Neutron flux measurements at D11 in the period 1998 to 2005

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Executive Summary

This report summarises the results of neutron flux measurements at D11 in the period 1998 to 2005, i.e. after installation of the Dornier-Astrium selector (June 1998) and before and during the collimation renewal project (2001 – 2005):

a) measurements with the calibrated monitor at the D11 sample position as a function of wavelength in the range $4.51Å \leq \lambda \leq 20Å$ for the standard collimation distance L_c=5.5m (i.e. guide length $L_g = 40.5 - L_c = 35$m) as well as a function of collimation distance $1.5m \leq L_c \leq 40.5m$ for 3 standard wavelengths $\lambda = 4.51$ Å, 6 Å & 10 Å.

b) gold-foil activation measurements at various positions between the sample position and the D11 selector area.

1. Introduction

Between 2001 and 2005 the collimation system at D11 has undergone a complete refurbishment. The work had been performed during several long winter shutdowns and consisted of a replacement of the 30-year old worn mechanics, installation of 6 diaphragm changers, refurbishment of the selector area, installation of 3 new collimation distances 34 m, 28 m and 1.5 m, replacement of the optical alignment system near the sample position, installation of new control automates and a replacement of the uncoated Borkron glass neutron guides with new uncoated Borofloat glass guides of the same cross section 30 x 50 mm, to name only the most important project elements. Before and during the various project phases systematic neutron flux measurements have been performed, in order to put on record the present situation and to provide a fixpoint for comparison with the outcome of the modifications. Details of the methods are given in previous ILL Technical Reports ([1], [2]).

The D11 collimation renewal project 2001 – 2005 has to be assessed in view of 2 aspects, a) mechanics and b) neutron guides:

a) the mechanical part of the project has been successfully completed with the recent delivery of the radiation shielding for the 3 diaphragm changers near to IN11. With the 3 new collimation distances, the 6 new diaphragm changers, the new mechanics including a complete re-alignment and the modifications at the selector area, the instrument has considerably gained in performance, flexibility and reliability, compared to the situation in 2001 and earlier.

b) the production of high quality neutron guides by CILAS failed twice, in 2001 and 2004. The requested specifications with respect to chamfer size and waviness were not fulfilled by the supplier and, as a consequence, the neutron flux is at D11 since 2002 lower than it should be. This can be deduced from the systematic flux measurement presented in this report (see chapters 2, 3 and 4).

The following table 1 explains the different operation phases before and during the D11 collimation renewal project.

Phase	Date	Guide material	Max. guide length	Comment
1a	1998–07/2001	Borkron (BK)	38m	BK guides from 1972 (CILAS)
	Summer shutdown 2001			Guide re-alignment at position L_c= 20.5m and at sample position
1b	08/2001-11/2001	Borkron (BK)	38m	
	Winter shutdown 2001/ 2002			Installation of 20m BF-guides (CILAS 2001) Temporary misalignment
2	02/2002–12/2002	Borkron (BK) + Borofloat (BF)	38m	20m BF (coll. dist. 40.5 – 20.5m) + 18m BK (coll. dist. 20.5m-2.5m)
	Winter shutdown 2002/ 2003			Installation of 19m BF-guides (CILAS 2001)
3	03/2003-09/2004	Borofloat (BF)	39m	39m BF (collimation distance 40.5 – 1.5m)
	Winter shutdown 2004/ 2005			Re-installation of 12.5m BK guides (CILAS 1972)
4	02/2005-08/2005	Borkron (BK) + Borofloat (BF)	39m	12.5m BK + 26.5m BF

Table 1: **Synopsis of the different experimental conditions for the D11 collimating system during operation phases 1 – 4 between 1998 – 2005 (mechanical work has been performed during the long shutdowns, marked in yellow)**

2. Result of flux measurements with the calibrated monitor at the sample position

In the following chapter 2 the results of flux measurements with the calibrated monitor at the sample position are summarized, details are given in [1], [2].

2a. neutron flux as a function of wavelength λ

Table 2 shows the flux measurements with variation of the wavelength λ in the range 4.51 Å ≤ λ ≤ 20 Å for collimation length L_c = 5.5 m (i.e. guide length L_g = 35 m) for the various operation phases (for definition see table 1).

