Fermi Gamma-ray Space Telescope

Towards Strong Evidences of CR Acceleration in SNRs

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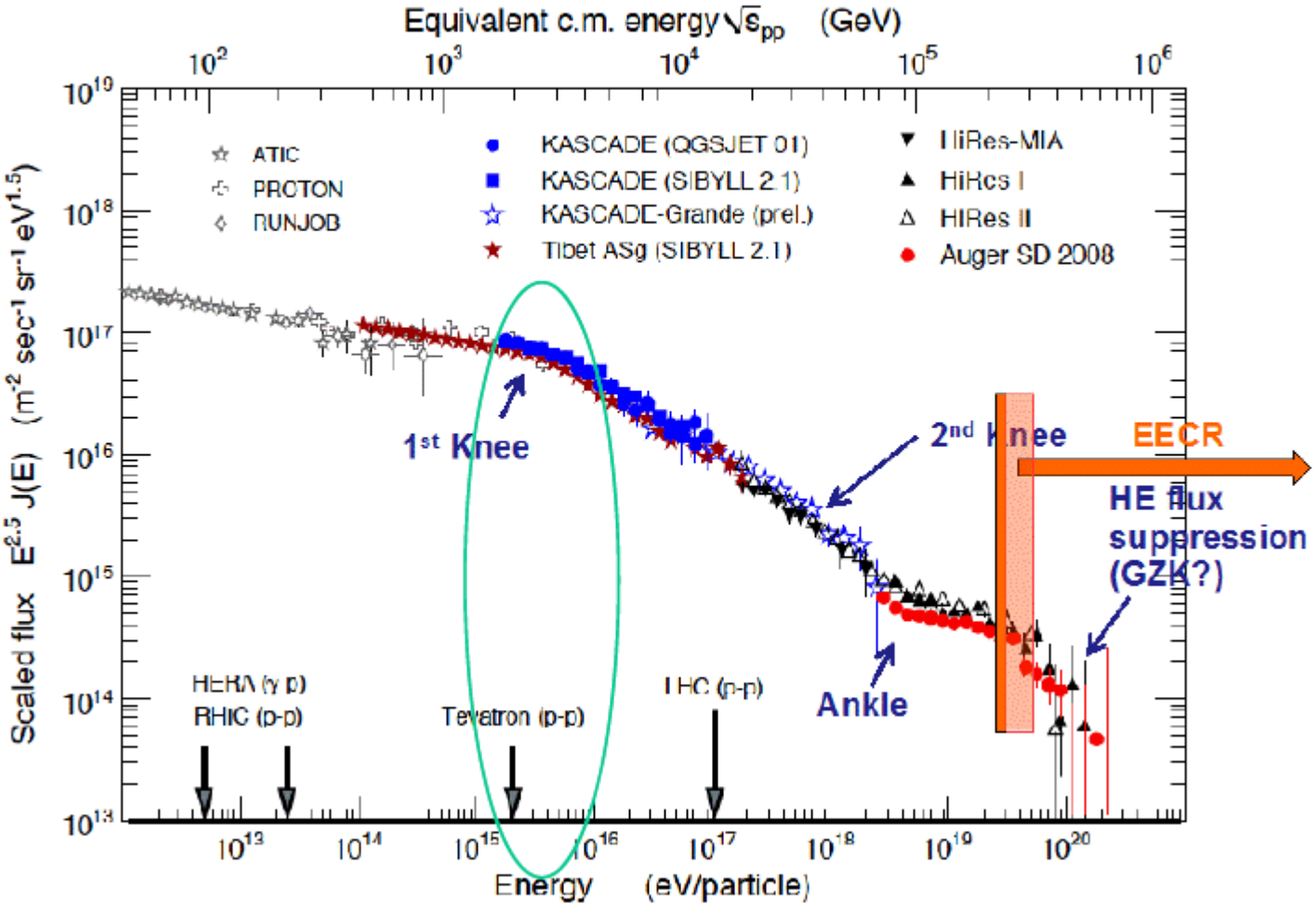
for the Fermi-LAT Collaboration

