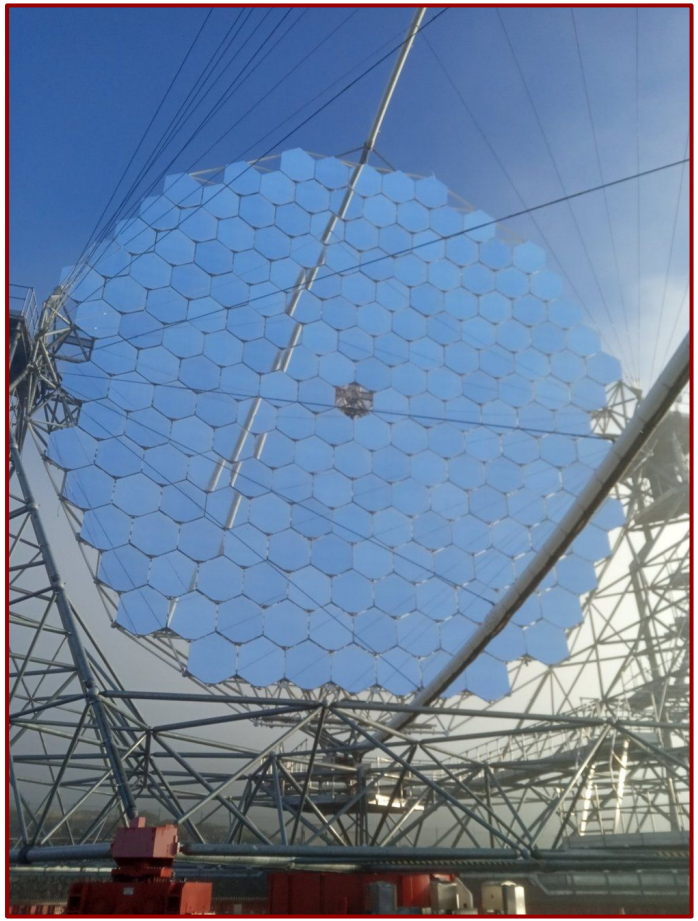
Real-time analysis for the LST-1

Ambra Di Piano

with A. Bulgarelli, L. Baroncelli, N. Parmiggiani, G. De Cesare, V. Fioretti, A. Addis, G. Panebianco

LST-1

- The LST-1 is one of 4 Large Sized Telescopes for the CTA North array and the **first instrument on site** at Roques de los Muchacos, Canary Islands (ES);
- It was inaugurated on October 10, 2018, and has been taking **commissiong data since December 2018**;
- LST-1 is an alt-azimuth telescope with a 23 meters parabolic primary mirror;
- It covers an energy range **from 20 GeV to 3 TeV**;
- It stands 45 meters tall and weight around 100 tonnes
- weights ~100 tonnes;
- It has a 1855 hexagonal pixels Cherenkov camera and a **field of view of 4.3 degrees** in diameter;
- Its required pointing precision is less than 14 arcsecond, with optimal **repositioning time less than 30 seconds**;
- It can observe any point in the sky above 24 degrees of elevation.



LST-1

On-Site shifts covered by our team since INAF entered the LST consortium:

- P030 (Summer 2021)
  Leonardo Baroncelli

- P038 (Spring 2022)
  Ambra Di Piano

The Real-Time Analysis / Science Alert Generation

Real-Time Analysis → an **on-site automated software system** that analyses data during observations.

- For LST-1 most of the software (approximately 95%) is the same developed for the Array Control And Data Acquisition (ACADA) system of CTA, namely the **Science Alert Generation (SAG)** system. Exceptions being the different interfaces.

- From LST-1, the **experience and learning are brought back into the SAG** system, enabling more robust development of the algorithms and speeding up the testing of fundamental software.

The Real-Time Analysis / Science Alert Generation

Real-Time Analysis → an **on-site automated software system** that analyses data during observations.

Provided by the SAG

- **RECO:** Low-Level Cherenkov data reconstruction;
- **DQ:** Online Data Quality of reconstructed Cherenkov data, to produce data quality summaries, data quality warnings and alarms;
- **SCI: High-Level Analysis**
  - Science Monitoring → science quick looks (i.e. skymaps, lightcurves) for the support astronomer;
  - Science Alert Generation → issuing of science alert.

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The Real-Time Analysis / Science Alert Generation

Being already on site and taking commissioning data, LST-1 provides the group with a priceless opportunity for tasting the real-time analysis system, well… in ***real-time*** and on ***real Cherenkov data***.

