Current and Future balloon and space experiments

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Tango, May 4-6th, 2009

Plan

I will focus on:

- **Future experiments which are going to measure e^+ and e^- CR in the forthcoming years.**
- **Experiments which results will improve our knowledge on CR source & propagation mechanisms.**
  - **Estimate primary, secondary and exotic e^+ and e^- flux**

ATIC - FERMI – PAMELA -> see this morning presentations
This talk : AMS02 - CREAM - CALET - CREST

e^+- e^- Measurements

Experimental challenge

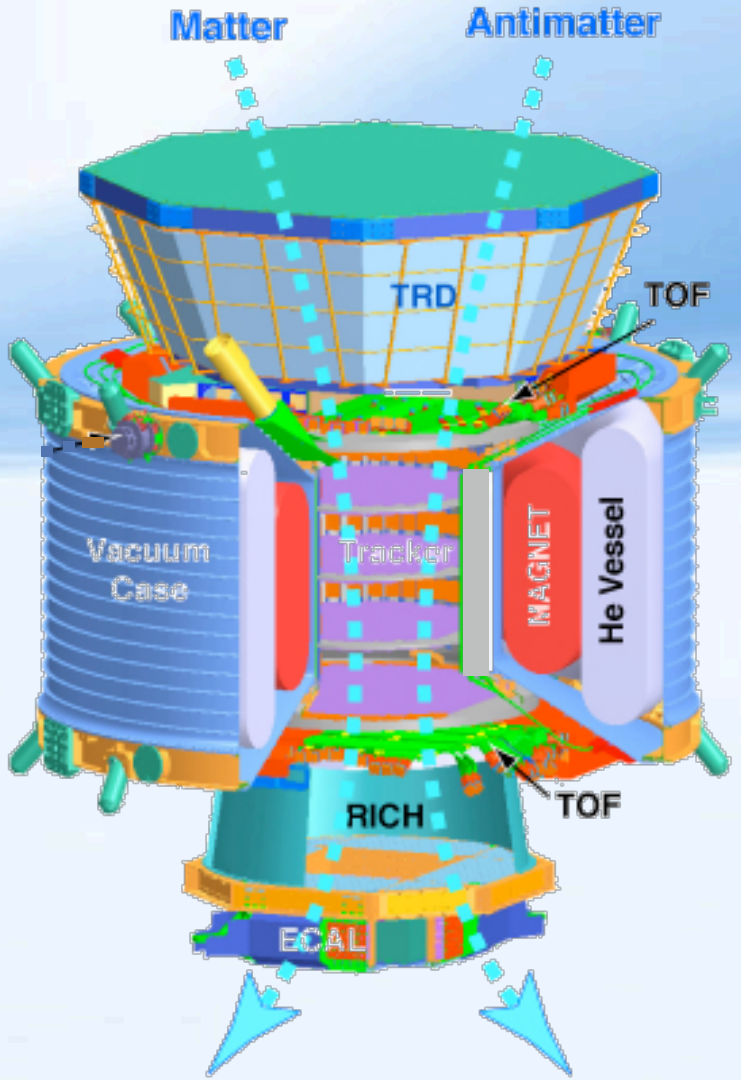
- Rare signal → large acceptance
  → long exposure time
- Huge background from p component
  e^-/p ~1% @ 1 GeV, ~0.1% @ 1 TeV,
  e^+/e^- ~0.1
  → optimal e/p separation
  → charge sign measurement
- Secondary production in atmosphere
  → stratospheric balloon
  → space

Experimental measurements

- All electron spectrum ($e^+ + e^-$). → e/p, acc
- Positron fraction (e^+/e^-+e^+) → e/p, charge
- Absolute fluxes e^+,e^- → e/p, charge, acc.

AMS02

Magnetic Spectrometer on ISS

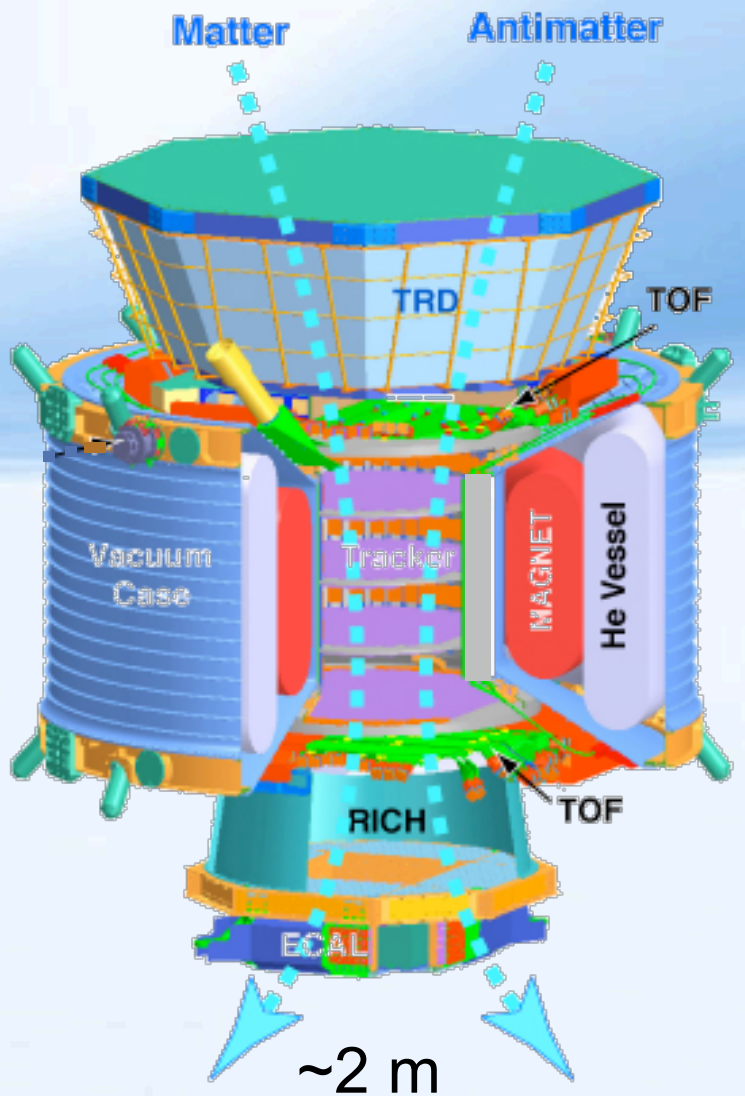


AMS experiment is to perform accurate, high statistics, long duration measurements in space of

