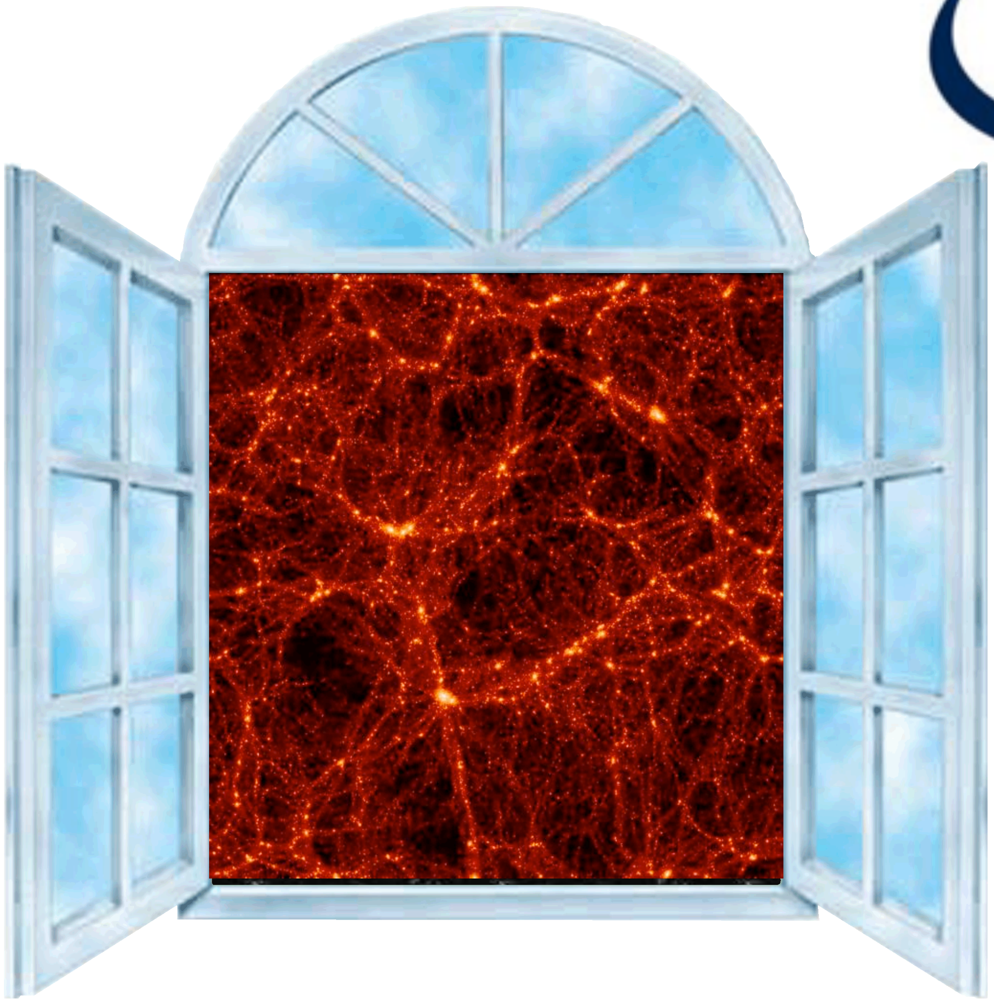
High-energy gamma-ray astronomy and dark matter searches with Imaging Air Cherenkov observatories: Status and prospects

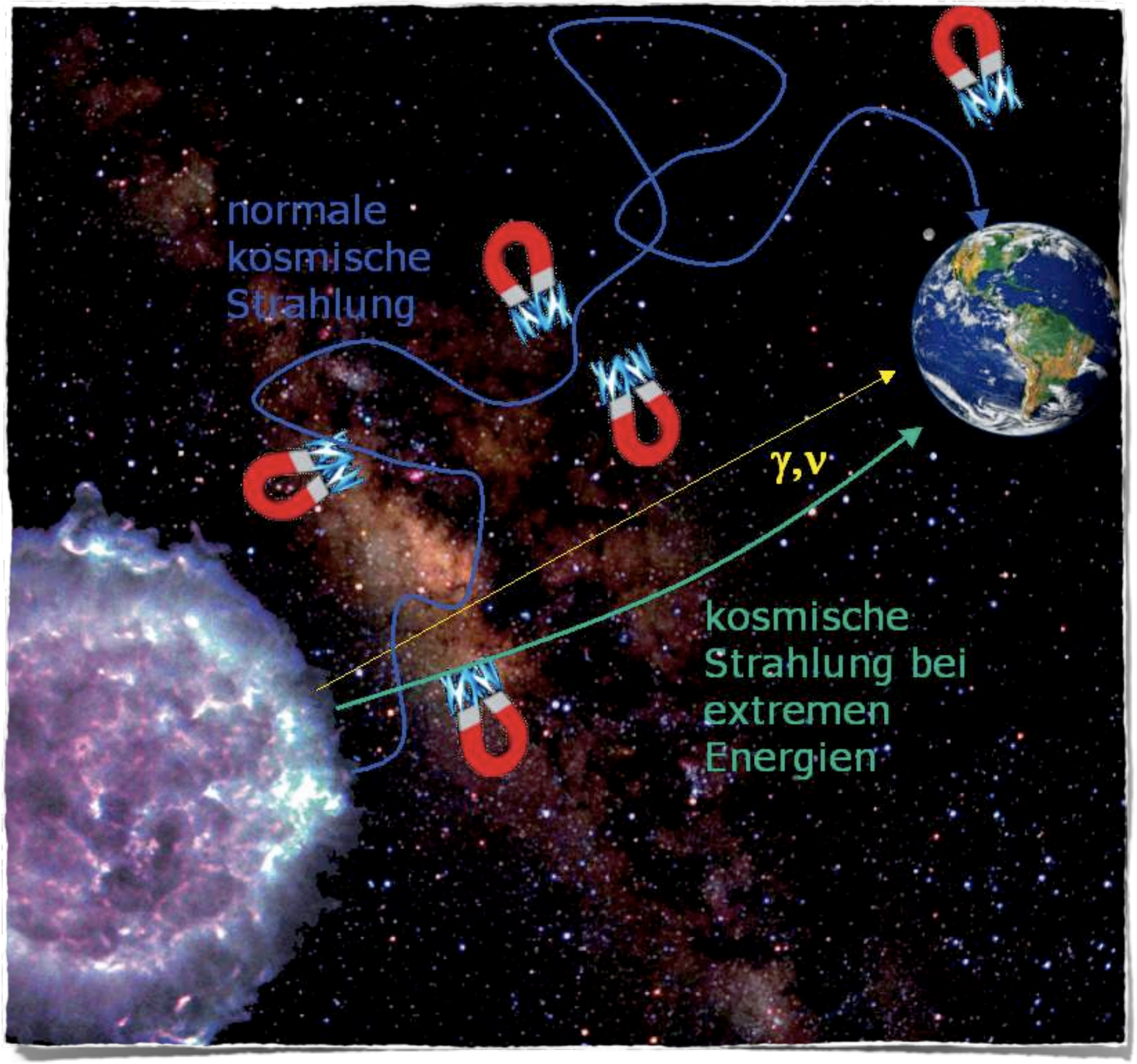


High-energy gamma-ray astronomy and dark matter searches with Imaging Air Cherenkov observatories: Status and prospects

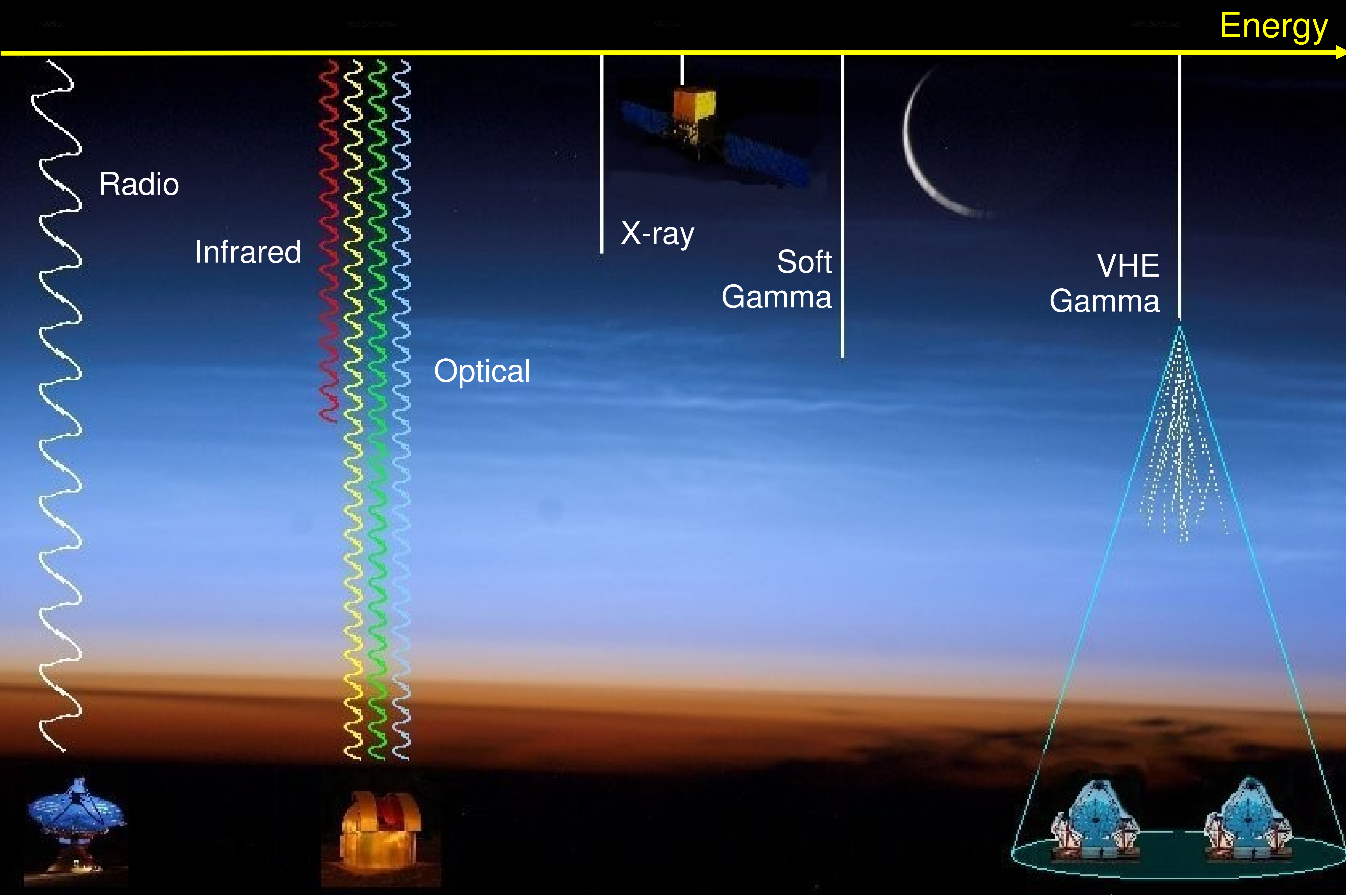
Robert Wagner
Oskar Klein Centre for Cosmoparticle Physics
Stockholm University

Setting the stage: messengers

- Gamma-rays are ideal messenger particles
- Trace non-thermal particle acceleration processes



Windows for Astronomy



Energy

Radio

Infrared

Optical

X-ray

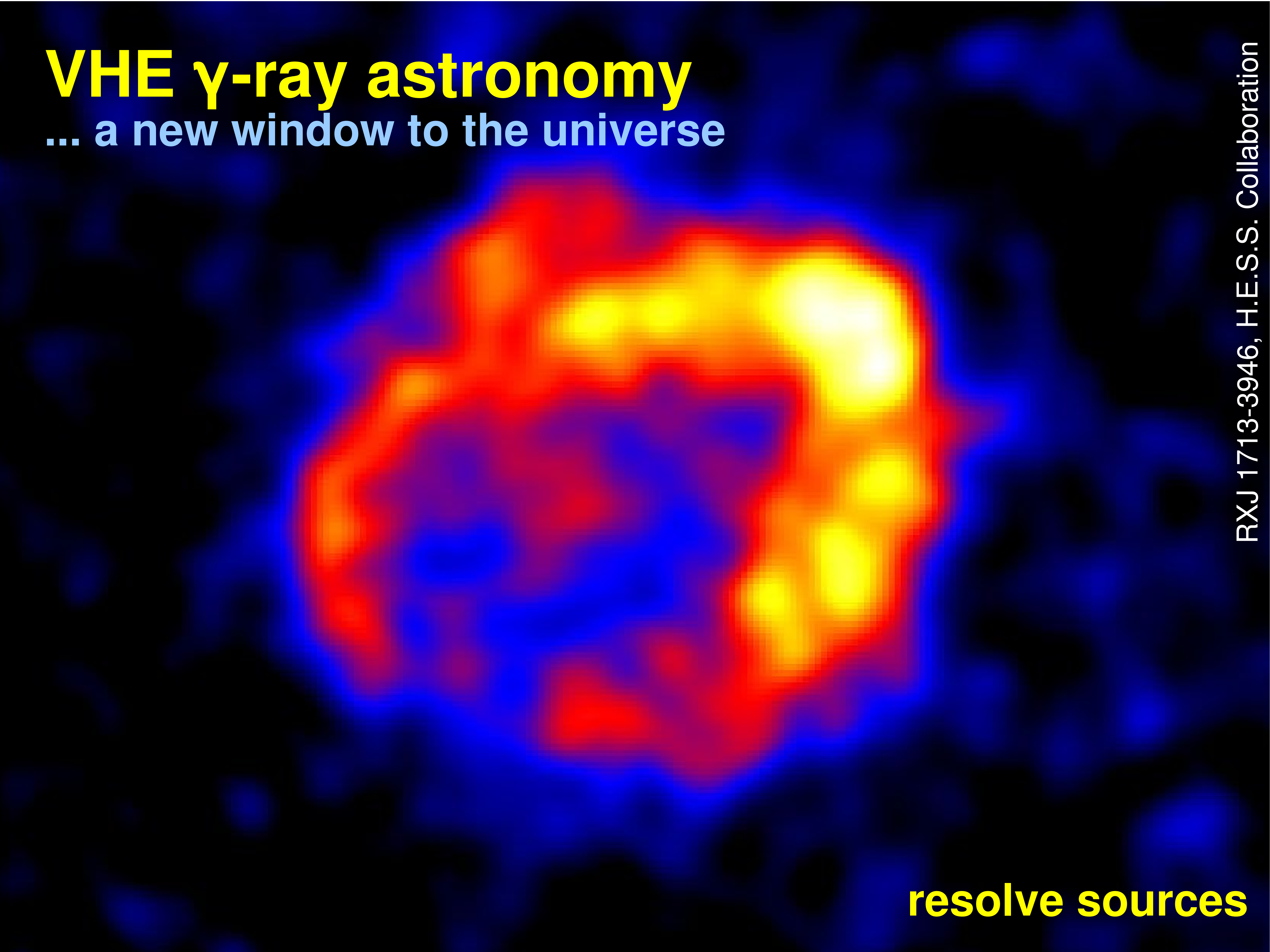
Soft Gamma

VHE Gamma

B. Giebels

VHE γ-ray astronomy

... a new window to the universe

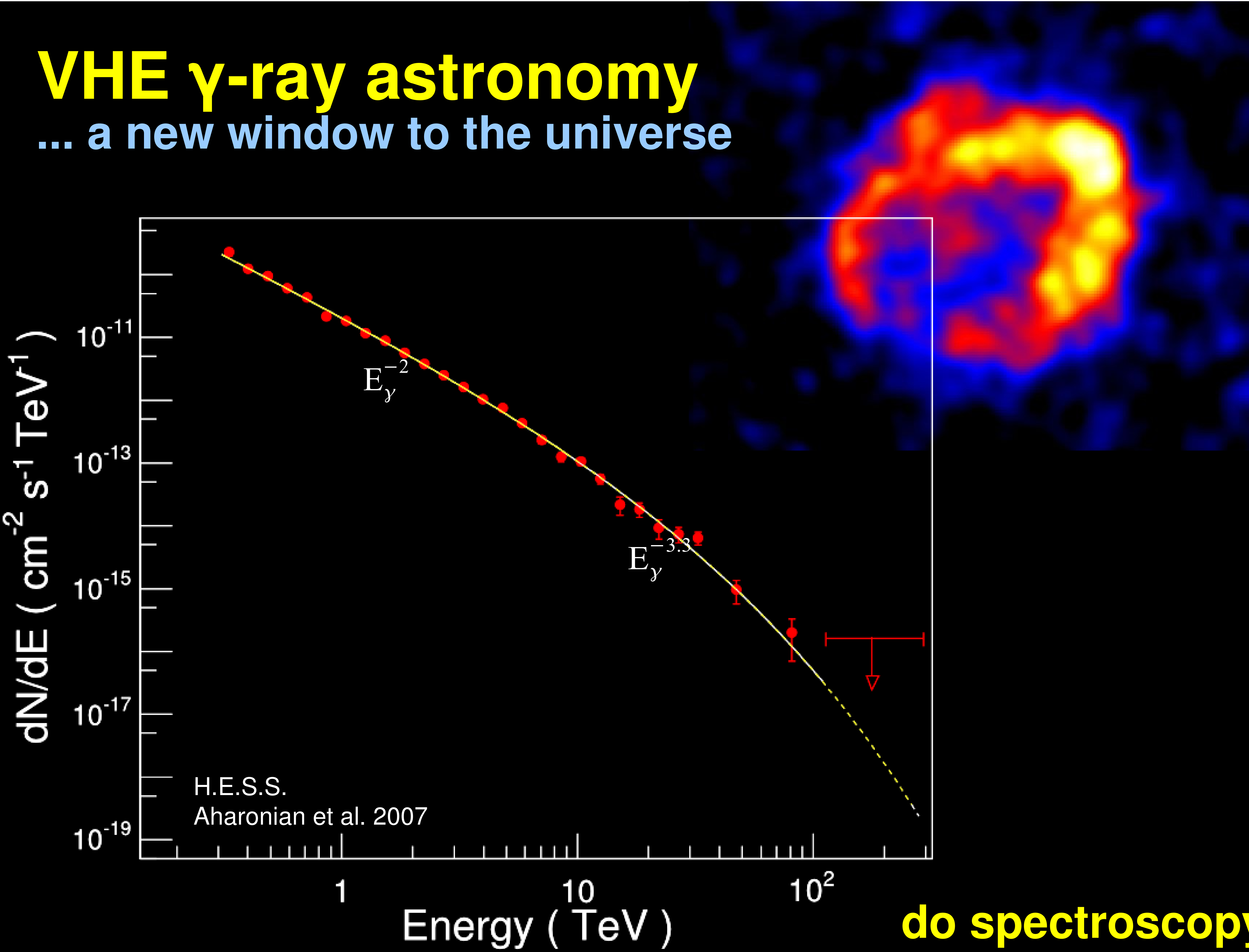


RXJ 1713-3946, H.E.S.S. Collaboration

resolve sources

VHE γ-ray astronomy

... a new window to the universe



H.E.S.S.
Aharonian et al. 2007

RXJ 1713-3946, H.E.S.S. Collaboration

do spectroscopy

VHE γ-ray astronomy

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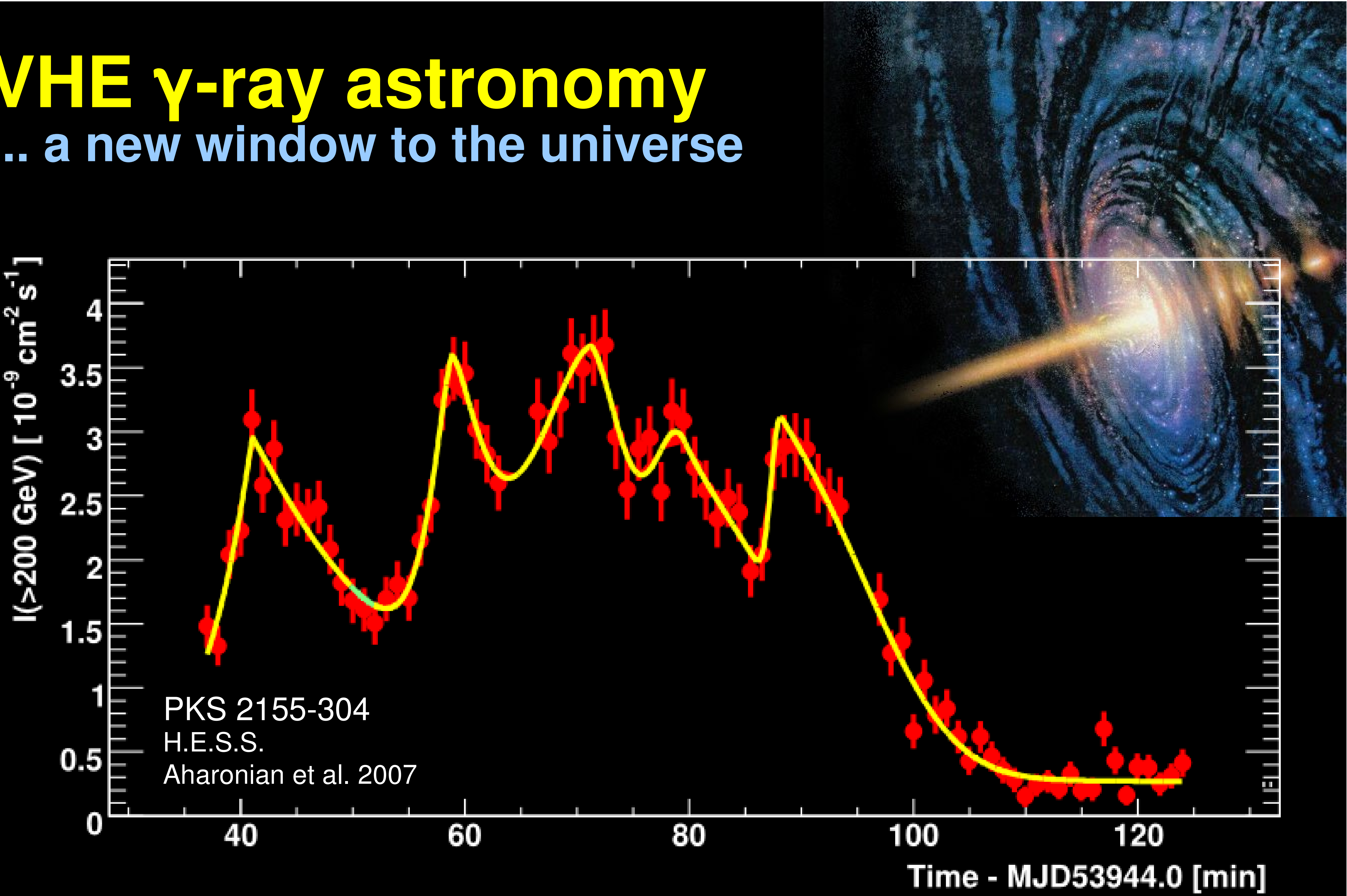
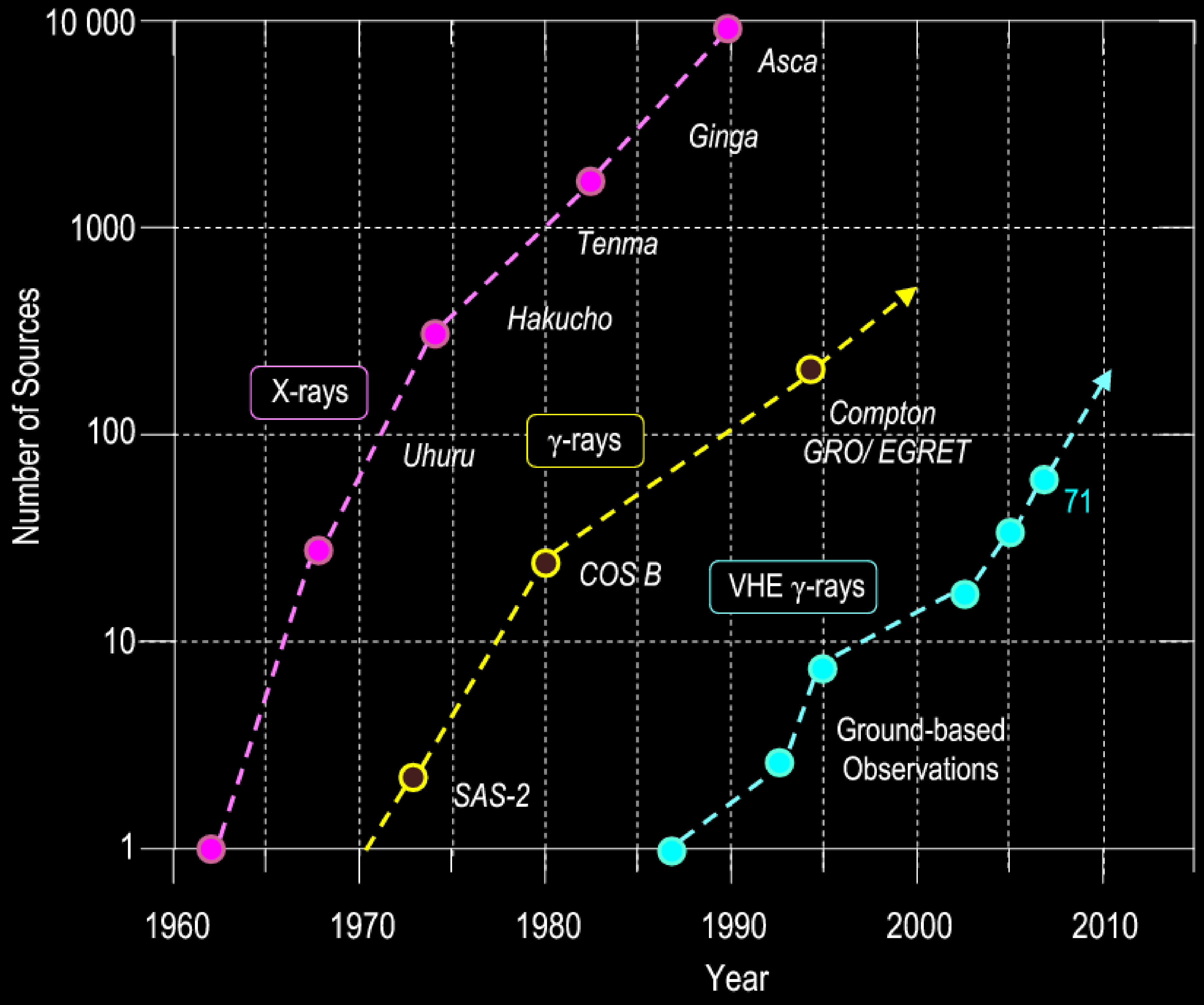


PKS 2155-304
H.E.S.S.
Aharonian et al. 2007

measure flux variability

VHE γ-ray sky

...more than 150 sources known



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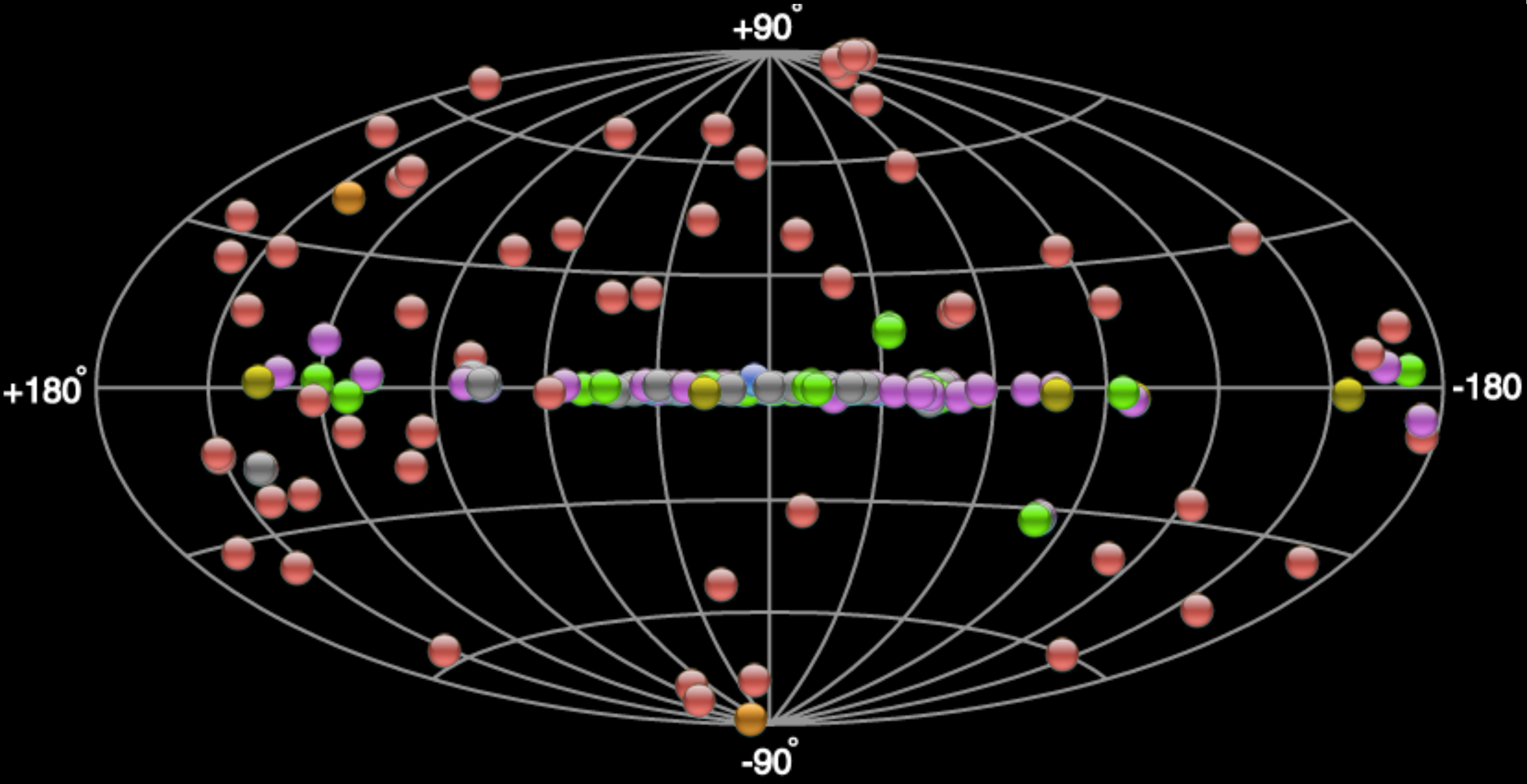
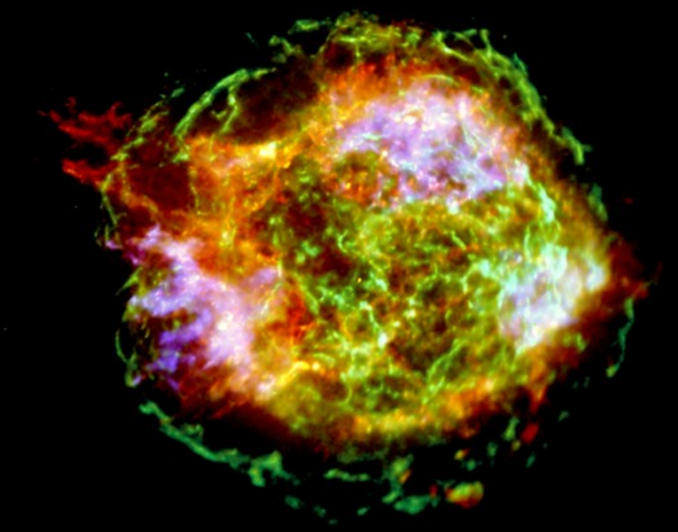


(Some) topics of VHE γ-ray astronomy

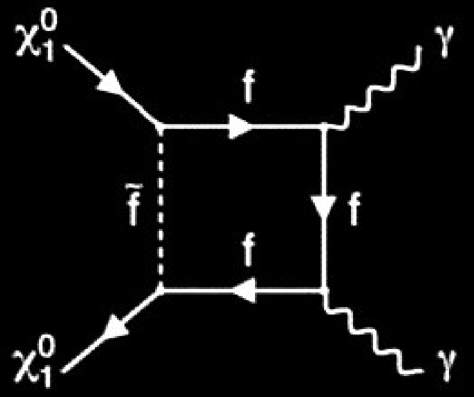


Astrophysics

- Which are the cosmic PeVatrons?
- How do they work?
- Acceleration, emission, propagation

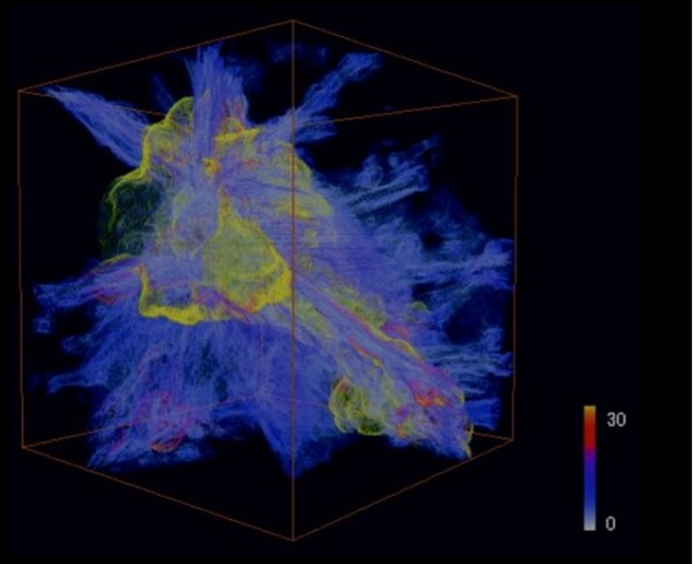
Fundamental Physics

- Indirect Dark Matter searches
- Energy dependence of speed of light



Cosmology

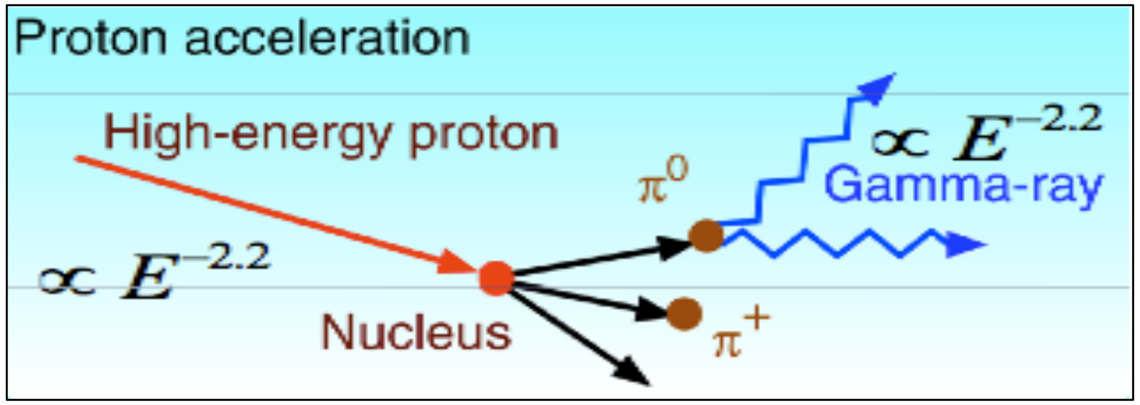
- Extragalactic Background Light
  → star formation in the early universe
- Galaxy clusters as storehouses of cosmic rays



