CORSIKA & CTA

Next-generation CORSIKA workshop - Karlsruhe - 2018, June 25th

Gernot Maier

The Cherenkov Telescope Array

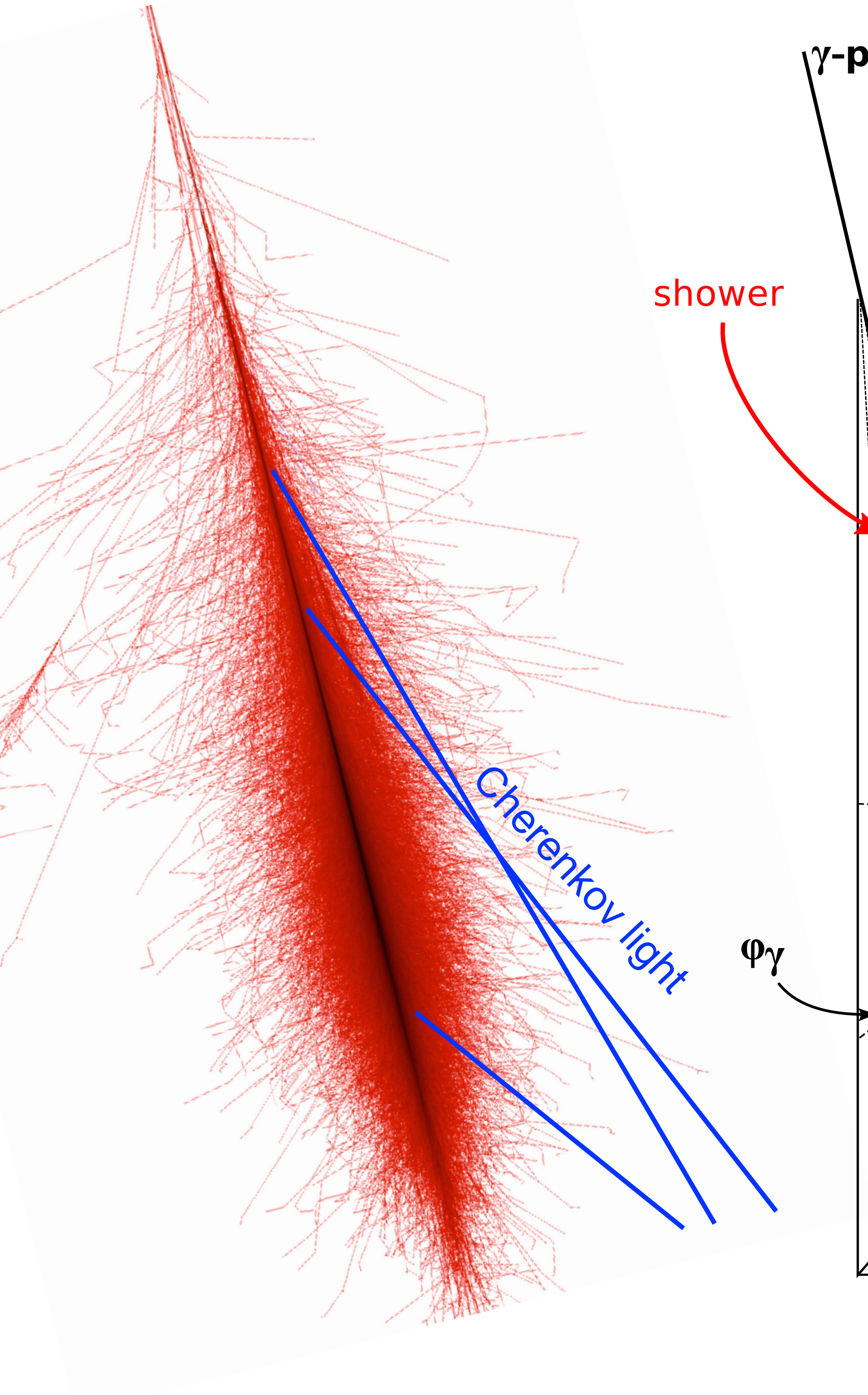
- **the upcoming gamma-ray observatory at energies from 20 GeV to beyond 300 TeV**

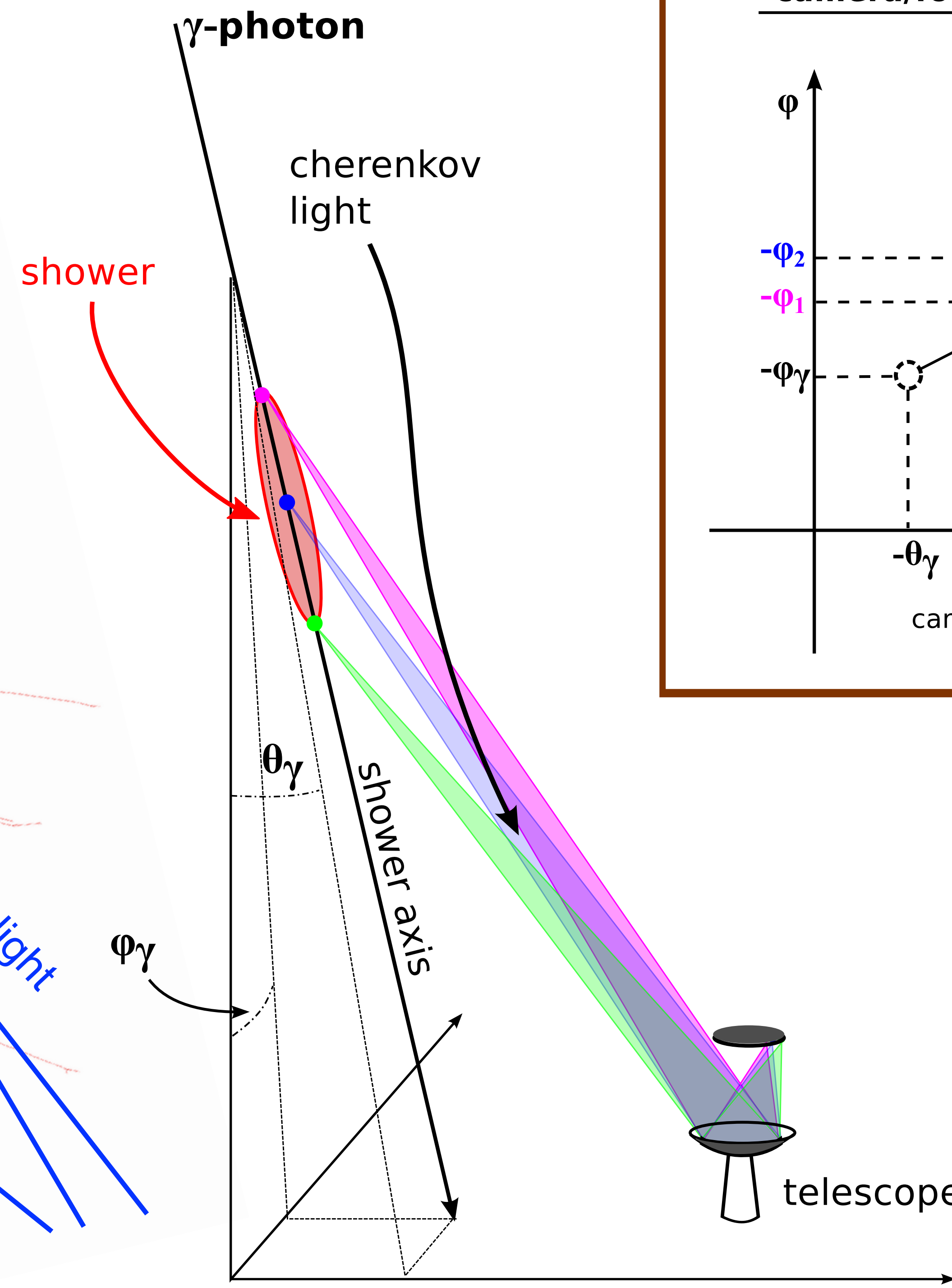
- will be the **largest ground-based gamma-ray detection observatory** in the world, with **more than 100 telescopes** in the northern and southern hemispheres

