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upper limits on SNR Cassiopeia A and diffuse emissions

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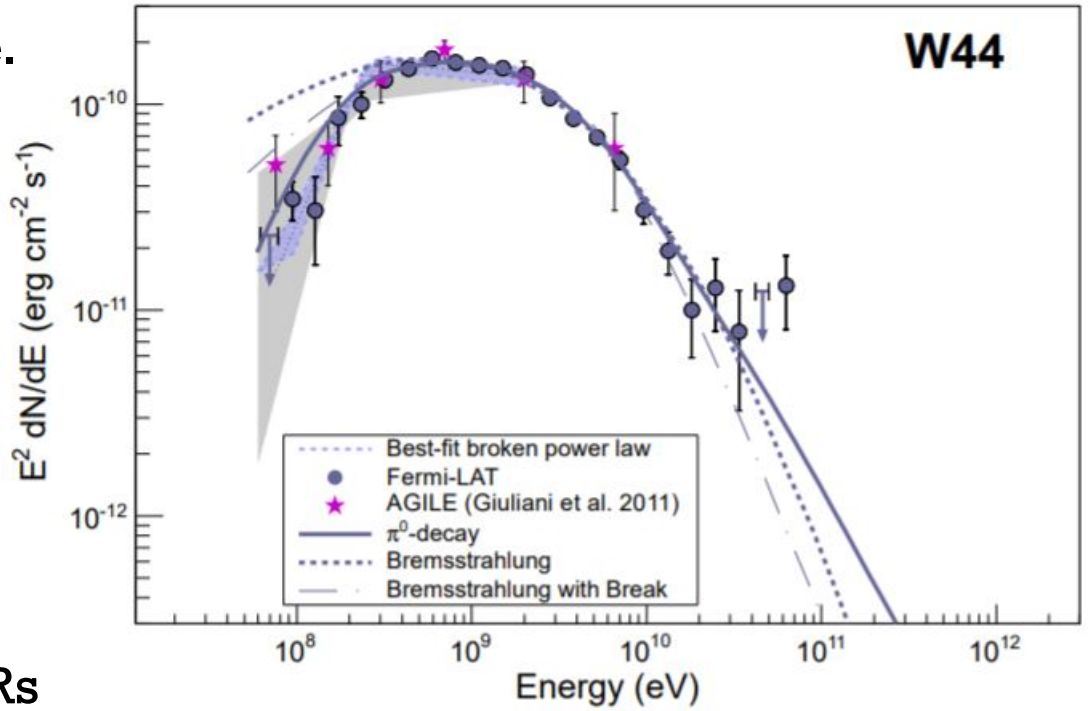
SNRs as CR source

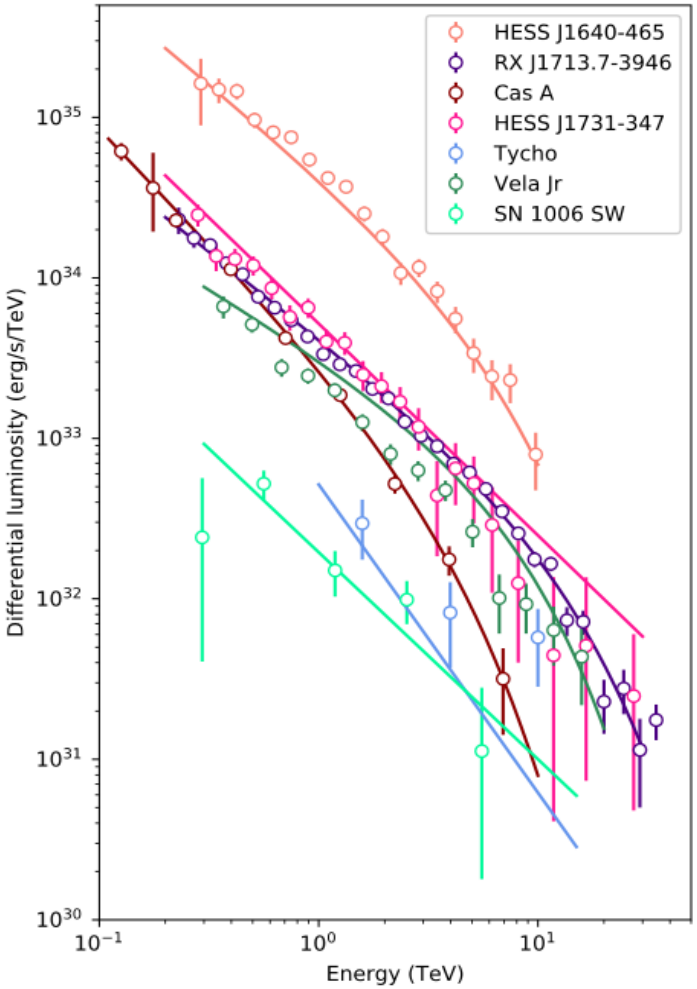
Mid-age SNRs

- Clear Pion-decay feature.
- Hadronic origin or Bremsstrahlung ?
- Break at ~ 10 GeV
- Cannot account for all CRs up to PeV



