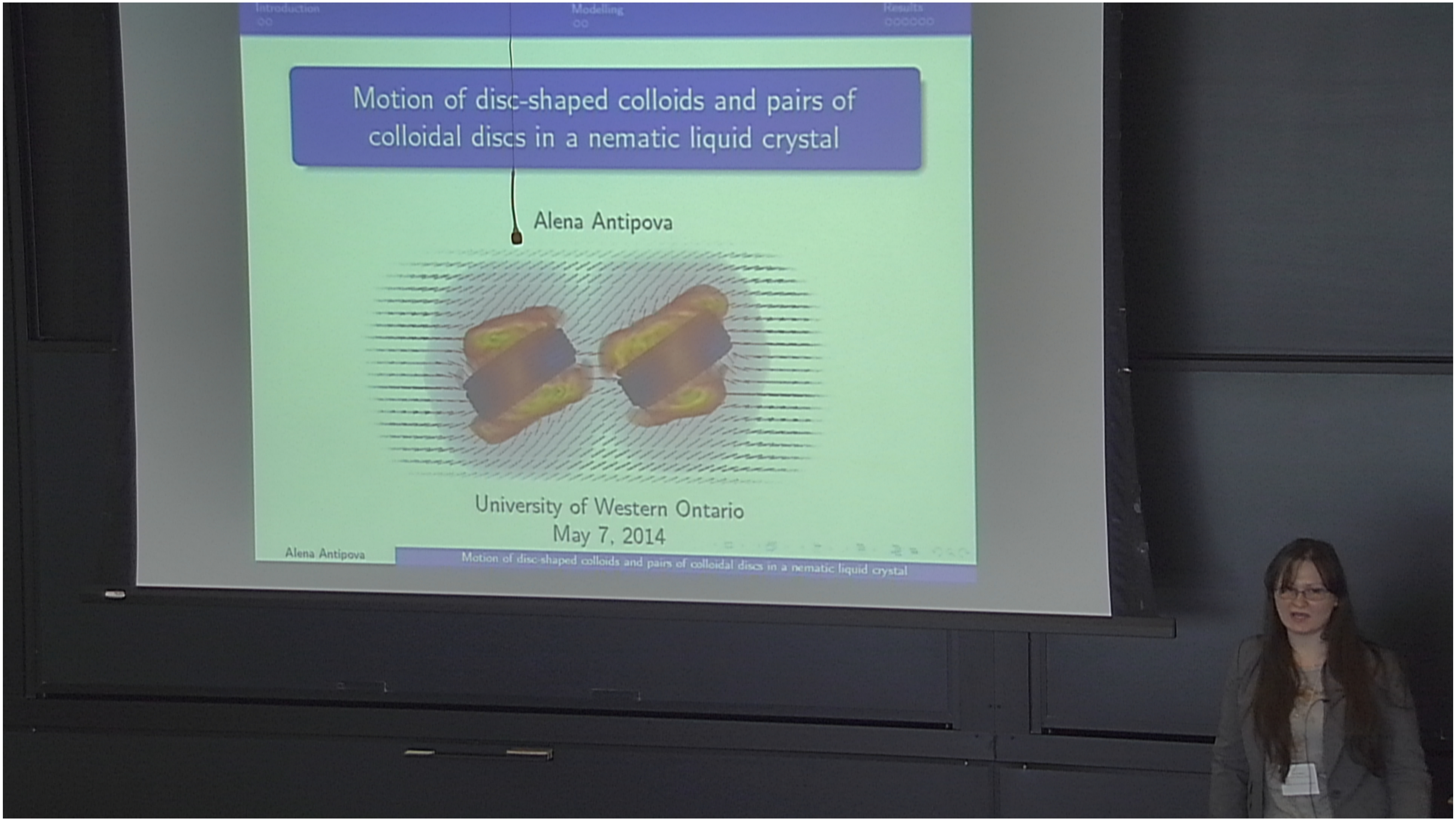
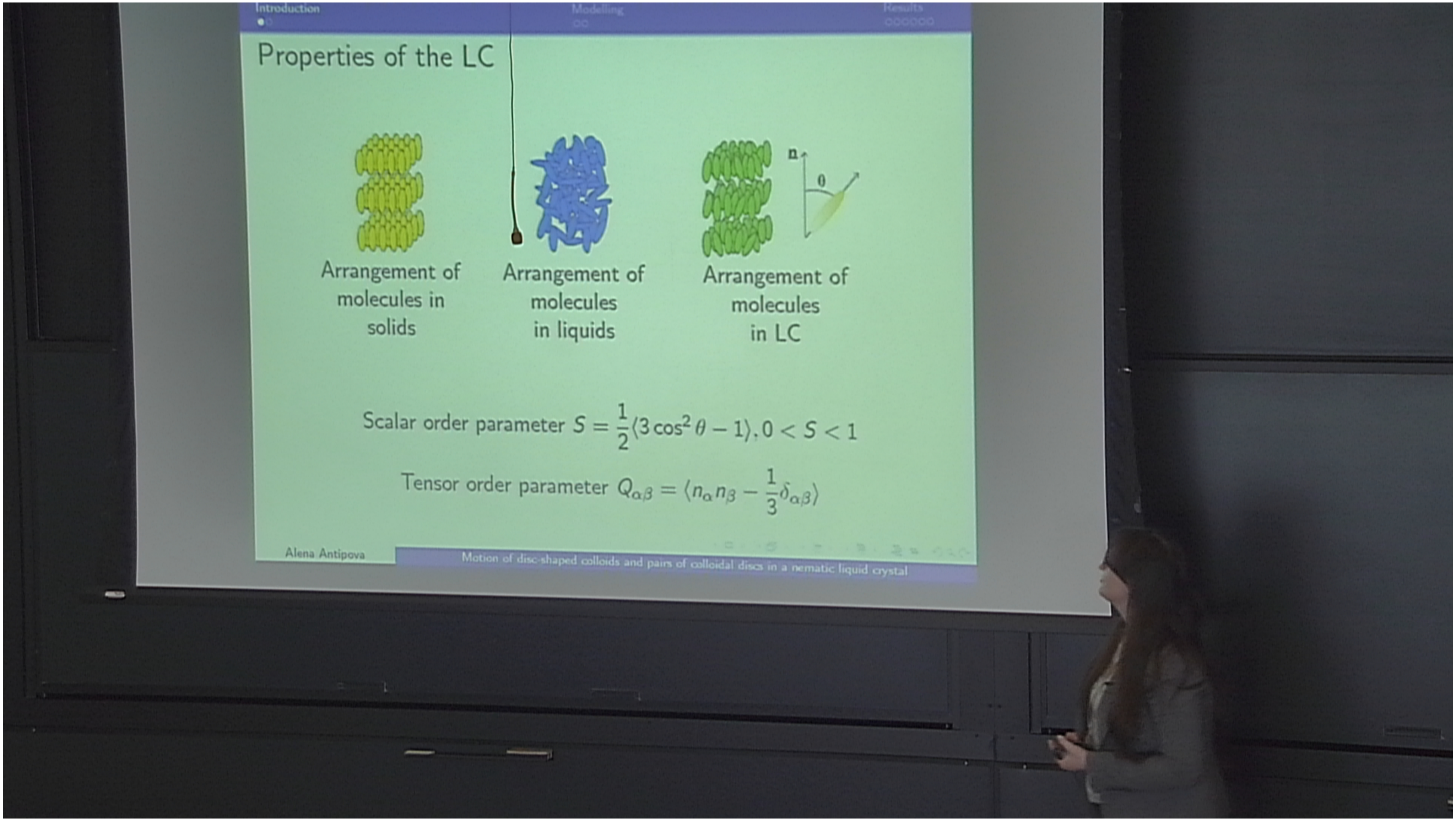
Title: Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal

Date: May 07, 2014 04:05 PM

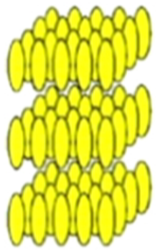
URL: http://pirsa.org/14050057

Abstract: In the present work the motion of disc-shaped particles in a nematic liquid crystal was simulated via a Lattice Boltzmann algorithm. Under the action of a rotating magnetic field the colloidal disc with perpendicular surface anchoring immersed in a nematic liquid crystal experiences a torque and continues turning following the field. However when the disc reaches some critical position when the director field around it is highly distorted the disc suddenly flips to minimize the free energy. Analyzing this motion and consequently the behaviour of two discs placed close together we examine the possible uses of this peculiar flip behaviour.


