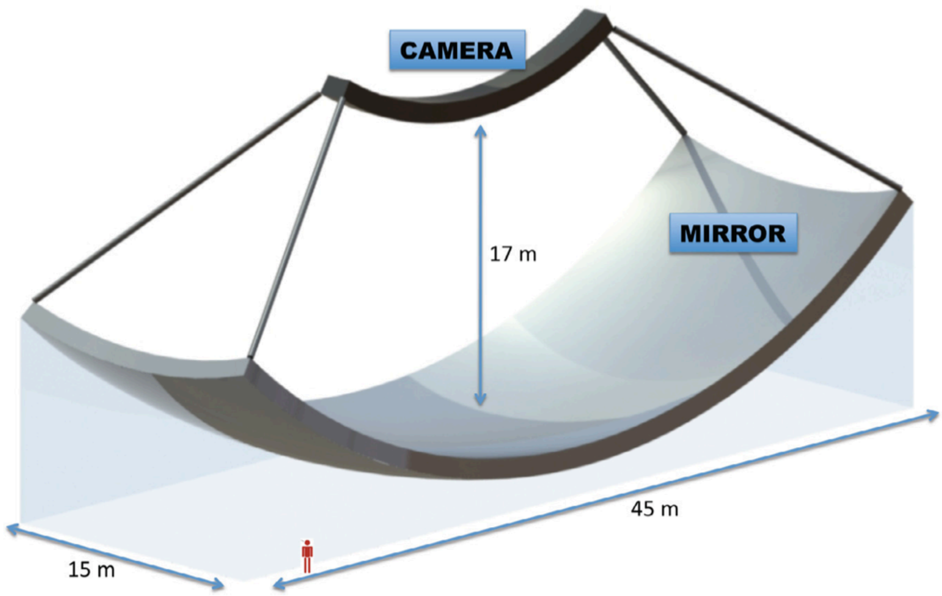
MACHETE: Towards a Preliminary Technical Design Report

J. Cortina, May 27th 2016

Instrument and physics in short

This section is an extract from Astroparticle Physics 72 (2016) 46–54.

MACHETE are two identical telescopes, ~100 m from each other in the east – west direction. General dimensions of one of the telescopes:



The longest axis of the telescope is aligned north - south. Here are the parameters of one camera:

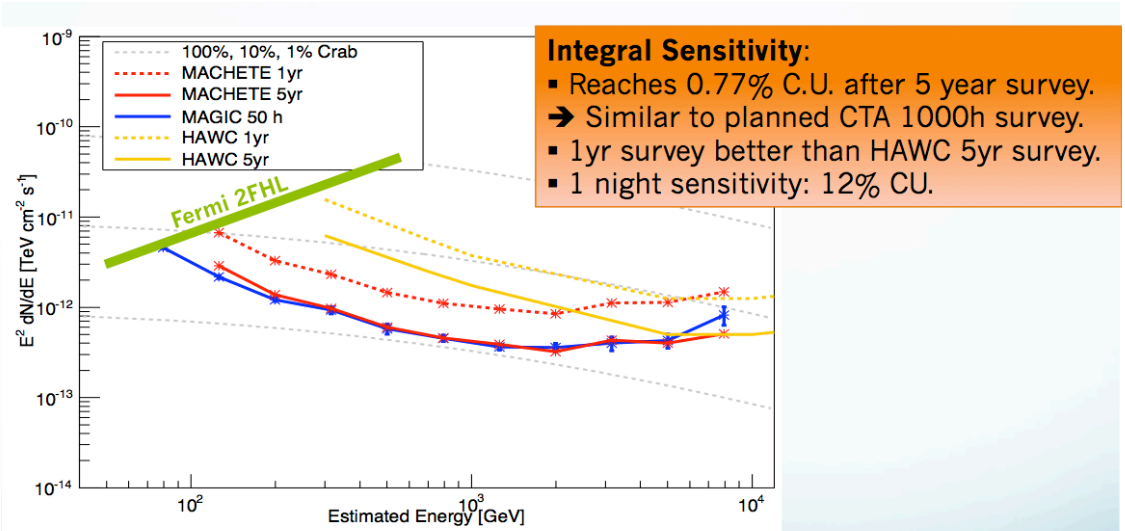
	D=12m, f=17m, f/D=1.42
Plate scale	300 mm/deg
$Ø_{pix}$ >~ $2r_{80\%}$	0.16° = 48 mm
Total mirror surface	619 m^2
Mirror surface viewed by a pixel	113 m^2
Camera FOV	60° × 5° = 300 deg^2
Number pixels	~15 000
Photosensor Ø (Light guide concentration factor in radius=3)	15 mm

Key facts of telescope operation:

- Every object in ~half of the sky drifts through the camera of MACHETE along a year.
- In one year we integrate ~15 hours for each of these objects (assuming only dark time).

