Existent collaboration of Dubna physicists with the Department of Theoretical Physics

Wojciech Broniowski

October 29, 2005

Some recent history:

- Sergo Gerasimov, 1990's (Bogolyubov-Infeld)
- Alexandr E. Dorokhov, 4 short-term (1-2 weeks) visits between 2000 and 2005, (Bogolyobov-Infeld), work with WB
- Anatoly Kotikov, 1 week in 2004, work with Krzysztof Golec-Biernat
- Yuri Surovtsev, 2 short visits in 2004 and 2005, work with Robert Kamiński
- Visits of Kamiński to Dubna
- Marcin Cerkaski in Dubna

Papers up to now:

- VANISHING DYNAMICAL QAURK MASS AT ZERO VIRTUALITY? A. E. Dorokhov and W. Broniowski, *Phys. Rev.*, **D65**:094007, 2002.
- VECTOR AND AXIAL-VECTOR CORRELATORS IN A NONLOCAL CHIRAL QUARK MODEL, A. E. Dorokhov and W. Broniowski, *Eur. Phys. J.*, **C32**:79–96, 2003.
- SCALAR AND TENSOR MESONS FROM THE COMBINED ANALYSIS OF THE PROCESSES $\pi\pi \to \pi\pi, K\bar{K}, \eta\eta$, Yu. S. Surovtsev, R. Kamiński, D. Krupa, M. Nagy (Bratislava), *Int. J. Mod. Phys. A* **20**, 561, 2005.

Present topics of our on-going collaboration:

- studies of non-local quark models and hadron phenomenology, structure of the pion, pion and photon light-cone wave functions, distribution amplitudes, QCD evolution
- analysis of the isoscalar S- and D-wave pion scattering aimed at studying the QCD nature of scalar and tensor mesons below 2 GeV

Department of Theoretical Physics

prof. dr hab. Wojciech Florkowski
prof. dr hab. Leonard Leśniak
doc. dr hab. Piotr Bożek
doc. dr hab. Wojciech Broniowski - head
doc. dr hab. Tadeusz Chmaj
doc. dr hab. Krzysztof Golec-Biernat
doc. dr hab. Beata Ziaja
doc. dr hab. Piotr Żenczykowski
dr Marcin Cerkaski
dr Robert Kamiński
dr Anna Staśto

mgr. Ewa Pagaczewska - secretary

Ph.D. students: Łukasz Bibrzycki, Mikołaj Chojnacki, Agnieszka Furman, Magdalena Sowa, Agnieszka Łuszczak, Vittorio Somá, Tomasz Lanczewski

Scientific profile

Hadronic physics:
DIS (HERA, Tevatron, LHC), low-x, saturation
Relativistic heavy-ion collisions (SPS, RHIC, LHC), statistical models, hydrodynamics, azimuthal asymmetry / elliptic flow, particle correlations, resonance production
Models of structure of hadrons Generalized Parton Distribution and Distribution Amplitude of the pion, meson correlations (CLEO,ALEPH)
Physics of mesons (TJLAB) pion and kaon scattering, f_0, a_0
Weak interactions B-decays, unitarity triangle (B-factories)
Nuclear matter: modern many-body calculations, correlations, propagators, vertices
Biophysics: electron cascades and imaging (Free Electron Laser)
Non-linear equations: application to cosmology and gauge theories

Main task: development of important topics in hadronic physics with feed-back from recents experiments, predictions for the future

International collaboration: Tuebingen, DESY, Uppsala, Dubna, Paris VI, Saclay, Granada, Coimbra, Budapest, Graz, Ljubljana, BNL, Arizona, Indiana; numerous visitors

Education: lectures for Int. PhD School at IFJ PAN and for the students of the High-Energy Specialization of the Jagellonian U.; visting students from Granada (E. Megias) and Arizona (G. Torrieri, S. Steinke)

Grants: 7 KBN (incl. 2 PhD grants), NATO, IN2P3

Kaleidoscope of results in 2003-2004

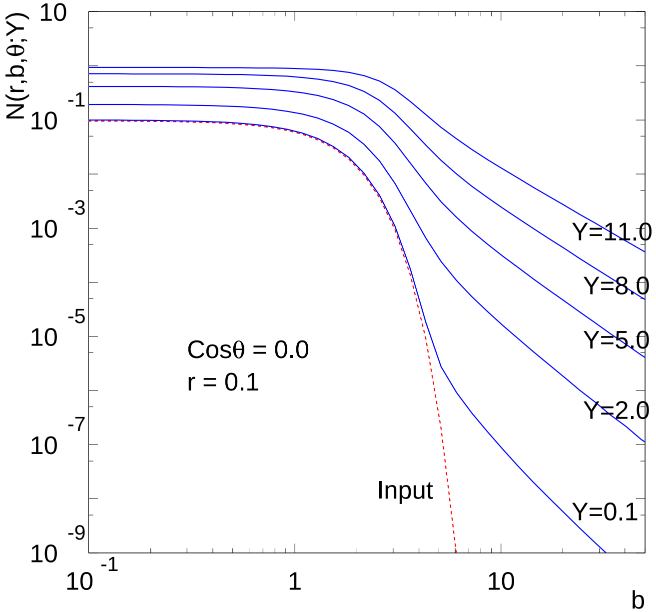
Impact parameter dependence in the Balitsky-Kovchegov equation

