

Aerodynamics of Heavy Vehicles

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Introduction

- Brief discussion of several relevant publications
- Progress in the laboratory
- Computation
- Recent DPIV measurements

- **“Detached-eddy simulation of an airfoil at high angle of attack”**, M. Shur, P.R. Spalart, M. Strelets, A. Travin, *Proceedings of the 1st AFOSR Conference on DNS/LES, Ruston, LA, August 1997*
- **“Comments on the feasibility of LES for wings, and on a hybrid RANS/LES approach”**, P.R. Spalart, W-H. Jou, M. Strelets, S.R. Allmaras
 - ◆ 200,000 grid points, fully 3-D calculation
 - ◆ RANS formalism for attached boundary layers
 - ◆ LES sufficiently far away from wall
 - ◆ Switches between the two automatically, (this is DES)
 - ◆ Captures bulk of unsteady flow behavior

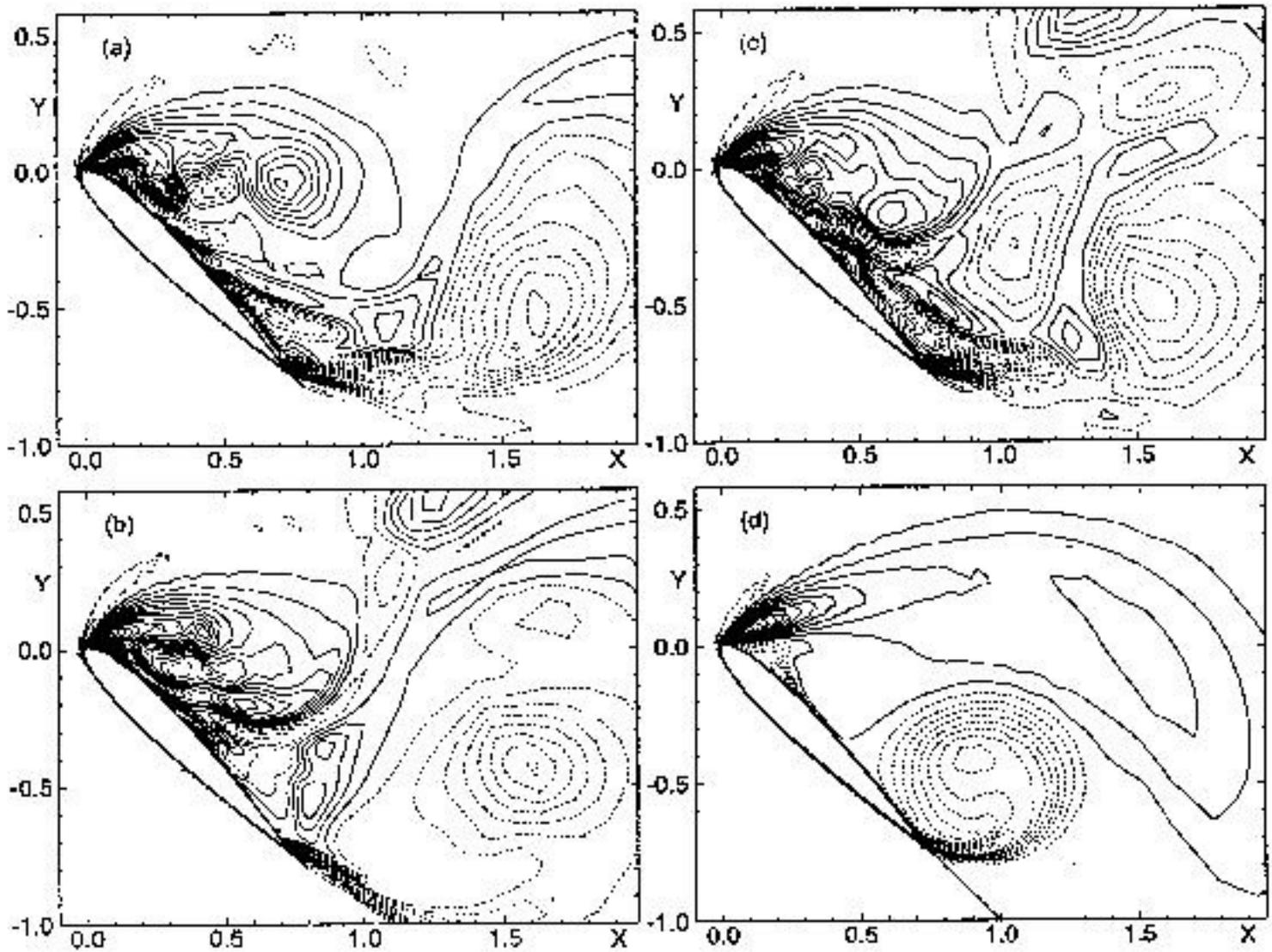
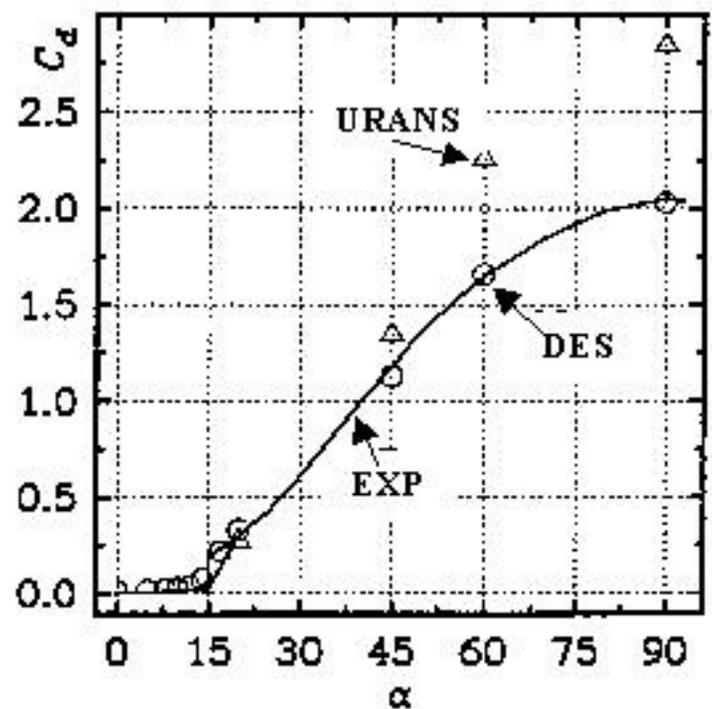
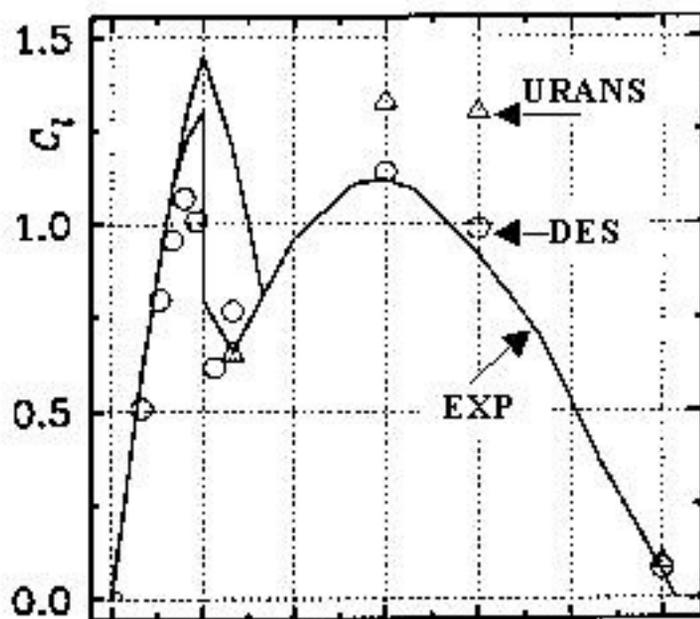
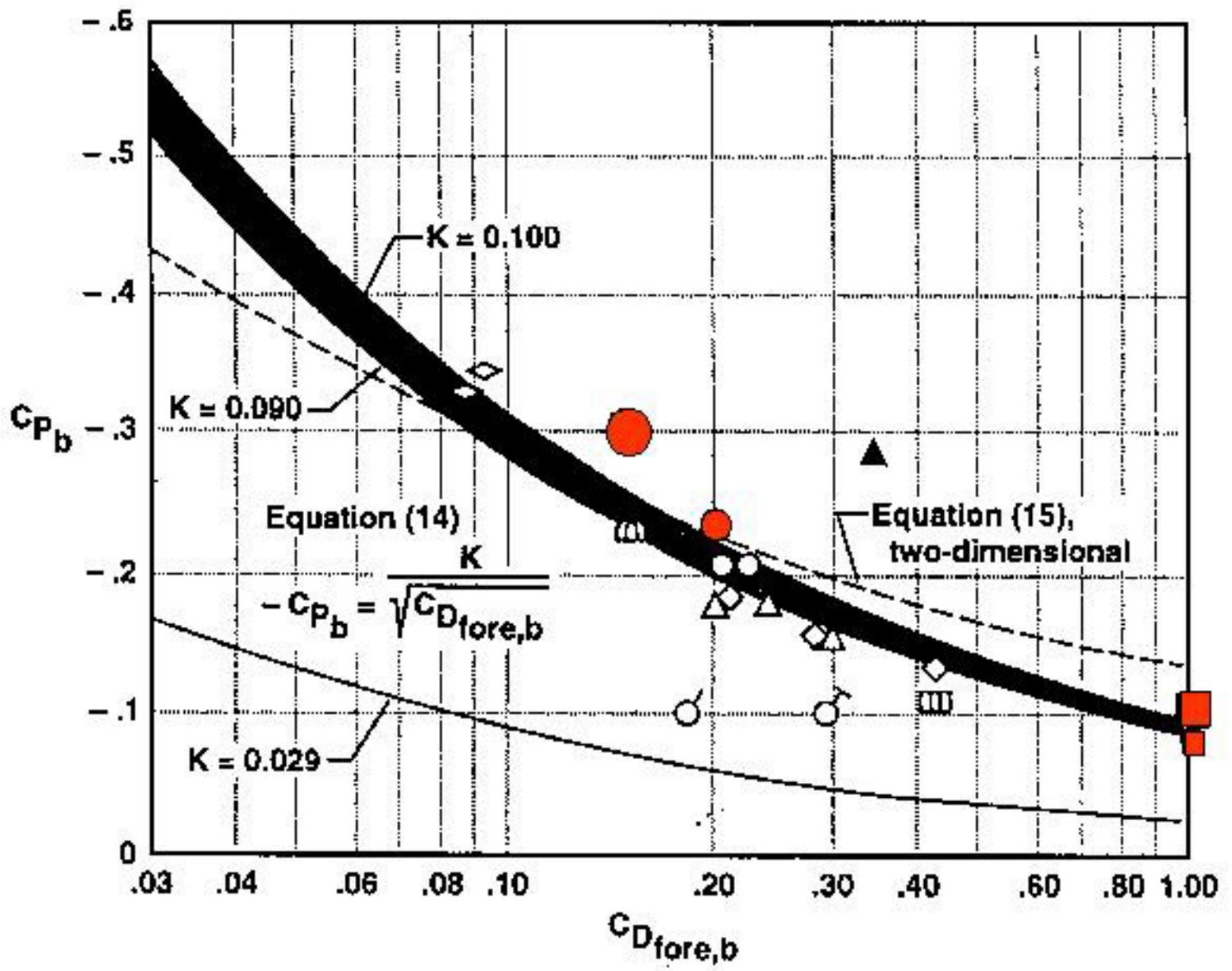


Figure 3. Side views at $\alpha = 45^\circ$. ω_z contours. (a) to (c), cross-sections of DES at $z/c = 0.25, 0.5, 0.75$. (d), URANS.



