MC simulations - production

CTA CCF Face-to-face meeting in Barcelona, 2016 June 20-24

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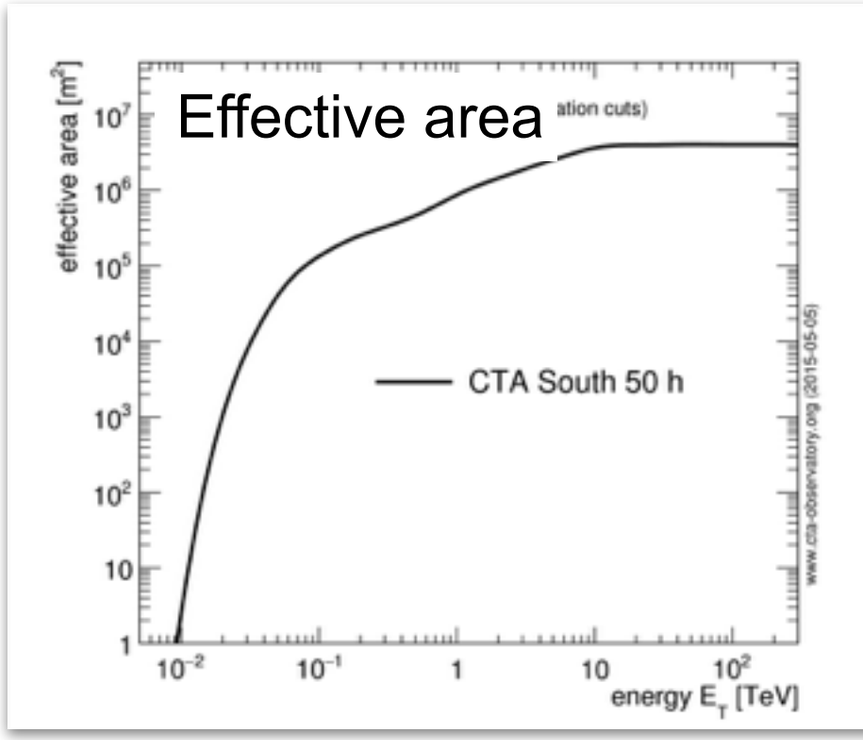
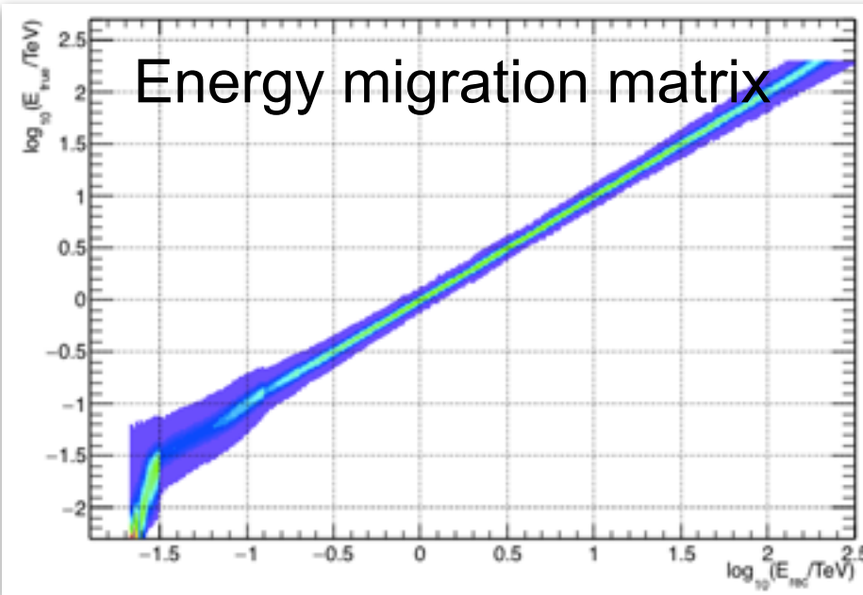
Monte Carlo Simulations are required for….

