SIGGRAPH 2022
VANCOUVER+ 8-11 AUG

THE PREMIER CONFERENCE & EXHIBITION ON
COMPUTER GRAPHICS & INTERACTIVE TECHNIQUES

PRACTICAL LEVEL-OF-DETAIL AGGREGATION OF FUR APPEARANCE

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HIGH LEVEL GOAL

- reducing #fur fibers
- while preserving the appearance

45M

0.45M

Why simplification?

MOTIVATION

300M

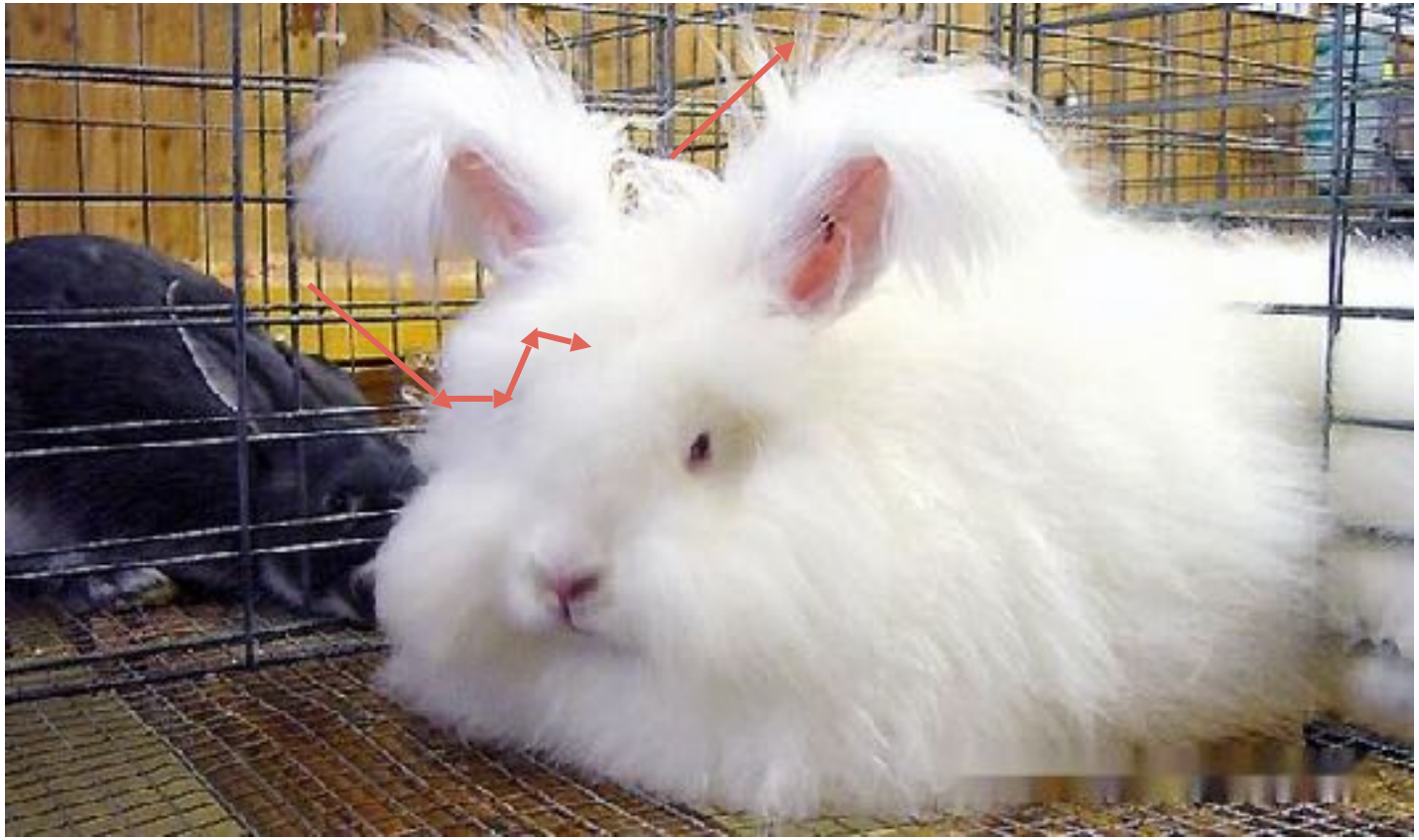
150M

1.5M

Memory consumption

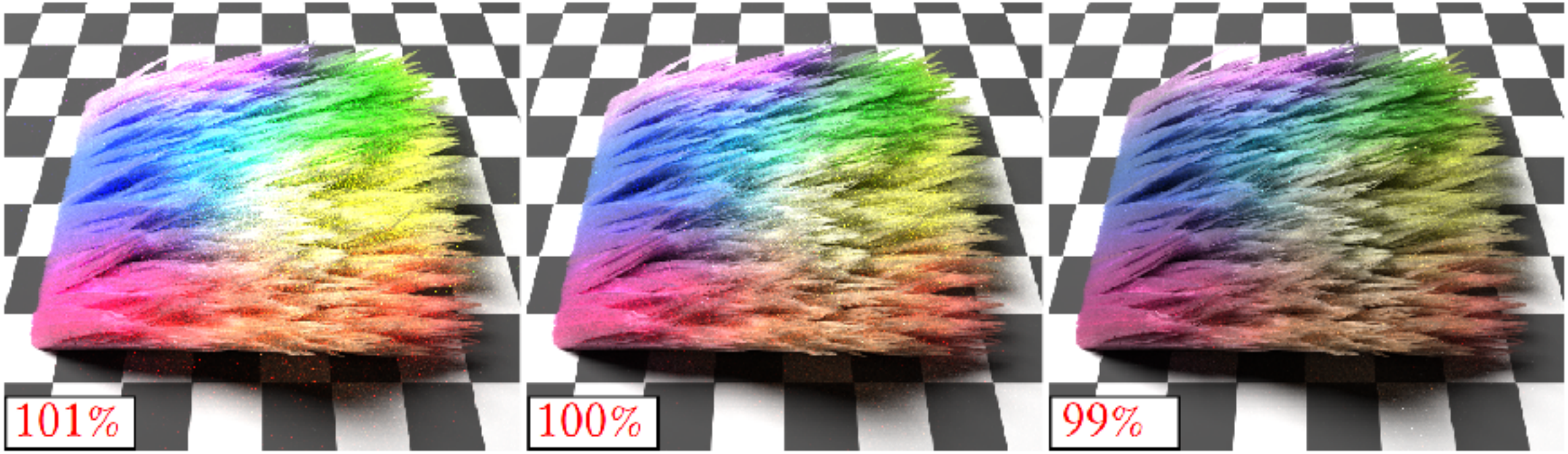
MOTIVATION

Complex multiple scattering **#bounces 30-150**



Performance

MOTIVATION



Energy conservation

Why aggregation?

MOTIVATION

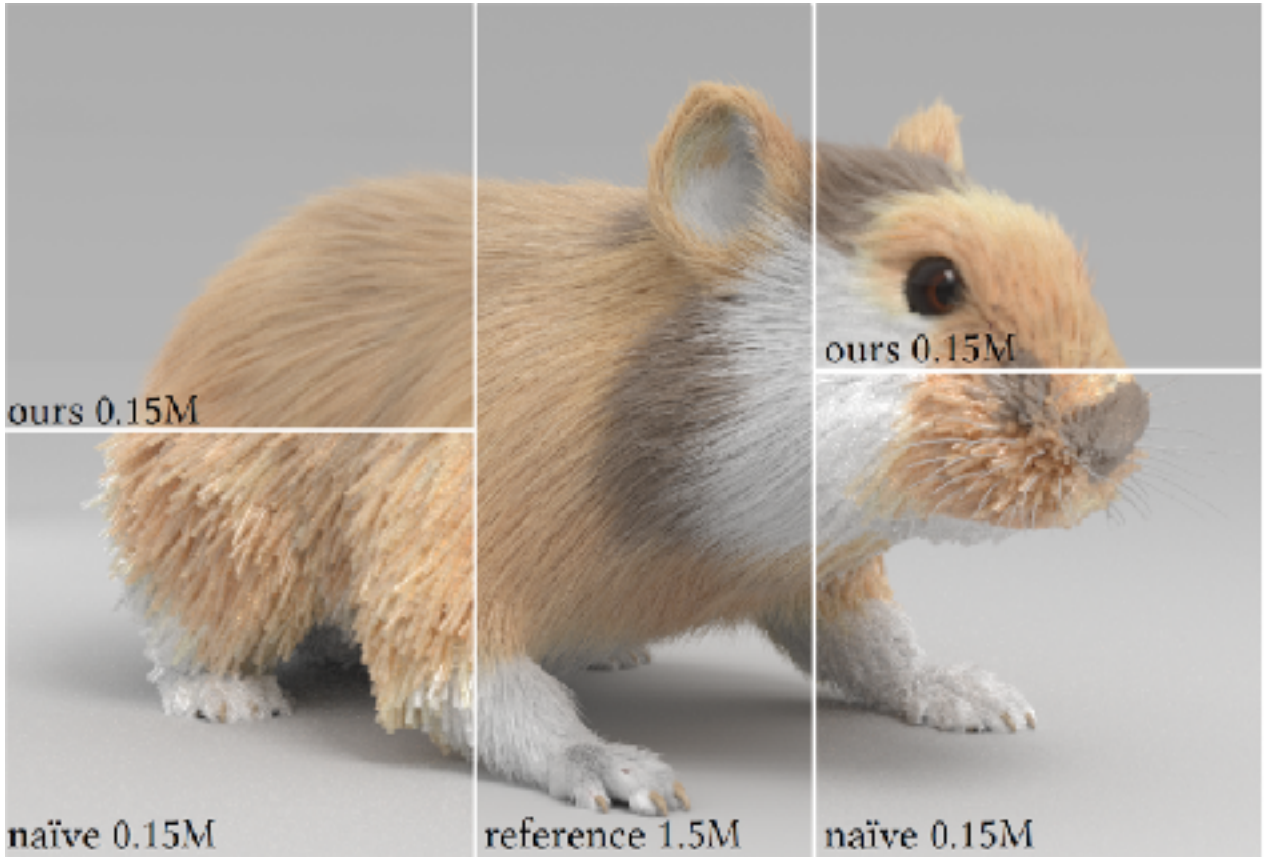
Level of details (LOD)

MOTIVATION

Naïve method：

simply reduce and thicken the fibers

- Drier
- Harder
- Brighter

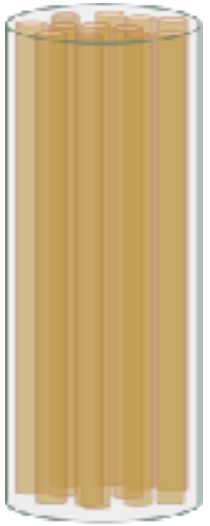


Complex geometry ←→ Complex appearance

OUR CONTRIBUTION

Simply thicken

Aggregation (our method)



