Bright Side of the High Energy Universe

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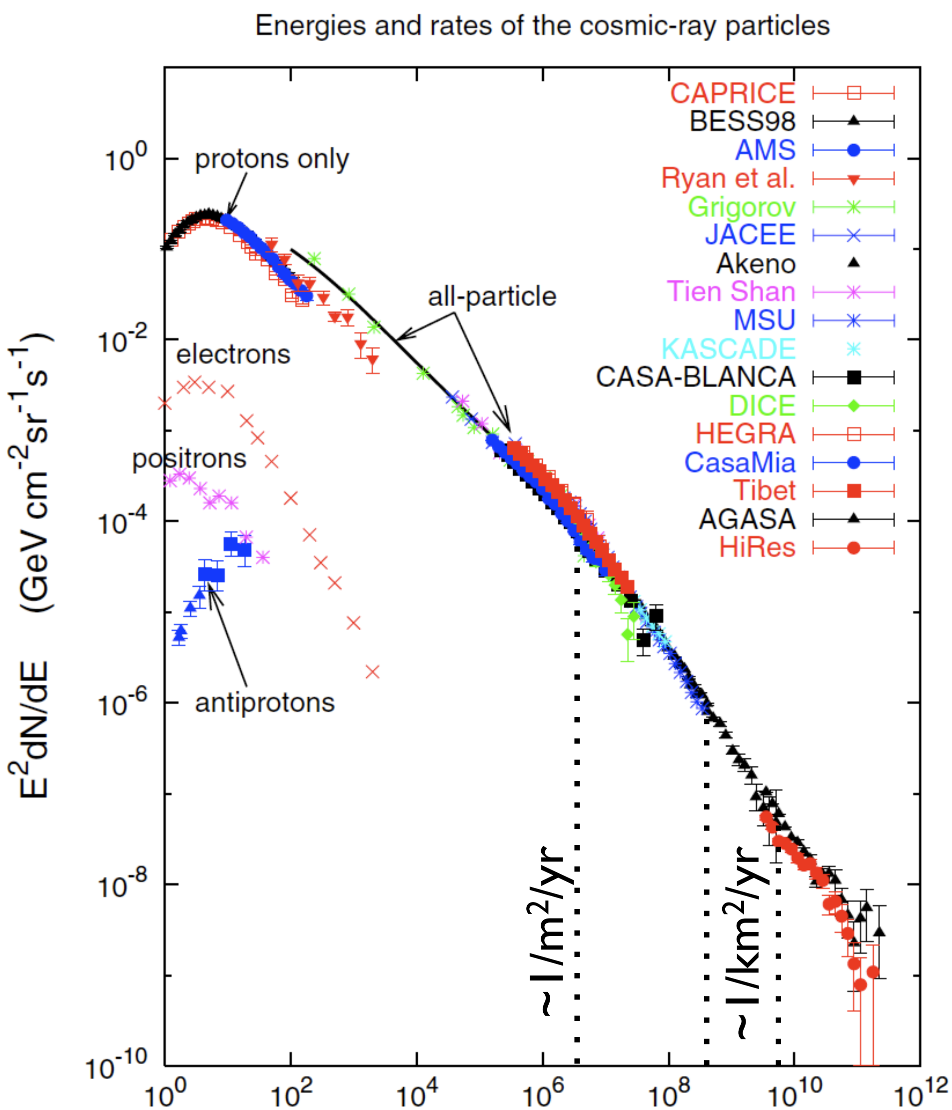
KEK
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

The Graduate University for Advanced Studies
Sokendai

Cosmic Rays



Gaisser 06

0th: Power law

$E<3\times10^{15}$eV (Knee)

$F \propto E^{-2.7}$

Supernova remnant

$L_{CR} \sim 10^{41}$erg/s$\sim 0.1 E_{SN}/t_{SN}$

$<E<5\times10^{18}$eV (Ankle)

$F \propto E^{-3-3.2}$

Galactic origin?

$<10^{14-15}$eV by SNR?

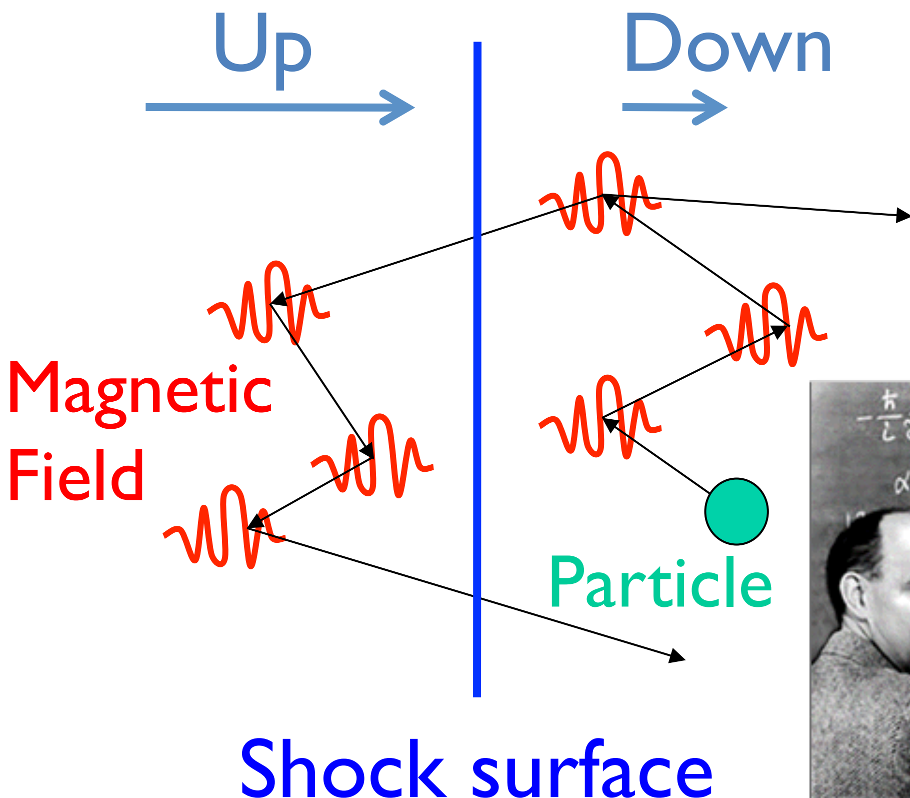
$<E<4\times10^{19}$eV (GZK cutoff?)

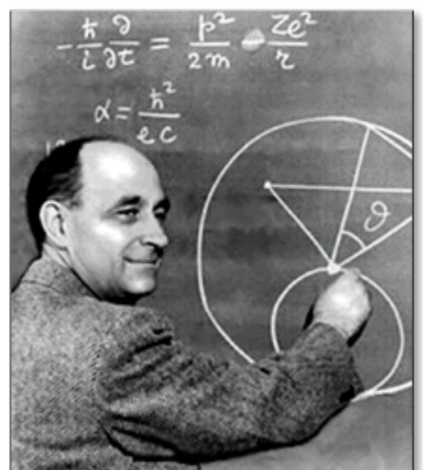
$F \propto E^{-2.7}$

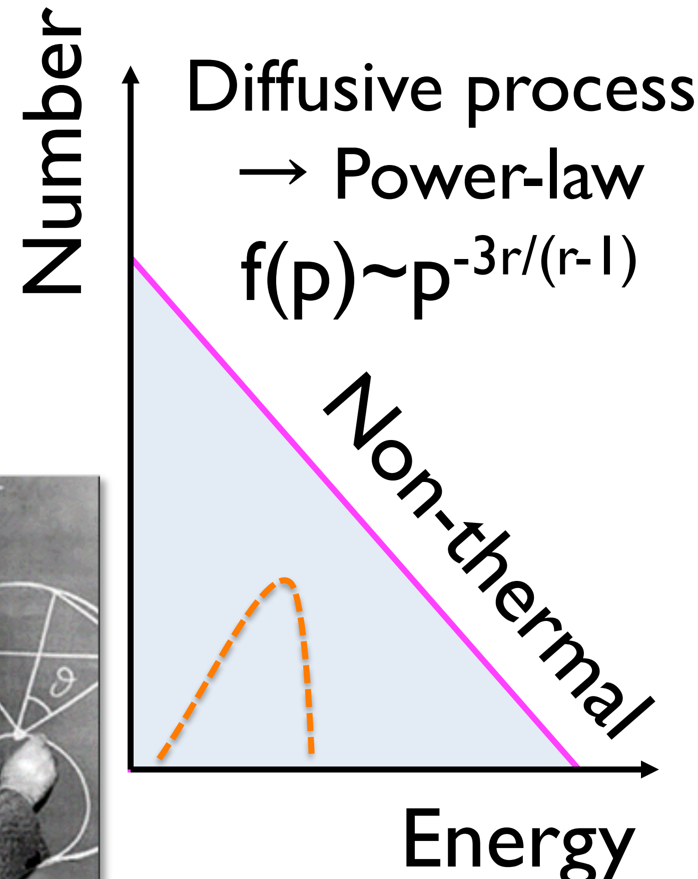
Extra-Galactic: AGN? GRB?

Particle Acceleration

Collisionless Shock

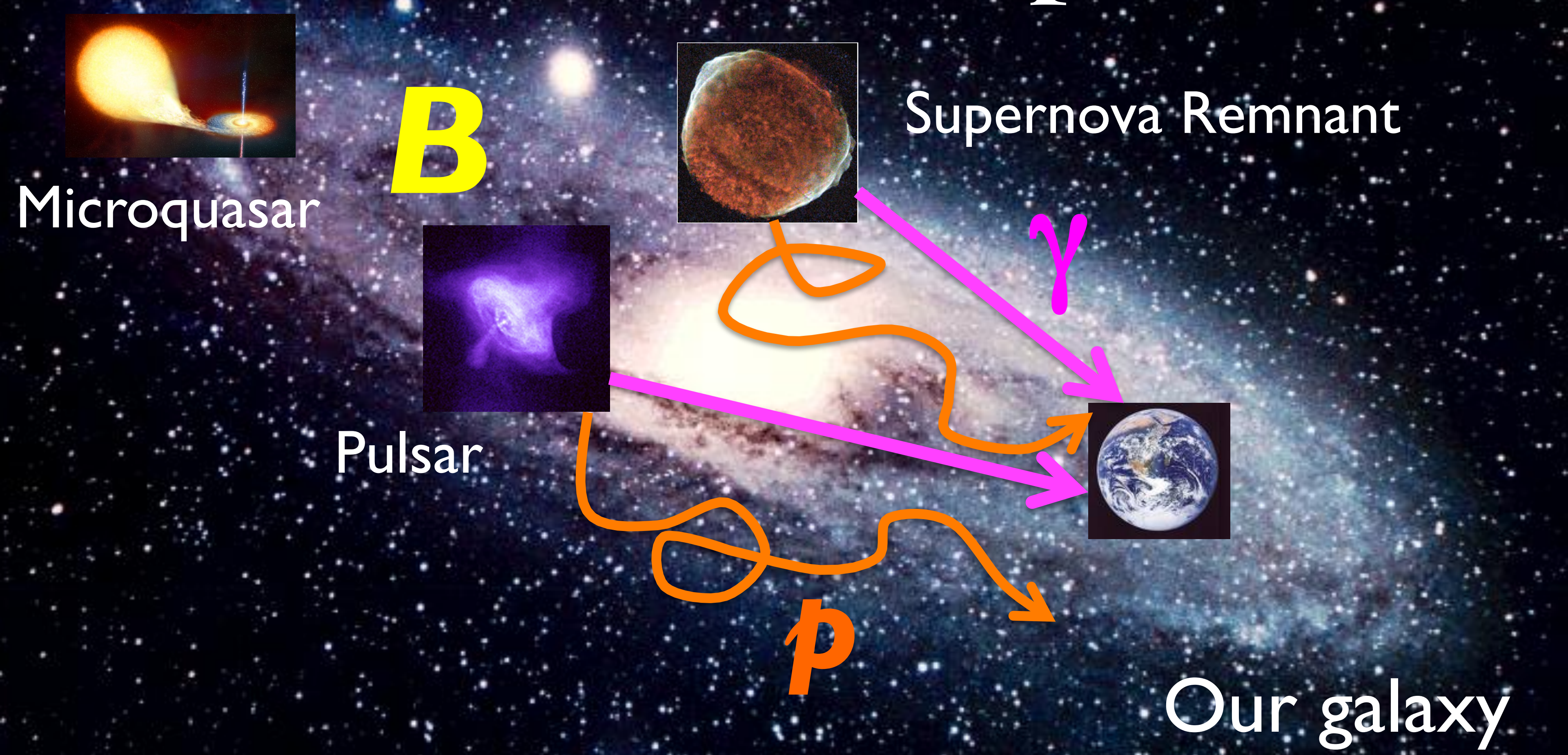






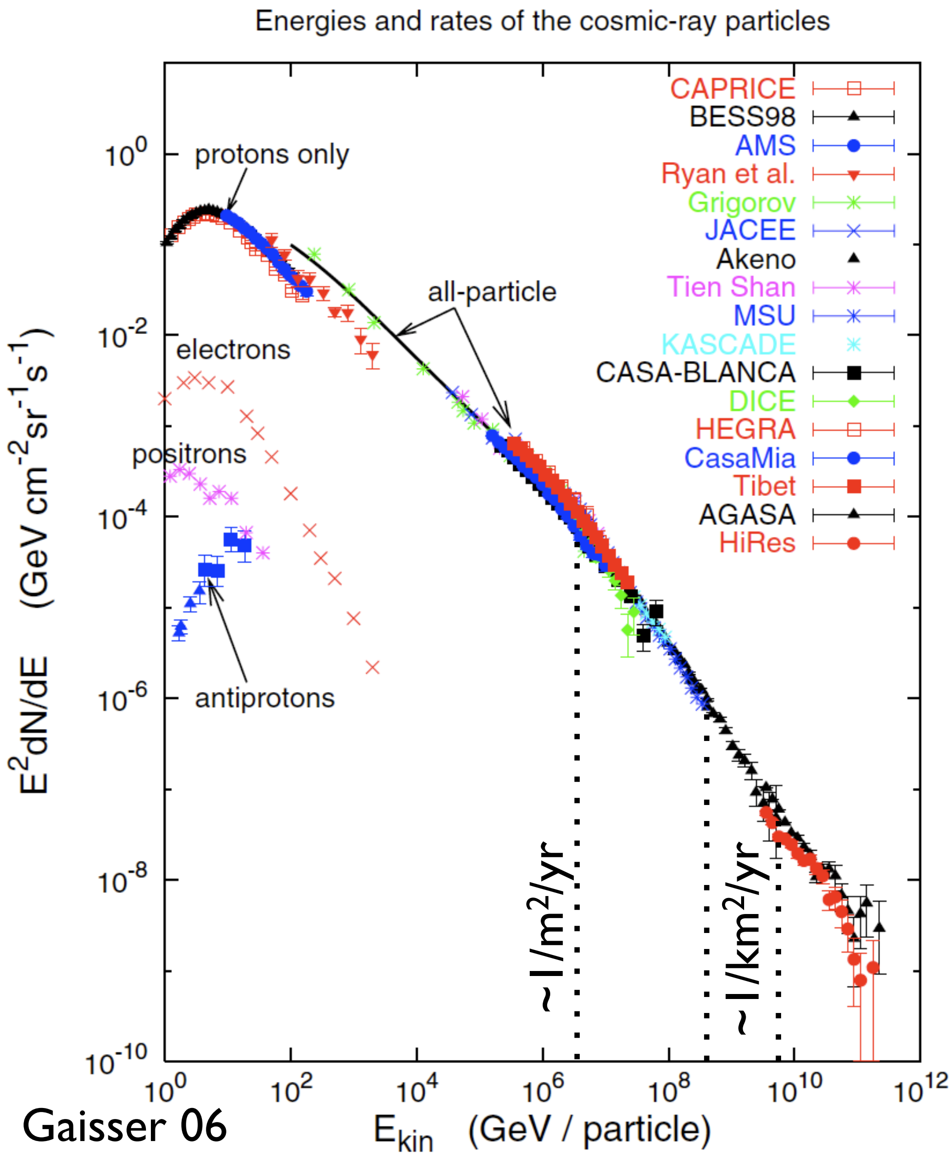
Diffusive Shock (Fermi) Acceleration

Diffusion in Space



$$\left\langle \delta B^2(k) \right\rangle \propto k^{-5/3} \left(\text{Kolmogorov?} \right)$$

Cosmic Rays



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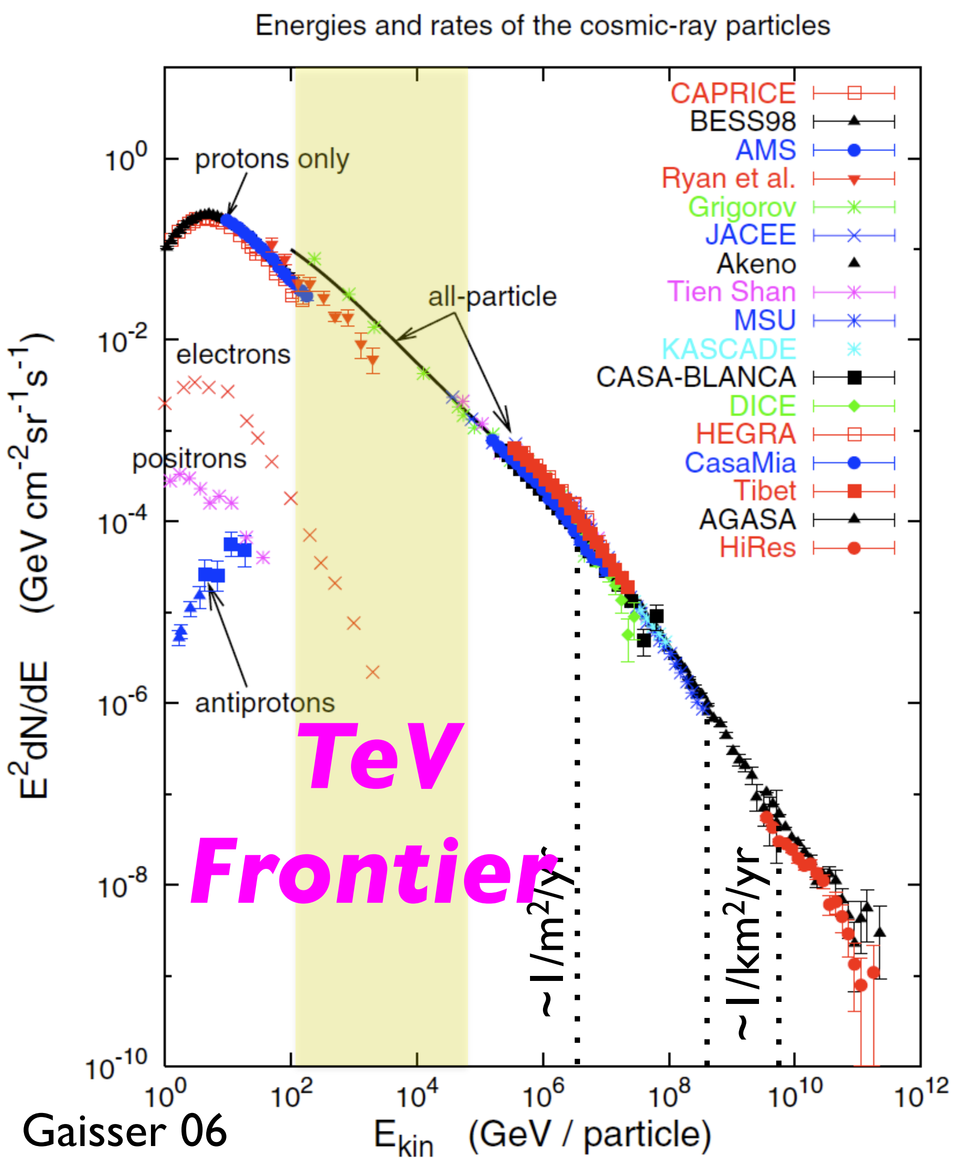
Cosmic Rays



Gaisser 06

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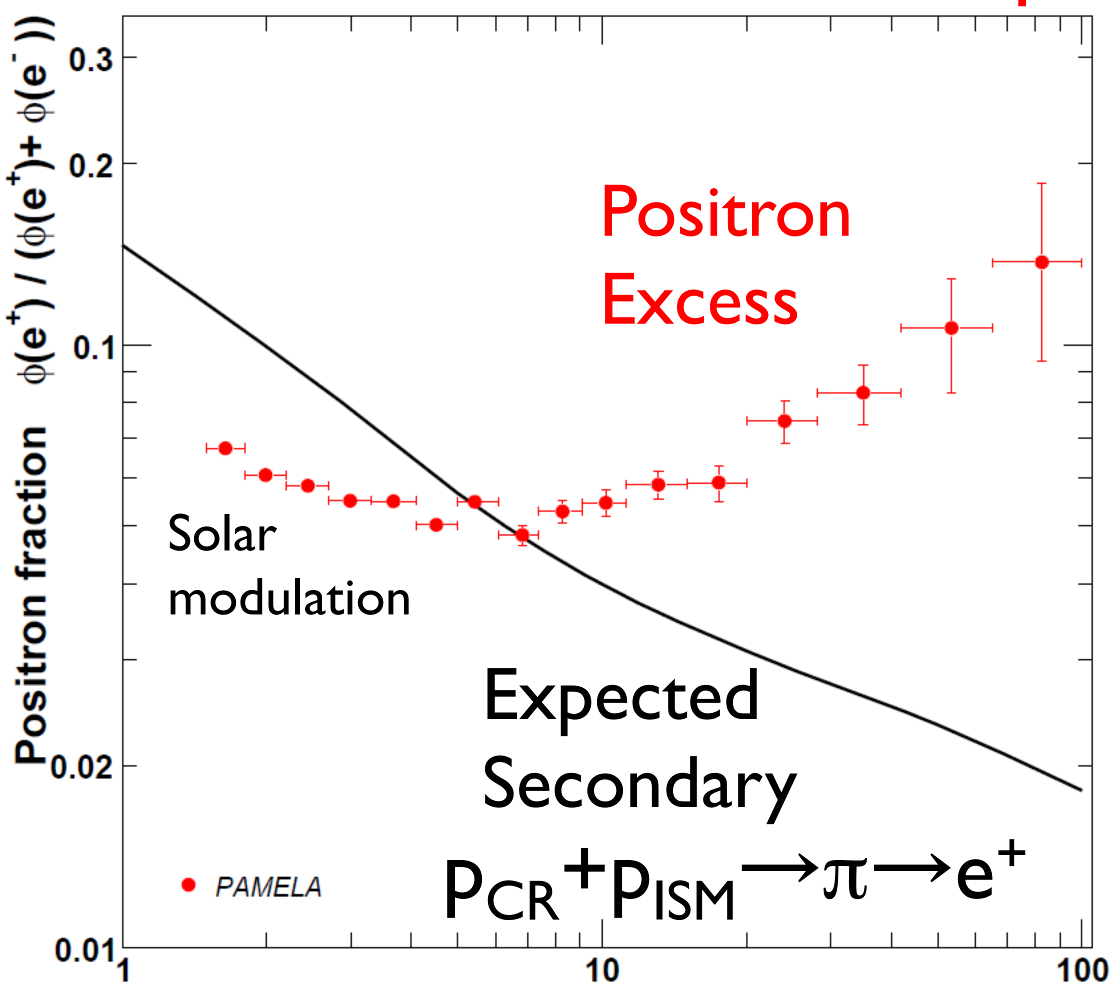
Contents

- **$e^{\pm}$ excess: *Astrophysical***
  - ✓ TeV spec., Anisotropy, … ***CALET***
- **$\bar{p}$: *No excess or pp?***
  - ✓ B/C ⇔ Li? ***AMS-02***
- ***He, C hardening: Superbubble?***
  - ✓ O, Ne, Mg, Si, Fe hardening?
- ***GeV γ-ray excess: DM? Pulsar?***
  - ✓ Inverse Compton at TeV? ***CTA***

PAMELA

Positron excess above the predicted secondary



Adriani+ 08, 10

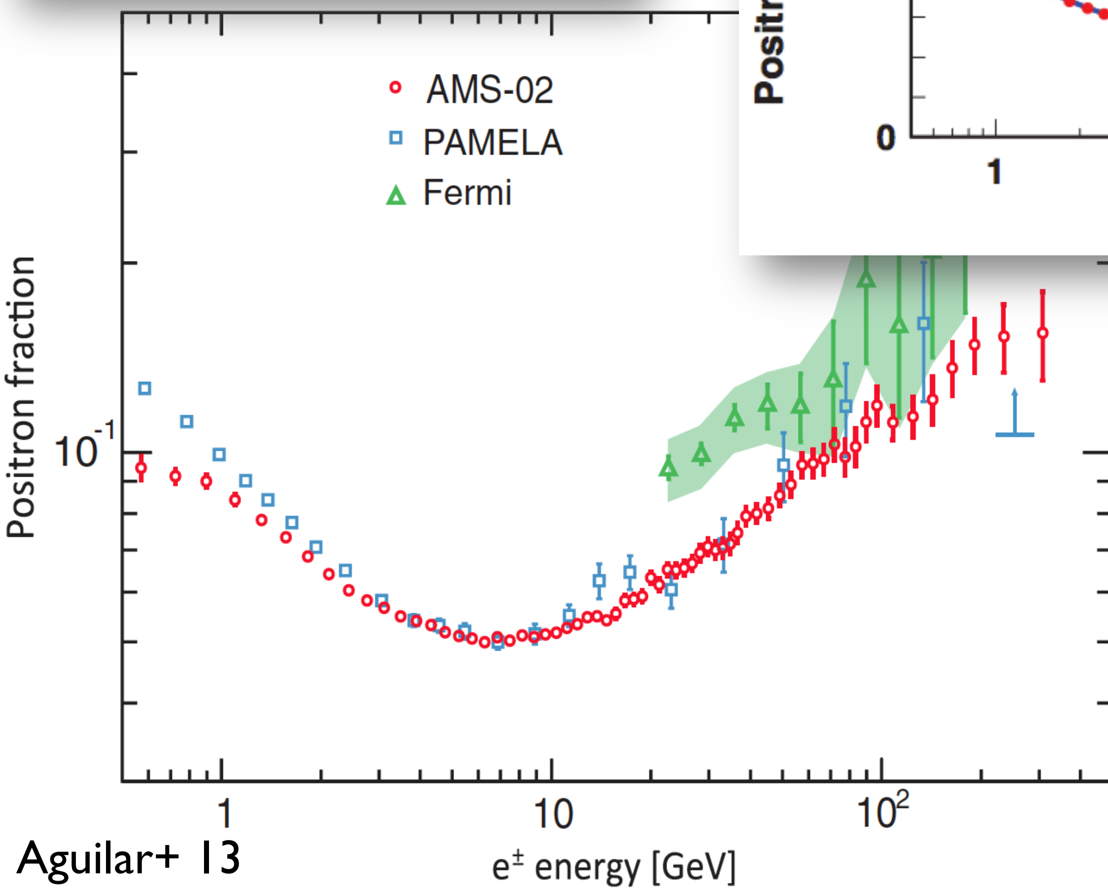
⇒ New sources
- Dark Matter?
- Astrophysical?

⇒ Many papers $>10^3$

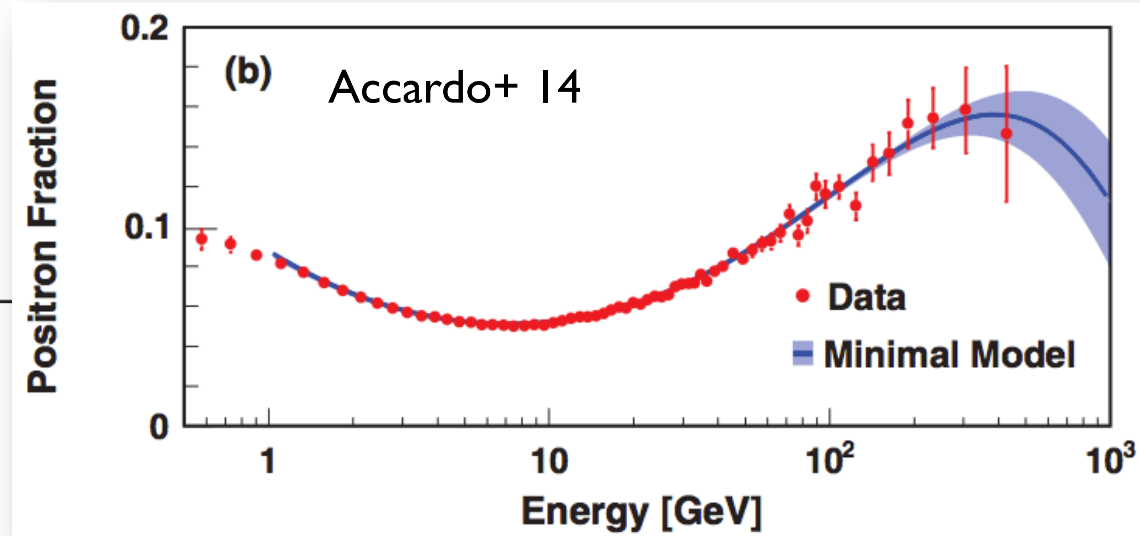
Jul 06 - Feb 08

151672 e-, 9430 e+

AMS-02

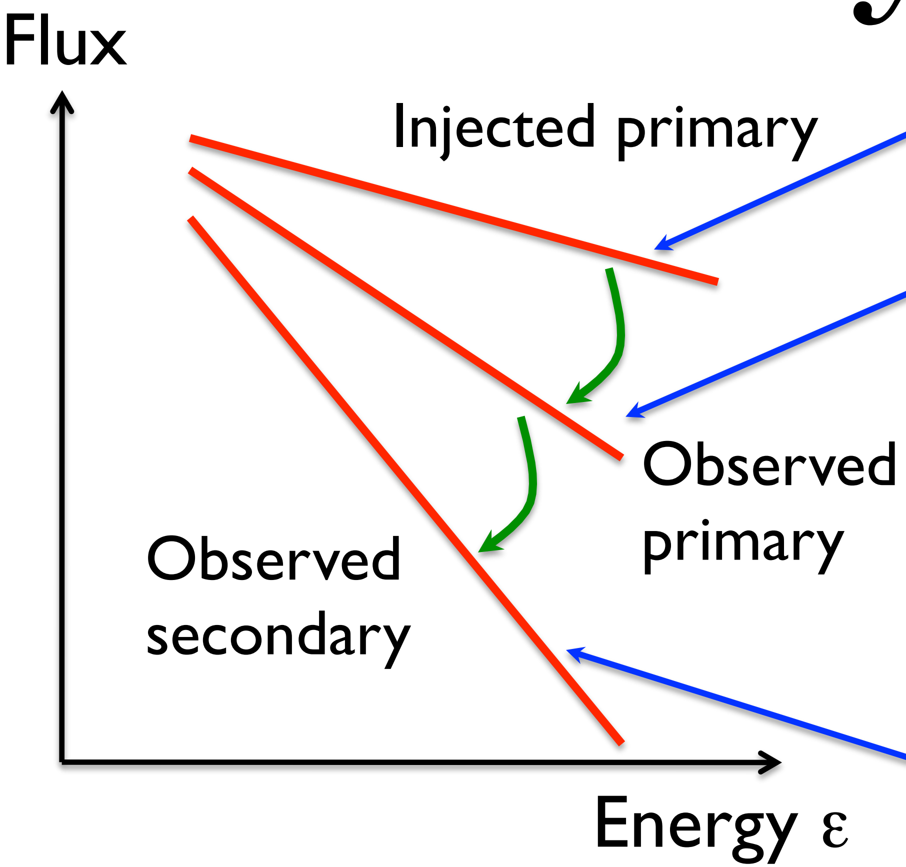


Aguilar+ 13



1. High precision
2. Up to ~500 GeV
3. No fine structure
4. Slope declines
5. No anisotropy $\delta<0.036$ (95%CL)

Secondary Positrons



$$\Phi_1 \sim \tau_{\rm esc}(\varepsilon) \bullet Q_1(\varepsilon)$$

$$\propto \varepsilon^{-\delta} \bullet \varepsilon^{-\gamma}$$

$$Q_2(\varepsilon) \propto \sigma \bullet \Phi_1(\varepsilon)$$

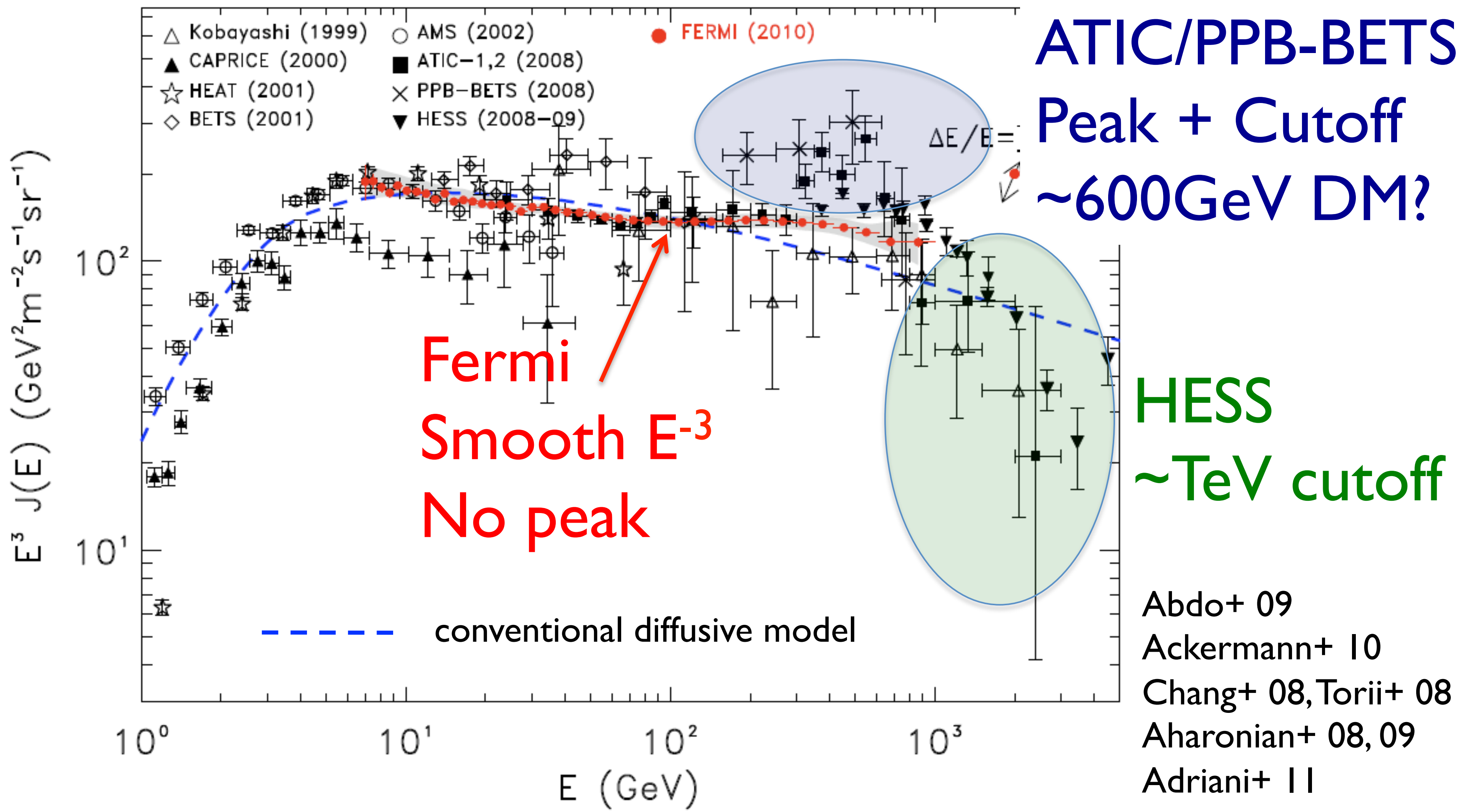
$$\Phi_2 \sim \tau_{\rm esc}(\varepsilon) \bullet Q_2(\varepsilon)$$

$$\propto \varepsilon^{-\delta} \bullet \varepsilon^{-\delta} \varepsilon^{-\gamma}$$

This is robust if escape/cooling is faster for higher energy

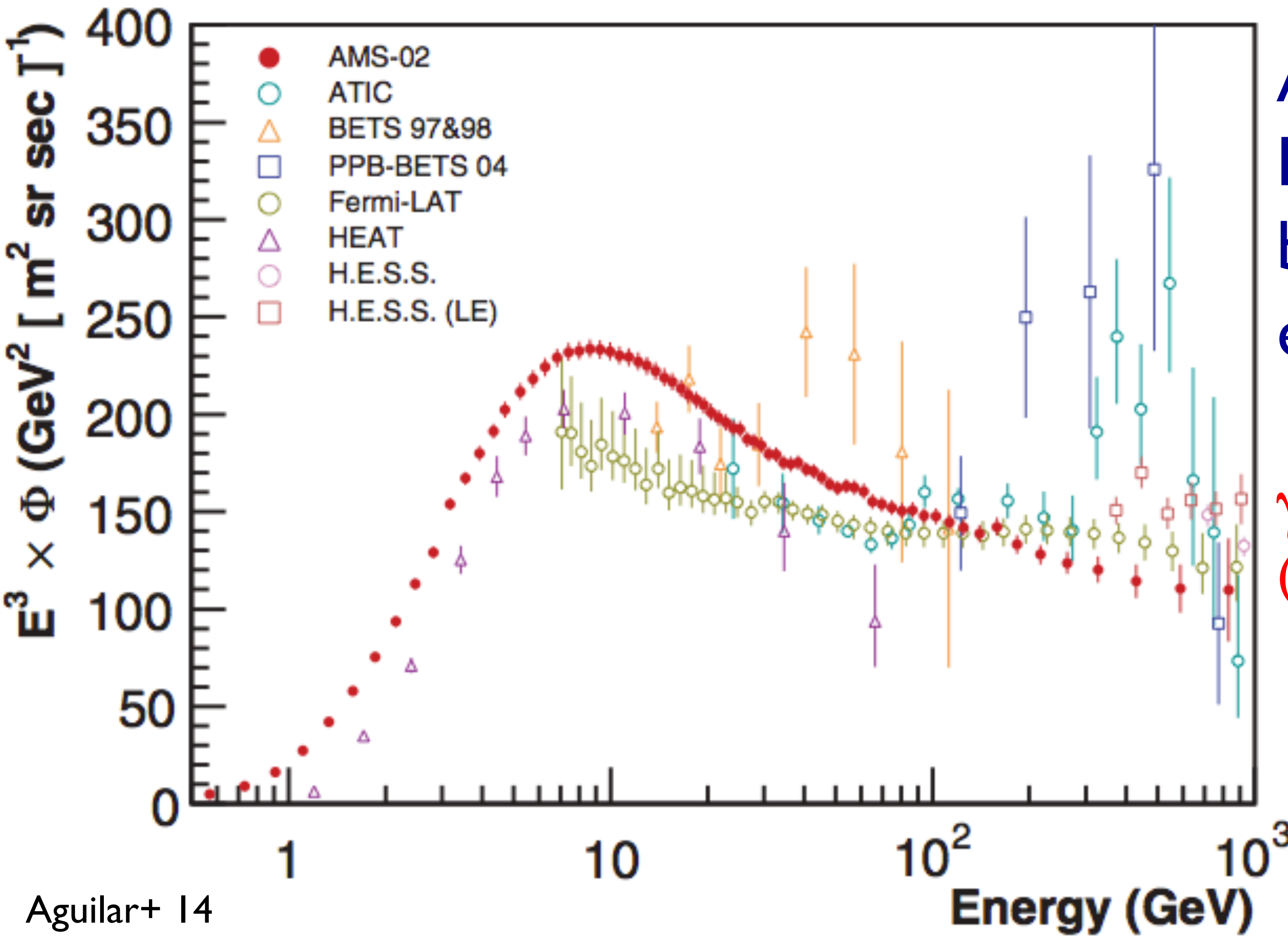
Cosmic-Ray Electron

An Excess also in ($e^+ + e^-$) Spectrum



Abdo+ 09
Ackermann+ 10
Chang+ 08, Torii+ 08
Aharonian+ 08, 09
Adriani+ 11

AMS-02 ($e^- + e^+$)

