Corsika-Fluor Onboarding

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OUTLINE

1. Light emission in EAS
2. Corsika
3. Corsika-fluor
4. Onboarding

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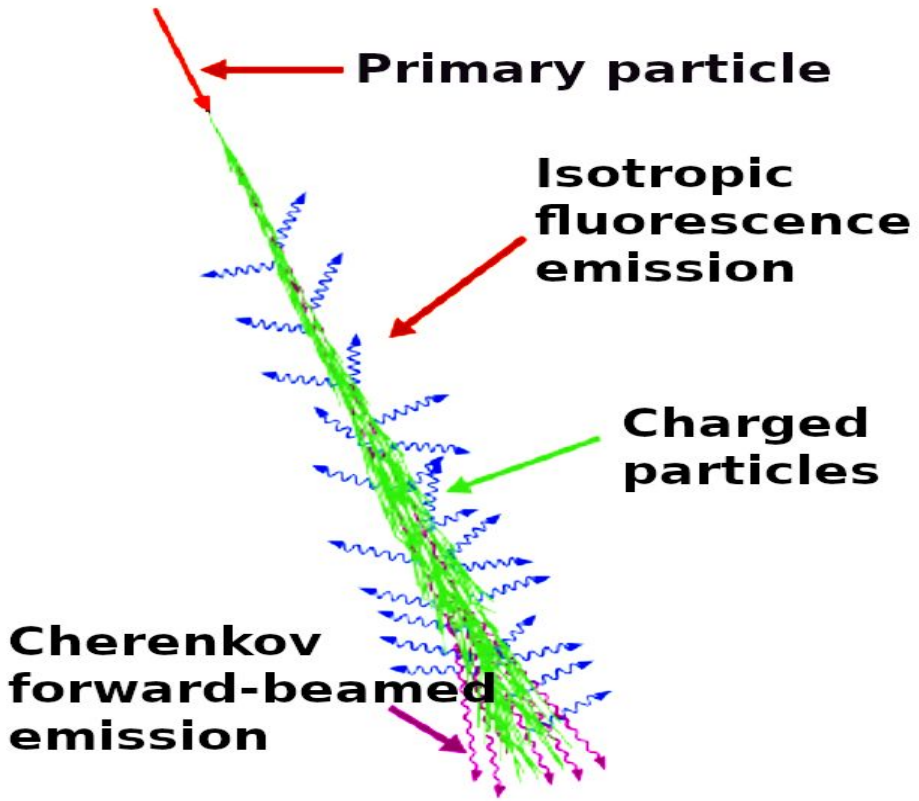
Extensive Air Shower (EAS): light emitted



Cherenkov

- Concentrated along the shower axis (~1º)
- Emission $\propto 1/\lambda^2$, peaking at 300-450 nm
- Pulse width ~nanoseconds

Fluorescence

- Isotropic
- De-excitation of N_2 molecules

Both cover the same spectral range and if you look along the shower axis both arrive simultaneously.

Different efficiency:

1-GeV electron in 1 m of atmosphere near the ground produces **30 Cherenkov** and **4 fluorescence** photons

