Background: *Cosmic Radiation: #11 Cobalt Blue* by Alexandra Hunts

A Numerical Approach to Angular Distributions in Hadronic Cascades

International Cosmic Ray Conference – 2021

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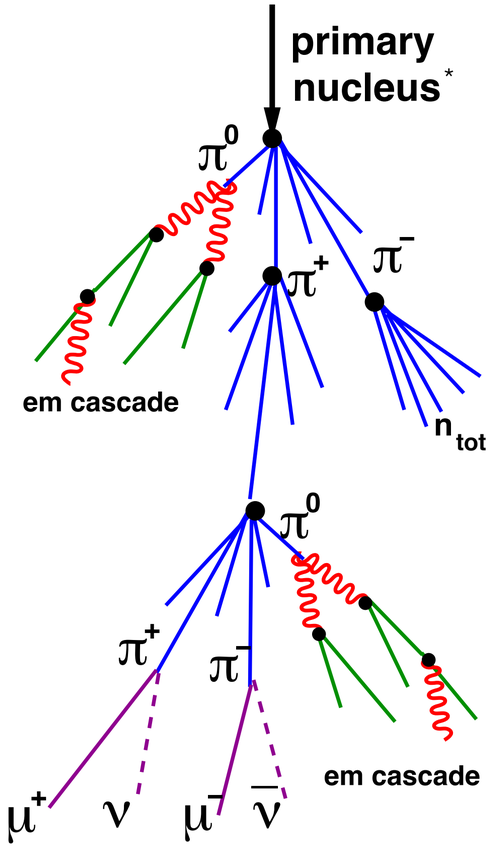
ICRR Institute for Cosmic Ray Research University of Tokyo

CARLSBERG FOUNDATION

UNIVERSITY OF COPENHAGEN

Hadronic cascades



> Central to the evolution of air showers;

> Rich in secondary particles, which are widely spread at low energies;

> For angular distributions of low-energy secondaries, need to develop the cascades in 3D

*Schematic from S. Mollerach and E. Roulet, Prog. Part. Nucl. Phys. 98 (2018).

Background: NASA

Hadronic cascades

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FLUKA

CORSIKA

KIT Karlsruhe Institute of Technology

GEANT4 A SIMULATION TOOLKIT

AIRES Simulation of Particle Air Showers

PHITS Particle and Heavy Ion Transport code System

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develops a **numerical approach** to angular distributions of $\mathcal{O}$**(GeV)** cascade secondaries:

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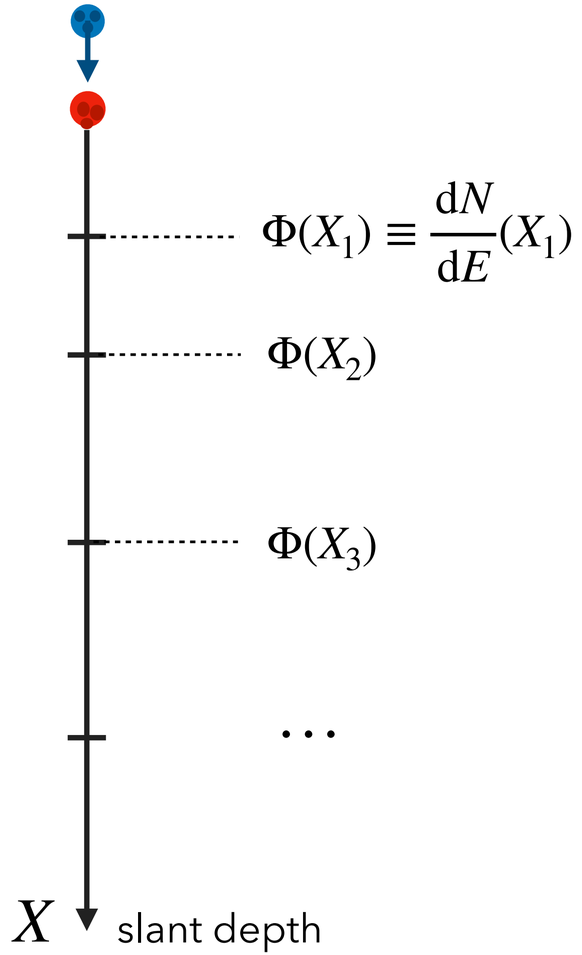
> Use MCEq*, a state-of-the-art numerical software for 1D cascade development;