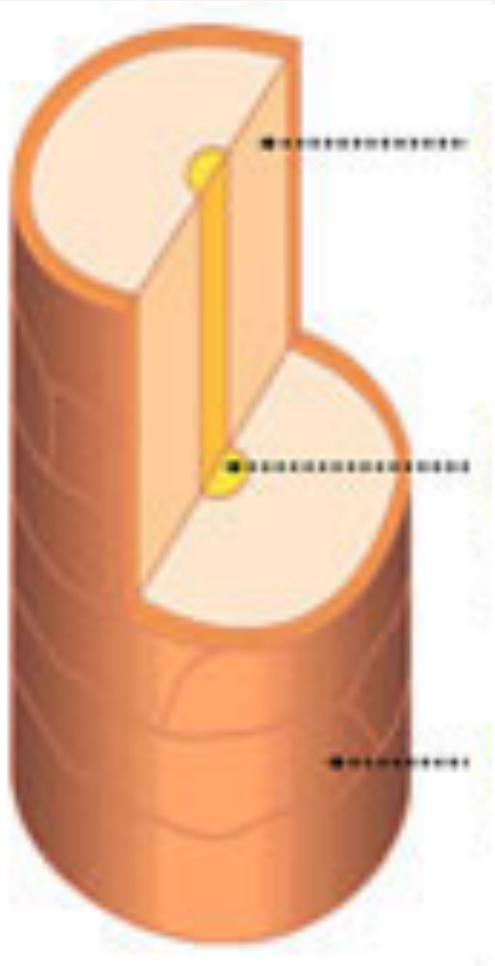
✓ Accuracy

✓ Efficiency

✓ LOD

BACKGROUND

MICRO STRUCTURE OF HAIR / FUR FIBERS



Cortex

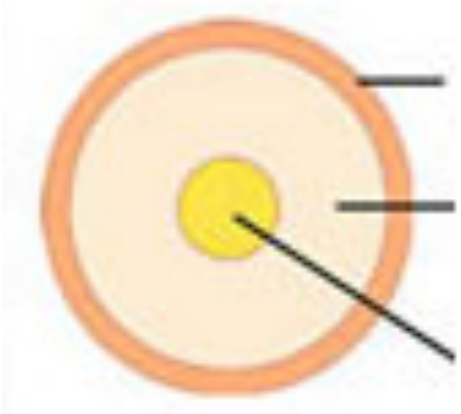
- Pigmented
- Absorbs light

Medulla

- Complex structure
- Scatters light

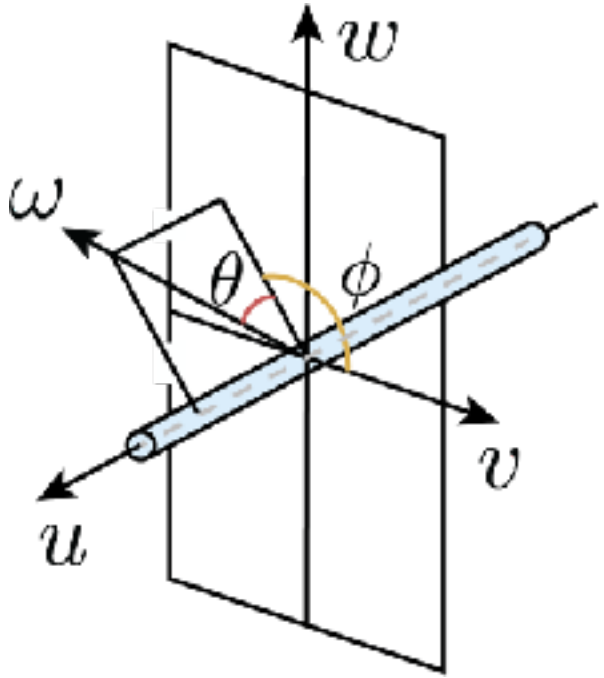
Cuticle

- Covered with scales

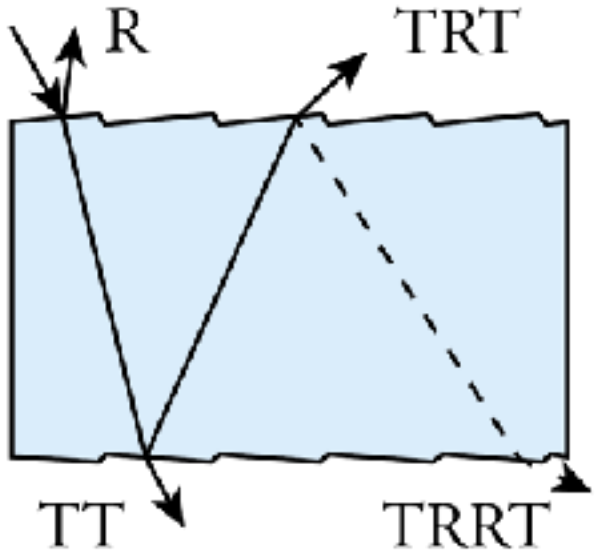


Common for hair/fur fibers

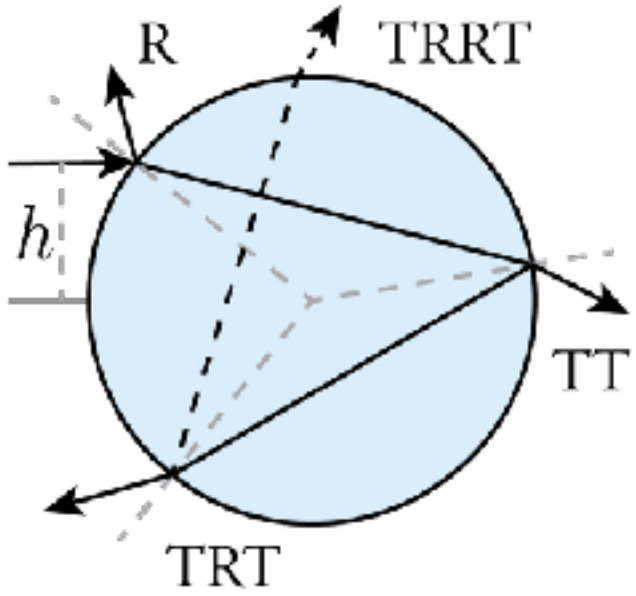
LONGITUDINAL-AZIMUTHAL DECOMPOSITION



3D illustration

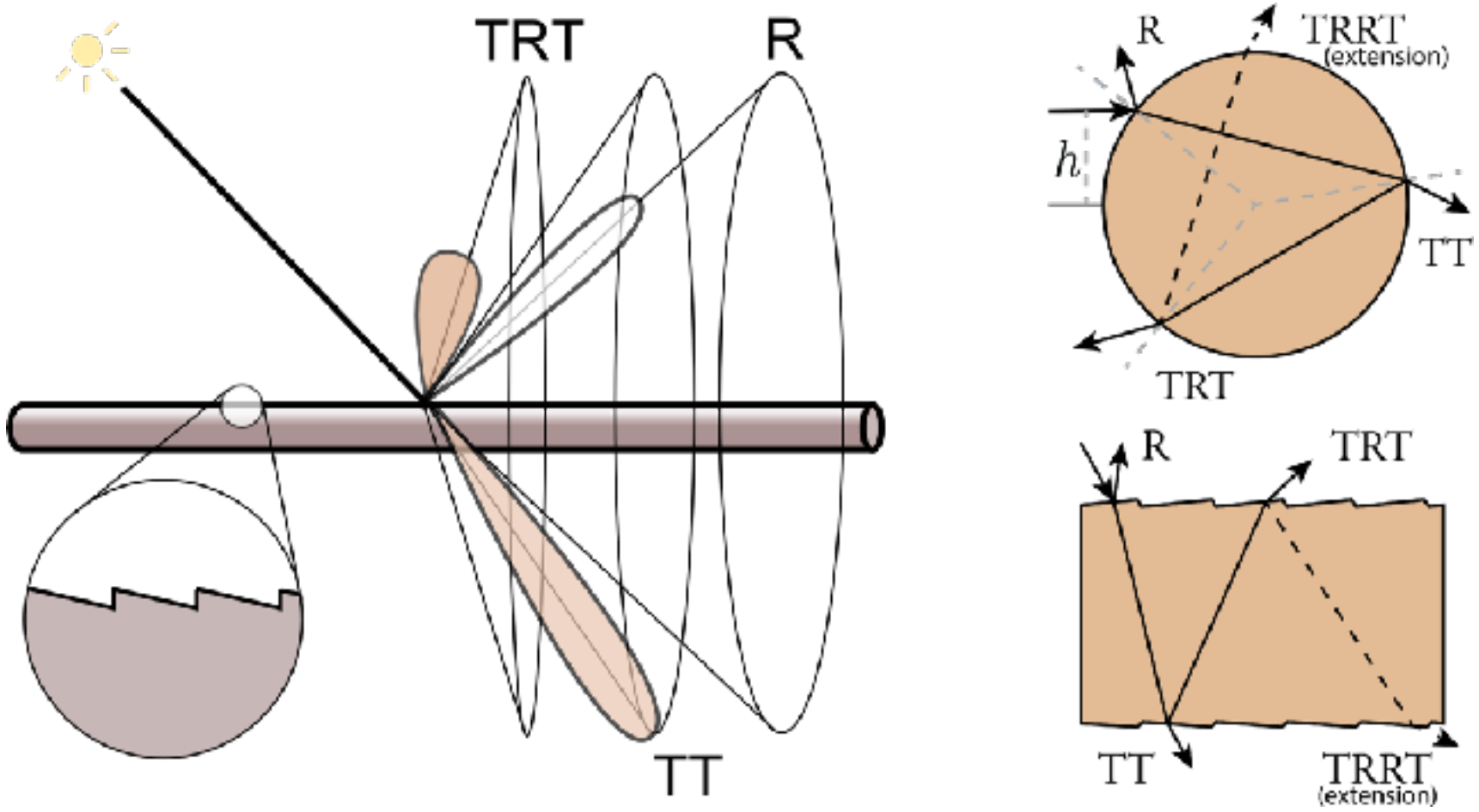


Longitudinal section



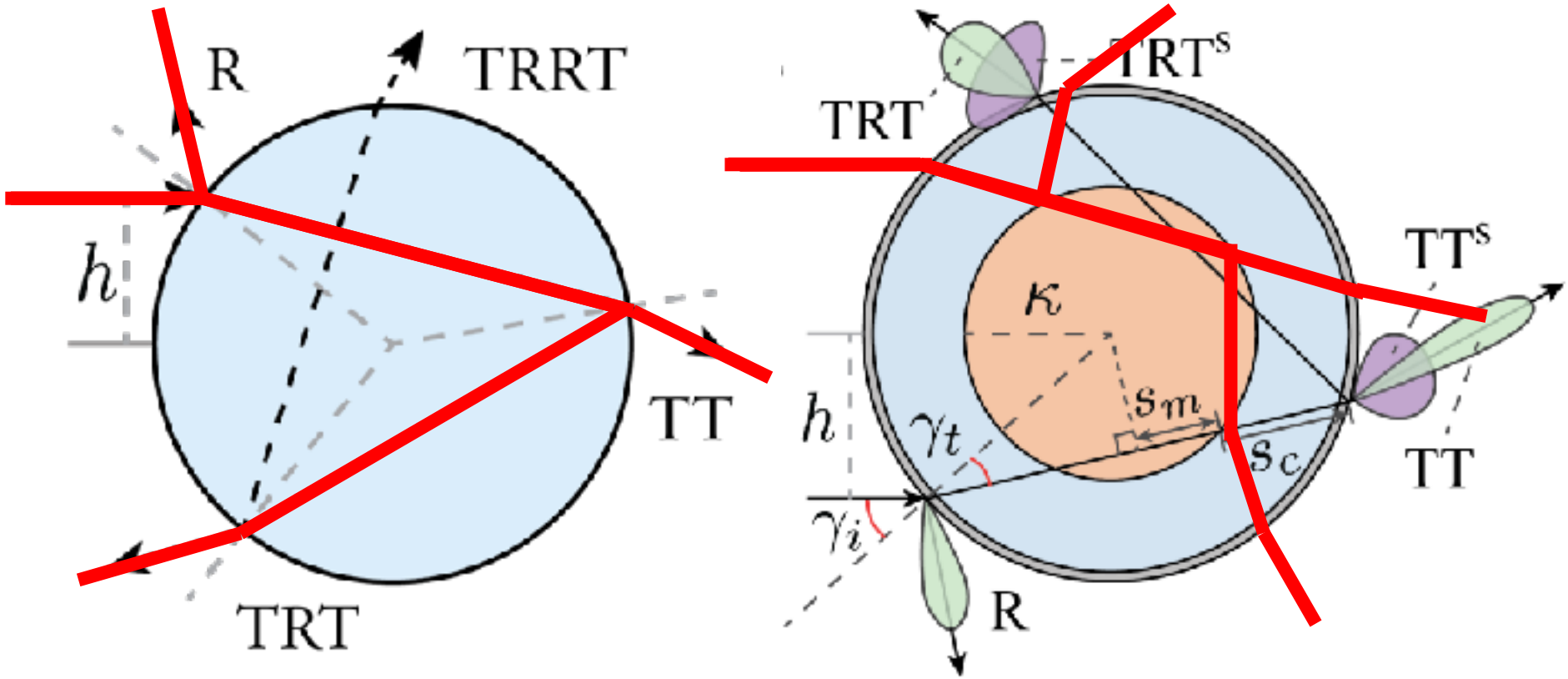
Azimuthal section

MARSCHNER MODEL



[Marschner et al. 2003]

DOUBLE CYLINDER MODEL (FUR MODEL)

