GAMMA-RAY ASTRONOMY AT THE HIGHEST ENERGIES WITH CTA

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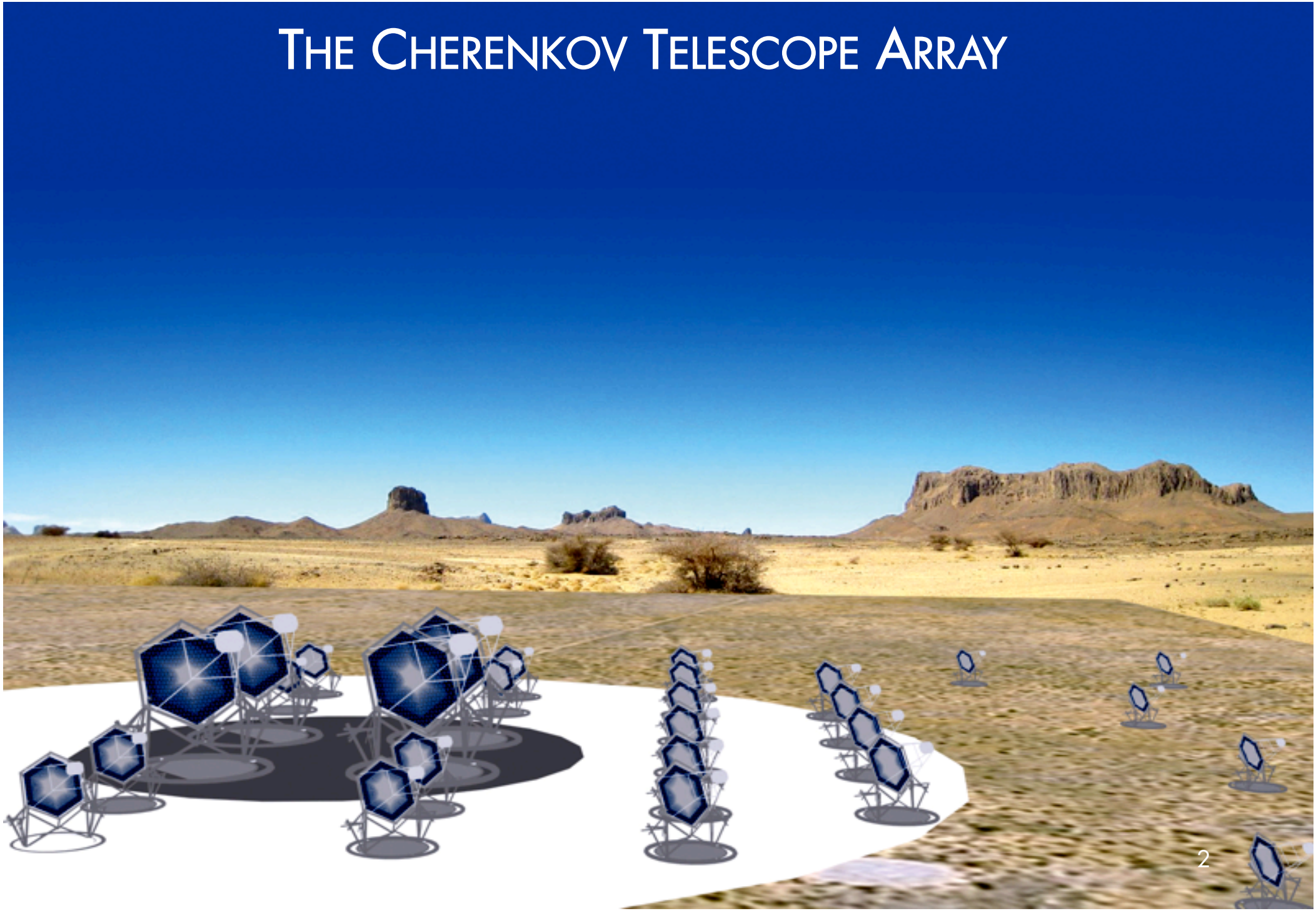
FOR THE UK CTA GROUPS

