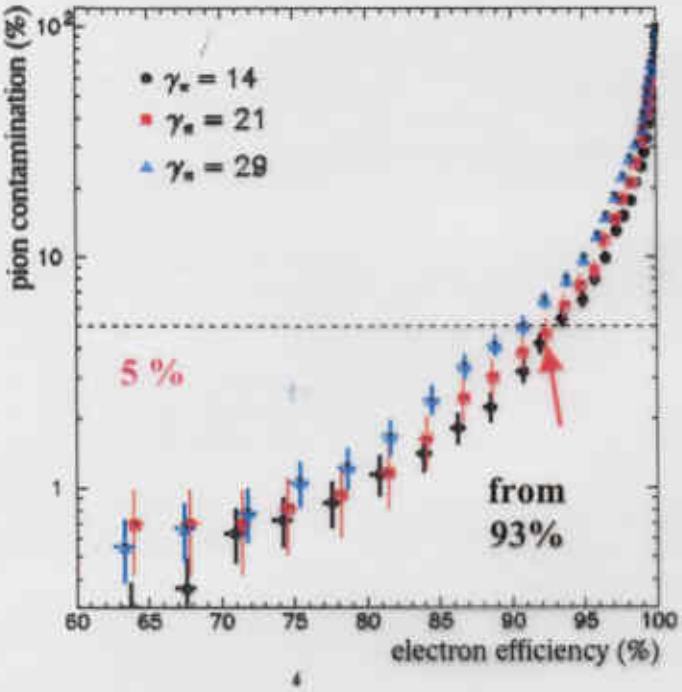
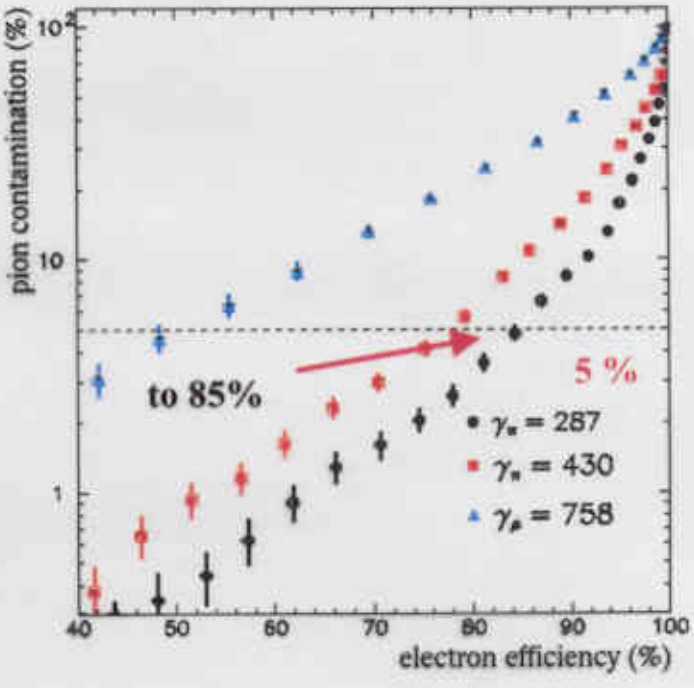
