SST physics (and system) requirements

Stefano Vercellone INAF/IASF-Pa
on behalf of INAF-CTAST

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

CTA

Do we need them?

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

CONTENTS v

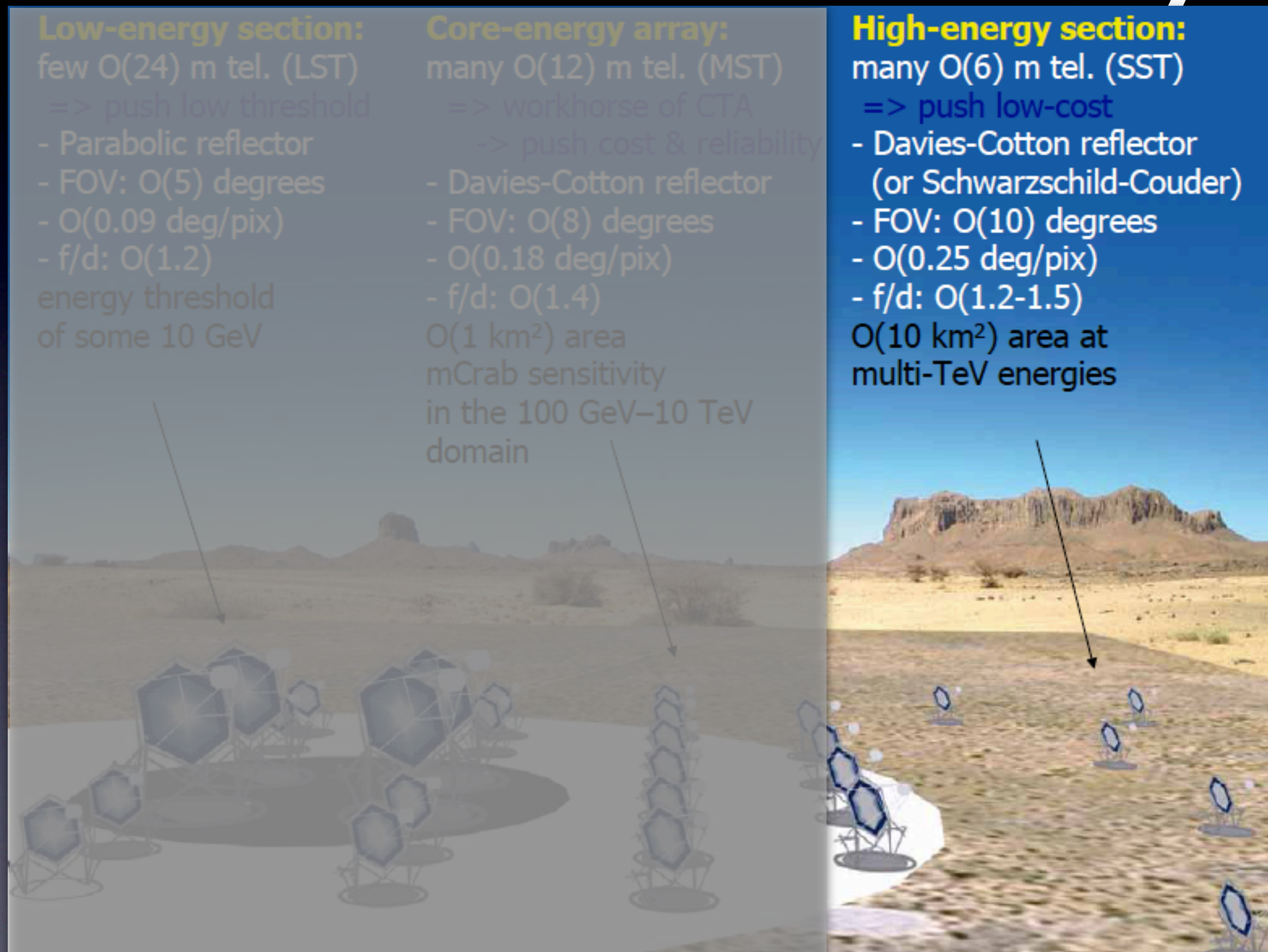
Contents

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]