OutLook

- ✓ CRs @ earth
- ✓ Galactic SNRs
- ✓ Young SNRs & Modeling
- ✓ Conclusions

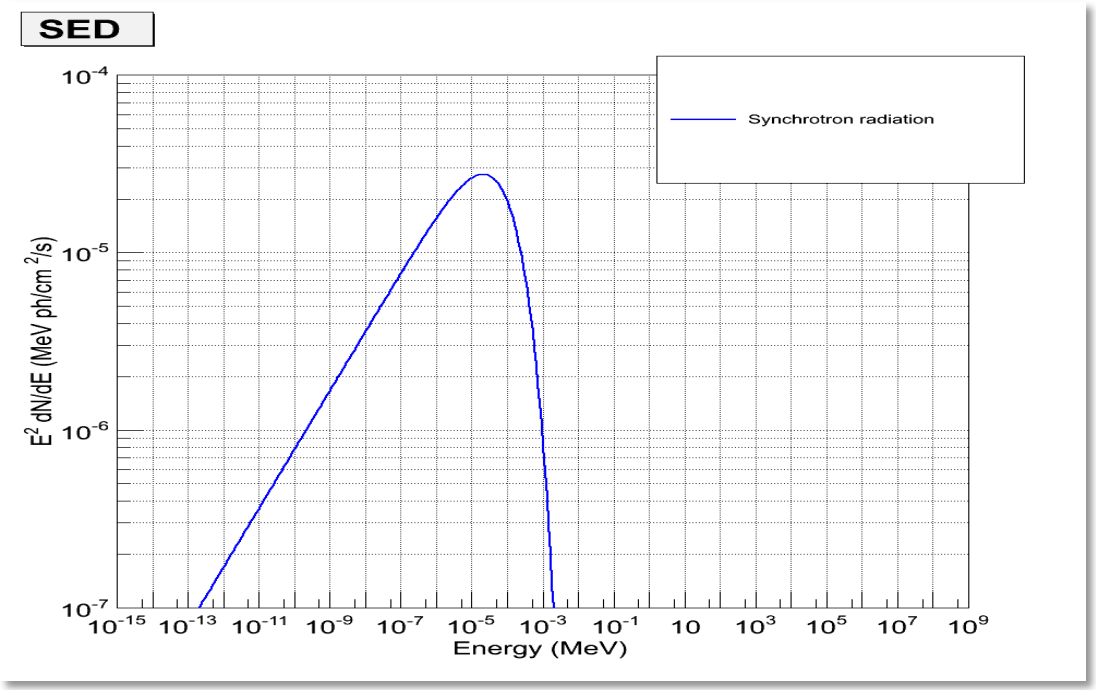
CRs @ earth

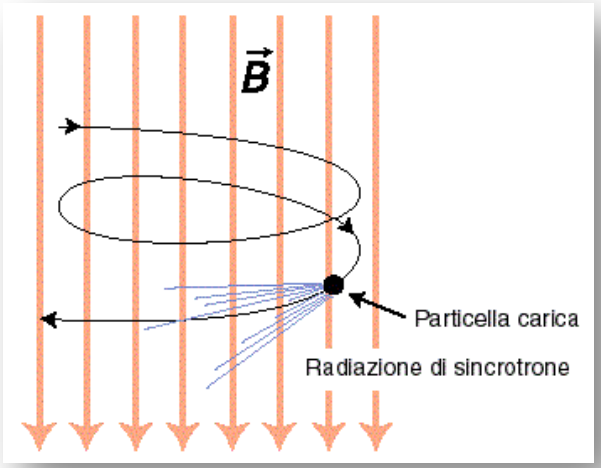

Equivalent c.m. energy $\sqrt{s_{pp}}$ (GeV)
10^2
10^3
10^4
10^5
10^6
Scaled flux $E^{2.5}$ J(E) (m^{-2} sec^{-1} sr^{-1} $eV^{1.5}$)
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande (prel.)
Tibet ASg (SIBYLL 2.1)
HiRes-MIA
HiRes I
HiRes II
Auger SD 2008
1st Knee
2nd Knee
EECR
HE flux suppression (GZK?)
Ankle
HERA (γ p)
RHIC (p-p)
Tevatron (p-p)
LHC (p-p)
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
Energy (eV/particle)

What do we mean as strong evidence of CR acceleration???

Non thermal emission processes

Synchrotron radiation



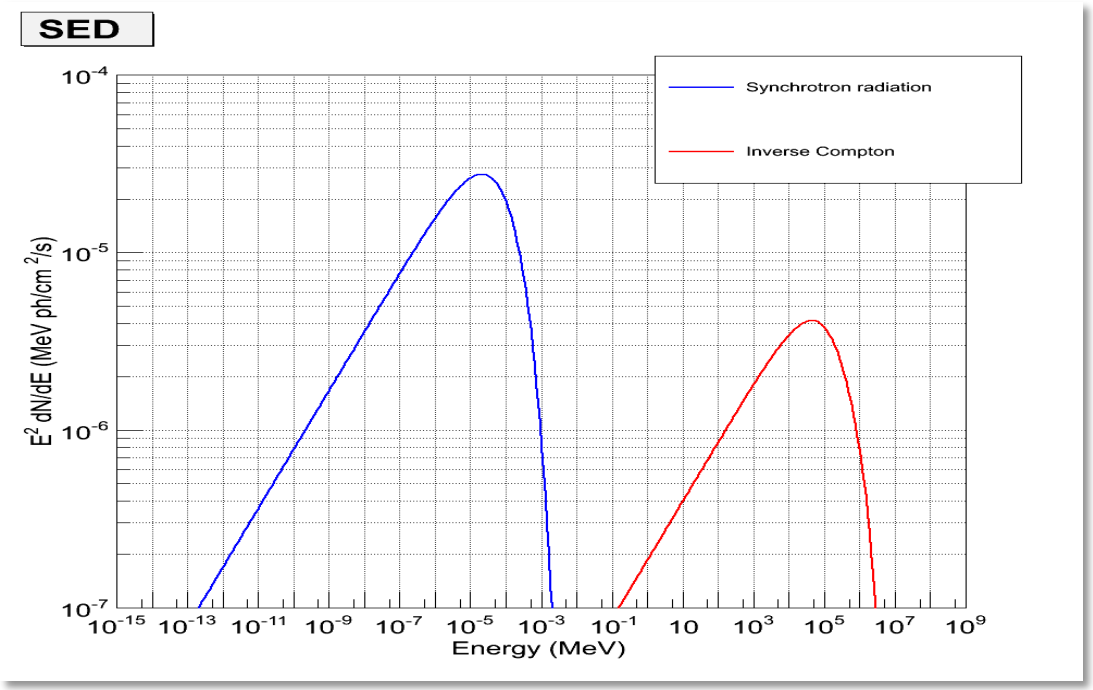


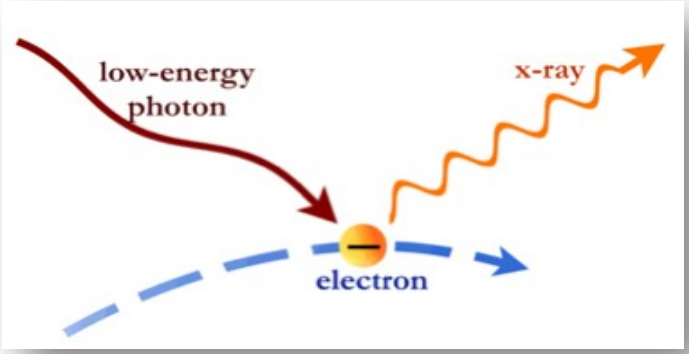
$$Q_\gamma(\omega) = \frac{\sqrt{3}\, B\, e^3}{2\pi\, m_e c^2} \int \frac{4\pi}{\beta c} \frac{dN_e}{dE_e} R\left(\frac{\omega}{\omega_c}\right) dE_e \qquad \omega_c = 1.5\, B\, p^2/(mc)^3$$

