The Cosmic Ray Electron Excess

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LETTERS

An excess of cosmic ray electrons at energies of 300–800 GeV

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Galactic cosmic rays consist of protons, electrons and ions, most of which are believed to be accelerated to relativistic speeds in supernova remnants[1–3]. All components of the cosmic rays show an

reviewed briefly here and in the Supplementary Information (section 1). The basic ATIC energy calibration is provided by cosmic-ray muons recorded just before each flight, as well as by the shower data itself.

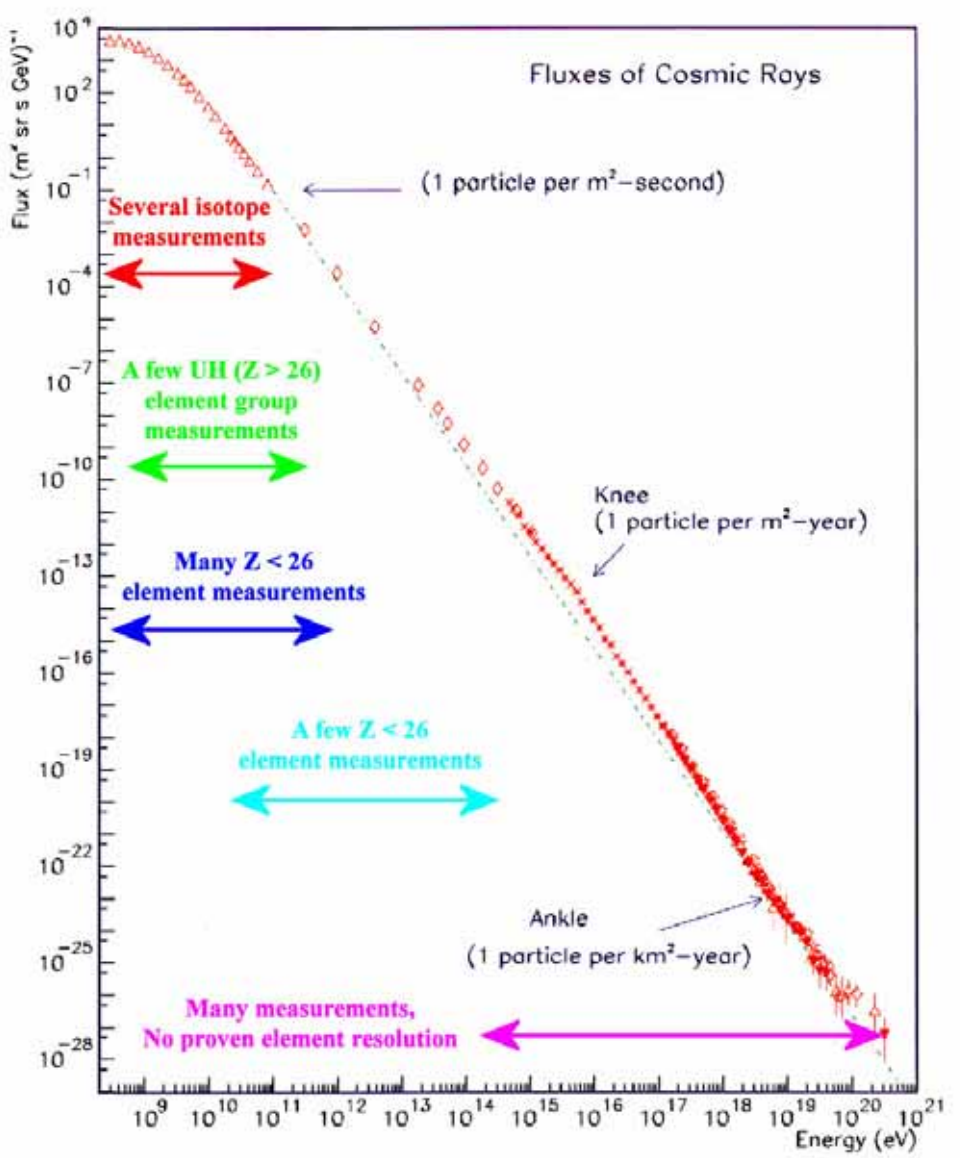
Cosmic Ray Research:
Determines Composition and Energy of Cosmic Rays to understand the "Cosmic Accelerator". Method: Measure Cosmic ray composition and spectrum and propagate back to source composition

Composition:

- All elements from H to "U"
- Relative abundance covers 11 orders of magnitude
- Mostly similar to "solar system" composition

Energy Spectrum:

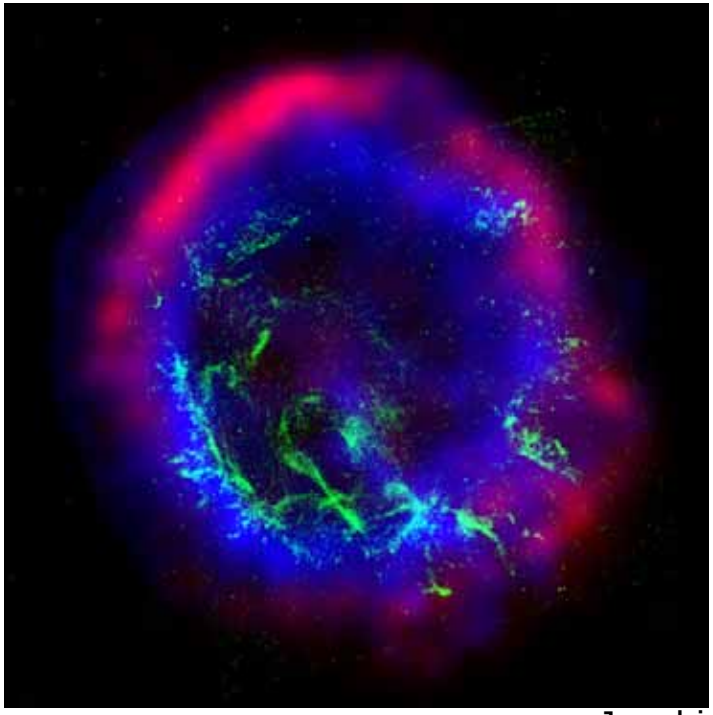
- Mostly a power law in energy with index ~ -2.7
- Energy covers more than 20 orders of magnitude
- Flux varies by more than 30 orders of magnitude



