Simulation of fluorescence radiation for Cherenkov observatories

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Outline

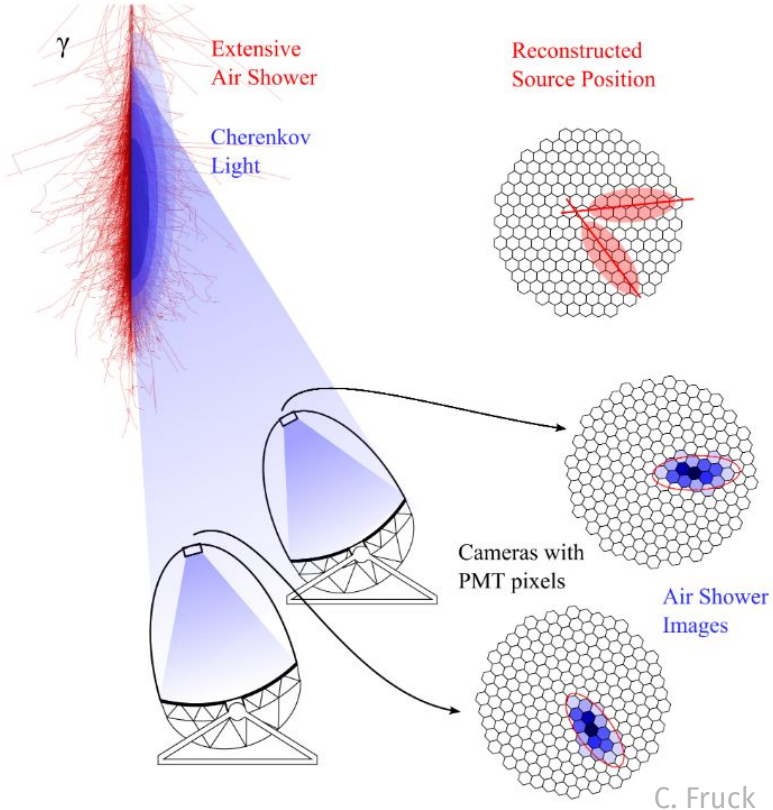
- Motivation: **Study of Cherenkov and fluorescence light from air showers**
- Method: **MC simulations**
- Results: **Fluorescence contamination** in the Cherenkov technique
- Ongoing work:
  - **Effect on the reconstructed shower parameters**
  - **Cherenkov telescopes in “fluorescence mode”**
- Conclusions and outlook

Cherenkov and fluorescence light from air showers

- Indirect detection of very-energetic particles using the atmosphere as a calorimeter through
  - **Cherenkov light flashes**
    - Pulse width ~ 10 ns
    - Spectral range: 300 - 500 nm

- Detection techniques:
  - Imaging Air Cherenkov Telescopes (IACTs)
  - Wide-angle Cherenkov detectors (WACDs)

- Simulations needed:
  - Instrument calibration
  - Signal reconstruction

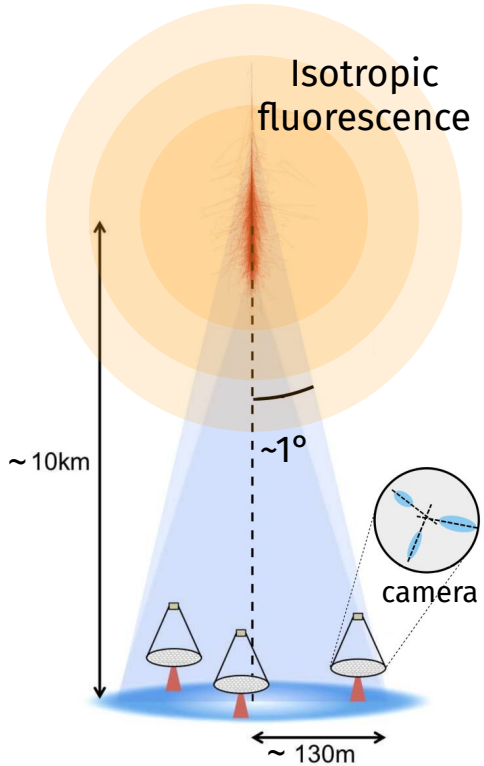


Cherenkov and fluorescence light from air showers

- **Fluorescence** light (de-excitation of N_2 states) also produced in air showers and **indistinguishable from Cherenkov** signal:
  - Same spectral range and pulse width

- Expected to be a **small contribution** compared with Cherenkov light and normally neglected:
  - Isotropic emission
  - Less efficient than Cherenkov

Is the fluorescence radiation always negligible in Cherenkov telescopes?



