D.Yu. BARDIN, OBITUARY: RCforGV, DIZET, TERAD, TERADlow, NUDIS1, NUDIS2, HECTOR, polHECTOR, μela, GENTLE/4fan, ZFITTER, SANC, MCSANC.

A.A. Sapronov **L.V. Kalinovskaya**

Laboratory for Nuclear Reactions,

Joint Institute for Nuclear Research,

Dubna, Russia

2018

Dmitry Yurievich Bardin (19.04.45 - 30.06.17)

On June 30, 2017 the distinguished scientist Professor **Bardin Dmitry Yurievich**, Doctor of Physical and Mathematical Sciences, working at the Department of Colliding Beams of the Laboratory of Nuclear Problems of the Joint Institute for Nuclear Research, Dubna, Russia passed away.

Citations summary

837 papers found, 754 of them citeable (published or arXiv)

Renowned papers (500+)	19
Famous papers (250-499)	28
Very well-known papers (100-249)	121
Well-known papers (50-99)	223
Known papers (10-49)	284
Less known papers (1-9)	67
Unknown papers (0)	12

hHEP index 126

1968, Moscow State University

Dmitry Yu. Bardin graduated the Moscow State University with honors in 1968.
Graduate thesis in JINR; supervisor: **Prof. S.M. Bilenky**.
Started research work at JINR.

1968-1974

First scientific interests of D.Yu. Bardin were devoted to elastic pion-electron scattering and rare decays of pions and kaons.
Collaboration with **S.M. Bilenky, N.M. Shumeiko** and **G.V. Mitselmakher**.
The results of the calculation of radiative corrections were used in the analysis of data of the Soviet-American collaboration and NA-7 collaboration for the study of the electromagnetic form factor of the pion.

Based on these results, in 1974 **Dmitry Yurievich** defended his Ph.D. thesis under the guidance of Professor S.M. Bilenky.

