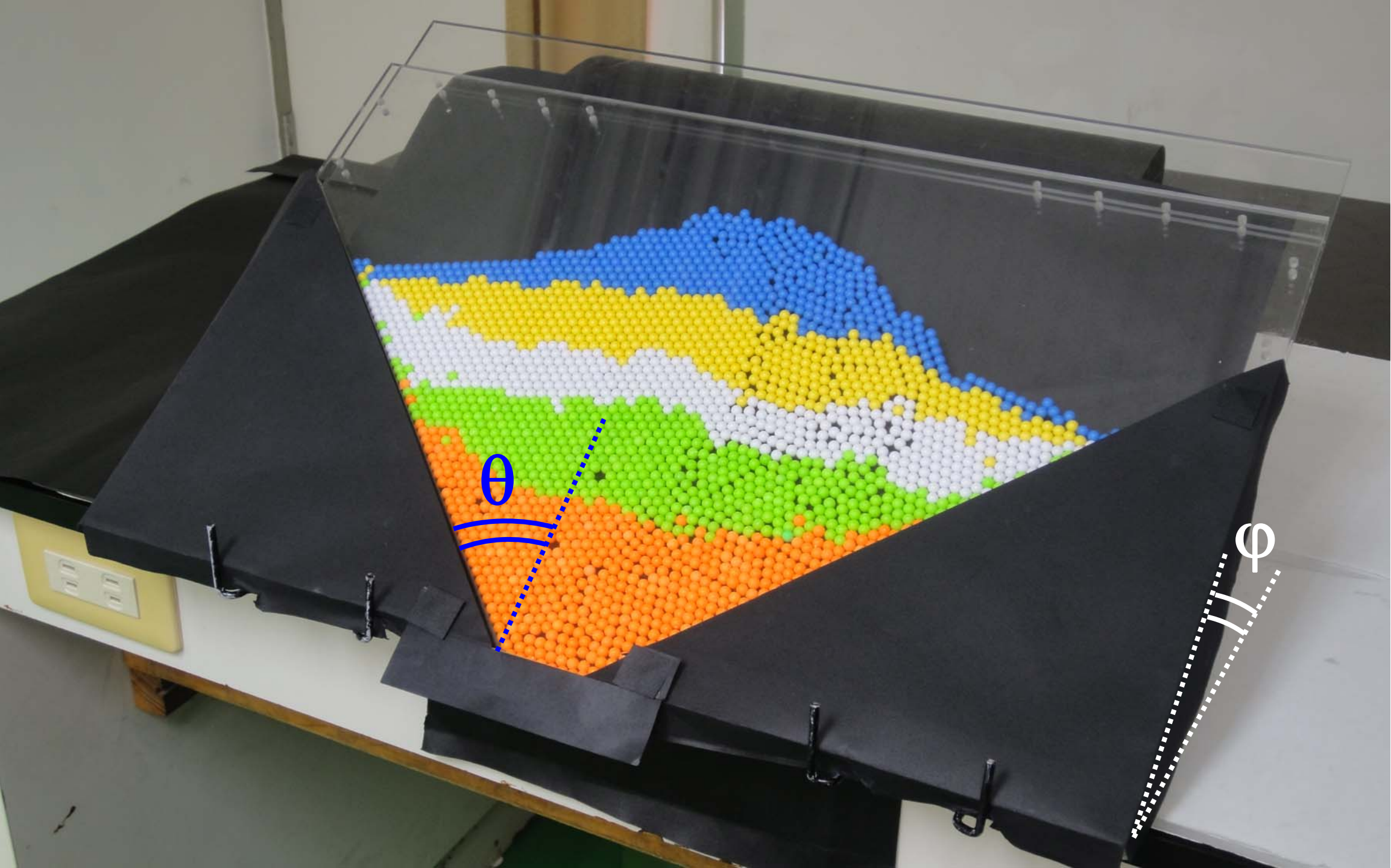
2012 APCYS

Reverse Ordering in Dynamical Two-Dimensional Hopper Flow

Hao-Wen Dong and Chen-Chieh Ping


θ
φ

Entry Order

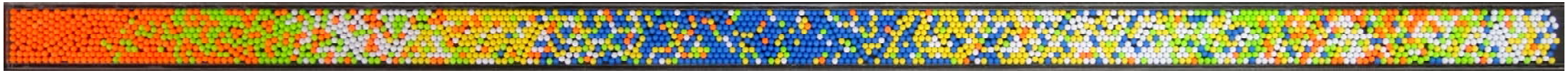
Earlier Later

Exit Order

$\theta=30^o$

Earlier Later

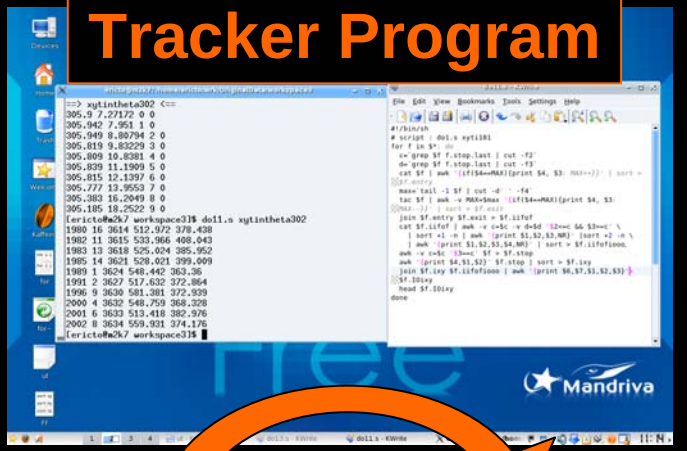