The Real-Time Analysis / Science Alert Generation

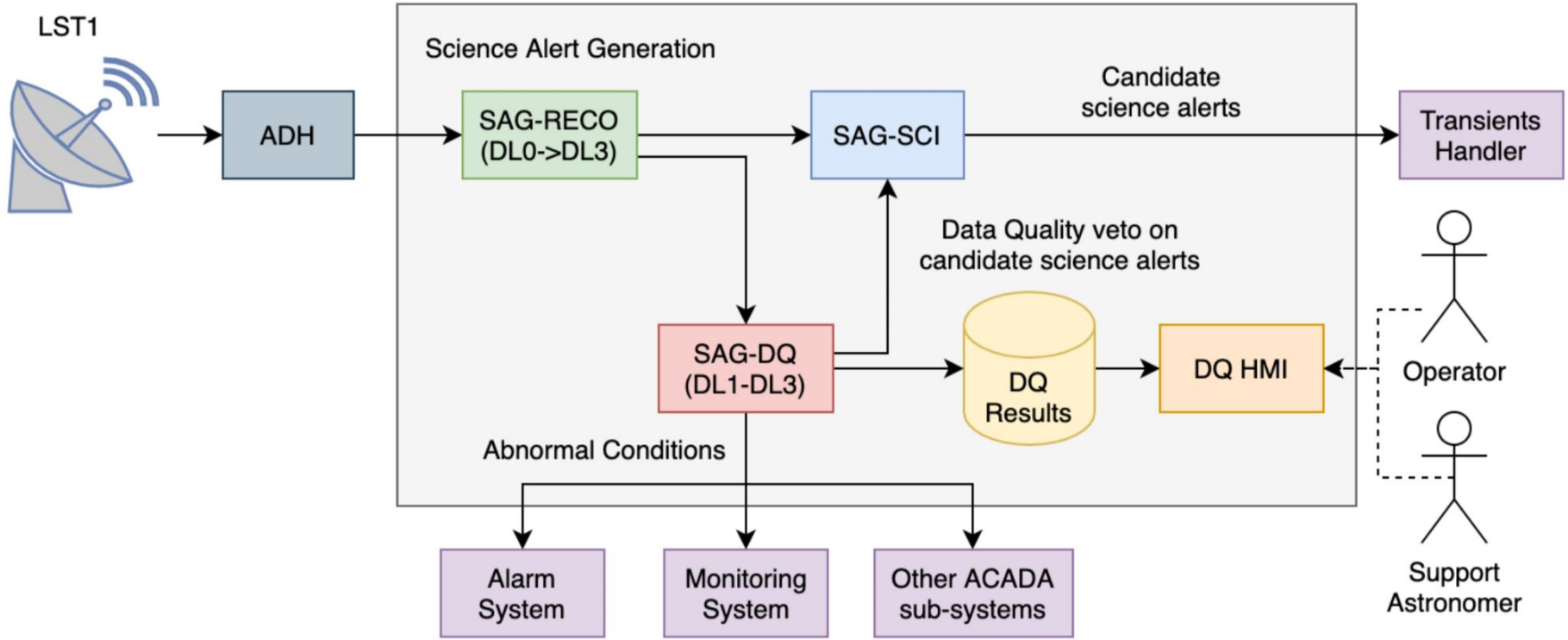


Image credits: Nicolò Parmiggiani

The Real-Time Analysis / Science Alert Generation

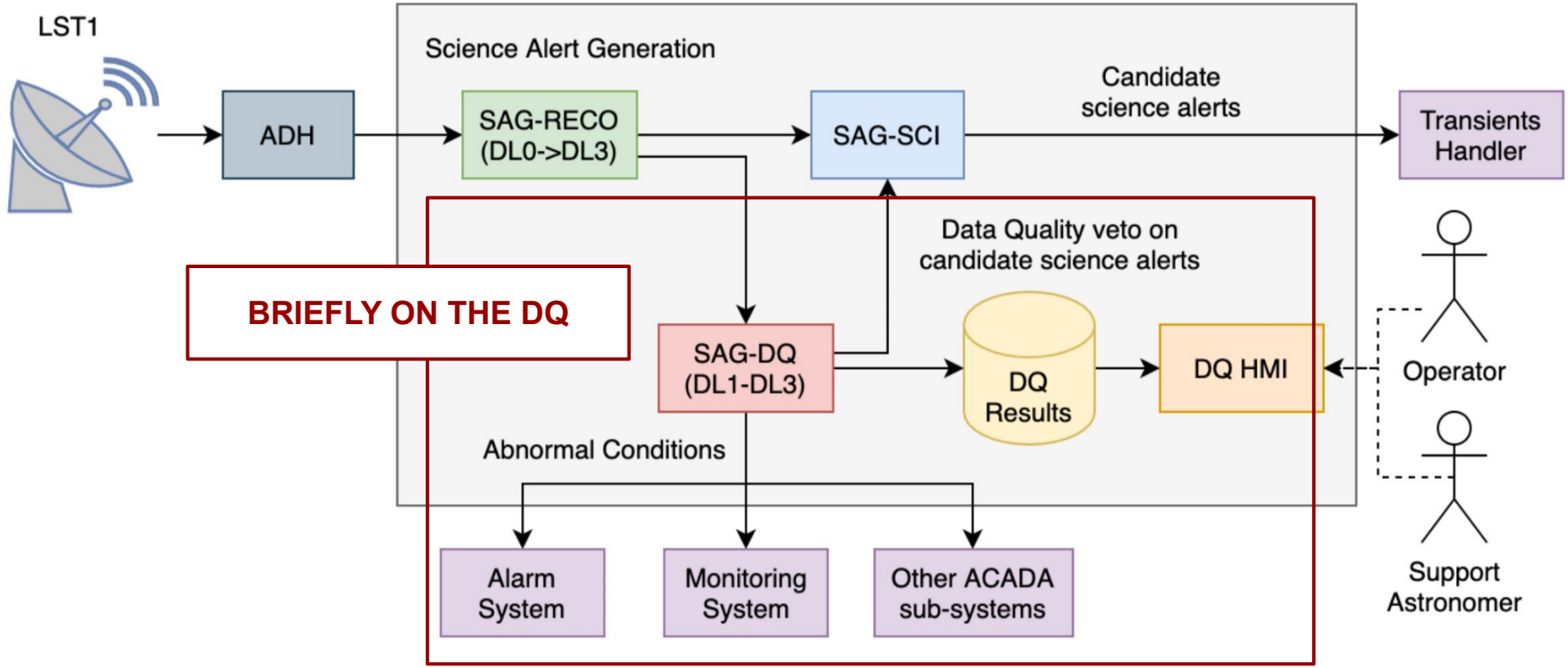


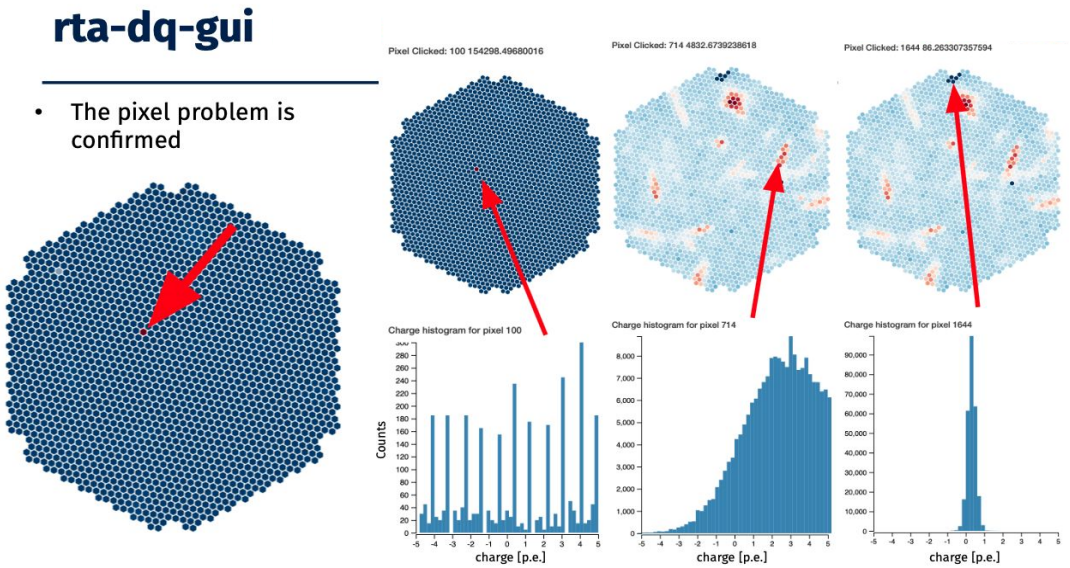
Image credits: Nicolò Parmiggiani

DQ pipelines

The pipelines perform a list of data quality checks:

- sum of camera pixels;
- average of camera pixels;
