Dish Antenna Searches for WISPy Dark Matter

Directional Resolution and Limitations for Small Masses

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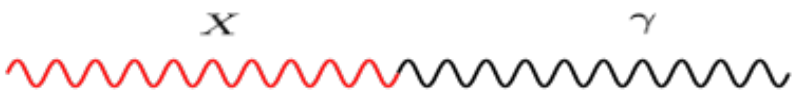
Lagrangians

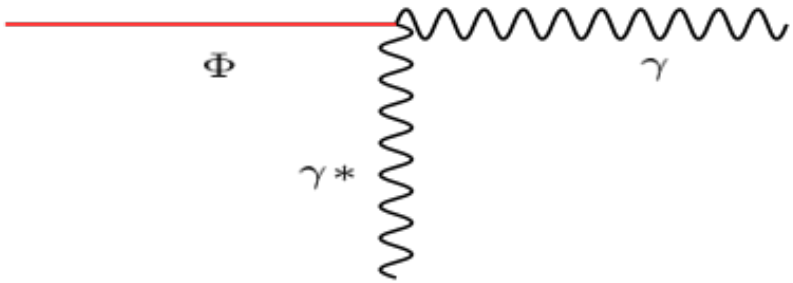
Hidden Photon

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}\tilde{X}_{\mu\nu}\tilde{X}^{\mu\nu} - \frac{\chi}{2}F_{\mu\nu}\tilde{X}^{\mu\nu} + \frac{m_{\gamma'}^2}{2}\tilde{X}_\mu\tilde{X}^\mu + J^\mu A_\mu$$

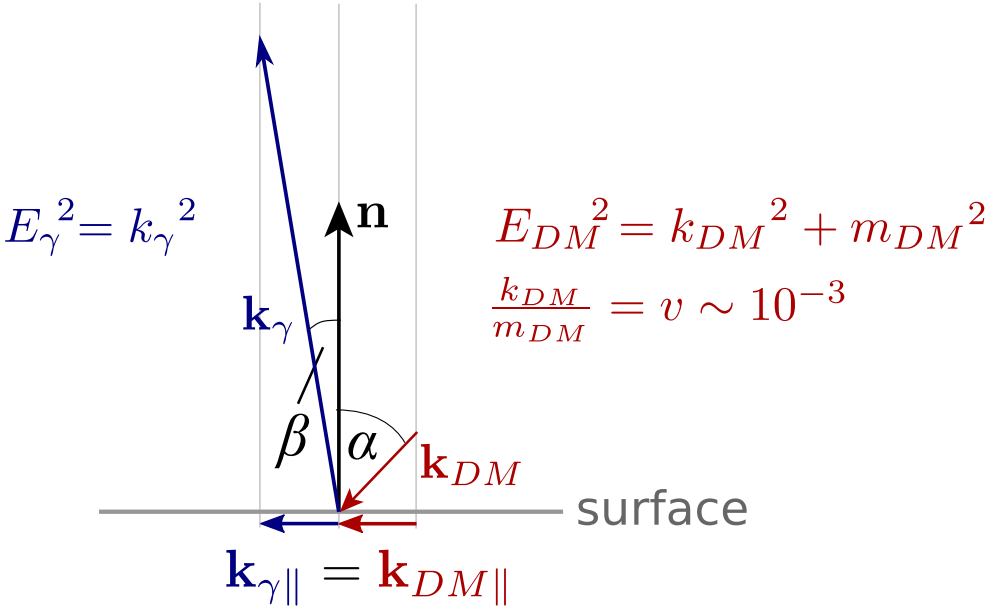


Axion-like Particles (ALPs)

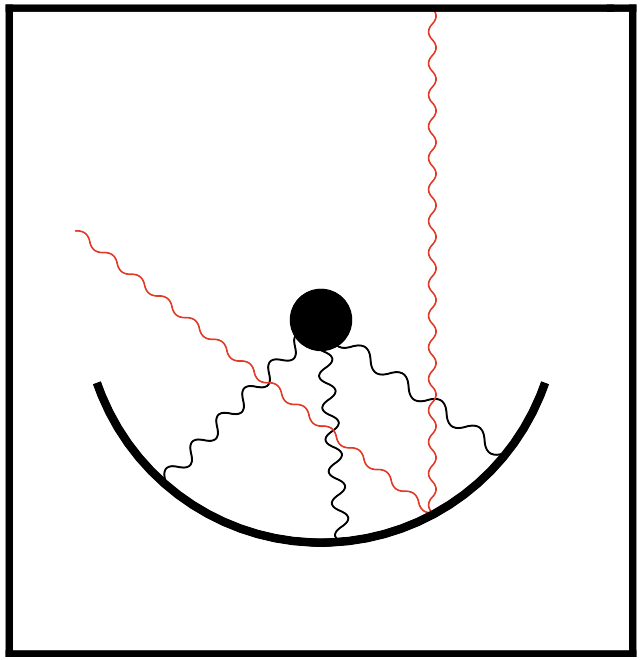
$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{g_{\phi\gamma\gamma}}{4}\phi F_{\mu\nu}\tilde{F}^{\mu\nu} - \frac{1}{2}m_\phi^2\phi^2$$