	Feb-05 II	Feb-05 I		Jul-04	Feb-04	Nov-03	Jun-03	Apr-03
Op. Phase	4	4, IN6 5.1Å		3	3	3	3	3
λ [Å]	Φ [ncm^{-2}s^{-1}]	Φ [ncm^{-2}s^{-1}]		Φ [ncm^{-2}s^{-1}]	Φ [ncm^{-2}s^{-1}]	Φ [ncm^{-2}s^{-1}]	Φ [ncm^{-2}s^{-1}]	Φ [ncm^{-2}s^{-1}]
4.51	4.59E+06	4.60E+06		3.79E+06	3.67E+06	3.94E+06	3.90E+06	3.96E+06
4.60								3.86E+06
4.75	4.17E+06	4.10E+06		3.49E+06	3.36E+06	3.60E+06	3.61E+06	
4.80								3.60E+06
5.00	3.76E+06	3.62E+06		3.19E+06	3.00E+06	3.21E+06	3.28E+06	3.34E+06
5.10	3.60E+06	3.44E+06						
5.20	3.45E+06	3.32E+06		2.96E+06	2.74E+06	2.94E+06	3.05E+06	3.10E+06
5.25	3.38E+06	3.25E+06		2.90E+06				
5.40	3.18E+06	3.08E+06		2.74E+06	2.58E+06	2.76E+06	2.82E+06	2.88E+06
5.50								
5.60	2.92E+06	2.89E+06		2.54E+06	2.43E+06	2.60E+06	2.62E+06	2.76E+06
5.75								
5.80	2.69E+06	2.66E+06		2.35E+06	2.26E+06	2.41E+06	2.42E+06	2.46E+06
6.00	2.48E+06	2.46E+06		2.18E+06	2.10E+06	2.23E+06	2.24E+06	2.28E+06
6.25	2.26E+06	2.23E+06		1.99E+06	1.91E+06	2.03E+06	2.04E+06	
6.50	2.05E+06	2.04E+06		1.80E+06	1.74E+06	1.84E+06	1.86E+06	1.89E+06
6.75	1.87E+06	1.85E+06		1.65E+06	1.59E+06	1.68E+06	1.69E+06	
7.00	1.70E+06	1.69E+06		1.51E+06	1.45E+06	1.53E+06	1.54E+06	1.57E+06
7.50	1.42E+06	1.41E+06		1.26E+06	1.21E+06	1.28E+06	1.29E+06	1.31E+06
8.00	1.20E+06	1.19E+06		1.07E+06	1.03E+06	1.08E+06	1.10E+06	1.11E+06
8.50	1.01E+06	1.01E+06		9.07E+05	8.68E+05	9.22E+05	9.30E+05	9.41E+05
9.00	8.51E+05	8.51E+05		7.69E+05	7.34E+05	7.81E+05	7.88E+05	8.00E+05
9.50	7.16E+05	7.16E+05		6.48E+05	6.20E+05	6.62E+05	6.67E+05	6.74E+05
10.00	6.08E+05	6.04E+05		5.53E+05	5.28E+05	5.62E+05	5.66E+05	5.73E+05
10.50								
11.00		4.52E+05		4.12E+05	3.94E+05	4.20E+05	4.21E+05	4.25E+05
12.00		3.49E+05		3.19E+05	3.07E+05	3.27E+05	3.27E+05	3.31E+05
12.50								
13.00		2.80E+05		2.54E+05	2.45E+05	2.63E+05	2.62E+05	2.65E+05
15.00								
16.00								
16.50		1.53E+05			1.33E+05	1.45E+05	1.45E+05	1.46E+05
17.00		1.41E+05			1.23E+05	1.35E+05	1.34E+05	1.36E+05
17.99		1.21E+05			1.05E+05	1.16E+05	1.16E+05	1.16E+05
19.00		1.04E+05			9.01E+04		9.97E+04	1.01E+05
20.00		9.00E+04			7.78E+04		8.74E+04	87660

