CTA Star Forming Region Consortium Paper
- Starburst galaxies -

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SFR Consortium paper: scientific items

- Star forming regions studies cover a wide class of sources: from the smallest to the largest scales.
- Galactic science
  - Massive young stellar objects
  - Massive stars and their winds
  - Massive star clusters, superbubbles and supernova remnants.
- Extragalactic science
  - The Magellanic clouds
  - Star formation in normal galaxies
  - **Starburst galaxies**
  - **Ultra Luminous Infra Red Galaxies (ULIRGs)**
- The Star formation rate - TeV gamma-ray relation

Starburst galaxies in the gamma-ray band

Typical starburst environment

- SFR $\simeq$ 10-100 $M_\odot\ yr^{-1}$
- Average ISM density $n \simeq 10^2$-10^3 cm^{-3}
- Magnetic field $B \simeq$ 50-250 μG
- Radiation field density $U_{rad} \simeq 10^3$ eV cm^{-3}
- Wind velocity $V_{wind} \simeq$500 km/s
- Supernova rate $\nu_{SN} \simeq$0.03-0.3 yr^{-1}
- Starburst lifetime $\tau \simeq$10 Myrs

➢ Efficient site of CRs acceleration and confinement

➢ CR reservoirs: gamma-rays and neutrinos are produced by hadronuclear interactions of CRs that are confined within the environment of the CR source.

$$p + p \rightarrow \pi^0 + \pi^\pm + \ldots$$

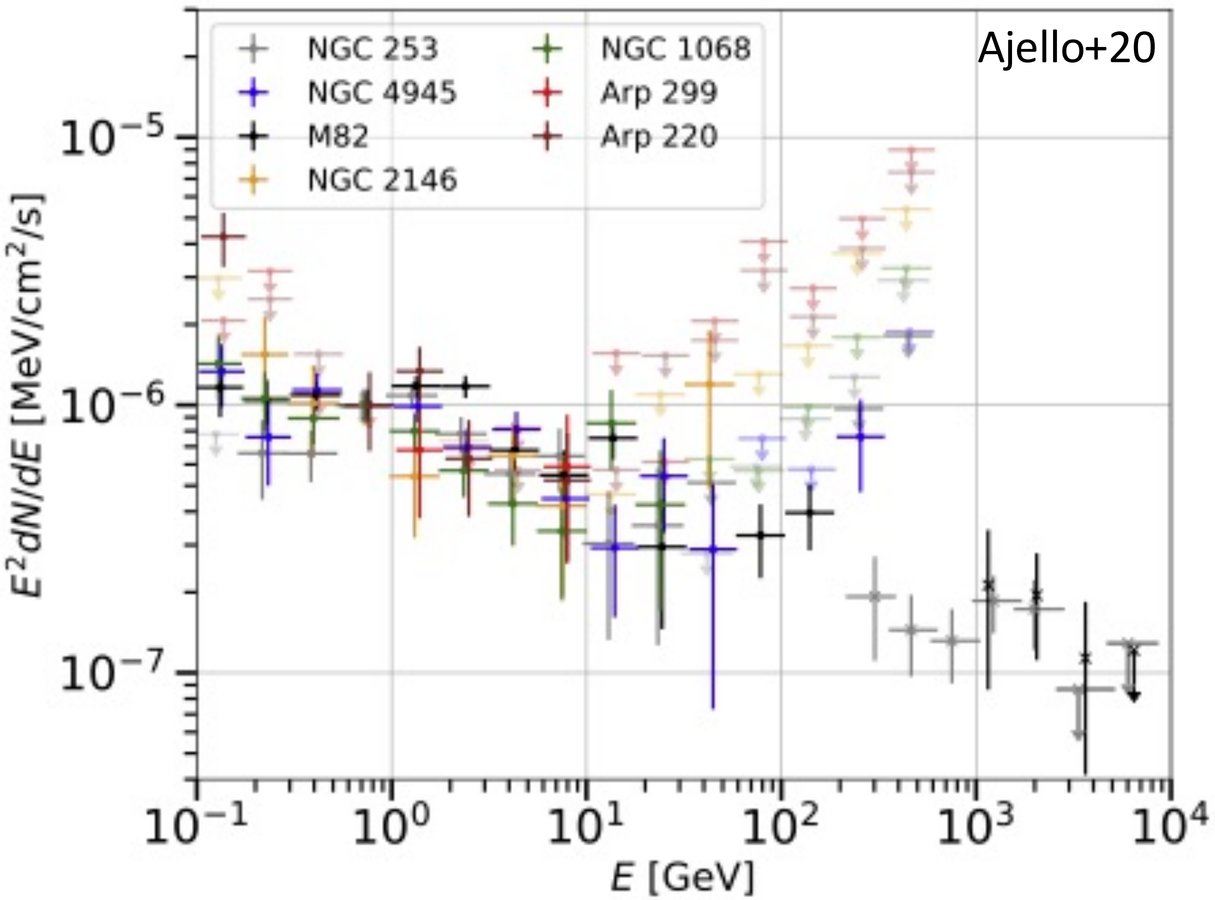
$$\pi^0 \rightarrow \gamma + \gamma$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\mu^+ \rightarrow e^+ + \nu_e + \overline{\nu_\mu}$$