Dish Antenna Experiments

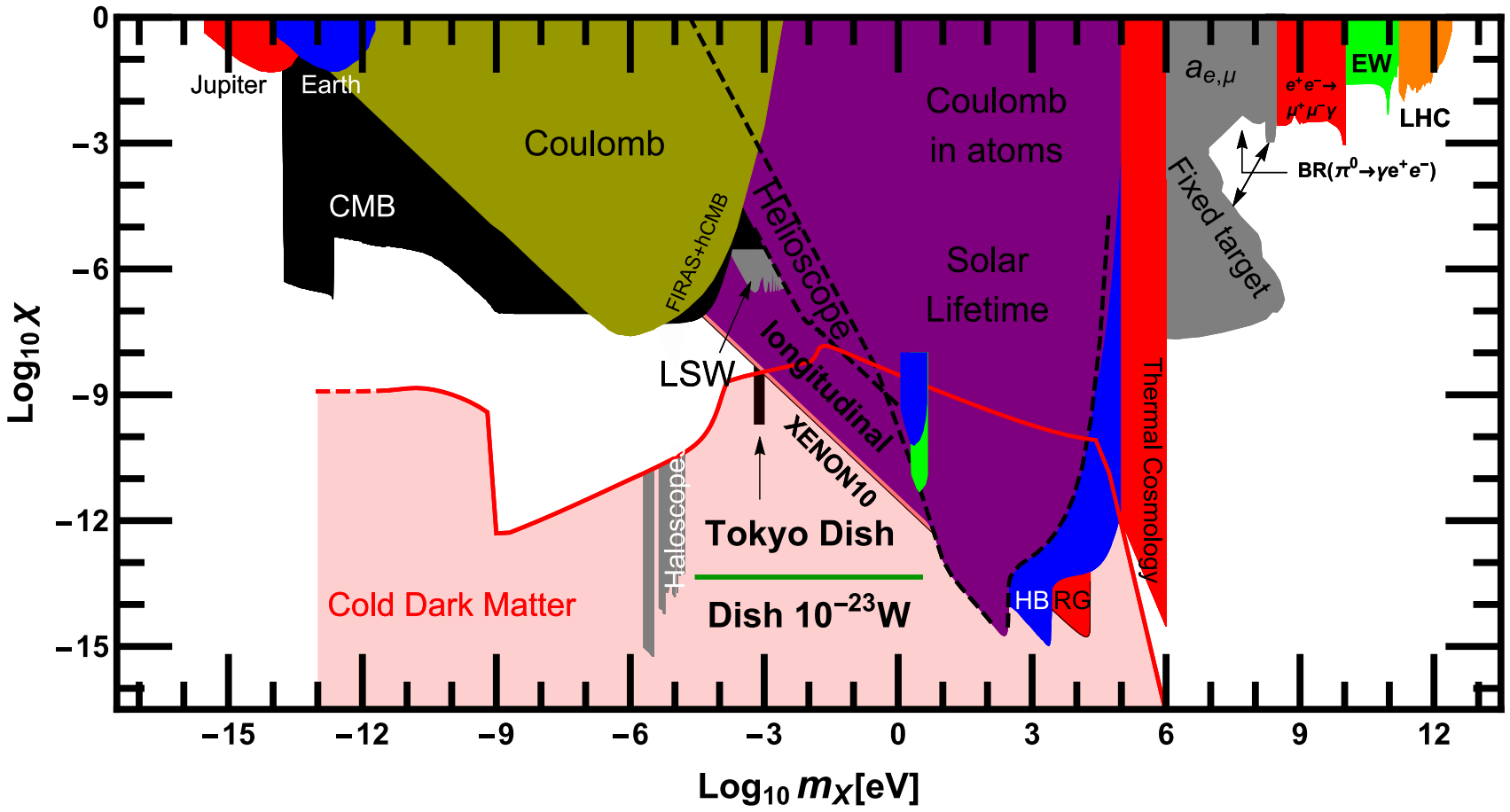


$$\sin(\beta) = v\sin(\alpha) \sim 10^{-3}$$



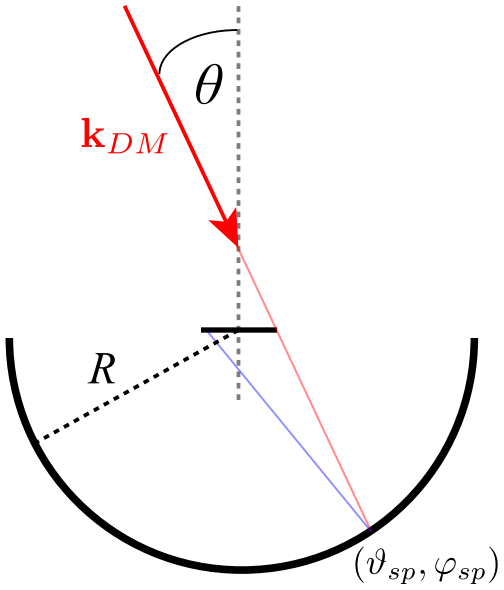
$$P_{\text{centre}} \sim \chi^2 \rho_{\text{CDM}} A_{\text{dish}}$$

Sensitivity?



A Directional Search

$$\sin(\beta) = v \sin(\alpha)$$

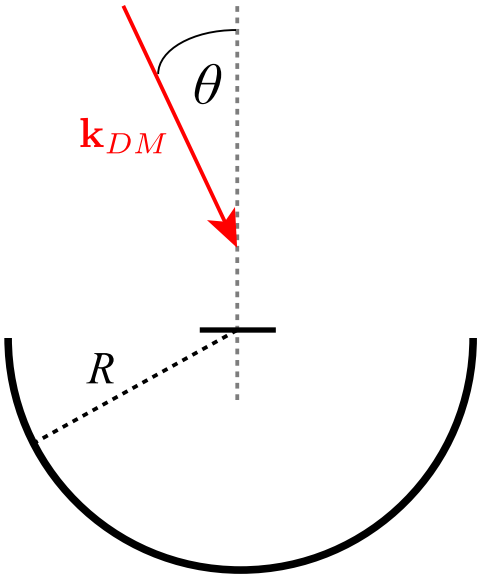


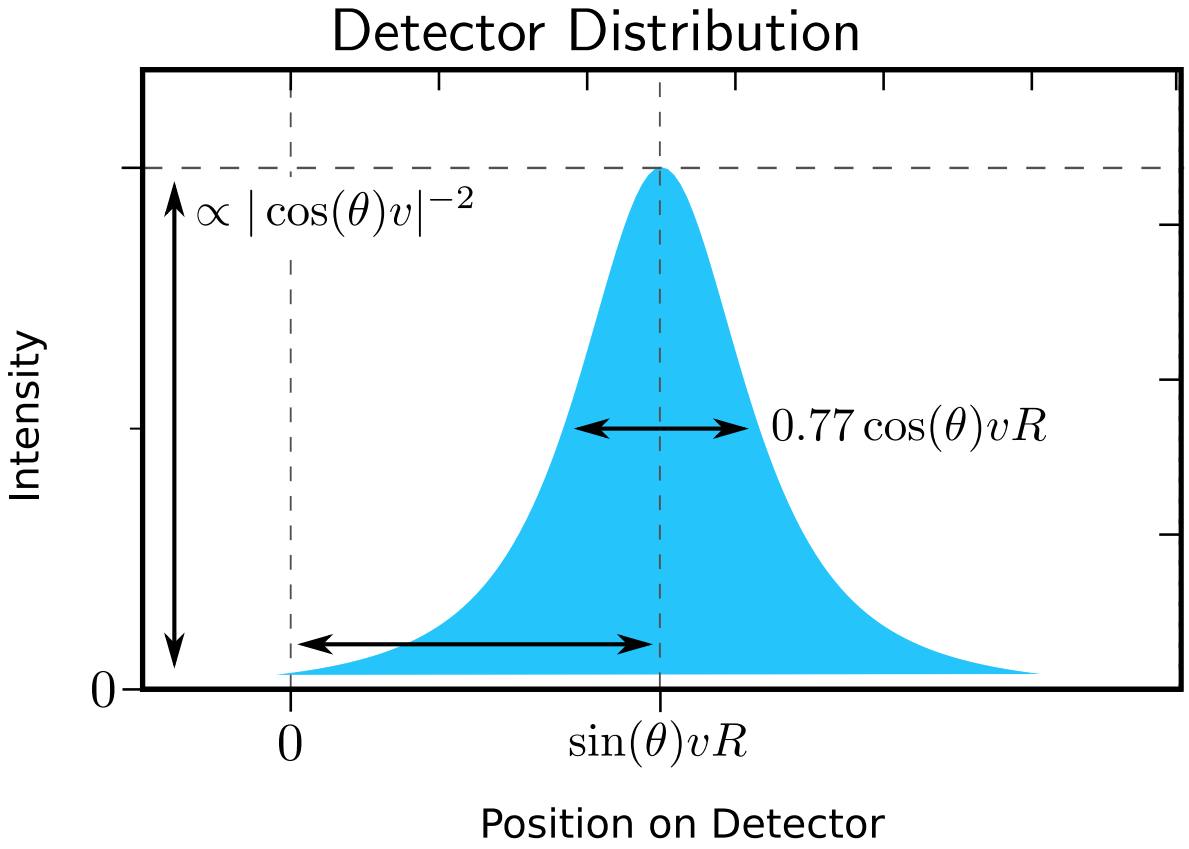
Ray Incident Position:

$$\frac{\Delta \mathbf{x}}{R} = \begin{pmatrix} \sin\theta \\ 0 \end{pmatrix} v - \begin{pmatrix} \cos\varphi_{sp} \\ \sin\varphi_{sp} \end{pmatrix} \tan\vartheta_{sp} \cos\theta v + \mathcal{O}(v^2)$$