$\theta=60^o$



Earlier Later

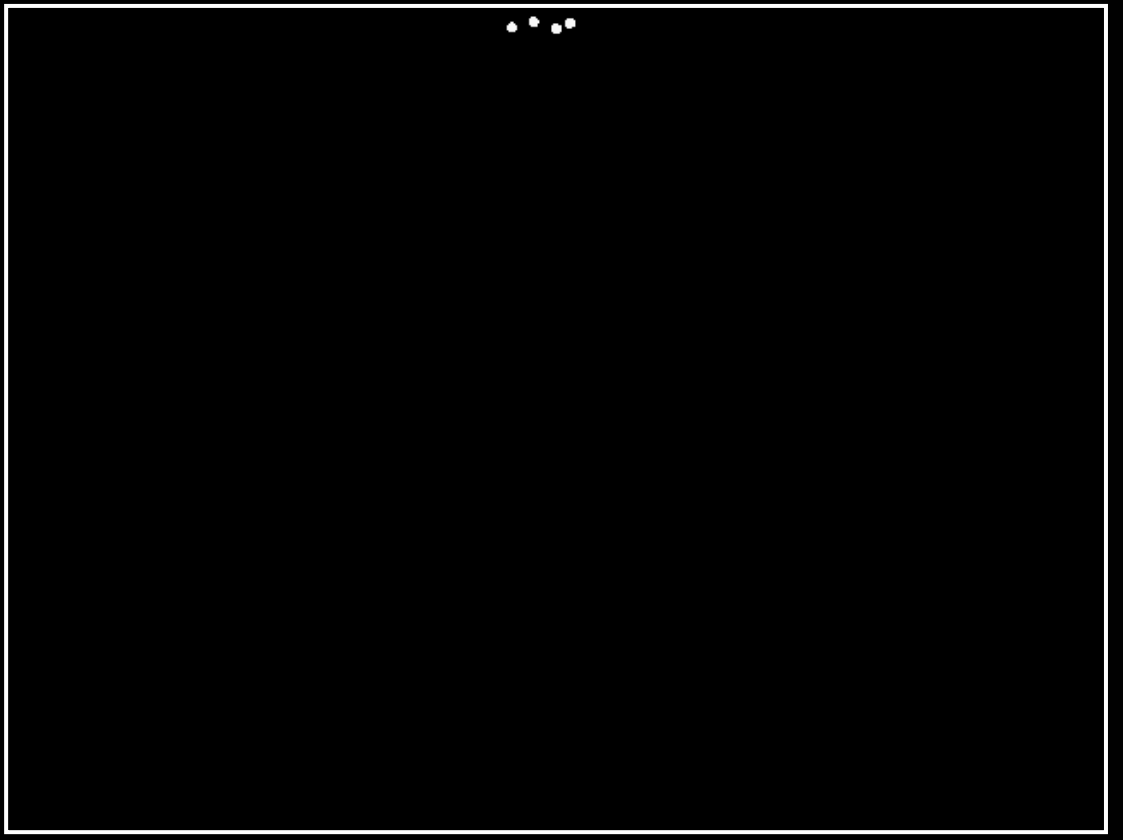
Reverse Ordering

Tracker Program

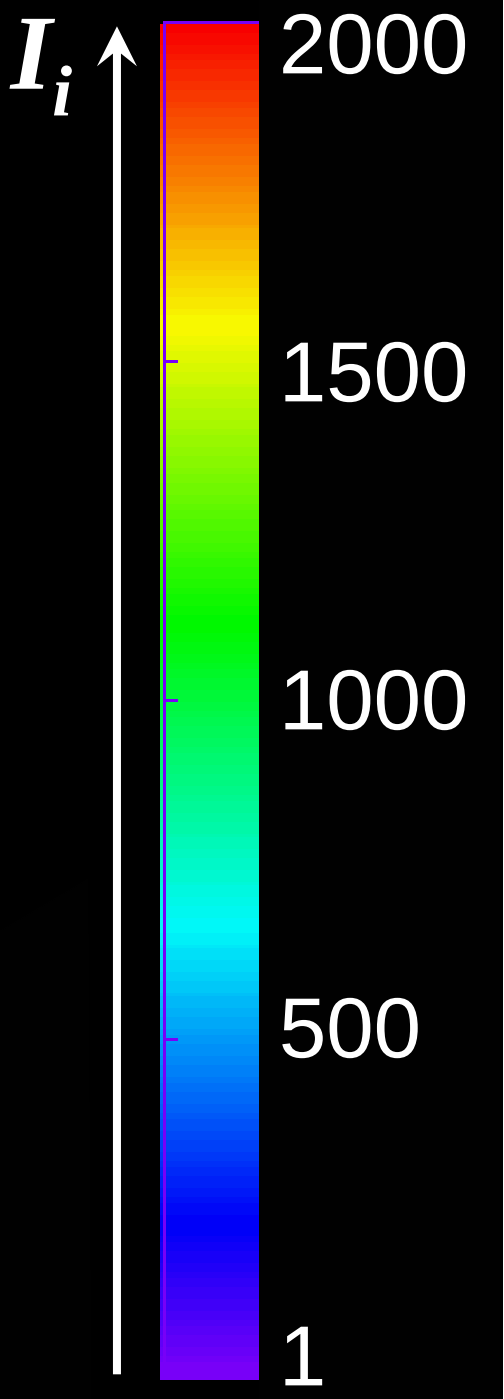


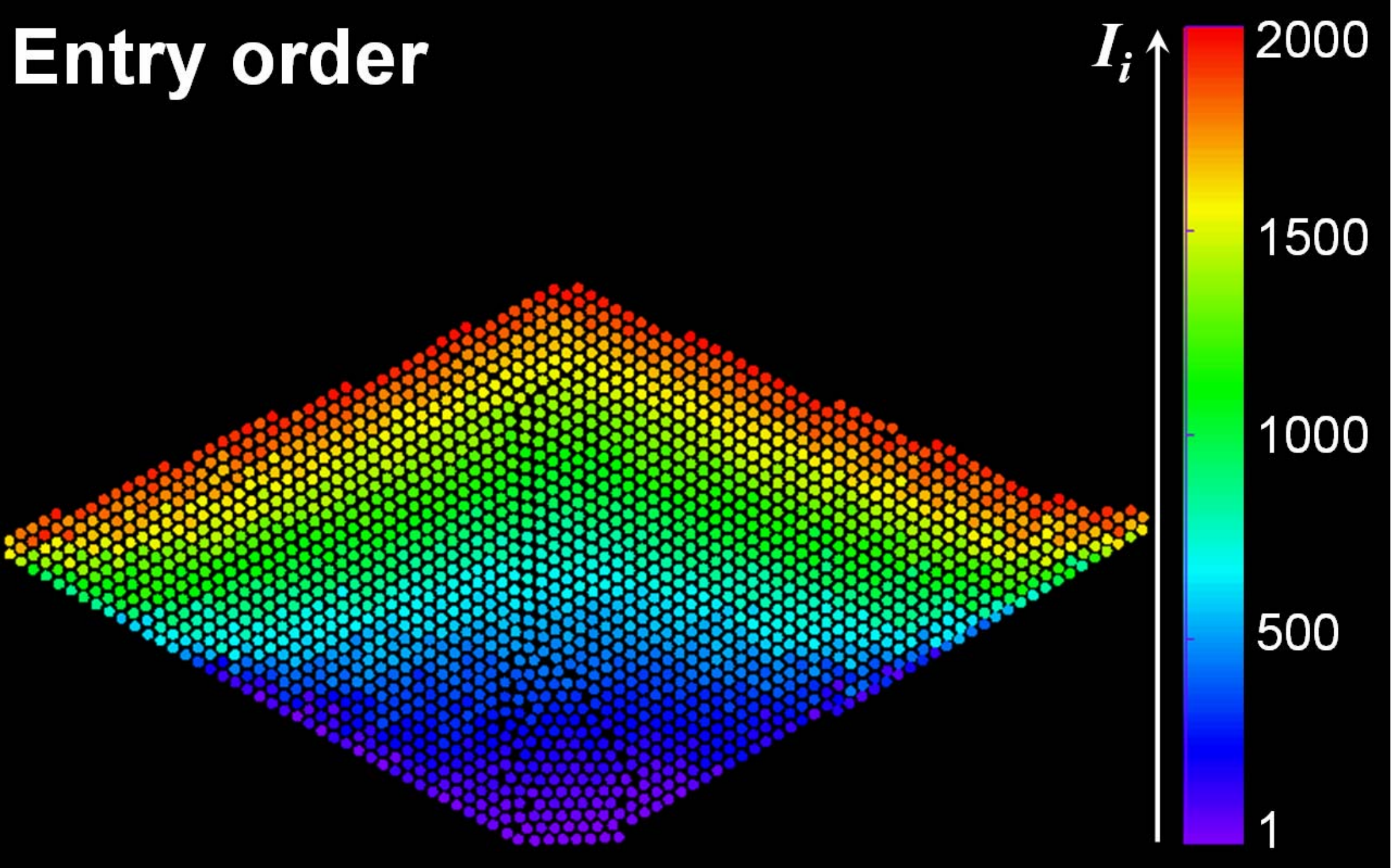
Original Video

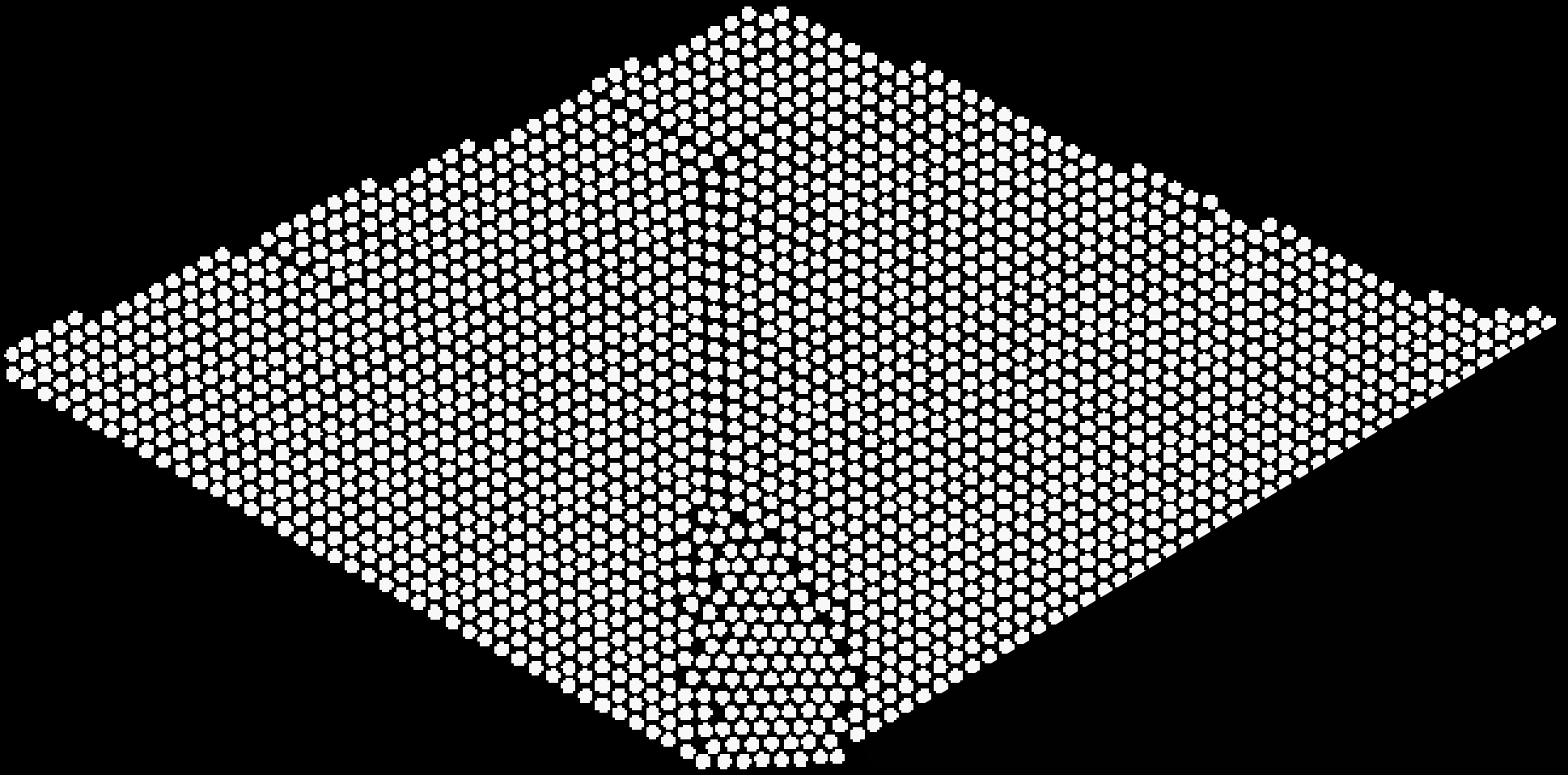
Program Output