Non-thermal Universe

Non-thermal Universe

- High-energy particles will end up producing gamma-rays:



Hadronic High-Energy particles
Neutrinos as “smoking gun”

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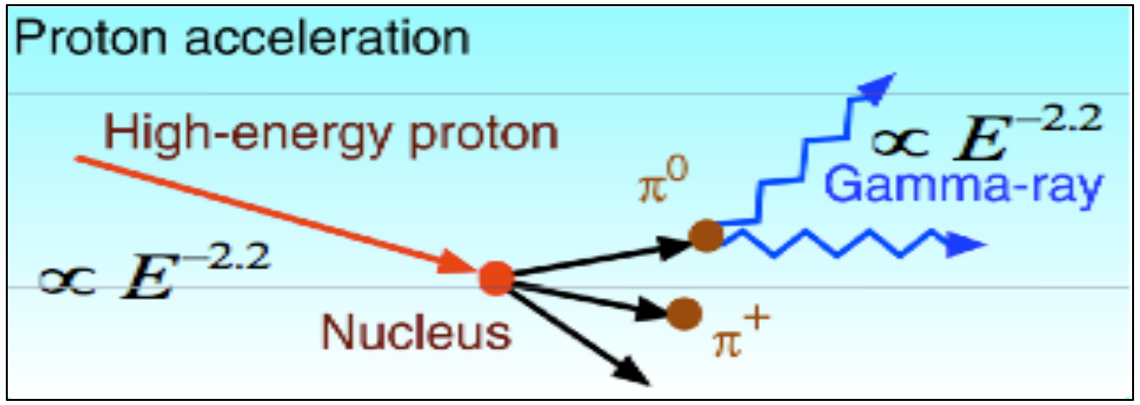

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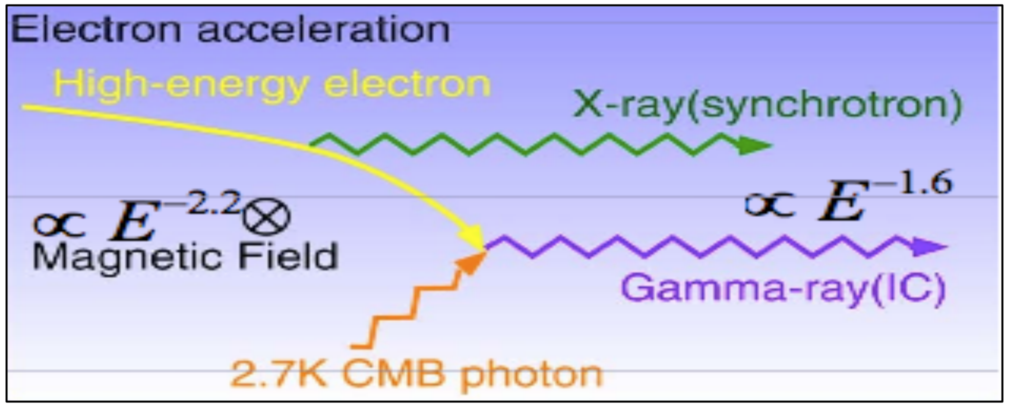

Leptonic High-Energy particles
Bremsstrahlung, Synchrotron Radiation,
Inverse Compton Scattering

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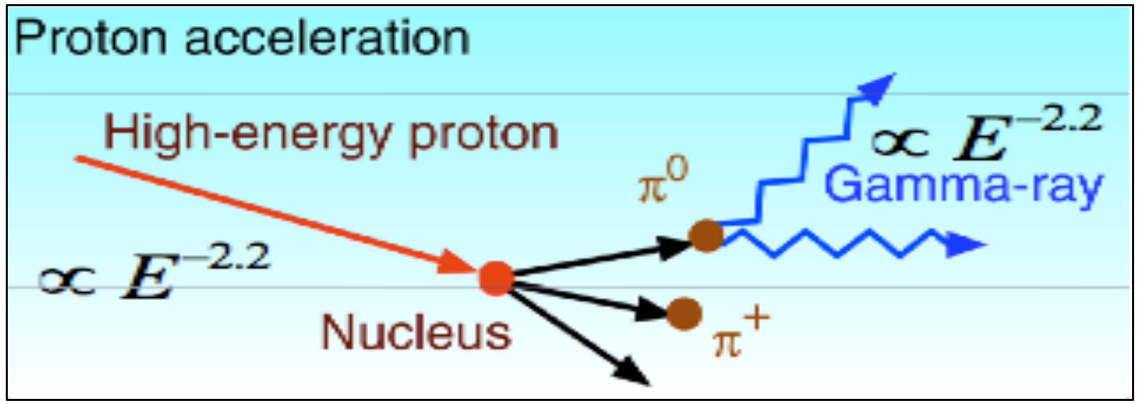

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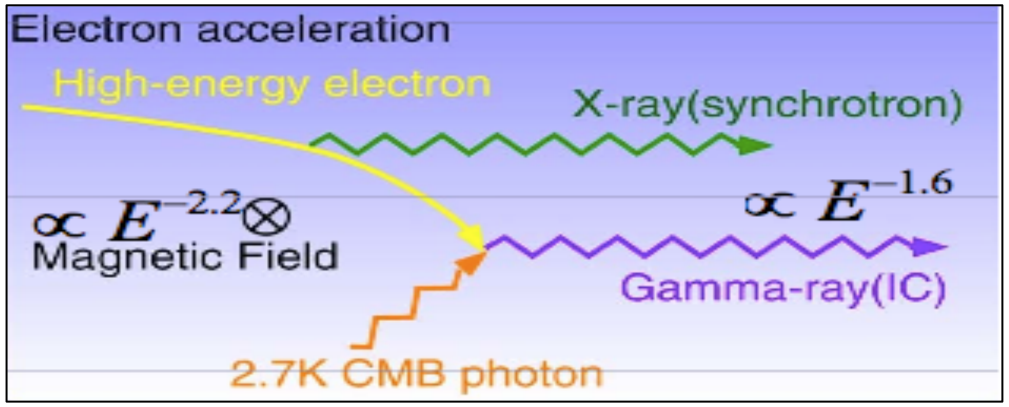

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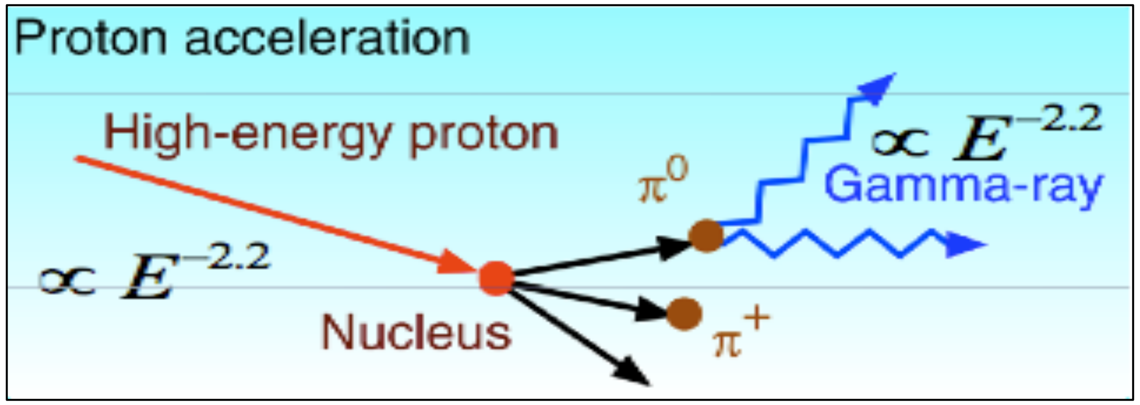

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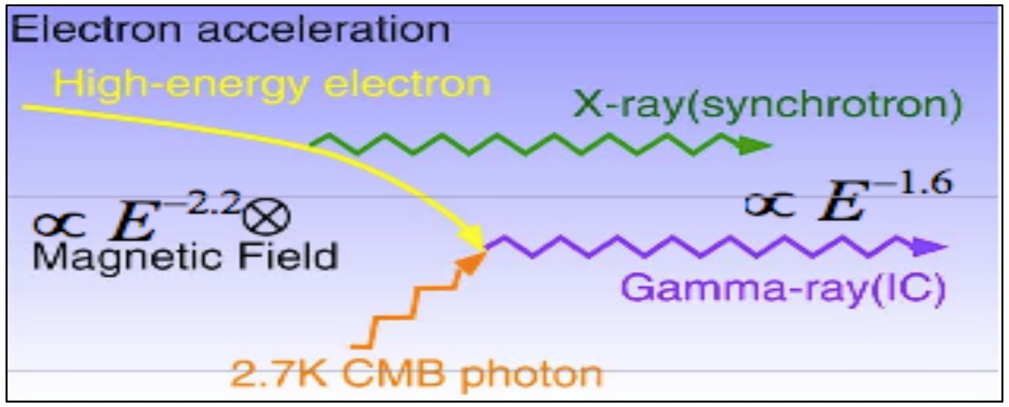

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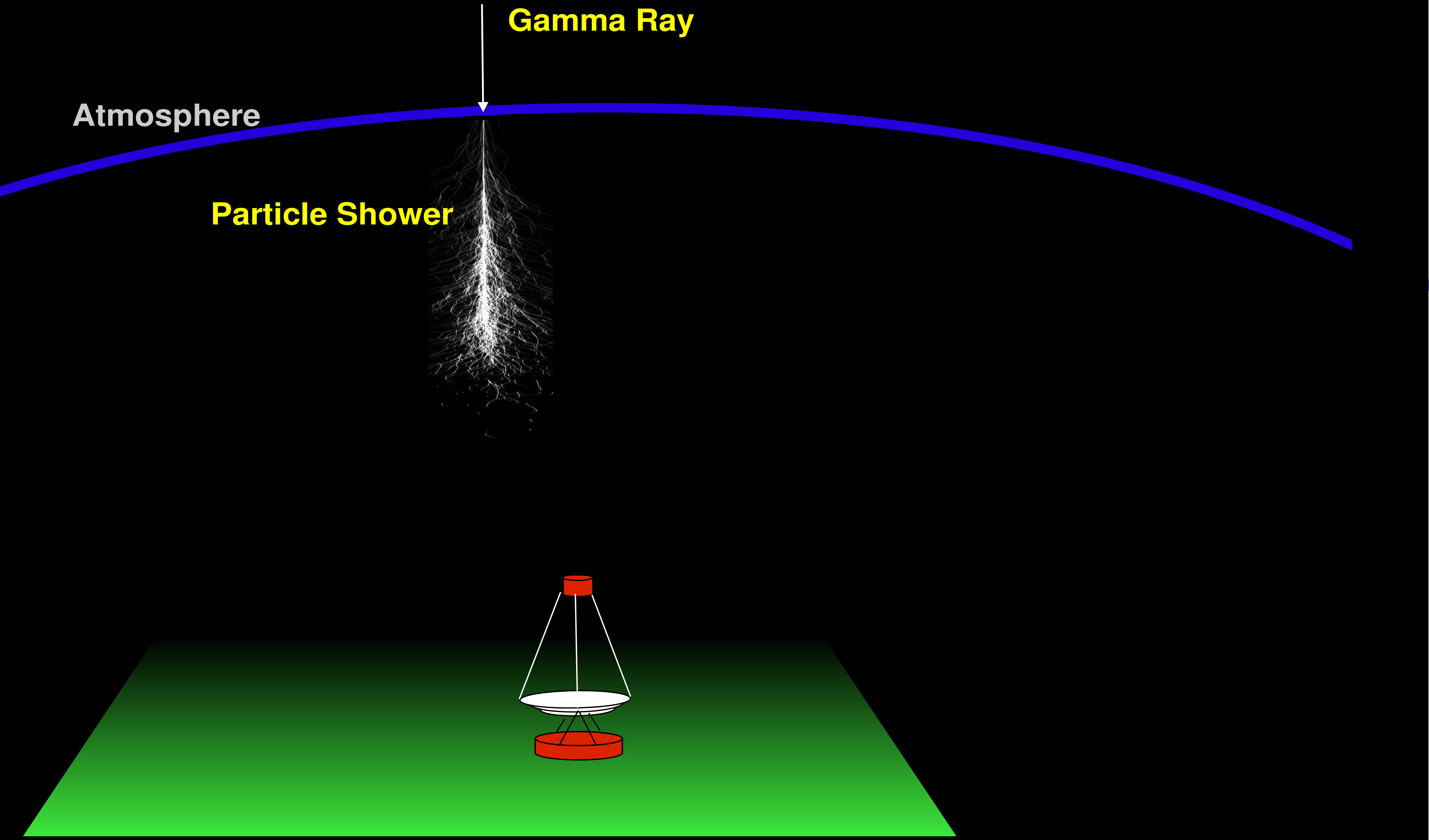
Information brought by the gamma-ray quanta:

1. Location **of the high-energy particles, source direction**
2. **Lower limit to the** energy **of the high-energy particles**
3. Time **information** – variable emission – key piece of information

THE IMAGING AIR CHERENKOV TECHNIQUE

Detection Principle



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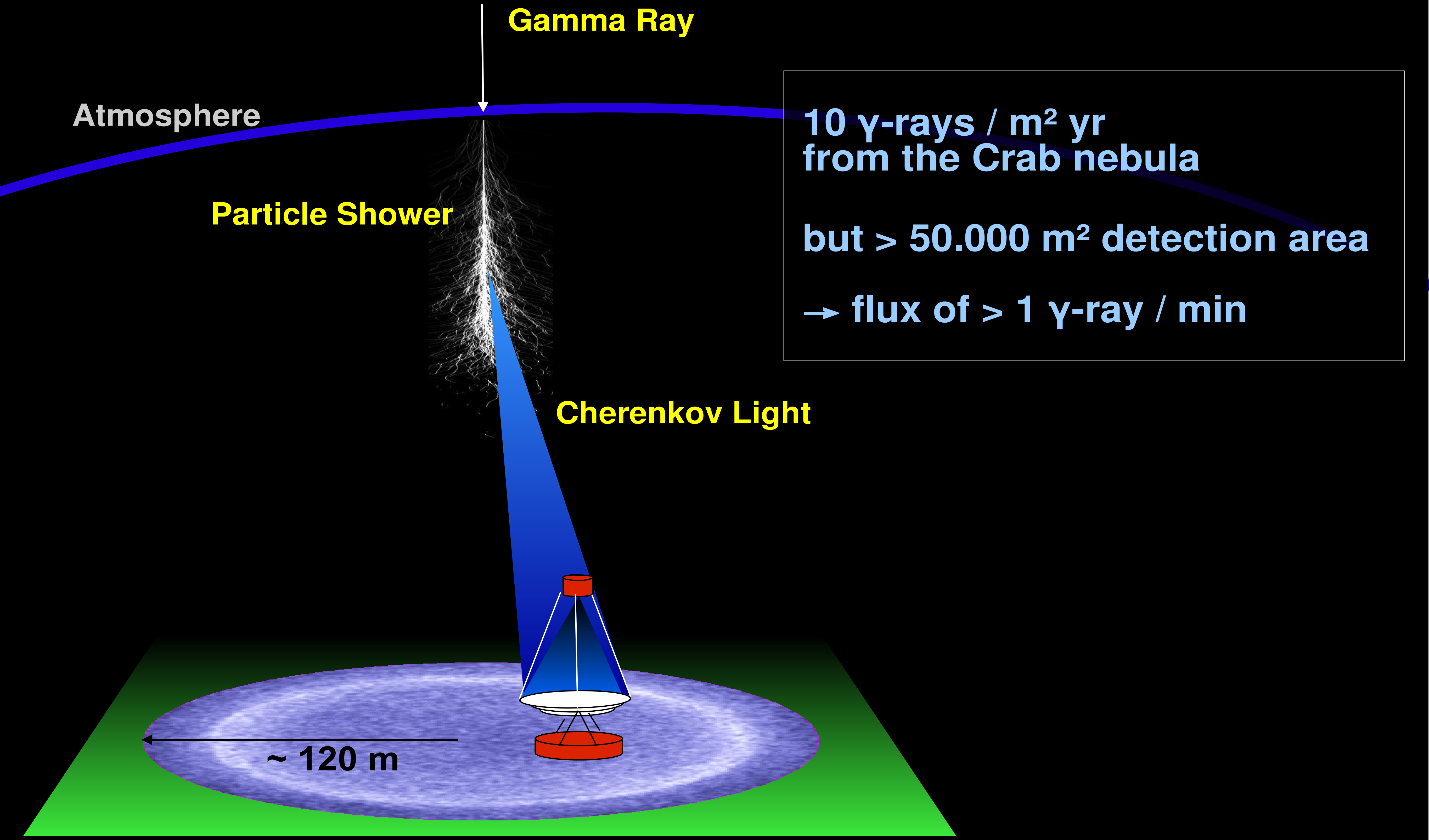
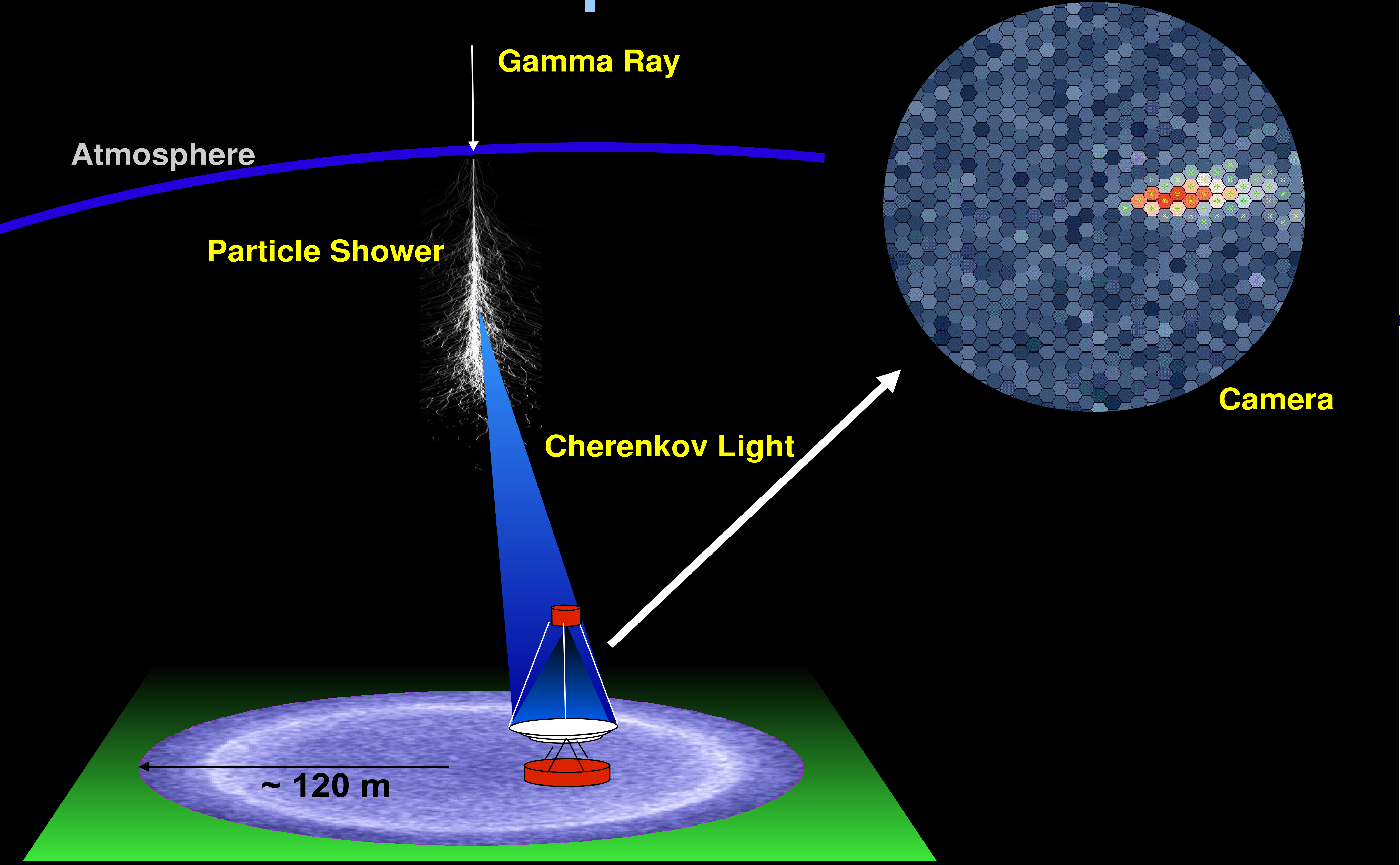


10 γ-rays / m^2 yr
from the Crab nebula

but > 50.000 m^2 detection area

→ flux of > 1 γ-ray / min

Detection Principle



Gamma Ray

Atmosphere

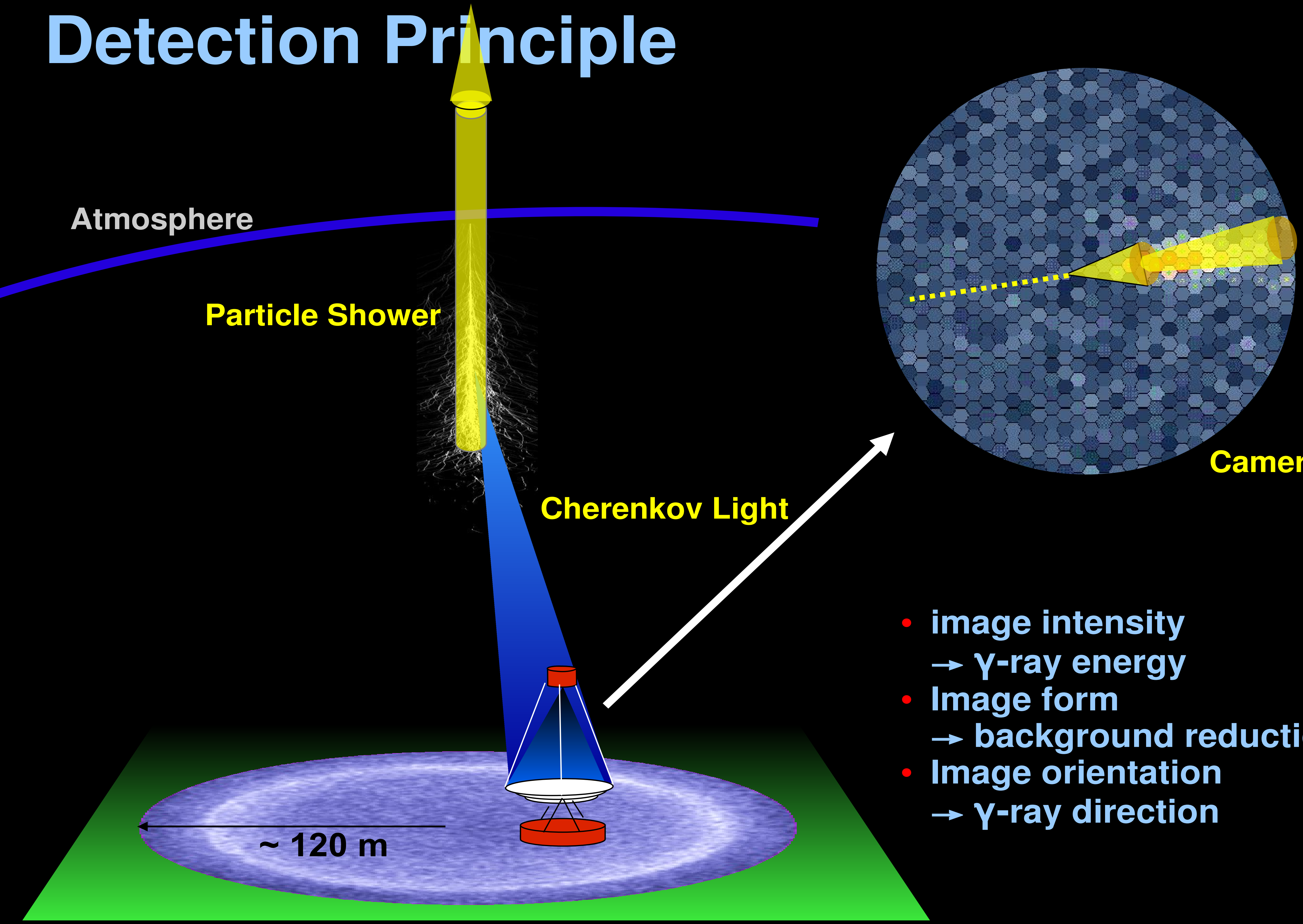
Particle Shower

Cherenkov Light

Camera

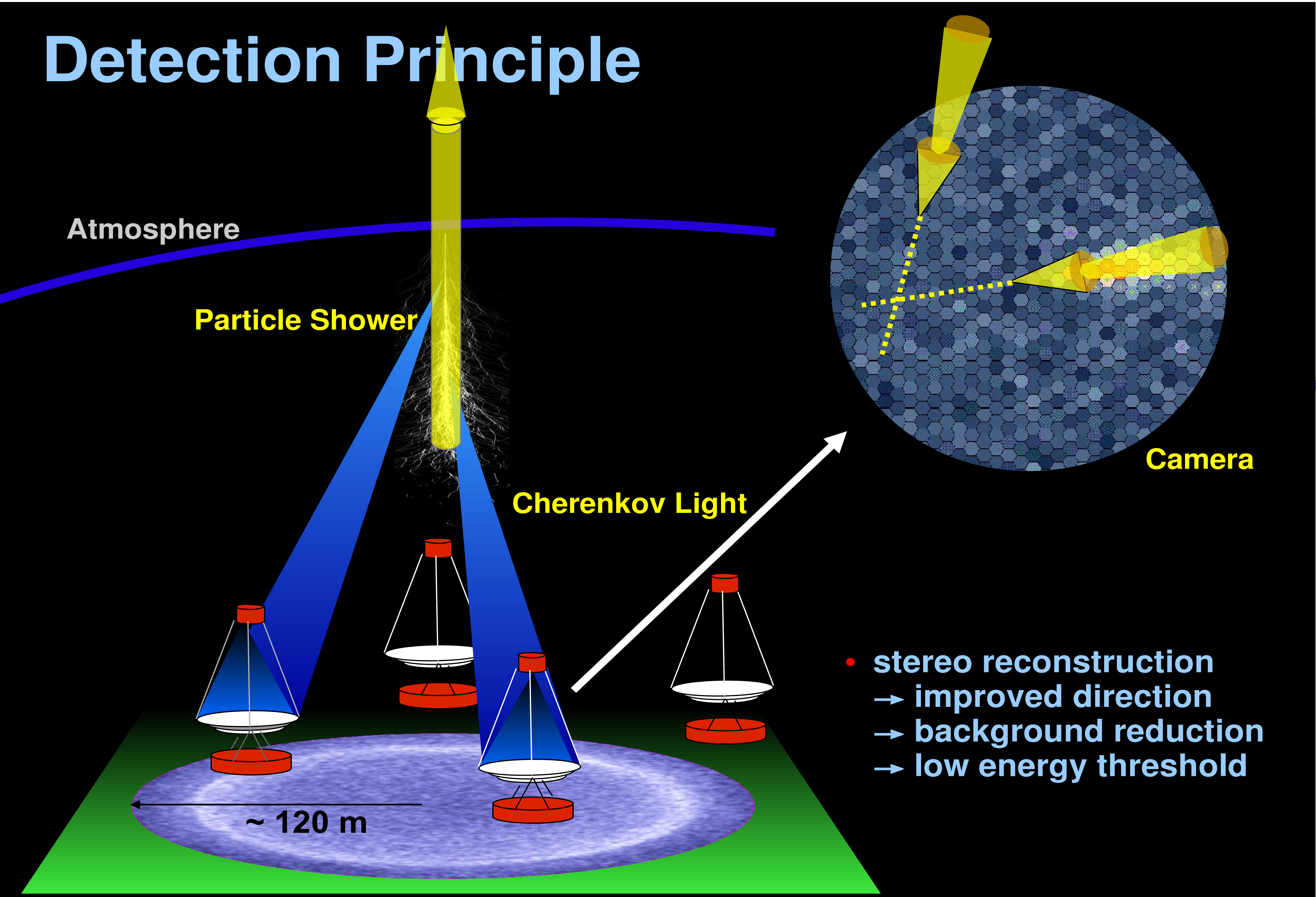
~ 120 m

Detection Principle



- image intensity
  → γ-ray energy
- Image form
  → background reduction
- Image orientation
  → γ-ray direction

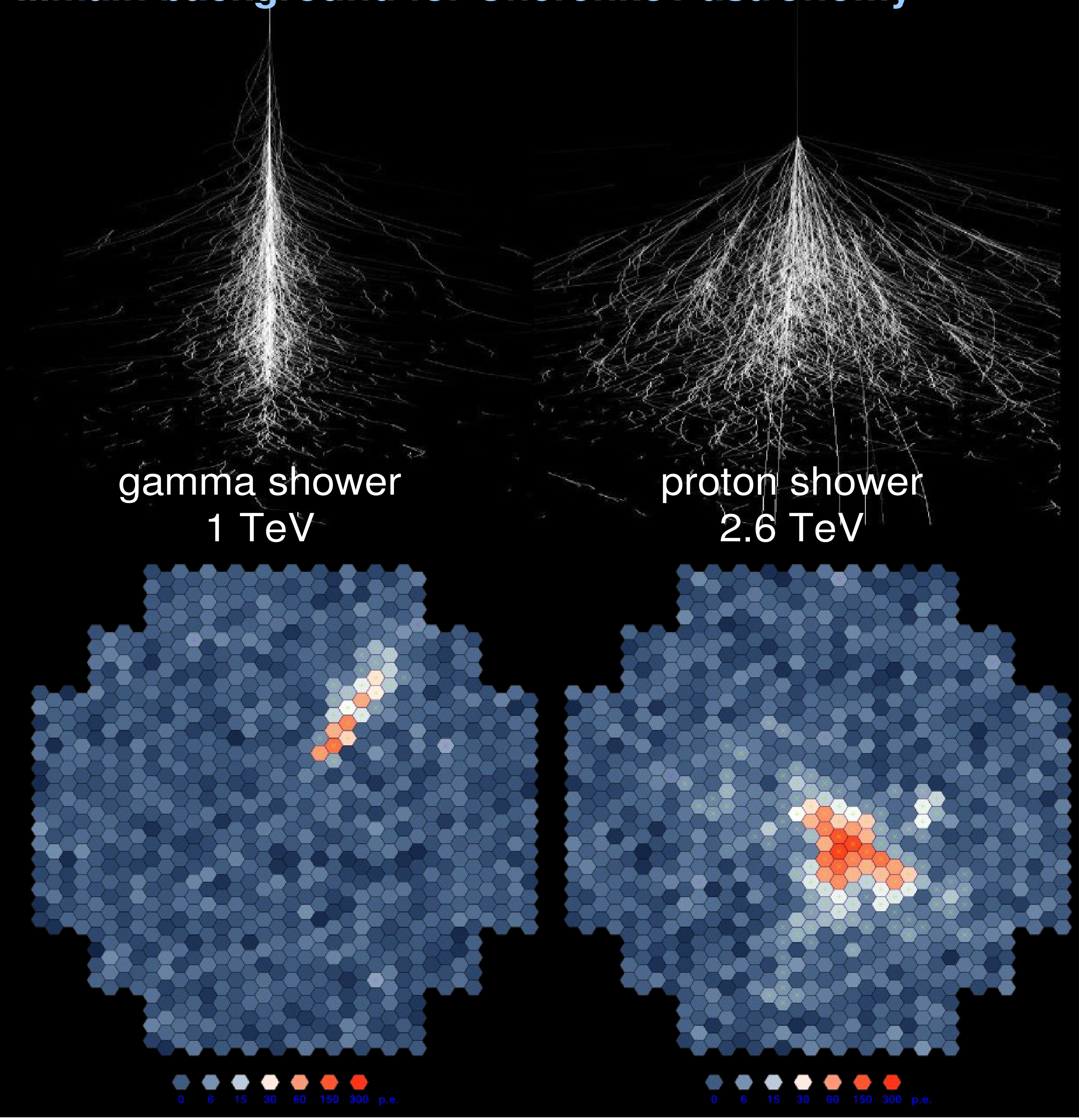
Detection Principle



- stereo reconstruction
  → improved direction
  → background reduction
  → low energy threshold

Cosmic Rays...

...main background for Cherenkov astronomy



K. Bernlöhr

- Ratio γ/hadron ≈ 1/1000
- Cuts on image parameters
→ 99.9% background reduction
- Remaining S/B ~ 1..10, depending on source strength and source size

CURRENT INSTRUMENTS: MAGIC, VERITAS, H.E.S.S.

Major IACTs to date

4x12m IACTs, Crab sensitivity ~36 σ/√hr,
1% Crab in 35 hours


VERITAS

2x17m IACTs ~ 19 σ/√hr,
2.2% of Crab in 50 hours


MAGIC


4x12m + 28m IACTs, Crab sensitivity ~43 σ/√hr

HESS

All instruments have similar light collection area and have a “peak energy” of around
50-120 GeV (trigger level) but ~150..300 GeV after typical tight analysis cuts

H.E.S.S. II

600 m^2 mirror area

0.07^o pixels

~20 GeV peak trigger rate in stand-alone mode

THE INDIRECT SEARCH FOR DARK MATTER

Why VHE Gamma Rays?

