Participation in the integration, qualification, instalation and commissioning of the LST prototype and its industrialization

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1) Motivation
2) Precedents
3) CTA
4) How it works
5) Simulations
6) Conclusions & Future Aims

Motivation

Outer space still has many enigmas which humanity is still looking an answer for

The answer to those mysteries may be found in different stellar bodies, such as:

- Supernovae and their remnants (black holes, pulsars)
- Dark matter
- Binary systems
- Cosmic voids

These bodies can be observed by means of specialized telescopes, capable of detecting the interaction of cosmic and γ rays with the atmosphere

Precedents

H.E.S.S. (High Energy Stereotypic System) in Göllschau (Namibia) since 2003

MAGIC (Major Atmospheric Gamma Imaging Cherenkov Telescopes) in the Roque de los Muchachos Observatory (La Palma, Spain) since 2004

VERITAS (Very Energetic Radiation Imaging Telescope Array System) in Fred Lawrence Whipple Observatory (EEUU) since 2007

CTA (I)

CTA: international consortium initiated for the construction of the Cherenkov Telescope Array

1350+ members, 216 institutions, 32 countries

Headquartered in Bologna (Italy)

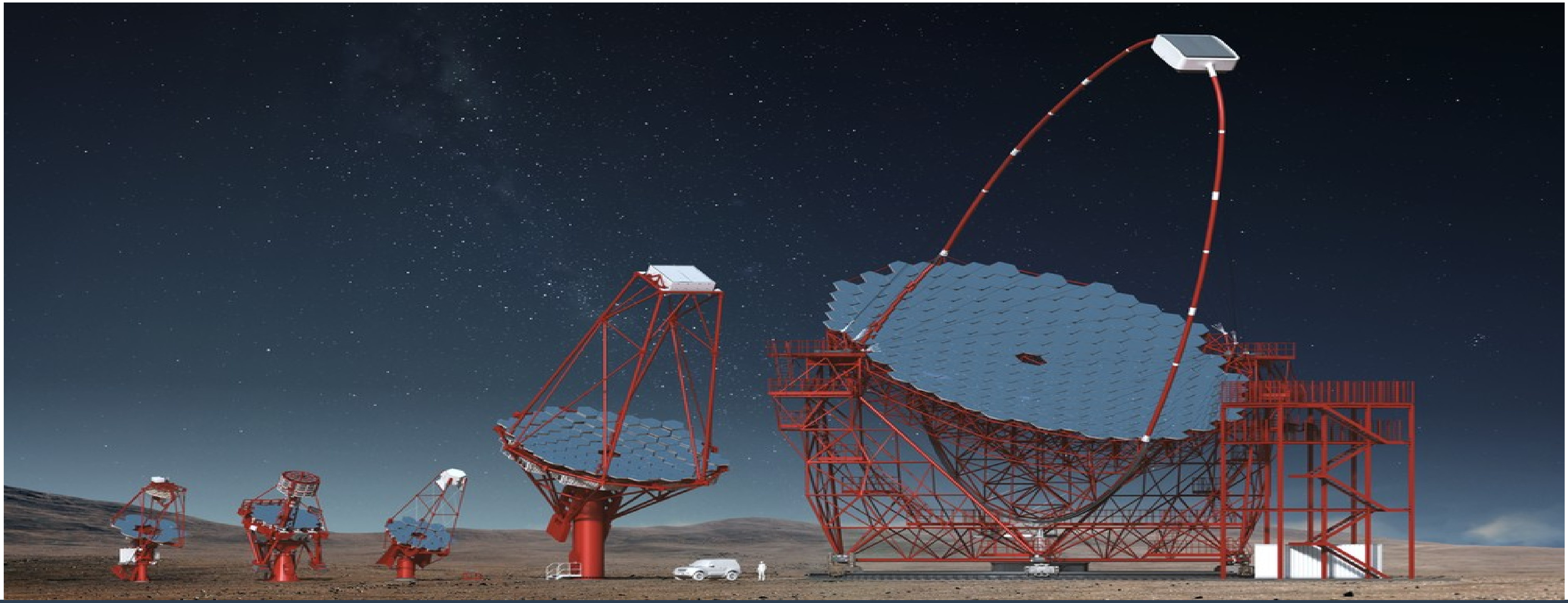
Data Management Center in Zeuthen (Germany)

Two telescope arrays undergoing construction: Roque de los Muchachos (La Palma) and Cerro Paranal (Chile)

CTA (II)

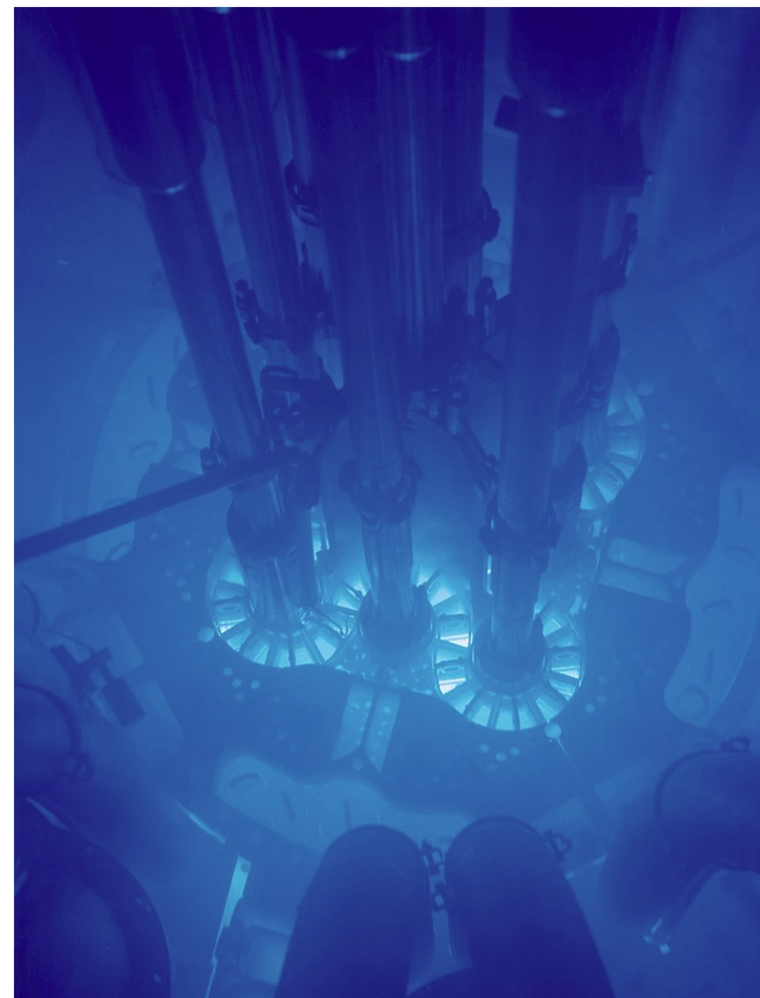
Five models of telescopes, three groups depending on size:

- SST: 6 metres of diameter, 5-300 TeV (70S)
- MST: 12 metres of diameter, 0.1-10 TeV (15N, 25S)
- LST: 24 metres of diameter, 20-200 GeV (4N, 4S)



How it works (I)
Cherenkov Radiation

Radiation emitted when a charged particle passes through a dielectric medium faster than the speed of light in that medium



Frank-Tamm: $\frac{d^2 E}{dx\, d\omega} = \frac{q^2}{4\pi}\mu(\omega)\omega\left(1 - \frac{c^2}{v^2 n^2(\omega)}\right)$

$$\frac{dE}{dx} = \frac{q^2}{4\pi}\int_{v>\frac{c}{n(\omega)}} \mu(\omega)\omega\left(1 - \frac{c^2}{v^2 n^2(\omega)}\right)d\omega$$

How it works (II)

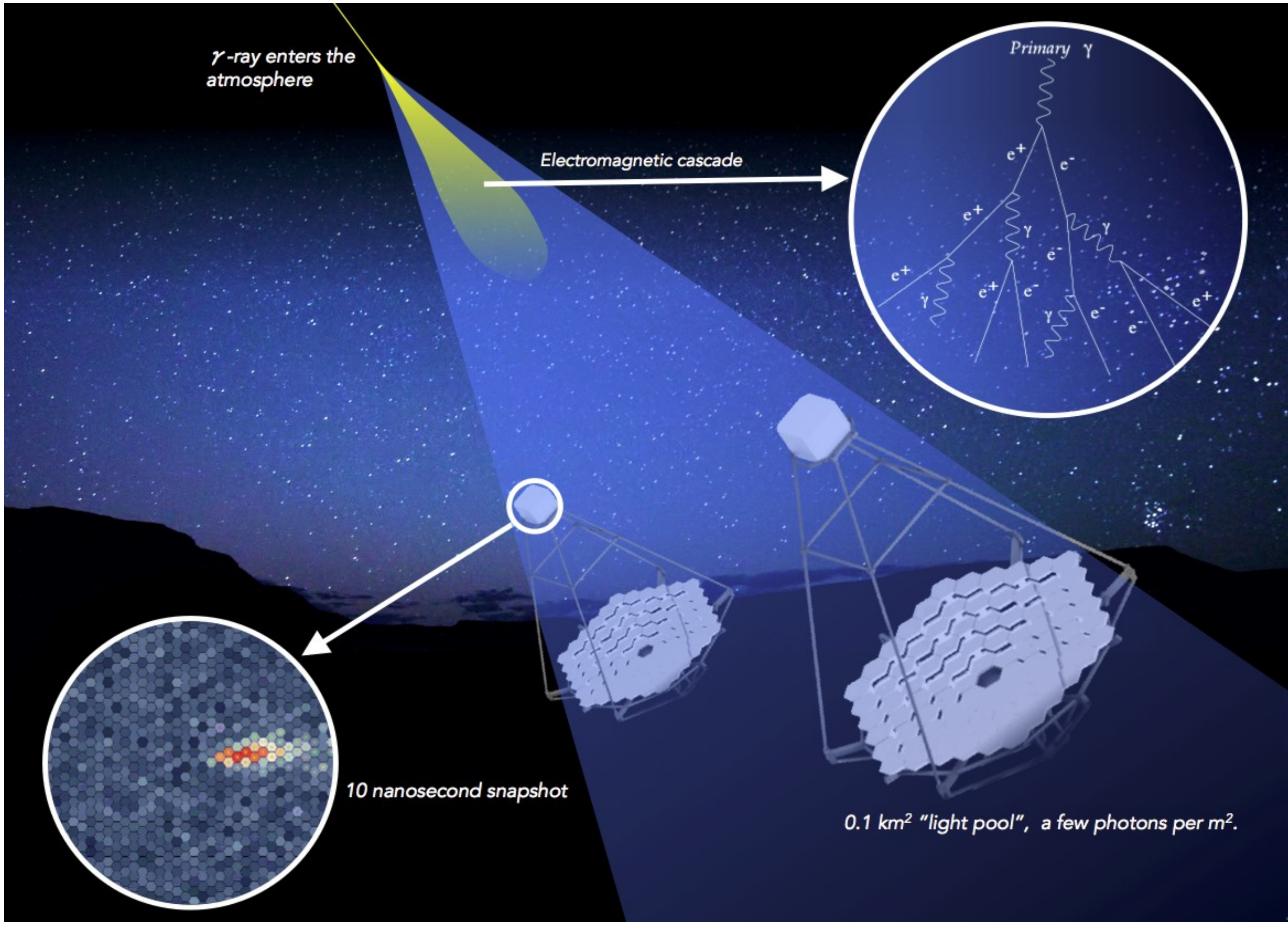
γ-ray Telescopes **(I)**

1. Cosmic/γ rays penetrate the atmosphere

2. An electromagnetic cascade is produced

3. Cherenkov radiation reaches the mirror

4. γ-rays are reflected and reach the telescope's camera

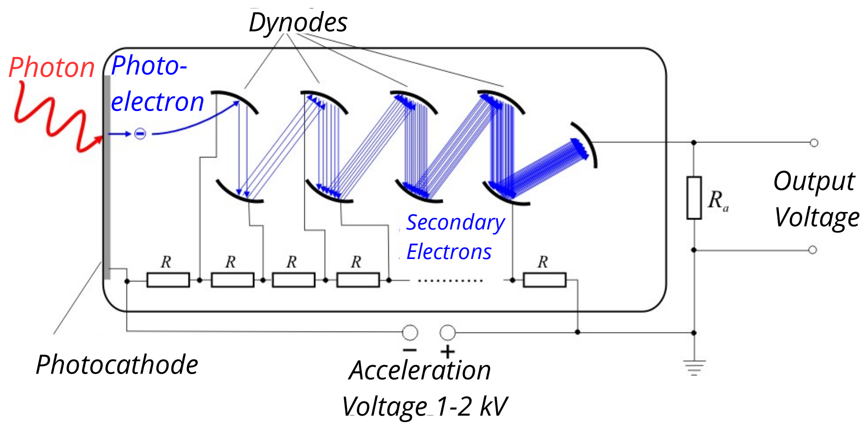


How it works (III)
γ-ray Telescopes (II)