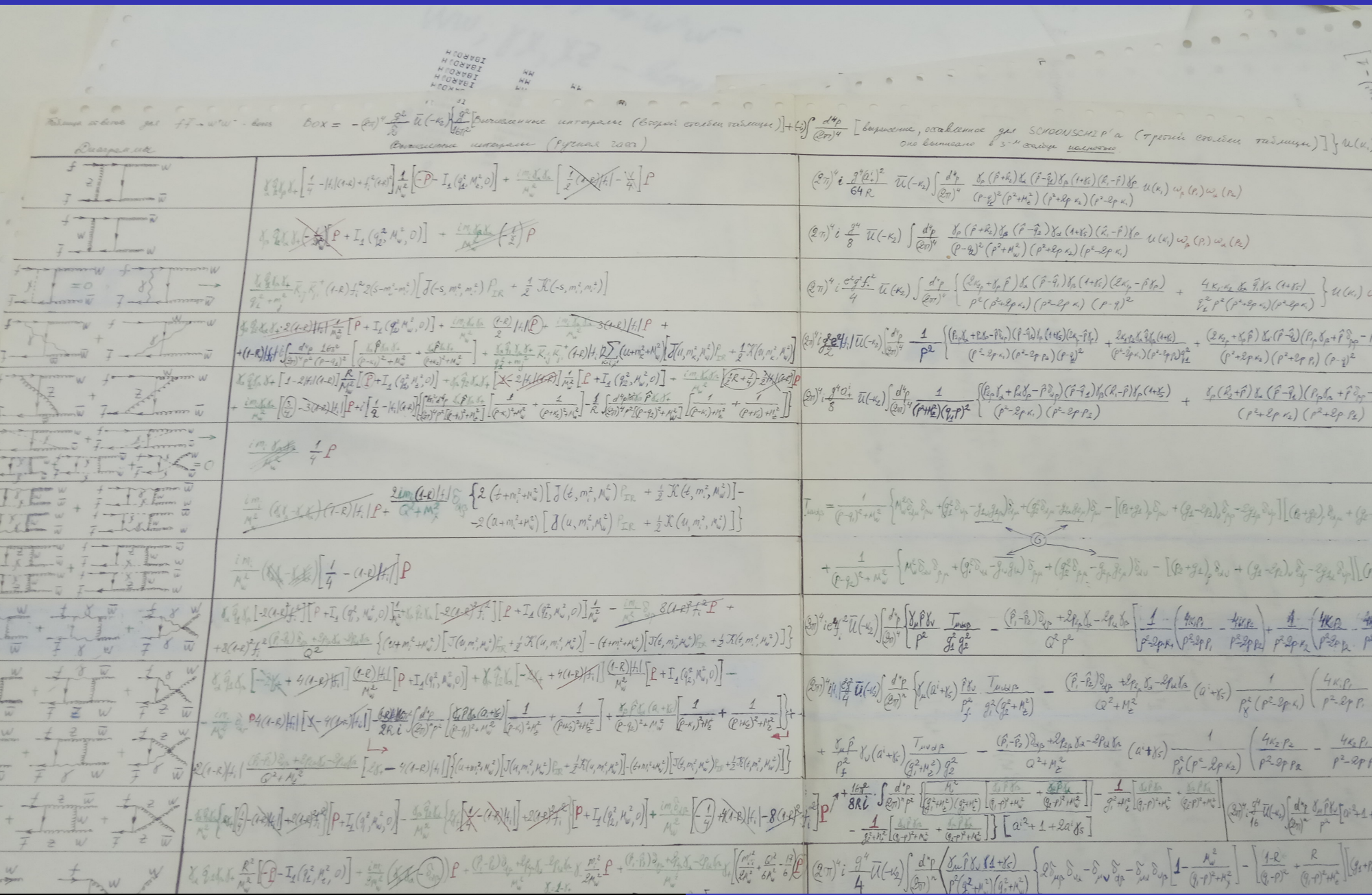
1974 - 2017

In 1974 **D.Yu. Bardin** started to work independently.
Since then, all the scientific work of **Dmitry Yurievich Bardin** was devoted to the phenomenology of elementary particle physics, precision physics, calculation of electroweak and QCD radiative corrections in the framework of the Standard Model for experiments at LEP1, LEP2, ILC, HERA, SPS and LHC.

1974-1980

At that time, **Dmitry Yurievich started complete calculations** of the electroweak radiative corrections (**EWRC**) in the Standard Model (SM). This work was performed together with **O. Fedorenko** (1951-1994) and **P.Ch. Christova** (1943-2016).
They developed a self-consistent on-the-mass-shell renormalization procedure in the unitary gauge.

