CTAO | LST COLLABORATION

MAGIC Major Atmospheric Gamma Imaging Cerenkov Telescopes

UNIVERSIDAD COMPLUTENSE MADRID

IPARCOS

The on-site analysis of the MAGIC and LST-1 telescopes

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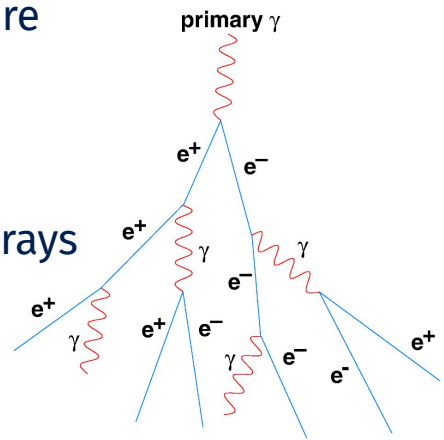
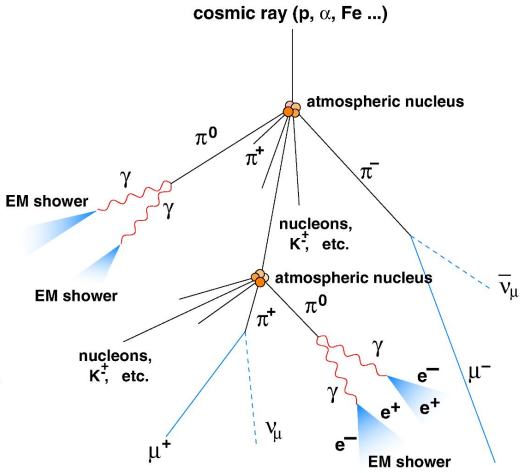
Very-high-energy (VHE) astrophysics

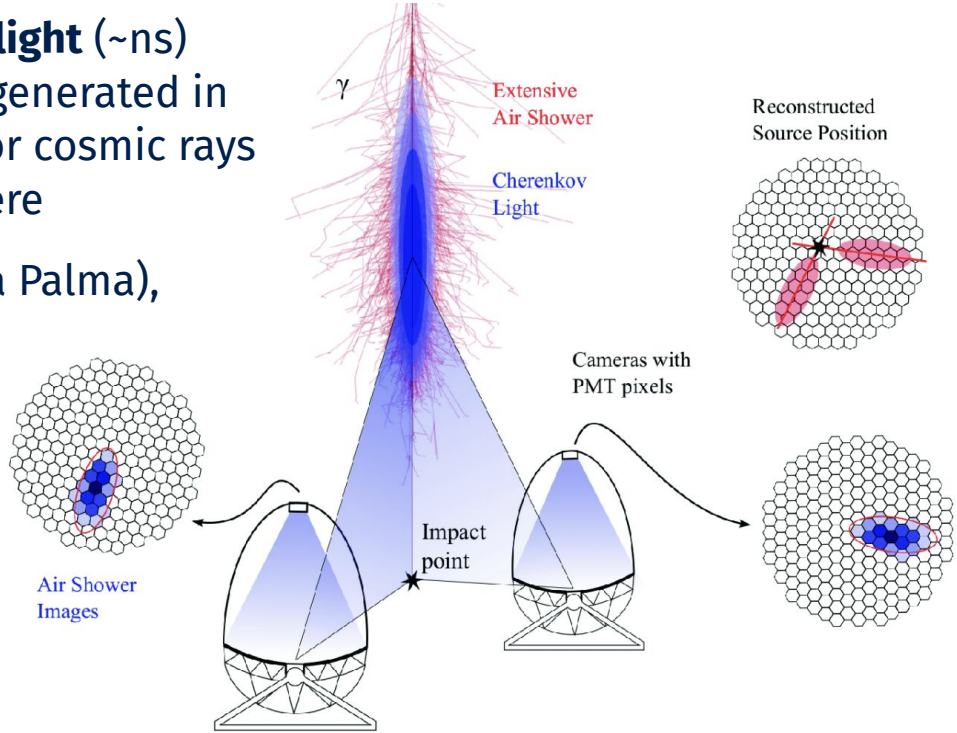
- VHE gamma rays: > 100 GeV
- **Electromagnetic showers**: generated by a gamma ray when it enters the Earth's atmosphere
  - $\gamma \rightarrow e^+e^-$ (pair creation)
  - $e^\pm \rightarrow \gamma$ (*Bremsstrahlung*)
- **Hadronic showers**: produced by cosmic rays (more diffuse and irregular structure)
  - CR + atm. nucleus → π^0, $\pi^\pm$ + N*
  - $\pi^\pm \rightarrow \mu^\pm + \nu$
  - $\pi^0 \rightarrow \gamma\gamma$ → electromagnetic shower