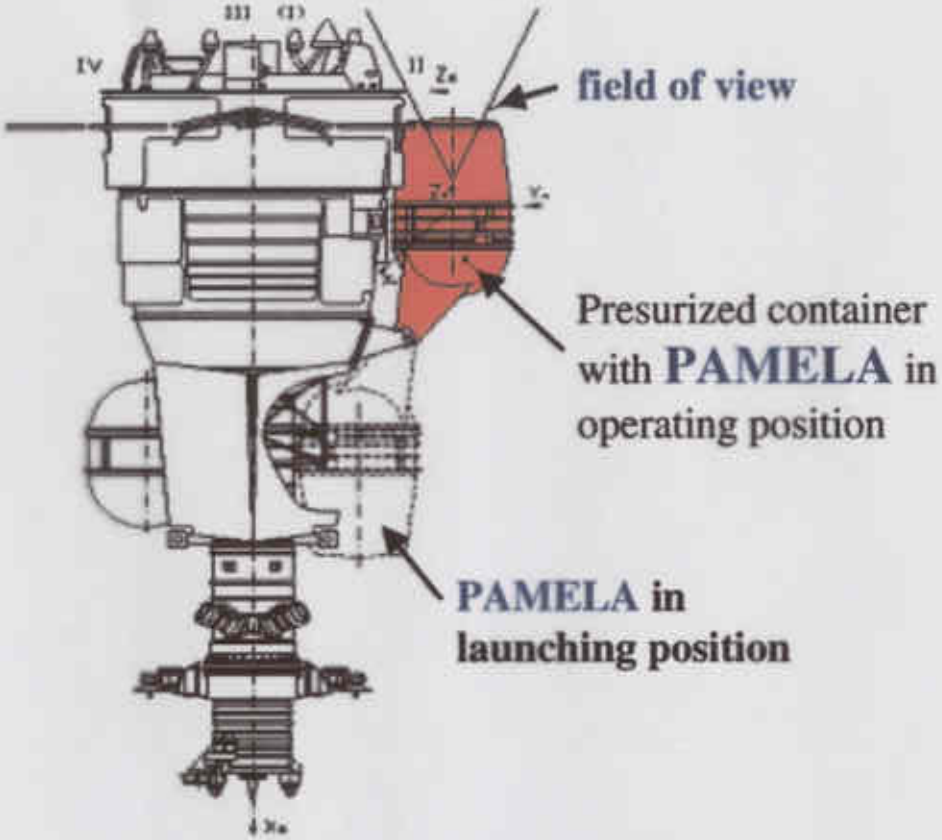