Fermi Collaboration 2013

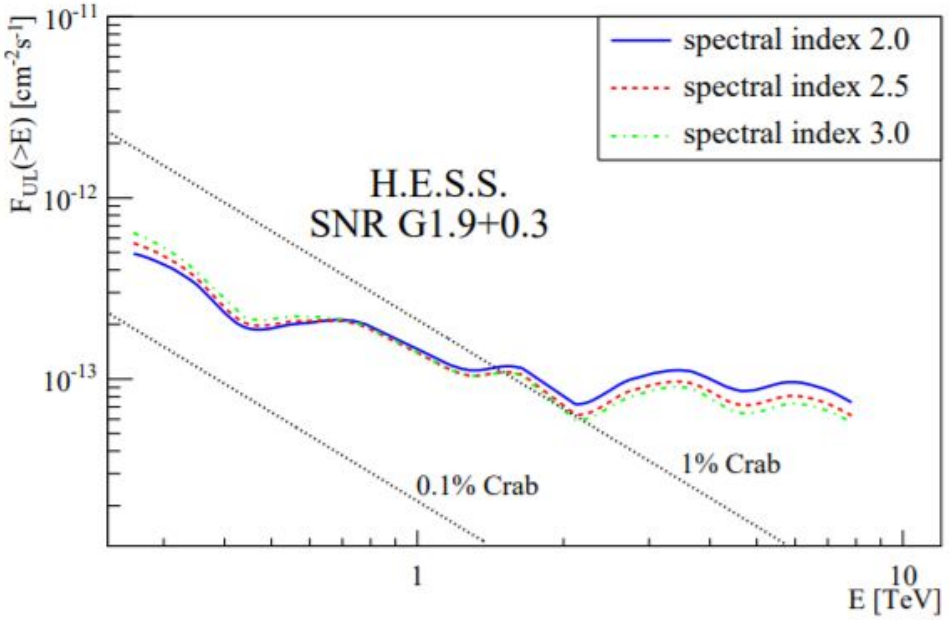
Gamma-ray observation of Young SNRs



- All gamma-ray spectrum young SNRs shows soft spectrum or early cutoff at ~ 10 TeV
- corresponding to CR energy of 100 TeV
- Hard to address a single power law spectrum of CRs up to PeV

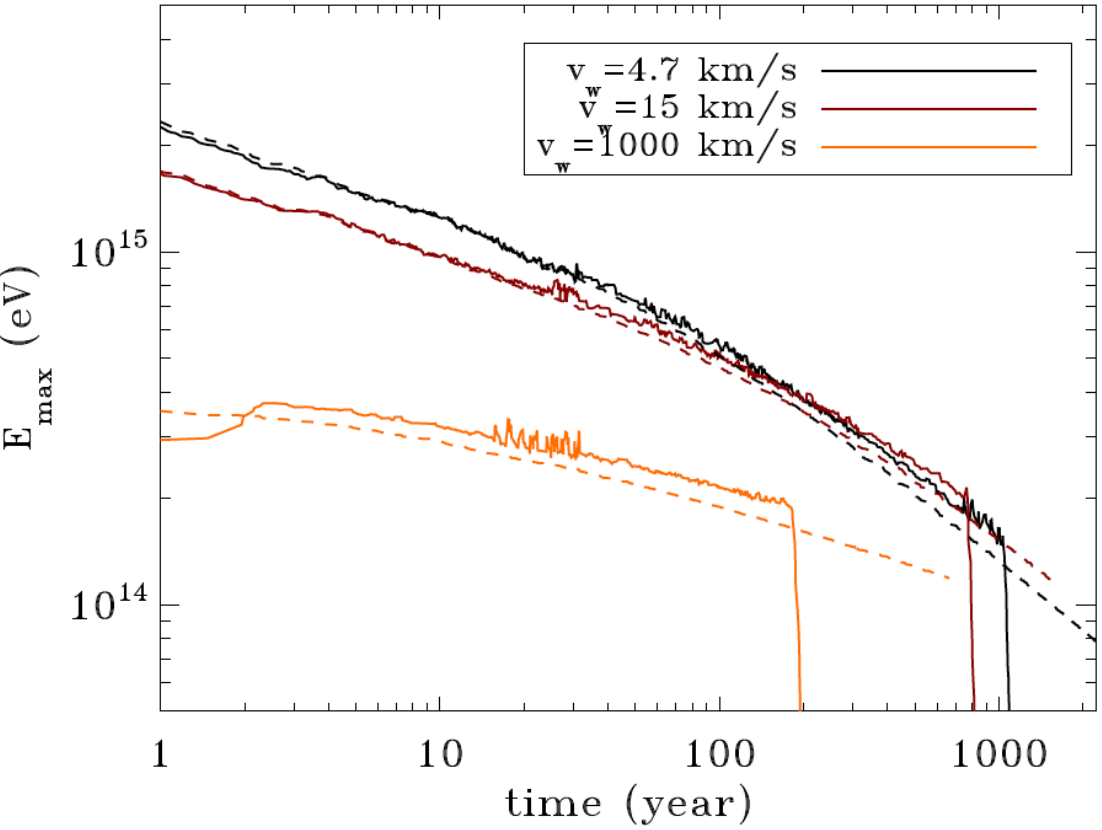
Very young SNRs?

- PeVatron phase could be accomplished only during the first years of the explosion (e.g., Bell et.al 2013)
- The youngest SNR in the Galaxy: G1.9+0.3, t ~ 100 yr
- VHE protons cannot propagate more than 30 pc.
- HESS reveals L(>1 TeV) < 1e32 erg/s can be used to set limit on proton energy budget.
- Considering a high density in the vicinity (near GC), the total energy on VHE protons are below 1e45 erg. Not enough to account for the CR flux up to the knee.



