Cherenkov Telescope Array

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Introduction

1. CTA (Cherenkov telescope array)

New generation ground based gamma ray instrument

(Exist : MAGIC, HESS, VERITAS …)

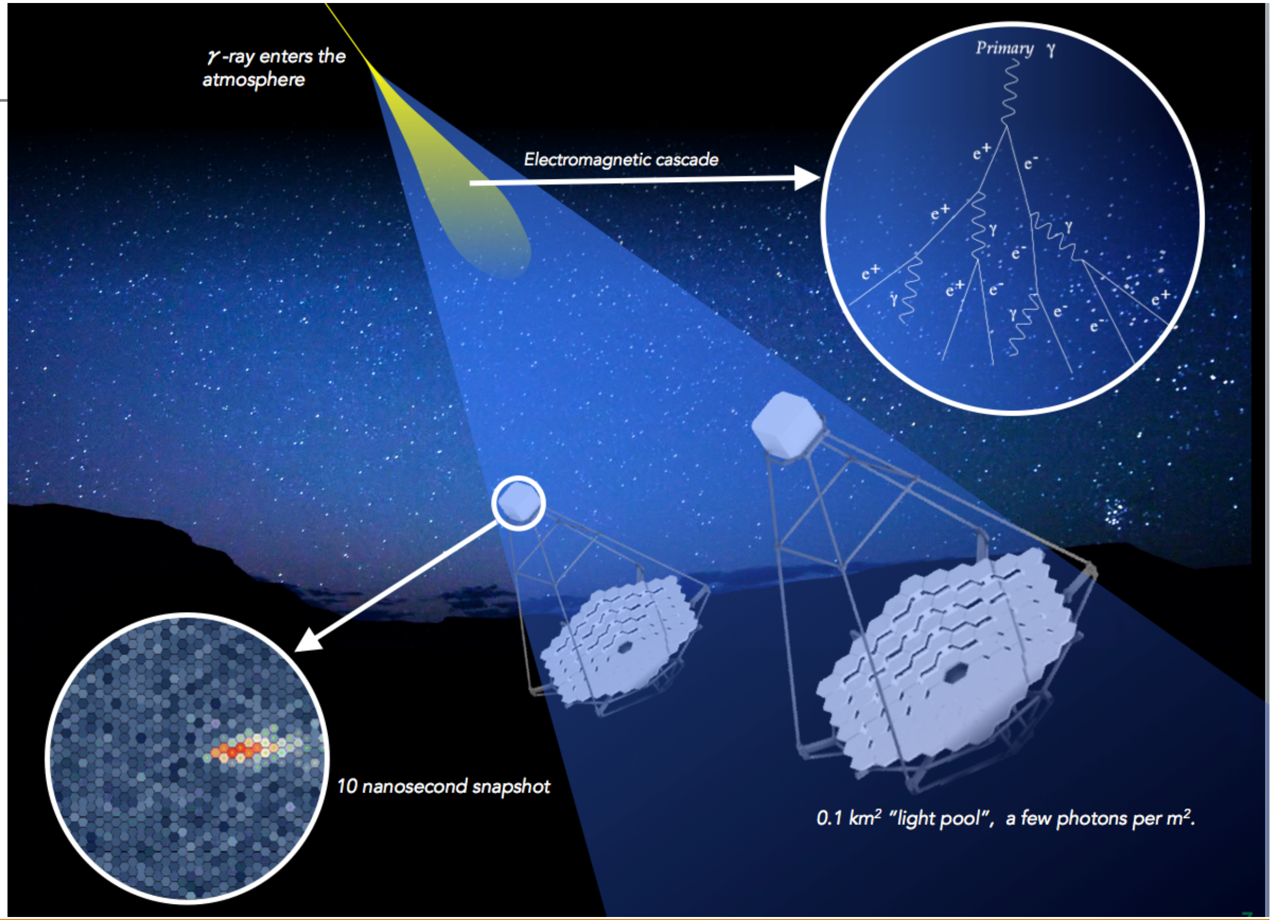
2. Concentrate on energy at gamma rays between 10 GeV – 300 TeV

3. Consist of 2 parts:

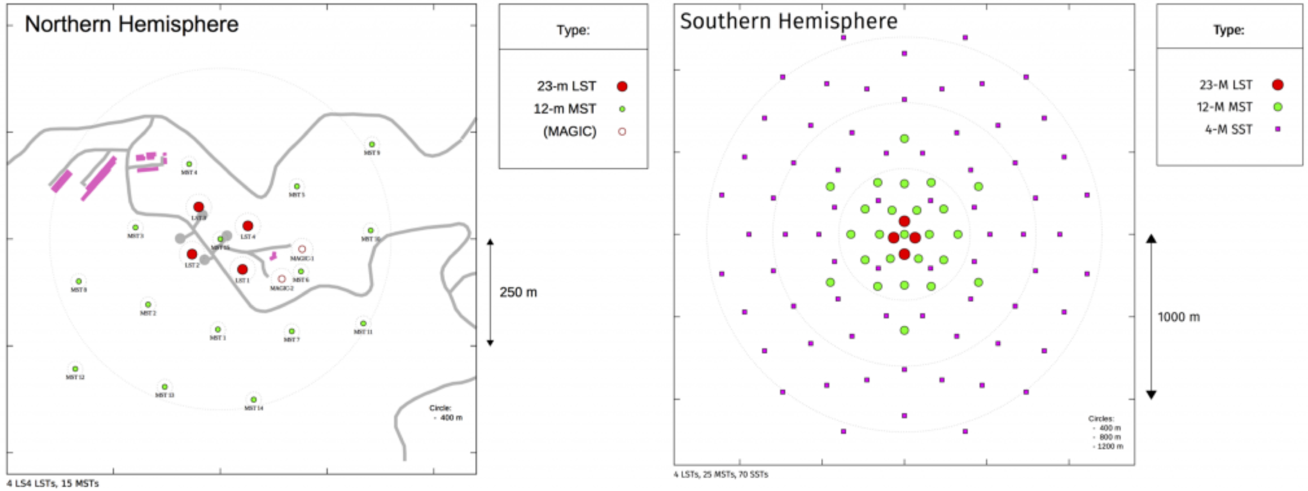
La Palma (Northern Hemisphere)
Chile (Southern Hemisphere)

How CTA works

1. High energy gamma ray from cosmic source
2. Produce air shower and emit Cherenkov photons
3. Only last 1 billionth second
4. Received by PMT



Telescopes



LST: Large-Sized telescope

23m, reposition in 20s

MST: Medium-Sized telescope

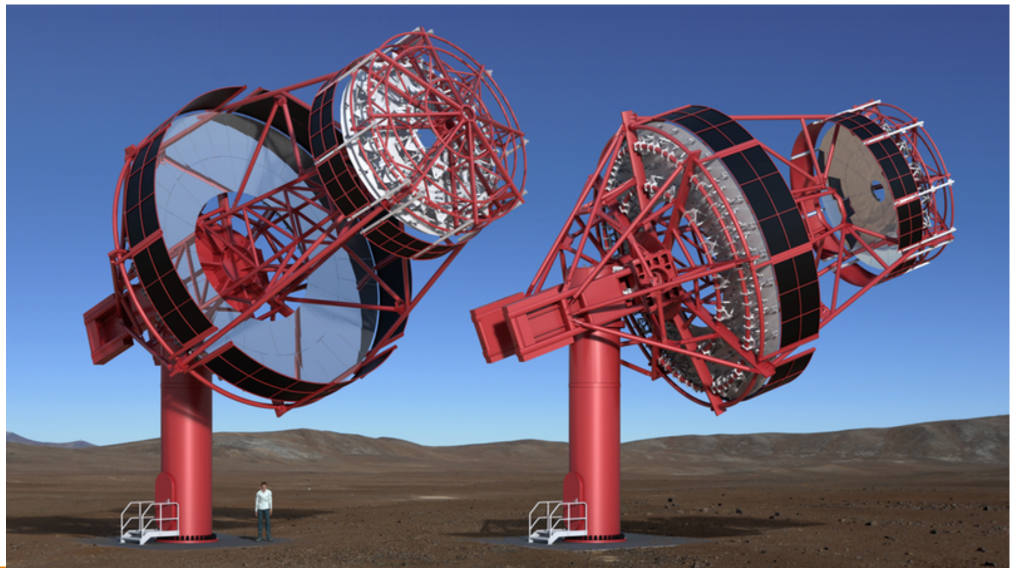
12m, take rapid survey, ‘workhorse’

SCT: Schwarzschild-Couder Telescope

10m, designed to provide minimal shadowing, control of stray light and protection from sunlight during daytime parking.

