Science of CR electron measurement at HERD

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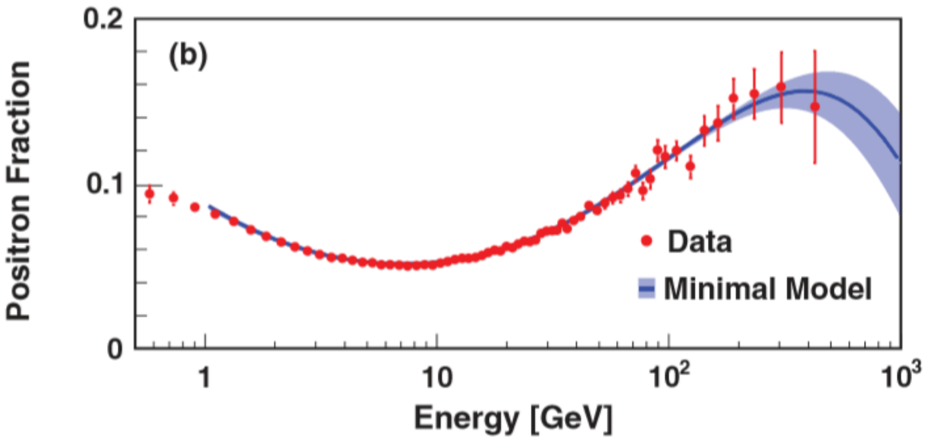
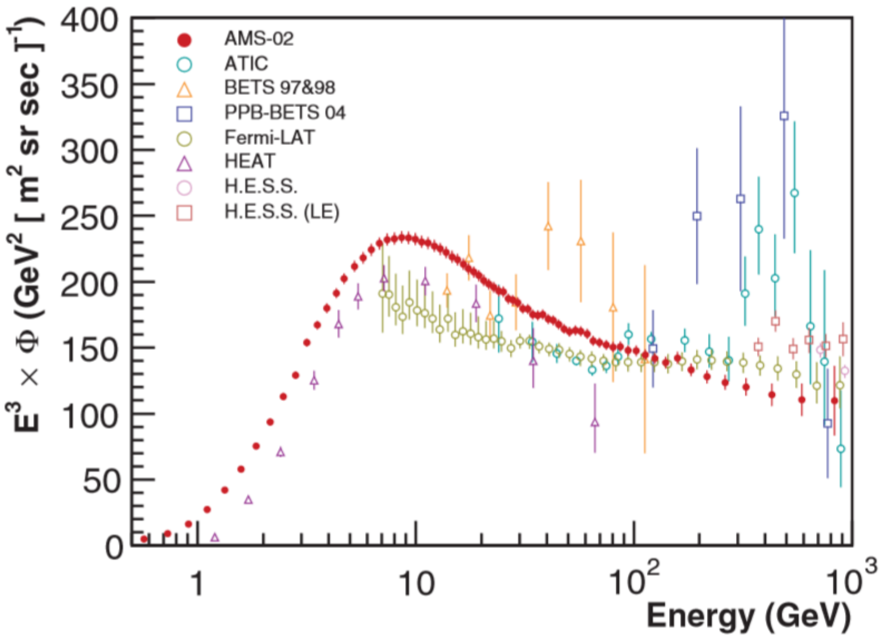
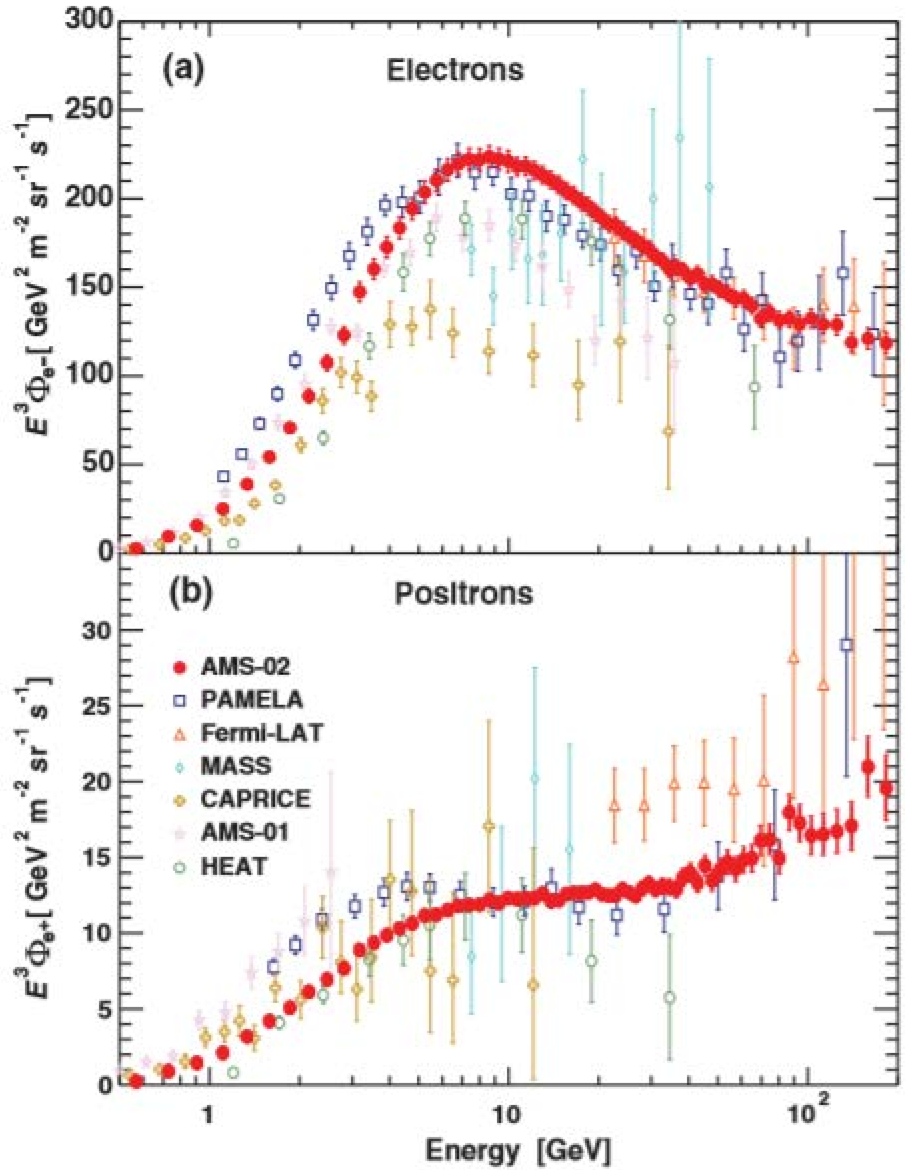
Outline

- Status of cosmic electron spectrum measurement and explanation
- Scientific objectives at HERD
- Summary