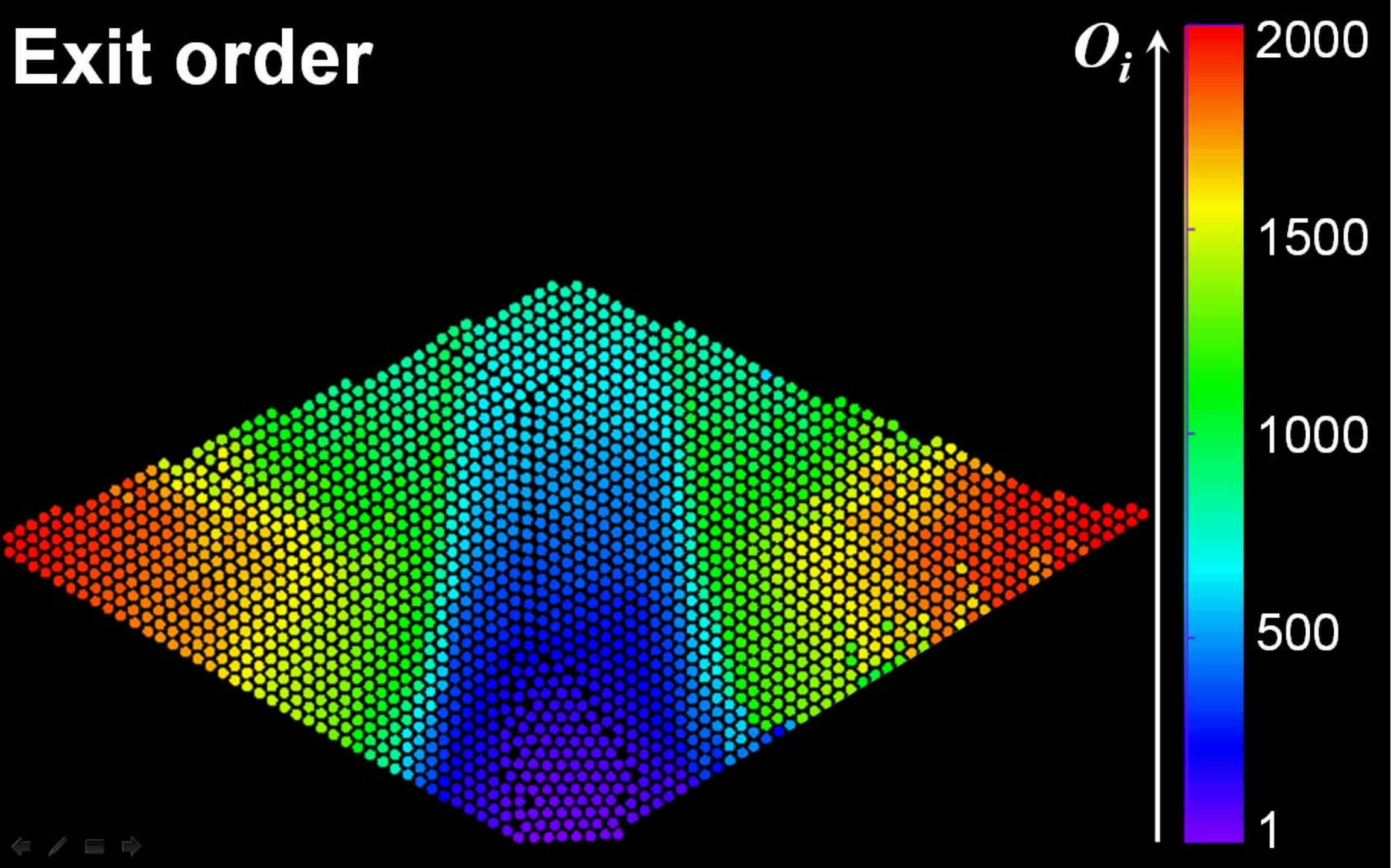
Entry order

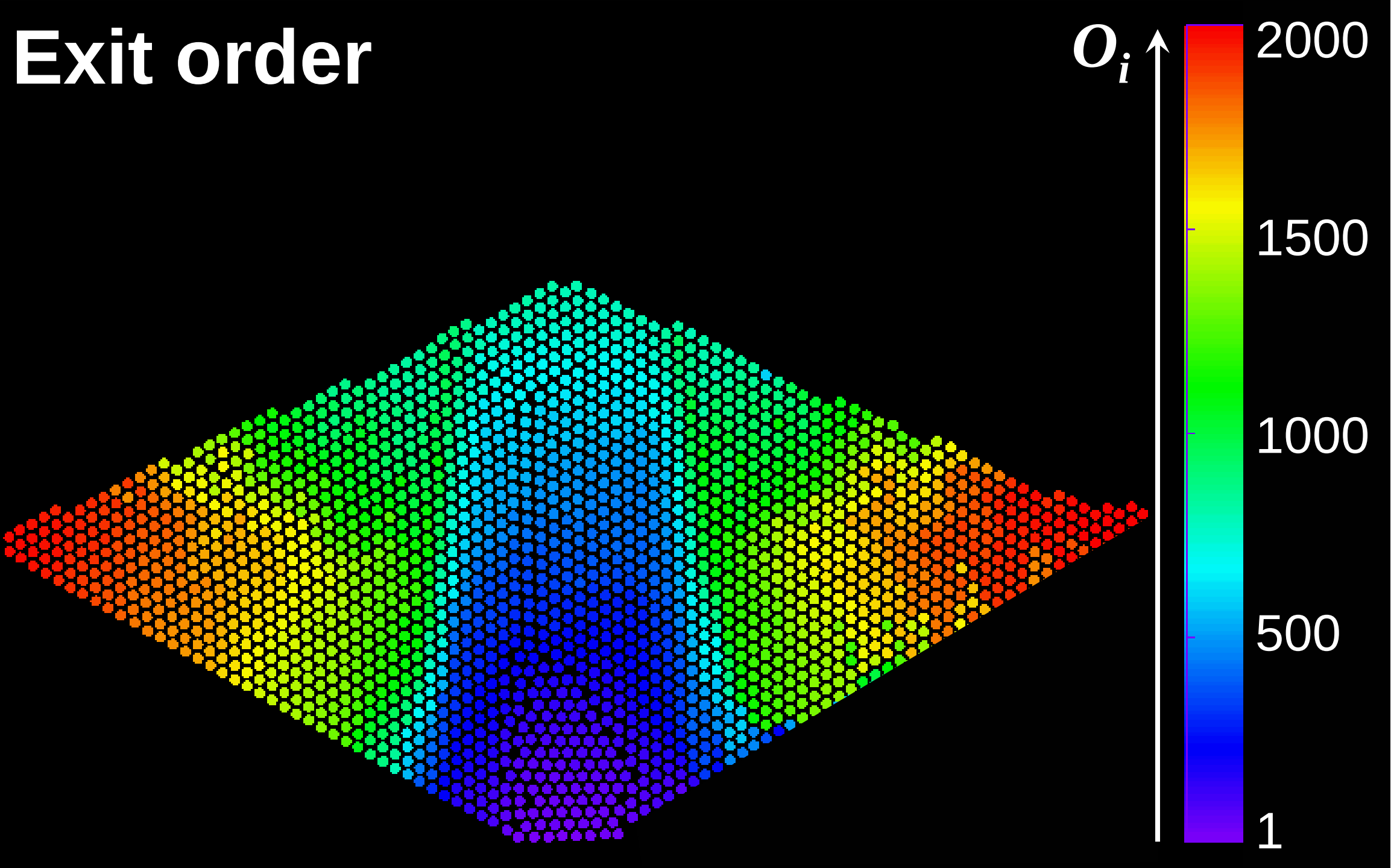


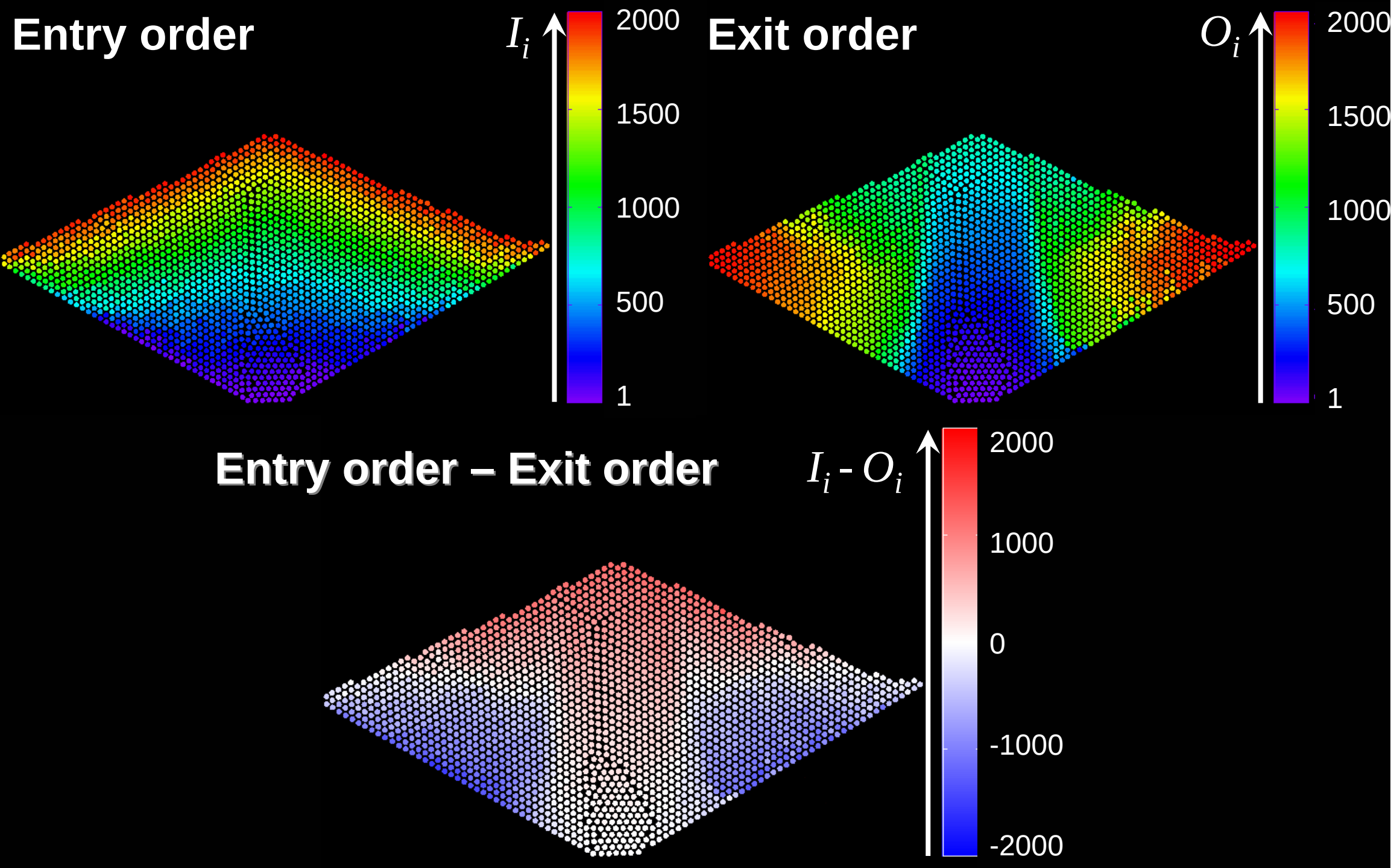

Entry order
I_i
2000
1500
1000
500
1

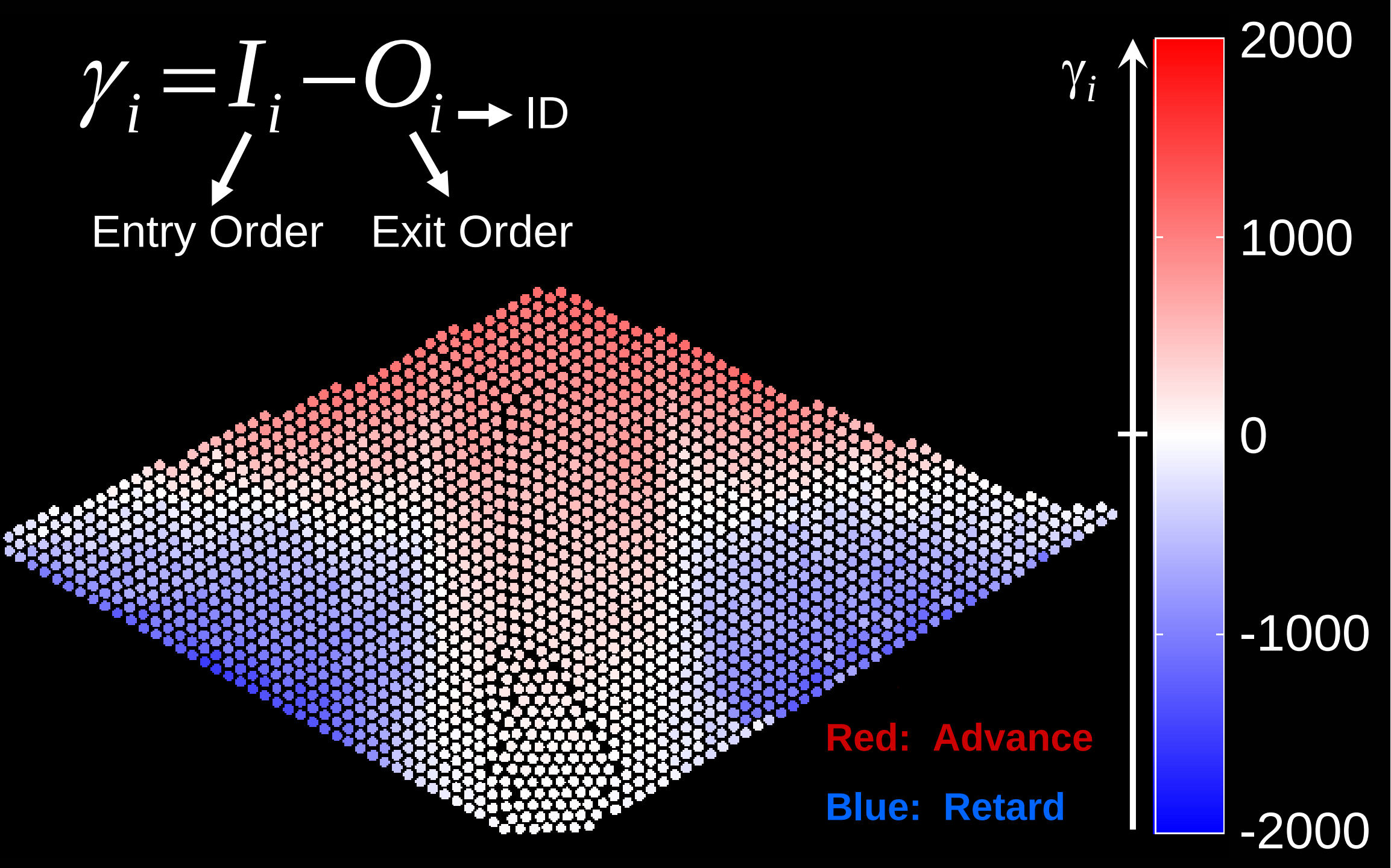


Exit order




Exit order
O_i
2000
1500
1000
500
1

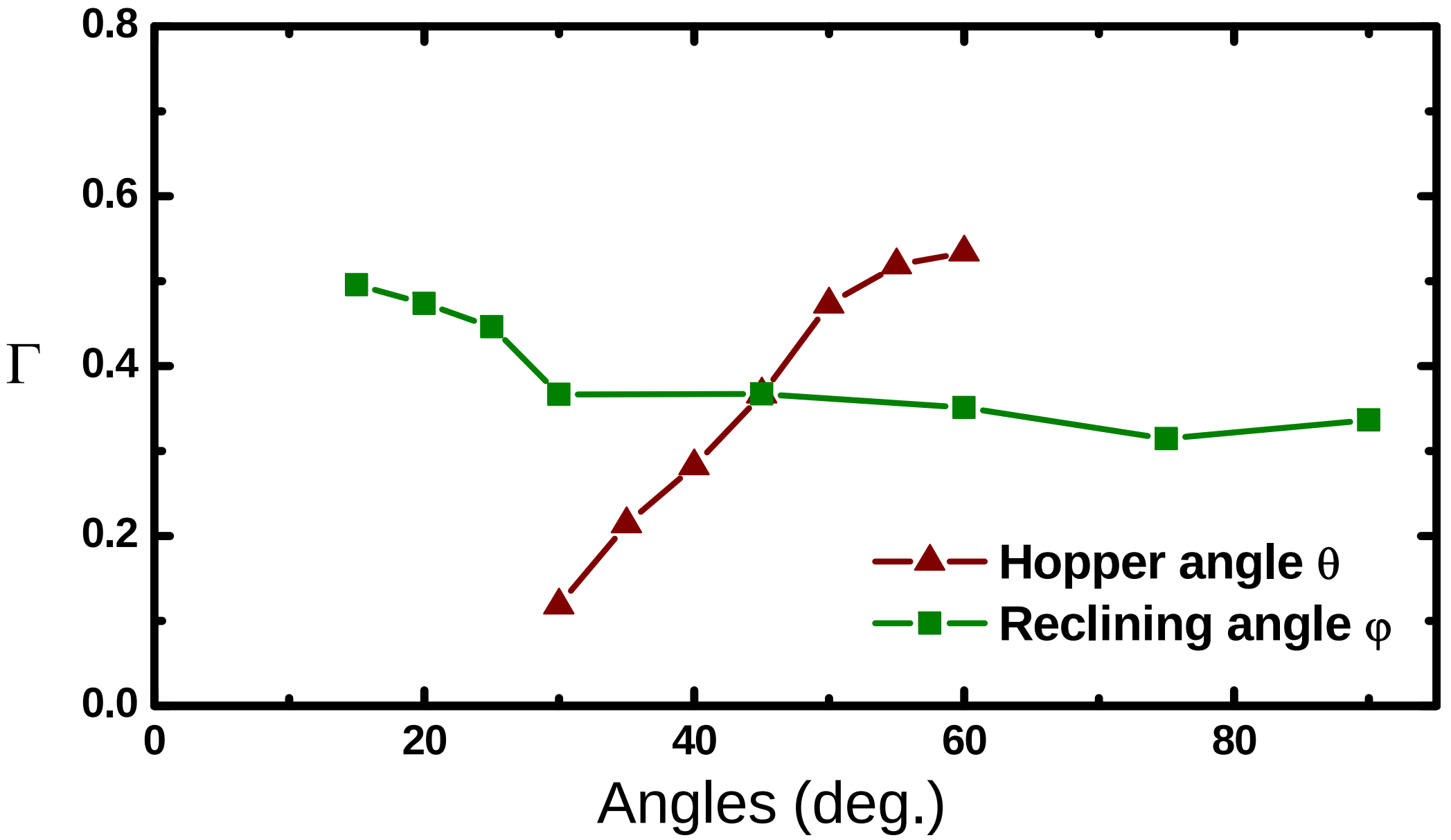