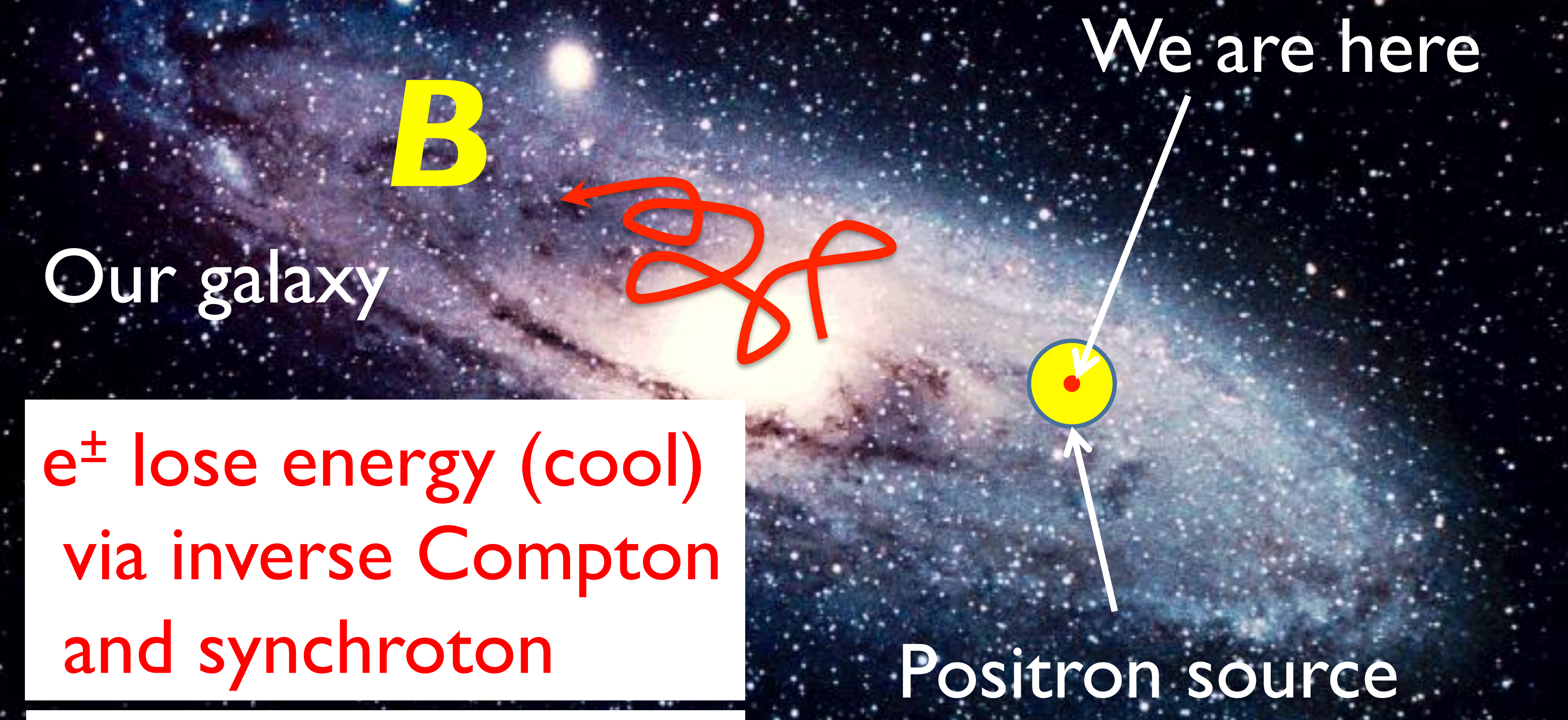


ATIC/ PPB-BETS bump is excluded

γ=-3.17 (30GeV-1TeV)

Aguilar+ 14

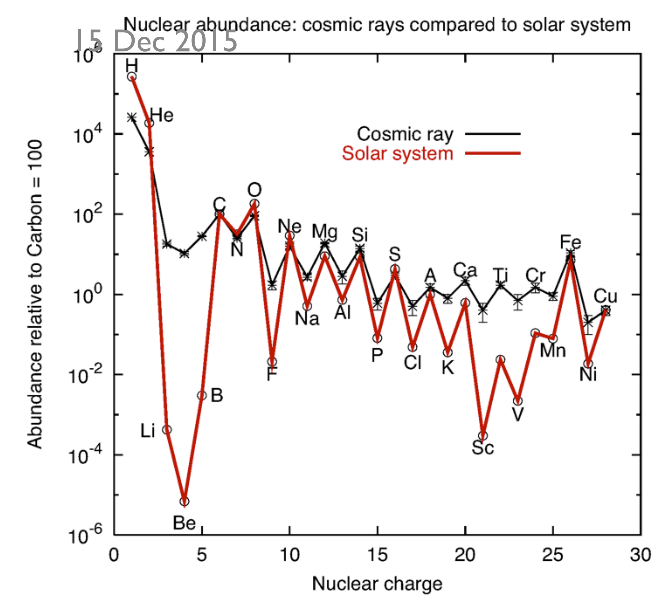
e± Cooling



e± lose energy (cool) via inverse Compton and synchroton

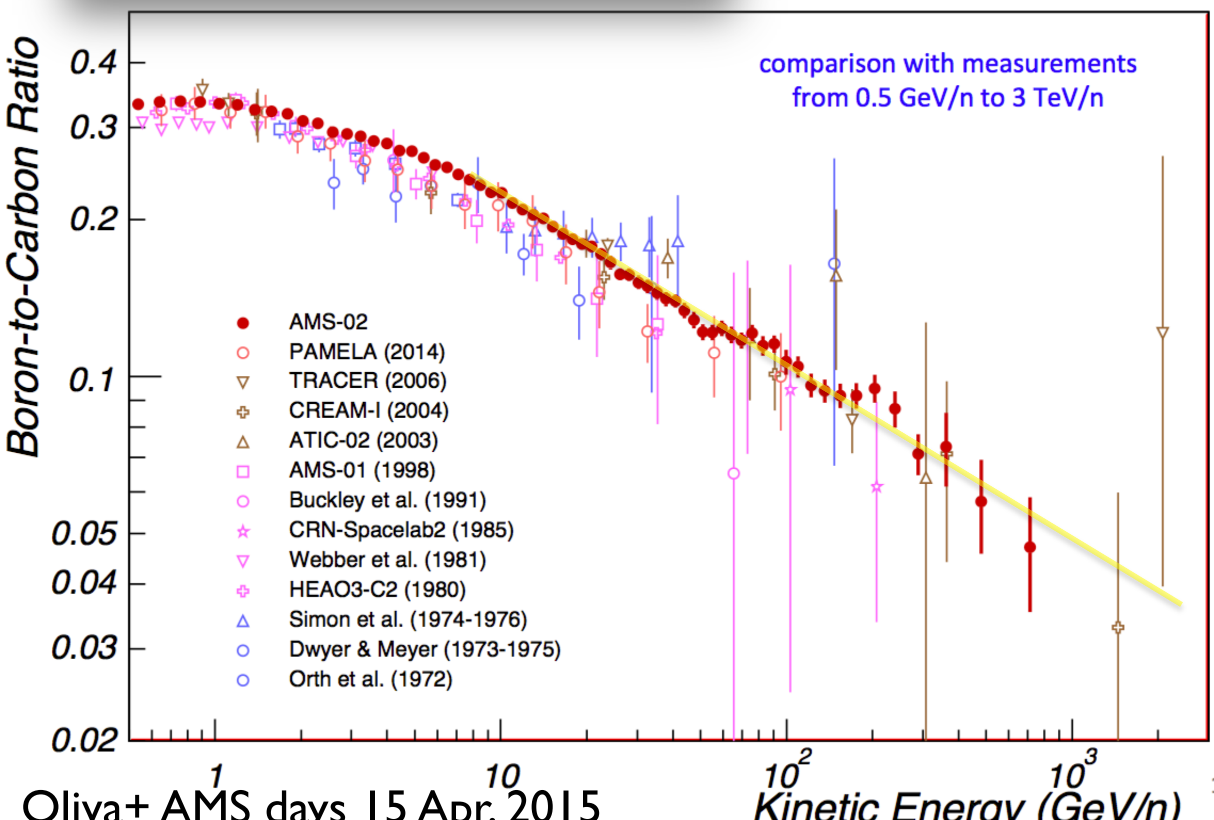
$$t_{\rm cool} \sim \frac{\varepsilon}{\frac{4\pi}{3}\sigma_T c\left(\frac{B^2}{8\pi}+U_\gamma\right)\left(\frac{\varepsilon}{mc^2}\right)^2}$$

$$d < 2\sqrt{D_{\rm diff}t_{\rm cool}} \sim 1\ {\rm kpc}\left(\frac{\varepsilon}{\rm TeV}\right)^{\frac{\delta-1}{2}}$$



Talk by Jin & Zhou

B/C



Oliva+ AMS days 15 Apr. 2015

Boron is 2ndary of Carbon

$D_{diff} \sim D_0 \ (\varepsilon/\varepsilon_0)^{-\delta}$

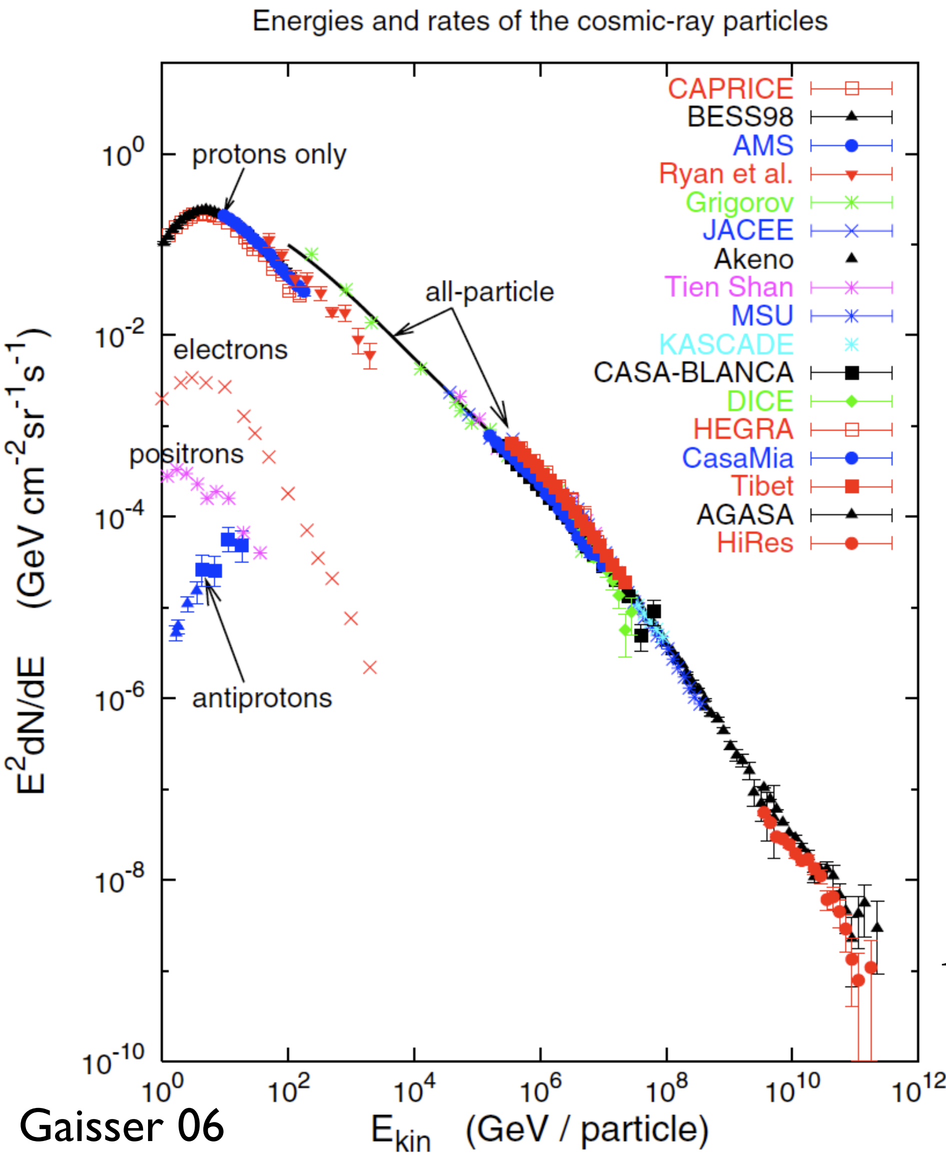
$\delta \sim 0.4$

$D_0 \sim 2 \times 10^{28}$ cm^2/s

Subject to change by
- Disk & halo
- Wind convection
- Turbulent diffusion
- Reacceleration

Isotope ratio: $^{10}Be/^{9}Be$

Energetics



Gaisser 06

$\rho_{proton} \sim 1\,eV/cm^3$

Supernova

$$R_p \sim \frac{10^{50}\,\mathrm{erg}}{100\,\mathrm{yr}}$$

$\rho_{e+} \sim 10^{-4}\,eV/cm^3$

@10GeV

$$R_{e^+} \sim \frac{\rho_{e^+}}{\rho_p}\frac{t_{\rm esc}}{t_{\rm cool}} R_p \sim \frac{10^{46}\,\mathrm{erg}}{100\,\mathrm{yr}}$$

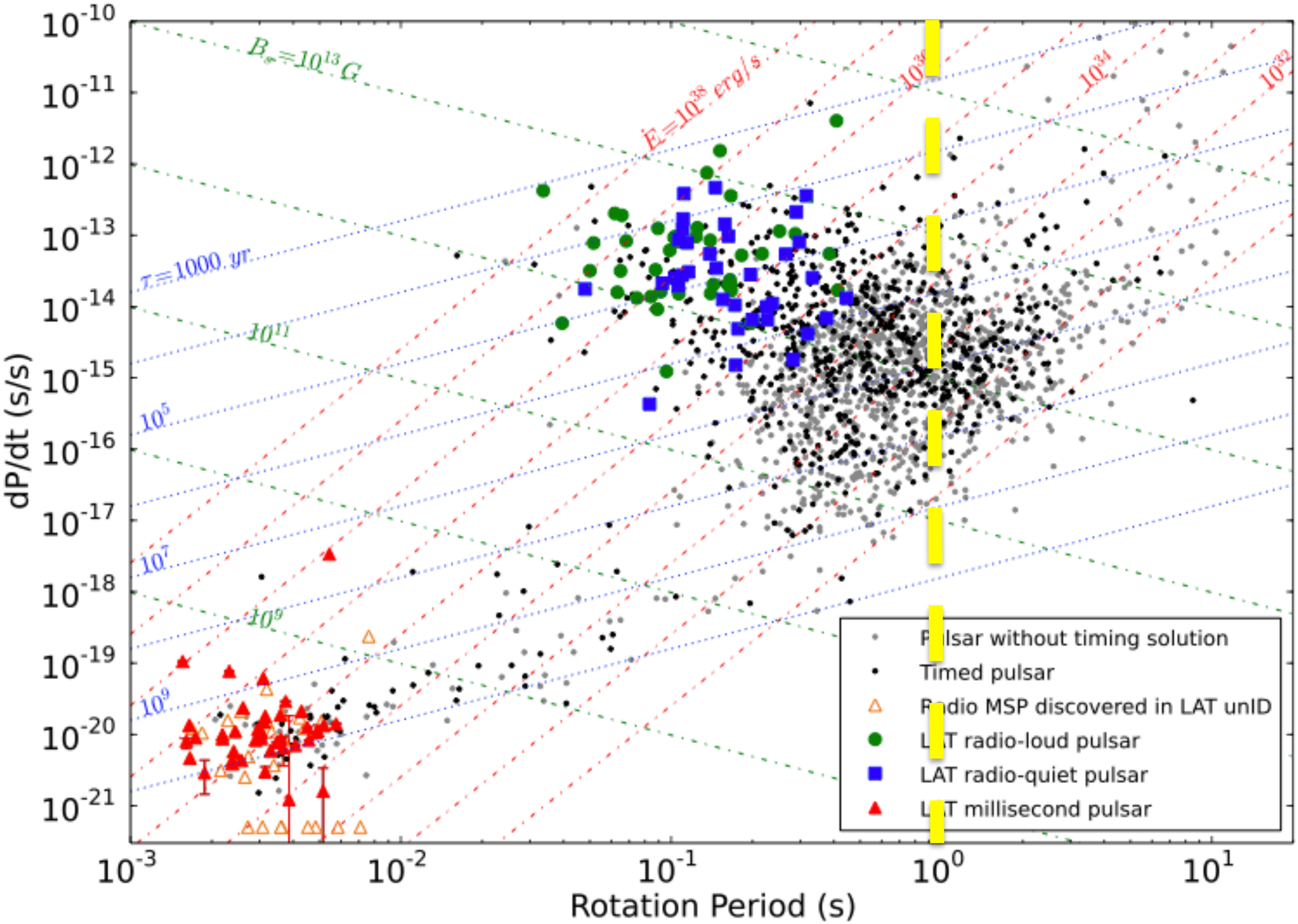
Astrophysical Models

$$E_{rot} \sim \frac{1}{2} I\Omega^2 \sim 10^{46} \mathrm{erg} \left(\frac{P}{\mathrm{sec}} \right)^{-2}$$

Energy required for $e^{\pm}$ excess

$$R_{e^+} \sim \frac{\rho_{e^+}}{\rho_p} \frac{t_{\mathrm{esc}}}{t_{\mathrm{cool}}} R_p \sim \frac{10^{46} \mathrm{erg}}{100 \mathrm{yr}}$$

Pulsars



Abdo+ 13

Fermi:

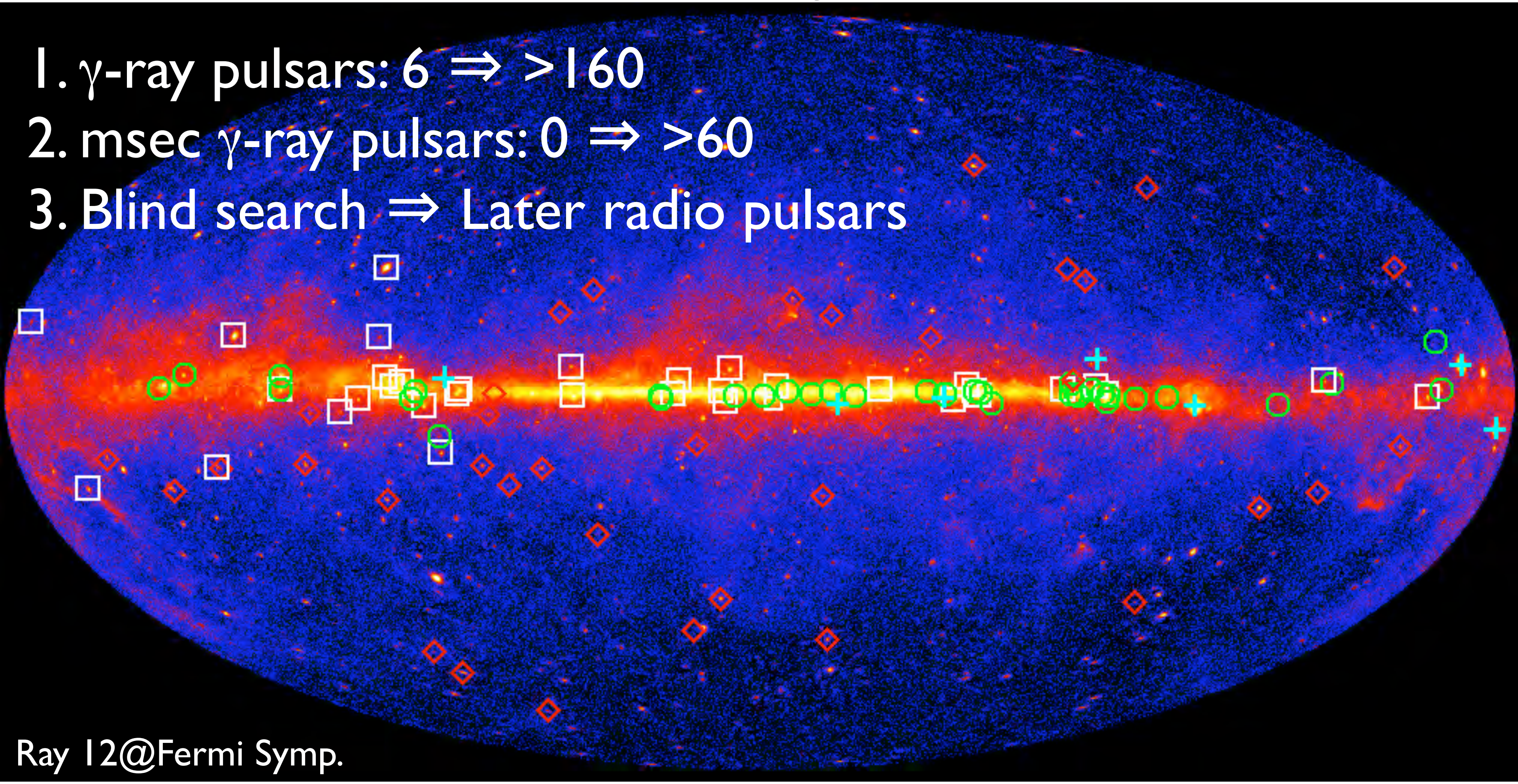
γ-ray PSRs

6 → >160

γ-ray MSPs

0 → >60

Gamma-Ray Pulsars

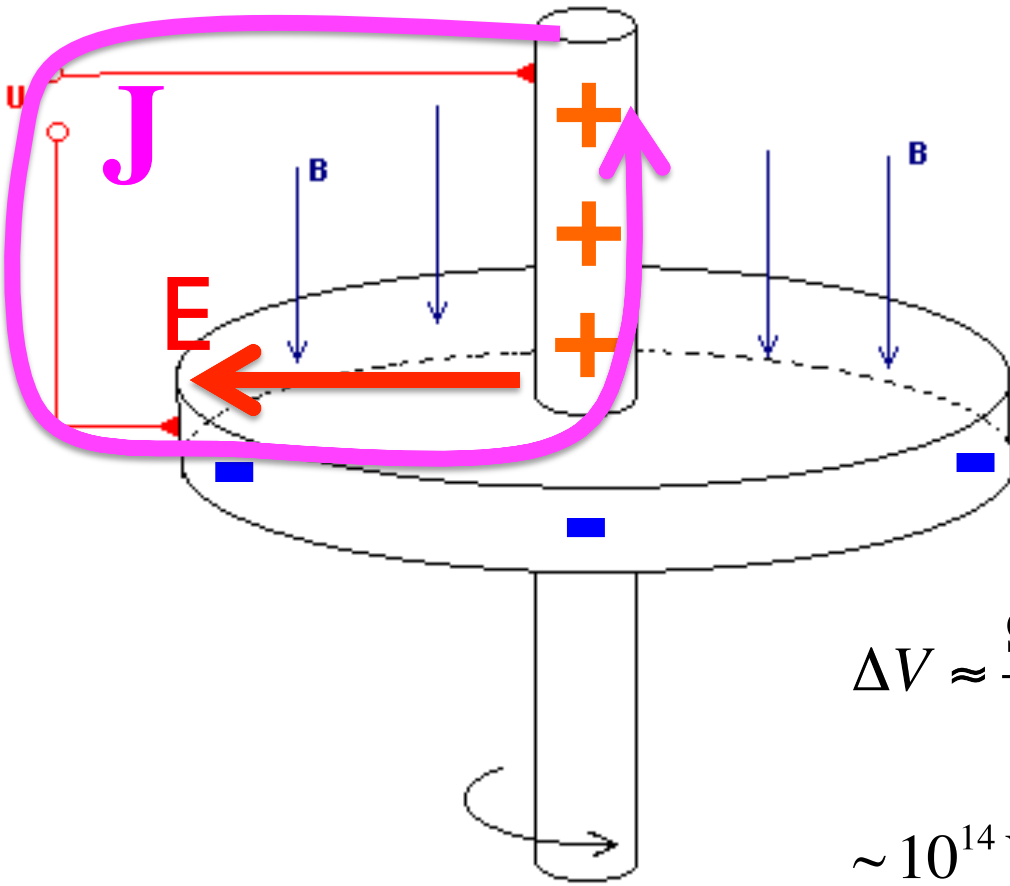


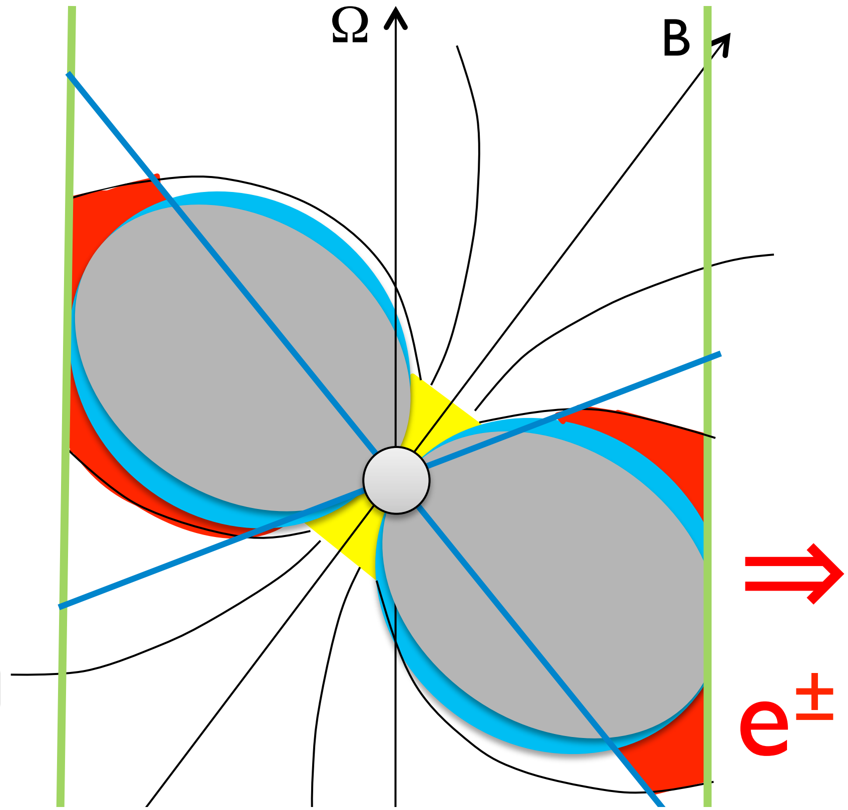
Fermi satellite (LAT) has found ***>160 γ-ray pulsars***

CGRO PSRs (+), young radio-selected (○), young gamma-selected (□), MSPs (◇)

Pulsars = $e^{\pm}$ Accelerators

Unipolar induction





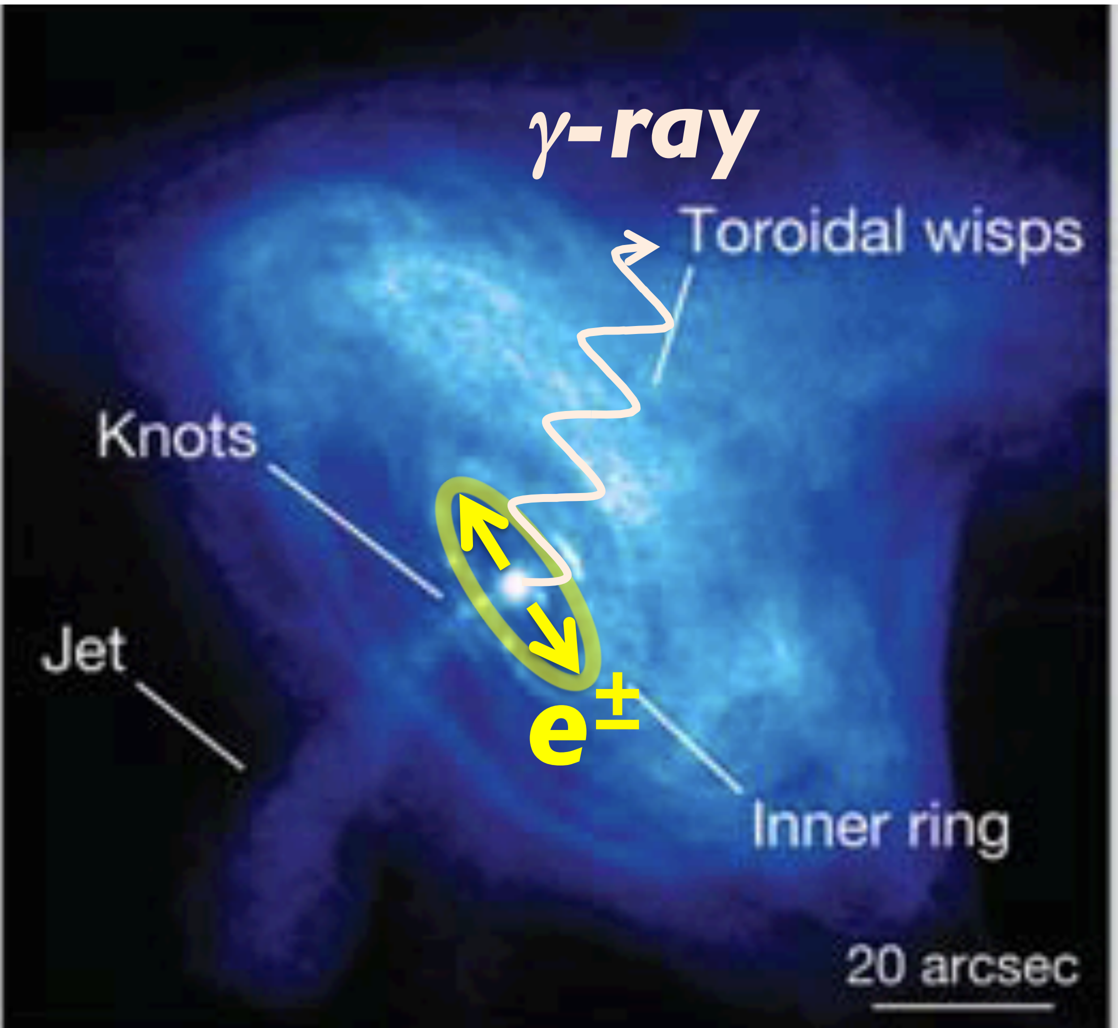
$$\Delta V \approx \frac{\Omega^2 B R^3}{2c^2}$$

$$\sim 10^{14}\,\mathrm{V}\left(\frac{\Omega}{1\ \mathrm{s}^{-1}}\right)^2\left(\frac{B}{10^{12}\,\mathrm{G}}\right)\left(\frac{R}{10^{6}\,\mathrm{cm}}\right)^3$$

Goldreich & Julian 69

Pulsar Wind Nebula

Most spin-down energy ⇒ Pulsar wind



(Relativistic plasma of magnetized $e^{\pm}$)

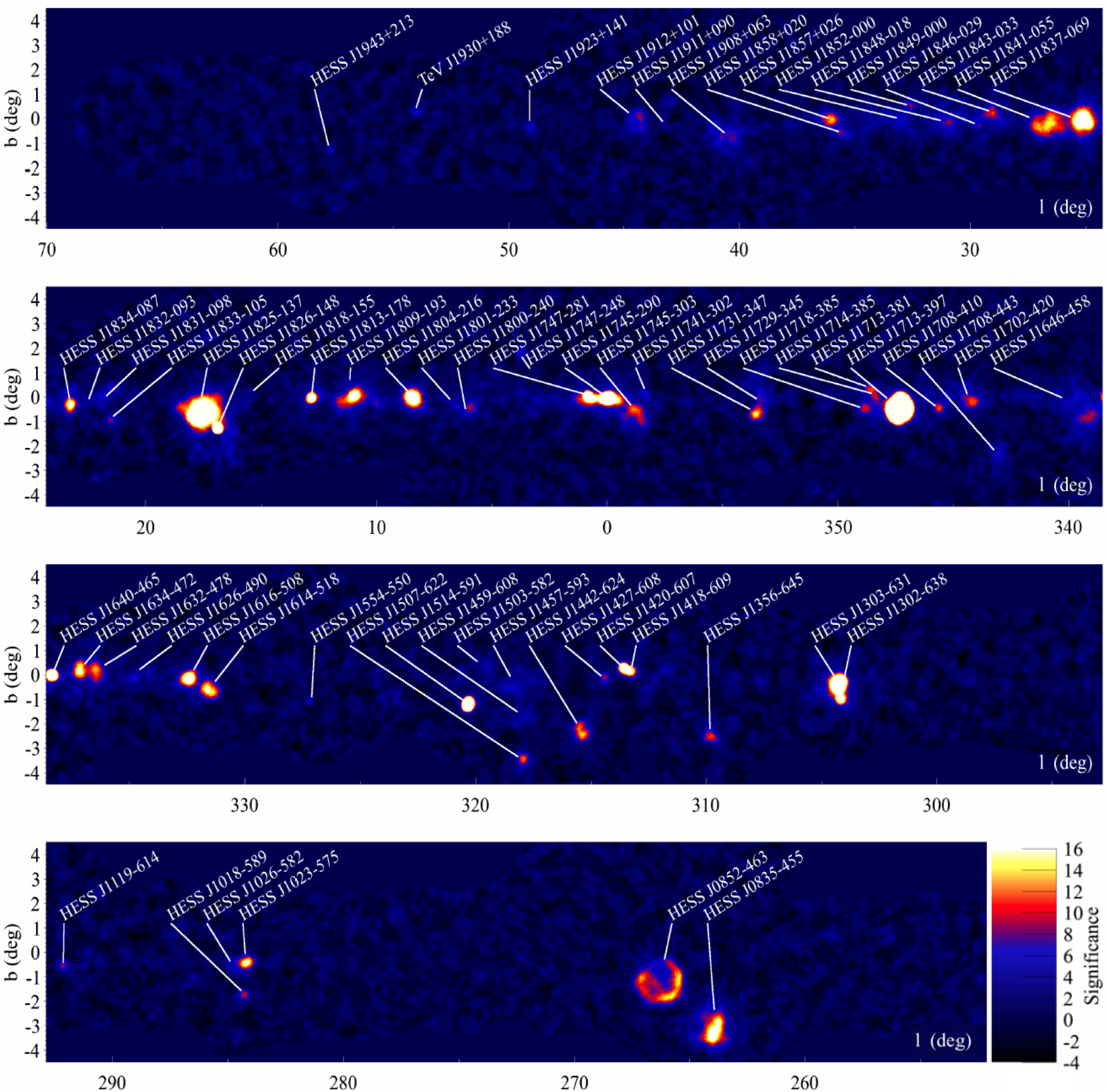
$$L_{e^{\pm}} \sim 10 L_{\gamma}$$

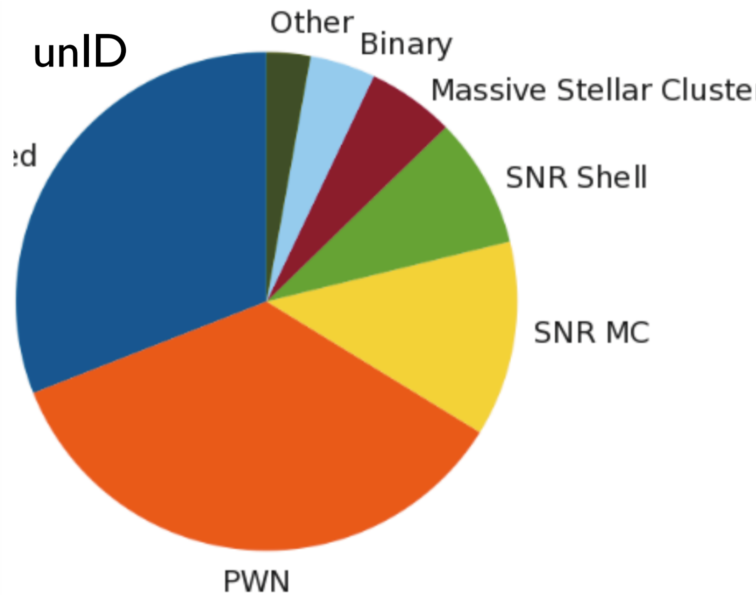
Termination shock
⇒ $e^{\pm}$ acceleration
⇒ Power law spec.