> Extend MCEq from **1D (*X*)** to 2D (X+θ);



* – Matrix Cascade Equations;
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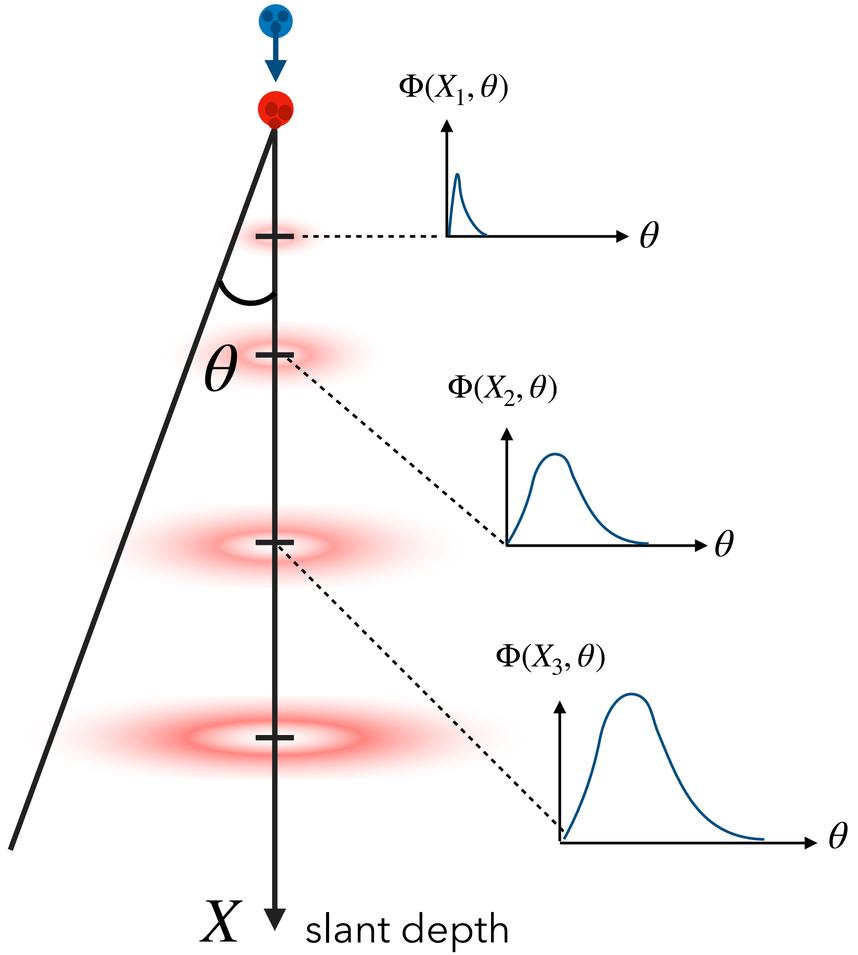

