



Second International Symposium on Marine Propulsors 2011

Workshop: Propeller Performance

Potsdam Propeller Test Case (PPTC)

LDV Measurements with the Model Propeller VP1304

Case 2.2

Potsdam, May 2011

Case 2.2

LDV Measurements

Test Description

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1 Introduction

In the intention to offer research groups the possibility to test and validate their numerical tools the SVA Potsdam GmbH (SVA) investigated the controllable pitch propeller VP1304. The test results are published in course of the propeller workshop of the Second International Symposium on Marine Propulsors 2011 (smp'11). The geometry and results of the propeller are presented by the name PPTC, an acronym for “Potsdam Propeller Test Case”.

In the following the LDV (Laser Doppler Velocimetry) measurements with the model propeller VP1304 are presented. Also the comparison between the measured data with the corresponding computational results is carried out.

A more detailed description of the LDV measurements conducted in the cavitation tunnel of the SVA is presented in the SVA report 3754 [1], which can be found on the website www.sva-potsdam.de.

2 Model propeller VP1304

The propeller is a controllable pitch propeller. This affects the propeller blade design near the hub and results in a 0.3 mm gap between hub and propeller blade near the leading and trailing edge of the propeller. In Table 1 the main data of the propeller is given.

Table 1: Main data of model propeller VP1304

VP1304			
Diameter	D	[m]	0.250
Pitch ratio $r/R = 0.7$	$P_{0.7}/D$	[–]	1.635
Area ratio	A_E/A_0	[–]	0.77896
Chord length $r/R = 0.7$	$c_{0.7}$	[m]	0.10417
Skew	θ_{EXT}	[°]	18.837
Hub ratio	d_h/D	[–]	0.300
Number of blades	Z	[–]	5
Sense of rotation		[–]	right
Type		[–]	controllable pitch propeller

3 LDV measurements

The velocity field was measured by means of LDV in the cavitation tunnel K 15 A (Kempf & Remmers) of the SVA Potsdam, utilising a test section with the length of 2600 mm and a cross section of 600x600 mm. The dynamometer J25 from Kempf & Remmers was arranged in front of the propeller model. The shaft inclination was zero degrees.

A 2D-LDV measuring system from TSI was used for the velocity measurements.

Angular based measurements of the transient flow field behind the rotating propeller operating in homogeneous inflow were carried out. Special attention was laid upon resolving the tip vortex. The

velocity field around the model propeller VP1304 was measured in seven planes $x/D = -0.2, 0.094, 0.10, 0.11, 0.13, 0.16$ and 0.20 , with respect to the propeller plane as shown in Table 2.

Table 2: Measuring planes

x -position	x/D	[–]	-0.200	0.094	0.100	0.110	0.130	0.160	0.200
x -position	x	[mm]	-50.0	23.5	25.0	27.5	32.5	40.0	50.0

One revolution of the propeller was resolved within 1440 angle classes, giving an angular resolution of 0.25° . The resolution in radial direction is shown in Table 3.

Table 3: Positions of the measuring points

measuring plane	start radius	end radius	distance	
			r/R	$\Delta r/R$
in front of the propeller $x/D = -0.20$	0.40	1.10	0.050	6.250
	0.40	0.70	0.050	6.250
	0.70	0.90	0.025	3.125
behind the propeller $x/D = 0.094, 0.10, 0.11, 0.13, 0.16,$ 0.20	0.90	0.95	0.010	1.250
	0.95	1.05	0.002	0.250
	1.05	1.10	0.025	3.125

All measurements were conducted for the same working point, given in Table 4. The test conditions are given in Table 5.

Table 4: Working point for the LDV measurements

Inflow speed	V_A	[m/s]	7.204
Number of revolutions	n	[s ⁻¹]	23
Advance coefficient	J	[–]	1.253
Thrust coefficient	K_T	[–]	0.250
Torque coefficient	$10K_Q$	[–]	0.725
Water density (for $t_w = 24.7^\circ\text{C}$)	ρ	[kg/m ³]	997.1
Kinematic viscosity of water (for $t_w = 24.7^\circ\text{C}$)	ν	[m ² /s]	0.903E-6

Table 5: Test conditions for the LDV measurements

Water density (for $t_w = 24.7^\circ\text{C}$)	ρ	[kg/m ³]	997.1
Kinematic viscosity of water (for $t_w = 24.7^\circ\text{C}$)	ν	[m ² /s]	0.903E-6

The LDV measurements were carried out along a line of constant angular position $\theta = 225^\circ$. The data is than related to the zero degree position, being defined as the 12 o'clock position.

The tests were conducted with a non-cavitating propeller.

4 Requested computations

It was requested to calculate the velocity field around the propeller for the working point and test conditions given in Table 4 and 5. The calculations should be conducted according to the thrust identity.

Four different evaluations were requested. The velocity distribution should be provided on three different radii each for two planes located 0.1 and 0.2 propeller diameters behind the propeller plane, see Table 6.

Table 6: Requested Computations

	$r/R [-]$	$x/D [-]$	$\theta [^\circ]$
Case 2.2.1	0.70	0.1, 0.2	-50° - 22°
Case 2.2.2	0.97	0.1, 0.2	-50° - 22°
Case 2.2.3	1.00	0.1, 0.2	-50° - 22°
Case 2.2.4	0.40 - 1.10	0.1, 0.2	

The velocity components for Case 2.2.1 -2.2.3 shall be made dimensionless by means of the inflow velocity, as follows $I-V_x/V_A$, V_r/V_A and V_θ/V_A .

The axial velocities are defined positive in flow direction, the radial velocities for increasing radii and the tangential velocities in direction of rotation.

5 Reference

- [1] Mach, K.
 Potsdam Propeller Test Case (PPTC), LDV with the Model Propeller VP1304,
 Report 3754, Schiffbau-Versuchsanstalt Potsdam, April 2011 (unpublished)

Case 2.2

LDV Measurements

Evaluation

6 Evaluation

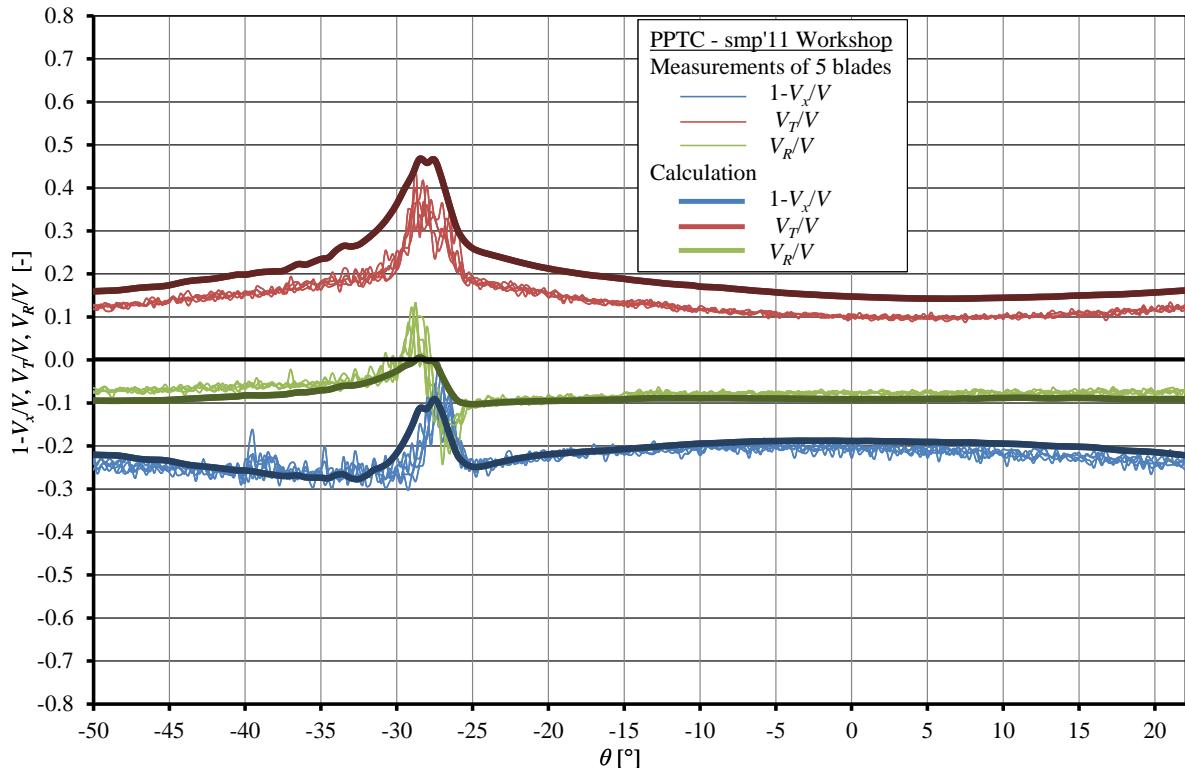
Calculations from 11 different groups were obtained for the evaluation of the flow field, employing 10 different solvers and submitting 13 calculations, of which are two for the comparison of different turbulence models. In the following all participants of the case 2.2 and the used solvers are listed:

Group	Solver	Acronym
Berg-Propulsion	OpenFOAM	Berg-OpenFOAM
Cradle	SC/Tetra	Cradle-SC/Tetra
HSVA	FreSCO+	HSVA-FreSCO+
	PPB	HSVA-PPB
INSEAN	PFC	INSEAN-PFC
MARIC	ANSYS Fluent	MARIC-Fluent
SSPA	ANSYS Fluent	SSPA-Fluent
TUHH	FreSCO+	TUHH-FreSCO
University of Genua	StarCCM+	UniGenua-StarCCM(ke)
	StarCCM+	UniGenua-StarCCM(kw)
University of Triest	ANSYS CFX	UniTriest-CFX
VOITH	Comet	VOITH-Comet
VTT	FinFlo	VTT-FinFlo

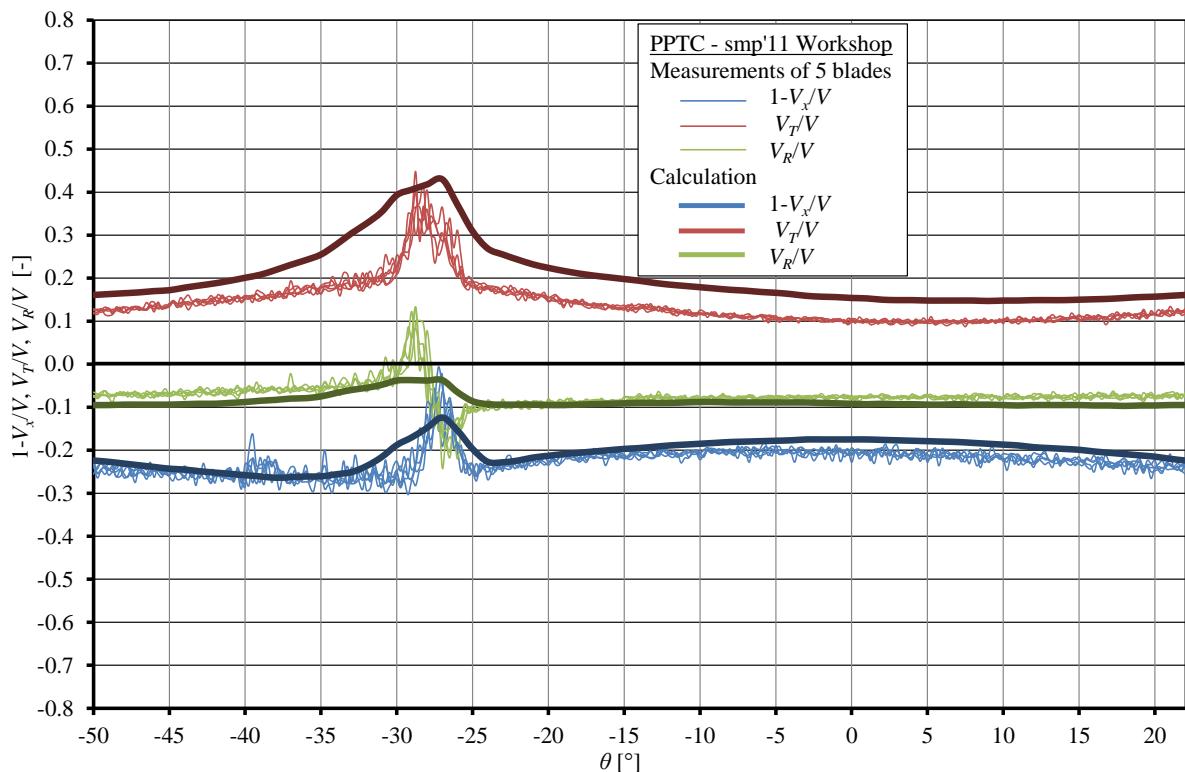
In the following the data is evaluated with respect to the dimensionless axial $I \cdot V_x/V_A$, tangential V_t/V_A and radial V_r/V_A velocity components.

In the LDV measurements the data was collected over one entire propeller revolution. The evaluation however was carried out over only one blade passage. For the evaluation of case 2.2.1-2.2.3 the velocities of the five blade passages were plotted on top of each other. For case 2.2.4 however the mean values of the five measured blade passages are plotted.

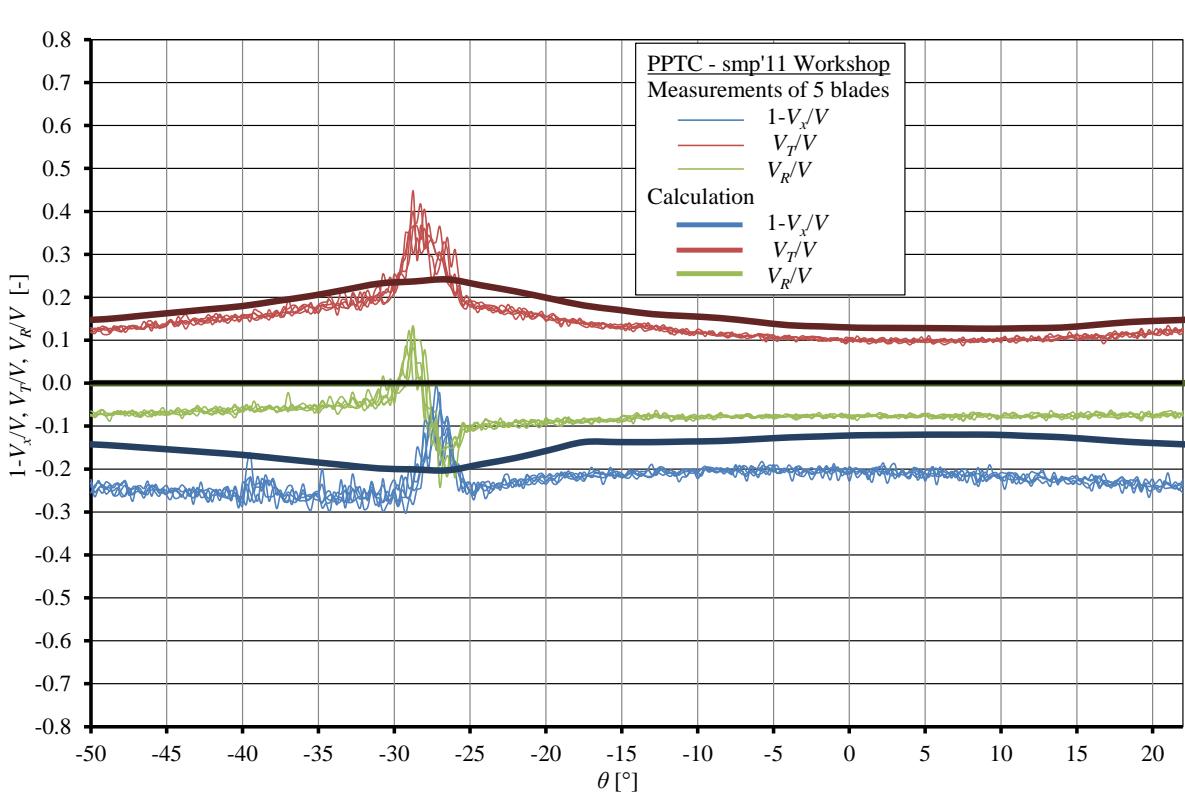
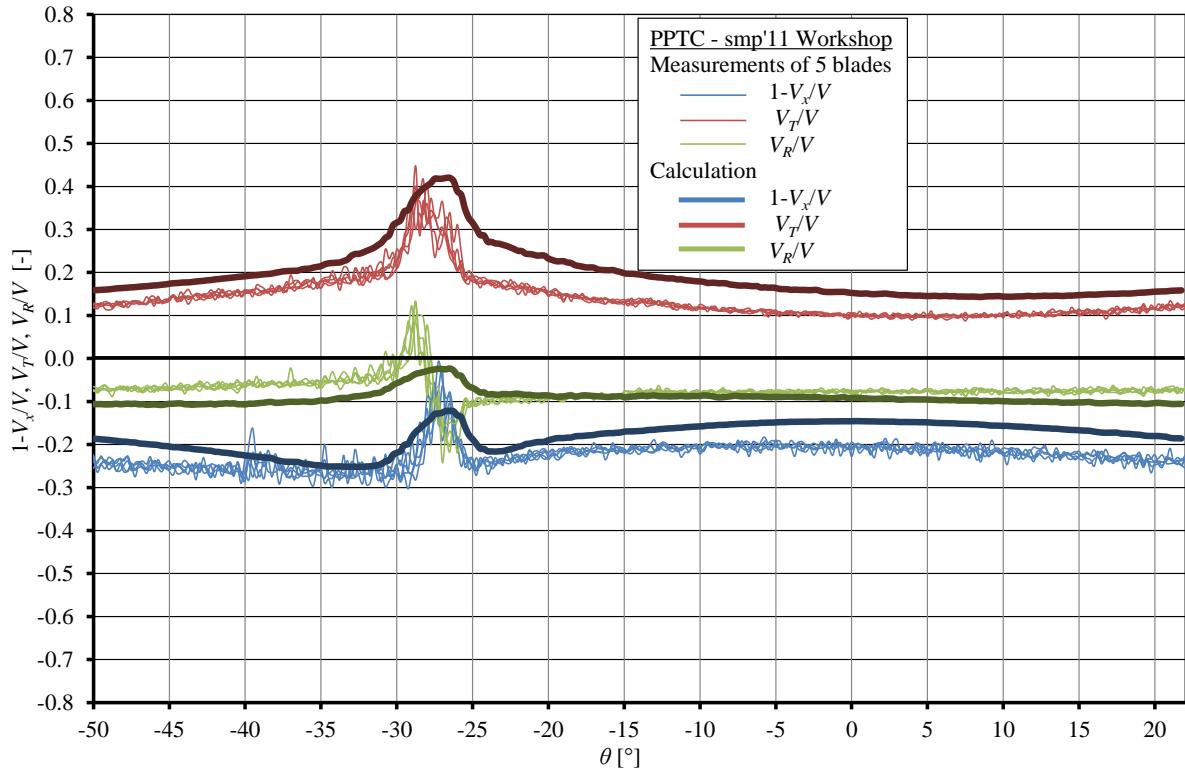
6.1 Case 2.2.1: $r/R = 0.70, x/D = 0.1$