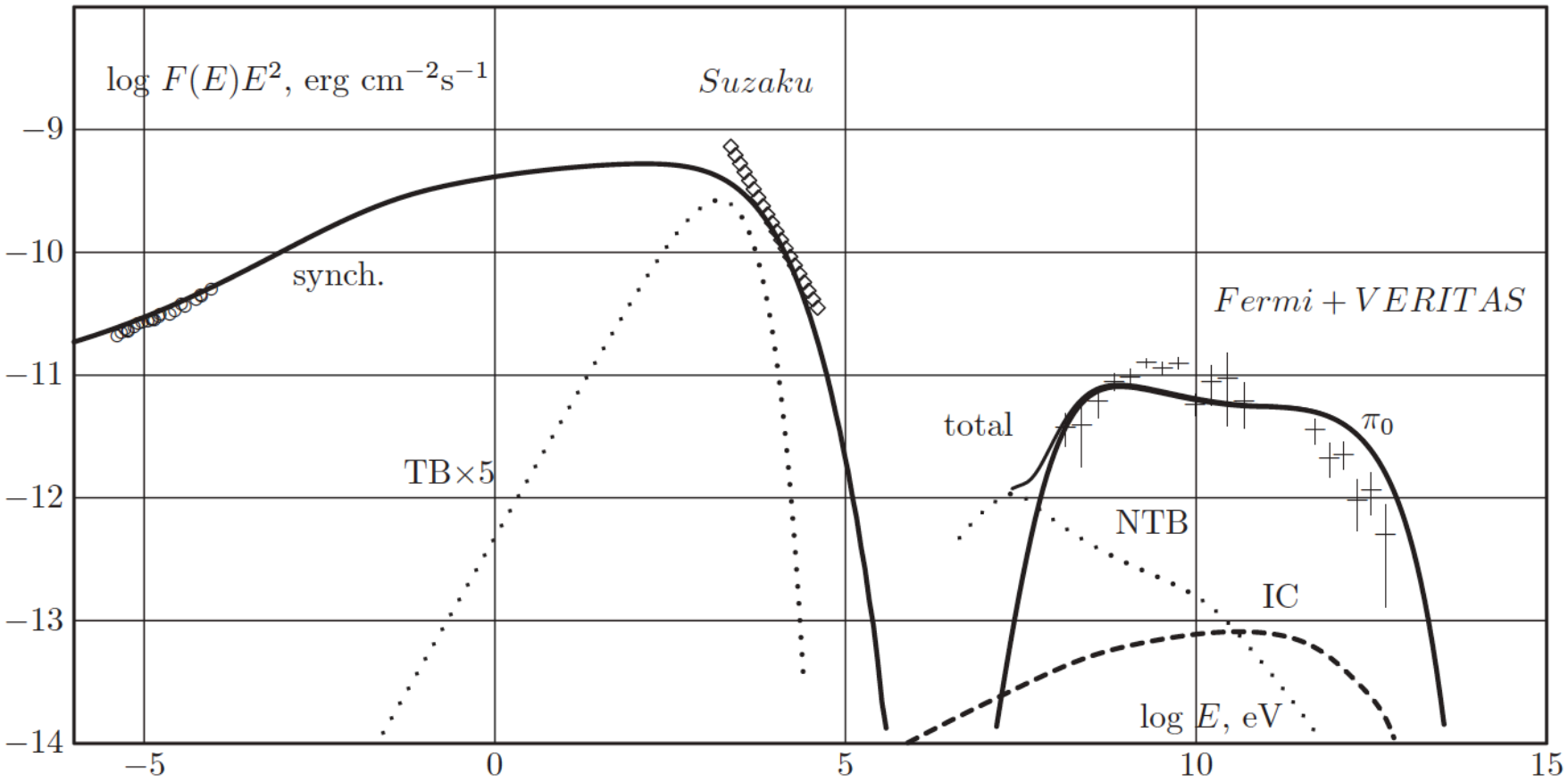
Cas A is special

- Dense environment
- Lager escaping current and more efficient magnetic field amplification
- Higher cosmic energy (Schure & bell 15)