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  DM has shaped the formation of the first stars and galaxies

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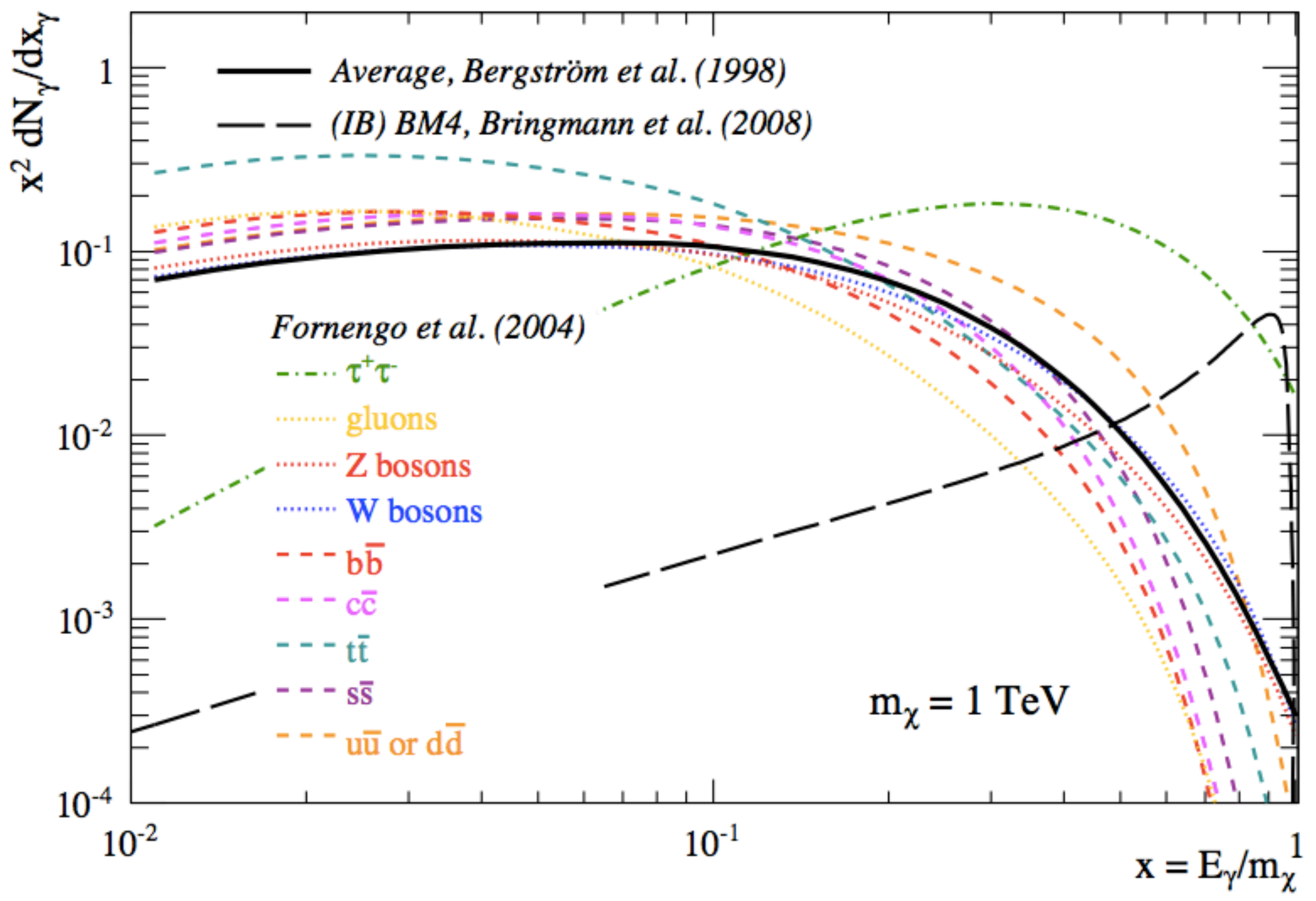
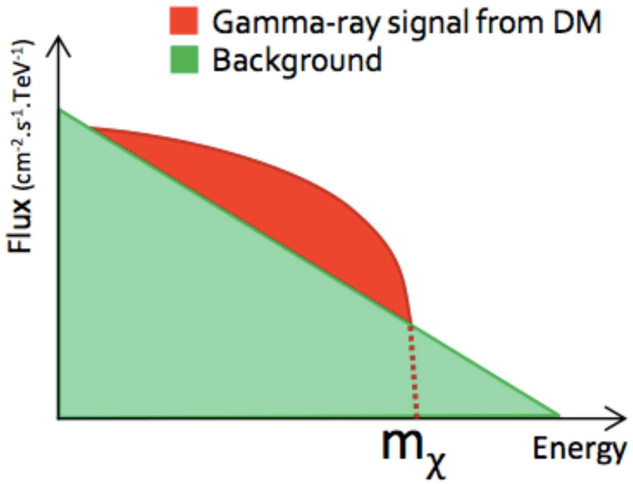
  - LHC results seem to indicate high-mass DM, TeV or above

History of a hunt

- searches started with the target classes that 10 years ago were supposed to be the best candidates:
  the galactic center, galaxy clusters and dwarf satellite galaxies
- More recently, the attention has been also focused on different kinds of searches:
  intermediate mass black holes, DM subhalos,
  signatures of line-emission.
- raised by the all-electrons and positron ratio anomalies observed in the past 5 years, – DM searches extended to signatures from **cosmic ray leptons**, observation which is also possible with IACTs.

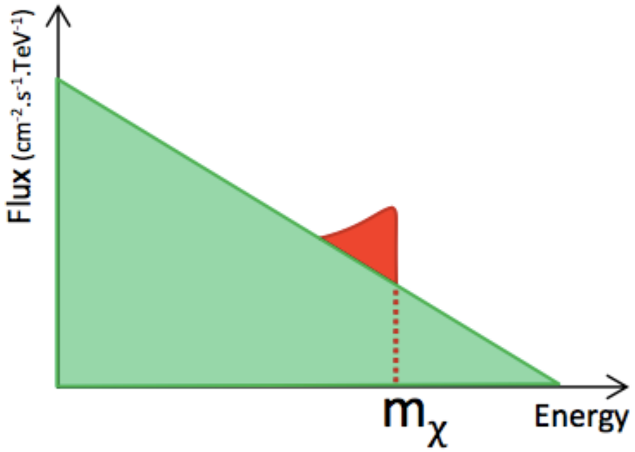
Gamma-Ray Emission



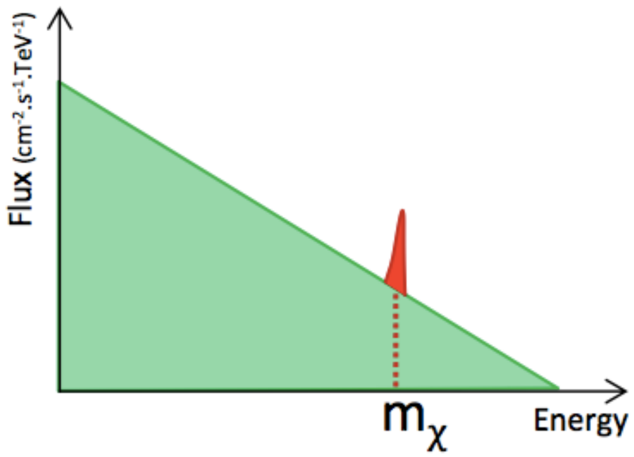


Continuous spectrum

but:
Eres
typically
30%



Extended spectral features



Monochromatic line

- neutral pion decays after hadronization of quarks
  → **broadband** spectrum terminating with a cutoff at the DM mass
- final-state radiation of leptons.
  → **broadband** spectrum and a cutoff, but with harder photons
- gamma rays from internal bremsstrahlung,
  → pronounced **bump** of gamma rays toward the mass cutoff
- from **line**-processes (direct two-body decay)
  → loop processes, whose intensity strongly depends on the specific DM realization

Gamma-Ray Photons

All in all, IACTs observe photons.
→ Every process is valuable as long as it provides enough photons to detect.
→ However, the more features the spectrum exhibits, the easier is the ID.

The astrophysical factor contains the line-of-sight integral of the squared dark matter density

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$$\frac{d\Phi}{dE}(E;\Delta\Omega) = \frac{B_F}{4\pi}\frac{\langle\sigma_{ann}v\rangle}{2\,m_\chi^2}\frac{dN_\gamma}{dE}\int_{\Delta\Omega}\int_{los} d\theta ds\,\rho^2(\theta,s)$$

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averaged annihil. cross section

velocity

gamma rays

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particle physics

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Boost factor

particle physics

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Boost factor

particle physics

density along line of sight
integrated over solid angle

J-factor
(astrophysics)

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gamma rays: # gamma rays

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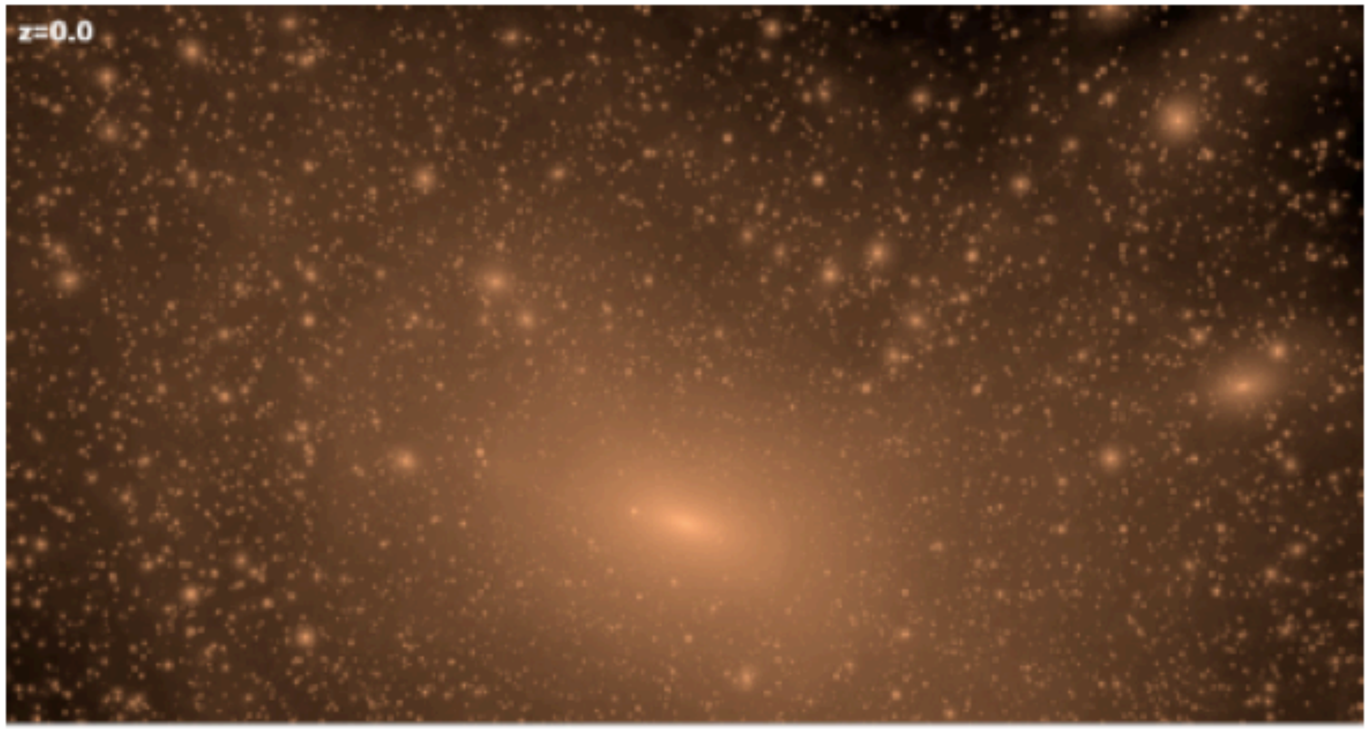
$\Gamma_{\mathrm{dec}}/m_\chi$ if decaying,
dependency linear

The astrophysical factor contains the line-of-sight integral of the squared dark matter density

So where to look then?

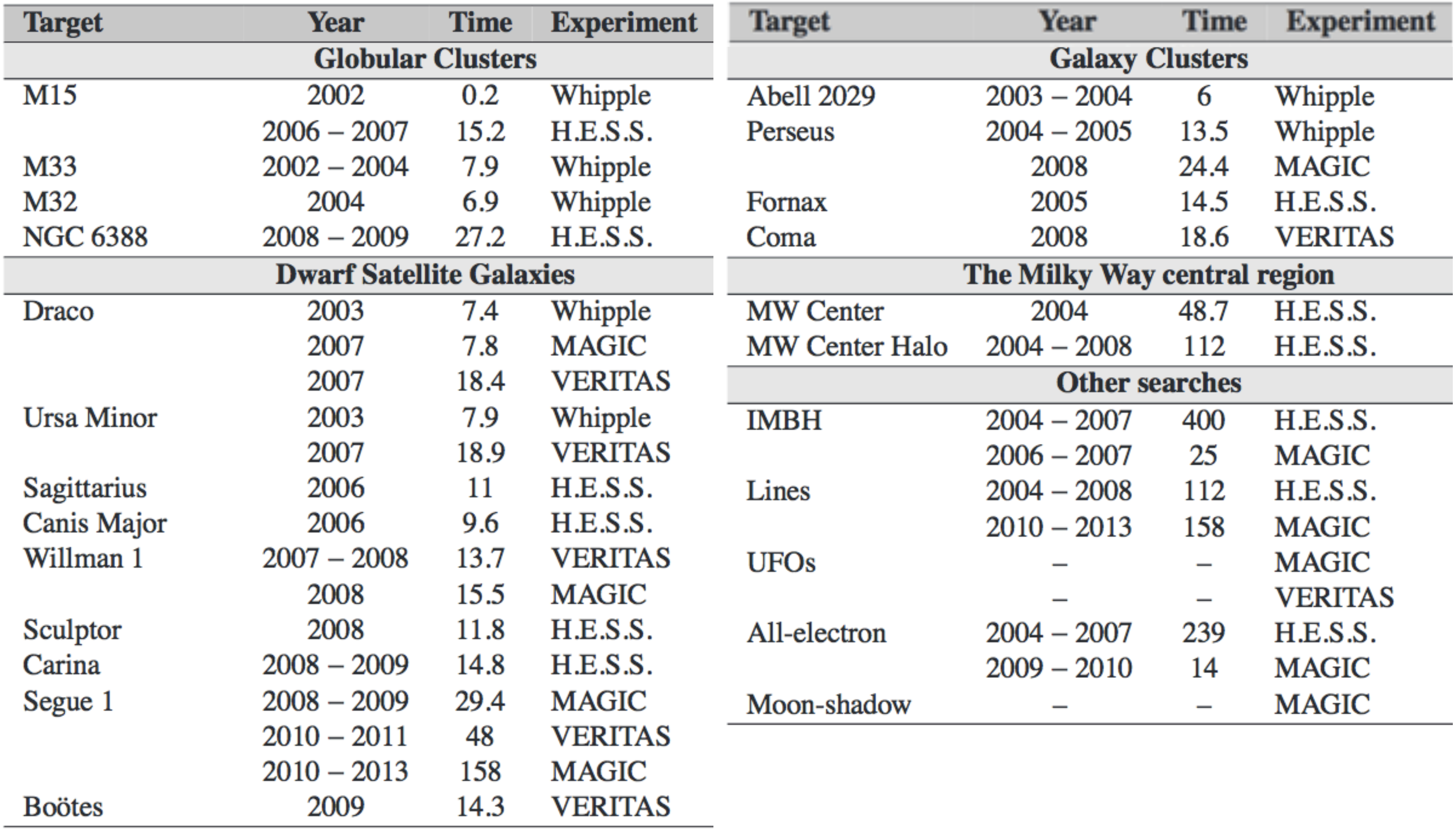
- Many models of dark matter densities are peaked towards the center- leading to a large signal from the center of a dark matter halo.
- Typical targets are either high signal sources, such as the galactic center, or have a large fraction of inferred dark matter versus ordinary matter- such as dwarf galaxies.



Via lactea n-body simulation of a galaxy

Doro 2014

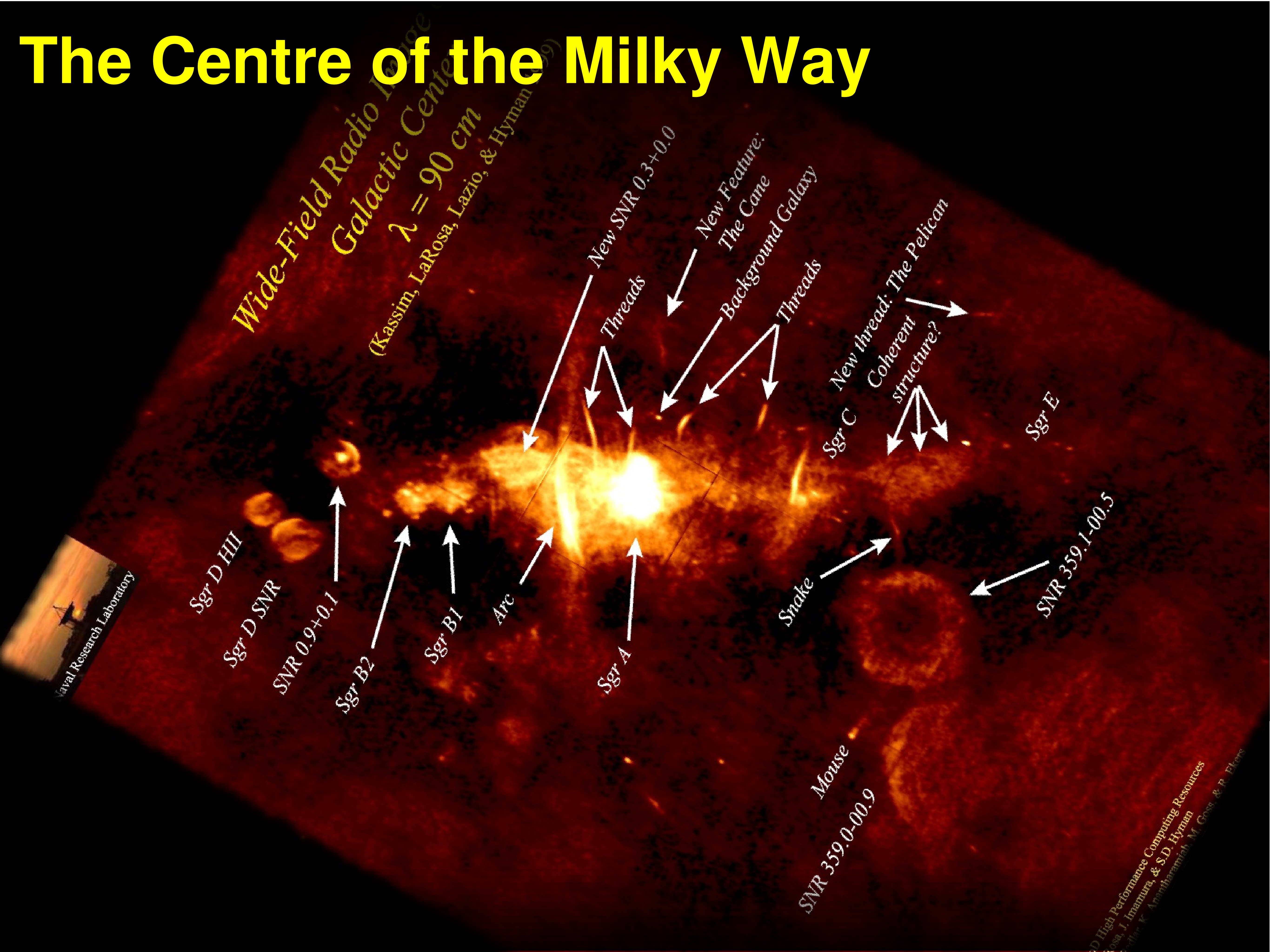
The “dark catalog”



Target	Year	Time	Experiment
Globular Clusters			
M15	2002	0.2	Whipple
	2006 – 2007	15.2	H.E.S.S.
M33	2002 – 2004	7.9	Whipple
M32	2004	6.9	Whipple
NGC 6388	2008 – 2009	27.2	H.E.S.S.
Dwarf Satellite Galaxies			
Draco	2003	7.4	Whipple
	2007	7.8	MAGIC
	2007	18.4	VERITAS
Ursa Minor	2003	7.9	Whipple
	2007	18.9	VERITAS
Sagittarius	2006	11	H.E.S.S.
Canis Major	2006	9.6	H.E.S.S.
Willman 1	2007 – 2008	13.7	VERITAS
	2008	15.5	MAGIC
Sculptor	2008	11.8	H.E.S.S.
Carina	2008 – 2009	14.8	H.E.S.S.
Segue 1	2008 – 2009	29.4	MAGIC
	2010 – 2011	48	VERITAS
	2010 – 2013	158	MAGIC
Boötes	2009	14.3	VERITAS
Galaxy Clusters			
Abell 2029	2003 – 2004	6	Whipple
Perseus	2004 – 2005	13.5	Whipple
	2008	24.4	MAGIC
Fornax	2005	14.5	H.E.S.S.
Coma	2008	18.6	VERITAS
The Milky Way central region			
MW Center	2004	48.7	H.E.S.S.
MW Center Halo	2004 – 2008	112	H.E.S.S.
Other searches			
IMBH	2004 – 2007	400	H.E.S.S.
	2006 – 2007	25	MAGIC
Lines	2004 – 2008	112	H.E.S.S.
	2010 – 2013	158	MAGIC
UFOs	–	–	MAGIC
	–	–	VERITAS
All-electron	2004 – 2007	239	H.E.S.S.
	2009 – 2010	14	MAGIC
Moon-shadow	–	–	MAGIC

- Several target classes, tens of sources, hundreds hour observation
- No hint so far…

The Centre of the Milky Way



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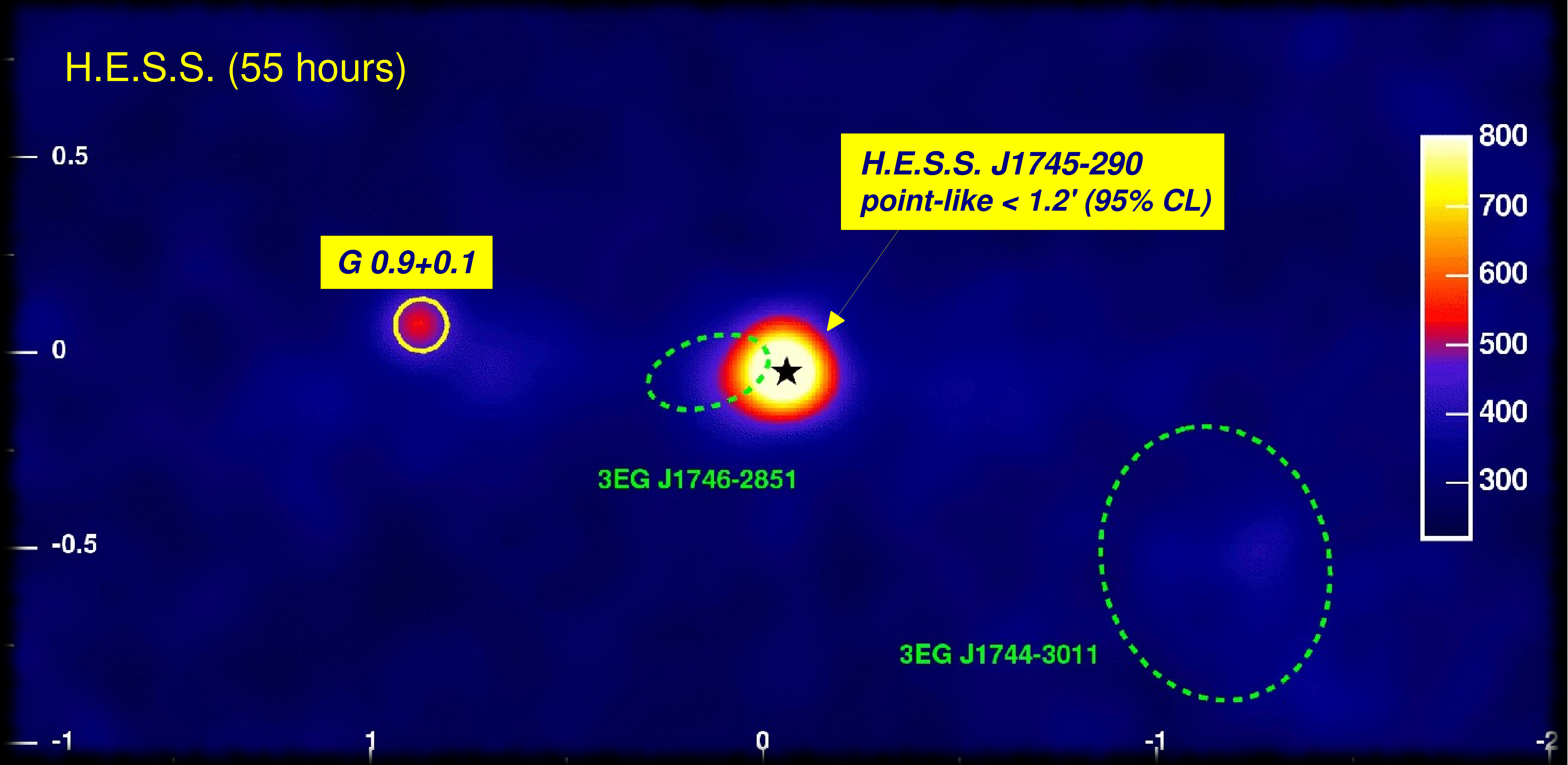

Aharonian et al. (2006)

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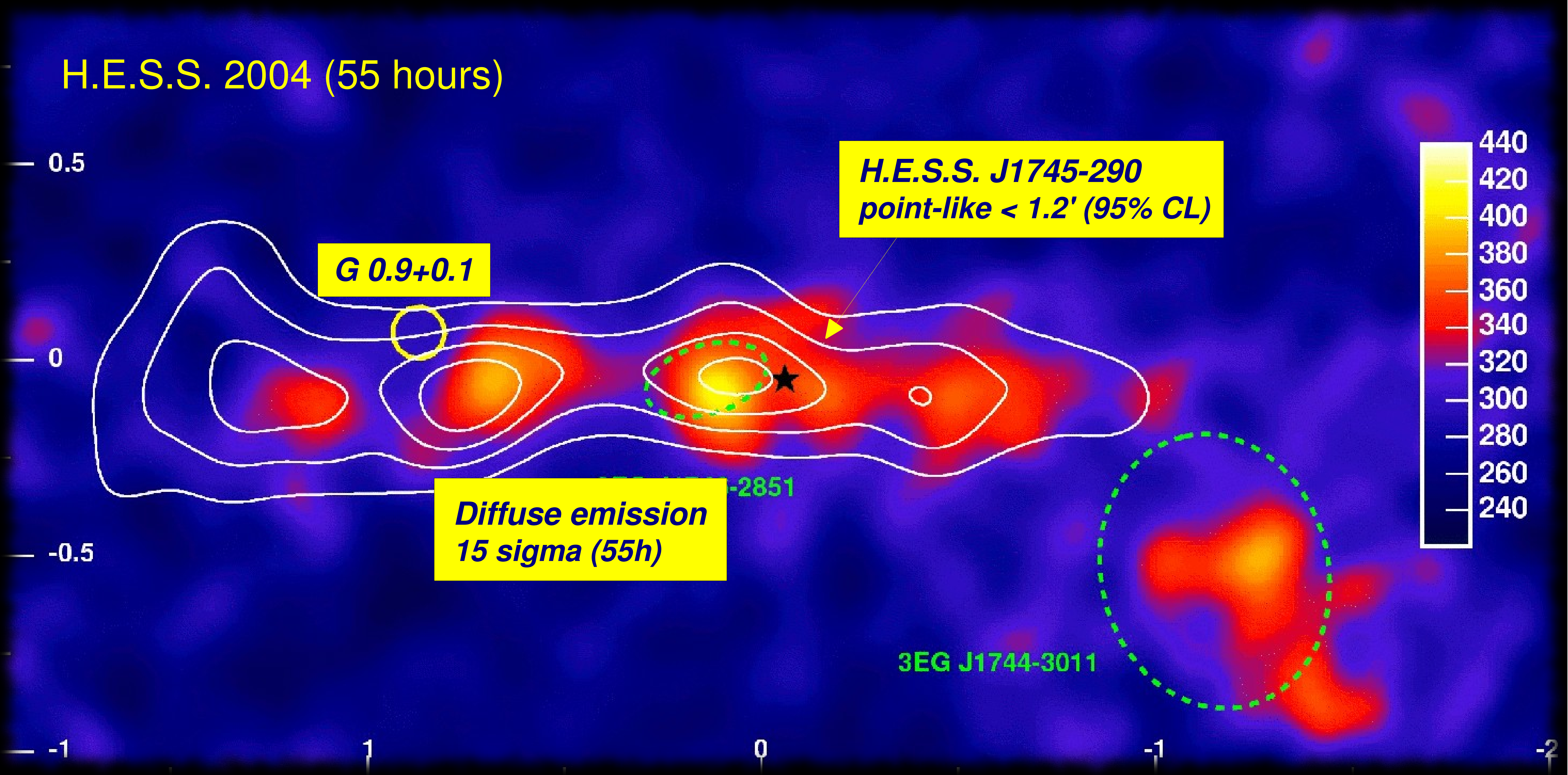


H.E.S.S. J1745-290
point-like < 1.2' (95% CL)

G 0.9+0.1

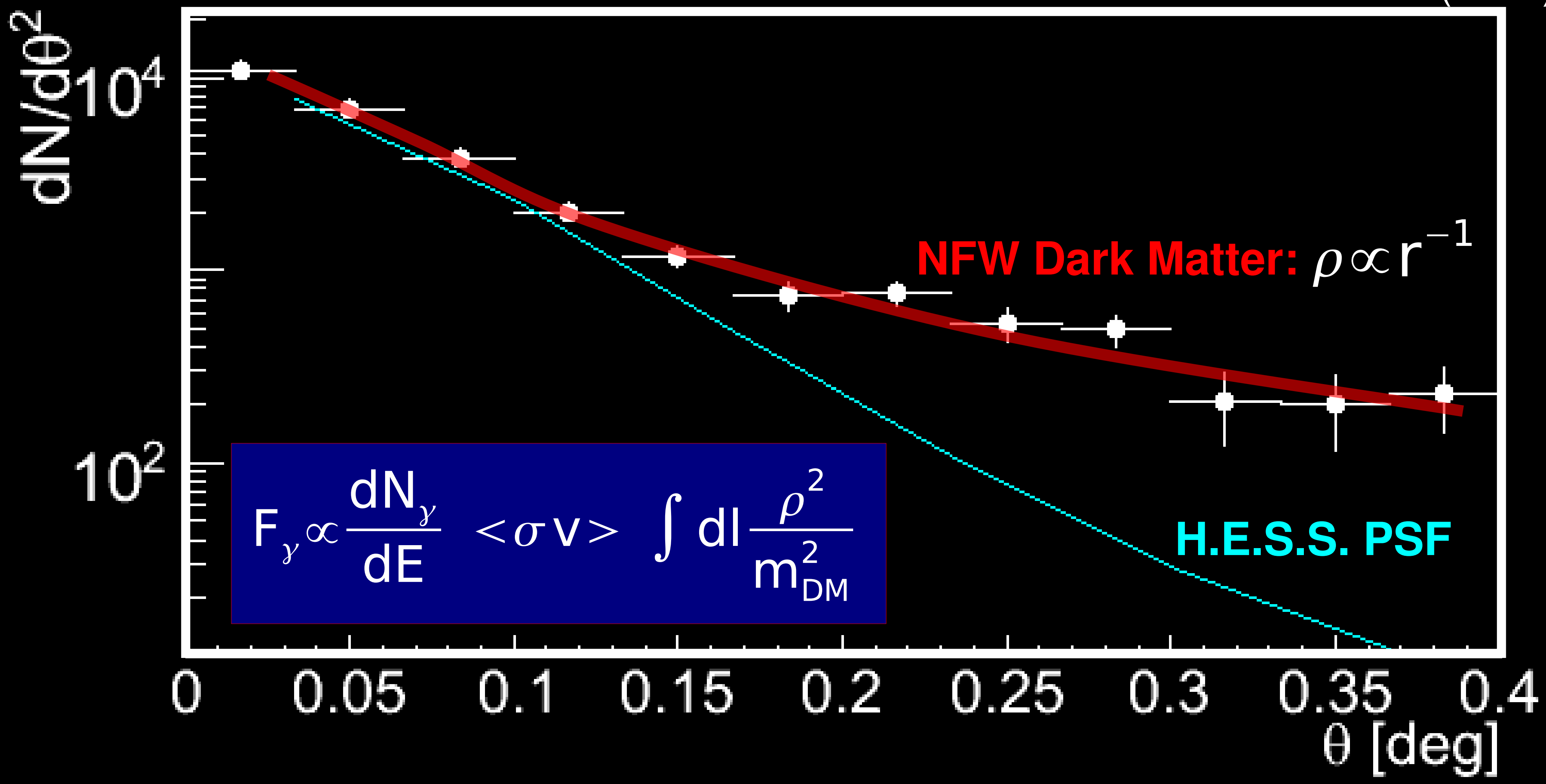
Diffuse emission
15 sigma (55h)

Aharonian et al. (2006)

HESS J1745-290

... not much room for Dark Matter

Aharonian et al (2006)

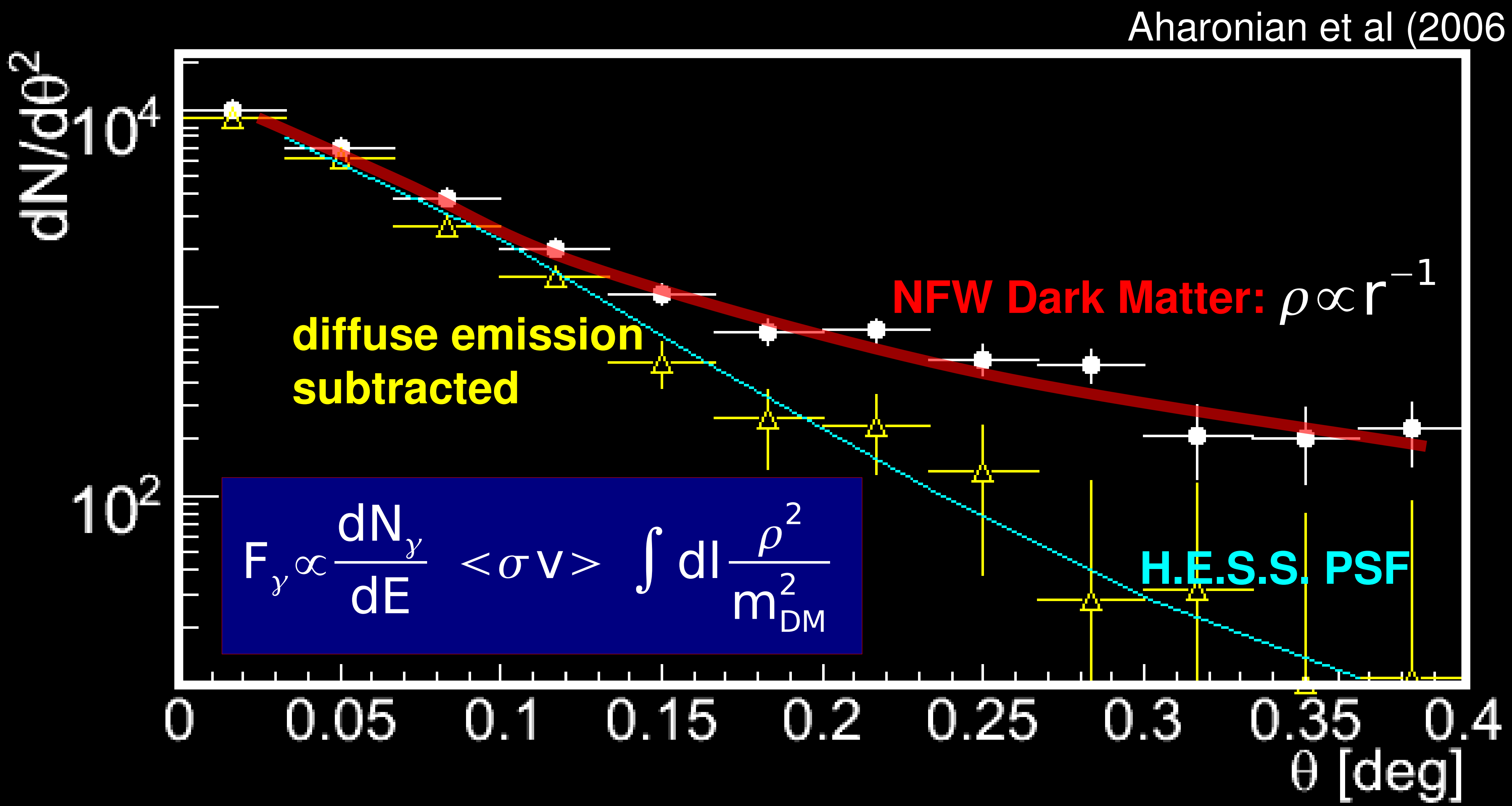


$$F_\gamma \propto \frac{dN_\gamma}{dE} \;<\sigma v>\; \int dl \frac{\rho^2}{m_{DM}^2}$$

- radial source profile fits NFW DM at first glance, but...

