The Cosmic-Ray Air Shower Signal in Askaryan Radio detectors

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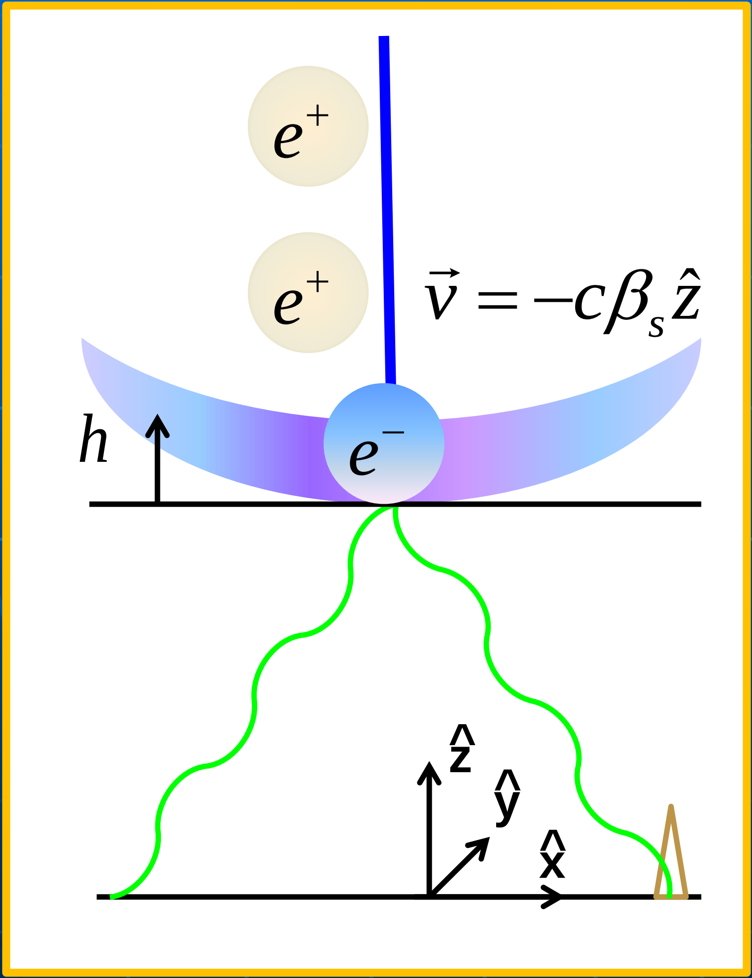
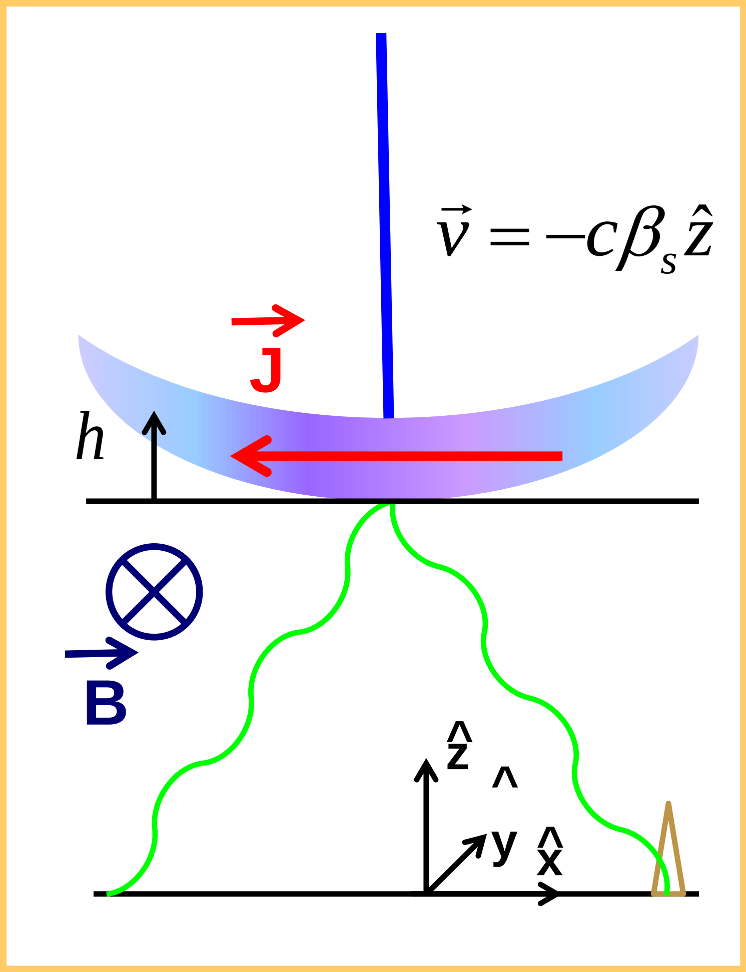
Radio Emission Mechanisms:

