FlashCam:
A novel camera for the Cherenkov Telescope Array

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for the CTA Consortium

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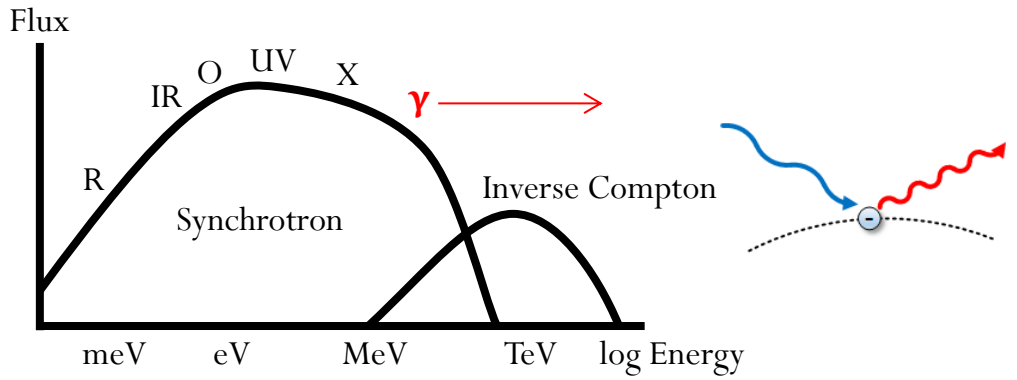
Gamma-ray astrophysics

- Very high energy (VHE) gamma-ray astrophysics: 10 GeV to >100TeV
- Sources: Supernova remnants, pulsars, active galactic nuclei, DM, …



- Gamma rays cannot be produced by thermal radiation and
- are not deflected by interstellar magnetic fields and hence allow

  $\Rightarrow$ the indirect probing of the population of highly relativistic cosmic particles

  $\Rightarrow$ study of particle acceleration mechanisms in cosmic sources

  $\Rightarrow$ possible detection of dark matter annihilation: $\mathrm{X} + \bar{\mathrm{X}} \rightarrow \gamma + \gamma$

Detection of the HE and VHE γ-rays

High energy (HE) regime of 30 MeV – 100 GeV

Detection with space-borne instruments

Detection technique: $\gamma \rightarrow e^+e^-$

✗ small detection area in the order of 1 m^2

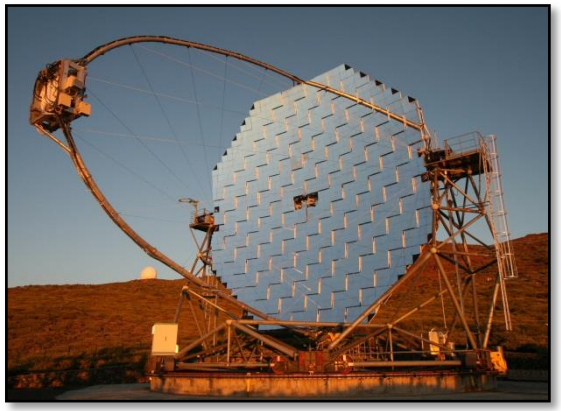
Very high energy (VHE) regime of 30 GeV – 100 TeV

Detection with ground-based instruments (e.g. Cherenkov telescopes)

Detection technique: $\gamma \rightarrow e^+e^-$ in atmosphere $\Rightarrow$ Cherenkov light

✓ large detection areas in the order of 10^5 m^2

✗ only useable during clear and dark night



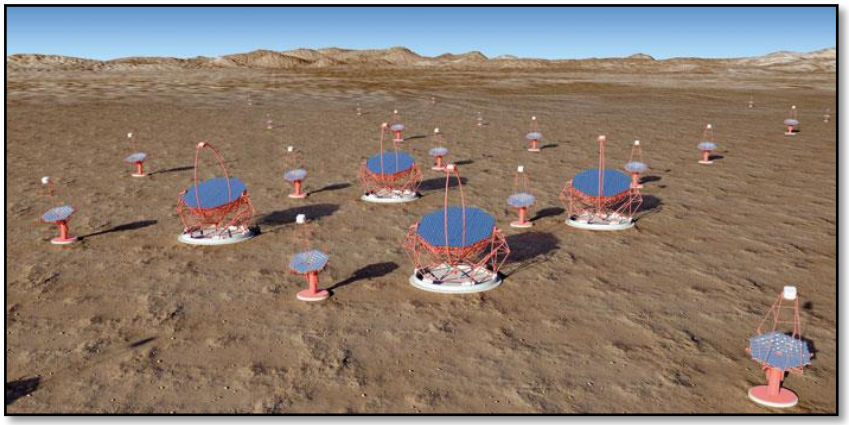
Credit: R. Wagner

Cherenkov Telescope Array (CTA)

