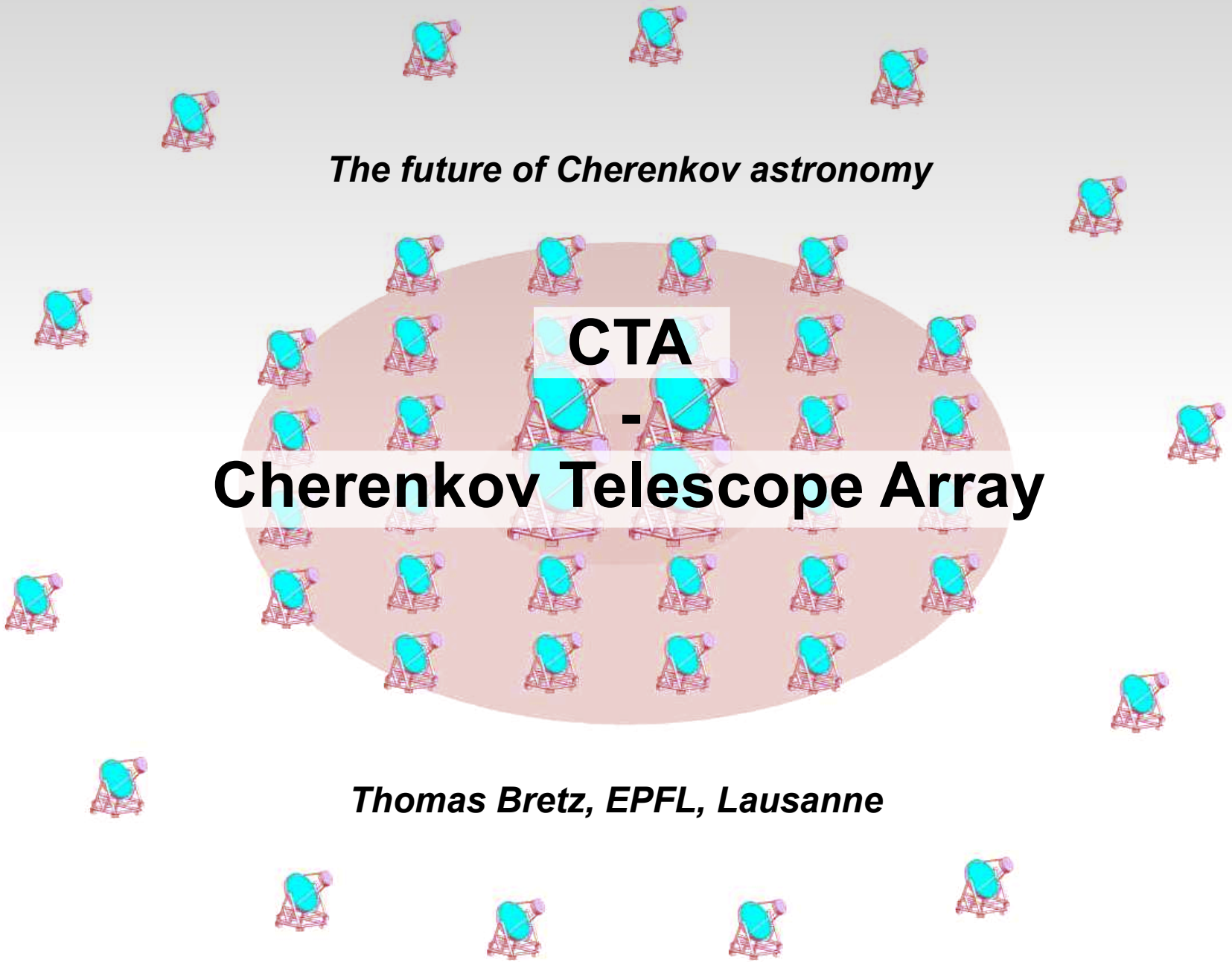
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

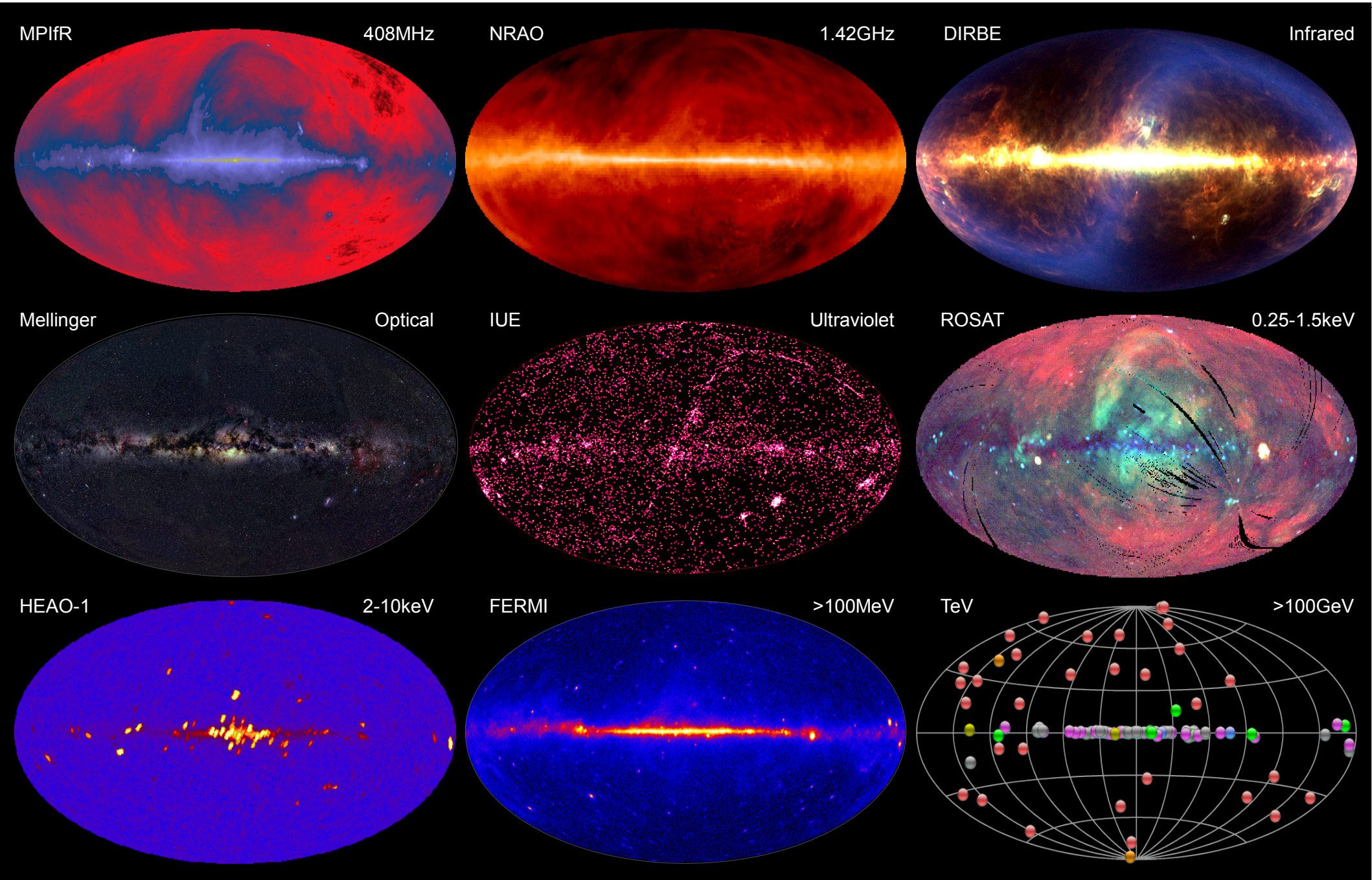
The future of Cherenkov astronomy



CTA
-
Cherenkov Telescope Array

Thomas Bretz, EPFL, Lausanne

The Multiwavelength-Sky



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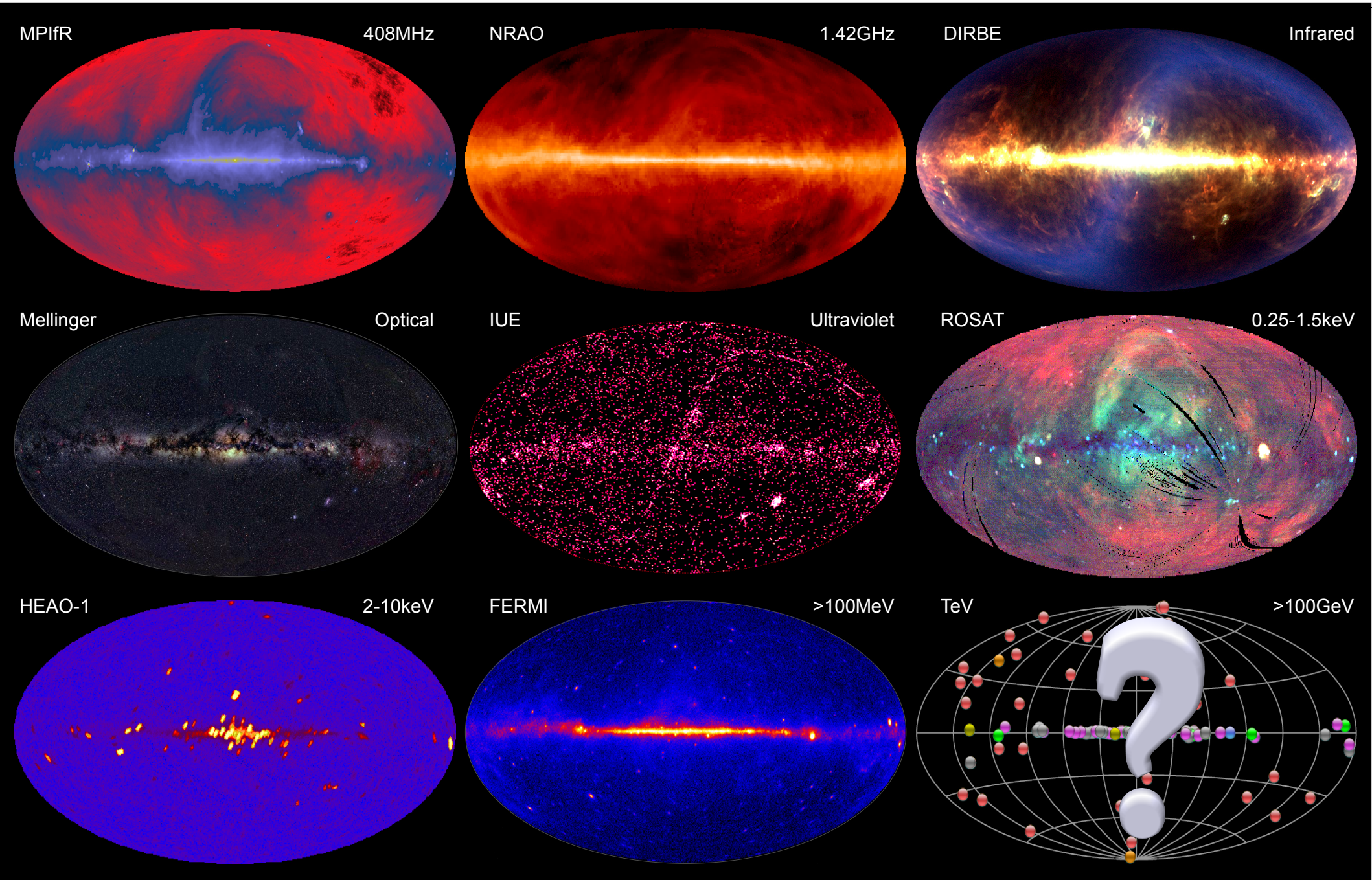
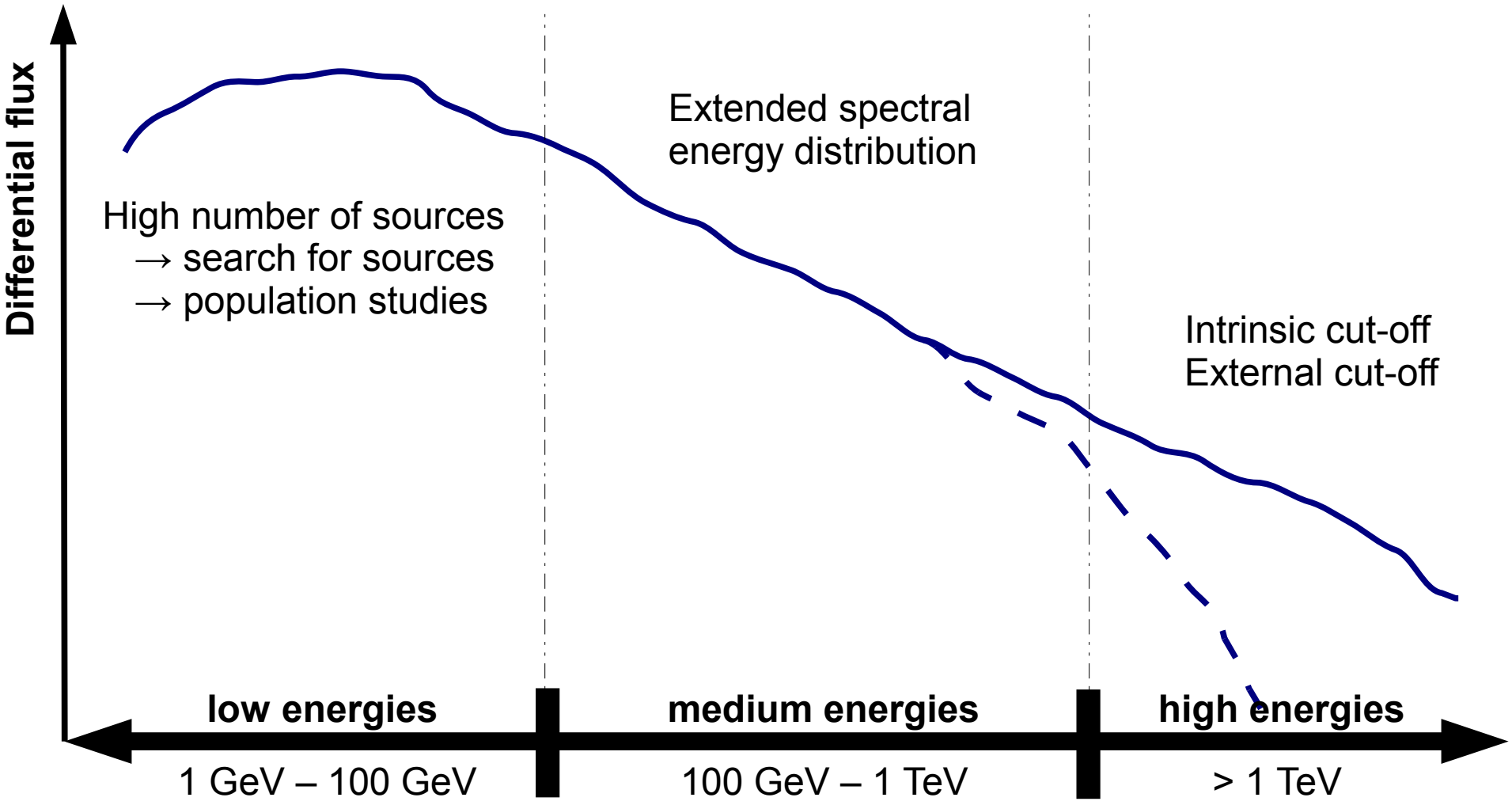
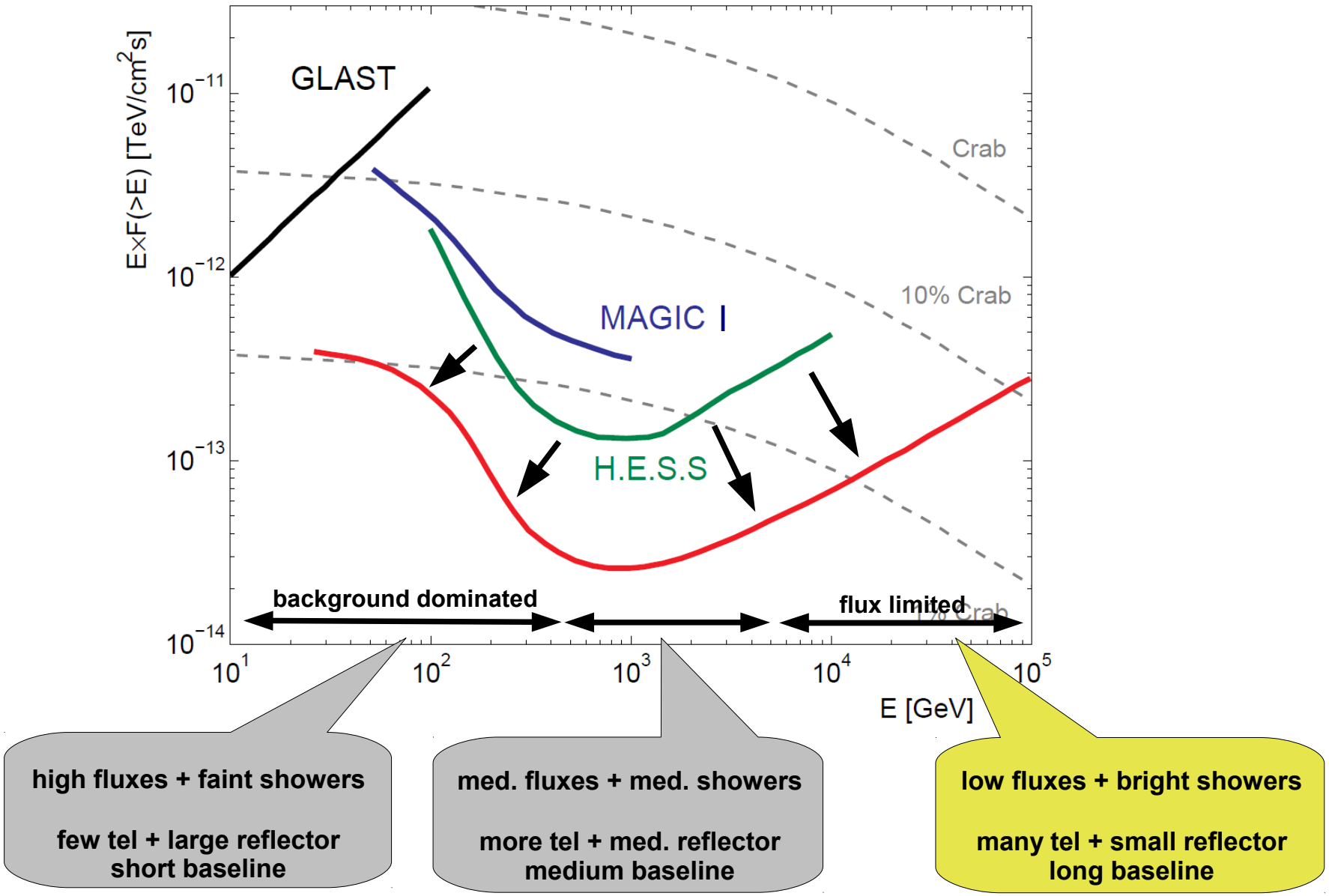