K. Golec-Biernat, A. Staśto, Nucl. Phys. **B668** (2003) 345

The basic equation of COLOR GLASS CONDENSATE in the dipole representation

$$\frac{\partial N(x,y)}{\partial Y} = \alpha_s \int \frac{d^2z}{2\pi} \frac{(x-y)^2}{(x-z)^2(z-y)^2} \{N(x,z)+N(z,y)-N(x,y)-N(x,z)N(z,y)\}$$

violates unitarity (Froissart bound) because of the power-like tails in the impact parameter



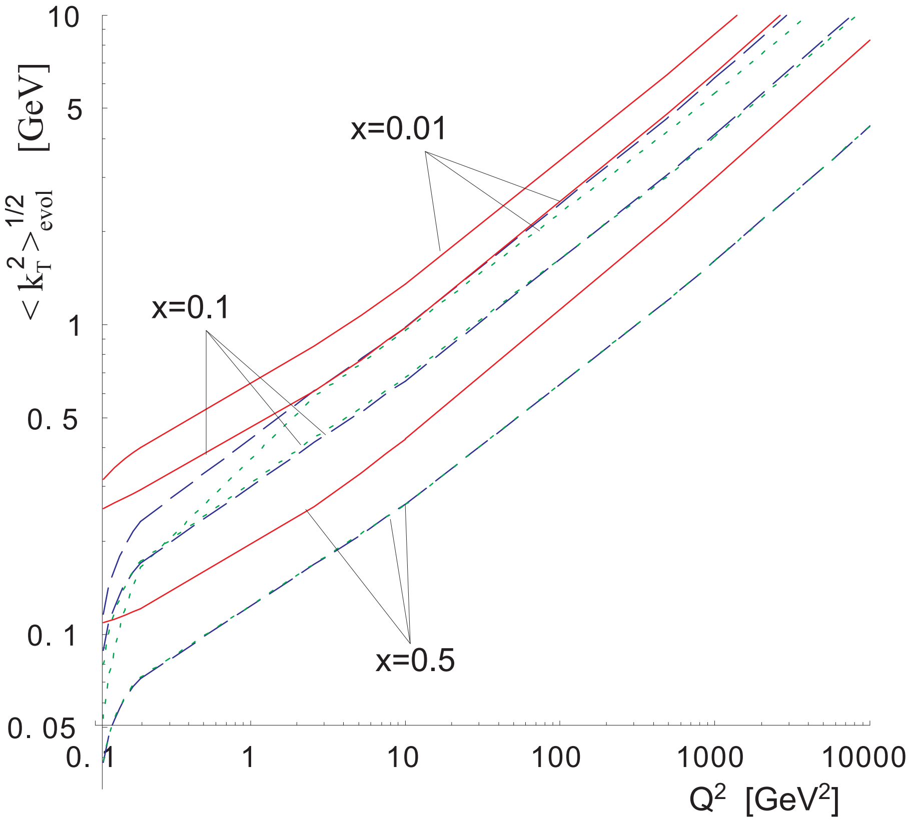
The violation is caused by long range contribution from large dipoles. The dipole splitting kernel

$$\frac{(x-y)^2}{(x-z)^2(z-y)^2} \qquad \longrightarrow \qquad \Big(\partial^i K_0(\mu|x-z|) + \partial^i K_0(\mu|z-y|)\Big)^2$$

should be improved by taking into account confinement effects (μ sets the scale for confinement radius).

Kwieciński evolution of unintegrated parton distributions

A. Gawron, J. Kwiecinski, W. Broniowski, *Phys. Rev.*, D68:054001, 2003.
E. Ruiz Arriola (Granada), W. Broniowski, *Phys. Rev.*, D70:034012, 2004.
A. Gawron, J. Kwiecinski, Phys. rev. D70:014003, 2004.