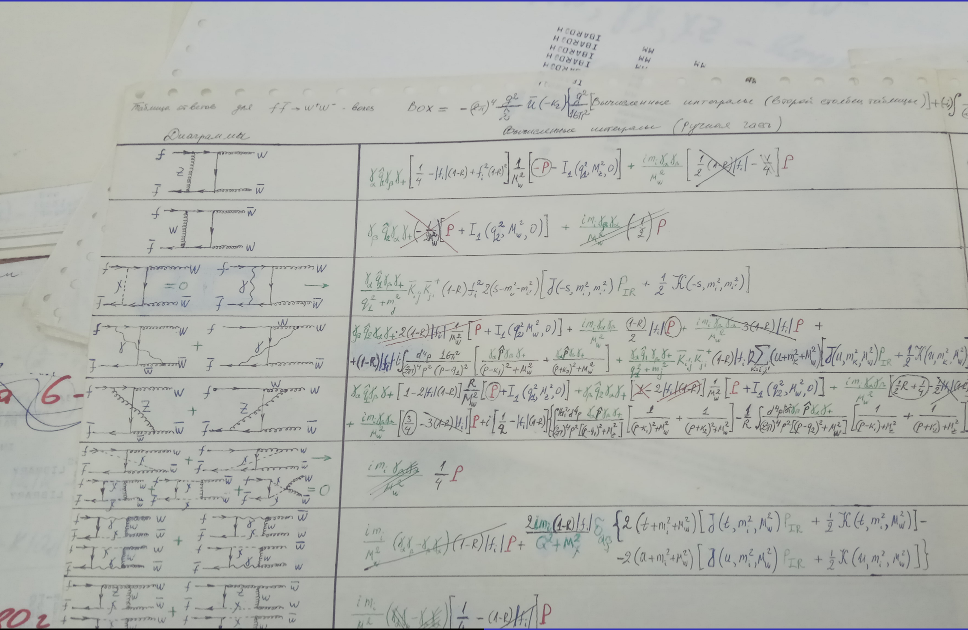
HOW IT WAS

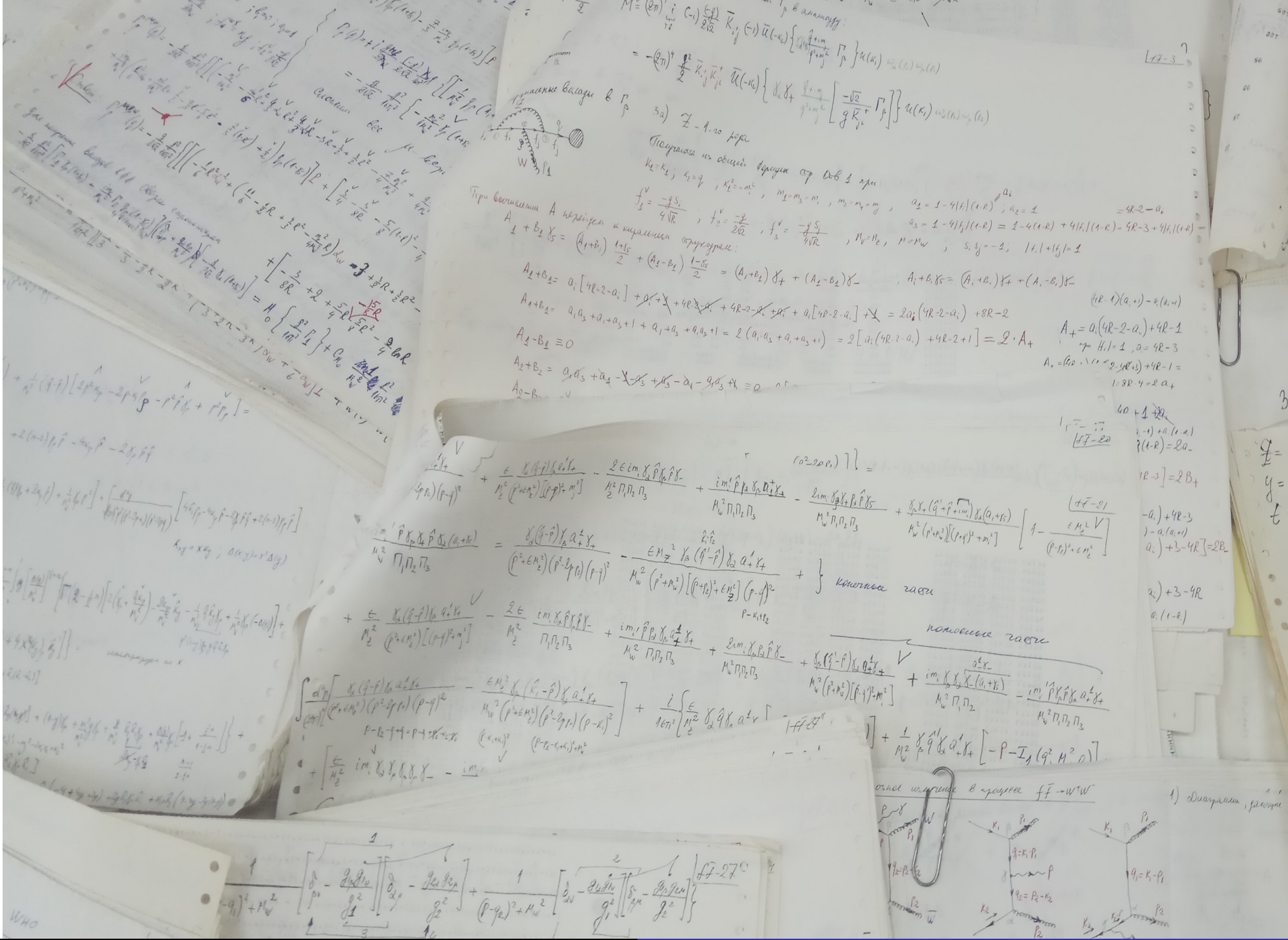


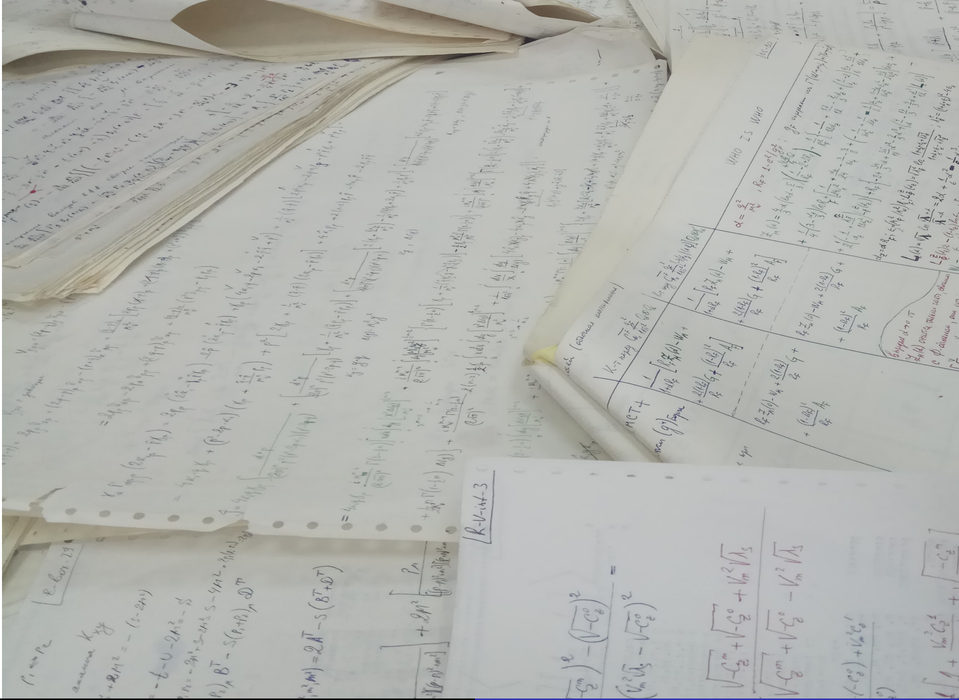
A.A. Sapronov, L.V. Kalinovskaya

D.Yu. BARDIN, OBITUARY

HOW IT WAS






WHO IS WHO

1974 -1980

Dmitry Yurievich together with **N.M. Shumeiko** and **A.A. Akhundov** developed a semi-analytical formalism for the calculation of QED corrections to deep inelastic scattering of charged leptons and neutrinos on nucleons and nuclei.
The latter was motivated by the needs of CERN experiment NA4 (BCDMS collaboration), which was approved around that time and in which some JINR experimental groups were heavily involved.

1980 -1984

In 1980 **D.Yu. Bardin** with colleagues were performing a calculation of QED RC to deep inelastic scattering of the charged leptons and neutrinos on nucleons and nuclei.
The applications of these complete radiative corrections in the Standard Model were done in close cooperation with deep-inelastic scattering experiments at CERN: BCDMS, NMC, CHARM-I, CDHSW, and later with CHARM-II in elastic neutrino-electron scattering.

Pena Christova Christova

Since 1979 and throughout his further scientific career, **Dmitry Yurievich** collaborated with **Pena Christova Christova (1943-2016)** from the Academy of Sciences of the Republic of Bulgaria.
She was really great, a hard worker, good physicist and friend. We were always impressed by her happiness and the kind of independence she had.

Pena Christova Christova

Tord Riemann

Since 1983 **Dmitry Yurievich** collaborated with **Tord Riemann** from Germany (Institute for High Energy Physics of the Academy of Sciences and after 1989 DESY, Zeuthen), who had spent four years in JINR: from September 1983 to September 1987.

1980 -1984

During these years they laid the foundation of long-term collaboration, which would later be known as the the Dubna-Zeuthen Radiative Corrections Group – DZRCG:**D. Bardin, A. Akhundov, A. Arbuzov, M. Bilenky, P. Christova, L. Kalinovskaya, T. Riemann, J. Biebel, M. Jack, D. Lehner, A. Leike, S. Riemann, M. Sachwitz.**

The great support of the Directorate of the institutes JINR-DESY and especially the director DESY Zeuthen - **Paul Söding** should be noted.

1984-1986

