Photomultiplier Ageing Studies for the Pierre Auger Observatory

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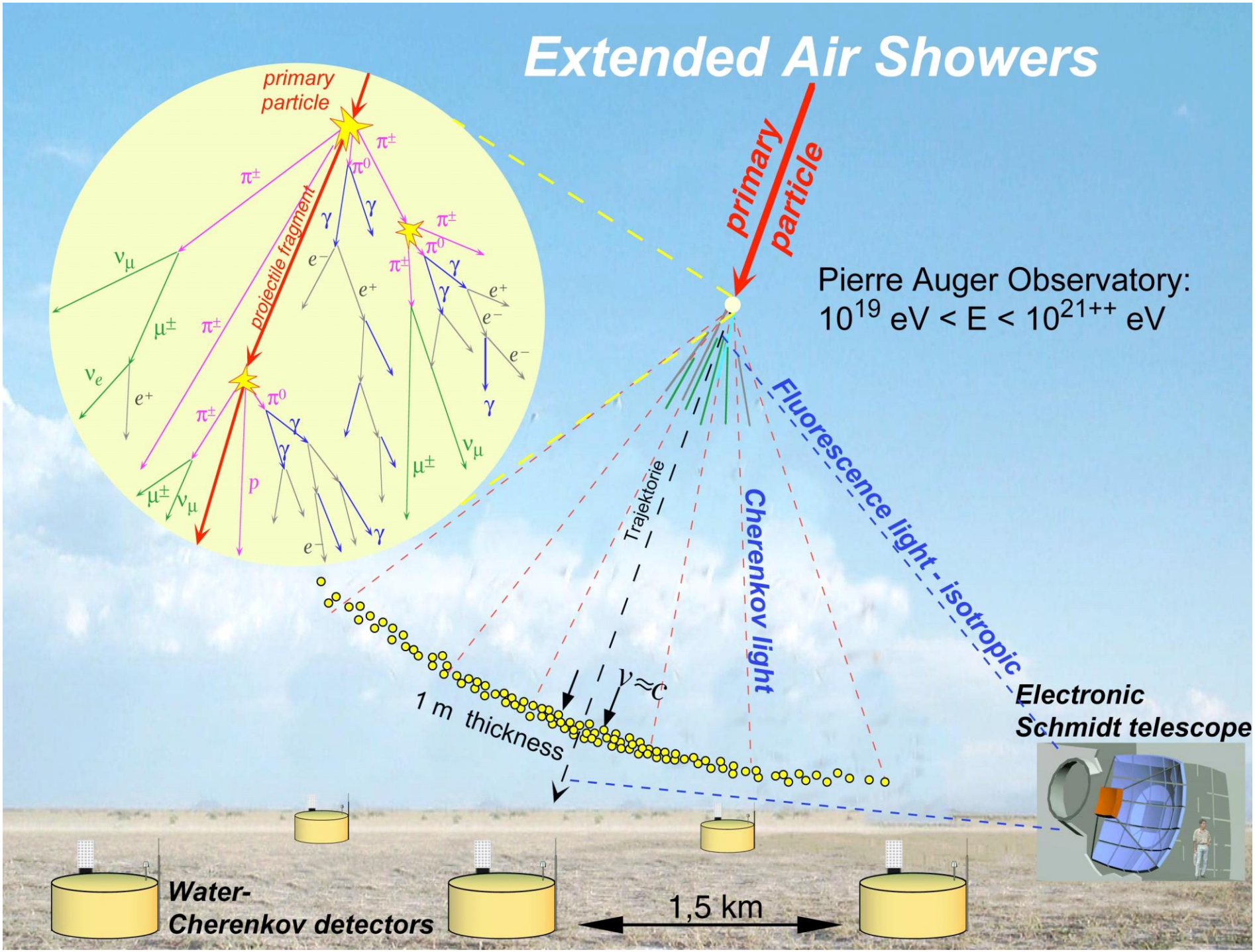
The science being addressed will have impact on a broad range of current astrophysics and high-energy physics. This projection is justified by the present high citation factors for publications based on H.E.S.S. and MAGIC. CTA will be one of a handful of major world observatories operated as user facilities in different spectral ranges like ALMA (Atacama Large Millimetre Array), ELT (Extremely Large Telescope), JWST (James Webb Space Telescope), SKA (Square Kilometre Array), LOFAR (Low Frequency Array) [20], and future space-based X-ray missions. Operating CTA in the mode proposed and providing an appropriate user-friendly data pre-processing will increase its complementarity by enabling its use by a broad community. Therefore, CTA will develop synergies with the broad spectrum of astrophysics.

Since astrophysical research is based on observations over the whole electromagnetic spectrum and on particle detections, telescopes and detectors applied to particular spectral ranges work per se complementarily, as e.g. the present-day panchromatic composition of target observations demonstrates. With re-