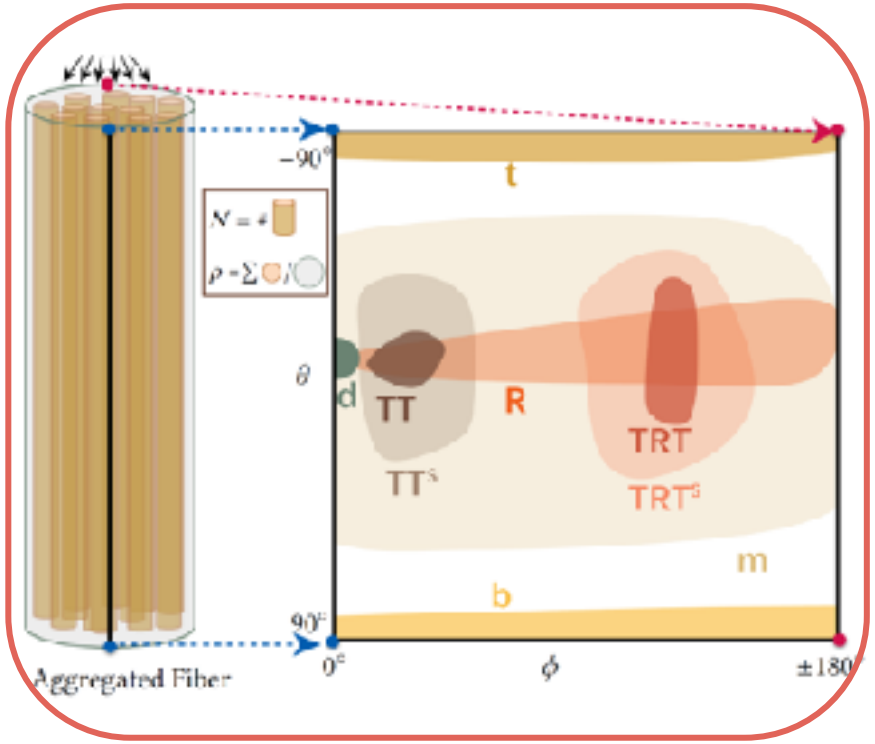


Marschner Model **Double Cylinder Model**

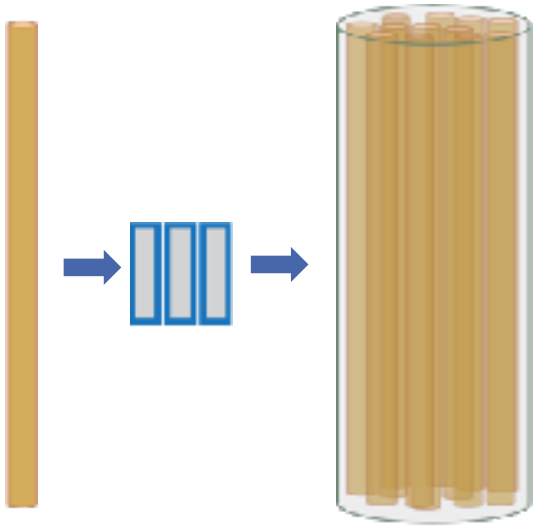
[Yan et al. 2017]

