Plans and Studies for Astroparticle Experiments measuring the Cosmic Radiation

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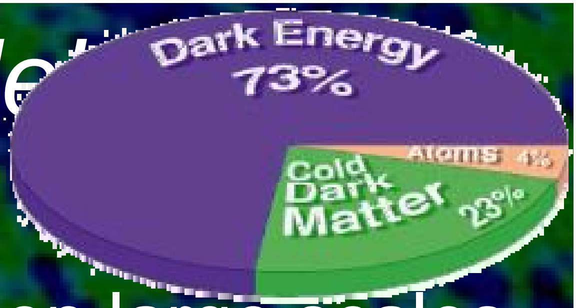
University and INFN of Perugia

IFAE 2007

Neaples

april 10th 2007

The Standard Cosmological Model



This model tell us that the Universe is:

- Spatially flat, homogeneous and isotropic on large scales
- Composed of

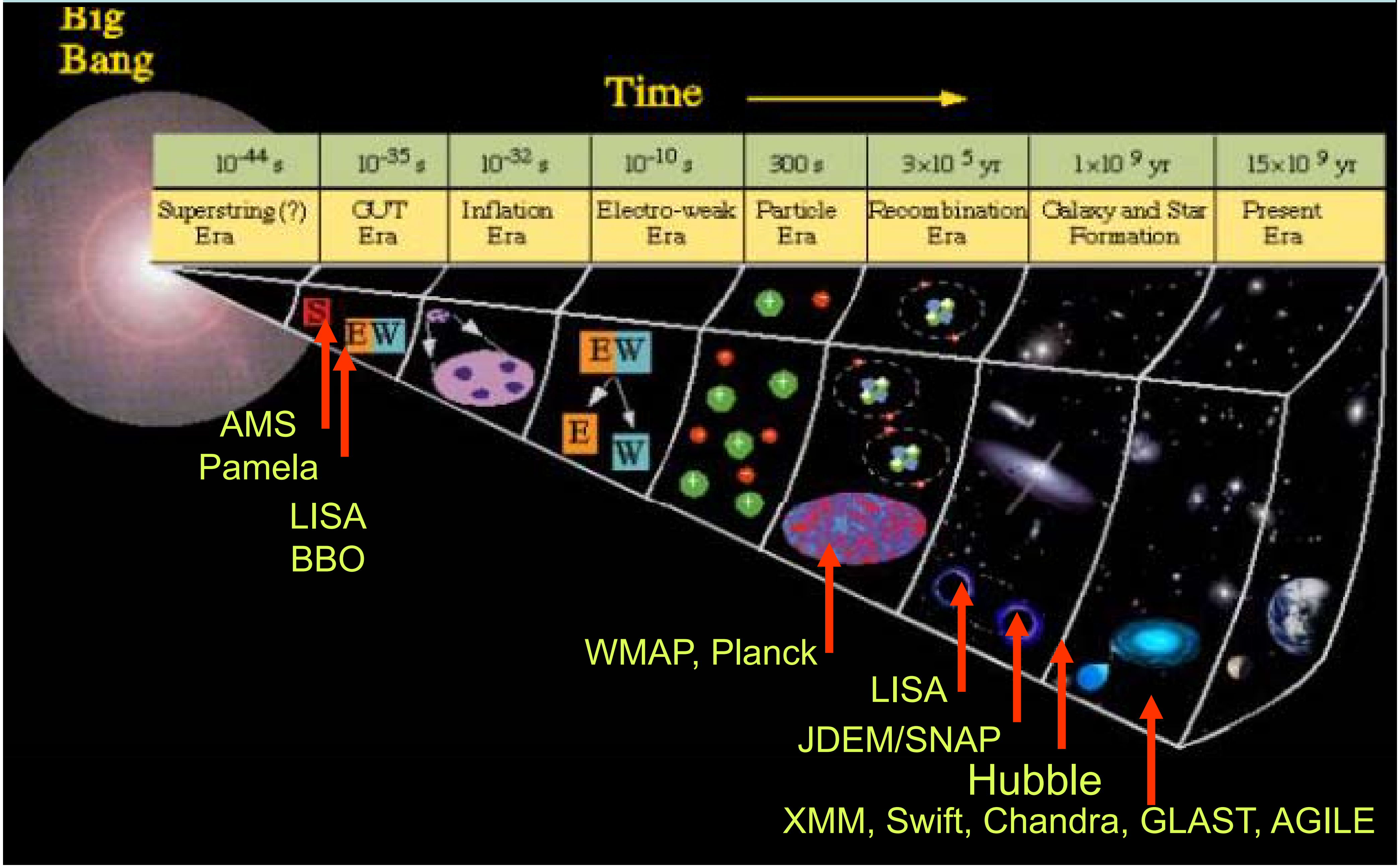
Never before we have been so knowingly ignorant about Nature

  - Anti Matter $< 10^{-6}$ matter

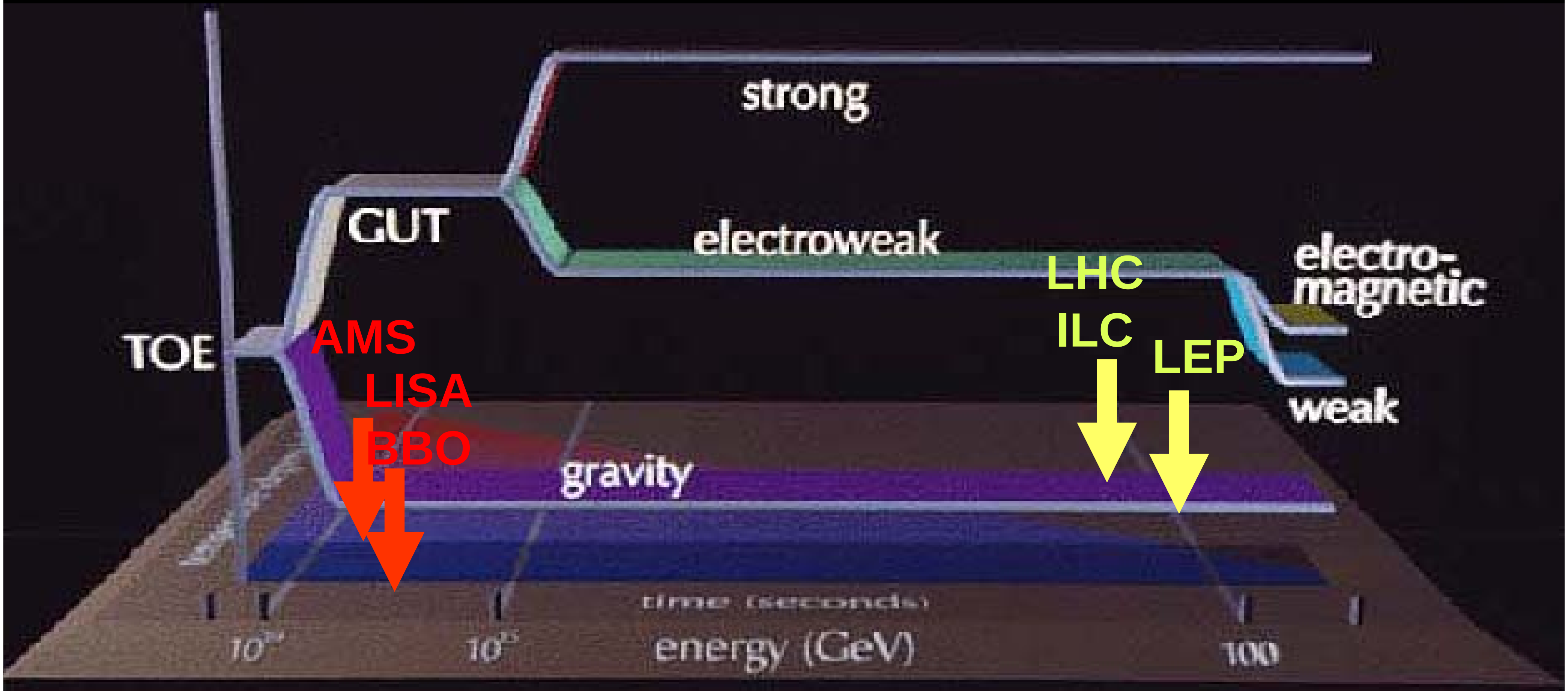
    which seems to have disappeared, but we do not know how

- Galaxies and large scale structures born from tiny adiabatic Gaussian fluctuations of matter and fields

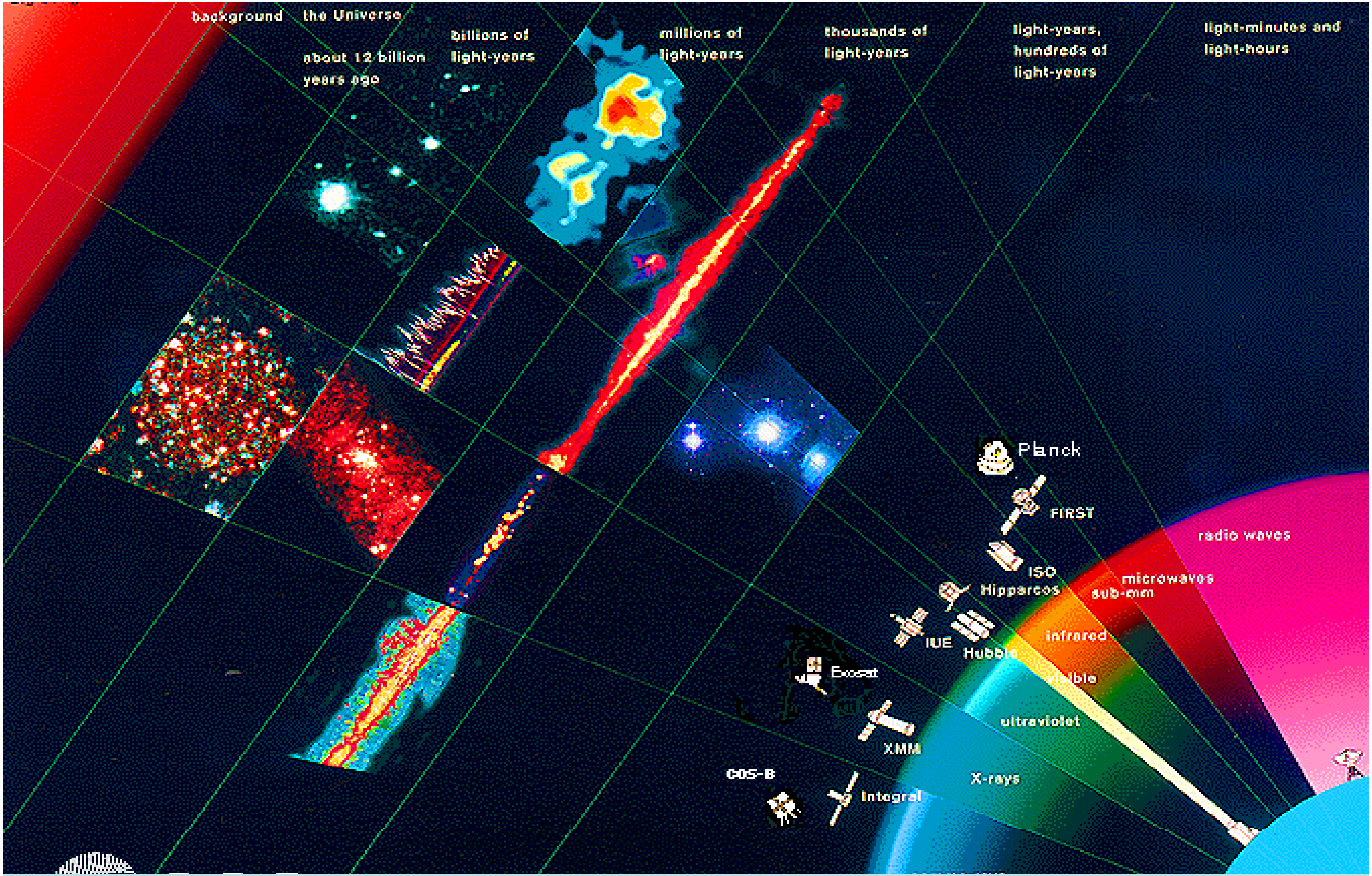
The universe is the ultimate laboratory to study fundamental physics…….



…….reaching energies which cannot be studied at accelerators………

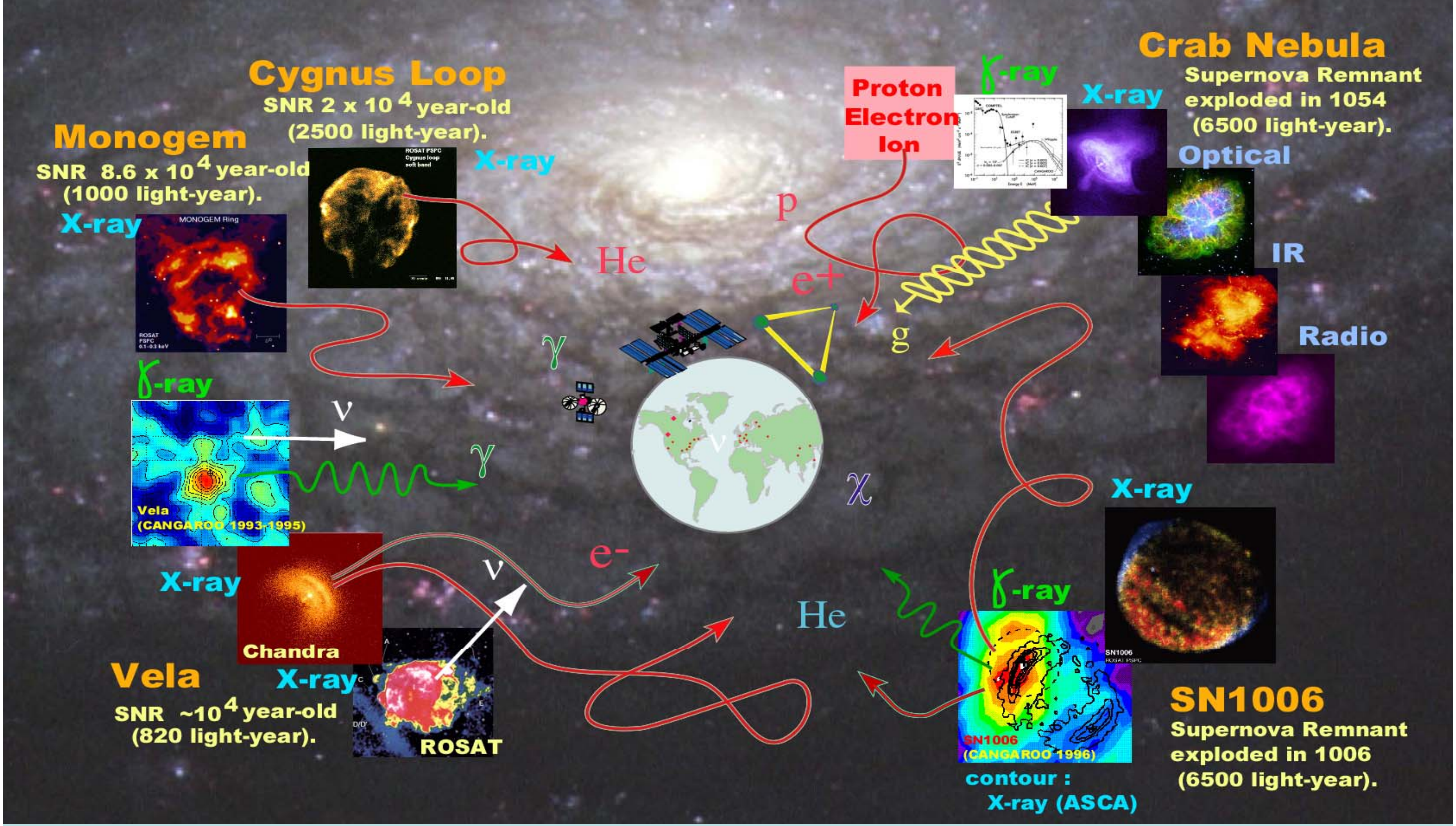


10^{-44} s	10^{-35} s	10^{-32} s	10^{-10} s	300 s	
rstring (?) Era	GUT Era	Inflation Era	Electro-weak Era	Particle Era	P



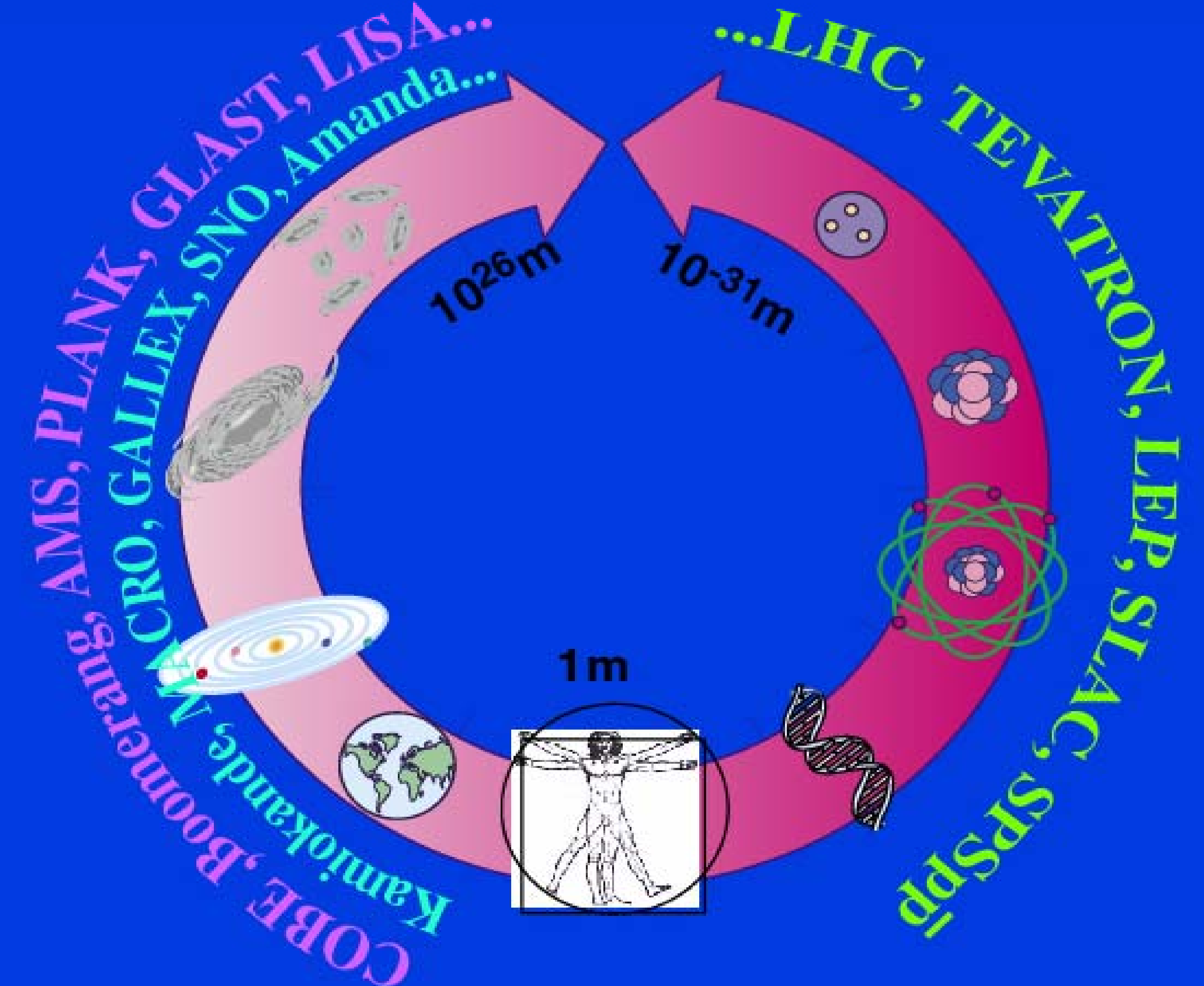
….by studying all kind of radiation reaching us, light….

High Energy Cosmic Rays in the Universe



….or charged/neutral particles, gravitational waves…….

Astro Particle Physics

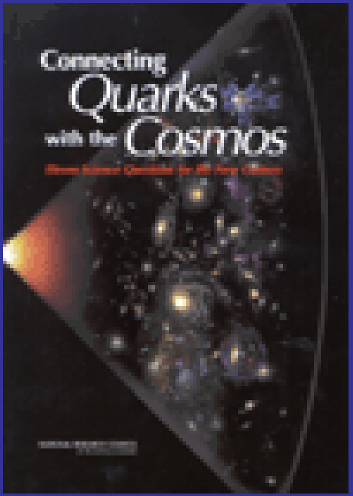


Examples of interagency cooperation on Astroparticle Physics in space

- INFN/ASI/Rosaviakosmos on the Pamela program
- NASA/DOE, INFN/ASI, CIEMAT/CDTI, DARA….. on the AMS program
- NASA/DOE , INFN/ASI…. on the GLAST program
- NASA/ESA on the LISA program
- ESA/NASA on the PLANCK program
- NASA/ESA/ASI/JAXA on the EUSO program --> JEM-EUSO ?
- NASA/DOE on the JDEM program

Some cooperation has been implemented, but worldwide coordinating bodies like ICFA or OECD Forums are basically missing for space programs, with risks of duplication of efforts (e.g. WMAP vs PLANCK), reduction of political support or negative interferences, making more difficult the start and the implementation of the most

Connecting Quarks with the Cosmos



National Academy of Sciences (NAS)
Committee on Physics of the Universe

- **11 questions**
  - CP/B violation,
  - dark matter,
  - dark energy,
  - CR acceleration,
  - origin of the heavy nuclei,
  - ……….
- **7 recommendations**
  - **Exploring the Basic Laws of Physics from Space**
  - **Interagency Initiative (NASA/DOE/NSF) on the Physics of the Universe**
  - …………

Measuring cosmic radiation of different kind (incomplete list)

- **Light (IR, visible, UV, X)   HUBBLE, Swift, JDEM…**
- **CMB (mm EW)   BRAIN/CLOVER, WMAP/PLANK**
- **Cosmic Rays (TeV charged particles) PAMELA/AMS**
- **Cosmic Rays (at or above the knee) Argo, Auger…**
- **Gamma Rays (GeV gamma rays) AGILE, GLAST**
- **Gamma Rays (TeV gamma rays) HESS/MAGIC, CTA**
- **Neutrinos (TeV neutrinos) AMANDA/ICECUBE, KM3 NET**
- **Gravitatonal Waves (0.001 to 100 Hz waves) VIRGO, LISA**

Cosmic Microwave Background

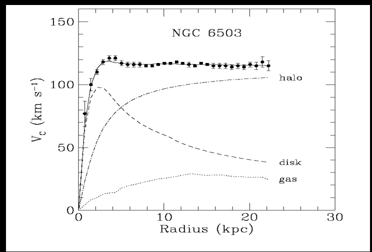
Dark Energy

Dark Matter

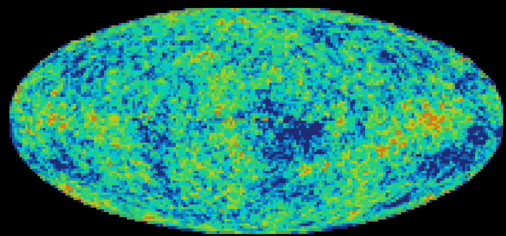
Evidence

Evidence for the existence of an unseen, "*dark*", component in the energy density of the Universe comes from several independent observations at different length scales:

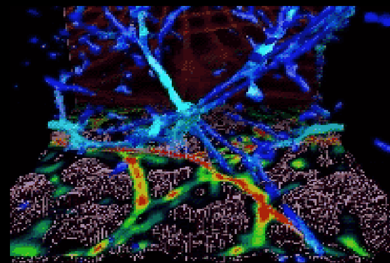
•Rotation curves of galaxies



•CMB



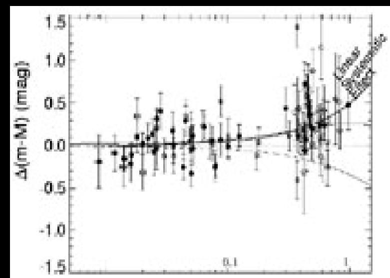
•Large Scale Structure



•Galaxy clusters

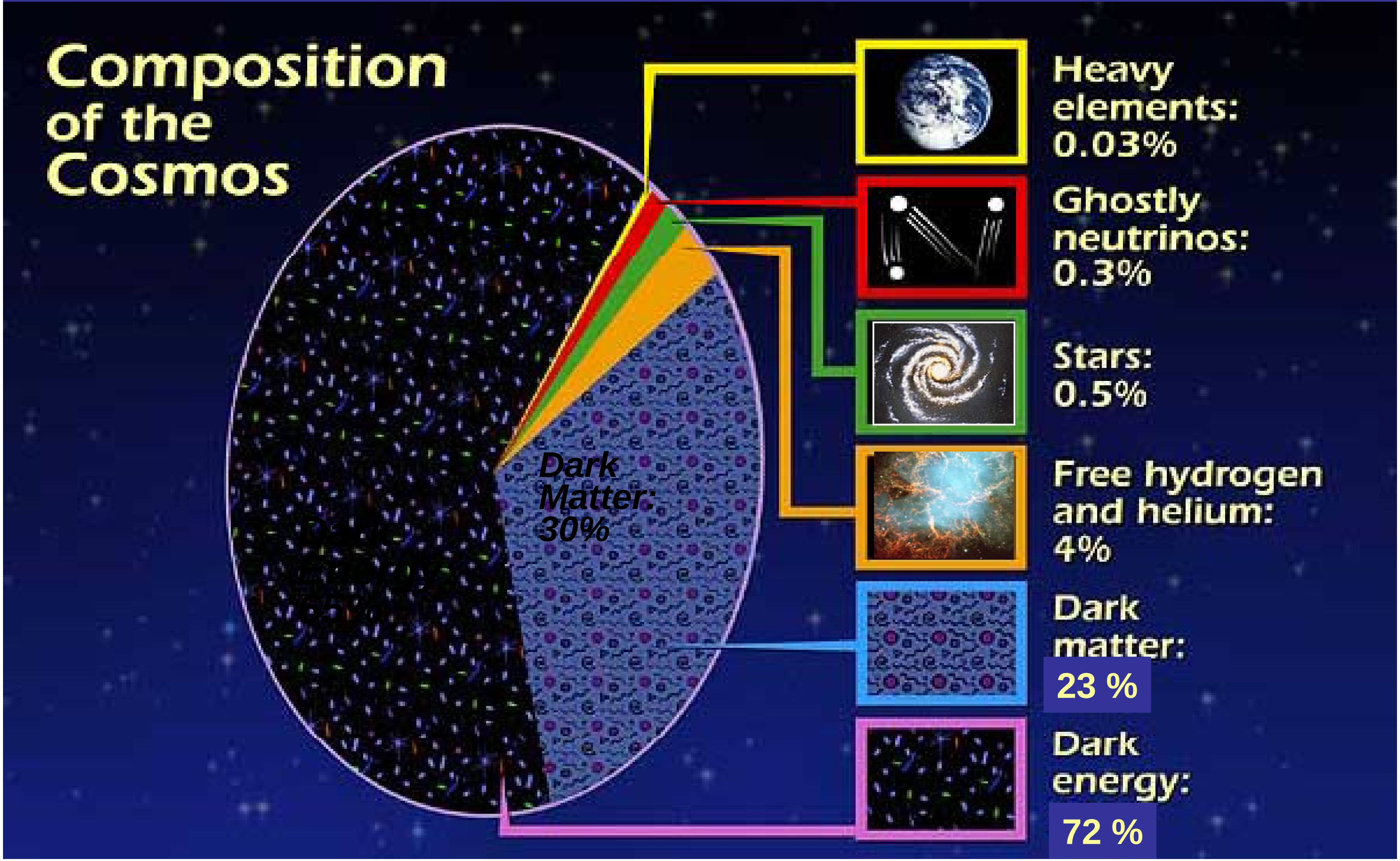
•Lensing

•SN Ia

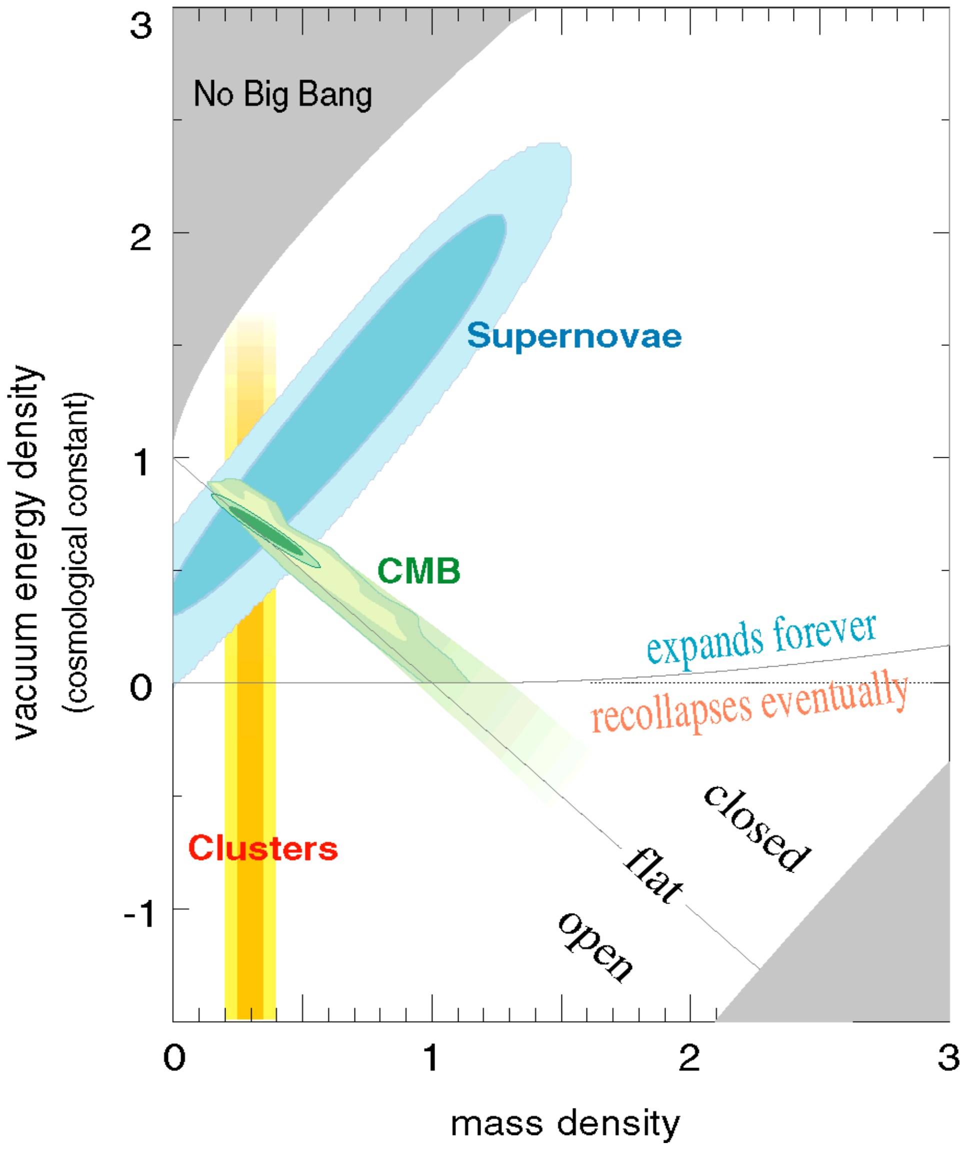


GB, Hooper & Silk, hep-ph/0404175. Bergstrom, hep-ph/0002126. Jungman et al, hep-ph/9506380

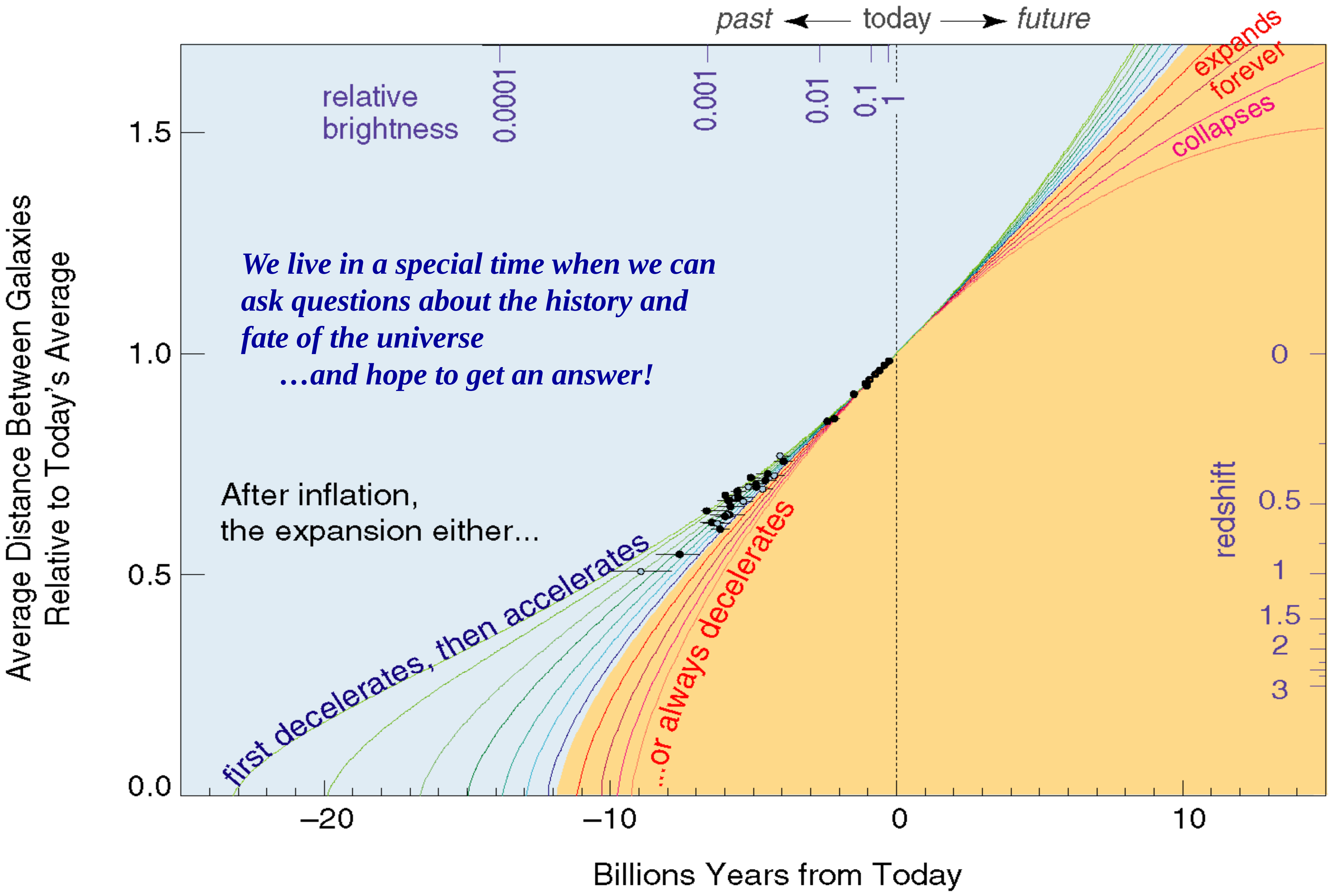
Energy budget of Universe



Current Results on Cosmological Parameters



The Expansion History of the Universe

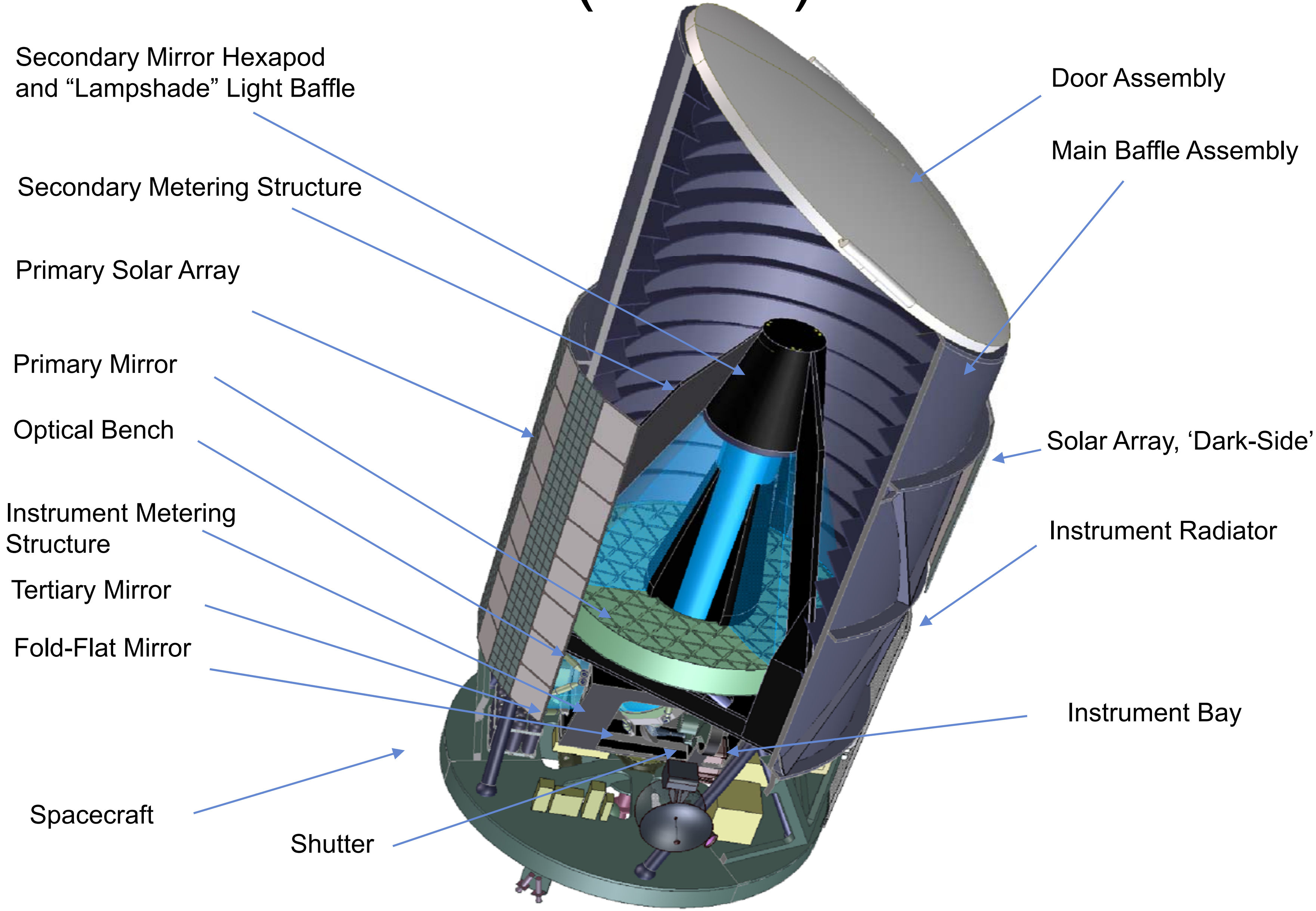


SS

Office of Science
U.S. Department of Energy

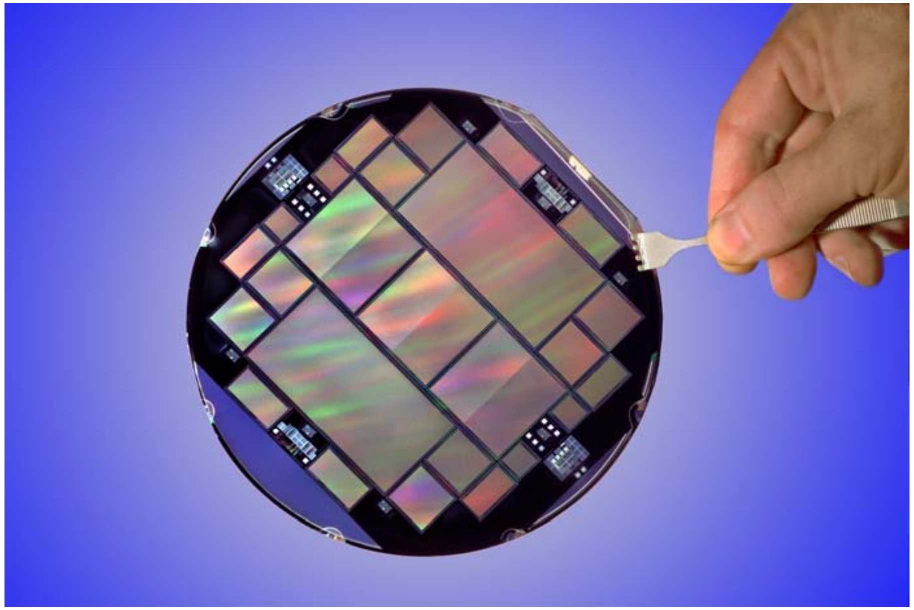
NASA-DOE
Joint Dark Energy Mission

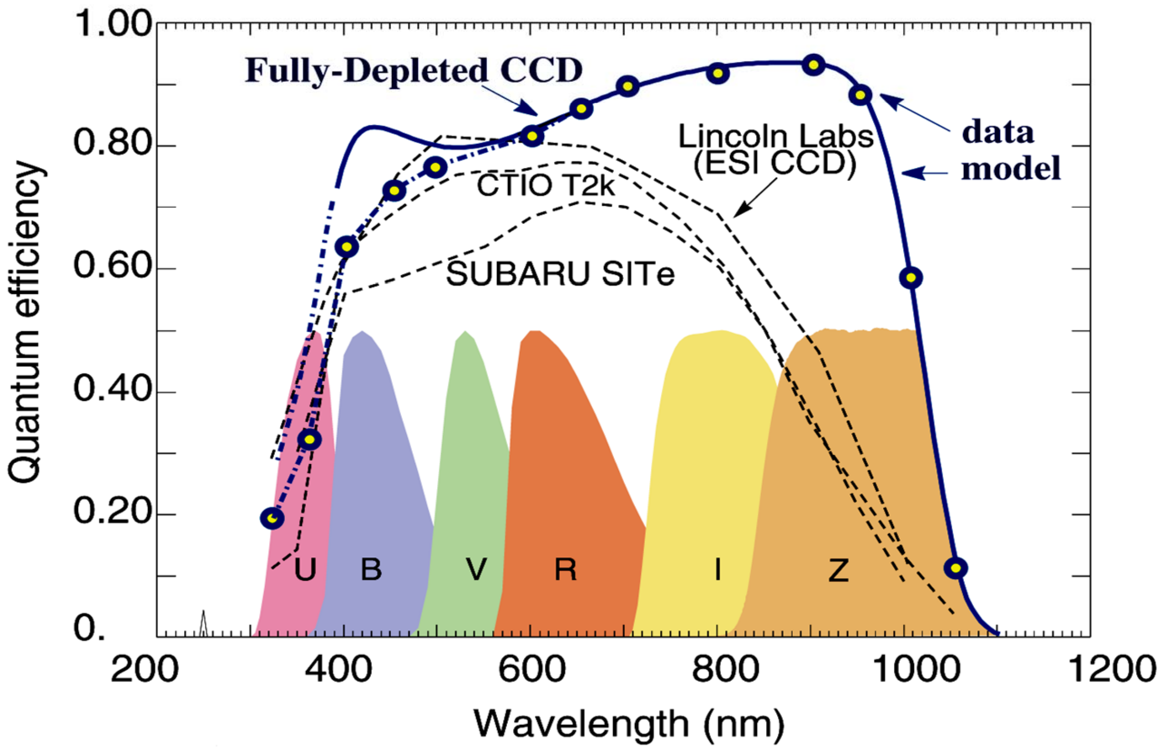
SPACECRAFT CONFIGURATION (SNAP)



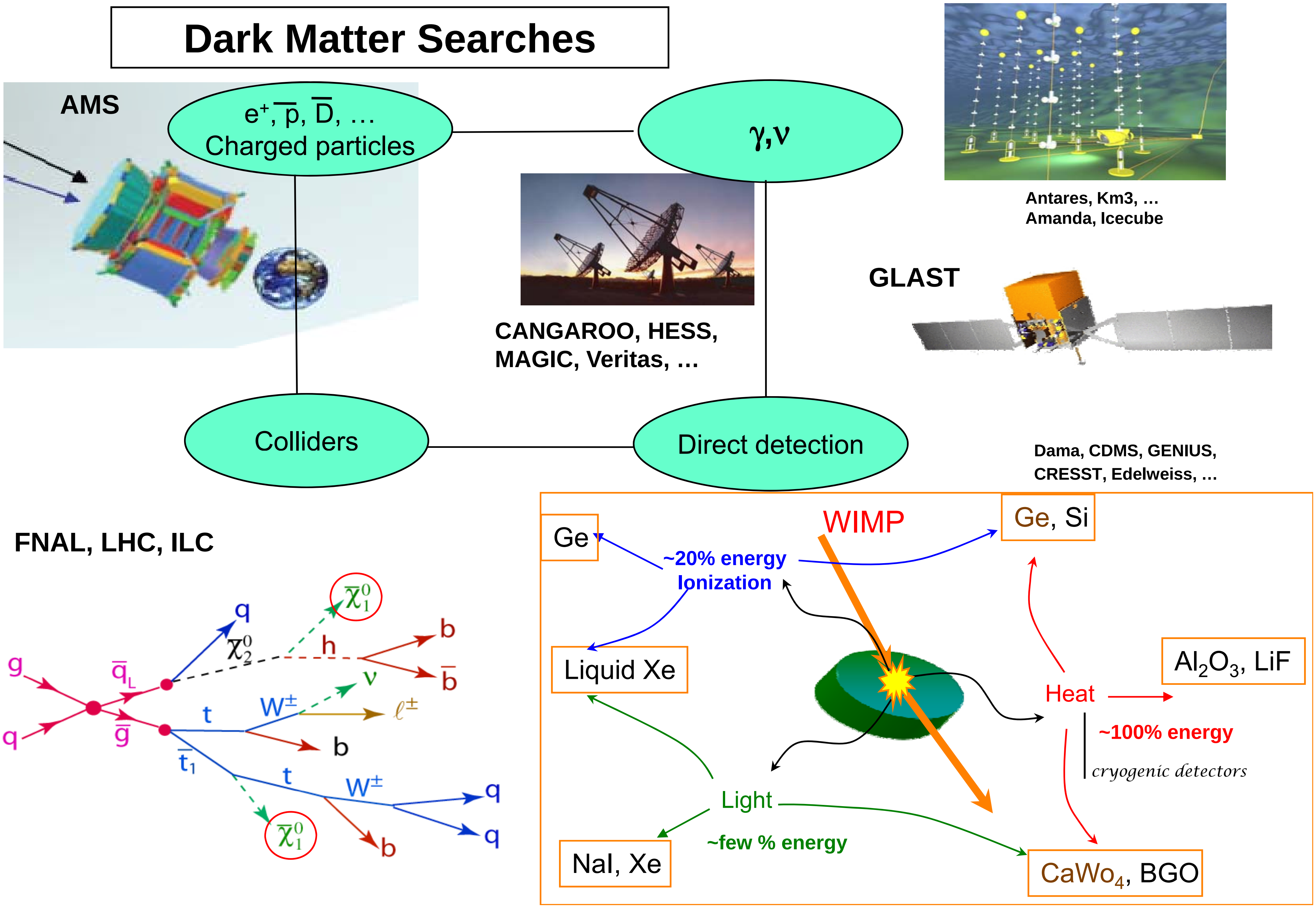
High-Resistivity CCD's

- New kind of Charged Coupled Device (CCD) developed at LBNL
- Better overall response than more costly "thinned" devices in use
- High-purity "radiation detector" silicon has better radiation tolerance for space applications
- The CCD's can be abutted on all four sides enabling very large mosaic arrays

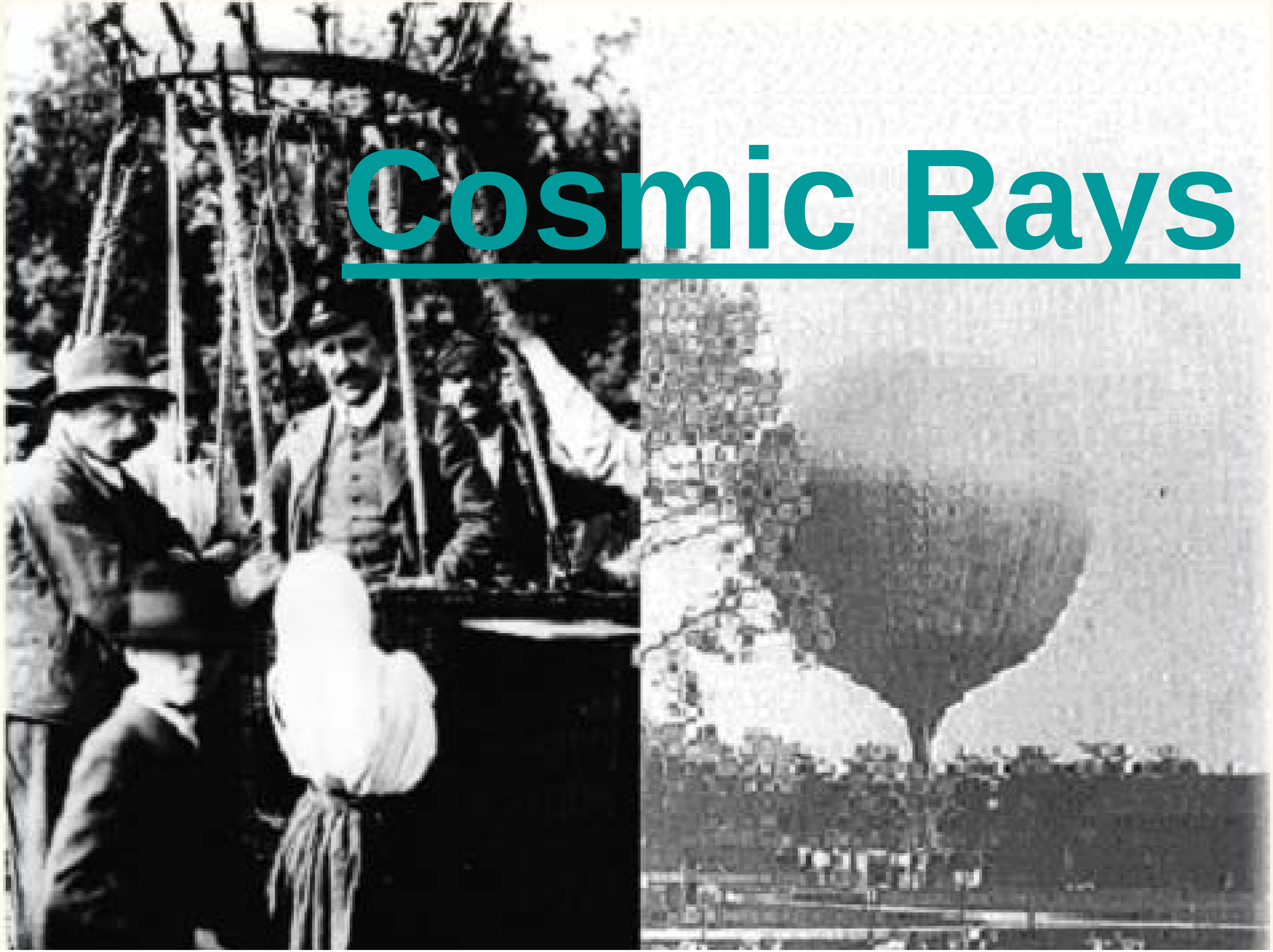




LBNL "Red Hots": NOAO September 2001 newsletter


Dark Matter Searches
AMS
e^+, $\bar{p}$, $\bar{D}$, …
Charged particles
γ,ν
Antares, Km3, …
Amanda, Icecube
CANGAROO, HESS,
MAGIC, Veritas, …
GLAST
Colliders
Direct detection
Dama, CDMS, GENIUS,
CRESST, Edelweiss, …
FNAL, LHC, ILC
WIMP
Ge
Ge, Si
~20% energy
Ionization
Liquid Xe
Al_2O_3, LiF
Heat
~100% energy
cryogenic detectors
Light
~few % energy
NaI, Xe
$CaWo_4$, BGO
g
q
$\bar{q}_L$
$\bar{g}$
χ_2^0
$\bar{\chi}_1^0$
h
b
$\bar{b}$
ν
$W^\pm$
$\ell^\pm$
t
$\bar{t}_1$
q

