High Energy Radiation from Centaurus A

Sergey Ostapchenko, Michael Kachelrieß, Ricard Thomas

NTNU, Trondheim

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Outline of the talk

1. Auger correlation claim
2. Test by multi-messenger approach?
   - Cen A – source & acceleration models
   - Our simulation
   - Results
3. Summary and outlook

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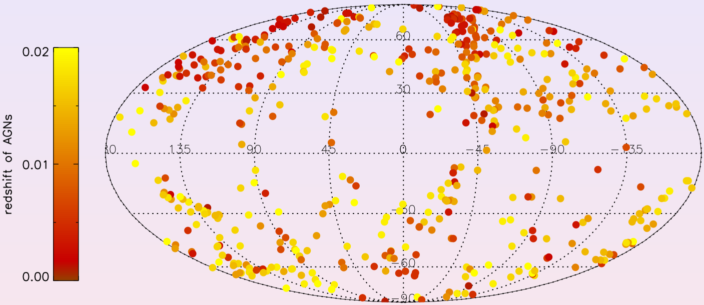

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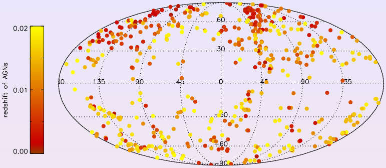

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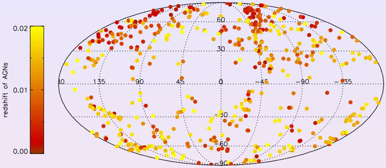

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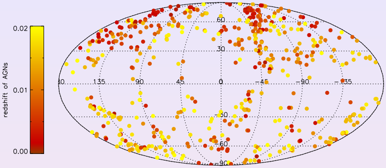

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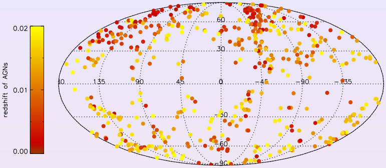

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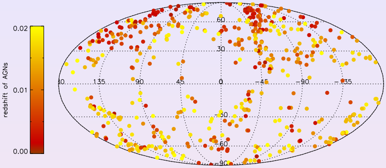

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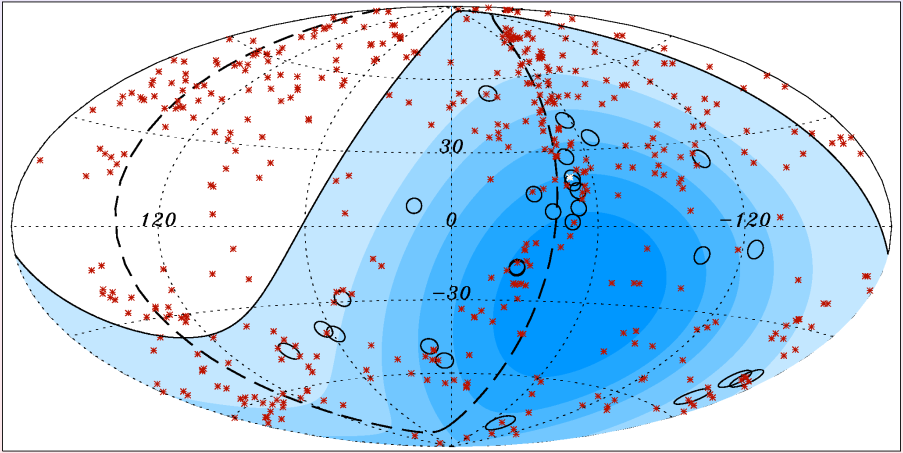
- just a "3 σ effect"
- AGN or something with similar distribution?

Correlations with AGNs: PAO analysis

- 27 CRs ($\odot$) and 472 AGN ($\color{red}{*}$):



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- large fraction of all AGN required to accelerate to $E > 10^{20}$eV
- internal inconsistencies:
  - energy scale
  - chemical composition
- independent/additional evidence?

