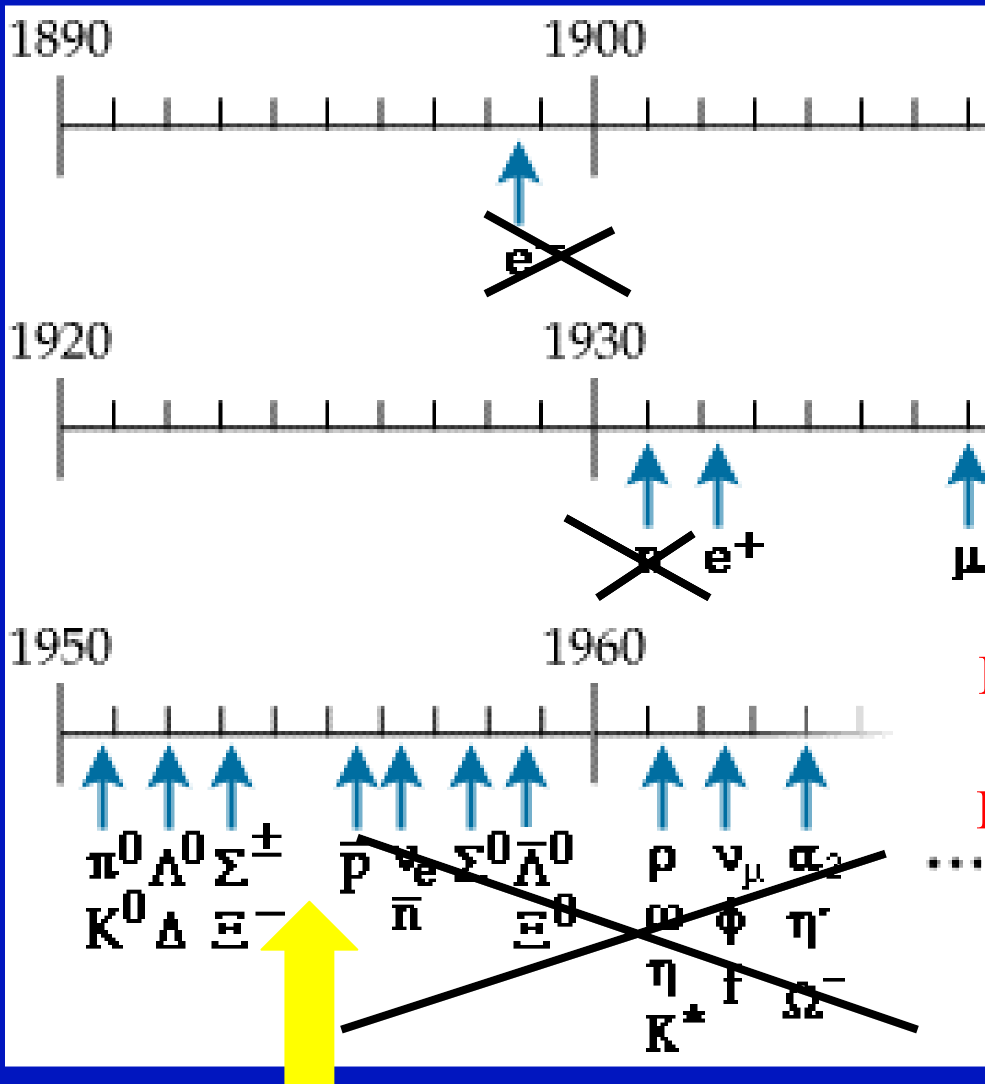
Astroparticle Physics from Space

Roberto Battiston
University and INFN of Perugia

Napoli
20 June 2002

Symposium on Cosmic Ray, 1939 (The University of Chicago, U.S.A.)

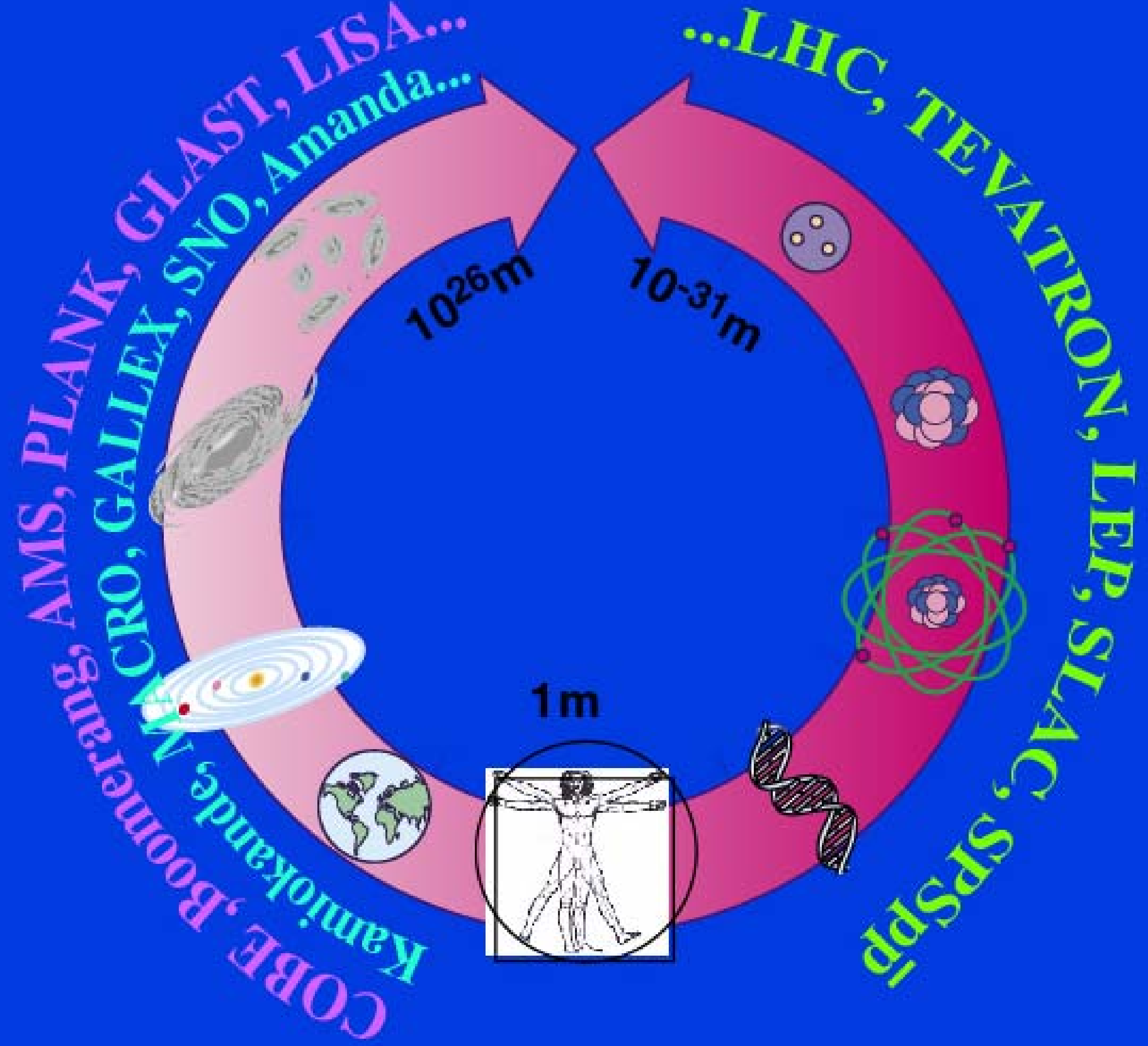
PARTICLE PHYSICS BIRTH WAS DUE TO COSMIC RAYS

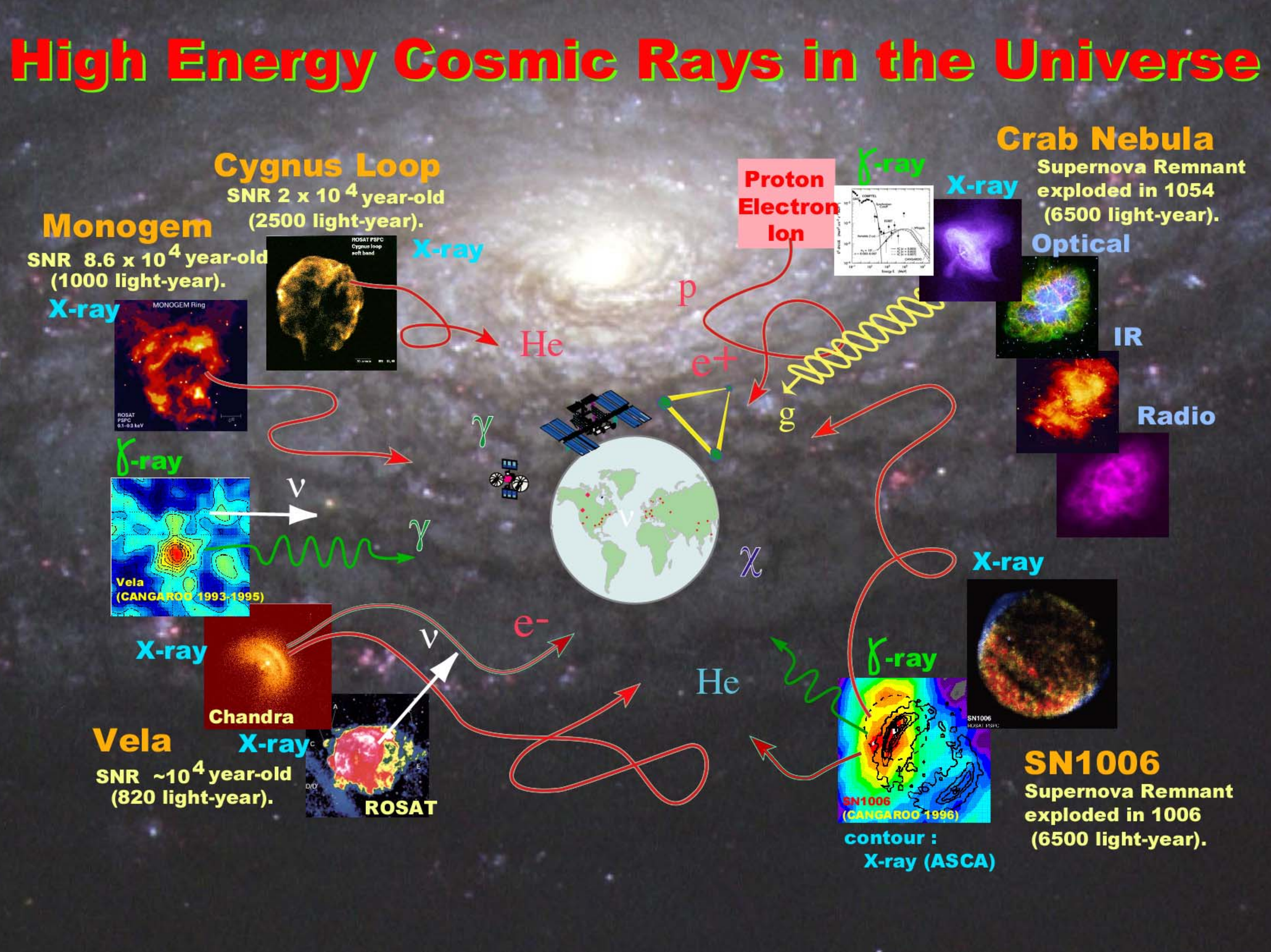


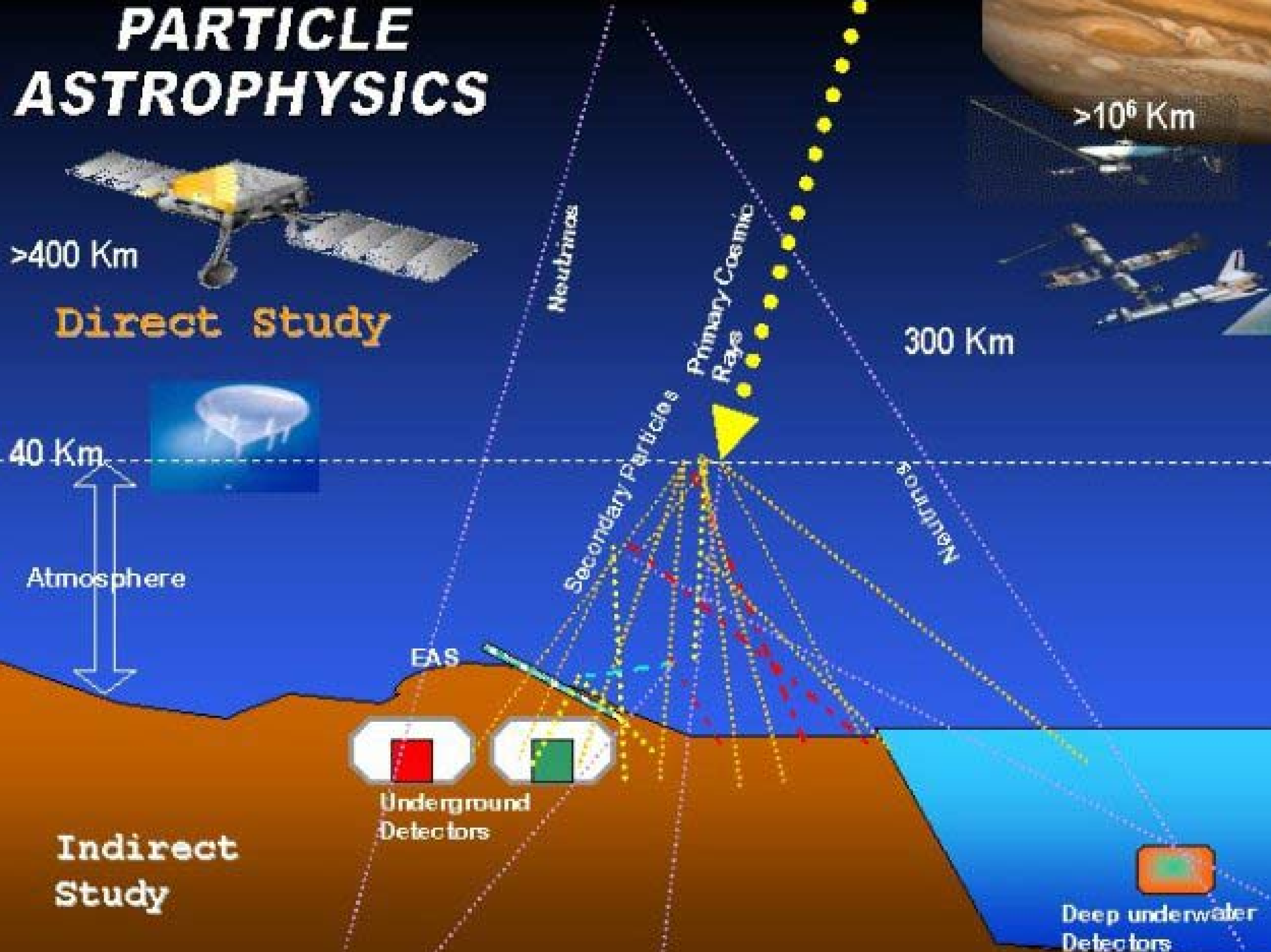
Hesse, Wulf, Wilson, Anderson,
Bothe, Kohlorster, Millikan,
Blackett, Skobeltsyn, Rochester,
Butler, Rossi, Pancini ,
Conversi, Powell, Occhialini
……

Advent of accelerators

Astro Particle Physics




High Energy Cosmic Rays in the Universe
Cygnus Loop
SNR 2 x 10 4 year-old
(2500 light-year).
ROSAT PSPC
Cygnus loop
soft band
X-ray
Monogem
SNR 8.6 x 10 4 year-old
(1000 light-year).
X-ray
MONOGEM Ring
ROSAT
PSPC
0.1-0.3 keV
He
p
Proton
Electron
Ion
γ-ray
X-ray
Crab Nebula
Supernova Remnant
exploded in 1054
(6500 light-year).
Optical
IR
Radio
e+
g
γ
γ-ray
ν
γ
Vela
(CANGAROO 1993-1995)
ν
χ
X-ray
e-
ν
He
X-ray
Chandra
Vela
SNR ~10 4 year-old
(820 light-year).
X-ray
ROSAT
γ-ray
SN1006
ROSAT PSPC
SN1006
(CANGAROO 1996)
contour :
X-ray (ASCA)
SN1006
Supernova Remnant
exploded in 1006
(6500 light-year).



PARTICLE ASTROPHYSICS
>10^6 Km
>400 Km
Direct Study
Neutrinos
Primary Cosmic Rays
300 Km
Secondary Particles
40 Km
Neutrinos
Atmosphere
EAS
Underground Detectors
Indirect Study
Deep underwater Detectors

Part A Calibrating nature's beam *(the real facts)*

Existing and future measurement of the hadronic CR component
Atmospheric neutrinos calculations

Part B Search for new particles *(hopes & dreams)*

Anti-matter search

Dark matter searches
Anti-protons
Anti-deuterons
Electrons/positrons
Gamma rays

Ultraheavy particle searches
EEHCR
Neutrinos

Part A

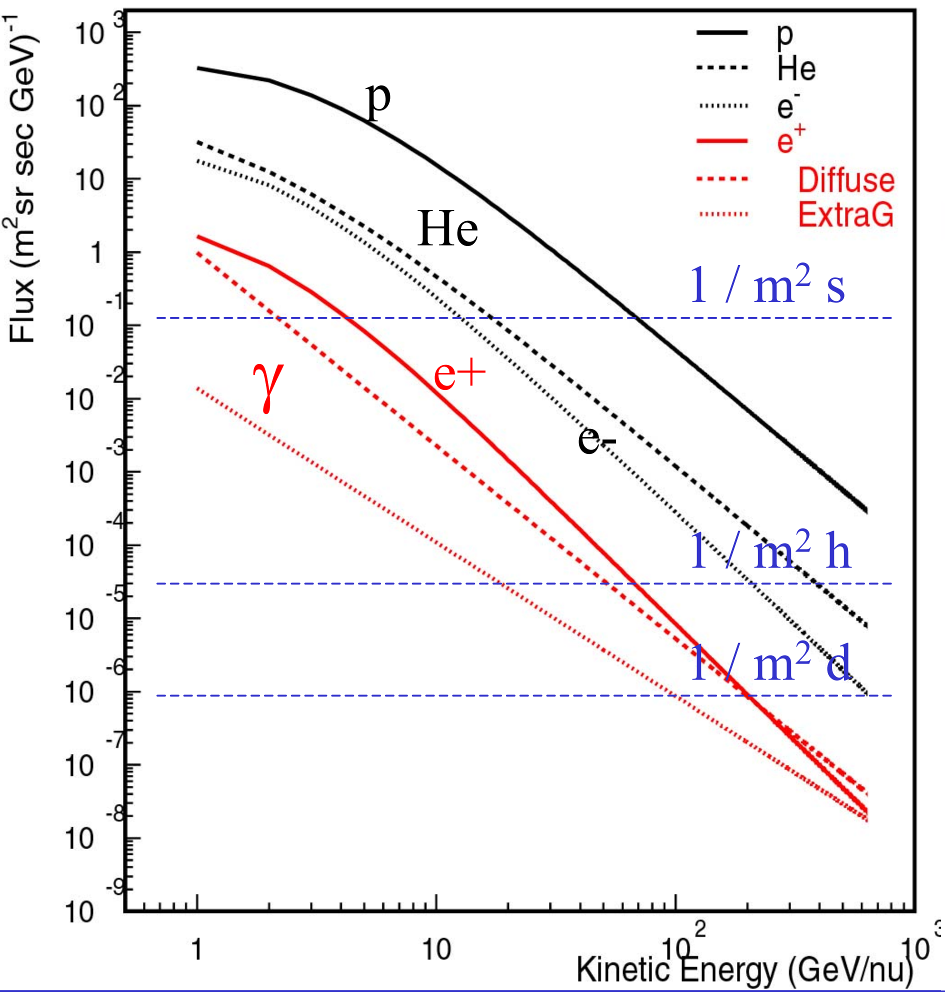
Calibrating Nature's Beam

Hadrons

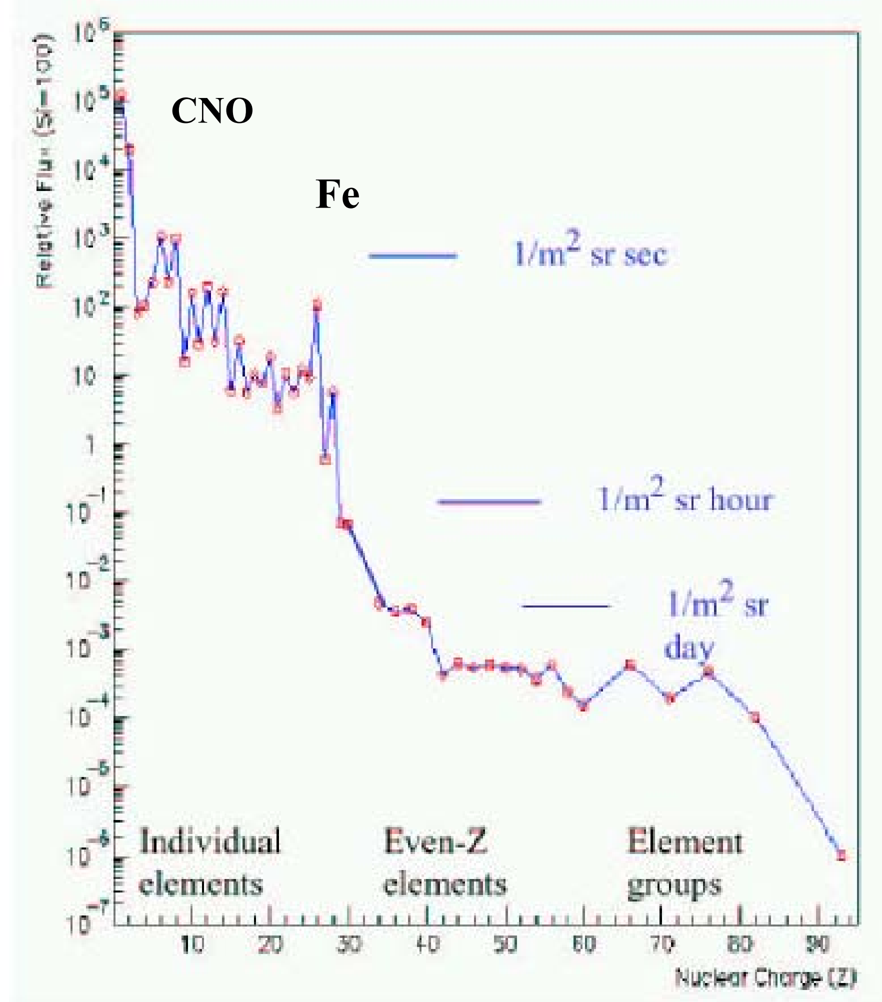
- Main components of Cosmic Rays (CR)
- Precise measurement of their abundances and spectra reveal
    - Source composition
    - Acceleration mechanisms ←→ Propagation models
    - Interaction with the ISM
- Background for searches of exotic CR. In order to search for very rare events the CR background should be known very precisely
- Input for atmospheric neutrino calculations

High Energy Cosmic Rays composition

Particle composition

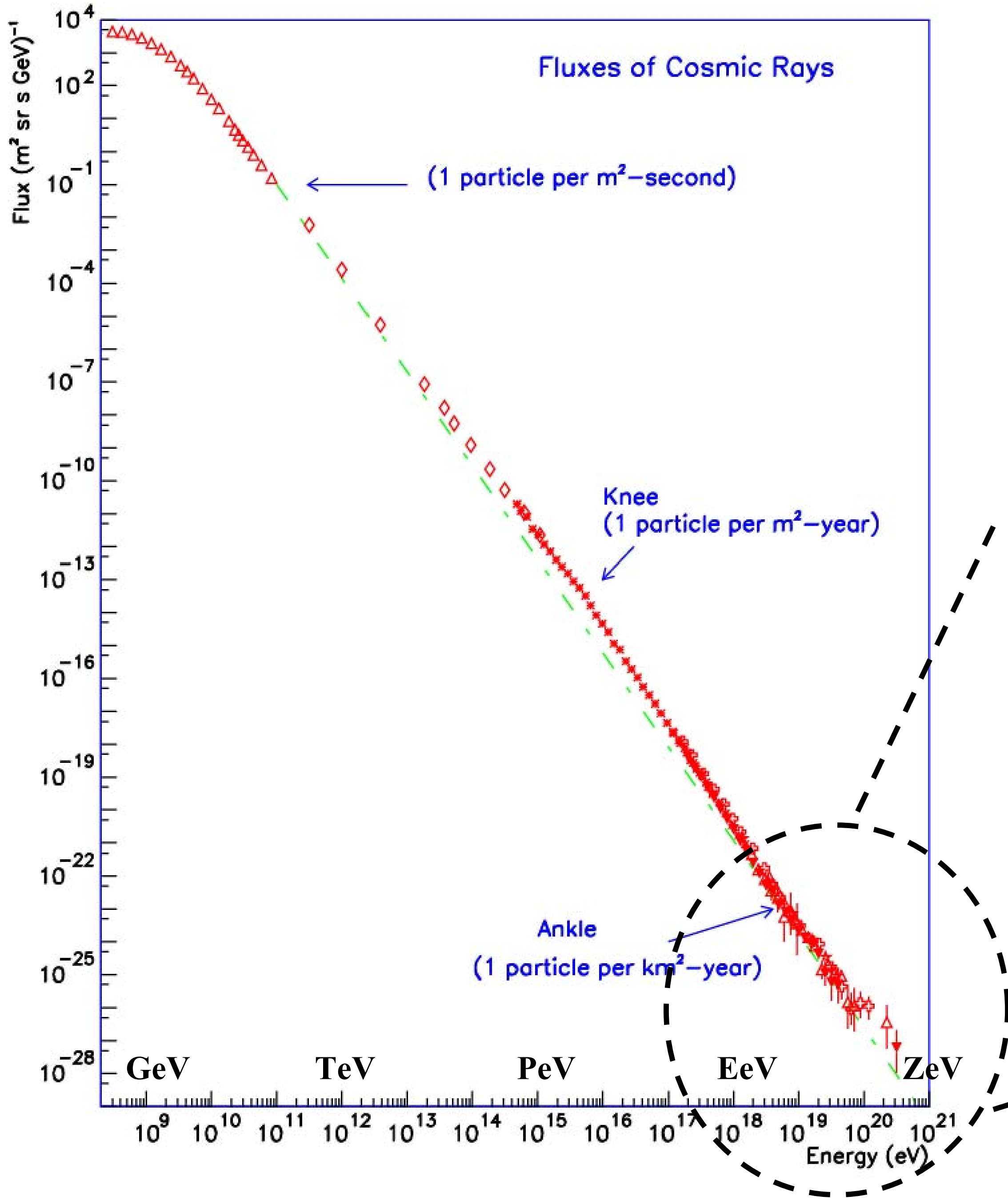


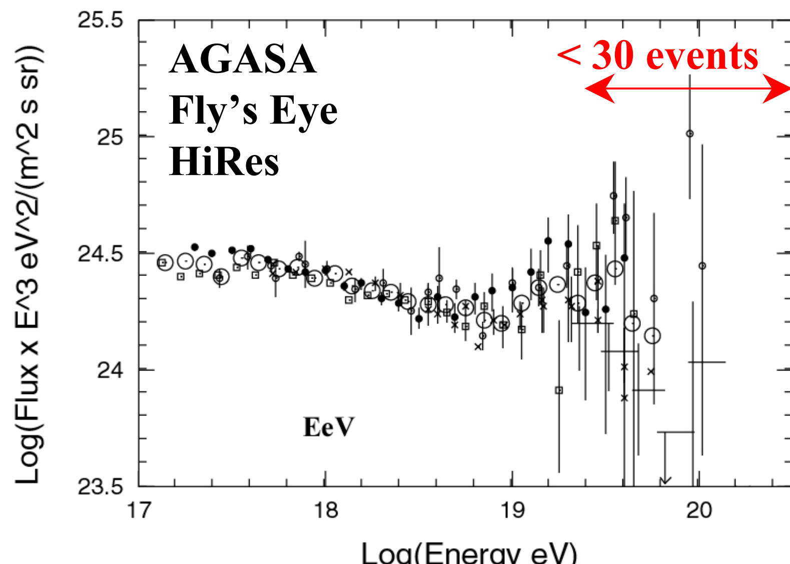
Elemental composition



CR spectrum

....charged....

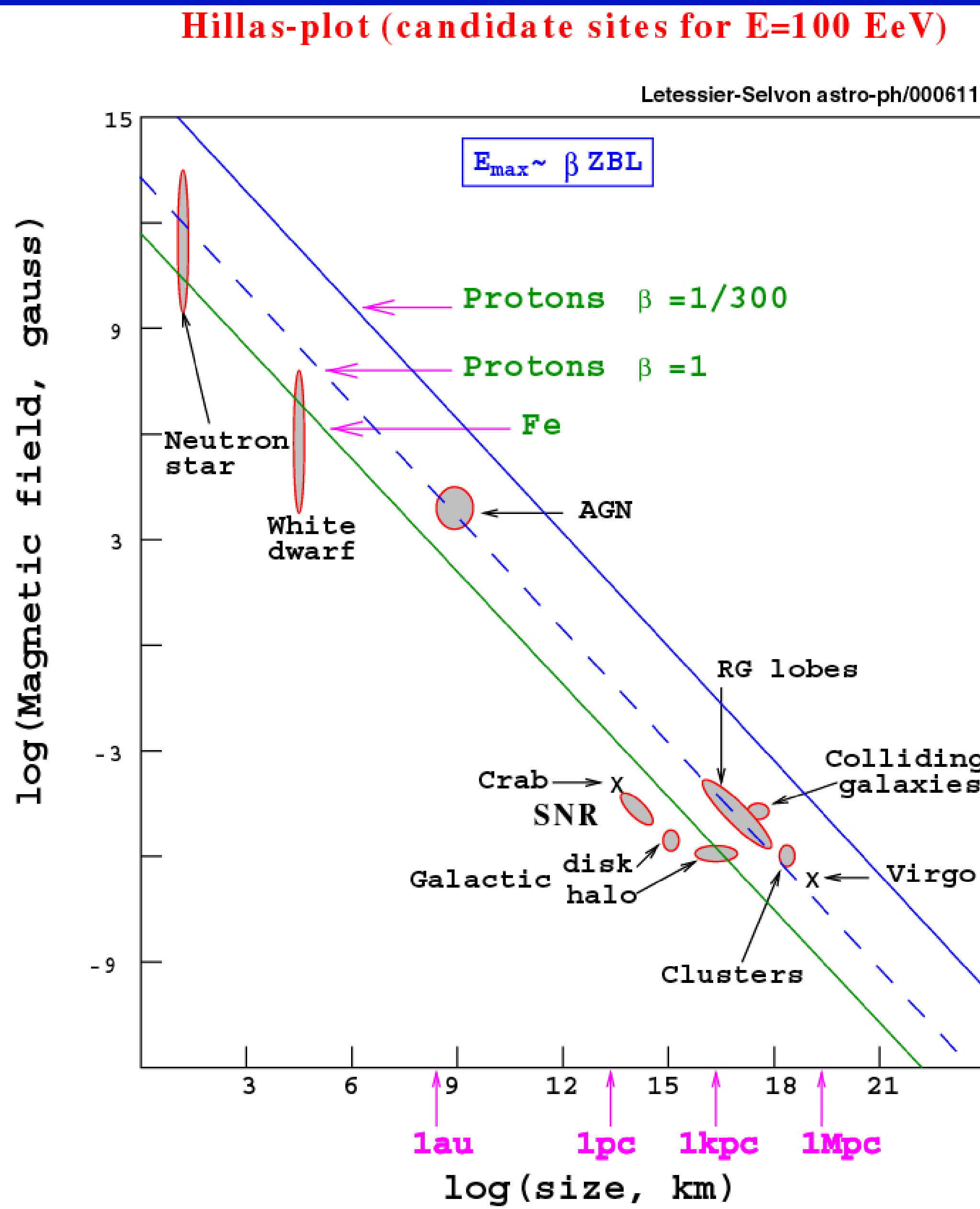




Where HE CR comes from?

Acceleration mechanism: particles bounces in magnetic field shock waves (Fermi....)