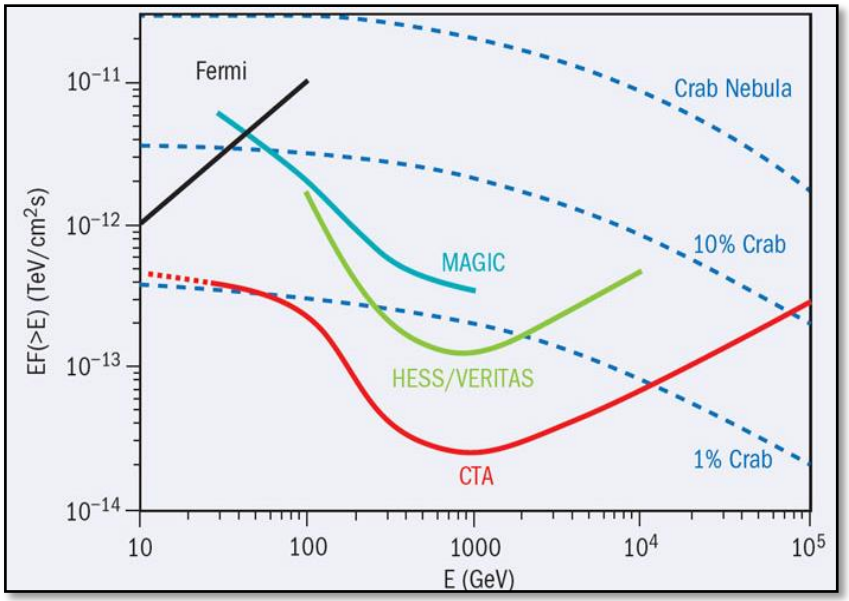
- Energy range: 20 GeV – 300 TeV
- 10 x better sensitivity than current instruments
- $\leq 0.05°$ angular resolution @ TeV energies
- $\leq$ 10% energy resolution @ TeV energies
- Full-sky coverage with south and north array

Dish ∅	South #	North #
4-7m	80-100	0
12m	25	15
23m	4	4

- For the southern side:
  - First telescopes on-site expected in 2016
  - Full operation expected in 2019