Figure: mean energy distribution of pions of 2 GeV/*c* (γ=14) and of electrons ($\gamma > \gamma_{sat}$) in the TRD.The contribution of the transition radiation is clearly visible for electrons.



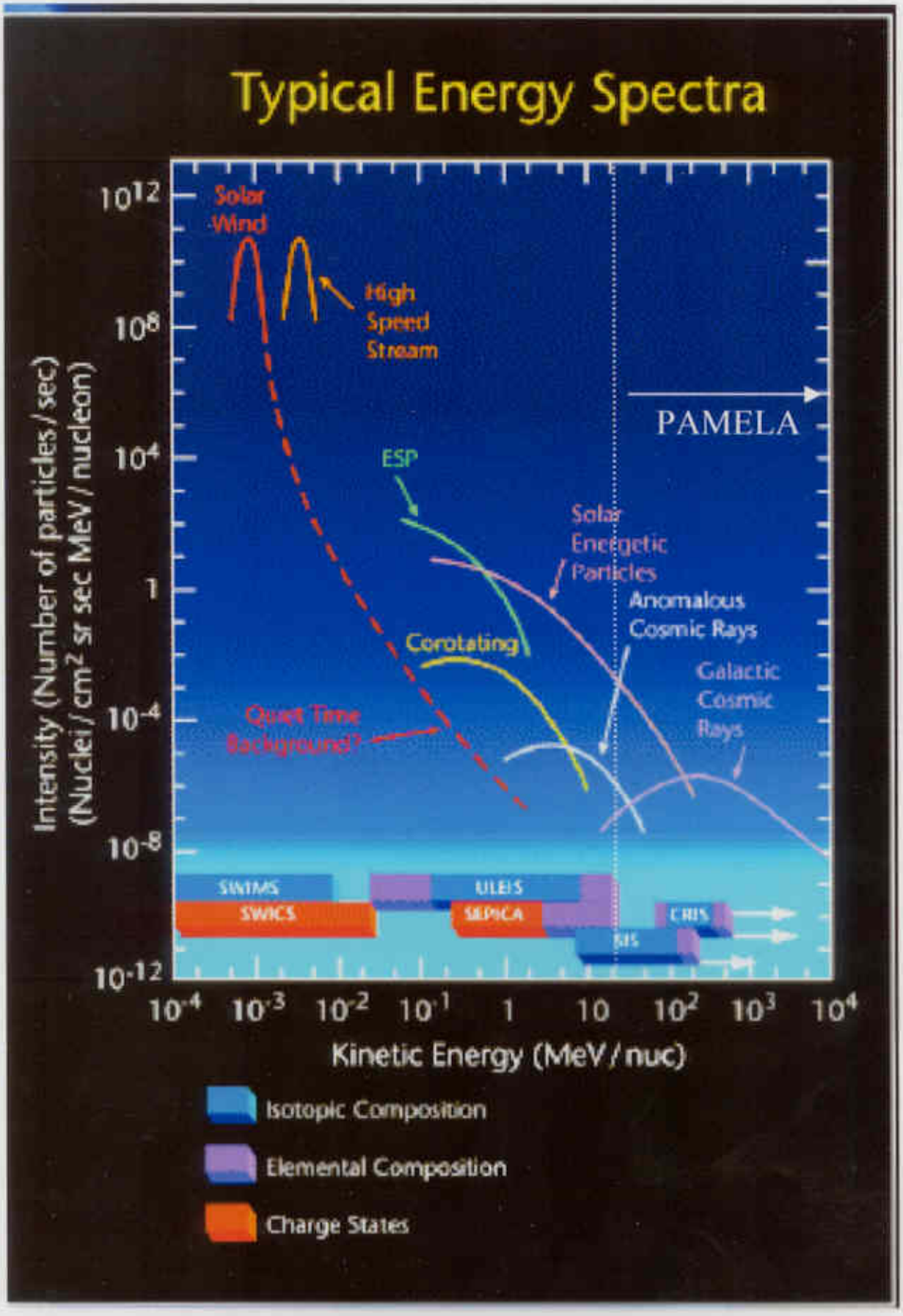


PAMELA Launch



Expected Date of launch :
beginning of 2003

The Resurs-DK1 satellite
Carrier rocket: SOYUZ


Typical Energy Spectra
Solar Wind
High Speed Stream
PAMELA
ESP
Solar Energetic Particles
Anomalous Cosmic Rays
Corotating
Galactic Cosmic Rays
Quiet Time Background?
SWICS
SEPICA
CRIS
Intensity (Number of particles / sec) (Nuclei / cm² sr sec MeV / nucleon)
Kinetic Energy (MeV / nuc)
Isotopic Composition
Elemental Composition
Charge States