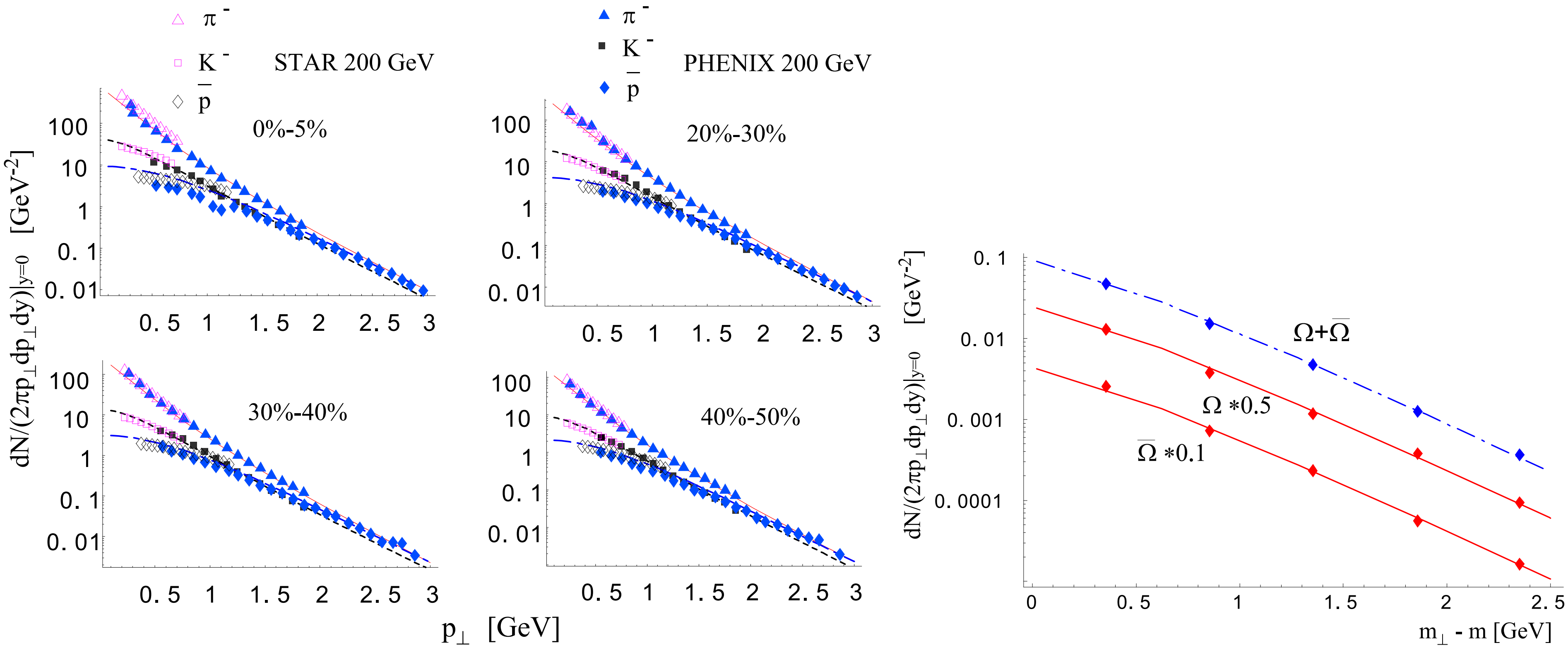


The rms transverse momenta of UPD's of the pion generated with the Kwiecinski evolution for $x = 0.01$, 0.1, and 0.5, plotted as functions of the renormalization scale Q^2. Solid lines – gluons, dashed lines – non-singlet quarks, dotted lines – singlet quarks. Spreading with increasing scale Q is manifest, with the asymptotic behavior $\langle k_\perp^2 \rangle \sim \alpha(Q^2) Q^2$.

Statistical hadronization at RHIC

A. Baran, W. Broniowski, W. Florkowski   Acta Phys. Pol. **70** (2004) 779

Further applications of the statistical model of hadron production in ultra-relativistic heavy-ion collisions (the Cracow model) were explored. In particular, the model describes well the data collected at RHIC at different centralities.



Note successful predictions for the production of hyperons

A very simple description of complicated processes has been achieved

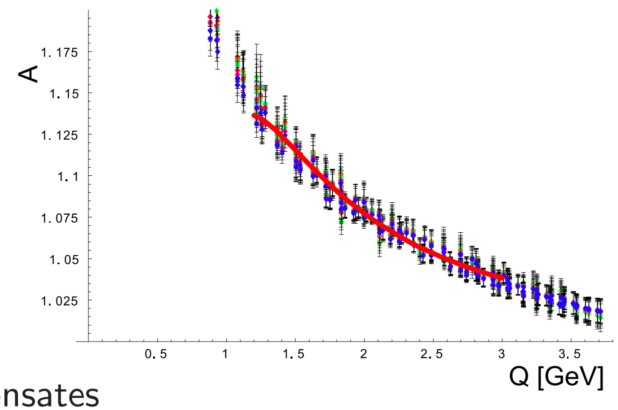
Landau-gauge condensates from the lattice

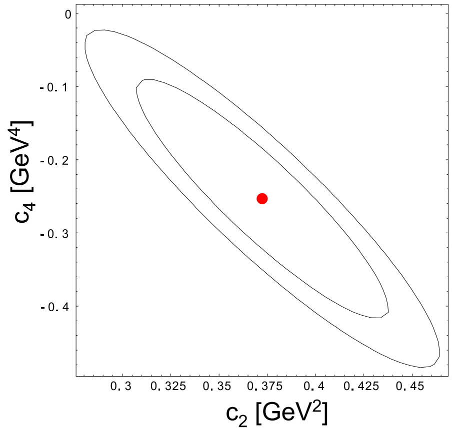
E. Ruiz Arriola (Granada), P. Bowman (Indiana), W. Broniowski, PRD **70** (2004) 097505