- **“Flight-determined subsonic lift and drag characteristics of seven lifting-body and wing-body reentry vehicle configurations with truncated bases”**, E.J. Saltzman, K.C. Wang, K.W. Iliff, *AIAA 99-0383, 1999*
- **“A reassessment of heavy-duty truck aerodynamic design features & priorities”**, E.J. Saltzman, R.R. Meyer, Jr., *Preliminary Report, NASA Dryden Flight Research Center, 1998*
 - ◆ A relationship exists between fore-body drag and base pressure coefficient for many bluff-base aerodynamic shapes. This may include heavy trucks.
 - ◆ If the form of the relationship is postulated, the minimum drag configuration can be determined



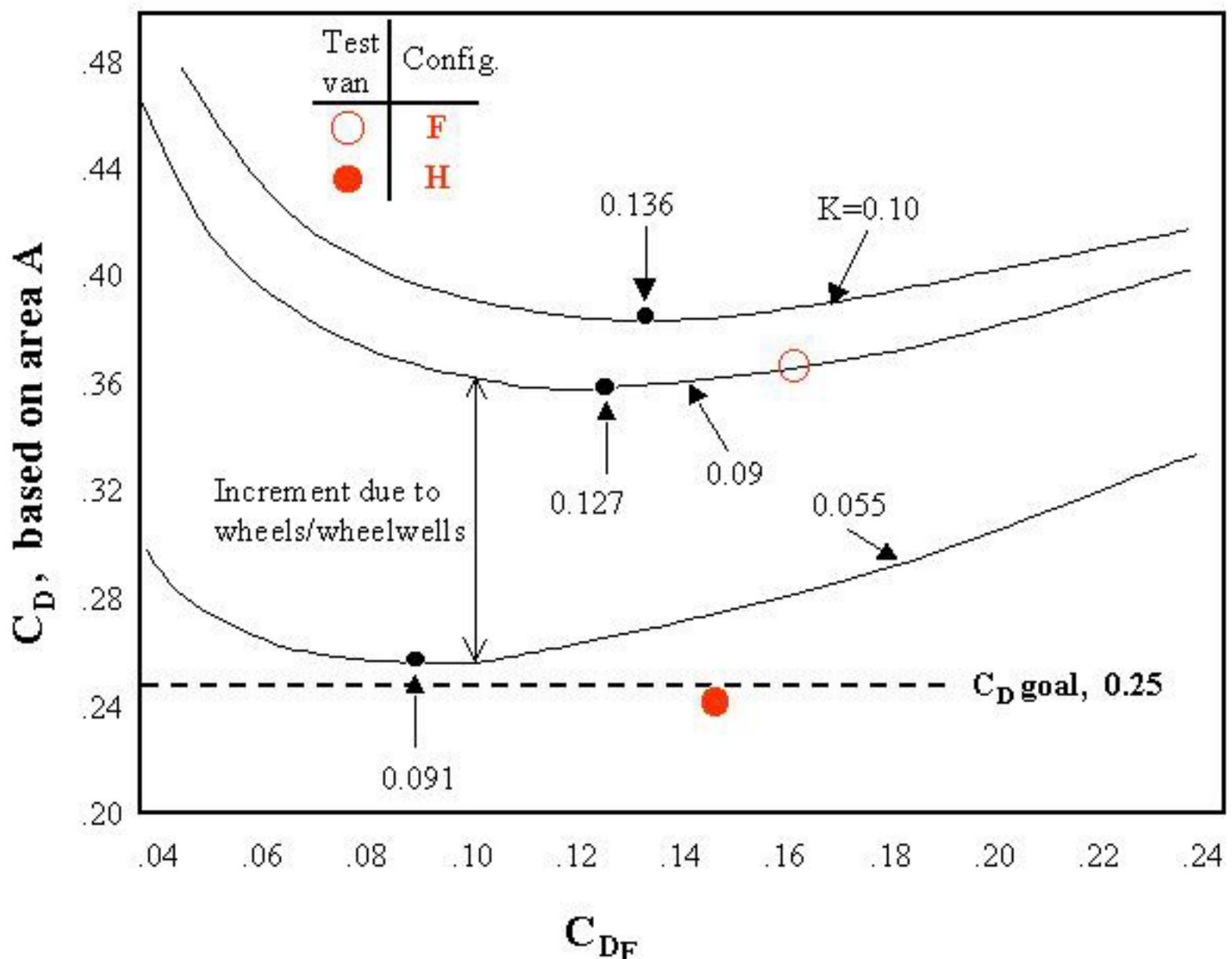
$$C_{DTotal} = C_{DF} + C_{DB} \quad (\text{Forebody} + \text{Base})$$

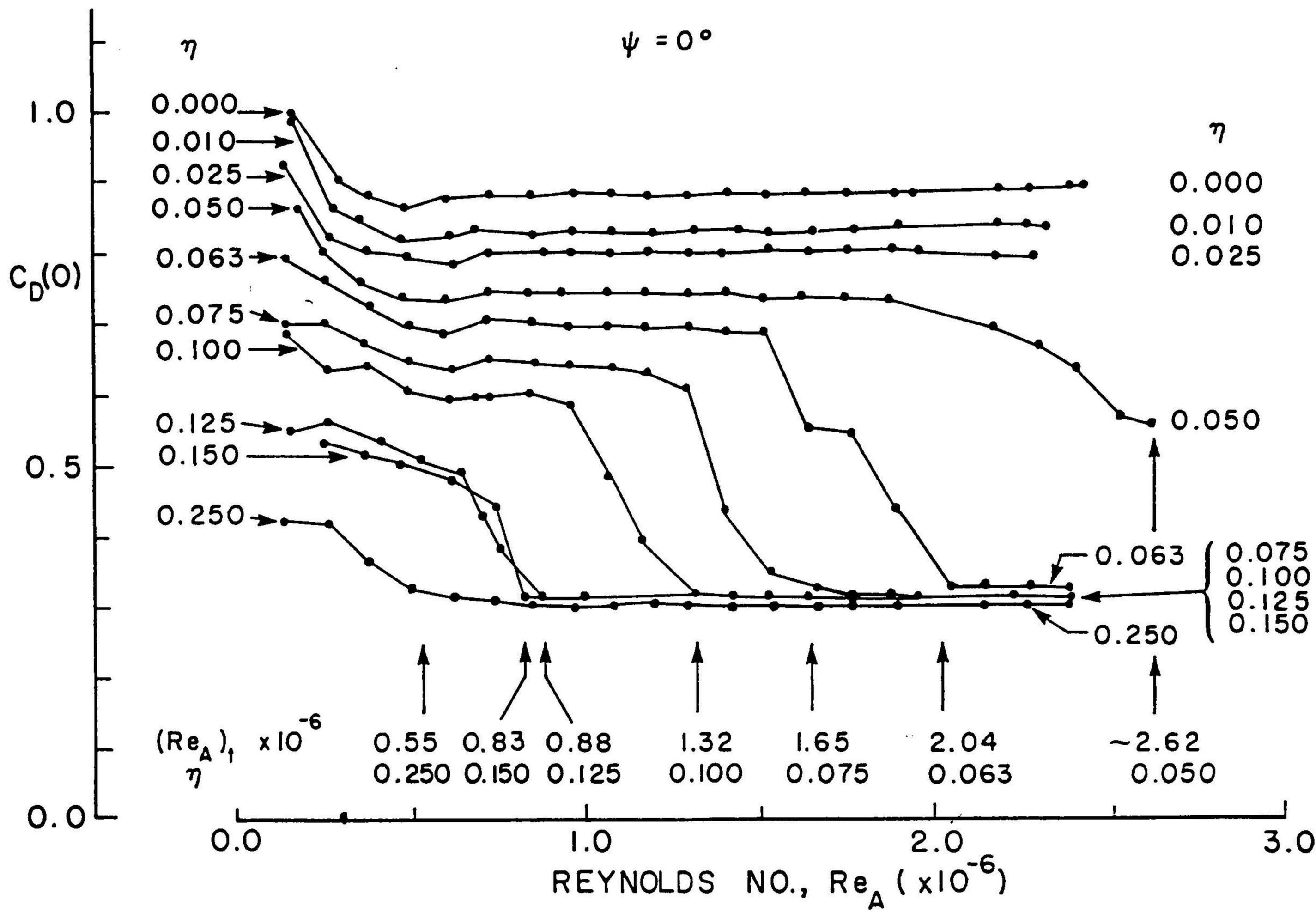
But $C_{DB} = -C_{PB}$, where C_{PB} = base pressure