OUR APPROACH

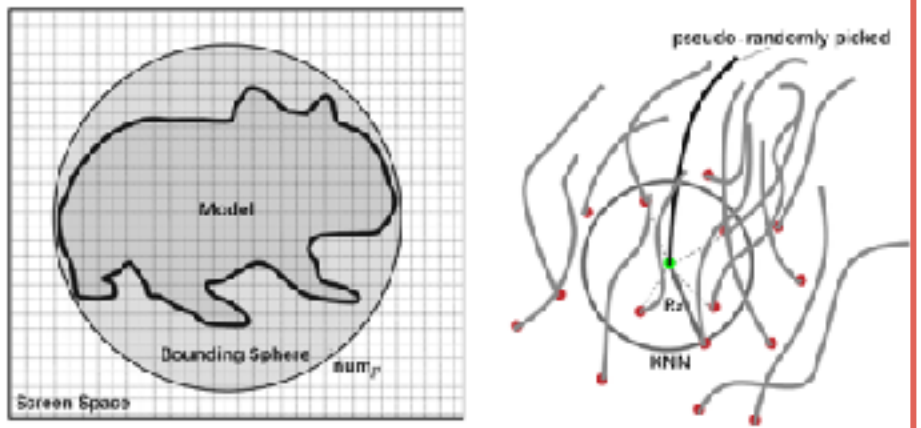
OVERVIEW



Simulating the aggregated BCSDF



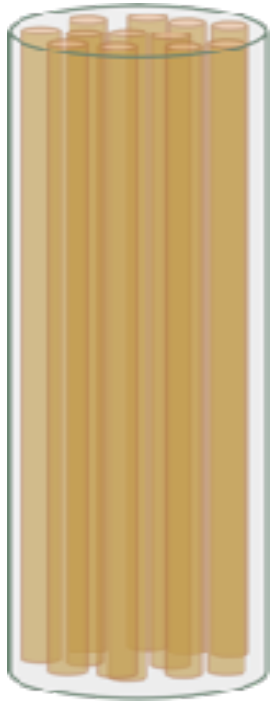
Single to aggregated BCSDF conversion



Runtime simplification

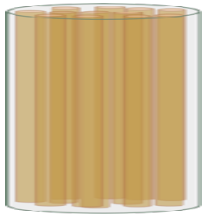
SIMULATING THE AGGREGATED BCSDF

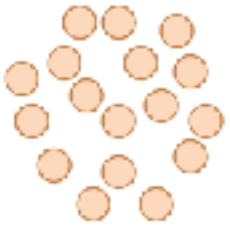
Aggregated fiber



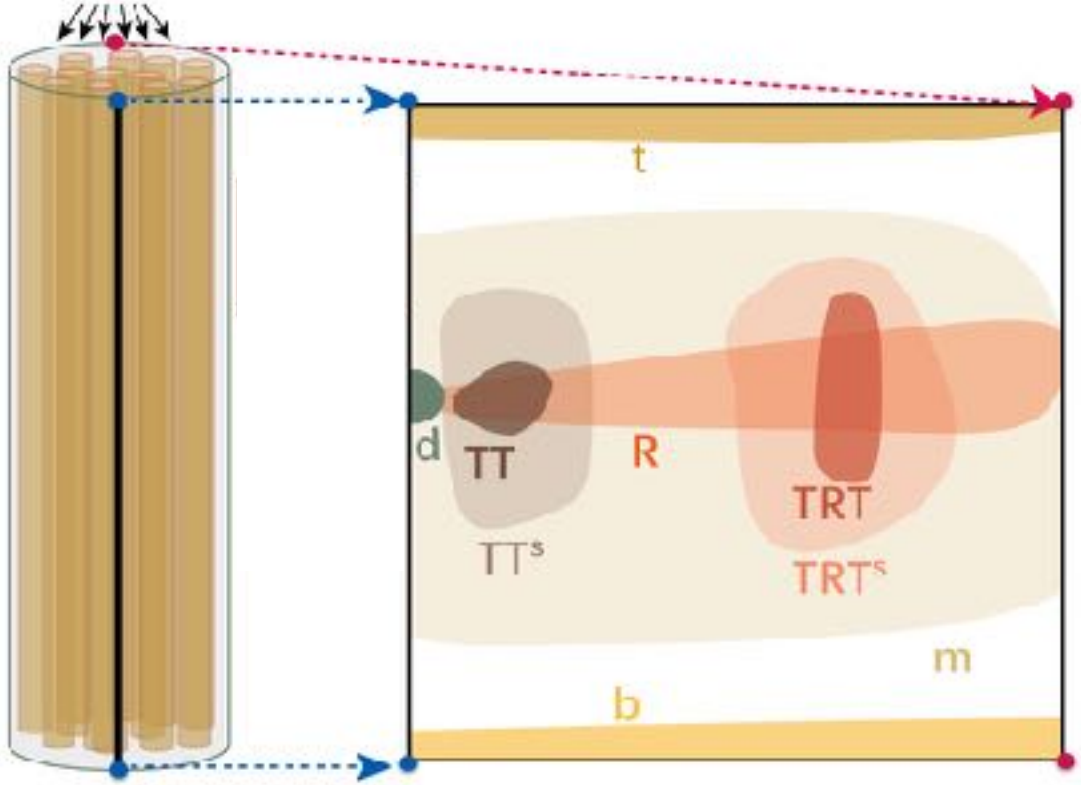
Single fiber parameters

Geometry parameters

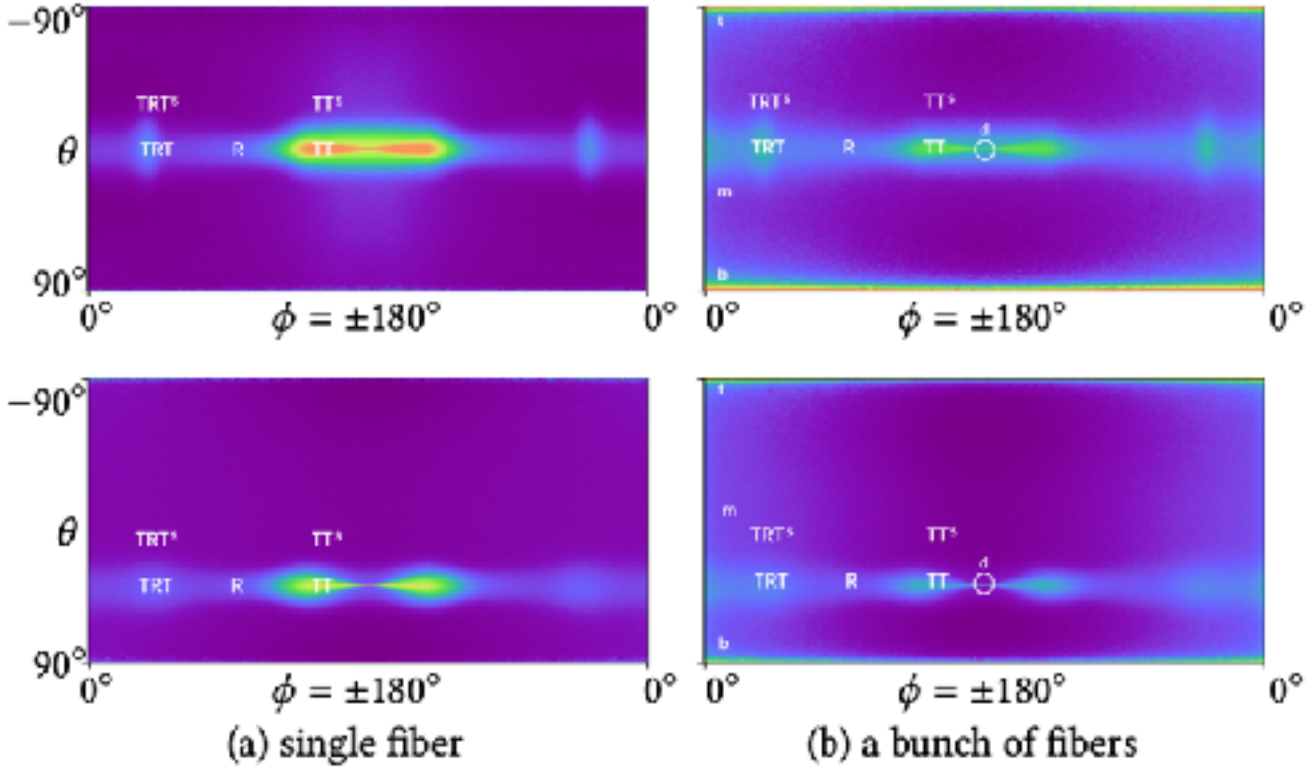
Number of fiber: $\sum$  in 

Density:  ÷ 

SIMULATING THE AGGREGATED BCSDF

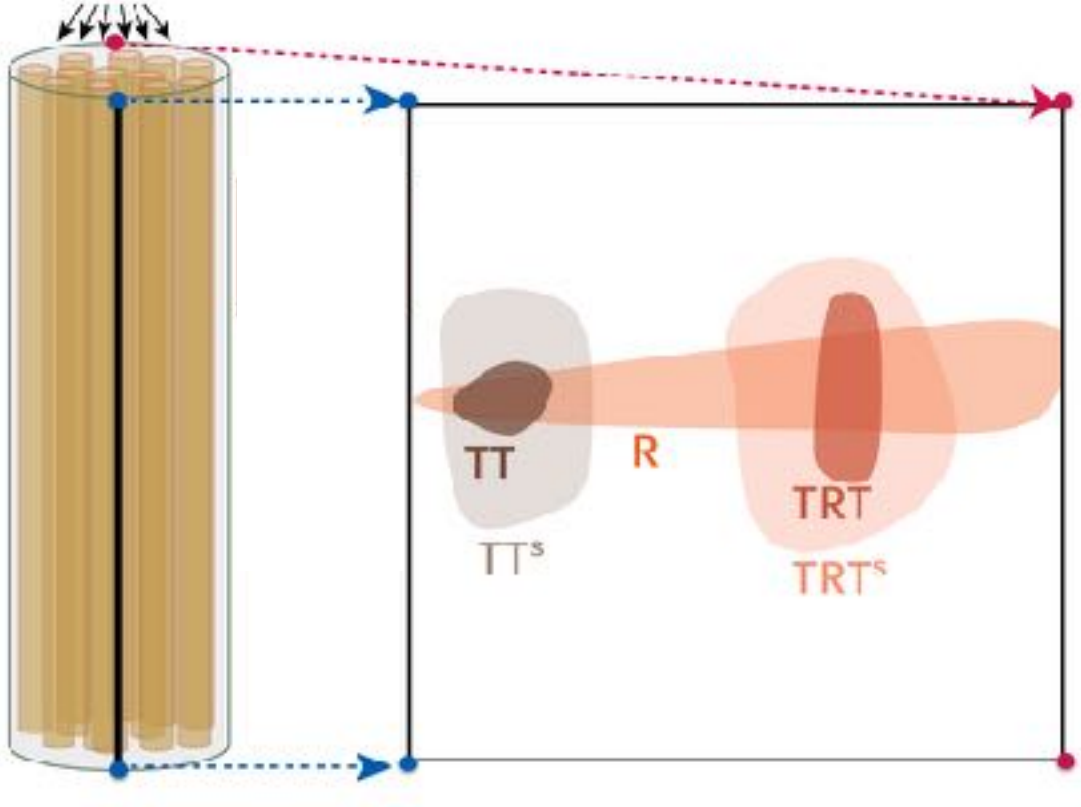


Radiance Distribution Map (RDM)



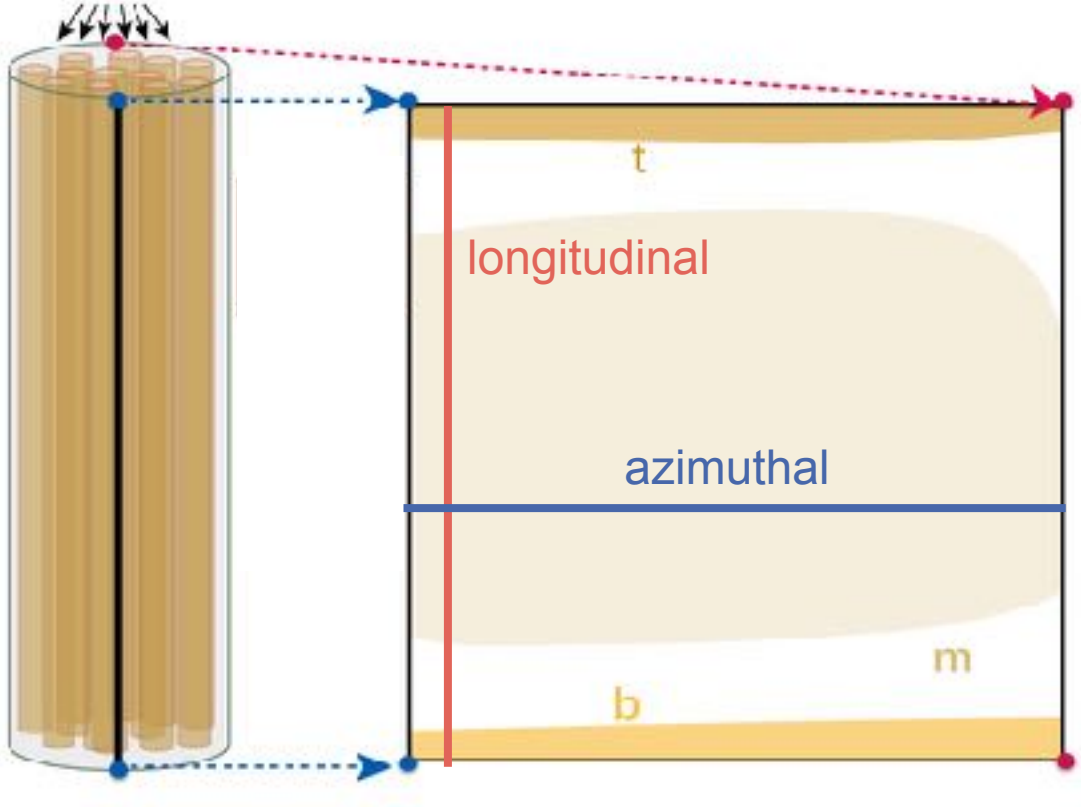
Inherited part, Extended part& Direct transport

