CTA in VO: needs and challenges

Konstancja Satalecka (UCM) SVO, 8th April 2014

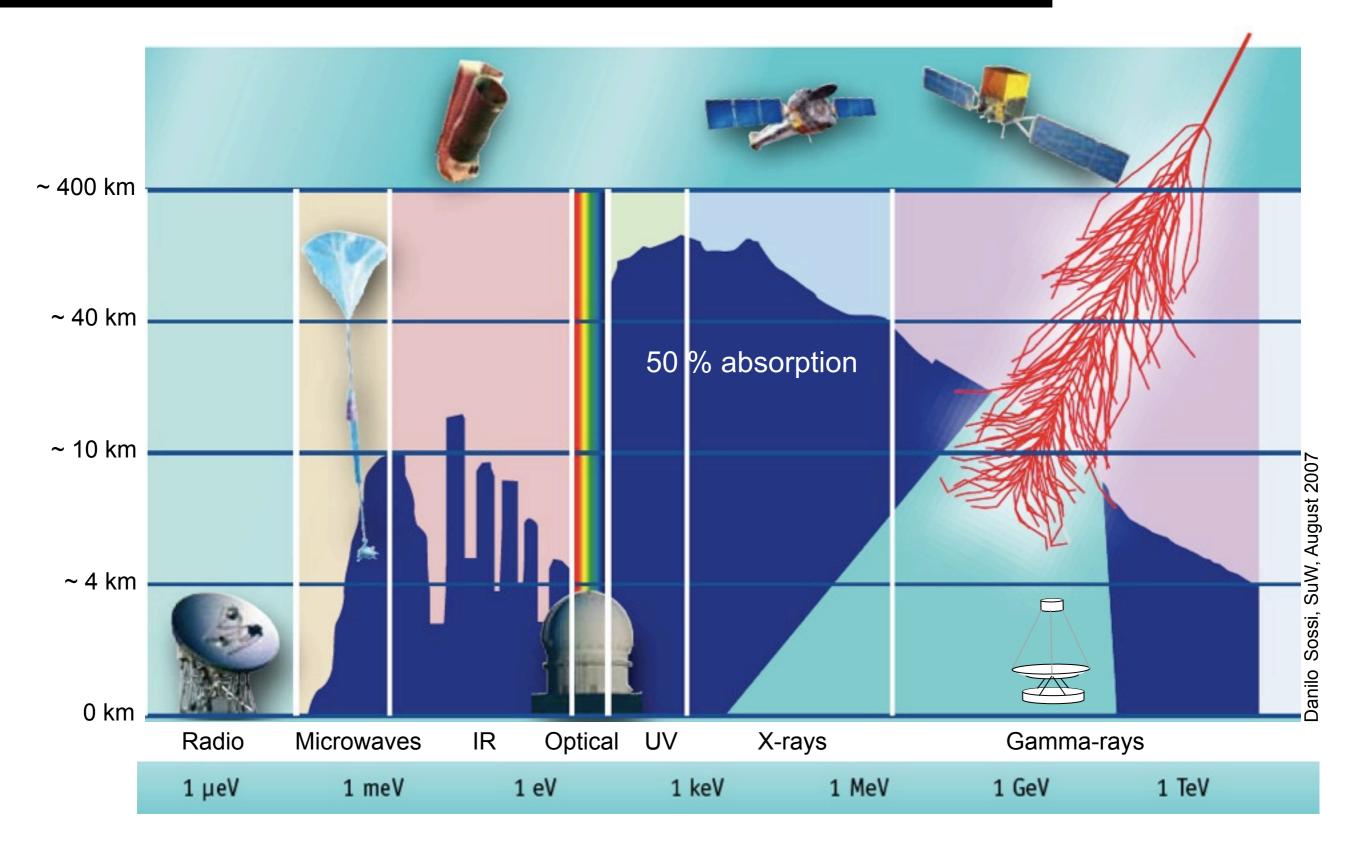
Outline

Imaging Atmospheric Cherenkov Telescopes

IACT data flow





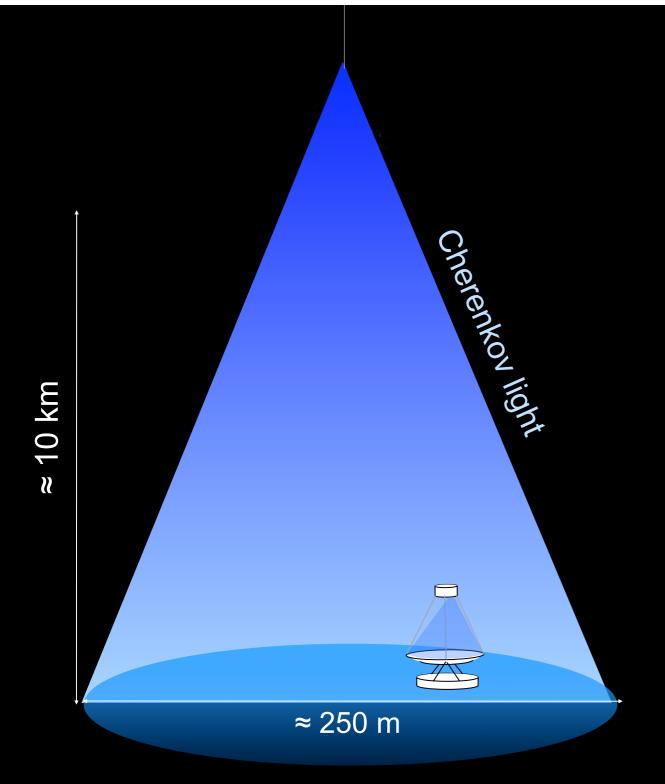




Very High Energy (VHE) γ -ray interacts with Earth's atmosphere and creates an electromagnetic cascade.