- performance characterisation of CTA
- almost any science analysis in CTA (instrument response functions)
- optimisation and validation of system parameters during prototyping and (pre-) construction phase



- determination of upgrade scenarios
- development of reconstruction algorithms
- evaluation of systematic uncertainties



The challenge…

Many science goals of CTA will be limited by systematics

Top Level Requirement

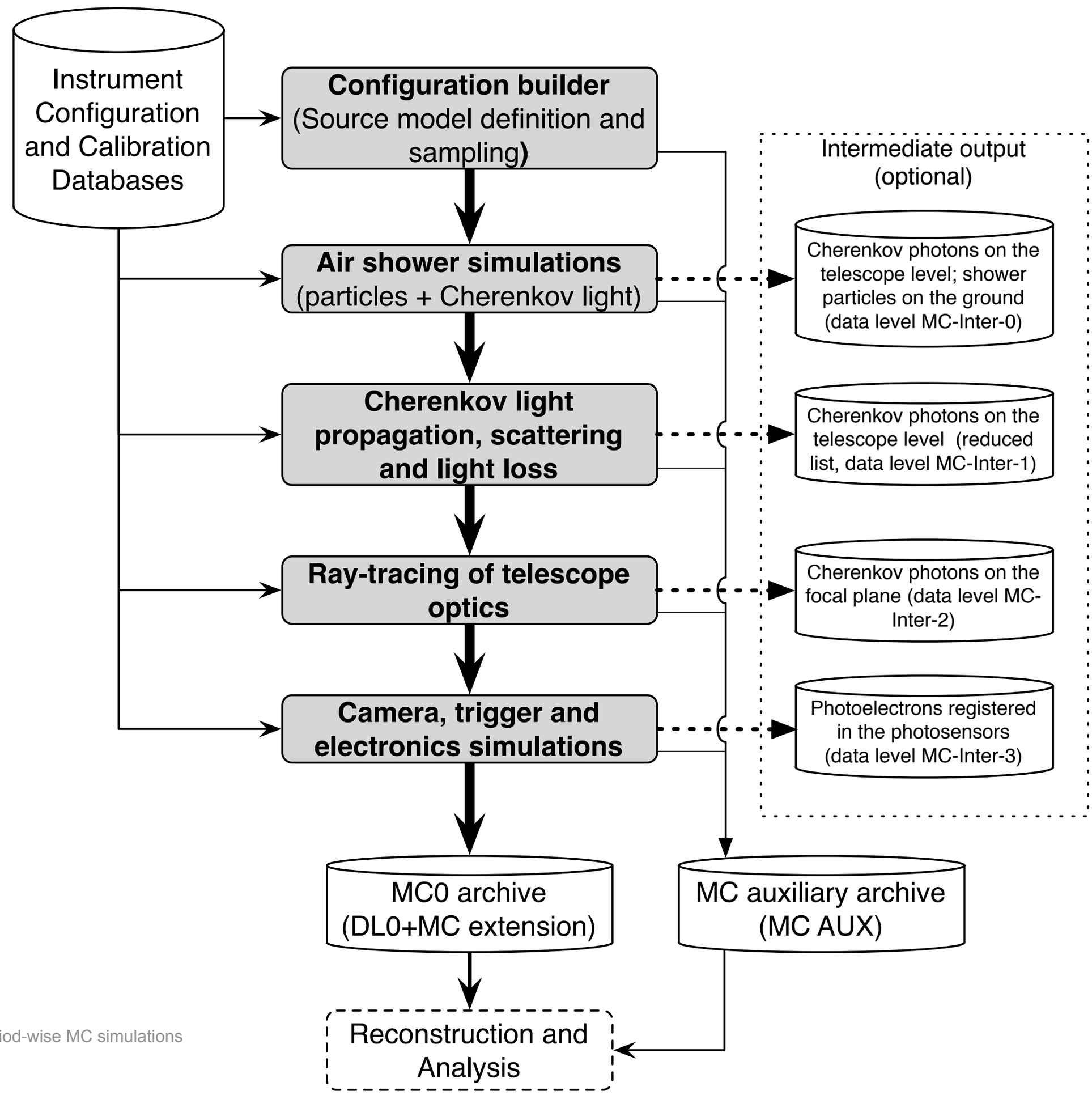
CTA Construction Project | Top Level Requirements | Science Requirements

Name:	SCI-170 Energy scale uncertainty
Description:	Systematic errors in the CTA energy scale must not exceed 10%.
Class:	Requirement
Applicable State:	All
Global ID:	CTA-20530
Project ID:	CTA-_-38
Status:	Approved