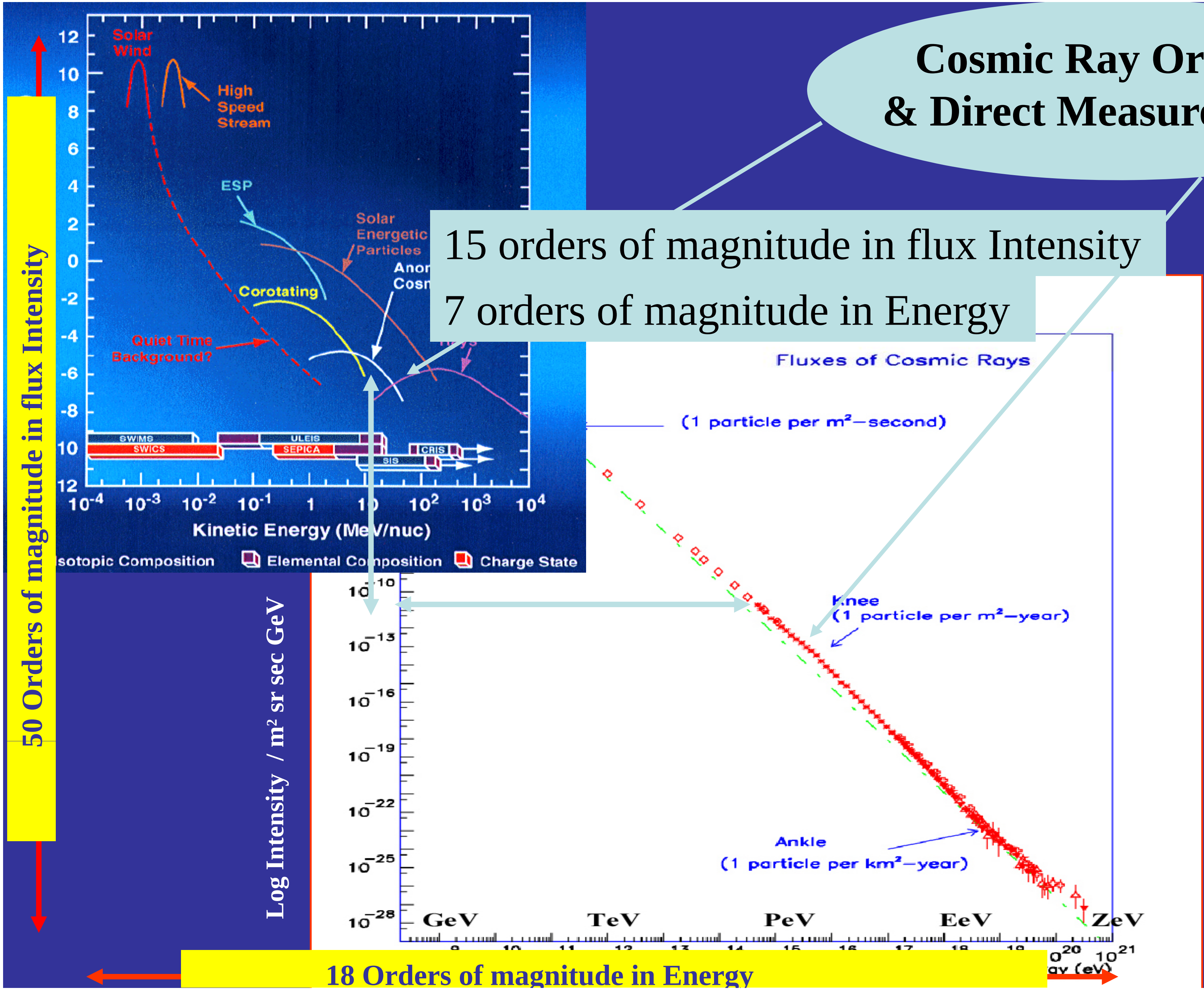
Cosmic Rays



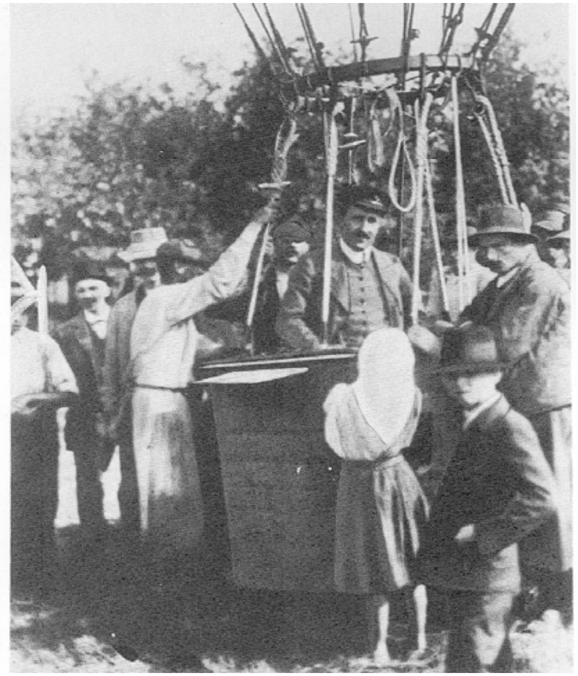
Cosmic Ray Origin & Direct Measurements

15 orders of magnitude in flux Intensity

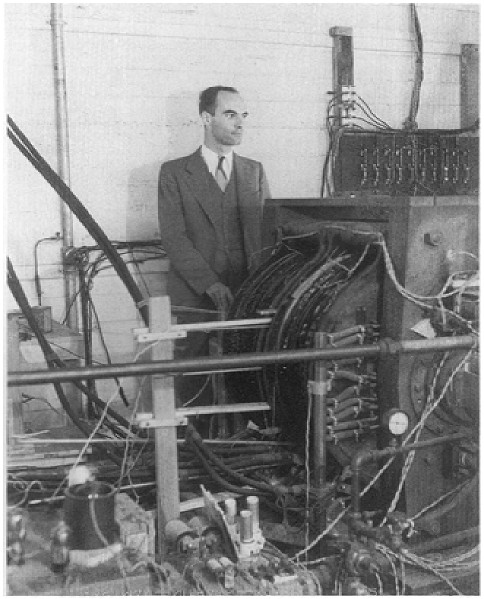
7 orders of magnitude in Energy



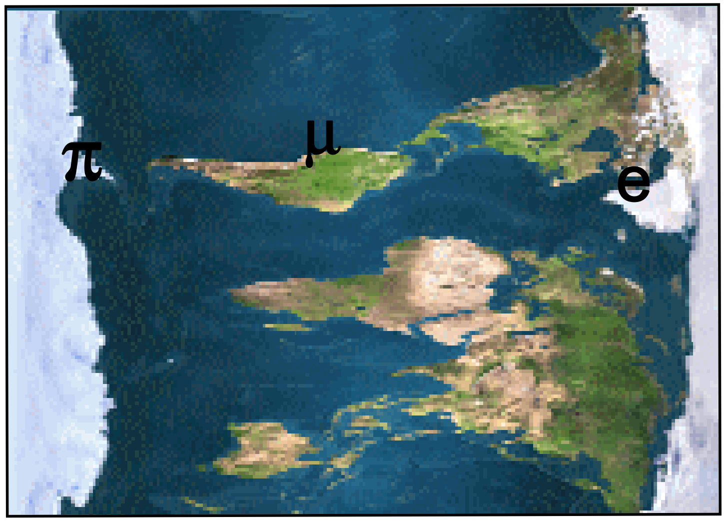
Physics of Charged Cosmic Rays



1912: Discovery of Cosmic Rays
V. Hess



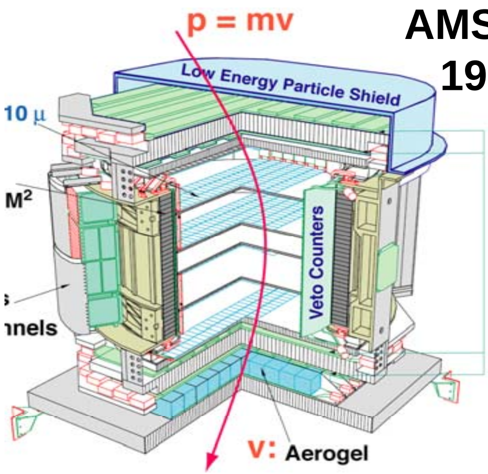
1932: Discovery of positron
C.D. Anderson



1947: Discovery of pions
C. Powell

Discoveries of

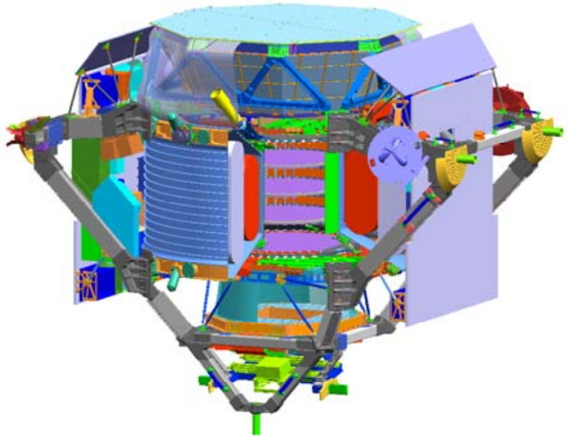
- 1936: Muon (μ)
- 1938: 10^{15} eV CR
- 1949: Kaon (K)
- 1949: Lambda (Λ)
- 1952: Xi (Ξ)
- 1953: Sigma (Σ)



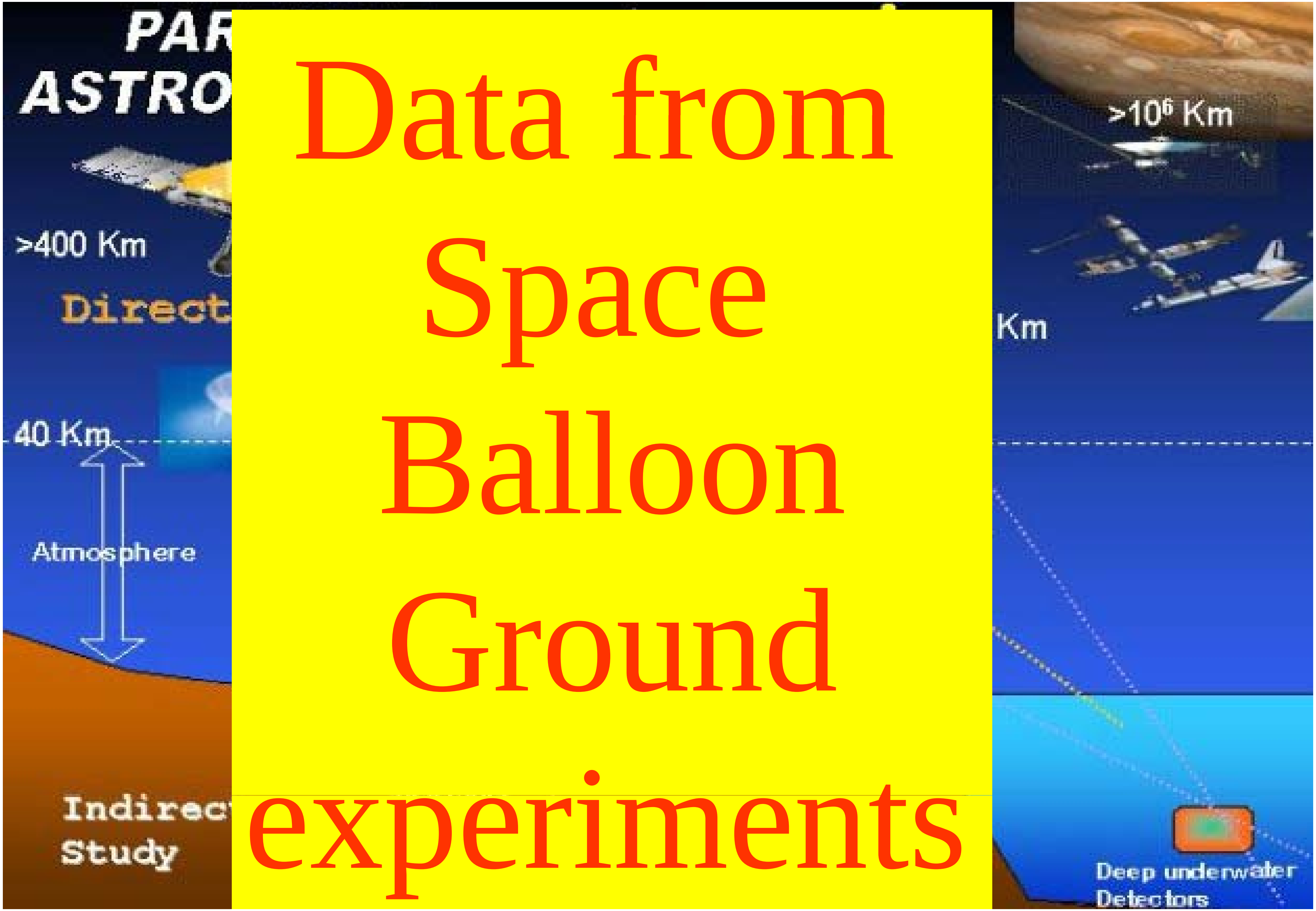
AMS 01
1998

PAMELA
2006

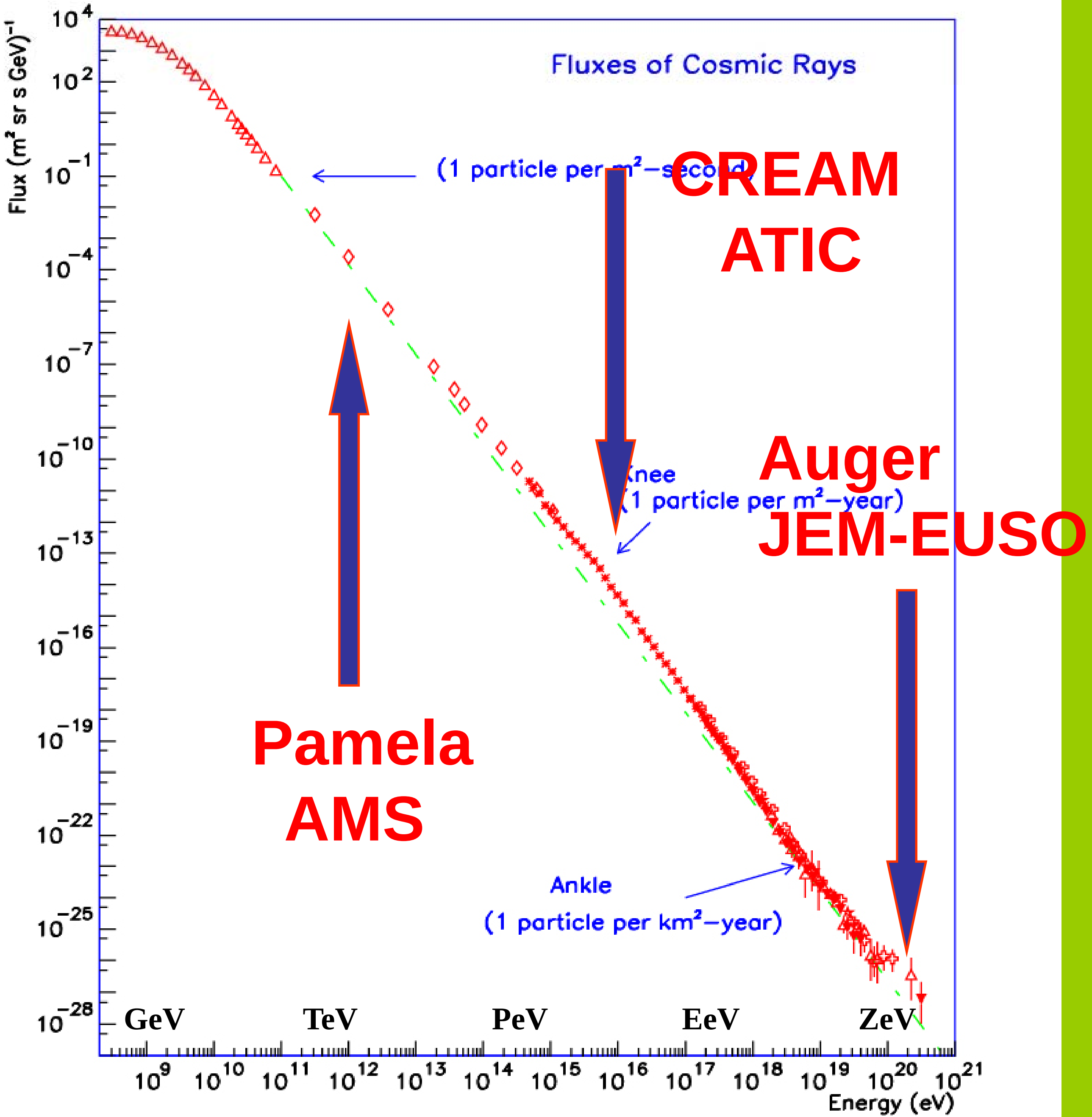
AMS 02
2009



Precision magnetic spectrometers in Space



Data from Space Balloon Ground experiments

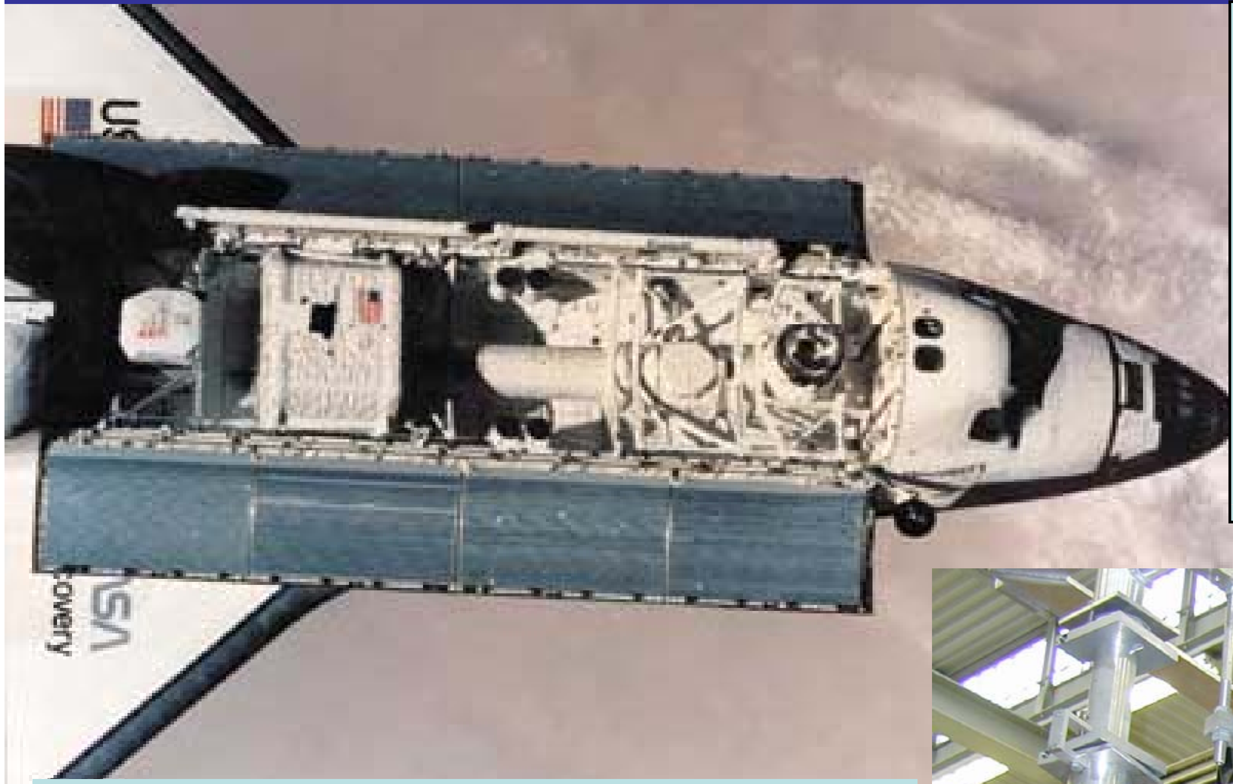


Very Accurate Measurement of the Charged CR Spectrum and Composition

Absence of Antimatter → CP violation, GUT

Dark Matter → SUSY, Axions

Atmospheric neutrinos → Neutrino mass



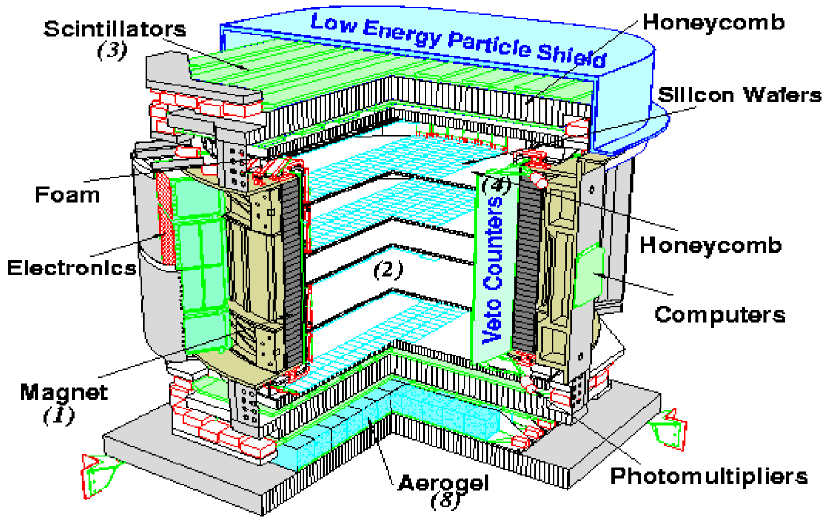
AMS-01
1998 7 days
100 M Trigger
6 Phys. Let.
1 Phys. Rep.
~ 20 other papers

First large
spectrometer in space

First high energy particle
physics in space

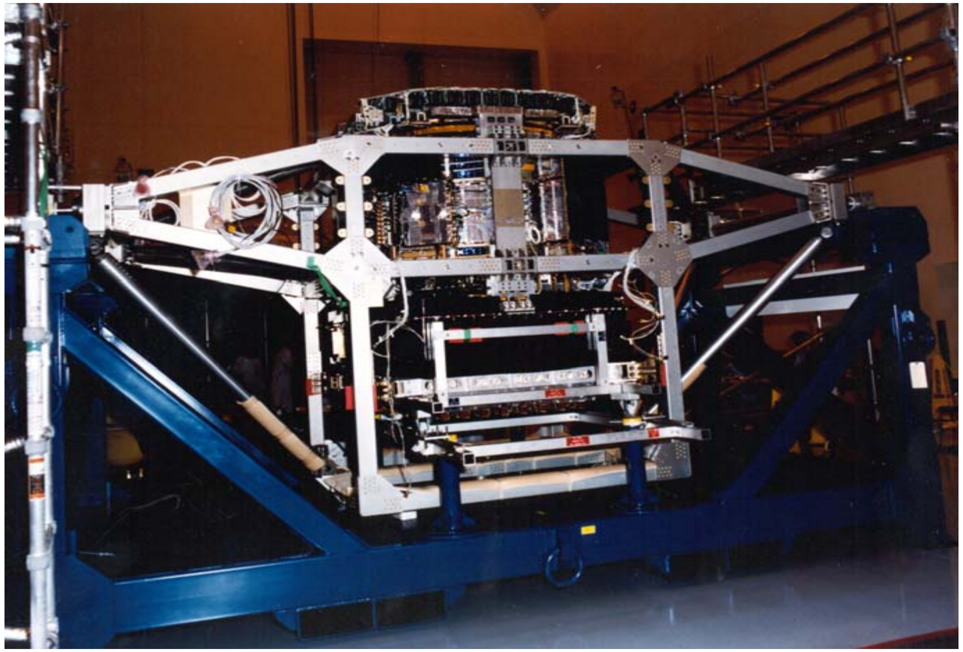
First precision tracking
in space

AMS-01: STS-91 1998 Flight Results

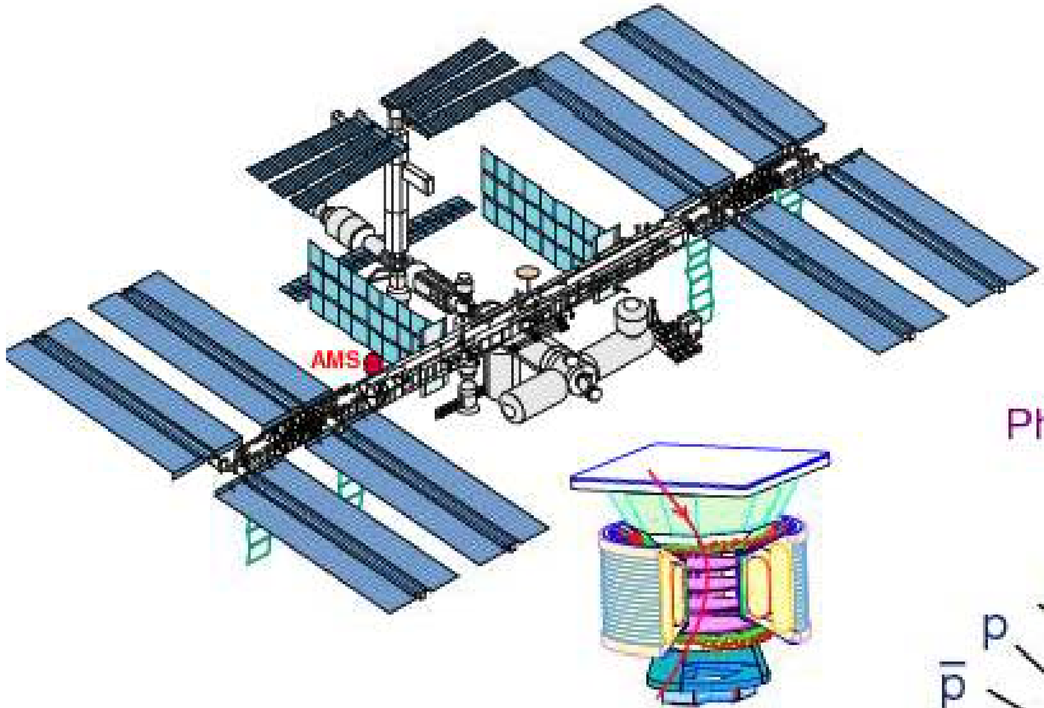


- Data taking ≈135 hours
- Shuttle altitude ≈370 km
- Trigger rate 100 – 700 Hz
- 100 million events recorded

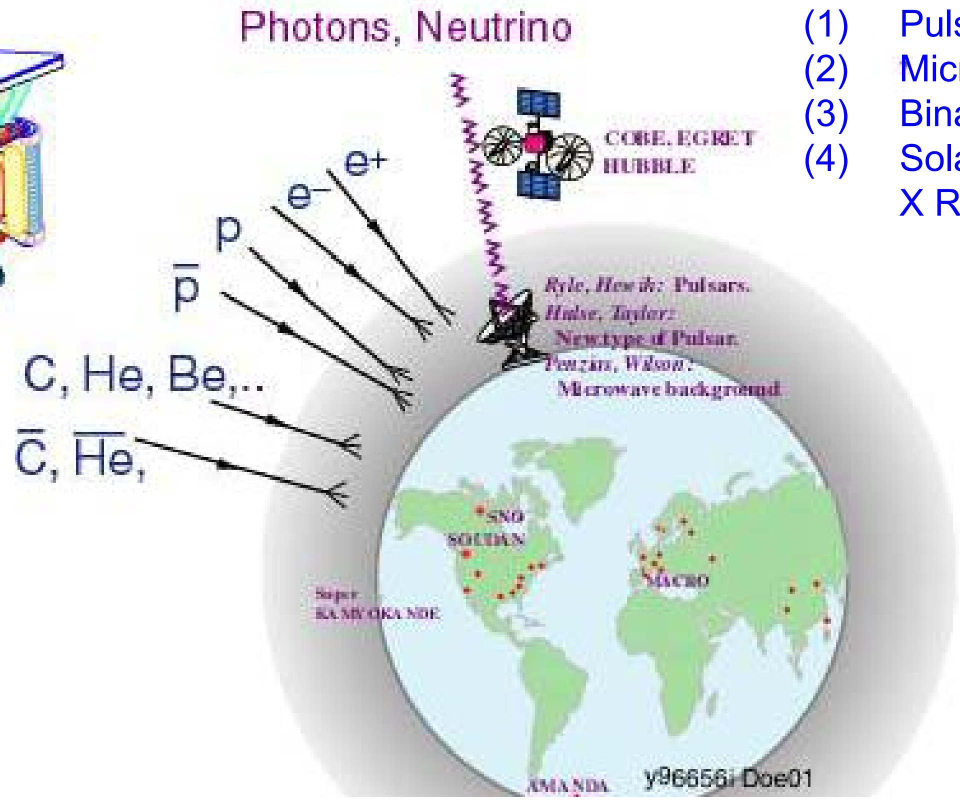
- Energy Range:
  100 MeV/n< E_k < 300 GeV/n
- Electronics channels: ≈ 70000
- Power: ≈ 1 kW
- Weight: 3 t



AMS is a particle physics experiment:



SUSY (Super Symmetry)
Grand Unified Theory
Baryon number violation
CP violation

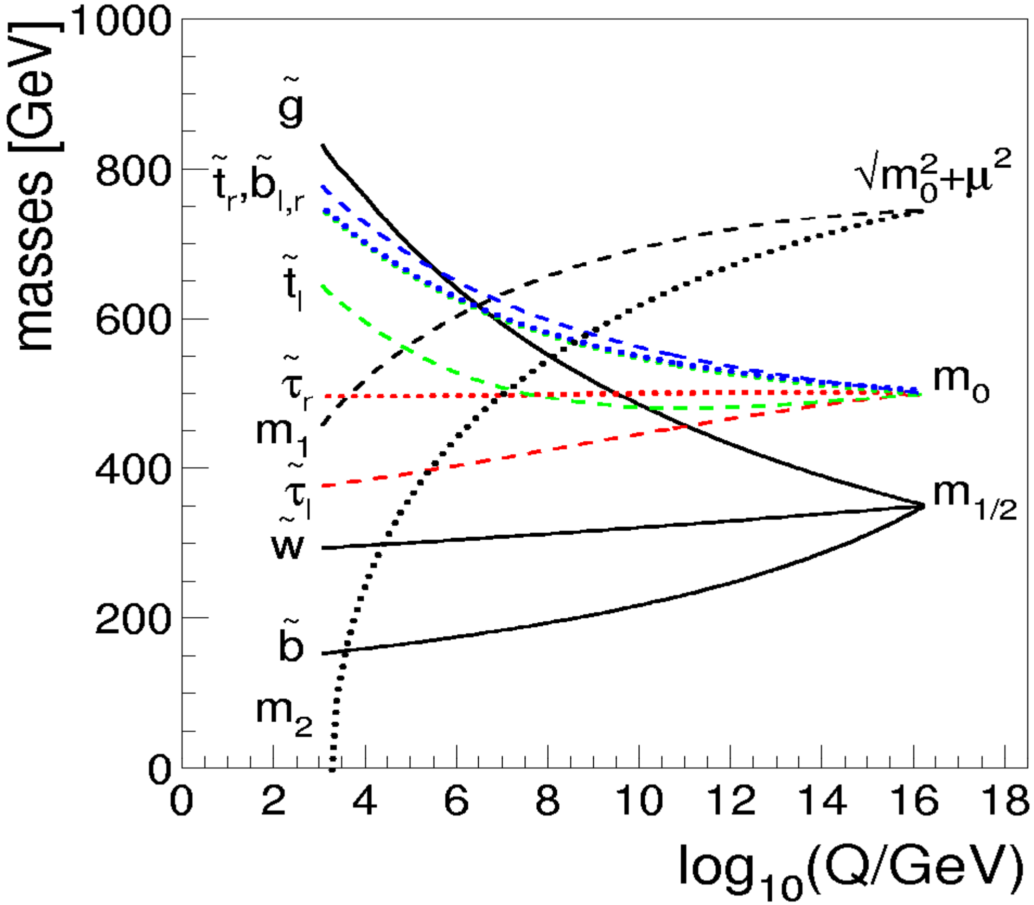


Nobel Prizes,
(1) Pulsar,
(2) Microwave,
(3) Binary Pulsars,
(4) Solar neutrino
X Ray sources

SUSY Dark Matter candidate: Neutralino

- MSSM and R-parity => Stable DM candidate: the LSP
- Preferred candidate: The Neutralino

$$\chi_i = N_{i,1}\left|\tilde{B}^0\right\rangle + N_{i,2}\left|\tilde{W}_3^0\right\rangle + N_{i,3}\left|\tilde{H}_1^0\right\rangle + N_{i,4}\left|\tilde{H}_2^0\right\rangle$$



Higgs (h, H, A, H±)

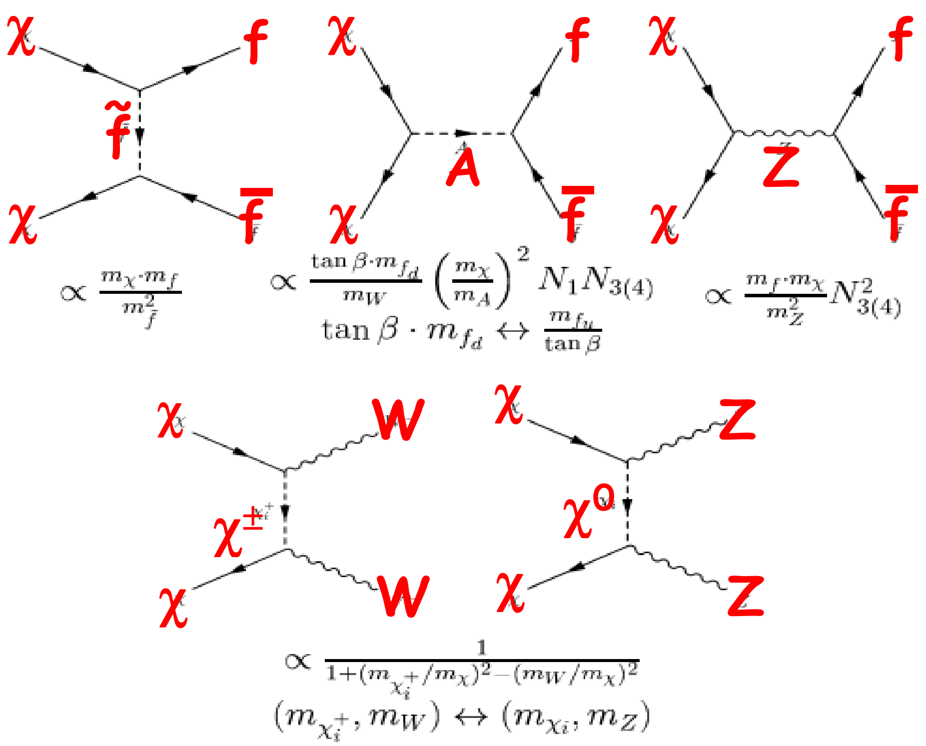
squarks & sleptonen

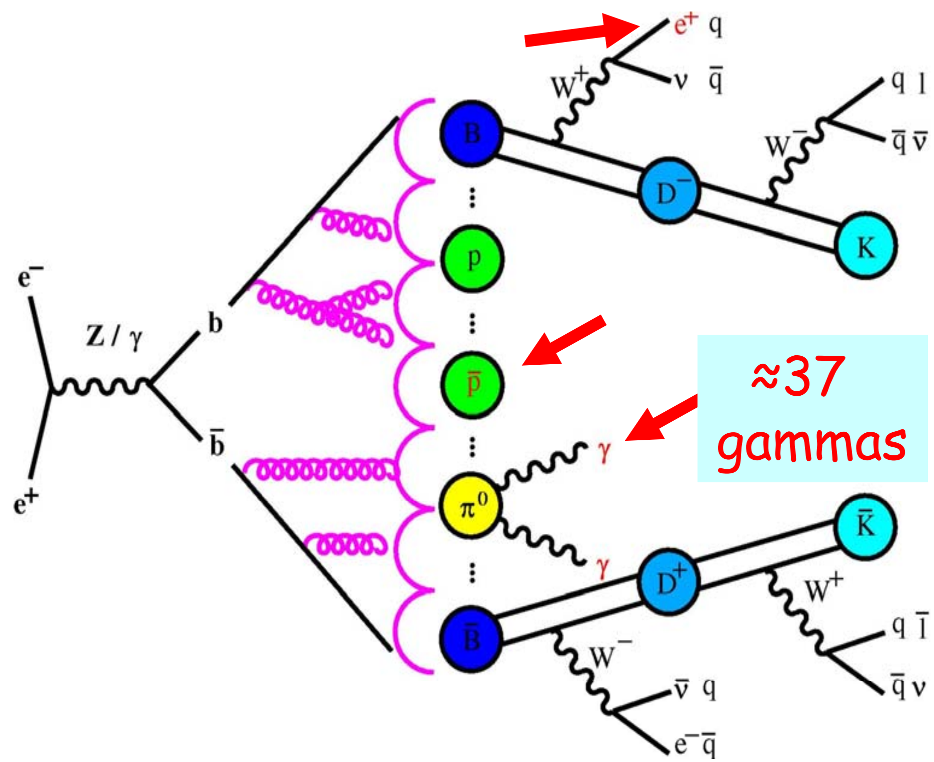
gaugino

MSSM Parameter:

$m_0, m_{1/2}, \tan\beta, sign(\mu), A_0$

DM Annihilation in Supersymmetry

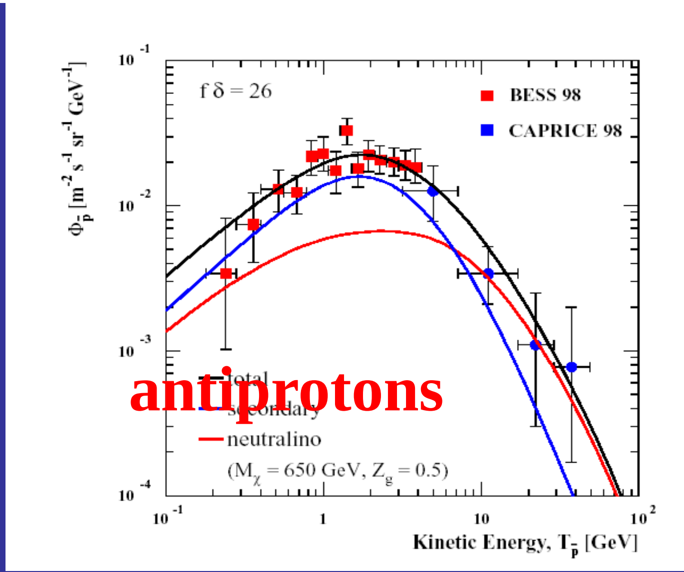




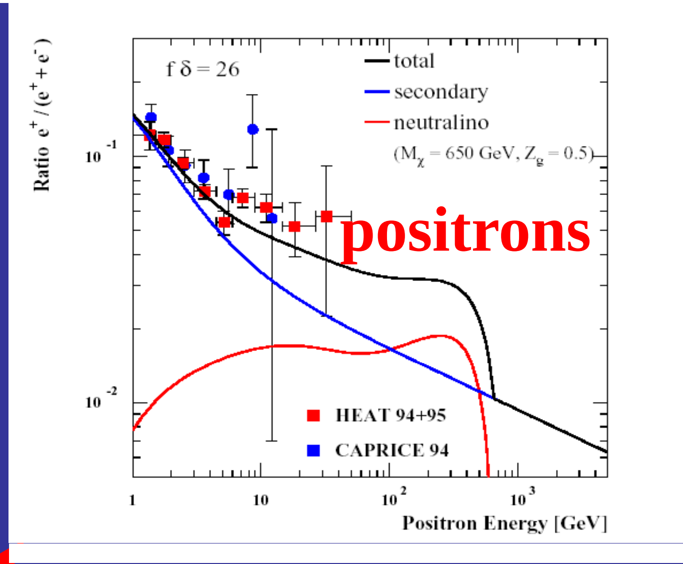
Dominant
χ + χ ⇒ A ⇒ b bbar quark pair

B-Fragmentation known!
Hence Spectra of Positrons,
Gammas and Antiprotons known!

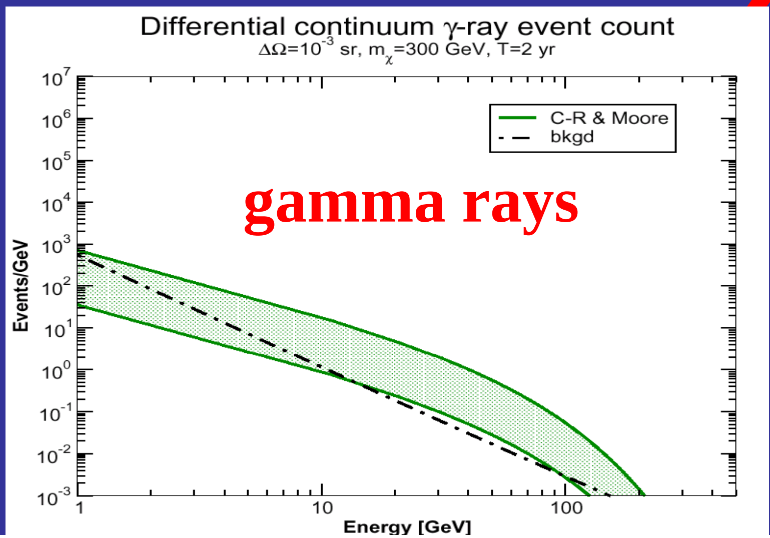
Galaxy = Super B-Fabrik with rate 10^{40} x B-Factory

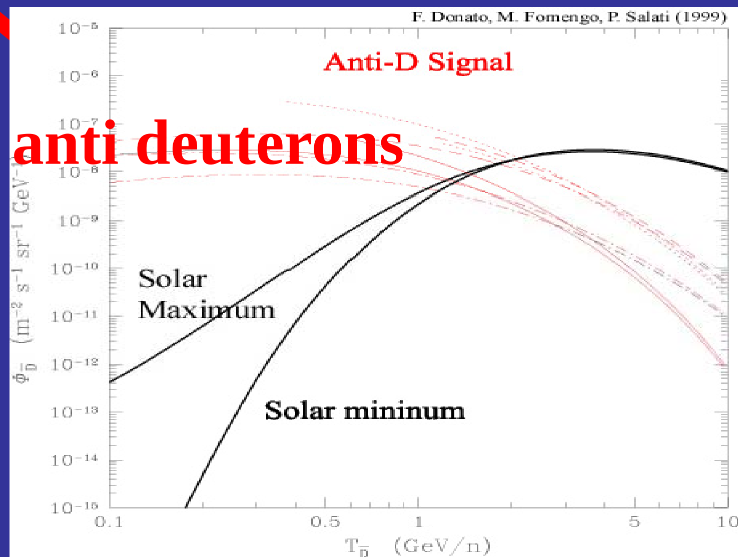


Unique Feature Of AMS



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





Supersymmetry introduces free parameters:

In the MSSM, with Grand Unification assumptions, the masses and couplings of the SUSY particles as well as their production cross sections, are entirely described once 5 parameters are fixed:

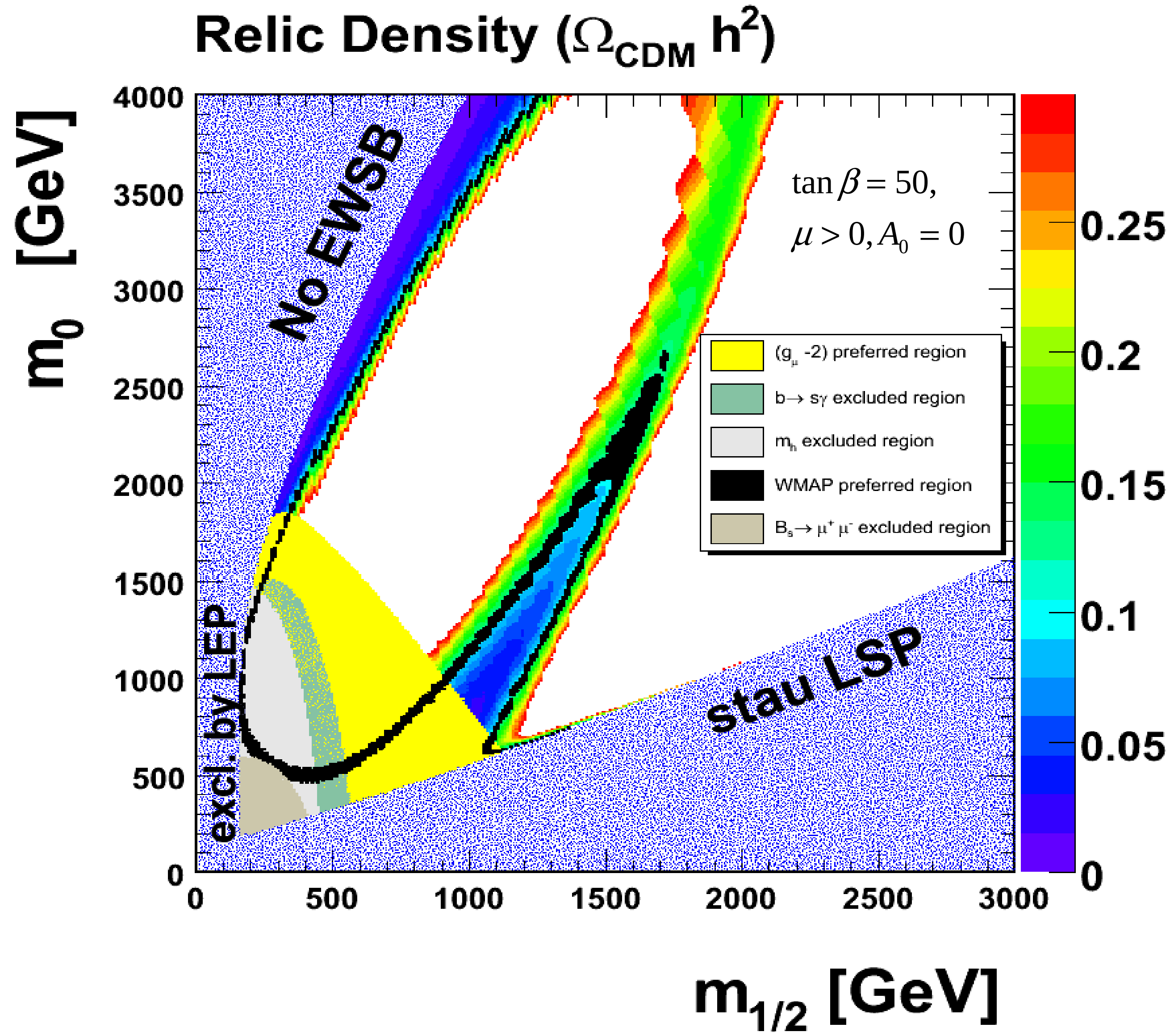
- $M_{1/2}$ the common mass of supersymmetric partners of gauge fields (gauginos)
- m_0 the common mass for scalar fermions at the GUT scale
- μ the higgs mixing parameters that appears in the neutralino and chargino mass matrices
- A is the proportionality factor between the supersymmetry breaking trilinear couplings and theYukawa couplings
- tang β = $v_2 / v_1 = \langle H_2 \rangle / \langle H_1 \rangle$ the ratio between the two vacuum expectation values of the Higgs fields

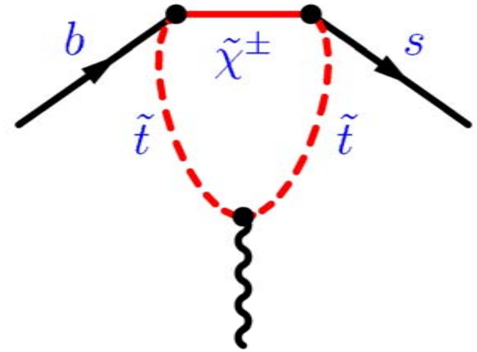
- From astrophysics and cosmology we get:

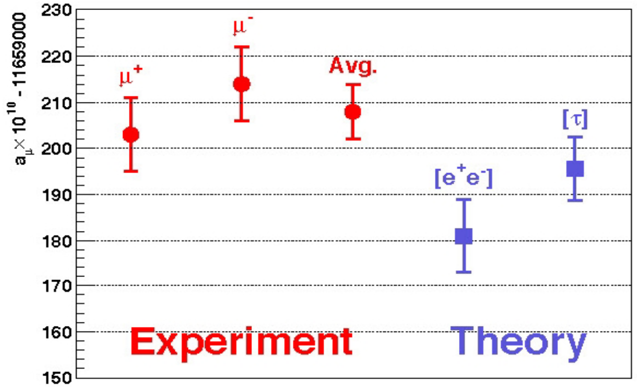
$$\Omega_{CDM} h^2 = 0.120 \pm 0.005$$

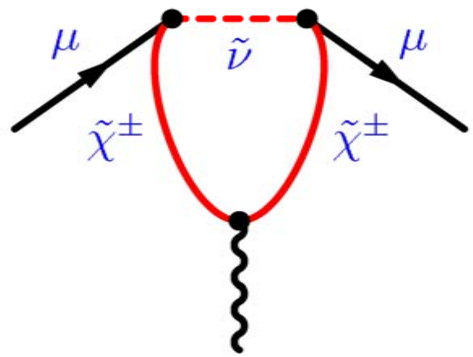
$$BR(B \to X_s \gamma)_{\exp} = (3.39^{+0.30}_{-0.27}) \cdot 10^{-4}$$

$$BR(B \to X_s \gamma)_{SM} = (3.70 \pm 0.30) \cdot 10^{-4}$$



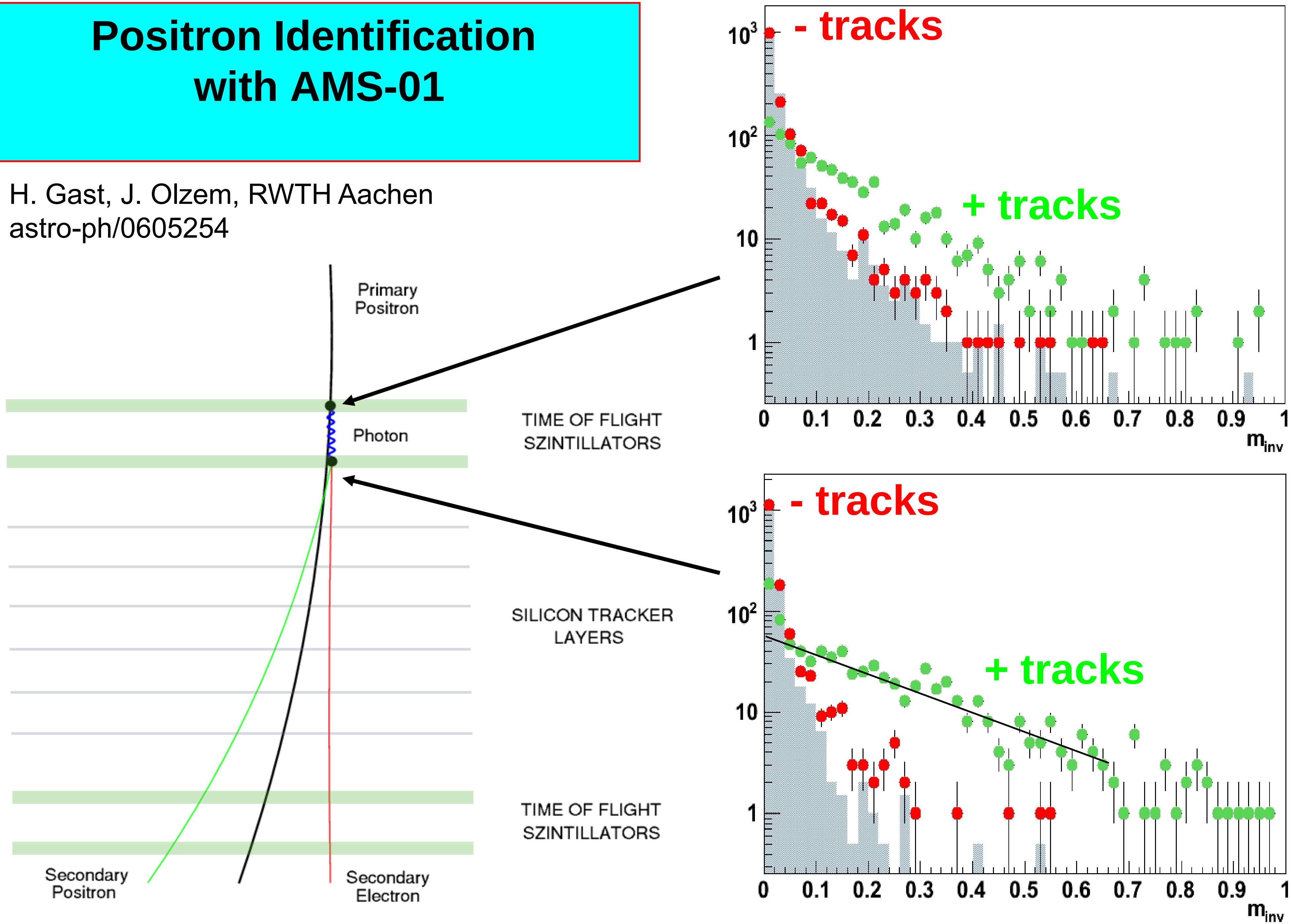


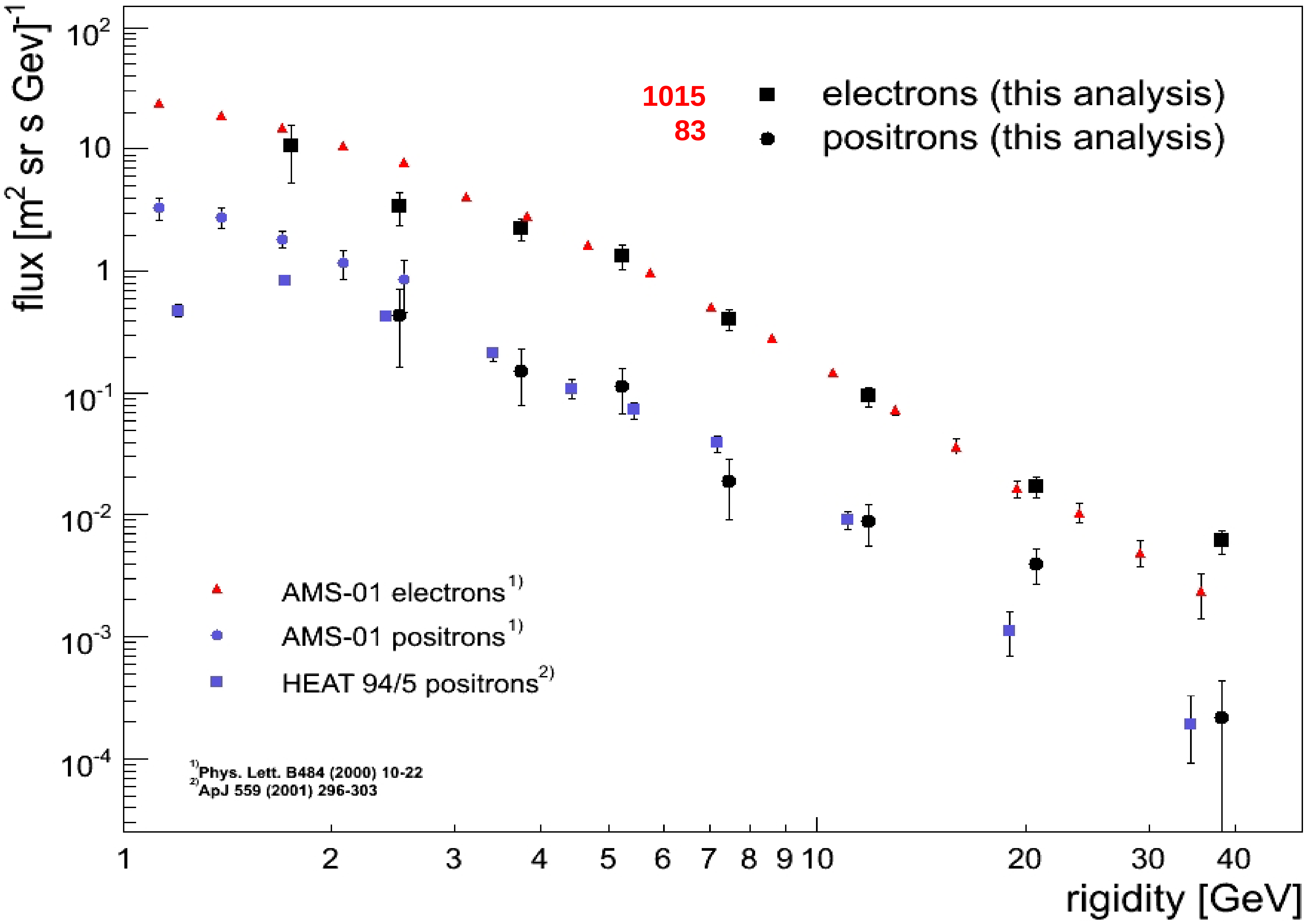




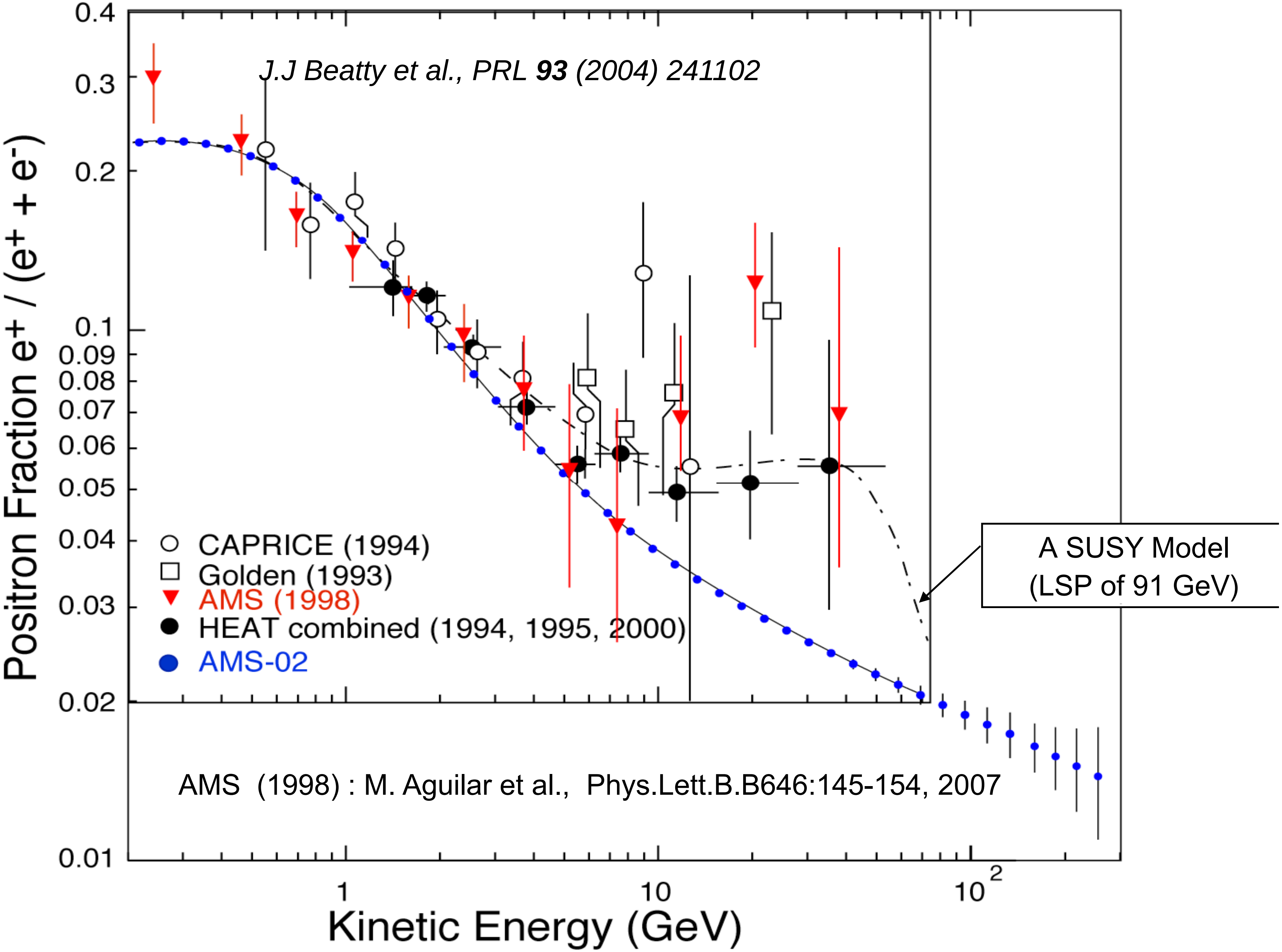
Positron Identification with AMS-01

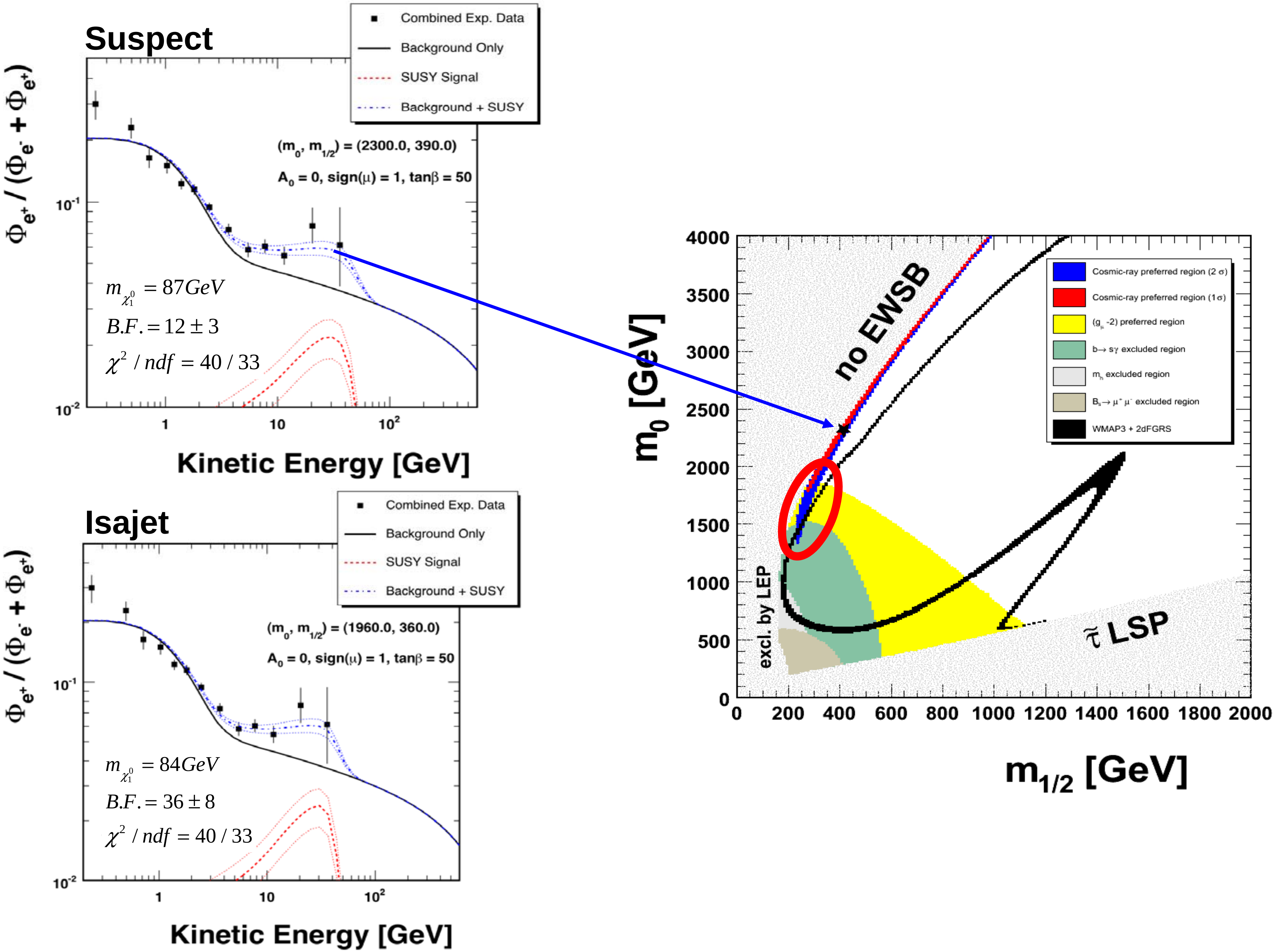
H. Gast, J. Olzem, RWTH Aachen
astro-ph/0605254



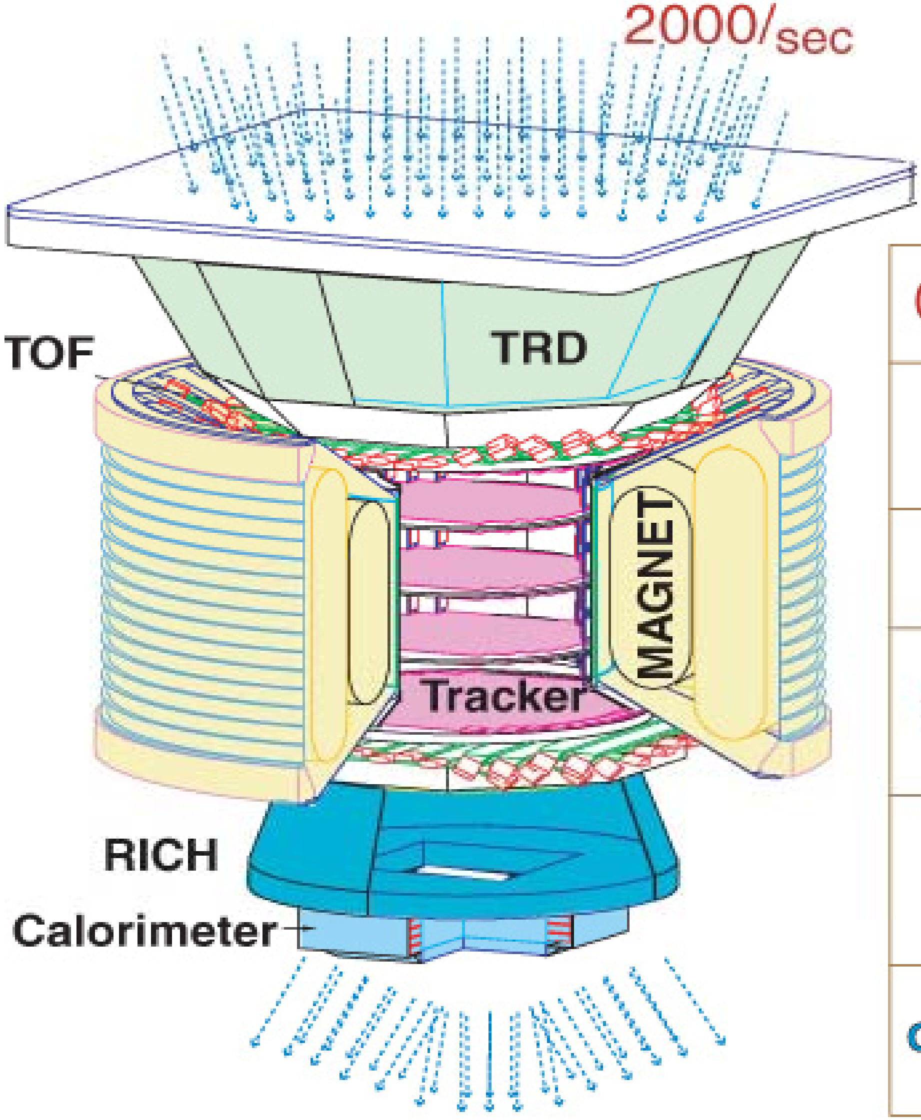


flux [m² sr s Gev]⁻¹
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
1015
83
electrons (this analysis)
positrons (this analysis)
AMS-01 electrons 1)
AMS-01 positrons 1)
HEAT 94/5 positrons 2)
1)Phys. Lett. B484 (2000) 10-22
2)ApJ 559 (2001) 296-303
1
2
3
4
5
6
7
8
9
10
20
30
40
rigidity [GeV]

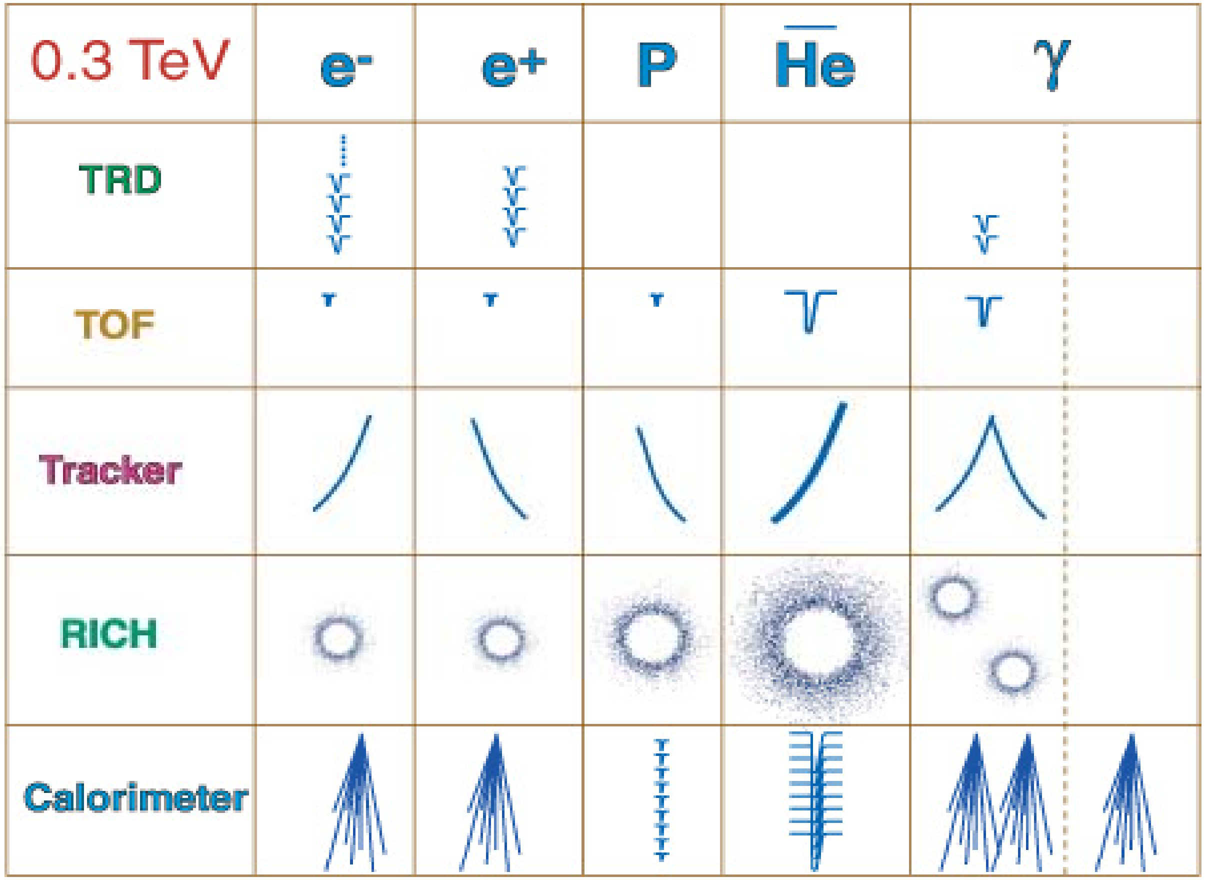

J.J Beatty et al., PRL 93 (2004) 241102
Positron Fraction e+ / (e+ + e-)
Kinetic Energy (GeV)
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
1
10
10^2
CAPRICE (1994)
Golden (1993)
AMS (1998)
HEAT combined (1994, 1995, 2000)
AMS-02
A SUSY Model
(LSP of 91 GeV)
AMS (1998) : M. Aguilar et al., Phys.Lett.B.B646:145-154, 2007


Suspect
Combined Exp. Data
Background Only
SUSY Signal
Background + SUSY
(m0, m1/2) = (2300.0, 390.0)
A0 = 0, sign(μ) = 1, tanβ = 50
$m_{\chi_1^0} = 87 GeV$
$B.F. = 12 \pm 3$
$\chi^2 / ndf = 40 / 33$
Φe+ / (Φe- + Φe+)
Kinetic Energy [GeV]
Isajet
Combined Exp. Data
Background Only
SUSY Signal
Background + SUSY
(m0, m1/2) = (1960.0, 360.0)
A0 = 0, sign(μ) = 1, tanβ = 50
$m_{\chi_1^0} = 84 GeV$
$B.F. = 36 \pm 8$
$\chi^2 / ndf = 40 / 33$
Φe+ / (Φe- + Φe+)
Kinetic Energy [GeV]
Cosmic-ray preferred region (2 σ)
Cosmic-ray preferred region (1 σ)
(gμ-2) preferred region
b→ sγ excluded region
mh excluded region
Bs→ μ+ μ- excluded region
WMAP3 + 2dFGRS
no EWSB
excl. by LEP
τ̃ LSP
m0 [GeV]
m1/2 [GeV]

AMS: A TeV Magnetic Spectrometer in Space

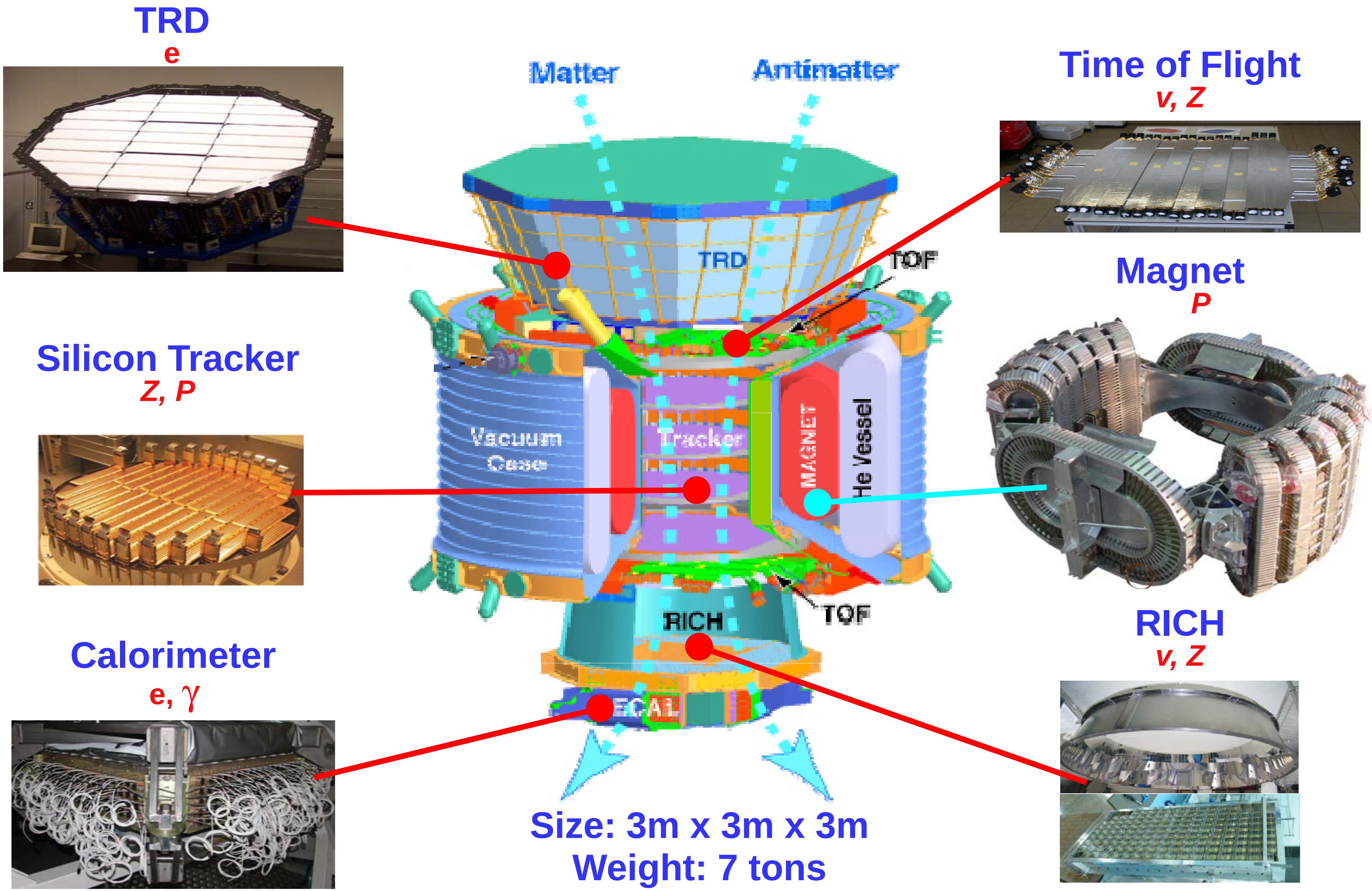


G.F. 5000 cm^2 sr
Exposure > 3 yrs



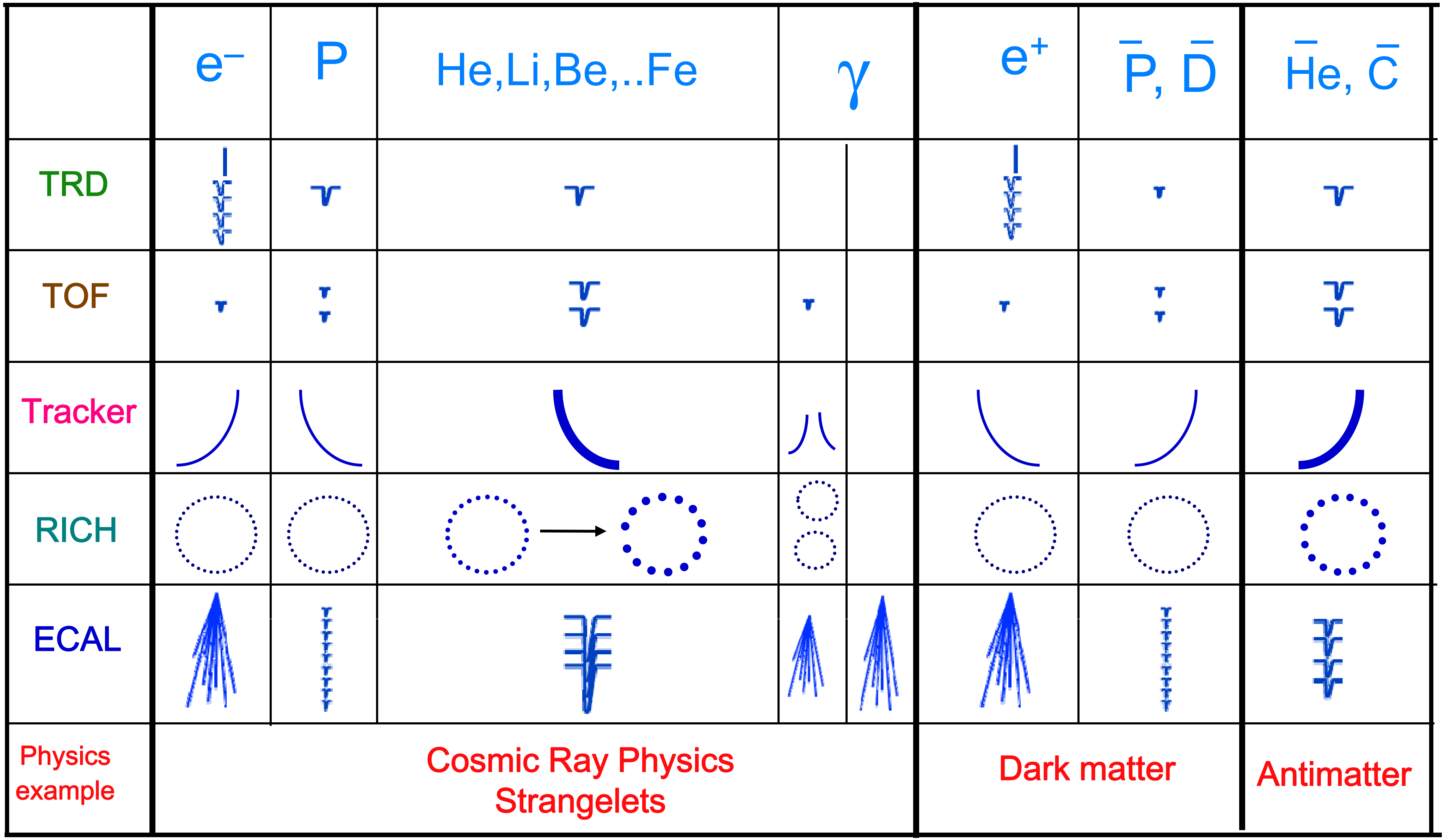
$dP/P^2 \sim 0.004$ → MDR = 2.5 TV, $h/e = 10^{-6}$ (ECAL +TRD)

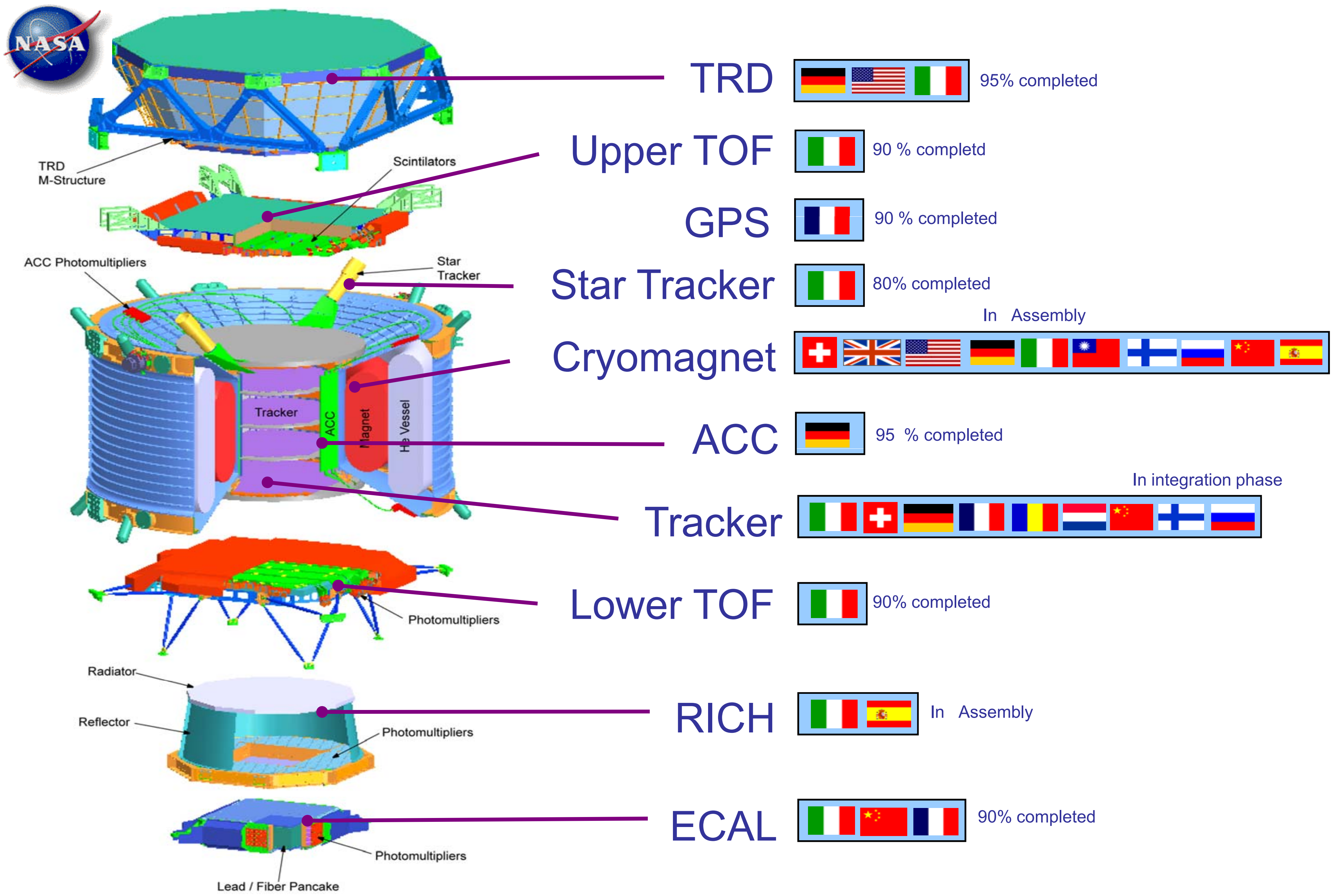
The AMS 02 Detector

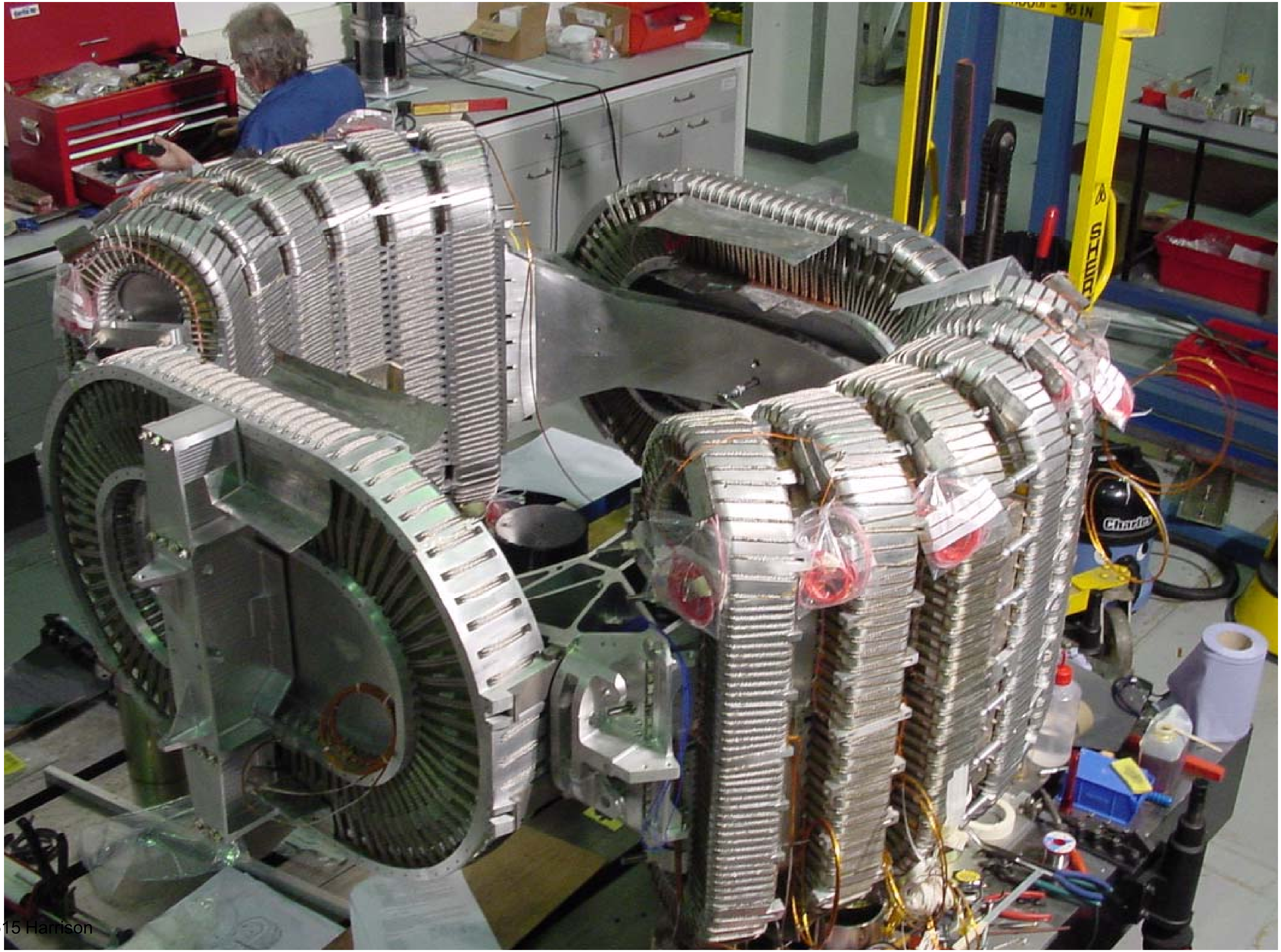


Characteristics of AMS-02

$\Delta t = 100$ ps, $\Delta x = 10$ μm, $\Delta v/v = 0.001$

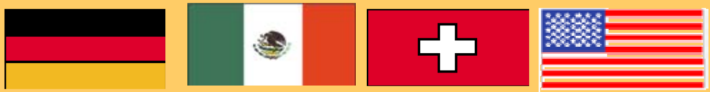


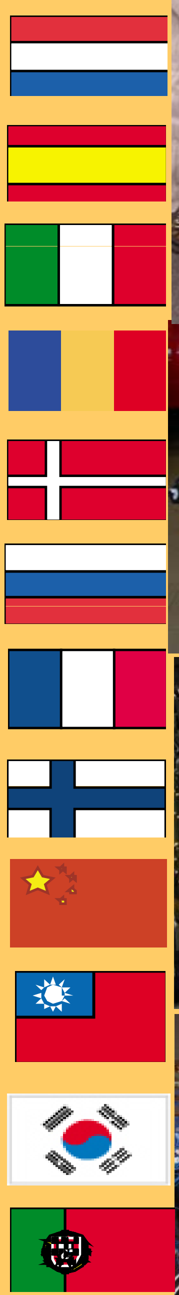

TRD
95% completed
Upper TOF
90 % completd
GPS
90 % completed
Star Tracker
80% completed
In Assembly
Cryomagnet
ACC
95 % completed
In integration phase
Tracker
Lower TOF
90% completed
RICH
In Assembly
ECAL
90% completed
TRD
M-Structure
Scintilators
ACC Photomultipliers
Star
Tracker
Tracker
ACC
Magnet
He Vessel
Photomultipliers
Radiator
Reflector
Photomultipliers
Photomultipliers
Lead / Fiber Pancake

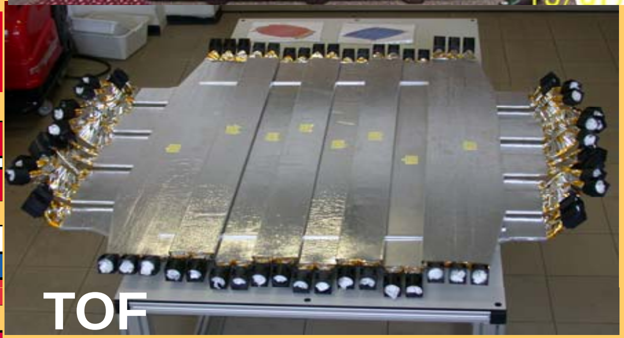


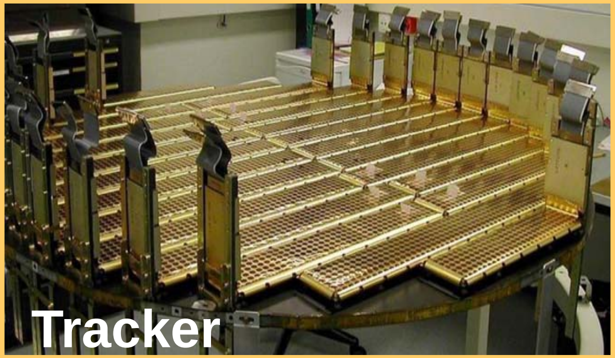
Y04K615 Harrison

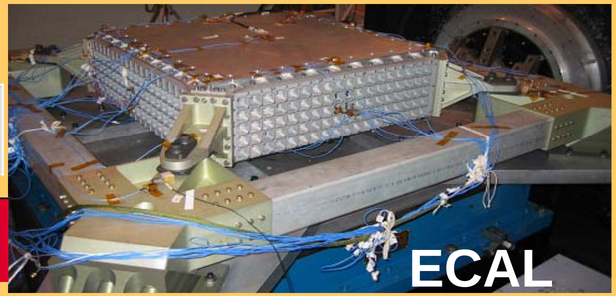
2006
Assembly of all detectors
onto the superconducting magnet

