Secondary content of the high energy cosmic ray electron spectrum

Jens Ruppel
Ruhr–Universität Bochum

Meeting of working group:

Very high energy gamma rays, cosmic rays and neutrinos & hadronic AGN emission models

December 2008

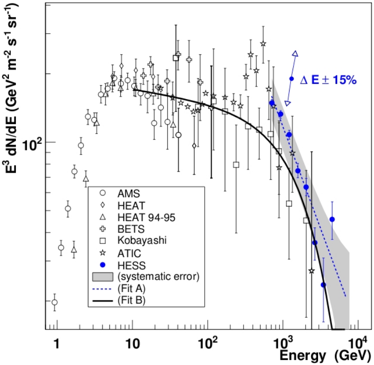
Motivation

H.E.S.S.–Paper:

The energy spectrum of cosmic-ray electrons at TeV energies

F. Aharonian[1,13], A.G. Akhperjanian[2], U. Barres de Almeida[8,*] A.R. Bazer-Bachi[3], B. Behera[14], W. Benbow[1], K. Bernlöhr[1,5], C. Boisson[6], A. Bochow[1], V. Borrel[3], I. Braun[1], E. Brion[7], J. Brucker[16], P. Brun[7], R. Bühler[1], T. Bulik[24], I. Büsching[9], T. Boutelier[17], S. Carrigan[1], P.M. Chadwick[8], A. Charbonnier[19], R.C.G. Chaves[1], A. Cheesebrough[8], L.-M. Chounet[10], A.C. Clapson[1], G. Coignet[11], L. Costamante[1,29], M. Dalton[5], B. Degrange[10], C. Deil[1], H.J. Dickinson[8], A. Djannati-Ataï[12], W. Domainko[1], L.O'C. Drury[13], F. Dubois[11], G. Dubus[17], J. Dyks[24], M. Dyrda[28], K. Egberts[1,†] D. Emmanoulopoulos[14], P. Espigat[12], C. Farnier[15], F. Feinstein[15], A. Fiasson[15], A. Förster[1], G. Fontaine[10], M. Füßling[5], S. Gabici[13], Y.A. Gallant[15], L. Gérard[12], B. Giebels[10], J.F. Glicenstein[7], B. Glück[16], P. Goret[7], C. Hadjichristidis[8], D. Hauser[14], M. Hauser[14], S. Heinz[16], G. Heinzelmann[4], G. Henri[17], G. Hermann[1], J.A. Hinton[25,‡] A. Hoffmann[18], W. Hofmann[1], M. Holleran[9], S. Hoppe[1], D. Horns[4], A. Jacholkowska[19], O.C. de Jager[9], I. Jung[16], K. Katarzyński[27], S. Kaufmann[14], E. Kendziorra[18], M. Kerschhaggl[5], D. Khangulyan[1], B. Khélifi[10], D. Keogh[8], Nu. Komin[15], K. Kosack[1], G. Lamanna[11], J.-P. Lenain[6], T. Lohse[5], V. Marandon[12], J.M. Martin[6], O. Martineau-Huynh[19], A. Marcowith[15], D. Maurin[19], T.J.L. McComb[8], C. Medina[6], R. Moderski[24], E. Moulin[7], M. Naumann-Godo[10], M. de Naurois[19], D. Nedbal[20], D. Nekrassov[1], J. Niemiec[28], S.J. Nolan[8], S. Ohm[1], J-F. Olive[3], E. de Oña Wilhelmi[12], K.J. Orford[8], J.L. Osborne[8], M. Ostrowski[23], M. Panter[1], G. Pedaletti[14], G. Pelletier[17], P.-O. Petrucci[17], S. Pita[12], G. Pühlhofer[14], M. Punch[12], A. Quirrenbach[14], B.C. Raubenheimer[9], M. Raue[1,29], S.M. Rayner[8], M. Renaud[1], F. Rieger[1,29], J. Ripken[4], L. Rob[20], S. Rosier-Lees[11], G. Rowell[26], B. Rudak[24], C.B. Rulten[8], J. Ruppel[21], V. Sahakian[2], A. Santangelo[18], R. Schlickeiser[21], F.M. Schöck[16], R. Schröder[21], U. Schwanke[5], S. Schwarzburg [18], S. Schwemmer[14], A. Shalchi[21], J.L. Skilton[25], H. Sol[6], D. Spangler[8], Ł. Stawarz[23], R. Steenkamp[22], C. Stegmann[16], G. Superina[10], P.H. Tam[14], J.-P. Tavernet[19], R. Terrier[12], O. Tibolla[14], C. van Eldik[1], G. Vasileiadis[15], C. Venter[9], J.P. Vialle[11], P. Vincent[19], M. Vivier[7], H.J. Völk[1], F. Volpe[10,29], S.J. Wagner[14], M. Ward[8], A.A. Zdziarski[24], and A. Zech[6]

