Air showers – from LHC to CTA

From the caverns of CERN to the top of the atmosphere and on to the Galactic plane

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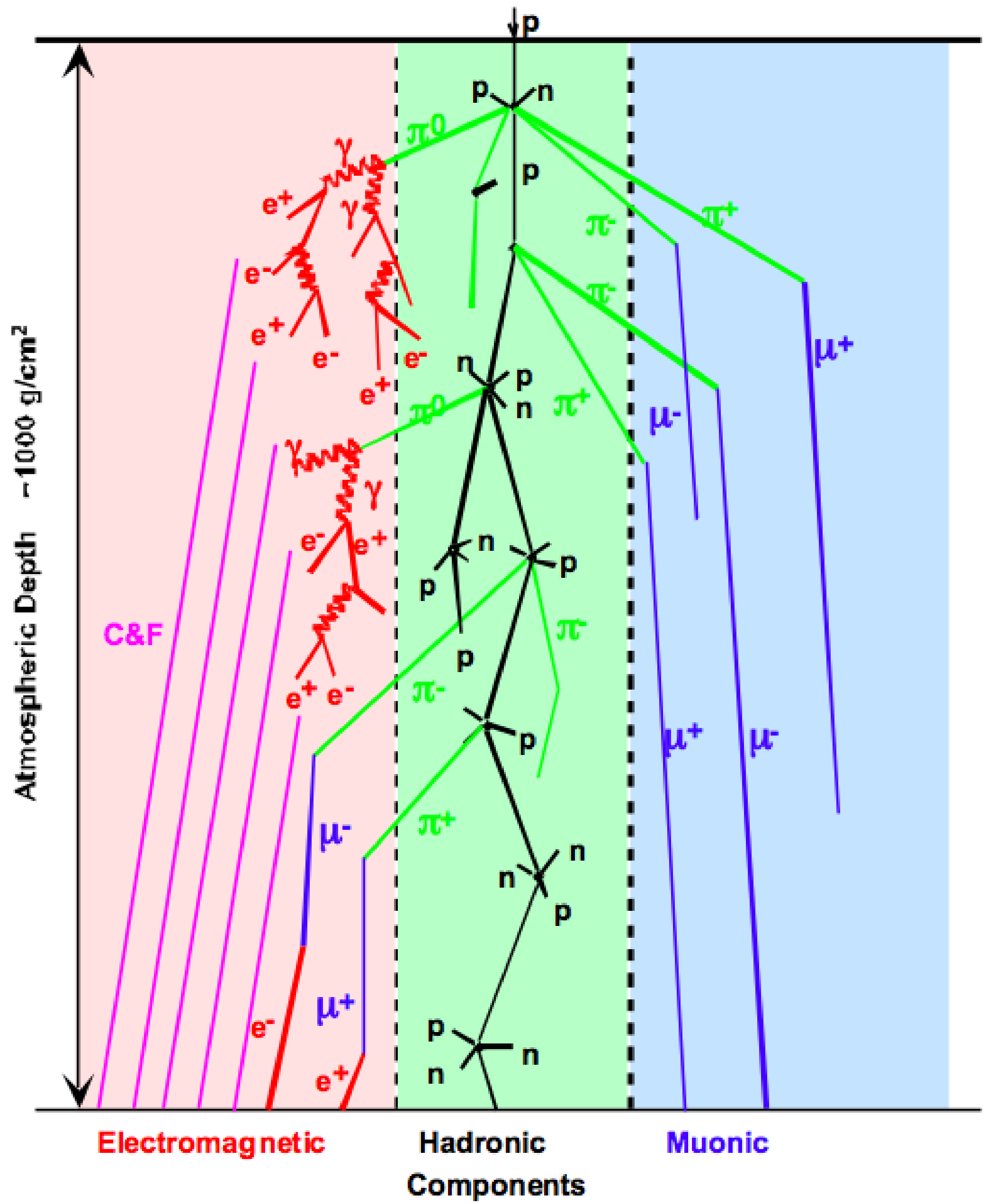
GRAPPA INSTITUTE
Gravitation **A**stro**P**article **P**hysics **A**msterdam

The air-shower connection

energy, particle type, direction ???