Pamela physics

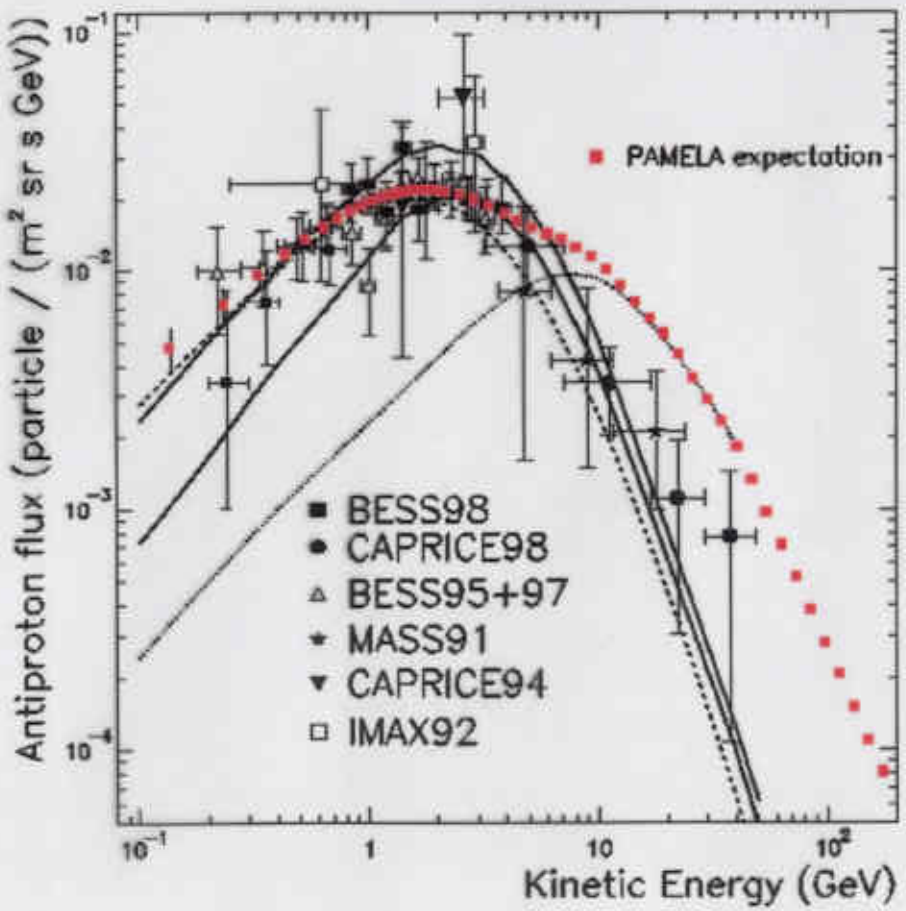
Trieste

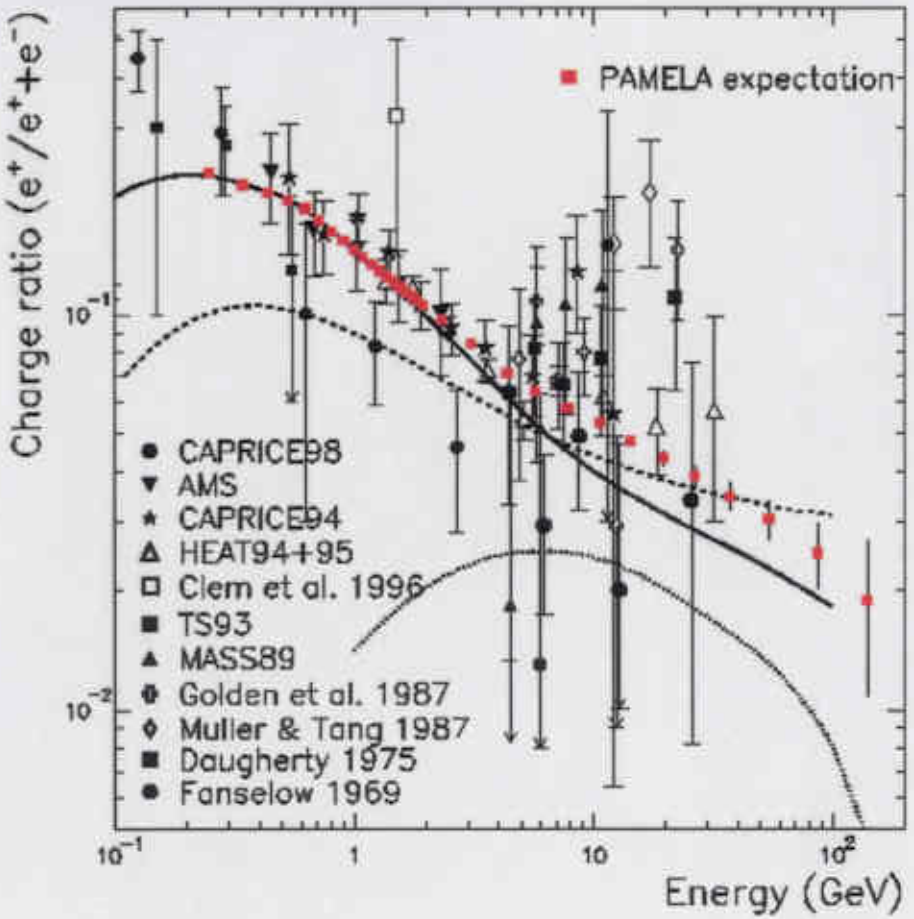
Main purpose : antiproton and positron fluxes in space