- root mean square of camera pixels;
- histograms for each camera pixel;
- histograms for hillas parameters;
- 2d correlation of hillas parameters;
- time-series plots.

Contextually, we also perform performance measures.



DQ deployed @ La Palma cluster
on LST-1 real data produced by RECO pipelines

Image credits: Leonardo Baroncelli

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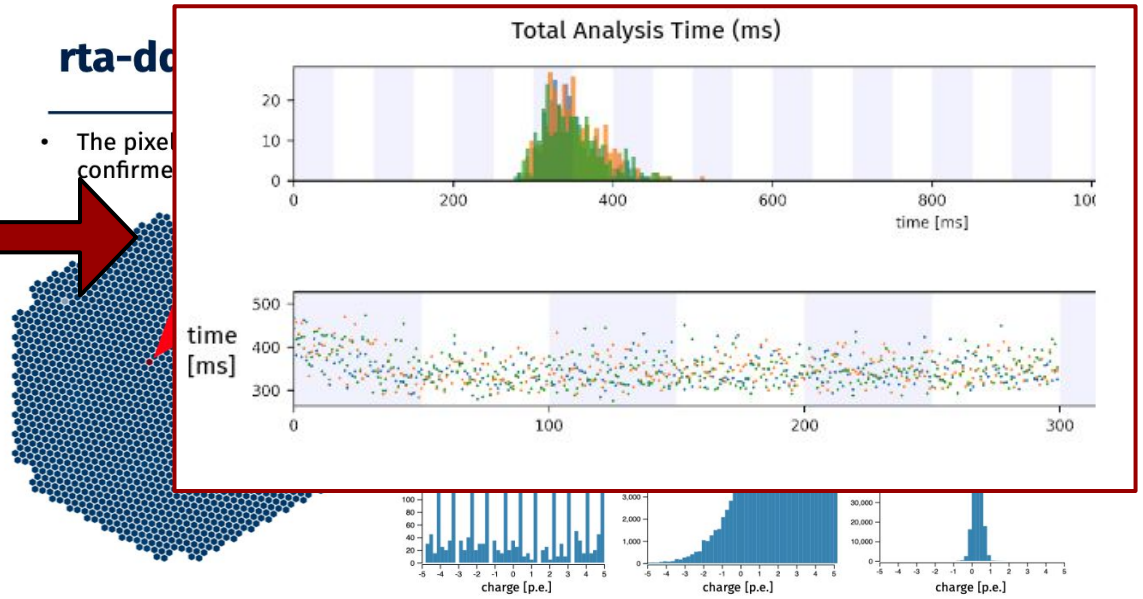