Measurement of cosmic electron and positron spectra by AMS-02

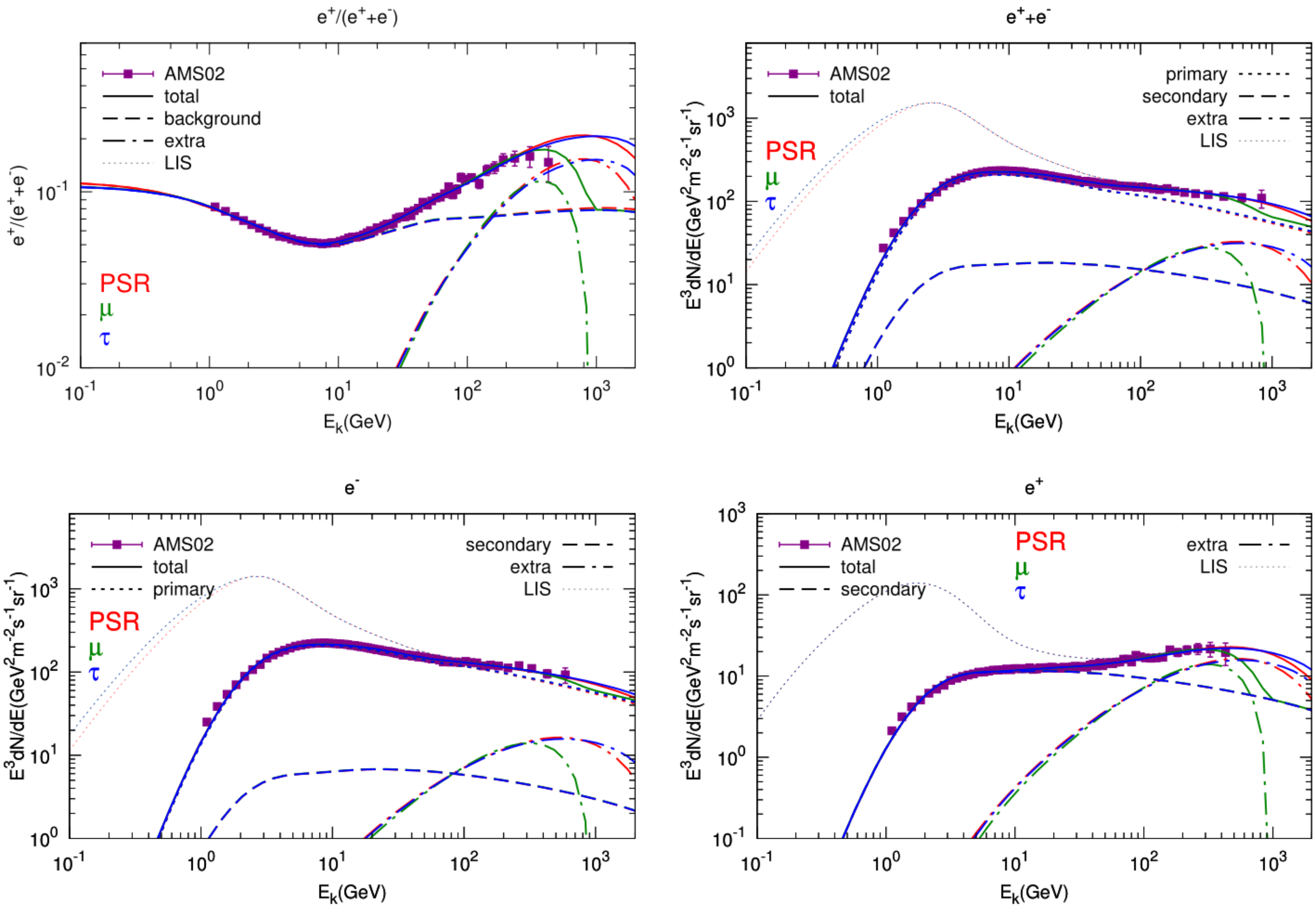






Positron/electron excess from DM annihilation or nearby pulsars

Lin SJ et al.
PRD91.063508, 2015



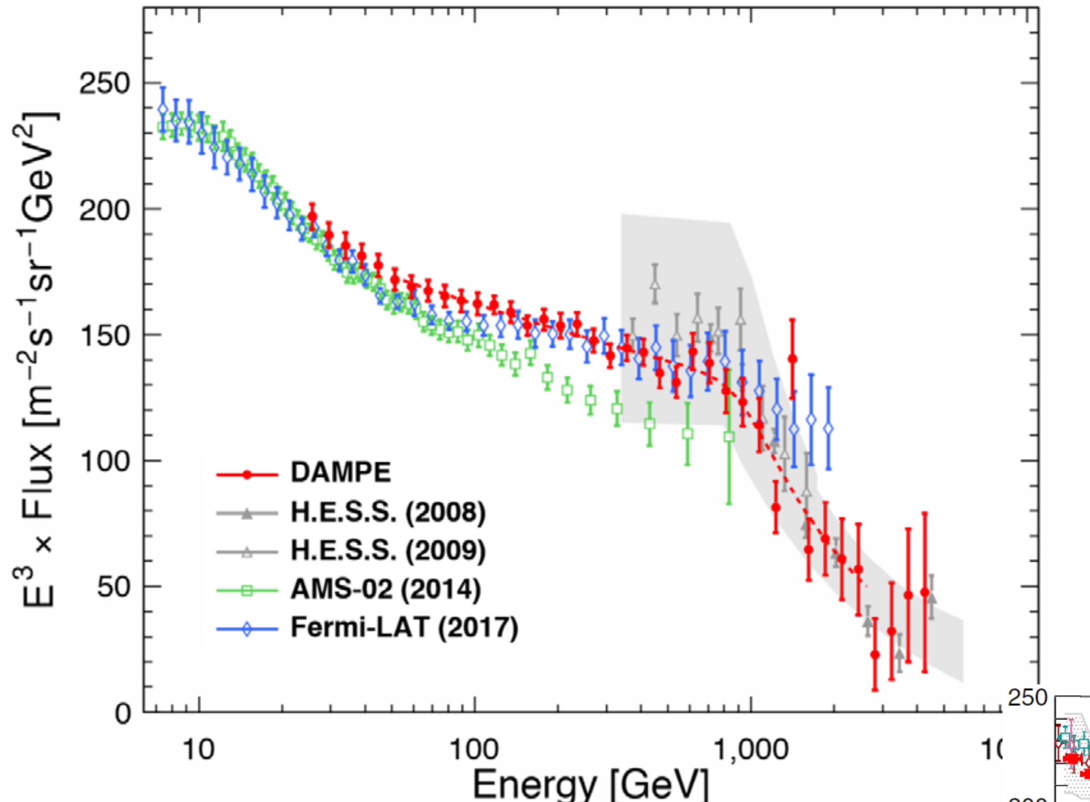
Remind: in some cases the two spectra can be nearly identical ; the DM spectrum refers the one by muon in the following.

Conclusions of the quantitative study II

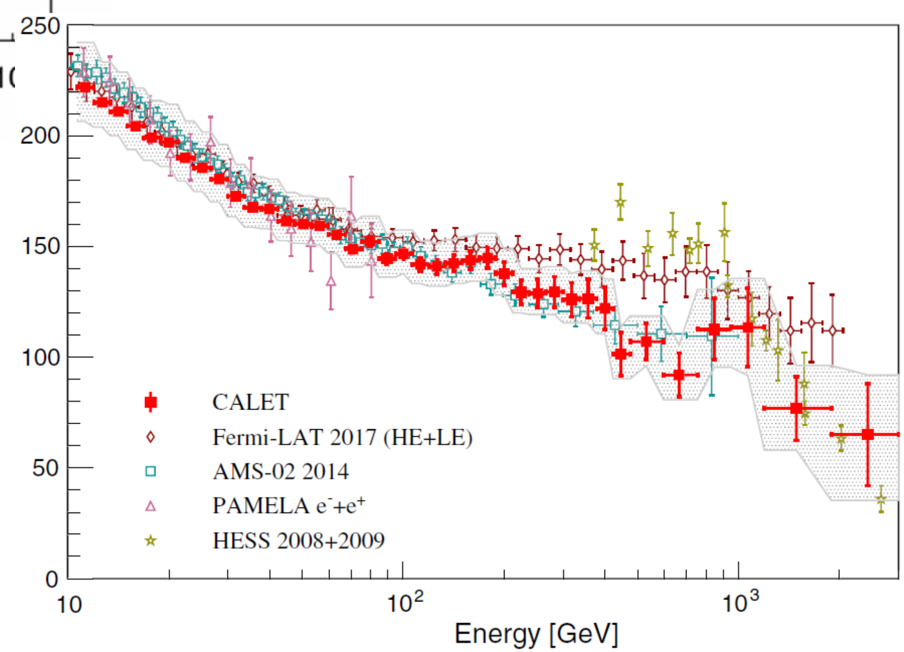
Both astrophysical sources, like pulsars, or dark matter can give good fit the AMS-02 data. AMS02 data can not distinguish the two scenarios.