However at Extreme Energies this does not work

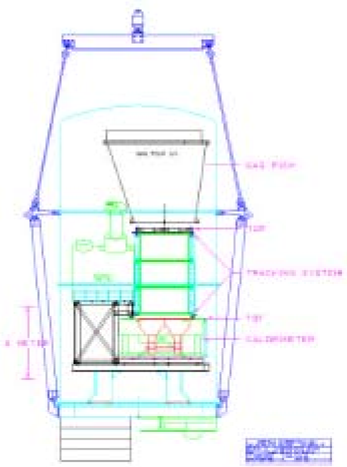


Size and magnetic field strength of possible acceleration sites. Objects below the diagonal lines cannot accelerate the corresponding elements (Iron with β = 1 or protons β = 1 and β = 1/300) above 10^{20}eV

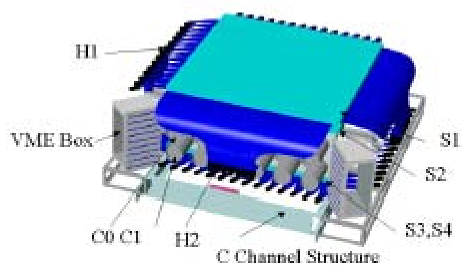
Balloons

- Magnetic Spectrometers (R,β,Z)
- Charge Identifiers (Z,β)
- Emulsion Chambers (E,Z)

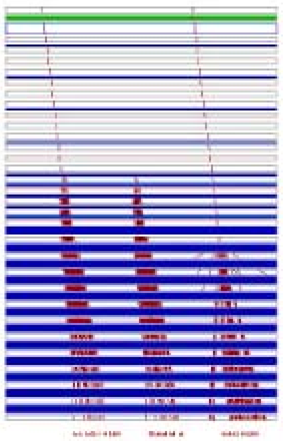
CAPRICE



TIGER



JACEE

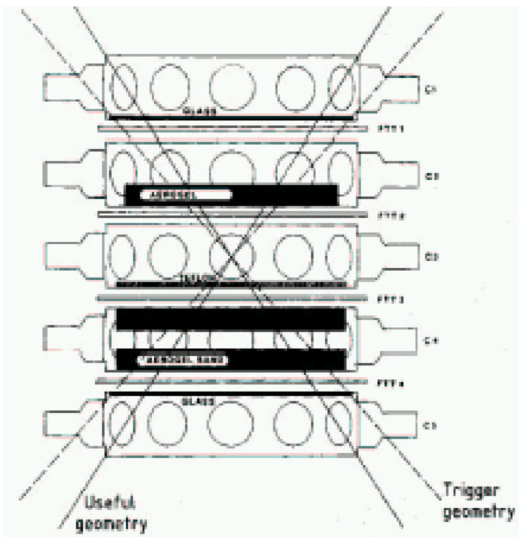


..for nearly 40 years sources of most data on CR

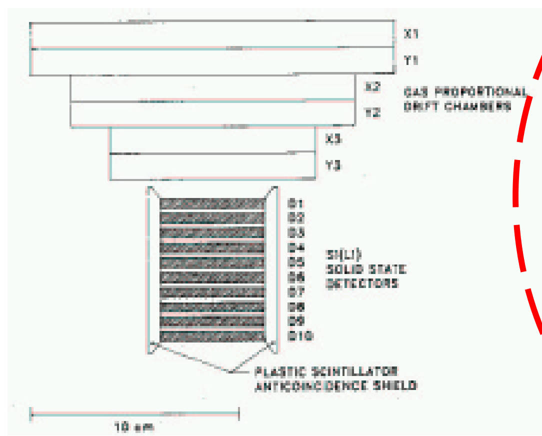
Space Borne

- Double Cerenkov (Z,β)
- Multiple dE/dx $\oplus$ Total E (Z^2M)
- Magnetic Spectrometers (R,β,Z)

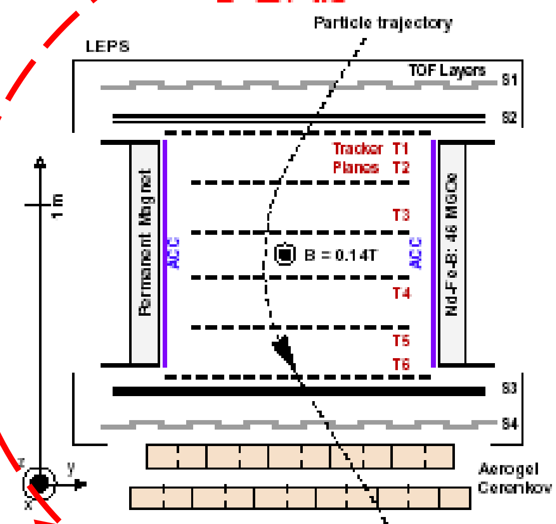
HEAO-3



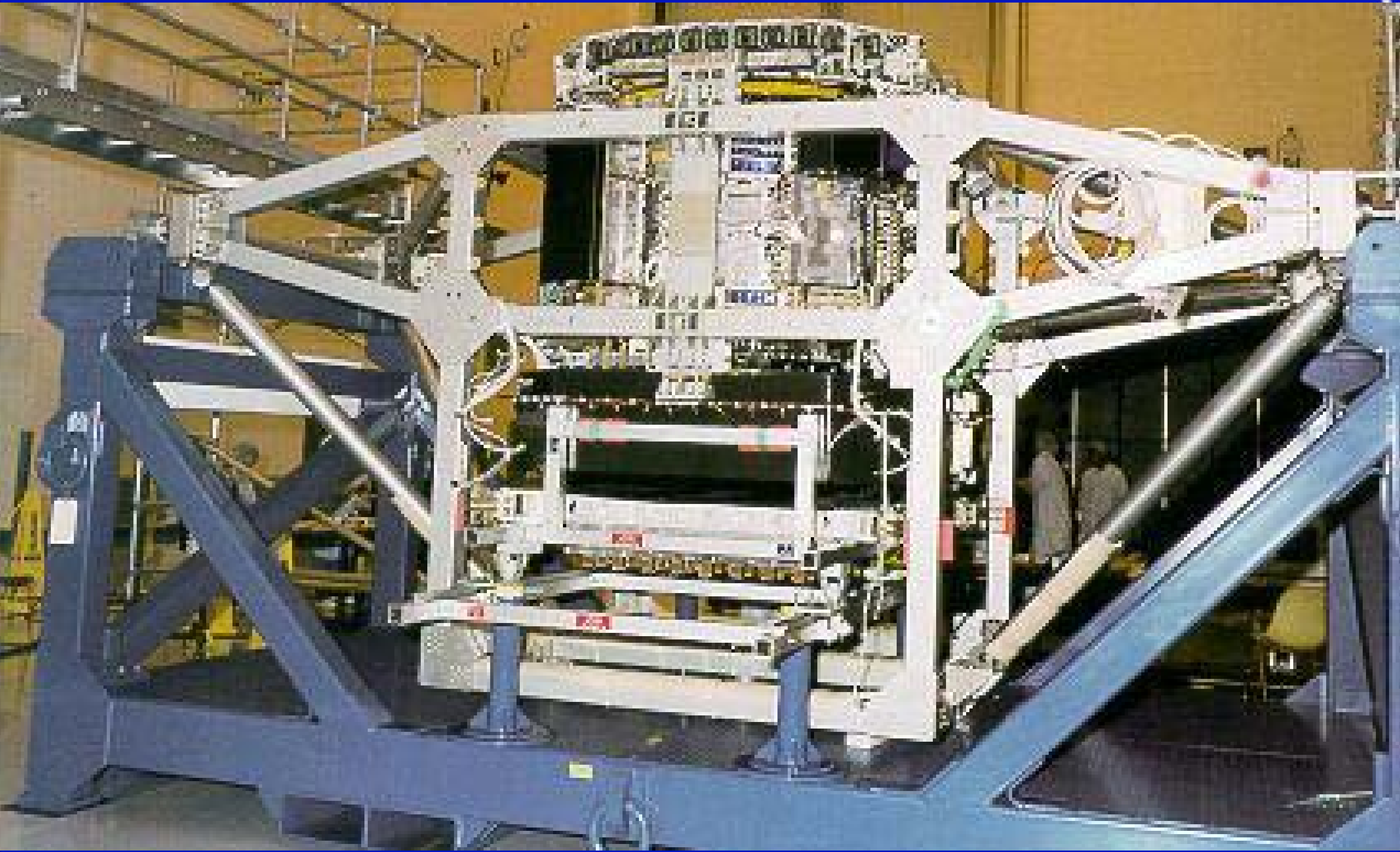
ISEE-3



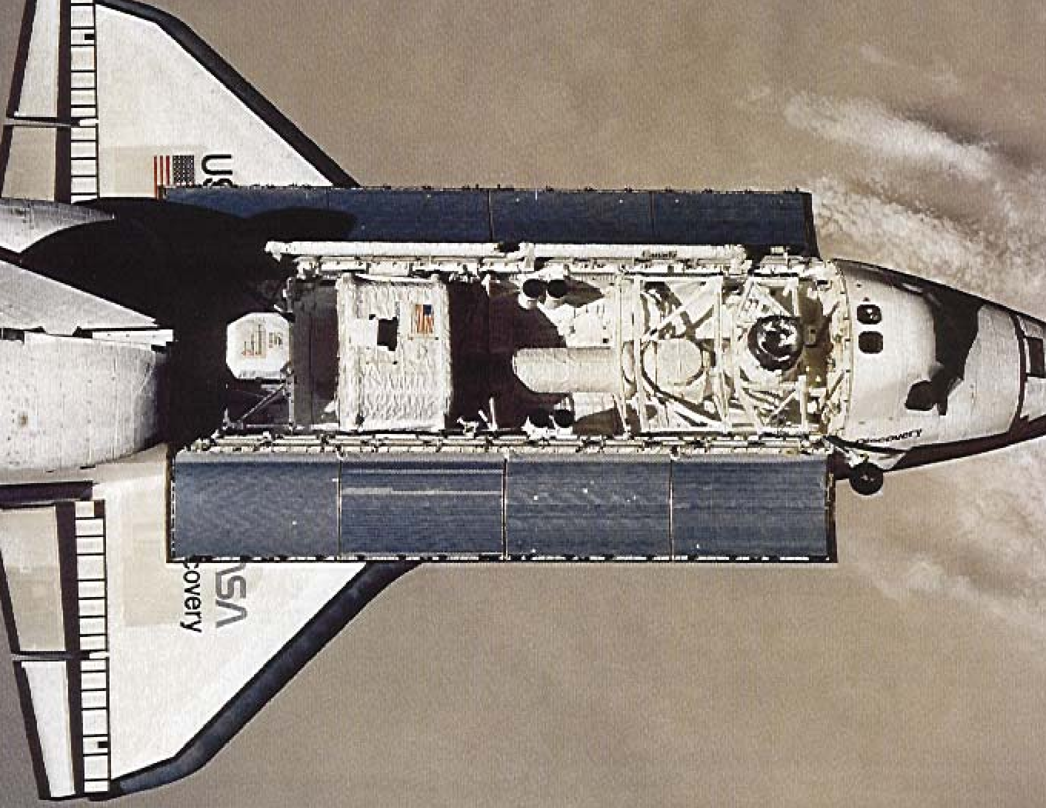
AMS



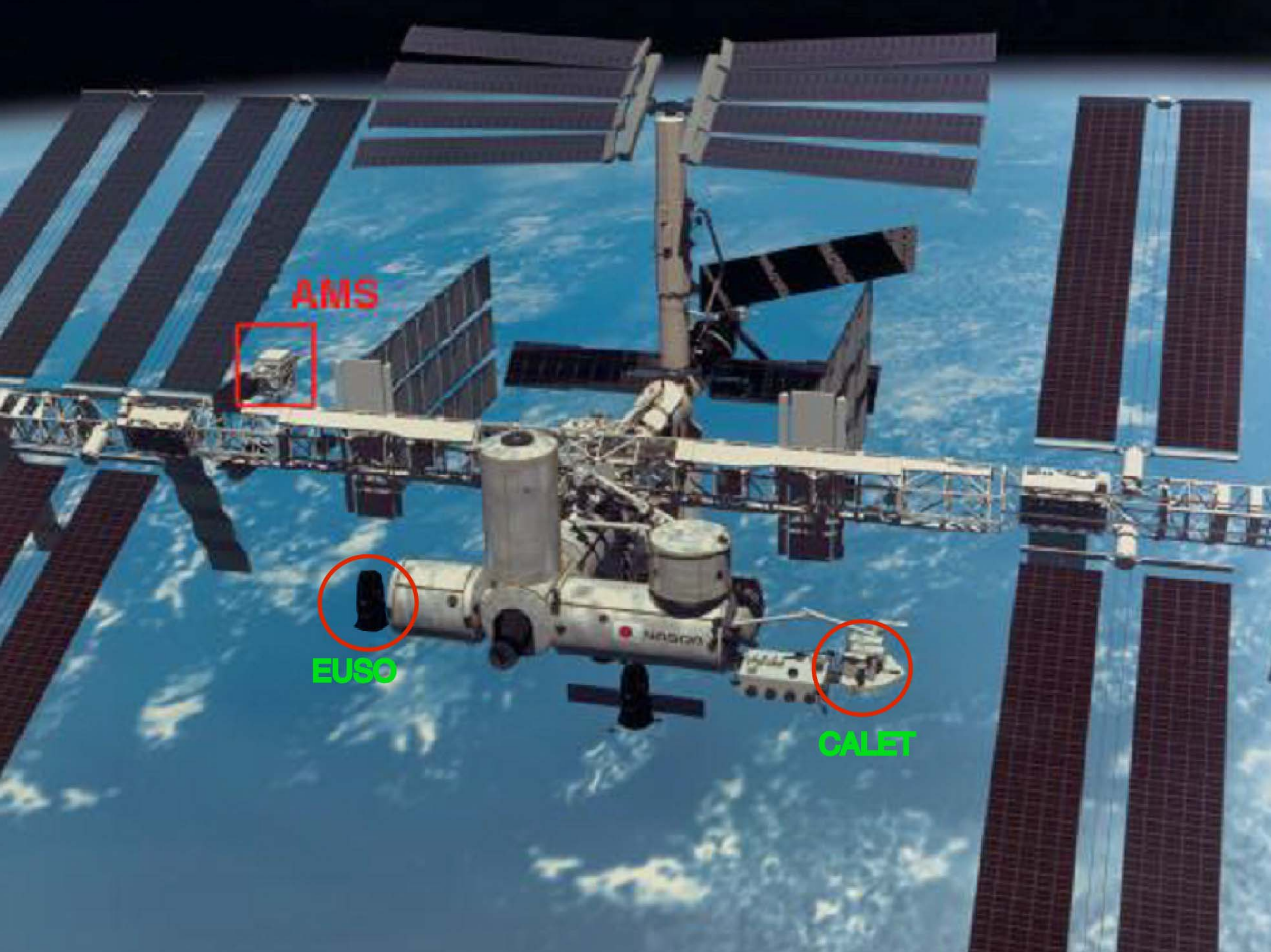
.....in the last years sources of most precise CR data

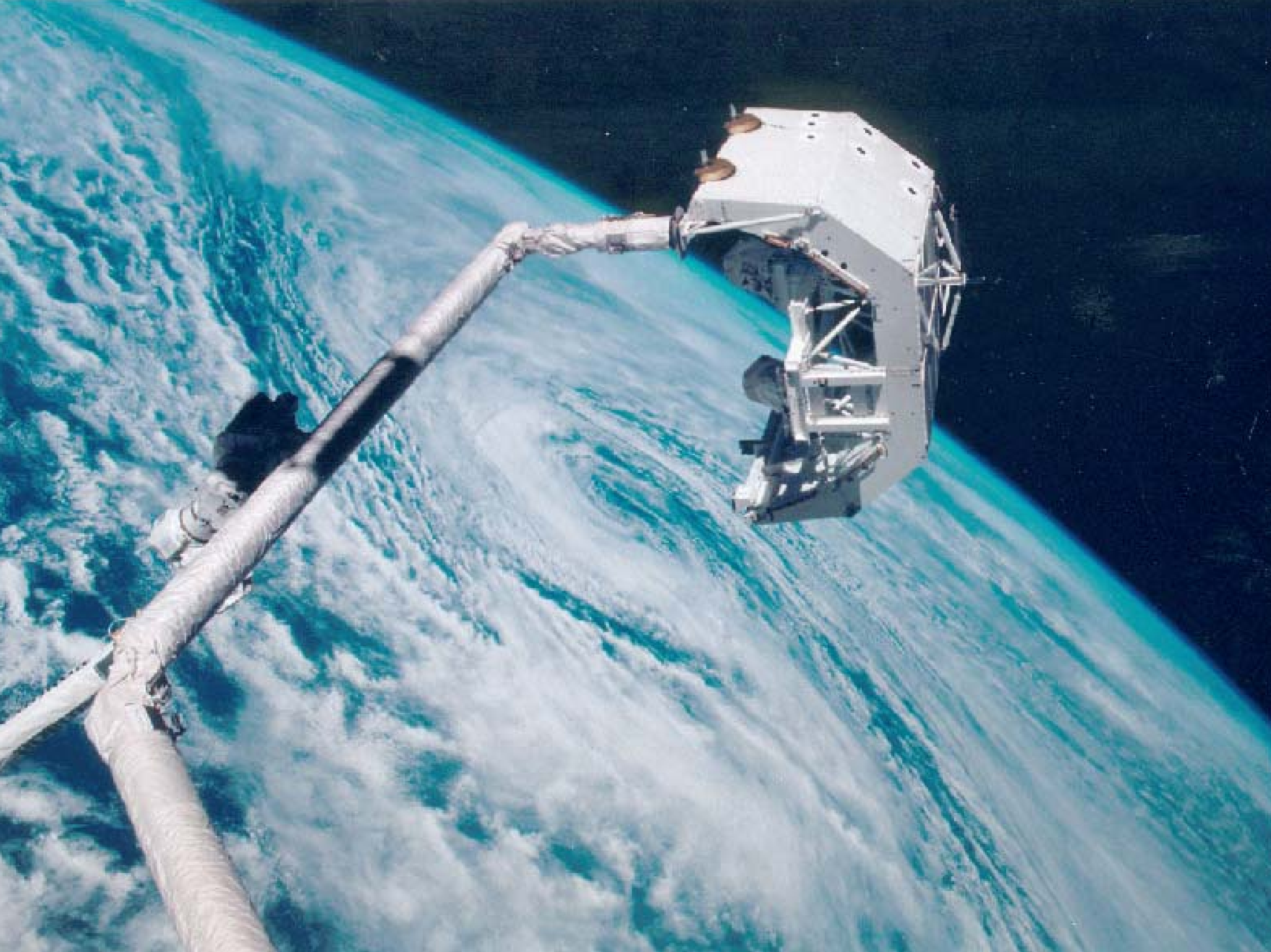


AMS at JSC before the installation on the Shuttle (1998)

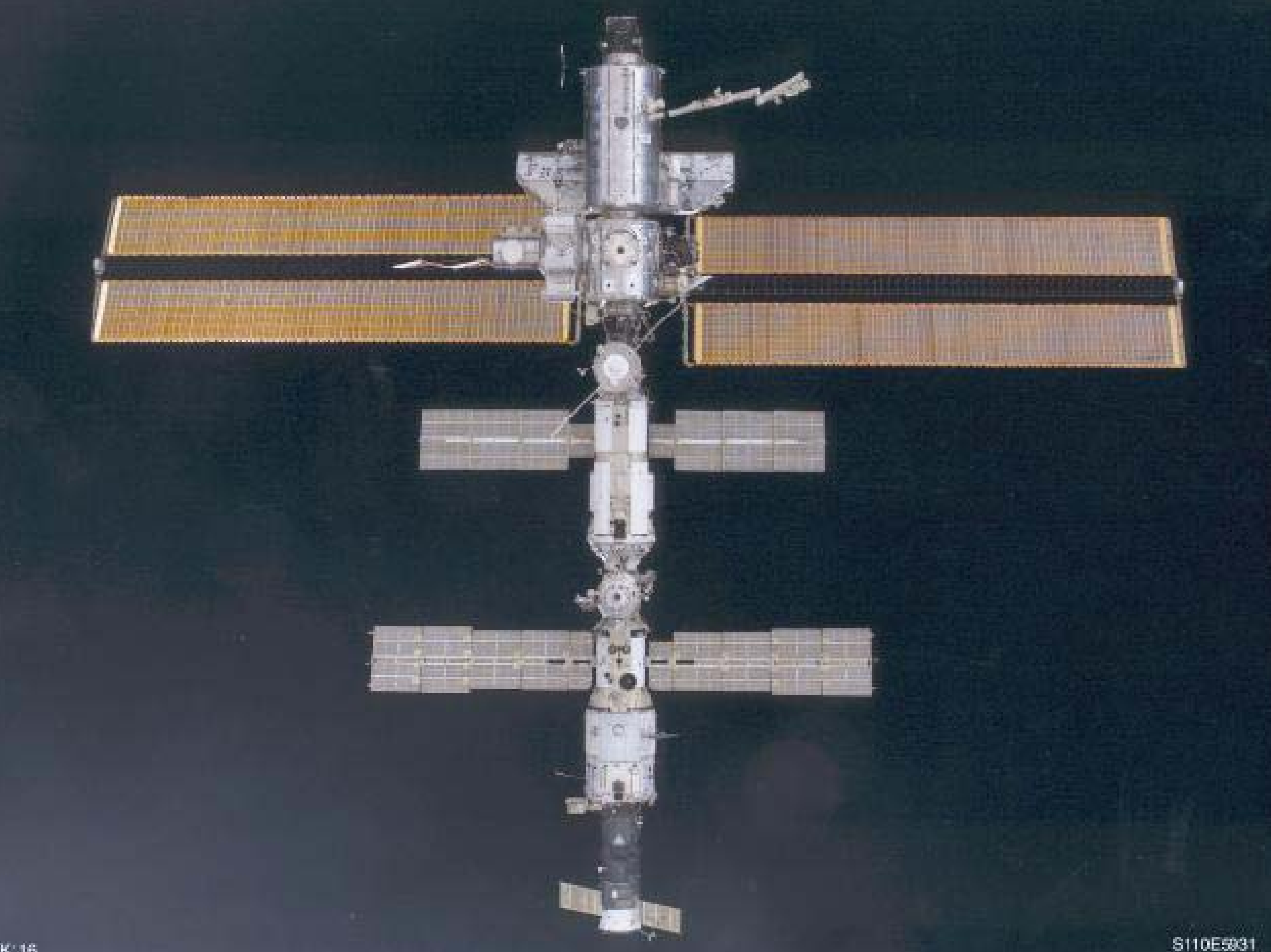


STS 91 Flight, June 1998


AMS
EUSO
CALET




117
S:10E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SUPPLY CROSSOVER
SHUTOFF VALVE
OPEN
INFN

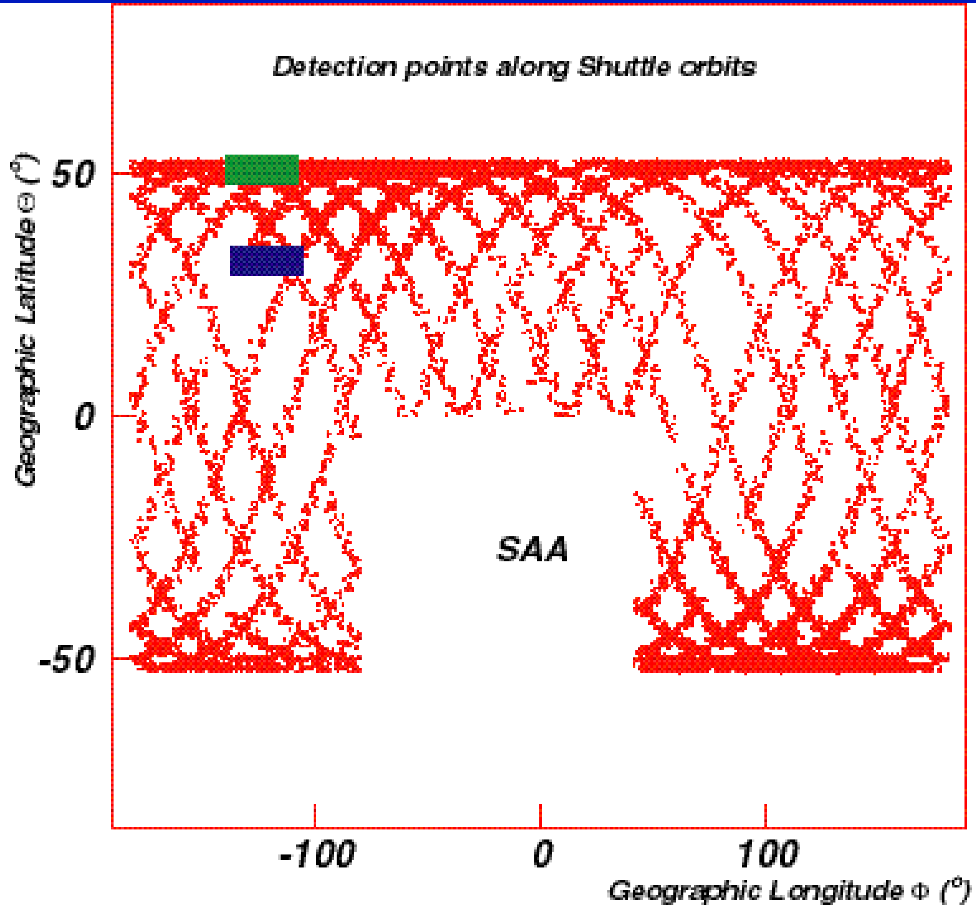
	BALLOONS	SPACE-BORNE
Geometrical Acceptance	√	√
Flight Duration	√	√
Measurement Redundancy	√	√
Atmospheric Corrections	√	√
Detector Accessibility	√	√
Flight Control	√	√
Price	√	√

⇒ New Experiments:

Acceptance & Duration

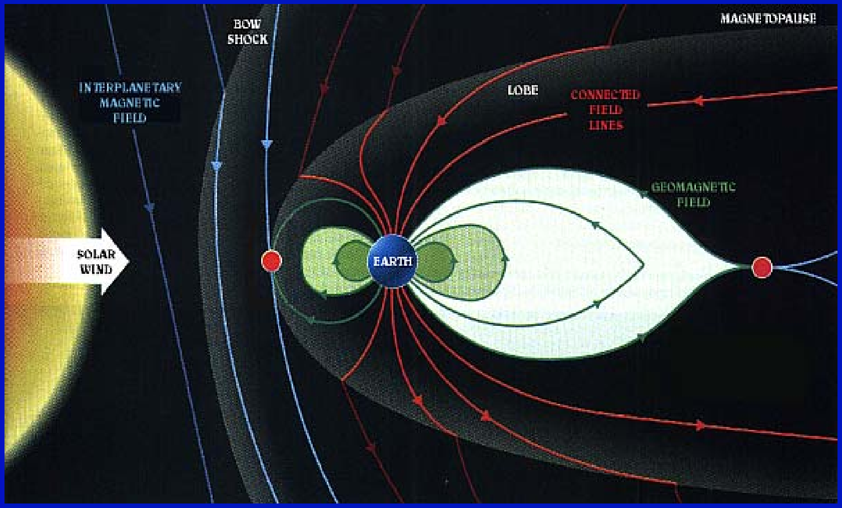
...in the future only space borne or long duration balloons

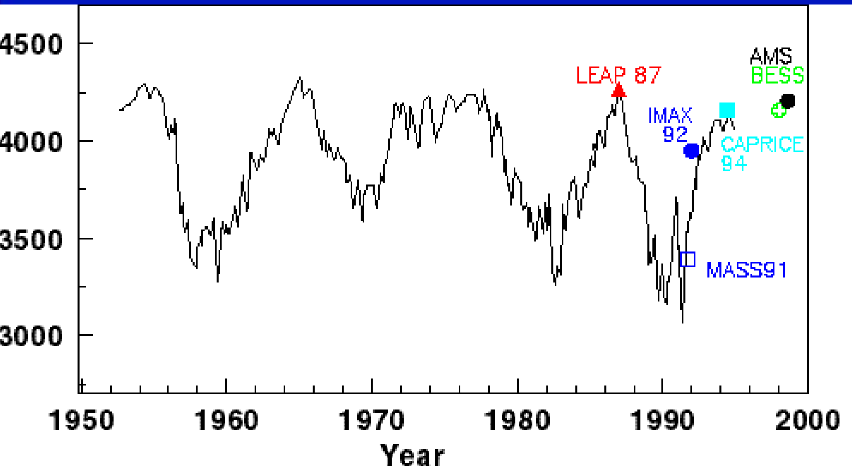
Geographical coverage much better for satellites

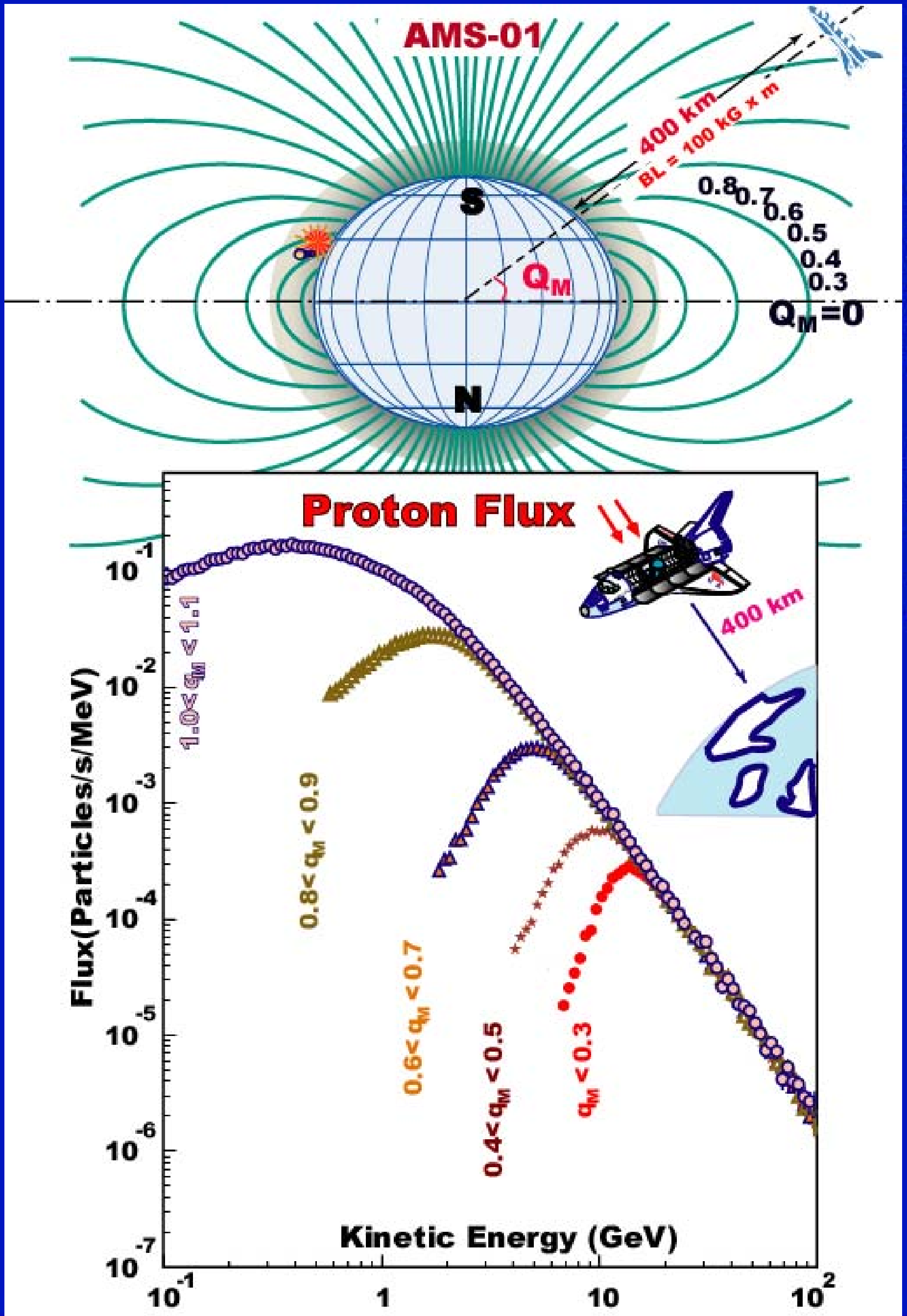


	Cutoffs(GV)	Latitudes	Longitudes
AMS		+/- 51.7	all (SAA excluded)
BESS98	<0.5		(Lynn Lake - Canada)
CAPRICE94		+56.5 N	101-117 W (Lynn Lake - Canada)
MASS91	4.3	+34 N	104 W (Forth Sumner)
IMAX92	0.37-0.63	+56.5 N	101-118 W (Lynn Lake - Canada
LEAP87	0.6-1.1	n.a.	n.a. (Prince Albert - Canada

Sun **Magnetosphere effects** Earth







At low energy (below cutoff, up to R ~ 15 GeV) latitude dependence and solar modulation influence the spectra

At high energy (above R~ 20 GeV) the measurement of the primary flux should give the same result in experiments performed at similar solar activities (LEAP, IMAX, CAPRICE, BESS, AMS)

Roberto Battiston CERN-ESA-ESO Workshop 2002

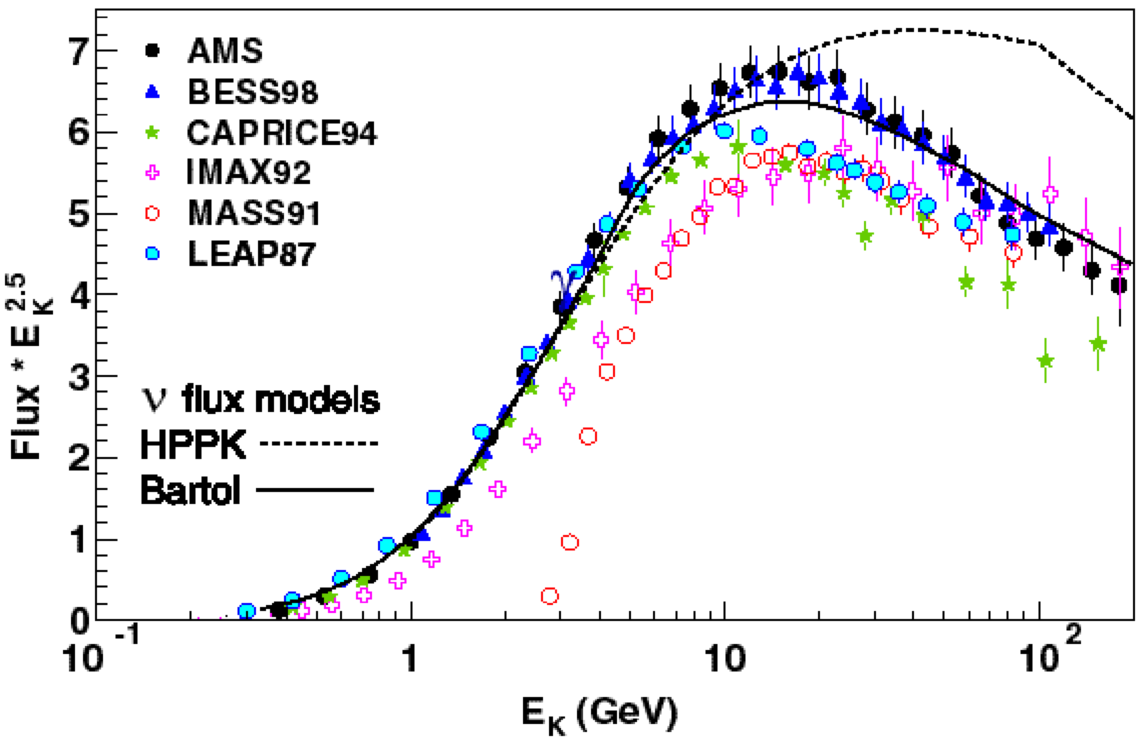
AMS STS91 Mission - June 1998 Science Results

Proton Spectra(1)

AMS Data Fit to Φ_o/R^{γ} for 10GV < R < 200GV :

$\gamma = 2.78 \pm 0.009(\text{fit}) \pm 0.019(\text{sys})$

$\Phi_o = 17.1 \pm 0.15\ (\text{fit}) \pm 1.3\ (\text{sys}) \pm 1.5(\gamma)\ \text{GV}^{2.78}/(\text{m}^2\ \text{s}\ \text{sr}\ \text{MeV})$



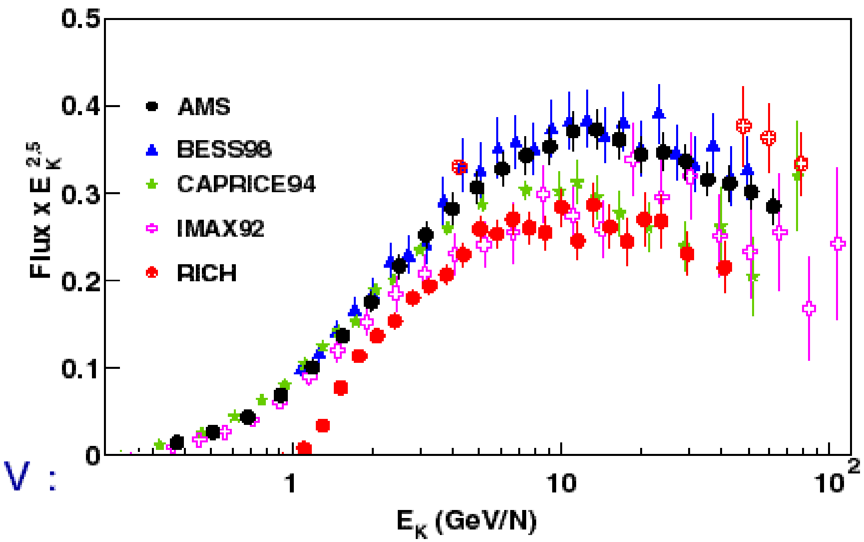
AMS STS91 Mission
June 1998
Science Results

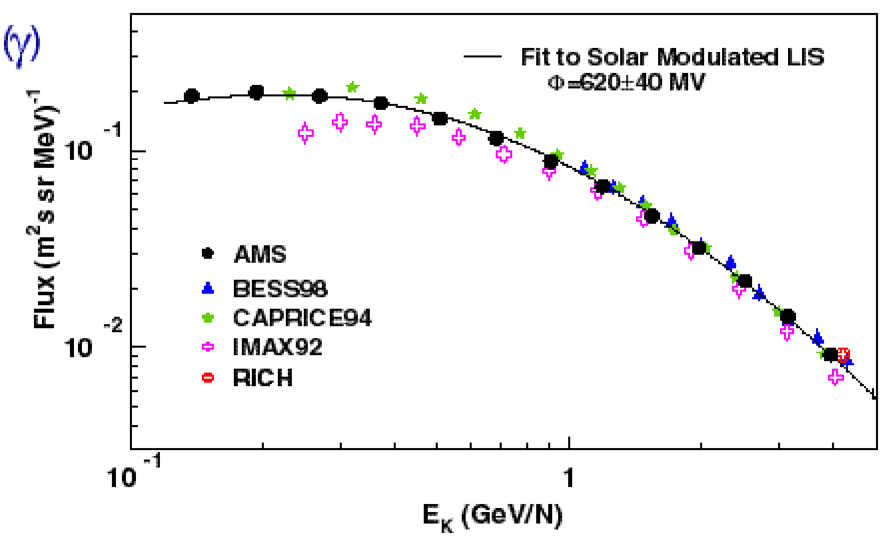
Helium spectra

AMS Data Fit to Φ_o/R for $R:[20,200]$ GV :

$\gamma = 2.740 \pm 0.010\,(\text{fit}) \pm 0.016\,(\text{sys})$

$\Phi_o = 2.52 \pm 0.09\,(\text{fit}) \pm 0.13\,(\text{sys}) \pm 0.14\,(\gamma)\ \frac{\text{GV}^{2.74}}{\text{m}^2\ \text{s sr MeV}}$