In these years they laid the grounds of the future **ZFITTER** project. They continued collaboration with several experimental groups. With different groups of authors **Dmitry Yurievich** was rewarded in the years 1984-1987 with four sequential first prizes of the Joint Institute for Nuclear Research.

Dmitry Yurievich Bardin

In 1987-1989, **Dmitry Yurievich's** scientific activity was devoted to the physics of LEP1. The DZRCG group took part in the workshop "Z Physics at LEP1“ in 1989, they had published a lot of papers on Z - resonance physics.

Together with **W. Hollik, B. Ward, T. Riemann and R. Kleiss** **D.Yu. Bardin** gave a course of lectures on "Radiation corrections for experimentalists"at CERN.

1989-1991

This period saw the completion of the **ZFITTER** project. The DZRCG took an active part in the Workshop on "Physics at HERA", DESY, 1990-1991. Within this Workshop the code TERAD91 was created, which was used later for the analysis of the first data from the HERA detectors.

1991-1994

From August 1991 **Dmitry Yurievich** stayed continuously at CERN for three years: two years for DELPHI experiment and in 1994 PA position at CERN TH. Some investigation results were presented at following Workshops:

- DELPHI Workshop on LEP2, 1992
- LEPC Workshop on LEP2, 1992
- DELPHI Workshop on LEP2, 1992
- Physics with *ee* linear collider at 500 GeV, Munich-Annecy-Hamburg, 1993

1995

Dmitry Yurievich, together with **W. Hollik and G. Passarino** coordinated, in the framework of the project LEP1, the work of the Precision Calculations Working Group at CERN. This group prepared and published a CERN Yellow Report 95-03 on LEP1 physics for CERN, which contains an analysis of the accuracy of calculations for the Z boson resonance.
Fifty-three scientists from eight countries had contributed to the report.

1991 - 1995

For LEP2 and NLC, together with **J. Biebel, M. Bilenky, A. Leike, D. Lehner and T. Riemann**, **Dmitry Yurievich** investigated four-fermion processes in e^+e^- annihilation. They calculated analytically the initial-state QED radiative corrections in a gauge-invariant manner for off-shell production W^+W^-. They performed complete analytic calculations of some four-fermion processes with all the "background" contributions. This four-fermion project was integrated into the LEP2 Workshop (1995) framework, where **Dmitry Yurievich** was one of conveners of the working group on event generators for the SM processes.