SST: Small-Sized telescope

4m, sensitive to high energy gamma ray from our own galaxy




2018.10.10， LST-1 inauguration

Main Parameters

	LST "large"	MST "medium"	SCT "medium 2-M"	SST "small"
Number	**4 (S)** **4 (N)**	**25 (S)** **15 (N)**	**≤ 36** **(S and N)**	**70 (S)**
Energy range	20 GeV to 200 GeV	100 GeV to 10 TeV	200 GeV to 10 TeV	5 TeV – 300 TeV
Effective mirror area	370 m^2	90 m^2	40 m^2	> 5 m^2
Field of view	> 4.5°	> 7°	> 8°	> 9°
Pixel size ~PSF θ_{80}	< 0.11°	< 0.18°	< 0.07°	< 0.25°
Positioning time	50 s, 20 s goal	90 s, 60 s goal	90 s, 60 s goal	90 s, 60 s goal
Target capital cost	7.4 M€	1.6 M€	< 2.0 M€	600 k€

Advantages and Disadvantages

1. the observation should in bright night like other optical telescopes

2. bright moonlight may affect the Cherenkov light

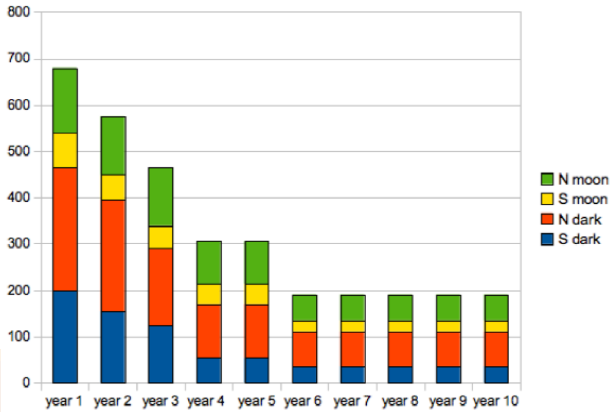
3. identification of background (mainly proton) is necessary

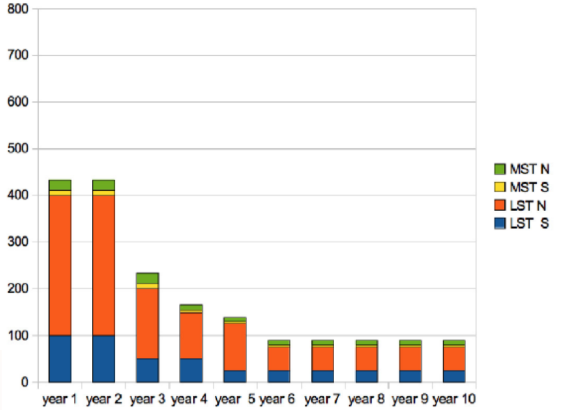
4. the field of view is very small

1. the sensitivity of telescope is very high

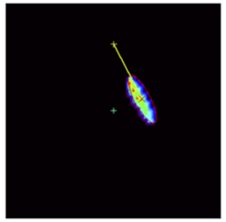
2. particle identification is easier than HAWC

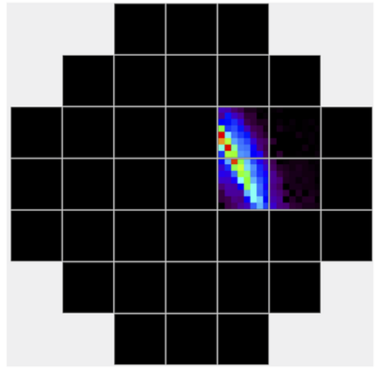
3. take suitable integration time can improve SN ratio





Progress





2017.06.04 CTA Prototype Telescope, ASTRI, Achieves First Light

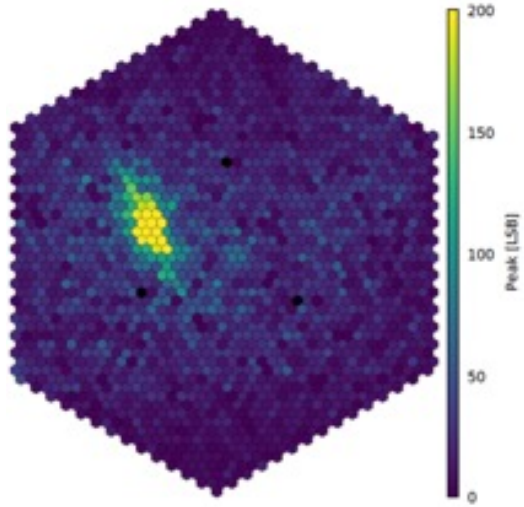
2017.08.31 CTA Prototype Telescope, the SST-1M, Catches its First Glimpse of the Sky

2017.12.04 The LST Prototype’s Dish is Mounted

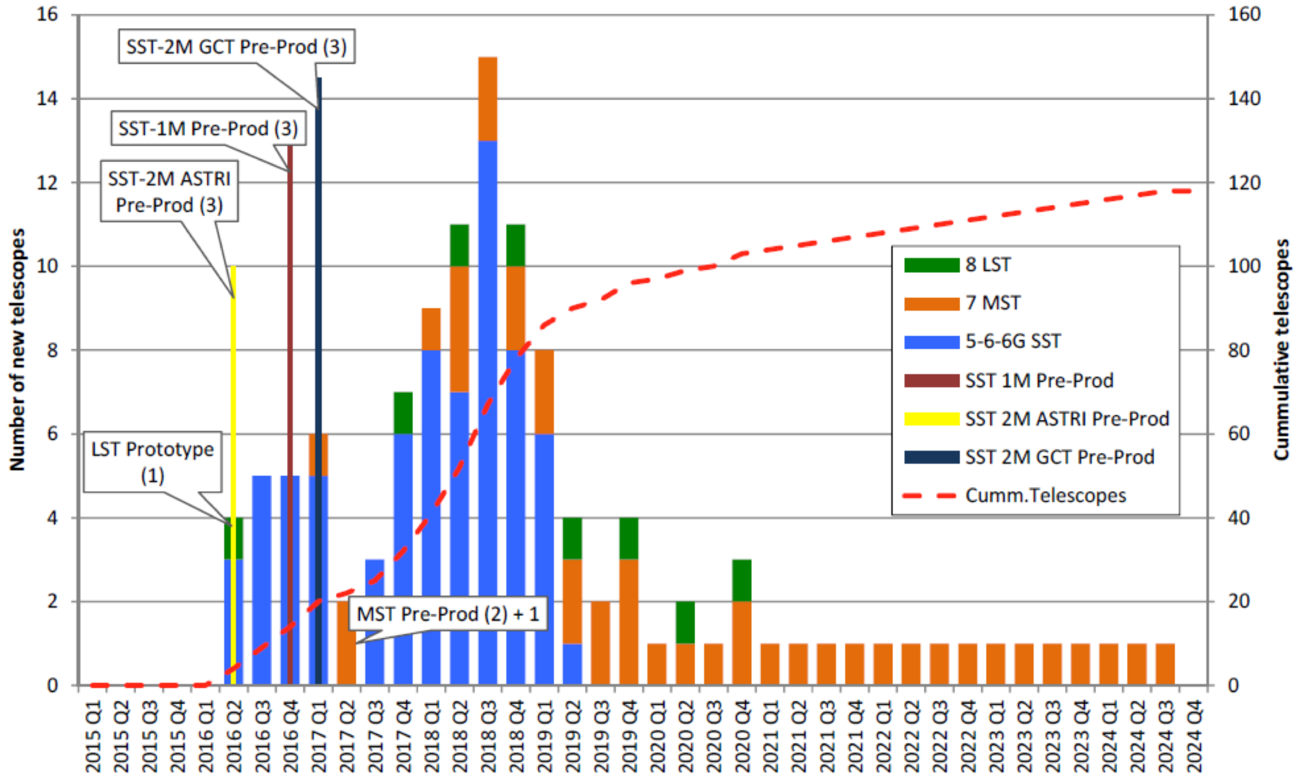
2018.04.26 prototype Schwarzschild-Couder Telescope (pSCT), under construction at the Whipple Observatory in Arizona, completed its primary mirror installation