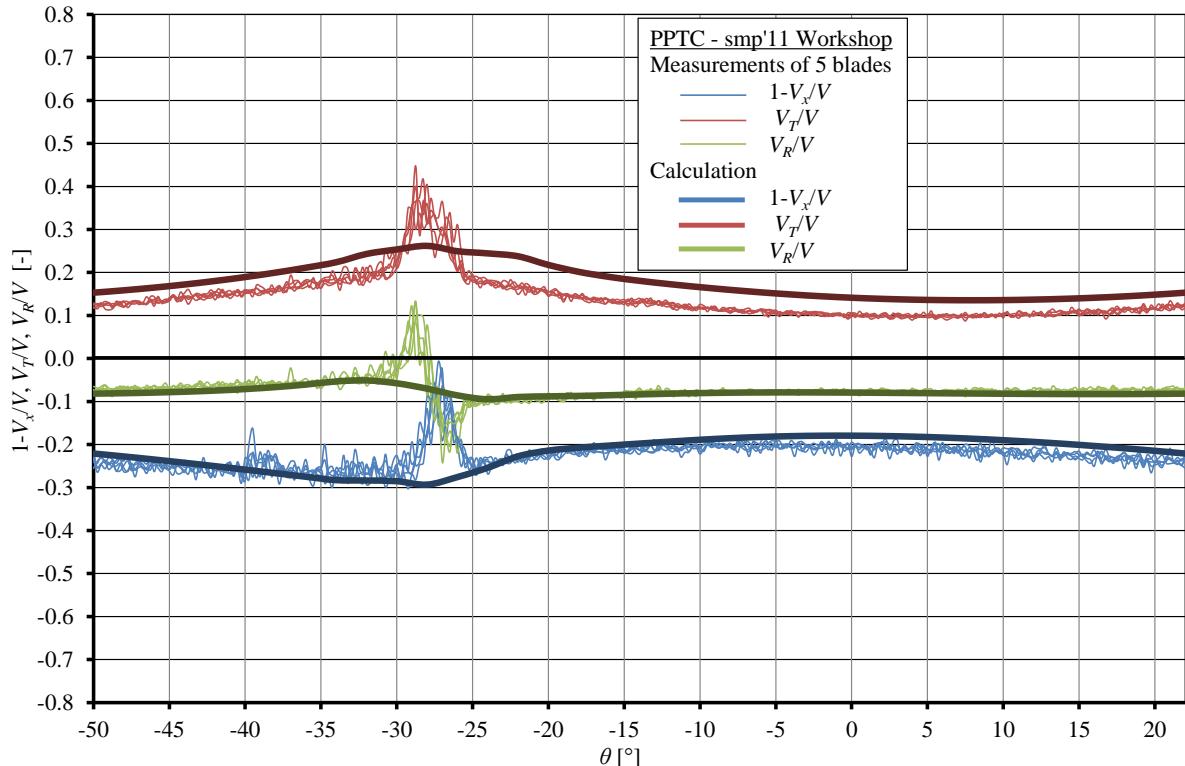


Berg-OpenFOAM, $r/R = 0.70, x/D = 0.1$

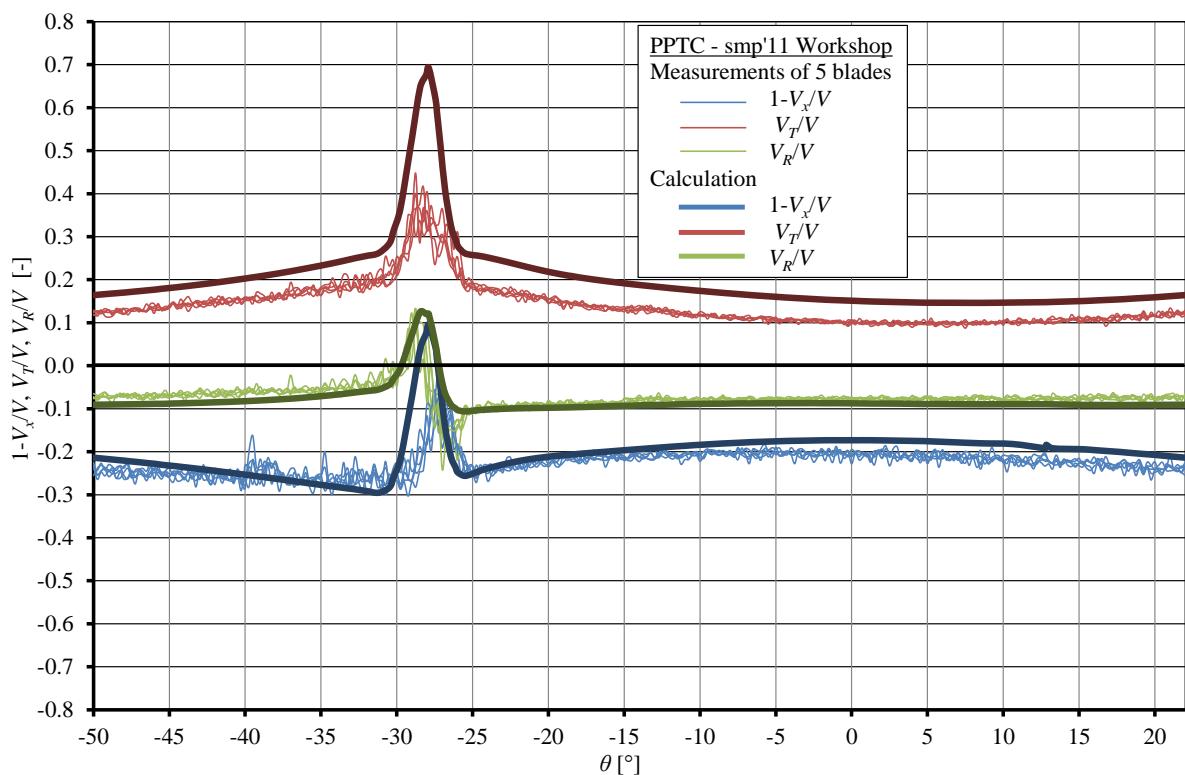


Cradle-SC/Tetra, $r/R = 0.70, x/D = 0.1$

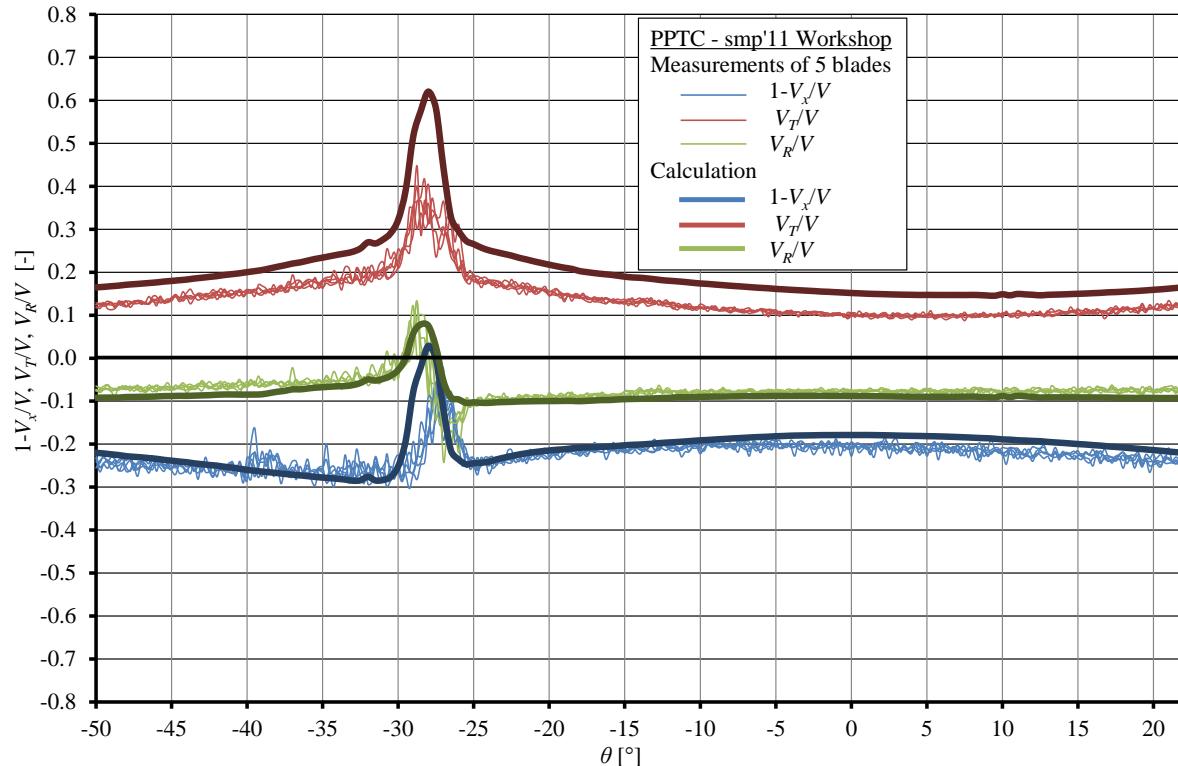




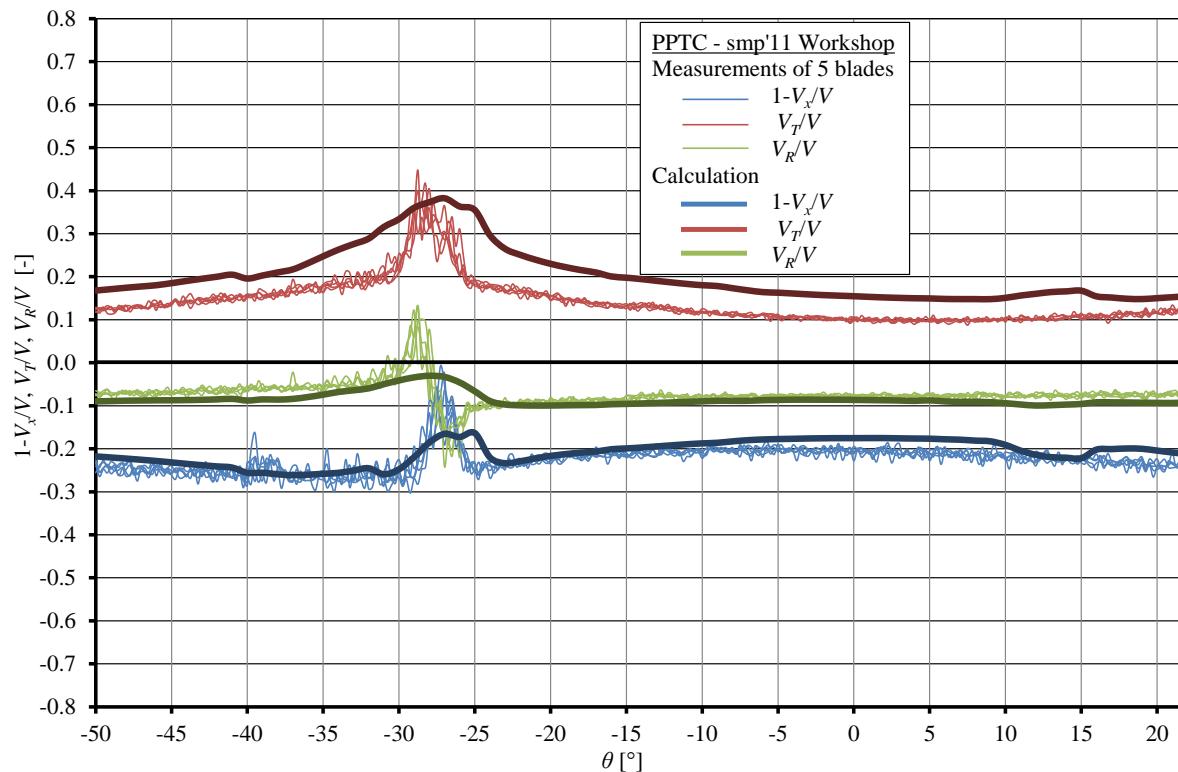
INSEAN-PFC, $r/R = 0.70$, $x/D = 0.1$



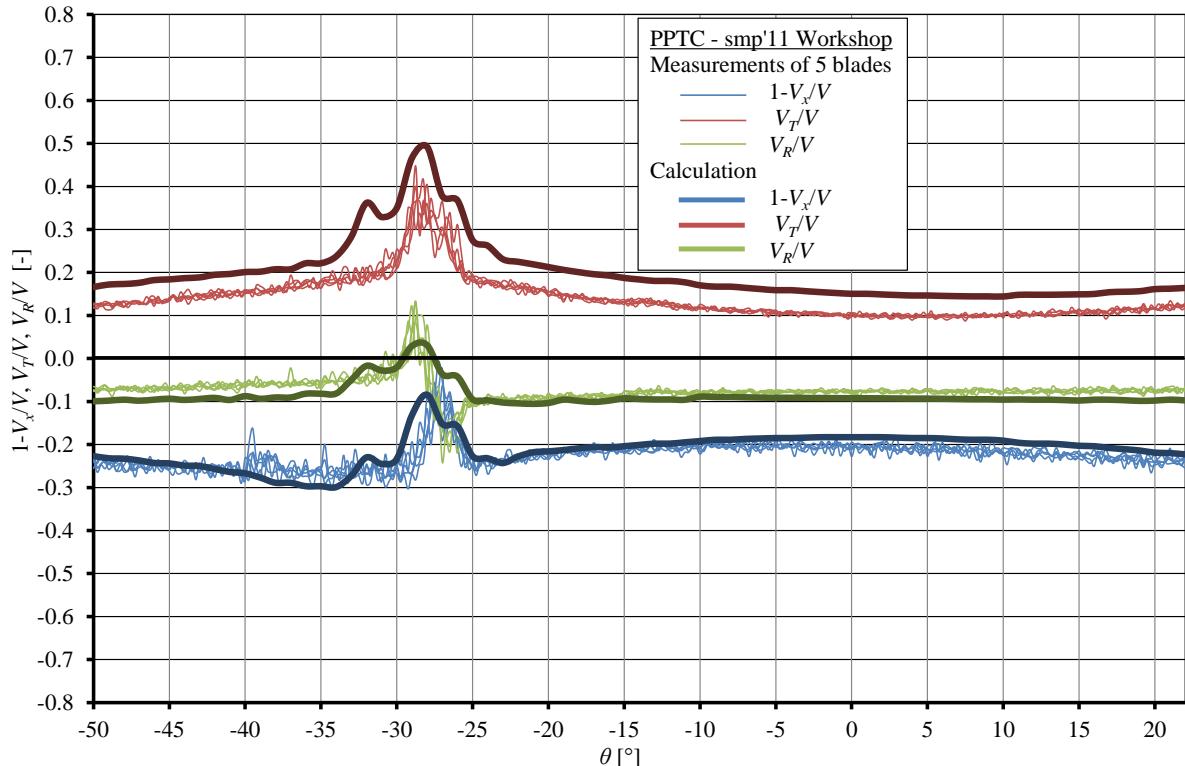
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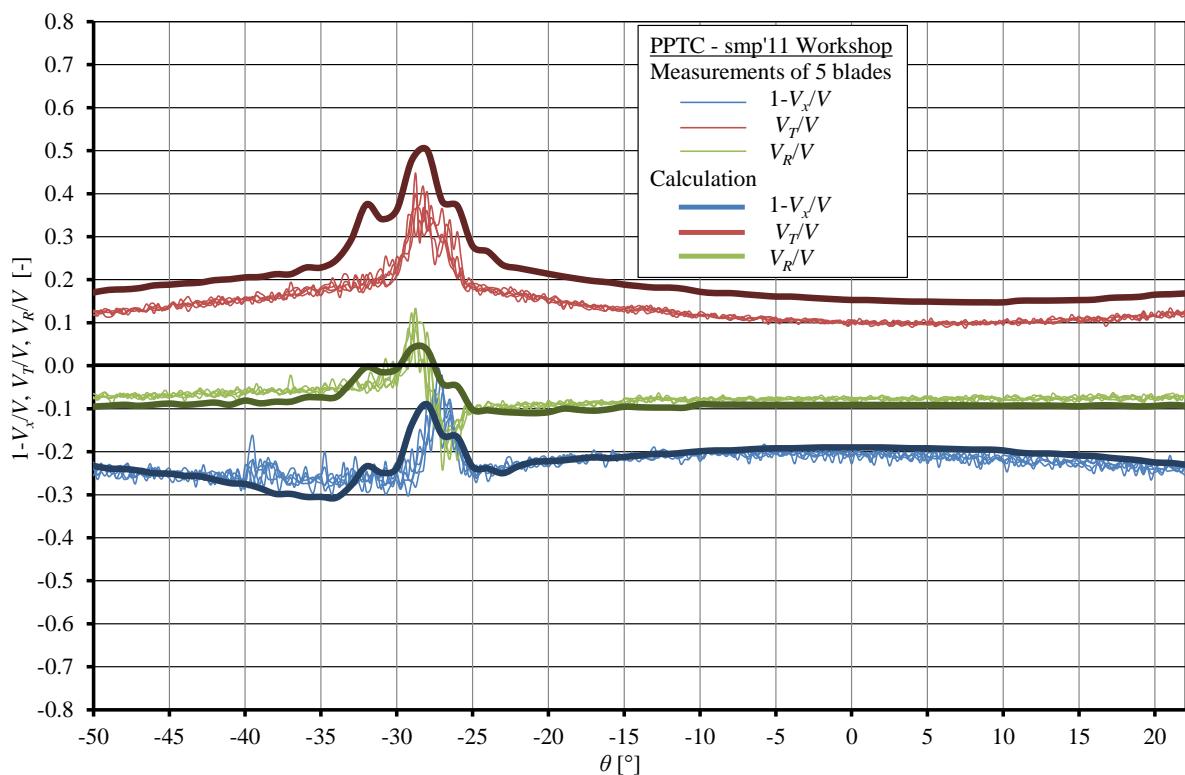
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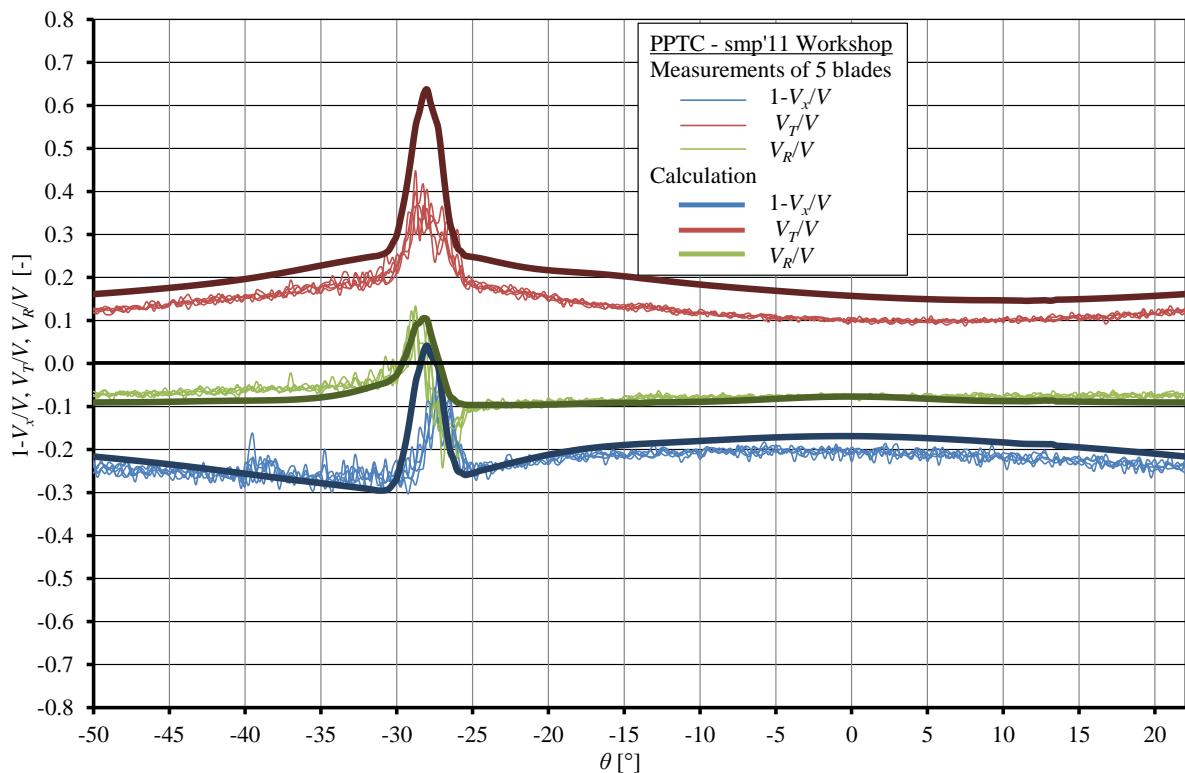
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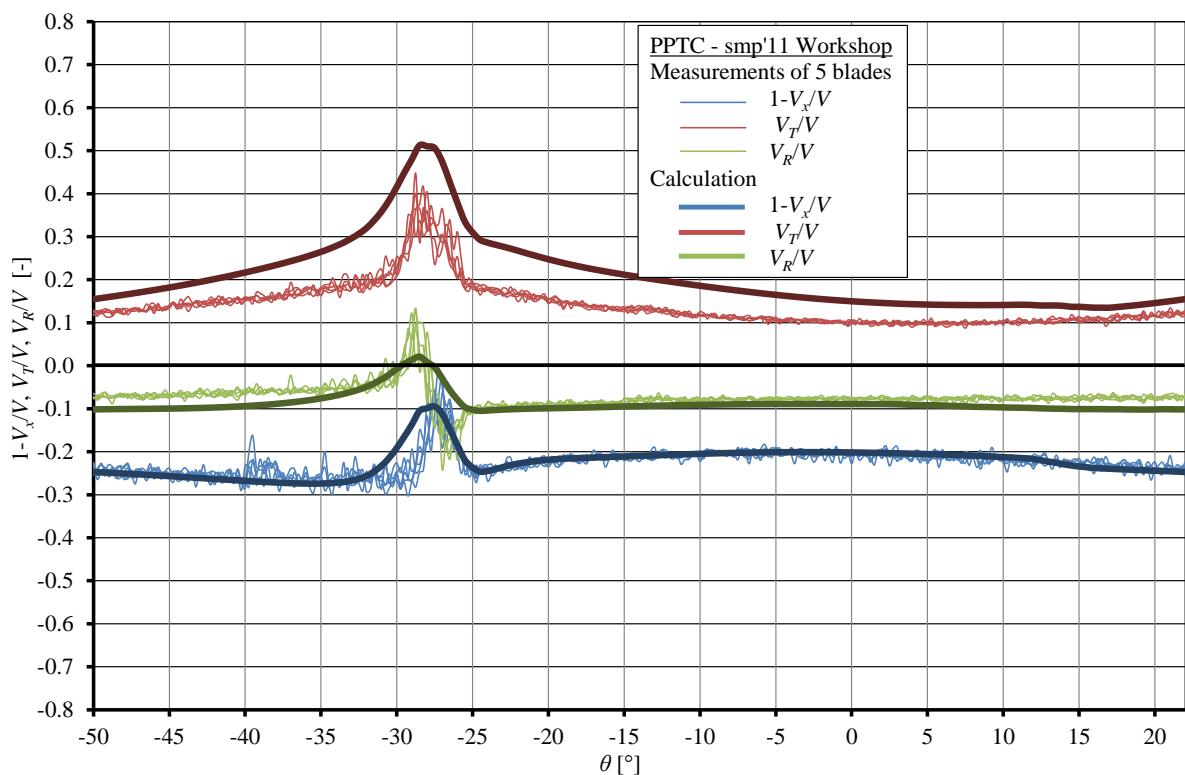
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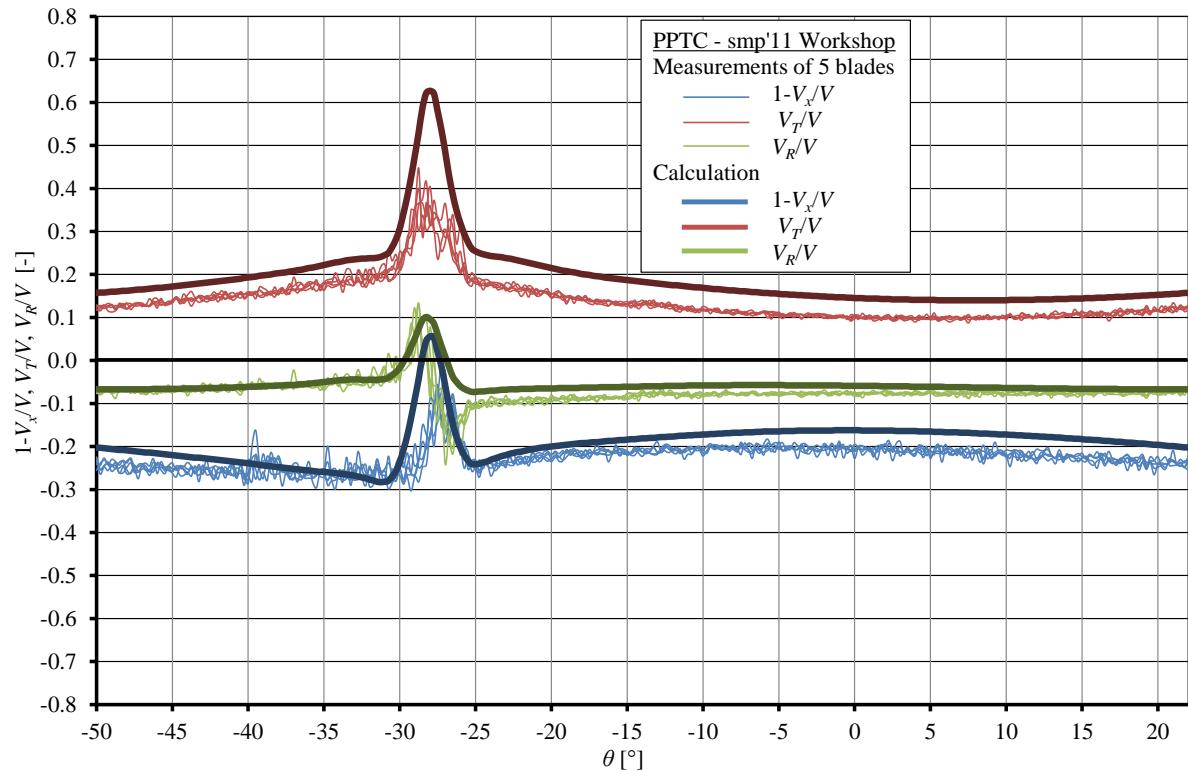
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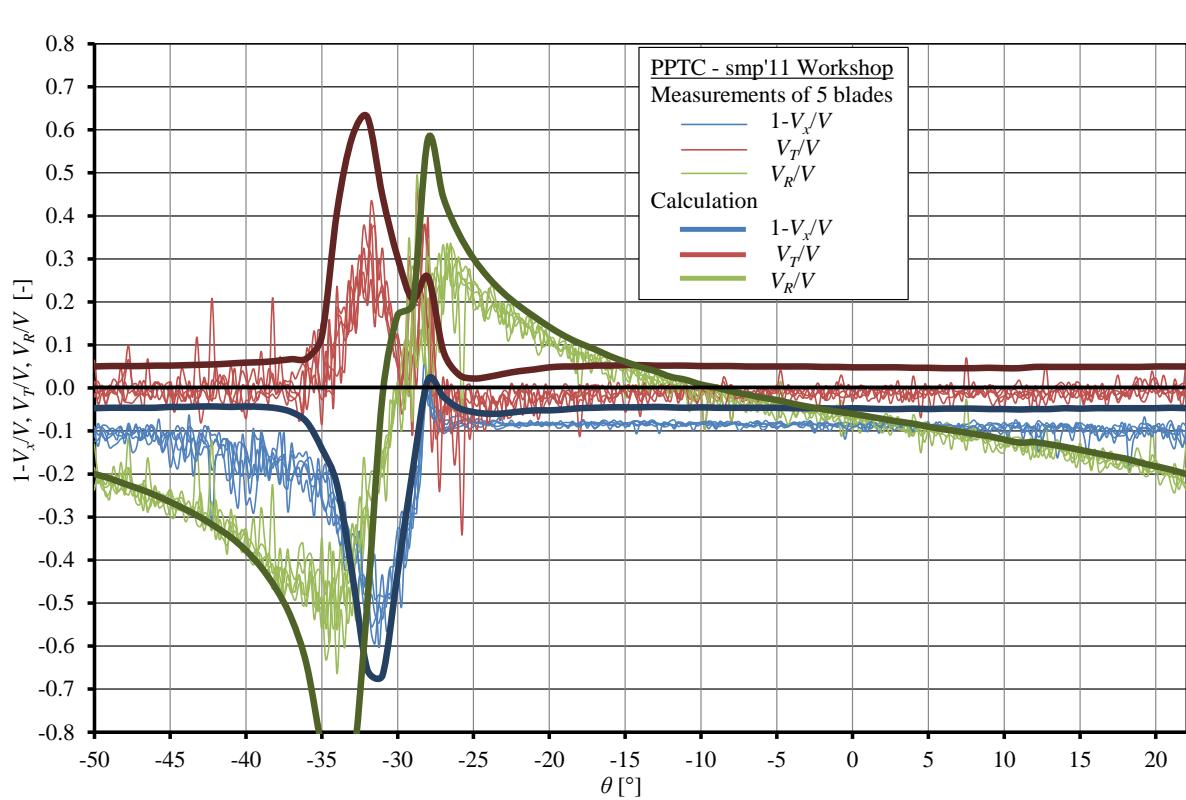
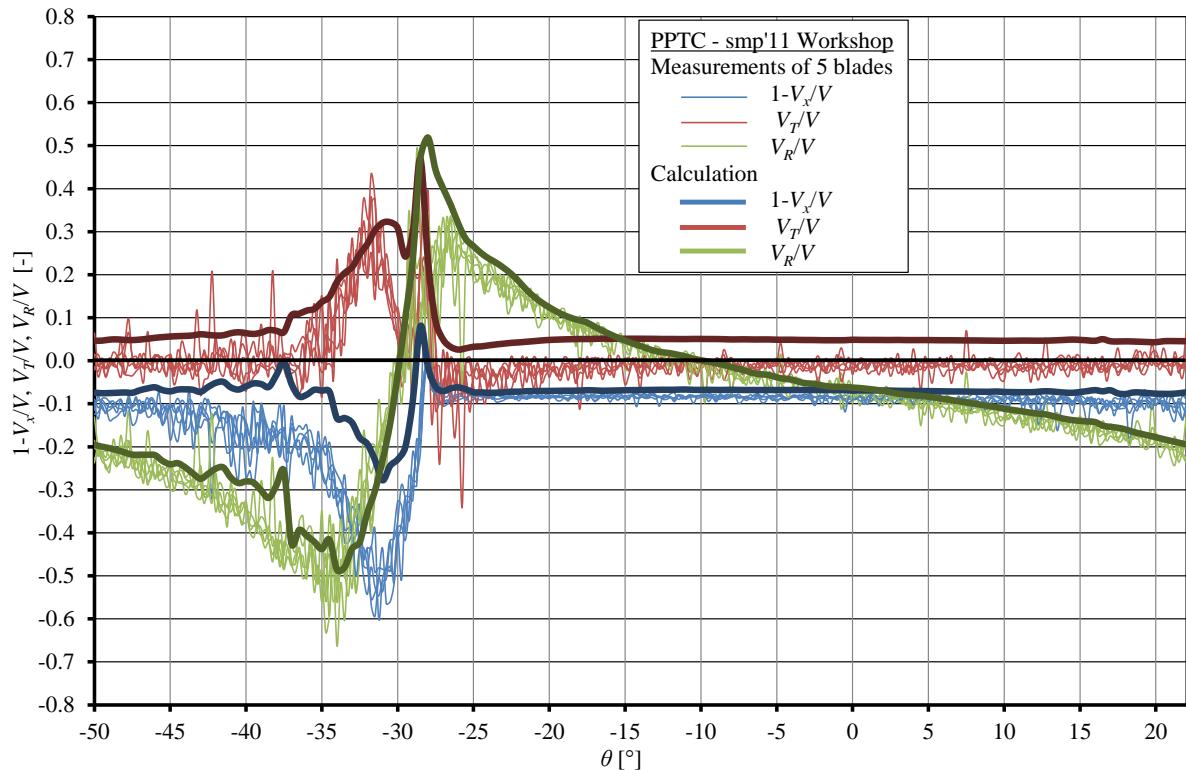
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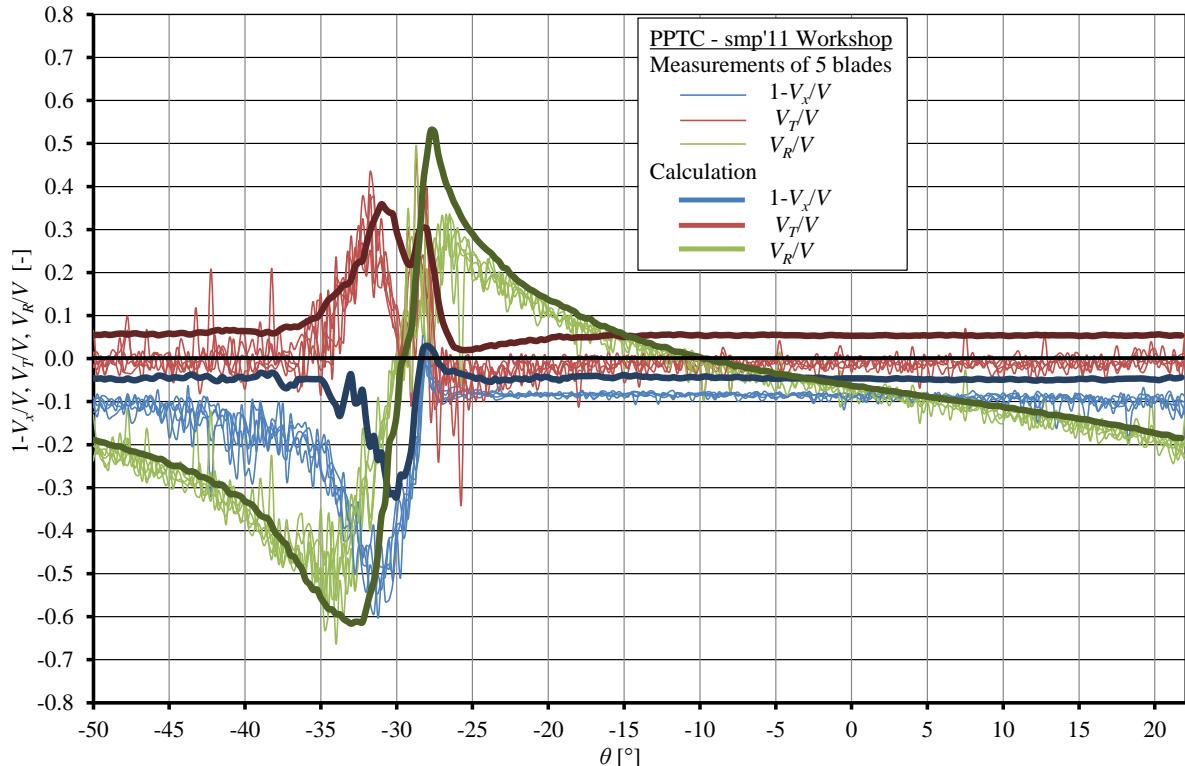


VOITH-Comet, $r/R = 0.70$, $x/D = 0.1$

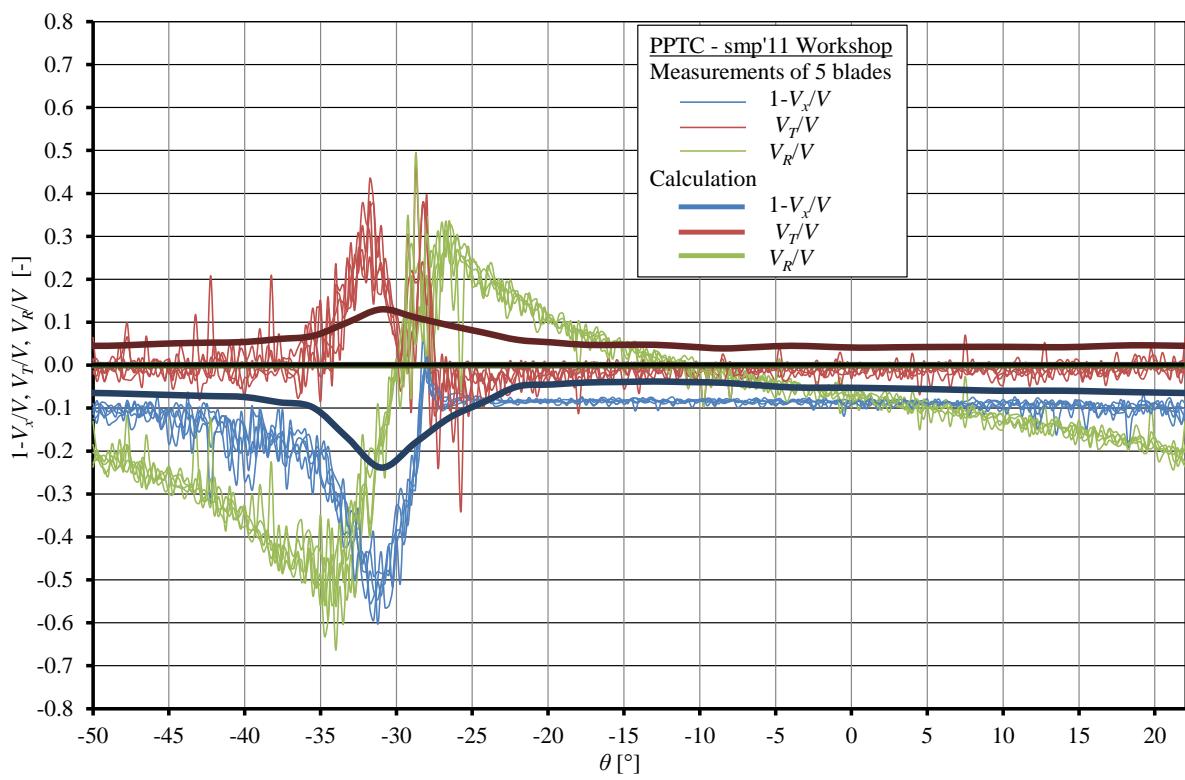


6.2 Case 2.2.2: $r/R = 0.97$, $x/D = 0.1$

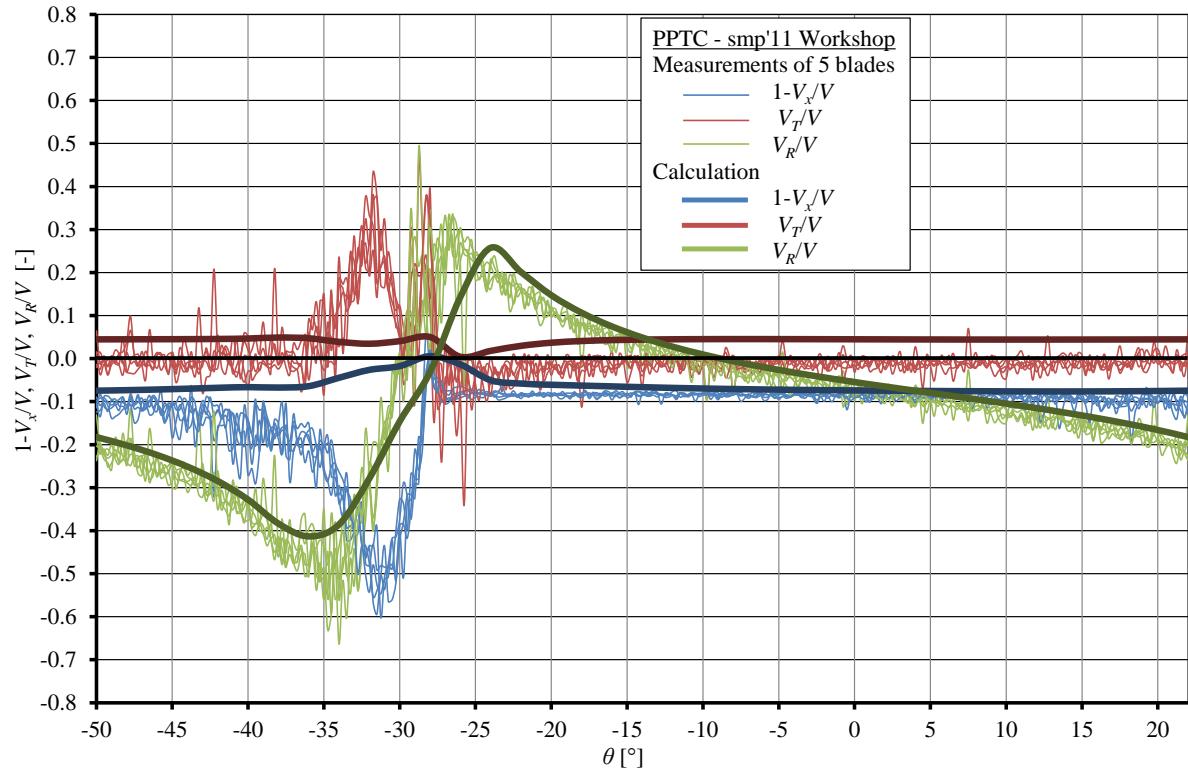




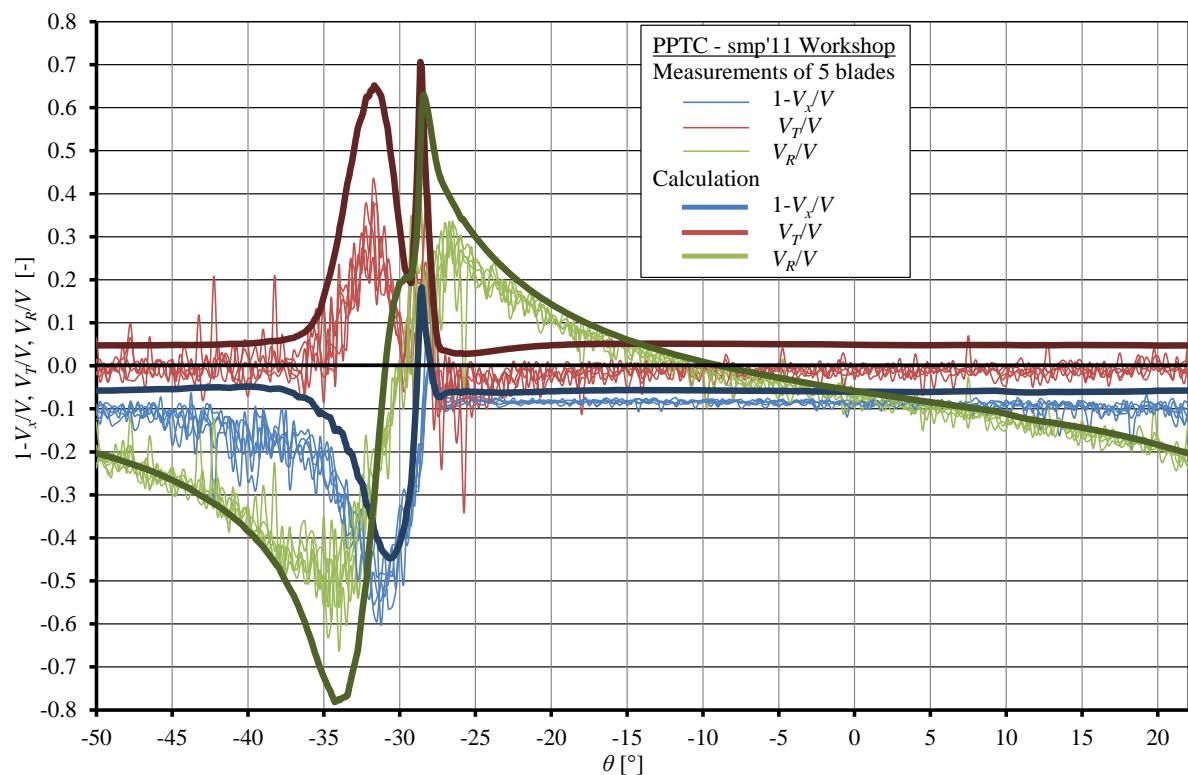
HSVA-FreSCO+, $r/R = 0.97$, $x/D = 0.1$



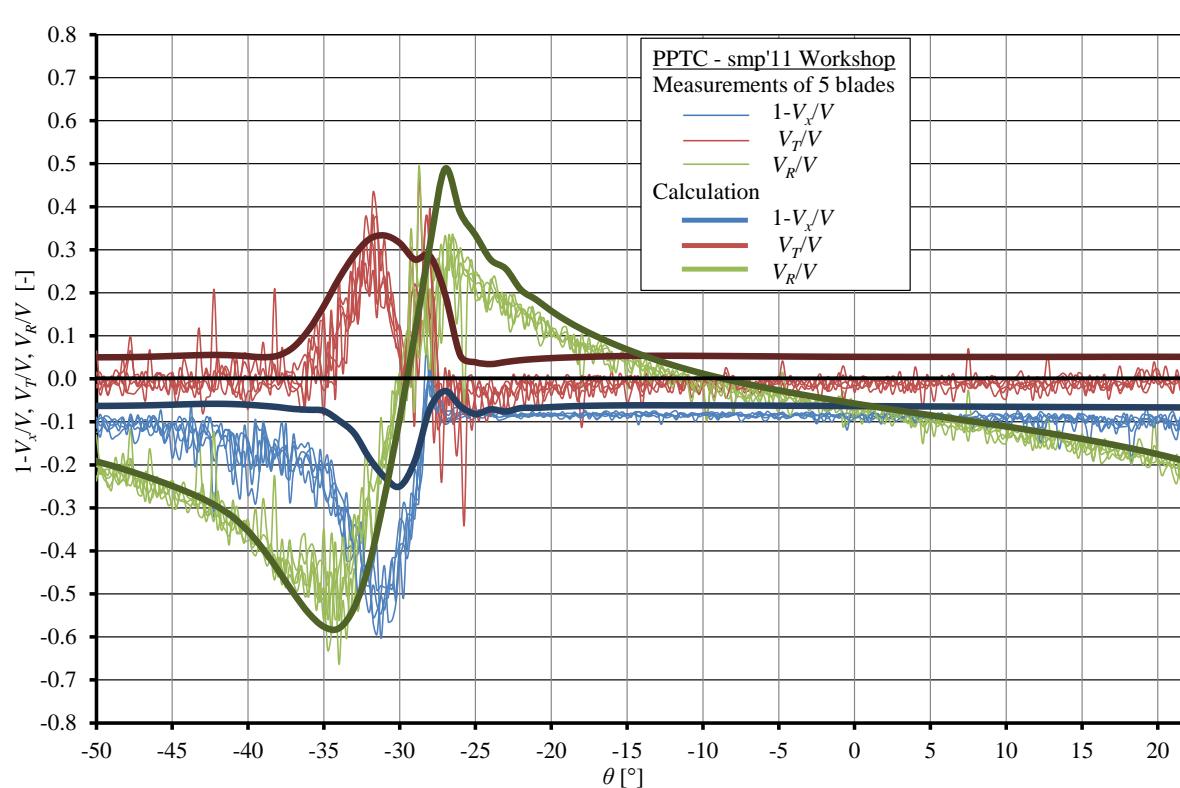
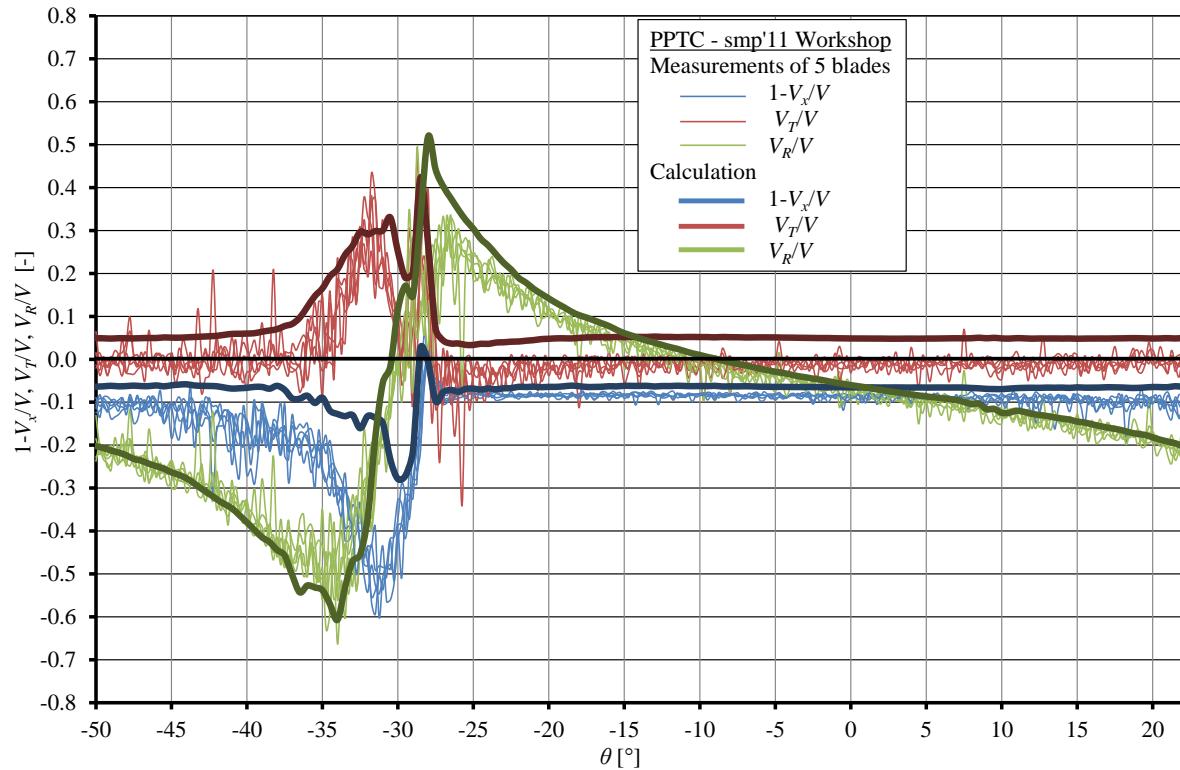
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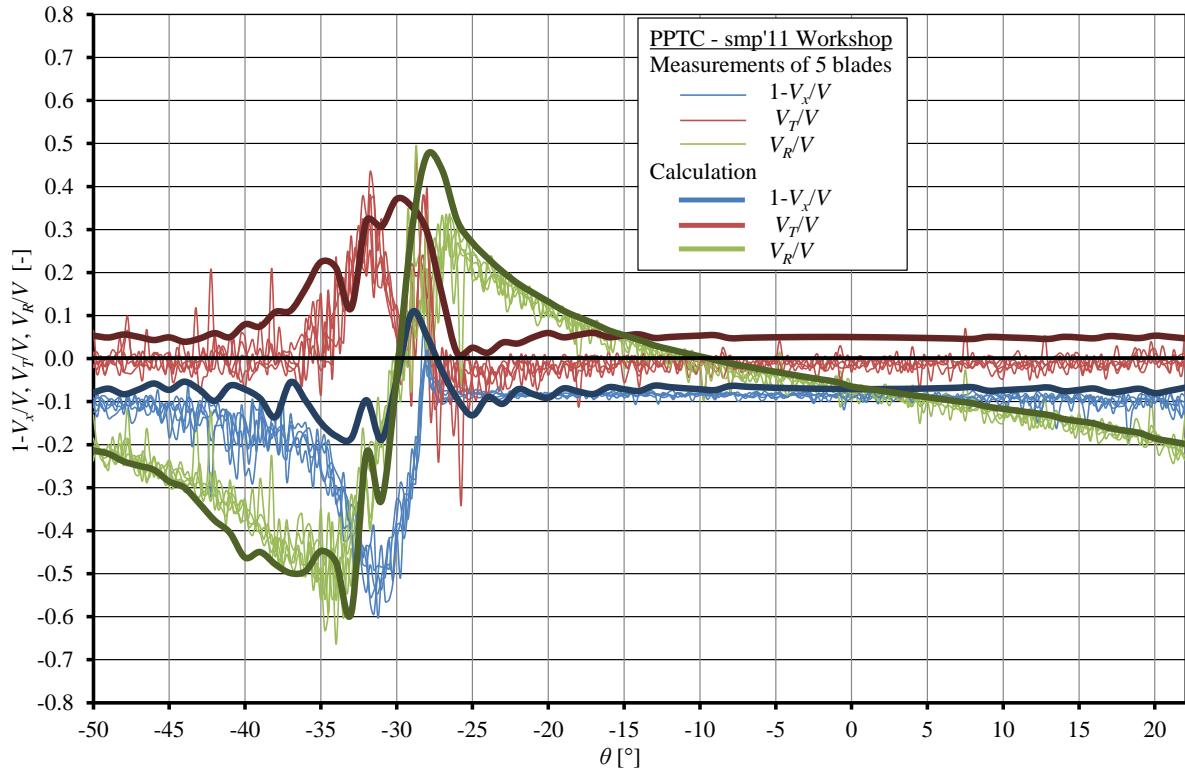