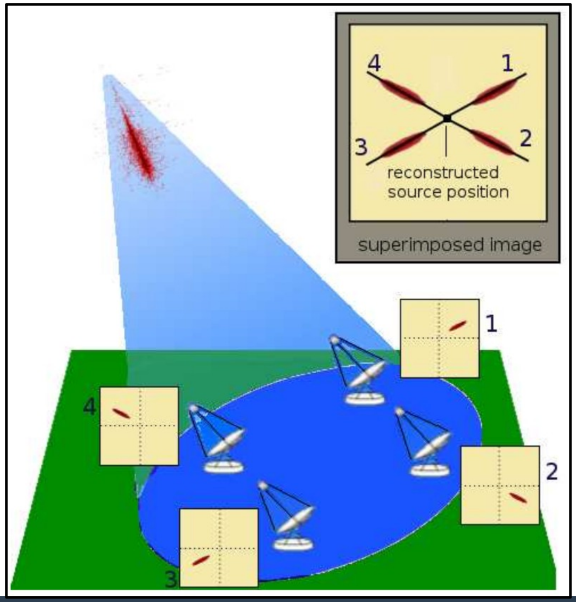
5. PMTs increase the signal

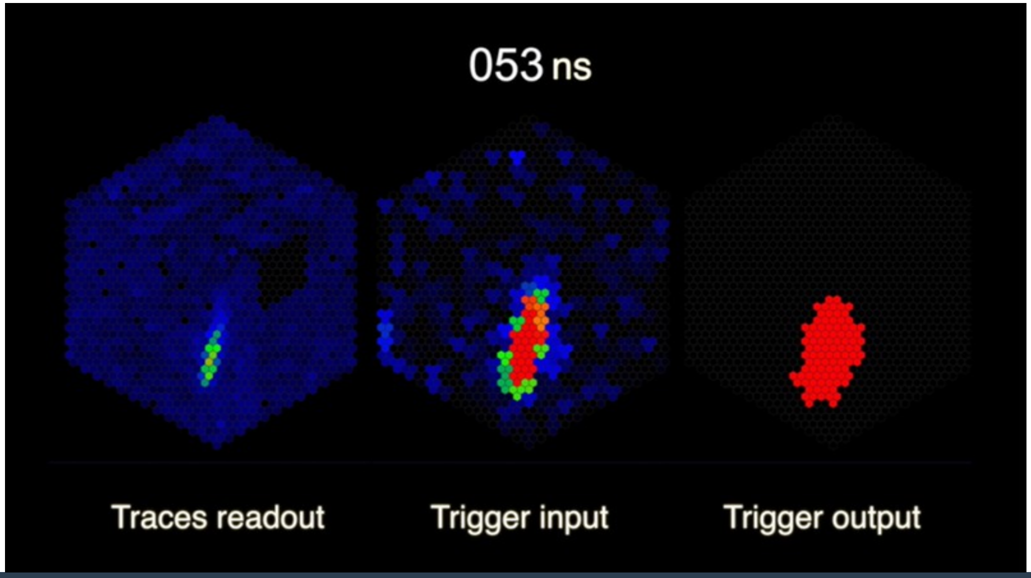
6. The actual signal is determined

7. The signal's characteristics are calculated



8. The source's characteristics are determined

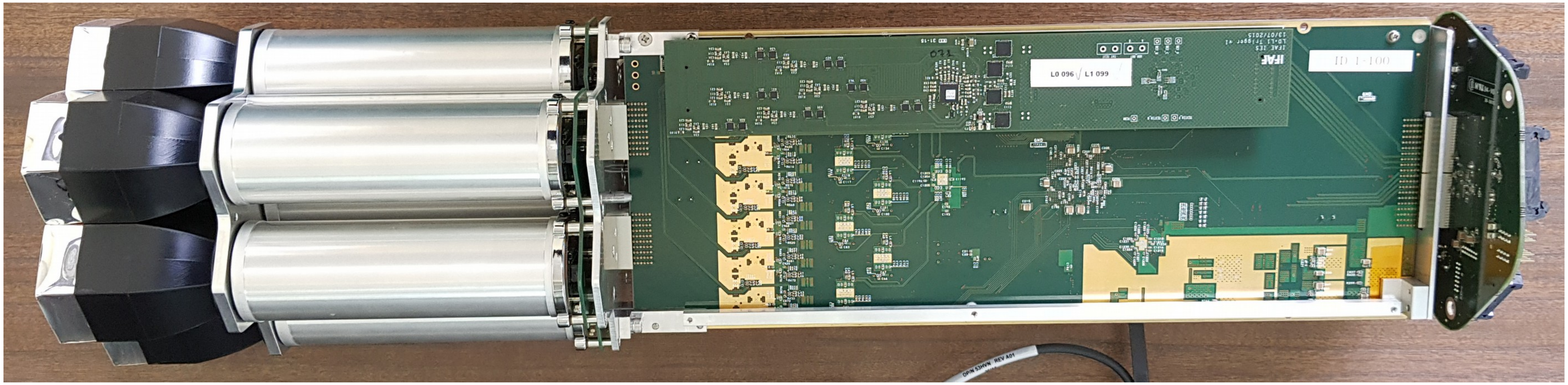




How it works (IV)

