My Adventures with Particle Correlations and Janek

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Happy Birthday!

Dubna in the early 1980s

Jan Pluta

Mikhail Podgoretsky

Vladimir Lyuboshitz

Richard Lednicky

Marek Gaździcki

Marek Kowalski

Tomasz Pawlak

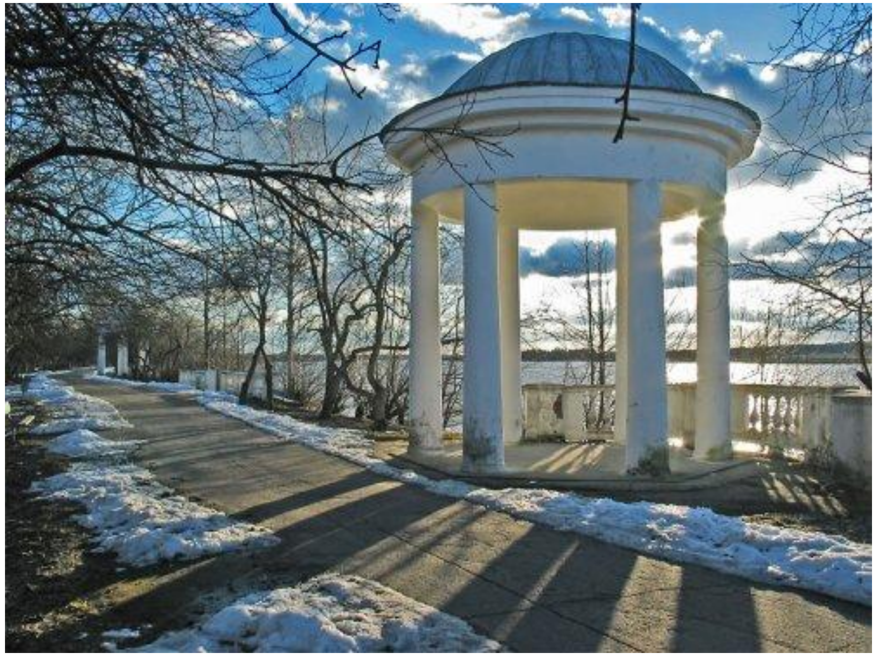
Wiktor Peryt

Jerzy Bartke

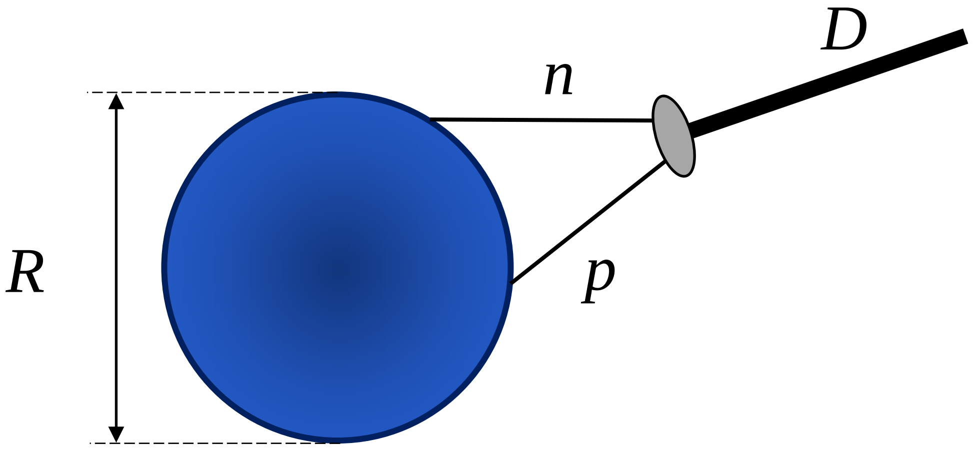
………….

………..

…….