Introduction
Modelling
Results
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal
Alena Antipova
University of Western Ontario
May 7, 2014
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal

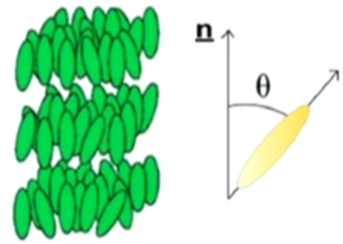

Introduction
Modelling
Results
Properties of the LC
n
θ
Arrangement of molecules in solids
Arrangement of molecules in liquids
Arrangement of molecules in LC
Scalar order parameter $S = \frac{1}{2}\langle 3\cos^2\theta - 1\rangle, 0 < S < 1$
Tensor order parameter $Q_{\alpha\beta} = \langle n_\alpha n_\beta - \frac{1}{3}\delta_{\alpha\beta}\rangle$
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal

Properties of the LC



Arrangement of molecules in solids

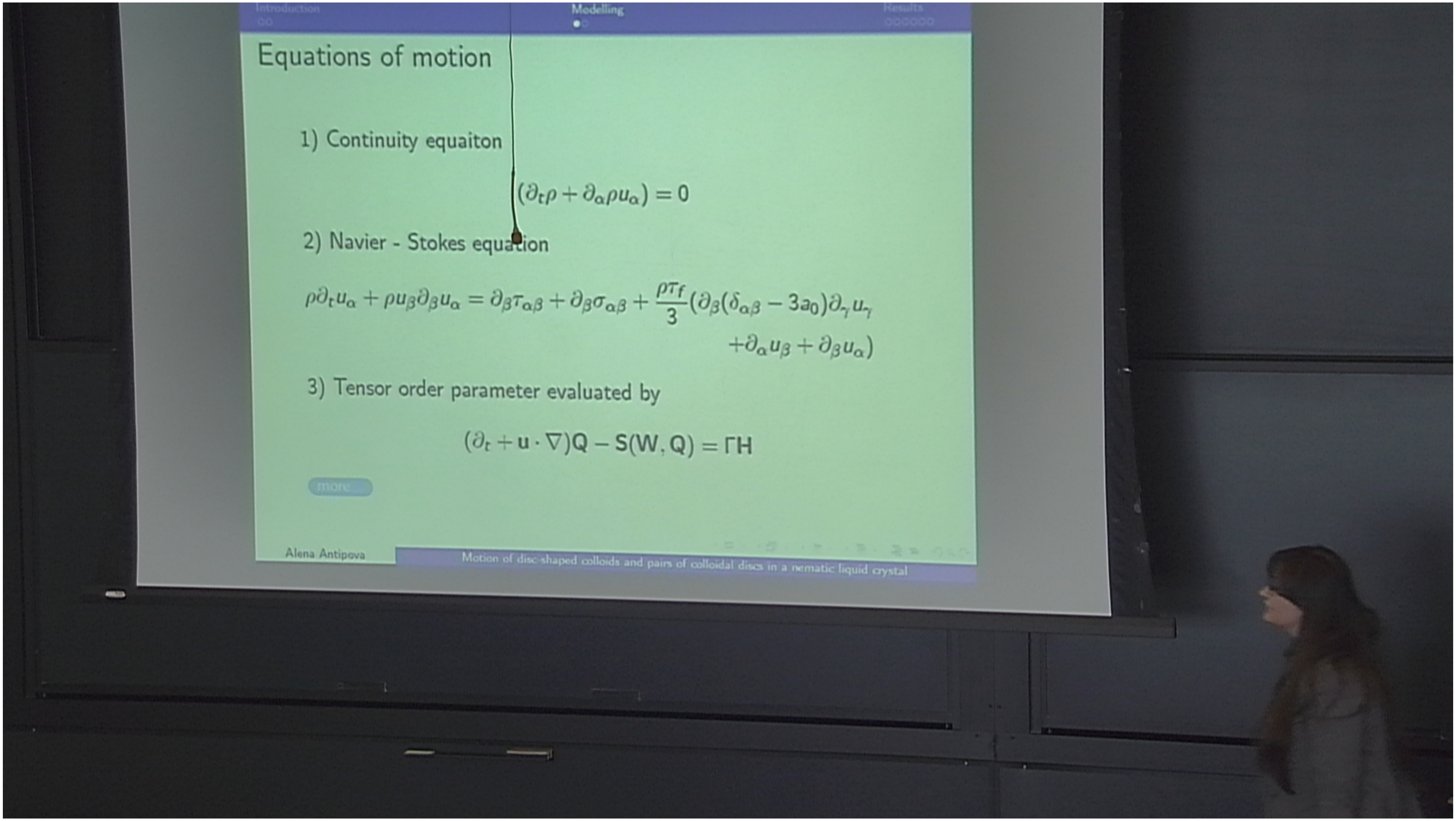
Arrangement of molecules in liquids



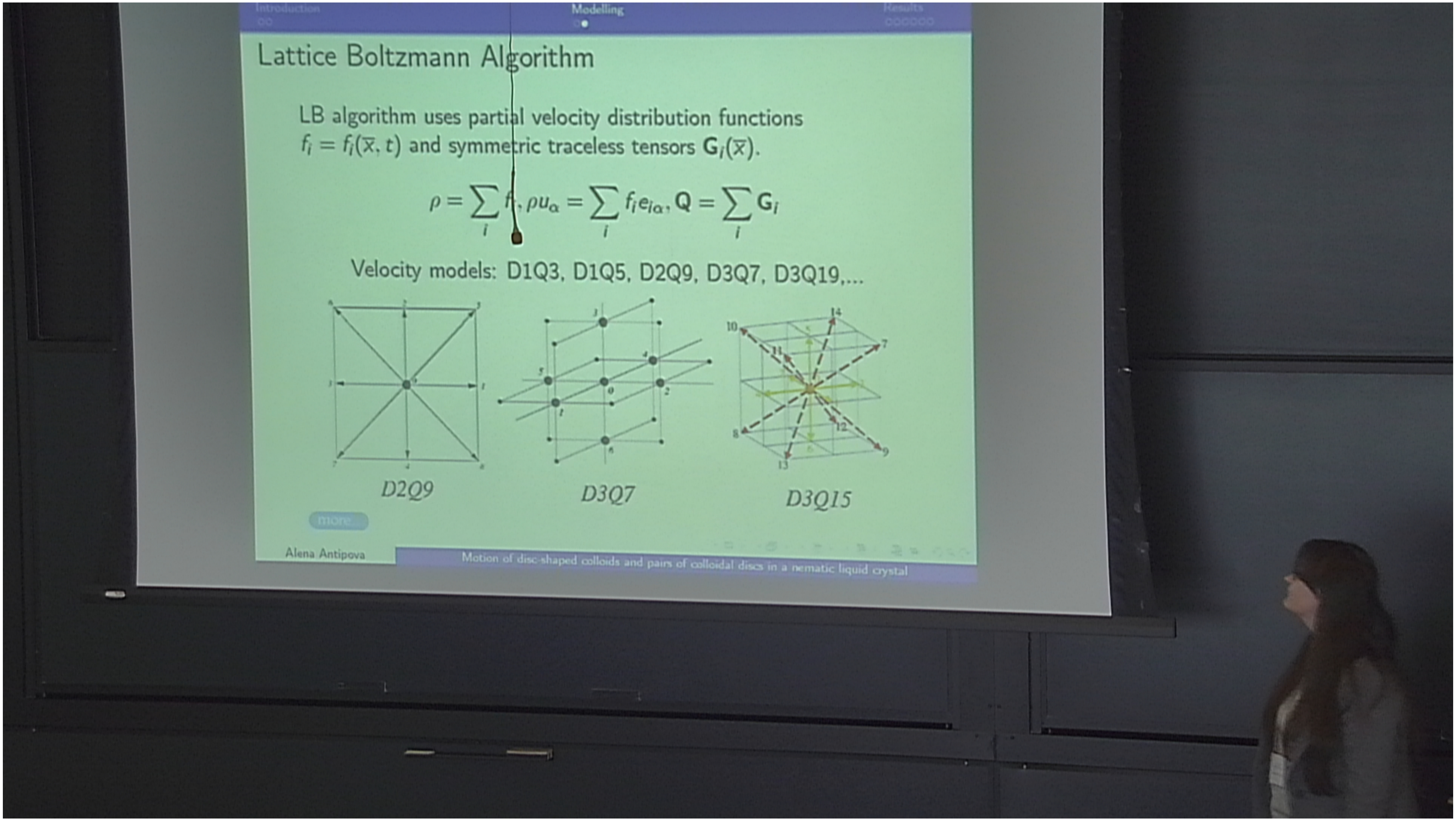
Arrangement of molecules in LC

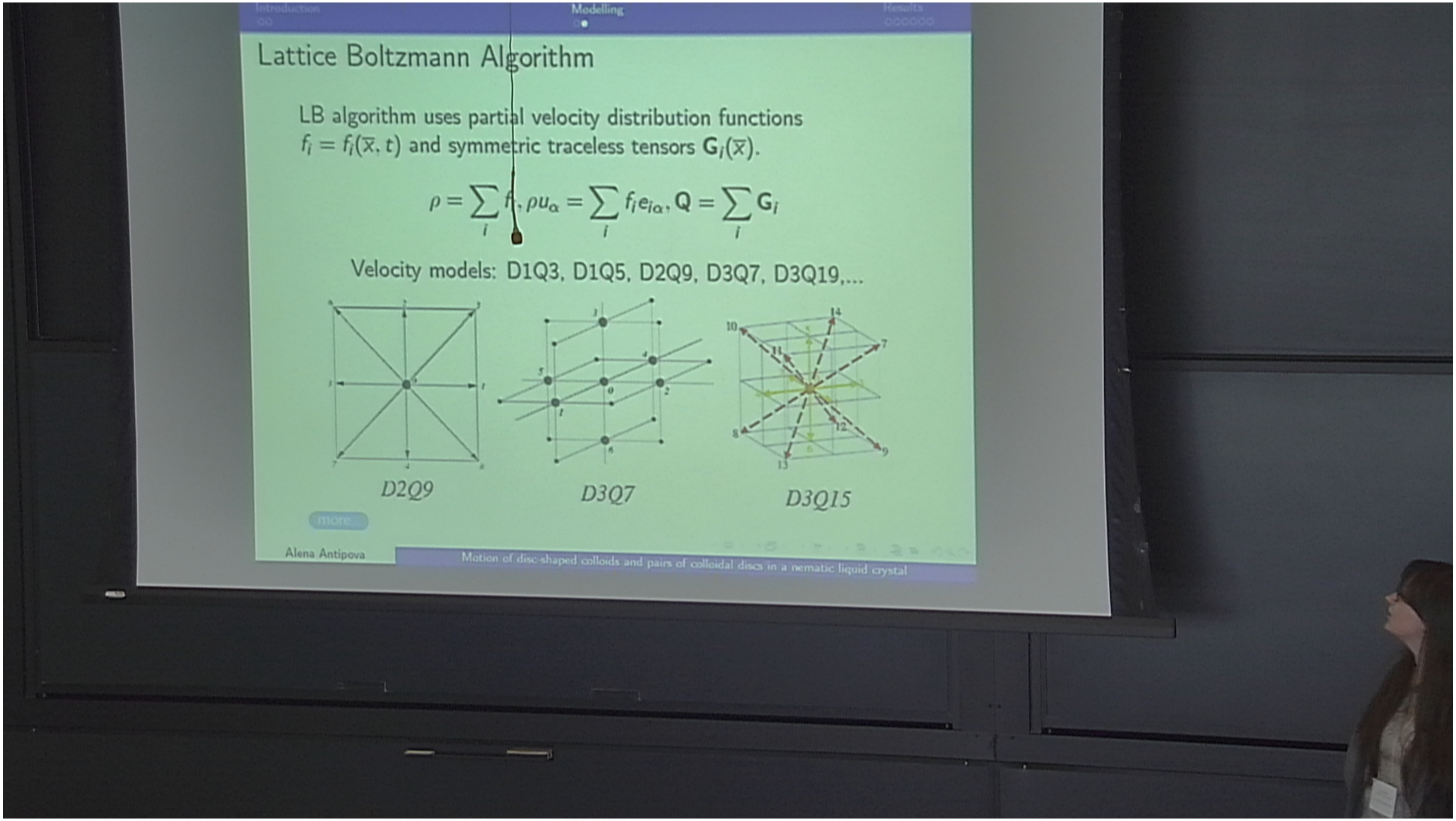
Scalar order parameter $S = \frac{1}{2}\langle 3\cos^2\theta - 1\rangle, 0 < S < 1$

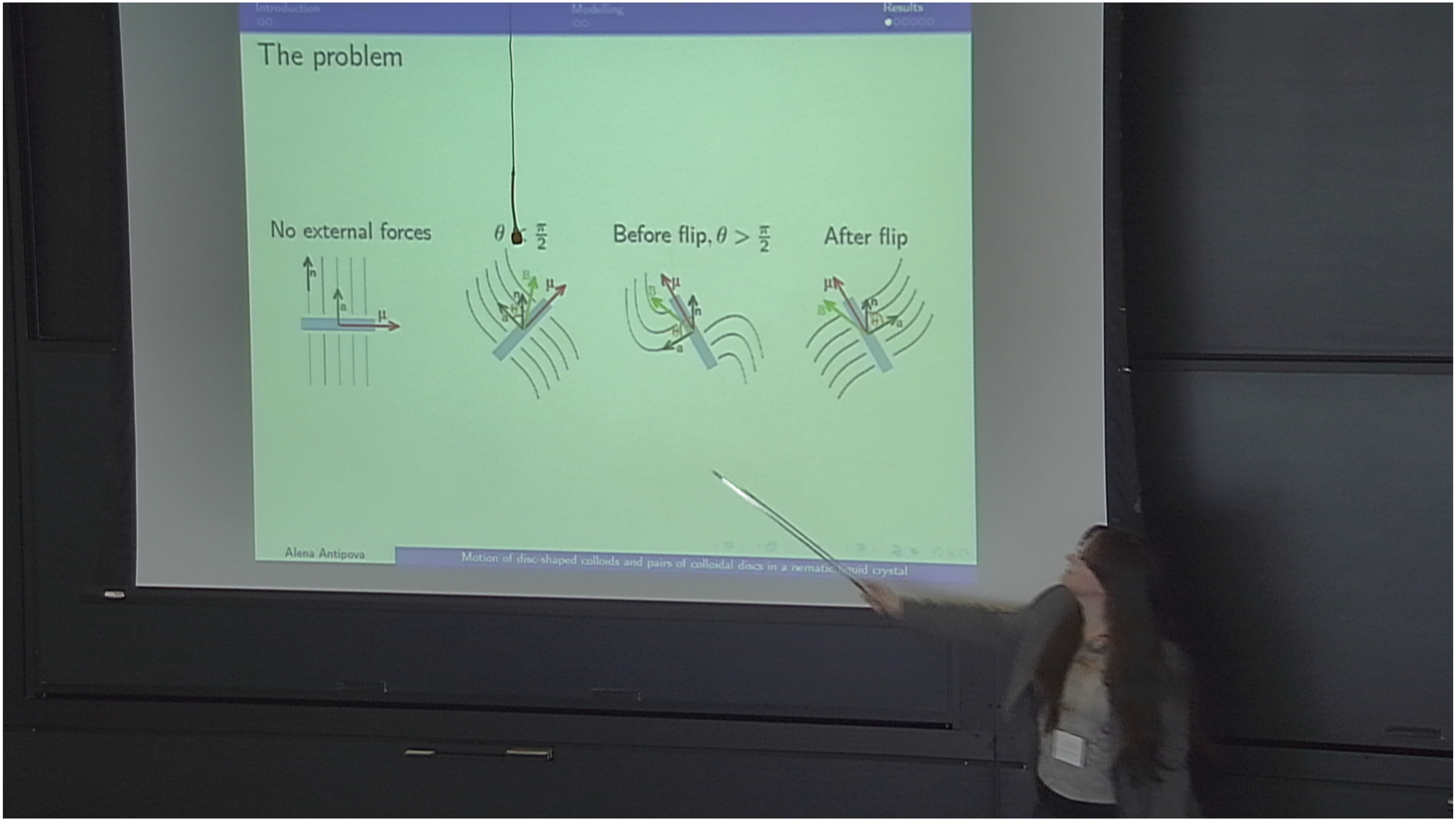
Tensor order parameter $Q_{\alpha\beta} = \langle n_\alpha n_\beta - \frac{1}{3}\delta_{\alpha\beta}\rangle$