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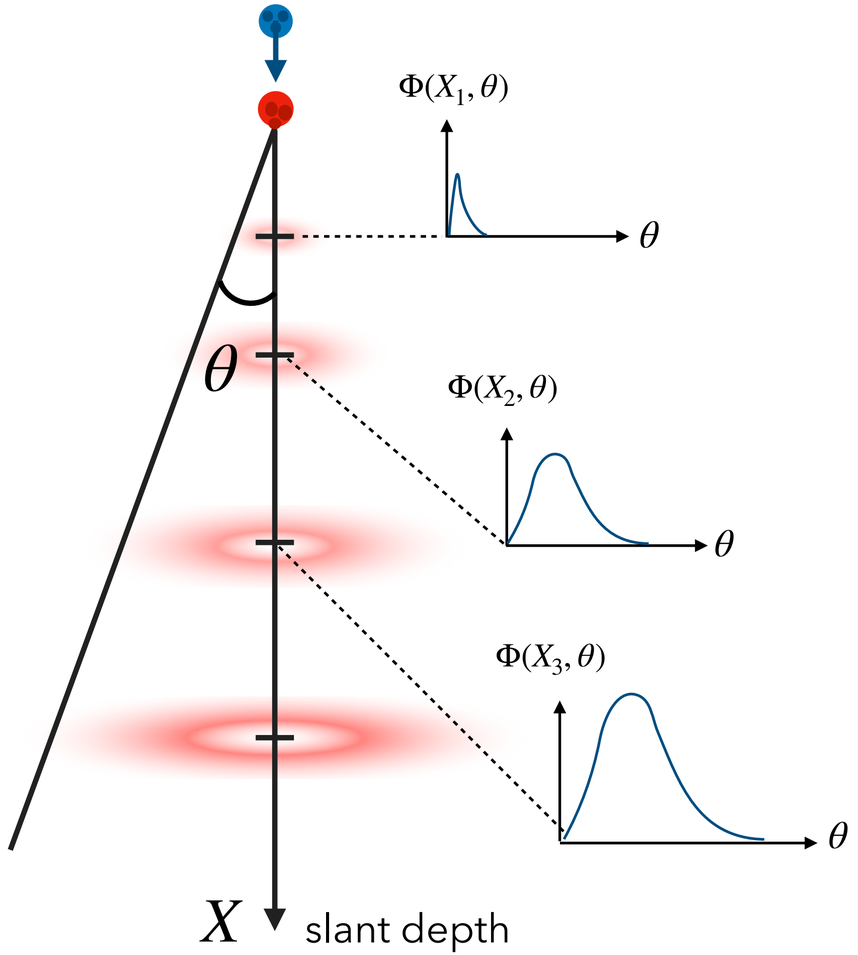
> Applications – fast and flexible modelling of **LE atmospheric ν fluxes.**



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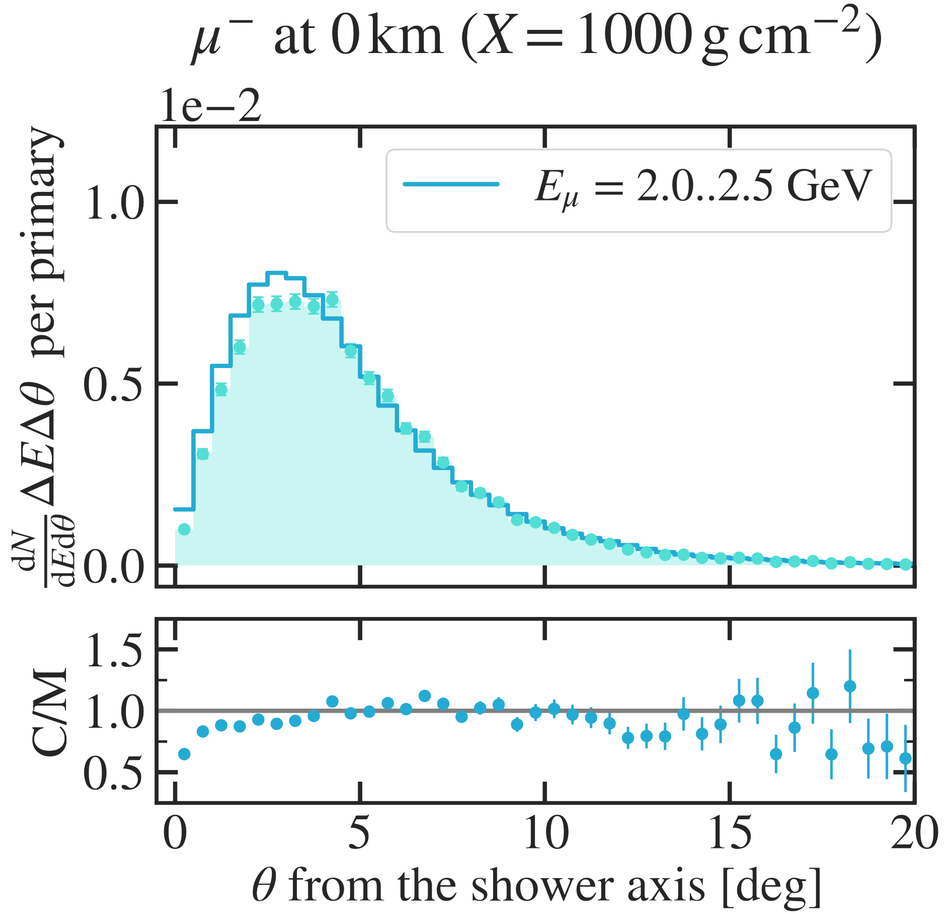
Selected results