$$\text{If } C_{PB} = \frac{-K}{\sqrt{C_{DF}}}$$

$$\text{Then } C_{DTotal} = C_{DF} + \frac{K}{\sqrt{C_{DF}}}$$

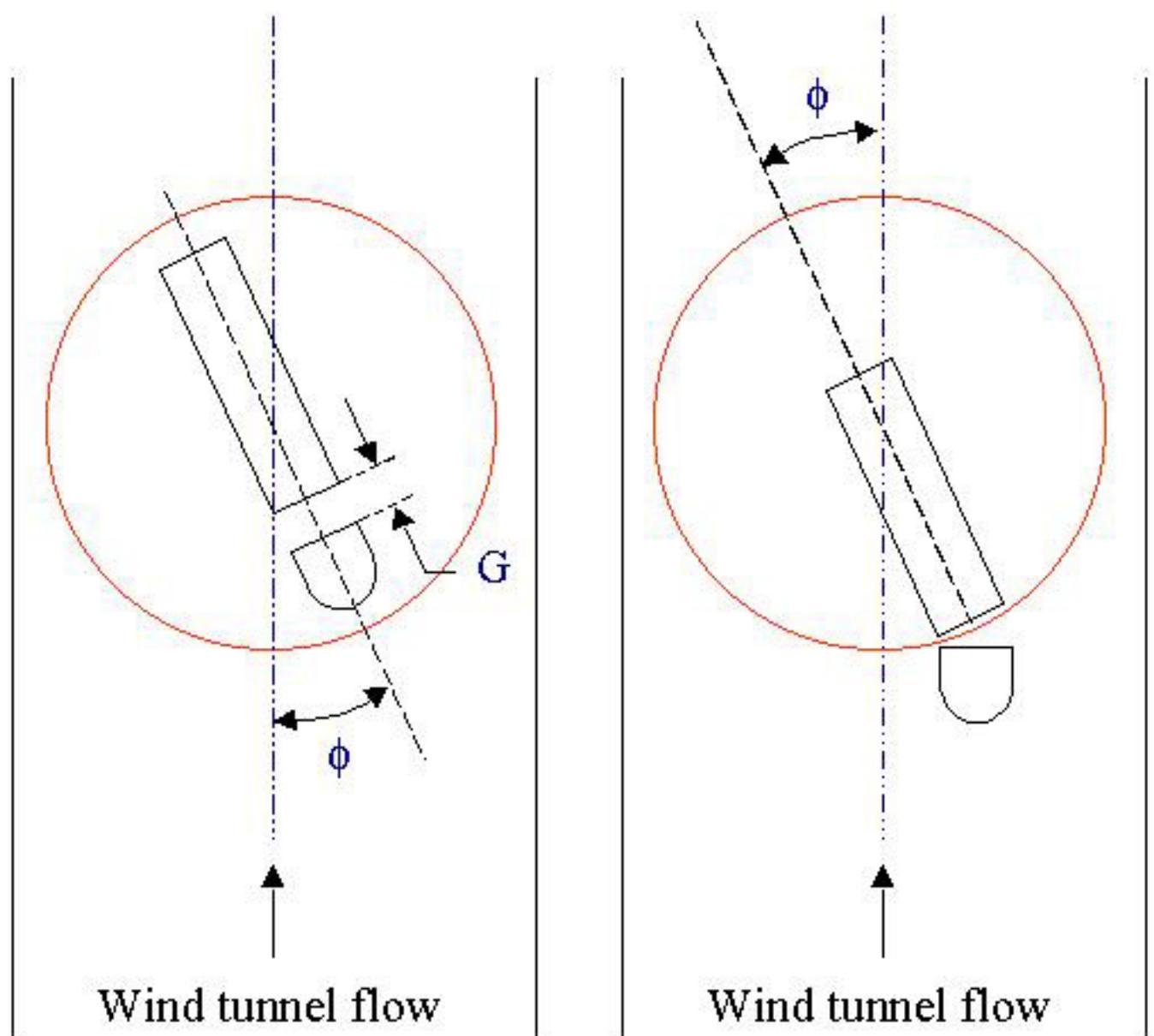
$$C_{PB} = \frac{-K}{\sqrt{C_{DF,B}}}, \text{ modification of Hoerner 3-D equation}$$



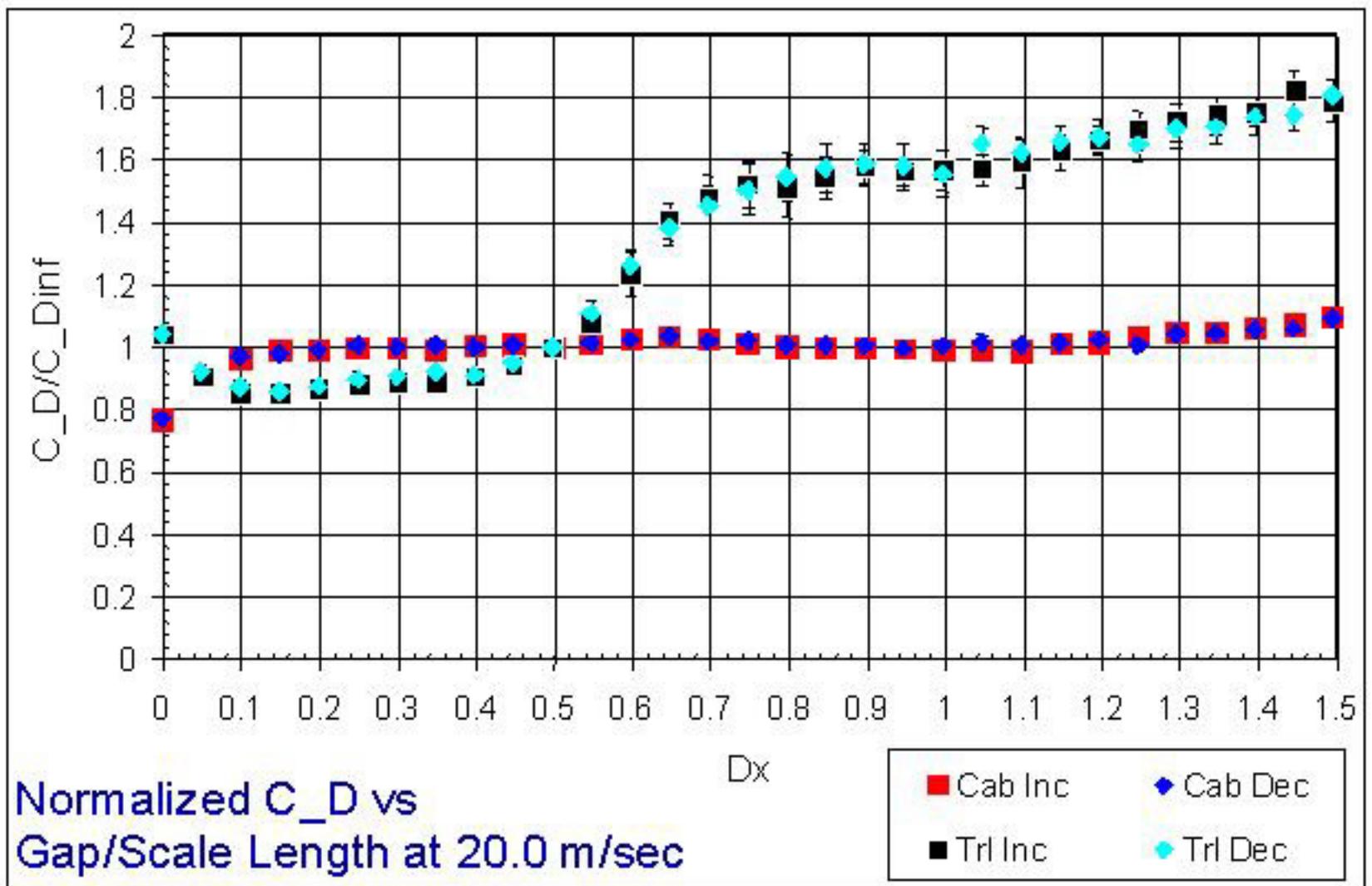
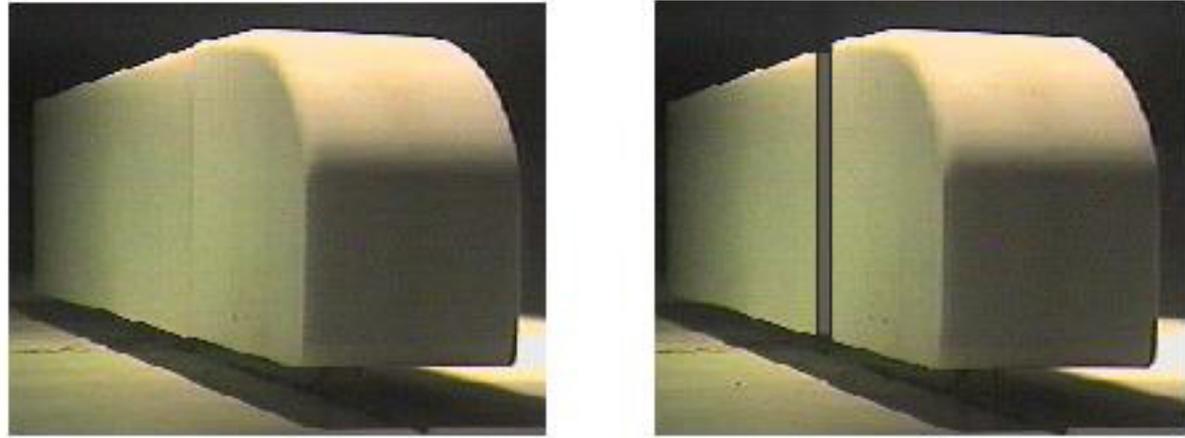


Progress in the laboratory

- Work area being remodeled (University pays \$25,000)
- Yaw turntable will be operational in April