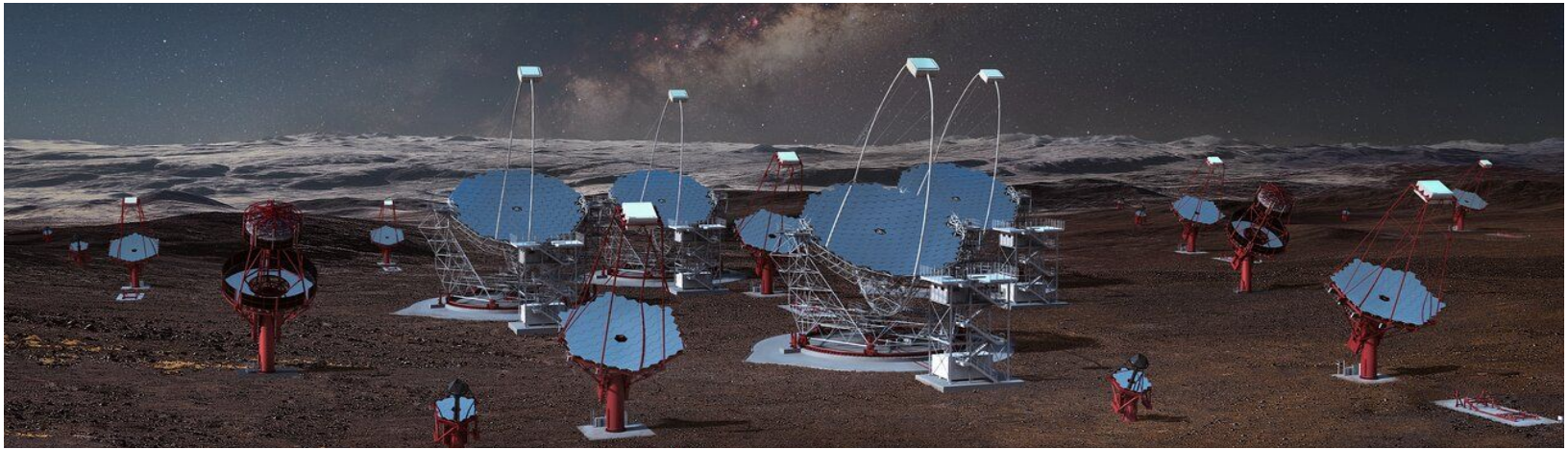
Imaging Atmospheric Cherenkov Telescopes (IACTs)

- They detect the flashes of **Cherenkov light** (~ns) produced by the secondary particles generated in the showers induced by gamma rays or cosmic rays in their interaction with the atmosphere
- Current generation of IACTs: **MAGIC** (La Palma), **VERITAS** (Arizona), **H.E.S.S.** (Namibia)
- **CTA (Cherenkov Telescope Array)**: next-generation of IACTs, with 64 telescopes in its first phase (13 in the northern hemisphere and 51 in the southern hemisphere)



CTA Observatory

- **Larged-Sized Telescopes (LSTs):** ∅ 23m, [10 - 100 GeV], 4 in CTA-North
- **Medium-Sized Telescopes (MSTs):** ∅ 12m, [100 GeV - 10 TeV], 9 in CTA-North (NectarCAM), 14 in CTA-South (FlashCam)
- **Small-Sized Telescopes (SSTs):** ∅ 4m, [5 - 100 TeV], 37 in CTA-South

