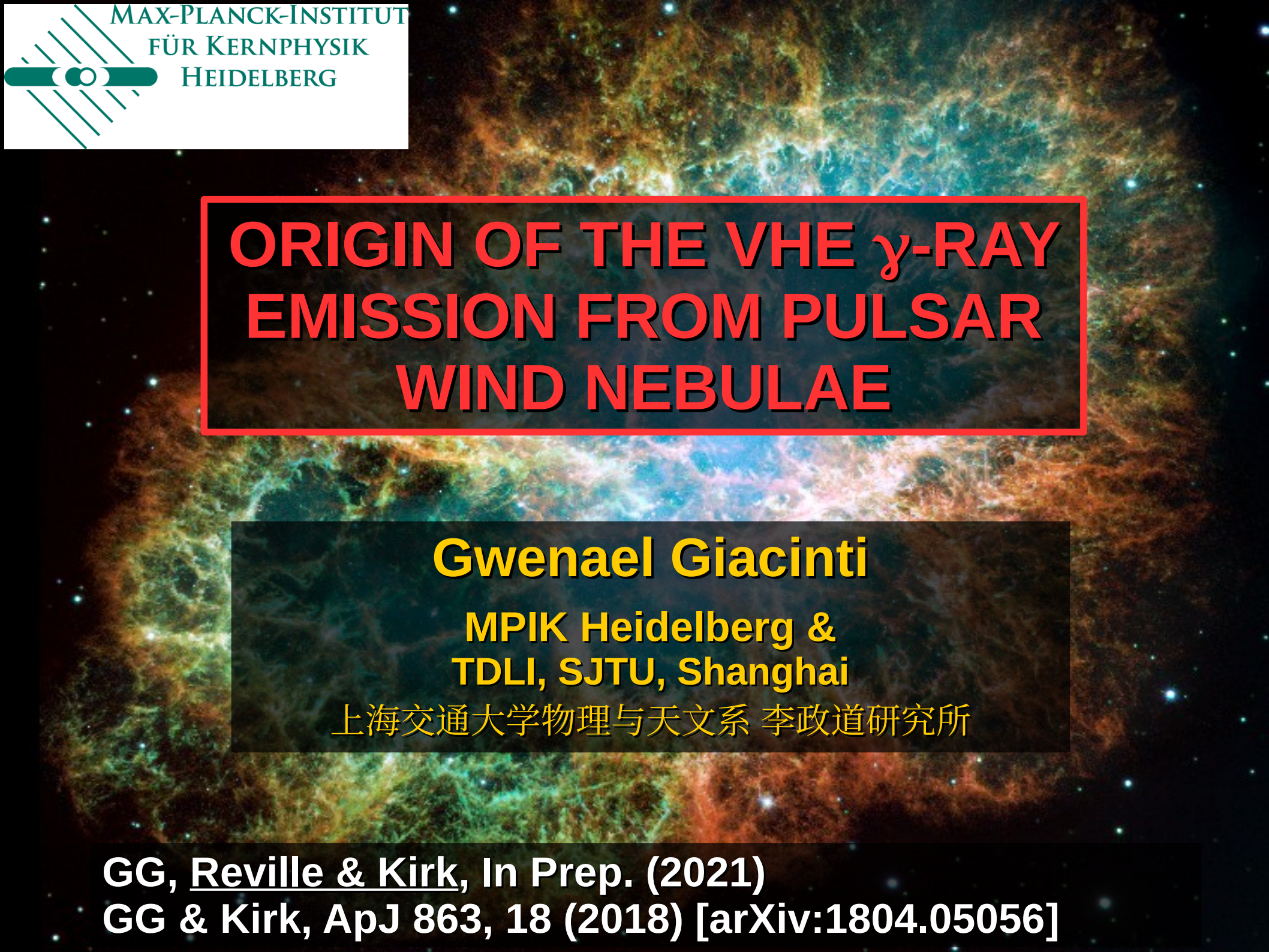

ORIGIN OF THE VHE γ-RAY EMISSION FROM PULSAR WIND NEBULAE

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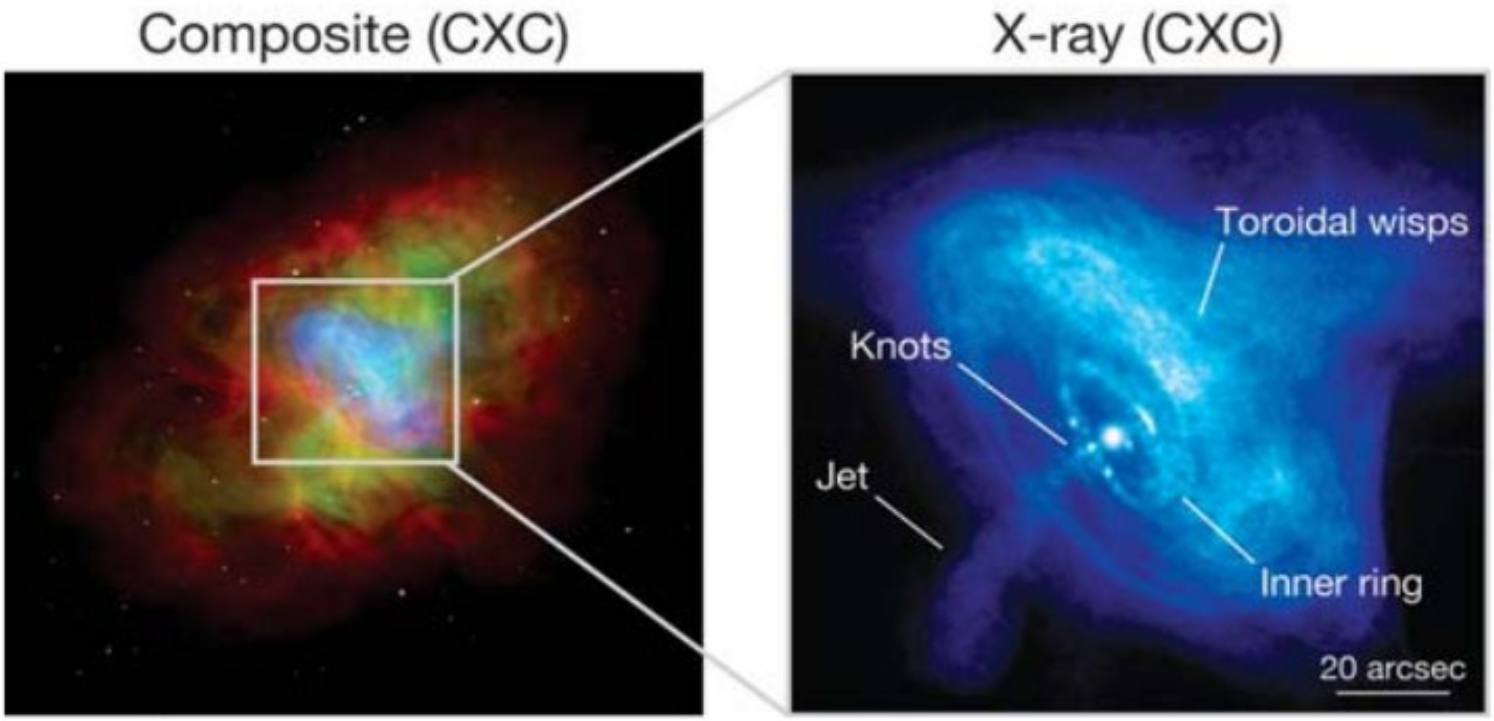
GG, Reville & Kirk, In Prep. (2021)
GG & Kirk, ApJ 863, 18 (2018) [arXiv:1804.05056]

Electron acceleration at the TS ?