HESS J1745-290

... not much room for Dark Matter



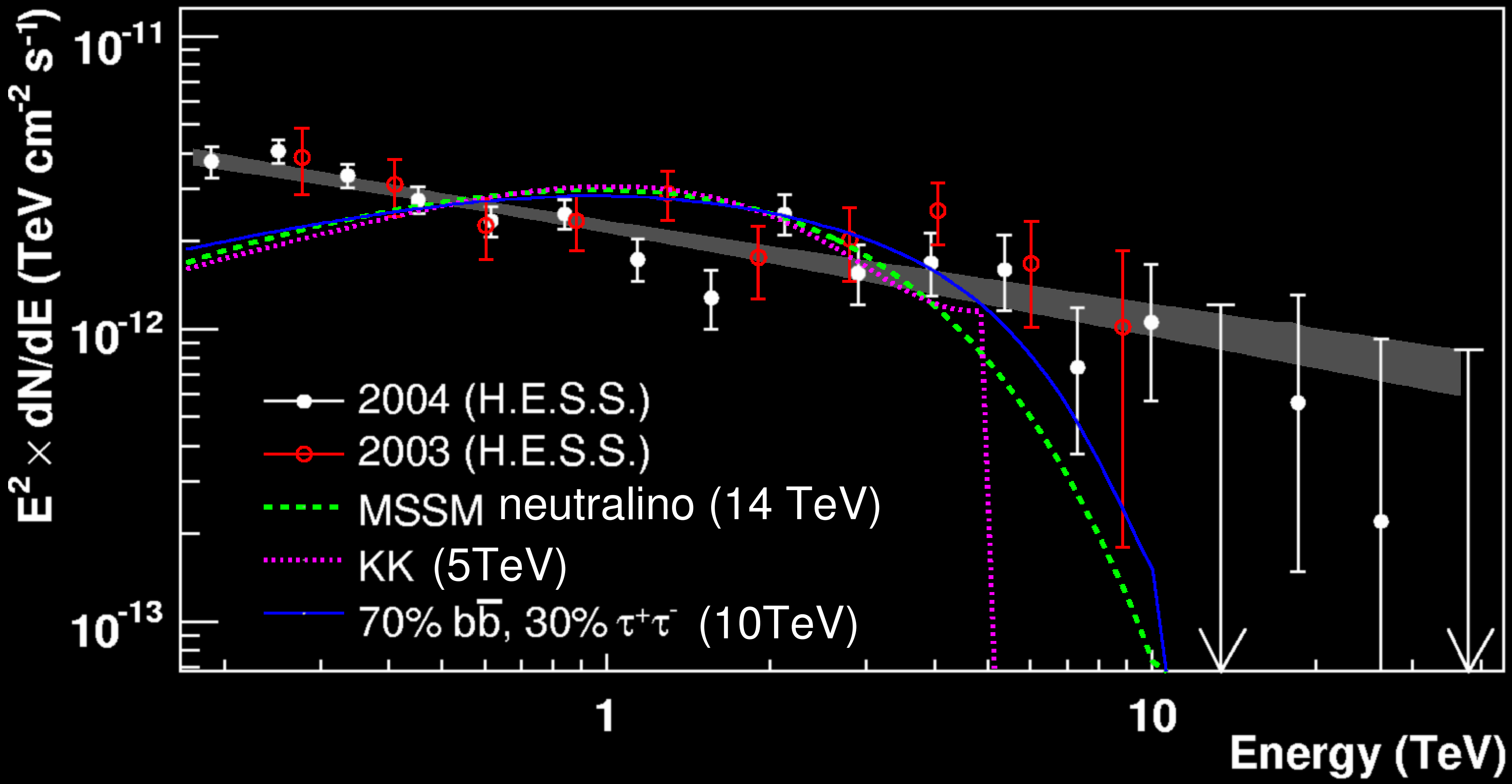
$$F_\gamma \propto \frac{dN_\gamma}{dE} <\sigma v> \int dl \frac{\rho^2}{m_{DM}^2}$$

- radial source profile fits NFW DM at first glance, but...
  ... point-like after subtraction of diffuse emission
- DM density stronger peaked than $r^{-1.2}$ (99% CL)

HESS J1745-290

... not much room for Dark Matter

- energy spectrum: straight powerlaw
  exponential cutoff: E_C > 9 TeV @ 95% CL
- curved annihilation spectra
  + “uncomfortably large” masses in MSSM
- 10% DM contribution not ruled out
  → derived limits on <σv> do not constrain models



Aharonian et al. 2006

Dwarf Satellite Galaxies

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- rather small (order 10^7 $M_\odot$), gravitationally bound to the Milky Way, located in the Milky Way dark matter halo, at distances below 250 kpc.

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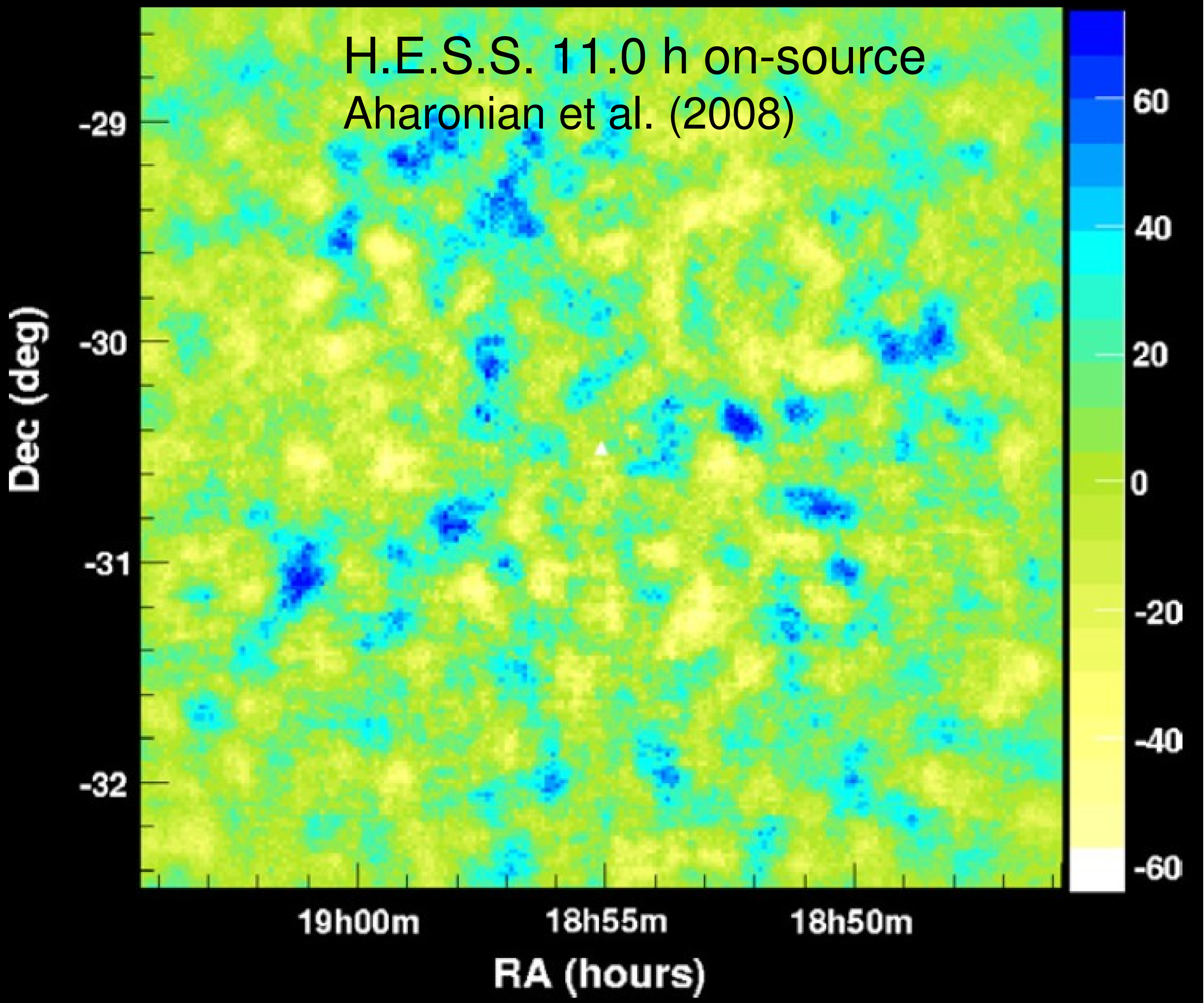
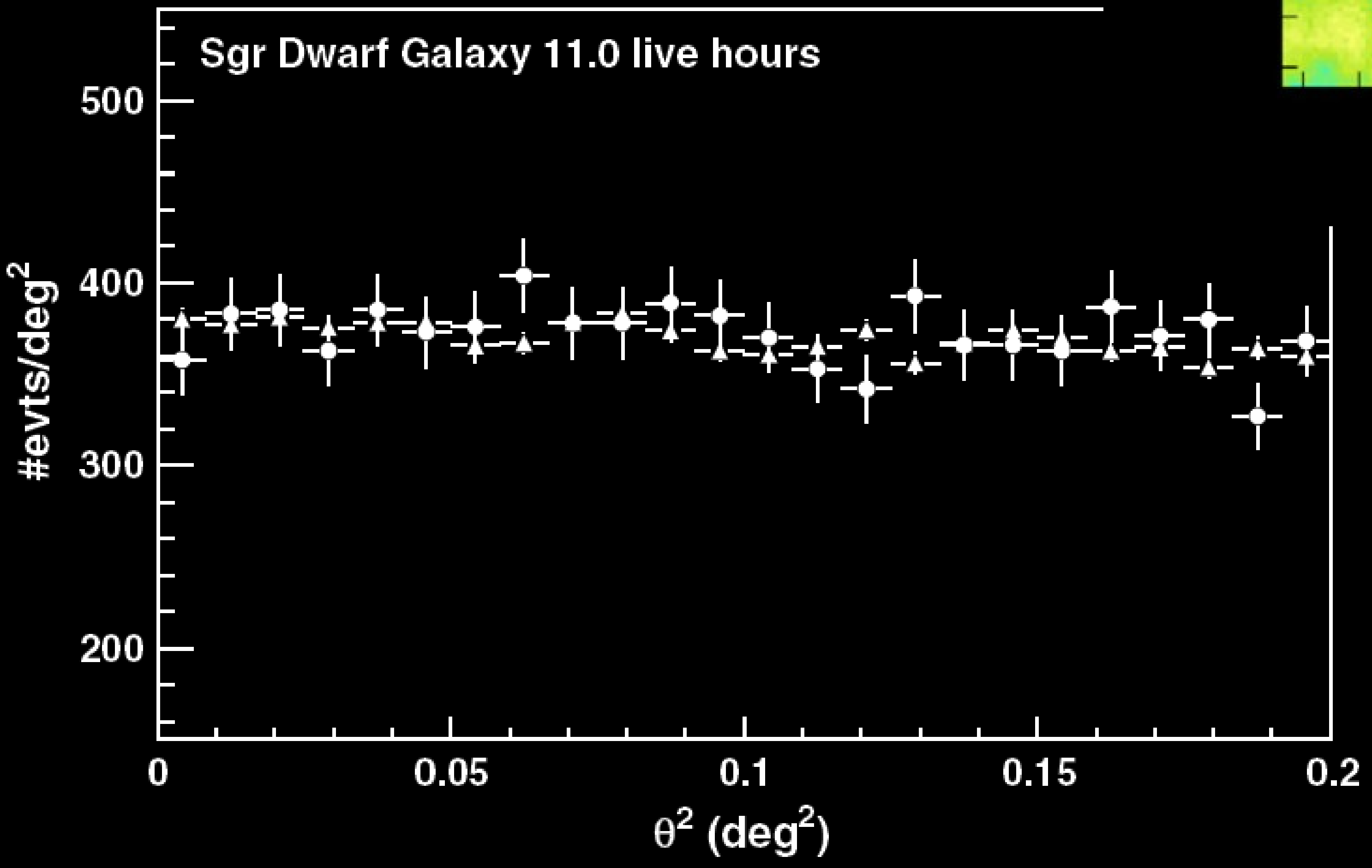
➥ exclusion limits obtained with DSGs are possibly the most robust for indirect DM searches with IACTs with upper limits reaching cross-section values of the order of 10^{-24} cm^3 s^{-1}.

Sagittarius Dwarf

- Satellite galaxy in the Local Group
- 24 kpc distance, so close-by
- Several Galactic disk crossings
  → likely disrupted w/o large DM content
- Galaxy core is point-like for H.E.S.S.





- No significant signal detected

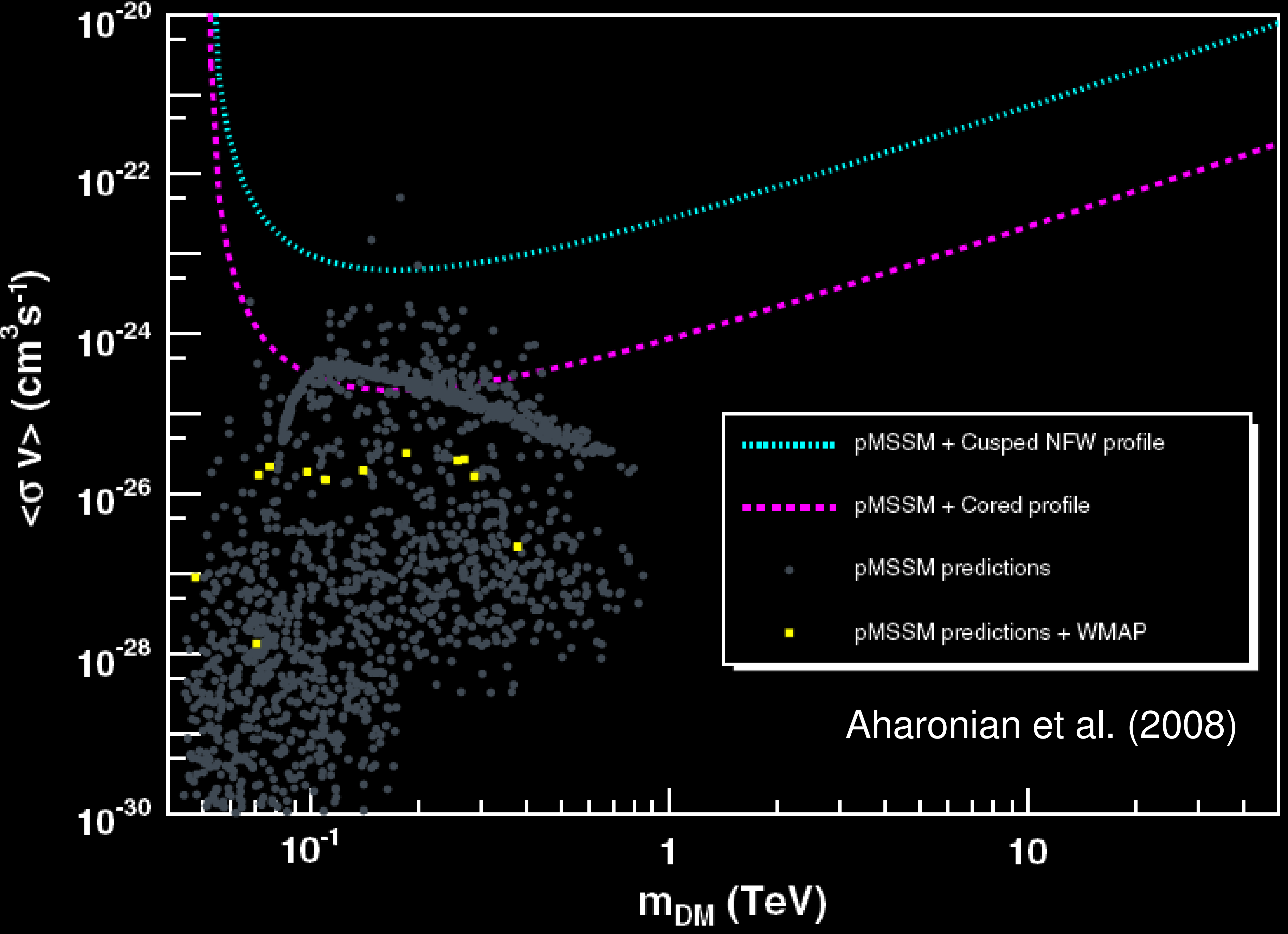
→ derive flux upper limit (95% CL):

$F(>250\,\mathrm{GeV}) < 3.6\times10^{-12}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$

or less than 56 γ-rays...

Sagittarius Dwarf

- Used both NFW and “cored” profile adjusted to object parameters
- Calculate pMSSM annihilation cross section limits
- Can constrain some models depending on core profile
- WMAP compliant models still viable



Aharonian et al. (2008)

Globular Clusters

- share some properties with DSGs,
  but in general are less bright and less massive.
- stellar population: GCs more homogeneous stellar content in terms of star classification.
- GCs M15, M32 and M33 observed from 2002 to 2004 by Whipple and later on M15 was reobserved together with NGC6388 by H.E.S.S. in 2006–2009.

➥ The best exclusion curves for annihilating DM come from the H.E.S.S. results, and are the order of $10^{-24} – 10^{-25}$ cm^3 s^{-1},
however they rely on strong assumptions of the dominance on DM in these objects.

Subhalos

- Prediction of the existence of small DM overdensities at all scales within a galaxy's main smooth halo.
- Some of these "subhalos" too small to have attracted enough baryonic matter to initiate star formation?
  → invisible to past and present astronomical observations at all wavelengths.
- Gamma rays due to annihilations or decays of DM?
  → "Dark Gamma-Ray Sources", need gamma-ray all-sky monitoring programs.

➥ Following this idea, the MAGIC and VERITAS collaboration investigated among the unidentified Fermi objects,
(no obvious counterparts, no variabilty, hard spectra)
that could be explained as subhalos

IMBHs

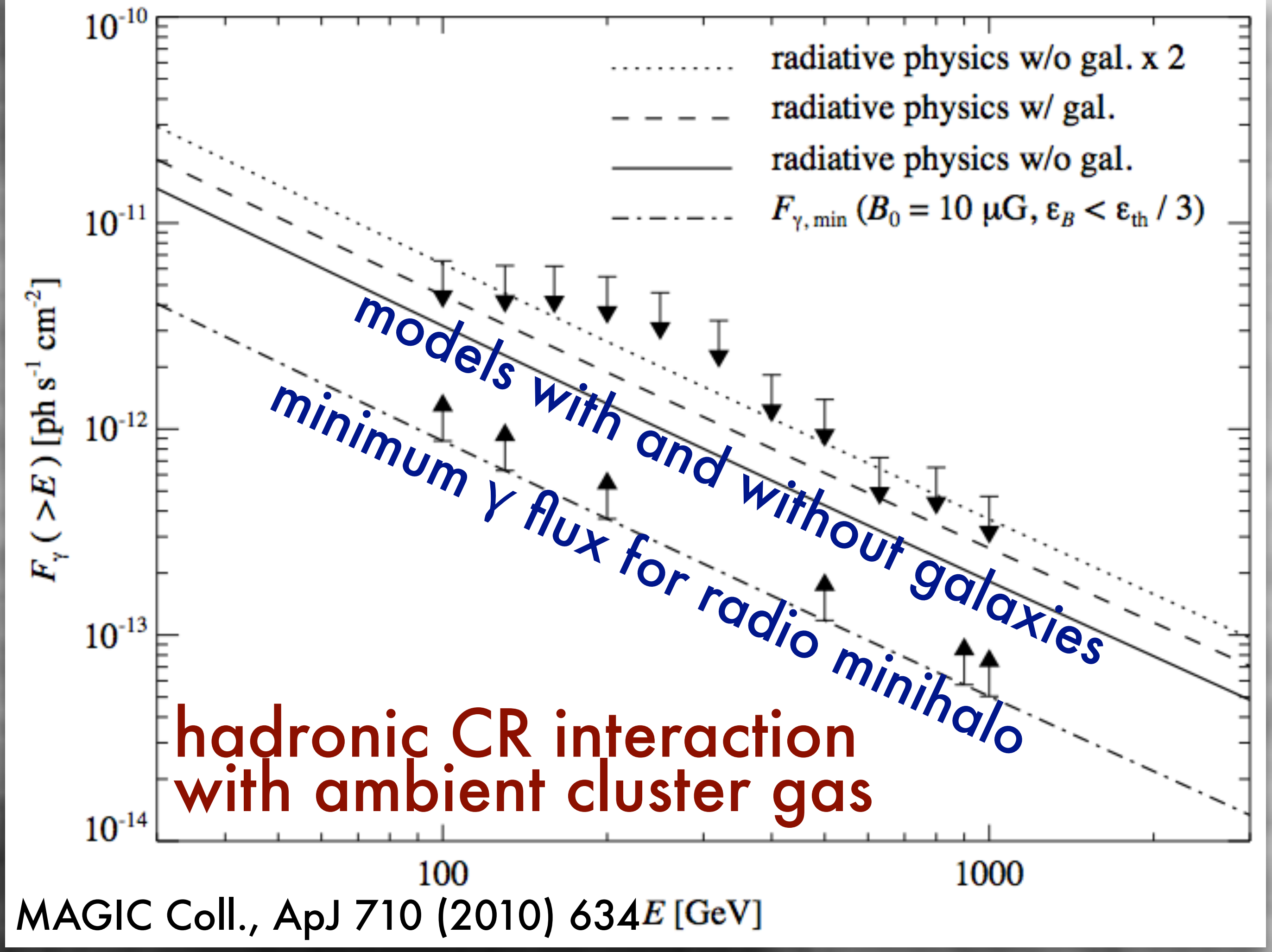
- between $10^2 - 10^6\ M_\odot$
- Many of them could reside in the Milky Way halo.
- Remnants of collapse of massive Population III stars → on the order of about a thousand.
- or originate from massive objects formed directly during the collapse of primordial gas → about a hundred.
- gravitational potential due to infalling baryons on a central accreting system, DM could have readjusted and shrunk, giving rise to the formation of what are called “mini-spikes”.
- adiabatic growth of the spike leads to a final DM density profile even cuspier than the NFW
- gamma-ray luminosity would be of the order of the gamma-ray luminosity of the entire Milky Way halo

➡ H.E.S.S. could exclude scenario B at a 90% confidence level for dark matter particles with velocity-weighted annihilation cross-section $\langle \sigma v \rangle$ above $10^{-28}\ \mathrm{cm}^3\ \mathrm{s}^{-1}$ and mass between 800 GeV and 10 TeV.

Clusters of Galaxies

- with masses around $10^{14} – 10^{15}$ M$\odot$, the largest gravitationally bound objects and the most recent structures to form
- DM account for up to 80% of mass budget
- complex environment, also other gamma-ray sources (NGC 1275, IC310)
- different **morphologies** of DM (extended), cosmic-ray (compact) and the individual galaxies (point-like) could be used as a discriminator for the different components, as well as the obvious differences in the expected gamma-ray spectra
- deepest exposures are performed with MAGIC (Perseus cluster) and VERITAS (Coma cluster). For DM searches, probably the strongest constraints come from the observation of the Fornax galaxy clusters, expected to be the most DM dominated one.
- only upper limits on any CR and DM associated emission. Fermi-LAT satellite measurements in the GeV mass range, complement the latter in the TeV mass range.

NGC 1265, also in the Perseus Cluster; O'Dea & Owen (1998)

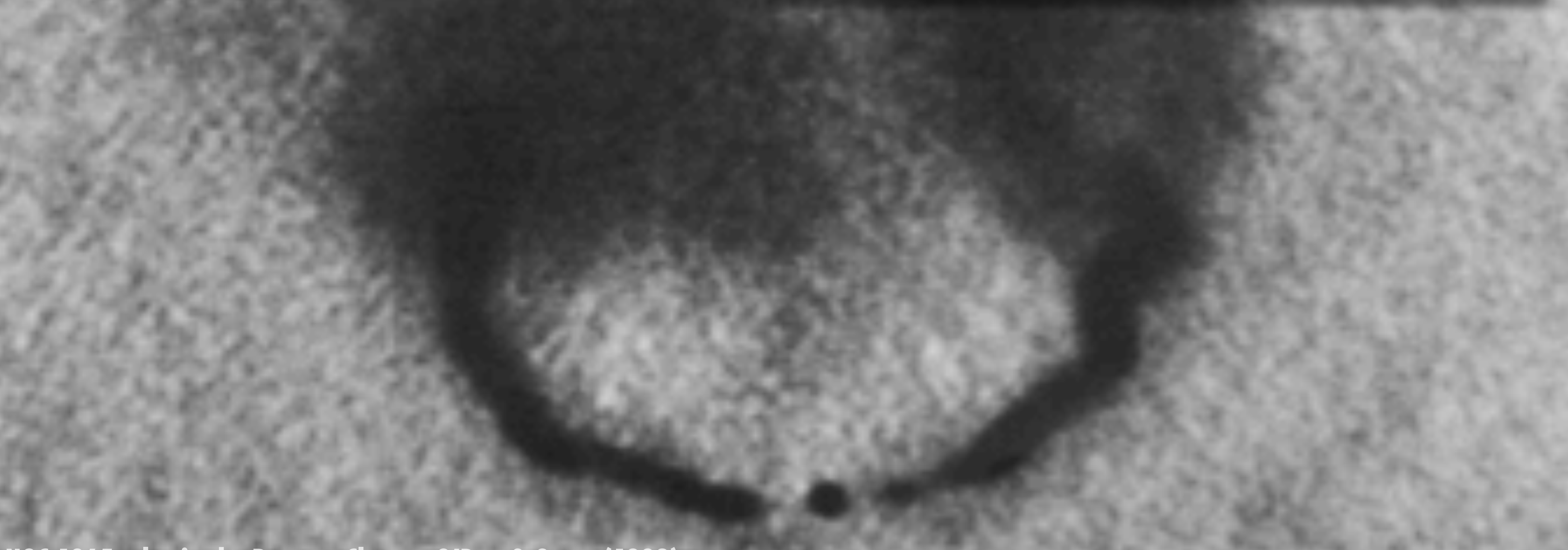


models with and without galaxies

minimum γ flux for radio minihalo

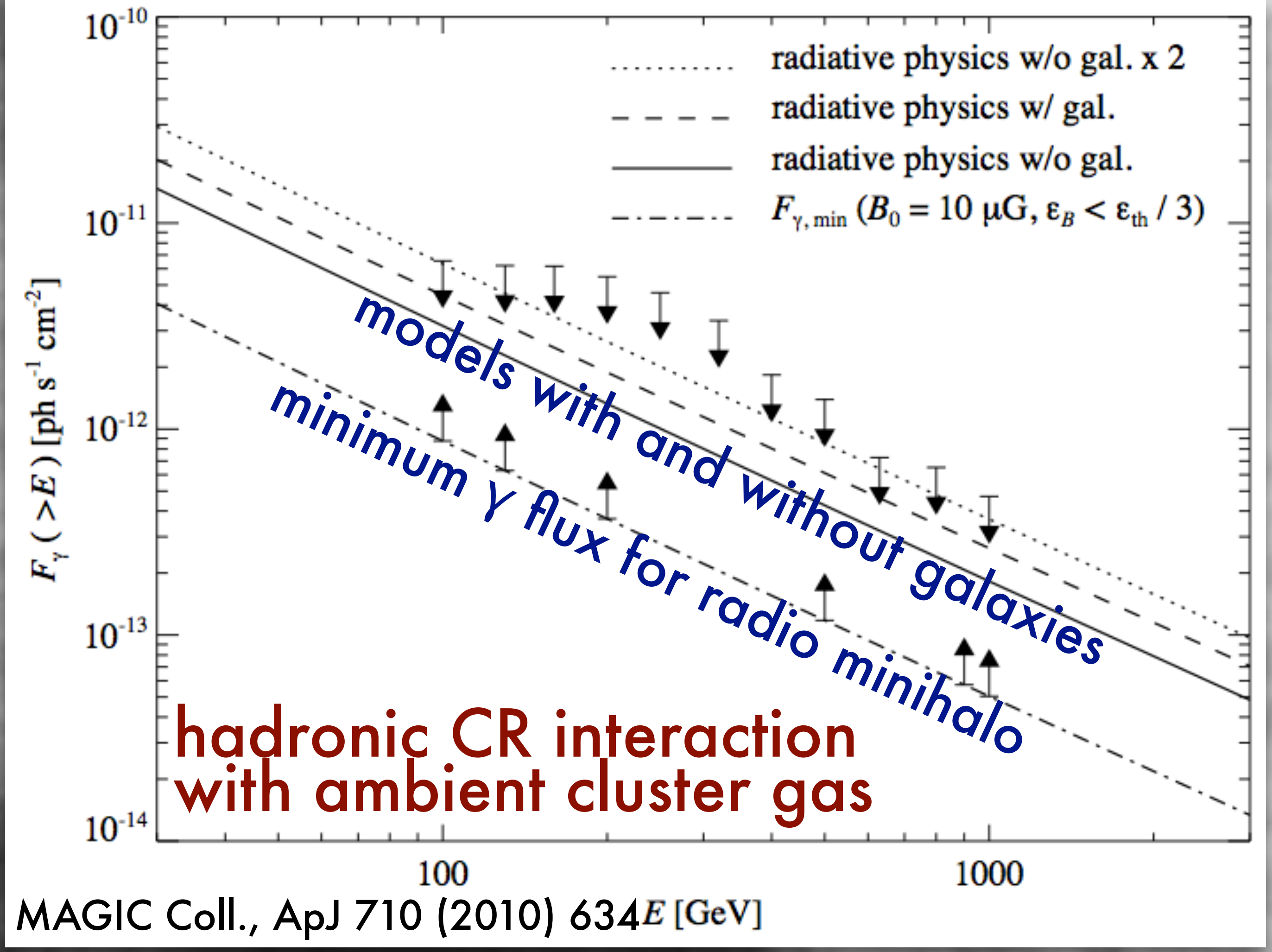
hadronic CR interaction
with ambient cluster gas

MAGIC Coll., ApJ 710 (2010) 634



NGC 1265, also in the Perseus Cluster; O'Dea & Owen (1998)

- Upper limits on the gamma-ray emission constraining the emission produced by
- cosmic rays: CR-to-thermal pressure <4% for cluster core, <8% for entire cluster
- dark matter annihilation: limit consistent with boost factors of ≈10^4
- central radio galaxy NGC1275: compatible with Fermi-LAT detection.