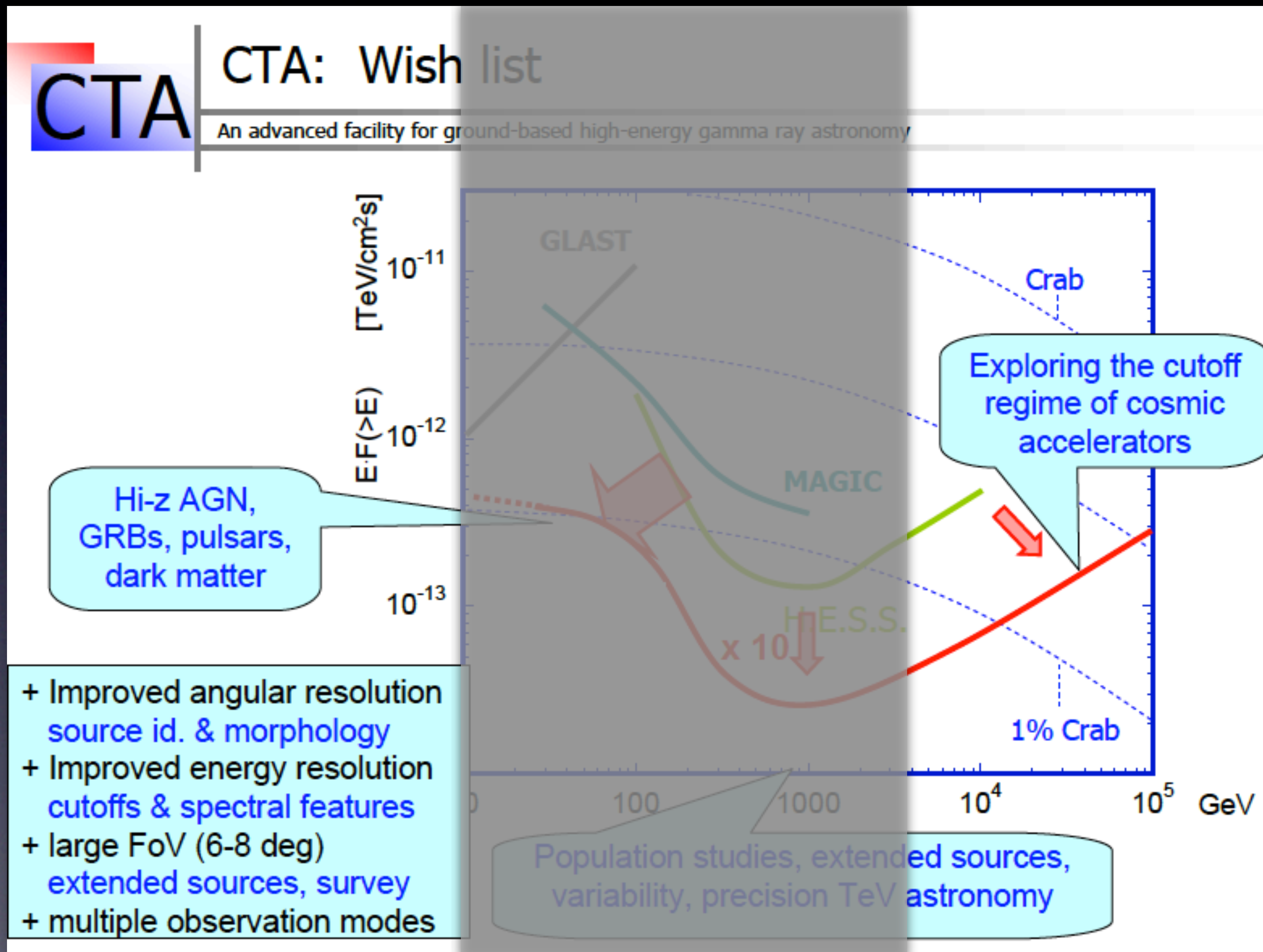
INAF
ISTITUTO NAZIONALE
DI ASTROFISICA
NATIONAL INSTITUTE
FOR ASTROPHYSICS

CTA-SST: the array



M. Martinez @ Zeuthen Meeting

CTA-SST: the science

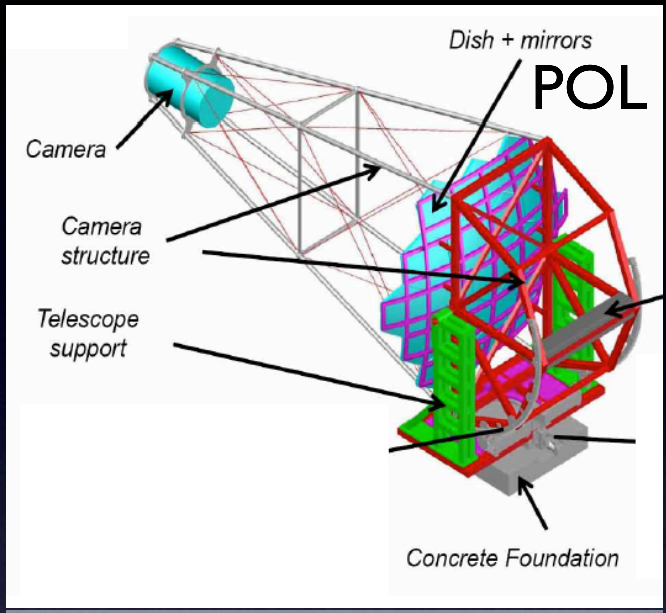


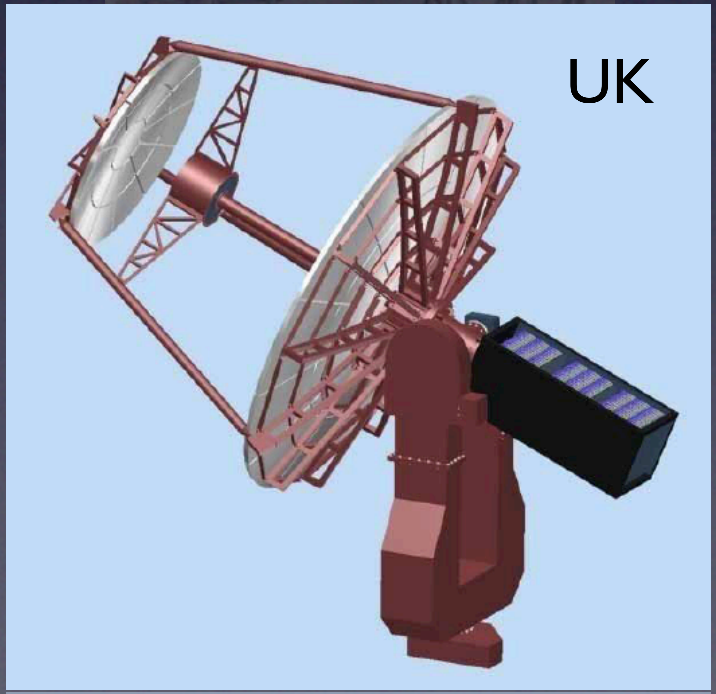