- **Energetic (0.1 GV - few TV) charged CR**
- **Energetic (>1 GeV) gamma rays.**

AMS02 detector

- *Measurements of particle:*
  - ***Rigidity: Silicon Tracker in super conducting magnet (0.9 T)***
  - ***e-γ energy: Electromagnetic Calorimeter (ECAL)***
  - ***(e/p) rejection: TRD & ECAL***
  - ***Charge: TOF, Tracker, RICH***
  - ***Velocity: TOF, RICH***



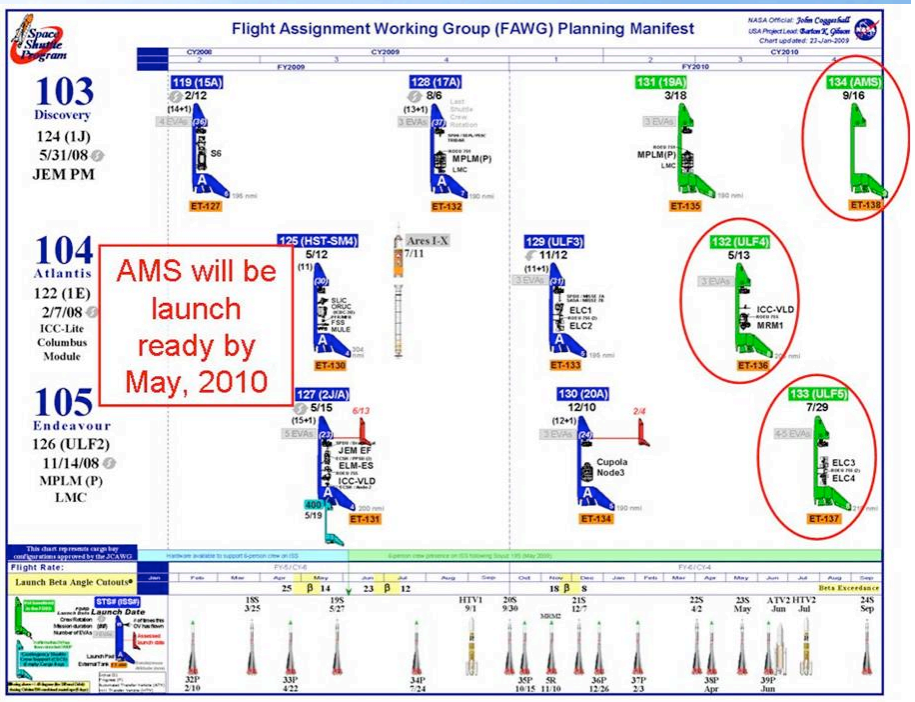
Geometrical acceptance: 0.45 m^2sr

AMS02: Status

- **AMS02 back in the official NASA schedule (manifest)**

  Launch date : July/Sept. 2010

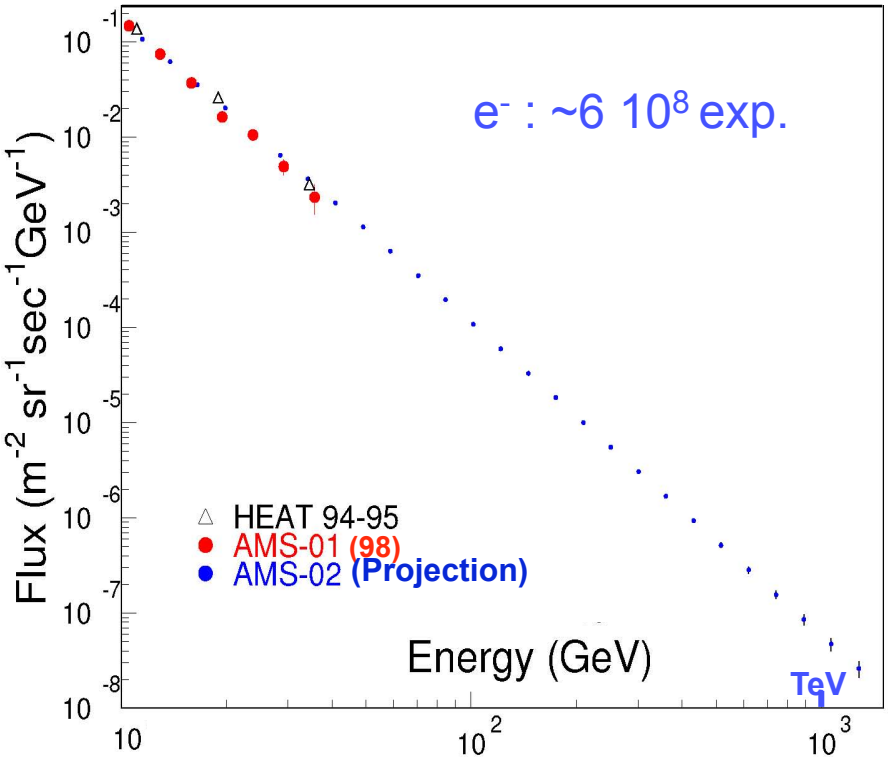
- **All AMS detectors validated with cosmics muons and testbeam.**
- **AMS Magnet under test @ CERN**
- **Detector to be delivered at KSC beginning of 2010**