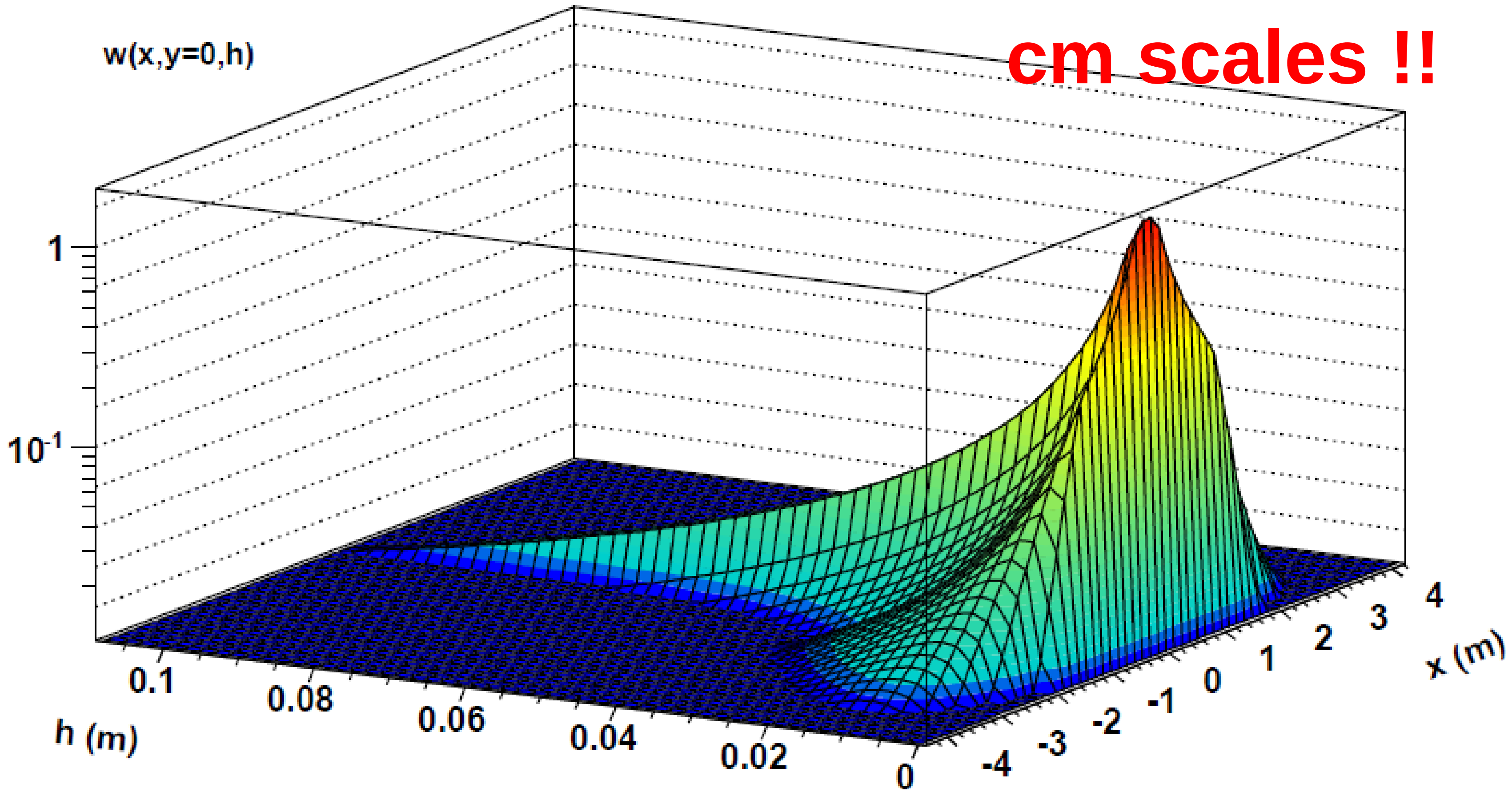
Charge excess:



Geomagnetic:



CX-MC-GEO+MCFIT:
The particle distributions in the shower front



K. Werner, et. al. Astropart. Phys. 37 (2012) 5-16; arXiv:1201.4471

Emission Mechanisms From Currents to radiation.

