Lessons from the DAMPE data

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joint work with Kfir Blum

to appear

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Why study Cosmic Rays?

- they exist! $\rightarrow$ learn about astrophysics
- search for dark matter via indirect detection

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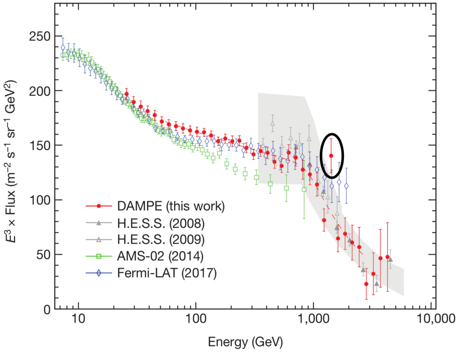
→ "WIMPs" found frequently!



[$e^- + e^+$ spectrum observed by DAMPE]

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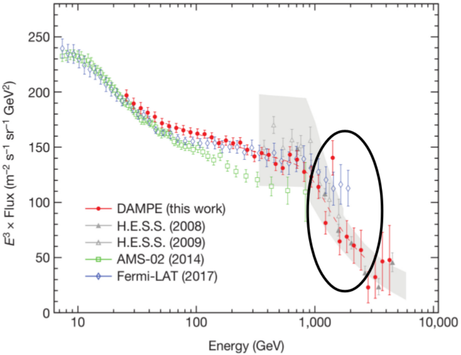
cooling break → age of cosmic ray sources



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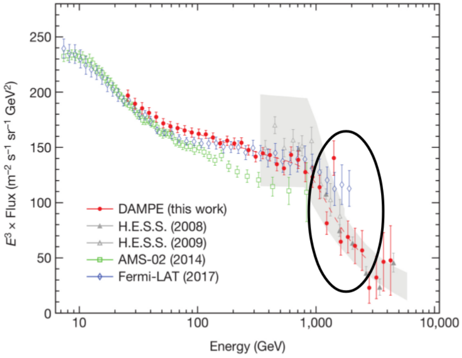
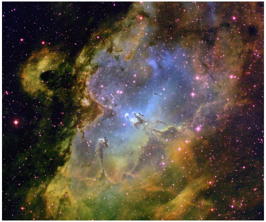


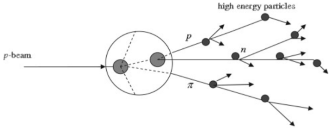
What else?

[$e^- + e^+$ spectrum observed by DAMPE]

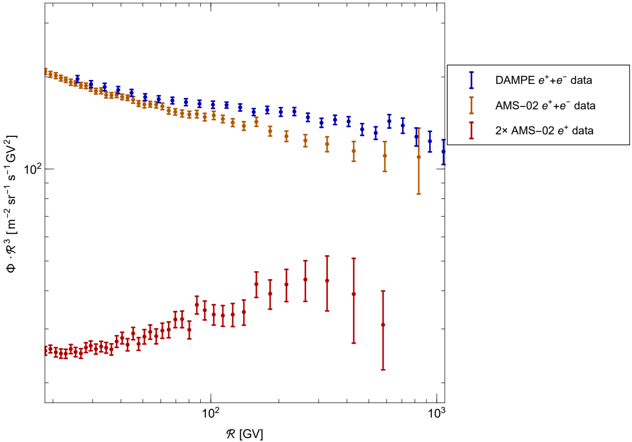
The Origin of Cosmic Rays

- primary sources: mainly supernova remnants, stars, pulsars (?), dark matter ?
- secondary particles: produced by spallation of cosmic rays
  → can be derived from interstellar fluxes and differential cross sections
  → only known source of antiparticles (e.g. e^+)
- particles propagate in the galaxy





Disentangle the Electron Component



Experiments measure combination of primary and secondary cosmic rays.

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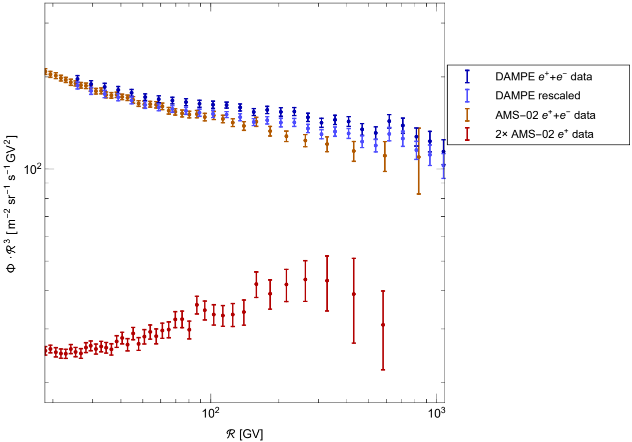