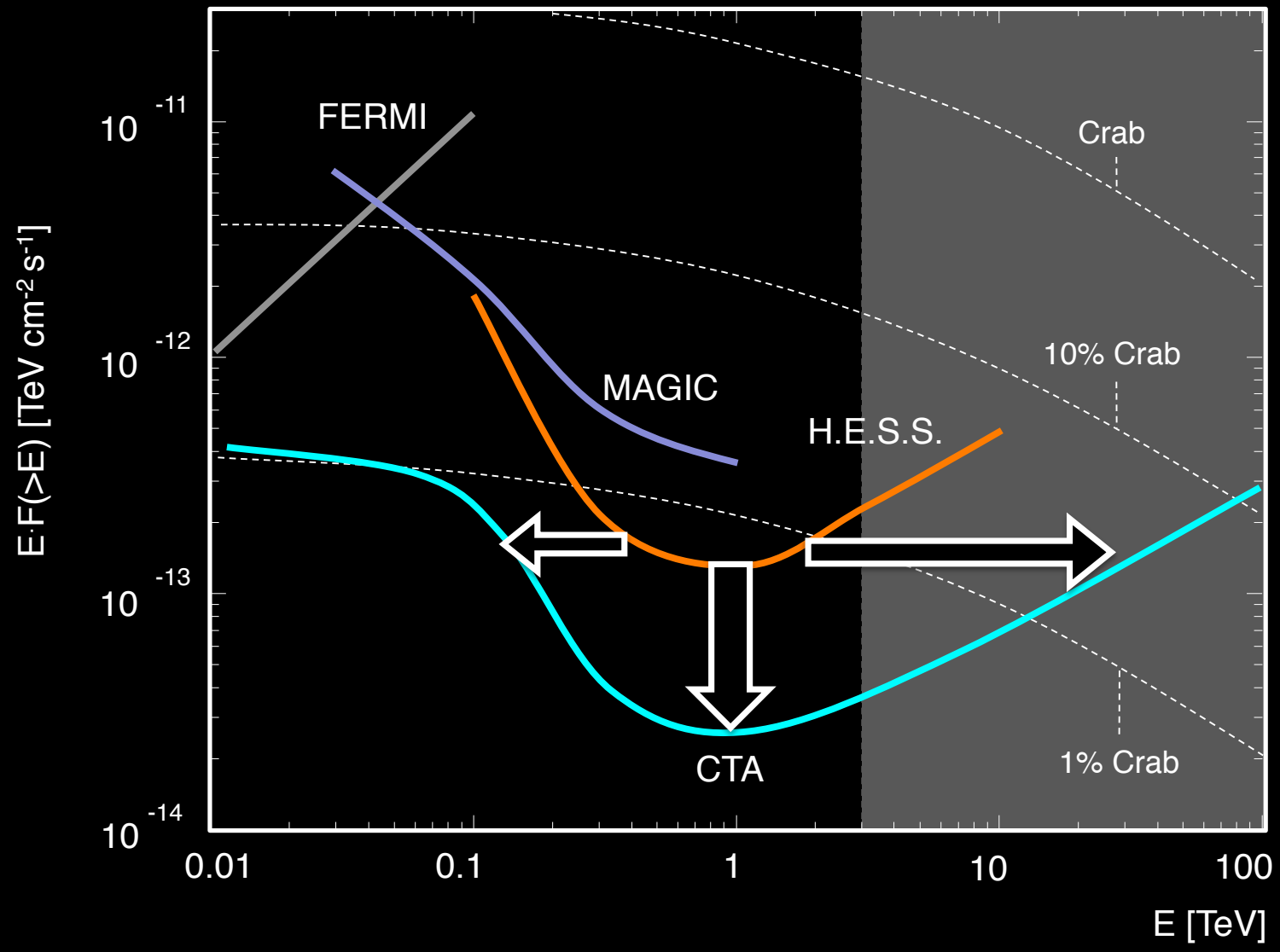
IOP, UCL, MARCH 2010

UNIVERSITY OF LEEDS

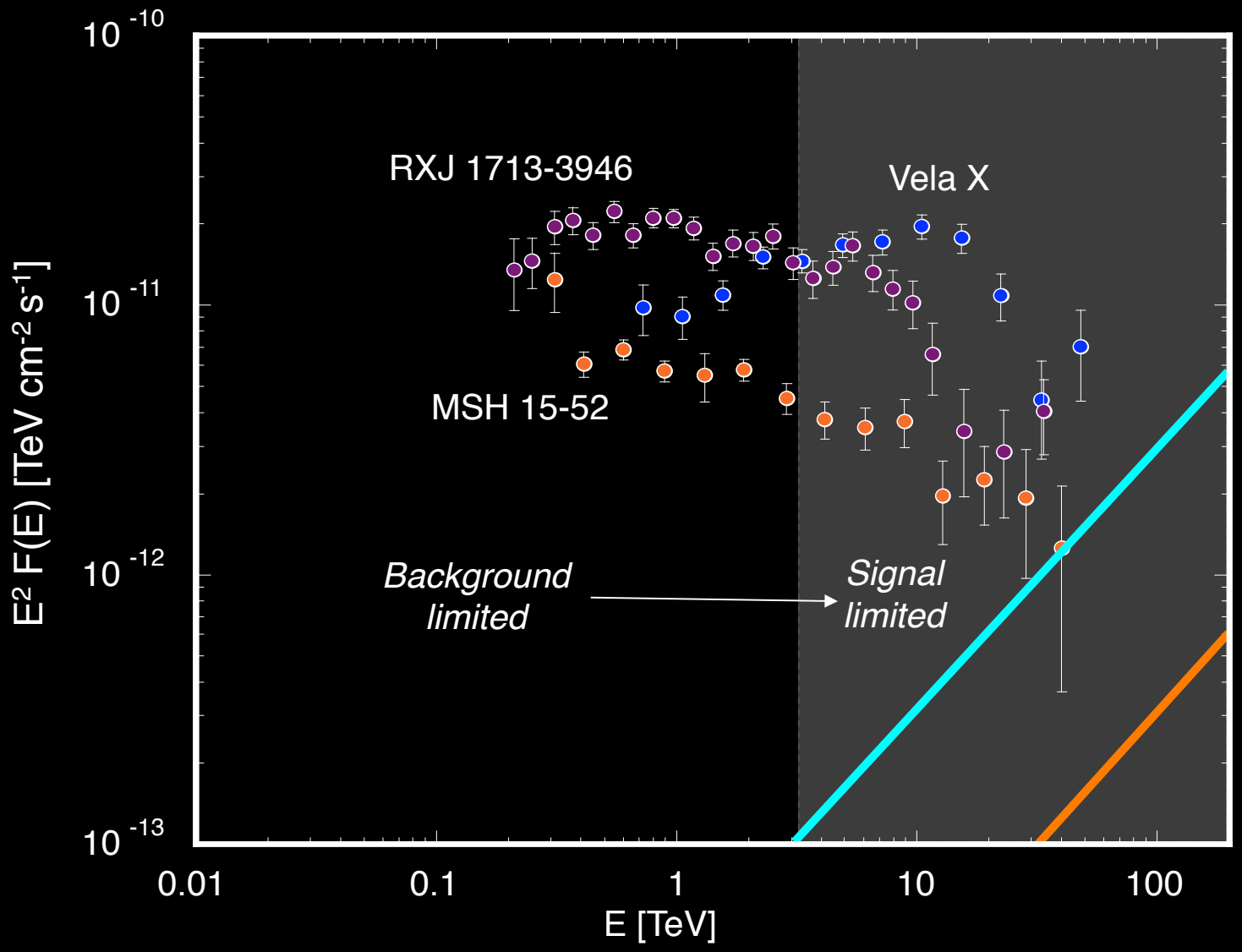
The Cherenkov Telescope Array



CTA Goal Sensitivity



The Problem at High Energies



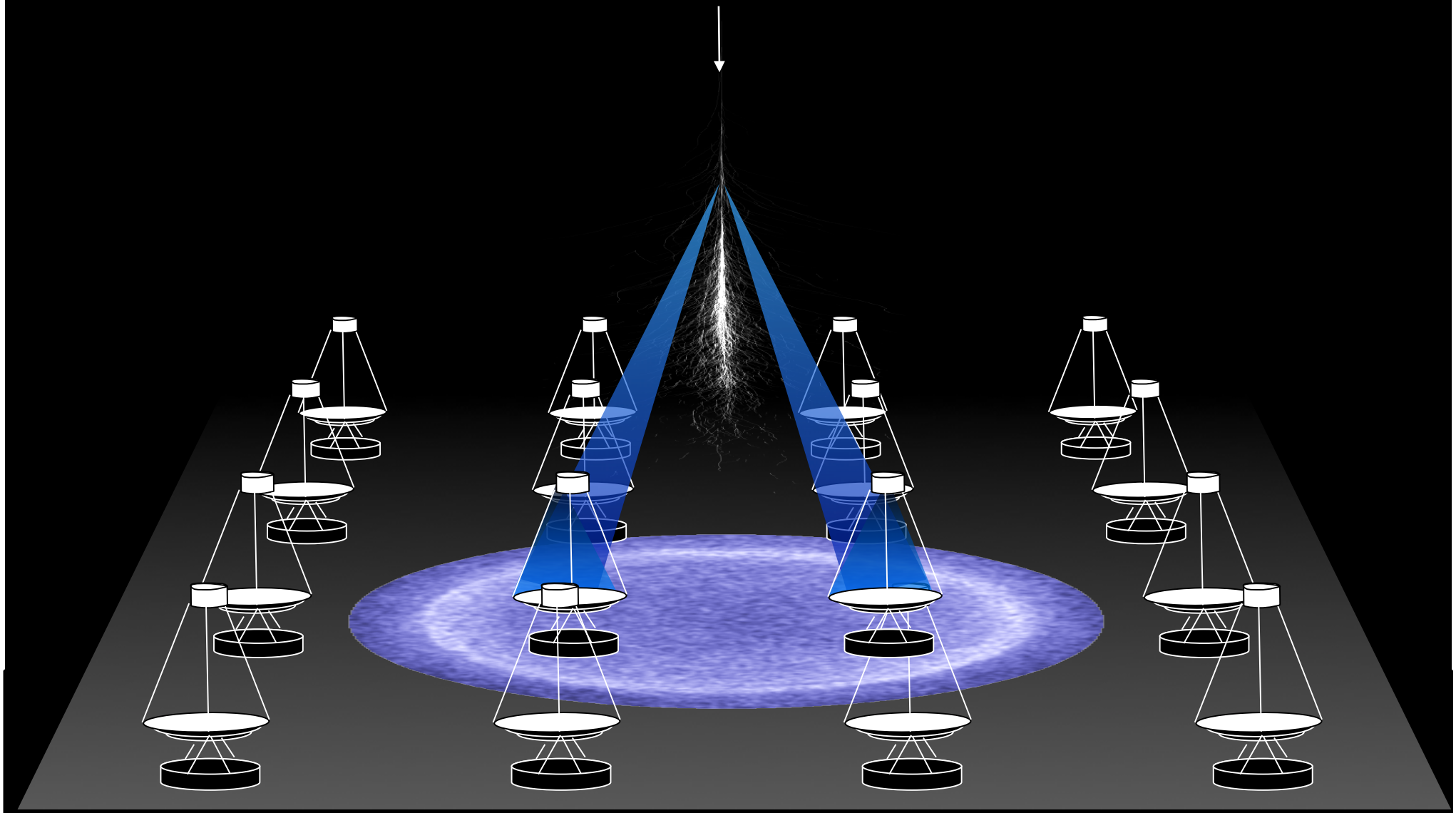
10 photons in:

10 km² hours

100 km² hours

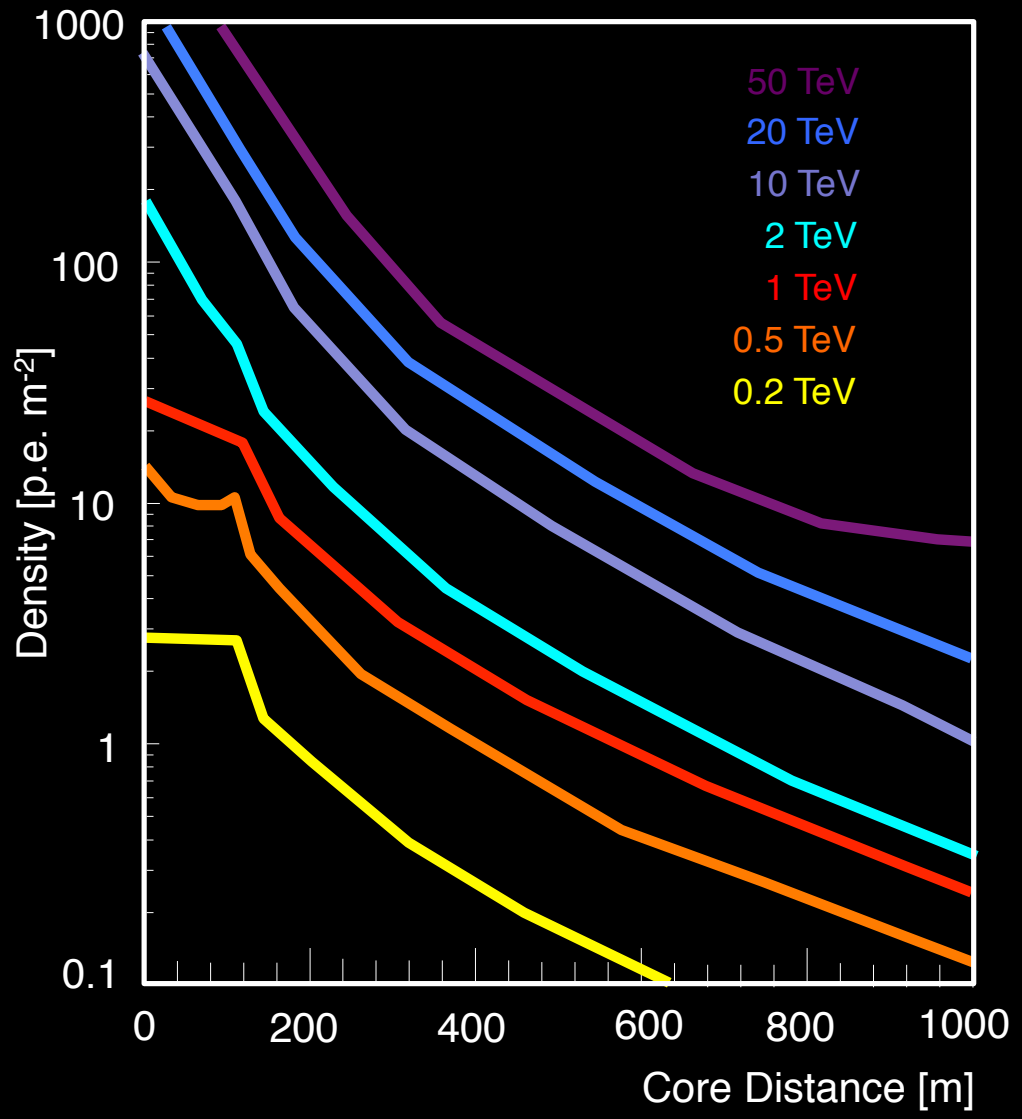
Adapted from Werner Hofmann

Collecting Cherenkov Light



Telescope Spacing

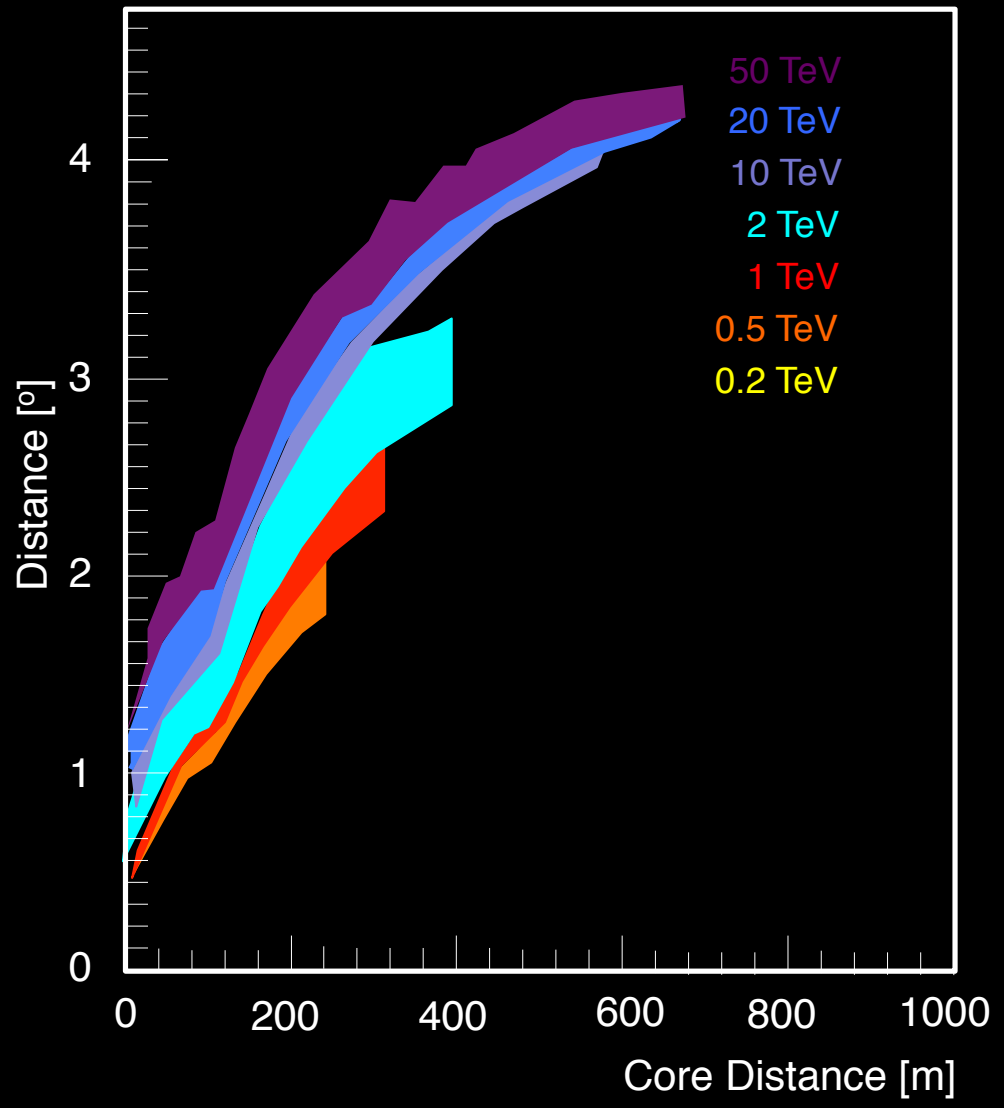
- Cherenkov light useful out to >600 m at few TeV
- Greater spacing requires larger reflectors.



Adapted from de La Calle Perez, Biller, 2006

Field of View

- Cherenkov light useful out to >600 m at few TeV
- Greater spacing requires larger reflectors.
- Greater spacing requires larger field of view:
  - 3 - 5° at 100 m (current)
  - 7 - 8° at 200 m
  - 10 - 11° at 600 m



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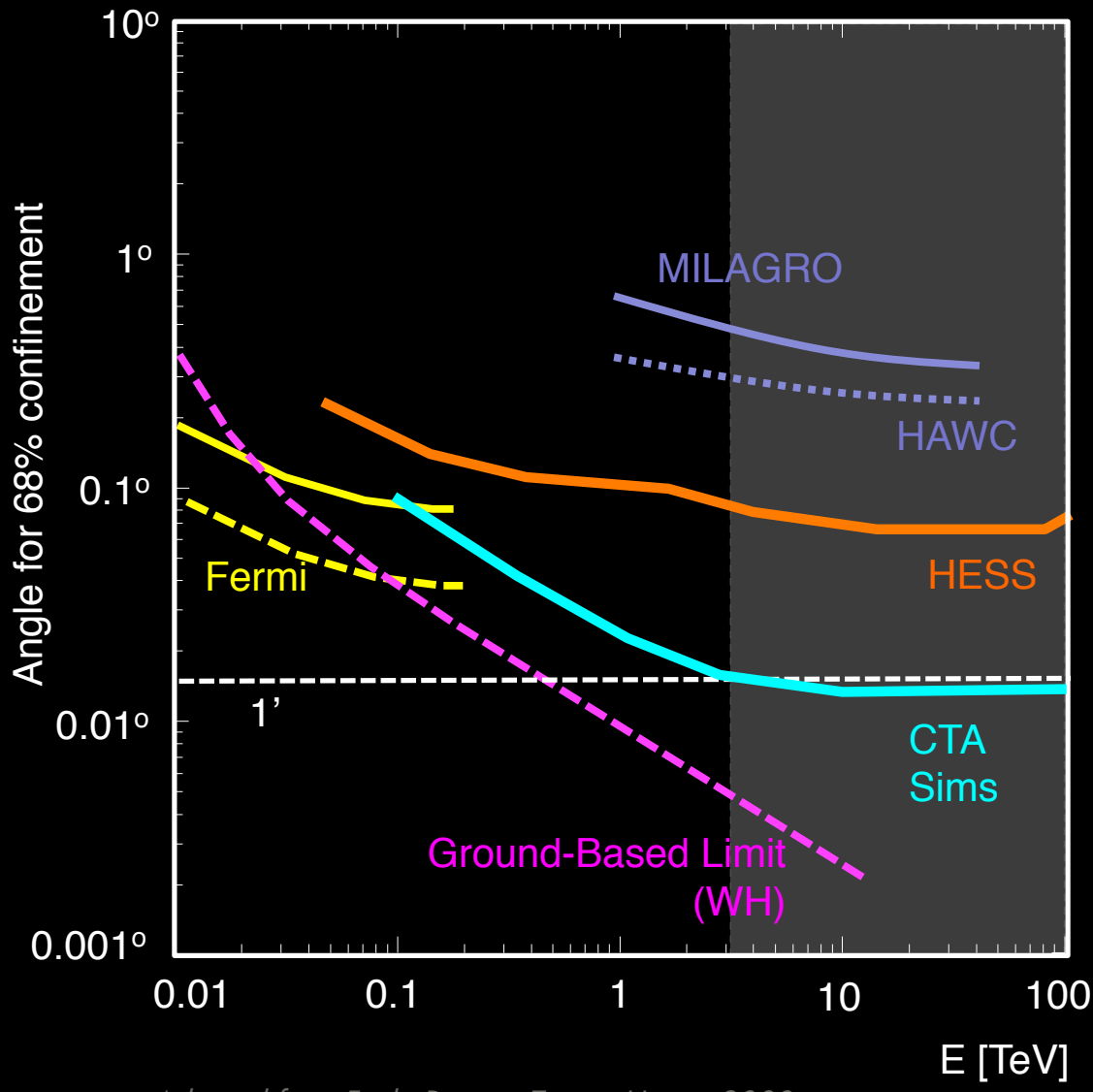
The Opportunity at High Energies

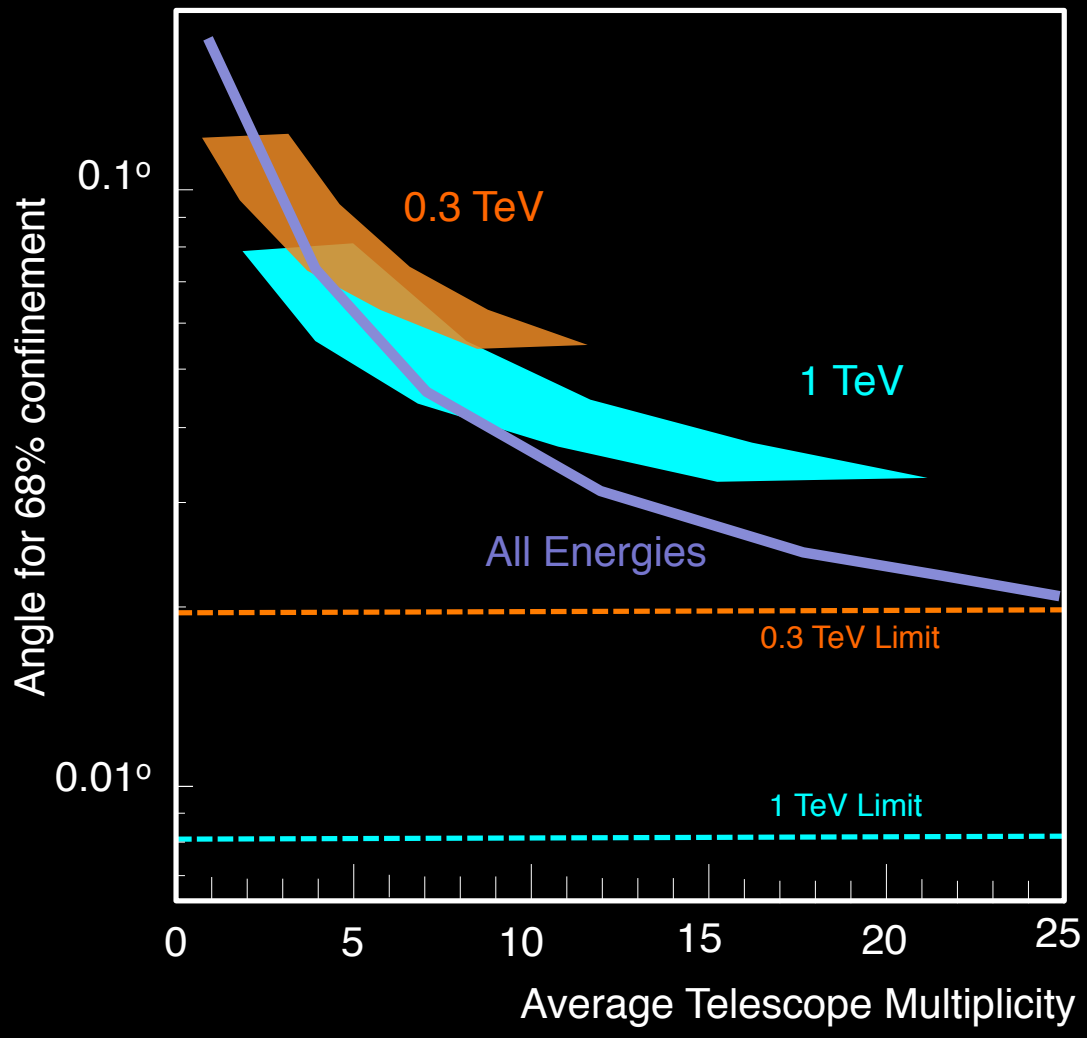
- Angular Resolution!
- High precision only achievable > TeV:
  - Limit: few " at 30 TeV
  - 1′ is achievable at 100 TeV with modest collection area.
  - x 5 improvement from HESS