$$A^{\mu}(\vec{x},t) = \frac{J^{\mu}(t')}{|D(\vec{x},t)|}$$

$$D = R(1 - n\beta\cos(\theta))$$

$$= R\frac{dt}{dt'}$$

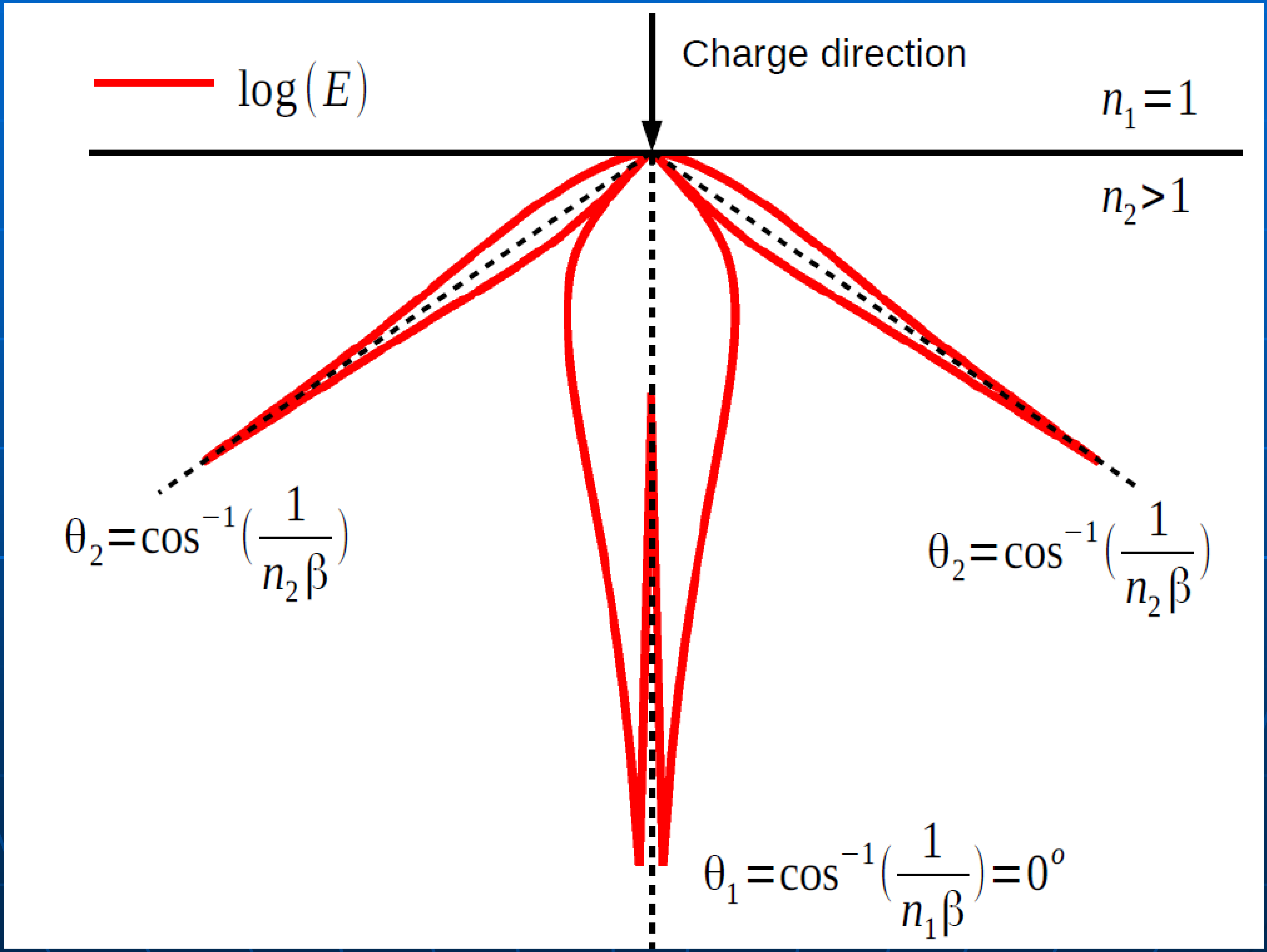
$$\vec{E}(\vec{x},t) = -\frac{d}{dt}\vec{A}(\vec{x},t) - \frac{d}{d\vec{x}}A^{0}(\vec{x},t)$$