PWN→SNR→ISM

TeV Gamma-Ray Sky

1307.4690

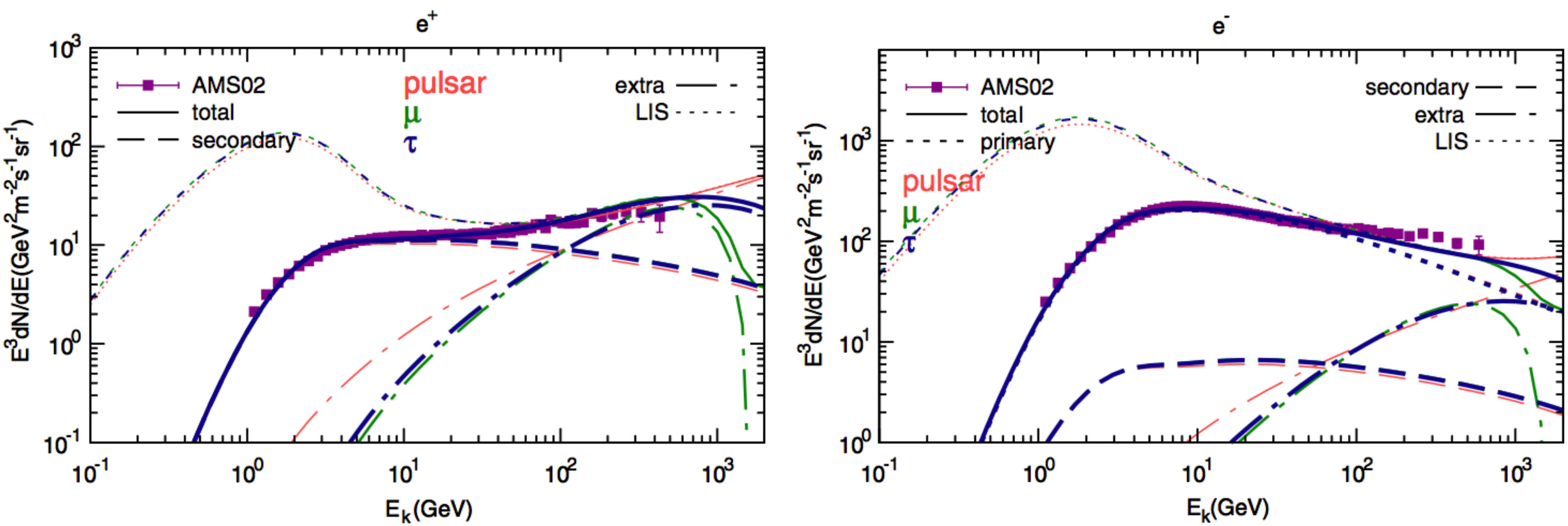




Pulsar Wind Nebula dominates TeV γ-ray sky

Spectral Fitting

Astrophysical models reproduce e^+ & e^- spectra



Lin+ 15

Supported by astrophysical observations
Consistent with a charge symmetric source term
Primary e^- spectrum may have hardening

Astrophysical Models

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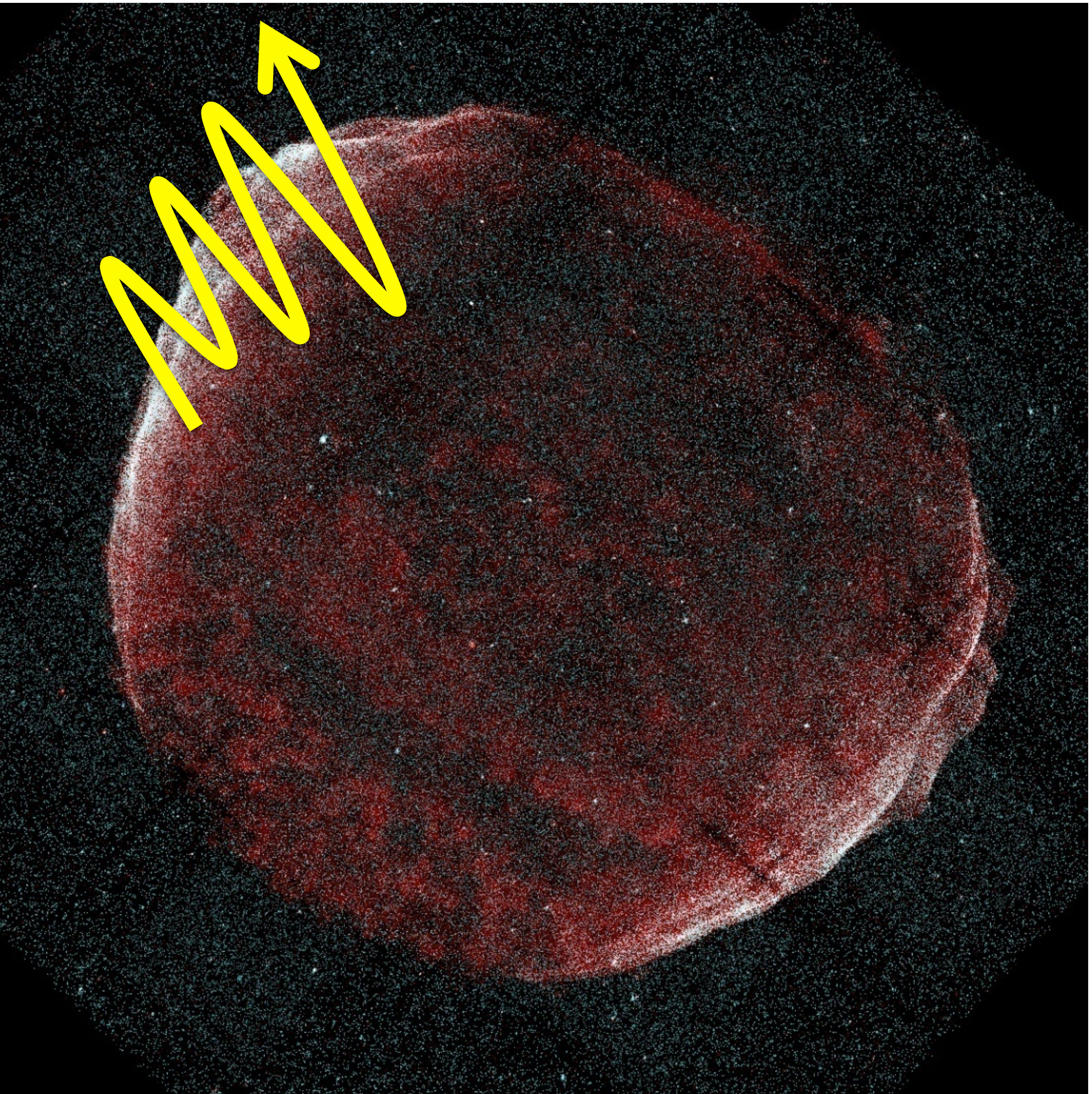
Energy required for $e^{\pm}$ excess

$$R_{e^+} \sim \frac{\rho_{e^+}}{\rho_p} \frac{t_{\mathrm{esc}}}{t_{\mathrm{cool}}} R_p \sim \frac{10^{46} \mathrm{erg}}{100 \mathrm{yr}}$$

Supernova Remnant



Major CR sources

$p_{CR} + p_{surrounding}$
$\rightarrow \pi \rightarrow e^+e^-$

Hadronic origin

Typical τ_{pp} is small

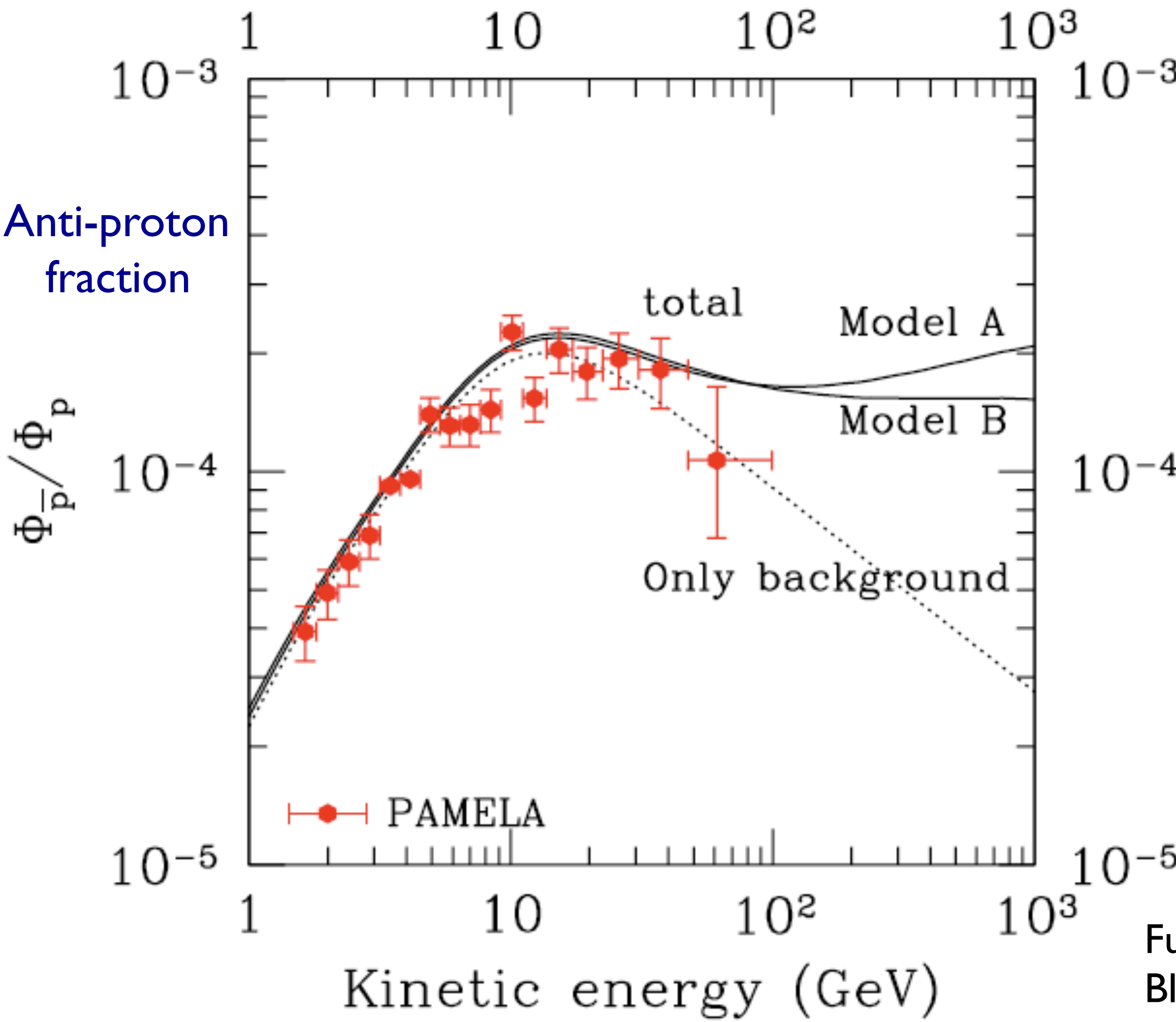
− Dense matter (molecular cloud)

− Reacceleration

Fujita, Kohri, Yamazaki & KI 09
Blasi & Serpico 09

Anti-Proton

Anti-proton fraction



SNR model:
pp → π → e^+e^-
(w/ surrounding)

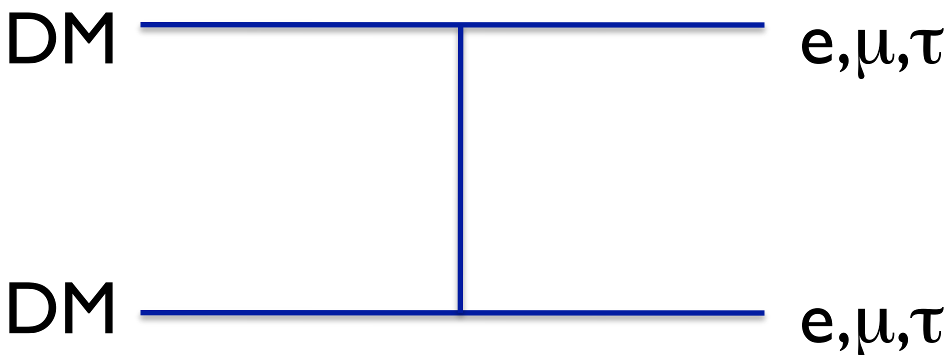
⇒ Inevitably anti-proton excess above ~100 GeV

⇒ AMS-02

Fujita, Kohri, Yamazaki, KI 09
Blasi & Serpico 09

Dark Matter?

Annihilation $\propto n^2$



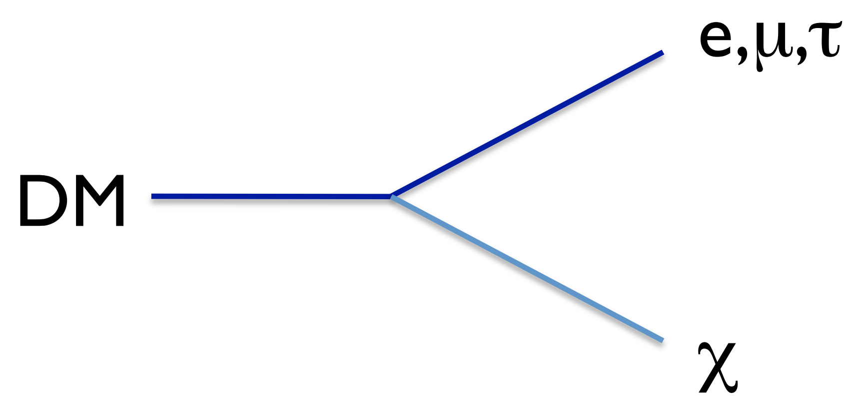
$$\langle \sigma v \rangle \sim \frac{\rho_{e^+}}{\rho_{\rm DM}\left(\frac{\rho_{\rm DM}}{m_{\rm DM}}\right) t_{\rm cool}}$$

$$\sim 10^{-24}\,{\rm cm^3 s^{-1}} \left(\frac{m_{\rm DM}}{\rm TeV}\right)$$

>3x10^{-26}cm^3/s (thermal)

boost factor ~100

Decay $\propto n$

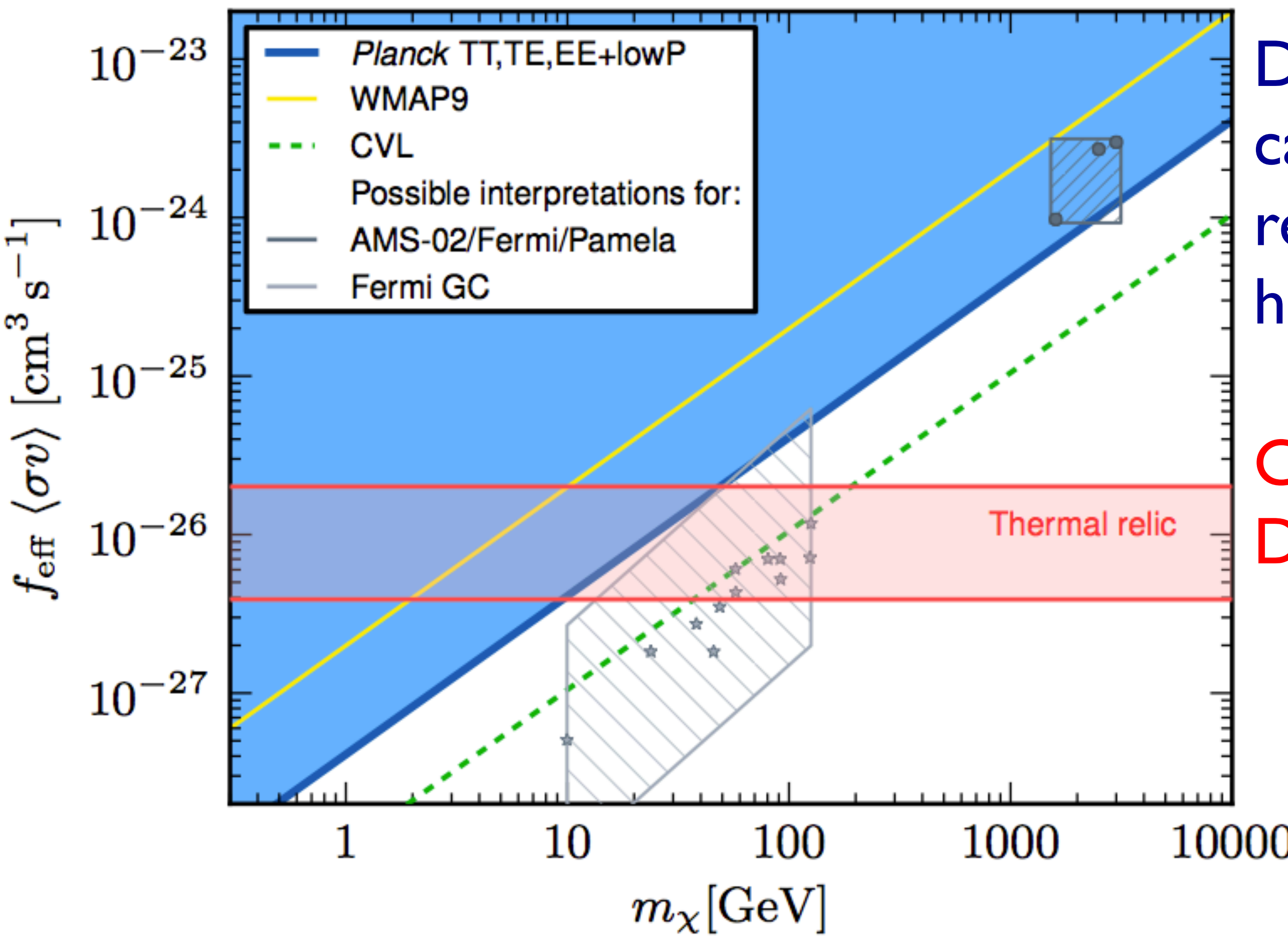


$$t_{\rm DM} \sim \frac{\rho_{\rm DM}}{\rho_{e^+}} t_{\rm cool}$$

$$\sim 6 \times 10^{26}\,{\rm s}$$

$$>> H^{-1}$$

Constraints on DM



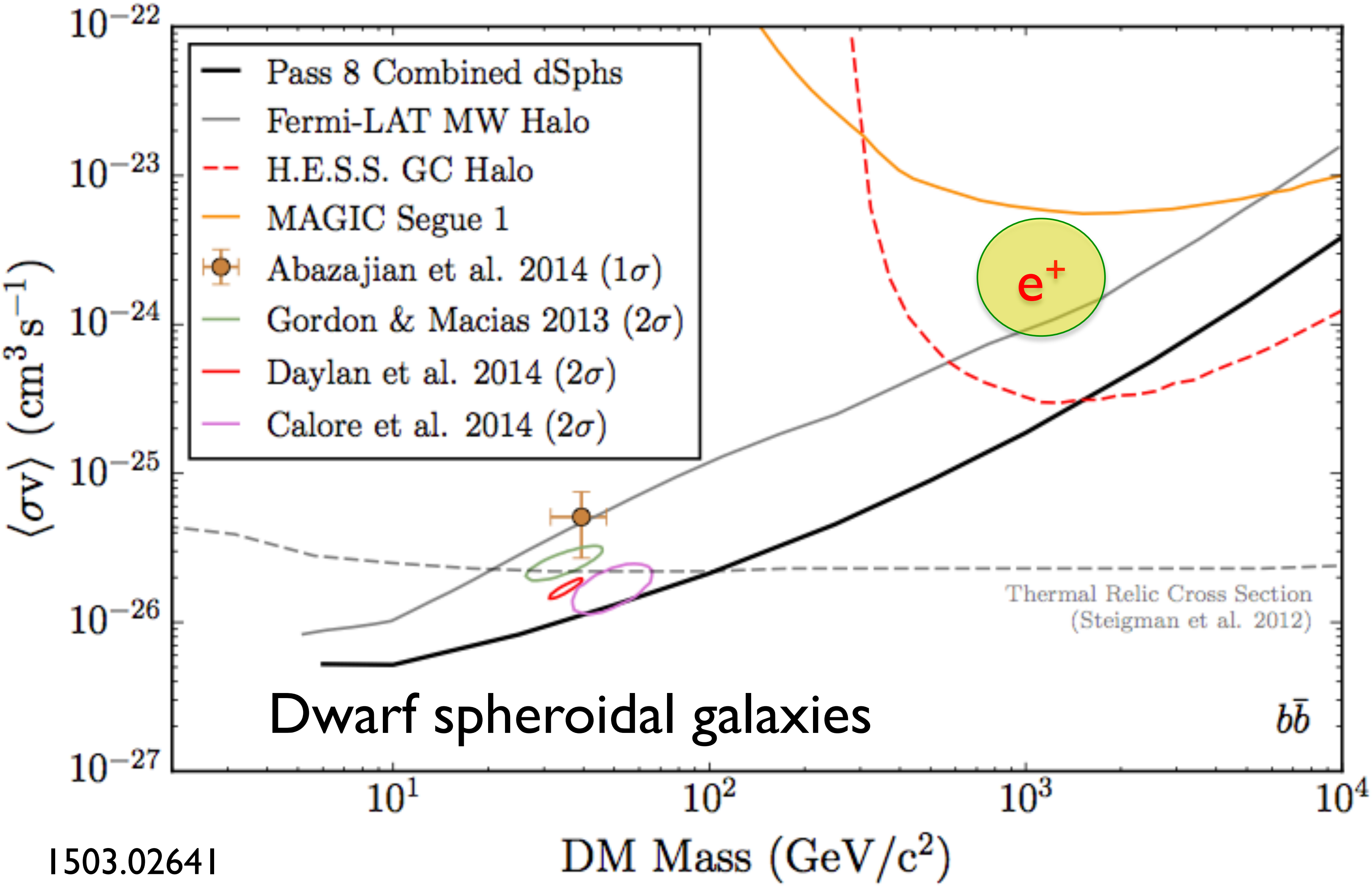
DM annihilation can alter recombination history

CMB excludes DM annihilation

Planck 1502.01589

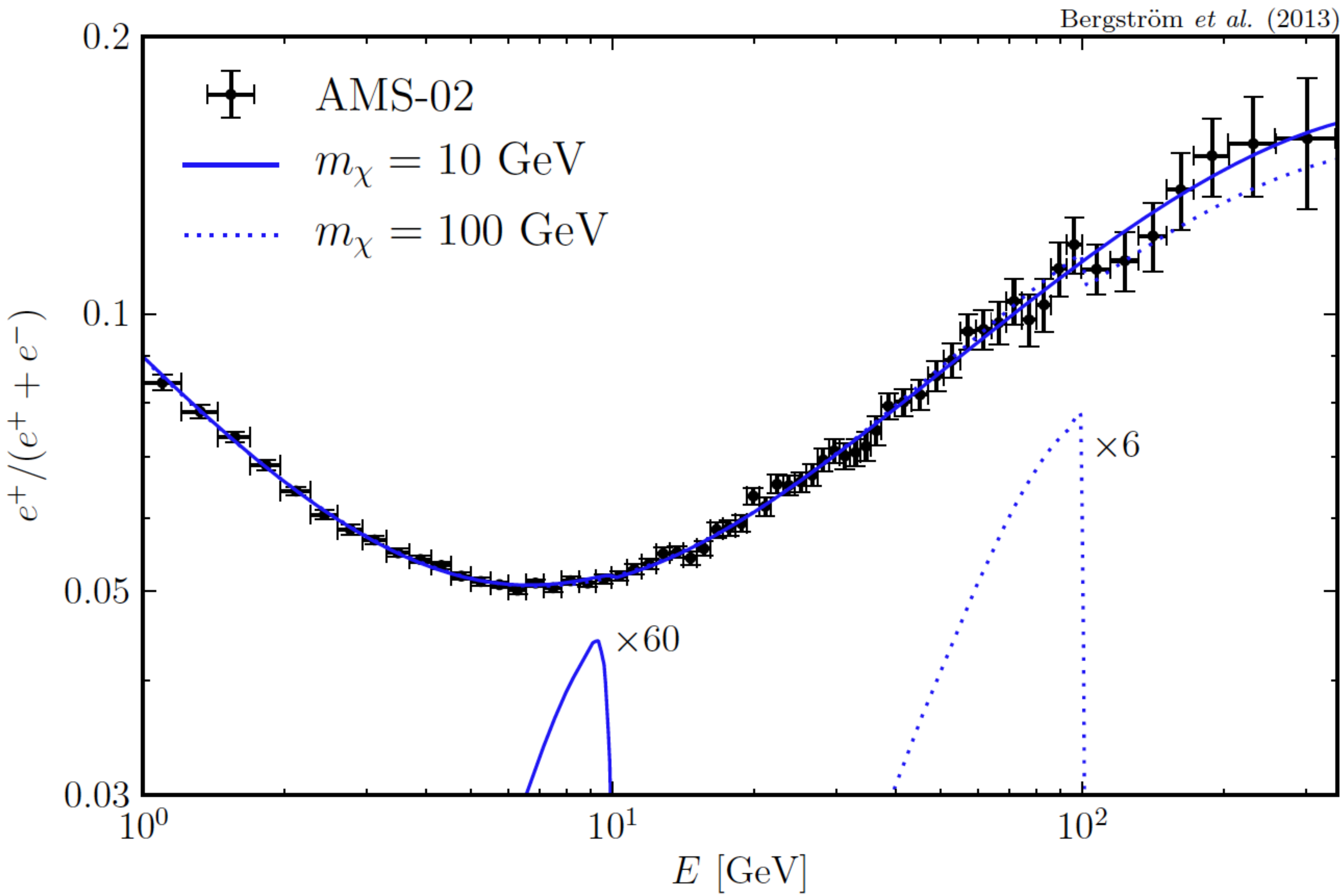
Morselli's talk

6yr Fermi Limits on DM



1503.02641

Limits on Cross Section



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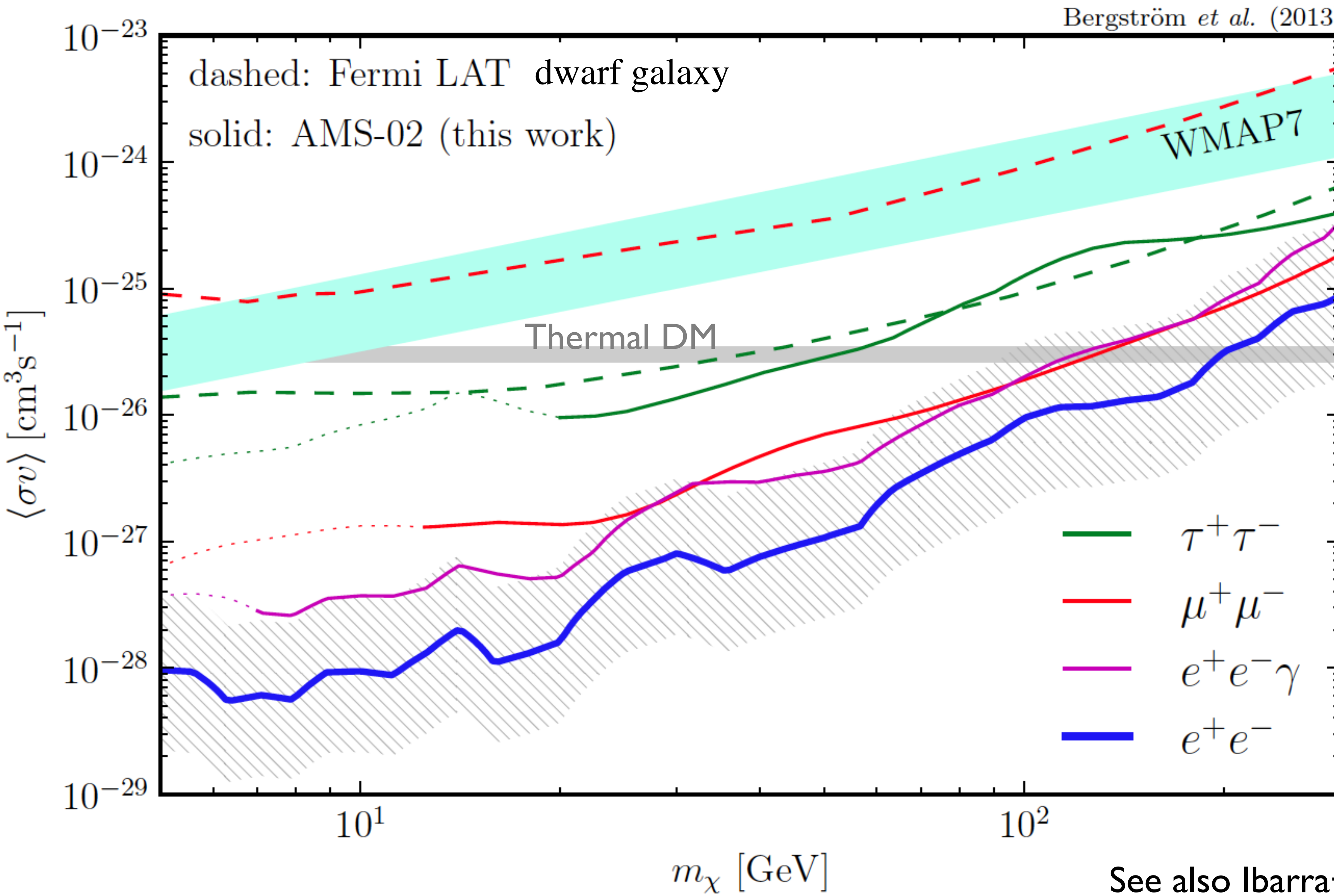
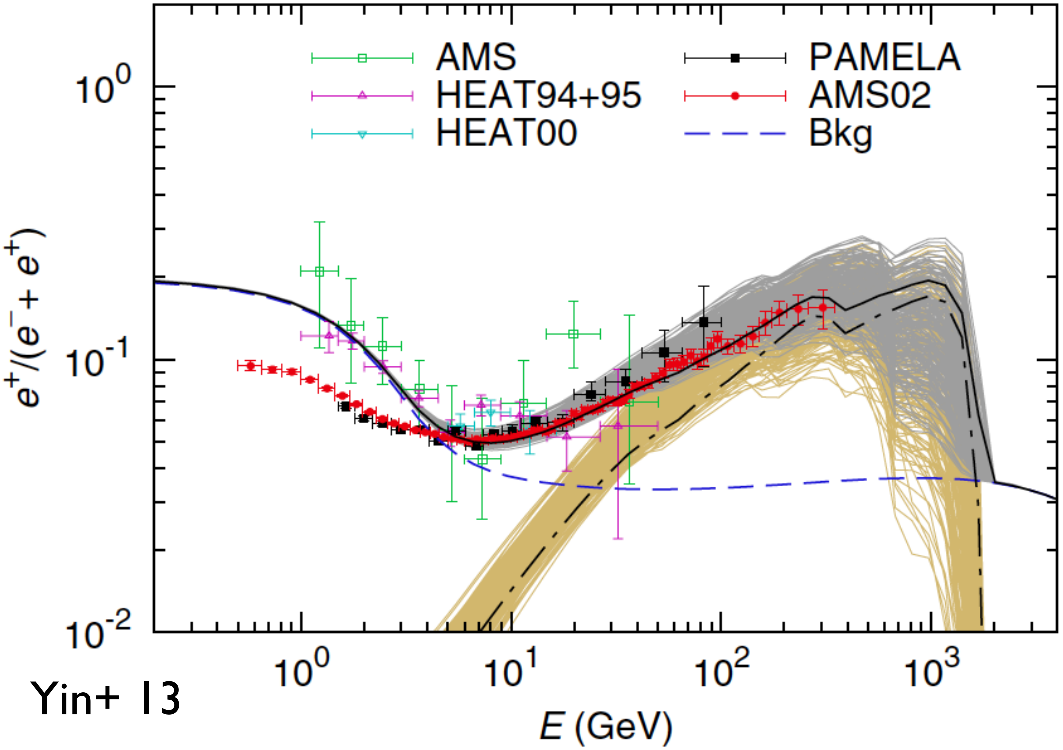


See also Ibarra+ 14

Future?

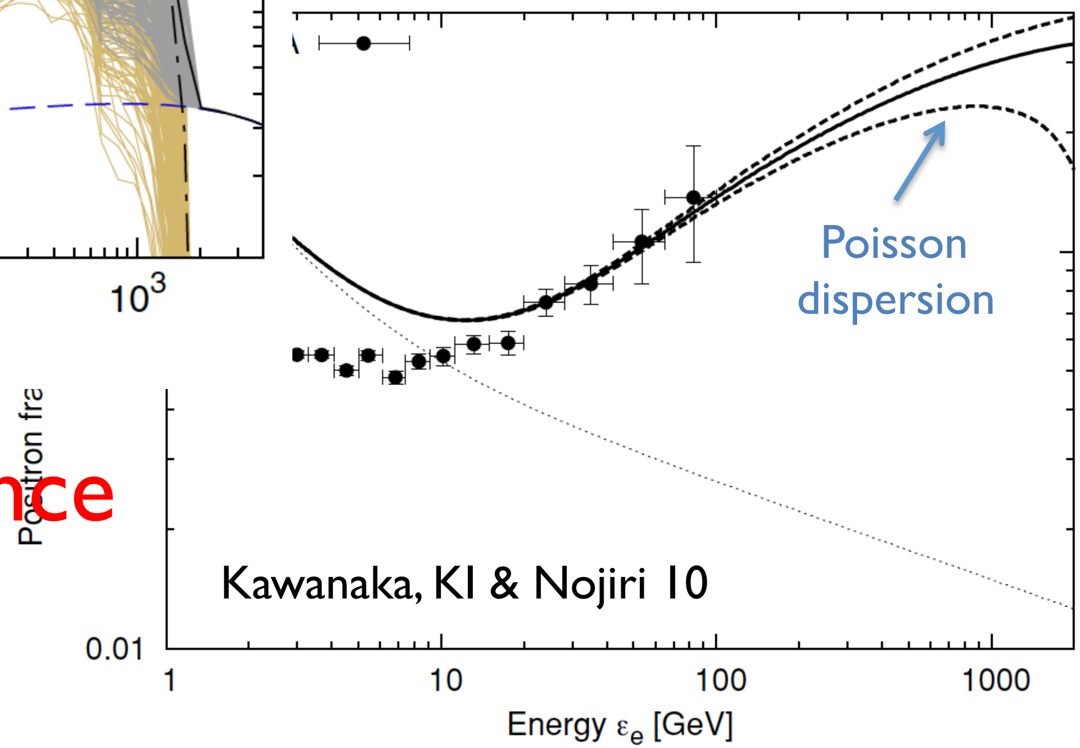
- Spectrum at >TeV
- Anisotropy
- Anti-proton, …

Spectrum: Fine Structure



Yin+ 13

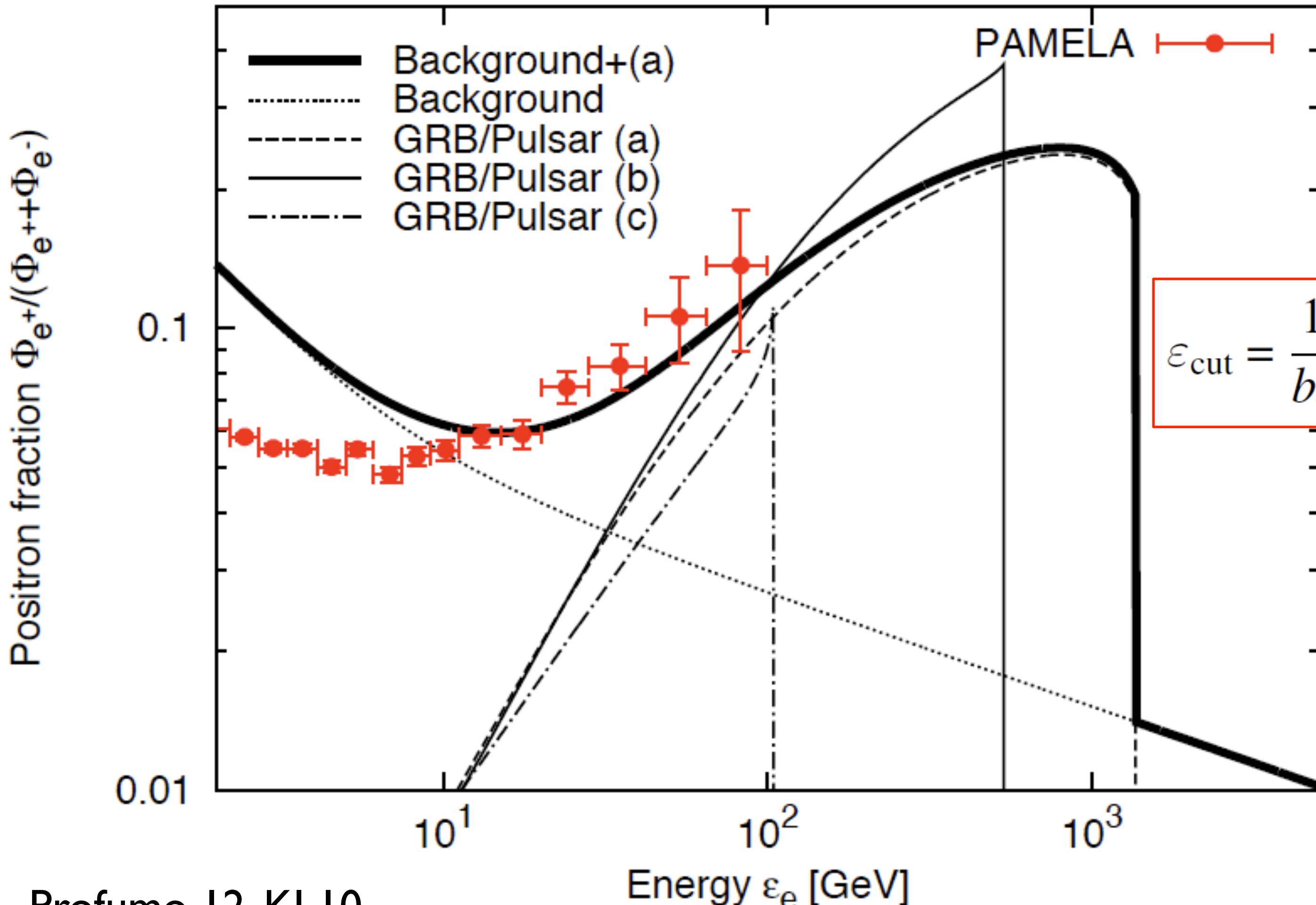
Multiple pulsars make fine structure



Large cosmic variance at high energy

DM-like Pulsar

High-energy $e^{\pm}$ lose energy by synch. & inv. Compton



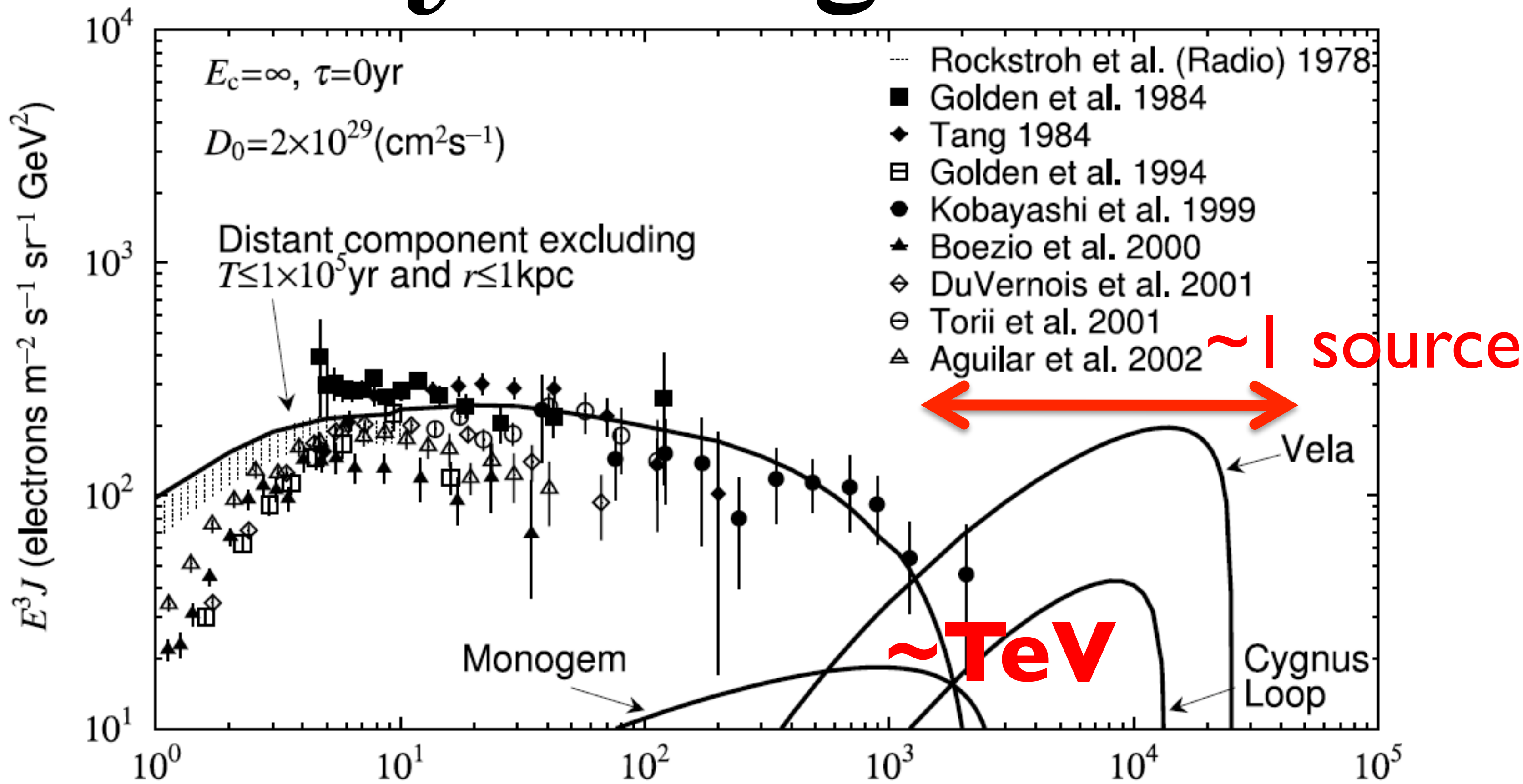
$$t_{cool} \propto \varepsilon_e^{-1}$$

$$\varepsilon_{\rm cut} = \frac{1}{bt} \simeq 300 \left(\frac{10^6 {\rm yr}}{t_{\rm age}} \right) {\rm GeV}$$