→ **Electrons up to PeV.**

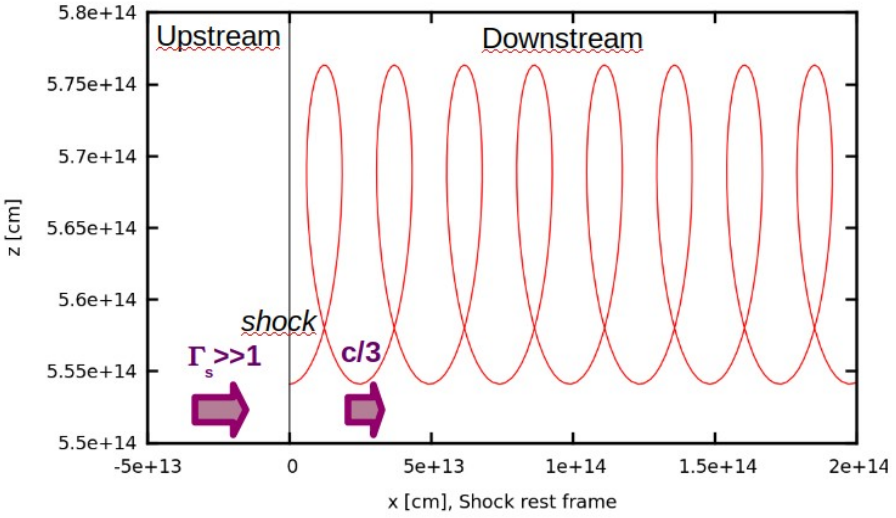
→ **Spectrum Nebula (X-rays):**

$\nu F_\nu \ \alpha \ \nu^{-0.1}$

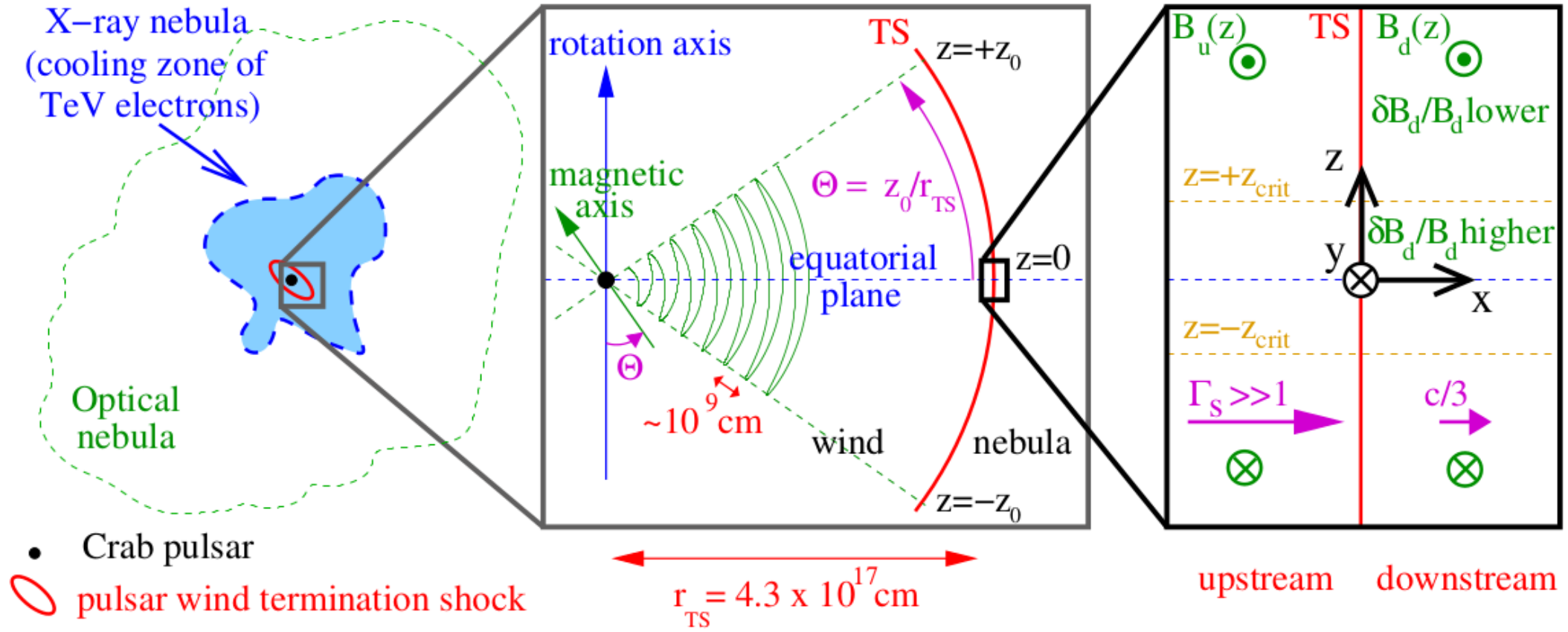
Part. spect.: ~ $E^{-2.2}$

BUT perpendicular shock

=> 1st order Fermi should NOT work !