$$\vec{E}(\vec{x},t) \propto \frac{1}{D^{2}}$$

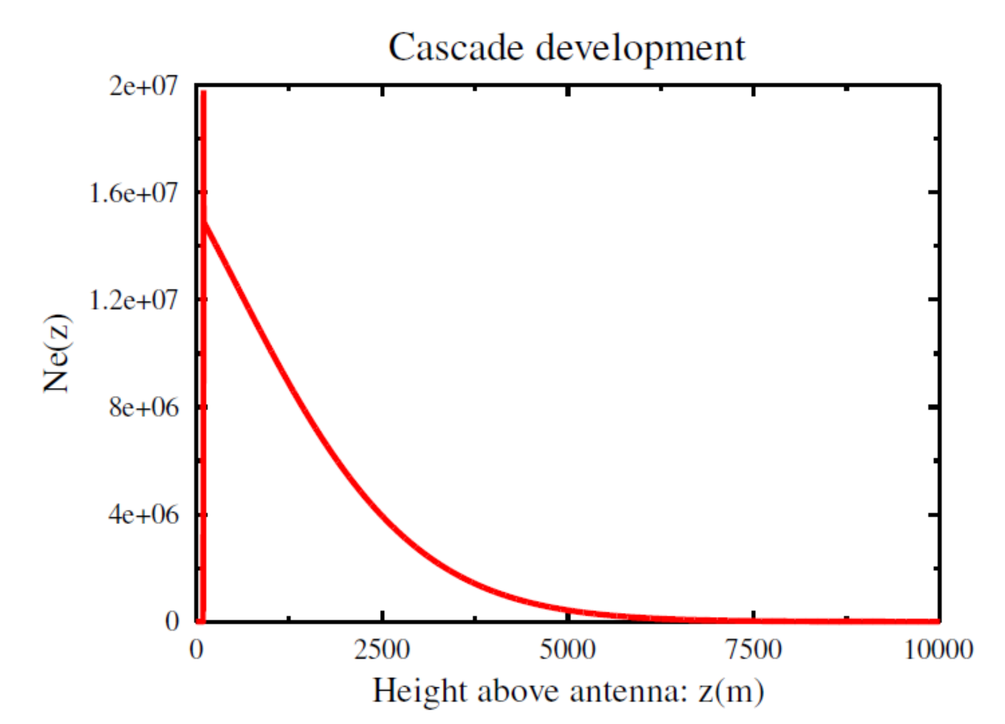
D can vanish for realistic cases,
n = n(z) ≠ 1 → Cherenkov !