$$\pi^- \rightarrow \mu^- + \overline{\nu_\mu}$$

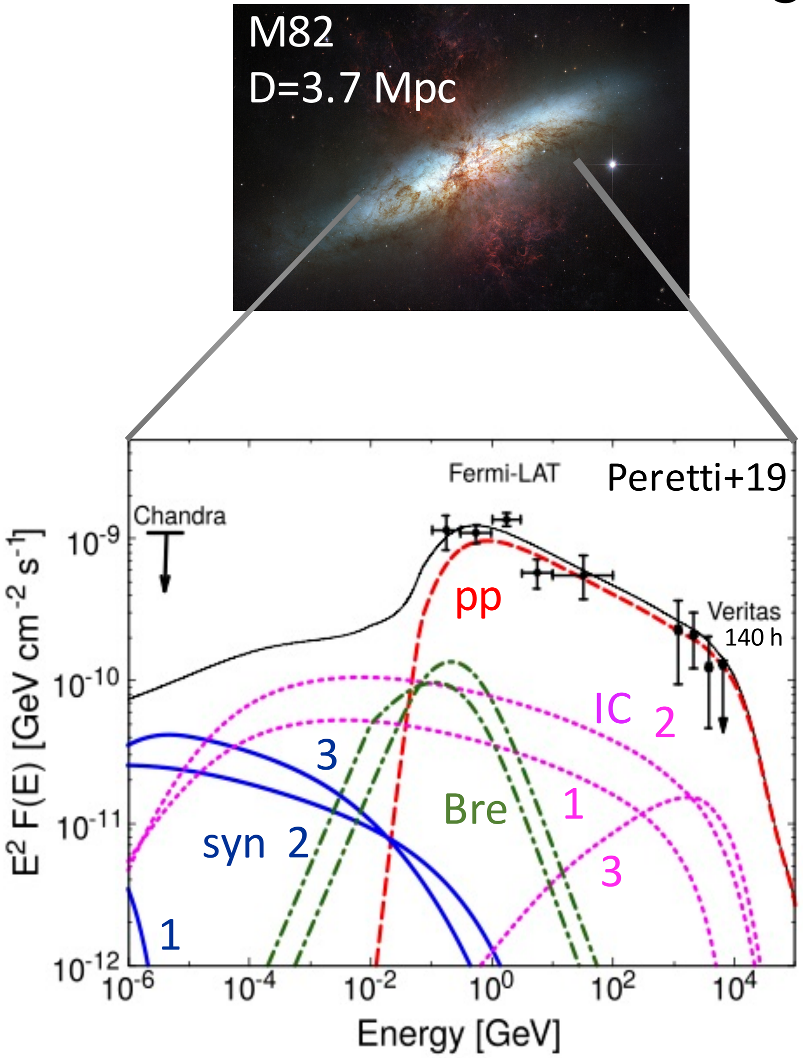
$$\mu^- \rightarrow e^- + \overline{\nu_e} + \nu_\mu$$