R. Blumenthal and R. J. Gould. In: Rev. Mod. Phys. 42 (1970).

Non thermal emission processes

Inverse Compton





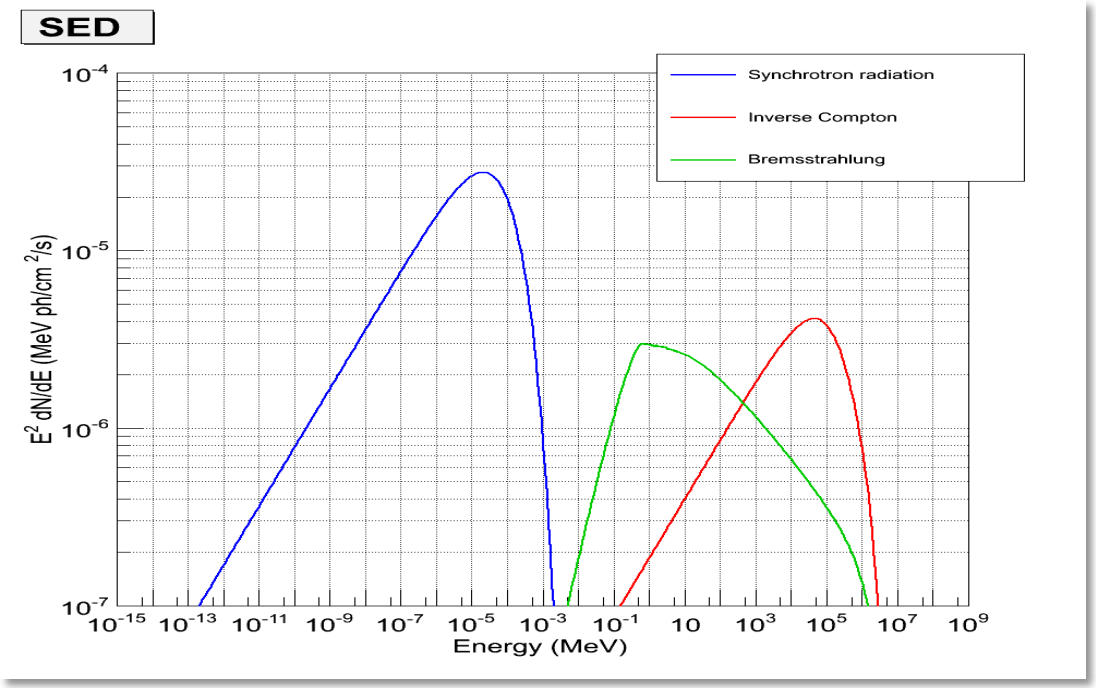
$$Q_\gamma(E_\gamma) = \int \frac{dN_e}{dE_e} dE_e \int n(E_s)\sigma_{K-N}(E_s, E_e, E_\gamma) dE_s$$

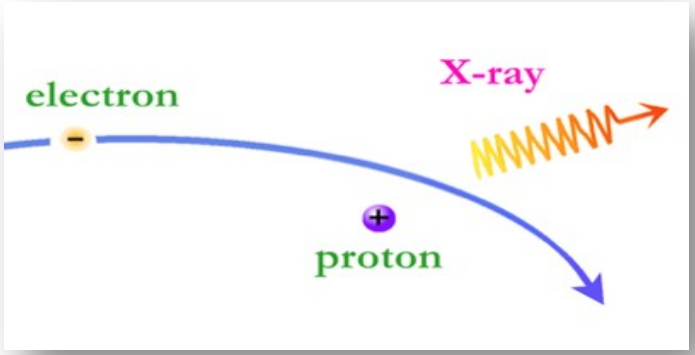
Klein-Nishina cross section

CMB spectrum (T=2.73 K) +
IR from dust emission (T=100 K)

Non thermal emission processes

Bremsstrahlung

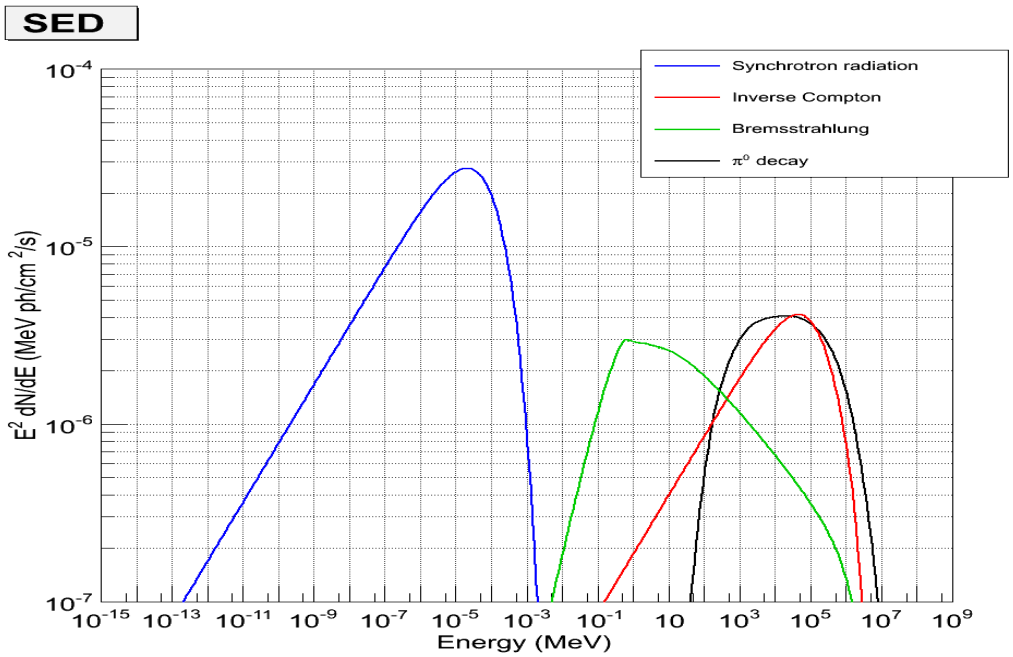




$$Q_\gamma(\epsilon) = 4\pi\, n_H \int \frac{dN_e}{dE_e}\frac{d\sigma_{B-H}}{d\epsilon} dE_e$$