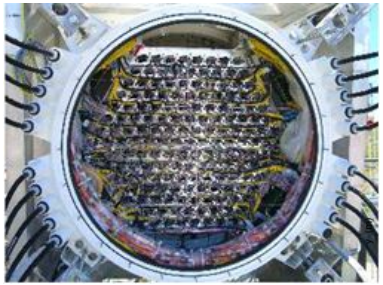


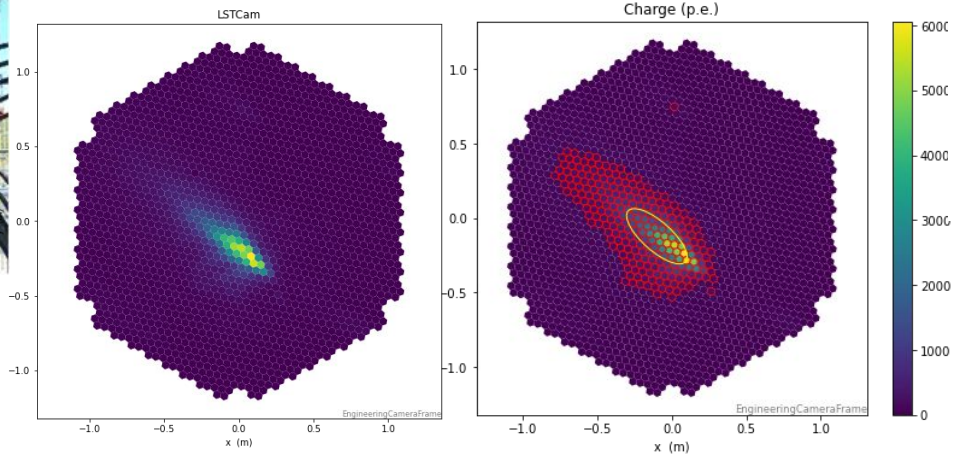
IACT telescopes: MAGIC y LST-1

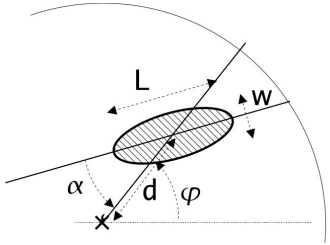
- Located in the Observatorio del Roque de los Muchachos (ORM) in La Palma (Canary Islands), at an altitude of ~2200 m
- **MAGIC**: 2 telescopes of 17 m of diameter
- **LST-1**: Larged-Sized-Telescope prototype of CTA-North (which includes 4 LSTs), 23 m of diameter

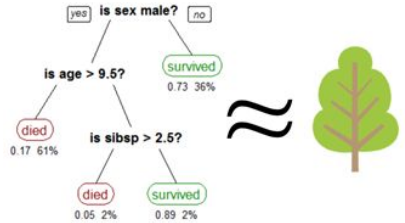
Data analysis of Cherenkov telescopes

Extracción señal y calibración → Limpieza y parámetros de imagen → Reconstrucción dirección y energía → Separación gamma/hadrón → Extracción señal γ y Análisis de alto Nivel