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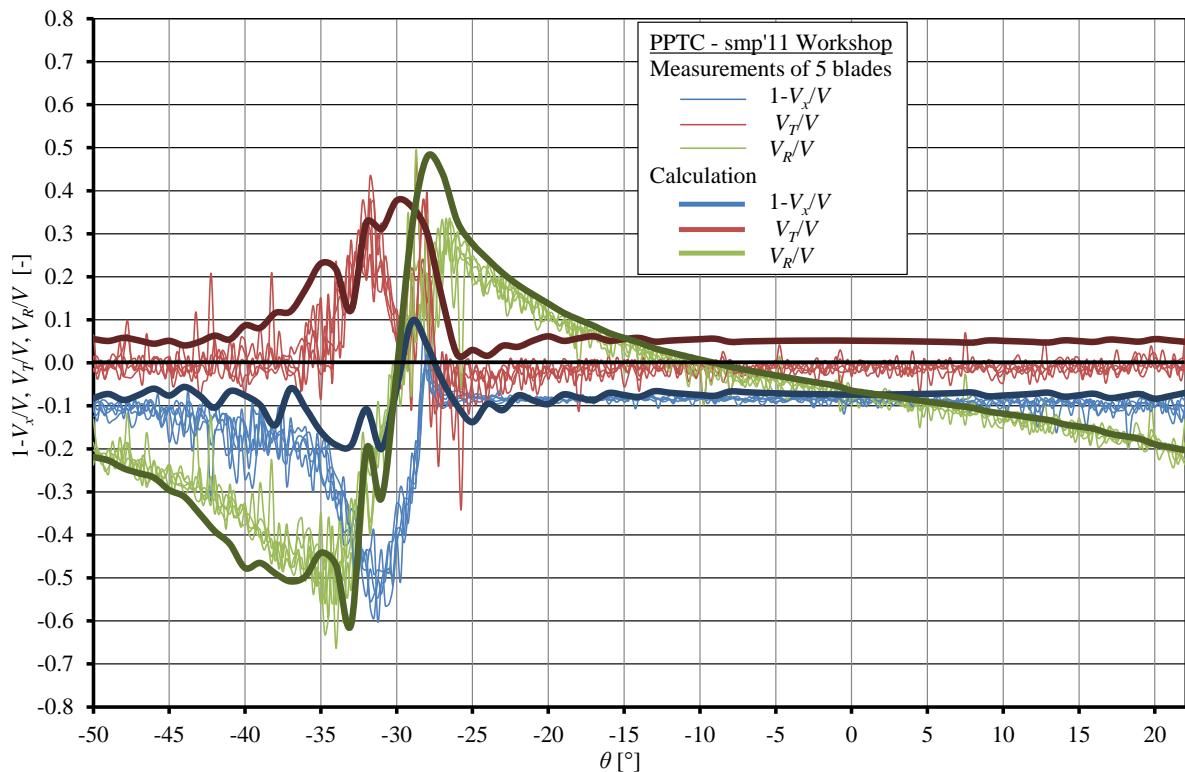


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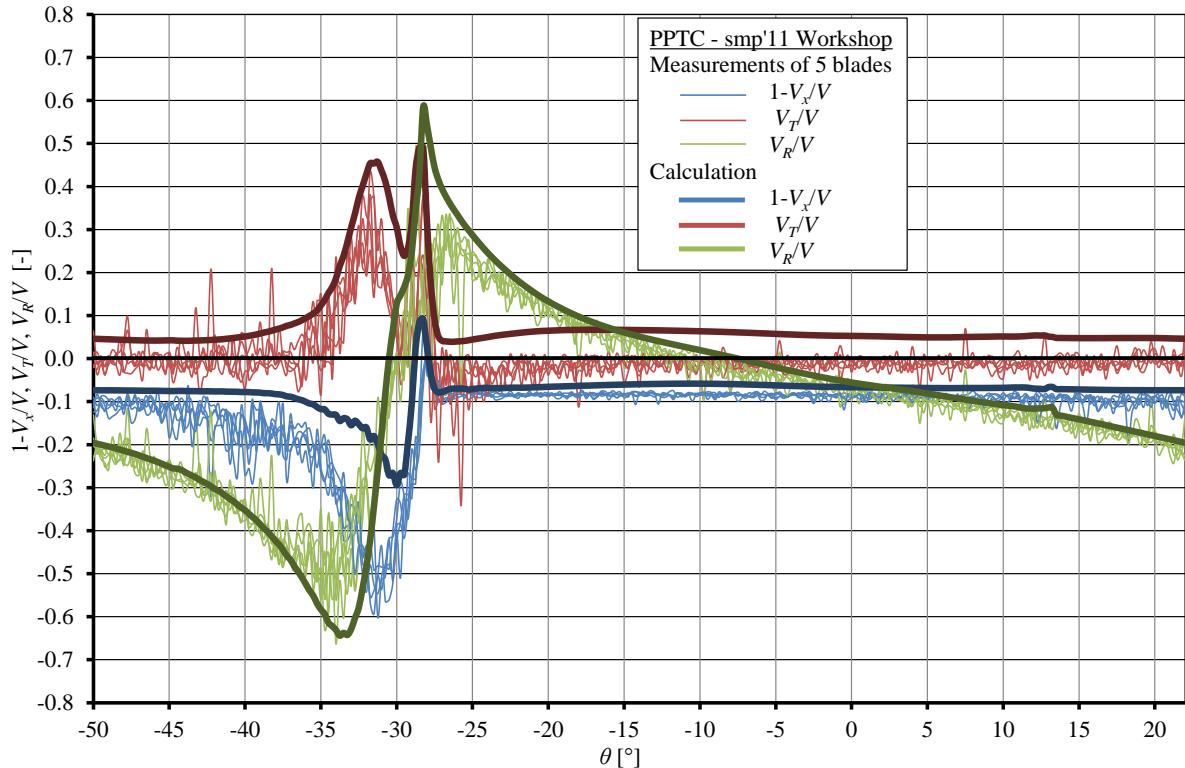




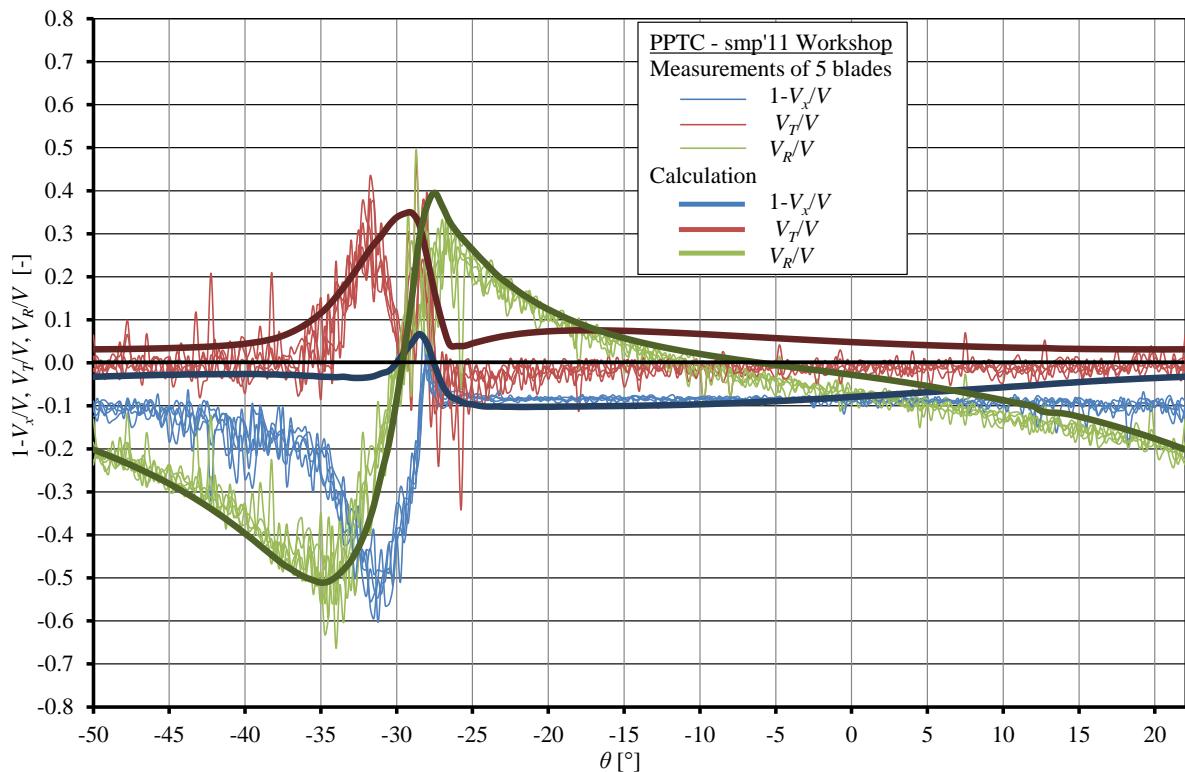
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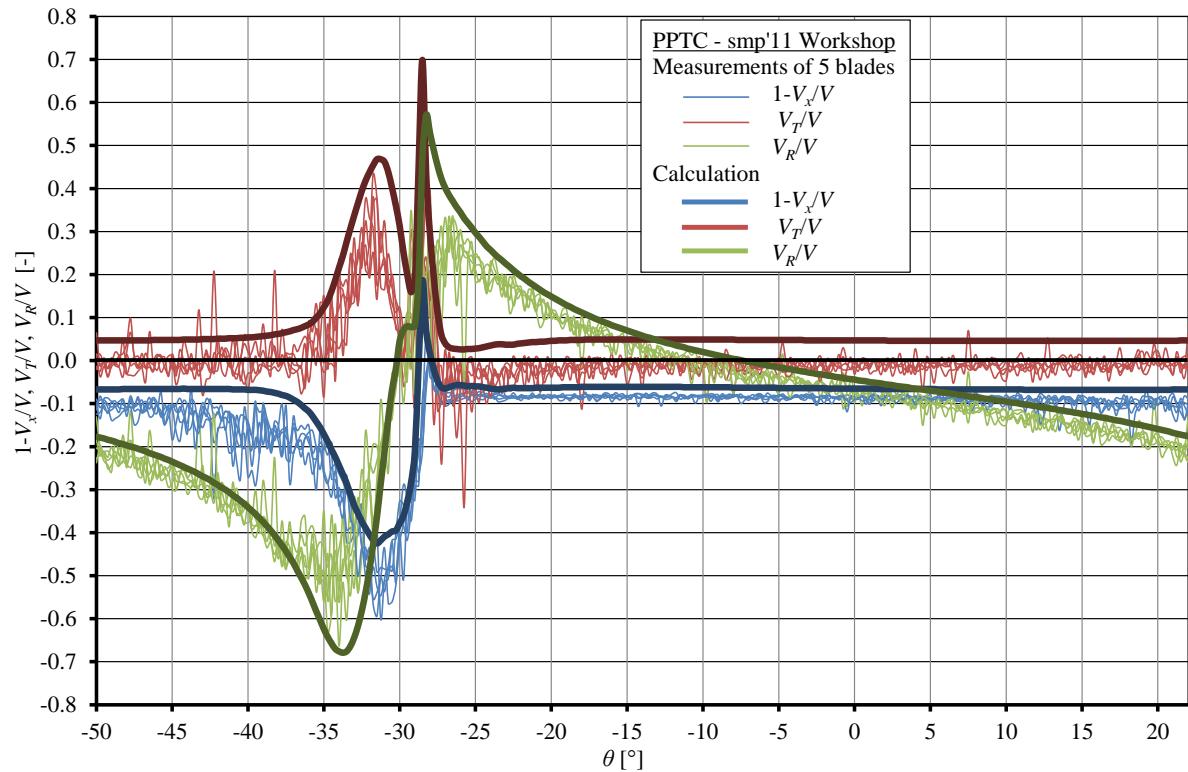
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UniTriest-CFX, $r/R = 0.97$, $x/D = 0.1$

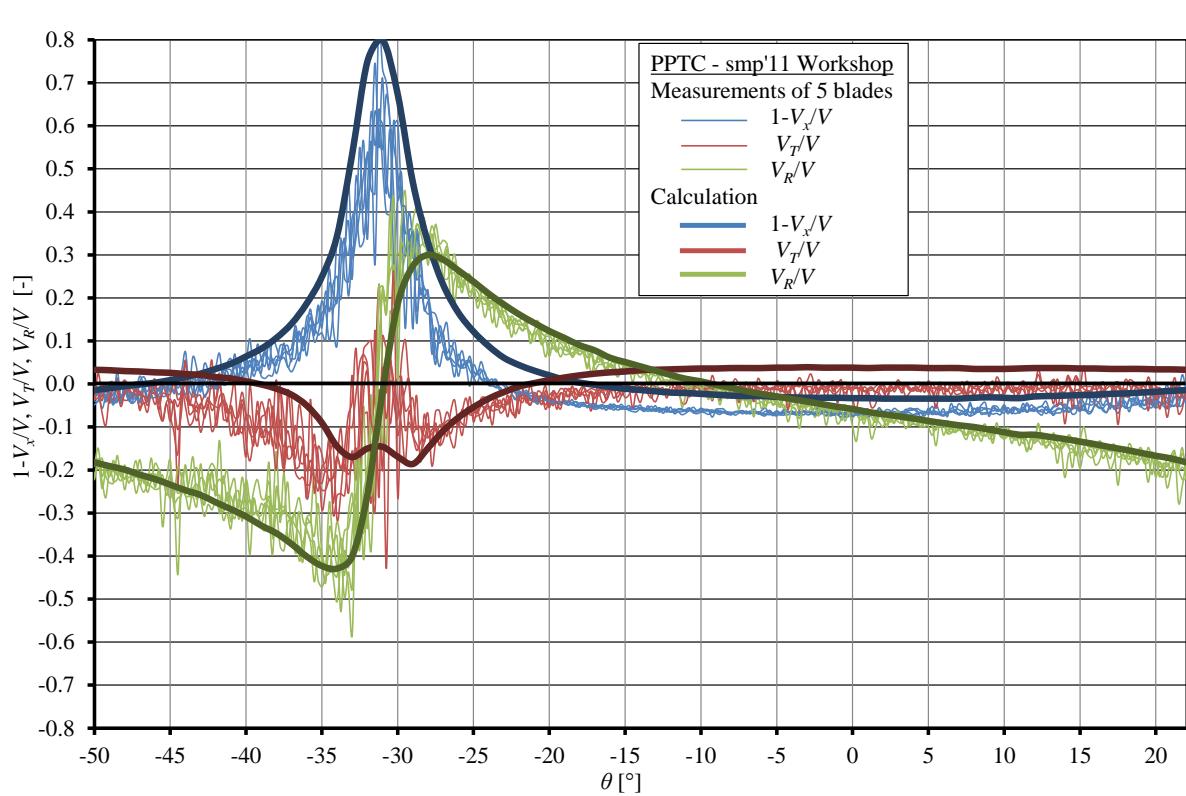
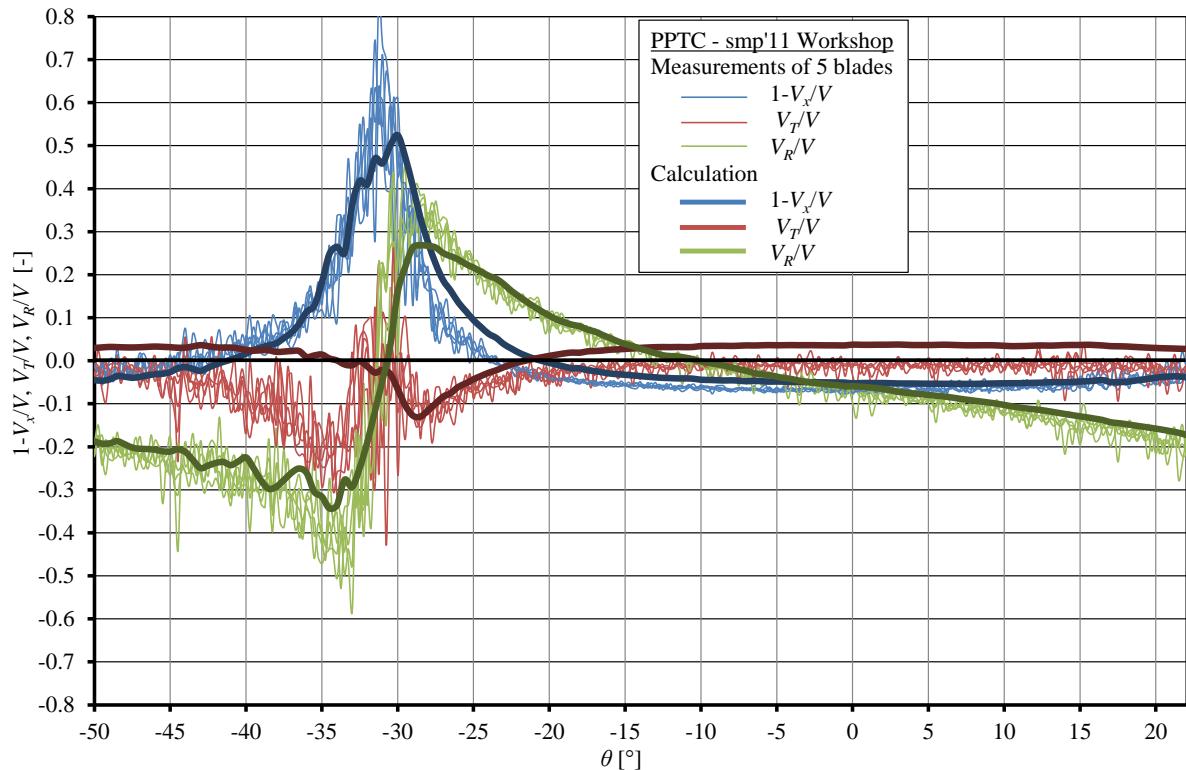


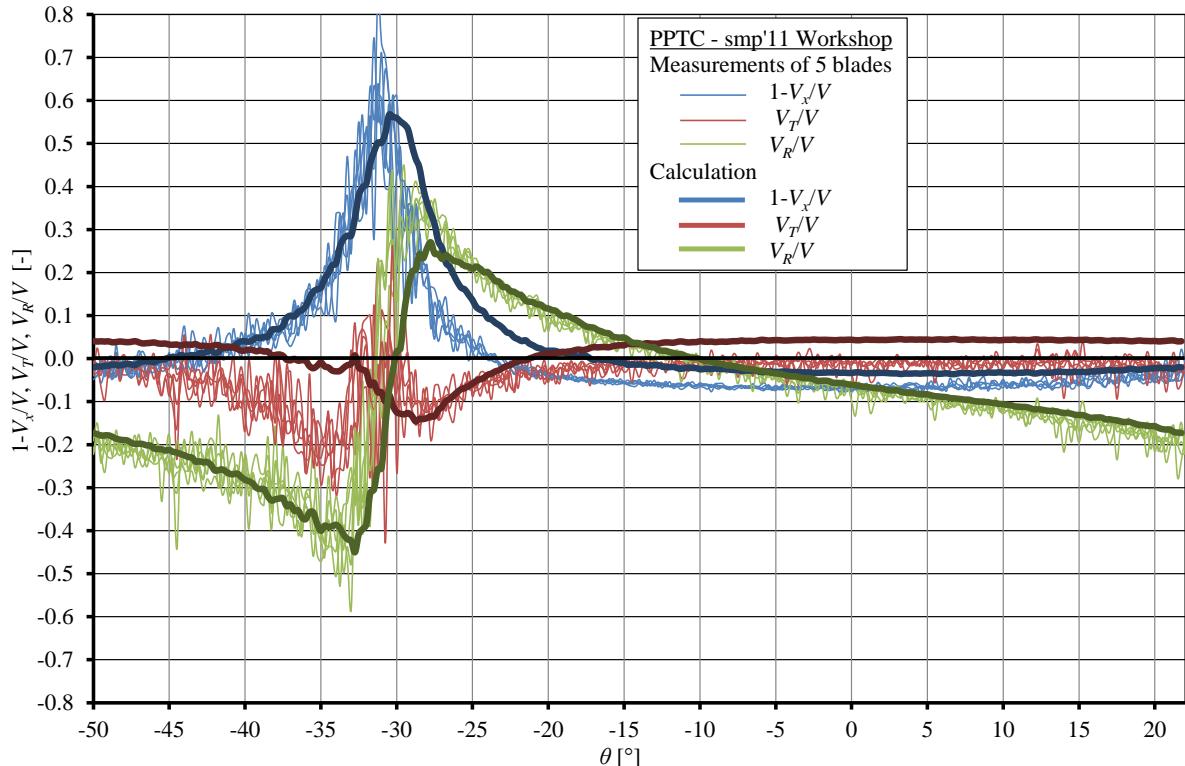
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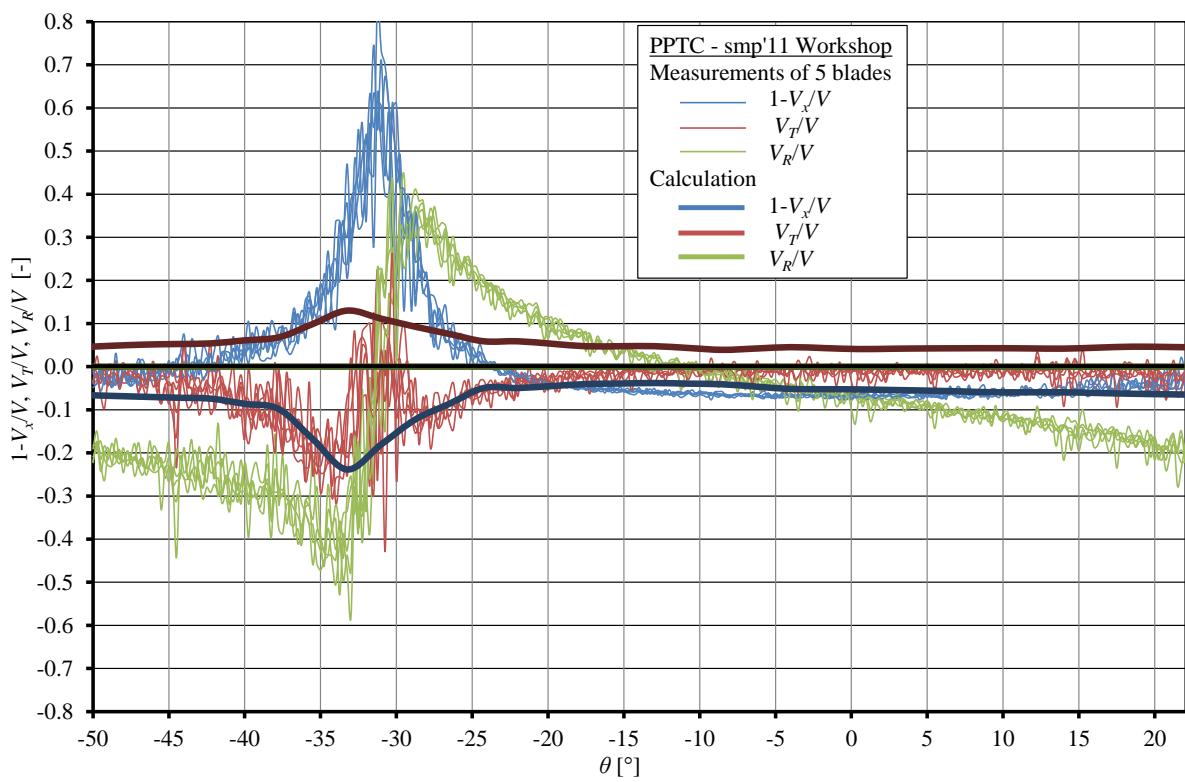
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6.3 Case 2.2.3: $r/R = 1.00, x/D = 0.1$