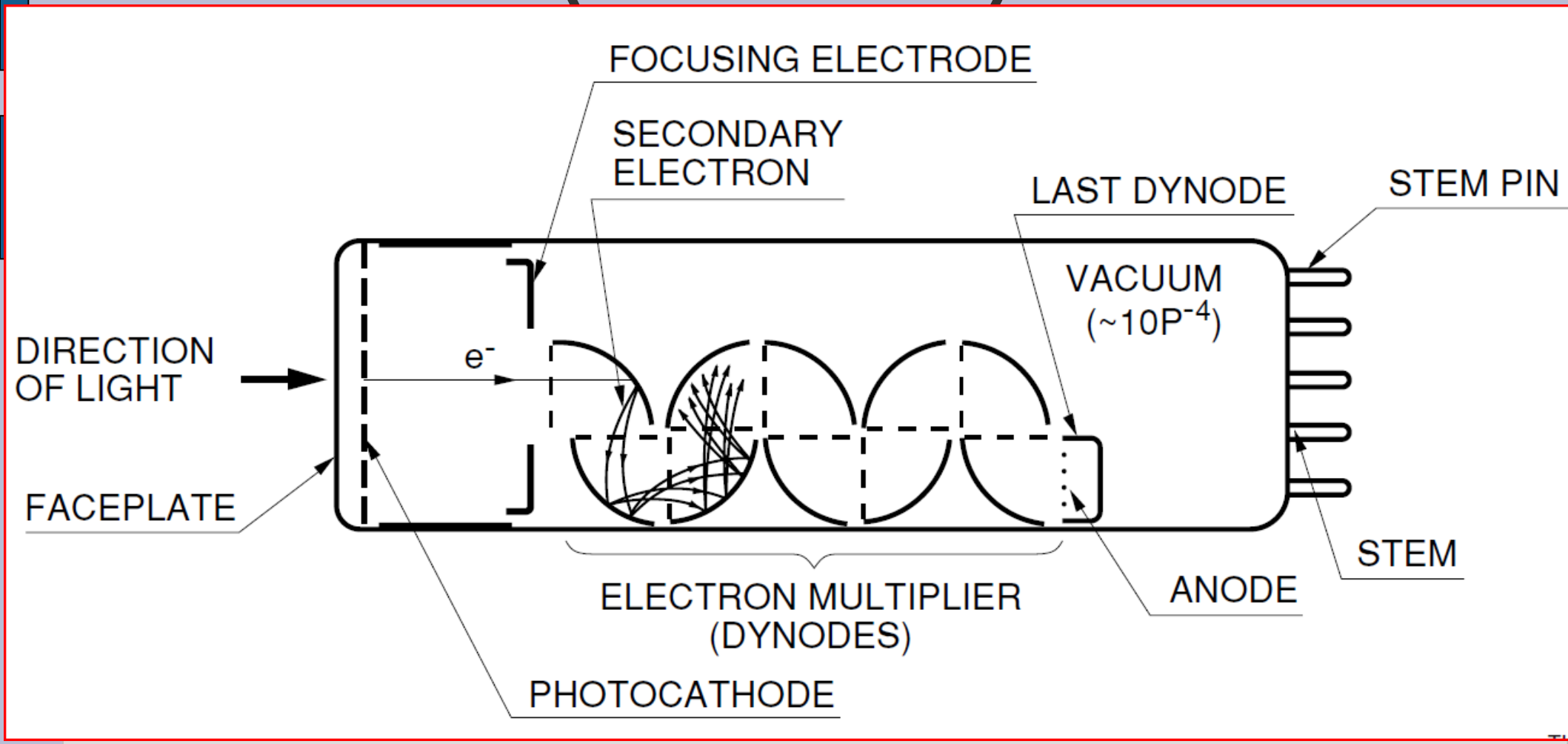
BMBF regards CTA as an outstanding research infrastructure with a high degree of innovation potential. CTA attracts the best researchers from around the world and will enhance Germany's standing as an extremely attractive location of scientific and technological developments. First and foremost, CTA trains young scientists, thereby playing a major role in combating the shortage of qualified personnel.

As you will remember, inclusion in the national roadmap implies the general willingness of the federal government to fund the projects. In spring this year, there was a change of ministers in the responsible ministry so that the funding decision had to be delayed. The basis for the ministry's decision were the results of the evaluation and of a parallel cost assessment as well as the budget situation in the ministry itself. Three of the nine projects of the pilot phase, namely CTA (Cherenkov Telescope Array), EU-OPENSCREEN and IAGOS (In-service Aircraft for a Global Observing System), received this declaration of intent from the ministry.

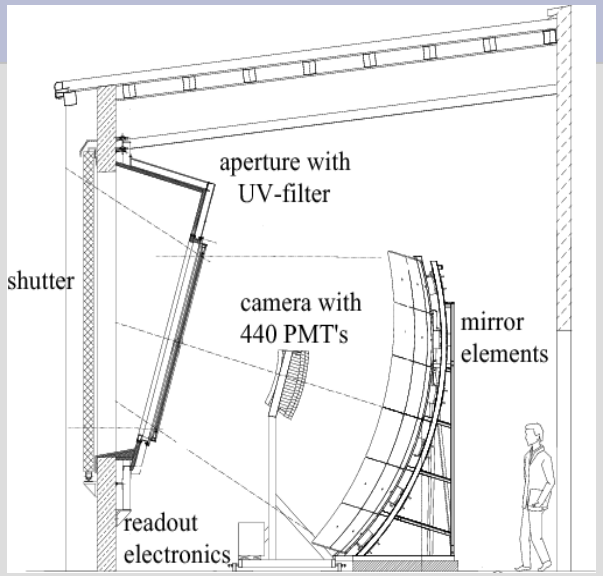

Extended Air Showers
primary particle
projectile fragment
primary particle
Pierre Auger Observatory:
10^{19} eV < E < 10^{21++} eV
Fluorescence light - isotropic
Trajektorie
Cherenkov light
$v \approx c$
1 m thickness
Electronic Schmidt telescope
Water-Cherenkov detectors
1,5 km

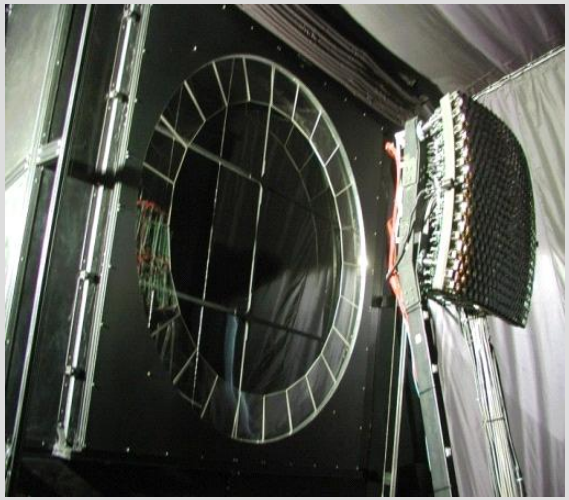
Until recently, photomultipliers have been the light detector of choice for high energy astrophysics.
They are:
sensitive (quantum efficiencies tens of percent),
fast (risetimes typically ~ns),
and generally quite robust.

