COSPA

the RADAR ECHO TELESCOPE

MARES:

A Macroscopic Approach to the Radar Echo Scatter

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on behalf of the RET Collaboration

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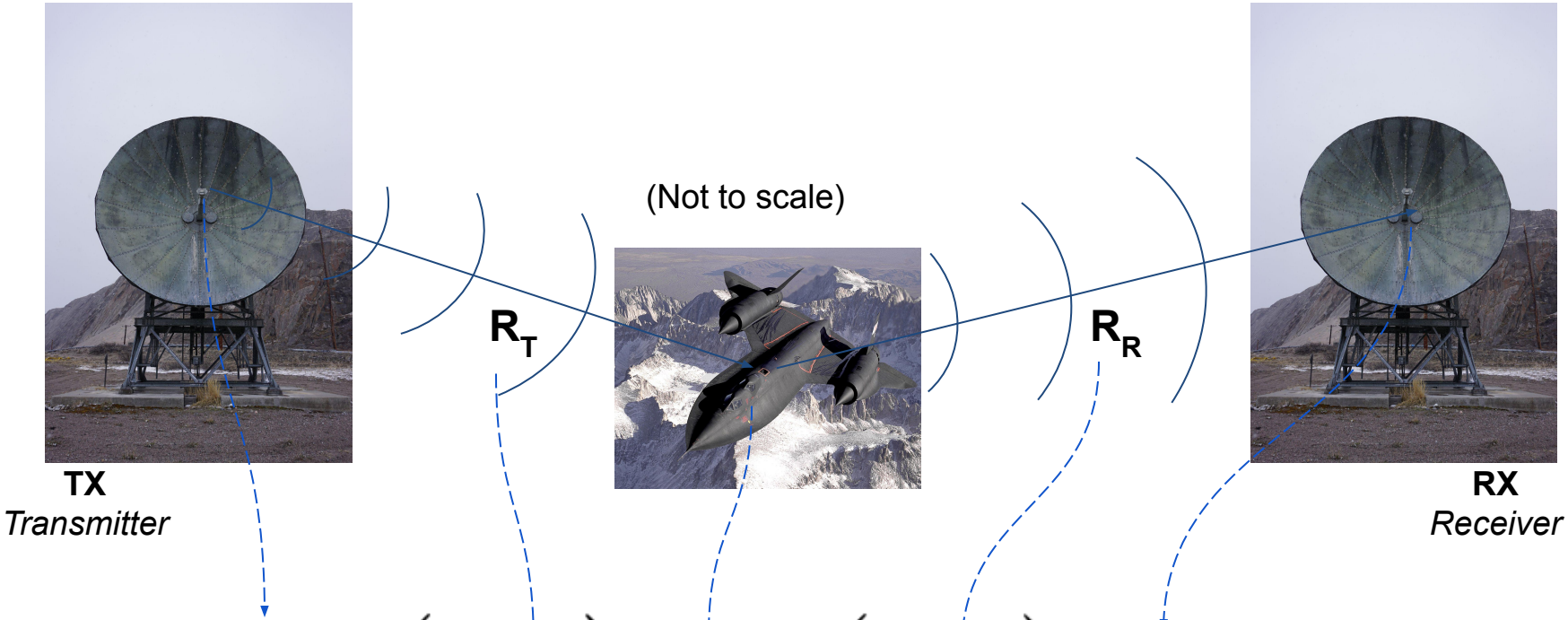
The Ohio State University · CCAPP · VUB · iihe Bruxelles Brussel · ULB · Radboud University · Wisconsin University of Wisconsin-Madison · Cal Poly San Luis Obispo · The University of Chicago · PennState · SLAC · KU The University of Kansas · National Taiwan University

Key concept 1:
Radar cross section

How does radar work?