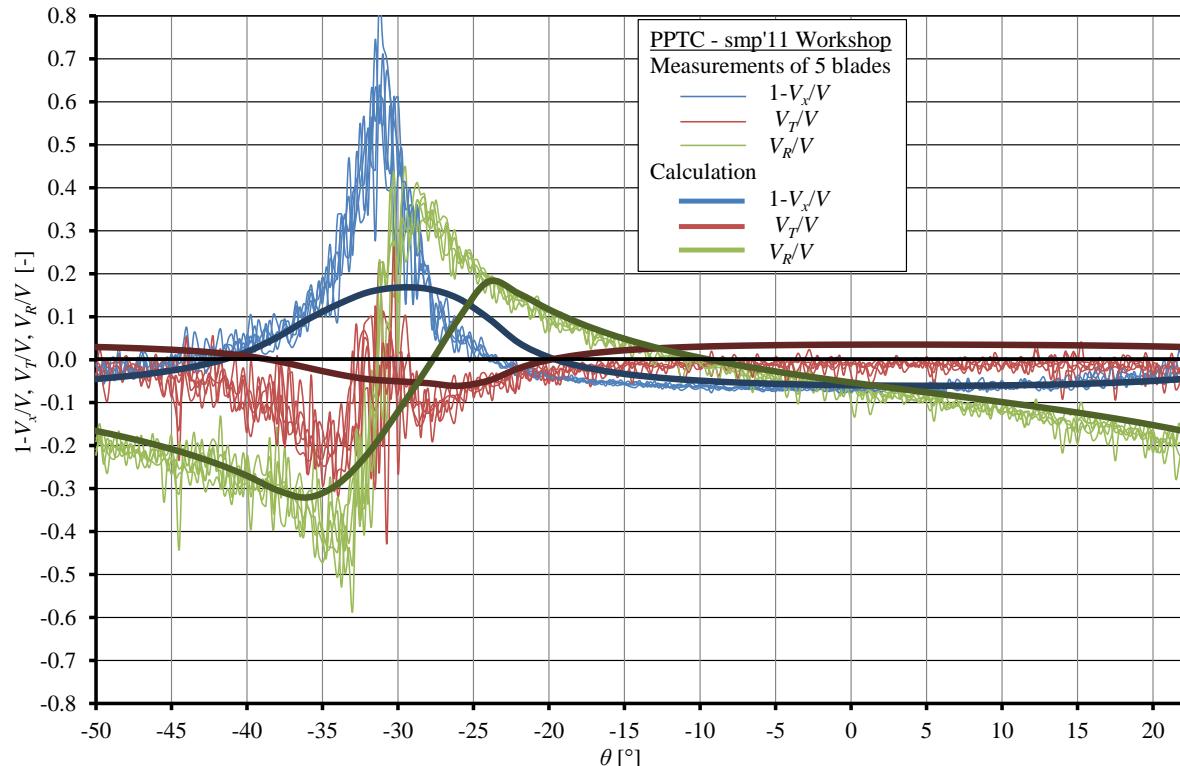




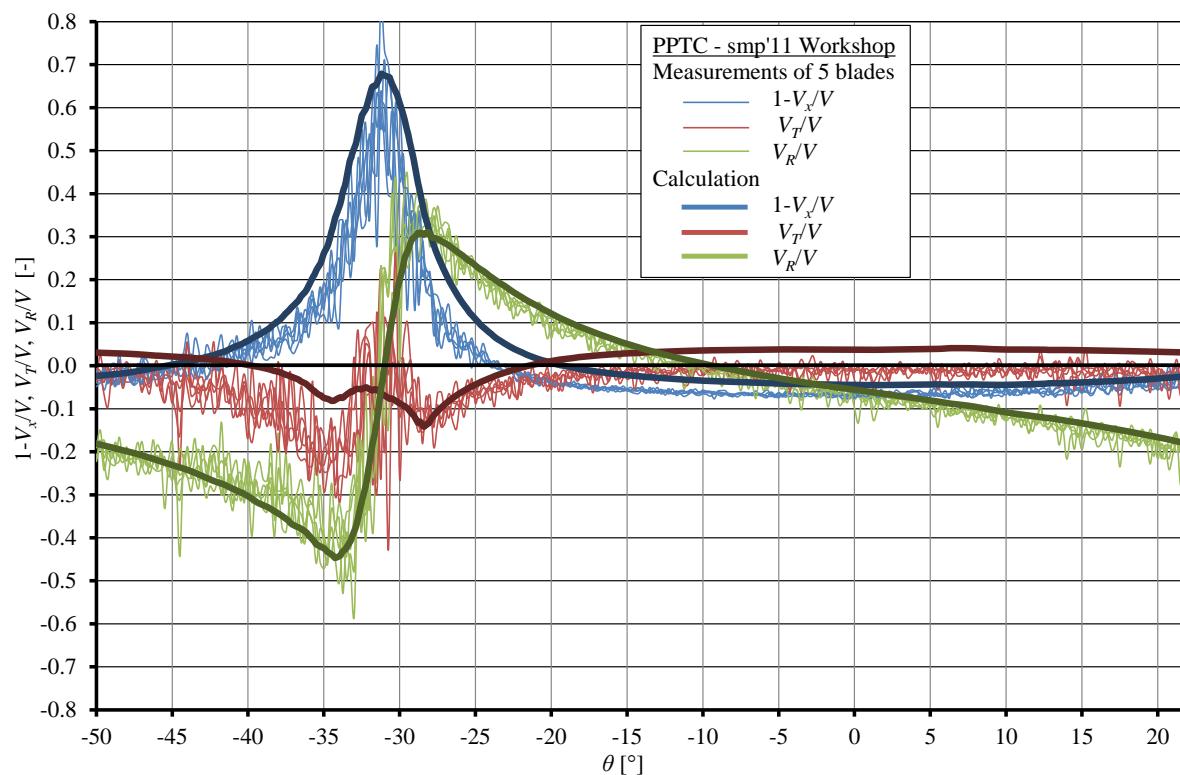
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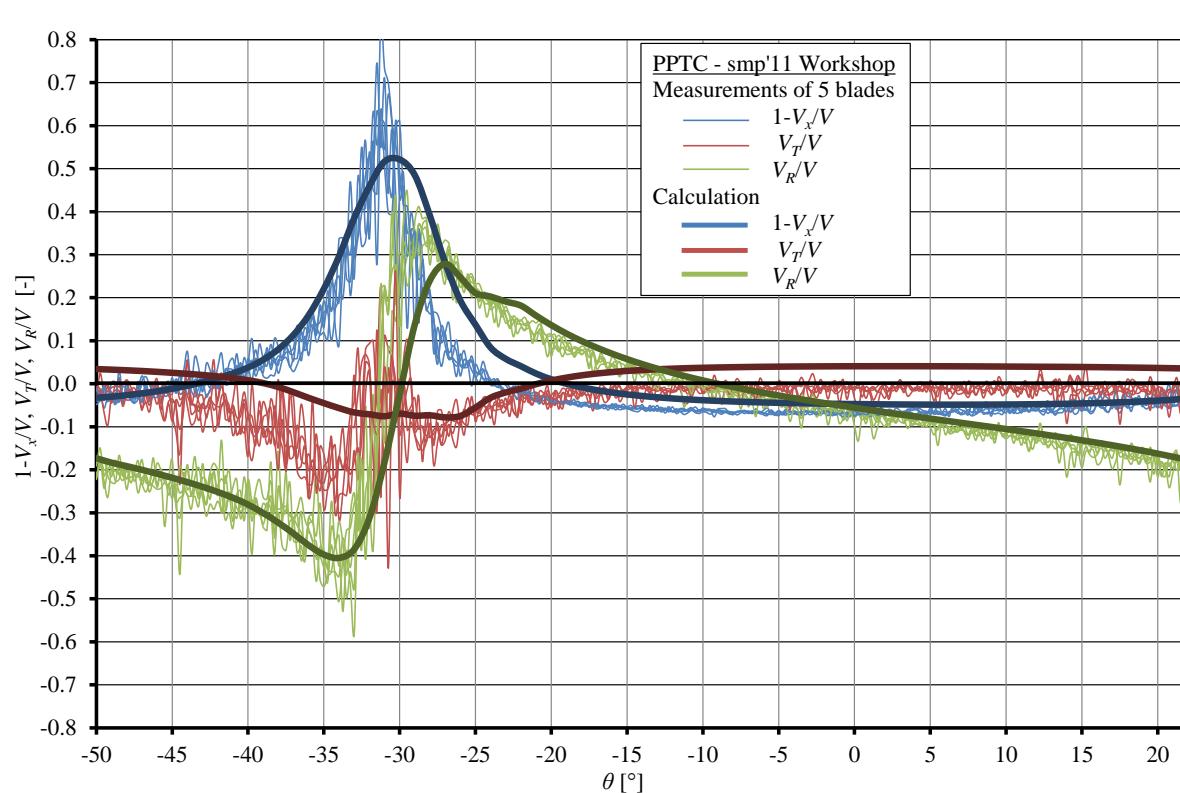
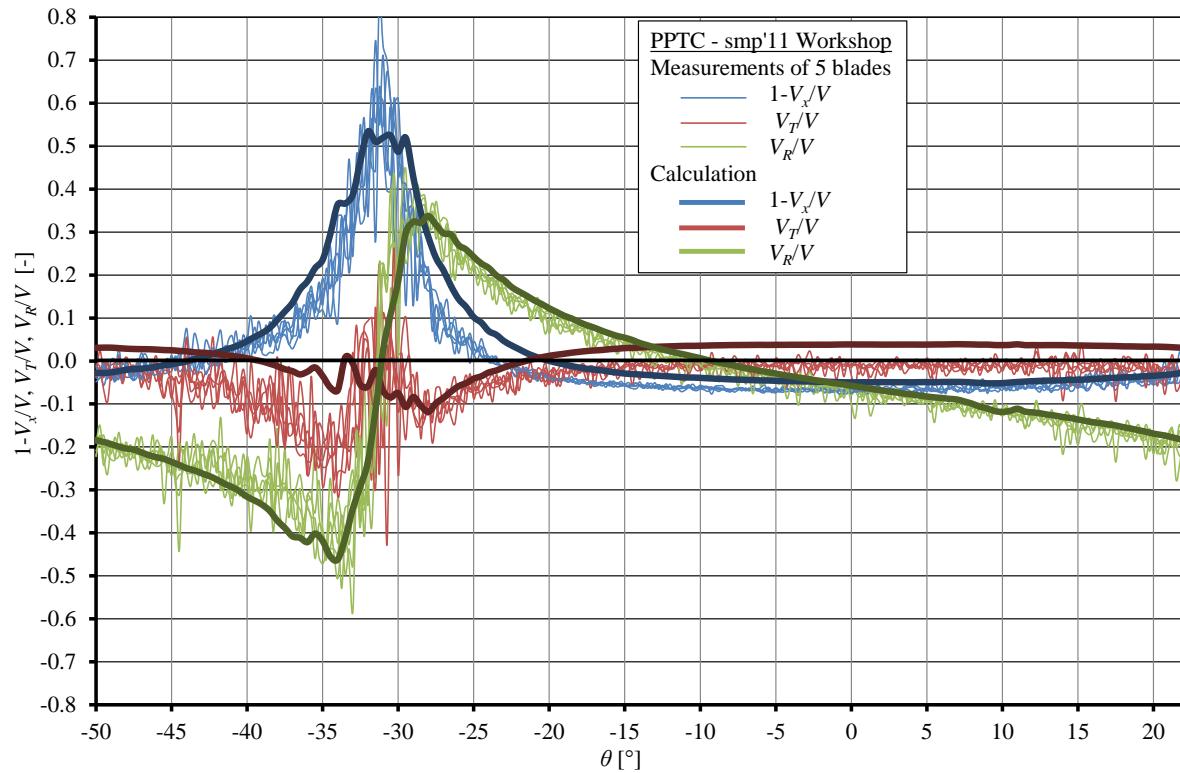
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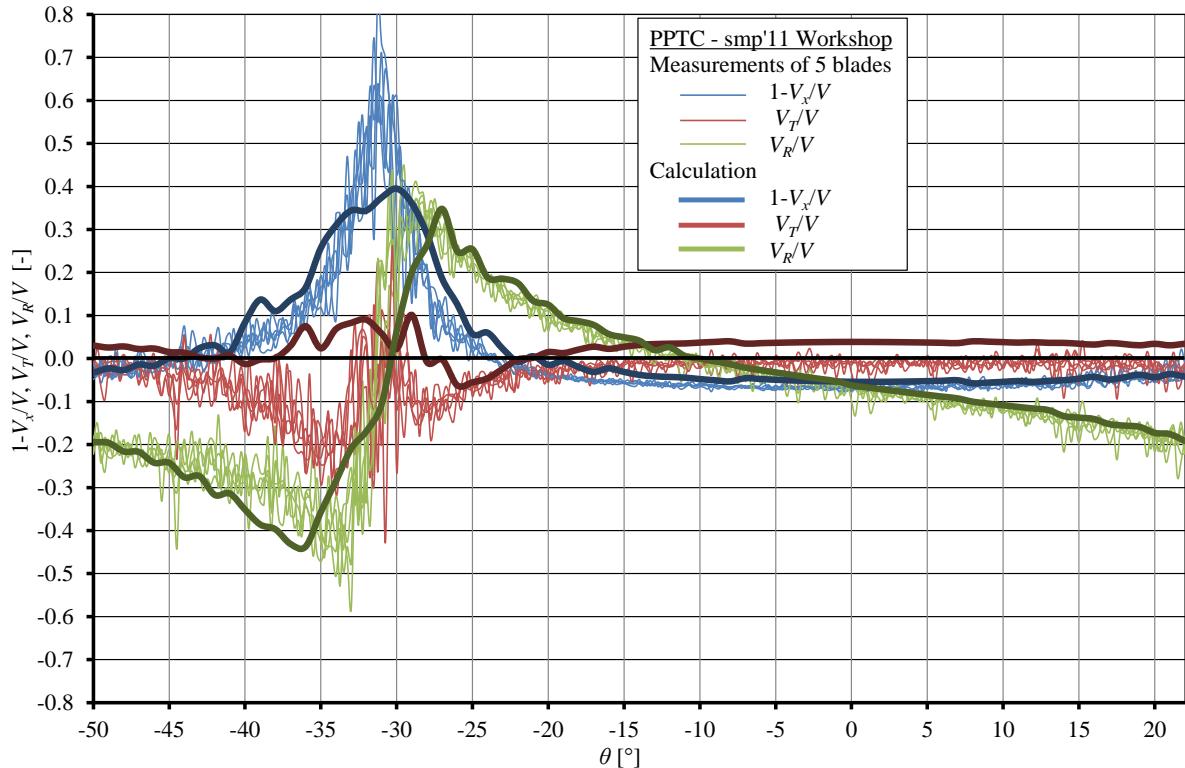
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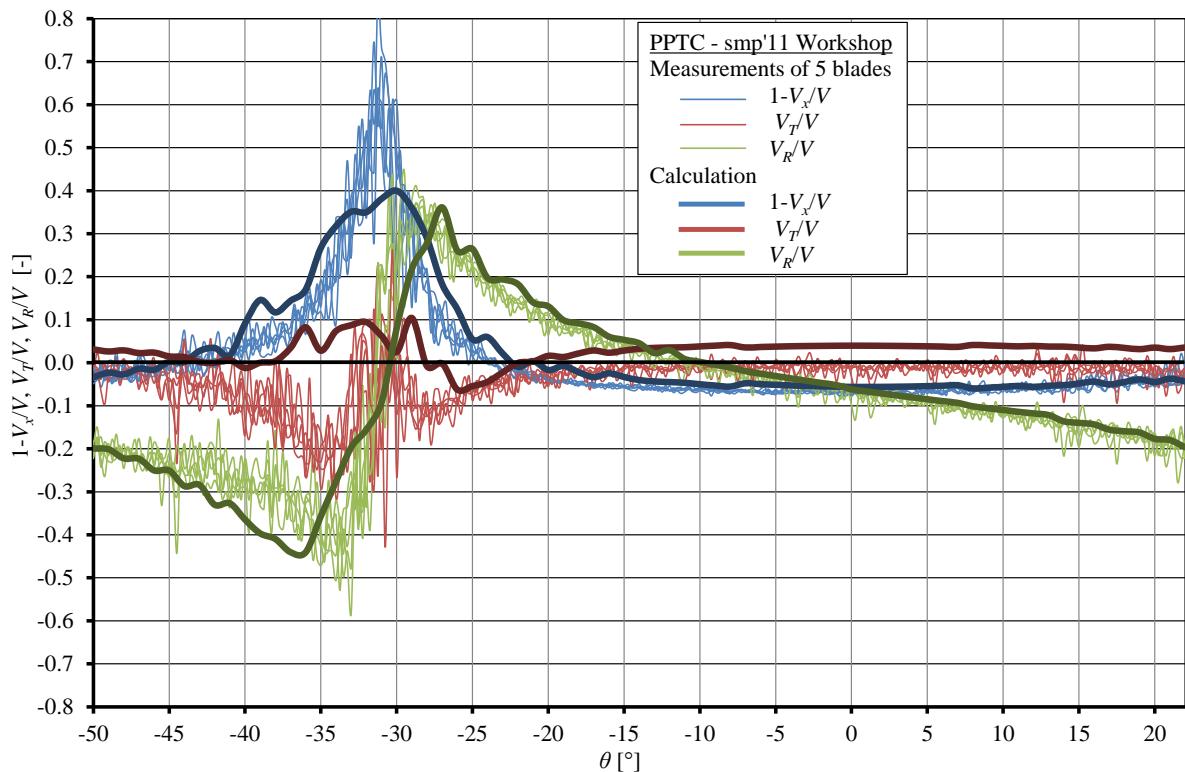
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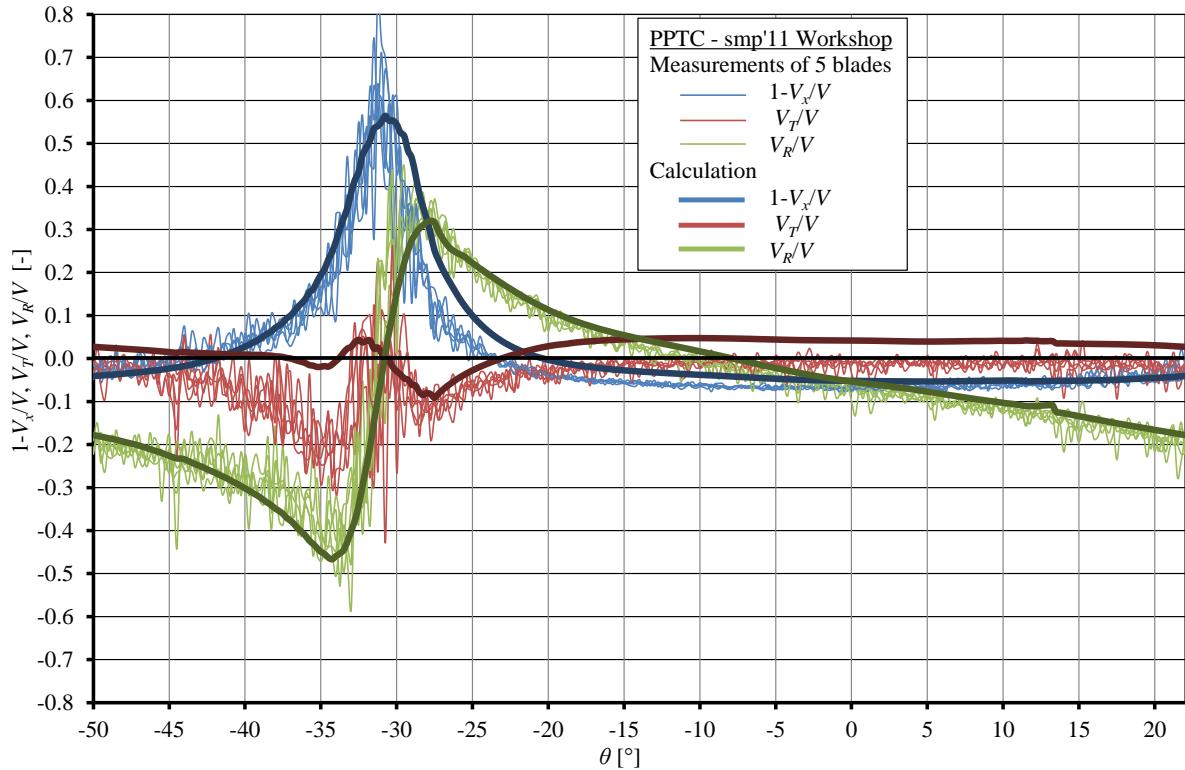
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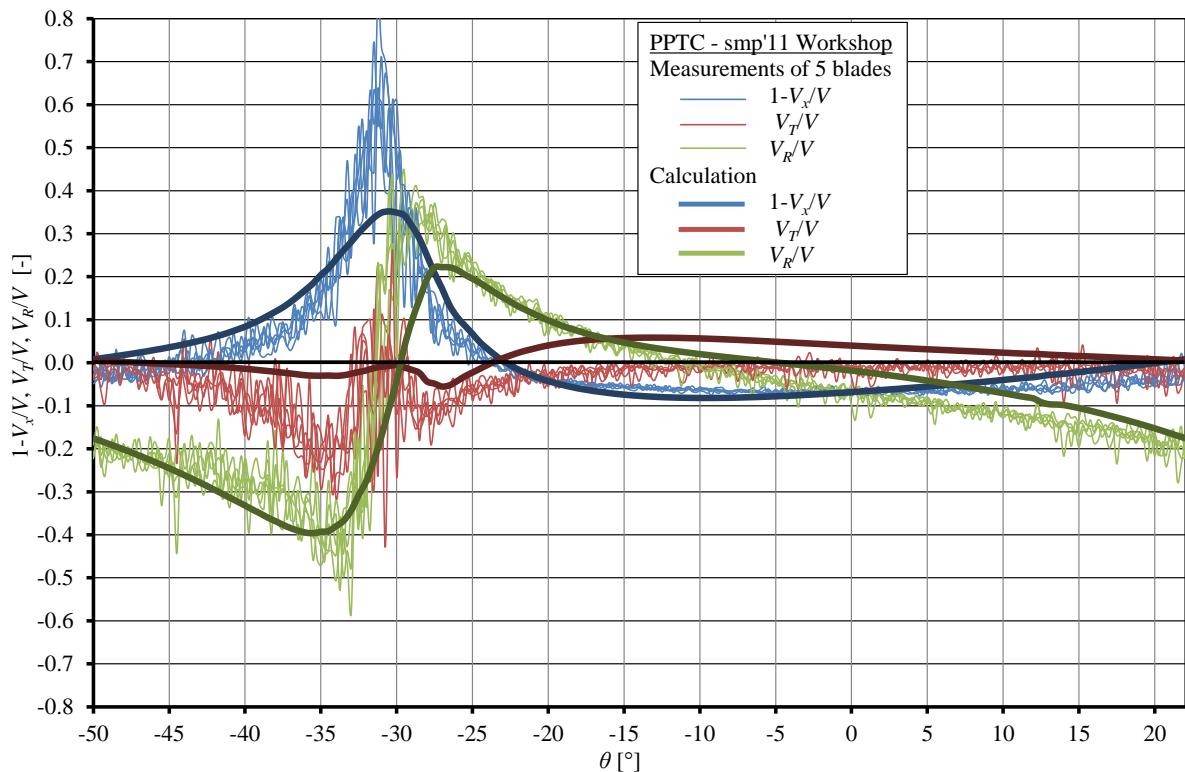
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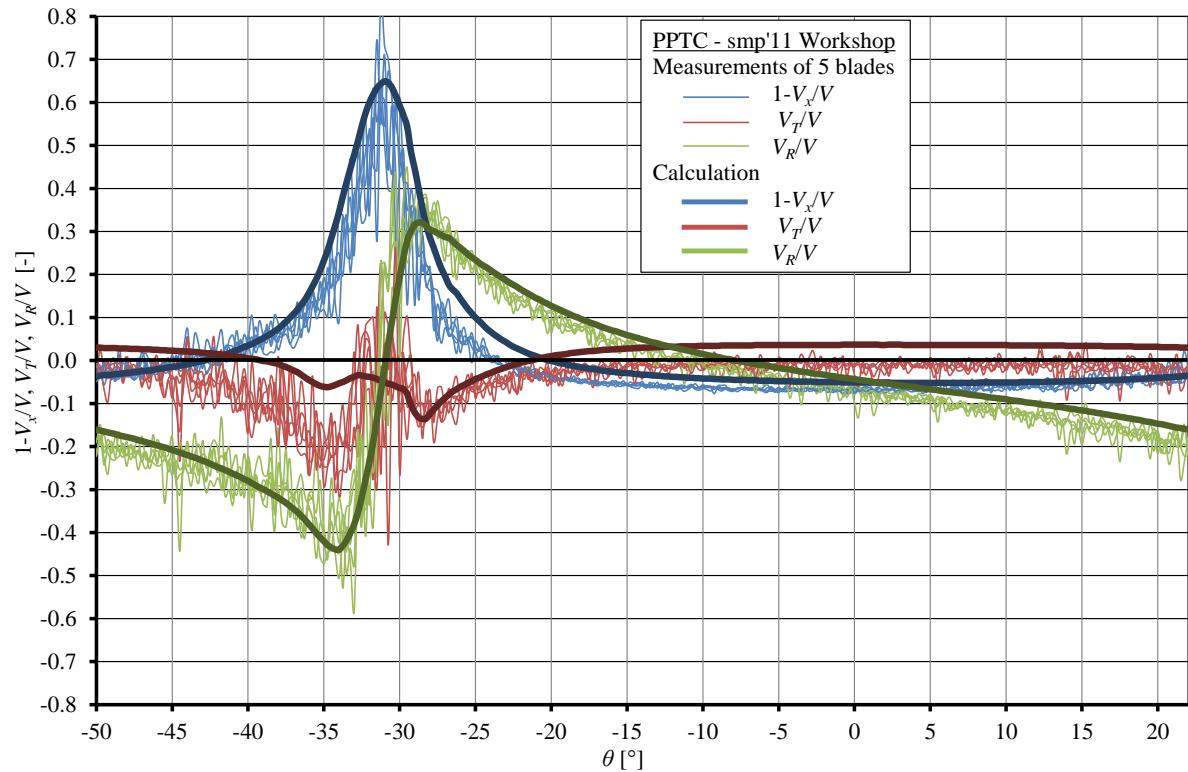
UniGenua-StarCCM(kw), $r/R = 1.00, x/D = 0.1$



UniTriest-CFX, $r/R = 1.00, x/D = 0.1$

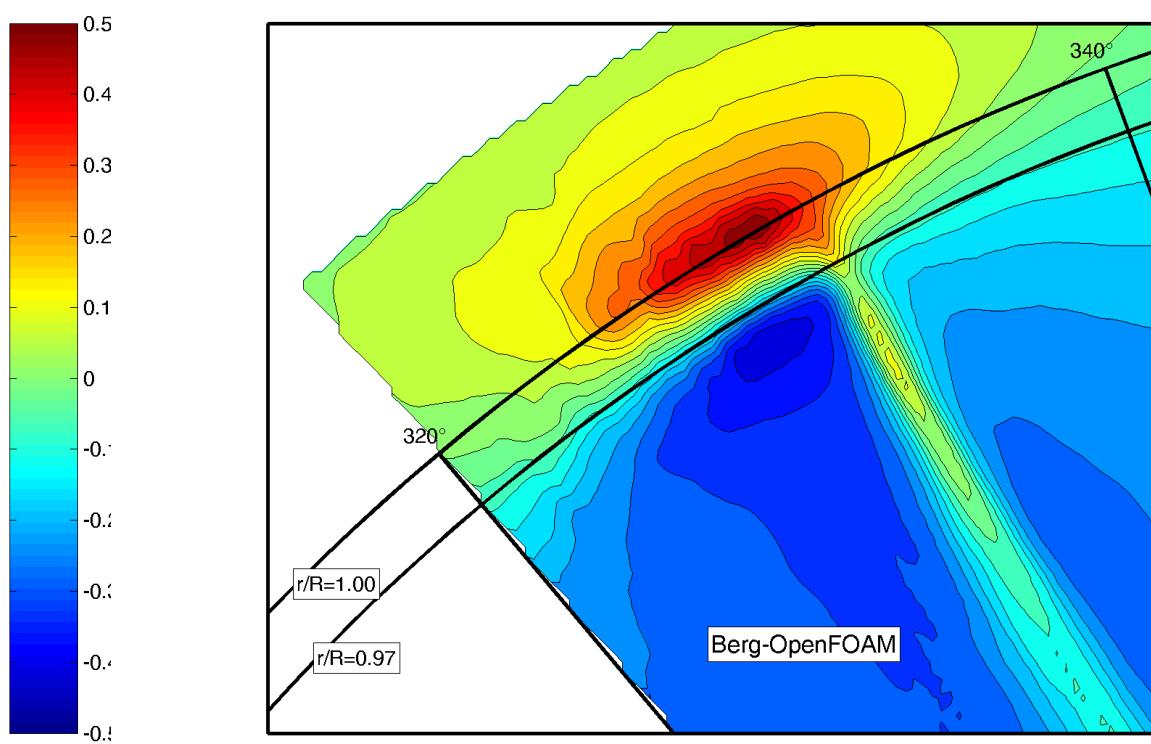
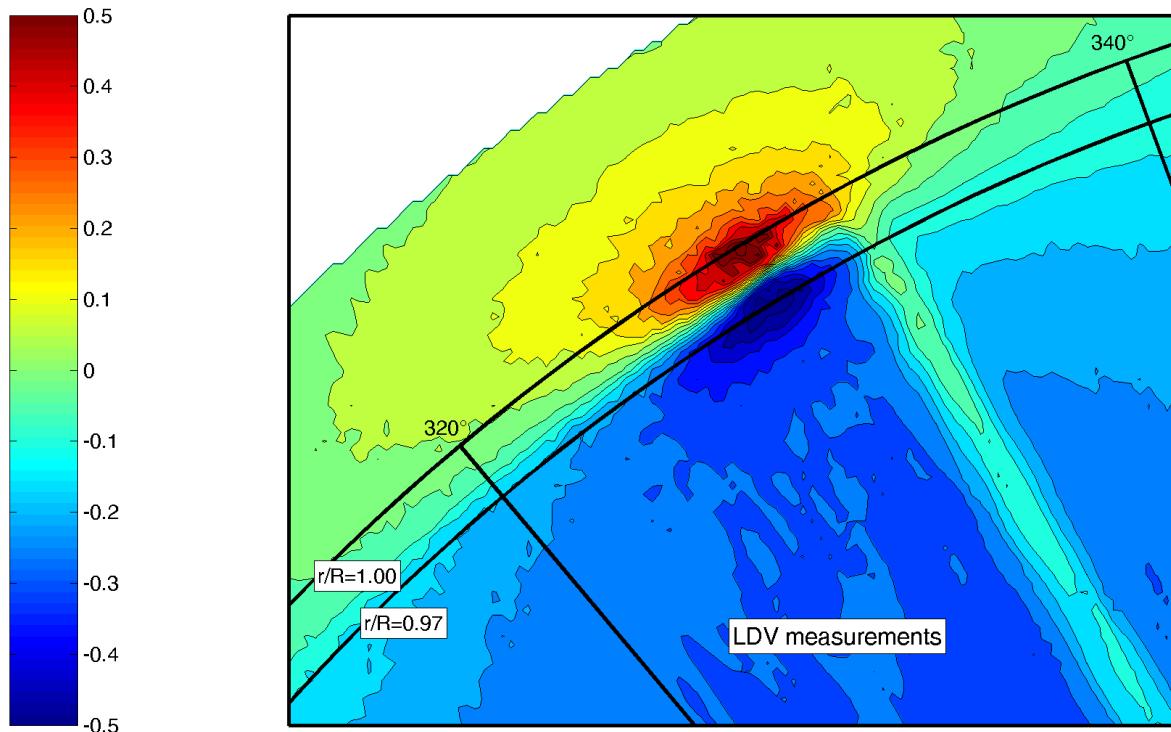


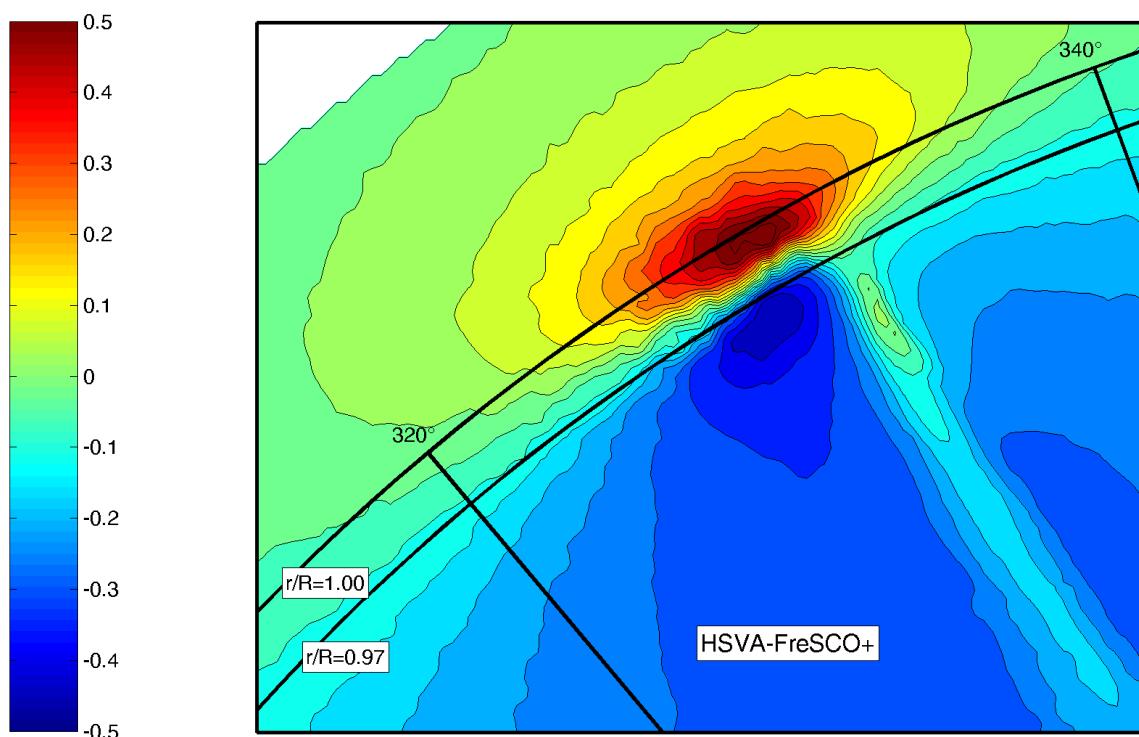
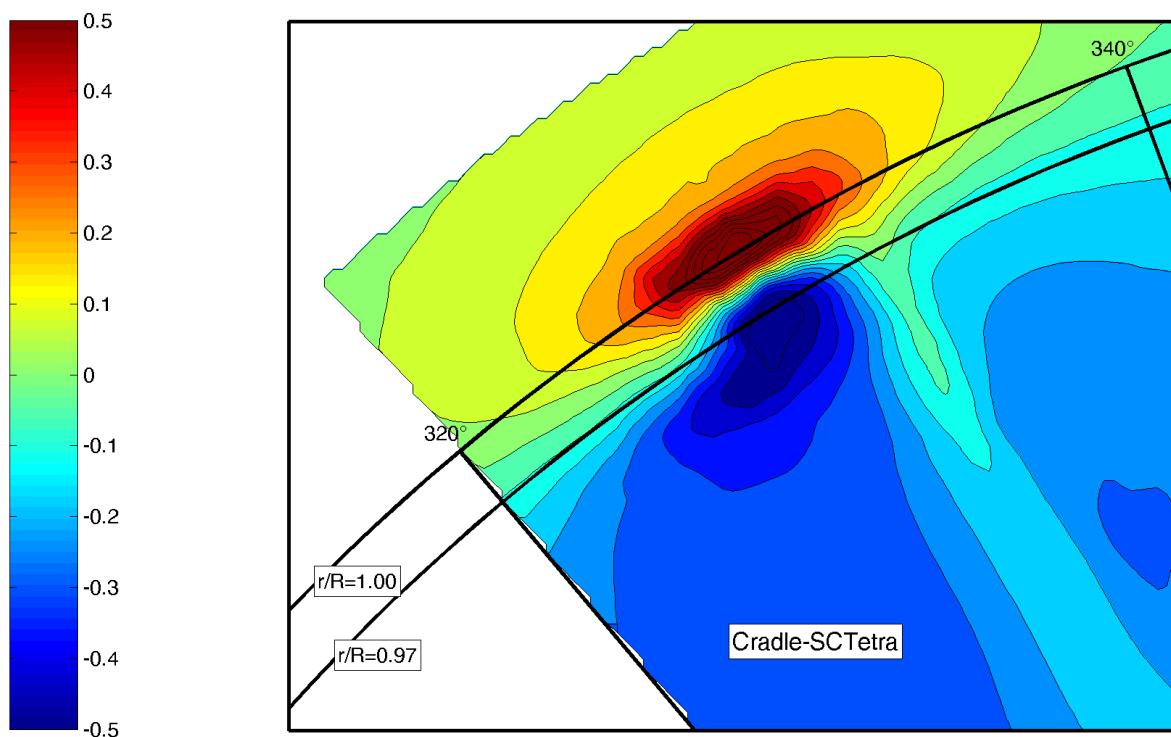
VOITH-Comet, $r/R = 1.00, x/D = 0.1$

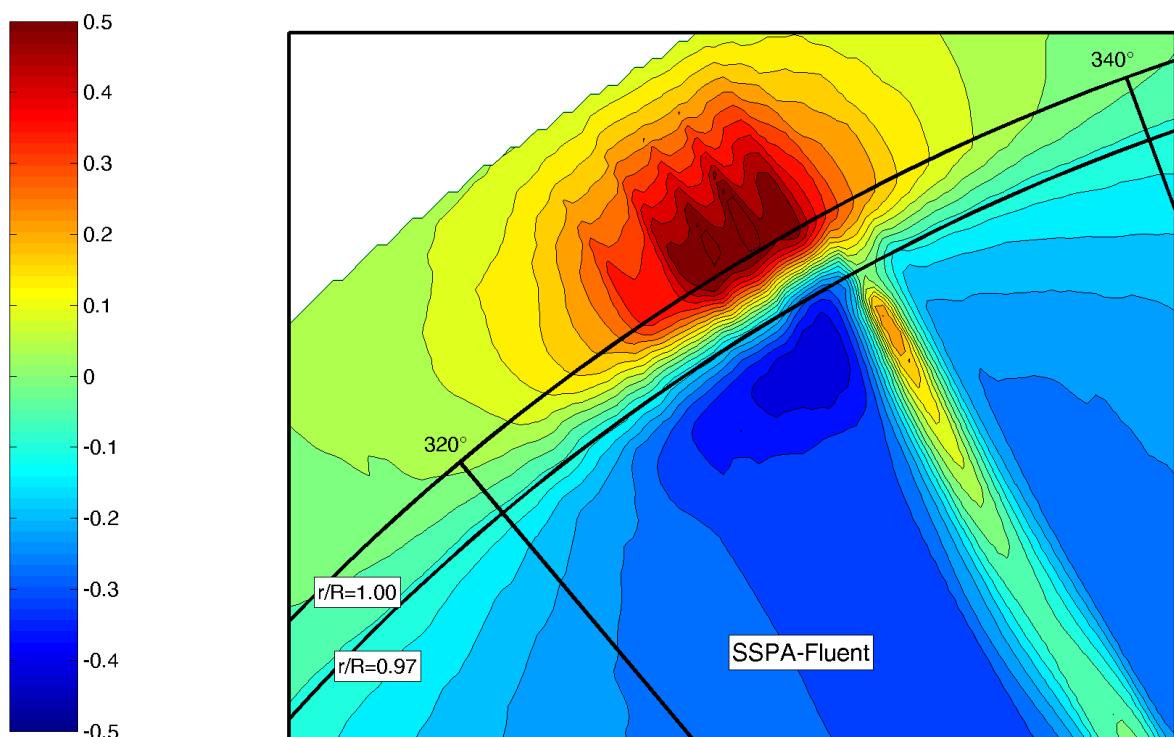
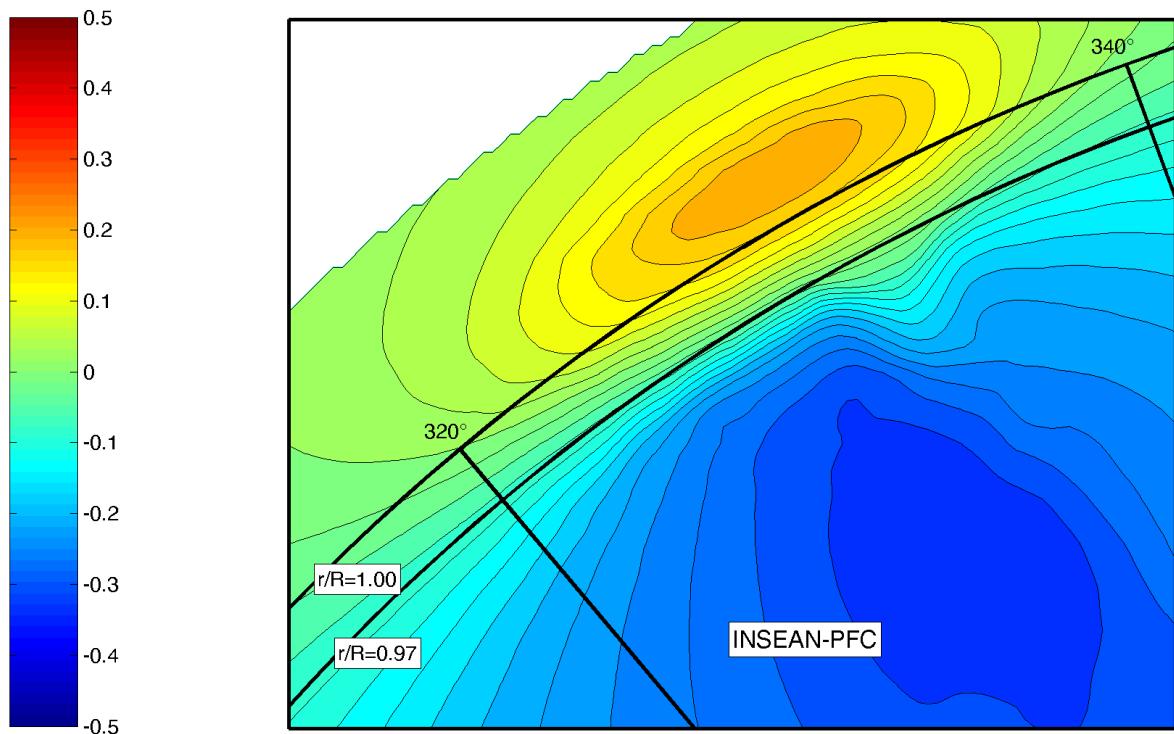


