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FOM-evaluation

Programme FP31: Fundamental Interactions
and
Programme FP52: Theoretical Subatomic Physics

Part II
Embedding of programmes and detailed results

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1 Embedding of FOM programme FP31 at the universities

The activities in FOM programme FP31 up to now were performed within FOM working groups at the six universities in the Netherlands, where physicists worked in theoretical high-energy physics. Since it is impossible to judge the activities without the context in which supervisors and collaborators work, we present here an overview of activities in the various FOM working groups, mostly in tabular form. The activities in the programmes are grouped together.

1.1 University of Amsterdam (UVA): FOM-A-01

staff	dates	employer	
prof.dr.ir. F.A. Bais		UvA	
drs. G.G.A. Bäuerle		UvA	
prof.dr. J. de Boer	from 1/9/2000	UvA	
prof.dr. R.H. Dijkgraaf		UvA	
prof.dr. K.J.F. Gaemers		UvA	
dr. L.J. van den Horn		UvA (CHEAF)	
prof.dr. J.H. Koch		NIKHEF/UvA	
dr. K. Skenderis	from 1/1/2003	UvA/NWO	
prof.dr. J. Smit		FOM FP31	
prof.dr. H.L. Verlinde	till 1/1/2000	UvA	
dr. J.C. Vink	1/10/1999-1/1/2002	UvA/FOM	
prof.dr. Ch.G. van Weert		UvA	
postdocs	**dates**	**employer**	**topic**
dr. M. Alishahiha	1/12/2000-1/8/2001	FOM FP31 FOM 99HT02	String field theory and tachyon condensation
dr. S. Bilke	8/12/1997-8/12/1999	FOM FP31	Fluctuating geometries and quantum gravity
dr. J.I. Skullerud	1/10/2001-1/10/2003	FOM FP31	Non-equilibrium field theories
dr. M. Serone	1/9/1998-1/9/2000	FOM 97PR1688	Anomaly cancelation for extended objects
dr. S. Terashima	1/9/2001-1/9/2003	FOM 97PR1688	Strings and K-theory
dr. M.A. Vazquez-Mozo	1/10/1998-1/1/2001	FOM 97PR1688	Nonperturbative string theory
dr. L. Cornalba	1/10/2001-1/10/2004	FOM 00PR1889	The physics of D-branes
dr. B.J. Schroers	1/9/1995-1/9/1998 1/9/1998-1/9/1999	NWO Pionier UvA	Non-abelian dualities

Ph.D. students	dates	employer	topic
drs. W.H. Tang	1/2/1993-1/2/1997	FOM Hth-A	Baryon number violation
drs. J.M. Smit	1/10/1991-1/10/1995	FOM Hth-A	Neutrinos in supernovae
drs. N.M. Muller	1/2/1994-1/2/1998	FOM Hth-A	Topology/quantum symmetries
drs. M. Sallé	1/2/1998-1/2/2002	FOM FP31	Non-equilibrium quantum fields
drs. J. Striet	1/5/1999-1/5/2003	FOM FP31	Alice electrodynamics
drs. R.H. Boels	1/8/2001-1/8/2005	FOM FP31 FOM 99HT02	String theory in time dependent backgrounds
drs. A.X. Arrizabalaga	1/9/1999-1/9/2003	FOM SF-A-b/3	Non-equilibrium dynamics of symmetry breaking
drs. J.A.E.F. van Dongen	1/2/1998-1/2/2002	NWO/Zeeman St./CHEAF	Einstein and unification
drs. R.J. Duivenvoorden	18/9/2000-18/9/2004	FOM 00PR1889	Strings/holography
drs. F. Hacquebord	1/1/1995-1/1/1999	NWO Pionier	Matrix string theory
drs. B.J. Nauta	1/7/1996-1/7/2000	UvA	High-T field theory
drs. J.S. Park	1/10/1995-1/10/1999	NWO Pionier	Cohomological field theories
drs. J.K. Slingerland	1/6/1998-1/6/2002	UvA	Hopf symmetries
drs. M. Temürhan	1/9/2001-1/9/2005	FOM 97PR1688	Holography
drs. A. Tranberg	1/10/2000-1/10/2004	UvA	Non-equilibrium QFT and early universe
drs. M.L. Vonk	1/10/1998-1/10/2002	FOM MF-A-a	Quantum gravity/strings/ gauge theories
drs. J.S. Wijnhout	15/4/2001-15/4/2005	FOM 97PR1688	Black holes/noncommutative geometry

Ph.D. degrees awarded in Amsterdam (UVA), 1998-2001.

1. N.M. Muller, *"Topological Interactions and Quantum Double Symmetries"*, promotor: prof. dr ir F.A. Bais, University of Amsterdam, Amsterdam, 2 October 1998, ISBN 90-5776-008-8.

2. J.M. Smit, *Neutrino Transport in Core-collapse Supernovae*, promotor: prof. dr E.P.J. van den Heuvel and prof. dr Ch.G. van Weert, copromotor dr L.J. van den Horn, University of Amsterdam, 20 May 1998, Universal Press, Veenendaal.

3. W-H. Tang, *Numerical Calculation of the Baryon Number Violation Rate in Hot Electroweak Theory*, promotor: prof.dr. J. Smit, University of Amsterdam, 1 September 1998, ISBN 90-5776-006-1.

4. F.H. Hacquebord, *Symmetries and Interactions in Matrix String Theory*, promotor prof.dr. H.L. Verlinde, Universiteit van Amsterdam, Amsterdam, September 22, 1999, 120p.

5. J.-S. Park, *Cohomological Field Theories on Complex Manifolds*, promotor prof.dr. H.L. Verlinde, Universiteit van Amsterdam, Amsterdam, November 23, 1999, 165p.

6. B.J. Nauta, *Dynamics of Gauge Fields at High Temperature*, promotor: prof.dr. Ch.G. van Weert, Universiteit van Amsterdam, Amsterdam, November 8, 2000, UvA, 128 pages, proefschrift.