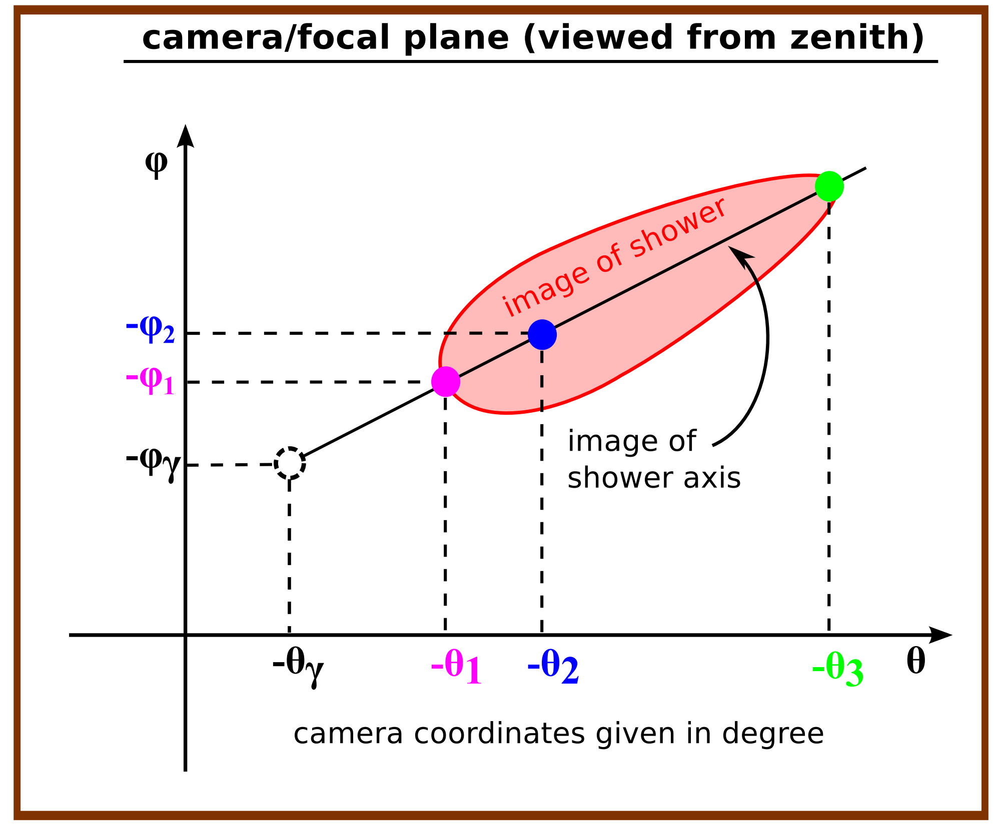
- will have **unprecedented accuracy**
—> reducing the systematic uncertainties will be key for the success of CTA

- **open** to the world-wide astronomical and particle physics communities
—> promise of continuous high quality data products for many years

Imaging Atmospheric Cherenkov Telescopes







Operation:

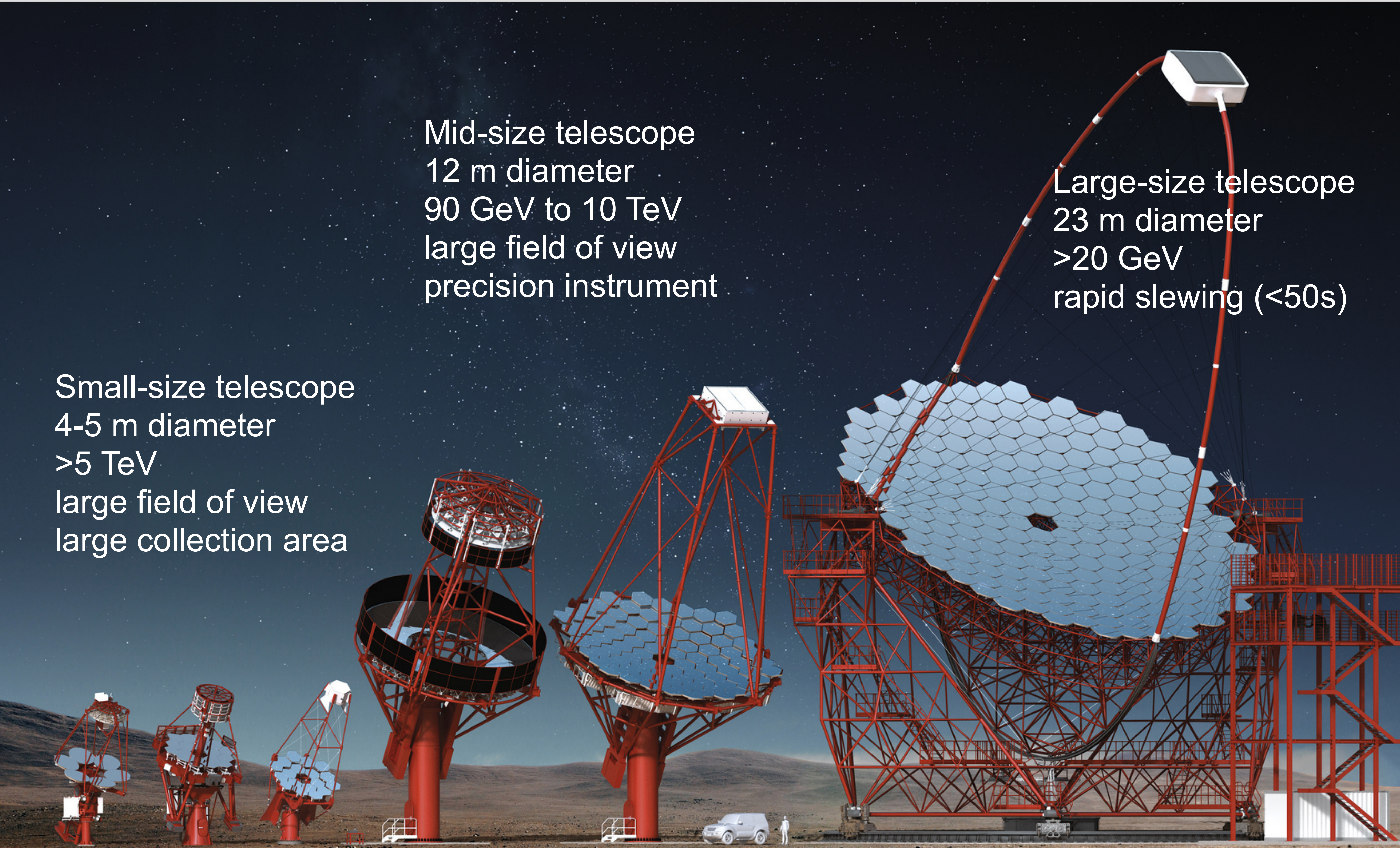
- mostly simulation of primary gamma rays

