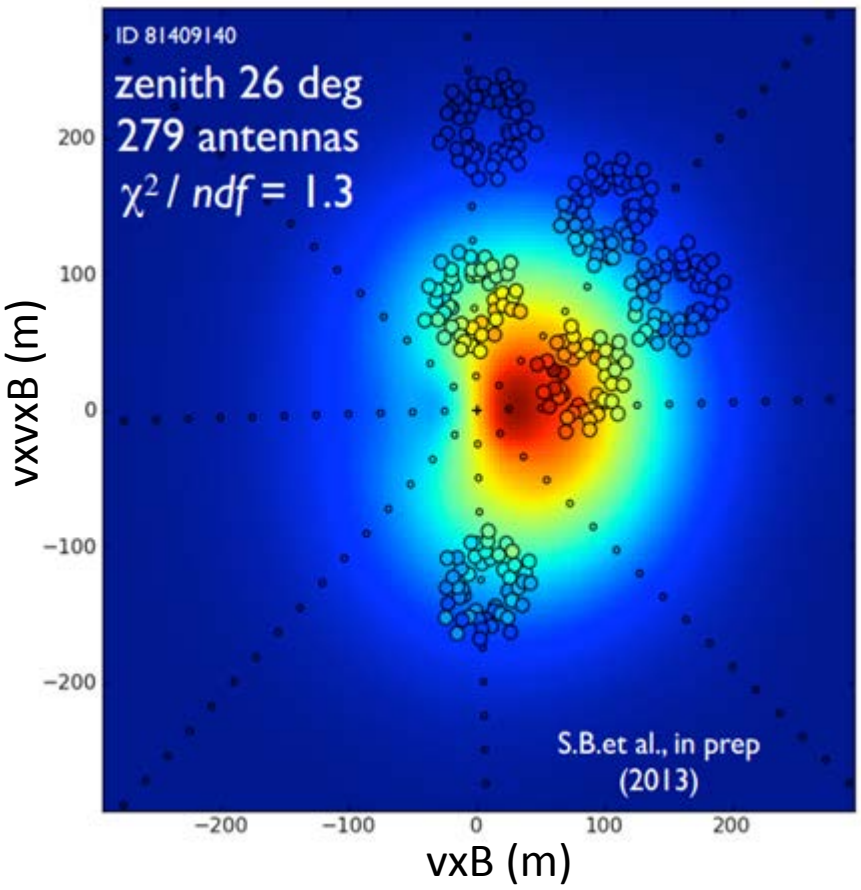
Effects of atmospheric electric fields on radio emission from air showers