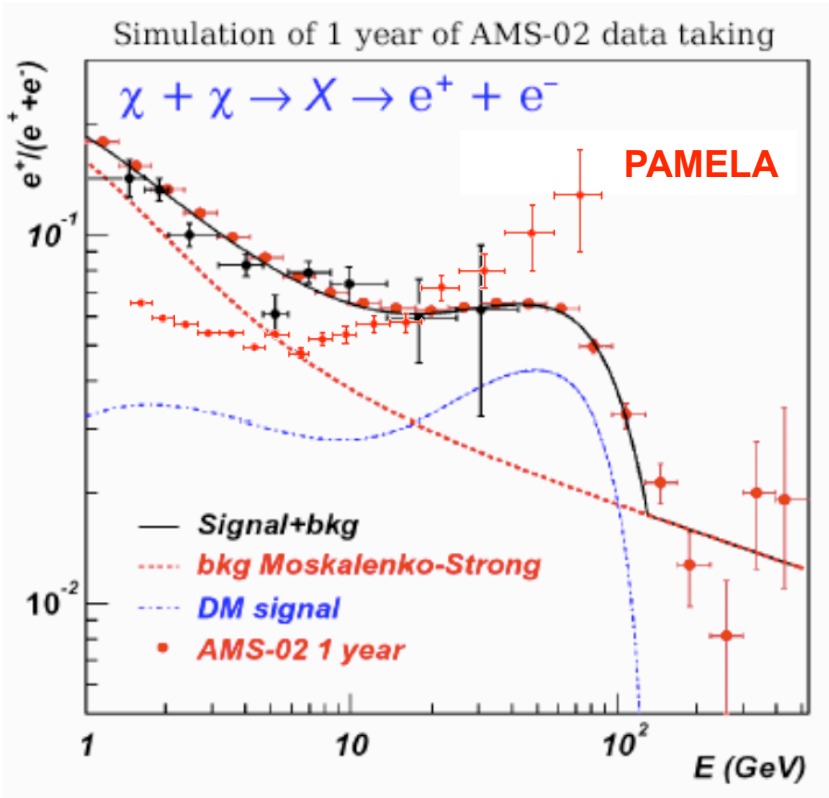


AMS02: e^+ and e^-

- **AMS02 will provide precise absolute flux for**
  - **e^+ up to 300 GeV**
  - **e^- up to 1 TeV**

High convidence level (e^+/p rejection factor > 10^5 up to 300 GeV)





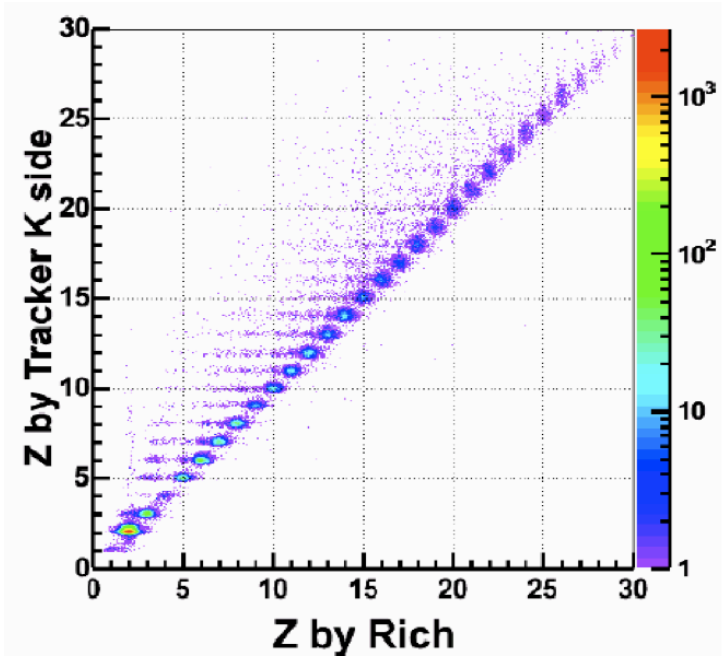
- **Possibility to study the anisotropy in e^- and e^+ arrival direction**

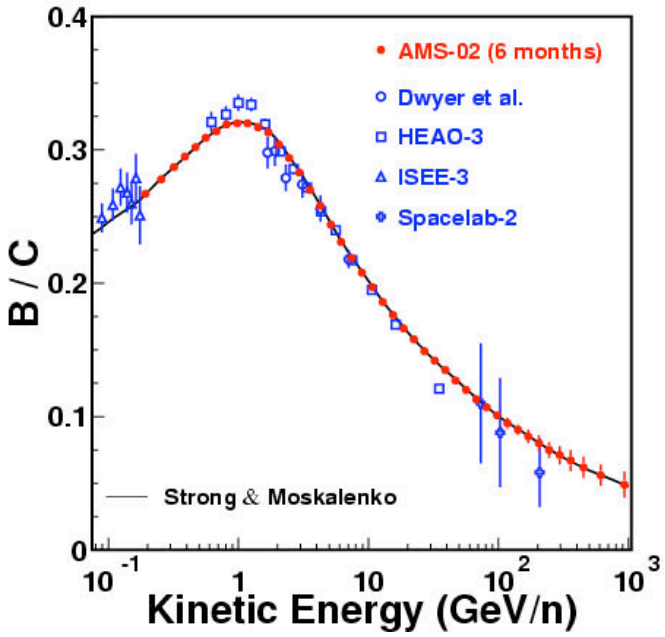
+Simultaneous measurement of $\bar{p}$ and search $\bar{d}$

AMS02 : Elemental flux and ratio

- **AMS02: charge identification from:**

  TOF, Silicon Tracker (Energy deposit) and RICH (Cherenkov light)