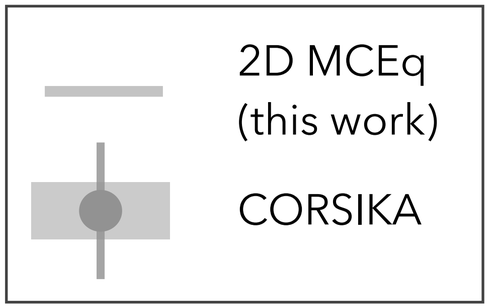
> Develop a **100 GeV proton cascade in the Earth's atmosphere** using 2D MCEq;

> Use CORSIKA as the benchmark Monte Carlo;

> Compare the angular distributions of the **secondary muons**:



CORSIKA:MCEq →

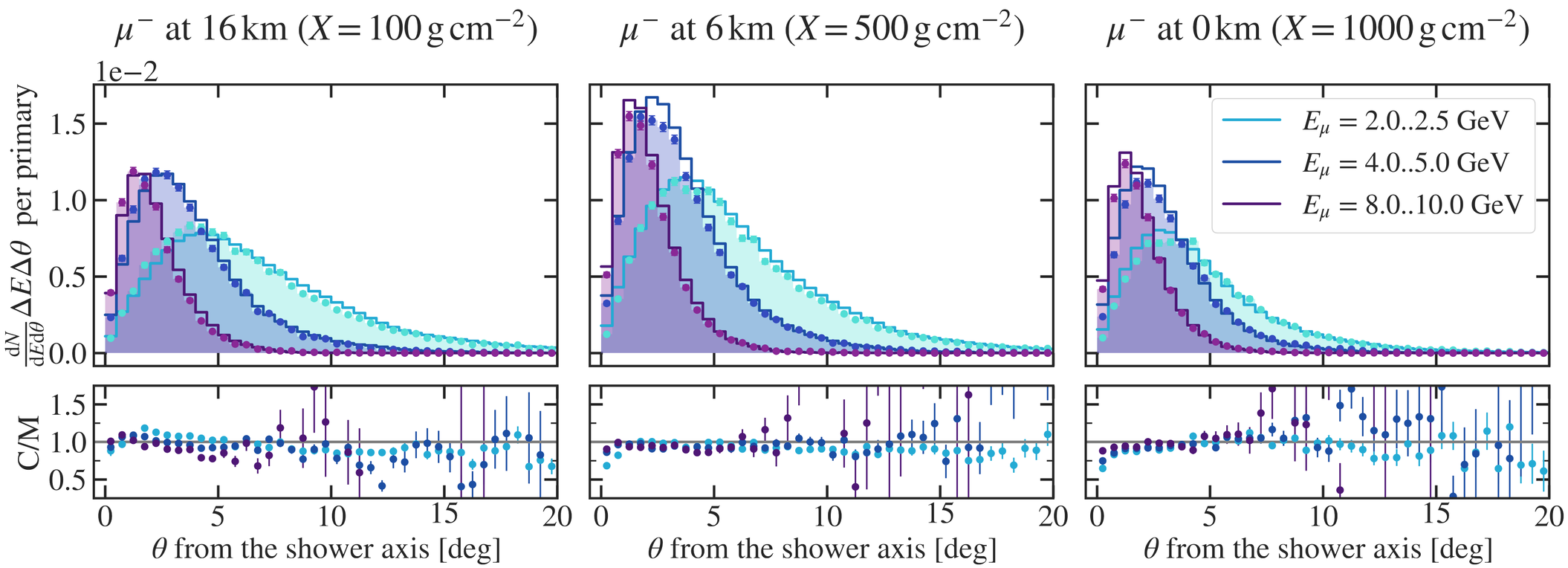


Selected results

2D MCEq (this work)