Gia Trinh

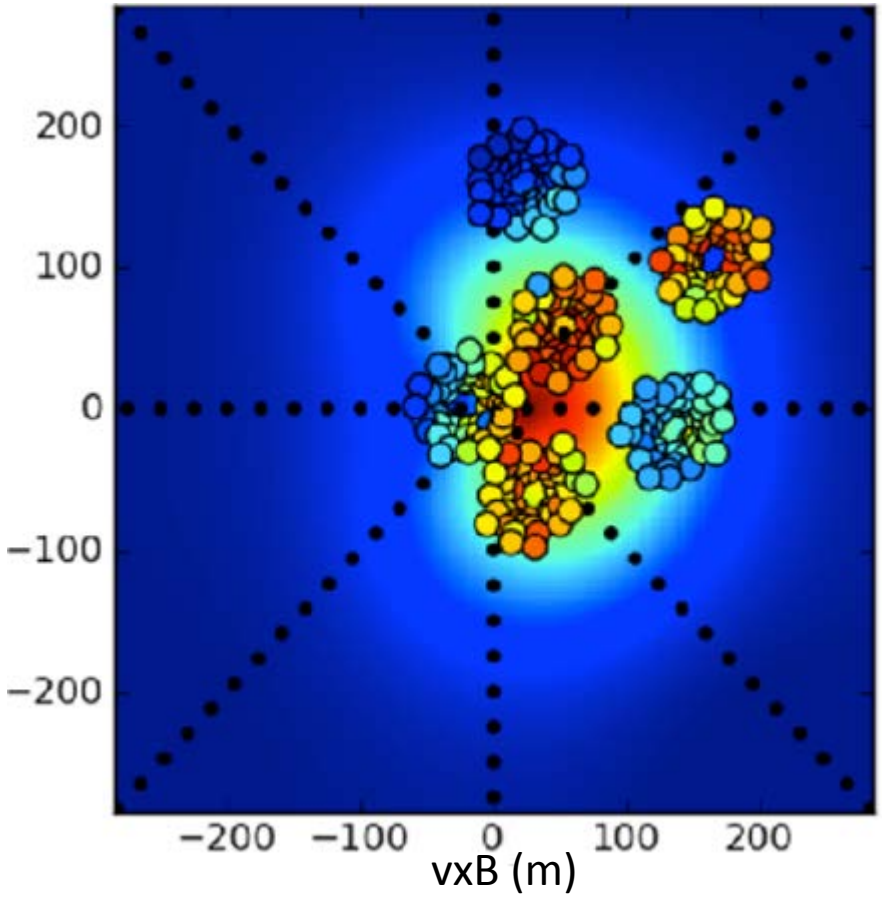
KVI – CART, University of Groningen

October 15th, 2014

Fair weather vs thunderstorm

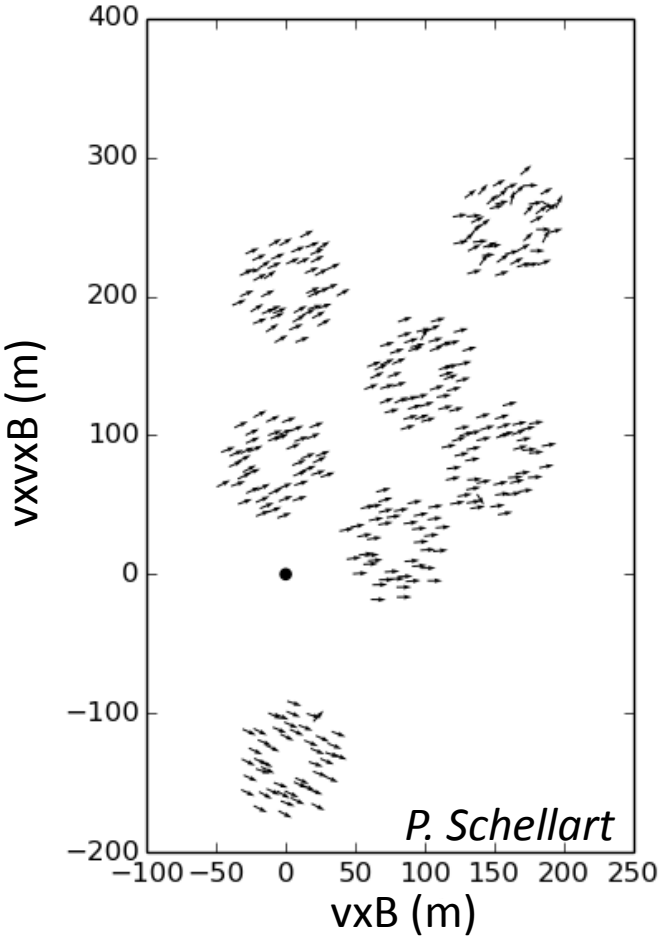


bean shape

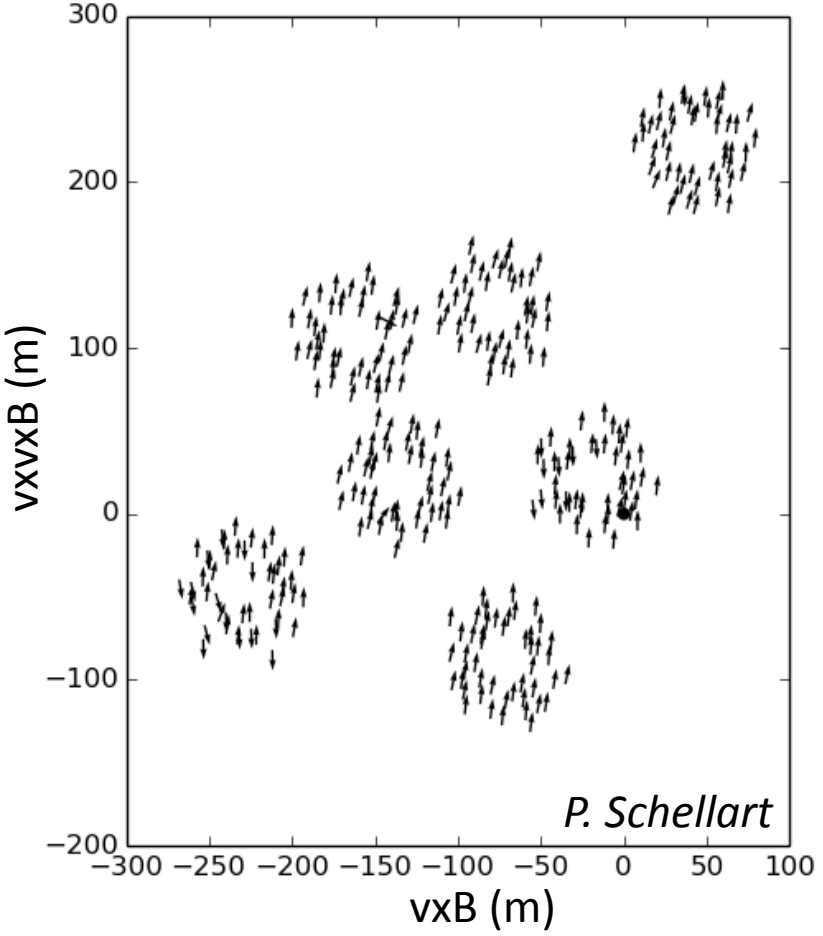


ring structure

Fair weather vs thunderstorm



$\vec{v} \times \vec{B}$ orientation



unique orientation

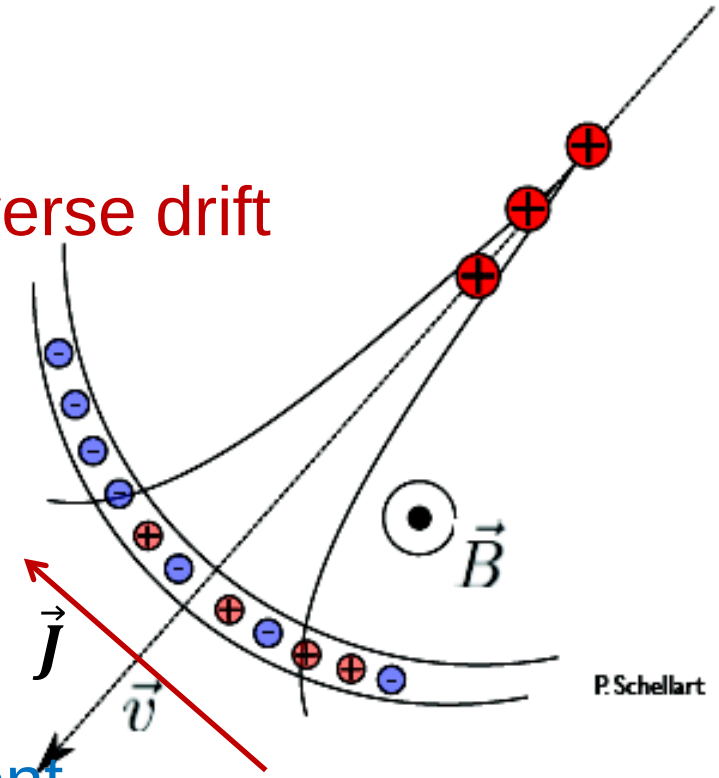
Motivation

1. Study effects of atmospheric electric fields (E-fields) on radio emission from air showers