2018.09.18 Medium-Sized Telescope Prototype Records First Cherenkov Light with the FlashCam Camera

2018.10.10 LST-1 inauguration



Schedule



SST-2M GCT Pre-Prod (3)
SST-1M Pre-Prod (3)
SST-2M ASTRI Pre-Prod (3)
LST Prototype (1)
MST Pre-Prod (2) + 1
Number of new telescopes
Cummulative telescopes
8 LST
7 MST
5-6-6G SST
SST 1M Pre-Prod
SST 2M ASTRI Pre-Prod
SST 2M GCT Pre-Prod
Cumm.Telescopes

Sensitivity

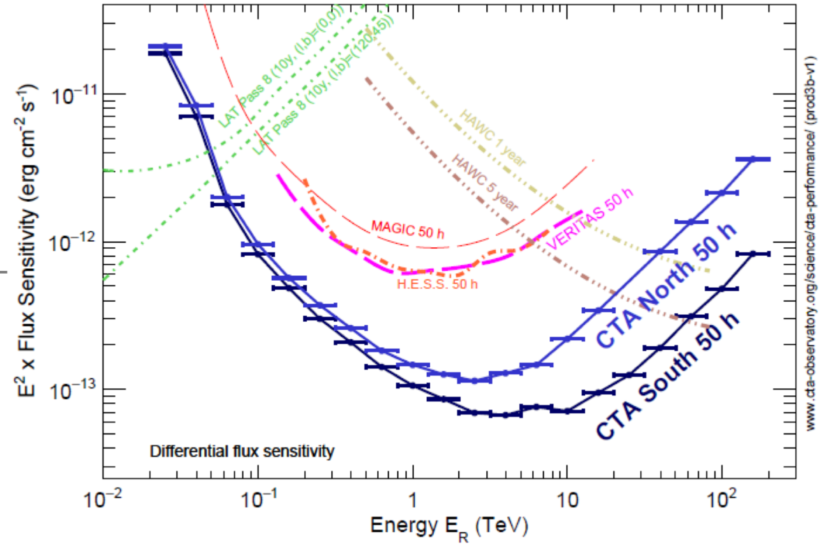
More events

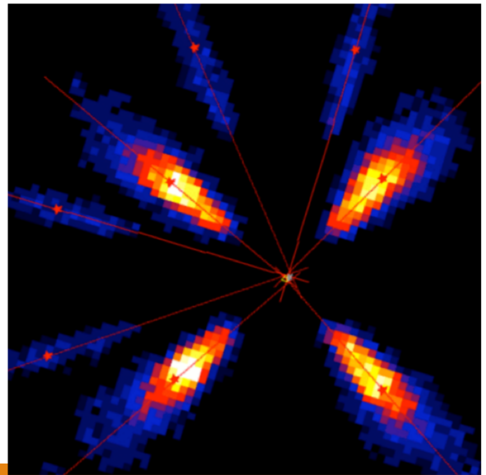
- Larger collection area for gamma-rays

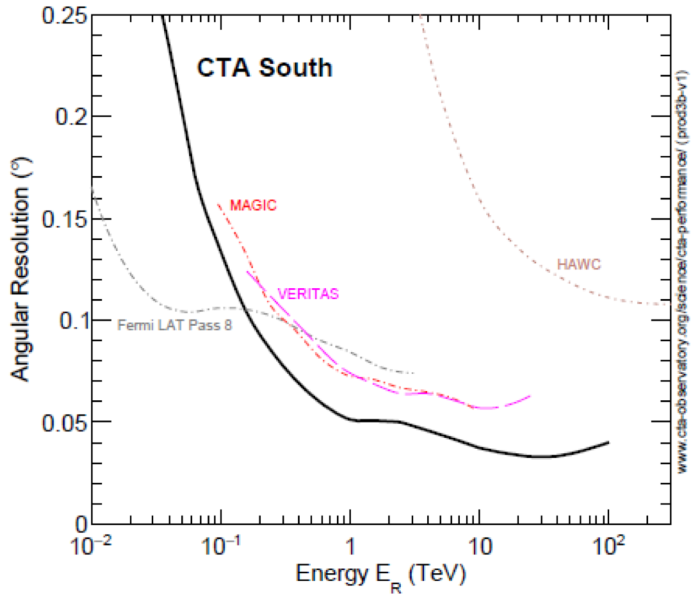
Better event

- Improved angular resolution
- Improved background rejection power

⇒ *MORE TELESCOPES!*





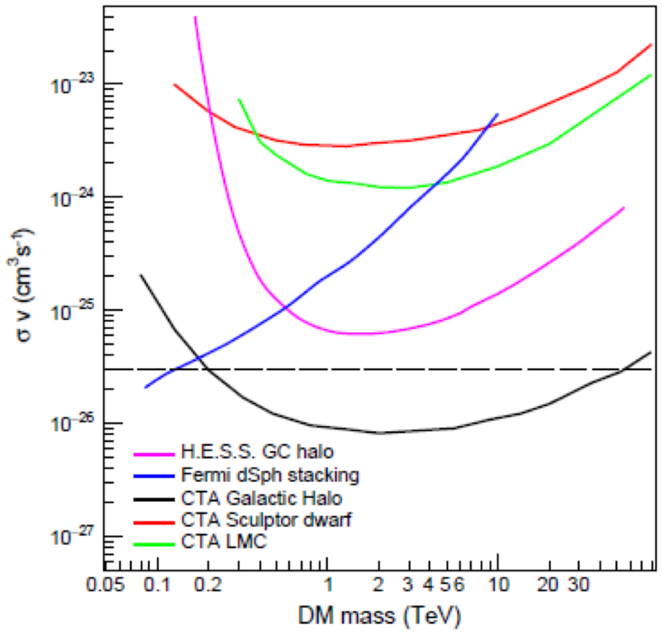


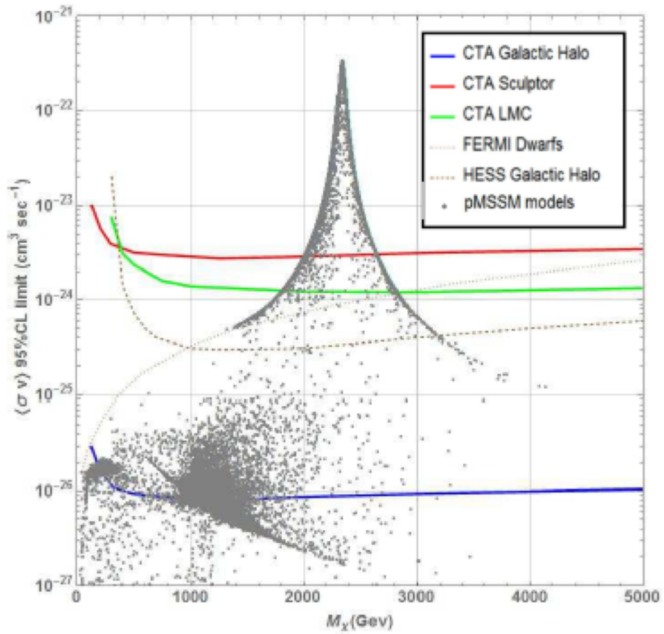
Theme		Question	Dark Matter Programme	Galactic Centre Survey	Galactic Plane Survey	LMC Survey	Extra-galactic Survey	Transients	Cosmic Ray PeVatrons	Star-forming Systems	Active Galactic Nuclei	Galaxy Clusters
Understanding the Origin and Role of Relativistic Cosmic Particles	1.1	What are the sites of high-energy particle acceleration in the universe?		✔	✔✔	✔✔	✔✔	✔✔	✔	✔	✔	✔✔
	1.2	What are the mechanisms for cosmic particle acceleration?		✔	✔	✔		✔✔	✔✔	✔	✔✔	✔
	1.3	What role do accelerated particles play in feedback on star formation and galaxy evolution?		✔		✔				✔✔	✔	✔
Probing Extreme Environments	2.1	What physical processes are at work close to neutron stars and black holes?		✔	✔	✔			✔✔		✔✔	
	2.2	What are the characteristics of relativistic jets, winds and explosions?		✔	✔	✔	✔	✔✔	✔✔		✔✔	
	2.3	How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?					✔	✔			✔✔	
Exploring Frontiers in Physics	3.1	What is the nature of Dark Matter? How is it distributed?	✔✔	✔✔		✔						✔
	3.2	Are there quantum gravitational effects on photon propagation?						✔✔	✔		✔✔	
	3.3	Do Axion-like particles exist?					✔	✔			✔✔	

