MAGIC technical challenges, upgrades and final performance

Image Credit: Urs Leutenegger (@urs.leutenegger)

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MAGIC and Technology

- **MAGIC founders mindset:** exploring uncharted VHE gamma-ray territory by a leap on state-of-the-art technology for IACTs.

- **Technical challenges:**

(1) Building a telescope catching as much Cherenkov photons as possible for lowest energy threshold:

* Large reflector
* Highly reflective mirrors
* Very sensitive camera

(2) Building a telescope as light as possible for fast repositioning for transients -> lightweight structure

MAGIC streamlined timeline

- 2003: MAGIC inauguration in October
- 2004: First MAGIC data
- 2005: First scientific papers
- 2007: First MAGIC upgrade (DAQ)
- 2009: MAGIC-2 installation and first data
- 2011/12: Major MAGIC-1 upgrade (camera, DAQ,

Technical challenges

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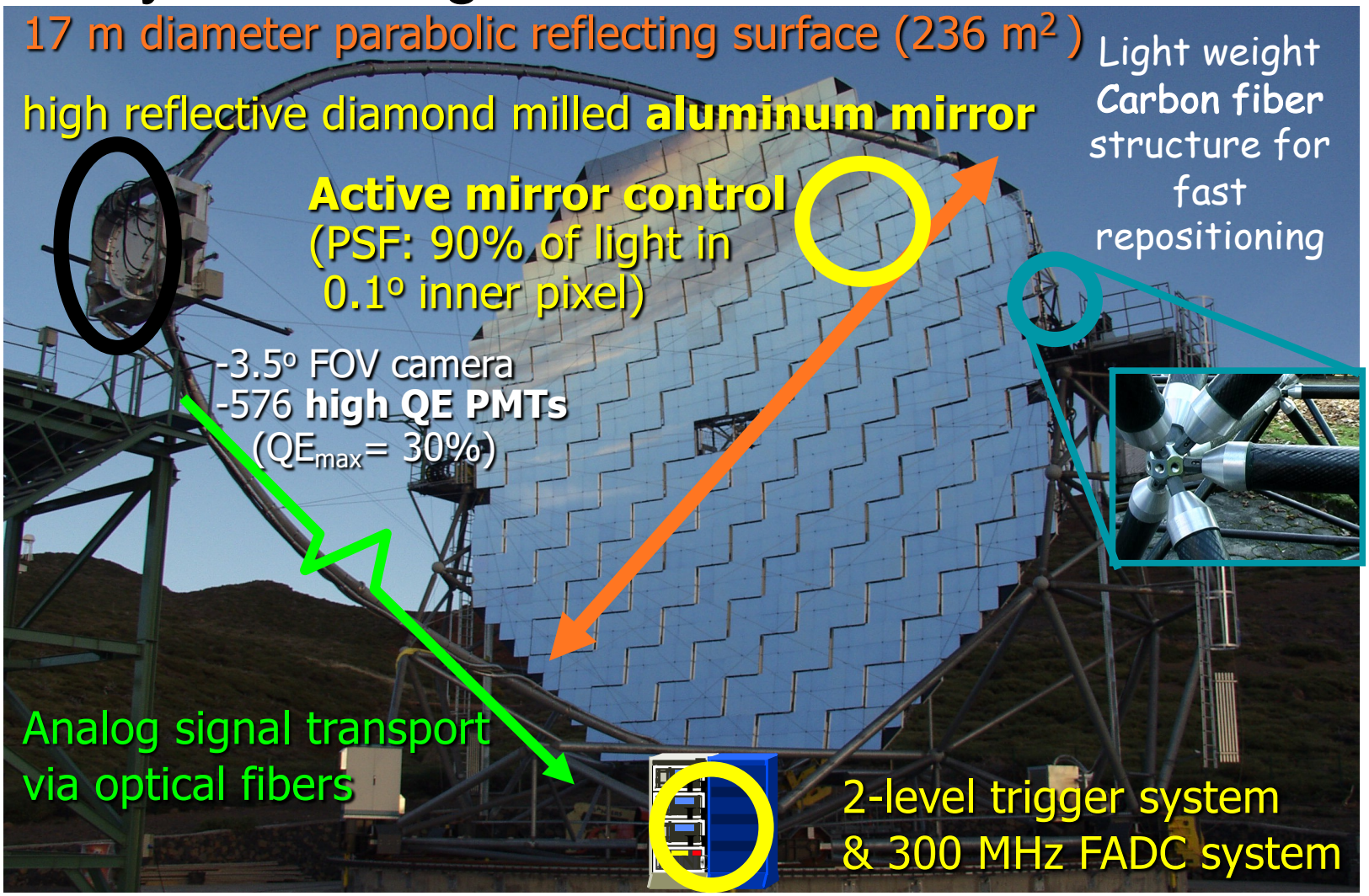
Key technological elements for MAGIC