Cosmic Rays induce similar showers (hadronic) – main background for IACTs, isotropic.





e⁻ and e⁺ from the cascade produce Cherenkov light

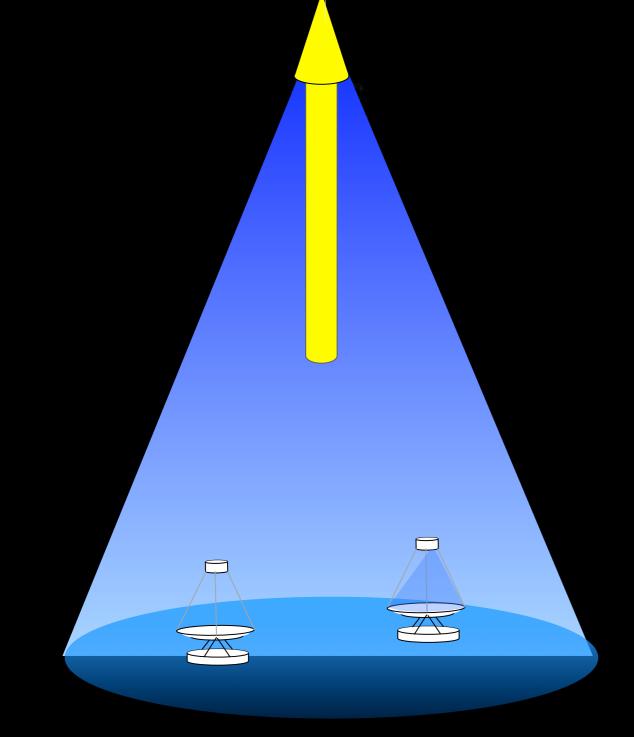
Image of the shower is recorded by the camera (PMTs).

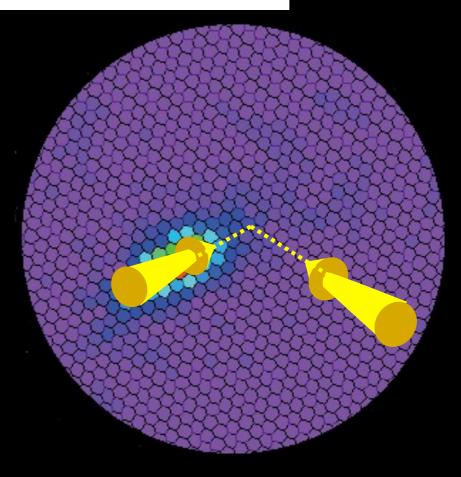
Cherenkov light

≈ 250 m

Energy of a shower is roughly proportional to the number of recorded photons.

Shape of the image helps to discriminate signal from background (CR).

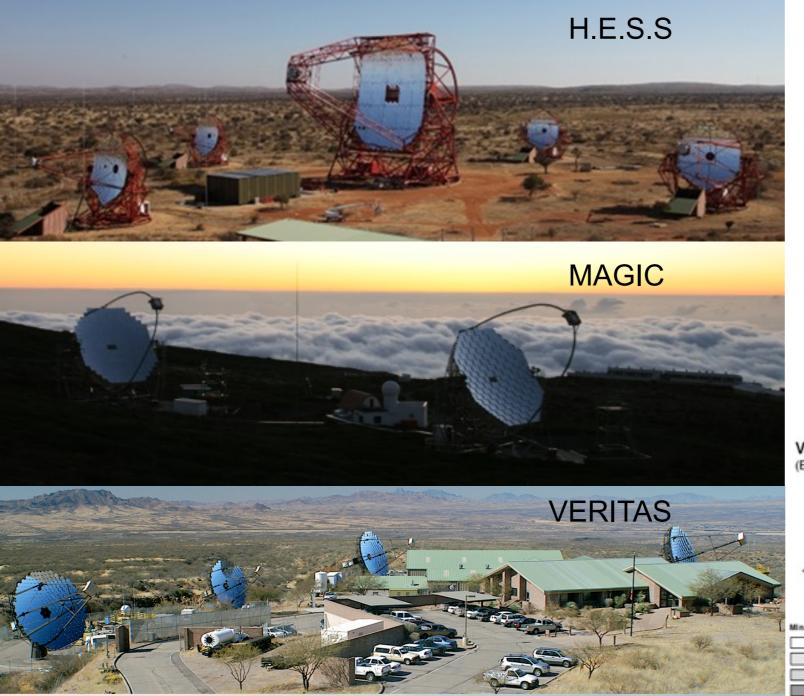




Stereoscopic view helps in:

- reconstruction of γ -ray direction
- energy reconstruction
- background rejection

IACTS

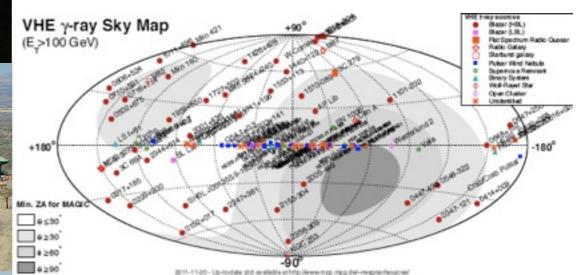


- ★ energy range 50 GeV 50 TeV
- \star energy resolution ~15% @ 1 TeV

★ angular resolution ~0.05 @ 1 TeV

★ physics: AGN, SNR, pulsars, GRBs, EBL, DM, LIV...