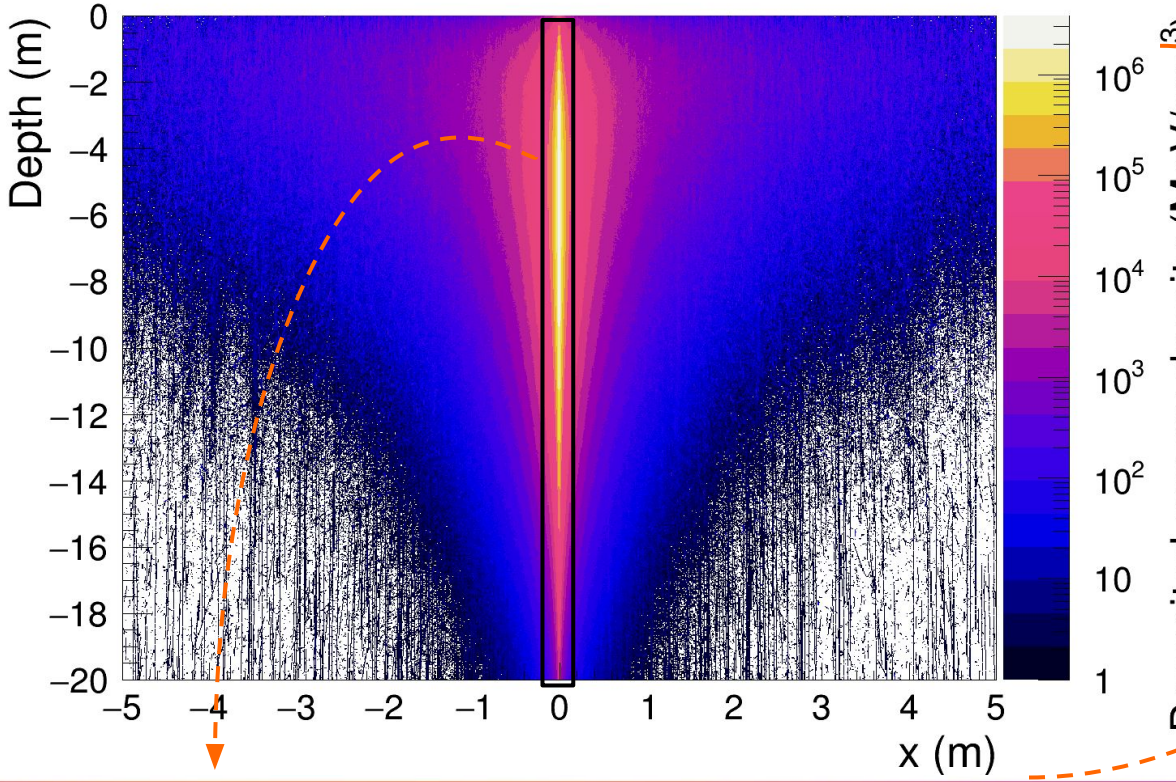
$$P_R = P_T \left(\frac{G_T}{4\pi R_T^2} \right) \sigma_{RCS} \left(\frac{1}{4\pi R_R^2} \right) A_{eff,R} [f_{att} \ldots]$$

Key concept 2:
Collisional electron plasma

What does a particle cascade in ice look like?