Joachim

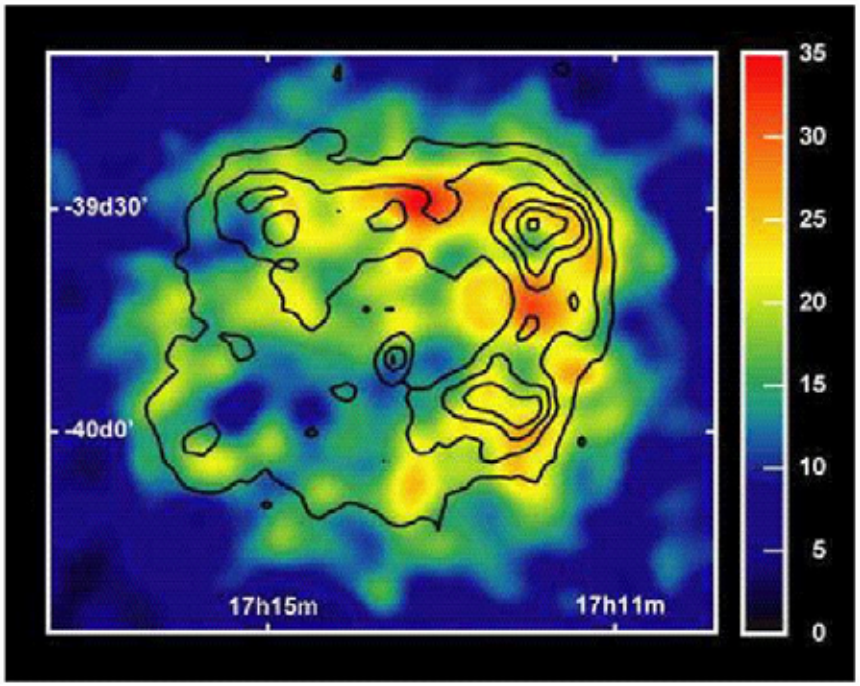
Potential candidates: Super Novas, Super Nova Remnants, Pulsars, Microquasars, Dark matter decay?, …..

Color-composite image of E0102-72.3: Radio from ATCA; X-ray from Chandra and Visible from HST.