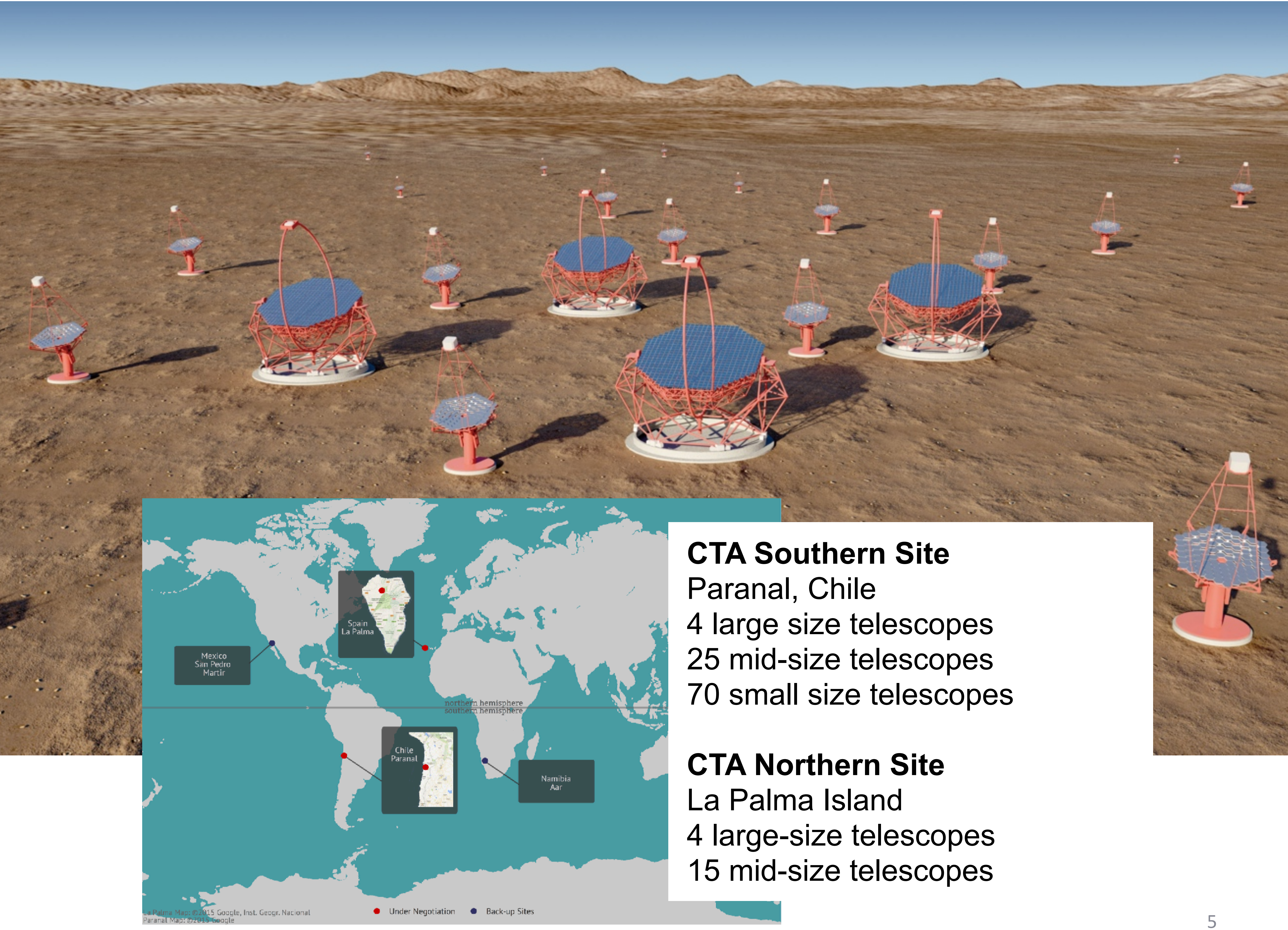
Preparation & Pre-construction phase:

- gamma rays, protons, electrons

+some special cases which might drive the accuracy needed (e.g. direct Cherenkov light)

