CORSIKA 8

A modern and universal framework for particle cascade simulations

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Current CORSIKA 7

- Monte Carlo simulations essential for interpretation of measured air-shower data
- CORSIKA 7 has monolithic FORTRAN code, key developers retired.
  Challanging to navigate, maintain, and extend by physicists today.
- Hand-optimized code: fast, but incurs limitations, e.g. exp. atmospheric models
- Difficult to adapt to modern computing environments: MPI-parallelized, but no multi-threading, no GPU parallelization

- More flexibel simulation tool is needed:
  - In-ice showers, cross-media showers, …
  - complex radio-signal propagation in ice, …

CORSIKA 8 simulation framework

- a modern reimplementation in C++, with focus on modularity
- designed with the needs of modern computing in mind
- coordinated by KIT, but as a true community effort

- First commit:
  Mon Apr 9 14:55:03 2018

CORSIKA 8 workshop, July 2023 at KIT

CORSIKA 8 simulation framework

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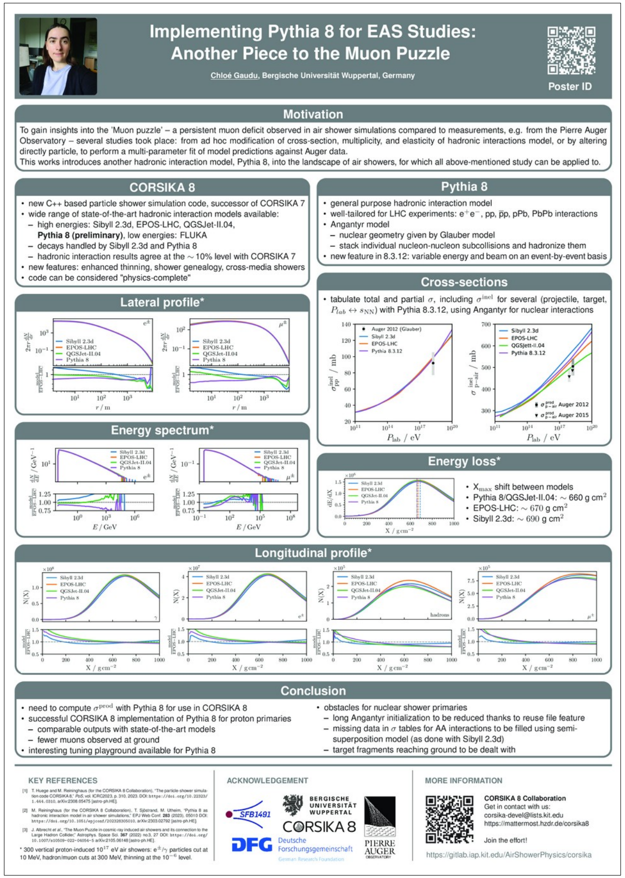
- More information / Get in contact:
  - https://www.iap.kit.edu/corsika/88.php
  - https://gitlab.iap.kit.edu/AirShowerPhysics/corsika/
  - https://mattermost.hzdr.de/corsika8/channels/town-square