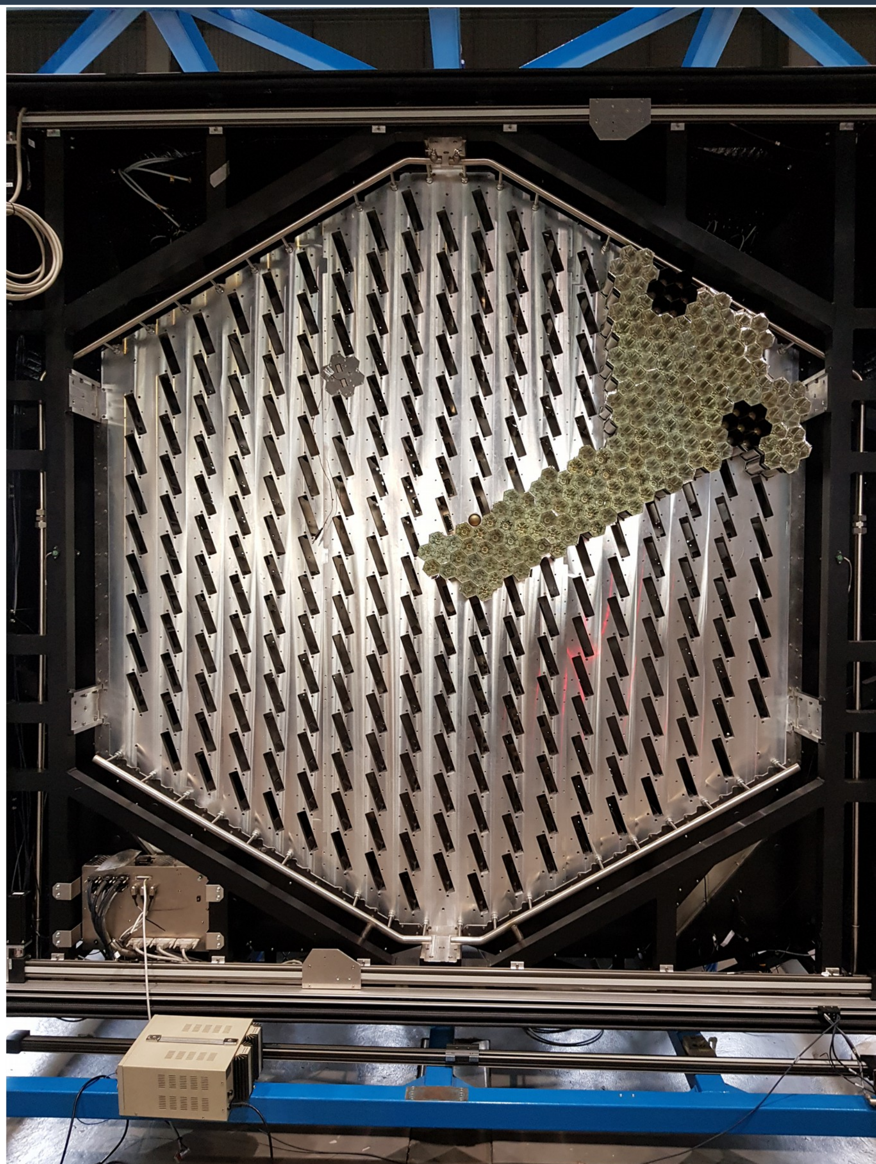
γ-ray Telescopes **(III)**

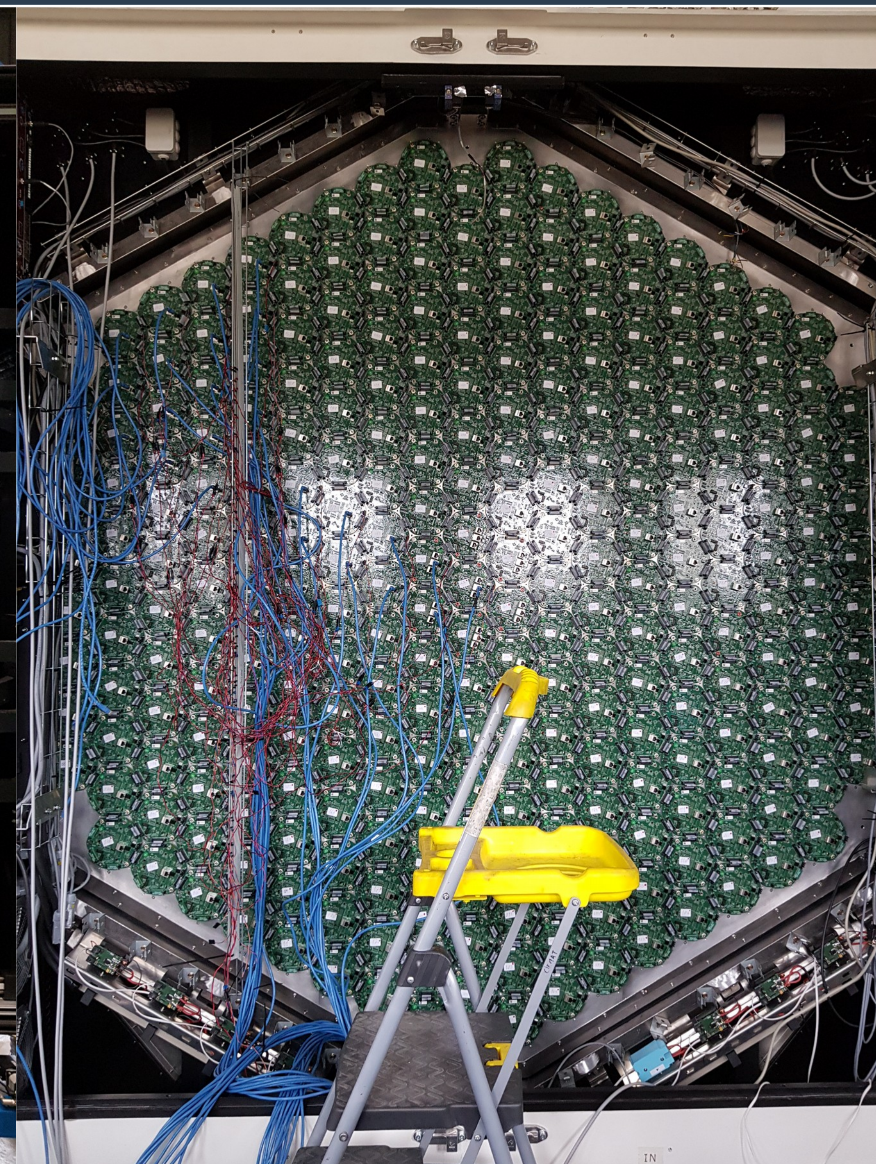
The LST is formed by 265 modules like this one. Each of them has 7 photomultiplier tubes (a total of 1855 pixels), a frontplane, a mezzanine an a backplane



The PMTs are directly connected to the frontplane, which receives the signals formed by the radiation impact. Using the mezzanine as support to carry out the calculations, it communicates with the rest of the telescope through the backplane, talking with the six modules surrounding it to determine whether a signal is “right” or not.