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Detecting EAS

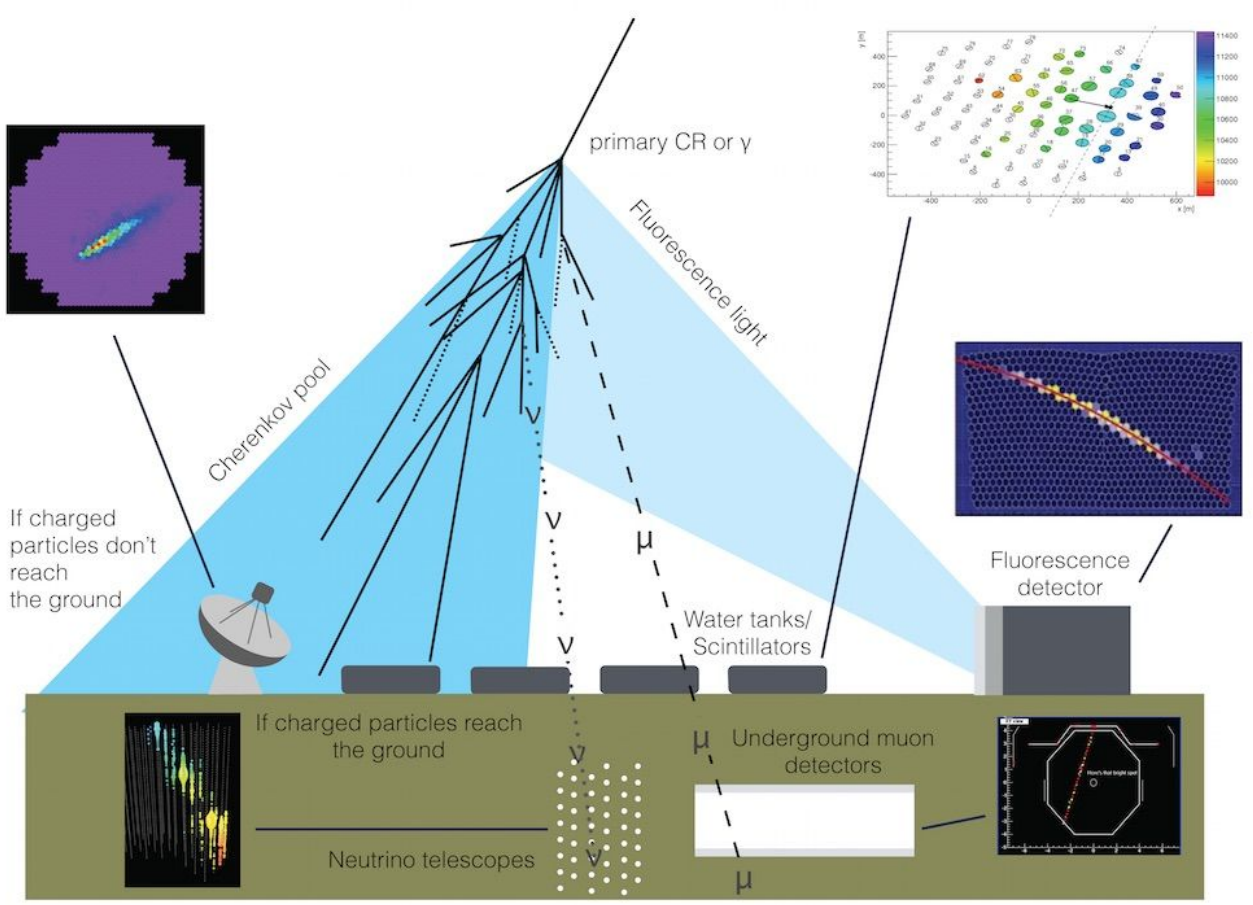
Surface particle detectors

Imaging air Cherenkov telescopes (IACT)

Wide angle Cherenkov detectors (WADC)

Fluorescence detectors

Radio



Atmosphere key element in the detection process, no way to characterize its end-to-end response -> **Monte Carlo simulation**

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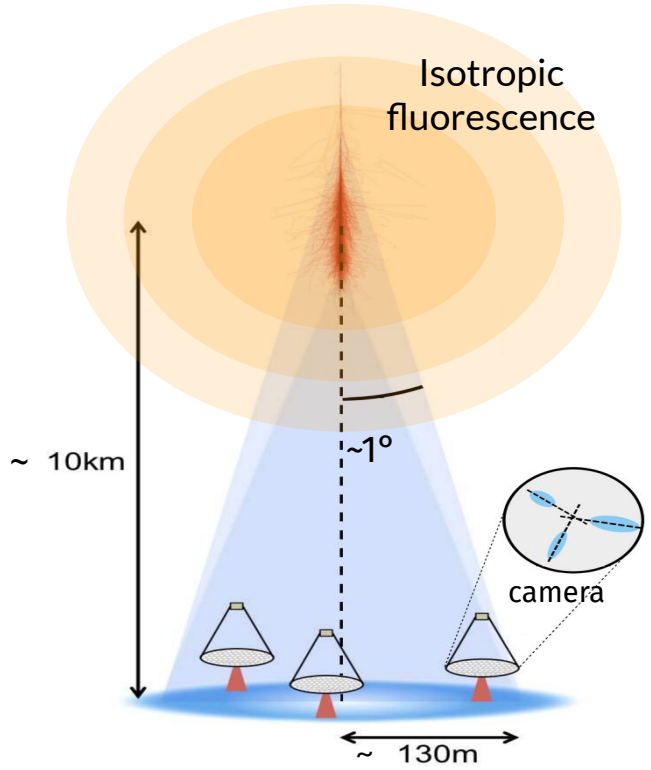
Fluorescence and Cherenkov light