Coalescence model



$$p_n + p_p \neq p_D$$

$$p_i = (E_i, \mathbf{p}_i), \quad E_i = \sqrt{m_i^2 + \mathbf{p}_i^2}$$

uncertainty of $\Delta p \sim \frac{1}{R} \sim \varepsilon_D = 2.5\,\mathrm{MeV}$

St. Mrówczyński, J. Phys. G **13** (1987) 1089

proton-proton correlations

сообщения
объединенного
института
ядерных
исследований
дубна

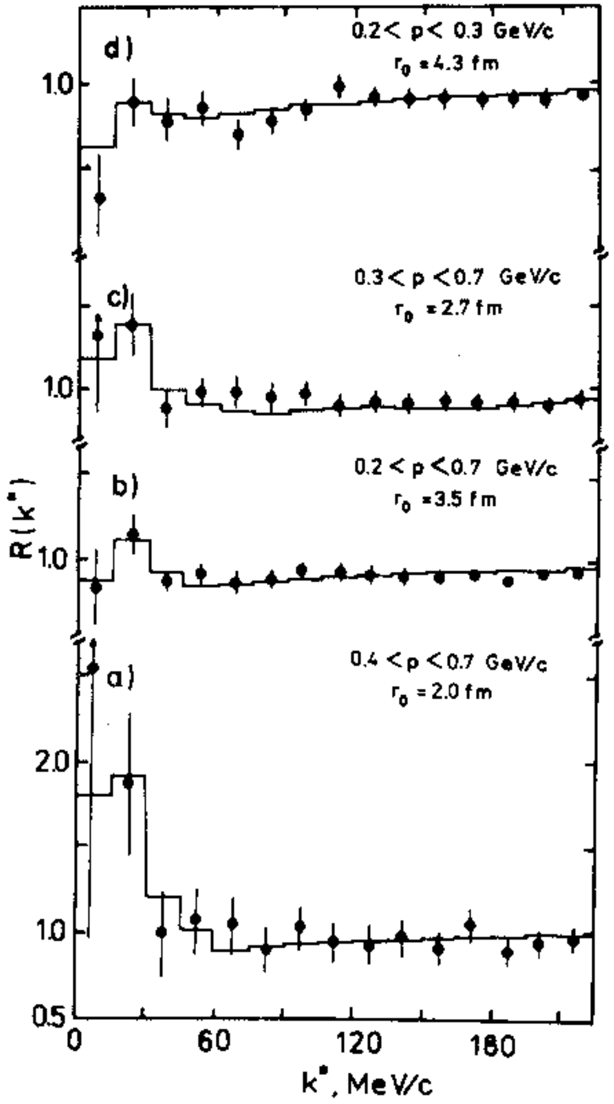
E1-86-332

J.Bartke[1], V.G.Grishin, M.Kowalski[1], K.Miller,
T.Pawlak[2], W.Peryt[2], J.Pluta, Z.Strugalski[2]

SIZE OF THE PROTON EMISSION REGION
IN PION-XENON INTERACTIONS
AT 3.5 GeV/c
FROM TWO-PARTICLE CORRELATIONS

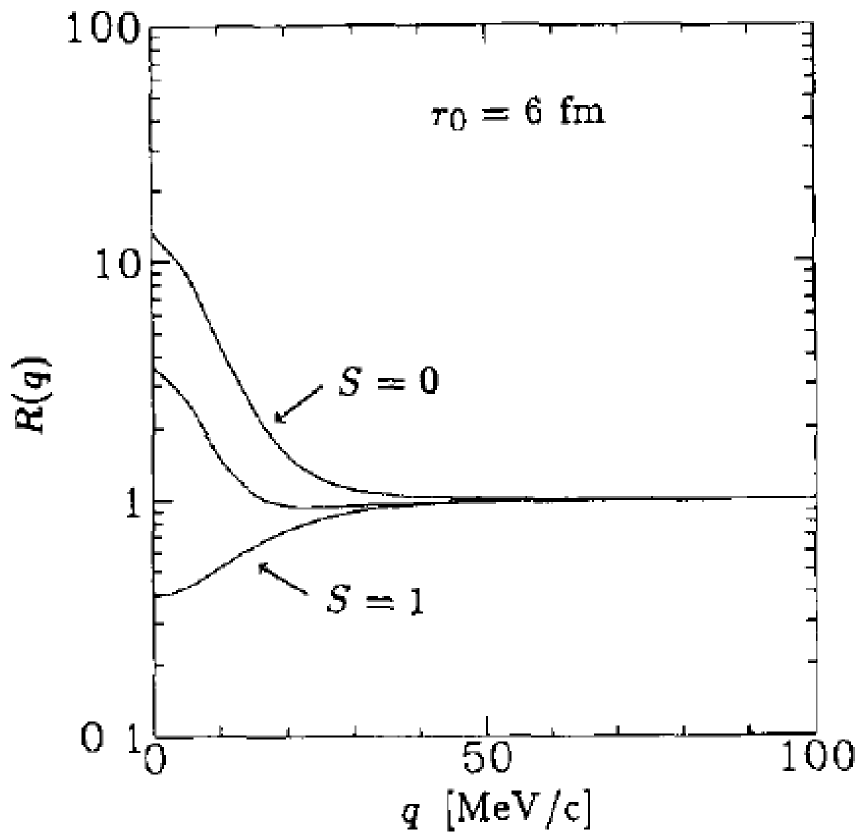
[1] Institute of Nuclear Physics, Cracow, Poland
[2] Warsaw Technical University, Warsaw, Poland