 \star >100 sources discovered so far



Future: CTA

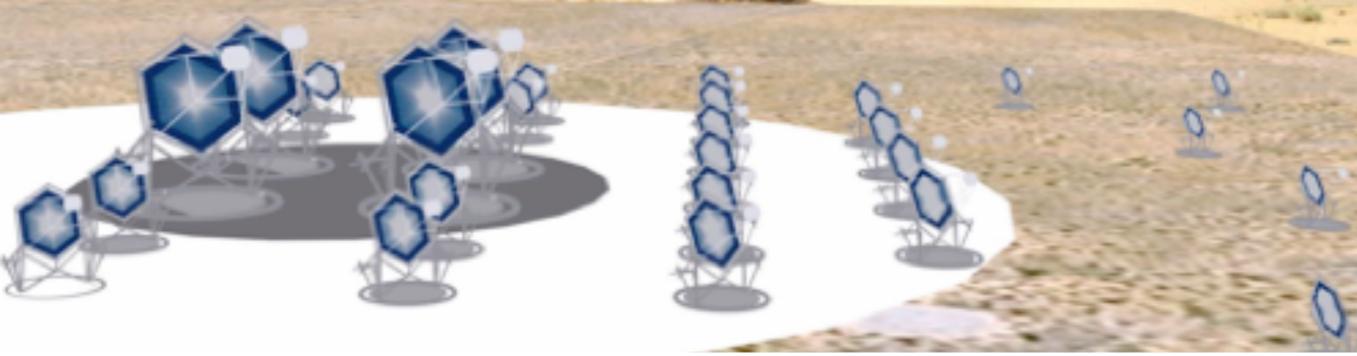
 \star CTA = Cherenkov Telescope Array: few 10s of IACTs of 3 different sizes, Northern & Southern hemisphere observatories, area: several km²

★ improved sensitivity x10 in the entire energy range
 ★ extended energy range, improved energy resolution (10–15%)
 ★ increased FoV (~10 deg > 1 TeV) with homogeneous sensitivity
 ★ improved angular resolution (0.03 deg @ 1 TeV)

 \star 1000 sources

★ expected raw data volume: 10–100 PB/yr (depending on scenario)

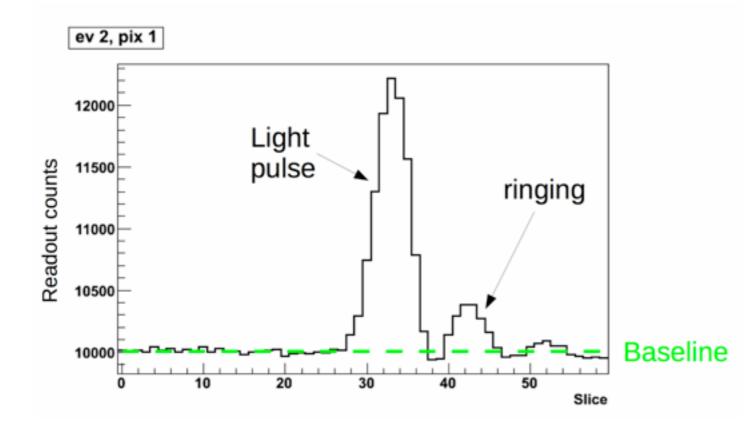
★ first IACT open observatory: external users will submit proposals and have to have an easy access to their data, analysis tools, simulations...



raw data: readout counts in time-slices, for each event and pixel, for N telescopes MC raw data: simulated readout counts in time-slices, for each event and pixel, for N telescopes

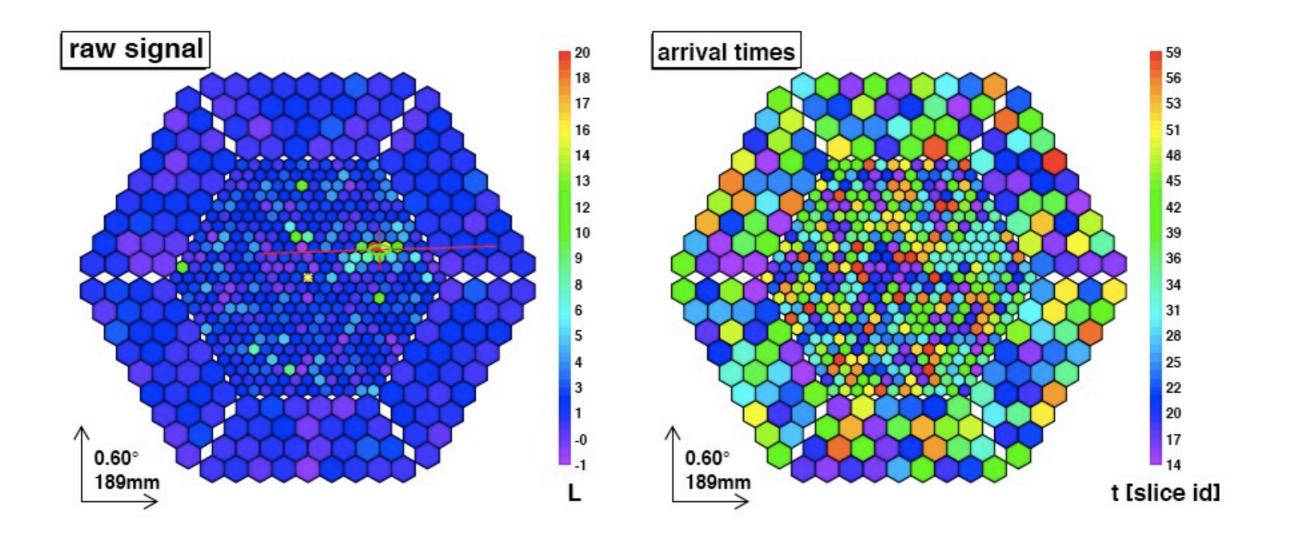
technical data: telescope monitoring & control, weather etc.