- **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

Work started to ask the question:
Is the fluorescence radiation ***always negligible*** in Cherenkov telescopes? → CTA



Cherenkov light pool

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Corsika

- Main Monte Carlo package for EAS simulation
- Two very different versions:
  - Corsika 7.X
    Used in all Cherenkov Observatories, KM3, etc..
    Fortran code. Difficult to maintain. Legacy
    Semi-open code
    Does not include Fluorescence radiation
  - Corsika 8
    New project to replace Corsika
    In development since 2-3 years
    C++, open code, modern software tools
    Does not include Fluorescence radiation yet

Operating observatories will likely maintain their simulation chains until decommissioning
→ Corsika 7

New observatories will need modern software tools and better precision
-> Corsika 8

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Fluorescence in Corsika 7.X

- First work on introducing fluorescence inside Corsika carried out inside ASTERICS
- Published and used to estimate systematics due to neglecting it in CTA simulations
- Continued with some work on integration with SimTelArray and moved to CTA gitlab
- Ported to all newer versions of Corsika : 7.71 7.74
- Improved performance.
- CONCORDIA

ASTERICS

D. Morcuende PhD.

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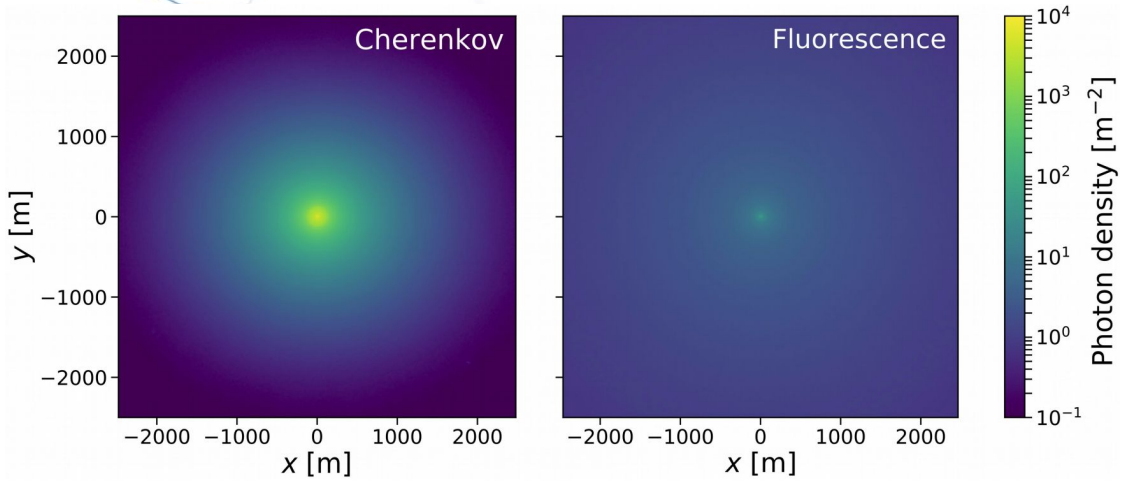
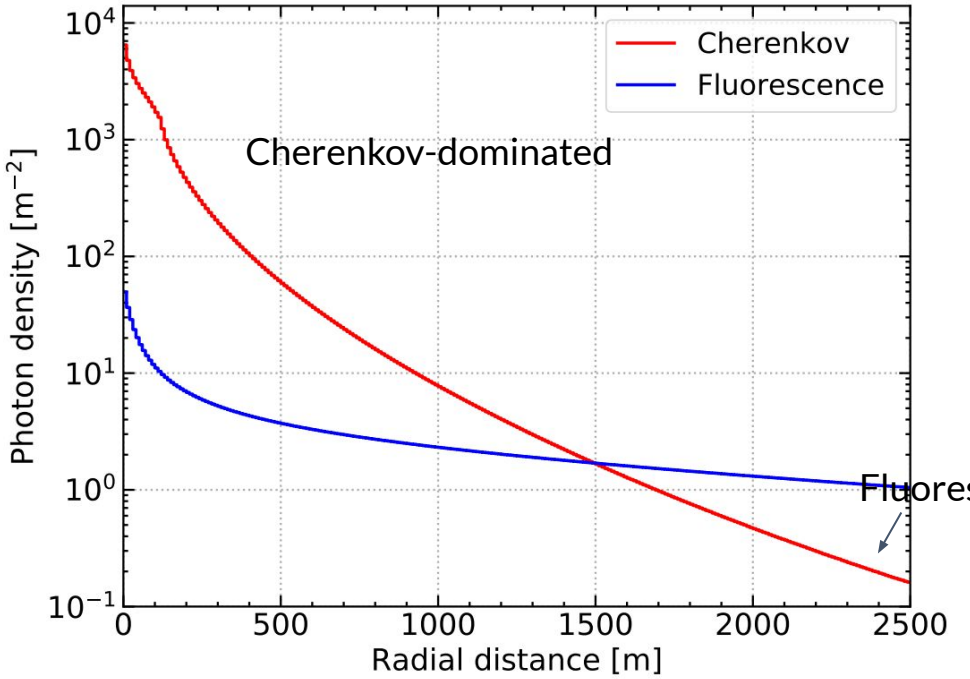
Results: distribution of light on the ground