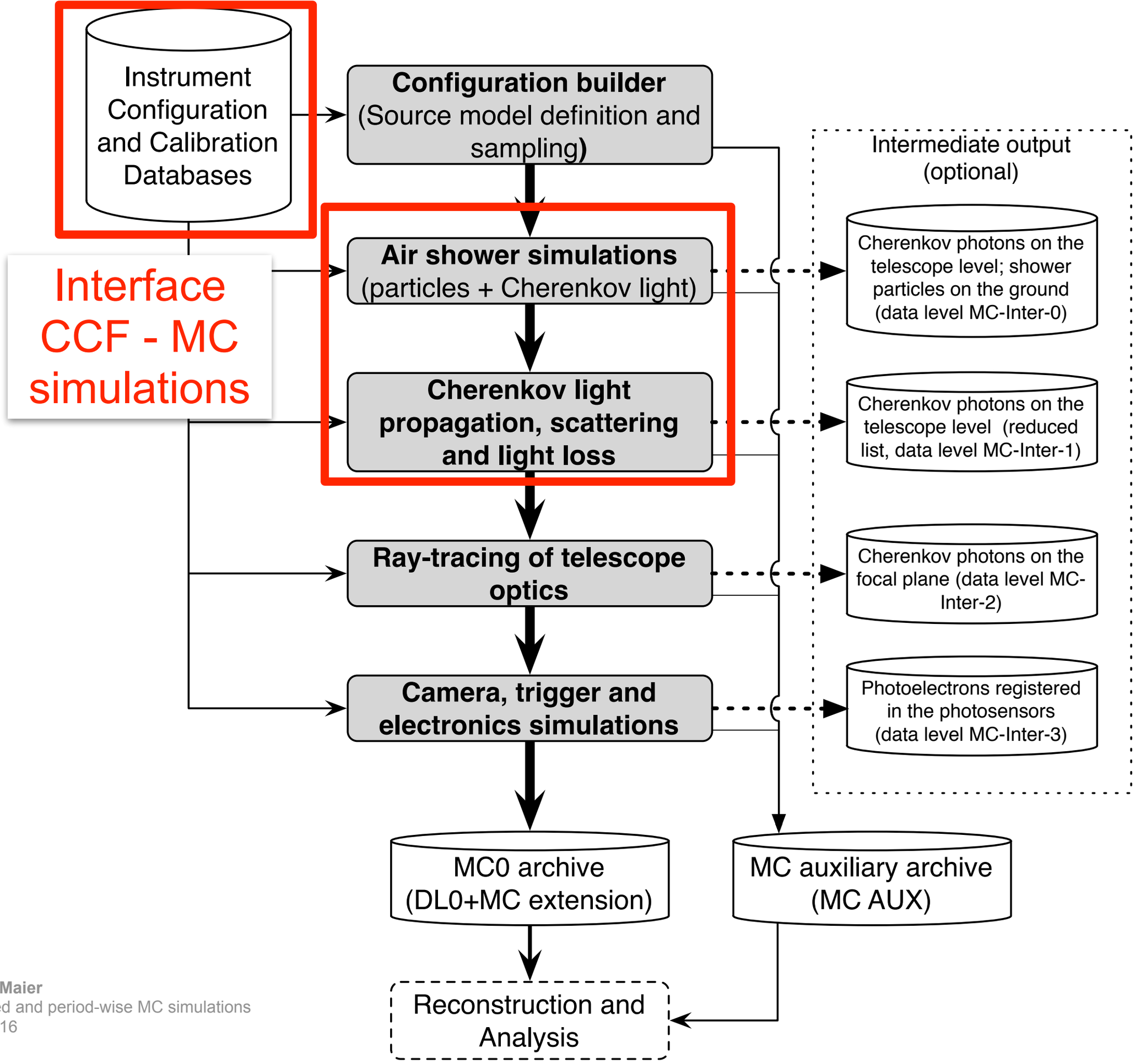
(note that in other places the allowed systematic uncertainty on the energy scale is 15%)

This is a major challenge,
not clear if we can achieve it.

MC pipeline


Instrument Configuration and Calibration Databases
Configuration builder (Source model definition and sampling)
Air shower simulations (particles + Cherenkov light)
Cherenkov light propagation, scattering and light loss
Ray-tracing of telescope optics
Camera, trigger and electronics simulations
MC0 archive (DL0+MC extension)
MC auxiliary archive (MC AUX)
Reconstruction and Analysis
Intermediate output (optional)
Cherenkov photons on the telescope level; shower particles on the ground (data level MC-Inter-0)
Cherenkov photons on the telescope level (reduced list, data level MC-Inter-1)
Cherenkov photons on the focal plane (data level MC-Inter-2)
Photoelectrons registered in the photosensors (data level MC-Inter-3)

MC pipeline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Interface CCF - MC simulations
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Reconstruction and Analysis

The atmosphere in air shower simulations

1. **density profile**
   - determines shower development

2. **refraction index profile**
   - determines Cherenkov light production and the image shapes

3. **extinction profile (absorption+scattering)**
   - determines light losses
   - probability that a photon with wavelength X emitted at a certain height reaches the array level

Variability on very different time scales:
seasonal; days/weeks (weather); hourly
Variability across the array (2x2km)?