CORSIKA 8 workshop, September 2024 at KIT

Status of CORSIKA 8

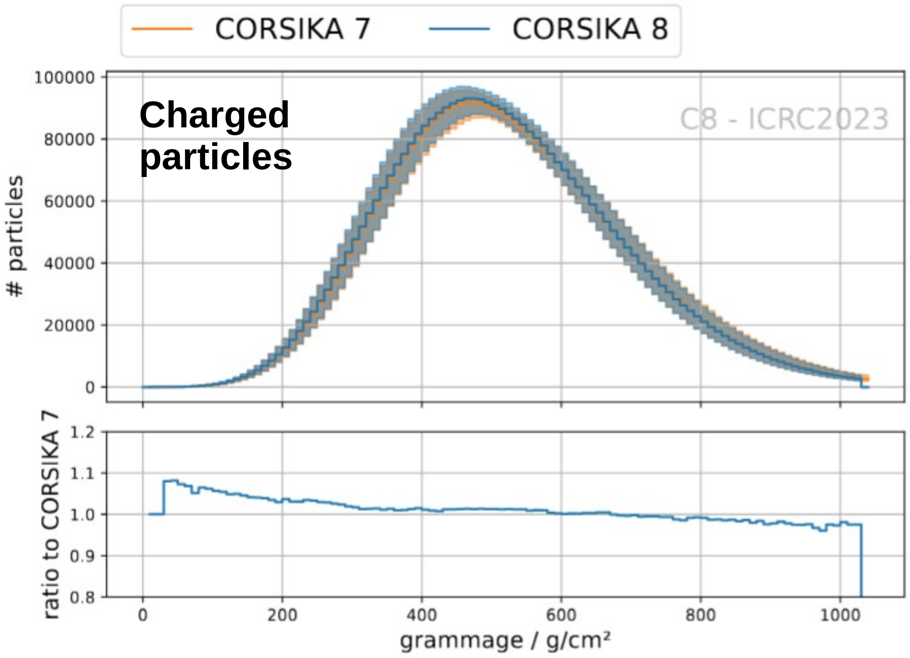
- code can be considered „physics-complete“ and is openly available
- *Many* crucial improvements over the last two years
  - FLUKA as low-energy interaction mode
  - Sibyll 2.3d, QGSJETII-04, EPOS-LHC as high-energy interaction models. Also Pythia 8.3 (preliminary version) available for the first time, cf. poster by Chloé Gaudu,
  - EM: Photohadronic interactions, LPM effect, Particle thinning
  - Fully integrated Cherenkov-light calculation
  - Fully realistic radio emission calculation with two formalisms
- extensive validation versus CORSIKA 7 and other codes
- still polishing user-level aspects (simulation steering, documentation, …)

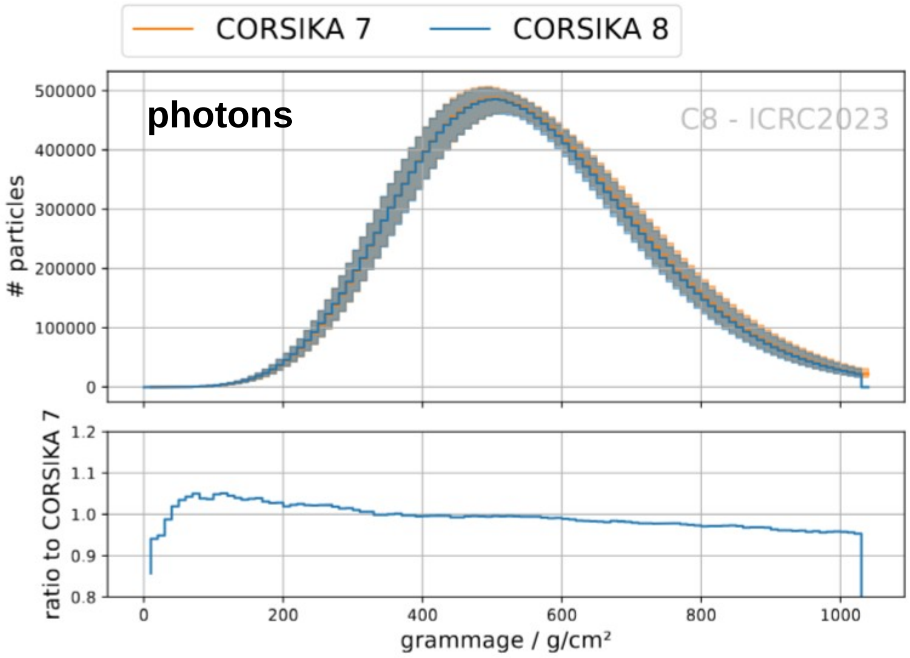


Electromagnetic showers

Alexander Sandrock PoS(ICRC2023)393

- New code for electromagnetic component
  - Corsika 8: PROPOSAL 7.6.2
  - Corsika 7: customized version of EGS4
- Comparing a 100 TeV primary
  - General agreement on the <10% level for longitudinal and lateral profile, energy distribution
  - Likely due to particle tracking & multiple scattering treatment





