

# SST physics (and system) requirements

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on behalf of INAF-CTAST



# Do we need them?

- 📌 YES !They allow us to establish a common framework among different groups.
- 📌 Are they frozen yet? Maybe not.
- 📌 This 1<sup>st</sup> SST meeting could be the right place to start working on them.

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# Top-level Requirements

- 📌 Define the Scientific Requirements for SST
- 📌 Cost vs. Performance trade-off for the single telescope and for entire array (e.g., SM vs DM, see J. Hinton & T. Bretz talks)
- 📌 Define the System Requirements (SR) for all the sub-packages (SR-STR, SR-MIR, SR-CAM)
- 📌 Production of both Scientific and System Requirements Documents
- 📌 Current Term of Reference: *Design Concepts for the Cherenkov Telescope Array* [ArXiv:1008.3703]

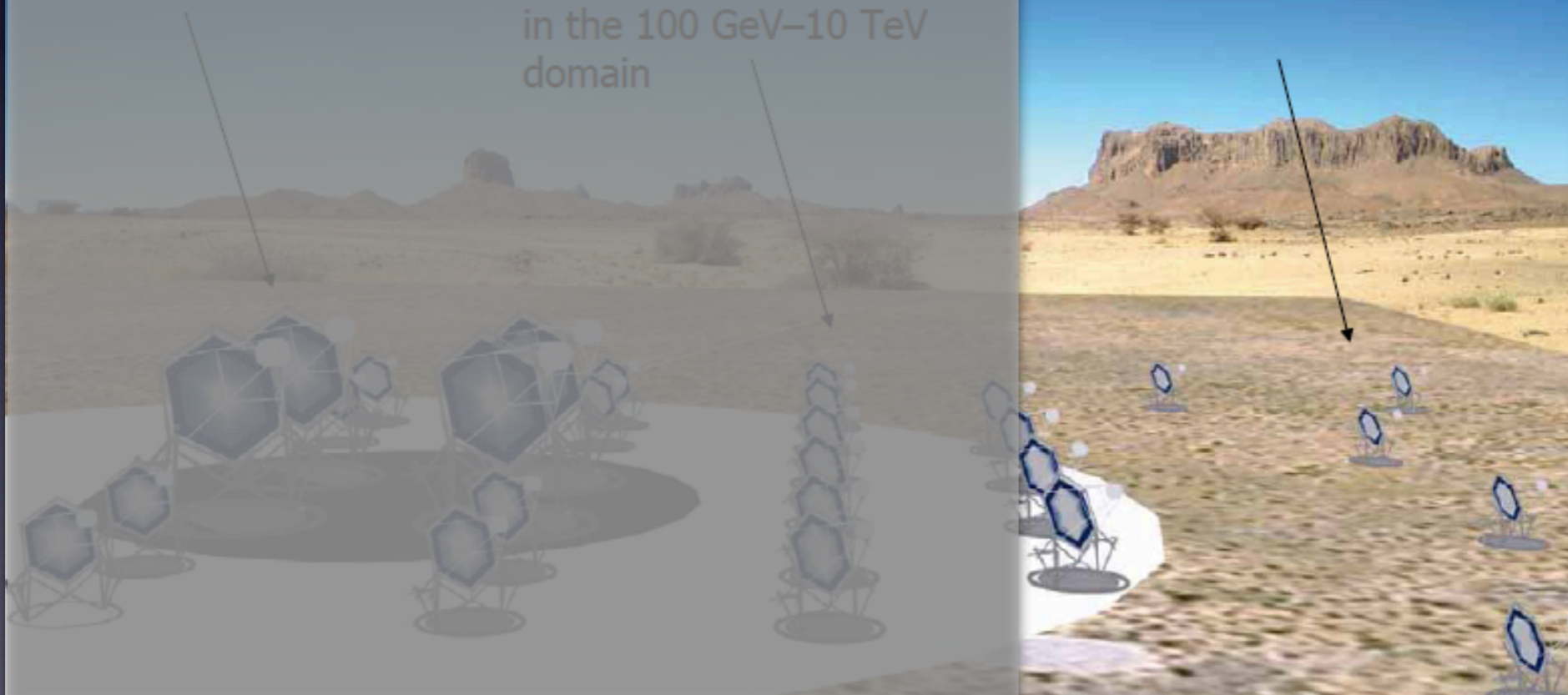


# CTA-SST: the array

**Low-energy section:**  
few O(24) m tel. (LST)  
=> push low threshold  
- Parabolic reflector  
- FOV: O(5) degrees  
- O(0.09 deg/pix)  
- f/d: O(1.2)  
energy threshold  
of some 10 GeV

**Core-energy array:**  
many O(12) m tel. (MST)  
=> workhorse of CTA  
-> push cost & reliability  
- Davies-Cotton reflector  
- FOV: O(8) degrees  
- O(0.18 deg/pix)  
- f/d: O(1.4)  
O(1 km<sup>2</sup>) area  
mCrab sensitivity  
in the 100 GeV–10 TeV  
domain