A Directional Search

$$\sin(\beta) = v \sin(\alpha)$$





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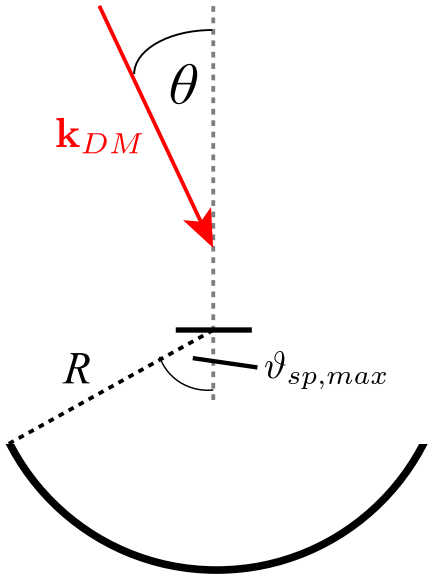
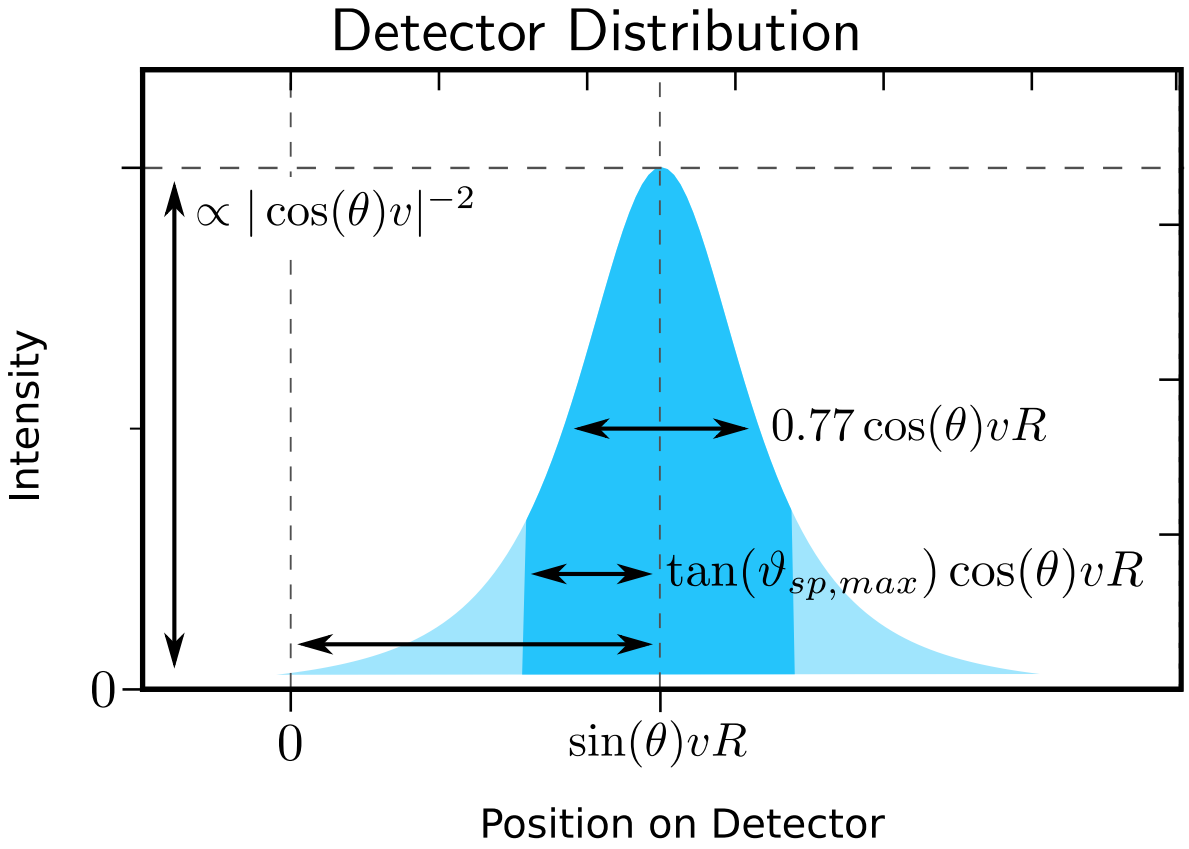