How it works (V)
γ-ray Telescopes **(IV)**

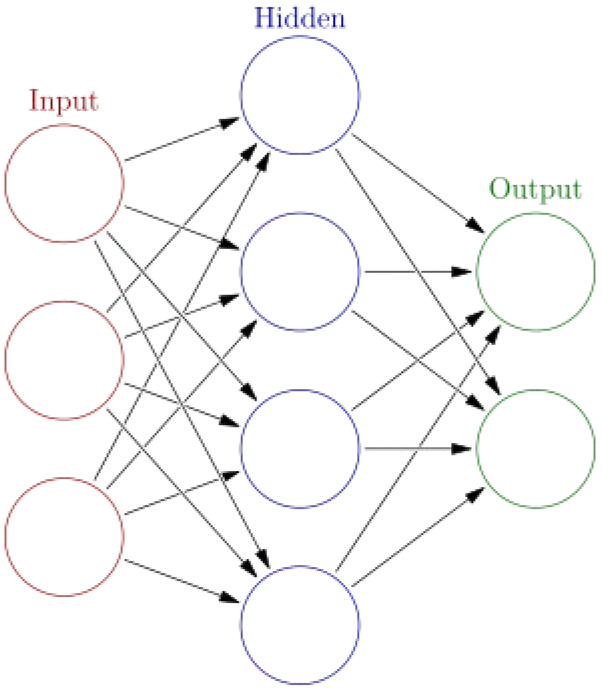




How it works (VI)
Neural networks

Computation system based on biological neural networks

Before being used, they require training with known inputs and outputs



The hidden neurons' values will then change during the training loops so as to better fit the values that will produce the most correct results

Here, the inputs will be the different images produced in the telescopes, and the outputs will be the source's features

Simulations (I)

CTA is currently in its construction phase, so we cannot offer any results provided by its telescopes

To begin preparing for the moment in which they are available, we are carrying out several different simulations

The results we obtain in these simulations will help us to train the tools that will be used when the production phase begins

Obtaining multiple potential relations between measurements and values will allow for redundancy and better outcomes

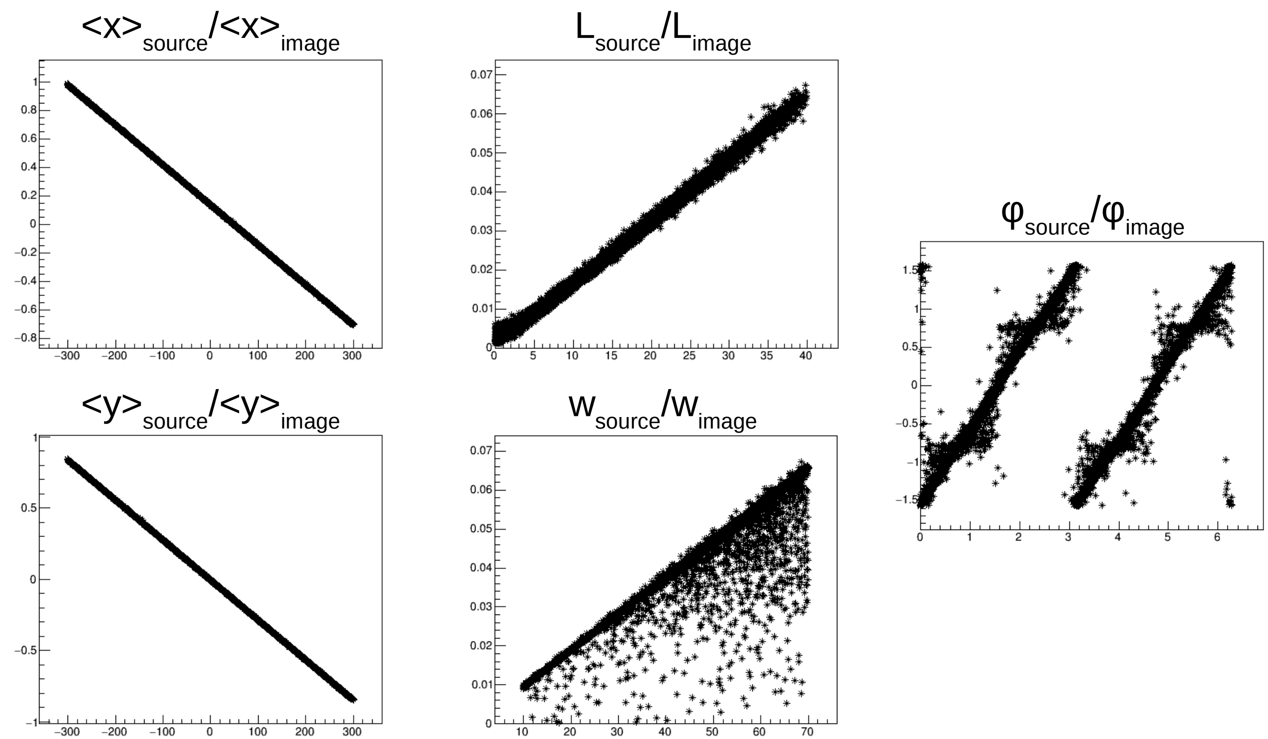
Simulations (II)
Electromagnetic Cascades (I)

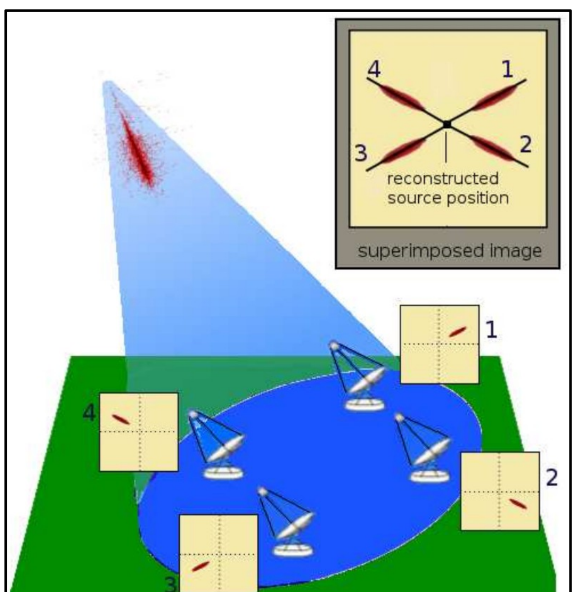
Simulations of electromagnetic cascades

- Every EM cascade produces Cherenkov radiation that can reach telescopes on Earth's surface
- These telescopes will be able to reproduce the received image
- Combining the images obtained by different telescopes the original source may be reconstructed
- By means of simulating a large number of cascades, as well as the images each event ought to produce, we can then calculate a direct relation between the different factors that make cascade and image