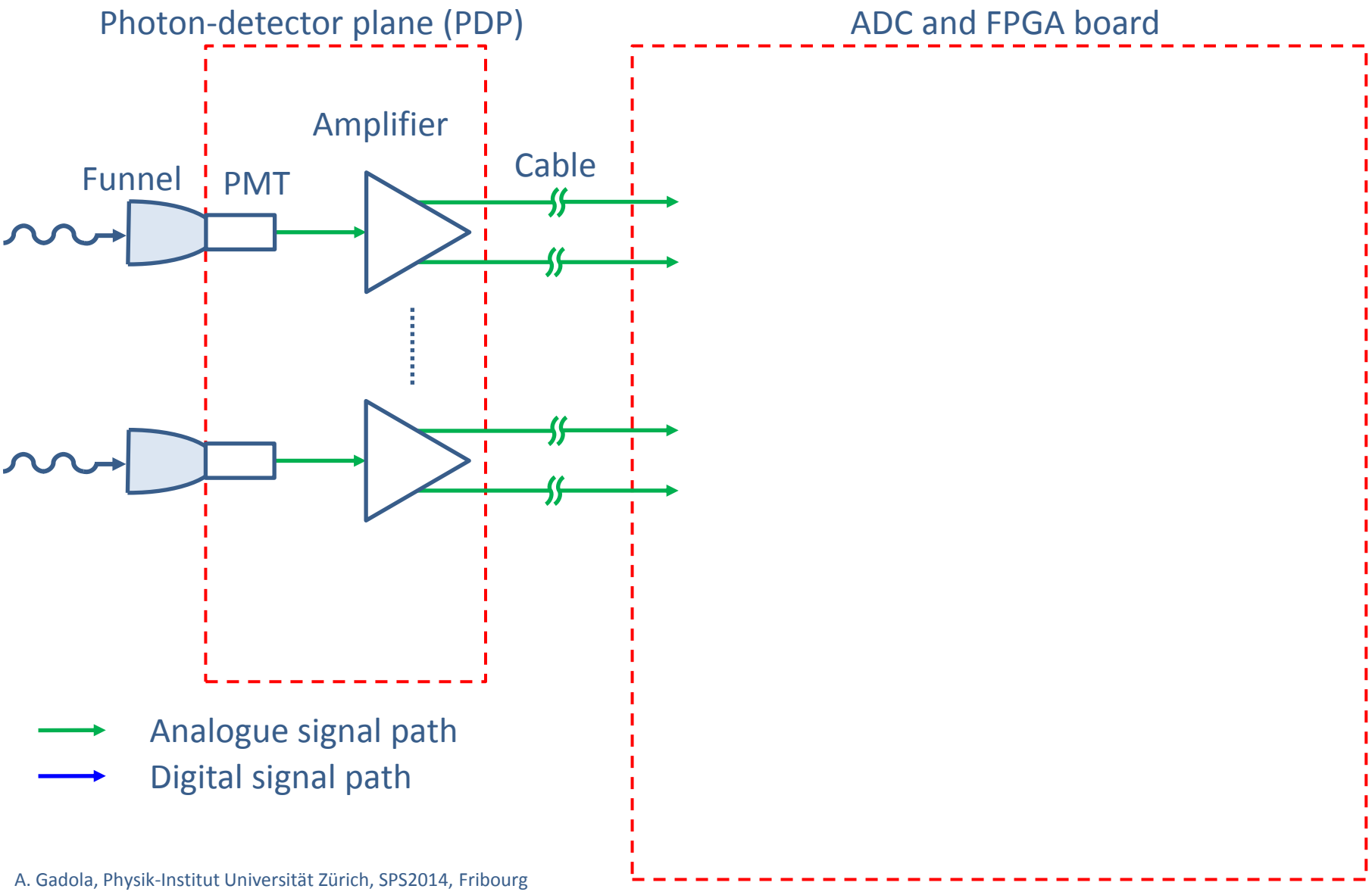
Credit: G Pérez/IAC/SMM



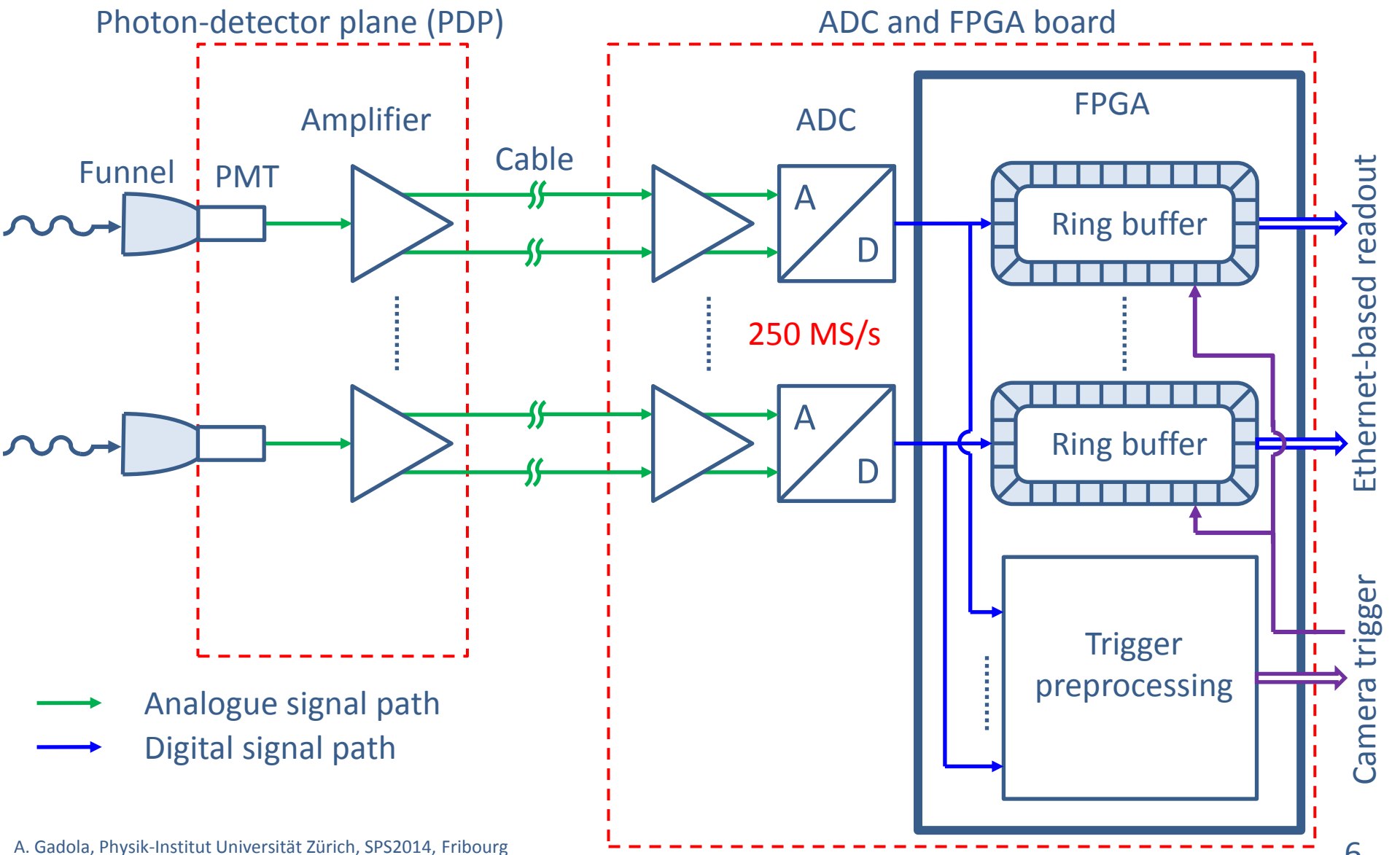
Instrument sensitivity for a Crab-like source spectrum for 50 hours of observation