Typical source spectrum



Sensitivity



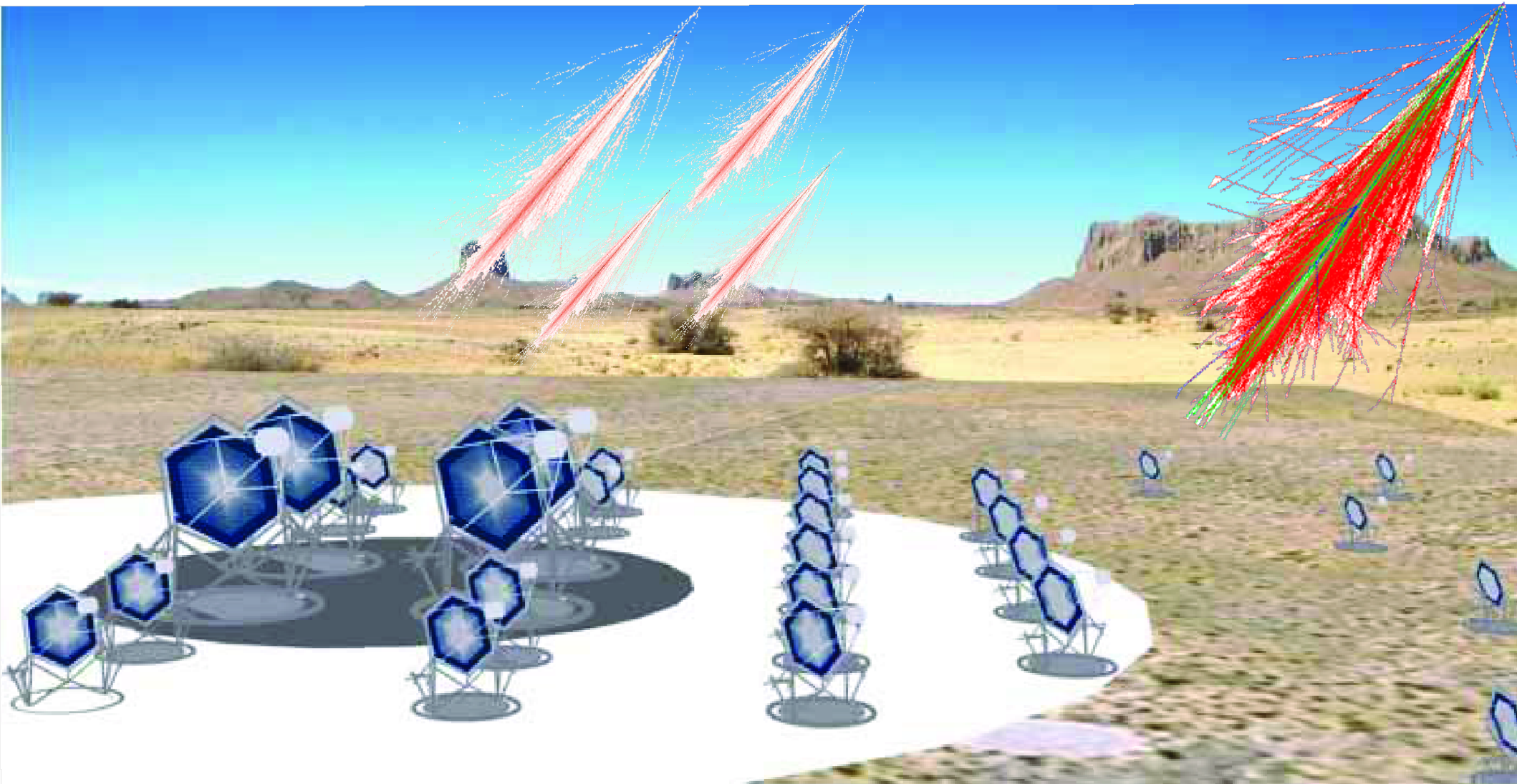
Solution – Hybrid Array

Low energy shower

- faint → light collection eff. important
- high fluxes → collection area unimportant

High energy shower

- bright → light collection eff. unimportant
- low fluxes → collection area important



Solution – Hybrid Array

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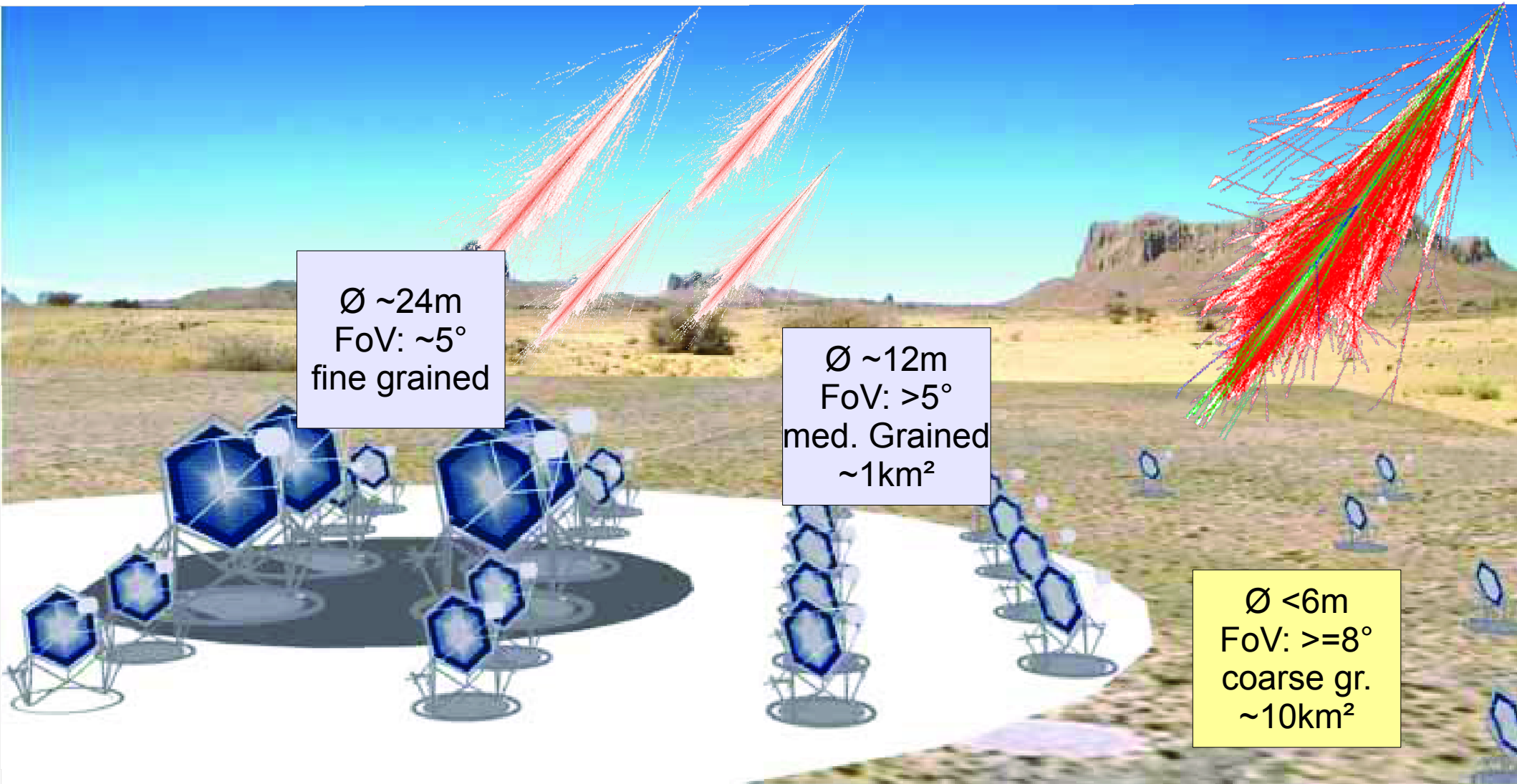
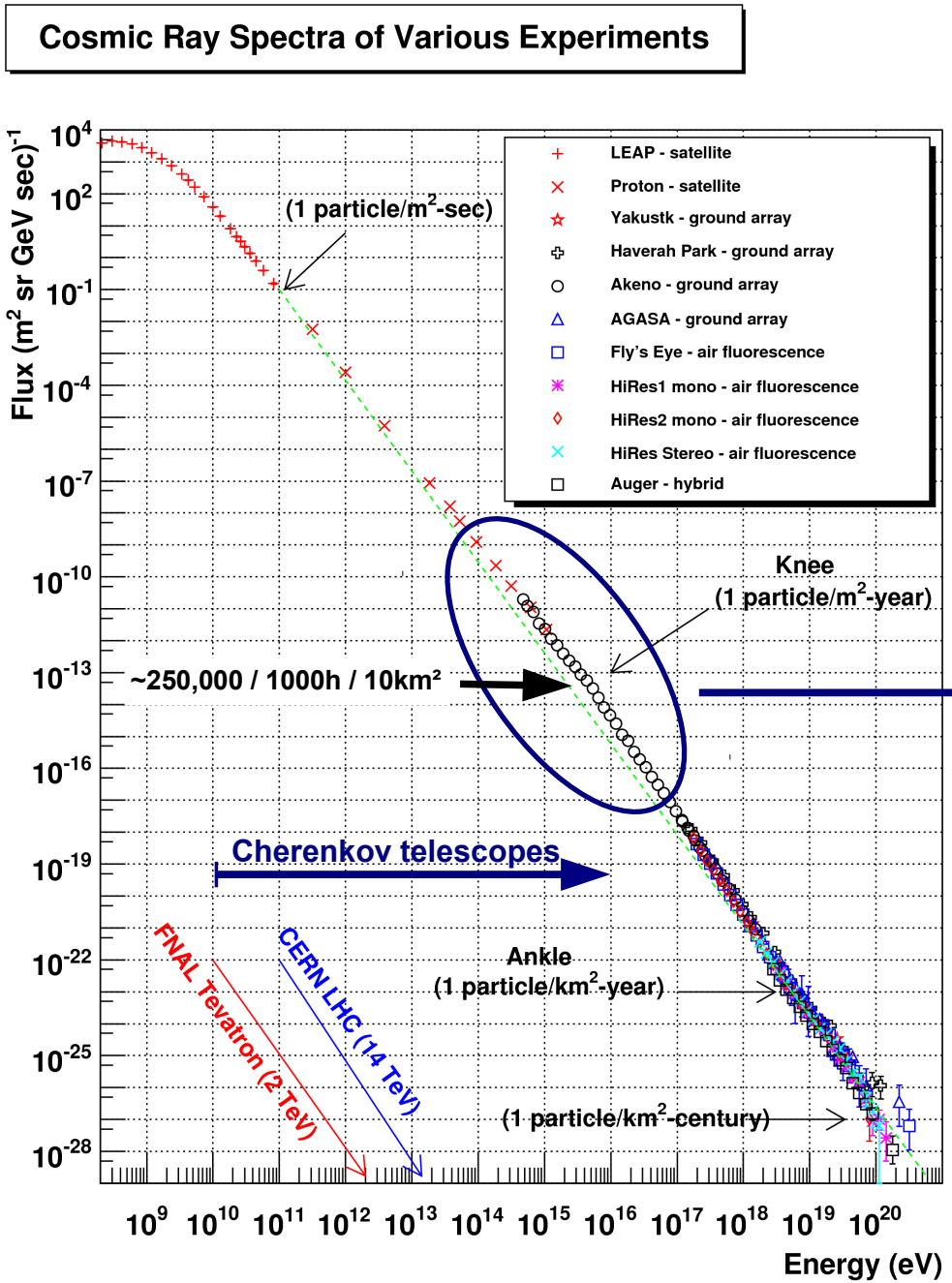