1986



R. Lednicky and V.L. Lyuboshitz,
Yad. Fiz. **35,** 1316 (1982)

neutron-proton correlations & deuterons



St. Mrówczyński, Phys. Lett. B **277**, 43 (1992)

For S = 1 the interaction is attractive
but the correlation is negative!

$$p\uparrow + n\uparrow \rightarrow D$$

Sum rule

Correlation function

$$R(\mathbf{q}) = \int d^3r\, D(\mathbf{r}) \left|\varphi_{\mathbf{q}}(\mathbf{r})\right|^2$$

$\varphi_{\mathbf{q}}(\mathbf{r})$ - wave function

$D(\mathbf{r})$ - source function

Sum rule

$$\int \frac{d^3q}{(2\pi)^3} \left(R(\mathbf{q}) - 1\right) = \quad ?$$

$$\int \frac{d^3q}{(2\pi)^3} \left(R(\mathbf{q}) - 1\right) = \int \frac{d^3q}{(2\pi)^3} \int d^3r\, D(\mathbf{r}) \left(\left|\varphi_{\mathbf{q}}(\mathbf{r})\right|^2 - 1\right) = \int d^3r\, D(\mathbf{r}) \int \frac{d^3q}{(2\pi)^3} \left(\left|\varphi_{\mathbf{q}}(\mathbf{r})\right|^2 - 1\right)$$

Sum rule cont.

Completeness of quantum states

$$\int \frac{d^3q}{(2\pi)^3}\left(\left|\varphi_{\mathbf{q}}(\mathbf{r})\right|^2-1\right)+\sum_{\alpha}\left|\varphi_{\alpha}(\mathbf{r})\right|^2 = \begin{cases} +\delta^{(3)}(\mathbf{r}) & \text{- identical bosons} \\ 0 & \text{- nonidentical particles} \\ -\delta^{(3)}(\mathbf{r}) & \text{- identical fermions} \end{cases}$$

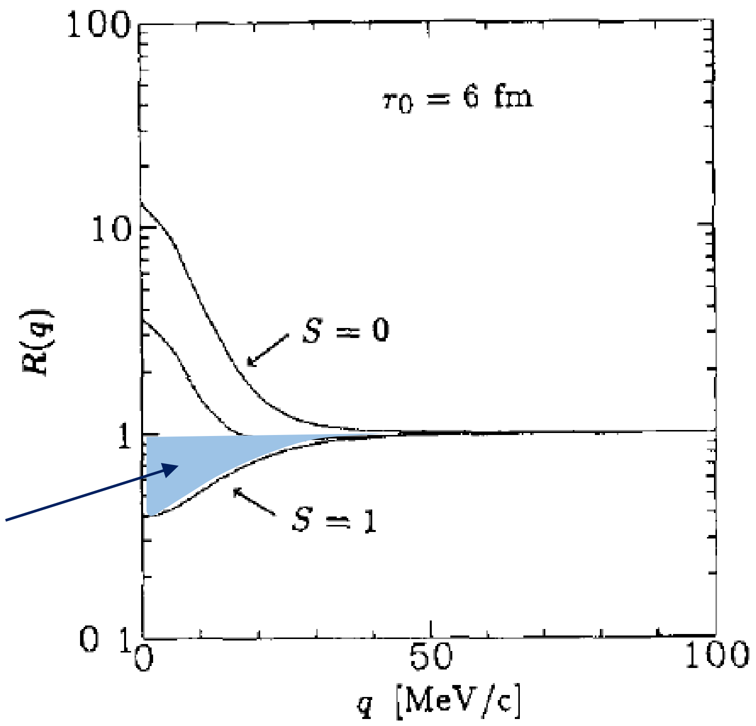
bound states

General sum rule

$$\int \frac{d^3q}{(2\pi)^3}\left(R(\mathbf{q})-1\right)=\pm\pi^3 D(\mathbf{r}=0)-\sum_{\alpha}A_{\alpha}$$