Access: only Privileged Users



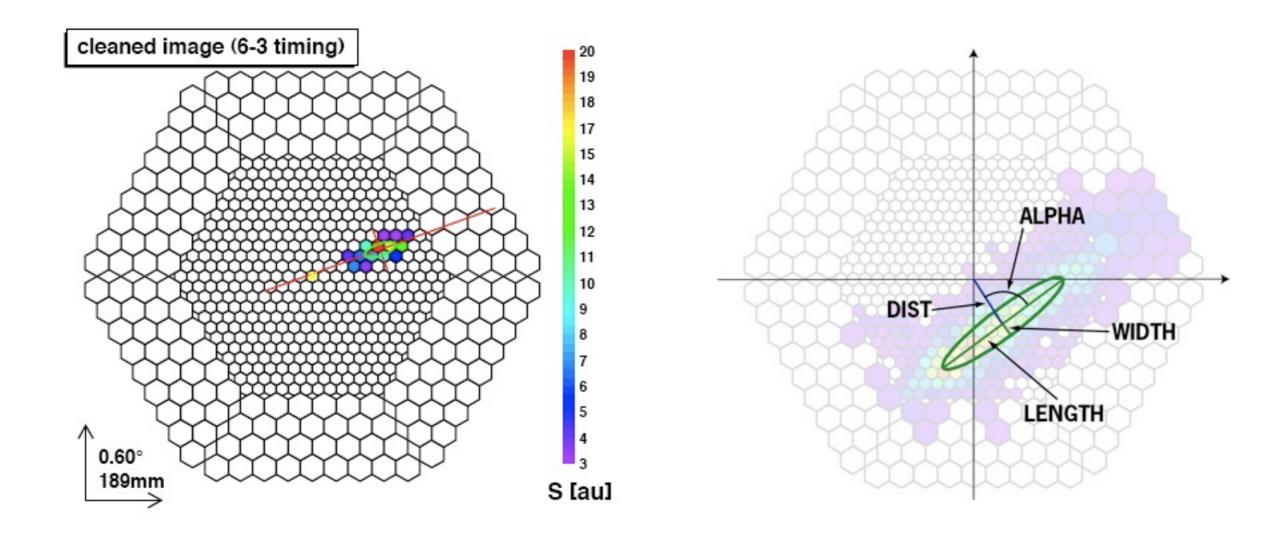
calibrated data: signal arrival time and charge for each event and pixel, for N telescopes calibrated MC: same but for simulated events

Access: only Privileged Users



reconstructed data: cleaned camera image, image parameters calculated, for each event, for N telescopes reconstructed MC data: same for simulated

Access: only Privileged Users

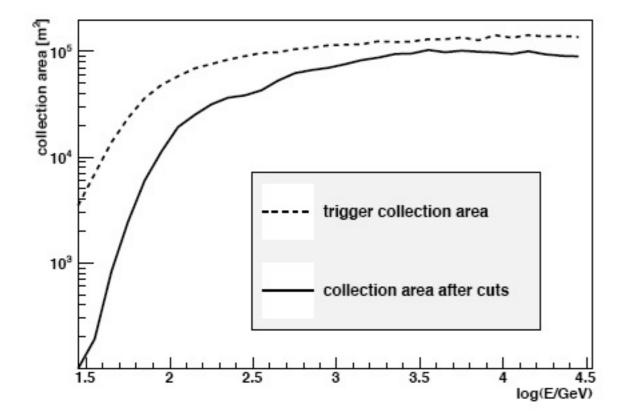


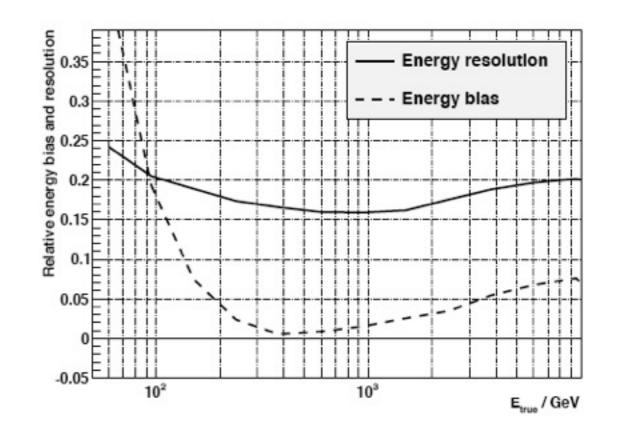
events lists (EL): gamma/hadron tag, reconstructed: energy, arrival direction, for each event MC events list (MCEL): same for simulated events Instrument Response Functions (IRFs): effective area, energy migration matrix, angular resolution

IMPORTANT:

- input from MC and technical data needed
- EL + MCEL + IRF come as a set with the same cuts, observational conditions etc.