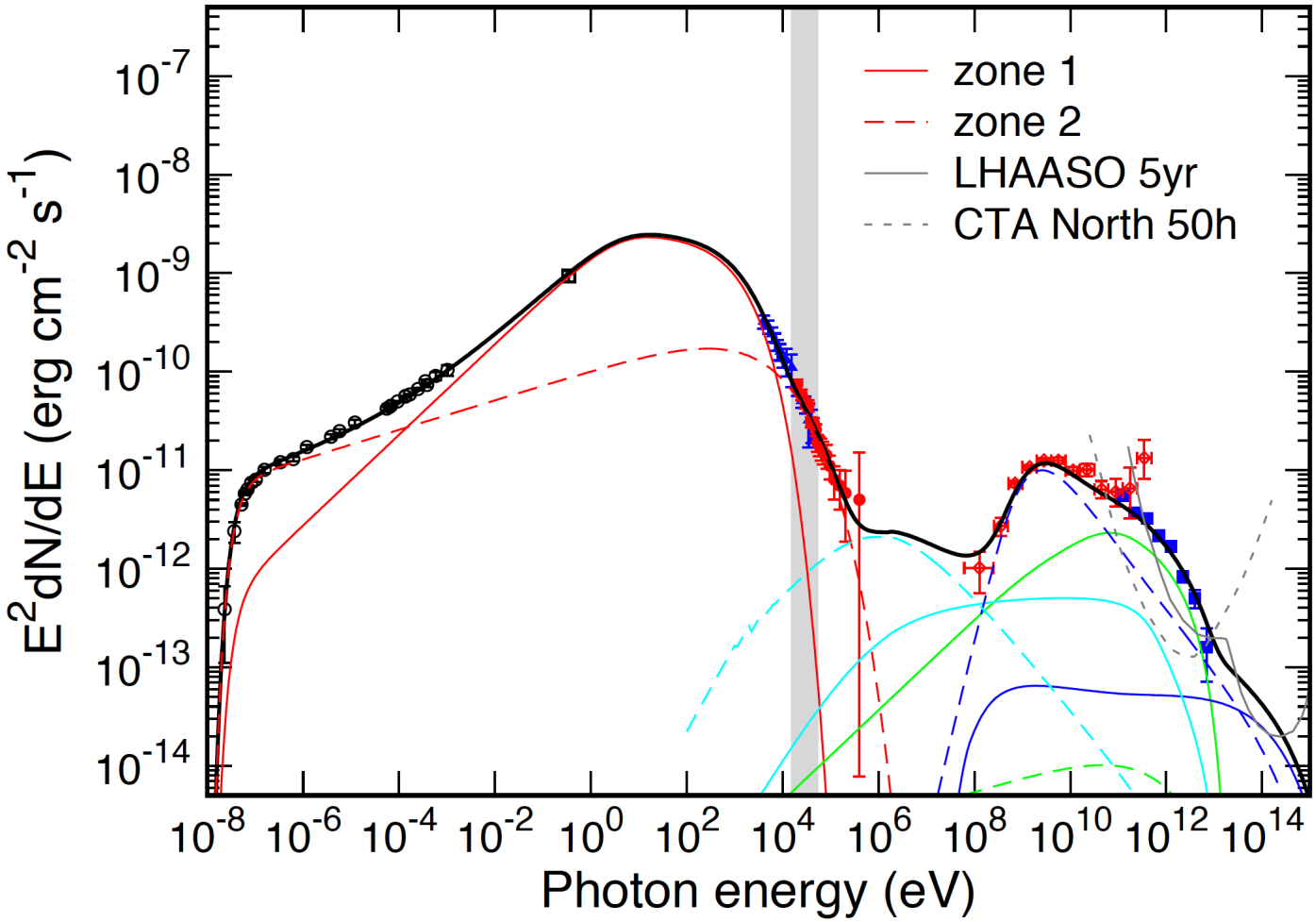
Can be Pevatron at first decade

Cas A is special



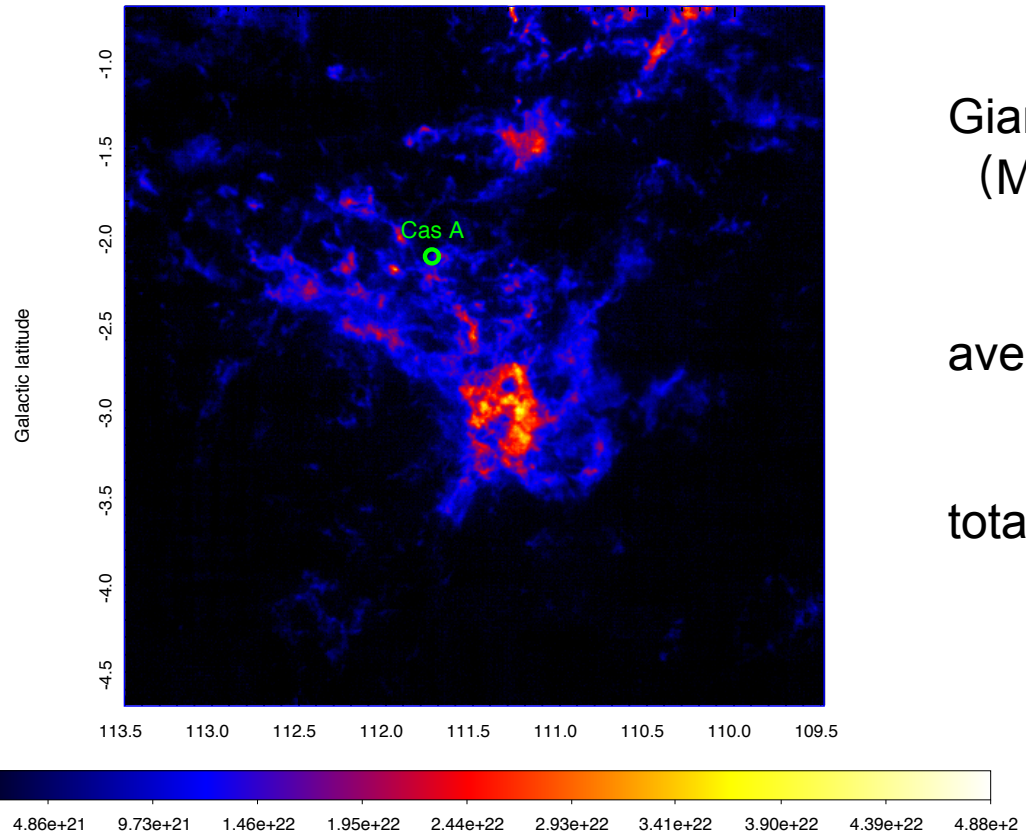
Multi-wavelength fitting, required a acceleration efficiency of more than 20% (Zirakashvili et.al 2014)

Cas A is special



Zhang & Liu 2019: Hadronic content in low density region (foward shock), can dominate in VHE