		$\frac{\chi^2}{\text{d.o.f.}}$	χ^2	$\frac{e^+}{e^+ + e^-}$	e^-	e^+
	PSR	0.92	175.4	42.95	54.22	78.26
DR	μ	0.89	171.6	39.94	55.36	76.26
	τ	0.91	175.2	42.72	55.21	77.24
	PSR	0.47	88.99	51.87	14.77	22.35
DC	μ	1.16	223.1	88.7	46.95	87.45
	τ	0.62	118.0	59.5	21.52	37.02

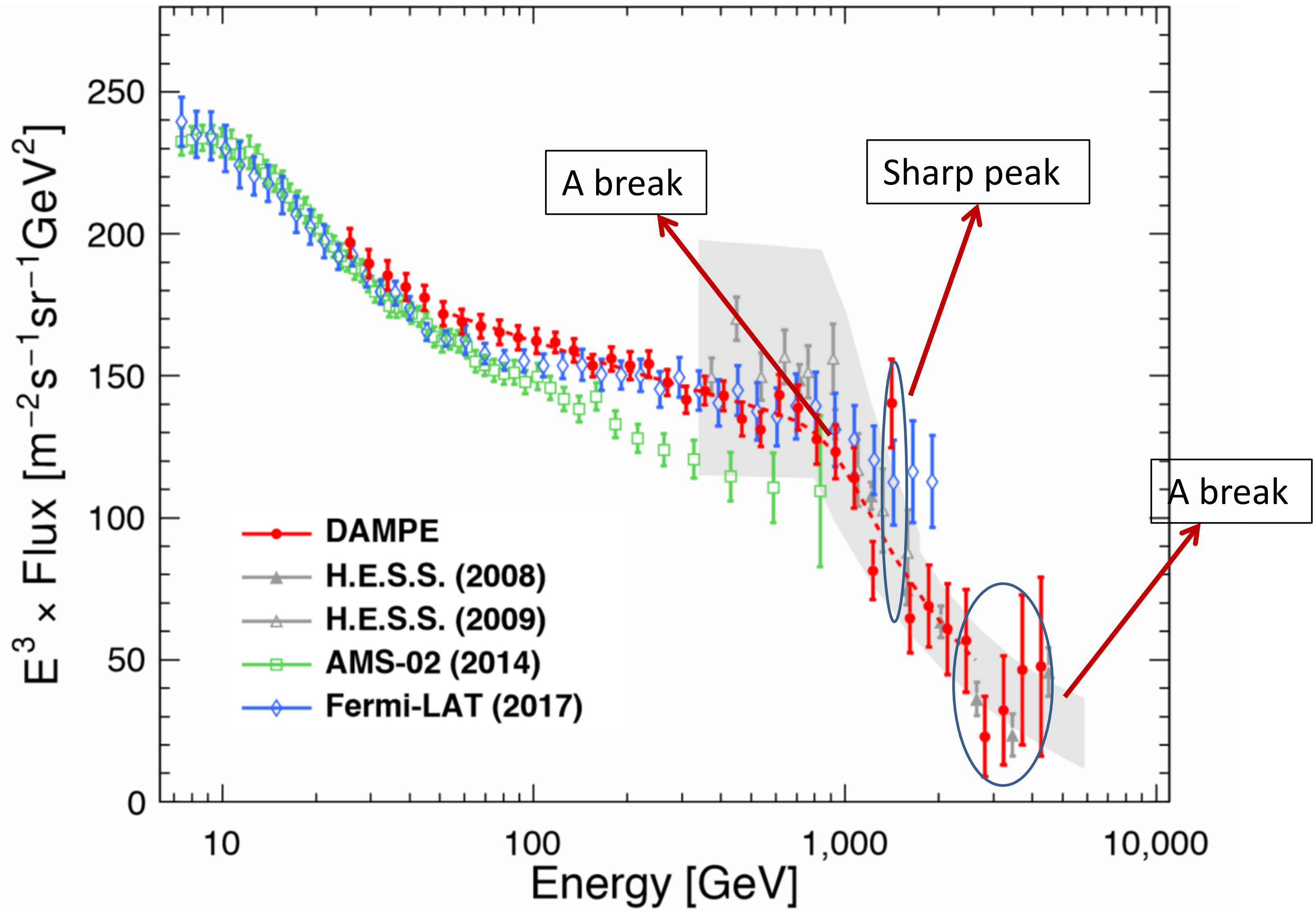
Measurements of (e^-+e^+) spectrum



Four direct measurements with three results!



DAMPE result –4.6TeV+ features



An interpretation of the DAMPE and AMS-02 data

SNRs are generally believed the sources of cosmic rays, the maximal energy from SNR(acce and loss balan) $E_{\rm max}^{\rm (synchrotron)} \sim 23\,{\rm TeV}\frac{u_1}{c}\frac{1}{\sqrt{B}}$
u1~5*10^8cm/s, B~10-30μG, Emax ~ 100TeV -> crab observation

A possible model for CR injection：

Fang K. et al. APJ 854 (2018) 57

- CR (electrons) are only released at the late time of SNR evolution when the shock waves become weak (~10^5yr); confinement of electrons leads to cooling and a low energy cutoff (dominant pop A)
- Only a small part of electrons from upstream can escape when SNR is young; the spectrum at the upstream is hard and lead to a hard component at high energy (pop B).

CR electron spectrum

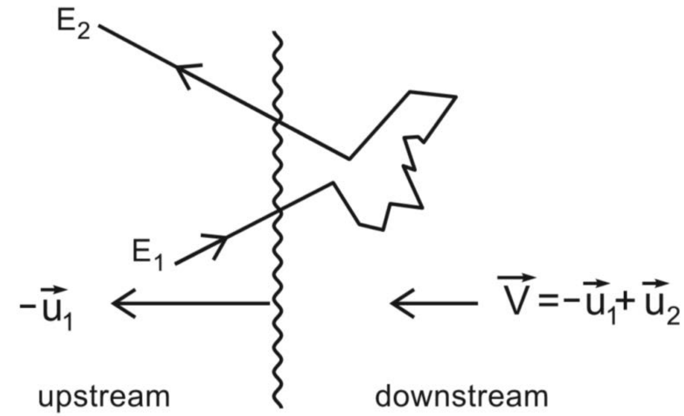


图 11.2: 平面激波加速示意图

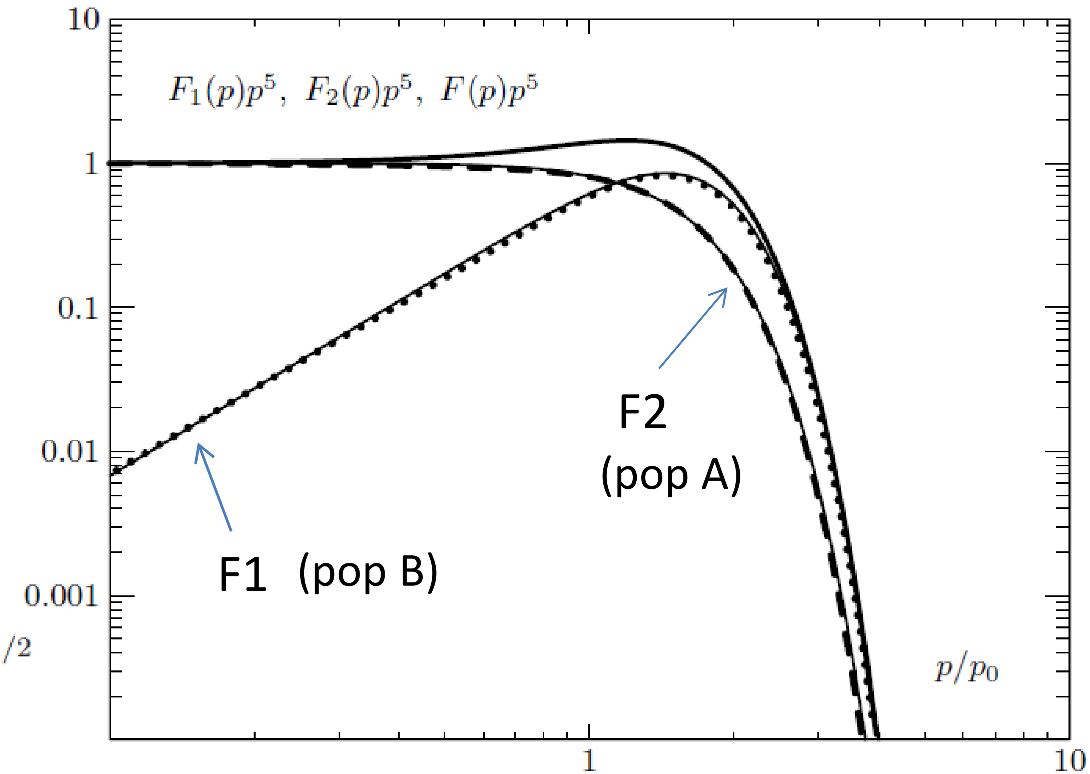
Integrated spectrum
at the up and down
stream of shock wave：

$$F_1(p) \propto p^{-3}\exp(-p^2/p_c^2),$$

$$F_2(p) \propto p^{-5}\exp(-p^2/p_c^2)$$

Cutoff decrease

$$p_c = 4.3\,\mathrm{TeV/c}\left(\frac{u_1}{300\,\mathrm{km\,s^{-1}}}\right)\left(\frac{B}{30\,\mu\mathrm{G}}\right)^{-1/2}$$