Model

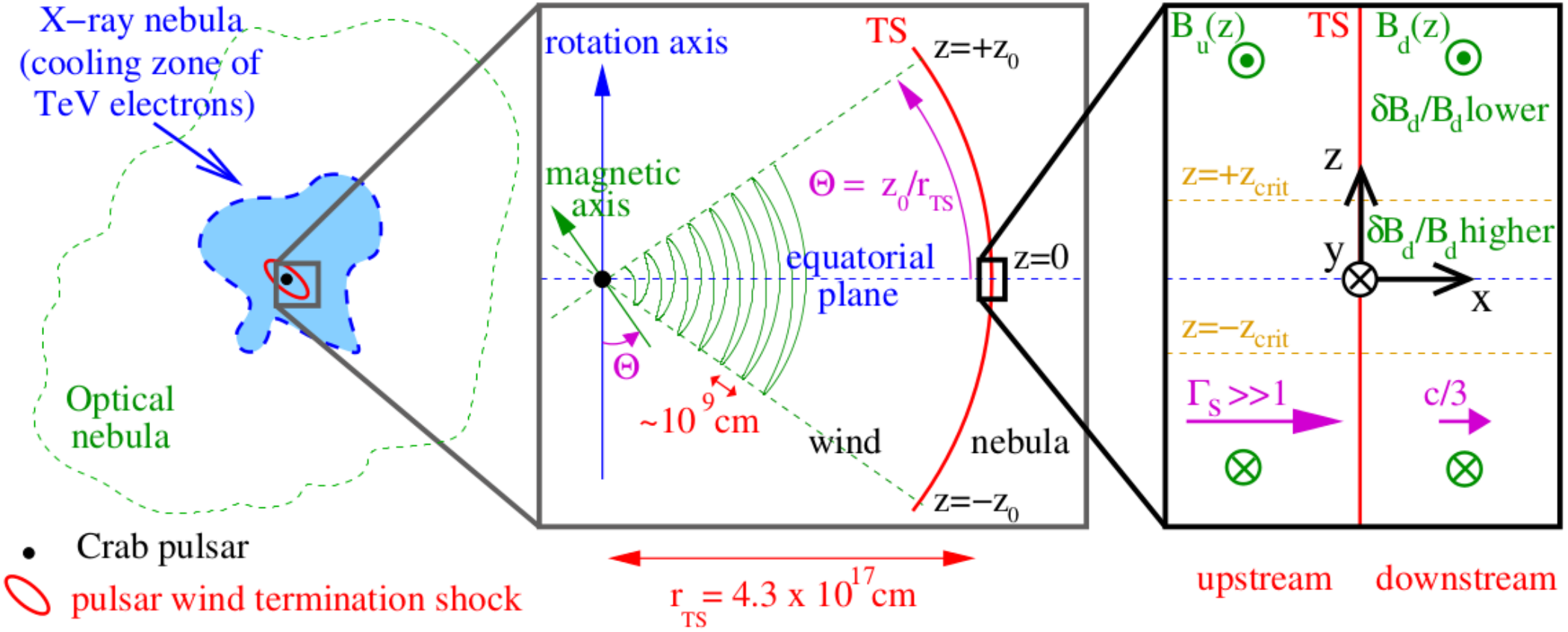


Fluid flow and B field model based on Crab MHD simulations from Porth *et al.* (2014, 2016)

$$\mathbf{B}_{\rm d}(z) = \quad -B_{\rm d,0}(z/z_0)\hat{\mathbf{y}} \quad \text{if } |z| \le z_0$$

$B_{\rm d,0}$ = +1mG

Model

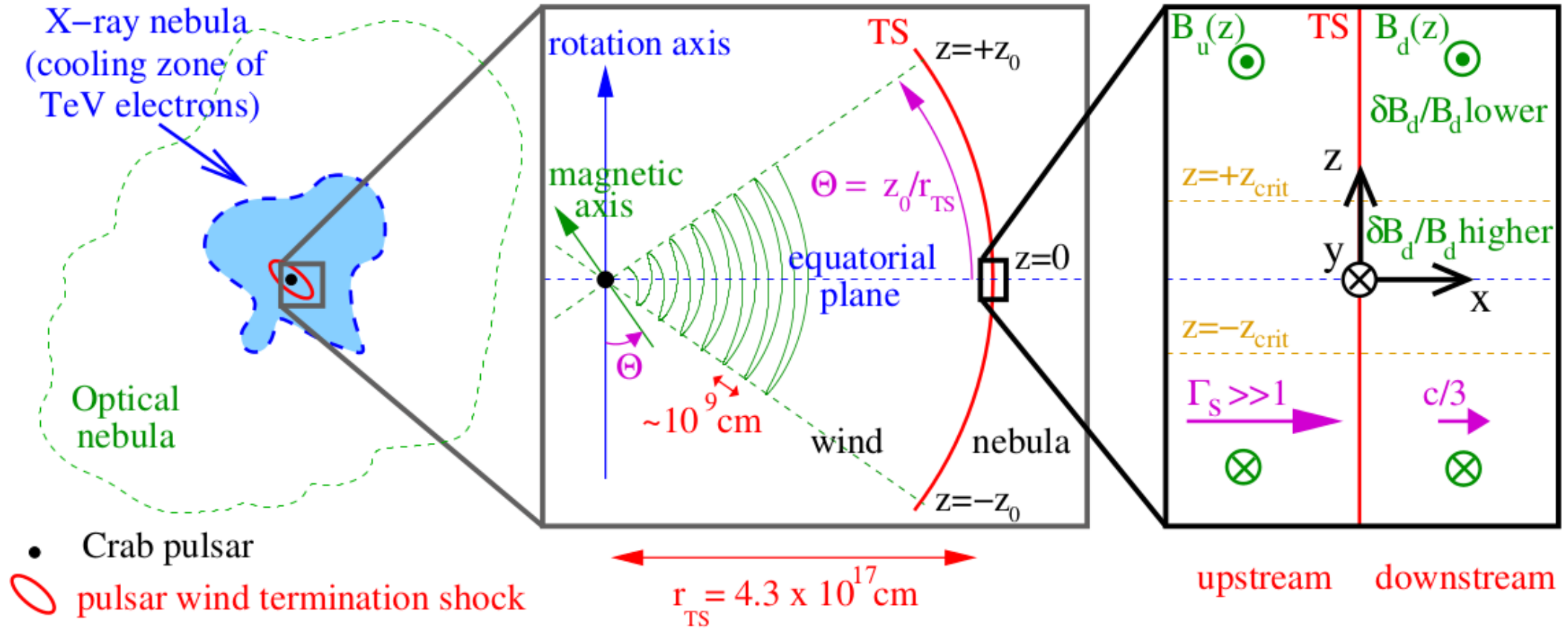


$$\mathbf{B}_{\mathrm{u}}(z) = \quad -B_{\mathrm{u},0}(z/z_0)\hat{\mathbf{y}} \quad \text{if } |z| \le z_0$$

Jump conditions: $B_{\mathrm{u,RF}} = (\Gamma_{\mathrm{d}}/3\Gamma_{\mathrm{u}})B_{\mathrm{d,RF}}$

+ 3D turbulent magnetic field on nested grids.