10 TeV vertical gamma shower



All photons, no angular cuts

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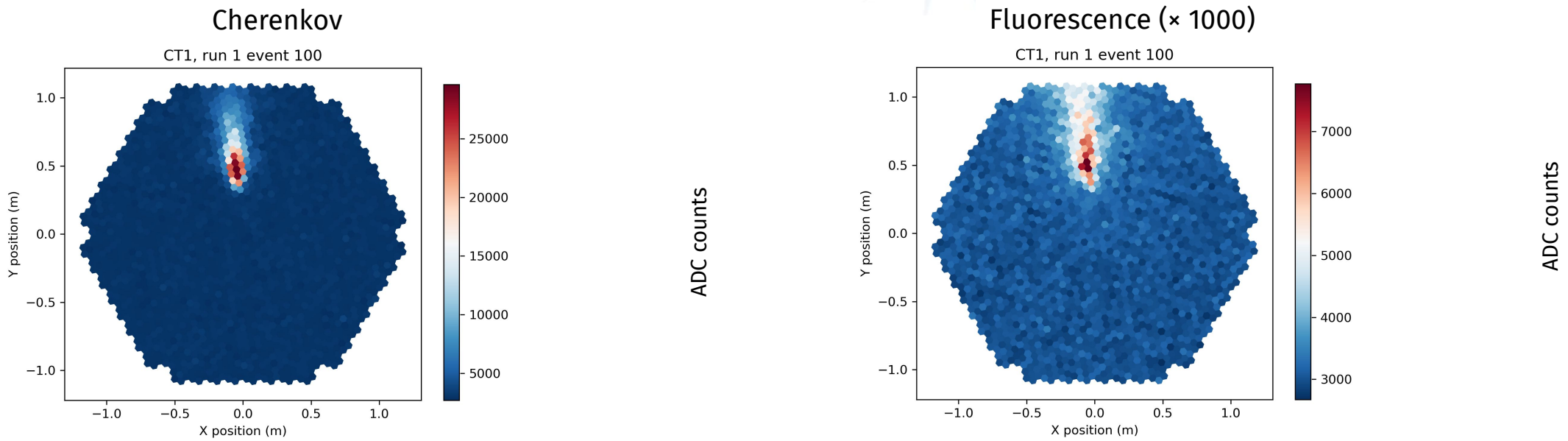
Similar distribution of light in the telescope camera of Cherenkov and Fluorescence

Shower seen in IACT mode (on axis)



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

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Why fluorescence wasn´t included before?

- Fluorescence is a small effect for Cherenkov Telescopes (50 GeV -10 TeV). Generating it is time demanding
- When fluorescence matters (P. Auger, Telescope Array, Fly´s Eye) the computational effort is too large → approximate treatments.
- This changes with CTA and ever-increasing computing power.
- Caveat: Our code is not valid with all Corsika options only with some versions