Entry order
I_i
2000
1500
1000
500
1
Exit order
O_i
2000
1500
1000
500
1
Entry order – Exit order
I_i - O_i
2000
1000
0
-1000
-2000

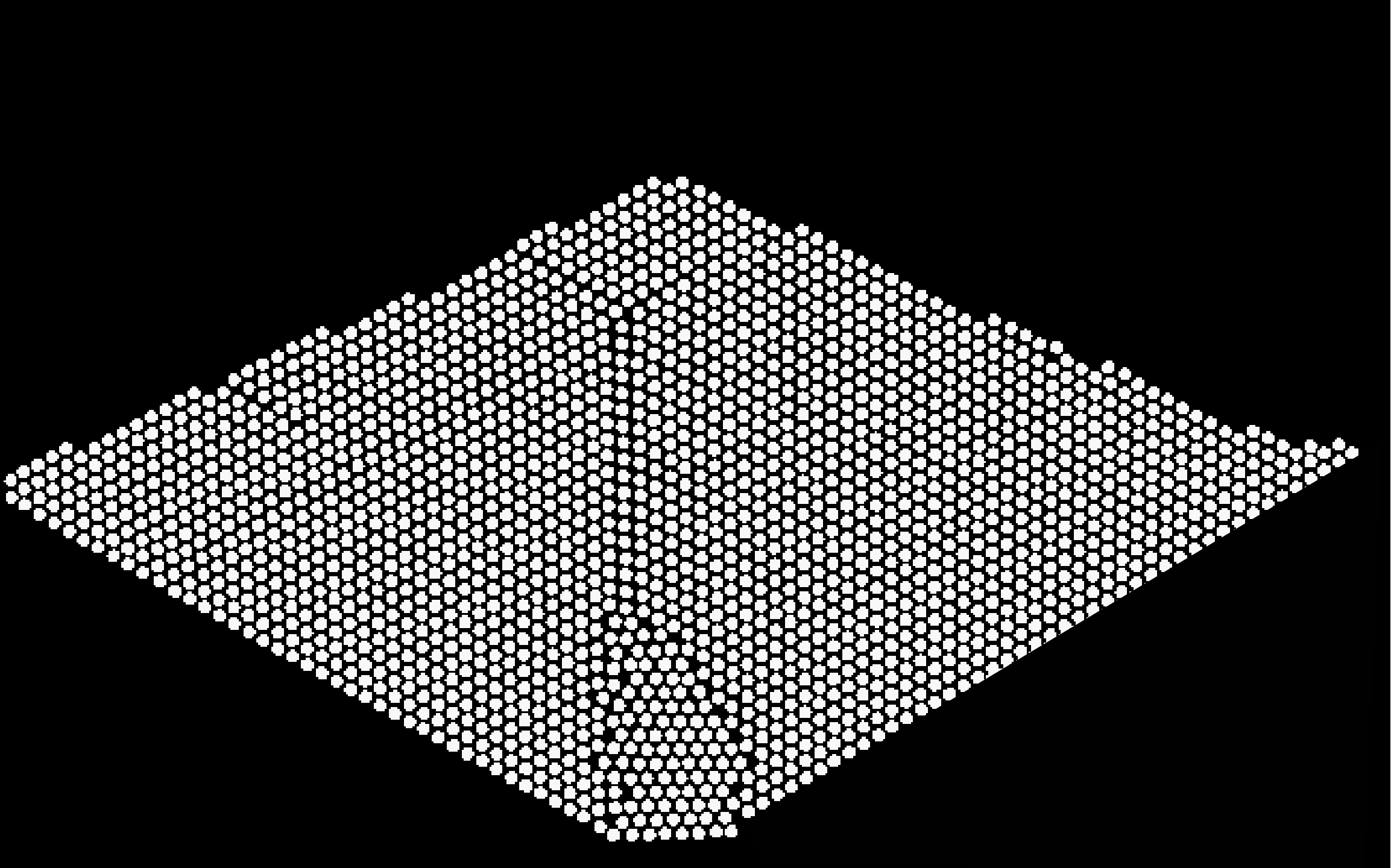

$\gamma_i \equiv I_i - O_i$
ID
Entry Order
Exit Order
γ_i
2000
1000
0
-1000
-2000
Red: Advance
Blue: Retard