The quark propagator at large Euclidean momenta in the Landau gauge

$$A(Q) \equiv Z^{-1}(Q) \to 1 + \frac{\pi\alpha_s\langle A^2\rangle}{N_c Q^2} - \frac{\pi\alpha_s\langle G^2\rangle}{3N_c Q^4} + \frac{3\pi\alpha_s\langle \bar{q} g_s \not{A} q\rangle}{4Q^4} + \ldots = 1 + \frac{c_2}{Q^2} + \frac{c_4}{Q^4} + \ldots$$

has been compared to the lattice data





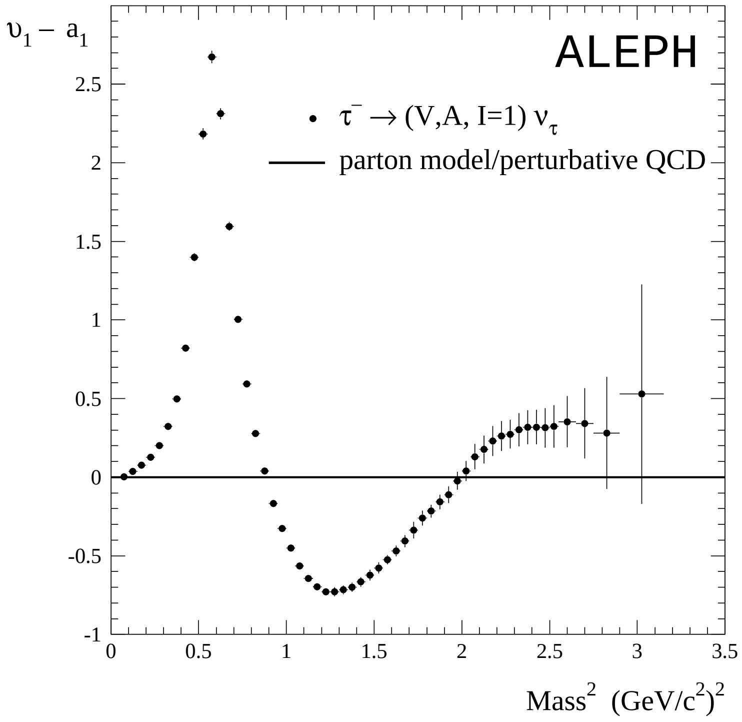
yielding values for the condensates

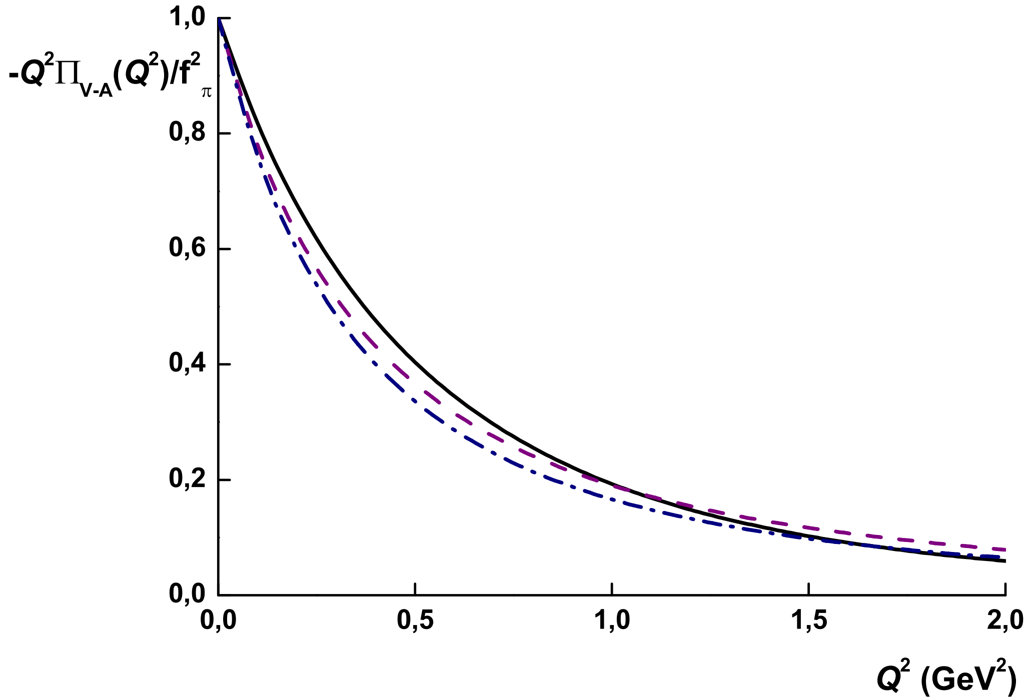
$$\alpha_s\langle A^2\rangle = (0.36 \pm 0.04)\ \mathrm{GeV}^2 \quad \text{and} \quad \alpha_s\langle \bar{q} g_s \not{A} q\rangle = (-0.11 \pm 0.03)\ \mathrm{GeV}^4$$

- for $\langle A^2\rangle$ agreement with other estimates, gauge-independent meaning of $\langle A^2\rangle$, first estimate for the mixed condensate

Meson correlators in quark models

A. E. Dorokhov (Dubna), W. Broniowski, "Vector and axial vector correlators in a nonlocal chiral quark model", Eur. Phys. J. C 32:79 (2003)





