

# The benefit of European networks and international cooperation for the development of PIV.

M. Stanislas & all participants to GARTEUR AG 19, EUROPIV 1 &2, PIVNET 1 &2 and PIV Challenge.

*Ecole Centrale de Lille  
Laboratoire de Mécanique de Lille*



**15 years of european cooperation on PIV :**

**GARTEUR AD AG 19 : January 1994 to 1996.**

**• 2 EC research projects :**

- EUROPIV                      1996-1998**
- EUROPIV 2                    2000-2003**

**• 2 EC Thematic networks :**

- PIVNET                        1997-2001**
- PIVNET 2                      2002-2007**

## **GARTEUR AD AG 19 : January 1994 to February 1996**

- **DLR**
- **DRA**
- **NLR**
- **FFA**
- **ONERA**
- **INTA**
- **CIRA**
- **Airbus Germany**
- **TU Delft**
- **CORIA**
- **Univ. Rome**
- **Univ. St Etienne**
- **Univ Warwick**
- **Univ Oldenburg**

# GARTEUR AD AG 19

- **Part 1 : Definition and construction of a Data Base of PIV recordings in order to test and compare various methods of analysis**
- **Part 2 : Evaluation of video recording**

# GARTEUR AD AG 19

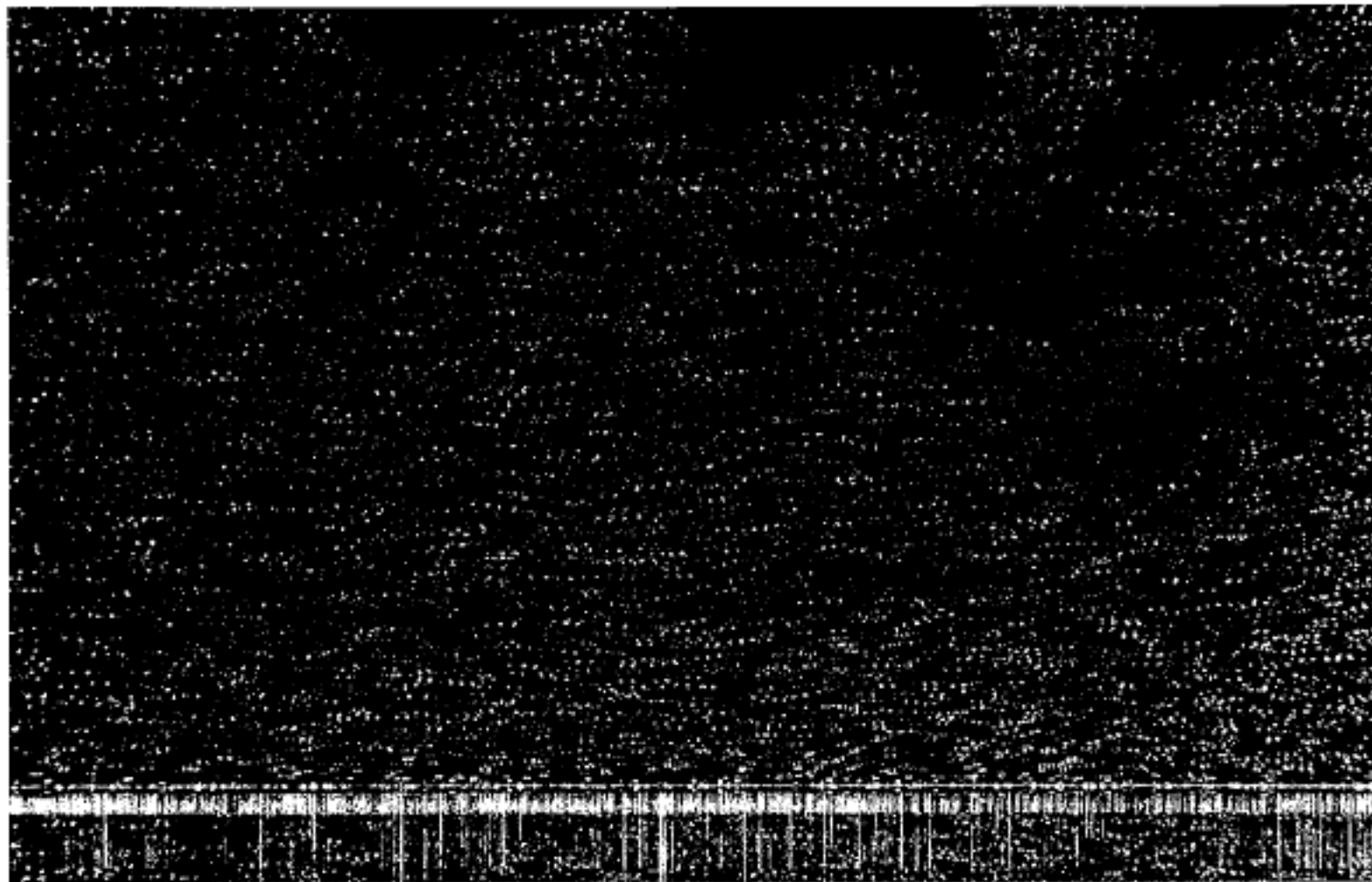
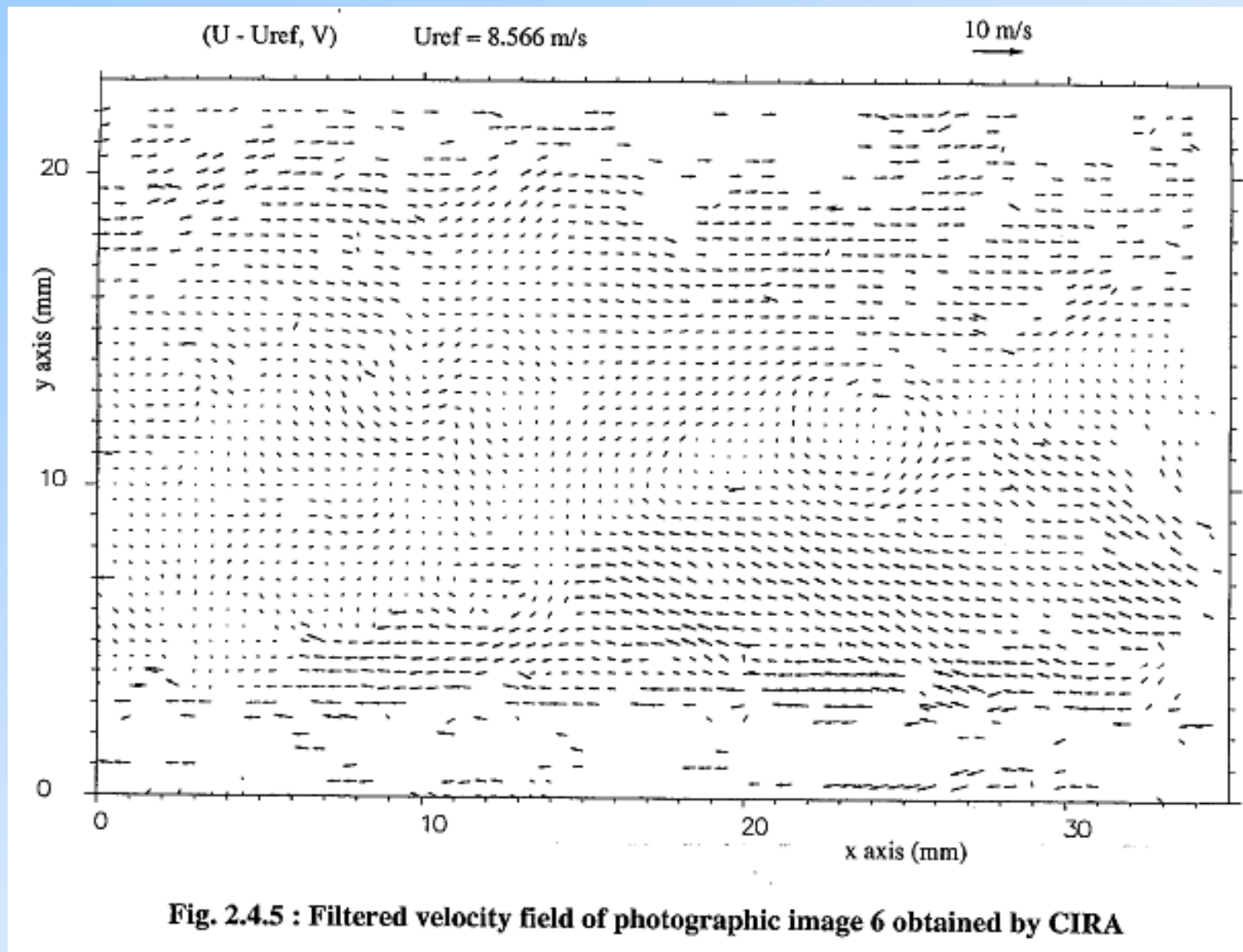
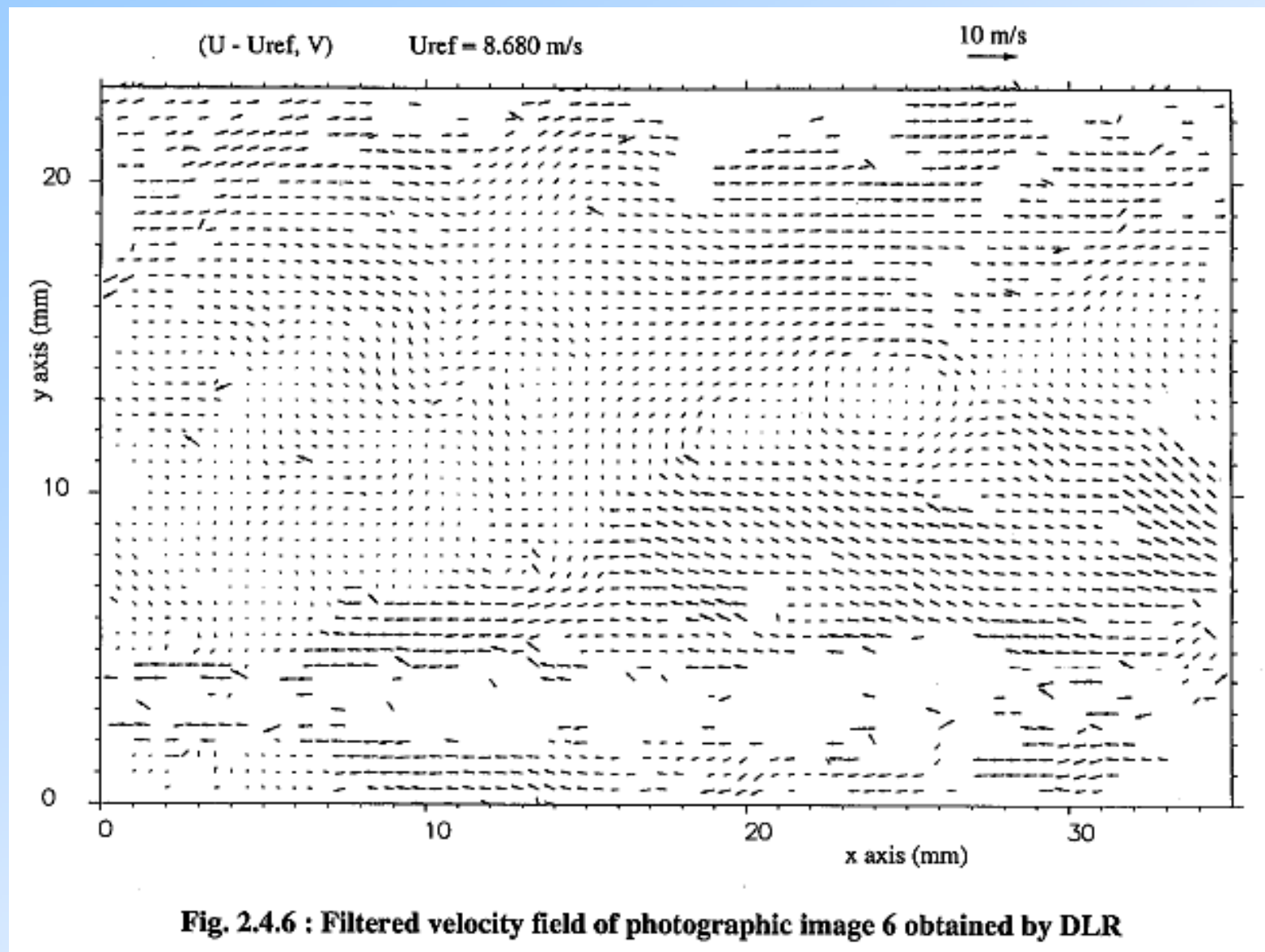