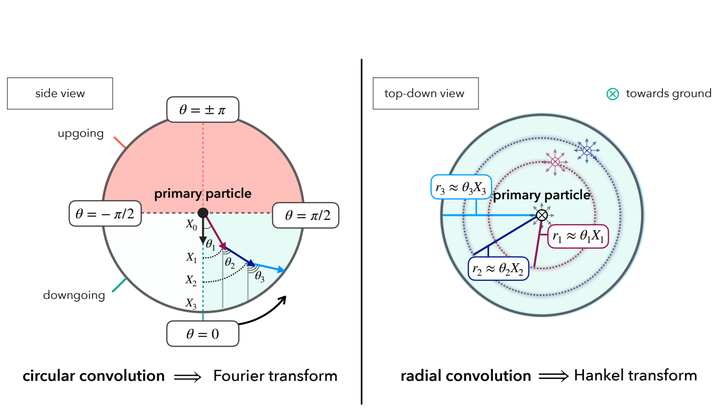
CORSIKA

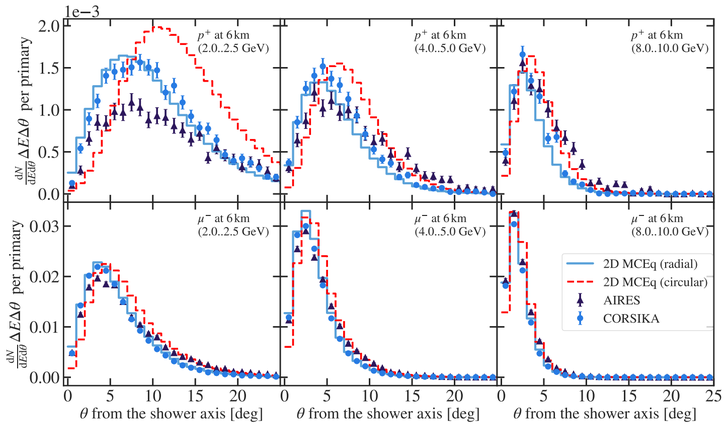
> Find a very good agreement at a range of altitudes and muon energies:

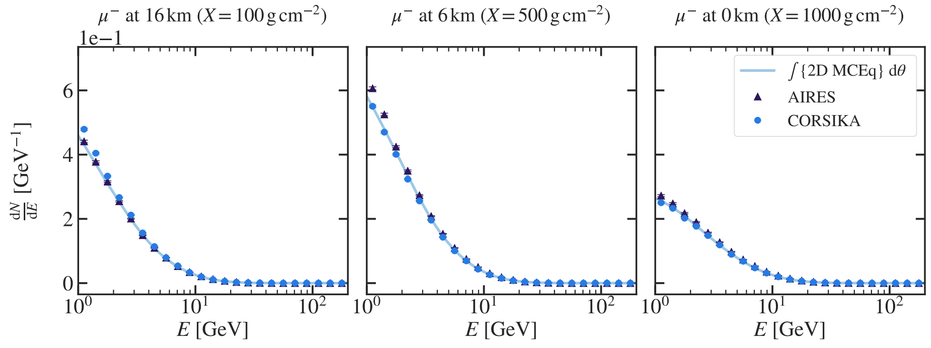


This suggests that **our tool can be a fast and accurate alternative** to the Monte Carlo cascade development approaches.