← Bethe-Heitler cross section

M. G. Baring et al, Astrop. Jour. 513 (1999),

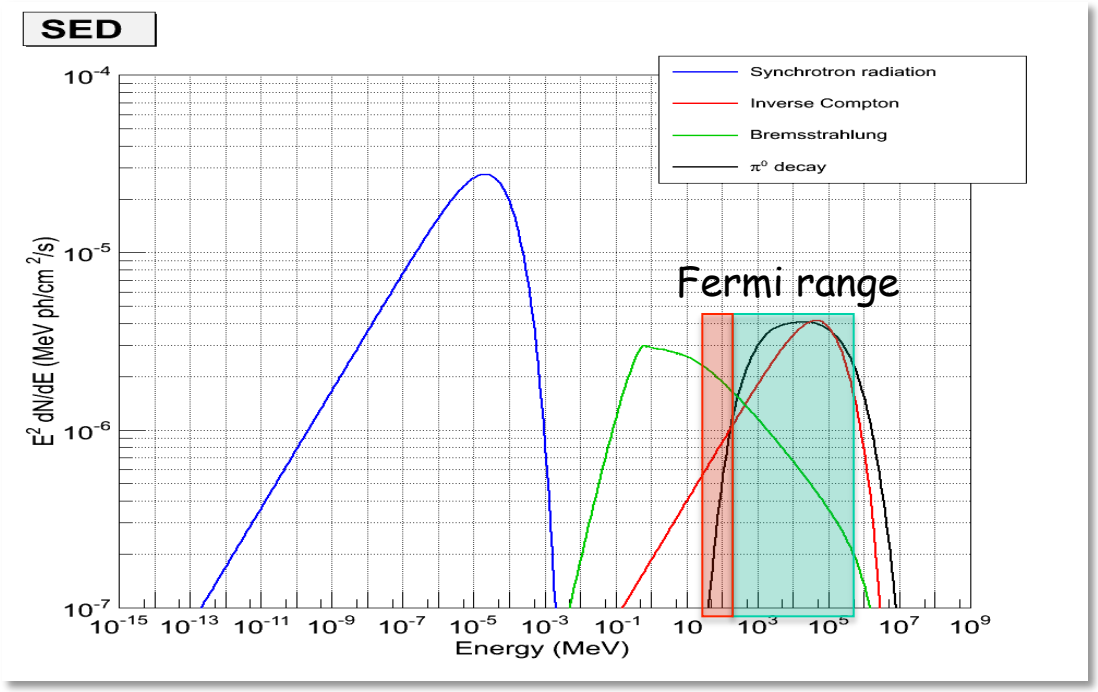


$$p + p \rightarrow \pi^0 + X$$
$$\hookrightarrow \gamma + \gamma$$

Photon emissivity

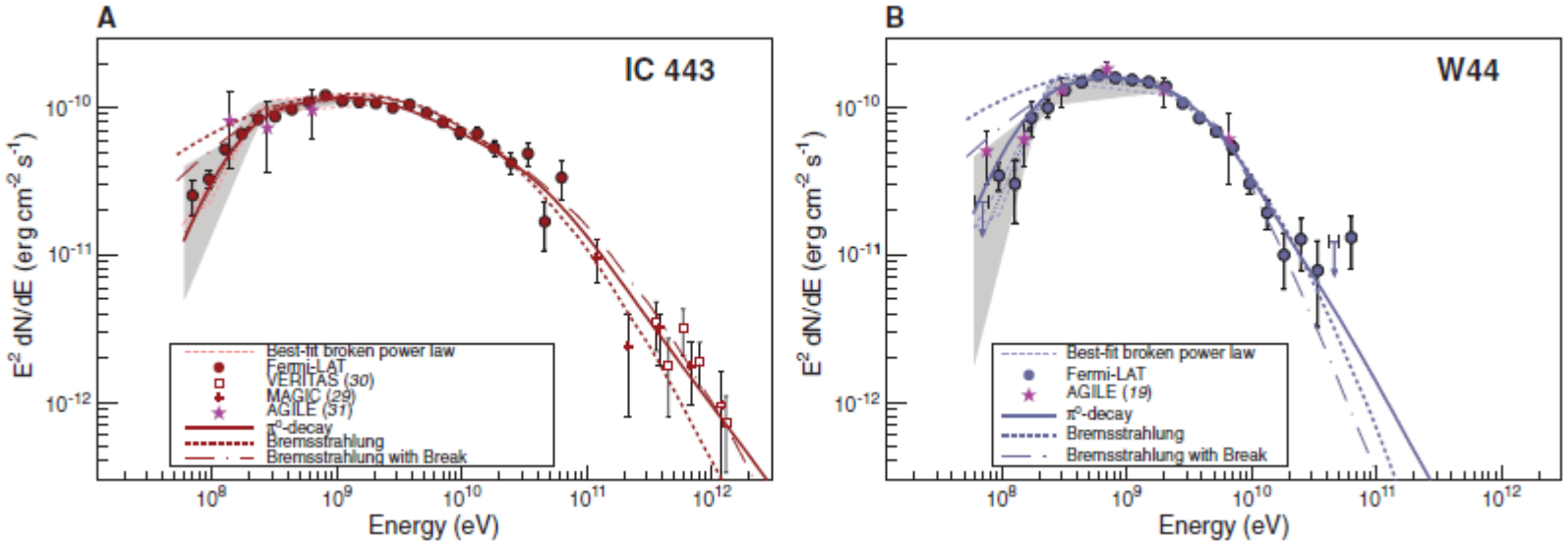
$$Q_\gamma(E_\gamma) = \int \frac{4\pi}{\beta c} n_H \frac{dN_p}{dE_p} \frac{1}{E_\gamma} \frac{d\sigma(E_p/E_\gamma)}{d\log(E_\gamma)} dE_p$$

Parametrization from Kamae et al. (2006)