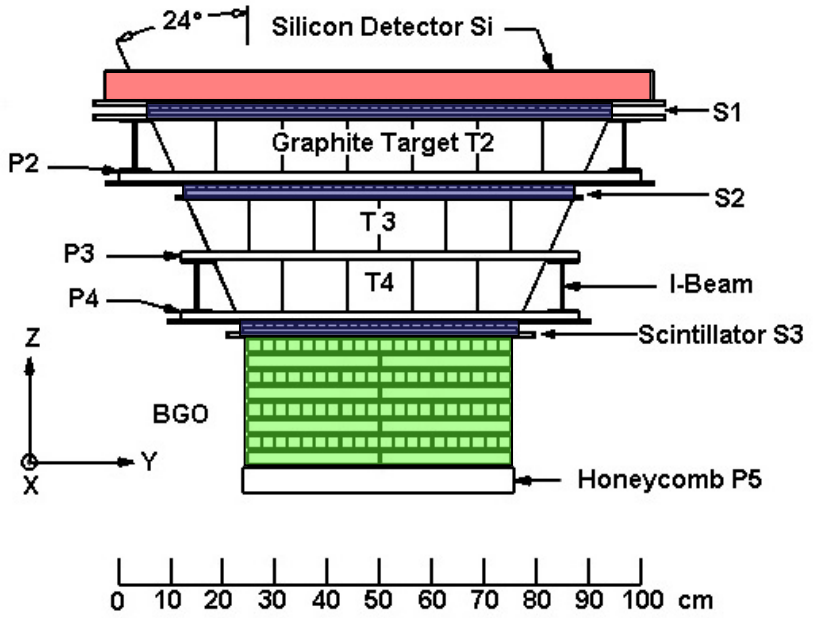


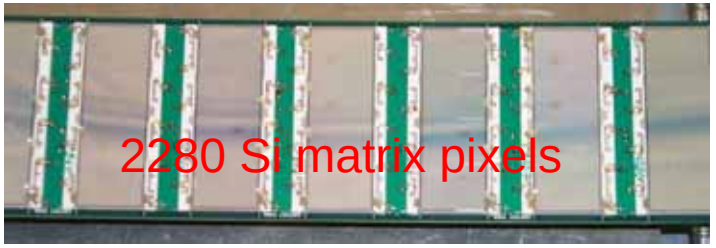
HESS image of RX J1713.7-3946

TeV gamma rays

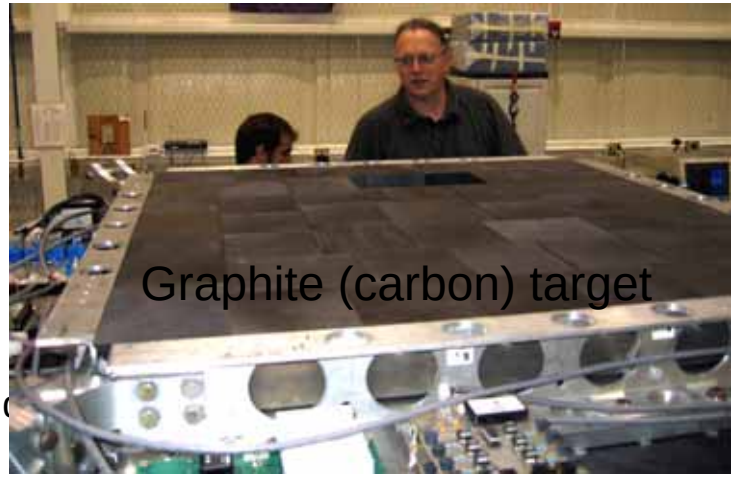


The ATIC Instrument

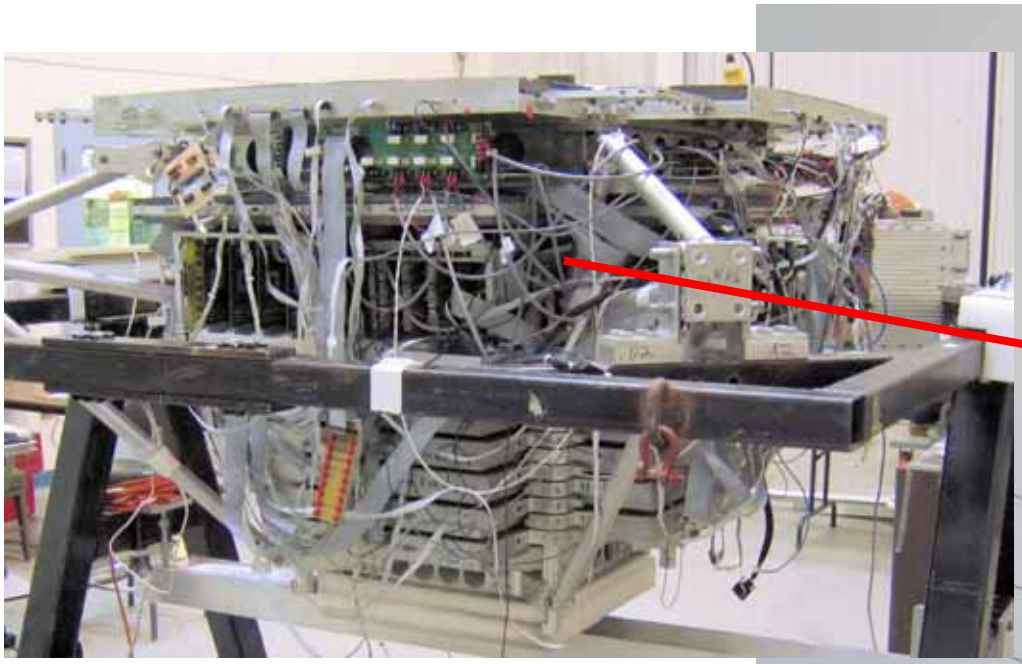


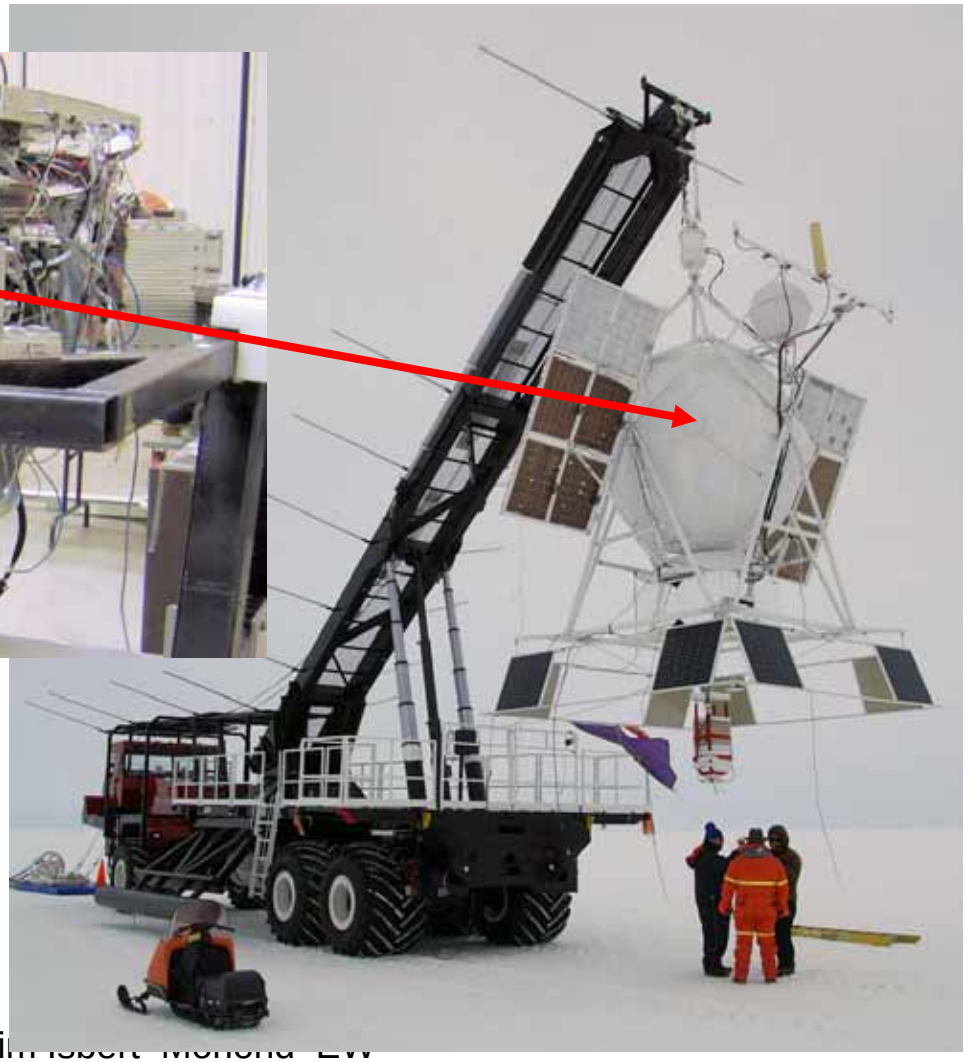


BGO calorimeter, 17.3 rl, 4 XY, planes, ATIC 1+2, 22.5 rl, 5 XY planes, ATIC 4

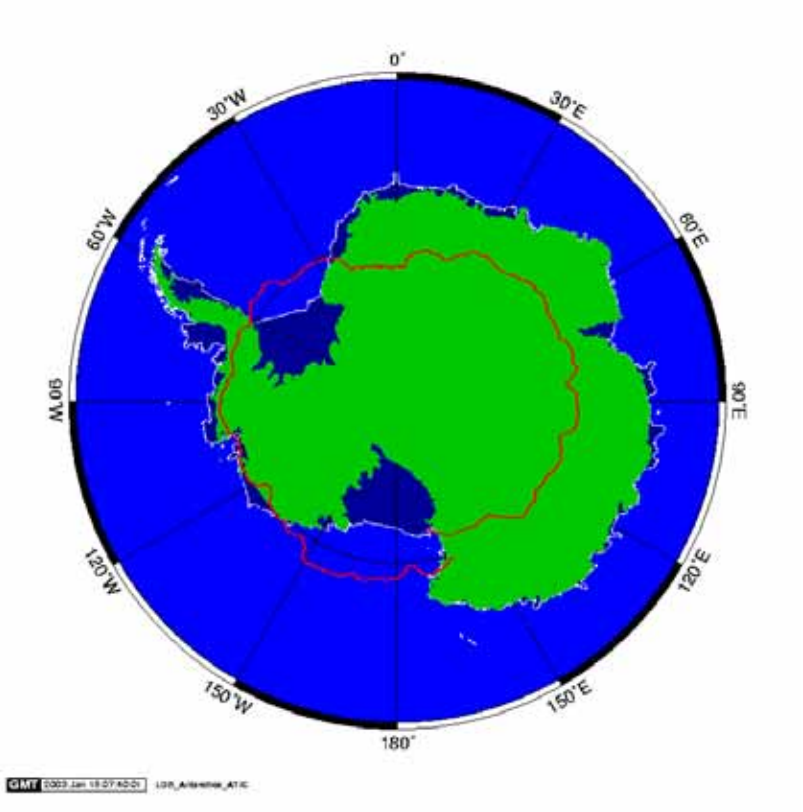


ATIC was constructed as a balloon payload



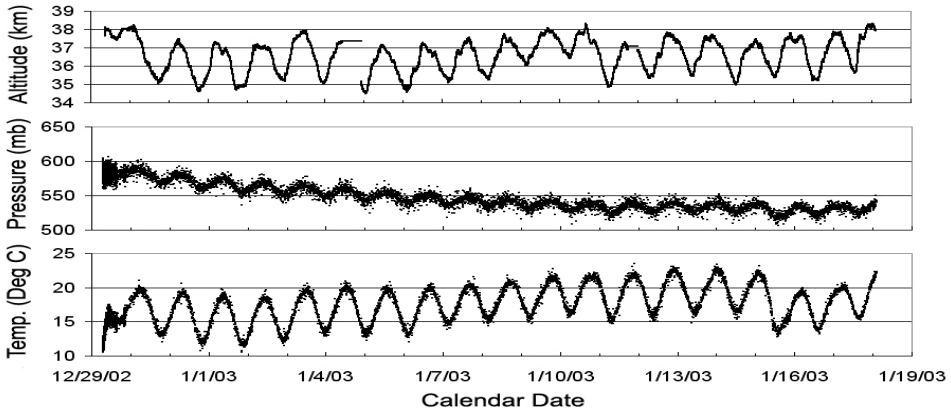


ATIC-2 Science Flight from McMurdo - 2002



- 65 Gbytes Recorded Data
- 16,900,000 Cosmic Ray events
- High Energy Trigger > 75 GeV for protons
- >96% Live-time
- Internal pressure (~8 psi) decreased slightly (~0.7 psi) for 1st 10 days then held constant
- Internal Temperature: 12 – 22 C
- Altitude: 36.5 ± 1.5 km