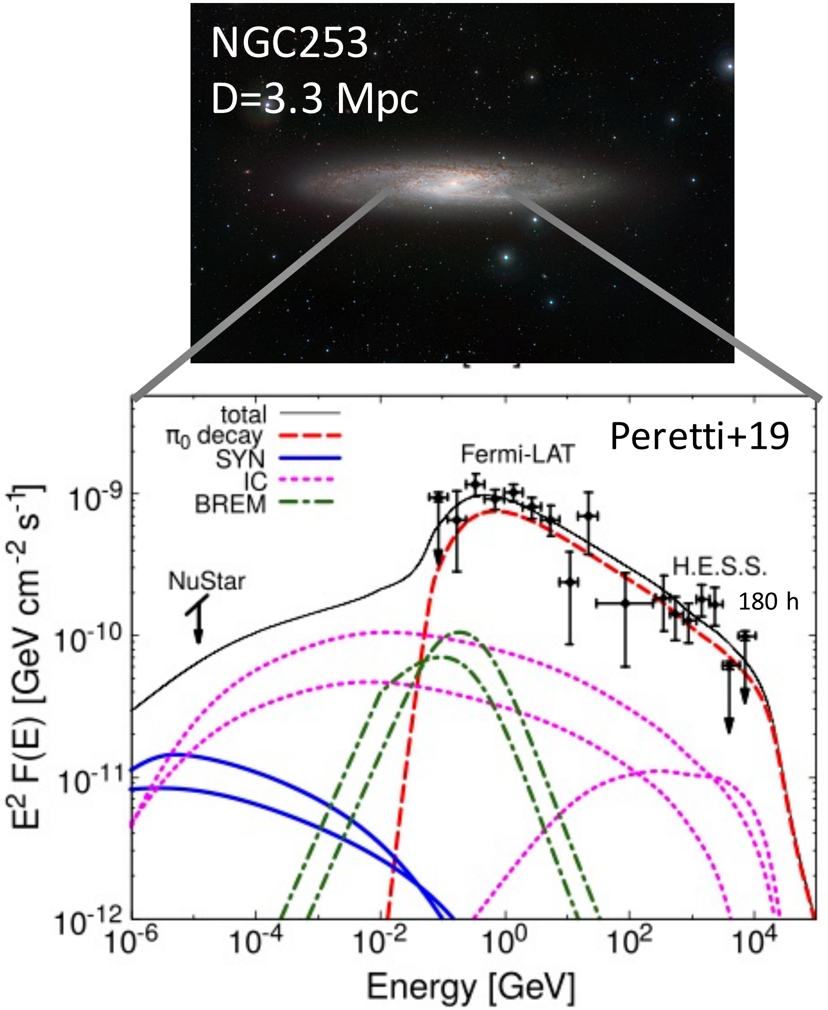


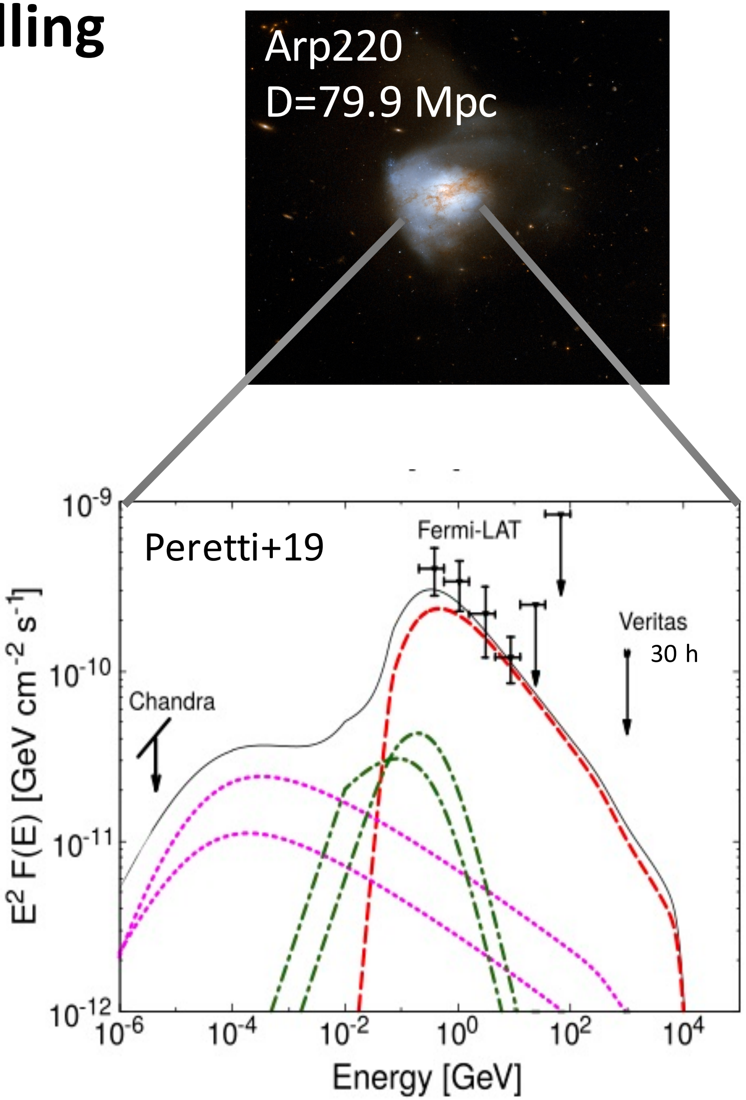
$\boxed{E_p \simeq 10\ E_\gamma \simeq 20\ E_\nu}$