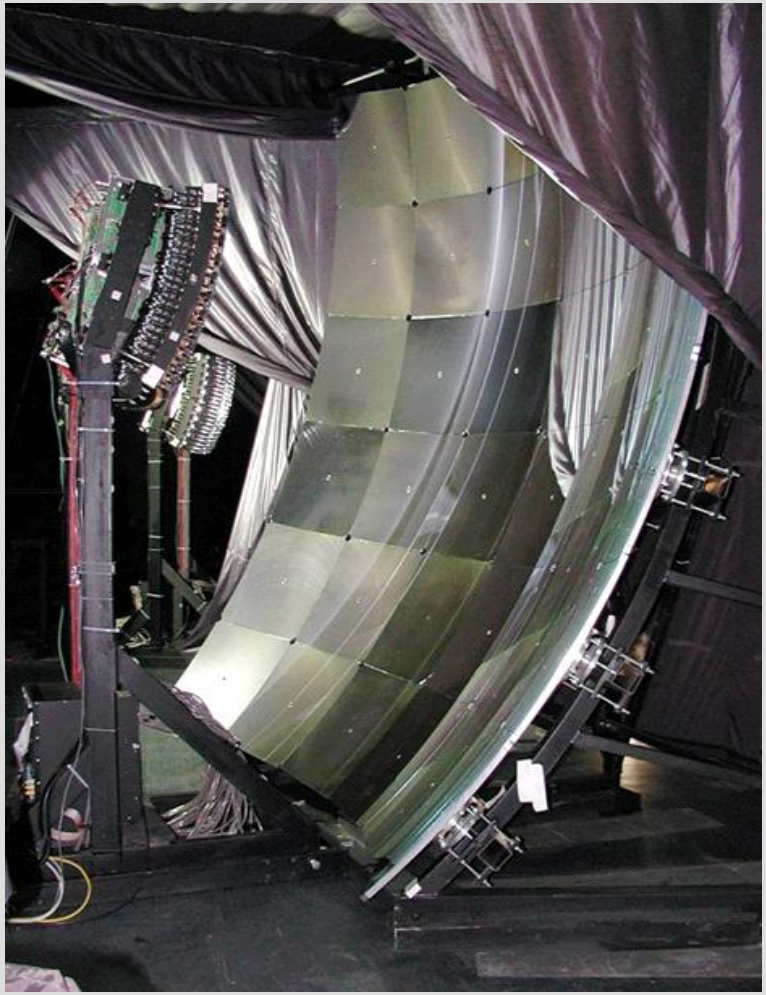
Photomultiplier Schematic (Hamamatsu)



Pierre Auger FD Telescopes







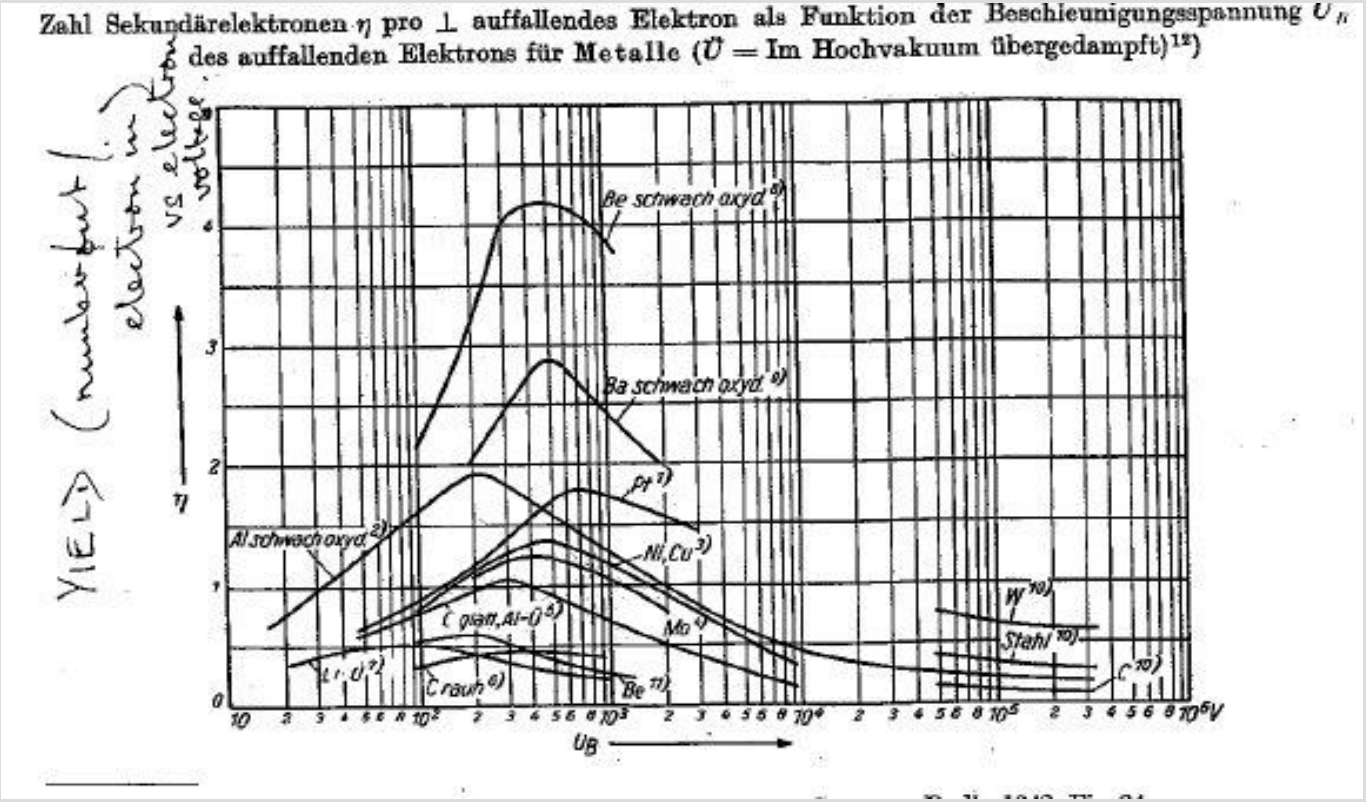
It has been known that photomultipliers deteriorate over time.