Model



→ **INJECTION :** e.g. Giacchè & Kirk (2017):

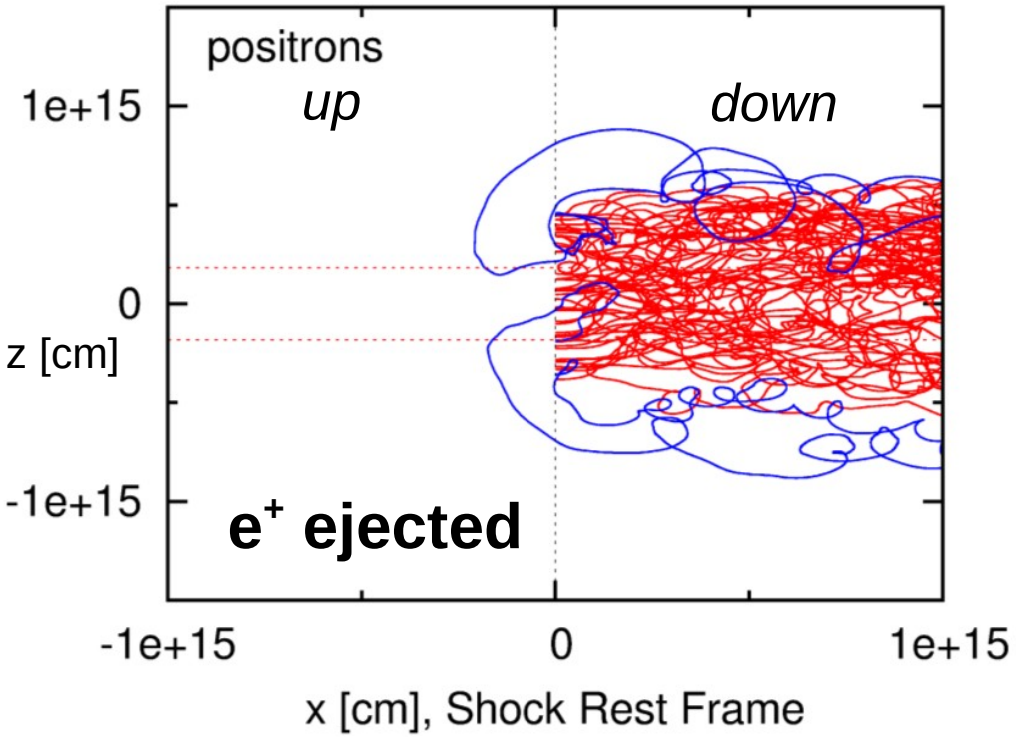
$$E_{\mathrm{inj,d}} = 1\,\mathrm{TeV}$$

→ Integrate the **trajectories** of **individual particules** in **3D** (**test particle limit**),

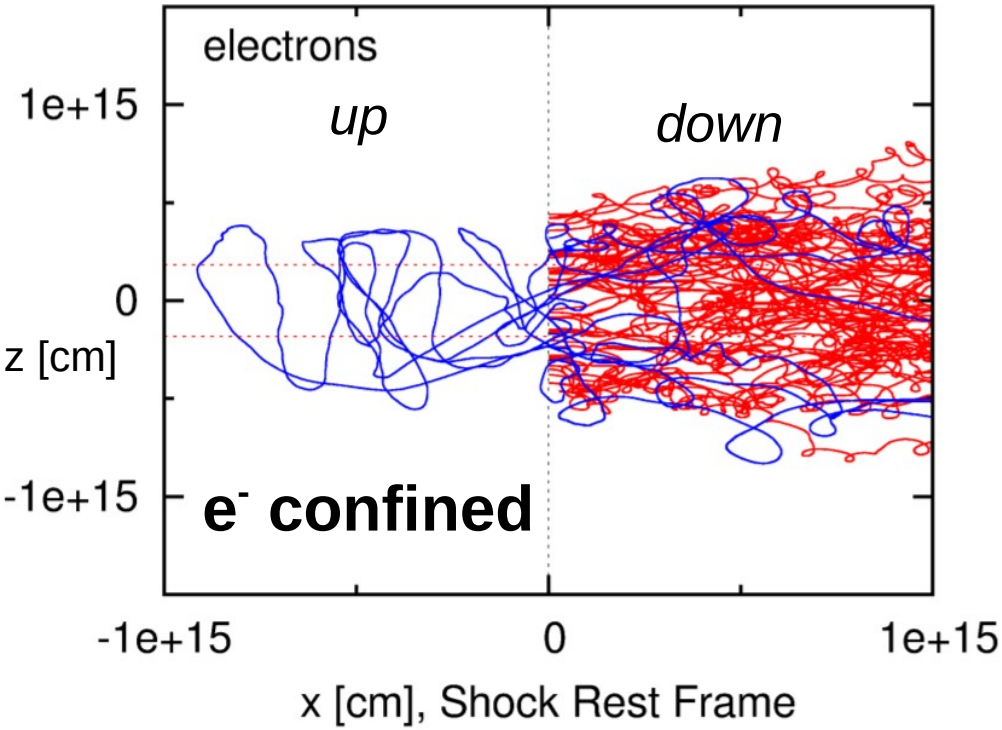
→ Integrate in the Upstream or Downstream RFs; Shock crossing: Do the Lorentz transfo.

Numerical simulations

Positrons :



Electrons :