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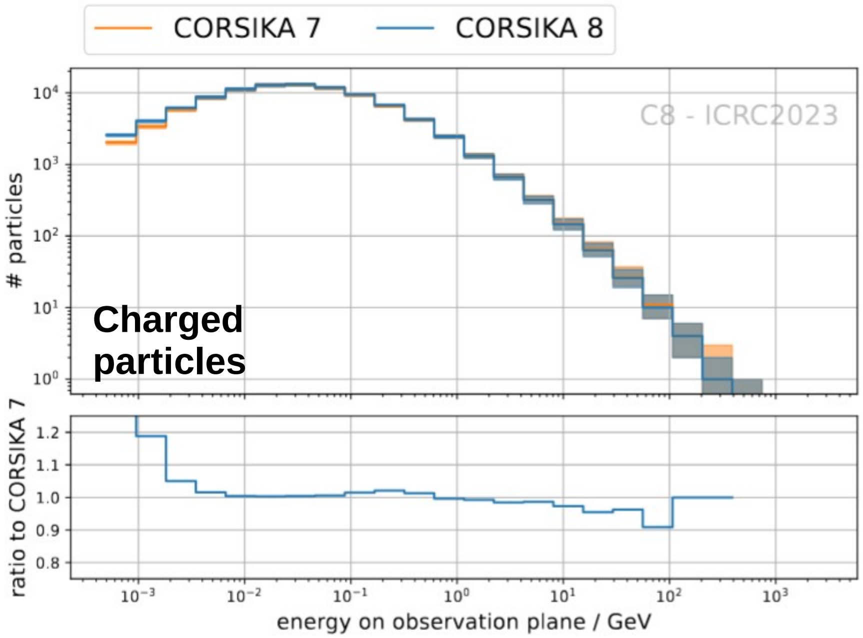