$\boxed{\Phi_\gamma \simeq 2\ \Phi_\nu}$

Starburst galaxies: theoretical modelling







1 → primaries

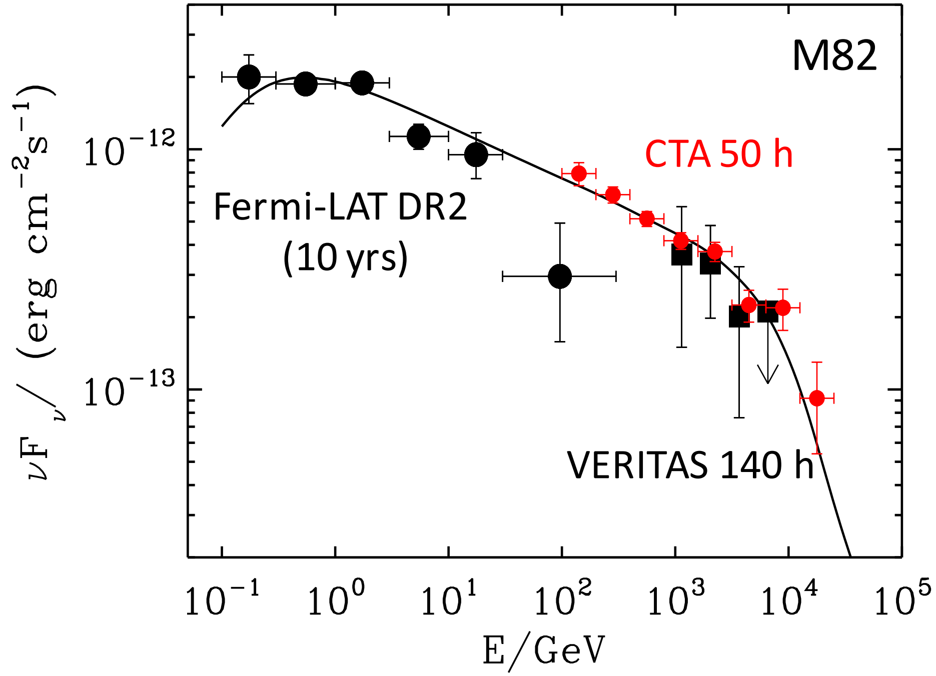
2 → secondaries $\pi^{\pm} \rightarrow \boldsymbol{\mu}^{\pm} \rightarrow e^{\pm}$

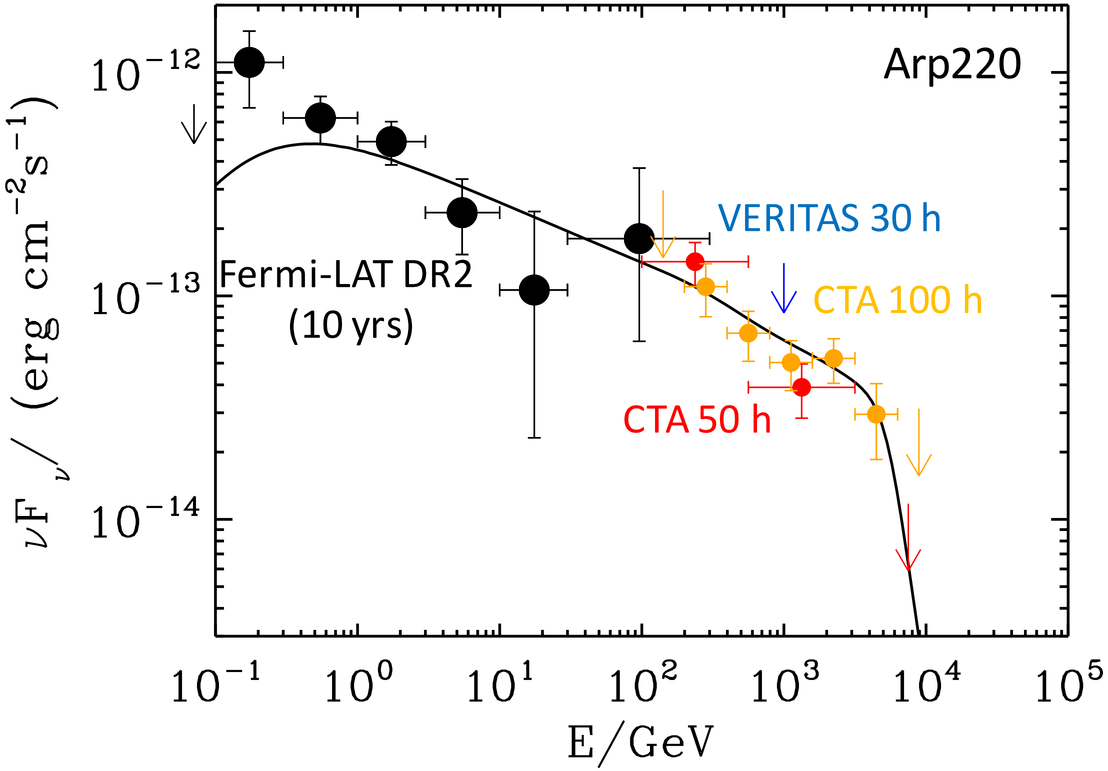
3 → tertiares $\gamma\gamma \rightarrow e^{+}e^{-}$