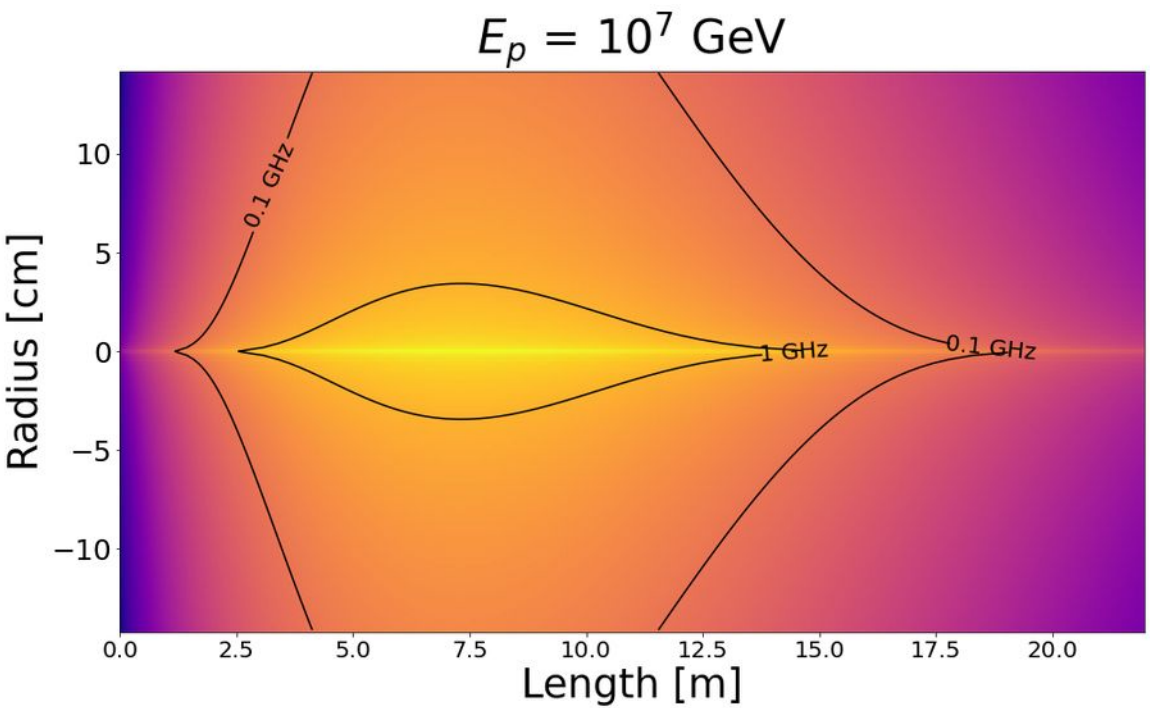
Credit: Simon de Kockere

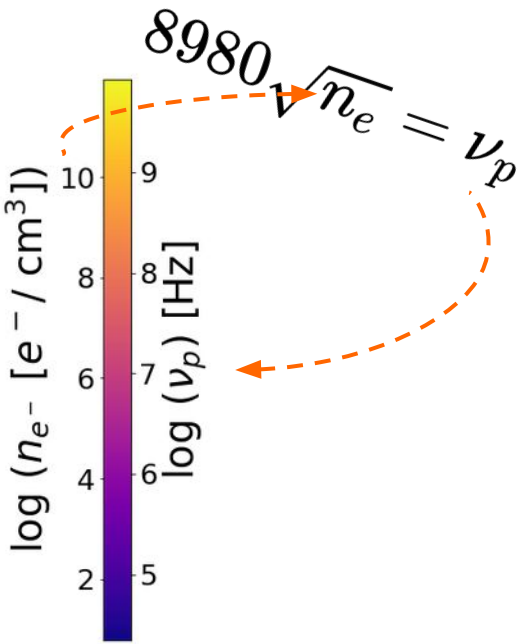
$$E_p = 0.1\ \text{EeV}$$
$$= 10^8\ \text{GeV}$$
$$= 10^{17}\ \text{eV}$$



$$\frac{10^6\ \frac{MeV}{cm^3}}{20\ \frac{eV}{e^-}} = 10^{11}\ \frac{e^-}{cm^3}$$

How can we describe the cascade's core?