On-site analysis: MAGIC OSA and lstosa

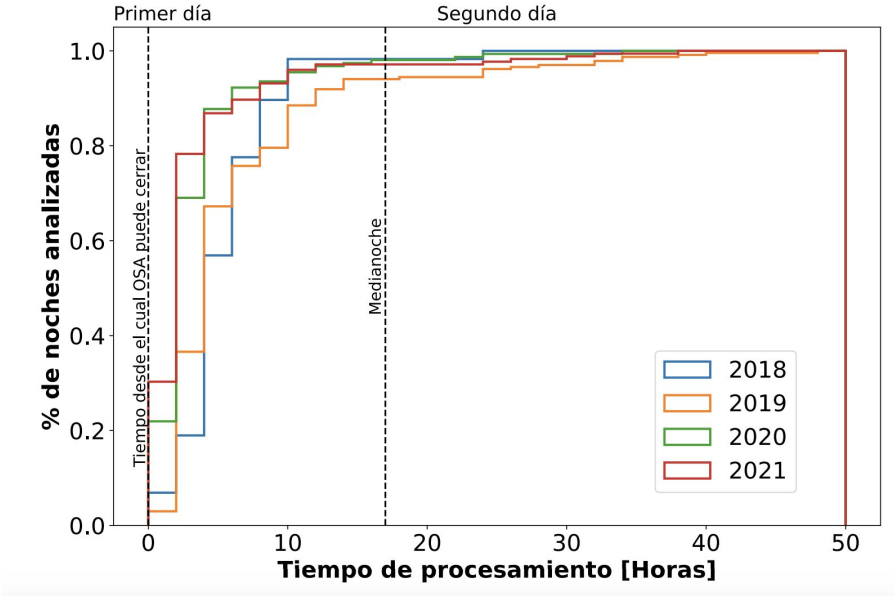
- **Fast on-site analysis** of the data taken each night by MAGIC and LST-1 → goals:
  - **reduce the size** of the data considerably (otherwise, due to the large size of the recorded raw data, their transfer to continental Europe would take too long)
  - provide **analysis products** available for the entire collaboration (important to be able to react quickly, e.g. GRBs)
  - **detect problems**
- ***MAGIC OSA***: operating steadily in MAGIC since years → maintenance and supervision
- ***lstosa***: in active development for the LST-1

On-site data centers:

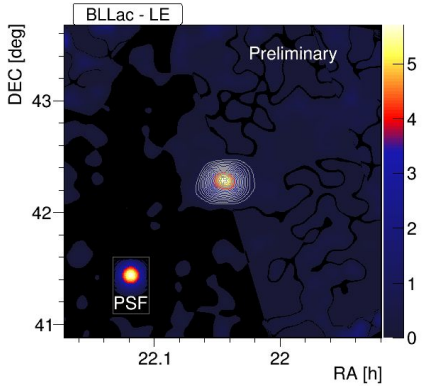
- **Both MAGIC and CTA have onsite data centers** located at the ORM observatory
  - **MAGIC** ~ around 10 analysis machines, 40 cores, 70 TB of disk
  - **CTA** ~ 60 machines, 1800 cores, 5.7 PB of disk

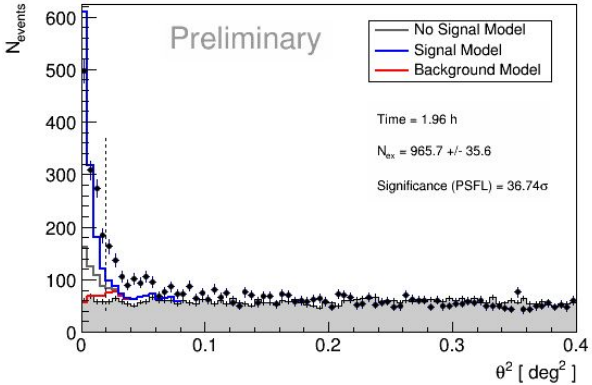
On-site analysis: MAGIC OSA

Next-day data processing:



High-level products:





On-site analysis: lstosa

A nearly automatic system running at LST IT center @ La Palma → allows all the data taken by LST-1 to be saved and processed (data acquisition rate: **3 TB/hour of observation**)

Open access code written in python:
github.com/cta-observatory/lstosa

Aims:

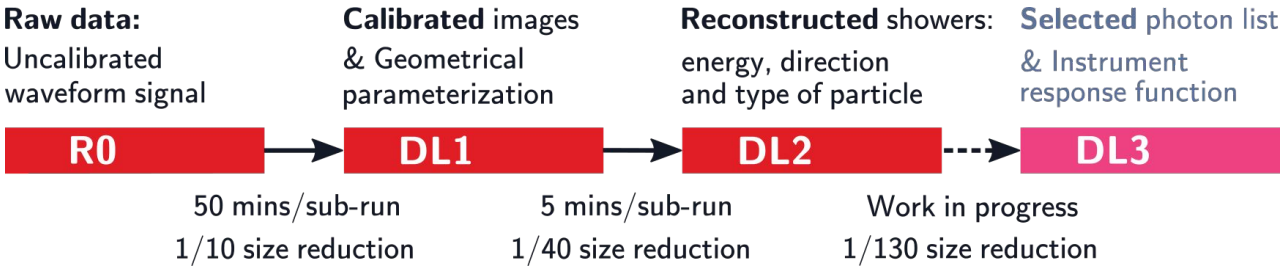
- Perform next-day standard analysis
- Provide data-quality plots
- Reprocess data with each major `cta-lstchain` release
- Produce gain selected (R0G) and volume reduced data (R0V)

How:

- Early morning cron jobs
- Pipe `cta-lstchain` analysis stages
- SLURM job scheduler integration

On-site analysis: lstosa

- **Next-day data processing**: data analysis steps implemented in ***cta-lstchain*** (https://github.com/cta-observatory/cta-lstchain), the standard analysis pipeline for LST-1 data



- For each subrun (~10 s of observation time), there are 4 streams of **R0 files** each with a size of ~1.3 GB (total of **~ 5 GB**). A **DL1 file** of a subrun has a size of **~700 MB**.

lstosa

*DL1b products from 5-7 hours of observations are ready the next day around noon (currently, only files up to DL1 level are being produced)

On-site analysis: lstosa

LSTOSA Sequencer in the LST onsite IT center

Sequencer at 2021-04-2009:50:05UTC Telescopes found: LST1

Tel	Seq	Parent	Type	Run	Subruns	Source	Wobble	Action	Tries	JobID	State	Host	CPU_time	Walltime	Exit	DL1%	MUONS%	DL1AB%	DATACHECK%	DL2%
LST1	0	None	PEDCALIB	4499	9	None	None	Check	1	7568741	COMPLETED	None	00:39:12	None	0:0	None	None	None	None	None
LST1	1	0	DATA	4490	109	None	None	Check	1	7568742	COMPLETED	None	01:21:56	None	0:0	100	100	100	100	100
LST1	2	0	DATA	4491	100	None	None	Check	1	7568743	COMPLETED	None	01:18:42	None	0:0	100	100	100	100	100
LST1	3	0	DATA	4492	95	None	None	Check	1	7568744	COMPLETED	None	01:19:42	None	0:0	100	100	100	100	100
LST1	4	0	DATA	4493	76	None	None	Check	1	7568745	COMPLETED	None	01:09:42	None	0:0	100	100	100	100	100
LST1	5	0	DATA	4494	130	None	None	Check	1	7568746	COMPLETED	None	00:42:34	None	0:0	100	100	100	100	100
LST1	6	0	DATA	4495	103	None	None	Check	1	7568747	COMPLETED	None	00:45:41	None	0:0	100	100	100	100	100
LST1	7	0	DATA	4496	144	None	None	Check	1	7568748	COMPLETED	None	00:40:45	None	0:0	100	100	100	100	100
LST1	8	0	DATA	4497	141	None	None	Check	1	7568749	COMPLETED	None	00:44:14	None	0:0	100	100	100	100	100
LST1	9	0	DATA	4498	145	None	None	Check	1	7568750	COMPLETED	None	00:43:07	None	0:0	100	100	100	100	100
LST1	10	0	DATA	4500	284	None	None	Check	1	7568751	RUNNING	None	00:40:27	None	None	100	100	99	66	58
LST1	11	0	DATA	4501	237	None	None	Check	1	7568752	RUNNING	None	00:33:32	None	None	100	61	20	0	0
LST1	12	0	DATA	4502	171	None	None	Check	1	7568753	RUNNING	None	00:16:52	None	None	100	0	0	0	0
LST1	13	0	DATA	4503	129	None	None	Check	1	7568754	RUNNING	None	00:02:52	None	None	77	0	0	0	0