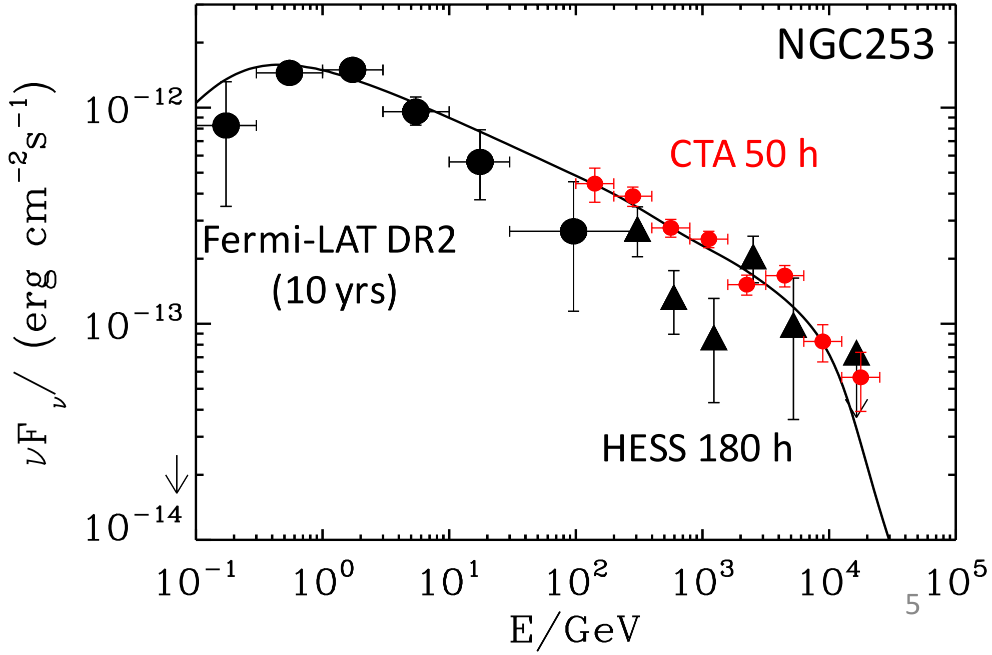
Prospects for observing starburst galaxies with CTA