Relevant developments at the university

The research in High Energy Theory at the UvA is mainly part of the Institute for Theoretical Physics (ITFA).

The String Theory group at the University of Amsterdam is a common initative of the institute for Theoretical Physics (ITFA) and the Korteweg-de Vries Institute for Mathematics (KdVI). It receives additional funds from the University Board through the Center of Mathematical Physics Amsterdam (CMPA, Dijkgraaf director), and external funding by FOM and NWO (GBE-Mathematics).

Amsterdam has from the beginning continuously supported this field, both from the mathematics and physics side. It was the first place in the Netherlands to offer permanent positions in this field (Dijkgraaf 1992, H. Verlinde 1994). With the aid of a NWO Pionier grant a number of infrastructure investments have been made. String theory is a main research theme in the research programme of both the ITFA and the KdV Institute and acts furthermore as a backbone of the CMPA.

String theory has a strong impact on and interaction with mathematics. This has been particularly encouraged in Amsterdam, and is reflected in the research profile at the KdV Institute. The recent appointments of Opdam and Landsman (with FOM support, also NWO pionier)) have strengthened this relation.

Dijkgraaf and J. de Boer are now heading the active research group in this field (H. Verlinde left per 1-1- 2000 to take up a full professorship at Princeton University, but is still associated to the UvA as visiting professor). A successful application was put in for a NWO Vernieuwingsimpuls grant for Kostas Skenderis. Skenderis is presently an Assistant Professor in the High Energy Theory group at Princeton University and will become Associate Professor at the UvA. Skenderis' project will start September 2002. His grant will partly used to finance postdocs and graduate students.

In 2001, the University has awarded a *honorary professorship* to Nobel laureate Prof. Martinus Veltman.

Dr J.C. Vink was appointed in the group of Prof. J. Smit to strengthen the efforts in computational field theory. His presence was highly productive but unfortunately he left the Institute to work in industry.

Specific research topics, 1998-2001.

The research is roughly divided in two parts. One part is concerned with

- String Theory and Quantum Gravity. This research is now part of the FOM programme FP57.

The other part concerns the investigation and application of non-perturbative aspects of QFT and covers the following topics.

- Electroweak baryogenesis
- High temperature field theory and heavy ion collisions
- Computational Field Theory
- Topological defects and topological interactions
- Quantum group symmetries and their breaking

1.2 Rijksuniversiteit Groningen: FOM-G-01

Staff	appointment dates	employed by	
Prof.dr. D. Atkinson	until May 2000	RUG	
Dr. M. de Roo		RUG	
Prof.dr. E.A. Bergshoeff		RUG	
Postdocs	**appointment dates**	**employed by**	**topic**
Dr. J.C.R. Bloch	1/9/96-1/9/98	FOM Hth-G	Dyson-Schwinger equations
Dr. U.G.V. Gran	1/10/01-1/10/03	FOM FP31	Domain walls
Dr. P. Sundell	1/9/99-1/9/01	FOM 98PR1751	Noncommutative geometry
Dr. D. Berman	1/9/99-1/9/00	TMR	Noncommutative geometry
Ph.D. students	**appointment dates**	**employed by**	**topic**
B. Janssen	1/9/94-1/9/98	FOM Hth-G	Properties of branes
A.H. Hams	1/9/96-1/9/98	FOM Hth-G	Dyson-Schwinger equations, computational physics
E.A. Eyras	1/9/95-1/12/99	FOM FP31	Kaluza-Klein monopoles
J.P. van der Schaar	1/9/96-1/9/00	FOM FP31	Domain wall/QFT correspondence
T.C. de Wit	1/10/99-1/10/03	FOM FP31	Susy Randall-Sundrum scenario
R.S. Halbersma	1/7/98-1/7/02	FOM 98PR1751	Susy Randall-Sundrum scenario
M.G.C. Eenink	1/9/01-1/9/05	FOM FP57	Non-Abelian Born-Infeld
D. Roest	1/9/00-1/9/04	RUG	Massive dualities
A. Collinucci	1/9/01-1/9/05	RUG	Non-Abelian Born-Infeld

PhD degrees awarded in Groningen (RUG), 1998-2001

1. B. Janssen, *Dualities of Strings and Branes*, University of Groningen, 12 june 1998 (Promotor: Prof.dr. D. Atkinson, referenten Dr. E.A. Bergshoeff, Dr. M. de Roo)
2. E.A. Eyras, *Brane Dynamics in Diverse Backgrounds*, University of Groningen, 11 june 1999 (Promotor: Prof.dr. D. Atkinson, referenten Dr. E.A. Bergshoeff, Dr. M. de Roo)
3. J.P. van der Schaar, *String Theory Limits and Duality*, University of Groningen, 30 june 2000 (Promotor: Prof.dr. D. Atkinson, referenten Dr. E.A. Bergshoeff, Dr. M. de Roo)

Relevant developments at the university

Prof.dr D. Atkinson retired in May 2000. In 2001 Dr. E.A. Bergshoeff was appointed as his successor. In 2000 our European TMR network *Quantum aspects of Gauge Theories, Supersymmetry and Unification* ended, and was continued as the RTN programme *The Quantum Structure of Spacetime and the Geometric Nature of Fundamental Interactions*. In the TMR network David Berman (Durham) joined our group as a postdoc for one year, in the RTN network Mikkel Nielsen (Goteborg) will come to Groningen for two years, starting in 2002. Contacts with Goteborg and other Scandinavian universities have been strengthened by our participation in the Nordisk Forskerutdanningsakademi (NORFA) programme *SupersymmetriskaFält- och Strängteorier* (1999-present).

Specific research topics, 1998-2001

In the period 1998-2001 our research programme centered on the following topics:

- Branes, and in particular domain walls (branes which D-2 spatial extensions in a D-dimensional spacetime) have played an important role in our research programme and have become a recurrent theme in our field. For instance, in the Randall-Sundrum scenario our universe is a domain wall

in a five-dimensional spacetime. The AdS/CFT correspondence can be extended to domain walls, and our group contributed to this Domain Wall/Quantum Field Theory correspondence.