HESS
Auger
IceCube / Antares / KM3Net

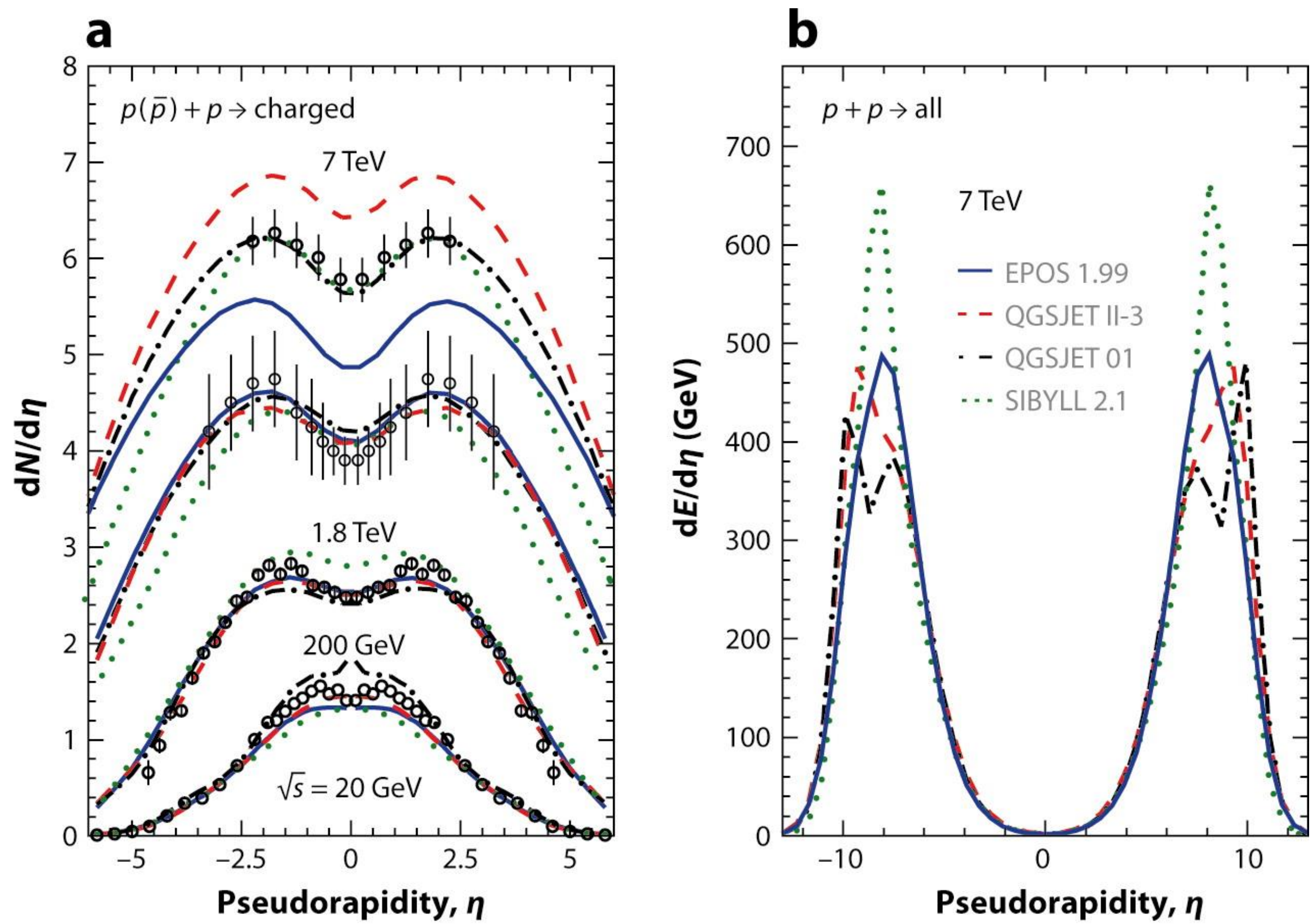


LHC input to understand hadronic physics in air showers (as input to APP experiments): well known use case, yet without almost *ANY* effort.

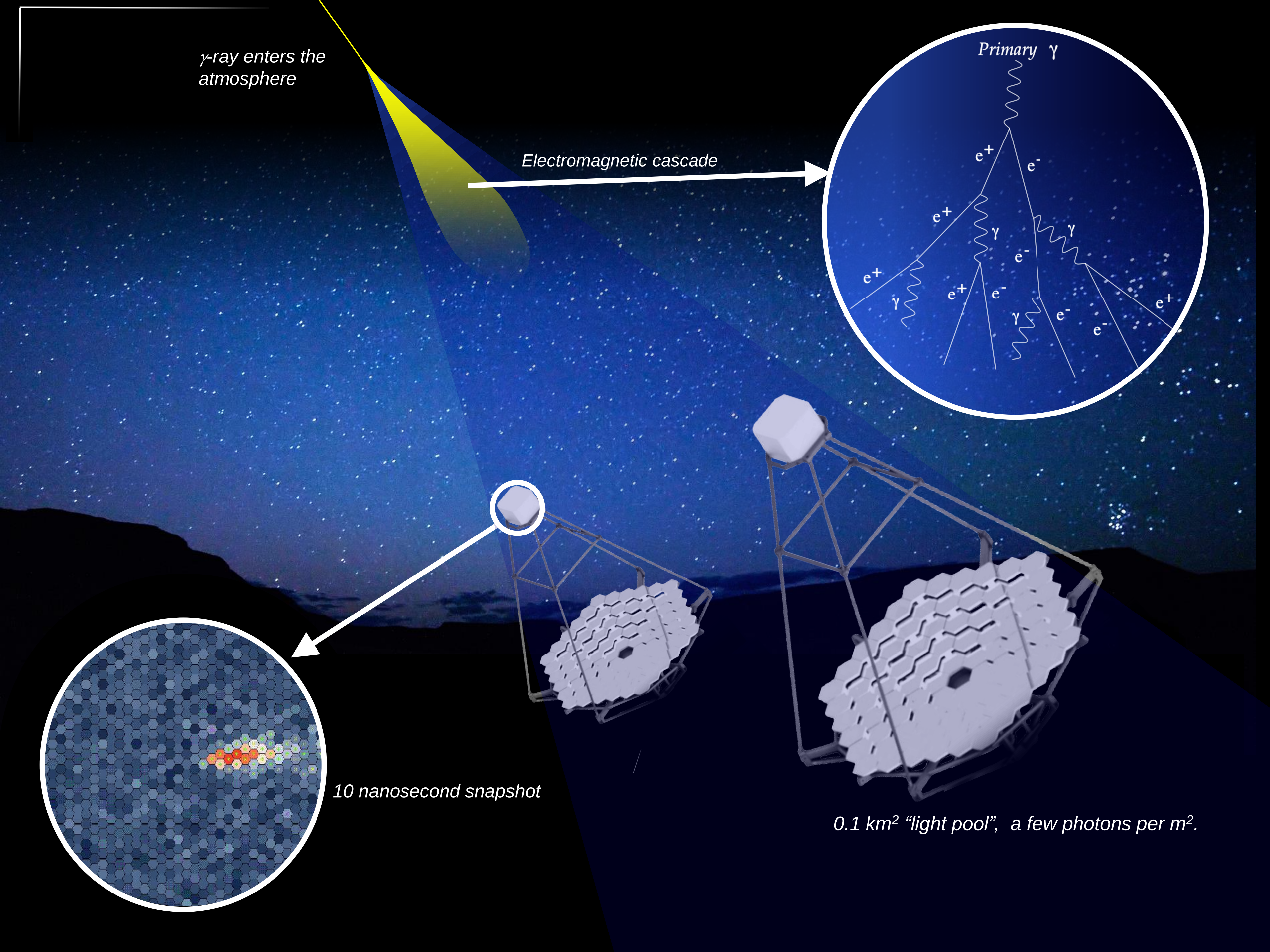
Probe energies beyond the CR knee at CERN