Fig. 2.4.2 : PIV photograph of the boundary layer (image 6)

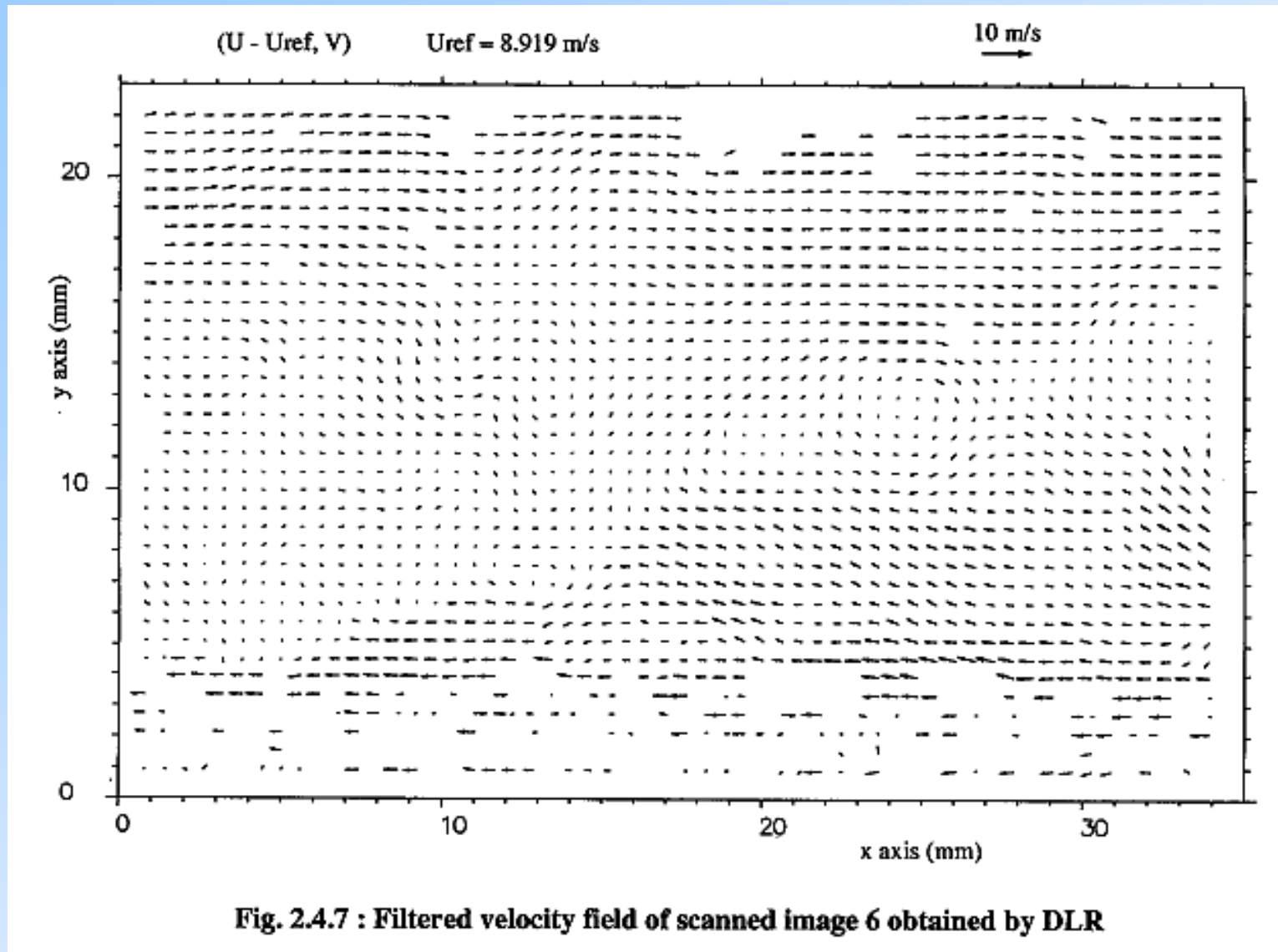
# GARTEUR AD AG 19



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RAW DATA	Ntotal	Nholes	Umean (m/s)	Vmean (m/s)	u' <sup>2</sup> (m <sup>2</sup> / s <sup>2</sup> )	v' <sup>2</sup> (m <sup>2</sup> / s <sup>2</sup> )
CIRA (**)	3150	0	6.638	- 0.305	12.035	5.214
DLR	3212	148	7.087	0.239	9.362	10.729
DLR (*)	2016	0	8.670	0.139	13.453	3.165
INTA	2512	23	8.450	- 0.045	7.400	4.330
ONERA	5867	271	8.793	0.083	2.743	0.325
Warwick	2015					

FILTERED DATA	Ntotal	Nholes	Nspurious	Umean (m/s)	Vmean (m/s)	u' <sup>2</sup> (m <sup>2</sup> / s <sup>2</sup> )	v' <sup>2</sup> (m <sup>2</sup> / s <sup>2</sup> )
CIRA (**)	2336	814	346	8.566	0.140	2.571	0.211
DLR	2558	802	332	8.680	0.156	2.511	0.241
DLR (*)	1786	230	62	8.919	0.091	2.504	0.161
INTA	2423	112	229	8.720	0.050	3.840	0.190
ONERA	5774	364	242	8.843	0.085	2.558	0.190
Warwick							

(\*) Scanned image, (\*\*) Workshop of Rome

TABLE 2.4.3 : STATISTICS of the RAW and FILTERED DATA of IMAGE 6

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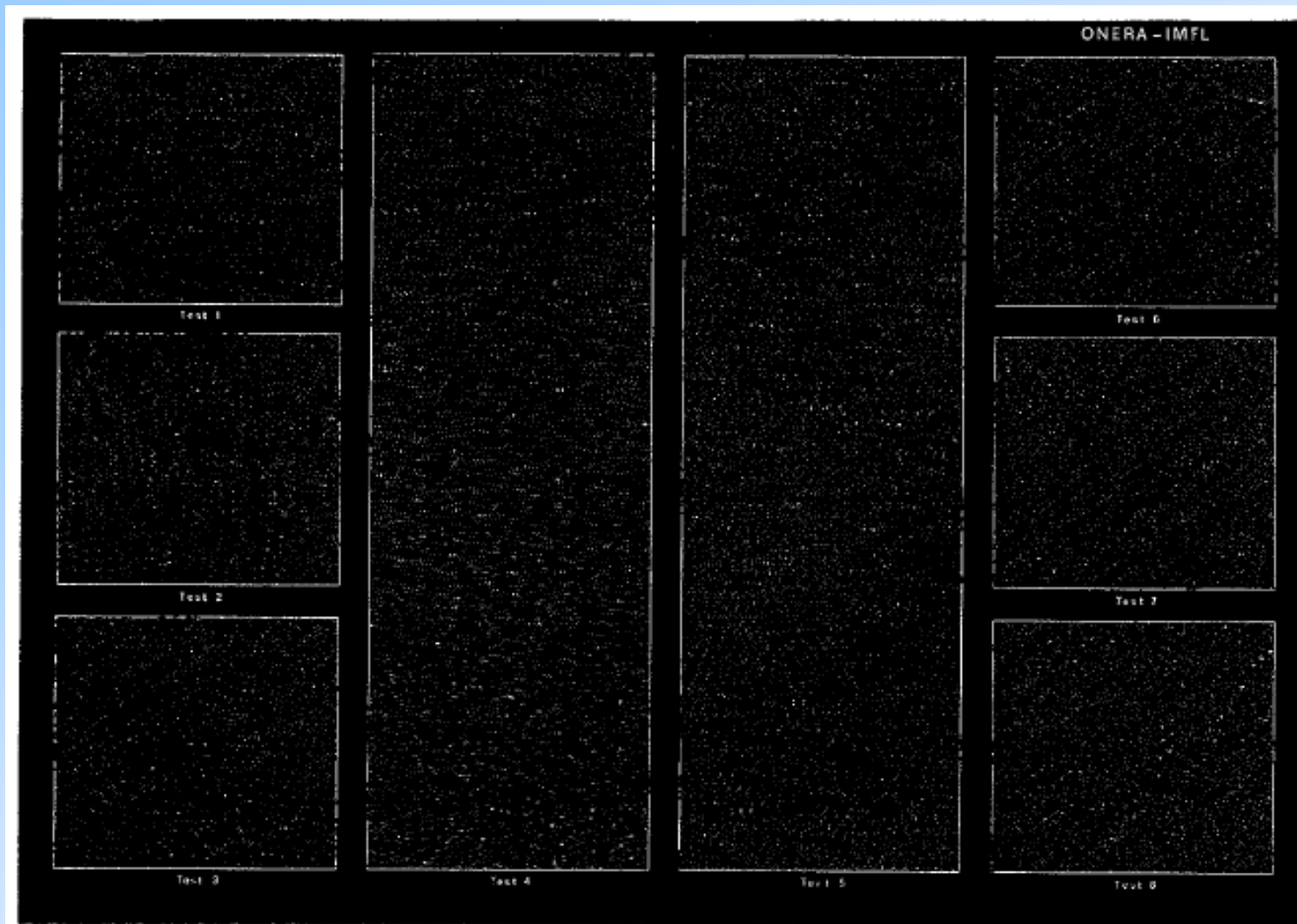