Possible source/acceleration scenarios

- mechanism: shock acceleration vs. acceleration in regular fields
- location: core, hot spots, along the jet
- target: gas vs. photons

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Fixing the source parameters:

- observations:
  - $d = 3.8\,\mathrm{kpc}$
  - $M = (0.5 - 2) \times 10^8 M_\odot$
  - $\dot{M} = 6 \times 10^{-4} M_\odot$
  - $L_X = 5 \times 10^{41} \mathrm{erg/s}$

$\Rightarrow$ efficiency $\eta = 5\%$

- supports standard thin, optical thick accretion disc with

$$T(r) = \left(\frac{3GM\dot{M}}{8\sigma\pi r^3} \left[1 - (R_0/r)^{1/2} \right] \right)^{1/4}$$

- add X-ray from hot corona
- simplify to 1-dim geometry

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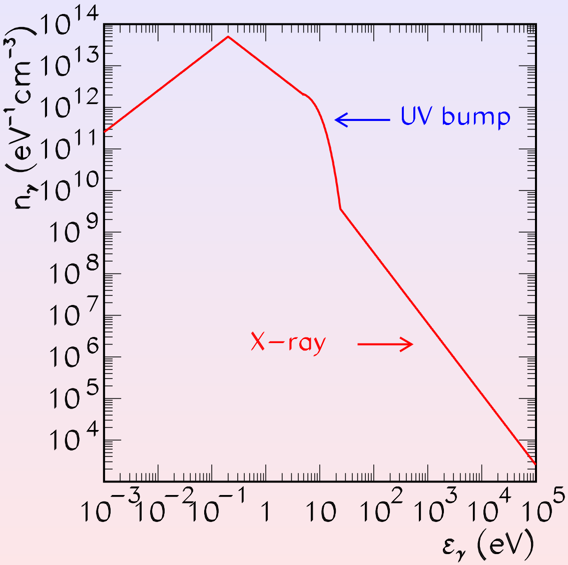
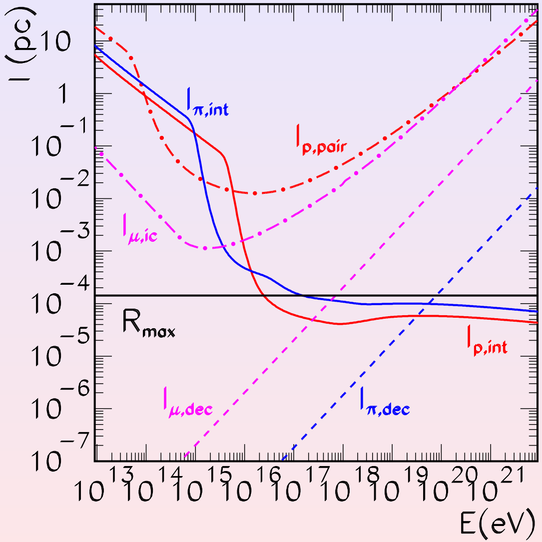
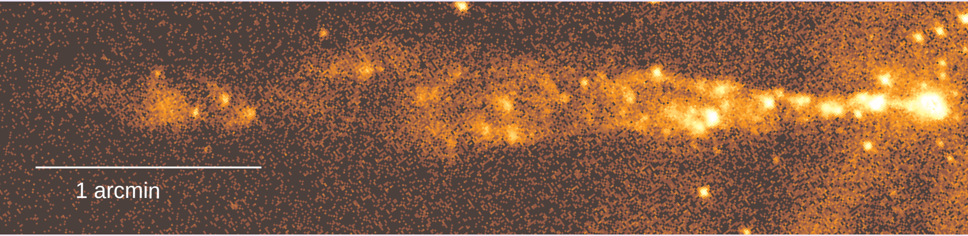
UV and X-ray background from the accretion disk