ctools v. 1.7.2, pubblic CTA IRF v. prod3b-v2

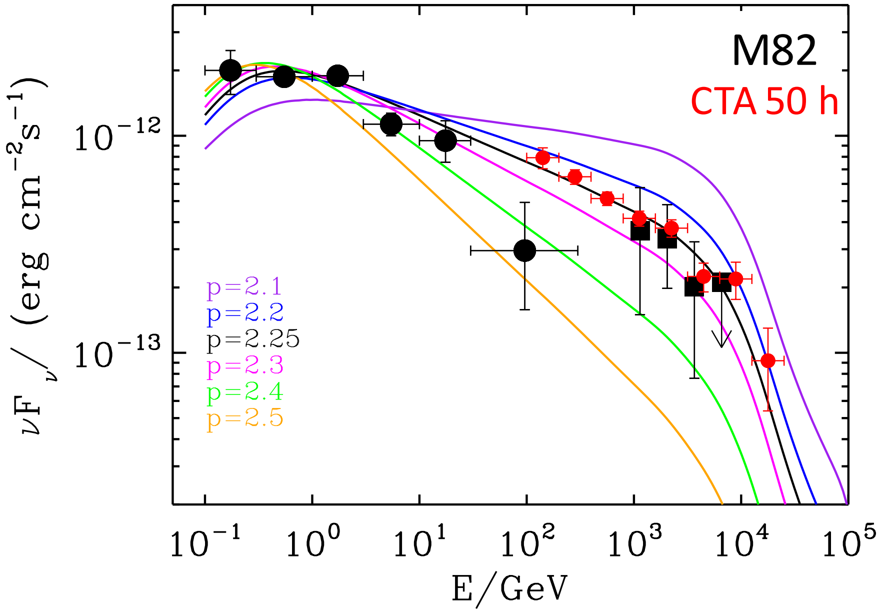
Source	Site	zAngle (deg)	IRF	Expo (h)	Bins	Energy (TeV)	TS	Number
M82	N	< 50	North_z40_50h	50	10	0.1–100	1872	1
NGC253	S	< 40	South_z40_50h	50	10	0.1–100	1272	1
Arp220	N	< 50	North_z40_50h	50	4	0.1–100	39.7	1
Arp220	N	< 50	North_z40_50h	100	10	0.1–100	110.8	1