This became an issue with the Pierre Auger Observatory Fluorescence detector which views the night sky (~16 m^2 light collector, 30^o x 30^o) with cameras made up of 440 photomultipliers.

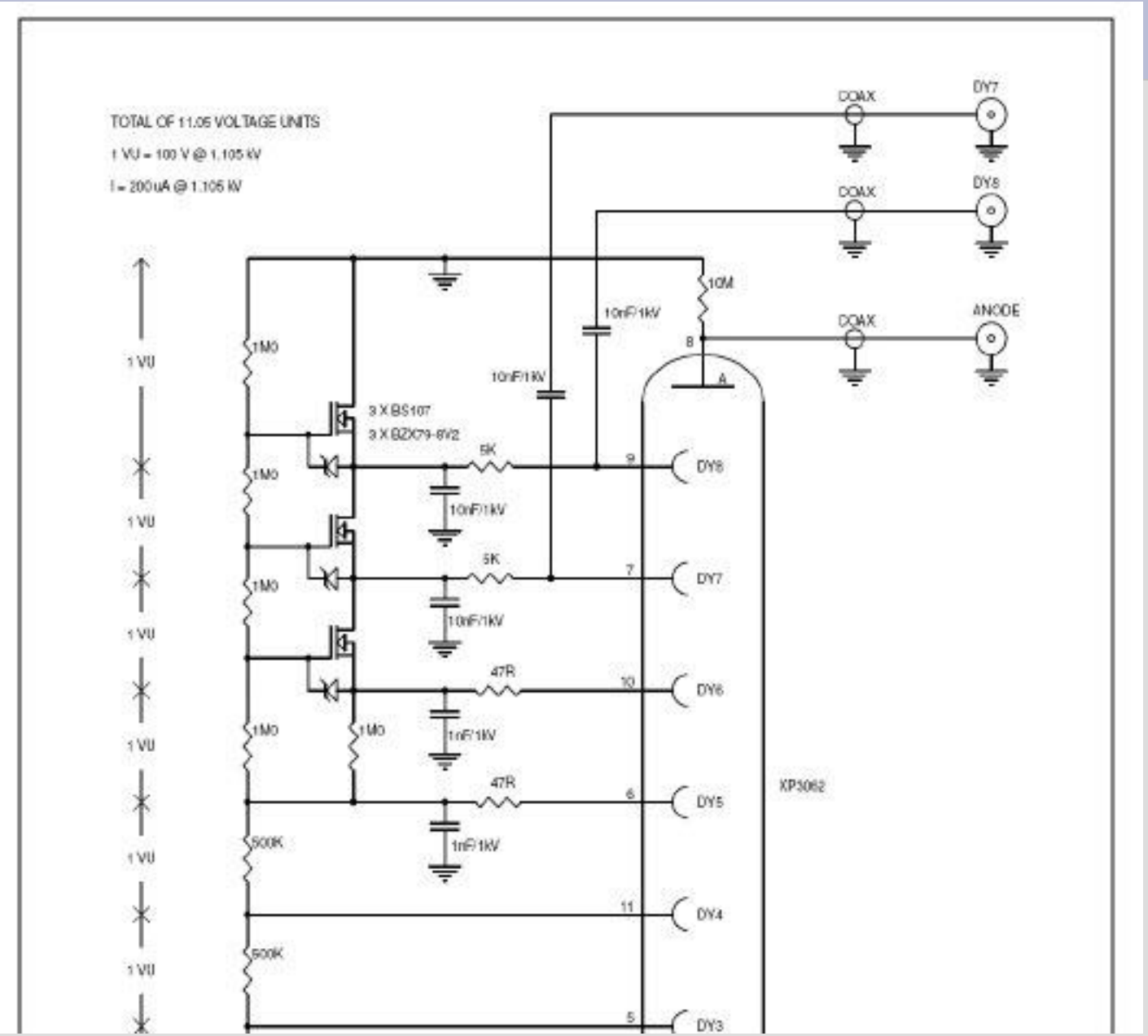
The tubes were observed to lose gain with time and the question was to ask what was actually happening and whether a reduction in moonlight observations wouold be necessary.

Photomultiplier Basics

The voltage between each stage is around 100 V (10^2 V on the graph below). This graph shows the electron yield (number out) for an incident electron of a certain energy on various surfaces.