- The dynamics of D-branes have been investigated. This resulted in a complete action for D-branes. Recently we have attempted to extend this work to the case where the fields on the branes include Yang-Mills fields, as in the Standard Model. Work along these lines is being continued at present.
- There is observational evidence for a small positive cosmological constant (de Sitter spacetime). The Randall-Sundrum scenario is hard to reconcile with supersymmetry, which is an essential part of string theory. We have made a specific proposal how to circumvent no-go theorems in this context.
- A intriguing aspect of branes is that, in a particular limit, the geometry on the brane becomes a so-called noncommutative geometry, in which coordinate functions no longer commute. The coordinates involved are the points where strings are attached to the brane. In the case of rolled-up membranes ending on higher branes the intersection is a circle, and we have shown that this gives rise to a noncommutative geometry of loops. This work has an interesting interface with mathematics, since not much is known about such geometries.

1.3 Universiteit Leiden (UL): FOM-L-01

Staff	appointment dates	employed by	topic
Prof. Dr. P.J. van Baal		UL	QFT
Prof. Dr. F.A. Berends		UL	Phenomenology
Dr. W.L.G.A.M. van Neerven		UL	Phenomenology
Dr. W.J.P. Beenakker	03/1995 - 09/1998	KNAW-fellow	Phenomenology
Prof. Dr. J. de Boer	01/1999 - 09/2000	FOM Springplank	Strings
Prof. Dr. A. Achúcarro	*from 04/2002*	*UL/FOM*	*Astro-Particle*
Postdocs	**appointment dates**	**employed by**	**topic**
Dr. T.G. Kovács	09/1998 - 09/2000	FOM FP31	QFT
Dr. F. Bruckmann	since 10/2001	FOM 99PR1797	QFT
Dr. A. Vogt	09/1998 - 09/2001	EU(TMR[1])	Phenomenology
Dr. C. Ford	since 07/2001	EU(Marie-Curie)	QFT
Ph.D. students	**appointment dates**	**employed by**	**topic**
Dr. A.P. Chapovsky	02/1996 - 11/1999	FOM FP31	Phenomenology
J. Schweizer[4]	09/2000 - 05/2001	FOM FP31	Phenomenology
Dr. T.C. Kraan	01/1996 - 04/2000	FOM 94MF14	QFT
Dr. J.A.H. Keurentjes	09/1996 - 09/2000)	UL	QFT/Strings
Dr. R.C.W. van Gulik[2]	05/1997 - 09/2001	UL/NIKHEF	Phenomenology/Exp
D. Nogradi[3]	since 12/2000	UL	QFT/Strings

[1)] FMRX-CT98-0194 (DG12-MIHT), TMR Research Network (EC), Quantum Chromodynamics and the Deep Structure of Elementary Particles. Coordinator W.J. Stirling, Durham, UK. Responsible scientist: W.L. van Neerven.
[2)] R. van Gulik, first and last year in Leiden, otherwise at NIKHEF and CERN. His output is not reported here, except for date and title of thesis.
[3)] D. Nogradi, is on unpaid leave from Oct 2001 for 9 months, to follow the Tripos III course at DAMTP, Cambridge, UK.
[4)] J. Schweizer, returned to home-University, Bern, Schwitzerland.

Ph.D. degrees awarded in Leiden 1998-2001.

1. A.P. Chapovsky, *Instability and radiative corrections in pair production of W-bosons*, 23 september 1999, Univ. Leiden, promotor: Prof. Dr. F.A. Berends, co-promotor: Dr. W.J.P. Beenakker.
2. T.C. Kraan, *Periodic Instantons and Monopoles*, Univ. Leiden, 30 March 2000. Promotor: Prof. Dr. P.J. van Baal.

3. J.A.H. Keurentjes, *New Vacua for Yang-Mills Theory on a 3-torus*, Univ. Leiden, 29 June 2000. Promotor Prof. Dr. P.J. van Baal, co-promotor Prof. Dr. J. de Boer.

4. R.C.W. van Gulik, *Resonance Production in Two-Photon Collisions*, Univ. Leiden, 22 November 2001. Promotores: Prof. Dr. F. A. Berends and Prof. Dr. F.L. Linde.

Relevant developments at the university

In Leiden some important changes in the staff will occur. Prof. F.A. Berends will retire at the end of 2003 and an important shift of research interests will be made with the appointment of Prof. A. Achúcarro to include active research in the field of theoretical cosmology and astroparticle physics. At present she is secretary of COSLAB, an ESF programme to support studies of cosmology in the laboratory. A few of her publications over the last 5 years are included under items 92-97 at the end of the Leiden publication list in part II. She will start 1 May 2002 and will be working with a postdoc in the programme FP31.

Specific research topics, 1998-2001.

The research topics in the Ht-L working group for this period fall under the themes 'Phenomenology' and 'Quantum field theory'. It also included 'Quantum gravity and string theory', in particular in the period that Jan de Boer was in Leiden on a FOM-springplank position.

1.4 University Nijmegen (KUN): FOM-N-01

staff	date	emplyed by	topic
Dr. W. Beenakker	from 1/2001	FOM FP31/KUN	Field theory, rad. corr.
Prof. Dr. R. Kleiss		KUN	field theory, MC, multijets
Dr. Th. Rijken		KUN	Baryon-Baryon interactions
Prof. Dr. C. Dullemond		emeritus	Field theory, quantum mechanics
Prof. Dr. J. de Swart		emeritus	Nucleon-Nucleon interactions
visitors			
J. Nagata	up to 07/1998	Min. of Educ., Japan	phase-shift analysis
C. Makamoto	04/1999 - 03/2000	Min. of Educ., Japan	hybrid quark models
R. Bryan	06/2000-07/2000 and 10/2001-12/2001	Texas A&M	scalar mesons
Ph.D. students			
A. van Hameren	up to 01/2001	FOM FP31	numerical methods
C. Dams	from 10/2000	FOM FP31	Unstable particle collisions
H. Polinder	from 04/1999	KUN	Kaon-Nucleon models
P. Draggiotis	from 08/1998	KUN	QCD multijet production

Ph.D. degrees awarded in Nijmegen (KUN), 1998-2001.