- Launch: 12/29/02 04:59 UTC
- Begin Science: 12/30/02 05:40 UTC
- End Science: 01/18/03 01:32 UTC
- Termination: 01/18/03 02:01 UTC
- Recovery: 01/28/03; 01/30/03



Recovery expeditions to the plateau



The good ATIC-1 landing (left) and the not so good landings of ATIC-2 (middle) and ATIC-4 (right)

ATIC is designed to be disassembled in the field and recovered with Twin Otters. Two recovery flights are necessary to return all the ATIC components. Pictures show recovery flight of ATIC-4

Joachim Isbert Moriond EW
2009

How are electrons measured?

- Silicon matrix identifies charge
- Calorimeter measures energy to $\pm 2\%$
- Key issue: Separating protons and electrons
  - Use interactions in the target
    - 78% of electrons and 53% of protons interact
  - Energy deposited in the calorimeter helps:
    - Electrons 85%; Protons 35% $\Rightarrow E_p = 2.4 X E_e$
    - Reduces proton flux by X0.23
  - Combined reduction is X0.15, then
  - Examine shower longitudinal and transverse profile

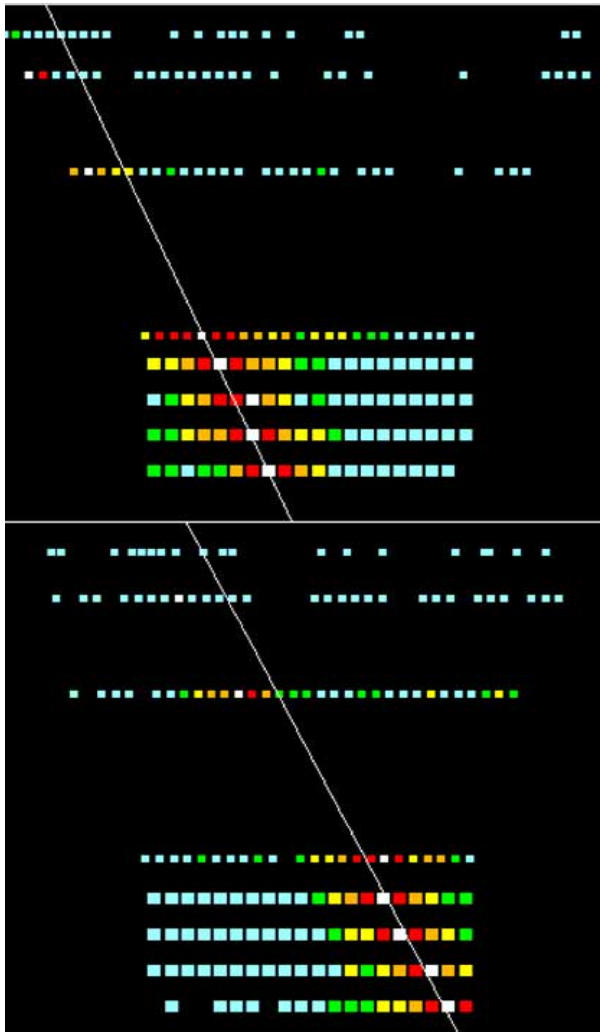
p,e,γ Shower image in ATIC (from Flight data)

Energy deposit in BGO ~ 250 GeV

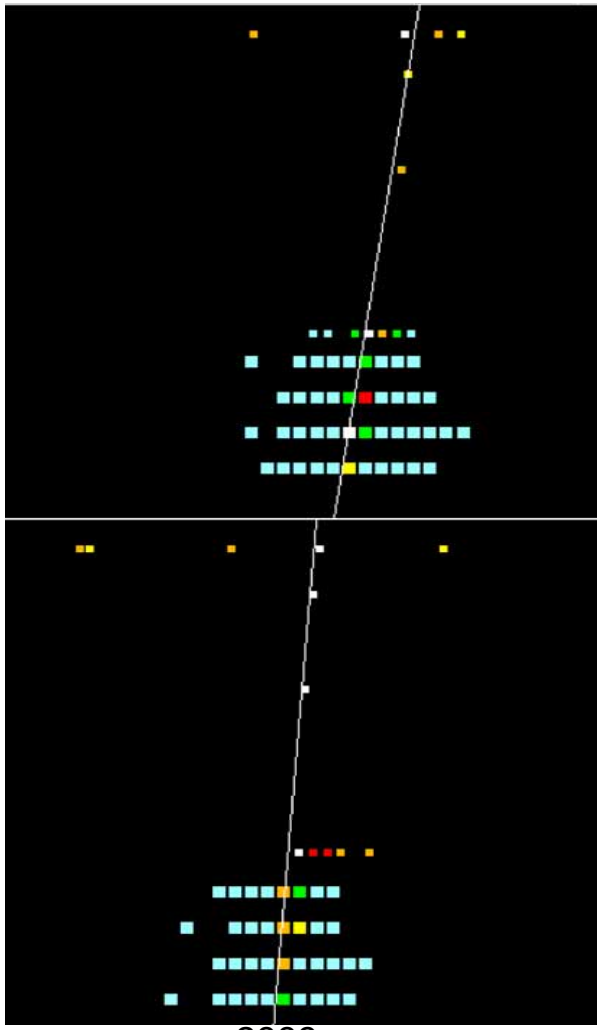
Electron and gamma-ray showers are narrower than the proton shower

