Onsite Analysis for the Large Size Telescope prototype of CTA

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The Cherenkov Telescope Array (CTA) will be the first open-access and the most powerful very-high energy gamma-ray observatory constructed to date. It will consist of telescopes of different sizes enabling sensitive observations to be performed over a wide energy range. The first prototype of the Large Size Telescope (LST) of CTA, is presently in the commissioning phase at the Observatorio del Roque de Los Muchachos (ORM) on the Canary Island of La Palma.

During normal operation, the LST prototype alone records more than 3 Terabytes of data per hour. To deal with it, a farm of processors has been installed on-site at ORM and a pipeline developed, *lstchain*, which is based on the CTA software, *ctapipe*. Data are analyzed on-site and quick feedback is provided for the commissioning. We provide an overview of the onsite analysis and examples of the first results that have been obtained through its use.

1. Context of the research

- *The Cherenkov Telescope Array (CTA)* [1] will be the largest ground-based gamma-ray observatory in the world, with more than 100 telescopes in the northern (La Palma, Spain) and southern hemispheres (Paranal, Chile) that combined will cover a full energy range of 20 GeV to 300 TeV[2].

- Currently, the first prototype of large-sized telescopes (**LST-1**) is installed on La Palma and is in the commissioning period[3][4].

Credit: Ivan Jimenez, IAC

- The **LST-1** has a 23 m diameter parabolic reflective surface and a 370 m^2 effective mirror area that collects and focuses the Cherenkov light onto the camera, where photomultiplier tubes convert the light to electrical signals that can be processed by dedicated electronics.

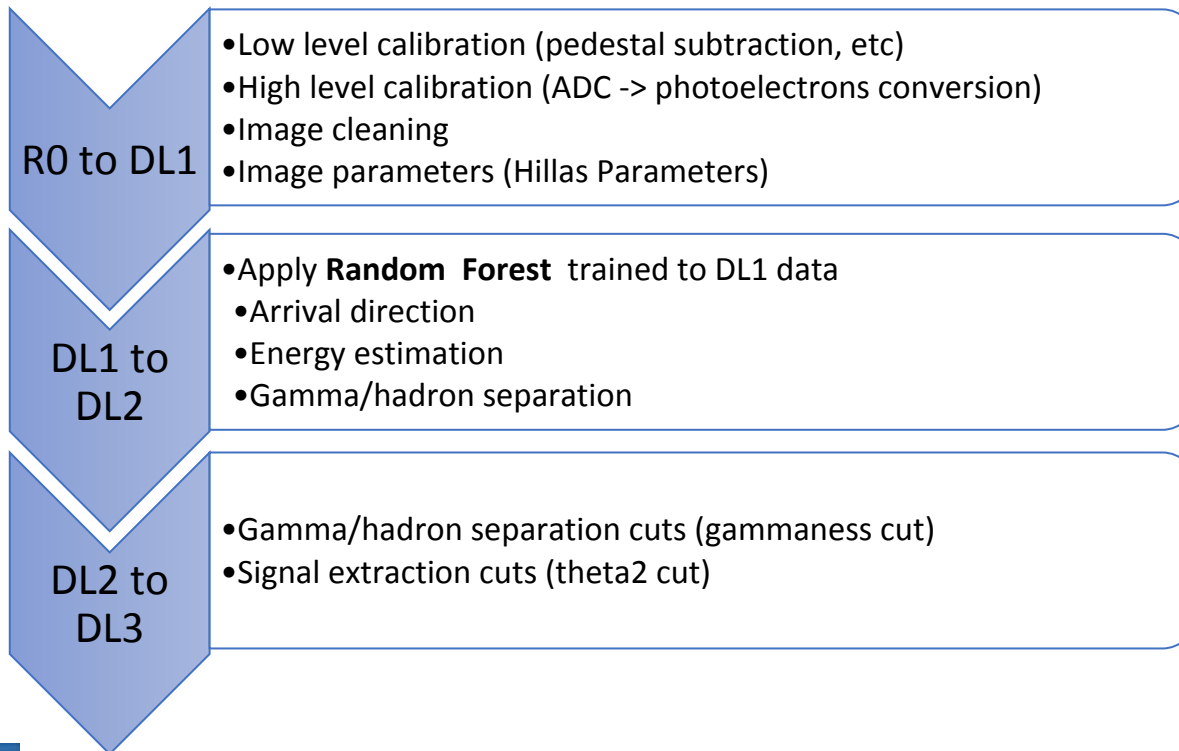 - The telescope has been taking commissioning data since September 2019.