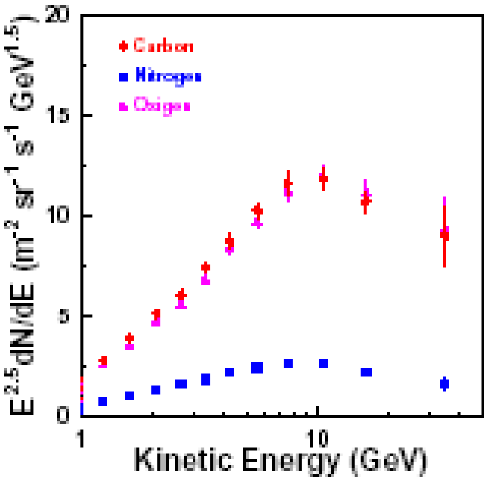




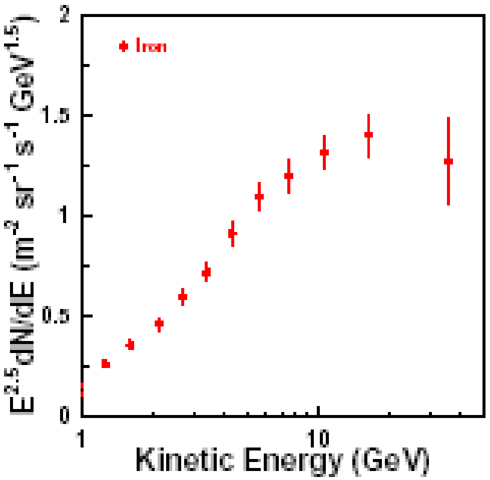
Z>2 particles

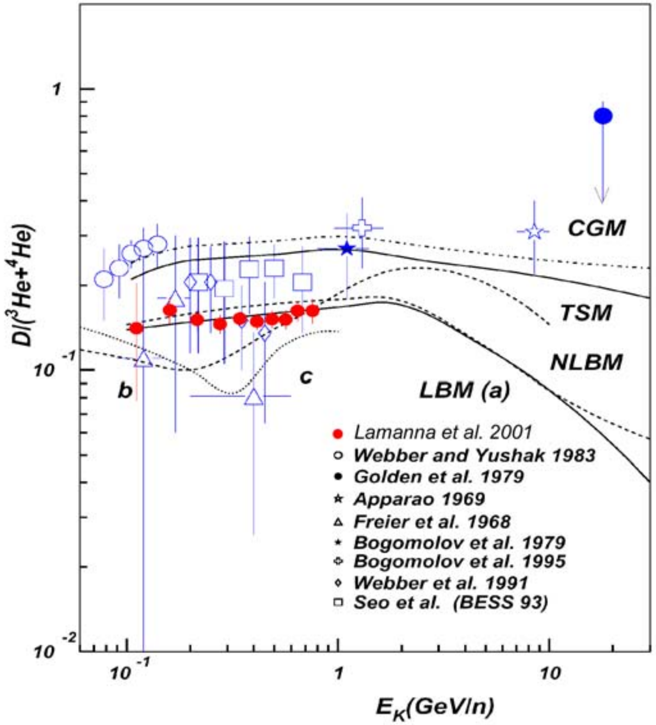
- Most precise measurements from HEAO-3
- Operated for 8 months in 1979 - 1980
- 7 million events with $4 \leq Z \leq 28$
- Charge resolution 0.12 - 0.2 units
- Absolute fluxes from 0.6 to 35 GeV/n
- Systematic Errors $\sim$ 5%

C N O



Fe

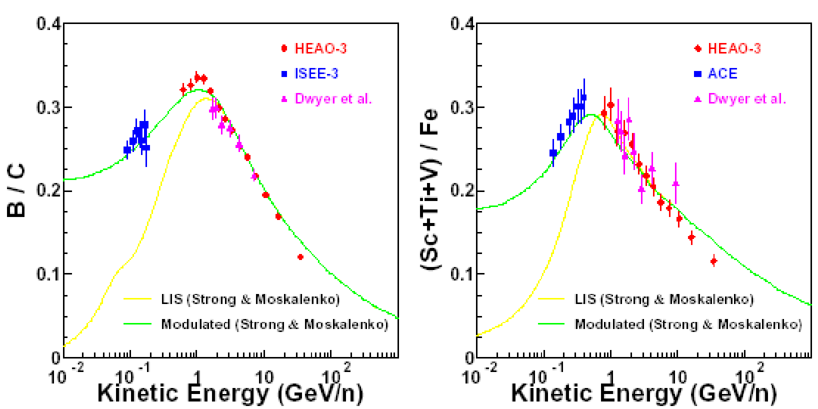




Deuterium and Higher Z nuclei are important to understand propagation effects (spallation)

- B/C and sub(Fe)/Fe measured for 0.1 GeV/n $\lesssim E \leq 35$ GeV/n
- Precision of $\sim 5\%$ for B/C and $\sim 10\%$ for sub(Fe)/Fe
- Data consistent with 9 g cm^{-2} crossed by primary CR

B/C (Sc+Ti+V)/Fe



Testing the trapping time in our galaxy

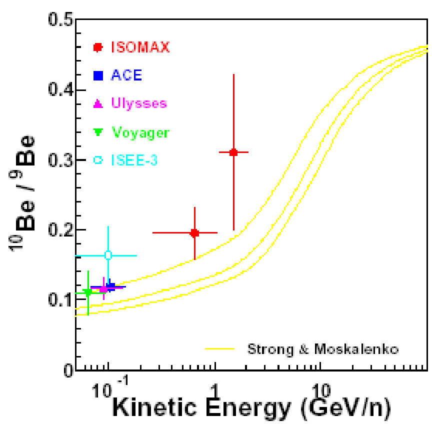
- Radioactive nuclei ≡ *CR Chronometers*
- ^{10}Be ($t_{1/2}$ = 1.51 Myr)
  ^{26}Al ($t_{1/2}$ = 4.08 Myr)
- Measurements in space

  $$E \approx 100\ \mathrm{MeV/n}$$

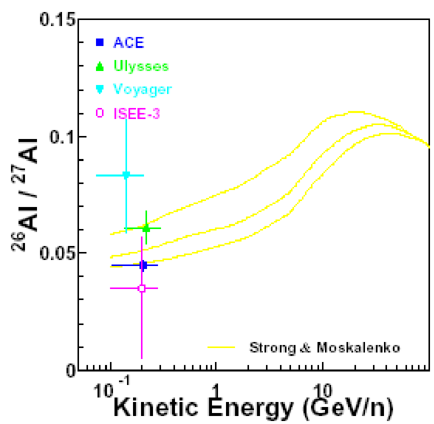
- Balloon measurement

  $$0.3\ \mathrm{GeV/n} \lesssim E \lesssim 2\ \mathrm{GeV/n}$$

$^{10}Be/^{9}Be$

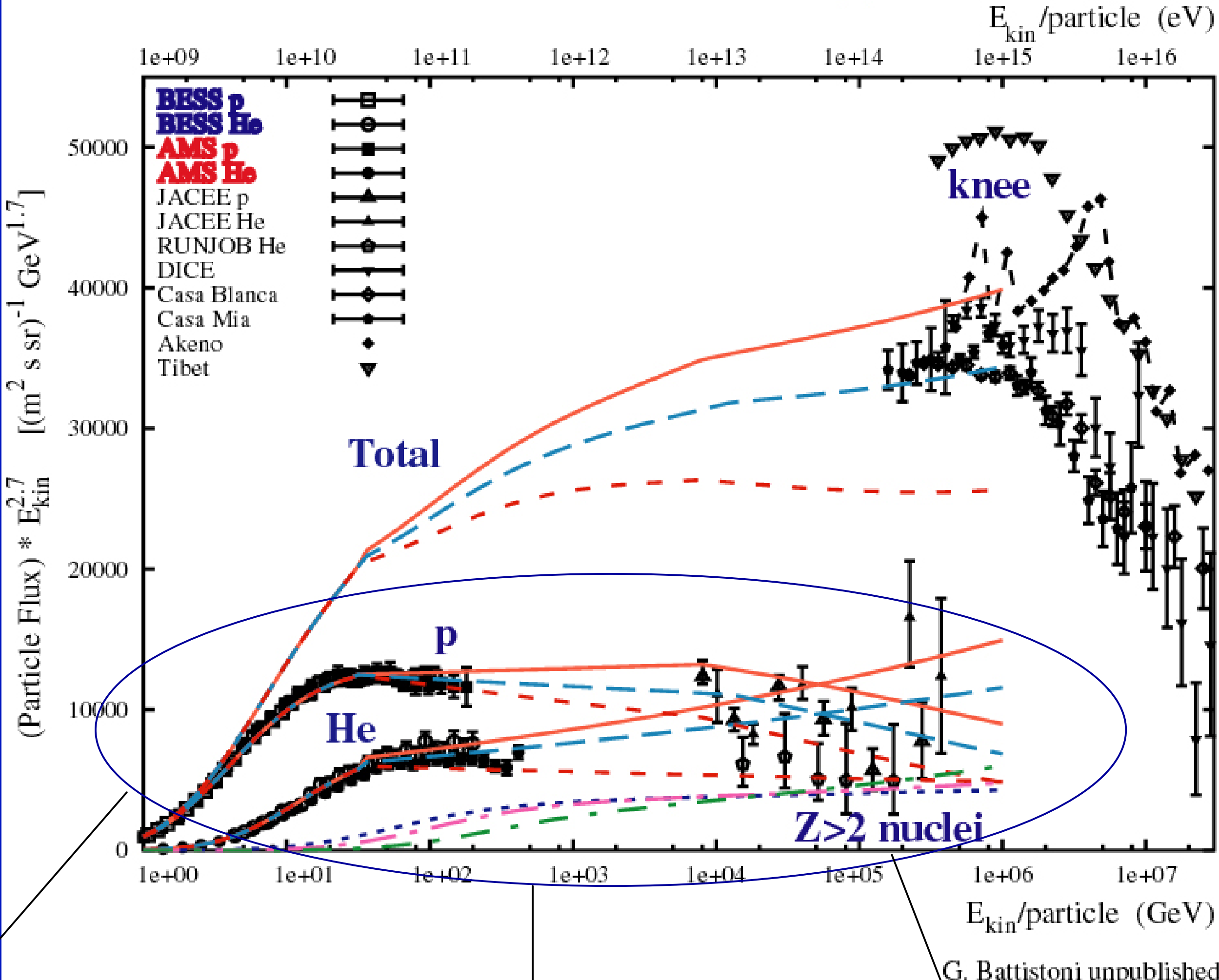


$^{26}Al/^{27}Al$



Today.....

CR Hadronic Component



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Hydrogen

- 0.1 GeV $\lesssim E \lesssim 100$ GeV

  Spectrometers: within 5%
- 100 GeV $\lesssim E \lesssim 1$ TeV

  Calorimeters: within $\approx 25\%$
- 1 TeV $\lesssim E \lesssim 1000$ TeV

  Emulsion Chambers: within $\approx 25\%$

Helium

- 0.1 GeV $\lesssim E \lesssim 100$ GeV

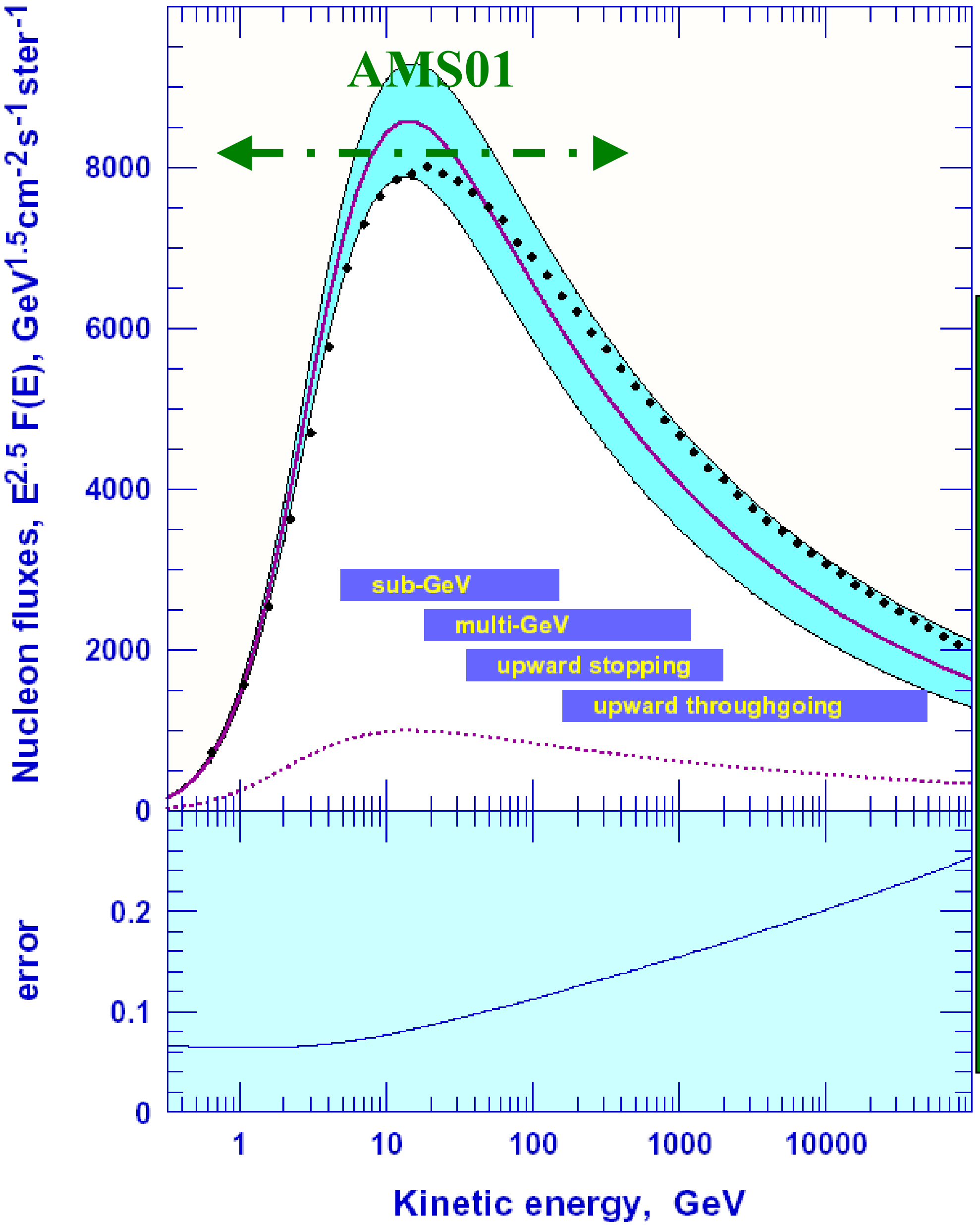
  Spectrometers: within 10%
- $E \gtrsim 100$ GeV

  Emulsion Chambers: Poor statistics

Z>2

- Absolute fluxes from 0.6 to 35 GeV/n
- Systematic Errors $\sim 5\%$

Stanev Trento 2001

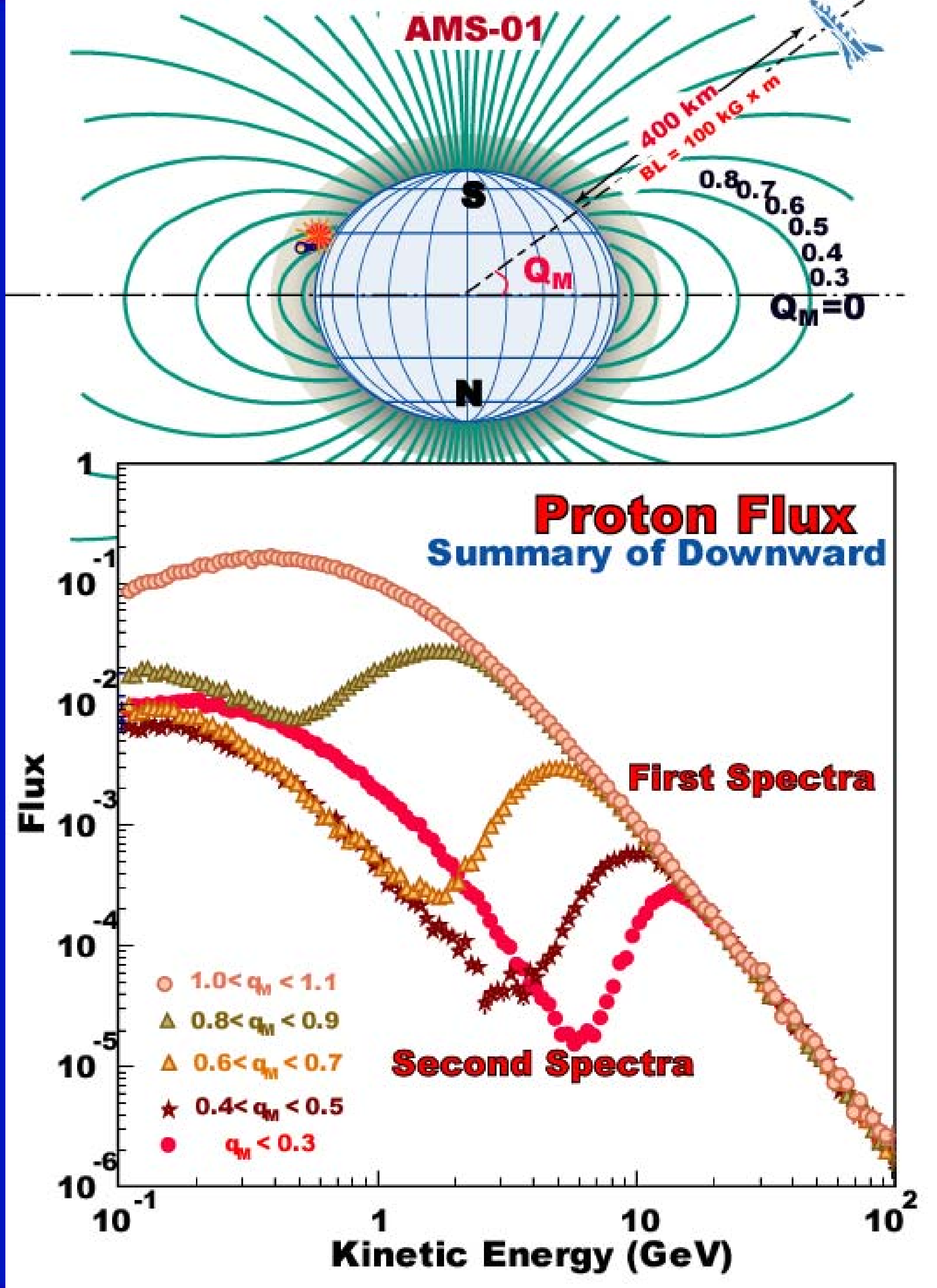


Atmospheric neutrinos relevant for ν oscillation searches are produced by CR with energy exceeding 10 TeV interacting with the atmosphere

Accurate knowledge of the CR primary Flux and composition over the entire Earth is possible only with space born detectors

AMS01 data are now the reference for atmospheric neutrinos calculations

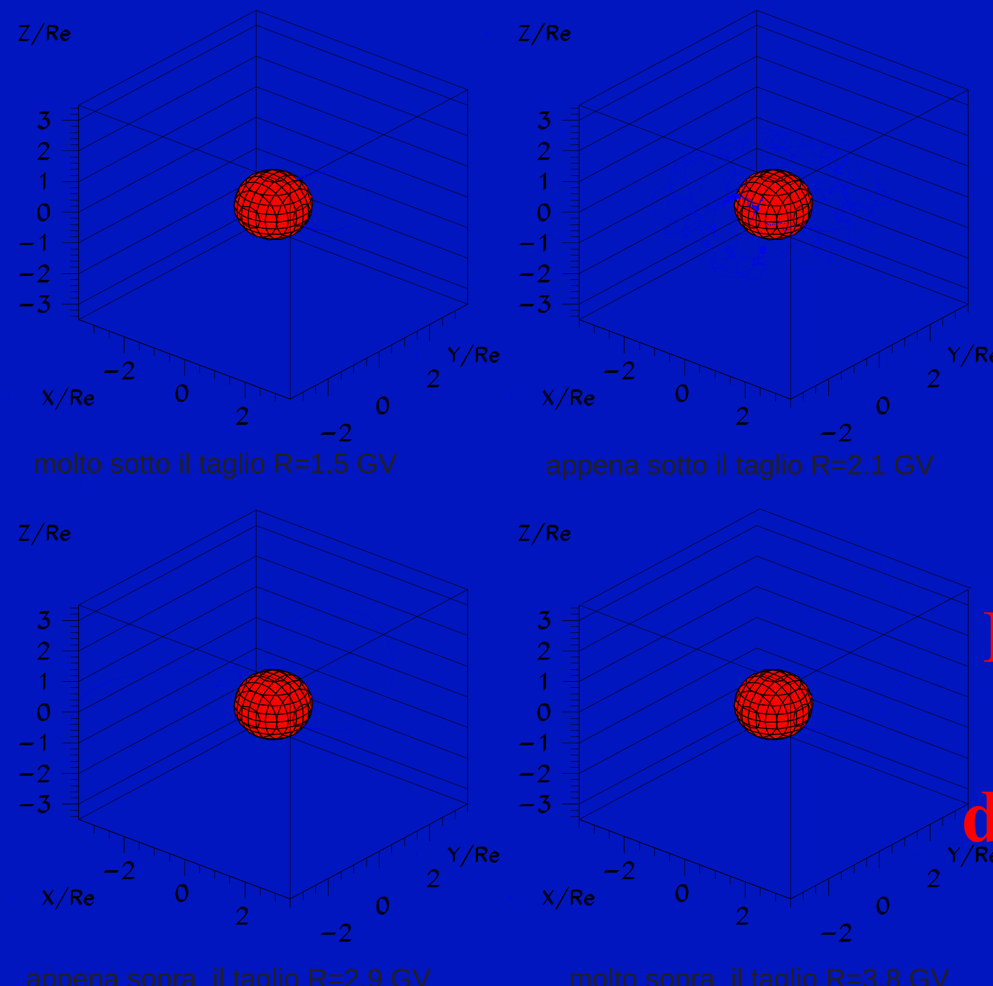
Precision measurement can provide nice surprises: observation of high energy Cosmic Rays trapped and quasi-trapped in the earth magnetic field at low altitudes (few 100s Km)



CR interaction with the geomagnetic field

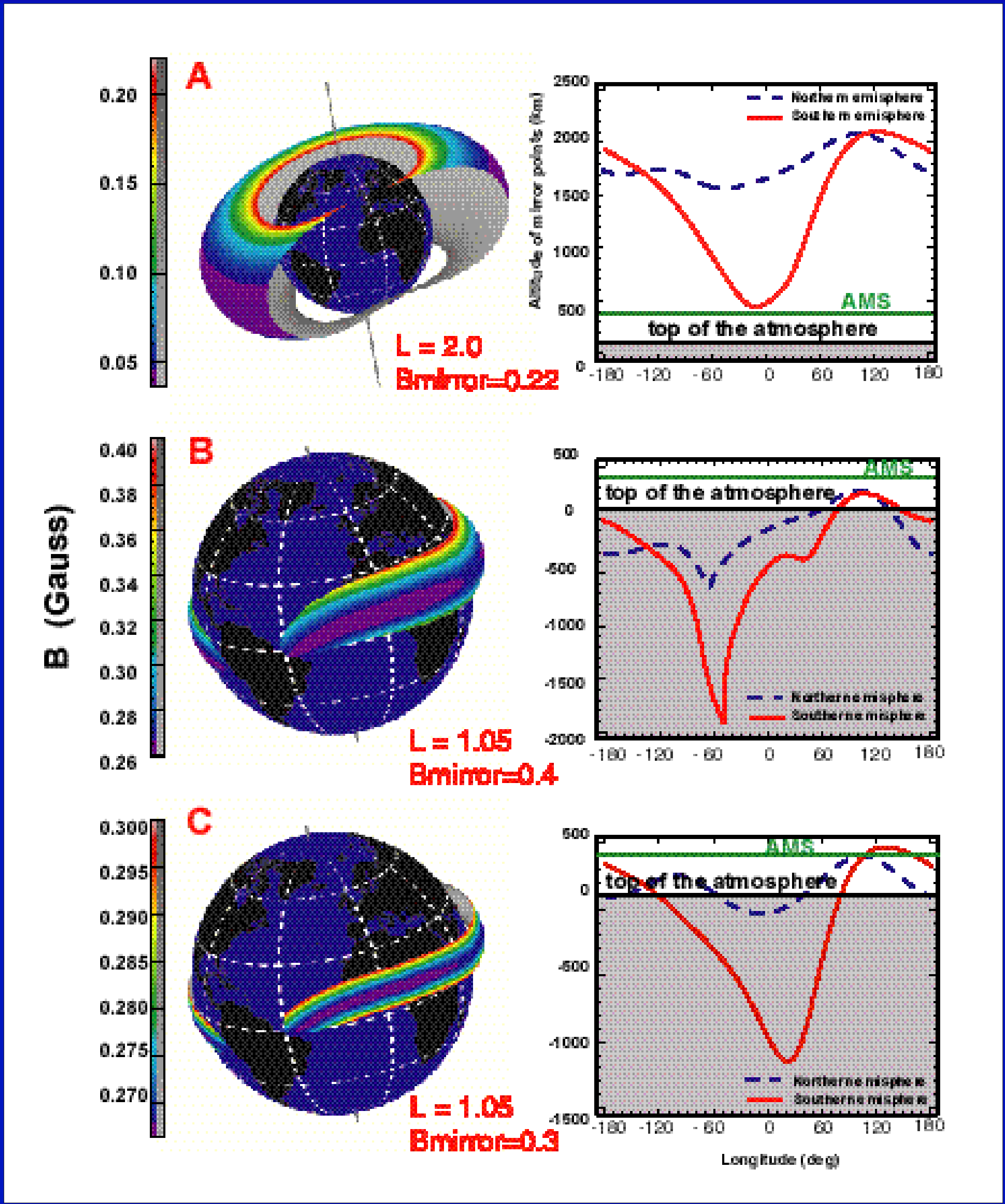
trapped (belts)

Caotic



Primary large deflection

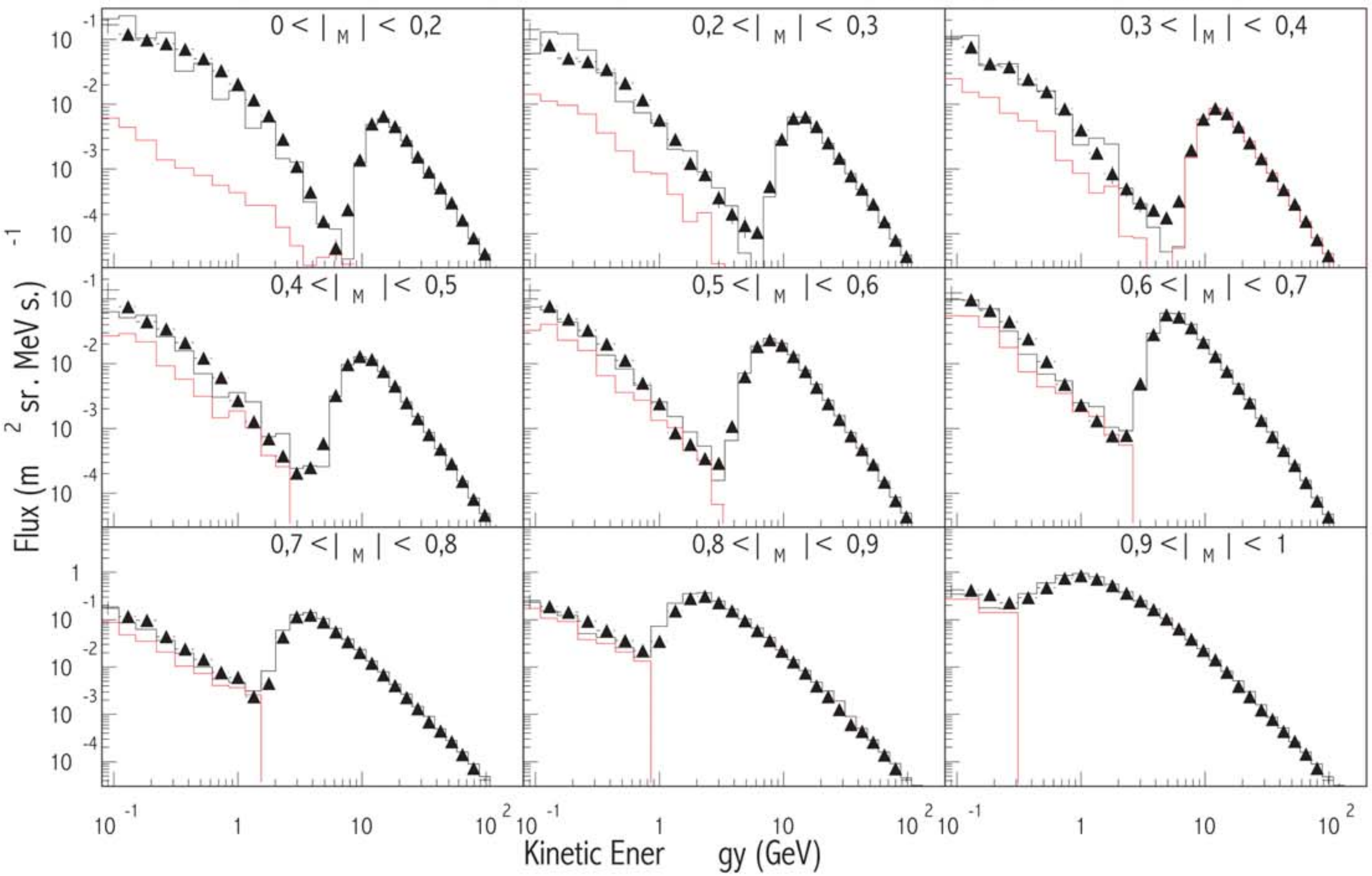
Primary small deflection



B (Gauss)
A
0.20
0.15
0.10
0.05
L = 2.0
Bmirror=0.22
Northern emisphere
Southern emisphere
AMS
top of the atmosphere
2500
2000
1500
1000
500
0
-180 -120 -60 0 60 120 180
B
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
L = 1.05
Bmirror=0.4
AMS
top of the atmosphere
500
0
-500
-1000
-1500
-2000
-180 -120 -60 0 60 120 180
C
0.300
0.295
0.290
0.285
0.280
0.275
0.270
L = 1.05
Bmirror=0.3
AMS
top of the atmosphere
500
0
-500
-1000
-1500
-180 -120 -60 0 60 120 180
Longitude (deg)

Down going proton Flux

P. Zuccon, et al. ICRC 2001



▲ AMS data *Solid Line* This simulation

Red Line "real" secondary flux

AMS belts vs Van Allen belts

- Van Allen belts:
  - Low energy from ~ 1 MeV to ~ 100 MeV
  - Contains e-, p
  - High L-shells ⇔ high altitude
  - Life time O(years) => trapped

⇒ **Decays of neutrons produced in interactions of primary with the atmosphere (CRAND)**

⇒ **Solar wind induced magnetic storms**

AMS belts vs Van Allen belts

- AMS belts:
  - High energy from ~ 1 GeV to ~ 10 GeV
  - Contains e+, e-, p, ^{3}He
  - e+ over e- dominance
  - Low L- shell ⇔ low altitude
  - Life time O(seconds) => quasi trapped (but also stably trapped component observed)

=> Secondary production from CR interaction with atmosphere

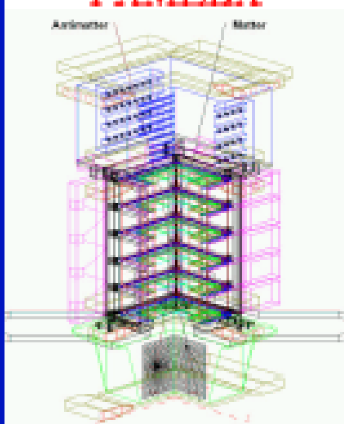
Future experiments

- Balloons

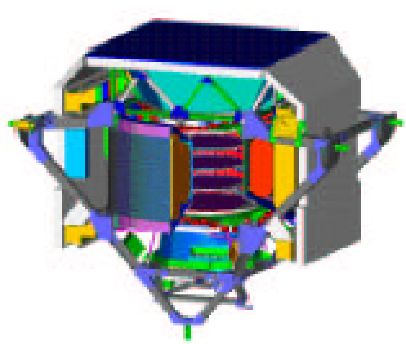
  Ultra Long Duration Balloon program (ULDB)

- Space-Borne
  - Magnetic Spectrometers

PAMELA



AMS-02

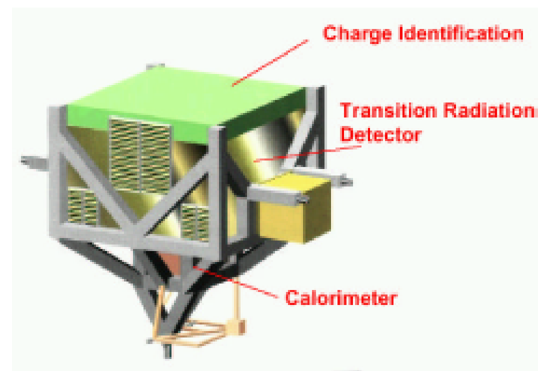


- Magnetic Spectrometers (R,β,Z)

mostly spectrometers 2003/4 →

calorimetric >2010

ACCESS



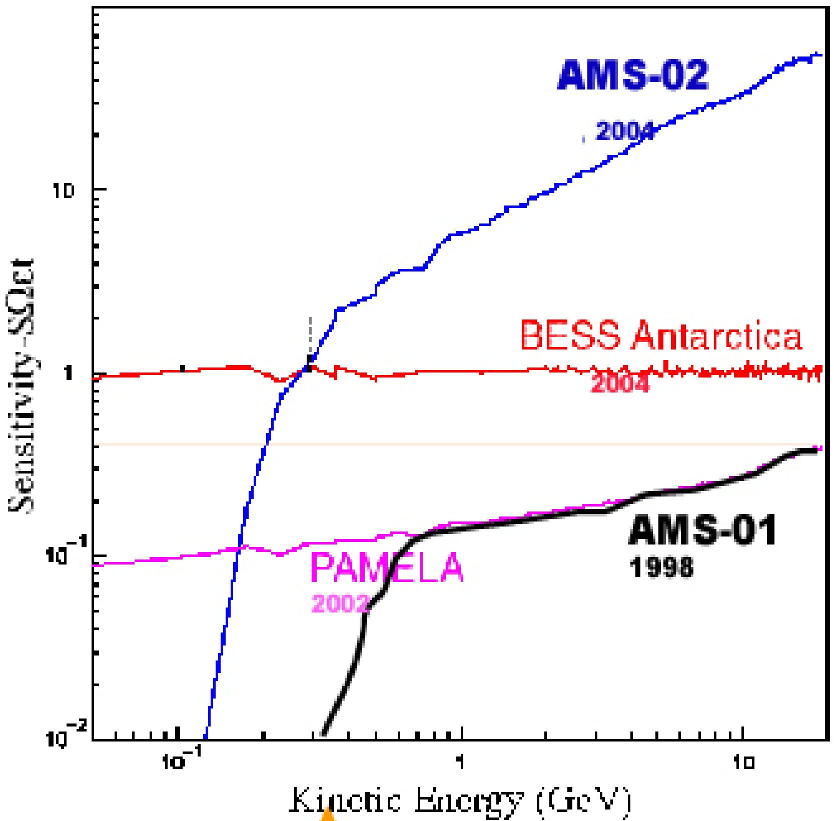
* Energy Spectra

  $1 \leq Z \leq 28$ for $E \lesssim 10^{15}$ eV

* Individual Element Abundances

  $Z > 28$

FUTURE MAGNETIC SPECTROMETERS



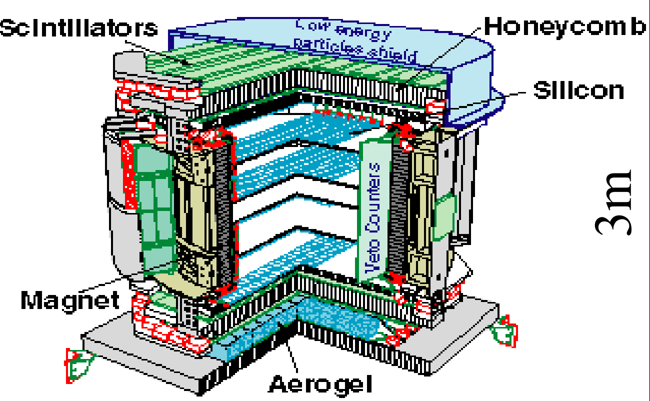
	AMS-01	AMS-02	BESS	PAMELA
Aperture ($cm^2 \cdot sr$)	2300	5000	3000	21
Duration (days)	10	1000	20	1000
Altitude (km)	320~390	320~390	36	690
Latitude (deg)	< 51.7 Space Station	< 51.7 Space Station	> 70 Ballooning	70 Satellite
Launching (year)	1998	2004	2004	2002