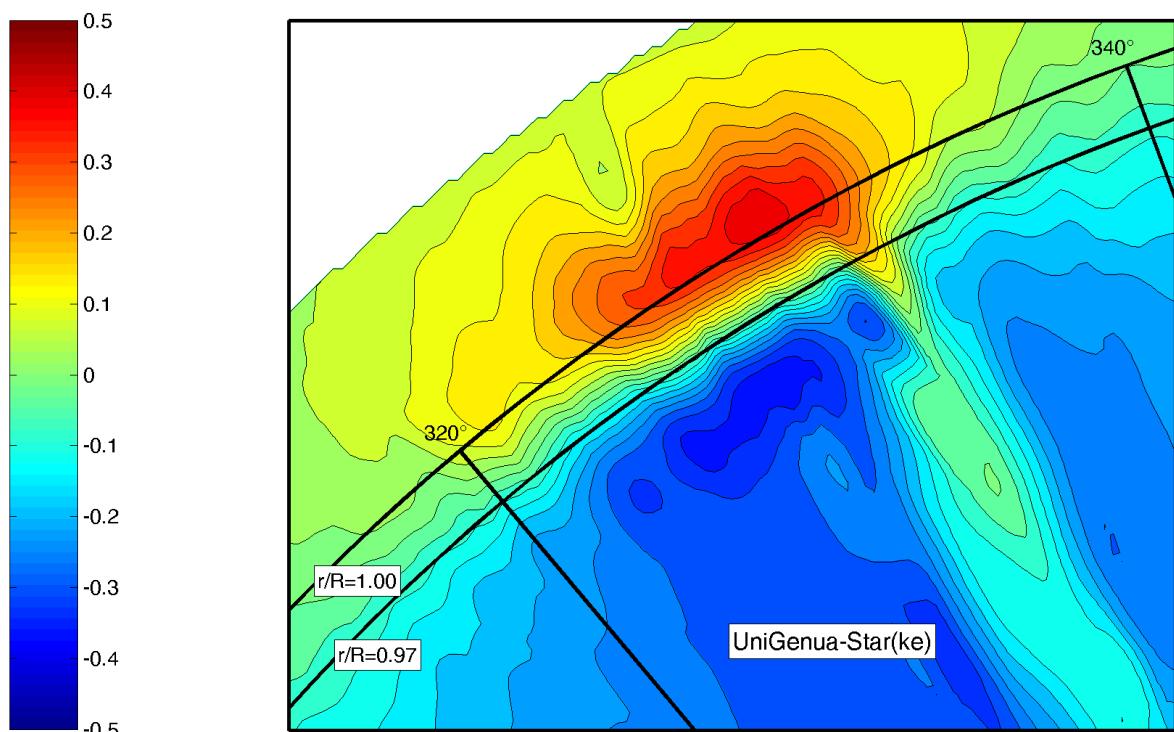
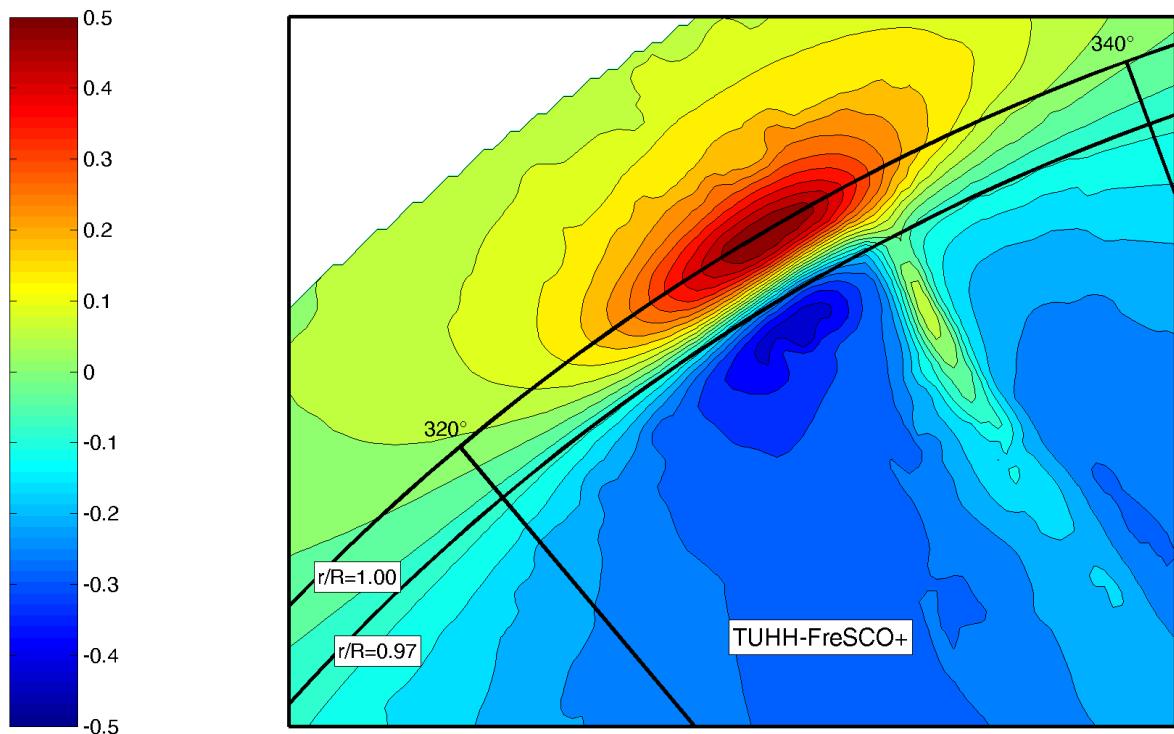
VTT-FinFlo, $r/R = 1.00$, $x/D = 0.1$

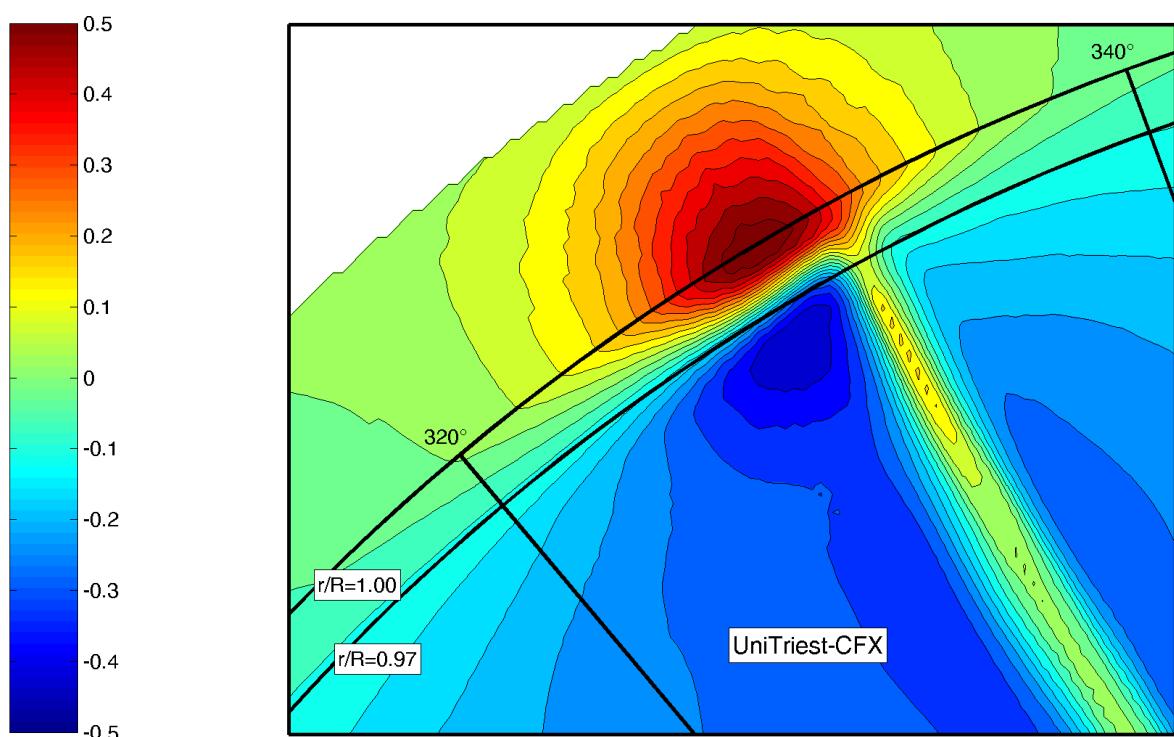
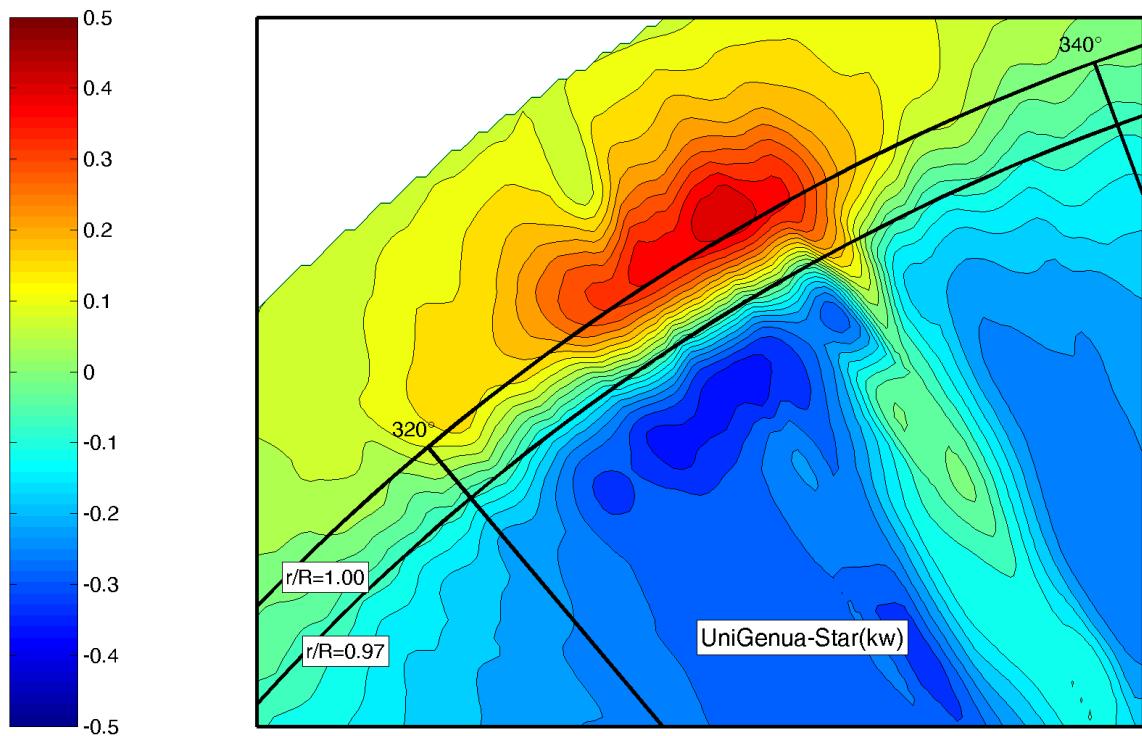
6.4 Case 2.2.4: Normalized axial velocity contours, $x/D = 0.1$

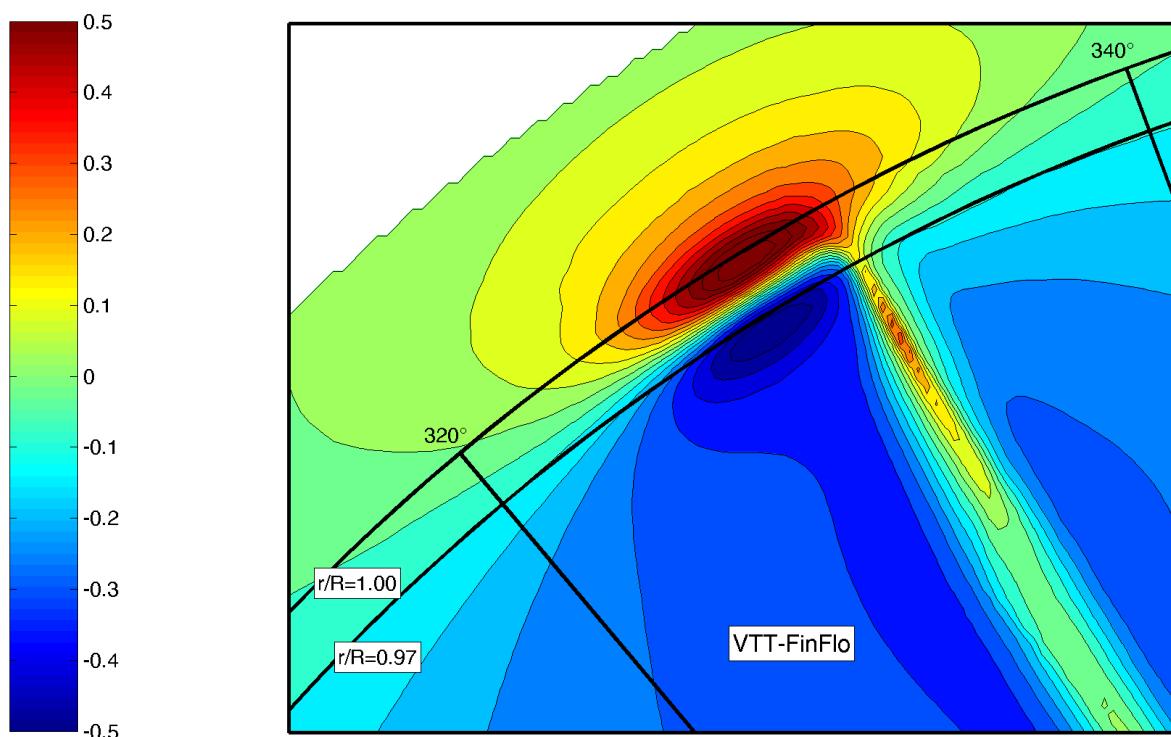
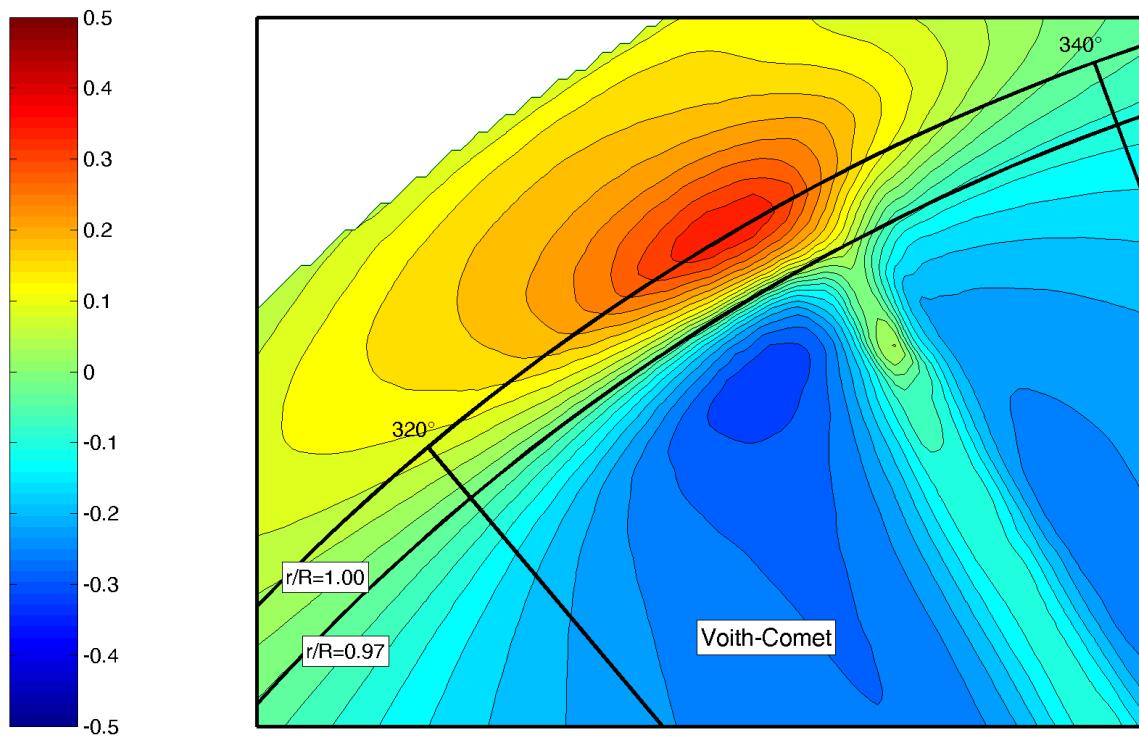




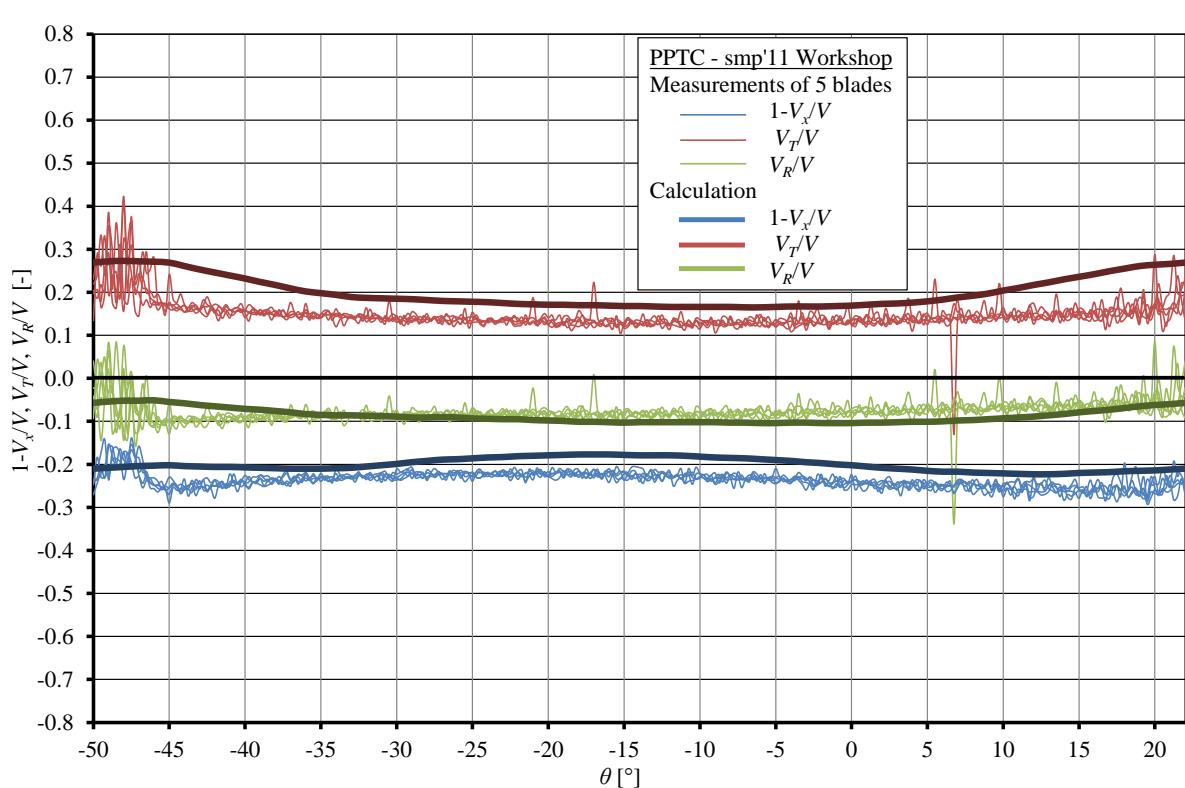
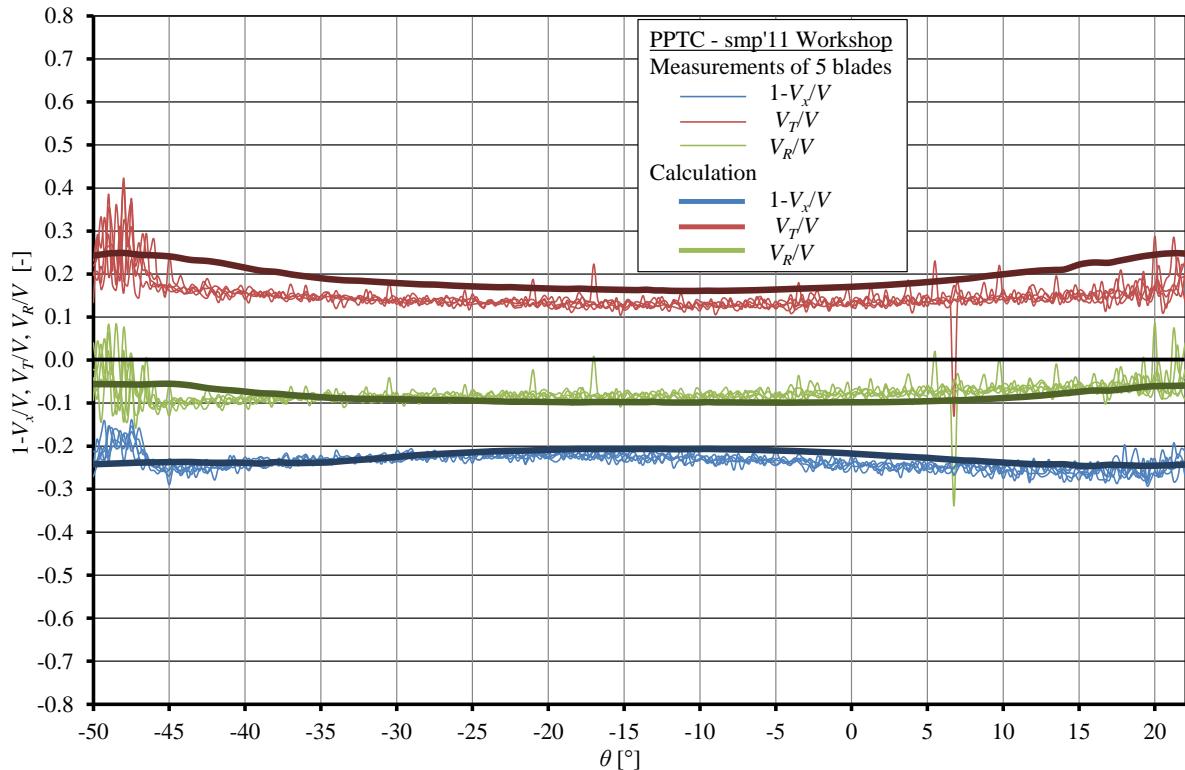


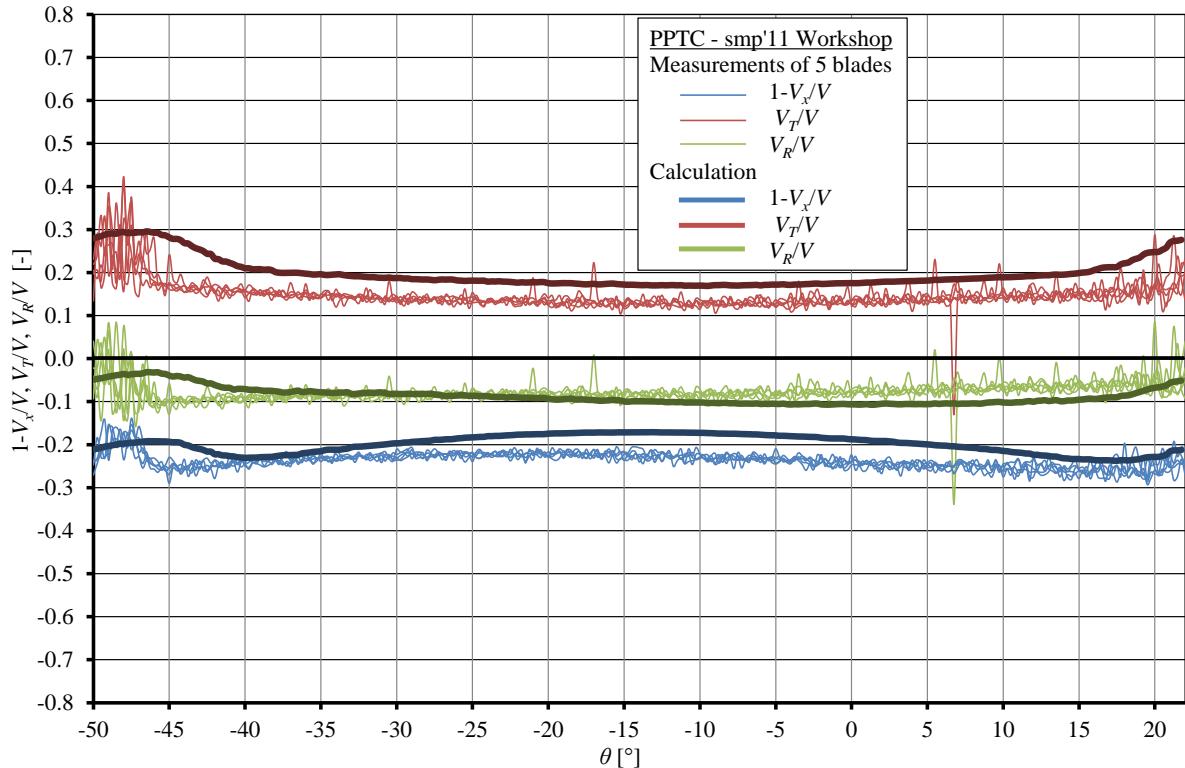




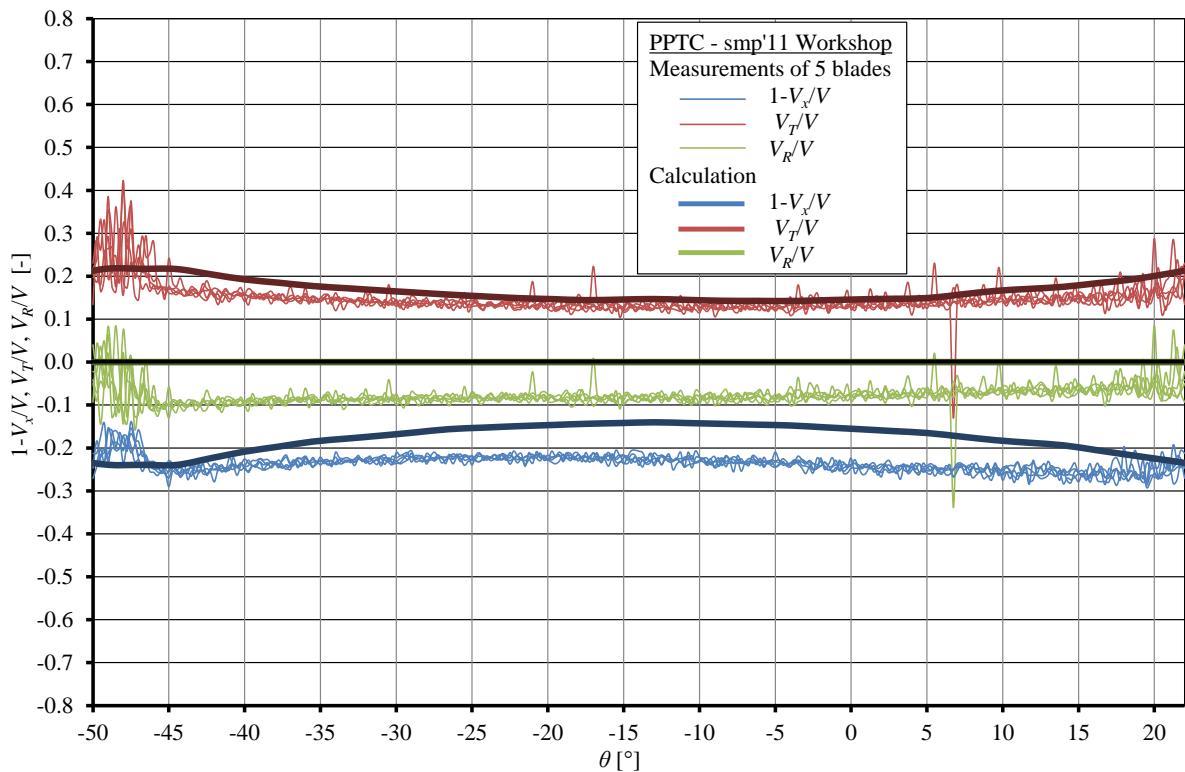


6.5 Case 2.2.1: $r/R = 0.70, x/D = 0.2$

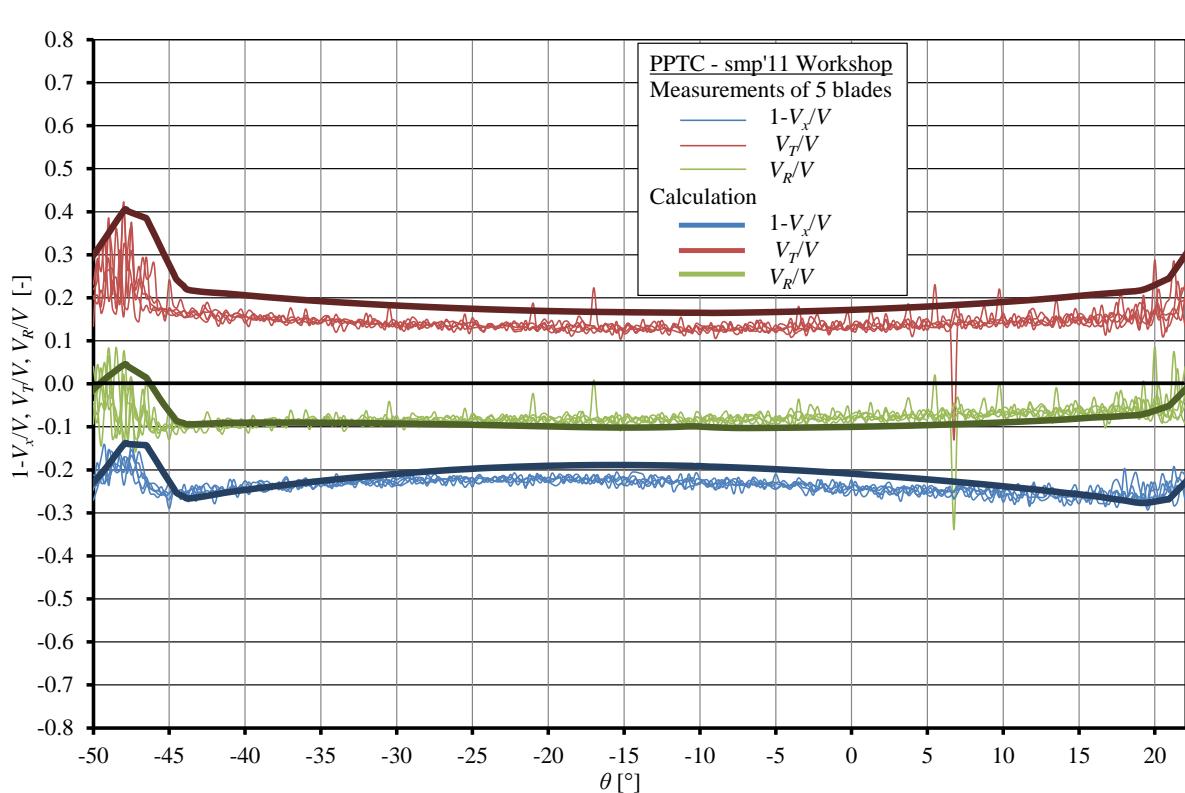
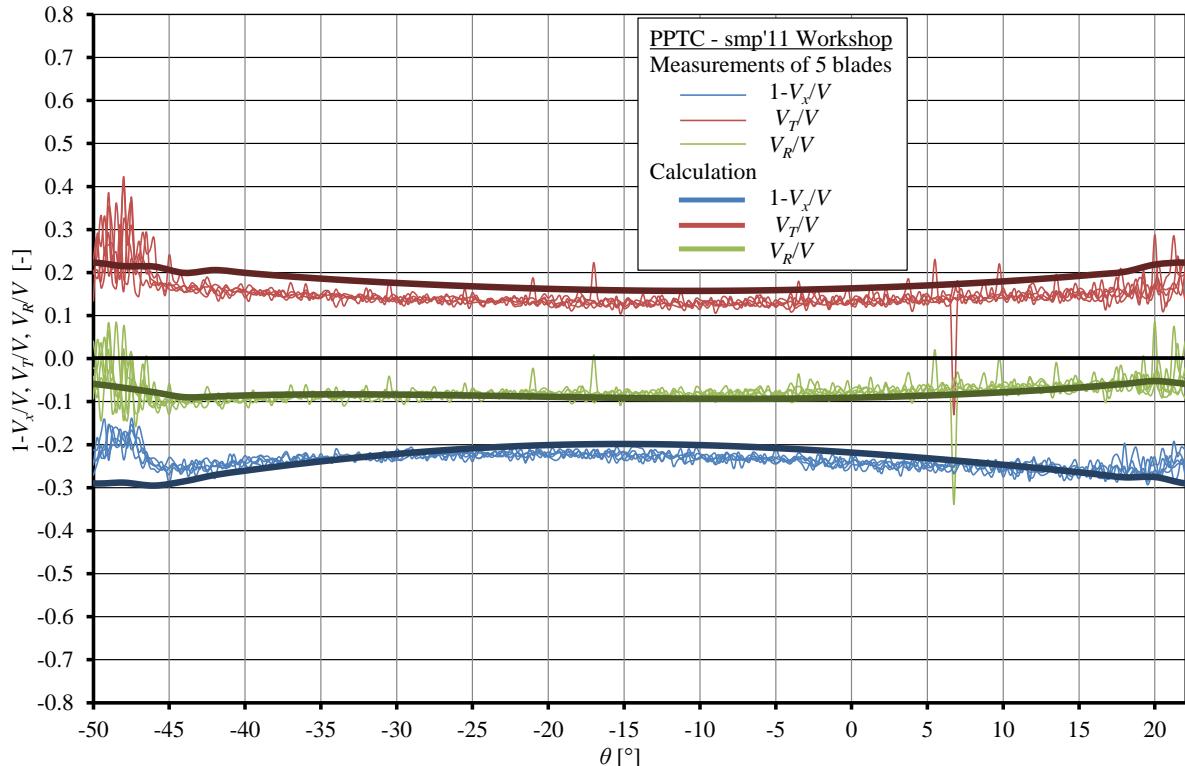