Dmitry Yurievich was the leader of the Working Group on Event Generators for Standard Model processes in LEP2 in 1995.

1993-1996

D.Yu. Bardin, in collaboration with **C. Burdik, P. Christova and T. Riemann**, calculated the complete semi-analytical electroweak corrections for deep inelastic *ep* scattering at HERA energies.
Together with **A. Arbuzov, J. Blümlein, L. Kalinovskaya, P. Christova and T. Riemann**, **Dmitry Yurievich** created in 1996 the software package **HECTOR** – for the calculation of deep inelastic scattering cross-sections of electrons and protons at HERA. This project includes model-independent calculations of radiative corrections in various variables for neutral and charged current scattering with unpolarized and polarized electrons. **HECTOR** comprises the well known codes **TERAD91** and **HELIOS** within one super-code, which is supposed to be **used in HERA collaborations** for an evaluation of QED, EW and QCD corrections to the deep inelastic scattering.

muela

A study of radiative corrections for μe polarized scattering with **L.Kalinovskaya** was completed for the SMC Polarimeter group at CERN.

project ZFITTER

The basis of the famous project **ZFITTER** was created from 1984 to 1986. The classical results of **D.Yu. Bardin** on the realistic description of the Z peak (together with **Misha Bilenky, G. Mizelmakher, Tord Riemann and Martin Sachwitz**), on the description of electroweak one-loop corrections to the decay of the neutral vector boson, (together with **Arif Akhundov** and **Tord Riemann**), and also the description of QED corrections in e^+e^- annihilation (together with **Misha Bilenky, Aleksei Chizhov, Andrey Sazonov, Oleg Fedorenko, Tord Riemann** and **Martin Sachwitz**) formed the basis of the project **ZFITTER**.

project ZFITTER

The **ZFITTER** project was the main LEP code for the LEP1 and LEP2 data analysis, and it is state of the art until now.
The authors of the main version **D. Bardin, A. Arbuzov, P. Christova, M. Jack, L. Kalinovskaya, A. Olshevsky, S. Riemann, T. Riemann** developed a unique, creative analysis tool.

The leaders of the project were **D.Yu. Bardin** and **T. Riemann**.
A huge, invaluable, painstaking work of support, both in physics and in programming laid on their shoulders for more than 25 years.

project ZFITTER

Together with **P. Christova** and **L. Kalinovskaya**, **Dmitriy Yurievich** actively participated in the work of two LEP2MC Workshops. The theoretical support for predicting the mass of the top quark and the mass of the Higgs boson was done using **ZFITTER**.
In the Nobel lecture of 2013 Peter Higgs has shown a world data fit. Its theoretical prediction of the mass of the Higgs boson relies on **ZFITTER**.

So far **ZFITTER** is **a basic software of the ATLAS and CMS collaborations for Z boson production**.

1999, book

Dmitry Yurievich made a decisive contribution to the development of techniques for calculating complete electroweak radiative corrections in the framework of the Standard Model.
In 1999, together with **Professor G. Passarino** D.Yu. Bardin published the fundamental monograph "The Standard Model in the Making, Precision Study of the Electroweak Interactions", which became a classic textbook on the technique of calculating one-loop radiative corrections and their extensive analysis.

2000, Habilitation

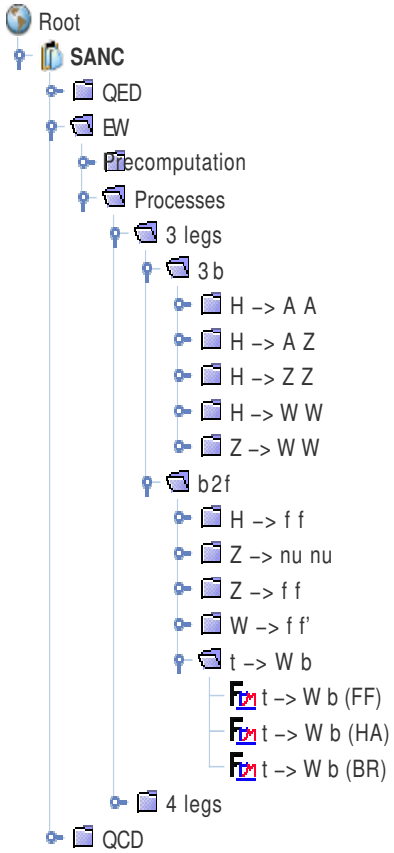
Habilitation. The fundamental monograph “The Standard Model in the Making, Precision Study of the Electroweak Interactions”,