Credit: Cern Courier

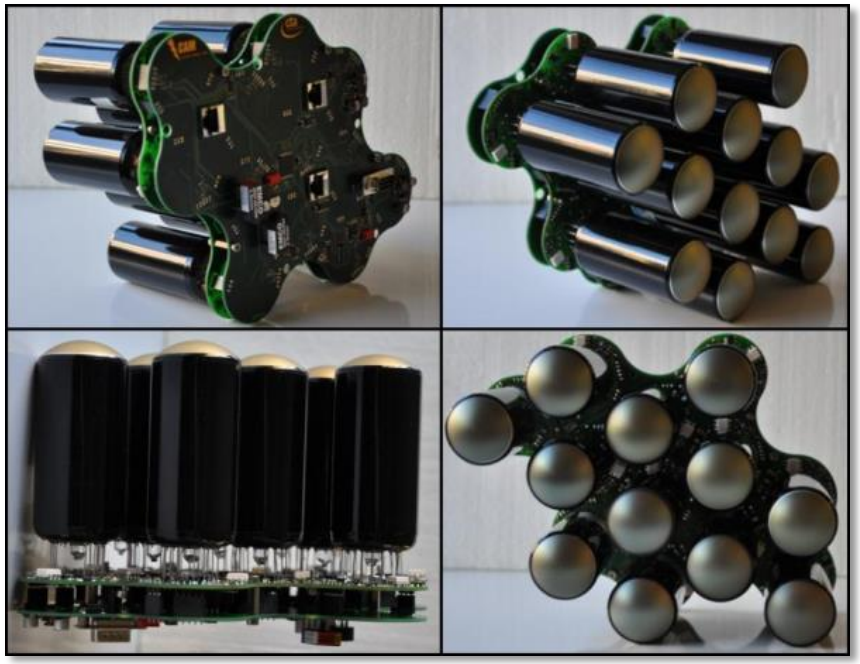
FlashCam concept



FlashCam concept

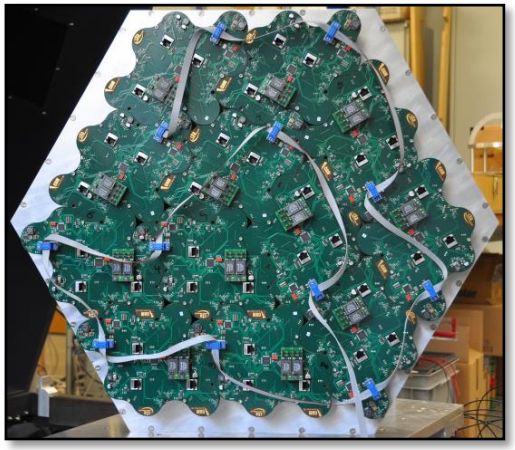


The two main protagonists



12 pixel photon-detector module

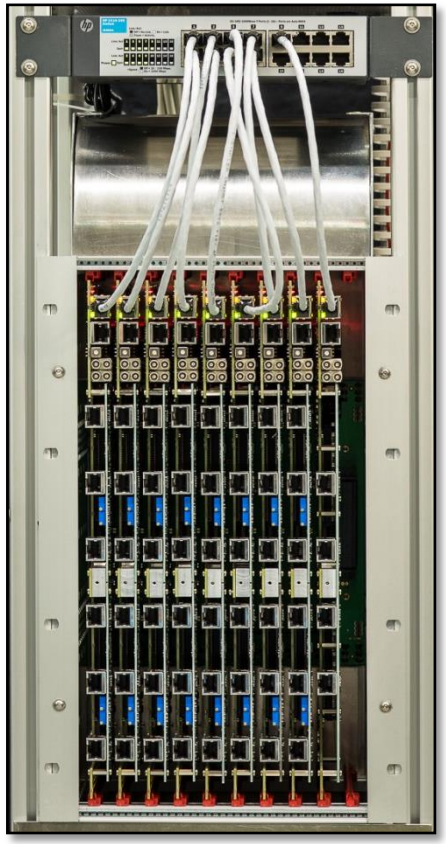
- On board HV, amplifiers, slow-control
- Analogue signal transmission via CAT5
- Adaptable for any sensors and pitches
- Scalable