Sum rule for *n-p* in triplet state

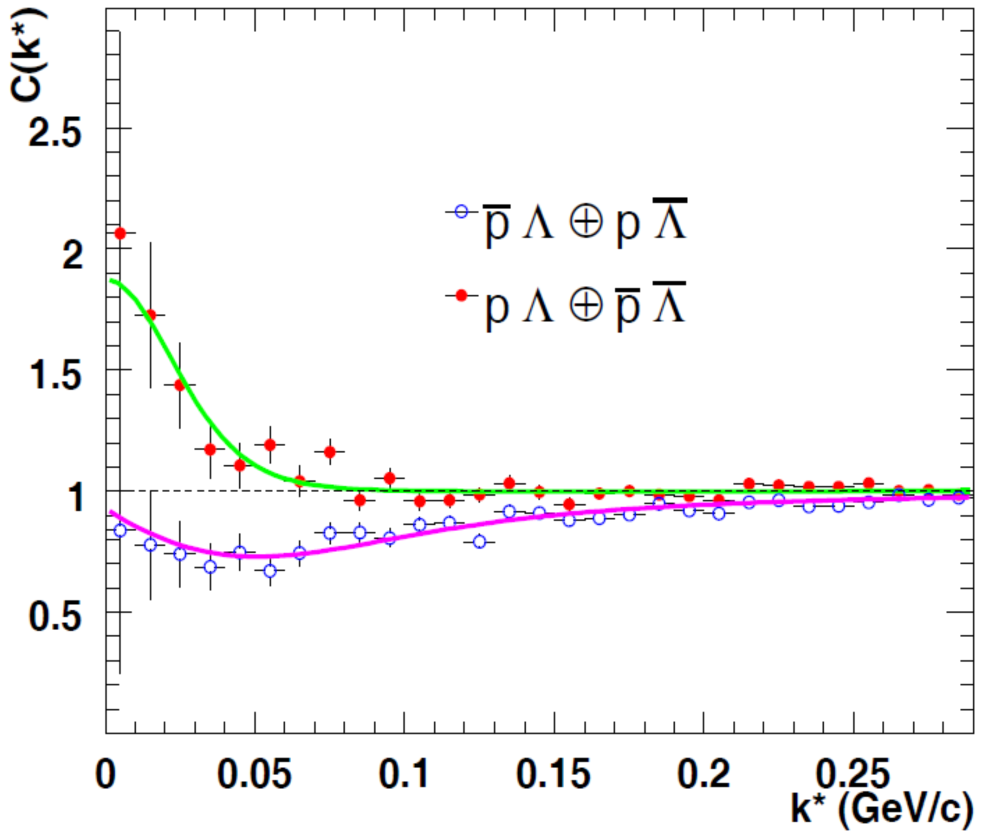
$$\int \frac{d^3q}{(2\pi)^3}\left(R_{S=1}(\mathbf{q})-1\right)=-A_D$$



deuterons

St. Mrówczyński, Phys. Lett. B **345**, 393 (1995)