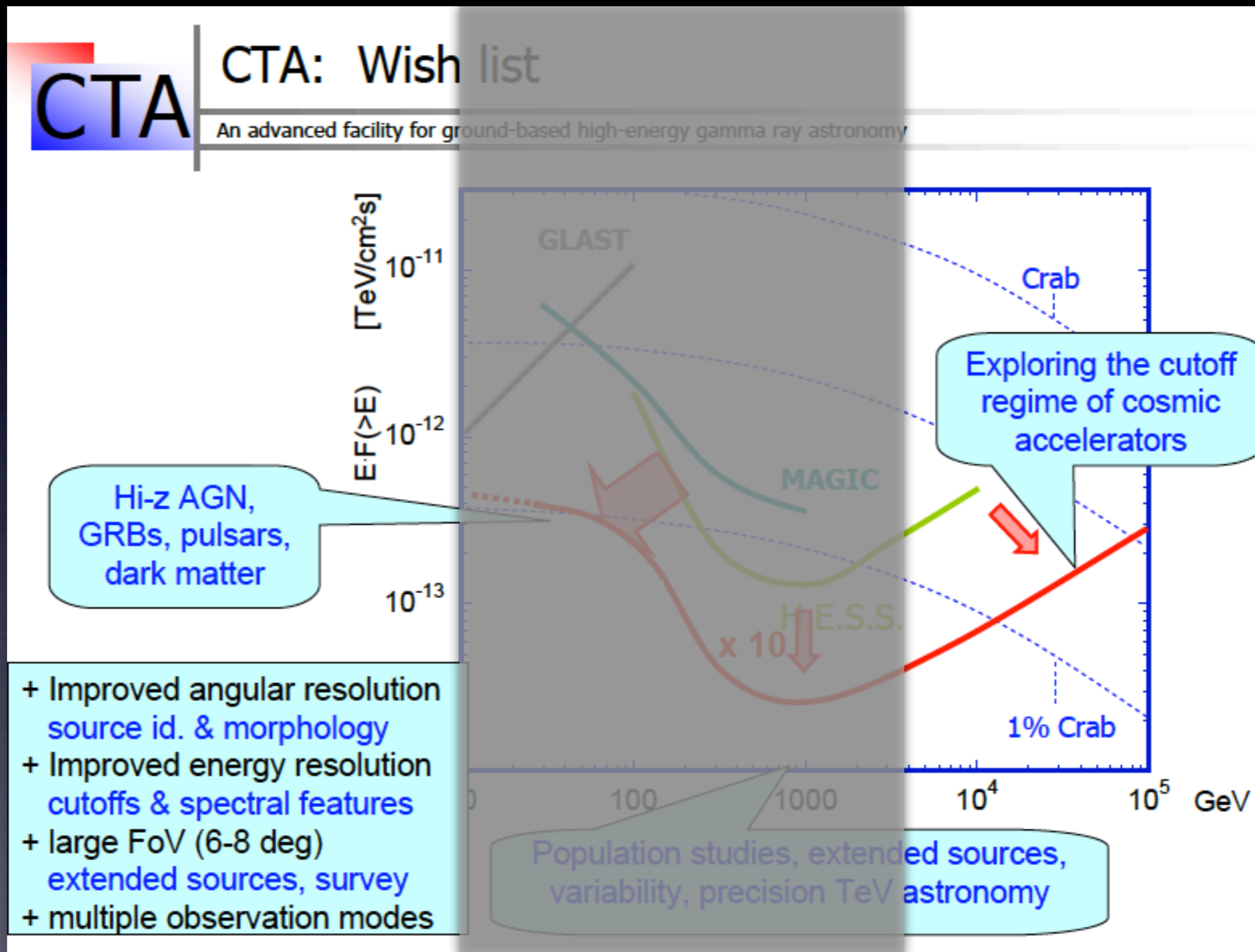
**High-energy section:**  
many O(6) m tel. (SST)  
=> push low-cost  
- Davies-Cotton reflector  
(or Schwarzschild-Couder)  
- FOV: O(10) degrees  
- O(0.25 deg/pix)  
- f/d: O(1.2-1.5)  
O(10 km<sup>2</sup>) area at  
multi-TeV energies



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# CTA-SST: the science

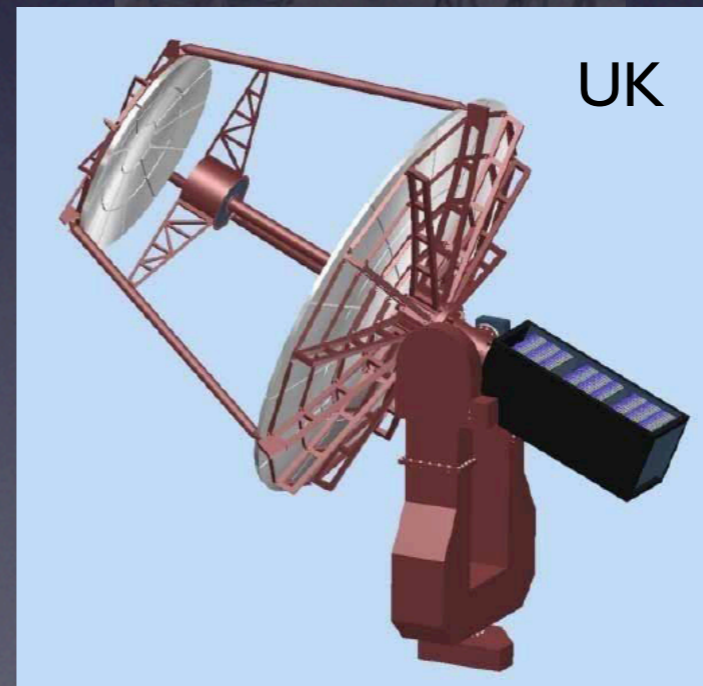
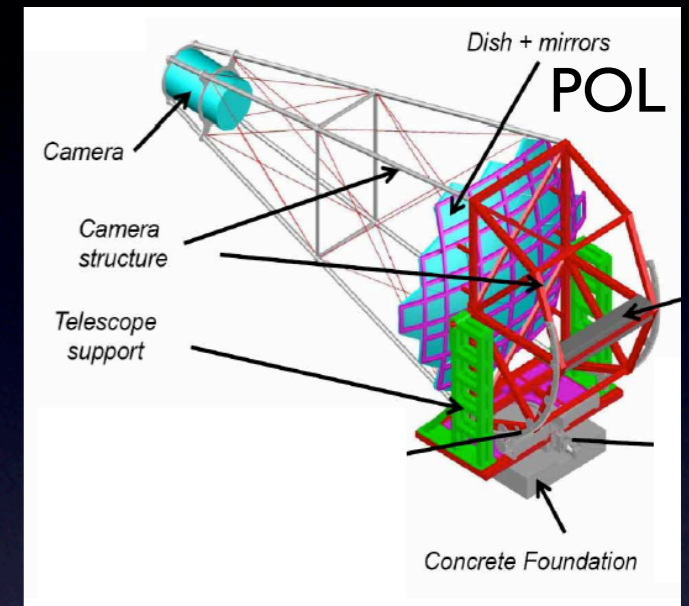