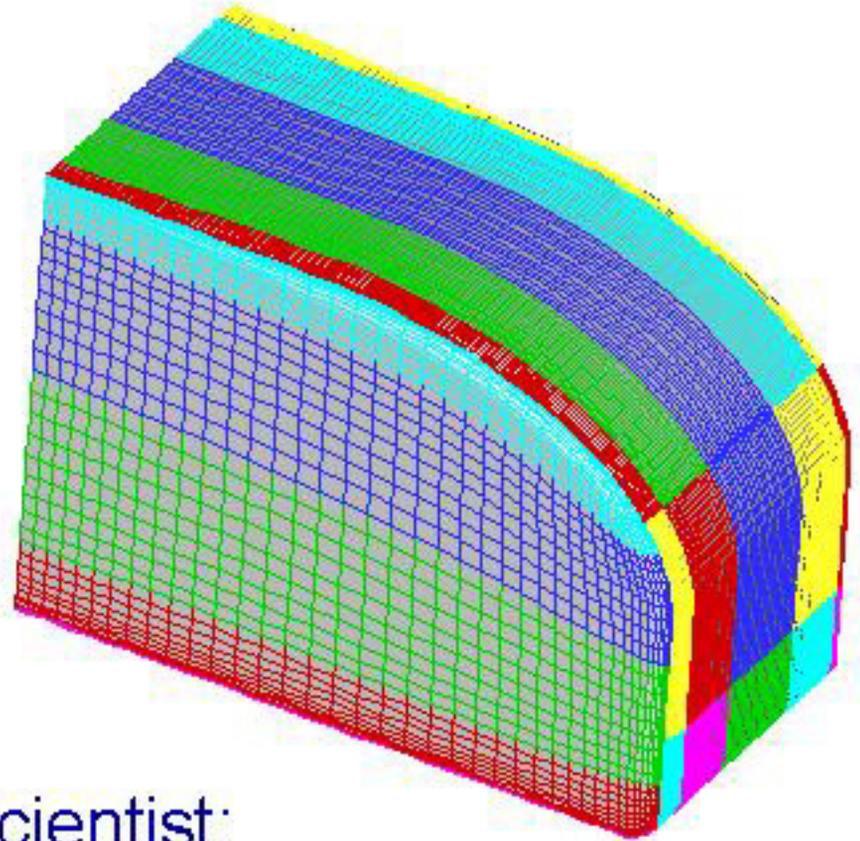


- SNL Truck Model has been fabricated and operated in the wind tunnel



Computations

- Panel code calculations PMARC



- Visiting Scientist:
Dr. Dieter Schwamborn
Head, CFD Group
Institute for Fluid Mechanics
DLR, Gottingen (Germany)
- DES: Smooth cab-trailer (with gap)
SNL Model (with cab-trailer gap)

Topics of Discussion

- Description of flow facilities
- Description of DPIV capabilities
 - ◆ Maximizing accuracy
 - ◆ Maximizing spatial resolution
 - ◆ Treating solid boundaries
- Experiments
 - ◆ Vehicle platooning
 - ◆ SNL truck model with gap

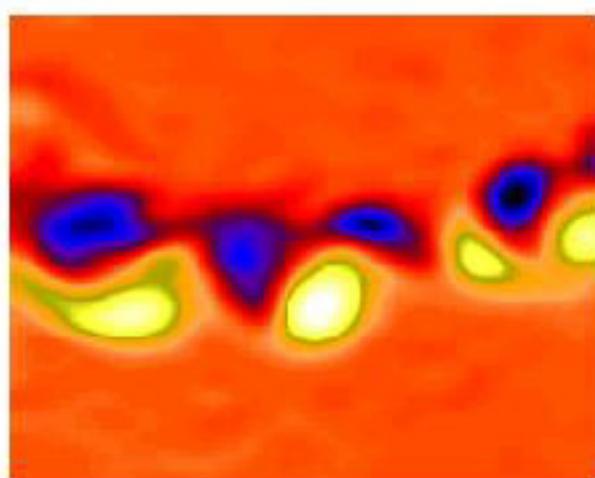
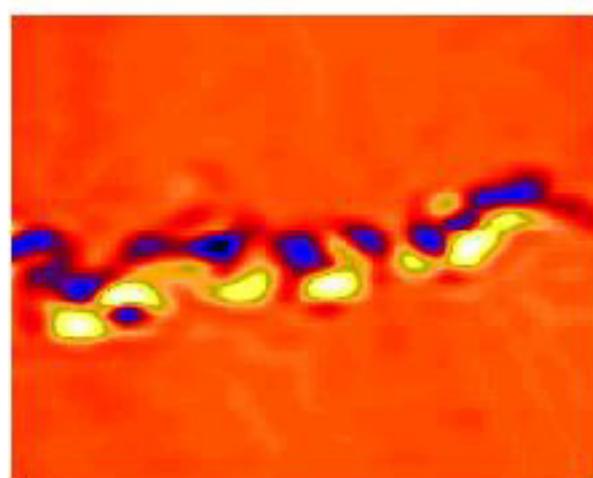
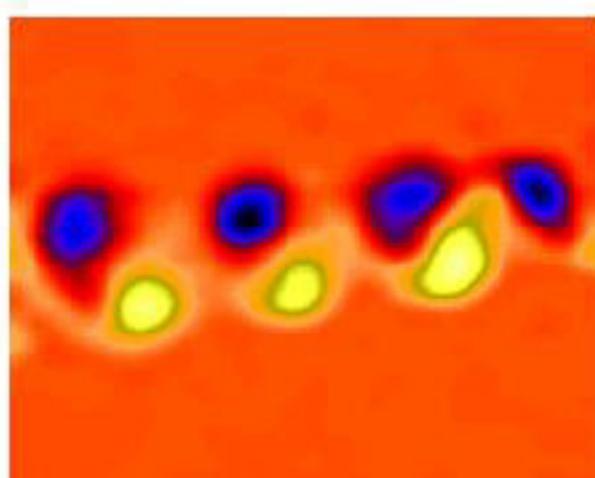
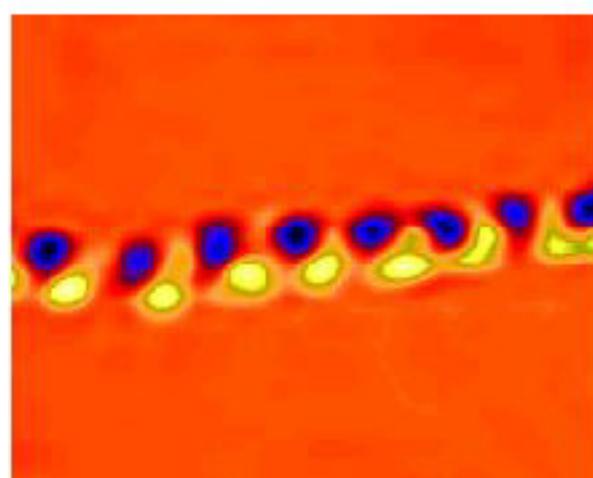
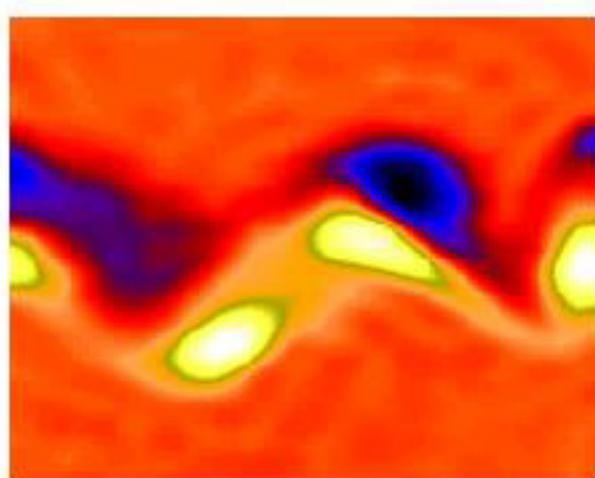
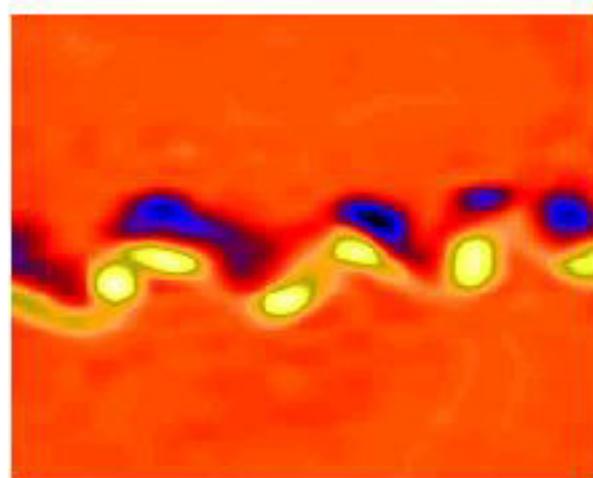
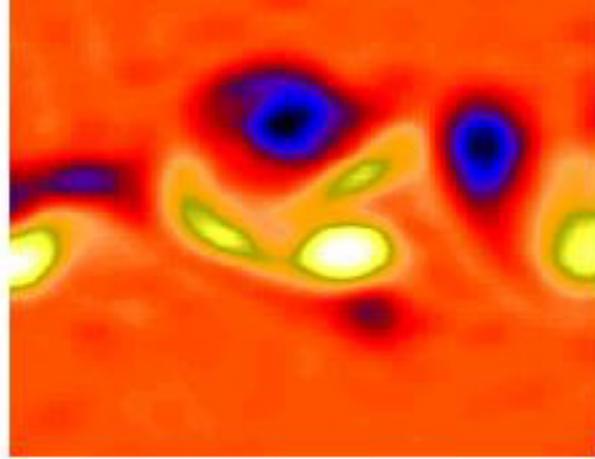
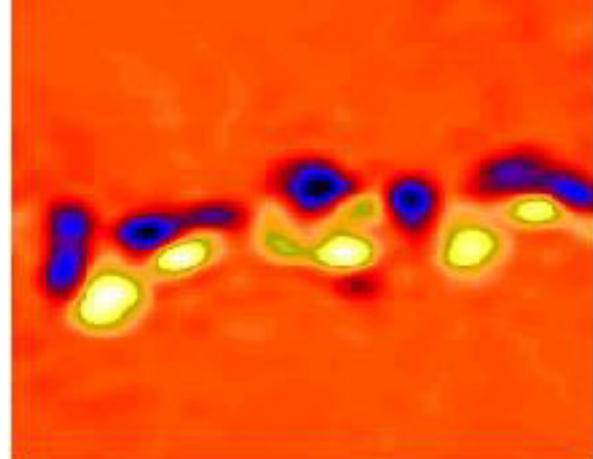
Flow facilities

- Dryden wind tunnel
 - ◆ Top speed 44 m/s (100mph)
 - ◆ Test section 1.3m x 1.3m (53" x 53")

- Nissan/Linac wind tunnel
 - ◆ Moving ground belt
 - ◆ Top speed 90 m/s
 - ◆ Test section 0.9m x 1.1m (36" x 42")

DPIV capabilities

- Two-dimensional PIV based on cross-correlation technique
- Dual channel CCD camera
 - ◆ 1 million pixels
 - ◆ 15 images pairs/sec
- Dual Nd-Yag laser
 - ◆ 160 mJ/pulse
 - ◆ 10 Hz
- Option for variable resolution
 - ◆ wide flow field
 - ◆ maximum spatial resolution
- CIV software tested for reliability and speed
- No-slip condition imposed at the walls
- Special treatment of the data close to the walls