Cooling cutoff mimics DM cutoff

Profumo 12, KI 10

Nearby Young Source



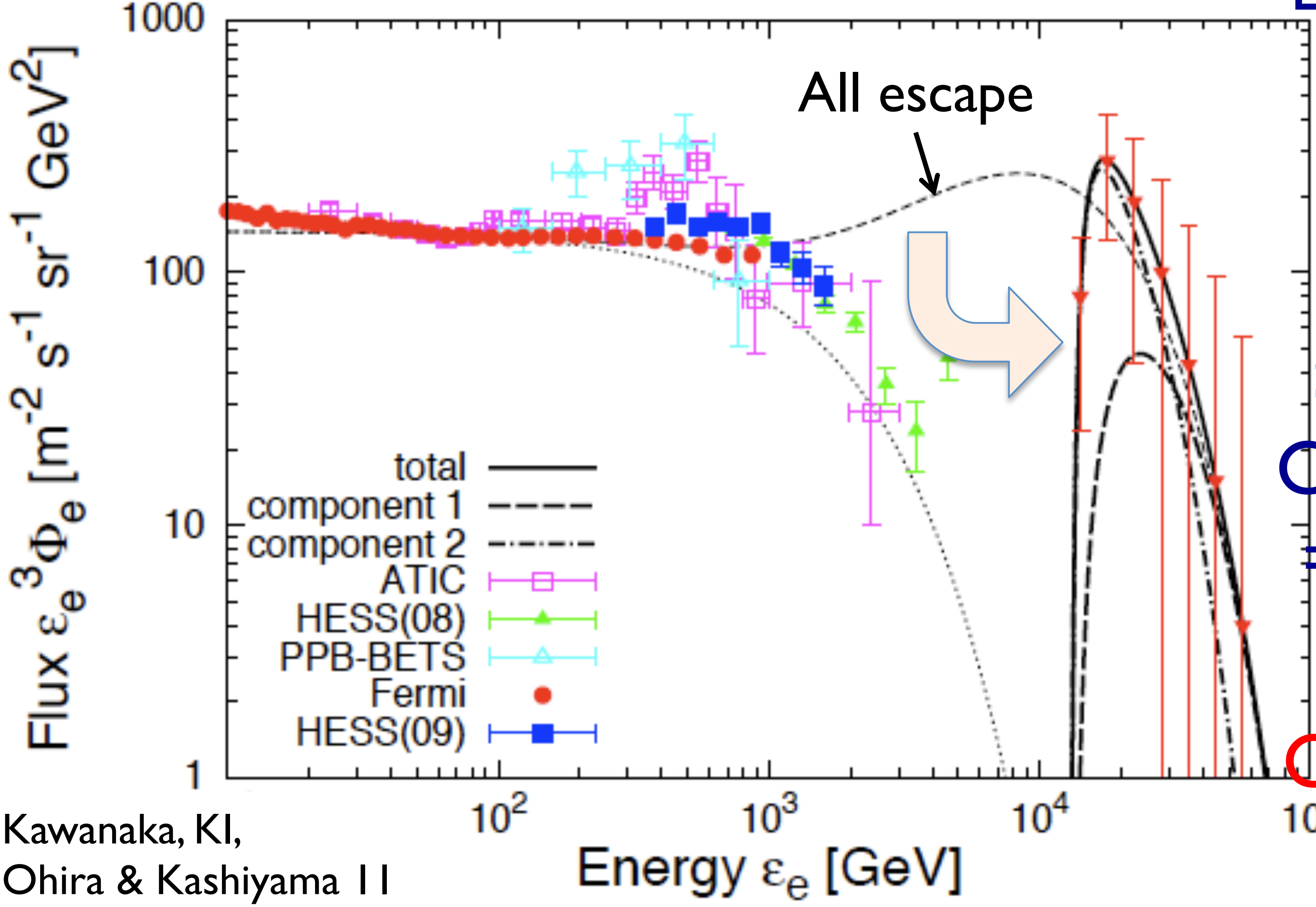
Kobayashi+ 04

$t_{cool} \propto 1/\varepsilon_e$

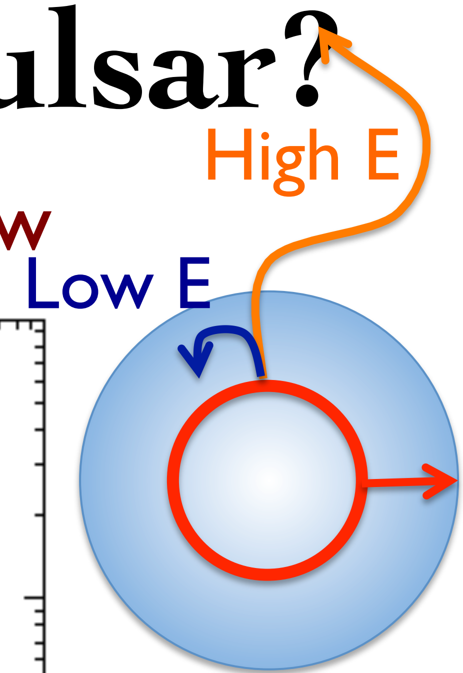
$$N_{\rm PSR}(\varepsilon_e) \sim 6 \left(\frac{\varepsilon_e}{\rm TeV}\right)^{-5/3} \left(\frac{R}{0.7\times10^{-5}\,{\rm yr}^{-1}\,{\rm kpc}^{-2}}\right)$$

Line Spectrum by Pulsar?

Nearby source (e.g., Vela) in TeV e window



Kawanaka, KI, Ohira & Kashiyama 11



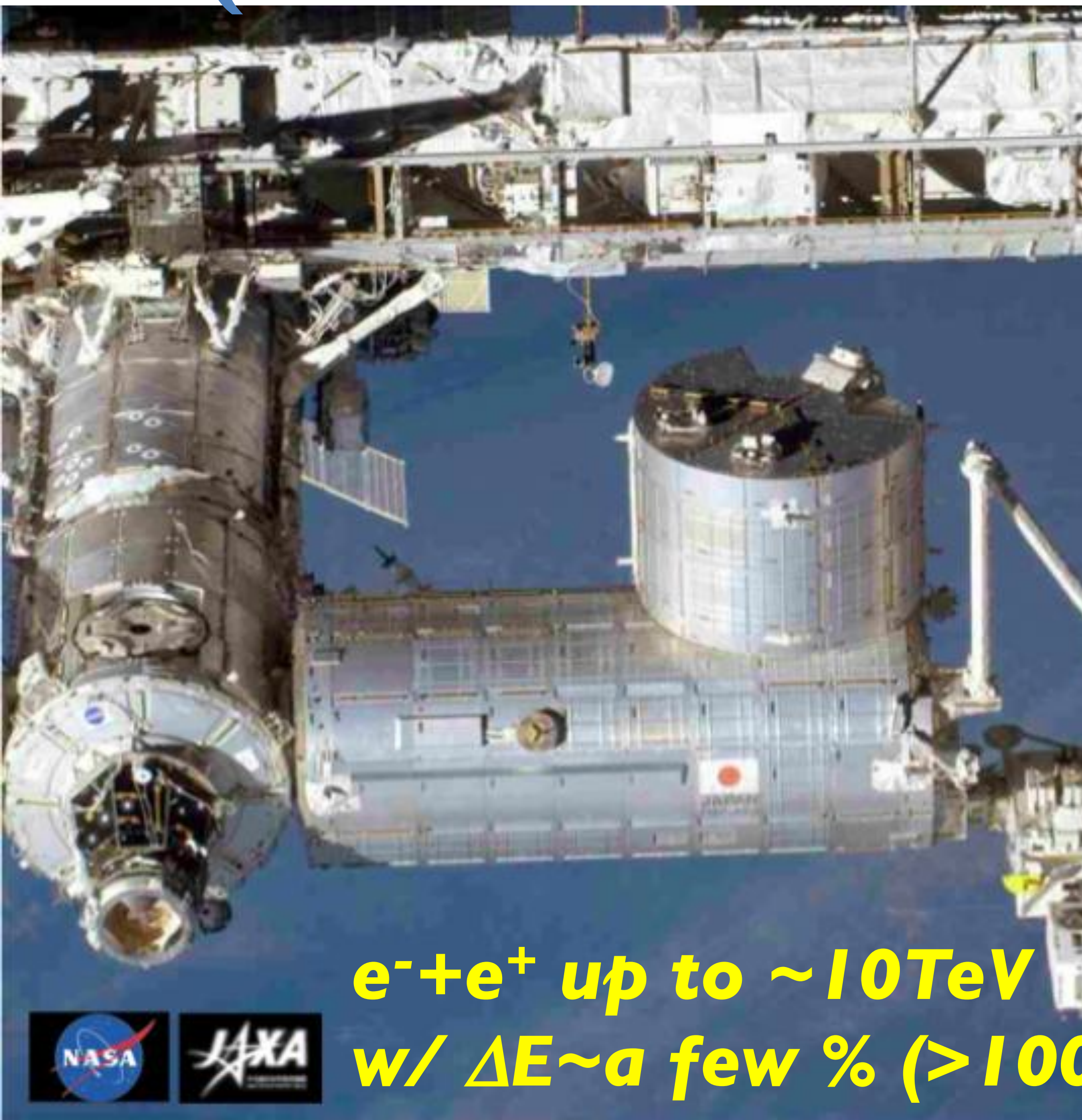
SNR w/ pulsar

Confinement $\Rightarrow$ Low Ene. cutoff

CALET, CTA, LHAASO

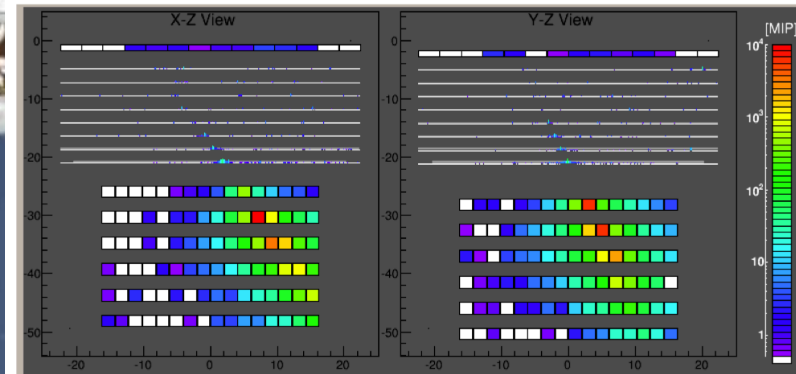
CALET

(CALorimetric Electron Telescope)



~1TeV electron candidate (#1128791625_17544)

(converted to MIP by calibration)



e^-+e^+ up to ~10TeV
w/ ΔE~a few % (>100GeV)

Set on Aug. 25

Data is taking!

DAMPE

DArk Matter Particle Explore

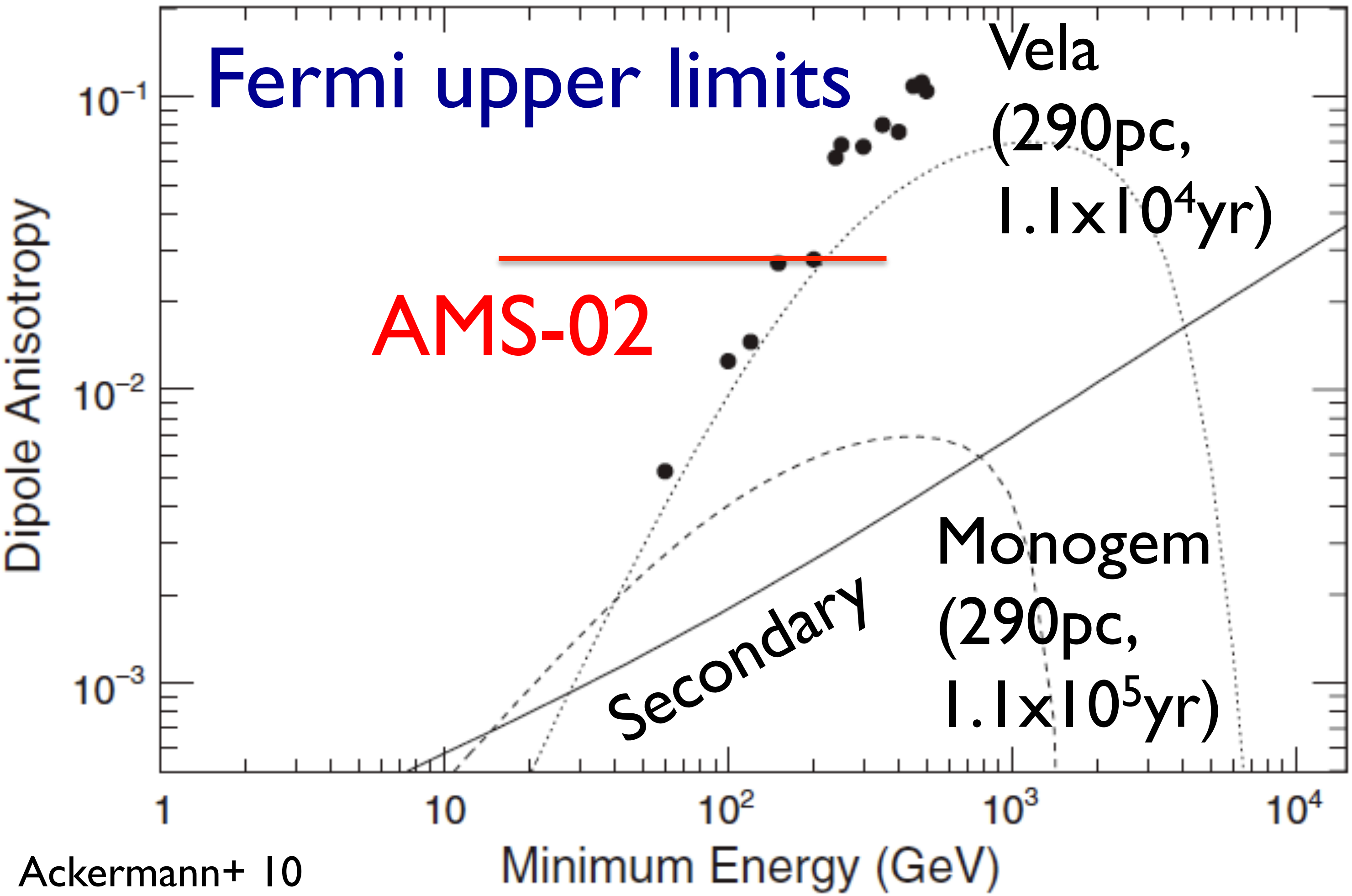
China, Swiss, Italy
Launch tomorrow?
Total: 33 rad length

e, γ: 5GeV-10TeV
ΔE=1%@800GeV
0.3 m^2

p: 100GeV-100TeV
ΔE=40%@800GeV
0.2 m^2

$\Delta\theta$=0.1°@100GeV

e⁻ Anisotropy



Ackermann+ 10

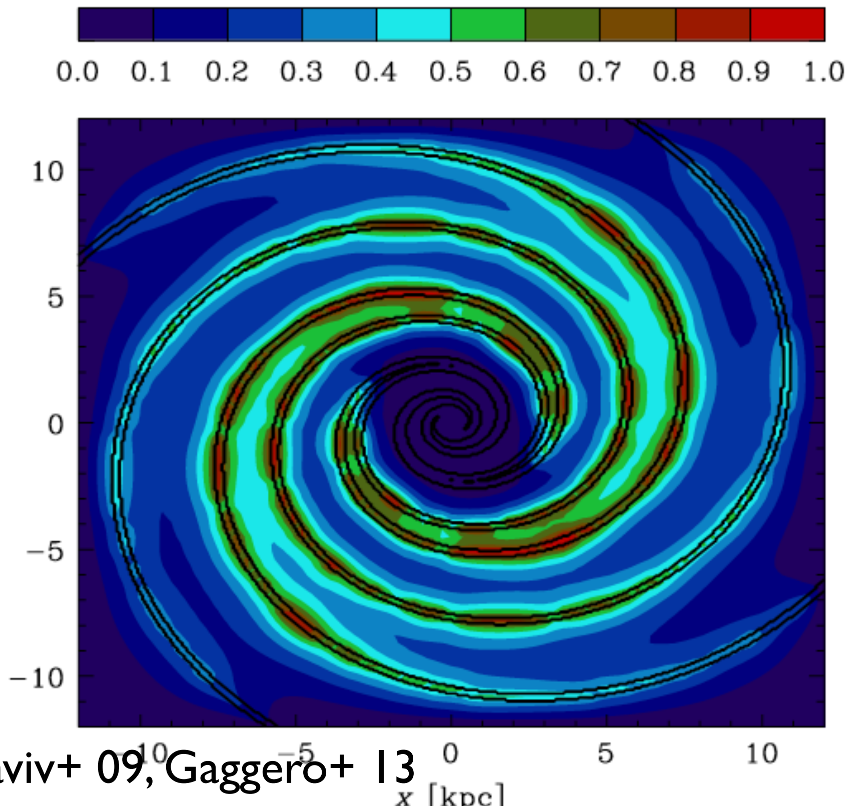
$$\delta = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{3K|\nabla f|}{cf} \sim \frac{3d}{2ct}$$

δ<0.030 (95%CL; 16-350GeV) by AMS-02

Limit∝t$^{-1/2}$; For multiple sources, anisotropy ↓

Local Structures

Spiral distribution

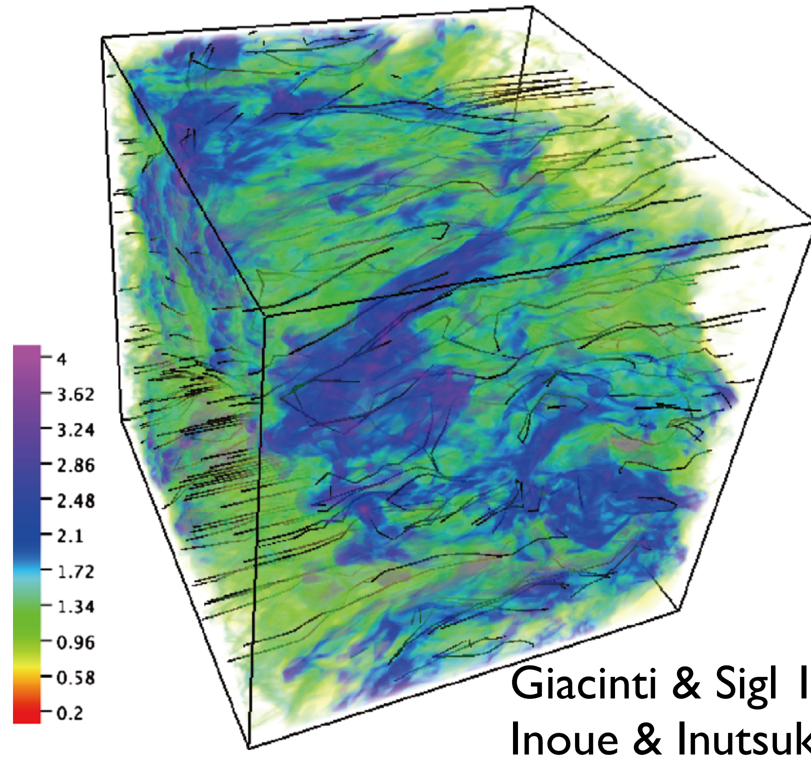


Shaviv+ 09, Gaggero+ 13

⇒ Less nearby sources

⇒ Less anisotropy

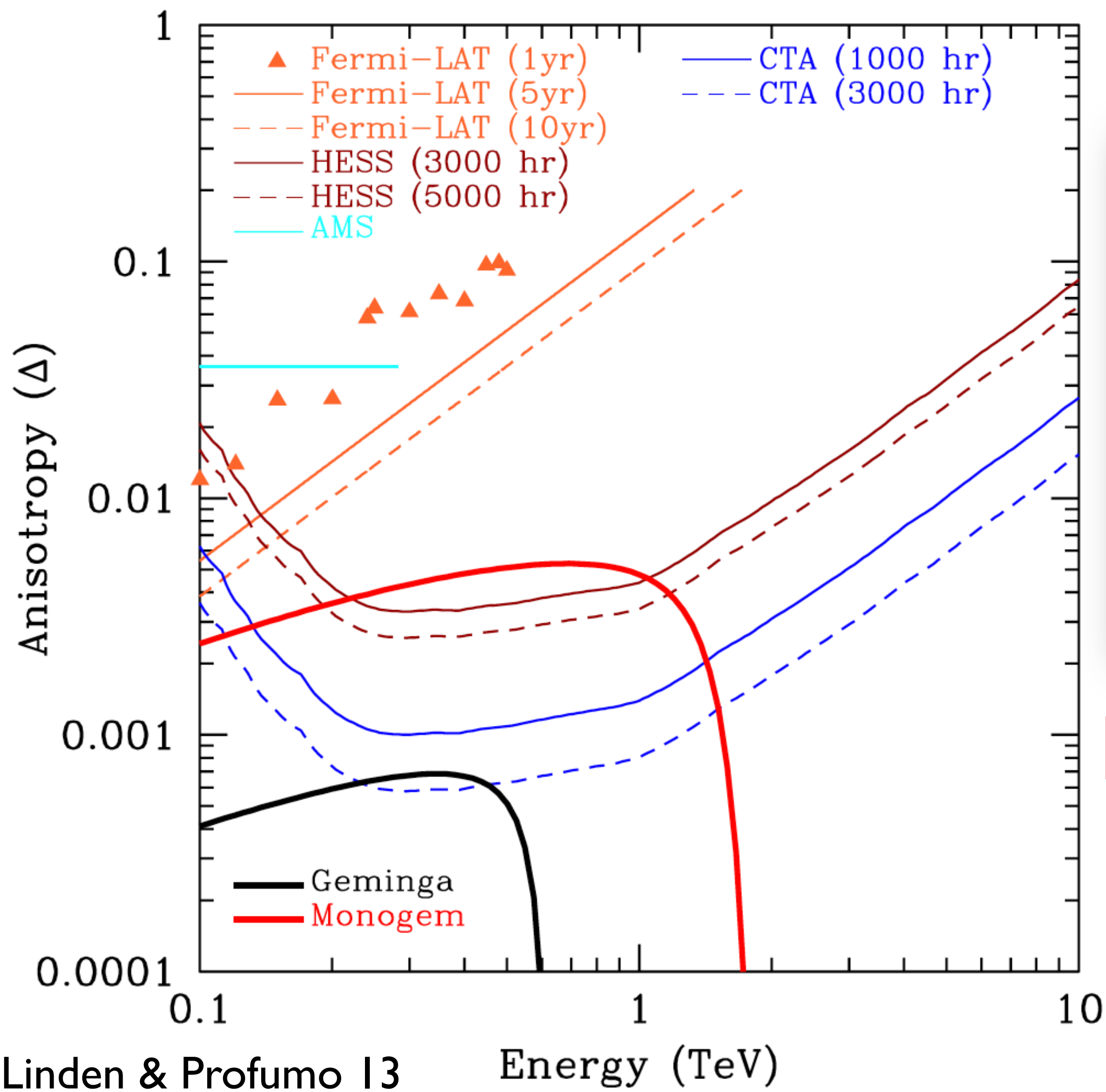
Local B Turbulence



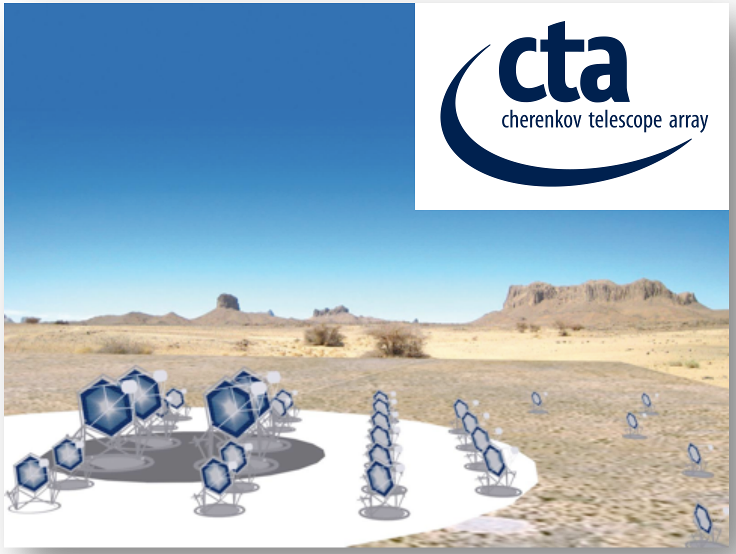
Giacinti & Sigl 12
Inoue & Inutsuka 12

$$r_g(p) \approx \frac{p}{eZB} \approx 10^{-3}\text{pc} \left(\frac{p/Z}{\text{TeV}}\right)\left(\frac{B}{\mu G}\right)^{-1}$$

Future: CTA



Linden & Profumo 13



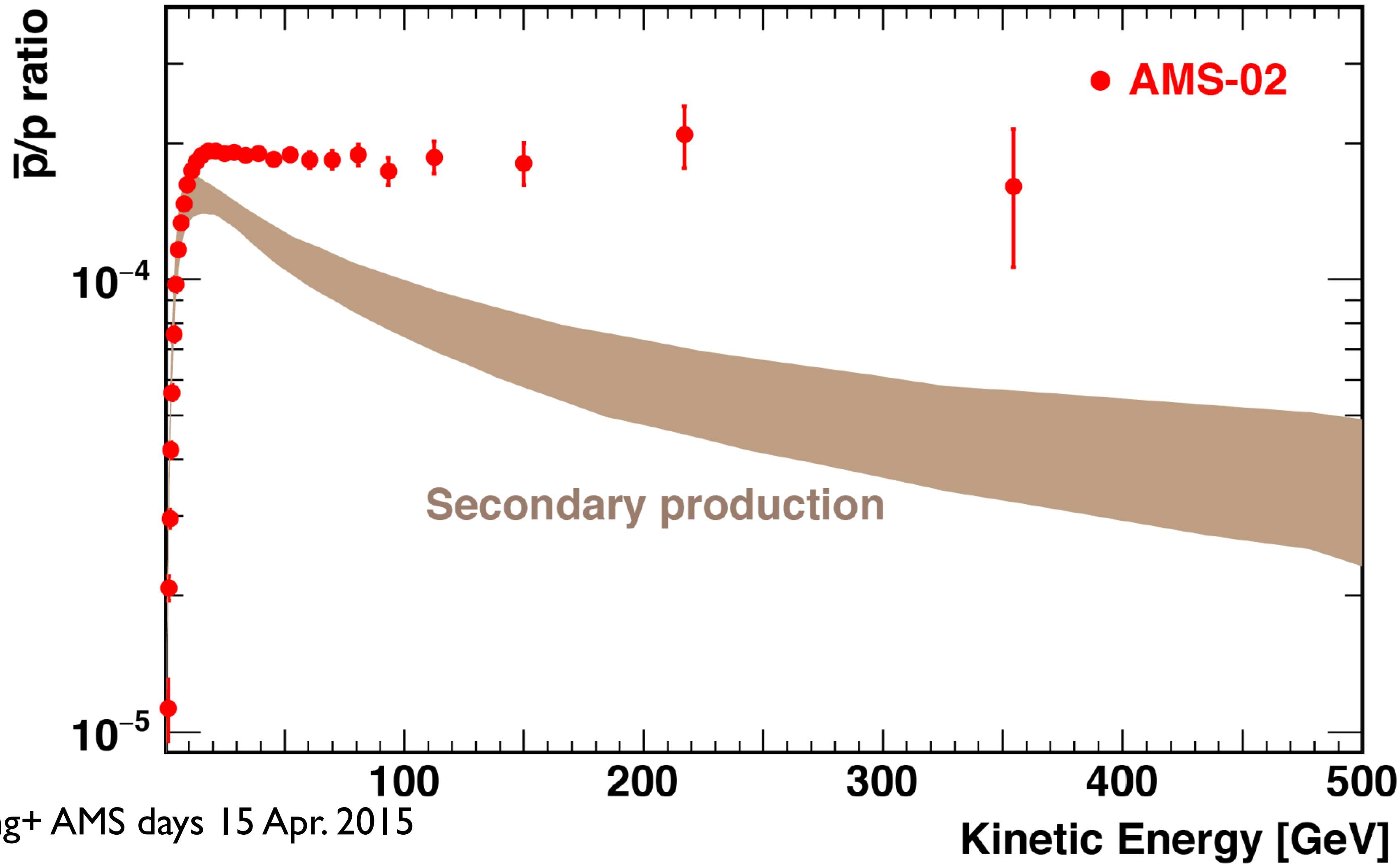
Huge effective area

It may be difficult to control the systematics

Contents

- **$e^{\pm}$ excess: *Astrophysical***
  - ✓ TeV spec., Anisotropy, … ***CALET***
- **$\bar{p}$: *No excess or pp?***
  - ✓ B/C ⇔ Li? ***AMS-02***
- ***He, C hardening: Superbubble?***
  - ✓ O, Ne, Mg, Si, Fe hardening?
- ***GeV γ-ray excess: DM? Pulsar?***
  - ✓ Inverse Compton at TeV? ***CTA***

AMS-02 Anti-Proton

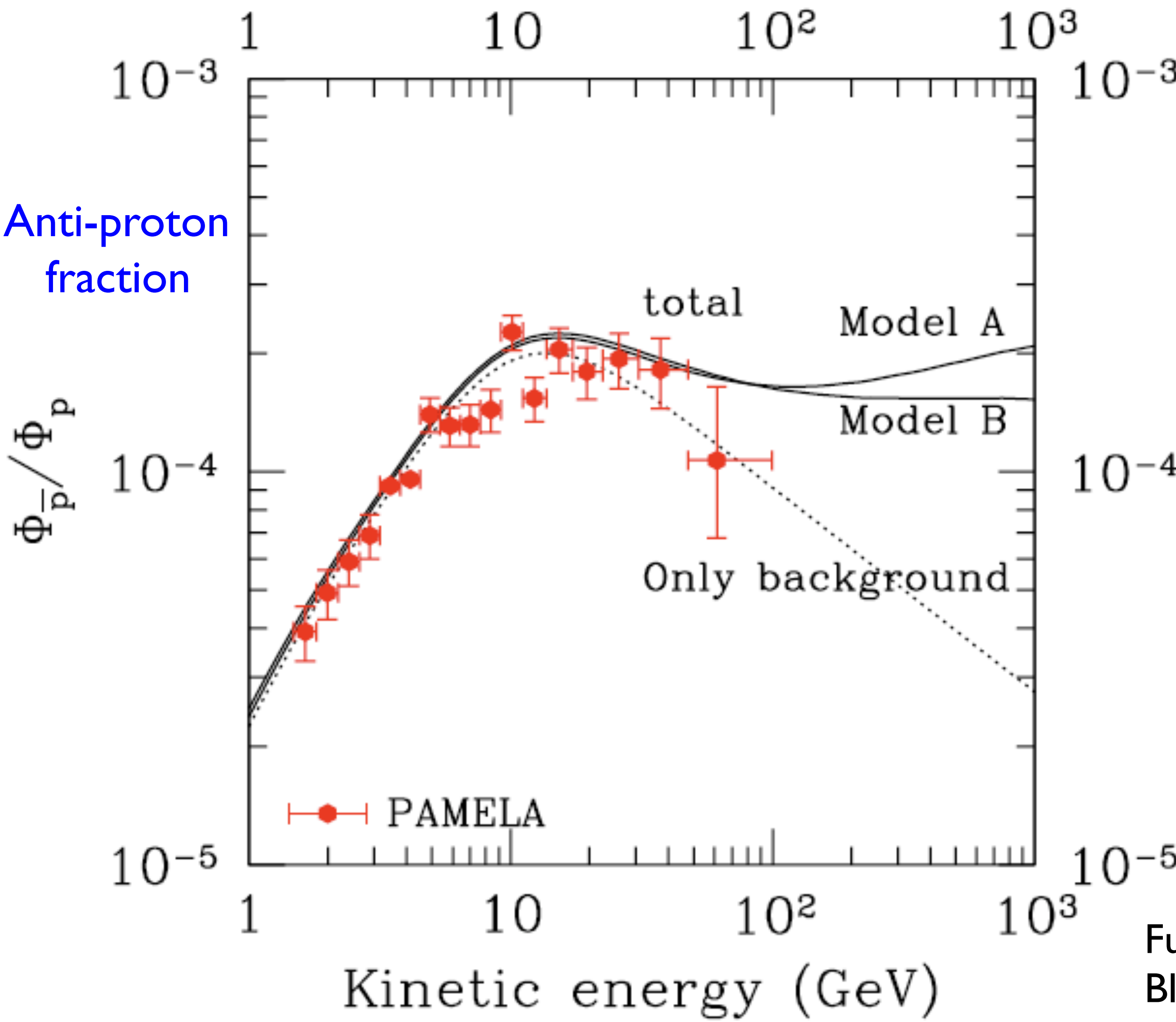


Ting+ AMS days 15 Apr. 2015

Figure 1. Antiproton to proton ratio measured by AMS. As seen, the measured ratio cannot be explained by existing models of secondary production.

Anti-Proton

Anti-proton fraction



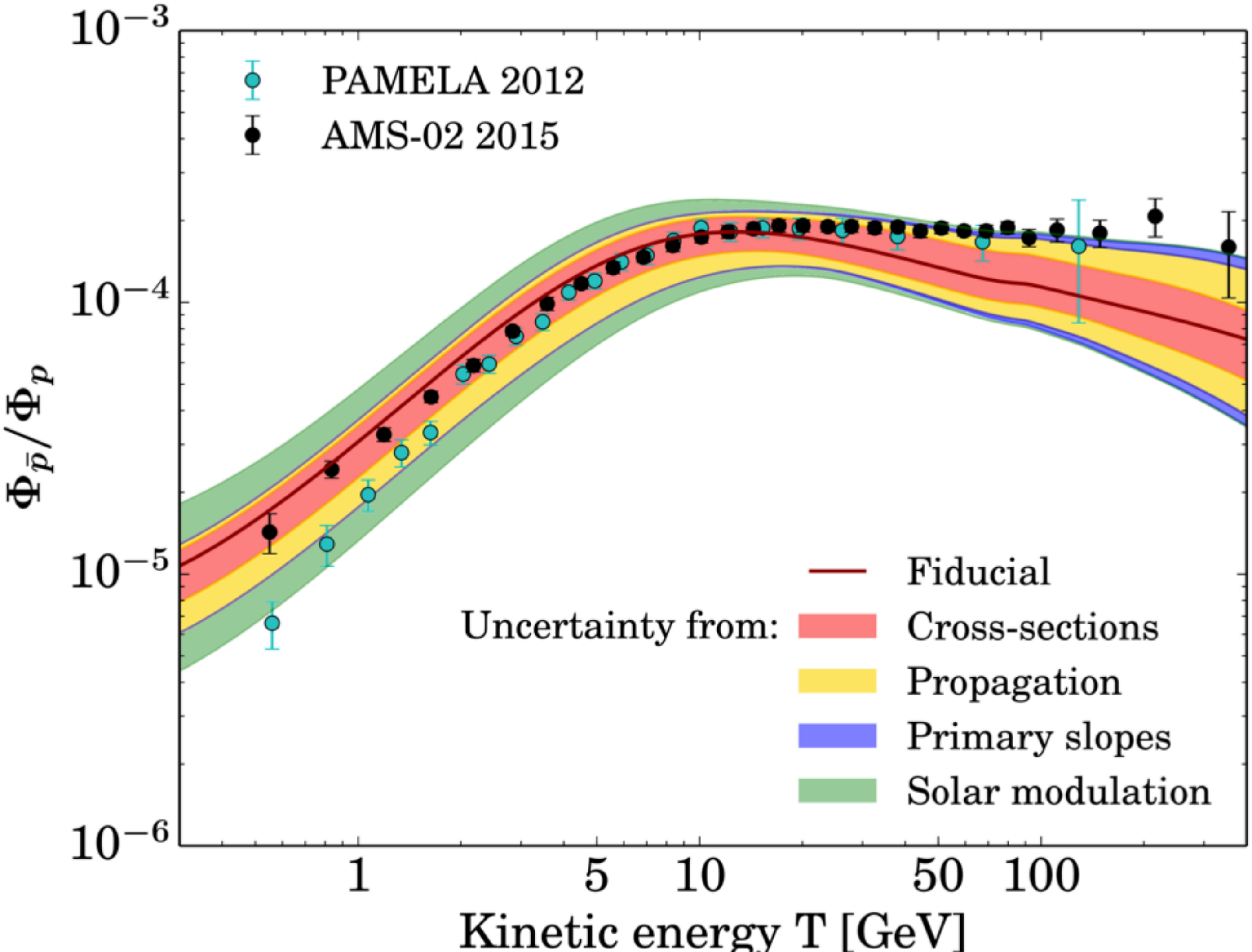
SNR model:
pp → π → e^+e^-
(w/ surrounding)

⇒ Inevitably anti-proton excess above ~100 GeV

⇒ AMS-02

Fujita, Kohri, Yamazaki, KI 09
Blasi & Serpico 09

Just 2ndary Anti-proton?