<u>Extrapolations needed:</u>

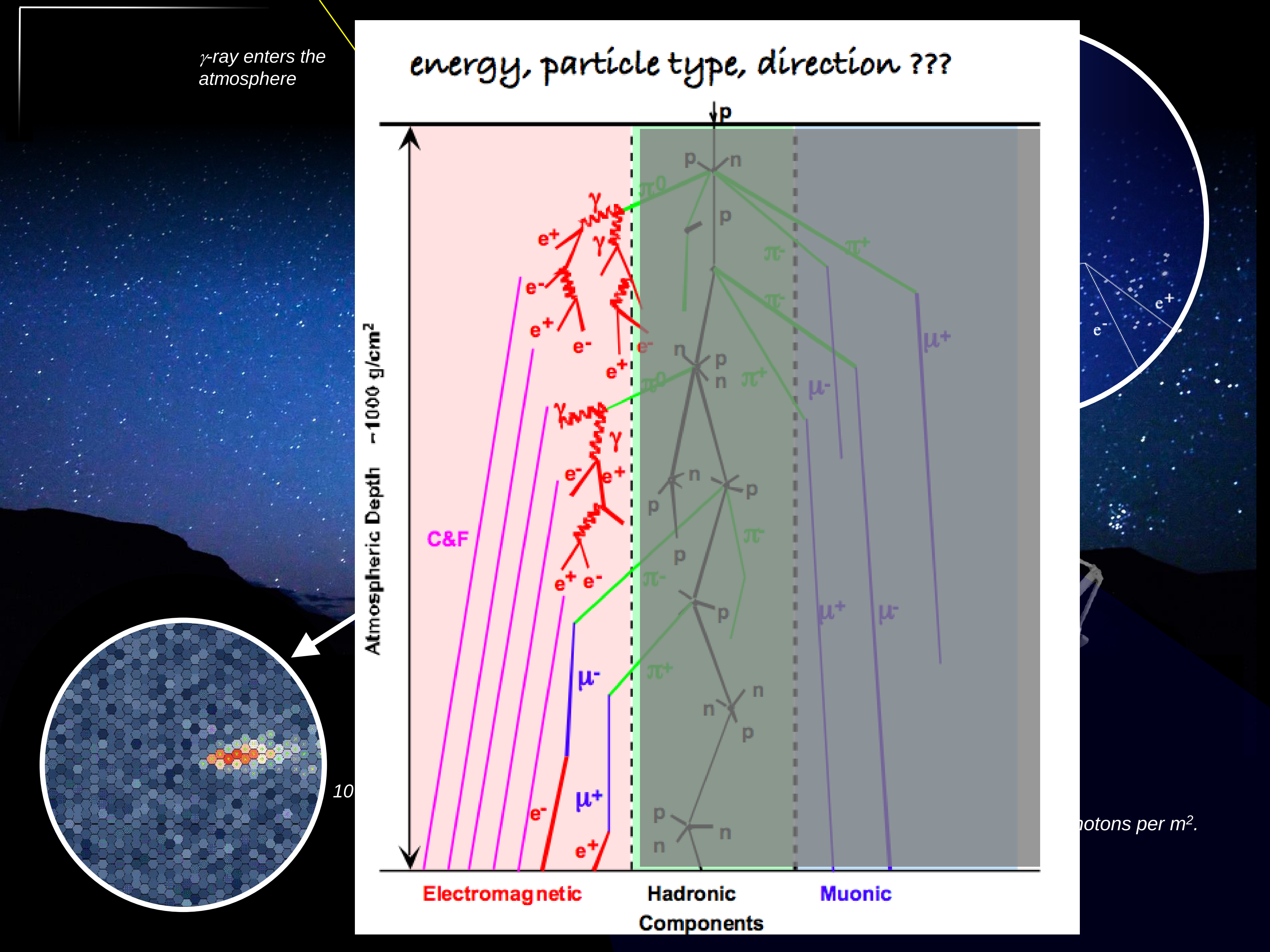
- Energy
- Central to very forward particle production
- proton-proton to proton-Air



Engel R, et al. 2011.
Annu Rev. Nucl. Part. Sci. 61:467–89



γ-ray enters the atmosphere
Electromagnetic cascade
Primary γ
e+
e-
γ
10 nanosecond snapshot
0.1 km^2 “light pool”, a few photons per m^2.

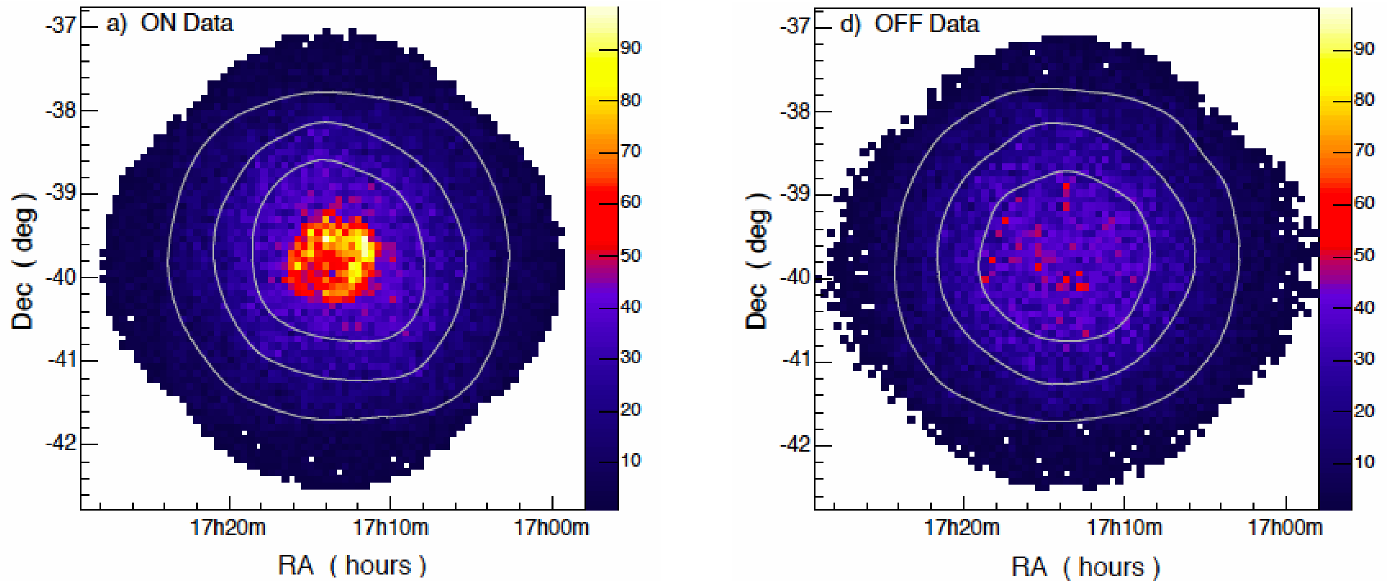


γ-ray enters the atmosphere
energy, particle type, direction ???
p
Atmospheric Depth ~1000 g/cm²
C&F
Electromagnetic
Hadronic
Muonic
Components
10
otons per m².