MAGIC design goal:
very fast re-pointing
to catch GRB

➔ not very rigid

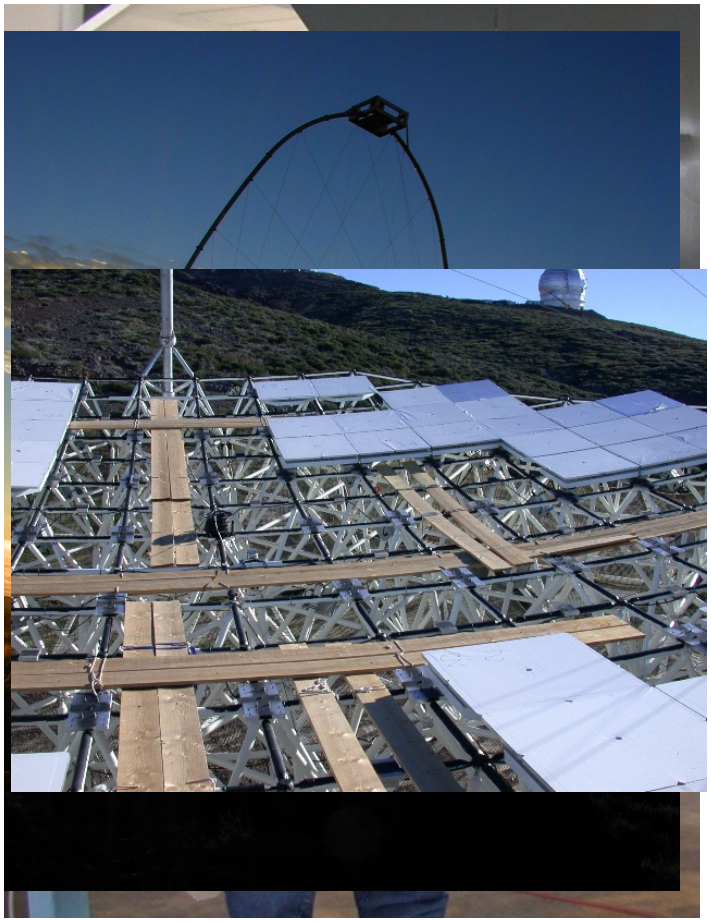
➔ need continuously realign the 234 mirror segments

➔ Active Mirror Control (AMC)

MAGIC@20

The reflector

- 17 m diameter!!
  3 x area of 10 m IACTs
- Parabolic: isochronous, allowing for bg reduction
- Tesselated reflector:
  - ~950 mirror elements
  - 49.5 x 49.5 cm^2
  - All-aluminum, quartz coated, diamond milled, internal heating
  - >85% reflectivity in 300-650nm