	Mar-02		Aug-01	Mar-01	Jun-00	May-00	Nov-99
Op. Phase	**2**		**1b**	**1a**	**1a**	**1a**	**1a**
λ [Å]	**Φ [$ncm^{-2}s^{-1}$]**		**Φ [$ncm^{-2}s^{-1}$]**	**Φ [$ncm^{-2}s^{-1}$]**	**Φ [$ncm^{-2}s^{-1}$]**	**Φ [$ncm^{-2}s^{-1}$]**	**Φ [$ncm^{-2}s^{-1}$]**
4.51			6.22E+06	5.31E+06	5.24E+06	5.29E+06	5.20E+06
4.60							
4.75			5.52E+06		4.75E+06	4.73E+06	4.70E+06
4.80							
5.00					4.22E+06	4.13E+06	4.18E+06
5.10							
5.20							
5.25					3.78E+06	3.66E+06	3.75E+06
5.40							
5.50			3.85E+06		3.39E+06	3.34E+06	3.36E+06
5.60							
5.75			3.49E+06		3.05E+06	3.06E+06	3.03E+06
5.80							
6.00	2.10E+06		3.12E+06	2.77E+06	2.75E+06	2.74E+06	2.73E+06
6.25							
6.50			2.54E+06		2.24E+06	2.24E+06	2.24E+06
6.75							
7.00			2.07E+06		1.83E+06	1.83E+06	1.83E+06
7.50			1.72E+06		1.53E+06	1.53E+06	1.52E+06
8.00			1.46E+06		1.29E+06	1.29E+06	1.29E+06
8.50			1.24E+06		1.10E+06	1.10E+06	1.09E+06
9.00			1.05E+06		9.31E+05	9.32E+05	9.27E+05
9.50			8.99E+05		7.94E+05	7.92E+05	7.90E+05
10.00			7.74E+05	6.88E+05	6.81E+05	6.80E+05	6.75E+05
10.50			6.73E+05		5.91E+05	5.93E+05	5.87E+05
11.00			5.88E+05		5.22E+05	5.19E+05	5.17E+05
12.00			4.64E+05		4.13E+05	4.11E+05	4.09E+05
12.50			4.18E+05		3.72E+05	3.71E+05	3.71E+05
13.00							
15.00			2.64E+05		2.38E+05	2.38E+05	
16.00			2.26E+05		2.03E+05	2.03E+05	2.01E+05
16.50							
17.00			1.94E+05		1.75E+05	1.75E+05	1.73E+05
17.99			1.68E+05		1.52E+05	1.52E+05	1.51E+05
19.00			1.47E+05		1.33E+05	1.33E+05	1.32E+05
20.00			1.29E+05		1.18E+05		1.16E+05

Table 2: **measured neutron flux Φ as a function of wavelength λ**
for collimation distance L_c = 5.5m (total guide length L_g = 35m)
yellow: standard wavelengths λ = 4.51Å, 6Å & 10Å
(for definition of operation phases see table 1)

2b. neutron flux as a function of guide length L_g

The following table 3 summarises the flux measurements with the calibrated monitor at the sample position with variation of the collimation distance L_c (i.e. guide length $L_g = 40.5 - L_c$) for 3 standard wavelengths $\lambda = 4.5$Å, 6Å & 10Å.

Note: new collimation distances L_c = 28 m and 34 m available after restart in March 2002, L_c = 1.5 m available after restart in March 2003.

λ = 4.51 Å		February 2005		June 2003		March 2001	
Oper. Phase		4		3		1a	
L_c[m]	L_g[m]	$\Phi=f(L_g)$	$\Phi(L_c)/\Phi(40.5)$	$\Phi=f(L_g)$	$\Phi(L_c)/\Phi(40.5)$	$\Phi=f(L_g)$	$\Phi(L_c)/\Phi(40.5)$
1.5	39	2.38E+07	46.24	1.86E+07	37.80		
2.5	38	2.35E+07	45.60	1.84E+07	37.57	2.26E+07	48.00
4	36.5	2.01E+07	39.09	1.56E+07	31.71	1.93E+07	40.86
5.5	35	1.47E+07	28.49	1.18E+07	24.04	1.45E+07	30.83
8	32.5	8.53E+06	16.58	7.24E+06	14.74	8.84E+06	18.75
10.5	30	5.45E+06	10.59	4.89E+06	9.96	5.71E+06	12.10
13.5	27	3.59E+06	6.98	3.33E+06	6.79	3.64E+06	7.72
16.5	24	2.54E+06	4.93	2.38E+06	4.85	2.58E+06	5.46
20.5	20	1.76E+06	3.42	1.69E+06	3.45	1.87E+06	3.97
28	12.5	1.03E+06	2.00	9.80E+05	2.00		
34	6.5	7.16E+05	1.39	6.81E+05	1.39		
40.5	0	5.15E+05	1.00	4.91E+05	1.00	4.72E+05	1.00