Cherenkov light pool

MC simulations

- **Implementation of fluorescence light emission in CORSIKA** (as detailed as Cherenkov light)
- `sim_telarray` adapted by K. Bernlöhr to handle these photons

CORSIKA → IACT output → `sim_telarray` → ctapipe

Air shower | Telescopes / detectors | Analysis

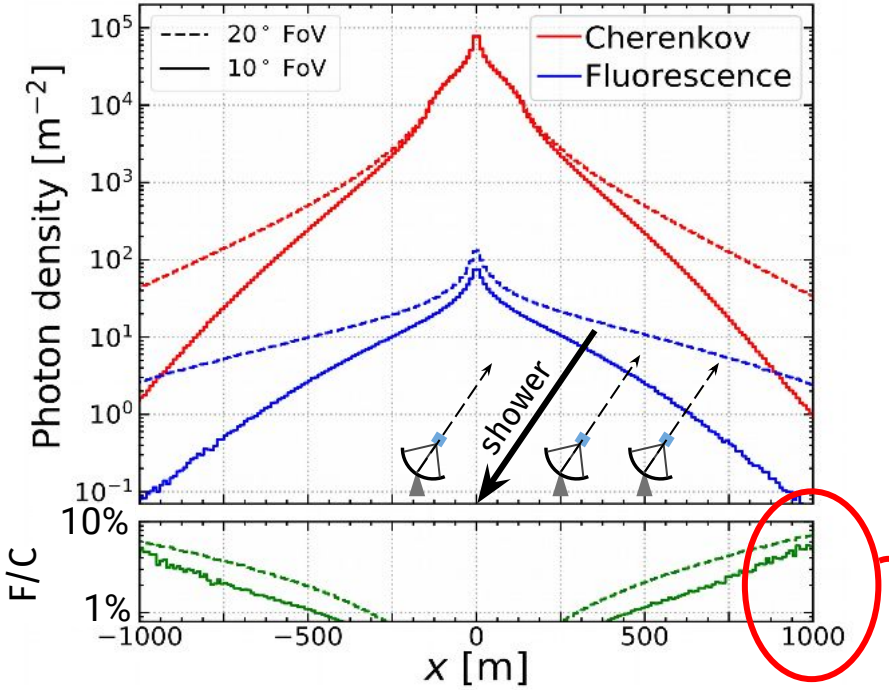
- Plan:
  - Include fluorescence subroutine in the official upcoming CORSIKA v7 releases
  - Implement it in the new CORSIKA8 code (C++ based)

In the meantime...

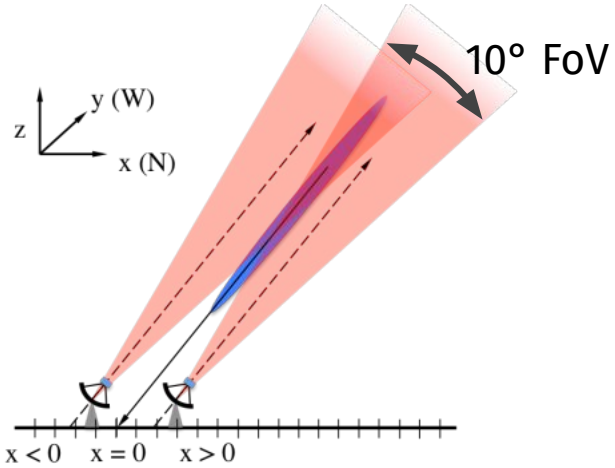
Modified CORSIKA code available under request