Measuring Cosmic Ray Electrons



arxiv.org/abs/0811.3894v1

How to measure CR electron flux only?

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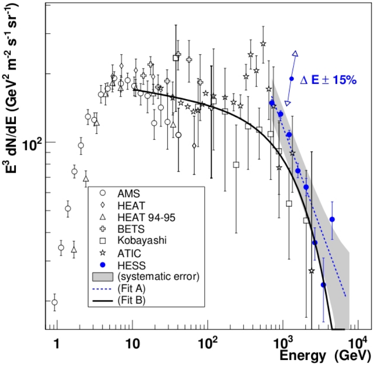

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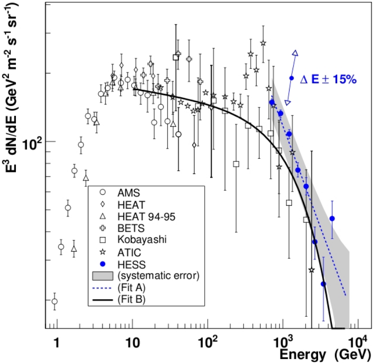

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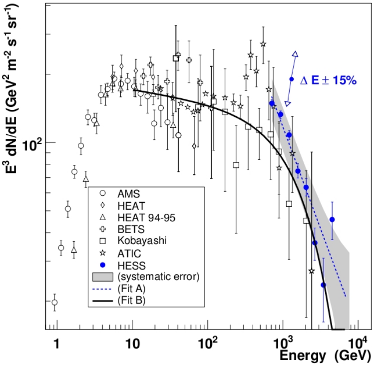

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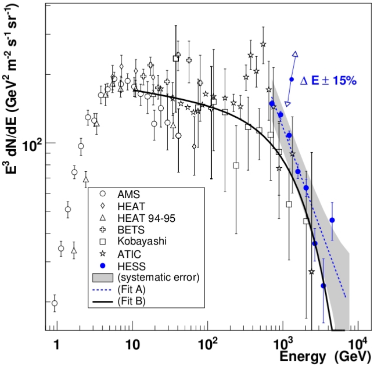

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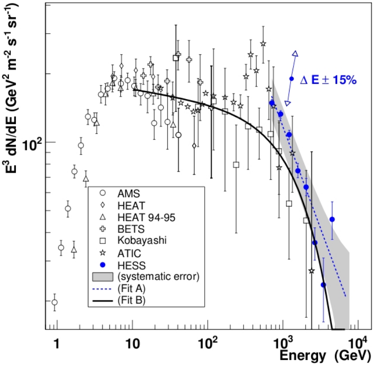

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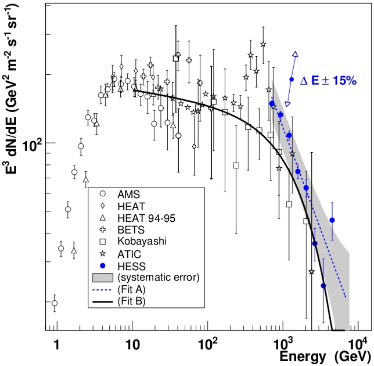

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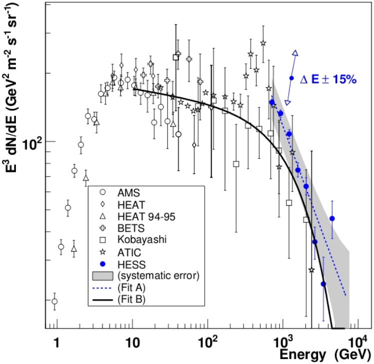

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- Secondary electron fraction?
- What can we learn from this measurement?