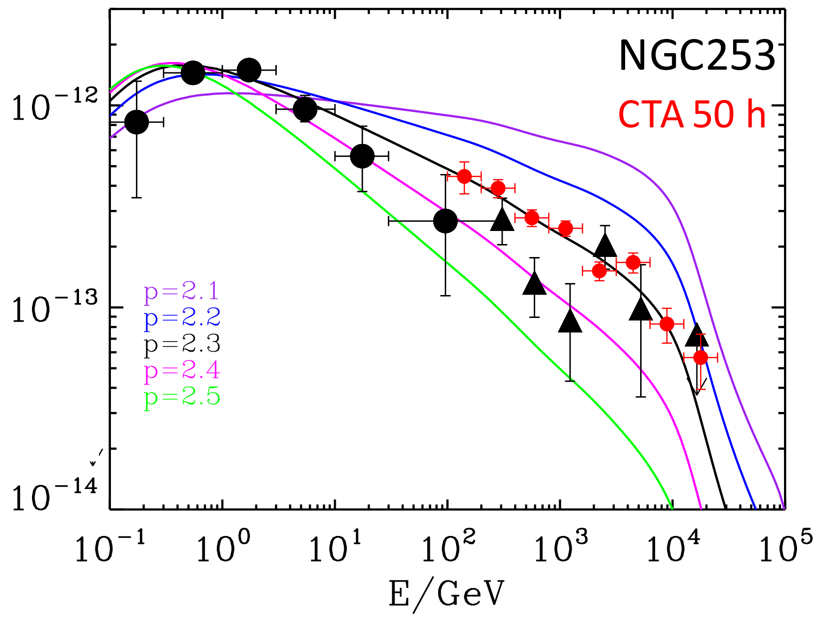


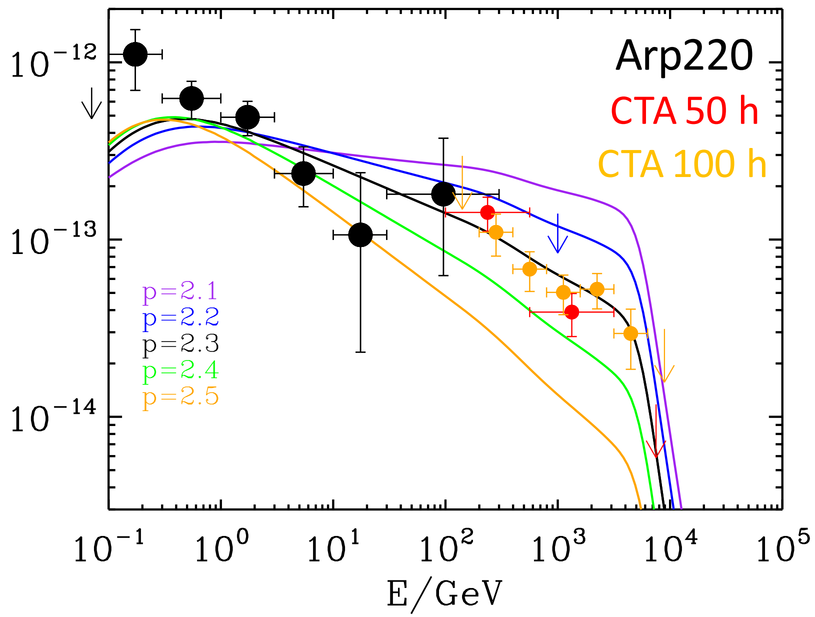




Characterizing the gamma-ray spectrum with CTA: proton spectral slope







M82 simulated spectrum:
proton spectral index p=2.25
proton maximum energy E_{max}=100 PeV
Int. abs + EBL abs

NGC253 simulated spectrum:
proton spectral index p=2.3
proton maximum energy E_{max}=100 PeV
Int. abs + EBL abs

Arp220 simulated spectrum:
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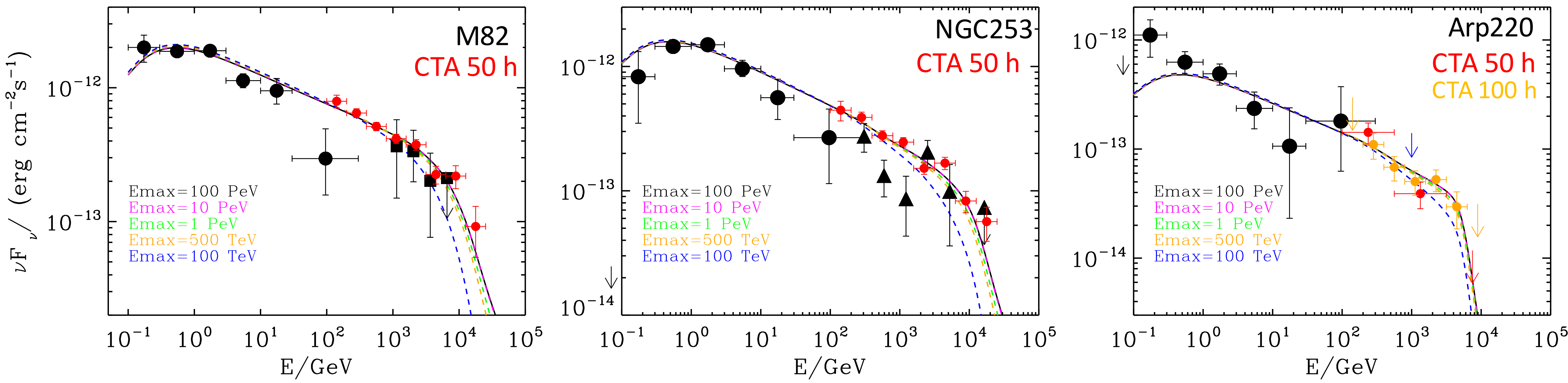
Int. abs + EBL abs