λ = 6 Å		February 2005		June 2003		April 2003	
Oper. Phase		4		3		3	
L_c[m]	L_g[m]	$\Phi=f(L_g)$	$\Phi(L_c)/\Phi(40.5)$	$\Phi=f(L_g)$	$\Phi(L_c)/\Phi(40.5)$	$\Phi=f(L_g)$	$\Phi(L_c)/\Phi(40.5)$
1.5	39	2.85E+07	77.09	2.72E+07	67.71	2.89E+07	68.36
2.5	38	2.66E+07	72.07	2.56E+07	63.66	2.70E+07	63.99
4	36.5	1.91E+07	51.68	1.85E+07	45.99	1.95E+07	46.12
5.5	35	1.24E+07	33.48	1.21E+07	30.06	1.27E+07	30.06
8	32.5	6.72E+06	18.21	6.72E+06	16.73	7.03E+06	16.64
10.5	30	4.15E+06	11.24	4.34E+06	10.80	4.54E+06	10.74
13.5	27	2.66E+06	7.20	2.87E+06	7.13	3.01E+06	7.12
16.5	24	1.84E+06	4.99	2.01E+06	5.00	2.11E+06	5.00
20.5	20	1.26E+06	3.40	1.41E+06	3.50	1.47E+06	3.49
28	12.5	7.28E+05	1.97	8.03E+05	2.00	8.42E+05	1.99
34	6.5	5.09E+05	1.38	5.59E+05	1.39	5.87E+05	1.39
40.5	0	3.69E+05	1.00	4.02E+05	1.00	4.23E+05	1.00

λ = 6 Å		March 2002		June 2000		November 1999	
Oper. Phase		2		1a		1a	
L_c[m]	L_g[m]	Φ=f(L_g)	Φ(L_c)/Φ(40.5)	Φ=f(L_g)	Φ(L_c)/Φ(40.5)	Φ=f(L_g)	Φ(L_c)/Φ(40.5)
1.5	39						
2.5	38	2.45E+07	55.04	2.82E+07	78.05	2.94E+07	78.41
4	36.5	1.82E+07	40.91	2.07E+07	57.34	2.15E+07	57.25
5.5	35	1.23E+07	27.54	1.30E+07	35.86	1.33E+07	35.47
8	32.5	7.06E+06	15.85	7.17E+06	19.86	7.42E+06	19.78
10.5	30	4.17E+06	9.37	4.53E+06	12.55	4.68E+06	12.50
13.5	27	2.54E+06	5.71	2.86E+06	7.92	2.97E+06	7.91
16.5	24	1.72E+06	3.87	1.99E+06	5.52	2.05E+06	5.48
20.5	20	1.55E+06	3.49	1.40E+06	3.87	1.45E+06	3.86
28	12.5	8.94E+05	2.01				
34	6.5	6.18E+05	1.39				
40.5	0	4.45E+05	1.00	3.61E+05	1.00	3.75E+05	1.00

λ = 10 Å		February 2005		June 2003		June 2000	
Oper. Phase		4		3		1a	
L_c[m]	L_g[m]	Φ=f(L_g)	Φ(L_c)/Φ(40.5)	Φ=f(L_g)	Φ(L_c)/Φ(40.5)	Φ=f(L_g)	Φ(L_c)/Φ(40.5)
1.5	39	9.11E+06	177.98	8.63E+06	151.37		
2.5	38	6.81E+06	133.09	6.57E+06	115.30	7.50E+06	133.38
4	36.5	3.51E+06	68.54	3.59E+06	62.94	3.72E+06	66.15
5.5	35	2.04E+06	39.79	2.10E+06	36.85	2.15E+06	38.22
8	32.5	1.04E+06	20.25	1.09E+06	19.08	1.13E+06	20.16
10.5	30	6.21E+05	12.13	6.71E+05	11.77	7.10E+05	12.61
13.5	27	3.87E+05	7.56	4.29E+05	7.53	4.53E+05	8.06
16.5	24	2.64E+05	5.15	2.96E+05	5.19	3.19E+05	5.67
20.5	20	1.77E+05	3.46	2.03E+05	3.56	2.22E+05	3.95
28	12.5	1.02E+05	2.00	1.15E+05	2.02		
34	6.5	7.10E+04	1.39	8.01E+04	1.40		
40.5	0	5.12E+04	1.00	5.70E+04	1.00	56264	1.00

Table 3: **measured neutron flux Φ [n cm^{-2} s^{-1}] as a function of guide length $L_g = 40.5 - L_c$ (L_c = collimation distance 1.5m ≤ L_c ≤ 40.5m) and relative flux at the sample position Φ(L_c)/Φ(40.5) for wavelengths 4.51Å, 6Å & 10Å (for definition of operation phases see table 1)**

3. Results from gold activation measurements

Flux measurements by gold foil activation have been performed in collaboration with ILL's radioprotection service (SPR) at different positions of the instrument between the exit of the primary H15 guide (position OS at the secondary beam shutter) and the sample position.