Dark Matter

- ✓ Milky way
- ✓ The dwarf spheroidal galaxies
- ✓ LMC
- ✓ Cluster of galaxies

- ➢ Existence of DM
- ➢ Distribution of DM
- ➢ Annihilation of DM
- ➢ Rate of gamma rays

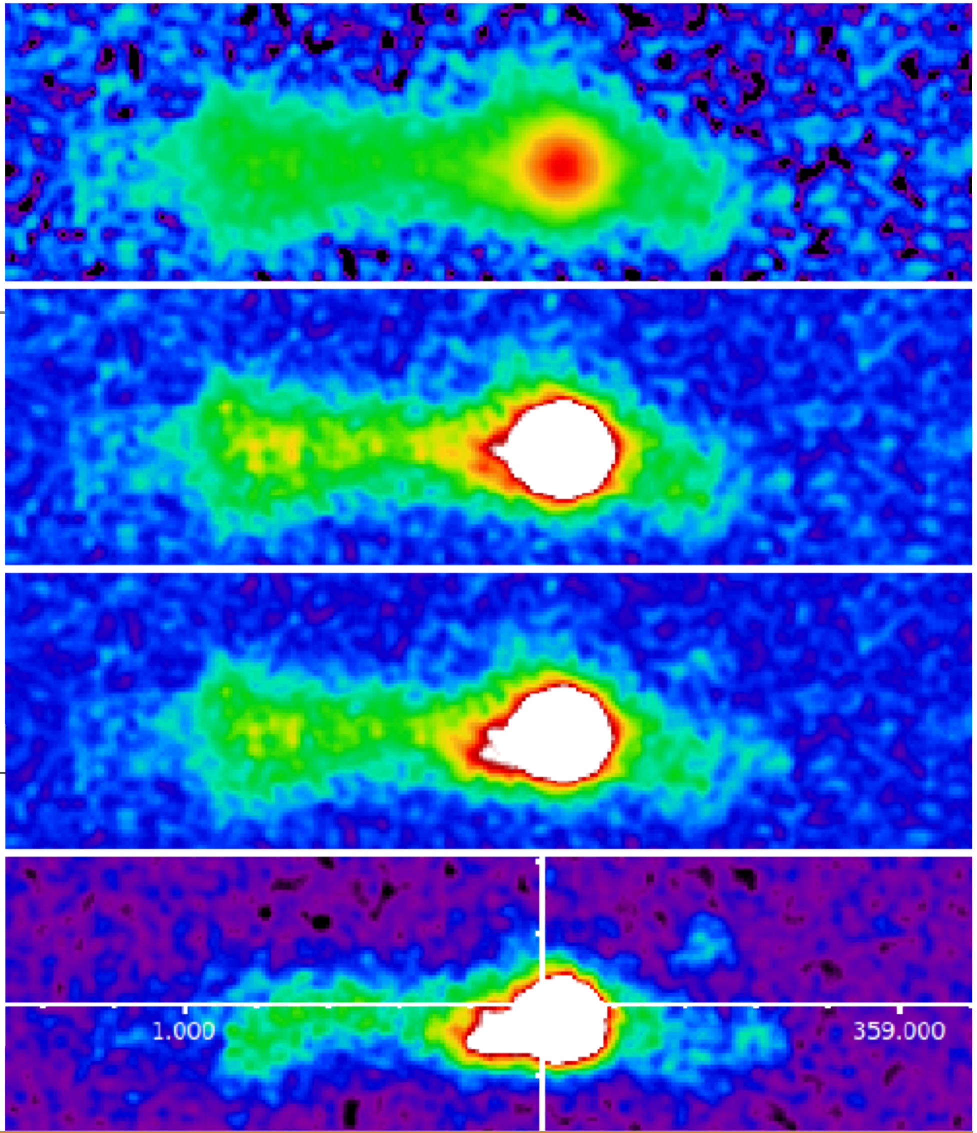




Galactic Center

- Revealing the nature of gamma ray source
- Diffuse VHE emission
- Exploring large-scale outflows
- SNR, PWN, Molecule Clouds

	Deep Exposure	Extended Survey	Monitoring+multi-waveband
Time requested	525 h	300 h	(coordinated with other instruments)
Priority	1	3	2
Strategy	survey	survey	periodic + coordinated
Site	S	S	S
Sub-array	Full	Full	Full
Zenith Range	$< 40°$	$< 50°$	$< 40°$
Atmosphere Quality	high	high	medium
Targets Covered	multiple	multiple	multiple

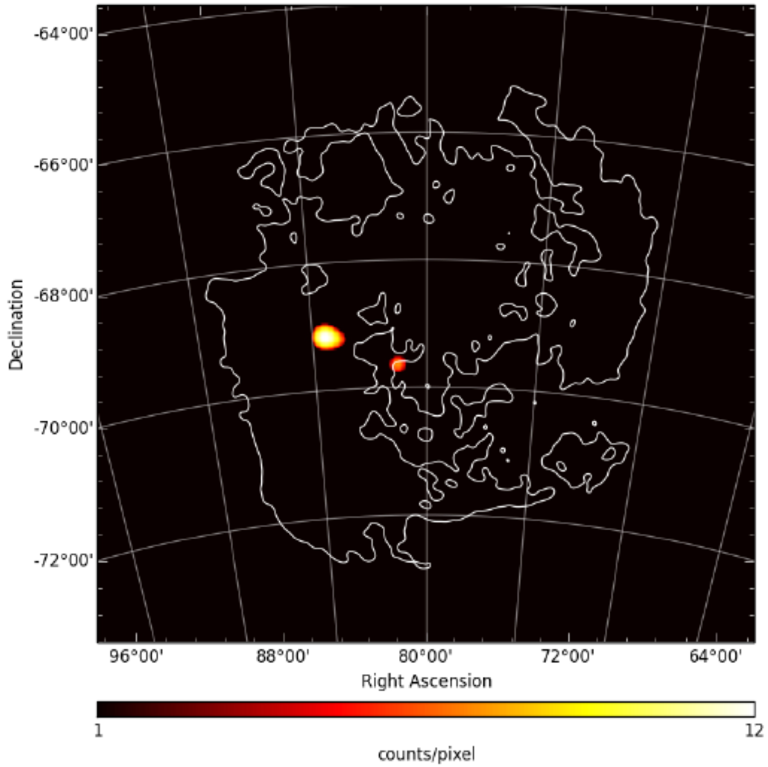


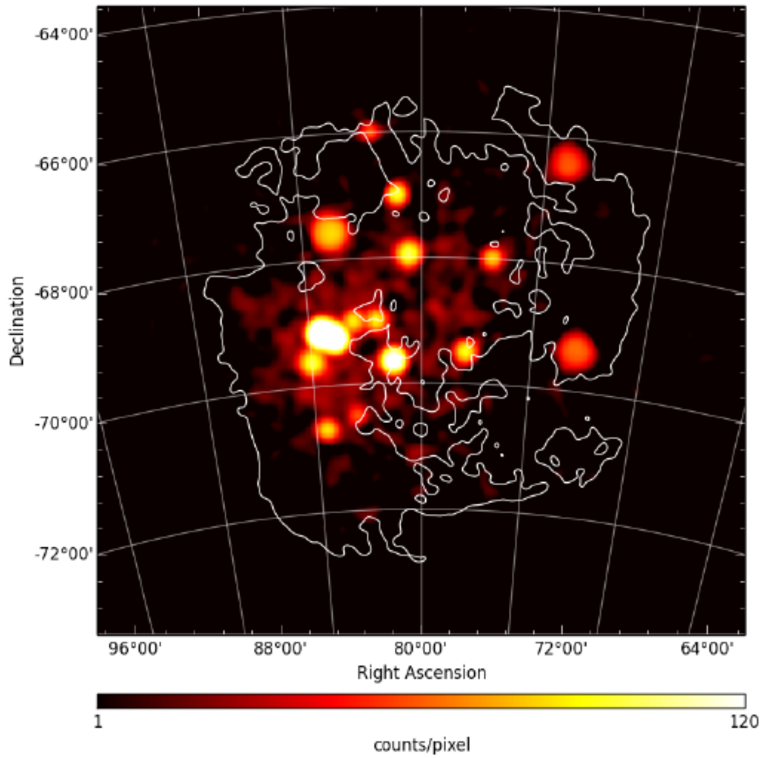
G0.9+0.1

LMC survey

1. A deep scan of 340 h, ideally performed over the first four years reach an effective exposure of 250 h

2. (optional)
Long-term monitoring of SN1987A, totaling 150 h, at the level of 50 h every two years if the object is detected in the first phase.