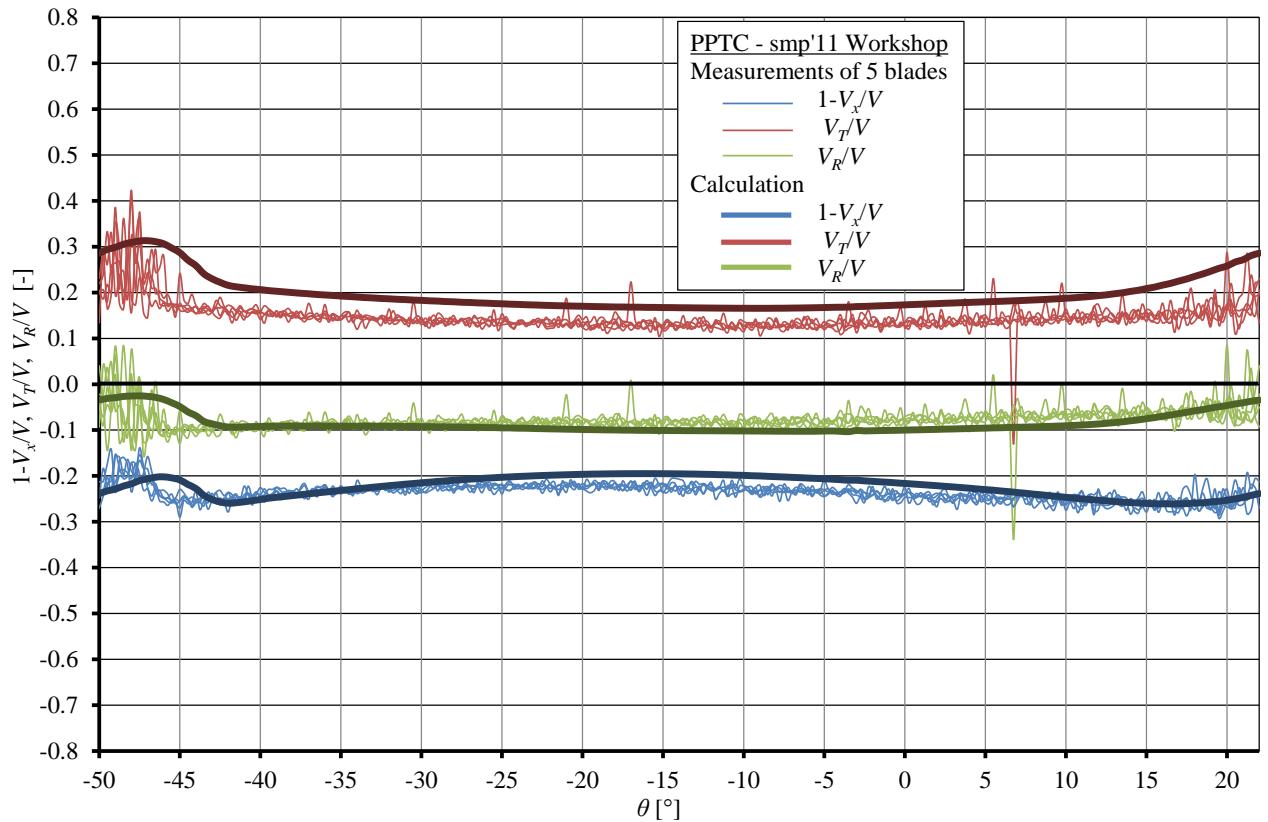


HSVA-FreSCO, $r/R = 0.70, x/D = 0.2$

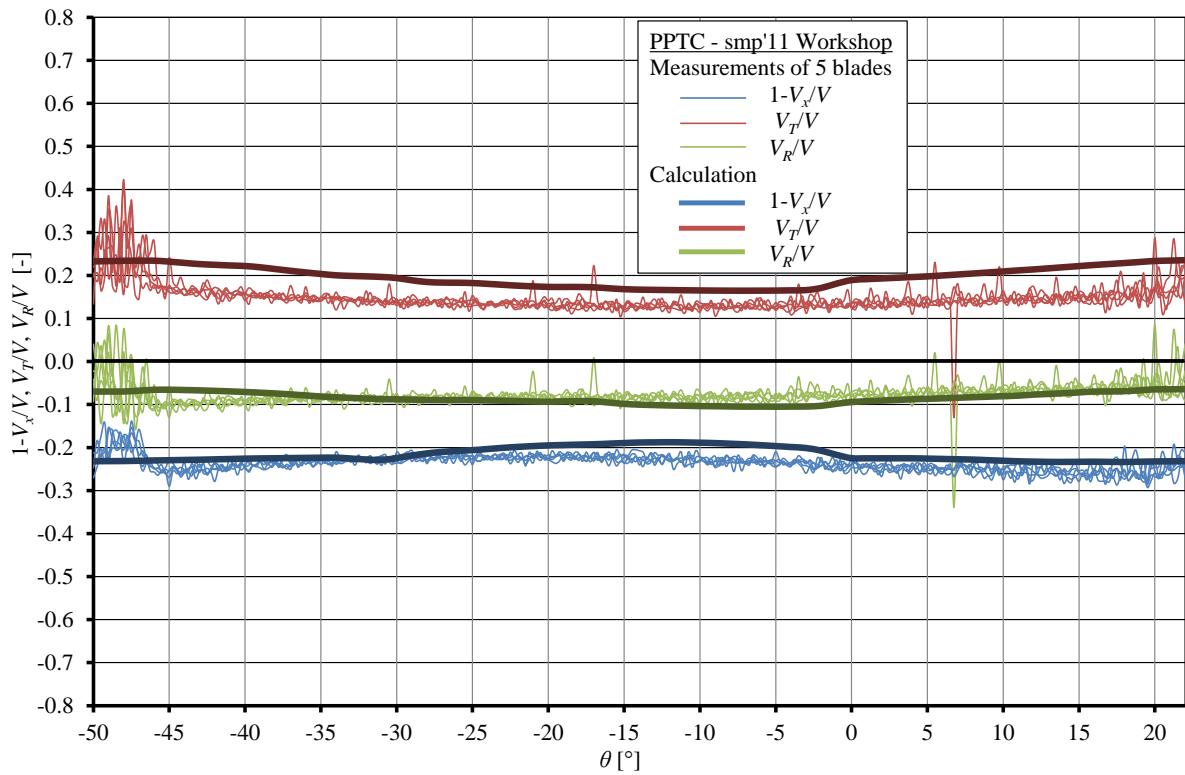


HSVA-PPB, $r/R = 0.70, x/D = 0.2$

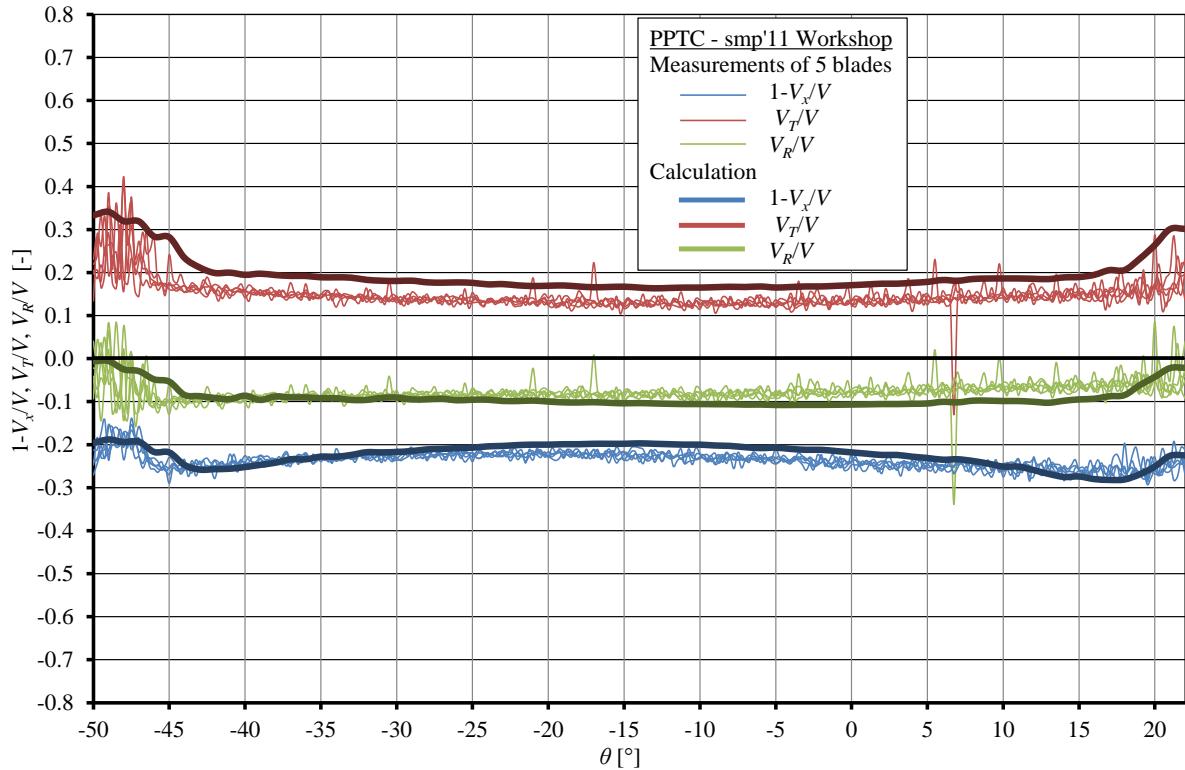




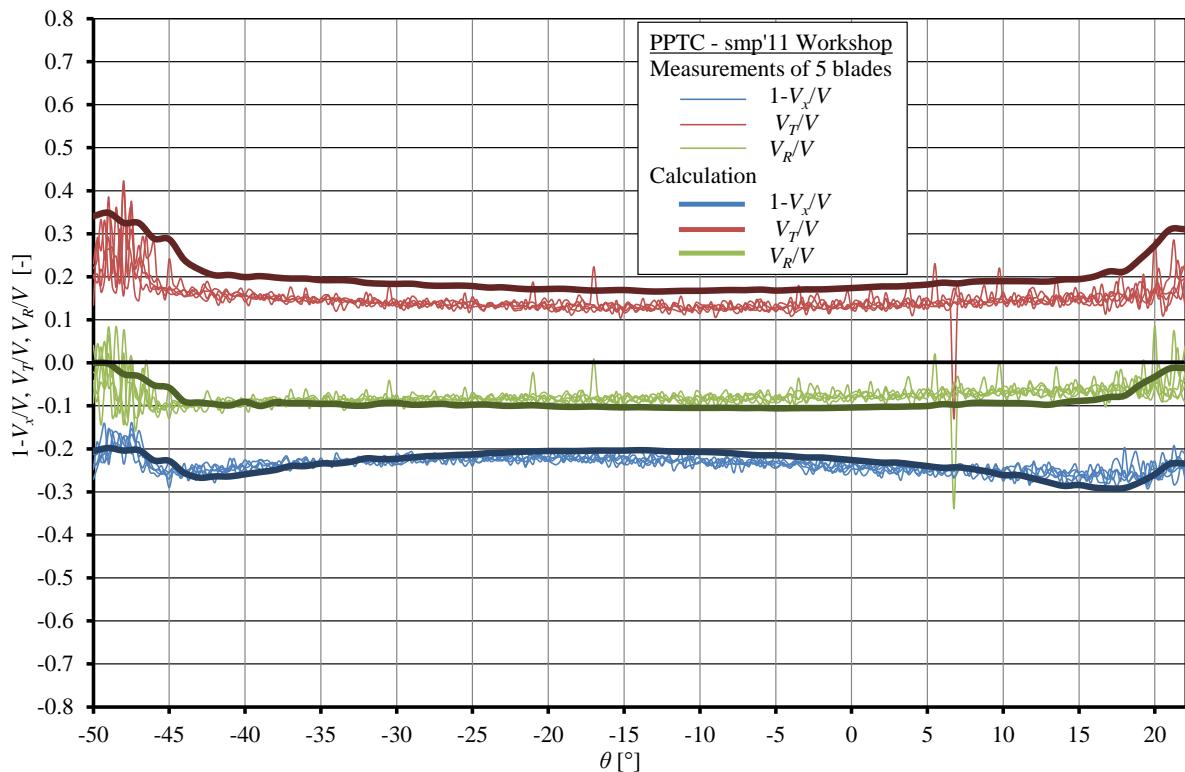
SSPA-Fluent, $r/R = 0.70$, $x/D = 0.2$



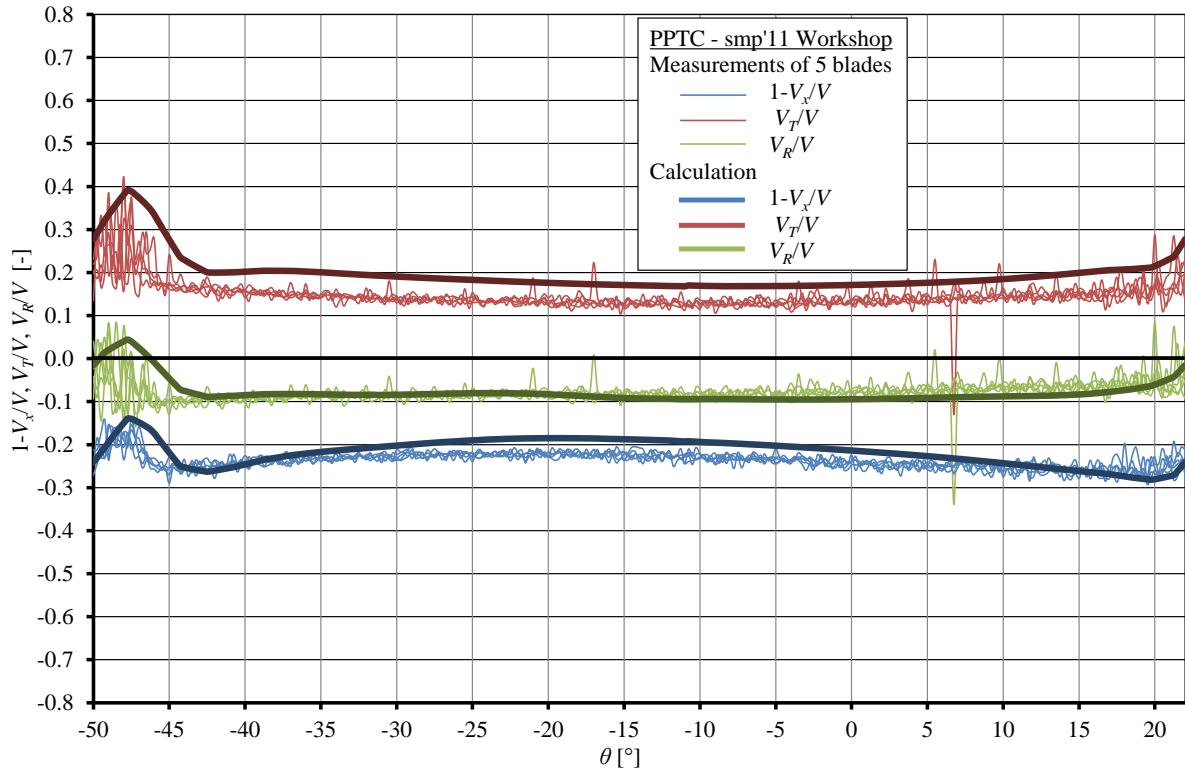
TUHH-FreSCO+, $r/R = 0.70$, $x/D = 0.2$



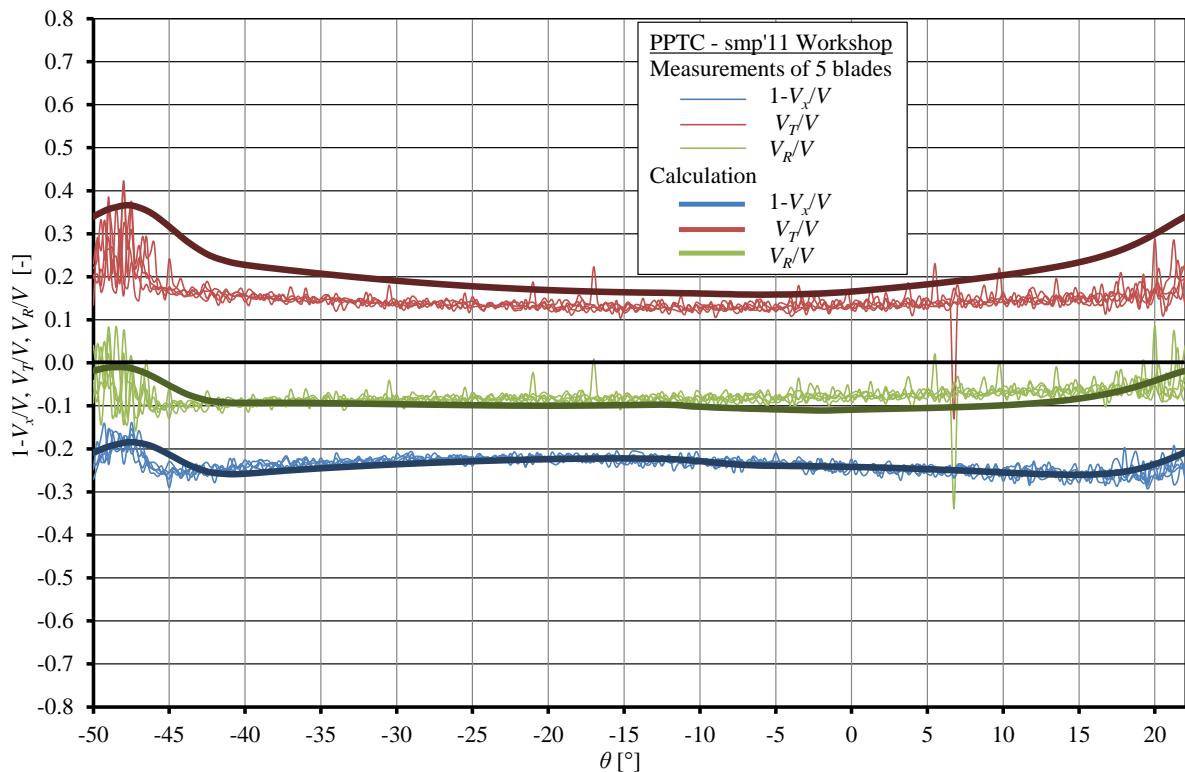
UniGenua-StarCCM(ke), $r/R = 0.70$, $x/D = 0.2$



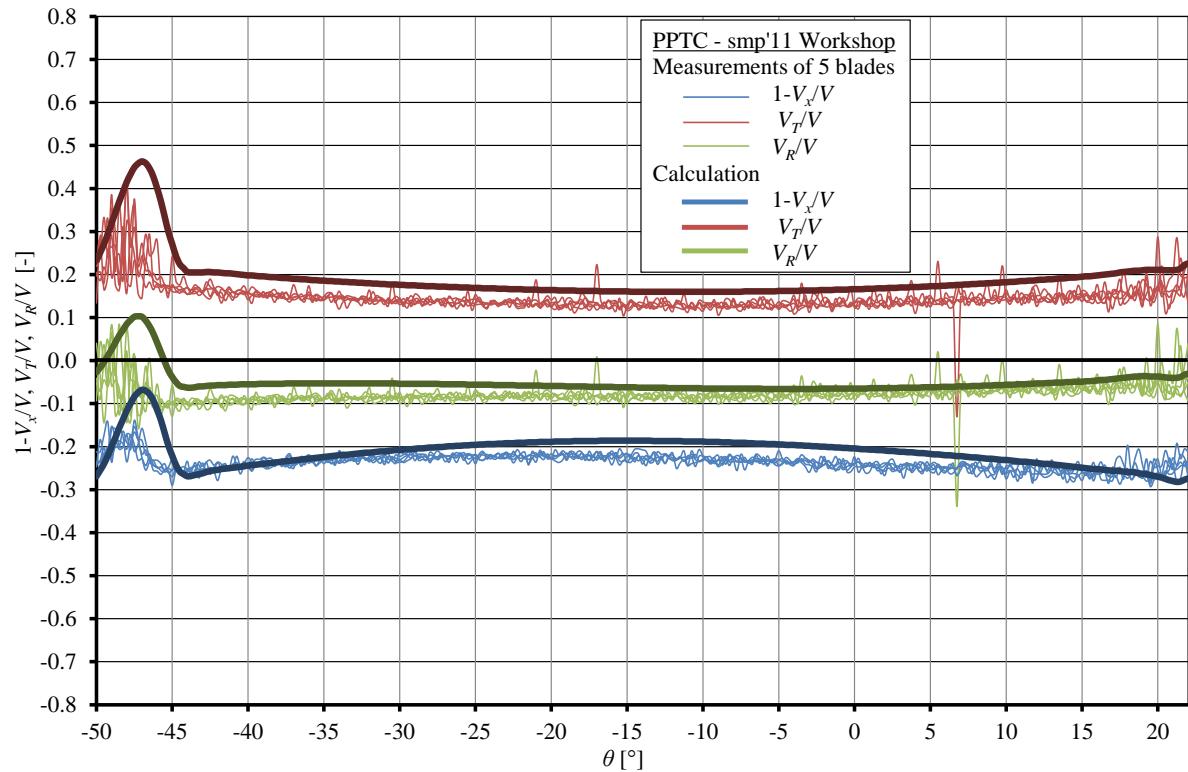
UniGenua-StarCCM(kw), $r/R = 0.70$, $x/D = 0.2$



UniTriest-CFX, $r/R = 0.70$, $x/D = 0.2$

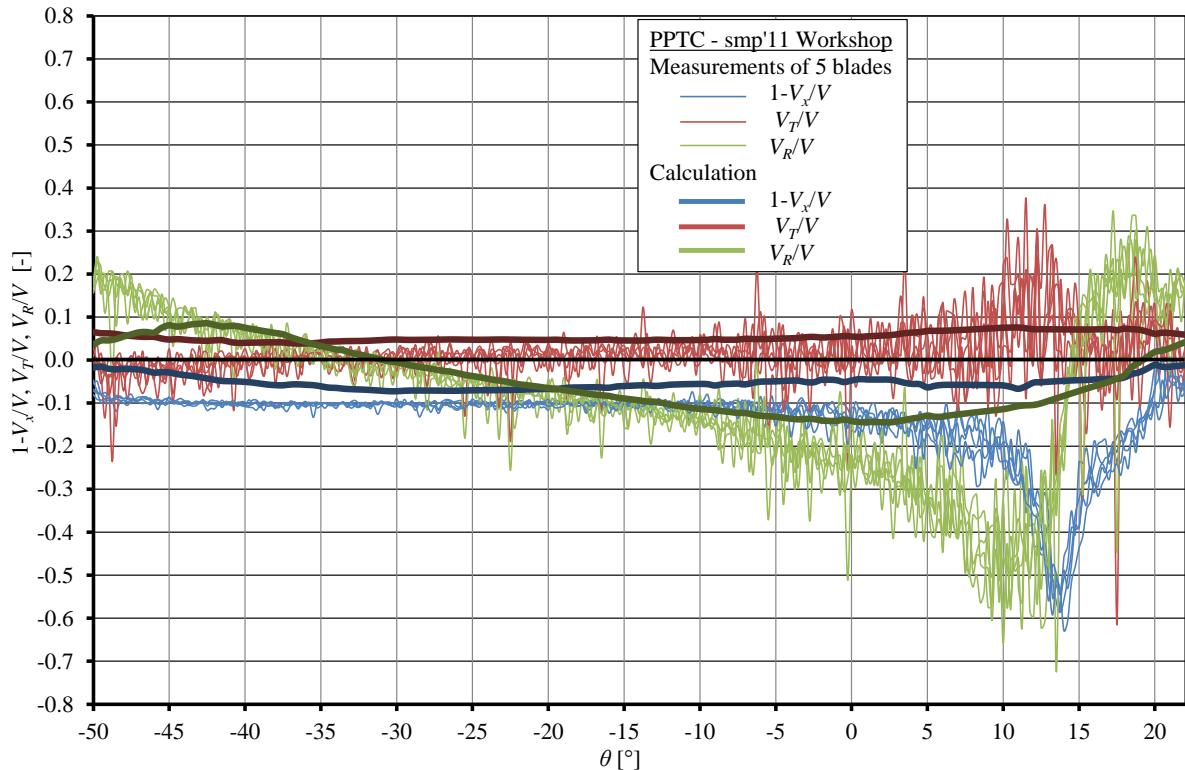


VOITH-Comet, $r/R = 0.70$, $x/D = 0.2$

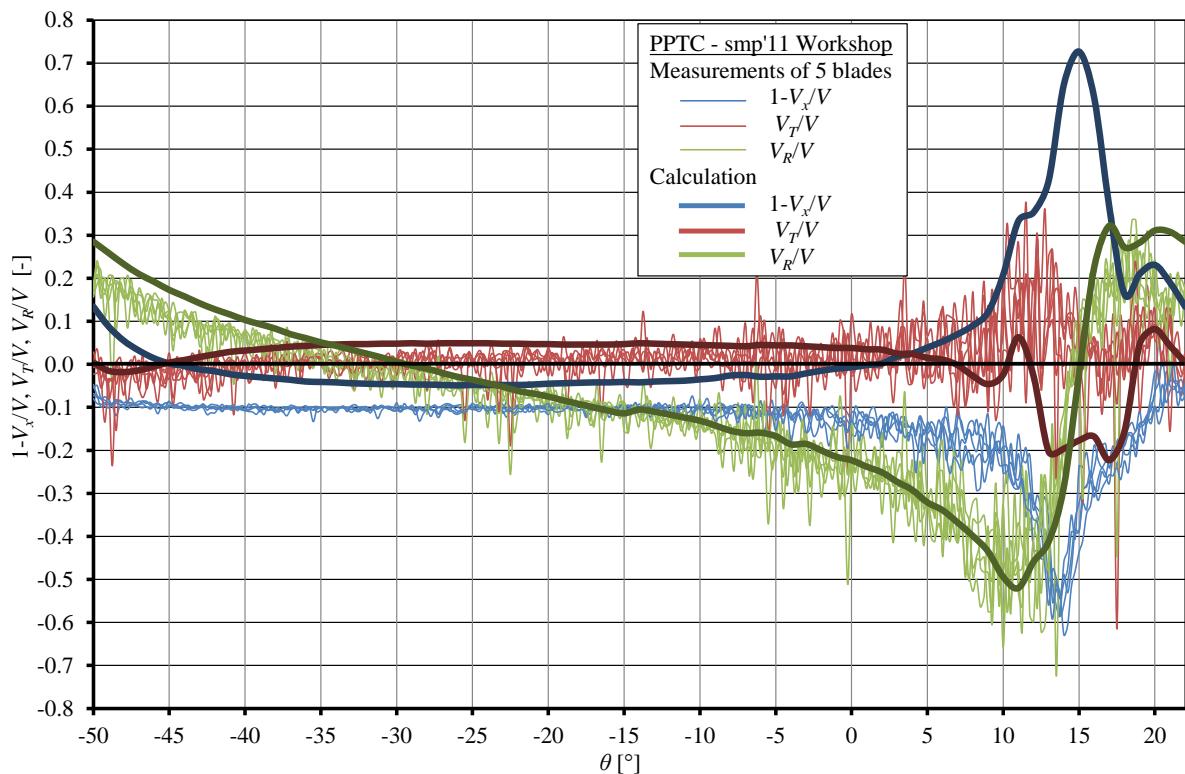


VTT-FinFlo, $r/R = 0.70$, $x/D = 0.2$

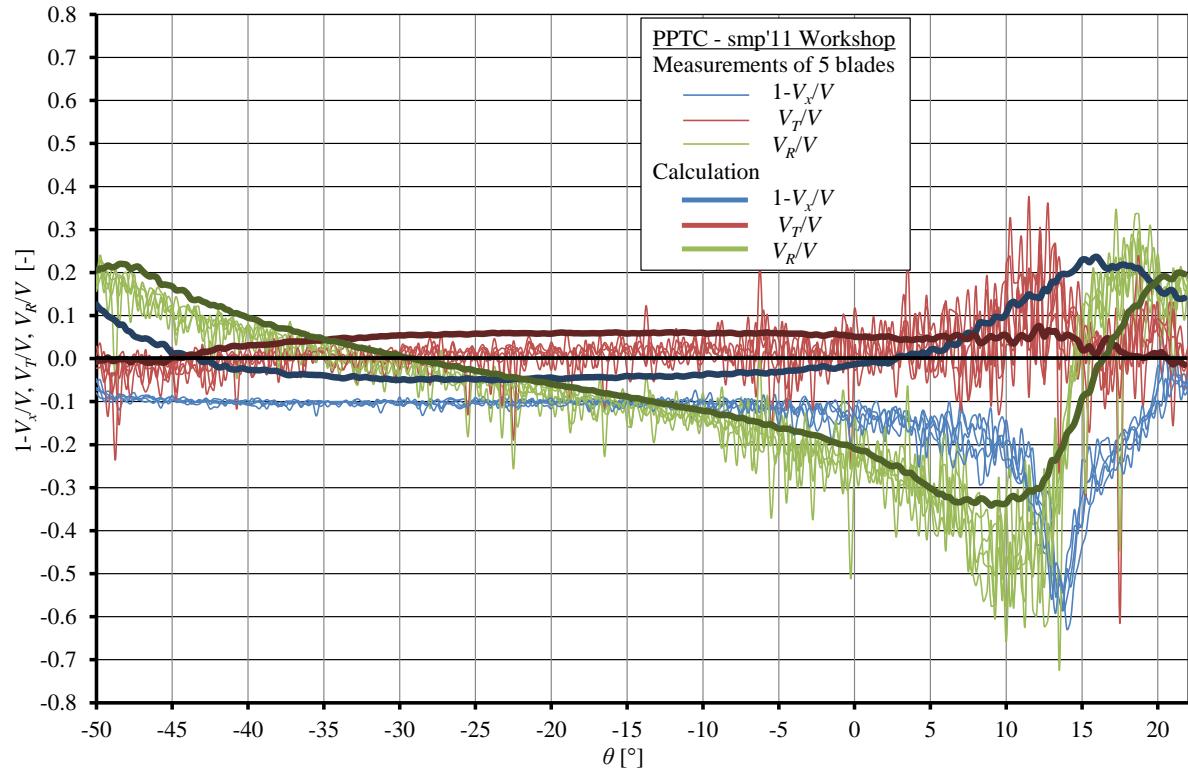
6.6 Case 2.2.2: $r/R = 0.97$, $x/D = 0.2$



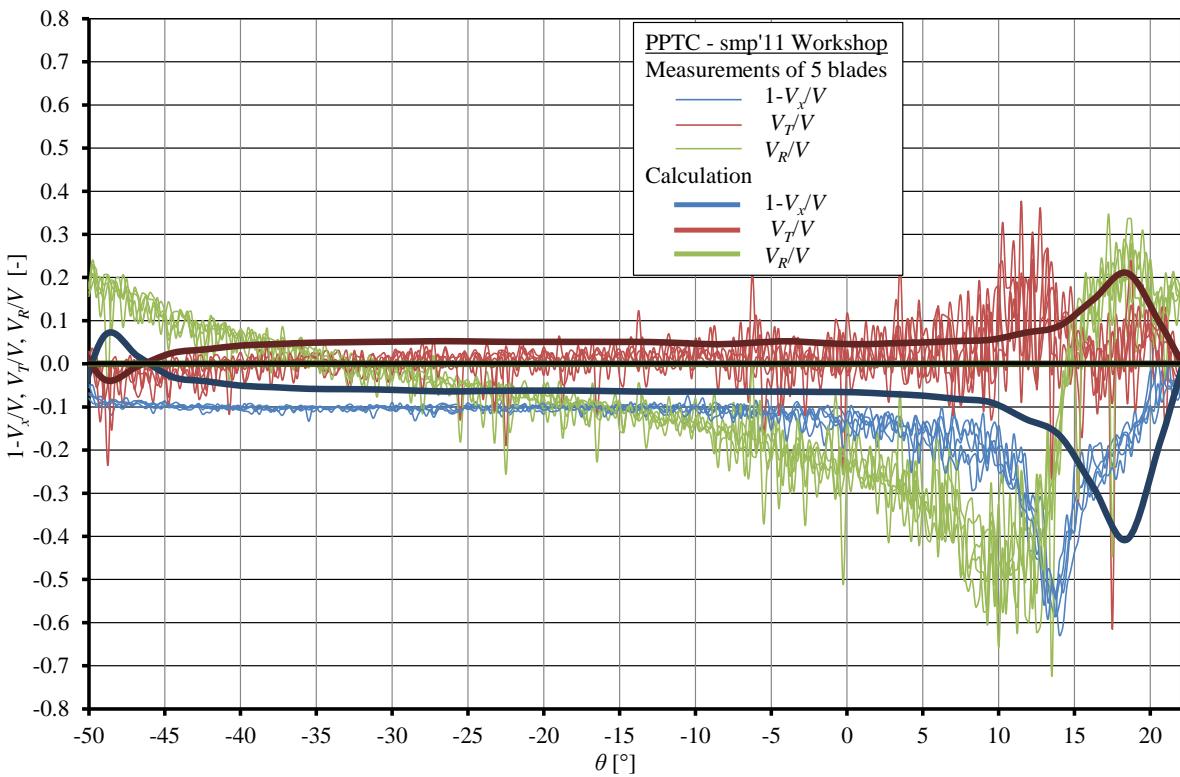
Berg-OpenFOAM, $r/R = 0.97$, $x/D = 0.2$