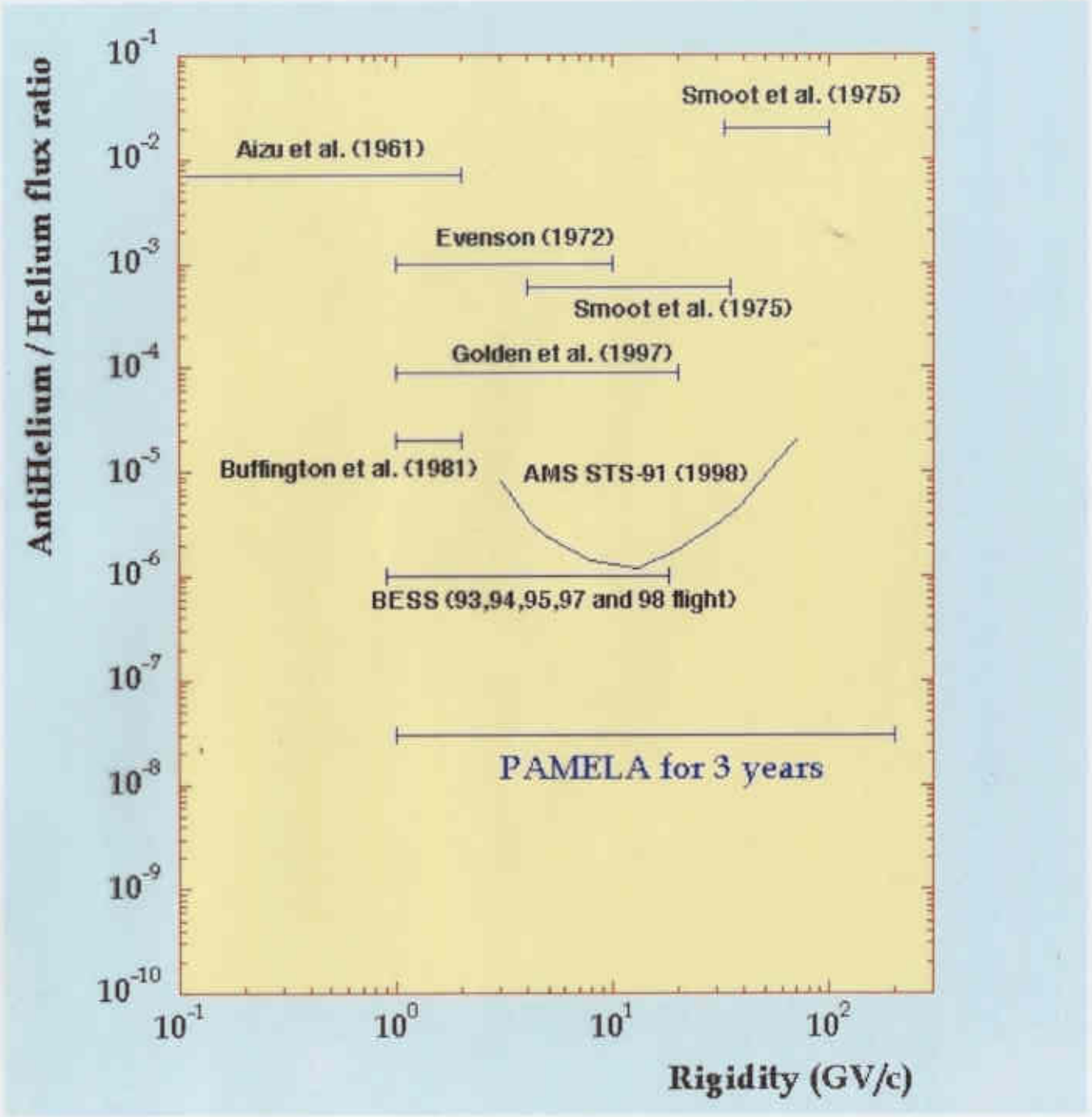
80 MeV → 190 GeV (anti-p) / 50 MeV → 270 GeV (e^+)

2 x 10^4 anti-p and 2 x 10^5 e^+ expected (2 years)

Also: H → C energy spectrum and search for anti-helium






AntiHelium / Helium flux ratio
Rigidity (GV/c)
Smoot et al. (1975)
Aizu et al. (1961)
Evenson (1972)
Smoot et al. (1975)
Golden et al. (1997)
Buffington et al. (1981)
AMS STS-91 (1998)
BESS (93,94,95,97 and 98 flight)
PAMELA for 3 years