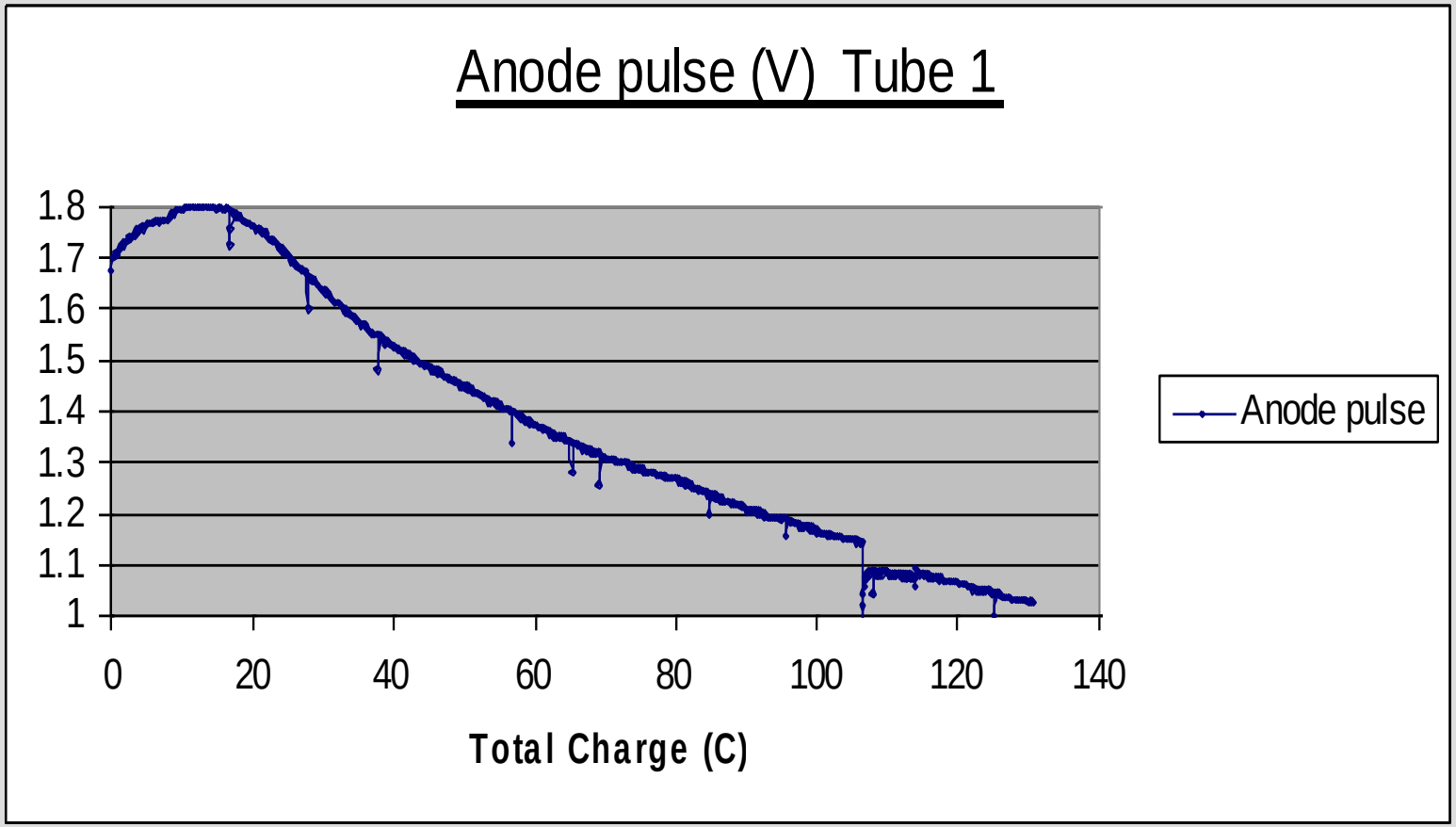


The critical end of the tube.....



Do the gains change for our tubes under test?

YES



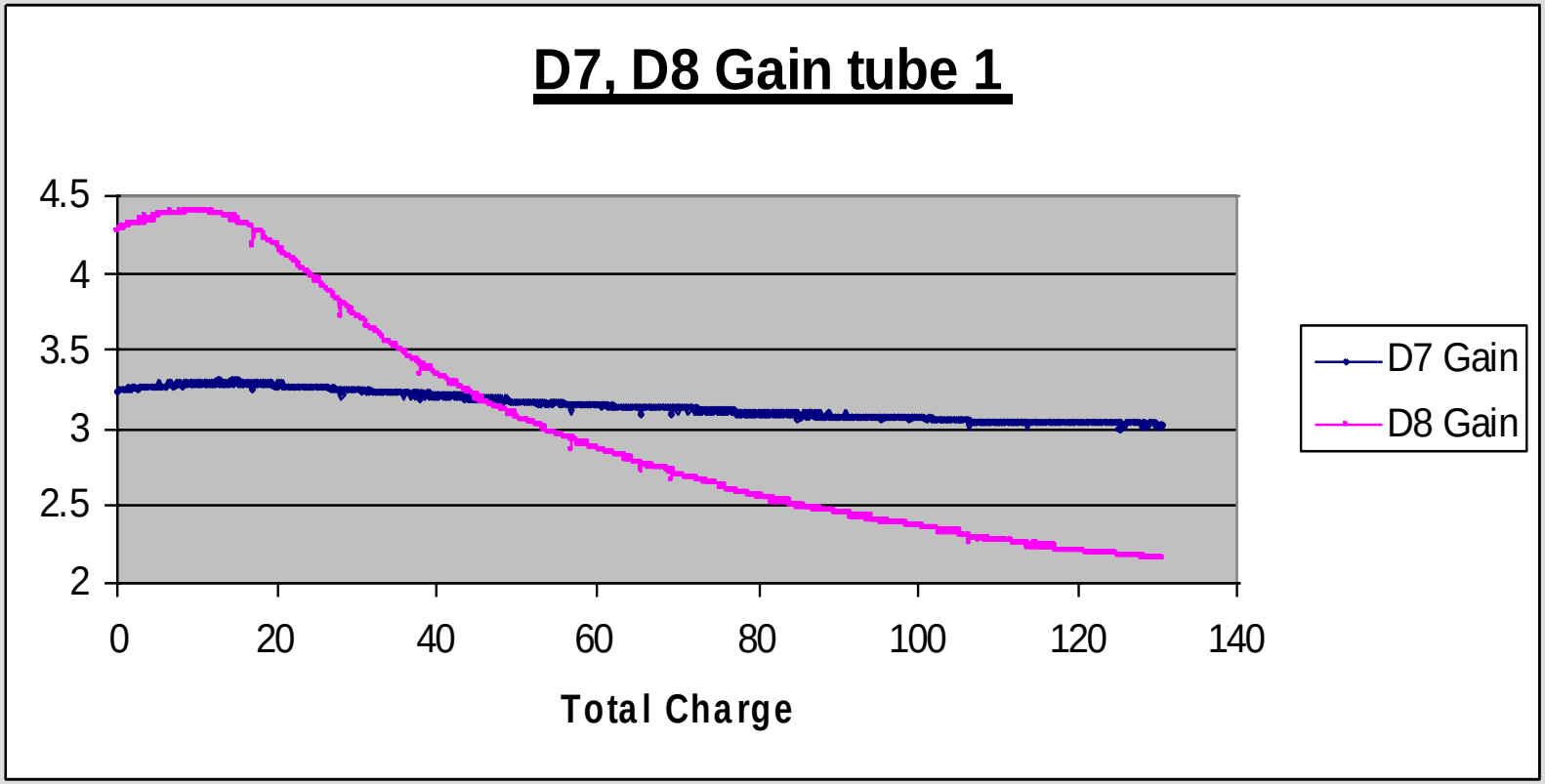
Where is the origin of this problem??