Cas A is special

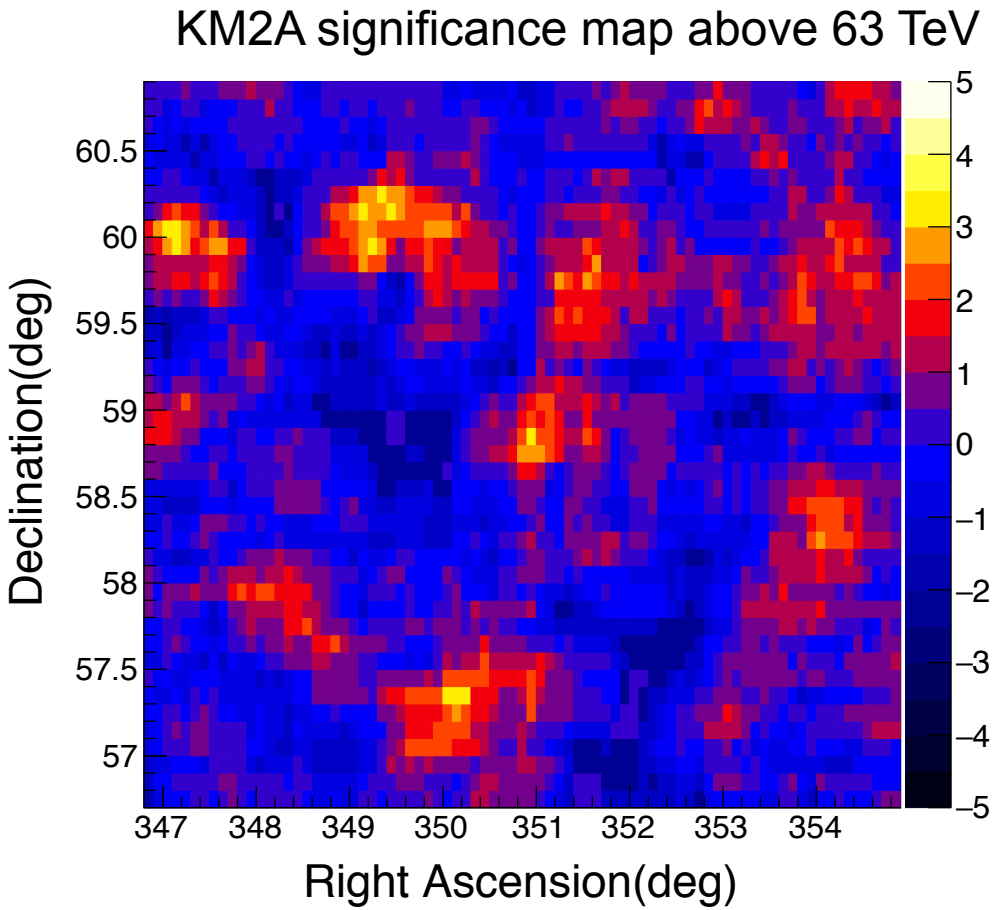


Giant Molecular clouds in the vicinity
(Ma et.al 2019 MWISP survey)