Simulations (III)
Electromagnetic Cascades (II)

Results of simulations of EM cascades on 1 telescope





$$\sigma_x^2=\langle x^2\rangle-\langle x\rangle^2,\ \sigma_y^2=\langle y^2\rangle-\langle y\rangle^2,\ \sigma_{xy}=\langle xy\rangle-\langle x\rangle\langle y\rangle,\ C=\begin{pmatrix}\sigma_x^2 & \sigma_{xy}\\ \sigma_{xy} & \sigma_y^2\end{pmatrix}$$

$$Tr(C)=\sigma_x^2+\sigma_y^2,\ Det(C)=\sigma_x^2*\sigma_y^2-\sigma_{xy}*\sigma_{xy}$$

$$W=\sqrt{0.5*Tr(C)-\sqrt{0.25*Tr(C)^2-Det(C)}},\ L=\sqrt{0.5*Tr(C)+\sqrt{0.25*Tr(C)^2-Det(C)}}$$

$$\varphi=\arctan\left(\frac{W^2-\sigma_x^2}{\sigma_{xy}}\right)$$

Simulations (IV)
J-Factor (I)

J-Factor calculations

- J-Factor: astrophyics flux factor
- It considers the distribution of dark matter, the problem's geometry and instrumental effects
- We use Navarro-Frenk-White density in our calculations

$$J(\Psi_0)=\frac{1}{4\pi}\int U(\Psi_0)B(\Omega)d\Omega$$

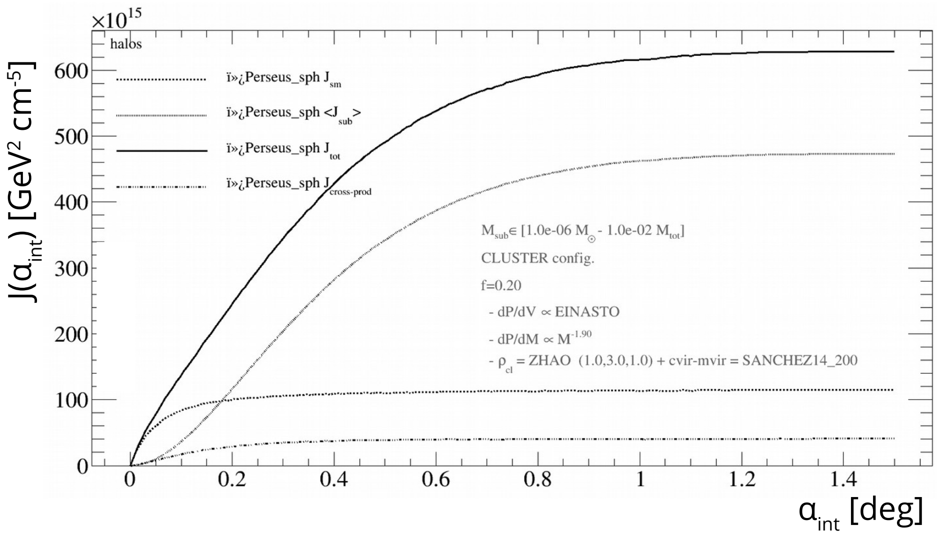
$$B(\Omega)d\Omega=\frac{1}{\sqrt{2\pi\sigma_t^2}}e^{\frac{-\theta^2}{2*\sigma_t^2}}\sin\theta\, d\theta\, d\phi$$

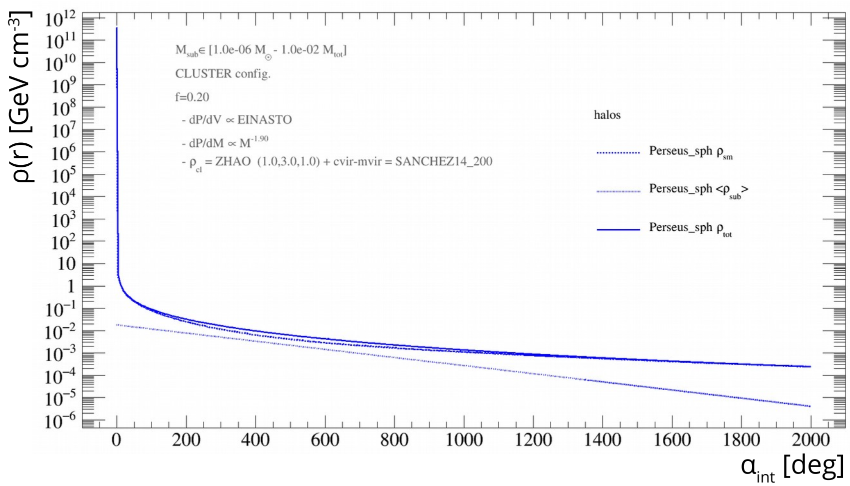
$$J=\int_{l.o.s.}\rho_{DM}^2(r)\,d\lambda,\quad r=\sqrt{\lambda^2+R^2-2\lambda R\cos\Psi}$$

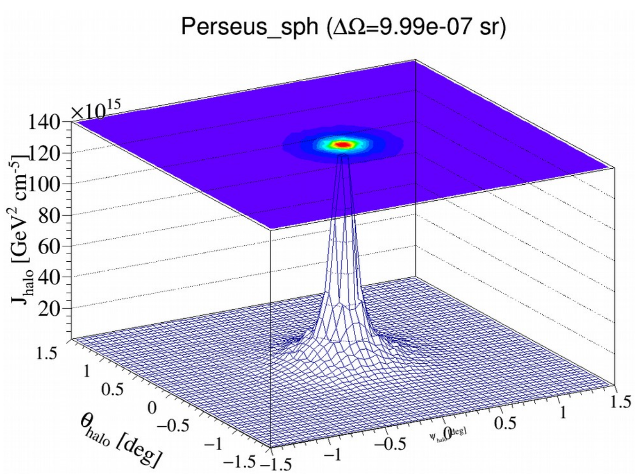
$$\rho_{NFW}(r)=\frac{\rho_c}{\left(\frac{r}{r_s}\right)^{\gamma}\left(1+\frac{r}{r_s}\right)^{3-\gamma}}$$