Photocathode?

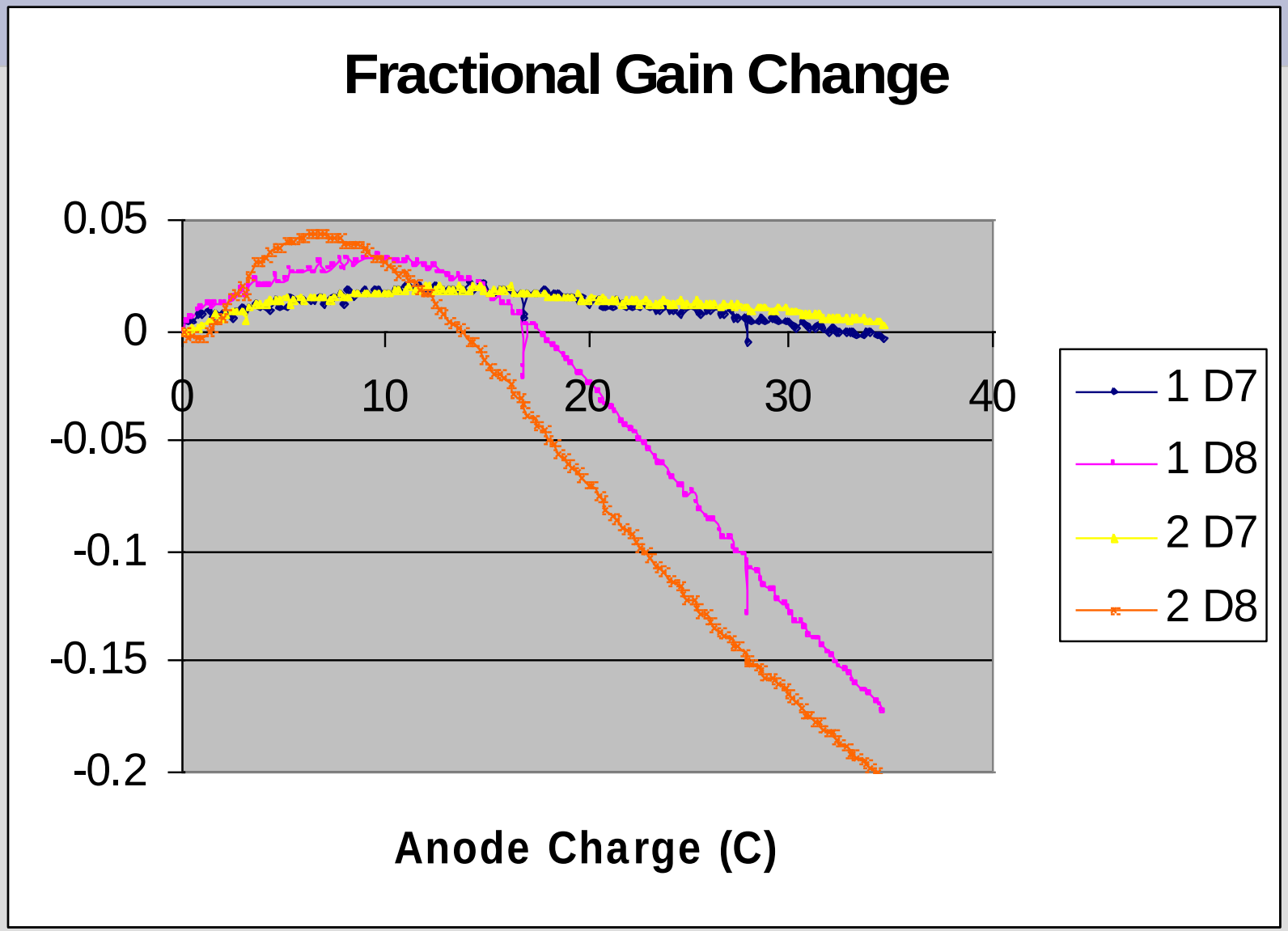
Charging in the whole tube?

Dynode carrying most charge?