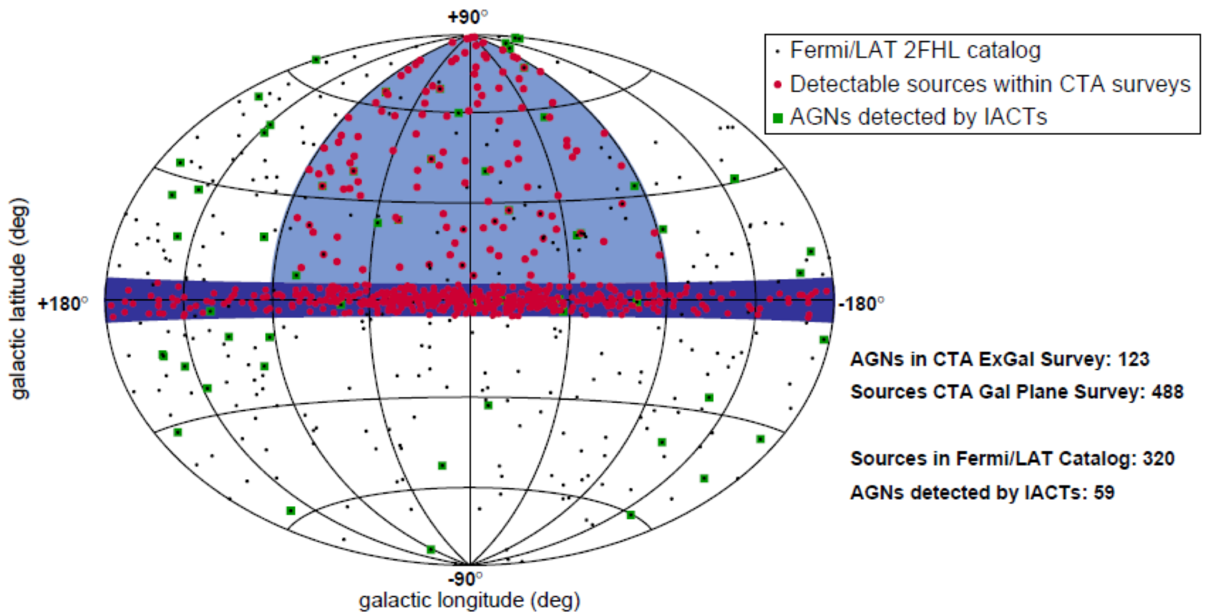


Extragalactic survey

- Blazars
- Extreme blazars
- Radio galaxies
- Starburst galaxies
- New source classes
- Gamma-Ray Bursts and other transients
- Large scale electron anisotropy
- Diffuse gamma-ray background
- Dark Matter clumps

✓ Totally 1000 h and cover 25% overhead sky

✓ Effective 3h for each point



Cont.

Possibility of several pointings for a given field of view

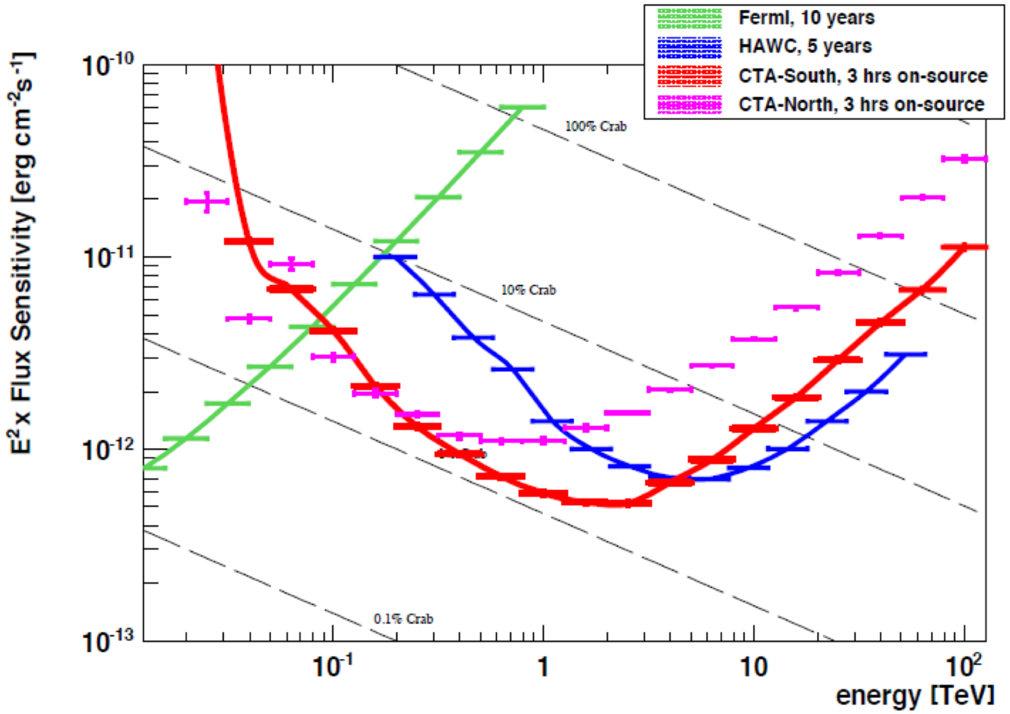
- 3h effective observation for each point
- Short bright transient

Shallow survey versus deep survey

- Deep survey result 50% less sources
- shallow survey should deep enough to coverage HAWK and Fermi sensitivity.

Target

- 25% of the sky

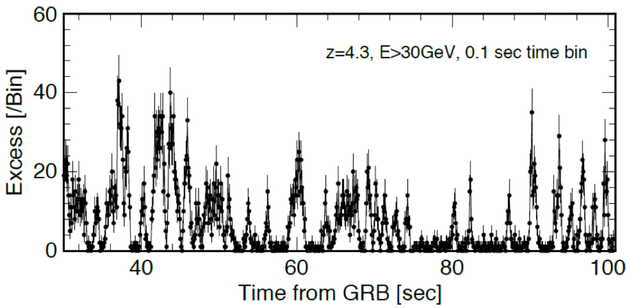


Transients

Target :

A) Gamma-ray bursts
B) Galactic transients
C) X-ray, optical and radio transients
D) High energy neutrino transient
E) GW transient
F) Serendipitous VHE transient
G) VHE transient survey

		Observation times (h yr^{-1} $site^{-1}$)			
Priority	Target class	Early phase	Years 1–2	Years 3–10	Years 1–10
1	GW transients	20	5	5	
2	HE neutrino transients	20	5	5	
3	Serendipitous VHE transients	100	25	25	
4	GRBs	50	50	50	
5	X-ray/optical/radio transients	50	10	10	
6	Galactic transients	150	30	0(?)	
	Total per site (h yr^{-1} $site^{-1}$)	390	125	95	
	Total both sites (h yr^{-1})	780	250	190	
	Total in different CTA phases (h)	1560	500	1520	2020



Follow-up priority	Target class	Detected @ HE	Trigger	Rate (yr^{-1})	Urgency	Activity duration	Obs. time (h) /night	Total time (h)	Site
1	Magnetar giant flares	–	MeV	0.1	1 min	1–2 d	Max. 1	10	A/B
2	PWN flares: Crab nebula	Y	HE	1	1 d	5–20 d (HE)	4	50	S&N
3	HMXB microquasars: Cyg X-3	Y	HE/X-ray	0.5	1 d	50–70 d (HE)	Max. 1	50	N
	Cyg X-1	Y	HE/X-ray	0.2	1 d	1–10 d ?	Max. 1	30	N
4	Unidentified HE transients	Y	HE	1	1 d	?	2	20	A/B
5	LMXB microquasars	?	X-ray/radio	1	1 d	Weeks	2	20	A/B
6	Novae	Y	HE/opt.	2	1 d	Weeks	2	20	A/B
7	Transitional pulsars	Y	Radio/opt.	0.5	1 d	Weeks	2	20	A/B
8	Be/X-ray binary pulsars	N	X-ray	1	1 d	Weeks	2	20	A/B

CR PeVatrons

1. Where and how in the Galaxy are cosmic rays accelerated up to PeV energies?

2. Are we sitting in a particular location of the Galaxy, or do the cosmic rays form a uniform sea within the whole Galaxy?