Lenght scales for acceleration close to the core

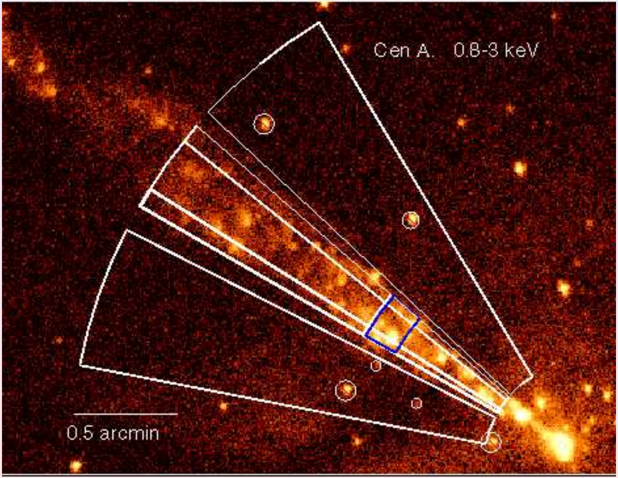


Chandra observation of X-ray emission in the jet

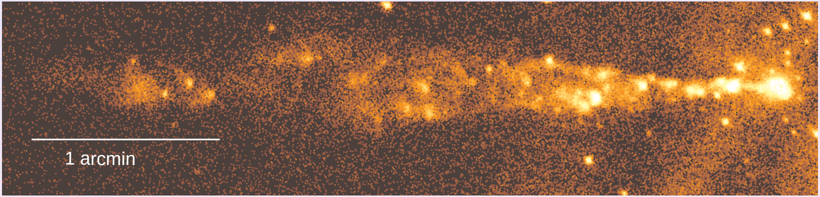


Chandra observation of X-ray emission in the jet

- divide in subareas
- separate fit to gas colum density X and spectral index α

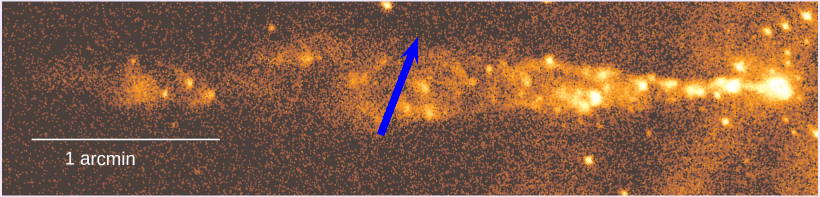


Chandra observation of X-ray emission in the jet: Results



- $X = 1.5 \times 10^{21}/\text{cm}^2$ in the jet

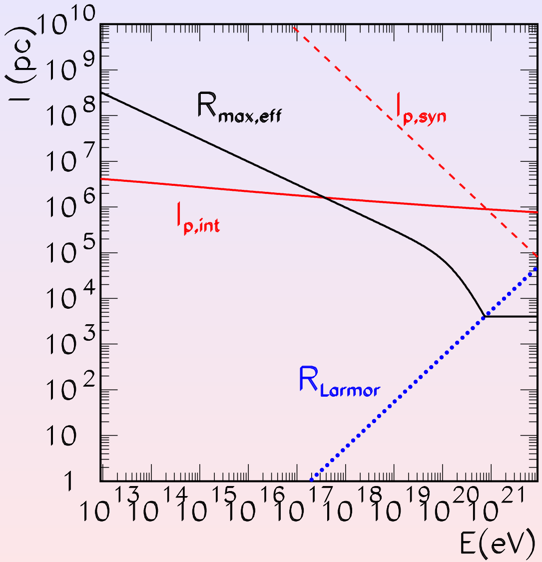
Chandra observation of X-ray emission in the jet: Results



- $X = 1.5 \times 10^{21}/\mathrm{cm}^2$ in the jet
- with $d = 0.4\,\mathrm{kpc}$ and $\sigma_{pp} = 150\mathrm{mbarn}$:

$\Rightarrow$ interaction depth $\tau_{pp} \sim 0.01$

Lenght scales for acceleration in the jet



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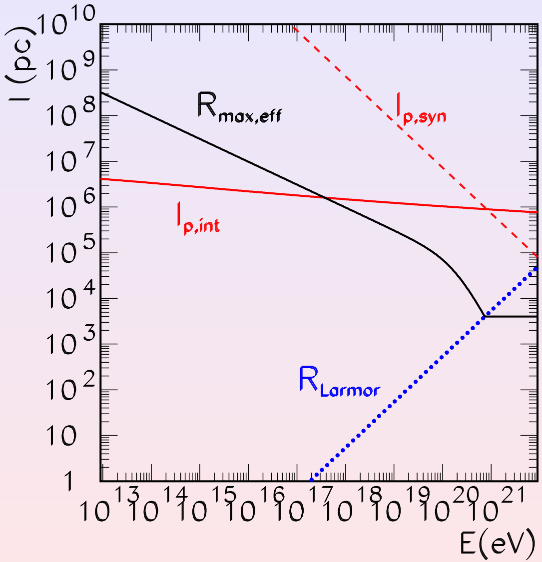

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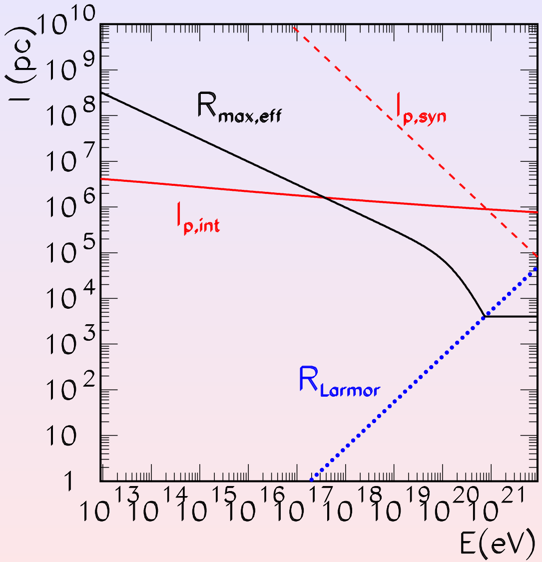


- diffusion increases effective size
- for pp no threshold
- $\tau = 1$ for $E = 10^{17}$eV, optimal for neutrino telescope

Our two base models

acceleration close to the core

acceleration in accretion shock/regular fields

$p\gamma$ interactions

$\tau_{\gamma\gamma} \gg 1$, synchrotron losses for $e^{\pm}$

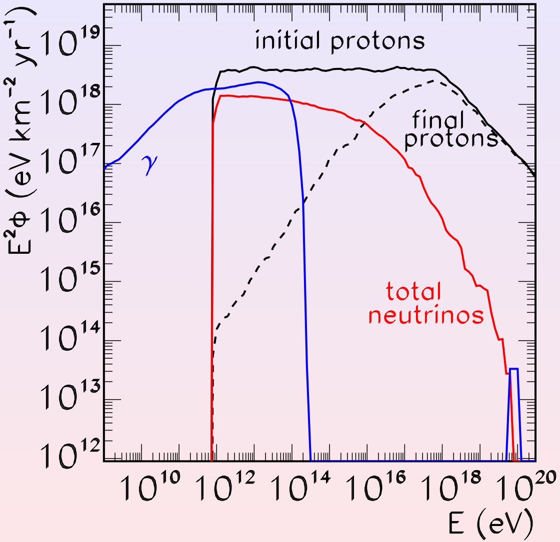
acceleration in jet

shock acceleration

pp interactions

$\tau_{\gamma\gamma} \ll 1$, synchrotron losses for $e^{\pm}$

Results for acceleration in jet: broken power-law



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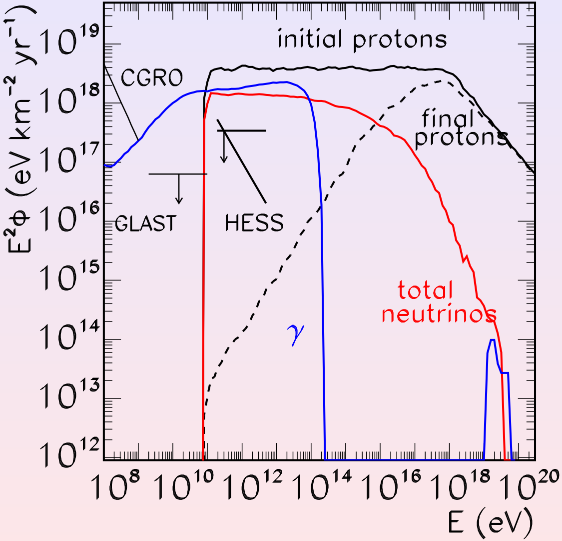