average cubic density > 10 cm^{-3}

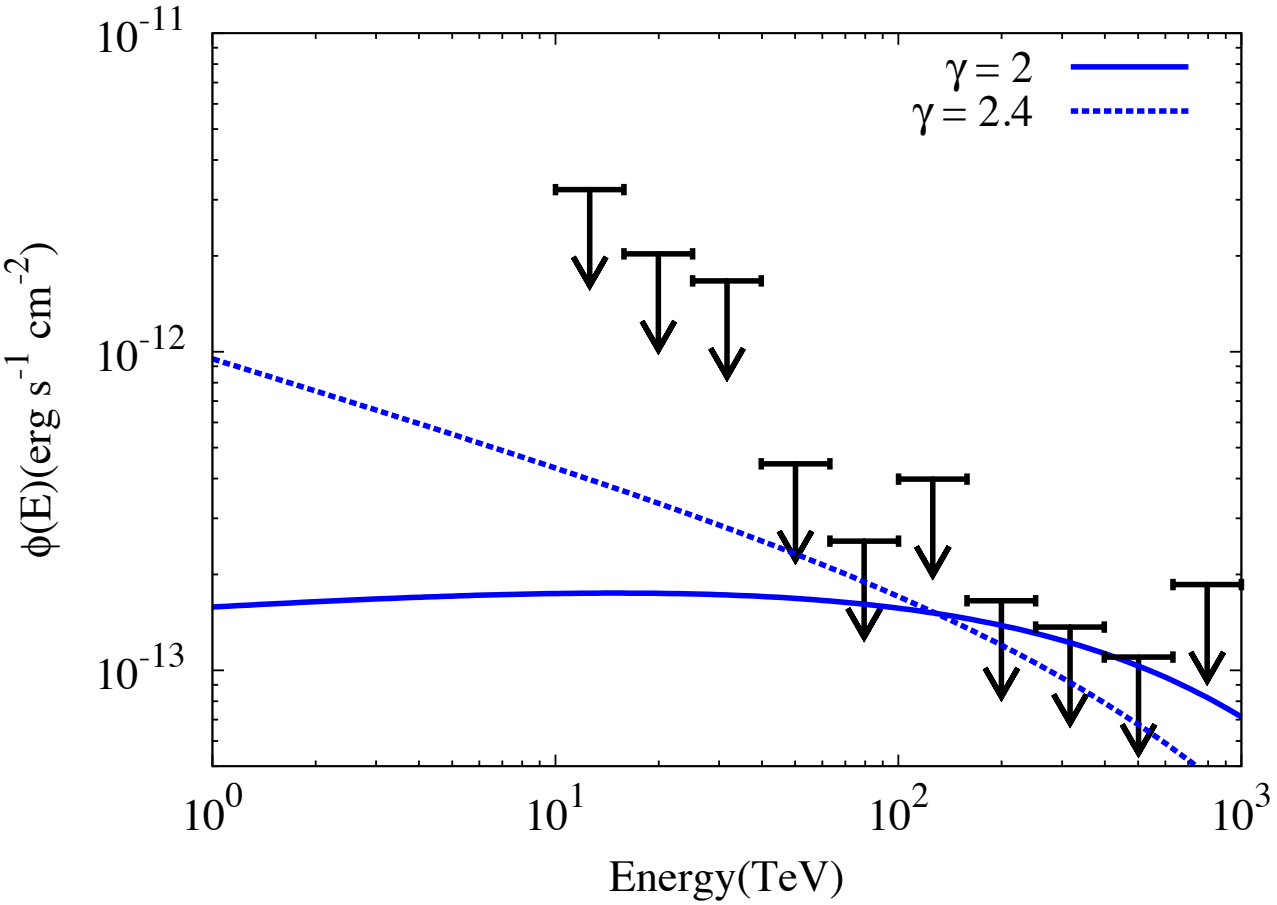
total mass ~10^6 solar mass

Two scenarios



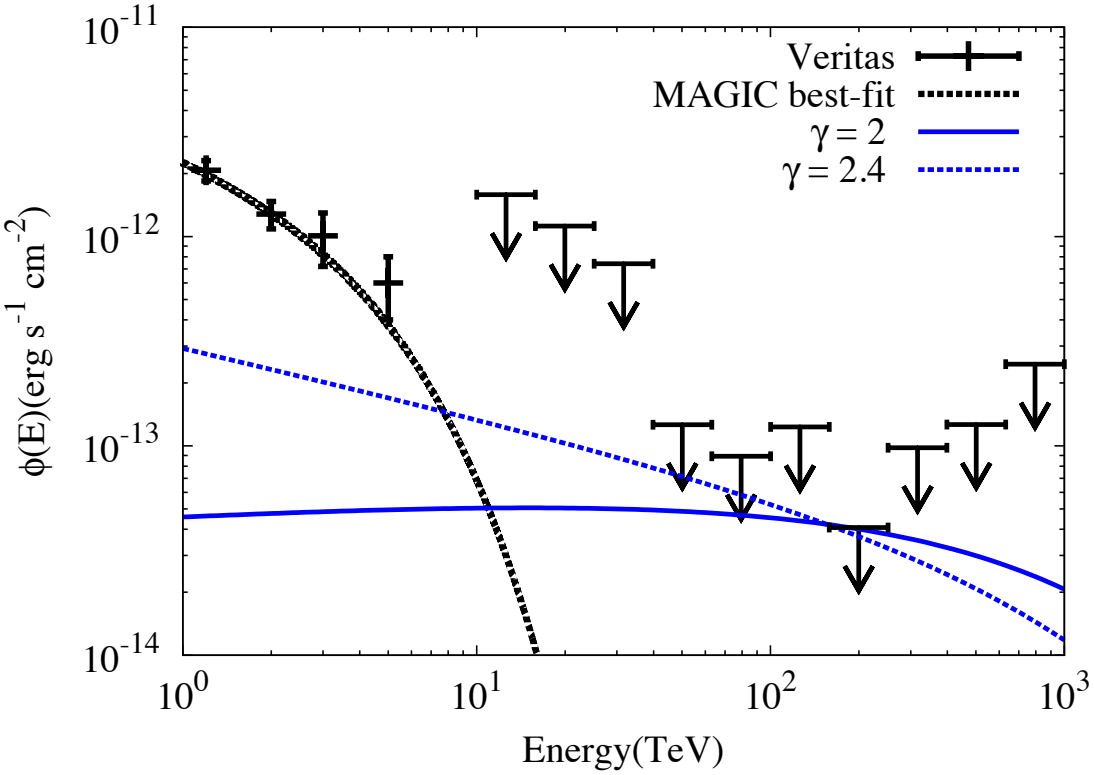
- The volume occupied by escaping CRs is determined by diffusion coefficient D(E)
- rd ~ 2 (DT)**0.5 ~ 30 pc (D/1e30 cm^2/s)**0.5
- Ballistic propagation regime for r< rb= R/c ~ 10 pc (D/1e30 cm^2/s)
- If rd > rb, diffusion regime and extended source , otherwise point source

KM2A upper limits (ext)



- Cas A like events once per century
- total CR injection rate above PeV < 5e37 erg/s for index of 2.0
- <4e37 erg/s for index of 2.4

KM2A upper limits (point source)



- total CR injection rate above PeV < 1.5e35 erg/s for index of 2.0
- In tension with estimated by Drury 2012 : 1 - 2 e40erg/s for index of 2.0, 4 -10e38 erg/s for index of 2.4

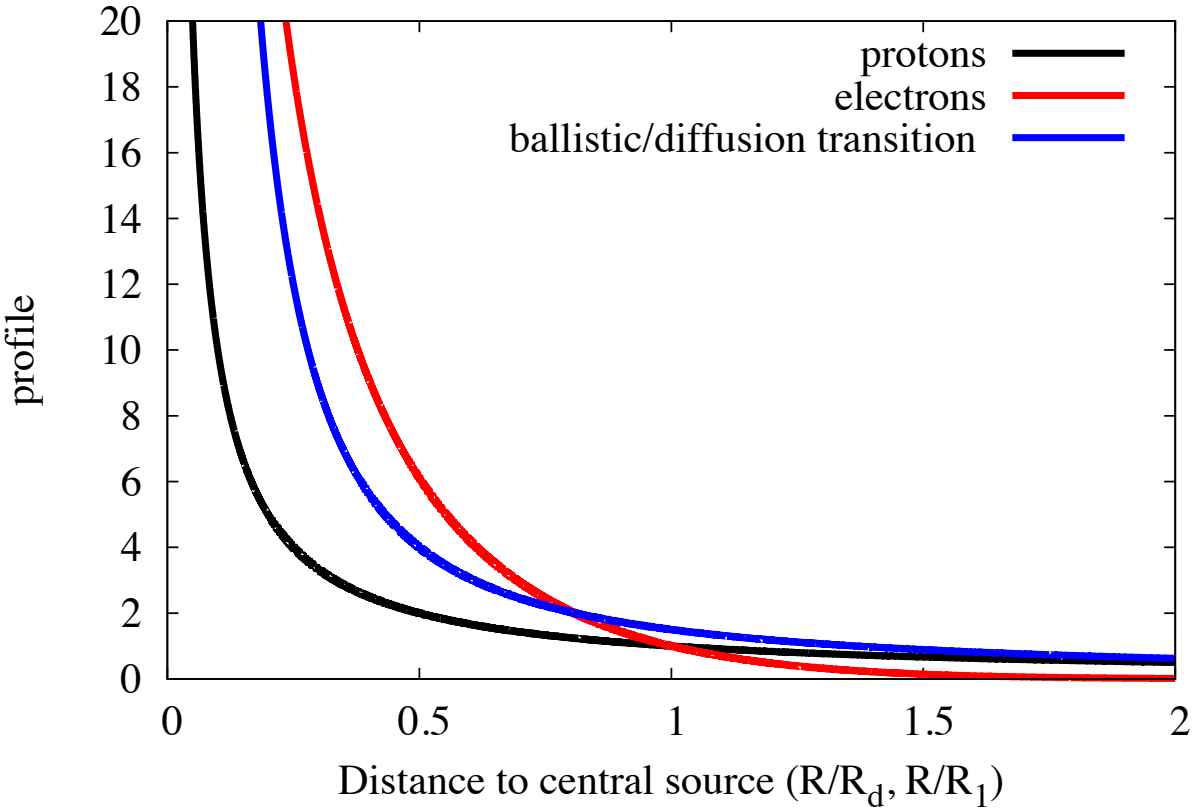
- physical implications:
  all PeV particles in Cas A trapped in a compact but low density region?
  other PeV candidates?