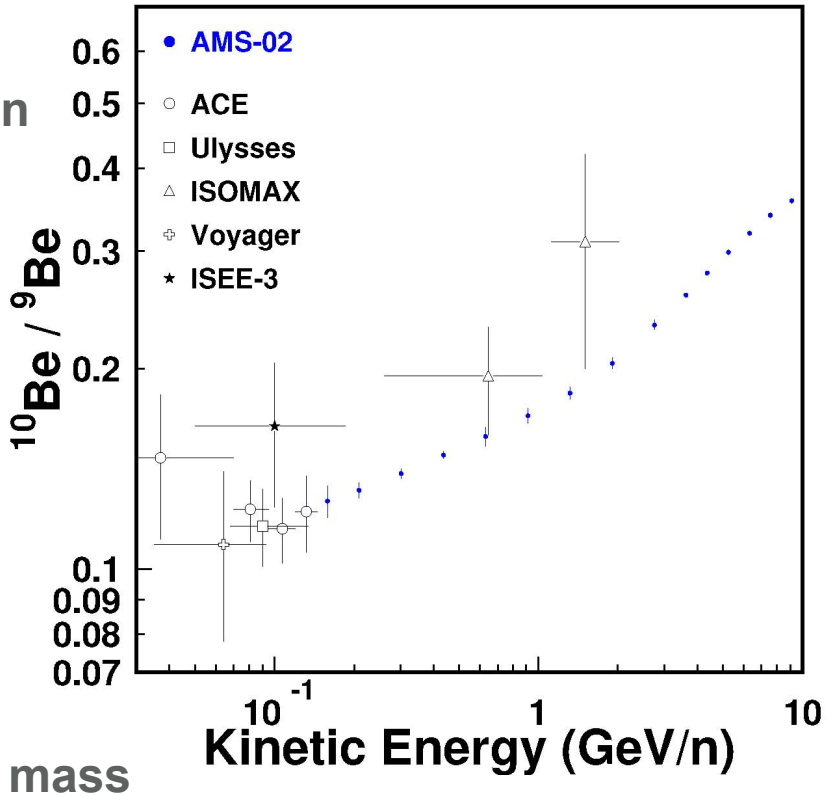


- **High-precision absolute flux measurement for all elements up to Z~30 and for 200 MeV/n < E < 1 TeV/n**

  ➡ **Complete set of data to constrain propagation models**

AMS02 : Radioactive Isotopes

- Confinement time of CR
- Breaks the degeneracy between diffusion strength (D_0) and diffusion halo size.
- Very important for DM annihilation flux estimate.
- But an instrumental challenge: mass identification
  - *Rigidity (Tracker) + Charge (Tracker /RICH) -> Momentum*
  - *Momentum + velocity (TOF/RICH) -> Mass*



Isotope identification relies on accurate mass identification ($\Delta m < 1$)

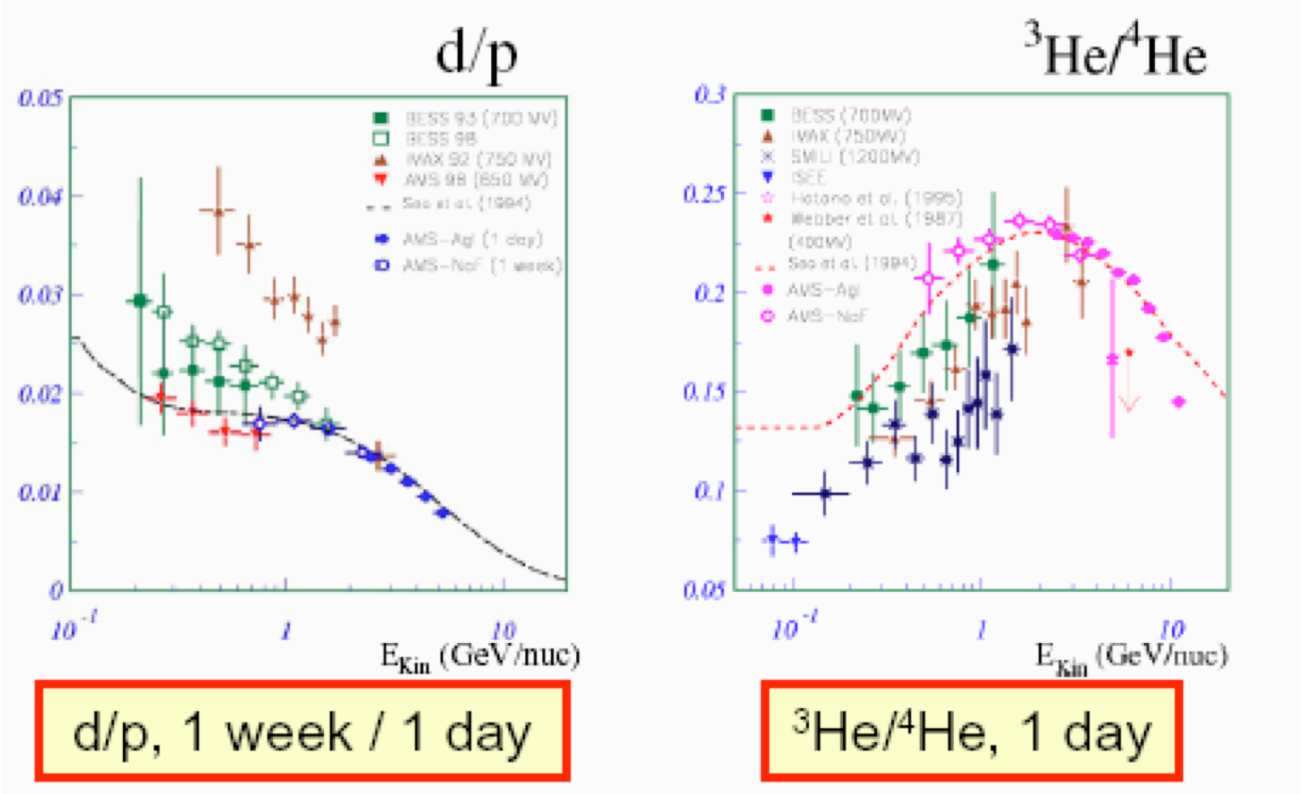
$$\frac{\Delta m}{m} = \frac{\Delta p}{p} \oplus \gamma^2 \frac{\Delta \beta}{\beta}$$

AMS02:

- Precise ^{10}Be/^{9}Be measurement up to 10 GeV/n
- But ^{26}Al and ^{36}Cl not measurable with AMS02