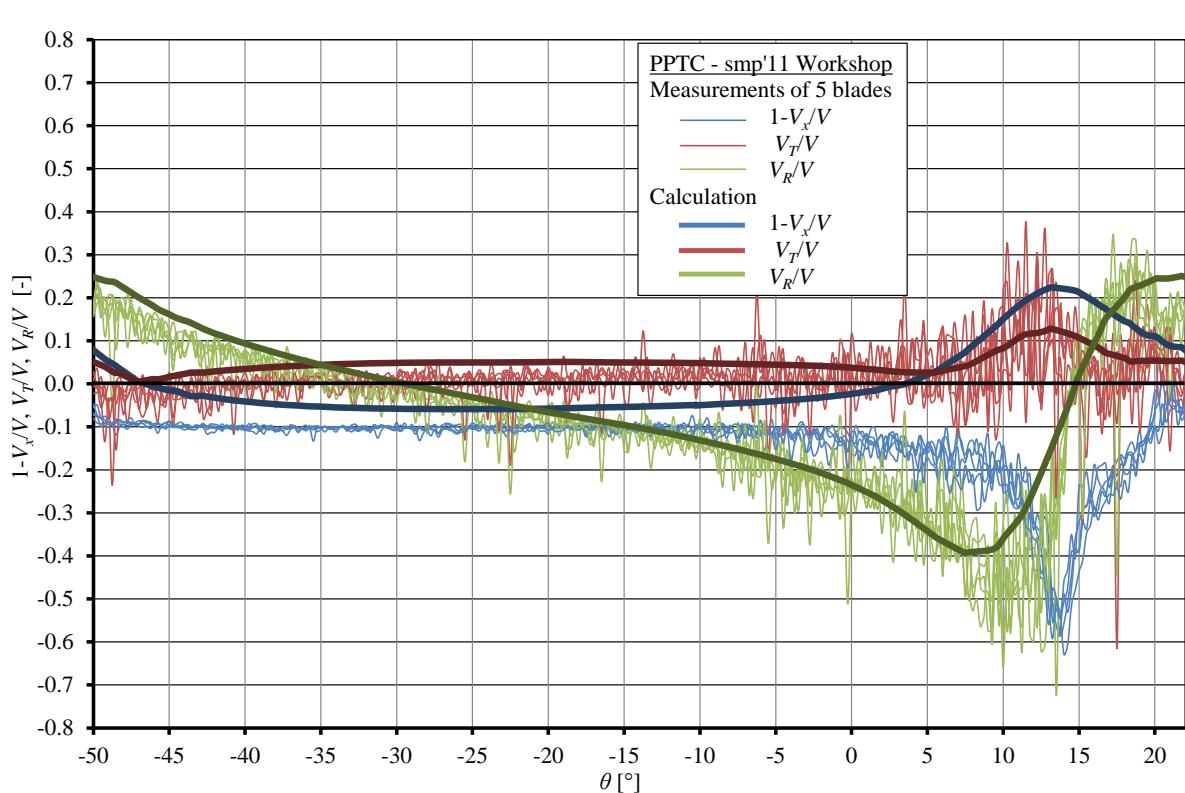
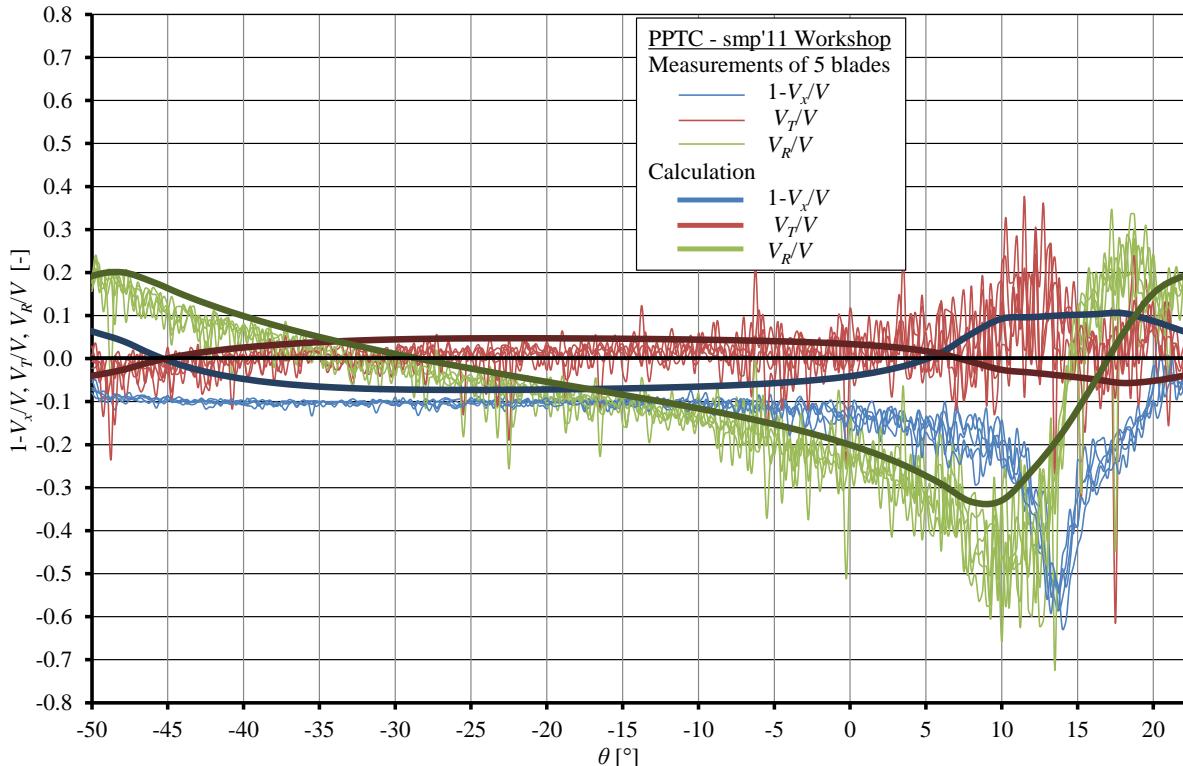
Cradle-SC/Tetra, $r/R = 0.97$, $x/D = 0.2$

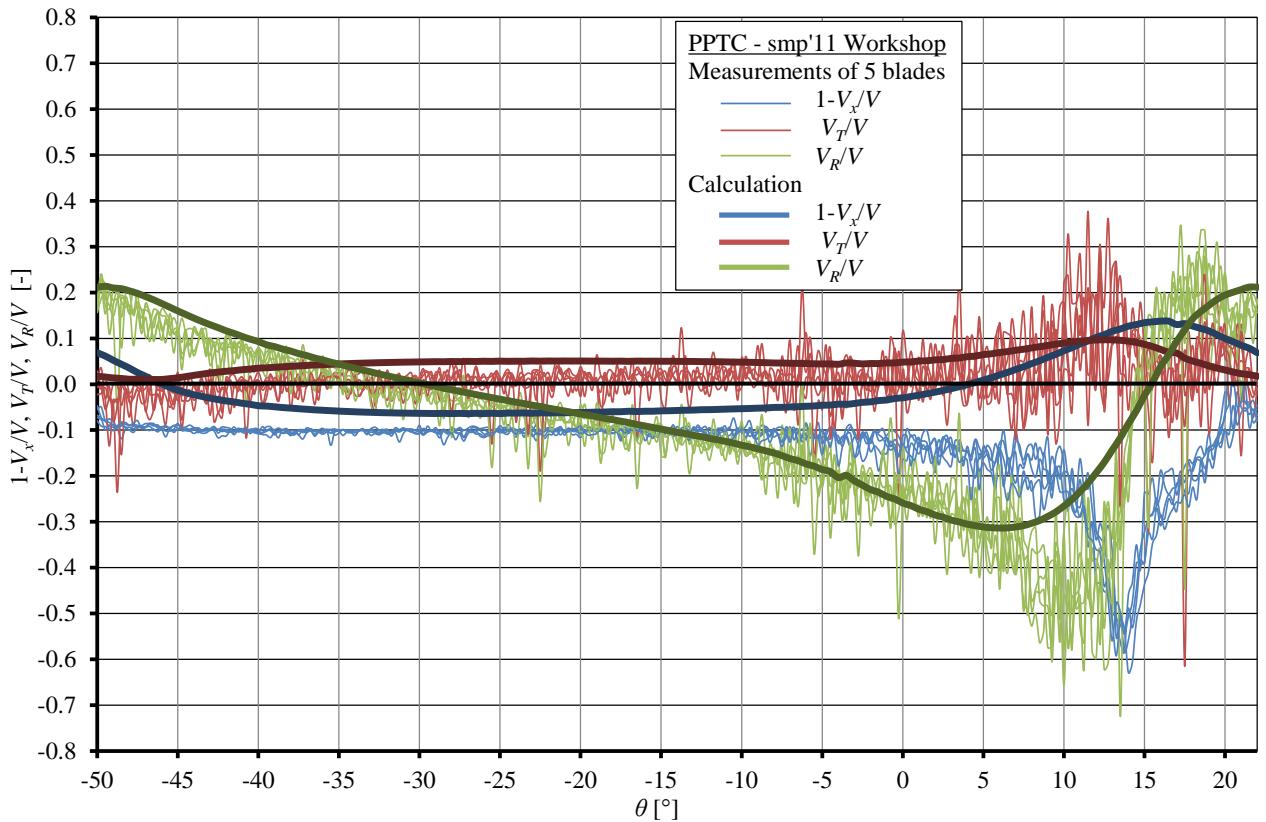


HSVA-FreSCO, $r/R = 0.97$, $x/D = 0.2$

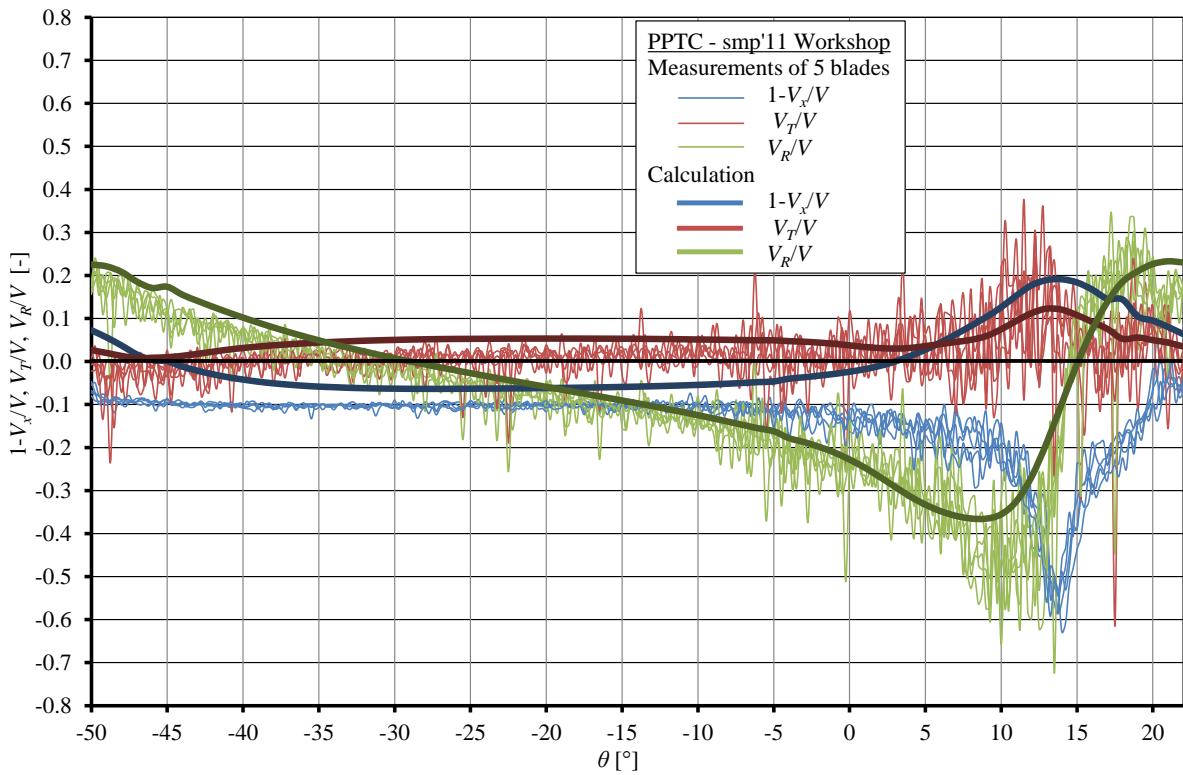


HSVA-PPB, $r/R = 0.97$, $x/D = 0.2$

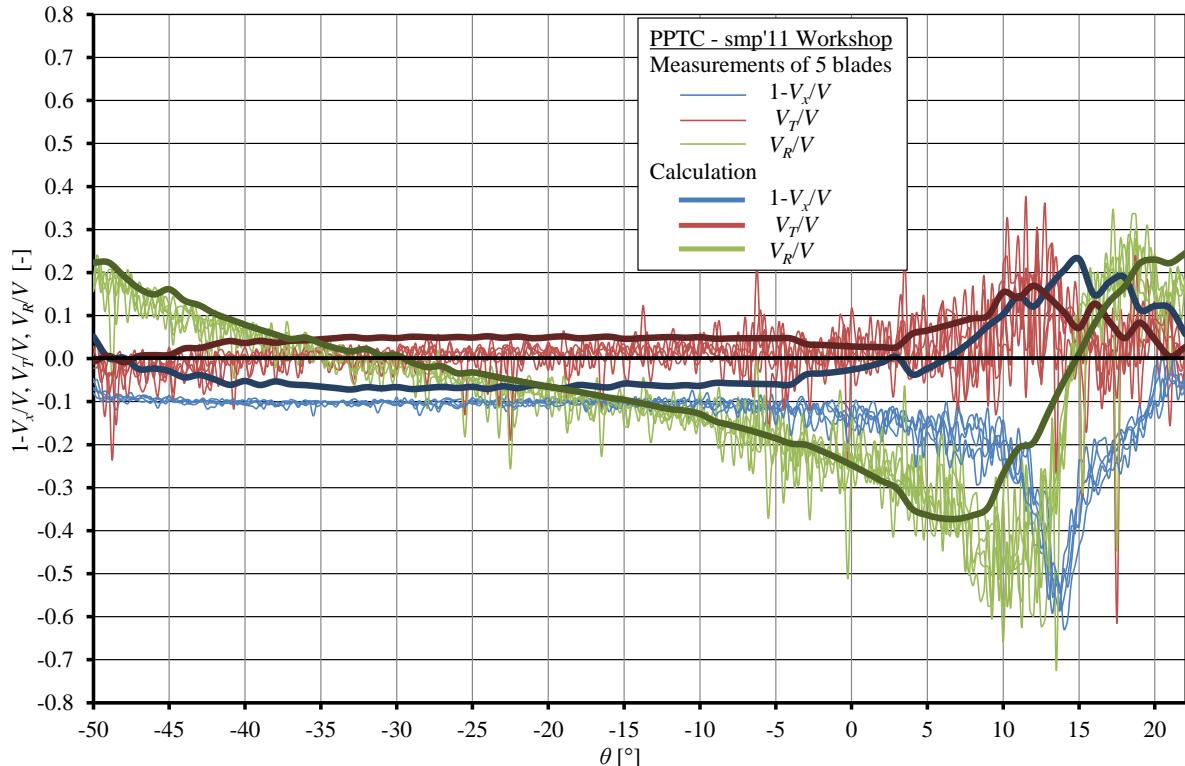




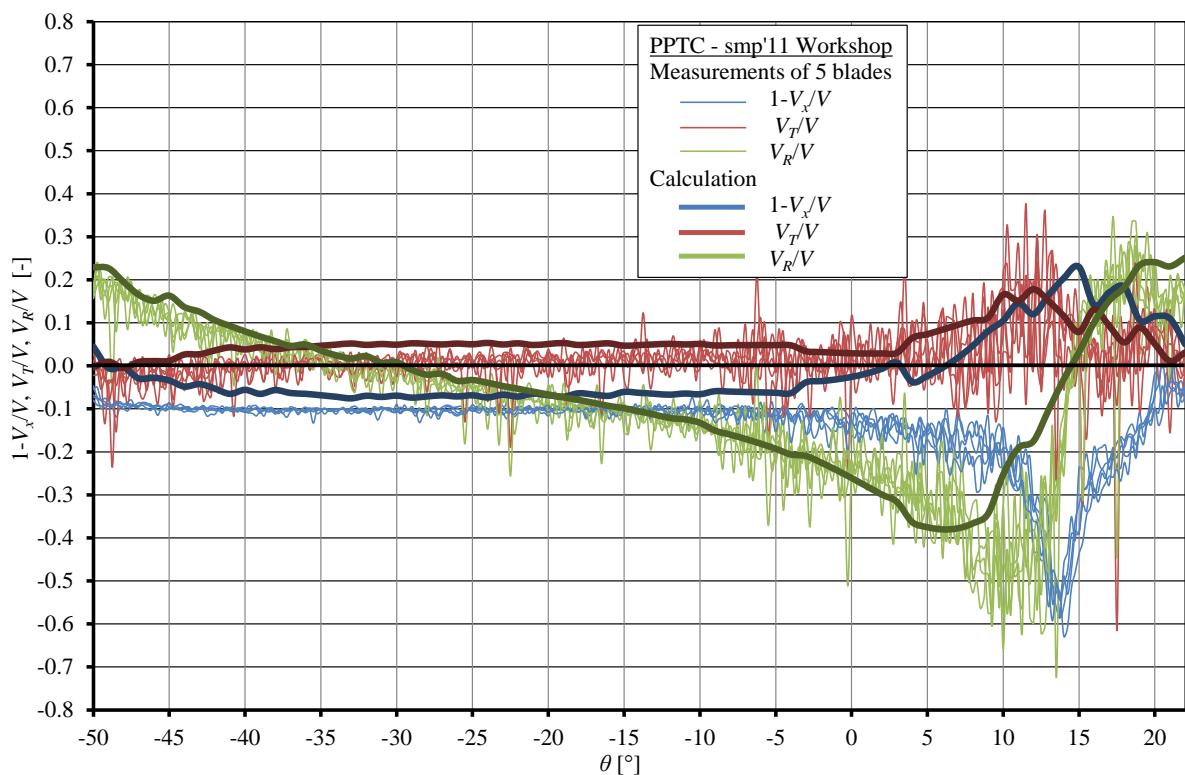
SSPA-Fluent, $r/R = 0.97$, $x/D = 0.2$



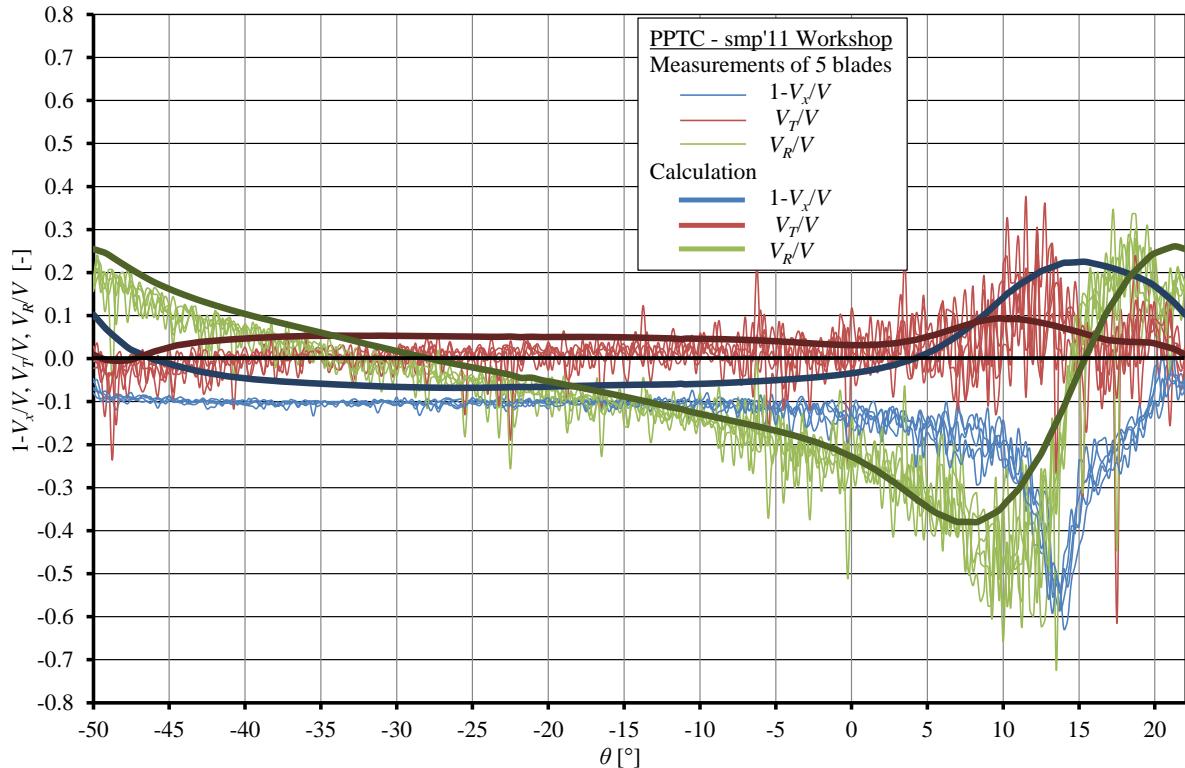
TUHH-FreSCO+, $r/R = 0.97$, $x/D = 0.2$



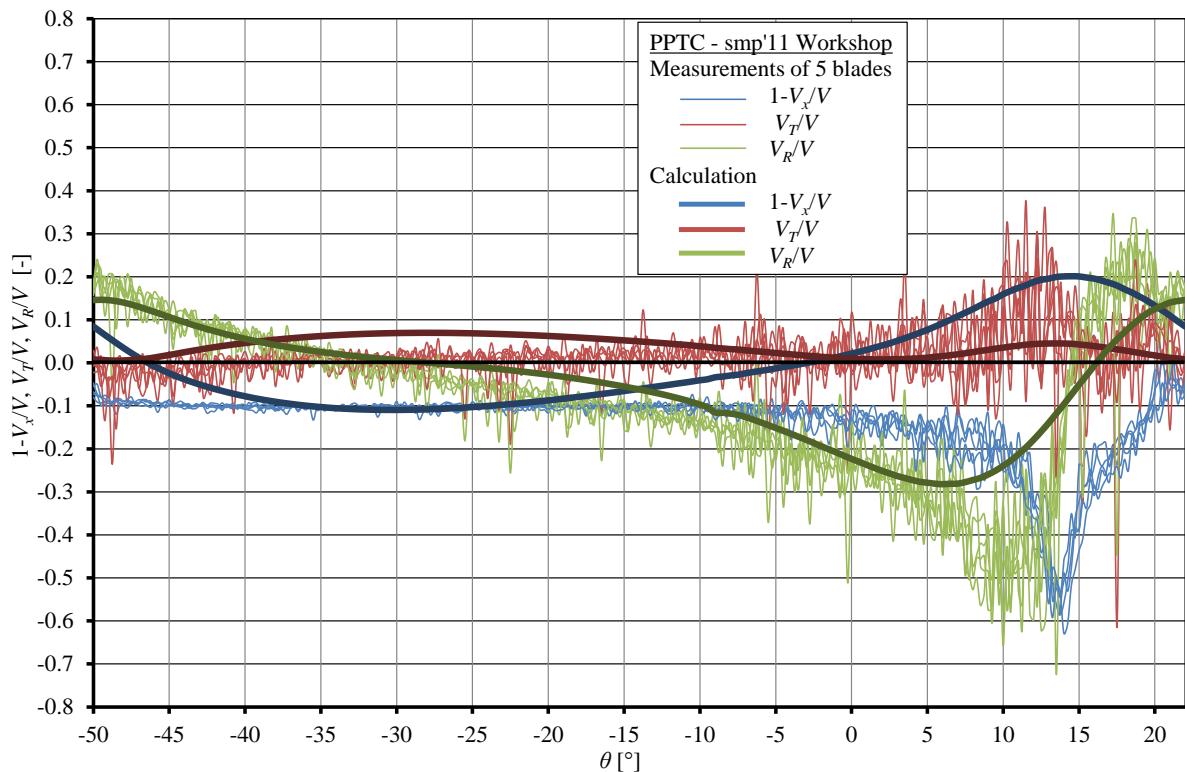
UniGenua-StarCCM(ke), $r/R = 0.97, x/D = 0.2$



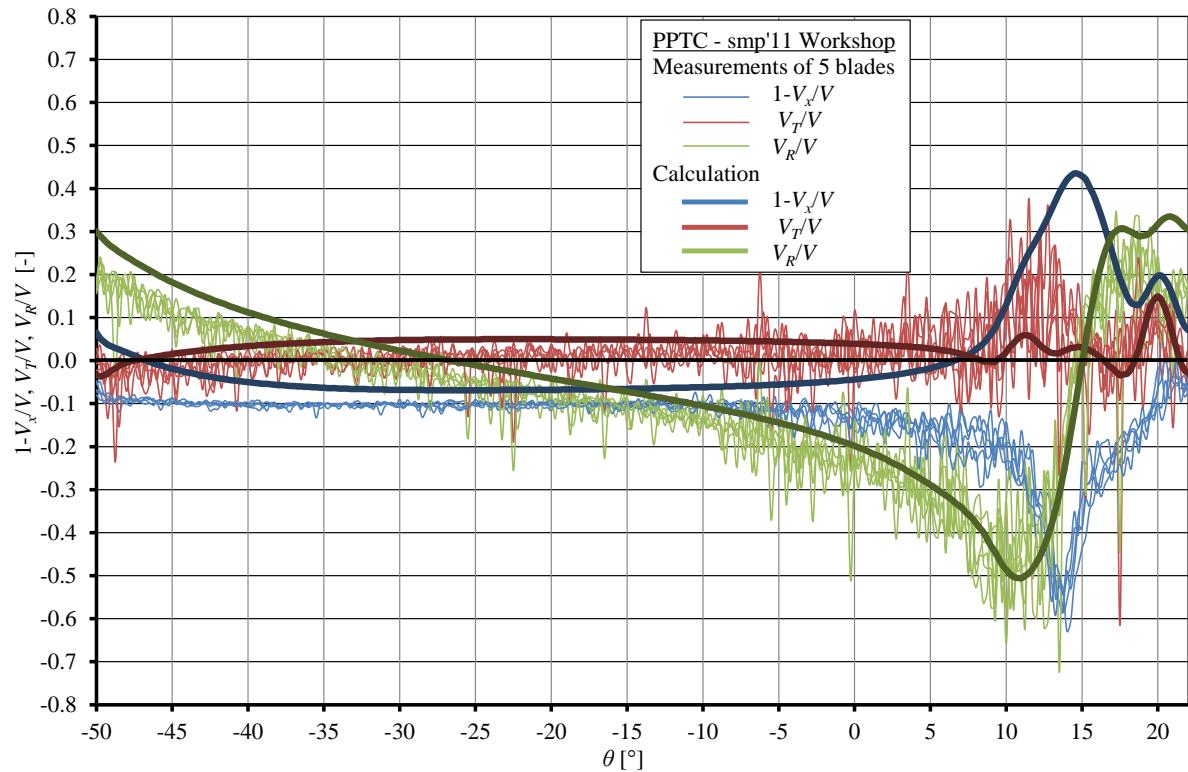
UniGenua-StarCCM(kw), $r/R = 0.97, x/D = 0.2$