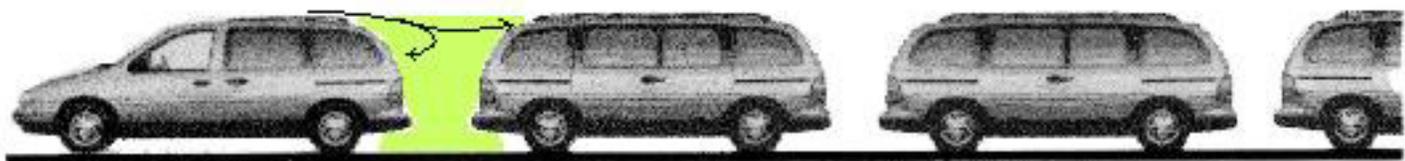


Aerodynamics of Platoons of Vehicles

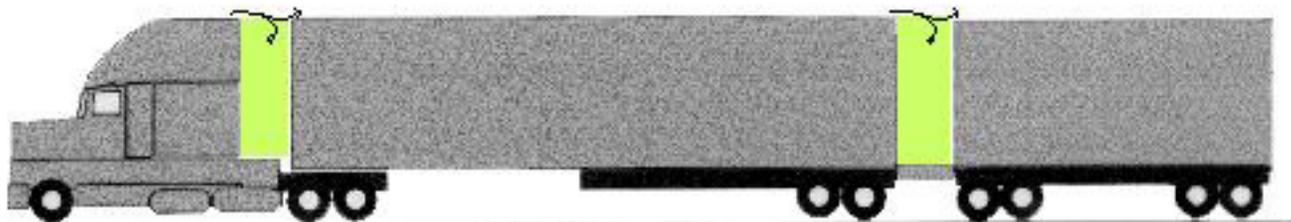
1. PATH concept: Platoon of intelligent vehicles



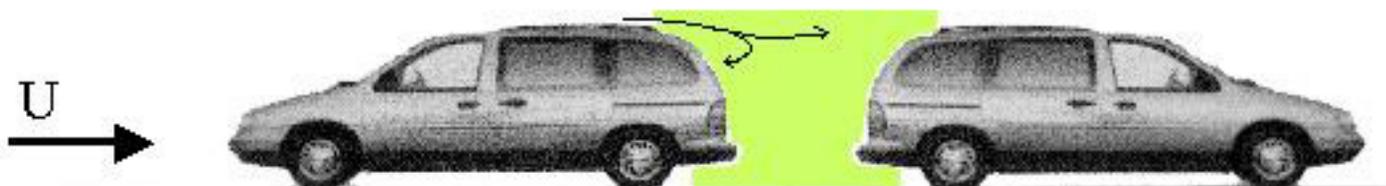
2. Platoon of vehicle modules & platoon "leader"



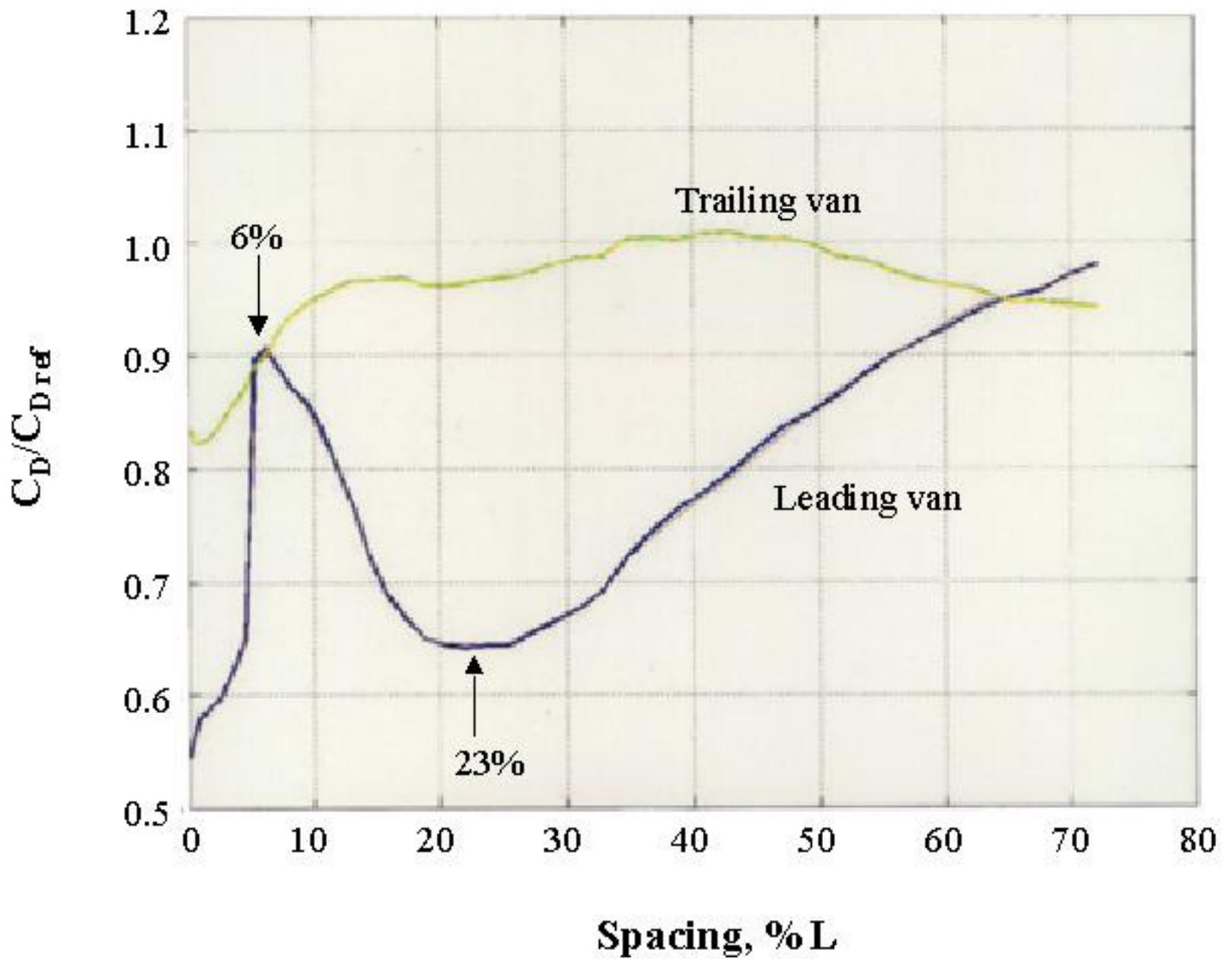
3. Tractor-trailer platoon



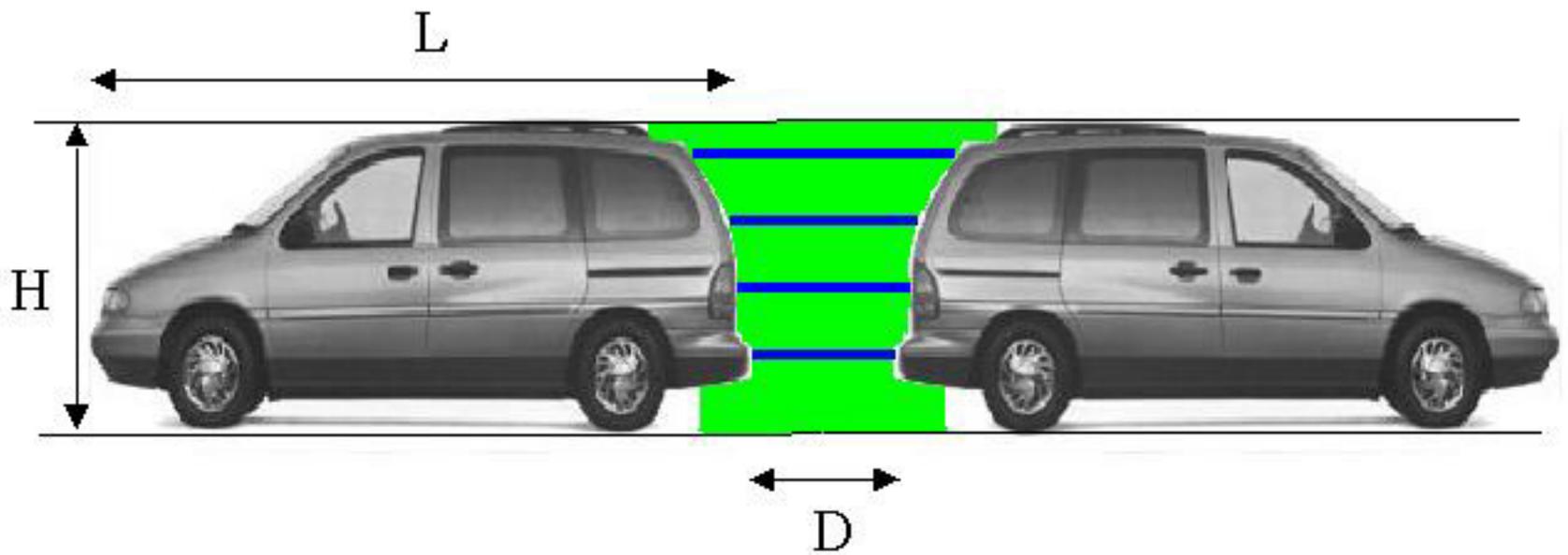
4. Test configuration for present experiment: Back-to-back geometry