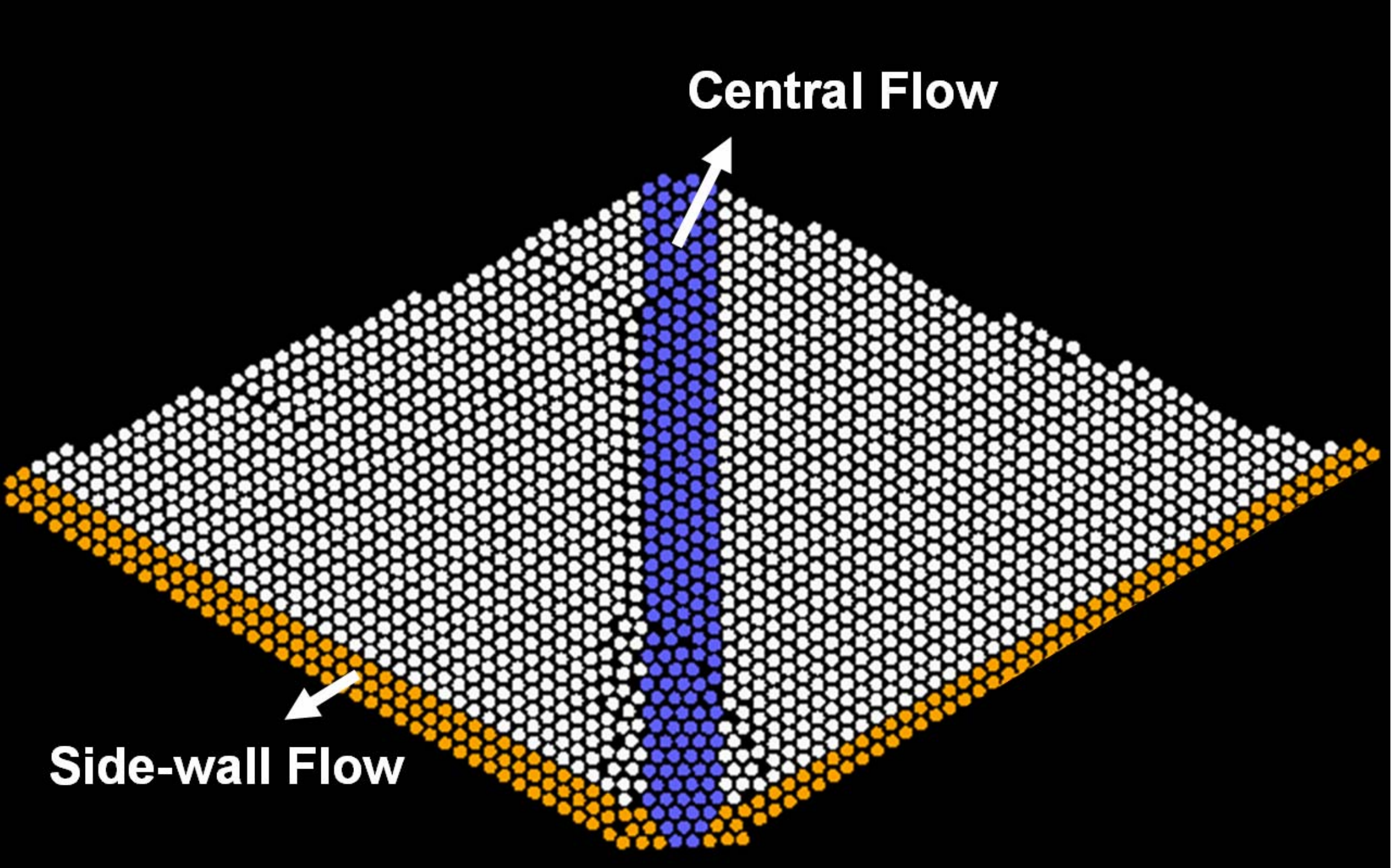
Degree of reverse ordering

$$\Gamma = \frac{1}{f(N)} \sqrt{\sum_{i=1}^{N} \gamma_i^{\,2}}$$

Hopper angle / Reclining angle and Γ

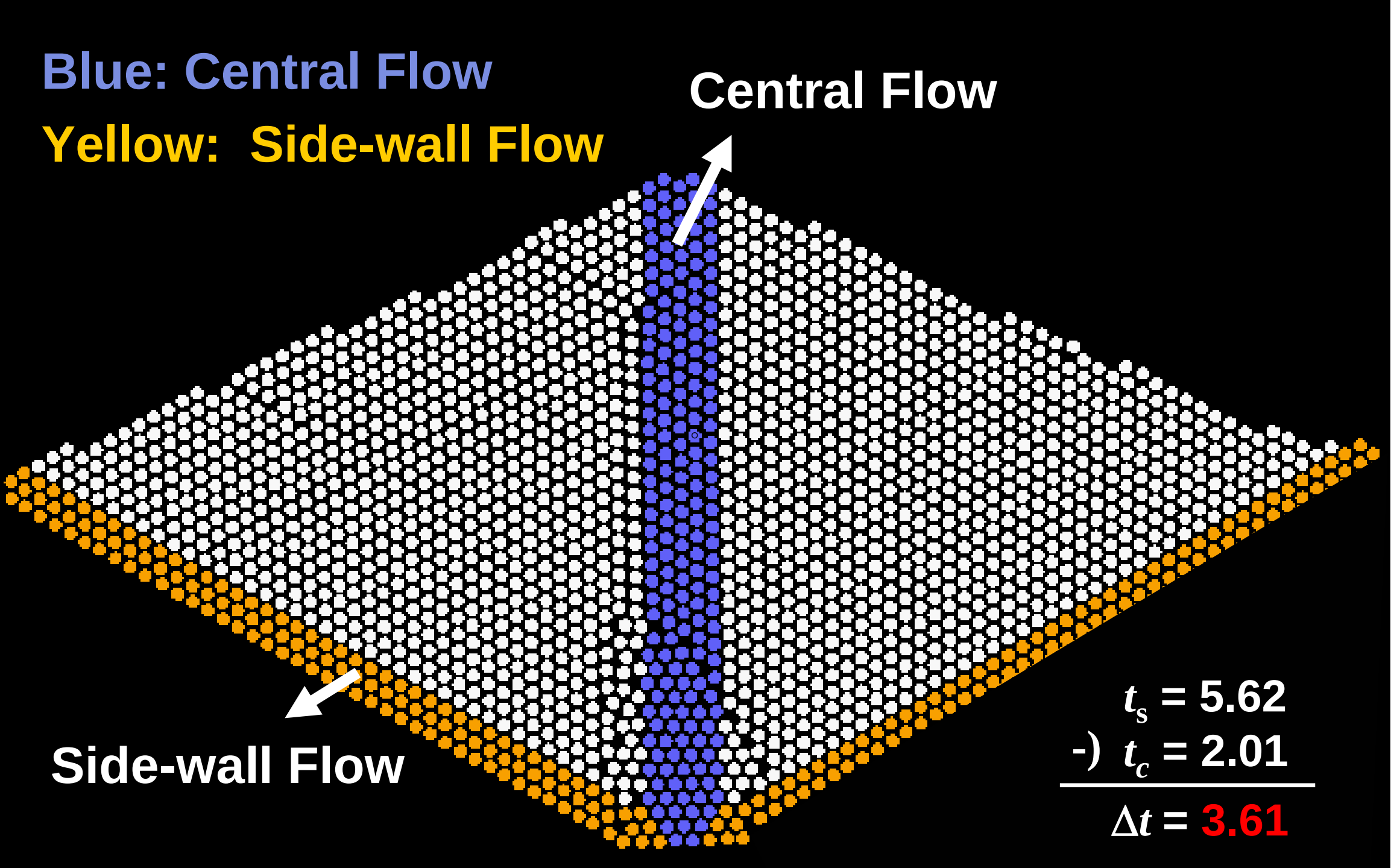





Central Flow
Side-wall Flow

Blue: Central Flow

Yellow: Side-wall Flow



t_s = 5.62

-) t_c = 2.01

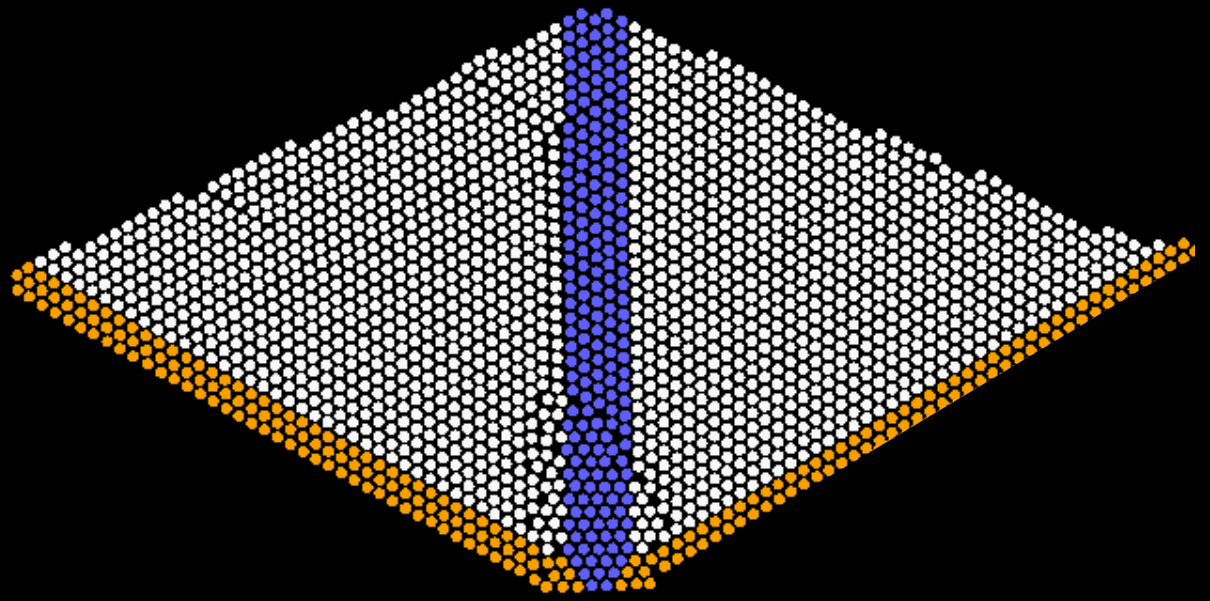
Δt = 3.61

t_s = 5.62

-) t_c = 2.01

Δt = 3.61

θ = 60°

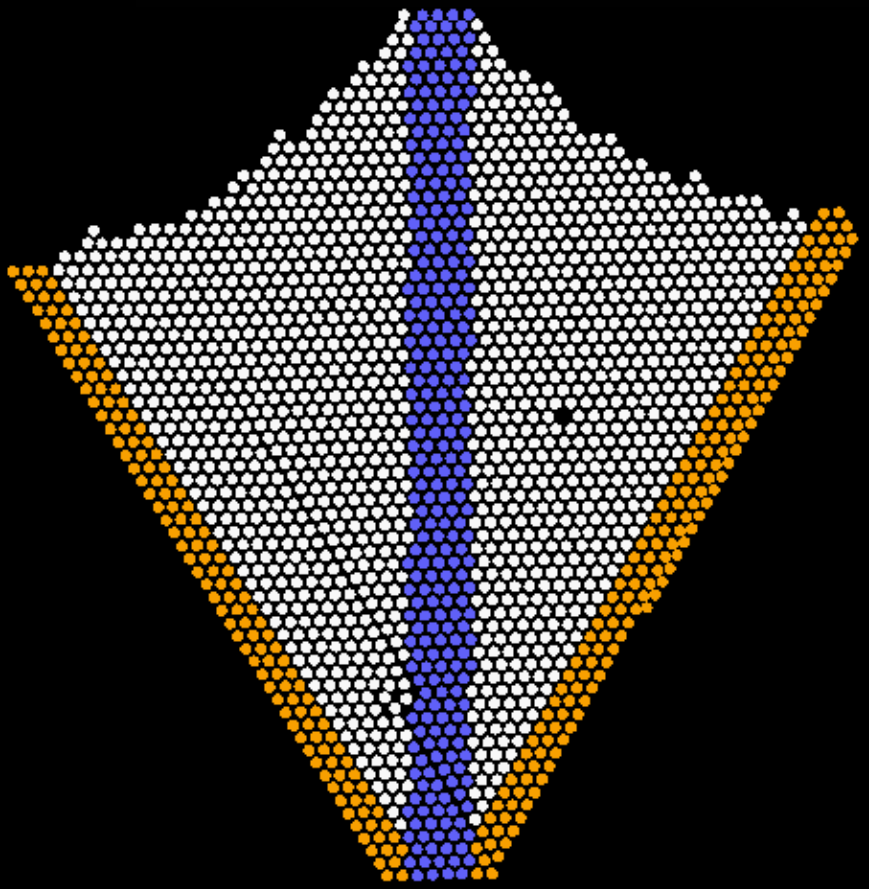


t_s = 5.62 t_c = 2.01

Δt = 3.61 (sec.)