Analysis types and requirements on IRF production

Time-averaged vs period-wise instrument response functions

1. **Level A: on-site, real-time analysis**
   - no requirements on systematic uncertainty
   - simplified analysis using time-averaged IRFs

2. **Level B: on-site, next-day analysis**
   - no requirements on systematic uncertainty
   - sophisticated analysis using time-averaged IRFs

3. **Level C: off-site analysis**
   - 10% requirement on systematic uncertainty
   - most sophisticated analysis using period-wise IRFs
   - (time-averaged IRFs still used as starting values)

Time-averaged ('classical') instrument response functions

- **generate full MC sets for each point in a large phase space**
  - fixed zenith, azimuth, offsets, night-sky background, array layout, etc.
  - phase space can be huge: ze (10) x az (4) x offset (6) x NSB (10) x ? x ? = 2400 phase space points points
- any significant change in the instrument (e.g. trigger settings, HV changes) requires a new MC set
  - significant computing effort
  - instrument ageing often ignored and corrected later using correction factors
- any significant change in the atmospheric conditions requires a new MC set
  - smaller changes often corrected using factors derived e.g. from muon measurements
  - need to understand what a 'significant change' is (procedure to be documented)
- required for RTA (Level A), next-day analysis (Level B), basic analysis of all CTA observations

computing effort: see Stefan Ohm's note:
https://forge.in2p3.fr/boards/195/topics/1248

Period-wise instrument response functions

- **period-wise: produce MC sets for certain observation periods**
  - a period is time span for which the observational conditions are *'constant'* (e.g. during a 'run'; probably >10 min to 1 hour long)
  - simulate (sub-)array of telescopes that are tracking a sky position
  - consider exact state of the instrument: broken pixels, calibration, night-sky background (Galaxy..), atmospheric conditions
- requires a reasonable quick turnaround of all calibration / validation steps
- only done for regions of interests where the systematic uncertainty requirement is applicable
  - (not needed to do this for measurements not limited by systematics)
- needs to be a fully (semi?) automatic process
- by definition much closer to reality than full phase-space approach - no need for data correction!

computing effort: see Stefan Ohm's note:
https://forge.in2p3.fr/boards/195/topics/1248

Interfaces MC production - CCF

really needs better documentation

Observatory
ACTL
Instrument teams
Calibration

Instrument Configuration and Calibration Databases

(I know that the names of the DBs are different (and still changing with time)