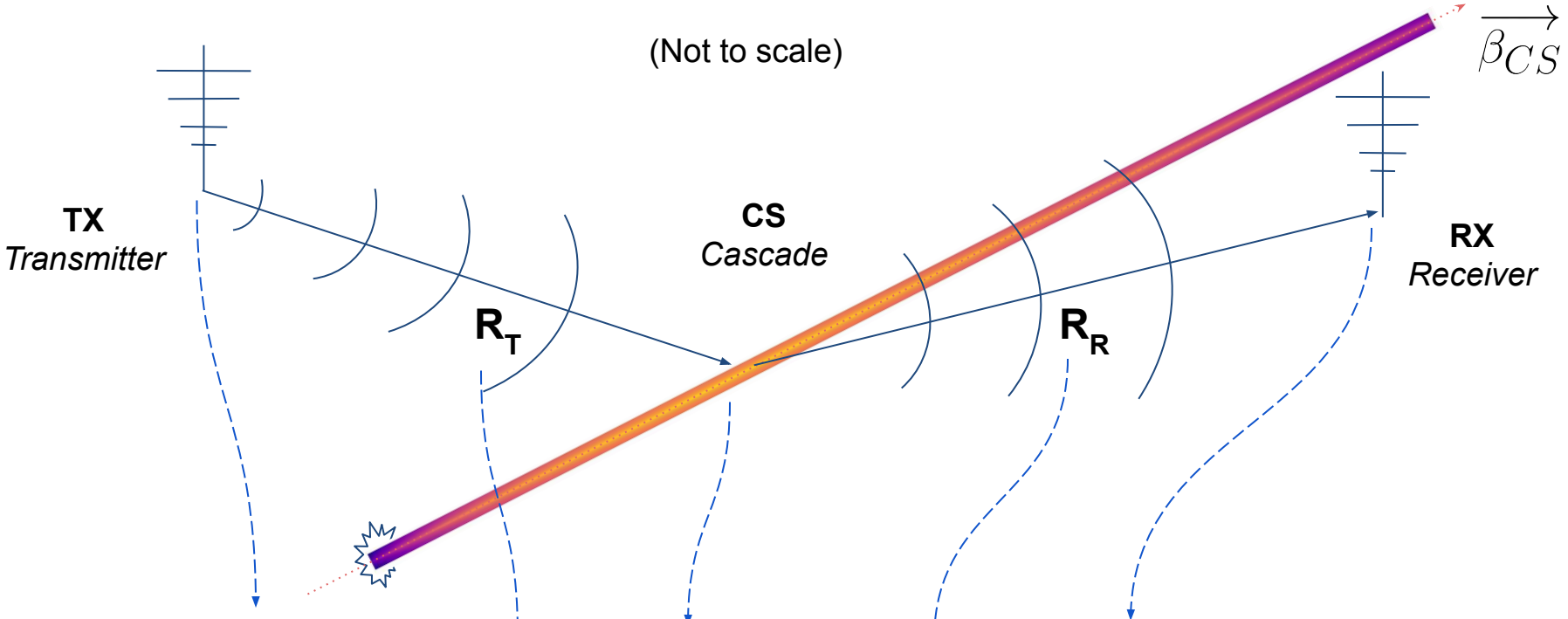




Nishimura, Kamata & Greisen: Air showers (Progr. Theoret. Phys. 6, 93 (1958) & Prog. Cosmic Ray Phys., vol. III (1965))
K. Werner, K. de Vries, O. Scholten: In-ice neutrino cascade (arxiv:1312.4331)
Simon de Kockere, *et al.* : Air shower cores from CR that propagate through ice (arXiv:2202.09211)

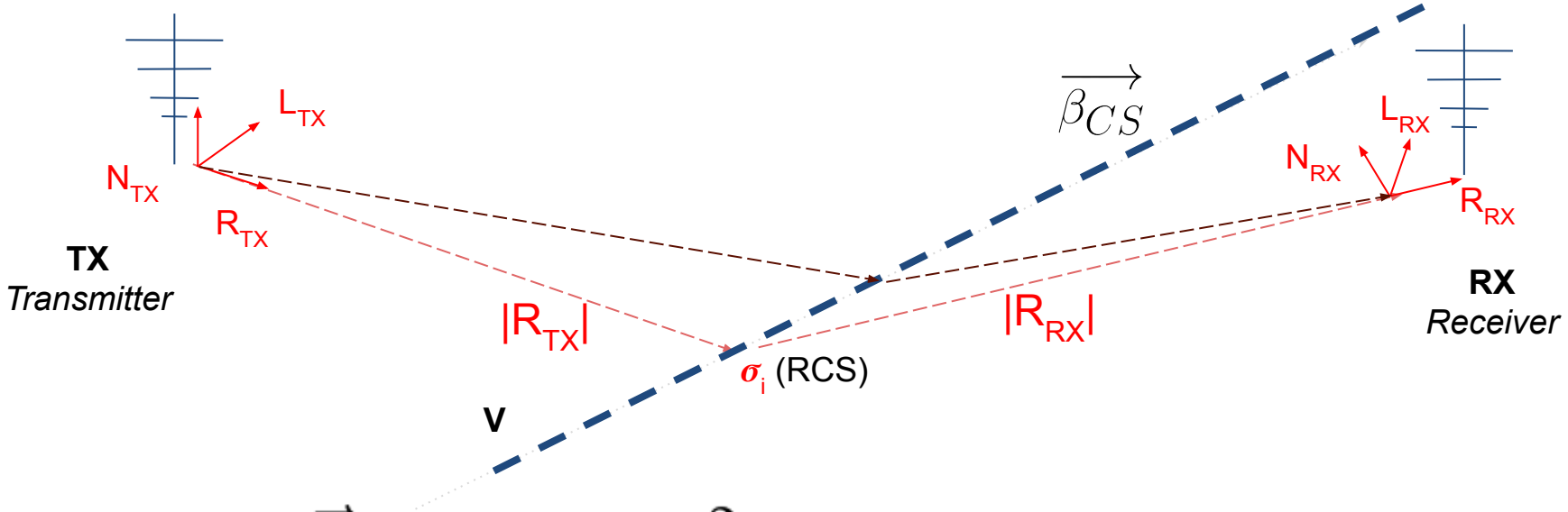
MARES:
The macroscopic scatter model

The radar scatter



$$P_R = P_T \left(\frac{G_T}{4\pi R_T^2}\right) \sigma_{RCS} \left(\frac{1}{4\pi R_R^2}\right) A_{eff,R}[f_{att} \cdots]$$