Results: fluorescence contamination in IACTs

Lateral light profiles



e.g. 100 TeV gamma-showers, θ = 20 deg



Small effect but sizable at large distance

Fluorescence ~ 5% of the recorded signal

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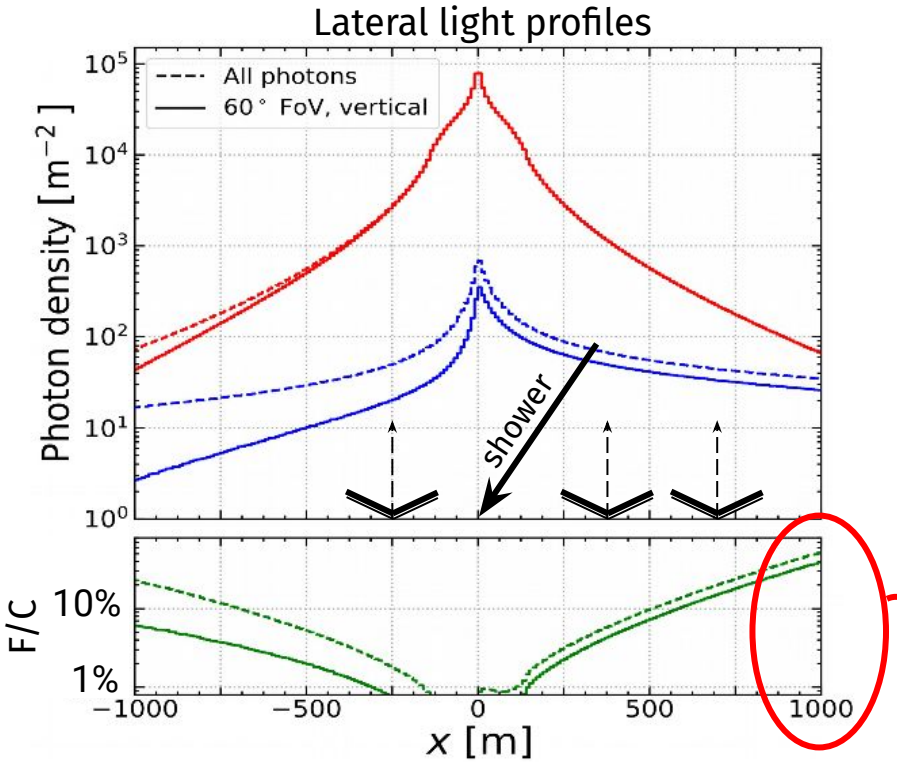
Results: fluorescence contamination in WACDs



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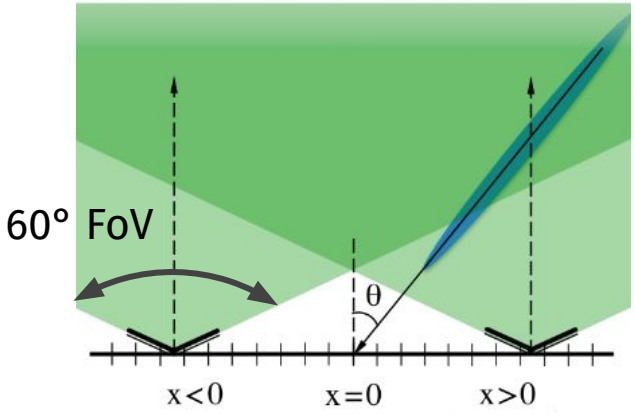