Want to know more?





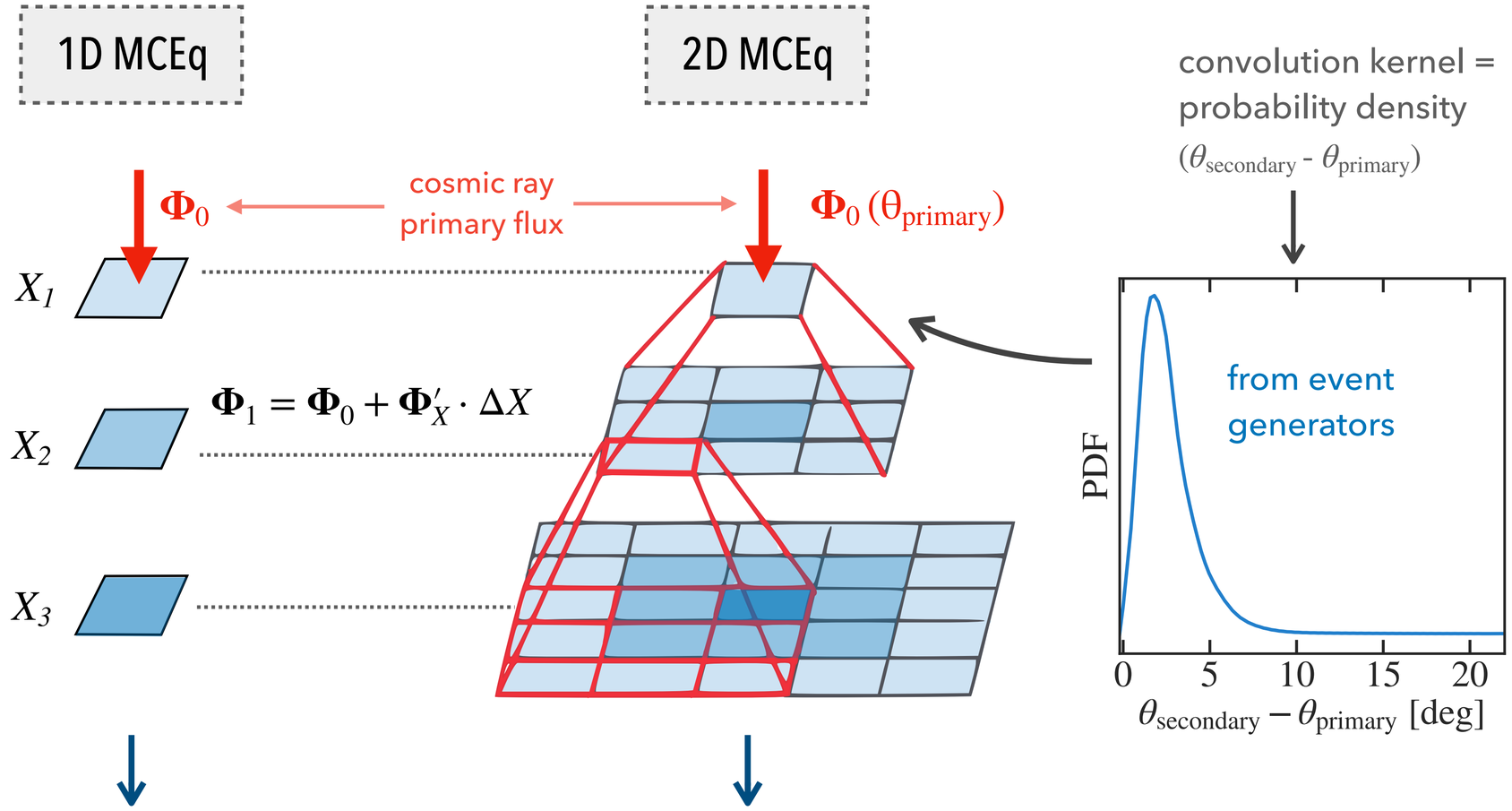


Talk to us at the presenter's forum, email tetiana.kozynets@nbi.ku.dk, or have a look at the proceedings.