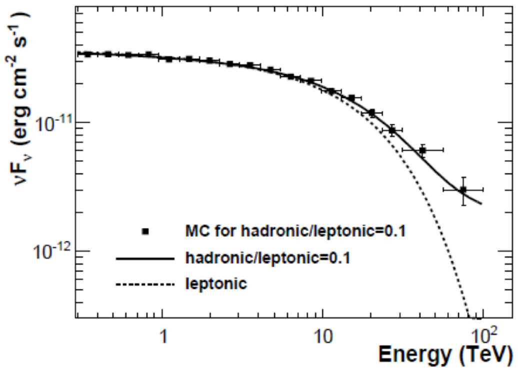
3. What is the distribution of PeVatrons in the Galaxy?

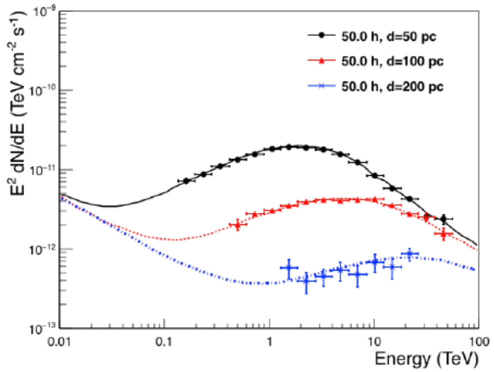
4. Do young shell-type SNRs accelerate hadronic cosmic rays up to PeV energies?

5. If so, up to which energies and how effective is this acceleration?

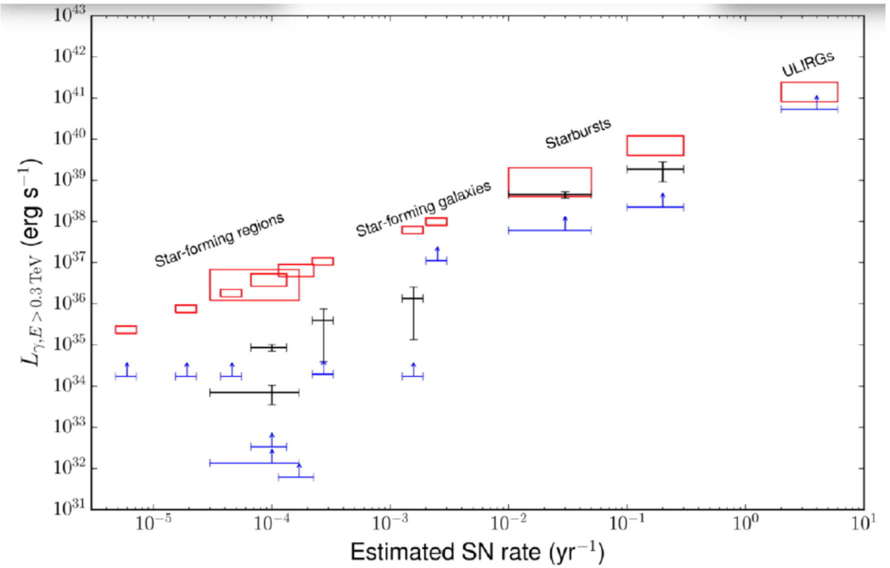
PeVatrons
RX J1713.7-3946

Target	Type	Exposure (h)	Array	Year	Configuration
RX J1713.7–3946	SNR	50	S	1 – 3	Full array
PeVatrons	Unknown	5×50	S	>3	MSTs + SSTs

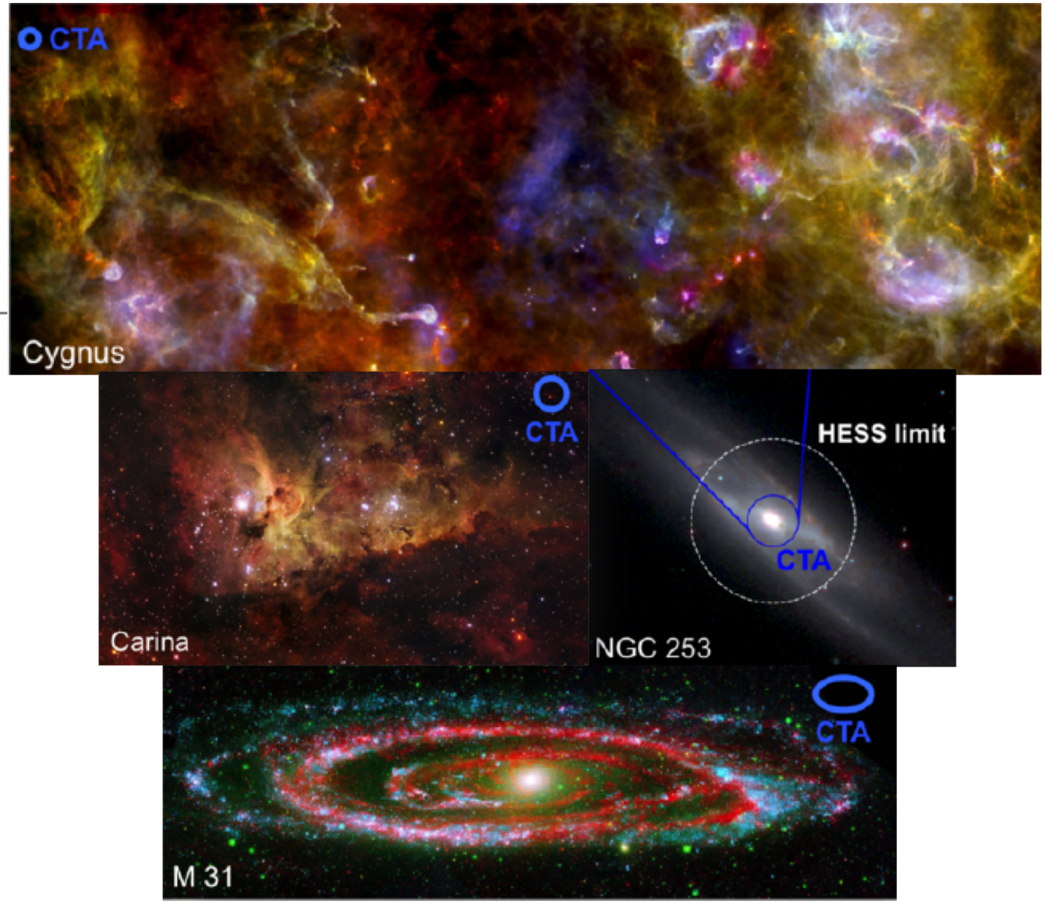




Star Forming Systems



Red : expected calorimetric gamma-ray luminosity
Blue arrows : the expected CTA sensitivity
Black points : measurements in the TeV domain



Target	Exposure (hrs)	Array	Year	Zenith	Moonlight fraction
Carina†	100	S	1 – 3	< 45°	0%
Cygnus (OB1/OB2)†	130	N	1 – 2	< 50°	0%
Wd 1†	40	S	0 – 1	< 50°	25%
M 31	150	N	2 – 5	< 45°	0%
NGC 253	100	S	1 – 3	< 40°	0%
M 82	100	N	1 – 3	< 55°	0%
Arp 220	100	S/N	2 – 5	< 50°	0%