SIMULATING THE AGGREGATED BCSDF



Inherited part : *R, TT , TRT , TT^s , TRT^s*

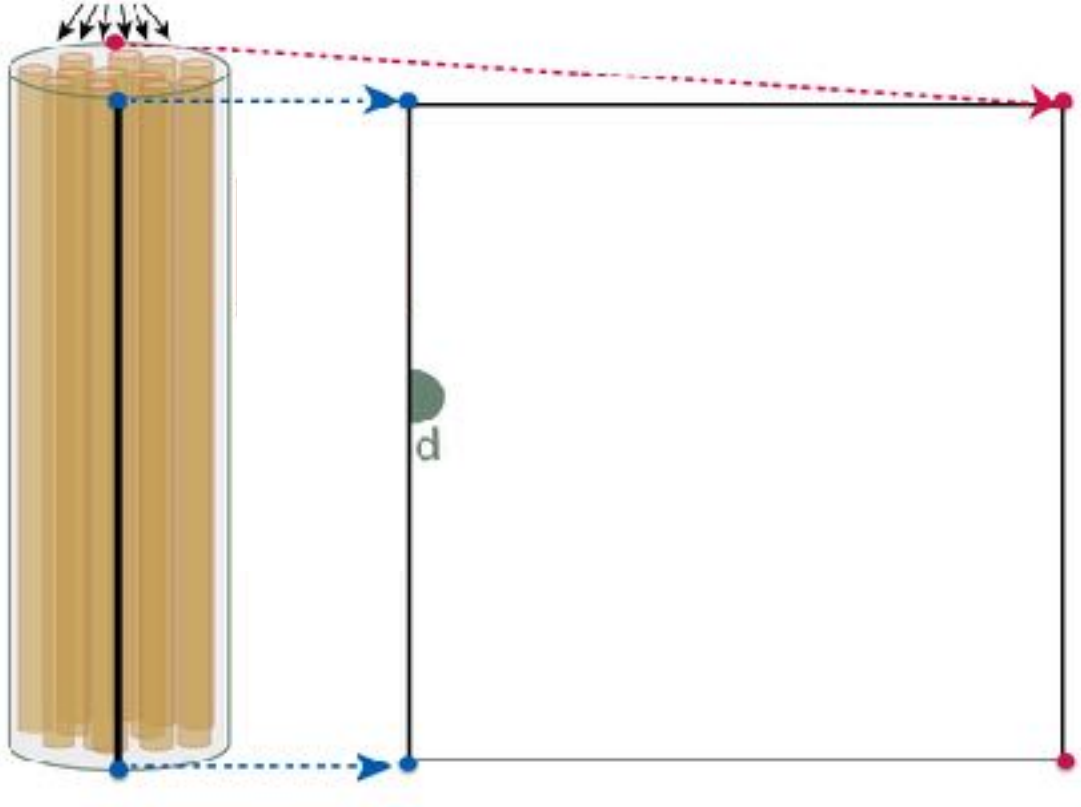
SIMULATING THE AGGREGATED BCSDF



Inherited part : *R, TT , TRT , TT^s , TRT^s*

Extended part: *t ,m and b*

SIMULATING THE AGGREGATED BCSDF

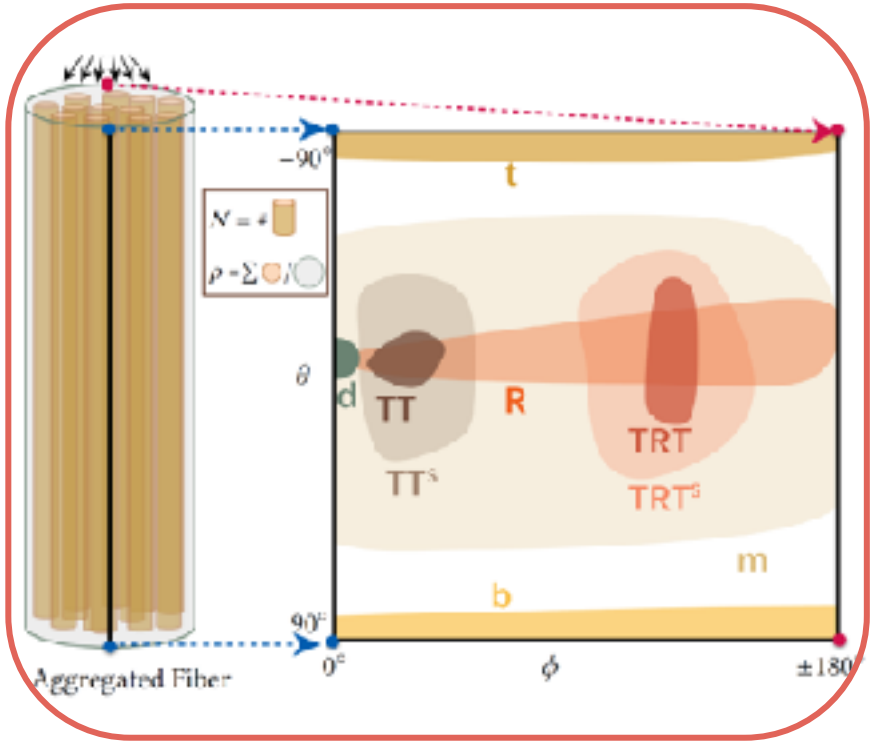


Inherited part : *R, TT , TRT , TT^s , TRT^s*

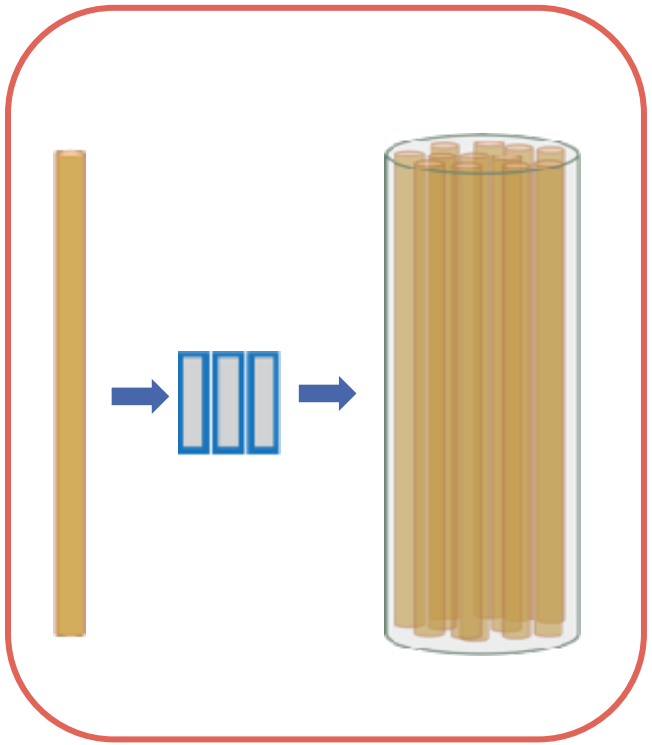
Extended part: *t ,m and b*

Direct transport: *d*

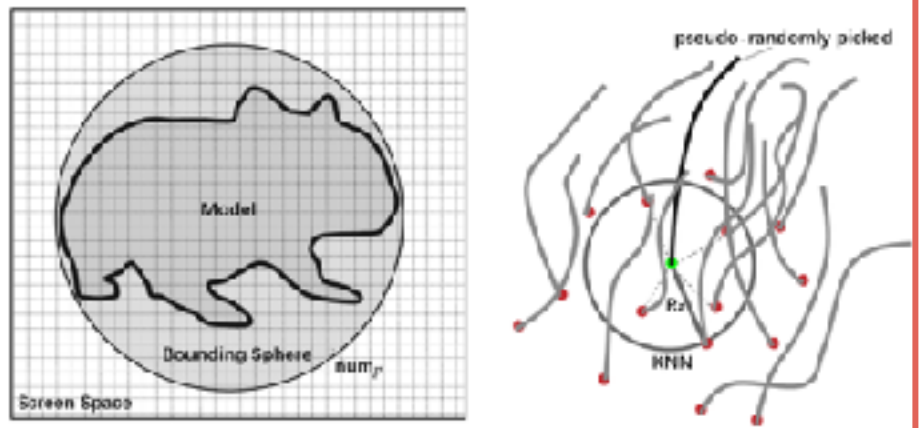
OVERVIEW



Simulating the aggregated BCSDF

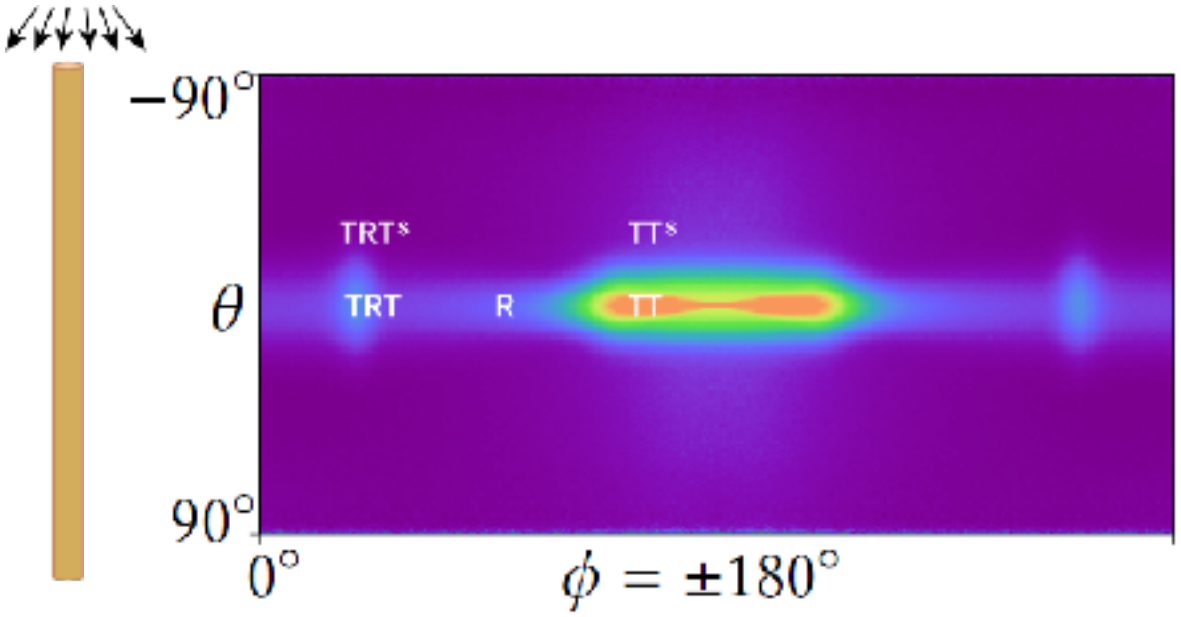


Single to aggregated BCSDF conversion

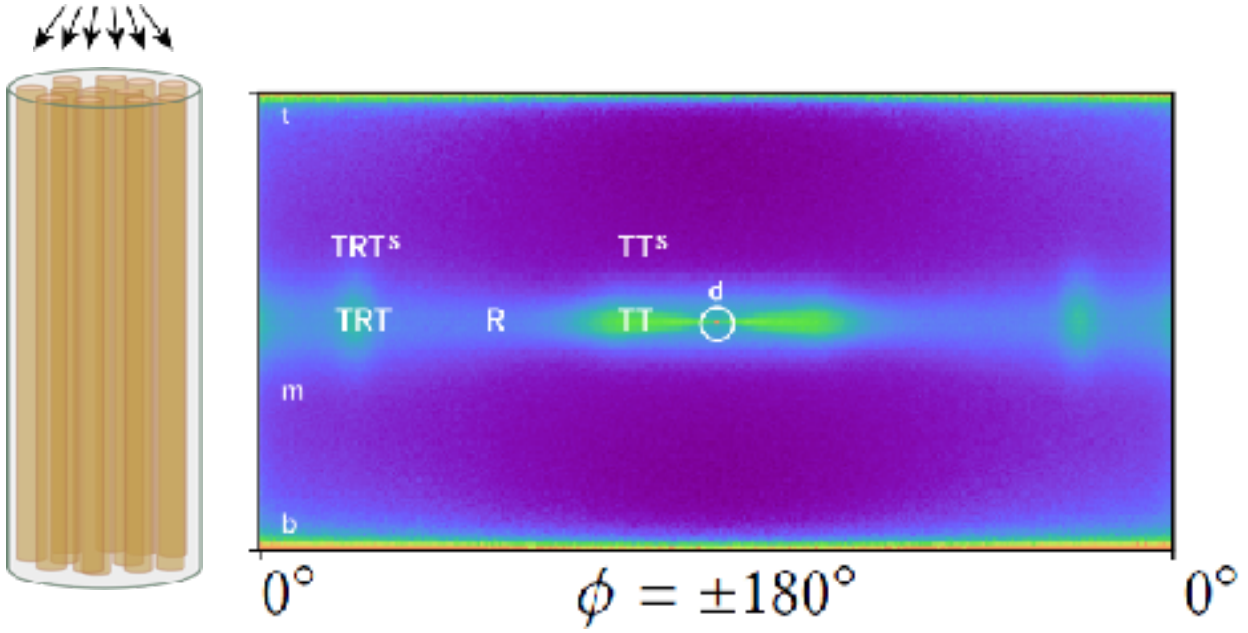


Runtime simplification

SINGLE TO AGGREGATED BCSDF CONVERSION

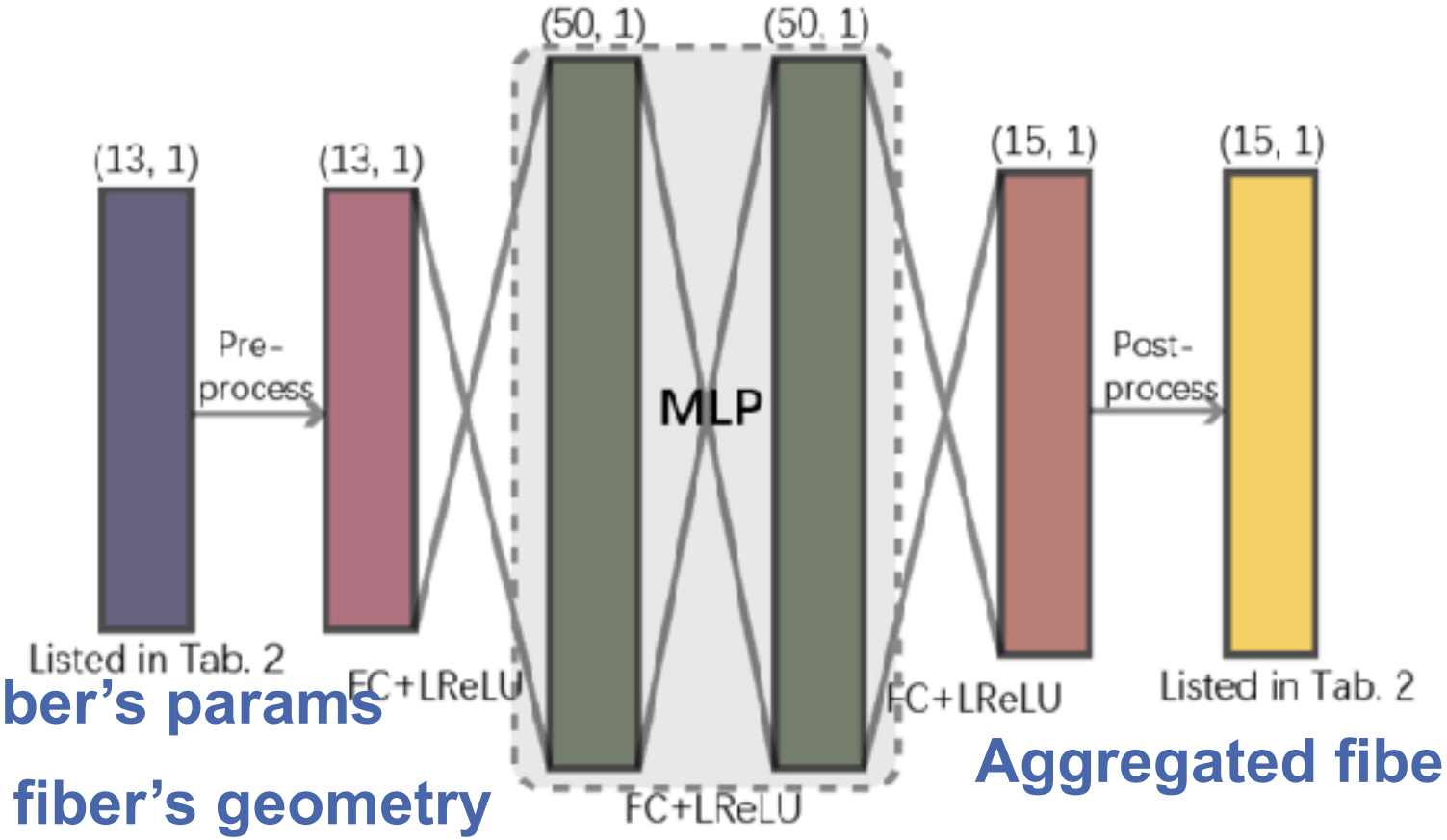


Single fiber (what we know)

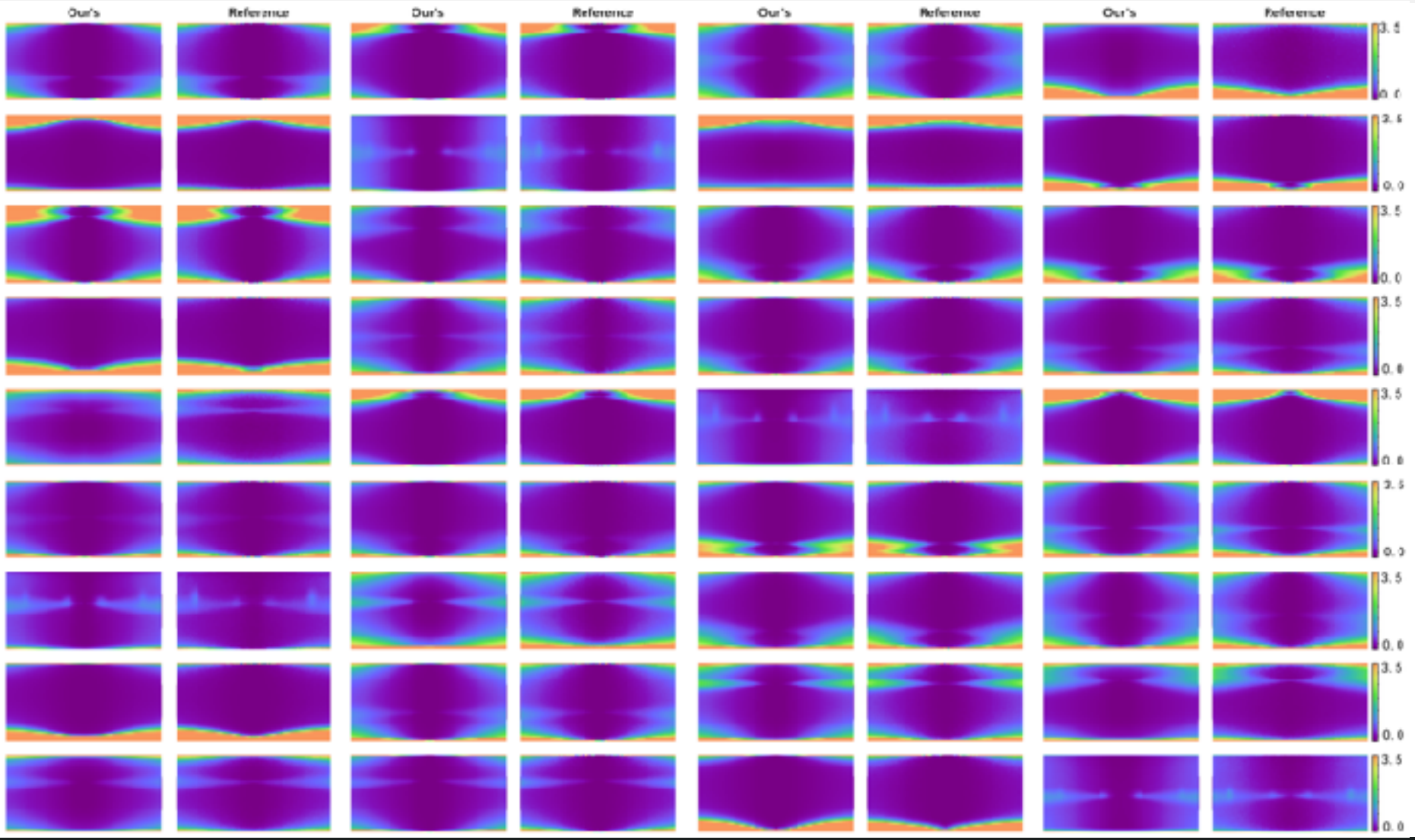


Aggregated fiber (what we want)