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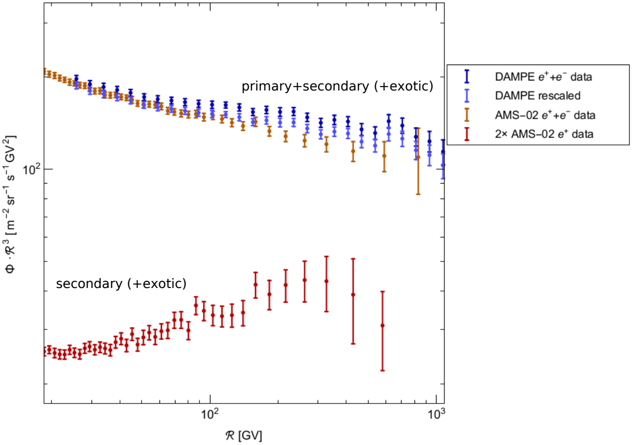

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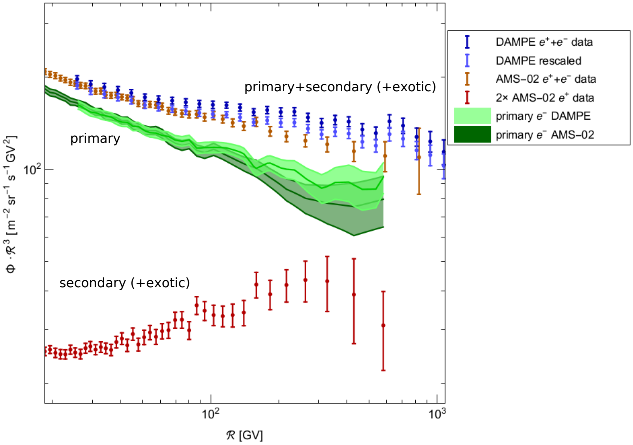
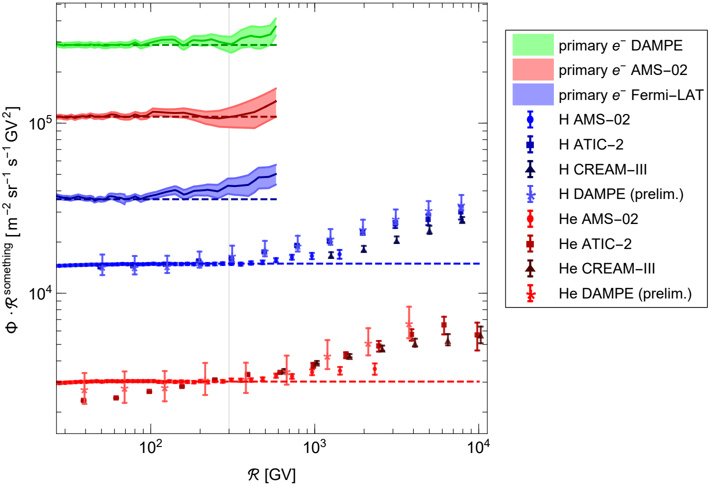


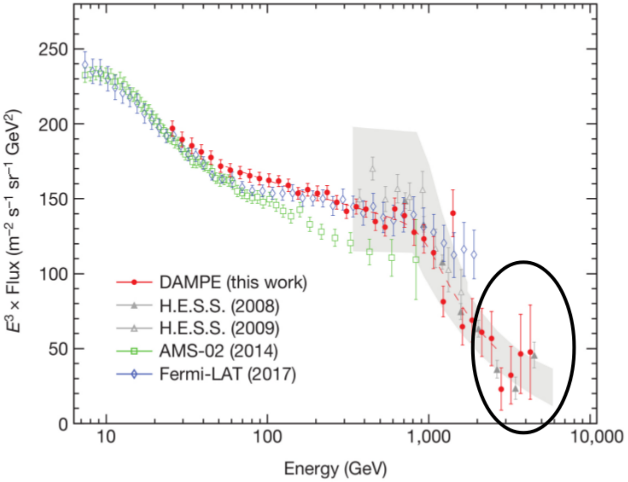
$$\underbrace{e^+ + e^-}_{primary+secondary} - \underbrace{2 \cdot e^+}_{''secondary''} = \underbrace{e^-}_{primary}$$

The Primary Electron Component



The primary electrons seem to indicate a spectral hardening around ~ 300 GV – just like the other cosmic rays!

Where do the high energy electrons come from?



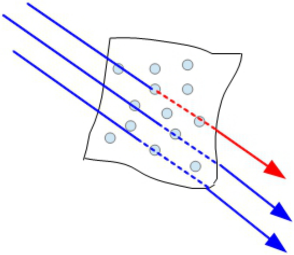
[$e^- + e^+$ spectrum observed by DAMPE]

Production of Secondary Cosmic Rays

Secondary Cosmic Rays are produced by the spallation of (mainly primary) Cosmic Rays on the Interstellar Medium

net source term:

$$Q = \sum_P n_P \frac{\sigma_{P \to S}}{m} - n_S \frac{\sigma_S}{m}$$



$n =$ cosmic ray flux
$\sigma =$ spallation cross section
$m =$ average mass of Interstellar Medium $\approx 1.3 m_\mathrm{p}$