The line approximation



$$P_{RX} \propto |\vec{E}_{RX}(R,t)|^2 =$$

$$\left| \sum_{i=1}^{N} E_{sc,i}(R_i,t) * e^{i(kR_i - \omega t|_{RX} + \psi_i)} \right|^2$$

The radar cross section

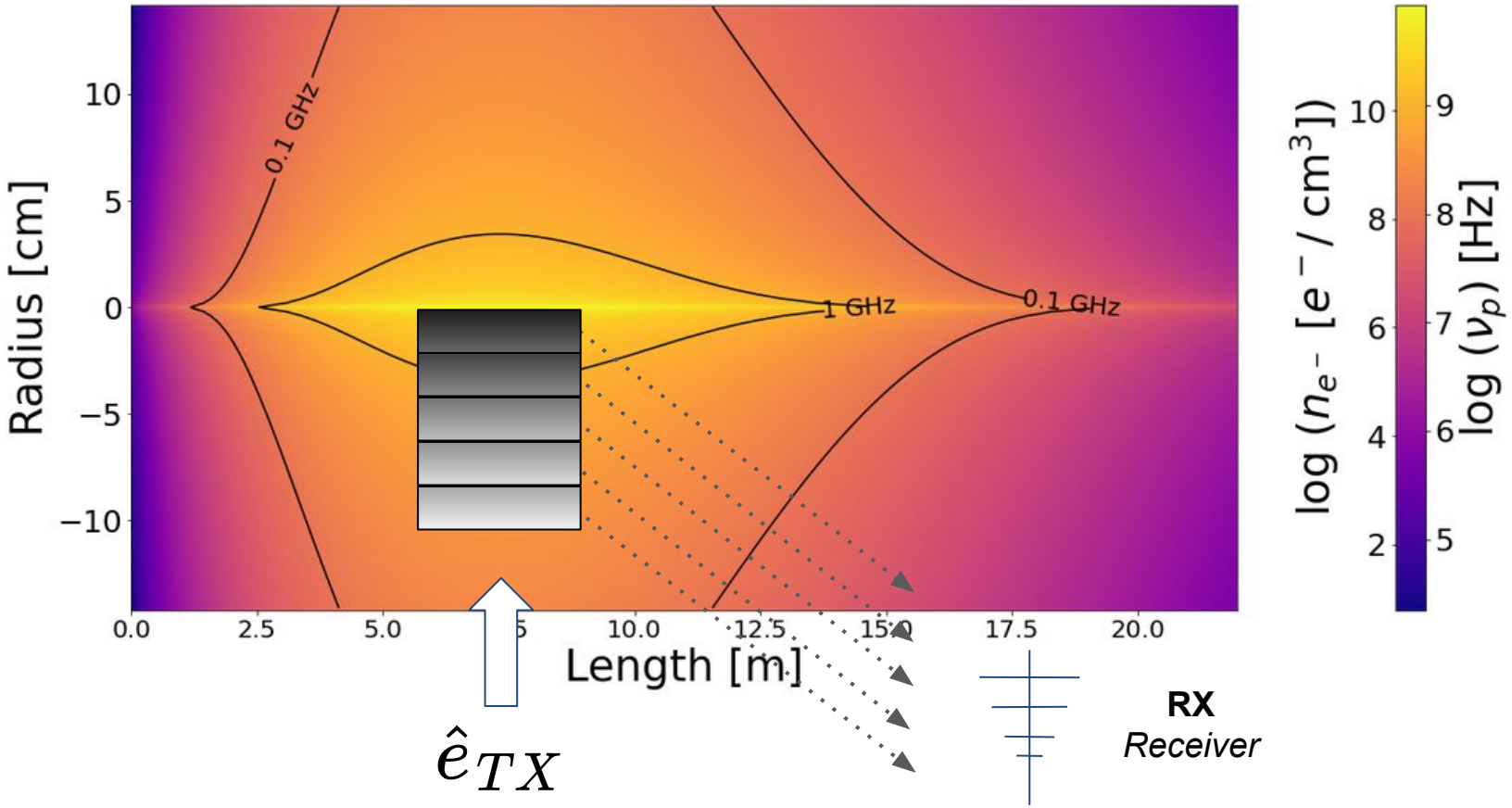
$$E_{sc,i} = \frac{\sqrt{2ZP_TG_T}}{4\pi R_{T,i}R_{R,i}}\sqrt{\sigma_{RCS,i}}$$