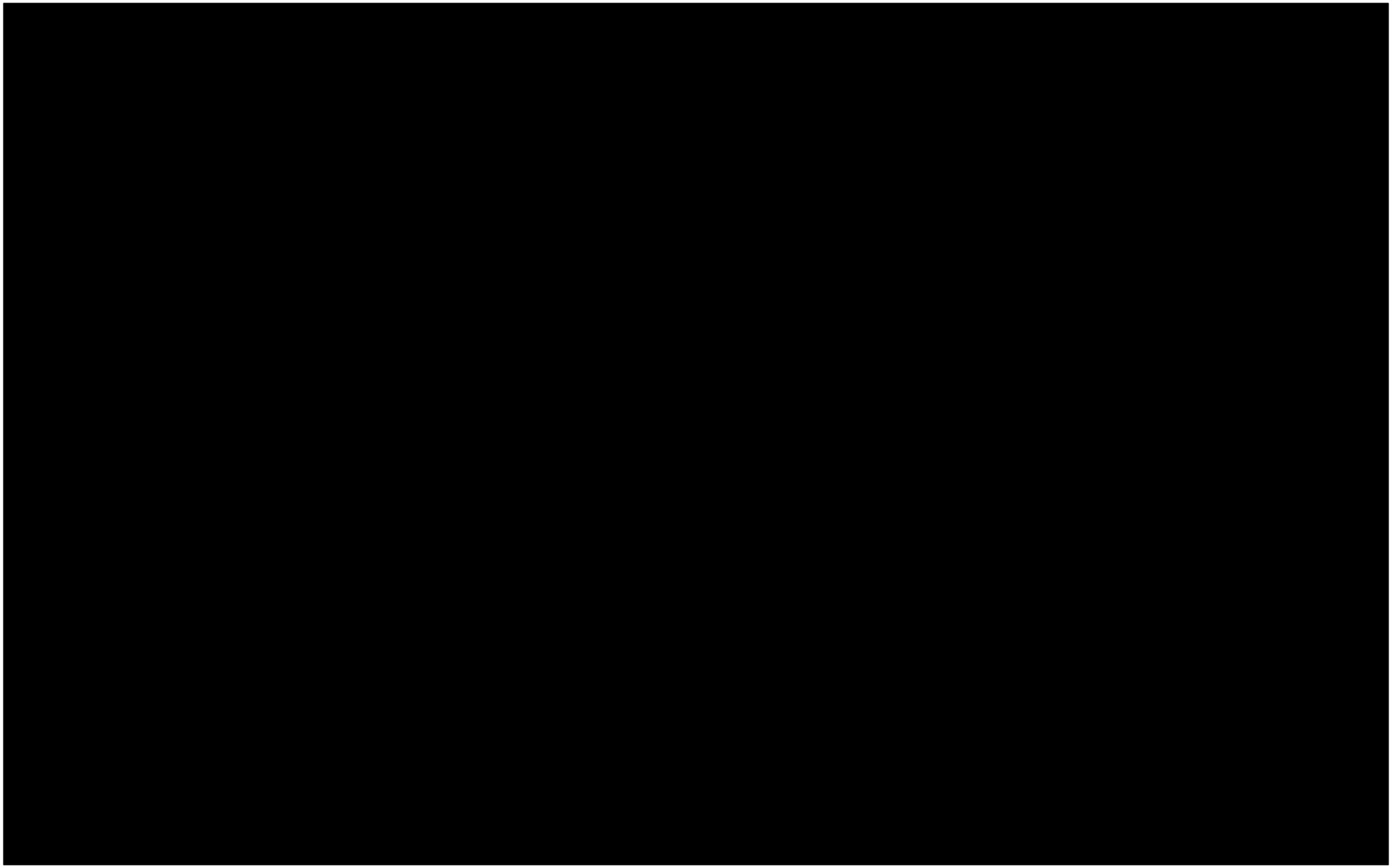
Configuration builder
(Source model definition and sampling)

Air shower simulations
(particles + Cherenkov light)

Cherenkov light propagation, scattering and light loss

Ray-tracing of telescope

The MC view of CCF



Typical queries by MC…

- what is the atmospheric density profile for 2019, May 5th, 10:00 UTC at CTA South?
  - where does the extrapolation happen if there are no measurements for this day?
  - (can replace atmospheric density here by extinction profile or refractive index)
- what is the average (mean + RMS) atmospheric density profile for 2019, May at CTA South?
  - who is doing the averaging?
- what is the throughput correction for 2019, May 5th relative to 2019, April 1st?
- expect to get one single value for each quantity, even if there are several measurements exists: CCF has the expertise to determine best values
- **expect to get for every quantity:**
  mean value + statistical uncertainty + systematic uncertainty
  - (correlation of some systematics, e.g. density profiles and refractive index?)

CCF data access

- lot's of information about the atmospheric conditions at both sites available
  - this meeting / past meetings
- variability of atmospheric conditions determines amount of MC sets required for averaged IRFs
  - determines computing needs, storage, …, costs
- can we access the historical records of atmospheric measurements at La Palma and Paranal? Where is all the data from CCF stored?
  - best would be to have it stored in a central CTA data base accessible to everybody in CTA
  - (very likely other working groups interested in this)
- first data of CTA? Probably also a good way to test the data flow and data models (provenance, etc.)

MC simulation pipeline software

- CTA MC simulation pipeline software is in development
  - CORSIKA/sim_telarray or CORSIKA/GrOPTICS/CARE can be used
- main focus is on MC configuration
  - technical development of data model / configuration reader and writer
  - compilation of all knowledge about CTA from the instrument teams and CCFs
- use case discussion:
  What are the typical use cases of CCF of the MC simulation pipeline?
  - muon simulations
  - ….

Documentation of productions

https://forge.in2p3.fr/projects/cta_science_mc/wiki