CTA Telescopes

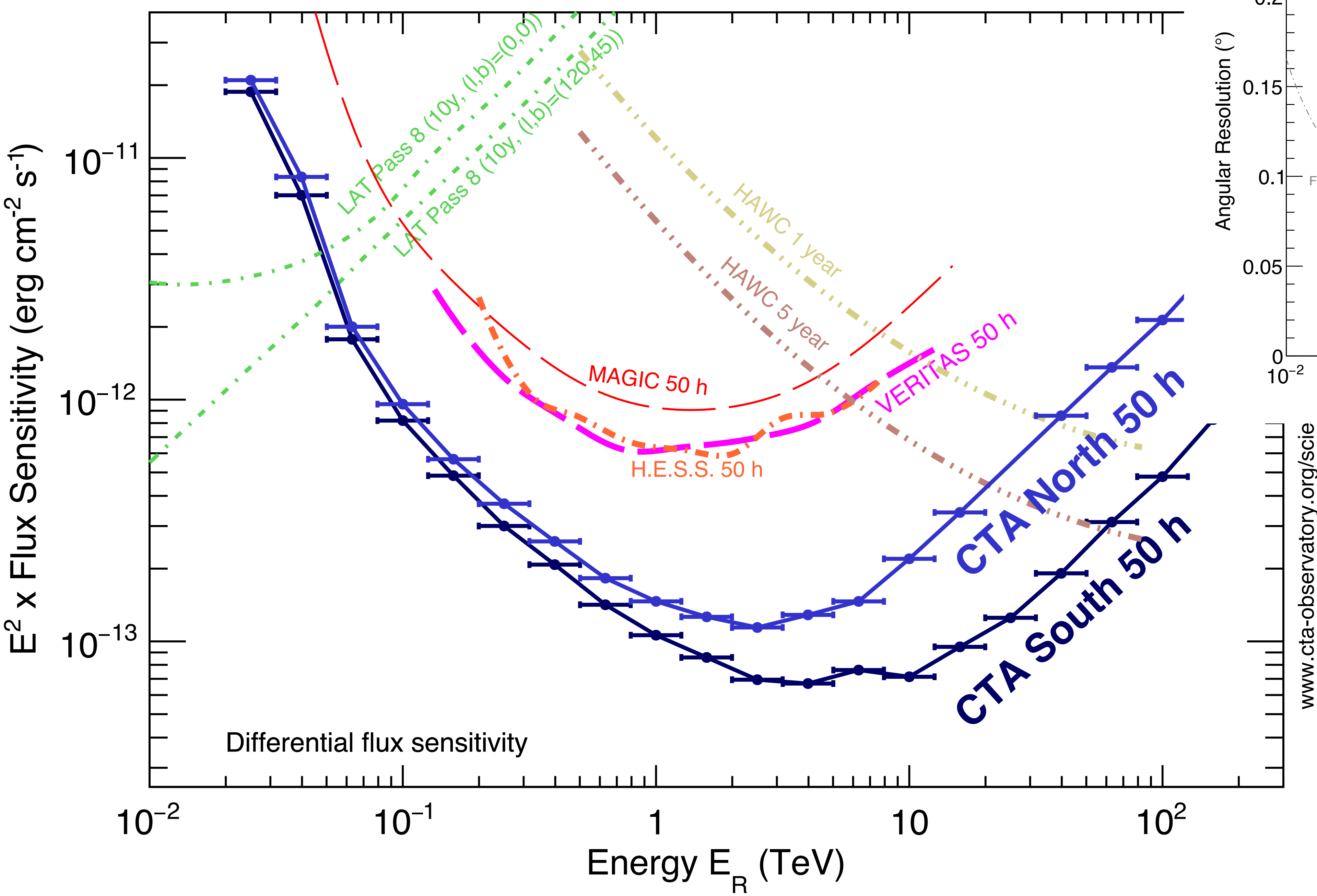


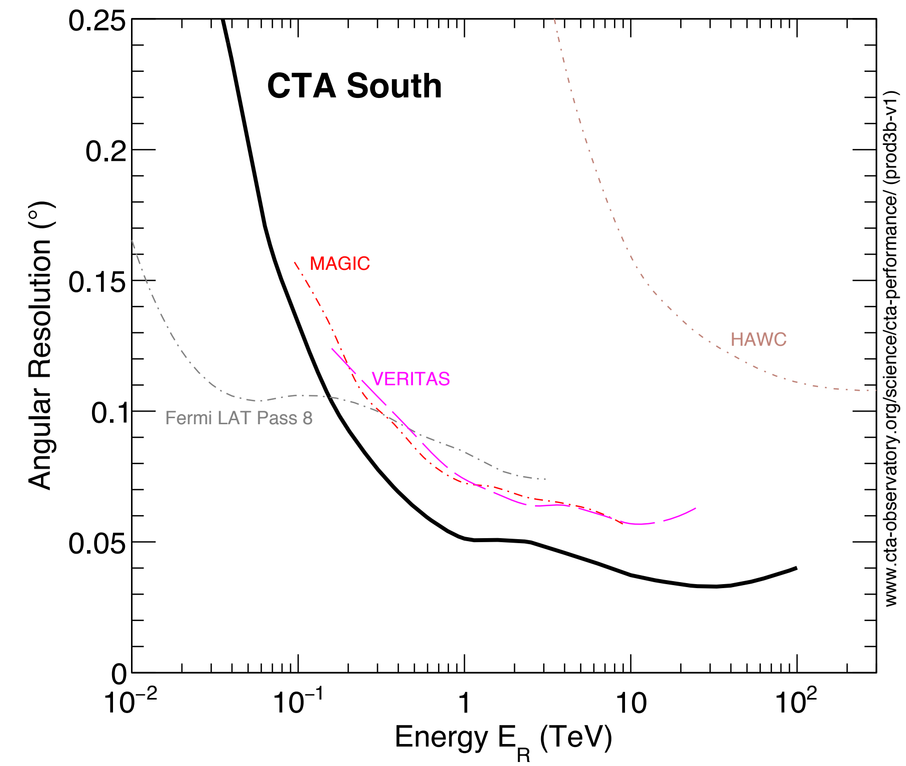


CTA Southern Site
Paranal, Chile
4 large size telescopes
25 mid-size telescopes
70 small size telescopes