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# The Current Status

- 📌 4 or 7 m  $\varnothing$  telescopes
- 📌 single-mirror (SM)
- 📌 dual-mirror (DM)
- 📌 8° - 10° FoV Diameter
- 📌 0.2° - 0.3° pixel
- 📌 Camera cost is critical





# SST physics drives the SST system requirements

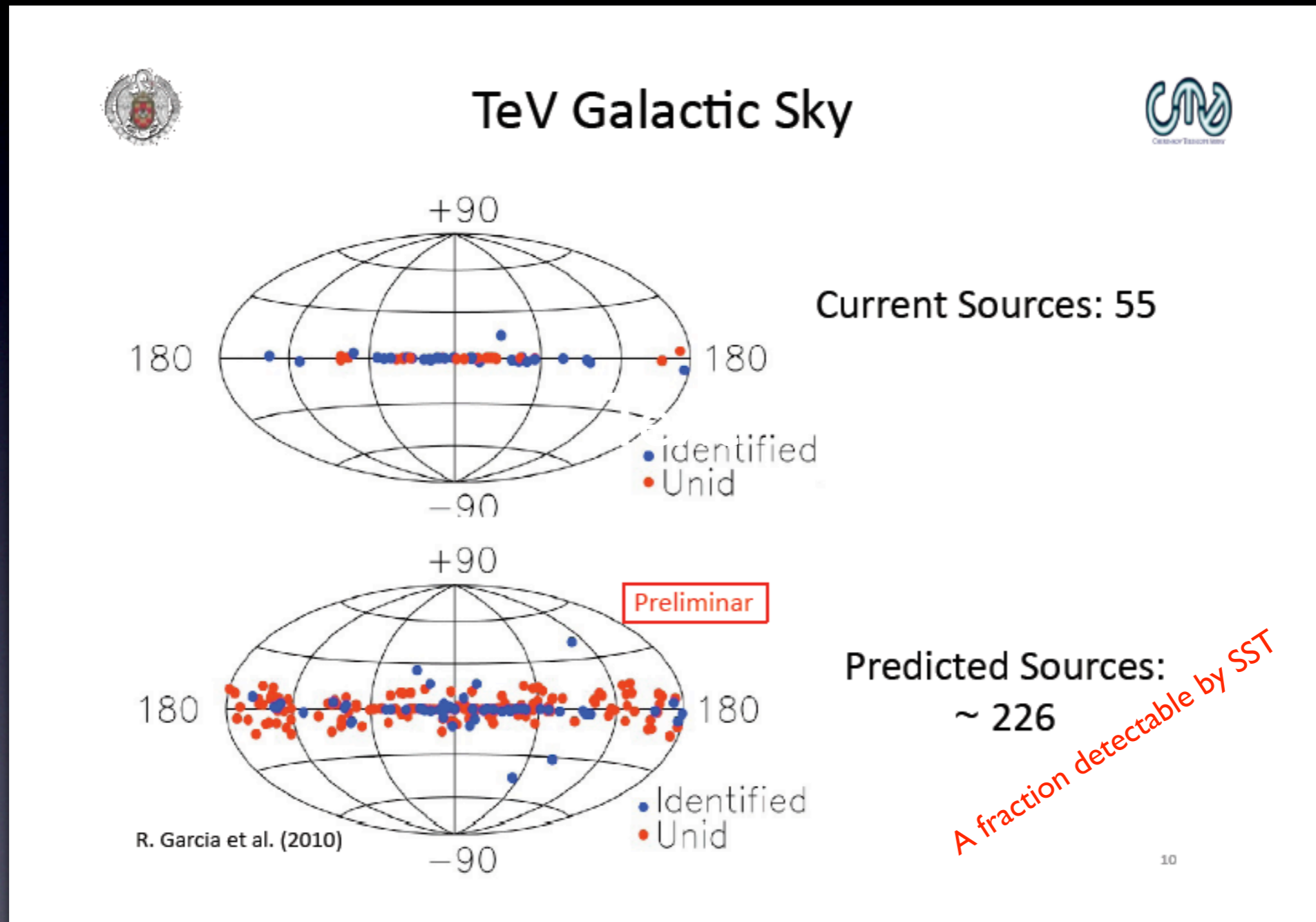


# Astrophysics with SST

- 📌 For the first time, the energy regime above a few TeV will be investigated at a flux level of a few percent of a Crab.
- 📌 This will be crucial for both Galactic (e.g., PWN, SNR) and extragalactic (e.g., blazars, radio-galaxies) sources.
- 📌 Moreover, the chance to operate the SST array as a combination of sub-arrays will allow a survey of the sky at extreme energies.