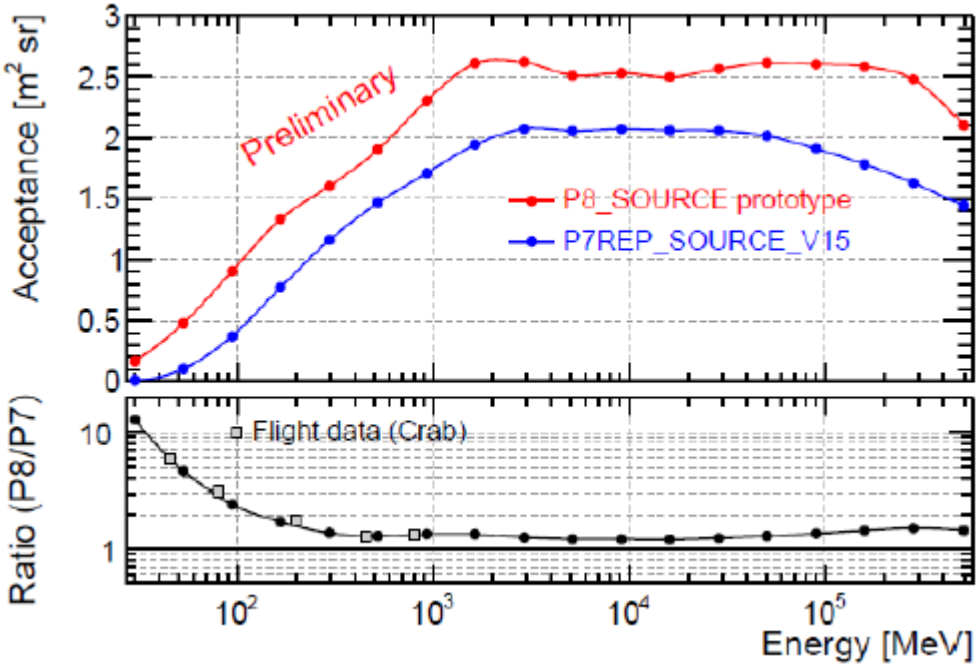
B=10μG
n_H=1 cm^{-3}
γ_e=2.3
$E_{b,e}$=5 TeV
$\gamma_{1,p}$=2.
$\gamma_{2,p}$=4.5
$E_{b,p}$=10 TeV