Extended source profile

- Cosmic ray cocoon and pulsar halo indeed have a same radial profile

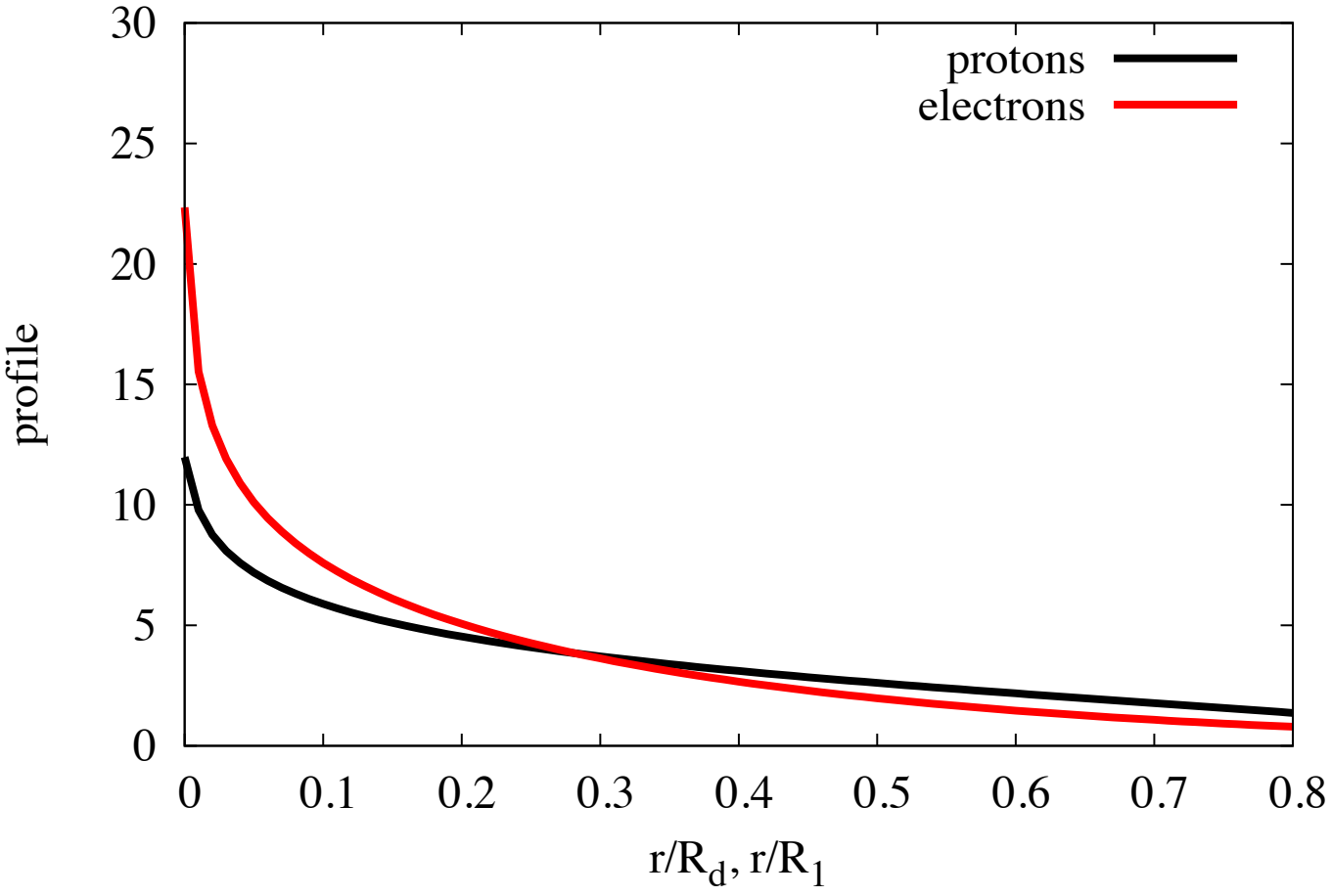
f ~ erfc(r/rd)/r. rd is the diffusion length, determined by cooling(electron)/age(proton)

- Generally, rd for proton is much larger
- Another possibility: transition from diffusion to ballistic



Extended source and Diffuse emissions

- After projection, ballistic similar to point source, the other two case become less cusp