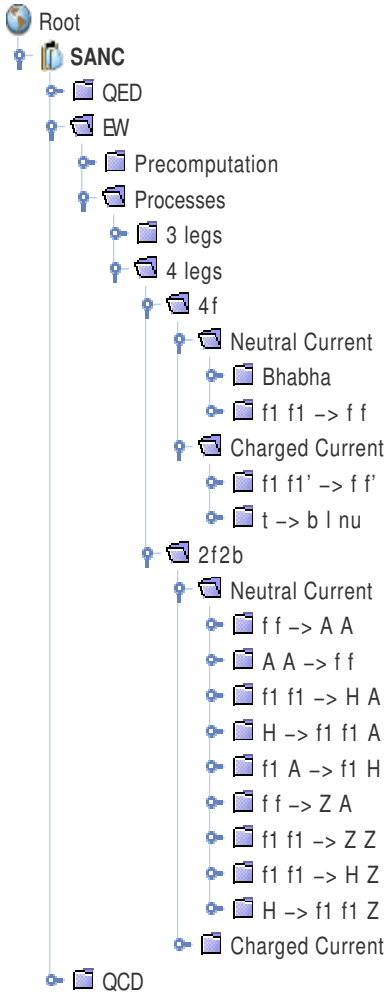
SANC: Support of Analytic and Numerical Calculations for Colliders

Since 2000 **D.Yu. Bardin** in collaboration with **A. Andonov, P.Ch. Christova, L.V. Kalinovskaya, V.A. Kolesnikov, L.A. Rumyantsev, R.R. Sadykov, A.A. Sapronov, E.D. Uglov,**
A.B. Arbuzov, S.G. Bondarenko, W. von Schlippe, T. Riemann, G. Nanava, Z. Was, Lucia Di Ciaccio, U. Klein, A. Glazov,
J. Kretzschmar created the software system **SANC** for calculations of QCD and electroweak radiative corrections in the framework of the Standard Model. The results of MC integrator `MCSANC` are actively used in the ATLAS collaboration at the LHC. Especially successful is the cooperation with **S. Jadach , Z. Was, W. Placzek, U. Klein**.

2000-2017, SANC

The SANC system deals with three models of elementary particle interactions – QED, EW and QCD. Processes for the EW branch are:





2000-2017, SANC

SANC tree:
Basic notions: precomputation, amplitudes, form factors

SANC application for selected processes:

- $t \to bl\nu$ decay
- $f_1 f_1 \to ZZ$
- Three channels of $f_1 f_1 HA \to 0$
- Three channels of $f_1 f_1 ZA \to 0$
- Two channels of $f_1 f_1 HZ \to 0$
- MC generator for $H \to 4\mu$ decay
- Drell Yan-like W and Z production: CC and NC Drell Yan processes distributions, QCD-EW interplay, Light pair corrections to Drell-Yan processes, Implementation HO corrections through $\delta\rho$.
- 4-boson study
- Auxiliary J functions

SANC, application to ATLAS

- MCSANC integrator
- EW corrections for ATLAS Drell Yan analysis
- Drell Yan processes: tuned comparison

2000-2017, SANC

Types of SANC Output Typical SANC outputs are:

• FORTRAN modules. These modules are available for general use in MC integrators and generators;

• Standalone MC generators: a) the generator for $t \to bl\nu$ decay; b) generators for NC and CC Drell–Yan processes;

c) generator for $H \to 4\mu$ decay in the single Z pole approximation;

• MCSANC integrator.

• Contribution to tuned comparison.

Les Houches Workshop, see Proceedings 2006,
TEVATRON for LHC Report, 2007,
and Precision studies of observables in $pp \to W \to l\nu_l$ and $pp \to \gamma, Z \to l^+l^-$ processes at the LHC, Report, 2017 .

2000-2017, SANC

As a result, the project solved most of the planned tasks. The results obtained by the participants have been presented in more than 50 publications in peer-reviewed journals and reported at international workshops and conferences. 10 diploma theses were defended for a bachelor's degree and 5 Master theses; 6 PhD theses were defended and 2 doctoral theses. All tasks of the project have been successfully performed in close co-operation with members of the ATLAS collaboration at CERN and DESY.