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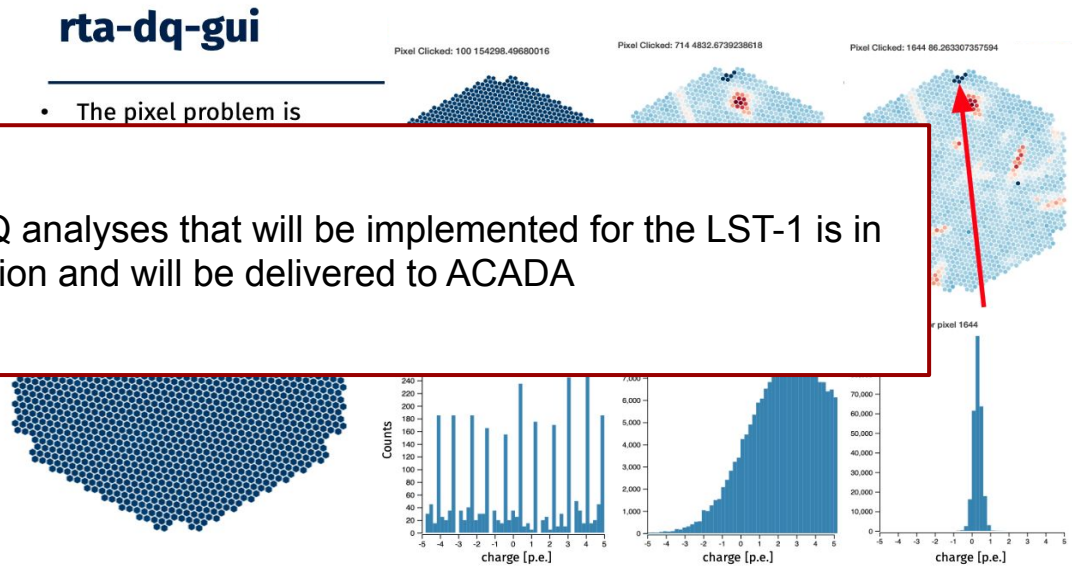
A document detailing all DQ analyses that will be implemented for the LST-1 is in preparation and will be delivered to ACADA



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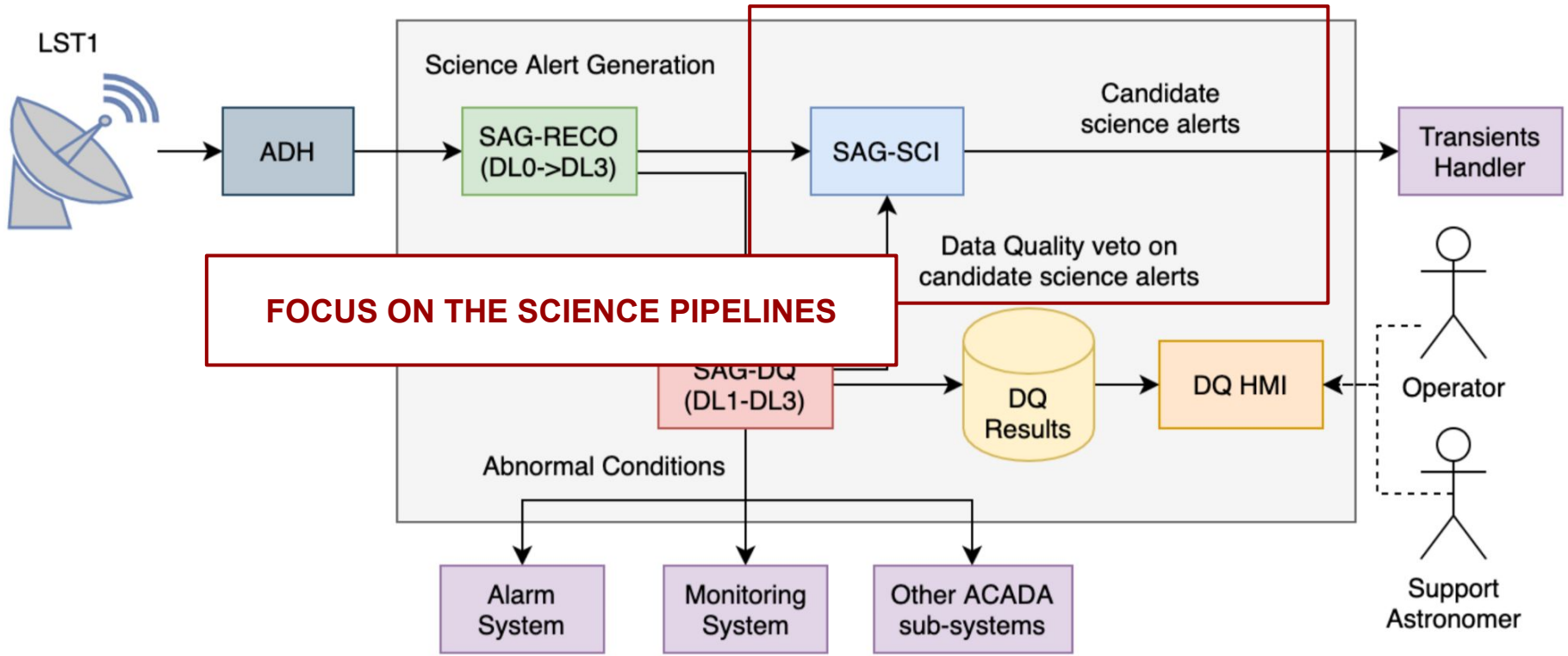