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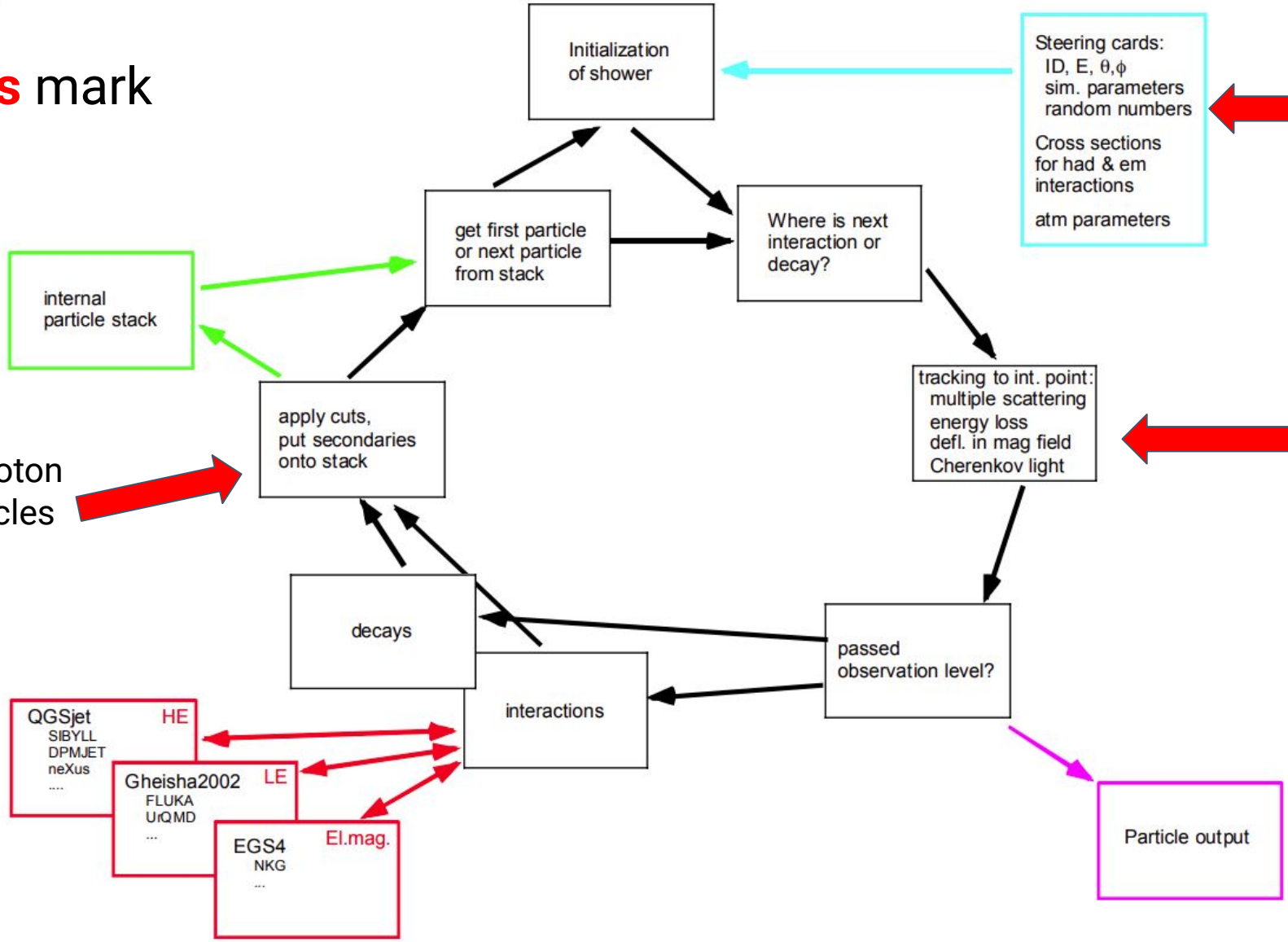
General workflow and modifications we added in Corsika flow