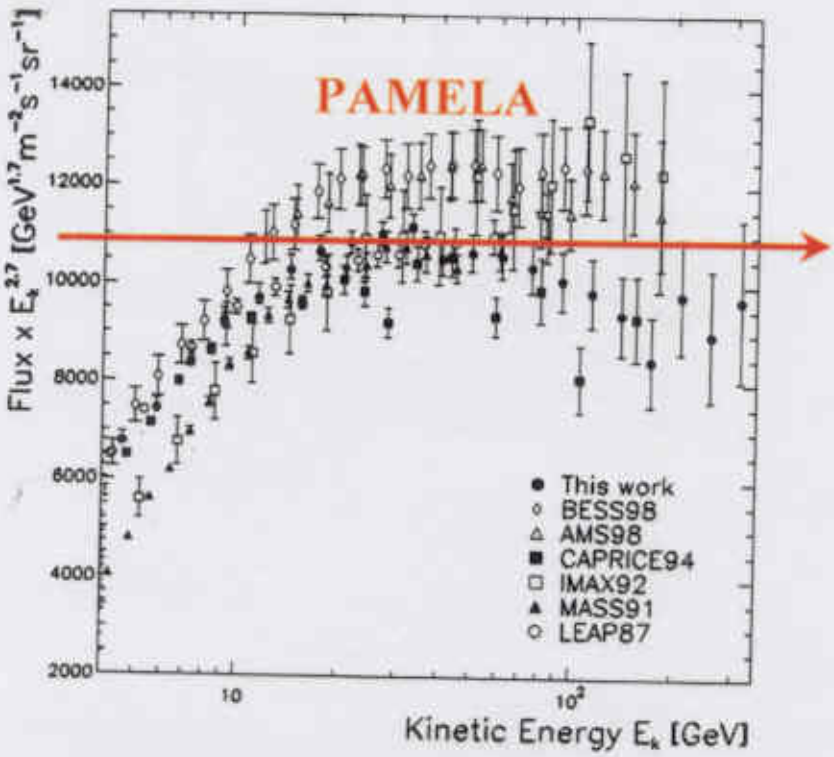
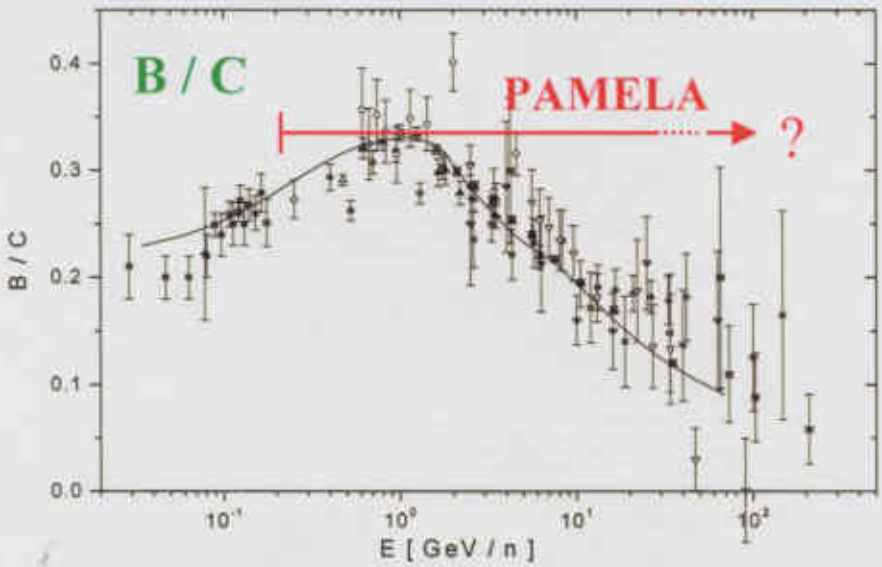