Significant at large distance

Fluorescence ~ 45% of the recorded signal

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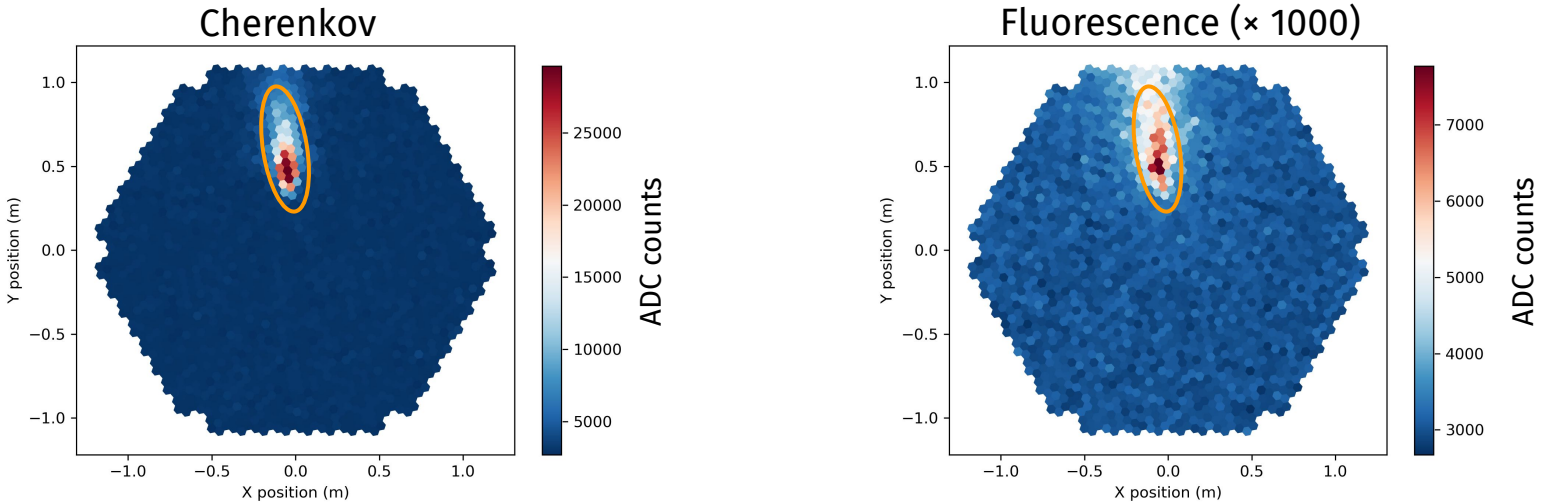
WIP: reconstruction of air shower parameters

cta**pipe**-based analysis:

- Effect on the reconstructed shower parameters (energy and direction) when including fluorescence light.



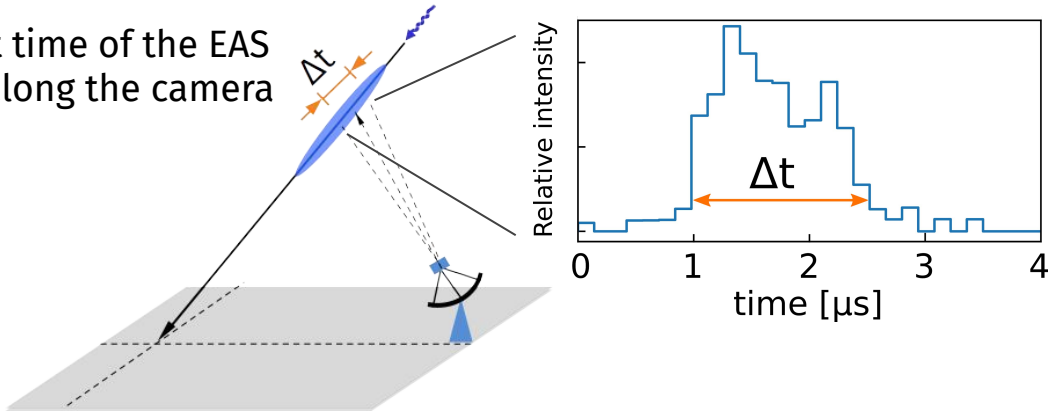
Simulated LST camera images from Cherenkov and fluorescence light. Impact parameter < 100 m

WIP: Cherenkov telescope in “fluorescence mode”

Simultaneously observing air showers transversely. PoS(ICRC2015)993

- MC simulations including the telescopes (`sim_telarray`)
  → Adapt the Trigger & Readout system of the cameras

Transit time of the EAS trace along the camera



Trace in the camera

- **Goal: larger detection effective area → reach higher energies not explored yet**

Conclusions & Outlook

- **Inclusion of fluorescence light emission in CORSIKA + `sim_telarray` ✓ Ready to be used!**

- **Fluorescence light contribution should not be always neglected in the signal registered by Cherenkov telescopes:**
  - Non-negligible (~ 5%) at large distances (≈ 1000 m) for IACTs
  - Significant (~ 45%) at large distances in the PeV region for WACDs

- Work in progress:
  - Detailed **MC study including telescope simulations** → more accurate fluorescence evaluation
  - Explore the possibility of using **Cherenkov telescopes as fluorescence detectors**