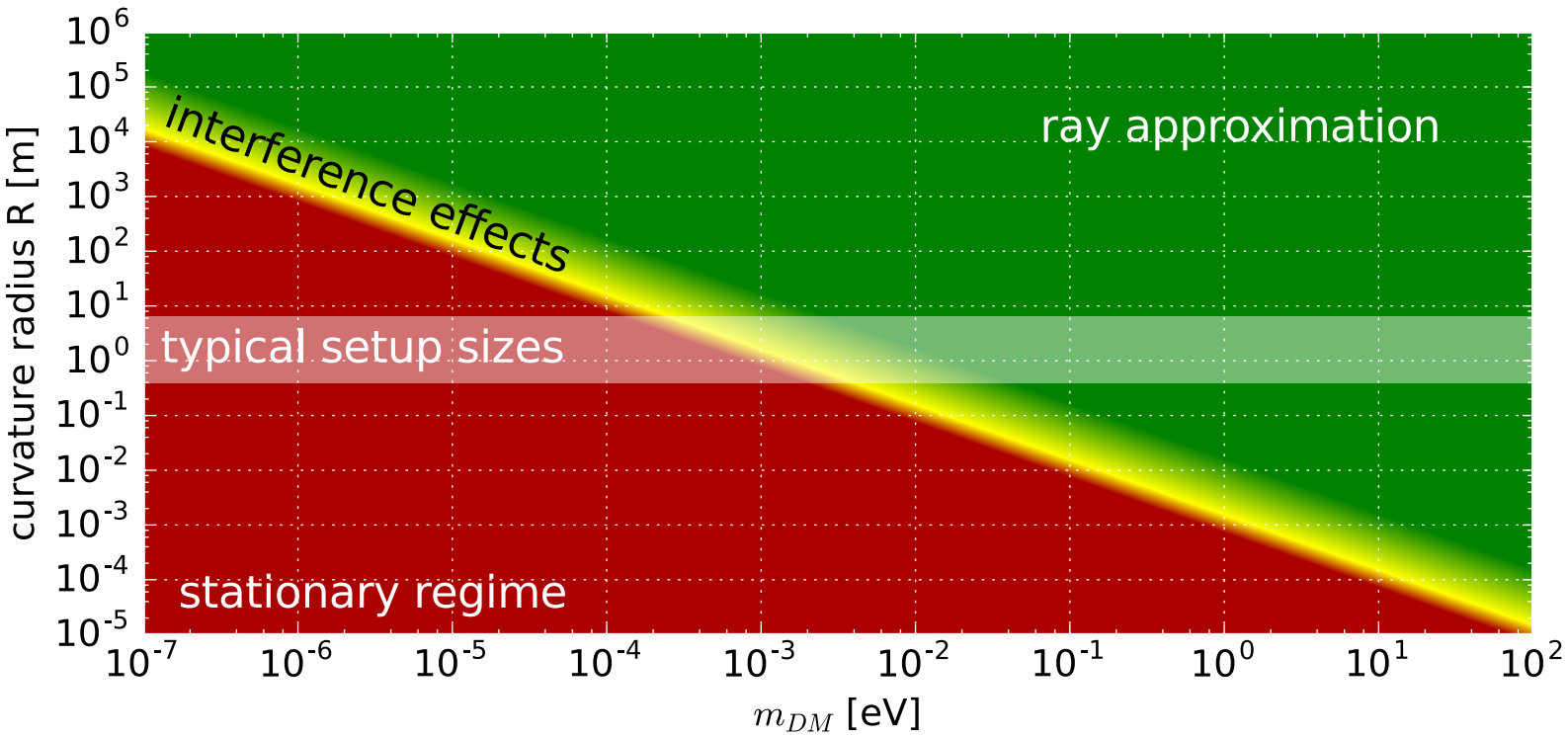


Low Mass Regime

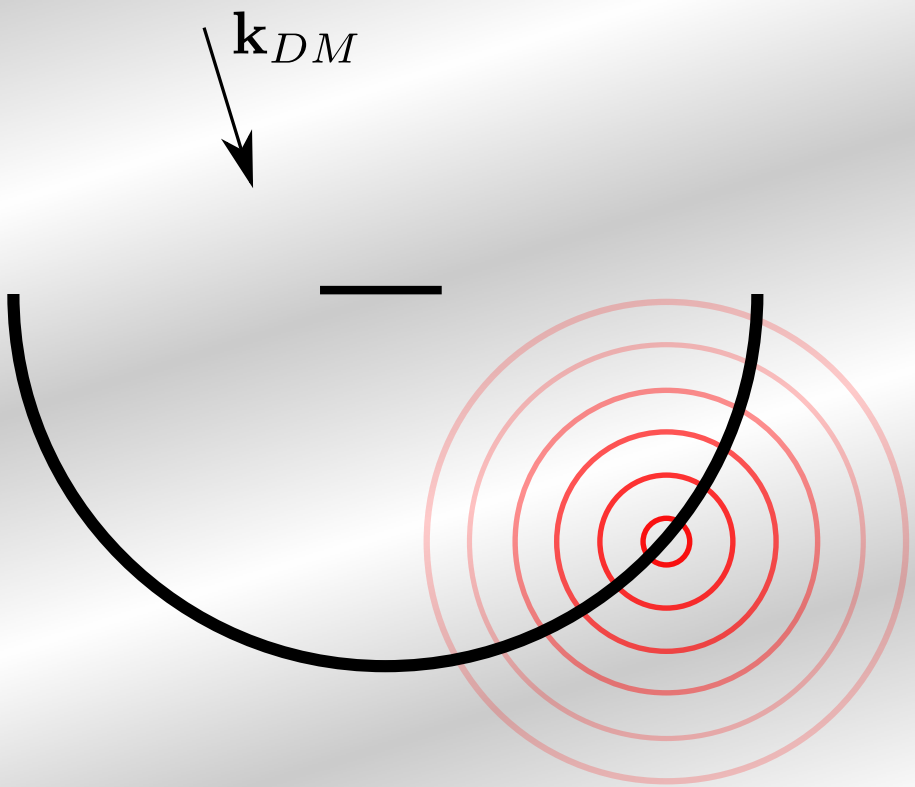
width of distribution $\Delta \sim v_{max} R \sim 10^{-3} R$

photon wavelength $\lambda_\gamma = 2\pi {k_\gamma}^{-1} \approx 2\pi {m_{DM}}^{-1}$

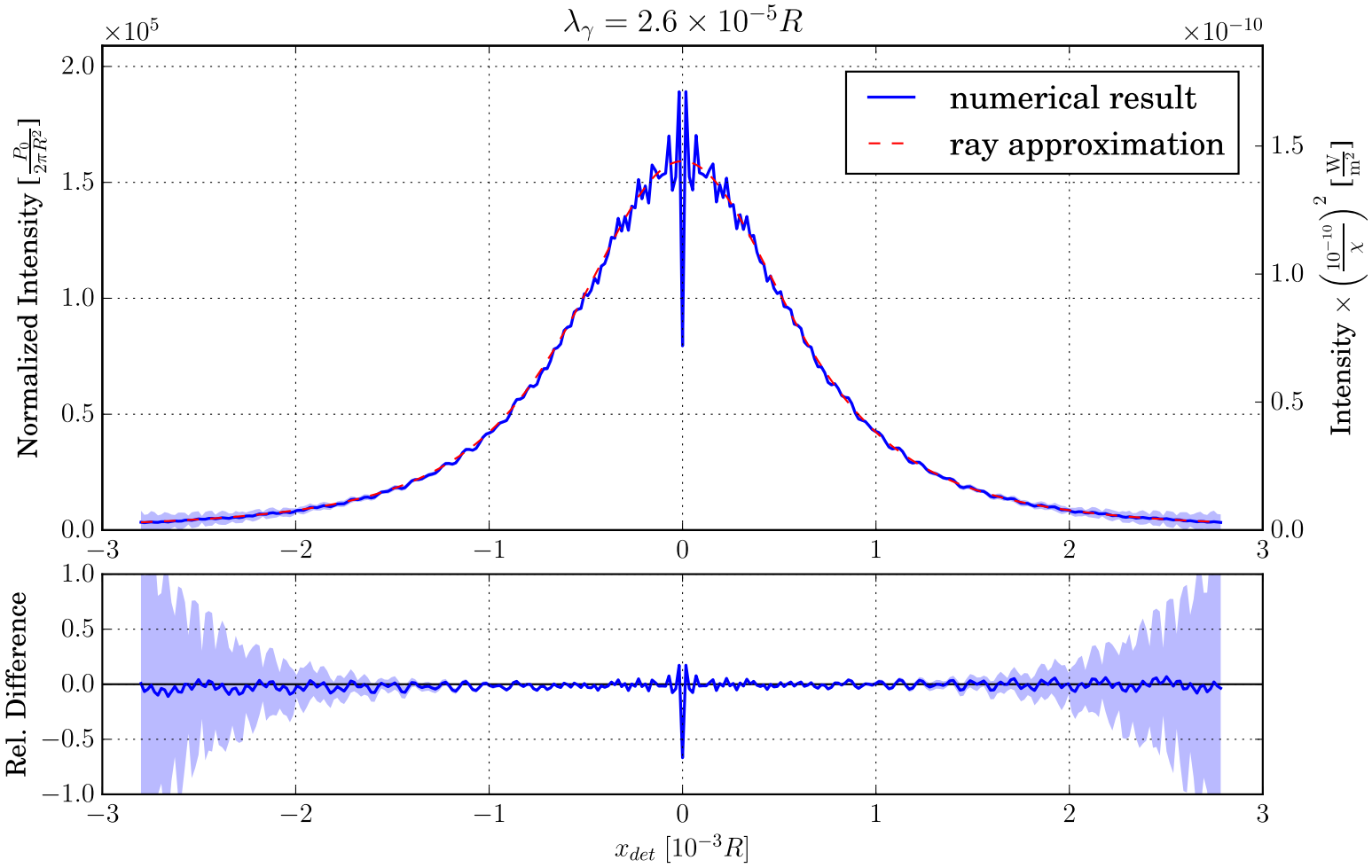
ray approximation: $m_{DM} \gg \frac{2\pi}{v_{max} R}$