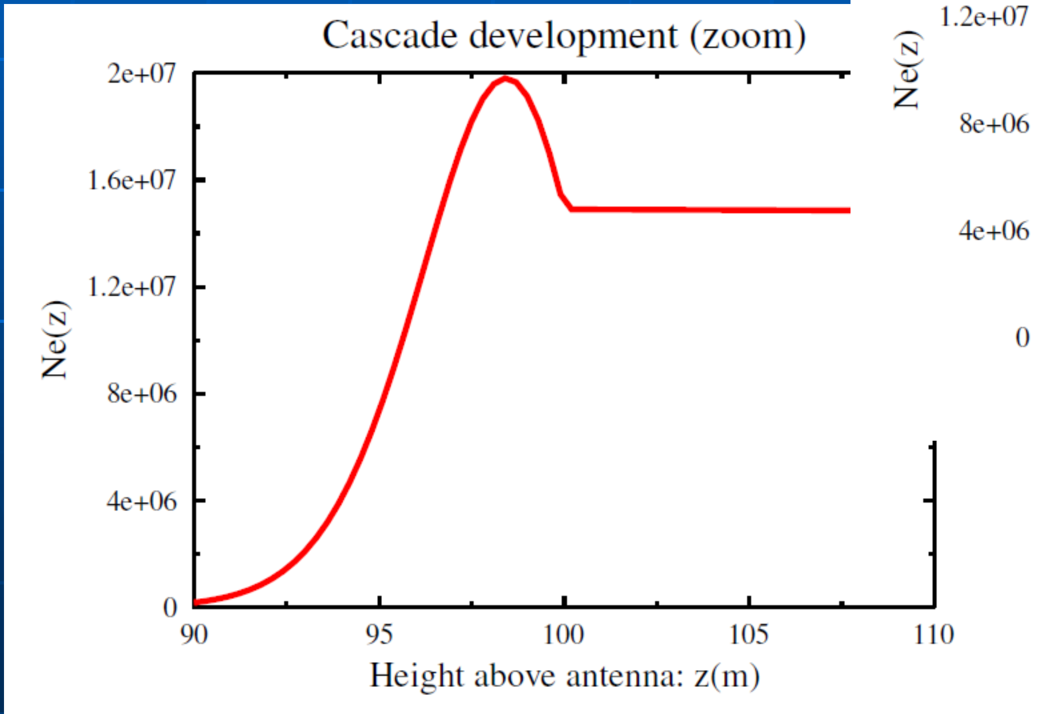
ArXiv: 1503.02808

Recent work: Coherent Transition Radiation



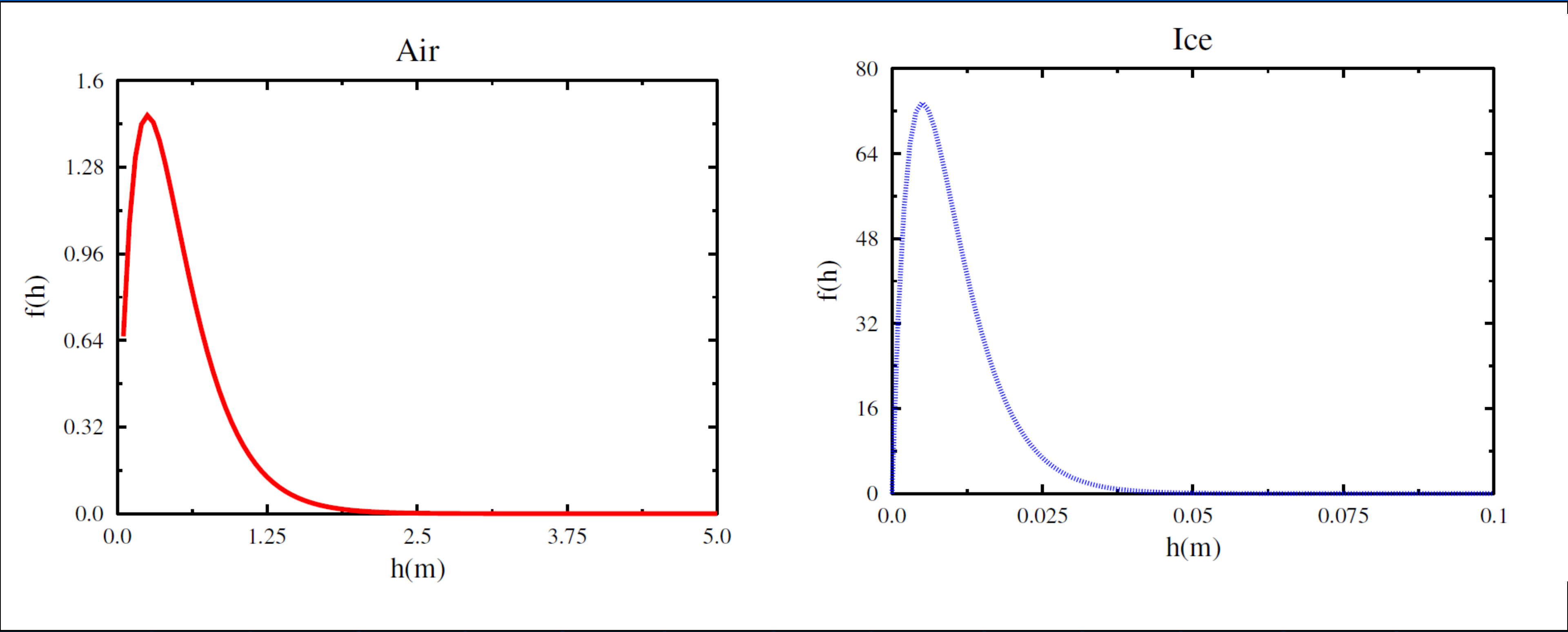
The cosmic-ray air shower hitting an ice surface