Adapted from Funk, Reimer, Torres, Hinton 2008

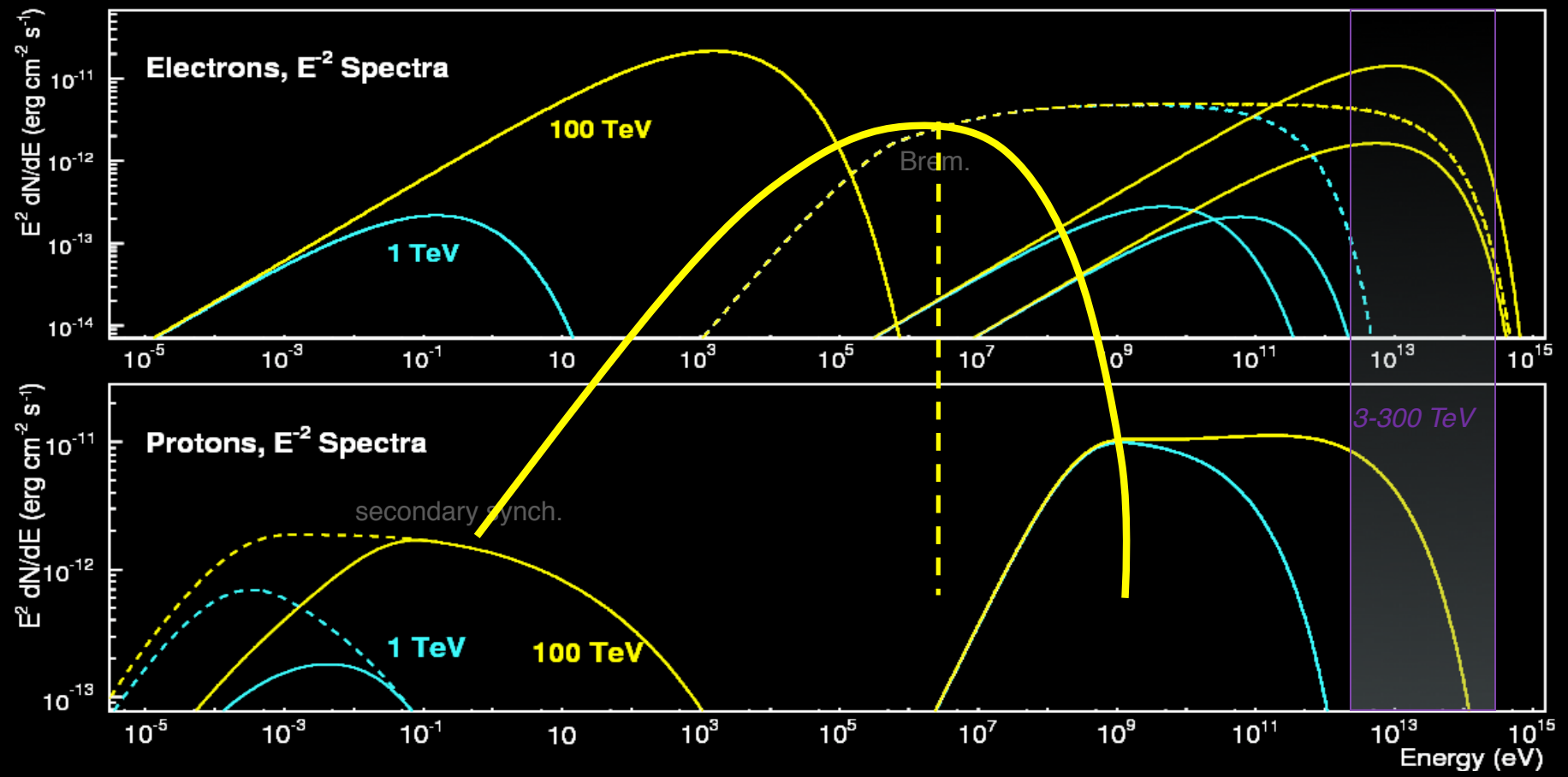
The Opportunity at High Energies

- Angular Resolution!
- High precision only achievable > TeV:
  - Limit: few " at 30 TeV
  - 1′ is achievable at 100 TeV with modest collection area.
  - x 5 improvement from HESS
- Angular Res. improves with multiplicity:
  - At 1 TeV ~16 telescopes.
  - > 1 TeV a very high multiplicity is needed for high angular resolution



Adapted from Funk & Hinton 2009

What are we Looking For?

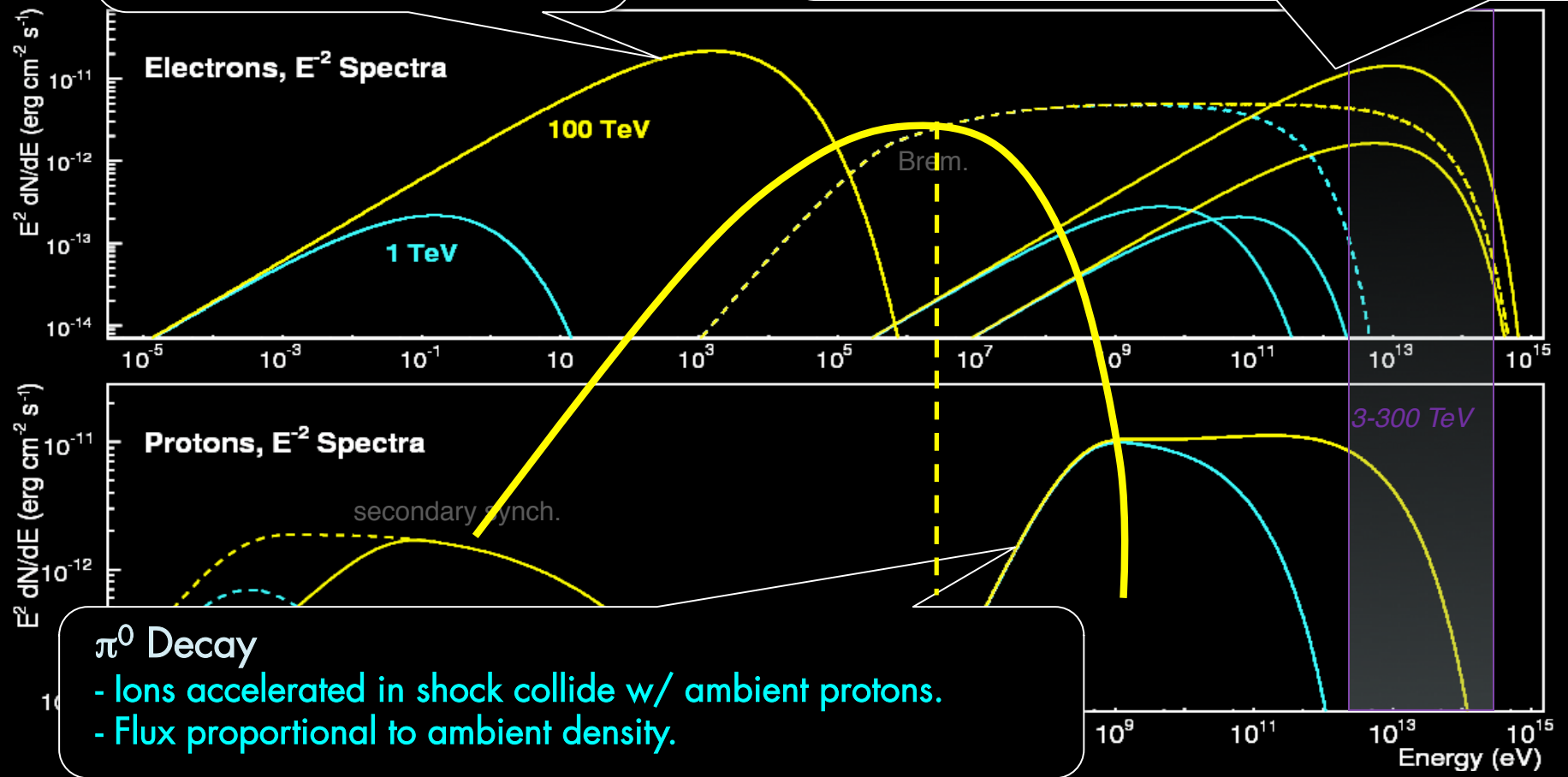


Reproduced from Hinton & Hofmann, 2009

What are we Looking For?

X-Ray Synchrotron (keV)
- Accelerated e- in B Field
- Depends on B Field

Gamma-Ray Inverse Compton (TeV)
- Acc. e- upscatter ambient photons to γ-rays
- CMB, local dust, starlight provide seed photons.



π^0 Decay
- Ions accelerated in shock collide w/ ambient protons.
- Flux proportional to ambient density.