The measurements are from the period 1998 – 2005 (i.e. after the commissioning of the new Dornier-Astrium selector at D11 in 1998 and before and during the collimation renewal project 2001 – 2005). For details see [1], [2].

The different positions are explained in the schematic Figure 1, the results are summarized in Table 3 (with the SPR-reference of each measurement campaign given in the last column).

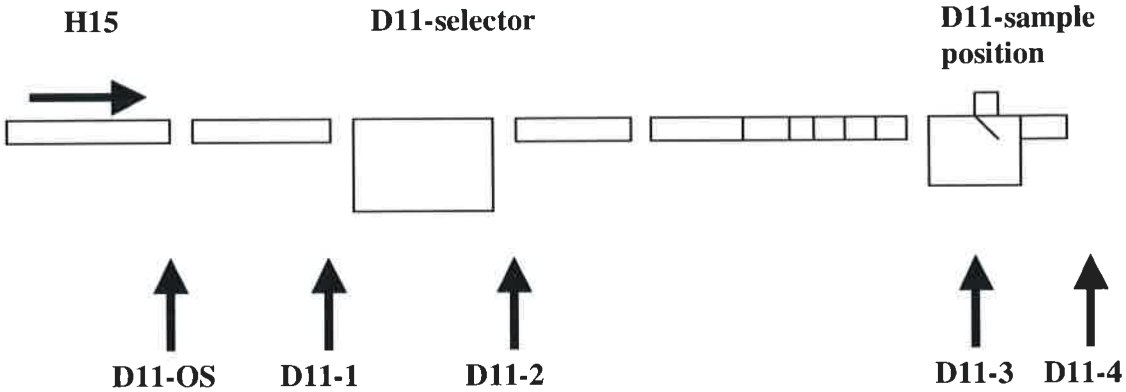

Figure 1: schematic view of different position for D11- gold foil activation measurements

date	λ [Å]	coll. dist. [m]	position D11-OS	position D11-1	position D11-2	position D11-3	position D11-4	SPR reference
29/03/05	6	1.5				3.72e7		DSPSE-05/134-MSjl
	6	2.5				3.59e7		
	6	4				3.02e7		
	6	5.5				2.08e7		
	6	8				1.10e7		
	6	10.5				6.76e6		
	6	13.5				4.18e6		
	6	16.5				2.79e6		
	6	20.5				1.86e6		
	6	28				1.05e6		
	6	34				7.32e5		
	6	40.5				5.27e5		
23/02/05				5.94e9				DSPSE-05/086-MS/jl
	6				1.28e8			
	6	2.5					3.07e7	
26/02/04			6.68e9	6.27e9				DSPSE-04/107/MS/jl
	6	2.5			1.35e8		2.83e7	
	10	2.5			5.60e7		7.22e6	

date	λ [Å]	coll. dist. [m]	position D11-OS	position D11-1	position D11-2	position D11-3	position D11-4	SPR reference
17/03/03				6.32e9				DSPSE-04/120/MS/jl
	6				1.36e8			
	10				5.77e7			
	6	1.5				3.07e7		
	6	2.5				3.04e7		
	6	4				2.59e7		
	6	5.5				1.88e7		
	6	8				1.07e7		
	6	10.5				6.55e6		
	6	13.5				4.08e6		
	6	16.5				2.78e6		
	6	20.5				1.85e6		
	6	28				9.38e5		
	6	34				5.20e5		
	6	40.5				5.15e5		
18/04/02	10	2.5					7.08e6	DSPSE-02/188-JML/HF/jl
15/03/02	6	2.5			1.41e8		2.66e7	
	10				5.88e7			
28/02/02			6.65e9	6.24e9				DSPSE-02/188-JML/HF/jl
22/05/01	10	2.5			4.71e7		8.42e6	DSPSE-01/196-JML/jl
	12				3.10e7			
	15				1.51e7			
02/04/01	6	2.5			1.34e8		2.96e7	DSPSE-01/141-HF/jl
	4.5				1.14e8			
	5				1.40e8			
	5.5				1.44e8			
	7				1.19e8			
	8				7.90e7			
23/10/00				6.51e9				DSPSE-00/453-JML/jl
	6	2.5			1.36e8		3.08e7	
	6	5.5					1.42e7	
	10	2.5			4.89e7		8.36e6	
	6	2.5				3.60e7		
	6	4				3.24e7		
	6	5.5				2.23e7		
	6	8				1.24e7		
	6	10.5				7.33e6		
	6	13.5				4.50e6		
	6	16.5				3.95e6		
	6	20.5				1.98e6		
	6	40.5				4.67e5		
29/07/98				6.94e9				DSPSE-98/338-MS/jl
	6	2.5			1.52e8		3.19e7	
	6	5.5					1.46e5	
	10	2.5			5.59e7		8.21e6	