$$\sigma_{RCS,i} = \sigma_{RCS,e^-} \cdot N_e^2 \cdot \mathfrak{T} \cdot [\Theta(t-t_0)e^{-2t/\tau_e}]_{t=t_{ret}}$$

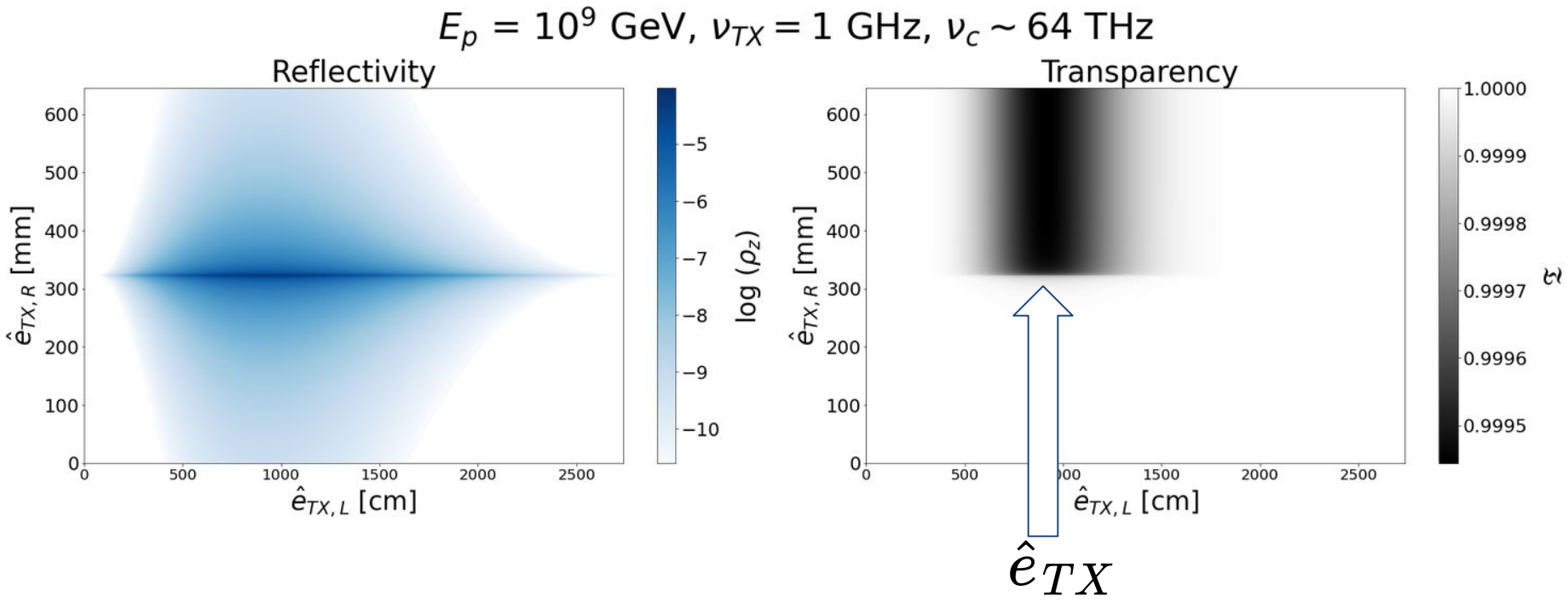
$$\sigma_{RCS,e^-} \simeq \sigma_{Thomson} \cdot \left(\frac{\omega}{\omega_c}\right)^2 \cdot G_{Hertz}$$

$$6.65 \cdot 10^{-25} cm^2 \qquad \sim 10^{-13} \rightarrow 10^{-10} \qquad \frac{3}{2}\sin^2(\theta)$$