Fig. 2.4.3 : Synthetic test image 9

# GARTEUR AD AG 19

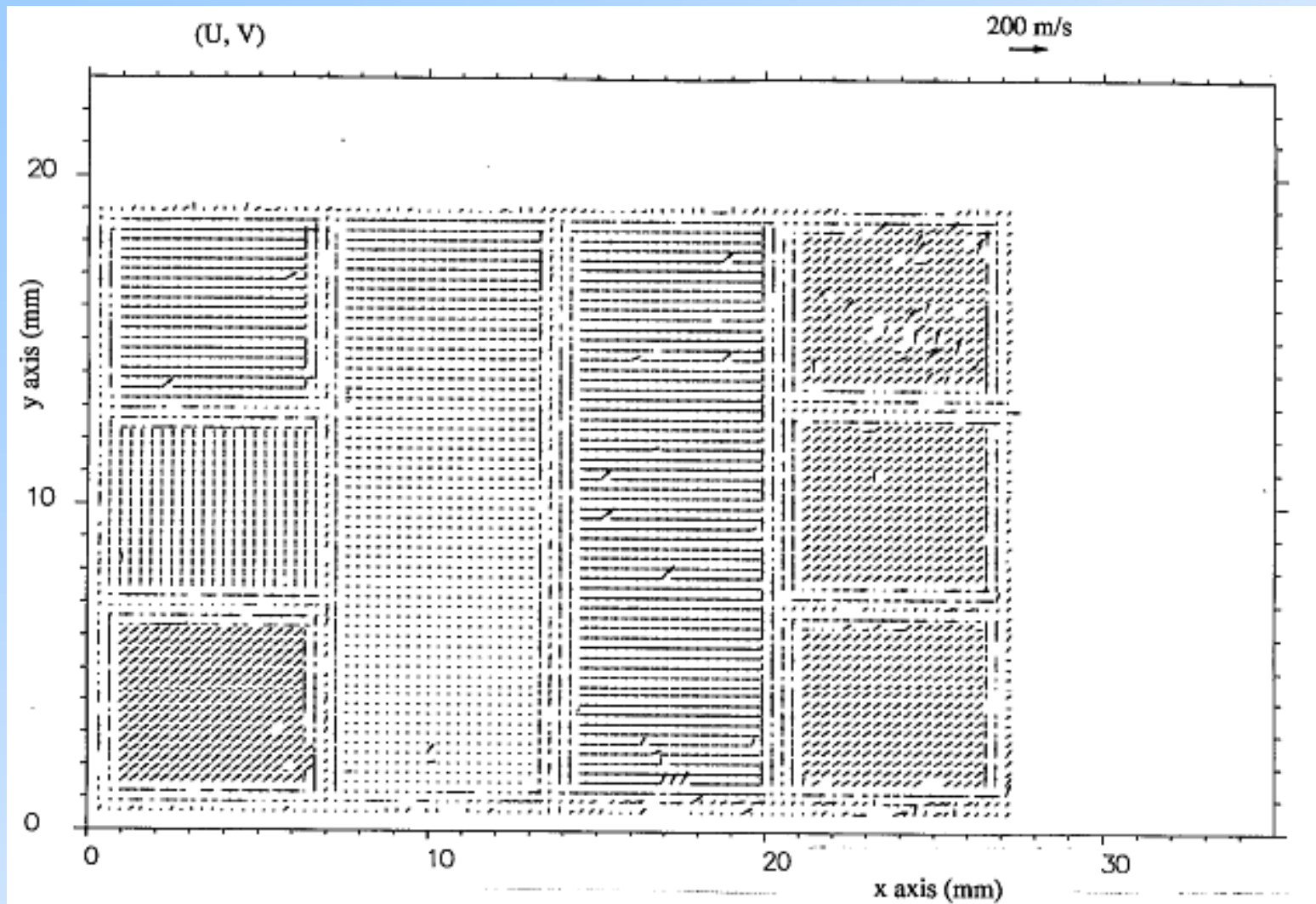


Fig. 2.4.13 : Filtered velocity field of scanned synthetic test image 9 obtained by DLR

# GARTEUR AD AG 19

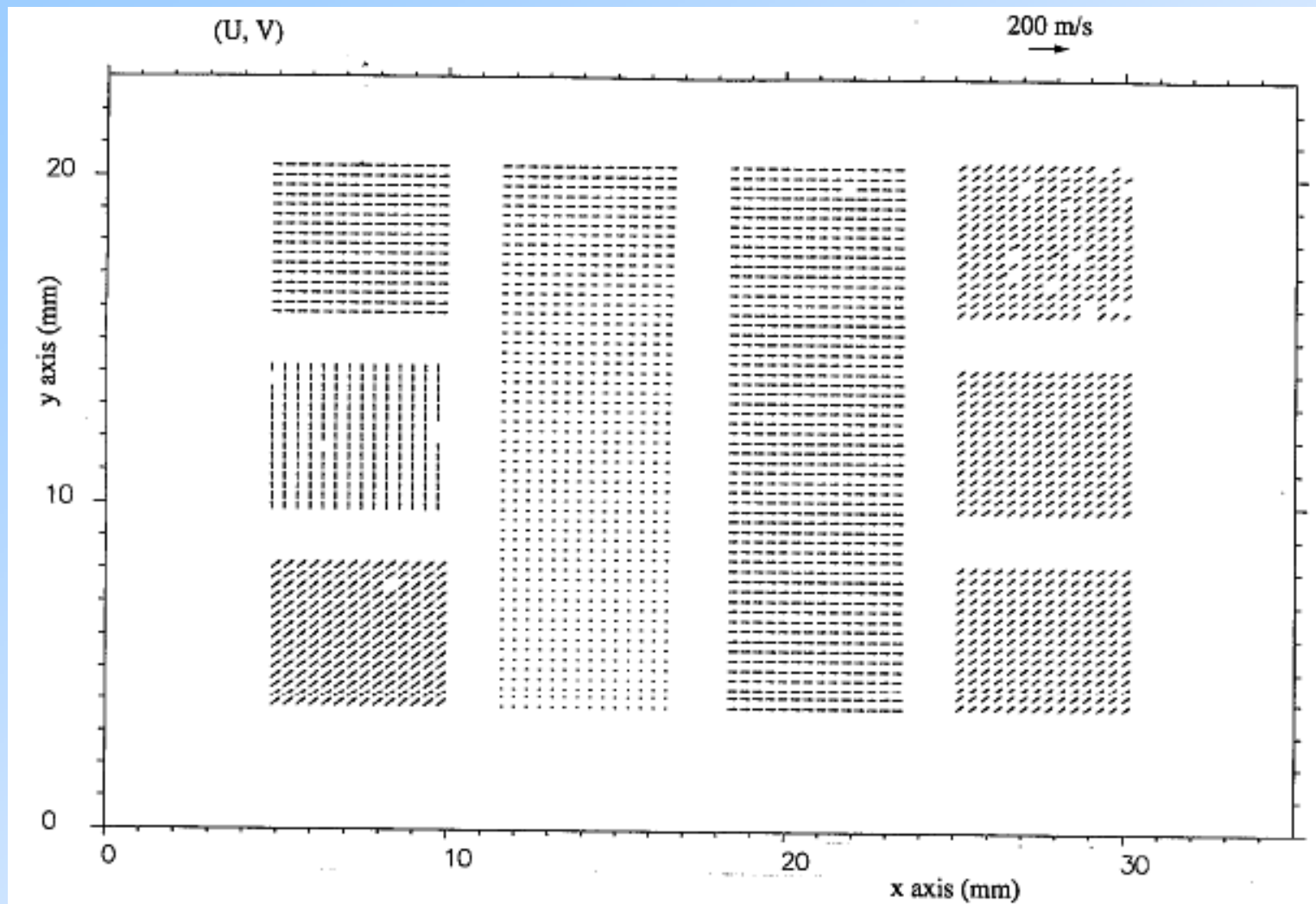


Fig. 2.4.15 : Filtered velocity field of photographic synthetic test image 9 obtained by ONERA