M. Martinez @ Zeuthen Meeting

CTA

The Current Status

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





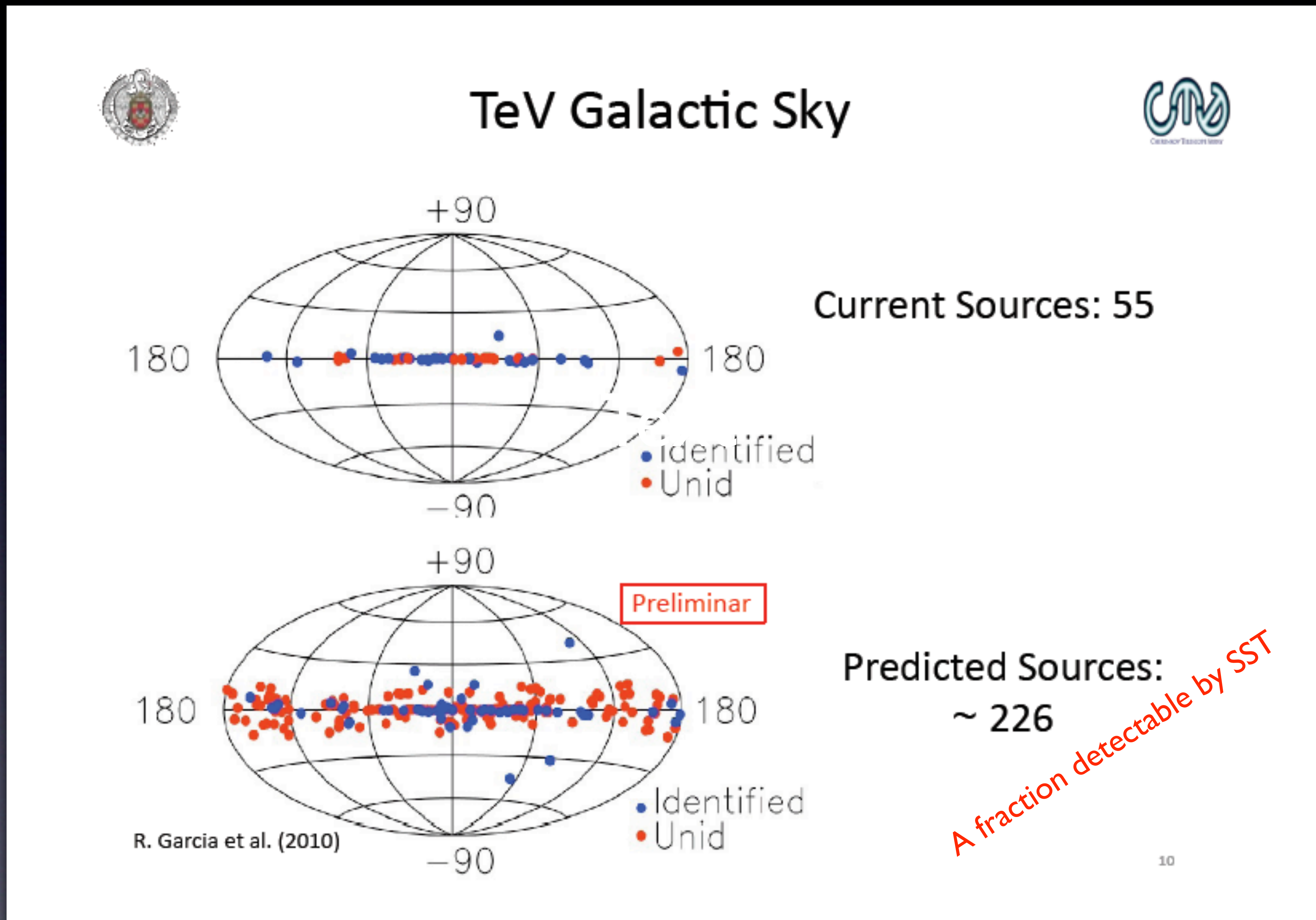
M. Panter @ Zeuthen Meeting

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.