The radial integration

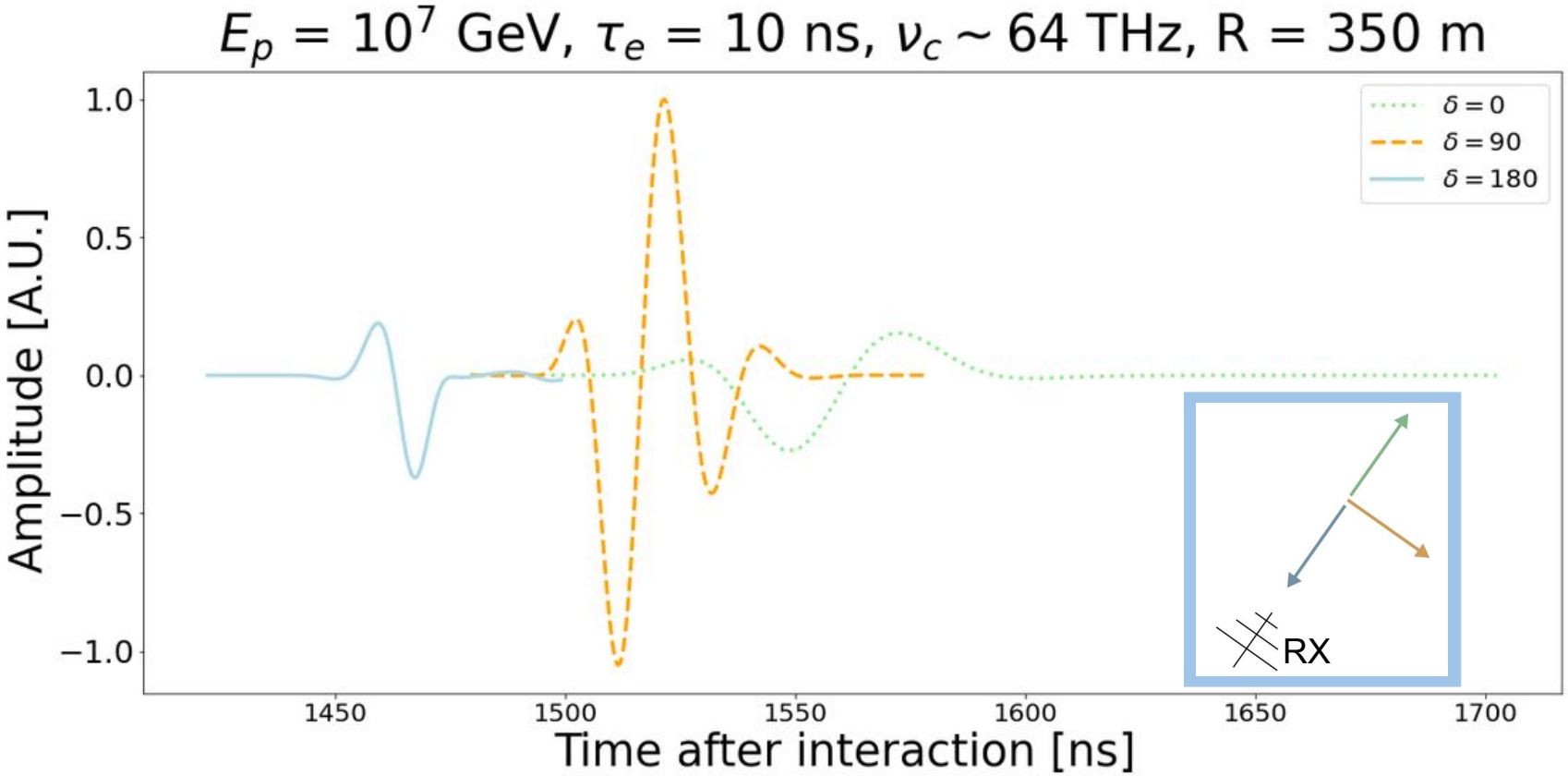


The transparency

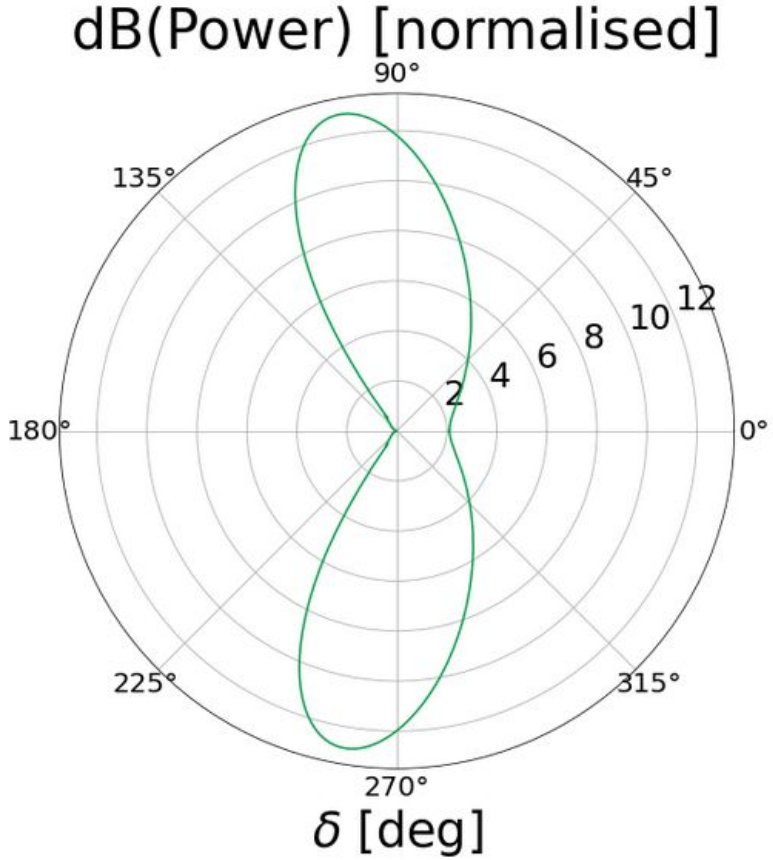