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# GARTEUR AD AG 19

Pipe flow

Digital PIV

Camera : TI 1016x1000 px

FOV : 40.2 x 39.6 mm<sup>2</sup>

Laser : 5 W argon-Ion

Rotating polygon mirror

Dt : 2.685 ms

30  $\mu\text{m}$  Optimage particle

5 particle image/redord

Bulk vel. : 0.132 m/s

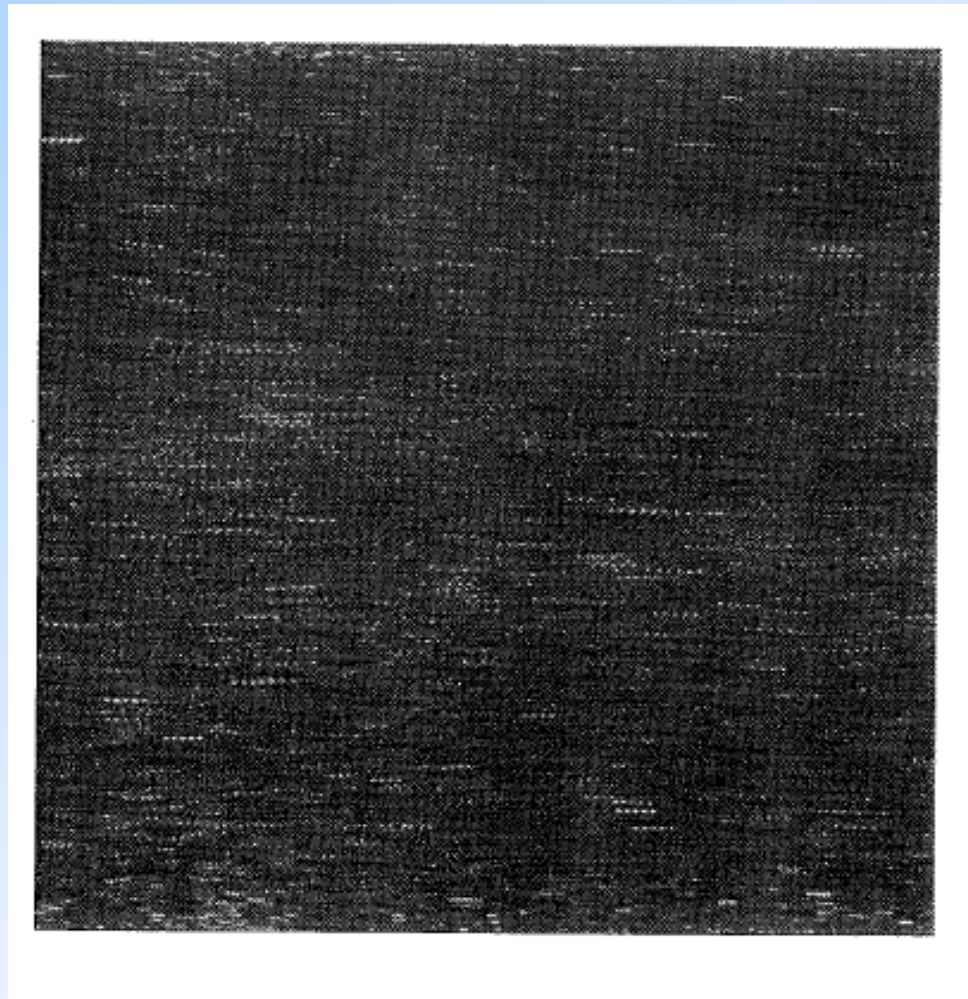


Image 14

## Part 2 : Evaluation of video recording

DLR works on a cross correlation camera containing a beam splitter and two CCD sensors. With this camera it will be possible to capture the two illuminations on different images. These two recordings can be processed with the cross correlation method.

Delft University has developed a digital recording system for PIV based on two 1024x1024 pixels CCD cameras and fast acquisition hardware to store a maximum of 256 images. So far this system has only been used for measurements in water flows. In the near future the system will also be used for air flows.

Rouen University has developed a crosscorrelation camera using the two half frames of an interlaced video image. This camera, with a size of 512x512 pixels has already given very interesting results. They work both on a larger size camera and on the stereoscopic approach.

# EUROPIV (1996-1998)



«A cooperative action to apply  
Particle Image Velocimetry to  
problems of industrial interest.»

**CONTRACT N°: BR.PR - CT95- 0118**

**Budget : 1.5 M€, .88 M€from EC**



# EUROPIV (1996-1998)

## Partnership

Industries	Research Organizations		Universities	
<b>DASSAULT AVIATION DASA SIREHNA</b>	<b>CIRA DLR DRA FFA INTA</b>	<b>ISL NLR ONERA VKI</b>	<b>Delft Lille (URA CNRS 1441) Madrid Oldenburg</b>	<b>Rome Rouen (URA CNRS 230) St Etienne (URA CNRS 842) Warwick</b>

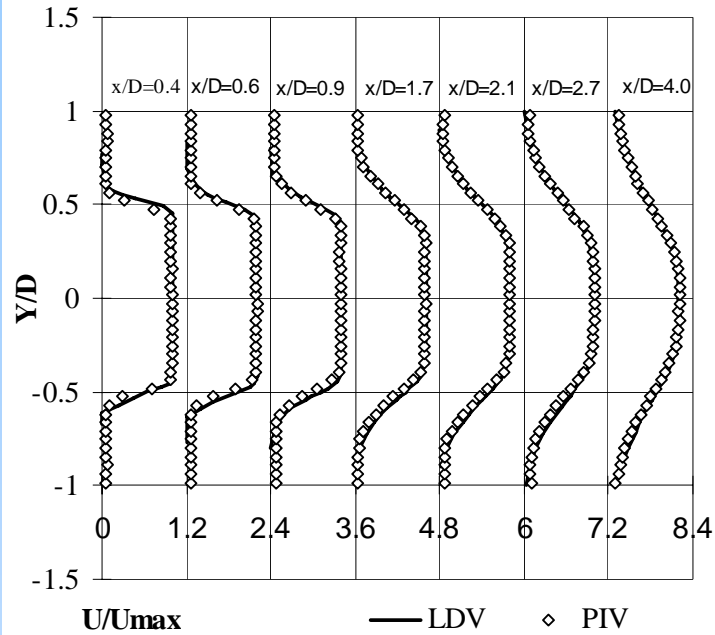
# EUROPIV (1996-1998)

## Work program

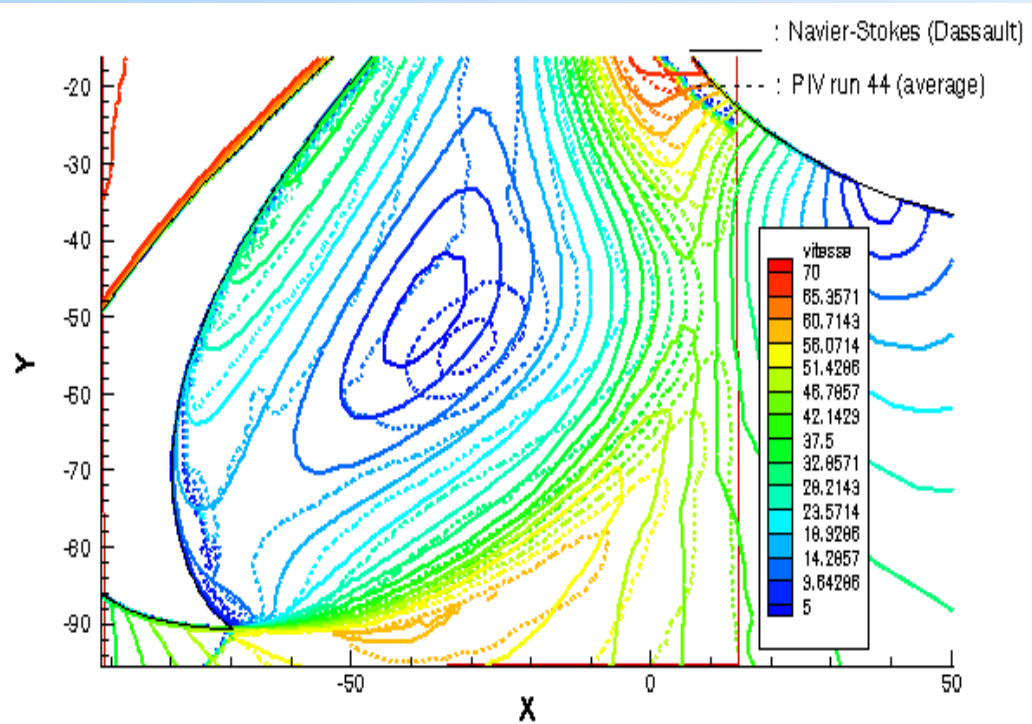
WP	WP 1		WP 2		WP 3			
Title	Turbulence & Near wall flow		Assessment of vortical structures		Full Scale Industrial Tests			
Manager	DELFT		DLR		DASA			
Task	T 1.1	T 1.2	T 2.1	T 2.2	T 3.1	T 3.2	T3.3	T3.4
Title	Turbulence	Near wall flows	Seeding behavior	Vorticity estimation	DASA W/T	Numerical simulations	Modane S2	DNW LST
Manager	CORIA	DELFT	DLR	DLR	DASA	DASSAULT	ONERA	NLR

WP	WP 4		WP 5	
Title	Advanced PIV Developments		Managment & Exploitation	
Manager	ISL		LML	
Task	T4.1	T4.2	T5.1	T5.2
Title	Advanced PIV techniques & algorithms		Holographic PIV	Expl.
Manager	MADRID		ISL	DLR

# EUROPIV (1996-1998)



Turbulent jet mean velocity profile : Comparison between PIV and LDV measurements at 40 m/s with swirl.