CTA Northern Site
La Palma Island
4 large-size telescopes
15 mid-size telescopes

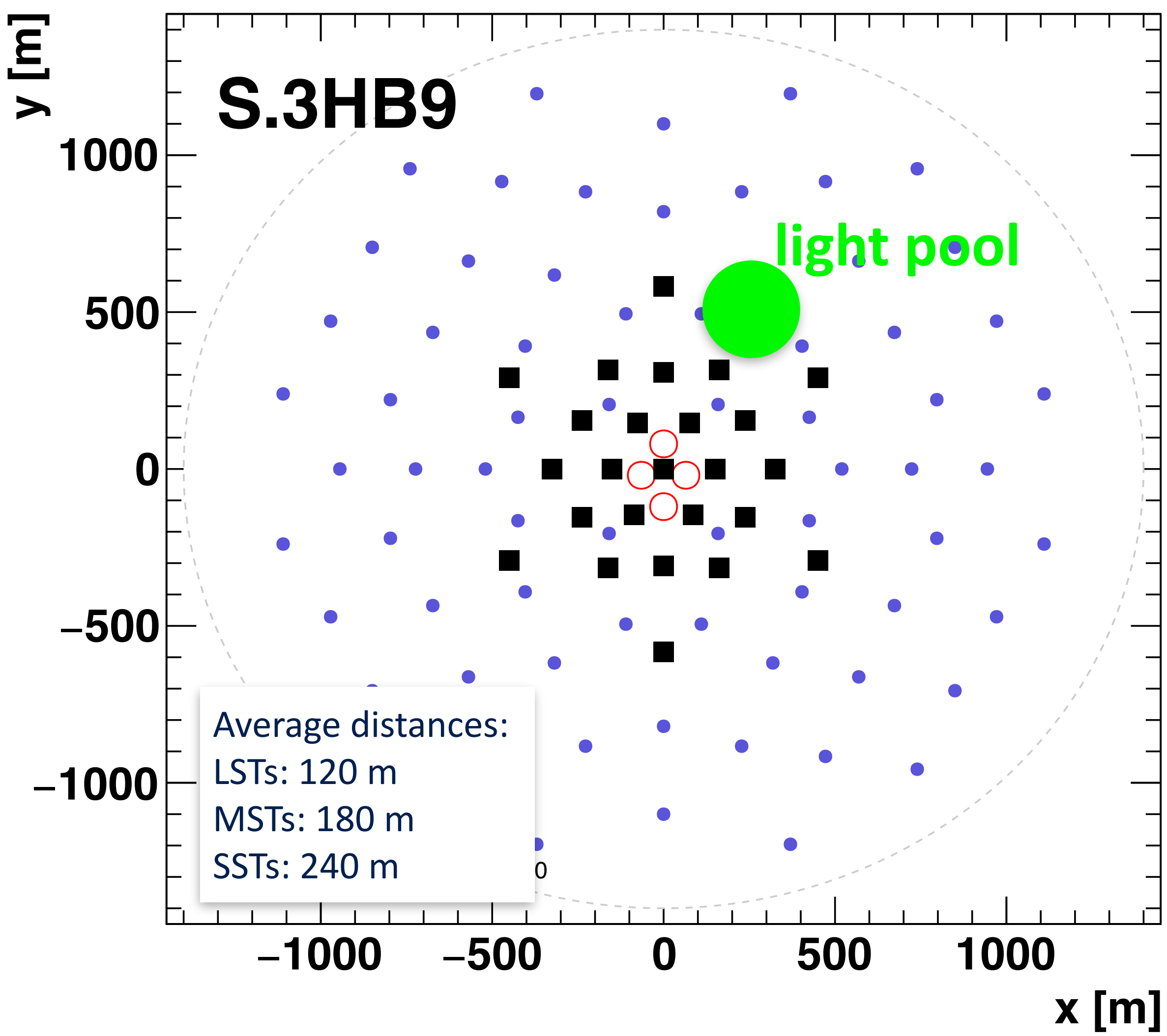
The Cherenkov Telescope Array

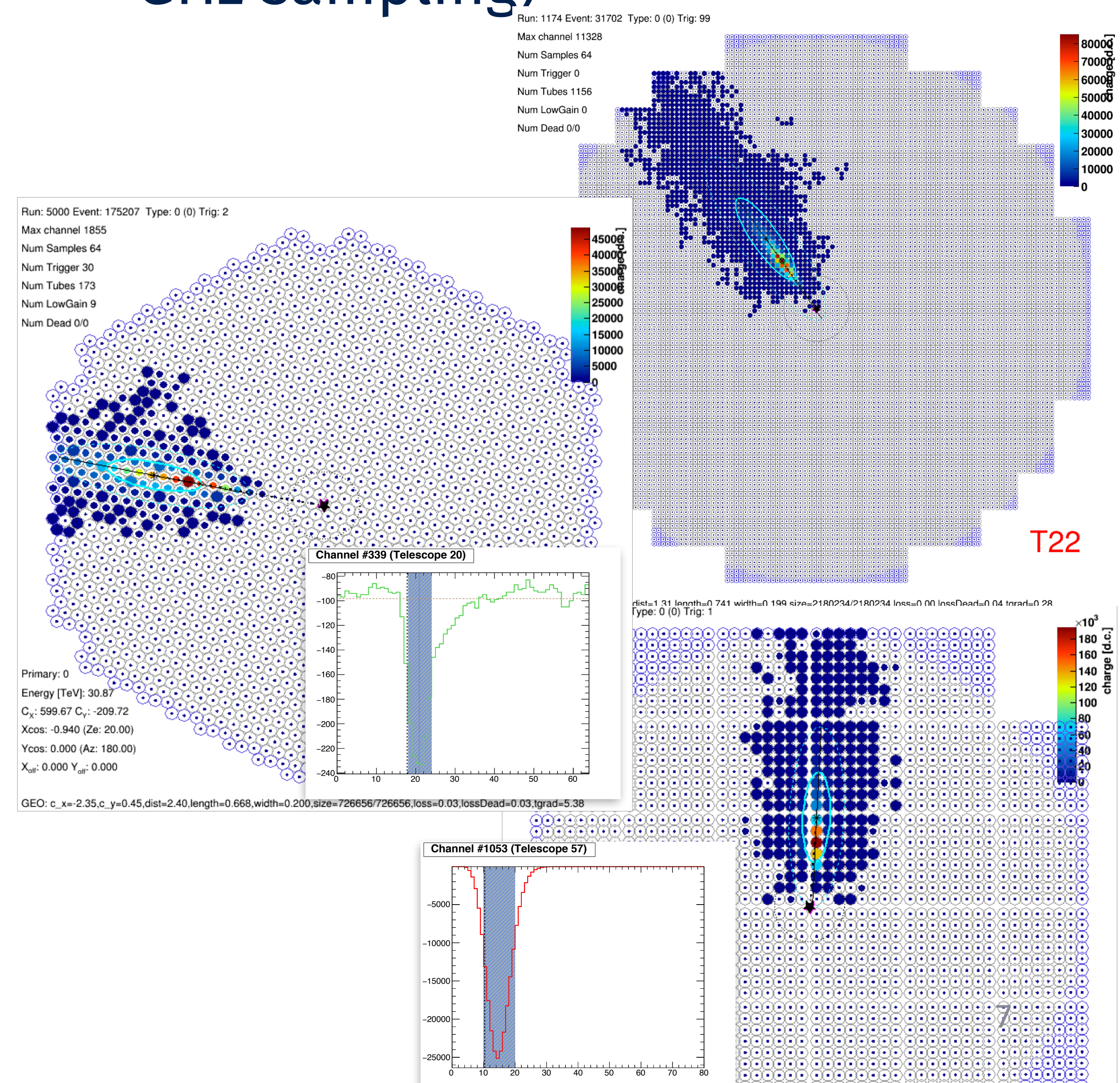




What will be different with CTA?

- high-multiplicity “inside events”
- large telescope distances (beyond the light pool edge)
- small pixelation and fast timing (0.07-0.25 deg; up to GHz sampling)