Background modeling for Cherenkov telescopes

Irreducible background

Berge, Funk, Hinton (2006)

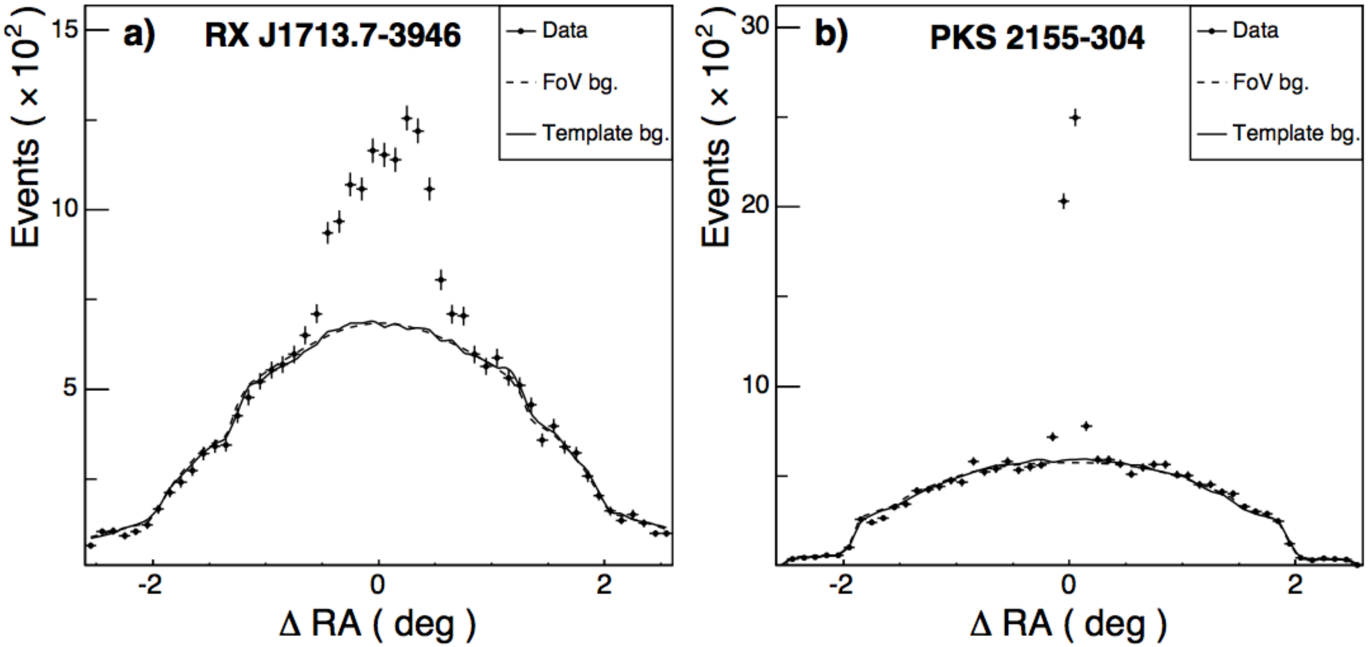


Ground-based γ-ray telescopes suffer from an irreducible and diffuse background, any "empty field" is not empty but rather a mix of:

- charged hadronic cosmic rays
- charged electrons
- large scale (diffuse) γ-ray emission

Irreducible background

Berge, Funk, Hinton (2006)



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Background modeling strategies

γ-ray-like background event rate =

CR flux ×

$\sigma_{pAir \rightarrow \gamma\ anything}$ ×

atmospheric transmission ×

detector response

Background modeling strategies

γ-ray-like background event rate =

CR flux ×

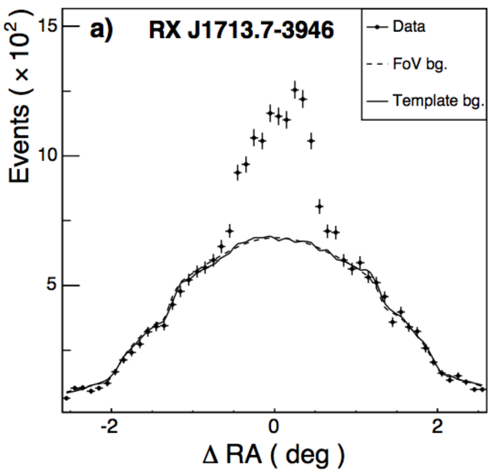
$\sigma_{pAir \rightarrow \gamma \text{ anything}}$ ×

atmospheric transmission ×

] Absolute level

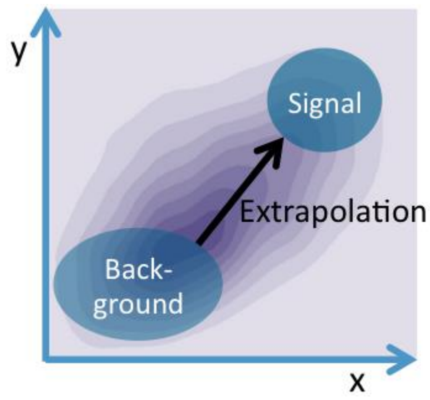
detector response

] Shape



Background modeling strategies

Sideband techniques (γ-ray free region) to estimate shape and level



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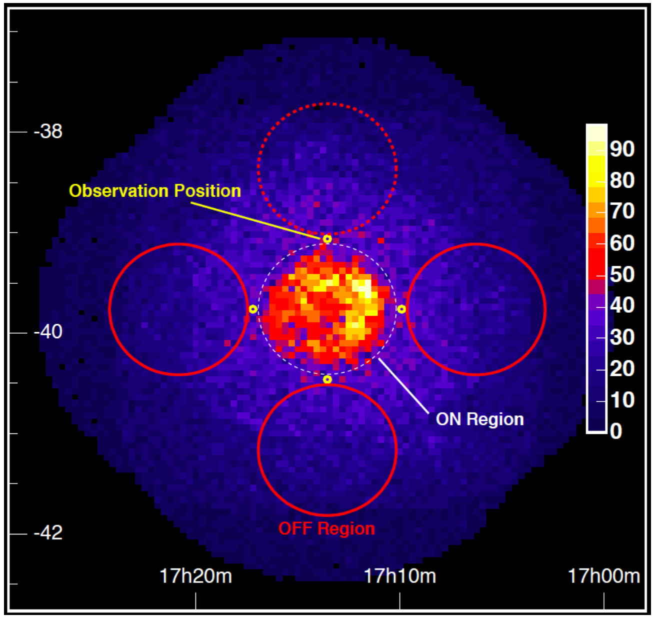