Comparison between wind tunnel PIV measurement and Navier-Stokes computation. Angle of attack :  $12.5^\circ$ , Reynolds number :  $1.8 \cdot 10^8$ , mean velocity in m/s.

# EUROPIV (1996-1998)

Team	Evaluation Method	Size of digital FFT	$N_s$	$N_h$	$N_t$	$N_t+N_h$	$u_{\text{mean}}$ [m/s]	$v_{\text{mean}}$ [m/s]	$u'^2$ [m/s] <sup>2</sup>	$v'^2$ [m/s] <sup>2</sup>
DLR	auto-cross, scan, dig	64x64	32	41	8929	8970	5.005	-0.0595	0.0366	0.0327
DLR	auto, opt/dig	256x256	22	72	3288	3360	4.994	-0.0786	0.0361	0.0357
DLR	auto, opt/opt	-	26	123	3237	3360	5.024	-0.2330	0.0347	0.0468
IMFL	auto-cross, scan, dig	64x64	0	57	8683	8740	5.004	-0.0572	0.0340	0.0329
IMFL	auto, dig/dig	256x256	4	5	3169	3174	5.000	-0.0607	0.0344	0.0316
INTA	auto, dig/dig	256x256	0	0	2881	2881	4.873	-0.0374	0.0270	0.0346
Madrid	auto, scan, dig	128x128	12	0	2166	2166	4.998	-0.0588	0.0311	0.0299
Madrid	auto-cross, scan, dig	64x64	0	65	8790	8855	4.997	-0.0542	0.0346	0.0338
CIRA	auto-cross, scan, dig	64x64	0	130	8840	8970	4.996	-0.0590	0.0373	0.0348

EUROPIV (1996-1998)



**René Descartes Prize**

# **PIVNET thematic network (1997-2001)**

**PivNet - A European collaboration on  
development and application of  
Particle Image Velocimetry between  
industry, research organizations and universities**

**Coordinator : DLR**

**Contract No: BRRT-CT97-5037**

# PIVNET thematic network (1997-2001)

## Partnership

DLR	DE	NLR	NL
Laboratoire de Mécanique de Lille	FR	FFA	SE
ONERA	FR	TU Graz	AT
Rolls Royce	GB	University of Ancona	IT
Daimler-Chrysler Aerospace	DE	University of Rome	IT
Airbus GmbH		Politecnico di Torino	IT
Pininfarina	IT	RWTH Aachen	DE
DANTEC A/S	DK	Zaragoza University	ES
Delft University of Technology	NL	Universität Stuttgart	DE
ALENIA	IT	University of Edinburgh	GB
Ansaldo Ricerche S.r.l	IT	University of Galway	IE
Aerospatiale	FR	DNW	NL
Quantel	FR	Instituto Superior Tecnico - Thermodynamic, Lisbon	PT
Thomson-CSF Laser BMI	FR	Lund Institute of Technology	SE
Eurocopter	DE	Laser-Laboratorium Göttingen	DE
BMW-RR	DE	AEA Technology	GB
Volkswagen AG	DE	Daimler-Chrysler	DE
OFS	GB	Institut für Technische und Angewandte Physik	DE
ABB-Corporate Research	CH	Universität Essen	DE
Institute von Karman de Dynamique des Fluides	BE	Instituto Superior Tecnico - Mechanical Engineering	PT
INSEAN	IT	University of Rouen	FR
CIRA	IT	TU Berlin	DE
INTA	ES		

# PIVNET thematic network (1997-2001)

## Work program

Task	Description	Task manager (sub task managers)
0	Coordination and General networking (all partners)	DLR
1	Exchange of information and know how	DLR (TU Delft)
2	Presentation of PIV to industry	Rolls Royce (EADS D, Pininfarina, DLR, INSEAN)
3	Manufacturers of PIV equipment	Dantec
4	Training and exchange of personnel	ONERA
5	Further developments of PIV techniques Workshops and conferences of the interest group	LML



## PIVNET thematic network (1997-2001)

*There is a high potential for application under complex flow conditions in the future !*

### Requests from the industrial point of view:

- ☛ Further improvement of 3 component PIV (stereo) to investigate both unsteady and steady (averaged) flow phenomena in wake as well as in boundary layer flows.
- ☛ Higher flexibility for application in an industrial environment (more variability for camera viewing angles i.e. easier optical access)
- ☛ Improved optical windows for high PIV resolution
- ☛ Seeding: Estimation of measuring errors due to entrainment processes and de-mixing in high gradient flows (for example, near to a wall)
- ☛ PIV measurements in rather thin boundary layers i.e. good spatial resolution at large models and large viewing distances (methods to suppress reflections near to a wall, application of improved methods to determine the velocity vector in high gradient flows)

## PIVNET thematic network (1997-2001)



## **PIVNET thematic network (1997-2001)**

### **Task 5 Future developments of PIV technique - Workshops and conferences of the interest group**

- **5 workshops**
- **First PIV challenge 2001**

## **EUROPIV 2 project (2000-2003)**

**“EUROPIV 2 : A Joint Program to Improve PIV  
Performance for Industry and Research.”**

**CONTRACT N°: G4RD-CT-2000-00190**

**Starting date : April 1st 2000 Duration : 36 months**

**Budget : 2.1 M€, 1.2 M€from EC**

# EUROPIV 2 project (2000-2003)

## Partnership

1	LML URA CNRS 1441	F		10	Delft University	NL
2	DASA	G		11	Madrid Carlos III University	SP
3	DASSAULT AVIATION	F		12	Oldenburg University	G
4	ITAP GmbH	G		13	Rome la Sapienza University	IT
5	CIRA	IT		14	CORIA UMR CNRS 6614	F
6	DLR	G		15	St Etienne University	F
7	ISL	F/G		16	Zaragoza University	SP
8	NLR	NL		17	DNW	NL
9	ONERA	F				