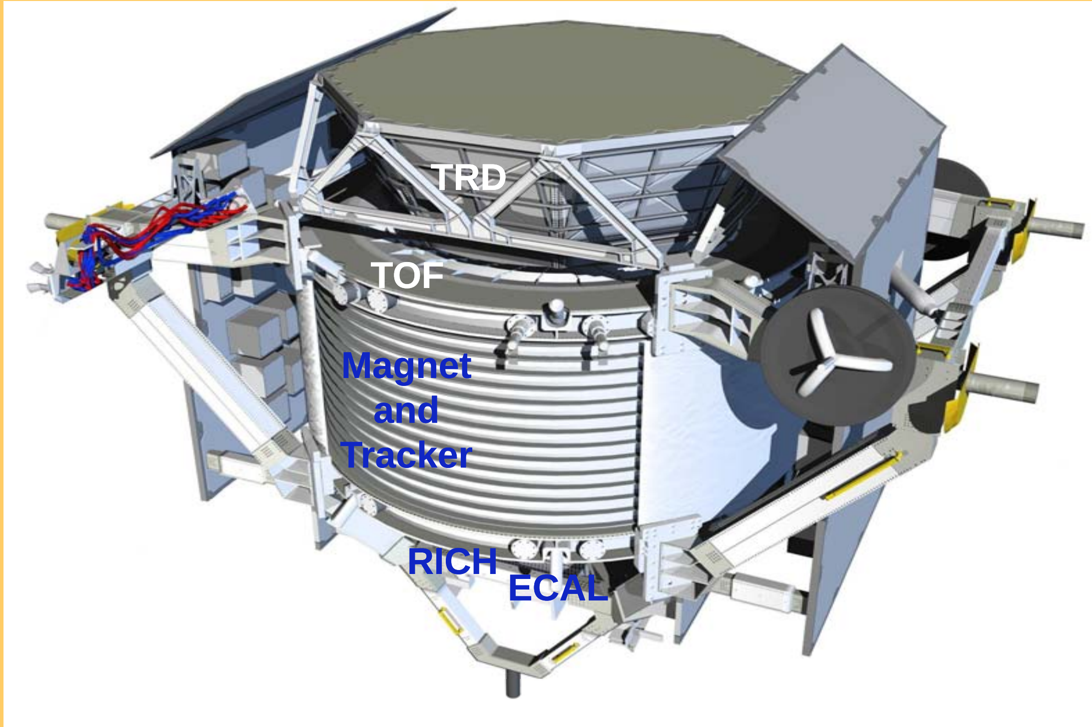




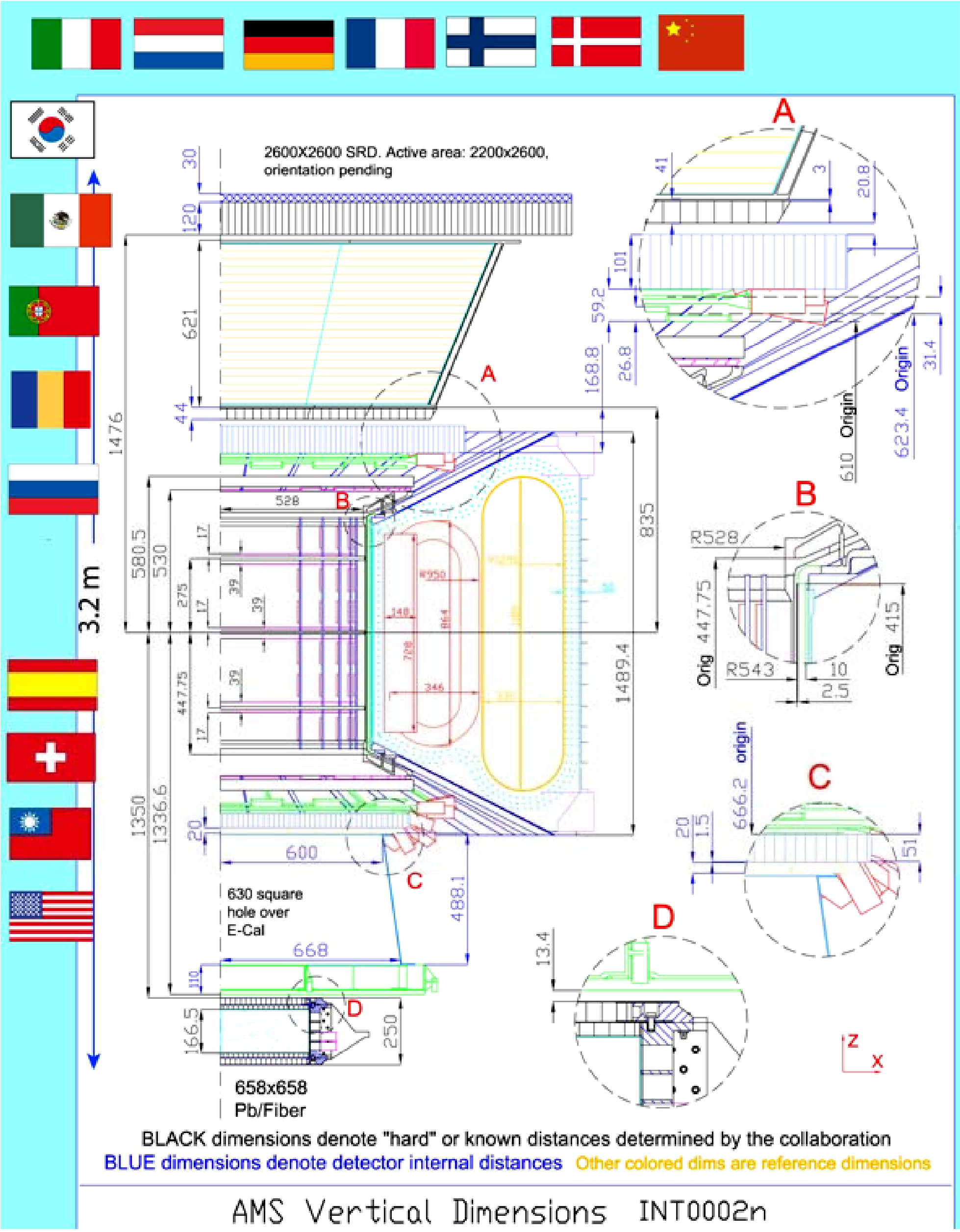








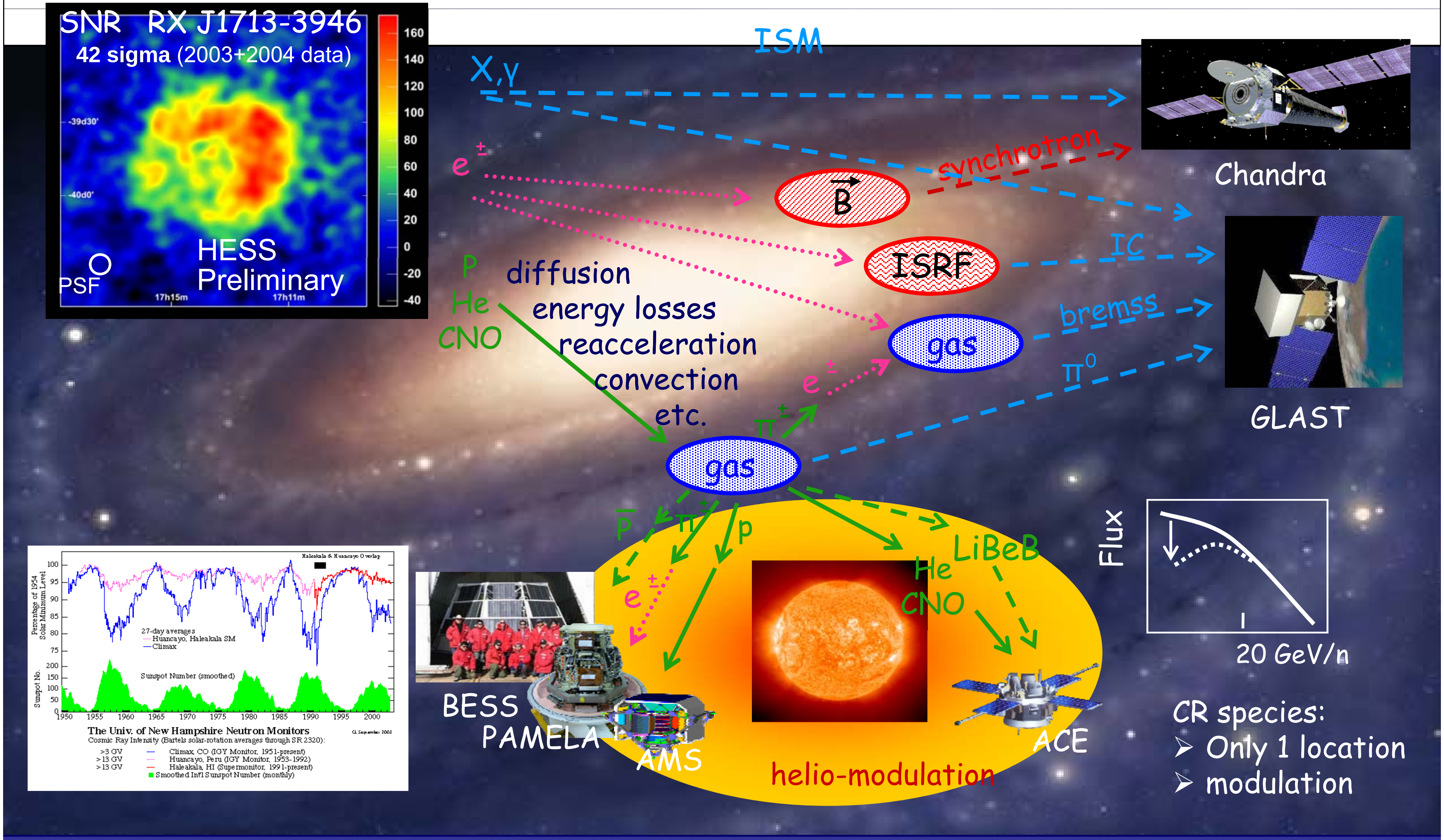
The 400 fast microprocessors



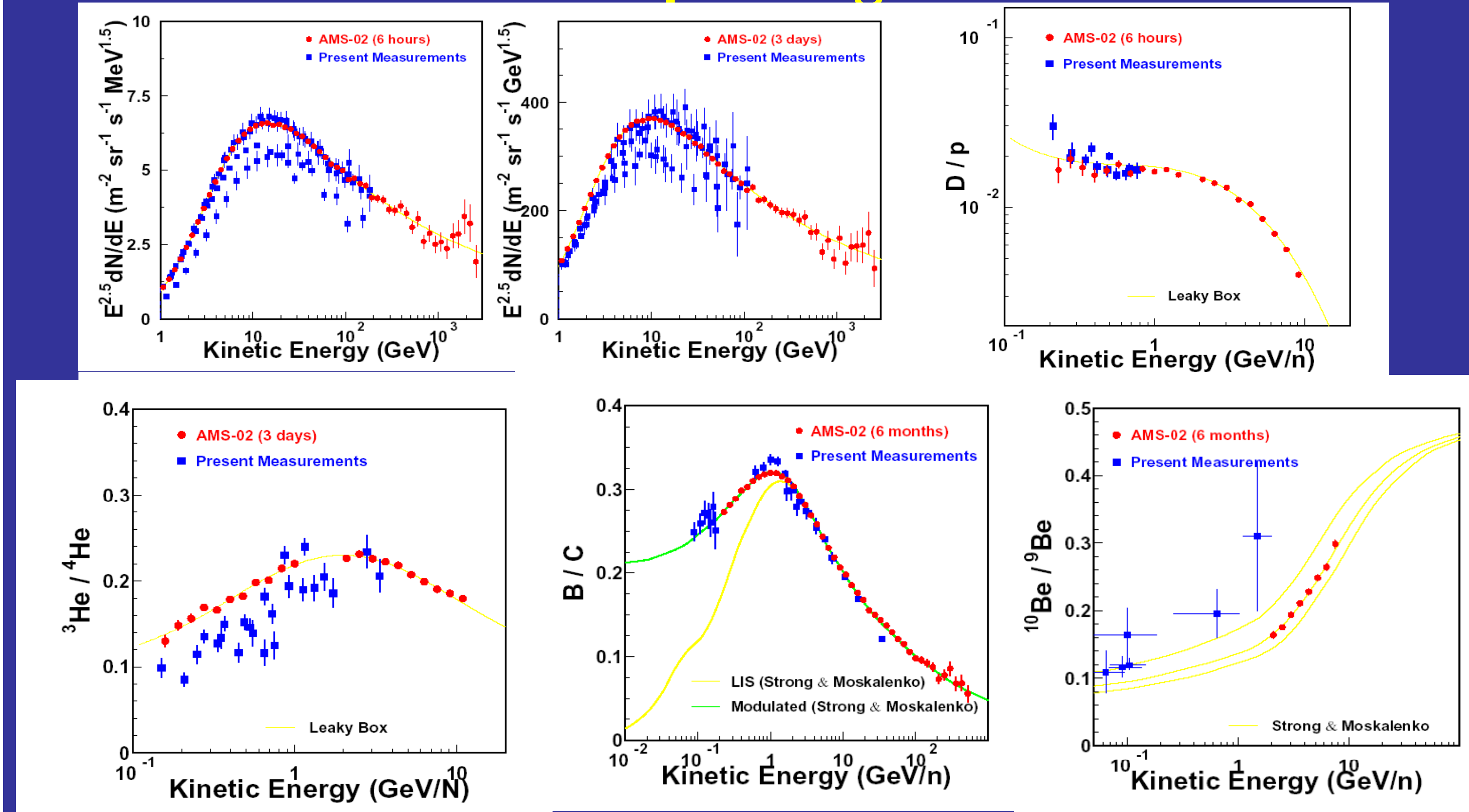
2007/8

Thermal vacuum test at ESA, Holland

CR Interactions in the Interstellar Medium

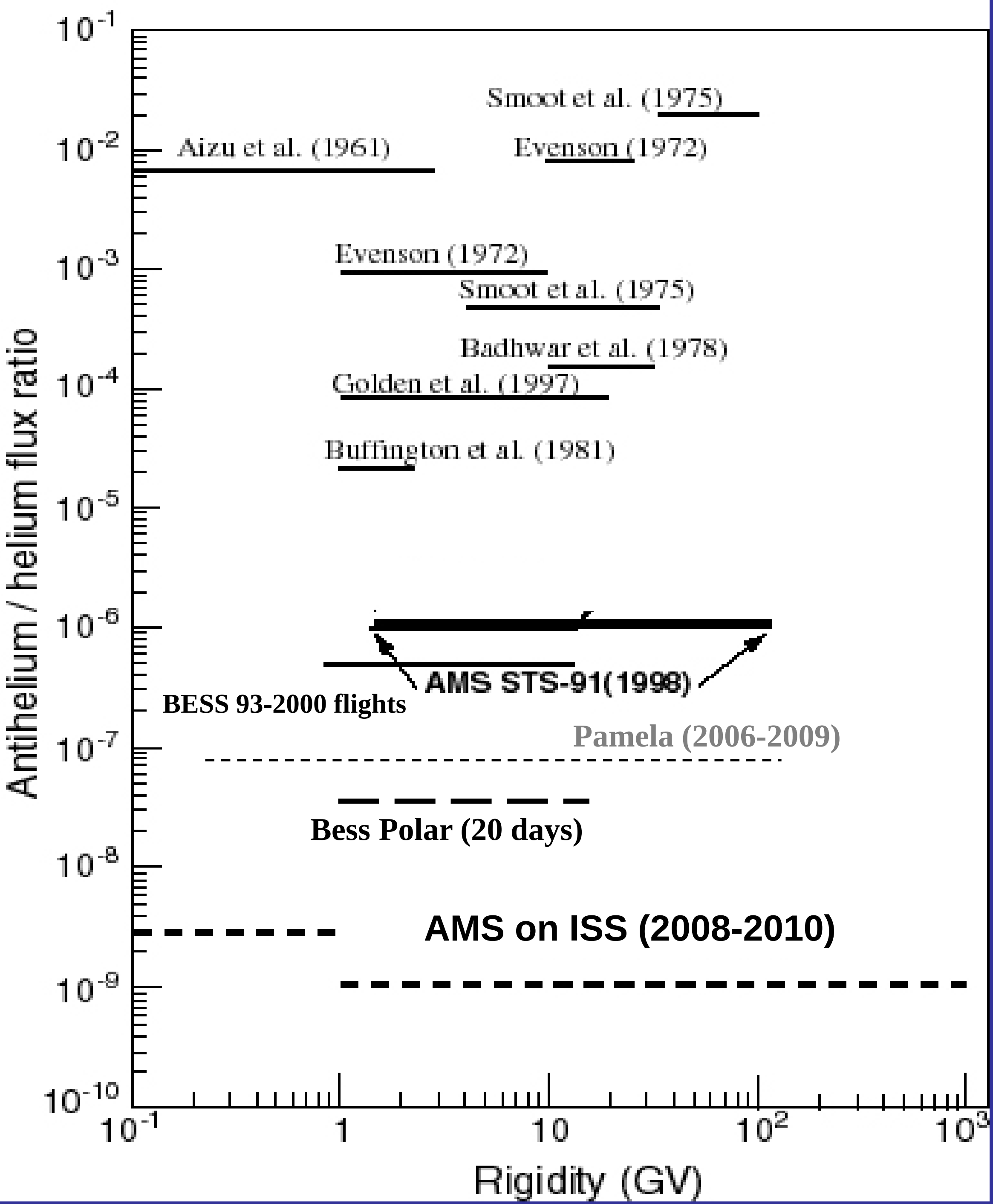


Tomorrow....(>2008)
after AMS starts operating on the ISS



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

Search for antimatter at the 10^{-9} level of sensitivity with AMS-02 on the ISS



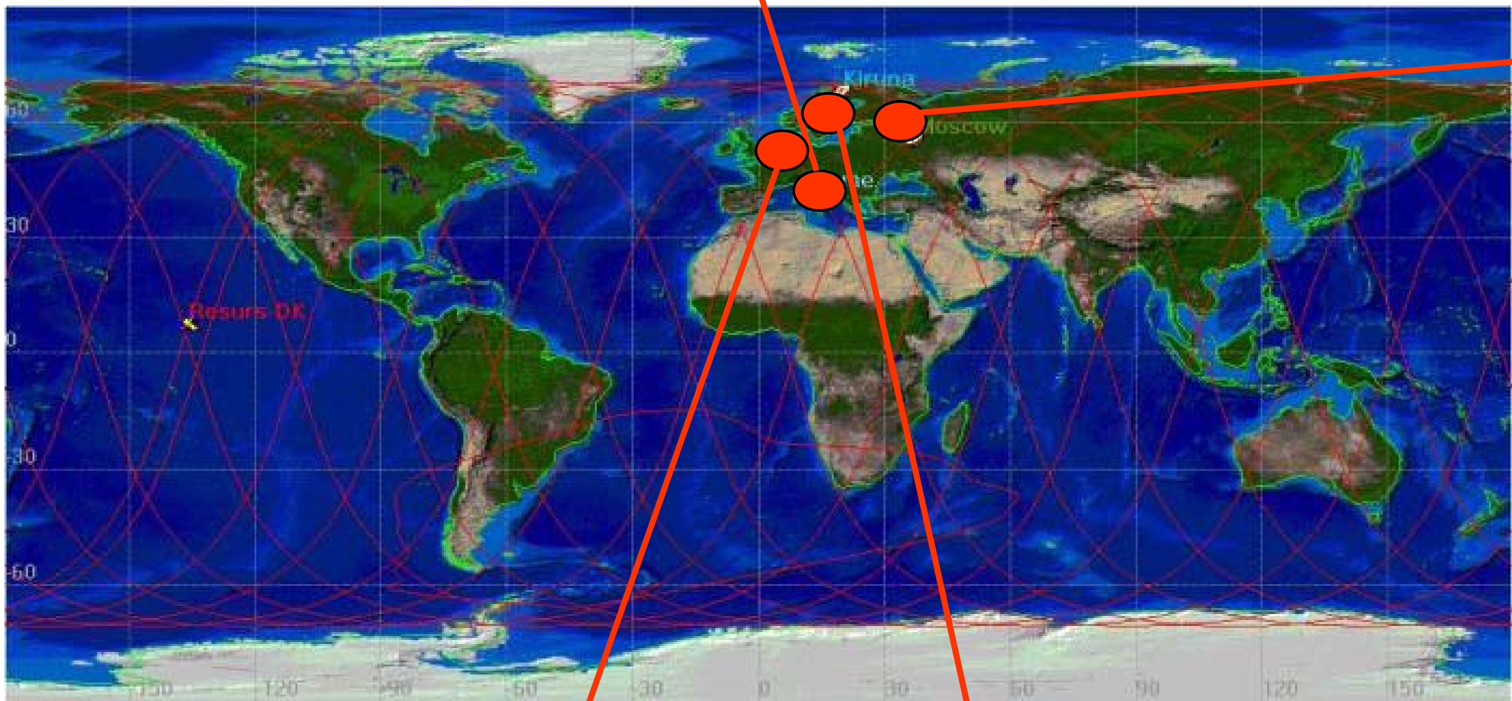
PAMELA Collaboration

Italy: Bari, Florence, Frascati, Naples, Rome, Trieste, CNR, Florence

Russia:

Ioffe Physico-Technical Institute

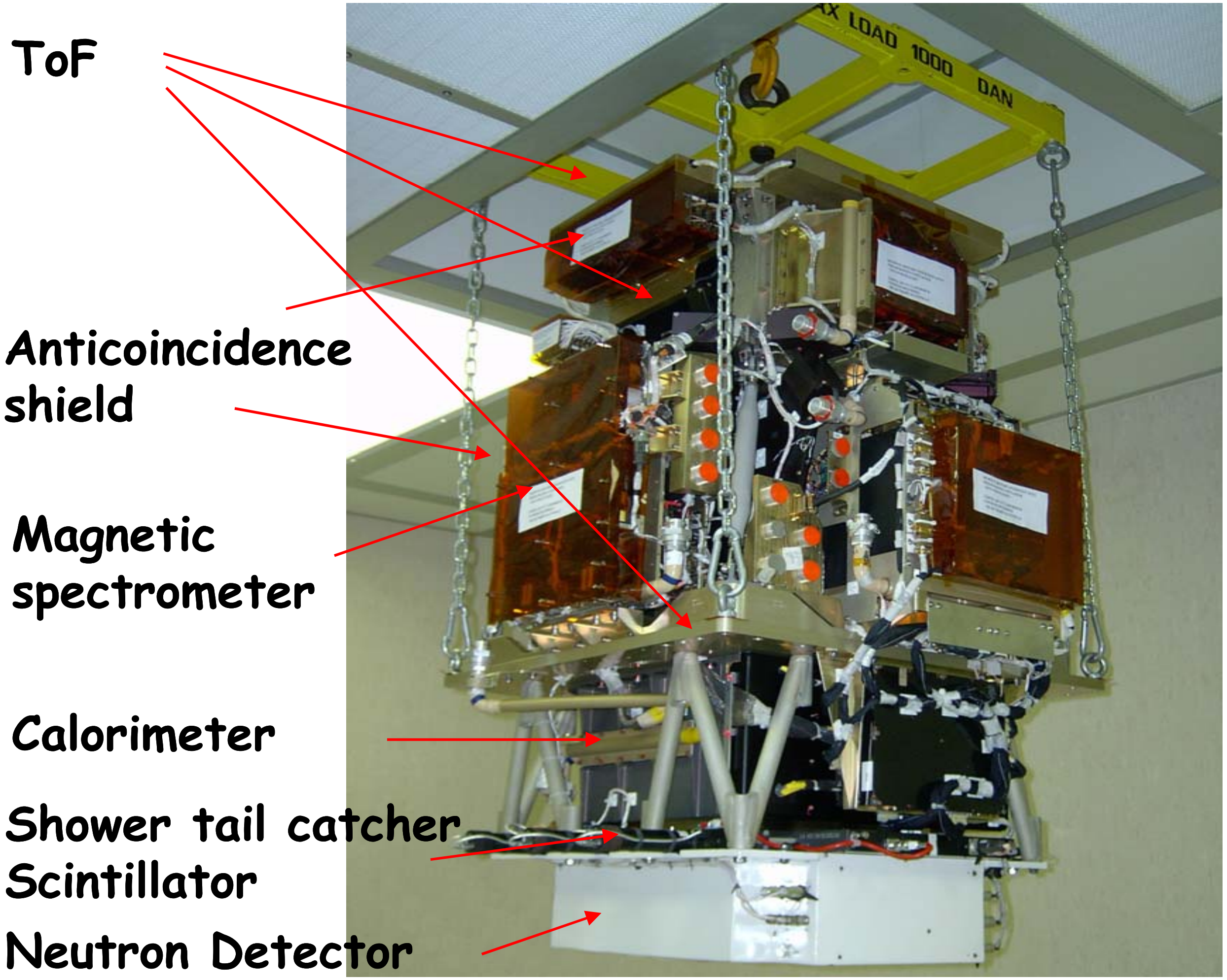
Moscow
St. Petersburg



Germany: Siegen

Sweden: KTH, Stockholm

PAMELA Instrument

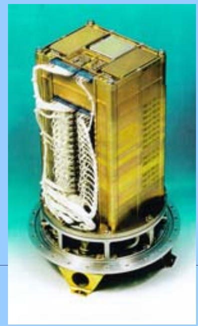


GF: 21.5 cm^2 sr
Mass: 470 kg
Size: 130x70x70 cm^3
Power Budget: 360W

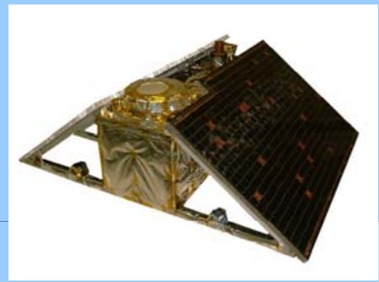
WiZard Russian Italian Missions

MASS-89, 91, TS-93, CAPRICE 94-97-98

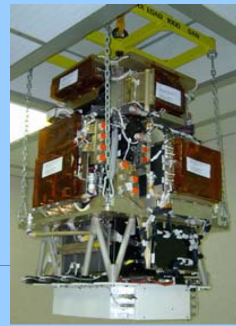
NINA-1

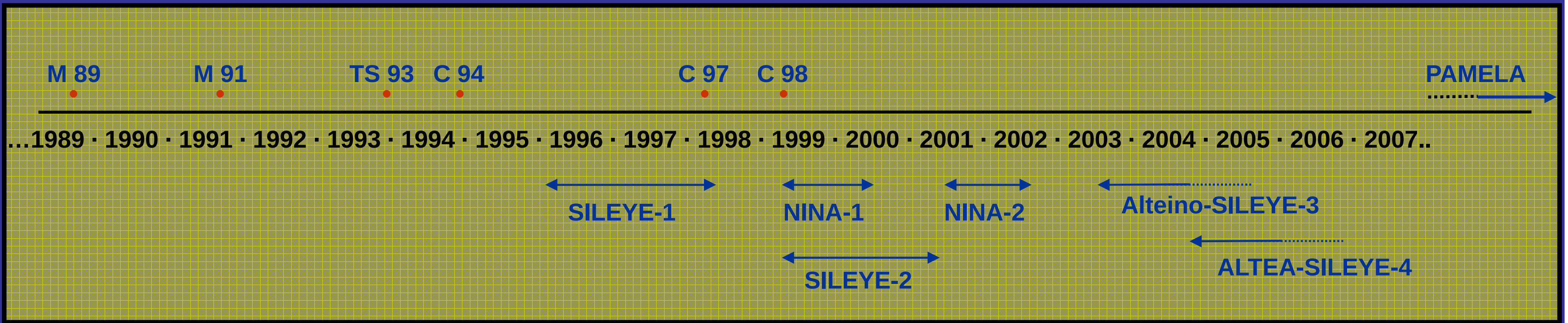


NINA-2



PAMELA





SILEYE-1

SILEYE-2

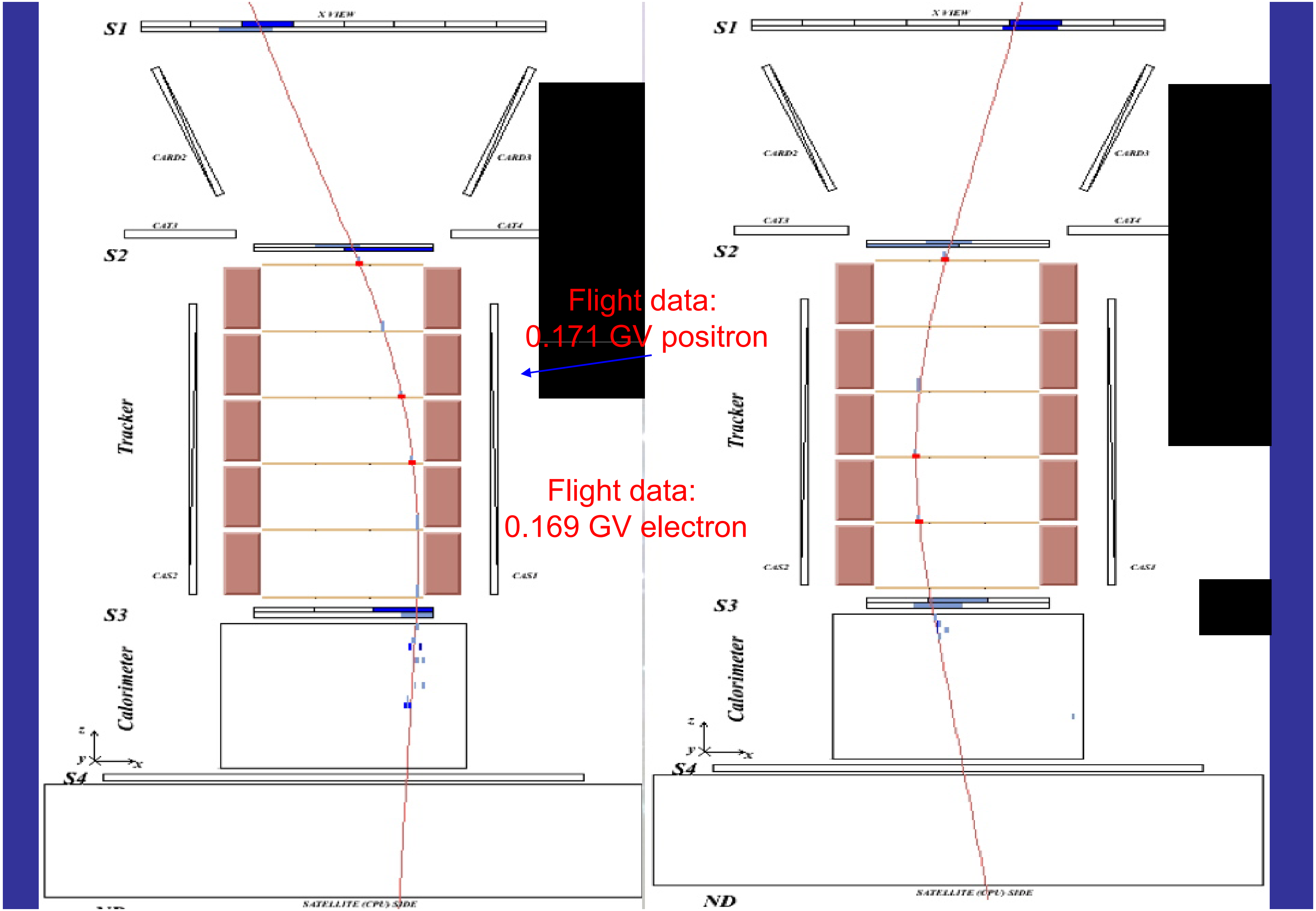
ALTEINO: SILEYE-3

LAZIO SIRAD

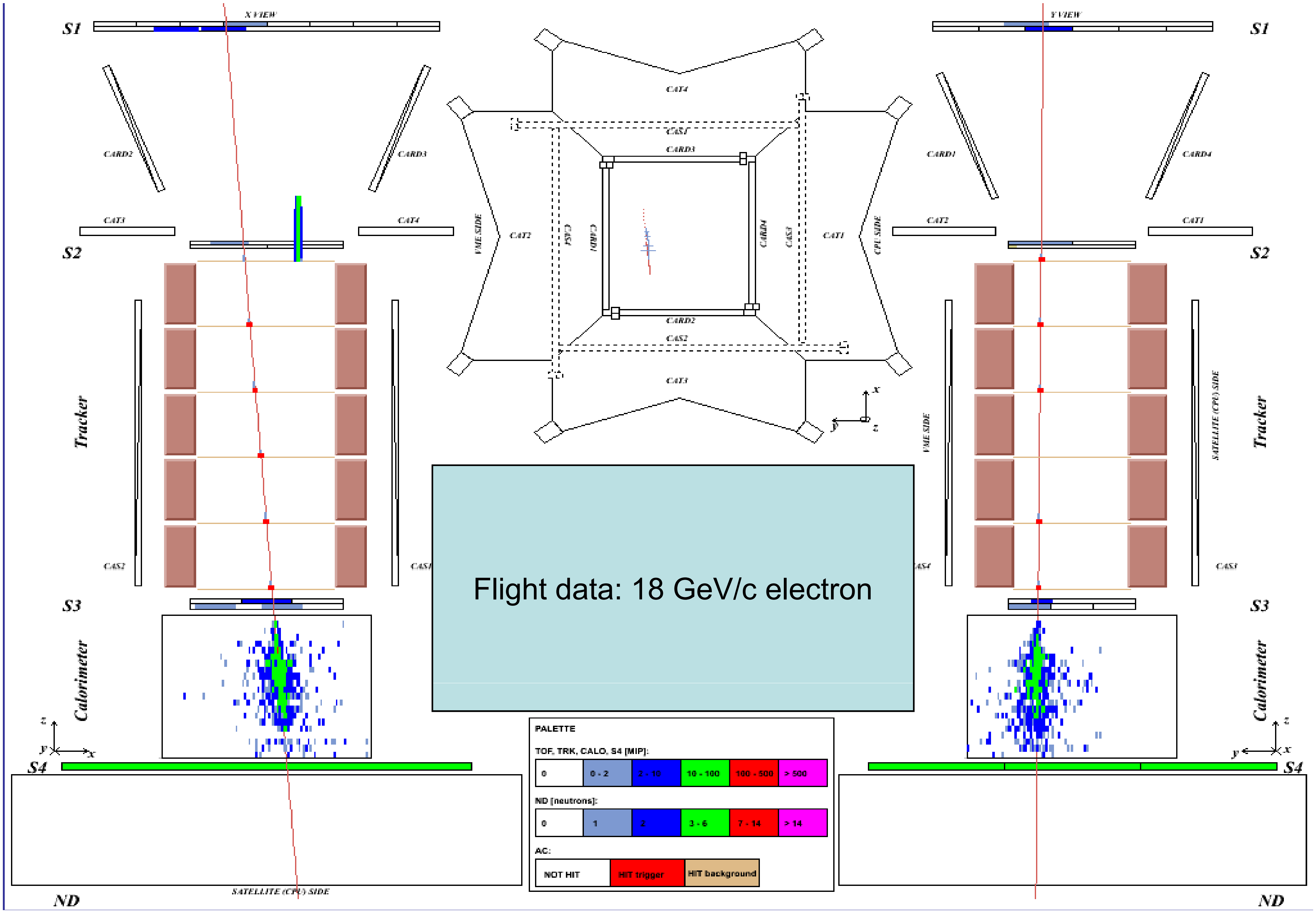
ALTEA: SILEYE-4

PAMELA nominal capabilities

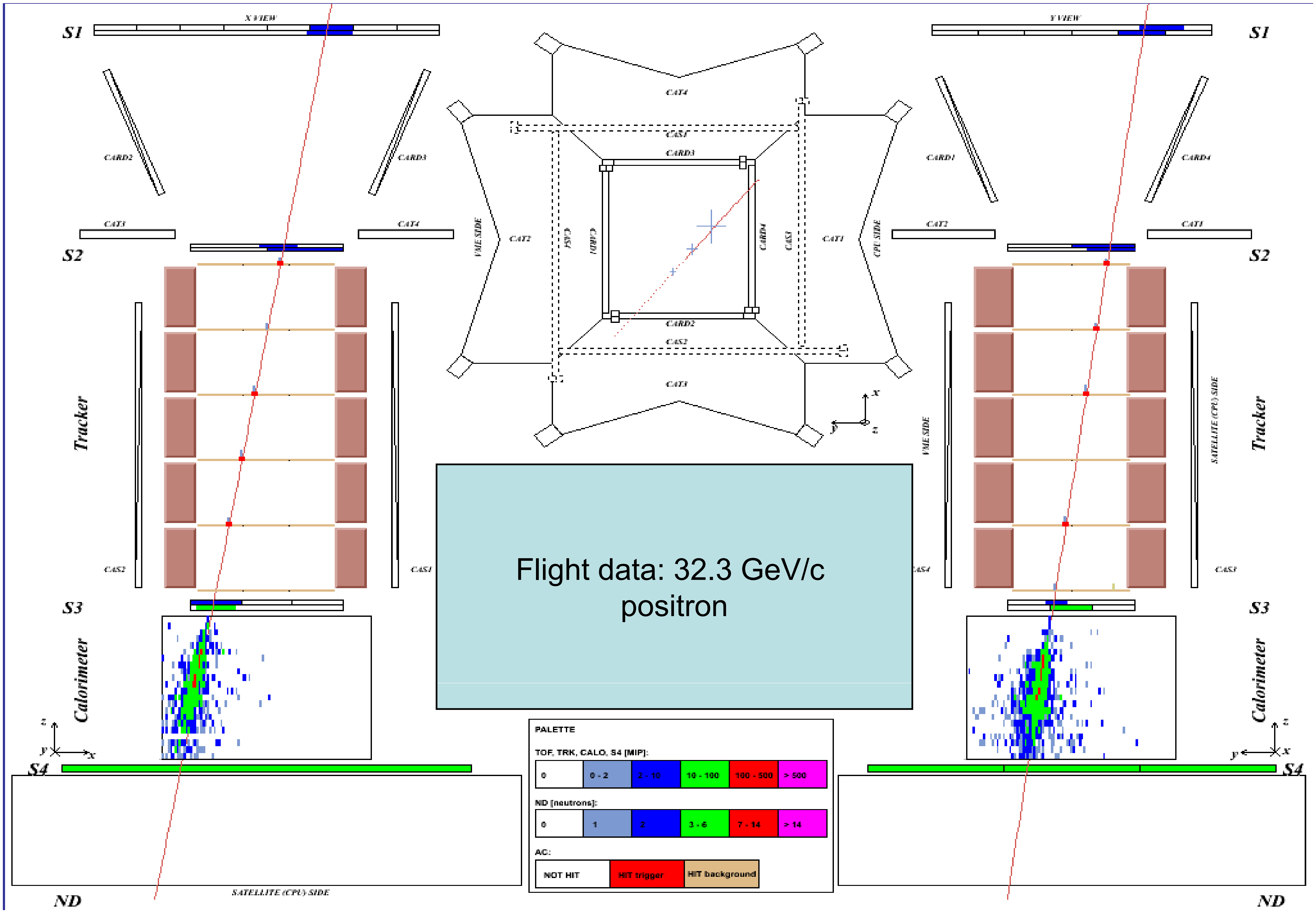
	energy range	particles in 3 years
• Antiprotons	80 MeV - 190 GeV	~ 10^4
• Positrons	50 MeV – 270 GeV	~ 10^5
• Electrons	up to 400 GeV	~ 10^6
• Protons	up to 700 GeV	~ 10^8
• Electrons+positrons	up to 2 TeV (from calorimeter)	
• Light Nuclei	up to 200 GeV/n He/Be/C:	~$10^{7/4/5}$
• AntiNuclei search	sensitivity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

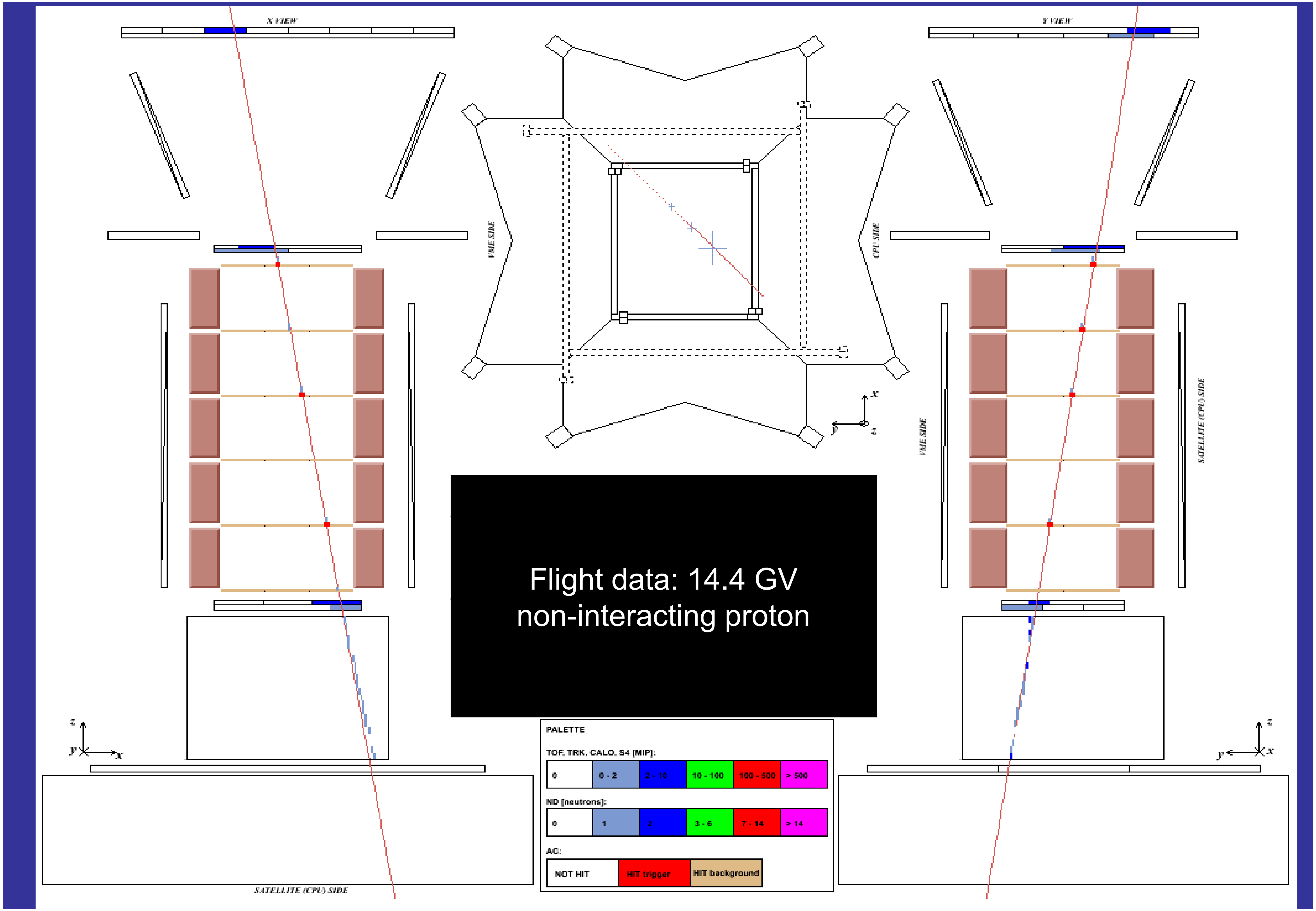


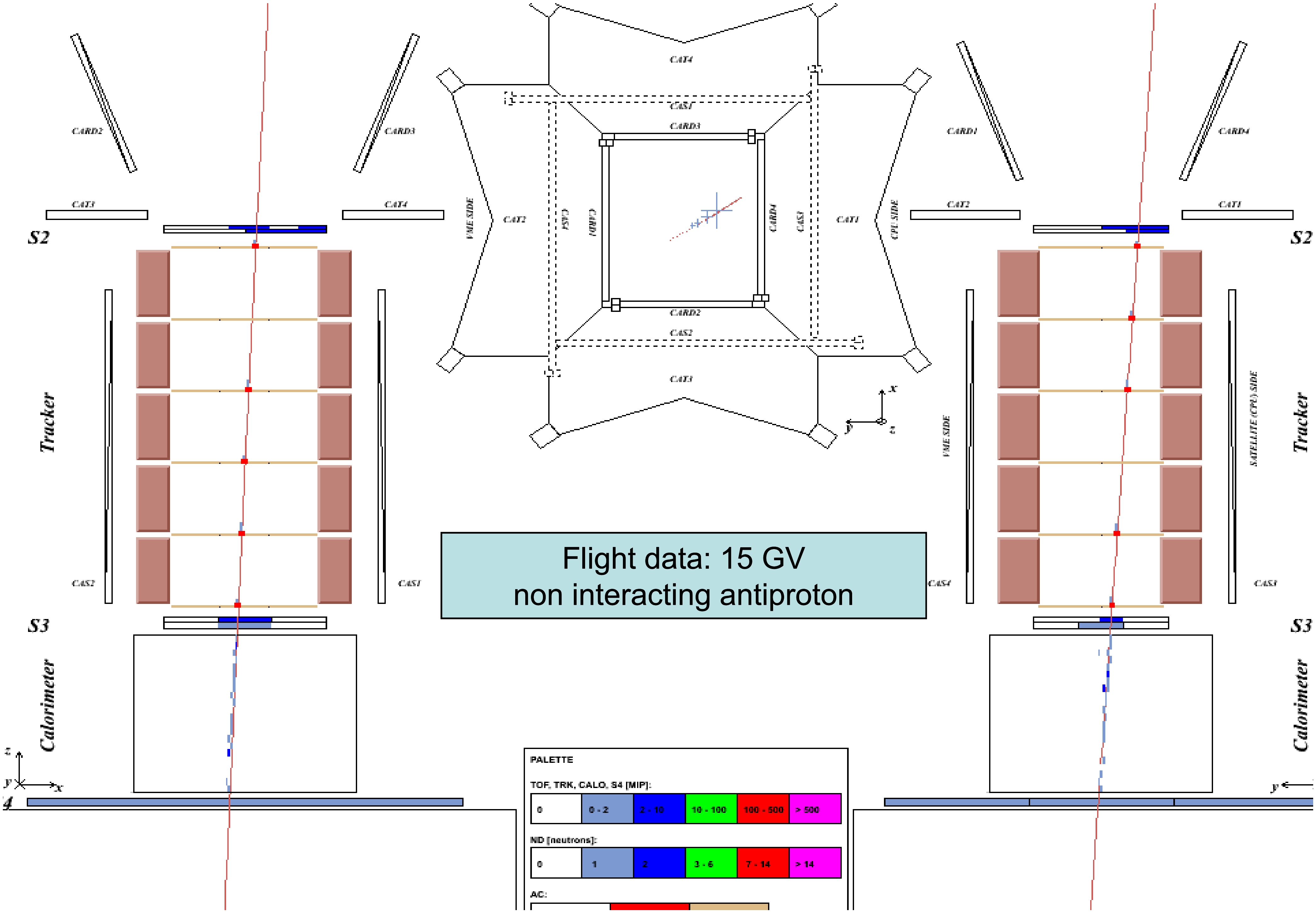
Flight data:
0.171 GV positron
Flight data:
0.169 GV electron
S1
X VIEW
CARD2
CARD3
CAT3
CAT4
S2
Tracker
CAS2
CAS1
S3
Calorimeter
S4
SATELLITE (CPU) SIDE
ND

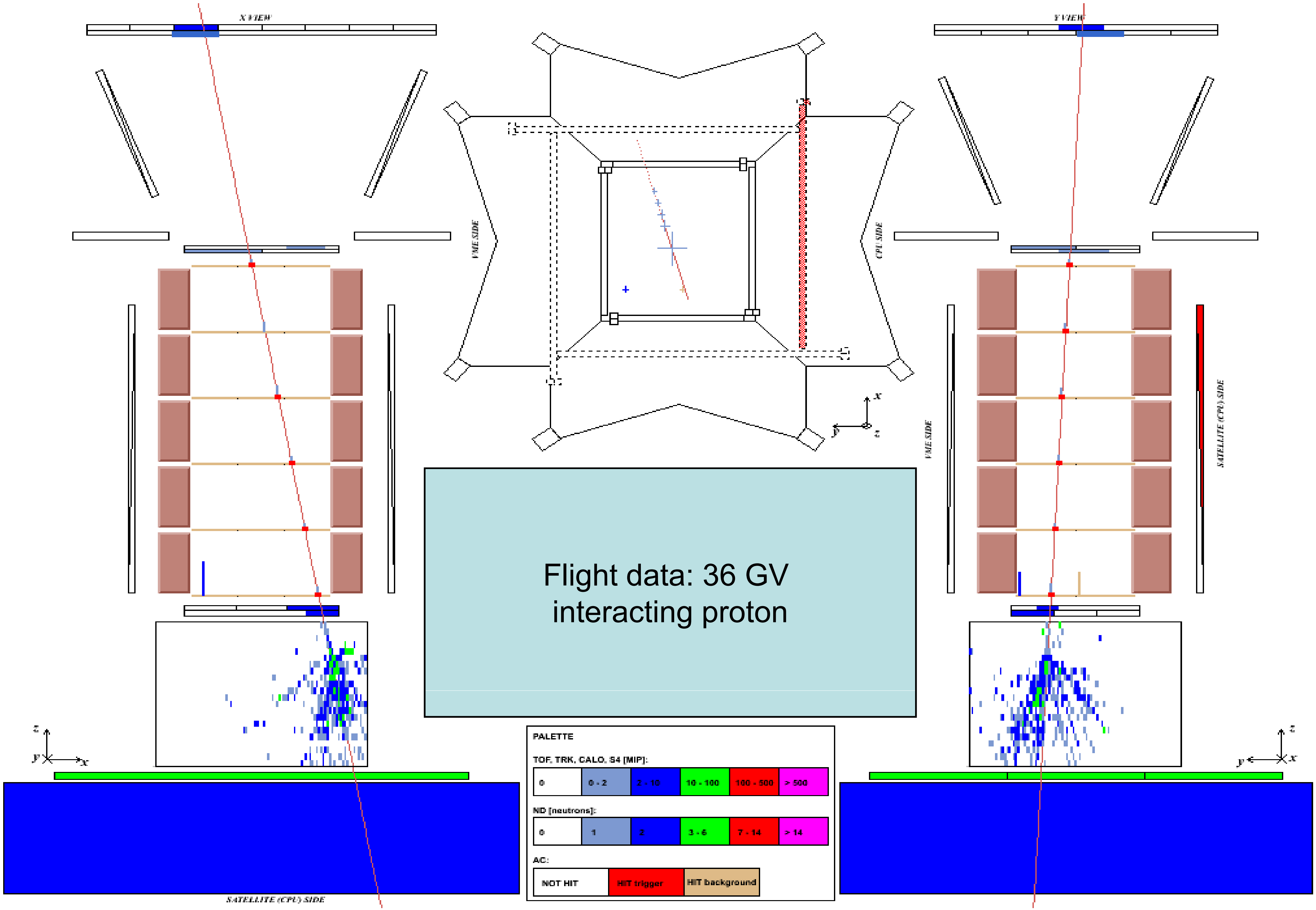

S1
X VIEW
Y VIEW
CARD2
CARD3
CARD1
CARD4
CAT3
CAT4
CAT2
CAT1
S2
Tracker
CAS2
CAS1
CAS4
CAS3
S3
Calorimeter
S4
ND
SATELLITE (CPU) SIDE
VME SIDE
CPU SIDE
Flight data: 18 GeV/c electron
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background

Flight data: 32.3 GeV/c positron

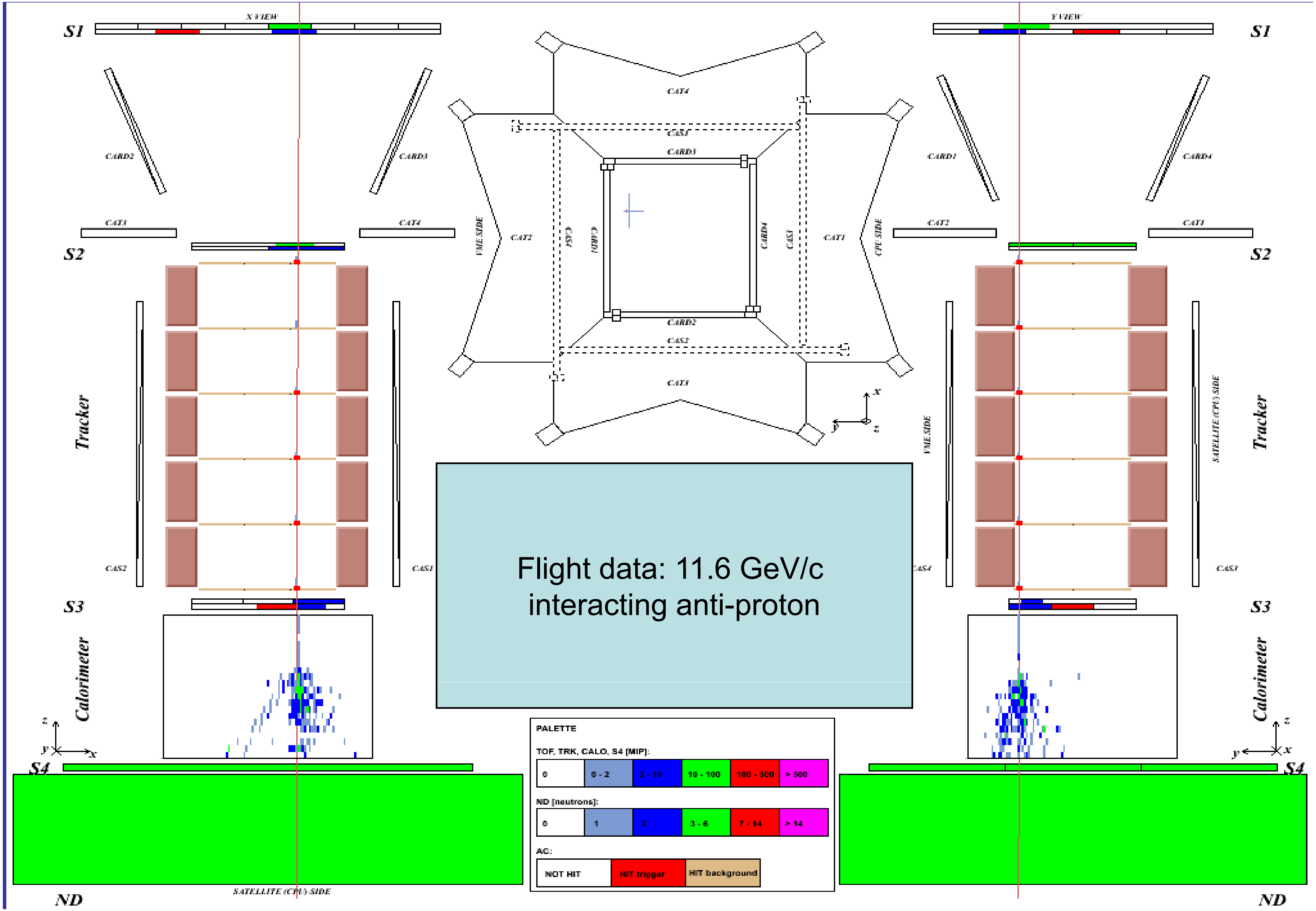



X VIEW
Y VIEW
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
Flight data: 14.4 GV
non-interacting proton
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background

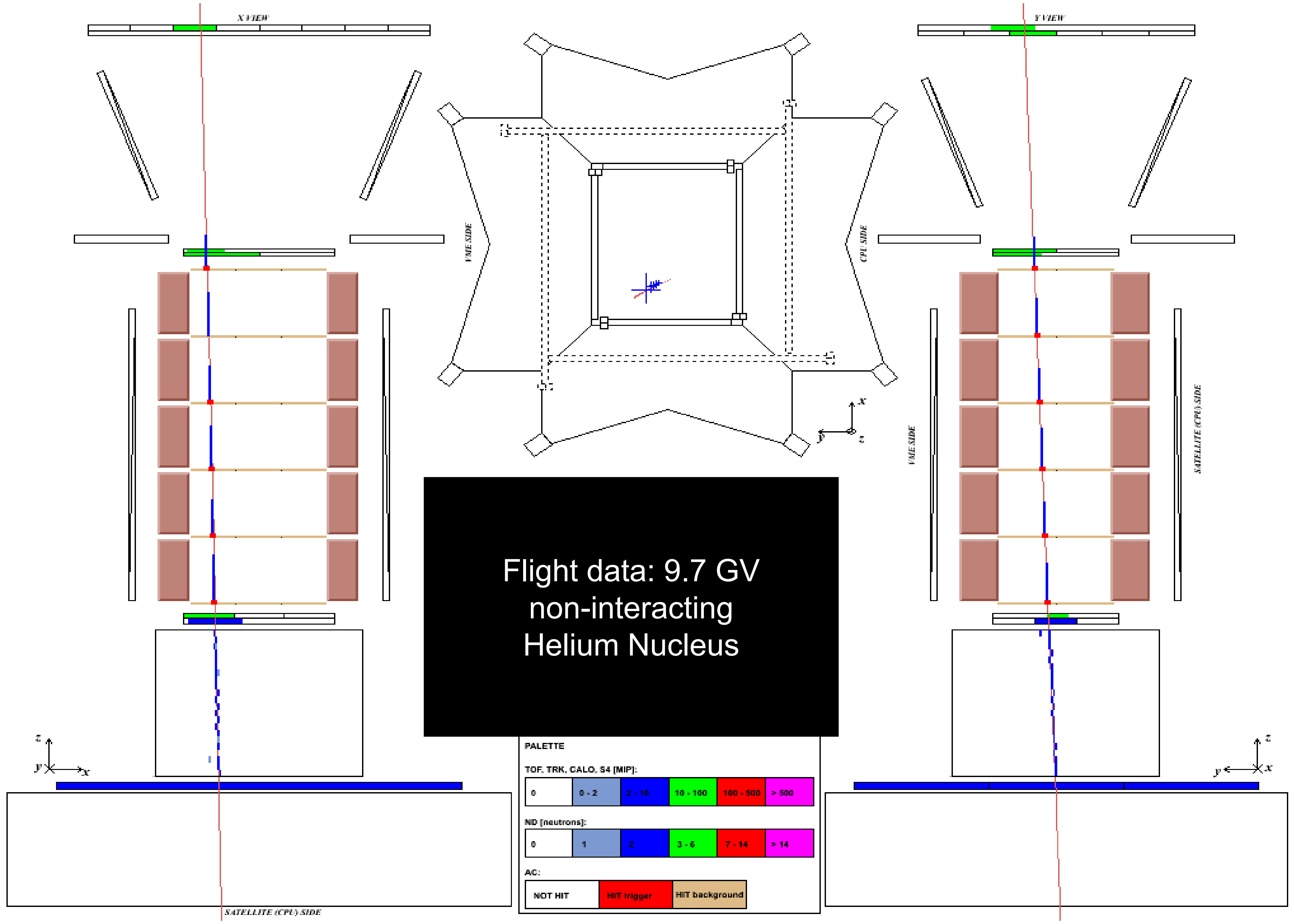

Flight data: 15 GV
non interacting antiproton
S2
S3
Tracker
Calorimeter
CARD2
CARD3
CARD1
CARD4
CAT3
CAT4
CAT2
CAT1
CAS2
CAS1
CAS4
CAS3
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:



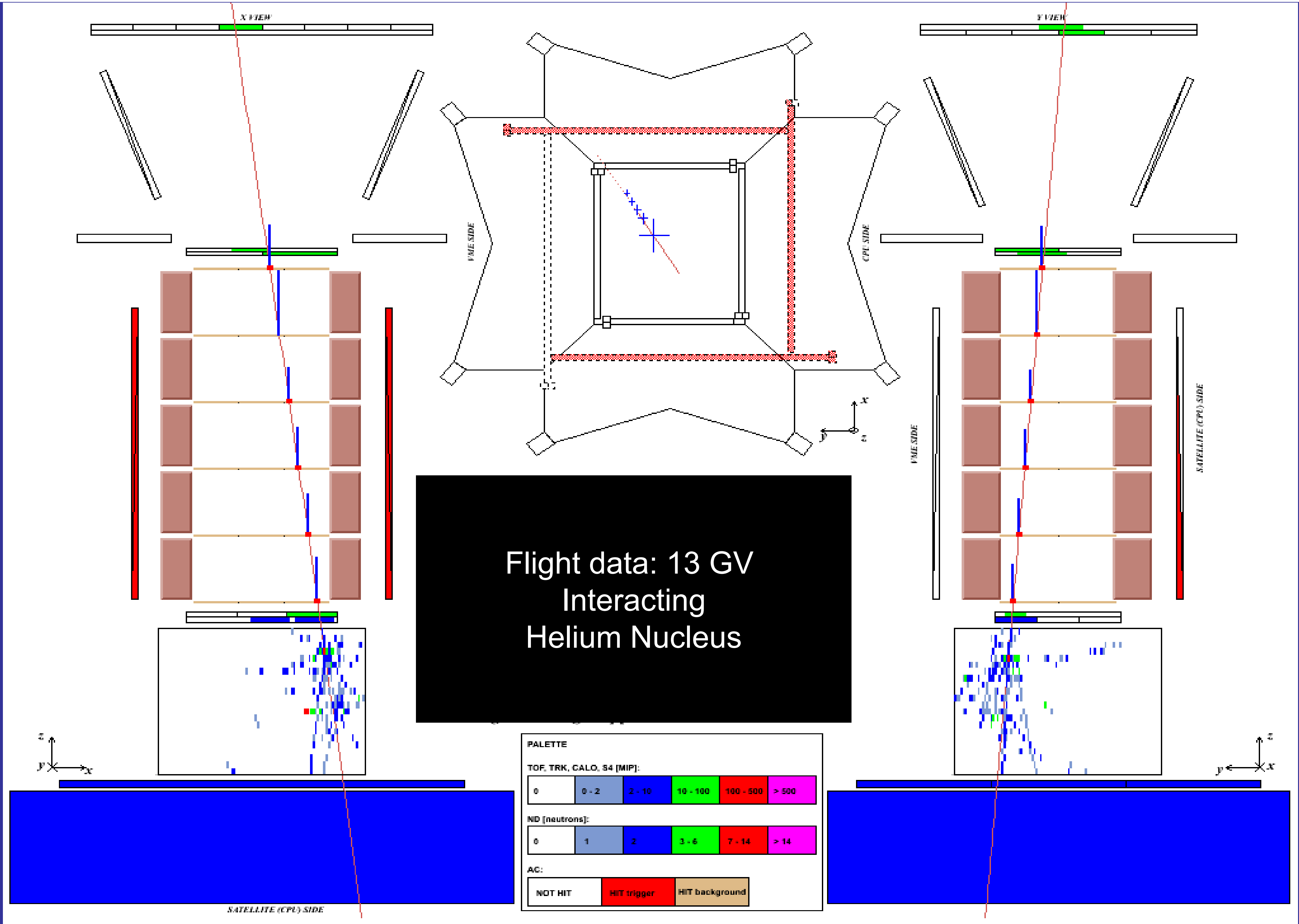
Flight data: 36 GV interacting proton

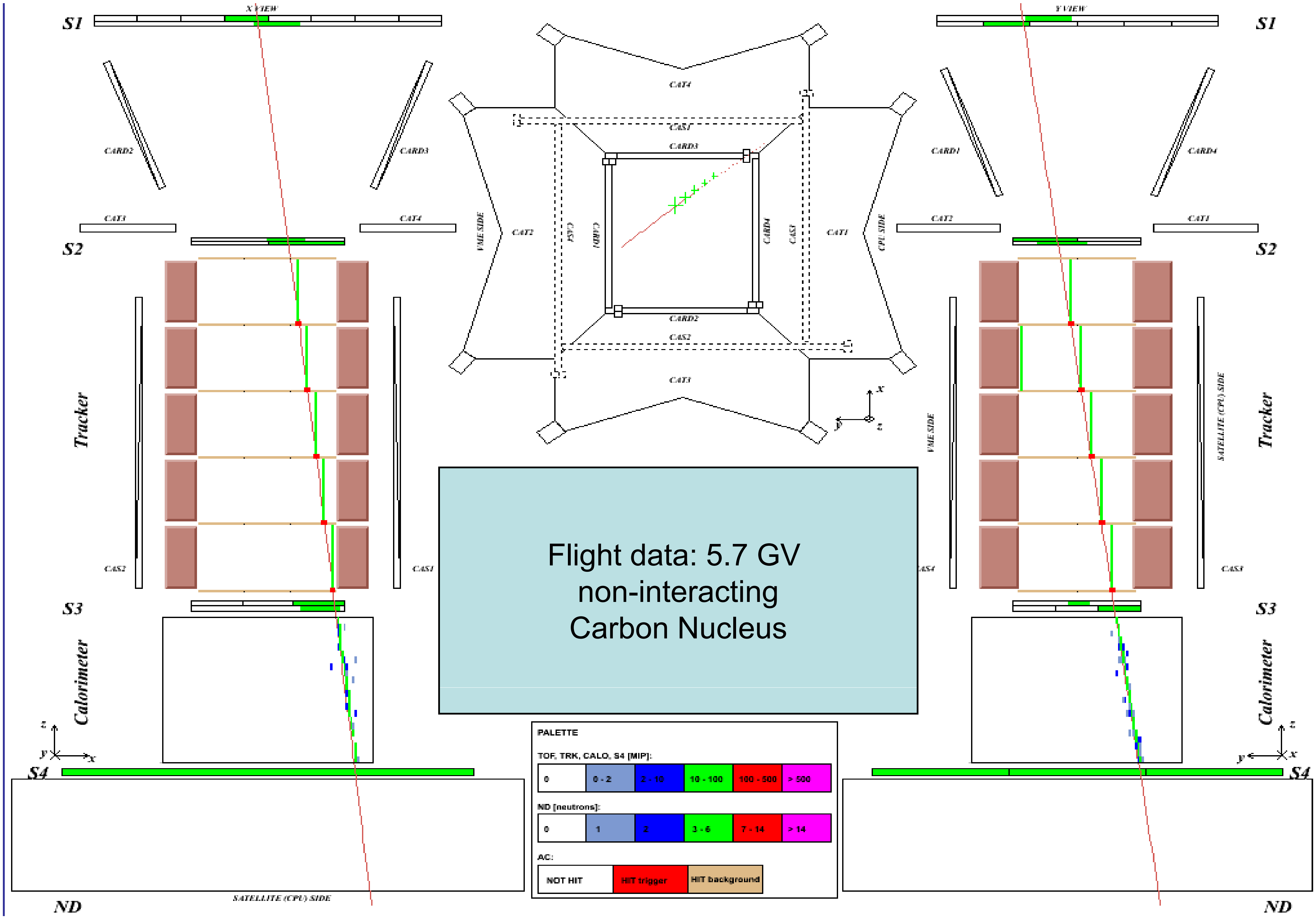


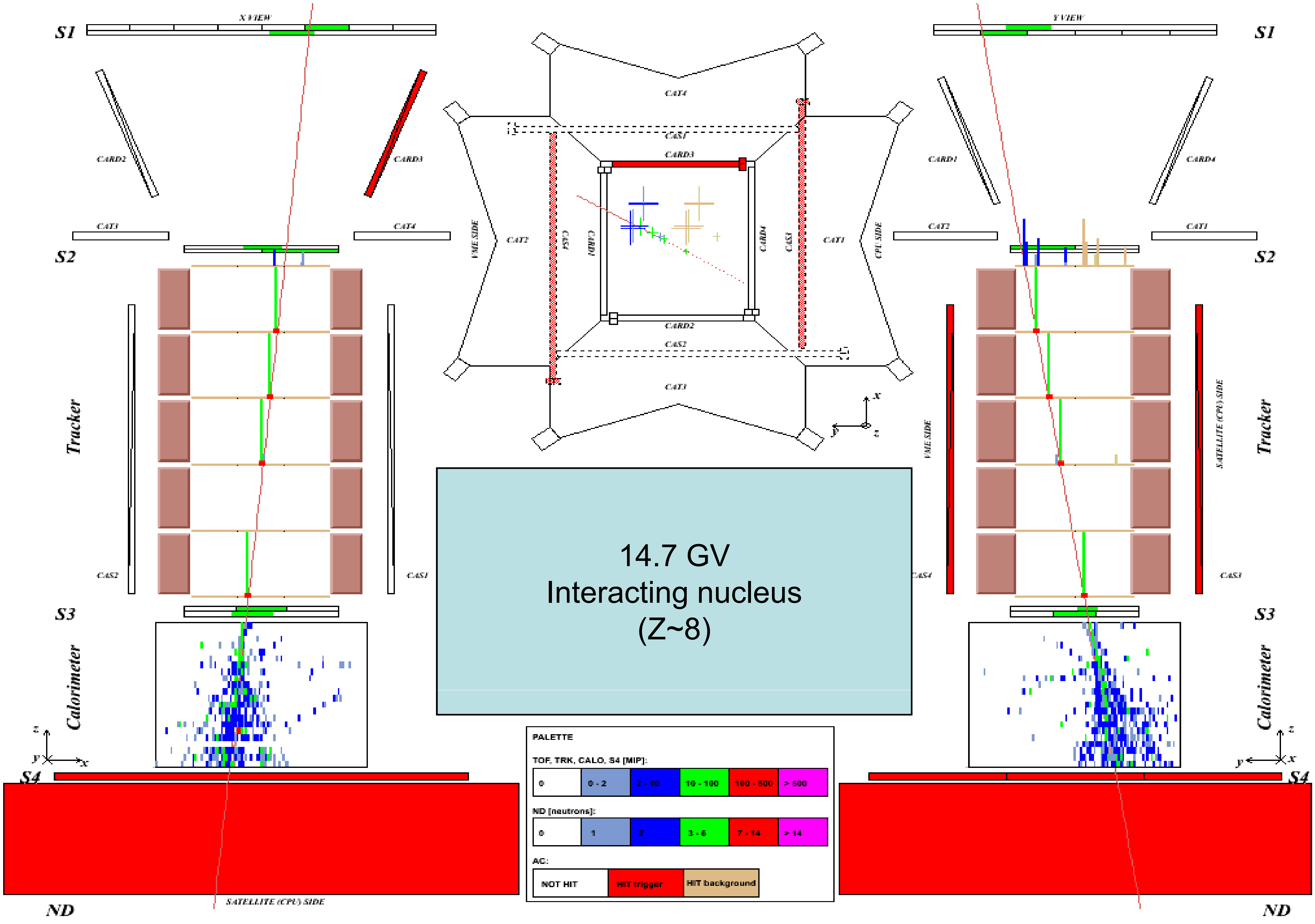
X VIEW
Y VIEW
S1
S2
S3
S4
ND
Tracker
Calorimeter
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
Flight data: 11.6 GeV/c interacting anti-proton
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background


X VIEW
Y VIEW
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
Flight data: 9.7 GV
non-interacting
Helium Nucleus
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

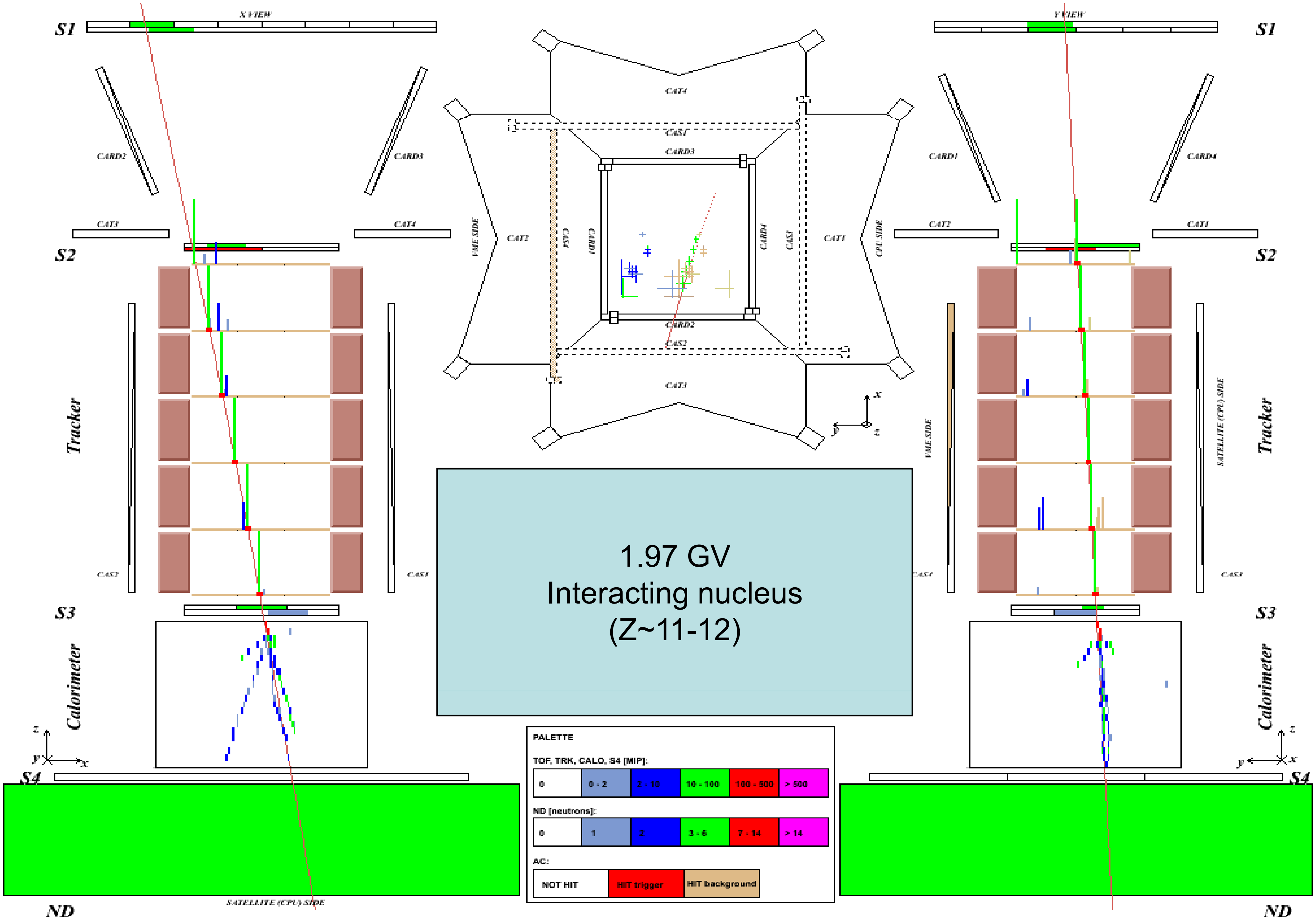
Flight data: 13 GV Interacting Helium Nucleus

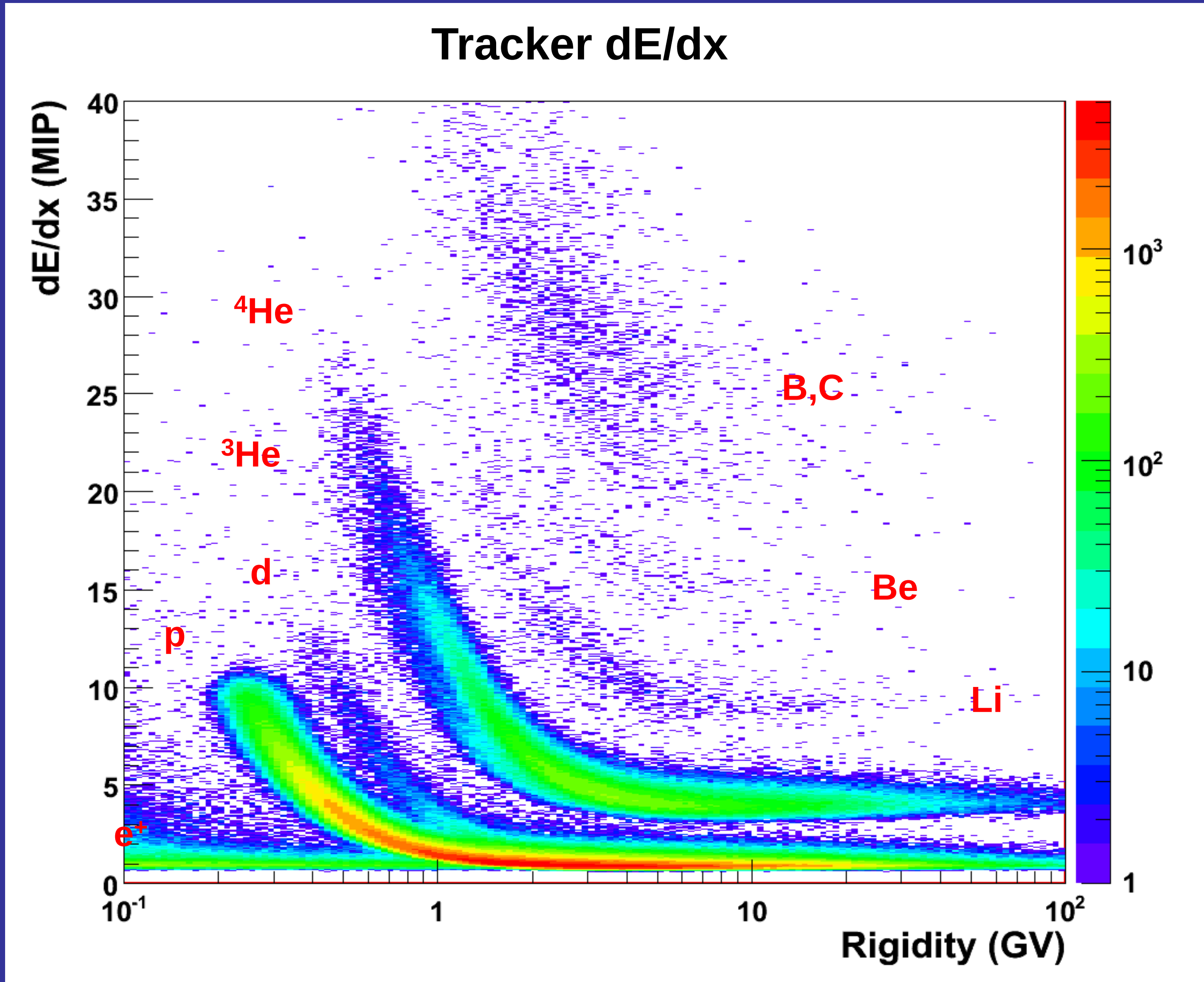



Flight data: 5.7 GV
non-interacting
Carbon Nucleus
S1
S2
S3
S4
ND
Tracker
Calorimeter
X VIEW
Y VIEW
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background
SATELLITE (CPU) SIDE

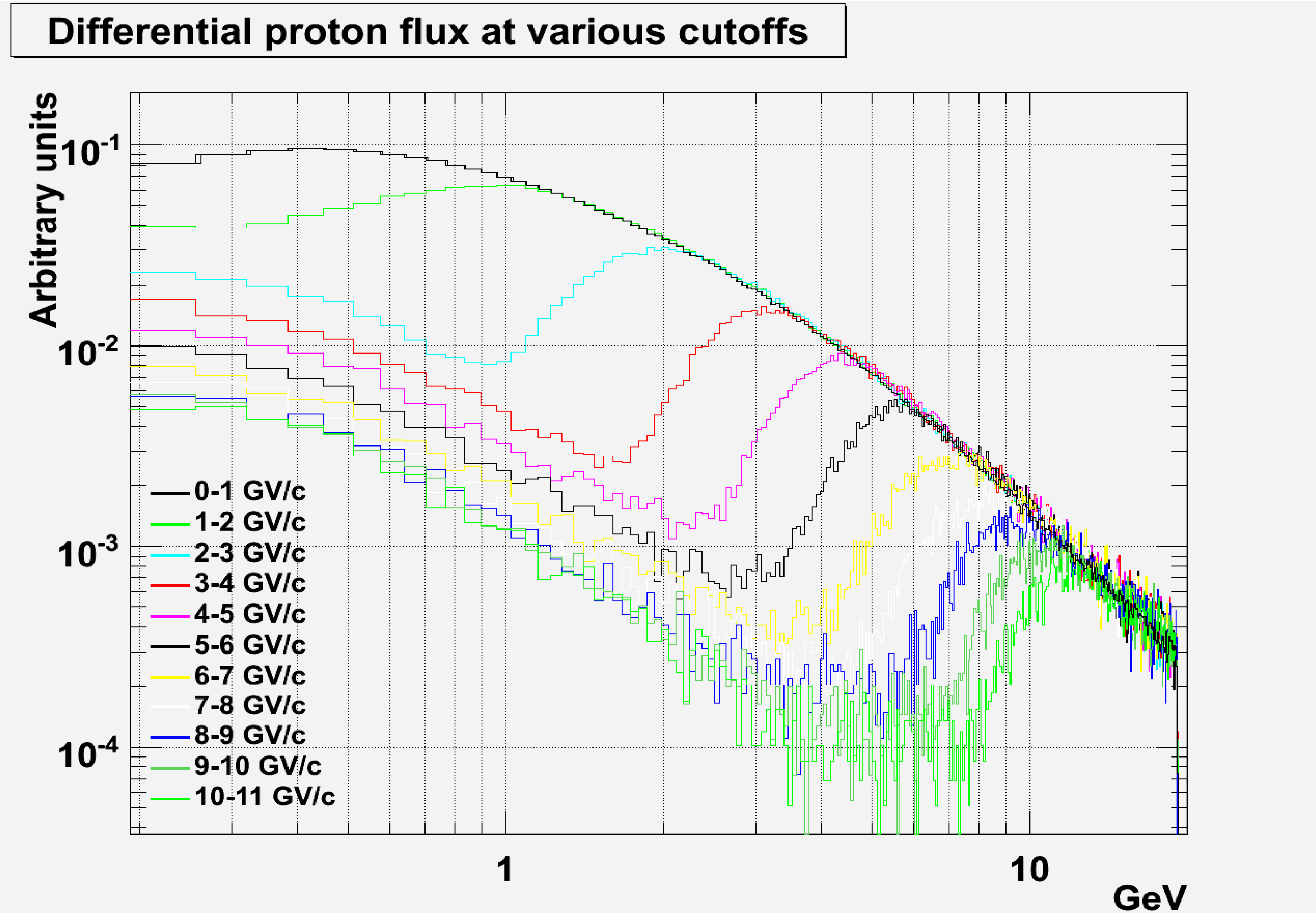


14.7 GV
Interacting nucleus
(Z~8)
X VIEW
Y VIEW
S1
S2
S3
S4
ND
Tracker
Calorimeter
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background


S1
X VIEW
Y VIEW
S2
S3
S4
ND
Tracker
Calorimeter
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
1.97 GV
Interacting nucleus
(Z~11-12)
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



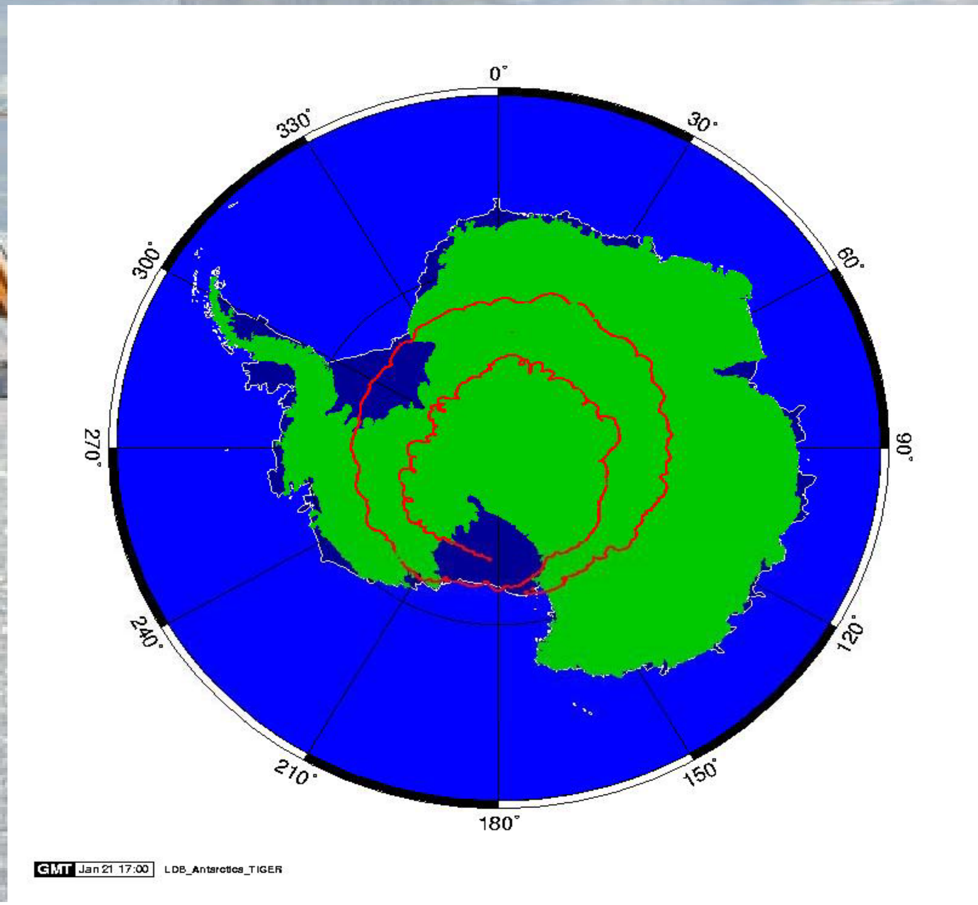
Tracker dE/dx
dE/dx (MIP)
40
35
30
25
20
15
10
5
0
4He
3He
d
p
e+
B,C
Be
Li
10-1
1
10
102
Rigidity (GV)
103
102
10
1

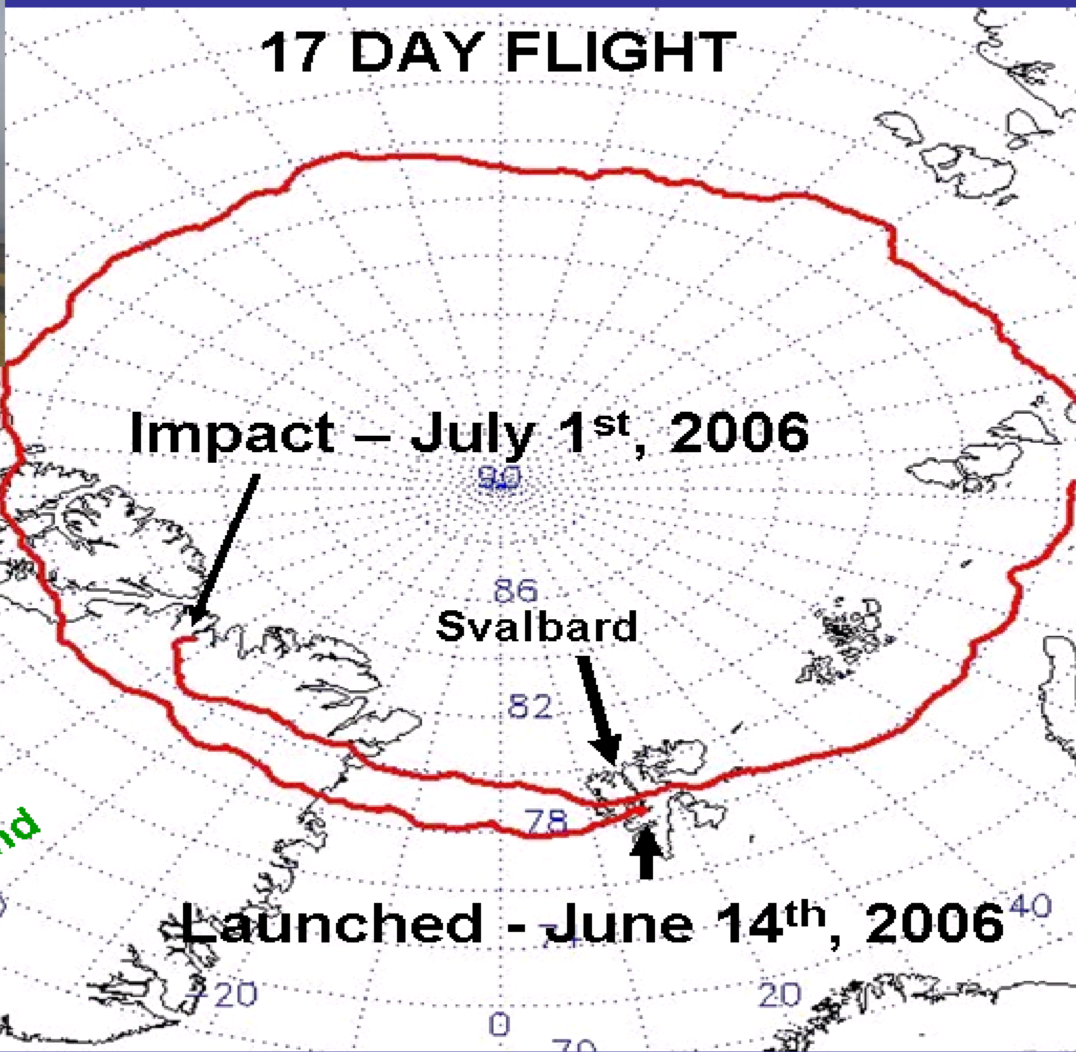


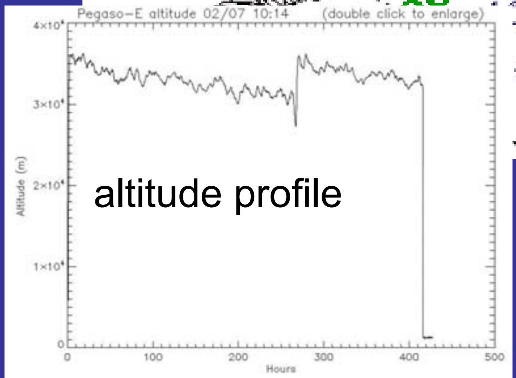
Differential proton flux at various cutoffs
Arbitrary units
10^-1
10^-2
10^-3
10^-4
1
10
GeV
0-1 GV/c
1-2 GV/c
2-3 GV/c
3-4 GV/c
4-5 GV/c
5-6 GV/c
6-7 GV/c
7-8 GV/c
8-9 GV/c
9-10 GV/c
10-11 GV/c

CREAM

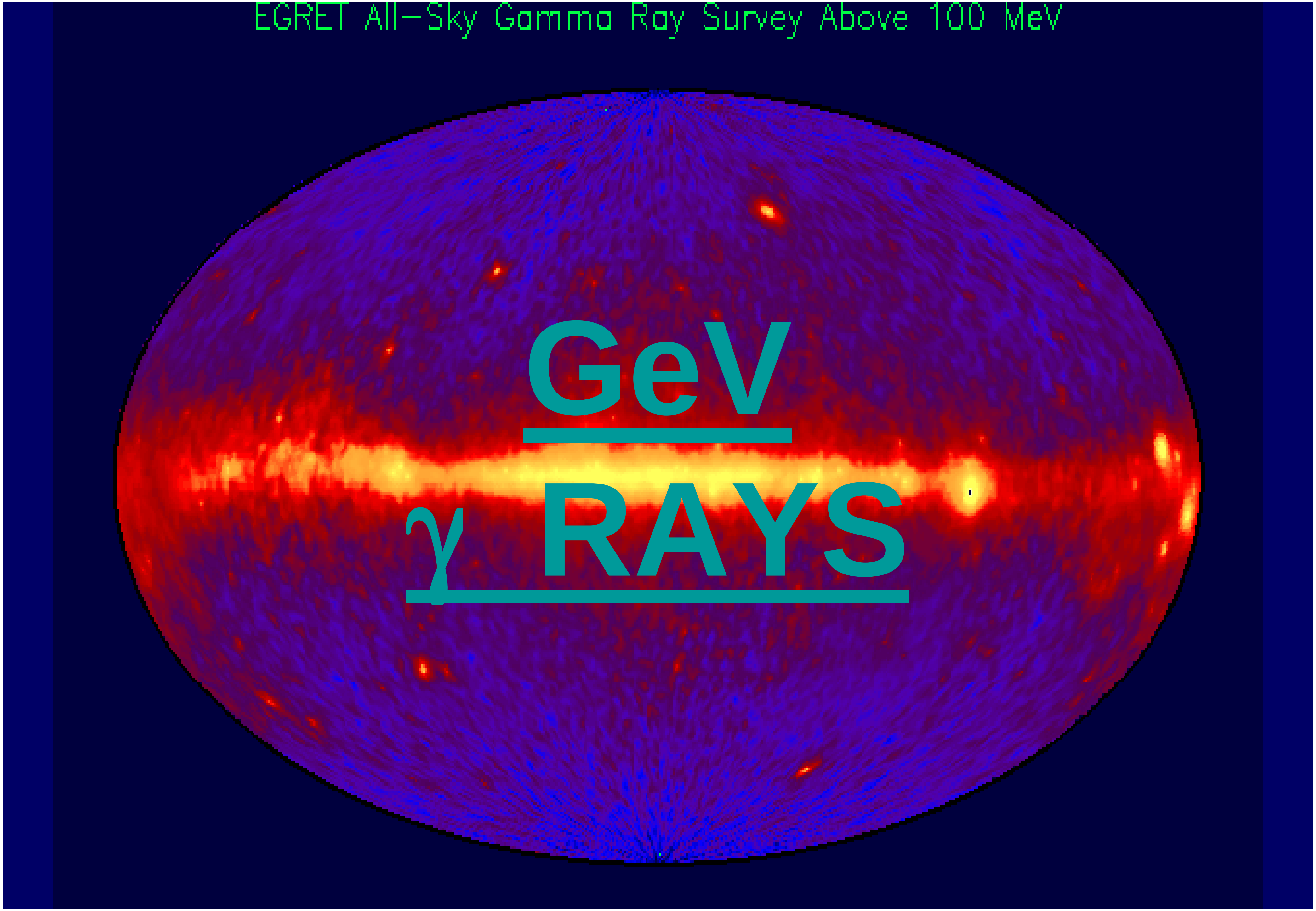
Record long duration antartica flight 47 days







High-altitude (~40km), long-duration (~20 days) balloon flights from Svalbard balloonport
Interesting alternative to space, allows recalibration of experiment and multiple journeys


EGRET All-Sky Gamma Ray Survey Above 100 MeV
GeV
γ RAYS


TeV
γ RAYS

The study of

The very large (Cosmology)

and

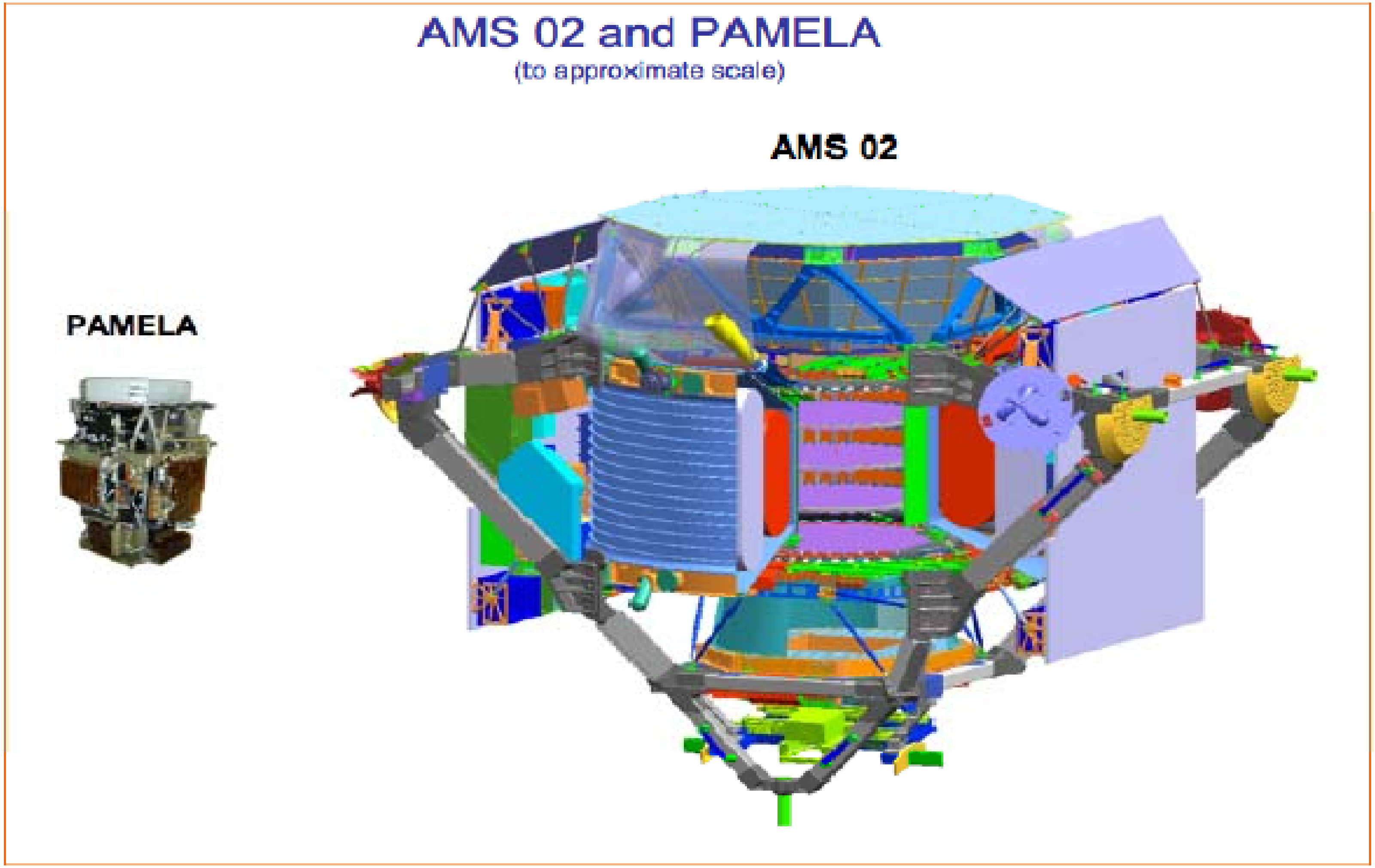
The Very Small (Elementary Particles)

is

COMING TOGETHER

David N. Schramm

….. and much of the data
which is bringing them together
<u>are</u> coming and <u>will</u> come
from the study of different
form of cosmic radiations with
increasingly high accuracy !


AMS 02 and PAMELA
(to approximate scale)
AMS 02
PAMELA

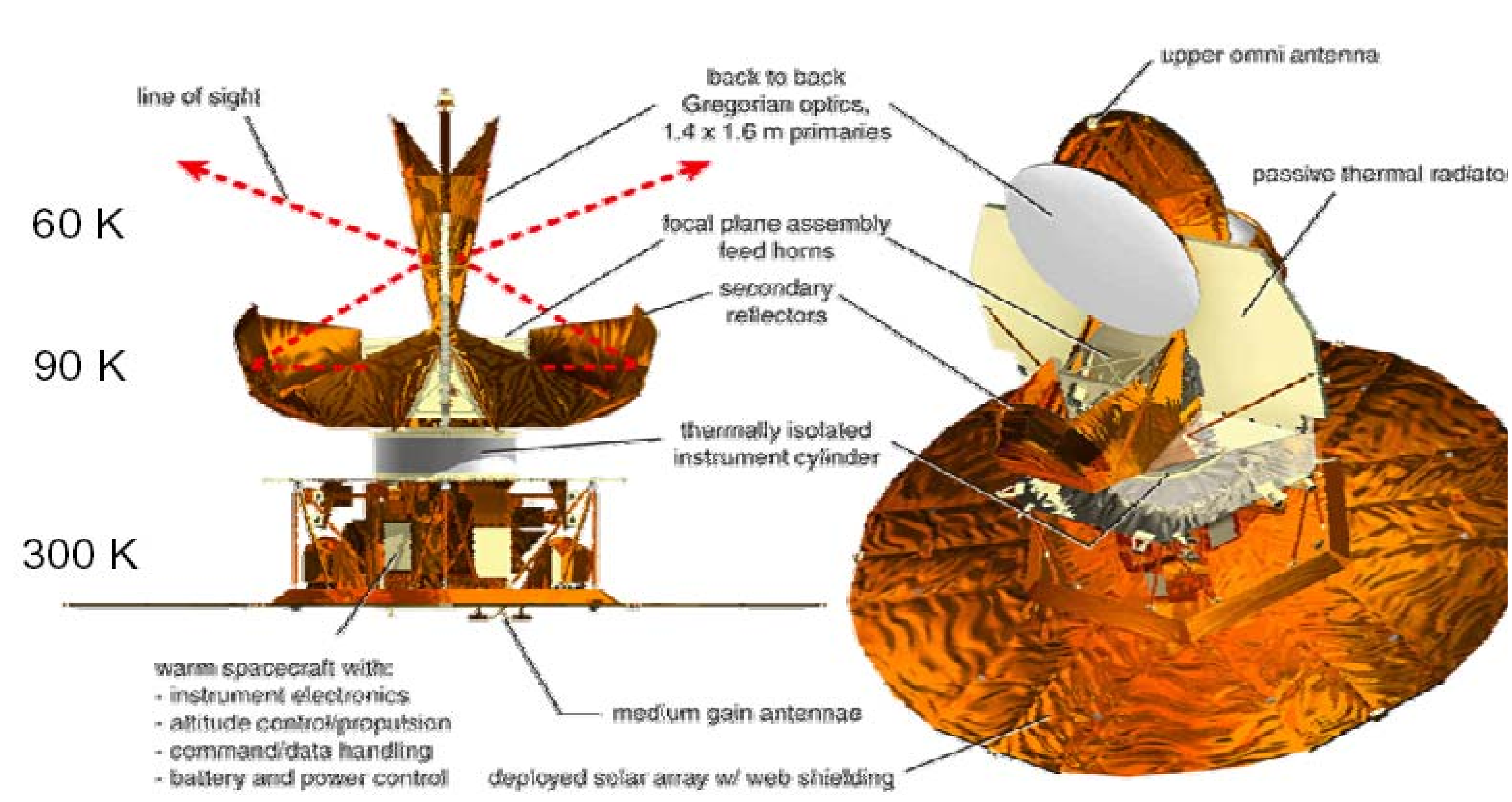
Positrons

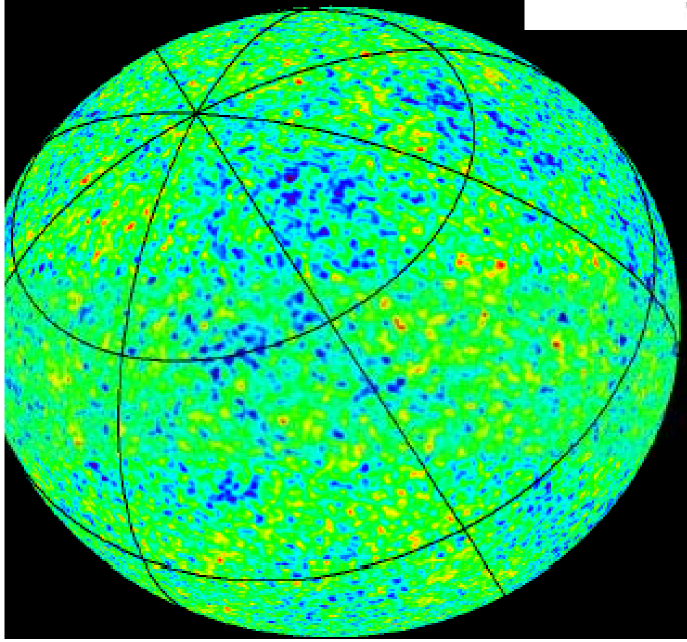
Parameters	PAMELA	AMS-02
Geom Acceptance	20.5 cm^2sr	950 cm^2sr
Max e^+ Energy	270 GeV	450 GeV
e^+ Events Per Year	100,000	2,700,000
e^+ Events at 90% Efficiency >100 GeV 3 Years >200 GeV 3 Years	 18 4	 800 200
p Rejection at 10 GeV	60,000	1,500,000
p Contamination in e^+ sample at 10 GeV	4-5 %	<0.2 %

AntiProtons

Parameters	PAMELA	AMS-02
Geom Acceptance	20.5 cm^2sr	4500 cm^2sr
Max $\bar{p}$ Energy	190 GeV	450 GeV
$\bar{p}$ Events Per Year	10,000	200,000
$\bar{p}$ Events at 90% Efficiency		
>100 GeV 3 Years	25	4500
>200 GeV 3 Years	0	1500
p Rejection at 10 GeV	>10,000	>10,000
e^- Contamination in $\bar{p}$ sample at 10 GeV	<1 %	<1 %

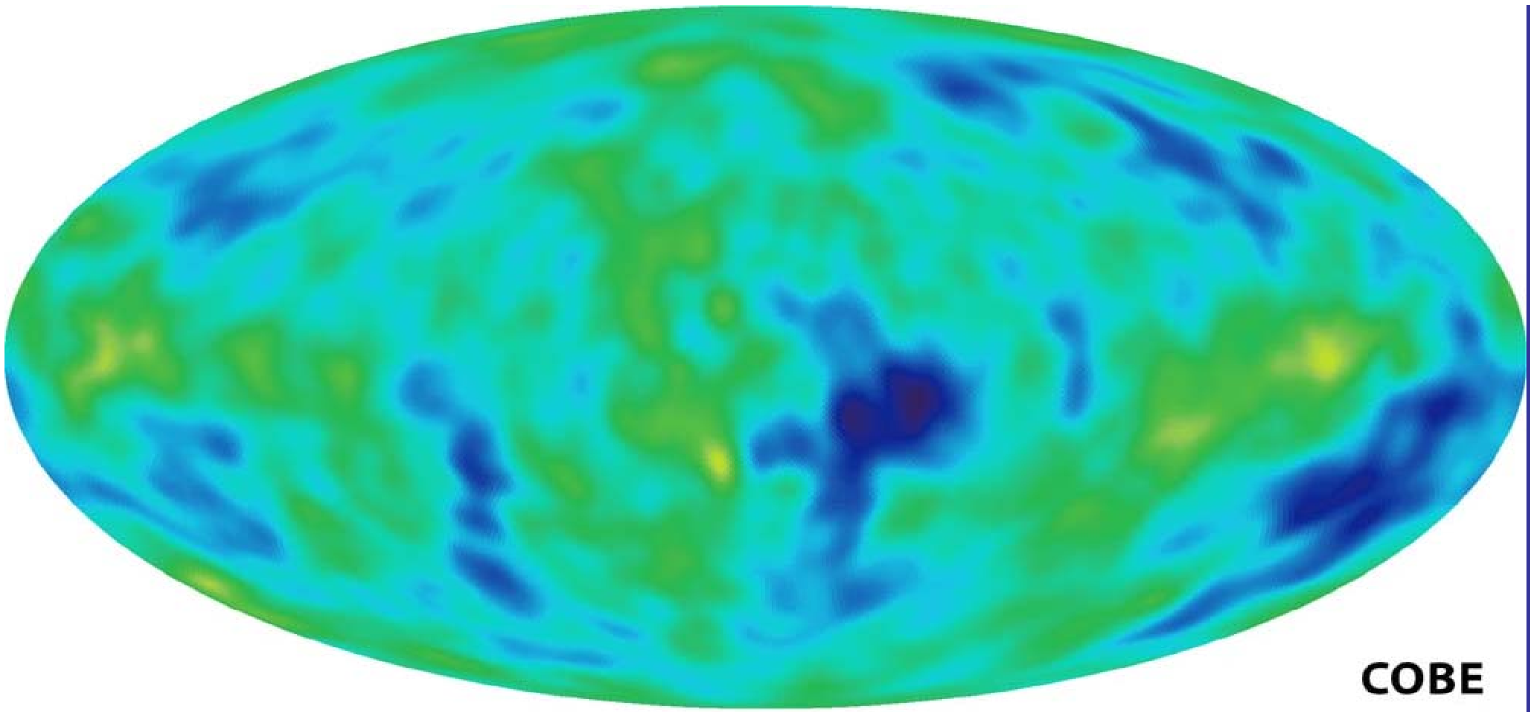
WMAP

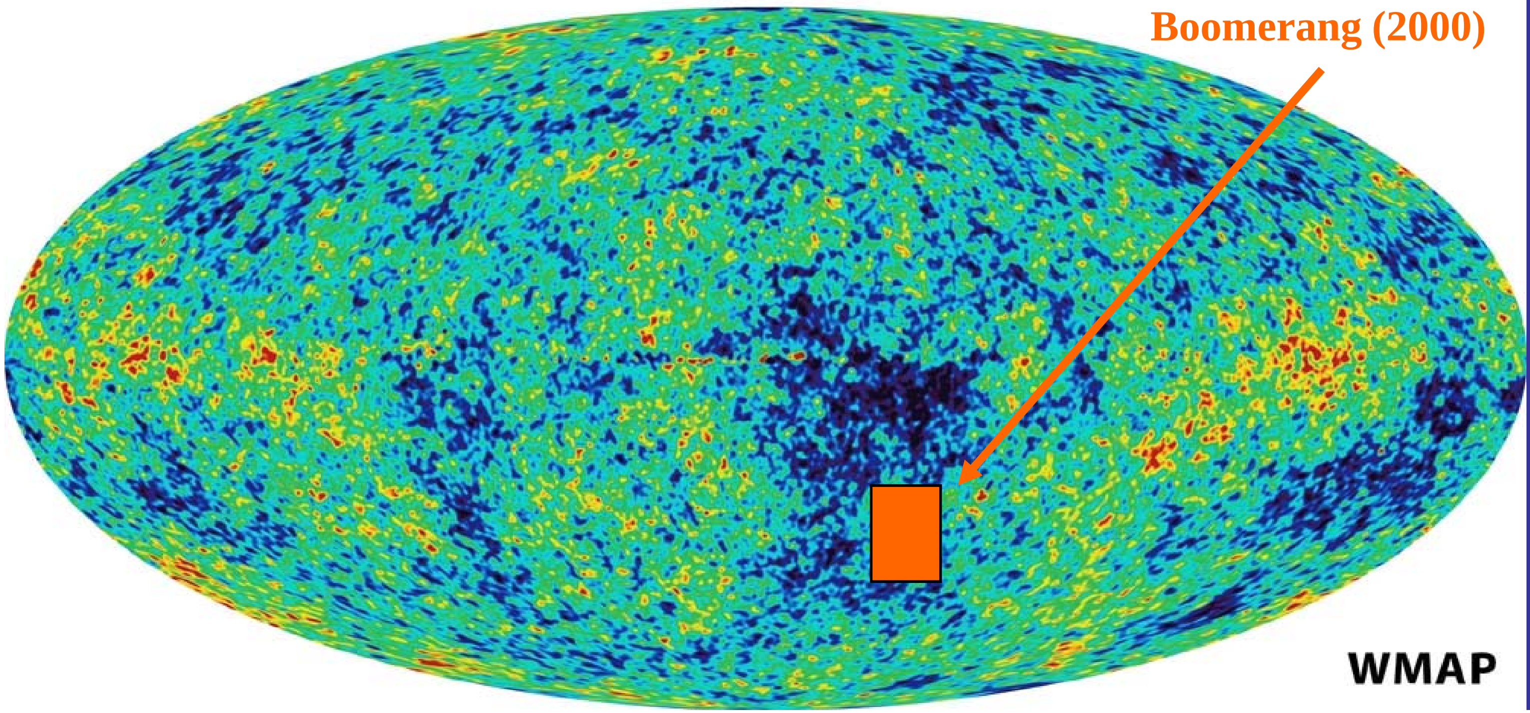




Wilkinson Microwave Anisotropy Probe

- ***Systematics controlled with extreme accuracy***
- ***Differential radiometers, L2 orbit, passive cooling, complex scan pattern***
- ***Design goal with 4 μK on systematic error reached***
- ***No systematic corrections needed in data analysis***