Numerical Simulation



Simulation Results



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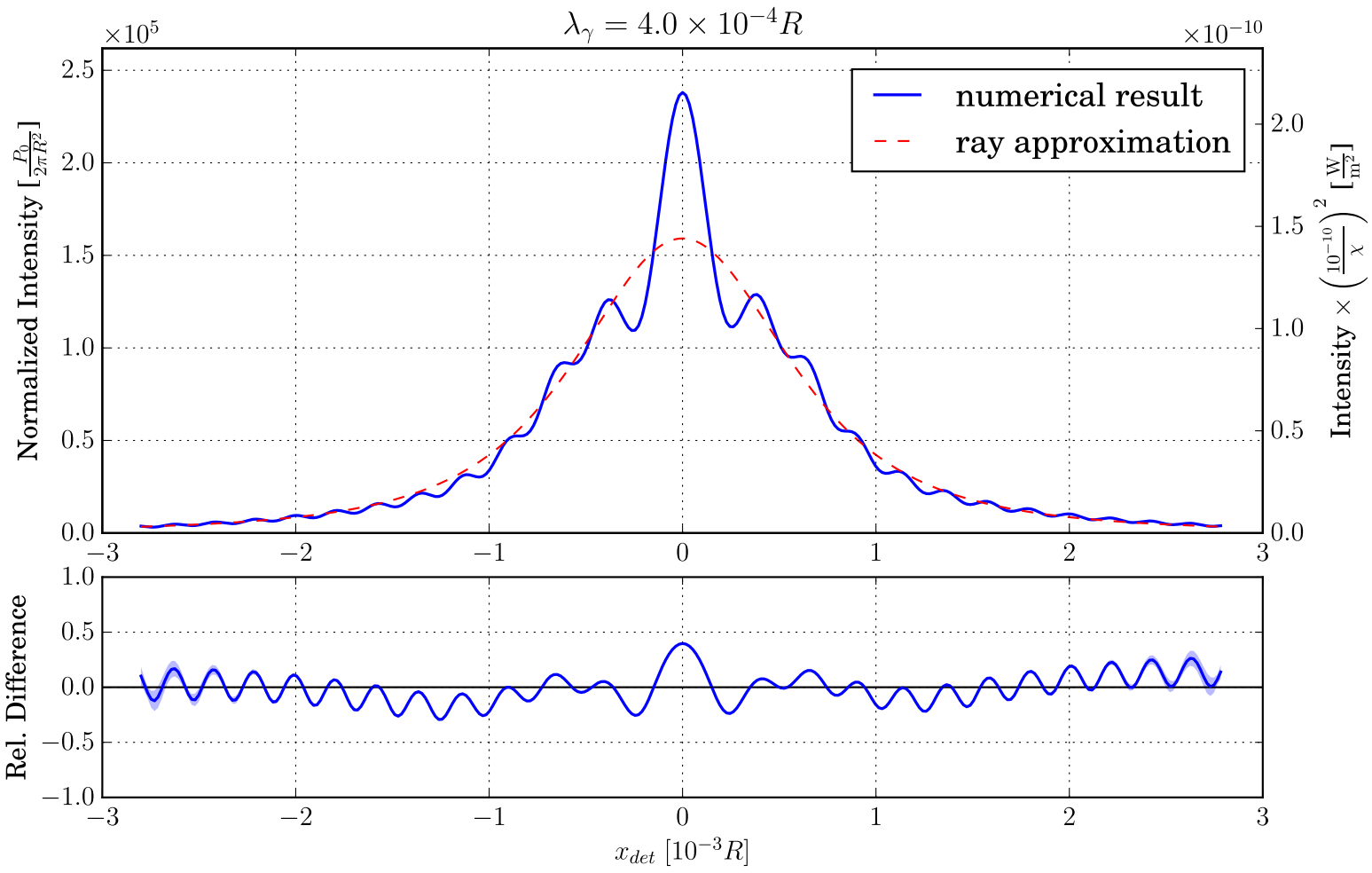