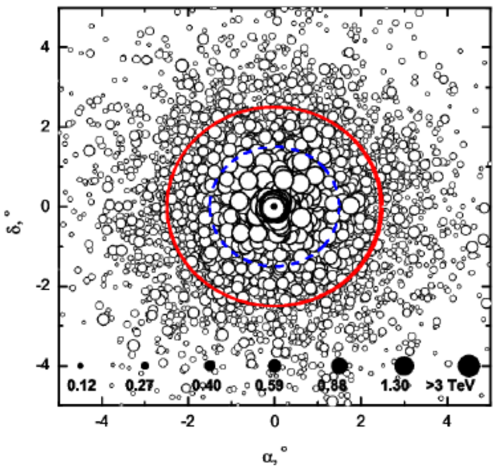
AGN

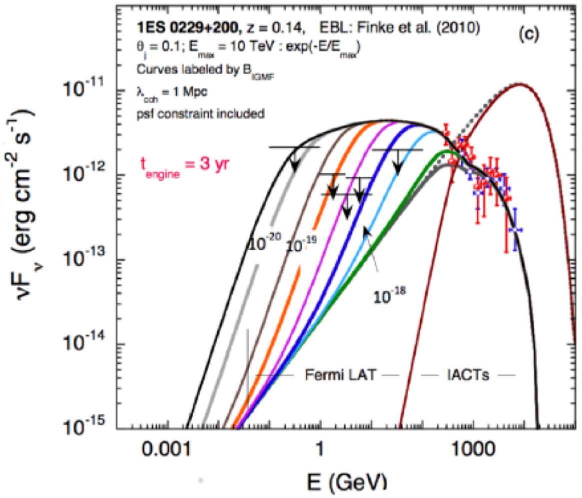
AGN plays an crucial role in CTA!

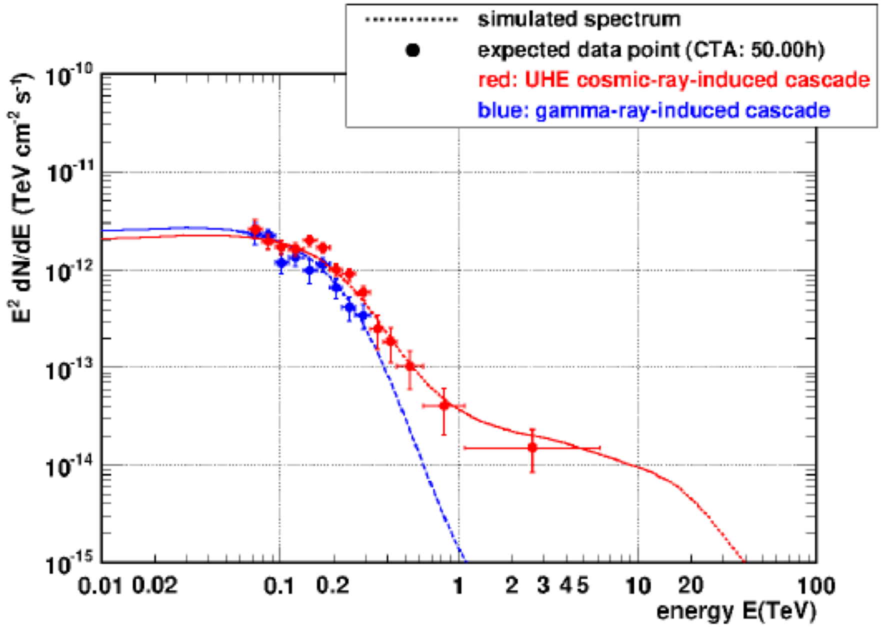
- ✓Probing Extreme environment
- ✓Understanding the Origin and Role of Relativistic Cosmic Particles
- ✓Exploring Frontiers in Physics

AGN

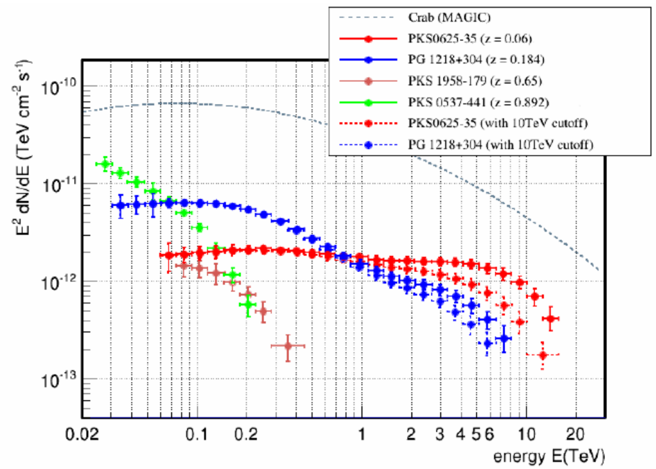
- Relativistic jets from supermassive black holes
- Blazars as probes of the universe
- UHECRs and fundamental physics







AGN

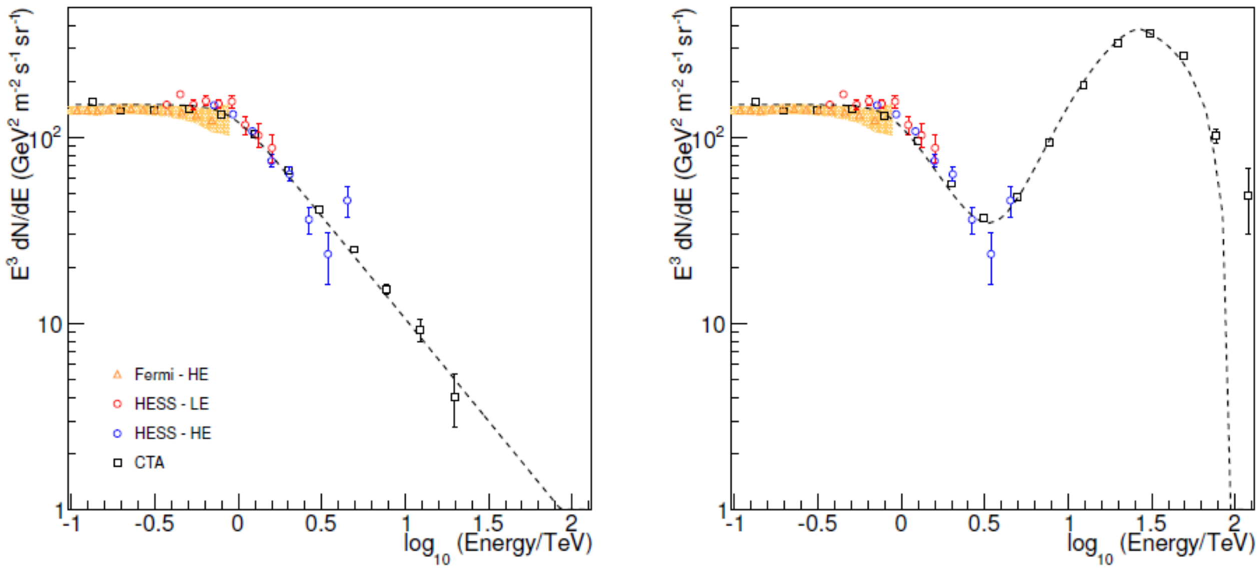


Programme	total N [h]	total S [h]	duration [yr]	observation mode
Long-term monitoring	1110	390	10 †	full array
AGN flares				
snapshots	1200	475	10 *	LSTs
snapshots	138	68	10 *	MSTs (assuming 10 sub-arrays)
verification ext. trig.	300	150	10 *	LSTs or MST sub-arrays
follow-up of triggers	725	475	10 *	full array
High-quality spectra				
redshift sample	195	135	3	full array
M 87 and Cen A	100	150	3	full array