# Galactic sources



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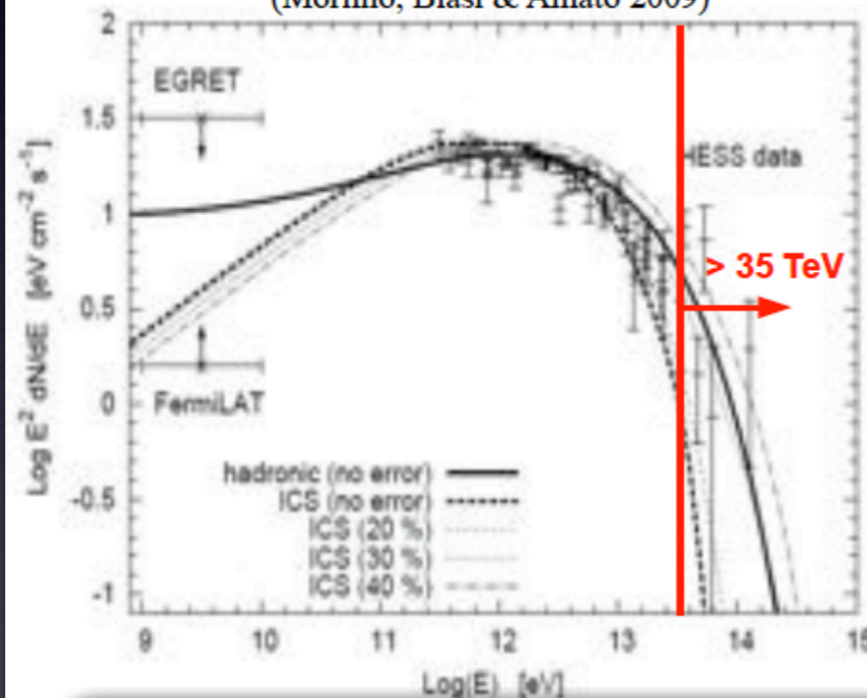
# Galactic sources

Good energy resolution will allow detailed spectral studies of similar SNRs.

## RX J1713.7-3946: CTA comparison

Significant emission above ~35 TeV → Nature of the VHE emission?

(Morlino, Blasi & Amato 2009)



10<sup>3</sup> HESS-like spectra >35 TeV

Config. B →  $S/N_{\alpha=1} = 2.56 \pm 0.75$   
 $S/N_{\alpha=0.1} = 3.33 \pm 0.92$

Config. D →  $S/N_{\alpha=1} = 4.21 \pm 0.66$   
 $S/N_{\alpha=0.1} = 5.45 \pm 0.95$

Config. I →  $S/N_{\alpha=1} = 5.86 \pm 0.67$   
 $S/N_{\alpha=0.1} = 7.33 \pm 0.88$

[HESS data points > 35 TeV : 2.5, 1.5 & 0.6  $\sigma$ ]