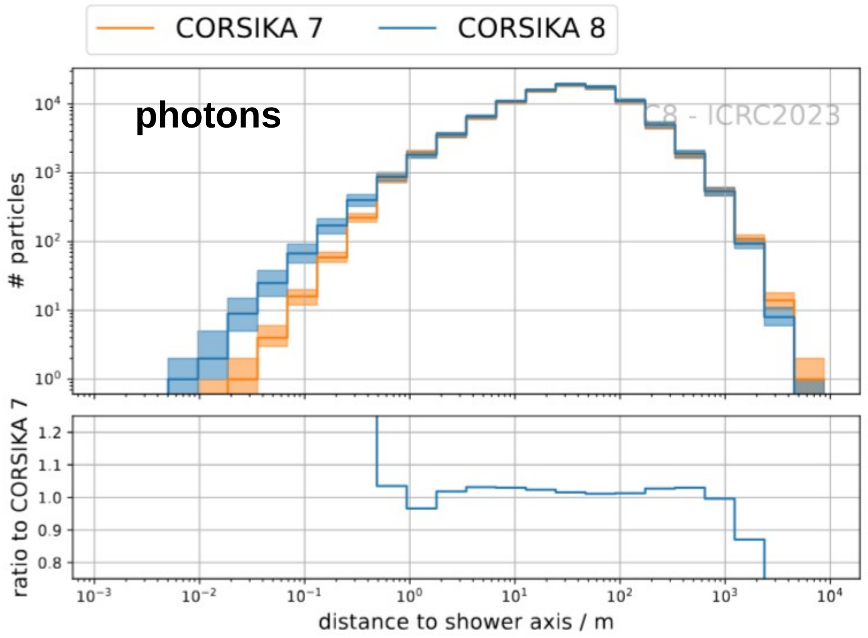
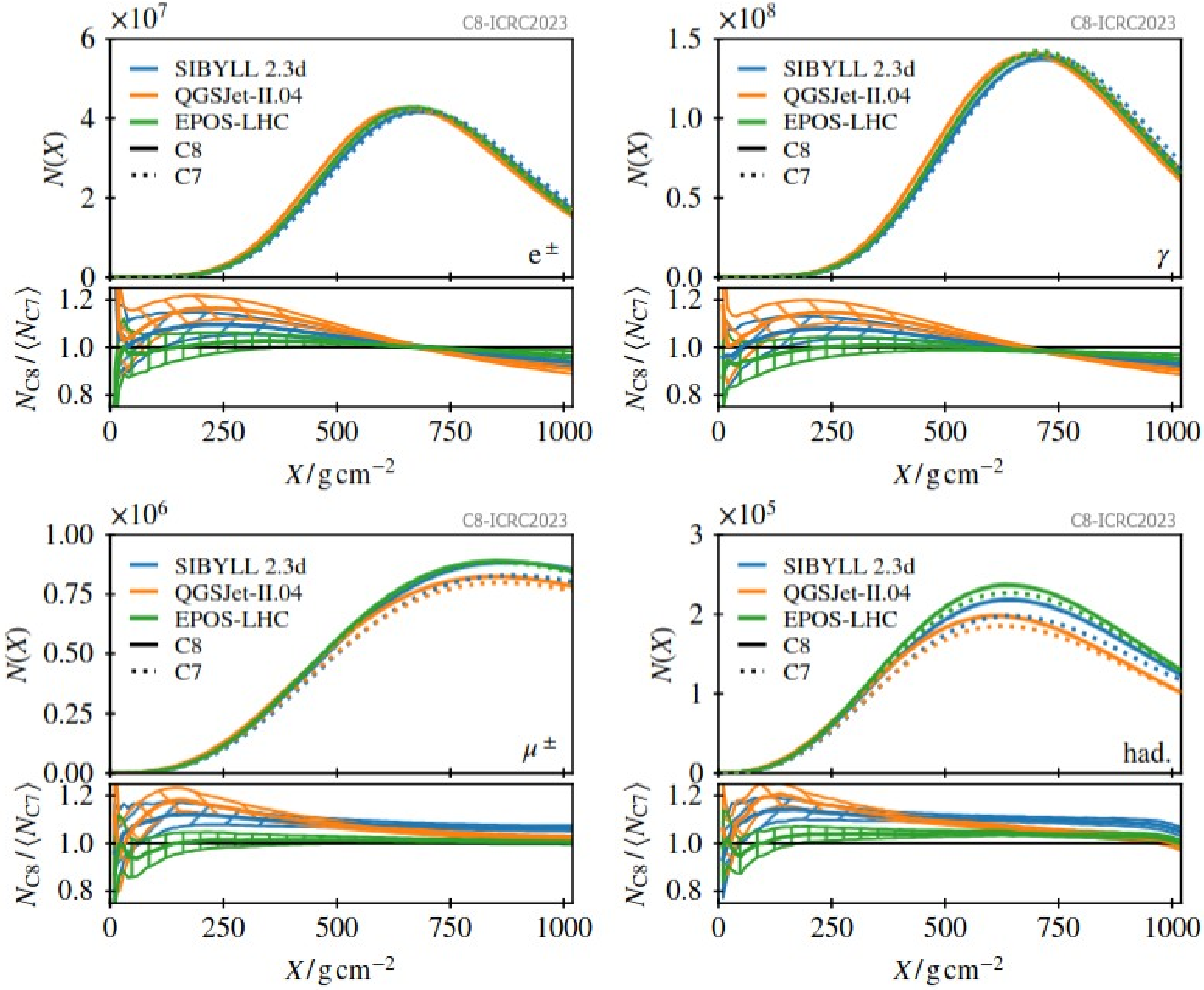