Characterizing the gamma-ray spectrum with CTA: proton maximum energy



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<u>Arp220 simulated spectrum</u>:
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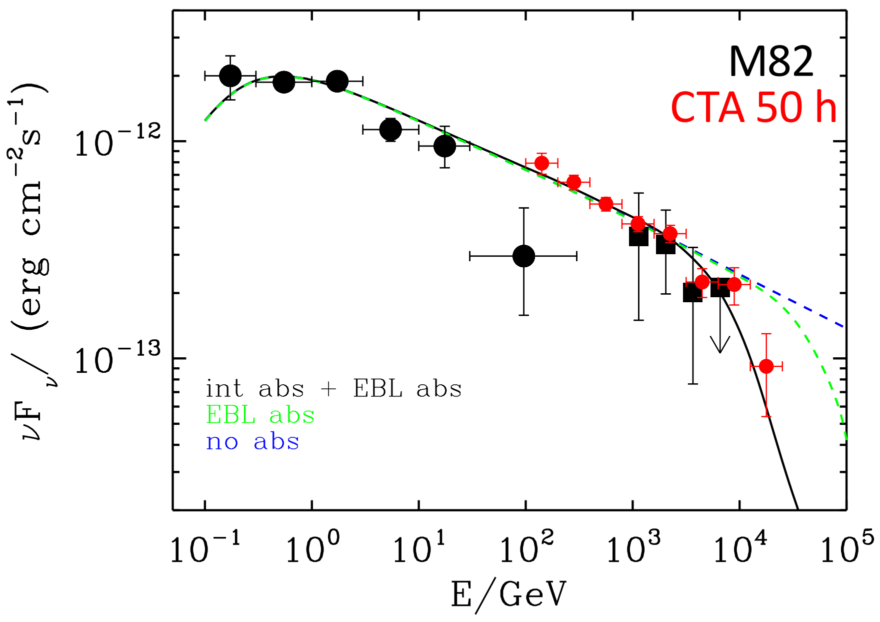
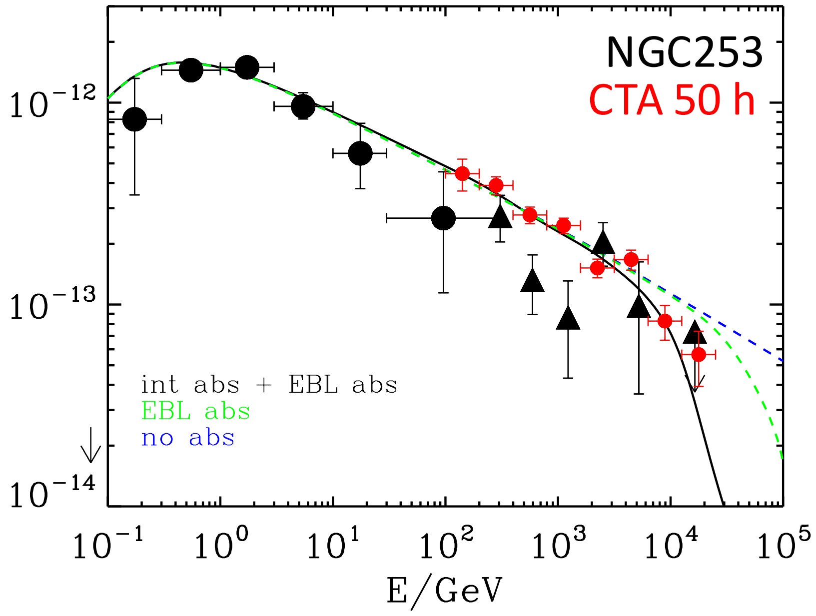
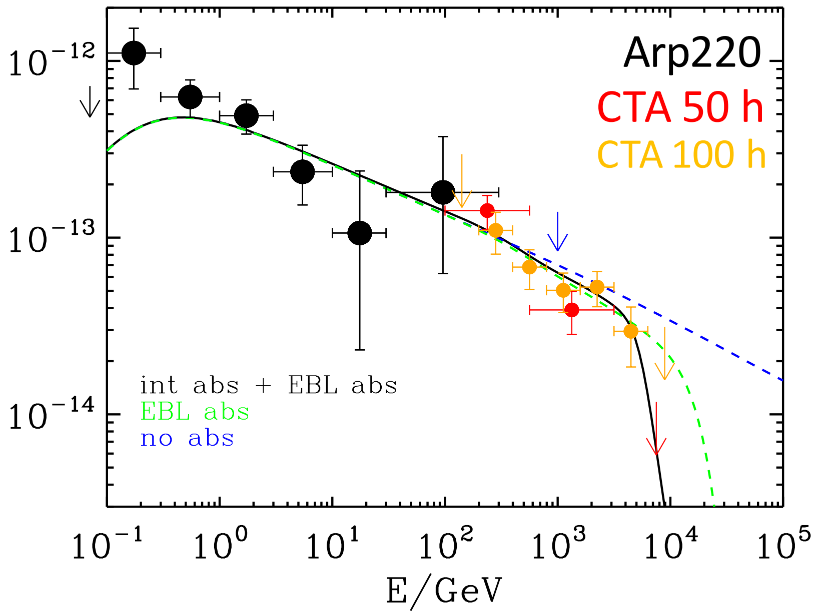
Characterizing the gamma-ray spectrum with CTA: gamma-ray absorption







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Summary

- ✓ CTA observation (50h) of the starburst galaxies M82 and NGC 253: constraints on the spectral slope and on the maximum energy of the accelerated protons. CTA will also allow us to test the effect of gamma-ray absorption inside the starburst nuclei.

- ✓ CTA observation (50h) of Arp 220: first detection of an ULIRG in the VHE band, constraints on the spectral slope, no constraints on the proton maximum energy and gamma-ray absorption even with a longer exposure time (100h).