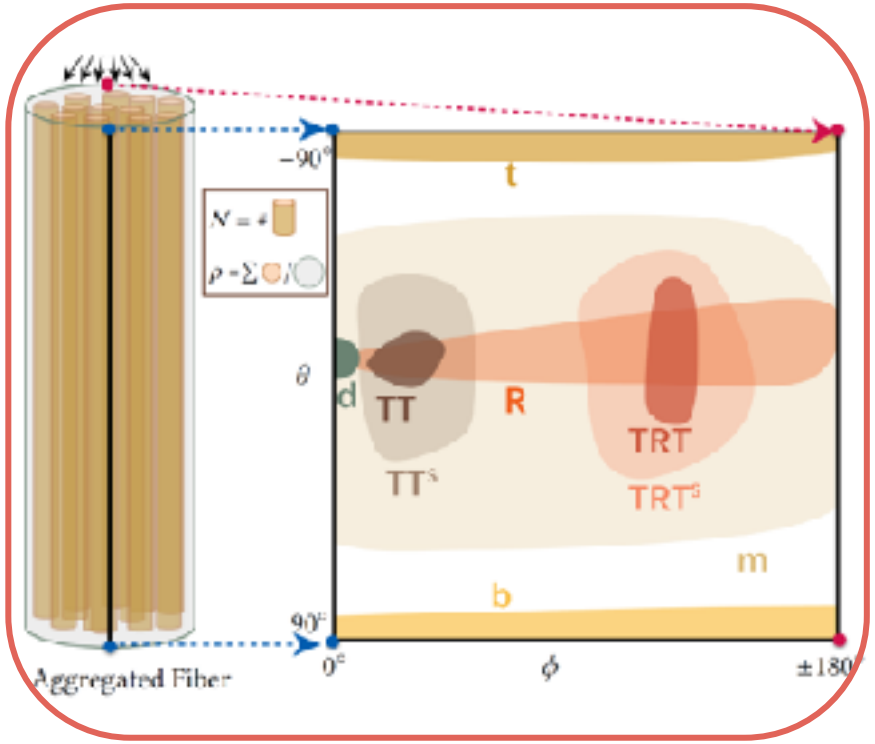
NETWORK



NETWORK RESULTS (RDM)



OVERVIEW



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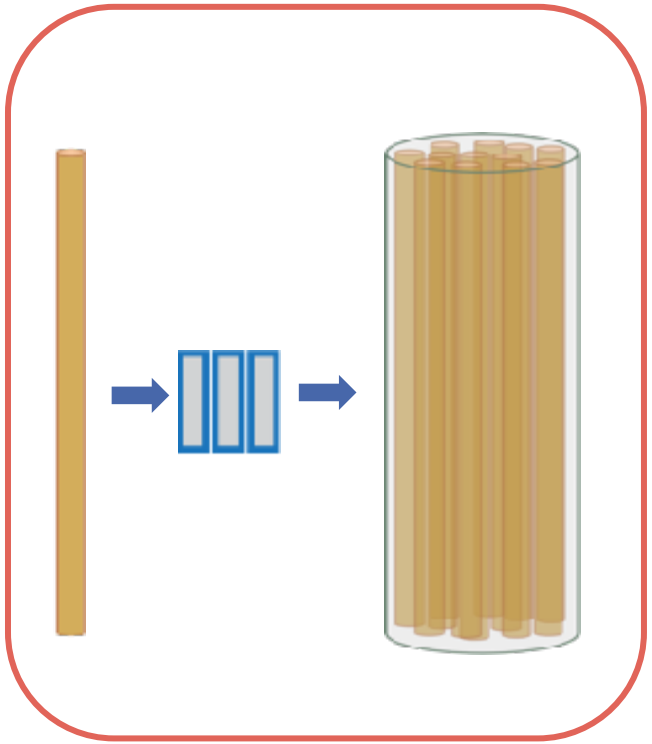
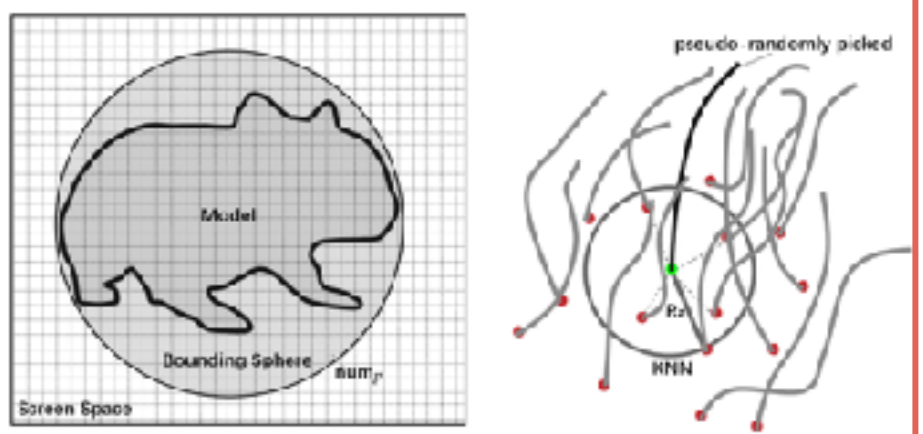


Single to aggregated BCSDF conversion



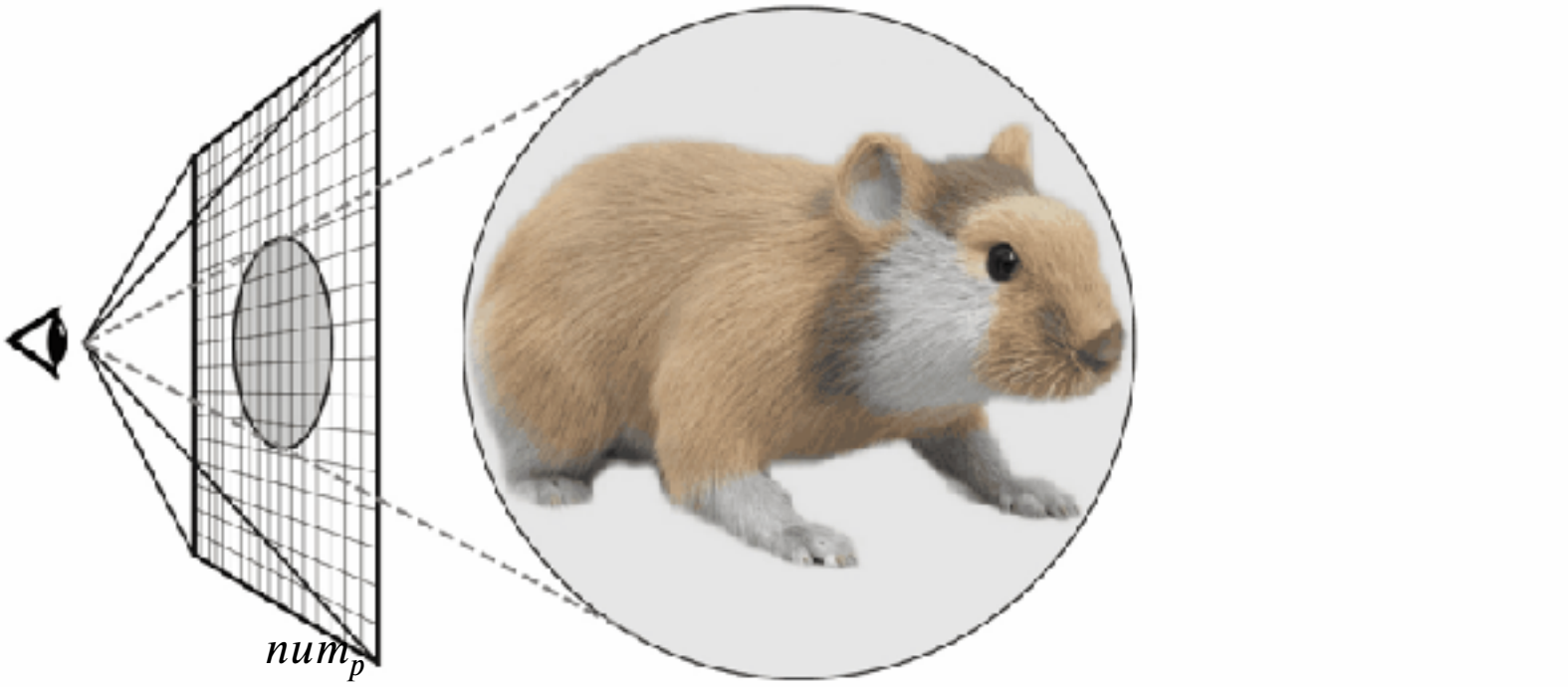
Runtime simplification

RUNTIME SIMPLIFICATION

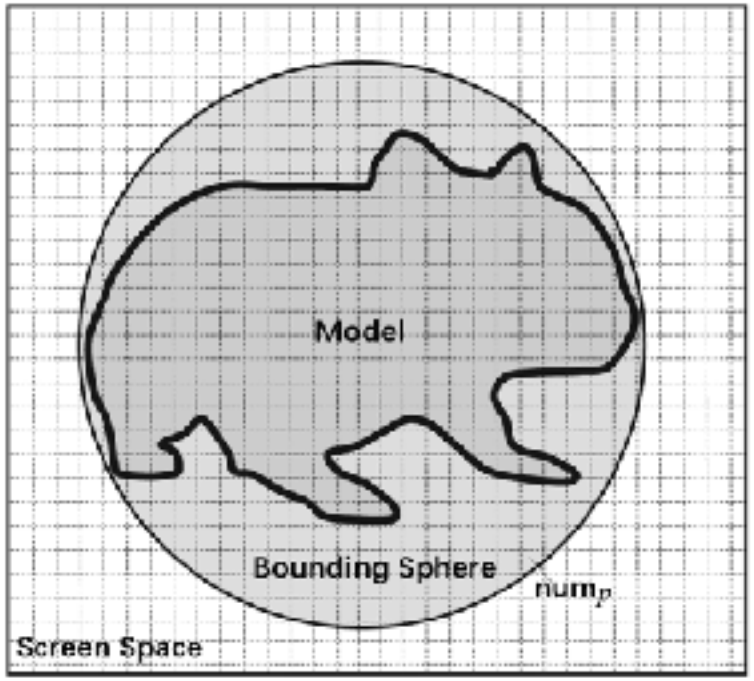
- *Heuristic simplification*
- *Selection of fibers*
- *Determining aggregated parameters*

HEURISTIC SIMPLIFICATION

Assume: Each pixel keeps same number of fibers



HEURISTIC SIMPLIFICATION



First bounce

$$\xi_1 = num_p \cdot \xi_a$$

$$\mathrm{num}_p = \mathrm{num}_{\mathrm{film}} \cdot \frac{\pi \cdot R_s^2}{4 \cdot \|O - C\|^2 \cdot \tan^2 \theta_{\mathrm{fov}}}$$

HEURISTIC SIMPLIFICATION

Use first bounce fibers for secondary bounces

50% fibers kept for secondary bounces

Not obviously seen!