1. A.F.W. van Hameren, *Loaded dice in Monte Carlo: importance sampling in phase space integration and probability distributions for discrepancies.*, Jan 2001. 160pp. Advisor: Prof. dr. R.H.P. Kleiss. e-Print Archive: hep-ph/0101094

2. M.C.M. rentmeester, *Applied Nucleon-Nucleon Partial-wave Analyses*, 21 May 2001. Advisor: Prof. dr. ir. J.J. de Swart

3. P. den Haan, *Aspects of QED renormalization in anti-de Sitter space*, 3 June 2001. Advisor: Prof. dr. C. Dullemond

Relevant developments at the university

In 2000, the EU program *Particle Physics Phenomenology at High Energy Colliders* was awarded, starting in August 2000 with a duration of 48 months. In 2001, Dr. W. Beenakker joined the group as UD with support from FOM programme FP31.

Specific research topics, 1998-2001.

The research topics in the Hth-N working group fall under the themes 'Phenomenology' and 'Quantum field theory'. Specifically we mention

- Discrepancy distributions: in numerical (Monte-Varlo or quasi-Monte Carlo) integration the *discrepancy, i.e.* the nonuniformity of the point set used governs the accuracy of the method. We have applied techniques from quantum field theory to compute the distribution of discrepancies for random point sets. This will enable a valid assessment of the quality of quasi-random point sets to be used in integration.

- Phase-space Monte Carlo algorithms: a set of MC algorithms (`SARGE`) was developed to model accurately the phase-space distribution of QCD antennae, thereby allowing the MC calculation of multijet production at high-energy colliders to be speeded up by a large factor.

- Multijet QCD: a program was developed that allows the computation of multijet production (up to at least 8 jets) in hadron collisions. This will be used for QCD studies and background studies at the LHC.

- Zero-dimensional field theories: these serve as both a pedagogical paradigm and as an approximation (static ultralocal limit) to realistic field theories. We have studied the validity of perturbation theory as a function of the complex values of the coupling constants, explicit solutions, and *recursive models* in which, for instance, higher-order corrections to certain amplitudes vanish beyond the one-loop order.

1.5 Universiteit Utrecht (UU): FOM-U-01

Staff	appointment dates	employed by	topic
prof. Dr. B. de Wit		UU	
prof. dr. G. 't Hooft		UU	
prof. dr. J.A. Tjon		UU	
prof.dr. E.P. Verlinde	till 2000	UU	
dr. S. Vandoren		UU	
dr. R. Loll		UU	
dr. N. Obers	1/7/2000 - 1/4/2002	FOM springplank	
Postdocs/visitors	**appointment dates**	**employed by**	**topic**
dr. V. Shevchenko	1/07/2001-1/7/2003	FOM FP31	
dr. S. Stanciu	1/10/1999-1/10/2001	FOM FP31	D-branes
dr. J. Barbon	1998-1999	NWO	
dr. D. Berman	1998-2000	EU	M-theory 5-brane
dr. G. Cardoso	1998-2000	EU/UU	supergravity/string theory
dr. M. O'Loughlin	1998-2000	NWO	
dr. Y. Lozano	1998-1999	UU	
dr. S. Massar	1997-1998	UU	quantum information theory
dr. H.J. Matschull	1996-1998	UU/EU	3-dim gravity
dr. M.K. Parikh	1998-2000	NWO/UU	
dr. K. Skenderis	1998-1999	NWO	
dr. S.N. Solodukhin	1998-2000	UU	
dr. A.E.M. v.d. Ven	1998-2000	UU	
dr. H. Anastopoulos	2001-2003	EU	Quantum gravity
dr. A. Sinkovics	2000-2000	UU	
dr. G. Arcioni	2001-2003	UU	
dr. G. Bonelli	1999-2001	NWO	branes/gravity
dr. A.M. Boyarsky	1999-2001	UU	branes/gravity
dr. B. Körs	2001-2003	NWO	
dr. J.F. Morales Morera	2000-2002	EU	
dr. M.K. Parikh	2001-2003	NWO/UU	branes/gravity
dr. H. Samtleben	2001-2003	UU	
dr. M.M. Taylor-Robinson	2001-2003	NWO	
dr. U. Theis	2001-2003	DFG	
dr. M. Trigiante	2000-2002	EU	D-branes
dr. S. de Haro	2001-2003	UU	
Ph.D. students	**appointment dates**	**employed by**	**topic**
drs. B.J.K. Kleijn	1/9/1994 - 1/9/1998	FOM Hth-U	supergravity
drs. V. Pascalutsa	1/9/1994 - 1/9/1998	FOM Hth-U	πN interaction
drs. G.A.P.T. Aarts	1/10/1995 - 1/10/1999	FOM FP31	baryogenesis
drs. J. Weda (oio)	1/9/1999 - 1/9/2003	FOM FP31	confinement in mesons
drs. J. Käppeli	1/4/1999 - 1/4/2003	FOM FP31	supersymmetry
drs. G.T.J. Zwart	1995-1999	FOM	extended objects in string th.
drs. C.M. Hofman	1996-2000	FOM MF	duality
drs. M. Holman	1/11/1999 - 1/11/2003	FOM PR/UU	
drs. I. Herger	1998-2001	EU/UU	supergravity and AdS/CFT
drs. I.L. Savonije	1998-2002	NWO	holography/cosmology
drs. B.J.W. van Tent	1998-2002	UU	cosmology
drs S. de Haro	1997-2001	UU	Black holes
drs. Z. Kadar	2001-2005	UU	
drs. S. Nobbenhuis	2001-2005	UU	

[1)] ERBCHBGCT940690, Physics at every scale. Coordinator: Universiteit Utrecht (J.E. van Himbergen).