Left:Inclusive vector minus axial vector spectral function, $v_1 - a_1$, measured by the ALEPH collaboration

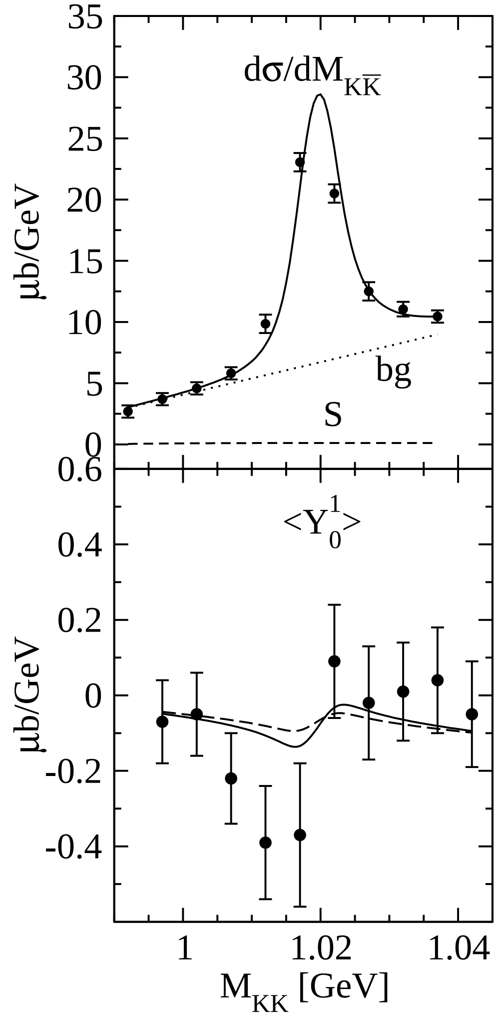
Right: Euclidean-momentum correlation function, $-Q^2\Pi_{V-A}(Q^2)/f_\pi^2$, constructed in the present model (solid line), in the model of deRafael et al. (dashed line), and reconstructed via dispersion relations from the ALEPH experimental spectral function (dash-dotted line).

High energy photoproduction of kaons on hydrogen

Ł. Bibrzycki, L. Leśniak, A. Szczepaniak (Indiana),
"K^+K^- photoproduction and S-P wave interference",
Eur. Phys. Journal **C 34** (2004) 335, hep-ph/0308267.

Motivation:
investigation of strong interactions between kaons in the S-wave and the role of scalar mesons $f_0(980)$ and $a_0(980)$ in the reaction dynamics.

Results:
1. explanation of the discrepancy between two experimental analyses and a good theoretical description of the data,
2. predictions at the energy of the upgraded electron accelerator at the Jefferson Laboratory in the USA
(American project - GlueX/ Hall D Collaboration).