Table 3: neutron flux Φ [$ncm^{-2}s^{-1}$] from gold foil activation measurements 1998 – 2005

4. Conclusions

Figure 2 below shows the relative flux at the D11 sample position with reference to August 2001, as a function of time, i.e. during the various operation phases (see table 1) between 1999 and 2005, for two standard wavelengths 6Å and 10Å. During the summer shutdown in 2001, the re-alignment of the beam exit and the diaphragms at the sample position and at collimation distance 20.5 m yielded a significant flux increase. The measured flux value in August 2001, taken as the reference in figure 1, was indeed the highest one observed during the period 1999 and 2005. The dramatic flux losses after replacing the old Borkron guides with Borofloat guides between 2001-2002 and 2002-2003 are clearly seen in Figure 2.

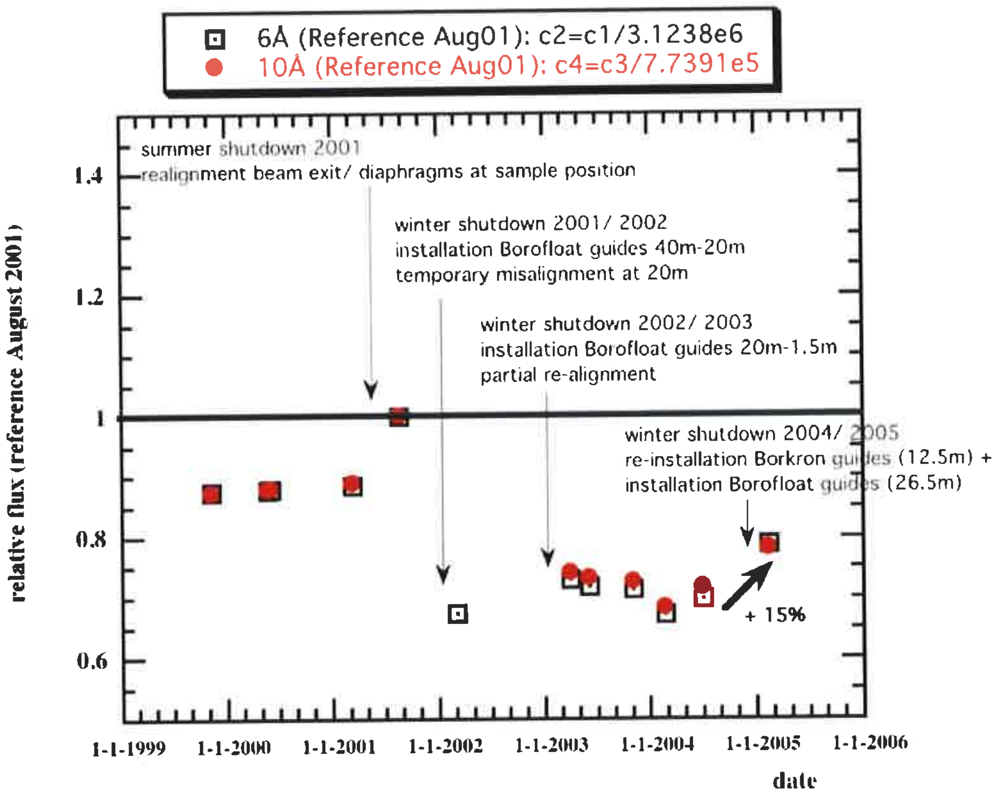

Figure 2: **relative flux at the D11 sample position as a function of time (1999 – 2005) with reference to August 2001, for 2 standard wavelengths λ = 6Å and 10Å and collimation distance L_c = 5.5m, cf. table 2).**