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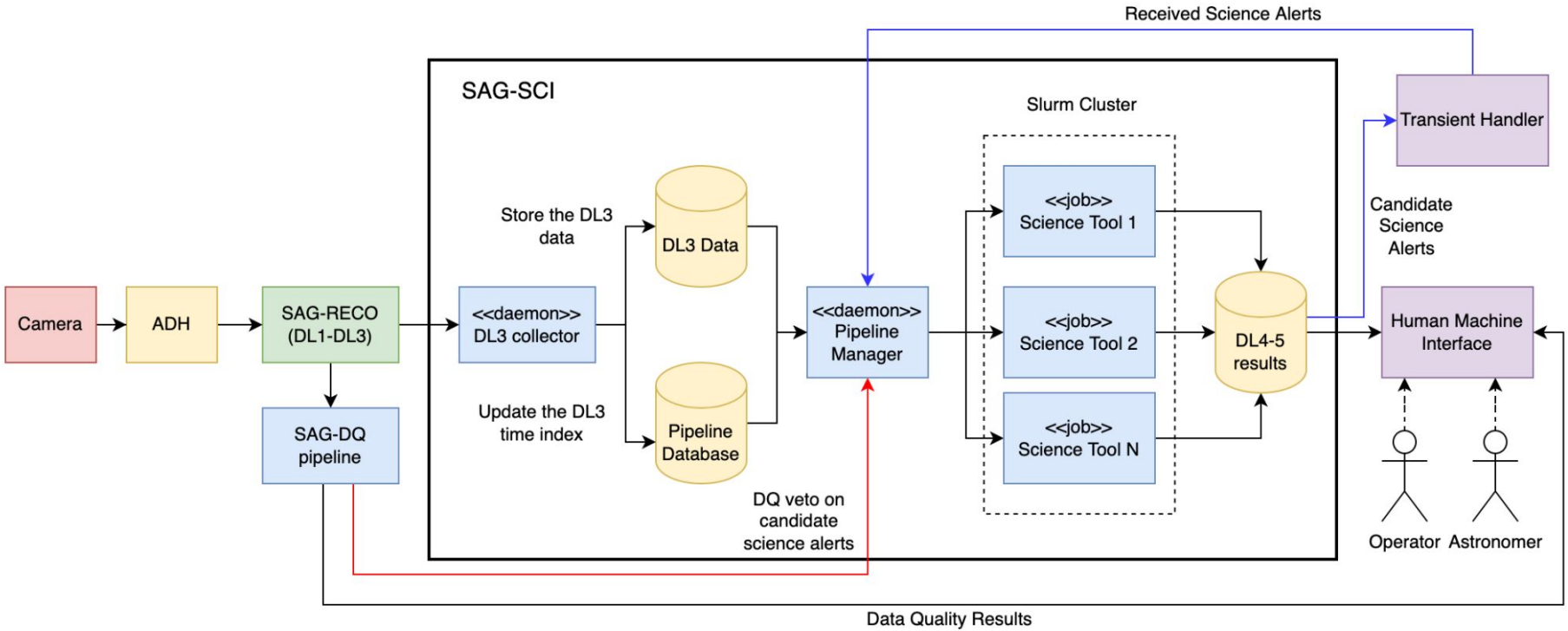
Software architecture