144 pixel test setup

Readout electronics

- Scalable up to 2304 pixel
- One unit serves up to 192 pixel
- 0.25 GS/s FADC commercial chip
- Low cost commercial FPGA
- Continuous signal digitization
- Digital trigger
- Data transmission over Ethernet:
  > 2 GByte/s, dead-time-free up to > 30kHz



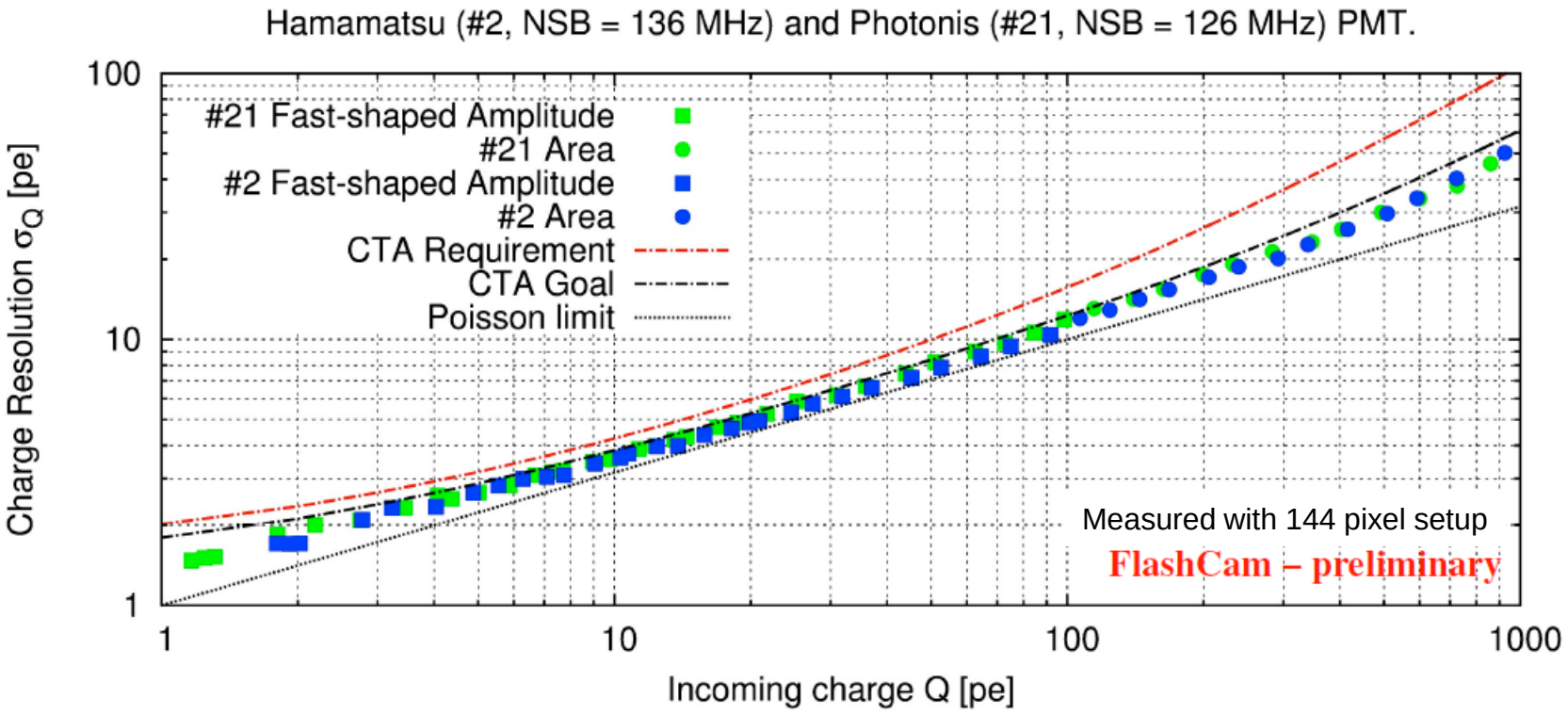
Amplitude resolution, single pixel

Amplitude determination with two overlapping regimes:

- Amplitude of signal: amplitude $\leq$ amplifier clipping amplitude ($\approx$100 pe)
- Pulse-area: amplitude $\geq$20 pe