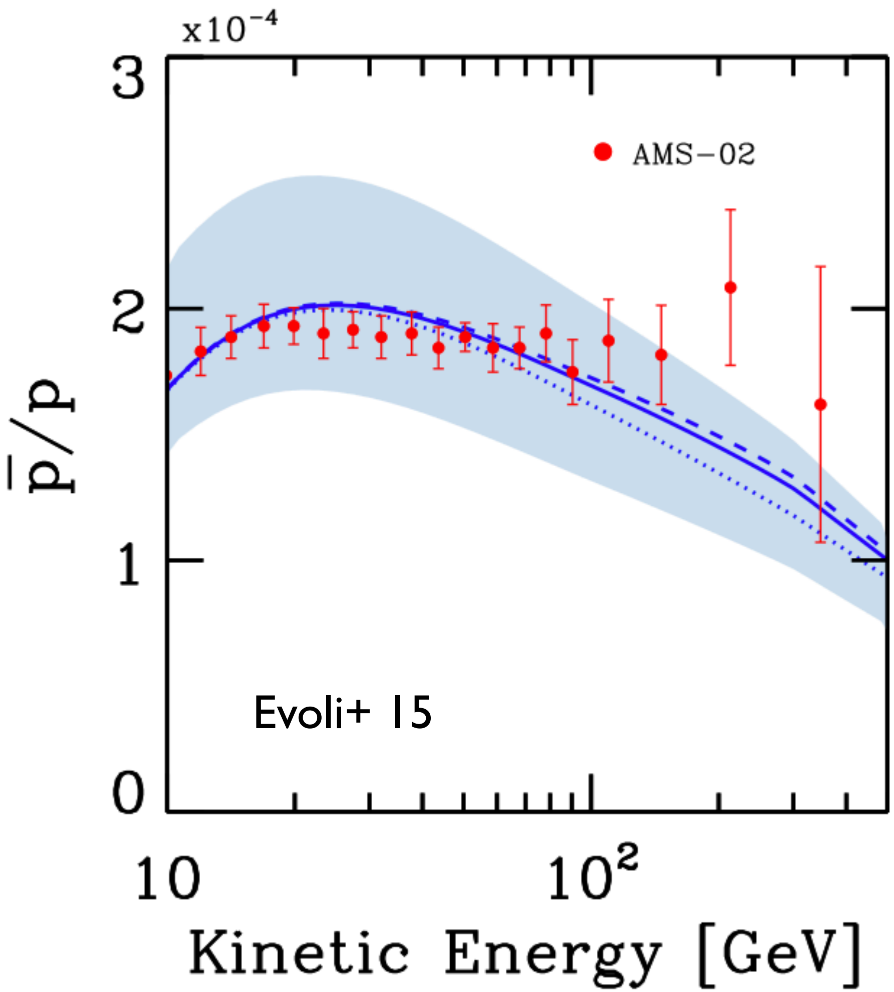
Giesen+ 15

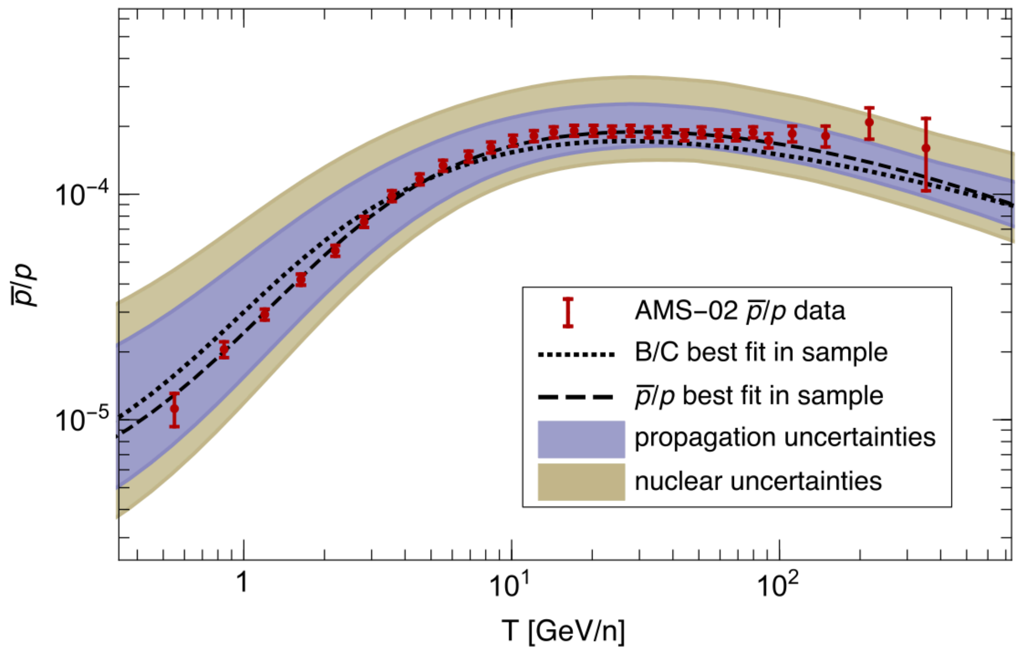
Excess is marginal?

- Small $|\delta|$ ($D_{diff} \sim \varepsilon^{-\delta}$)
- N49 exp. @CERN
- Hard p, He

Just 2ndary Anti-proton?

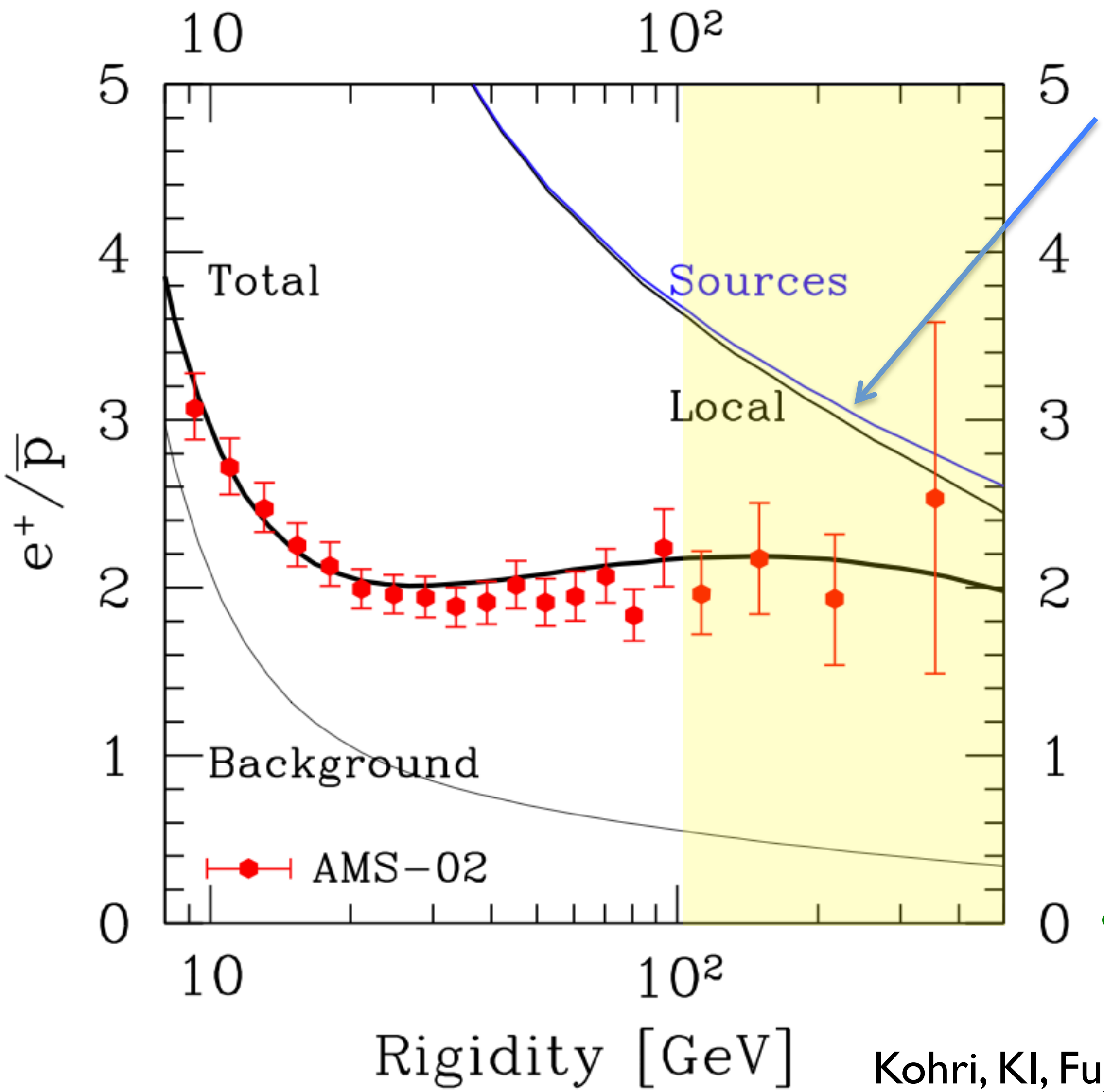
Similar results on anti-proton uncertainties





Kappl+ 15

Right Branching Fraction



Branching ratio of $pp \to e^+$ & $\bar{p}$ within a factor 2 at >100 GeV!

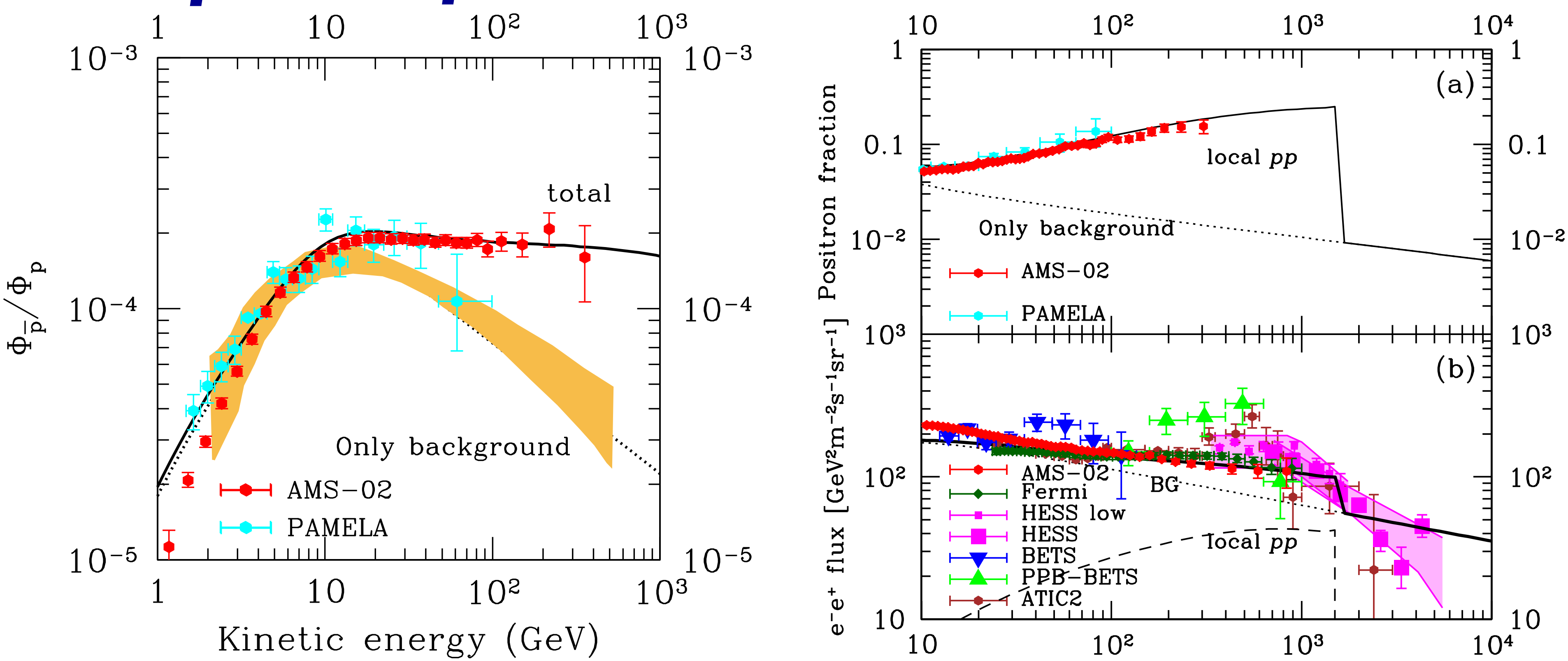
pp or coincidence?

Ratio is robust since the same r_{Larmor} gives the same diffusion

Kohri, KI, Fujita & Yamazaki 15

pp in Supernova Remnant without Pulsars nor DM?

Anti-proton fraction / Positron & Electron



Kohri, KI, Fujita & Yamazaki 15

δ=0.42, D_0=2e28cm^2/s
Dense cloud n=50cm^{-3}, R=40pc
s=2.15, E_{max}=100TeV, E_{tot}=2.6e50erg, d=200pc

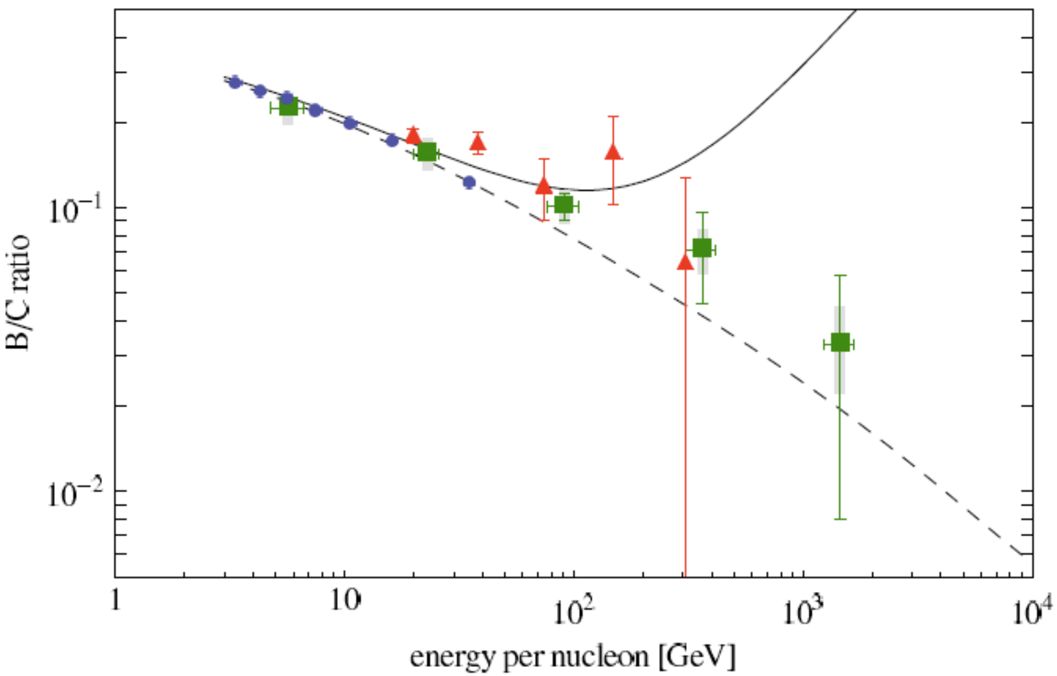
Simultaneous Fittings

B/C for $e^{\pm}$ Excess

Similar B/C upturn was predicted for $e^{\pm}$ excess

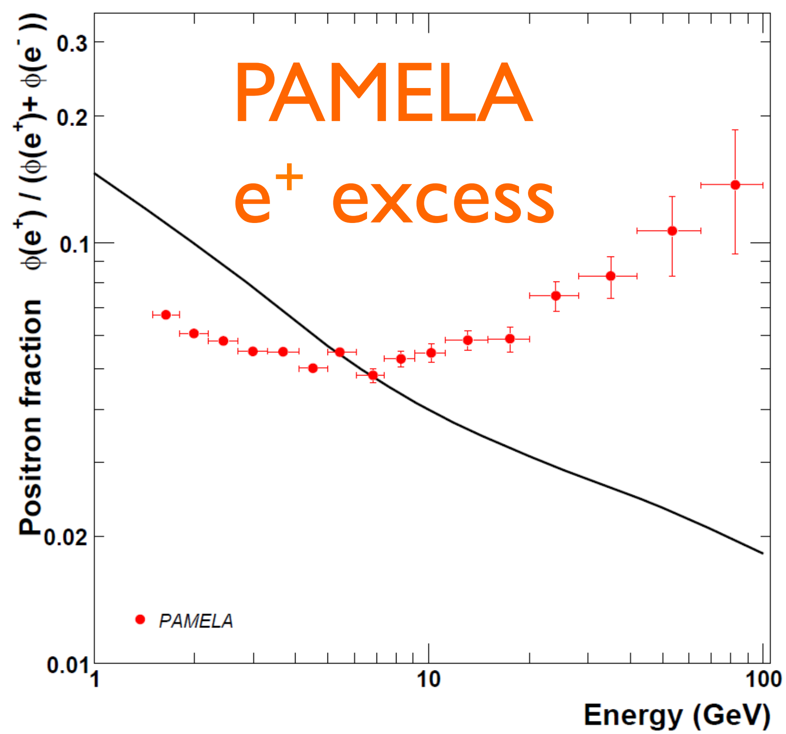
e^{+}, anti-proton & boron are 2ndary

No B/C upturn ⇒ SN happens in low metal region?



Mertsch & Sarkar 09

Also nested-leaky box by Cowsik & Burch 09

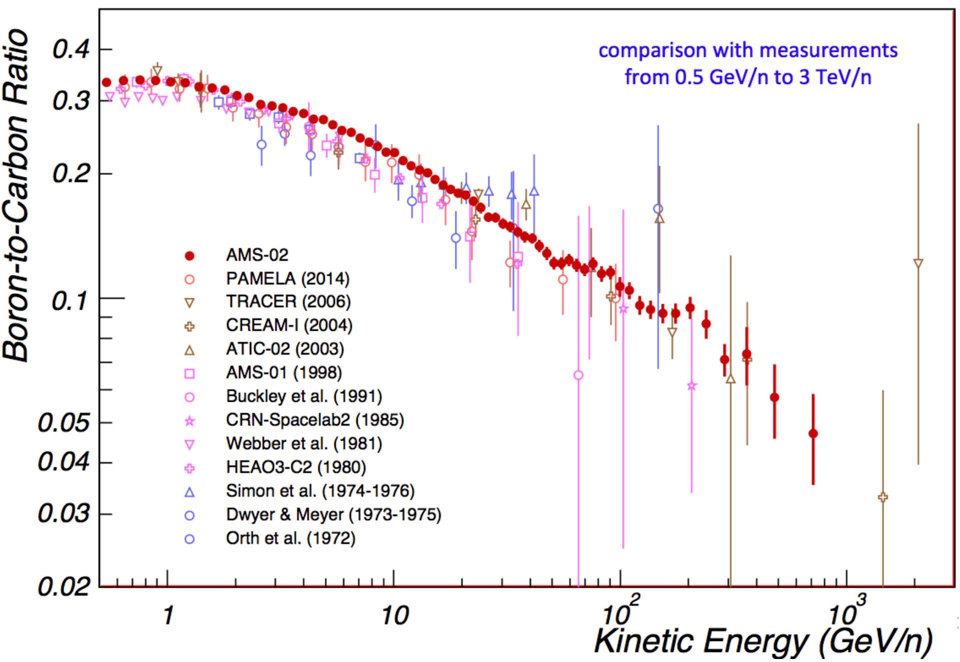


Adriani+ 08, 10

B/C v.s. Li

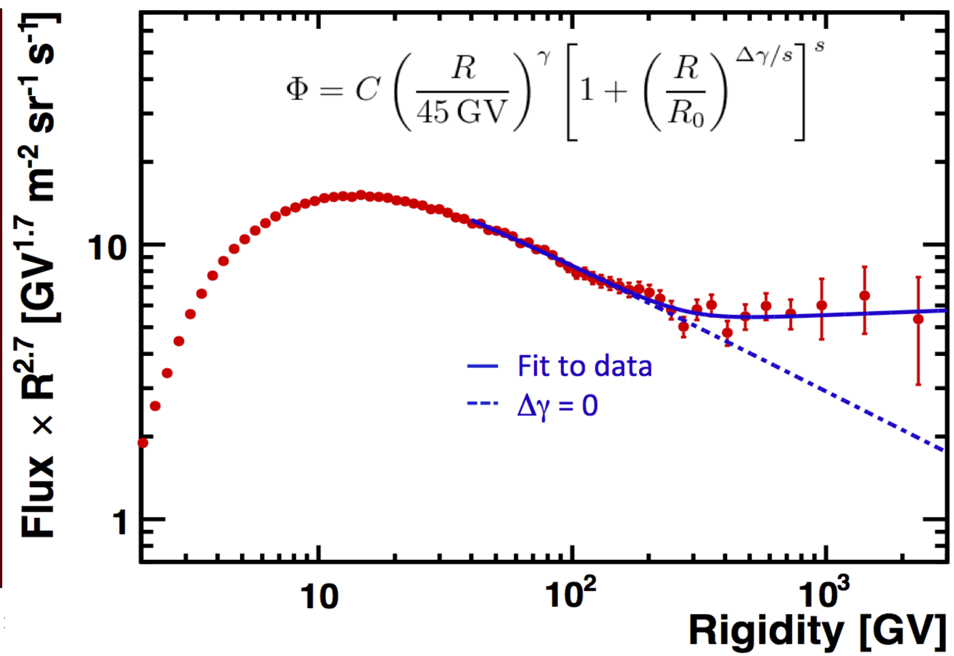
AMS-02 has internal inconsistency

B/C



Oliva+ AMS days 15

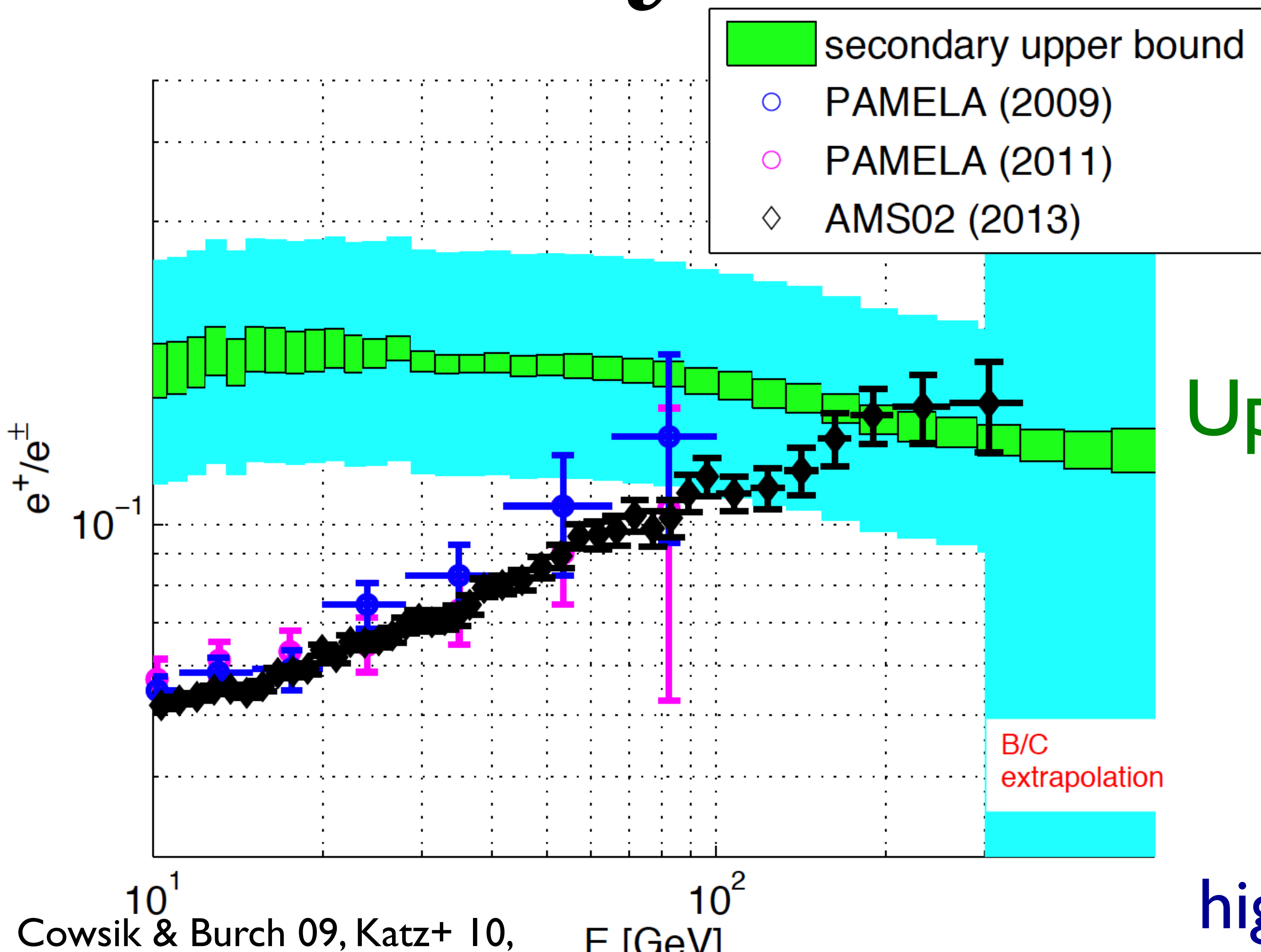
Li



Derome+ AMS days 15

Both boron and Lithium are secondary

Secondary e^+ still Viable?



$p_{CR} + p_{ISM} \rightarrow \pi^+ \rightarrow e^+$

Upper Limits by B/C

$e^+/e^\pm$ rise if t_{escape} is longer at higher energy

Cowsik & Burch 09, Katz+ 10, Blum+ 13, Cowsik+ 13

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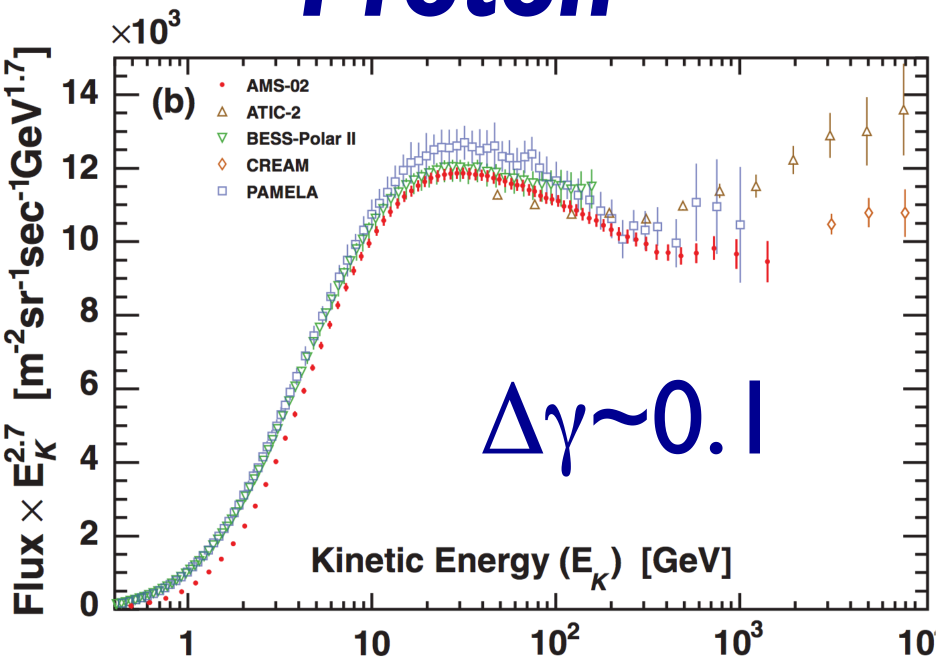
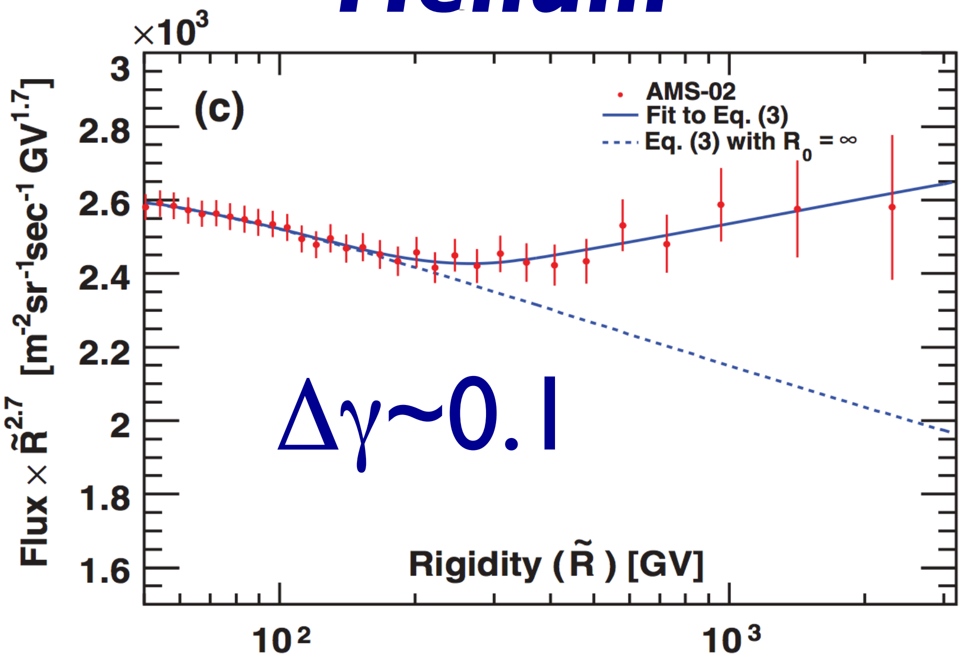
  - ✓ Inverse Compton at TeV? ***CTA***

Spectral Breaks

Proton



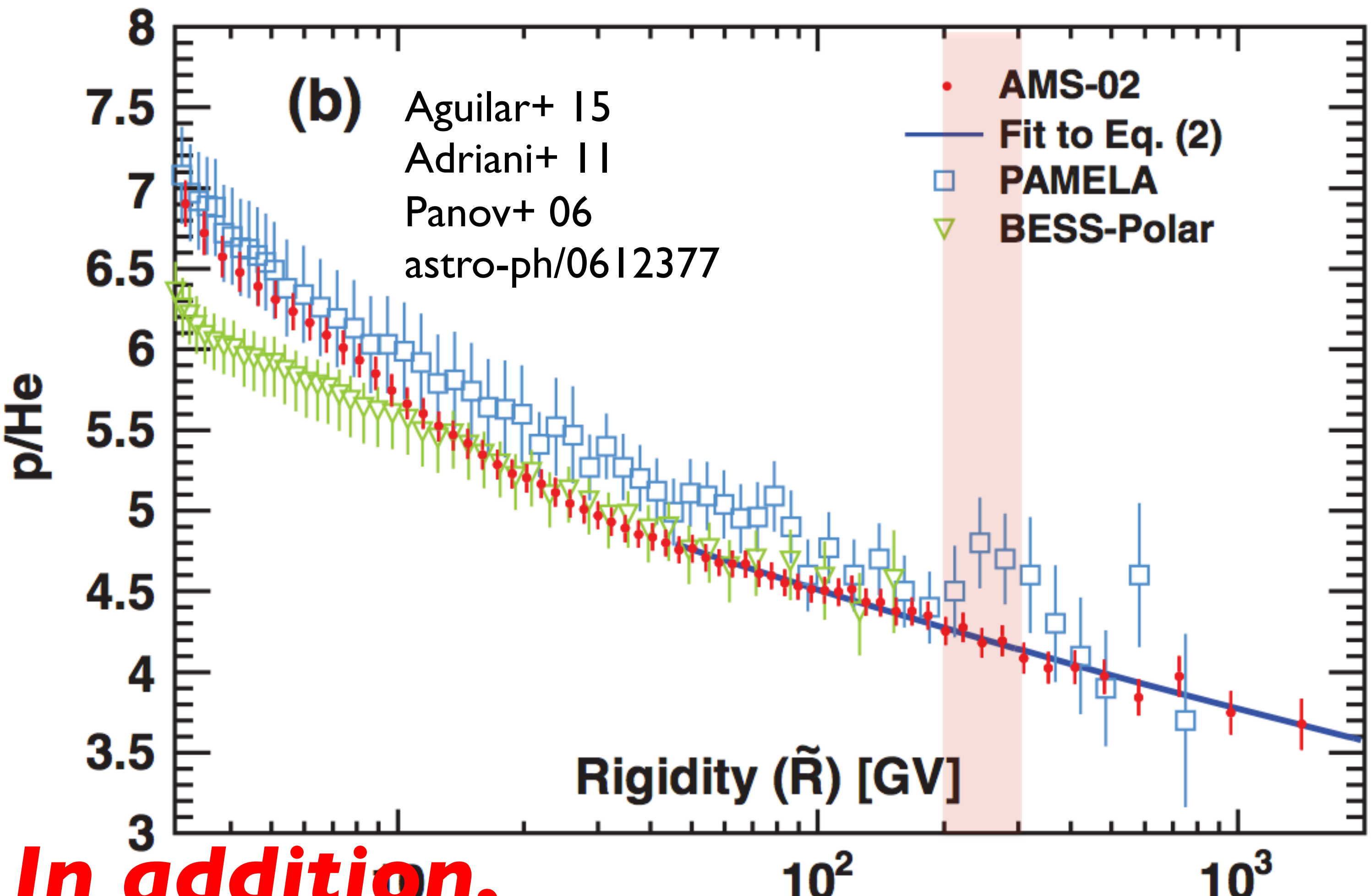
Helium



Aguilar+ 15a,b
Ahn+ 10

AMS-02 confirms that p & He spectral indices hardens at >200GV

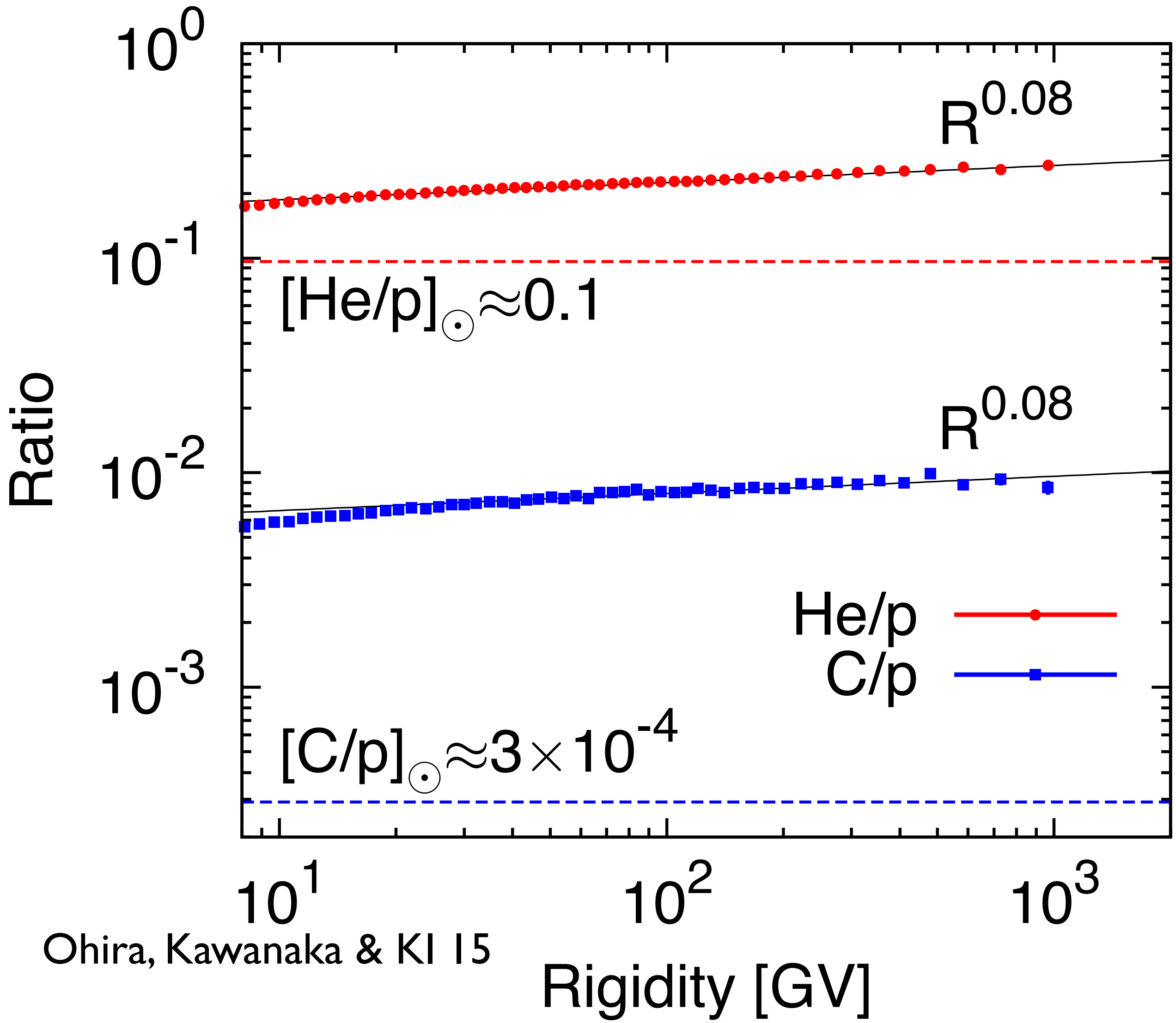
Spectral Difference



p/He has no break

In addition,
He is harder than proton by $\gamma_{p/He}$=-0.077

He/p & C/p



Ohira, Kawanaka & KI 15

He/p ≠ const

C/p ≠ const

He/p ∝ $R^{0.08}$

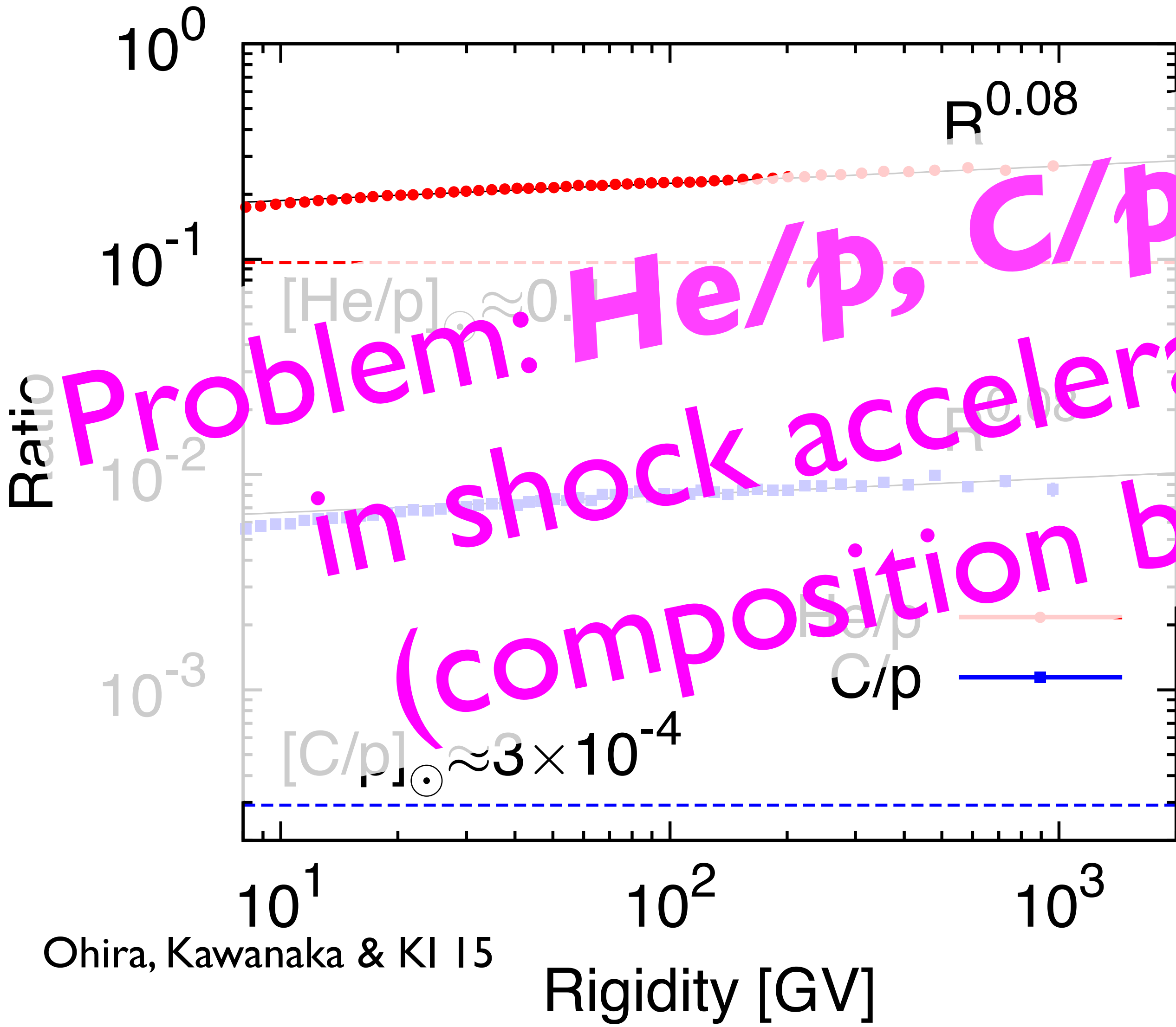
C/p ∝ $R^{0.08}$

He/p>$[He/p]_\odot$

C/p>$[C/p]_\odot$

No breaks

He/p & C/p



Ohira, Kawanaka & KI 15

He/p ≠ const

C/p ≠ const

He/p ∝ C/p ∝ $R^{0.08}$

He/p>$[He/p]_\odot$

C/p>$[C/p]_\odot$

No breaks

Problem: He/p, C/p=const in shock acceleration (composition blind)