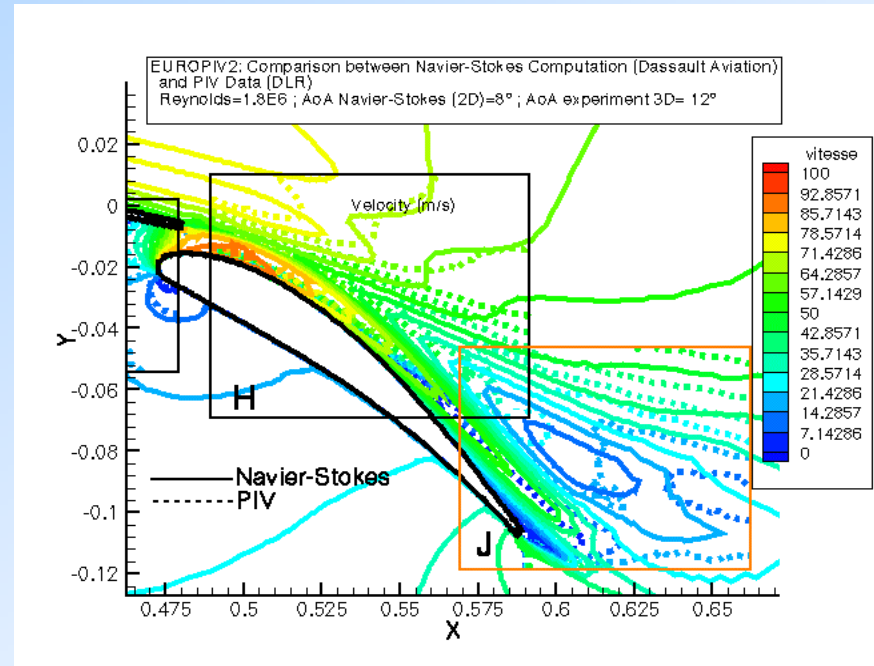
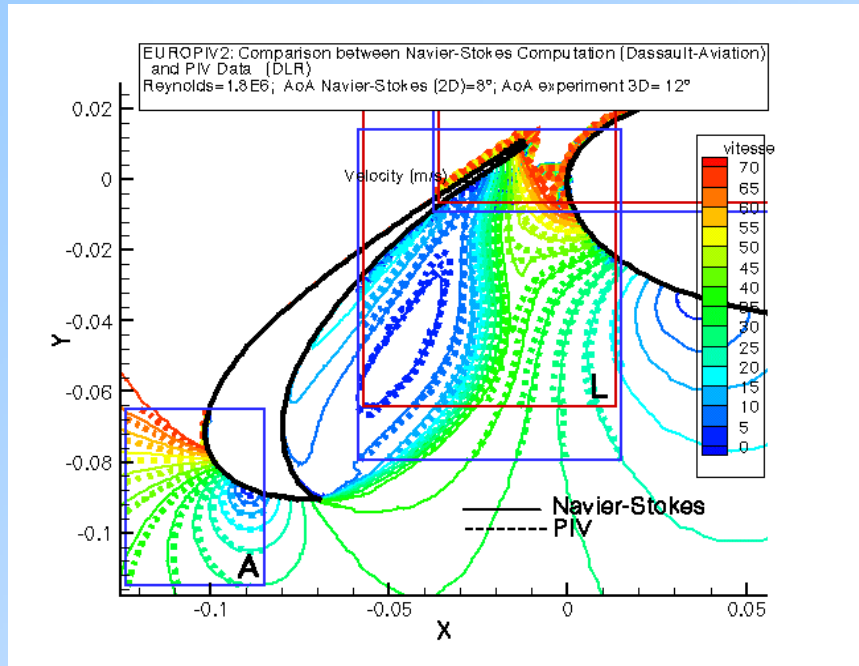
# EUROPIV 2 project (2000-2003)

## Work program

WP	WP 1		WP 2		WP 3			
Title	Turbulence & Near wall flow		Assessment of vortical structures		Full Scale Industrial Tests			
Manager	DELFT		DLR		DASA			
Task	T 1.1	T 1.2	T 2.1	T 2.2	T 3.1	T 3.2	T3.3	T3.4
Title	Turbulence	Near wall flows	Seeding behavior	Vorticity estimation	DASA W/T	Numerical simulations	Modane S2	DNW LST
Manager	CORIA	DELFT	DLR	DLR	DASA	DASSAULT	ONERA	NLR

WP	WP 4		WP 5	
Title	Advanced PIV Developments		Managment & Exploitation	
Manager	ISL		LML	
Task	T4.1	T4.2	T5.1	T5.2
Title	Advanced PIV techniques & algorithms		Holographic PIV	Mngt. Expl.
Manager	MADRID		ISL	LML DLR

# EUROPIV 2 project (2000-2003)



Mean velocity modulus under the slat (left) and over the flap (right) for  $\alpha = 12^\circ$ . Comparison between computations and PIV data.

# **PIVNET 2 thematic network (2002-2007)**

**PivNet-2 A European collaboration on  
development, quality assessment, and  
standardization of Particle Image Velocimetry for  
industrial applications**

**Contract No: G4RT-CT-2002-05081**

**Budget : 1.5 M€from EC**



# PIVNET 2 thematic network (2002-2007)

## Partnership

Partner	Organisation	Country Code
1	Deutsches Zentrum für Luft- und Raumfahrt e.V.	D
2	Centre National de la Recherche Scientifique, LML	F
3	Airbus Deutschland GmbH	D
4	Von Karman Institute for Fluid Dynamics	B
5	Technische Universiteit Delft	NL
6	Industrie Pininfarina s.p.a.	I
7	Office National d'Etudes et de Recherches Aéropatiales	F
8	Istituto Nazionale per Studi ed Esperienze di Architettura Navale	I
9	German-Dutch Wind Tunnels	NL
10	Centro Italiano Ricerche Aerospaziali ScpA	I
11	Volkswagen AG	D
12	Nationaal Lucht- en Ruimtevaartlaboratorium	NL
13	LaVision GmbH	D
14	Intelligent Laser Applications GmbH	D
15	Università degli Studi di Ancona	I
(16)	withdrawn	
17	Finmeccanica S.p.A. – Alenia Aeronautica	I
18	Dassault Aviation SA	F
19	Eurocopter Deutschland GmbH	D
20	Rolls-Royce Deutschland Ltd & Co KG	D

Partner	Organisation	Country Code
21	Dantec Dynamics A/S	DK
22	Polish Academy of Sciences	PL
23	Swedish Defence Research Agency	S
24	Technische Universität Graz	A
25	Università di Roma 'La Sapienza'	I
26	Politecnico di Torino	I
27	Rheinisch Westfälische Technische Hochschule Aachen	D
28	Universidad de Zaragoza	E
29	Universität Stuttgart	D
30	Carl-von-Ossietzky Universität Oldenburg	D
31	The University of Edinburgh	UK
32	National University of Ireland, Galway	IRL
33	Lund University / Lund Institute of Technology	S
34	Center for Innovation, Technology and Policy Research, Istituto P Superior Tecnico	P
35	Université de Rouen	F
36	Technische Universität Berlin	D
37	Universidad Carlos III de Madrid	E
38	HARDsoft Microprocessor Systems	PL
39	RUAG Aerospace	CH

# PIVNET 2 thematic network (2002-2007)

## Workprogram

Workpackage	Description	Workpackage manager
1	Coordination and general networking, knowledge base, gateway, and exploitation (all partners)	DLR
2	Exchange of information and know how with industry	DLR
3	Presentation of PIV to industry	DA
4	Quality and standards for PIV in industry	TU Delft
5	Supporting new applications, interaction with manufacturers of PIV systems and SME's, training	VKI
6	Further assessment of PIV technique, ERCOFTAC SIG 32 and international PIV challenge	LML(CNRS)