- Objects in ~1/4 sky spend about 20 minutes every night in the FOV of the telescopes.

Expected performance:



Angular resolution is 0.1° and spectral resolution 20-15% (both similar to MAGIC and much better than HAWC).

Physics case:

- A survey of half of the sky:
  - New Active Galactic Nuclei (Fermi 2FHL: about 230 AGNs detected >50 GeV, most of them not detected by IACT yet).
  - New galactic sources, especially if built in the south.

  … and the unknown:
  - “Dark sources” = sources emitting only in VHE.
  - Hadronic AGNs
  - Dark matter clumps?
  - New types of transients.

- Valuable archive: would provide years-long data sample for phenomena discovered in the future (periodicities, transients)

- Monitor bright VHE sources:
  - Unbiased light curves of AGN and galactic sources.
  - Establish unknown duty cycles (e.g. IC-310).
  - Trigger CTA and other telescopes.

Cost estimate

Mirrors:

- Mirrors or camera can be heavier: assuming 1k€/m^2 for mirrors (M. Mariotti, M. Doro, INFN Padova) and 619 m2/telescope, it’s 1.2 M€ for two telescopes.
- Reminder: all mirror facets are equal so production, testing and installation benefits from maximum economy of scale.

Camera:

- Number of pixels similar to CTA SCT (15000 in MACHETE and 11328 in SCT) and planned readouts are almost identical.

- They are already building a prototype so their cost estimate is solid. Let's consider CTA cost book (MAN-PLANS/140505) and V. Vassiliev, SCT presentation at CTA STAC meeting, June 2015.
- Cost of camera, including photosensors (6.2mm side SiPM), readout electronics et al, plus **labor** and **contingency** = 0.9 M$ =0.8 M€. Scaling with number of pixels in MACHETE, 2.1 M€ for two telescopes.
- However MACHETE's pixels would be larger by factor 5.9. For an SCT, photosensors represent 41% of the camera cost. Assuming SiPM cost scales linearly, MACHETE photosensors would cost 5.3 M€/2 telescopes.
- In conclusion cost of the 2 MACHETE cameras is estimated as 7.1 M€.
- There's significant potential to reduce the cost of the SiPM: e.g. FBK is advertising 0.3 $/mm2 and even lower prices.

Mechanics, foundation:
- Since telescope will be fixed to the ground, we assume that we need no mirror actuators.
- No steering (no motors, corresponding electronics and power).
- Foundation: forces are reduced because
    - Mirror is horizontal (and could be shielded) so wind force is small.
    - No acceleration forces.
- Mirror surface of LST is 400 m2 and foundation costs 0.5 M€/LST. Let's assume 0.5 M€ for both MACHETE telescopes.
- Mechanics hard to estimate with no full design, because it's different than most IACTs. Let's assume a rather simple steel construction and 0.5 M€ for both MACHETE telescopes.

Item	Capital cost for 2 telescopes
Mirrors	1.2 M€
Camera: photosensors	5.3 M€
Camera: readout and others	1.8 M€
Foundation	0.5 M€
Mechanical structure	0.5 M€
Auxiliary, computing and others	0.5 M€
TOTAL	**9.8 M€**

The experimental context

MACHETE will compete with CTA for a fraction of the physics:
- Extragalactic survey of MACHETE is as good as proposed survey of CTA.
- MACHETE can provide some of the triggers for transients and AGNs that are included in CTA KSPs.
- However MACHETE is a dedicated experiment: CTA cannot spend its whole time on systematically looking for transients.

MACHETE will compete with CTA for funds and manpower:
- Both Abelardo and Juan have strong roles in CTA and are trying to secure funding of CTA.
- It is not only about the money: jumping into another experiment would look like we are not sure about CTA.

New in the last months: only ~60% of the full budget of CTA is secured. CTA plans to stage construction, i.e. start with only ~60% of the telescopes. CTA is also facing troubles with escalating operation costs and delays in funding of key countries (main one: France). This all means that the full array will not be ready for the first 10 (?) years even after construction is finished (i.e. no full array before ~2033).