Gamma shower: No signal in the Si matrix detectors around the shower axis

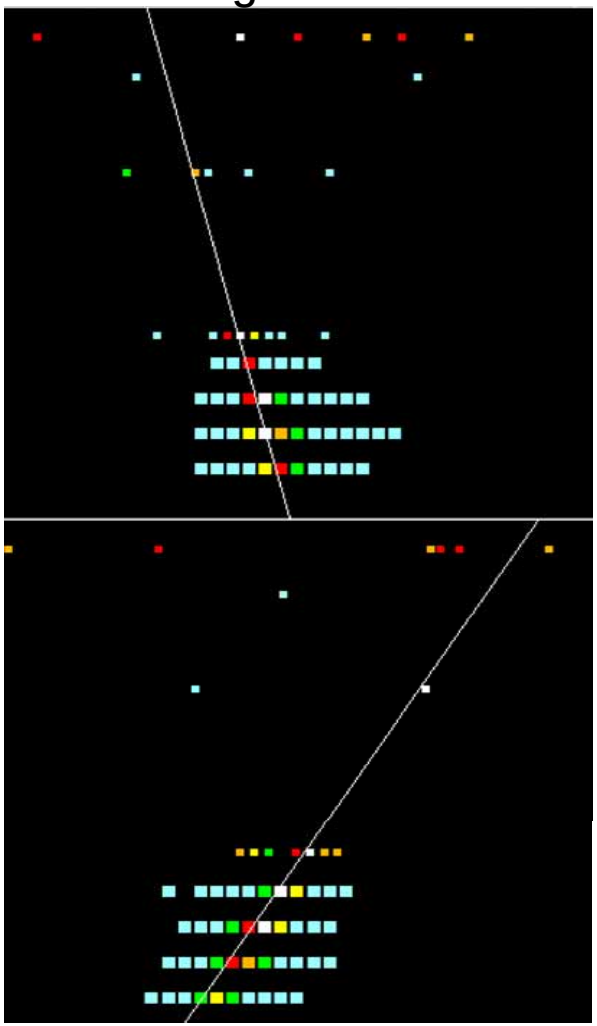
Proton



electron



gamma



Parameters for Shower analysis

- RMS shower width in each BGO layer

$$\langle r.m.s. \rangle^2 = \sum_{i=1}^{n} E_i (X_i - X_C)^2 / \sum_{i=1}^{n} E_i$$

- Weighted fraction of energy deposited in each BGO layer in the calorimeter

$$F_j = \langle r.m.s. \rangle^2 \left[E_j / \sum_{i=1}^{n} E_i \right]$$

The method to select electron events:

1. Rebuild the shower image, get the shower axis, and get the charge from the Si-matrix detector:

0.8<Z<1.6, E>50GeV, χ^2<1.5, good geometry

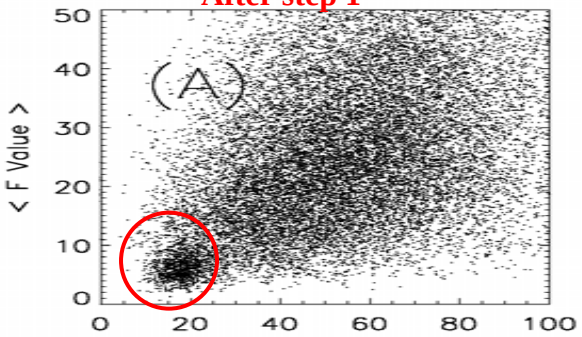
2. Shower axis analysis

Reject Protons which have their first interaction point in carbon

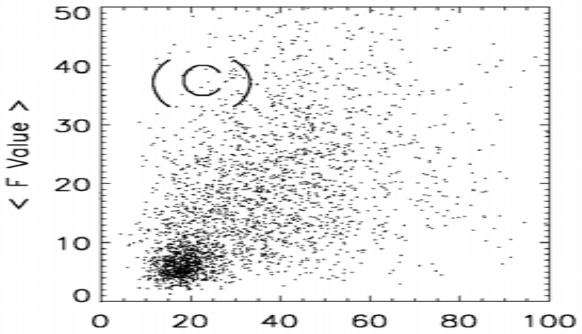
3. Shower width analysis:

Cut F values for BGO1, BGO2 and BGO7, BGO8

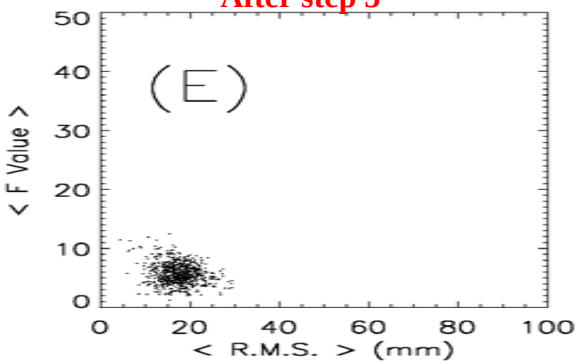
After step 1



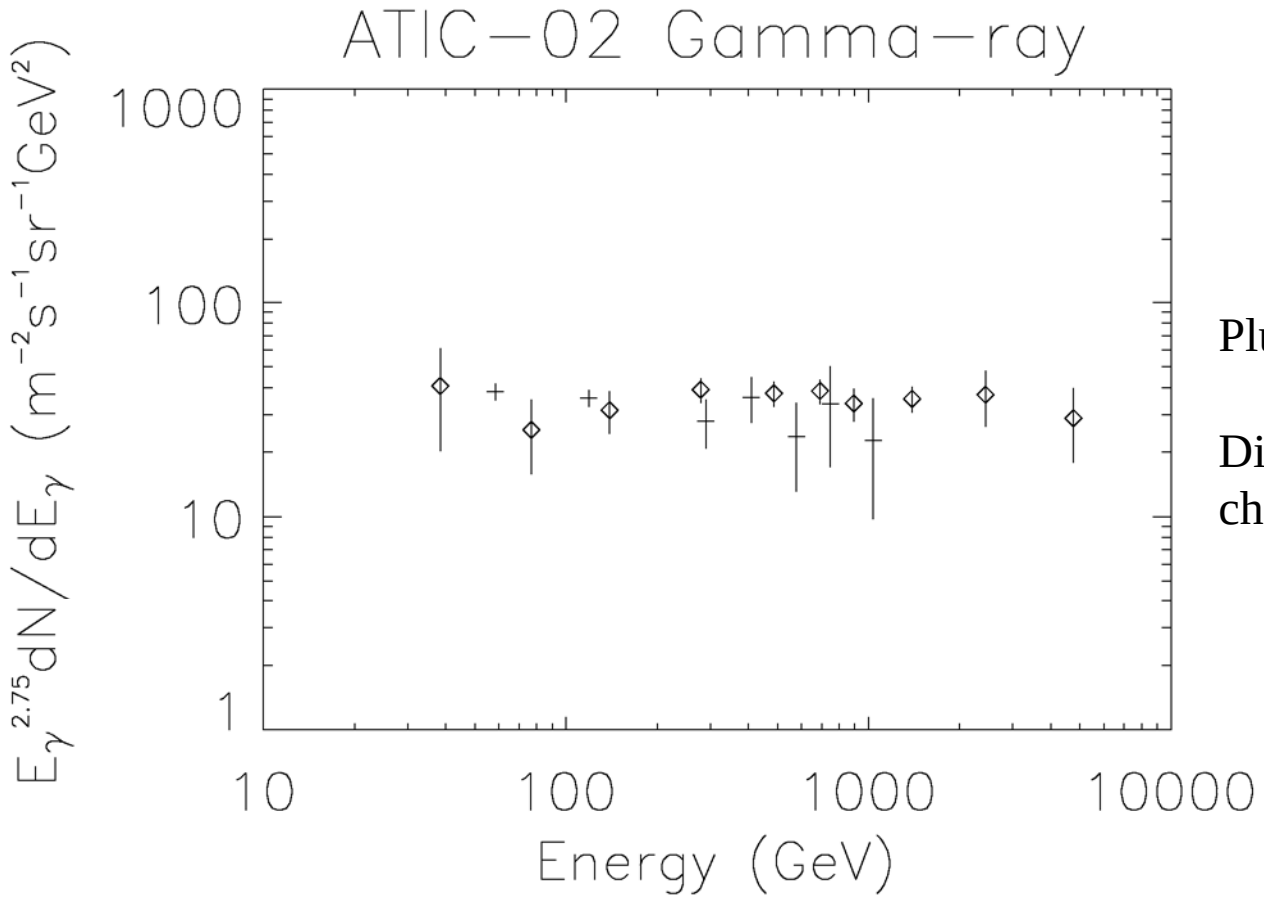
After step 2



After step 3



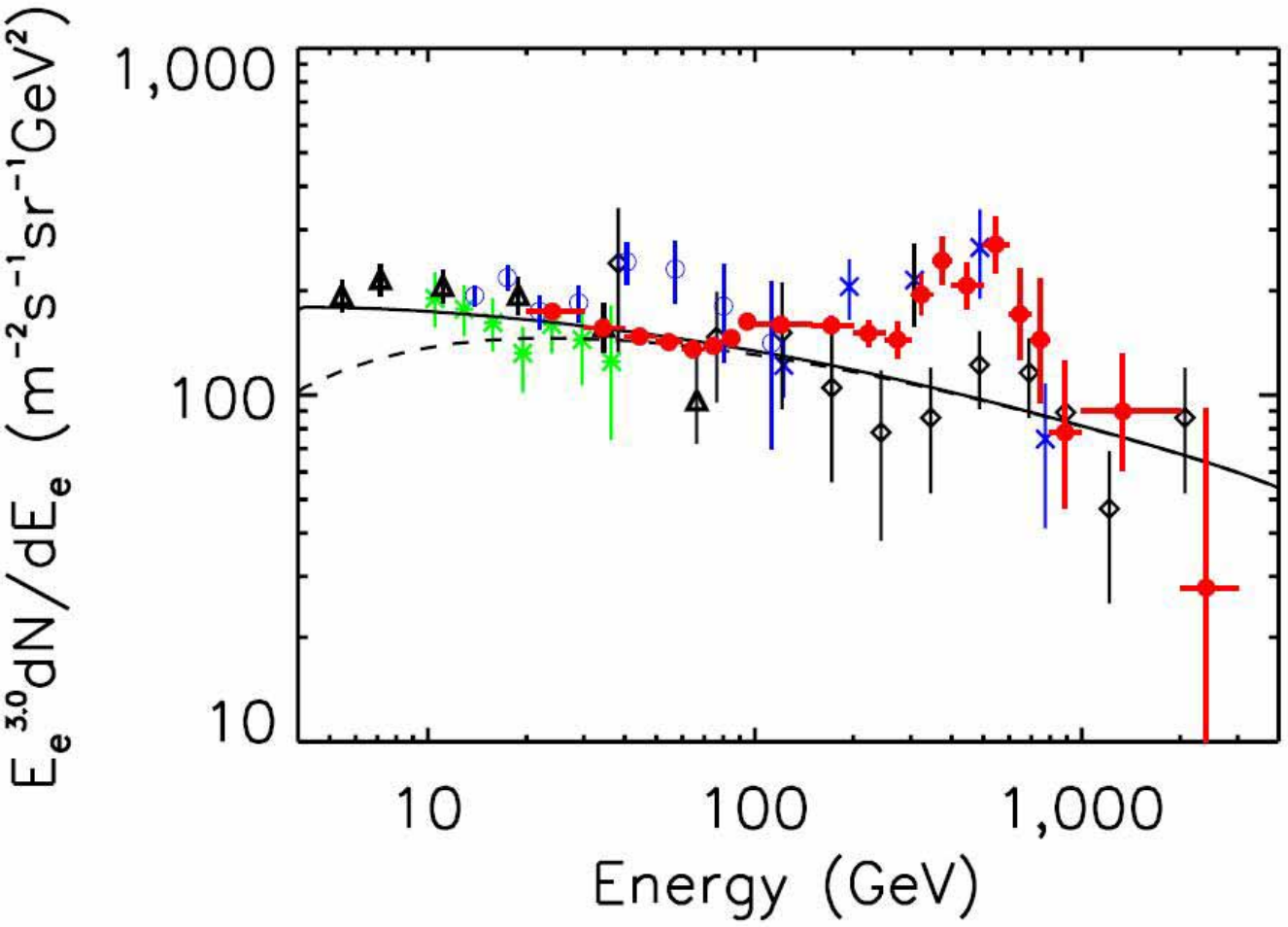
Atmospheric Gamma-rays:
Test of the electron selection method



Plus: ATIC

Diamond: Emulsion chamber

Measured Electron Spectrum



AMS (stars)

HEAT (triangles)

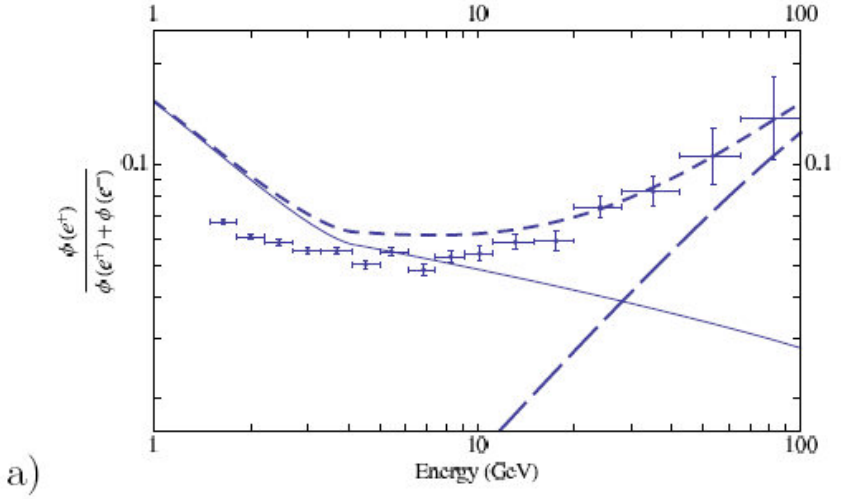
BETS (circles)

PPB-BETS (crosses)