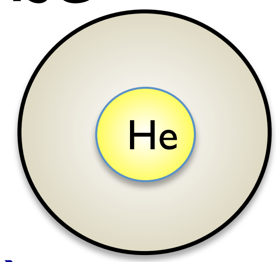
Helium is Special

- He/p ~ **$3\times Y_{\odot}$!** @100TeV
- Stellar nucleosynthesis never double the mean Y ($\because$ Schonberg-Chandrasekhar)

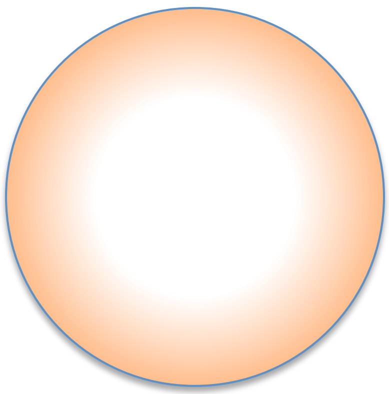
: Reason to invoke ***Big Bang***

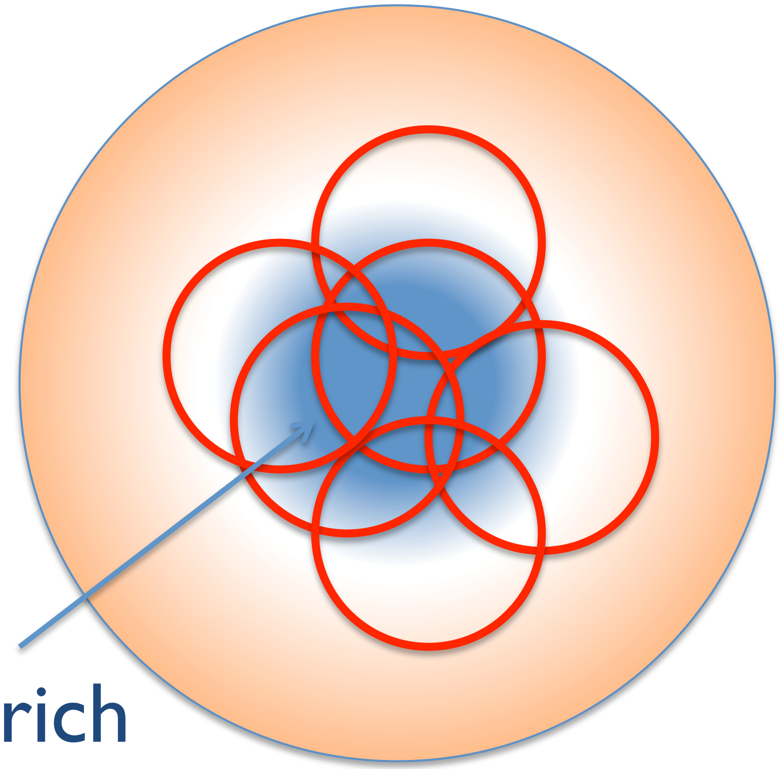
$\Rightarrow$ Ejecta-enriched region

$M_{He}/M < q_{SC} \sim 0.1$



CR origin ~ Superbubble?





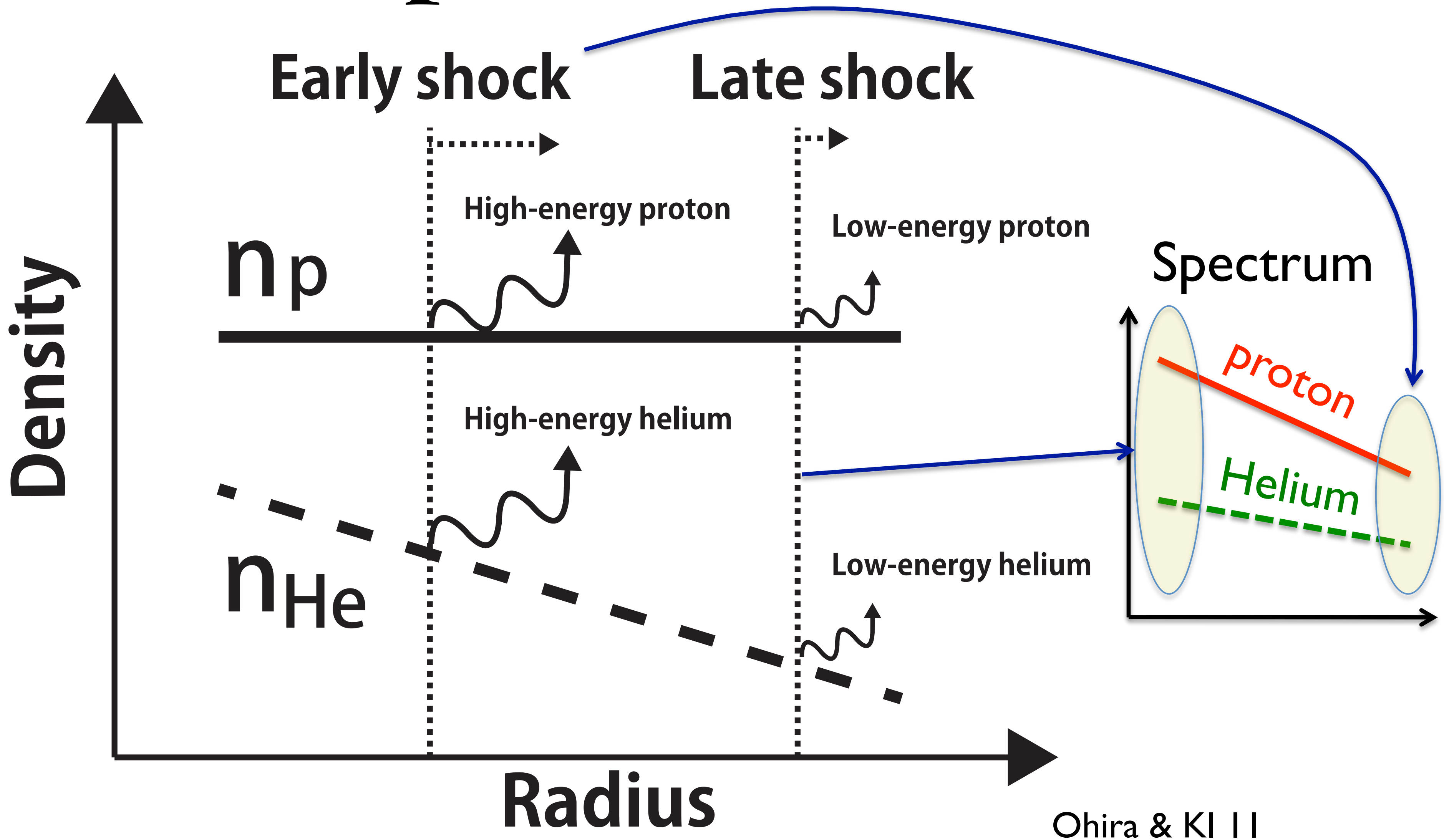
Isolated SNR
(~Fermi SNR)

not a main channel??

Multiple SNR
Superbubble

Predict hardenings of heavy elements

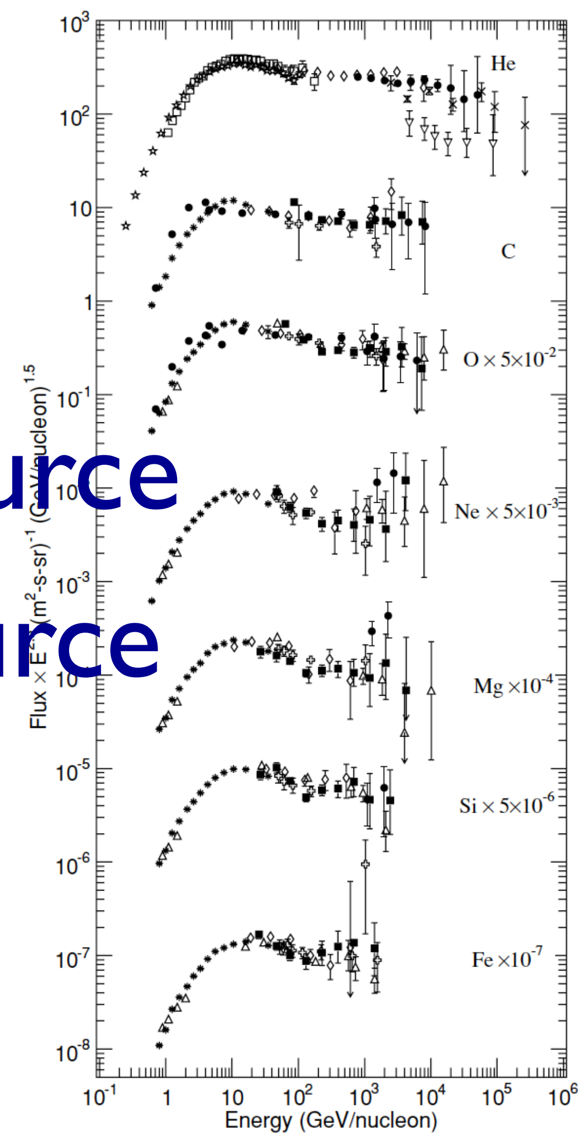
Composition Gradient



Ohira & KI 11
Ohira, Kawanaka & KI 15

Scenarios for Break

1. Propagation
2. Injection
3. Local high-energy source
4. Local low-energy source



Vladimirov+ 12

B/C break?

O, Ne, Mg, Si, Fe breaks?

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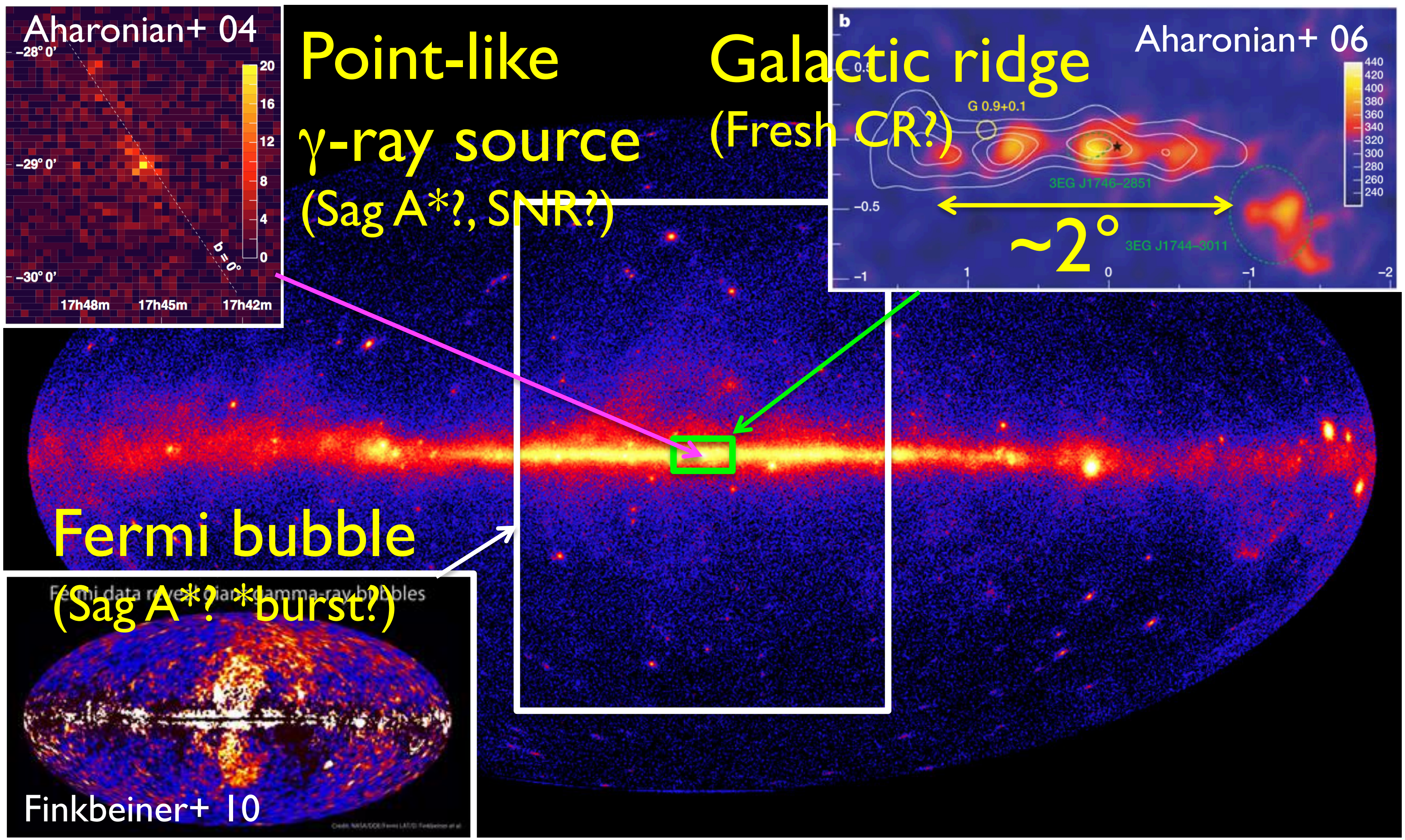
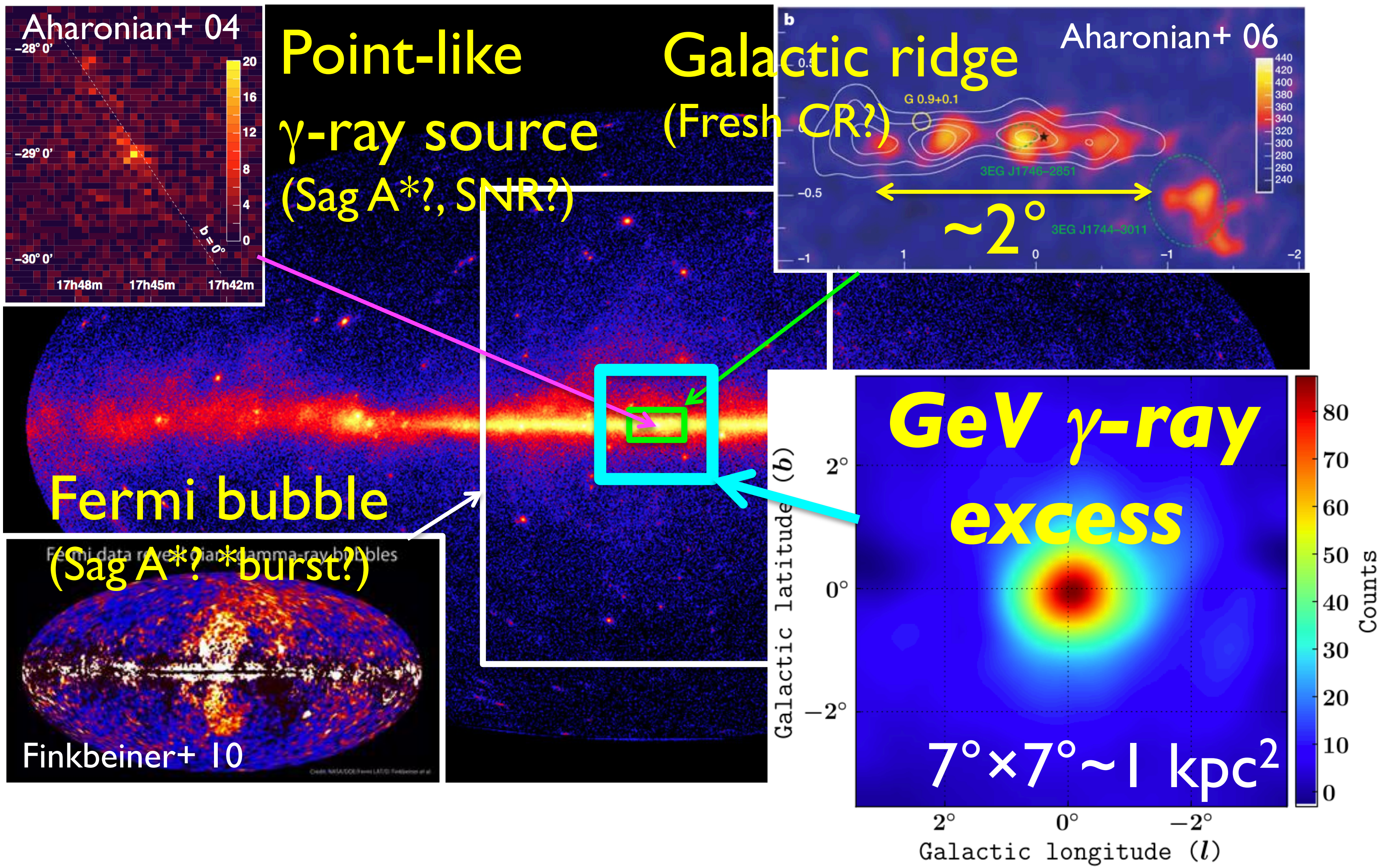
Galactic Center

Morselli's talk

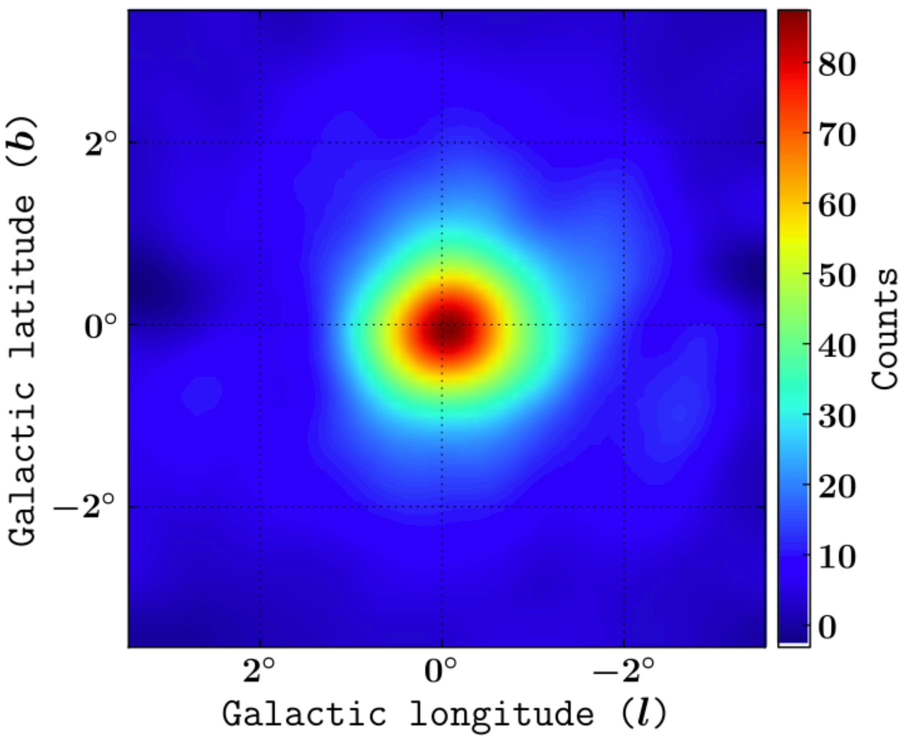


Galactic Center

Morselli's talk



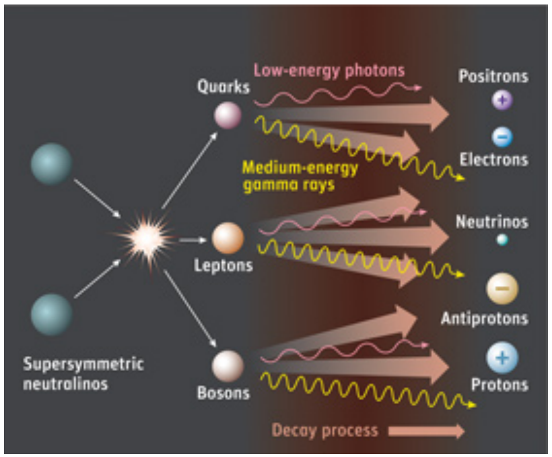
GeV γ-ray Excess

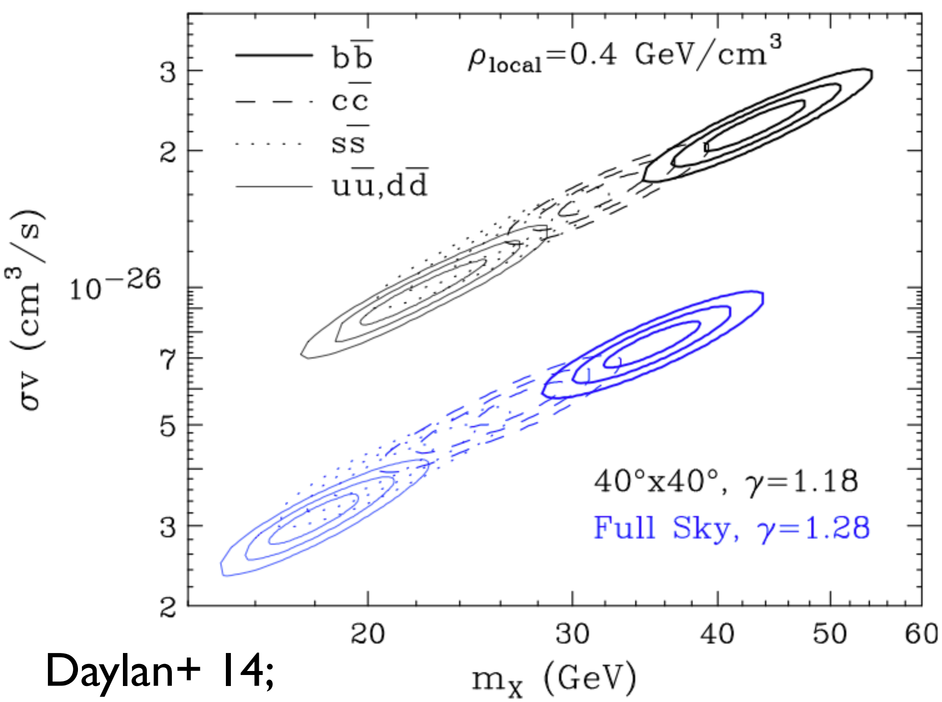


Goodenough & Hooper 09
Vitale & Morselli 09
Hooper & Goodenough 11
Boyarsky+ 11
Hooper & Linden 11
Abazajian & Kaplinghat 12
Gordon & Macias 13
Huang+ 13
Abazajian+ 14
Daylan+ 14
Zhou+ 14
Calore+ 14
Bertone+ 15
Fermi collaboration 15 …

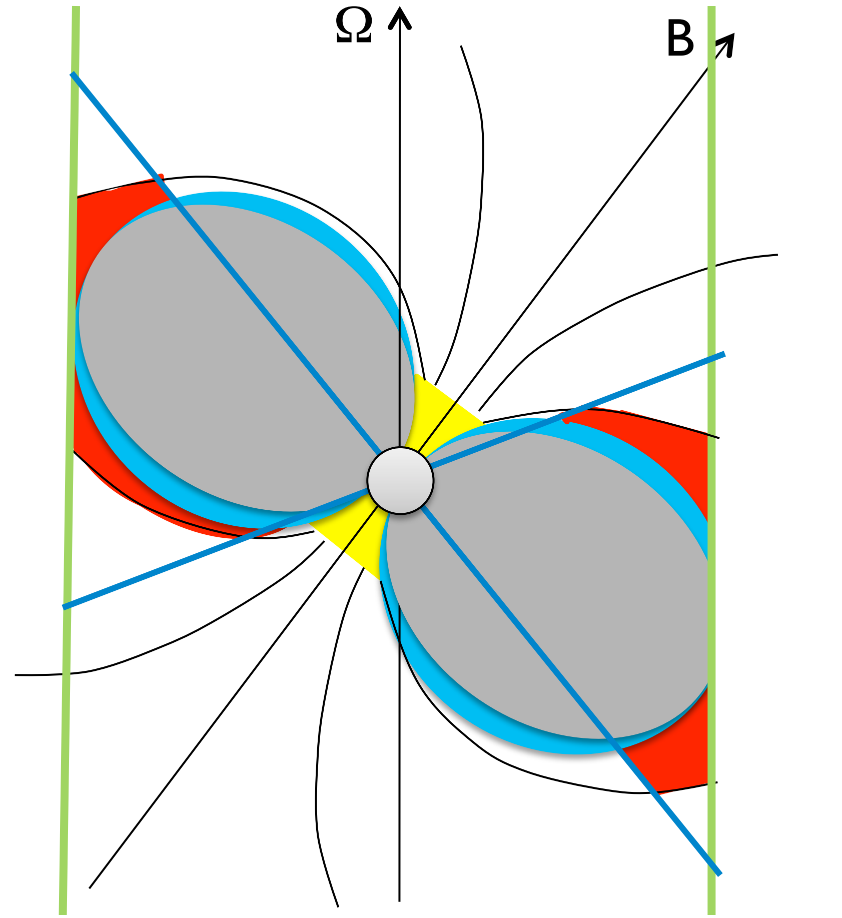
Caveat: Background model systematics is not small

Dark Matter v.s. Pulsar





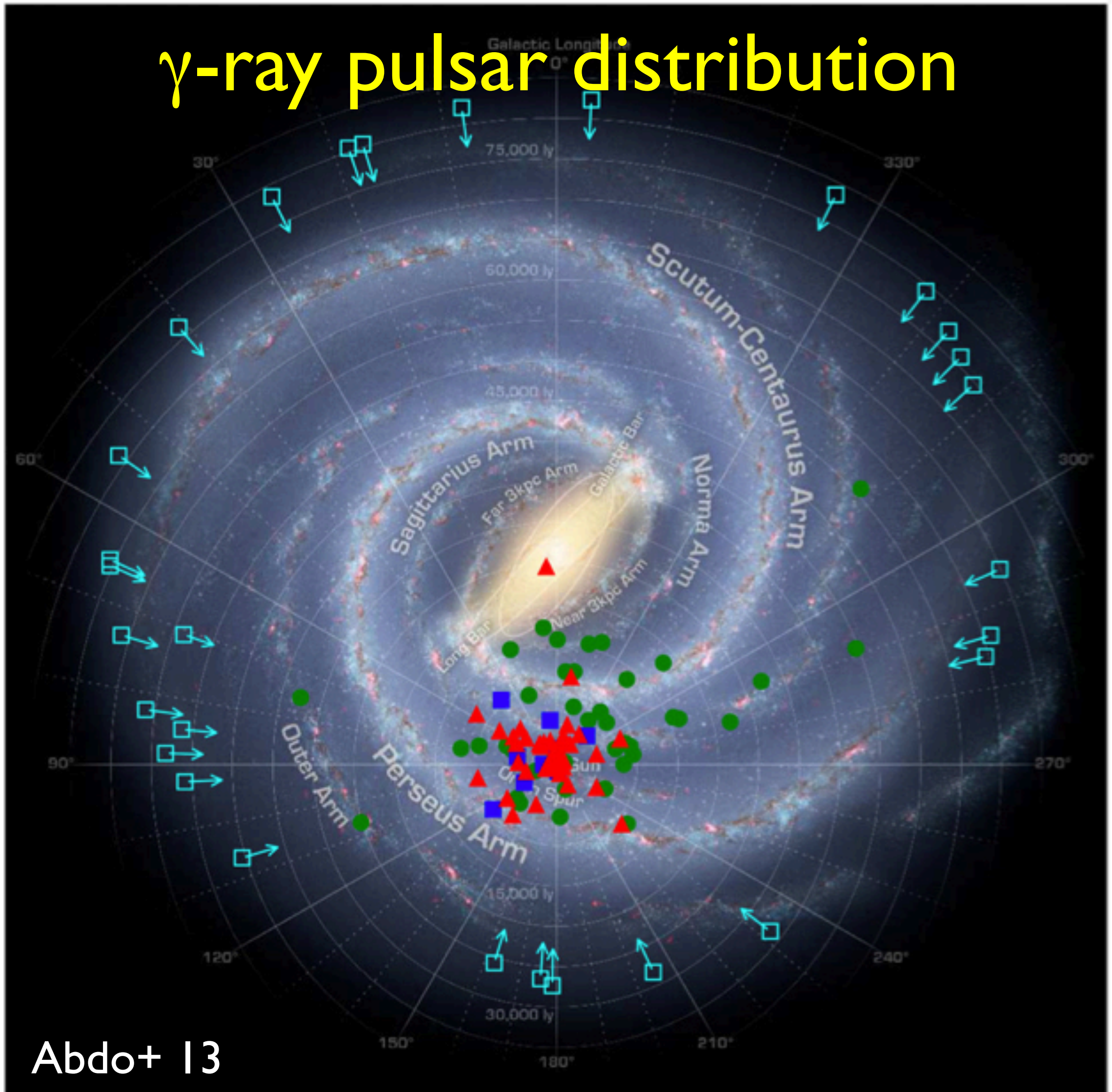
Daylan+ 14;



$$\Delta V \approx \frac{\Omega^2 B R^3}{2c^2} \sim 10^{14}\,{\rm V} \left(\frac{\Omega}{100\ {\rm s}^{-1}}\right)^2 \left(\frac{B}{10^8 {\rm G}}\right) \left(\frac{R}{10^6 {\rm cm}}\right)^3$$

Or cosmic-ray bursts? (Carlson & Profumo 14; Petrovic+ 2014; Cholis+ 15)

Most Pulsars are Unseen



We are observing only nearby pulsars

MSPs are faint

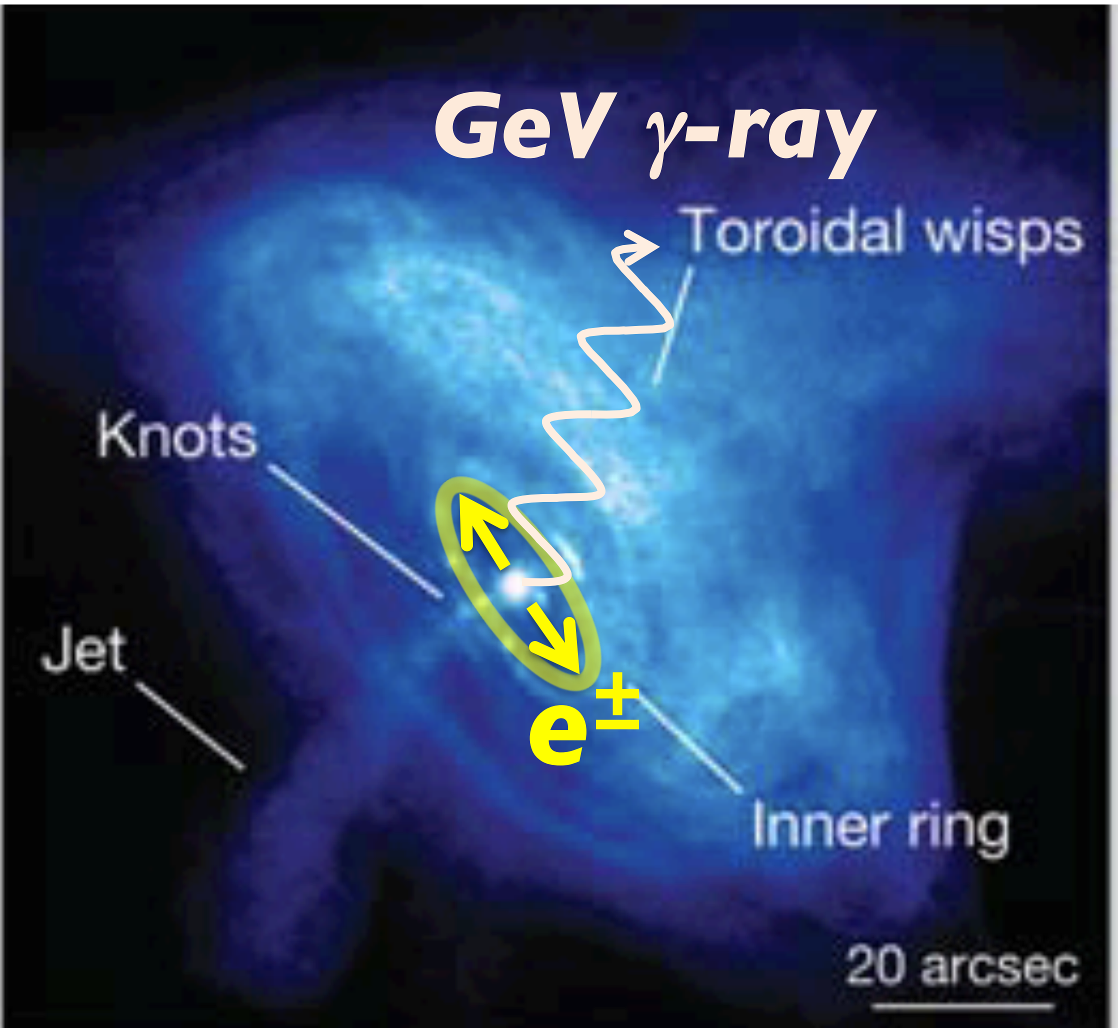
Galactic center may have ***O*(10$^{3-4}$)** MSPs ⇒ GeV excess?