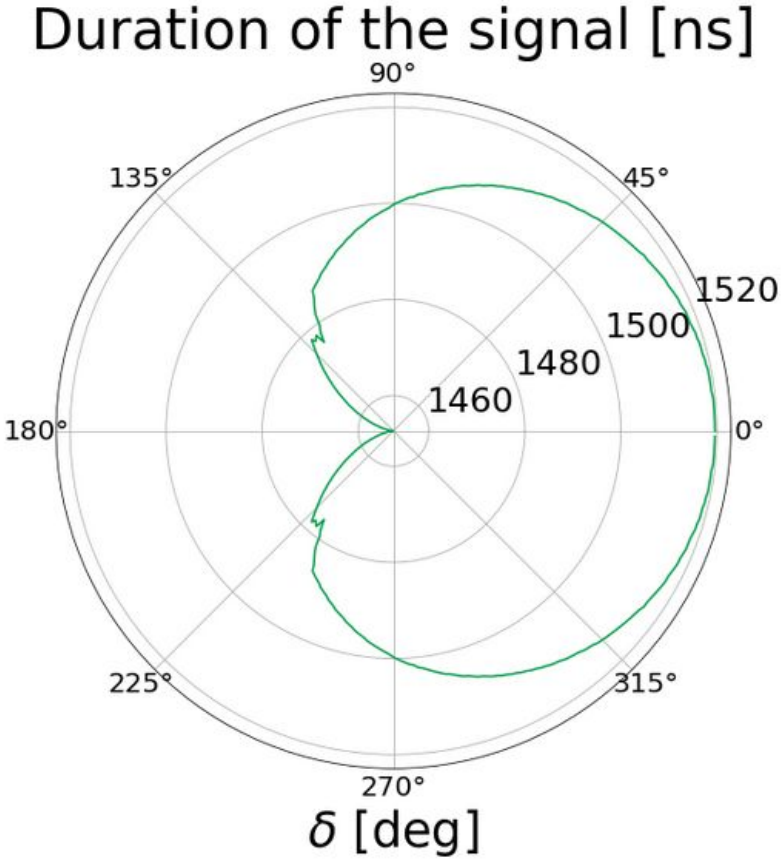
Results:
What does the signal look like?

The MARES received signal



The MARES signal features





Thank you!