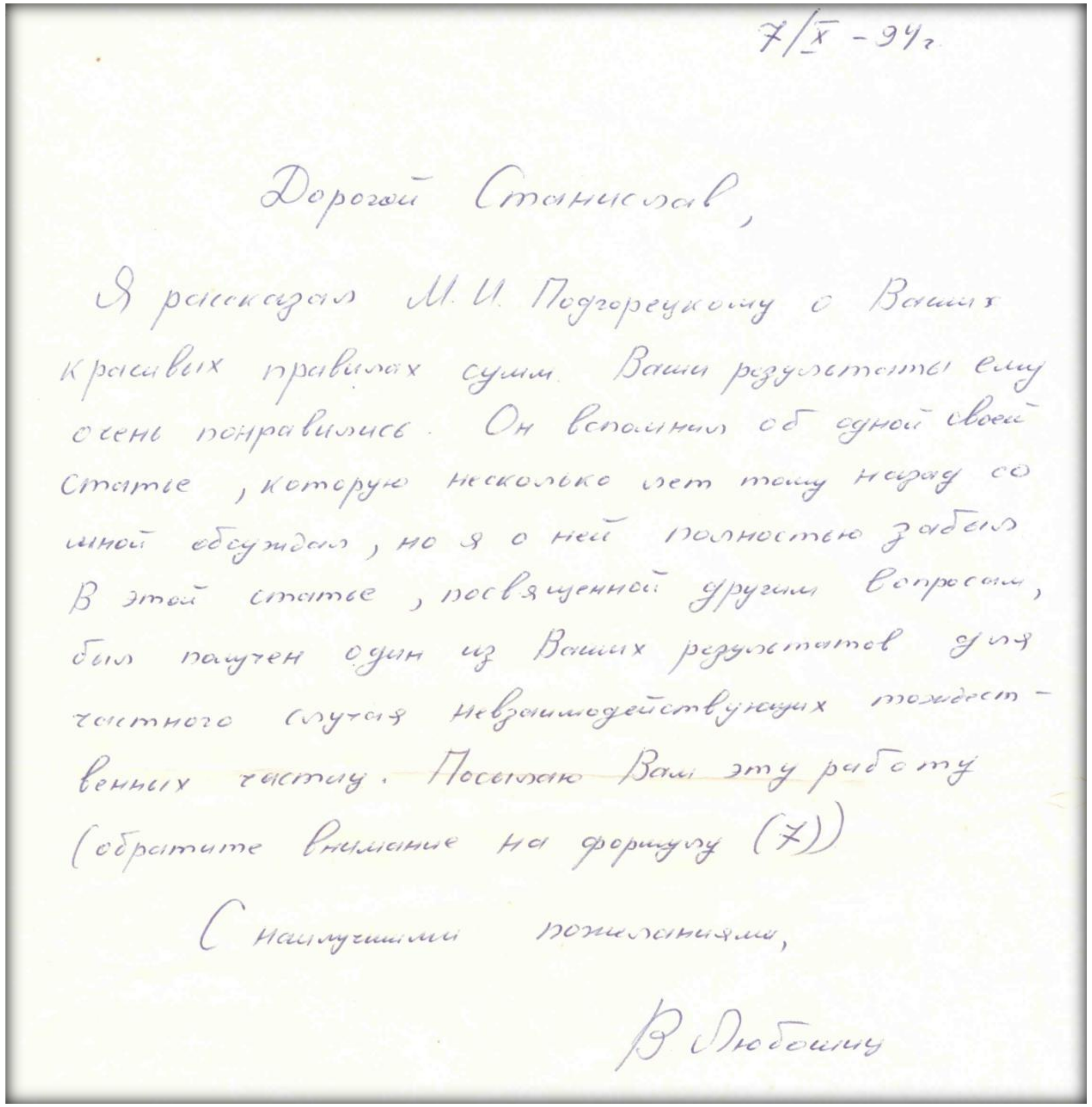
Correlation due to absorptive interaction



$$p + \bar{\Lambda} \rightarrow \pi + K$$

J.Adams et al. [STAR Collaboration], Phys. Rev. C **74**, 064906 (2006)

Letter from Lyuboshitz


7/X - 94г.

Дорогой Станислав,

Я рассказал М.И. Подгорецкому о Ваших красивых правилах сумм. Ваши результаты ему очень понравились. Он вспомнил об одной своей статье, которую несколько лет тому назад со мной обсуждал, но я о ней полностью забыл. В этой статье, посвященной другим вопросам, был получен один из Ваших результатов для частного случая невзаимодействующих тождественных частиц. Посылаю Вам эту работу (обратите внимание на формулу (7))

С наилучшими пожеланиями,

В. Любошиц

Sum rule for free π-π

$$\int \frac{d^3q}{(2\pi)^3}\left(R(\mathbf{q})-1\right)=\pi^3 D(\mathbf{r}=0)$$

$$\varphi_{\mathbf{q}}(\mathbf{r})=\frac{e^{i\mathbf{q}\cdot\mathbf{r}}+e^{-i\mathbf{q}\cdot\mathbf{r}}}{\sqrt{2}}$$

M.I. Podgoretsky, Yad. Fiz. **54**, 1461 (1991)