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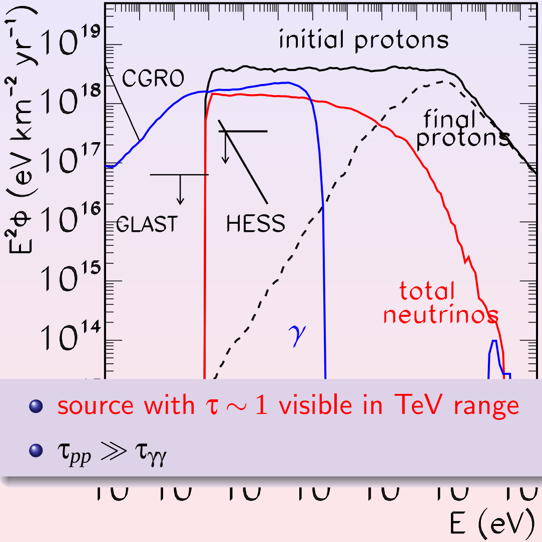

- source with $\tau \sim 1$ visible in TeV range
- $\tau_{pp} \gg \tau_{\gamma\gamma}$

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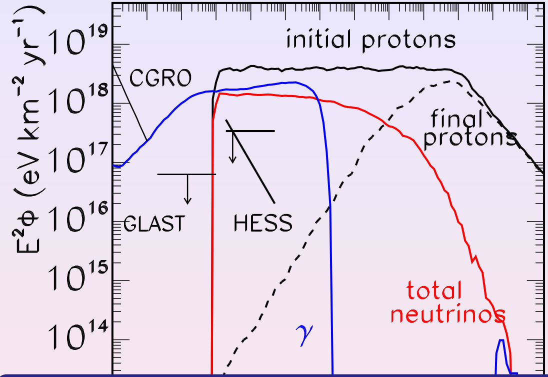


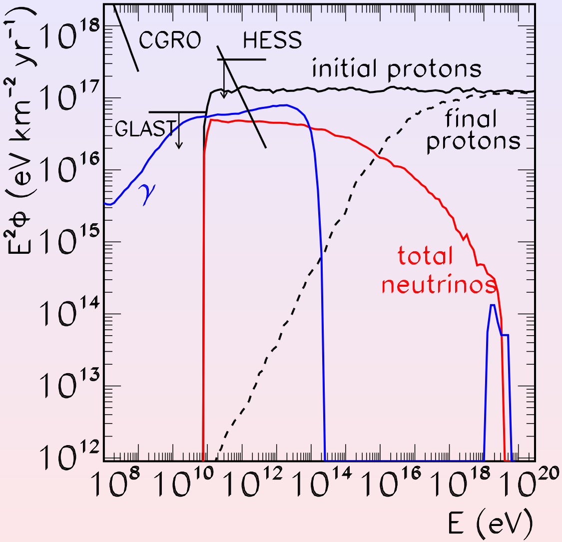
$\alpha = 2.7$ required for diffuse CR flux in "dip model"

- disfavoured as spectrum of single source Cen A

$\Rightarrow$ diffuse spectrum = superposition of single sources with $dn/dE_{\max}$ distribution