May 10-12 2010

CTA meeting – DESY Zeuthen

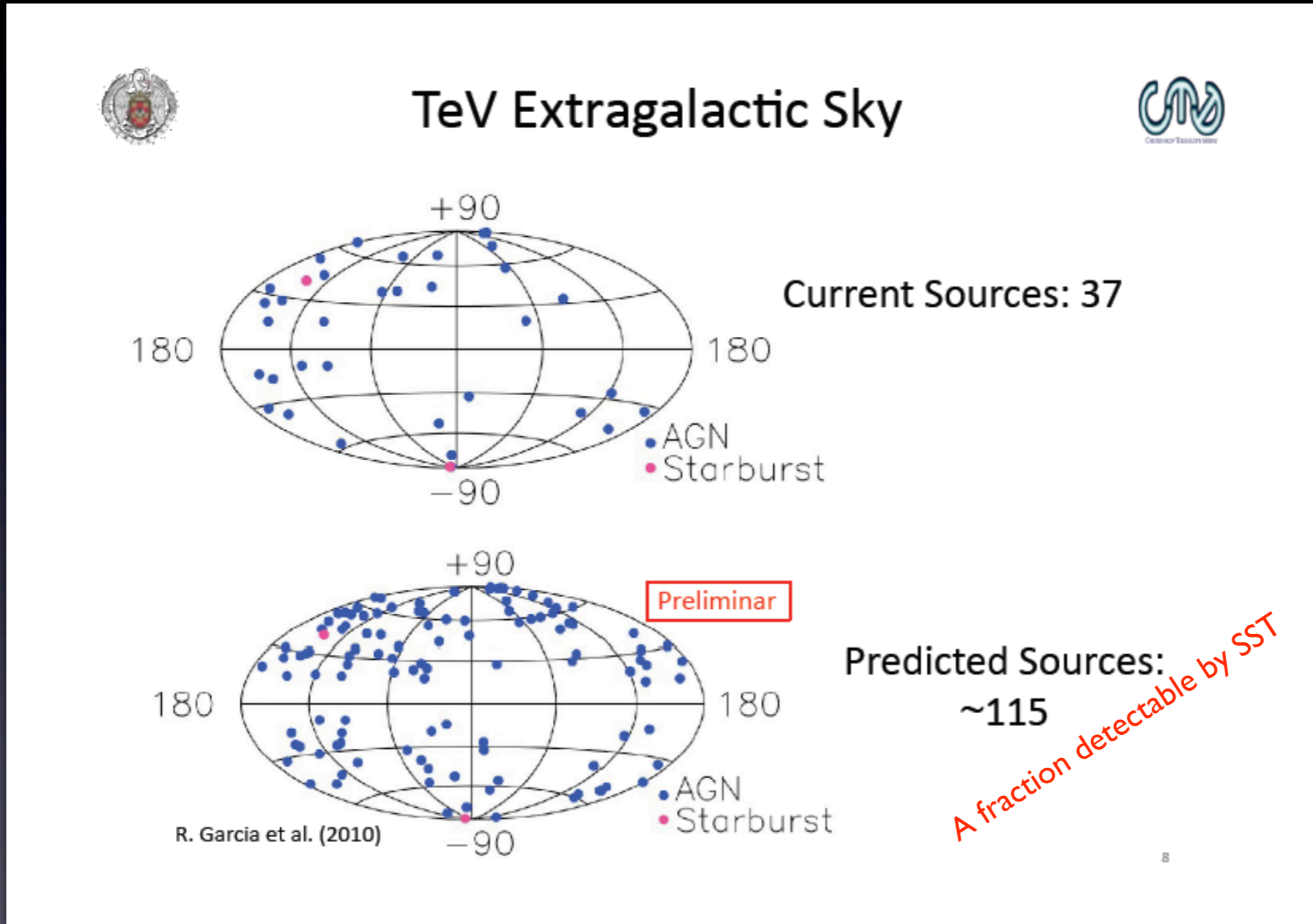
May 10-12 2010

CTA meeting – DESY Zeuthen

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# Extragalactic sources

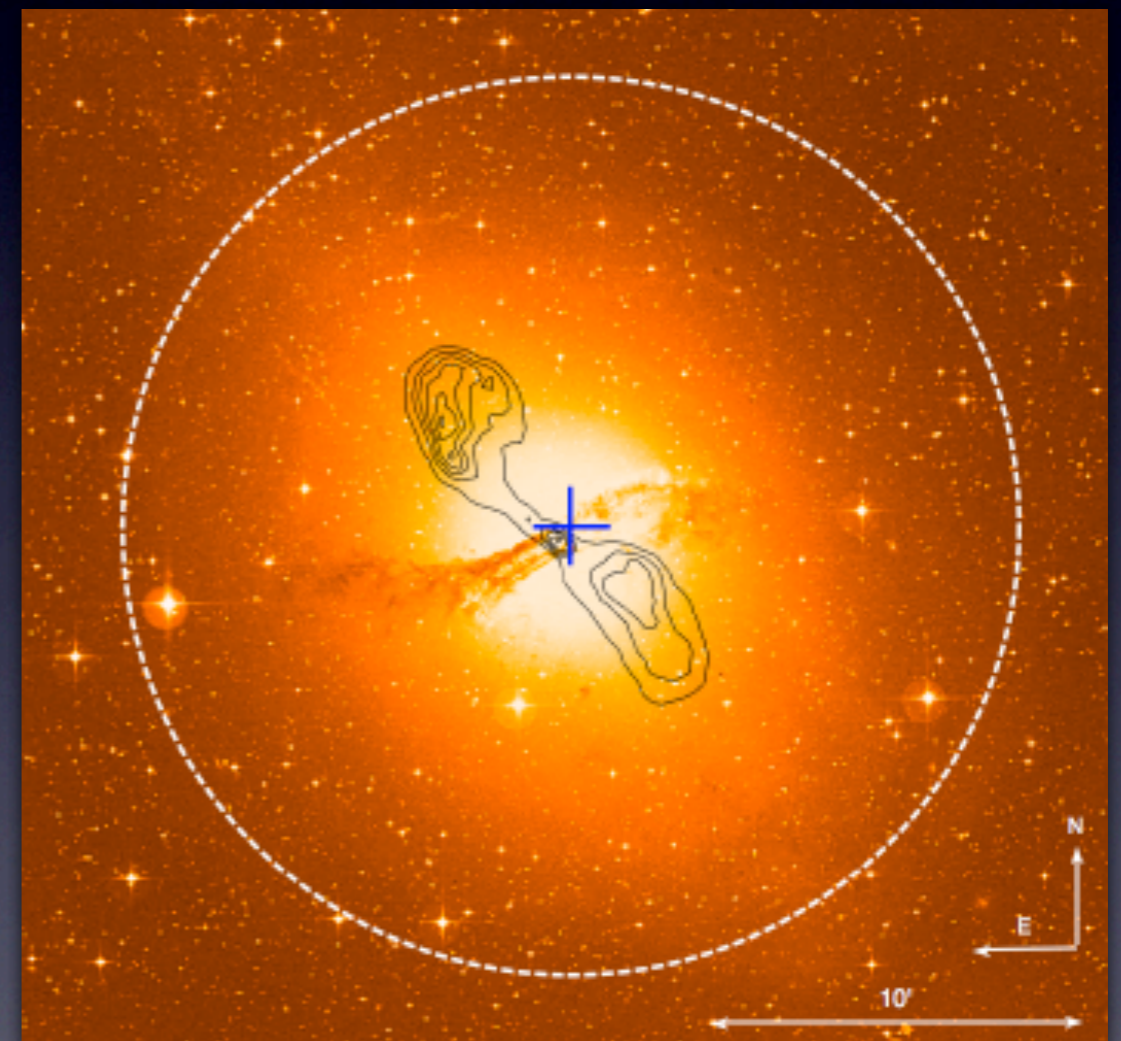
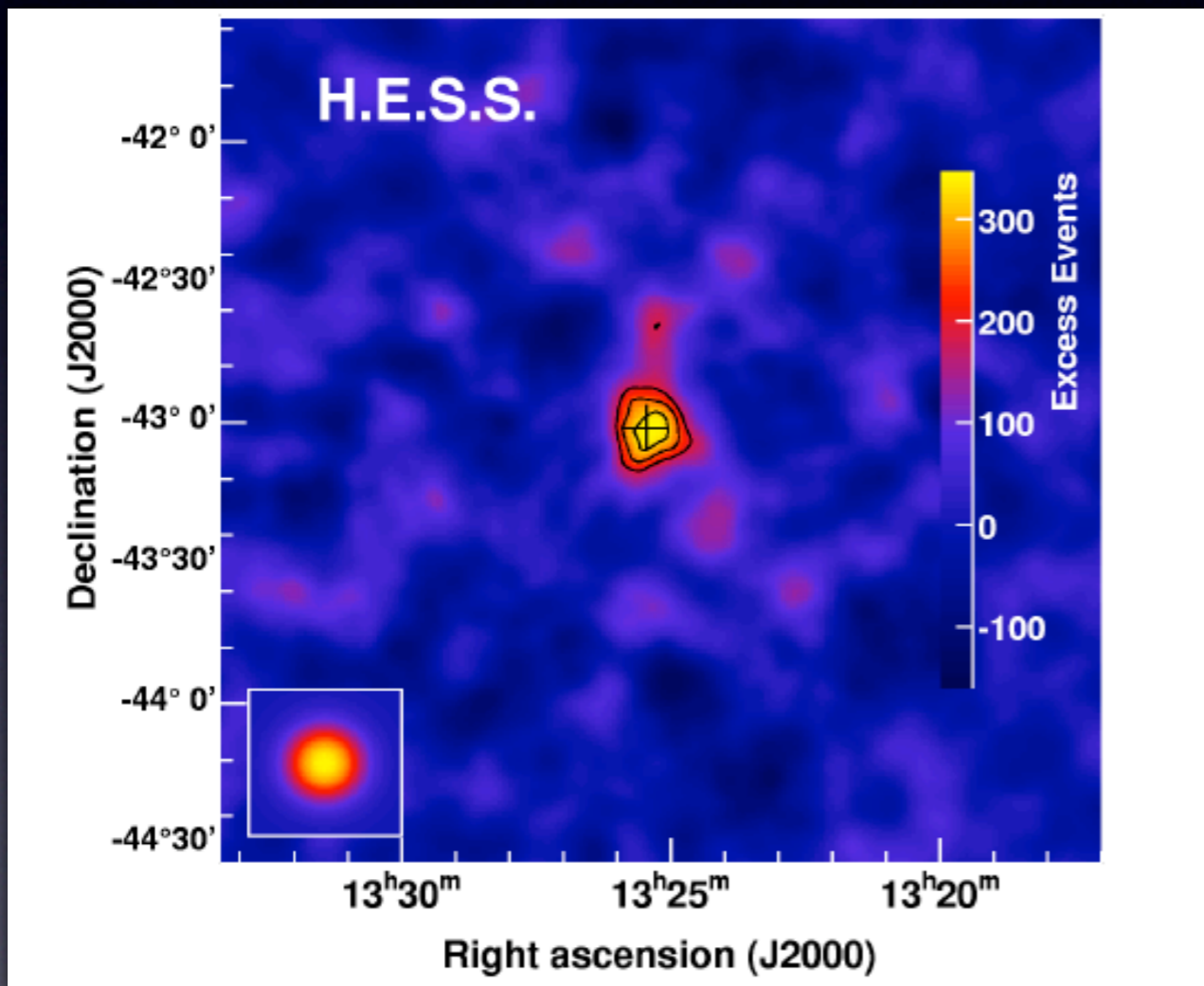