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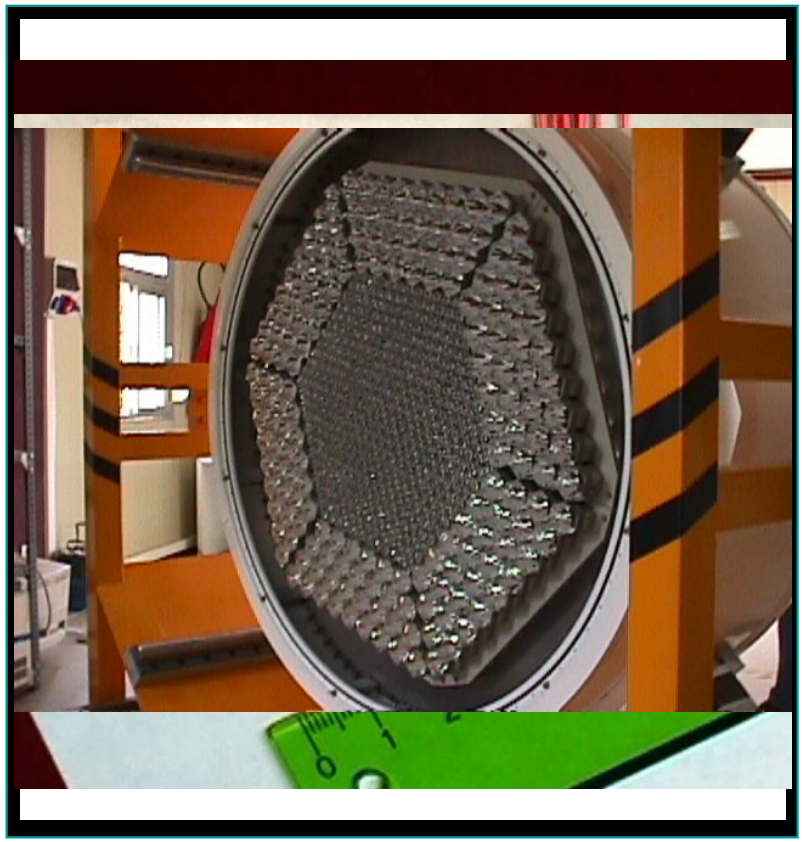
Active Mirror Control of MAGIC

(lasers used to calibrate AMC)

The camera

- **Matrix of 577 PMTs**
  - Two sections:
    - Inner part: 0.1^0 PMTs
    - Outer part: 0.2^0 PMTs
- **Pixels**
  - Bialkali PMTs, <QE>~26% (330-450 nm)
  - Modular Pixels.
- **Plate of Wiston cones**
  ⇒ Active camera area ~100%



MAGIC@20

The readout

Shower cherenkov light pulses are typically ~ ns long

- **Pixel signal transported ~100 m over analog optical fibre using VCSELs:**
  - Signal still short
  - Cable weight, optically decoupled, noise inmune.
- **Digitization using 300 MHz-1GHz FlashADCs:**
  - γ/h discrimination through signal shape
  - Noise reduction
  - Event buffering, telescope system synchronization...

Upgrades

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Upgrades on MAGIC-1:

- After inauguration for Mono:

* DAQ upgrade, from Siegen FADC to MUX,

* SumTrigger for MAGIC-1

- After MAGIC-2 already in operation (2011-2012):

* Camera of MAGIC-1,

* DAQ from Domino-2 to Domino-4 ring samplers chips

The largest upgrade: MAGIC-2 (2009)

MAGIC-1 Control house MAGIC-2

Further overal improvements:

- **SumTrigger for MAGIC stereo**,
  => increase sensitivity at lowest gamma-ray energies
  → Detection of Geminga pulsar

- **Very Large Zenith Angle observations**
  => increase sensitivity at highest gamma-ray energies
  → Detection of Crab at 100 TeV

- **LIDAR for monitoring atmosphere**,
  => MAGIC currently only IACT using customarily this technique