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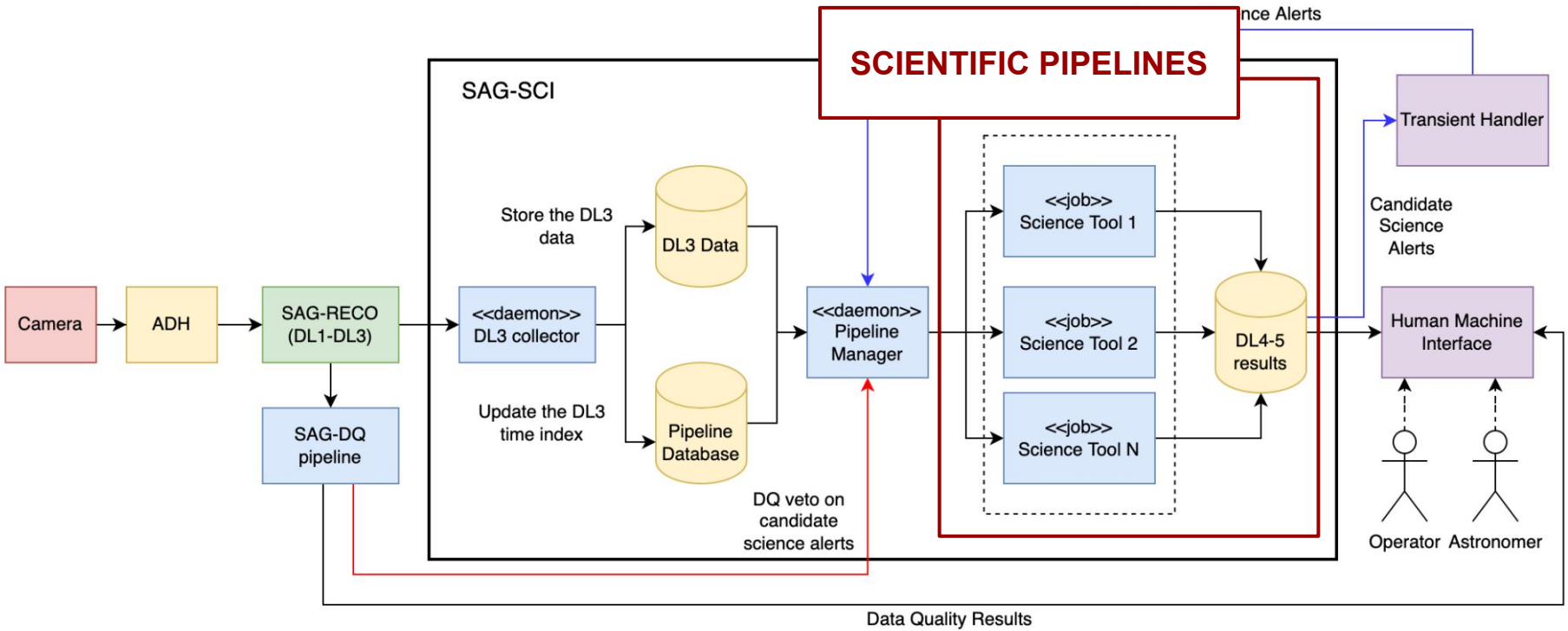

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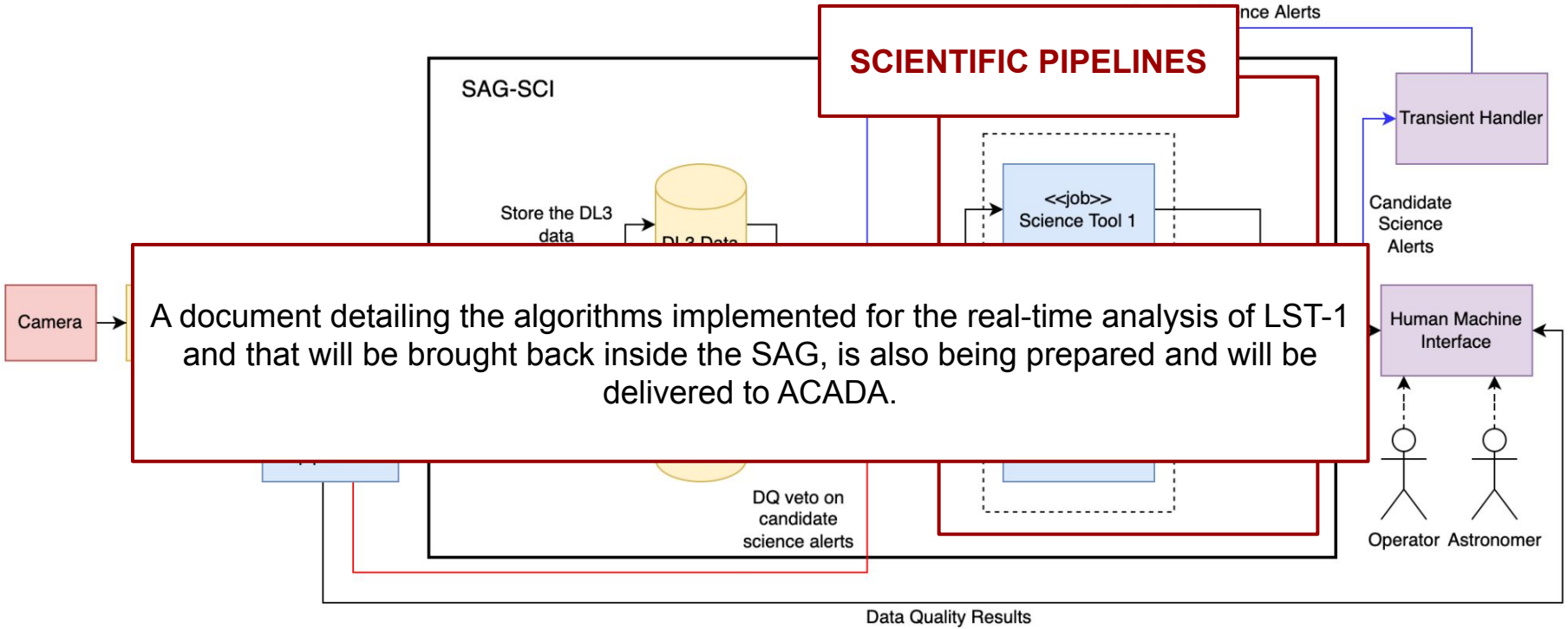