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# Extragalactic sources

Good angular resolution will allow to study the VHE emission in different regions of Cen A



Centaurus A

Aharonian+09



# Galactic Requirements

- Good **sensitivity** will allow:
  - Detection of SNRs whose spectrum extend up to hundreds of TeV ( $N^{\text{SNR}}[\text{exp}] \sim 10$ ) → evidence of CR acceleration at VHE
- Good **energy resolution** will allow:
  - Detailed measure of the VHE absorption in the Interstellar Radiation Field (20 - 300  $\mu\text{m}$ ) → possible detection of an absorption feature @ 50 TeV as a spectral cut-off
- Good **angular resolution** will allow:
  - Detailed study of spectra in different region of PWN → see upcoming slides...



# Extragalactic Requirements

- Good **sensitivity** will allow:
  - Blazar fast time-scale flux variability → geometry of the central engine
- Wide **field of view** will allow:
  - detection of weak nearby objects at  $E >$  a few TeV → moderately deep survey at VHE
- Good **angular resolution** will allow:
  - investigation of possible VHE emission in different regions in Radio Galaxies (Cen A)



# Fundamental Physics

- 📌 “In-situ” study of cosmic ray acceleration
- 📌 Detailed studies of SNR at energies of about 100 TeV, in combination with a good angular resolution ( $< 1$  arcmin) and a wide FoV.
- 📌 Detection of Direct Čherenkov light:
  - 📌 Measurements of the spectra of CR electrons and nuclei. Needs excellent angular resolution, wide FoV and accurate timing.
- 📌 Quantum Gravity effects:
  - 📌 Excellent sensitivity above 1 TeV is required to investigate QG effects beyond the current limits of the *Fermi-LAT* observatory



Several system requirements  
were already addressed  
(see [ArXiv:1008.3703](https://arxiv.org/abs/1008.3703))

Many of them will be discussed  
during this meeting.



# Example: SST-STR

- 📌 Mounting Type: Alt-Az,
  - 📌 Circular rail (H.E.S.S, MAGIC)
  - 📌 Central positioner (VERITAS) → good for SST because of its low weight.
- 📌 Tracking precision: 6 arcmin
- 📌 Pointing precision: 10 arcsec
- 📌 Max operational wind: 50 km/h
- 📌 Max. survivable wind: 180 km/h



# Example: SST-MIR

- Mirror facet: 700 mm semi-diagonal
- Optical PSF: < 1 mrad (80% containment radius)
- Alignment of mirror facets: < 0.1 mrad
- Time dispersion: < 3 ns