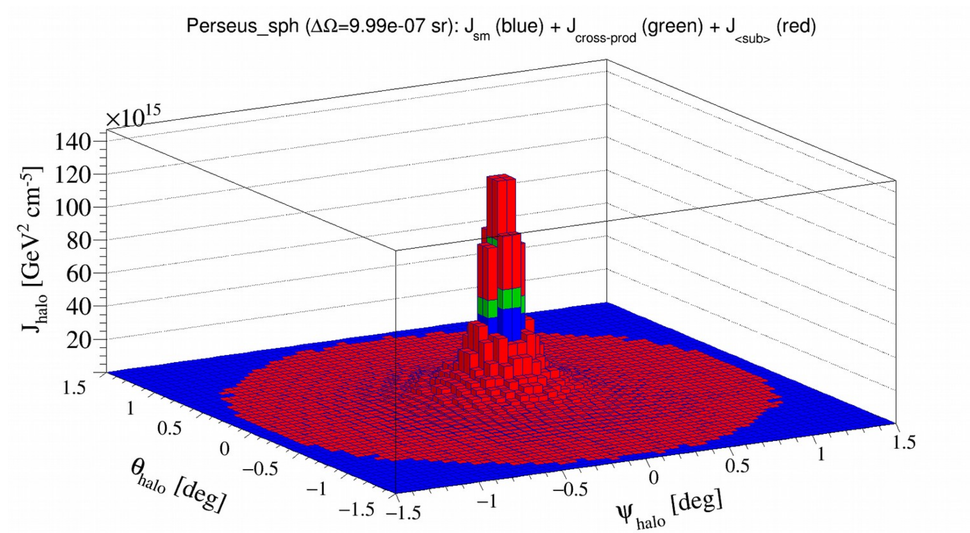
Simulations (V)
J-Factor (II)