Area*time 1 : 217 : 2.6 : 1.1

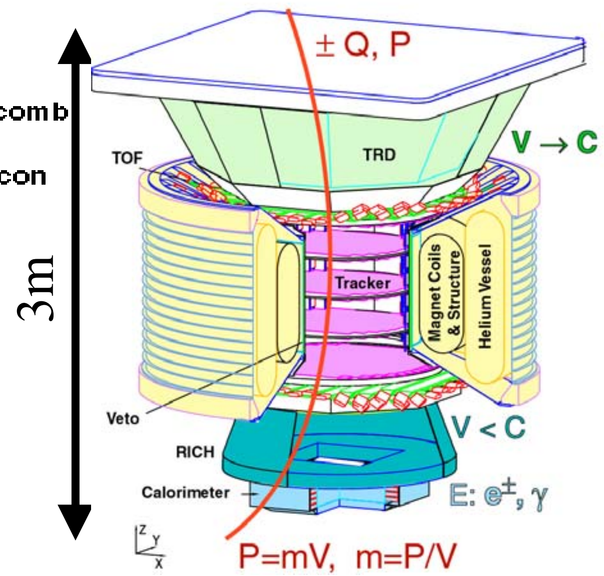
AMS-02 most sensitive > 0.3 GeV ----> TeV

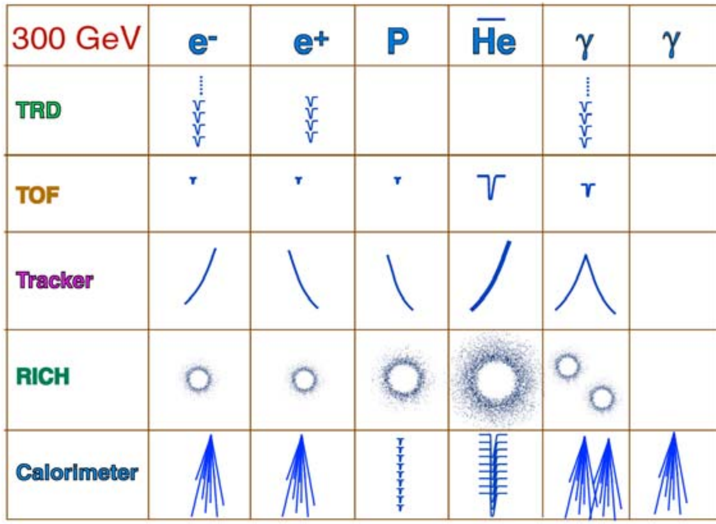
BESS most sensitive < 0.3 GeV ----> low E

AMS01 vs AMS02



AMS01



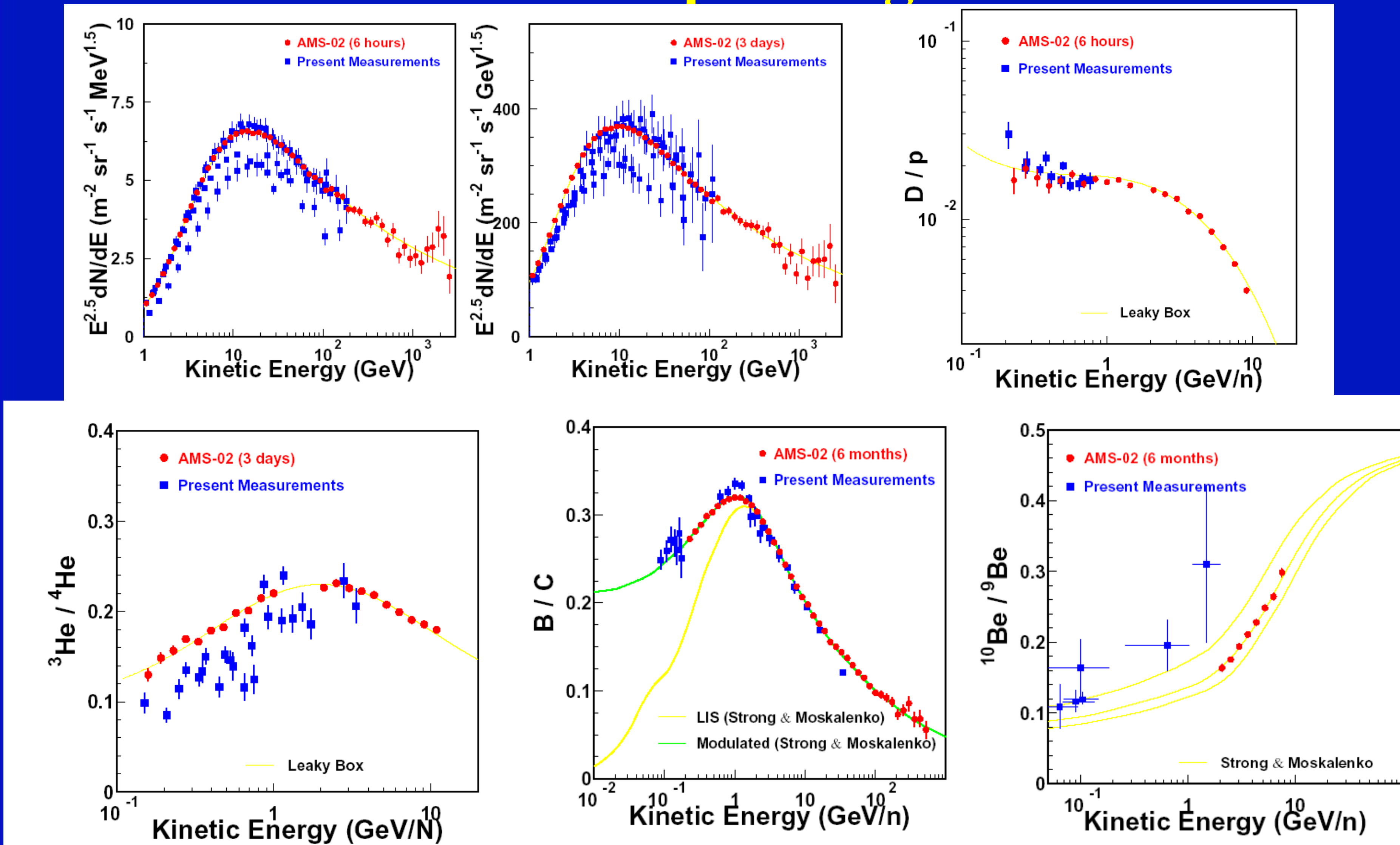


AMS02

Improved detector (larger acceptance, 5 times stronger magnetic field)

Largely improved particle id (TRD, RICH, EM Calorimeter)

Tomorrow....(>2004)
after AMS starts operating on the ISS



...our knowledge of CR up to several TeV will be largely improved

Part B
Searching for new particles

Nuclear anti-matter search

Strangelets

Dark matter searches

Anti-protons

Anti-deuteron

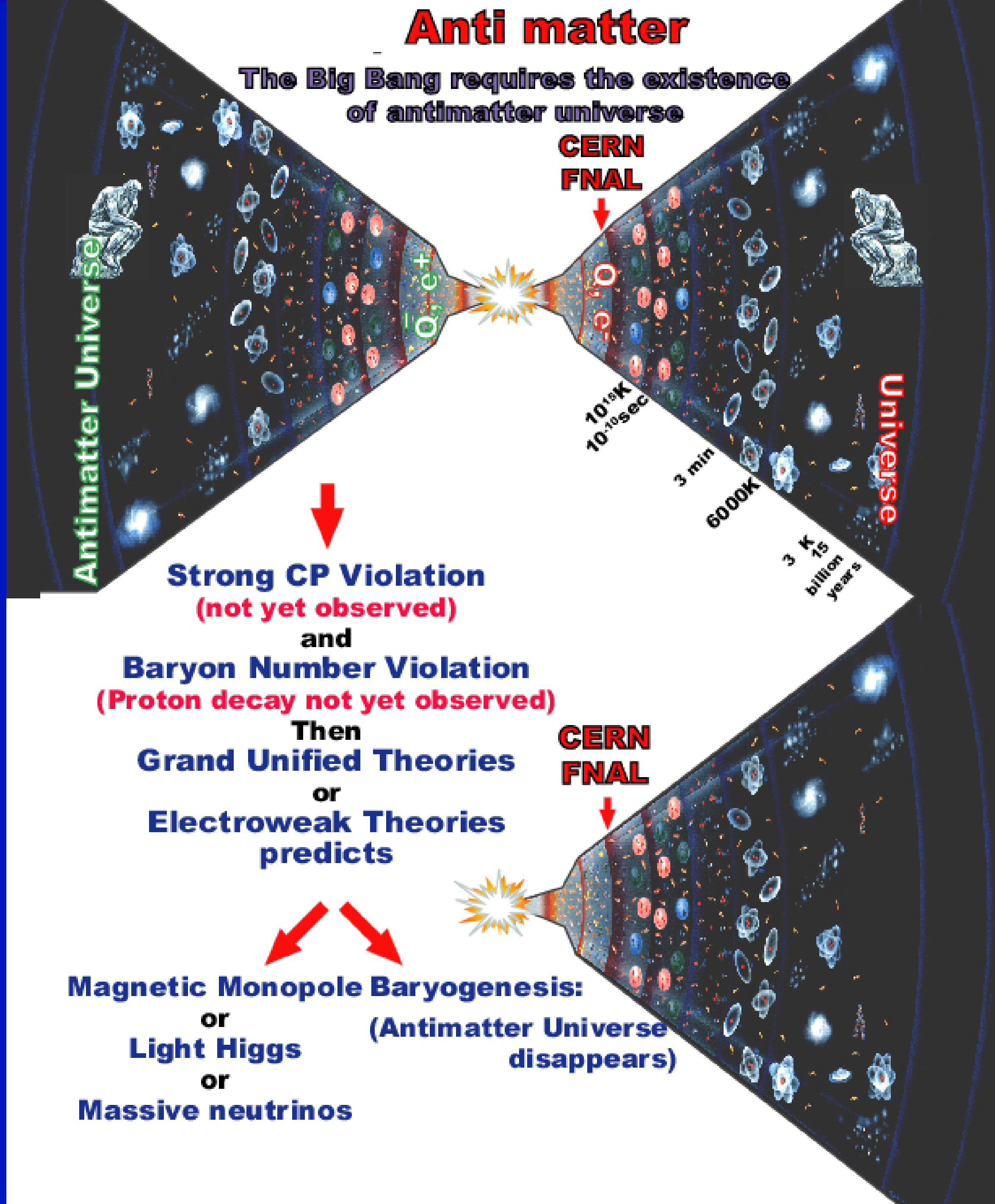
Positrons/electrons

Gamma rays

Ultraheavy particle searches

EEHCR

Neutrinos



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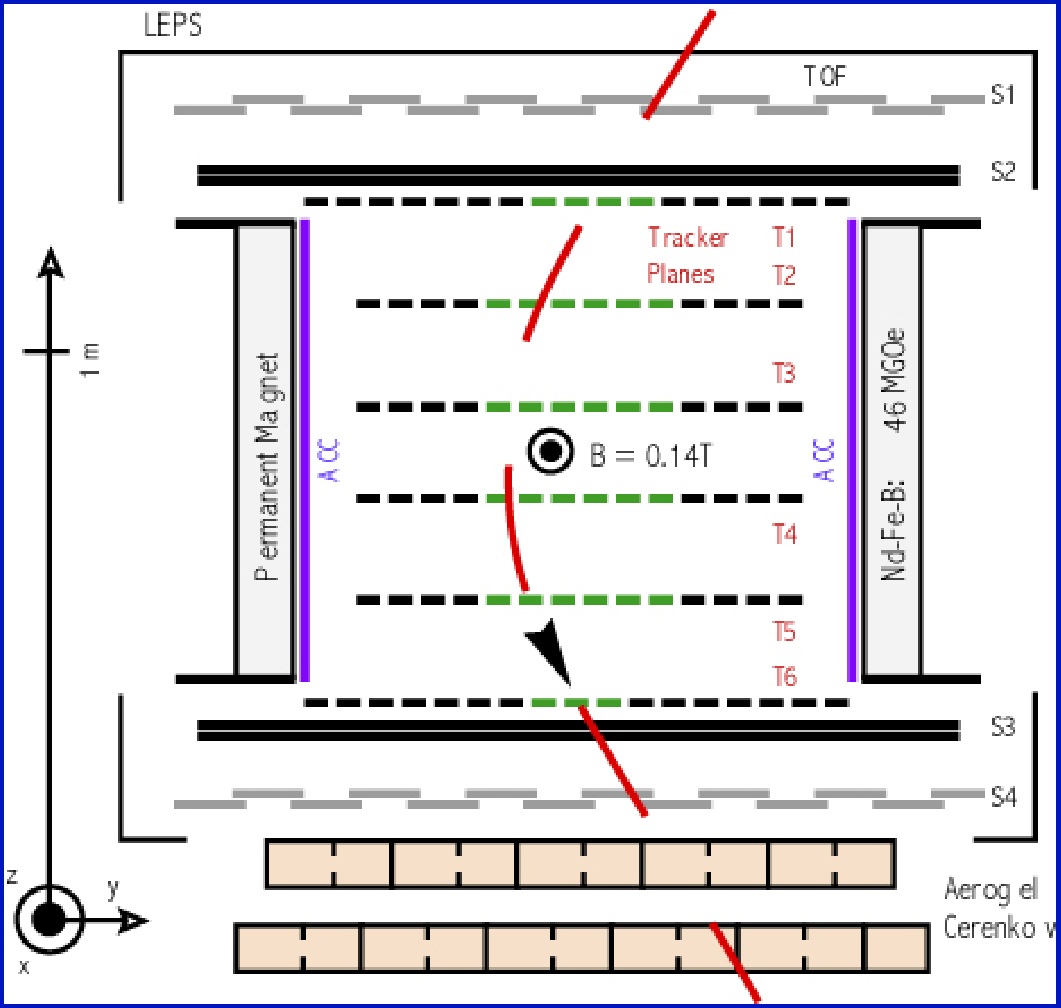


Measure

Rigidity (R, R1, R2)

Sign of Rigidity

Absolute value of Z

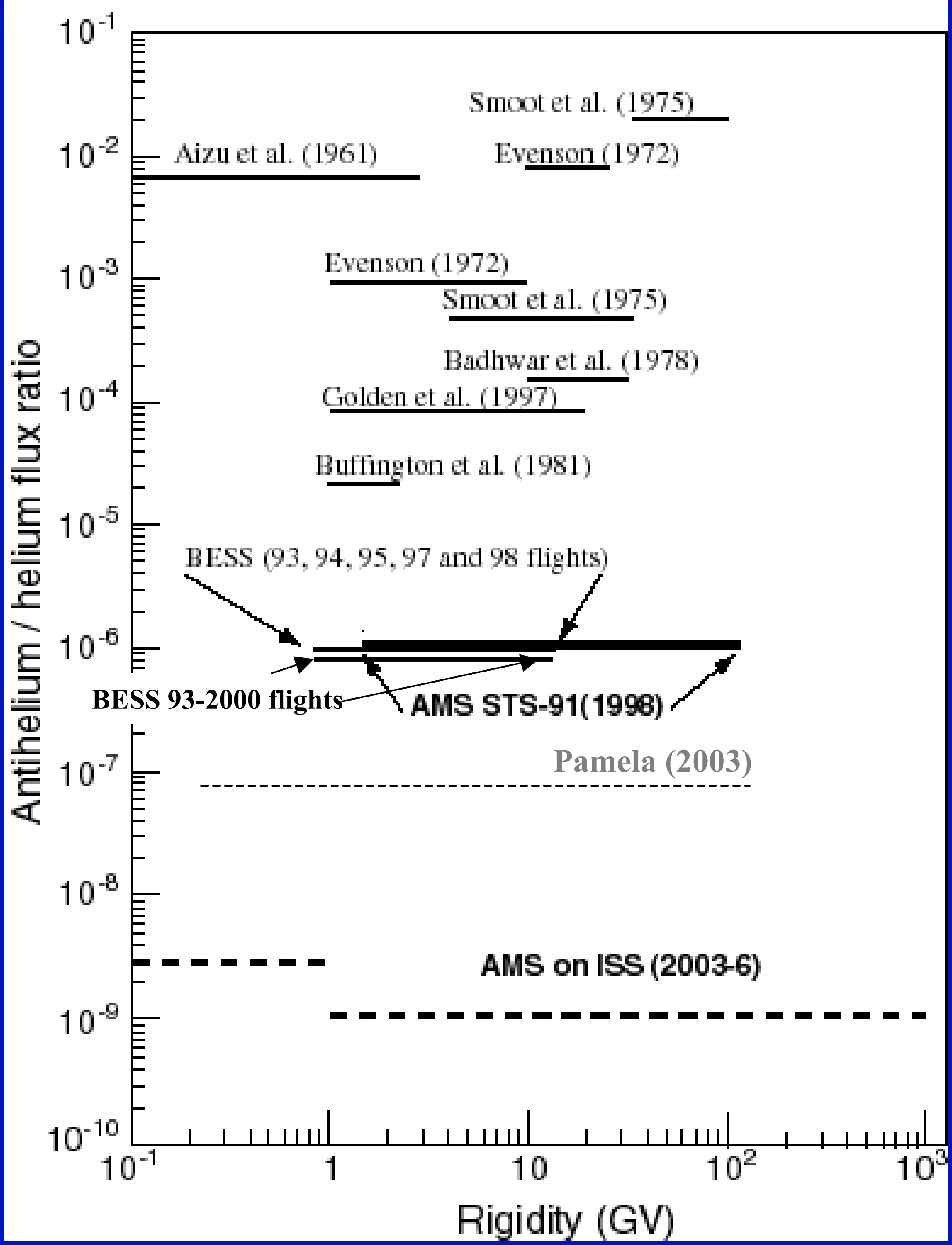
Velocity (β)

Apply cuts

Test antiHe hypothesis

Compute limit

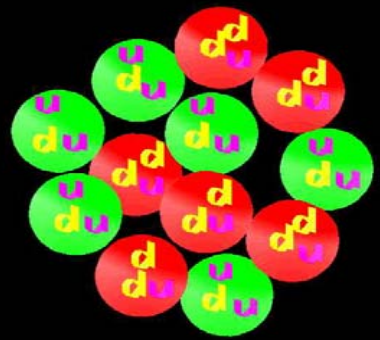
Model dependent limit



Strange Quark Matter, Strangelets

Normal Matter is made up of nucleons (neutrons, protons) each with 3 *up* and *down* quarks

Carbon Nucleus



Lumps of strange quark matter (Strangelets) are a single "super nucleon" with many *up*, *down* and *strange* quarks.

Strangelet

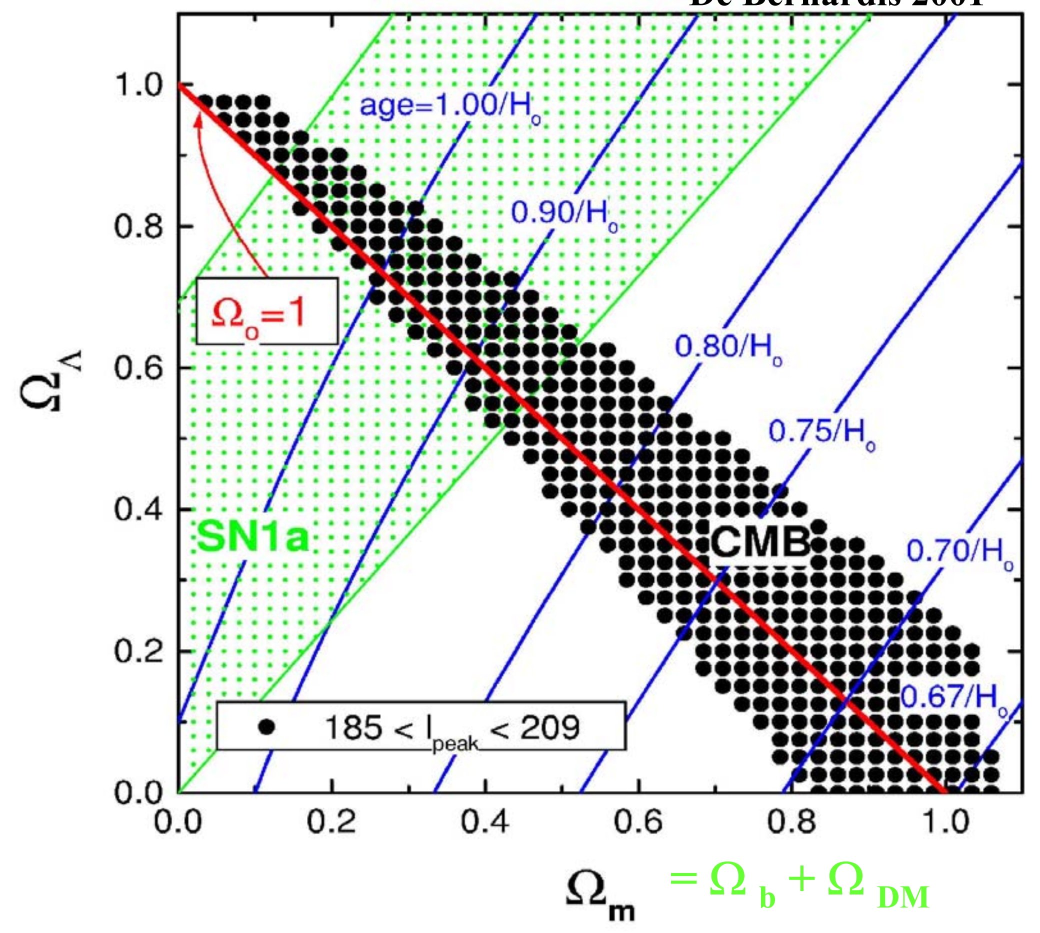
- Low charge to mass ratio
- Mass from ~100 to ~10^{57} times proton mass
- Many interesting, unusual properties

J. Sandweiss, J. Madsen

Dark Matter in the Universe

- At all scales (galaxies, clusters, superclusters..) the visible mass is not sufficient to explain the observed dynamical effects

De Bernardis 2001



$= \Omega_b + \Omega_{DM}$

$\Omega_b < 0.03$, $h=0.7 \pm 0.1$

before CMB data →

$\Omega_{DM} > 0.95$

after Boomerang →

$\Omega_0 = 1$

together with high-z Supernova data →

$\Omega_0 = 1$

$\Omega_{DM} = 0.2 - 0.3$

$\Omega_\Lambda = 0.6 - 0.7$

The SUSY DM solution

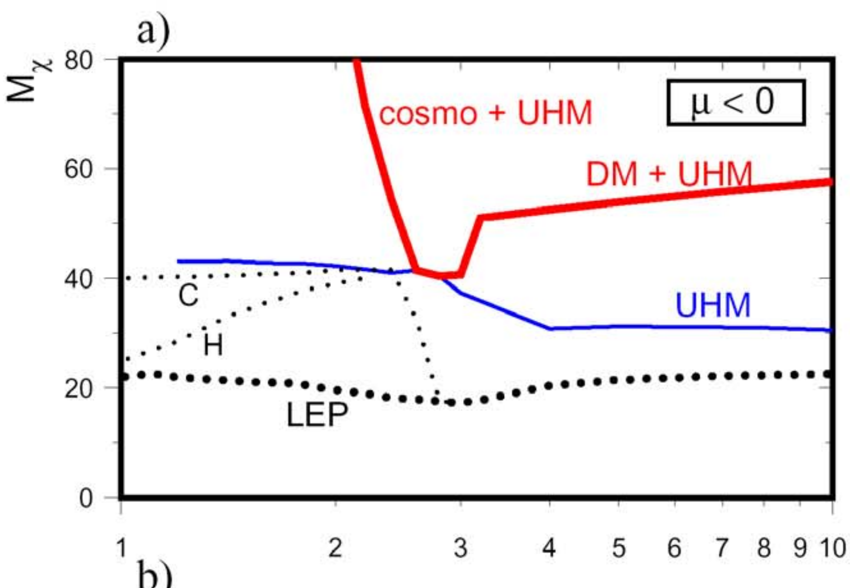
- Supersymmetry links the existing SM particles to a set of new heavier super particles through R-parity conservation:

$$R = (-1)^{3B-L+2S}$$

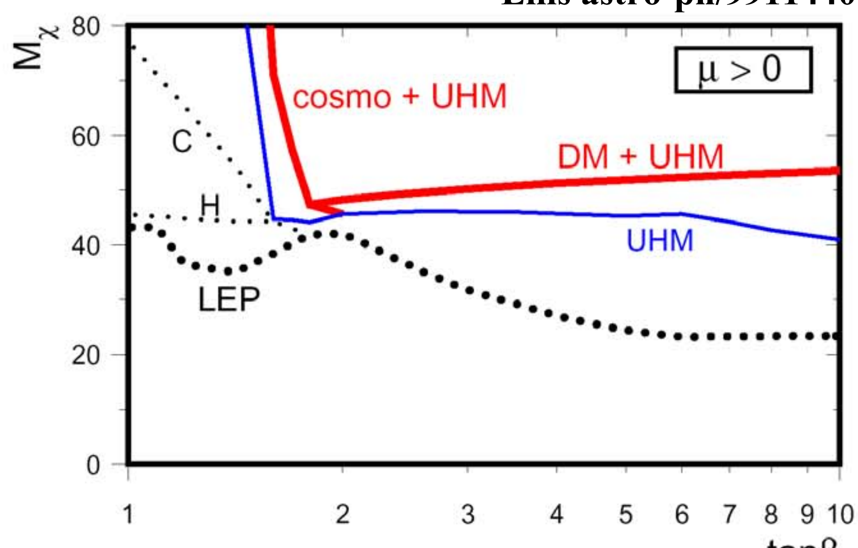
→ **R=1 for SM particles**

→ **R=-1 for SUSY particles**

- R-conservation requires that the Lightest SUSY Particle (LSP) is stable: LSP is heavy (LEP > 45 GeV) this can be a good candidate for CDM.



Ellis astro-ph/9911440

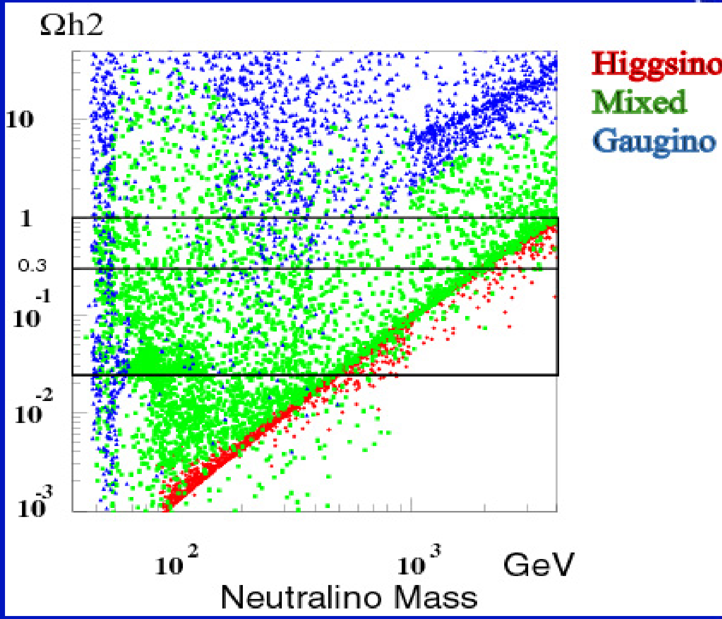


- SUSY can be reduced to a **7** parameters (!) theory:
  - higgsino mass parameter, μ
  - gaugino mass parameter, M_2
  - ratio of the Higgsino vacuum expectation values, $\tan\beta$
  - mass of the CP-odd Higgs, m_A
  - scalar mass parameter, m_0
  - Trilinear soft SUSY breaking parameters A_b/m_0, A_t/m_0

- LSP (neutralino) can be espressed as superposition of the neutral gauge (γ and W) and Higgs boson superpartners:

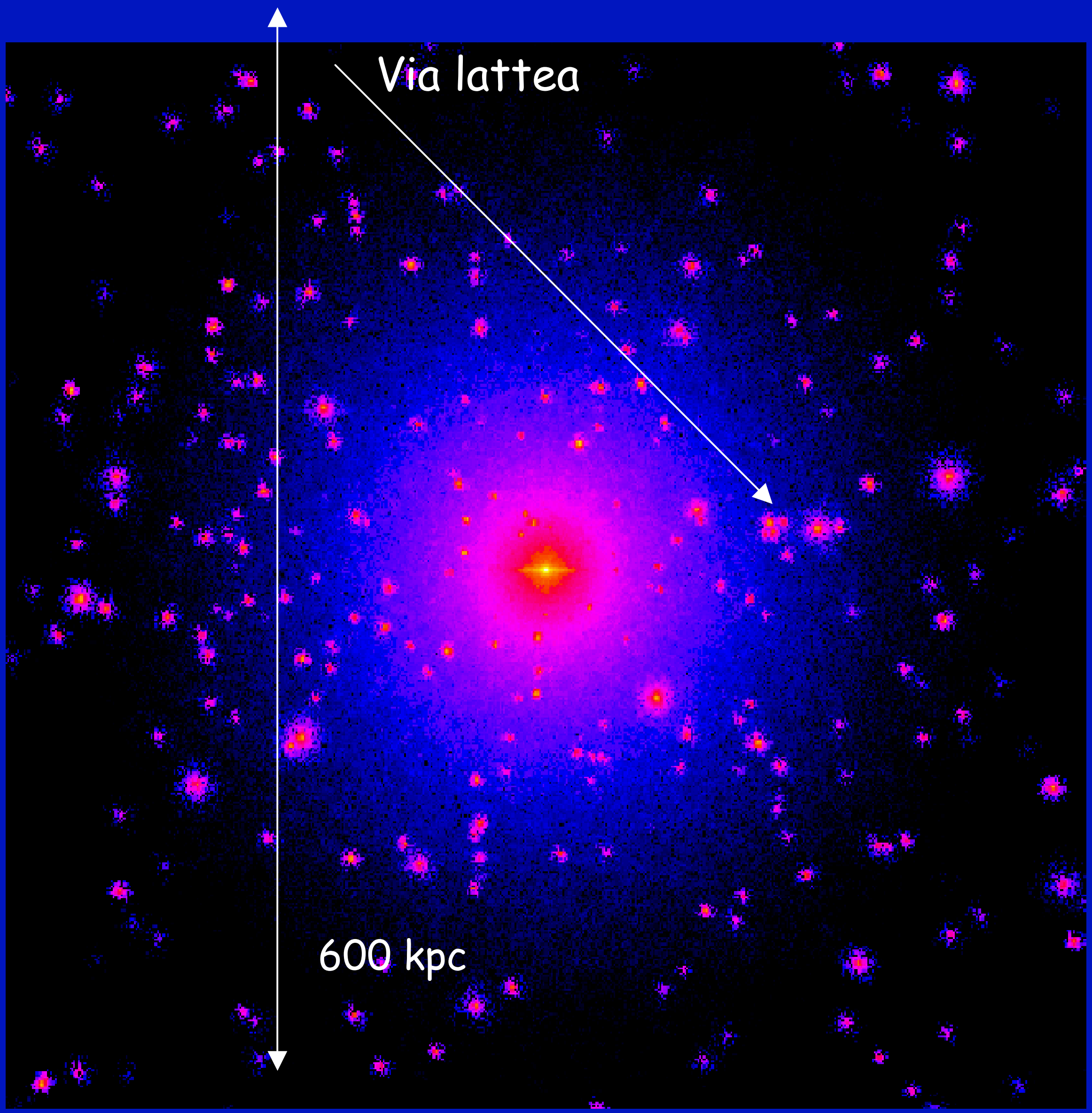
$$\tilde{\chi}^0_1 = N_{11}\tilde{B} + N_{12}\tilde{W}^3 + N_{13}\tilde{H}^0_1 + N_{14}\tilde{H}^0_2$$

Bino, Wino and Higgsinos

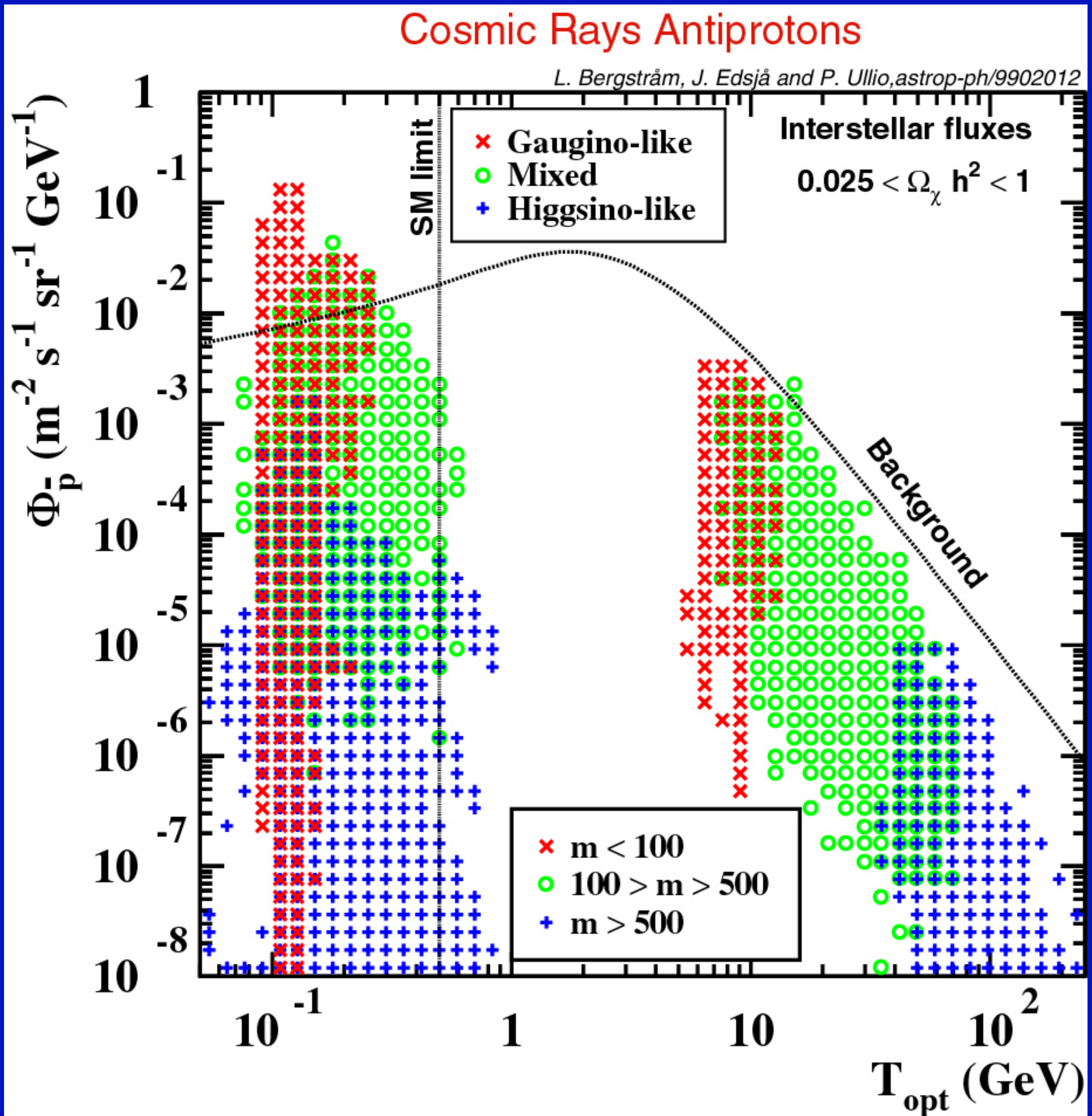


- Parameters of this superposition define the LSP
  - **mass, $M\chi$**
  - **cosmological density, $0.1 < \Omega\chi < 0.3$**
  - **annihilation cross section, $\sigma\chi\chi$**
  - **annhilation BR's into detectable particles. In CR : $\bar{p}$, e+, $\bar{D}$, γ....**

Dark matter halo around our galaxy ?