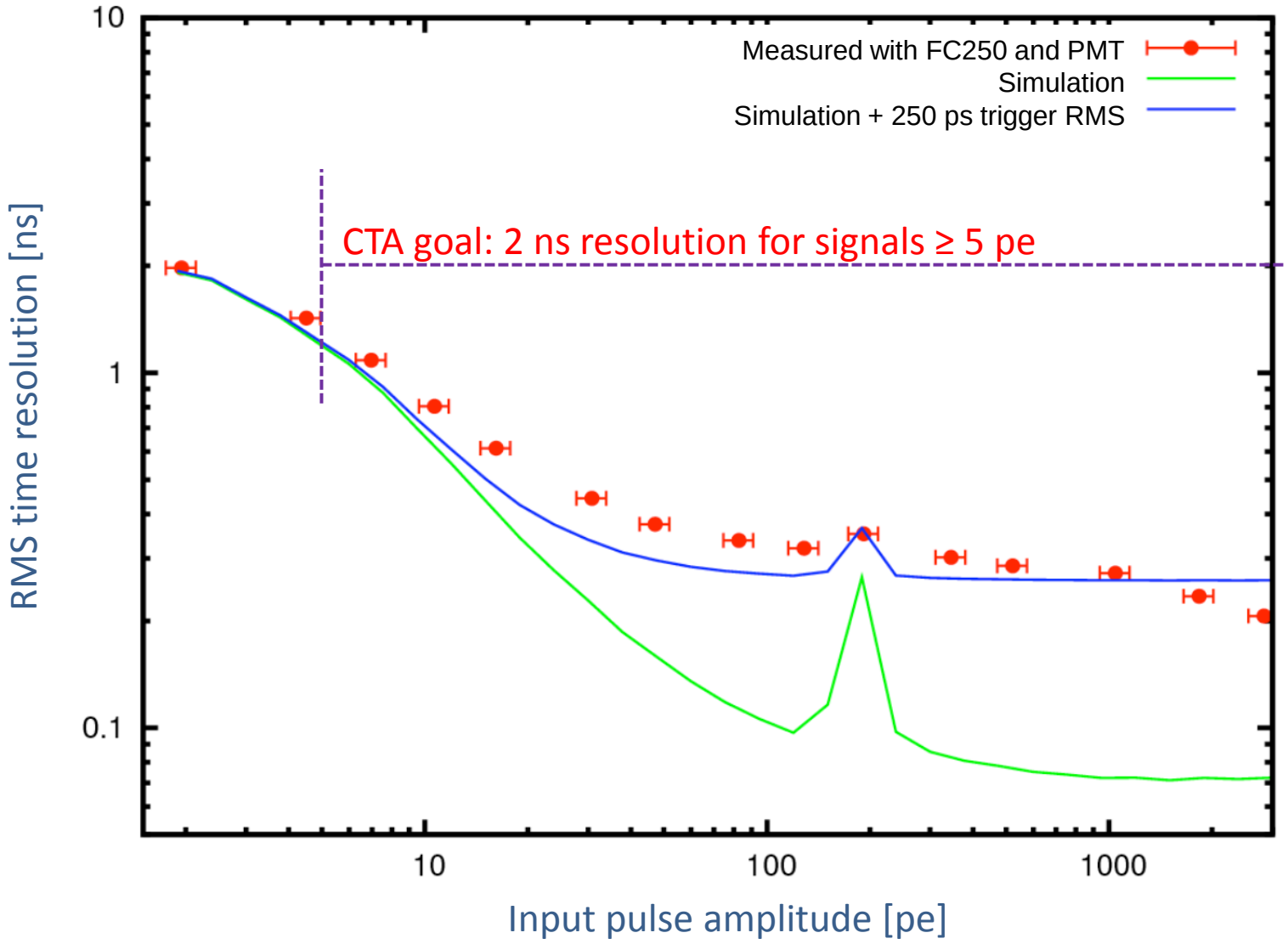
$\Rightarrow$ Cross-calibration of regimes possible