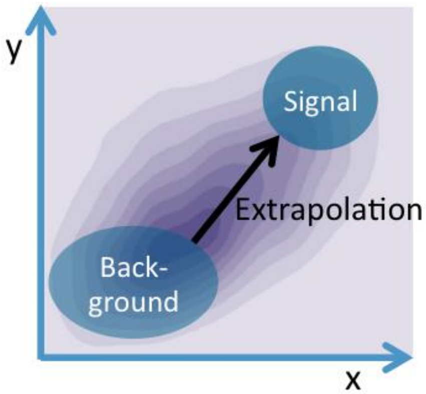

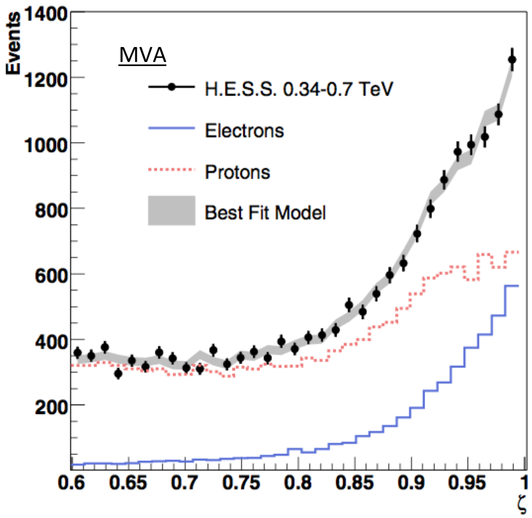

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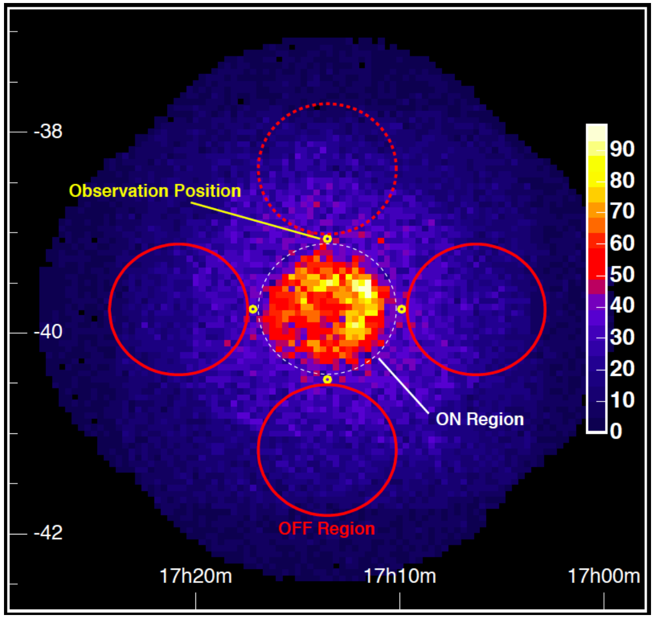
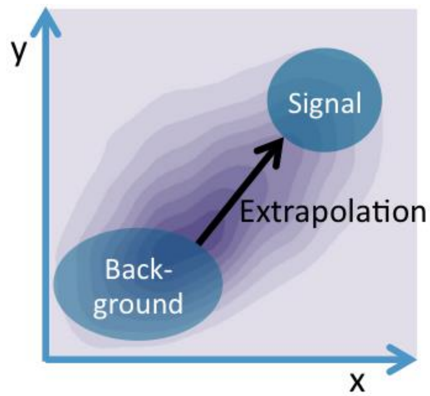
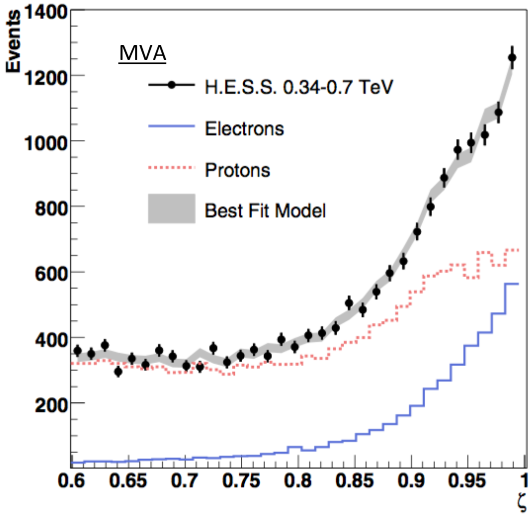
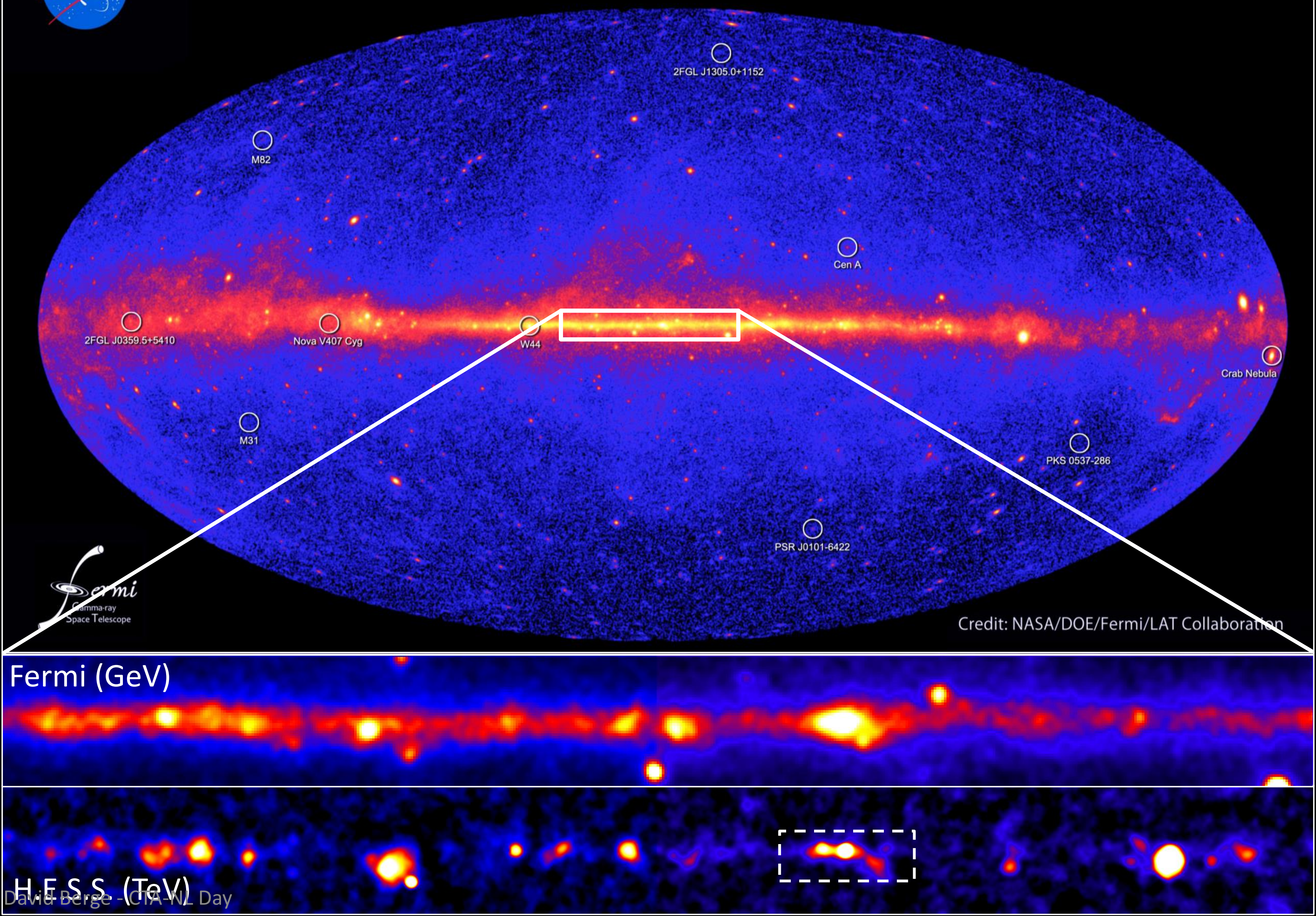