Average drag force coefficients

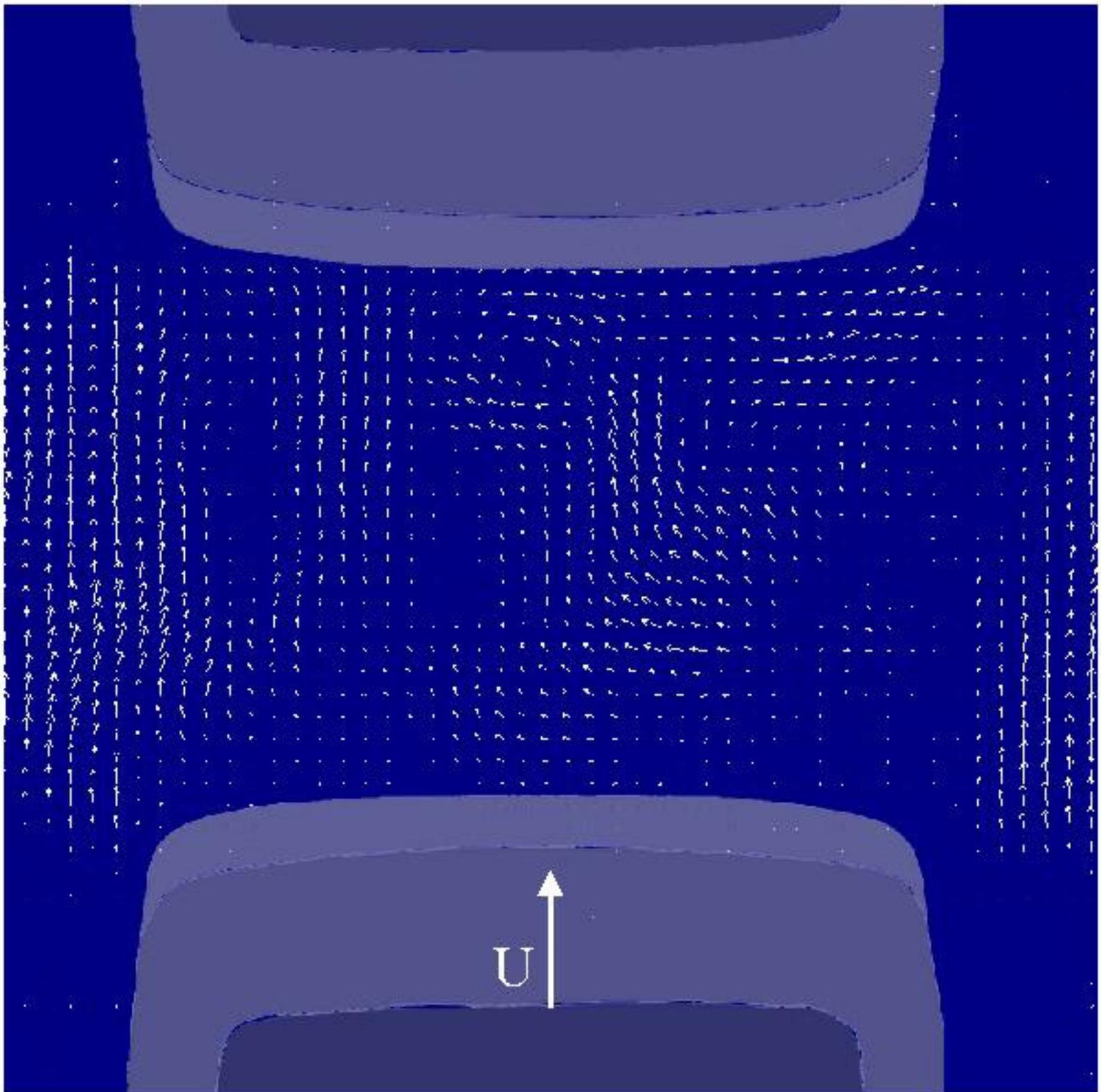


Vans in back-to-back configuration

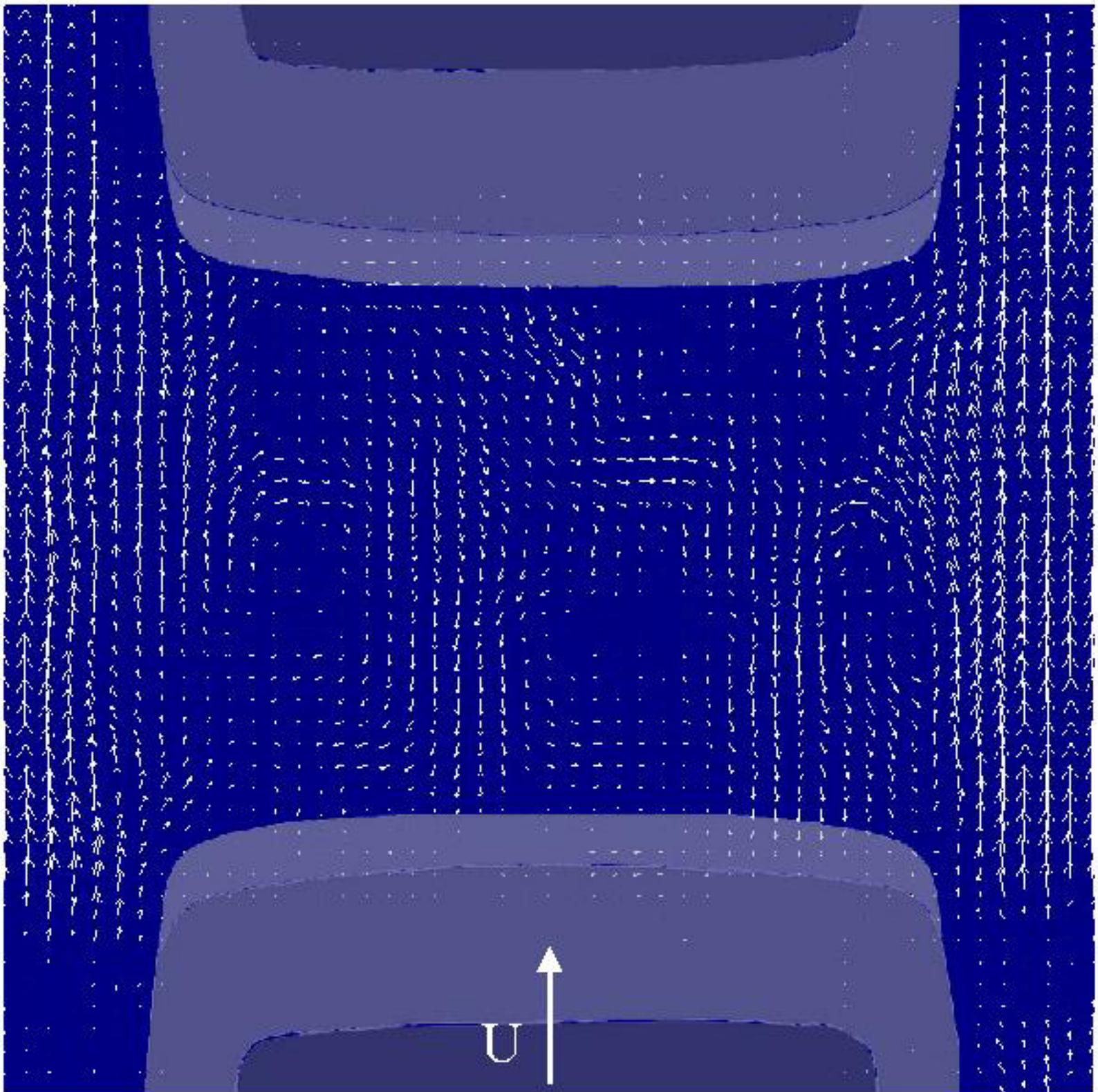


Van dimensions	$L=25''$, $H=8''$
Free-stream velocity	25 m/s
Horizontal planes	28%, 46%, 65%, 84% of H
Vertical plane	Centerline
Spacing	$D/L=23\%$ and 6%
Seeding	One-micron droplets
Illumination	Two Nd-Yag lasers, 160 mJoule/pulse
Acquisition rate	10 Hz
Camera	1000 x 1000 pixels, dual channel CCD
Image processing	CIV/USC

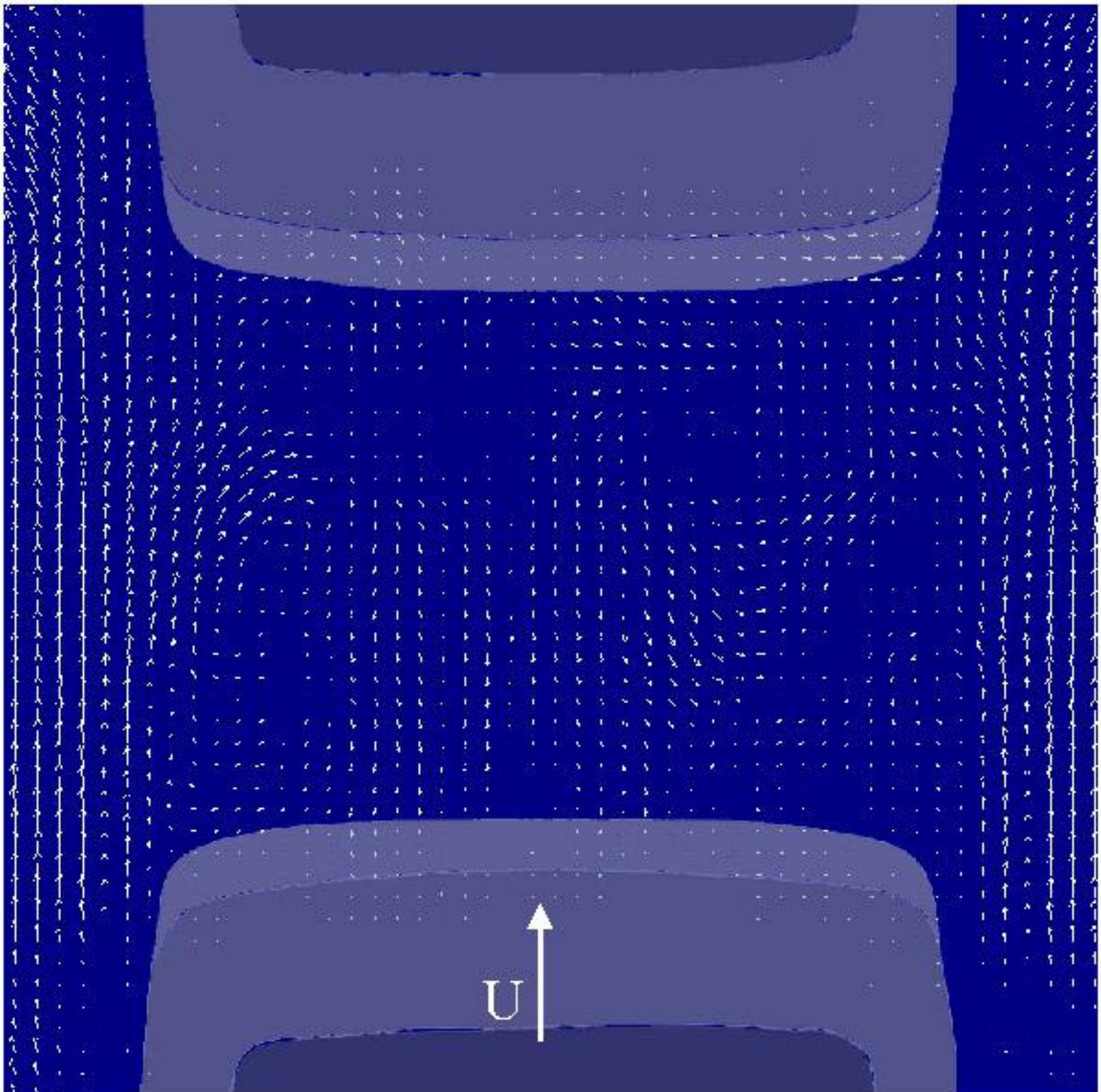
Velocity field for $D/L=23\%$
Horizontal plane at $Z/H=0.28$