Cosmic ray composition

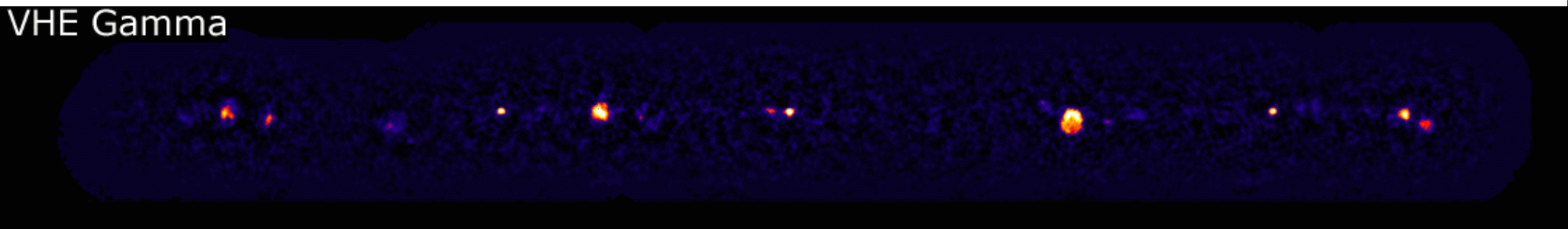


- Origin of cosmic rays still unknown
- Knee most probably due to a change in the cosmic ray composition
- Cherenkov telescopes are a promising tool to distinguish the particle types

→ **Measurements of diffuse low fluxes need high sensitivities (large coll. areas) and a large field-of-view**

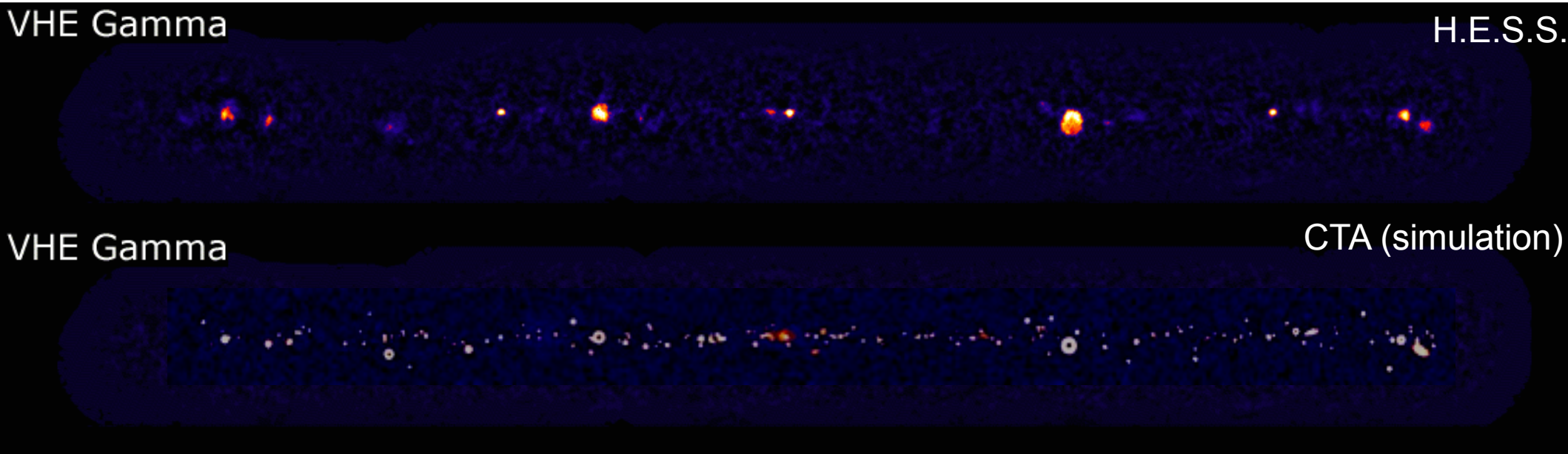
Galactic sources

- H.E.S.S. has done a very successful scan of the galactic plane
- They discovered a high number of new sources (many of them not yet identified)

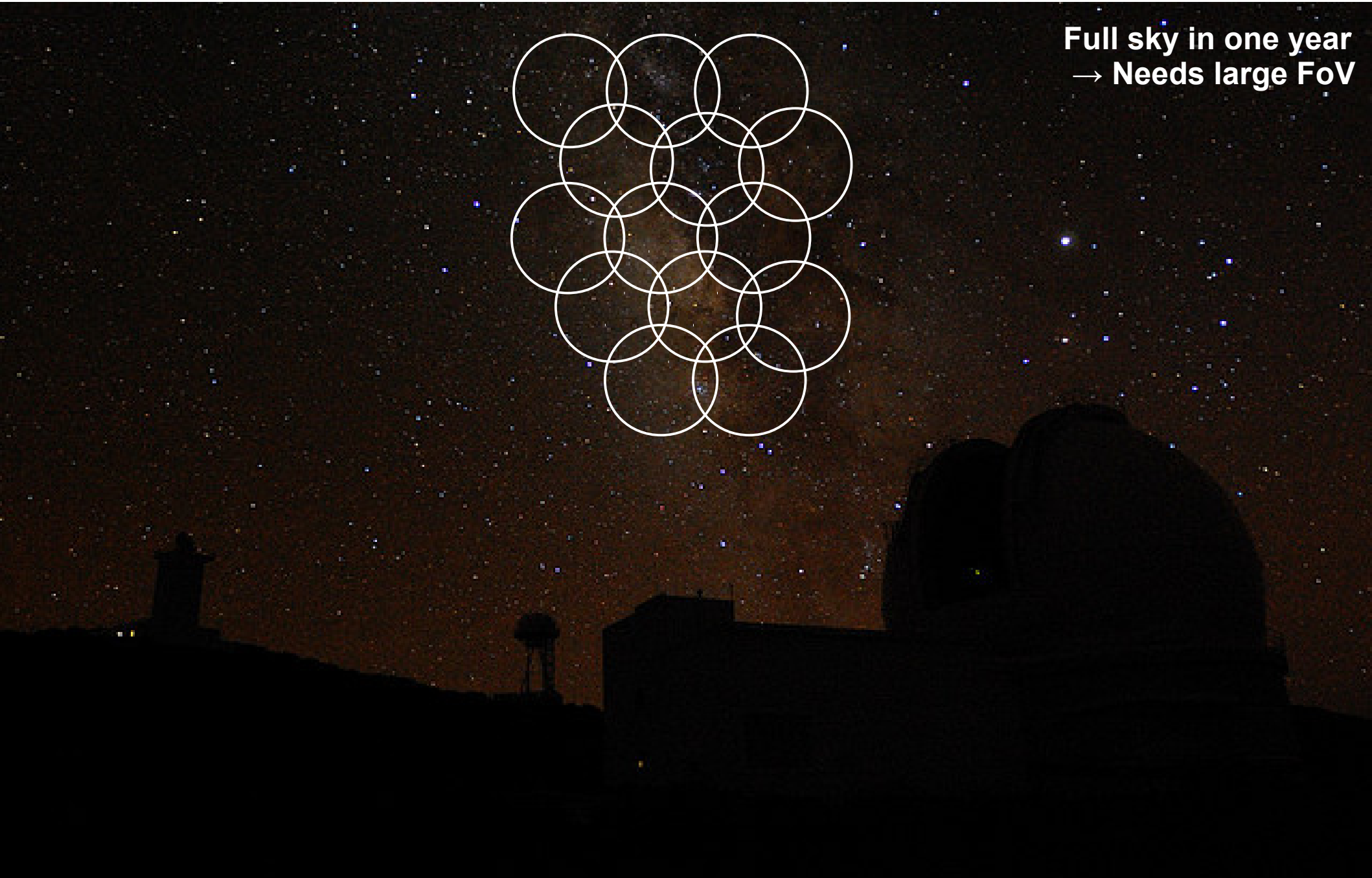


Galactic sources

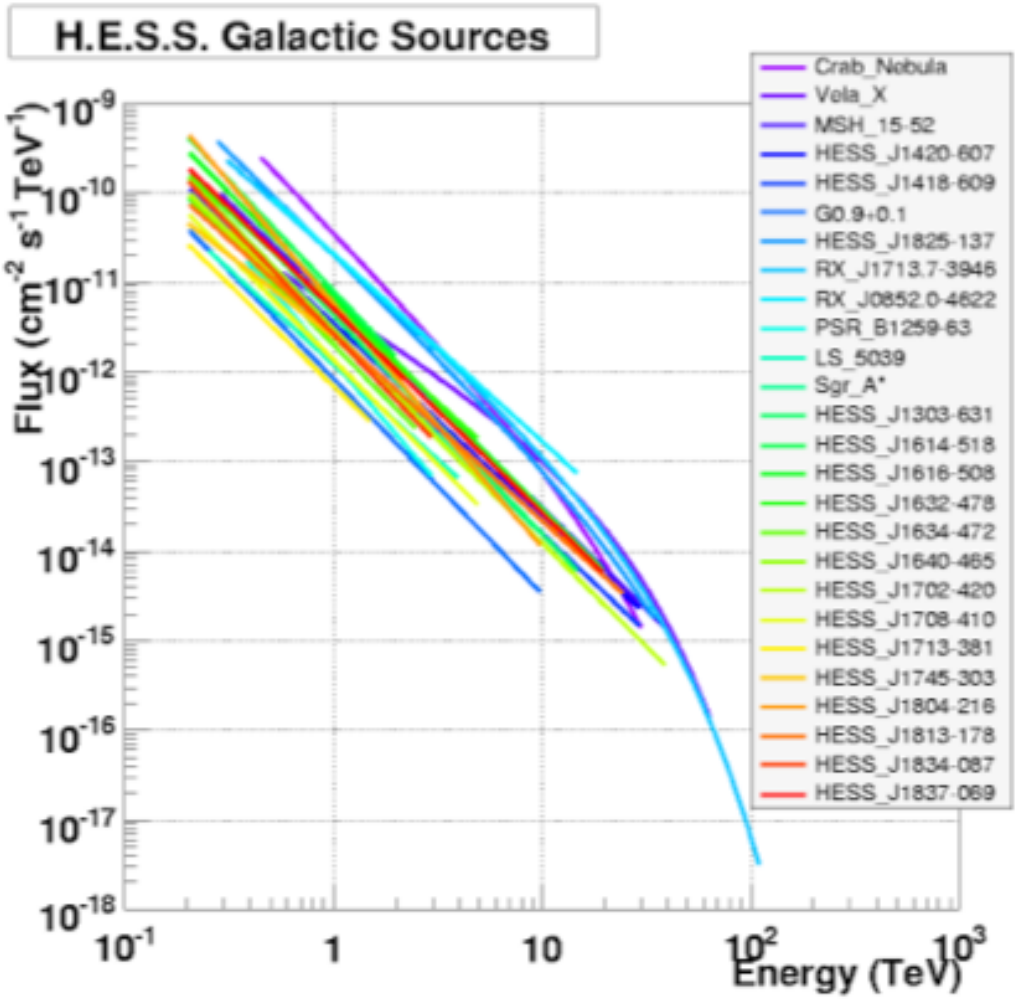
- H.E.S.S. has done a very successful scan of the galactic plane
- They discovered a high number of new sources (many of them not yet identified)
  - With a much higher sensitivity and a better angular resolution, CTA could further increase the number of detected sources and have a great impact on their identification



Scan mode



Intrinsic cut-off



Depending on the acceleration mechanism,

- spectral slope and shape and
- a possible cut-off energy

might be different.

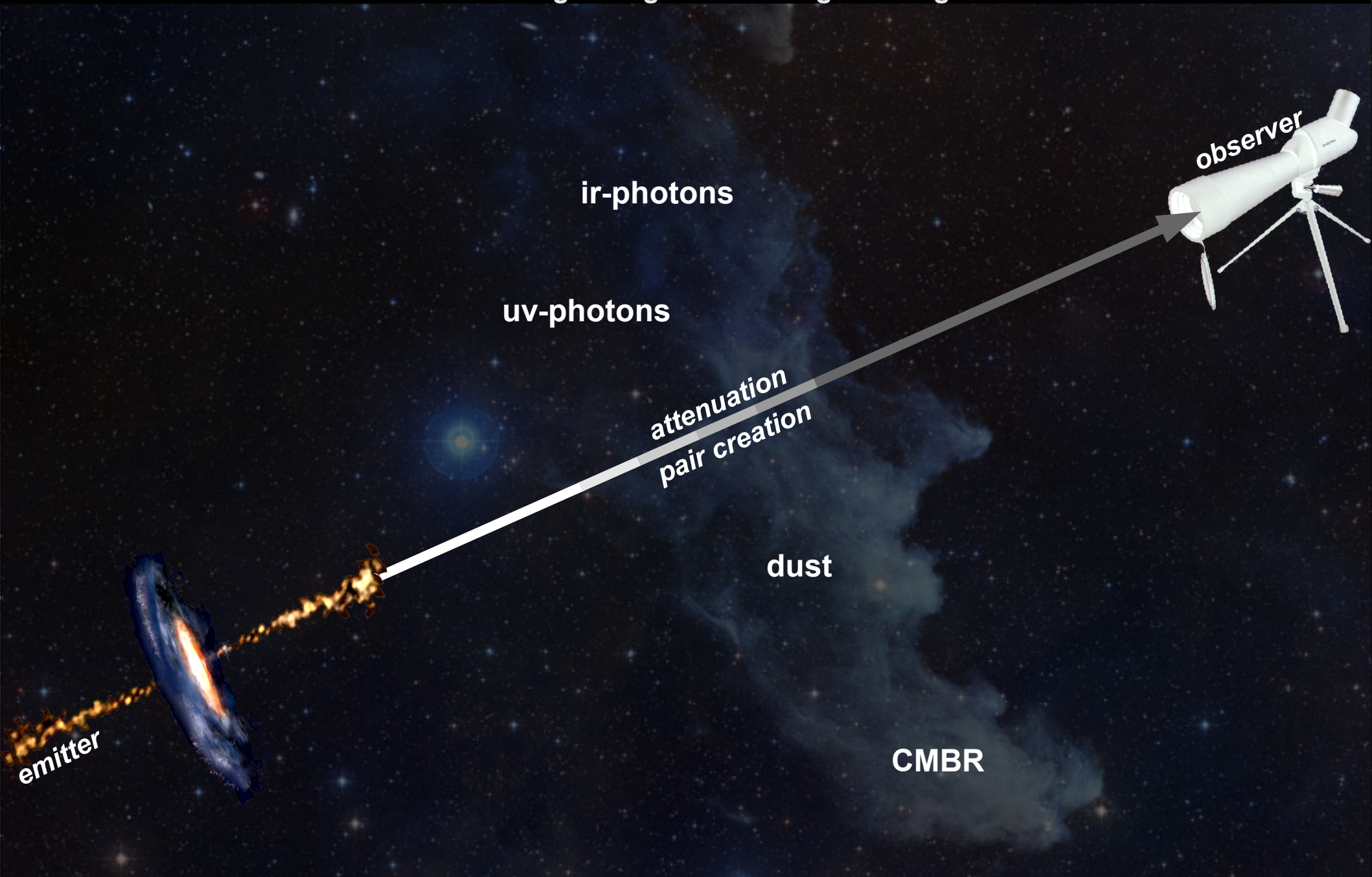
Measurements of TeV spectral cut-off contain information about