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Kelner, Aharonian, Bugayov (2006)

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Secondary Electrons
Motivation...
What we did...
Results...
Conclusions...

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Hadron–Hadron Cross Section:

$$\sigma_{hh}^{\pi}(\gamma_h) = \left(34.3 + 1.88L + 0.25L^2\right)\left[1 - \left(\frac{E_{\mathrm{th}}}{E_h}\right)^4\right]^2 \mathrm{mb}$$

with $L = \ln(E_h/\mathrm{TeV})$; $E_{\mathrm{th}} = 1.22\,\mathrm{GeV}$

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Interstellar gas density:

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$$\mathbf{Q(\vec{r},\gamma) = 1.26\, N_0(\vec{r}_\odot)\, n(\vec{r})\, c \int_\gamma^\infty \frac{d\gamma_h}{\gamma_h} F_e(\gamma,\gamma_h)\, H(\gamma_h)\, \sigma_{hh}^{\pi}(\gamma_h)}$$

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Very–high energy cosmic ray electrons:

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$$\begin{aligned}
\text{with} \quad a_0 &= 36.2\, c\, \sigma_T\, n_H\, \tau \\
a_1 &= 1.4 \cdot 10^{-3}\, \eta\, \tau^{-1} \\
a_2 &= 7.2 \cdot 10^{-8}\, \epsilon\, \tau^{-1} \left(U_{\text{mag}}/\text{eV cm}^{-3}\right) \left(n_H/\text{cm}^{-3}\right)^{-1} \\
\text{and} \quad \epsilon &= 3/4 + U_{\text{rad}}/U_{\text{mag}} \\
\tau &= 1 + 1.54\, n_e/n_H \\
\eta &= 1 + 0.95\, n_e/n_H
\end{aligned}$$

$$\Rightarrow |\dot{\gamma}| = 7.22 \cdot 10^{-13}\, n_H(\vec{r}) \Big[1 + 1.54\, x + 1.4 \cdot 10^{-3} (1 + 0.95\, x)\, \gamma + 7.2 \cdot 10^{-8} \frac{W(\vec{r})}{n_H(\vec{r})}\, \gamma^2 \Big]$$

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$$\Rightarrow N(\vec{r},\gamma) = |\dot{\gamma}|^{-1} \int_\gamma^\infty du\, Q(\vec{r},u)$$

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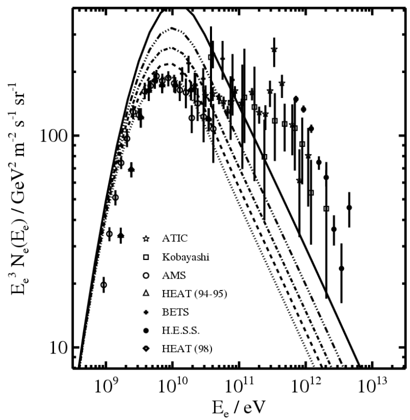
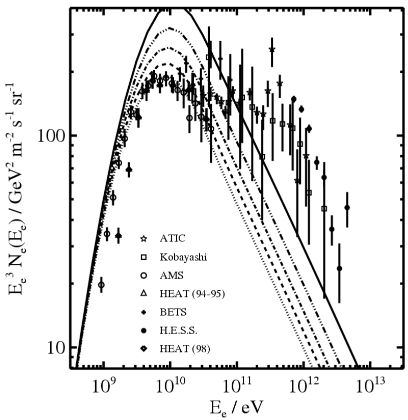
$$\times \int_{\gamma}^{\infty} du \int_{u}^{\infty} \frac{d\gamma_h}{\gamma_h}\, F_e(u, \gamma_h)\, H(\gamma_h)\, \sigma^{\pi}_{hh}(\gamma_h)$$

Cosmic Ray Electron Spectrum

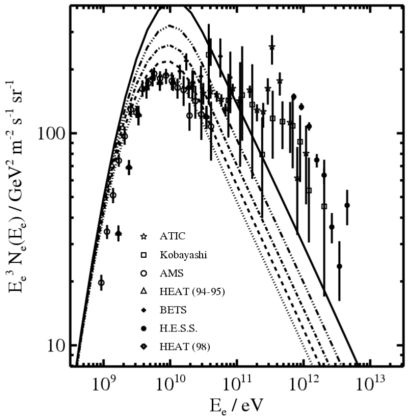


Cosmic Ray Electron Spectrum



Only depends on ratio W/n_H.