Access: Privileged Users and Guest/Archive Users



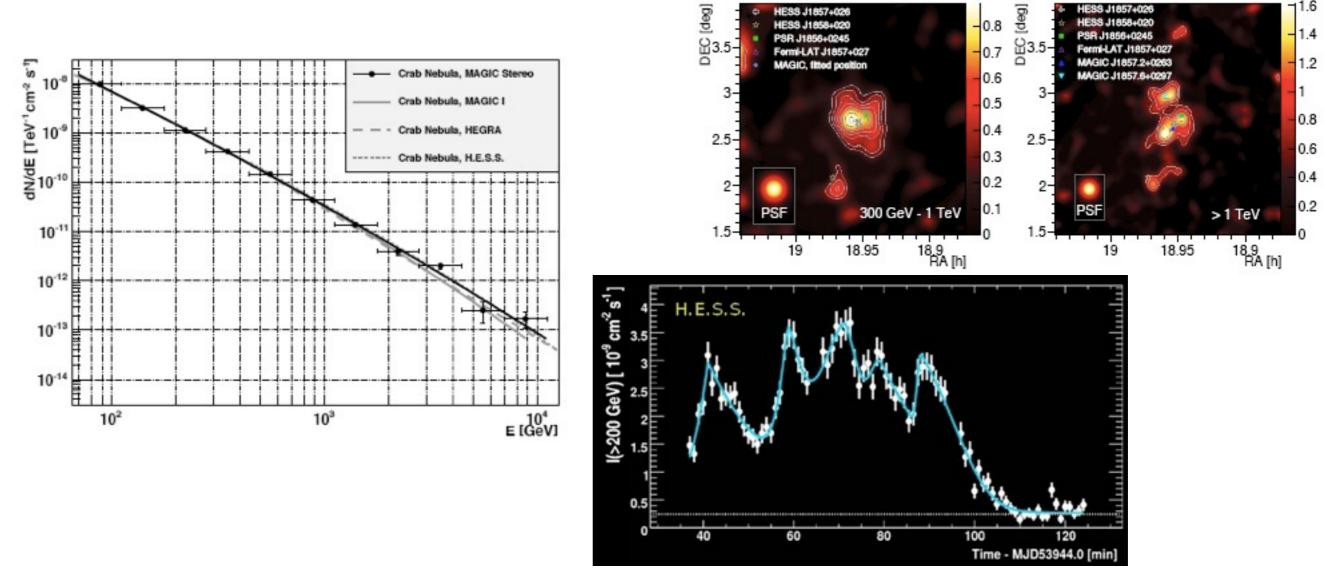


high level data: light curve, spectrum, sky map for each source/observation

IMPORTANT:

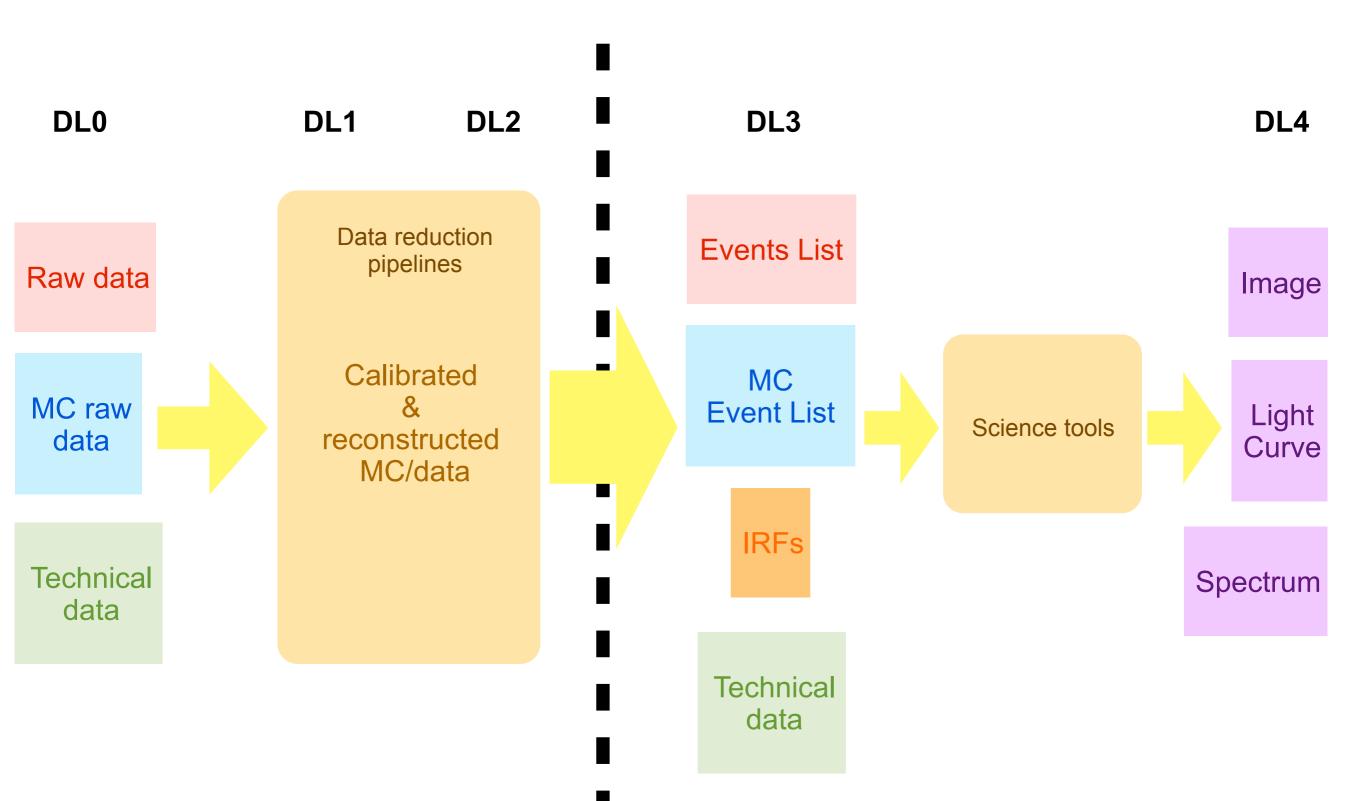
- produced from L3 events list using the corresponding IRFs
- might be a combination of data from different observations