Γ = 0.53

θ = 30°



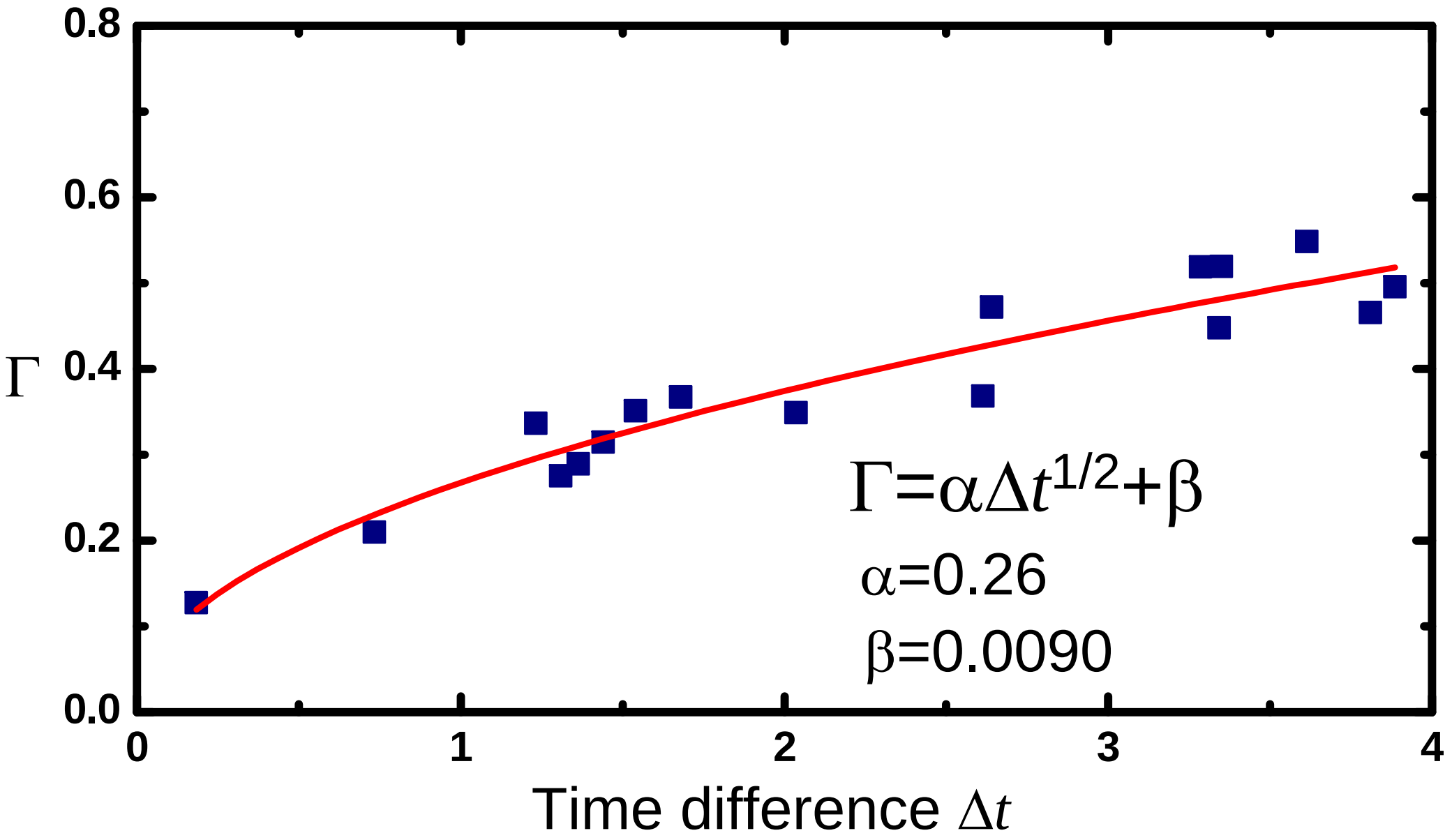
t_s = 3.80 t_c = 3.62

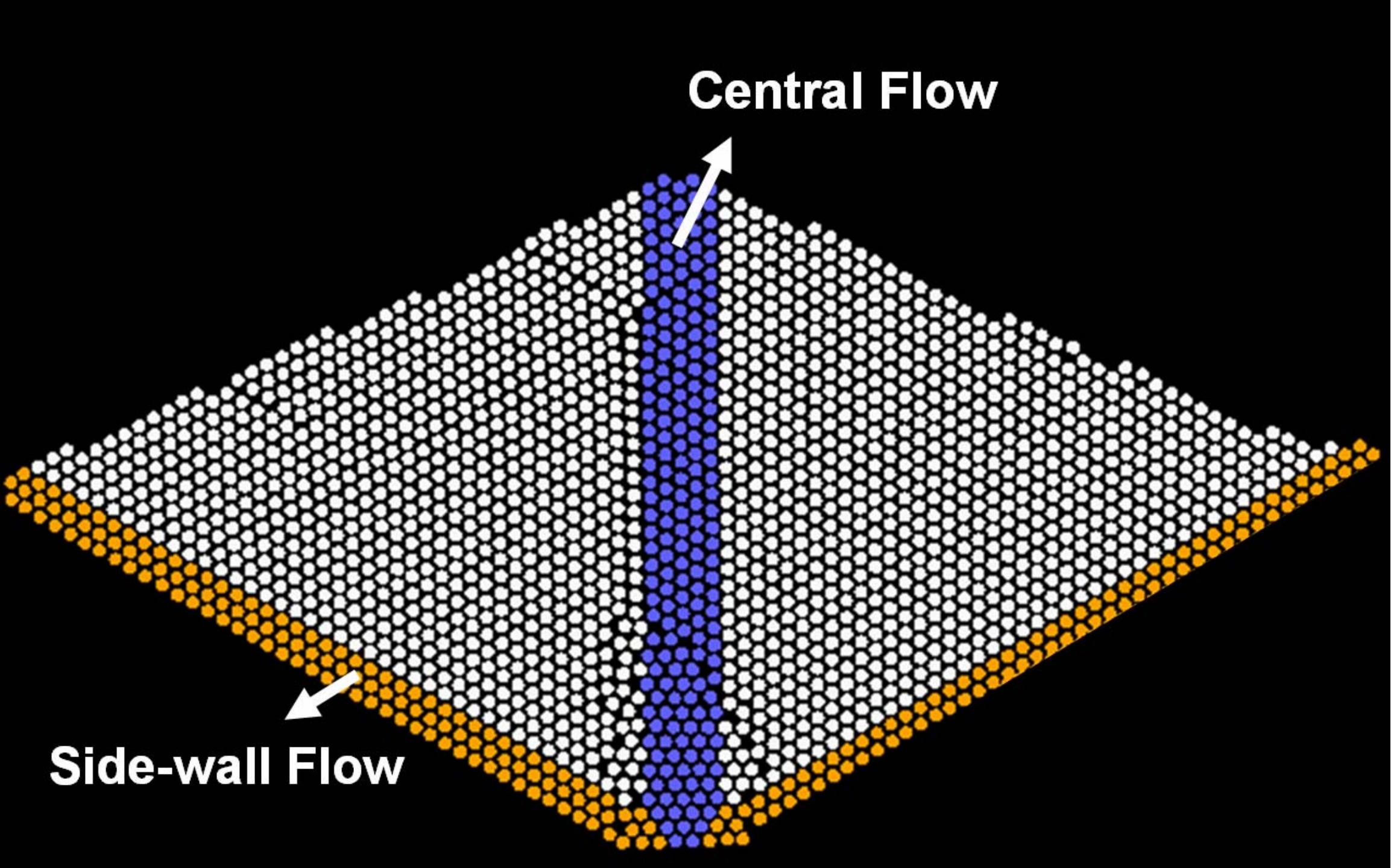
Δt = 0.18 (sec.)

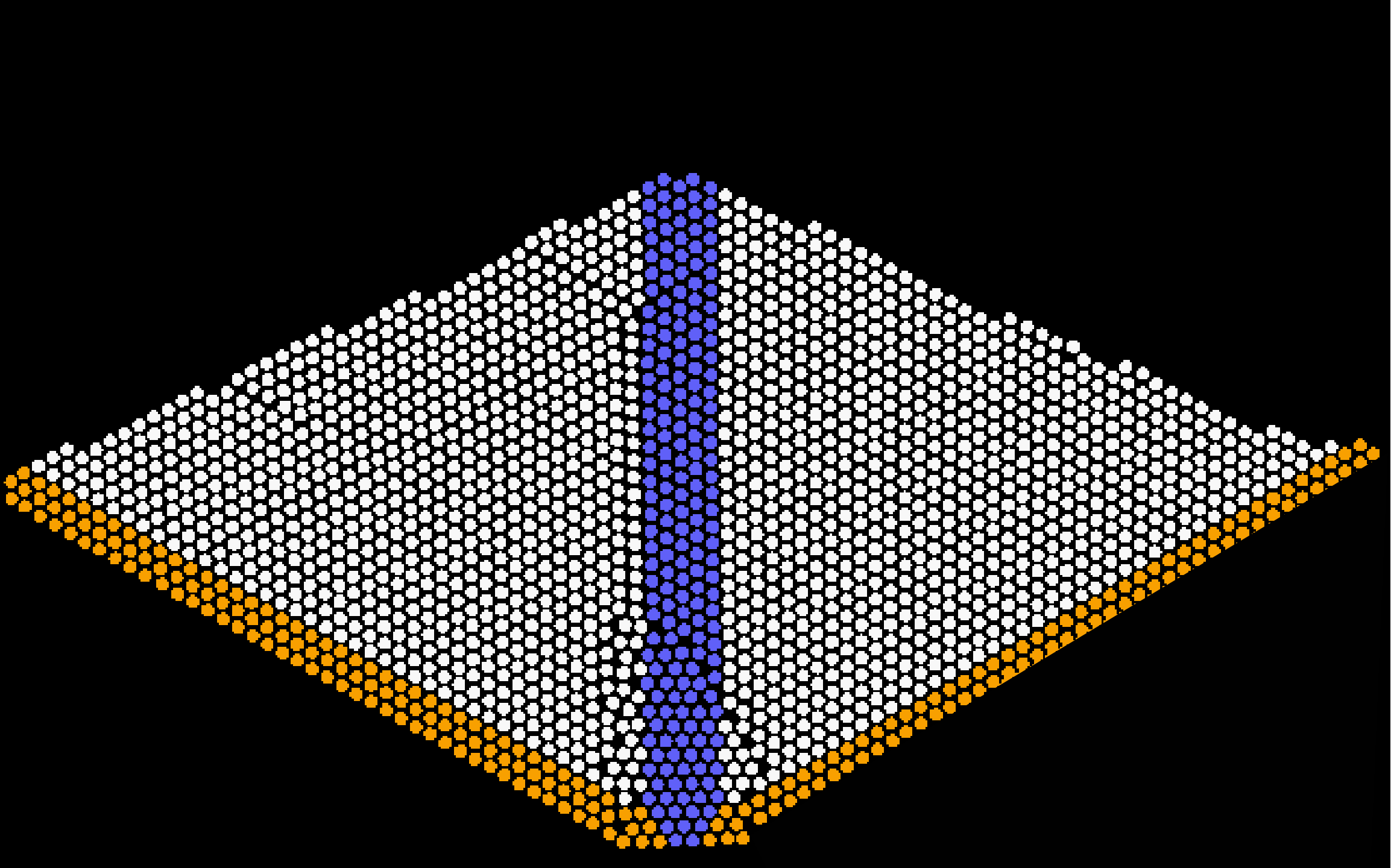
Γ = 0.12

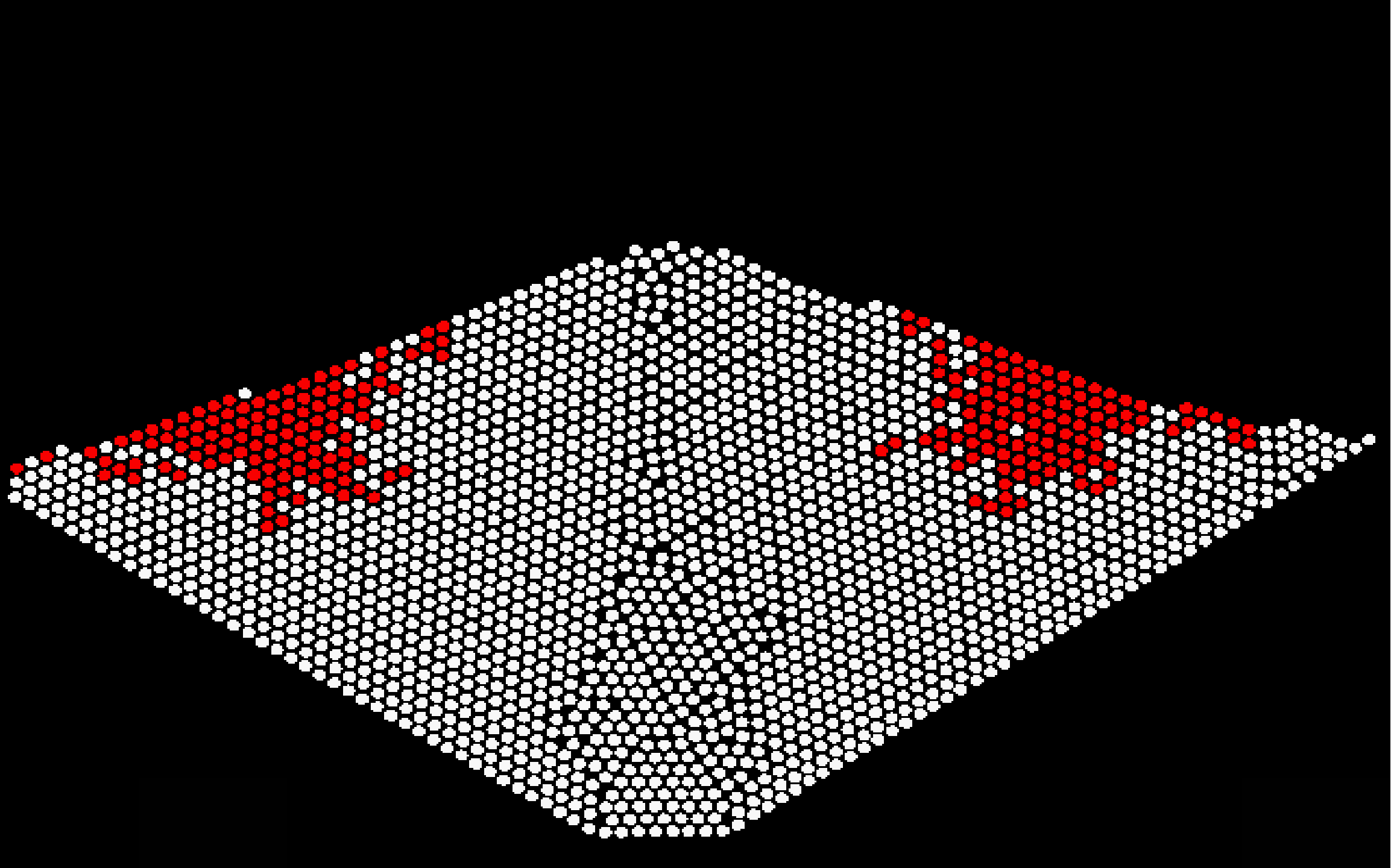
Not in real time.