J-Factor calculations

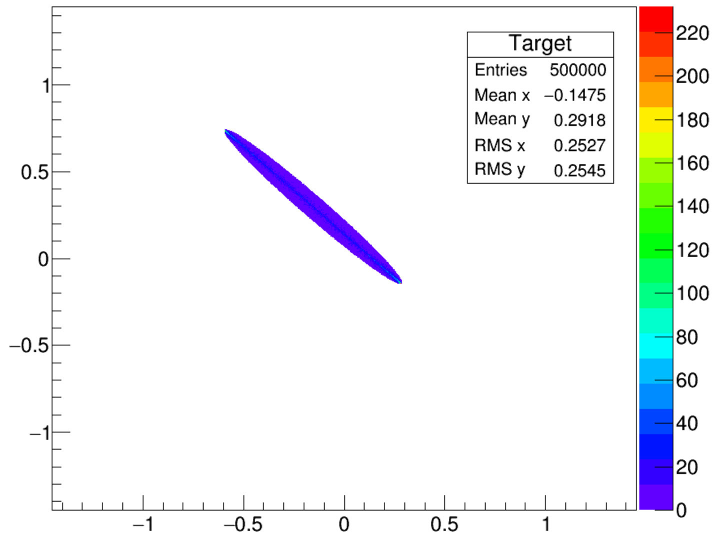


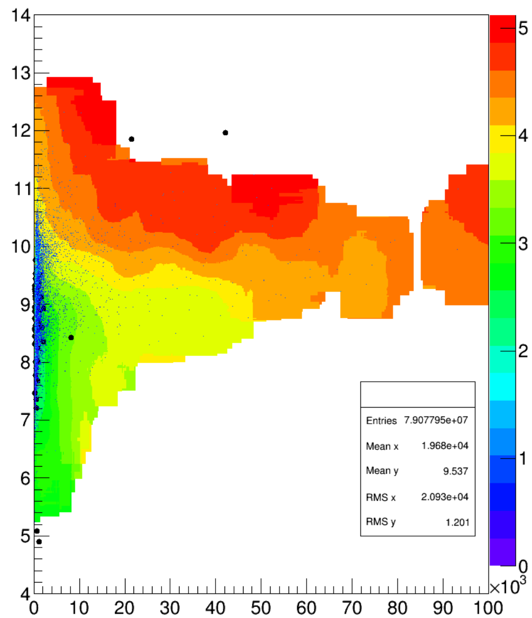


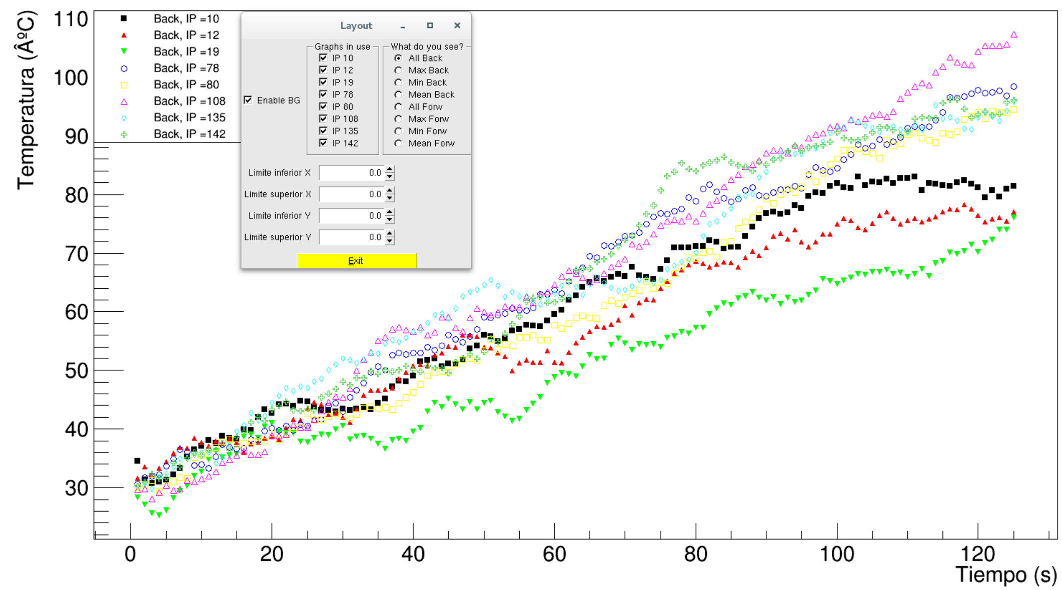


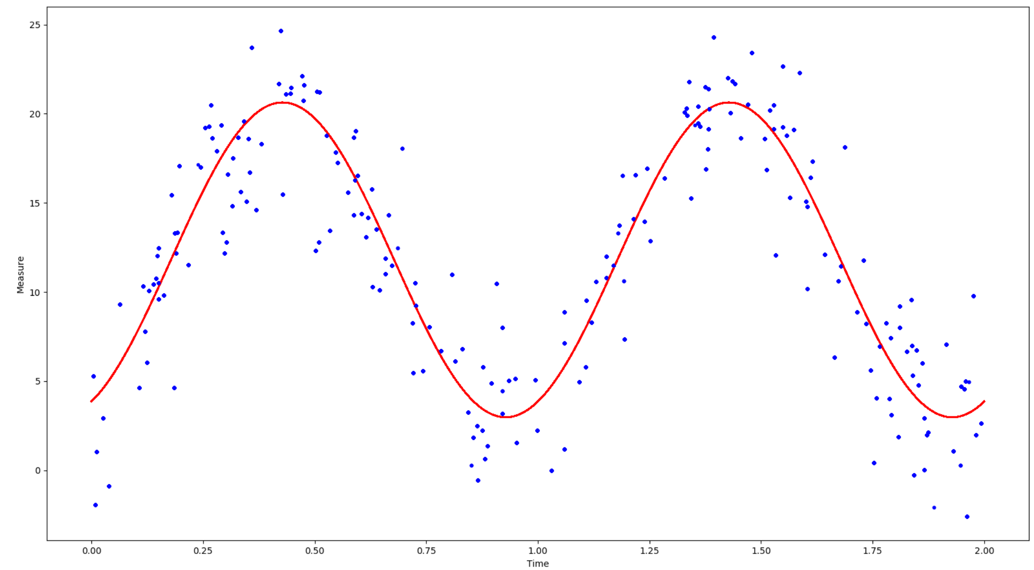


Simulations (VI)
Other work





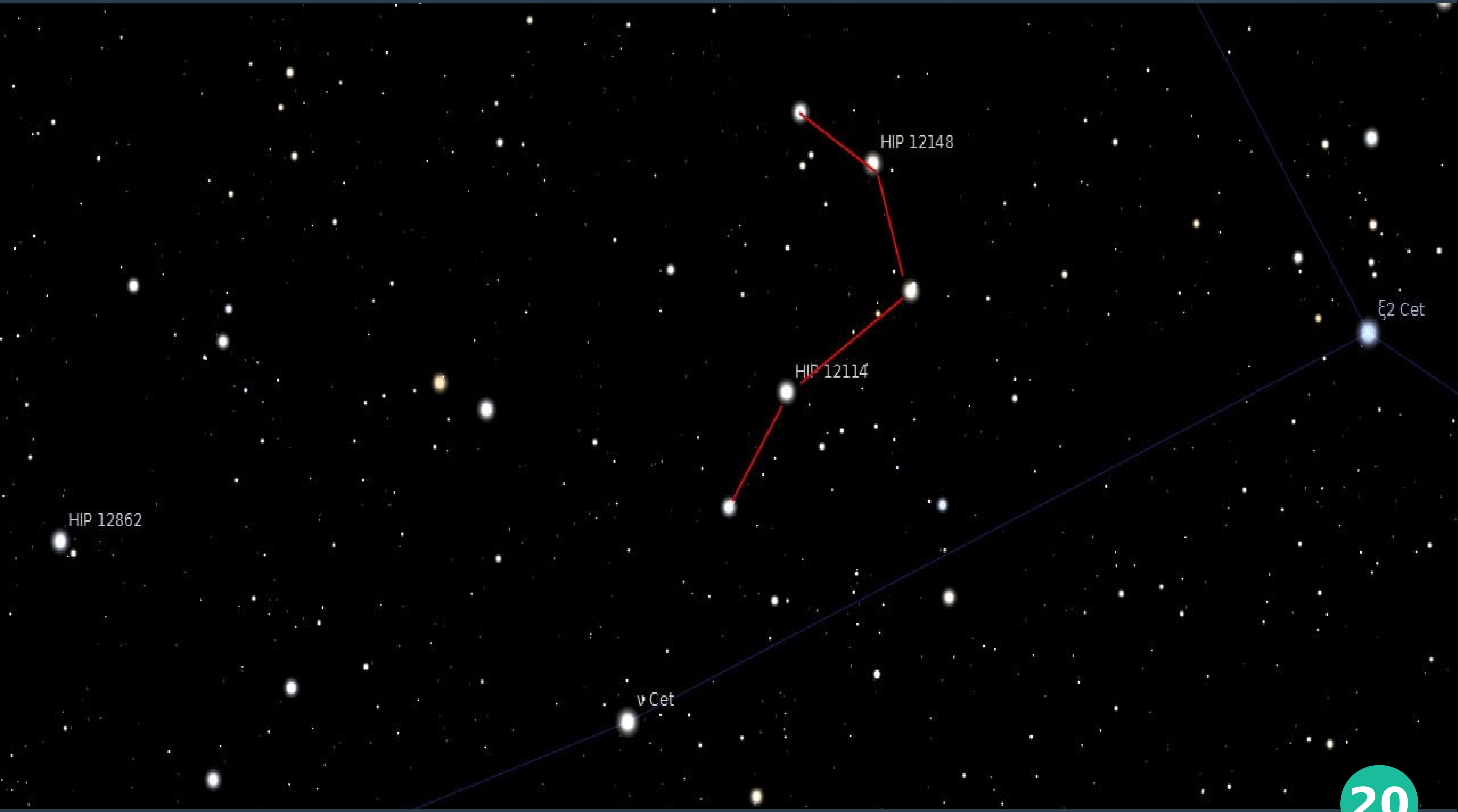




Conclusions & Future Aims

- Simulations are producing encouraging results that, as indicated, shall help better interpret real measurements
- We expect the first real results in Q3 2018, when the 1st prototype is finally built
- The other telescopes will begin to be built in 2019, along with the pre-production phase
- Production phase will start in 2022
- Construction phase should end in 2025

Any questions?



Thank you for your attention