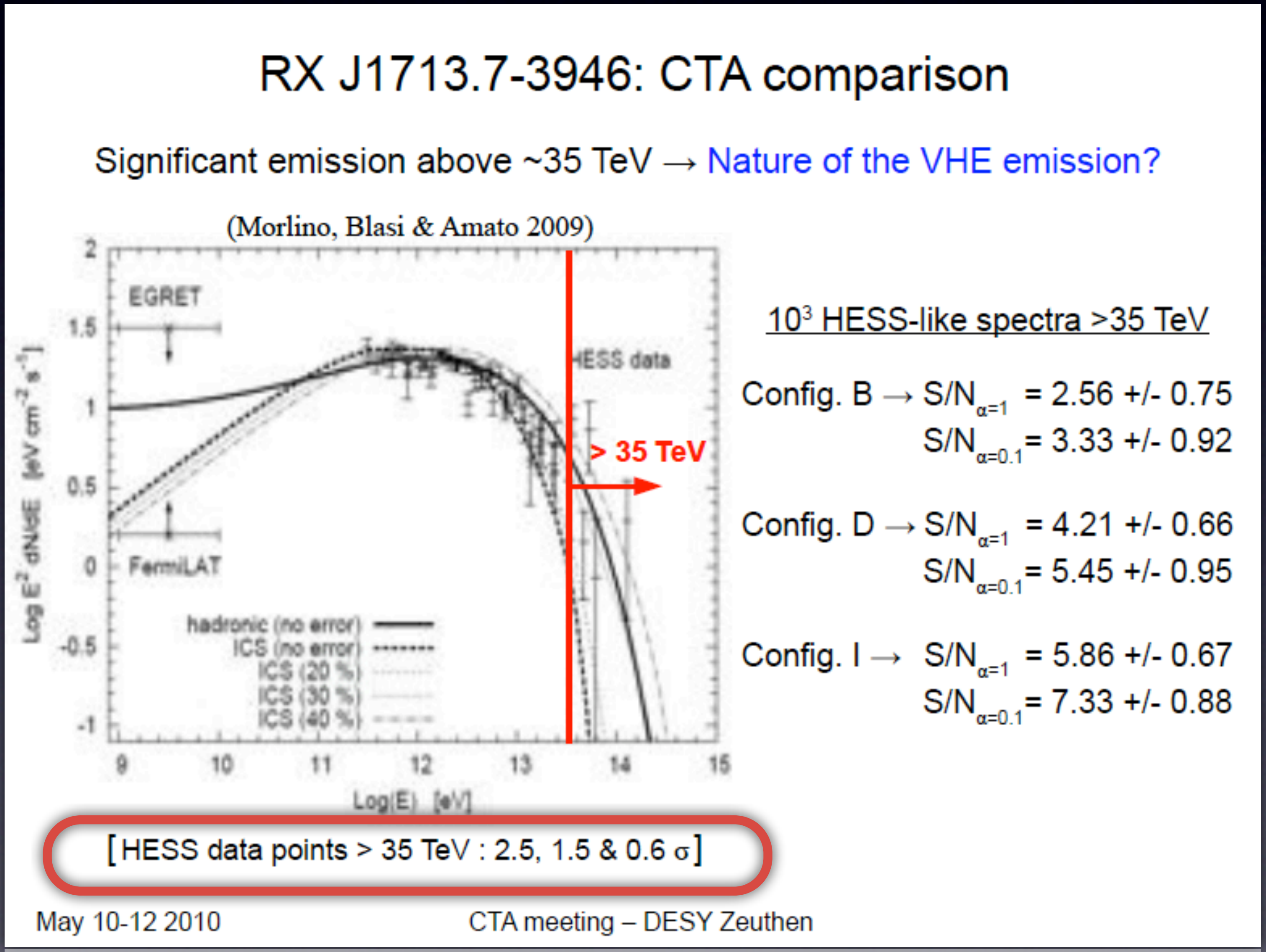
Galactic sources



R. Garcia @ Zeuthen Meeting

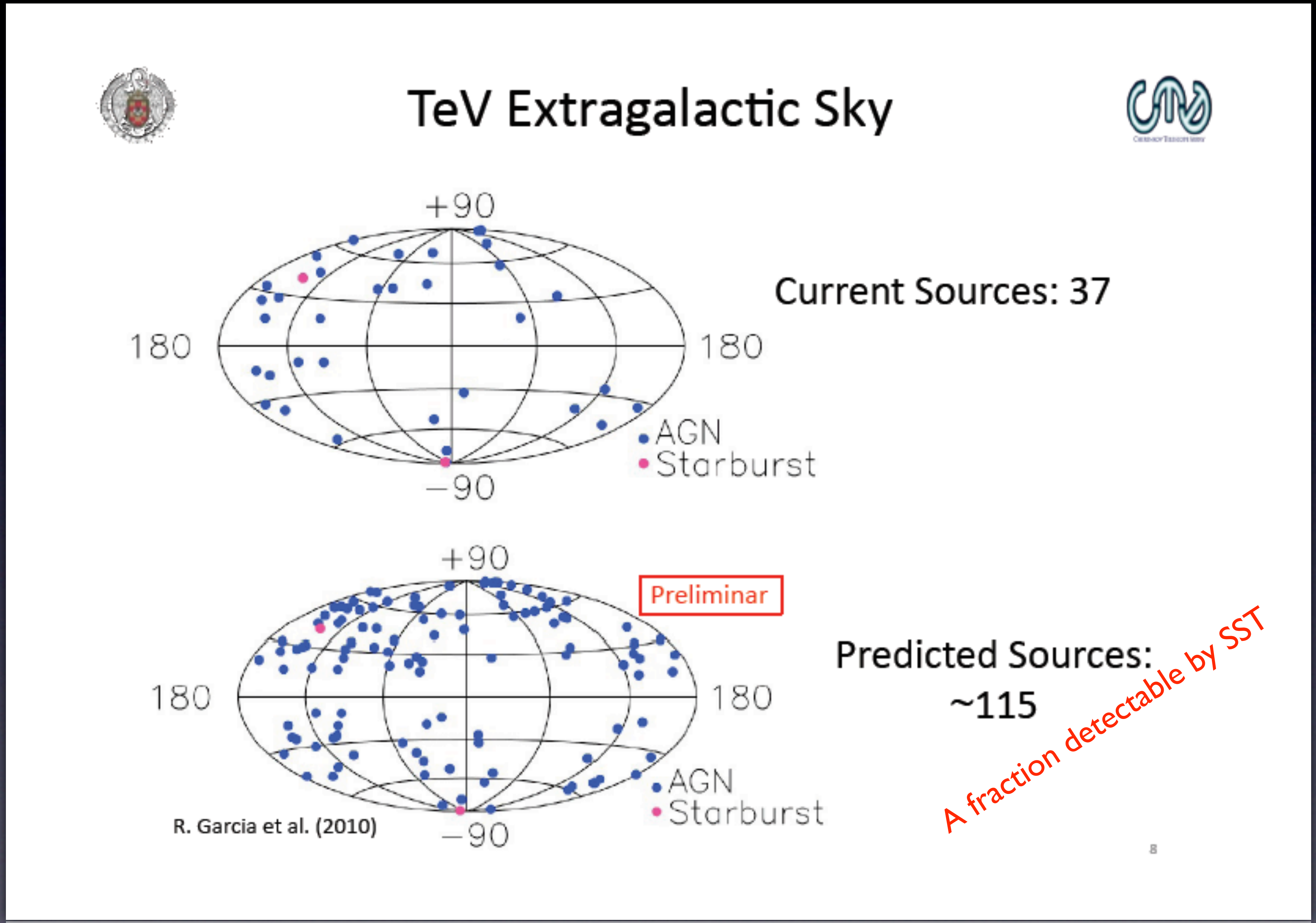
Galactic sources

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