- **the acceleration process**

- **Measurements of the cut-off need high sensitivities (large coll. areas)**

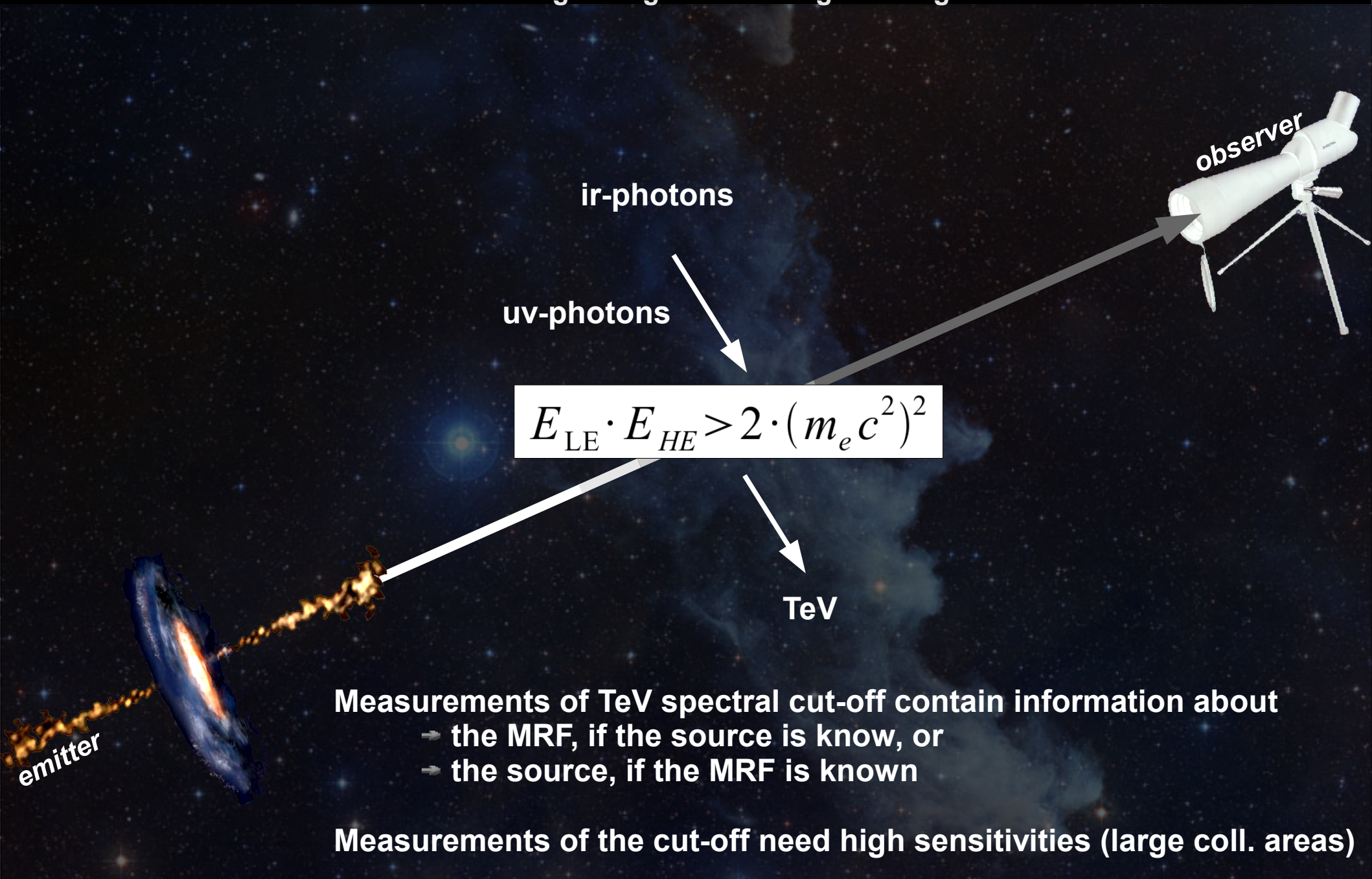
Metagalactic radiation field

Evolving extragalactic background light



Metagalactic radiation field

Evolving extragalactic background light

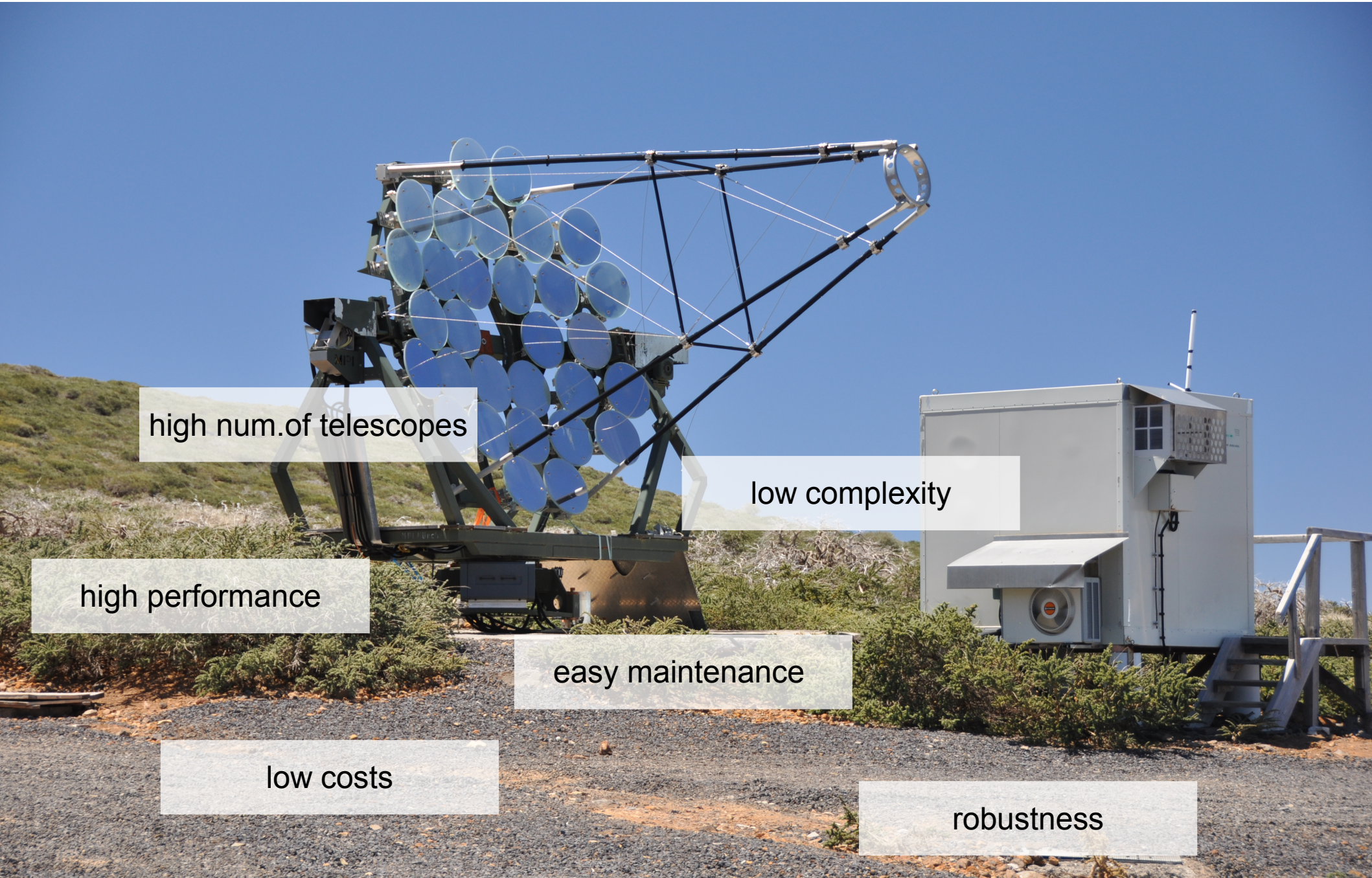


Measurements of TeV spectral cut-off contain information about

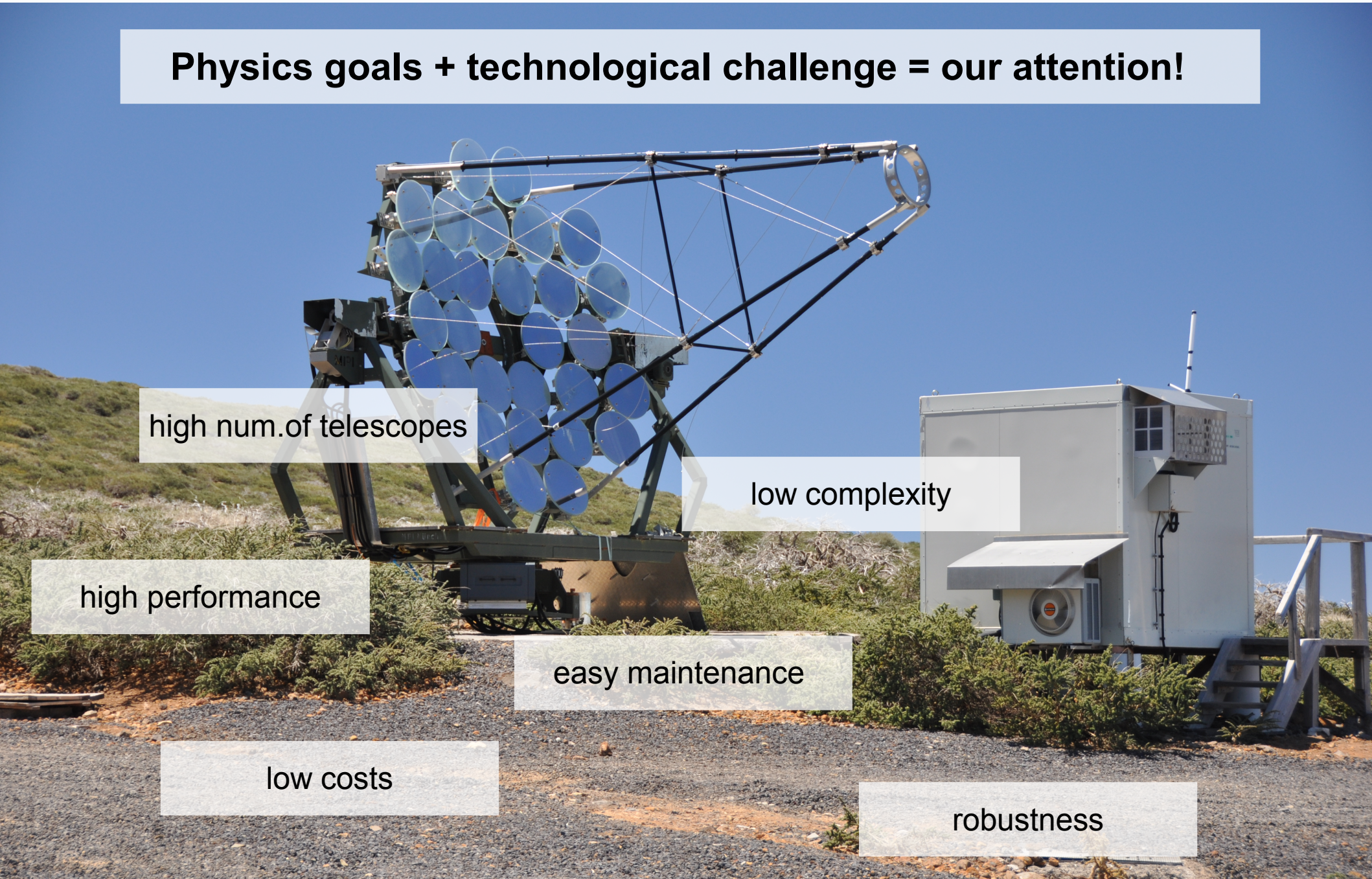
- **the MRF, if the source is know, or**
- **the source, if the MRF is known**

Measurements of the cut-off need high sensitivities (large coll. areas)

Technological challenge



Small size telescopes

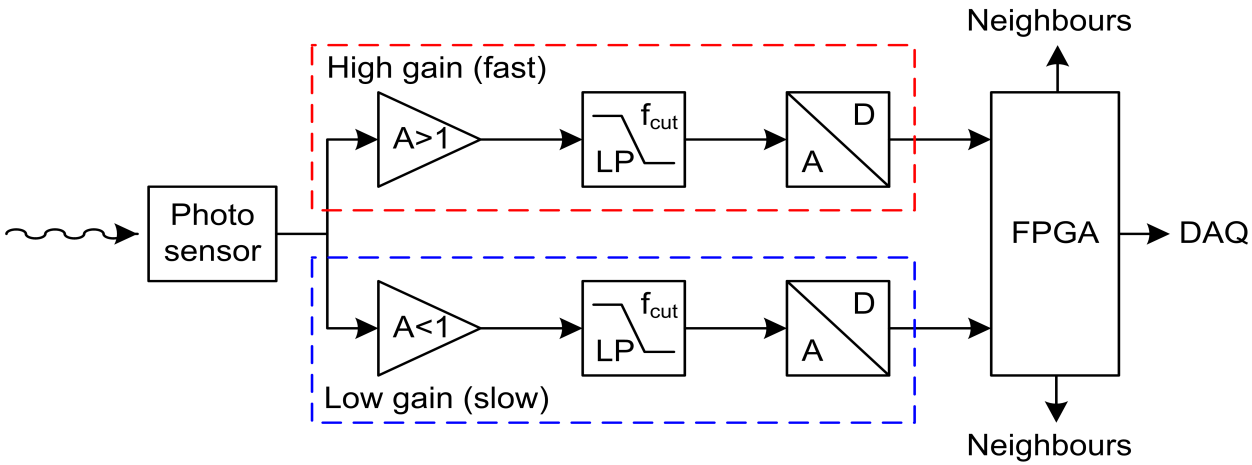


Data acquisition

Flash camera (UNIZ)