Access: Privileged Users and Guest/Archive Users



Privileged User

Guest/Archive User



Our VO needs for CTA

We would like to make accessible through VO:
★ DL4 data: light curves, spectra, sky maps
★ DL3 data: event lists, IRFs, technical data

Challenges:

 \star Observations are long, but consist of many short time units (1-2 h) taken during various conditions: array/environment/processing (different IRFs!)

- -> DL4 products combination of data taken during different epochs
- -> We would like to combine data into sets including EL+IRF+MC

-> We would like to include the history of the data set: environmental conditions, array configuration, processing pipeline...

* We would like to publish "diffuse backgrounds" of gamma/electrons/hadrons

★ We have doubts, if the ObsCore model for spectra is enough for VHE data (what we see are counts/time unit – model (IRF) needed to convert them into flux)

★ We think some keywords (Utypes) are missing & some are not applicable (e.g. we would need PSF instead of aperture)

 \star We use different units

(e.g. spectral info given as a function of energy in [GeV] instead of wavelength in [m])

Our experience with VO: MAGIC

We offer VO services in two ways:

- via VO search tools (VOSED)
- via our own VO server (vobs.magic.pic.es), where you can fill out form or send a query through address line of your browser
- At the moment, we only support spectra and light curve protocols (SSA protocol)
- Access to sky maps in preparation...
- Results are returned in VOtable format, and as links referring to the generated results (in FITS format)
- Results expire after 24 hours
- Search is done over the public MAGIC results only