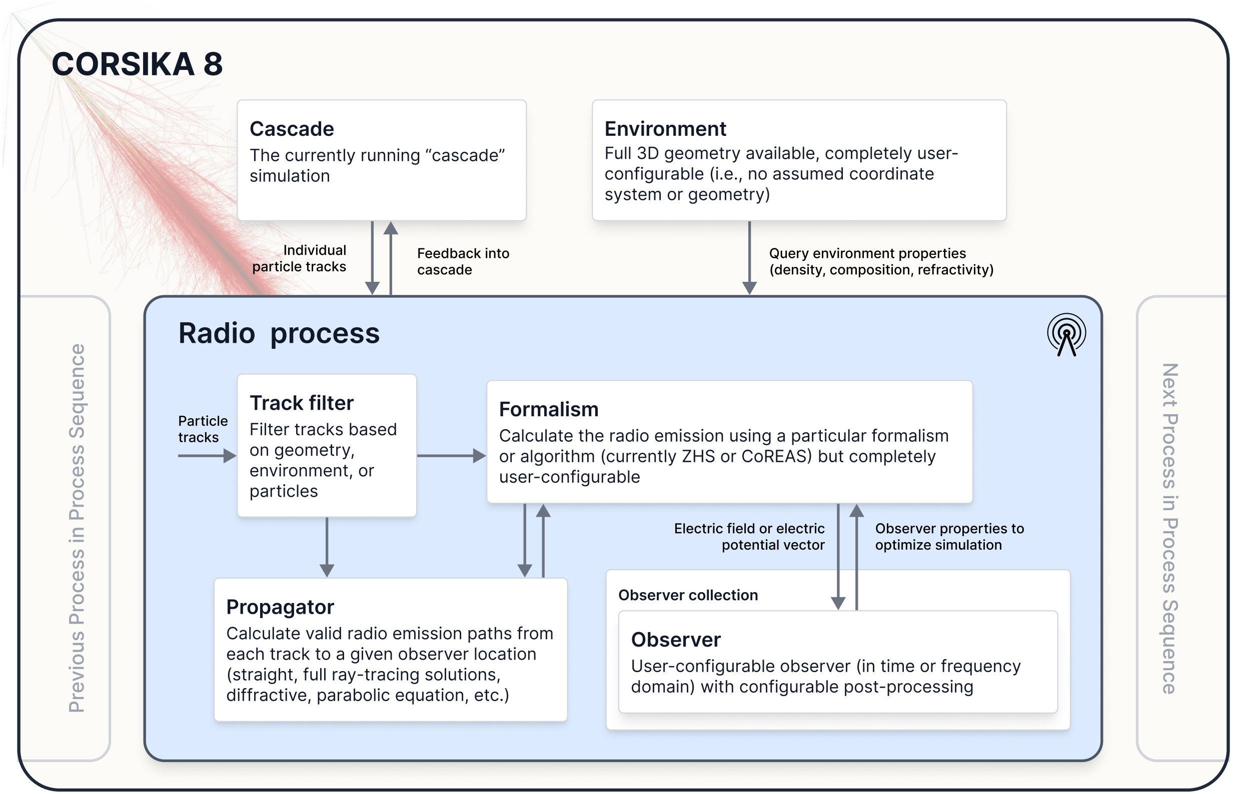
Hadronic showers

- Longitudinal distributions for the averages of 300 vertical proton-induced 100 PeV air showers
- Dependence on interaction model
- Will be investigated in more detail
- Agreement for electrons/positrons, photons, muons and hadrons within ~ 10%