- continuous digitization
- software trigger (FPGA or PC)
- real time pulse extraction
- real time data analysis

→ dramatically reduces costs and complexity of the system



Automatic mirror alignment

Active mirror control (UNIZ)

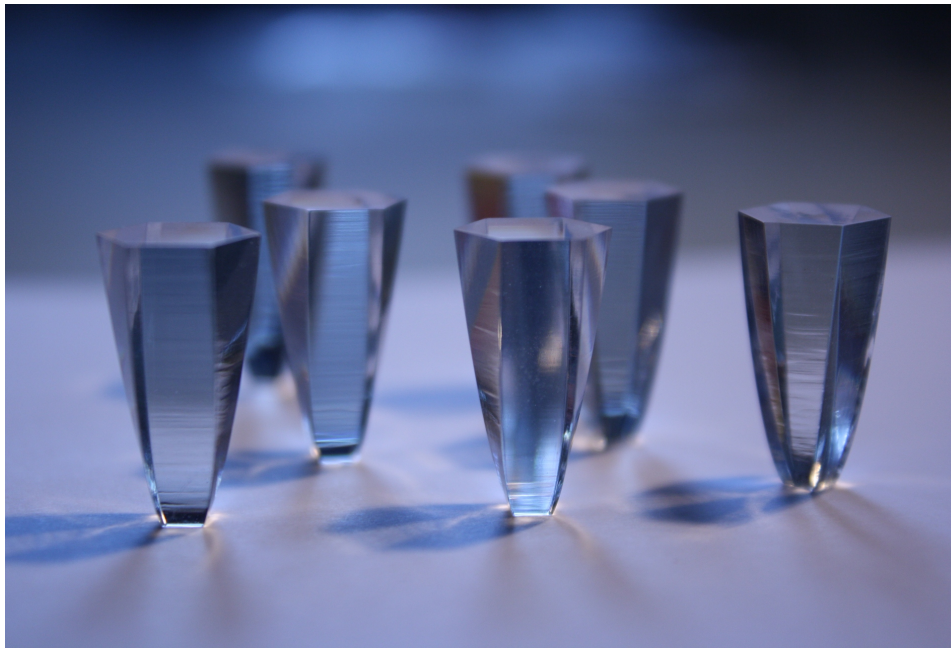
- prototype for a robust and scalable system
- high reliability
- Low costs and power consumption

→ improves maintenance and performance

Photon detection

Solid light guides (UNIZ, ETHZ)

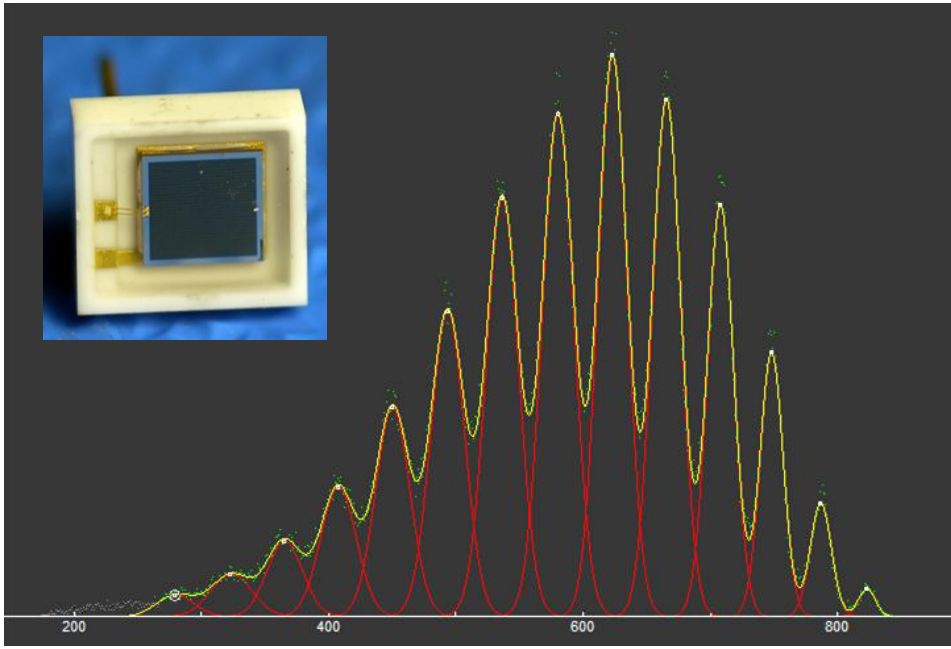
- Improved performance
- Low costs for large numbers



G-APD characterization (ETHZ, EPFL, PSI)

- Performance measurements
- Test setups

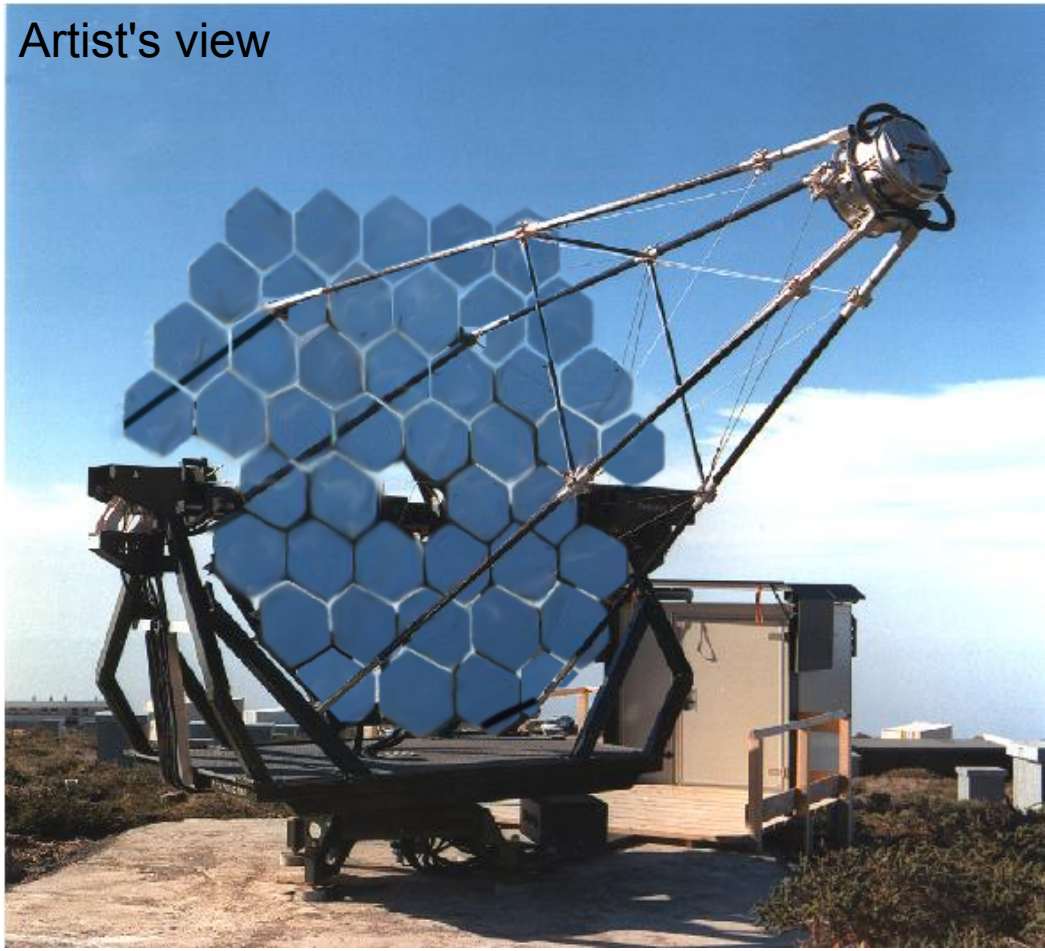
- Obvious improvement on robustness and reliability



Prototype telescope

FACT (ETHZ, EPFL, ISDC + 2 German Institutes)

- essential to gain experiences with these new components before decisions for CTA are taken.
  - ***Details: NEXT TALK***



Telescope design / Array layout

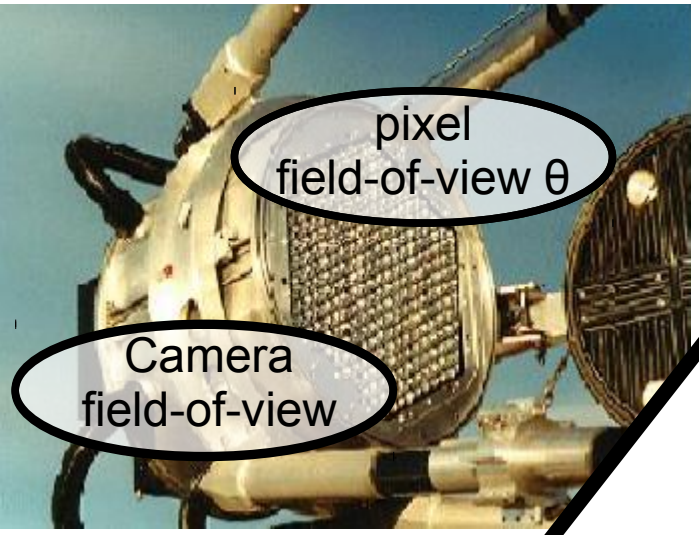
Telescope design + array layout (EPFL)

- Monte Carlo studies (incl. cosmic ray studies)

- Increase collection area
- Decrease costs

- Problem: HUGE phase space
  - Pixel field-of-view
  - Mirror diameter
  - Focal length
  - Number of telescope
  - Distance between telescopes
  - ...

Telescope properties



pixel phys.
area A

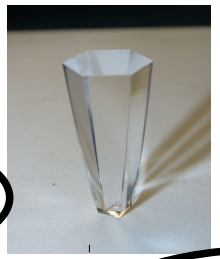
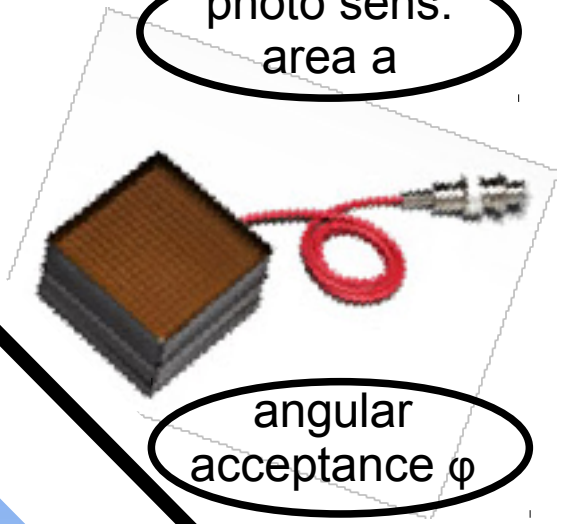
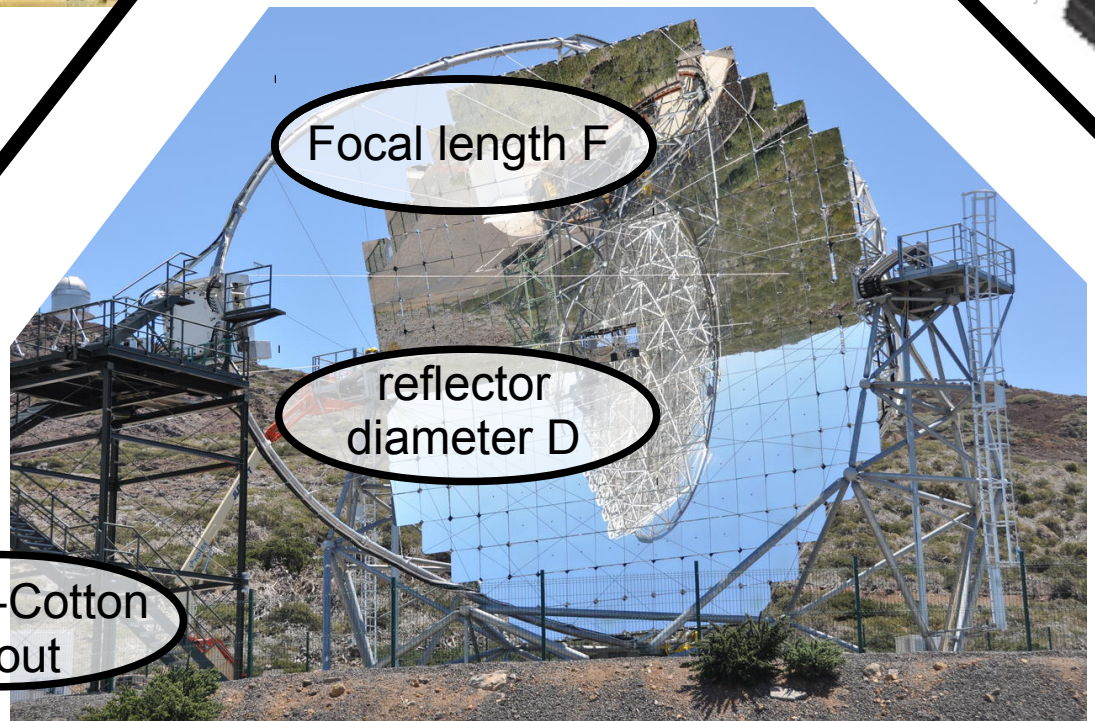