2. Build a simple model of E-fields
3. Reconstruct thunderstorm events

What causes radio emission?

Geomagnetic field:

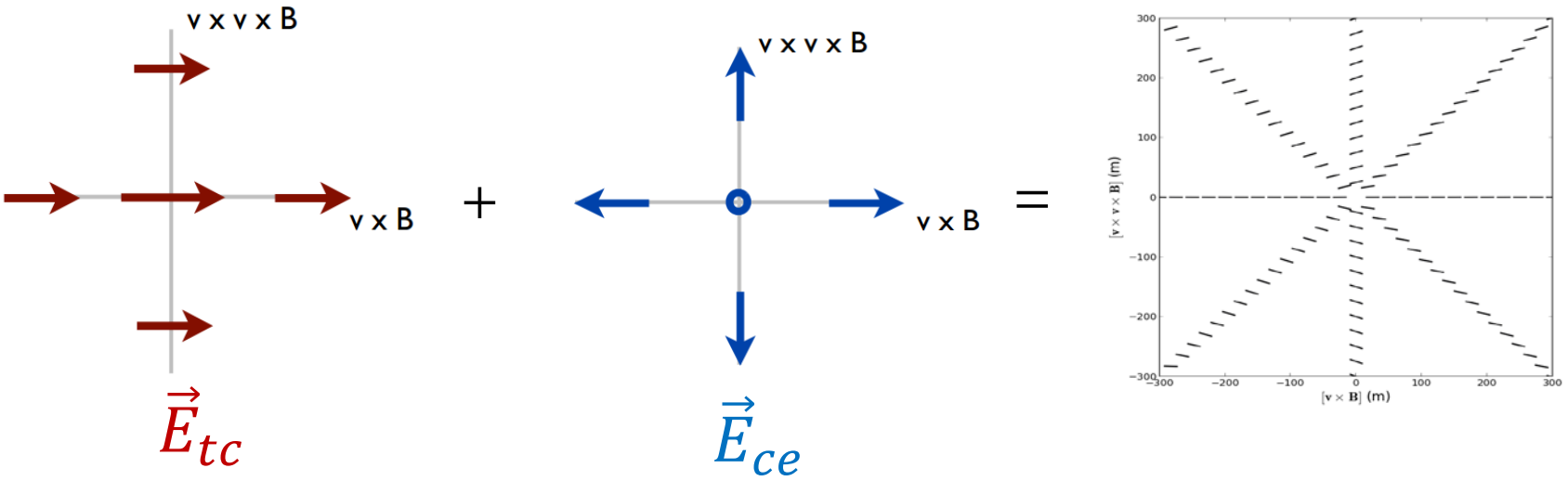
- electrons & positrons have transverse drift
- $E_{tc} \sim \frac{dJ}{dt} \sim v_d \frac{dN}{dt}$
- Polarization: along $\vec{v} \times \vec{B}$



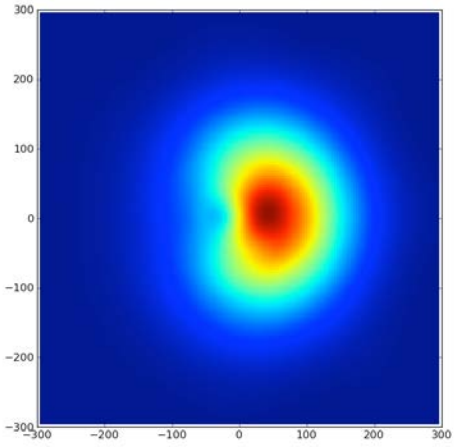
Charge excess:

- negative charge at the shower front
- $E_{ce} \sim \frac{d(N_e - N_p)}{dt}$
- Polarization: radial

What causes radio emission?