Image credits: Nicolò Parmiggiani

Scientific pipelines

Science tools wrappers:

- ctools (old prototype)
- **rtaph (real-time aperture photometry tool)**
- gammapy *(work in progress)*

RTAPH wrapper:

- photometric counts
- Li&Ma significance
- cross and reflection methods
- counts map
- integrated flux => requires IRF (effective area and psf)
- stack option

GAMMAPY wrapper:

- requires IRF
- hotspot search => target coordinates
- photometric counts
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- spectral fit
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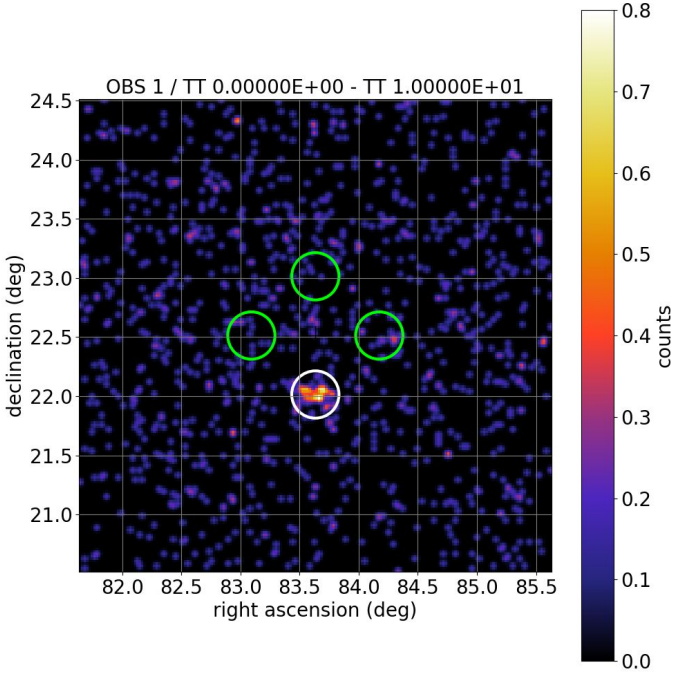
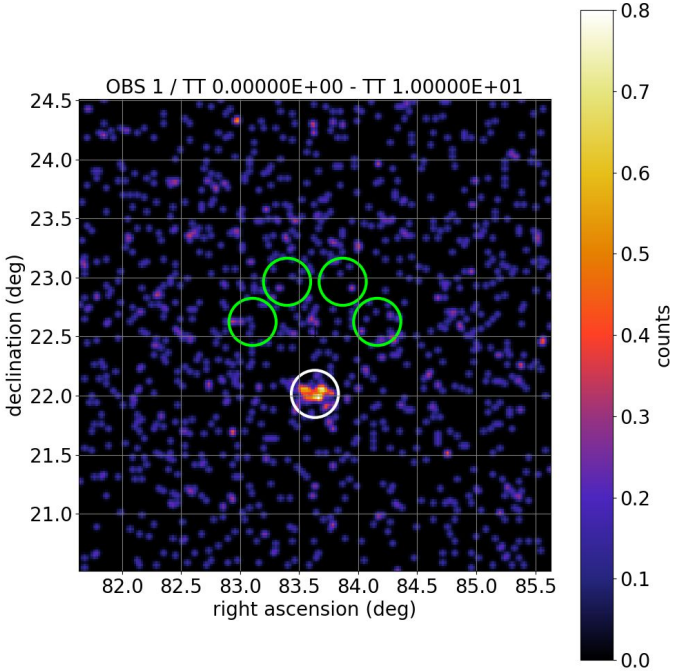
Background estimation methods



Cross



Reflection

Testing the pipelines @ La Palma cluster

Online the scientific pipelines interact with the database to receive the reconstructed DL3 data and store the analysis results.

- **Time binned** as well as **cumulative** analysis mode are available, where in the former only single batches of data (of given exposure) are analysed while the latter performs the analyses on the data acquired since the start of the run.

- To optimise the runtime, a **stack option** is provided for cumulative results as to avoid recomputing batches of data previously analysed. Currently this option allows to stack within a single run of observation but stacking of multiple runs will also be implemented in the future.