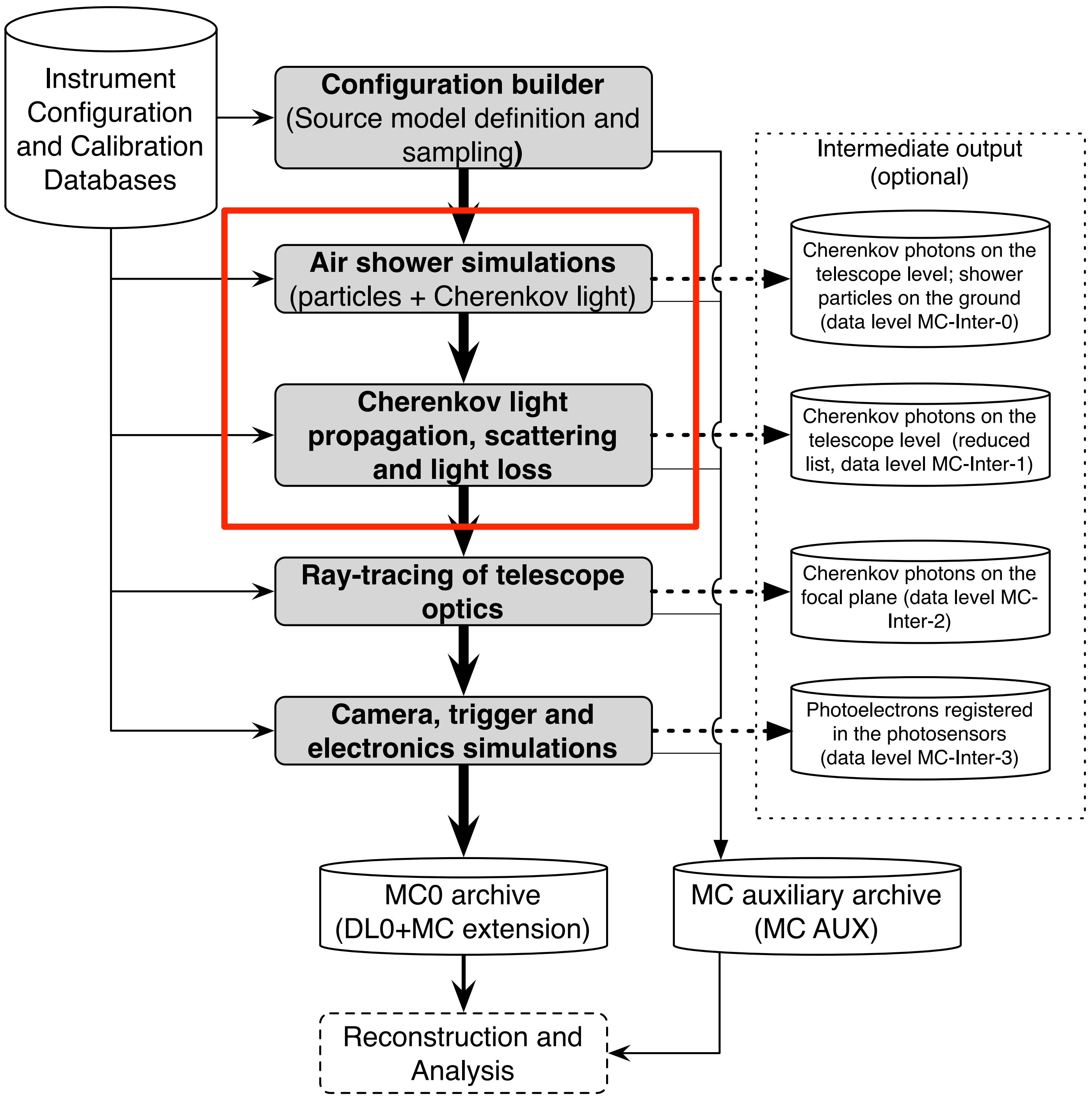
Systematic Uncertainty Budget

Requirement for systematic uncertainties on energy scale: <10%

	currently achived	goal for CTA	
Simulation codes	5 %	1-2 %	
Simplification in Detector MC	2 %	2 %	
Cherenkov light production	5 %	2 %	mainly molecular profile
Ozone absorption	3 %	1 %	Potential vorticity, spectrometer
Molecular extinction	2 %	1 %	Radio sondes and GDAS
Cirrus layer extinction	5-10%	1-2%	Raman LIDARS and FRAM
Boundary layer extinction	5-10%	1-2%	Raman LIDARS and FRAM
Scattered Cherenkov light	<1%	<2%	

CTA Simulation Production Chain

- typical production chain with air-shower + telescope simulation chain
- **run-wise Monte Carlo production**
  - simulate (sub-)array of telescopes that are **tracking a sky position**
  - consider e.g. broken pixels, calibration, night-sky background, **atmospheric model** for this run



Cherenkov emission in CORSIKA

- original Cherenkov emission implemented for non-imaging arrays (rectangular detector setup on a horizontal plane)
- extension to CORSIKA: **IACT/ATMO package** (‘bernloehr package’)
  - non-rectangular array layouts and IACT geometry
  - use of tabulated atmospheric profiles
  - atmospheric refraction
  - own data format

See Johan’s / Luisa’s presentation for the relevant routines

Unification of all Cherenkov modules??

- for the new CORSIKA version: coordinate the needs of the different instrumental group and obtain one single Cherenkov module?
  - aim also for better integration of IACT module in CORSIKA

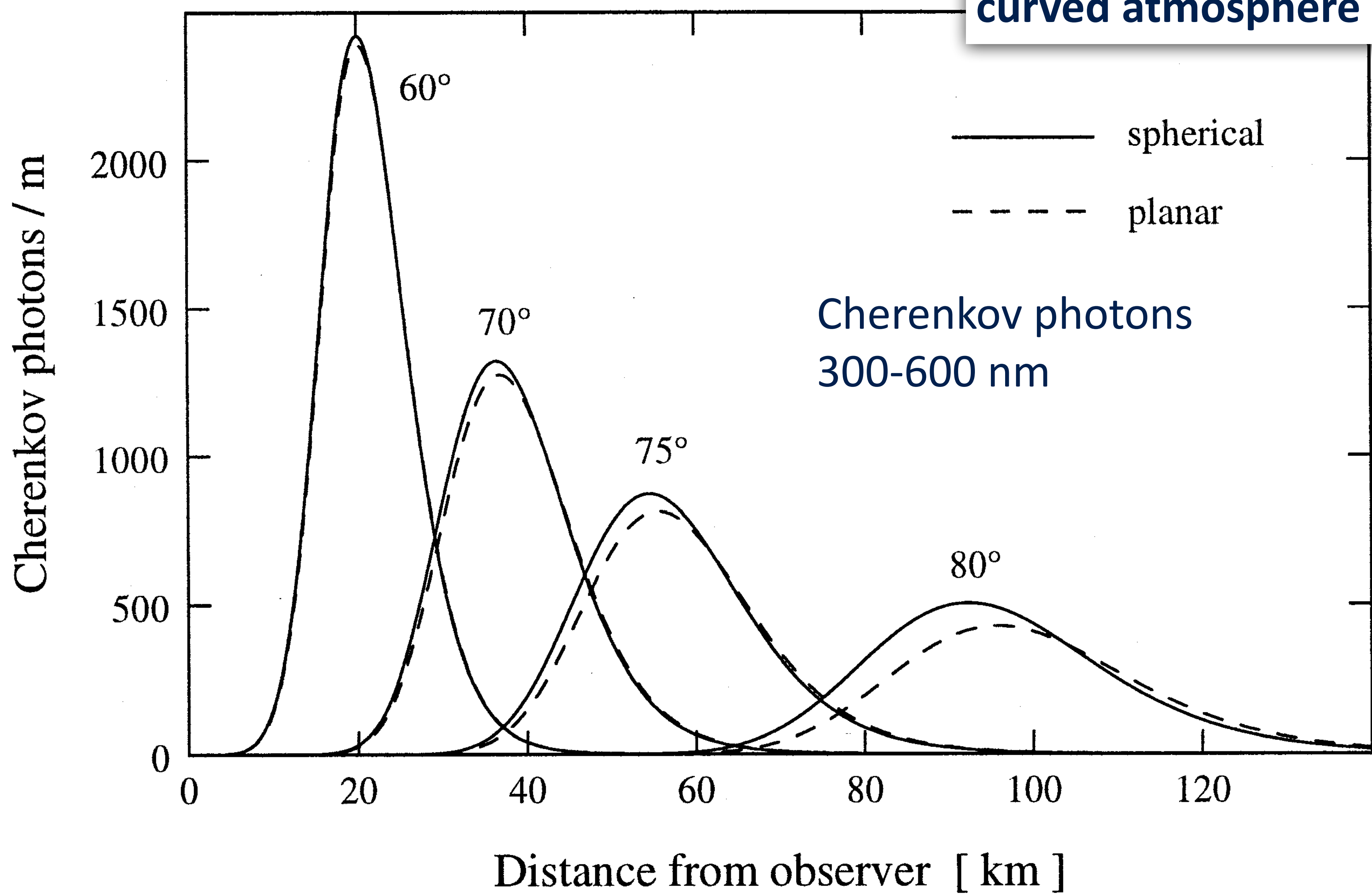
(same for fluorescence?)