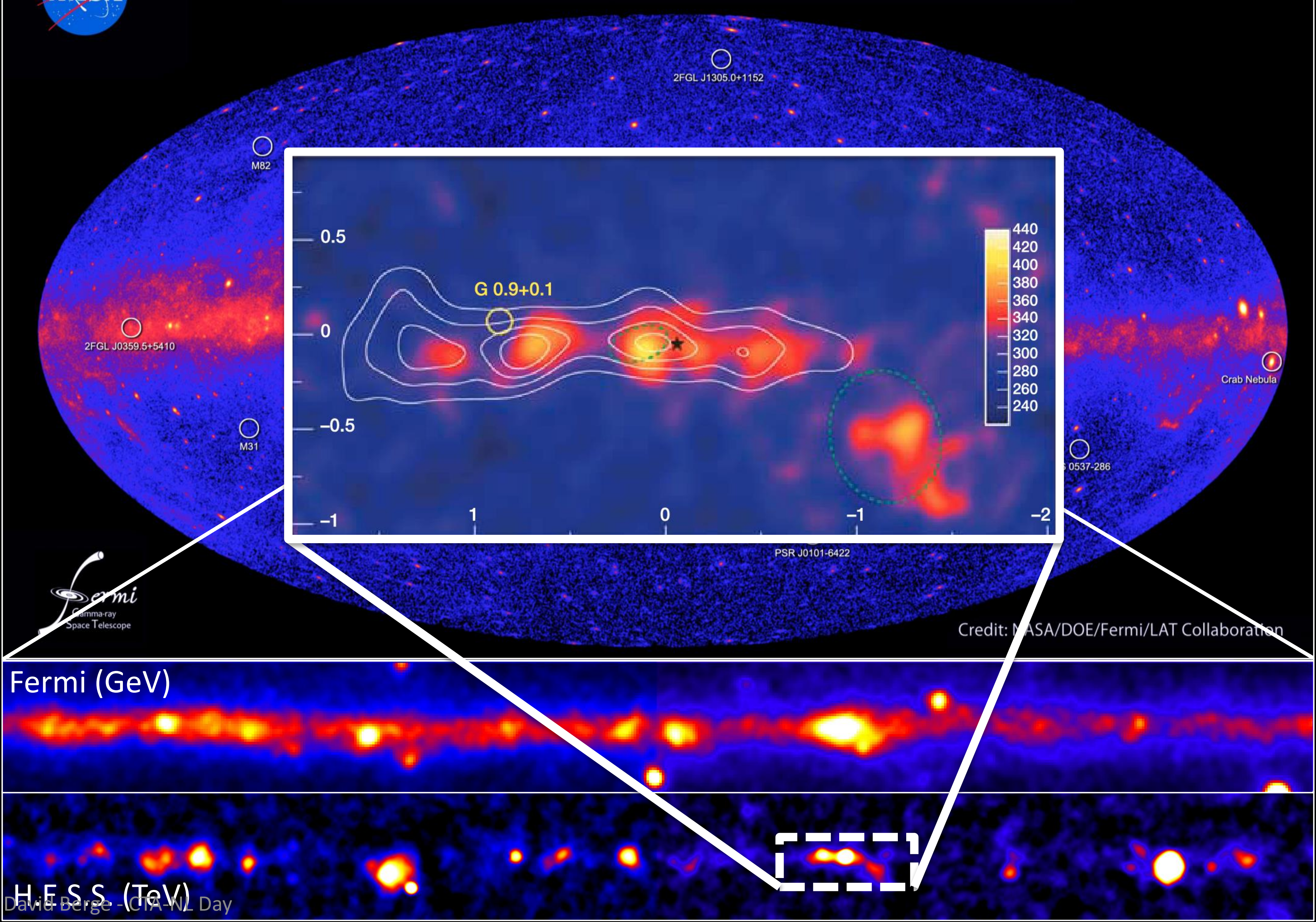


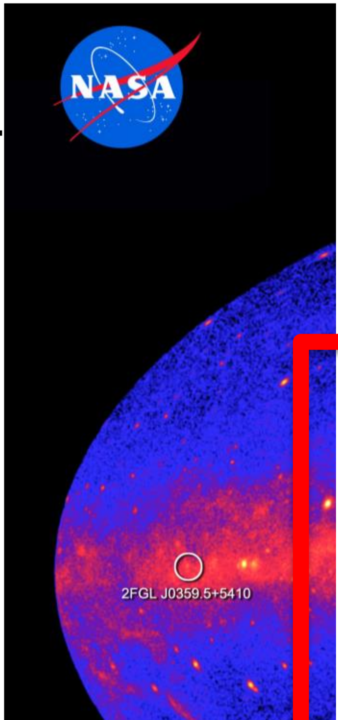
Background modeling challenging for large emission regions