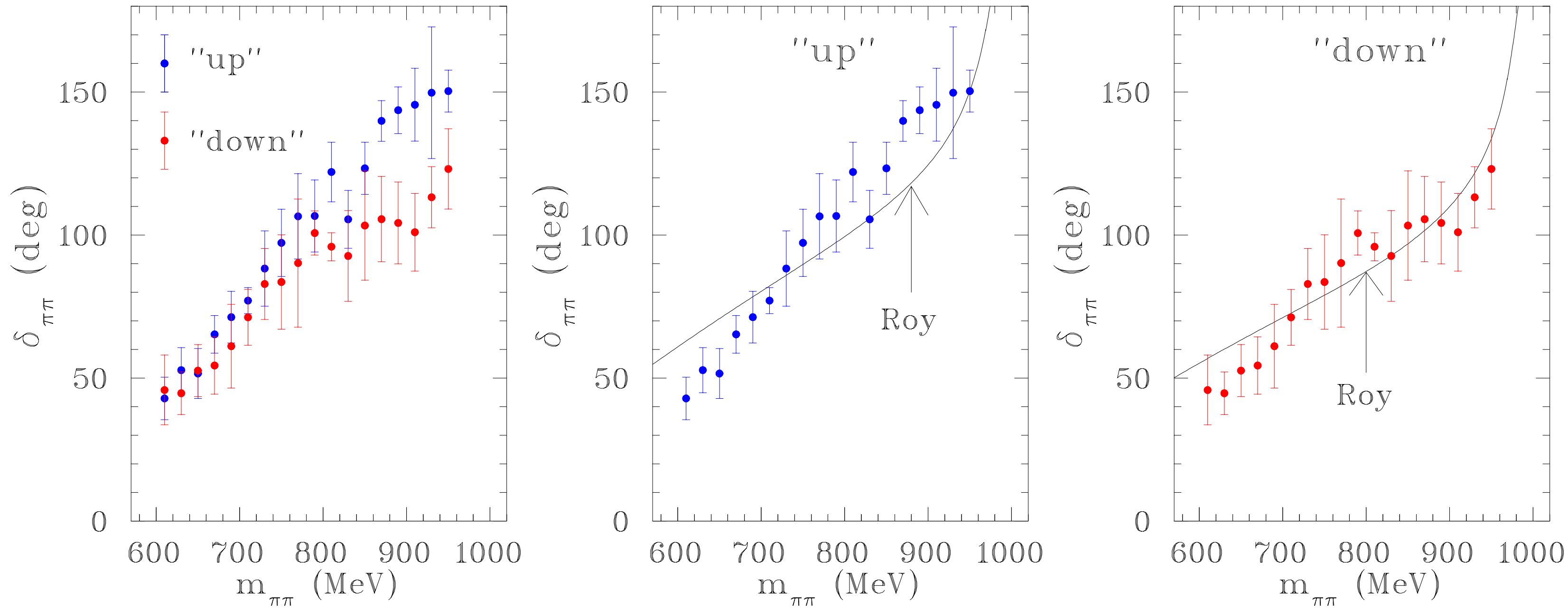


Elimination of ambiguities in the $\pi\pi$ phase shifts

R. Kamiński, L. Leśniak and B. Loiseau (Paris), "Elimination of ambiguities in $\pi\pi$ phase shifts", Phys. Lett. **B**551 (2003) 241

The "up-down" ambiguity in the $\pi\pi$ S-wave isospin 0 phase shifts below 990 MeV has been eliminated using Roy's equations for the scalar-isoscalar, scalar-isotensor and the vector-isovector $\pi\pi$ amplitudes.

The data, based on the CERN-Kraków-Münich results, were obtained by R. Kamiński, L. Leśniak and K. Rybicki in 1997.



- Conclusion: only the solution "down" is acceptable as physical
- This conclusion is in agreement with the results of the joint analysis of the $\pi^+\pi^-$ and $\pi^0\pi^0$ data
- These experimental data allow us to construct the theoretical $\pi\pi$ amplitudes from the $\pi\pi$ threshold up to 1600 MeV

Simultaneous resolution of long-standing puzzles in weak radiative and nonleptonic hyperon decays

P. Żenczykowski, Acta Phys. Pol. **B34** (2003) 2683; Nucl. Phys. Proc. Suppl. 115 (2003) 24

	1950's	Nonleptonic (NL)	1960's-1980's	Weak Radiative (WR)
theory	P-wave: S-wave: $d_P = d_S$	f_P, d_P CA commutator + corr. $f_S/d_S = f_P/d_P$	Hara's Theorem: Quark Model:	parity-viol. $\Sigma^+ \rightarrow p\gamma$ amplitude vanishes in exact SU(3) Hara's theor. violated in exact SU(3)
data	$d_P \approx 2d_S$	$f_S/d_S \approx -2.5$ $f_P/d_P \approx -1.8$	**asymmetry**	$\boldsymbol{\alpha(\Sigma^+ \longrightarrow p\gamma) = -0.76 \pm 0.08}$ $0 - corr. \leftrightarrow -1 + corr.$
PUZZLES		**P ↔ S ?**		**LARGE SU(3) BREAKING ?** **HARA'S THEOR. VIOLATED ?**
predictions (P.Ż 95)			$\alpha(\Xi^0 \rightarrow \Lambda\gamma)$	$-0.8 \pm 0.2 \leftrightarrow +0.8 \pm 0.2$ (HT) (QM)

RESOLUTION: **EXPERIMENTAL** - NEW 2003 data (NA48) ⇒ $\boldsymbol{\alpha(\Xi^0 \longrightarrow \Lambda\gamma) = -0.78 \pm 0.18}$

THEORETICAL (P.Ż):

SYMMETRY of CURRENTS connects WR to ***corrections to CA commutator*** **in NL**: large corrections

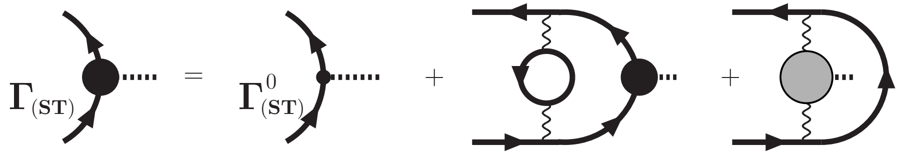
$$\boldsymbol{f_S = f_P - b_{WR}} \qquad \textbf{EXP}(\text{WR}): \quad b_{WR} \approx -d_P/2 \qquad d_S \approx d_P/2$$

$$\boldsymbol{d_S = d_P + b_{WR}} \qquad (\text{size: WR branch. ratios; sign:}\ \alpha(\Xi^0 \rightarrow \Lambda\gamma)) \quad \Rightarrow \quad f_S/d_S \approx 1 + 2f_P/d_P = -2.6$$

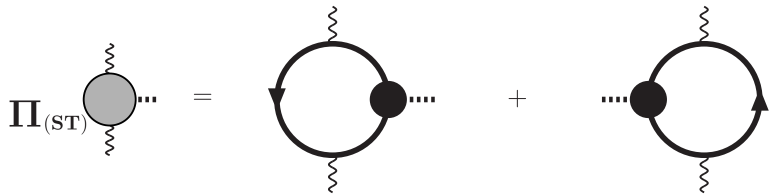
- simultaneous **PARAMETER-FREE** resolution of NL and WR puzzles