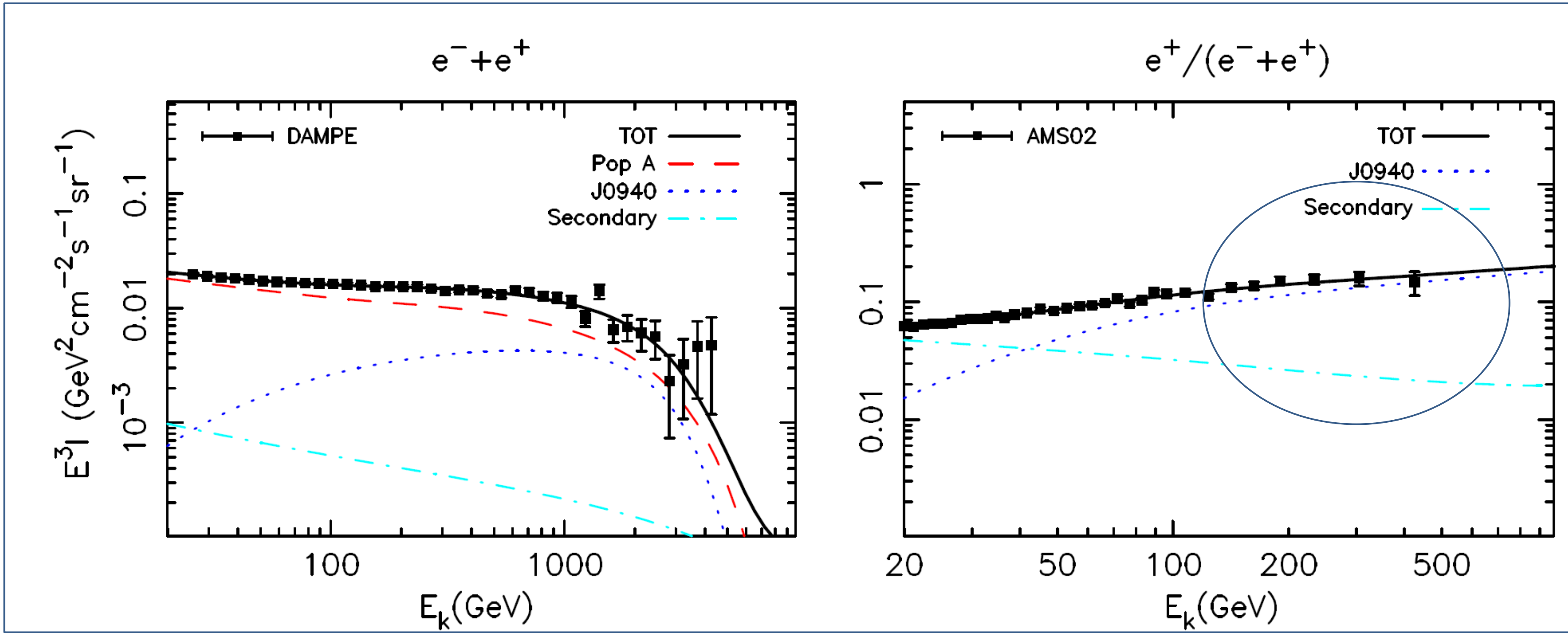


U1 vel of shock， B is downstream mag

V. N. Zirakashvili & F. Aharonian 2007

result1

model1：pulsar J0940-5428， no Pop B

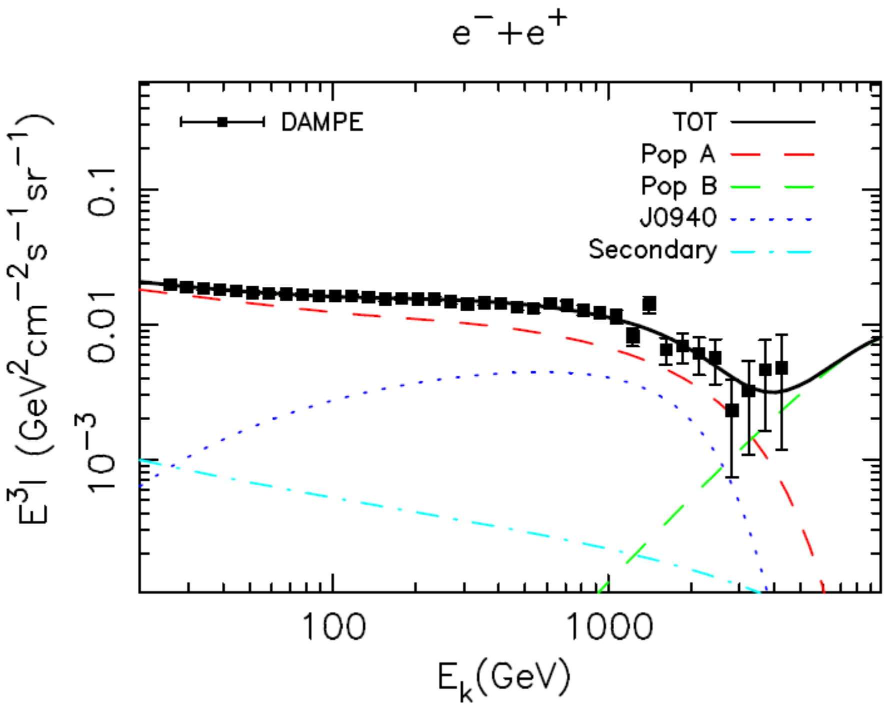


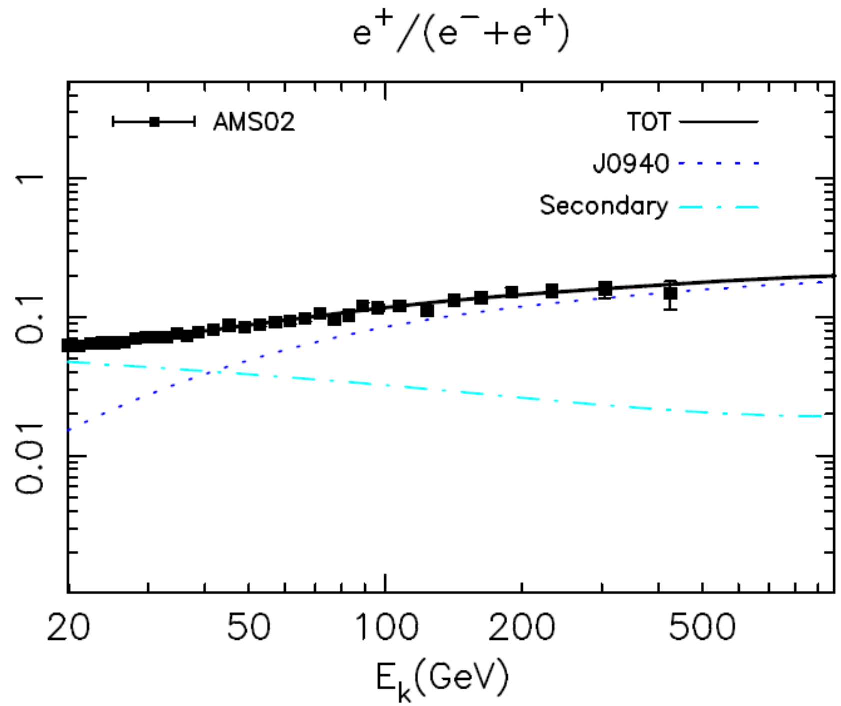
Best fit t_end 0.94x10^5 yr， typical age of SNR