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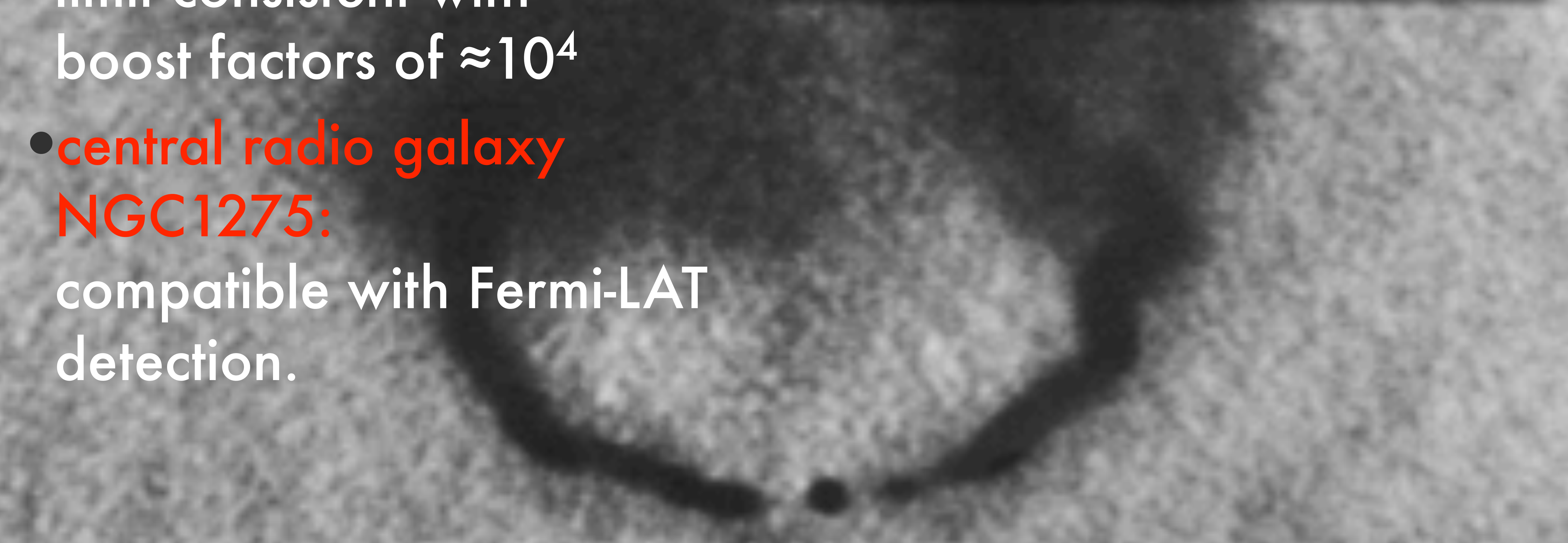
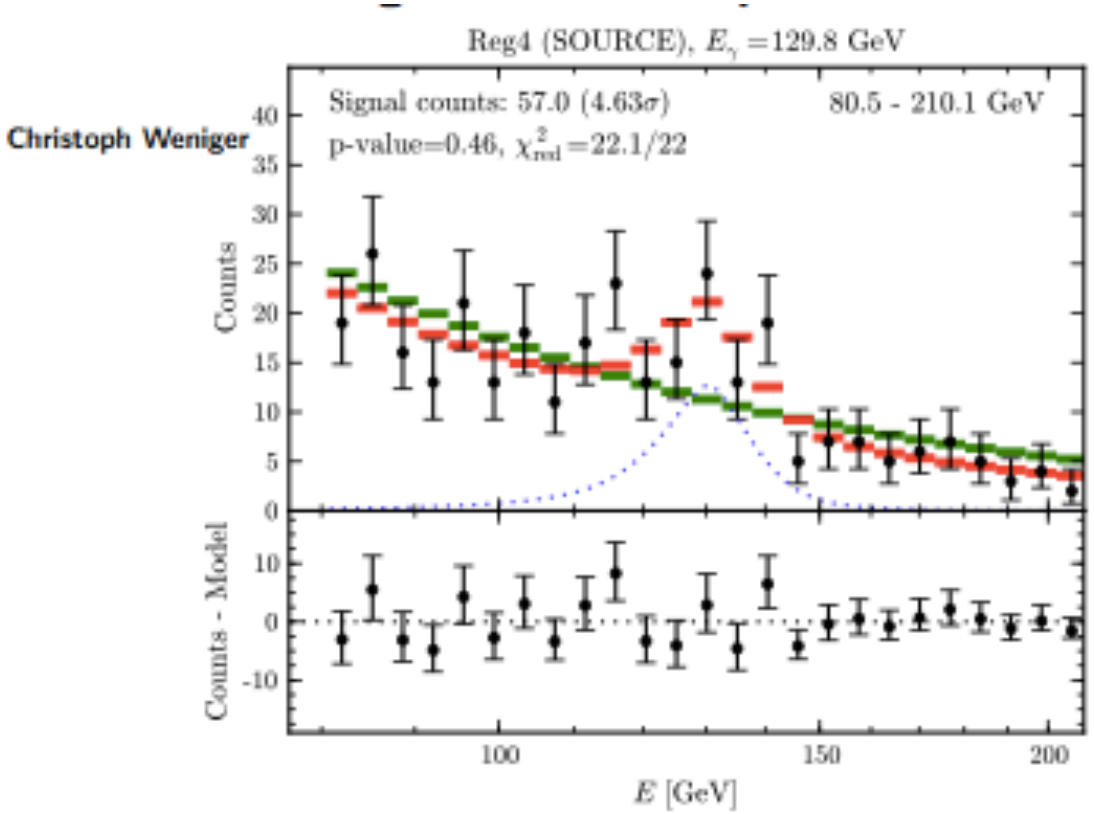
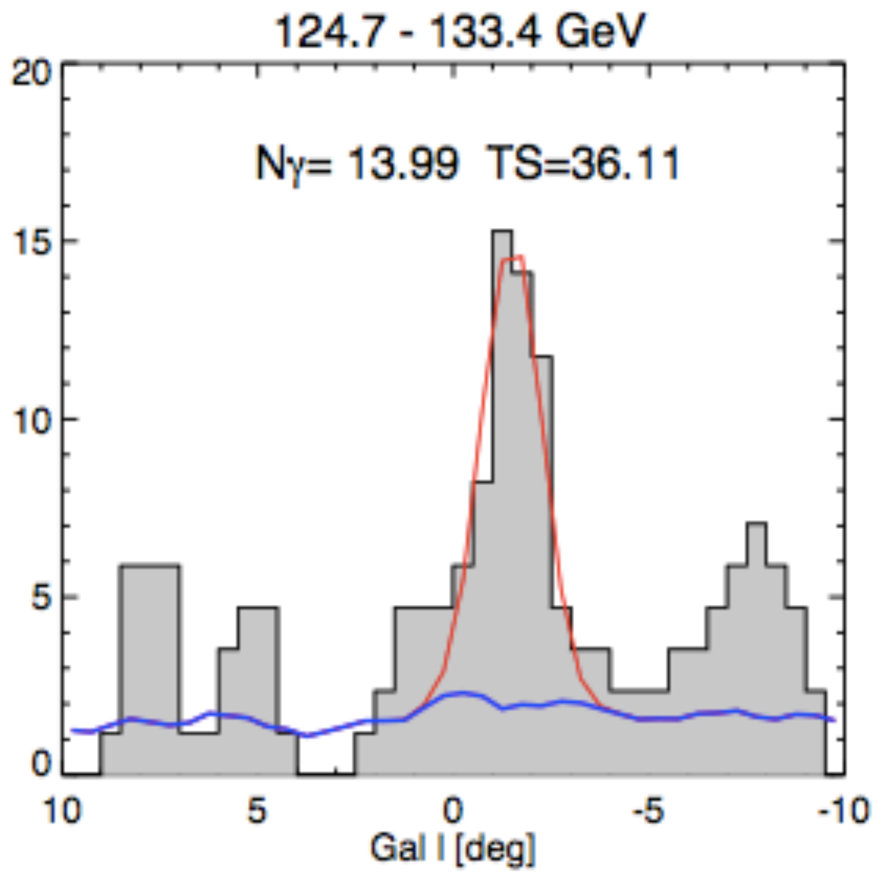


NGC 1265, also in the Perseus Cluster; O'Dea & Owen (1998)

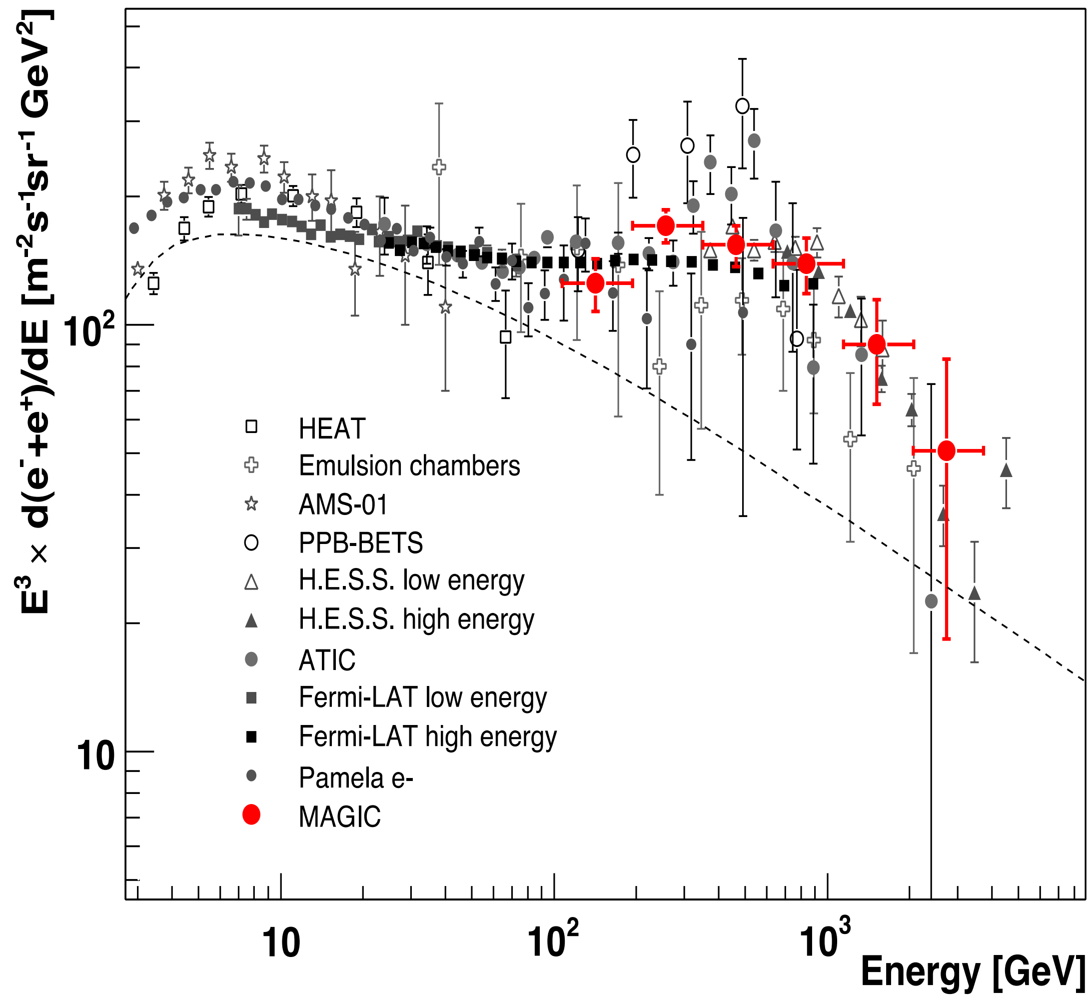
Line emission

- An analysis by Weniger of Fermi-LAT data(arxiv:1204.2797v2) showed a line feature in the spectrum at 130 GeV from the galactic center, with a 3.2σ significance.
- The feature corresponded to a cross section of <σv>=1.27e-27 cm^3/s.
- Su and Finkbeiner (arxiv: 1206.1616) located the signal at 1.5° west of the galactic center, and found a 5σ detection.
- The significance has been seen to be decreasing with more data.

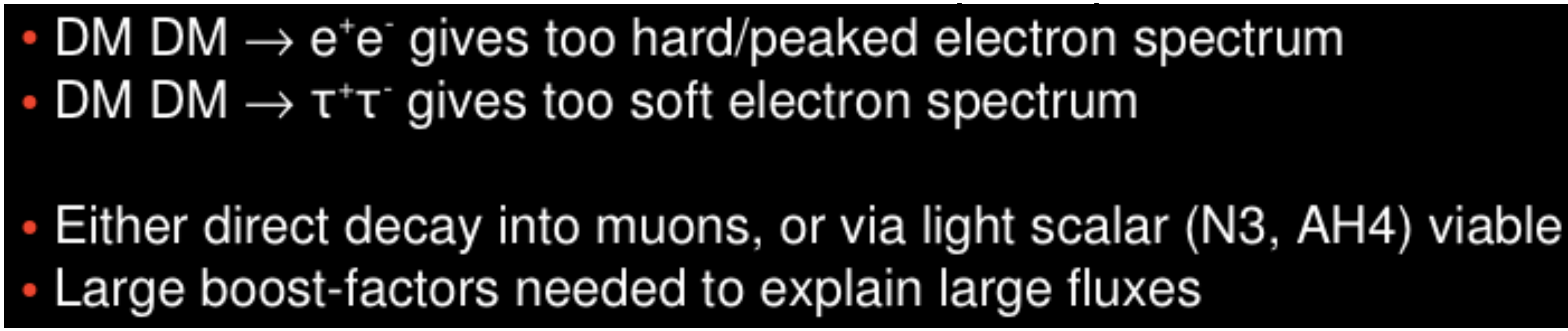




DM searches via CR electron(s)



- Many experiments find anomalies in CRs fluxes
  - PAMELA, AMS+: rising e+/e± ratio above 10 GeV
  - Fermi, HESS: rising e± spectrum above 100 GeV
- Explanations: nearby astrophysics sources, Dark Matter annihilation/decay, different CR propagation

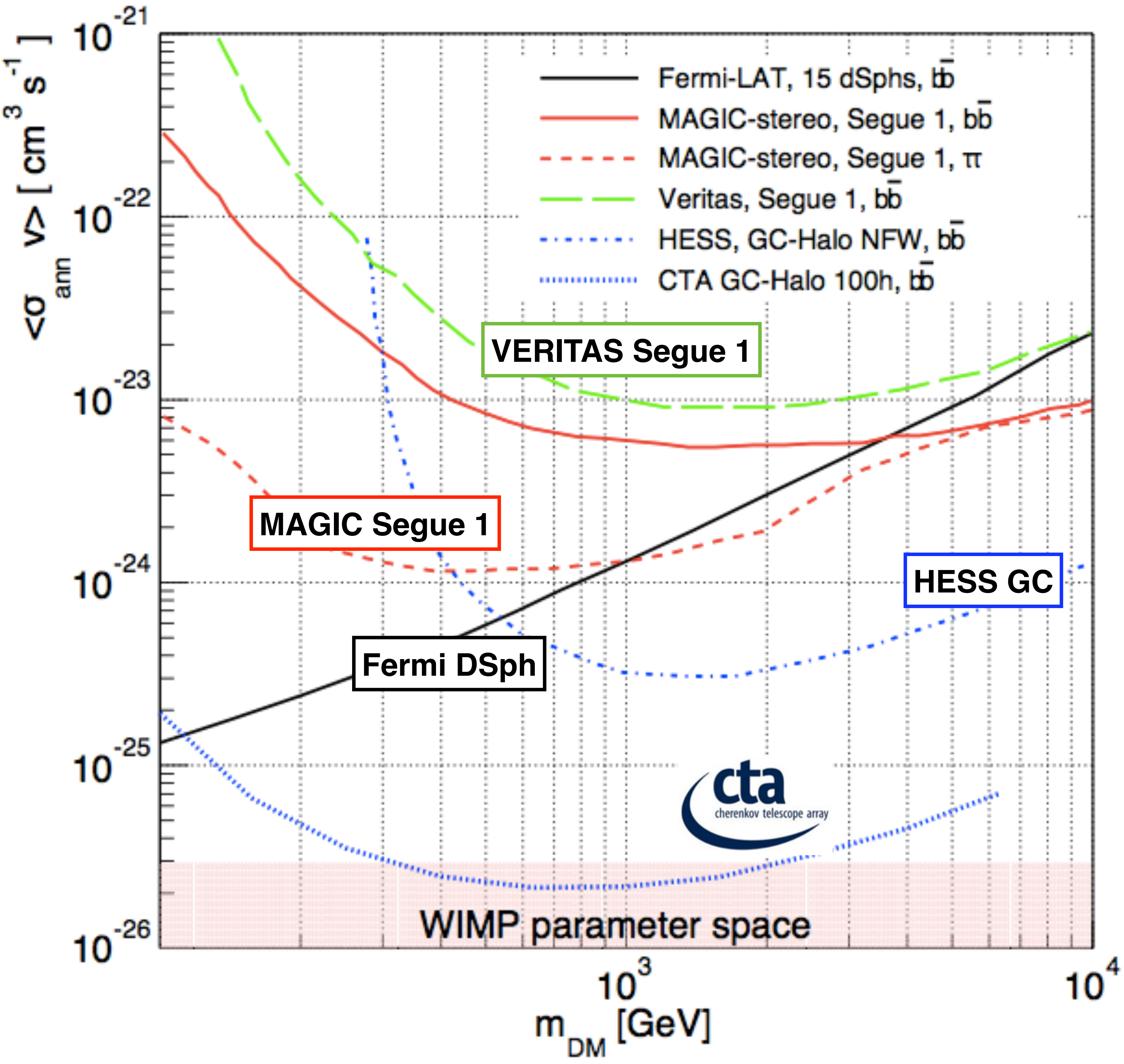


- DM DM → e^+e^- gives too hard/peaked electron spectrum
- DM DM → $\tau^+\tau^-$ gives too soft electron spectrum

- Either direct decay into muons, or via light scalar (N3, AH4) viable
- Large boost-factors needed to explain large fluxes

Doro 2014

Status today



- Fermi is more sensitive below few hundreds GeV
- Observation at dSph needs large boost factor for detection
- Galactic Center observation are promising
- *Are we close or far?*

Highly successful, but …

Some key object classes still elusive, e.g.

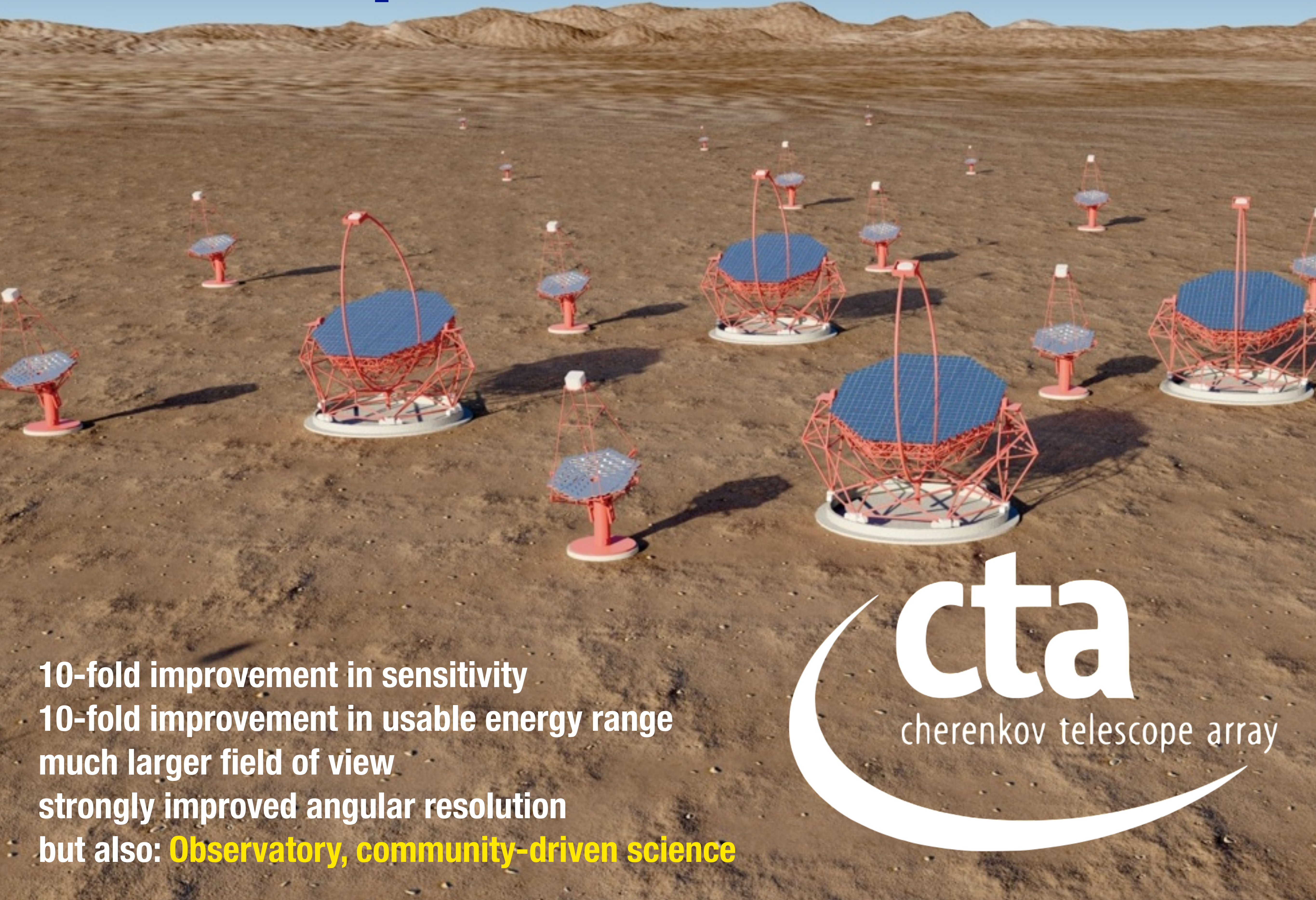
- Galaxy clusters as cosmological storehouses of CRs
- Very high energy emission from GRB
- Dark Matter annihilation signatures

Some key mechanisms remain to be understood, e.g.

- Supernovae as sources of cosmic rays: do they provide sufficient peak energy & energy output?
- Cosmic ray escape from accelerators and propagation
- Energy conversion in pulsars

Energy range & angular resolution of current instruments insufficient to probe details

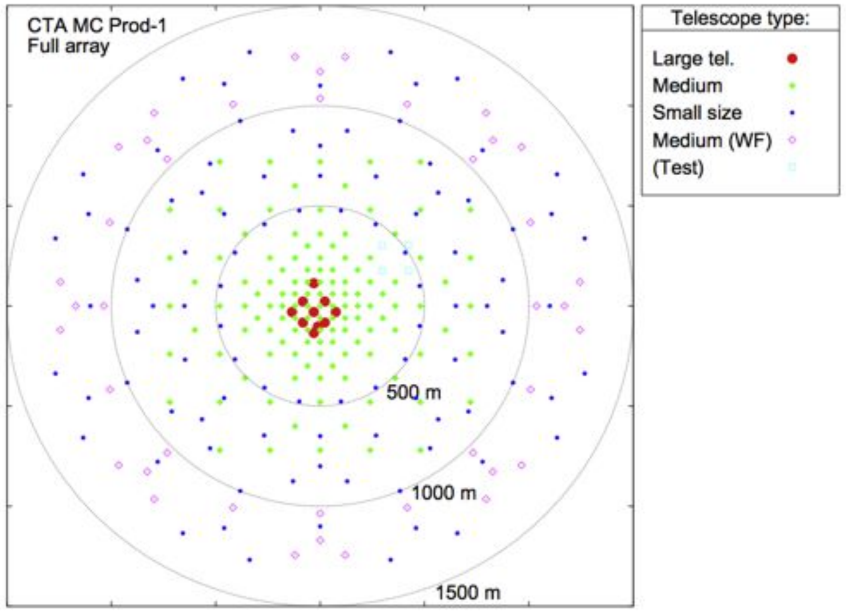
A crucial step forward: Enter CTA



10-fold improvement in sensitivity
10-fold improvement in usable energy range
much larger field of view
strongly improved angular resolution
but also: Observatory, community-driven science

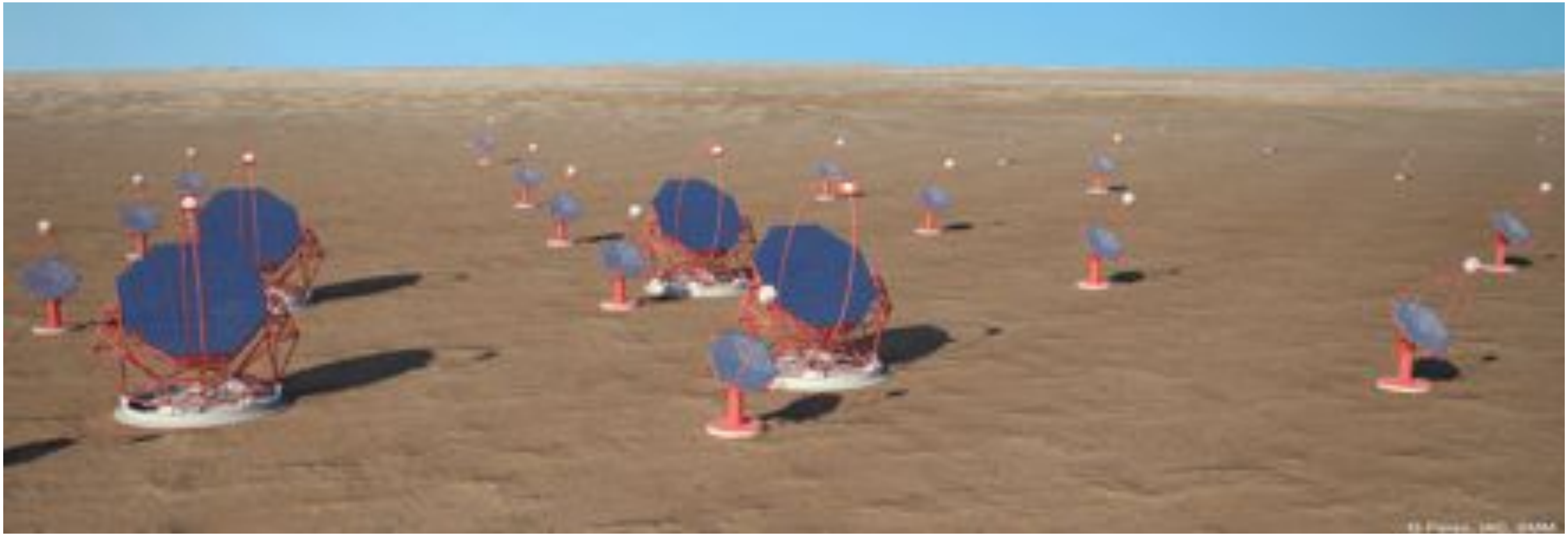
cta
cherenkov telescope array

Cherenkov Telescope Array

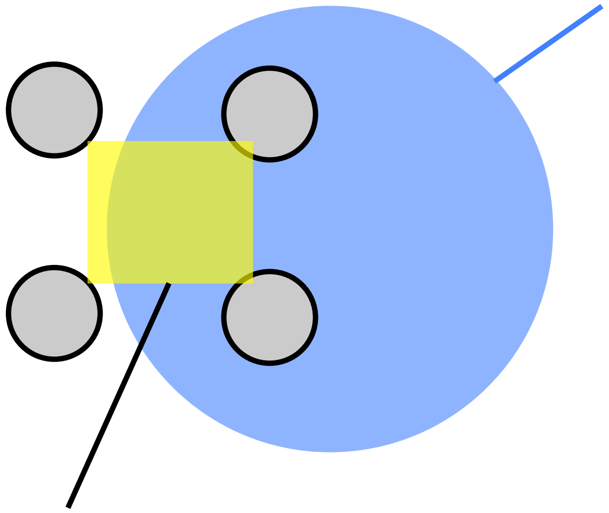


- A project for a new generation of Cherenkov Telescopes
- Gamma-ray precision astronomy and astrophysics from **few tens of GeV to >100 TeV**
- **Two sites**: one Southern and one Northern
- **Hundred telescopes** in total

http://www.cta-observatory.org/



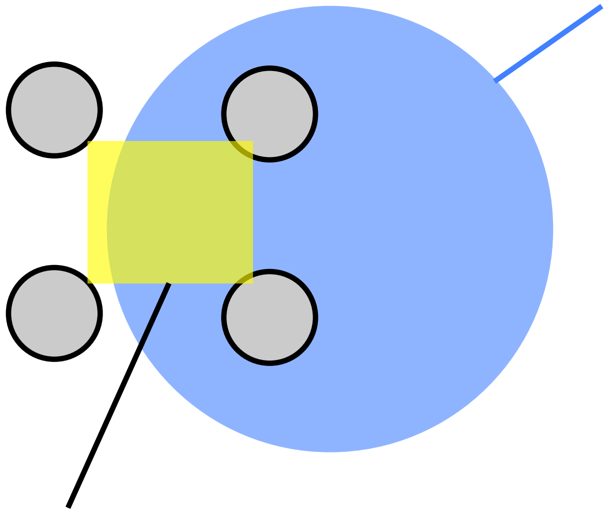
From current arrays to CTA



Light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
Most shower cores miss it!

From current arrays to CTA



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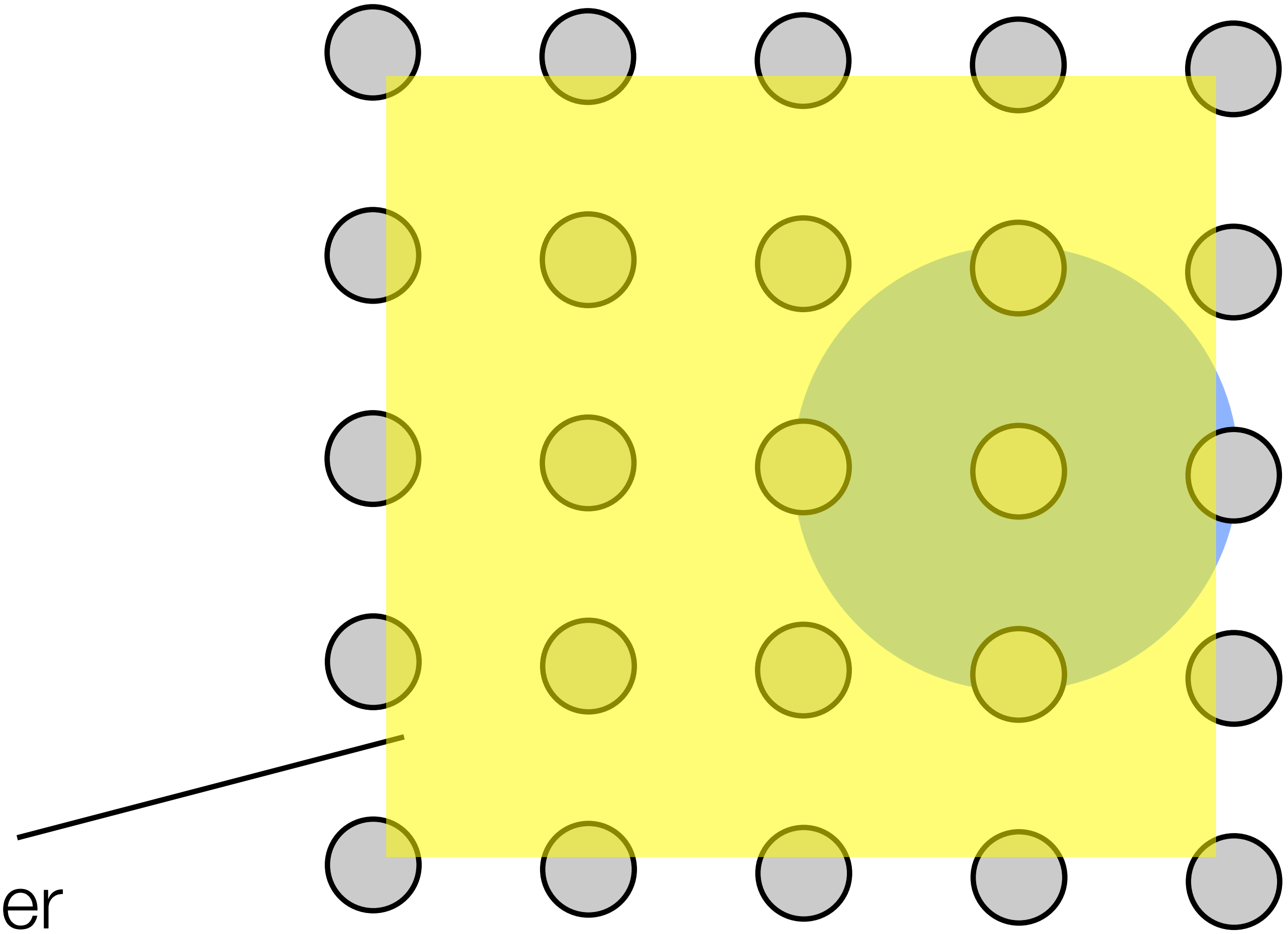
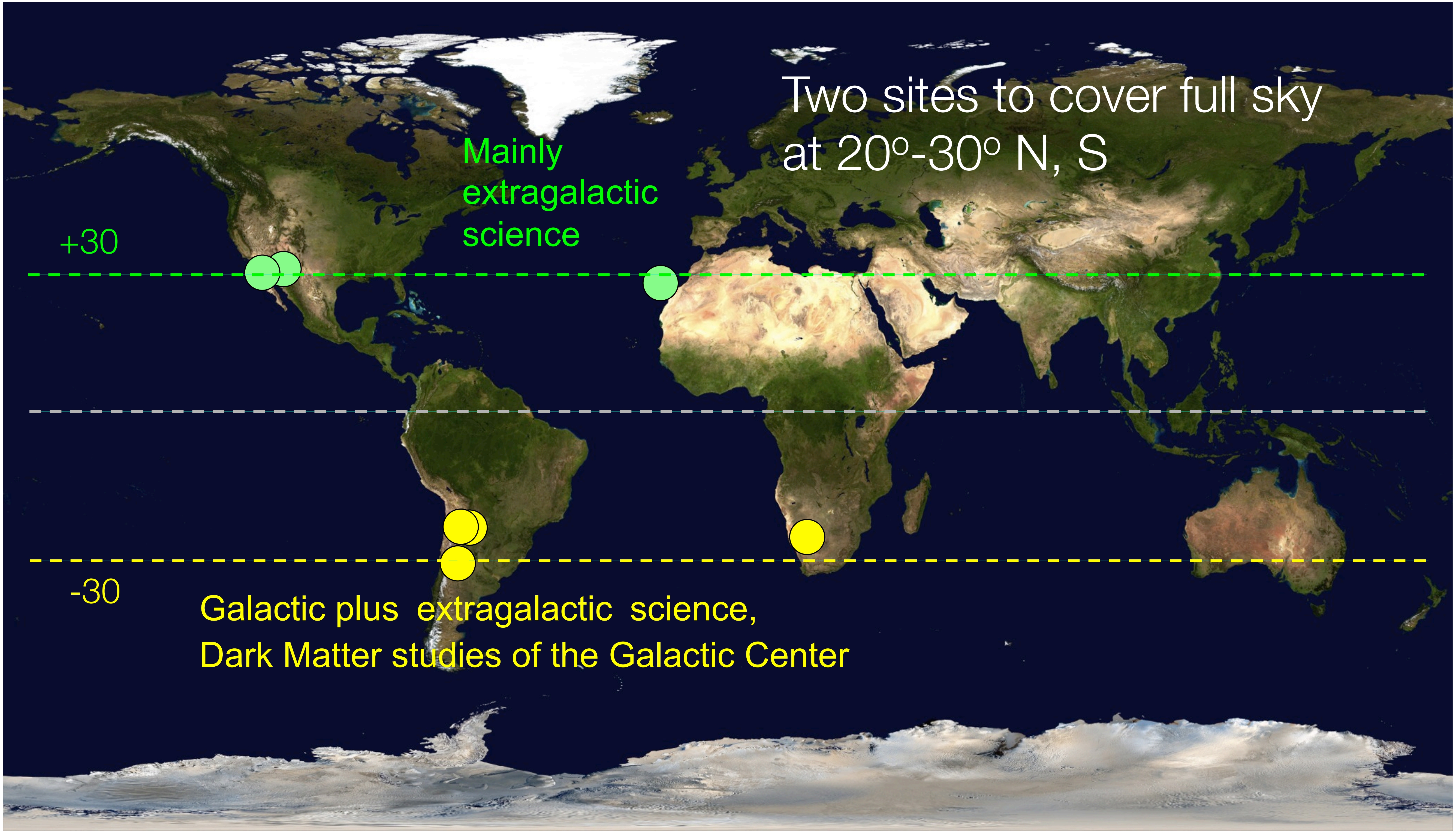


Large detection area
More images per shower
Lower trigger threshold

Sites: Candidates



Two sites to cover full sky at 20°-30° N, S

Mainly extragalactic science

Galactic plus extragalactic science,
Dark Matter studies of the Galactic Center

PHYSICS AHEAD

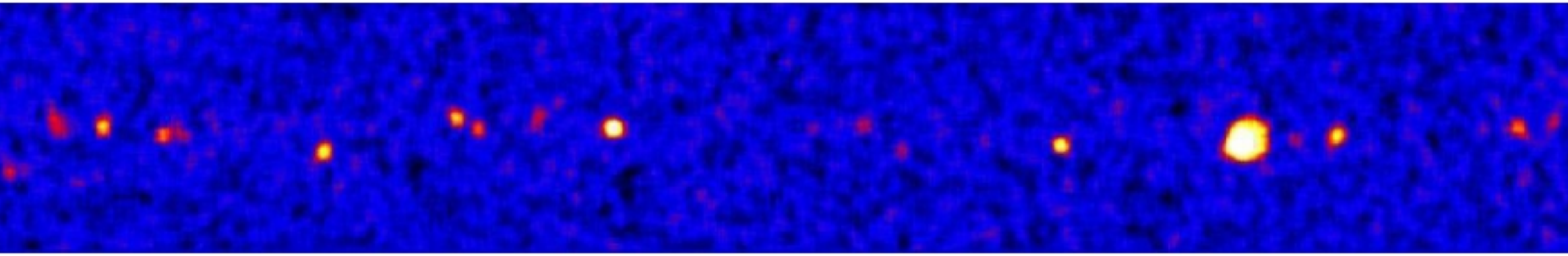
Unique science goals with CTA

Unique in the sense that no other instrument
has a similar ability in the same energy regime.

