e± in Cosmic Rays

Positrons from secondary production
p-ISM → π⁺ → μ⁺ → e⁺

- e± lose energy rapidly $\propto E^2$
  → high energy electrons are “local.”

- e± produced in pairs (in ISM).

- $e^+/(e^+ + e^-)$ fraction is small ($\approx 10\%$)
  → substantial primary $e^-$ component.
Why do we care?

Structure in the CR Positron fraction - as first observed by HEAT instrument - could be DM signature* (or nearby pulsars or...?**)


A number of measurements have been made .. some as early as mid 1960s
CR Positron measurements are challenging

Flux of CR protons in the energy range 1 – 50 GeV exceeds that of positrons by a factor of $5 \times 10^4$.

Proton rejection of $10^6$ is required for a positron sample with less than 1% proton contamination.

The single largest challenge in measuring CR positrons is the discrimination against the vast proton background!
1965, 1966: Manitoba
(Fanselow, Hartman, Hildebrand, Meyer, 1969)

1967: Italy
(Agrinier et al. 1969)

1972: Manitoba
(Daugherty, Hartman, Schmidt, 1975)

1972: Texas
(Buffington, Orth, Smoot, 1974)

1974: Manitoba
(Hartman and Pellerin, 1976)

1976: Texas
(Golden et al., 1987)

1984: Hawaii
(Müller and Tang, 1987)
CR positron measurements
The early years: 1965 - 1984

Dramatic rise at high energies?
CR positron measurements: The 90s

1989: Saskatchewan
  (MASS - Golden et al., 1994)

1991: New Mexico
  (MASS - Grimani et al., 2002)

1993: New Mexico
  (Golden et al., 1996)

1994: New Mexico
  (Heat – Barwick et al., 1995)

1994: Manitoba
  (CAPRICE - Barbiellini et al., 1996; Boezio et al 2002)

1994: Manotoba
  (AESOP – Clem & Evason 1996)

1995: Manitoba
  (HEAT – Barwick et al., 1997)

1998: New Mexico
  (CAPRICE – Boezio et al., 1999)

1999: Manitoba
  (AESOP – Clem & Evason, 2002)

2000: New Mexico
  (HEAT – Beatty et al, 2004)

2000: Manitoba
  (AESOP – Clem & Evason, 2002)

2002: Manitoba
  (AESOP – Clem & Evason, 2004)
HEAT-e± was first to employ powerful particle ID (rigidity vs. TRD vs. EM shower development) resulting in improved hadron rejection ($\geq 10^{-5}$).

Trend consistent with secondary production [Moskalenko & Strong ApJ 493, 694 (1998)] (but high energy data lies above the curve.)

Solar modulation only affects low energy.
HEAT- $e^\pm$ (1994 & 1995)

HEAT- $\bar{p}$

HEAT 2000

HEAT 1994 & 1995

Positron Fraction $e^+/(e^++e^-)$

Kinetic Energy [GeV]
Mass Resolution

Select rigidity bands and fit restricted average dE/dx distributions.

Highly Gaussian shape allows for good particle separation/count.

before event selection
CR positron measurements: Space

1998: Low Earth Orbit (shuttle)
   (AMS-01 - Aguilar et al., 2007)
2006 - ?: Low Earth Orbit (satellite)
   (PAMELA - Grimani et al., 2002)
Predicted Electron Spectrum

- Spectral shape of HE electrons should be strongly affected by the number of nearby sources, and their distance distribution.

- If no such features in the high-energy electron spectrum are observed it will call into question our understanding of CR sources and propagation.

Assuming a 20 TeV cut off energy, diffusion parameters, and source power, shown.
Galactic Cosmic Ray Electrons

- Strong (indirect) evidence for supernova shock acceleration of galactic CR electrons through observations of non-thermal X-rays and TeV gamma rays from SN remnants.

Non-thermal emission from rim. Morphology correlates well between x-ray and radio bands.

Thermal emission from core.

Synchrotron emission from SN1006

CREST: Cosmic Ray Electron Synchrotron Telescope

- LDB experiment designed to extend electron flux measurements up to 50 TeV.
- Detects UHE Electrons through their synchrotron radiation in the earth’s magnetic field.

Technique first described in 70’s by Prilutskiy, and fully developed in 80’s by Stephens & V.K. Balasubrahmanran
Mechanical Layout

1024 BaF$_2$ crystals w/ PMT and CW base

2.3 m

4 $\pi$ plastic scintillator shield (0.5 cm thick)
Spectral Sensitivity

Two curves represent the expected result for 100 days of exposure for two extremes: no source, and for a uniform distribution of sources.