Abazajian 11; Gordon & Macias 13; Yuan & Zhang 14; Petrovic+ 15; Bartels+ 15; Lee+ 15 Hooper+ 13; Cholis+ 15

▲MSP; ●Radio-loud; ■Radio-quiet

Pulsar Wind Nebula

Most spin-down energy ⇒ Pulsar wind



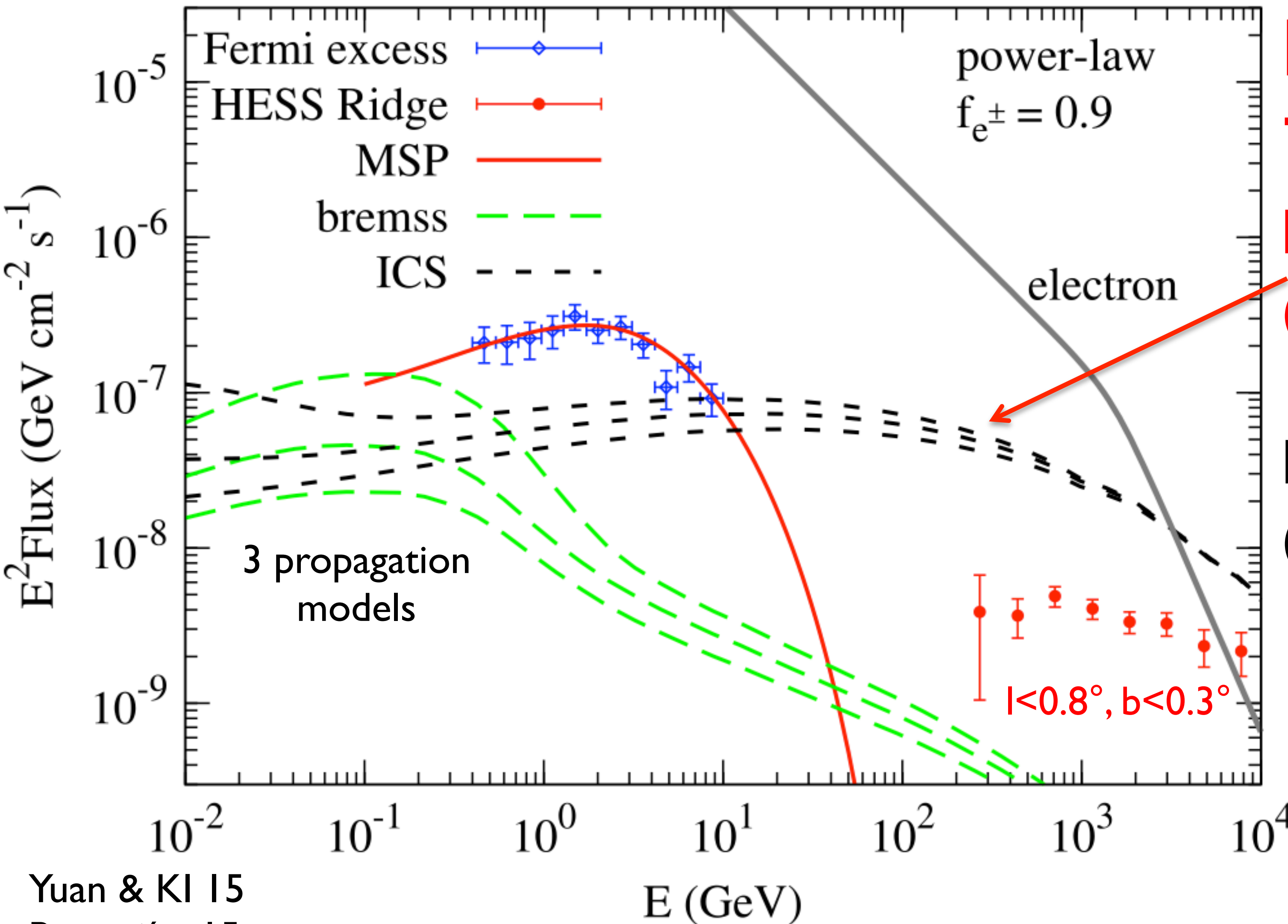
(Relativistic plasma of magnetized $e^{\pm}$)

$$L_{e^{\pm}} \sim 10 L_{\gamma}$$

PWN→SNR→ISM

⇒ Inverse Compton emission

Inverse Compton Spectrum

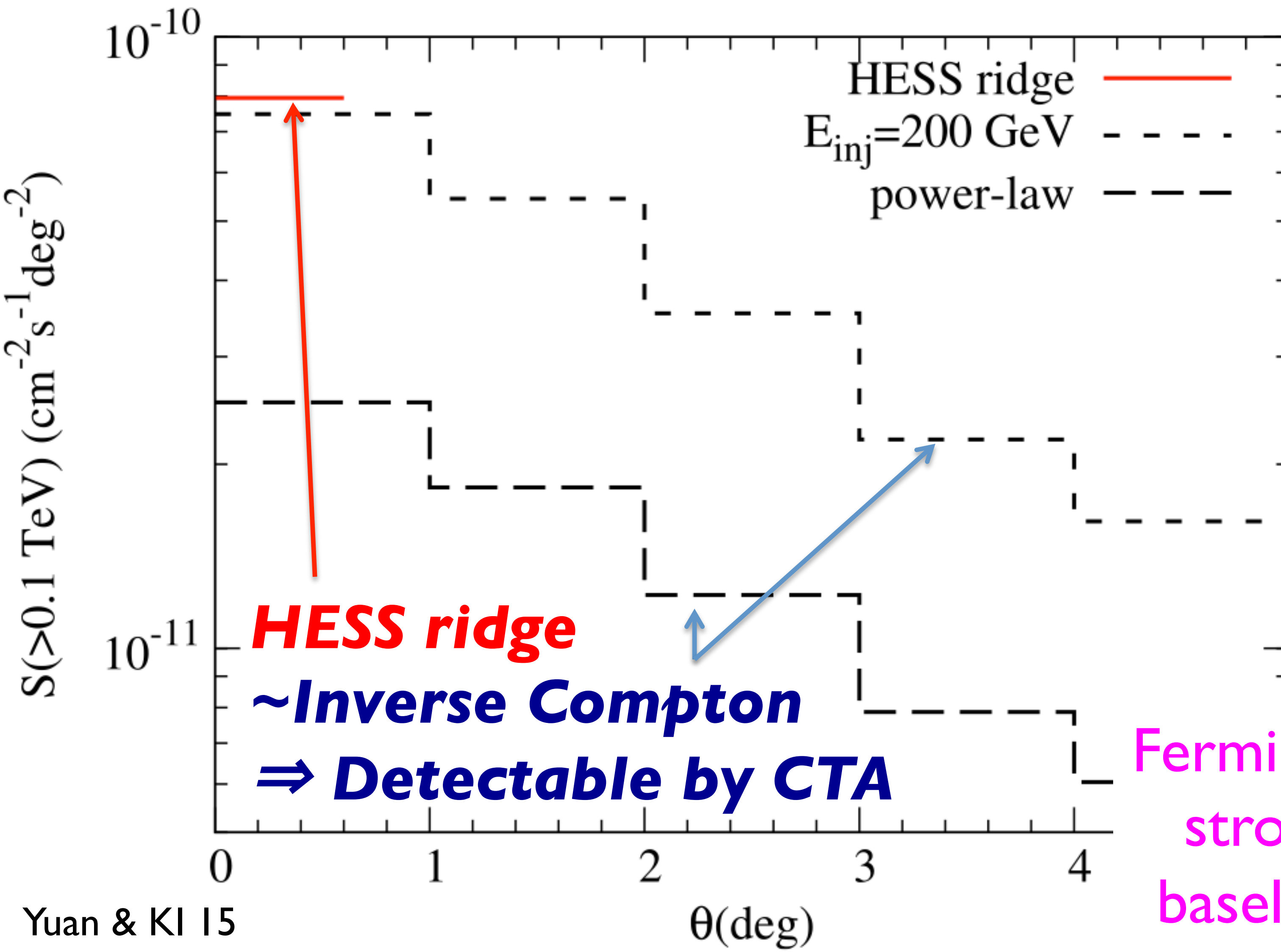


Extended
7°×7°
Power law E^{-2}
(E_{max}=50TeV)

Electron BG
(Isotropic)

Yuan & KI 15
Petrović+ 15

Surface Brightness



$\sim\theta^{-0.9}$
shallower than GeV

Fermi suggests IC stronger than baseline models

Yuan & KI 15

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- ***GeV γ-ray excess: DM? Pulsar?***
  - ✓ Inverse Compton at TeV? ***CTA***

Thank You

p/He & Break

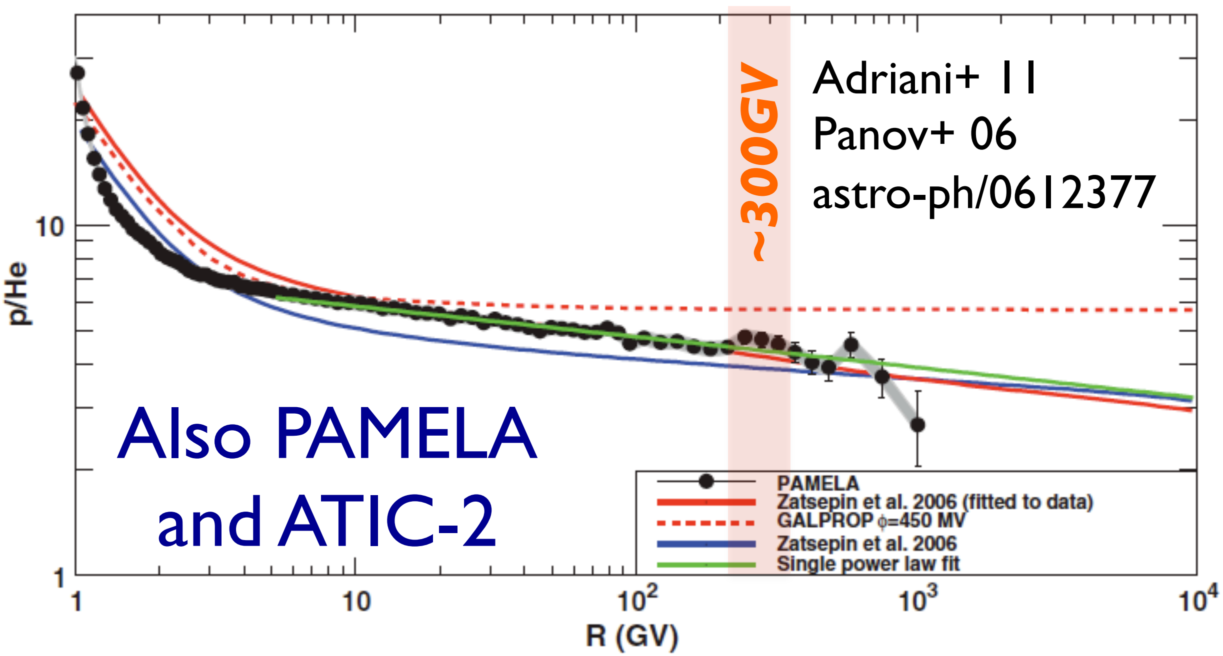
2. Break

$\Delta\gamma_p \sim 0.12 \pm 0.02$

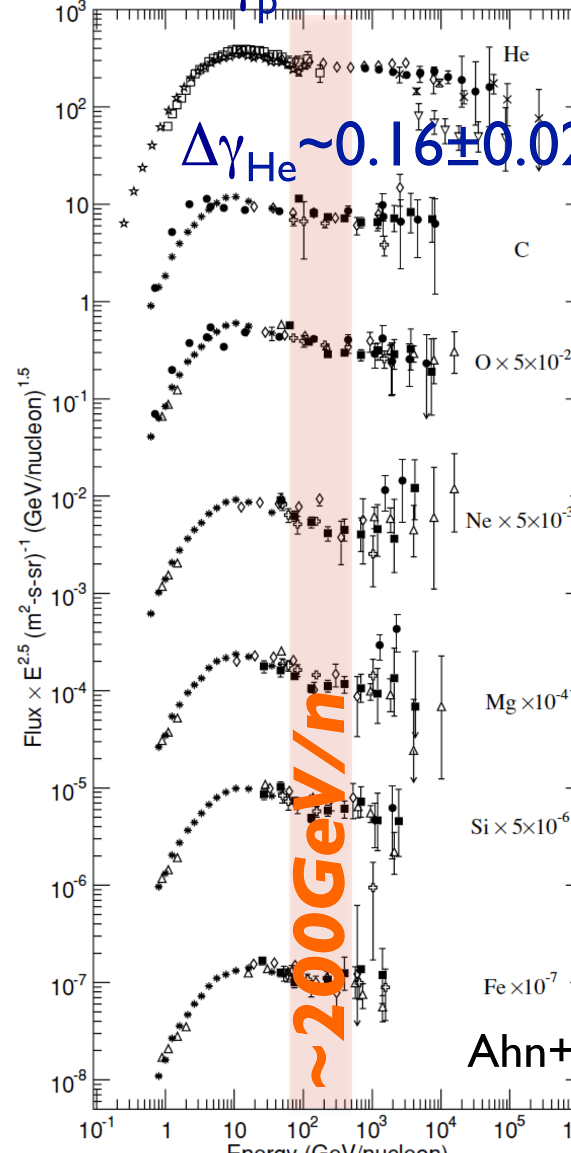
$\Delta\gamma_{He} \sim 0.16 \pm 0.02$

Two types of anomalies

1. Proton/Helium Ratio



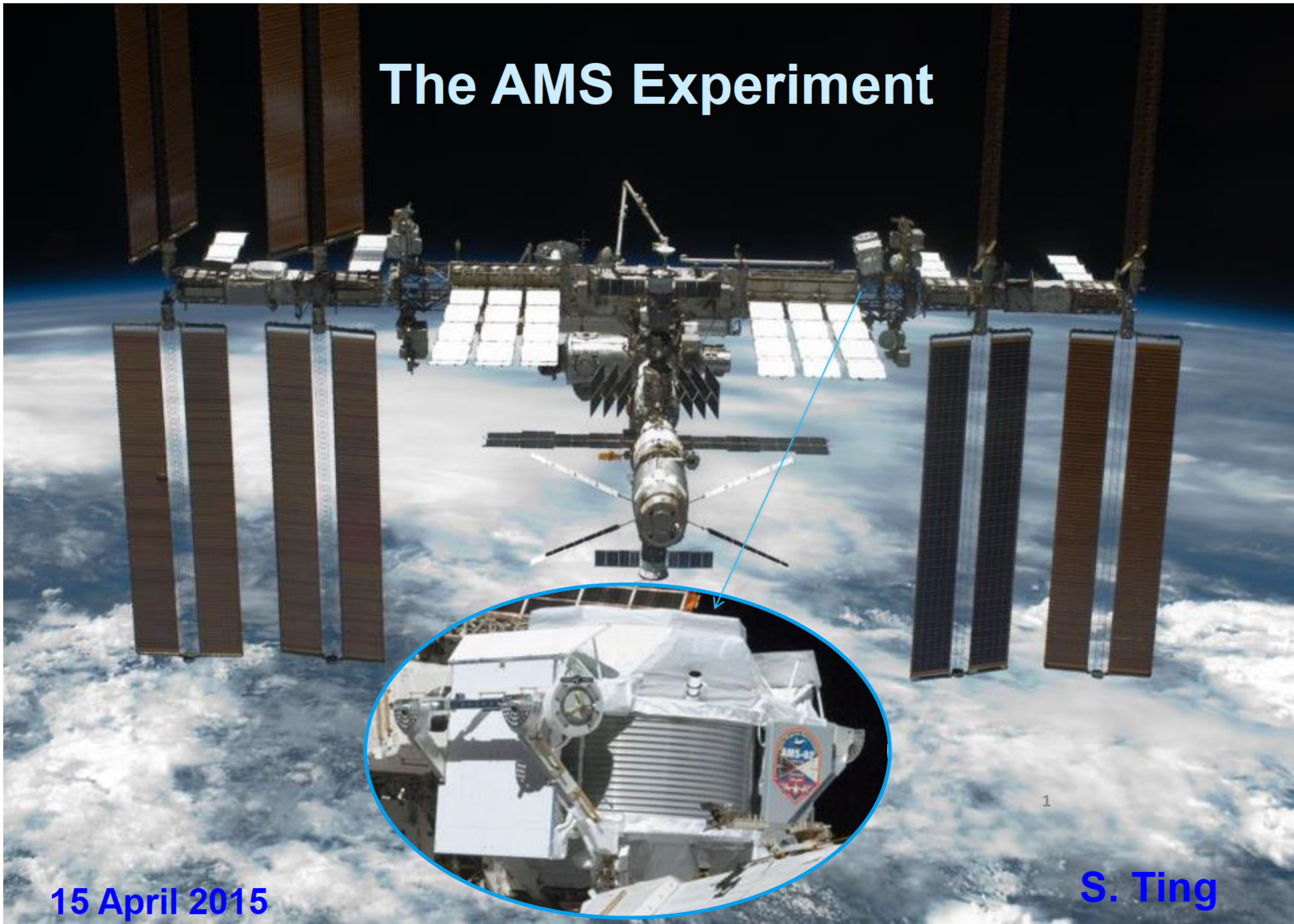
Also PAMELA and ATIC-2



Ahn+ 10

p/He is continuous across break

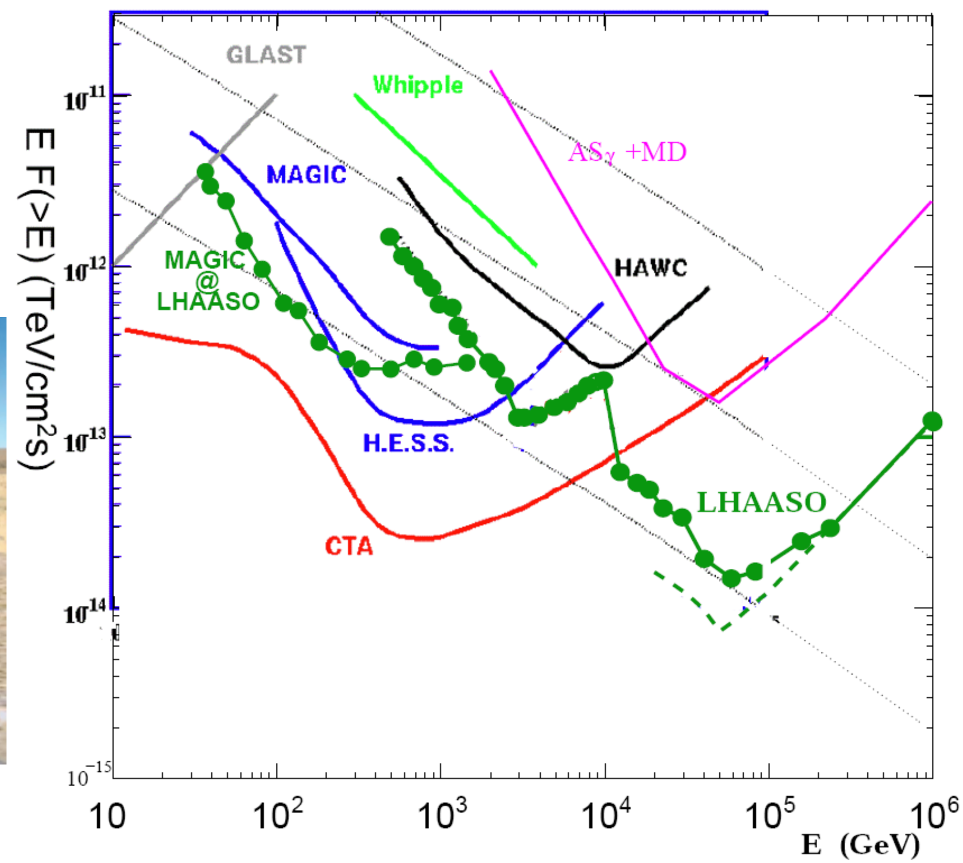
AMS-02 New Results



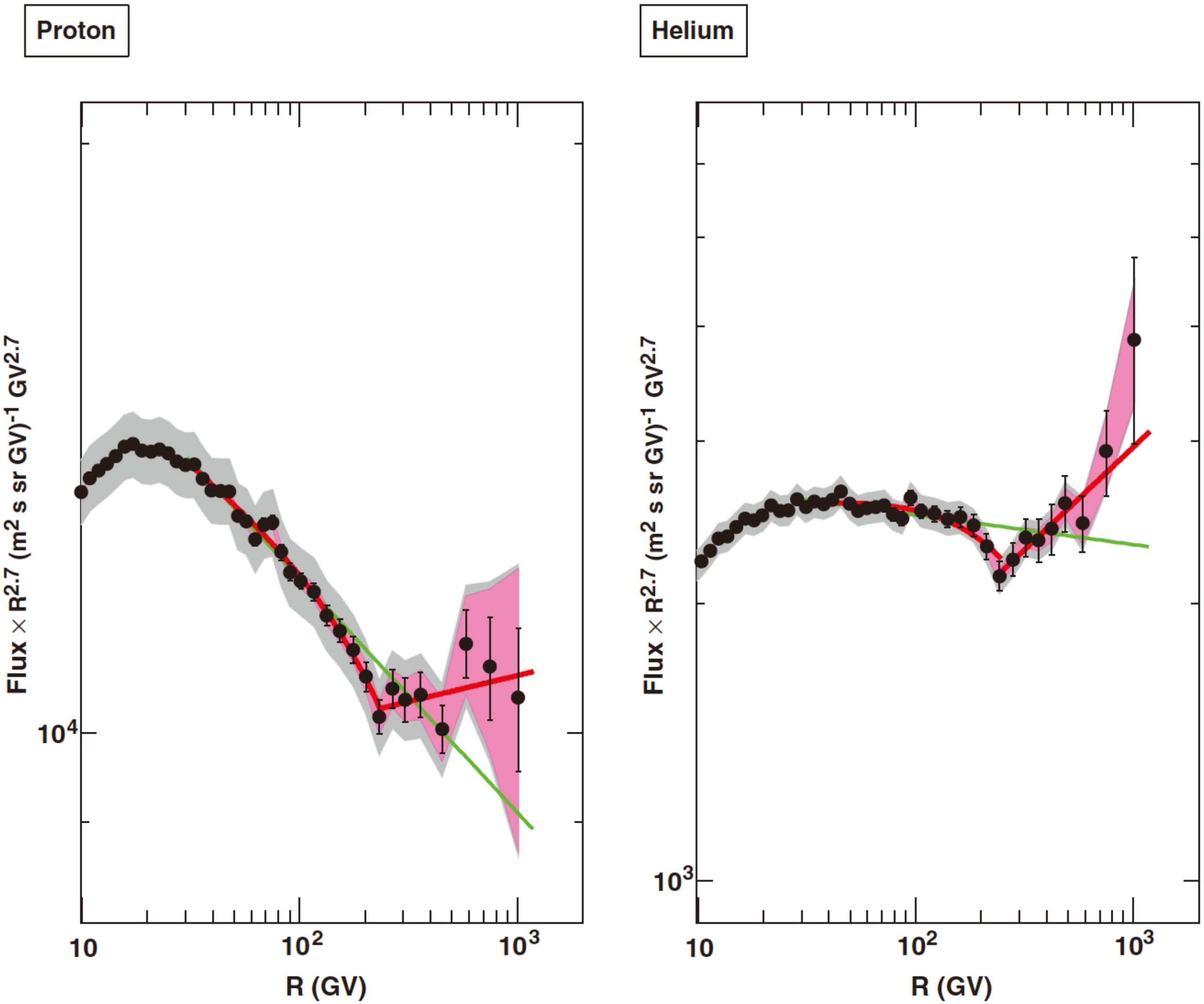
Air Shower

CTA

LHAASO



p & He Breaks



CREAM+ 10
PAMELA+ 11

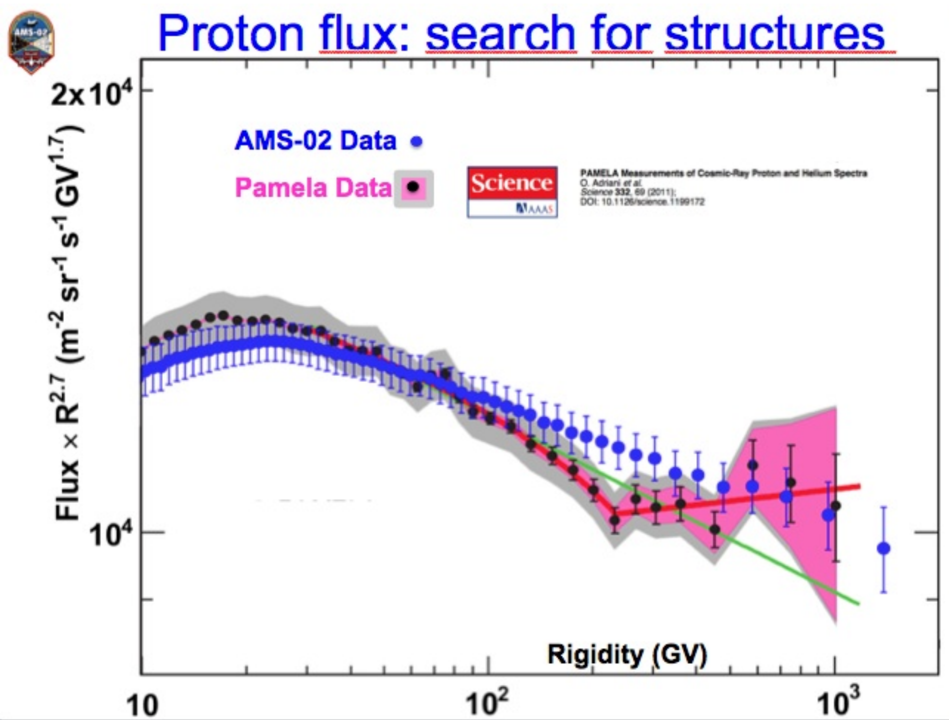
p & He

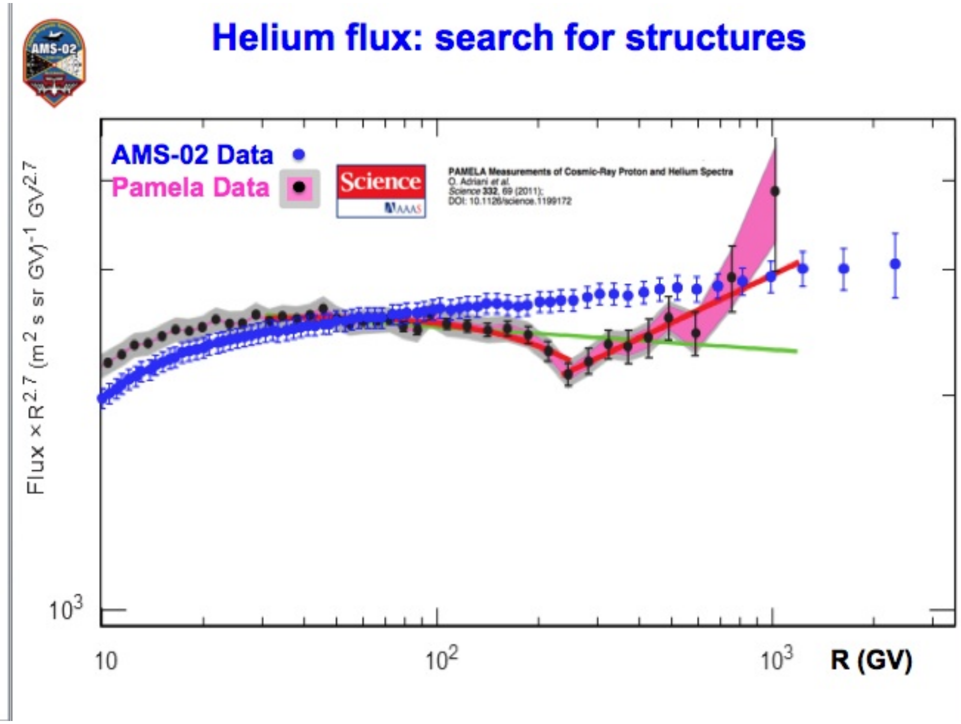
Index hardening
$\Delta\gamma_p \sim 0.12 \pm 0.02$
$\Delta\gamma_{He} \sim 0.16 \pm 0.02$

AMS-02: p & He

Spectral breaks disappear?

AMS-02, ICRC13

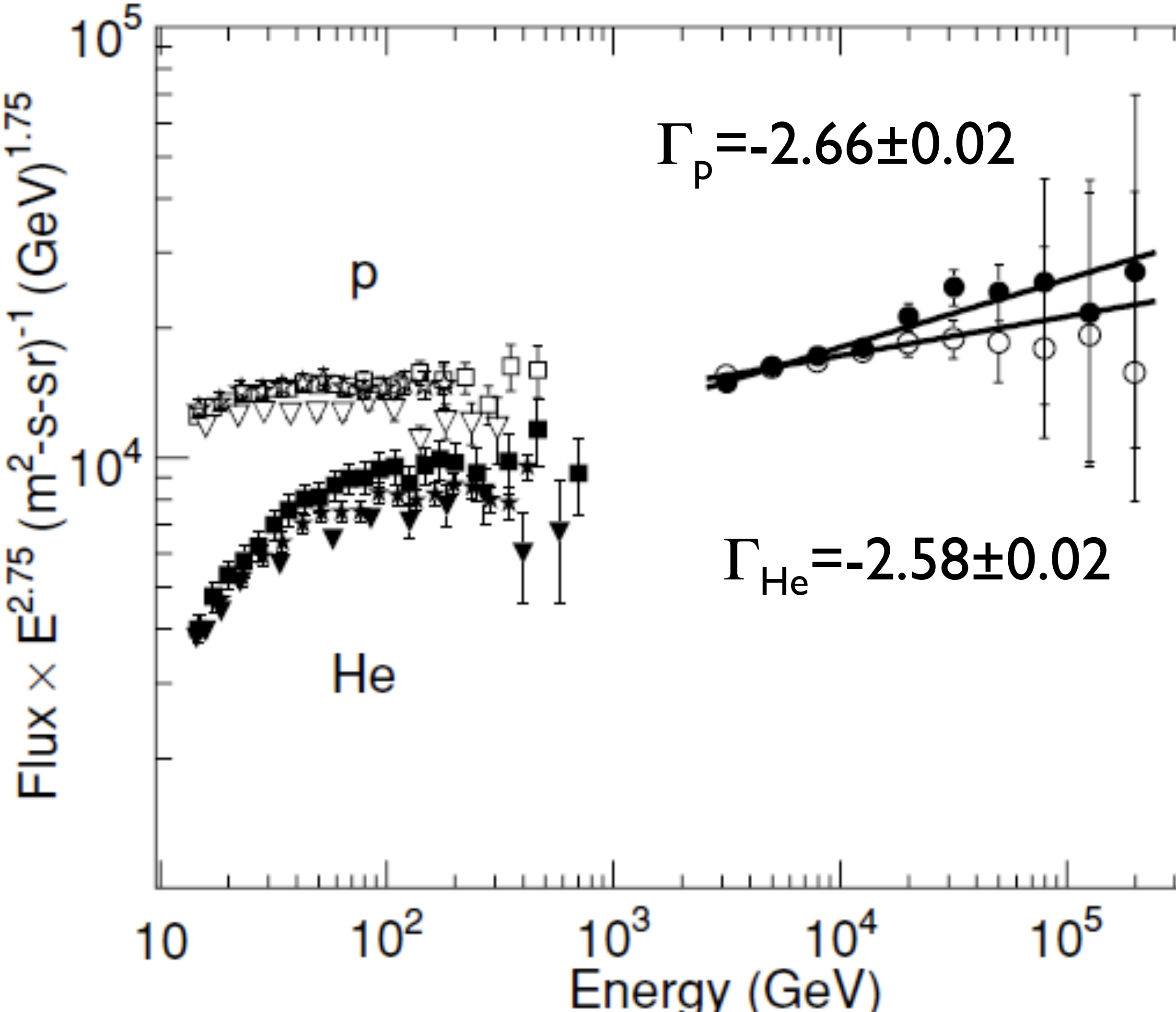




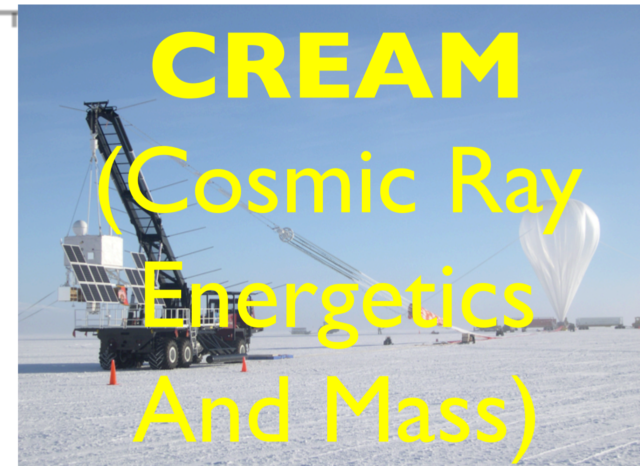
AMS-02 has changed the claim as events increase

✔ He remains harder than p Ohira & KI 11

CR Helium Hardenings



Ahn+ 10



1. He/p hardening
   ~0.2~$Y_\odot$ @GeV
   x~3 @100TeV
2. Spectral Break
   @~200GeV/n
   for all (p-Fe)

Origin of Different Spectra

TABLE 1
SCORE SHEET FOR MODELS OF DIFFERENT COSMIC-RAY SPECTRA

Model	Mechanism	Score	Comment	Reference
Propagation	Spallation	⦸	Grammage	Blasi & Amato (2012)
Different sources	Wind	△	H wind	Biermann et al. (2010)
	Reverse shock	△	Energetics	Ptuskin et al. (2013)
Injection	Gyroradii	⦸	C/He ≠ const.	Malkov et al. (2011)
Inhomogeneous environment	Ionization	⦸	C/He ≠ const.	Drury (2011)
	Superbubble	✓	Mixed ejecta	Ohira & Ioka (2011)

The last 3 are related to
the nature of CR accelerators

Mixing Fraction of ISM

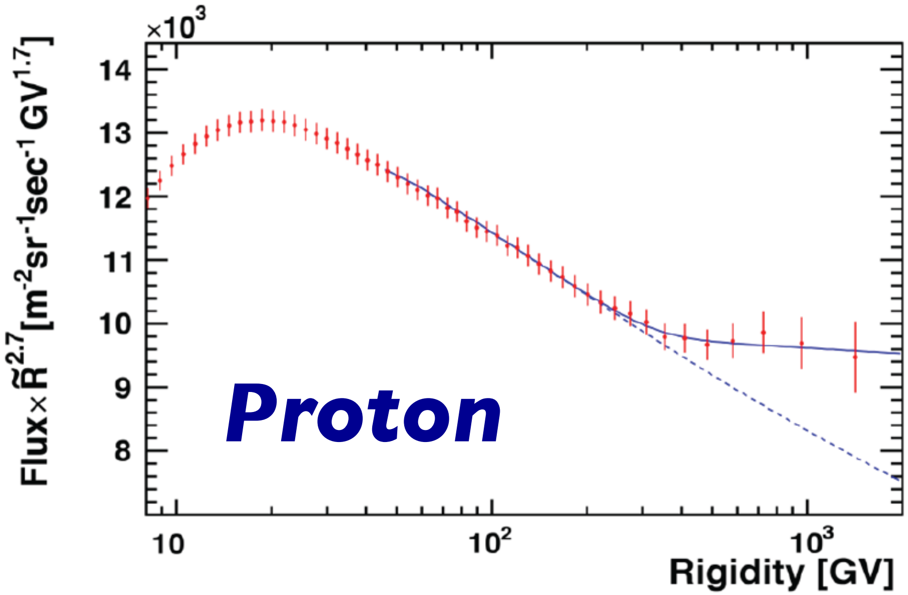
- $[He/p]_{Ejecta}$~$[He/p]_{ISM}$
- $[C/p]_{Ejecta}>>[C/p]_{ISM}$
- AMS-02: C/He~const within ~20%

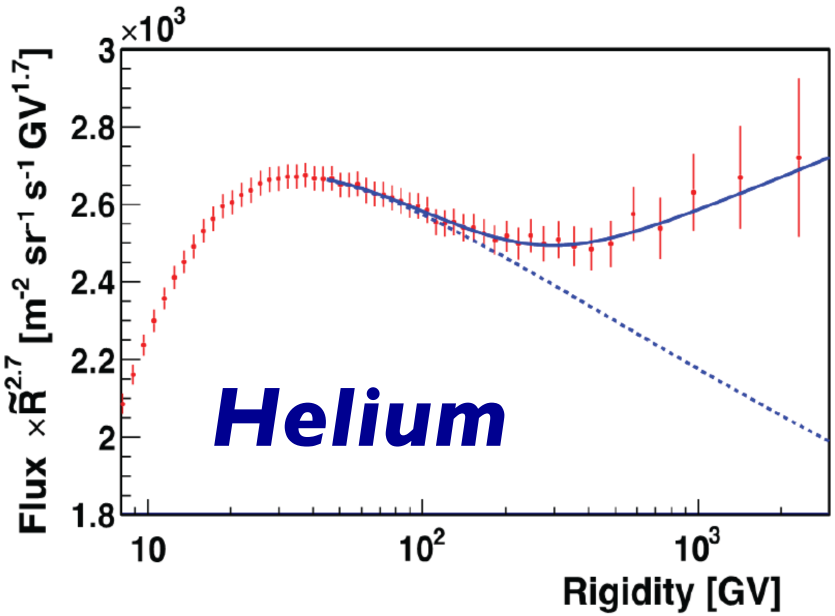
⇒ ISM fraction <20% at ~10 GV

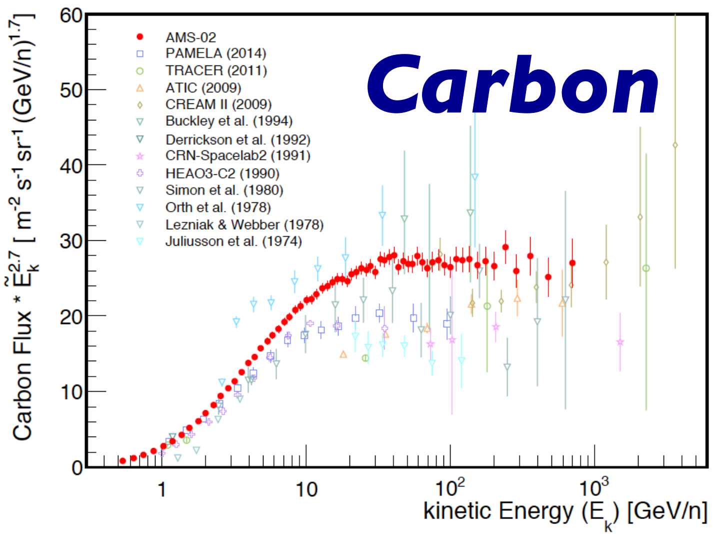
<10% at ~10 TV

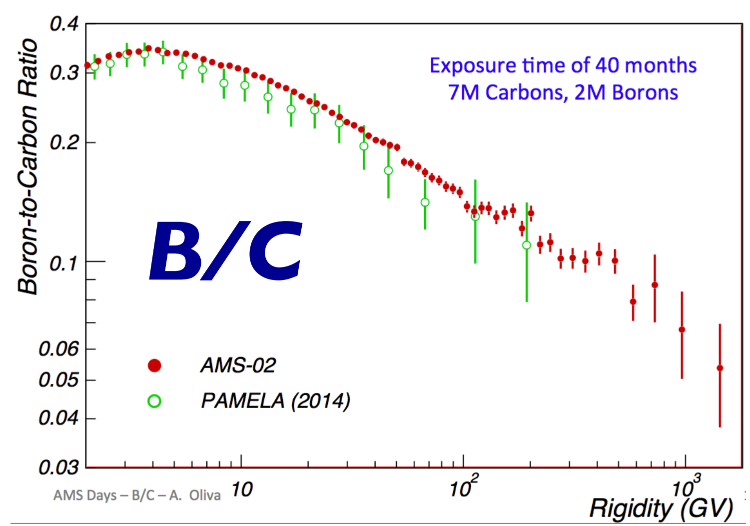
- Cosmic rays originate PRIMARILY from supernova ejecta!