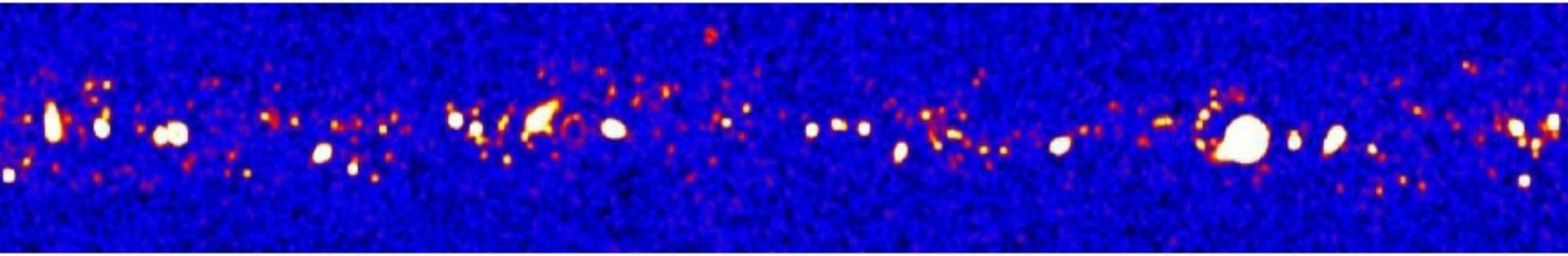
- SURVEY
  - The ability of producing the deepest surveys of the sky (with unprecedented angular and energy resolution, and energy coverage) at gamma-ray energies
- TIME DOMAIN
  - The ability to perform the first sensitive observation of short timescale phenomenology at gamma-ray energies

Simulated Galactic Plane surveys

H.E.S.S.



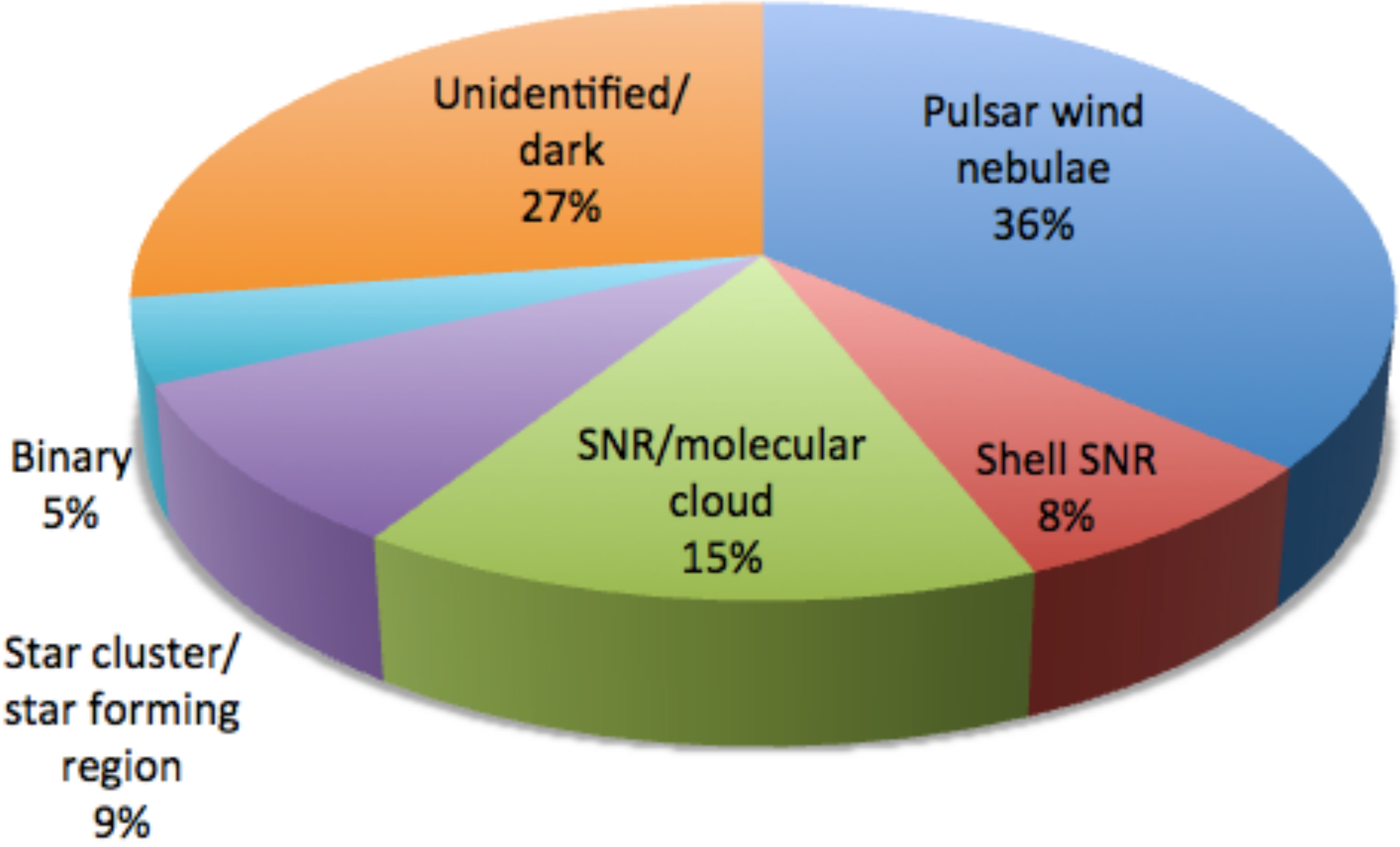
CTA, for same exposure



Expect ~1000 detected sources over the whole sky

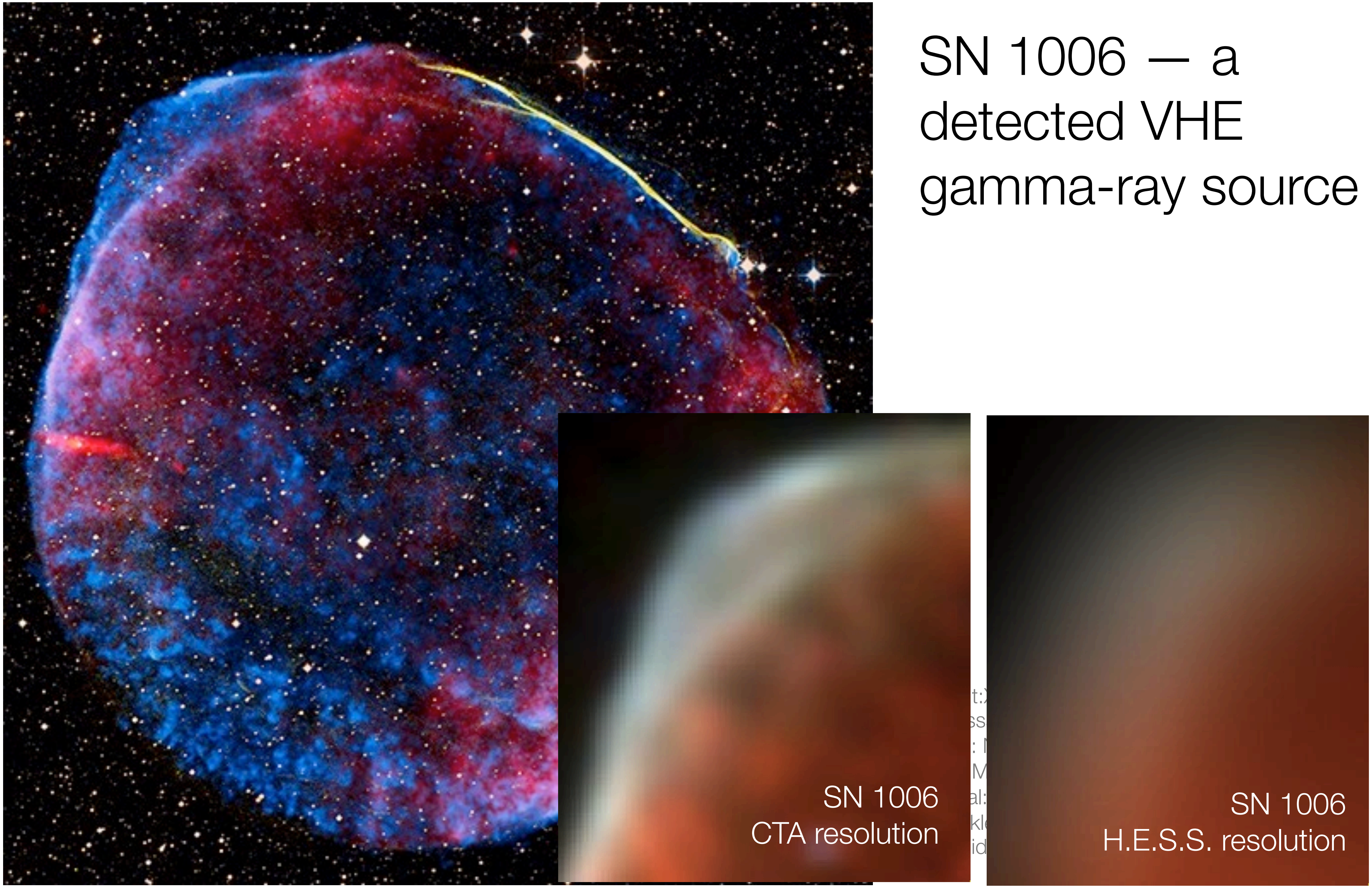
Funk et al., *Amer. Inst. Phys. Conf. Proc.* 1085, 886 (2008)

Source types, galactic

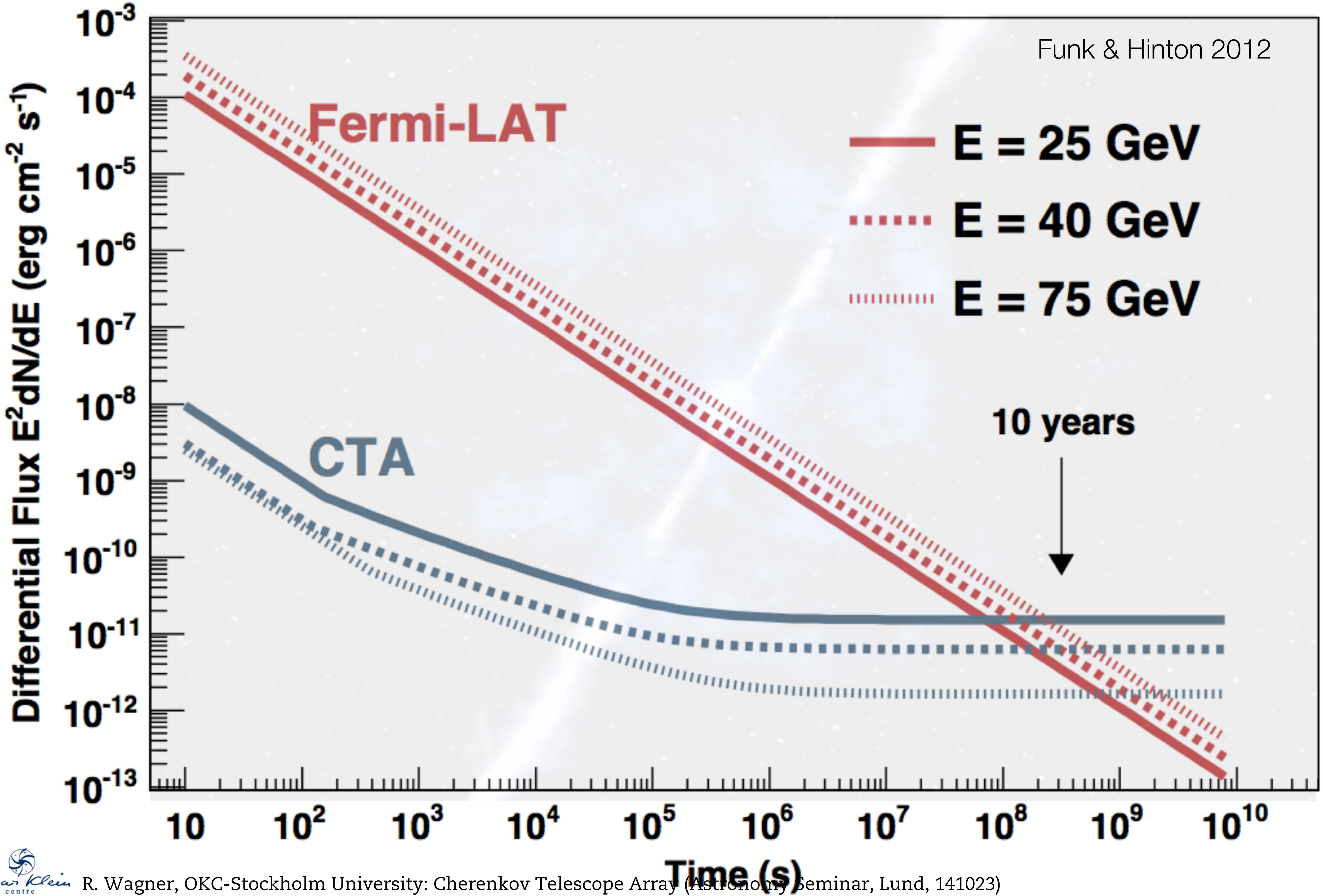


Resolving complex sources

SN 1006 — a detected VHE gamma-ray source

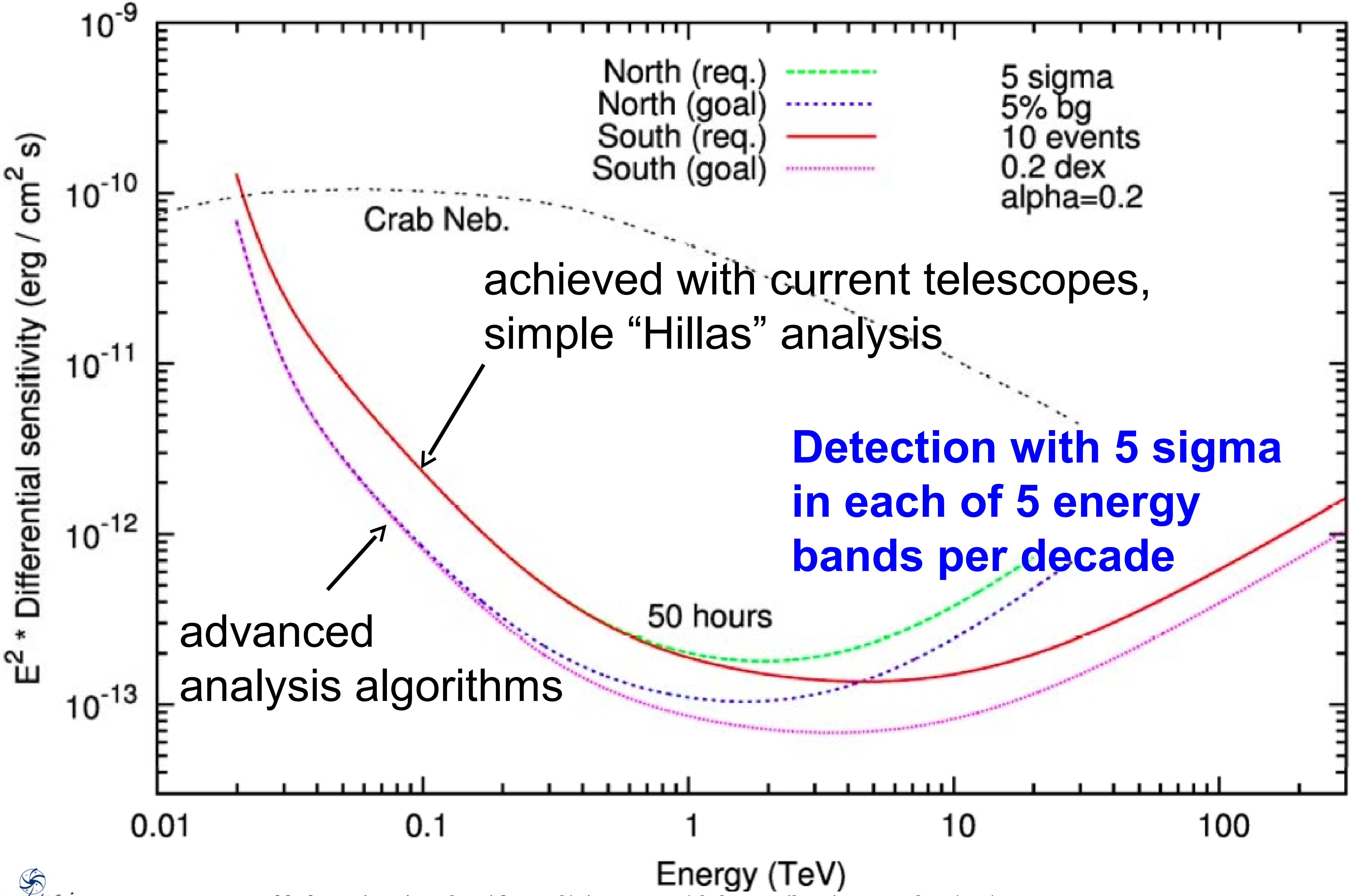


Opening up the Transient domain



CTA AND THE HUNT FOR DARK MATTER

Differential sensitivity



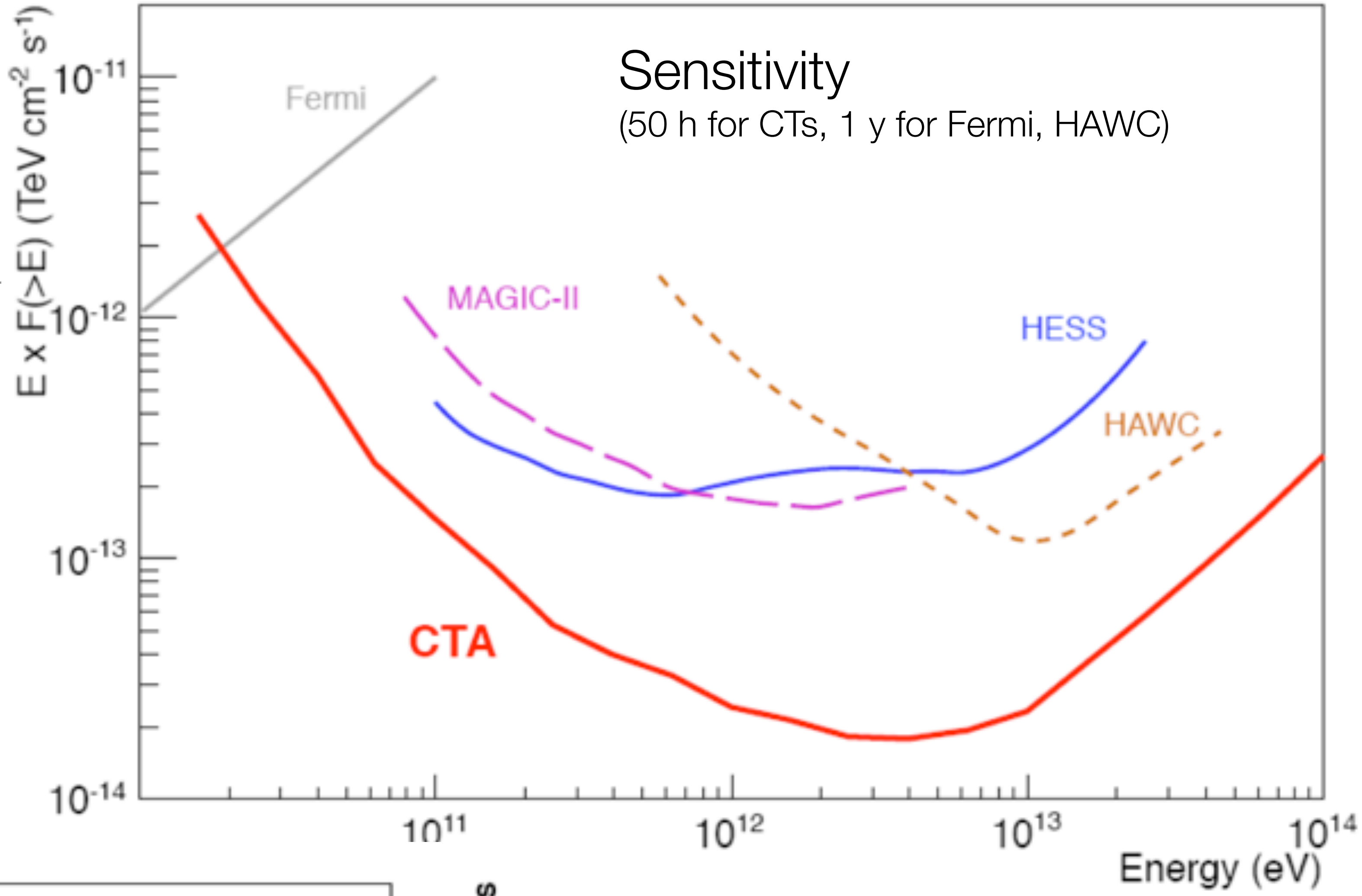
achieved with current telescopes, simple “Hillas” analysis

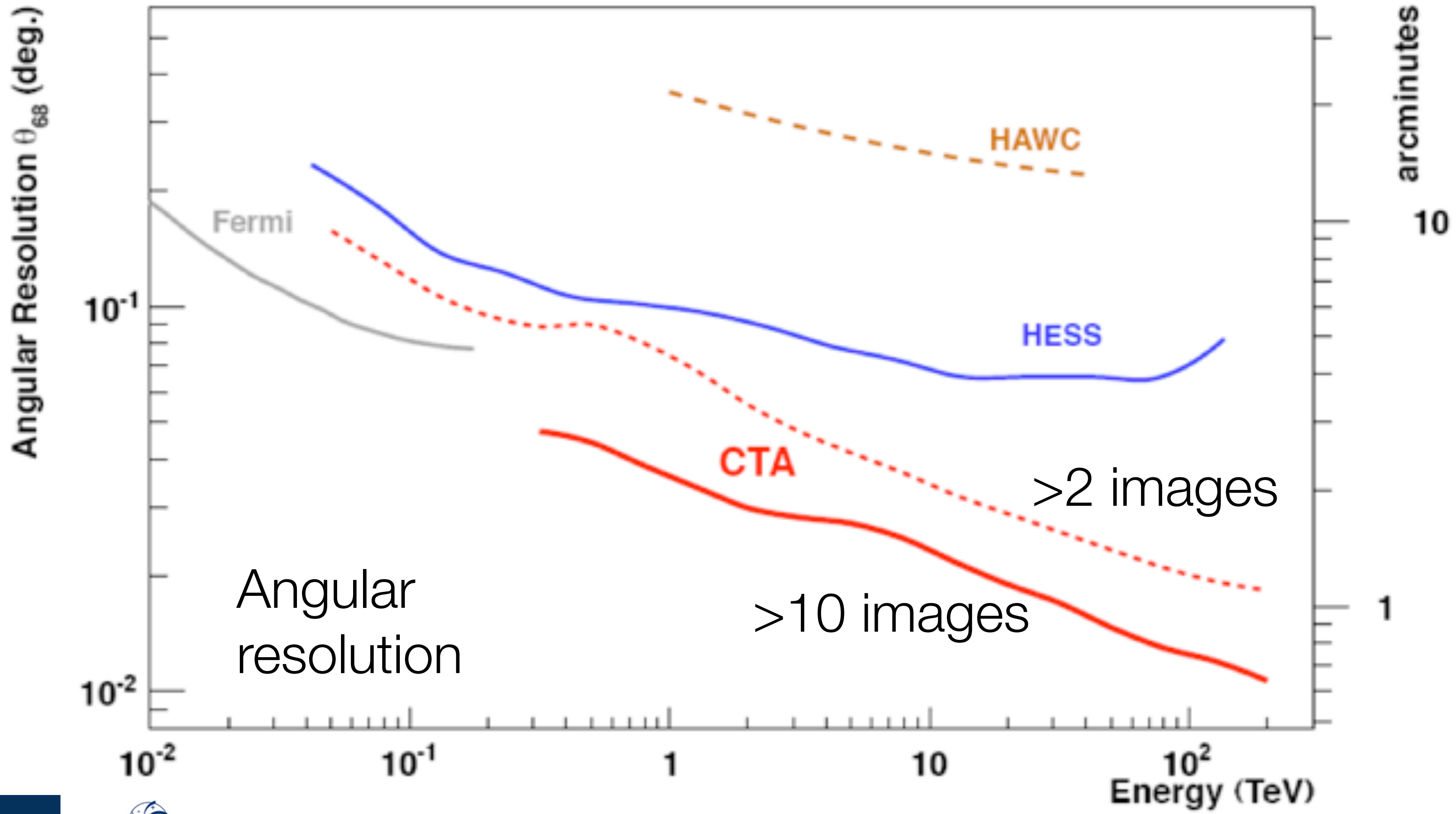
advanced analysis algorithms

Detection with 5 sigma in each of 5 energy bands per decade

Performance

Significant improvements due to new analysis algorithms



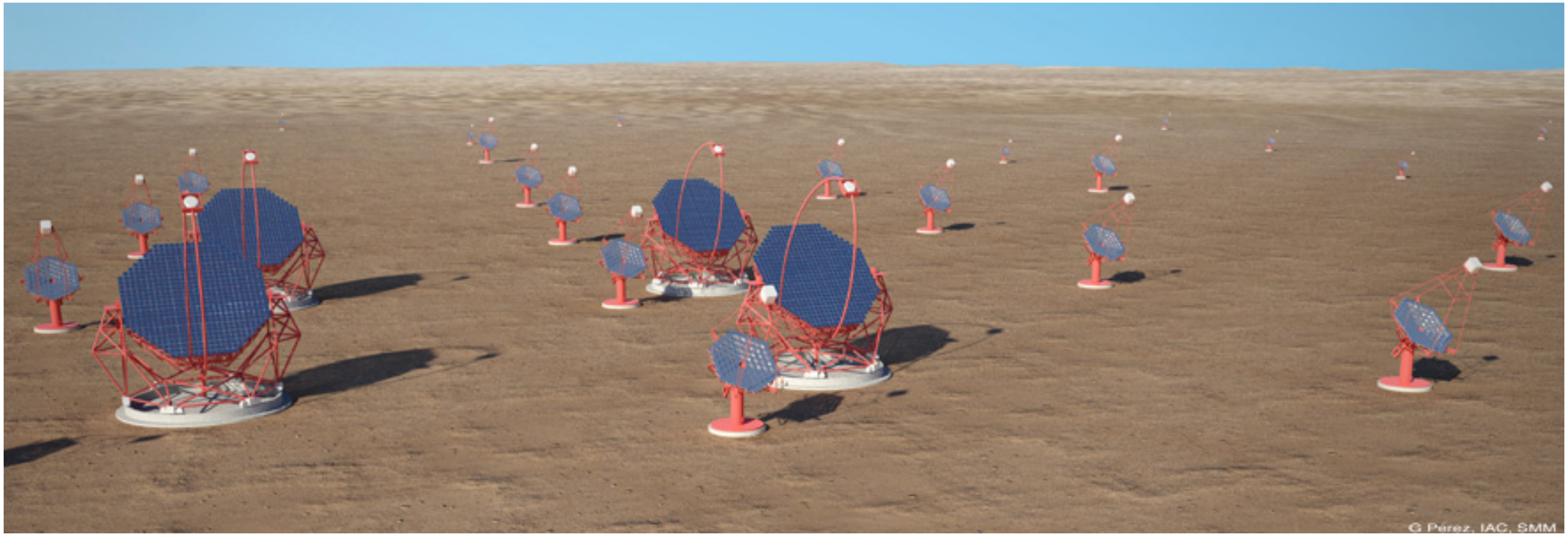


Up to factor 10 compared to HESS or MAGIC

Arc-minute scale angular resolution at high energies

The CTA Concept

CTA Consortium,
Experimental Astronomy, Volume 32, Issue 3, pp.193-316

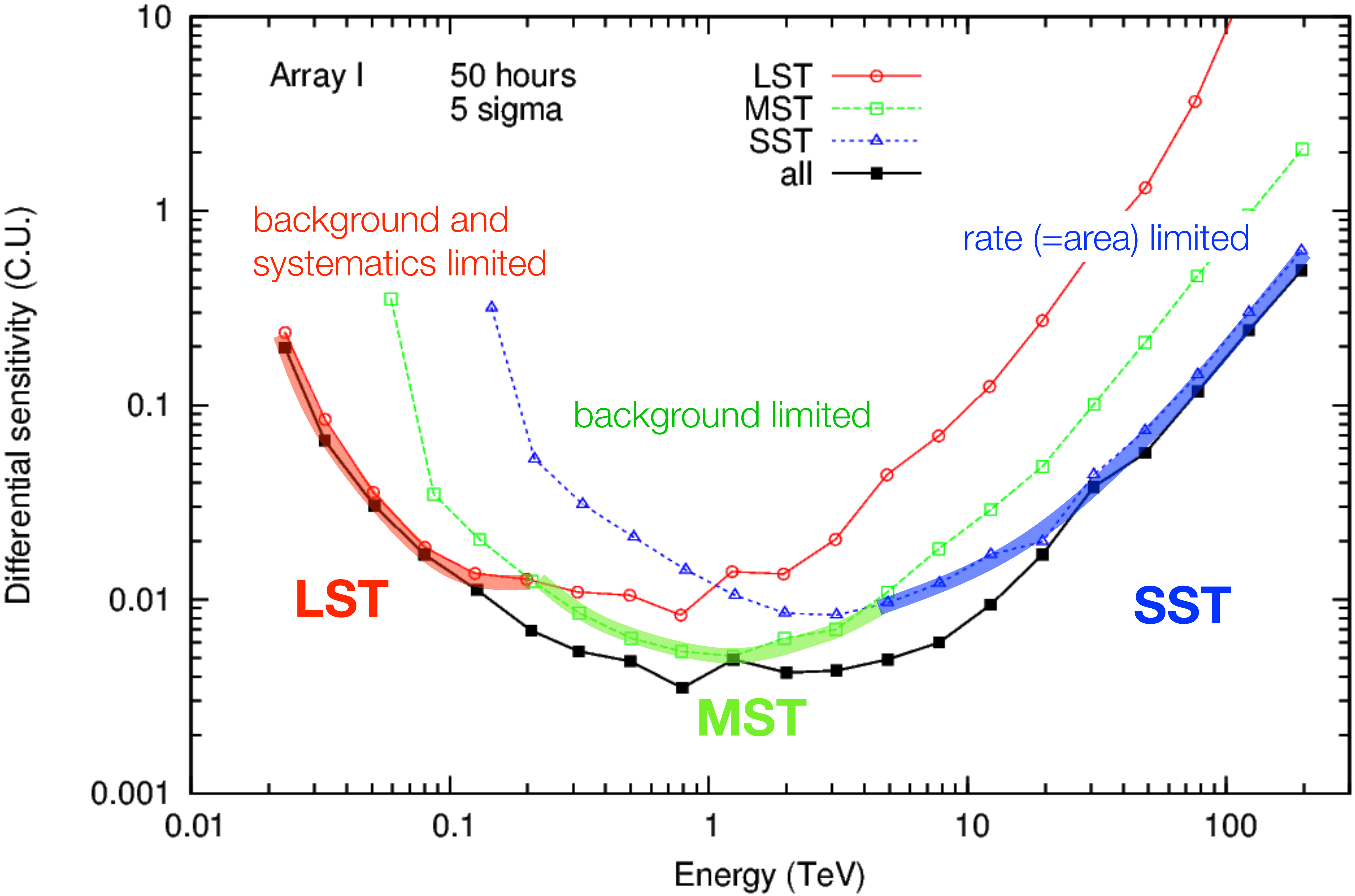


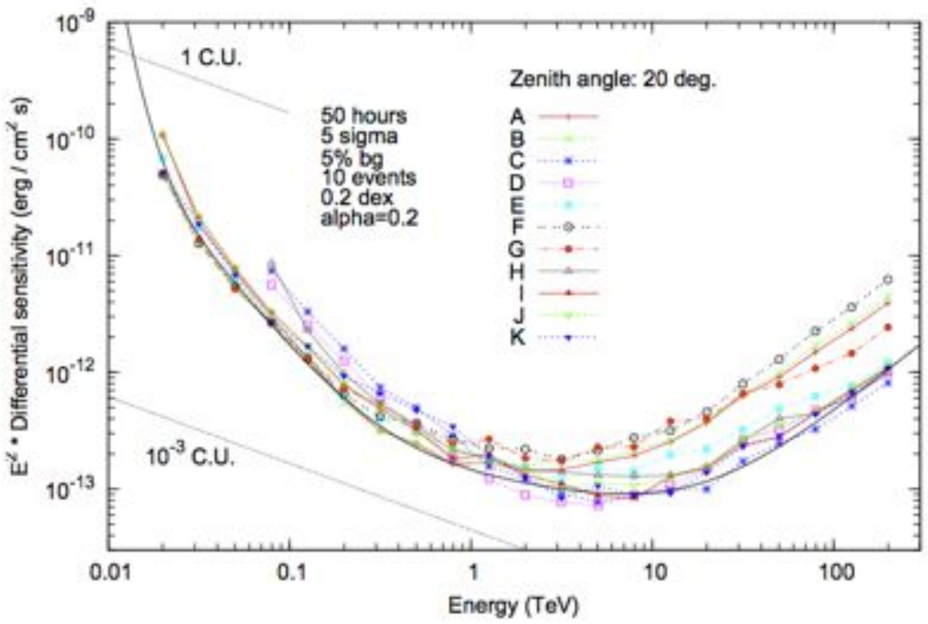
G Pérez, IAC, SMM

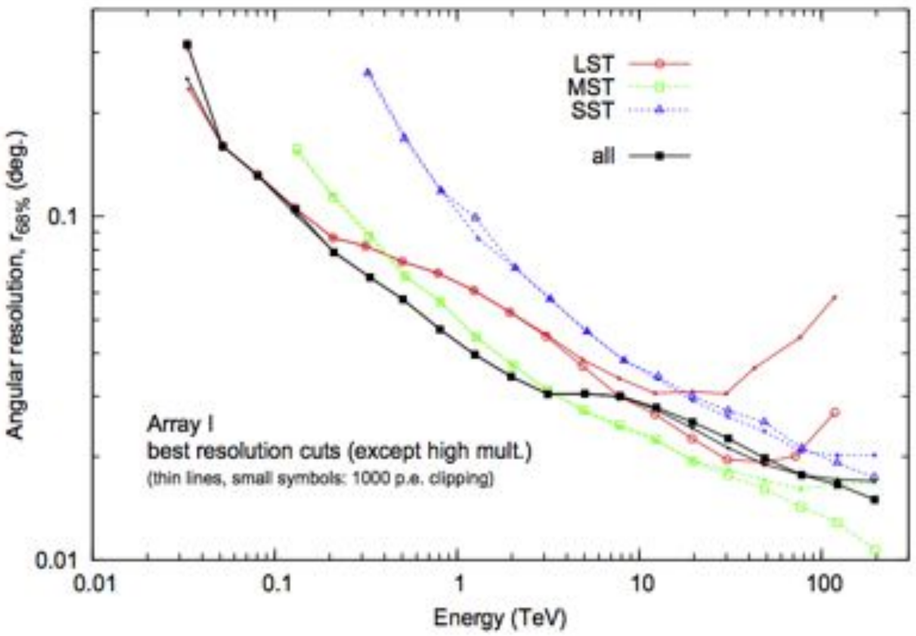
- Arrays in northern and southern hemispheres for full sky coverage
- 4 large (~23 m) telescopes in the center (LSTs)
    - Threshold of ~30 GeV
- ≥25 medium (9-12 m) telescopes (MSTs) covering ~1 km^2
    - Order of magnitude sensitivity improvement in 100 GeV–10 TeV range
- Small (~4 m) telescopes (SSTs) covering >3 km^2 in south
    - >10 TeV observations of Galactic sources
- Construction begins in ~2015