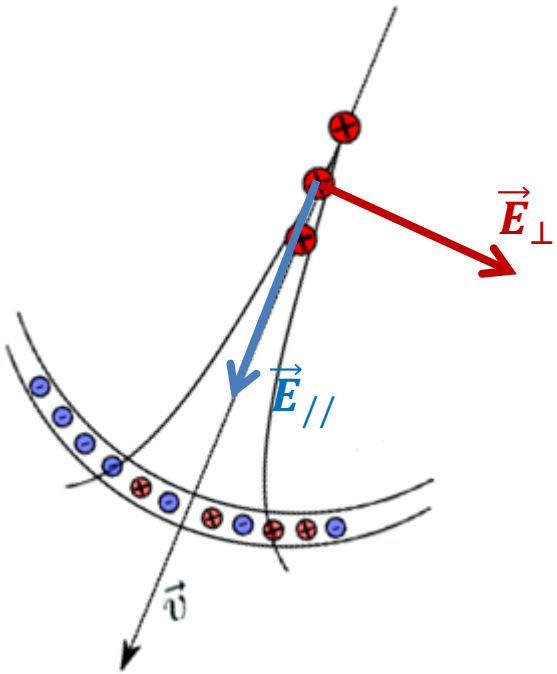


The full signal: $\vec{E} = \vec{E}_{tc} + \vec{E}_{ce}$
modified by time-compression effects.



Effects of E-fields on radio emission

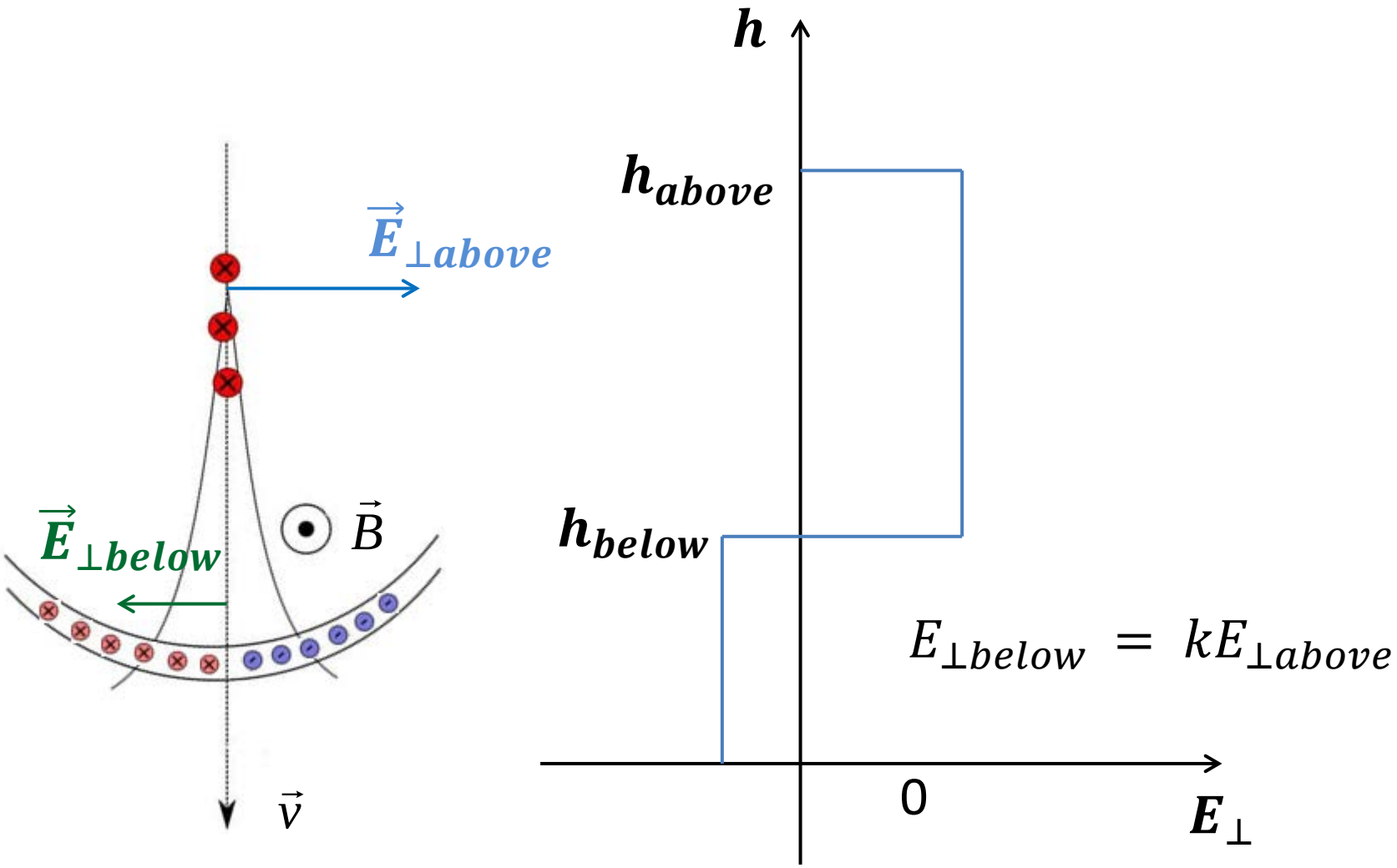
$$\vec{E} = \vec{E}_{//} + \vec{E}_{\perp}$$