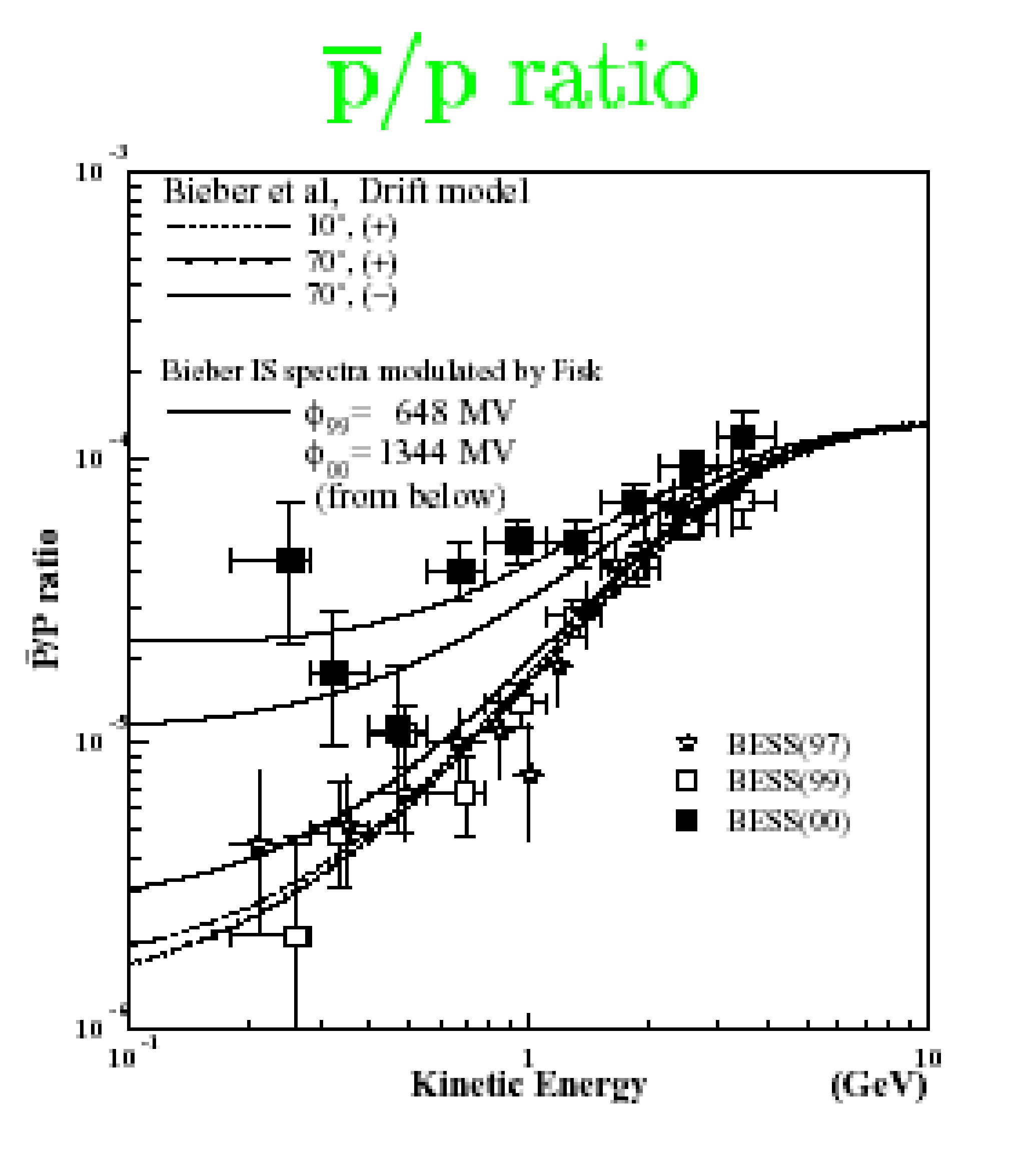


Anti proton spectrum and SUSY DM



Low energy anti-proton spectrum

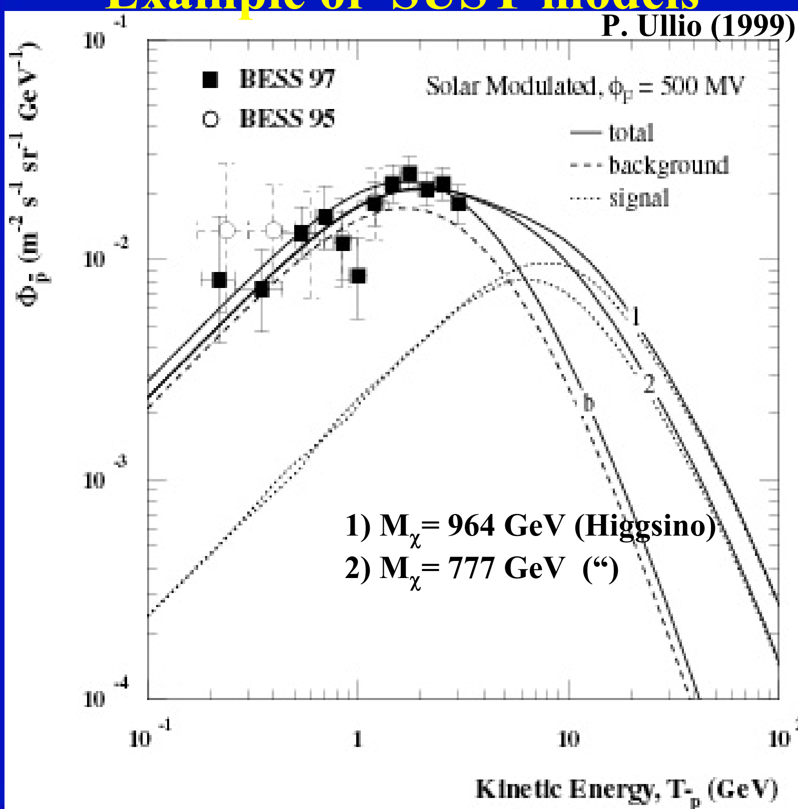
Large corrections at low energy induced by correcting solar modulation



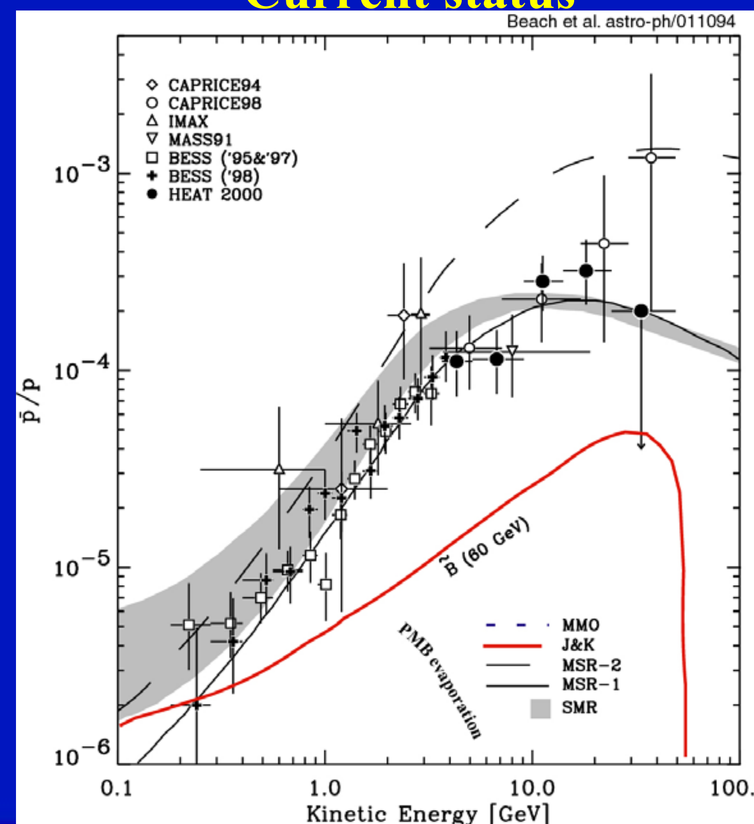
High energy anti-proton spectrum

- The background shape has much less uncertainty.
- No effect from solar modulation.
- Rate from supersymmetry are indeed too small :
  - high χ mass and Flux $\propto 1/M_{\chi}^{2}$
  - Unless hypothesis on the Dark Matter distributions (clumps of DM)

Example of SUSY models

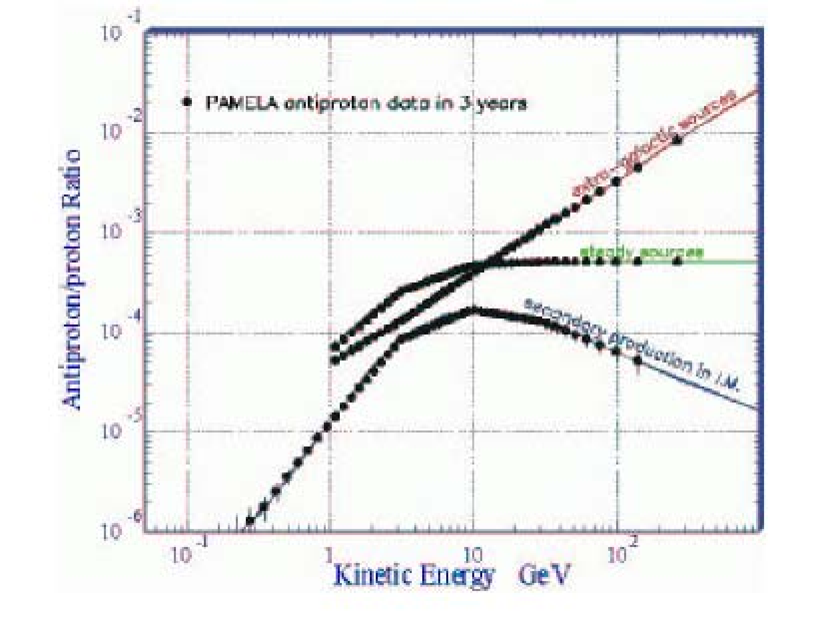


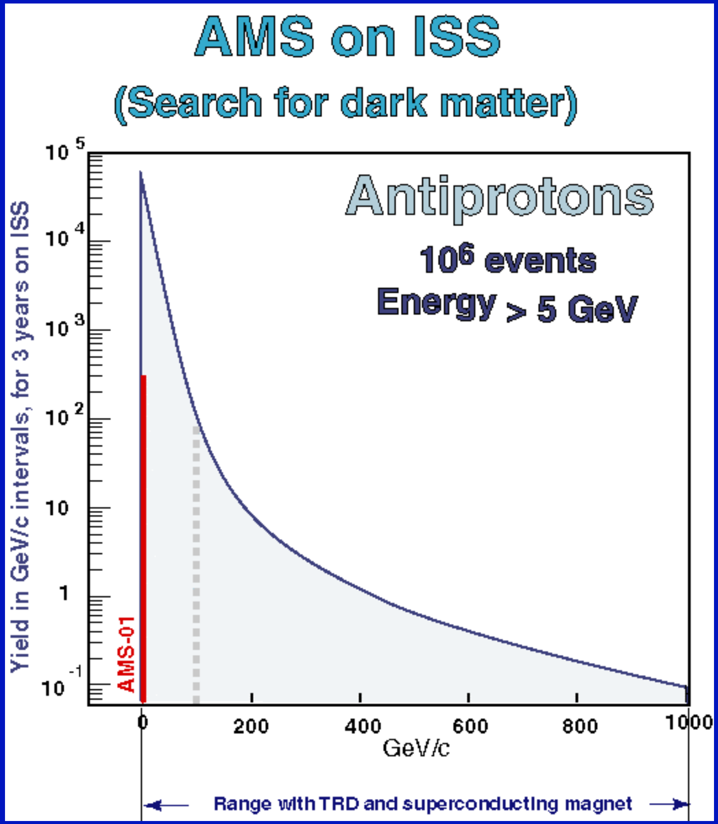
Current status



High statistics space born experiments in the near future will allow a precise measurements of the High Energy Spectrum

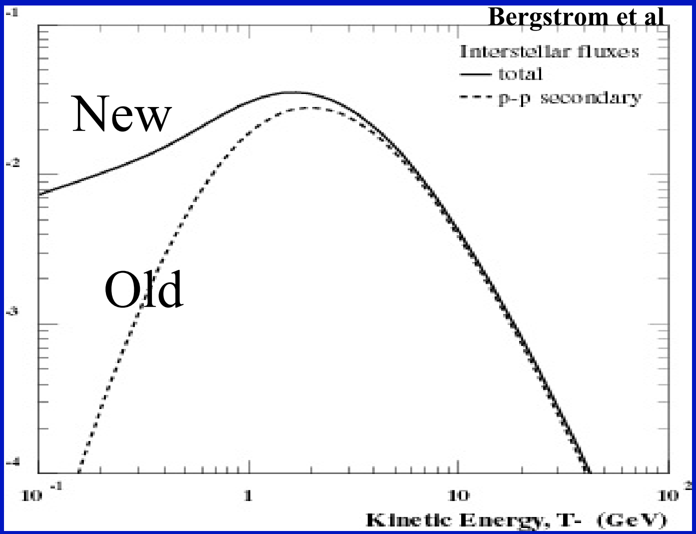
Pamela 10^4 anti-p in 2 y





Remember: cosmic beam calibration

Theoretical



–Theory predicted a very distinctive spectrum at low energy

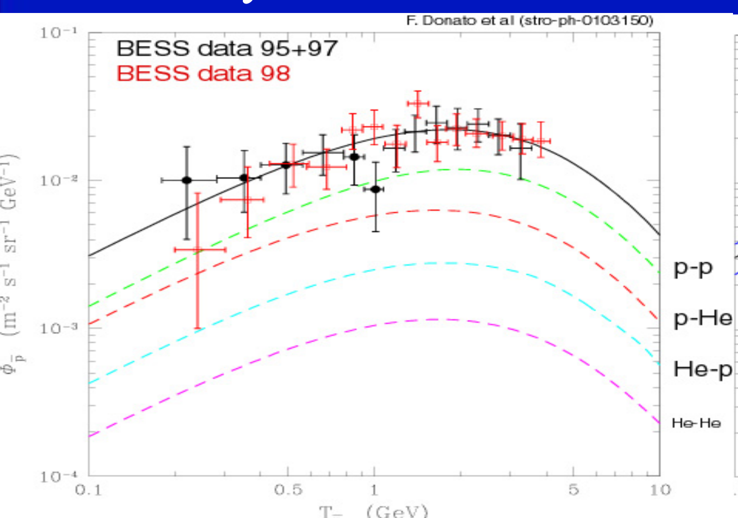
- –Flat for χ annihilations.
- –Suppressed from (pp $\rightarrow$ anti-p + X).

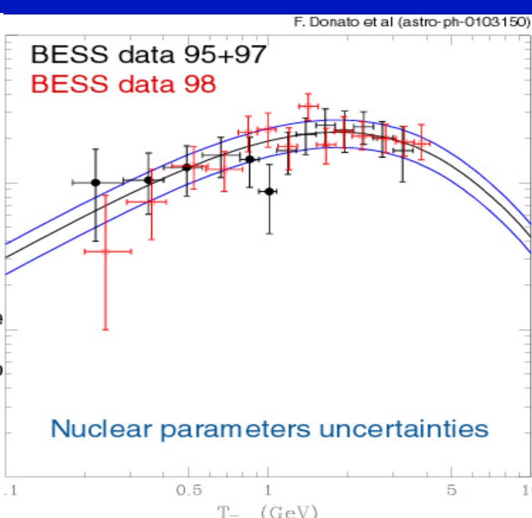
–more complete computations include

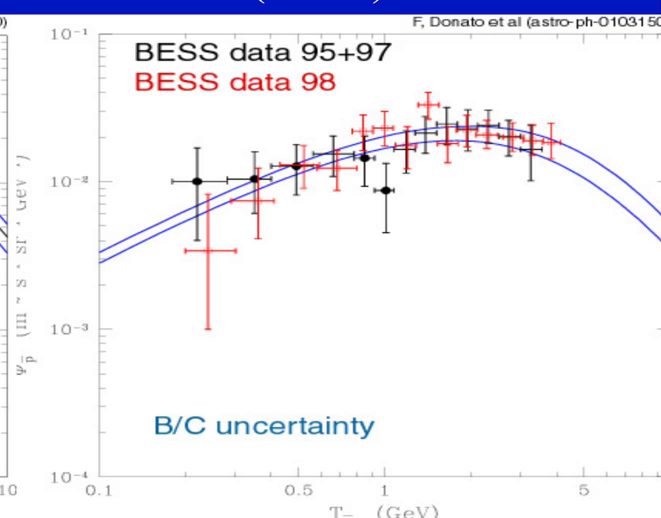
- –Inelastic scattering (non annihilating)
- –Scattering on Helium

Spallation processes

Uncertainty on the normalization from measurements from HEAO3 (1990) : 25%







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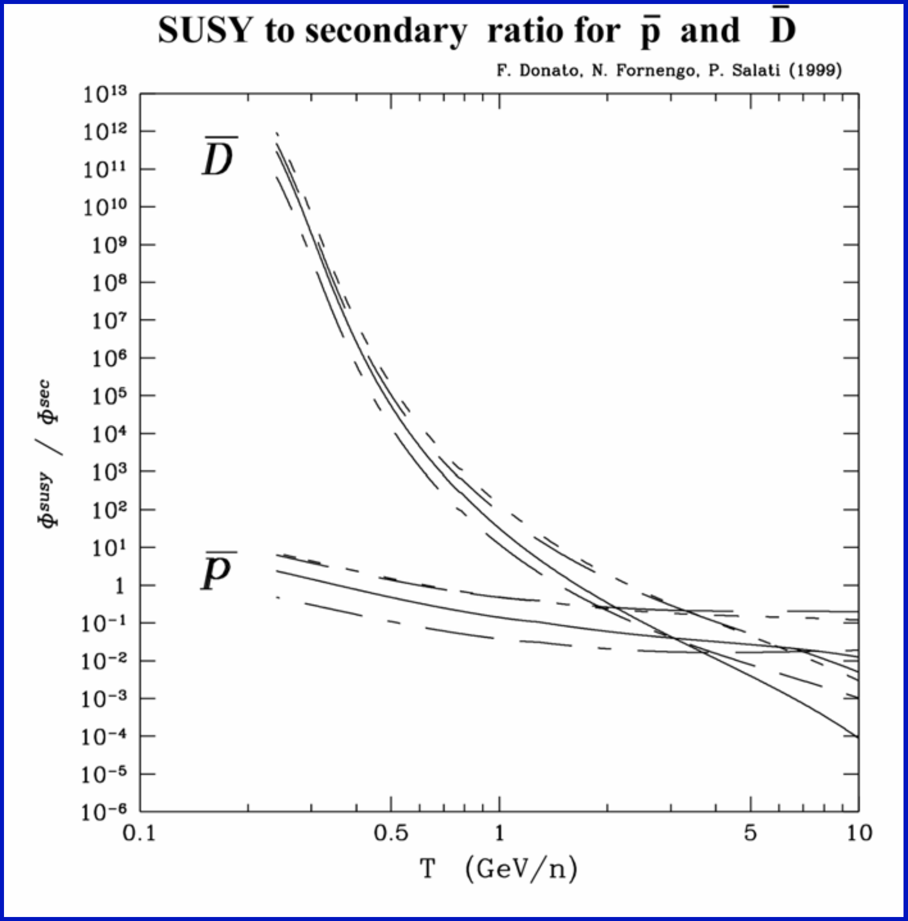
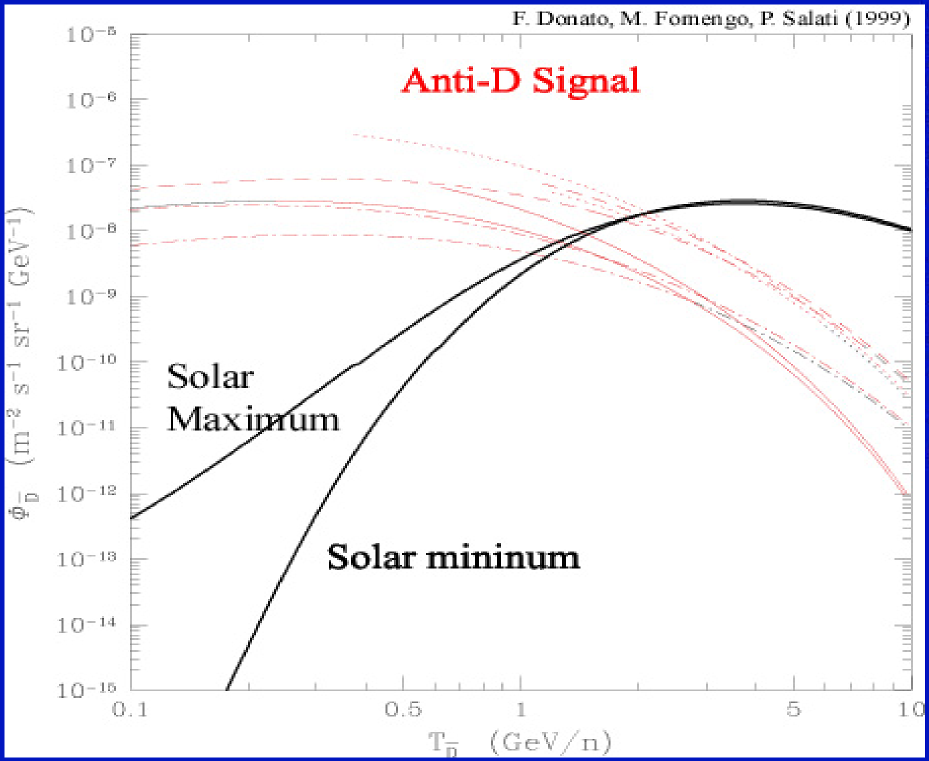
Antideuterons and SUSY DM

- Anti-proton spectrum at low E appears to be less favorable than initially anticipated to probe an additional spectrum of exotic origin:
  - No distinctive spectrum.
  - Solar wind modulation not so well known.
  - Normalization still uncertain (even if improved).

- Anti-Deuterons seems to be a good signature
  - The χ signal has a flat spectrum (as for anti-protons)
  - The background component is suppressed at low energy.
  - But Flux is smaller.

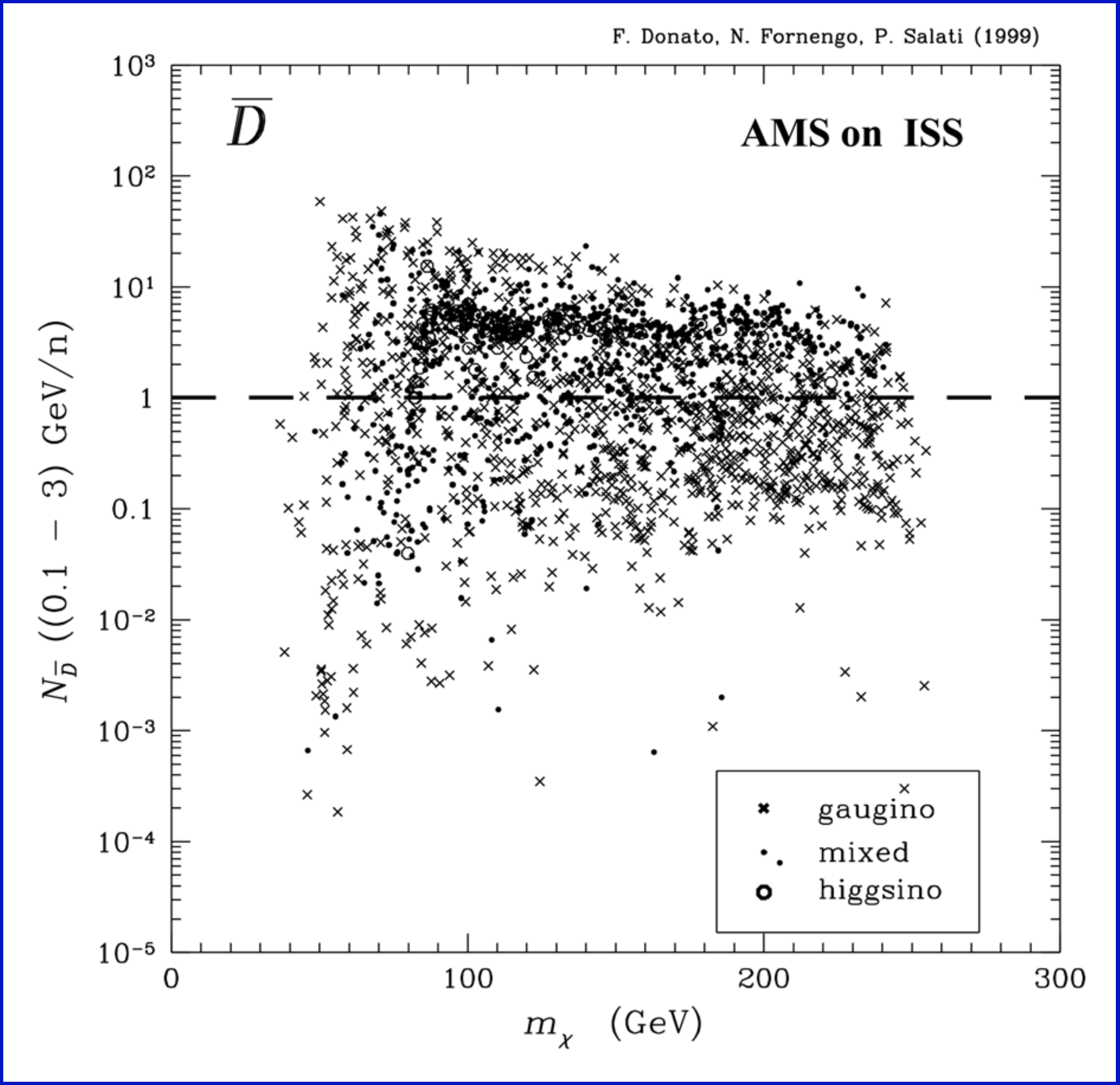
Anti-D dominant over anti-P at low energies





4 MSSM scenarios considered AT maximum / minimum solar modulation

Promising for long exposures large acceptance in space



e+ e- spectra and SUSY DM

From the first direct evidence of CR electrons......

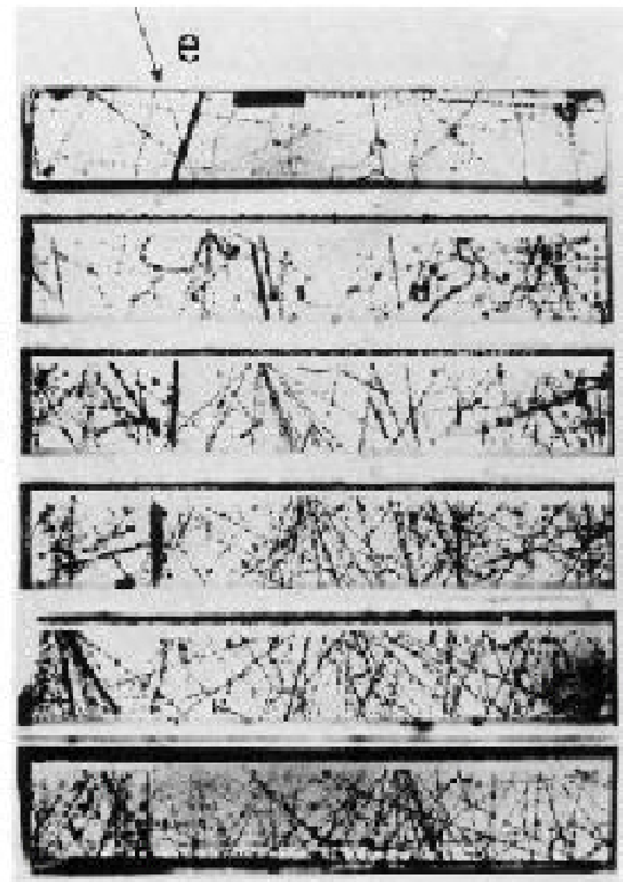
J.A. Earl, PRL 6(1961) 125

Balloon Flight: May 1960
Residual atm : 4.5 gr cm^{-2}

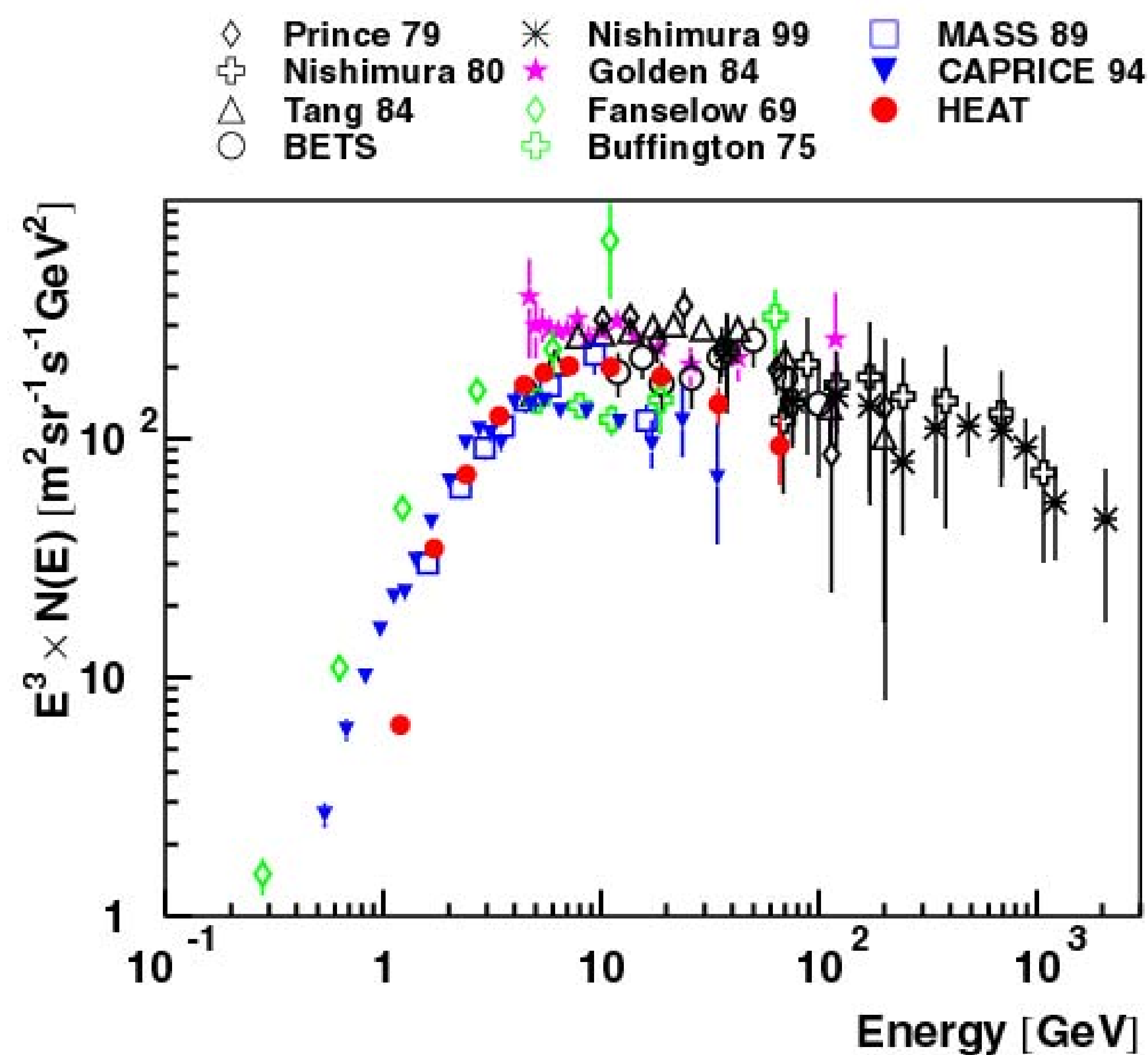
Multiplate cloud chamber
$\lambda = 5.5\ X_0$