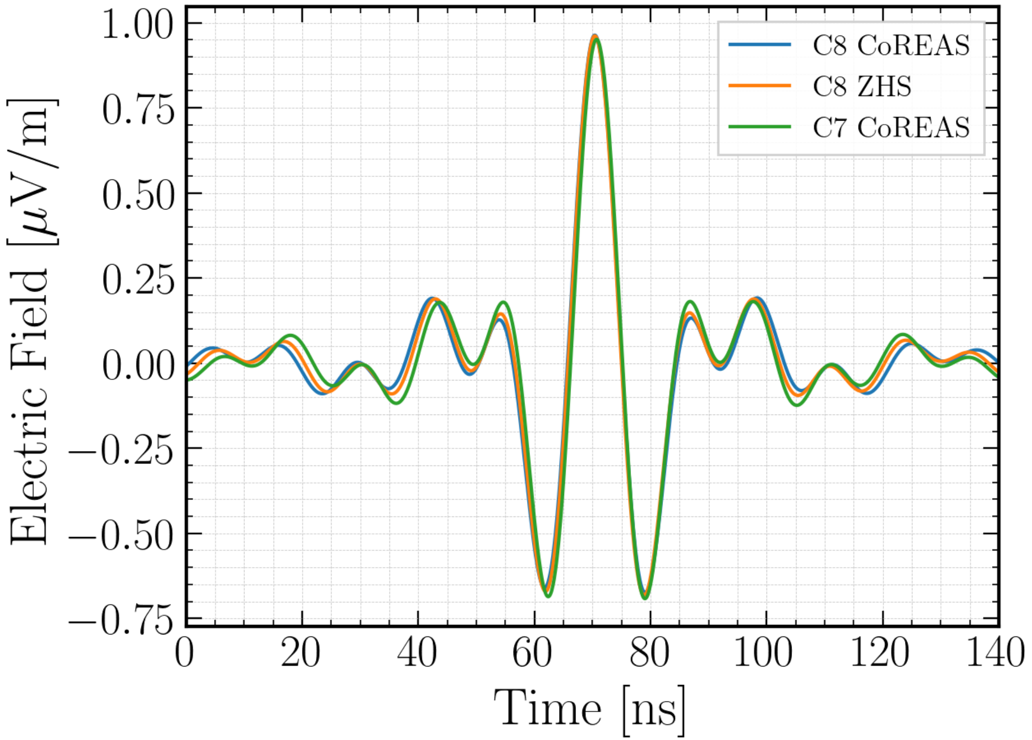


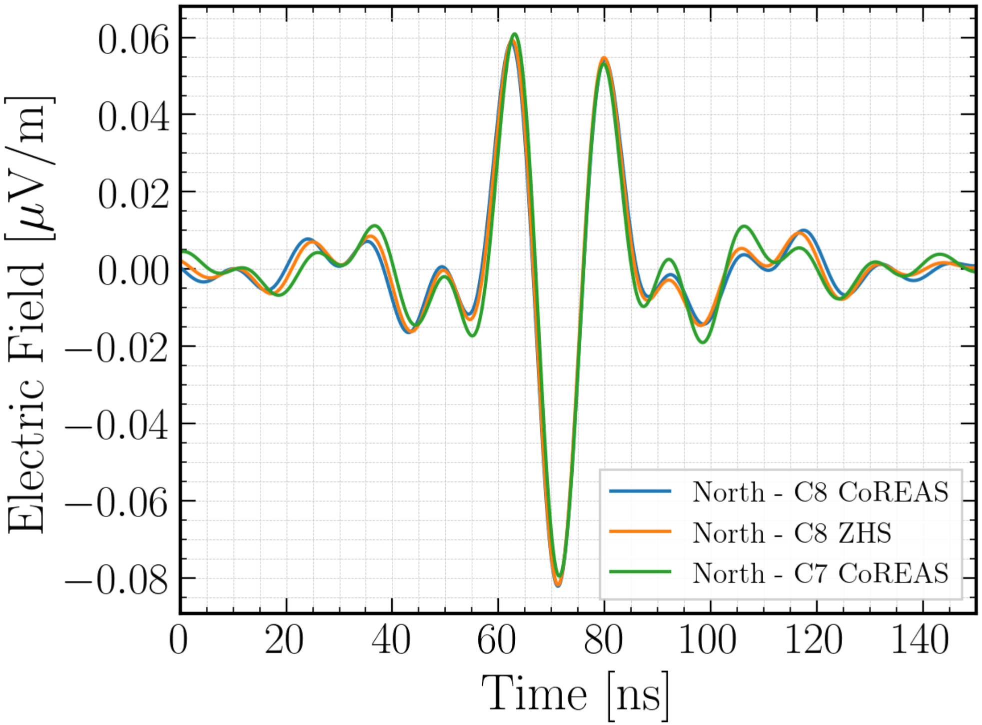
Radio emission

- Calcultion of radio emission from particle cascades fully implemented
  - „CoREAS“ (endpoints) à la C7
  - „ZHS“ à la ZHAireS
- Both formalism in same code, can compare for exact same air shower
- Generic structure: filter, formalism, and propagator can be configured separately
- Paper submitted to Astroparticle Physics, very positive review