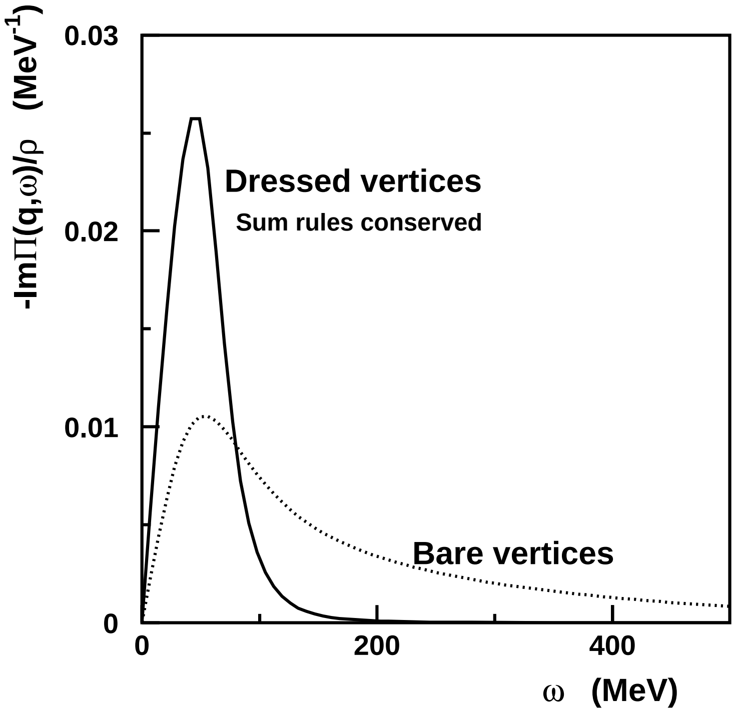
In-medium effects in the response function

P. Bożek, Physics Letters **B579** (2004) 309



Response function from dressed vertices for the coupling of the external field to fermions
Bethe-Salpeter equation





Response functions for correlated systems beyond the usual mean-field + random-phase-approximation scheme
Dressing of vertices must be included, difficult but now possible, physically consistent response function can be calculated for correlated systems.

Applications in nuclear physics (neutrino cross sections, photon and meson emission, lepton scattering experiments) and in solid state physics

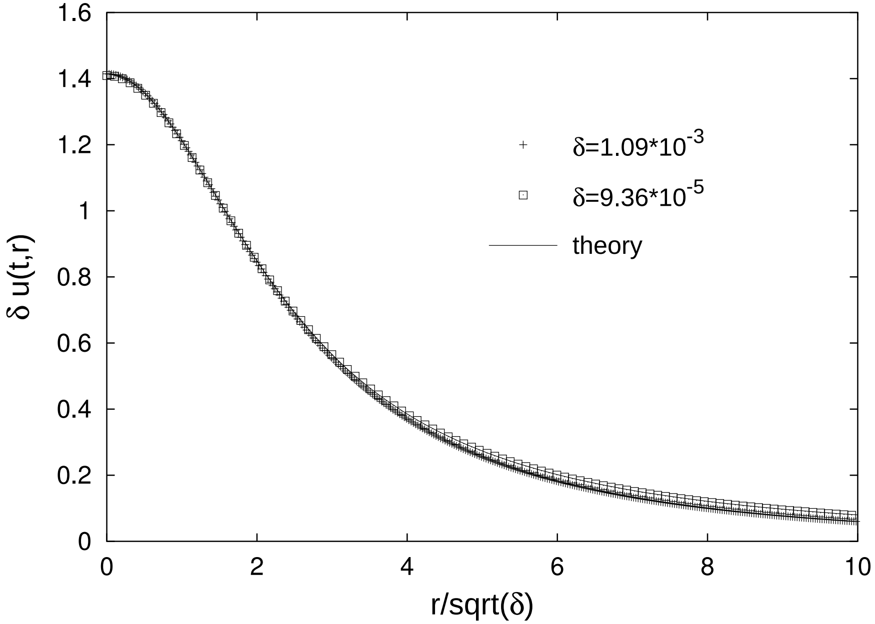
Formation of singularities in nonlinear evolution equations