*

Backup

Our approach

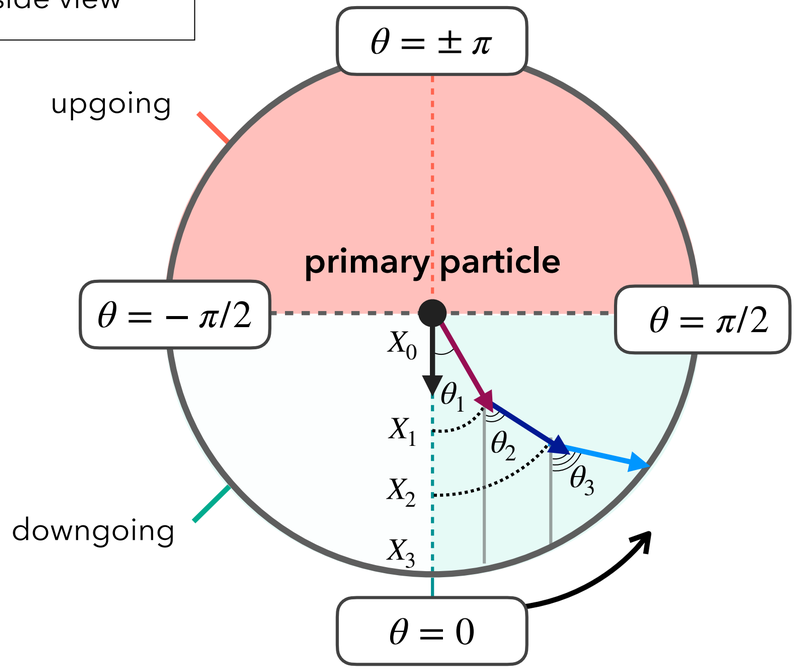


1D cascade equations

2D cascade equations → solve in frequency domain

Attempted convolution methods

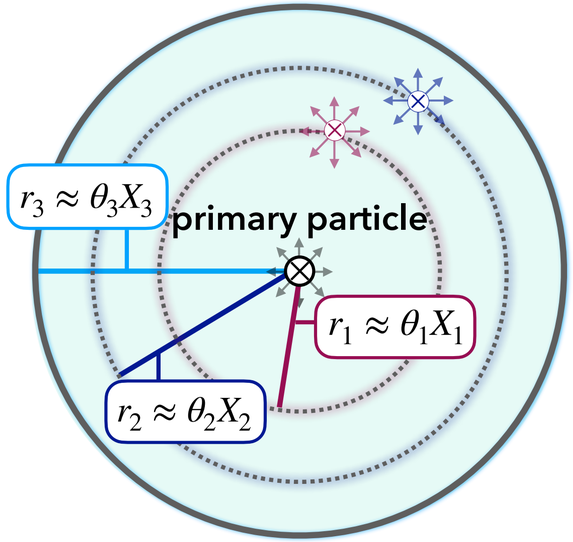
side view