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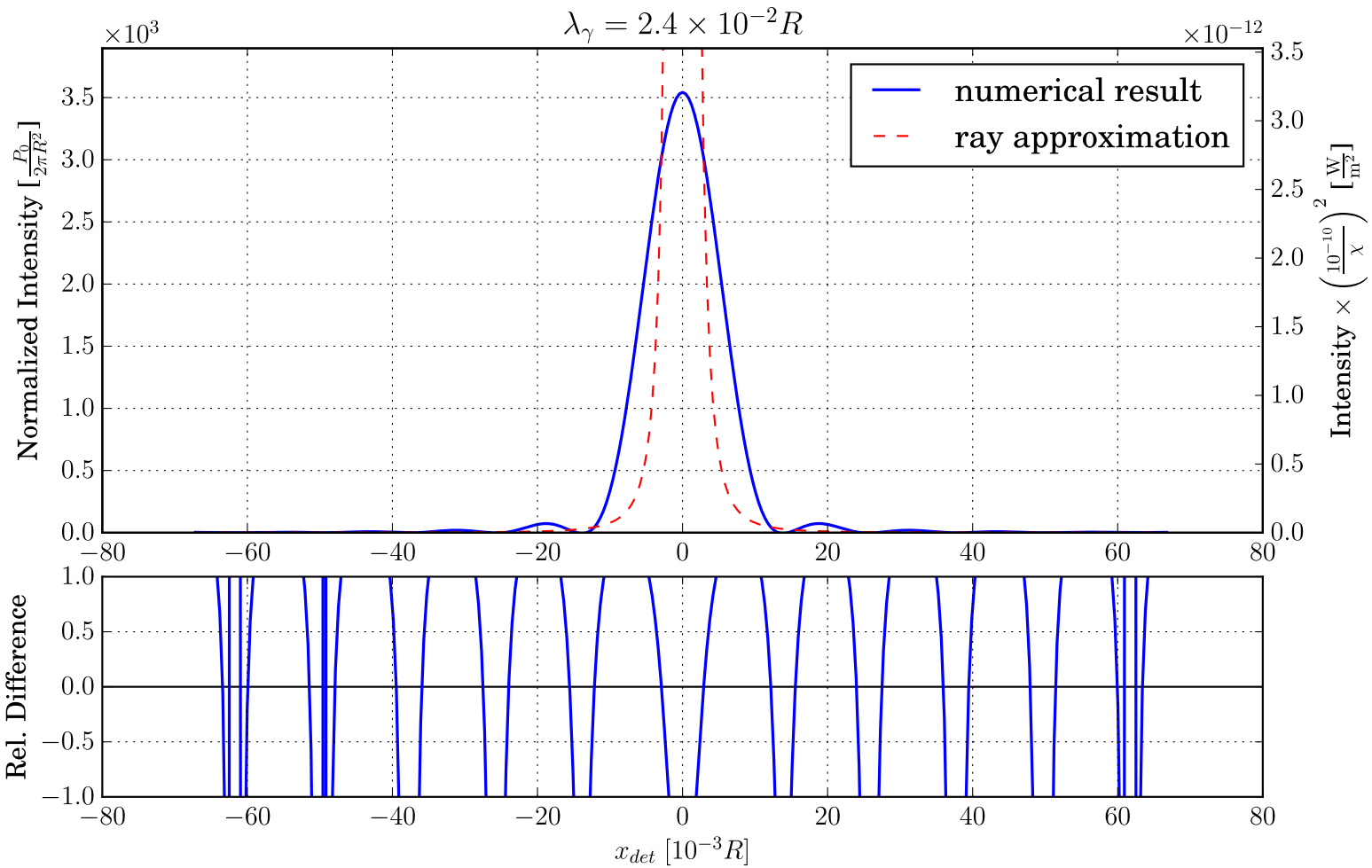
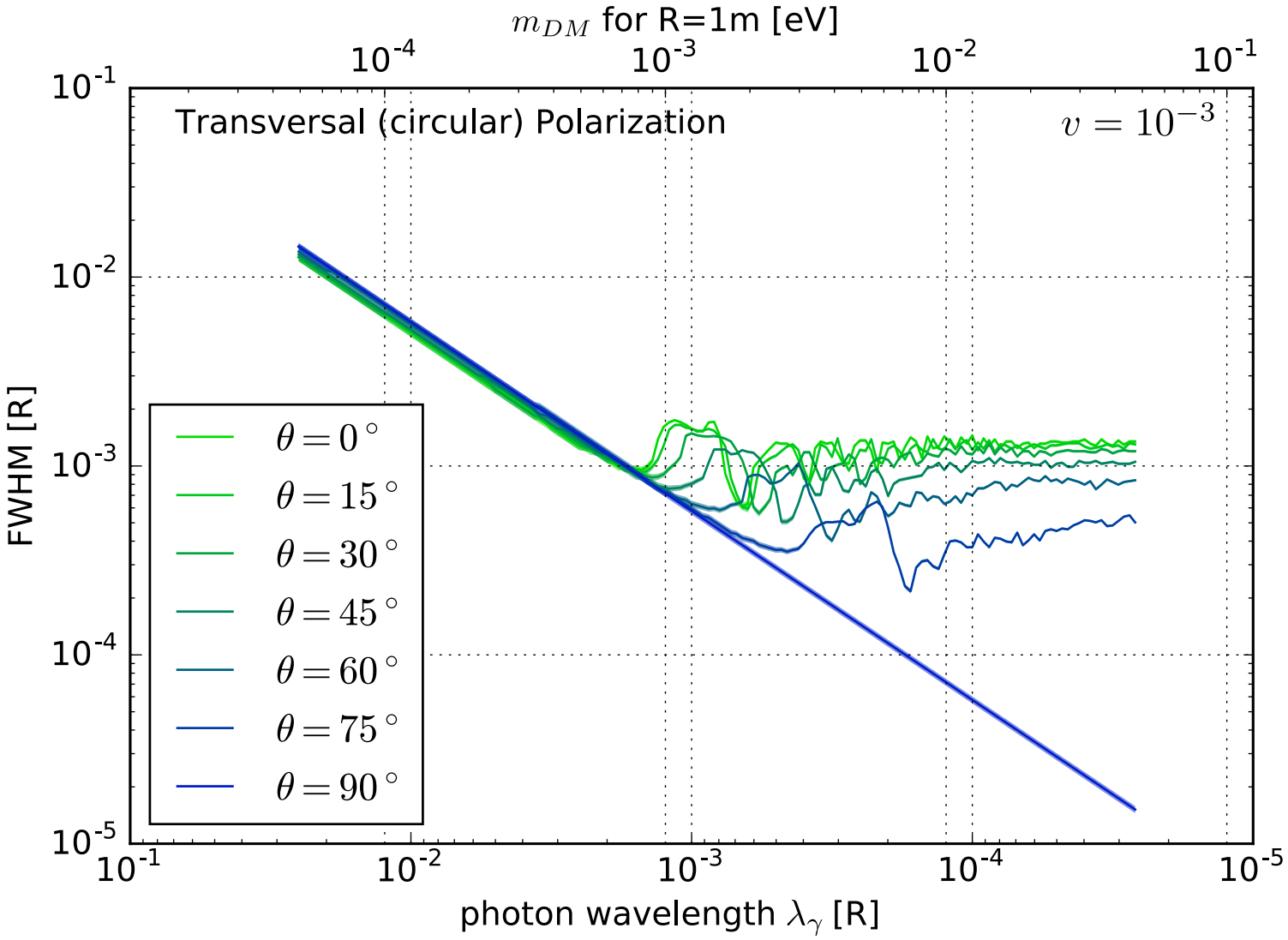
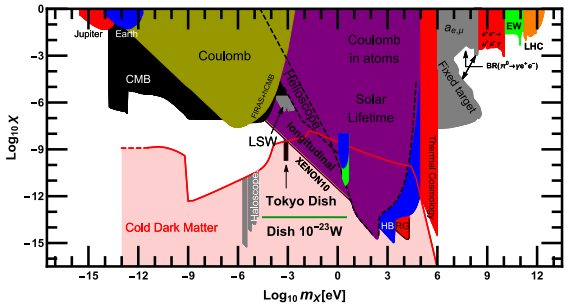


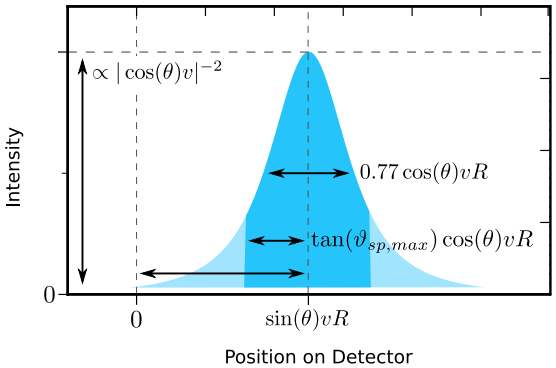
Distribution Widths



Conclusions

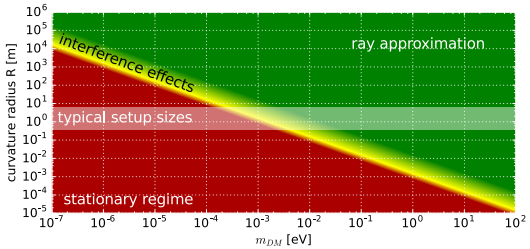


maximize signal → maximize A_{dish}



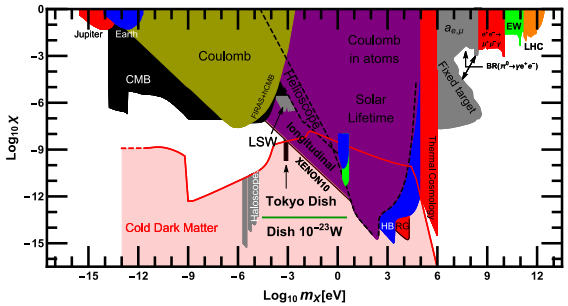
detect everything → detector radius $\gtrsim v_{max}R$