Our experience with VO: MAGIC

	🗯 Firefox File Edit View History B	Bookmarks Tools Window Help	S C # * 11 O 7	🕈 🜒 📻 🖅 (2:27) Thu 12:05 PM Q	
	000	MAGIC Virtual O	bservatory Search		
Image:	Vobs.magic.pic.es		☆ ァ C*] 🚼 • how	to make screen shot in mac Q	
MACIC Data Virtual Observatory Search POSITION: The centure of the region of interest. Coordinates are yeen in decirated degrees. Coordinates are yeen in decirated degrees. Coordinates are yeen in decirated degrees. The centure of the region of interest. Coordinates are yeen in decirated degrees. Coordinates are yeen in decirated degrees. The centure of the region of interest. The centure of the region of interest. Coordinates are yeen in decirated degrees. The region of interest. The file of the region of interest. DEC (regio): DEC (regio): DEC (regio): DEC (regio): Dectrib bandpass of the search. For MACIC data, it was is always geven as it for 2014 for 10 are interest. Conserved to the region of interest. Dectrib bandpass of the search. For MACIC data, it does not make search. The time coverage of the search. The film coverage of the search		dlines 🔹 🧧 Gazeta Wyborcz 🗯 Apple 🛛 ?? Yahoo! [Go	oogle Maps 🕒 YouTube 🐨 Wikipedia 🔛 News * 🚞 Popular *	Bookmarks *	
POSITION: SIZE: The contract of the region of interest. To aduits of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE: The radius of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. Spectral bandpass of the search. For MAGIC date, if so value is always goint as a 16-20/16-16 m range (conseponds to 10 deV) 100 regregs). The firm coverage of the search. Band (m) 16-20/16-16 The firm coverage of the search. For MAGIC date, if does not make sense to so constrain the search the sparameter. The (YVYY-MM-DD): 2004-01-01 / 2014-04-02 Decended of the search and	MAGIC Virtual Observatory Sear +				
POSITION: SIZE: The contract of the region of interest. To aduits of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE: The radius of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. Spectral bandpass of the search. For MAGIC date, if so value is always goint as a 16-20/16-16 m range (conseponds to 10 deV) 100 regregs). The firm coverage of the search. Band (m) 16-20/16-16 The firm coverage of the search. For MAGIC date, if does not make sense to so constrain the search the sparameter. The (YVYY-MM-DD): 2004-01-01 / 2014-04-02 Decended of the search and					
POSITION: SIZE: The contract of the region of interest. To aduits of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE: The radius of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. Spectral bandpass of the search. For MAGIC date, if so value is always goint as a 16-20/16-16 m range (conseponds to 10 deV) 100 regregs). The firm coverage of the search. Band (m) 16-20/16-16 The firm coverage of the search. For MAGIC date, if does not make sense to so constrain the search the sparameter. The (YVYY-MM-DD): 2004-01-01 / 2014-04-02 Decended of the search and					
POSITION: SIZE: The contract of the region of interest. To aduits of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE: The radius of the region of interest. It is goelfied in the decimal degrees. If none are specified, "ALL" is assumed. SIZE (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. It is goelfied in the decimal degrees. If none is assumed. Size (deg): DEC (deg): DEC (deg): The radius of the region of interest. Spectral bandpass of the search. For MAGIC date, if so value is always goint as a 16-20/16-16 m range (conseponds to 10 deV) 100 regregs). The firm coverage of the search. Band (m) 16-20/16-16 The firm coverage of the search. For MAGIC date, if does not make sense to so constrain the search the sparameter. The (YVYY-MM-DD): 2004-01-01 / 2014-04-02 Decended of the search and	MAGIC Data Virtual Observatory Search				
The center of the region of interest. Coordinates are given in decimal degrees. If none are specified, "ALL" The radius of the region of interest. It is specified in the decimal degrees. If none is set, 1 deg is assumed. BAND: Size [deg]: Size [deg]: DEC [deg]: DEC [deg]: The format in which the returned results will be in. For MAGIC data, this value is always given as a 1e-20/1e-16 m range (corresponds to -10 GeV / 100 TeV in energy). The format in which the returned results will be in. For MAGIC data, the dester of the search. Formats currently supported by MAGIC are listed below. For MAGIC data, the dester of the search. Formats currently supported by MAGIC are listed below. For MAGIC data, the dester on the search. Formats currently supported by MAGIC are search is queried for. Currently supported by MAGIC are search is queried for. Currently supported by MAGIC are search is queried for. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0 Search for: Spectrum is Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0 Submit XII coments, suggestions and requests send to jetenes/Itse.es. Submit	MAGIC				
The center of the region of interest. Coordinates are given in decimal degrees. If none are specified, "ALL" The radius of the region of interest. It is specified in the decimal degrees. If none is set, 1 deg is assumed. BakD: Size [deg]: Size [deg]: DEC [deg]: BAND: Size [deg]: Spectral bandpass of the search. For MAGIC data, this value is always given as a 1e-20/1e-16 m range (corresponds to -10 GeV / 100 TeV in energy). FORMAT: Band [m]: 1E-20/1E-16 The format in which the returned results will be in. Formats currently supported by MAGIC are listed below. For MAGIC data, it does not make sense to constrain the search. For MAGIC data, it does not make sense to constrain the search with this parameter. Time [YYYY:MM-DD]: TYPE OF DATA:: Type of Data the search is queried for. Currently supported by MAGIC are searches for Spectra and/or Light Curves. Search for: ZM coments, suggestions and requests sent to jelena@Hae.es. Submit					
The center of the region of interest. Coordinates are given in decimal degrees. If none are specified, "ALL" The radius of therest. It specified in the decimal degrees. If none is set, 1 deg is assumed. BAND: Size [deg]; DEC [deg]; DEC [deg]; DEC [deg]; The format in which the netword results will be in. For MAGIC data, this value is always given as a fe-20/fe-16 m range (corresponds to -10 GeV / 100 TeV in energy). Format: ALL Band [m]: 1E-20/IE-16 TIME: Type OF DATA: The time coverage of the search. Type of Data the search is queried for. Currently supported by MAGIC are listed below. For MAGIC data, it does not make sense to constrain the search with this parameter. Type of Data:: Type of Data the search is queried for. Time [YYYY:MM-DD]: 2004-01-01 / 2014-04-0 Search for: Spectrum is Xeret Submet					
Image: Section of interest. The cardius of the region of interest. Image: Section and sections are specified, "ALL" Ra [deg]: Email Size [deg]: Size [deg]: DEC [deg]: Email FORMAT: NAGIC data, this value is always given as a fe-20/fe-16 m range (corresponds to -10 GeV / 100 TeV in energy). Band [m]: 1-2-02/1E-16 Email: The formatine which the returned results will be in. Format: Currently supported by MAGIC are listed below. For MAGIC data, this value is always given as a fe-20/fe-16 m range (corresponds to -10 GeV / 100 TeV in energy). Band [m]: 1-2-02/1E-16 Image: Section barrenter Time (TYYY-MM-DD): 2004-01-01 / 2014-04-0 Format: Currently supported by MAGIC are searches for Spectra and/or Light Curves. For MAGIC data, it does not make sense to constrain the search with the search is queried for. Currently supported by MAGIC are searches for Spectra and/or Light Curves. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0 Search for: Spectrum it Submit MI coments, suggestions and requests sent to jelena@Hae.es. Submit Submit		POSITION:	SIZE:		