UniTriest-CFX, $r/R = 0.97$, $x/D = 0.2$

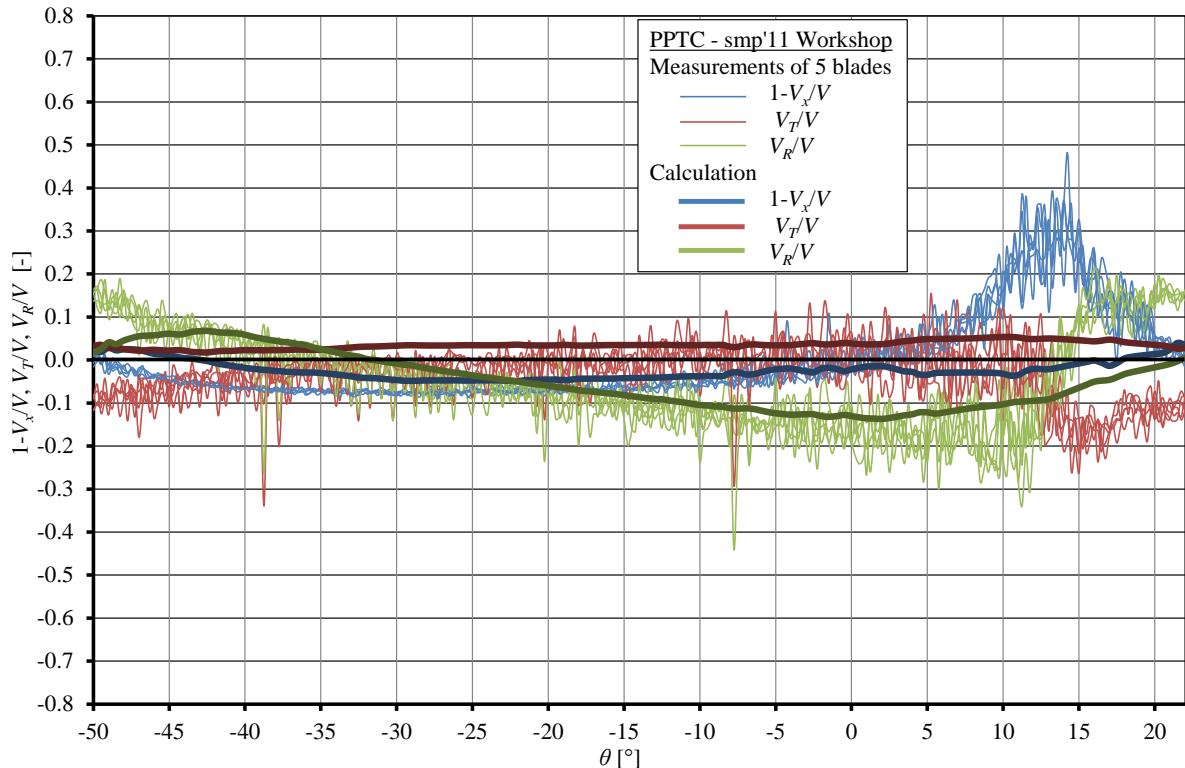


VOITH-Comet, $r/R = 0.97$, $x/D = 0.2$

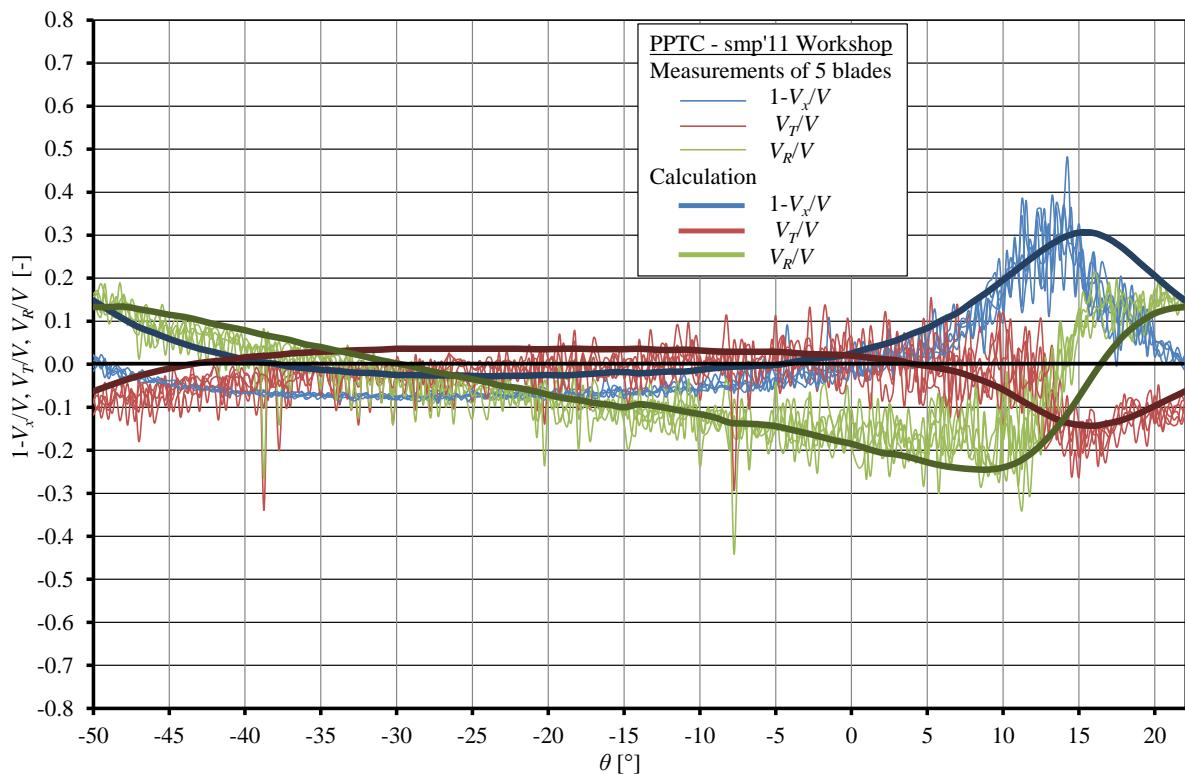


VTT-FinFlo, $r/R = 0.97$, $x/D = 0.2$

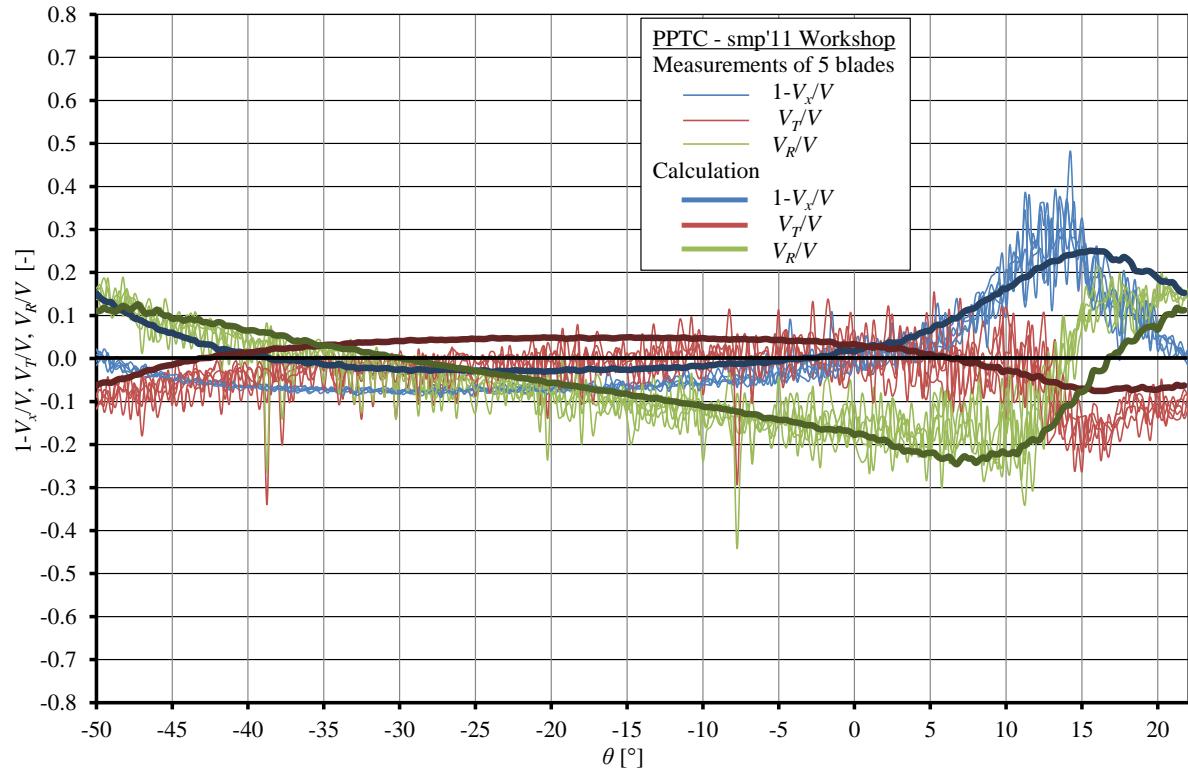
6.7 Case 2.2.3: $r/R = 1.00, x/D = 0.2$



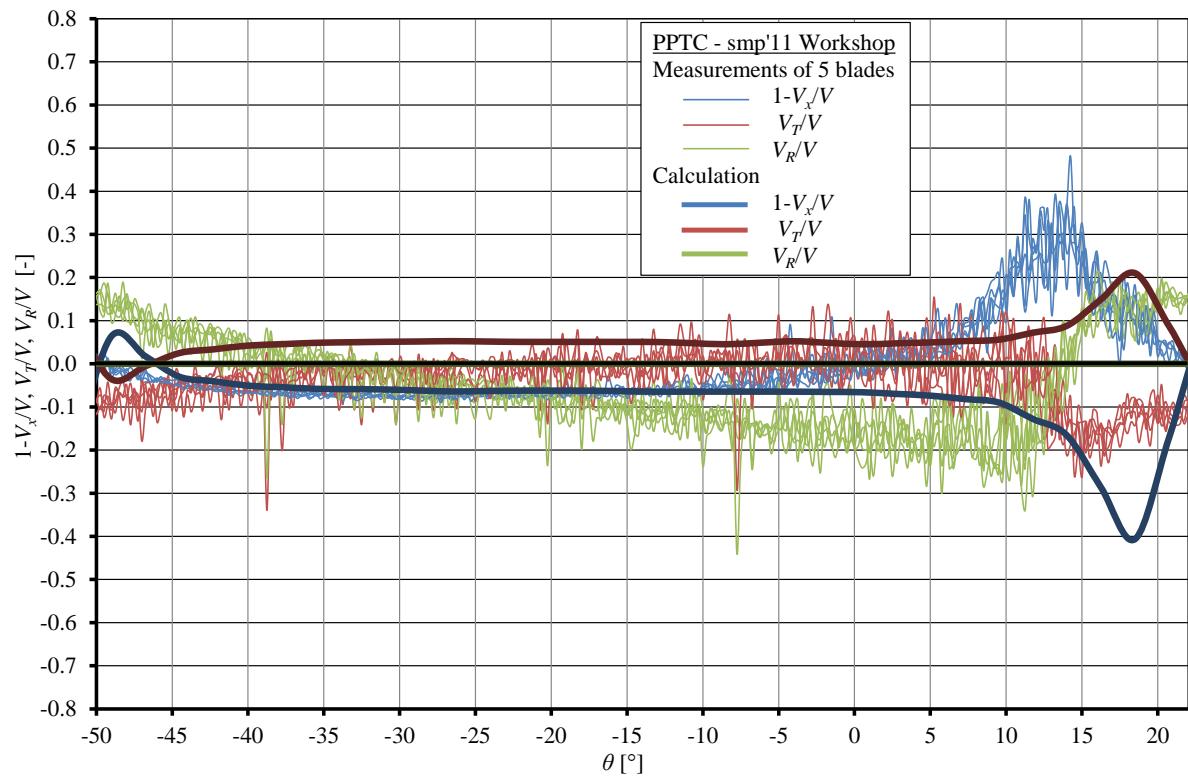
Berg-OpenFOAM, $r/R = 1.00, x/D = 0.2$



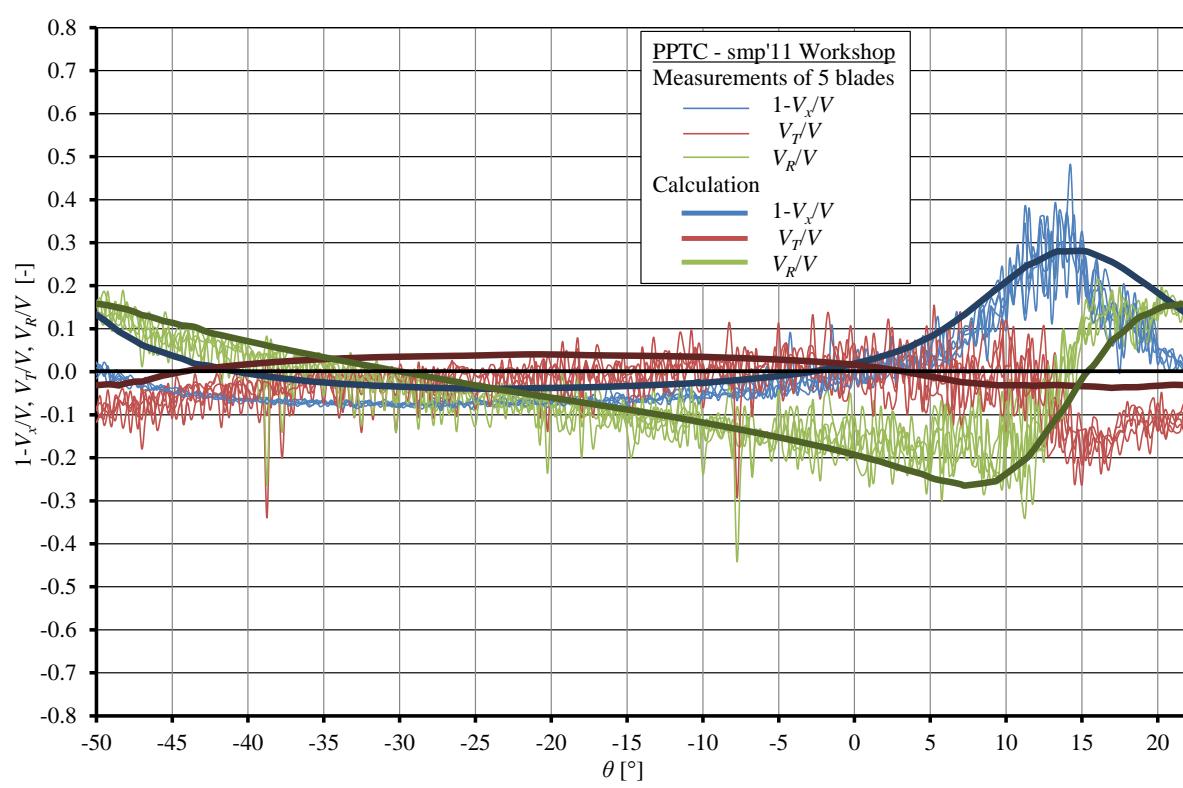
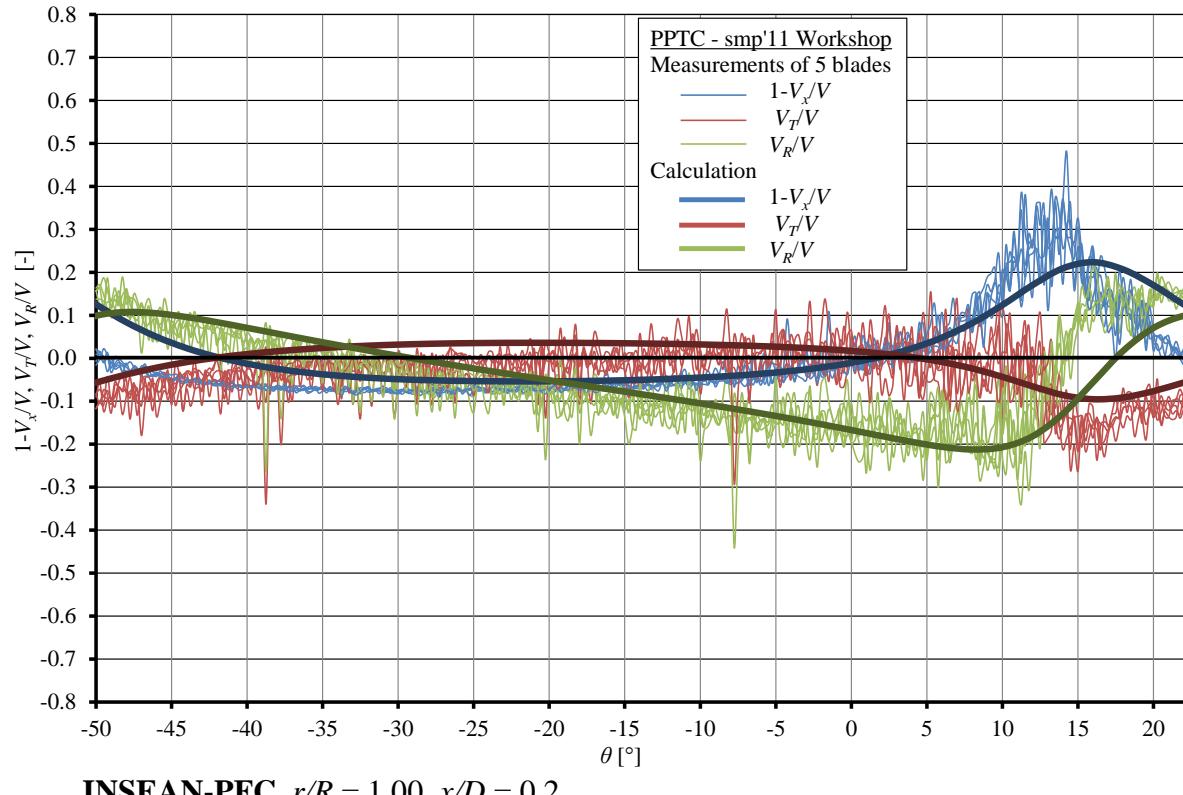
Cradle-SC/Tetra, $r/R = 1.00, x/D = 0.2$

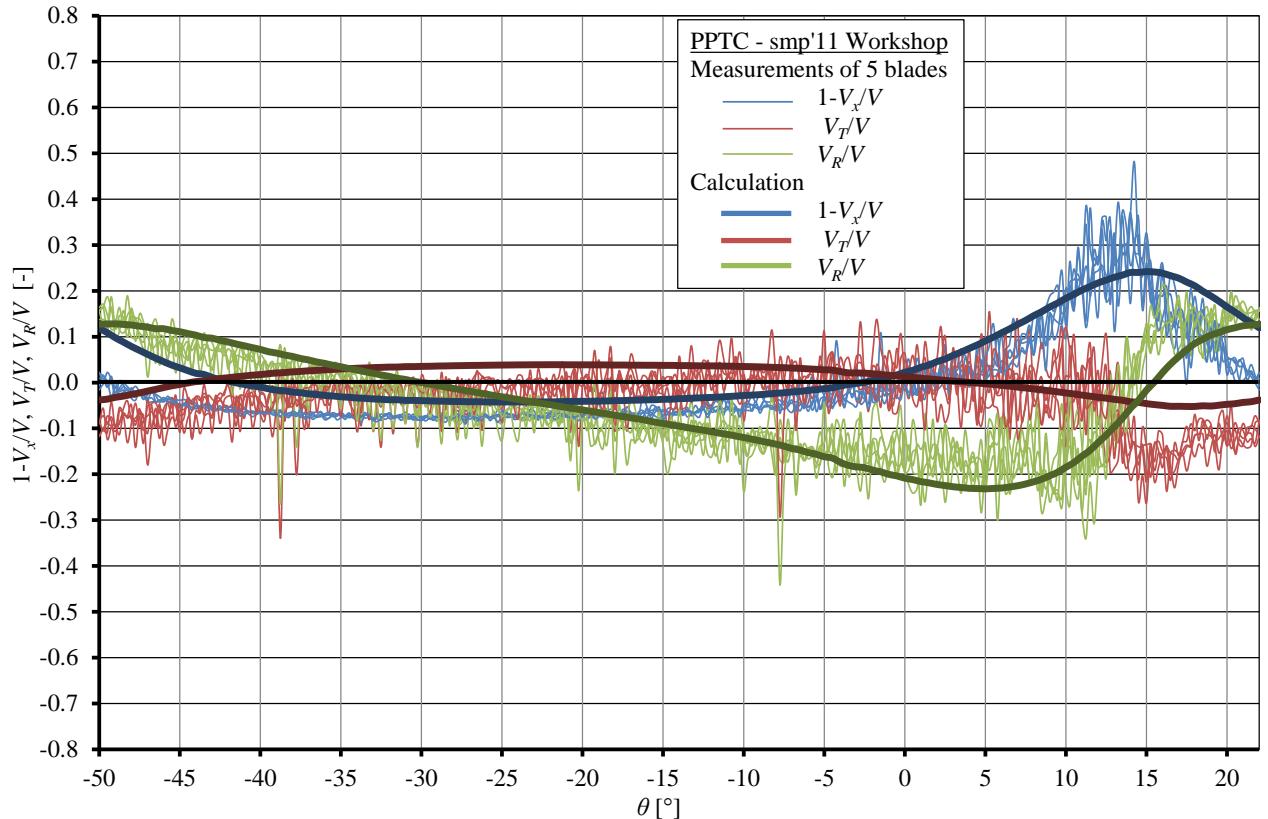


HSVA-FreSCO, $r/R = 1.00$, $x/D = 0.2$

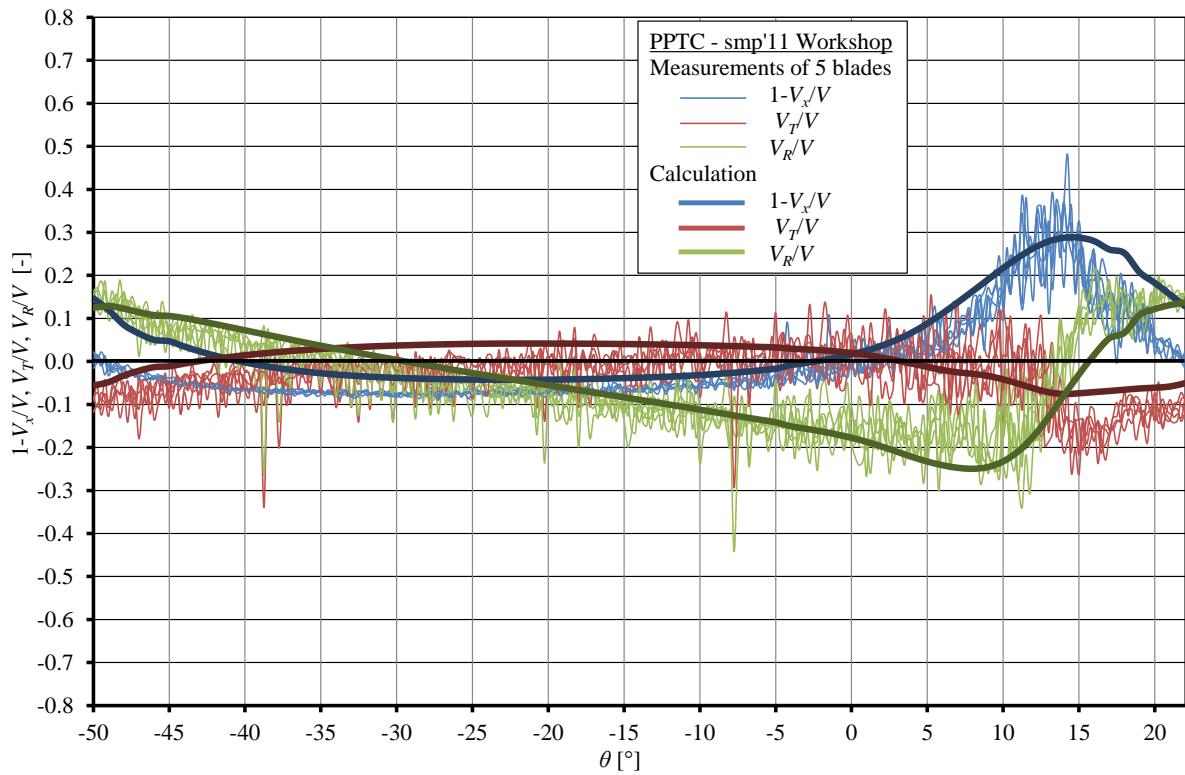


HSVA-PPB, $r/R = 1.00$, $x/D = 0.2$

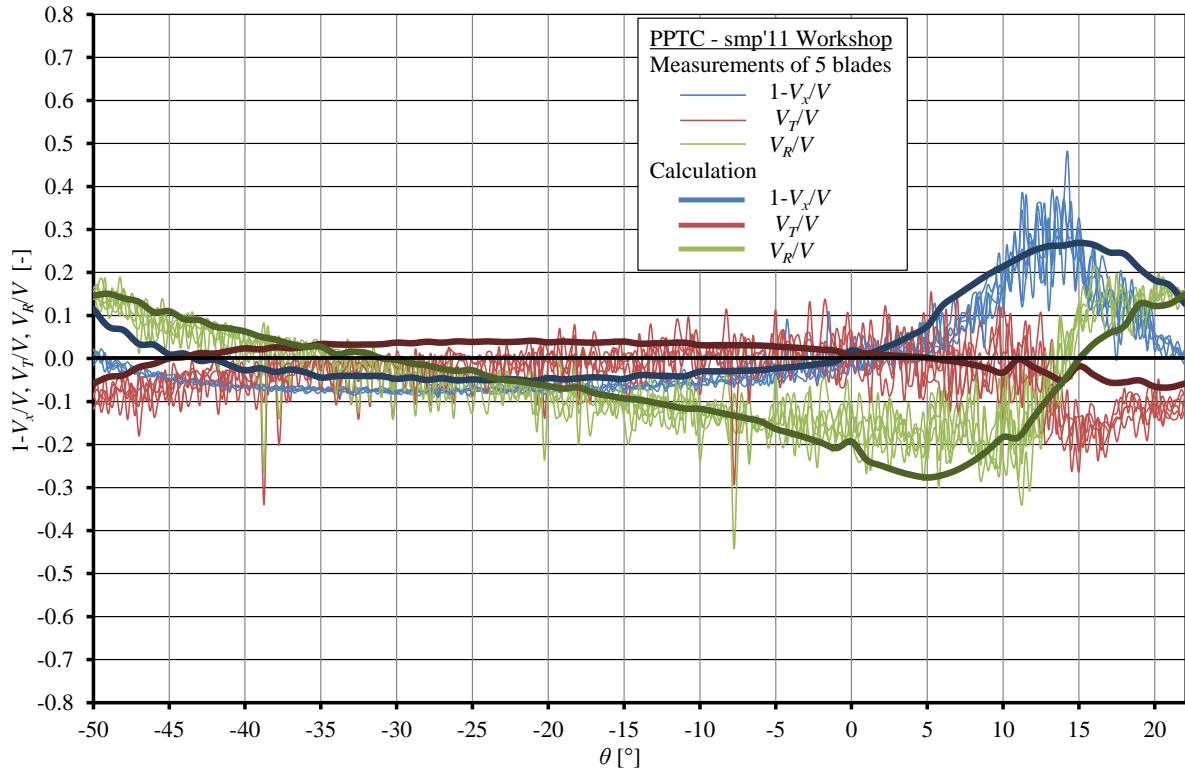




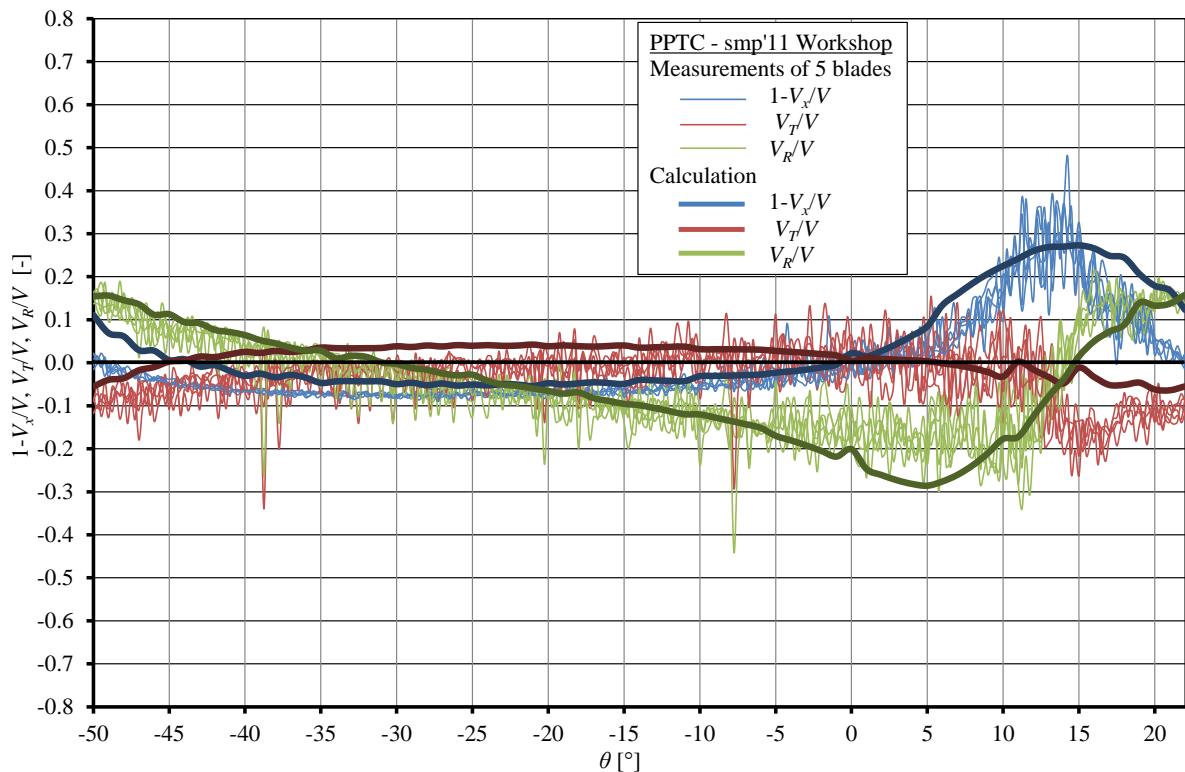
SSPA-Fluent, $r/R = 1.00$, $x/D = 0.2$



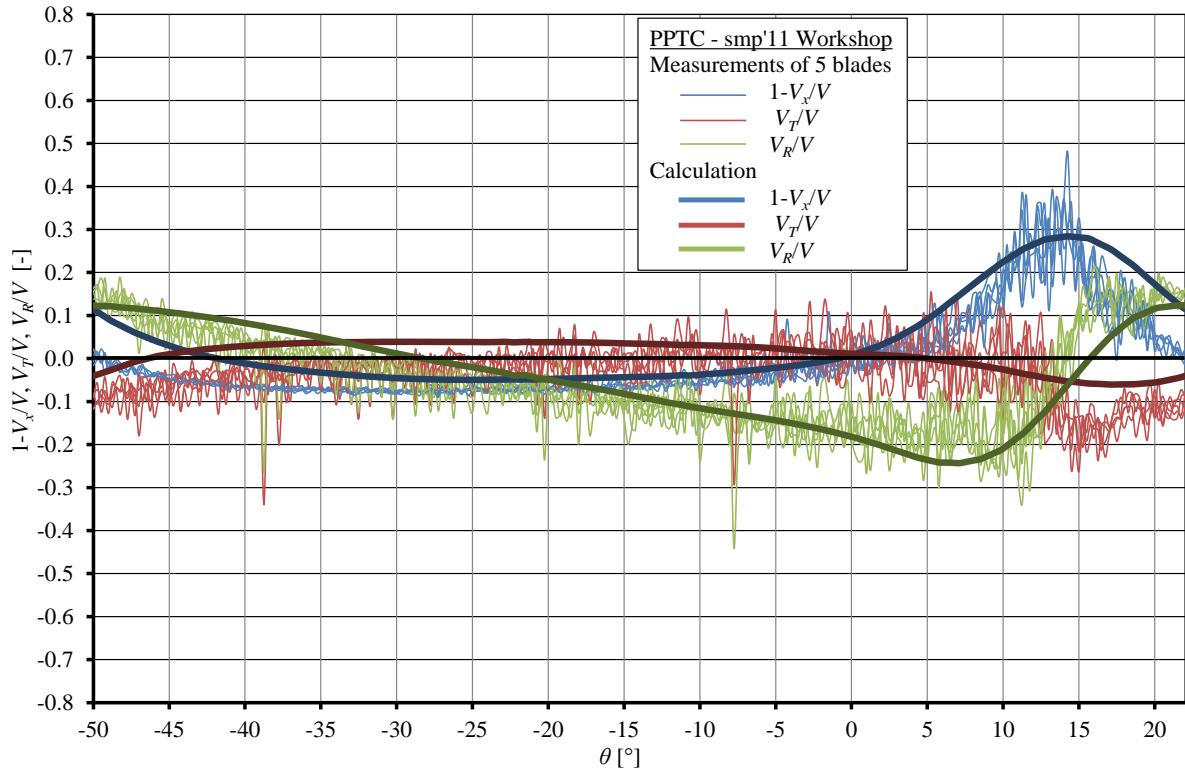
TUHH-FreSCO+, $r/R = 1.00$, $x/D = 0.2$



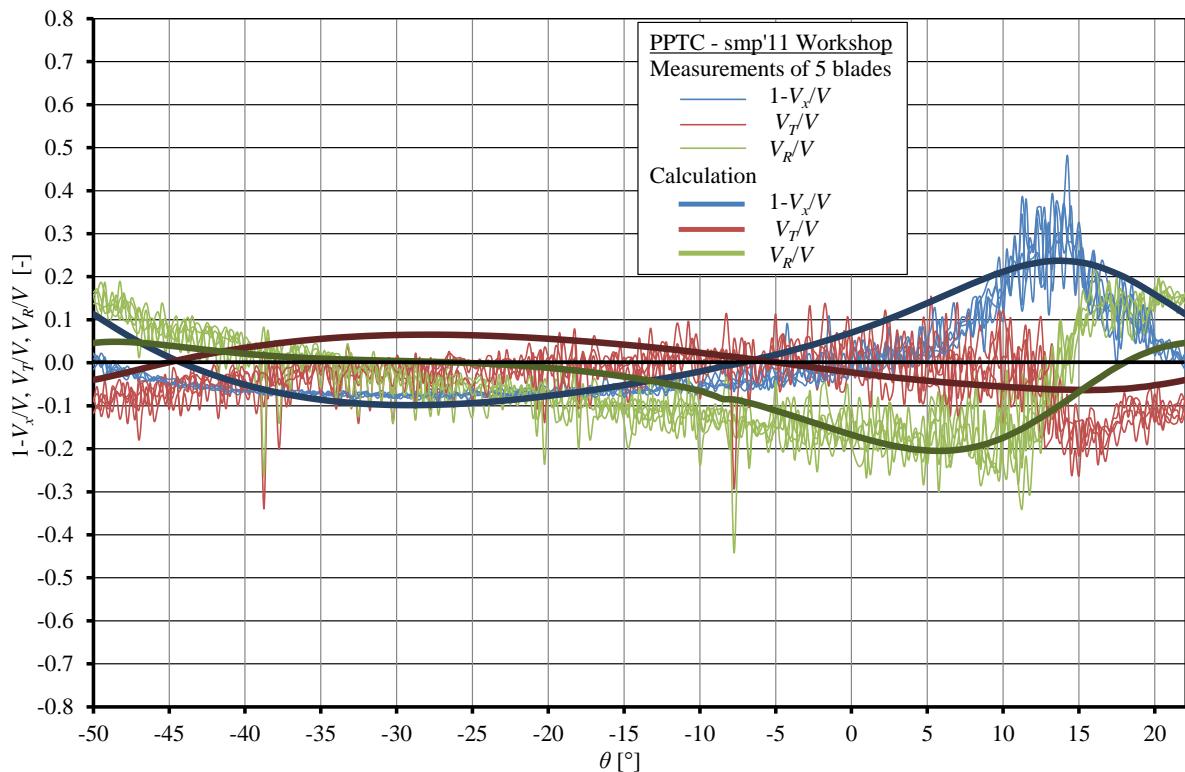
UniGenua-StarCCM(ke), $r/R = 1.00$, $x/D = 0.2$



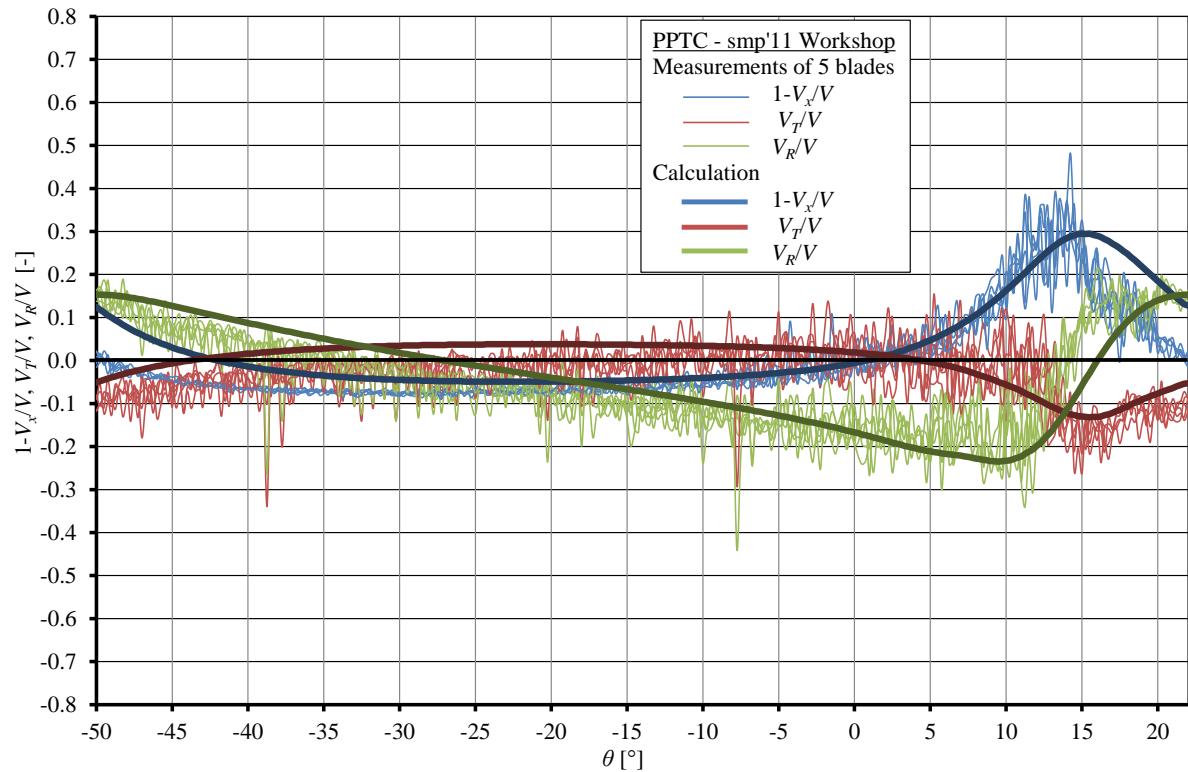
UniGenua-StarCCM(kw), $r/R = 1.00$, $x/D = 0.2$



UniTriest-CFX, $r/R = 1.00, x/D = 0.2$



VOITH-Comet, $r/R = 1.00, x/D = 0.2$



6.8 Case 2.2.4: Normalized axial velocity contours, $x/D = 0.2$