M. Ranaud @ Zeuthen Meeting

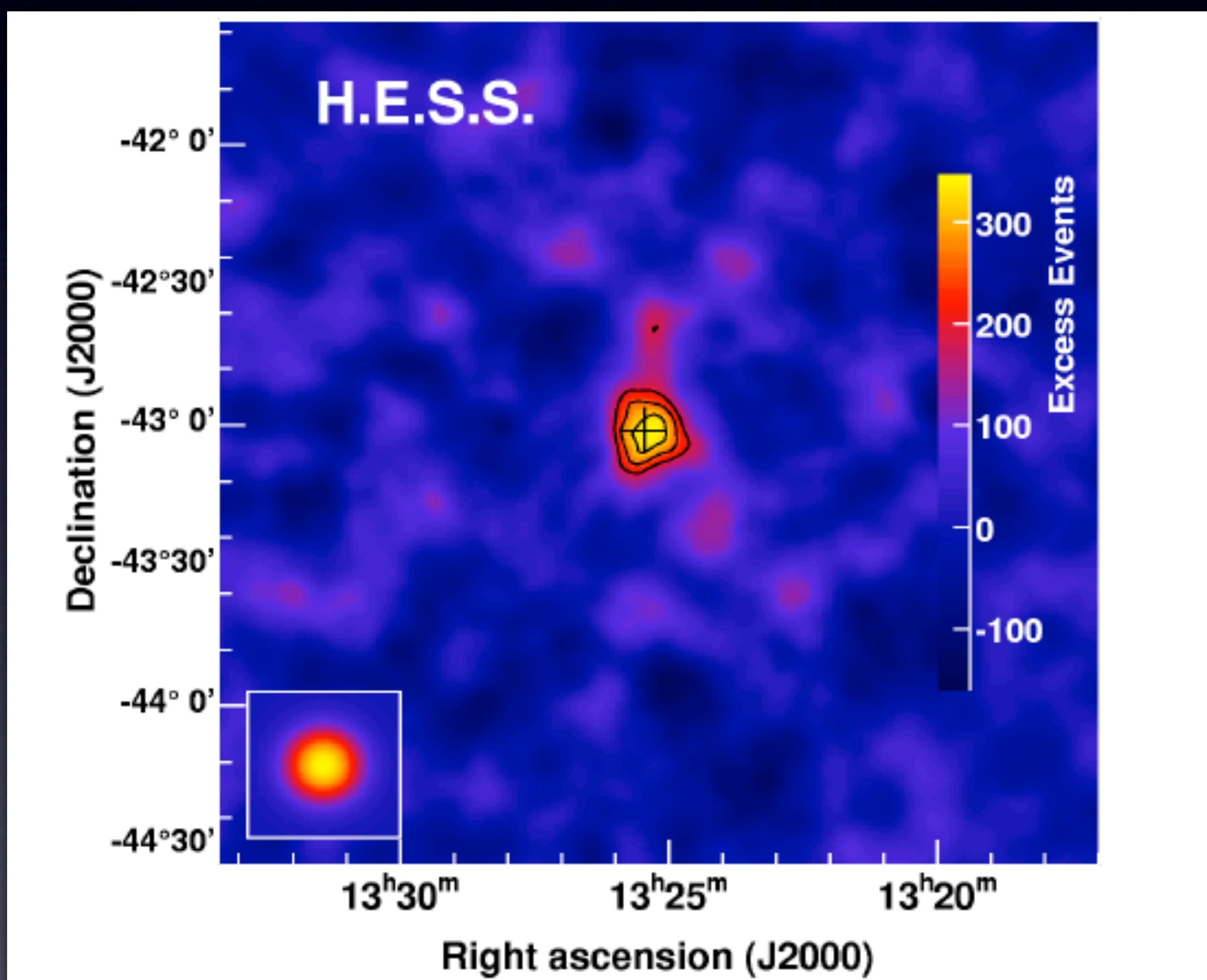
Extragalactic sources

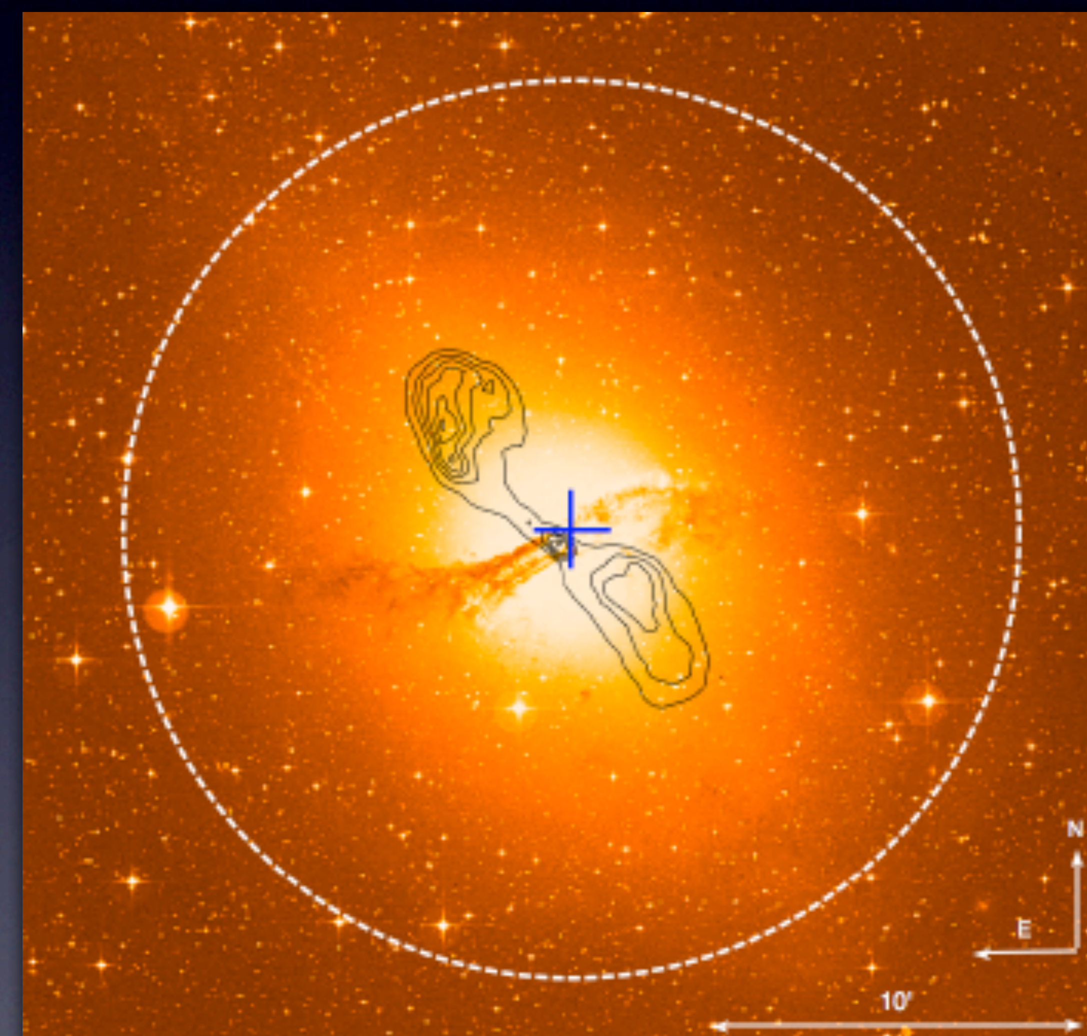


R. Garcia @ Zeuthen Meeting

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^{SNR}[exp] ~ 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 µm) ➔ 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)