photo sens.
area a



angular
acceptance φ



Davies-Cotton
layout

Photon detector properties

Free parameter

pixel field-of-view θ

Requirement

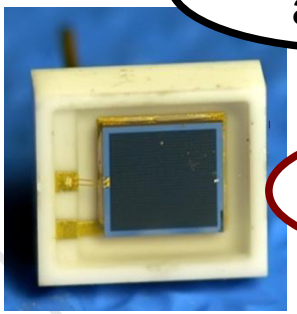
Camera field-of-view

unknown

pixel phys. area A

defined

photo sens. area a



Requirement

use G-APDs

angular acceptance φ

defined

unknown

Focal length F

reflector diameter D

unknown

Requirement

Davies-Cotton layout

Constraints from light concentrators

Free parameter

pixel field-of-view θ

Requirement

Camera field-of-view

unknown

pixel phys. area A

defined

photo sens. area a

Requirement

use G-APDs

Light concentrators

A, α ↔ a, φ

unknown

Focal length F

angular acceptance φ

defined

reflector diameter D

unknown

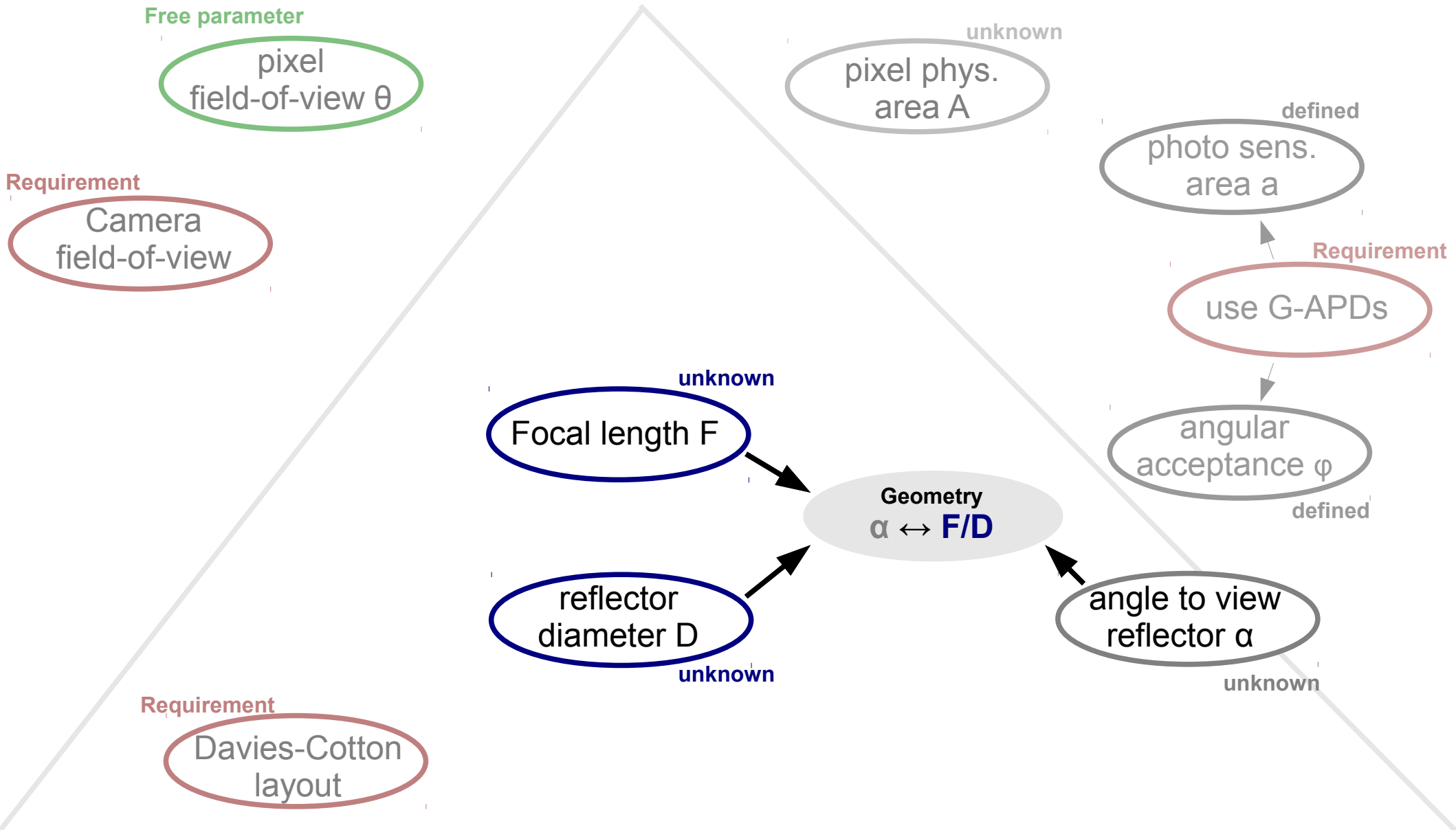
angle to view reflector α

unknown

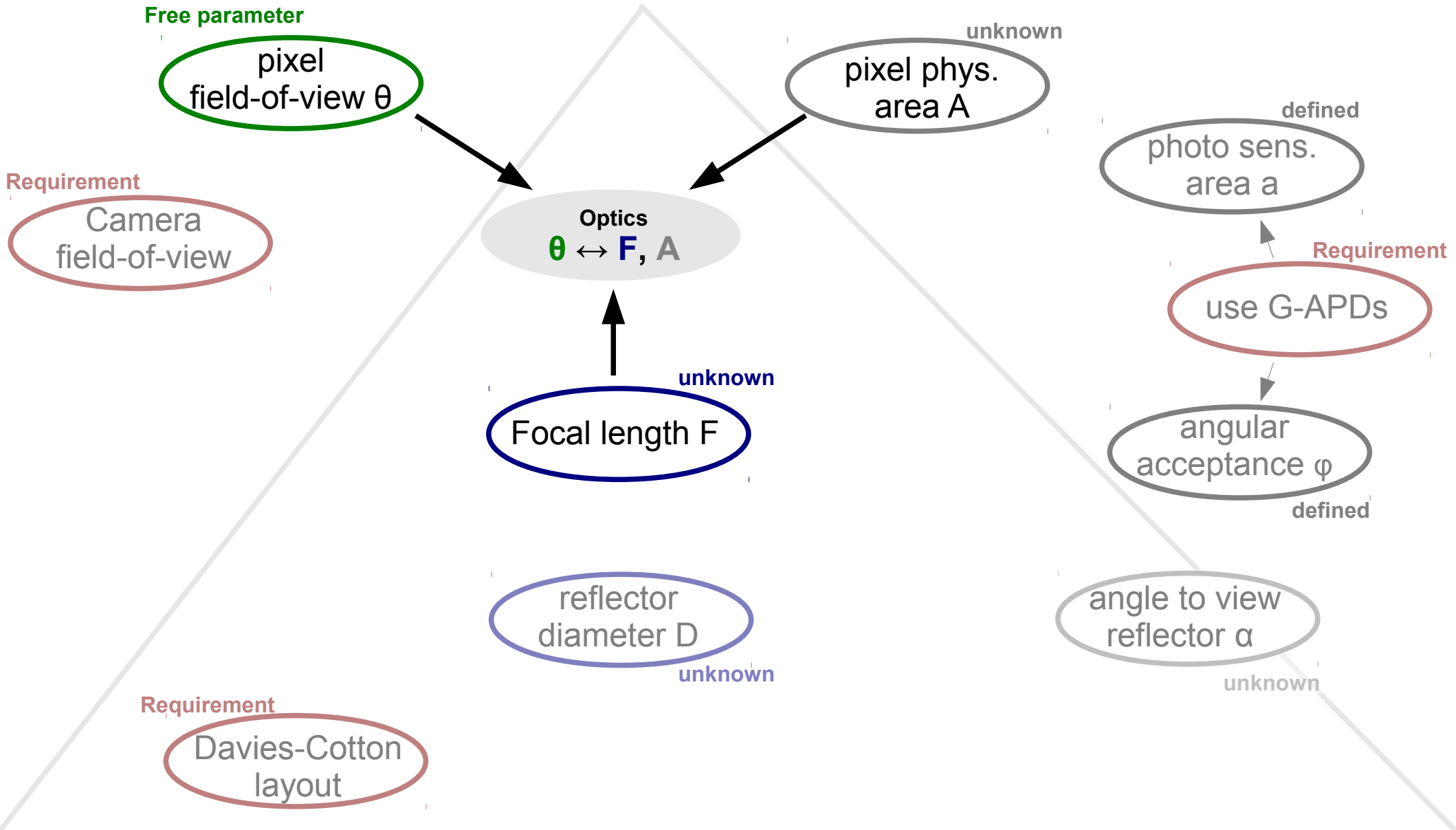
Requirement

Davies-Cotton layout

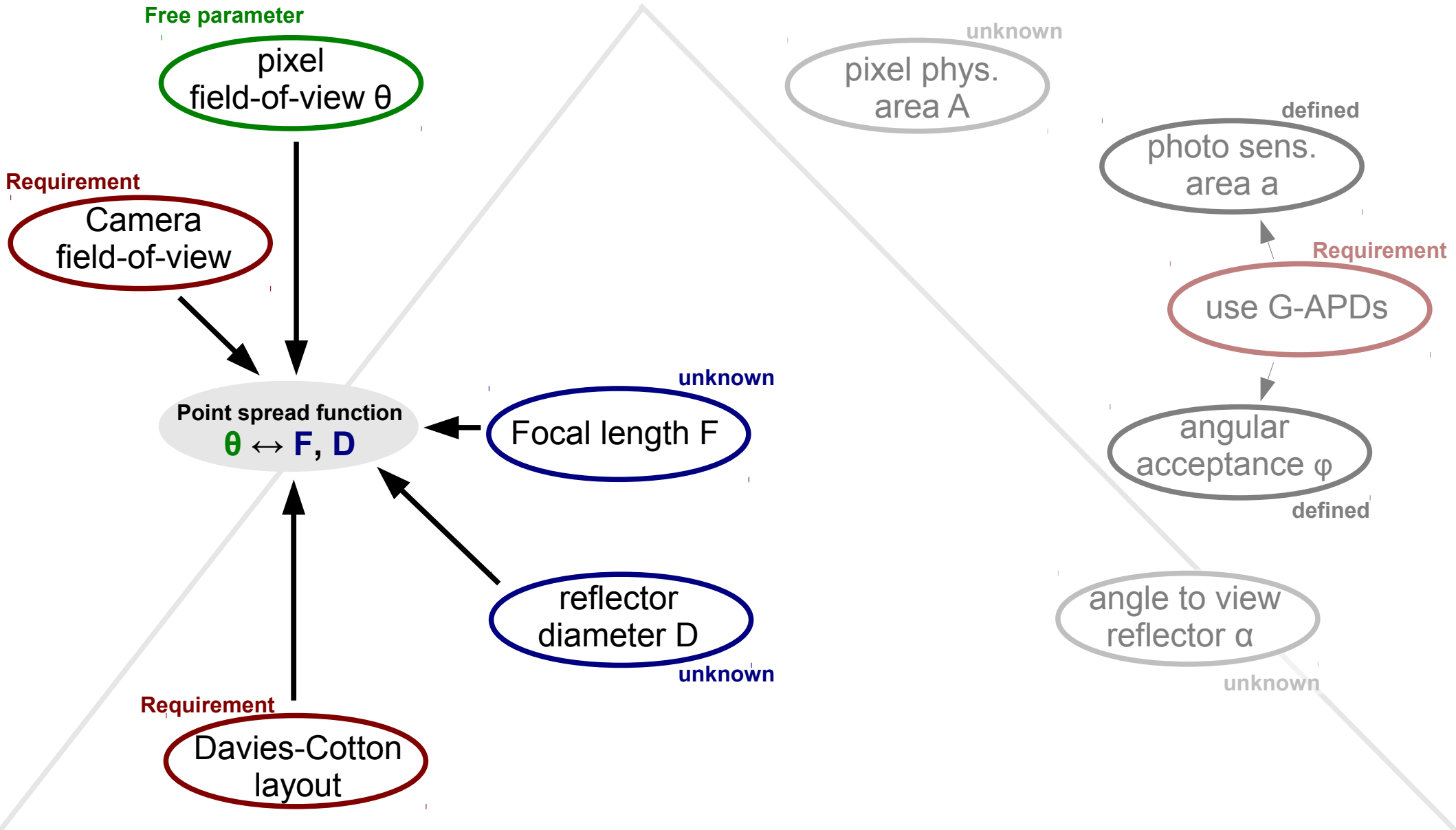
Geometrical relation



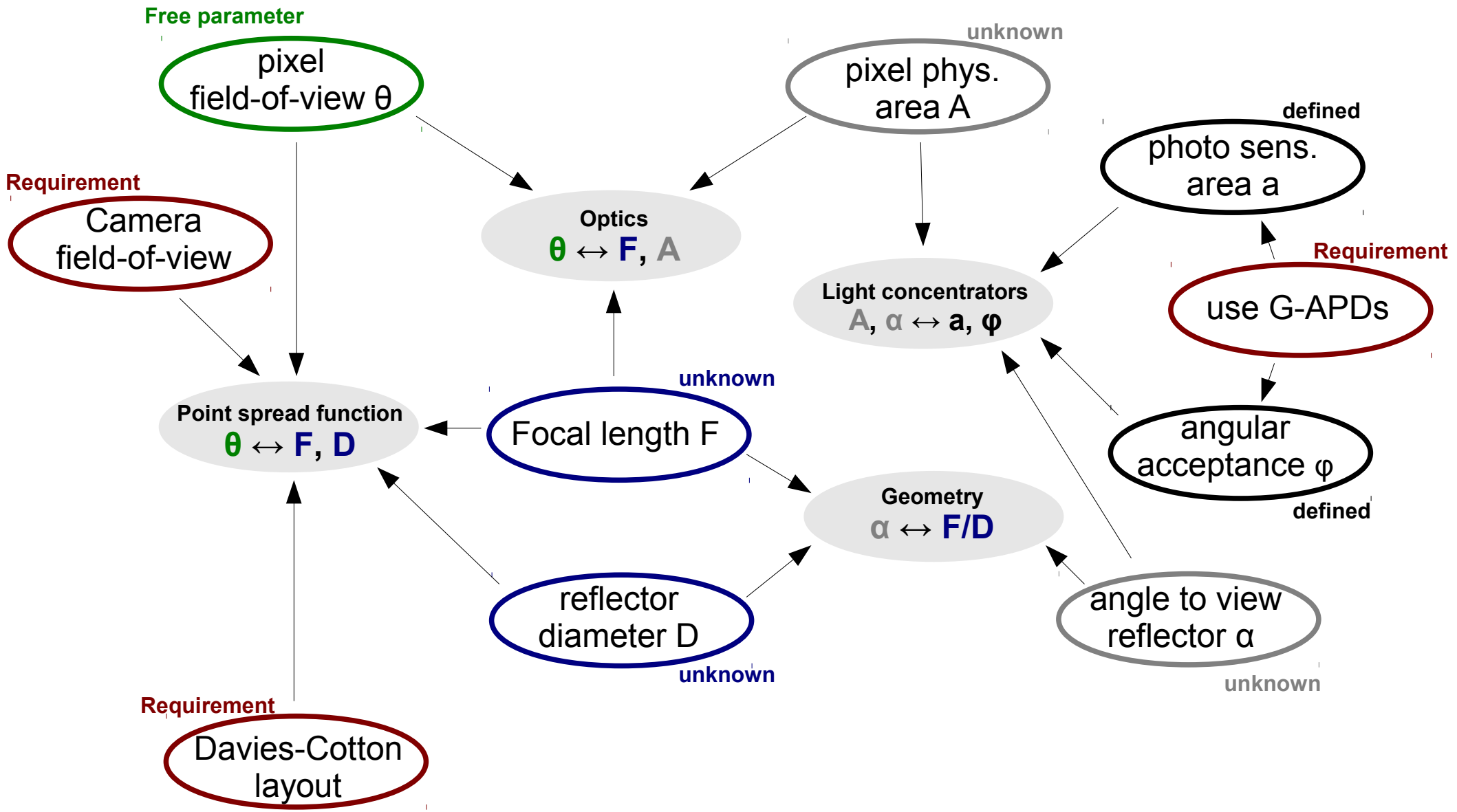
Optics


Free parameter
pixel
field-of-view θ
unknown
pixel phys.
area A
defined
photo sens.
area a
Requirement
Camera
field-of-view
Optics
θ ↔ F, A
Requirement
use G-APDs
unknown
Focal length F
angular
acceptance φ
defined
reflector
diameter D
unknown
angle to view
reflector α
unknown
Requirement
Davies-Cotton
layout