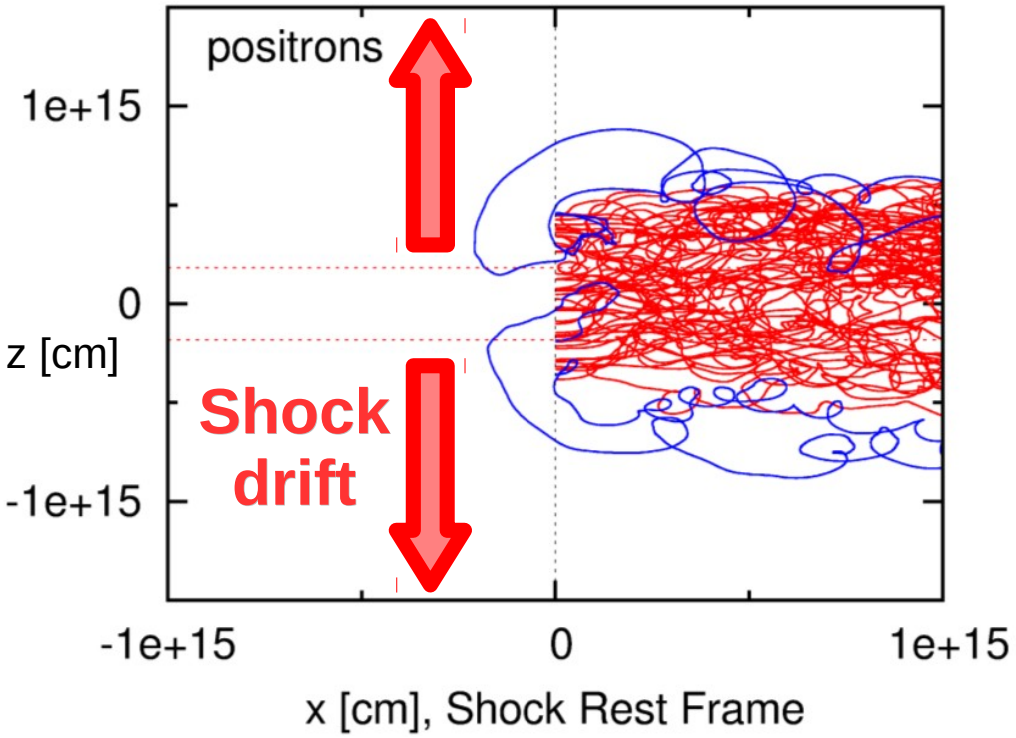
No/little acceleration

Acceleration

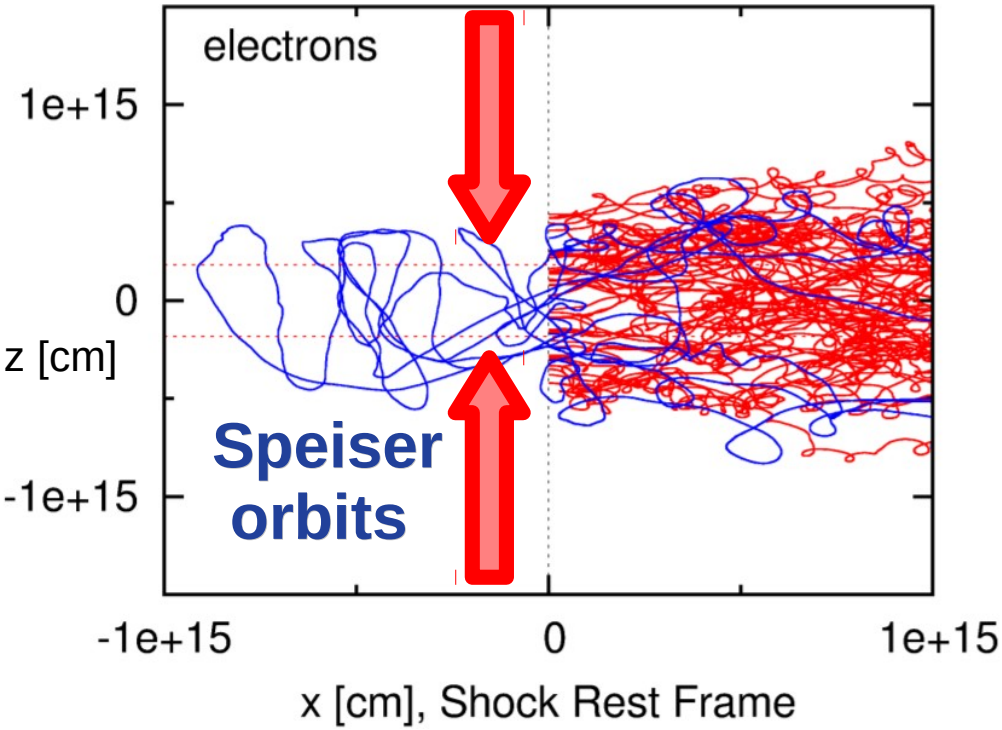
(… or vice versa, depending on the polarity)

Numerical simulations

Positrons :

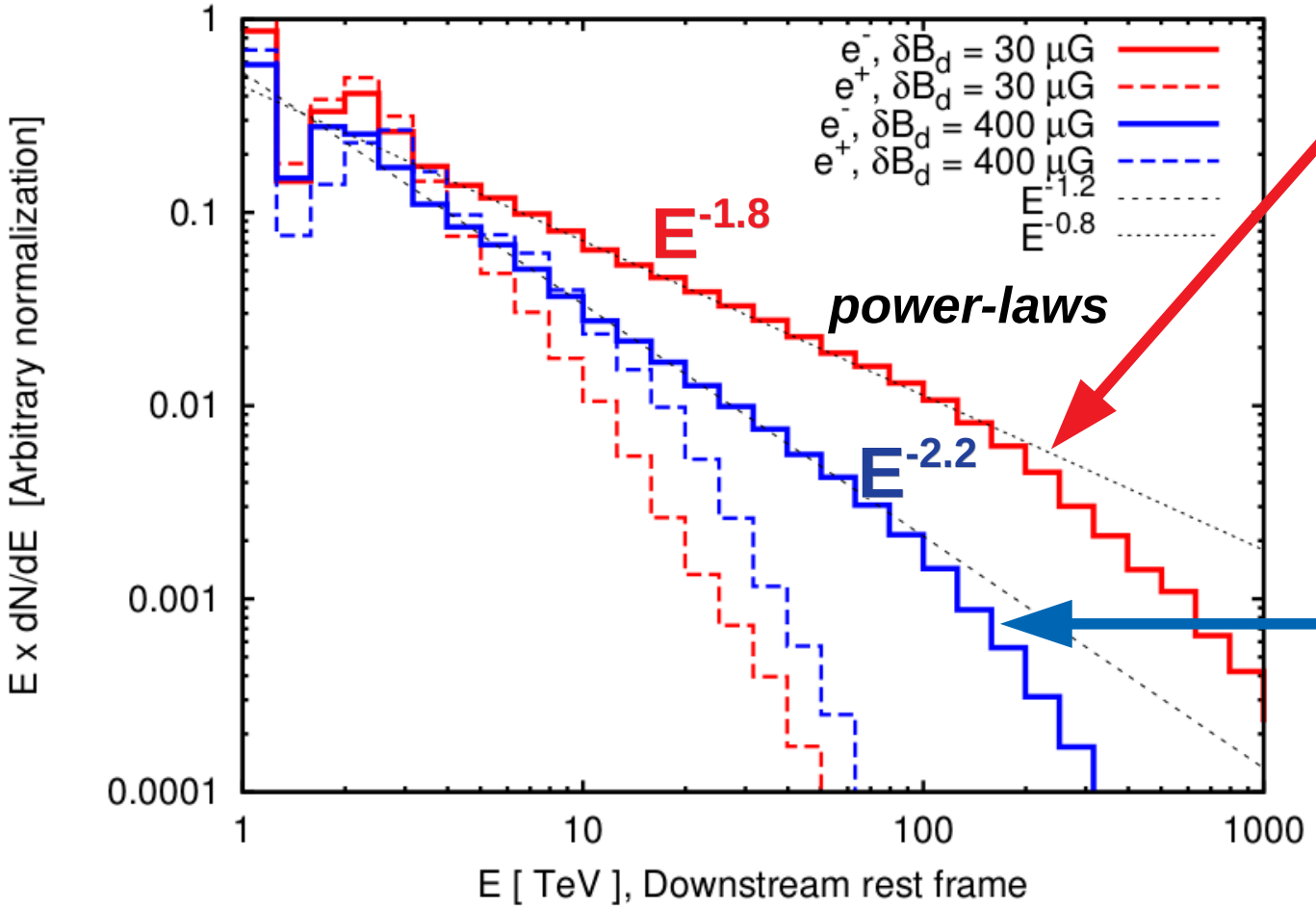


Electrons :