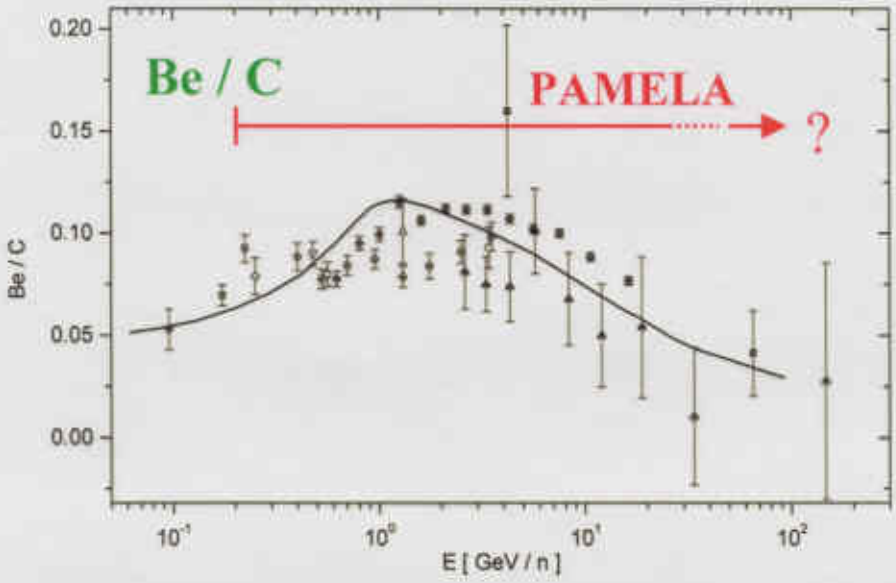
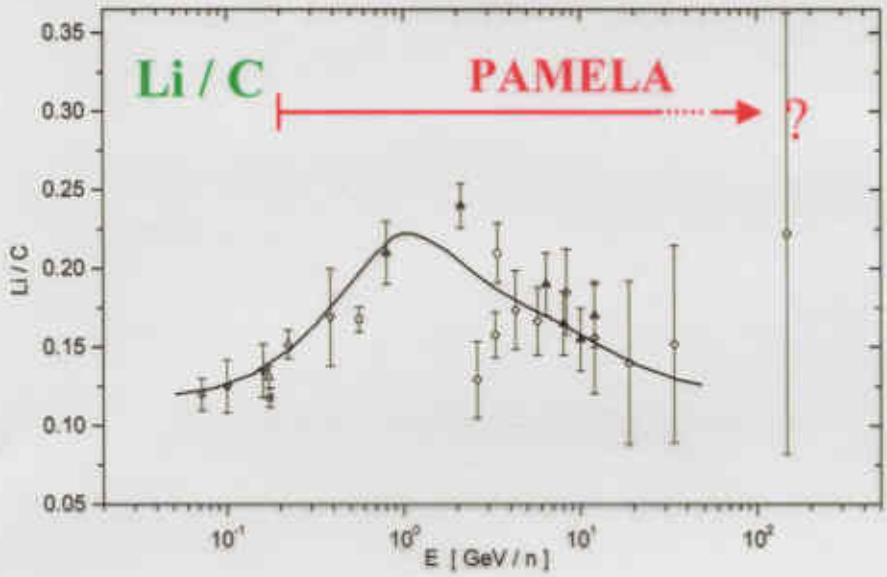