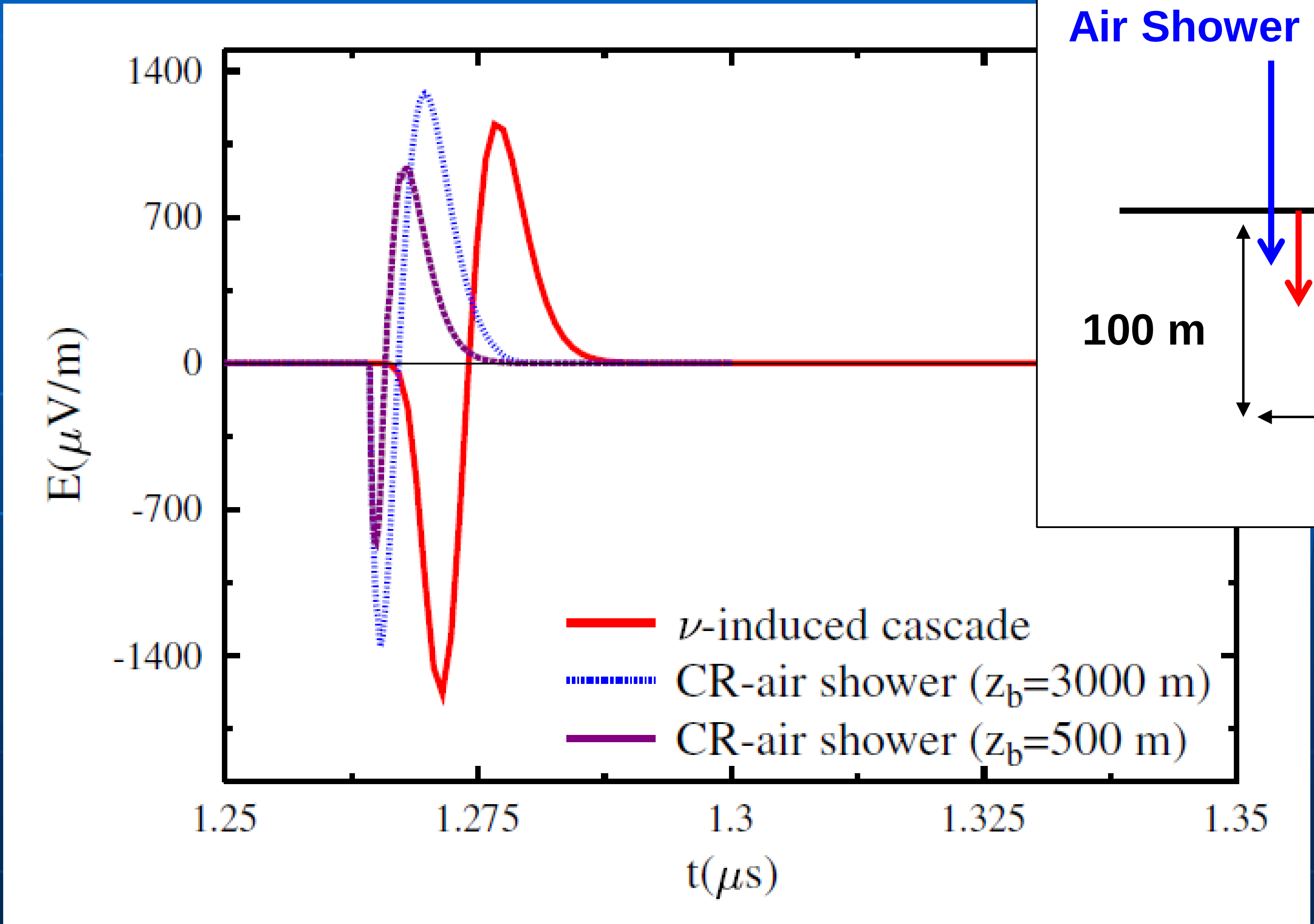
The cosmic-ray air shower hitting an ice surface

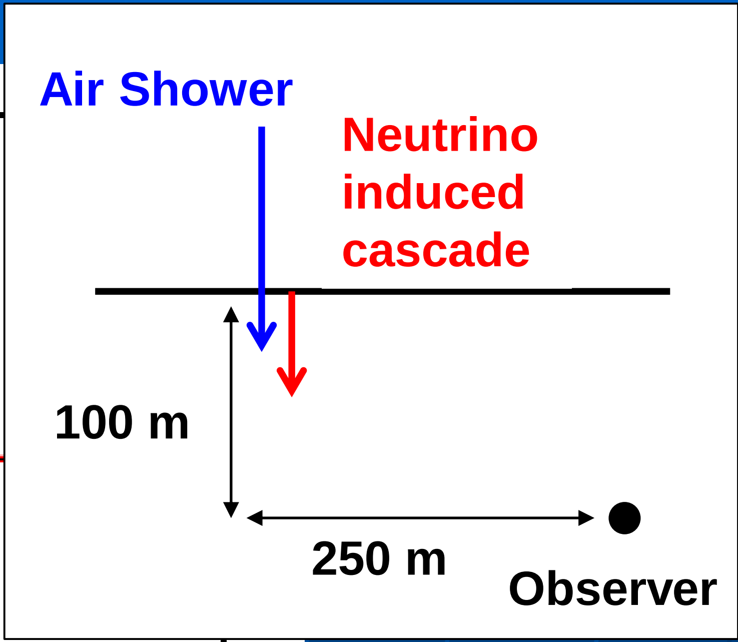
Effective parameterization of the air shower front.



Lateral dimension folded onto longitudinal dimension. Full 3D description is under development.