- HE γ observations constrain UHECR models

Results for acceleration in jet: $\alpha = 2$



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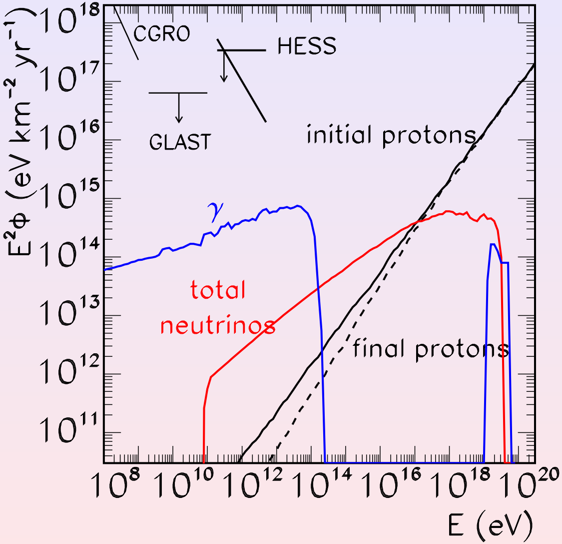
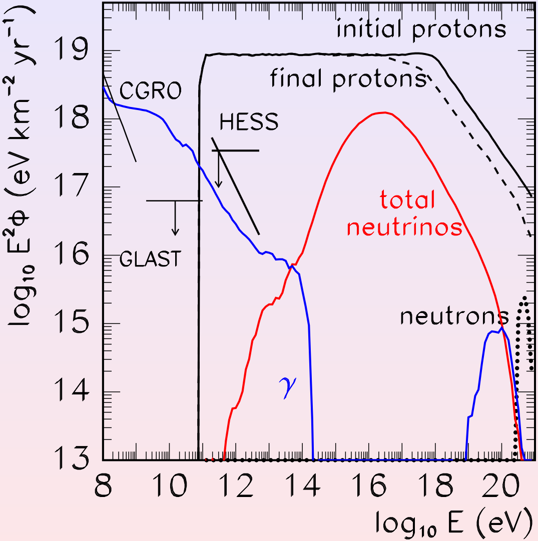
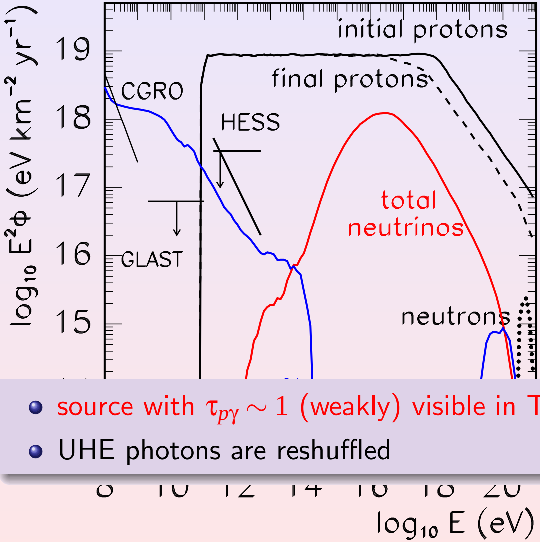


Results for acceleration close to the core: broken power-law





- source with $\tau_{p\gamma} \sim 1$ (weakly) visible in TeV range
- UHE photons are reshuffled

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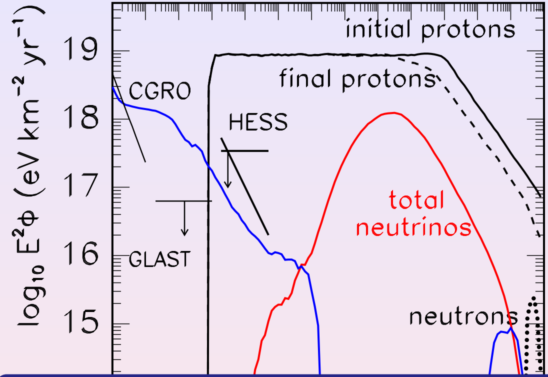