Moscow State University

Based on his vast experience Professor D.Yu. Bardin developed a course of lectures for students of Lomonosov Moscow State University on "Standard Theory and Precision Calculations". From 2009 to 2014 **Dmitry Yurievich** was professor at the Moscow State University.

top 100-300: GENTLE

GENTLE/4fan v. 2.0: A Program for the semianalytic calculation of predictions for the process $e^+e^- \to 4f$.
Dmitri Yu. Bardin, J. Biebel (DESY, Zeuthen), D. Lehner (Freiburg U.), A. Leike (Munich U.), A. Olchevski (Dubna, JINR), T. Riemann (DESY, Zeuthen). Dec 1996. 38 pp. Published in Comput.Phys.Commun. 104 (1997) 161-187 DESY-96-233 DOI: 10.1016/S0010-4655(97)00051-9 e-Print: hep-ph/9612409 | PDF
TopCite – 109

top 100-300: Hector 1.00

Hector 1.00: A Program for the calculation of QED, QCD and electroweak corrections to ep and $\ell^{\pm}N$ deep inelastic neutral and charged current scattering.
A. Arbuzov (Dubna, JINR), Dmitri Yu. Bardin (DESY, Zeuthen & Dubna, JINR), J. Blümlein (DESY, Zeuthen), L. Kalinovskaya (Dubna, JINR), T. Riemann (DESY, Zeuthen). Nov 1995. 74 pp. Published in Comput.Phys.Commun. 94 (1996) 128-184 DESY-95-185 DOI: 10.1016/0010-4655(96)00005-7 e-Print: hep-ph/9511434 | PDF
TopCite – 130

top 100-300: Dizet

Dizet: A Program Package for the Calculation of Electroweak One Loop Corrections for the Process $e^+e^- \to f^+f^-$ Around the Z^0 Peak.
D.Yu. Bardin, Mikhail S. Bilenky (Dubna, JINR & Dubna, JINR), T. Riemann, M. Sachwitz, H. Vogt (DESY, Zeuthen). Jun 1989. 17 pp. Published in Comput.Phys.Commun. 59 (1990) 303-312 PHE-89-09 DOI: 10.1016/0010-4655(90)90179-5

TopCite – 225

top 100-300: basement ZFITTER

Energy Dependent Width Effects in e^+e^- Annihilation Near the Z Boson Pole. D.Yu. Bardin (Dubna, JINR), A. Leike, T. Riemann, M. Sachwitz (DESY, Zeuthen). Jan 1988. 4 pp. Published in Phys.Lett. B206 (1988) 539-542 PHE-88-03 DOI: 10.1016/0370-2693(88)91627-9

TopCite – 204

top 100-300: basement ZFITTER

Electroweak One Loop Corrections to the Decay of the Charged Vector Boson.
D.Yu. Bardin, S. Riemann, T. Riemann (Dubna, JINR). Mar 1986. 10 pp.
Published in Z.Phys. C32 (1986) 121-125 JINR-E2-86-169 DOI:
10.1007/BF01441360
TopCite – 107

top 100-300: basement ZFITTER

On the Lowest Order Electroweak Corrections to Spin 1/2 Fermion Scattering. The One Loop Amplitudes.
D.Yu. Bardin (Dubna, JINR), P.Kh. Khristova (Preslavski U.), O.M. Fedorenko (Petrozavodsk State U.). Jul 1981. 44 pp. Published in Nucl.Phys. B197 (1982) 1-44 JINR-E2-81-486 DOI: 10.1016/0550-3213(82)90152-3
TopCite – 167

top 100-300: basement

Electromagnetic Corrections to the Deep Inelastic μp Scattering at High-Energies.
A.A. Akhundov (Baku State U.), D.Yu. Bardin (Dubna, JINR), N.M. Shumeiko (Belarus State U.). Mar 1977. 18 pp. Published in Sov.J.Nucl.Phys. 26 (1977) 660, Yad.Fiz. 26 (1977) 1251-1257 JINR-E2-10471
TopCite – 113

top 100-300: basement

An Exact Calculation of the Lowest Order Electromagnetic Correction to the Elastic Scattering (In Russian).
D.Yu. Bardin (Dubna, JINR), N.M. Shumeiko (Belarus State U.). Sep 1976. 17 pp. Published in Nucl.Phys. B127 (1977) 242-258 JINR-P2-10113 DOI: 10.1016/0550-3213(77)90213-9
TopCite – 102

top 300-500: ZFITTER

ZFITTER v.6.21: A Semianalytical program for fermion pair production in e^+e^- annihilation.
Dmitri Yu. Bardin (Dubna, JINR), P. Christova (Shoumen U.), M. Jack (DESY, Zeuthen), L. Kalinovskaya (Dubna, JINR), A. Olchevski (Dubna, JINR & CERN), S. Riemann, T. Riemann (DESY, Zeuthen). Aug 1999. 192 pp. Published in Comput.Phys.Commun. 133 (2001) 229-395 DESY-99-070 DOI: 10.1016/S0010-4655(00)00152-1 e-Print: hep-ph/9908433 | PDF
TopCite – 405

top 300-500: basement

QED corrections with partial angular integration to fermion pair production in e^+e^- annihilation.
Dmitri Yu. Bardin, Mikhail S. Bilenky, A. Sazonov, Yu. Sedykh (Dubna, JINR), T. Riemann, M. Sachwitz (DESY, Zeuthen). Oct 1990. 7 pp.
Published in Phys.Lett. B255 (1991) 290-296 PHE-90-17 DOI: 10.1016/0370-2693(91)90250-T e-Print: hep-ph/9801209 | PDF
TopCite – 305