AMS02: The quartet

- Lightest nuclei in CR: p – d – ^{3}He – ^{4}He
  - ⇨ **Additional Secondary/Primary ratio: d/p and ^{3}He/^{4}He**
- mass identification needed (RICH)



d/p, 1 week / 1 day

^{3}He/^{4}He, 1 day

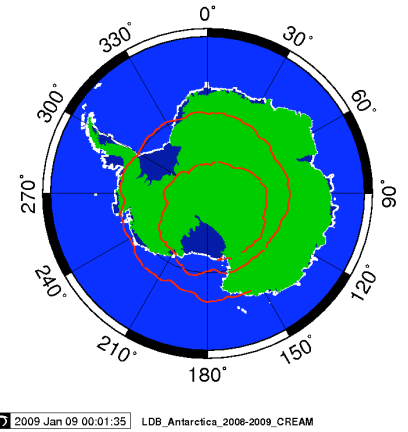
Provides additional inputs to test CR propagation models

The CREAM experiment

CREAM (Cosmic Ray Energetics and Mass):

- Balloon borne experiment, dedicated to high energy cosmic ray measurements between 1 TeV – 1000 TeV

- 4 LDB flights achieved: CREAM I-IV
  - **>100 days of cumulative exposure**
- Instrument:
  - **•Energy measurement: Tungsten-Calorimeter**
  - **•Charge identification:**
    - **–Silicon detectors**
    - **–Imaging Cherenkov Camera**
  - **•No e/p identification**
- Elemental spectra measurement:
  - **• Extends direct measurements to ground-based air shower energies.**
  - **• Secondary/Primary ratio at high Energy: "direct" constrain on the diffusion index (δ).**

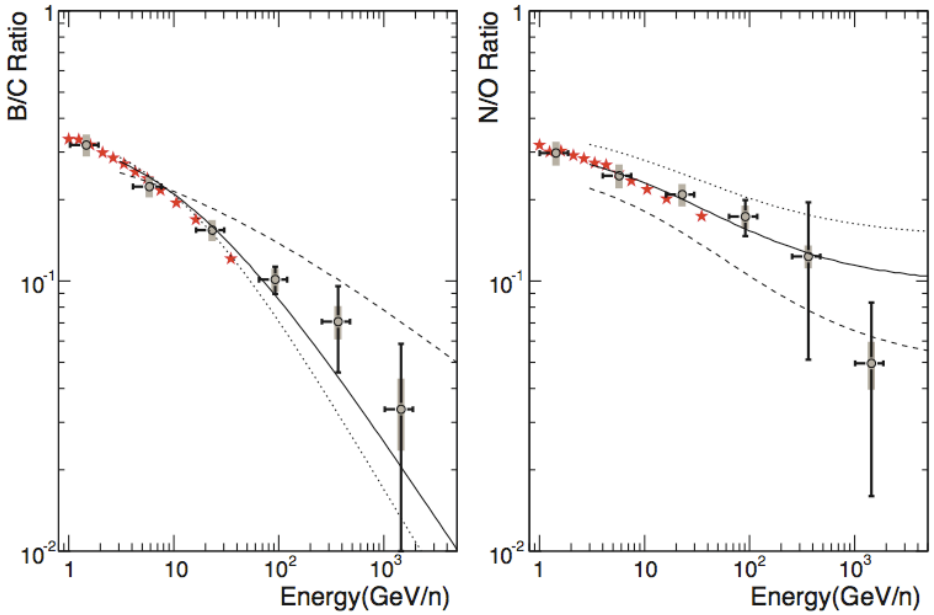


CREAM IV trajectory: 21 days flight

CREAM Coll. : US, Korea, Italie, Mexico, France

CREAM

- **CREAM I: B/C and N/O Ratio**



- **CREAM II: Elemental flux measurement to be released soon**
- **CREAM III & IV: Analysis in progress…**

- **CREAM V: Next flight campaign this (Antarctic) summer**

Mid-long term future : Ultra Long Duration Balloon (ULDB) flights

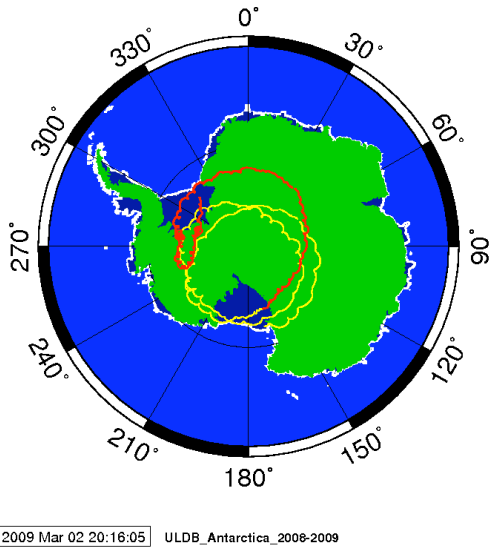
ULDB

NASA Balloon Program is developing a Super Pressure Balloon.

- **Sealed and pressurized to maintain constant altitude night and day**
- **0.6 million m^3 balloon able to carry a one-ton instrument for 100 days**

Test flight during the Antarctica campaign 08-09

- **0.2 million m^3 balloon (scale 1/3 model)**
- **Sets new flight record of 54 days**