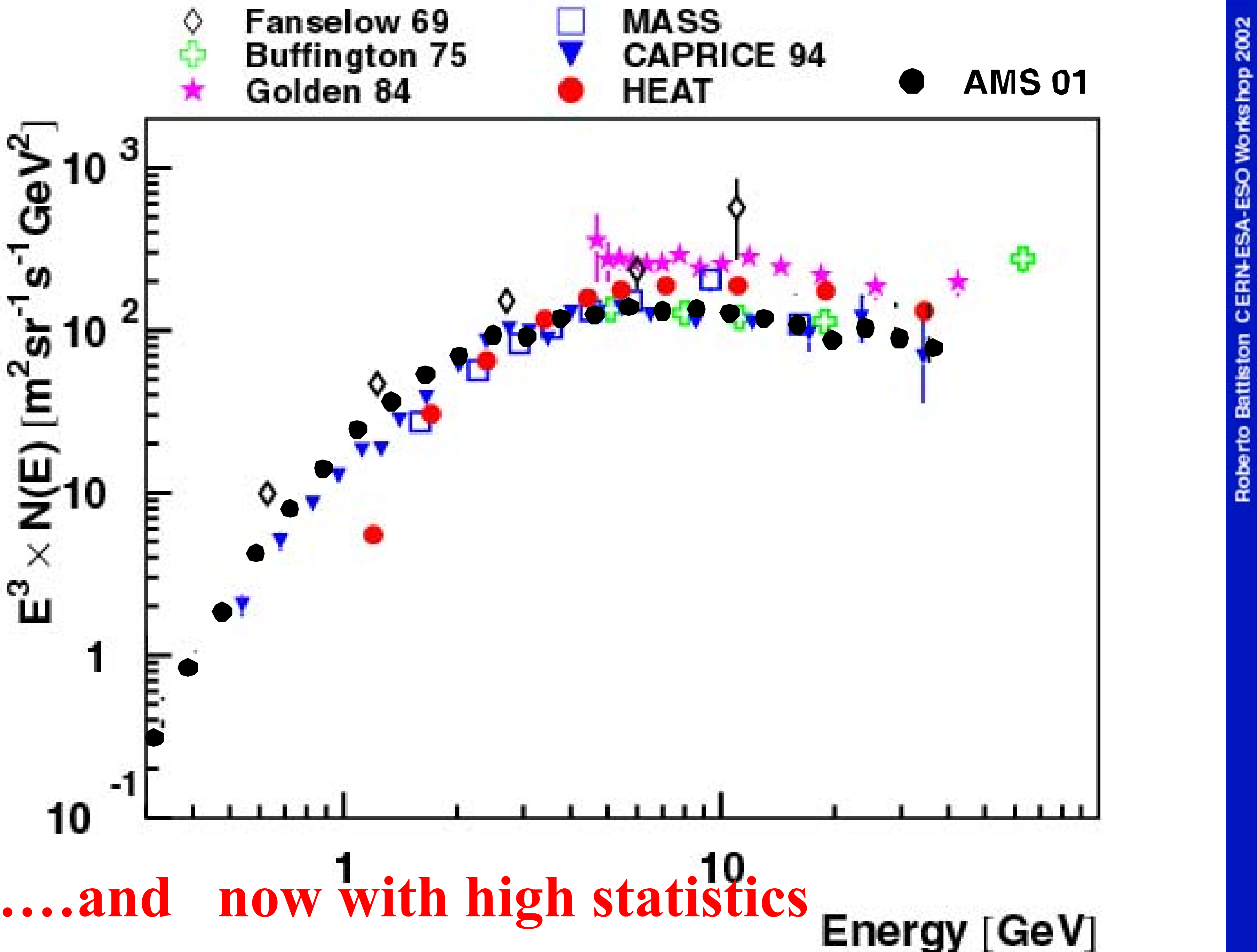
11 electrons 0.5 -3 GeV
6 photons
284 p

I_e/I_p = 3 +/-1%



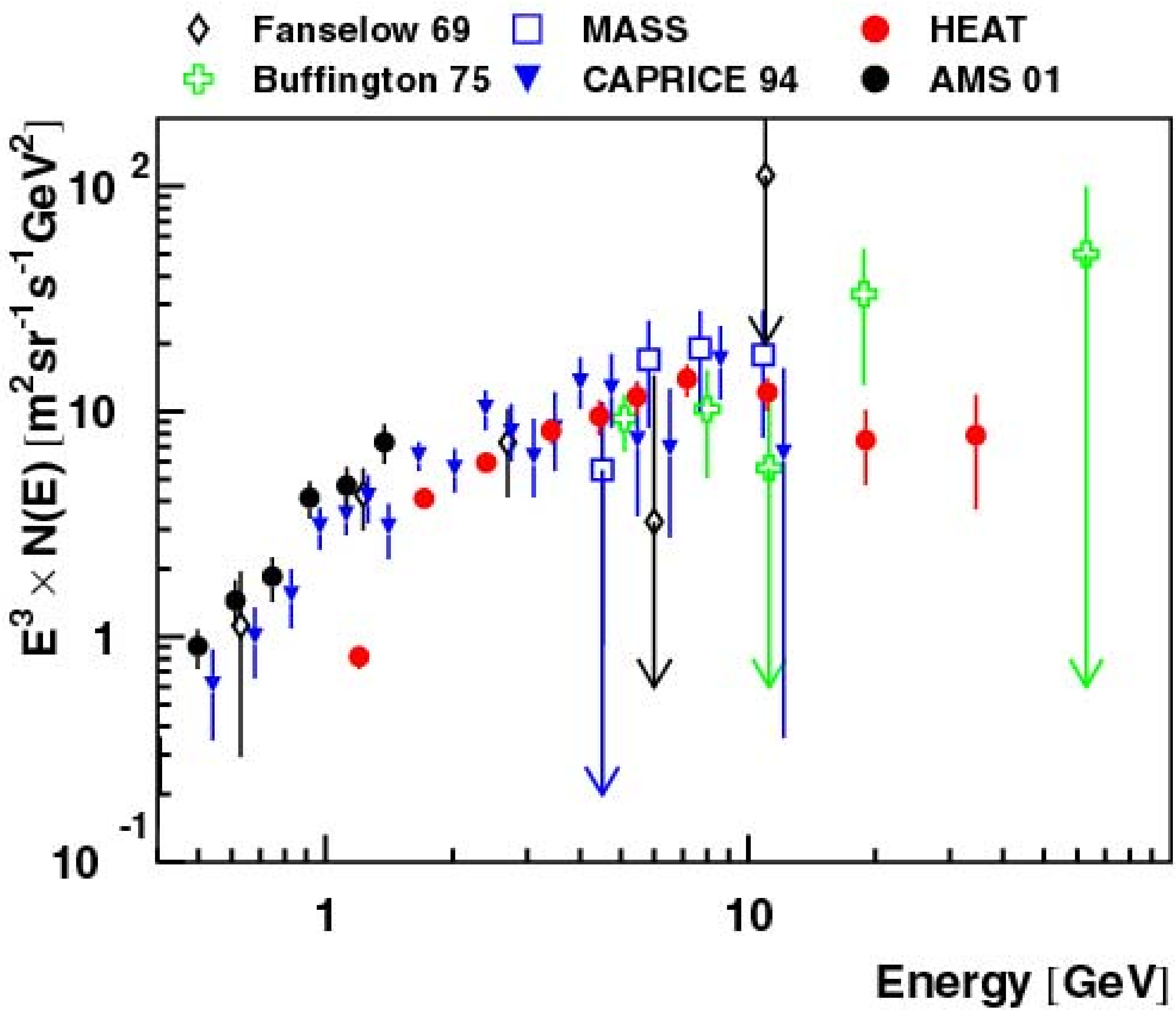
measurements from balloons…





……and now with high statistics from space

Positrons spectrum



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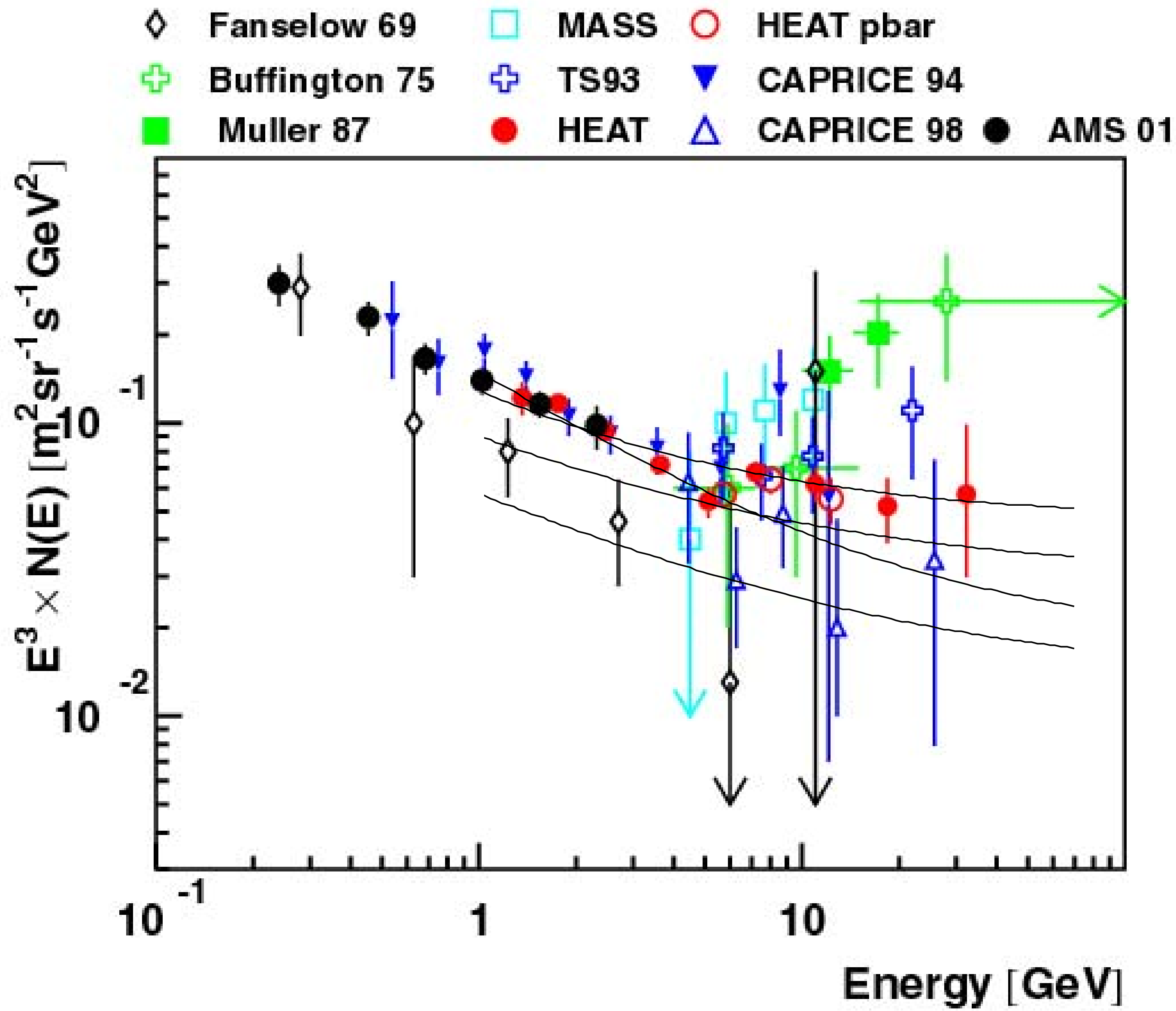
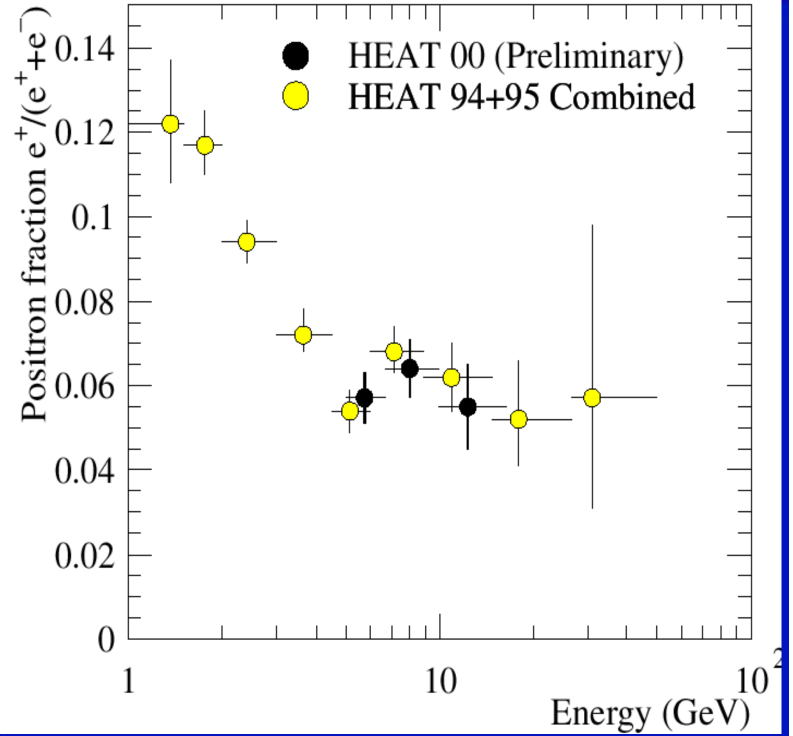
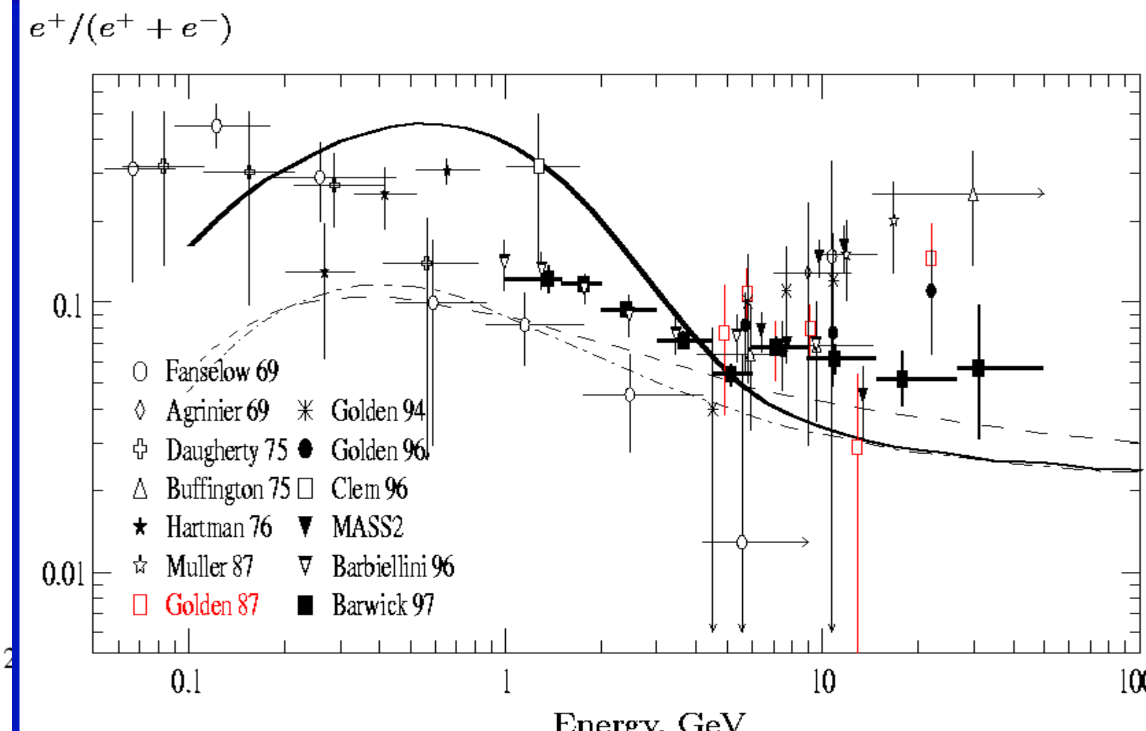
e+/e- ratio

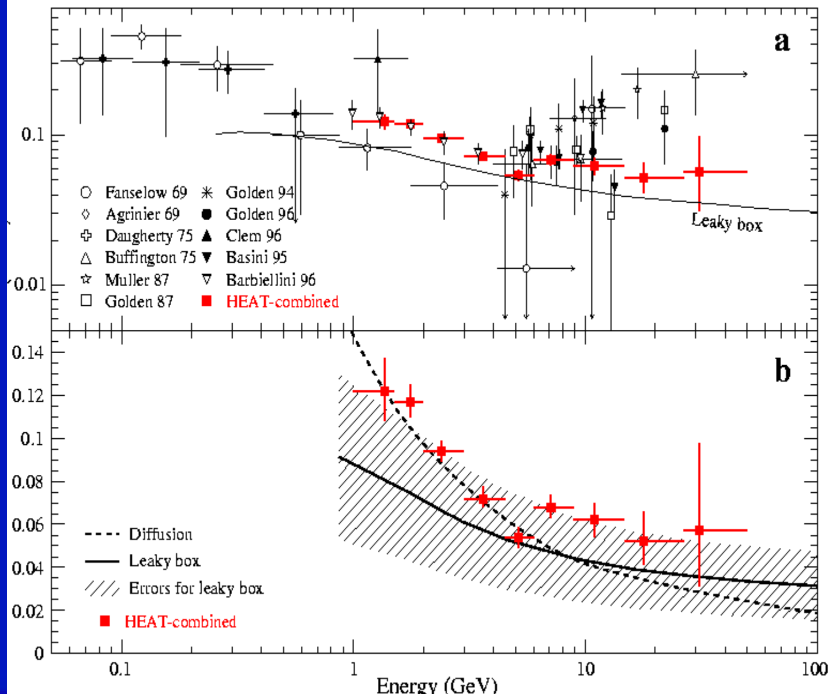


Fanselow 69
MASS
HEAT pbar
Buffington 75
TS93
CAPRICE 94
Muller 87
HEAT
CAPRICE 98
AMS 01
$E^3 \times N(E)$ [$m^2 sr^{-1} s^{-1} GeV^2$]
10^{-1}
10^{-2}
10^{-1}
1
10
Energy [GeV]



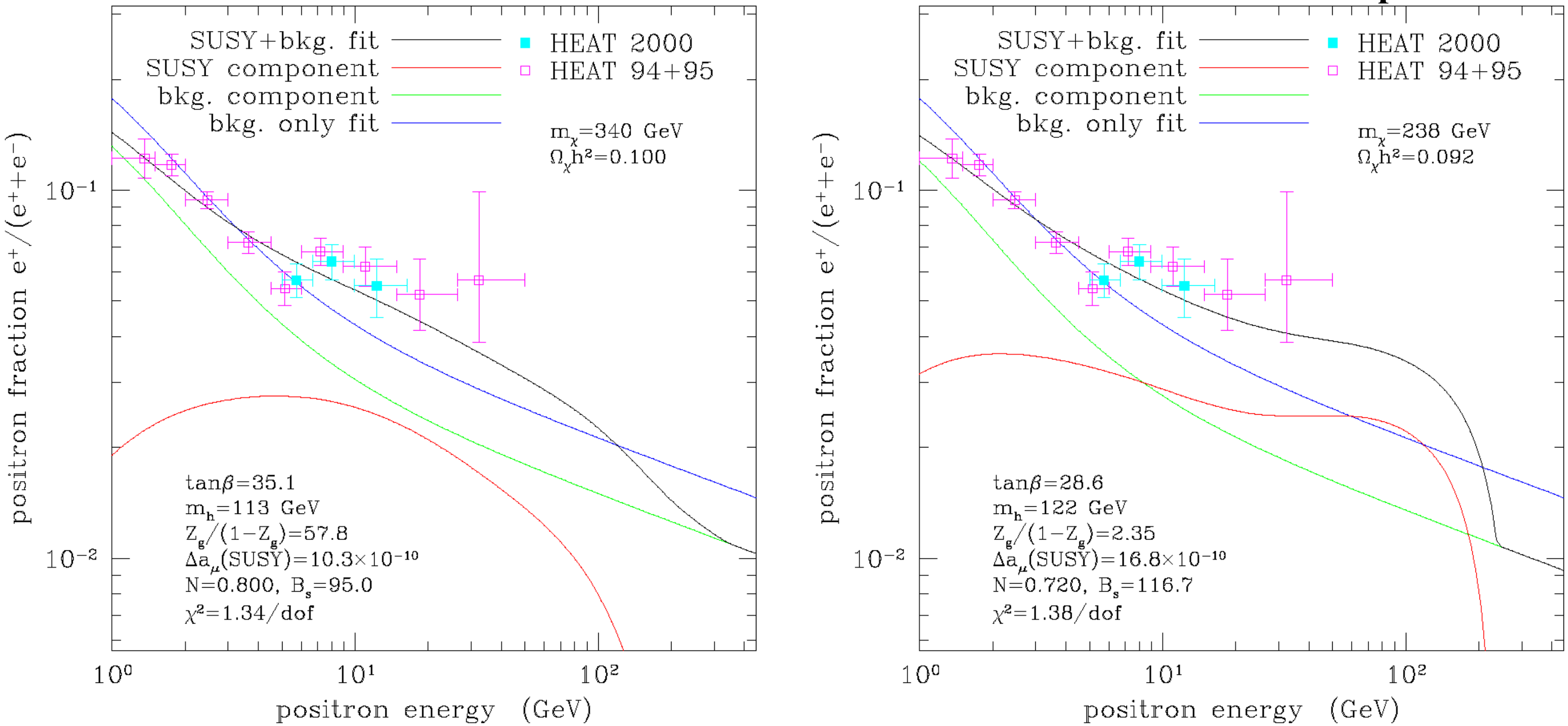


- Difficult to reconcile the shape of the spectrum with what is expected from the conventional CRs.
- Solar modulation at the time of data taking : worse.
- Though large uncertainty
- No component to explain a change of slope



SUSY fit to HEAT positron excess around 10 GeV

Baltz et al. astro-ph 0109318

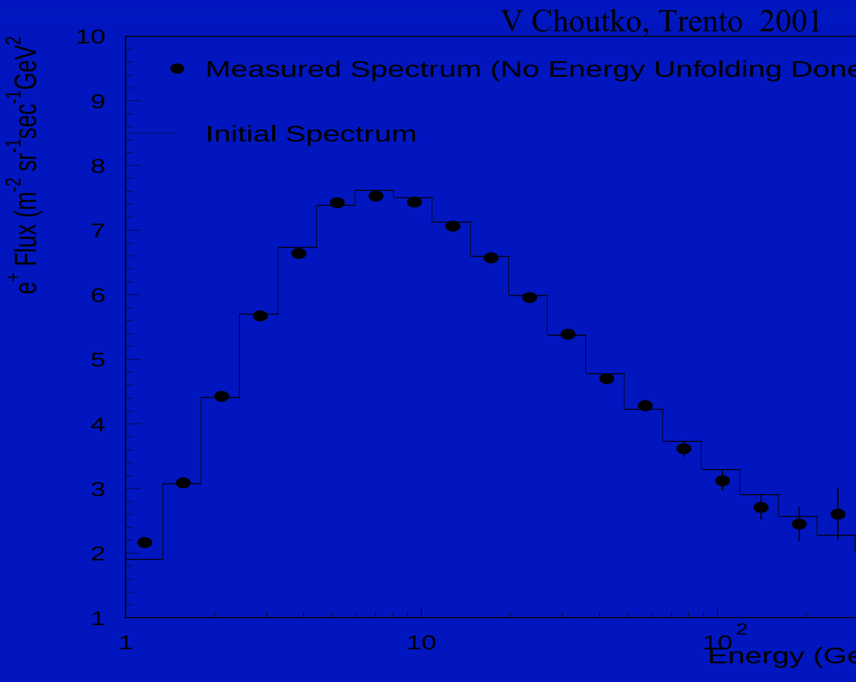


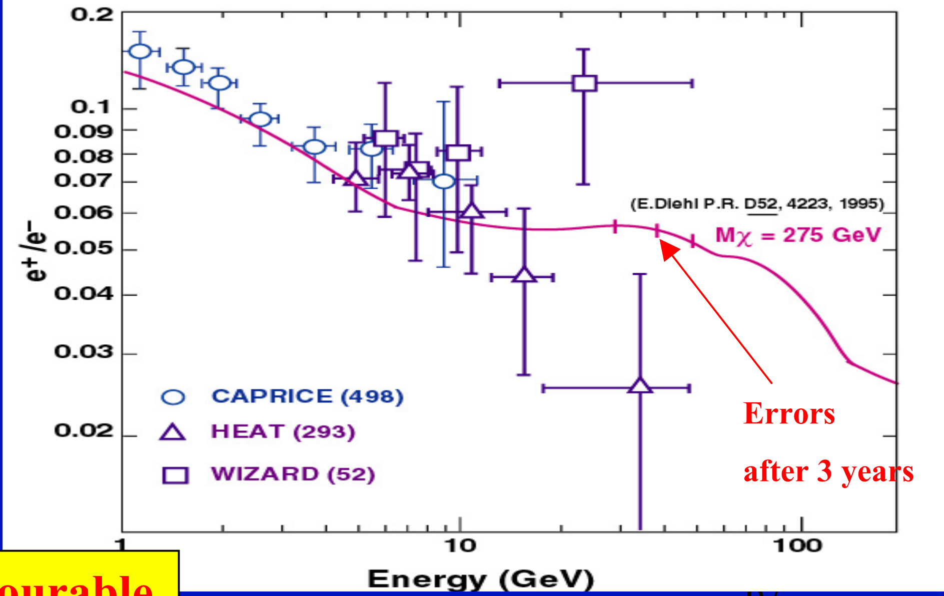
Need enhancement to have enough rate (clumpy DM distributions).

Does explain " the bump" really

Positrons in AMS-02

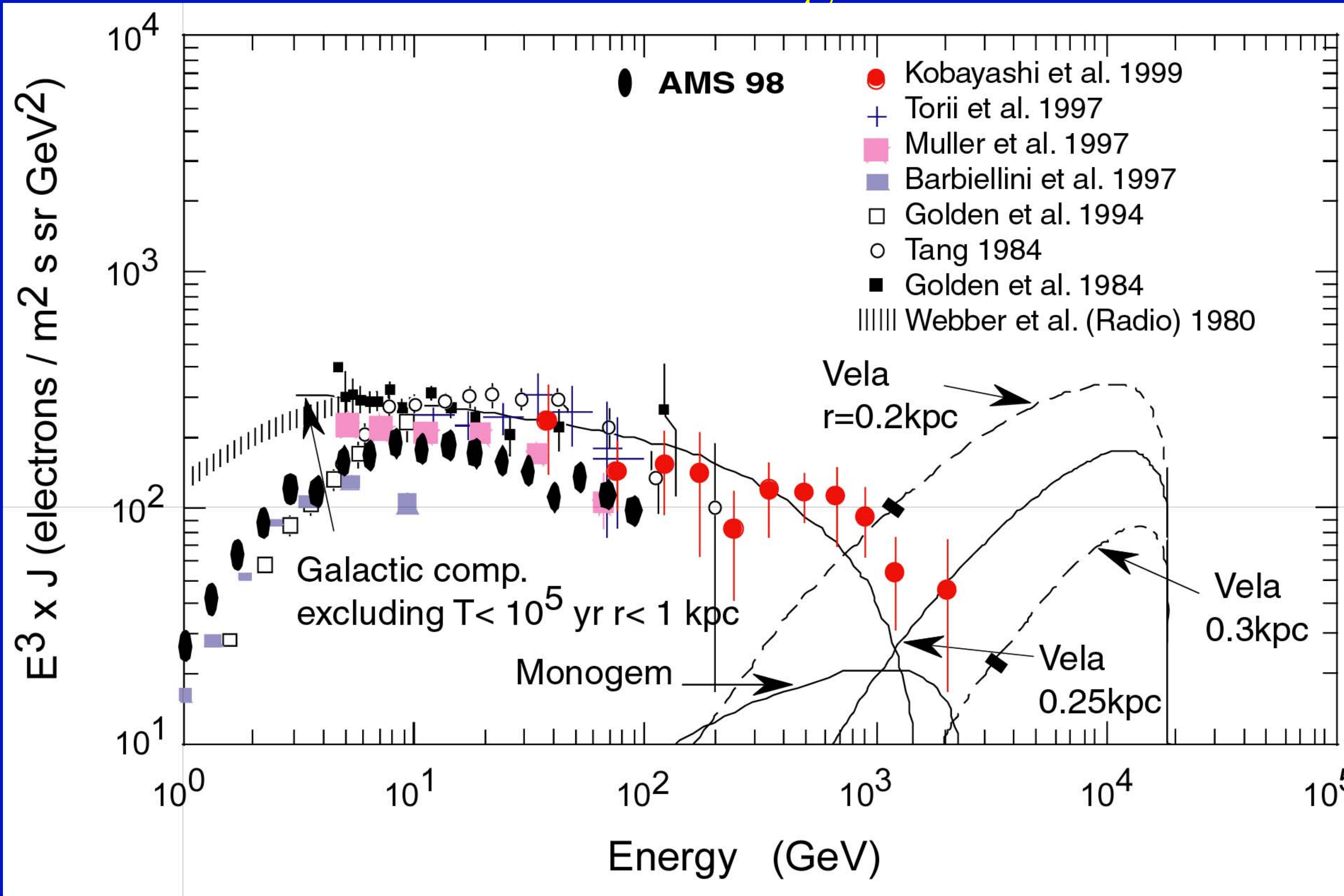
- Spectrum after 3 years of data taking.
- Improvement on range and error with respect to available measurements.
- Region around 7 GeV will be well measured.
- ~30% stat error at 300 GeV.
- ~1% stat error at 50 GeV. Sensitivity to exotic fluxes $> 10^{-7} E^{-2} (cm^2 .s.sr.GeV)^{-1}$.





One of the most favourable SUSY model

High Energy data on electrons have reached the TeV range



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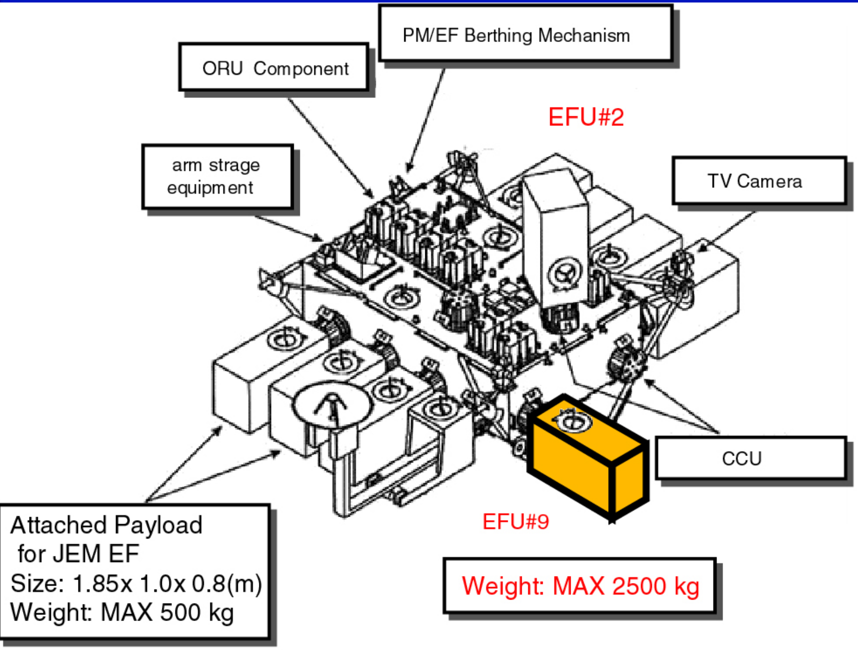
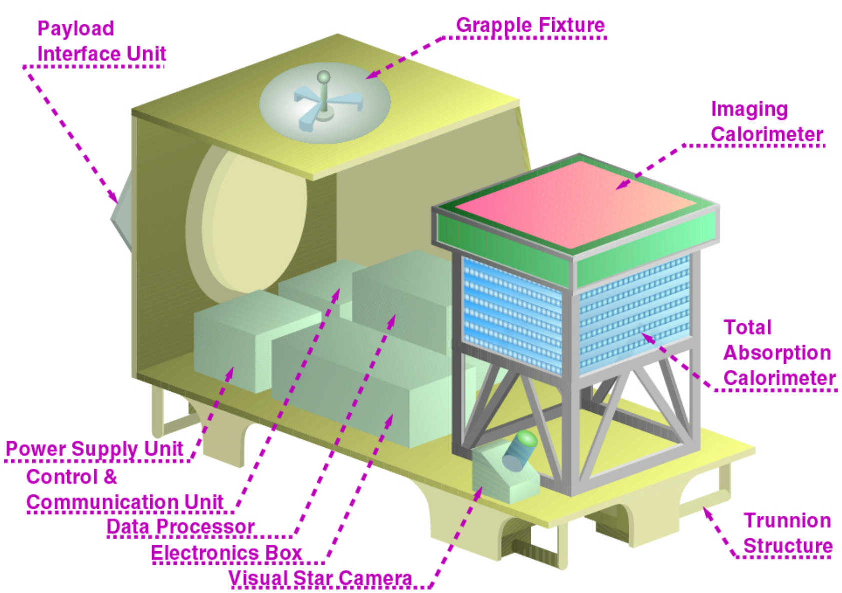
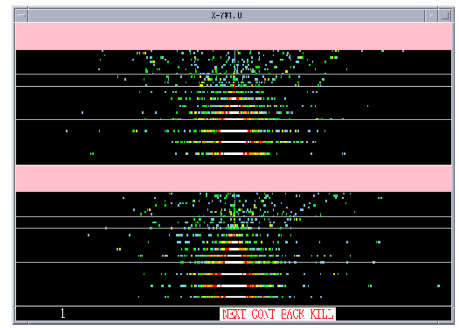
CALET experiment on the japanese exposed facility on the ISS (>2006)

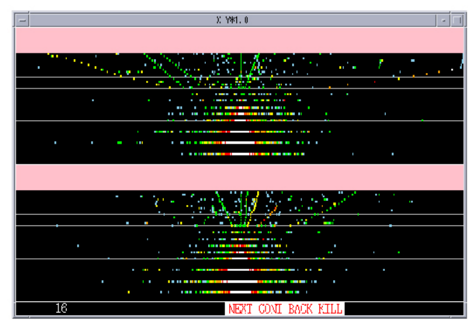




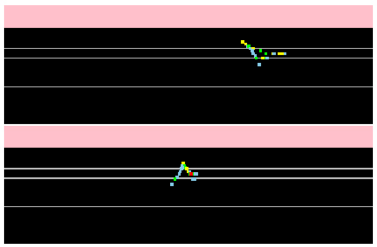
Electron 1 TeV



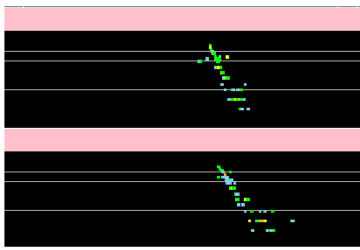
Proton 3 TeV



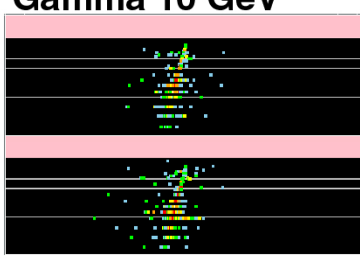
Gamma 100 MeV



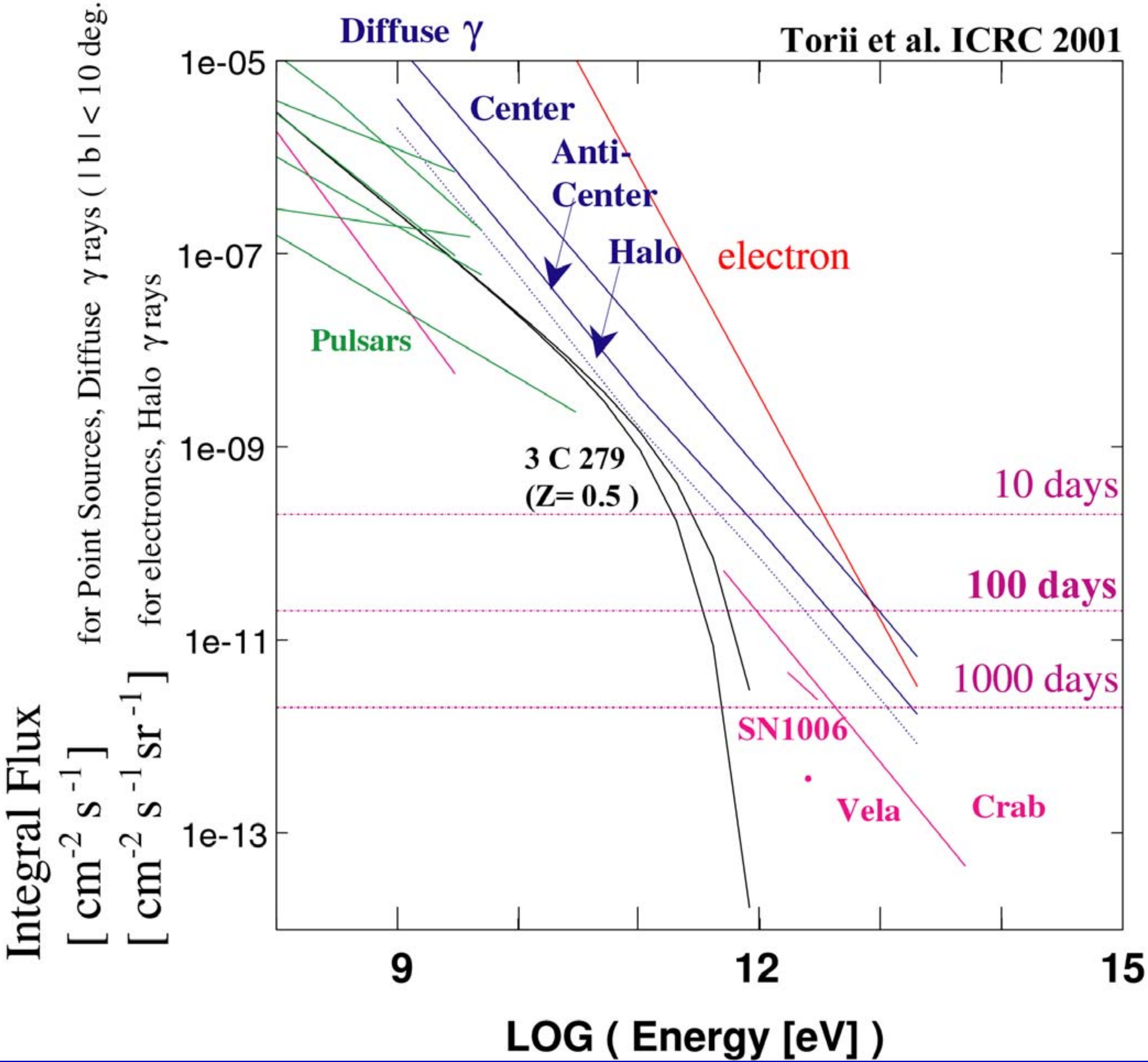
Gamma 1 GeV



Gamma 10 GeV



Detection limits for point sources and diffuse components
CALET detector on the ISS

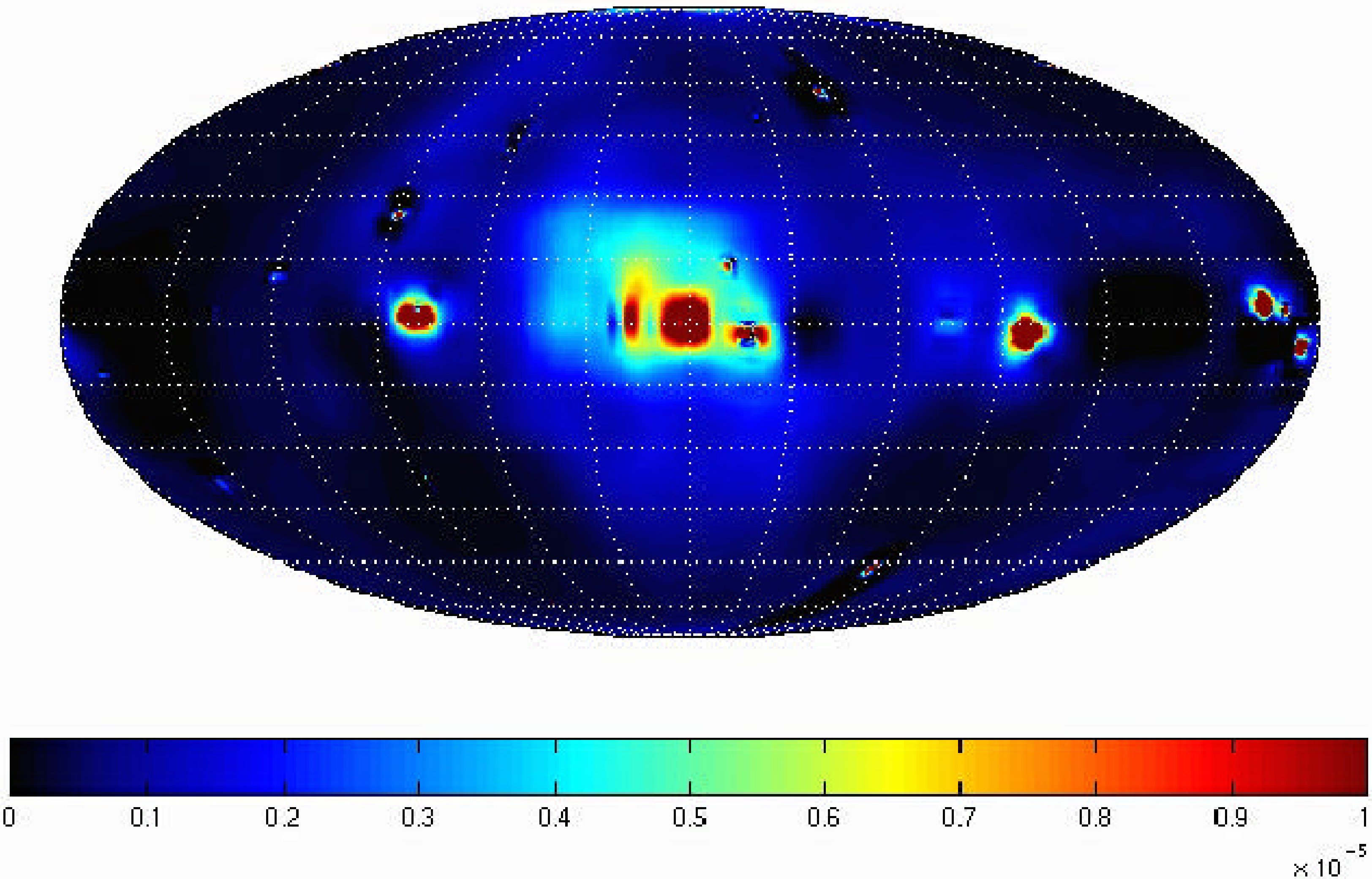


Gamma rays and SUSY DM

AMS02-γ	$\geq$ 2005
Agile	$\geq$ 2003
GLAST	$\geq$ 2006

Egret on CGRO stopped in 1999/2000

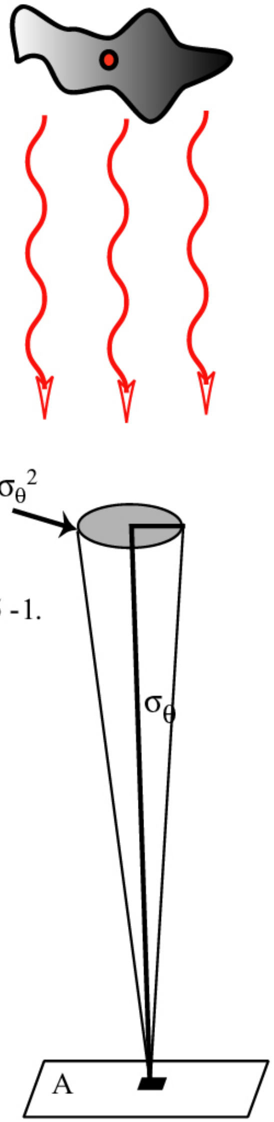
Search for the Nature of Dark Matter



Contours of photons intensity in units of 10^{-5} ph cm^{-2} sec^{-1} sr^{-1} for $E\gamma > 1$GeV, after subtraction of "best estimate of Galactic Diffuse model. Data indicates presence of a galactic halo (Dixon et al. 1998).