Reproduced from Hinton & Hofmann, 2009

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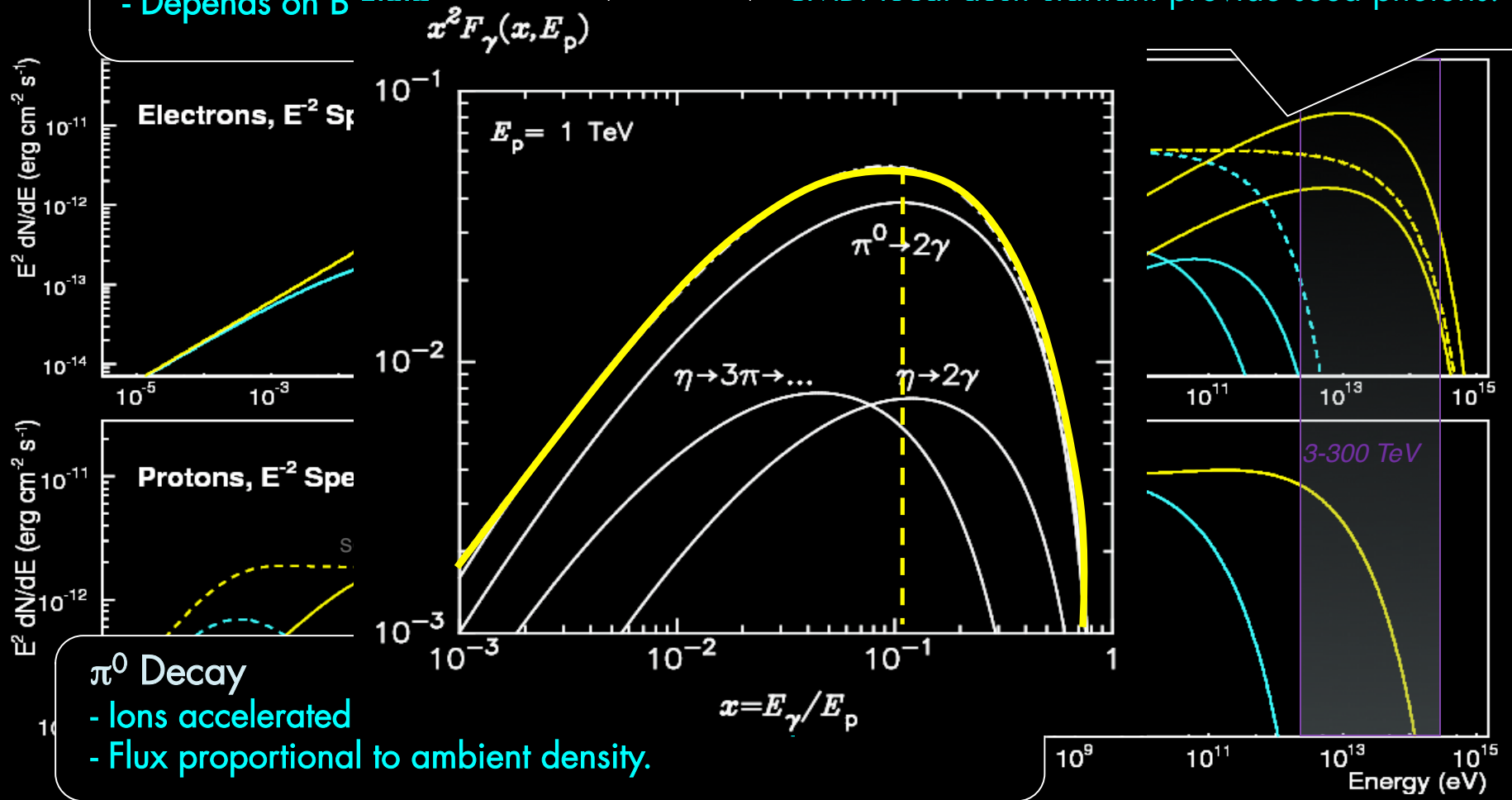

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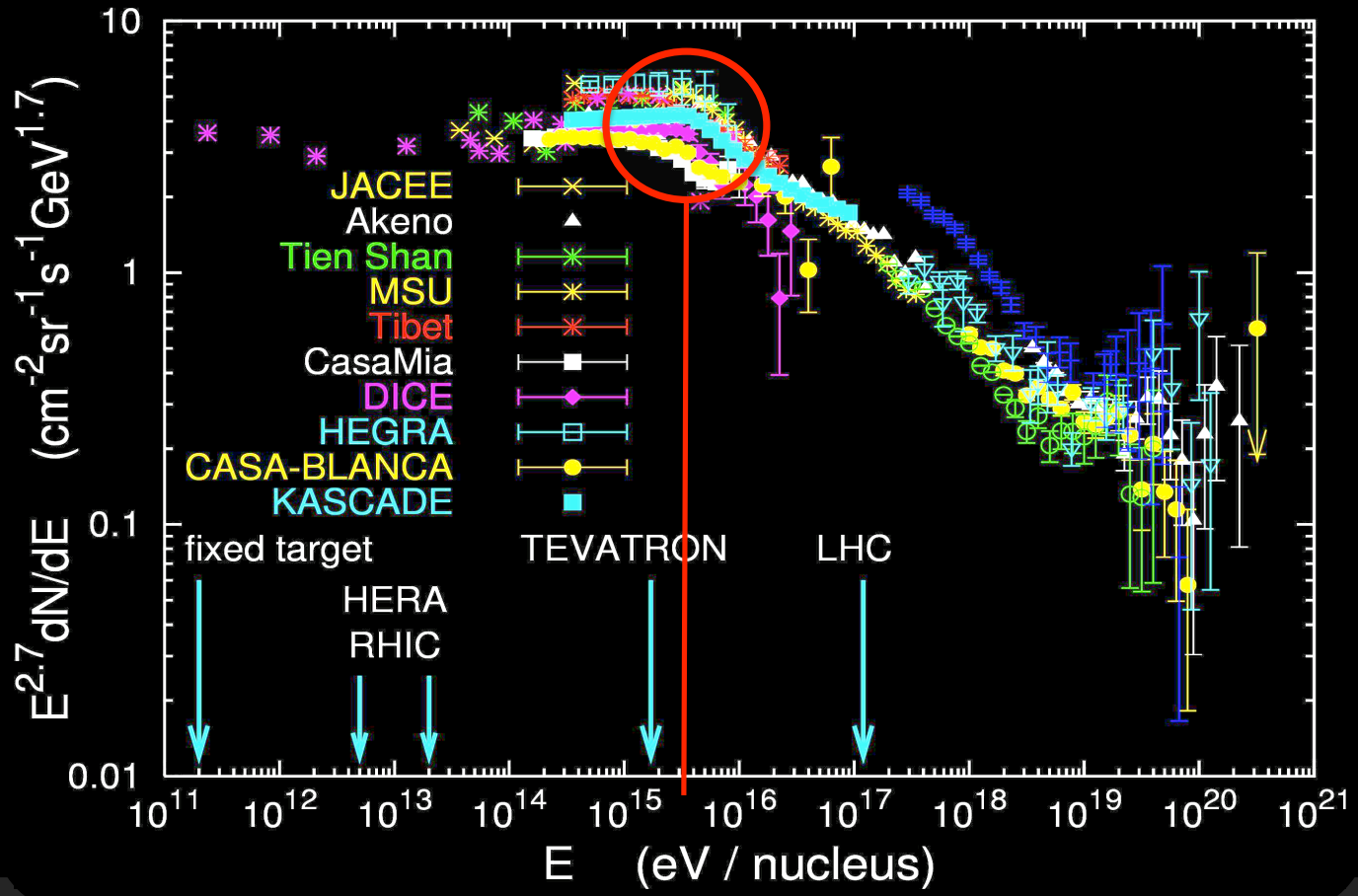
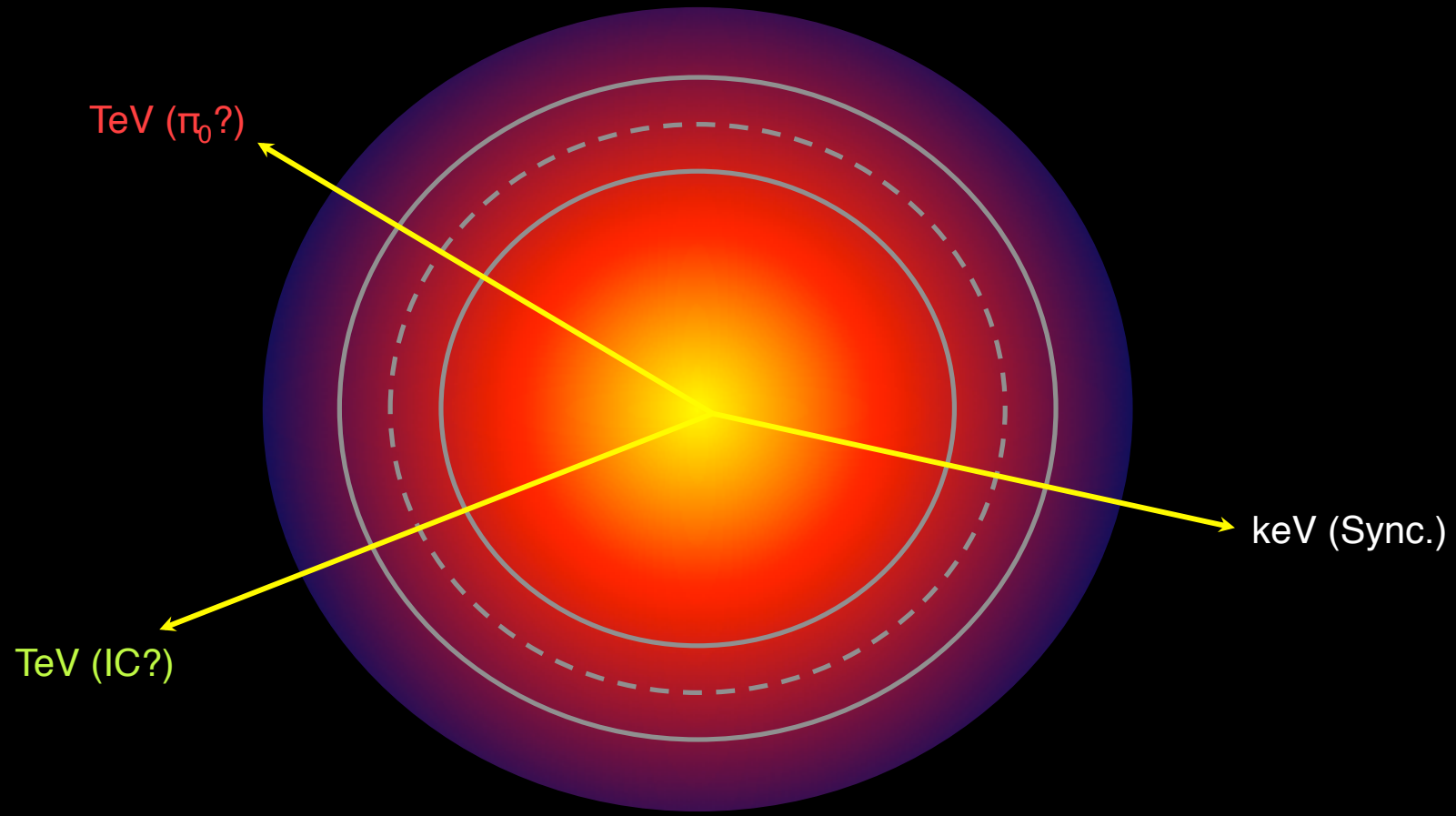
GALACTIC PEVATRONS