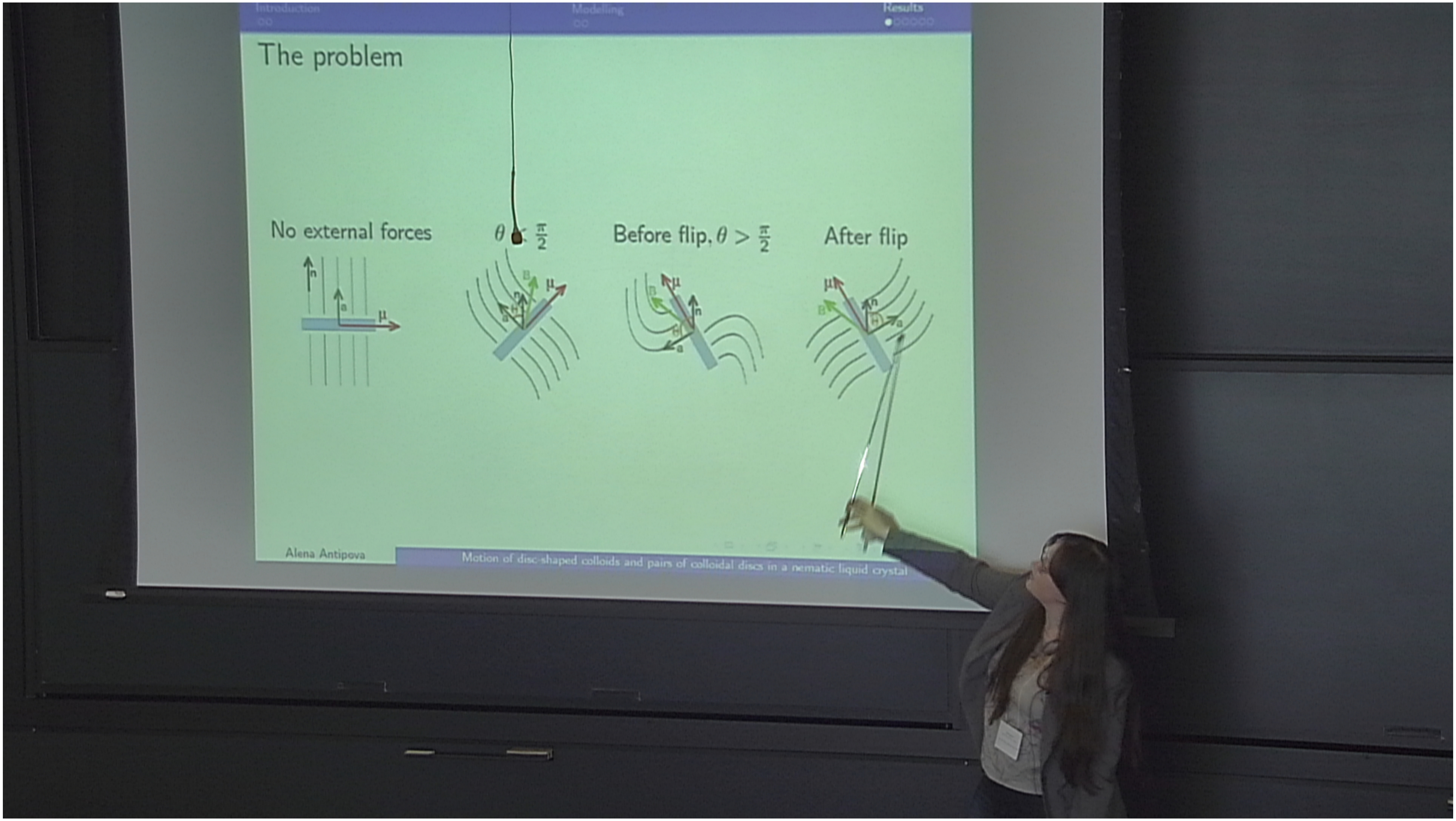


Introduction
Modelling
Results
Equations of motion
1) Continuity equaiton
$(\partial_t \rho + \partial_\alpha \rho u_\alpha) = 0$
2) Navier - Stokes equation
$\rho \partial_t u_\alpha + \rho u_\beta \partial_\beta u_\alpha = \partial_\beta \tau_{\alpha\beta} + \partial_\beta \sigma_{\alpha\beta} + \frac{\rho \tau_f}{3}(\partial_\beta(\delta_{\alpha\beta} - 3a_0)\partial_\gamma u_\gamma + \partial_\alpha u_\beta + \partial_\beta u_\alpha)$
3) Tensor order parameter evaluated by
$(\partial_t + \mathbf{u} \cdot \nabla)\mathbf{Q} - \mathbf{S}(\mathbf{W}, \mathbf{Q}) = \Gamma \mathbf{H}$
more...
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal