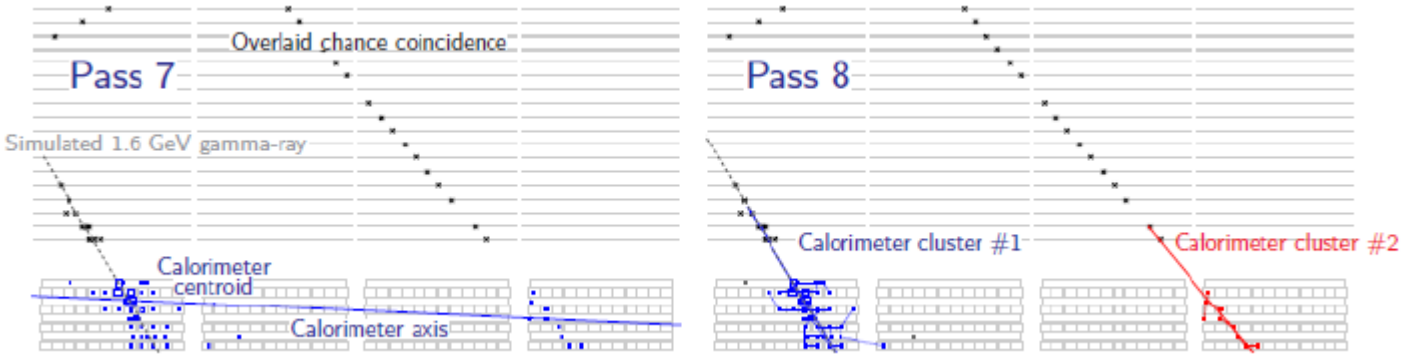
2013Sci...339..807A Results



Pass 7 reprocessed data already allowed us to go at low energy for "easy" guys

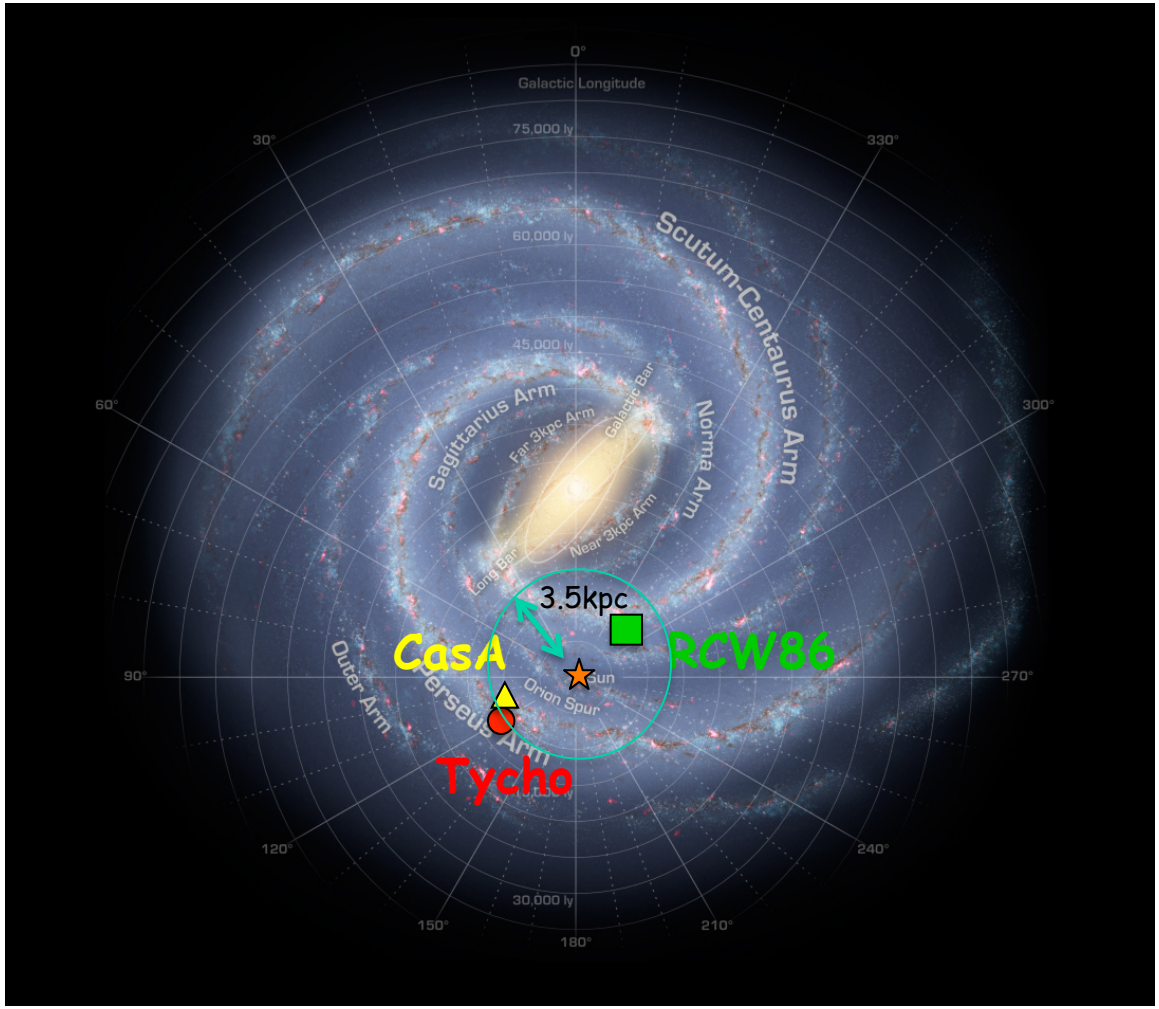
Pass 8 data





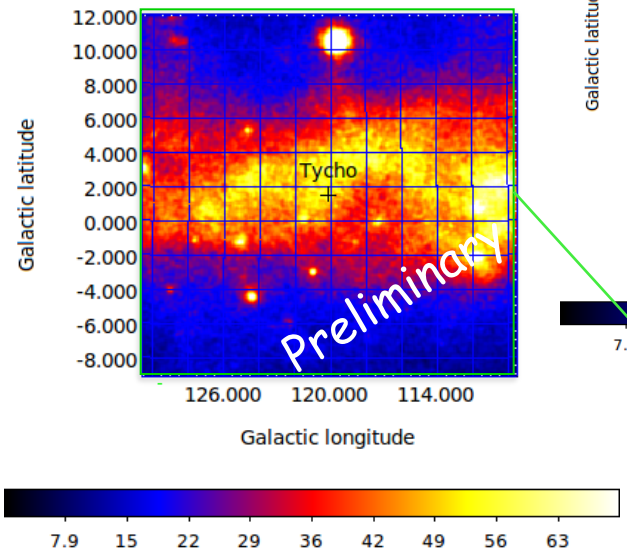
Bruel talk wed.