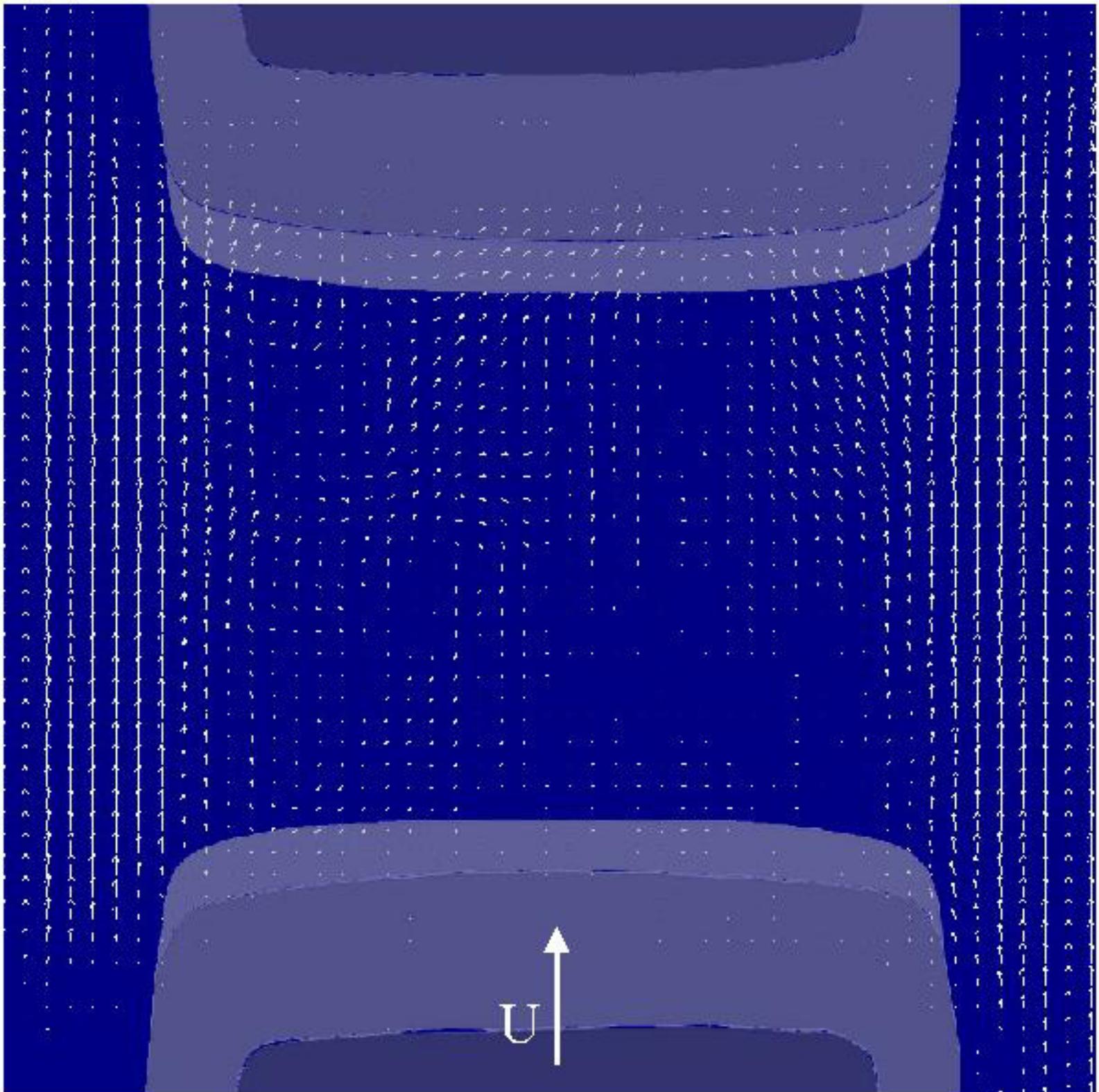
Velocity field for $D/L=23\%$
Horizontal plane at $Z/H=0.46$



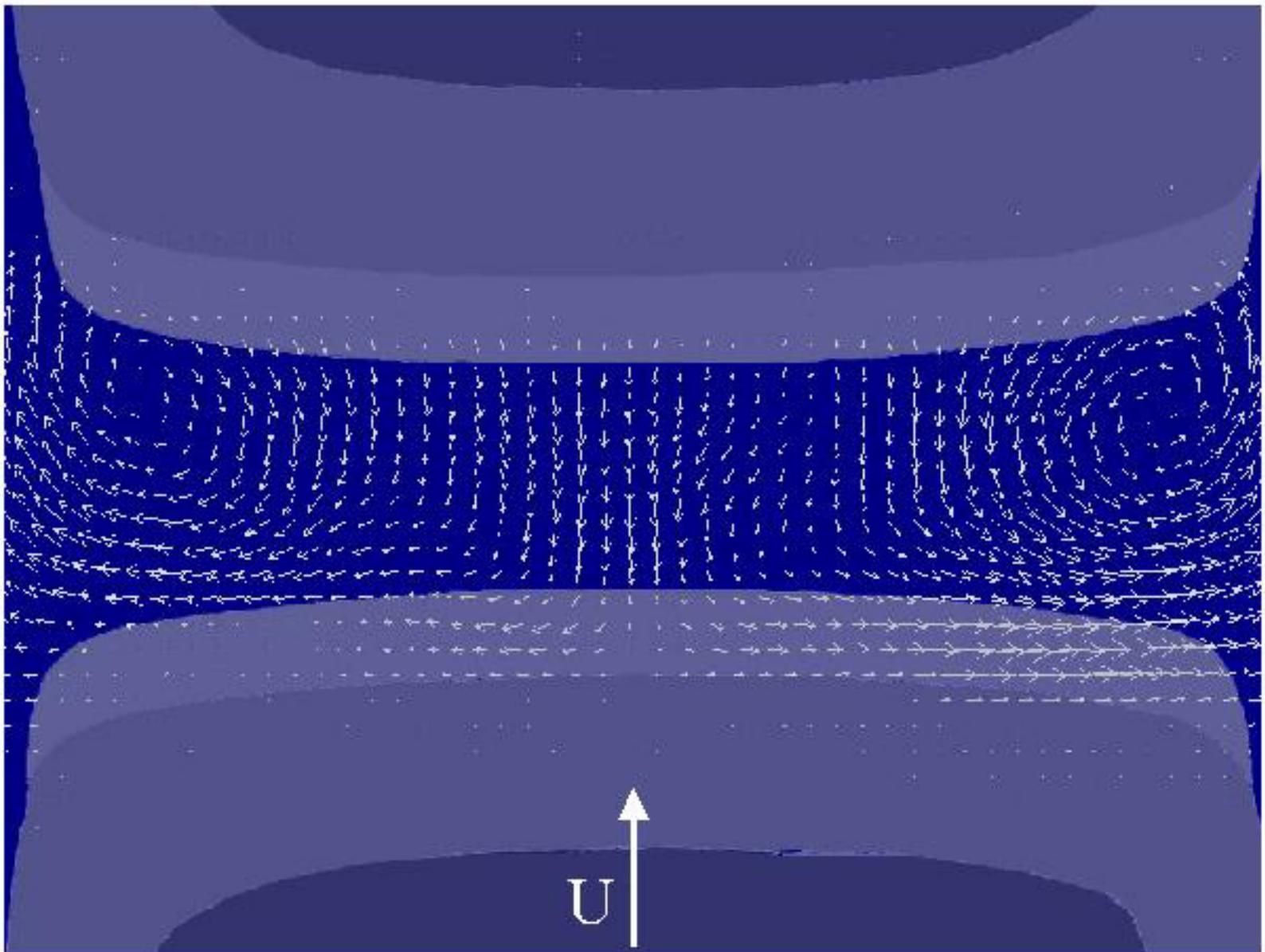
Velocity field for $D/L=23\%$
Horizontal plane at $Z/H=0.65$