- Cosmic-Ray spectrum is smooth until ~3 PeV
  - Galactic origin at least this far
  - SNR are a good candidate…

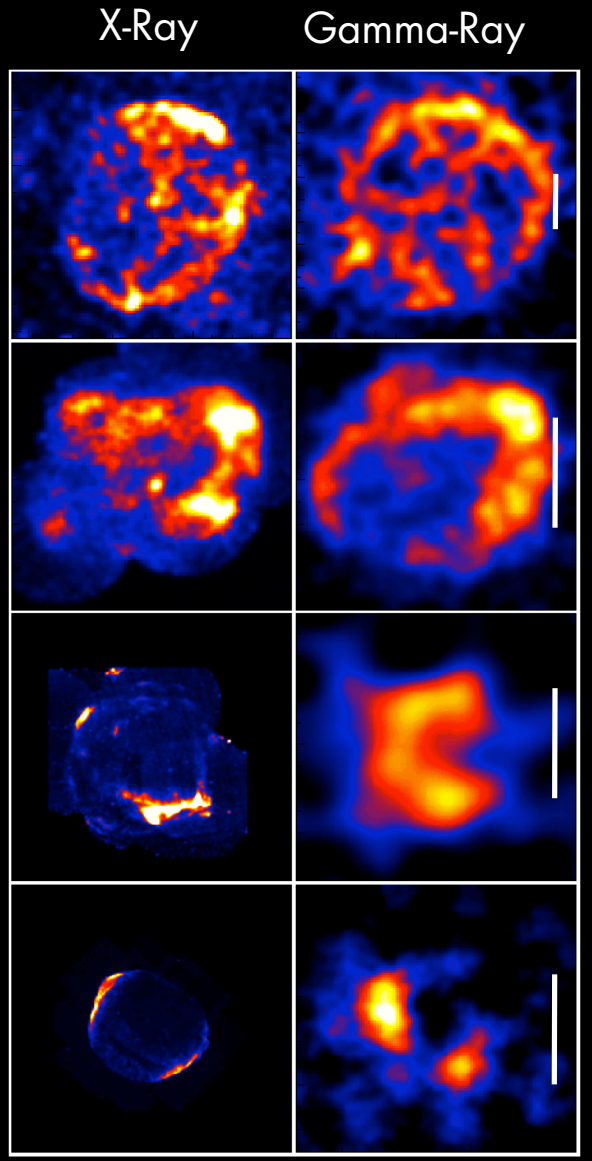


MORPHOLOGY: 1990S



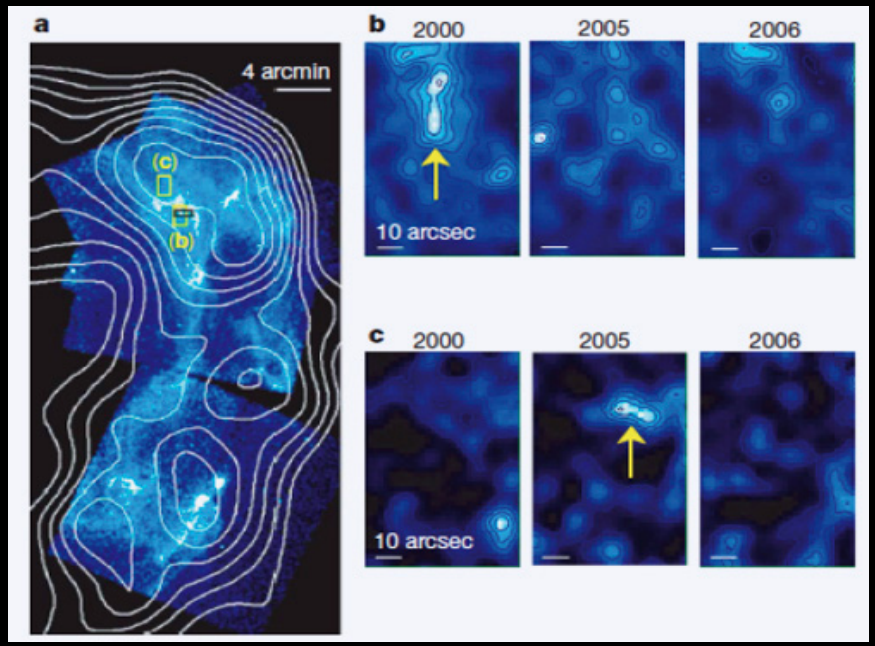
MORPHOLOGY: 2000S

- 4 shell-like objects detected in TeV.
- Young historical SNRs:
  - RX J1713.7-3946
  - Vela Junior
  - RCW 86
  - SN 1006
- Point-source emission from Cas A.
- All resolved shells show correlation with X-Ray emission.
- Electron acceleration to > 100 TeV



MORPHOLOGY: 2000S

- B-Field Amplification in SNR
  - Evidence:
    - X-Ray Filaments
    - X-Ray Variability
  - Implies CR Pressure is significant
  - <10% radius B-Field structure expected.
- TeV Morphology provides:
  - Differentiate between leptonic and hadronic acceleration
  - Test theory of magnetic field amplification in CR modified shocks.



Reproduced from Uchiyama et al., 2007

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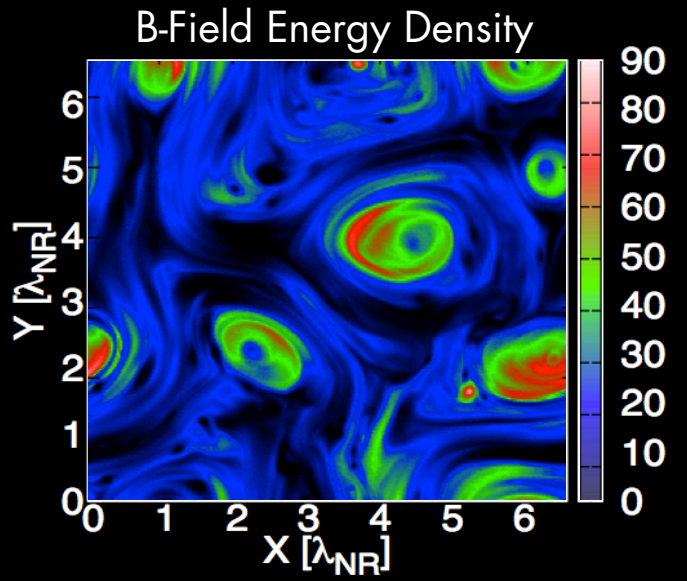
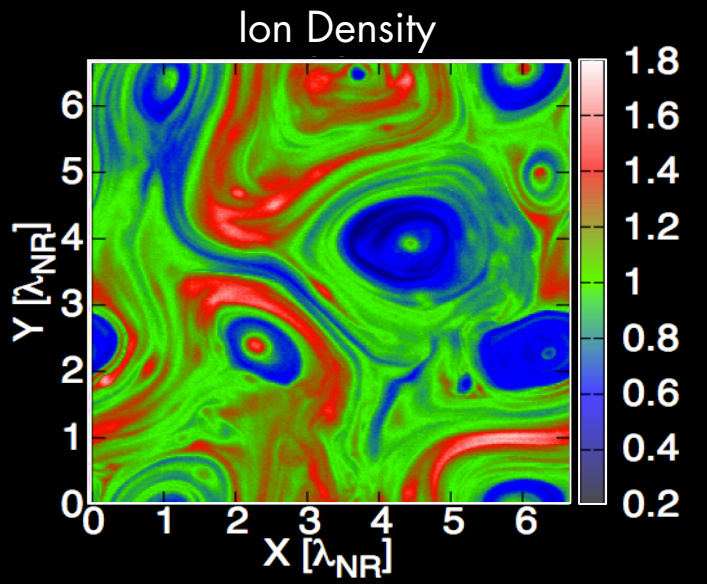