Charge-excess component
- Amplitude: 0/+
- Polarization: more radial

Transverse-current component
- Amplitude: ++
- Polarization: direction changes

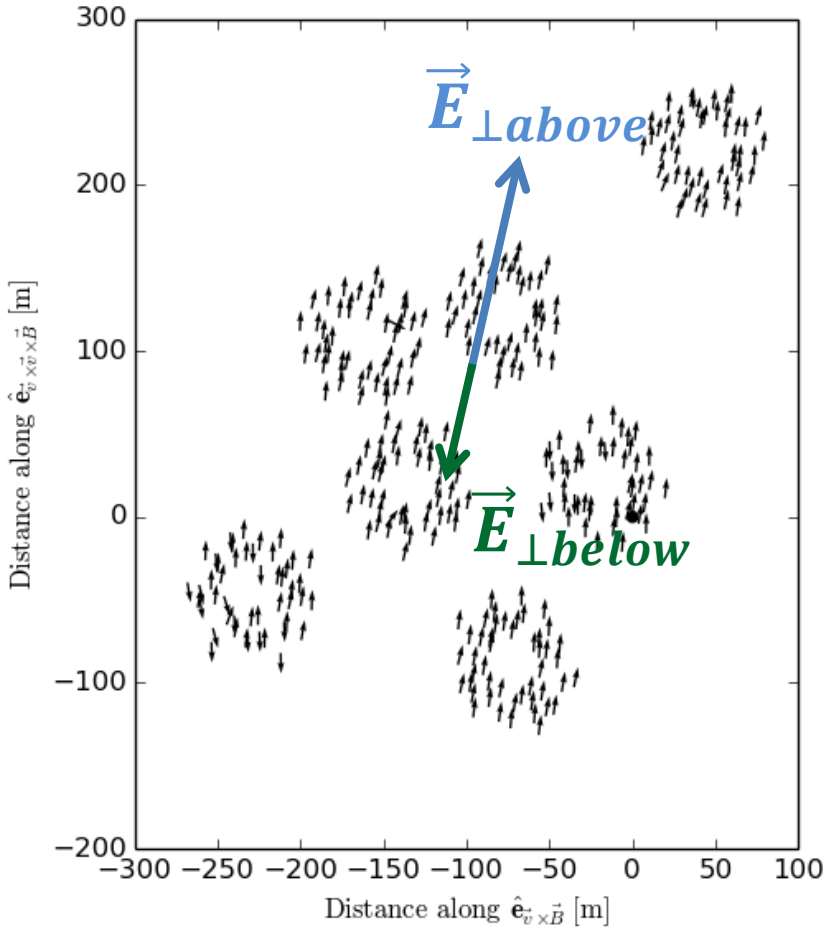
A two-layer model of E-fields



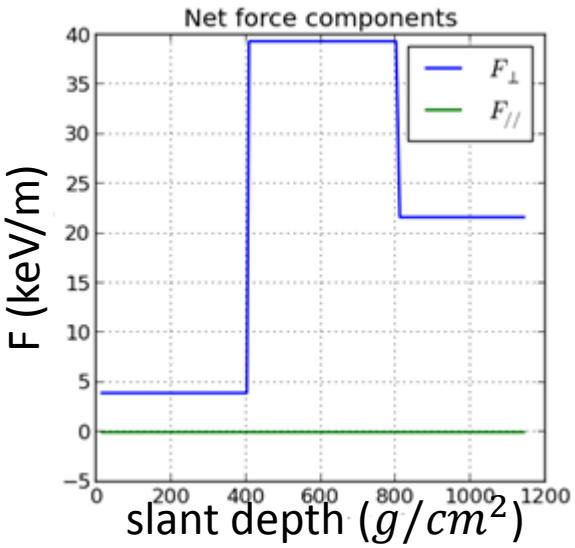
- reversal of $\vec{E}_{\perp}$ → destructive interference between emission of two layers → ring structure