Responsible scientist: G. 't Hooft. Duration: 1-12-94/1-3-98
[2)] ERBCHRXCT940621, Gauge theories in elementary particle physics and gravitation. Coordinator: Foundation for Research and Technology-Hellas, Crete (E.N. Economou). Responsible scientist: G. 't Hooft. Duration: 1-1-95/31-12-98
[3)] INTAS-contract: 96-0308, Quantum structure of gauge theories and extended supersymmetry. Coordinator: Univ. of London, King's College (P. Howe). Responsible scientist: B. de Wit. Duration: 1-10-97/1-10-99
[4)] ERBFMRX-CT96-0045, Quantum aspects of gauge theories, supersymmetry and unification. Coordinator: Katholieke Universiteit Leuven, België (A. Van Proeyen). Responsible scientist: B. de Wit. Duration: 1-9-96/1-9-00

Ph.D. degrees awarded in Utrecht (UU), 1998-2001.

1. Kleijn, B.J.K.: New couplings in $N = 2$ supergravity. Promotor: B. de Wit. Utrecht, May 25, 1998.

2. Pascalutsa, V.: Covariant description of pion-nucleon dynamics. Promotor: prof.dr. J.A. Tjon. Utrecht, October 19, 1998.

3. Peeters, K.: Geometrical aspects of supersymmetry. Spinning particles, string dualities and the eleven-dimensional supermembrane. Promotor: B. de Wit. Utrecht, June 3, 1998.

4. Welling, M.: Classical and quantum gravity in 2+1 Dimensions. Promotor: G. 't Hooft. Utrecht, January 19,1998.

5. Aarts, G.A.P.T.: *Dynamics in equilibrium and nonequilibrium quantum field theory*, Promotor: prof.dr. J. Smit. Utrecht, October 4, 1999.

6. Zwart, G.T.J.: *String perspectives on gauge theories.* Promotor: prof.dr. E.P. Verlinde, Utrecht, November 29, 1999.

7. Hofman, C.M.: *Strings, Matrices, and Noncommutative Gauge Theory.* Promotor: prof. dr. E.P. Verlinde, Utrecht, September 19. 2000.

8. Haro Ole, S. de: *Quantum gravity and the holographic principle (type I).* Advisor: prof. dr. G. 't Hooft, Utrecht, Juni 18. 2001.

Relevant developments at the university

The theoretical high-energy physics activities are carried out in the context of the program *Quantum Gravity, Strings and Supersymmetry* of the Spinoza Institute and the program *Quantum Gravity, Strings and Elementary Particles* of the Institute for Theoretical Physics. Both Institutes belong to the Department of Physics and Astronomy of Utrecht University.

Some developments (Nobel prize, Erik Verlinde, ...)

Specific research topics, 1998-2001.

The research topics in the FOM program Fundamental Interactions cover all three themes 'Quantum gravity and string theory', 'Quantum field theory' and 'Phenomenology'.

1.6 Vrije Universiteit Amsterdam (VUA): FOM-V-01

Staff	dates	employer	topic
Prof. Dr. P.J. Mulders	since 01/01/1998	VUA	
Dr. B.L.G. Bakker		VUA	
Dr. D. Boer	since 01/07/2001	KNAW	
Postdocs/visitors	**dates**	**employer**	**topic**
Dr. A. Metz	01/09/2000-01/12/2001	EU-IHP[2)]	Chiral symmetry and
	01/12/2001-01/07/2002	FOM FP31	fragmentation functions
Dr. R. Kundu	01/10/2000-01/12/2001	FOM FP31	Lightcone field theory
Dr. M. Boglione	15/10/1997-15/02/1999	EU-TMR[1)]	Deep inelastic scattering
	16/02/1999-01/07/2000	FOM 98PR1714	and azimuthal asymmetries
Prof. Dr. E. Leader	1998 - 2002	FOM 98PR1714	Deep inelastic scattering
Dr. B. Krippa	01/03/1999-31/05/2001	FOM 98PR1714	Chiral symmetry
		Russian Academy	
Dr. J.G. Milhano	01/10/2001-01/10/2003	VUA	Low x/Phases of QCD
Ph.D. students	**dates**	**employer**	**topic**
Drs. N. Schoonderwoerd	15/12/1995-01/03/1999	FOM Hth	Lightcone field theory
Drs. M. van Iersel	01/08/1999-01/08/2003	FOM FP31	Lightcone field theory
Drs. A. Bacchetta	01/11/1998-01/11/2002	FOM 98PR1714	Transverse spin polarization
Drs. A. Henneman	01/10/1996-01/08/2001	VUA	Evolution and transverse momentum
Drs. J. Rodrigues	1994 - 1998	external[3)]	Gluon correlations in DIS
Drs. F. Pijlman	01/11/2001-01/11/2005	VUA	DIS/intrinsic transverse momentum
Drs. H. Warringa	01/12/2001-01/12/2005	VUA/USF	Phases of QCD

[1)] EU-TMR HAPHEEP: ERBFMRX-CT-96-0008, TMR Research Network (EU), Hadronic Physics with High Energy Electromagnetic Probes. Coordinator J.-M. Laget, Saclay, France. Responsible physicist: P.J. Mulders

[2)] EU-IHP ESOP: HPRN-CT-2000-00130, IHP Research Network (EU), Electromagnetic Scattering off Confined Partons. Coordinator J.-M. Laget, Saclay, France. Responsible physicist: P.J. Mulders

[3)] supported by the University of Lisbon and PRAXIS programme.

Ph.D. degrees awarded in Amsterdam (VUA), 1998-2001.

1. D. Boer, *Azimuthal asymmetries in hard scattering processes*, 15 Sep 1998, Vrije Universiteit. Promotor: Prof. dr. P.J.G. Mulders.