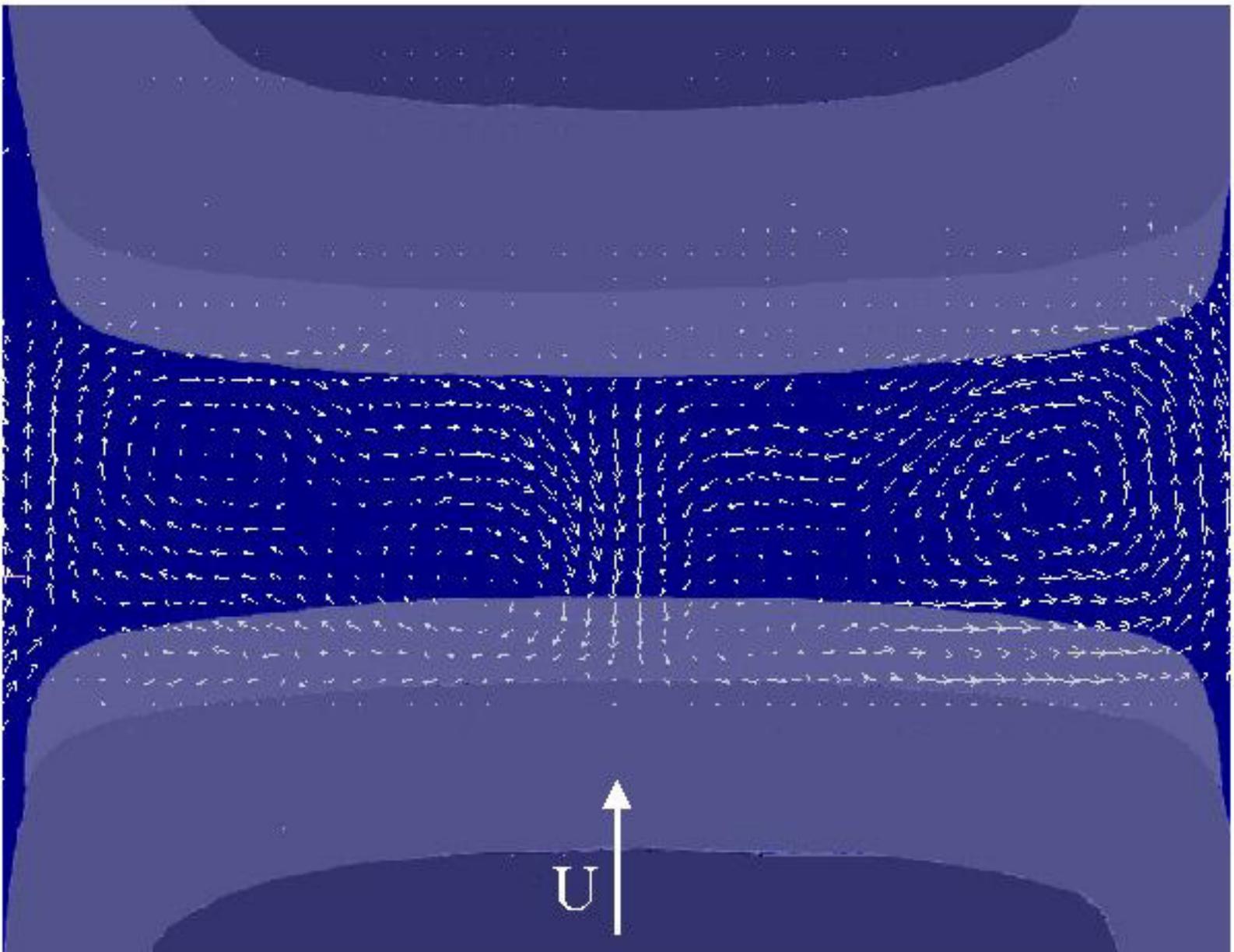
Velocity field for $D/L=23\%$
Horizontal plane at $Z/H=0.84$



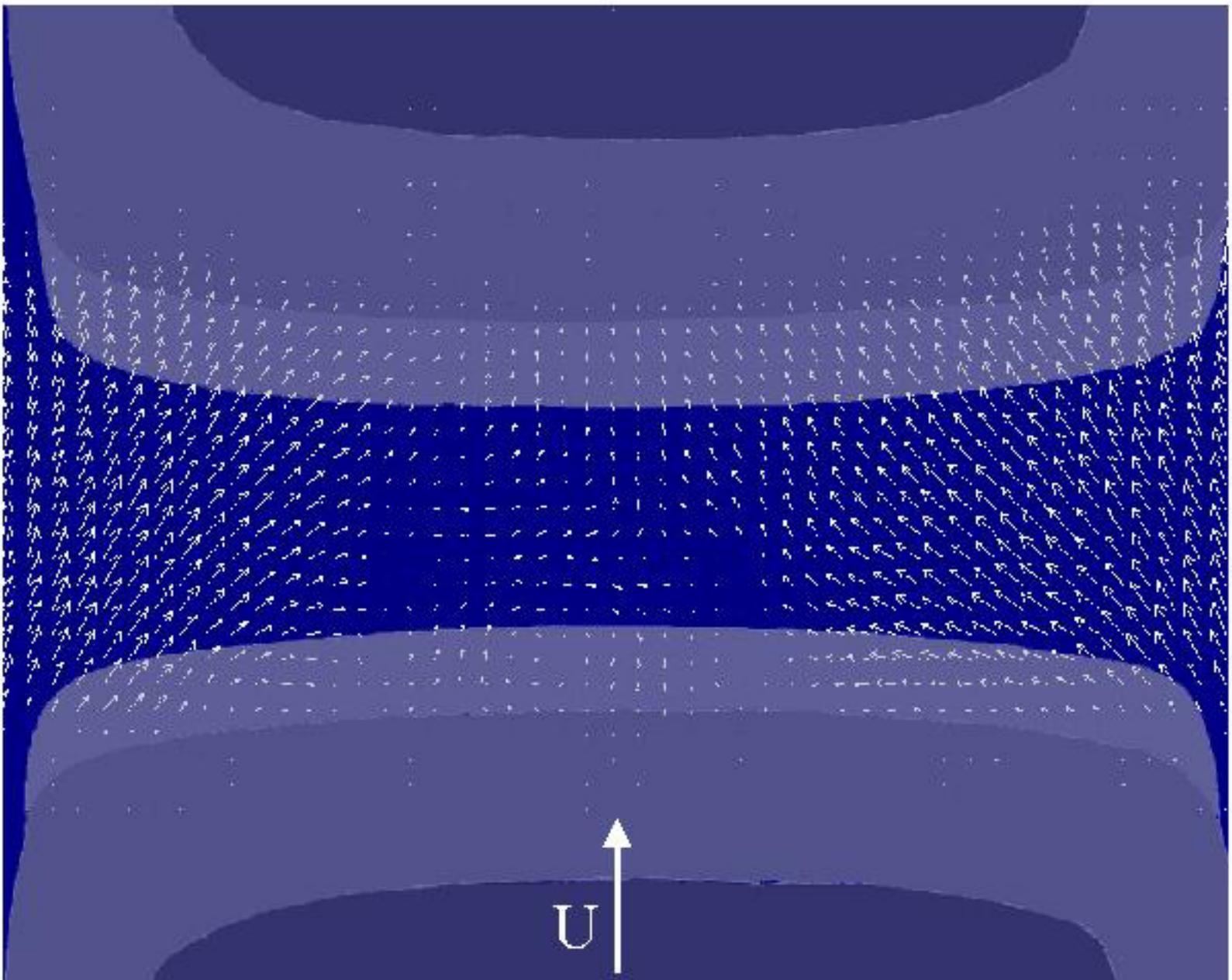
Velocity field for $D/L=6\%$
Horizontal plane at $Z/H=0.46$



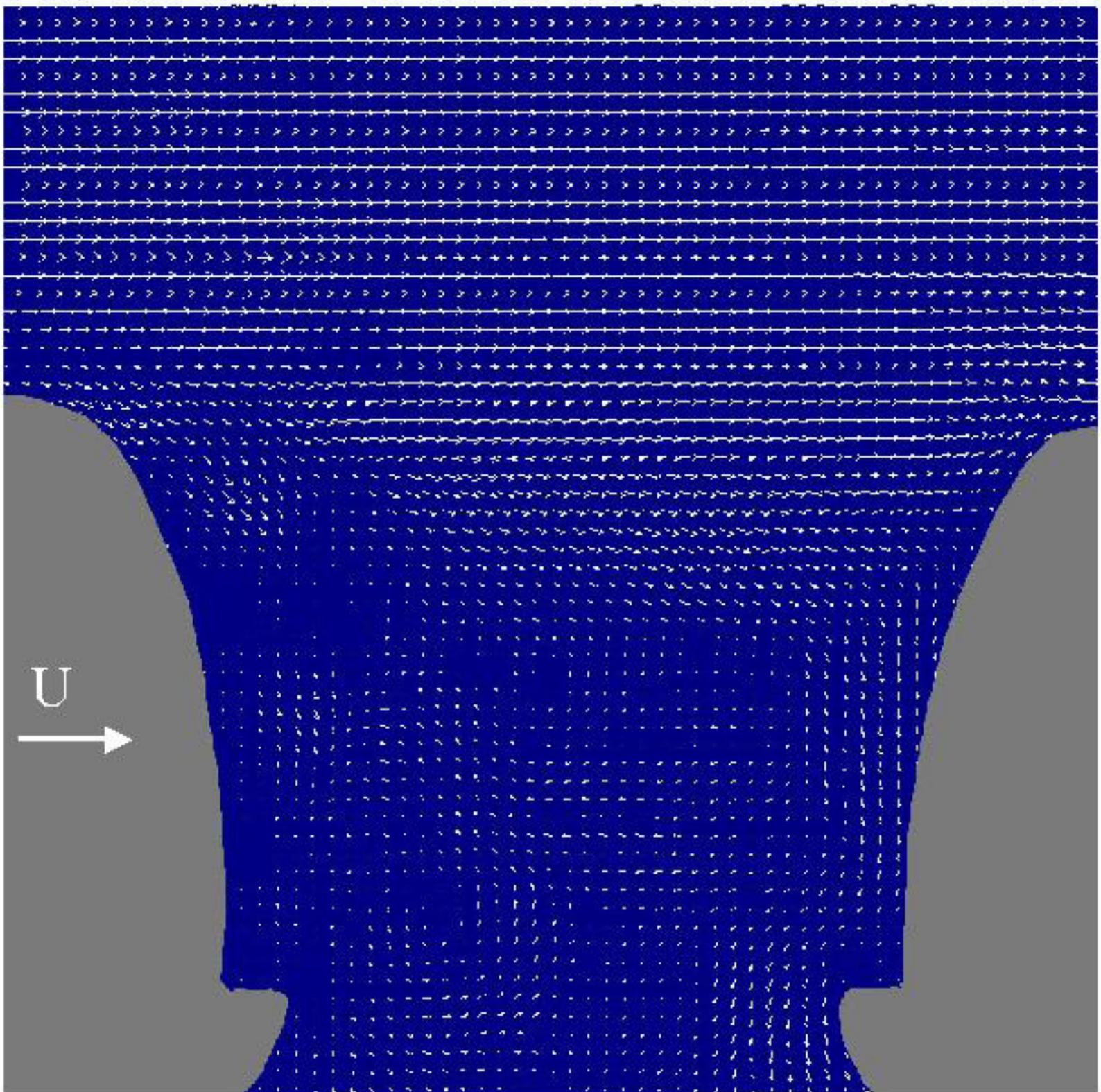
Velocity field for $D/L=6\%$
Horizontal plane at $Z/H=0.65$



Velocity field for $D/L=6\%$
Horizontal plane at $Z/H=0.84$



Instantaneous velocity field
Vertical mid-plane, $D/L=23\%$



Instantaneous velocity field
Vertical mid-plane, $D/L=6\%$