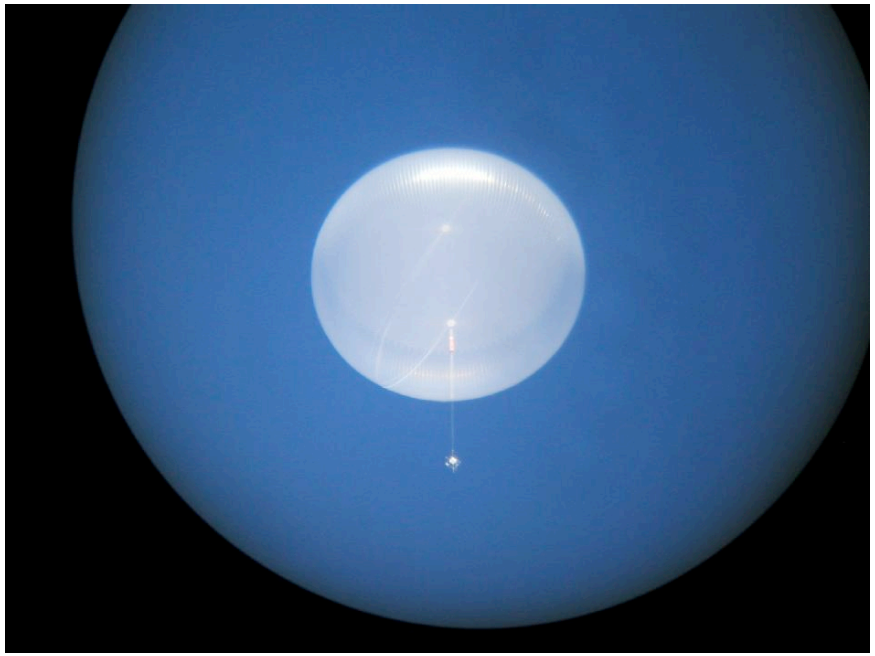


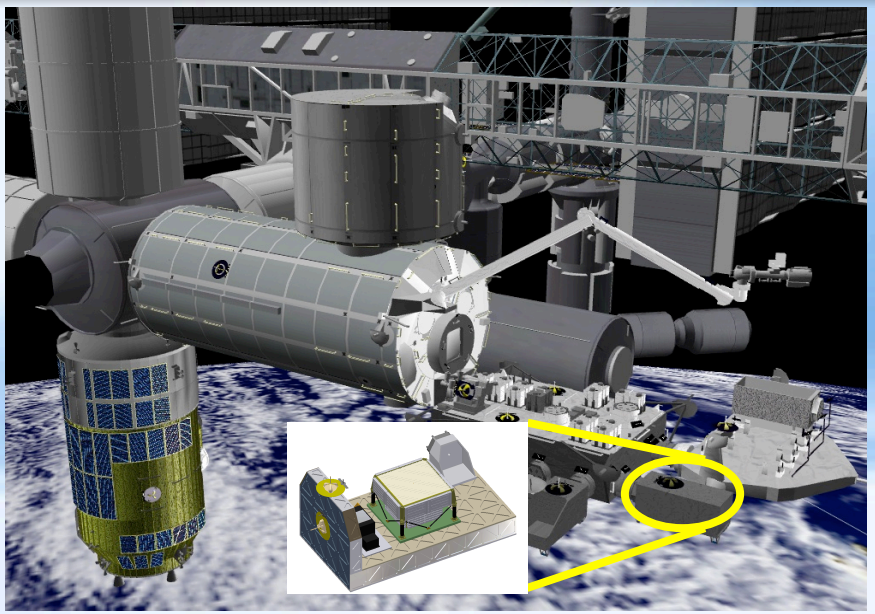
Image of the SPB taken through a telescope

First ULDB scientific flight in forthcoming years

CALET: CALorimetric Electron Telescope

CALET Mission Concept

- **Instrument:**
  High Energy Electron and Gamma-Ray Telescope Consisted of
  - Imaging Calorimeter (IMC)
  - Total Absorption Calorimeter (TASC)
- **Launch:**
  HTV: H-IIA Transfer Vehicle
- **Attach Point on the ISS:**
  Exposed Facility of Japanese Experiment Module (JEM-EF)
- **Life Time:**
  >3 years
- **Mission Status**
  Launch around 2013 in Plan



CALET Payload:

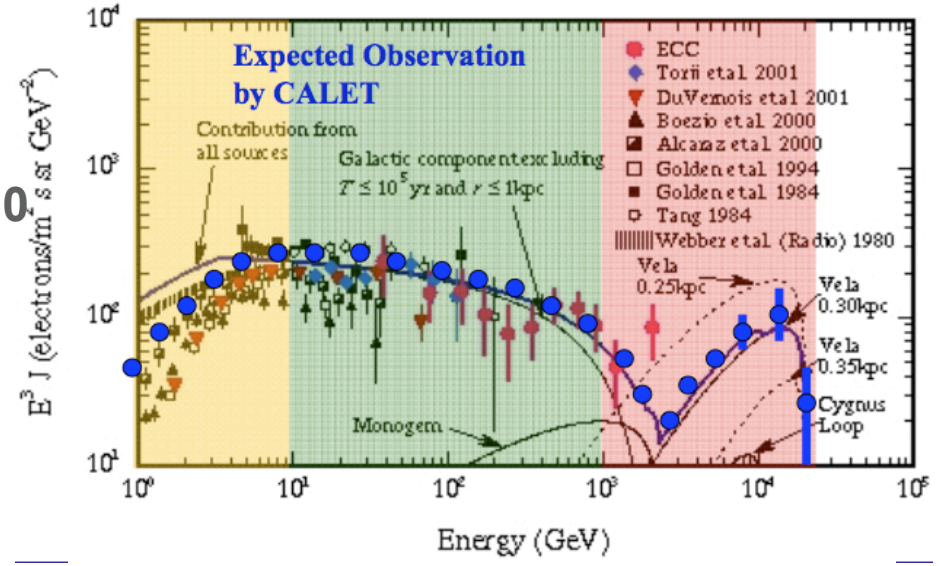
- 1GeV ~ 10 TeV for electrons ($e^+ + e^-$)
- 20 MeV ~ TeV for gamma-rays
- Several 10 GeV ~ 1000 TeV for nuclei
- Geometrical Factor: 1 $m^2 sr$

Japan/USA/Italie/China (PPB-BETS coll.)