2. Description of the project

Onsite Data Reduction at La Palma

The analysis running on site, produces low and high level analysis products

R0 to DL1
- Low level calibration (pedestal subtraction, etc)
- High level calibration (ADC -> photoelectrons conversion)
- Image cleaning
- Image parameters (Hillas Parameters)

15 GB/min

1/5 reduction

DL1 to DL2
- Apply **Random Forest** trained to DL1 data
  - Arrival direction
  - Energy estimation
  - Gamma/hadron separation

3 GB/min

1/100 reduction

DL2 to DL3
- Gamma/hadron separation cuts (gammaness cut)
- Signal extraction cuts (theta2 cut)

0.03 GB/min

IT Cluster on La Palma

55 computational nodes
x 32 cores
1760 total cores
264 GB RAM memory each

LSTOSA is the software package based on **lstchain** and **ctapipe** that performs the first steps of LST analysis providing low-level analysis products and spotting potential issues that may affect the data
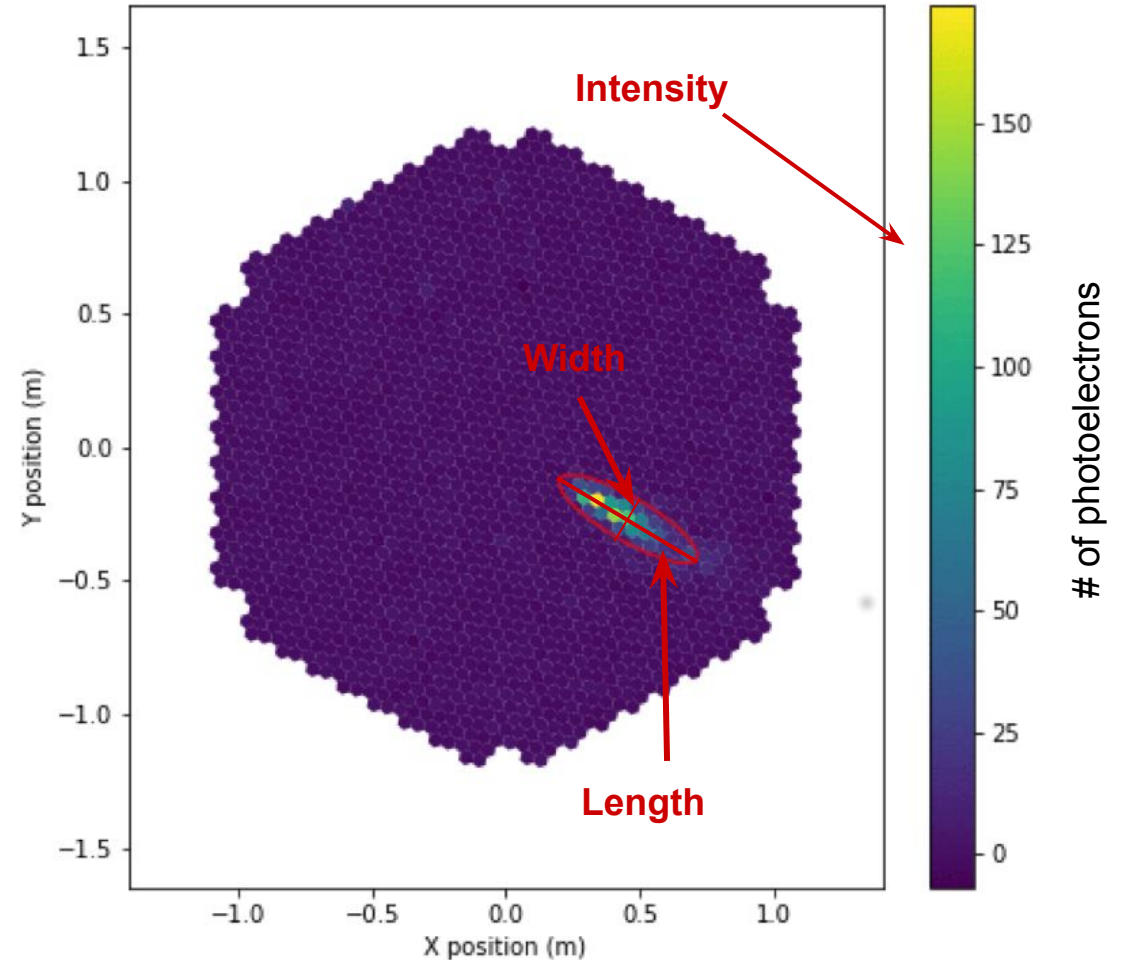
3. Results

Image parameters & Random Forest

Gamma-ray initiated showers give rise to images on the focal plane that are elliptical in shape and can be described naturally by image parameters known as Hillas parameters [5] .

We use these image parameters as input for the machine learning technique of **Random Forest** [6] to get:

Energy estimation
Arrival direction
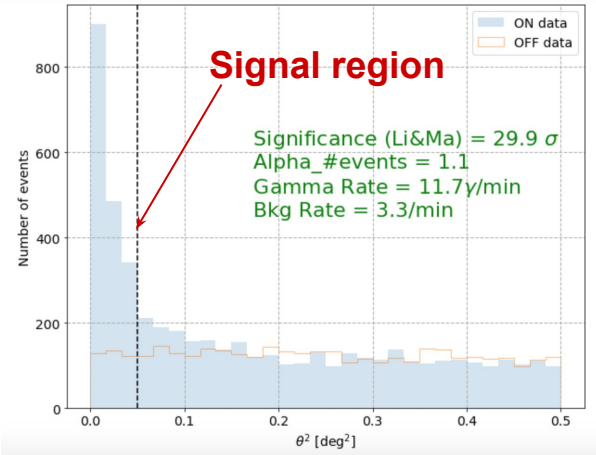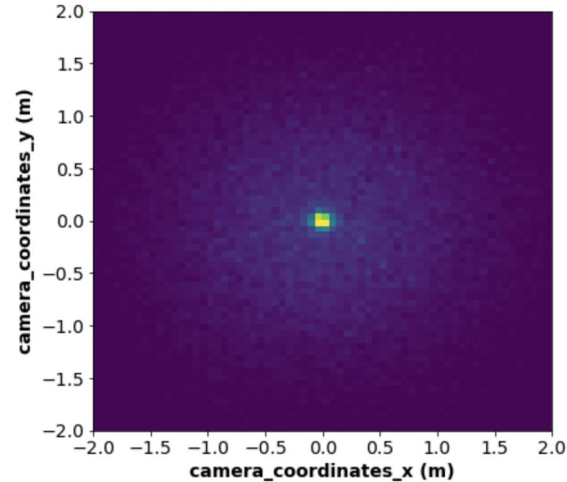**Type of particle γ/hadron**

Based on image parameters

3. Results

First Crab campaign observations 20191123
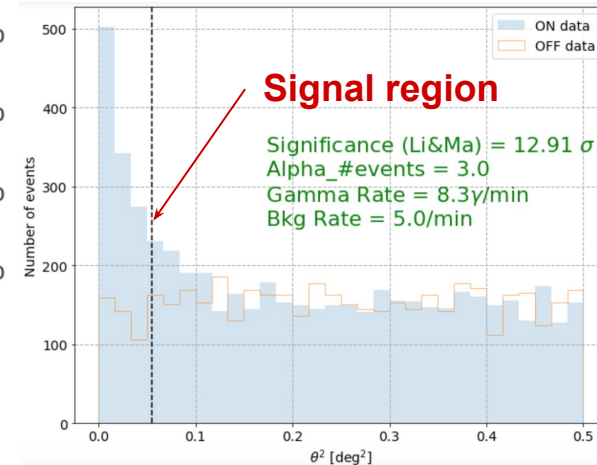
115 min of observation

Signal extraction

Significance (Li&Ma) = 29.9 σ
Alpha_#events = 1.1
Gamma Rate = 11.7γ/min
Bkg Rate = 3.3/min

Excess on camera plane

First Mrk 421 Observations 20200131

90 min of observation

Signal extraction

Significance (Li&Ma) = 12.91 σ
Alpha_#events = 3.0
Gamma Rate = 8.3γ/min
Bkg Rate = 5.0/min

Excess on camera plane
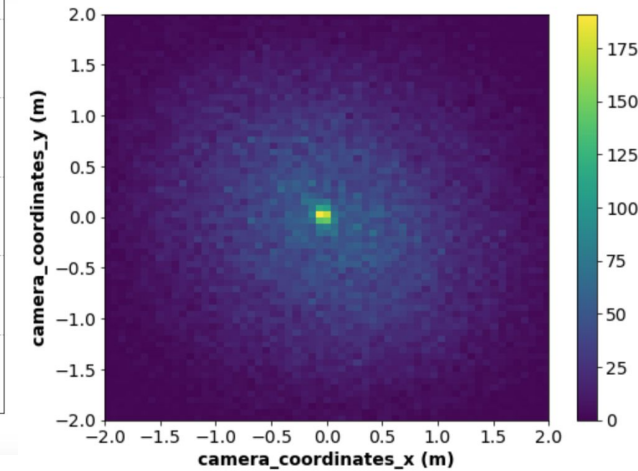
- *Distributions of angular distances between the source and the direction shower*

- *We can see a clear excess of events from the source direction*

4. Impact and prospects for the future

Summary

- *The LST prototype is taking data since september of 2019*
- *Data are analyzed on site in semi-automatic way*
- *The clear detection of The Crab Nebula and Mrk421 has been achieved during the commissioning*

Next steps:
- *The commissioning period will finish this year*
- *A total of four LSTs will be built on The CTA-North site*

CTA-North design on Roque de los Muchachos, La Palma (Spain)

Rendering Credit: Gabriel Pérez Diaz, IAC, SMM

References

[1] CTA Consortium Collaboration, B. S. Acharya et al., Science with the Cherenkov Telescope Array. WSP, 2018. arXiv:1709.07997 [astro-ph.IM].

[2] Mazin, D. et al.,The Cherenkov Telescope Array, PoS, Vol. ICRC 2019., pp. 741, 2019

[3] Cortina, J. et al., Status of the Large Size Telescopes of the Cherenkov Telescope Array, PoS, Vol. ICRC 2019., pp. 653, 2019.

[4] Di Pierro, F. et al., Monte Carlo Studies of Combined MAGIC and LST1 Observations, PoS, Vol. ICRC 2019., pp. 659, 2019.

[5] Hillas, A. M., Cherenkov light images of EAS produced by primary gamma rays and by nuclei, Proc. XIX ICRC, Vol. 3, pp. 445-448, 1985.

[6] L. Breiman. Random Forests. *Machine learning*, Vol. 45(1), pp. 5–32, 2001.