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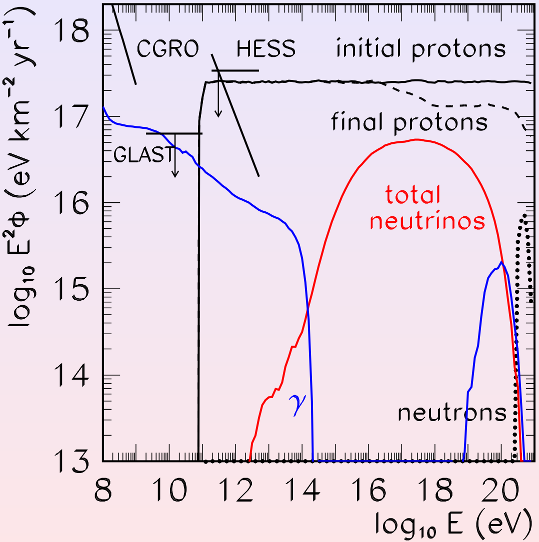
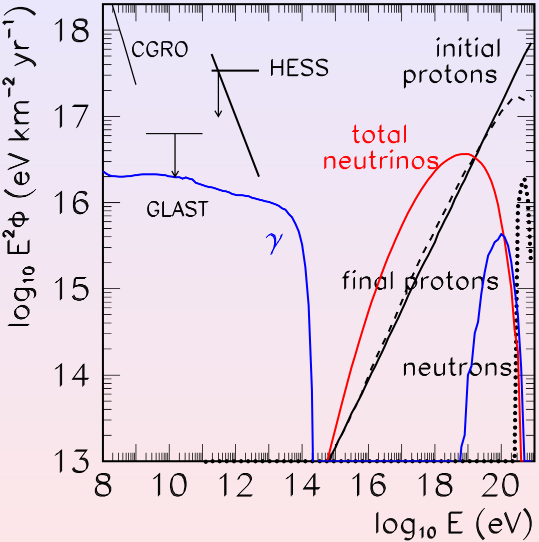
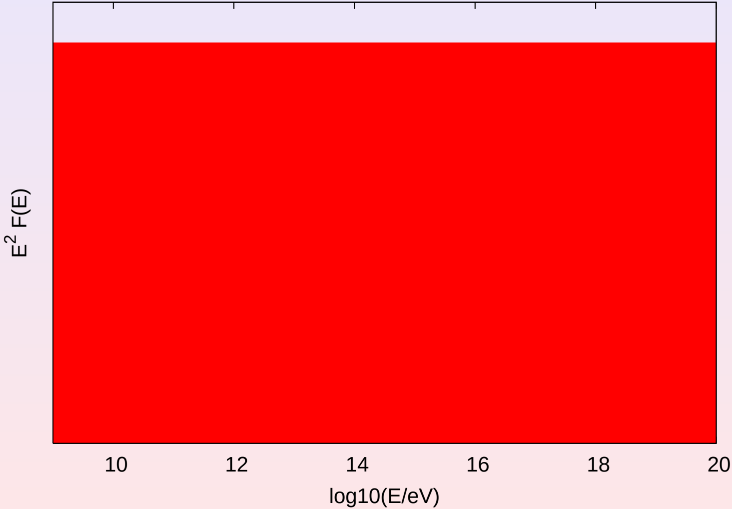