M. Mariotti @ Zeuthen Meeting



## Table of specs (temp!)

|     |                       | SST-SC  |        | SST-DC                                       | MST                 | LST                  |
|-----|-----------------------|---|--------|--|---------------------|----------------------|
|     |                       | Prime   | Second |  |                     |                      |
| M01 | Shape                 | ?   | ?      | hex.   | hex.                | hex.                 |
| M02 | Size                  | ?   | ?      | 1.2m FTF?                                    | 1.2m FTF            | 1.5m FTF?            |
|     | Area                  | ?   | ?      | 1.27 m <sup>2</sup> ?                        | 1.27 m <sup>2</sup> | 1.9 m <sup>2</sup> ? |
| M03 | Surface shape         | Asph.   | Asph.  | Sph.   | Sph.                | Sph.(+asph.)         |
| M04 | Focal length          | ?   | ?      | ?  | ~ 16.5 m            | ~ 28 – 35 m          |
| M05 | Weight                | 30 kg or 23 kg m <sup>-2</sup>                  |        |  |                     |                      |
| M06 | Thickness             | < 8 cm  |        |  |                     |                      |
| M07 | Rear surface          | Flat?   |        |  |                     |                      |
| M08 | Stiffness             | Enough to maintain optical specs at focal plane |        |  |                     |                      |
| M09 | Temp. survival        | -15, +60°C survival, -10, +30°C operational     |        |  |                     |                      |
| O01 | Ang. resolution       | d80 < 1/3 pixel size                            |        |  |                     |                      |
| O02 | Local surface refl.   | > 80% between 300 – 600 nm                      |        |  |                     |                      |
| O03 | Total reflectance     | > 80% between 300 – 600 nm                      |        |  |                     |                      |
| O04 | Surf. roughness       | Shall we put a parameter?                       |        |  |                     |                      |
| T01 | Mounting Points       | ?   | ?      | 3 points at about 2/3 of the radial distance |                     |                      |
| T02 | Mirror Alignment      | Fix/IAS   | Fix    | IAS/AMC                                      | IAS/AMC             | AMC                  |
| T03 | AMC motors weighth    |   |        |  |                     |                      |
| T04 | Distance tel-rear mir |   |        |  |                     |                      |

○ M = mechanical, O = optical, T = telescope



# Example: SST-MIR

## Difficulties in making mirrors

| SAGs<br>[mm]     | CTA-SST<br>D-C 7 m | CTA-SST<br>S-C 4 m | CTA-SST<br>S-C 7 m | CTA-SST<br>3MT 4 m | CTA-SST<br>3MT 7 m |    |
|------------------|--------------------|--------------------|--------------------|--------------------|--------------------|----|
| <b>Primary</b>   | 12                 | 25                 | 14                 | 40                 | 46                 |    |
| <b>Secondary</b> |                    | 230                | 130                | 92                 | 106                |    |
| <b>Tertiary</b>  |                    |                    |                    | 160                | 80                 | 92 |
|                  |                    |                    |                    | 80                 | 184                | 92 |

- Mild curvature, doable with cold glass slumping TBC
- Mild curvature with aspherical profile, doable with cold glass slumping TBC
- Strong and/or peculiar curvature, doable with a mixed cold+hot glass slumping TBC
- Very strong and peculiar curvature, NOT doable with glass slumping

“We want to go to the Moon  
 We want to go to the Moon  
 in this decade and do the other things  
 not because they are easy but because they are hard.”

JFK



# Example: SST-CAM

- Sensitivity range: 300 - 650 nm
- Sensor area:  $0.25^\circ$  (SM  $\sim$  35 mm) or  $0.2^\circ$  (DM  $\sim$  6 mm)
- Sensor non-uniformity:  $< 10\%$
- Sensor filling factor:  $\geq 90\%$
- Dynamic range: up to 5000 p.e., linearity  $<$  a few %
- Temporal response: desirable to determine the pulse arrival times with sub-nanosecond precision for sufficiently large light pulses.
- Lifetime:  $> 10$  yrs (assuming 2000 hrs/yr of exposure)
- Spurious rate: after-pulse probability  $< 10^{-4}$
- Cross-talk:  $<$  a few %



# Example: SST-CAM

Bonanno &  
 Catalano, in prep.



|                           | Pixel Size | #Pixel per Unit | Unit Dimensions | Unit Weight | Dead Space | Efficiency (@ 400 nm) | Intrinsic Gain      | Dark current | Anode Non-uniformity | Optics design | ROM cost |
|---------------------------|------------|-----------------|-----------------|-------------|------------|-----------------------|---------------------|--------------|----------------------|---------------|----------|
| Unit                      | mm         |                 | mm              | g           | %          | %                     | -                   | nA           | %                    |               | EURO     |
| <b>Vacuum Device</b>      |            |                 |                 |             |            |                       |                     |              |                      |               |          |
| Hamamatsu R3479           | 15         | 1               | 19 $\emptyset$  | 15          | 25         | ~30                   | ~10 <sup>6</sup>    | 10           | --                   | D-C           | 350      |
| R7600U-200                | 18         | 1               | 30x30           | 33          | 40         | ~40                   | ~10 <sup>6</sup>    | 2            | --                   | D-C           | 1250     |
| R7600U-200 M4             | 9          | 2x2             | 30x30           | 33          | 40         | ~40                   | ~10 <sup>6</sup>    | 2            | ~20                  | S-C<br>3MT    | 1250     |
| R8900-100 M16             | ~6         | 4x4             | 30x30           | 33          | 22         | ~34                   | ~10 <sup>5</sup>    | 8            | ~25                  | S-C<br>3MT    | 1500     |
| R7600 M64                 | ~2         | 8x8             | 26x26           | 60          | 40         | ~23                   | ~510 <sup>5</sup>   | 0.2          | ~50                  | S-C<br>3MT    | 1500     |
| Flat Panel H8500          | ~6         | 8x8             | 52x52           | 117         | 10         | ~27                   | ~1.510 <sup>6</sup> | 6            | ~50                  | S-C<br>3MT    | 1700     |
| Flat Panel H9500          | ~3         | 16x16           | 52x52           | 117         | 10         | ~27                   | ~1.510 <sup>6</sup> | 13           | ~50                  | S-C<br>3MT    | 2200     |
| <b>Solid State Device</b> |            |                 |                 |             |            |                       |                     |              |                      |               |          |
| Hamamatsu MPPC S10931     | 3          | 1               | 3.8x4.3         | ~4          | 40         | ~40                   | ~10 <sup>6</sup>    | 5000         | --                   | S-C<br>3MT    | ~150     |
| Photonique SSPM_0710G9MM  | 3          | 1               | 4.5x5           | ~4          | 50         | ~10                   | 1.810 <sup>5</sup>  | 75000        | --                   | S-C<br>3MT    | ~150     |



# Going further...

Can we improve our current figures in order to achieve a better science with SST?