Relation between Γ and the time difference

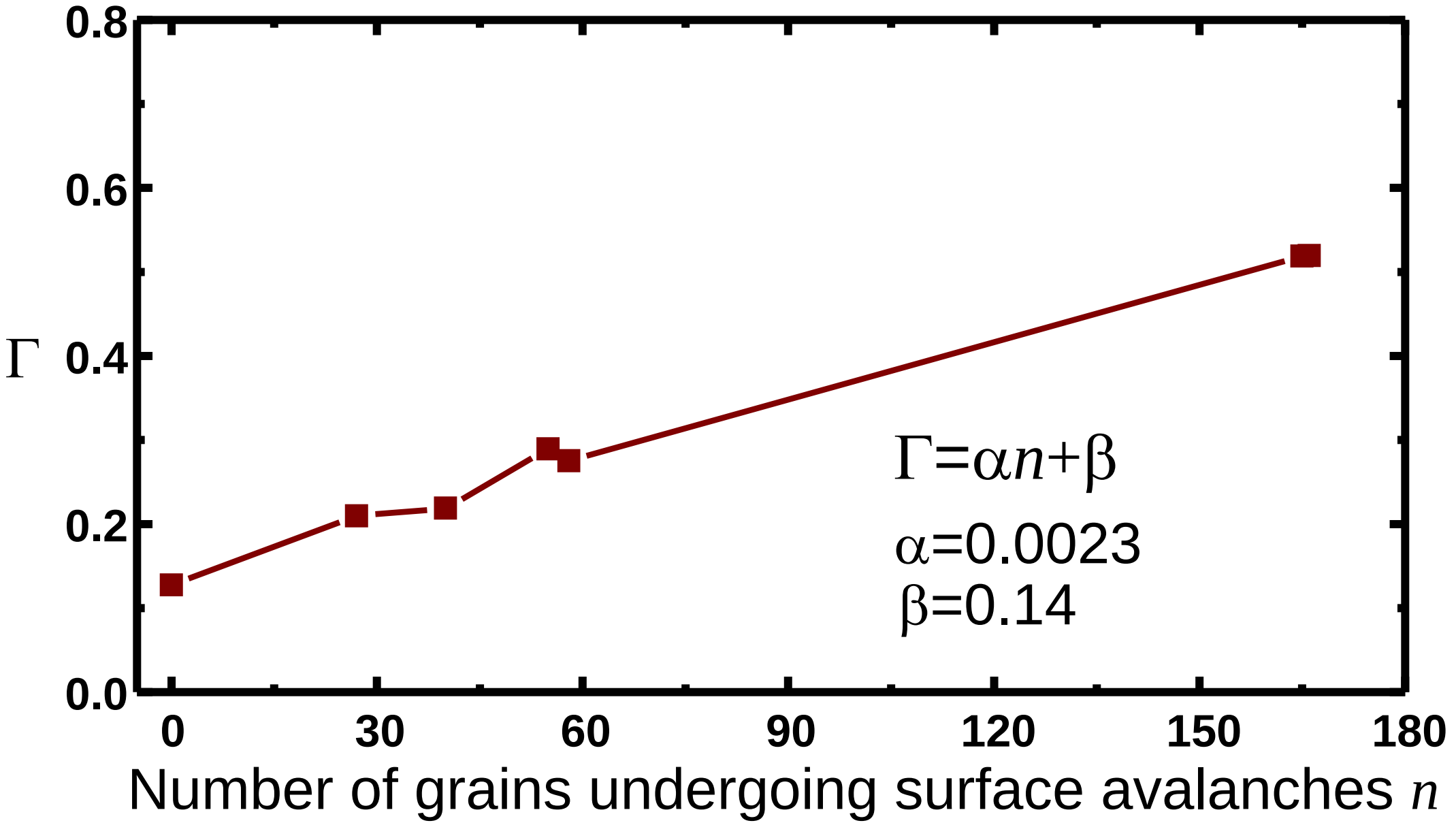



Central Flow
Side-wall Flow

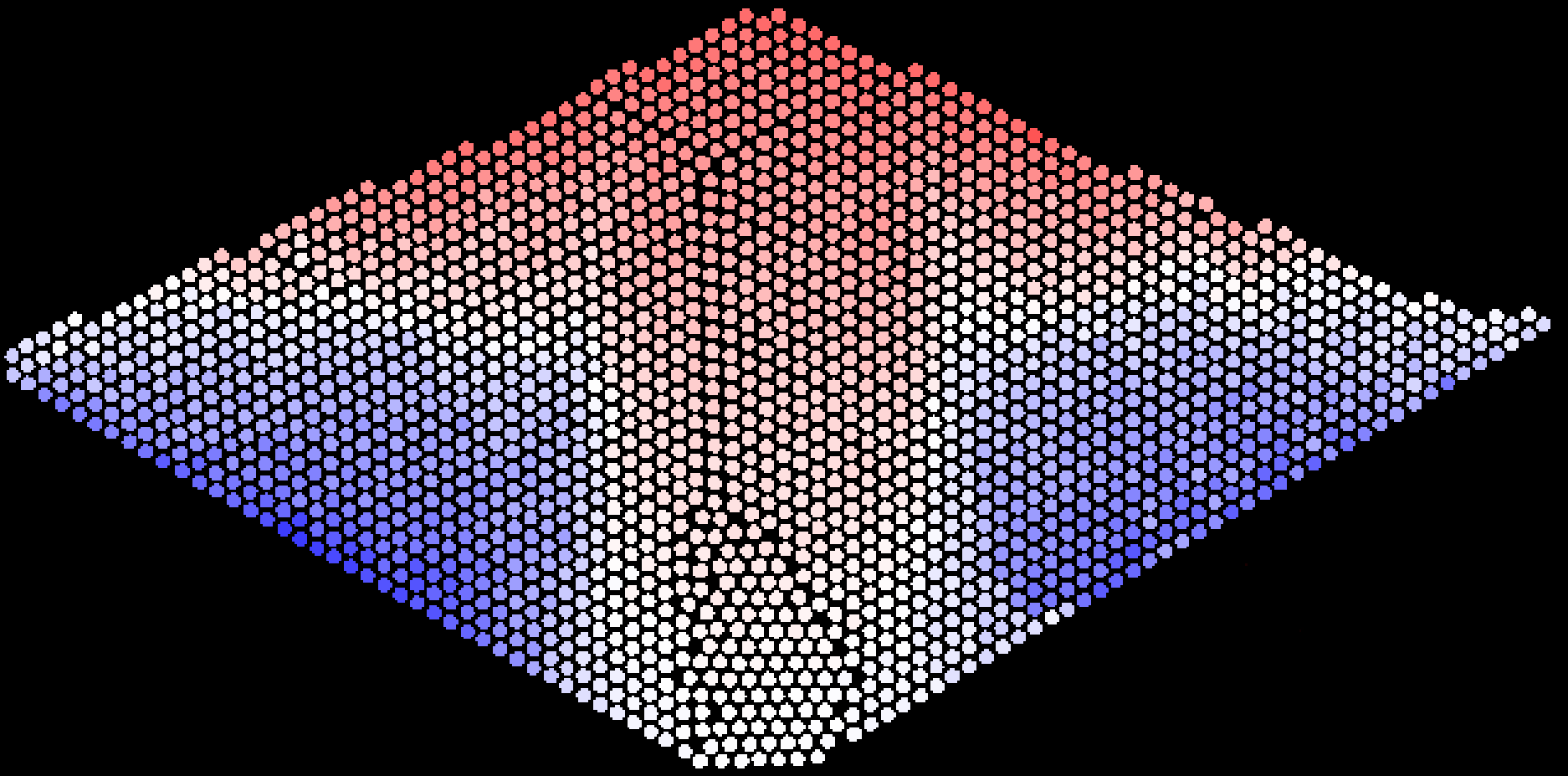


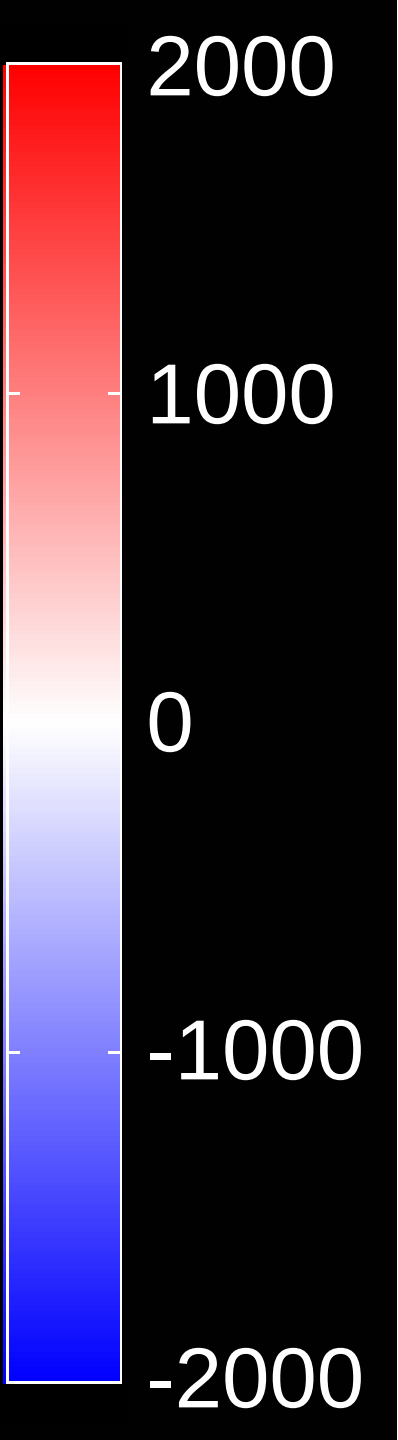


Relation between Γ and avalanches



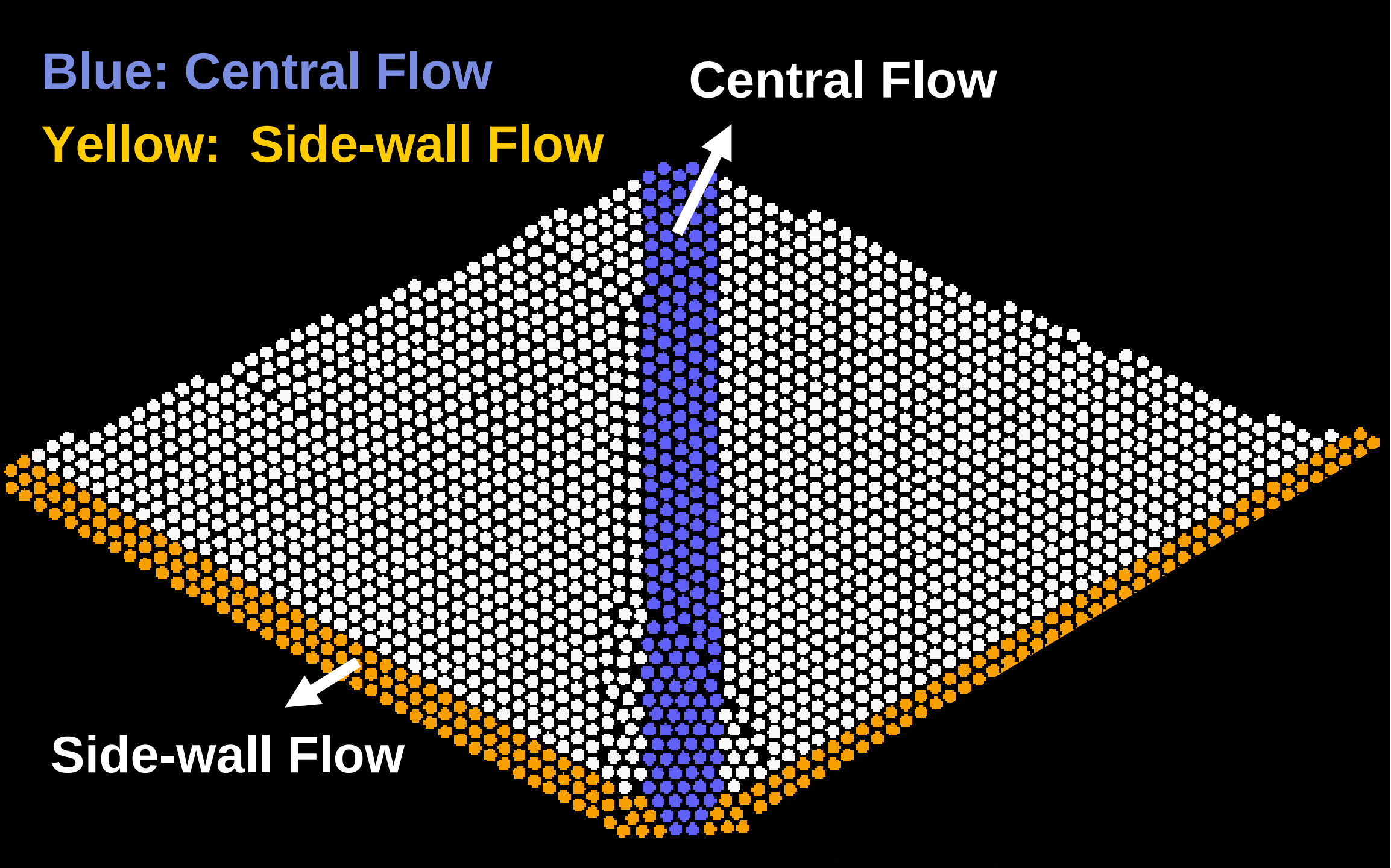
$$\Gamma = \frac{1}{f(N)} \sqrt{\sum_{i=1}^{N} \gamma_i^{\,2}}$$

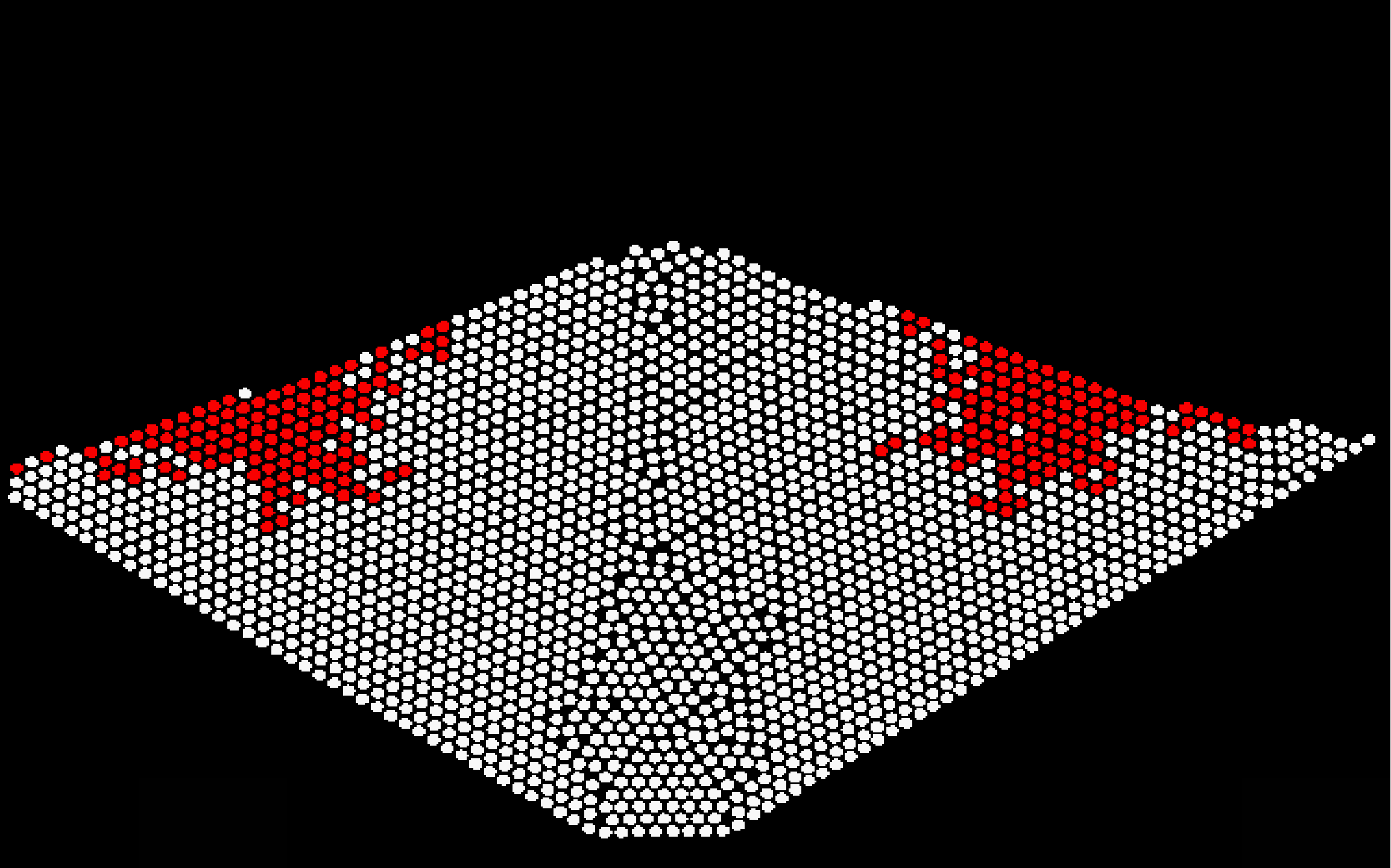




Blue: Central Flow

Yellow: Side-wall Flow

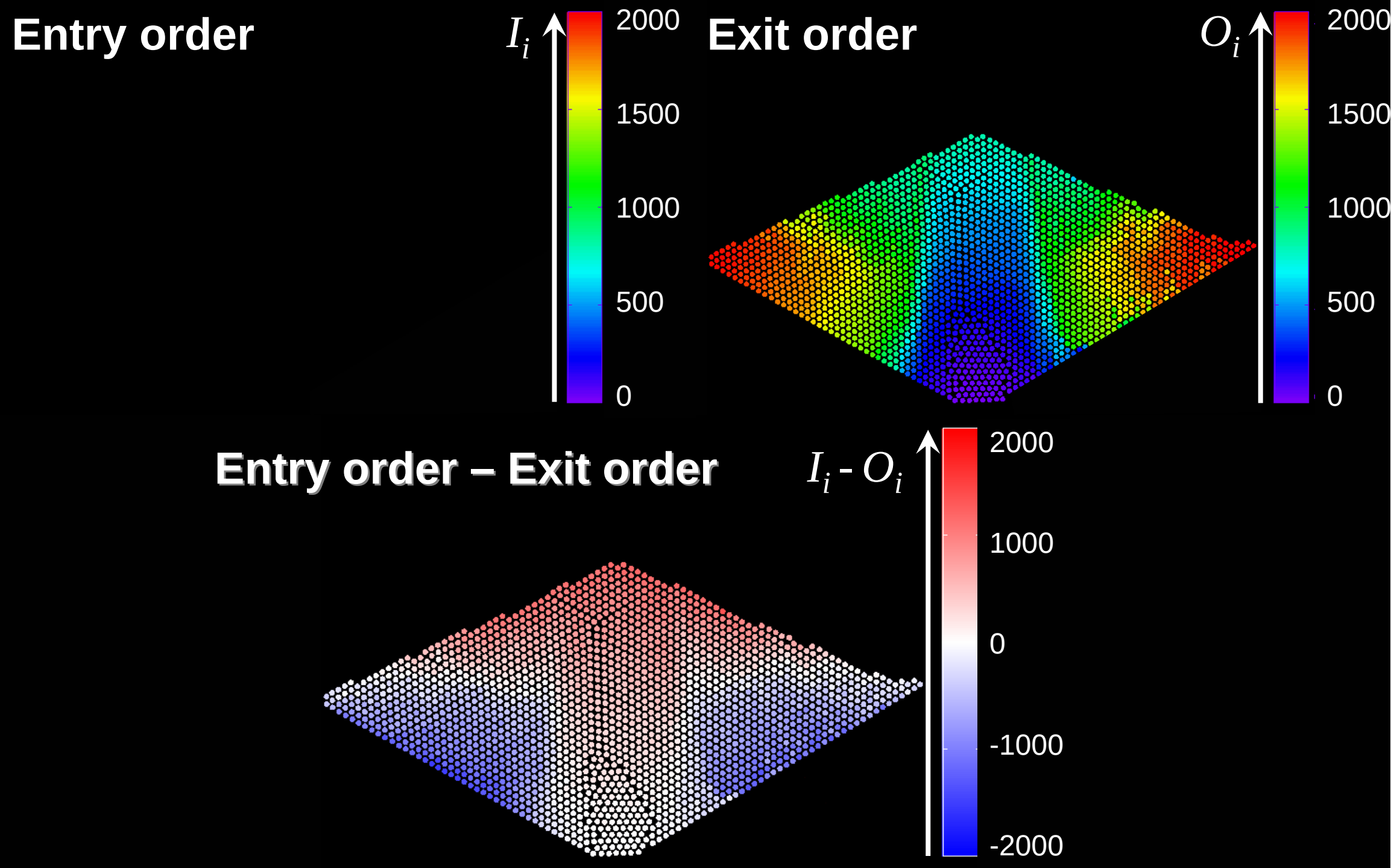




References

[1] T. Nguyen, C. Brennen, R. Sabersky (1980). Funnel Flow in Hoppers. Journal of Applied Mechanics, 102 (4). pp. 729-735.

[2] M. Hou, W. Chen, T. Zhang, K. Lu, C. K. Chan (2003). Global nature of dilute-to-dense transition of granular flows in a 2D channel. Phys. Rev. Lett., 91. pp. 204301.


Entry order
I_i
2000
1500
1000
500
0
Exit order
O_i
2000
1500
1000
500
0
Entry order – Exit order
I_i - O_i
2000
1000
0
-1000
-2000