top 300-500: basement

Analytic approach to the complete set of QED corrections to fermion pair production in e^+e^- annihilation.
Dmitri Yu. Bardin, Mikhail S. Bilenky, A. Chizhov, A. Sazonov (Dubna, JINR), O. Fedorenko (Petrozavodsk State U.), T. Riemann, M. Sachwitz (DESY, Zeuthen). Mar 1990. 48 pp. Published in Nucl.Phys. B351 (1991) 1-48 PHE-89-19 DOI: 10.1016/0550-3213(91)90080-H e-Print: hep-ph/9801208 | PDF

TopCite – 404

top 300-500: basement

A Realistic Approach to the Standard Z Peak.
D.Yu. Bardin, Mikhail S. Bilenky, Guenakh Mitselmakher (Dubna, JINR), T. Riemann, M. Sachwitz (DESY, Zeuthen). Apr 1989. 33 pp. Published in Z.Phys. C44 (1989) 493 PHE-89-05 DOI: 10.1007/BF01415565
TopCite – 455

top 300-500: basement

Electroweak One Loop Corrections to the Decay of the Neutral Vector Boson.
A.A. Akhundov (Baku, Inst. Phys.), D.Yu. Bardin, T. Riemann (Dubna, JINR). Aug 1985. 13 pp. Published in Nucl.Phys. B276 (1986) 1-13
JINR-E2-85-617 DOI: 10.1016/0550-3213(86)90014-3
TopCite – 394

Dmitry Yurievich Bardin

Under the leadership of **Dmitry Yurievich Bardin** 12 Ph.D. theses were defended. **Dmitry Yu. Bardin** is on the list of the Top 100 most cited Russian scientists according to the RINC. According to the database INSPIRE **D.Yu. Bardin** is co-author of more than 850 scientific publications. He presented his work at seminars at JINR, CERN/TH, CERN/PPE, DESY, IfH, Universities of Bielefeld, Lyon, Karlsruhe, and acted at numerous world-class conferences like ACAT, CALC, RADCOR, Loops and Legs. He gave main lectures at several schools jointly organized by CERN and JINR.
The group headed by **Dmitry Yurievich** was awarded six times with **first research prizes** of the Joint Institute for Nuclear Research.

List of software products

Dmitry Yurievich Bardin was world-leading expert in the field of theoretical support the experiments in HEP.

Here a listing of software products by **D.Yu. BARDIN**:

RCforGV, DIZET,
TERAD, TERADlow,
NUDIS1, NUDIS2,
HECTOR, polHECTOR, μela,
GENTLE, ZFITTER, MCSANC.

Dmitry Yurievich Bardin

We cannot mention here all the scientists with whom he actively collaborated. Besides above mentioned colleagues we should name: **Andrei Kataev, Ansgar Denner, Valentina Dokuchaeva, Barbara Badelek, Bernd Kniehl, Christian Spiering, Christian Stegmann, Fred Jegerlehner, Giampiero Passarino, Hubert Spiesberger, Janusz Gluza, Johannes Blümlein, Johann Kühn, Max Klein, Konstantin Chetyrkin, Mark A. Jack, Martin Grünewald, Martin Sachwitz, Max Klein, Mihail Tentyukov, Mikhail Kalmykov, Mikhail Khankhasayev, Sven Olaf Moch, Lew Okun, Oleg Tarasov, Alberto Sirlin, Dmitri Shirkov, Dorothe Schaile Sabine Riemann, Stanislaw Jadach, Wyacheslav Placzek, Stefan Dittmaier, Uta Klein, Vladimir Smirnov, B.F.L. Ward, Wolfgang Friedrich Lohmann, Wolfgang Hollik, Zbigniew Was.**

Dmitry Yurievich Bardin

Dmitry Yurievich contributed faithful and selfless to fundamental science. It is difficult to overestimate his role in creating an atmosphere of high demands on the level of scientific research. With broad knowledge, extensive experience and diligence, **Dmitry Yurievich** was a true professional in his field. A severe, debilitating and prolonged illness brought a lot of suffering and pain, but despite this, **Dmitry Yurievich** continued to work until the very last day.

Dmitry Yurievich Bardin

Dmitry Yurievich was not only an outstanding scientist, but also a reliable friend, colleague and wonderful family man.
For Anna, he was a loving husband, a great father for Maria and Ilia, and a caring grandfather for Basil, Lucien, Elsa and Fleury, and also an attentive son and brother.
The pain we feel cannot be expressed in words, not only personally, but also as a scientific community.

SANC, DZRCG, colleagues and friends at work