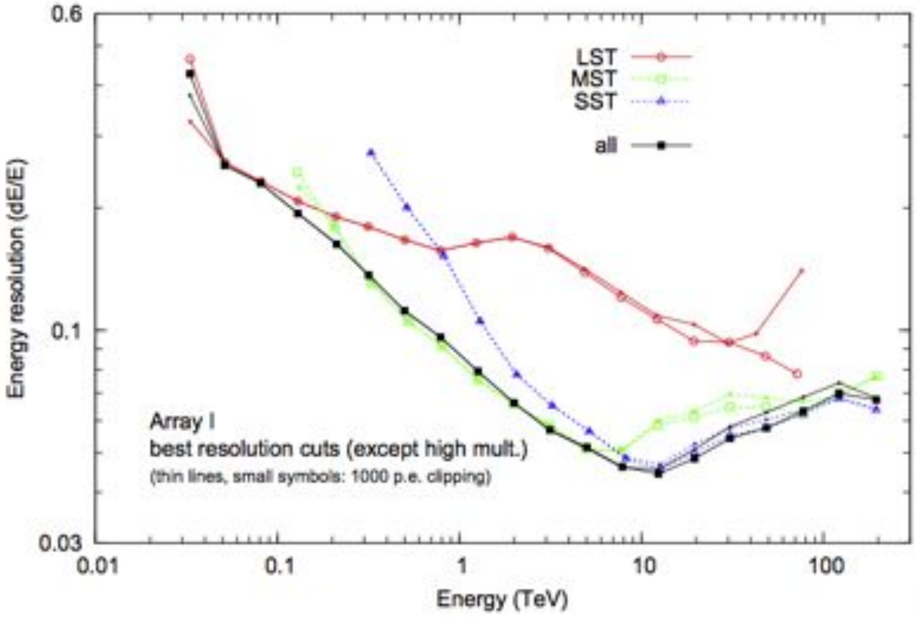
Sensitivity in units of Crab flux

for detection in each 0.2-decade energy band

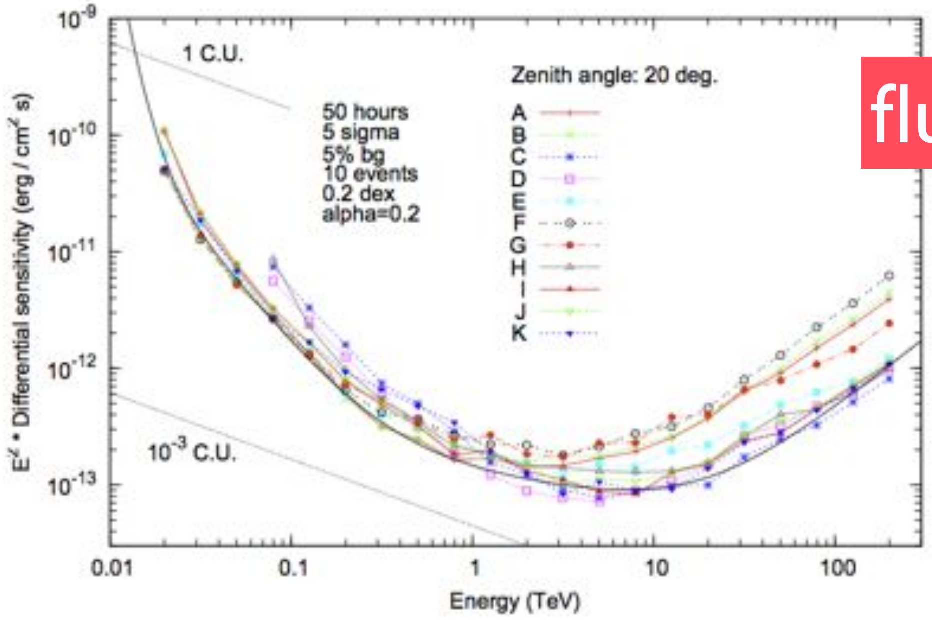


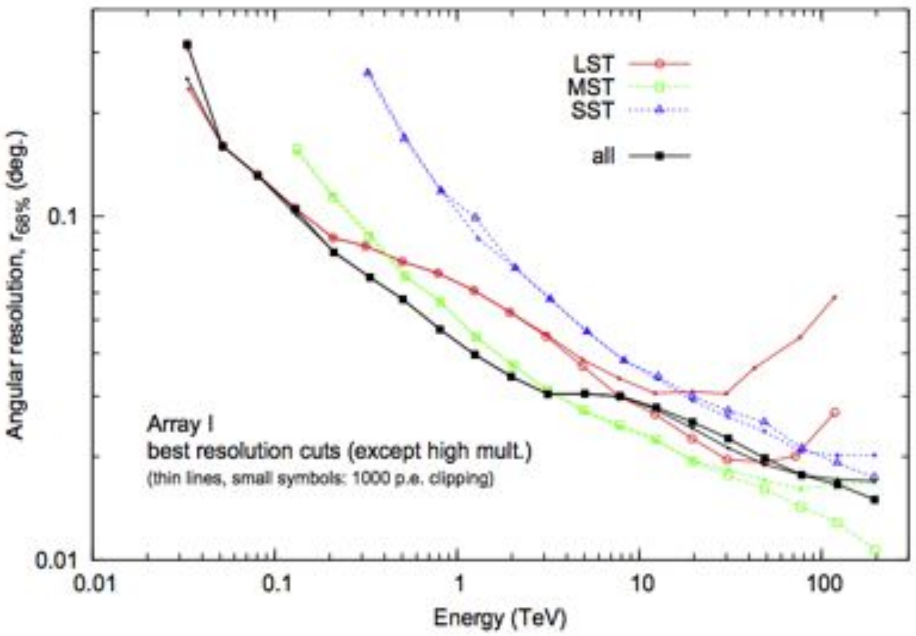

1 C.U.
50 hours
5 sigma
5% bg
10 events
0.2 dex
alpha=0.2
Zenith angle: 20 deg.
A
B
C
D
E
F
G
H
I
J
K
10^-3 C.U.
E^2 * Differential sensitivity (erg / cm^2 s)
10^-9
10^-10
10^-11
10^-12
10^-13
0.01
0.1
1
10
100
Energy (TeV)

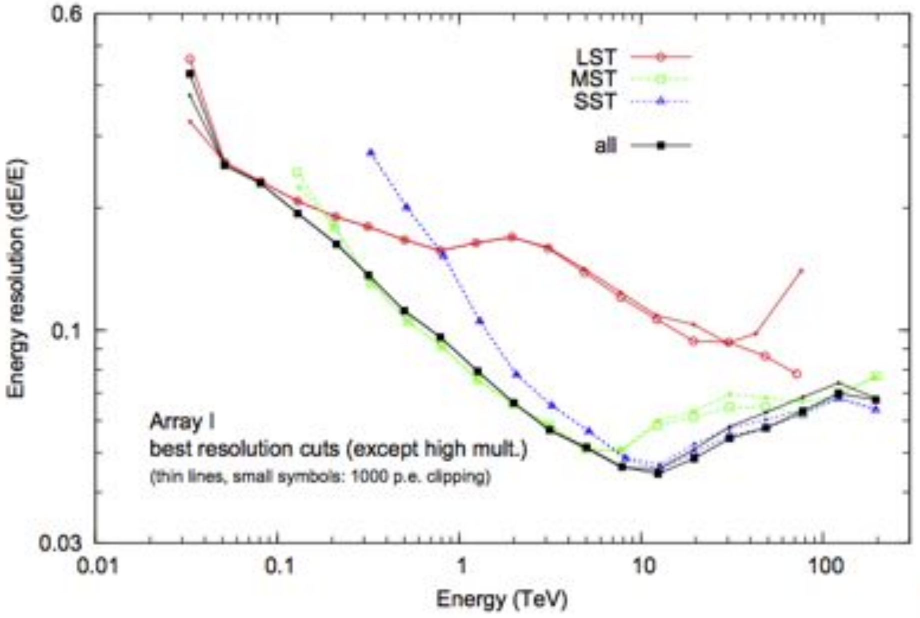

LST
MST
SST
all
Array I
best resolution cuts (except high mult.)
(thin lines, small symbols: 1000 p.e. clipping)
Angular resolution, r68% (deg.)
0.1
0.01
0.01
0.1
1
10
100
Energy (TeV)

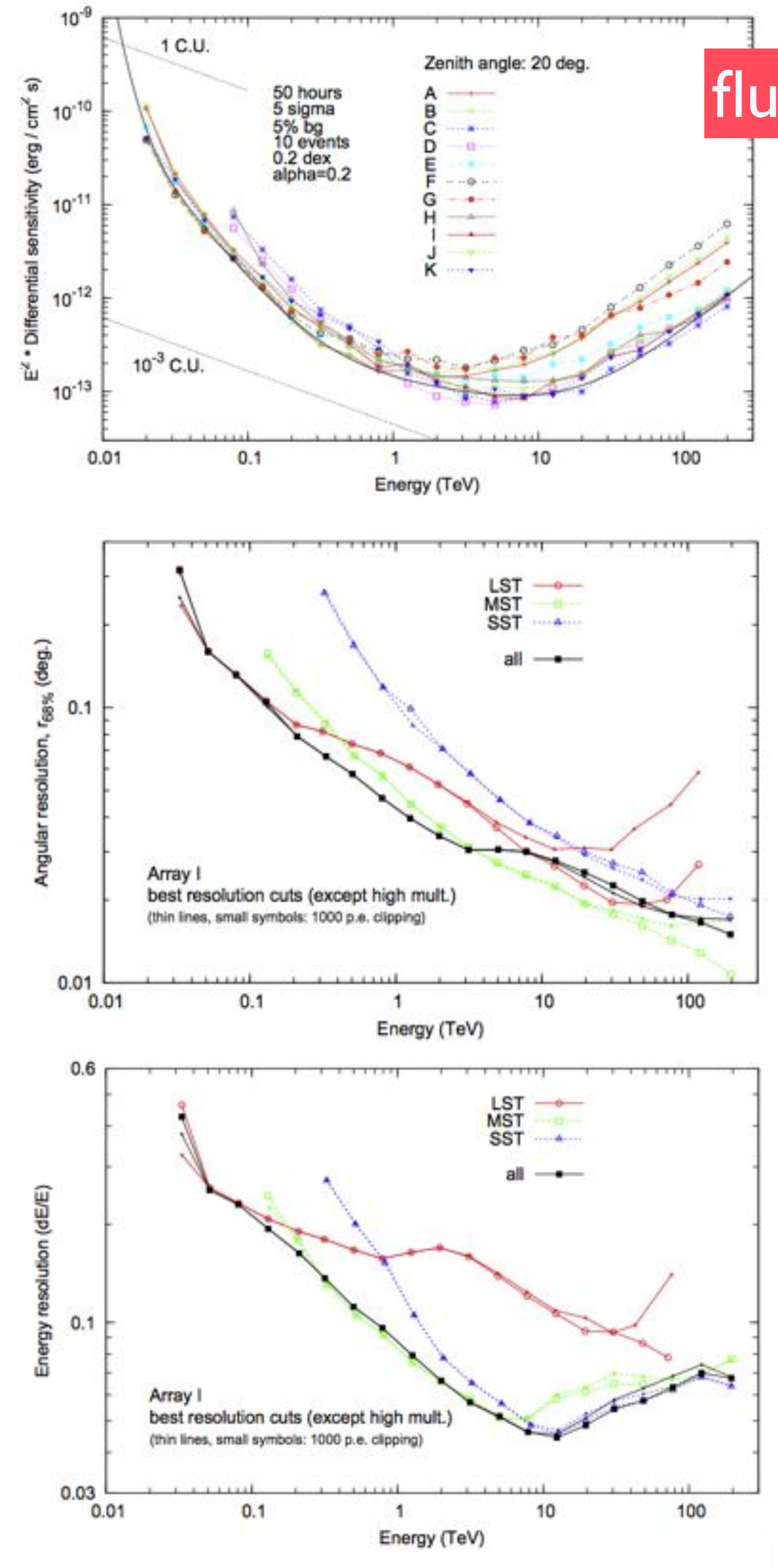

LST
MST
SST
all
Array I
best resolution cuts (except high mult.)
(thin lines, small symbols: 1000 p.e. clipping)
Energy resolution (dE/E)
0.6
0.1
0.03
0.01
0.1
1
10
100
Energy (TeV)

flux sensitivity



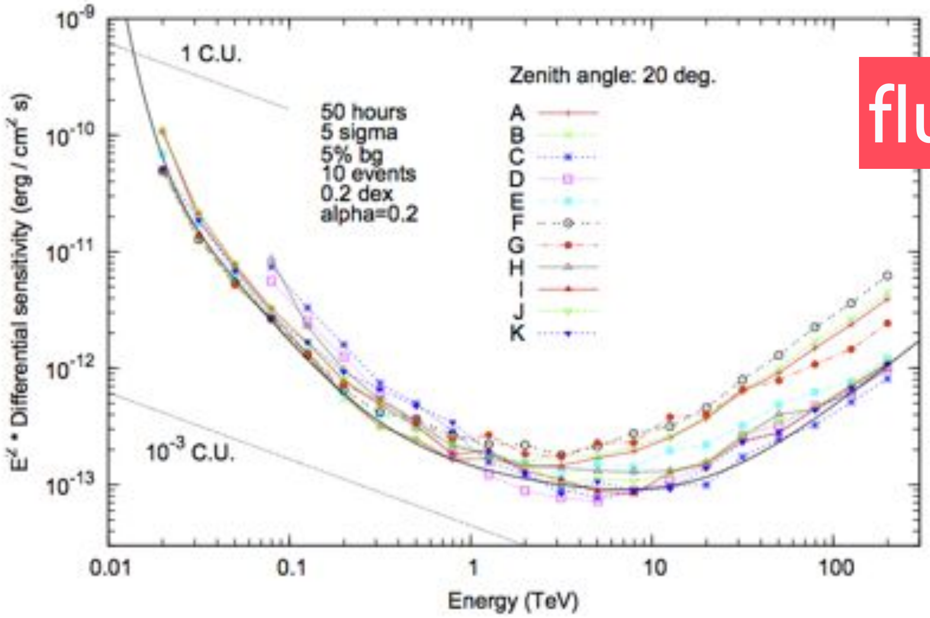






flux sensitivity

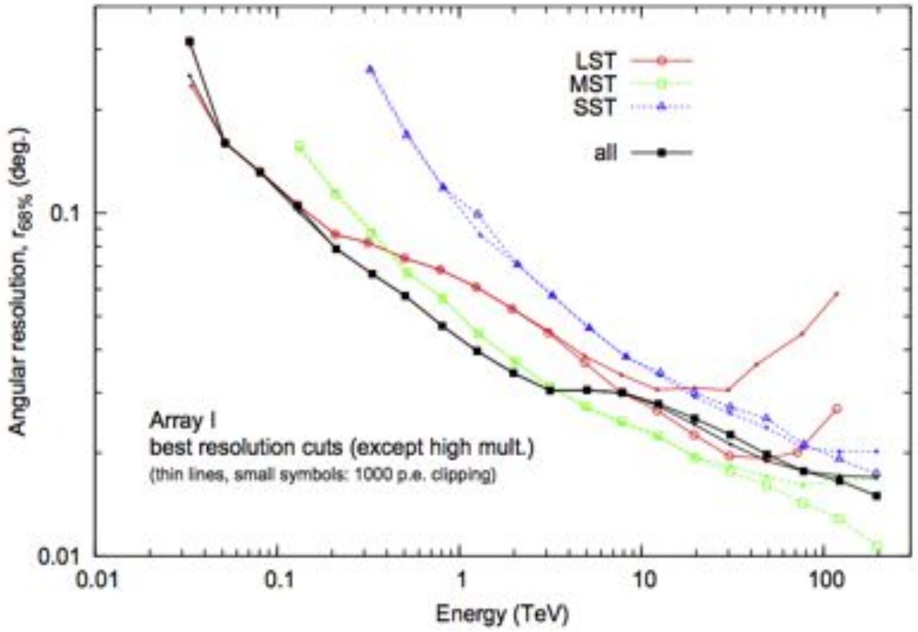
improved sensitivity → detection probability

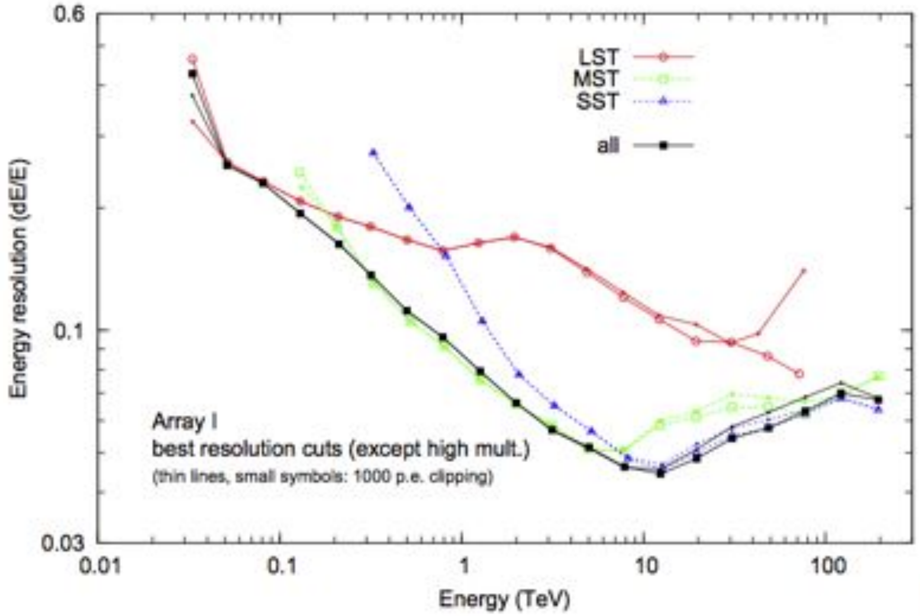


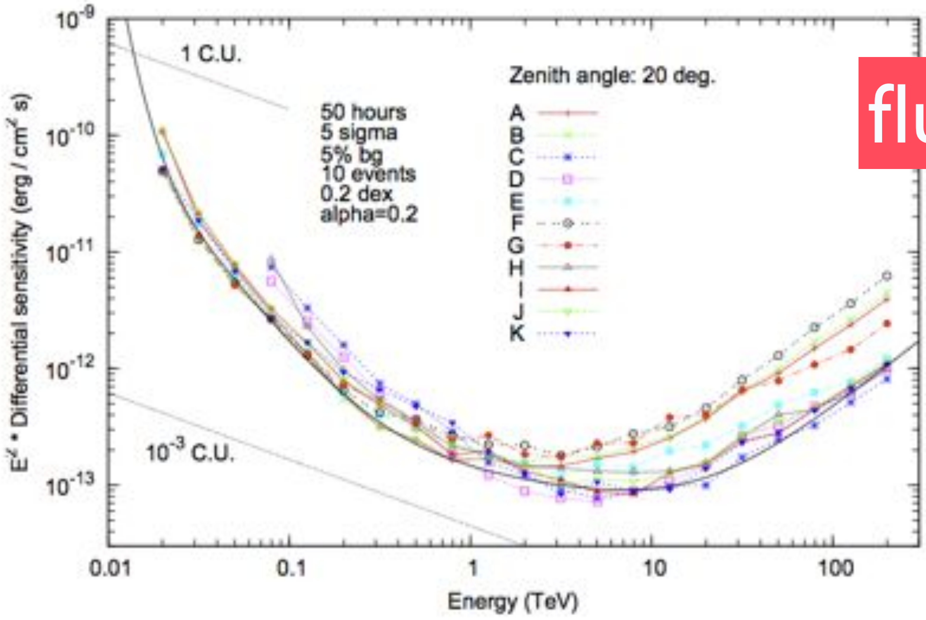
flux sensitivity

improved sensitivity → detection probability

extended energy range: overlap with Fermi-LAT, sensitivity to lower m



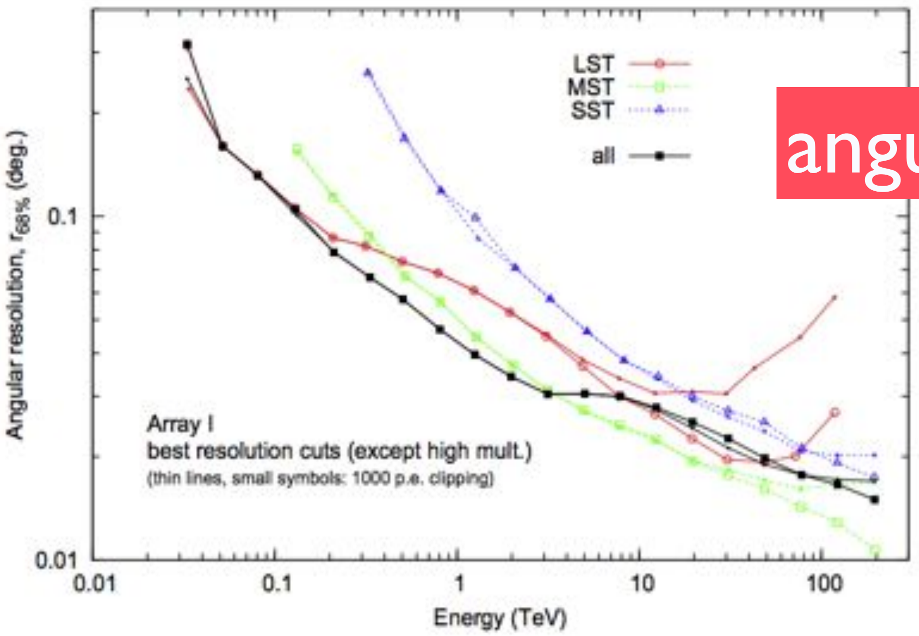




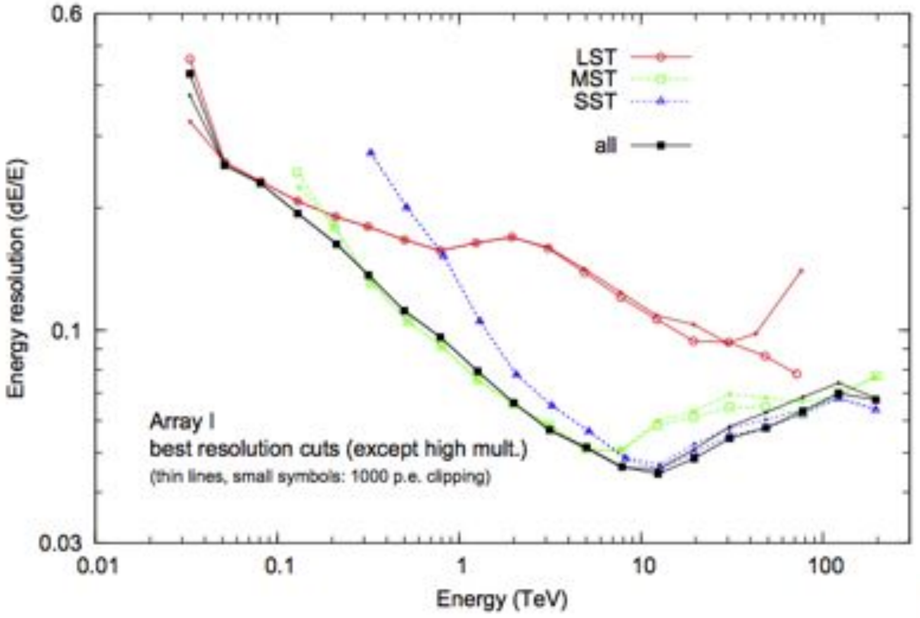
flux sensitivity

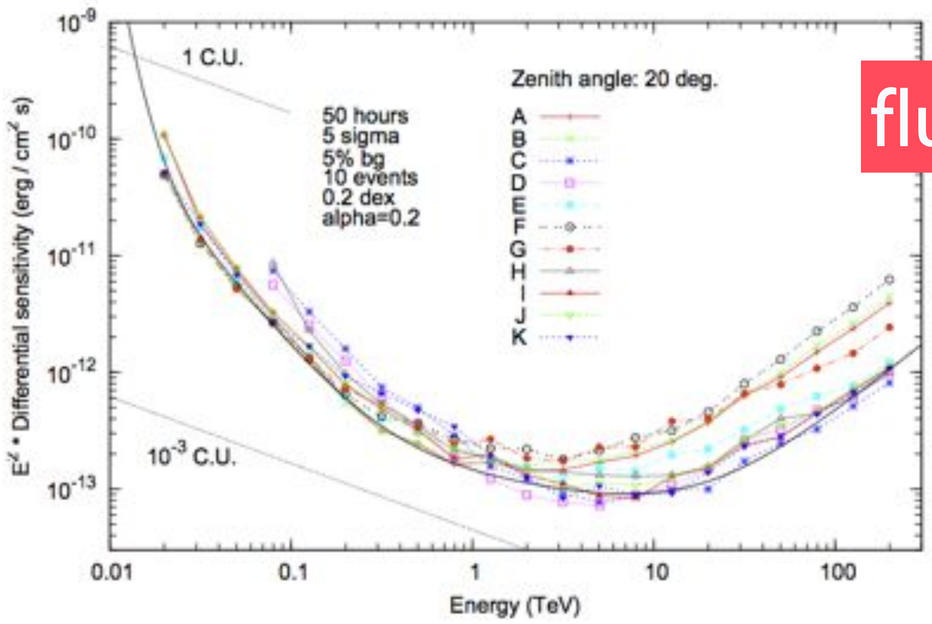
improved sensitivity → detection probability

extended energy range: overlap with Fermi-LAT, sensitivity to lower m



angular resolution



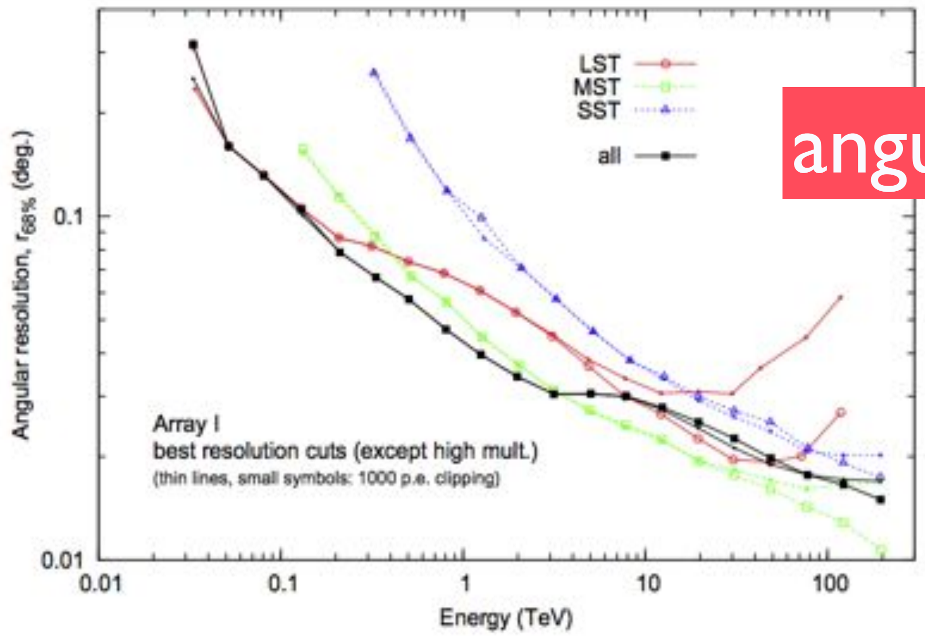


flux sensitivity

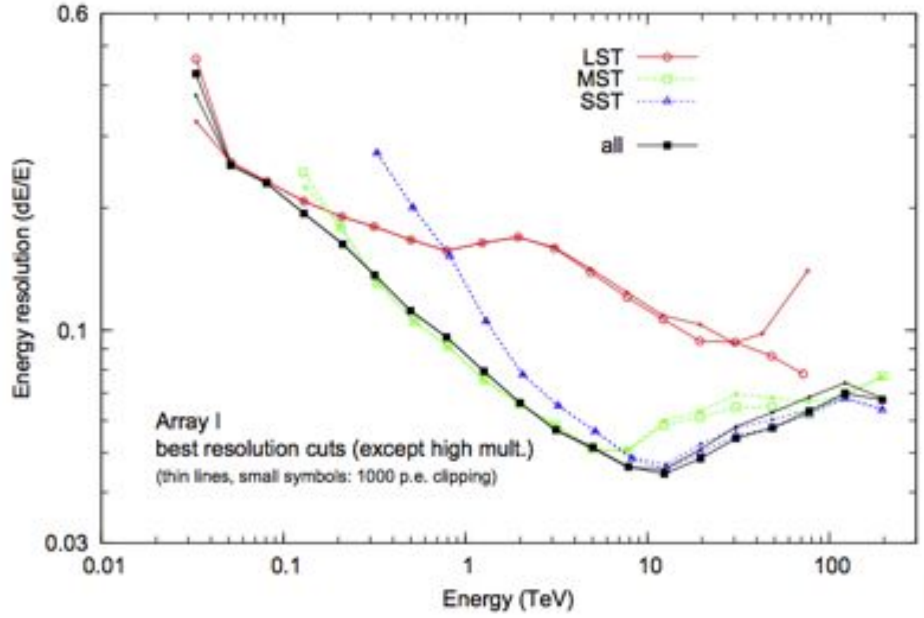
improved sensitivity → detection probability

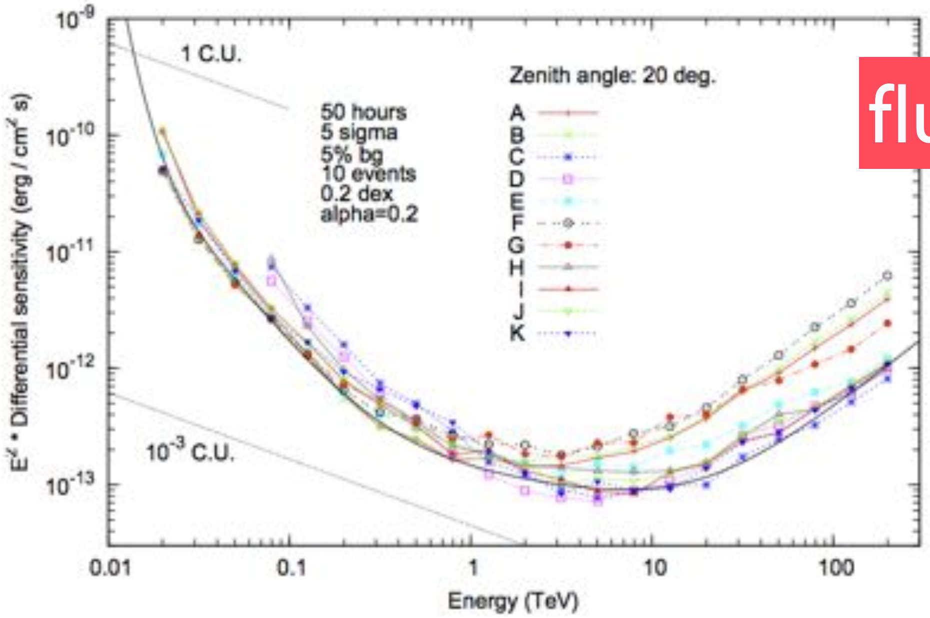
extended energy range: overlap with Fermi-LAT, sensitivity to lower m

increased FoV, more homogeneous: extended srcs, anisotropies



angular resolution





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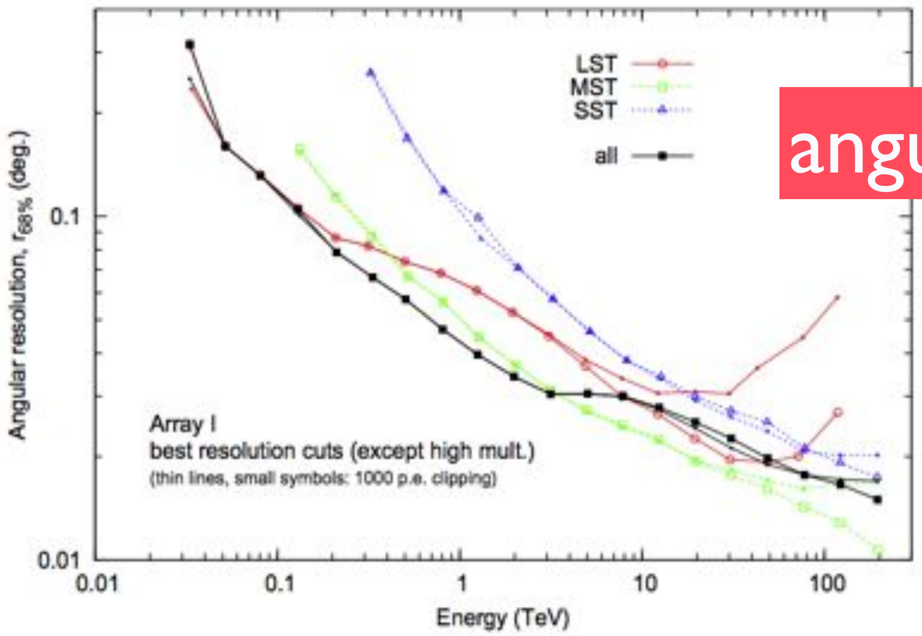
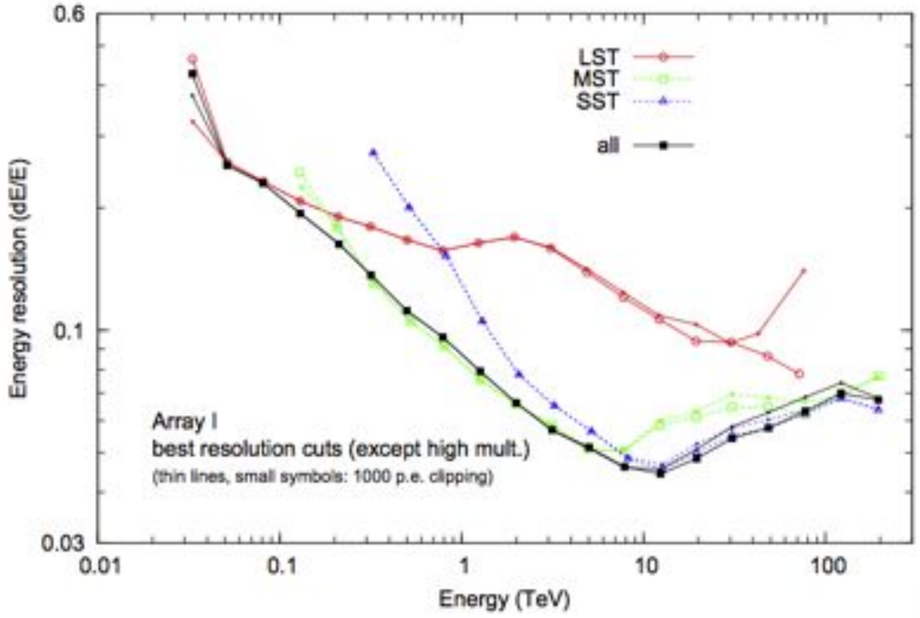


angular resolution

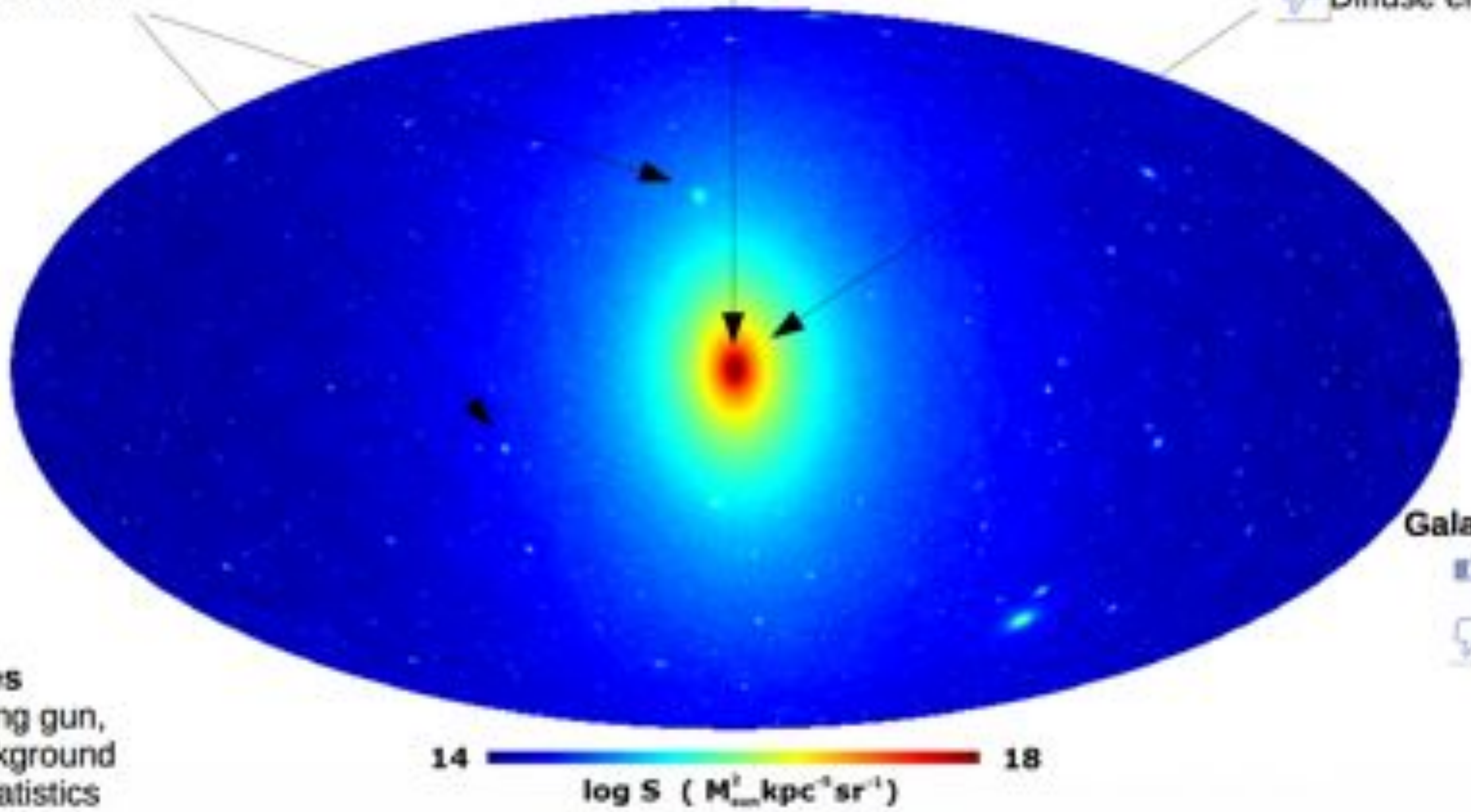
increased FoV, more homogeneous: extended srcs, anisotropies



increased energy resolution: spectral form, features

We can point the telescopes!