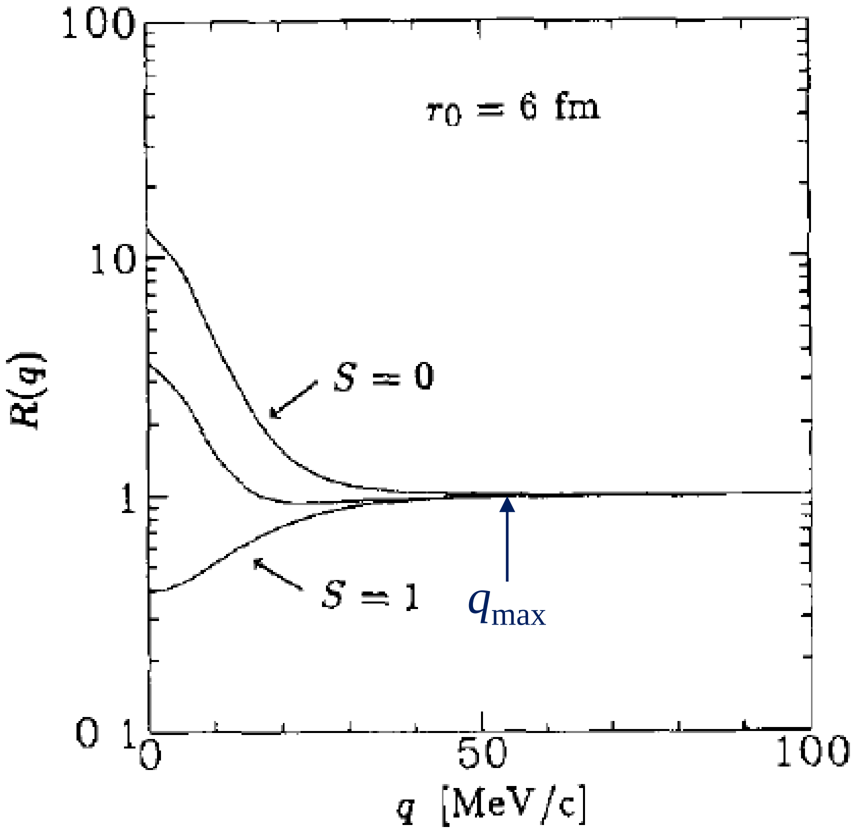
Is the sum rule useful ?

Spin average *n-p* correlation function

$$\bar{R}(q) = \frac{3}{4} R_{S=1}(q) + \frac{1}{4} R_{S=0}(q)$$

?

$$A_D = -\frac{1}{2\pi^2} \int_0^{q_{max}} dq\, q^2 \left(R_{S=1}(q) - 1\right)$$



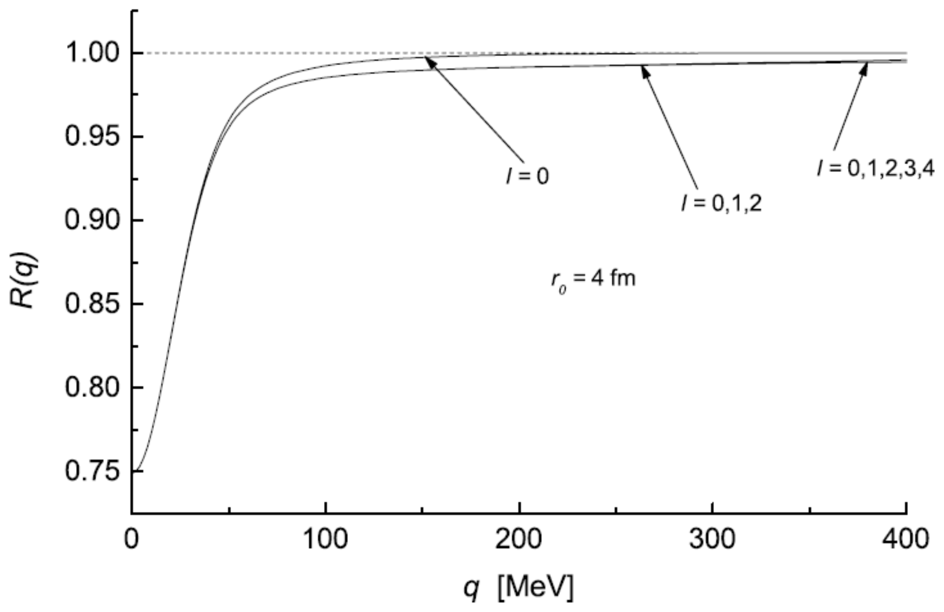
The sum rule does not work! $q_{max} = ?$