There may be few (5?) MSTs in the north and only ~60% (~15) in the south. Pressure will build to concentrate on galactic physics in the south, so it will be hard to make an extragalactic survey either in the south due to lack of time or in the north due to lack of telescopes. There are already discussions about dropping some Key Science Programs and the extragalactic survey may be one of them. This gives MACHETE an option to beat CTA in the extragalactic survey.

On the other hand prospects are good to build 4 LSTs in the north and 4 LSTs are especially good for transients. This may be a good match for MACHETE if it is built in the north and relatively close to LSTs (La Palma or Tenerife) to maximize common observations.

MACHETE may have become an integral part of CTA if it had been proposed before the concept of CTA was complete. Now it is too late. It is probably better to keep them separate, but sign a cooperation agreement with CTA so that:

- MACHETE delivers triggers and positions of new sources to CTA and members of MACHETE get included in corresponding papers.
- MACHETE can use CTA's analysis and MC software, data formats (in principle CTA plans to open its software).

Proposal: finish PTDR by Summer 2017

I am personally very busy with LST until Spring 2017. Then the design and the installation of parts that I'm responsible for is over. In fact many Spaniards will be in the same situation because the Spanish money will flow through IAC and will be spent by companies through public biddings. However we can get some money at IFAE for design studies and limited prototyping.

Hopefully detailed plans and construction schedule of CTA will settle by the end of 2016 (otherwise even better for MACHETE). Once settled we can apply for money in 2017 because goals and timelines are clear.

MACHETE has been presented at several places: ICRC, La Palma, UCLA, recently in an internal workshop at MPK Heidelberg. No significant issues have been raised. Most of the discussion has focused on the cost estimate. It is clear that we need a more realistic cost estimate.

Proposal is to finish a Preliminary Technical Design Report by Summer 2017, including a realistic cost estimate. If we are satisfied with the technical solution, the expected performance and the cost estimate, we can apply for funding of full-scale prototype or key elements.

PTDR: considerations and work distribution

We can benefit from the technical developments of CTA:

- Pixel size of MACHETE similar to LST and MST
- There are developments at INFN for the future LST SiPM camera.
- SCT has almost as many pixels as MACHETE.

In order to save resources and facilitate common work, we should keep compatibility with CTA in:

- Analysis software.
- MC software.
- Data format.
- Physics tools.

Since the telescope is fixed to the ground and we expect to need no Active Mirror Control, there are few moving parts. On the other hand, operation is straightforward: no schedule, just taking data whenever weather and Moon allows. The telescope can aim at:

- Zero maintenance.
- Robotic operation.

How can we split the work? Here are some ideas, but it is essential up to you.

1. I have now some experience in mechanical design and foundation. IFAE could take care to make the mechanical design of the telescope, including the sun protection and the lids. CIEMAT has experience in camera mechanics and may be interested too.

2. IFAE could design the onsite and offsite analysis system: i.e. define needs for computing and storage.

3. The light concentrators are essential in the instrument because they define the PSF. I have been working on the subject and would like to remain involved. Other groups have lots of experience too and may want to collaborate: ETH built the light concentrators for FACT and INFN Padova is working in the design of the concentrators of the LST SiPM camera.

4. Mirrors: we must make them cheap (~1 k€/m2) but we can relax the weight constraint. But we need realistic numbers for both cost and weight, so we must choose a specific technology.

5. Photodetectors: many reasons why SiPMs are optimal for MACHETE. They drive the cost and the threshold of the instrument so it is essential to find the right device (or array). I have heard many good reports about the latest model of FBK ("Characterization of three high efficient and blue sensitive Silicon photomultipliers", A. Nepomuk Otte et al, submitted) and I have heard from R. Ong that they are cheap (<<1 $/mm2).

6. Readout: a major challenge, because it is 15000 pixels / camera and very high rate (~10 kHz). Riccardo Paoletti actually proposed to use TARGET and a specific system to read only a Region of Interest around the triggering pixels.

7. We should avoid active mirror control but we need to make sure that it is possible. How to align the mirrors is actually an open question because the telescope cannot track stars or point to any arbitrary reference light source. Arecibo uses photogrammetry every X years (MST hired a company to do the same for their prototype in Berlin).

8. The robotic operation of FACT is a success. ETH may advice here.

9. We need to design the telescope so that we can make optical observations at the same time, i.e. every pixel must have a DC-coupled branch where one can measure the absolute level of the light background. The corresponding readout, storage and analysis chain must be designed too.