Coordinates are given in blochile degrees. If none are specified, ALL degrees. If none is set, 1 deg is assumed. Ra [deg]: DEC [deg]: DEC [deg]: Size [deg]: DEC [deg]: Termatic marks are given in blochile is set, 0. For MAGIC data, the value is siven as a te-20/16-16 m range (corresponds to - 10 GeV / 100 TeV in energy). The format in which the returned results will be in. For MAGIC data, the value is siven as a te-20/16-16 m range (corresponds to - 10 GeV / 100 TeV in energy). The format in which the returned results will be in. For MAGIC data, the value is always given as a te-20/16-16 m range (corresponds to - 10 GeV / 100 TeV in energy). Formats: Band [m]: 11E-20/1E-16 TYPE OF DATA: Type of Data the search with this parameter. Type of Data the search is queried for. Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Time [VYYY-MMLDD]: 2004-01-01 / 2014-04-0 Submt All coments, suggestions and requests send to jelena@Hae.es. Submt		The center of the region of interest.			
Na (ong): DEC (deg); DEC (deg); EAND: Spectral bandpass of the search. FORMAT: For MAGIC data, this value is always given as a 1 e-20/16-16 m range (corresponds to -10 GeV / 100 TeV in energy). The formatin which the returned results will be in. Band [m]: 1E-20/1E-16 The formatin which the returned results will be in. For MAGIC data, this value is always given as a 1 e-20/1E-16 Formats currently supported by MAGIC are listed below. Format IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	Coord		degrees. If none is set, 1 deg is assumed.		
DEC [deg] BAND: BAND: FORMAT: Spectral bandpass of the search. For MAGIC data, this value is adways given as a 1 e-20/16-16 m range (corresponds to -10 GeV / 100 TeV in energy). The formati in which the returned results will be in. Band [m]: 1E-20/1E-16 The format in which the returned results will be in. For MAGIC data, this value is adways given as a 1 e-20/1E-16 Format: The format in which the returned results will be in. Band [m]: 1E-20/1E-16 The format in which the returned results will be in. Formats currently supported by MAGIC are listed below. For MAGIC data, it does not make sense to constrain the search with this parameter. Type of Data the search is queried for. Currently supported by MAGIC are searches for Spectra and/or Light Curves. Search for: Spectrum (*) Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0 Search for: Spectrum (*) XII coments, suggestions and requests send to [blema@Hae.es. Submit		Ra [deg]:	Size [deg]:		
BAND: ForMAGIC data, this value is always given as a 1e-20/1e-16 m range (corresponds to - 10 GeV / 100 TeV in energy). ForMAGIC data, this value is always given as a 1e-20/1e-16 The formati in which the returned results will be in. Formati currently supported by MAGIC are listed below. Band [m]: 1E-20/1E-16 Format: Image: TYPE OF DATA: TIME: Type of Data the search is queried for. Currently supported by MAGIC are search is queried for. Time [YYYY-MMM-DD]: 2004-01-01 / 2014-04-01 Search for: Search for: Time [YYYY-MMM-DD]: 2004-01-01 / 2014-04-01 Search for: Submit					
Spectral bandpass of the search. For MAGIC data, this value is always given as a 1e-20/1e-16 m range (corresponds to ~ 10 GeV / 100 TeV in energy). The formati in which the returned results will be in. Band [m]: 1E-20/1E-16 The formati in which the returned results will be in. For MAGIC data, this value is always given as a 1e-20/1e-16 Formatic unrently supported by MAGIC are listed below. Band [m]: 1E-20/1E-16 Formatic unrently supported by MAGIC are listed below. For MAGIC data, it does not make sense to constrain the search with this parameter. Type of Data the search is queried for. Currently supported by MAGIC are searches for Spectra and/or Light this parameter. Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC are searches for Spectra and/or Light Currently supported by MAGIC		DEC [deg].			
For MAGIC data, this value is always given as a 1e-20/1e-16 m range (corresponds to ~ 10 GeV / 100 TeV in energy). The format in which the returned results will be in. Band [m]: 1E-20/1E-16 TIME: Format: The time coverage of the search. Type of Data the search is queried for. For MAGIC data, it does not make sense to constrain the search with this parameter. Type of Data the search is queried for. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0. Reset Submit		BAND:	FORMAT:		
(corresponds to ~ 10 GeV / 100 TeV in energy). Band [m]: 1E-20/1E-16 Band [m]: 1E-20/1E-16 Format: Image: Time: The time coverage of the search. Type of Data the search is queried for. For MAGIC data, it does not make sense to constrain the search with this parameter. Type of Data the search is queried for. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-00 Search for: Spectrum Reset Submit	Co.M		The format in which the returned results will be in.		
Baind [m]: It=20/IE=16 TIME: TYPE OF DATA: The time coverage of the search. Type of Data the search is queried for. For MAGIC data, it does not make sense to constrain the search with this parameter. Type of Data the search is queried for. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0 Search for: Spectrum I Reset Submit	Porm	(corresponds to ~ 10 GeV / 100 TeV in energy).	Formats currently supported by MAGIC are listed below.		
The time coverage of the search. Type of Data the search is queried for. For MAGIC data, it does not make sense to constrain the search with this parameter. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0. Search for: Spectrum : Reset Submit		Band [m]: 1E-20/1E-16	Format: ALL		
The time coverage of the search. Type of Data the search is queried for. For MAGIC data, it does not make sense to constrain the search with this parameter. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0. Search for: Spectrum : Reset Submit					
For MAGIC data, it does not make sense to constrain the search with this parameter. Currently supported by MAGIC are searches for Spectra and/or Light Curves. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0. Search for: Spectrum Reset Submit		TIME:	TYPE OF DATA:		
this parameter. Curves. Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0: Search for: Spectrum : Reset Submit	1.00				
Reset Submit	For M				
All coments, suggestions and requests send to jelena@ifae.es.		Time [YYYY-MM-DD]: 2004-01-01 / 2014-04-0.	Search for: Spectrum		
All coments, suggestions and requests send to jelena@ifae.es.					
	Reset		Submit		
	All coments, suggestions and requests send to jeld	ena@ifae.es.			
Visit our MAGIC Fits Database		Visit our MAGIC	Fits Database		

Summary

 \bigstar CTA: first open IACT observatory - we have to publish the data for the whole astrophysics community

★ VO seems to be a good solution, but...
★ our experience with VO is limited
★ no standards yet for VHE data