Young SNRs with P8

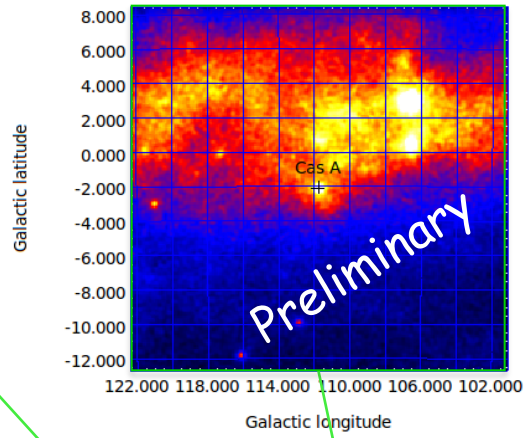


Count Maps

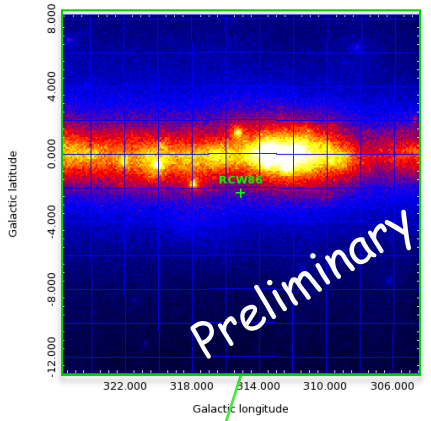
Tycho

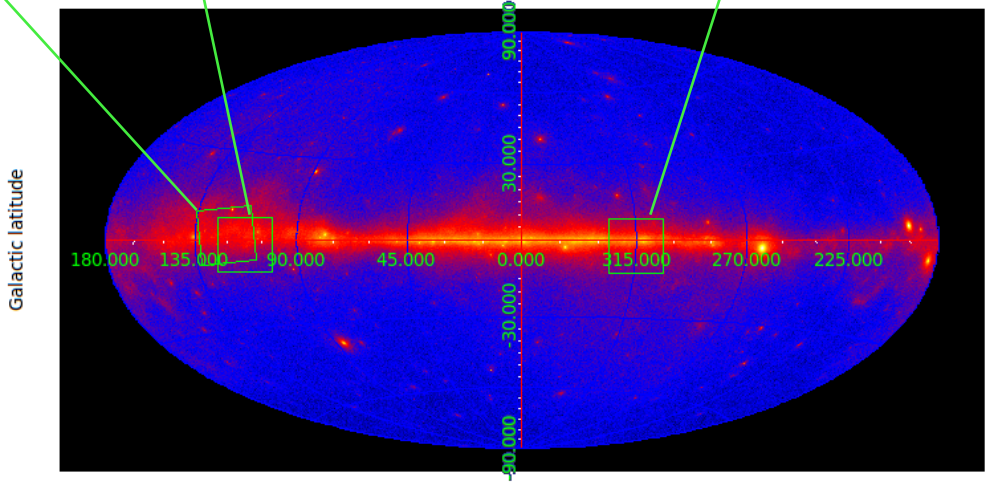


Cas A



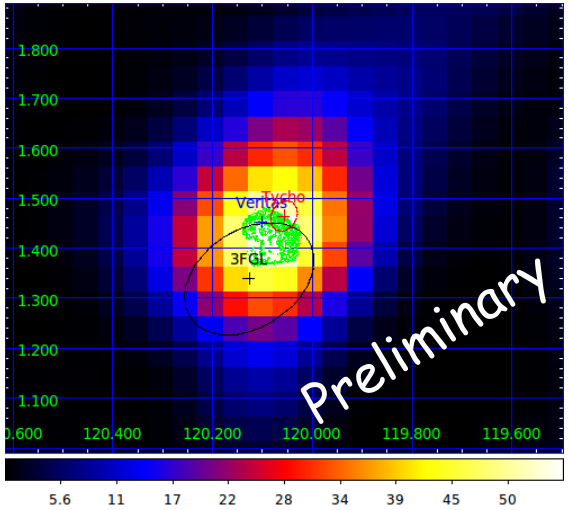
RCW86





Tycho SED & Modeling

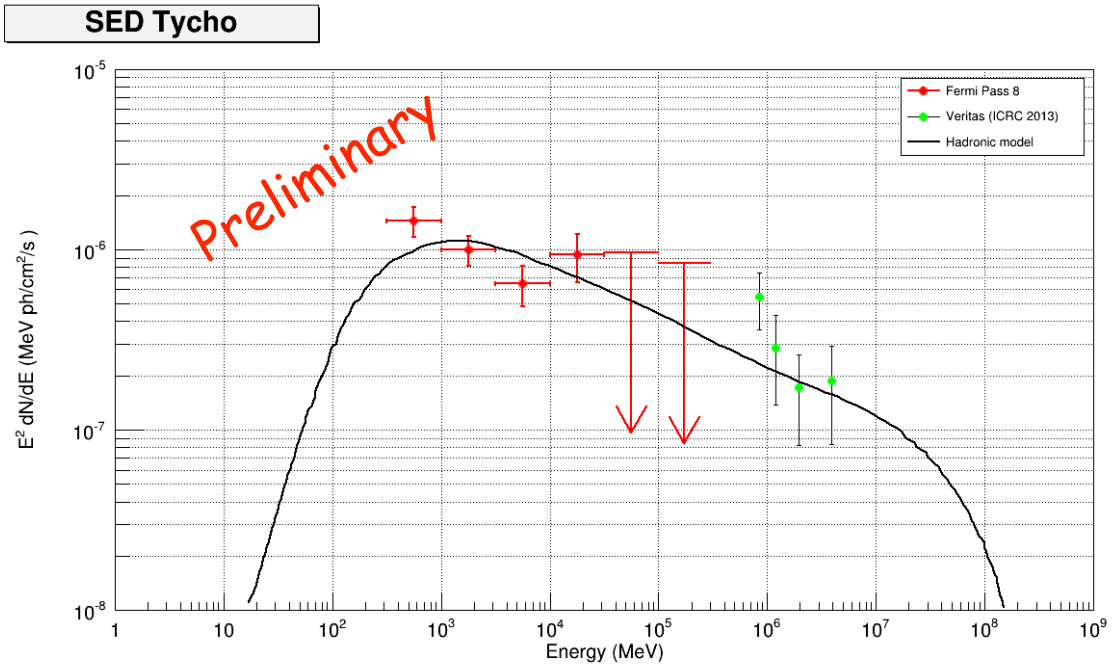
Pass8 data
69 months
Energy 300MeV-300GeV
ROI 15 deg



TS map for E>1 GeV

$n_H = 0.2\ cm^{-3}$
d = 3.5kpc

$s_e = 2.34 \pm 0.04$
$p_{cut,e} = (5.1 \pm 0.3)$ TeV
$s_p = 2.31 \pm 0.03$
$p_{cut,p} > 100$ TeV
$W_p = 5\%$
$K_{ep}=8\cdot10^{-3}$