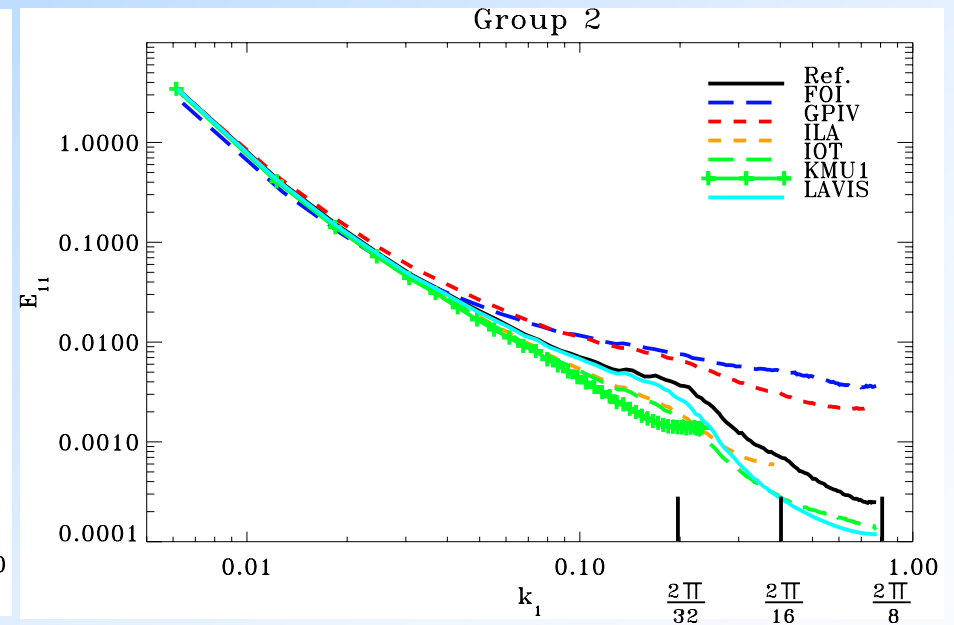
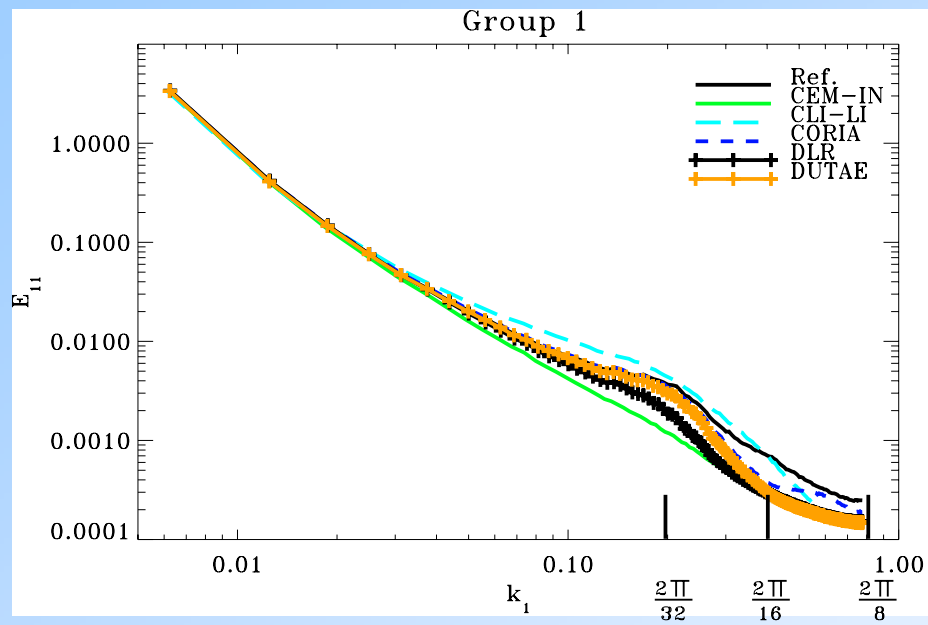
## **PIVNET 2 thematic network (2002-2007)**

### **Task 6 Further assessment of PIV technique, ERCOFTAC SIG 32 and international PIV challenge**

- **5 workshops**
- **Second PIV challenge 2003 Busan**
- **Third PIV challenge 2005 Pasadena**

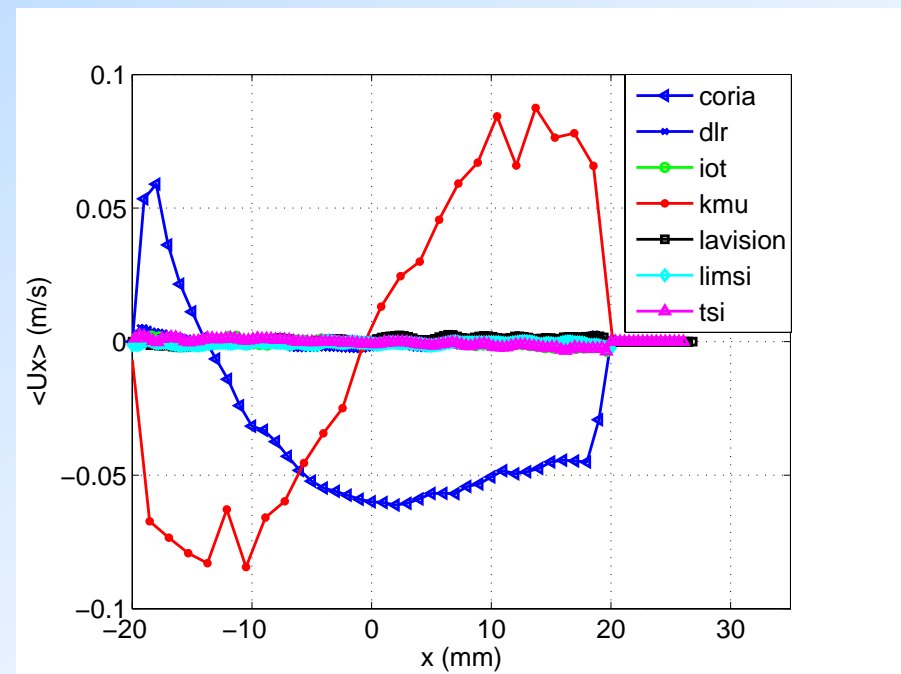
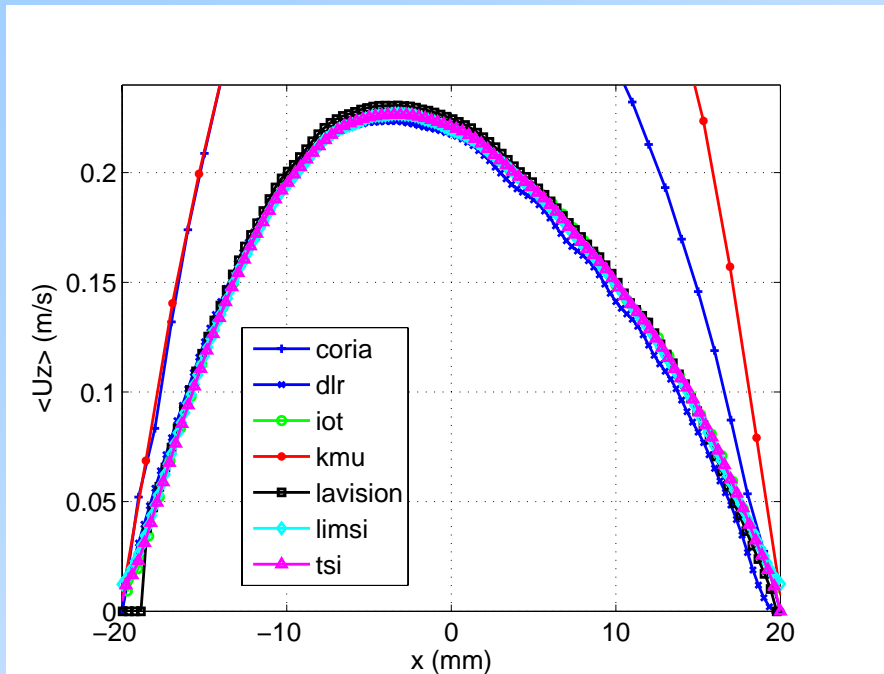
# PIVNET 2 thematic network (2002-2007)

## PIV Challenge 2005



# PIVNET 2 thematic network (2002-2007)

## PIV Challenge 2005



# Conclusion

- **Strong support of Europe to PIV development (~5M€ in 10 Y).**
- **Large and active European PIV community**
- **Fruitful exchanges and cooperations**
- **Wide spread of the know-how**
- **Significant contribution to the progress of the technique**