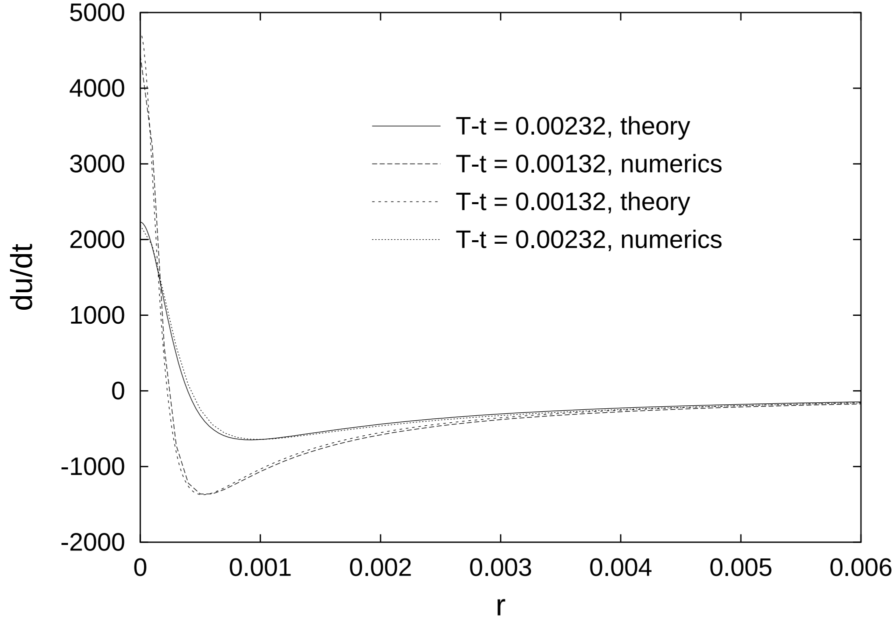
P. Bizoń (Jagellonian), T. Chmaj, Z. Tabor (Jagellonian), Nonlinearity **17** (2004) 2187

For the semilinear wave equations with focusing power nonlinearity

$$u_{tt} - \Delta u = u^p, \qquad p = 3, 5, 7$$

we show that for generic large initial data that lead to singularities, the spatial pattern of blowup can be described in terms of linearized perturbation about the fundamental, self-similar (homogeneous in space) solution. For $p = 5, 7$ we identify critical solutions that separate blowup from dispersal.



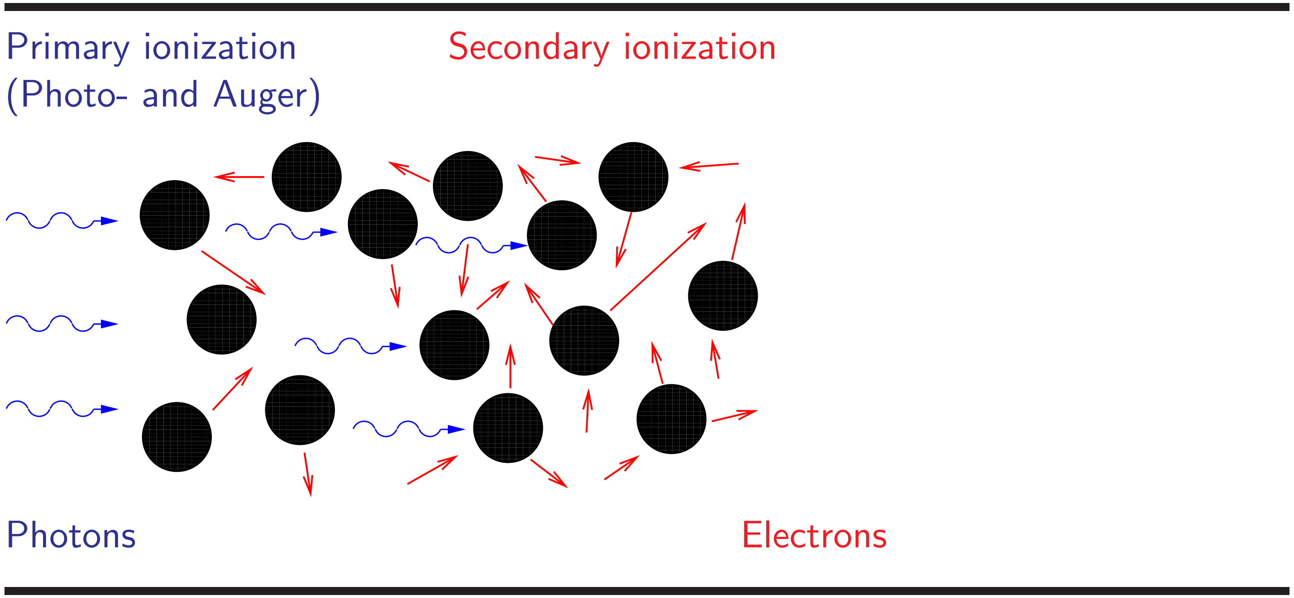


- evidence that ODE-type blowup is generic, analytical description of generic blowup and critical solutions
- insight in the mechanism of singularity formation and critical behaviour

Interaction of radiation emitted from the free-electron-laser with matter

B. Ziaja, R. London (LLNL), J. Hajdu (Uppsala), "Unified model of secondary electron cascades in diamond", accepted in Journal of Applied Physics

Objective: Quantitative characteristics of the interactions of secondary electrons with matter



- Construction of a unified model describing the creation of electron cascades in diamond after absorption of a single photon from the FEL at the photon energy range, $E = 0.1 - 10$ keV. This model included the results of the band structure calculations for describing the electron trajectories at low energies, $E < 50$ eV.
- A simple fit for the electron mean free paths in solids, including the results of the band structure calculations, has been tested for 9 elements and 2 compounds. It works both at high and at low energies.

Prospects for the future

- Excellent experiences!

- Joint scientific interests concerning modern hadronic physics

- "Human mobility"

- Involvement of young people

- Collaboration evolved naturally

- Small scale, but very useful and productive, work "off-line" between the visits