maximize resolution → minimize $\vartheta_{sp,max}$



$$m_{DM} \lesssim \frac{2\pi}{v_{max}R} \rightarrow$$ Low Mass Limitations

Thank You very much



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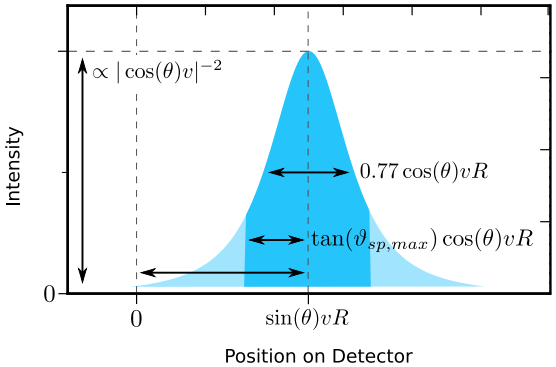

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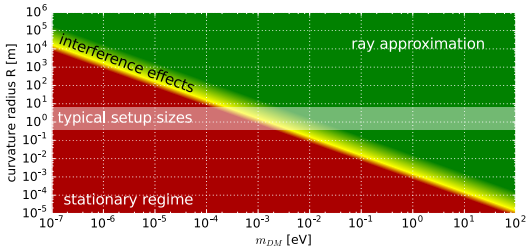

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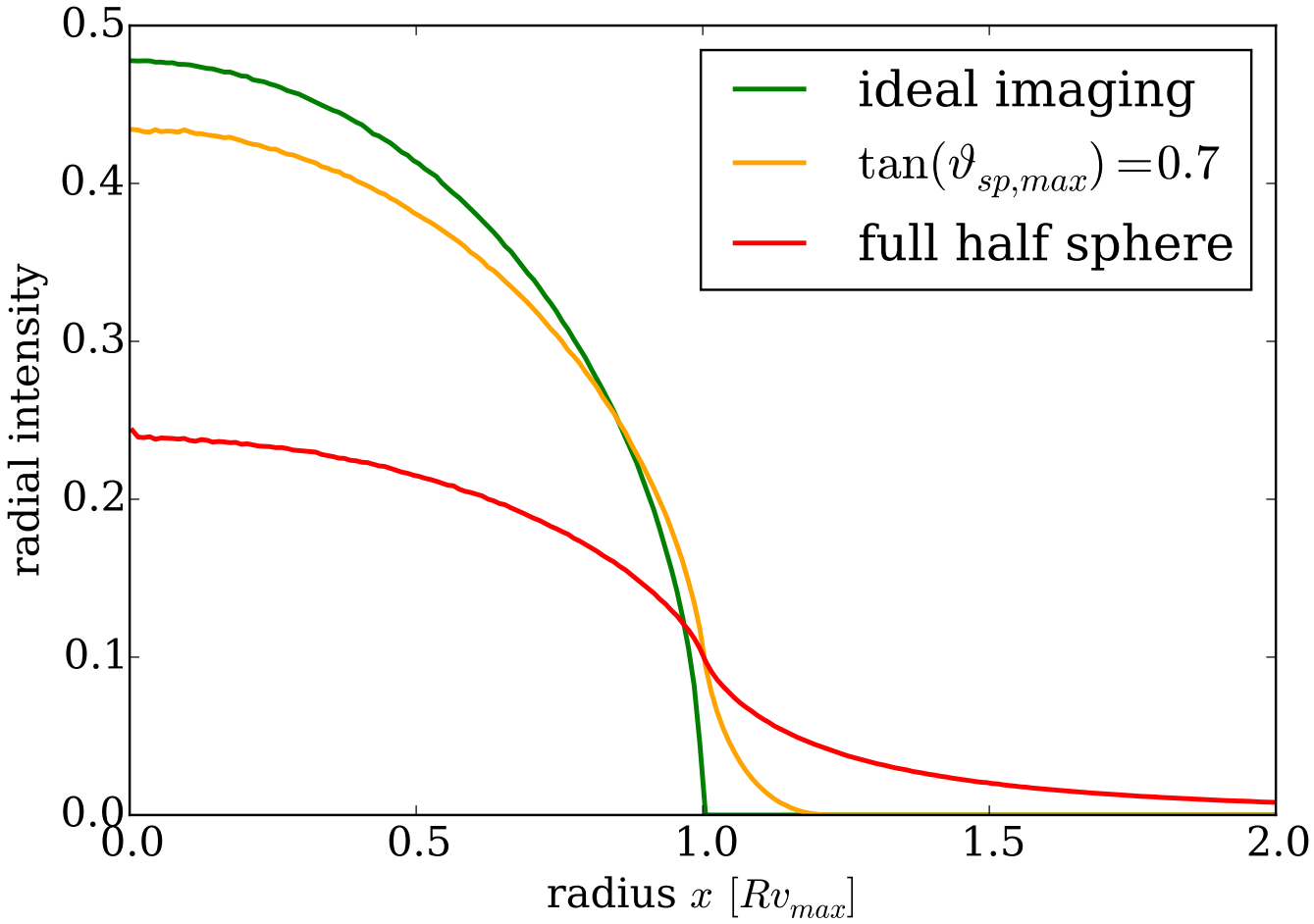
Integrating over a DM velocity distribution