Blue component can also be a DM contribution; it's contributio is submerged under the primary electron component. Diff origins lead to a fine structure.

result2

model2： pulsar J0940-5428， with Pop B





Best fit t_end为0.89x10^5 yr
Pop B injcetion 10^33 /GeV/s， for a source of 10^4yr like Vela， the hard component take <u>10^-5 </u>total energy of SNR

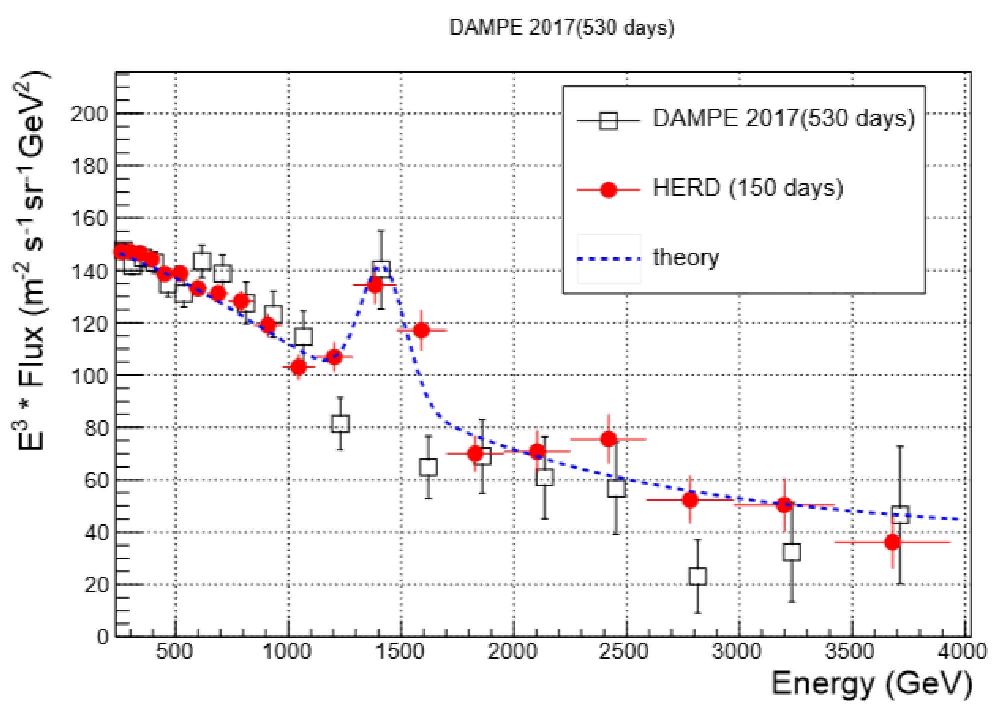
summary of present status

- Positron excess at AMS-02 can be explained by both DM and pulsar well; no distinction
- Measurements of cosmic e+- spectrum is not consistent
- A natural model to explain the ‘break’ of electron spectrum is due to cutoff of primary electron spectrum; DM or pulsar component to e+/e- is submerged under the background.

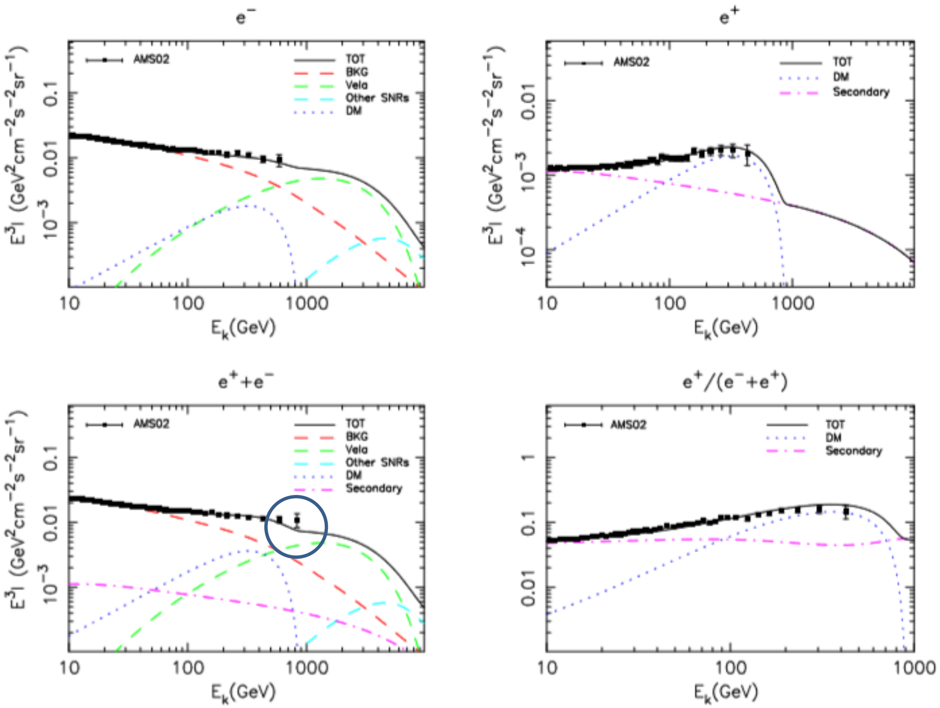
Scientific objectives at HERD

1, Measure the total e+- spectrum

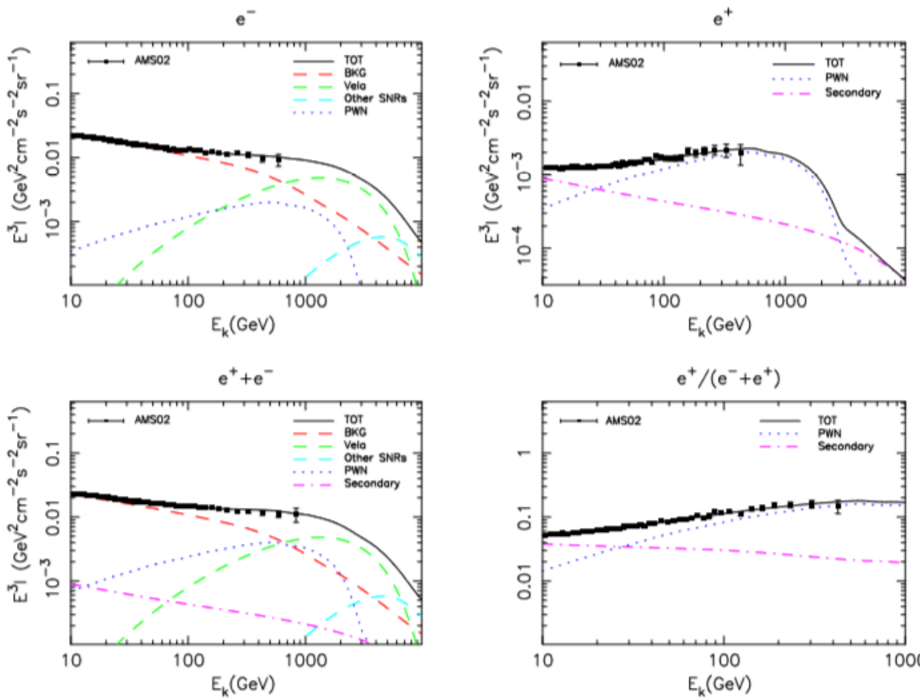
- This is an obvious objective since the present measurements are not consistent
- To test the sharp peak at the DAMPE spectrum which is about 3σ and induces a lot of interests