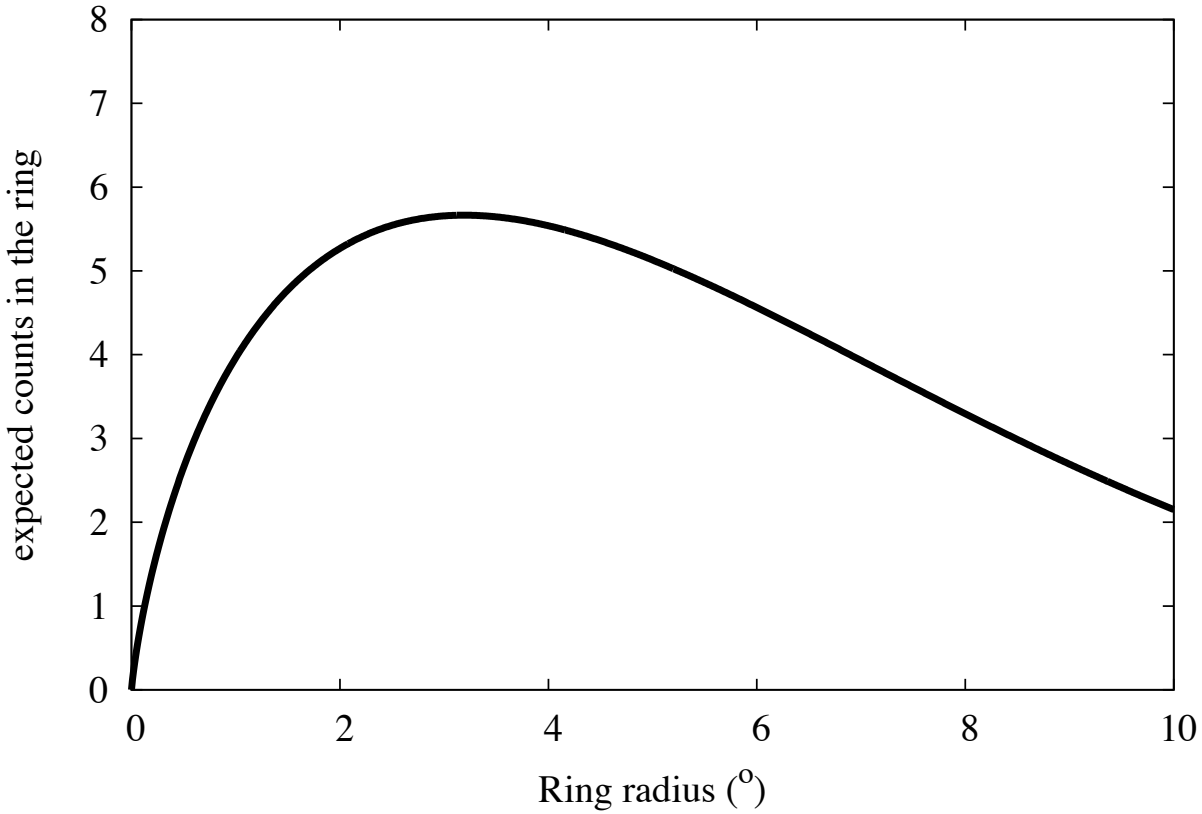


Extended source and Diffuse emissions

Consider a very weak cocoon or halo， only several photons can be detected.

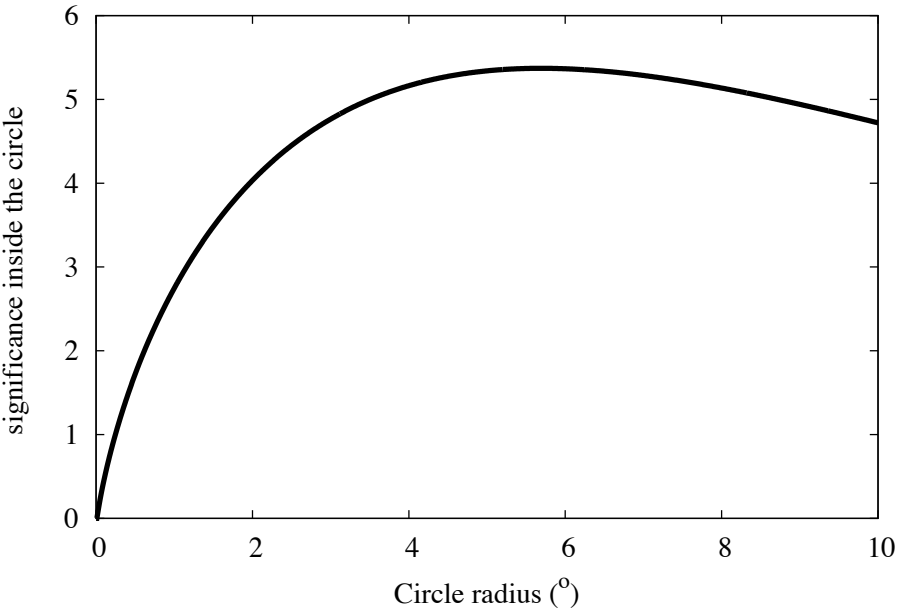
The photon observed at the distance r' from the source center can be estimated as (rd=10 degree)

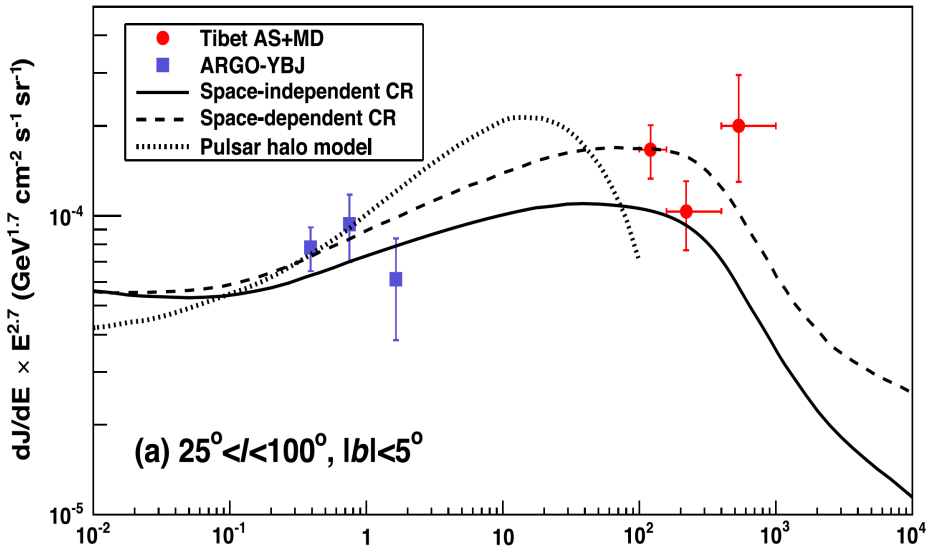
$$N(r') \sim \pi \int_{r'}^{r'+dr'} f(r) r dr = 2 \int_{r'}^{r'+dr'} \int_{r}^{R_1} \frac{erfc(R/R_d)}{\sqrt{R^2 - r^2}} dR r dr$$



Extended source and Diffuse emissions

The significance scale as N_src/sqrt(N_bg), may increase with integration radius





- Thus such sources photons can be detected firstly far from the center
- Be identified as “diffuse emission”
- They are “diffuse emission” but not from the CR “sea”
- Account for the As-gamma results ?