circular convolution $\Longrightarrow$ Fourier transform

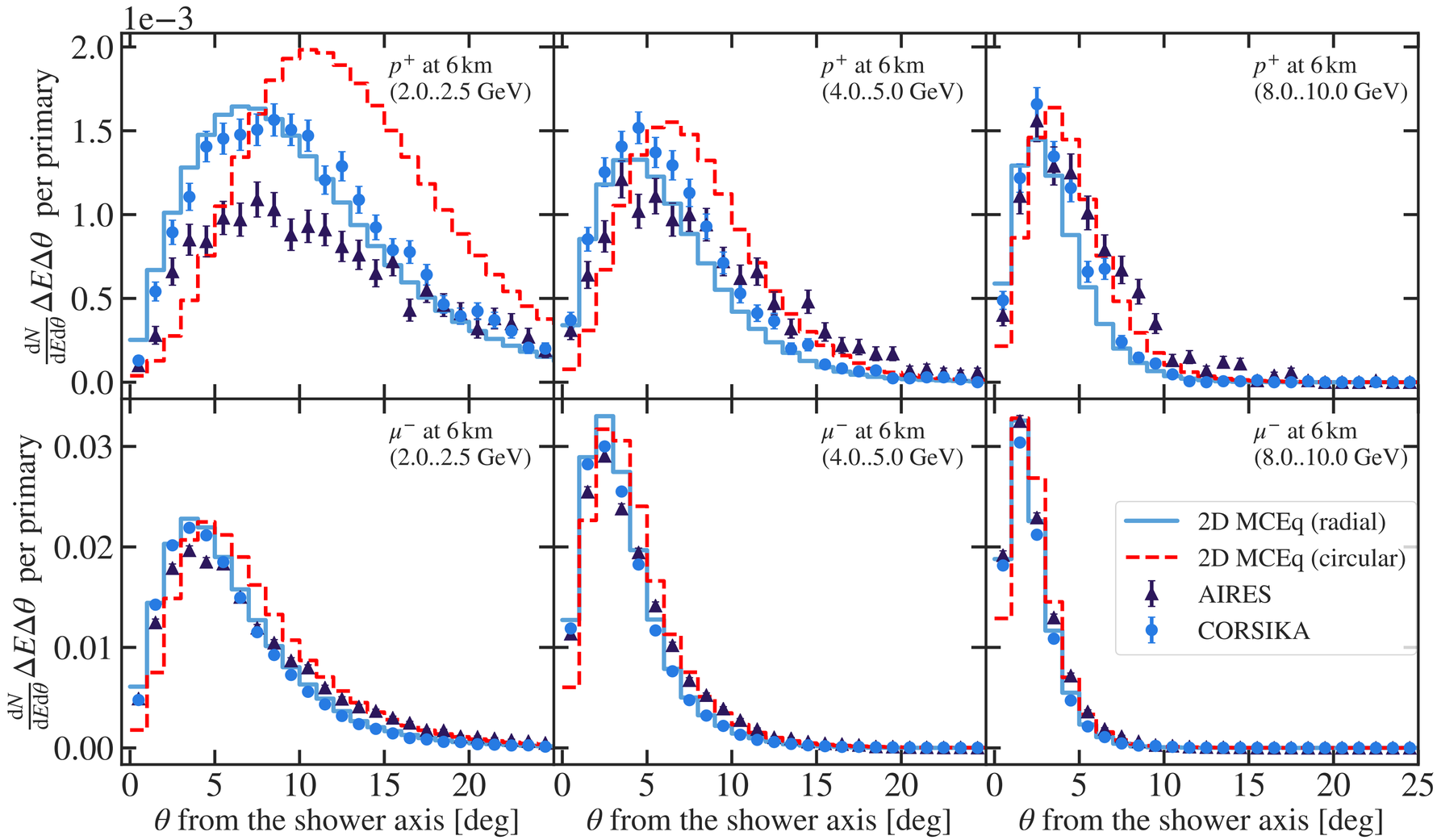
top-down view

⊗ towards ground



radial convolution $\Longrightarrow$ Hankel transform

Benchmarking, part II



Angle-integrated spectra