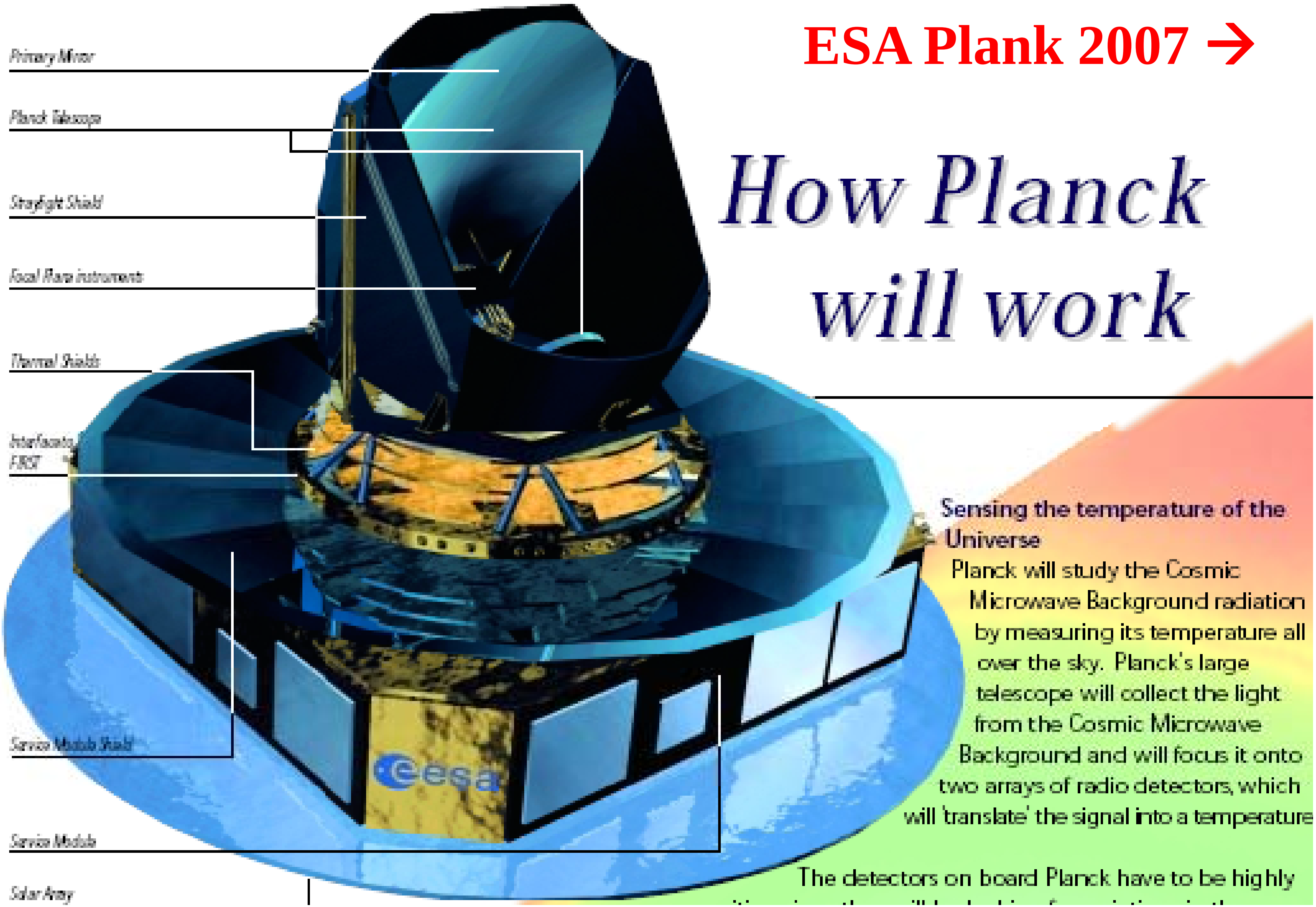




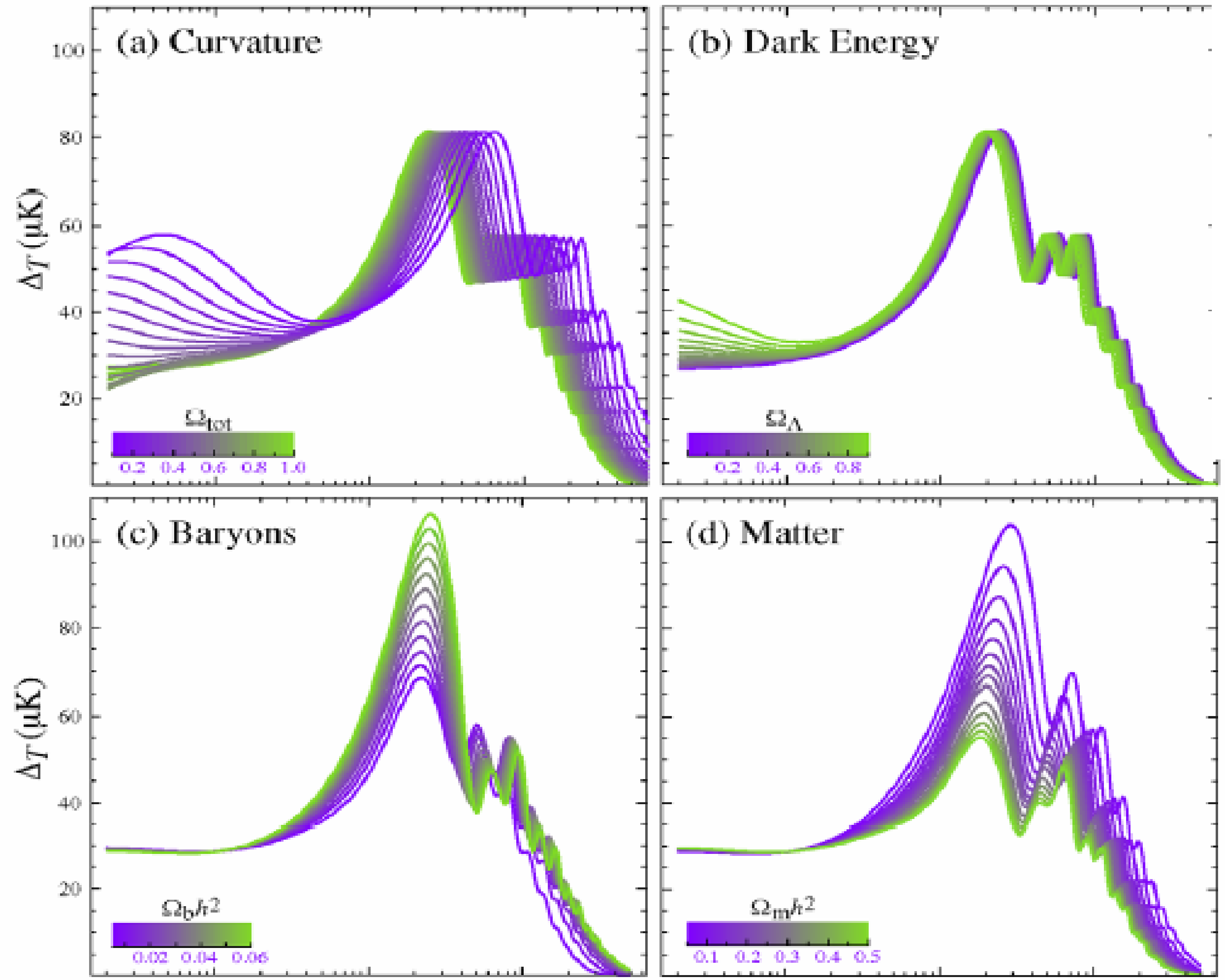
COBE
(1992)
7°

WMAP
(2003)
10’

ESA Plank 2007 →

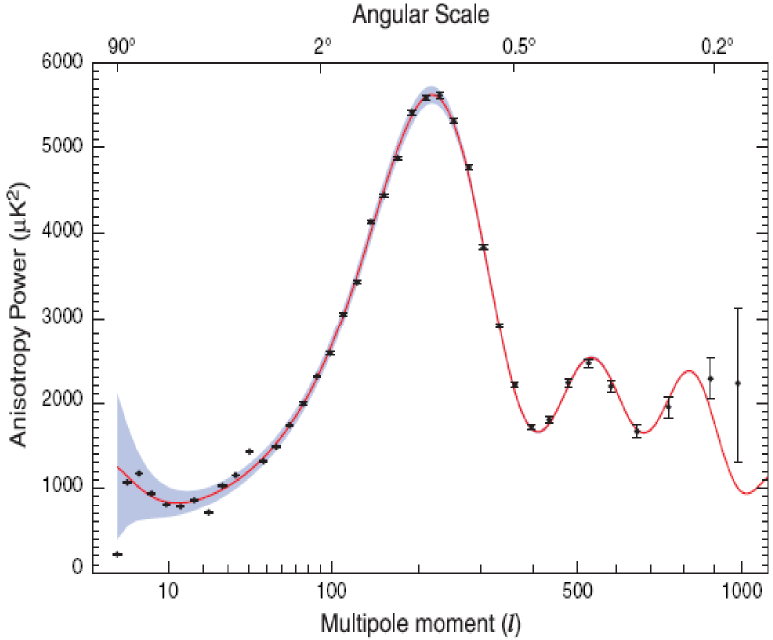


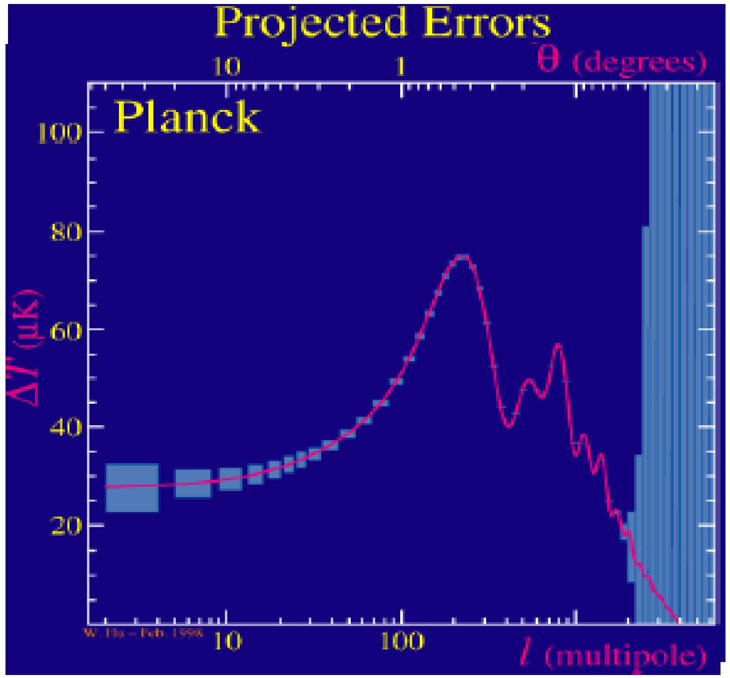
See Wayne Hu's WWW-page: http://background.uchicago.edu/~whu/



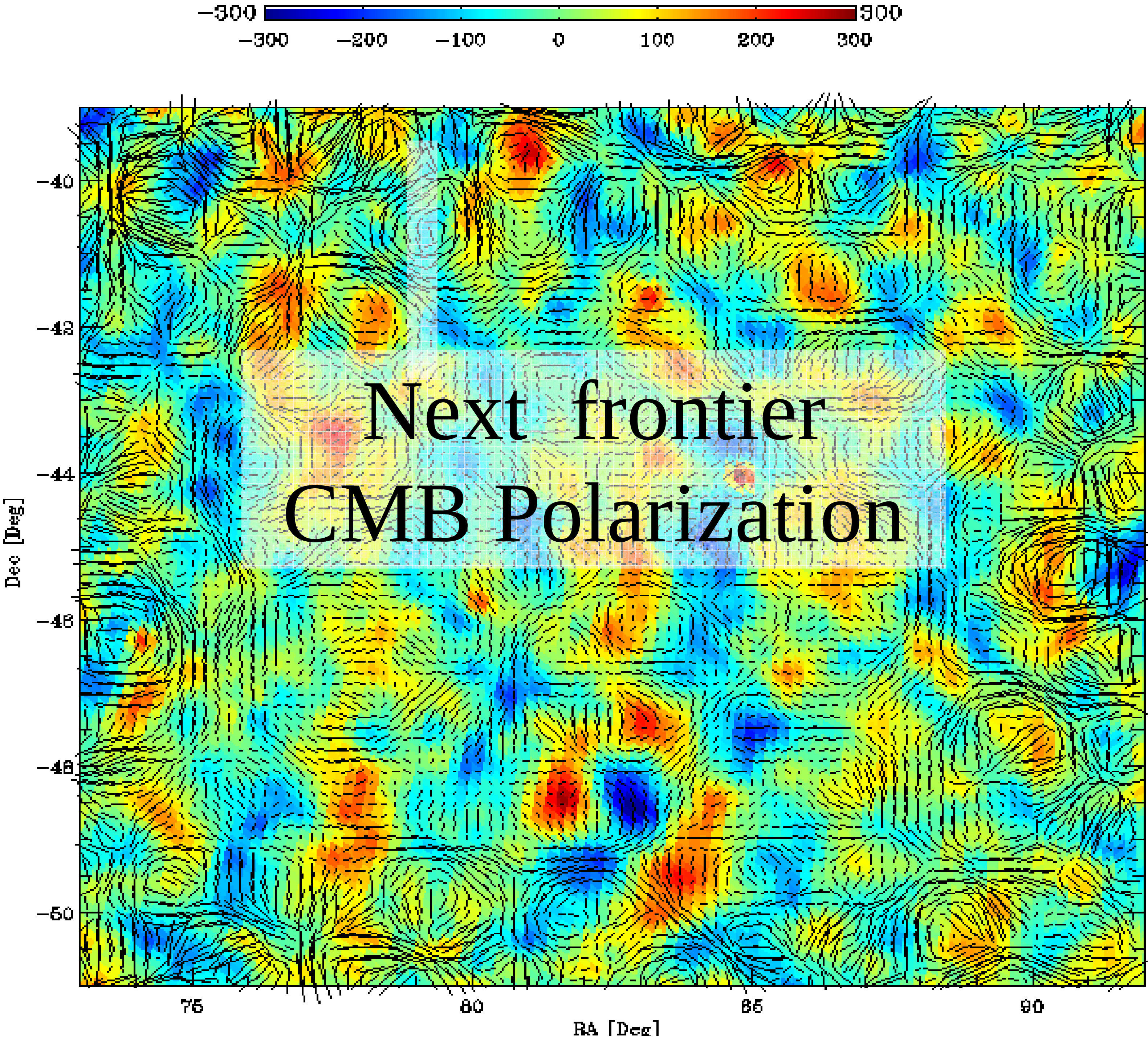
$$\Omega_{tot} = 1,\ \Omega_\Lambda = 0.65,\ \Omega_b h^2 = 0.02,\ \Omega_m h^2 = 0.147$$

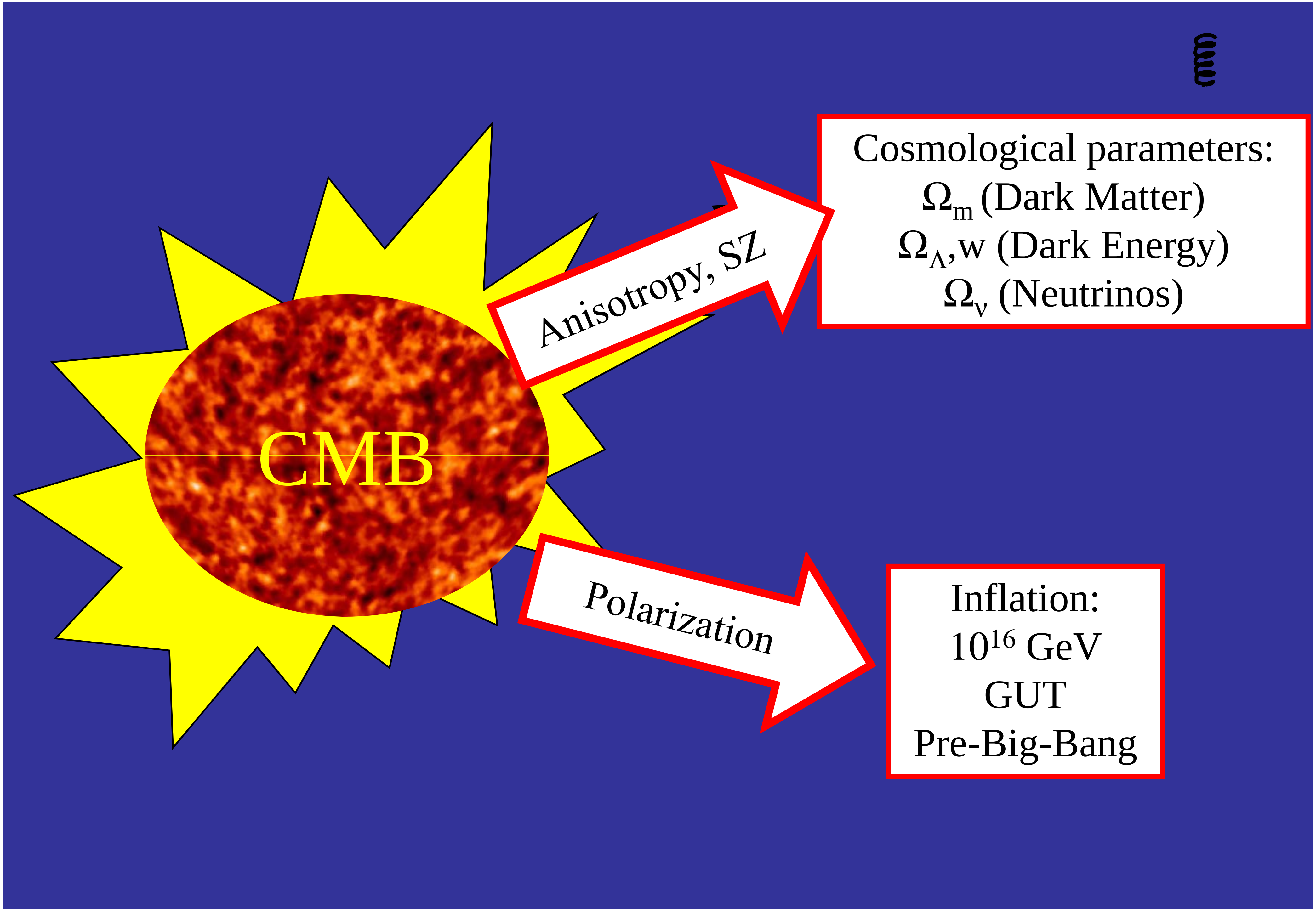
$$H_0 = 100\ h\ km/s/Mpc$$



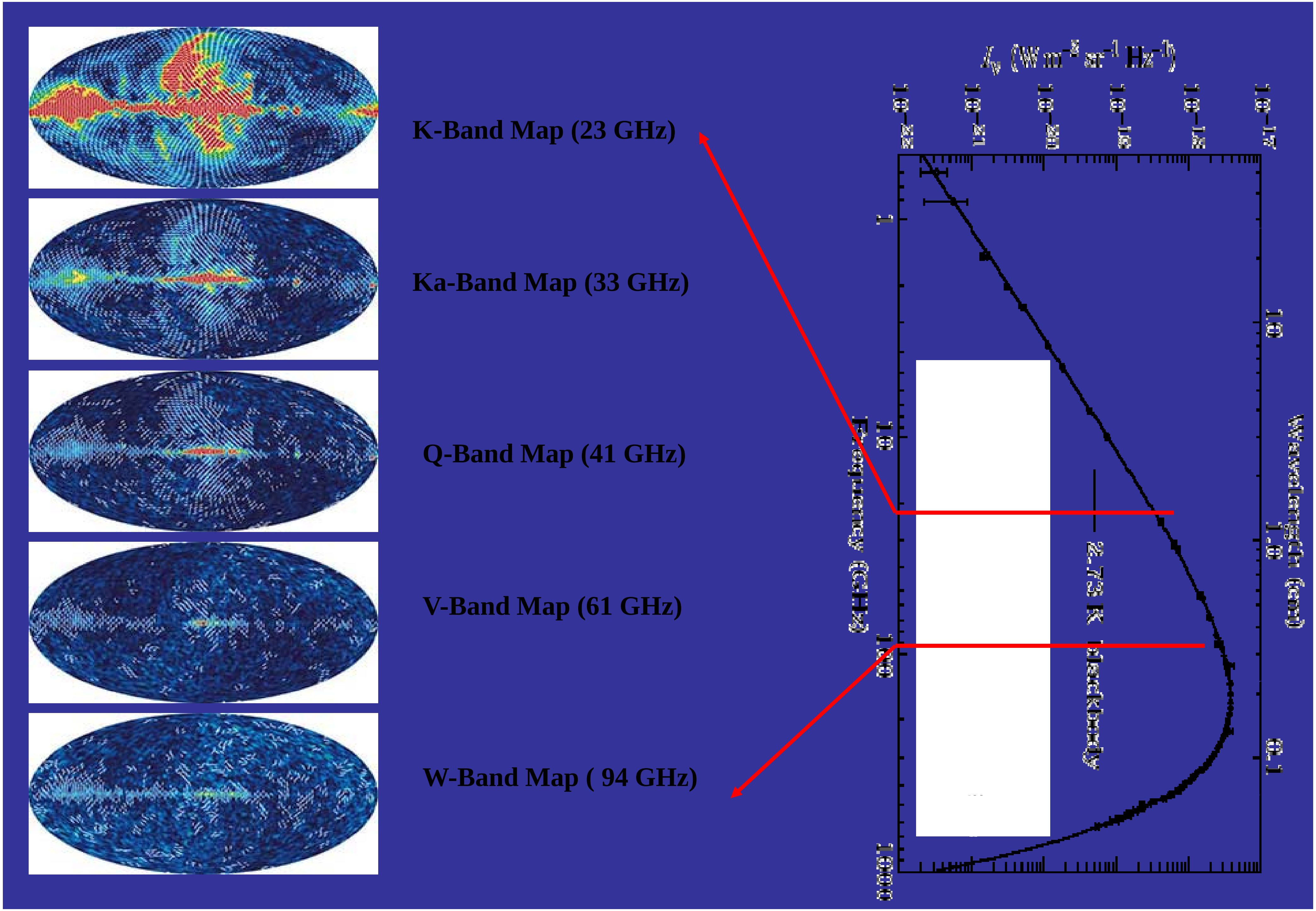


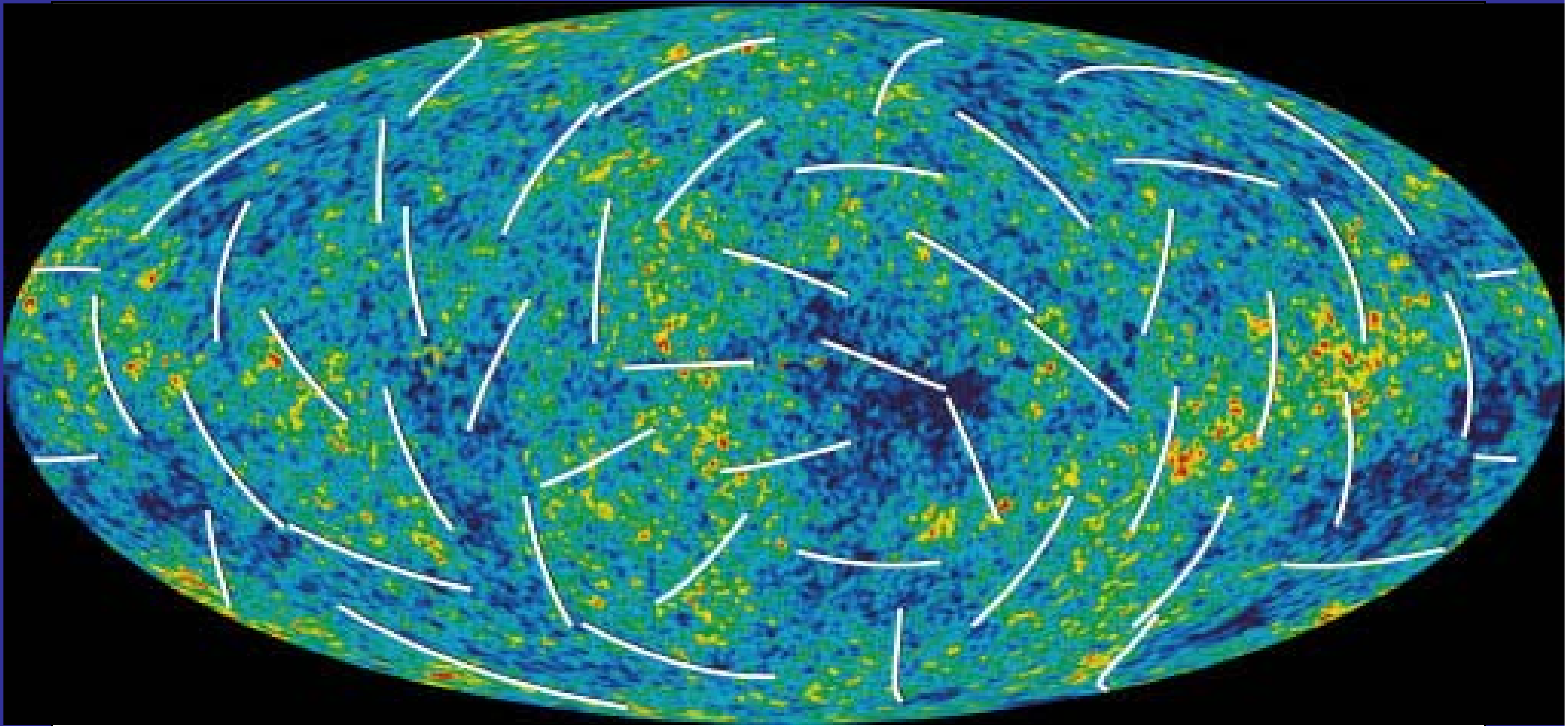
Next frontier
CMB Polarization



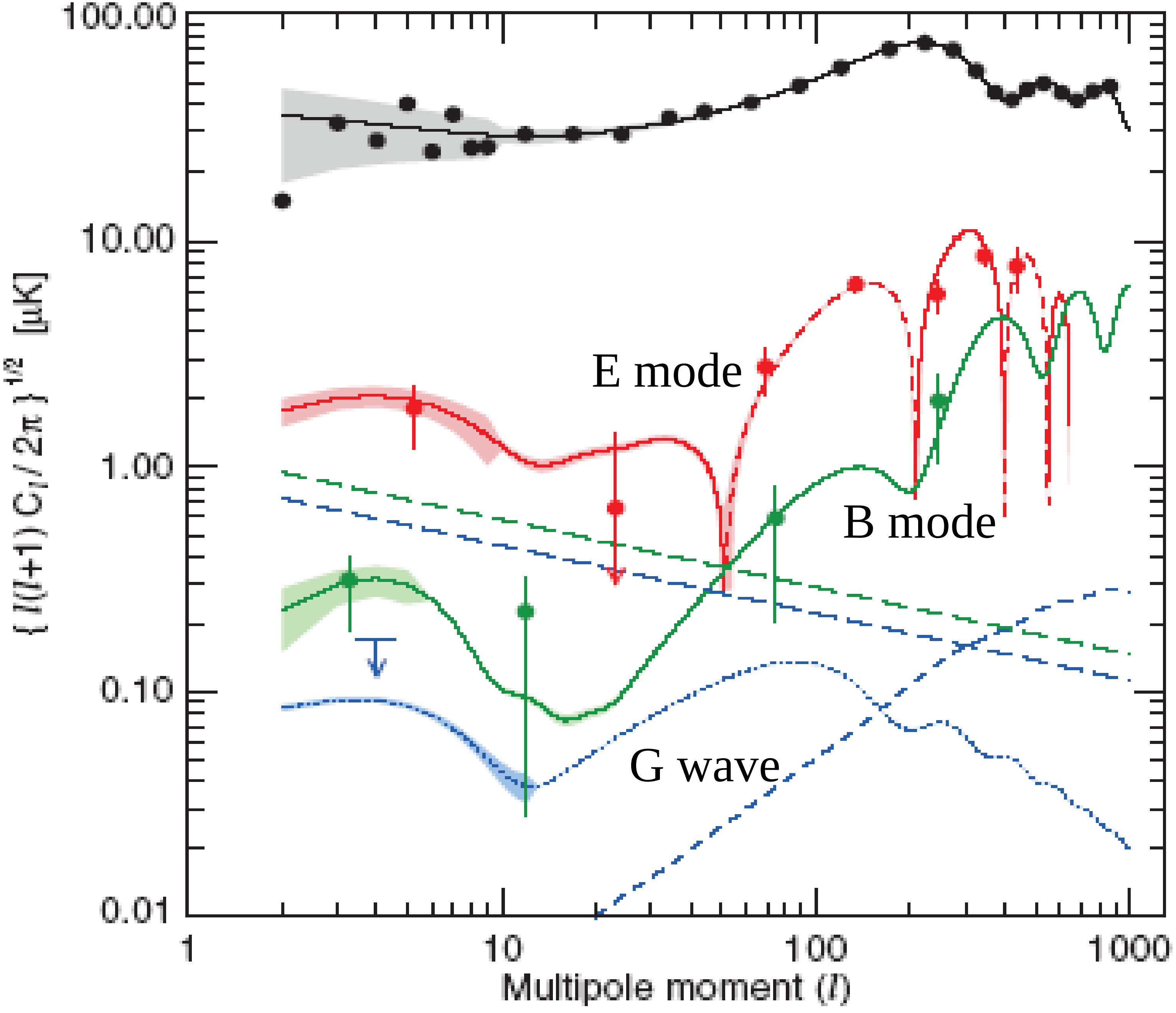


CMB
Anisotropy, SZ
Polarization
Cosmological parameters:
Ω_m (Dark Matter)
Ω_Λ,w (Dark Energy)
Ω_ν (Neutrinos)
Inflation:
10^{16} GeV
GUT
Pre-Big-Bang

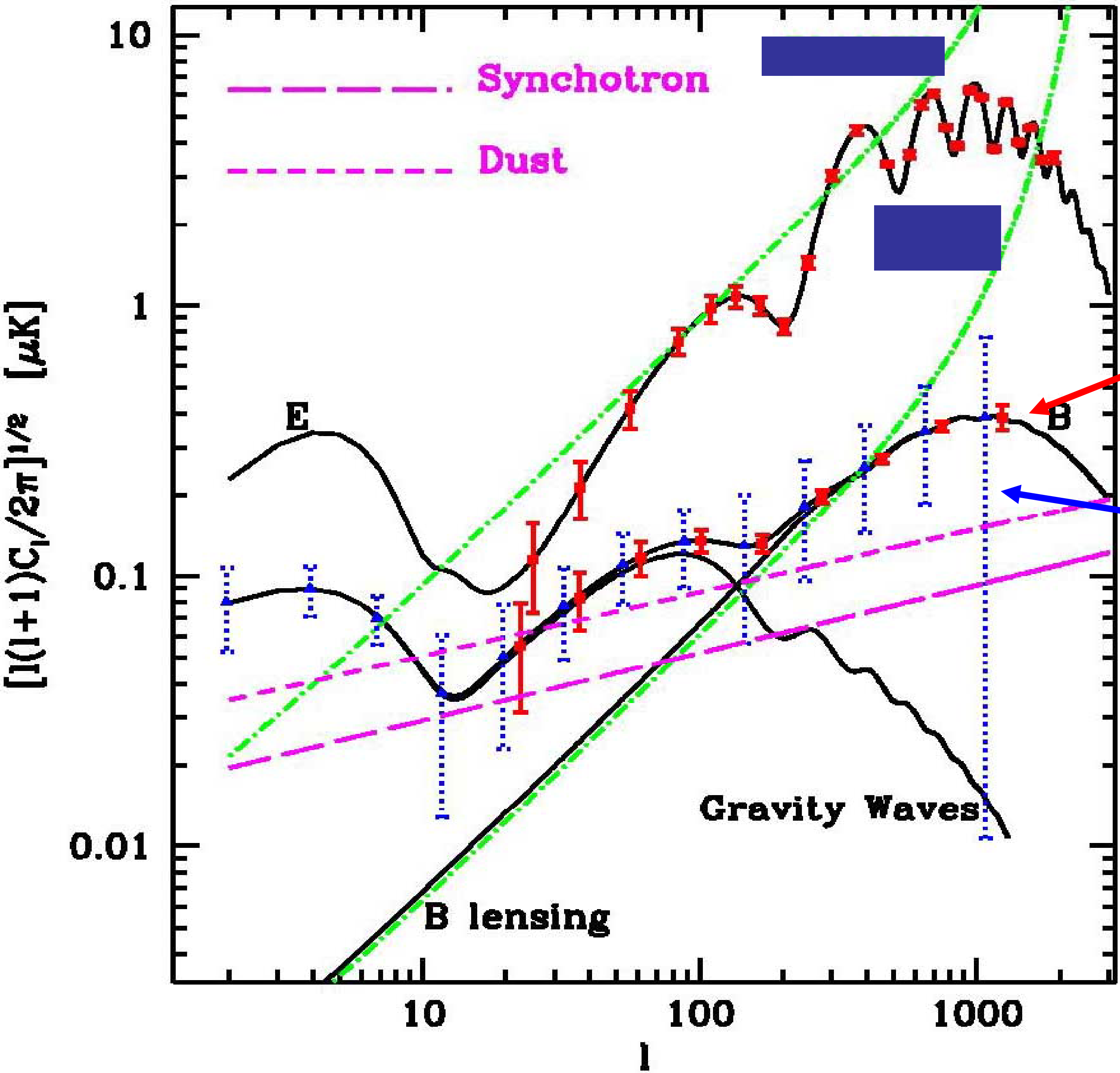

K-Band Map (23 GHz)
Ka-Band Map (33 GHz)
Q-Band Map (41 GHz)
V-Band Map (61 GHz)
W-Band Map (94 GHz)
Wavelength (cm)
Frequency (GHz)
2.73 K blackbody



“For the first time we look at brightness patterns from inflation and know it's from inflation and not from the first stars“ WMAP PI 2006 C. Bennett

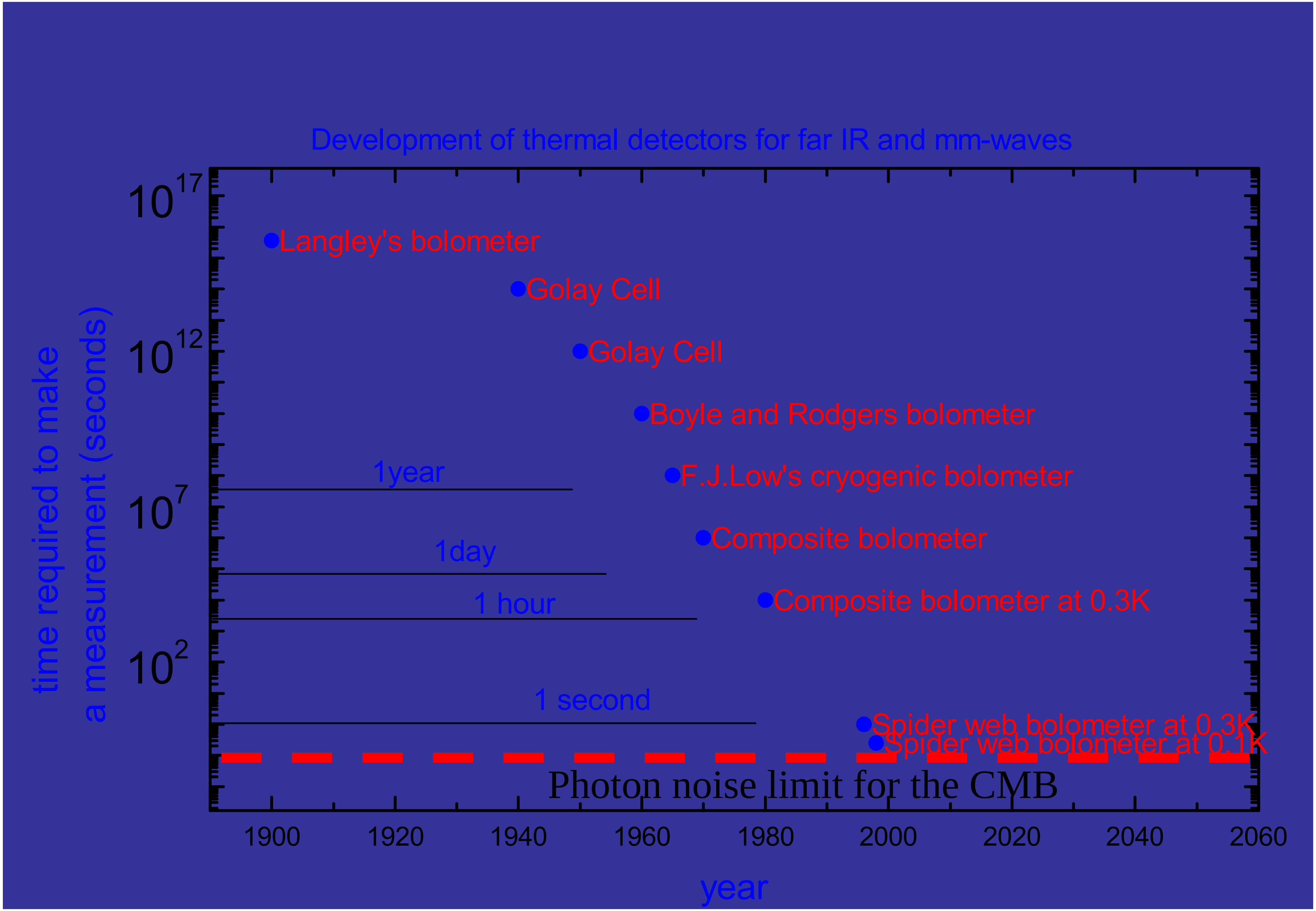


100.00
10.00
1.00
0.10
0.01
{ l(l+1) C_l / 2π }^{1/2} [μK]
1
10
100
1000
Multipole moment (l)
E mode
B mode
G wave



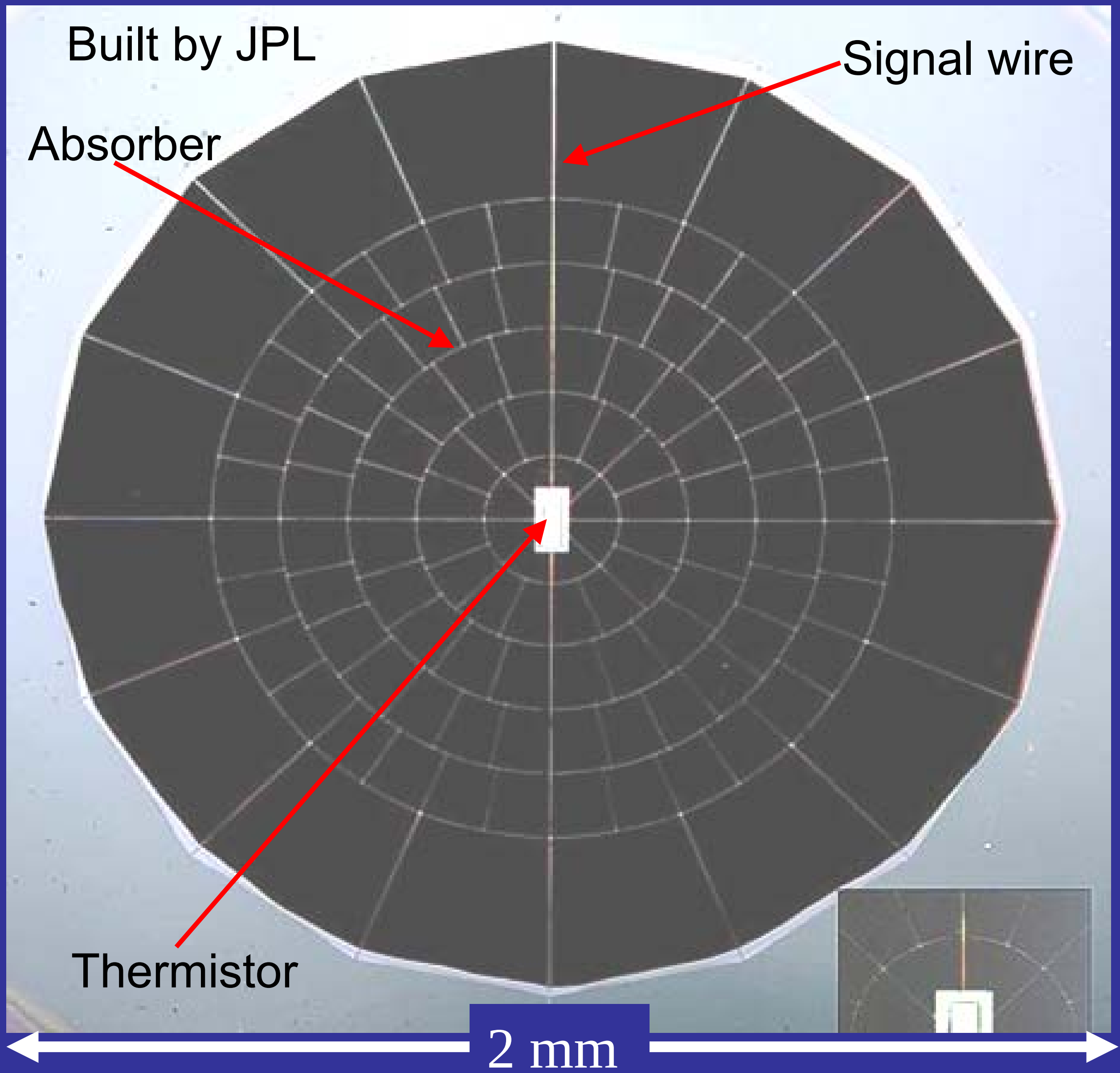
Bolom.
Array

From the
EBEX
(balloon)
proposal

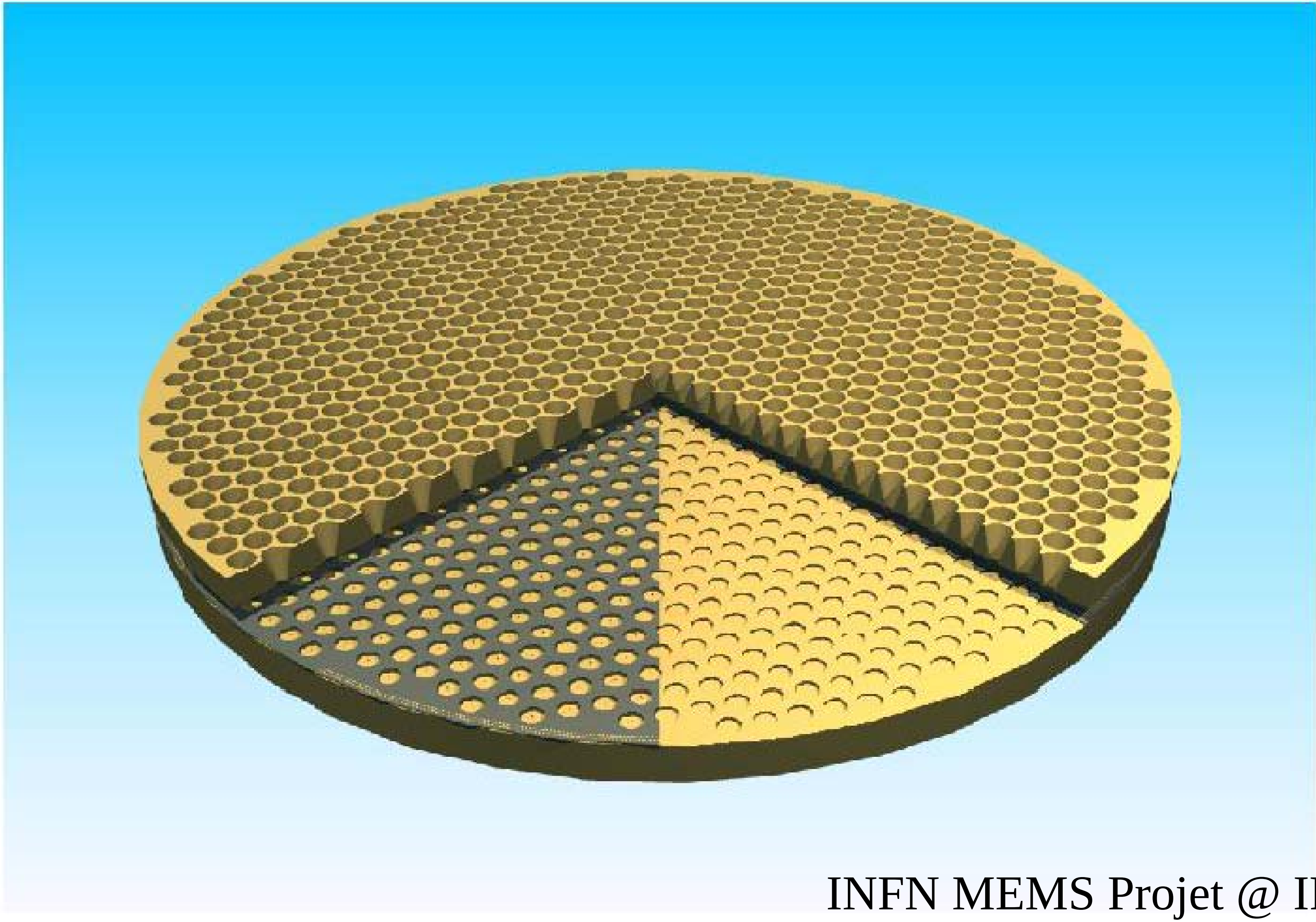

Development of thermal detectors for far IR and mm-waves
time required to make
a measurement (seconds)
10^{17}
10^{12}
10^{7}
10^{2}
Langley's bolometer
Golay Cell
Golay Cell
Boyle and Rodgers bolometer
F.J.Low's cryogenic bolometer
Composite bolometer
Composite bolometer at 0.3K
Spider web bolometer at 0.3K
Spider web bolometer at 0.1K
1year
1day
1 hour
1 second
Photon noise limit for the CMB
1900
1920
1940
1960
1980
2000
2020
2040
2060
year

Spider-Web Bolometers

- The absorber is micro machined as a web of metallized Si_3N_4 wires, 2 μm thick, with 0.1 mm pitch.
- This is a good absorber for mm-wave photons and features a very low cross section for cosmic rays. Also, the heat capacity is reduced by a large factor with respect to the solid absorber.
- NEP ~ 2 10^{-17} W/$Hz^{0.5}$ is achieved @0.3K
- 150μK_{CMB} in 1 s
- Mauskopf *et al.* Appl.Opt. **36**, 765-771, (1997)

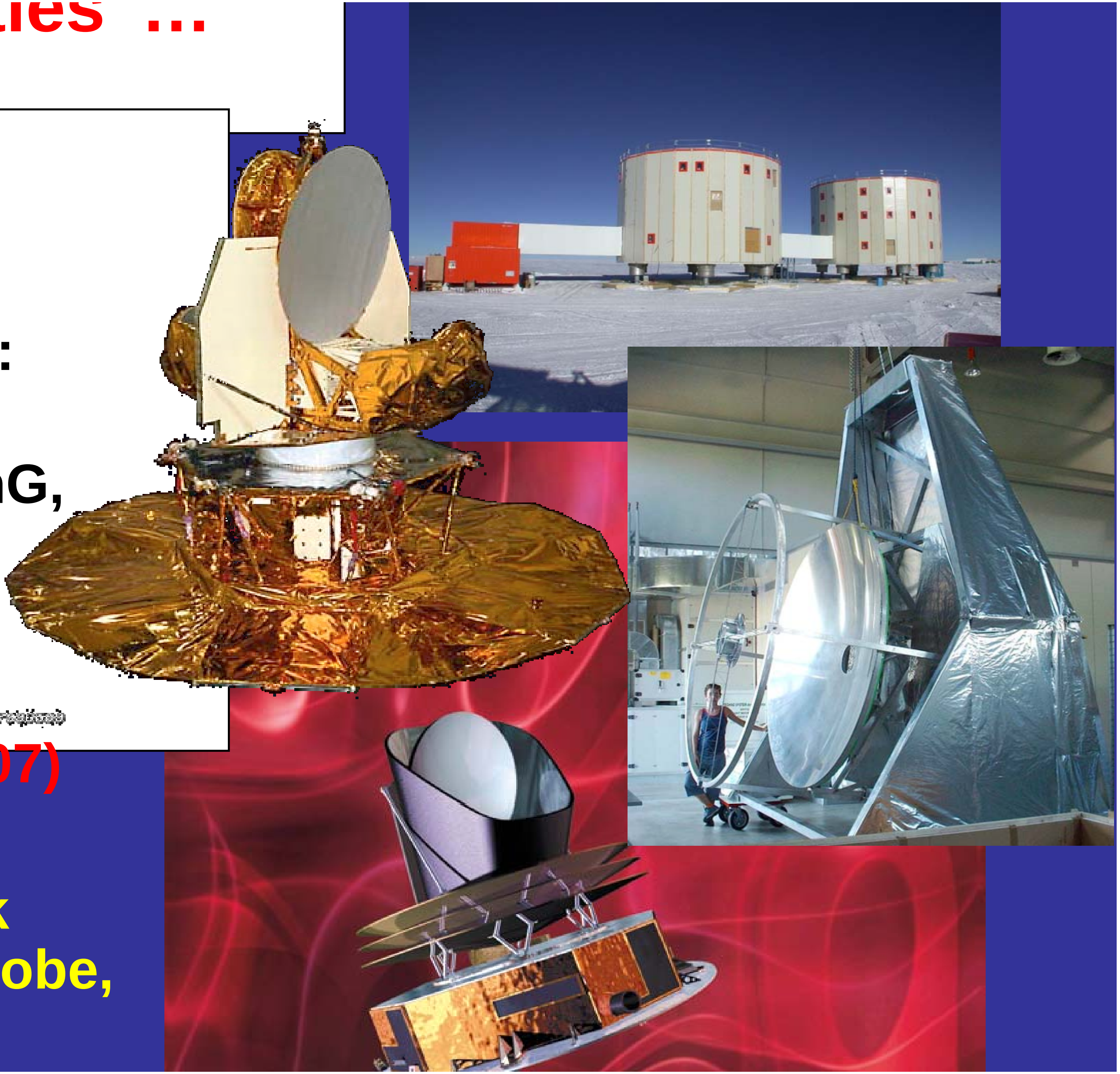


μW-Detector arrays



INFN MEMS Projet @ IRST

CMB facilities …



Stratosphere :