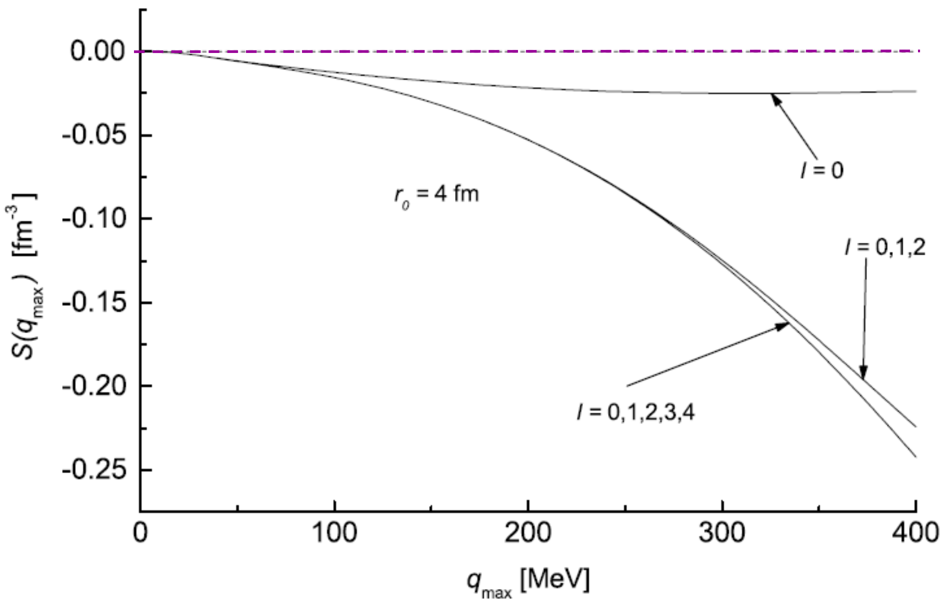
R. Maj diploma thesis, Kielce, 2002

How many partial waves are needed?

Nonidentical hard spheres

$$S(q_{\max}) = 4\pi \int_0^{q_{\max}} dq\, q^2 \big(R(q) - 1\big) \quad \xrightarrow[q_{\max} \to \infty]{} \quad 0 \quad ?$$