The last one - dynode carrying most charge - Dynode 8.



Does this apply similarly to other tubes?

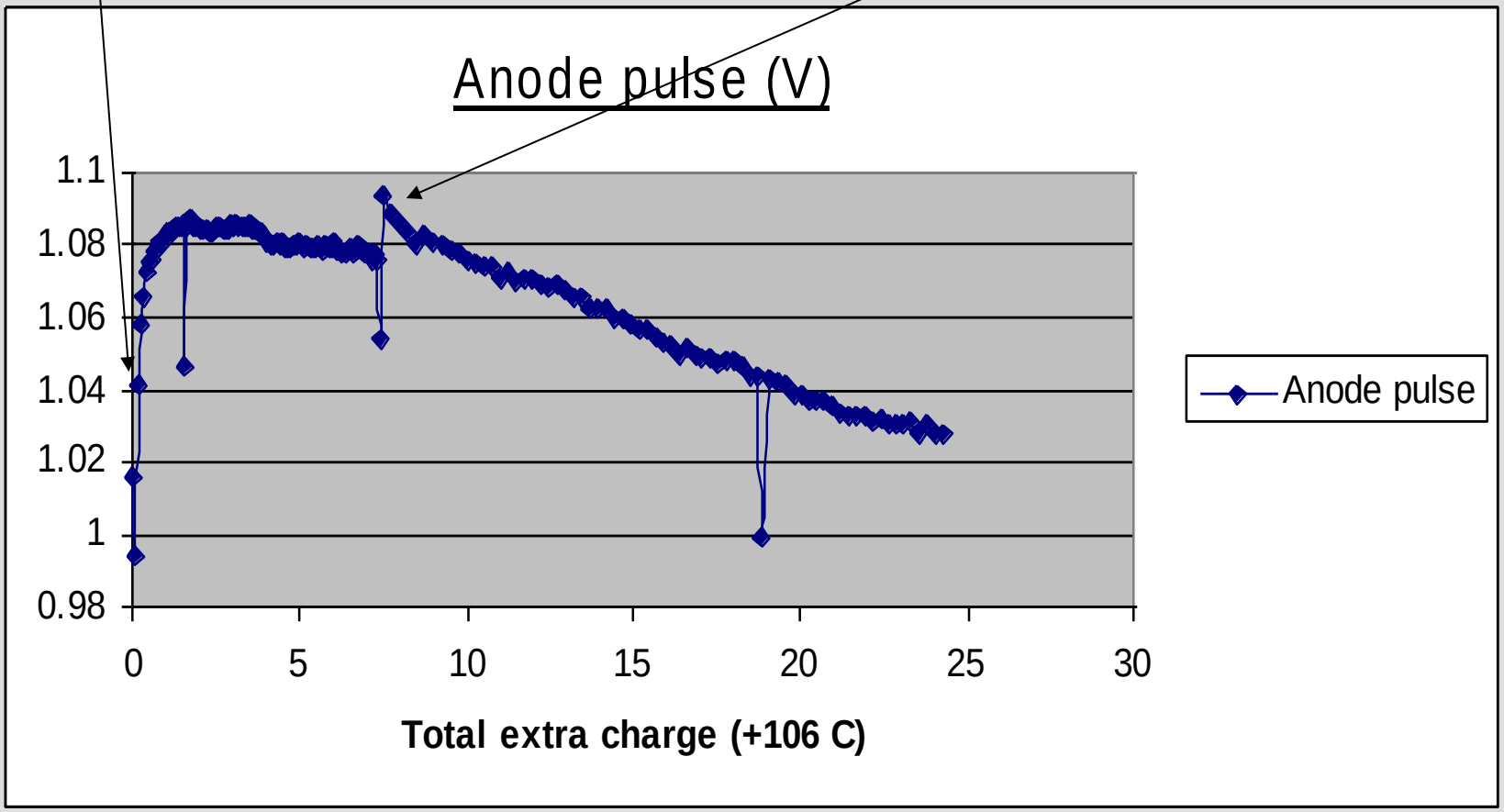


In real life, Auger does not run continuously.