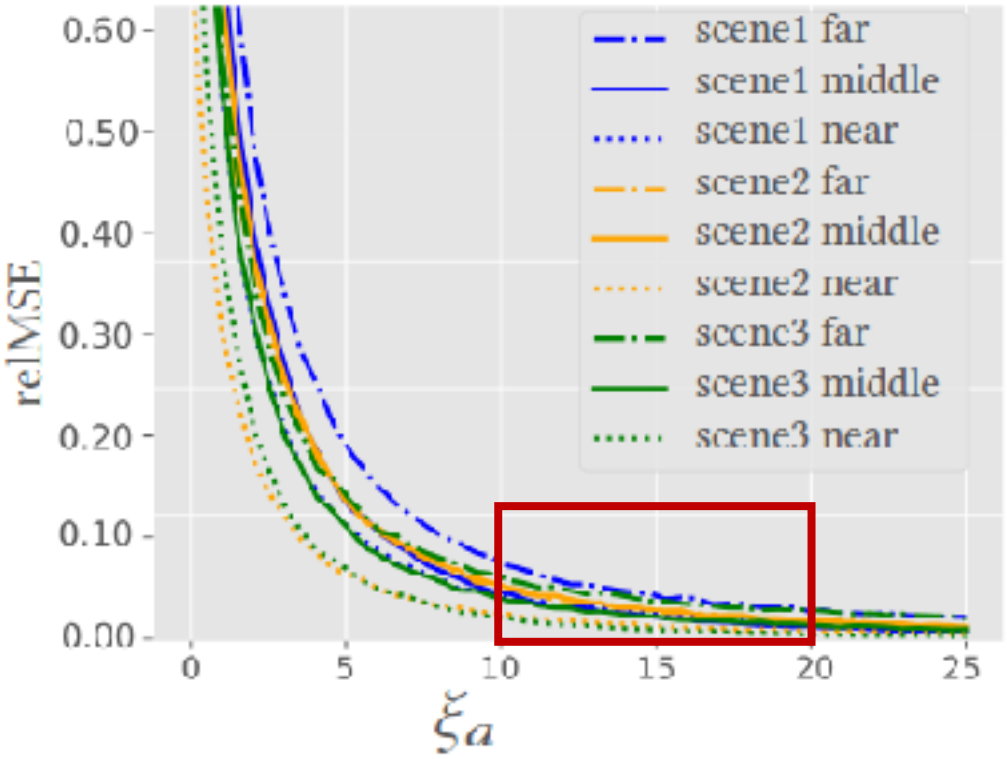
More aggressively simplification than first bounce fibers

Secondary bounces

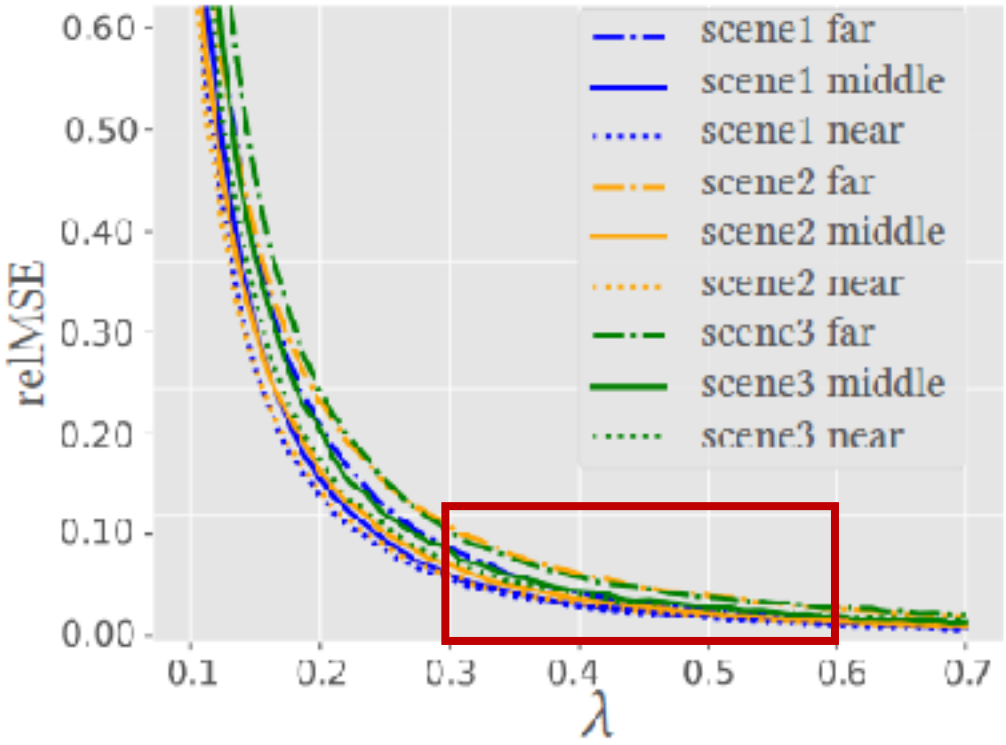
$$\xi_n = \xi_1 \cdot \lambda^{\max\{n-1,4\}} \quad (n \geq 2)$$

HEURISTIC SIMPLIFICATION

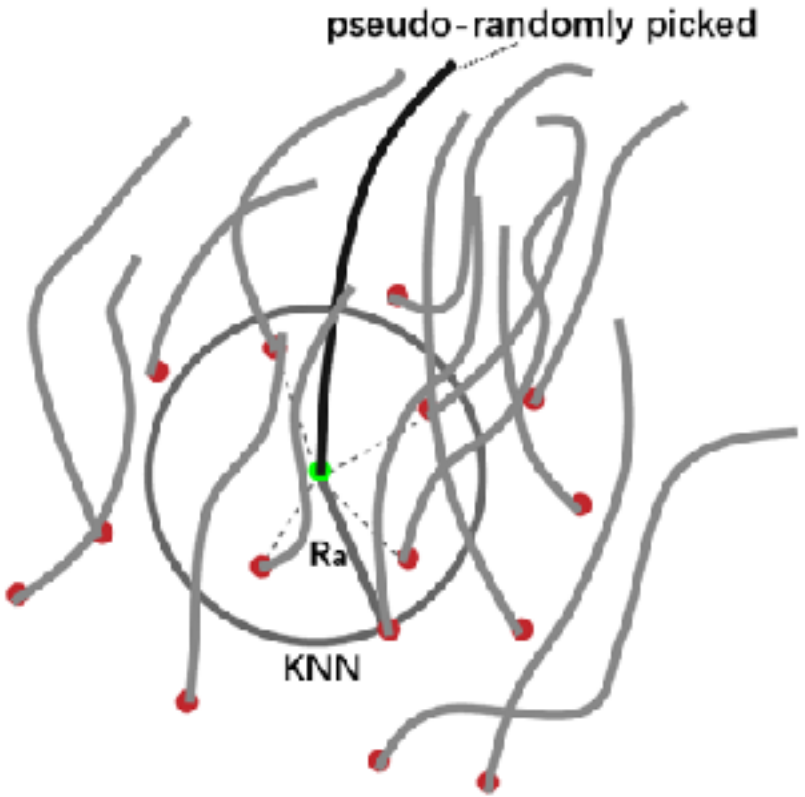
Proper range



Proper range



SELECTION OF FIBERS

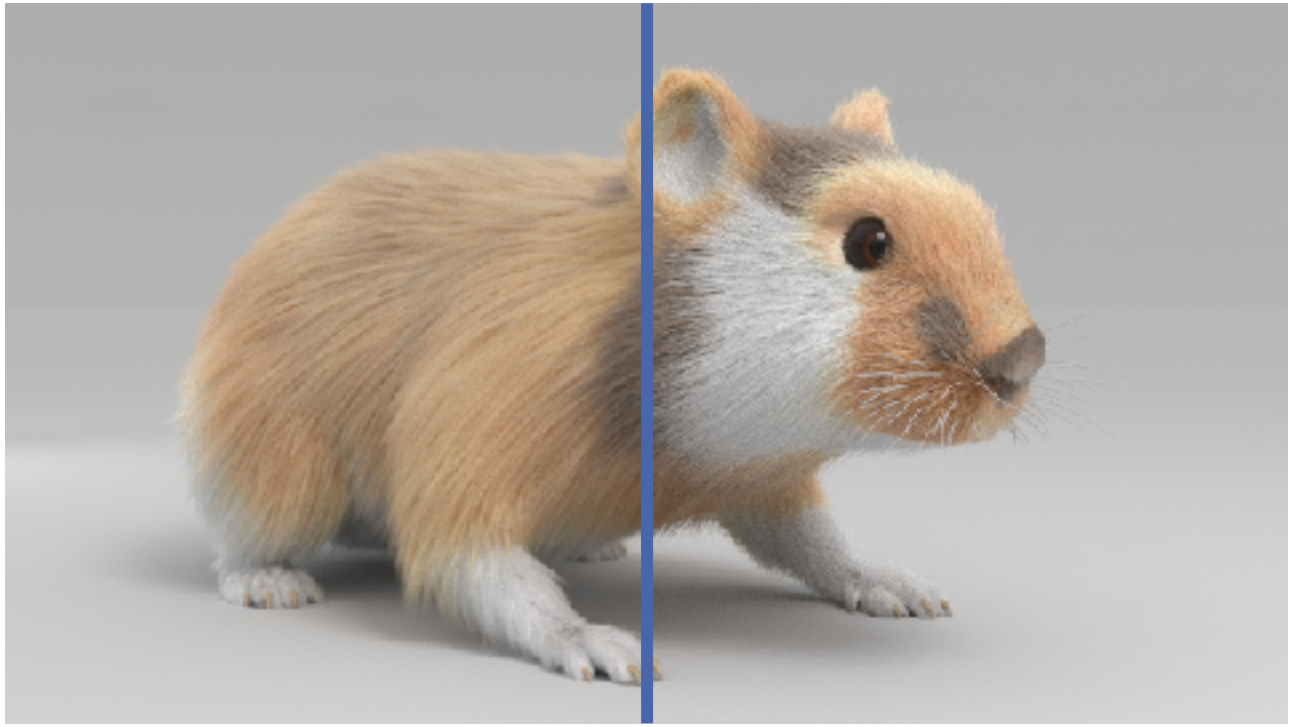


low-discrepancy sequence

- *avoids clumping*
- *temporal coherence*

DETERMINING AGGREGATED PARAMETERS

Match the appearance



Radius (KNN)

Density (recalculate)