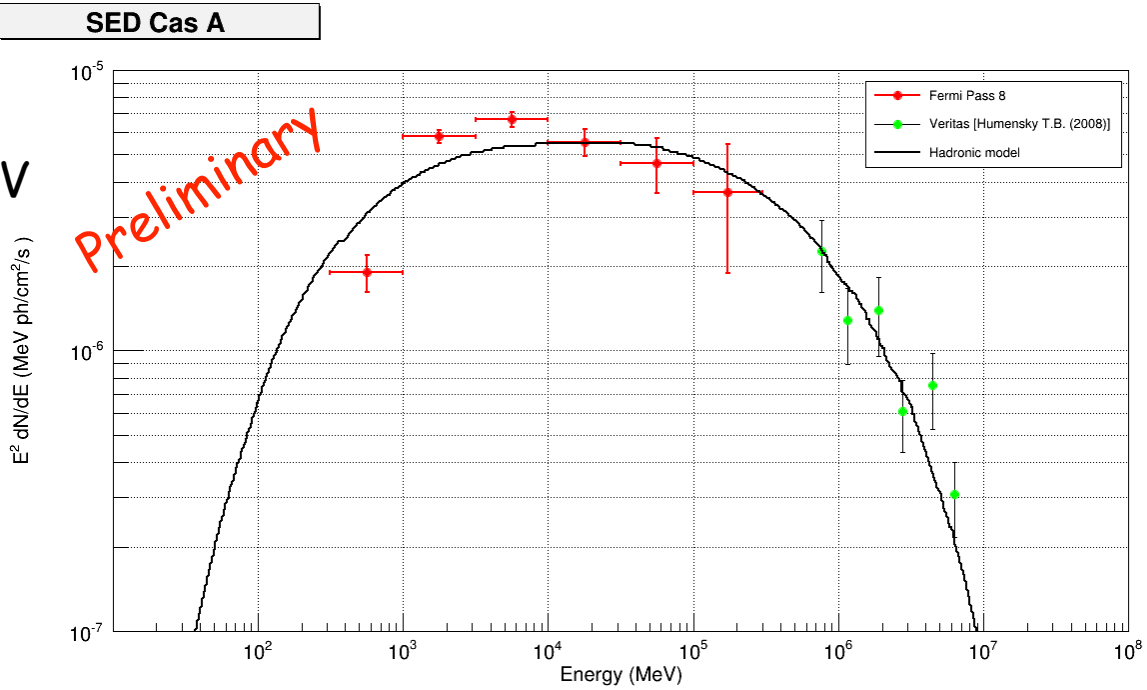


CasA: SED and Modeling

Pass8 data
69 months
Energy: 300MeV-300GeV
ROI 15 deg

$n_H = 10\ cm^{-3}$
d = 3.4kpc

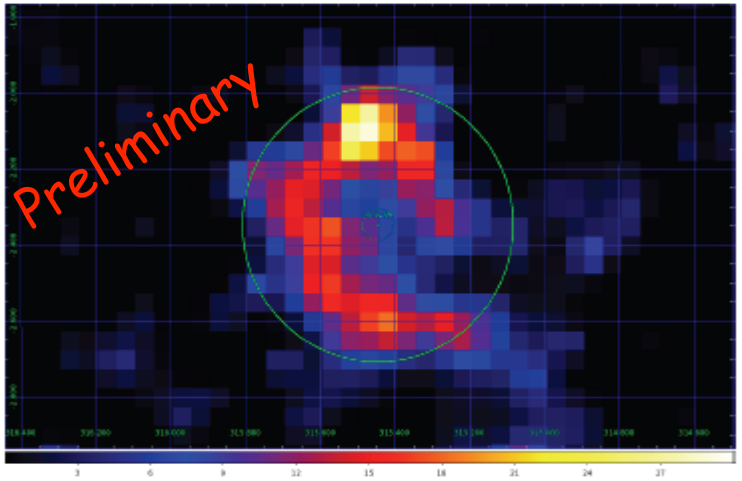
$s_e = 2.34 \pm 0.04$
$p_{cut,e} = (40.3 \pm 0.2)$ TeV
$s_p = 1.98 \pm 0.03$
$p_{cut,p} = 10.5 \pm 0.9$ TeV
$W_p = 2\%$
$K_{ep}=10^{-1}$



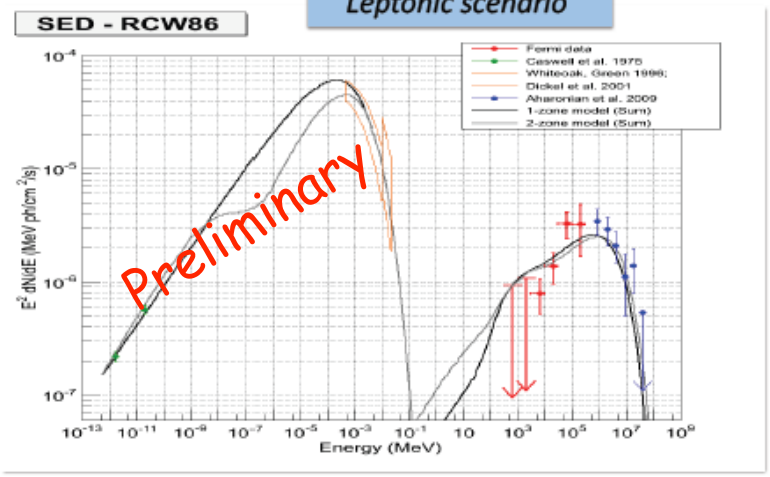
RCW86: SED & Modeling

	Leptonic model			Hadronic model		
	One-zone	Two-zone		One-zone	Two-zone	
		radio	X-ray		radio	X-ray
B (μG)	15	>10	15	400	>10	>50
Γ	2.3	2.2	2.0	1.8	2.2	1.8
$E_{break,e}$ (TeV)	-	-	-	0.004	-	3.0
$E_{break,p}$ (TeV)	25	0.2	25	7	0.2	20
$E_{max,p}$ (TeV)	100	-	100	80	-	80
η_e ($x10^{-2}$ $d^2_{2.5}$)	2	<2.5	0.04	0.004	<2.5	0.006
η_p ($x10^{-2}$ $d^2_{2.5}/n_{cm^{-3}}$)	<2	-	<4	7	-	7
K_{ep}	>0.1	-	>0.006	0.002	-	0.001

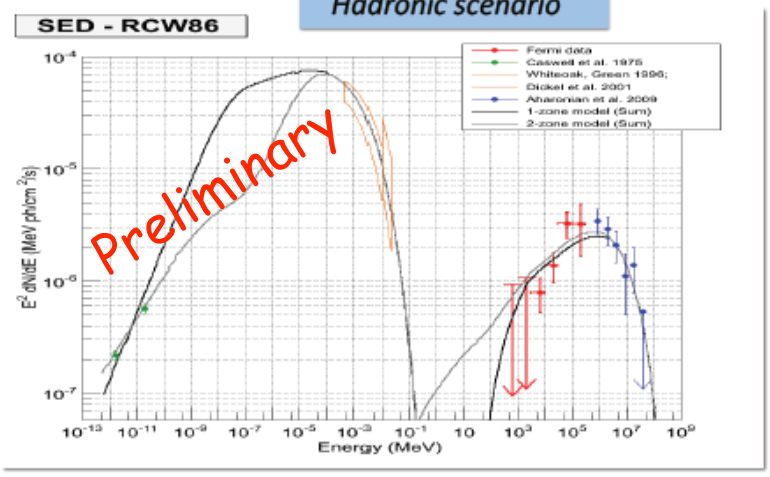
Lemoine-Goumard el al. 2012



Leptonic scenario



Hadronic scenario



See poster by Caragiulo M. et al

Conclusions

- Improved statistics -> higher significance of the detections
- New SEDs
- Extensions for RCW86 and others (see Hewitt talk)

- The work is still in progress within Fermi-LAT to go as lowest as possible in energy
- Keep in mind that <100MeV the energy dispersion plays a key role

- Stay tuned… new pass8 data and results are coming