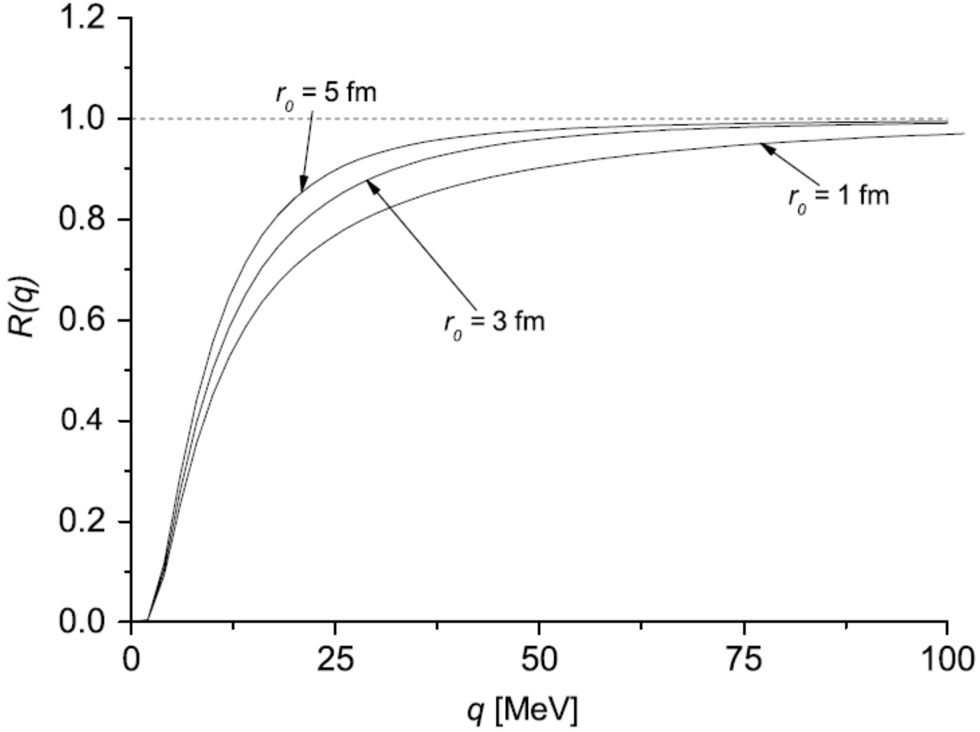


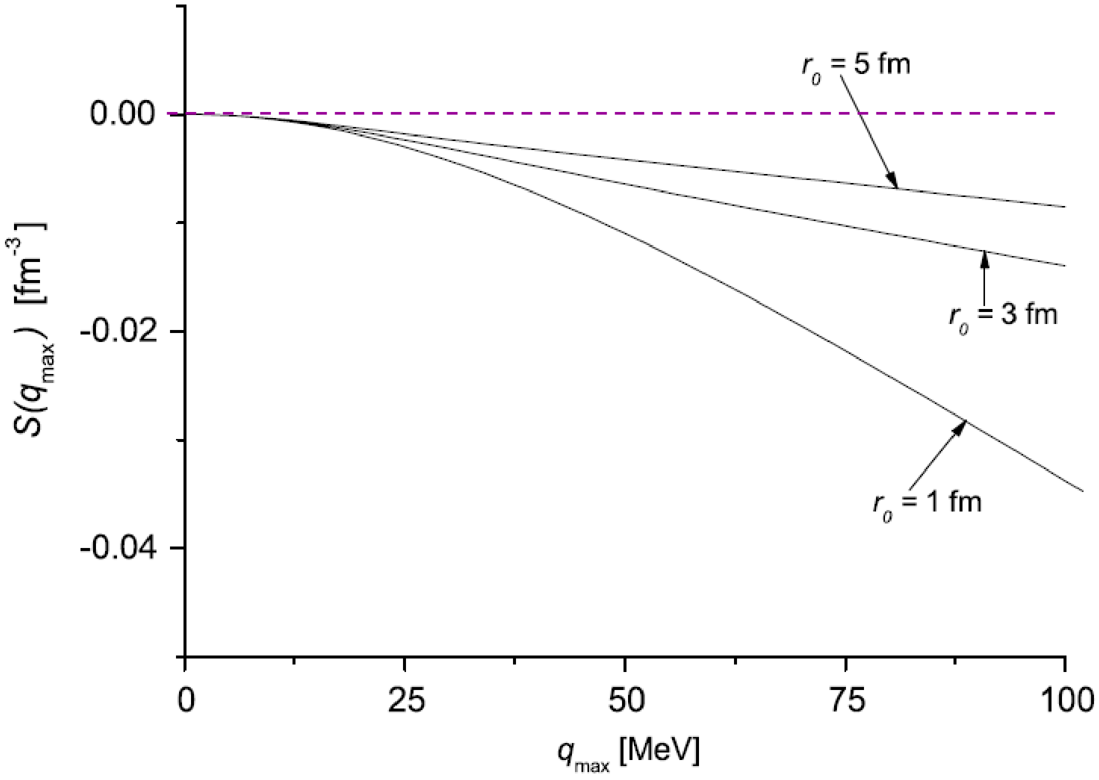
R. Maj & St. Mrówczyński, Phys. Rev. C **71**, 044905 (2005)

Exact Coulomb correlation function

Nonidentical repelling particles

$$S(q_{\max}) = 4\pi \int_0^{q_{\max}} dq\, q^2 \big(R(q) - 1\big) \underset{q_{\max} \to \infty}{\longrightarrow} -\infty$$ **!**





R. Maj & St. Mrówczyński, Phys. Rev. C **71**, 044905 (2005)

The sum rule does not work!

Why the sum rule does not work ?

$$\int \frac{d^3q}{(2\pi)^3}\left(R(\mathbf{q})-1\right)=\int \frac{d^3q}{(2\pi)^3}\int d^3r\, D(\mathbf{r})\left(\left|\varphi_{\mathbf{q}}(\mathbf{r})\right|^2-1\right)=\int d^3r\, D(\mathbf{r})\int \frac{d^3q}{(2\pi)^3}\left(\left|\varphi_{\mathbf{q}}(\mathbf{r})\right|^2-1\right)$$

- The integral over **q** can be interchanged with the integral over **r**, if the integrals are finite.
- The integral $\int d^3q\left(R(\mathbf{q})-1\right)$ is, in general, divergent!
- The sum rule is correct, provided the integral $\int d^3q\left(R(\mathbf{q})-1\right)$ is finite.

Moral

- Mathematics matters!
- The sum rule is useless but ….
- it was nice to play with it.