Requirements fulfilled over full dynamic range

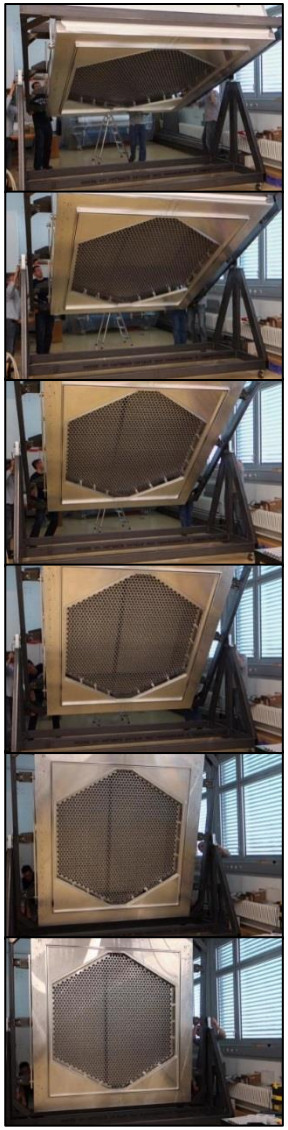


Time resolution, single pixel

Night sky background = 240x10^6 photoelectrons/s



FlashCam camera body



1764 PMT pixel

Camera body weight (no electronics): 1183 kg

Expected final camera weight ≤ 1.7 t

Dimensions approximately: (3 x 3 x 1.1) m^3

Camera body rear view

Camera body front-side view

Camera inside with racks

Conclusion and outlook

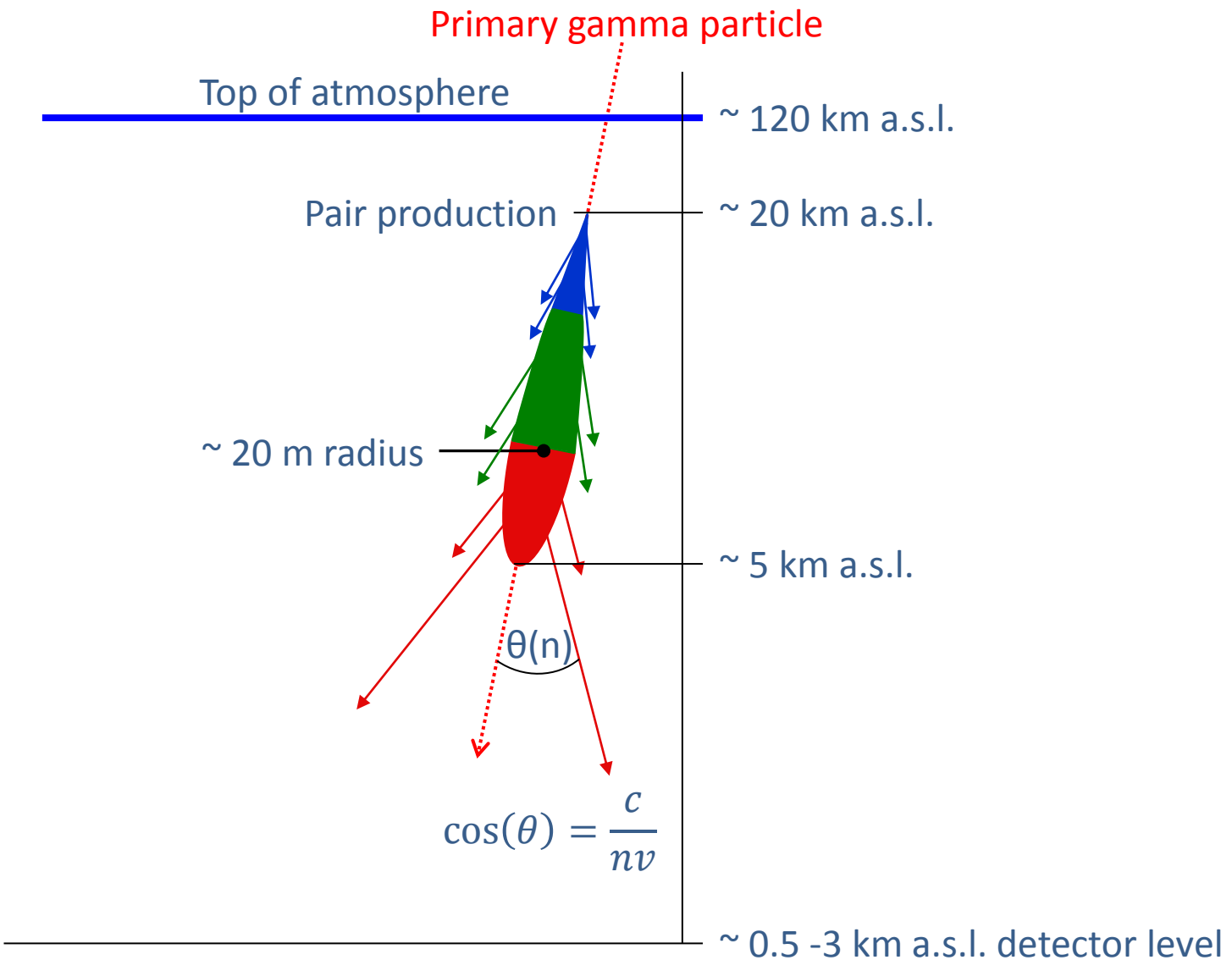
- FlashCam is an excellent option for CTA cameras:
  - Commercial components only
  - Dead-time-free and continuous digitization
  - Very flexible digital trigger
  - Easy maintenance due to modular construction and simple camera access
  - Easy adaption for new generation sensors