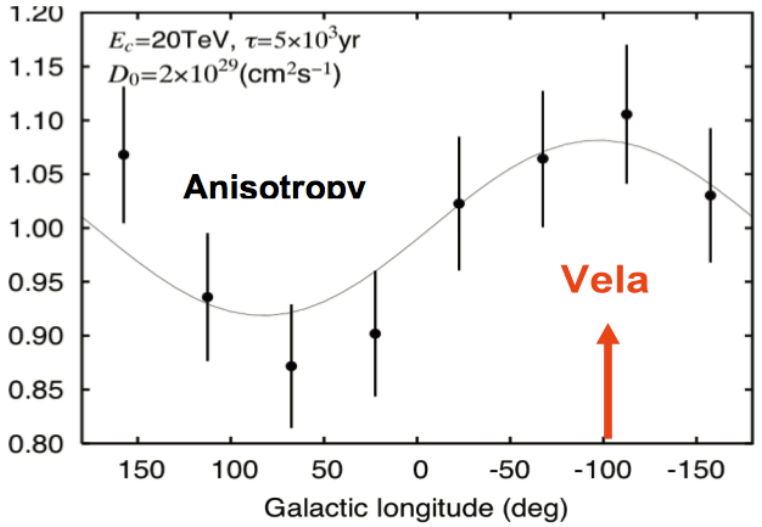
CALET: All electron flux

➢All electron (e^- + e^+) flux up to 20 TeV

- *Precise flux from GeV to TeV range*
- *Above 1 TeV, sensitive probe of nearby accelerating sources.*

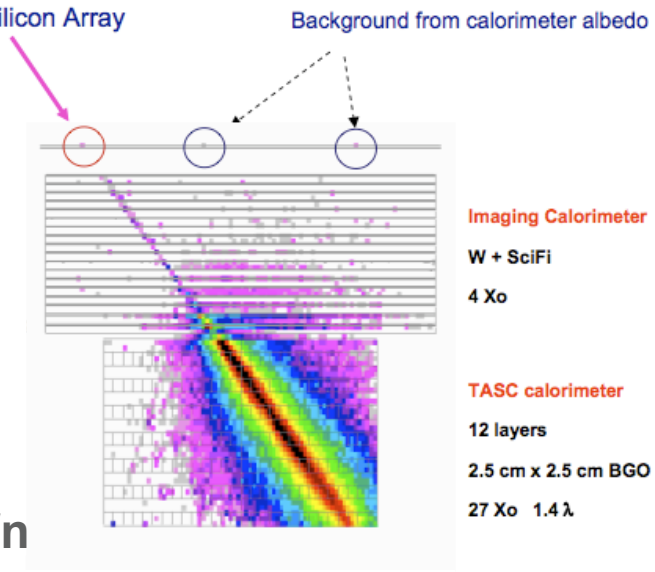


➢Measurement of the anisotropy in electron arrival directions due to local source

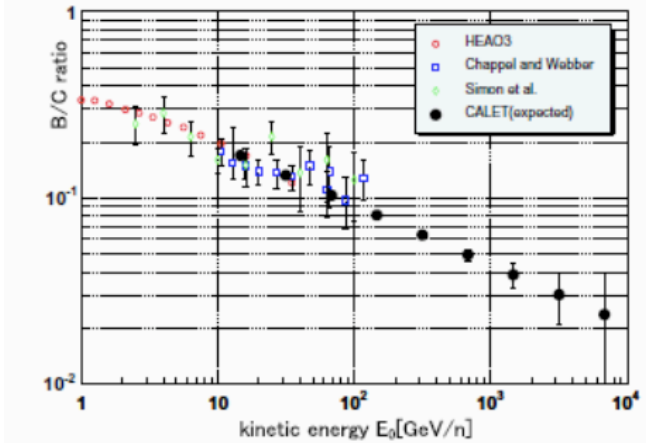


CALET: Elemental flux

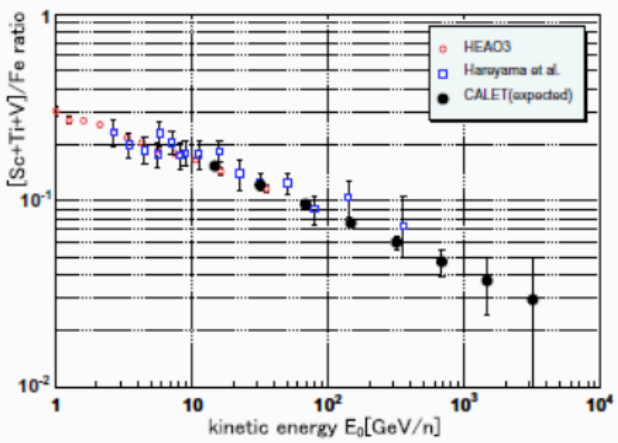
- CALET will also measure proton and heavier nuclei flux.
- Secondary/Primary ratio up to several TeV/n



B / C Ratio



Sub Fe / Fe



bCALET

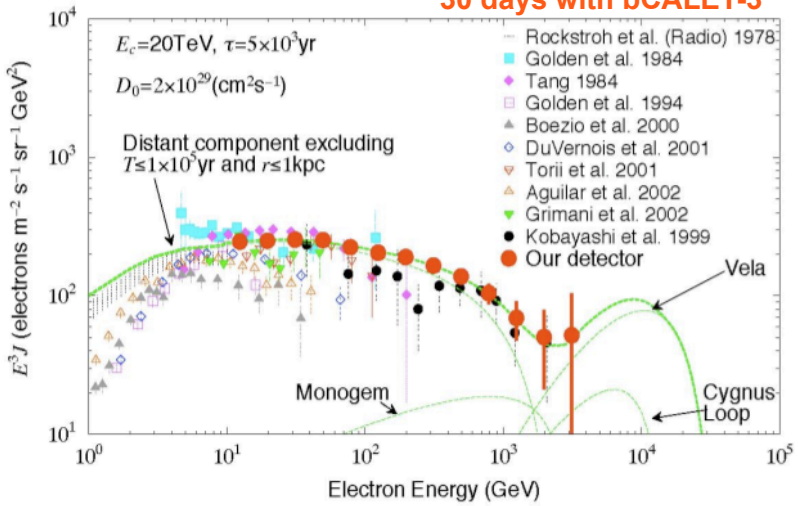
bCALET : CALET on balloon

- **bCALET-1 (1/64 scale of CALET)**
  Was flown in 2006 from Sanruki Balloon Center