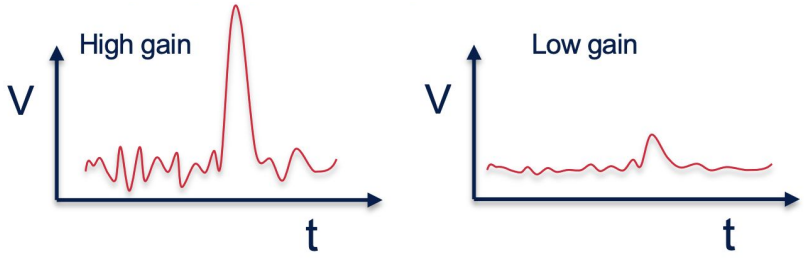
lstosa

lstosa: gain selection and data volume reduction

Running out of space in FEFS disk in the IT center (its size is 5.7 PB)

⇨ solution: reduce R0 size by producing reduced files

- **R0G** (keep only significant gain)
- **R0V** (+keep only significant pixels)



- **R0 data** from the LST camera consists of digitized waveforms for every pixel
- **Two gains** per pixel (high & low signal amplification), to increase dynamic range - high gain saturates at O(100) p.e. per pixel

lstosa: gain selection and data volume reduction

R0 (raw data)

- Digitized waveforms for every pixel
- Two gains

*Only applied to sky-data runs. The rest of R0 files (such as calibration runs) cannot be transformed into R0G or R0V and are directly copied to the final directories.

R0G

- One gain, contains all pixels for files with sky_data with showers.
- Interleaved FF/pedestal contains two gains and all pixels*
- Data are transferred to the Offsite Centers

~60% of the original (R0)

~21% of the R0G

R0V

- One gain
- Useful pixels are selected based on the DL1 data
- Data are kept in the IT Container

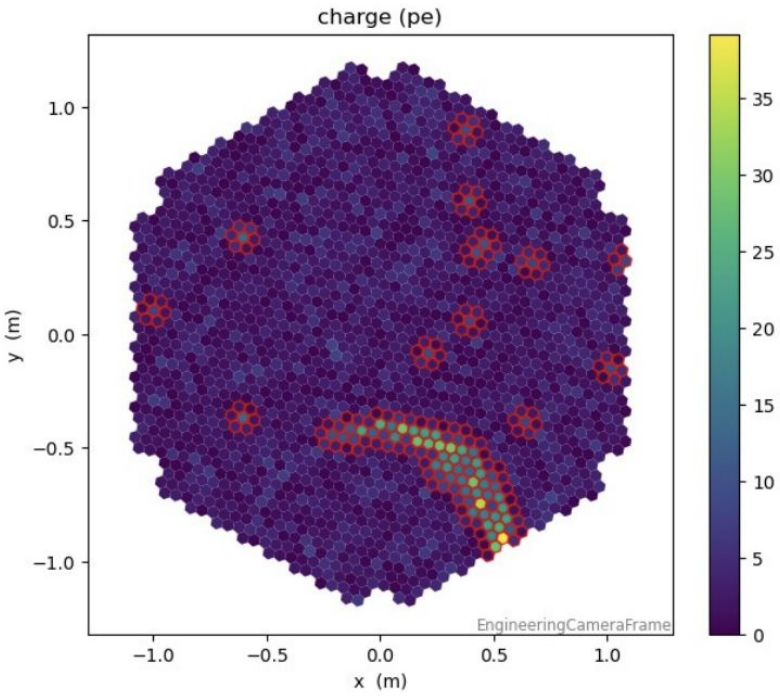
~13% of the original (R0)

*LST-1 takes data at a rate of (6–10) kHz. Interleaved pedestals (camera triggered to record “noise-only events”) and interleaved flatfield events (camera illuminated uniformly) are taken at ~100 Hz.