Red arrows mark our mods



1. New control cards for fluorescence simulation

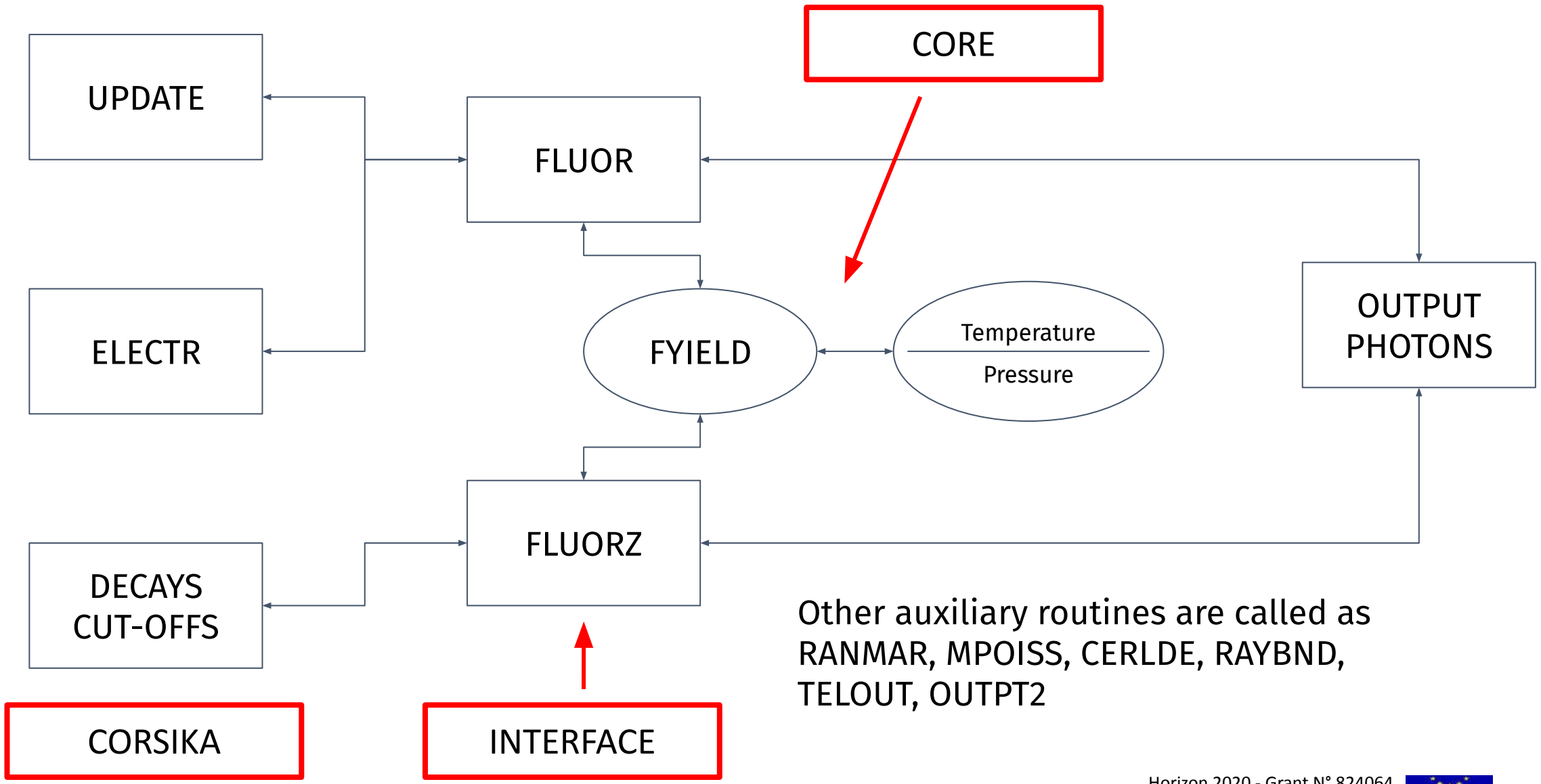
2. Fluorescence photon production and tracking after ionization losses

3. Fluorescence photon production by particles below simulation threshold

4. Storing fluorescence photons

Credit: J. Knapp

Production of Fluorescence photons



Other auxiliary routines are called as RANMAR, MPOISS, CERLDE, RAYBND, TELOUT, OUTPT2

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Onboarding - 1

- Onboarding Corsika+fluor == distributing the whole Corsika code → Difficult on the licensing side.
- A possible way out is providing instructions + a patch, which applied on the Corsika code would update it → prone to errors
- The most important part is the "Core" →
  - Computes number of photons based on height, Pressure, Temperature
  - Generates the wavelengths according to the emission bands
  - Includes approximations to speed up the generation
- We have opted to extract the "Core", complement it with a toy driving program that shows how to use the package functions, and adapt the necessary auxiliary functions.
- Corsika 7 interface is documented and provided on demand.
- Physics based detailed in the publications

D. Morcuende, J. Rosado, J. L. Contreras, F. Arqueros, Astroparticle Physics, **107,** 2019, 26-34
F. Arqueros, J. Rosado, D. Morcuende and J. L. Contreras 2019 J. Phys.: Conf. Ser. **1181** 012047

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Onboarding - 2

- Dedicated git repository for the stand alone version available
- Documentation ready for standard version → has to be updated to include the stand alone one
- Not yet registered on Zenodo

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Thanks !

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