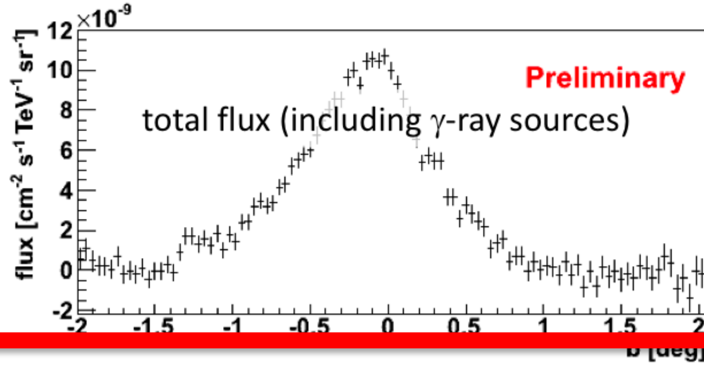
Fermi two-year all-sky map

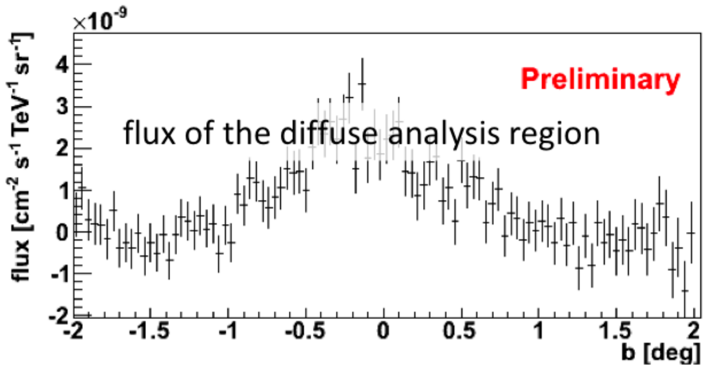


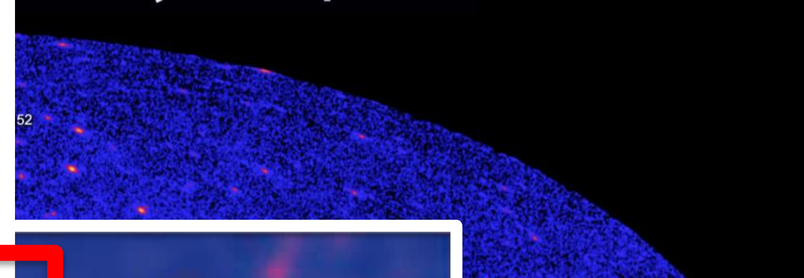
Fermi two-year all-sky map



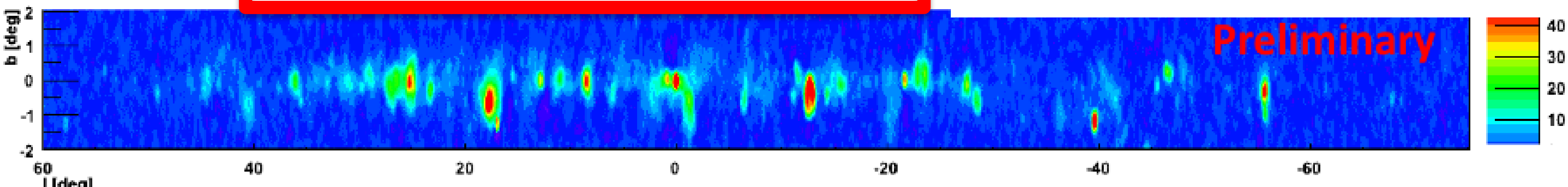




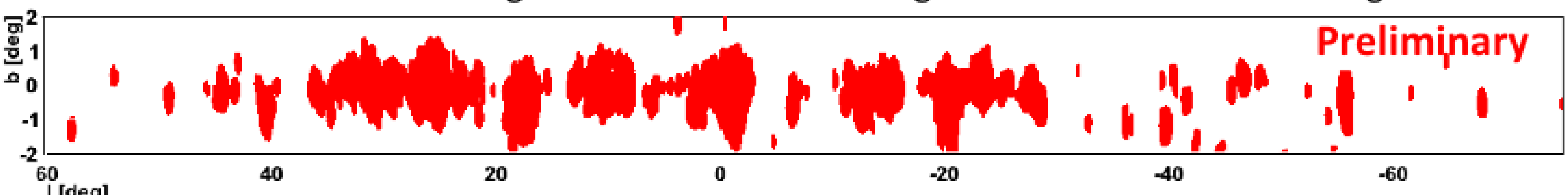


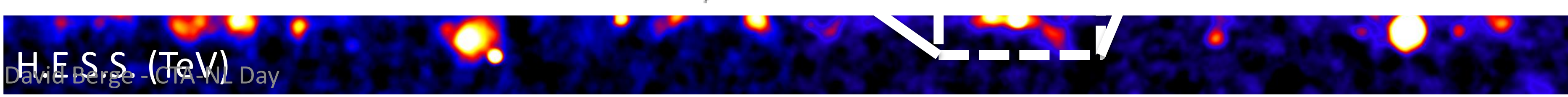


HESS at ICRC'13, diffuse TeV γ-ray flux starts to be accessible!



regions excluded from background subtraction according to criterion (1)