- **bCALET-2 (1/32 scale of CALET)**
  In preparation

- **bCALET-3 (1/4 scale of CALET)**
  Long Duration Flight

30 days with bCALET-3



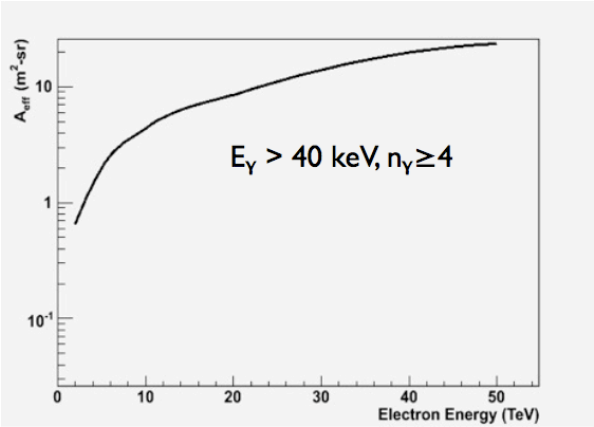
CREST

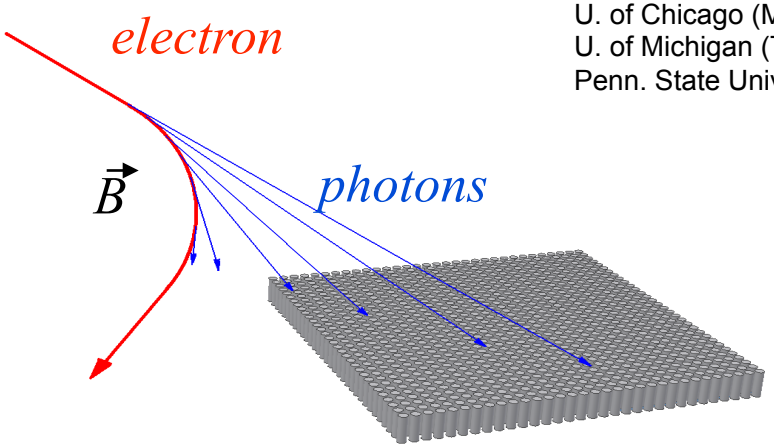
Cosmic-Ray Electron Synchrotron Radiation Telescope

Extend all electron (e^-+e^+) flux measurements up to 50 TeV

Synchrotron x-rays from electrons in earth's magnetic field

- **Key Idea: Effective Area > Physical Detector Size**





Indiana University (Musser)
U. of Chicago (Müller/Wakely)
U. of Michigan (Tarle)
Penn. State Univ. (Coutu)

- **Detector: 1024 BaF_2 Crystal+PMT Array**
  - **Event selection via fast timing and geometry**
  - **Electron energy from x-ray photon energy**

position sensitive detector (2.5 x 2.5 m)

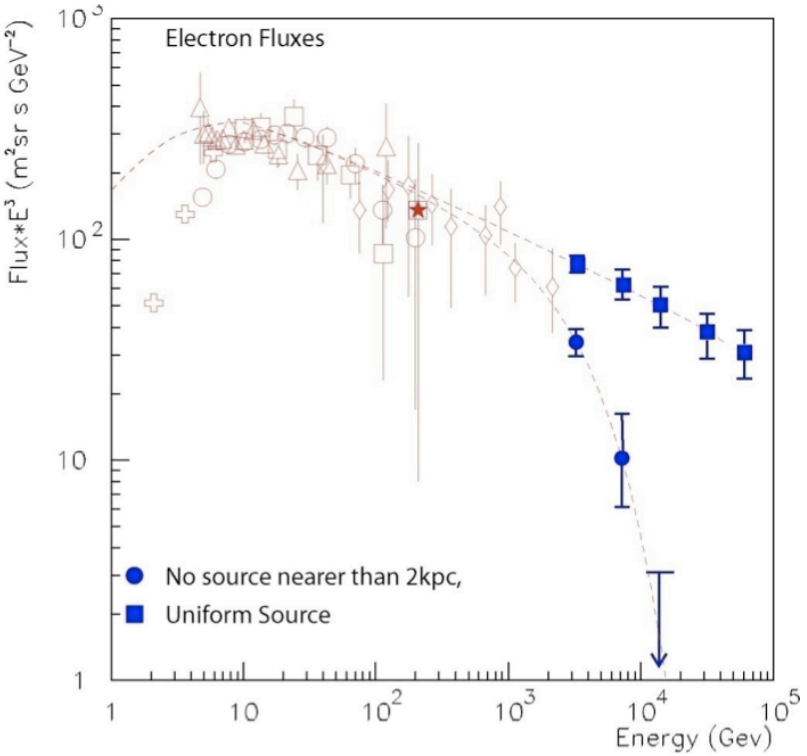
CREST

CREST calendar:

- **CREST test flight is currently taking place (Ft. Summer)**
- **LDB/ULDB Flight in Antarctica in the forthcoming seasons**
- **Long-term future : CREST in Space**

No atmosphere, lower x-ray threshold, longer exposure

Expected result: 100-day CREST exposure for two extremes: no local source, and for a uniform source distribution



About 2 events/day above 2 TeV
Assumes $E^{-3.3}$ spectrum with no cutoff

Conclusions

- Current and future experiments in the forthcoming years:
  - **Space experiments : PAMELA - FERMI - AMS02 - CALET**
  - **Balloon experiments : ATIC – CREAM – bCALET - CREST**
    - ULDB : research platform for the future

- They will provide new e^- and e^+ measurement with:
  - **More statistics**
  - **Absolute fluxes for e^+, e^-**
  - **Extended energy range**

- These new data should confirm (or not) the e^+ and e^- excess and allow to investigate their origin.

- New nuclei (elemental and isotopic) precise flux measurements

Very important data to understand source & propagation mechanisms:

- **Better constrains on propagation models.**
- **Better estimation of primary, secondary and exotic e^+ and e^- flux.**