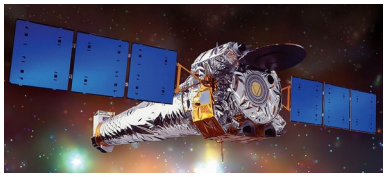
Effects of drift motions on the shock surface

e^+, e^- spectra vs Observations



CENTER

Chandra



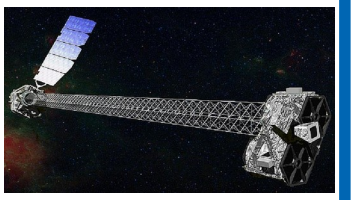
Photon index s ~ 1.9

Mori et al. (2004)

GOOD FIT

TOTAL NEBULA

NuSTAR

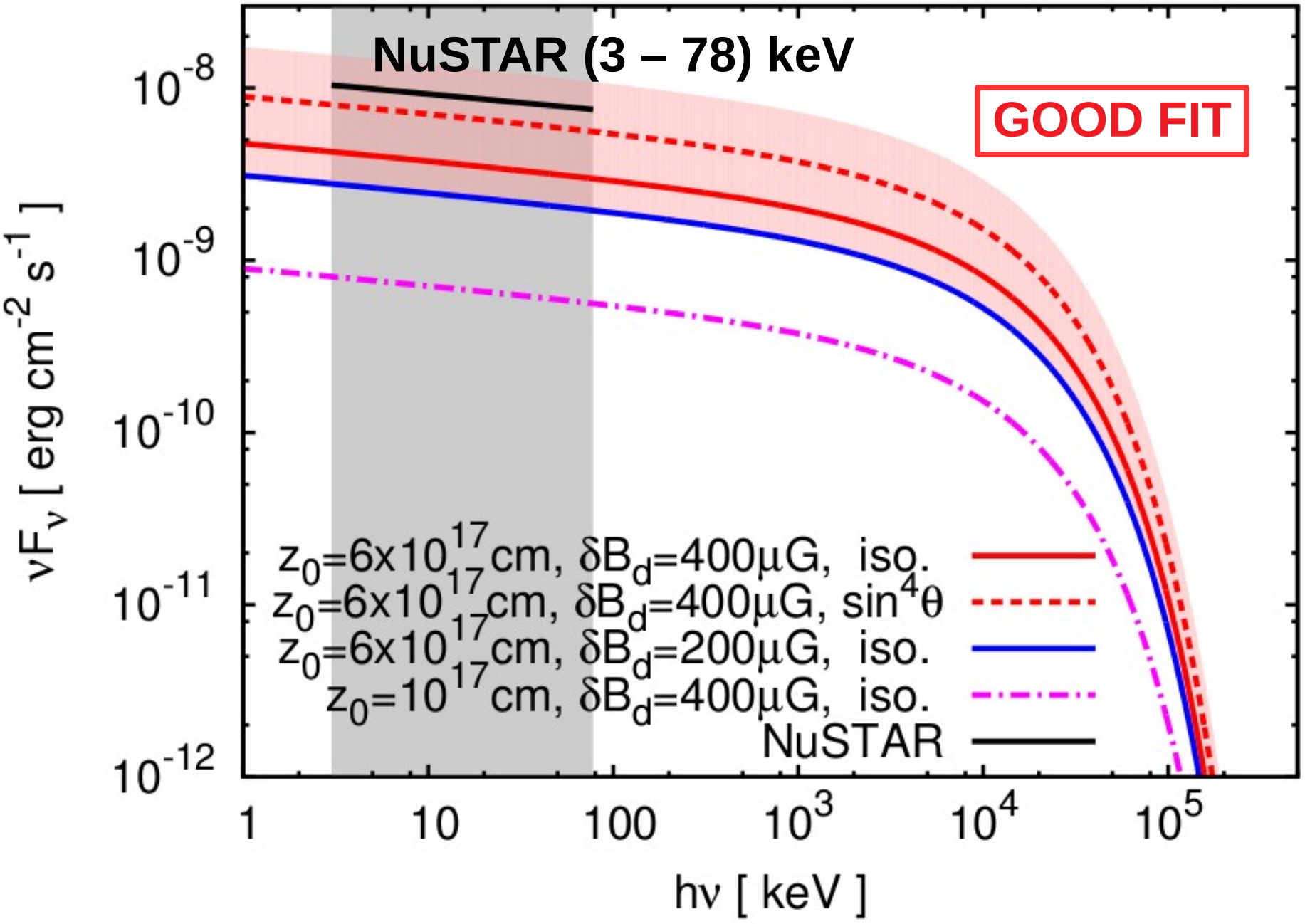


$\nu F_\nu \ \alpha \ \nu^{-0.1}$

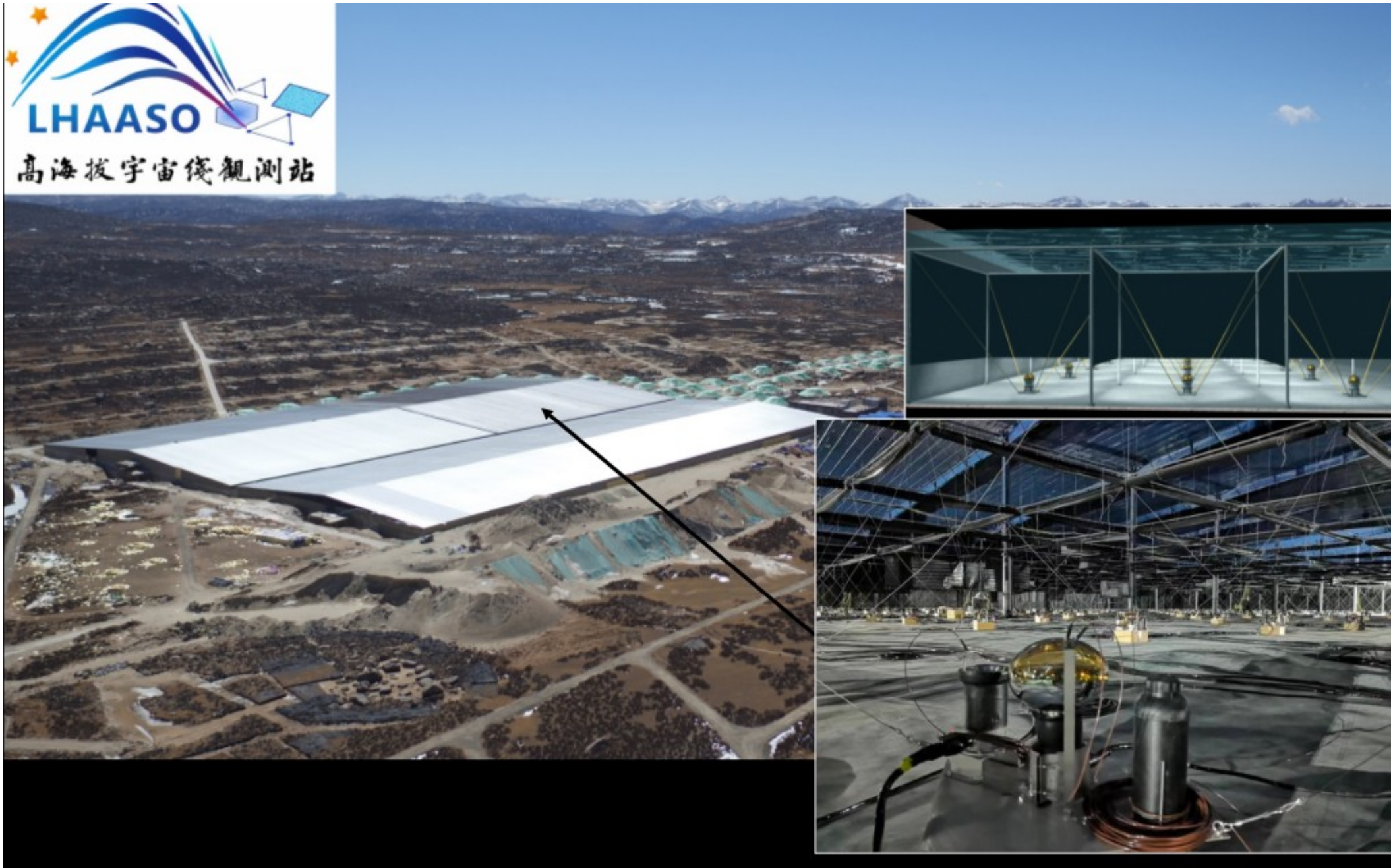
GOOD FIT

Spectral **index ~ -2.4 … -1.8**

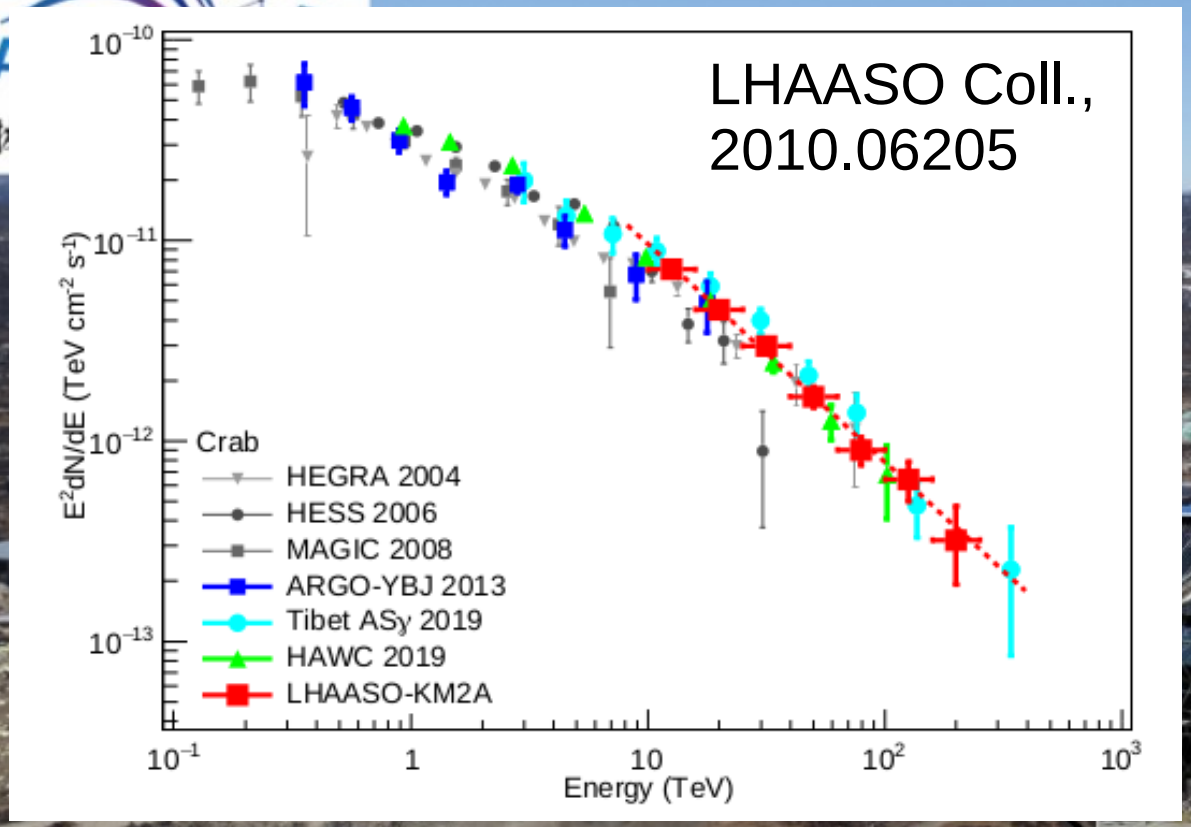
Synchrotron emission (X-rays)