Curved Atmosphere

CTA: elevation range from 20 to 90 deg

Current separation of planar and curved atmosphere 'artificial'

Bernlöhr 2000



Cherenkov photons 300-600 nm

hadronic showers: differences in shower development

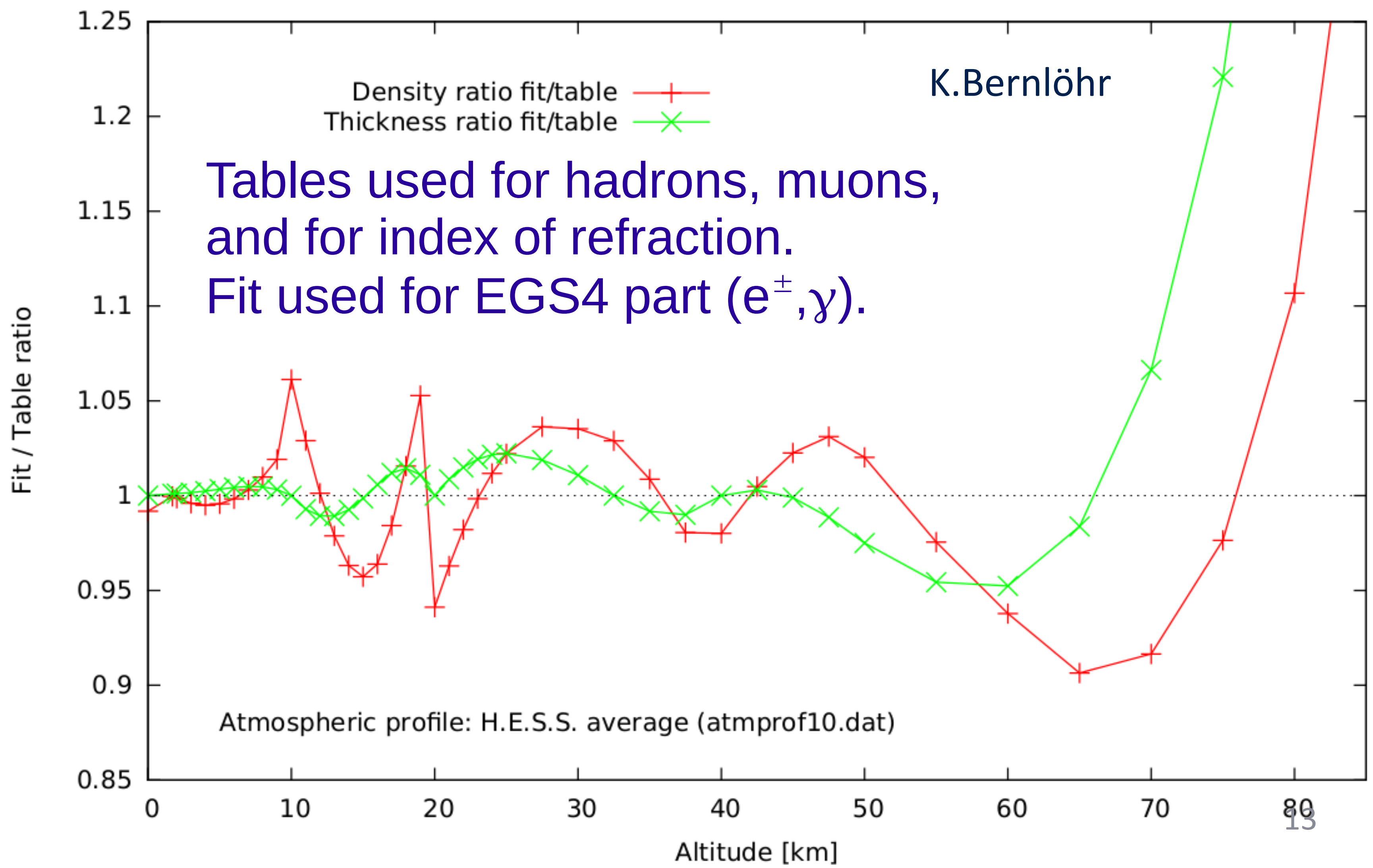
Geomagnetic field

- more realistic assumption on geomagnetic field (~roughly)
- e.g. shower at large zenith angle extents over 10-100 km: geomagnetic field changes both in direction and intensity +change in height (effect of a few percent only, but possibly relevant in future)