- The **RTApipe framework** provides an HMI to visualise and easily access data and the results stored by the pipelines

Testing the pipelines @ La Palma cluster

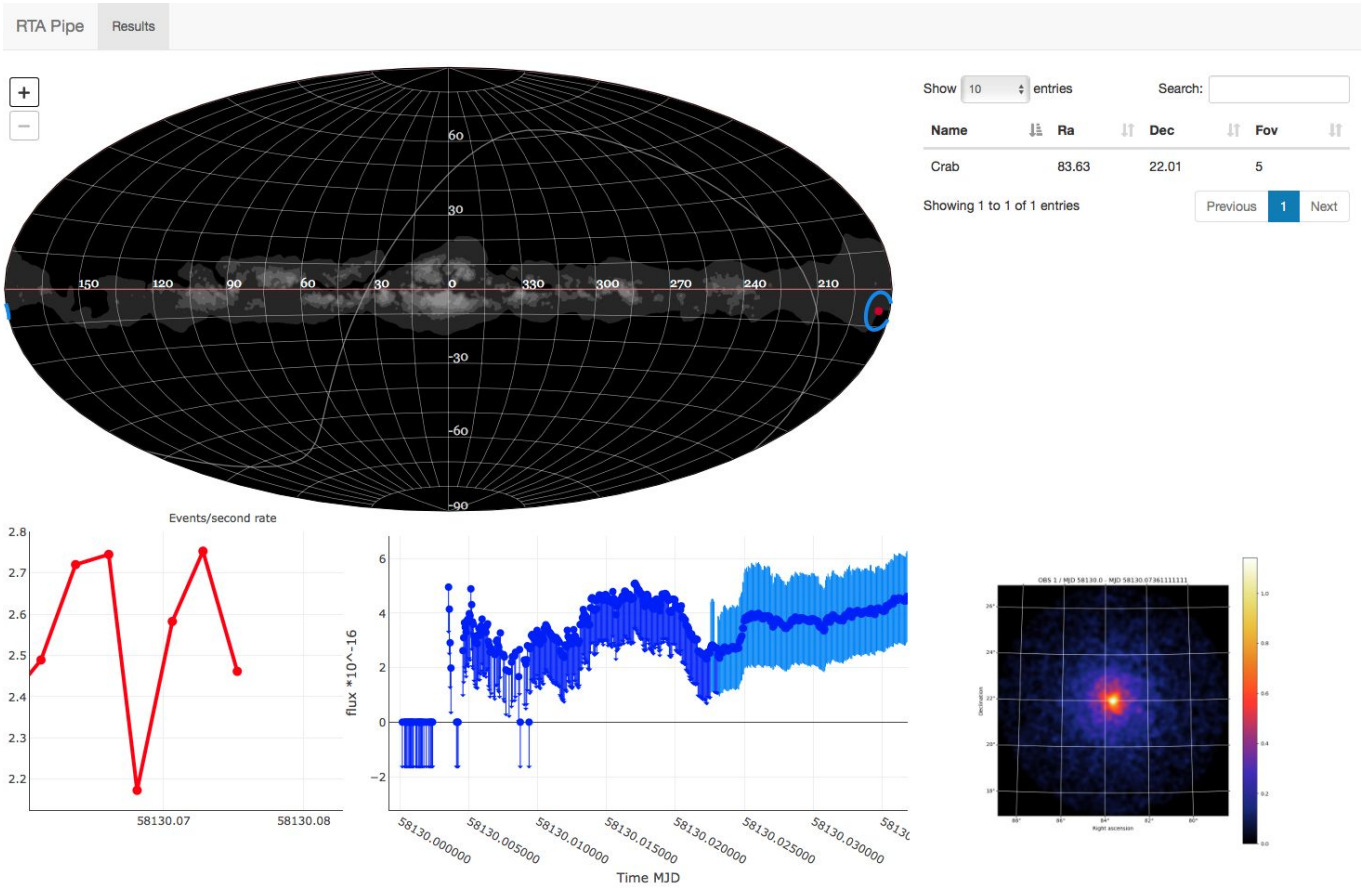


Image credits: Nicolò Parmiggiani

Testing the pipelines on LST-1 data

!!! YOU SHALL NOT PASS !!!

Preliminary results are shown **ONLY** during the talk and are not available online due to policies

Conclusions

- Computation of photometric counts, significance, counts maps and integrated flux (provided the IRF) either binned or integrated in time;
- Results are stored in a database and used to provide sky maps, lightcurves and other products via HMI to the support astronomer;
- A number of optimisations are implemented in order to improve the performance of the pipelines;
- The experience gained on LST-1 (both on-site and off-site) is crucial for the development of the Science Alert Generation (SAG) system of CTA-ACADA since the software is one and the same.

Future improvements (towards ACADA)

- Link wobble observations in the database to allow stacking of multiple runs;
- Implementation of a θ^2 plot;
- Implementation of a blind search tool for the rtaph wrapper;
- Overall optimisation of the gammapy wrapper to satisfy performance requirements;
- Implementation of significance maps;
- Catalogue query to create mask regions and/or associate hotposts with already known sources;
- Quality corrections due environmental and systematic degradation.