2. N.C. Schoonderwoerd, *Light front hamiltonian field theory; towards a relativistic description of bound states*, 14 Jan. 1999, Vrije Universiteit. Promotor: Prof. dr. P.J.G. Mulders; copromotor: Dr. B.L.G. Bakker.

3. J. Rodrigues, *Modelling quark and gluon correlation functions*, 16 Oct. 2001, Vrije Universiteit. Promotor: Prof. dr. P.J.G. Mulders.

Relevant developments at the university

The theoretical high-energy physics activities at the VU are part of the Theoretical Physics department within the Division of Physics and Astronomy. In 1999 the university has approved a proposal of Prof. Mulders to initiate studies on *Phases of QCD*. This program has started recently and is performed in collaboration with Dr. D. Boer, who has been appointed as a KNAW fellow in 2001.

Specific research topics, 1998-2001.

In VU theory group working in particle physics, a number of topics are addressed belonging to themes 'Quantum field theory' and 'Phenomenology'.

- Deep inelastic scattering processes. The emphasis of the group is on the inclusion of effects of parton intrinsic transverse momentum. This gives rise to azimuthal asymmetries, in particular in polarized processes. For this a detailed analysis of quark distribution and fragmentation functions in polarized hadrons has been made.
- Lightcone quantization. Quantization in the front form is in principle equivalent to instant form quantization. In practice many details remain to be studied. For QCD front form quantization may be a promising route, because the wave functions in the hamiltonian formulation can be directly connected to the quark distribution functions in deep inelastic scattering.
- The study of phases in QCD, that may have played a role in early-universe physics, is a research line that has just started in 2001.

2 FOM programme 52 at NIKHEF[1)]

Staff	dates	employer	
Prof. Dr. J.W. van Holten		NIKHEF/FP52	
Prof. Dr. J. Koch		NIKHEF/FP52	
Prof. Dr. E. Laenen		NIKHEF/FP52	
Prof. Dr. A.N. Schellekens		NIKHEF/FP52	
Dr. J.A.M. Vermaseren		NIKHEF/FP52	
Postdocs	**dates**	**employer**	**topic**
dr. J. Plefka	1996-1998	NIKHEF/FOM	String th. & supergravity
dr. A. Waldron	1997-1999	NIKHEF/FOM	String th. & supergravity
dr. S. Moch	1997-2000	NIKHEF/FOM	Phen. & QCD
dr. S. Weinzierl	1998-2000	NIKHEF/FOM	Phen. & QCD
dr. V. Pascalutsa	1998-1999	NIKHEF/FOM	Phen. & hadron physics
dr. K. Schalm	1999-2001	NIKHEF/FOM	String th. & supergravity
dr. M. Zhou	2000-2002	NIKHEF/FP52	Phen. & QCD
dr. A. Vogt	2001-2003	NIKHEF/FP52 and FP7[2)]	Phen. & QCD
dr. F. Riccioni	2001-2003	NIKHEF/FP52	Supersymmetry & supergravity
Ph.D. students	**dates**	**employer**	**topic**
L. Haakman	1994-1998	NIKHEF/FOM	Phen. & QCD
S. Groot Nibbelink	1997-2000	NIKHEF/FOM	Supersymmetry & supergravity
T.O. Eynck	1998-2002	NIKHEF/FOM	Phen. & QCD
T.S. Nyawelo	2000-2004	NIKHEF/FP52	Supersymmetry & supergravity
J. van der Heide	2000-2004	NIKHEF/FP52	Finite temp. QCD & Phen.
K. Peeters	1994-1998	FOM 94BR1253	String th. & supergravity
D. Boer	1994-1998	FOM 94BR1217	Phen. & QCD
L. Huiszoon	1998-2002	FOM 97MF02/03	String th.
N. Sousa	1998-2002	Min. Science Portugal[3)]	String th.
L. Phaf	1999-2003	NIKHEF/FP7[2)]	Exp. & QCD
M. Lutterot	1999-2001	NIKHEF/FP21[2)]	Finite temp. QCD & Phen.
A. Fuster	2001-2005	Basque Min. Educ.[4)]	Supersymmetry & supergravity
Visitors	**year**	**financial support**	
E. Laermann (Bielefeld)	1999, 2000	NIKHEF/FP52 and FP21[2)]	
J. Smith (SUNY)	2000	NIKHEF/FOM	
A. Mueller (Columbia)	2000	NIKHEF/FOM	
P. Yndurain (Madrid)	2001	NIKHEF/FP52	
P. Horvathy (Tours)	2001	NIKHEF/FP52	
P. Jarvis (Tasmania)	2001	NIKHEF/FP52	
M. Veltman	(perm.)	NIKHEF/FP52	

[1)] The programme provides the complete support for staff, research and infrastructure of the NIKHEF Theory Group.

[2)] FP7 is the experimental ATLAS programme, FP21 the ALICE programme.

[3)] Fundação para a Ciência e Technologia

[4)] Depart. de Educación. Universidades e Investigación

Ph.D. degrees awarded in NIKHEF Theory Group 1998-2001.

1. K. Peeters, *Geometrical Aspects of Supersymmetry*, June 1998, Univ. Utrecht; promotor: Prof. Dr. B. de Wit, co-promotor: Dr. J.W. van Holten.

2. L.P.A. Haakman, *QCD Aspects of the Pomeron: from soft to hard scales*, June 1998, Univ. of Amsterdam; Promotor: Prof. Dr. J. Koch.

3. D. Boer, *Azimuthal Asymmetries in hard Scattering Processes*, Free Univ. Amsterdam, September 1998; Promotor Prof. Dr. P.J. Mulders.

4. S. Groot Nibbelink, *Supersymmetric non-linear Unification in Particle Physics*, Free Univ. Amsterdam, November 2000; Promotor: Prof. Dr. J.W. van Holten.

Relevant developments at the NIKHEF institute

Several NIKHEF scientists hold special chairs at one of the universities, where they contribute to teaching and research. In theoretical physics van Holten is associated with the Free University (VUA), Koch with the university of Amsterdam (UvA), Laenen with the university of Utrecht (UU), and Schellekens with the university of Nijmegen (KUN).