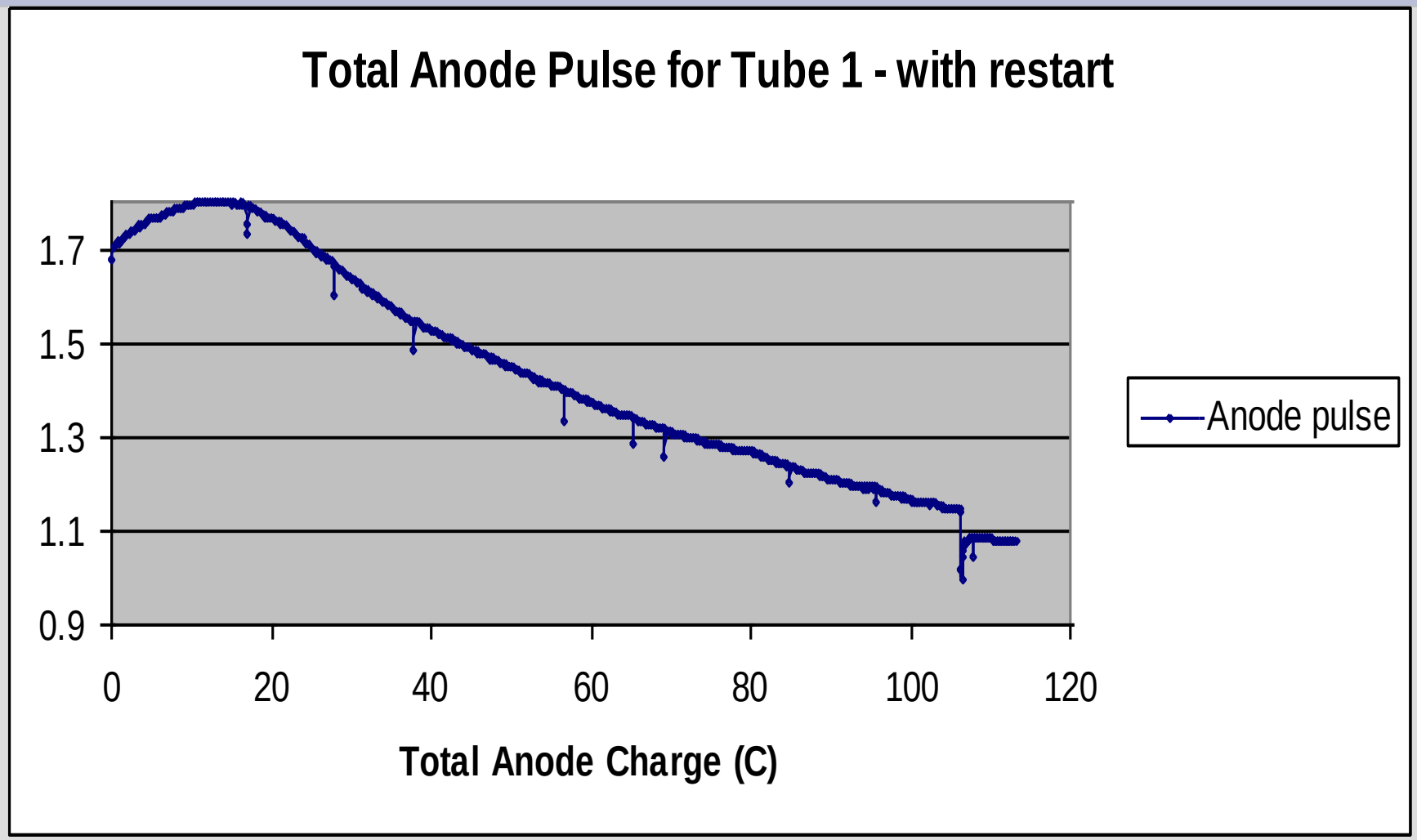
So, do tubes recover when rested? Not really.

Tube 1 restarted after about 1 month in dark.

Brightness increased by about 3x at 8 coulomb time



Is this restart issue a big issue in the scheme of things – perhaps not.



What is relevant to CTA.

Photomultipliers are the baseline workhorses of VHE gamma-ray telescopes.

Their ageing varies between tubes by a few %.

It is the final dynodes which age when charge is removed from them typically over a few tens of Coulombs.

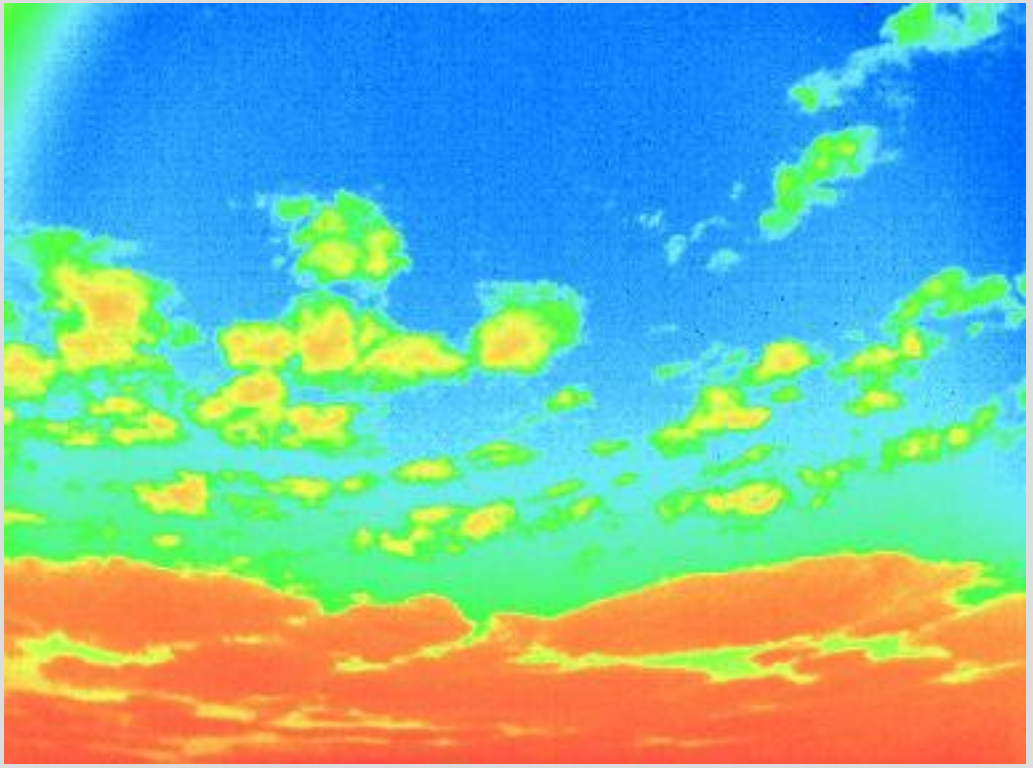
They take time (Coulombs) to settle down after new moon observing periods.

What have I learned from the Pierre Auger Observatory that is particularly relevant to CTA?

- Multiple Groups working on related analysis produce robust results.
- Credit needs to be given to people who just care that the instrument is the very best.
- Knowledge of the environment affects results at the few % level – this becomes important when dealing with fluxes which fall steeply with energy.
- Choice of a great project manager is crucial

Adelaide cloud cameras provide images of clouds in the night sky either in specific directions OR over the full sky.
Such information could enable CTA to observe more efficiently.

Thanks for help from AAL.




Thanks