Following the latest delivery of bad-quality Borkron neutron guides by CILAS in November 2004, D11 has restarted after the winter shutdown 2004/ 2005 in a temporary state: it has been decided to dismantle 12.5m Borofloat (2001) guides and re-install 12.5m old Borkron (1972) guides. The situation is now somewhat improved (15% flux gain, see Fig.2) but the neutron flux at the instrument is for maximum flux conditions still decreased by about 20%, compared to August 2001.

The loss in neutron flux as a function of wavelength for different guide qualities is illustrated with Figure 3 below, for collimation distance 5.5 m, i.e. guide length 35 m. We compare the situation in August 2001 (phase 1b, best conditions so far, 35 Borkron guides) with phase 3 (February 2004: 35 m pure Borofloat guides) and with phase 4 (February 2005: 26.5m Borofloat guides + 12.5 m old Borkron guides).

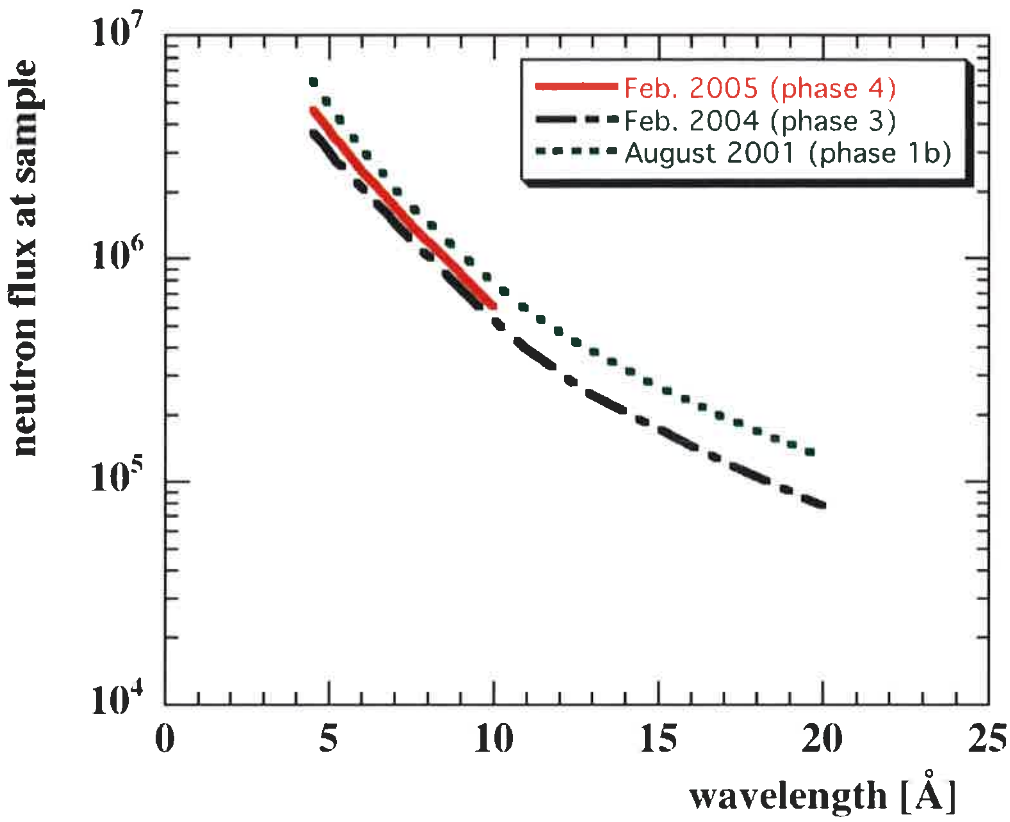

Figure 3: **neutron flux as a function of wavelength for collimation distance L_c = 5.5 m (i.e. guide length L_g = 35 m) for operating phases 1b (August 2001, green dotted line), 3 (February 2004, black dash-dotted line) and 4 (February 2005, red full line), cf. table 1 and table 2.**

Given the overall unsatisfactory situation at D11, we have recently started a new campaign of McStas simulations, with the ultimate aim to investigate if the collimation system can be further improved with an innovative guide design change, i.e. by widening the cross section from 30 x 50 mm to 45 x 50 mm.