- Performance validation of all components of 144 pixel test setup nearly finished:
  - all CTA requirements are fulfilled so far
  - 4x10 Gbit readout successfully tested

- A full-size camera prototype with 1764 pixel for a 12 m telescope is ongoing:
  - Camera body nearly finished
  - Readout electronics, sensor electronics, cooling and slow control procurement in preparation

BACKUP

Imaging the Cherenkov light



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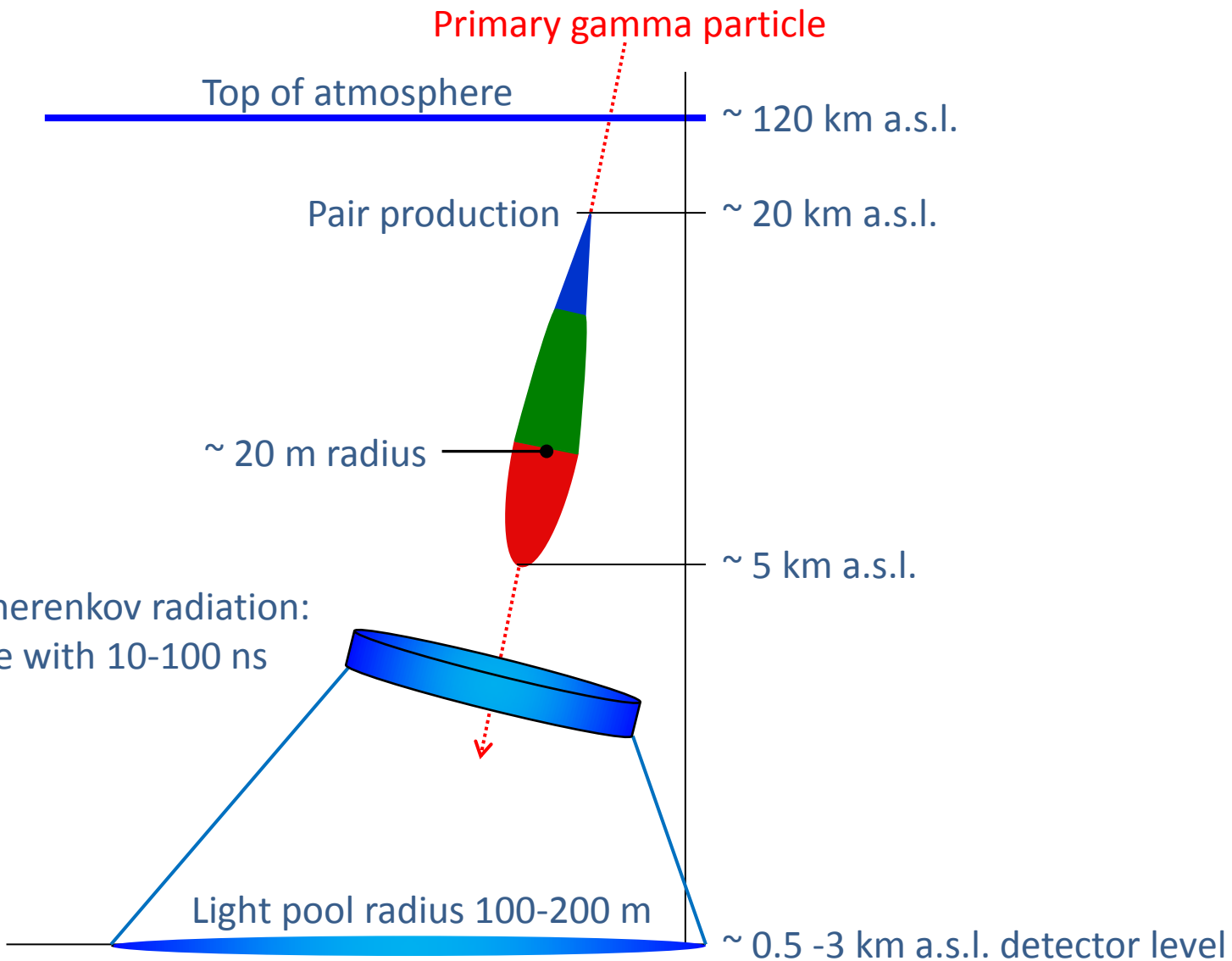

Sum of all Cherenkov radiation:
⇒ light pulse with 10-100 ns duration

Imaging the Cherenkov light