Final performance

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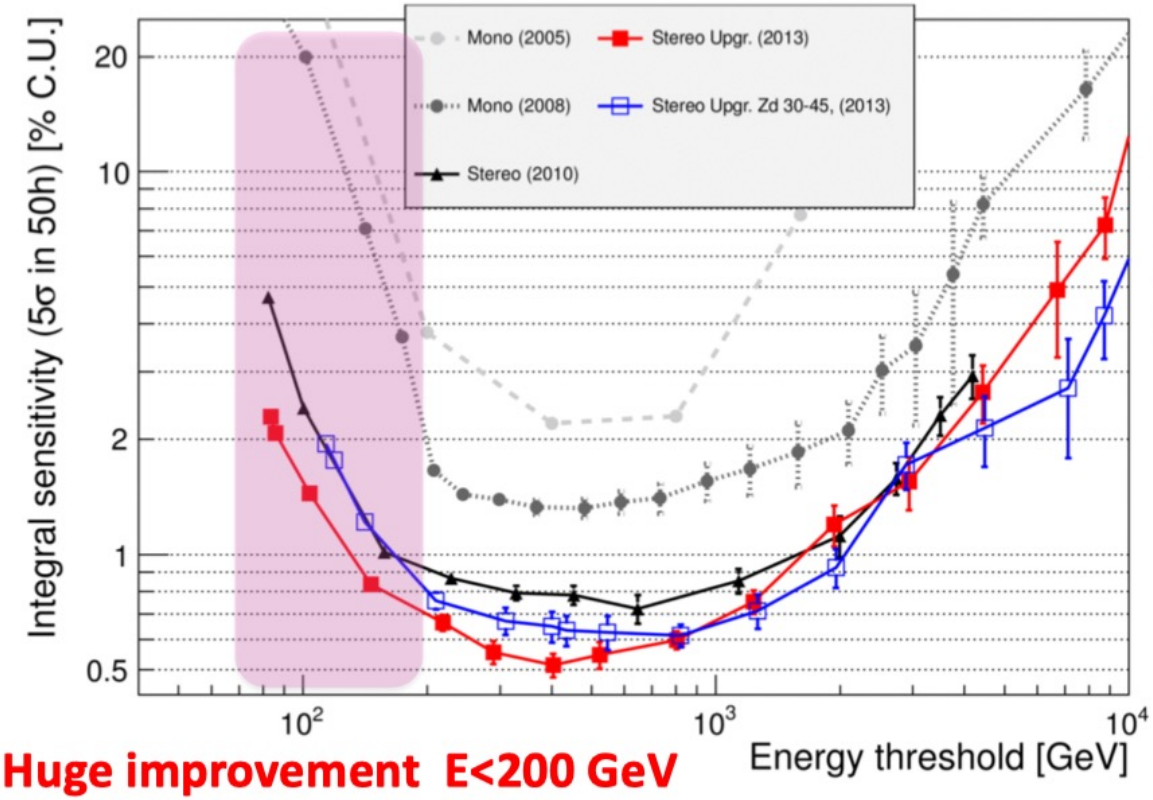
Evolution of the MAGIC Performance

4-fold improvement in sensitivity over the last 20 years

→ More than 10-fold improvement below 200 GeV

→ Obs. time for detection reduced 100 times below 200 GeV



Aleksic et al., (MAGIC collab.) Astroparticle Physics 72, 76-92, 2016

Huge improvement E<200 GeV

Better sensitivity + Lower energy threshold = More science !!

Final performance...?

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The first CTA-LST (→ LST-1) is in place

Virtual visit to the CTA-North observatory:
https://tour.klapty.com/NH20OJ5Iae/?deeplinking=true&startscene=0&startactions=lookat(-67.07,23.81,90,0,0)

MAGIC-LST1 proximity allows joint observations for better angular & energy resolution, and better sensitivity (*Soft. and Hard. trigger*)

About 1.3-1.5 better sensitivity → ***reduction of obs. time by ~2.0***

Thank you for your attention!