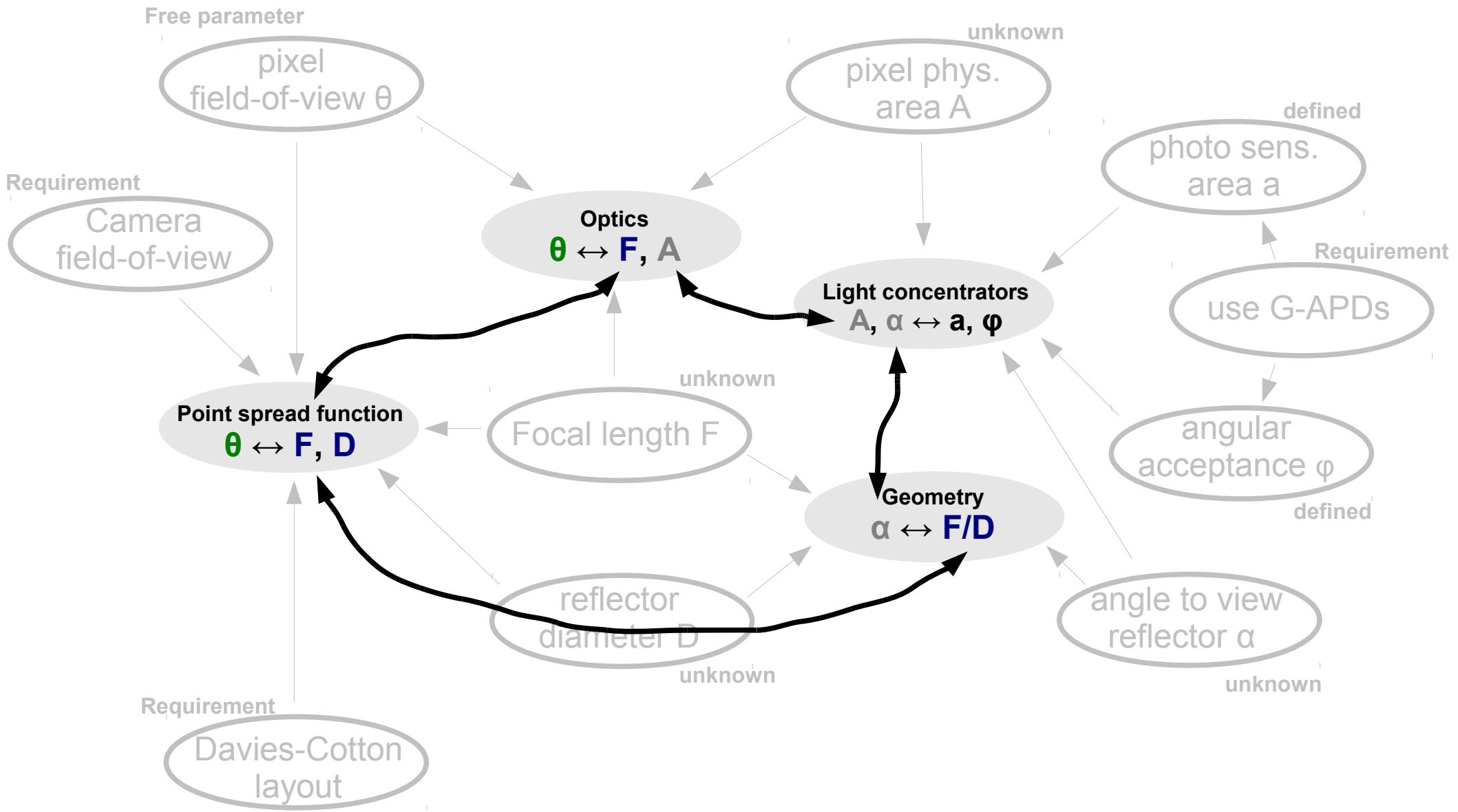
Reflector quality



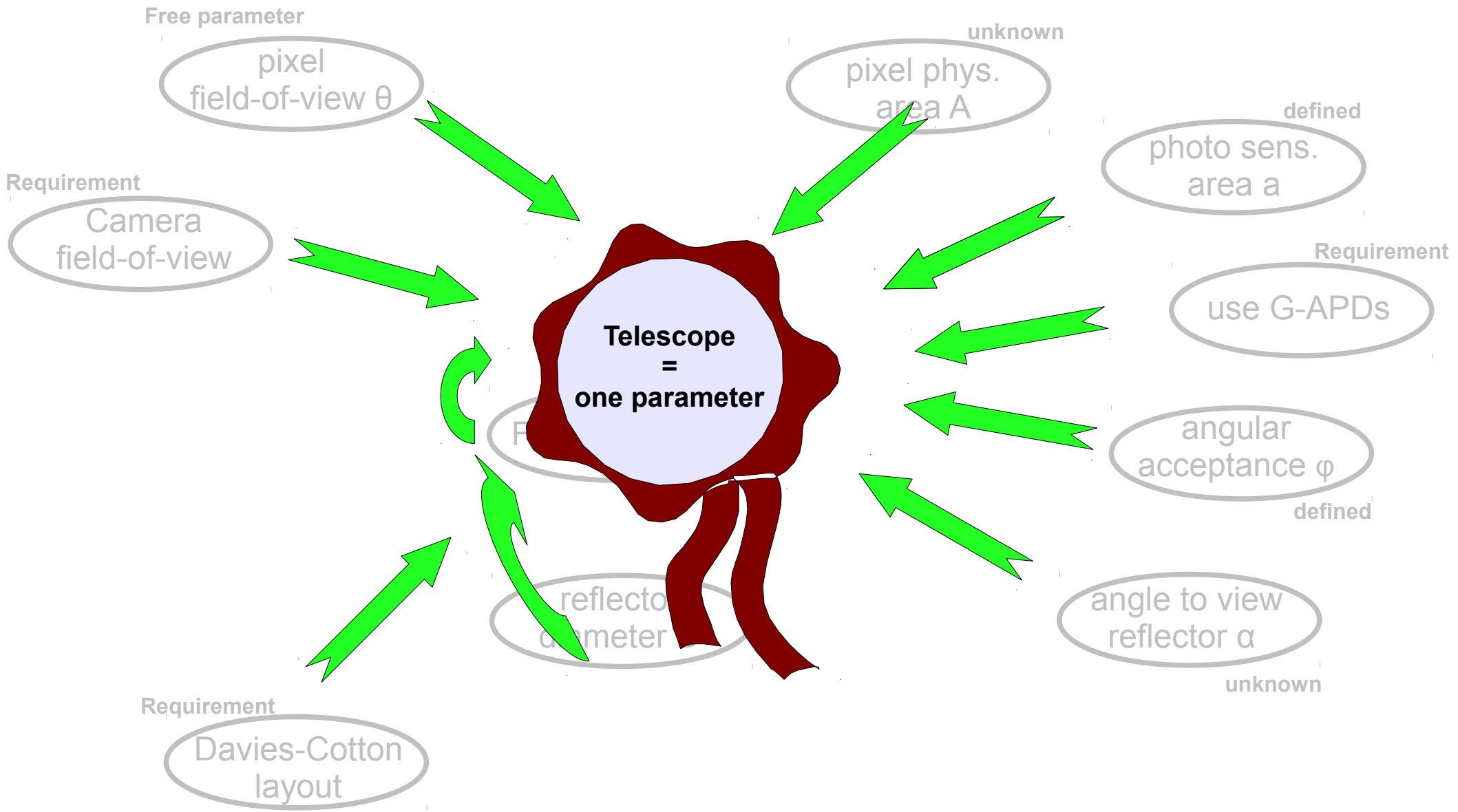
Relations – an overview



Relations – reduction



Relations - reduced

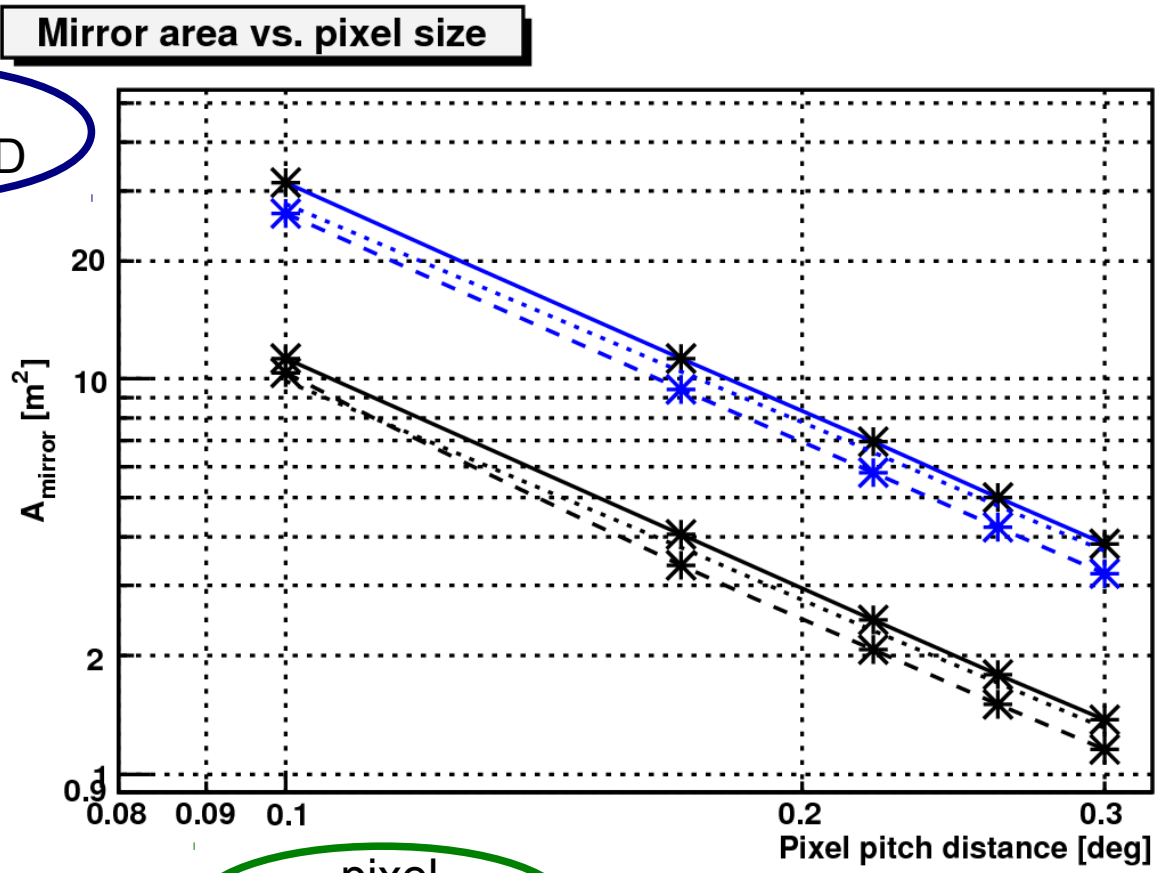


Telescope design - result

reflector diameter D

Camera field-of-view

FoV = 8°



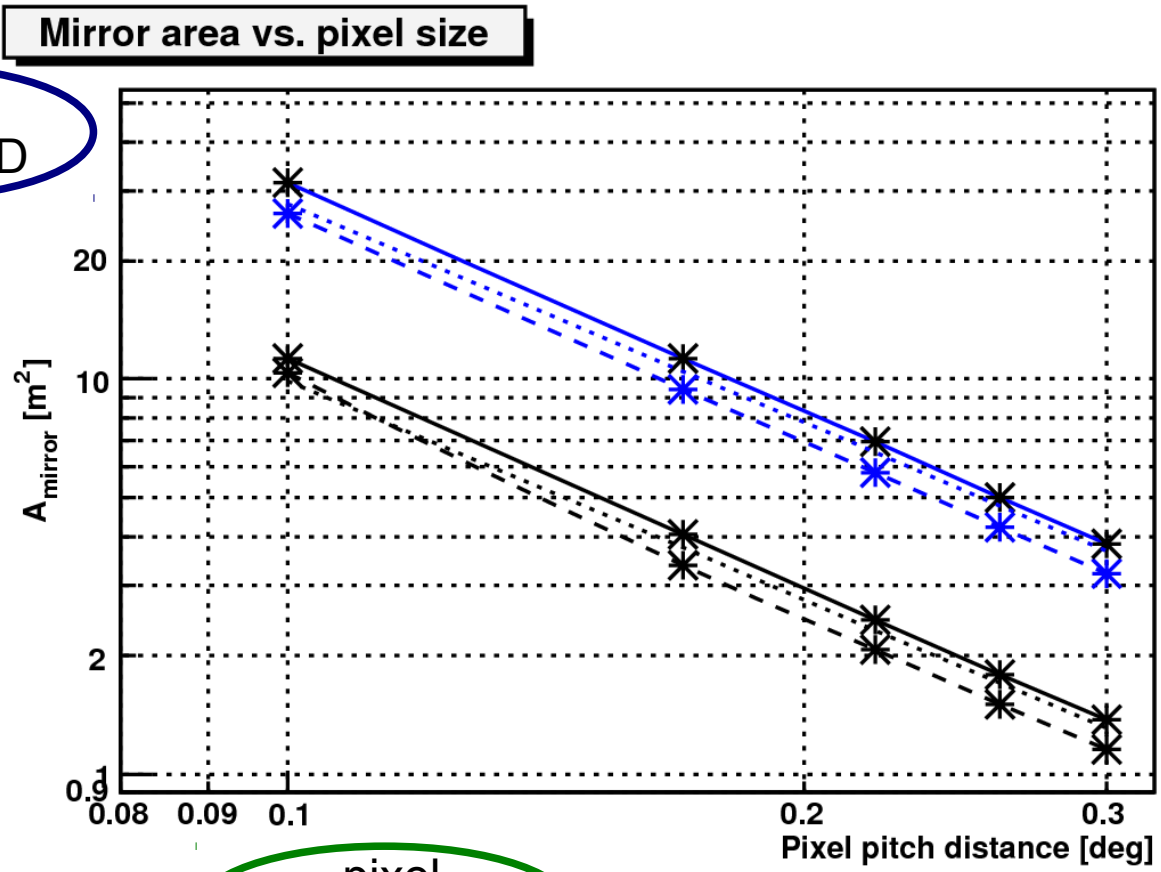
pixel field-of-view θ

use G-APDs

5mm x 5mm (in prep.)