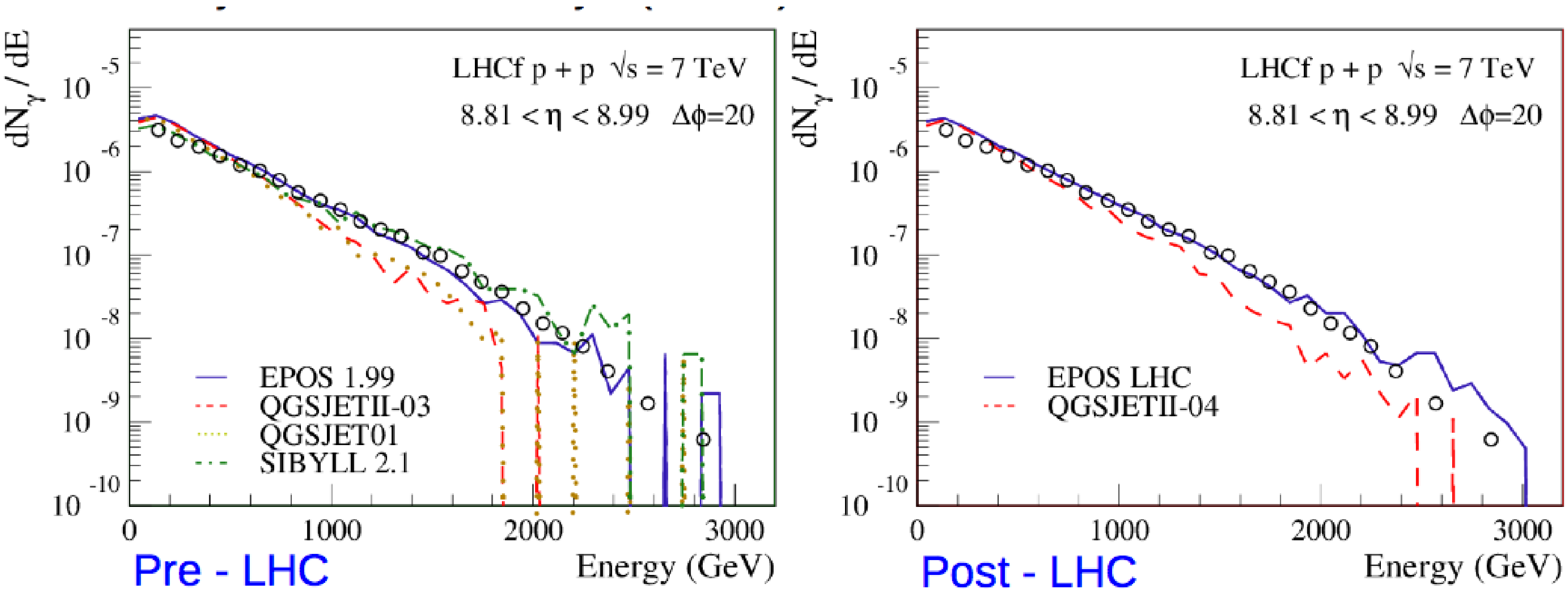
Opportunity: improve air-shower simulations with LHC data for γ-ray astronomy

Air-shower simulations for γ-ray astronomy

- Pre-LHC tunes used everywhere (as far as I know)
- But now for CTA, atmospheric and system monitoring will be MUCH better
- A real use case for improving Monte Carlo simulations (and allow for background Monte Carlo modeling)!
- Particularly interesting: LHCf measurements of forward photons

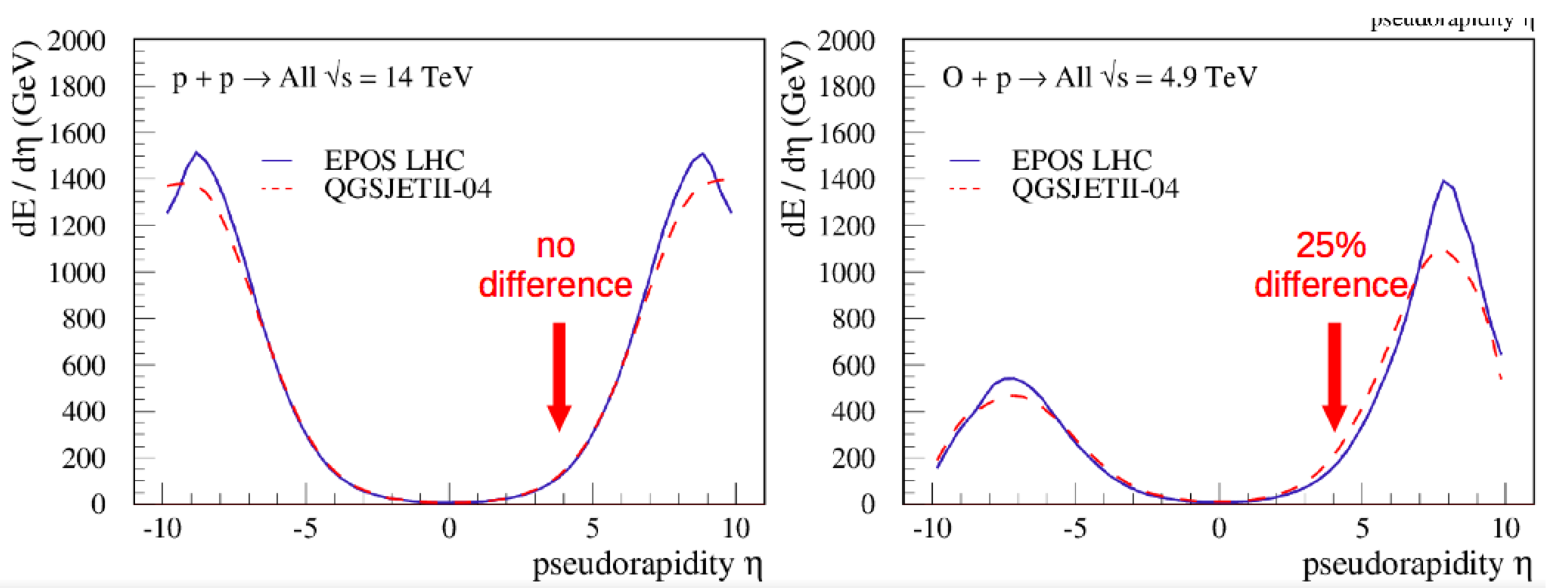
LHCf photon spectra

EPOS LHC tuned to multiplicity spectra with significantly improved data agreement



Future at LHC: p-Air…?

- LHC currently upgrading from 8 to 13 (14) TeV
- Will yield little improvement for air shower simulations
- Much more useful would be to run proton-Oxygen collisions (discussions ongoing…)



Air showers – from LHC to CTA

- Good opportunity in the NL with Nikhef / LHC groups
- And MC simulations are of course even more important for Auger
- Also relevant for neutrino telescopes (high-energy neutrino production in the atmosphere from charmed mesons…)