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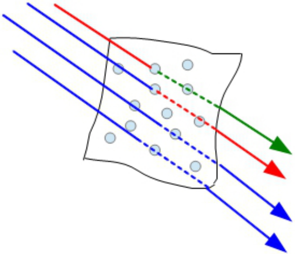

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Cosmic Ray Transport

- more or less complex models → many assumptions
- model-independent approach: assume simple scaling law

[Ginzburg et al.]

$$\frac{n_a}{n_b} = \frac{Q_a}{Q_b} \quad \Rightarrow \quad n_a = X_{\mathrm{esc}} Q_a$$

with $X_{\mathrm{esc}} = \frac{n_b}{Q_b}$ = 'grammage' [g/cm^2], independent of particle species b, does depend on particle's rigidity $\mathcal{R} = \frac{p}{Z}$

meaning: average column density 'seen' by cosmic rays

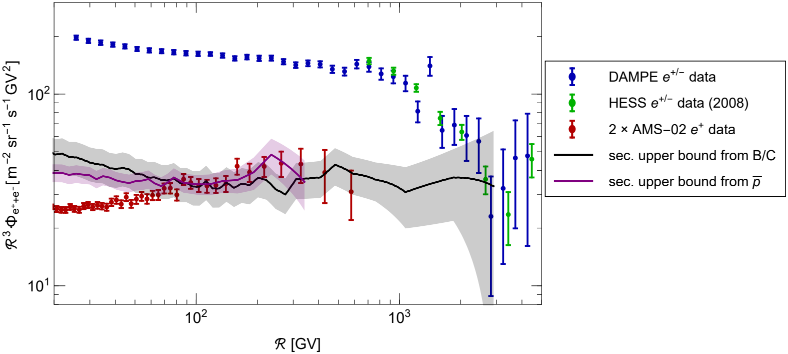
For leptons, energy losses can be relevant: $n_{e\pm} = f_e X_{\mathrm{esc}} Q_{e\pm}$

Upper Bound on the Secondary Contribution

Setting $f_e = 1$ results in an upper bound on the secondary part:

[Katz, Blum, Waxman]

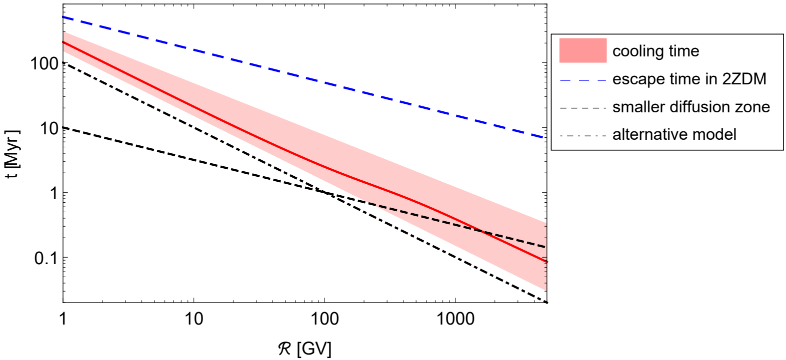
$$n_{e\pm} = X_{\rm esc} Q_{e\pm} \qquad n_{e\pm} = \frac{Q_{e\pm}}{Q_{\bar{p}}} n_{\bar{p}}$$



It saturates with the measured spectrum above the cooling break!

Energy Losses

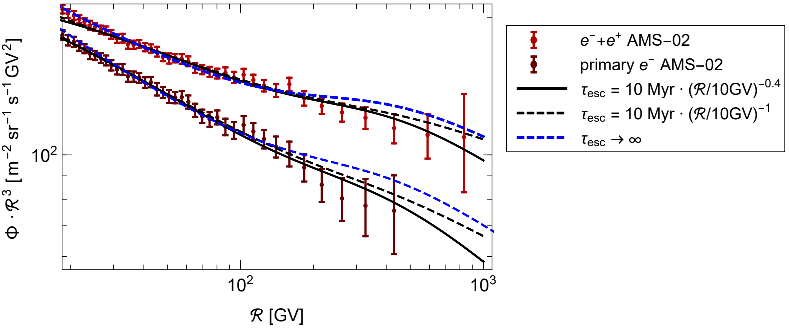
For leptons, energy losses play an important role if $t_{cool} < t_{esc}$.



So far, all observations are consistent with models where escape dominates over energy losses!

(Ir)relevance of Energy Losses

- origin of energy losses: Compton scattering & synchrotron radiation
- depending on radiation fields, Thomson limit fails → Klein-Nishina regime → causes "steps" in spectrum [Schlickeiser & Ruppel '09]



no clear hint for Klein-Nishina step → no evidence for relevant cooling!

Summary

There seems to be a spectral hardening in the primary electron spectrum – too!

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In principle, the high energy $e^{-} + e^{+}$ could be secondary.

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So far, no clear evidence for relevant $e^{\pm}$ cooling → further investigation (data!) urgently needed!