Radio pulses



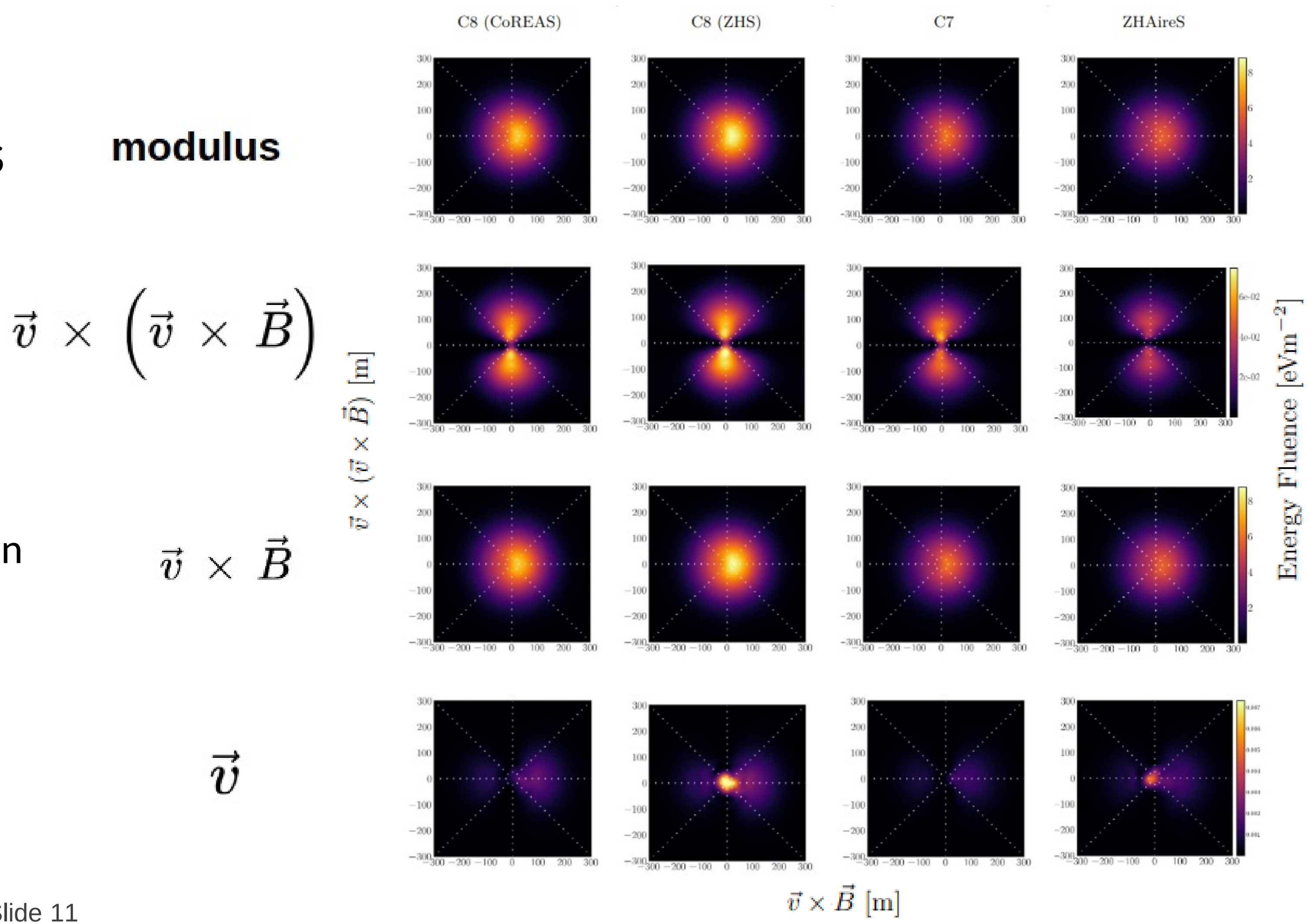


- Pulse for 1 PeV vertical shower at 100 m distance from core
- Pulses agree nicely for high-precision simulations