Results for acceleration close to the core: $\alpha = 1.2$

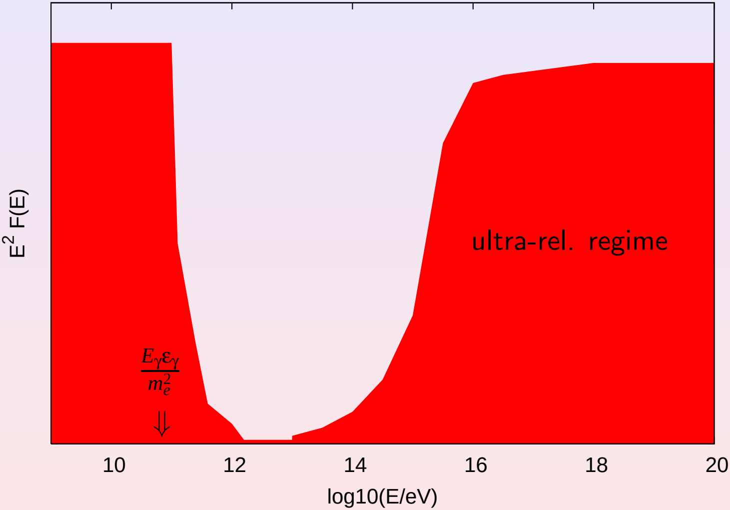


- injections spectrum $F_\gamma(E) \propto 1/E^2$



Regenerating TeV photons: a) in the source

- : thin above 10^{16}eV, ultra-rel. regime



Regenerating TeV photons: b) on CMB

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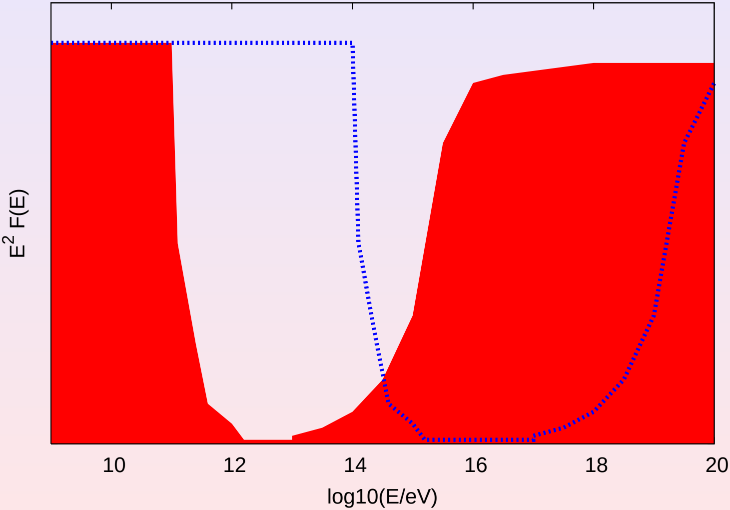

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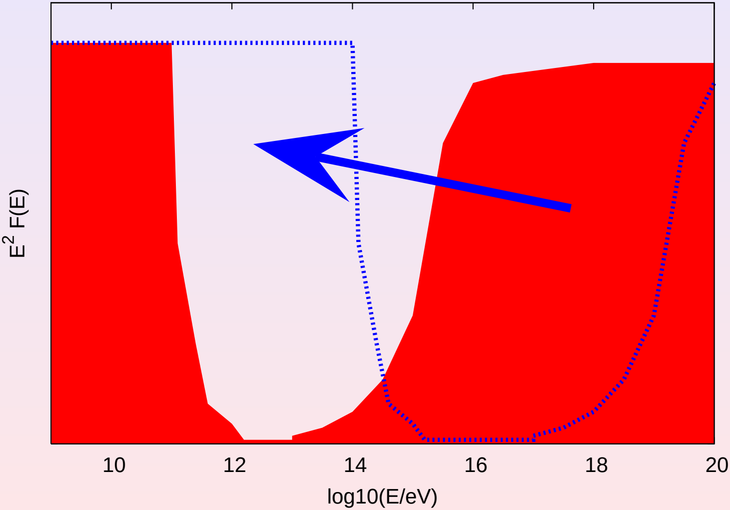

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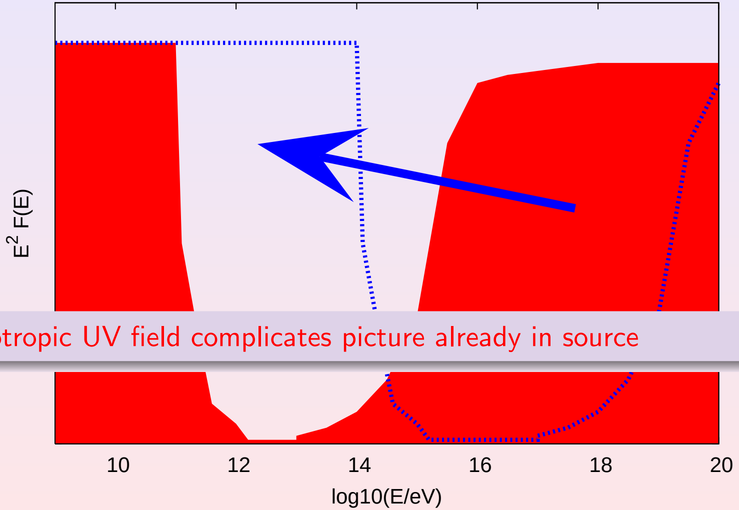

anisotropic UV field complicates picture already in source

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- general: TeV photon sources may be also good neutrino sources