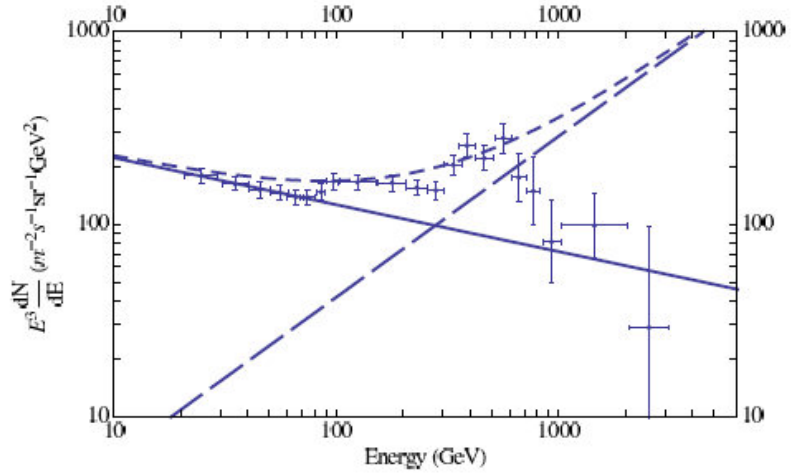
Emulsions (diamonds)

ATIC (red circles)

A connection between the PAMELA and ATIC measurements?



a)



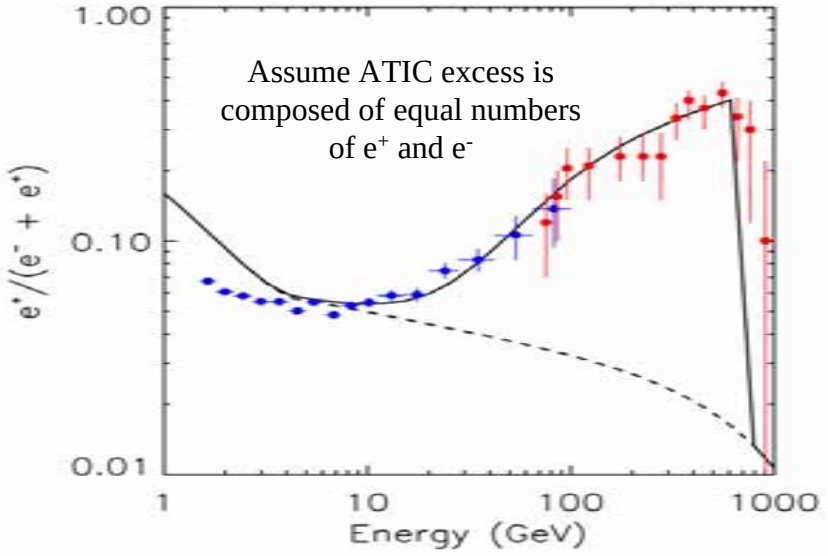
b)

Simple argument from Cholis et al. (arXiv: 0811.3641v1), 2008

Fit power law component to > 10 GeV PAMELA positive fraction (a)

Assume this component is composed of equal numbers of e^+ and e^- and extrapolate to ATIC energy range (b)

Solid line: Spectrum + galprop for 620 GeV particle decay.



Conclusions

- The ATIC excess is evidence for a nearby cosmic ray electron source
- The ATIC and PAMELA results taken together could point to a nearby source of electrons and positrons, possibly from dark matter annihilation
- A measurement of the positron contend in the ATIC excess is needed

The ATIC-3 attempt ended in disaster!

- ATIC-3 was launched Dec. 19, 2005
- Balloon failure occurred almost immediately after launch
- Reached only 75,000 feet before starting down
- Had to quickly terminate as ATIC was headed out to sea
- Landed only 6 miles from edge of ice shelf

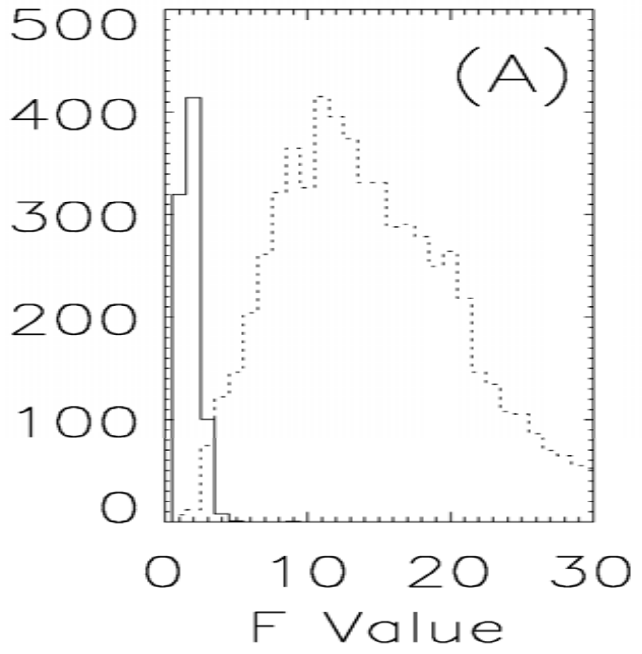
- The instrument was fully recovered instrument and refurbished in preparation for the 4th and final flight of ATIC in 2007.

F distribution comparison of protons and electrons in BGO between Simulation (GEANT) and CERN data taken 1999