Reproduced from Ohira, Reville, Kirk 2009

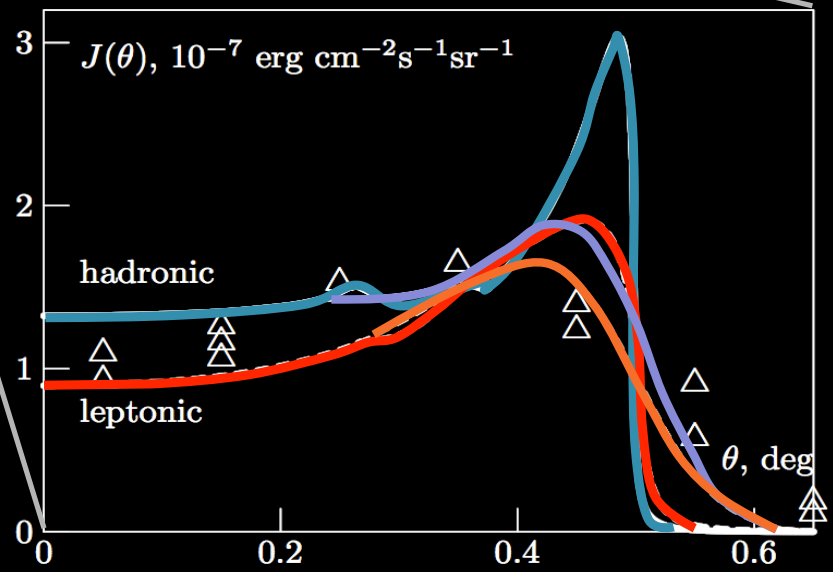
Morphology: 2000s

RX J1713.7-3946

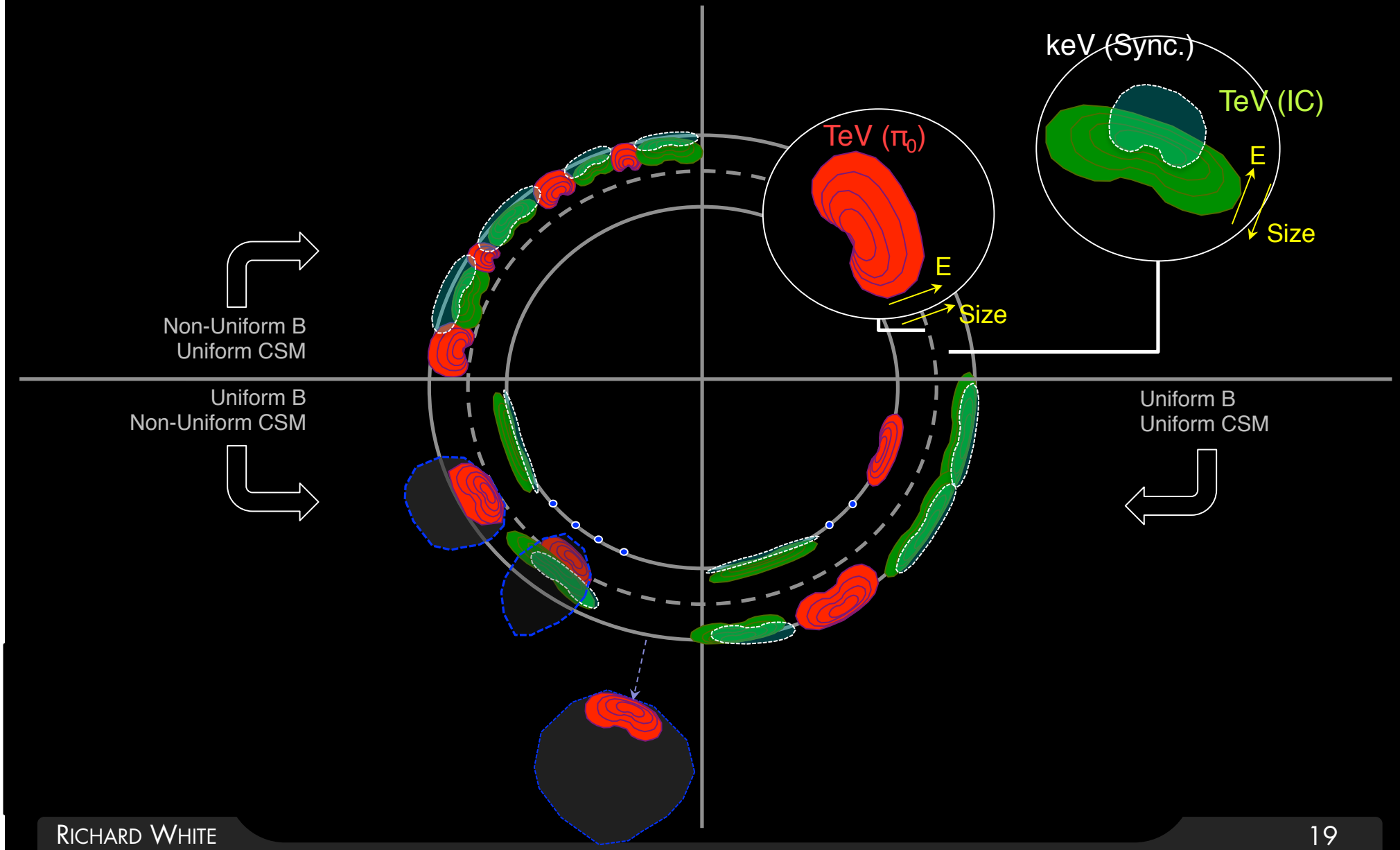
Gamma-Ray: HESS 5′

X-Ray: ASCA 5′

X-Ray: ASCA 1.5′



MORPHOLOGY: 2010S



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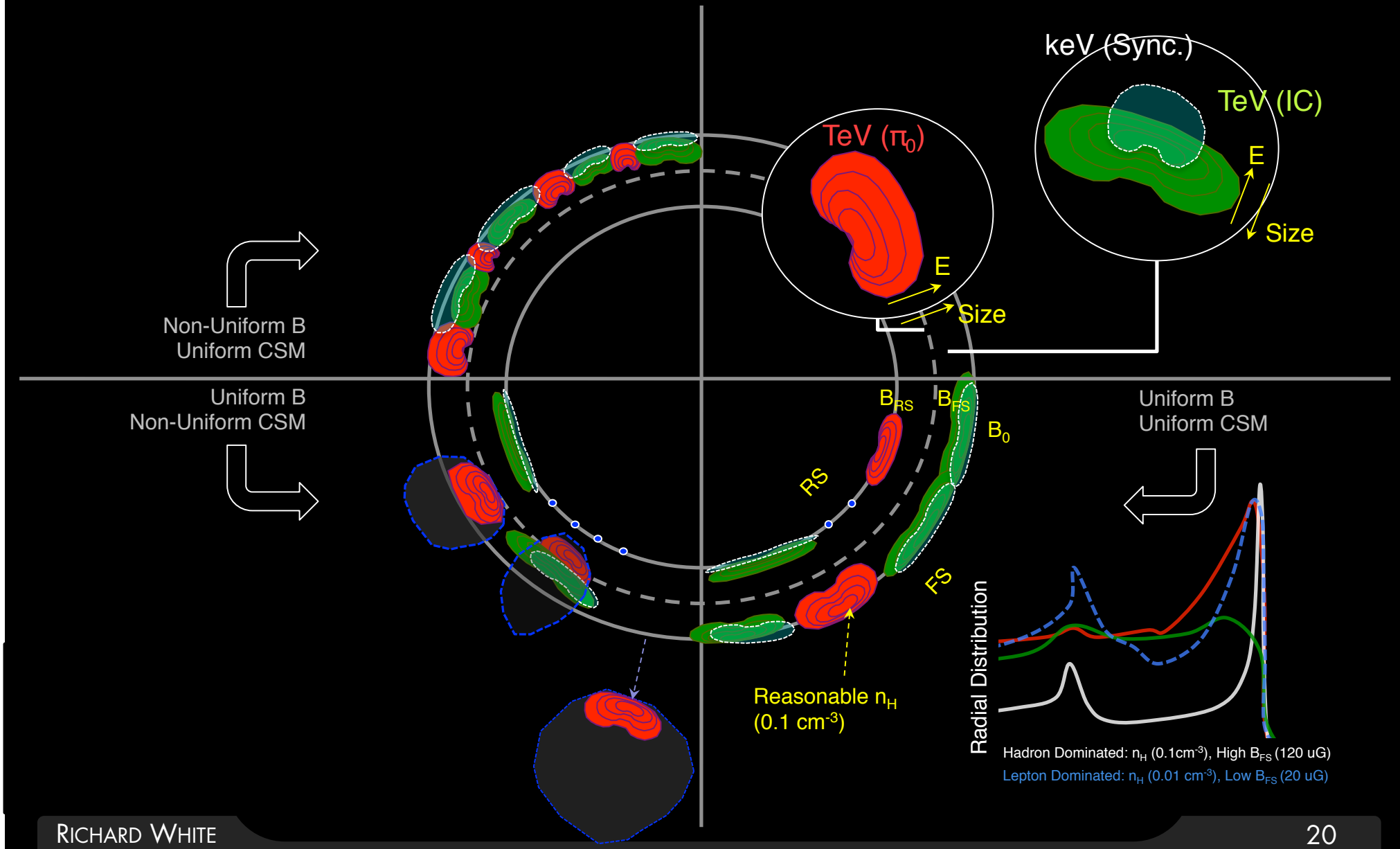