The NIKHEF Theory Group is instrumental in the context of the total NIKHEF programme by direct contributions to the physics analysis of some experiments, by advising on scientific issues, by active involvement in the development of the scientific programme of the institute, and by participation in academic training programmes.

NIKHEF Research Programme 1998-2001

The research of the NIKHEF Theory Group covers a broad range of subjects from hadron structure, QCD and supersymmetry to string theory, with an emphasis on particle physics phenomenology. The main topics are summarized here.

- *QCD: physics of the standard model and beyond*
  Work in QCD centers around high-order perturbation theory and its applications to phenomenology. We mention three projects in particular:
  a. The precision of present day collider experiments requires NNLO calculations in QCD to match theory with experiments. To carry out accurate tests of the standard model and search for signals of new physics at the Tevatron and LHC, a precise knowledge of the running coupling $\alpha_s(\mu^2)$ and the parton densities inside the nucleon is mandatory. The calculations necessary to determine the nucleon structure functions to the required level of precision involve huge numbers (thousands) of Feynman diagrams, and can only be performed using the most sophisticated computer algebra techniques available. The programme FORM developed by Vermaseren represents the state of the art, and is the de facto world standard for calculations in high-energy physics. In collaboration with S. Moch, A. Vogt and M. Botje he is involved in a project to develop a complete new set of parton distribution functions in NNLO meeting the highest standards for the LHC.
  b. Resummation techniques allow to go one step beyond perturbation theory, or to improve perturbation theory when large radiative corrections are present which do not become negligeable at any order of perturbations theory. In particular, the effect of soft gluons and long-range correlations are taken into account by Sudakhov-resummation of large logarithms factorizing in cross sections and decay rates. Laenen and co-workers have developed such techniques for various processes, including $\bar{t}t$ production at NLO in proton collisions, and the electroproduction of charm to NNLO. They lead to markably improved results, such as strongly reduced scale-dependence of cross sections and better control over tranverse momentum effects.
  c. To relate theoretical calculations with experimental data, it is important to develop Monte Carlo programs for the calculation of event distributions of various types. At NIKHEF Laenen c.s. (Weinzierl, Phaf, Eynck) have developed NLO Monte Carlo generators for heavy quark production in photon and ep collisions, as well as for single top production in pp-scattering. The latter one is

presently being integrated in the D0-experiment and will allow the determination of top couplings in the CKM matrix.

- *Hadrons at finite temperature*
  The transition between the confined and unconfined phases of QCD is preceded by a transition region in which the structure of hadrons changes: a 'melting' process in which the size increases and partons can move more freely at large distances. To investigate these processes, Koch has initiated a programme to study hadron form factors at finite temperature. The lattice calculations on which these studies are based are carried out in collaboration the university of Bielefeld (E. Laermann).

- *Supersymmetry*
  a. Supersymmetry appears in many guises; in field theory it can be used as a Bose-Fermi symmetry to extend the standard model, directly or in a gauge unification scenario. In supergravity it is elevated to the status of a local symmetry. As the unification scale is supposedly close to the Planck scale, both linear and non-linear gauge-unification scenarios can be incorporated in a supergravity frame work. Consistency of such scenarios depends on the cancellation of anomalies; van Holten and co-authors have found a way to circumvent previous no-go theorems in this context allowing anomaly matching in non-linear unification schemes based on Kaehler coset spaces like $SO(10)/SU(5)\times U(1)$ or $E_6/SO(10)\times U(1)$.
  b. Supersymmetries also arise in the context of the quantum mechanics of spinning particles and strings; in certain non-trivial background fields, associated with monopoles, instantons or black holes, non-standard supersymmetries can be realised, first discovered jointly by Gibbons, Rietdijk and van Holten. This work has been extended and applied to various systems; it has also inspired work to find an expression for anomalies in space-times with torsion and non-trivial boundaries (Peeters and Waldron).

- *Open string theory*
  String theory is the main candidate for a theory of quantum gravity, and is expected to include all other matter and interactions as well. Its most successful description is based on a perturbative expansion in terms of conformal field theories on Riemann surfaces. This formalism is relatively well-developed for closed strings (closed oriented Riemann surfaces), but faces interersting new challenges for surfaces with boundaries and without orientation. This results in new states in the conformal field theory that correspond geometrically to D-branes and O-planes; these have been shown to open up new avenues in string phenomenology. Schellekens and his students study this formulation of conformal field theory, with special emphasis on features related to non-orientable surfaces such as the Klein bottle and the Möbius strip. This work will be continued in the context of the FOM-programme *Strings and Quantum Gravity* (FP57).

- *Classical gravity*
  Classical gravity and cosmology are sidelines of theoretical research at NIKHEF. Van Holten has studied exact gravitational-wave solutions and perturbative expansions for geodesic motion in gravitational background space-times. Groot-Nibbelink and van Tent (UU) have developed a theory of cosmological scalar fields and fluctuations in the CMBR in the context of supersymmetry.

A Contributions in FOM year reports for FP31

B Contributions in FOM year reports for FP52

C Publications

C.1 Publications FOM-A-01

1. G. Aarts and J. Smit, *Classical Approximation for Time Dependent Quantum Field Theory: Diagrammatic Analysis for Hot Scalar Fields*, Nucl. Phys. B511 (1998) pp. 451-478.

2. F.A. Bais, N.M. Muller, *Topological field theory and the quantum double of SU(2)*, Nucl. Phys. B530 (1998) 349-400.

3. F.A. Bais, B.J. Schroers, *Quantization of monopoles with nonAbelian magnetic charge*, Nucl. Phys. B512 (1998) 250-294.

4. F.A. Bais, et al., (ed), *Strings*, Proceedings International Conference "Strings'97", Amsterdam, the Netherlands, June 16-21, 1997, Nucl. Phys. B, Proc. Suppl. 68 (1998) 397 .