Atmospheres in EGS4

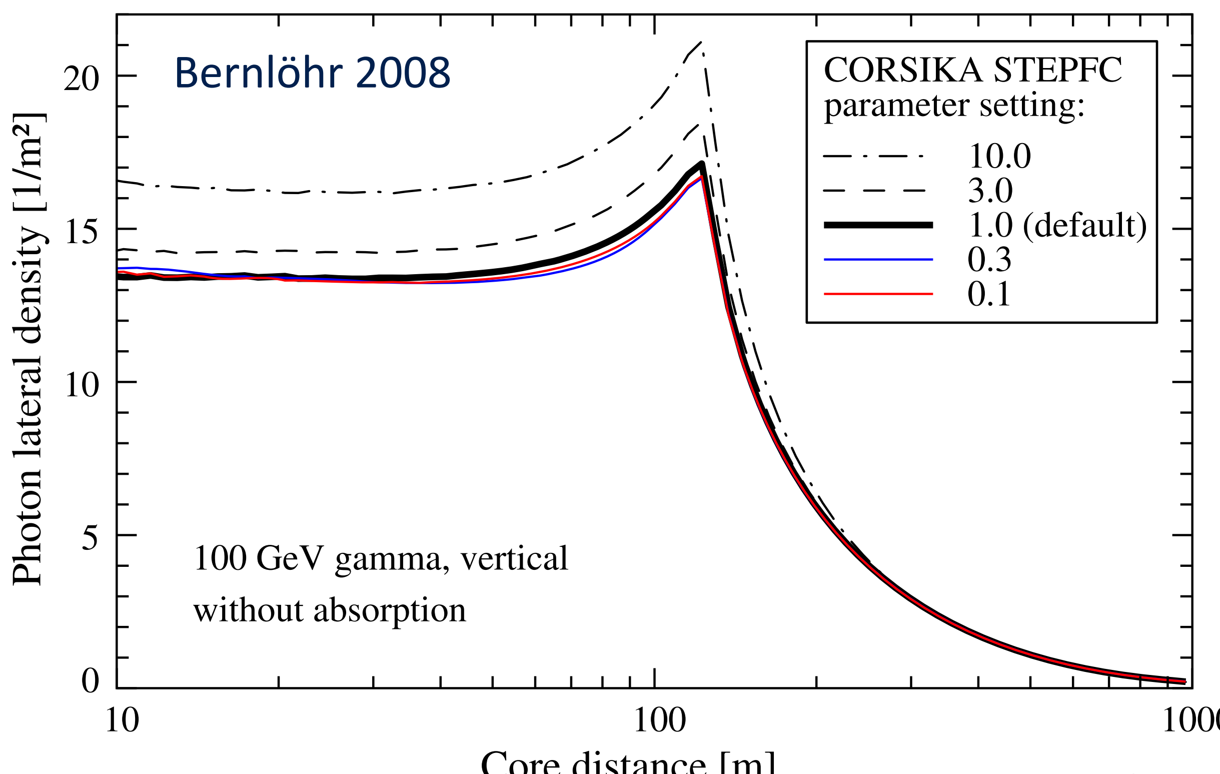
- EGS part in CORSIKA (and output data) hardcoded with five atmospheric layers (4 exponential, 1 linear density gradient).
- Simultaneously fitting density and thickness of tabulated atmosphere, with up to a few percent differences for relevant altitudes …
- percentage-scale impact on energy scale?

Probably the most pressing issue for CTA: affects already now the systematic uncertainty



Particle transport - step sizes

- high angular resolution of IACTs (smallest pixel size: 0.06 deg) maximum step sizes in CORSIKA with IACT option are smaller than without IACT
- track segments can have lengths up to several km at high altitudes
- maximum bending in geomagnetic field between two track segments must be below pixel size
- multiple scattering angle between track segments must be well below pixel size
- limits are hard-coded
  - need to be reconsidered…



CTA & CORSIKA

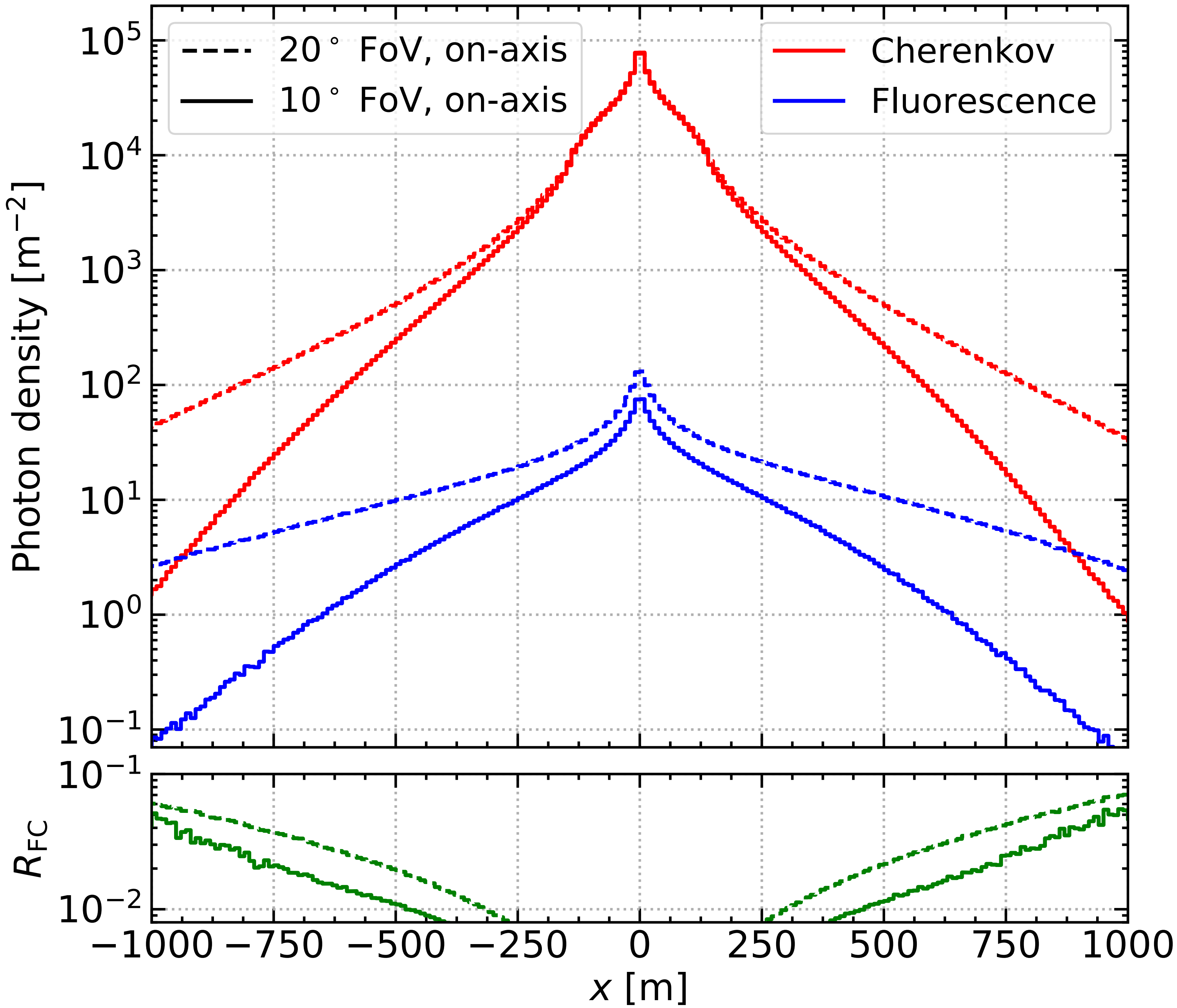
- CORSIKA is one of the core software tools essential for the success of CTA

- Essentials, given the lifetime of CTA (30 years+):
  - code quality, documentation, and maintainability

- CORSIKA is a key tool for CTA - long term support from CTA Consortium and/or Observatory for maintenance and development can be expected

Backup

Fluorescence light



Morcuende et al 2018