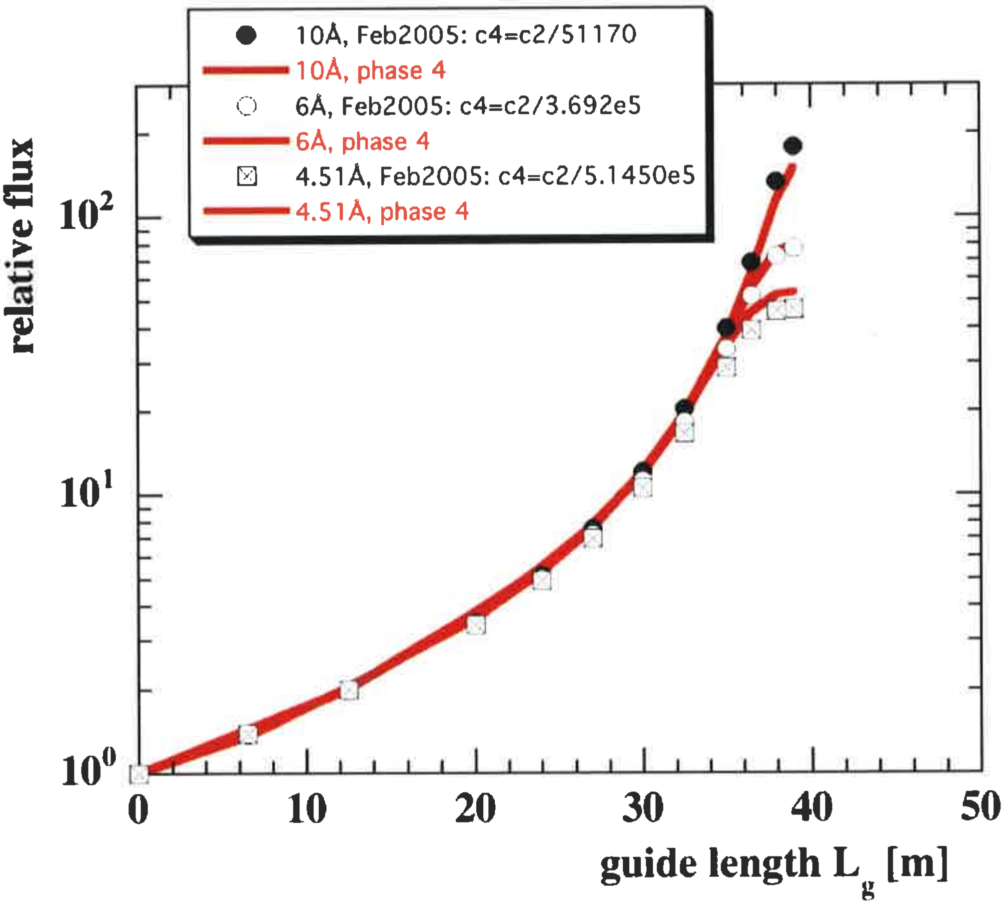

Figure 4: **Comparison of neutron flux measurements as a function of guide lengths L_g at 3 different wavelengths (cf. table 2) with recent McStas simulations (red lines, [3]) for operating phase 4 (February 2005).**

Results of these new simulations (performed by Klaus Lieutenant [3], [4]) are as follows:

- we observe now a nearly quantitative match with flux measurements (1999 – 2005) for different guide qualities (Borkron, Borofloat) and wavelengths (cf. Fig. 4).
- it is confirmed that the bad Borofloat guide quality (high waviness and large chamfers) is at the origin of the neutron flux loss ≥ 2002.

- it is confirmed that the decision in 2001 for uncoated glass was correct.
- the simulations predict a significant flux gain for a large range of collimation distances with a new widened glass guide with an opening 6.5m trumpet (30 mm -> 45 mm width) at the collimation entrance and a focusing trumpet at the collimation exit, near to the sample position.

Based on these recent simulation results it has been decided in spring 2006 to replace the neutron guides at D11 completely over 39 m with new, high quality Borofloat material, in the framework of the ongoing D11 Millennium Project in 2007/ 2008 (installation of a larger and faster SANS detector in a new detector tank, thus increasing the resolution and the dynamic range of the instrument [5]).

The flux results presented in this report will serve as a reference for evaluating the upcoming modifications.

5. References

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