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

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

CTA

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

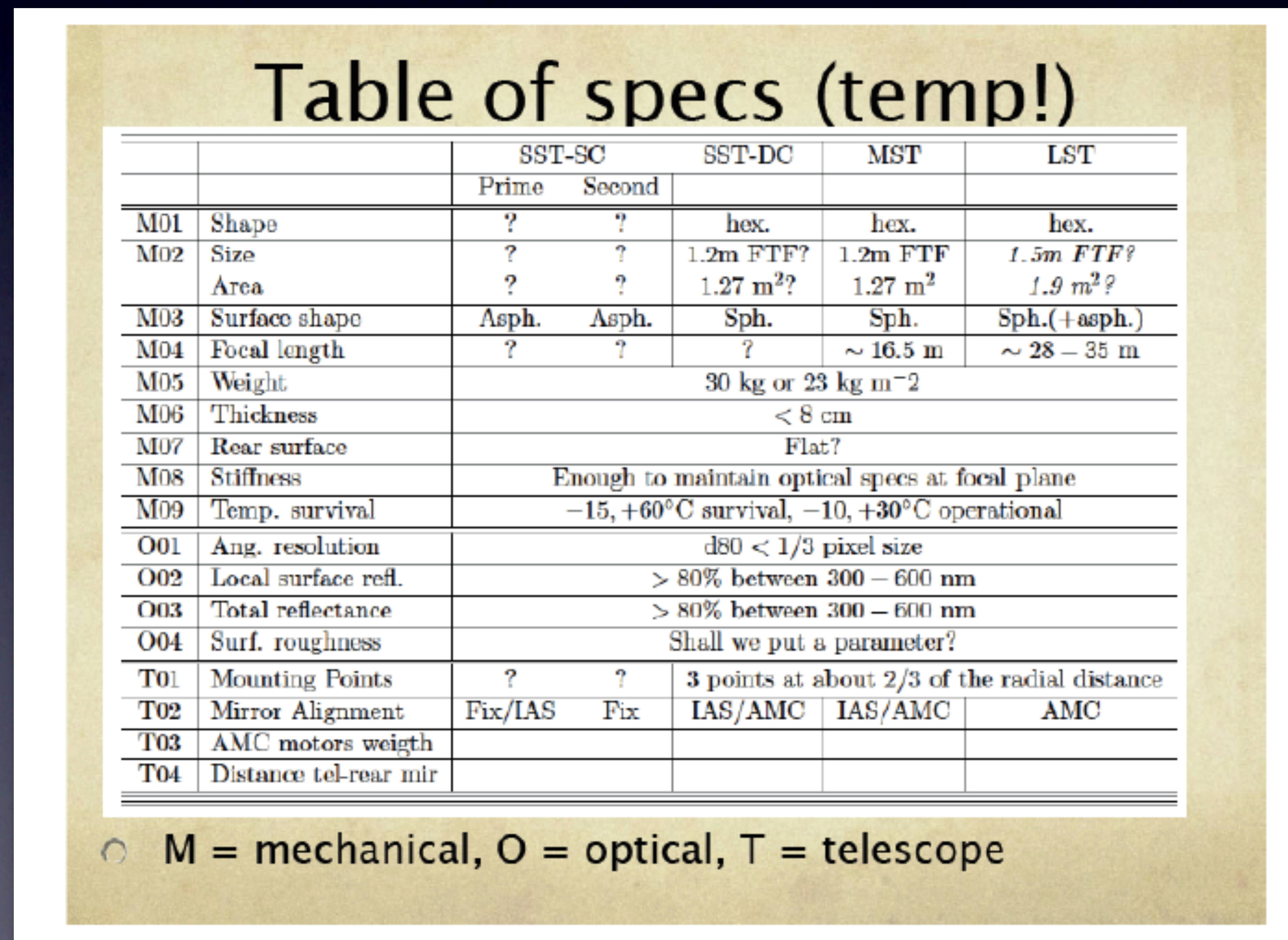


Table of specs (temp!)

		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^2?	1.27 m^2	*1.9 m^2?*
M03	Surface shape	Asph.	Asph.	Sph.	Sph.	Sph.(+asph.)
M04	Focal length	?	?	?	~ 16.5 m	$\sim 28-35$ m
M05	Weight	30 kg or 23 kg m^{-2}				
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 weigth					
T04	Distance tel-rear mir					

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

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA
NATIONAL INSTITUTE
FOR ASTROPHYSICS

CTA

Example: SST-MIR

Difficulties in making mirrors

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

R. Canestrari @ Zeuthen Meeting

Example: SST-CAM

- Sensitivity range: 300 - 650 nm
- Sensor area: 0.25° (SM ~ 35 mm) or 0.2° (DM ~ 6 mm)
- Sensor non-uniformity: < 10 %
- Sensor filling factor: ≥ 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 %

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Example: SST-CAM

Bonanno & Catalano, in prep.