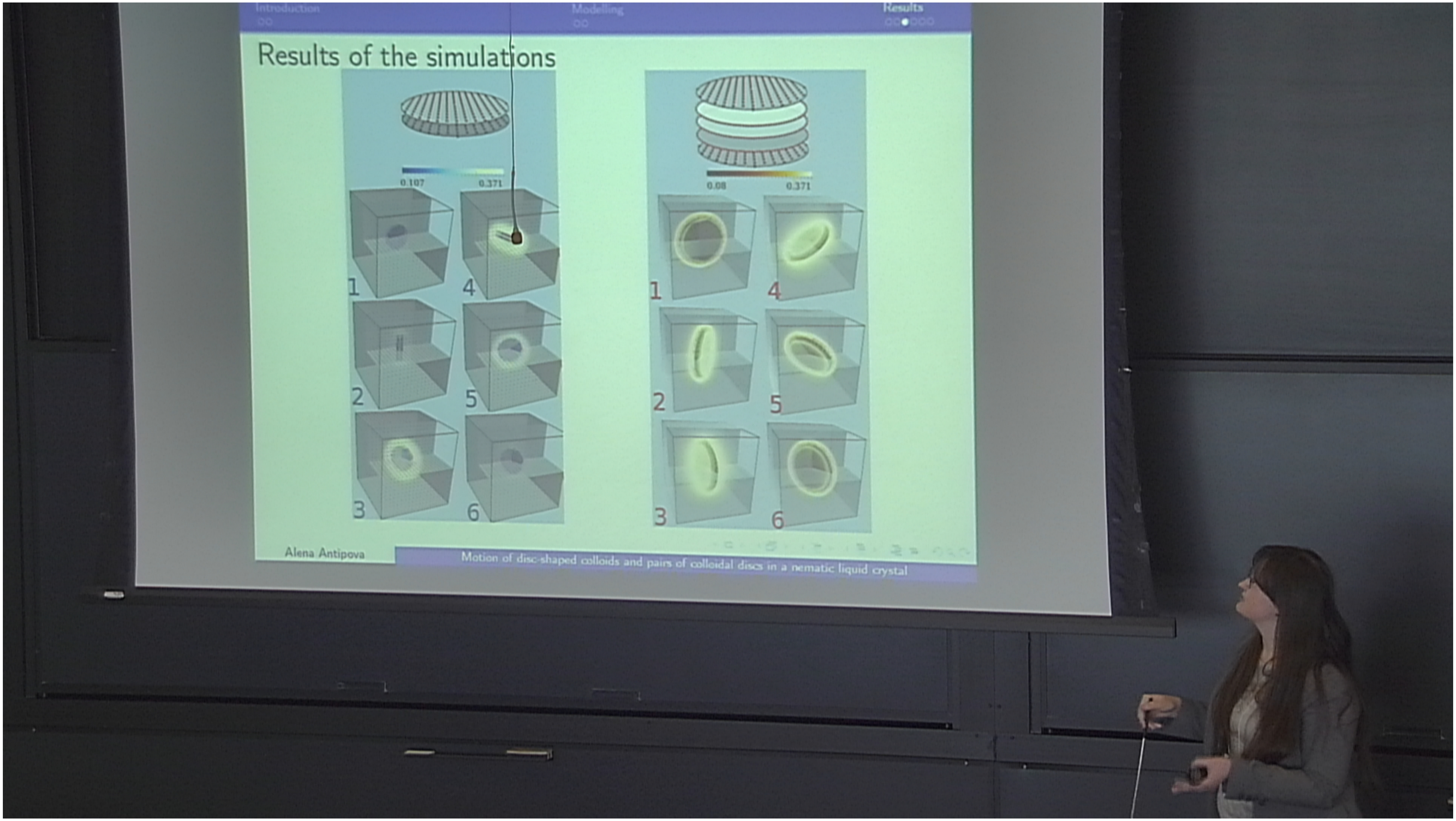

Introduction
Modelling
Results
Lattice Boltzmann Algorithm
LB algorithm uses partial velocity distribution functions
$f_i = f_i(\overline{x}, t)$ and symmetric traceless tensors $\mathbf{G}_i(\overline{x})$.
$\rho = \sum_i f_i, \rho u_\alpha = \sum_i f_i e_{i\alpha}, \mathbf{Q} = \sum_i \mathbf{G}_i$
Velocity models: D1Q3, D1Q5, D2Q9, D3Q7, D3Q19,...
D2Q9
D3Q7
D3Q15
more...
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal


Introduction
Modelling
Results
Lattice Boltzmann Algorithm
LB algorithm uses partial velocity distribution functions
$f_i = f_i(\overline{x}, t)$ and symmetric traceless tensors $\mathbf{G}_i(\overline{x})$.
$\rho = \sum_i f_i, \rho u_\alpha = \sum_i f_i e_{i\alpha}, \mathbf{Q} = \sum_i \mathbf{G}_i$
Velocity models: D1Q3, D1Q5, D2Q9, D3Q7, D3Q19,...
D2Q9
D3Q7
D3Q15
more
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal

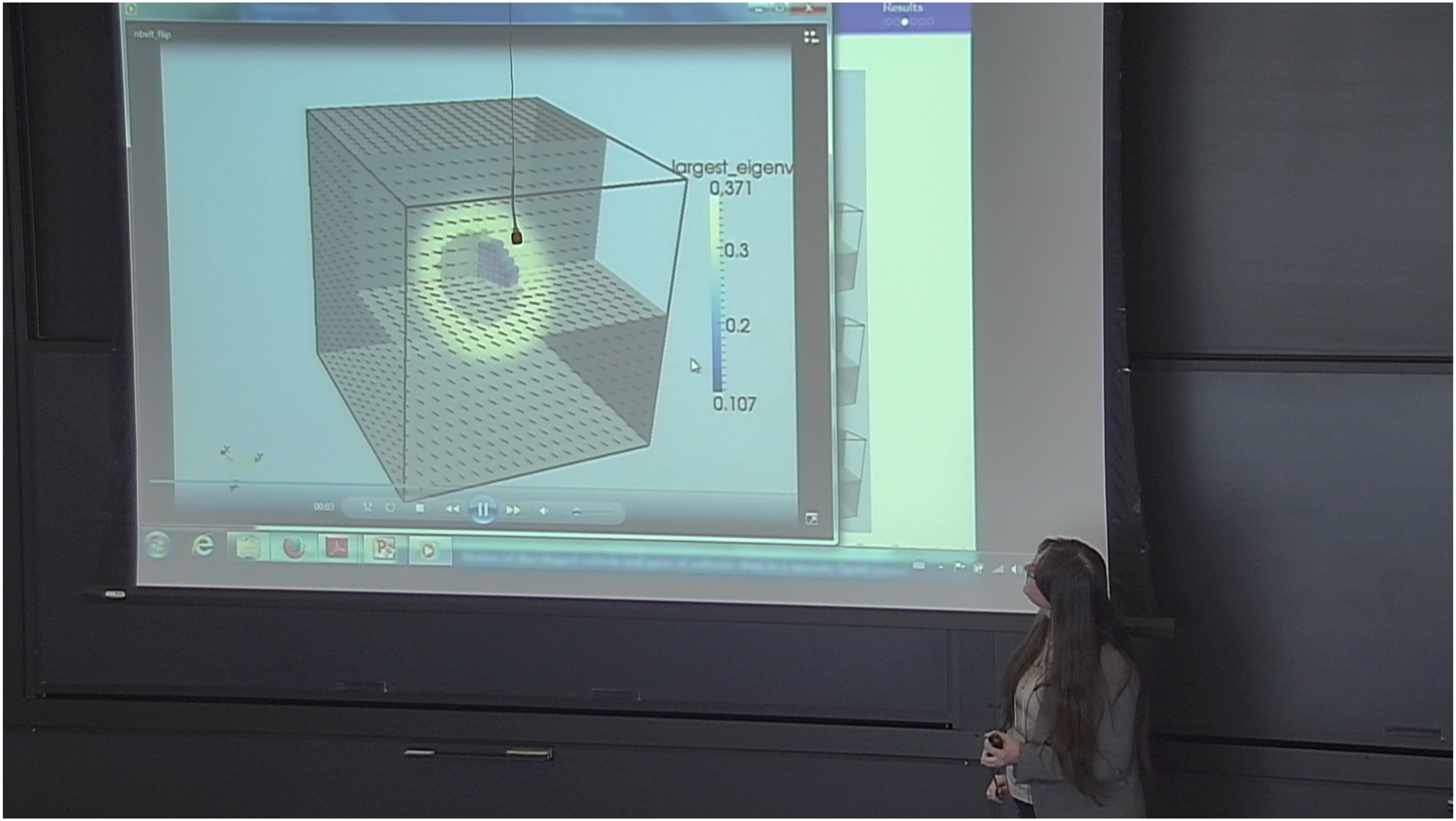

Introduction
Modelling
Results
The problem
No external forces
Before flip, θ > π/2
After flip
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic

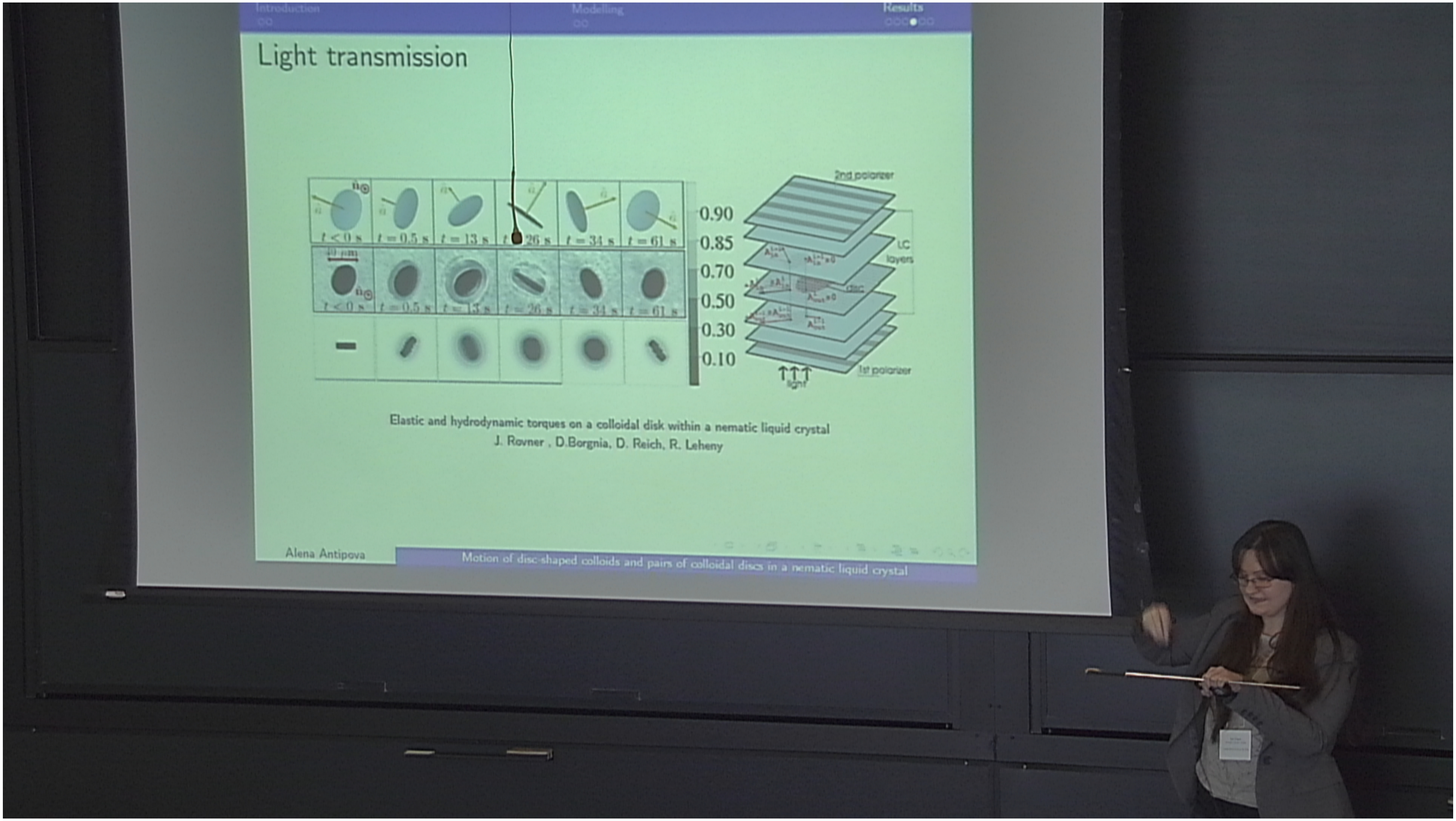


Introduction
Modelling
Results
The problem
No external forces
Before flip, $\theta > \frac{\pi}{2}$
After flip
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal



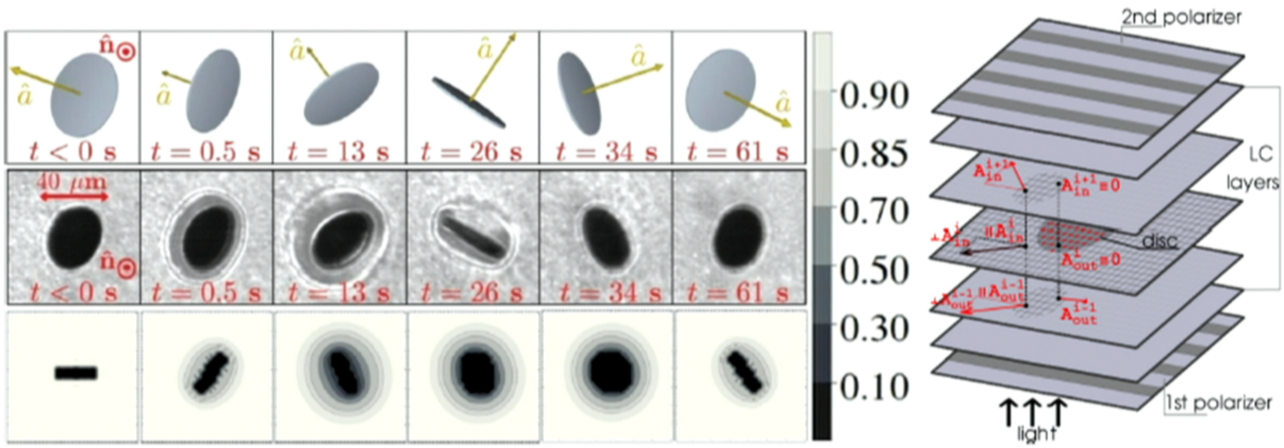
Introduction
Modelling
Results
Results of the simulations
0.107
0.371
0.08
0.371
1
2
3
4
5
6
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal


Results
nbelt_flip
largest_eigenv
0.371
0.3
0.2
0.107

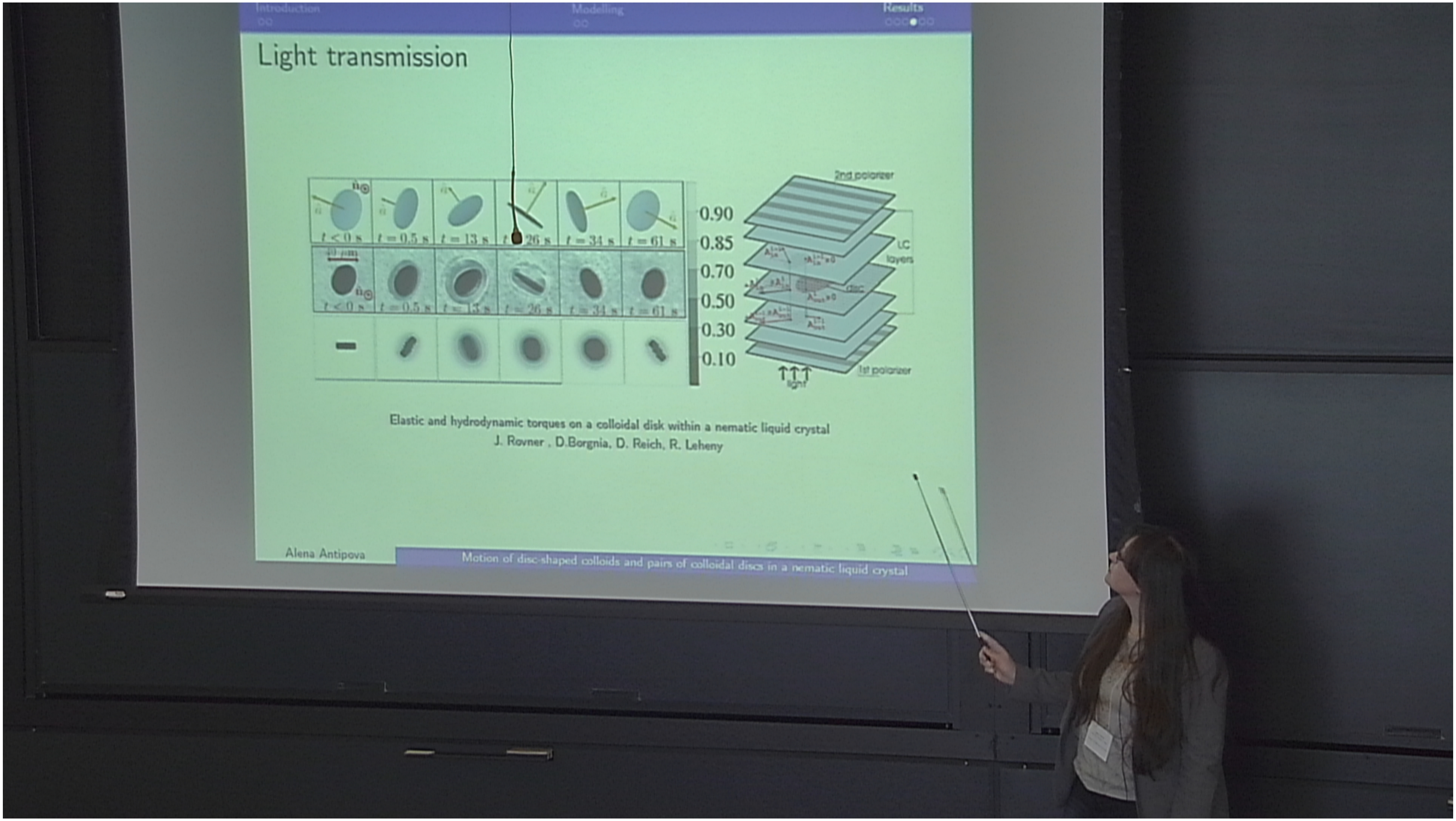


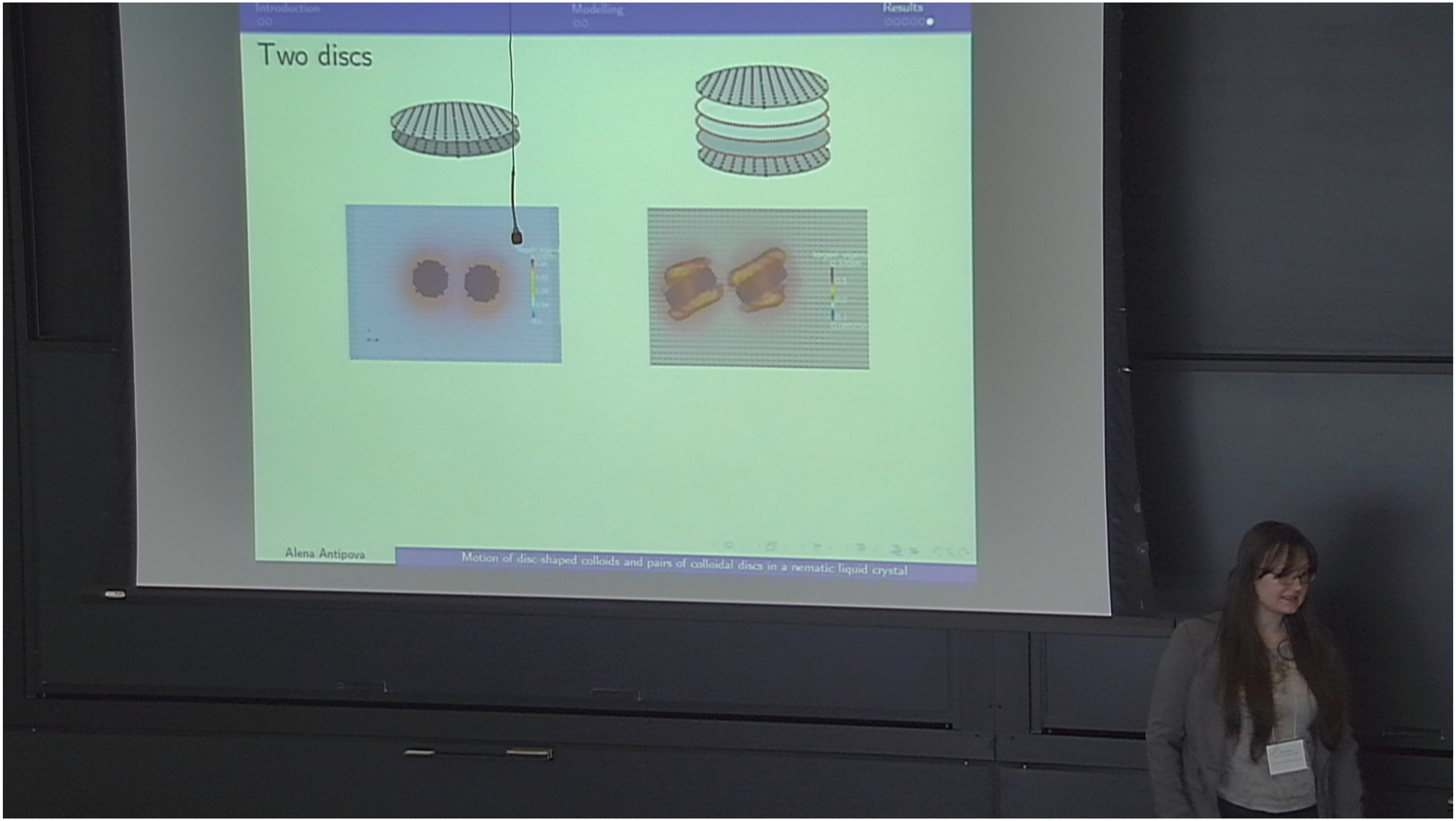
Results
Light transmission
2nd polarizer
LC layers
disc
1st polarizer
light
0.90
0.85
0.70
0.50
0.30
0.10
Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal
J. Rovner , D.Borgnia, D. Reich, R. Leheny
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal

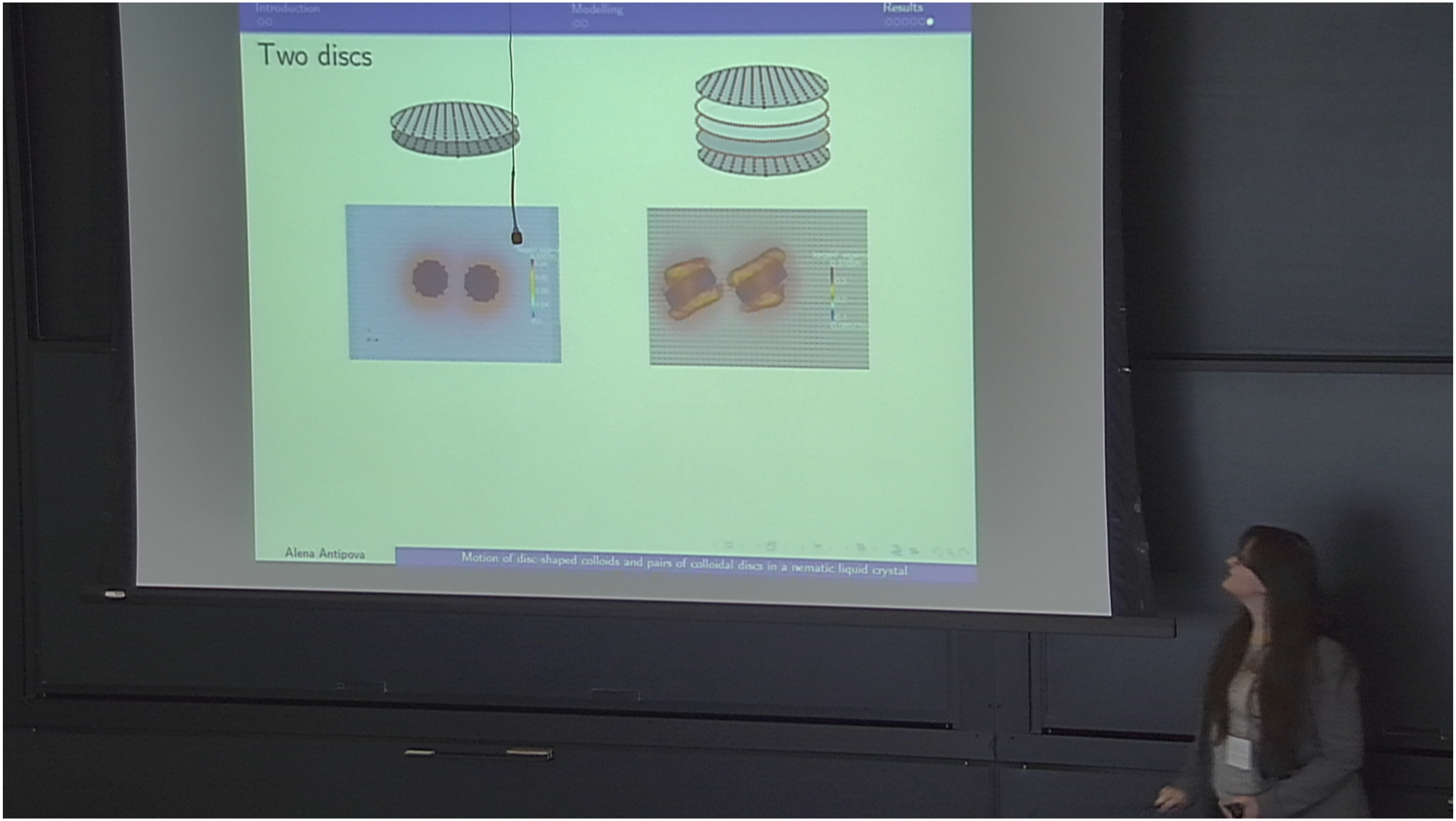
Light transmission

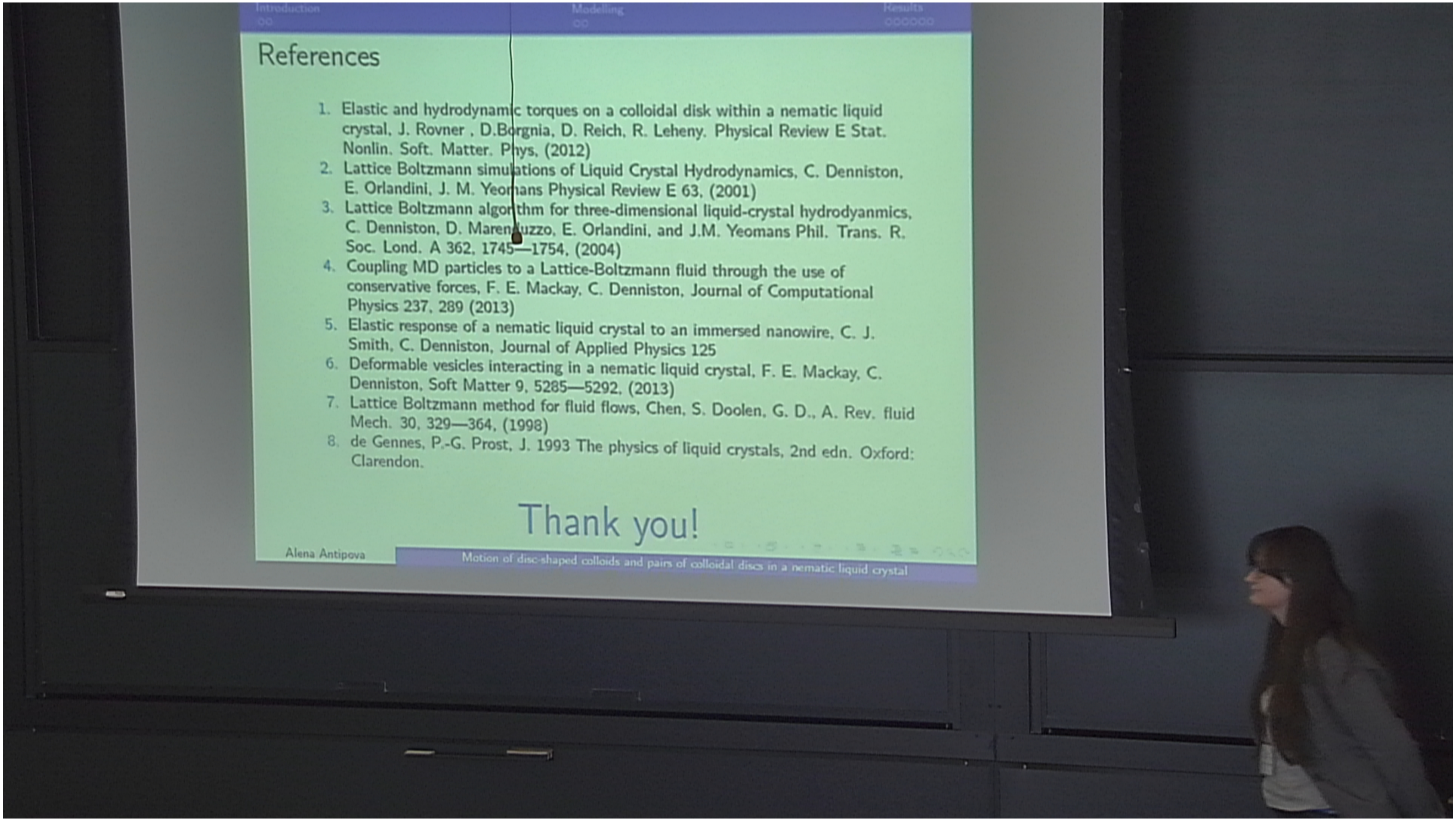


Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal
J. Rovner , D.Borgnia, D. Reich, R. Leheny


Introduction
Modelling
Results
Light transmission
0.90
0.85
0.70
0.50
0.30
0.10
2nd polarizer
LC layers
disc
1st polarizer
light
Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal
J. Rovner , D.Borgnia, D. Reich, R. Leheny
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal


Introduction
Modelling
Results
Two discs
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal


Introduction
Modelling
Results
Two discs
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal


Introduction
Modelling
Results
References
1. Elastic and hydrodynamic torques on a colloidal disk within a nematic liquid crystal, J. Rovner , D.Borgnia, D. Reich, R. Leheny. Physical Review E Stat. Nonlin. Soft. Matter. Phys, (2012)
2. Lattice Boltzmann simulations of Liquid Crystal Hydrodynamics, C. Denniston, E. Orlandini, J. M. Yeomans Physical Review E 63, (2001)
3. Lattice Boltzmann algorithm for three-dimensional liquid-crystal hydrodyanmics, C. Denniston, D. Marenduzzo, E. Orlandini, and J.M. Yeomans Phil. Trans. R. Soc. Lond. A 362, 1745—1754, (2004)
4. Coupling MD particles to a Lattice-Boltzmann fluid through the use of conservative forces, F. E. Mackay, C. Denniston, Journal of Computational Physics 237, 289 (2013)
5. Elastic response of a nematic liquid crystal to an immersed nanowire, C. J. Smith, C. Denniston, Journal of Applied Physics 125
6. Deformable vesicles interacting in a nematic liquid crystal, F. E. Mackay, C. Denniston, Soft Matter 9, 5285—5292, (2013)
7. Lattice Boltzmann method for fluid flows, Chen, S. Doolen, G. D., A. Rev. fluid Mech. 30, 329—364, (1998)
8. de Gennes, P.-G. Prost, J. 1993 The physics of liquid crystals, 2nd edn. Oxford: Clarendon.
Thank you!
Alena Antipova
Motion of disc-shaped colloids and pairs of colloidal discs in a nematic liquid crystal