Point Source

$$S/\sqrt{B} \sim \frac{\sqrt{A\ t}}{\sigma_\theta}$$



$\Delta\Omega = \pi\ \sigma_\theta^2$

$\sigma_\theta \sim E^{-\alpha}$

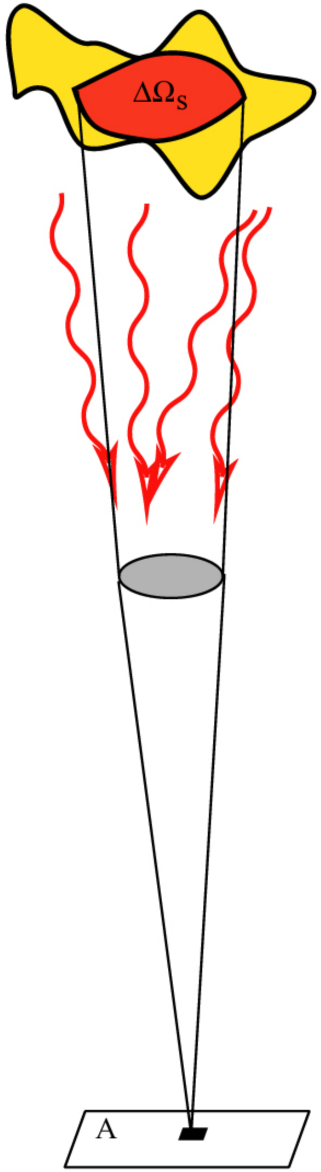
$\alpha \sim 0.5 - 1.$

$$S = \int \Phi_S(E)\ dE\ \ A\ t \sim \Phi_{oS}\ A\ t$$

$$\sqrt{B} = \sqrt{\int \Phi_B(E)\ dE\ \ \Delta\Omega\ A\ t} \sim \sqrt{\Phi_{oB}\ \Delta\Omega\ A\ t}$$

Extended Source

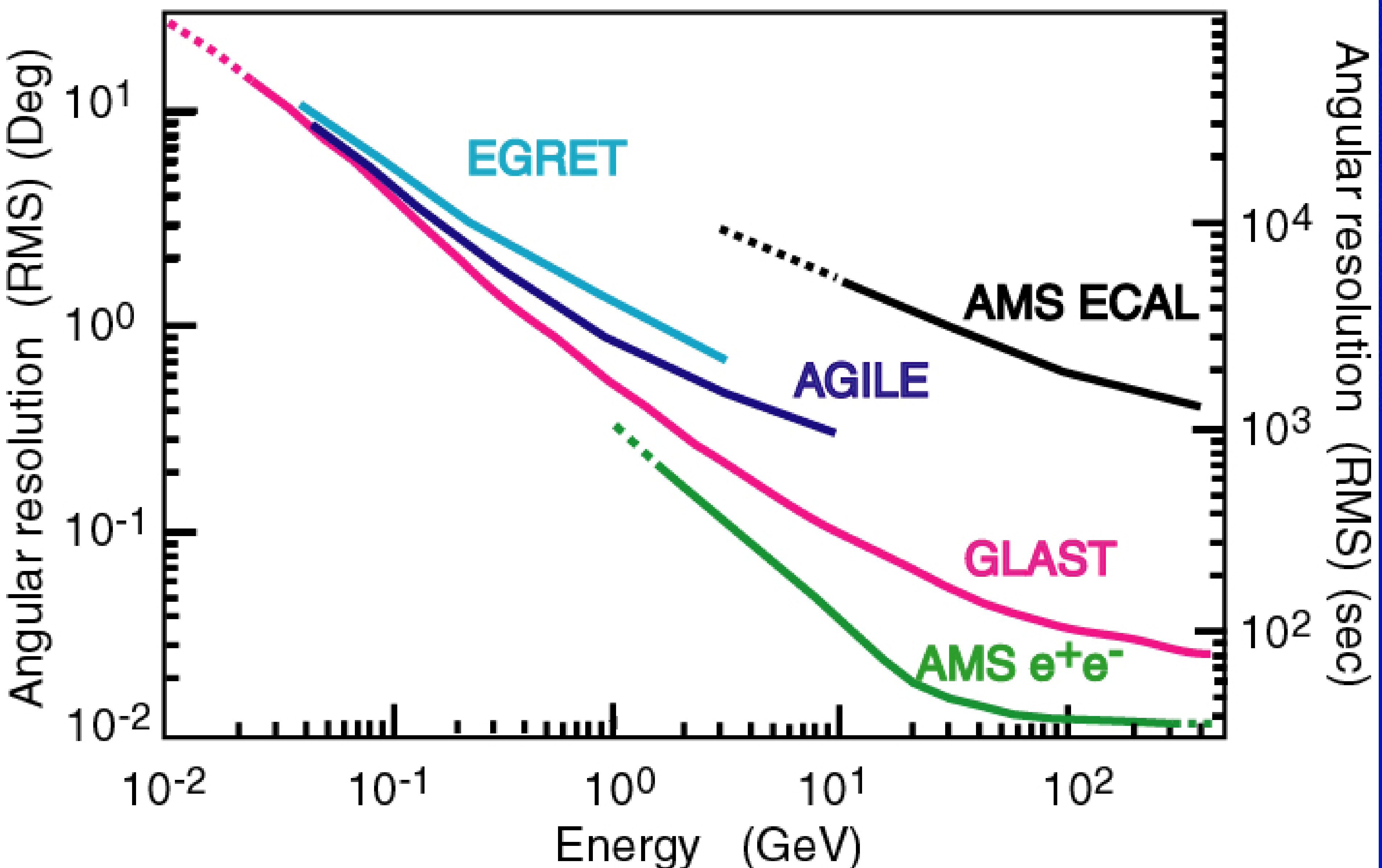
$$S/\sqrt{B} \sim \sqrt{A\ t}$$



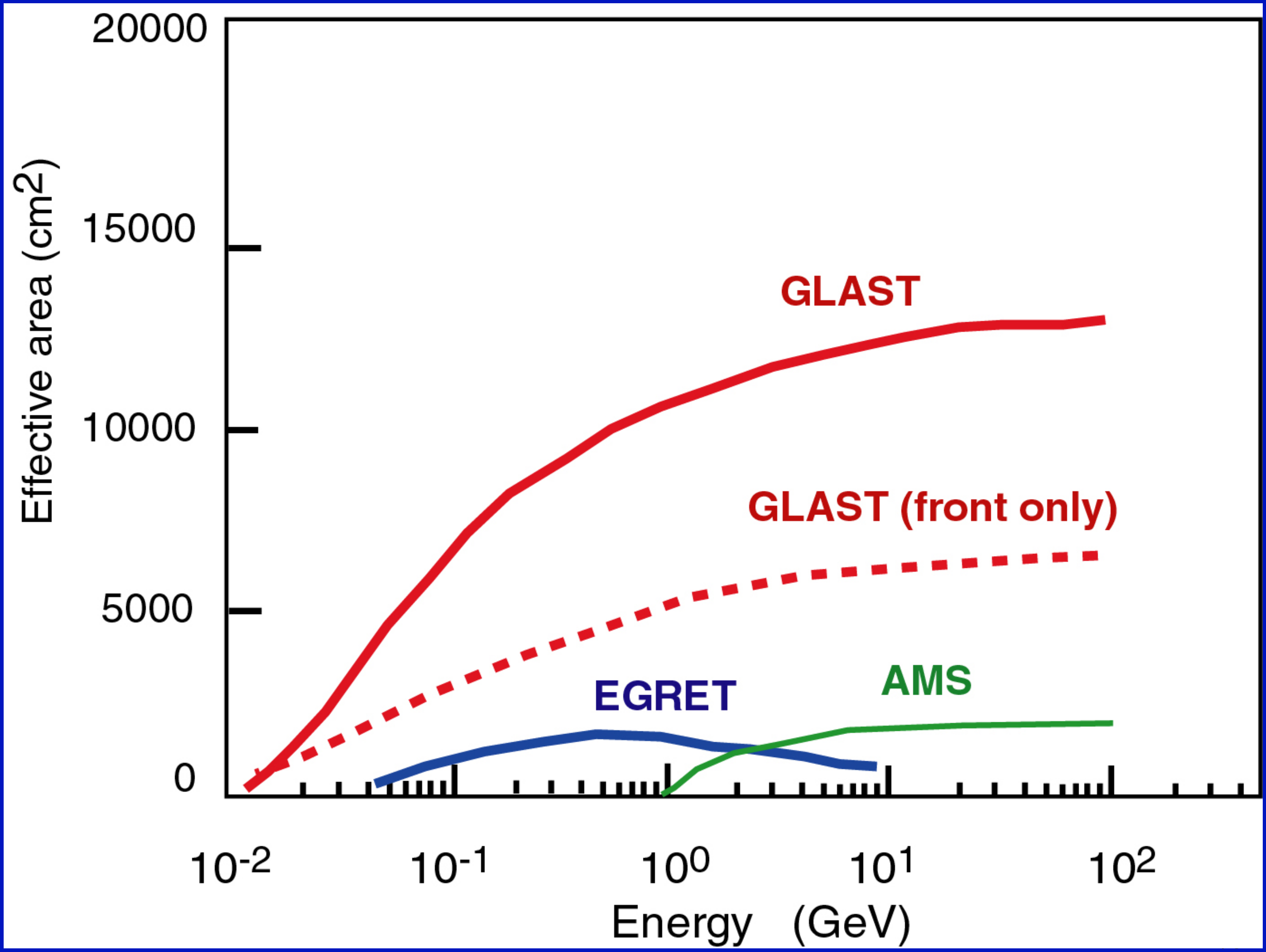
$$S = \int \Phi_S(E)\ dE\ \ A\ t \sim \Phi_{oS}\ \Delta\Omega_S\ A\ t$$

$$\sqrt{B} = \sqrt{\int \Phi_B(E)\ dE\ \ \Delta\Omega\ A\ t} \sim \sqrt{\Phi_{oB}\ \Delta\Omega_S\ A\ t}$$

Angular resolution of space born γ–ray Detectors



Effective area of gamma ray detectors



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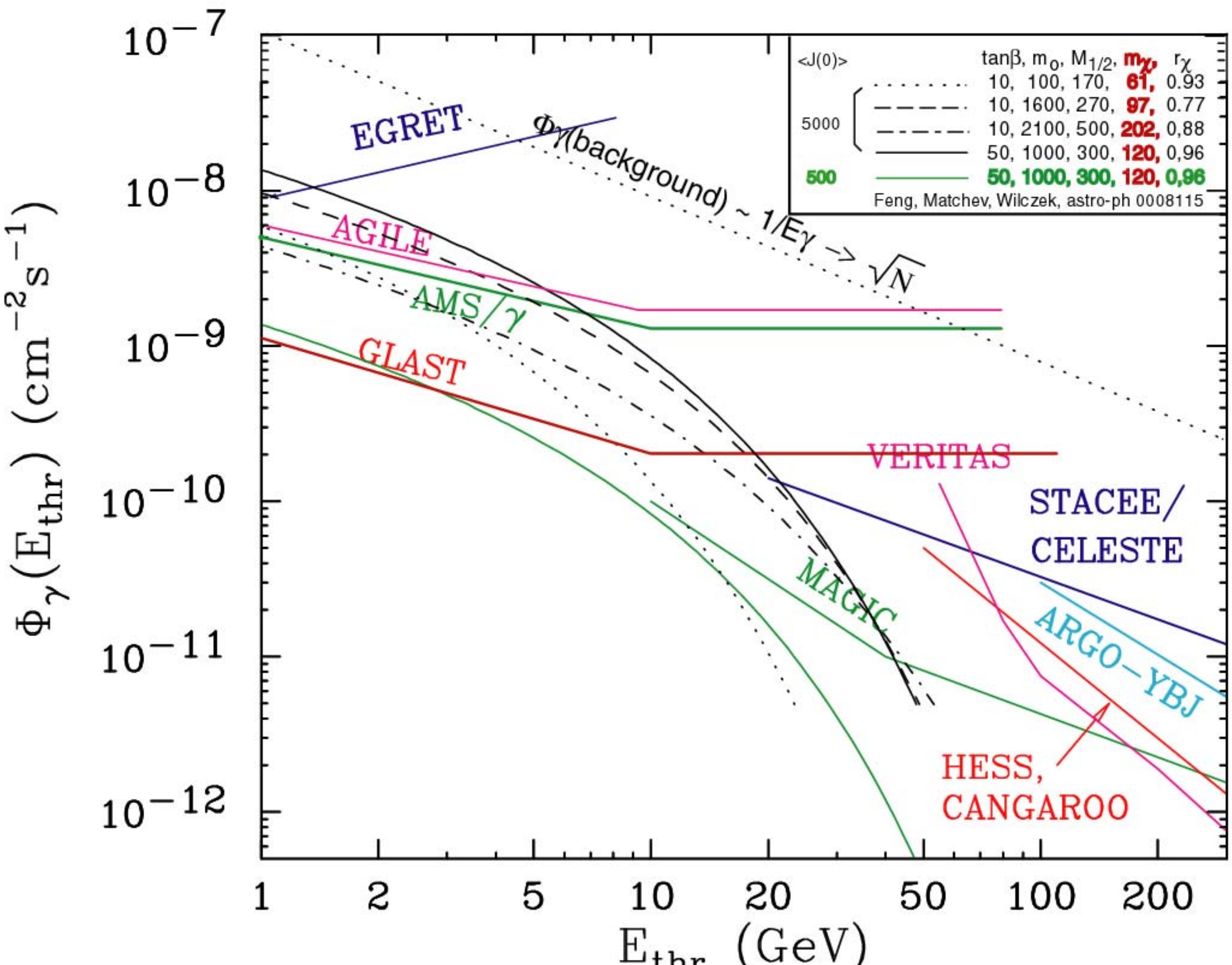
SUSY D.M. γ fluxes above E_{thr} vs Point Source Sensitivity



Interesting to consider sensitivity at lower E_{thr} for GLAST or AGILE (see Morselli's poster)

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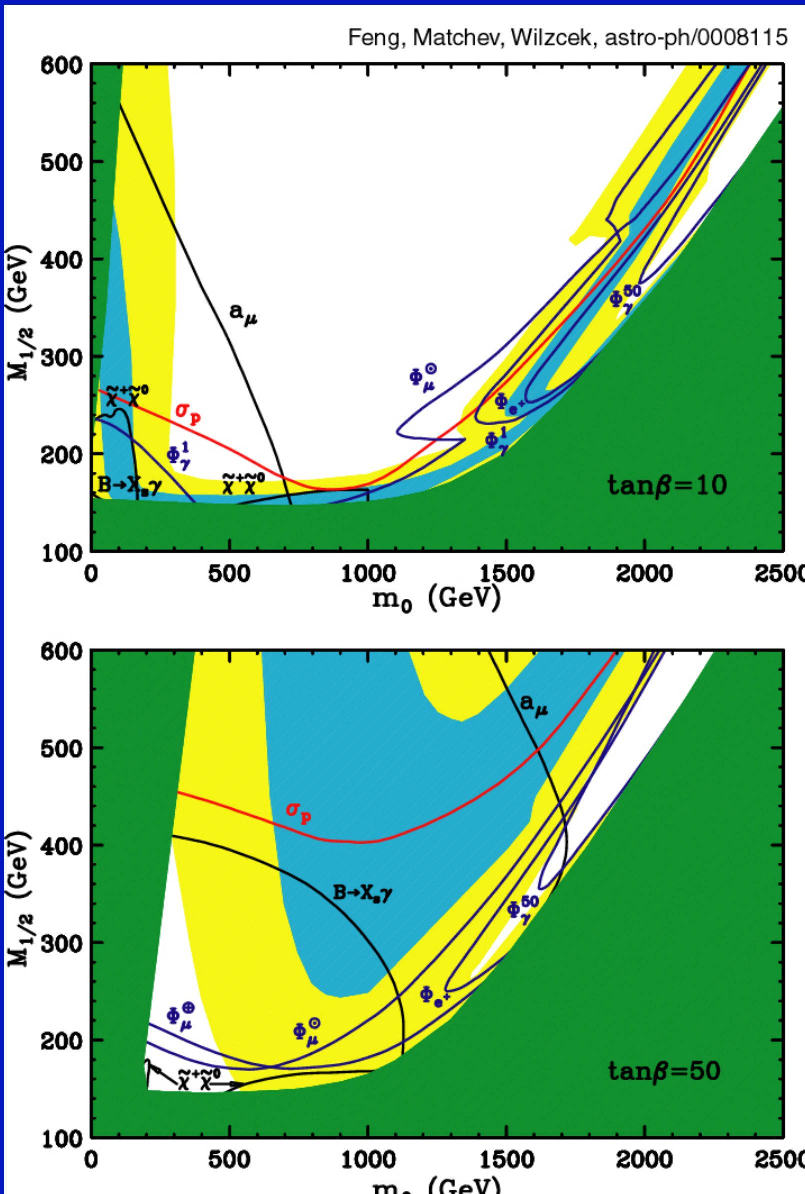
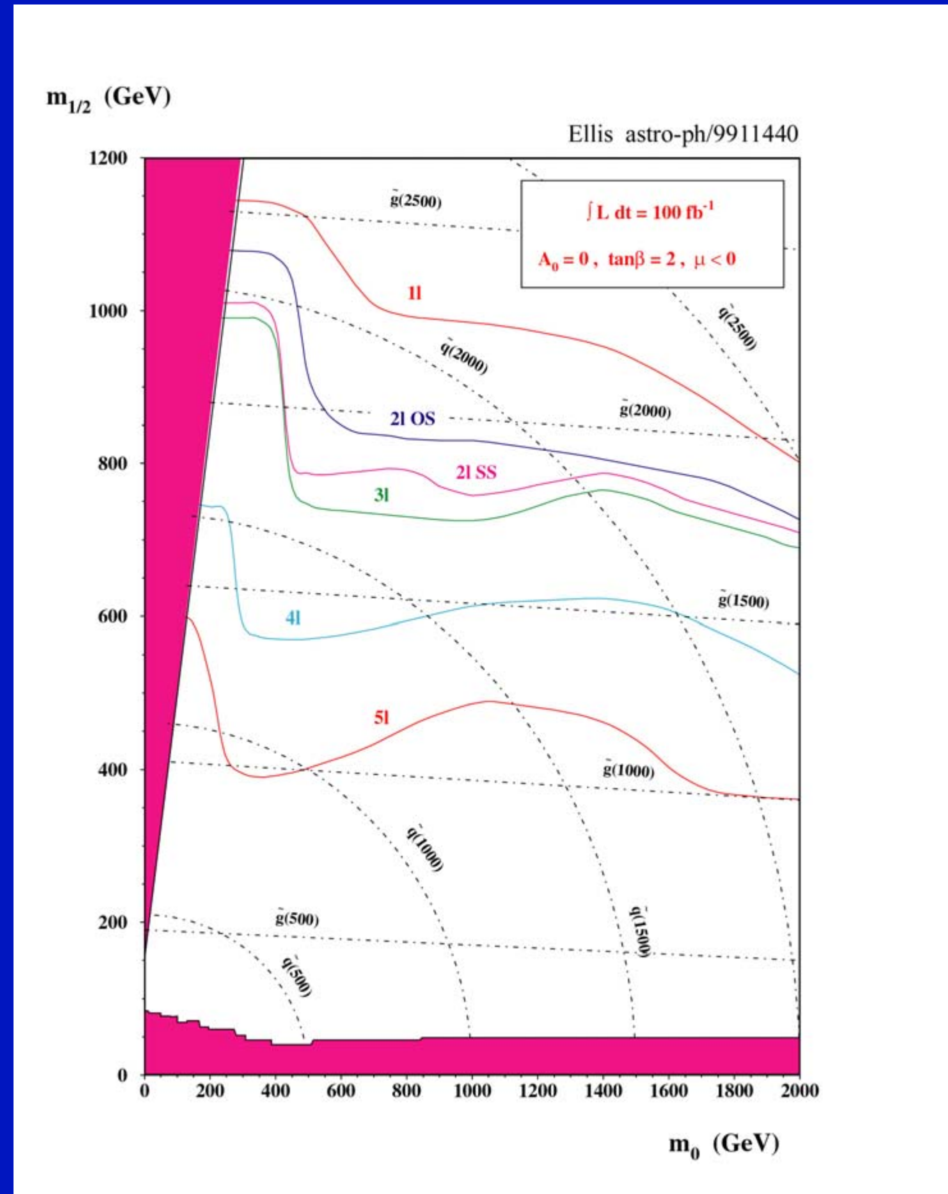
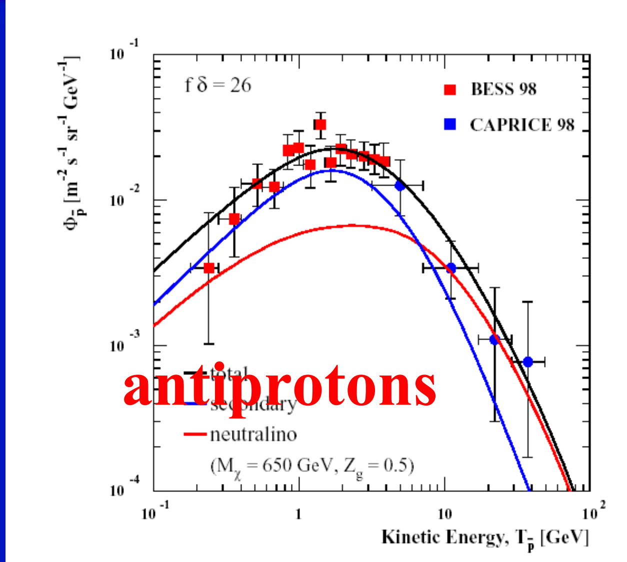
Exploration of SUSY parameter space (next 5-10 years)