5. S. Bilke, Z. Burda, A. Krzywicki, B. Petersson, G. Thorleifsson, *4-D Simplicial Quantum Gravity unteracting with Gauge Matter Fields*, Phys.Lett. 418B (1998) 266-272.

6. S. Bilke, Z. Burda, A. Krzywicki, B. Petersson, G. Thorleifsson, *4-D Simplicial Quantum Gravity: Matter Fields and the corresponding effective action*, Phys.Lett. 432B (1998) 279-286.

7. R. Dijkgraaf, H. Verlinde and E. Verlinde, *Notes On Matrix And Micro Strings*, Nucl. Phys. Proc. Suppl. 67 (1998) 225-250 and Nucl. Phys. Proc. Suppl. 68 (1998) 28-54.

8. *Les Houches Lectures on Fields, Strings and Duality,* in "Quantum Symmetries," Les Houches LXIV, 1995, Eds. A. Connes, K. Gawedzki, J. Zinn-Justin Elsevier, Amsterdam, 1998, 3–147, hep-th/9703136.

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10. L.P.A. Haakman, A.B. Kaidalov and J.H. Koch, *Charm production in deep inelastic and diffractive scattering*, Eur. Phys. Journal C1 (1998) 547-561.

11. C.M. Hofman and J.-S. Park, *Monads, Strings, M-Theory*, Nucl. Phys. B 520 (1998) 229-260.

12. J.H. Koch, H.R. Mall and S. Lenz, *Stochastic methods for zero energy quantum scattering*, Comp. Phys. Communications 108 (1998) 115-146.

13. T.H. Koornwinder, F.A. Bais, N. Muller, *Tensor product representations of the quantum double of a compact group*, Commun. Math. Phys. 198 (1998) 157-186.

14. B.J. Nauta and Ch.G. van Weert, *Time Dimensional Reduction in Thermal Field Theory*, Proceedings of the 5th International Workshop on Thermal Field Theories and Their Applications, U. Heinz (ed.), hep-ph/9811469, 1998.

15. B.J. Schroers, F.A. Bais, *Charge sectors and S duality in SU*(3) *Yang-Mills theory with non-abelian unbroken gauge group*, Nucl. Phys. B535 (1998) 197-218.

16. J. Smit, *Classical Approximation for Time Dependent Quantum Field Theory: Diagrammatic Analysis for Hot Scalar Fields, Proceedings of the conference Strong and Electroweak Matter*, F. Csikor and Z. Fodor eds. (World Scientific 1998) pp. 284-288.

17. J. Smit, *Real Time Simulations and the Electroweak Phase Transition*, Proceedings of Lattice 97: 15th International Symposium on Lattice Field Theory, Nucl. Phys. (Proc. Suppl.) 63 (1998) pp. 89-94.

18. W.H. Tang and J. Smit, *Numerical Study of Plasmon Properties in the SU(2) Higgs Model*, Nucl. Phys. B510 (1998) pp. 401-420.

19. H. Verlinde, *Five-branes and Matrix Strings*, Nucl.Phys.Proc.Suppl. 62 (1998) 348-362.

20. G.A.P.T. Aarts and J. Smit, *Real time dynamics with fermions on a lattice*, Nucl. Phys. B555 (1999) 355-394.

21. G.A.P.T. Aarts and J. Smit, *Dynamics of fermions and inhomogeneous Bose fields on a spacetime lattice*, in: Proc. of Strong and Electroweak Matter '98, NORDITA and Niels Bohr Institute, Copenhagen, Denmark, December 2-5, 1998, World Scientific Publ., Singapore (1999) 168-172.

22. M. Berkooz and H.L. Verlinde, *Matrix Theory, AdS/CFT and Higgs-Coulomb Equivalence*, hep-th/9907100, JHEP 9911 (1999) 037.

23. S. Bilke and G. Thorleifsson, *Simulating four-dimensional simplicial gravity using degenerate triangulations*, Phys. Rev. D59 (1999) 124008-124012.

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25. S. Bilke, Z. Burda, A. Krzywicki, B. Petersson, K. Petrov, J. Tabaczek and G. Thorleifsson, *The strong-coupling expansion in simplicial quantum gravity*, Nucl. Phys. Proc. Suppl. 73 (1999) 798-800.

26. R. Dijkgraaf, *Fields, strings, matrices and symmetric products*, in: Proceedings of the Conference 'Moduli of curves and abelian varieties', Vieweg, Braunschweig, Duitsland, 1999, pp. 151-199.

27. R. Dijkgraaf, *Instanton strings and hyper-Kähler geometry*, Nuclear Phys. B 543 (1999) 545-571.

28. S.B. Giddings, F.H. Hacquebord and H.L. Verlinde, *High Energy Scattering and D-pair Production in Matrix String Theory*, Nucl.Phys. B537 (1999) 260-296.

29. F.H. Hacquebord, *Symmetries and Interactions in Matrix String Theory*, promotor prof.dr. H.L. Verlinde, Universiteit van Amsterdam, Amsterdam, September 22, 1999, 120p.

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31. T. H. Koornwinder, B. J. Schroers, J. K. Slingerland and F. A. Bais, *Fourier transform and the Verlinde formula for the quantum double of a finite group*, [math.qa/9904029], J. Phys. A: math.gen. 32 (1999) 8539-8549.

32. J.-S. Park, *Cohomological Field Theories on Complex Manifolds*, promotor prof.dr. H.L. Verlinde, Universiteit van Amsterdam, Amsterdam, November 23, 1999, 165p.

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38. G. Aarts and J. Smit, *Particle Production and Effective Thermalization in Inhomogeneous Mean Field Theory*, Phys.Rev. D61 (2000) 025002-105027.

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40. G. Arcioni, J.L.F. Barbón, J. Gomis and M.A. Vazquez-Mozo, *On the stringy nature of winding states in noncommutative thermal field theories*, hep-th/0004080, JHEP 0006 (2000) 038.

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