Cosmic Ray Electron Spectrum



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Here:
$W/n_H = 2 \ldots 6\,\mathrm{eV}$

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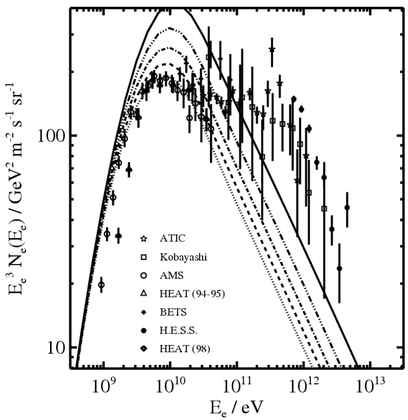

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Good fit:
$$4.5\,\text{eV} < \frac{W}{n_H} < 6.0\,\text{eV}$$
with $B = 4\,\mu\text{G}$
$n_H = 0.3\,\text{cm}^{-3}$

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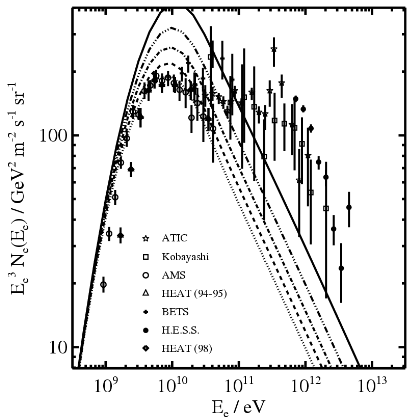
Cosmic Ray Electron Spectrum



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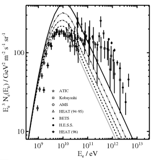
with $B = 4\,\mu\text{G}$
$n_H = 0.3\,\text{cm}^{-3}$

Using $W = 0.75\,U_{\text{mag}} + U_{\text{rad}}$ we obtain:

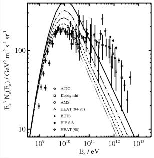
$$\Rightarrow \quad 1.05\ \text{eV}\,\text{cm}^{-3} \leq U_{\text{rad}} \leq 1.5\ \text{eV}\,\text{cm}^{-3}$$

Conclusions



- Cosmic ray electrons below 50 GeV might be secondaries.

Conclusions



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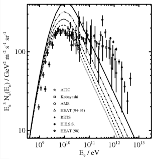
- Above this energy, the secondary fraction of the cosmic ray electrons is decreasing.

Conclusions



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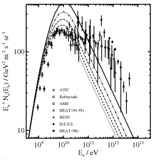
Conclusions



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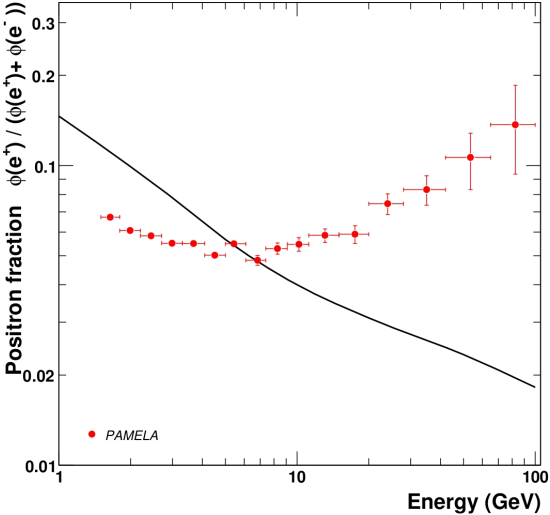
- The observed excess of electrons above 50 GeV suggests the presence of a local source of primary cosmic ray electrons.

Thanks for your attention!

Pamela vs. Moskalenko & Strong



Pamela vs. Other Data