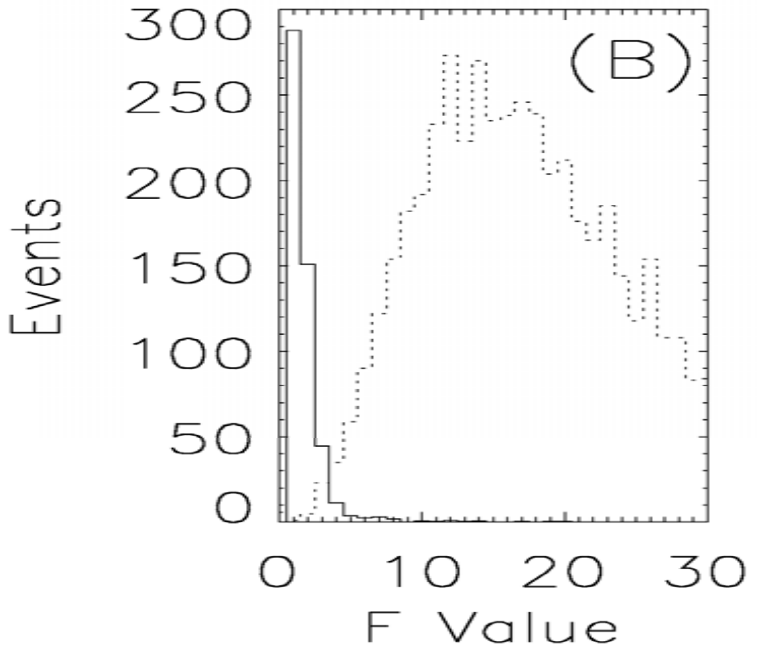
Solid line: 150 GeV electrons

Dashed line: 375 GeV protons → comparable energy deposit in BGO

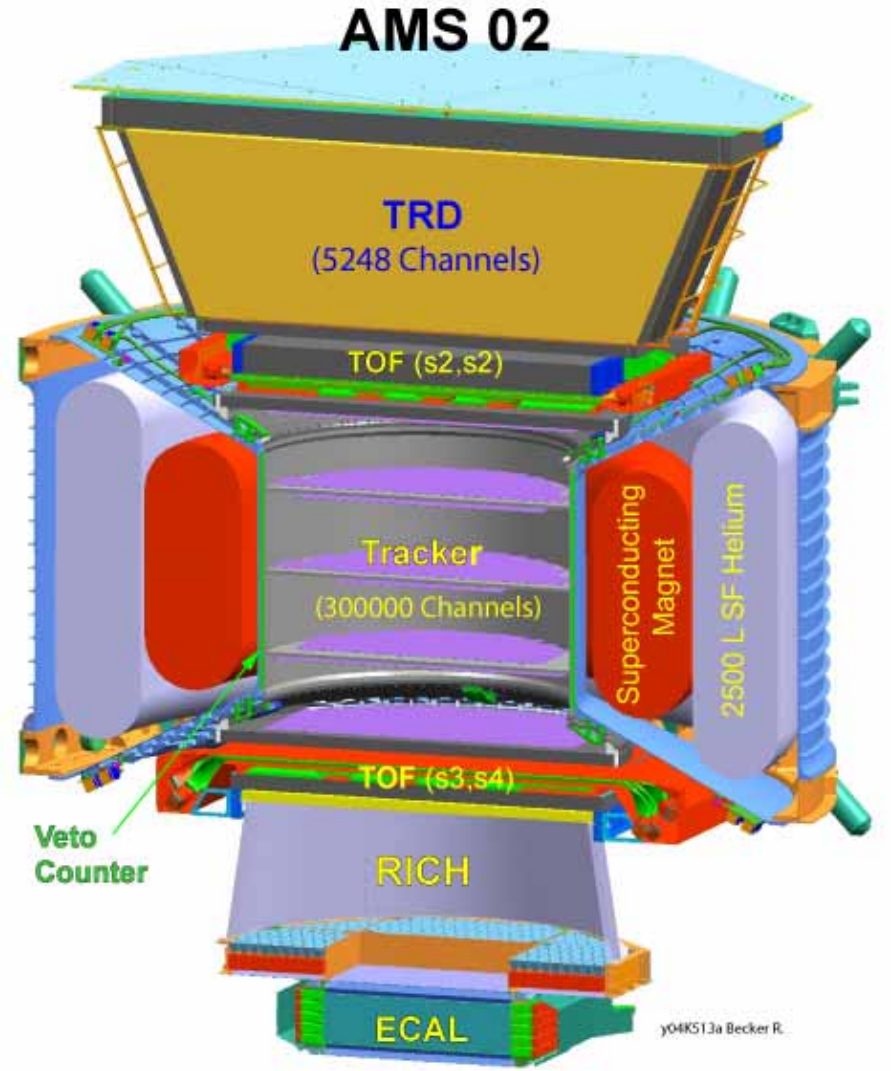
Simulation



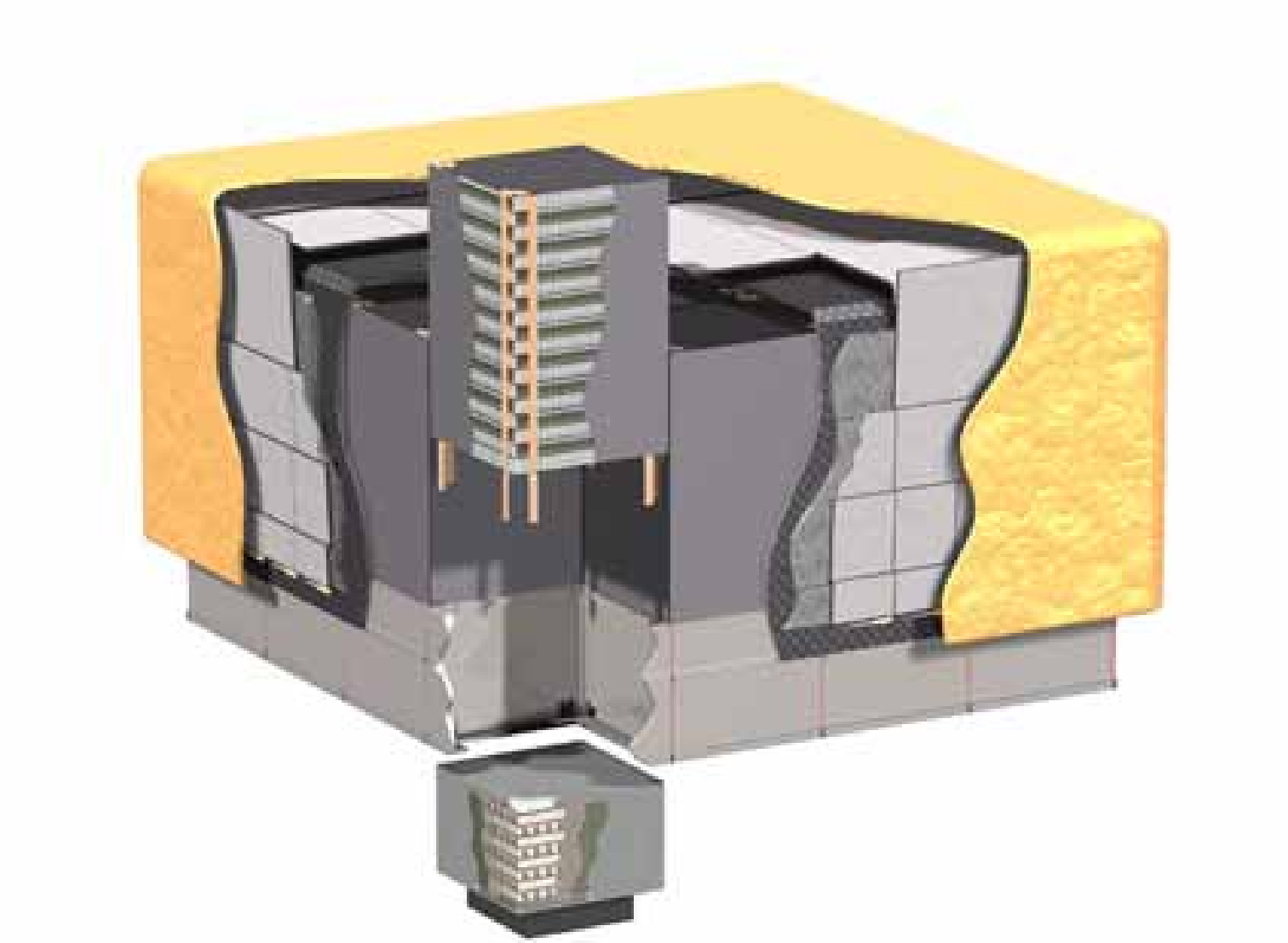
CERN calibration



Alpha Magnetic Spectrometer



FERMI (former GLAST) LAT



HEPCaT on OASIS