The air shower signal vs the neutrino induced cascade





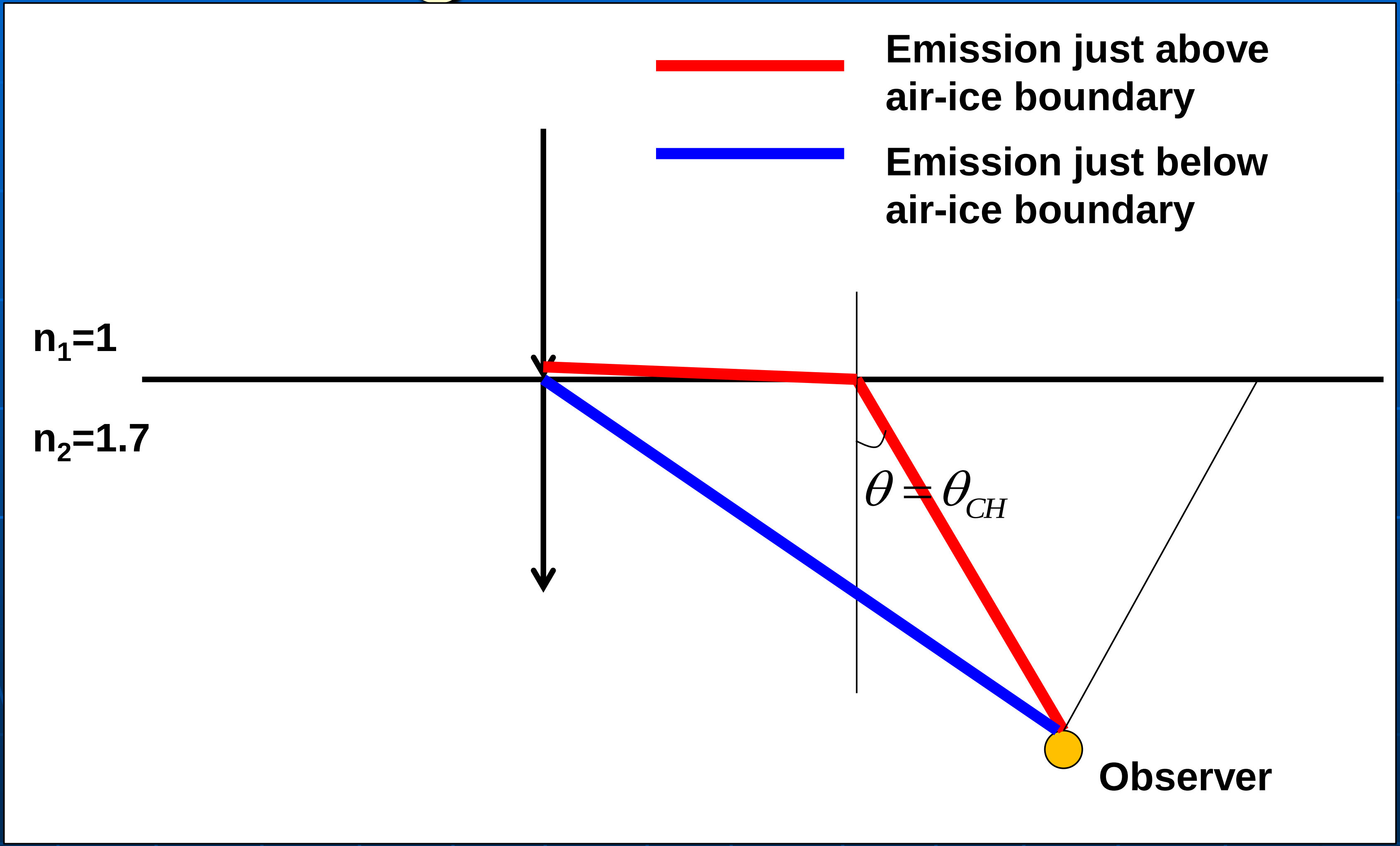
What can we learn from the Cosmic-Ray air shower signal?

- The in-ice emission is due to the same mechanism (Askaryan emission) as for a neutrino induced cascade. The expected signal is similar for CR and neutrino induced cascades.