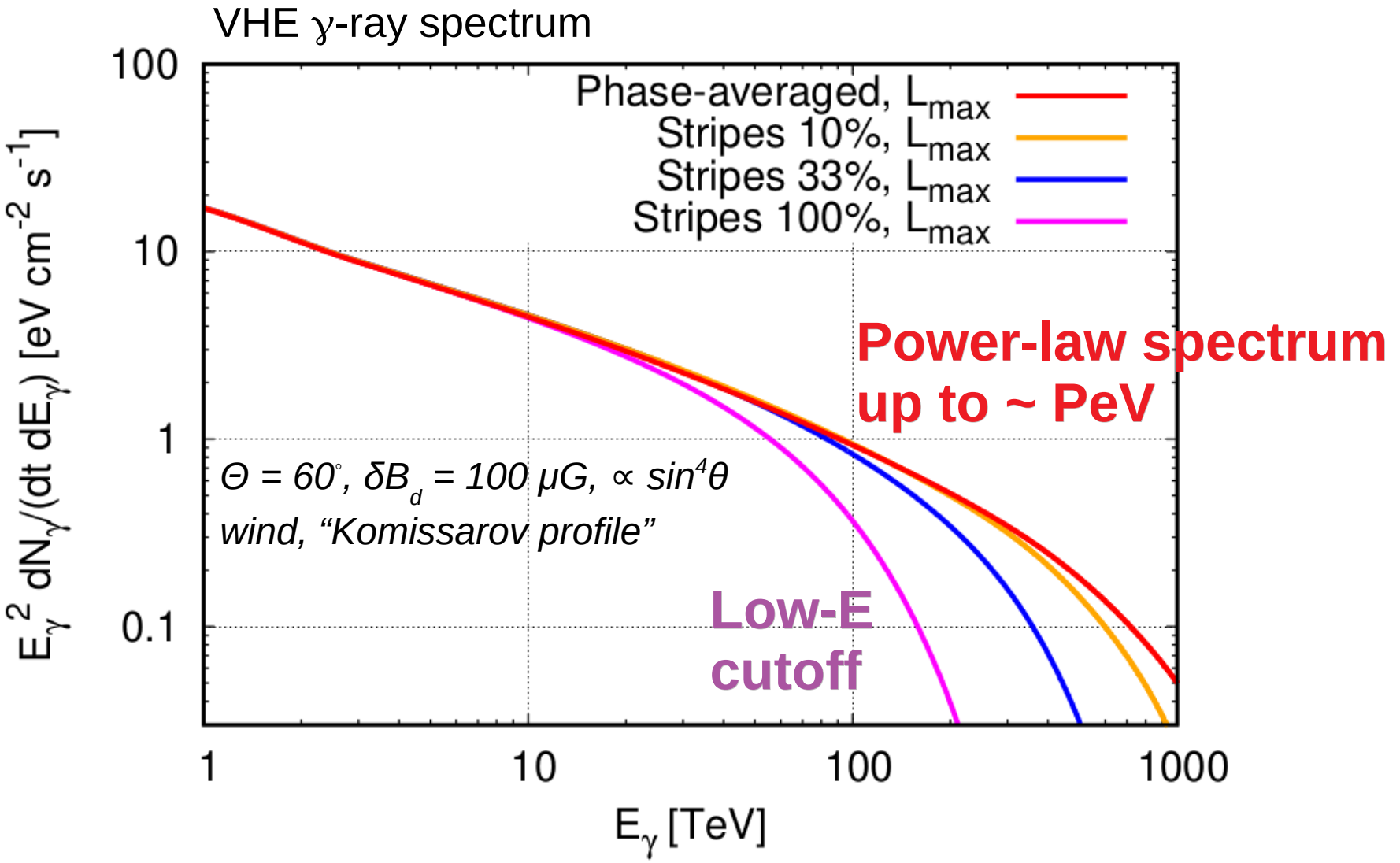
LHAASO（高海拔宇宙线观测站）



LHAASO（高海拔宇宙线观测站）



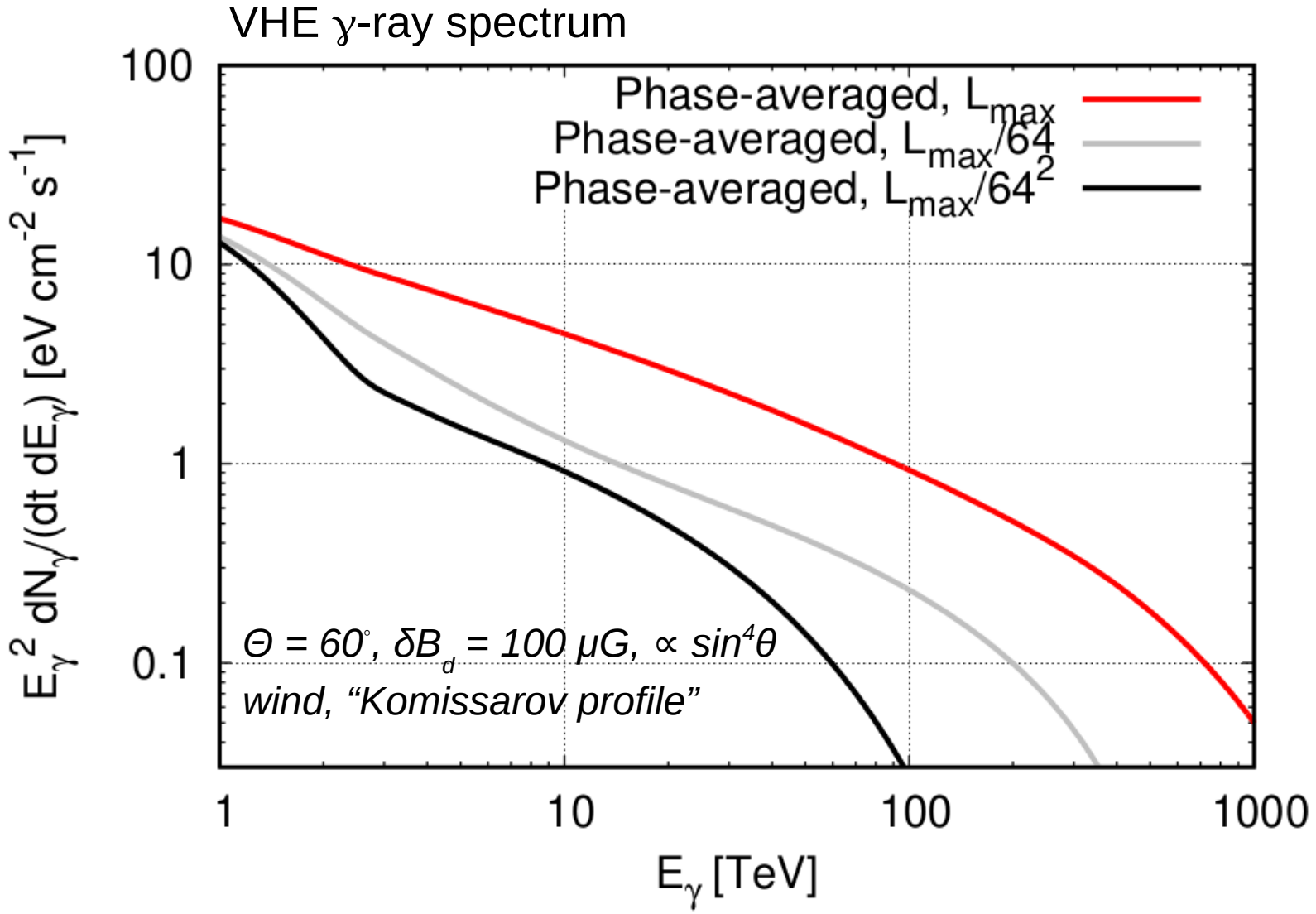
PeV γ-rays from the Crab Nebula ?



Our model will fit the data for some parameters, but not for others.

=> LHAASO will be able to constrain the Crab <u>WIND</u>'s parameters with future > 200TeV measurements.

PeV γ-rays from the Crab Nebula ?



Our model will fit the data for some parameters, but not for others.

=> LHAASO will be able to constrain the Crab NEBULA's parameters with future > 200TeV measurements.

Conclusions & Perspectives:

→ **1st numerical 'proof' of e^- acceleration to > PeV at pulsar wind termination shocks via 1st order Fermi**,

→ **Large-scale anisotropy of the transverse B-field profile** allows for efficient particle acceleration close to the eq. plane,

→ **Speiser orbits around the eq. Plane**; **Shock-drift**,

→ Fits the X-rays and γ-rays from the Crab Nebula,

→ Soon: New constraints on pulsar winds from PeV data !
=> LHAASO will constrain striped pulsar wind parameters,

→ **Either e^- or e^+** acc. to HE (depending on the pulsar **polarity**)
=> Crucial implications for the **positron excess.**