$$p(\mathbf{v}) \propto \theta\left(|\mathbf{v}| - v_{max}\right)$$



Incoherent DM Velocity Distribution

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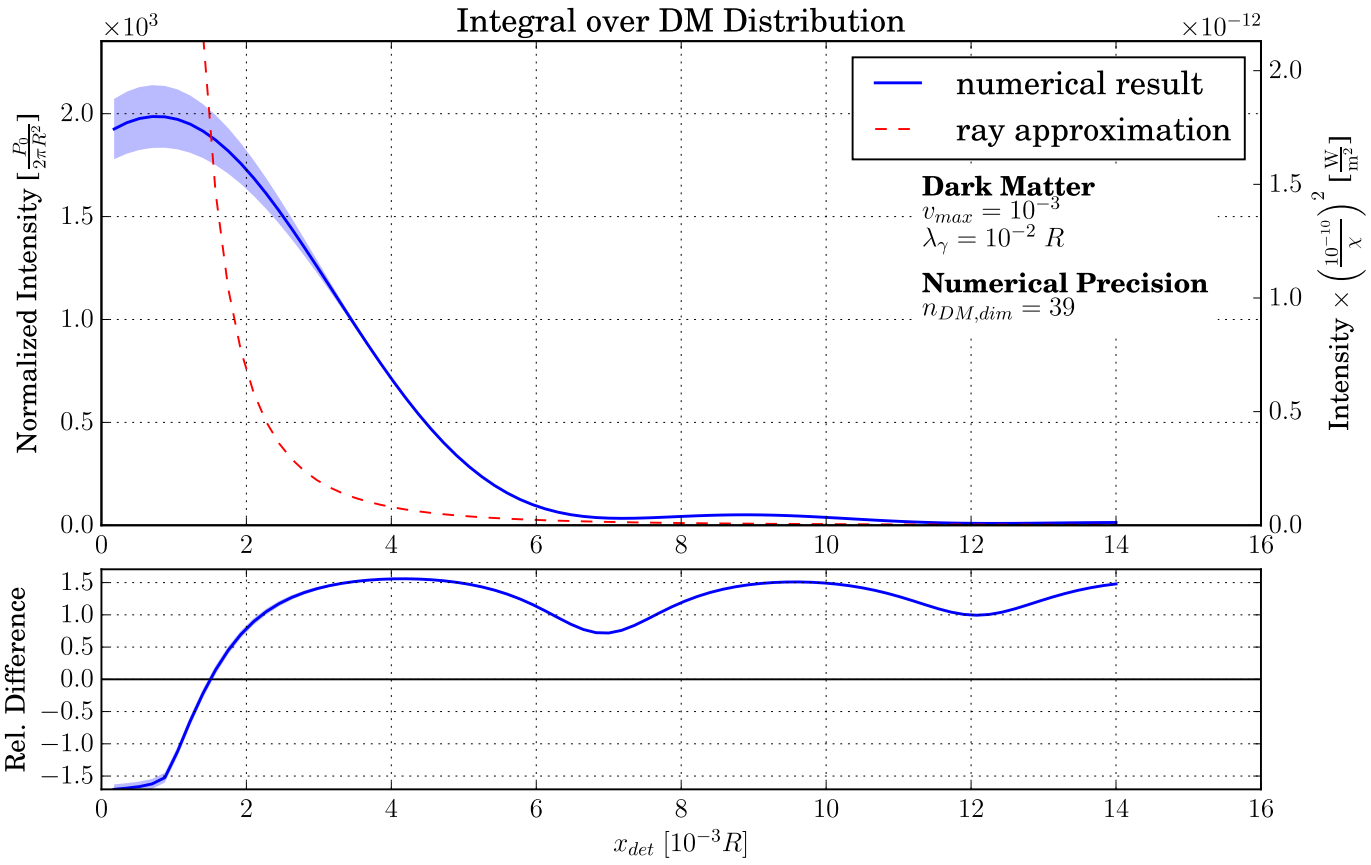

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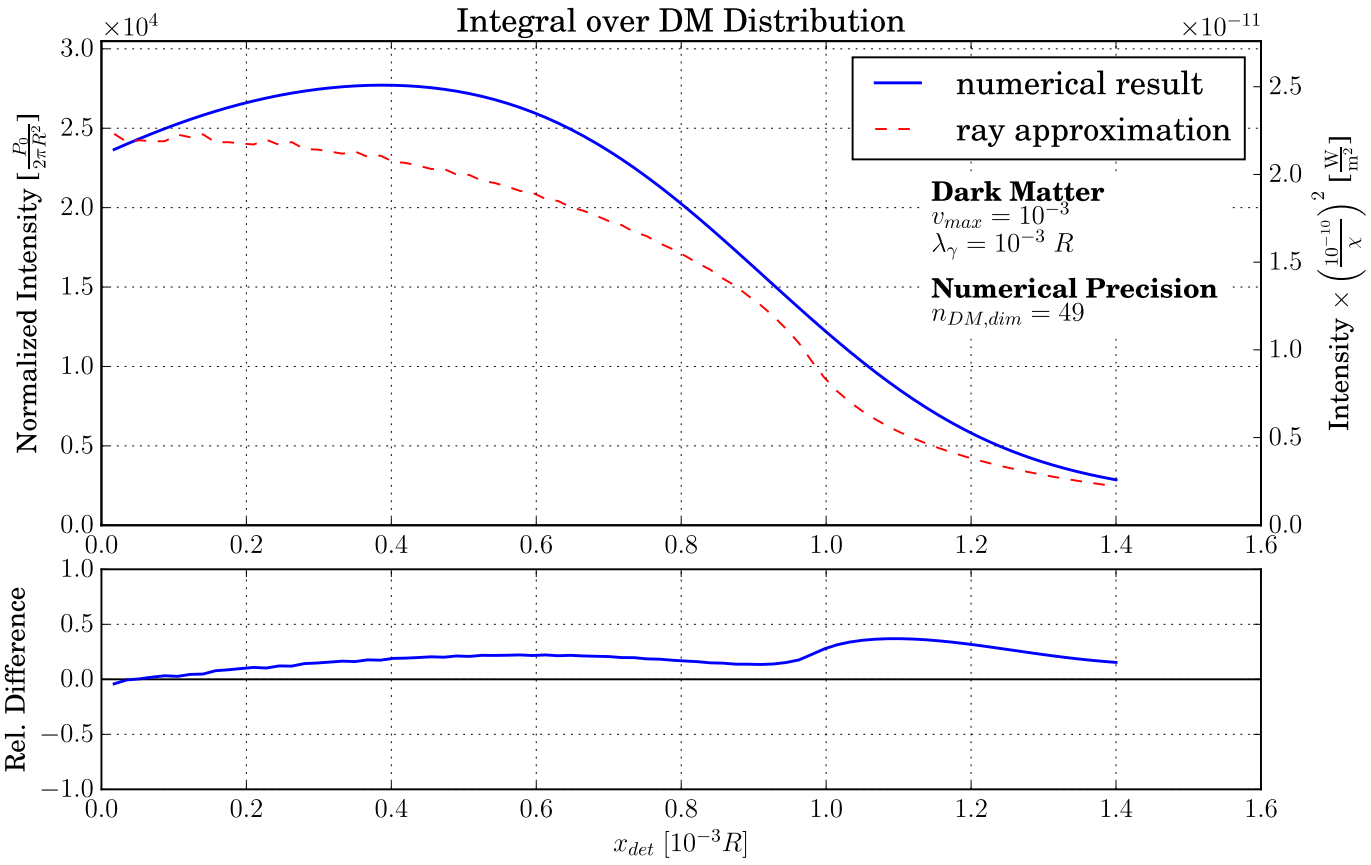

References

[1] Dieter Horns, Joerg Jaeckel, Axel Lindner, Andrei Lobanov, Javier Redondo, and Andreas Ringwald. Searching for WISPy Cold Dark Matter with a Dish Antenna. *JCAP*, 1304:016, 2013.

[2] Joerg Jaeckel and Javier Redondo. An antenna for directional detection of WISPy dark matter. *JCAP*, 1311:016, 2013.

[3] Joerg Jaeckel and Stefan Knirck. Directional resolution of dish antenna experiments to search for wispy dark matter. *JCAP*, 2016(01):005, 2016.