- **Balloons: BOOMERanG, OLIMPO….**

Space :

- **WMAP**
- **Planck (2007)**

Future :

- **Post-Planck (Inflation Probe, BPOL …)**

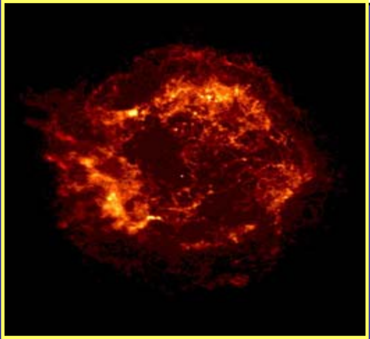
Major IACTs in the world

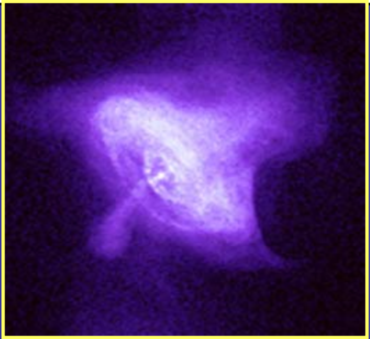
HESS-II and MAGIC-II can be good R&Ds for CTA

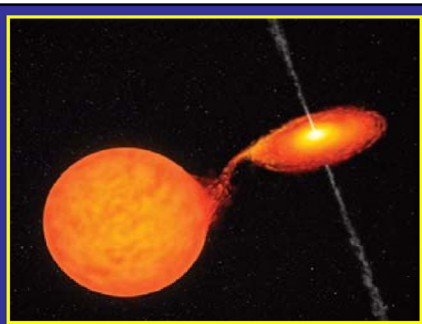
HESS-II
28m diameter telescope
Lower threshold energy
In 2008

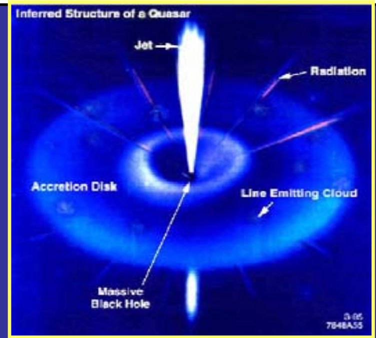
MAGIC-II
2x17m, High Q.E. detectors
Lower threshold energy
High Precision
In 2007

Scientific Objectives


SNRs


Pulsars and PWN


Micro quasars X-ray binaries

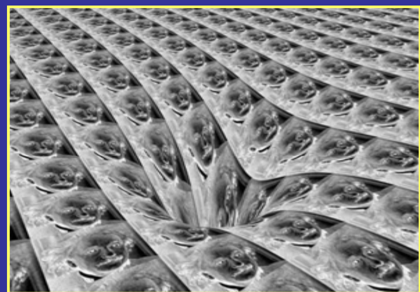


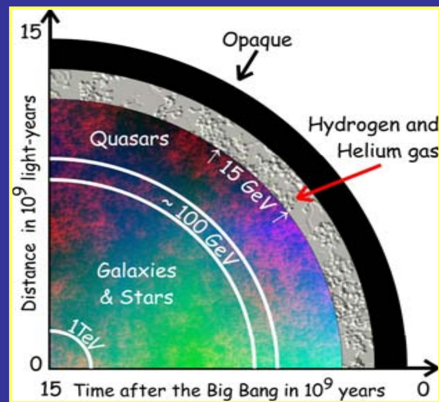
AGNs


GRBs


Origin of cosmic rays

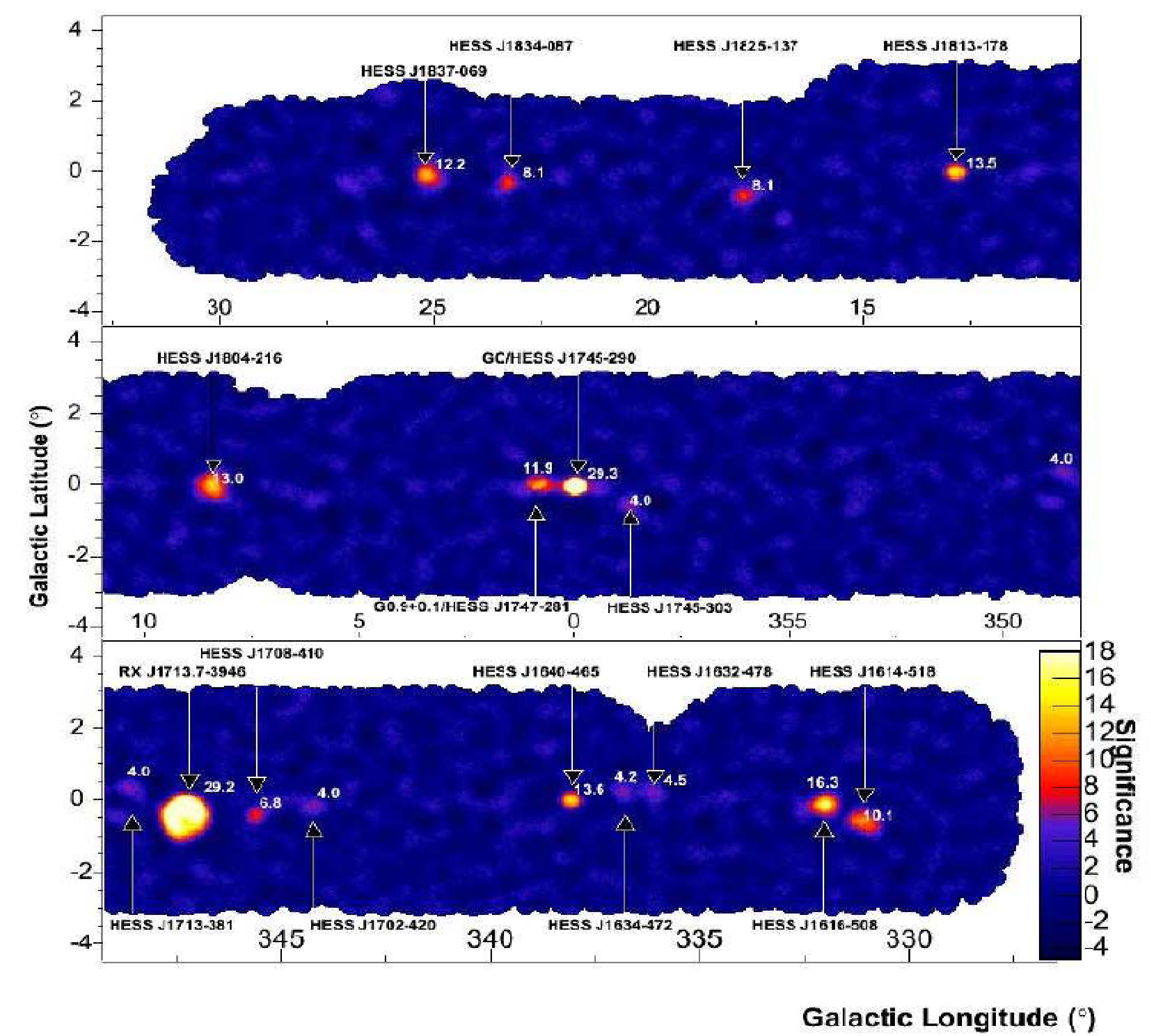
Dark matter


Space-time & relativity



Cosmology

Great success by HESS
Galactic place survey



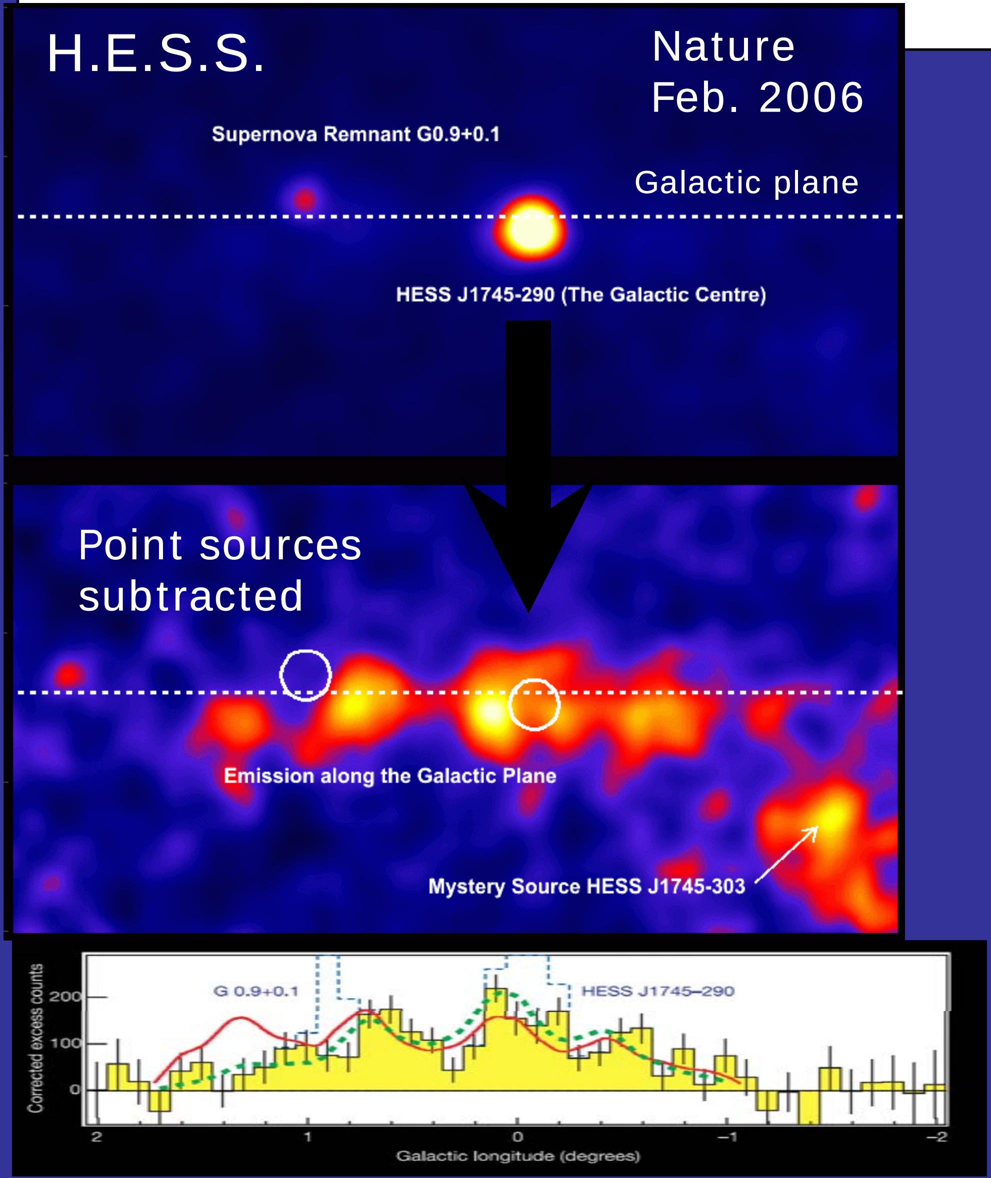
HESS Galactic plane Survey

Survey in 2-3% Crab unit

Astro-ph/0510397
17 sources + Several

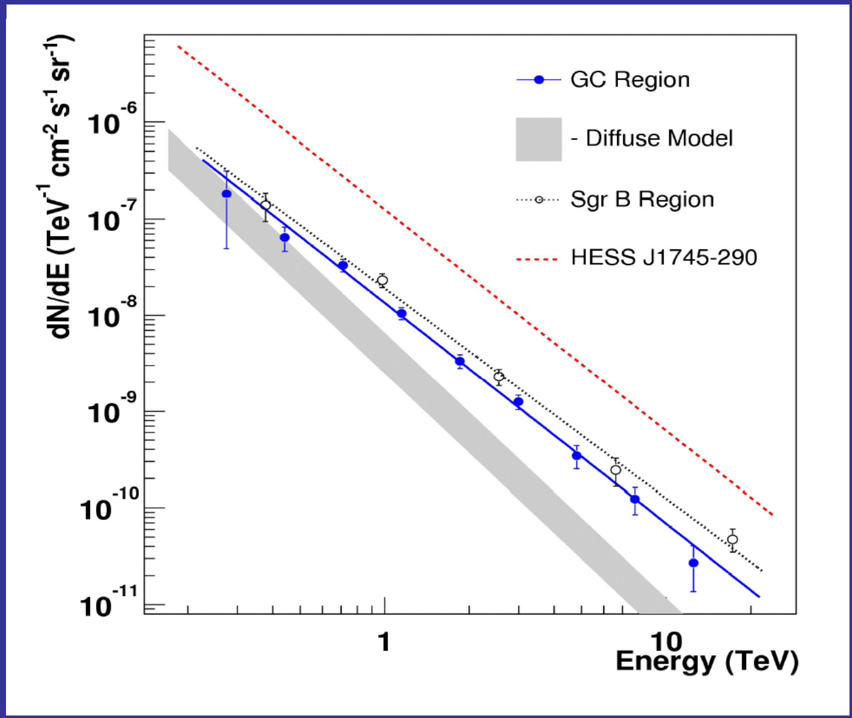
PWNs
Shell type SNRs
X-Ray Binary (Microquasars)
Un-ID sources

Probing Cosmic rays in the Galaxy



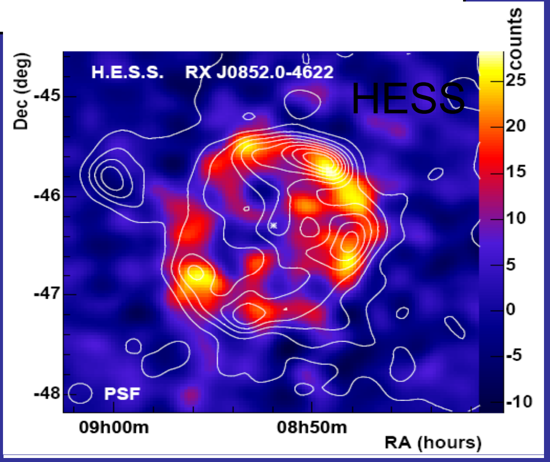
Spectral index
2.29 ± 0.07 ± 0.20

Implies harder
CR spectrum than in
our solar system

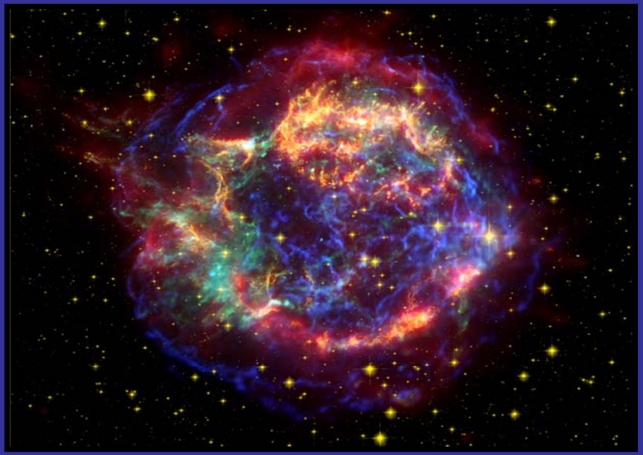


SNRs (9)

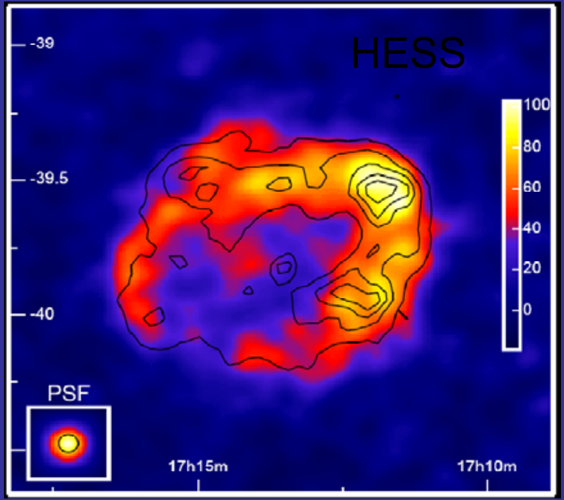
Category	Name	Discovery	Observ.
SNR	Cas-A	HEGRA	
SNR	Vela Junior, RX J0852.0-4622	CANGAROO	HESS
SNR/Un-ID	HESS J1640-465 (G338.3-0.0; 3EG J1639-4702)	HESS	
SNR	HESS 1713-381, G348.7+0.3 ?	HESS	
SNR	RX J1713.7-3946, G347.3-0.5	CANGAROO	HESS
SNR/PWN	HESS J1804-216 (G8.7-0.1 / W30; PSR J1803)	HESS	
SNR	HESS J1813-178 (G12.8-0.02; AX J1813-178)	HESS	MAGIC
SNR	HESS J1834-087 (G23.3-0.3 / W41)	HESS	MAGIC
SNR/PWN/Un-ID	HESS J1837-069 (G25.5+0.0; AX J1838.0-0655)	HESS	



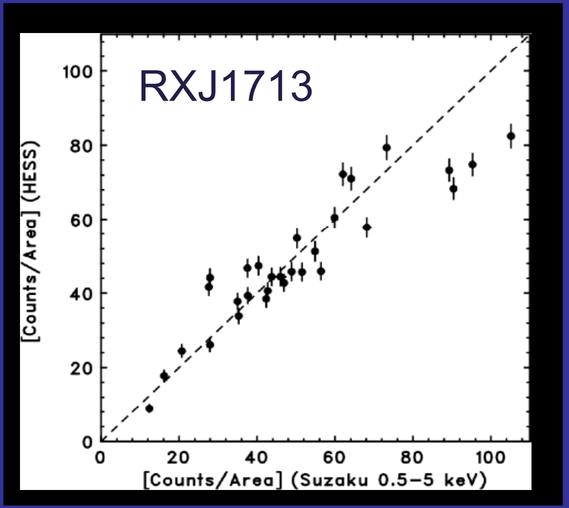
Vela Junior



Cas-A



RX J1713

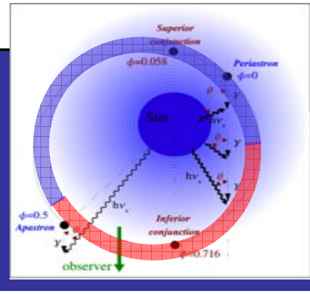


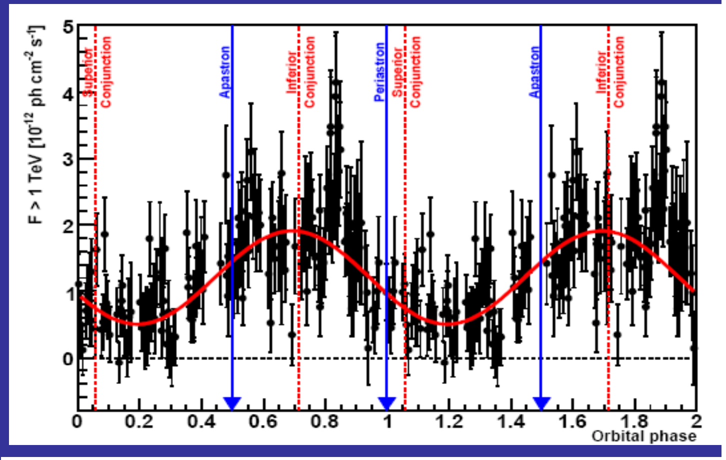
Y. Uchiyama, T. Takahashi
Texas Symp. 2006

Binary System (5)

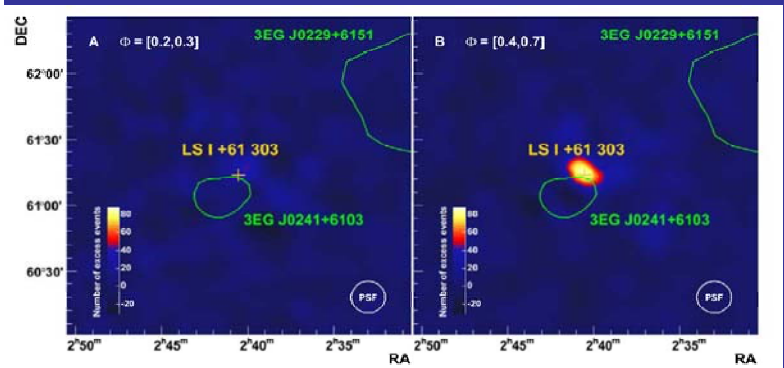
Category	Source	Discovery	Observation
Binary	PSR B1259-63 / SS 2883	HESS	
XRB	IGR J16320-4751	HESS J1632-478	
XRB/SNR	IGR J16358-4726 ?; G337.2+0.1 ?	HESS J1634-472	
XRB	LS 5039	HESS	
XRB	LSI+61303	MAGIC	VERITAS

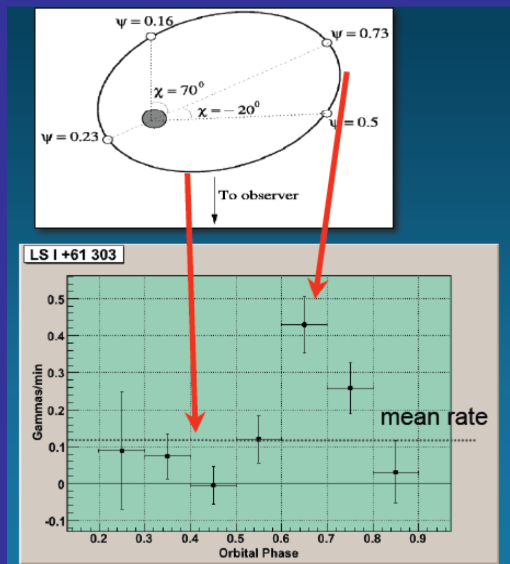
LS 5039
HESS

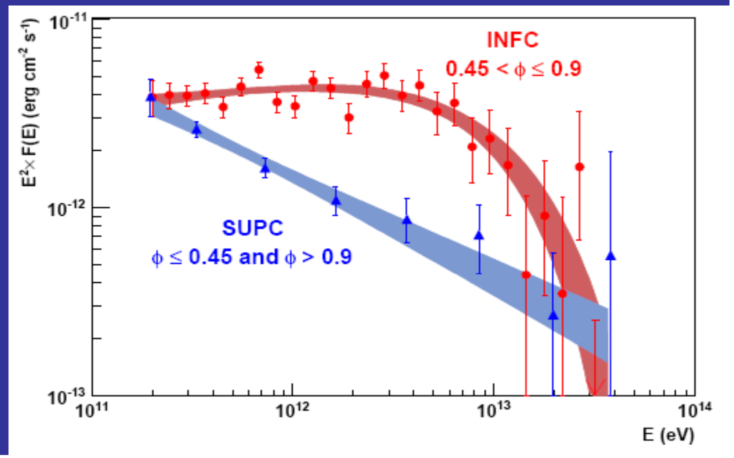




LS I +61 303 VERITAS



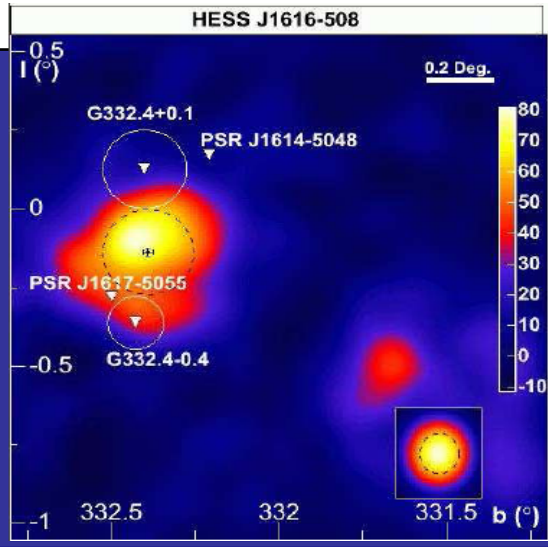




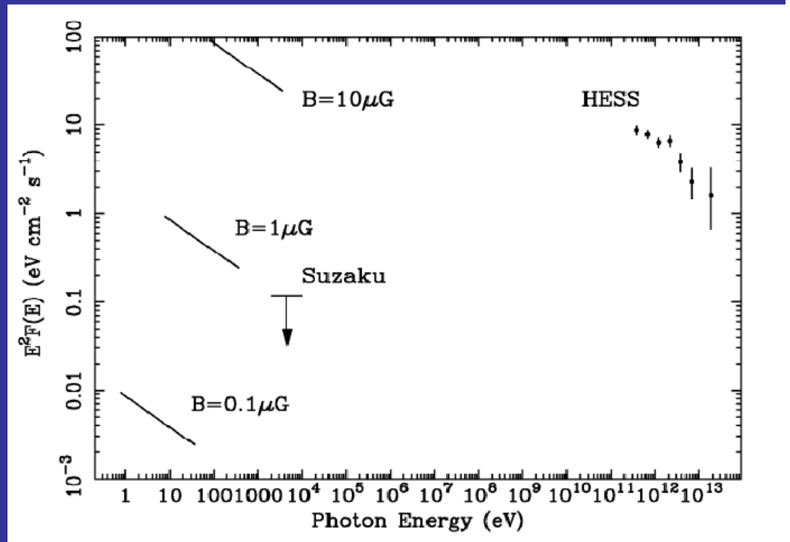
MAGIC LSI +61303

Un-IDs (Dark Source)

Category	Source	Discovery	Observation
Un-ID	TeV J2032+4130	HEGRA	
Un-ID	HESS J1303-631	HESS	
Un-ID	HESS J1614-518	HESS	
Un-ID	HESS J1702-420	HESS	
Un-ID	HESS J1708-410	HESS	
Un-ID	3EG J1744-3011 ?	HESS J1745-303	



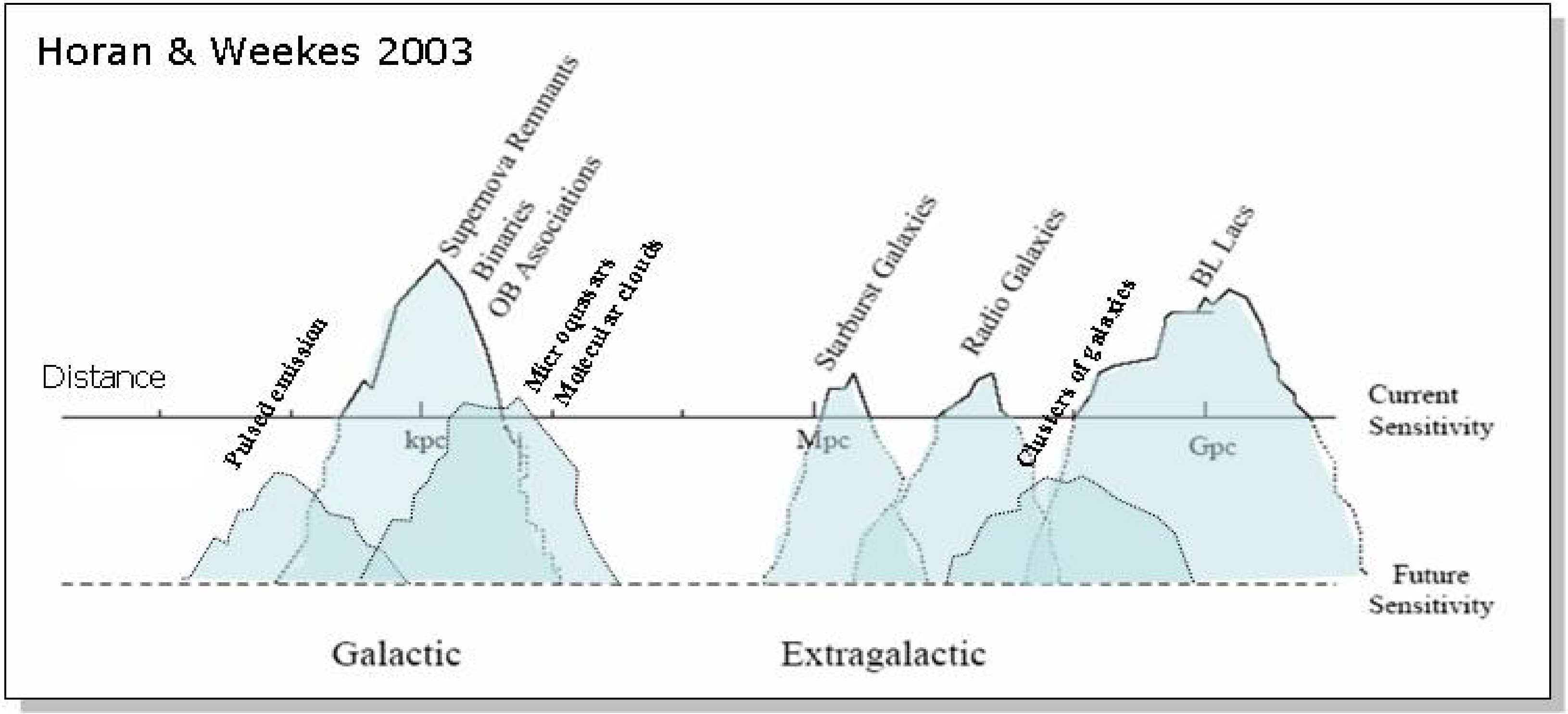
Name	Possible counterpart	Type^a	$\Gamma^b_{\rm TeV}$	$f^c_{\rm TeV}$	$N^d_{\rm H}$	$\Gamma^e_{\rm X}$	$f^f_{\rm X}$	$f_{\rm TeV}/f_{\rm X}$	Reference^g
HESS J0852−463	RX J0852−4622	SNR	2.1	6.9	4	2.6	~10	~0.7	1, 2, 3
HESS J1303−631	—	?	2.4	1.0	20	2.0	<0.64	>1.6	4, 5
HESS J1514−591	PSR B1509−58	PWN	2.3	1.6	8.6	2.0	3.2	0.5	6, 7
HESS J1632−478	AX J1631.9−4752	HMXB?	2.1	1.7	210	1.6	1.7	1.0	8, 9
HESS J1640−465	G338.3−0.0	SNR	2.4	0.71	96	3.0	0.30	2.4	8, 10
HESS J1713−397	RX J1713.7−3946	SNR	2.2	3.5	8	2.4	54	0.065	11, 12
HESS J1804−216	Suzaku J1804-2142	?	2.7	0.48	2	-0.3	0.025	19	8, 13
HESS J1804−216	Suzaku J1804-2140	?	2.7	0.48	110	1.7	0.043	11	8, 13
HESS J1813−178	AX J1813−178	?	2.1	0.89	110	1.8	0.70	1.3	8, 14
HESS J1837−069	AX J1838.0−0655	?	2.3	1.4	40	0.8	1.3	1.1	8, 15
TeV J2032+4130	—	?	1.9	0.20	?	?	<0.20	>1.0	16
HESS J1616−508	—	?	2.4	1.7	4.1	2.0	<0.031	>55	This work



Suzaku (Matsumoto et al. 1996)

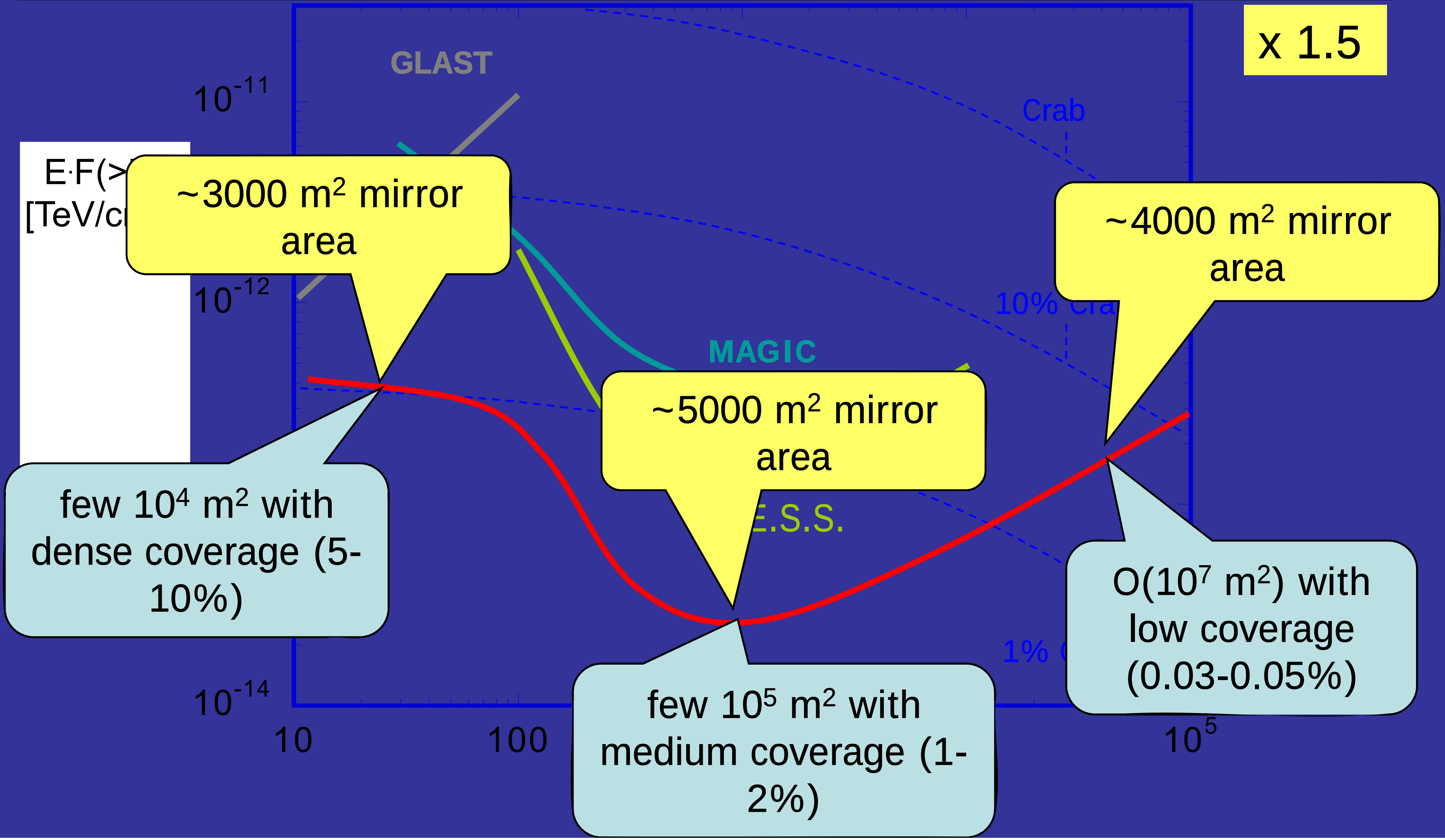
Science potential

An advanced facility for ground-based high-energy gamma ray astronomy

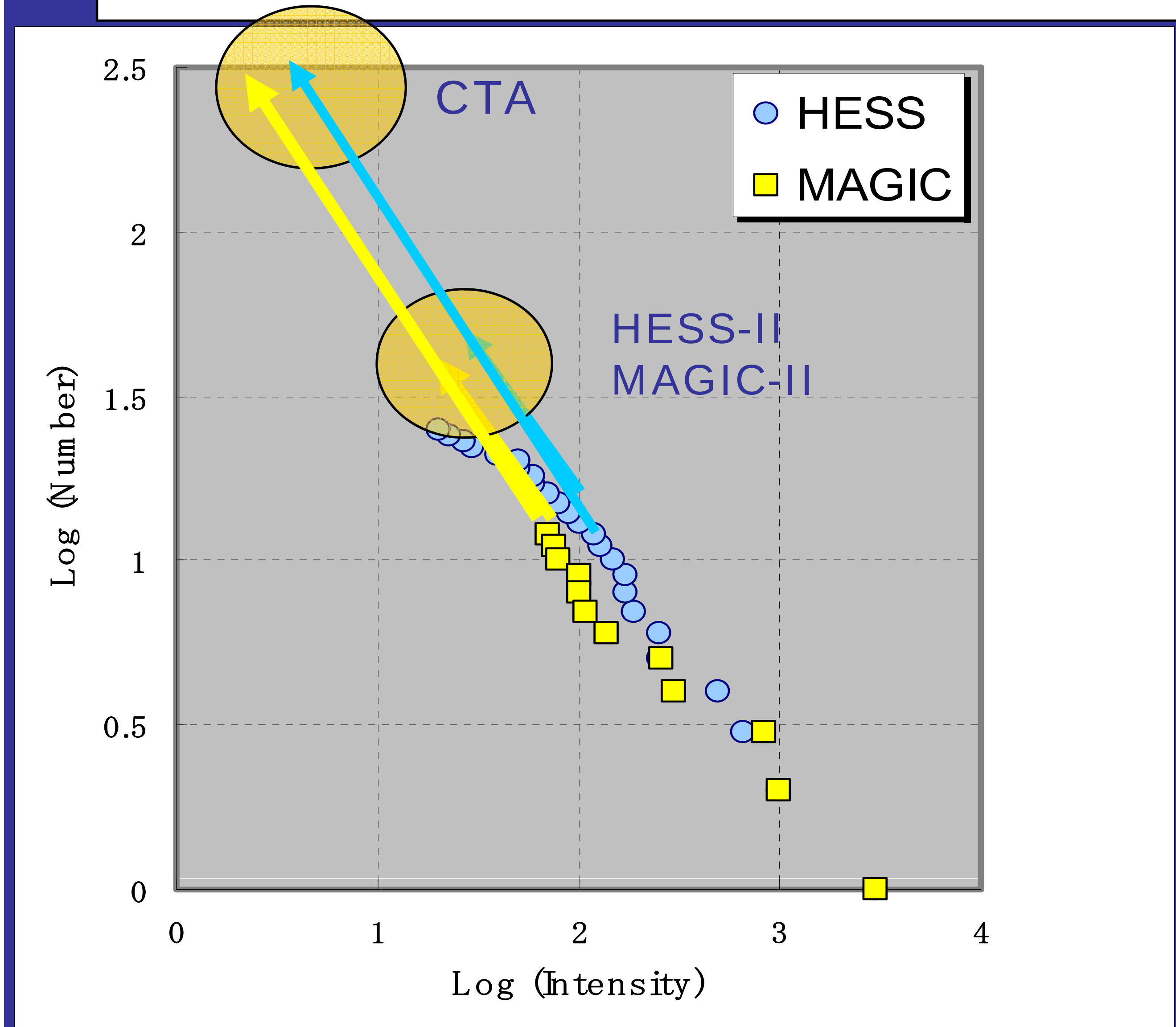


- Current instruments have passed the critical sensitivity threshold and reveal a rich panorama, but this is clearly only the tip of the iceberg
- Broad and diverse program ahead, combining guaranteed astrophysics with significant discovery potential

Possible CTA sensitivity



VHE Log(S)-Log(N) plot



HESS-I ~33 sources
MAGIC-I ~20 sources

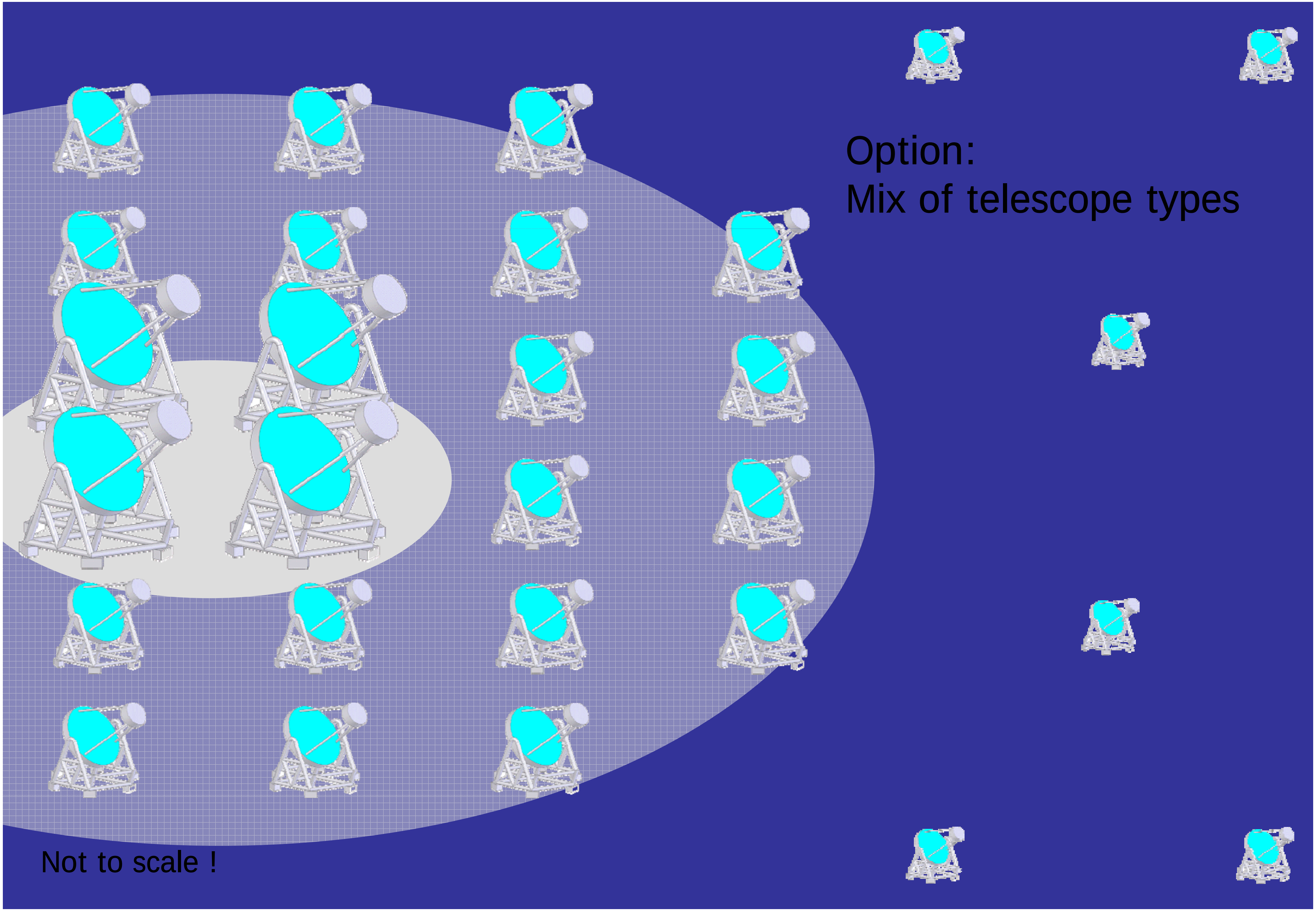
Log(N) ~ -1.0 Log(S) ???

HESS-II ~60 sources
MAGIC-II ~40 sources

CTA South ~300 sources
CTA North ~200 sources

The Cherenkov Telescope Array facility

- aims to explore the sky in the 10 GeV to 100 TeV energy range
- builds on demonstrated technologies
- combines guaranteed science with significant discovery potential
- is a cornerstone towards a multi-messenger exploration of the nonthermal universe


Option:
Mix of telescope types
Not to scale !

European Strategy Forum
on Research Infrastructures

ESFRI

EUROPEAN ROADMAP FOR RESEARCH INFRASTRUCTURES

Report 2006

>Emerging proposals

During the preparation of the roadmap the experts have also received and identified emerging proposals that may constitute a base for future upgrades of the roadmap itself.

They are listed here below divided by the name of the corresponding ESFRI Roadmap Working Group. At this stage ESFRI does not offer any opinion on whether they will subsequently enter the full roadmap in the future. It is fully expected that future editions will substantially add to this

Physical Science and Engineering

CTA

is an advanced facility for ground based high-energy gamma ray astronomy, based on the observation of Cerenkov radiation. This approach has proven to be extremely successful for gamma rays of energies above few tens of GeV. The facility will consist in an array of telescopes enhancing the all sky monitoring capability.

DACA

DATA CURATION and ANALYSIS for Software and Data Management, is a networked infrastructure developing data analysis methods and software for the use of various sciences. Each node of the network operates in connection with a specific heavy user of data analysis and management methods, and the networks cooperate on the application-independent aspects of the work.

European Infrastructure for Synthetic Biology

Synthetic biology is concerned with applying the engineering paradigm of systems design to biological systems in order to produce predictable and robust systems with novel functionalities that do not exist in nature. In essence, synthetic biology will enable the design of "biological systems" in a rational and systematic way. The objective of this infrastructure would be to provide key service functions to the synthetic biology community, to enable standardisation of biological parts on which synthetic biologists can draw, including the provision of reference methods and materials, as well as associated research and top level training.

European Infrastructure for Research in Biomedical Imaging (EIRBI)

A number of *in vitro* techniques are now available to biologists for assessing, at the molecular level, the occurrence of abnormal gene expression that accompanies the development of a pathological state. The field of biomedical imaging is challenged to translate these tremendous achievements into early diagnosis and efficient follow-up of therapeutic treatments as well as developing novel, imaging-guided, drug-delivery and minimally invasive treatments. The establishment of EIRBI is essential to this challenge, and will further maintain the competitiveness of European industries and academic institutions in the field of imaging.