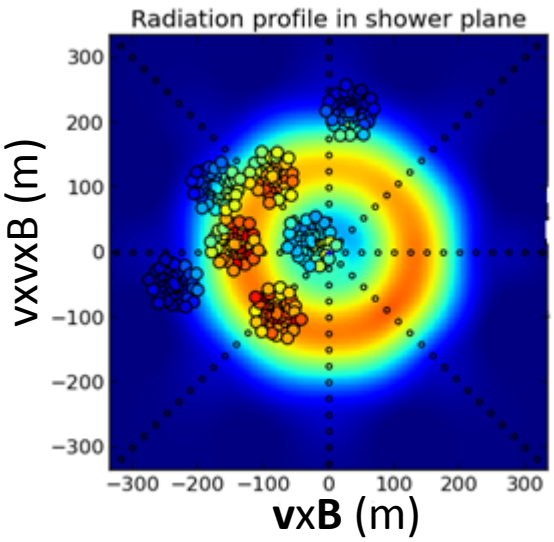
Direction of E-fields

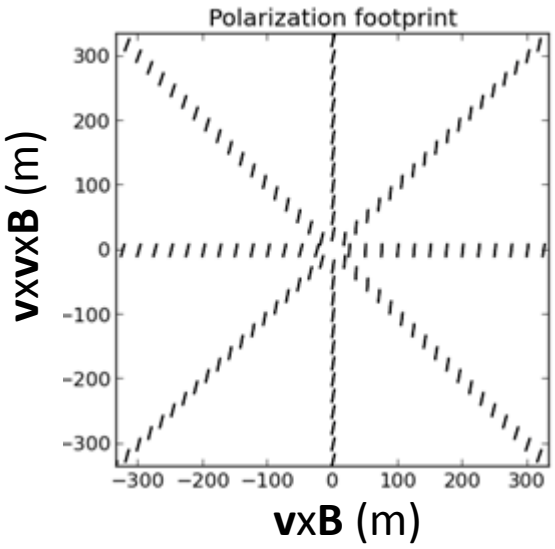
Can be determined from polarization patterns