Select most promising targets
Competition: Have ~1200 h/yr
Have “just” 5-10° FoV



Dwarf galaxies
- 👍 Low background, small uncertainties
- 👎 Low statistics

Galactic centre
- 👍 Large statistic
- 👎 Source confusion, DM density uncertainties

Galactic halo
- 👍 Large statistic
- 👎 Diffuse emission

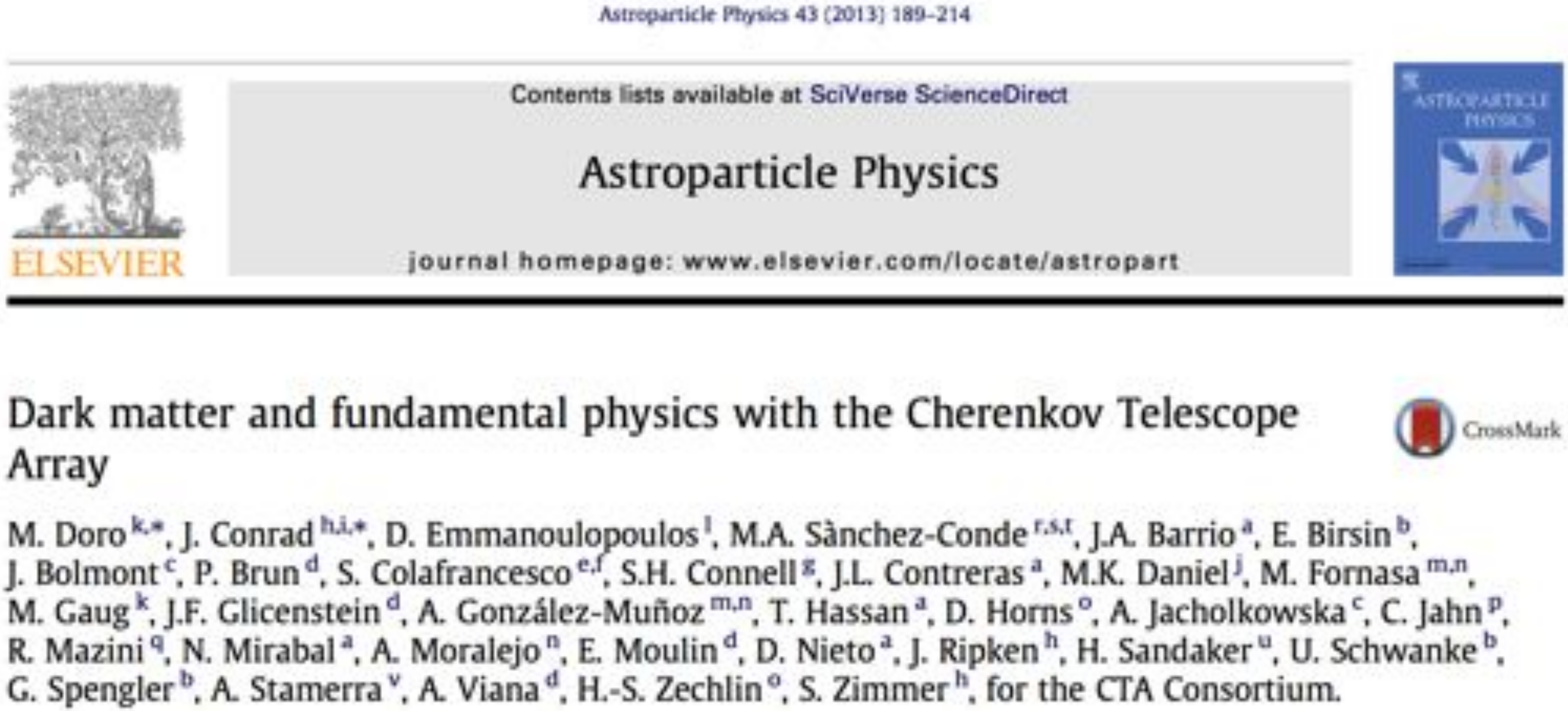
Galaxy clusters
- 👍 Large reservoir (decay)
- 👎 Low statistics, astrophysical bk

Spectral lines
- 👍 Smoking gun, no background
- 👎 Low statistics

Extragalactic
- 👍 Large statistics
- 👎 Astrophysical bkg

Dark Matter and Fundamental Physics with CTA

- Prospects published in 2013 by CTA
- Dark matter, Lorentz Invariance Violation, Axion-like particles, and more
- Tests capabilities of different array layouts



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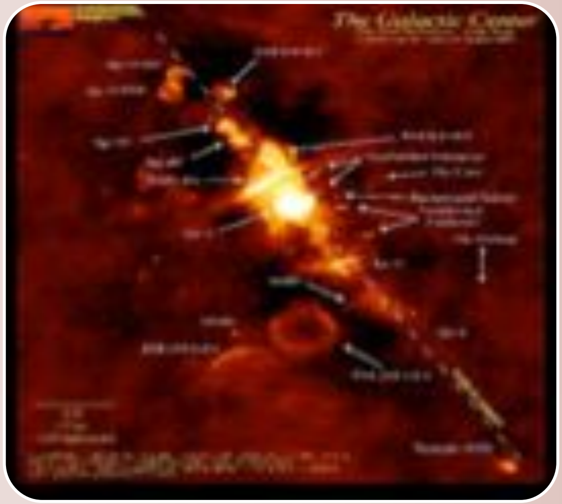
Dark matter and fundamental physics with the Cherenkov Telescope Array

M. Doro[k,*], J. Conrad[h,i,*], D. Emmanoulopoulos[l], M.A. Sànchez-Conde[r,s,t], J.A. Barrio[a], E. Birsin[b], J. Bolmont[c], P. Brun[d], S. Colafrancesco[e,f], S.H. Connell[g], J.L. Contreras[a], M.K. Daniel[j], M. Fornasa[m,n], M. Gaug[k], J.F. Glicenstein[d], A. González-Muñoz[m,n], T. Hassan[a], D. Horns[o], A. Jacholkowska[c], C. Jahn[p], R. Mazini[q], N. Mirabal[a], A. Moralejo[n], E. Moulin[d], D. Nieto[a], J. Ripken[h], H. Sandaker[u], U. Schwanke[b], G. Spengler[b], A. Stamerra[v], A. Viana[d], H.-S. Zechlin[o], S. Zimmer[h], for the CTA Consortium.

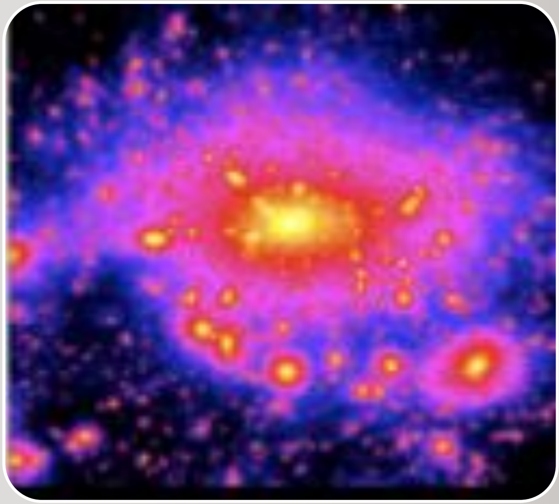
Best targets to point with CTA



GALACTIC CENTER+GALACTIC HALO

Possible observation time: 300-500h

Very good prospects if profile is cusp, i.e. baryons do not reduce the DM density



GALATIC SUBHALOS (DSPH, DARK CLUMPS…)

Possible observation of 100 h per year

- Cleanest from astrophysical sources and less background systematics
- News expected in next years

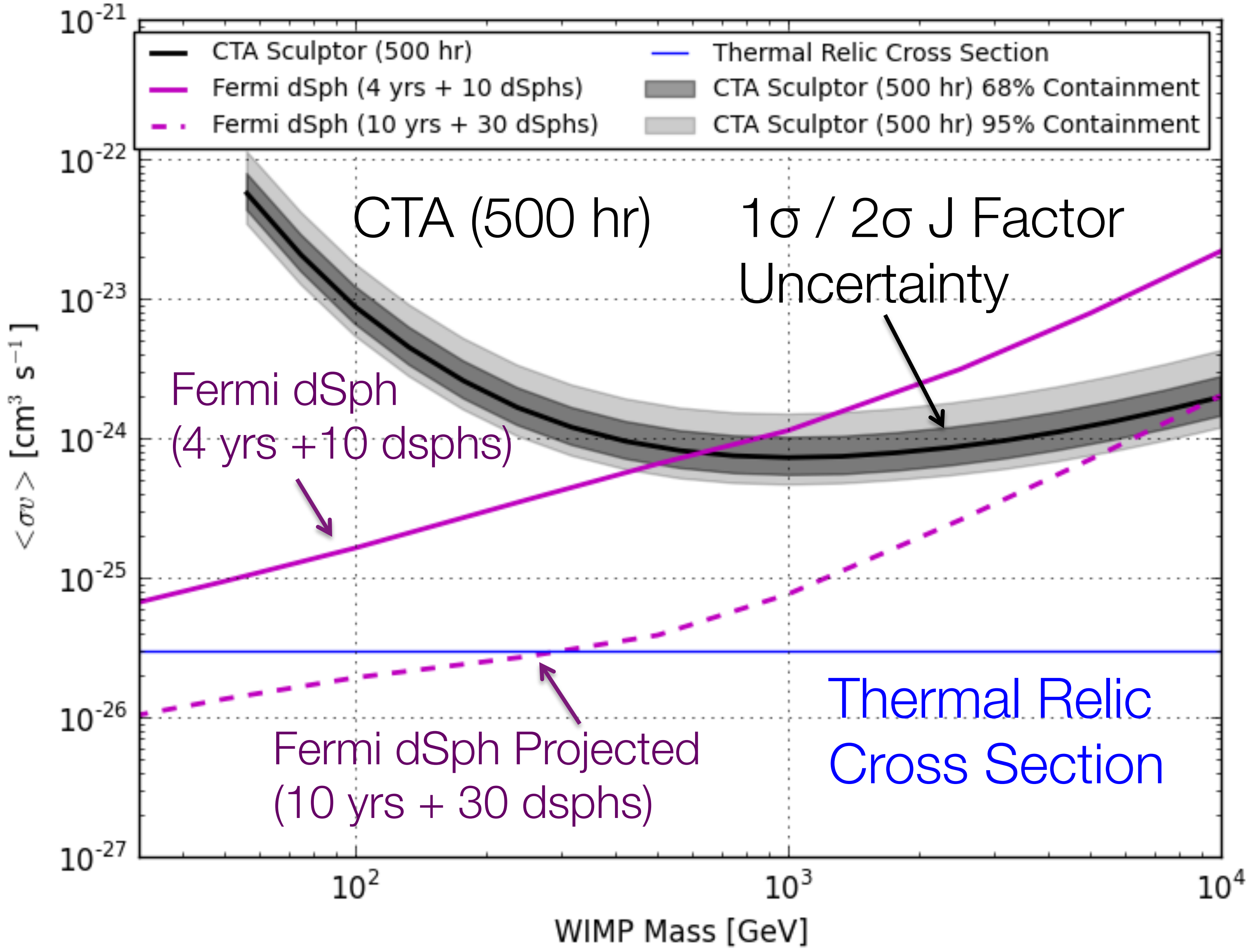
GALAXY CLUSTERS

- Expectations for annihilating DM are low
- Promising targets for **decaying** DM

Sculptor Limits (bb channel)

Sculptor Halo Parameters:

$J = 7\times10^{18}$ GeV^2 cm^{-5} $r_s = 1.7$ kpc



CTA (500 hr)

1σ / 2σ J Factor Uncertainty

Fermi dSph (4 yrs +10 dsphs)

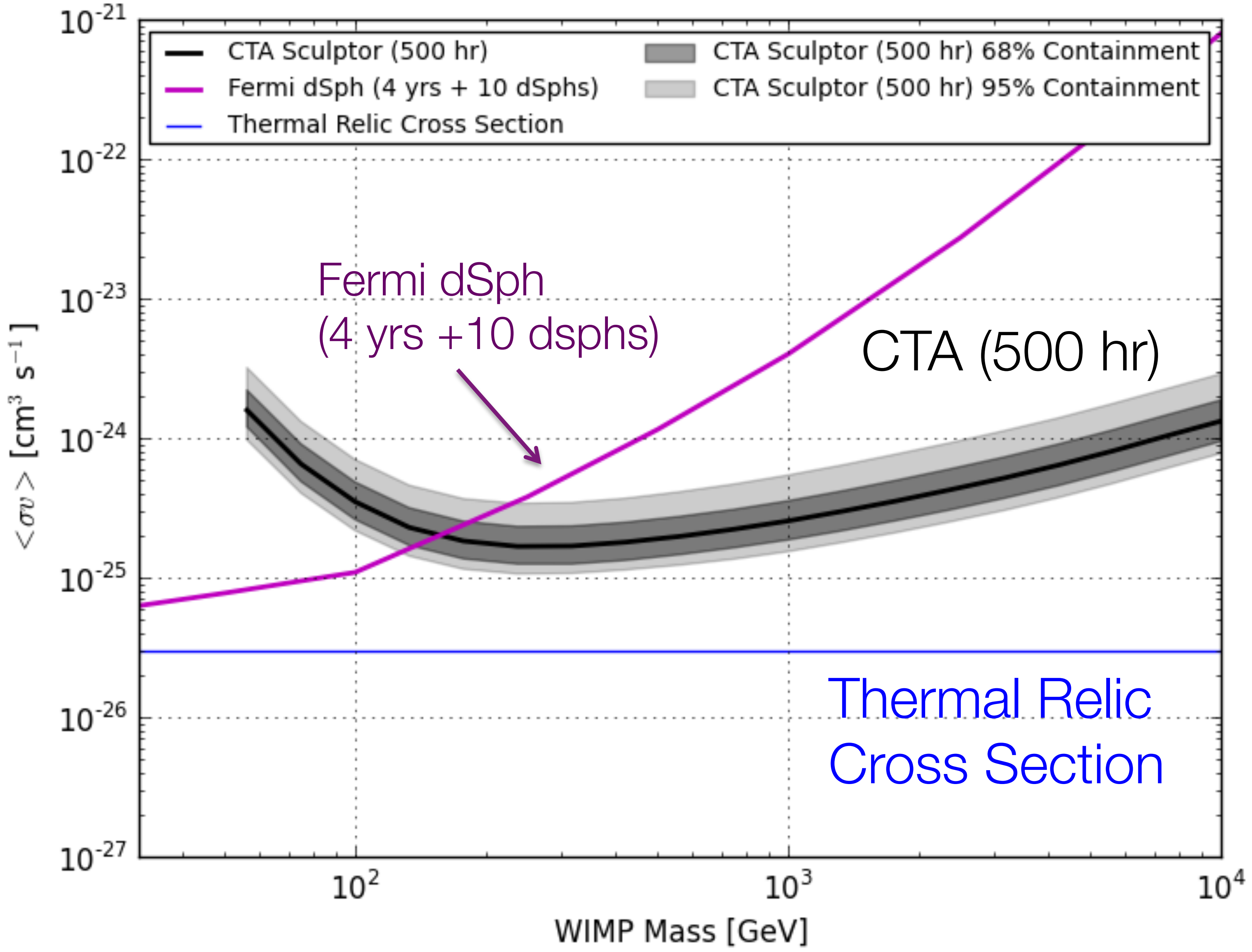
Fermi dSph Projected (10 yrs + 30 dsphs)

Thermal Relic Cross Section

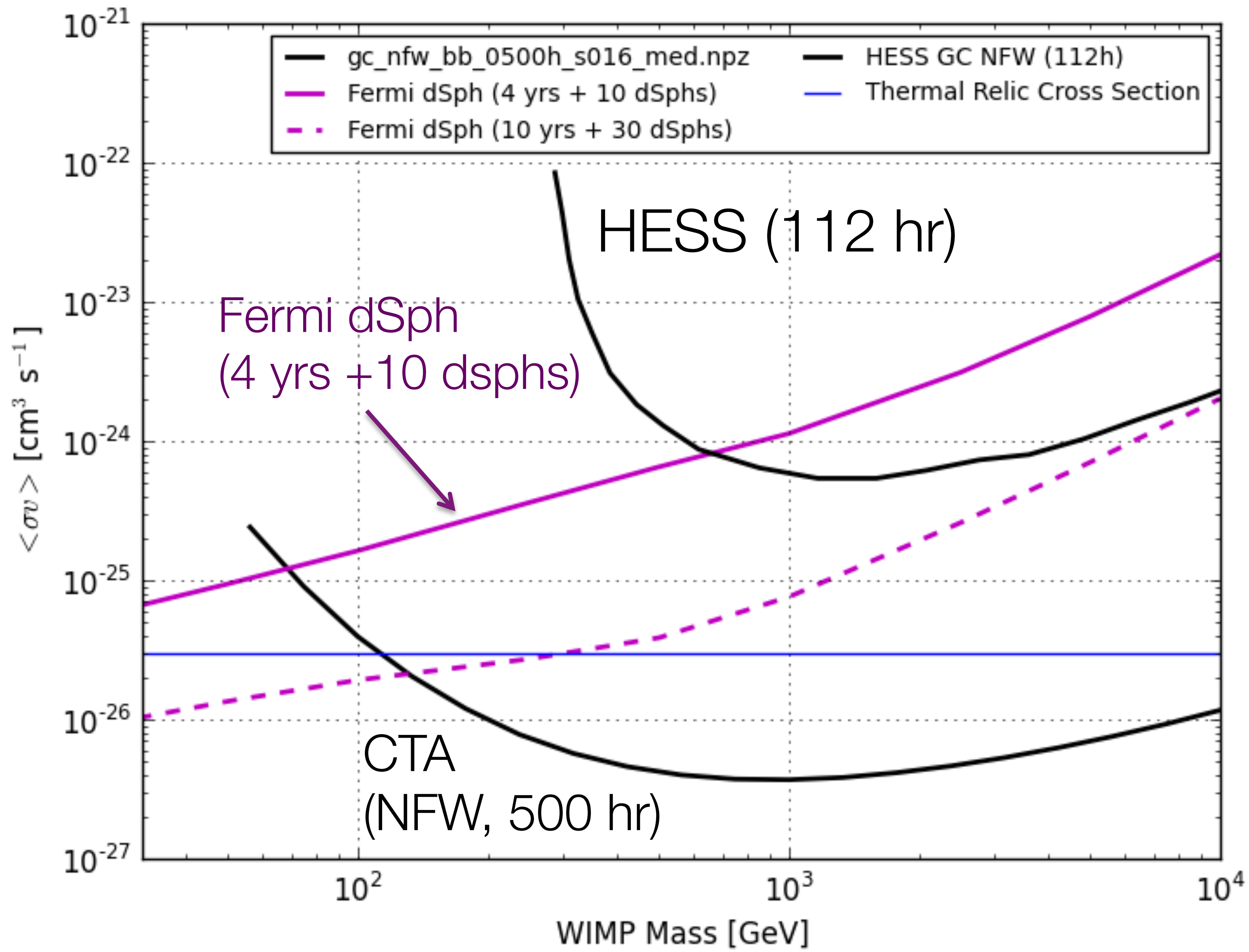
Sculptor Limits (tau channel)

Sculptor Halo Parameters:

$J = 7 \times 10^{18}\ \mathrm{GeV}^2\ \mathrm{cm}^{-5}$ $r_s = 1.7$ kpc

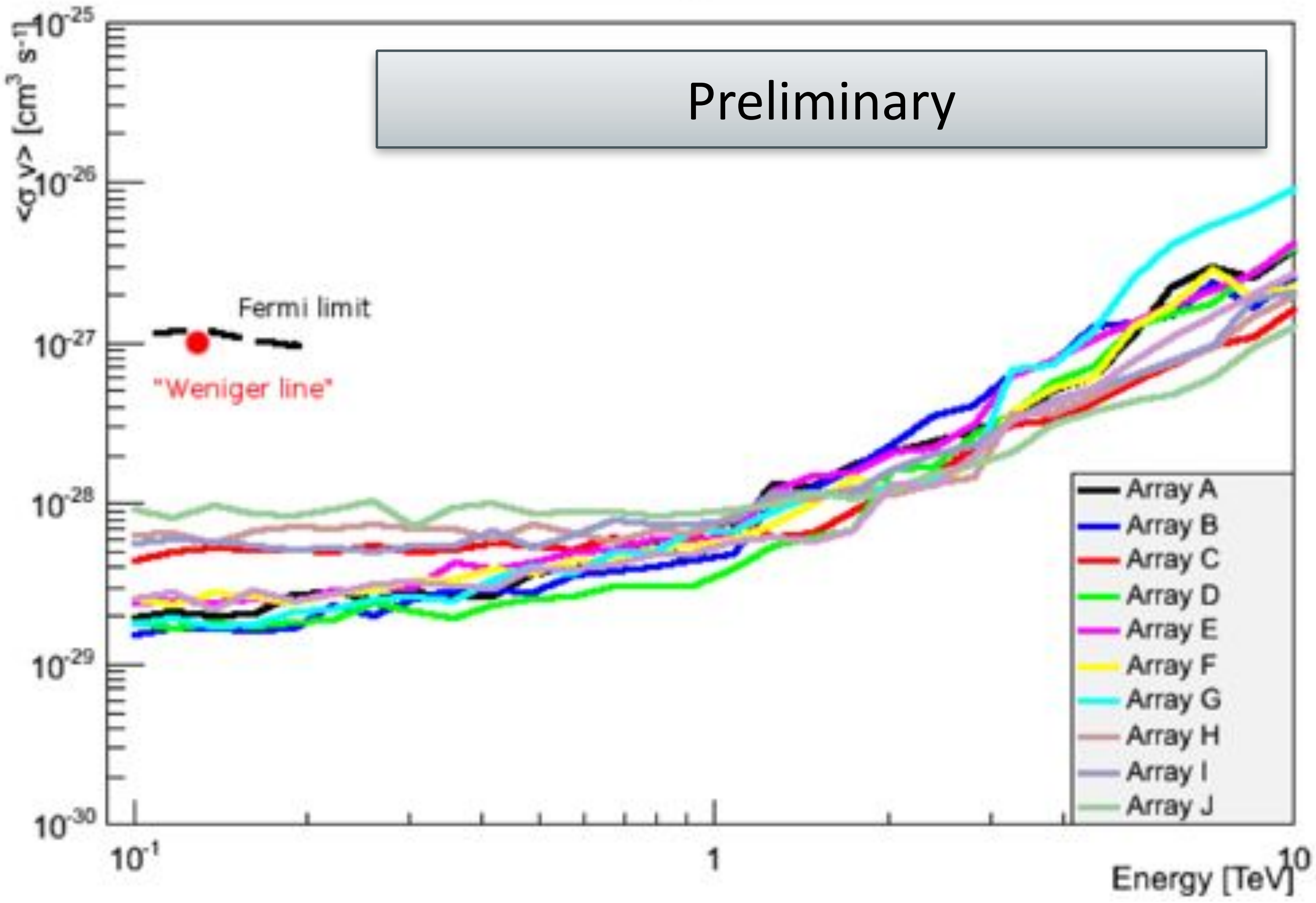


GC Halo Limits (bb channel)

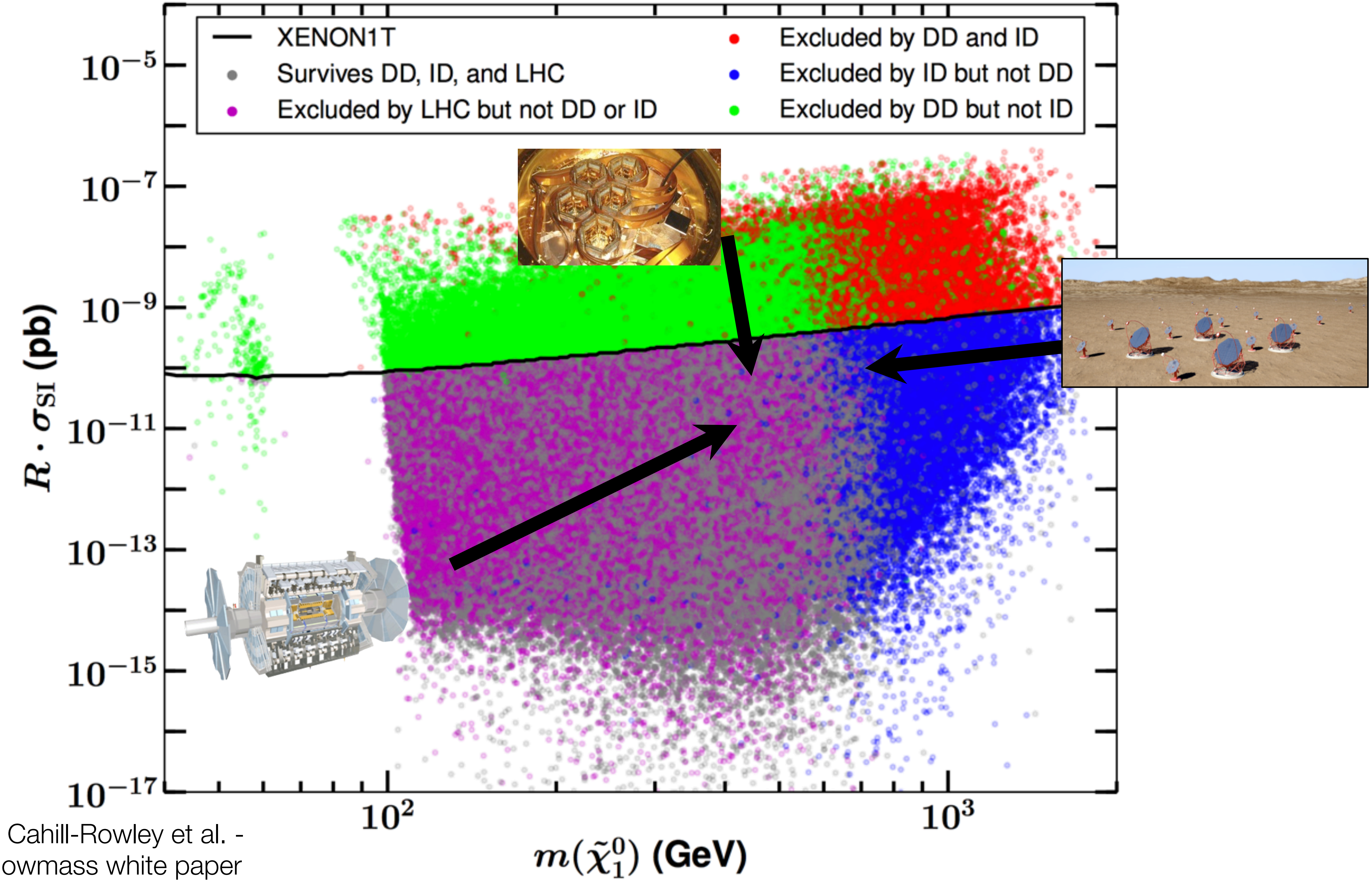


Line searches

- A large effort is currently at place in CTA to improve the energy resolution and bias through through instrument and atmospheric calibration
- Low-energy threshold and larger sensitivity go along well with line searches
- GC is the best target
- Basically every CTA array under discussion will have sensitivity to the Bringmann-Weniger line



Complementarity -SUSY scan (pMSSM)

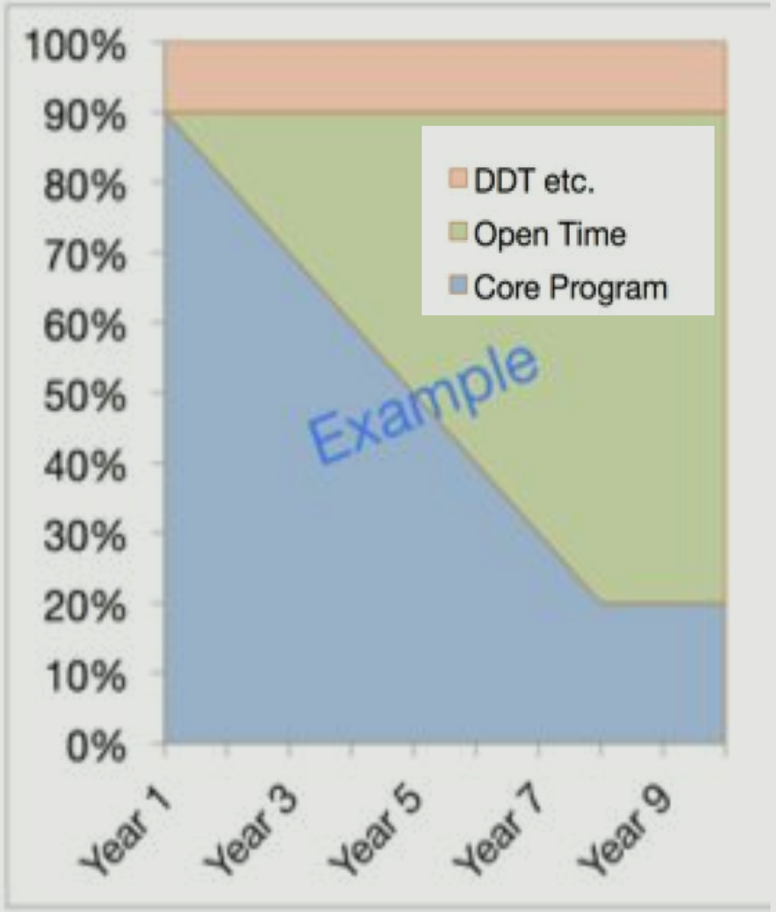


M. Cahill-Rowley et al. -
Snowmass white paper

COMMENTS AND CONCLUSIONS

Do you believe in CTA?

1. We have shown that there is at least a part (for now) of the **parameter space** that we can curb with CTA (DM at the GC-halo)
2. In case LHC-14 do not discover DM, CTA has still chance if **DM is heavy**
3. CTA can be the **sole player** if DM is heavy for 2020-2030.
4. CTA can make **identification**



- CTA science community is currently working on Key-Science Projects definitions:
  - To define core program
  - To secure proprietary time
  - To define schedule
- Guest time relevant and photons will be distributed along with analysis tools a-la Fermi
- First time of a **Cherenkov *observatory***!

Summary

- CTA has good prospects for reaching WIMP models with thermal relic cross section and **mass > 100 GeV**
- **Galactic Center**: Fraction of parameter space finally accessible with CTA – particularly at high LSP masses (>1 TeV)
- **Dwarf Galaxies:** need high boost factor or new sources discovered (possibly dark clumps, HVC?)
- **Other probes** (electrons, anisotropy) are viabl
- CTA will **be complementary** to LHC and direct detection searches and can be unique player in some regions of the parameter space
- CTA is the first ground-based Cherenkov telescopes observatory

Thanks, tusen takk, tack så mycket!