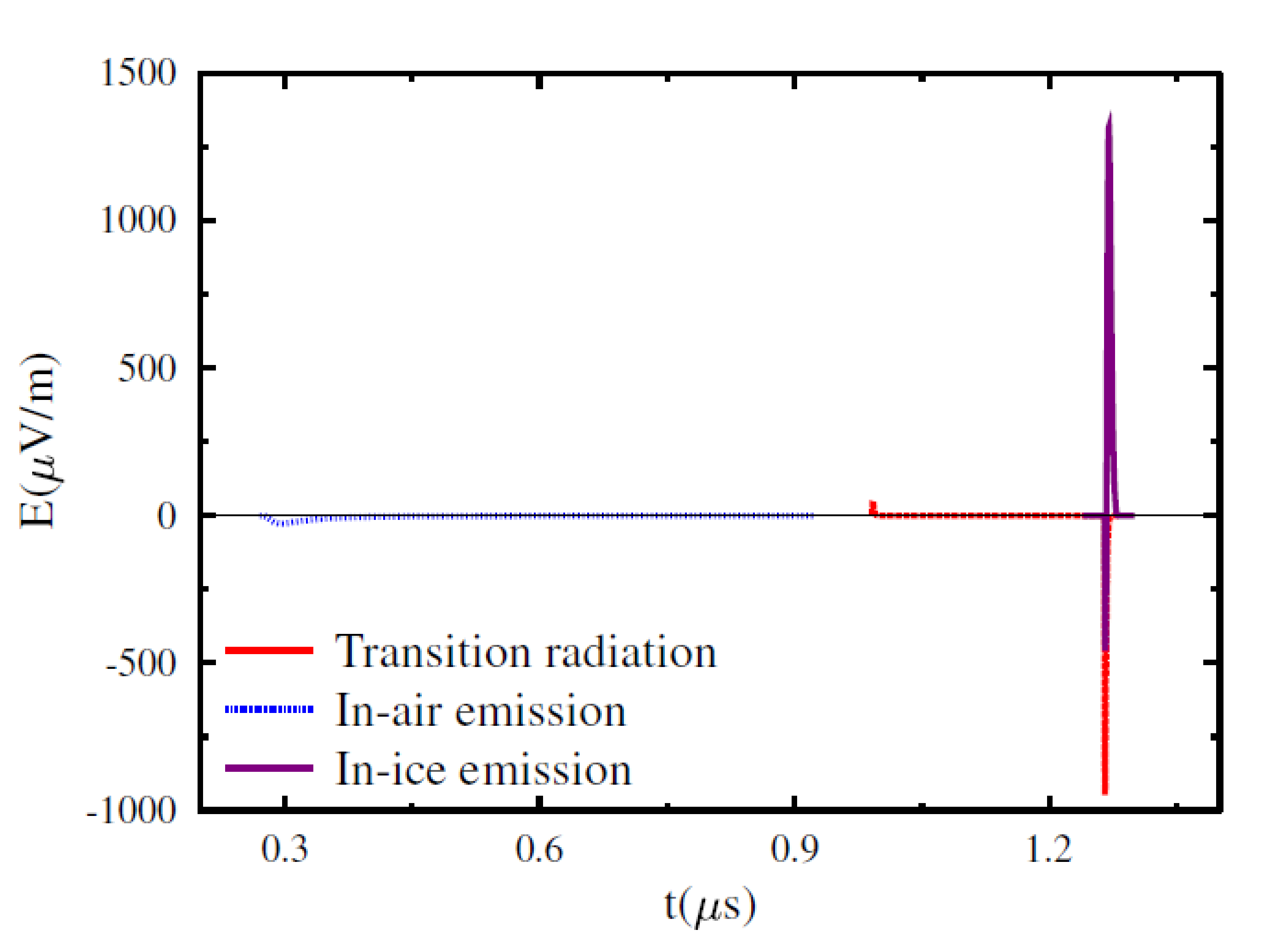
- In combination with surface detector the detected signal might provide an excellent (cross-) calibration.

- The in-ice Askaryan radio detector can be used as a cosmic-ray air shower detector.

The cosmic-ray air shower hitting an ice surface



The cosmic-ray air shower hitting an ice surface



Conclusions and Outlook

- The cosmic-ray air shower signal in Askaryan radio detectors has been modeled giving:
  1) The in-air emission solving for refraction.
  2) The transition radiation at the air-ice surface.
  3) The in-ice emission.

- The signal is comparable to that of a neutrino induced cascade and should thus be measurable. Possible applications are:
  1) (Cross-) calibration in combination with a surface detector.
  2) Air shower physics
  3) On-site feasibility of the detection technique.

- A more detailed modeling of the shower front is under development.

Recent work: Coherent Transition Radiation

$$\vec{E}(\vec{x},t) = \frac{ex^i}{4\pi\varepsilon_0 c}\lim_{\varepsilon\to 0}\left(\frac{1}{D^2{}_{z_B+\varepsilon}} - \frac{1}{D^2{}_{z_B-\varepsilon}}\right)\delta(z - z_B)$$

The delta-function can be resolved by considering coherent emission over a macroscopic particle distribution!!!

$$\vec{E}(\vec{x},t) = \frac{eN_e(t_r)f(h)x^i}{4\pi\varepsilon_0 c}\left(\frac{1}{D^2{}_{z_B+\varepsilon}} - \frac{1}{D^2{}_{z_B-\varepsilon}}\right)_{h=ct_r - z_B}$$

ArXiv: 1503.02808