2, fine structure at the spectrum



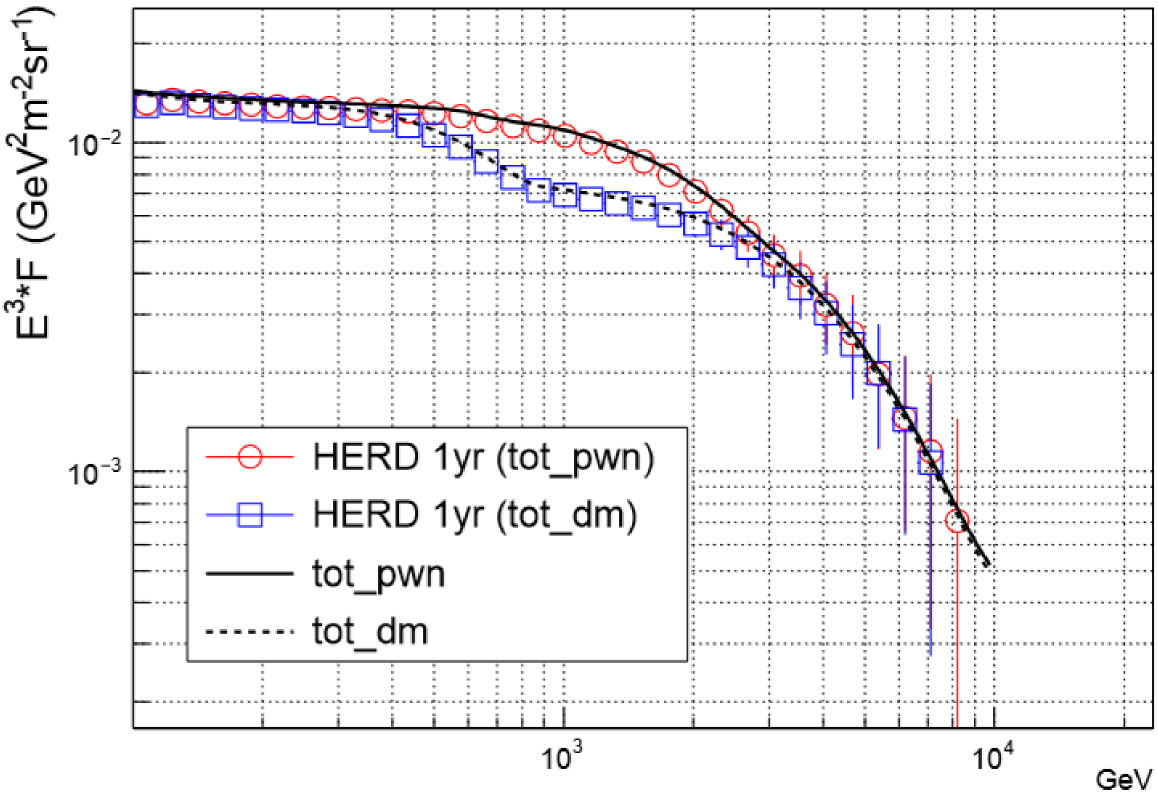
Positrons by DM annihilation



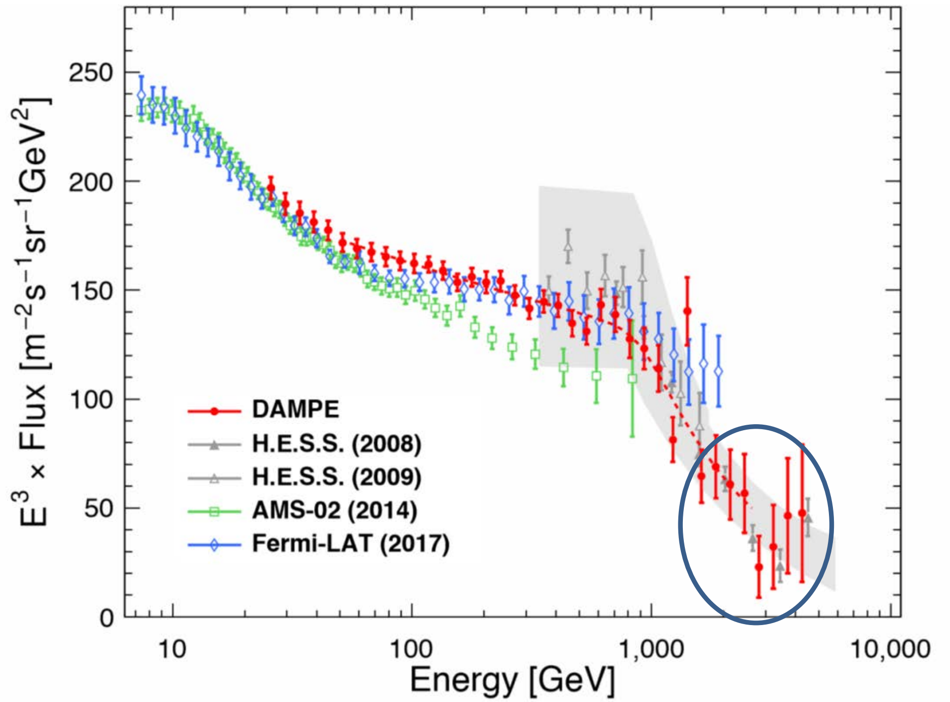
Positrons by a pulsar

Simulation to find such feature

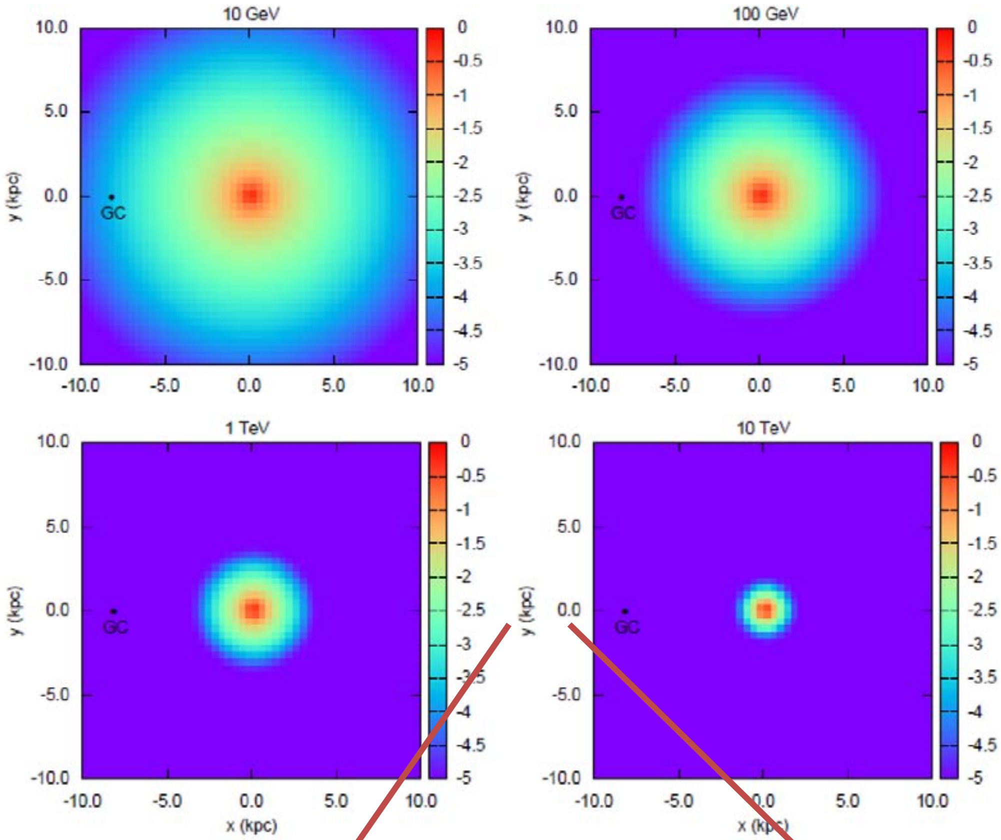
- A fast simulation shows that HERD can find such a feature by 1 year and determine the cutoff energy. DM mass is determined then.