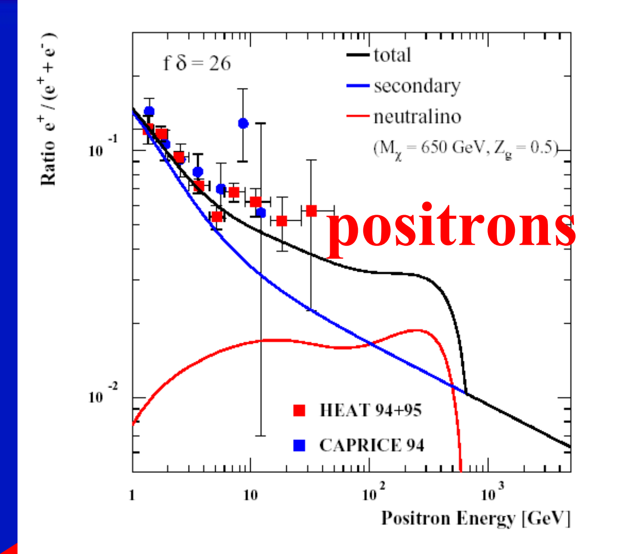




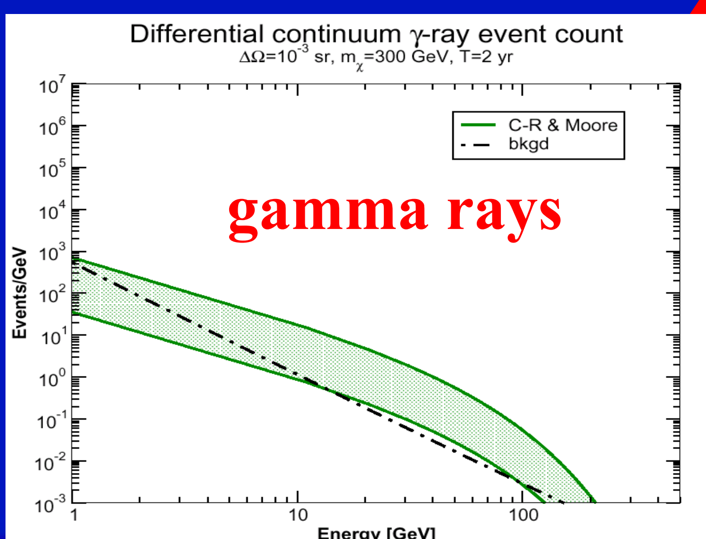
from cosmic rays esperiments

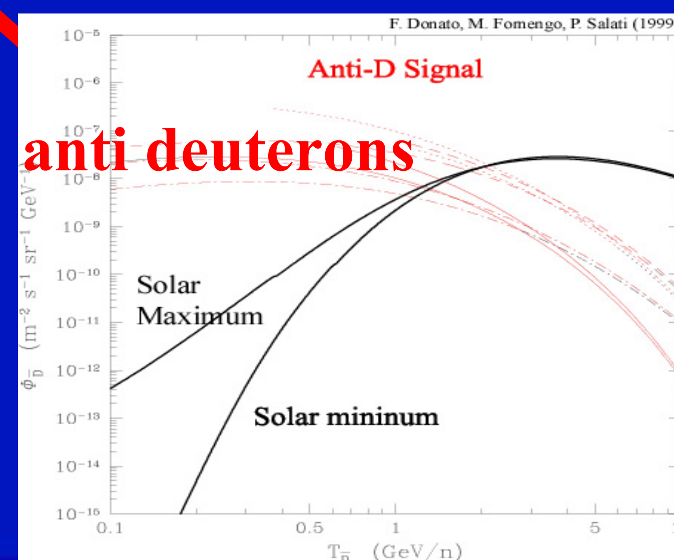
from LHC experiments





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

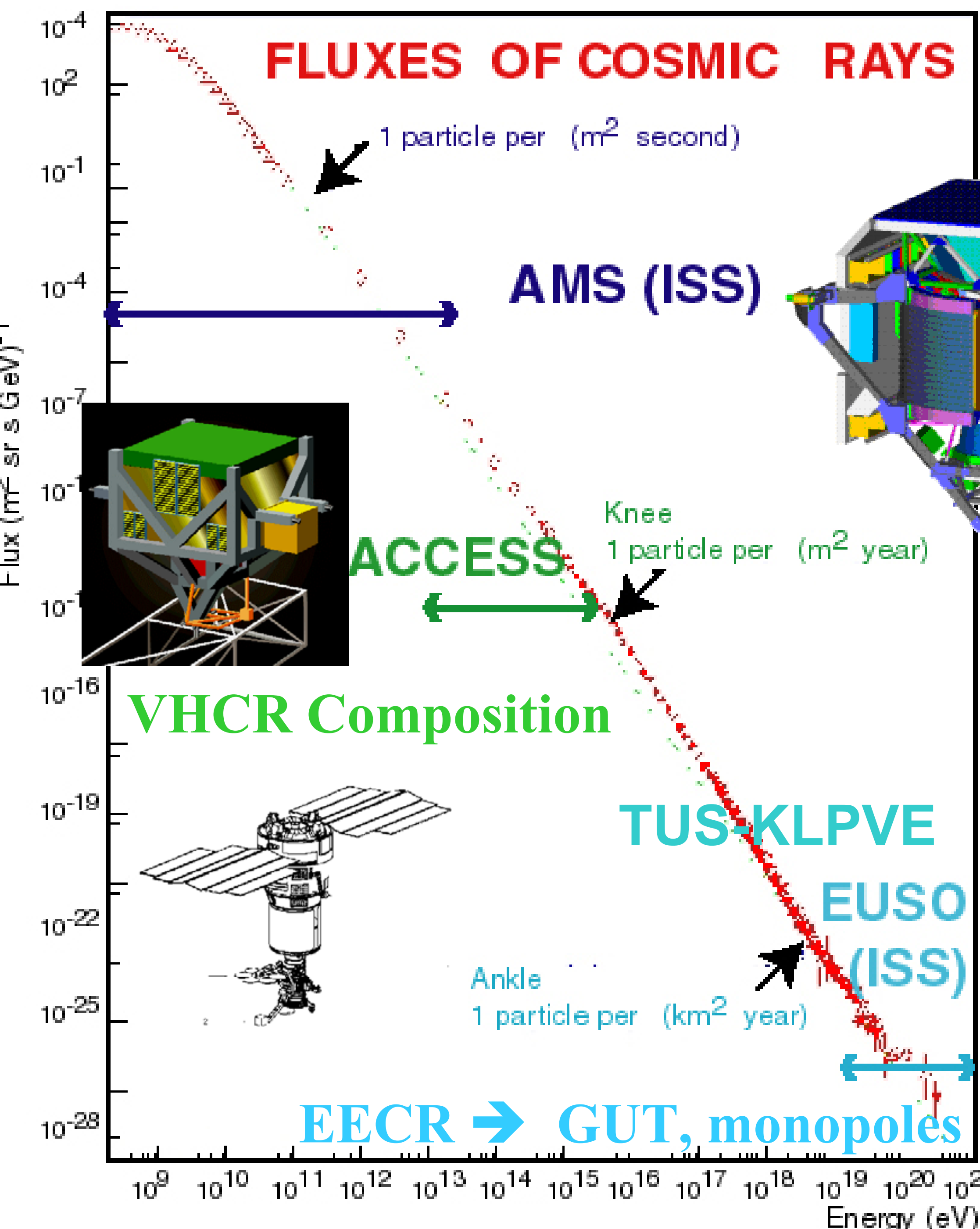


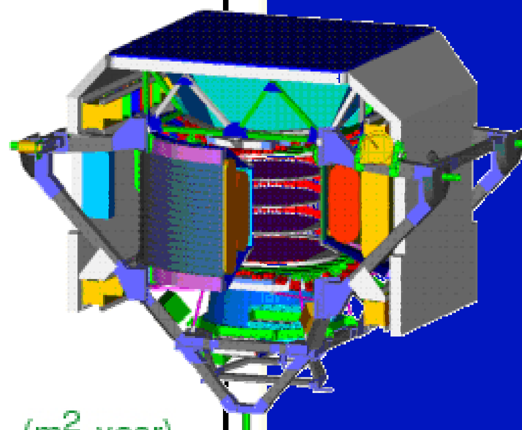


Ultraheavy particle searches

EECR

EE Neutrinos

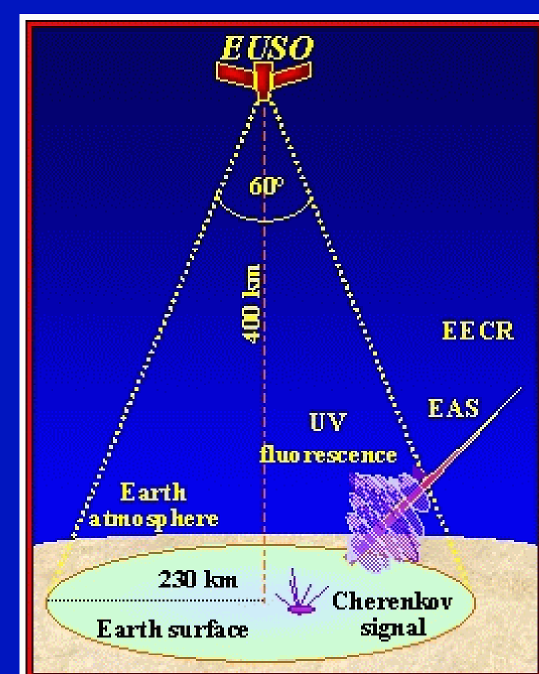




Absence of Antimatter → CP violation, GUT

Dark Matter → SUSY, Axions

Atmospheric neutrinos → Neutrino mass



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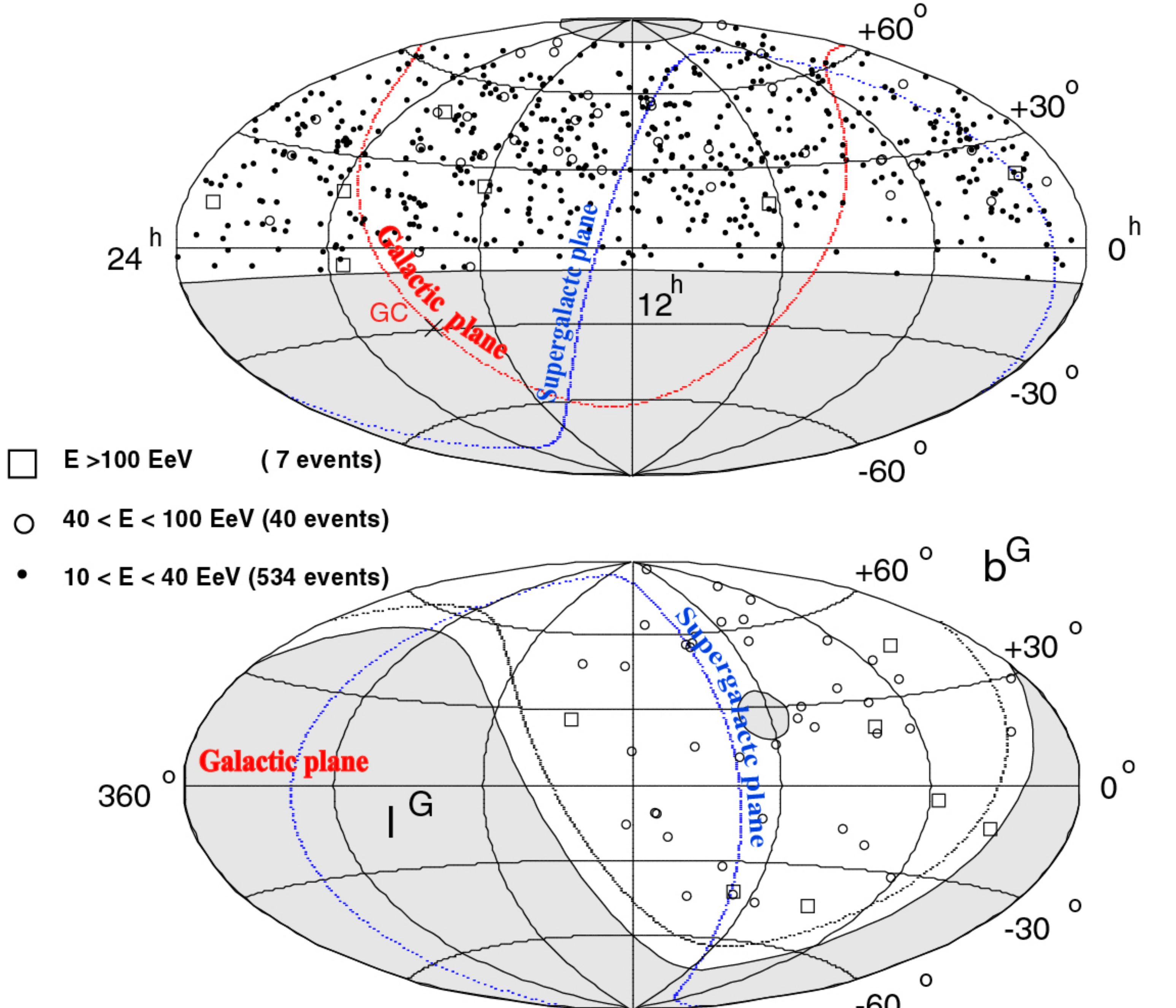
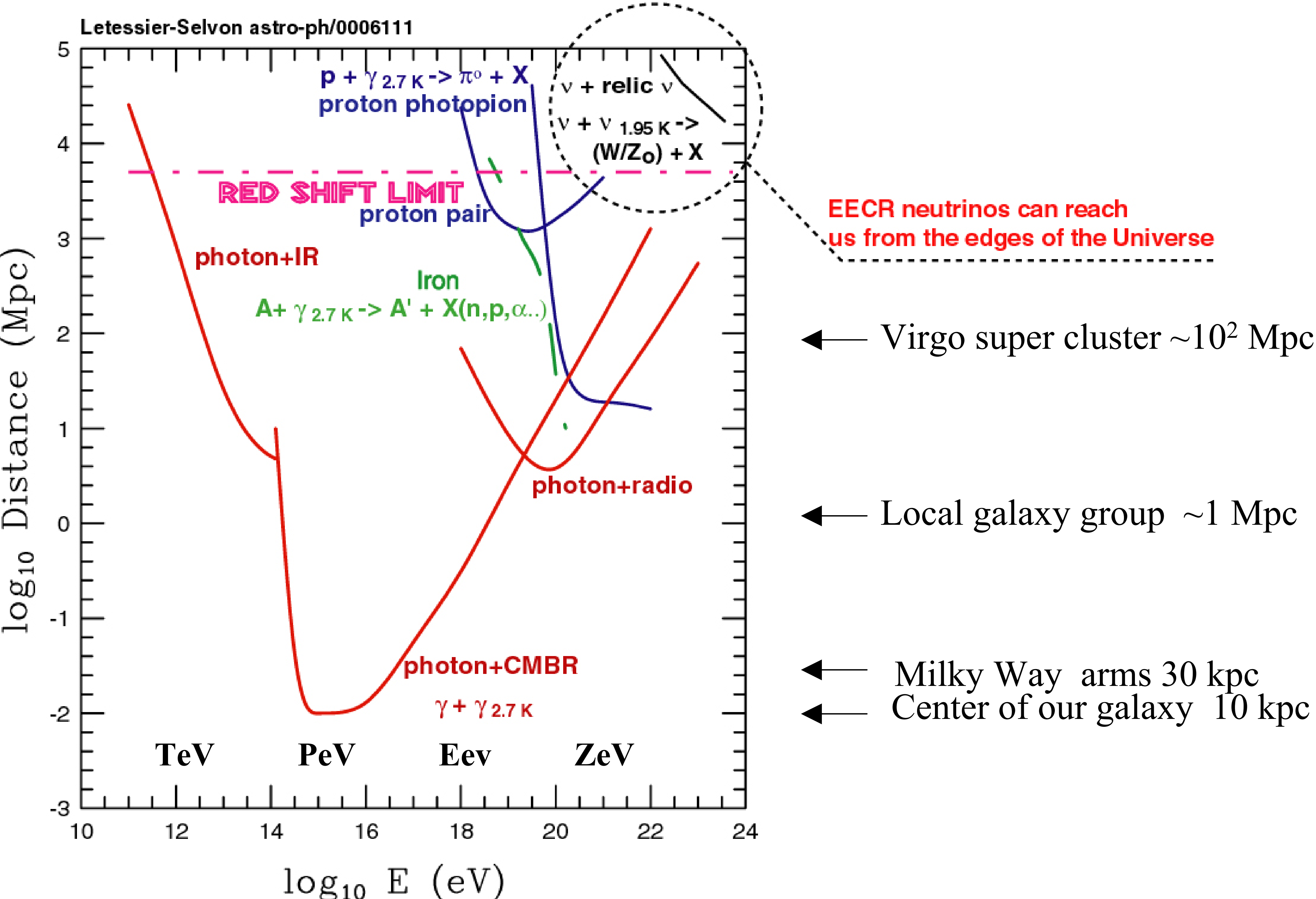
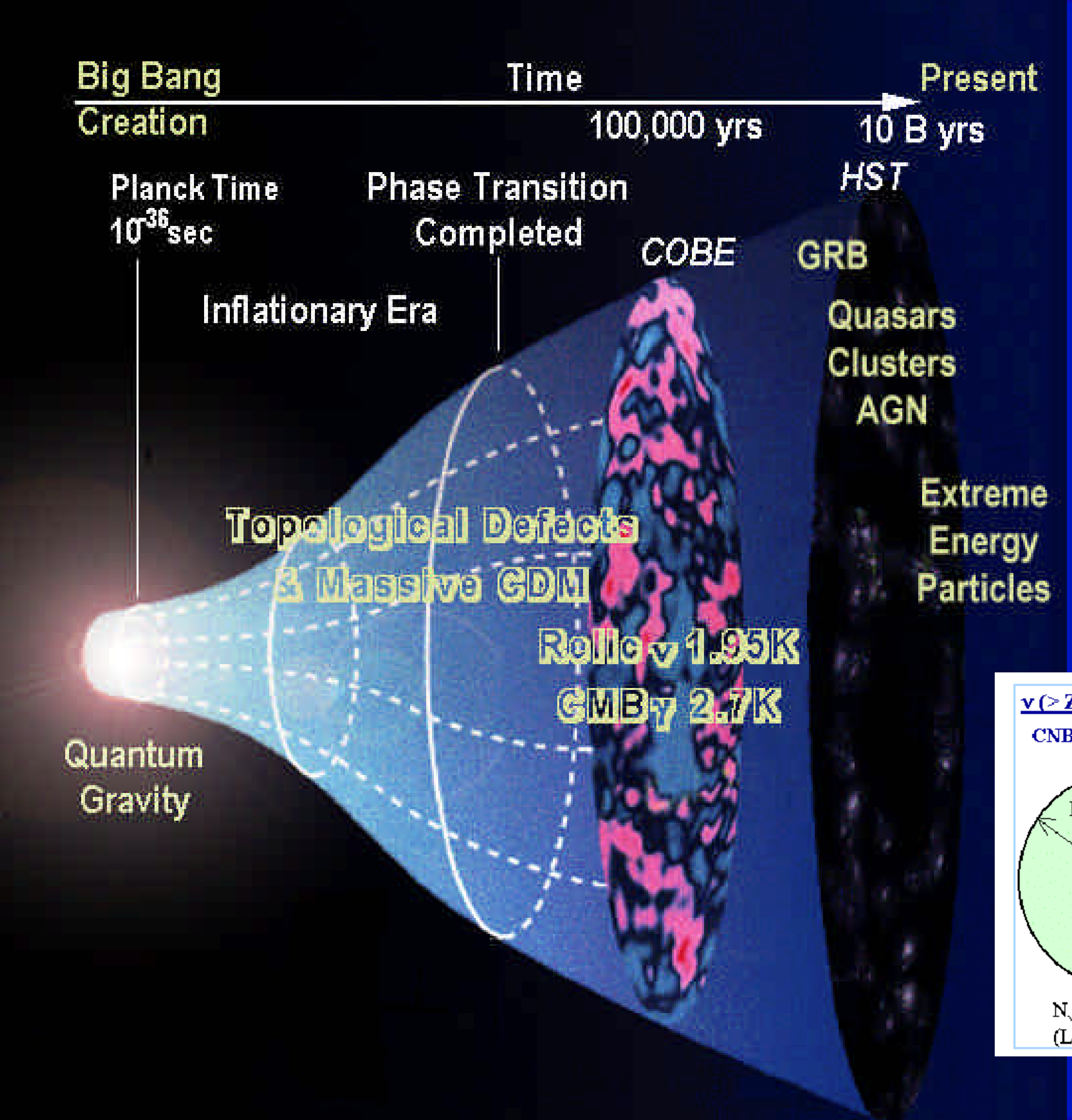
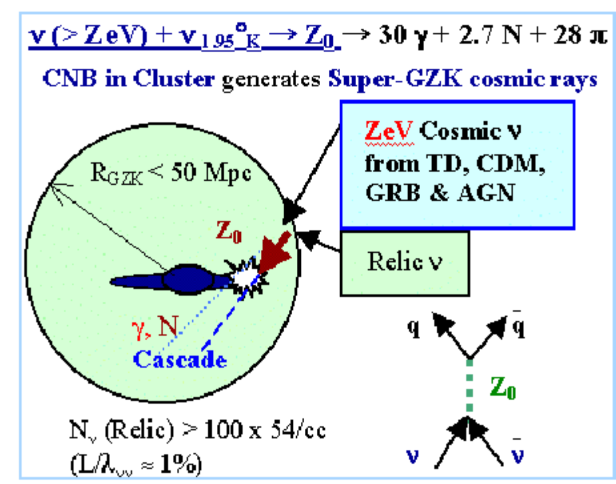
AGASA Takeda et al. astro-ph/9902239



The universe is opaque to EECR except neutrinos (GKZ cutoff)







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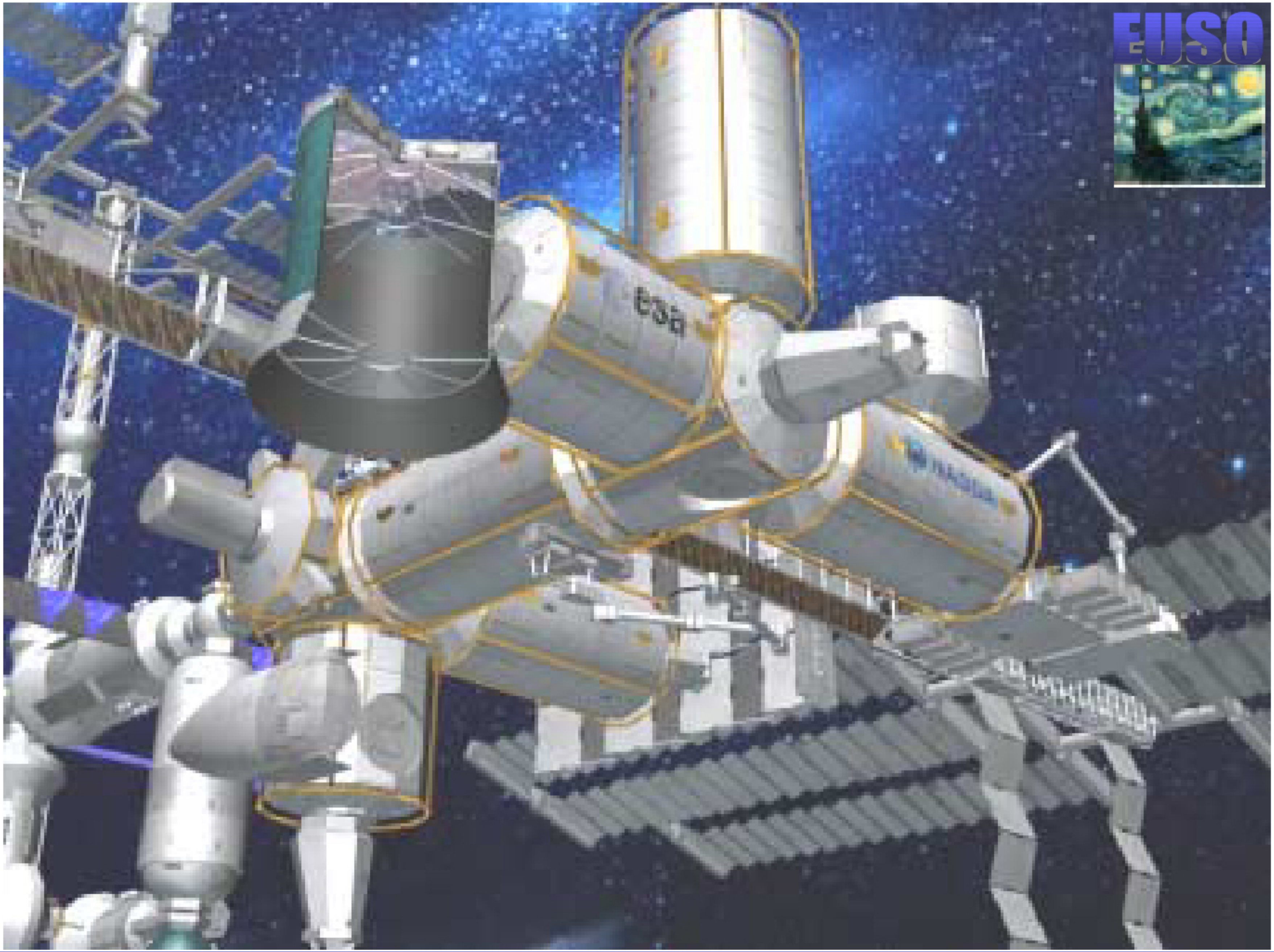
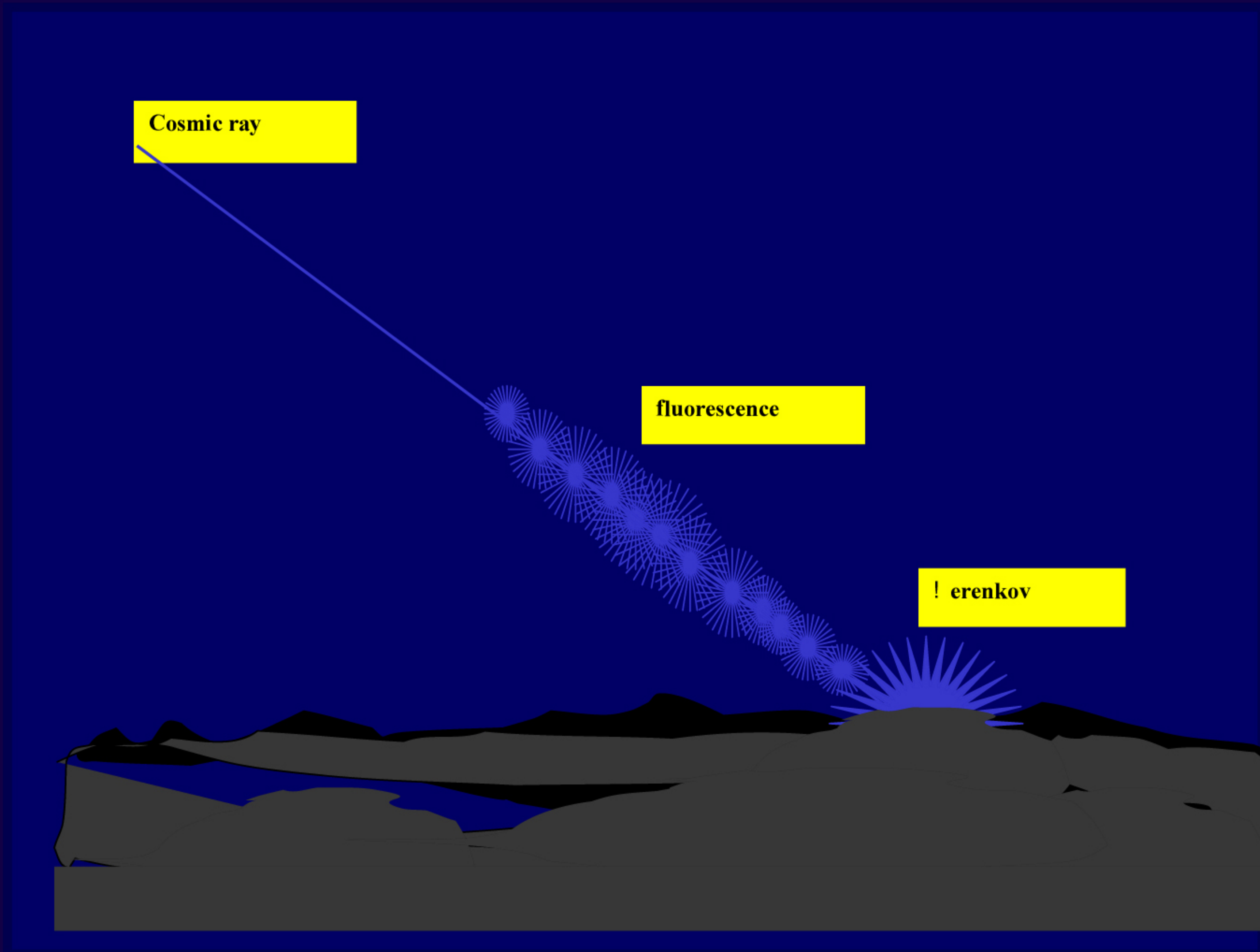
Extreme Universe Space Observatory - EUSO

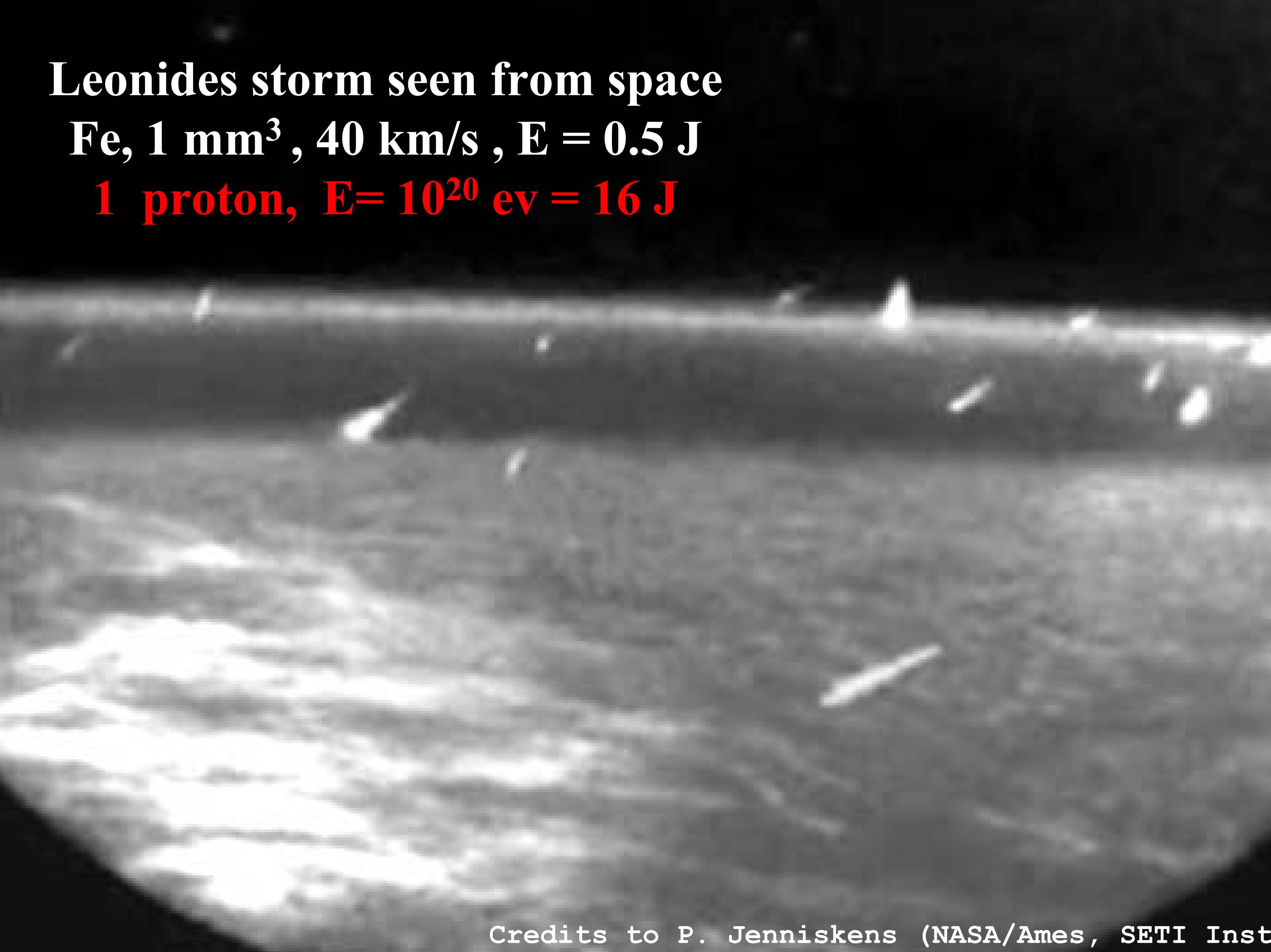



Cosmic ray
fluorescence
! erenkov

Leonides storm seen from space

Fe, 1 mm^3 , 40 km/s , E = 0.5 J

1 proton, E= 10^{20} ev = 16 J



Credits to P. Jenniskens (NASA/Ames, SETI Inst

....neutrinos...

SEEN

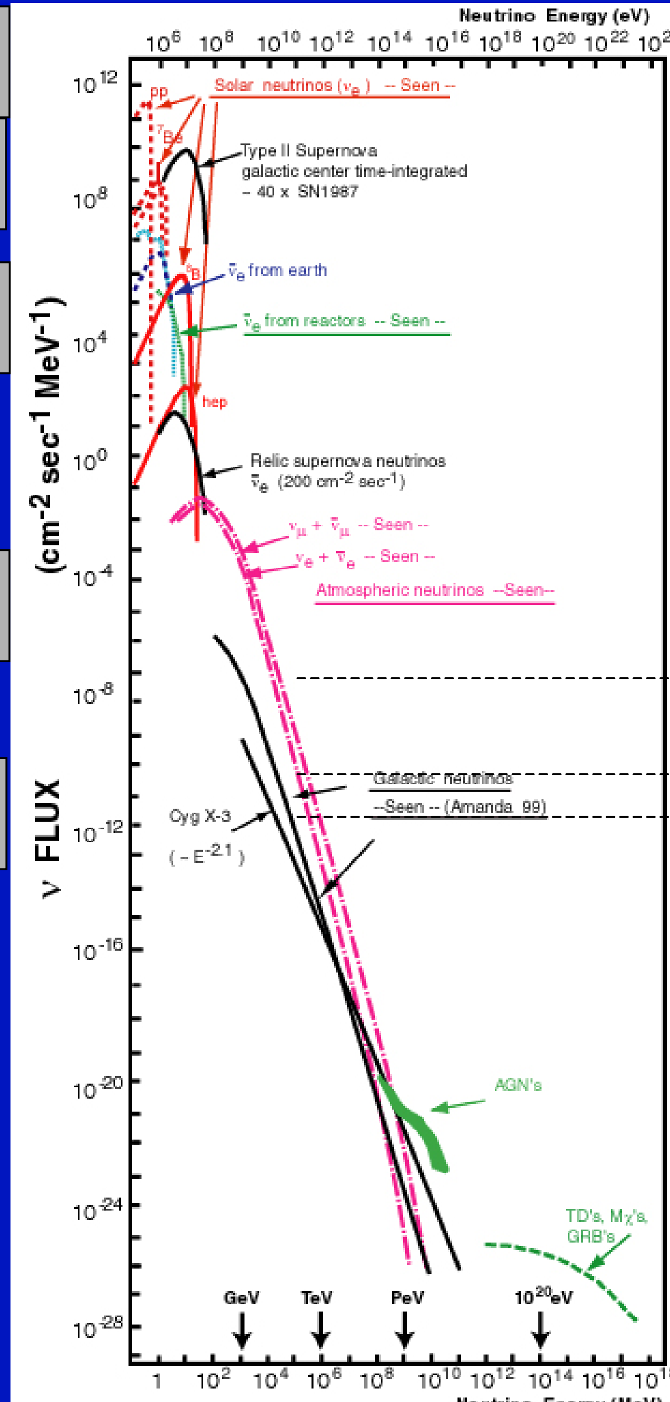
solar

supernova 1987

reactor

atmospheric

galactic



1 /m² s GeV

1 /m² h GeV

1 /m² d GeV

relic

UNSEEN (yet)

AGN's

TD,Mχ,GRB

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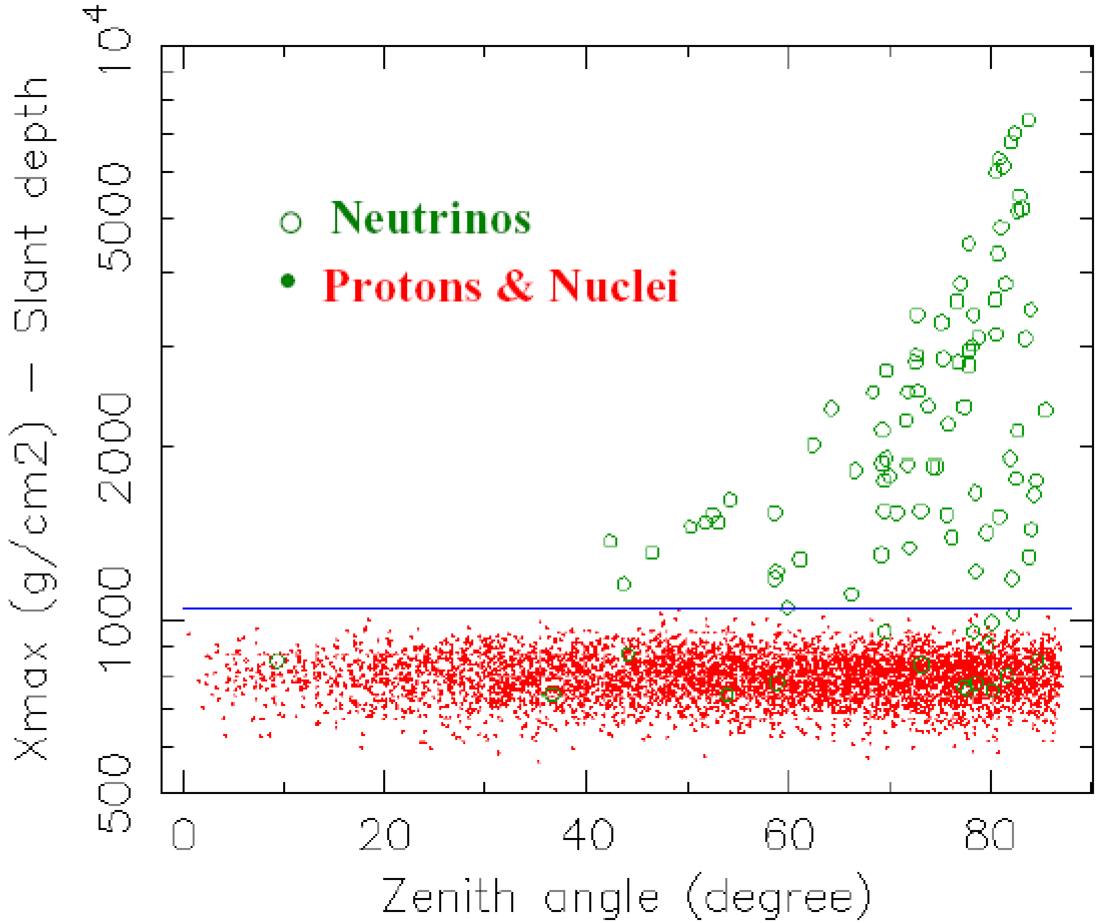


Neutrinos
Protons & Nuclei
Xmax (g/cm2) – Slant depth
10^4
5000
2000
1000
500
0
20
40
60
80
Zenith angle (degree)

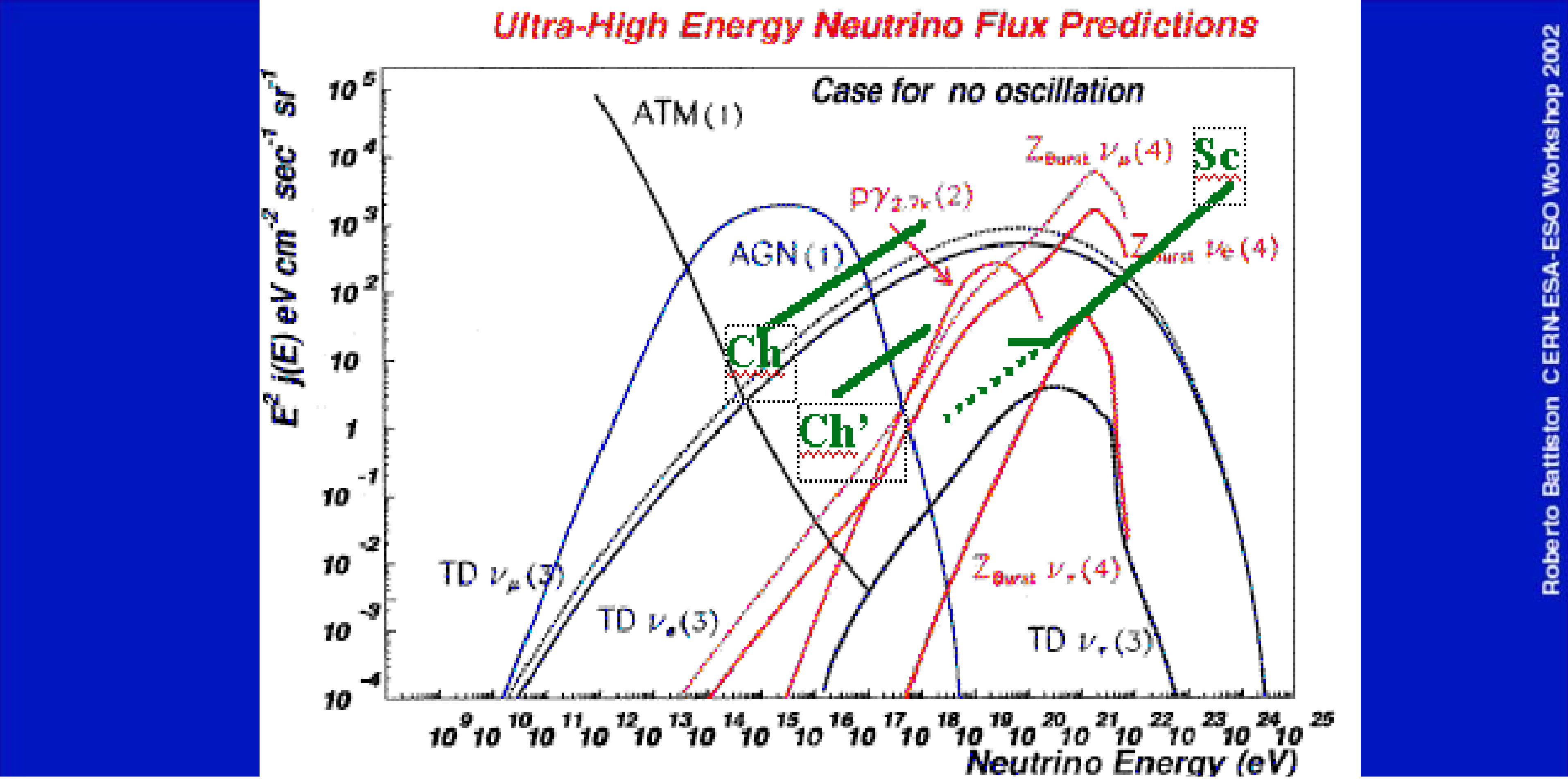


Table 1.3 - Neutrino event rates with ***EUSO*** for four major origins. The energy dependence of the neutrino cross section ($\sigma \propto E^{0.5}$) is applied to the calculations. Targets used here are one-half of atmosphere and a partial Earth crusts (2000 r.l. at 10^{20} eV). The ratio of the event rate in the atmosphere and Earth-crust at 10^{20} eV is ~ 1:2. The numbers represent the interacted events of only ν_μ and ν_e.

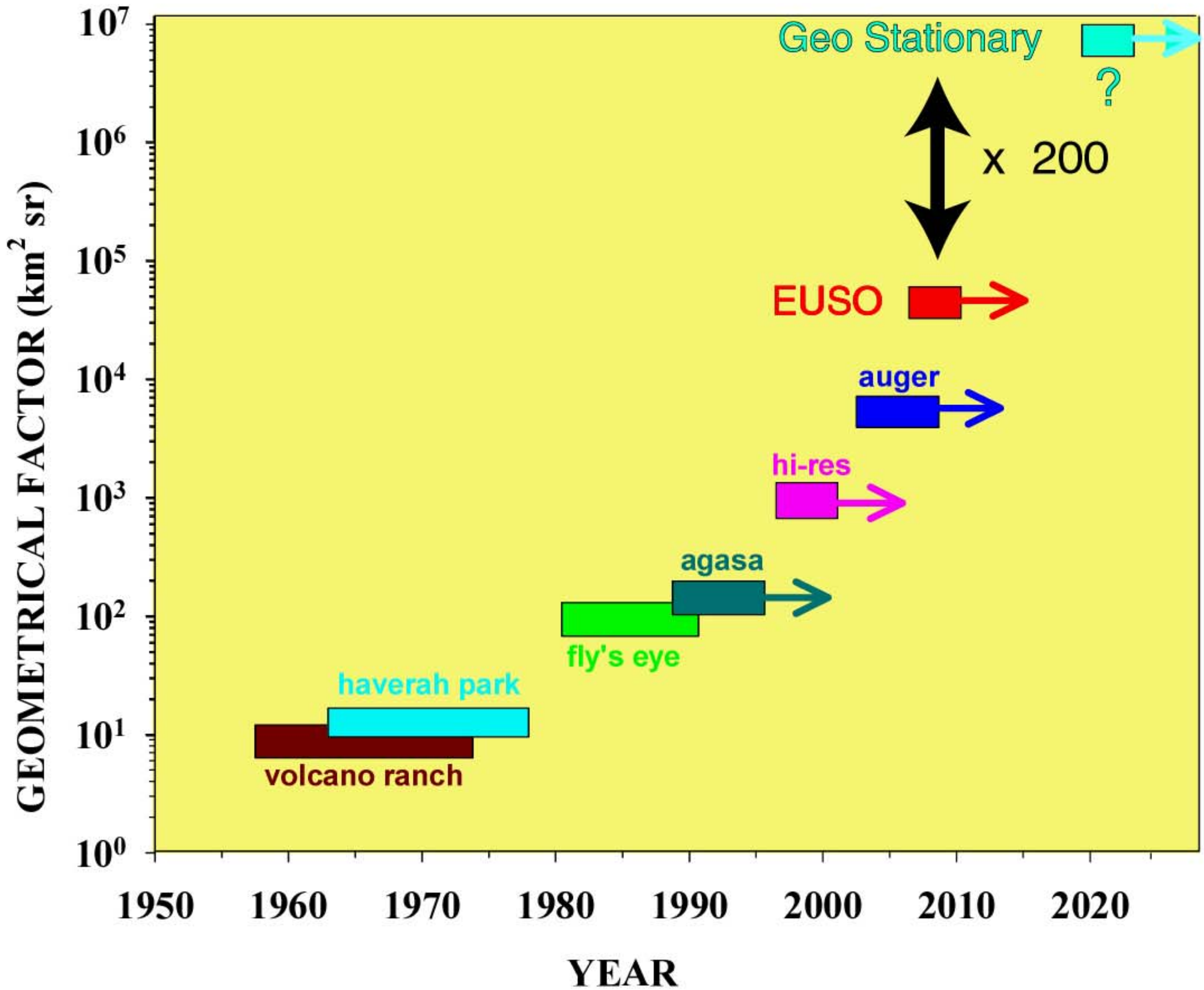
Sources	#/yr (E > 10^{19} eV)	# /yr (E > 10^{20} eV)	Source Location	β for ($E^{-\beta}$ dE)
Greisen ν's	2 – 10	0.1 - 2	Isotropic & uniform	> 3
TD ν's	10 - 100	5 - 40	Discrete	~ 1.5
GRB ν's	0 - 80	0 - 50	Point source; isotropic	~ 2; ~ 1
Blazar ν's	< 10	< 1	Point source; isolated	~3.5

Table 1.2 - Target mass for the ***EUSO*** satellite. The target amount is: (1) air target for ordinary downward fluorescence method, (2) Earth crust for near-horizontal upward showers, (3) Earth crust for vertical, upward ν_τ showers ($E>10^{15}$ eV).

EUSO	Air (1)	Earth Crust (2)	Earth crust (3) (0.5 km at 10^{15} eV)
ν -Target mas	$\sim 10^{13}$ tons	$\sim 2 \times 10^{12}$ ton (crust)	$6.5 \times 10^{14} \times (E/10^{15}$ eV) tons

The largest planned ground experiment for neutrino observation (ICECUBE) has 10^9 tons target mass.

Comparison of UHECR Experiments



Study of Cosmic Rays with modern instruments, one hundred years after their discovery, still giving important information about our Universe.

Space Experiments gives today accurate measurements of Cosmic Rays up to O(100) GeV → High Energy CR belts, Atmospheric ν

Space born precision CR measurements will extend to O(TeV) during the next few years.

DISCOVERY POTENTIAL

High precision CR measurements from space in the 10-1000 GeV region have a potential to discover the origin of Dark Matter or to discover nuclear antimatter.

EECR experiments from space have a potential for discovery new superheavy particles and have also a large potential for HE neutrino astronomy

www.pg.infn.it/spacepart