Spectral Breaks









$e^{\pm}$ Propagation

$$\frac{\partial}{\partial t} f\left(t, \varepsilon_e, \vec{x}\right) = \boxed{K(\varepsilon_e)\nabla^2 f} + \boxed{\frac{\partial}{\partial \varepsilon_e}\left[b\varepsilon_e^2 f\right]} + \boxed{q\left(t, \varepsilon_e, \vec{x}\right)}$$

Diffusion

Energy loss by IC & synchro.

Injection

$$b \sim 10^{-16}\,\mathrm{GeV}^{-1}\mathrm{s}^{-1}$$

$$K(\varepsilon_e) \sim 5.8\times 10^{28}\,\mathrm{cm}^2\mathrm{s}^{-1}\left(1+\frac{\varepsilon_e}{4\mathrm{GeV}}\right)^{1/3}$$

← B/C ratio

For a single burst with $q \propto \varepsilon_e^{-\alpha}$ Power law spectrum

$$f = \frac{q_0 \varepsilon_e^{-\alpha}}{\pi^{3/2} d_{diff}^3}\left(1 - bt\varepsilon_e\right)^{\alpha-2} e^{-\left(d/d_{diff}\right)^2}$$

Atoyan+ 95, Shen 70

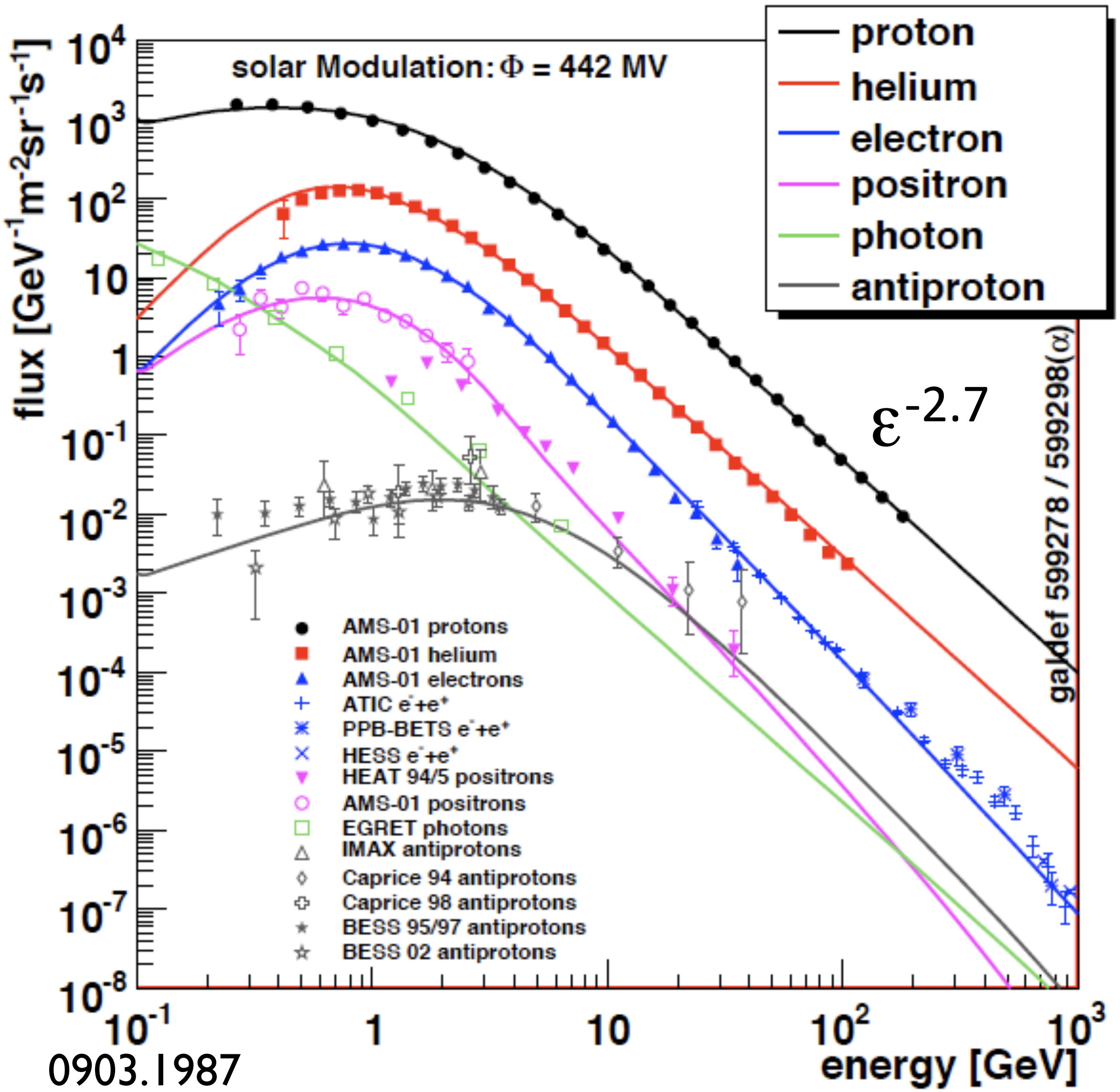
Spatially uniform over

$$d_{diff}(t, \varepsilon_e) \sim 2\left[K(\varepsilon_e)t\right]^{1/2}$$

Spectral cutoff

$$\varepsilon_{\mathrm{cut}} \sim \frac{1}{bt}$$

Energetics



0903.1987

U(proton) ~1eV/cm^3

← Supernova remnants

U(electron) ~10^{-2}eV/cm^3

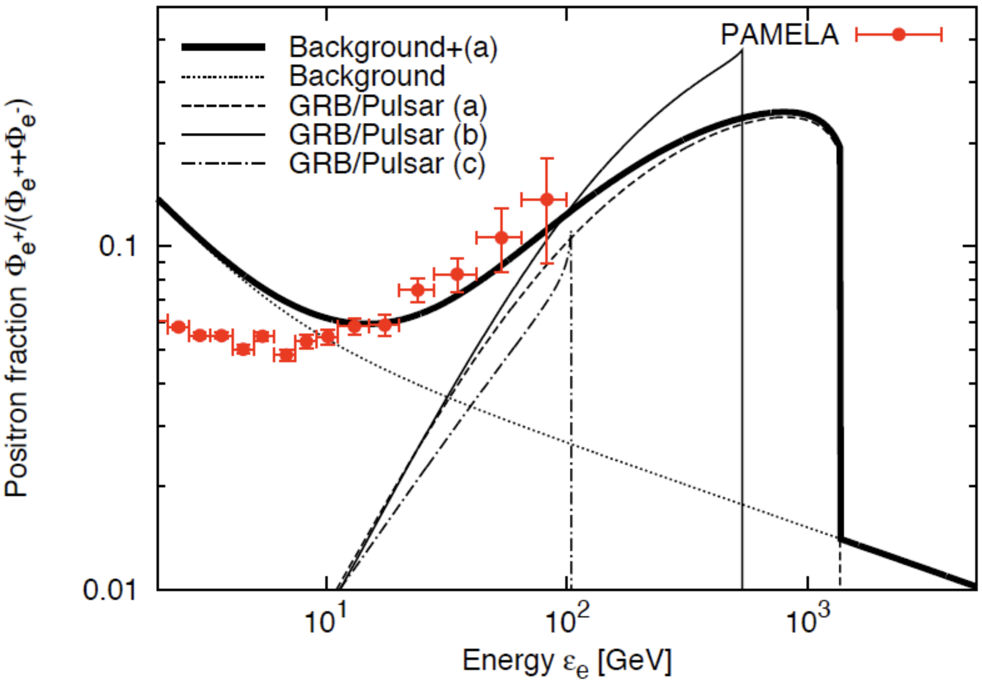
U(positron) ~10^{-3}eV/cm^3

~ 0.1% of p

Even less @TeV

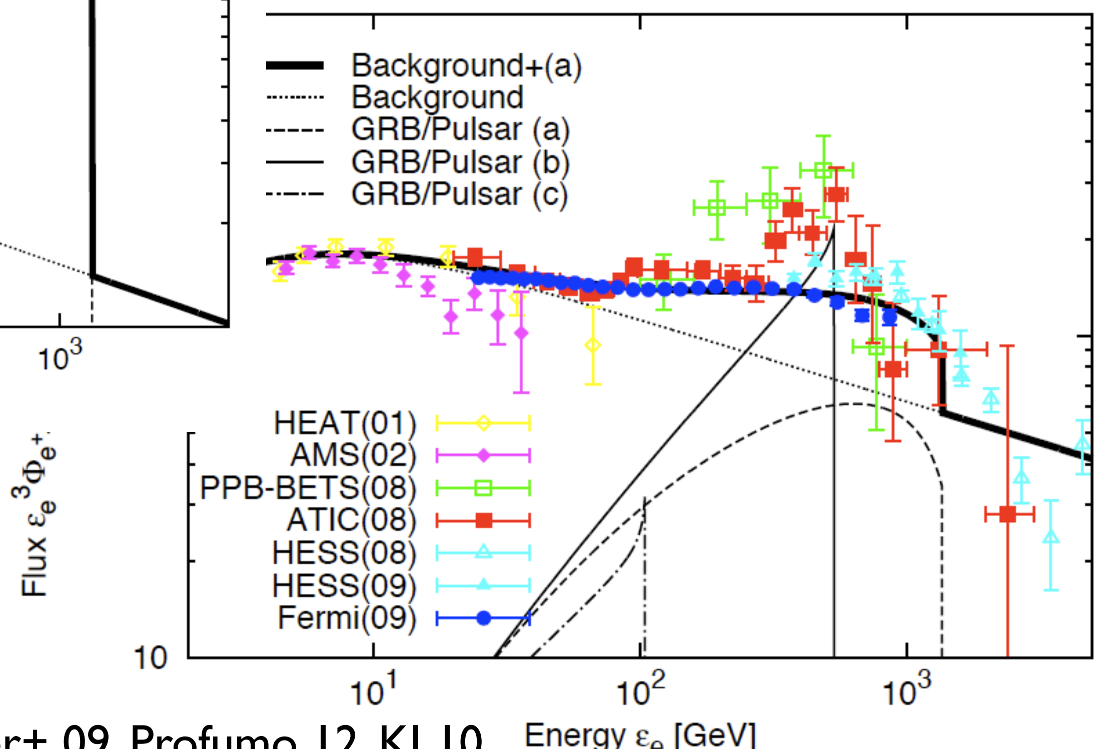
Spectral Fitting

Positron



Both $e^{\pm}$ can be fitted by the same model

Electron



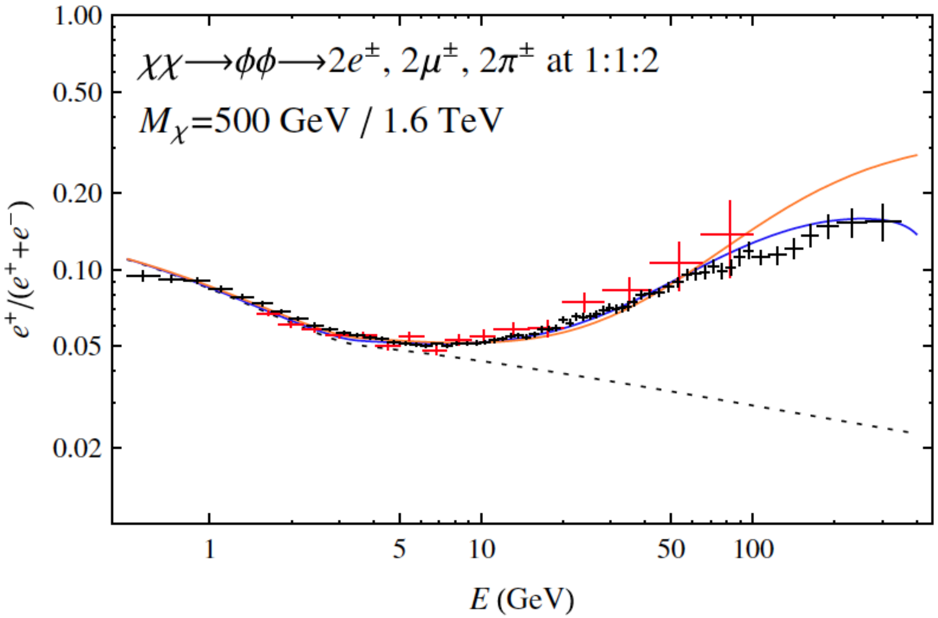
d=1kpc

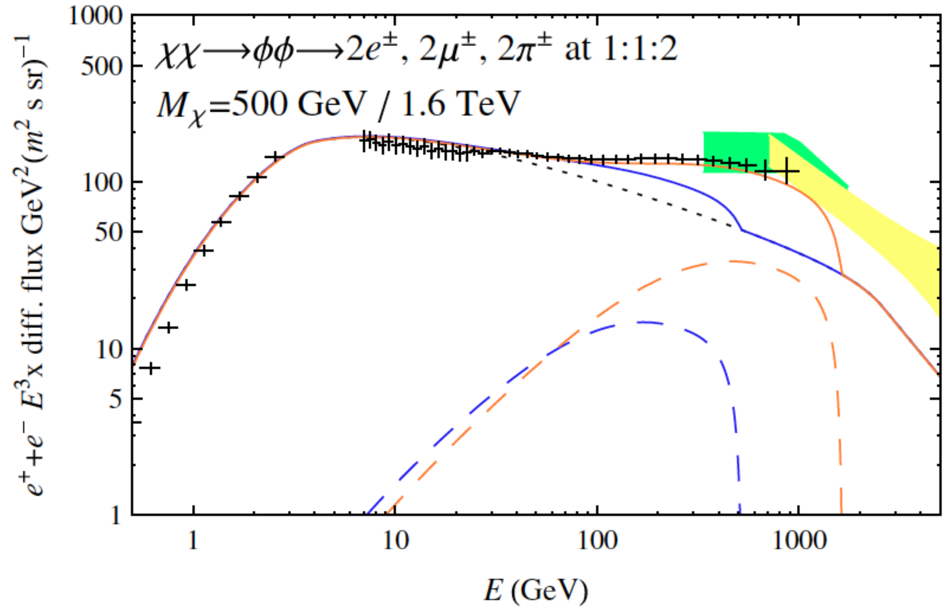
(a)Fiducial	(b) Harder	(c) Older
0.9e50 erg	0.8e50 erg	3e50 erg
2e5 yr	5.6e5 yr	3e6 yr
α=2.5	α=1.8	α=1.8

e.g, Hooper+ 09, Profumo 12, KI 10

Tension with Fermi?

Slope declines ⇒ Does not fit Fermi data

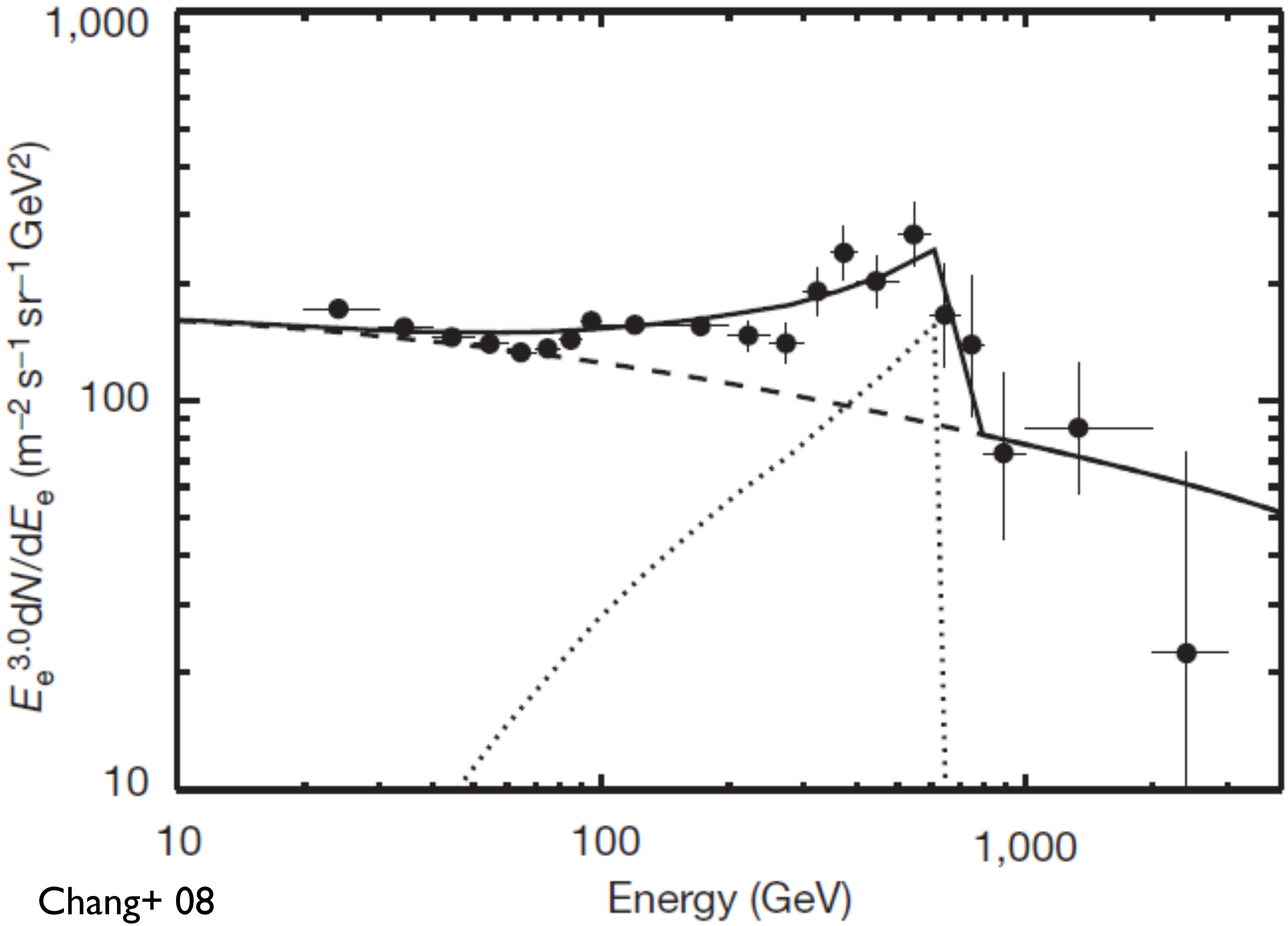




For both DM and pulsar models
Still within the Fermi systematics

Cholis & Hooper 13, Ibe+ 13
Yuan+ 13, Yuan & Bi 13
Masina & Sannino 13, Jin+ 13
De Simone+ 13, Feng+ 13
Gaggero & Maccione 13

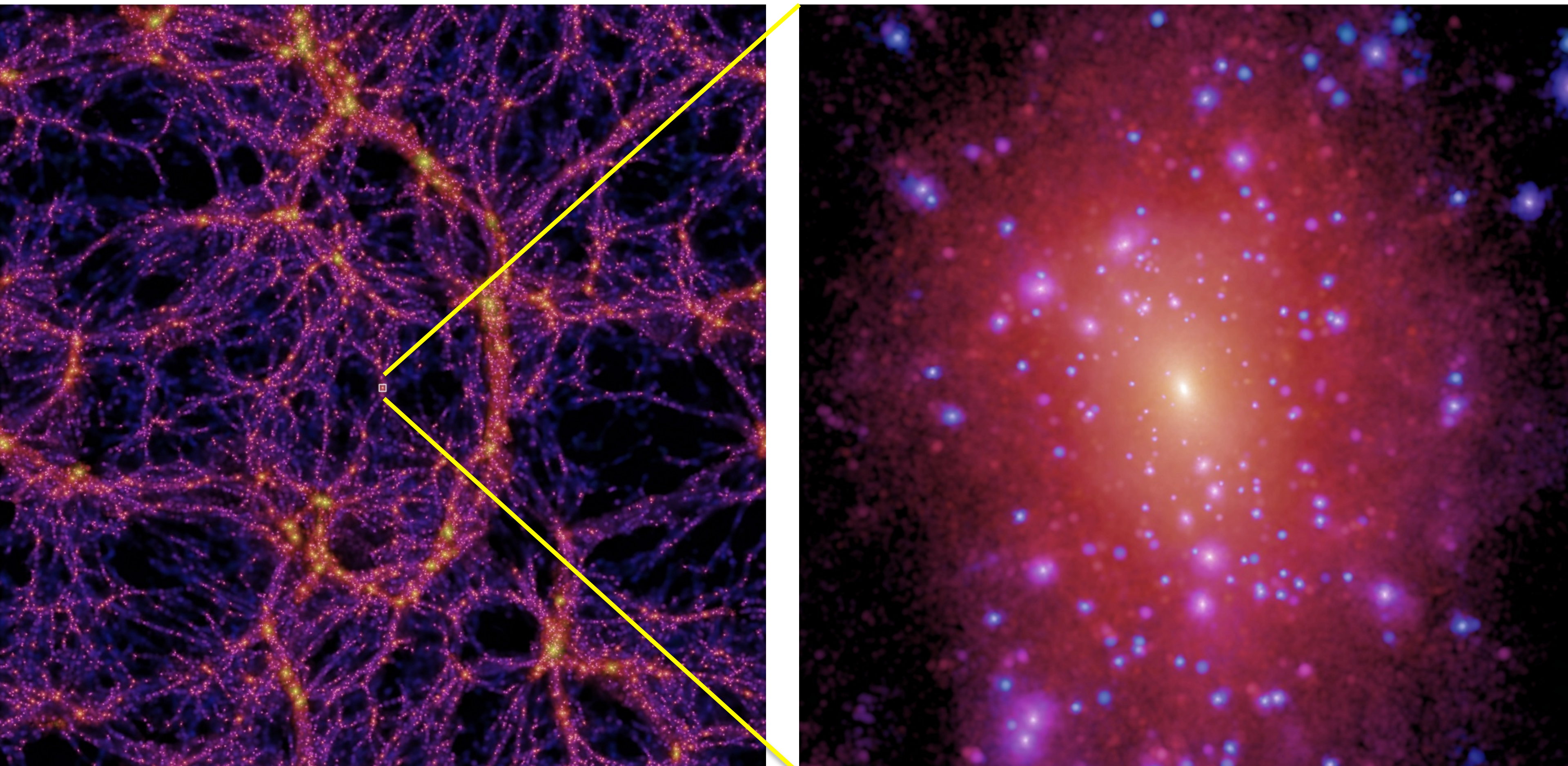
Spectrum



Peak + Cutoff = DM?

Chang+ 08

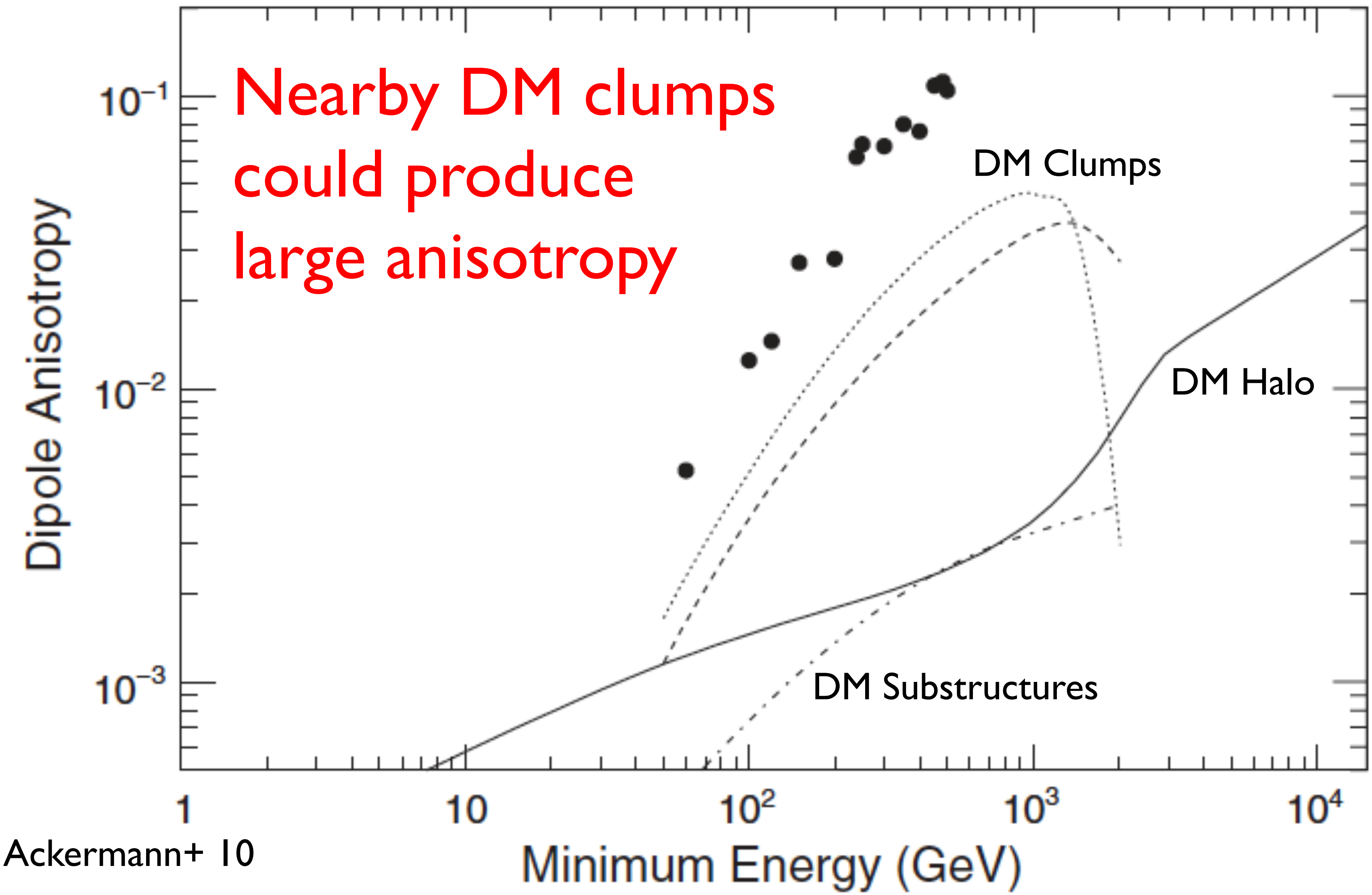
Dark Matter Structure



N-body Simulation

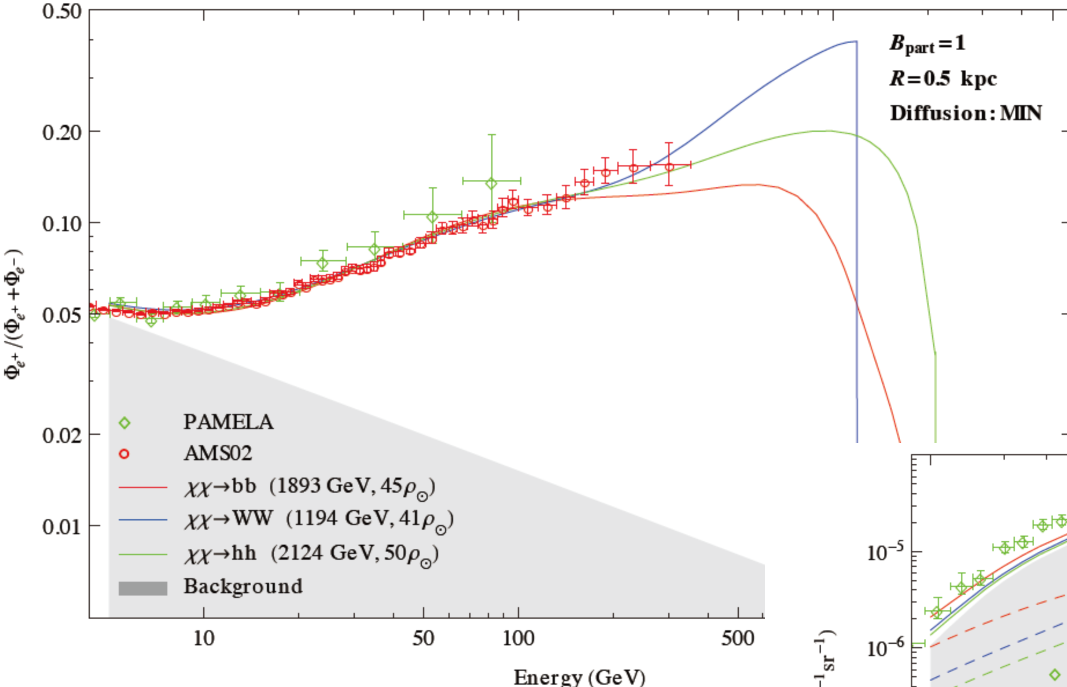
The Aquarius Project

e⁻ Anisotropy: Dark Matter

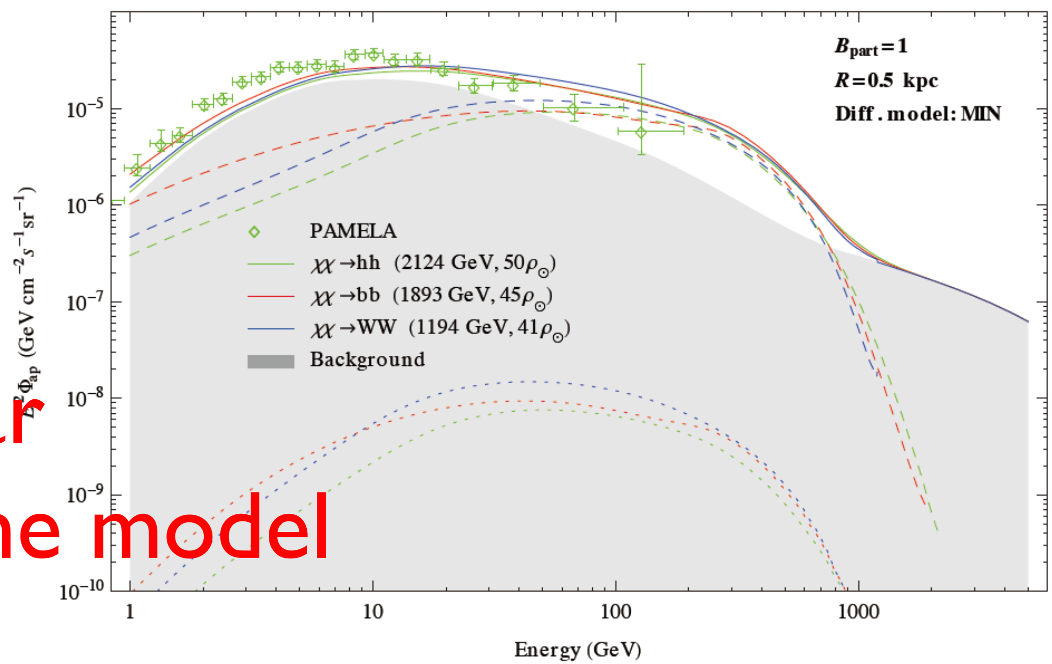


Ackermann+ 10

DM Over-Density



DM clump models can use hadronic modes to fit $e^+/e^\pm$

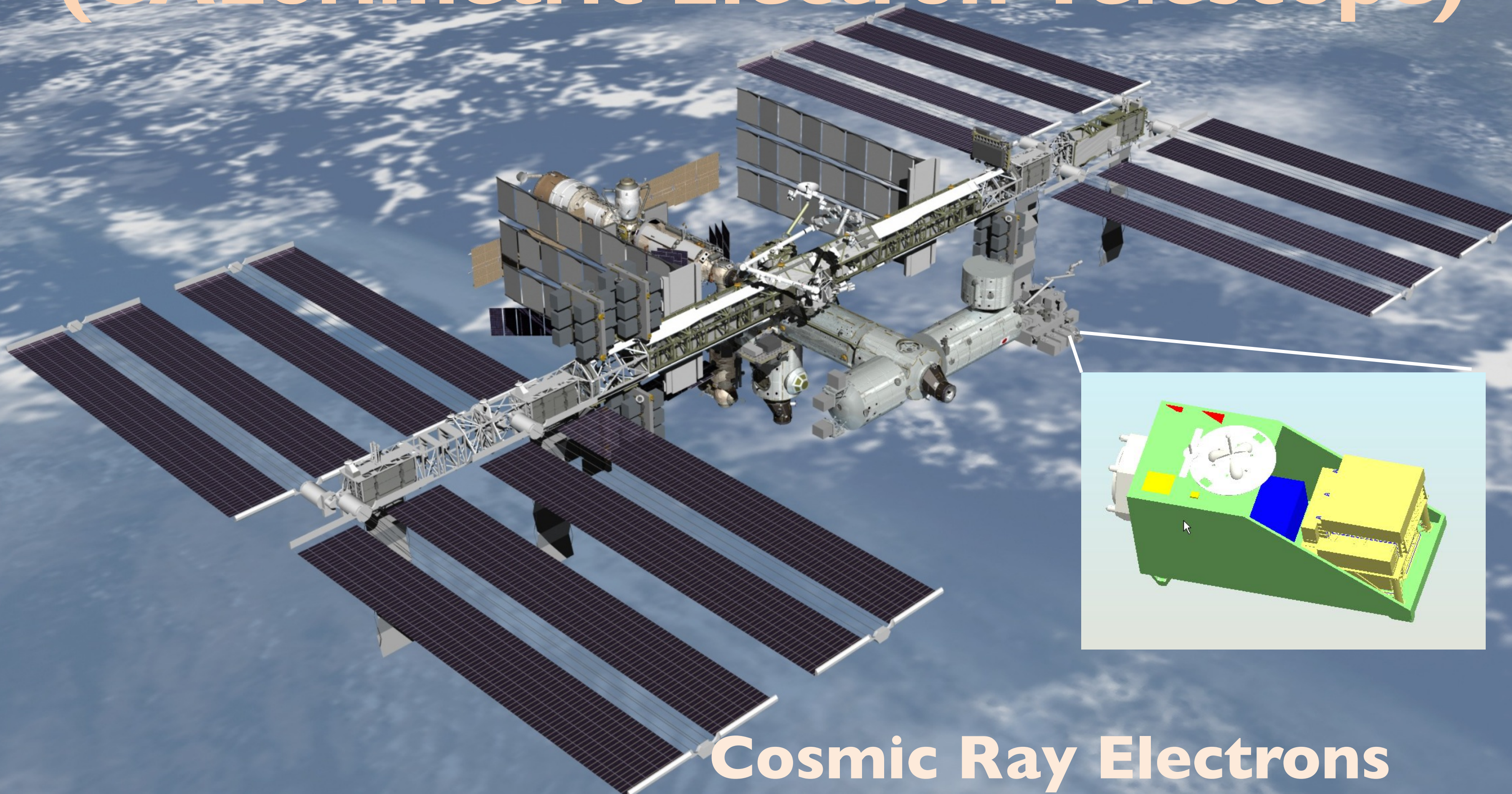


Consistent with pbar

AMS-02 pbar test the model

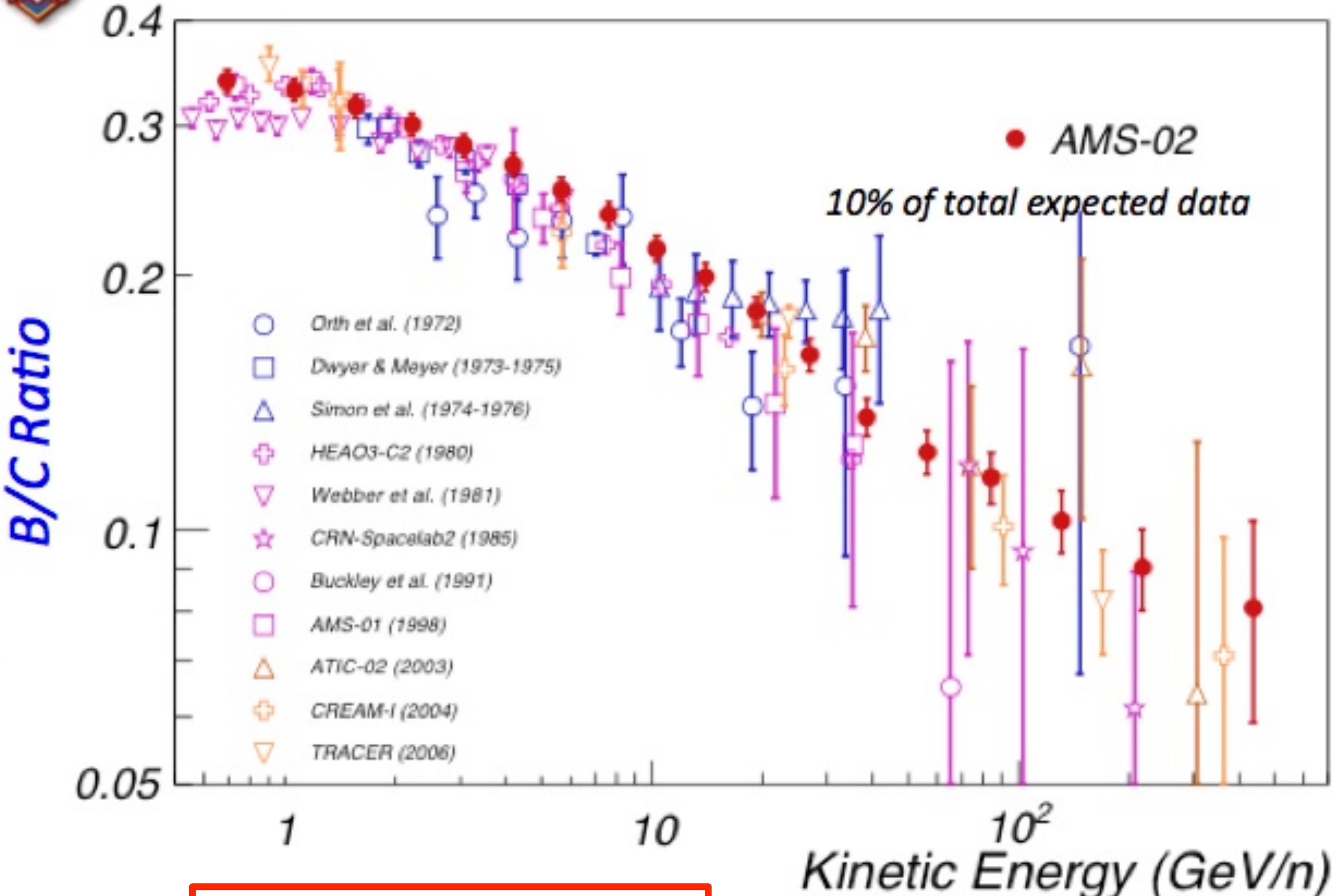
Hektor+ 13

CALET
(CALorimetric Electron Telescope)



Cosmic Ray Electrons
up to ~10TeV
w/ ΔE~a few % (>100GeV)

Boron-to-Carbon ratio compared with previous data



$$D(\varepsilon) \propto \varepsilon^{-0.2\sim0.3}$$