Fig. 3. The proton energy spectrum at the top of atmosphere detected by CAPRICE98. Results from other recent experiments are also shown (BESS98: Sanuki et al., 2000; AMS98: Alcaraz et al., 2000; CAPRICE94: Boezio et al., 1999b; IMAX92: Menn et al., 2000; MASS91: Bellotti et al., 1999; LEAP87: Seo et al., 1991).

The Current Situation on the Secondary / Primary Ratios







INFN Trieste

PAMELA (RIM-2)

An International Collaboration:

INFN Sections of Bari, Firenze, LNF, Rome 2 and Trieste, Italy
Royal Institute of Technology (KTH), Stockholm, Sweden
University of Siegen, Siegen, Germany
Tata Institute of Fundamental Research, Bombay, India
NASA/Goddard Space Flight Center, Greenbelt, USA
New Mexico State University, Las Cruces, USA
Electronic Engineering Department, University of Tor Vergata, Roma, Italy
Istituto di Ricerca Onde elettromagnetiche del CNR, Firenze, Italy
Lebedev Physics Institute, Russia
Ioffe Physical-Technical Institute, Russia
Moscow Engineering and Physics Institute, Moscow, Russia

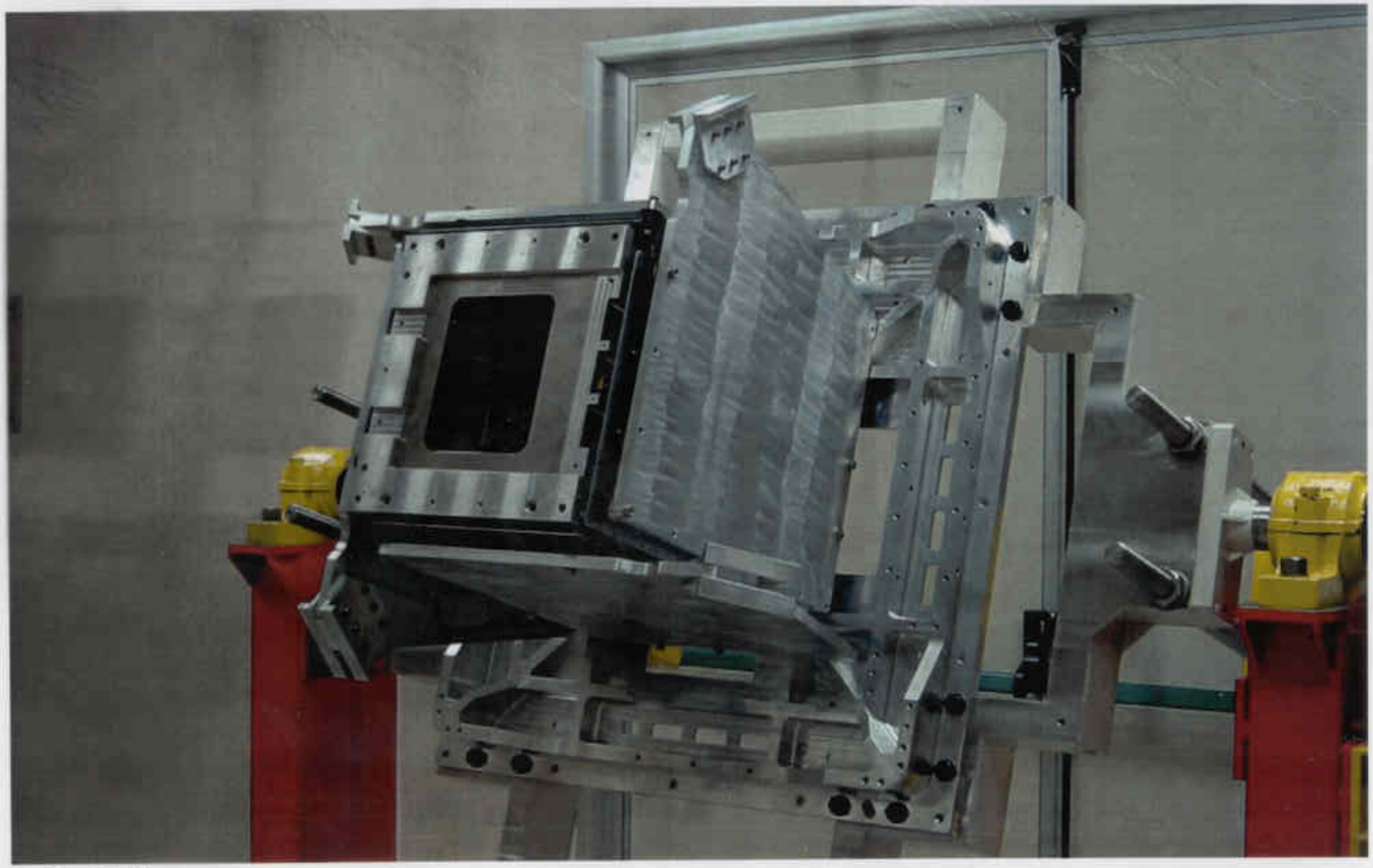








Mass and Thermal Model



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