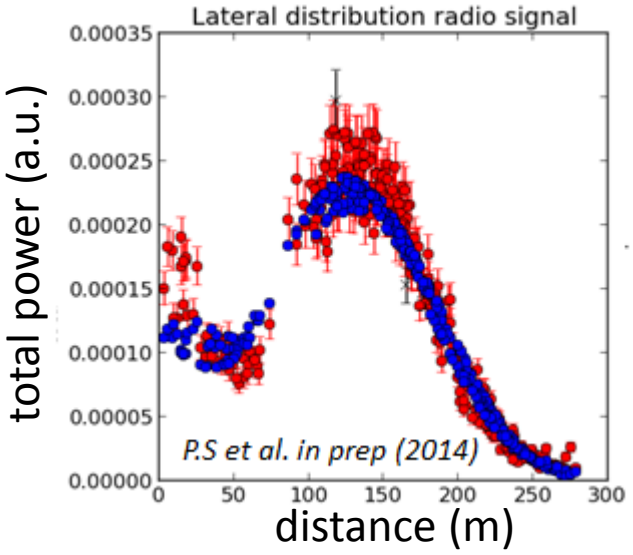


Thunderstorm event



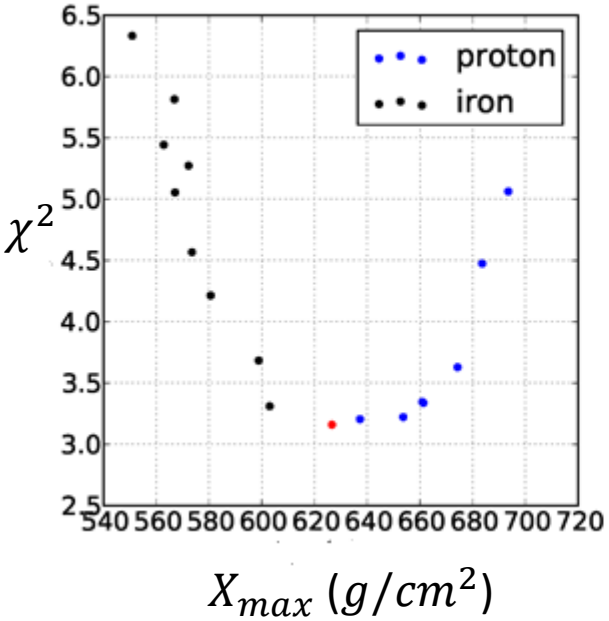


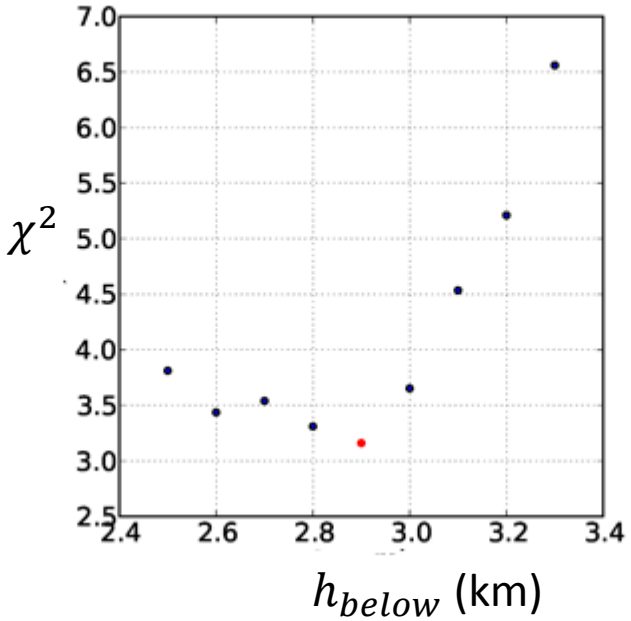


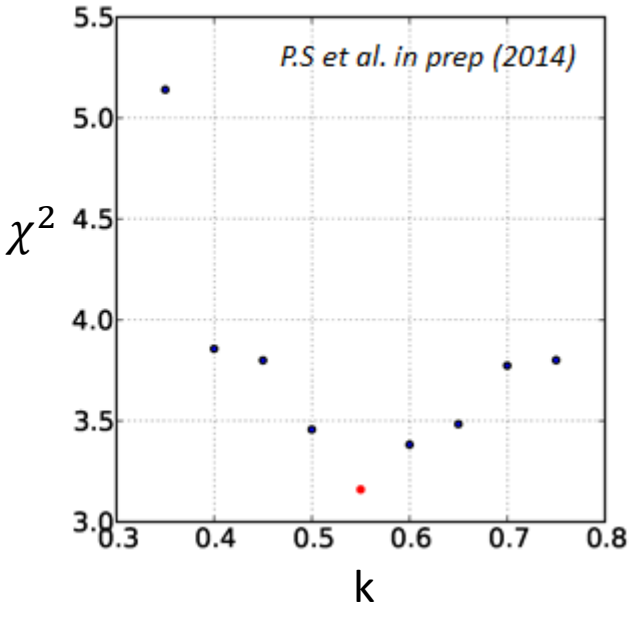


Particle data is also fit very well.