3, hard component from nearby sources – features at spectrum and anisotropy



e^{+-} Propagation distance



High energy e^{+-} can only come from nearby sources – the nearby SNR or pulsar induce <u>large anisotropy, DM not</u>

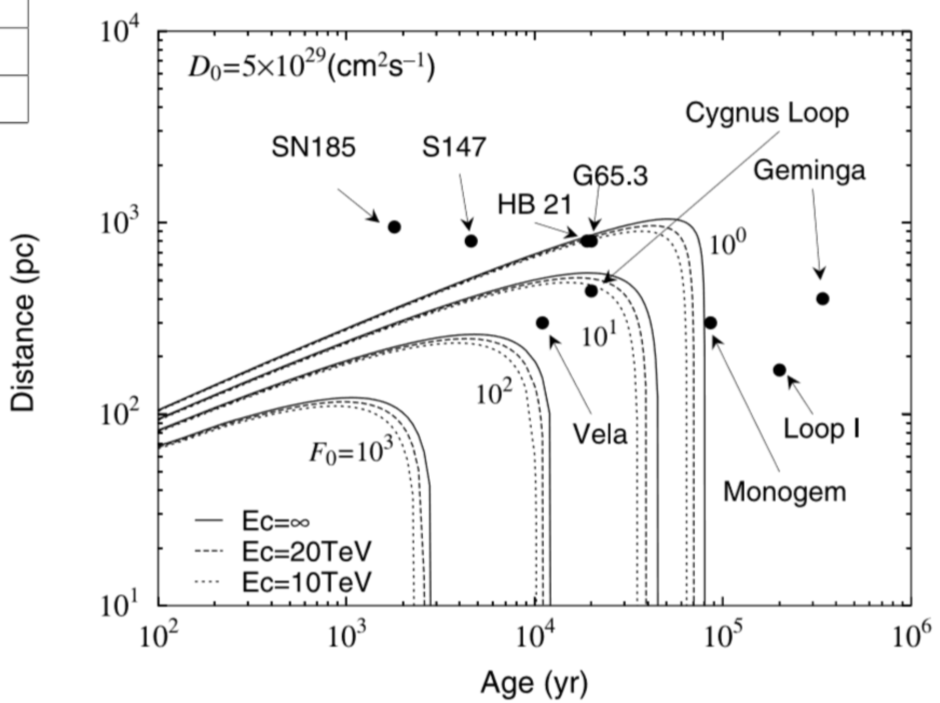
If coming from nearby pulsar or SNR they may have possible <u>features at higher energies, DM not</u>

Parameters of SNRs

Source	Other Name	$B_r^{1\text{GHz}}$[Jy]	α_r	Size[arcmin]	r[kpc]	t[kyr]	Ref.
G065.3+05.7	-	52	0.58	310 × 240	0.9	26	[21–24]
G074.0–08.5	Cygnus Loop	175	0.4	230 × 160	0.54	10	[21, 25, 26]
G114.3+00.3	-	6.4	0.49	90 × 55	0.7	7.7	[21, 27–29]
G127.1+00.5	R5	12	0.43	45	1	[20, 30]	[21, 27, 28, 30, 31]
G156.2+05.7	-	5	0.53	110	1.0	[15, 26]	[21, 28, 32–35]
G160.9+02.6	HB9	88	0.59	140 × 120	0.8	[4, 7]	[21, 27, 28, 36, 37]
G203.0+12.0	Monogem Ring	-	-	-	0.3	86	[38, 39]
G263.9–03.3	Vela YZ	varies	varies	255	0.29	11.3	[21, 40–43]
G266.2–01.2	Vela Jr.	50	0.3	120	0.75	[1.7, 4.3]	[21, 44–47]
G328.3+17.6	Loop I (NPS)	-	-	-	0.1	200	[48, 49]
G347.3–00.5	RXJ1713.7-3946	4	0.3	65 × 55	1	1.6	[21, 50, 51]

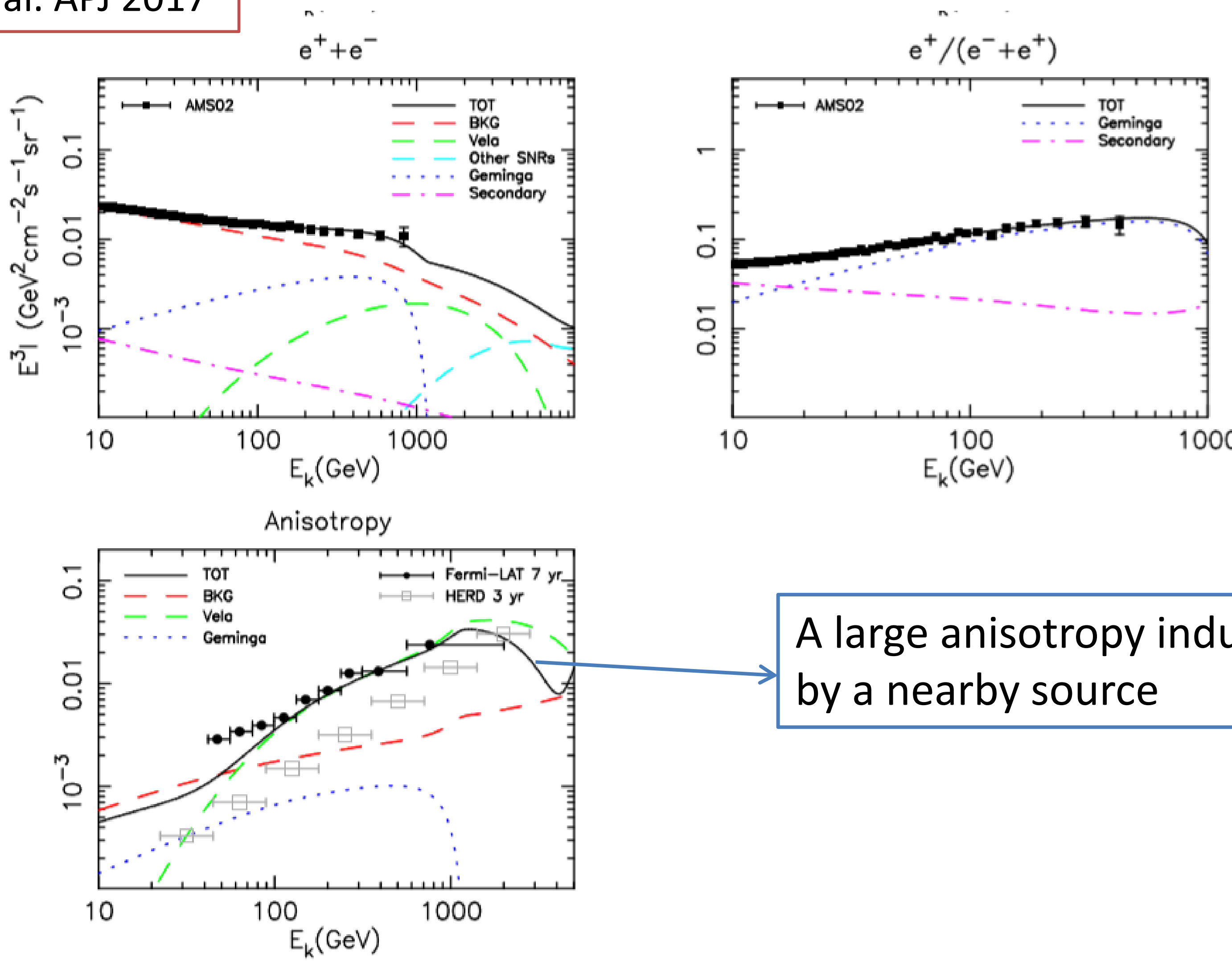
We examined the nearby sources (SNRs and pulsars)- left table.
The relative importance of nearby sources are shown below.