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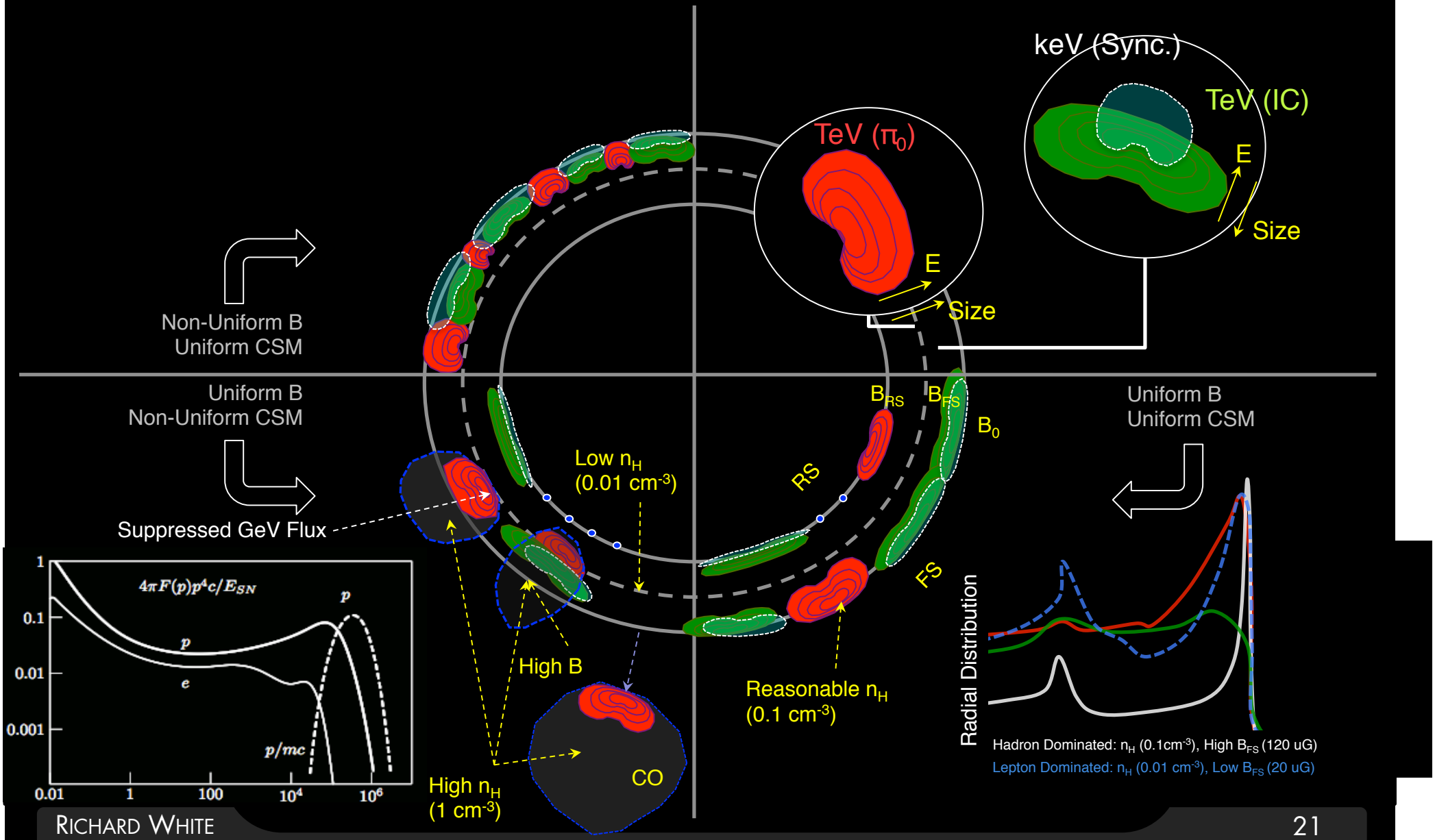

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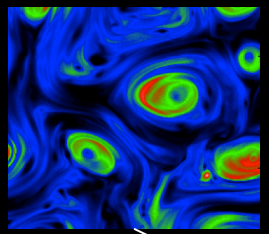
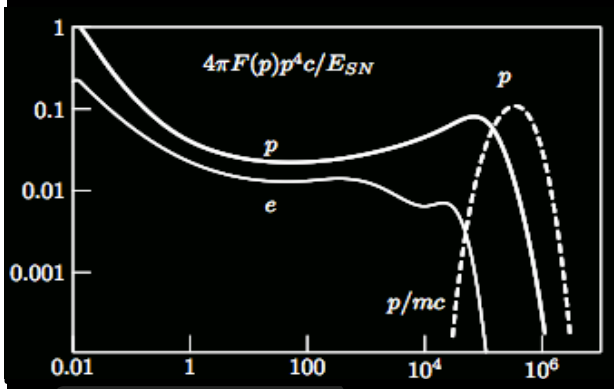


Non-Uniform B
Uniform CSM

Uniform B
Non-Uniform CSM

Suppressed GeV Flux



TeV (π_0)

E

Size

keV (Sync.)

TeV (IC)

E

Size

B_{RS}

B_{FS}

B_0

RS

FS

Low n_H
(0.01 cm^{-3})

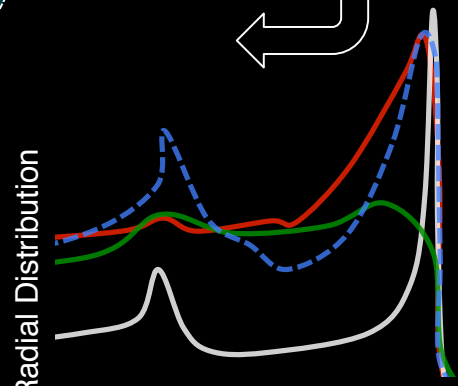
High B

High n_H
(1 cm^{-3})

CO

Reasonable n_H
(0.1 cm^{-3})

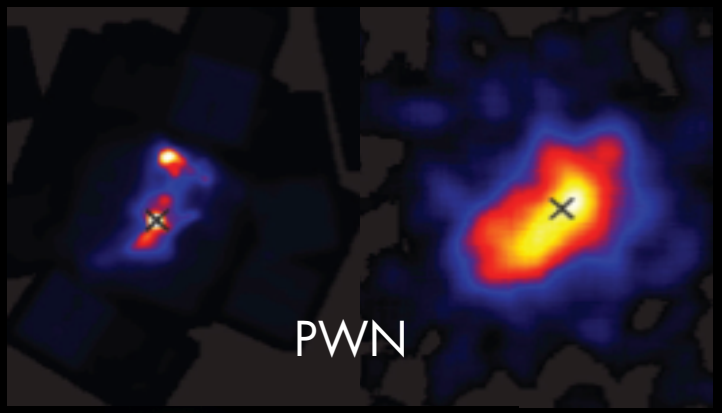
Uniform B
Uniform CSM



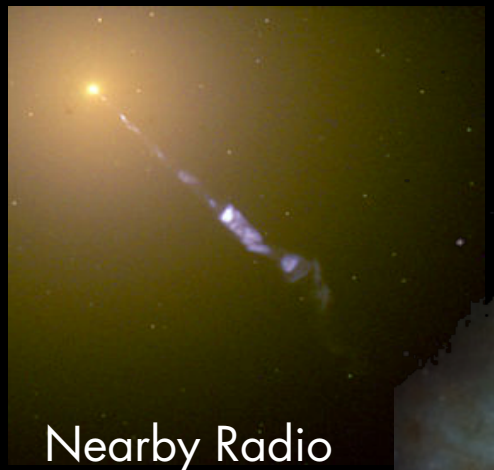
Hadron Dominated: n_H (0.1cm^{-3}), High B_{FS} (120 uG)

Lepton Dominated: n_H (0.01 cm^{-3}), Low B_{FS} (20 uG)

What Else:

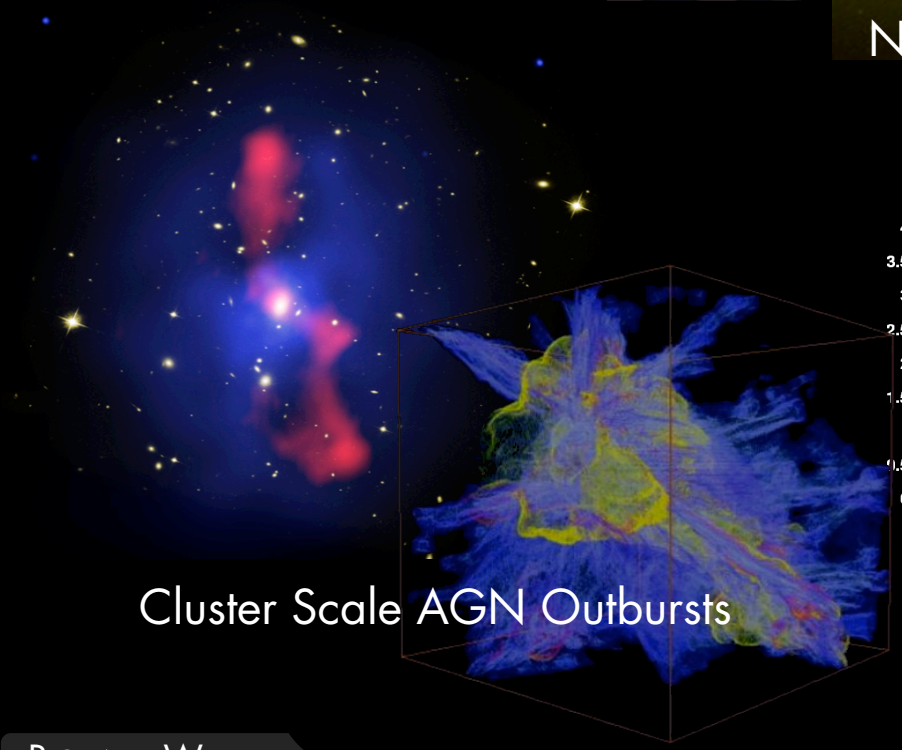


PWN

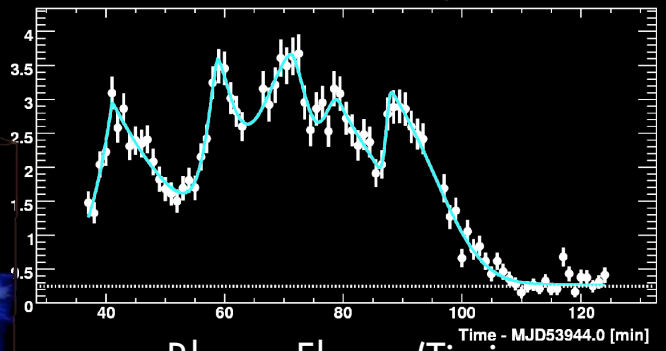


Nearby Radio Galaxies

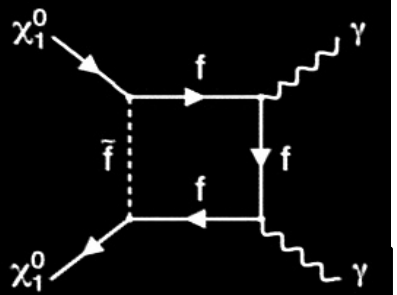
Starburst Galaxies



Cluster Scale AGN Outbursts



Blazar Flares (Timing, Lorentz Invariance)



Decay of Heavy WIMPs

CONCLUSIONS

- CTA will provide unprecedented sensitivity across a wide energy range.
- 3 – 300 TeV sensitivity is critical to address major questions in astroparticle physics.
- Excellent angular resolution (the best possible anywhere above ~100 keV) is possible and required.