χ^2 mapping

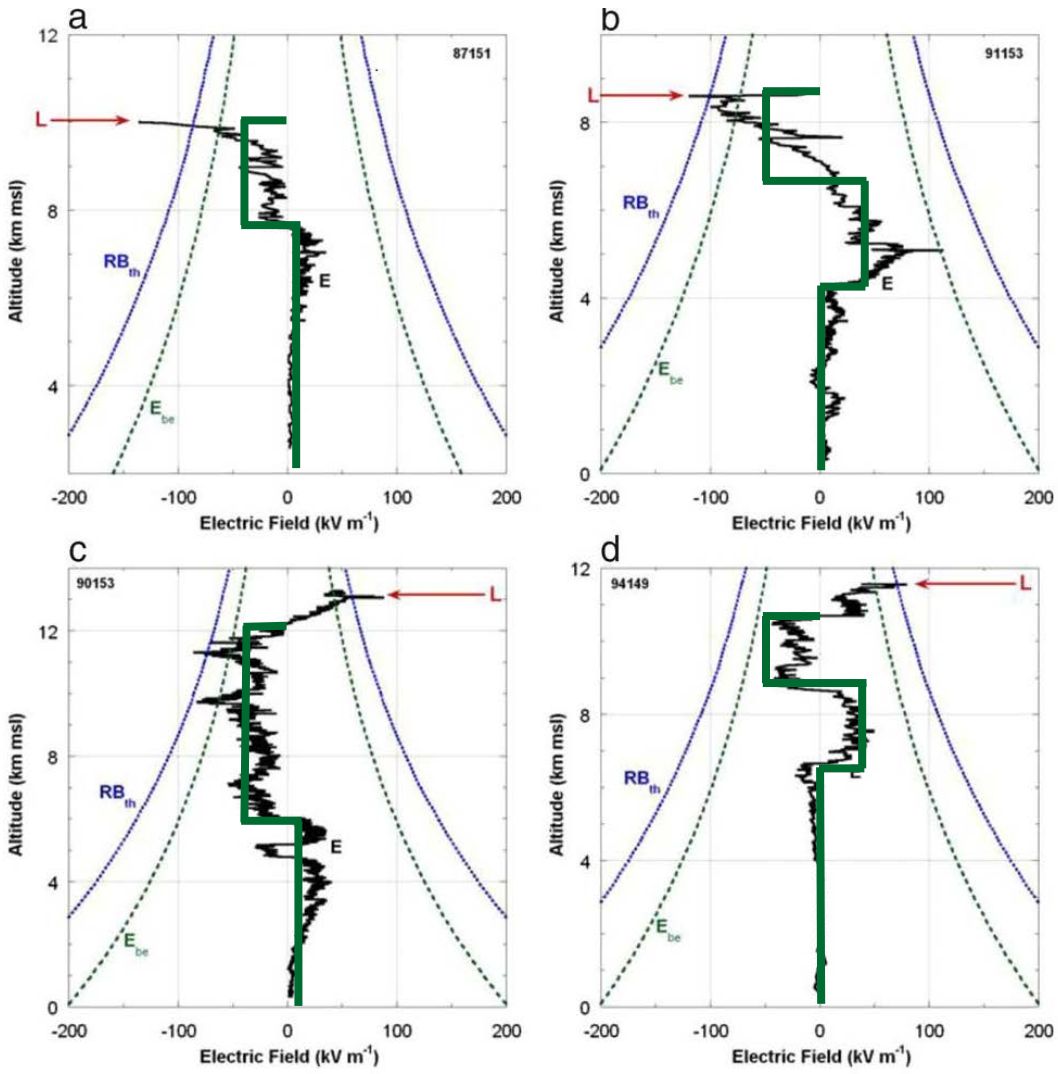






$\boldsymbol{h_{below}}$ and k are well-defined.

E-fields measured by balloons



Conclusion

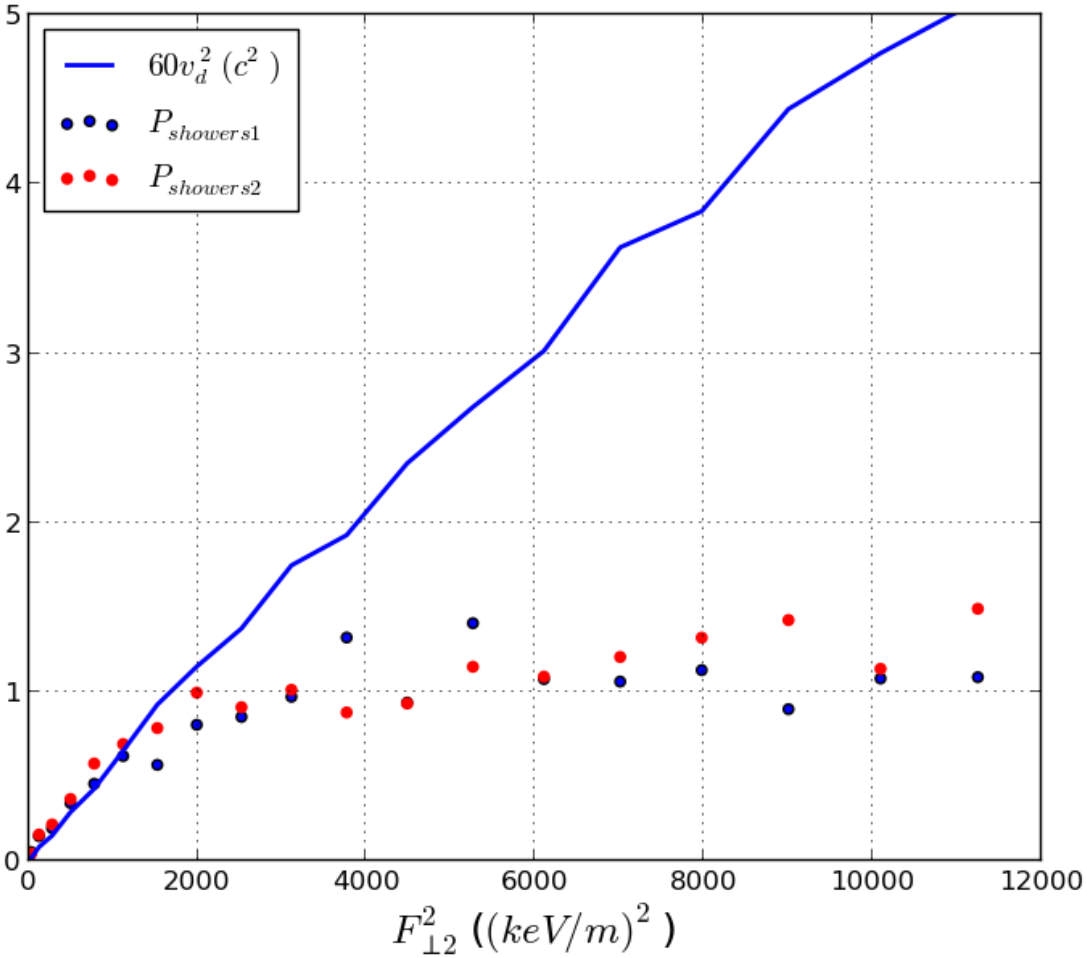
The two-layer model works quite well.

- Determine directions of E-fields
- Very sensitive to h_{below}, not to h_{above}
- Sensitive to the strength of E-fields up to 45kV/m
- Reconstruct 3 thunderstorm events

Outlook:

- Reconstruct more thunderstorm events
- Study effects of E-fields on the transverse current quantitatively

Strength of E-fields



- Sensitive to $\vec{E}_{\perp}$ up to about 45 kV/m
- Not sensitive to $\vec{E}_{//}$ (in the presence of strong $\vec{E}_{\perp}$)

Height dependence of E-fields