Here: 30-80 MHz,
same for 50-350 MHz

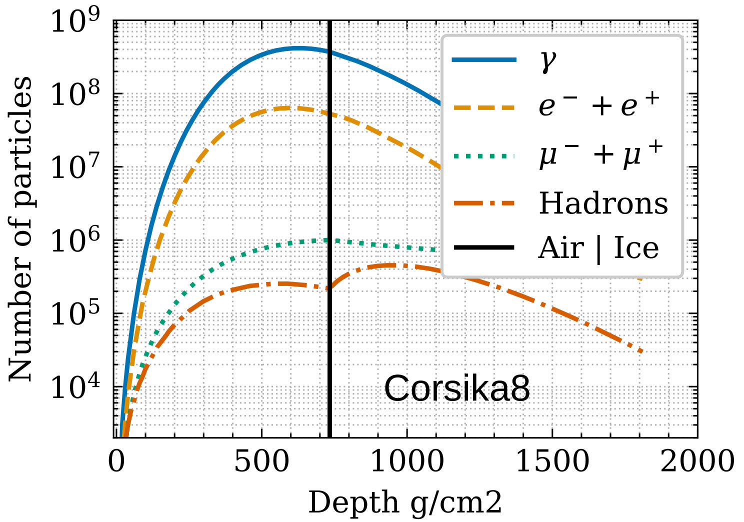
Radio emission components

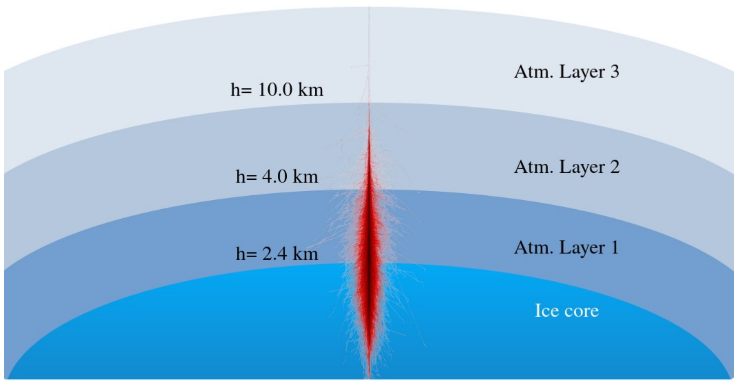
- Patterns and polarizations match predictions of CoREAS and ZHAireS
- C8 produces slightly more signal with default setting of technical parameters
- Radiation energy converges to within 1-2% for high-precision simulations

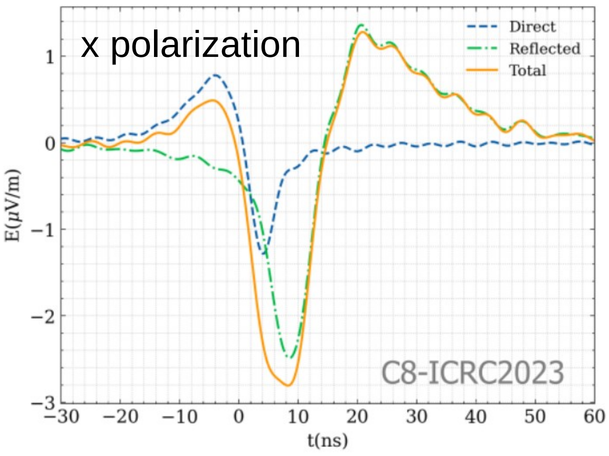


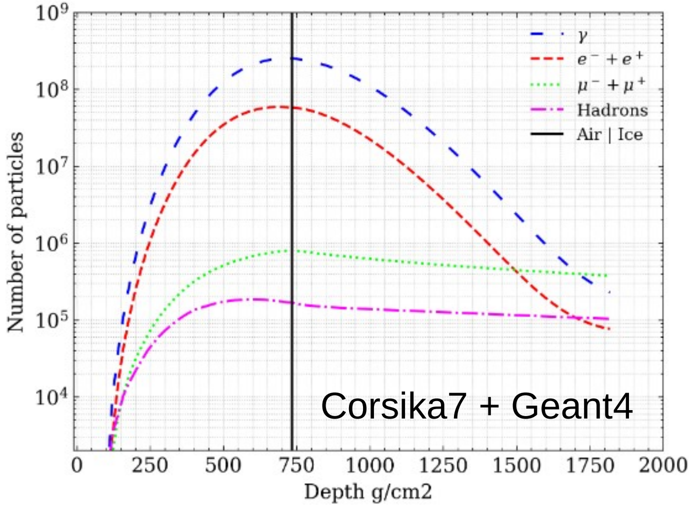
Cross media showers

- Example: particle showers penetrating from air in to ice.
- Comparing Corsika8 with combination of Corsika7 + Geant4
- Rehadronization when the showers intersects the ice due to the dominance of the hadronic interaction. Missing in Geant4 due to absence of hadronic interaction models in-ice.
- Medium-specific propagators for radio emission.
  In ice: direct and reflected path









Expert release

- We will have an expert release for Christmas to gather broader feedback from the community
- Basic steering available, advanced one using config file under development
- Python library to read corsika8 output, examples scripts are provided

```
c8_air_shower --pdg 2212 --energy 1e5 --zenith 35 --azimuth 0
--filename test_shower

config.yaml  energyloss         interactions  primary  summary.yaml
CoREAS       interaction_hist   particles     profile  ZHS

energyloss:
config.yaml  dEdX.parquet  summary.yaml

particles:
config.yaml  particles.parquet  summary.yaml
```

Summary

- Tremendous progress in the development of CORSIKA 8, considered “physics-complete”.
- Expert release for Christmas, feedback from the community very much appreciated.
- Only single tool for simulation of cross-media showers.

- Validation against CORSIKA 7 results shows agreement generally on a ≈10% level.
- CORSIKA 8 radio implementation successfully validated. ZHS and CoREAS formalisms converge at the same result within 1-2%.
- Already succesfully used by community working on radio emission in ice, excellent agreement with previous results

The CORSIKA8 Collaboration

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