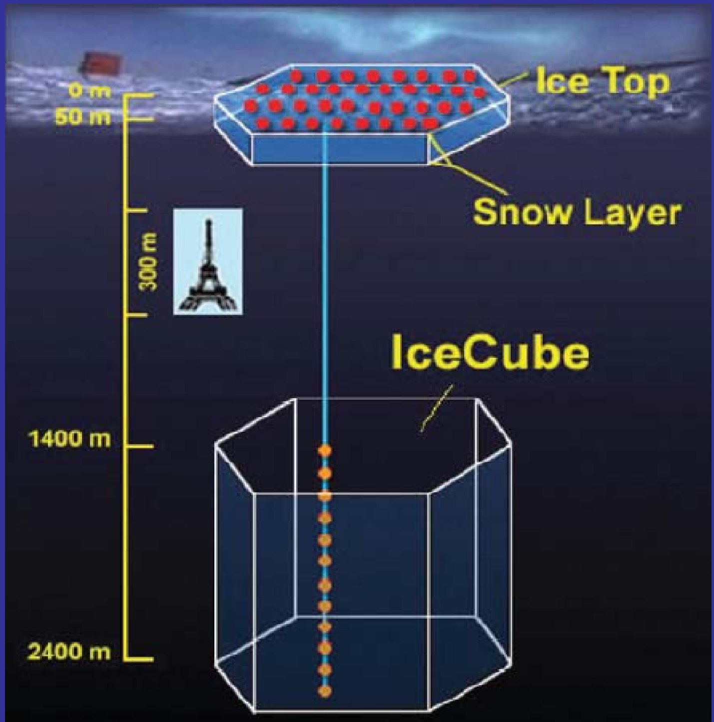
High security laboratories for emerging and zoonotic diseases and

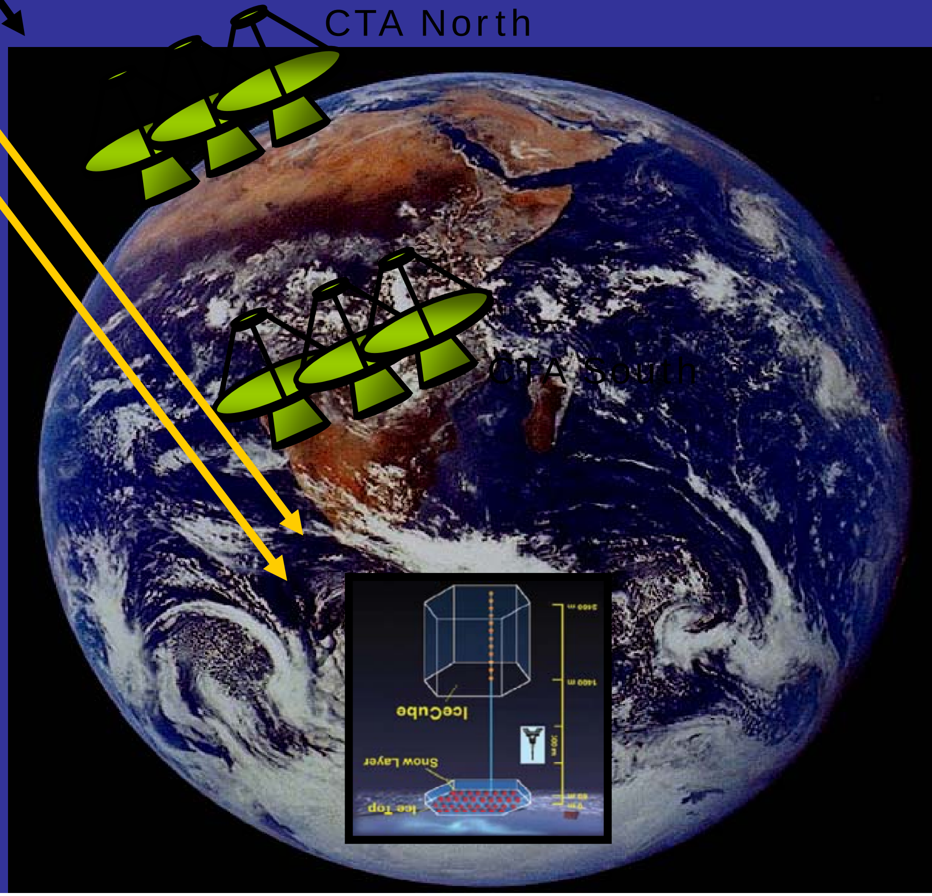
Multi-Messengers observation
All sky observatory (N,S stations)

Gamma Rays

Gamma Ray &
X-Ray Satellites

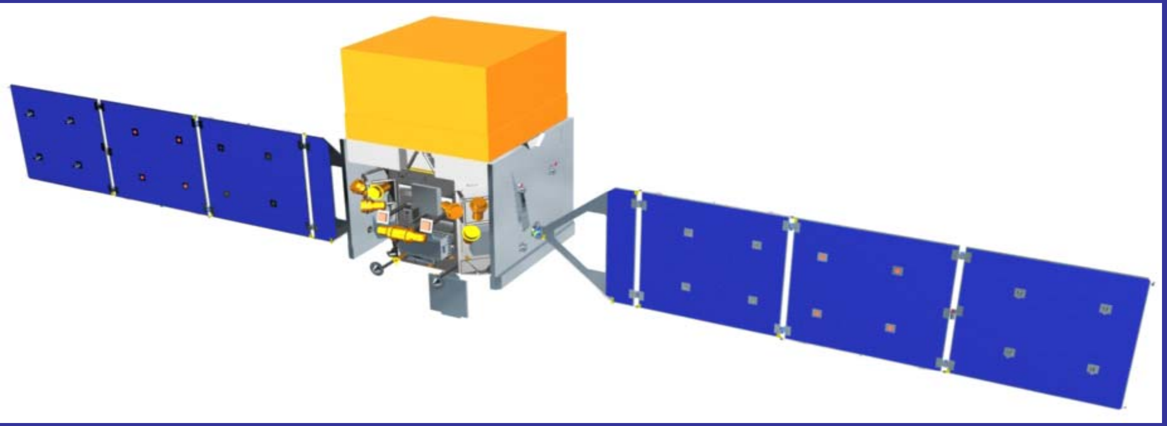
Neutrinos

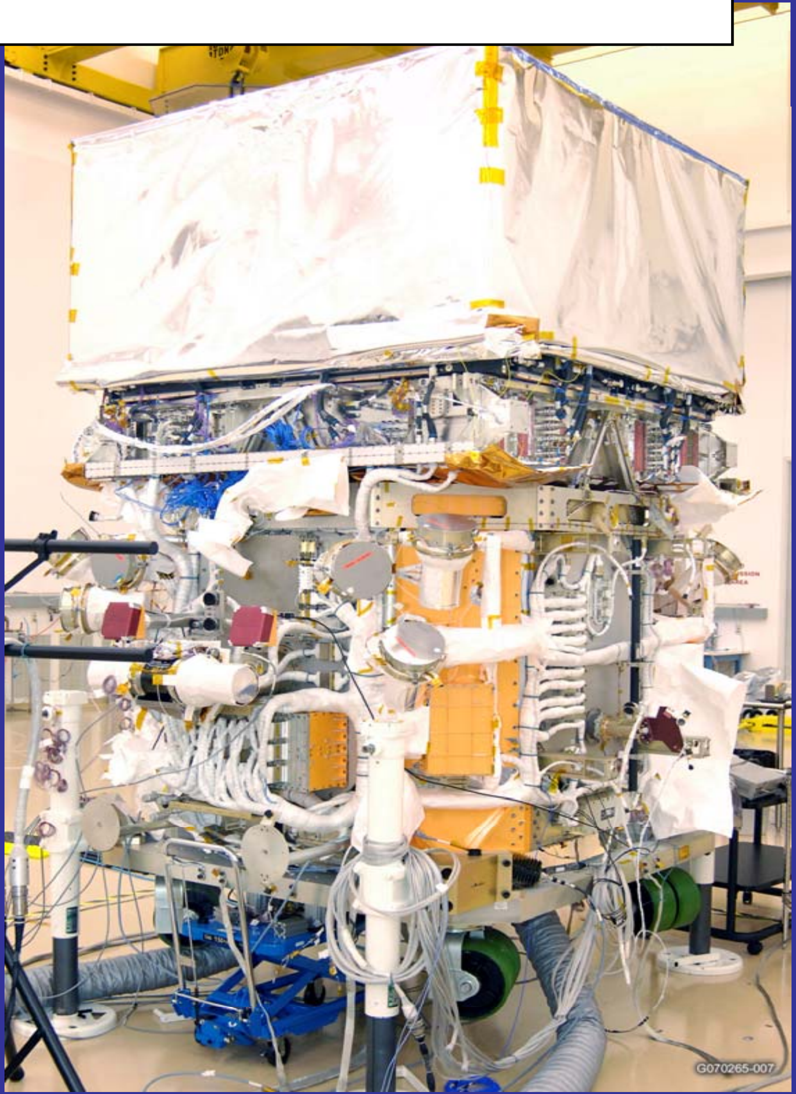




IceCube:
2010 Completion of the construction

GLAST





<u>Two GLAST instruments</u>:
LAT: 20 MeV – >300 GeV
GBM: 10 keV – 25 MeV

Launch Readiness Date
14/12/2007

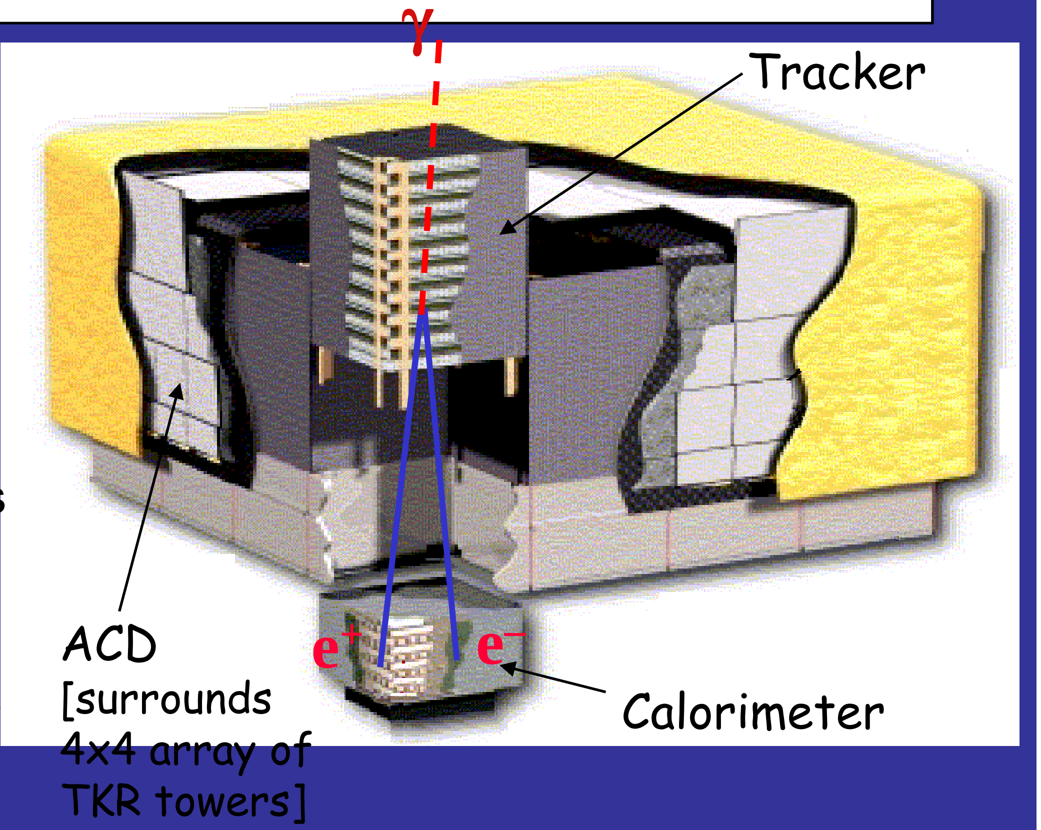
Components of the LAT

Precision Si-strip Tracker (TKR) 18 XY tracking planes with tungsten foil converters. Single-sided silicon strip detectors (228 µm pitch, 900k strips) Measures the photon direction; gamma ID. (INFN key role)

Array of 1536 CsI(Tl) crystals in 8 layers. Measures the photon energy; image the shower.

89 plastic scintillator tiles. Rejects background of charged cosmic rays; segmentation mitigates self-veto effects at high energy.

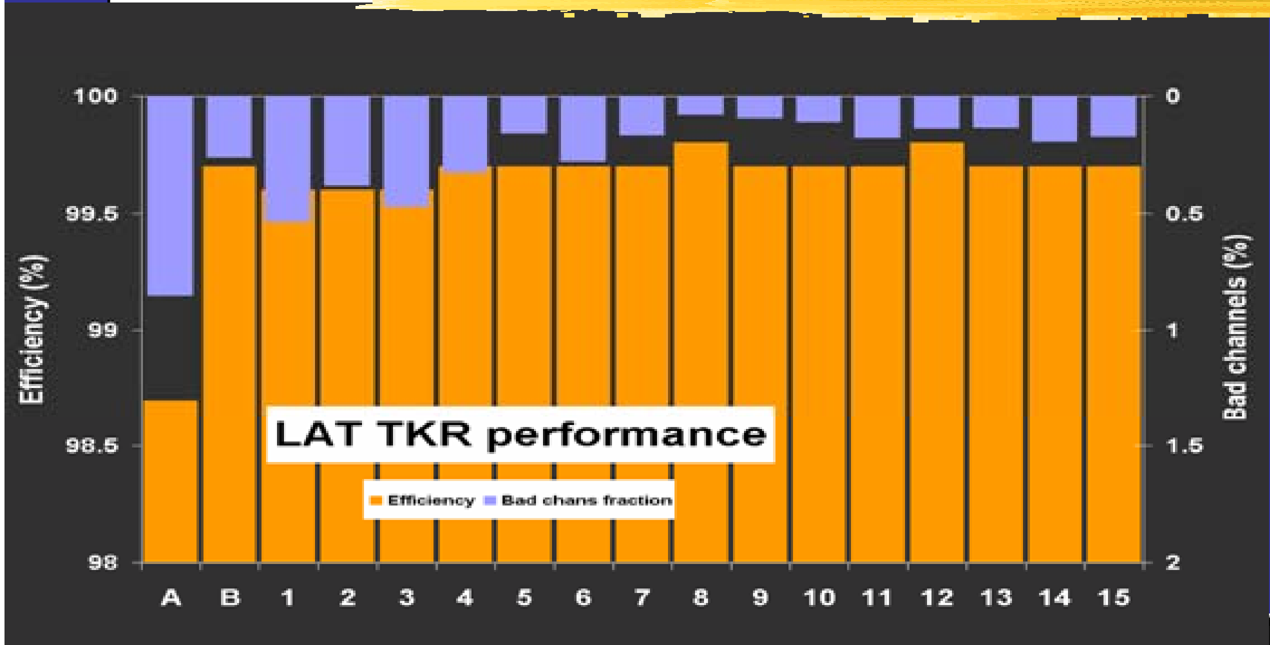
Includes flexible, robust hardware trigger and software filters.

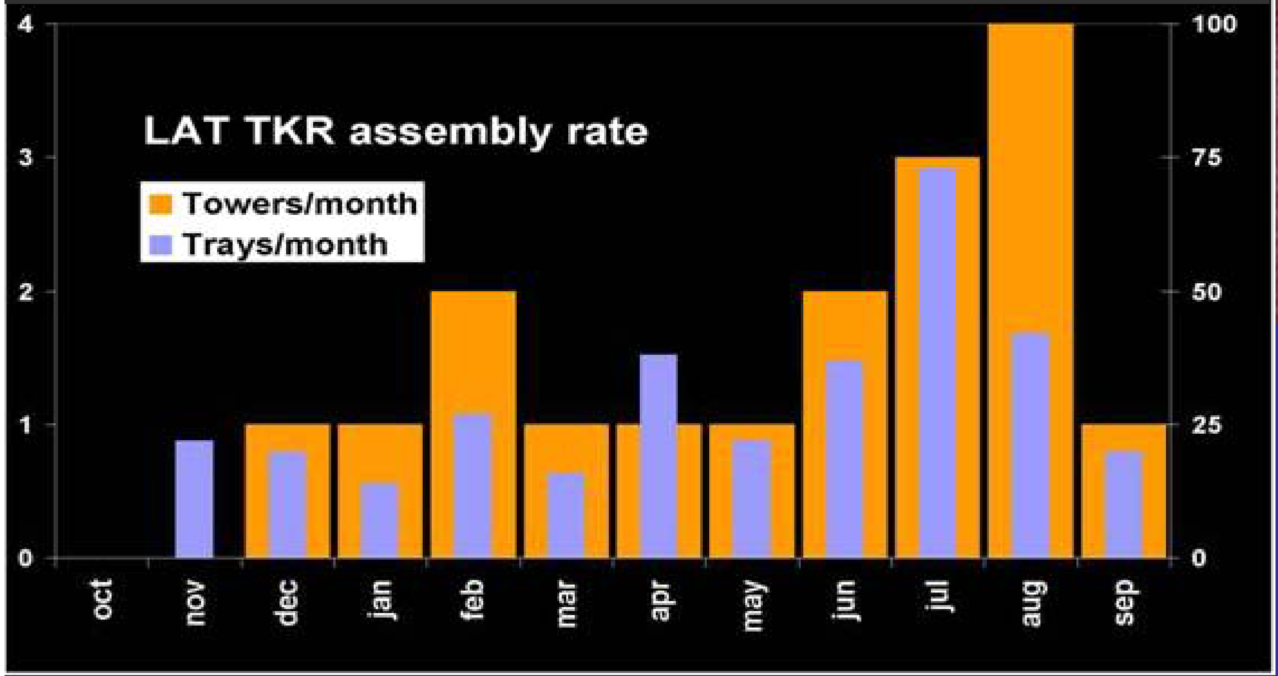


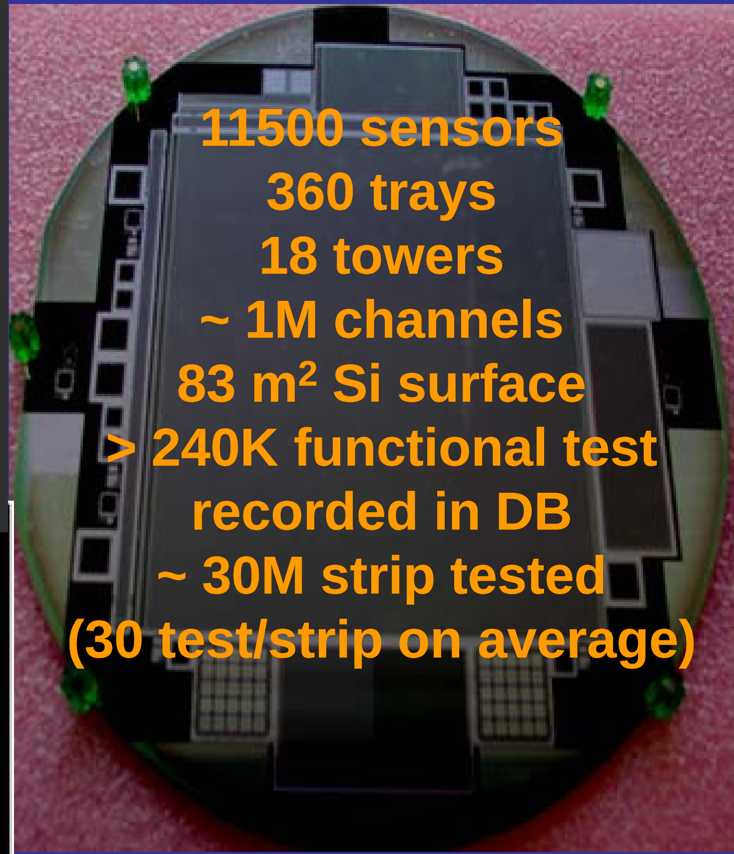
GLAST @ SLAC

16/16 Towers in the GRID on 20/10/05

The LAT Tracker numbers

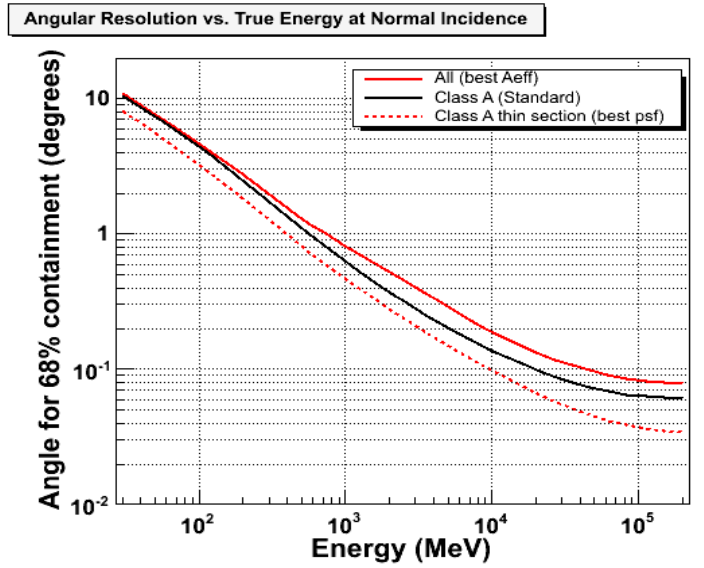


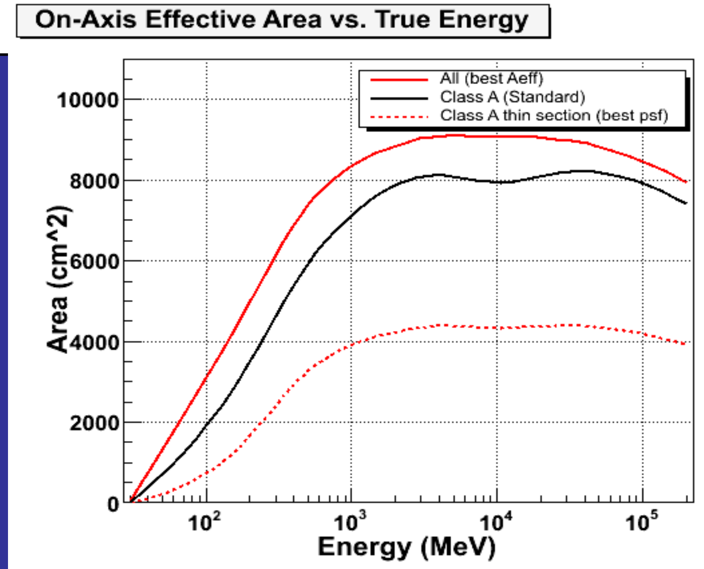


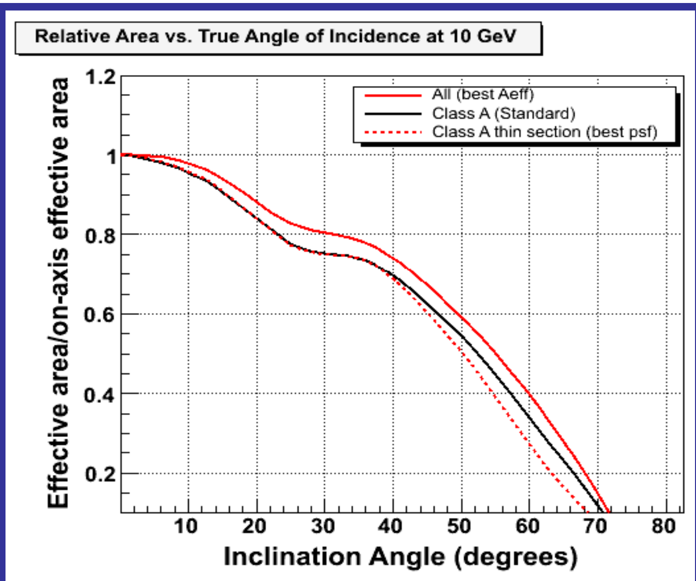


> 60 physicist and engineers involved in the italian teams from INFN (Trieste, Udine, Padova, Pisa, Perugia, Roma2, Bari) in partnership with ASI

GLAST LAT PERFORMANCES





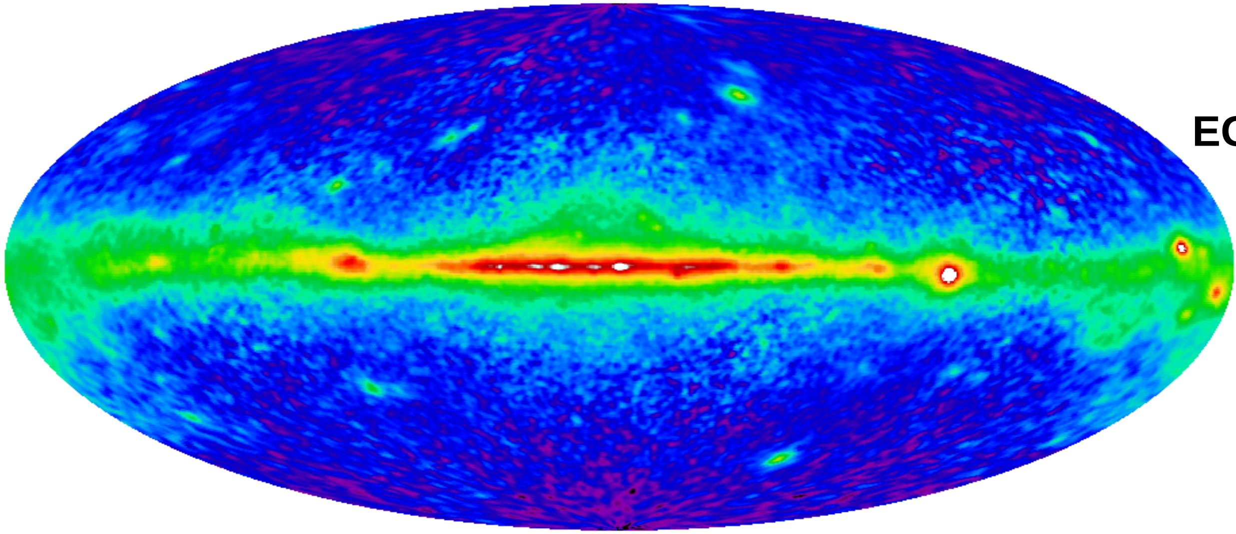


Science Performance Requirements Summary

From the SRD:

Parameter	SRD Value	Present Design Value
Peak Effective Area (in range 1-10 GeV)	>8000 cm^2	10,000 cm^2 at 10 GeV
Energy Resolution 100 MeV on-axis	<10%	9%
Energy Resolution 10 GeV on-axis	<10%	8%
Energy Resolution 10-300 GeV on-axis	<20%	<15%
Energy Resolution 10-300 GeV off-axis (>60º)	<6%	<4.5%
PSF 68% 100 MeV on-axis	<3.5°	3.37° (front), 4.64° (total)
PSF 68% 10 GeV on-axis	<0.15°	0.086° (front), 0.115° (total)
PSF 95/68 ratio	<3	2.1 front, 2.6 back (100 MeV)
PSF 55º/normal ratio	<1.7	1.6
Field of View	>2sr	2.4 sr
Background rejection (E>100 MeV)	<10% diffuse	6% diffuse (adjustable)
Point Source Sensitivity(>100MeV)	<6x10^{-9} $cm^{-2}s^{-1}$	3x10^{-9} $cm^{-2}s^{-1}$
Source Location Determination	<0.5 arcmin	<0.4 arcmin (ignoring BACK info)
GRB localization	<10 arcmin	5 arcmin (ignoring BACK info)

GLAST Science opportunities



EGRET (>100 MeV)

- 60% galactic diffuse emission
- 30% isotropic emission
- 10% point sources

Many opportunities for exciting discoveries:

Signal rate from WIMP annihilati

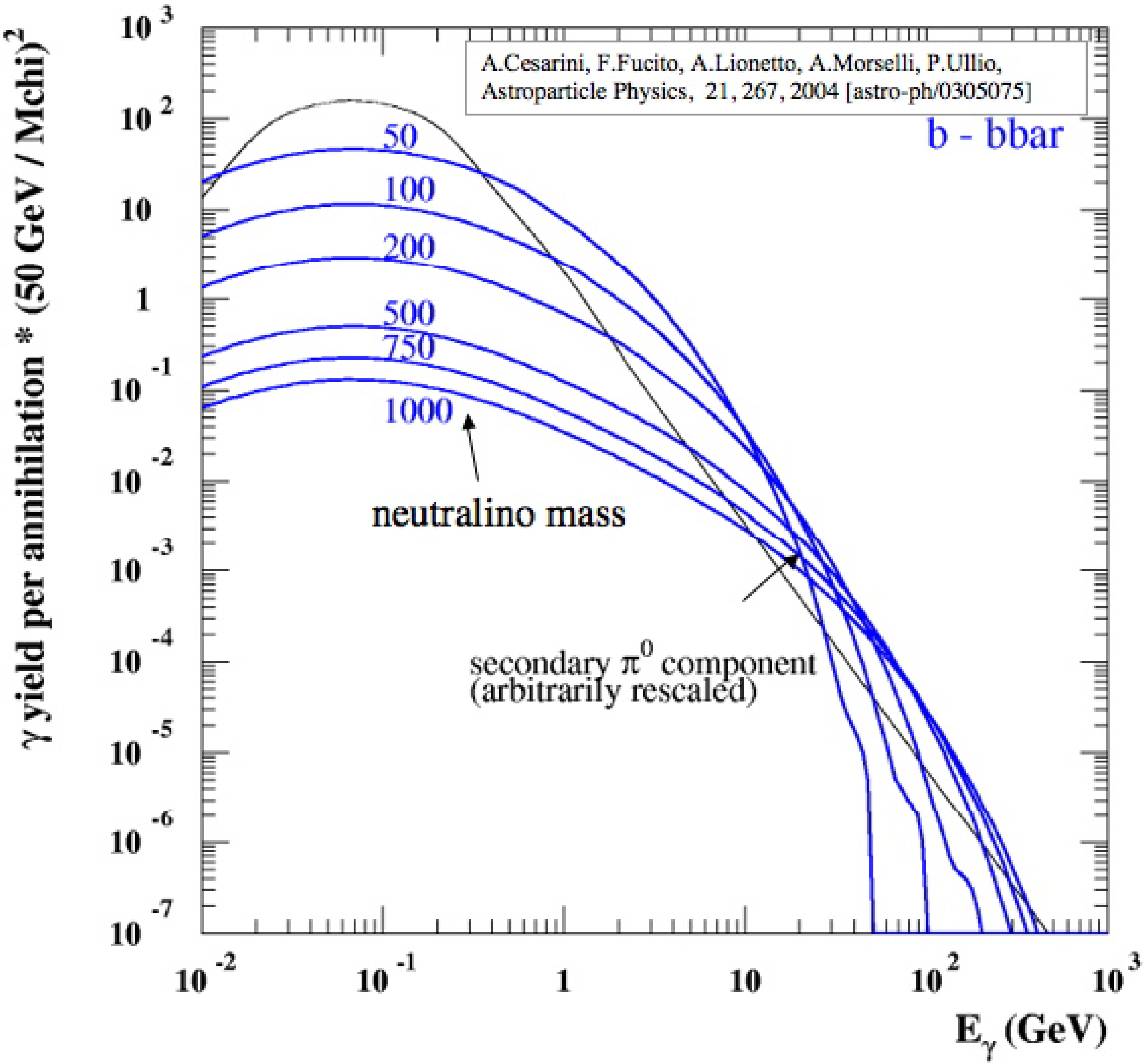
gamma-ray flux from
WIMP annihilation

$$\phi(E, \Delta\Omega) \propto \left(\frac{\sigma v}{m_\chi^2}\right) \int_{l.o.s} \int_{\Delta\Omega} \rho^2(l)\, dl\, d\Omega$$

governed by
particle physics
(supersymmetric
 parameters .. etc)

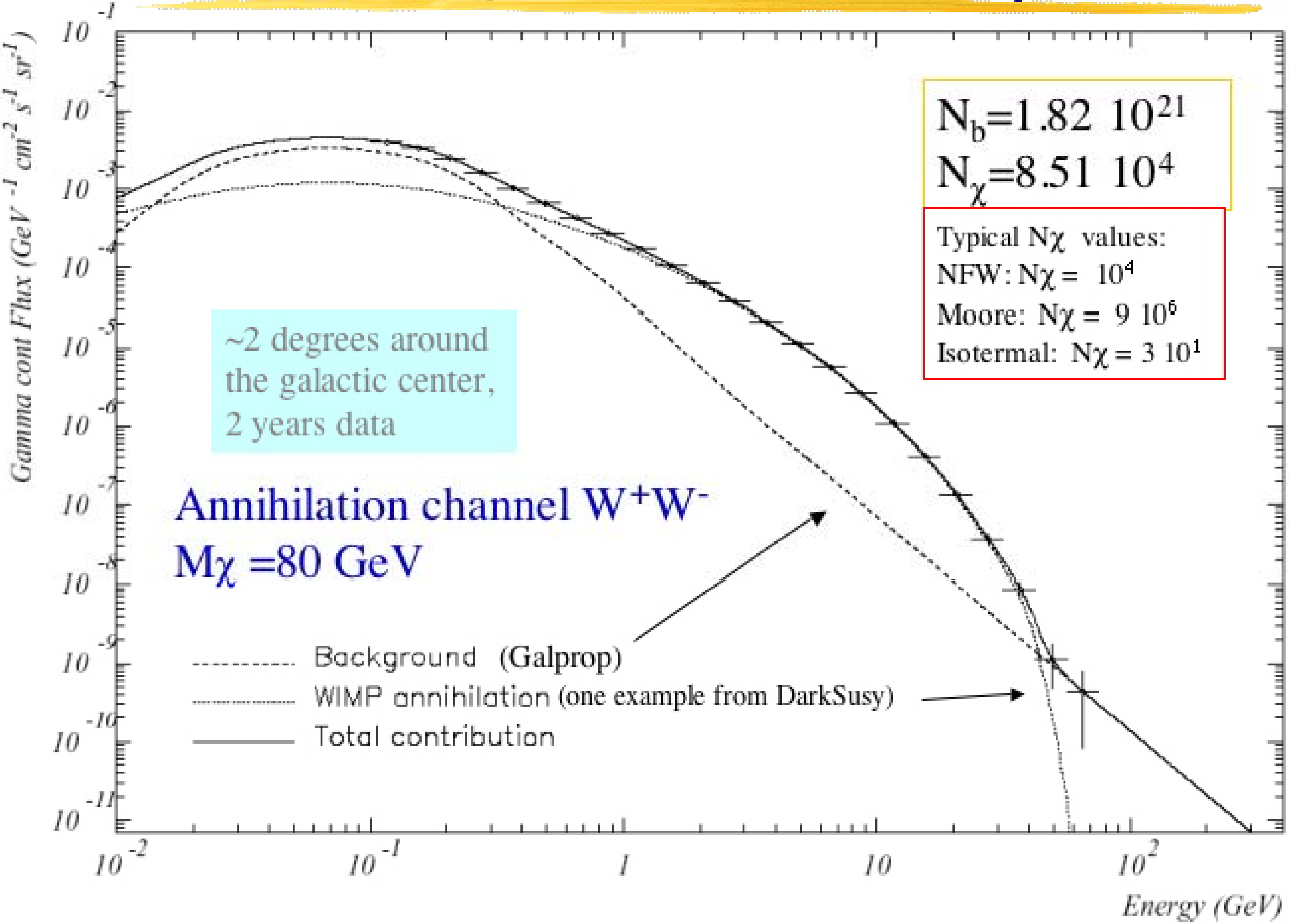
governed by
halo distribution

Differential ... for b ba...



Spectral shape depends on the neutralino mass

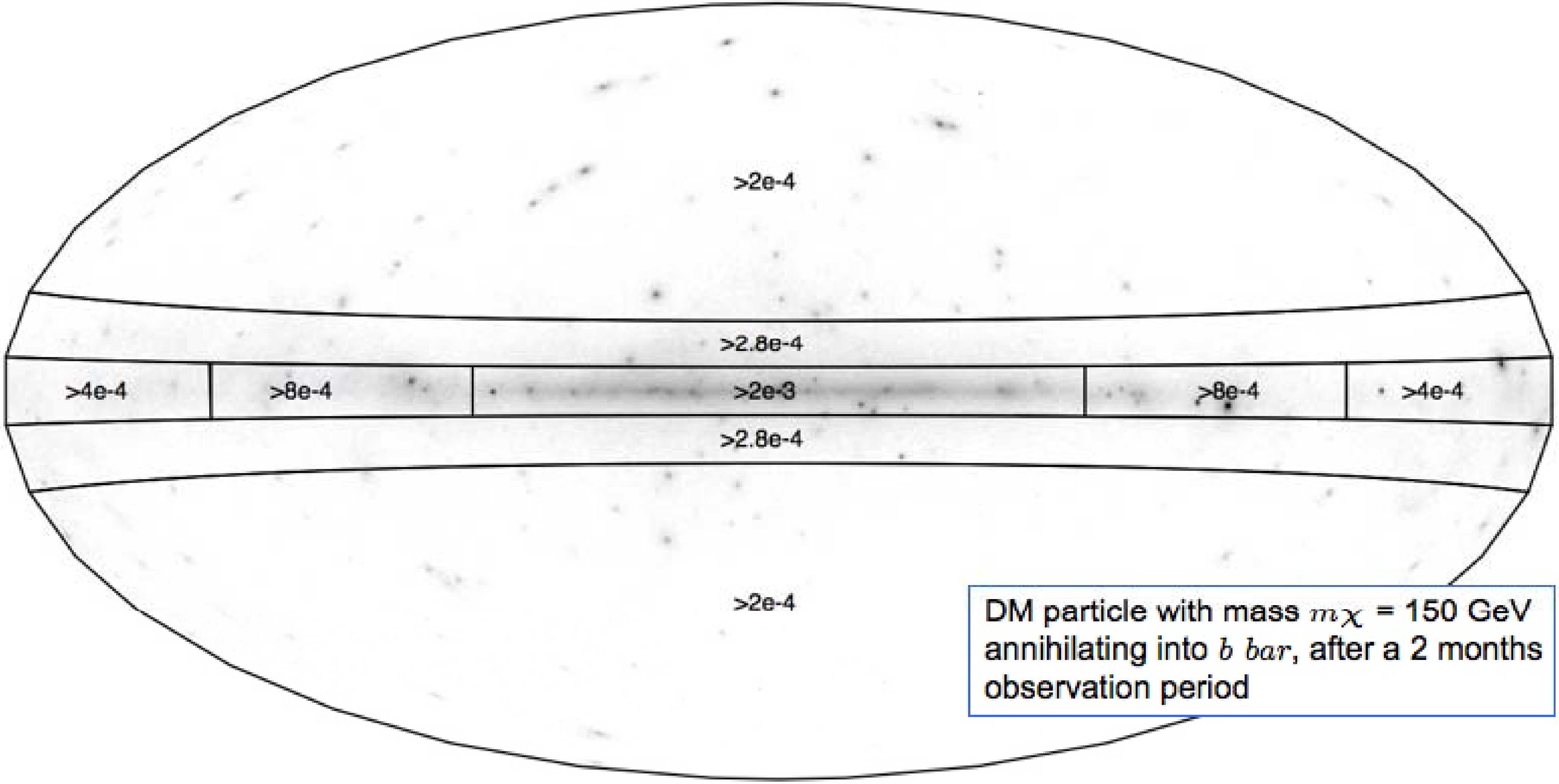
GLAST Expectation & Susy models



A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

GLAST sensitivity map for the identification of point sources of Dark Matter annihilation

minimum flux above 100 MeV, in units of [ph m^{-2} s^{-1}]



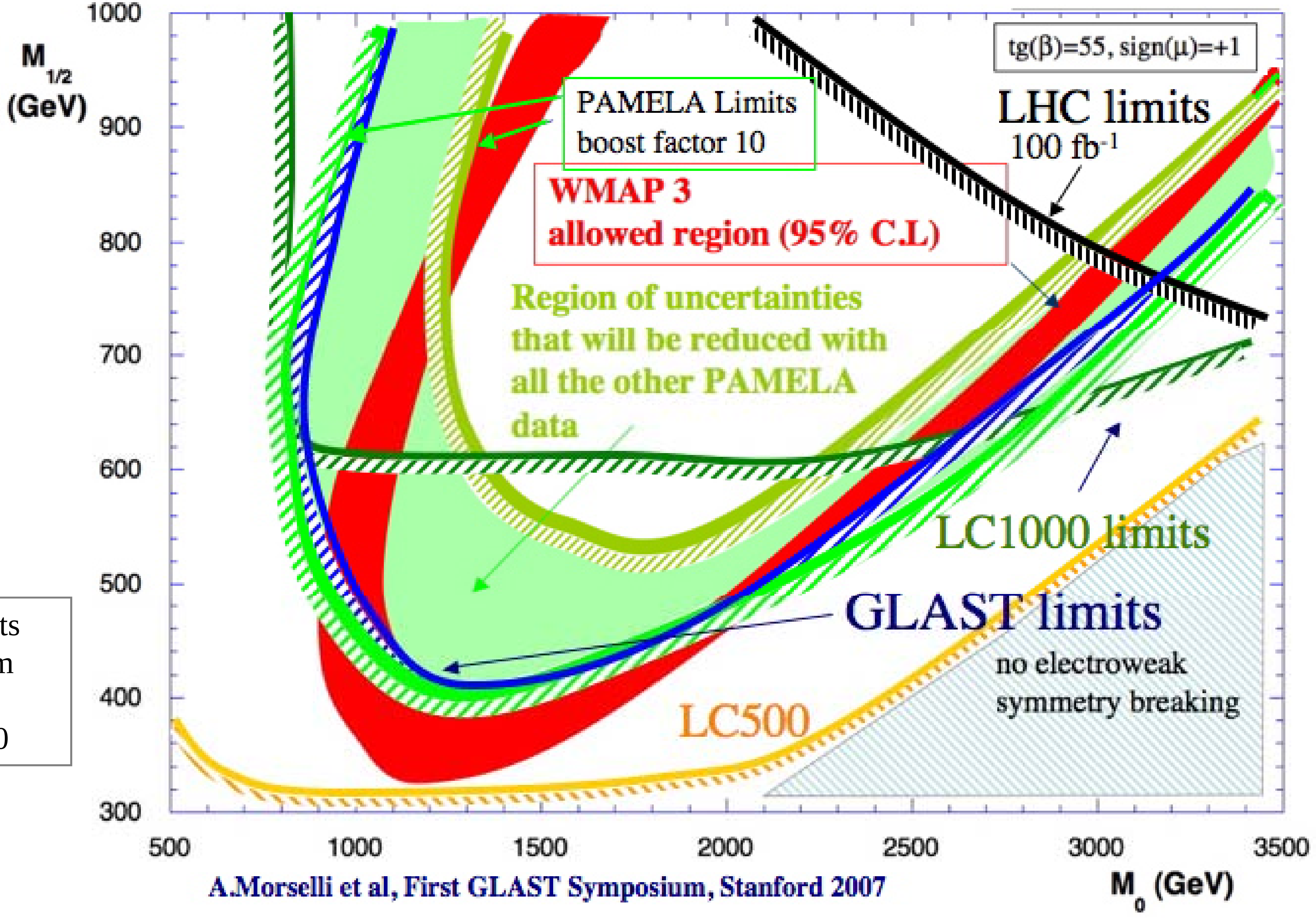
DM particle with mass m_χ = 150 GeV annihilating into b bar, after a 2 months observation period

G. Bertone, T. Bringmann, R. Rando, G. Busetto, A. Morselli astro-ph/0612387

GLAST, PAMELA, LHC, LC Sensitivities to Dark Matter Search

mSUGRA

Sensitivity plot f
5 years
observation of
mSUGRA for
GLAST for
tg(b)=55
and for other
experiments.
GLAST 3σ
sensitivity is
shown at the blu
line and below
for truncated
NFW halo profil



accelerator limits
@ 100 fb^{-1} from
H.Baer et al.,
hep-ph/0405210

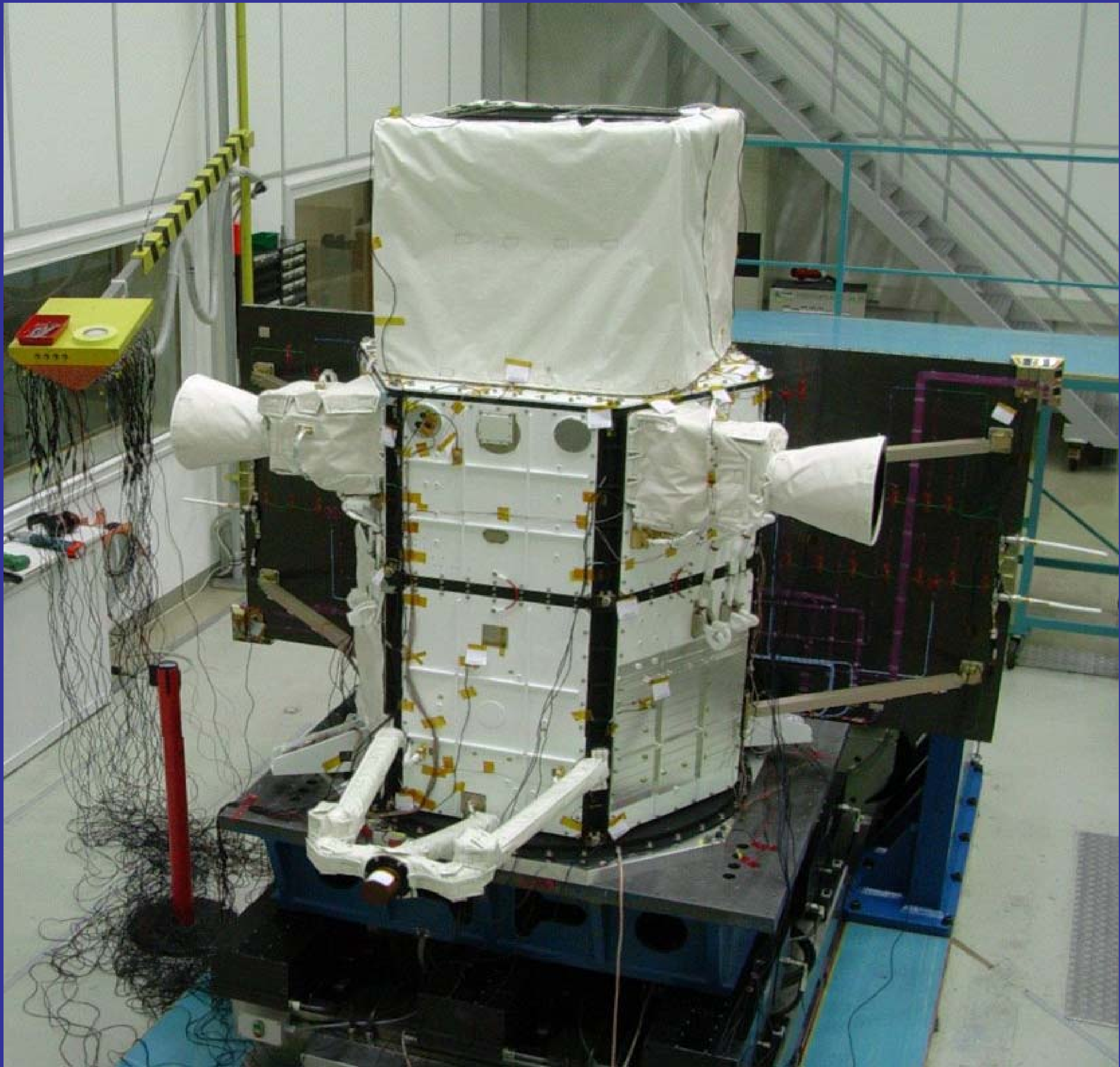

agile
Astro-rivelatore Gamma
a Immagini Leggero
INAF
INFN
Alenia
telespazio

AGILE Mission

- **AGILE is an Scientific Mission supported by ASI (PhaseB: June 1999) with scientific and programmatic participation by INAF and INFN dedicated to gamma-ray astrophysics**

  (*Imaging* 30 MeV-50 GeV, 10-40 keV)
- **Planned to be operational in 2006**
- **Mission entirely dedicated to gamma-ray astrophysics (E>30 MeV) during the period 2006-2008**
- **Emphasis to rapid reaction to transients**
- **Multiwavelength follow-up program**
- **Small Mission with a *Guest Observer Program***

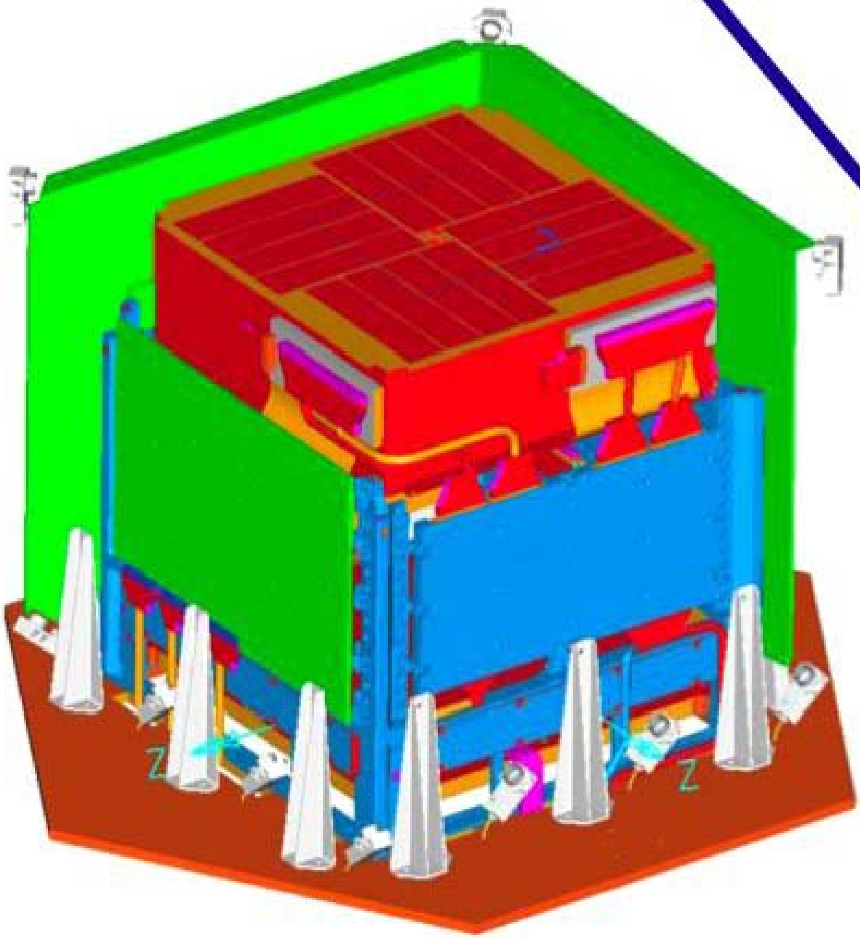
- Total satellite mass ~ 350 kg
- Scientific Instrument mass: 120 kg

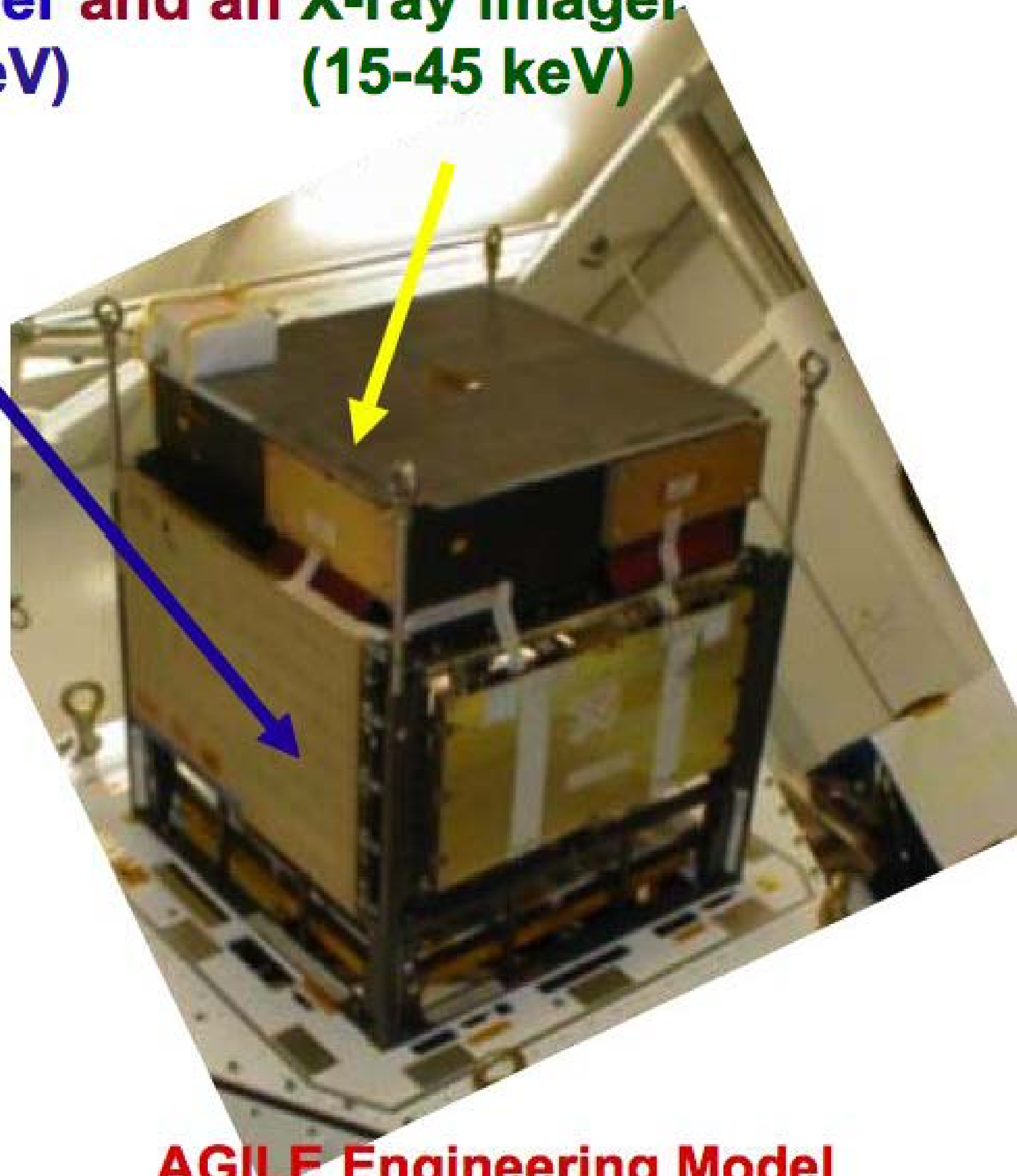


AGILE Sate
(IABG, Mur
June 16, 20

Agile: FIRST and unique combination of a gamma-ray imager and an X-ray imager

(30 MeV-30 GeV) (15-45 keV)





AGILE Engineering Model