Flux at 3TeV



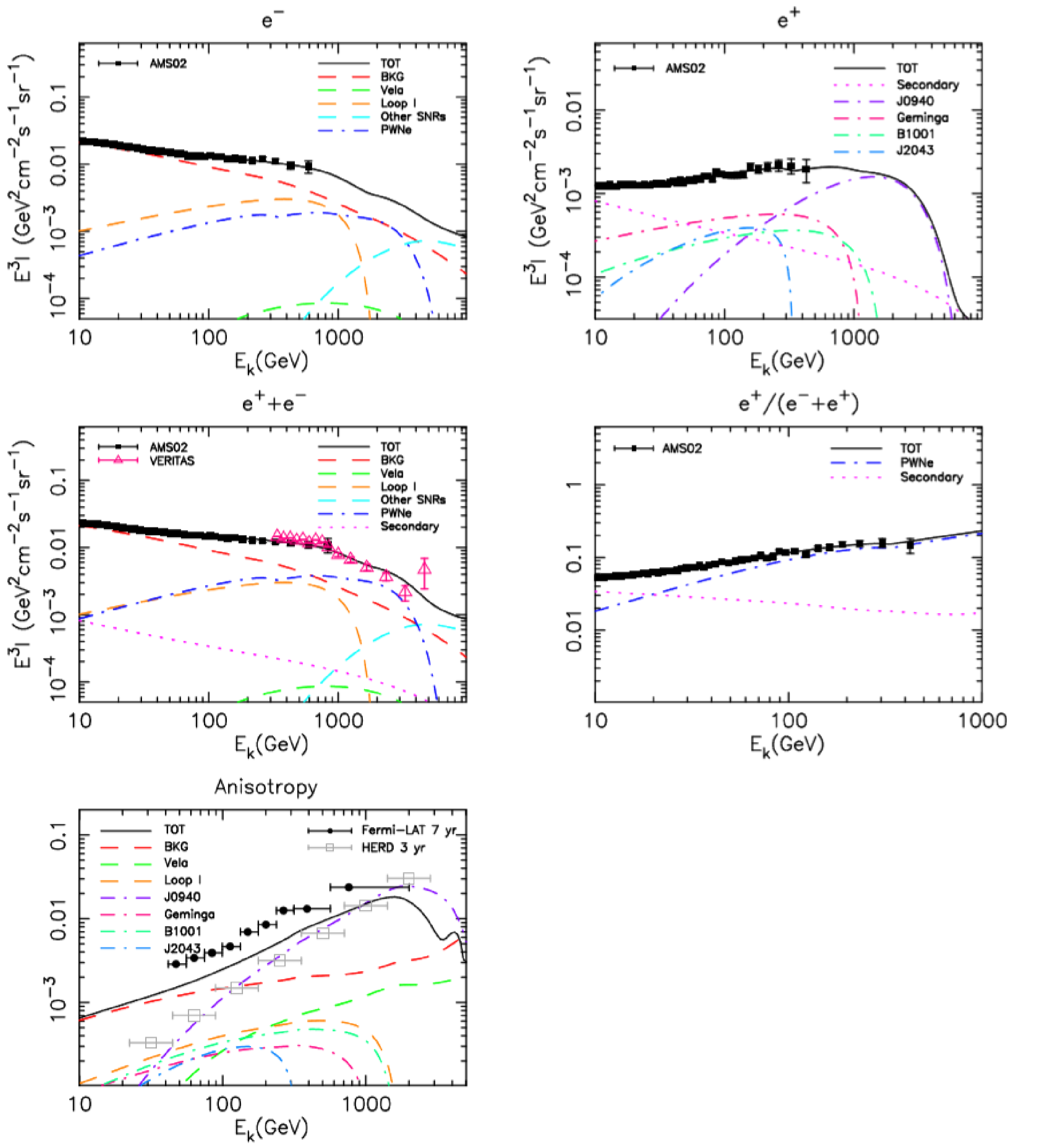
Fitting to AMS-02 lepton data by Vela XY and constraint by Fermi anisotropy limit and HERD sensitivity

Fang,k. et al. APJ 2017

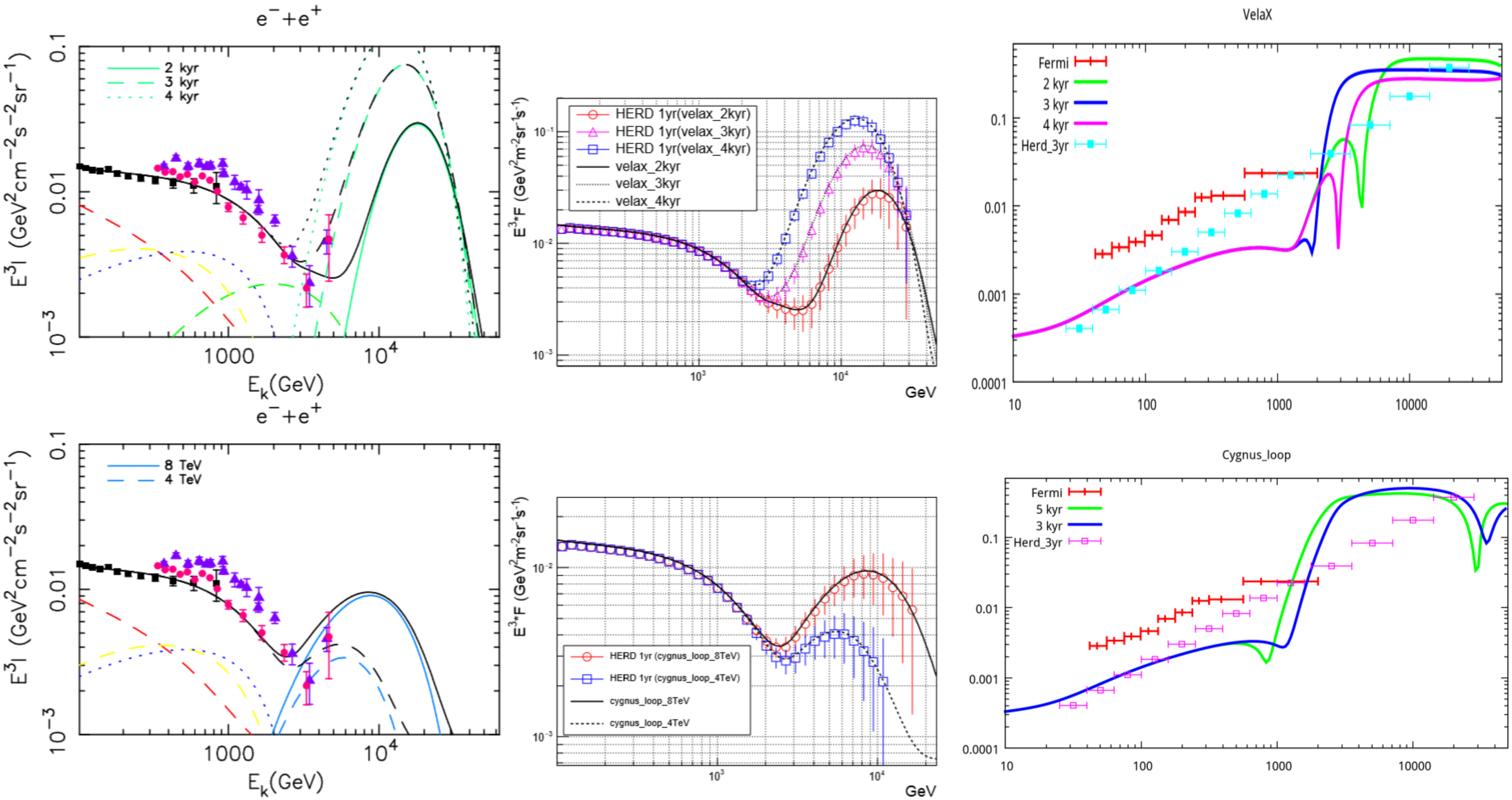


A large anisotropy induced by a nearby source

Fitting to present data by several nearby sources implies constraint from HERD



Spectra and anisotropy of nearby sources : Vela-X, Cygnus loop



HERD can probe the bump above 10s TeV from the local sources. If this bump is detected it favors a pulsar origin of positron excess

Summary of scientific objectives

- To give an independent measurement and test the sharp peak at DAMPE spectrum.
- To distinguish DM anni a[illegible] contribution from fine structures at th[illegible]m
- Possible features at high energies and anisotropy measurement can help to identify the local contribution.

Preliminary!