	Pixel Size	#Pixel per Unit	Unit Dimensions	Unit Weight	Dead Space	Quantum Efficiency (@ 400 nm)	Intrinsic Gain	Dark current	Anode Non-uniformity	Optics design	ROM cost
Unit	mm		mm	g	%	%	-	nA	%		EURO
Vacuum Device											
Hamamatsu R3479	15	1	19 ∅	15	25	~30	~10^{6}	10	--	D-C	350
R7600U-200	18	1	30x30	33	40	~40	~10^{6}	2	--	D-C	1250
R7600U-200 M4	9	2x2	30x30	33	40	~40	~10^{6}	2	~20	S-C 3MT	1250
R8900-100 M16	~6	4x4	30x30	33	22	~34	~10^{5}	8	~25	S-C 3MT	1500
R7600 M64	~2	8x8	26x26	60	40	~23	~$5\,10^{5}$	0.2	~50	S-C 3MT	1500
Flat Panel H8500	~6	8x8	52x52	117	10	~27	~$1.5\,10^{6}$	6	~50	S-C 3MT	1700
Flat Panel H9500	~3	16x16	52x52	117	10	~27	~$1.5\,10^{6}$	13	~50	S-C 3MT	2200
Solid State Device											
Hamamatsu MPPC S10931	3	1	3.8x4.3	~4	40	~40	~10^{6}	5000	--	S-C 3MT	~150
Photonique SSPM_0710G9MM	3	1	4.5x5	~4	50	~10	$1.8\,10^{5}$	75000	--	S-C 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

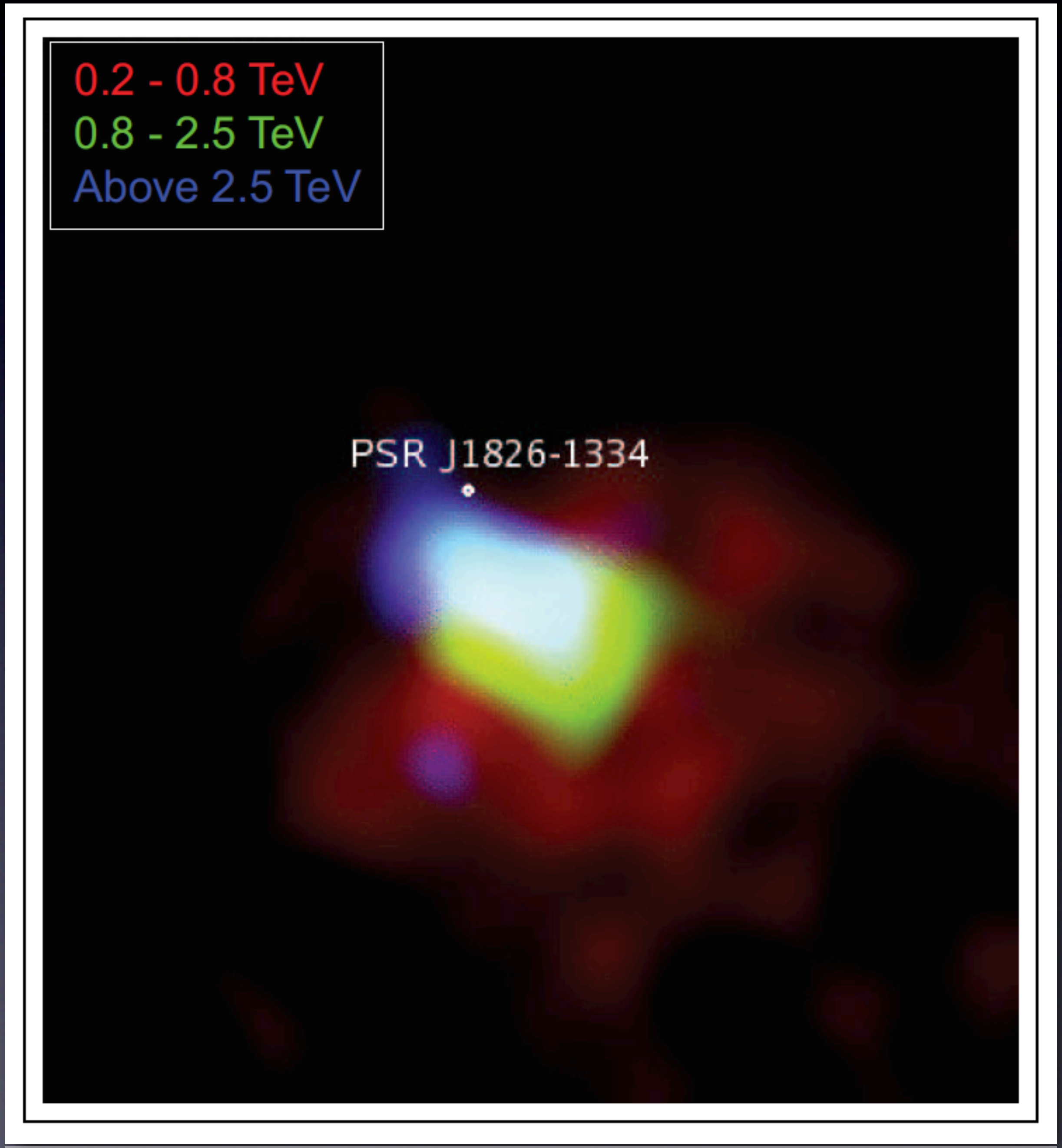
- So what's the problem?
  - We can probably do better! (goal sen. conservative at HE)
- Sensitivity is not the whole story – angular resolution is (so far) not excellent at high energies – and it could be – direct impact on science
  - e.g. energy dependent morphology in PWN and perhaps SNRs

– Better angular resolution very likely → more science

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA
NATIONAL INSTITUTE
FOR ASTROPHYSICS

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.