Or better phrased:

Can we achieve a better science with SST at the current cost?



# ...maybe yes...

M. Panter @ Zeuthen Meeting

## Can reach goal sensitivity in budget

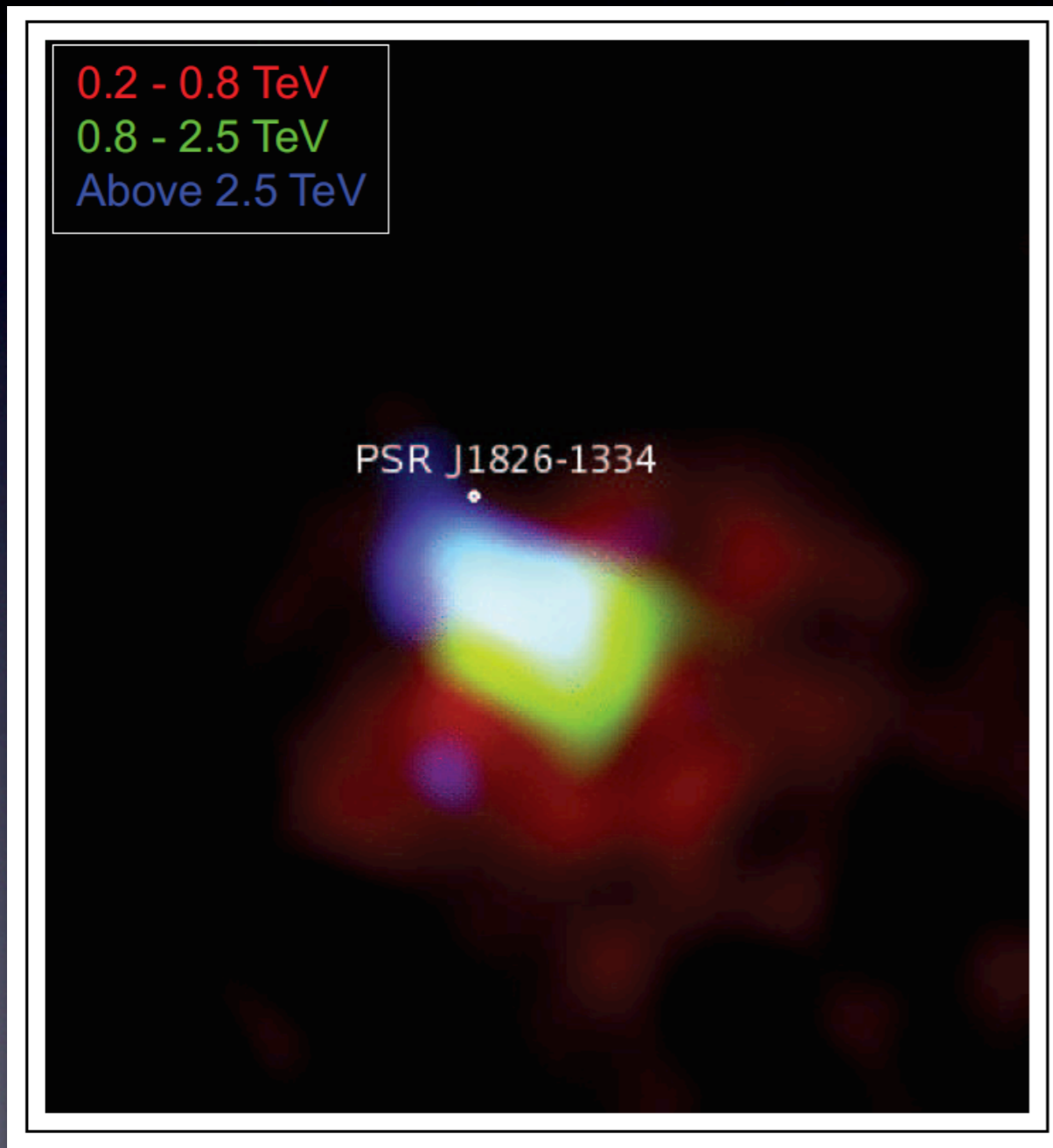
- So what's the problem?
  - We can probably do better! (goal sen. conservative at HE)
- Sensitivity is not the whole story – angular resolution is (so far) not excellent at high energies – and it could be – direct impact on science
  - e.g. energy dependent morphology in PWN and perhaps SNRs

– Better angular resolution very likely → more science



# A possible example

Aharonian+06, Funk+08



H.E.S.S. detection of off-set  
PWNe

Energy dependent  
morphology in the PWN  
candidate HESS J1825-137

Decreasing of gamma-ray  
extension with increasing  
energy



# Next Steps

- 📌 Update and freeze our Scientific Requirements.
- 📌 Choose the telescope and array configuration that better matches these requirements at a fixed or equivalent cost.
- 📌 Write down our requirements.
- 📌 Maybe a dedicated panel could be useful.