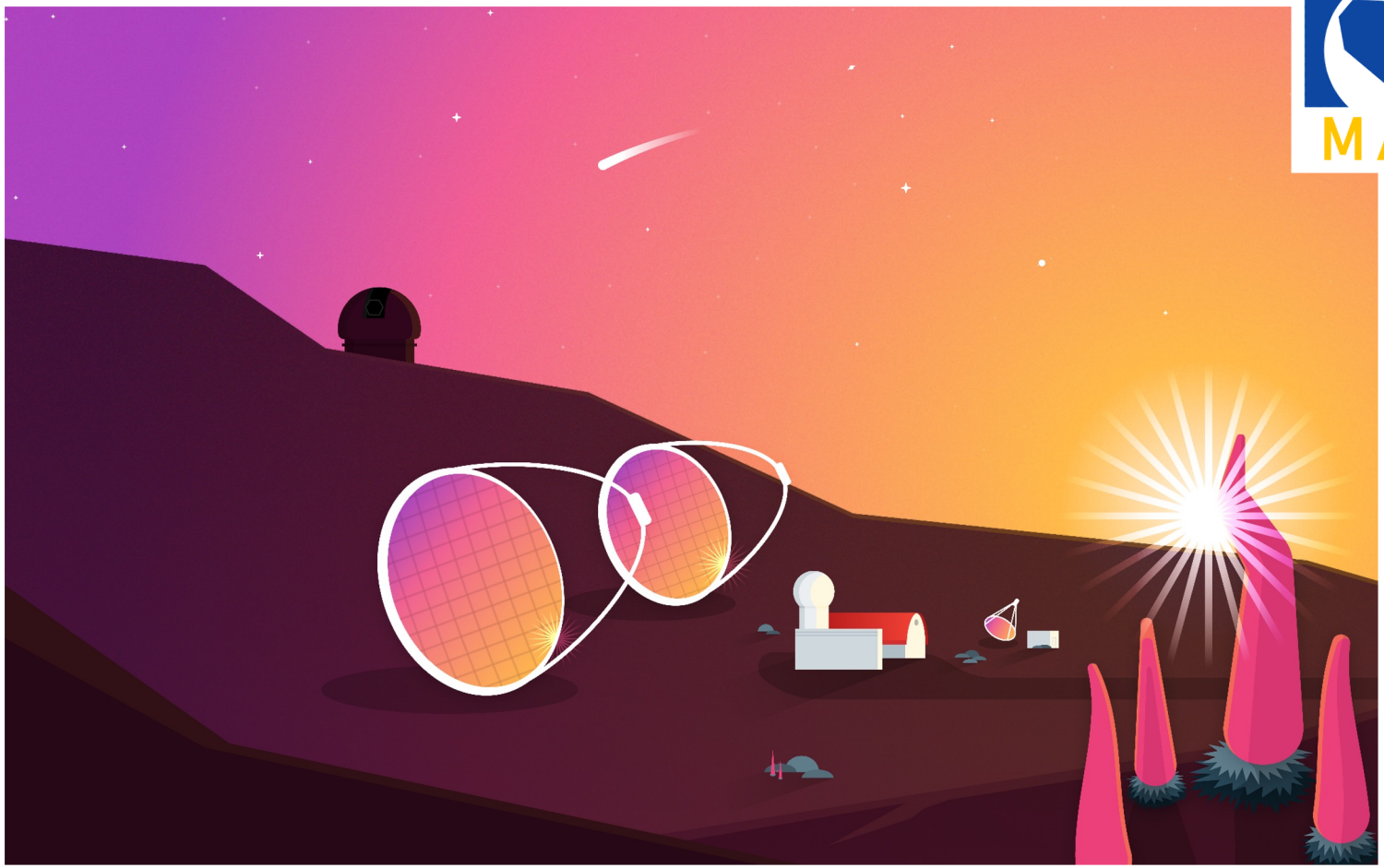

Image credit:: Jayant Abhir

02-07 October 2023 – 20 MAGIC years