Data volume reduction

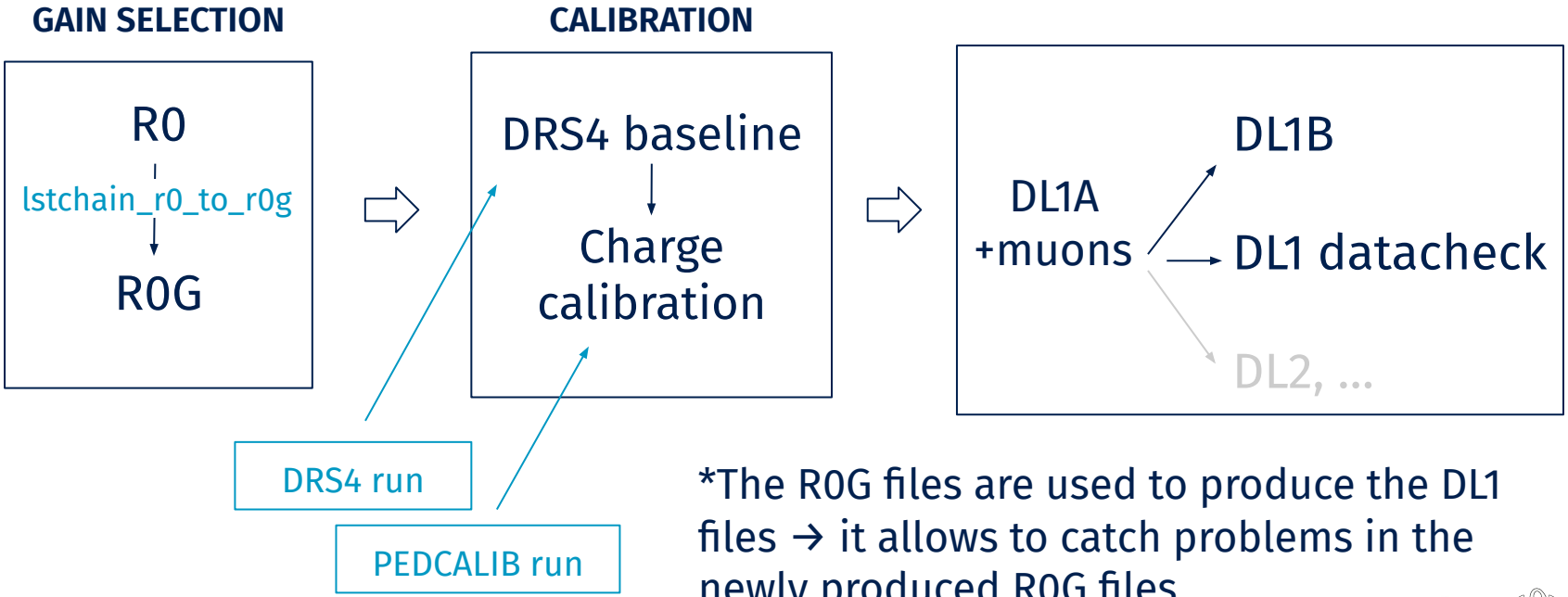
Pixel selection algorithm based on **DL1a**:

- keep **all pixels above 8 p.e.** (default cleaning picture threshold)
- keep **1 ring of neighbour pixels** around those
- for high-NSB data, the 8 p.e. value is raised in steps of 1 p.e. until the fraction of surviving pixels in cosmics is ≤10%
- For large showers (≥ 500 selected pixels), all pixels are kept (gain-selected)



lstosa: automatic gain selection

CURRENT WORKFLOW



*The R0G files are used to produce the DL1 files → it allows to catch problems in the newly produced R0G files.

Summary

- On-site analysis of MAGIC and LST-1: **MAGIC OSA** and **lstosa**
- **Fast on-site analysis** of the data taken each night by MAGIC and LST-1 to reduce the size of the data considerably + provide analysis products
- lstosa: **gain selection** and **data volume reduction**

THANK YOU FOR YOUR ATTENTION!

backup

lstosa workflow