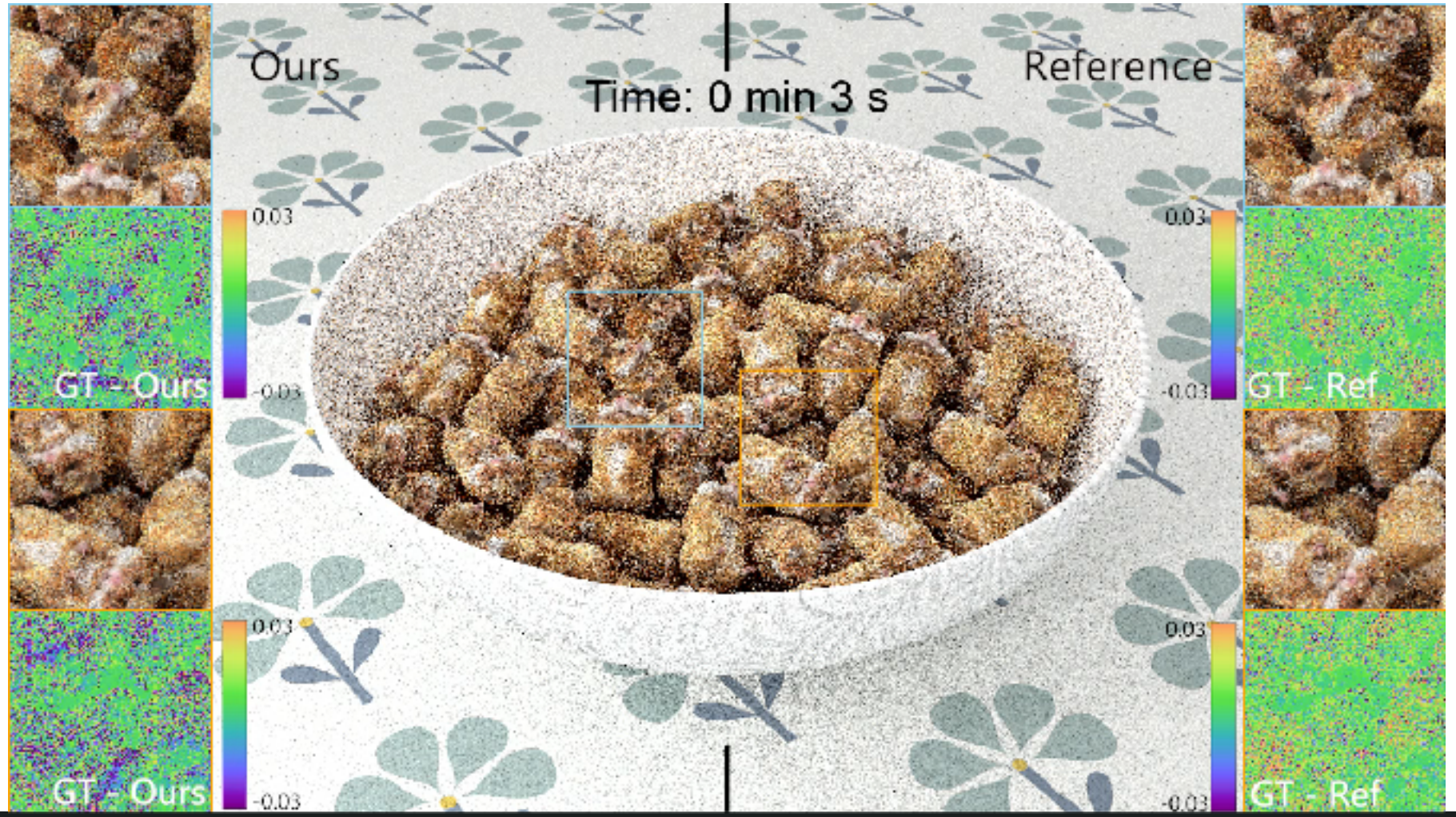
Absorption (average)

RESULTS AND COMPARISONS

ZOOM IN/OUT

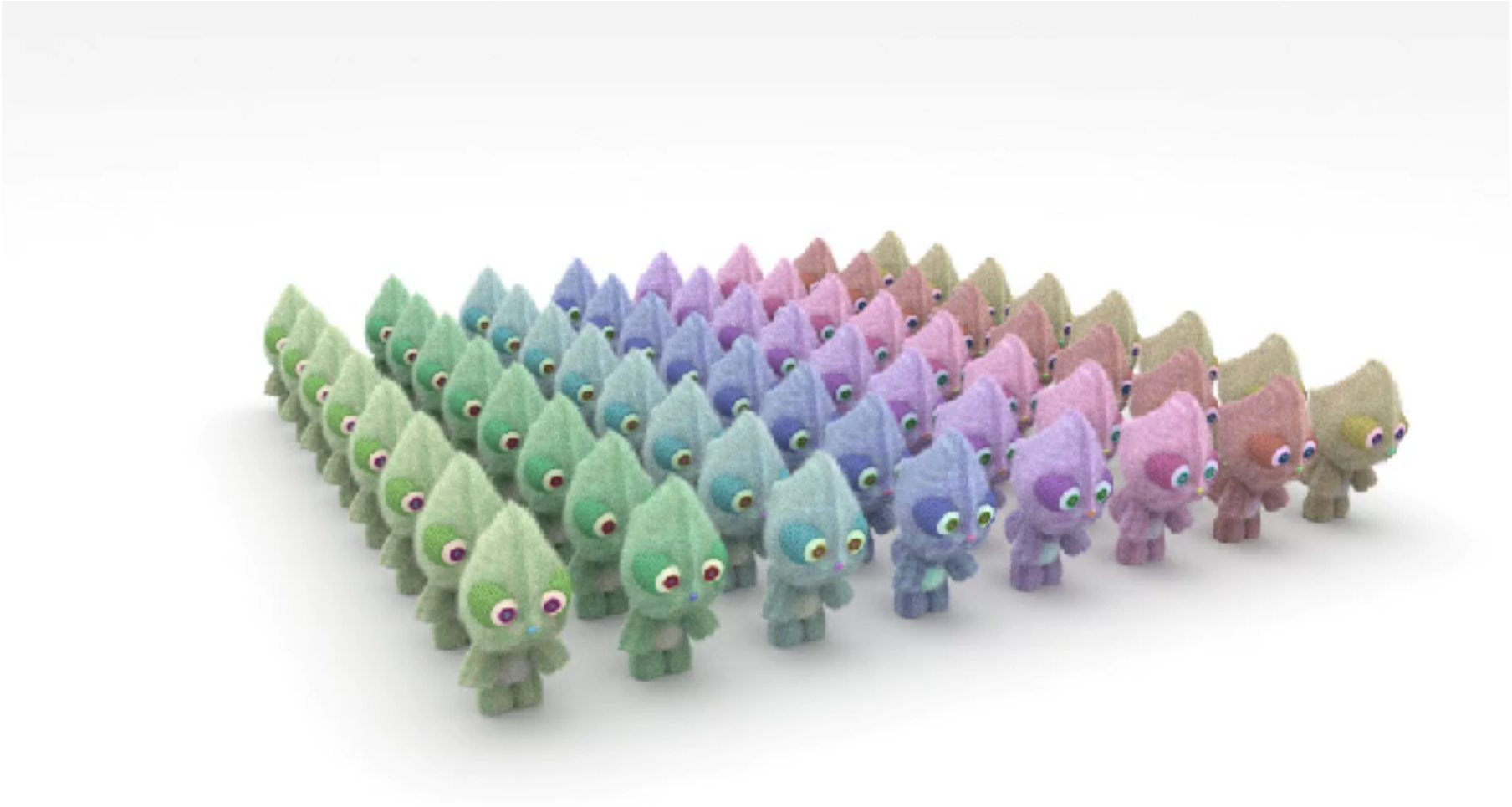
PROGRESSIVE RENDERING

#fibers: 1.8M / 147M



LARGE SCALE SCENE

DYNAMIC GEOMETRY

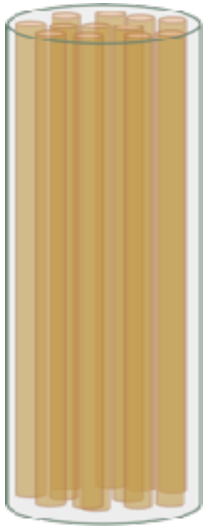


CONCLUSION
LIMITATIONS
FUTURE WORK

OUR CONTRIBUTION

Simply thicken

Aggregation (our method)



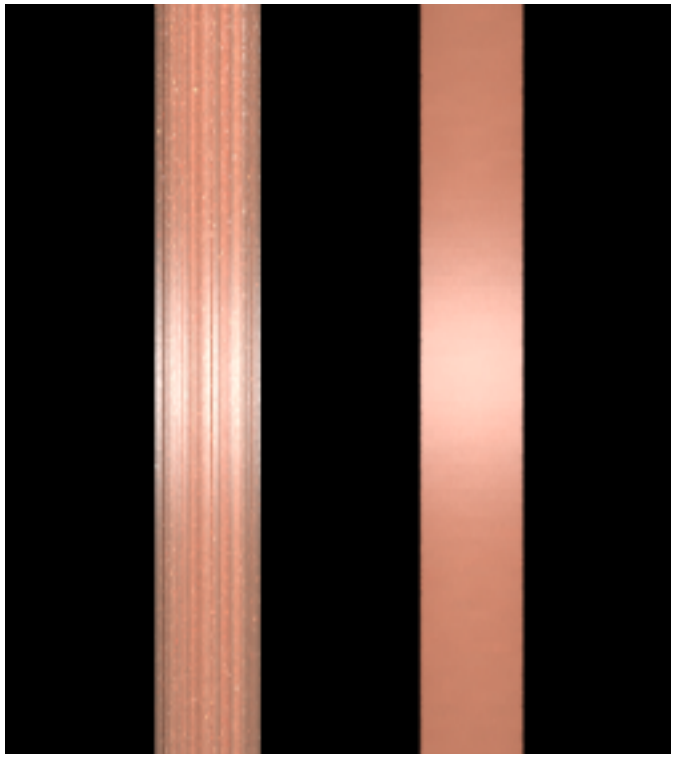
✓ Accuracy

✓ Efficiency

✓ LOD

LIMITATION

- ***Far-field only***
- ***Fly-away fibers and fiber misalignment***
- ***Spatially-varying simplification***



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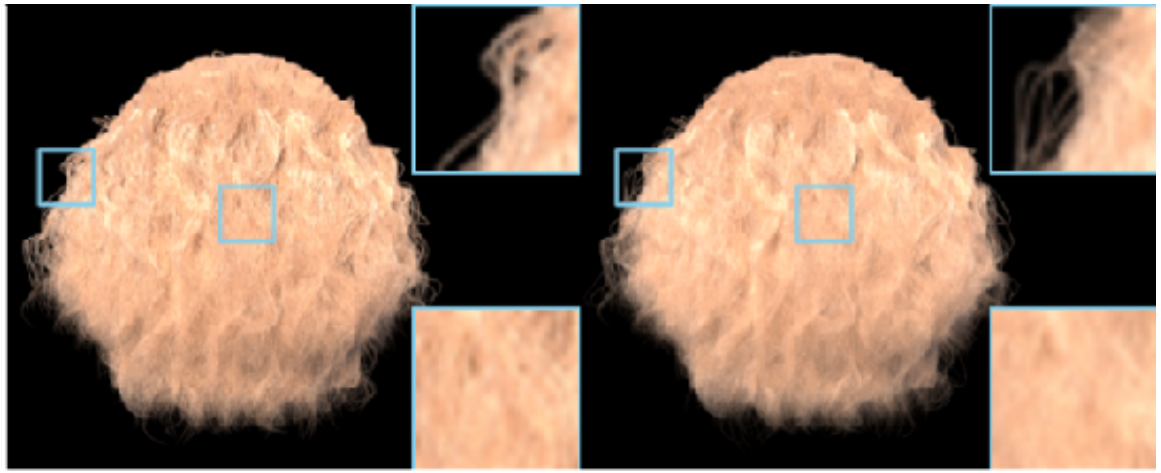

LIMITATION

- *Far-field only*
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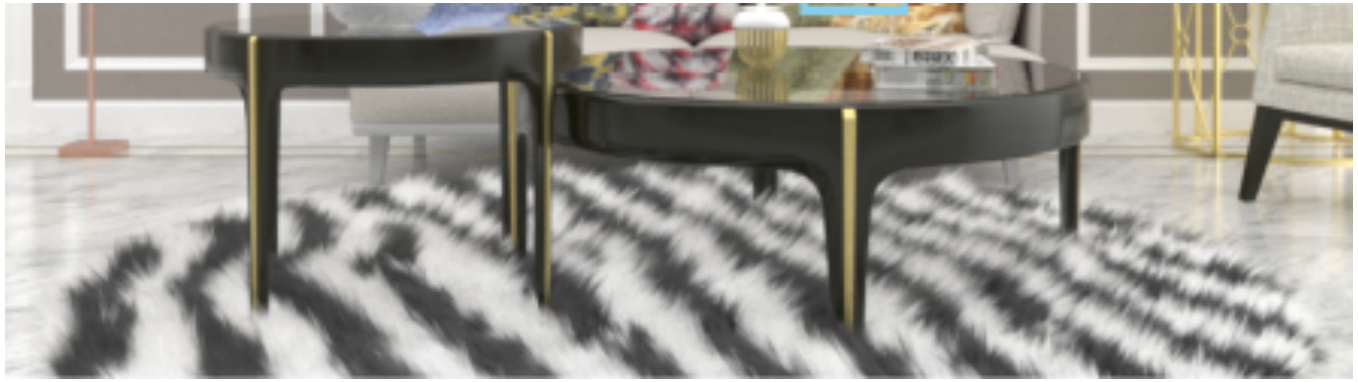
- ***Spatially-varying simplification***



FUTURE WORK

- ***Real-time rendering***
- ***Artist-friendly interpretation***
- ***Cloth rendering***

THANK YOU!

ACKNOWLEDGEMENTS

- *Anonymous reviewers*
- *National Key R&D Program of China No. 2020YFB1708900*
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- *Ling-Qi Yan is supported by gift funds from Adobe, Dimension 5 and XVerse*