3mm x 3mm (available)

Telescope design - result



reflector diameter D

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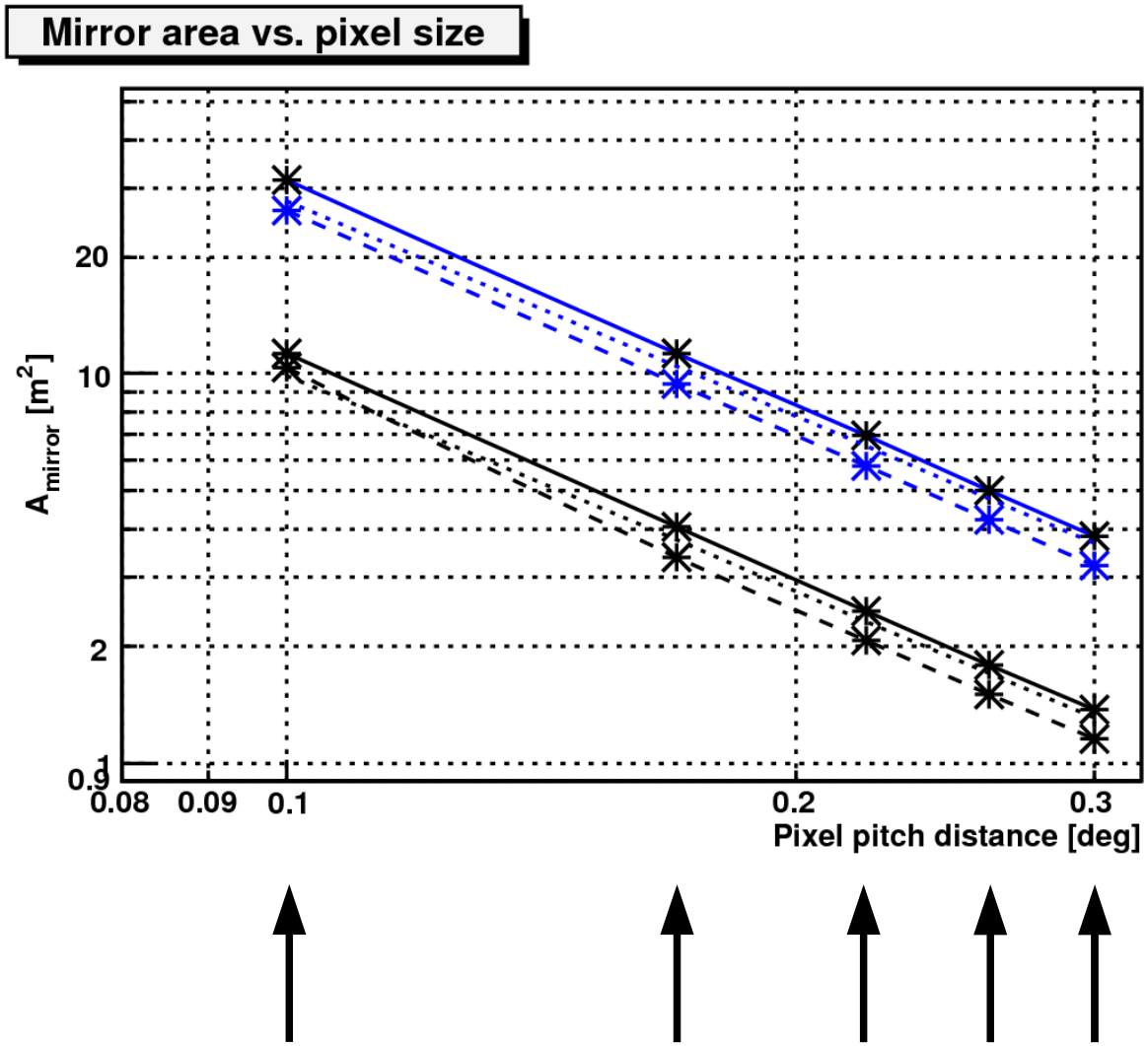
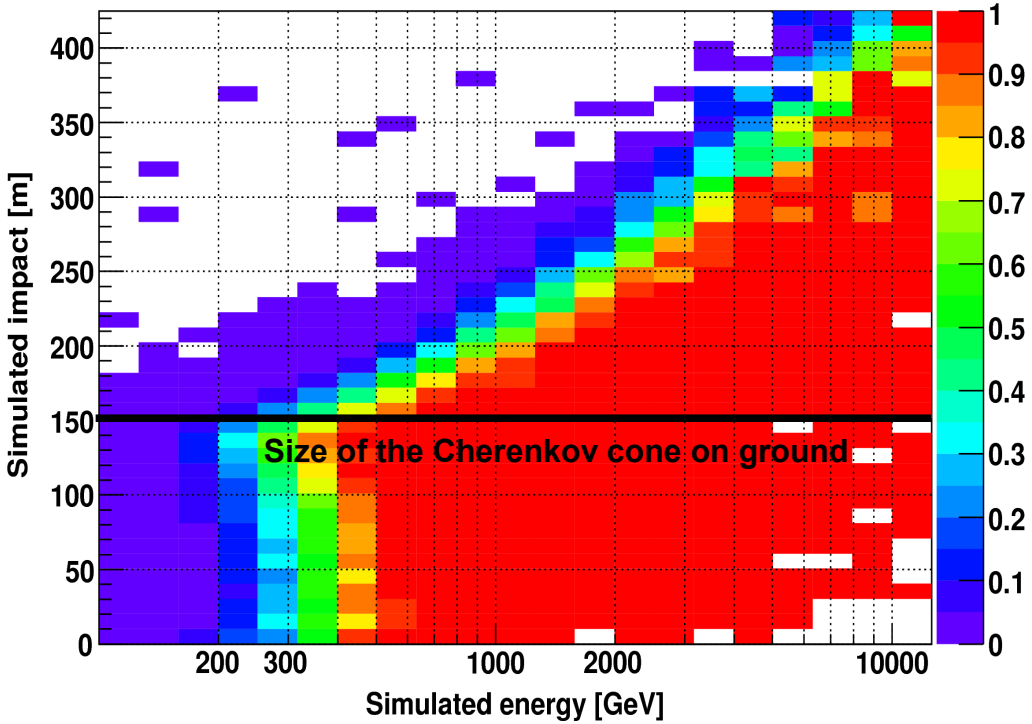
Array layout

Telescope design - simulations



Do a Monte Carlo simulation for these telescopes

Array layout



Simulation of a few telescope setups

↓

Trigger efficiency versus
- primary particle energy
- distance from telescope axis

↓

parametrization / fit

↓

pitch distance, num. telescopes

↓

Toy-MC

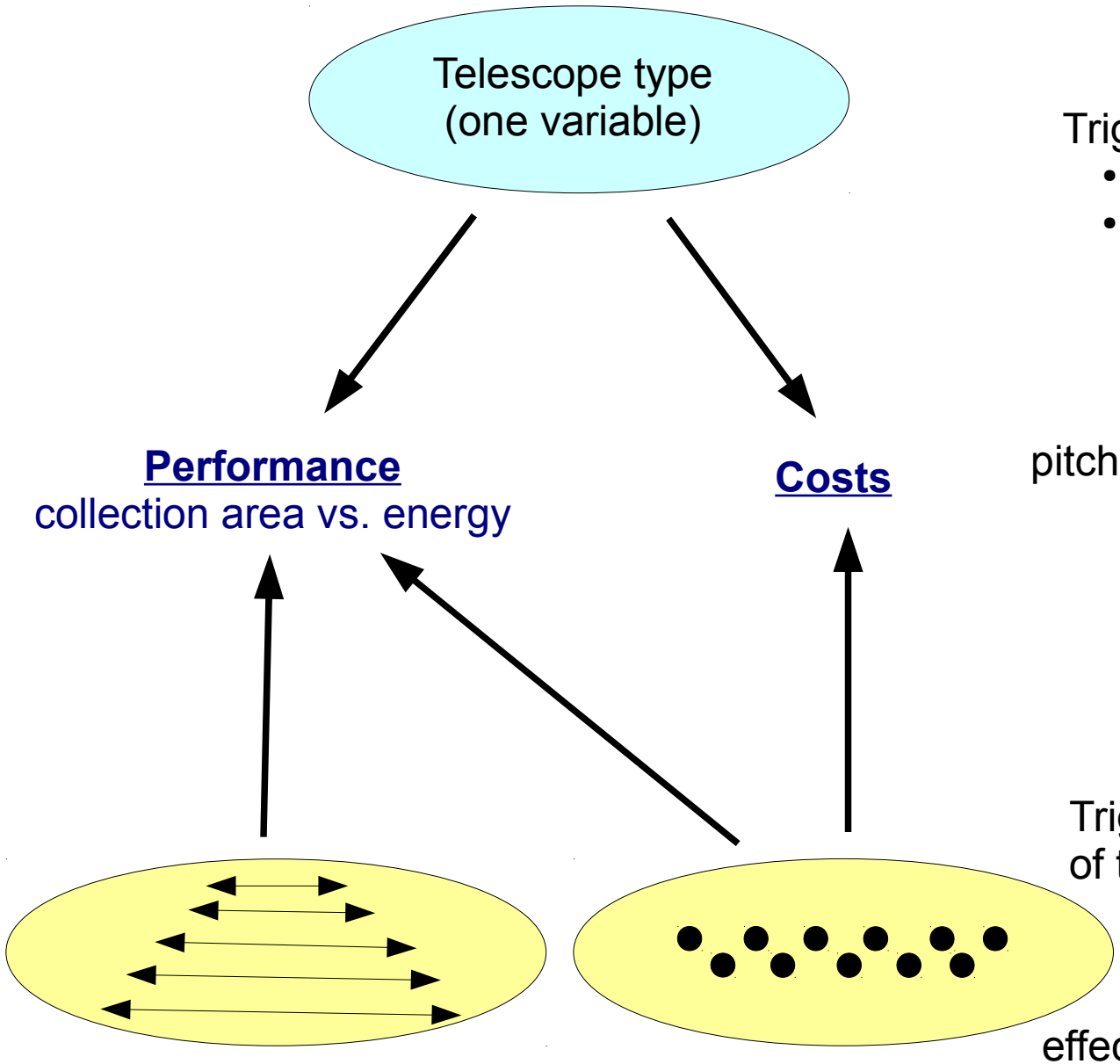
↓

Trigger efficiency for an array of telescopes (e.g. multiplicity 3)

↓

effective collection area vs. energy

Array layout



Simulation of a few telescope setups

Trigger efficiency versus
- primary particle energy
- distance from telescope axis

parametrization / fit

pitch distance, num. telescopes

Toy-MC

Trigger efficiency for an array of telescopes (e.g. multiplicity 3)

effective collection area vs. energy

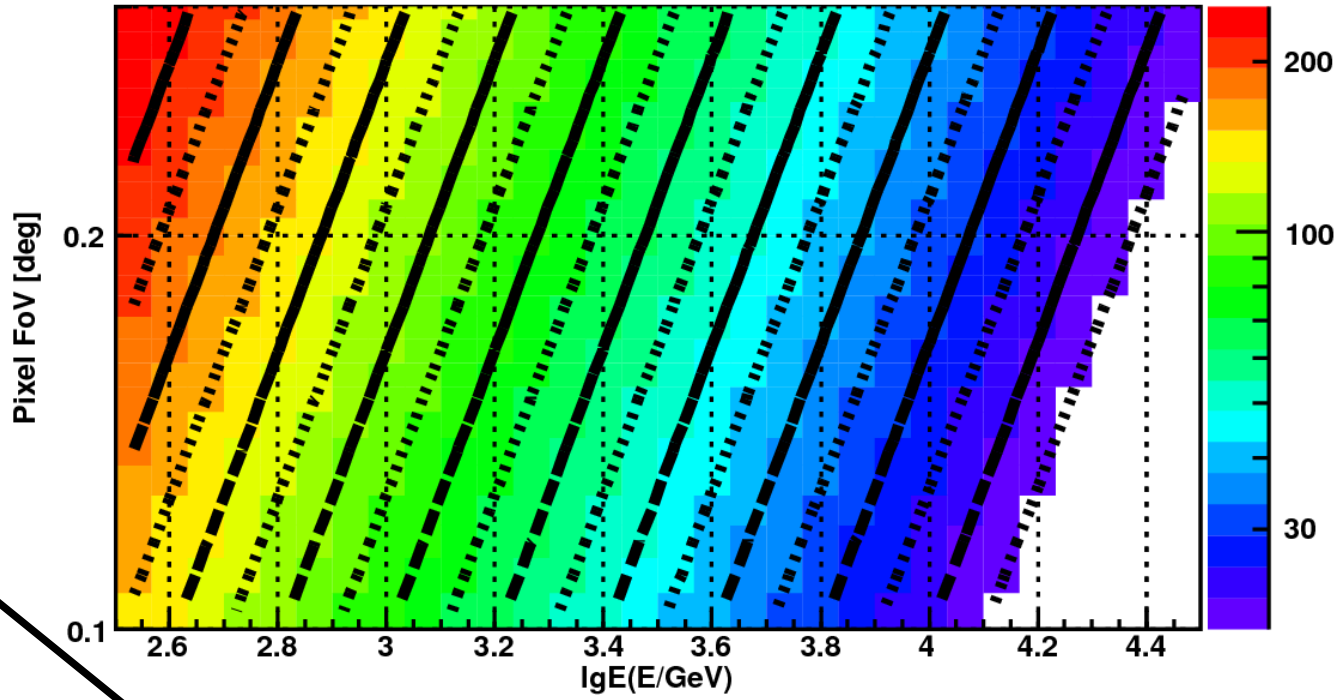
Array layout – a result

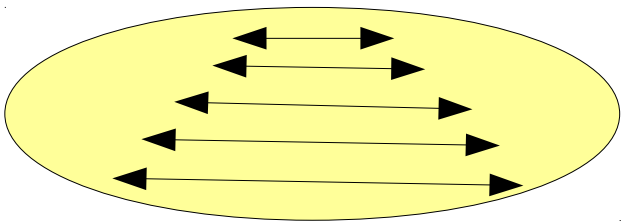
Telescope type
(one variable)

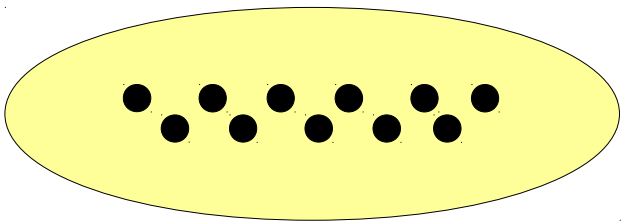
Number of telescope needed to reach an effective collection area of 4km² for

- a given telescope type (pixel FoV)
- at a given energy

Performance
collection area vs. energy







Conclusions

- World wide project with major contributions from Europe
- CTA is the future of Cherenkov astronomy and offers a lot of interesting and exciting physics
- It will turn Imaging air Cherenkov *experiments* into a Cherenkov *observatory*

- Studies have shown that the phase space of possible solutions is rather limited, which makes it easy to optimize the performance of the full array
- Several prototype studies are already on-going including a full featured telescope (FACT)

- CTA's official *preparatory phase* is starting right now and will last roughly three years
  - **Swiss institutes** could be well prepared to play a **leading role** in the **design and construction** of the **small size telescopes**, which would be a **major contribution** to CTA