object	RA	DEC	class	σ(20 h)	redshift	TeVCat	t [h] (20σ)	N/S
IC 310	49.169	41.322	HBL	35.63	0.019	yes	6	N
Mrk 421 (lt)	166.121	38.207	HBL	212.50	0.031	yes	(1)	N
Mrk 501 (lt)	253.489	39.754	HBL	101.46	0.034	yes	(1)	N
1ES 2344+514	356.759	51.705	HBL	66.95	0.044	yes	2	N
Mrk 180	174.100	70.159	HBL	27.55	0.046	yes	11	N
1ES 1959+650	300.007	65.158	HBL	28.60	0.047	yes	10	N
PKS 0521-36	80.85	-36.34	RG	9.25	0.06	no	23 (10σ)	S
PKS 0548-322	87.669	-32.260	HBL	14.34	0.069	yes	39	S
PKS 0625-35	96.704	-35.479	RG	26.14	0.055	yes	12	S
PKS 1440-389	221.011	-39.145	HBL	27.28	0.065 (?)	no	11	S
PKS 2005-489	302.360	-48.830	HBL	60.83	0.071	yes	2	S
MS 13121-4221	198.749	-42.696	HBL	85.52	0.108	yes	1	S
VER J0521+211	80.449	21.220	IBL	53.45	0.108	yes	3	N
VER J0648+152	102.225	15.281	HBL	18.10	0.179	yes	24	N
PKS 2155-304 (lt)	329.721	-30.219	HBL	131.71	0.116	yes	(1)	S
1ES 1215+303	184.460	30.104	HBL	22.34	0.130 (?)	yes	16	N
1H 1914-194	289.441	-19.365	HBL	25.37	0.137	no	12	S
1ES 0229+200 (lt)	38.20250	20.29	UHBL	-	0.14	yes	(1)	N
TXS 1055+567	164.666	56.459	IBL	22.78	0.143	no	15	N
PG 1218+304	185.337	30.194	HBL	32.22	0.184	yes	8	N
1ES 0347-121	57.3458	-11.97	UHBL	-	0.188	yes	1	S
1H 1013+498	153.773	49.427	HBL	21.59	0.212	yes	17	N
PKS 0301-243	45.868	-24.128	HBL	39.46	0.260	yes	5	S
PMN J1936-4719	294.214	-47.356	BLL	20.10	0.265	no	20	S
PMN J0816-1311	124.091	-13.177	HBL	18.17	0.290 (II)	no	24	S
3C 66A (lt)	35.669	43.035	IBL	49.64	0.33 (II)	yes	(3)	N
1ES 0502+675	77.038	67.624	HBL	41.65	0.340	yes	5	N
TXS 0506+056	77.394	5.714	IBL	13.17	0.210 (II)	no	46	N
MS 1221.8+2452	186.146	24.628	HBL	13.09	0.218	yes	47	N
PG 1553+113	238.942	11.190	HBL	67.27	0.43 (II)	yes	2	N
4C +21.35	186.220	21.377	FSRQ	13.74	0.434	yes	42	N
1ES 0647+250	102.712	25.081	HBL	24.75	0.490 (II)	yes	13	N
KUV 00311-1938	8.407	-19.361	HBL	22.07	0.506 (II)	yes	16	S
PMN J1610-6649	242.726	-66.849	HBL	14.70	0.447 (II)	no	37	S
PKS 1424+240	216.766	23.790	HBL	29.33	0.600 (II)	yes	9	N
PKS 1958-179	300.28	-17.87	FSRQ	7.0	0.65	no	41 (10σ)	S
B3 0133+388	24.147	39.100	HBL	14.22	0.750 (II)	yes	40	N
PKS 0537-441	84.714	-44.088	LBL/FSRQ	19.33	0.892	no	21	S
4C +55.17	149.421	55.377	FSRQ	8.53	0.899	no	27 (10σ)	N
PKS 0426-380	67.178	-37.937	LBL/FSRQ	10.63	1.111	no	18 (10σ)	S

Capabilities beyond Gamma Rays

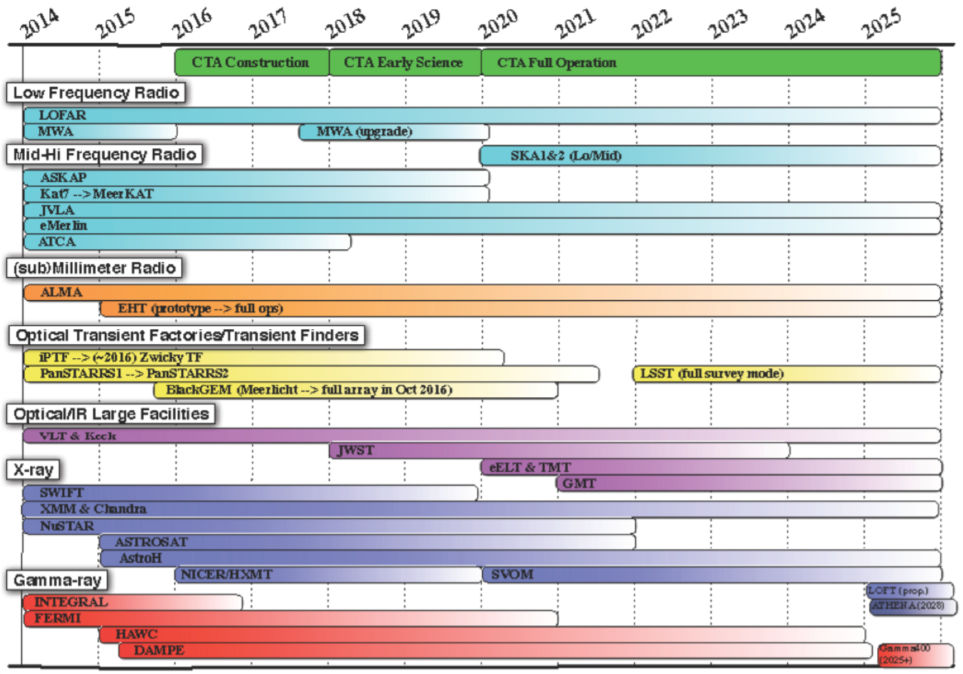
1. Cosmic-ray Nuclei
2. Cosmic-ray Electrons
3. Optical Measurements with CTA

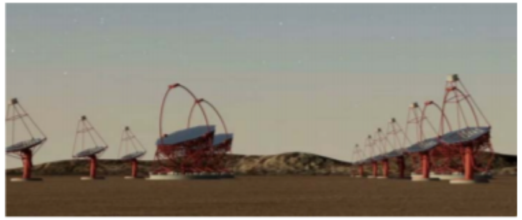


Simulation

- based on the CORSIKA code
- include realistic assumptions of the atmospheric conditions
- Sim at the two CTA sites
- absorption and scattering of the Cherenkov photons response of the telescopes simulated with the tool sim telarray

Synergies





Wide FOV

100% duty cycle

N hemisphere

Moderate resolution

Moderate FOV

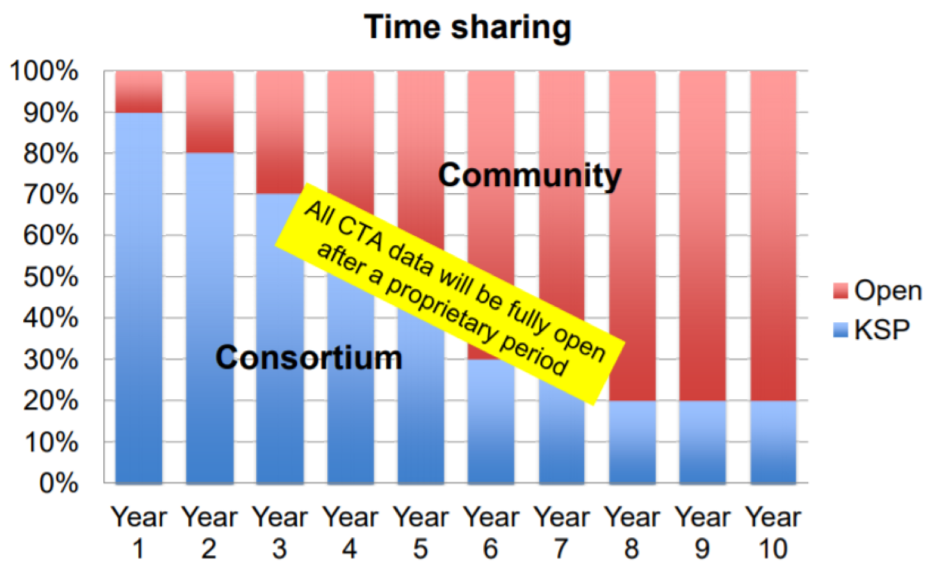
15% duty cycle

N & S Hemispheres

Excellent resolution

Summary

1. CTA is designed to detect gamma rays over a larger area and a wider range of views with more than 100 telescopes located in the northern and southern hemispheres.
2. CTA will be ten times more sensitive and have unprecedented accuracy in its detection of high-energy gamma rays.
3. CTA arrays will be the first ground-based gamma-ray observatory open to the worldwide astronomical and particle physics communities as a resource for data from unique, high-energy astronomical observations.



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