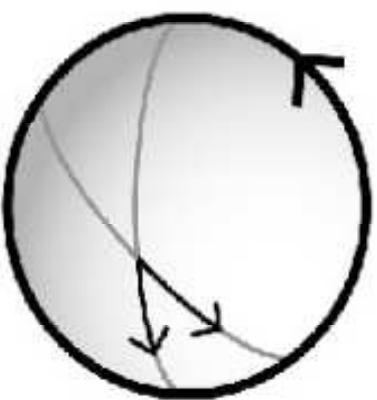


Model wpływu gluonów na strukturę hadronu

Sebastian Marek Dawid

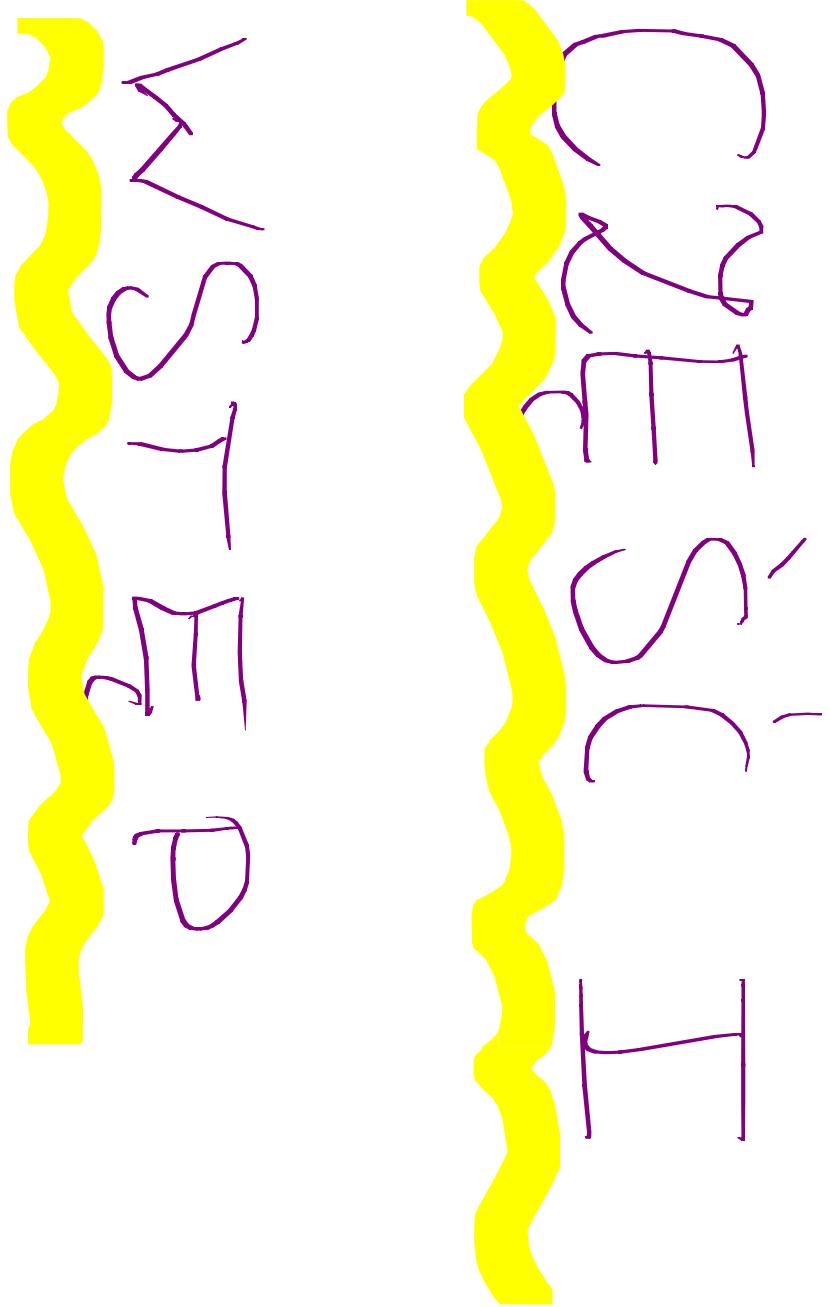
Studenckie Koło Fizyki UW



23. XI 2015 r.



Warszawa



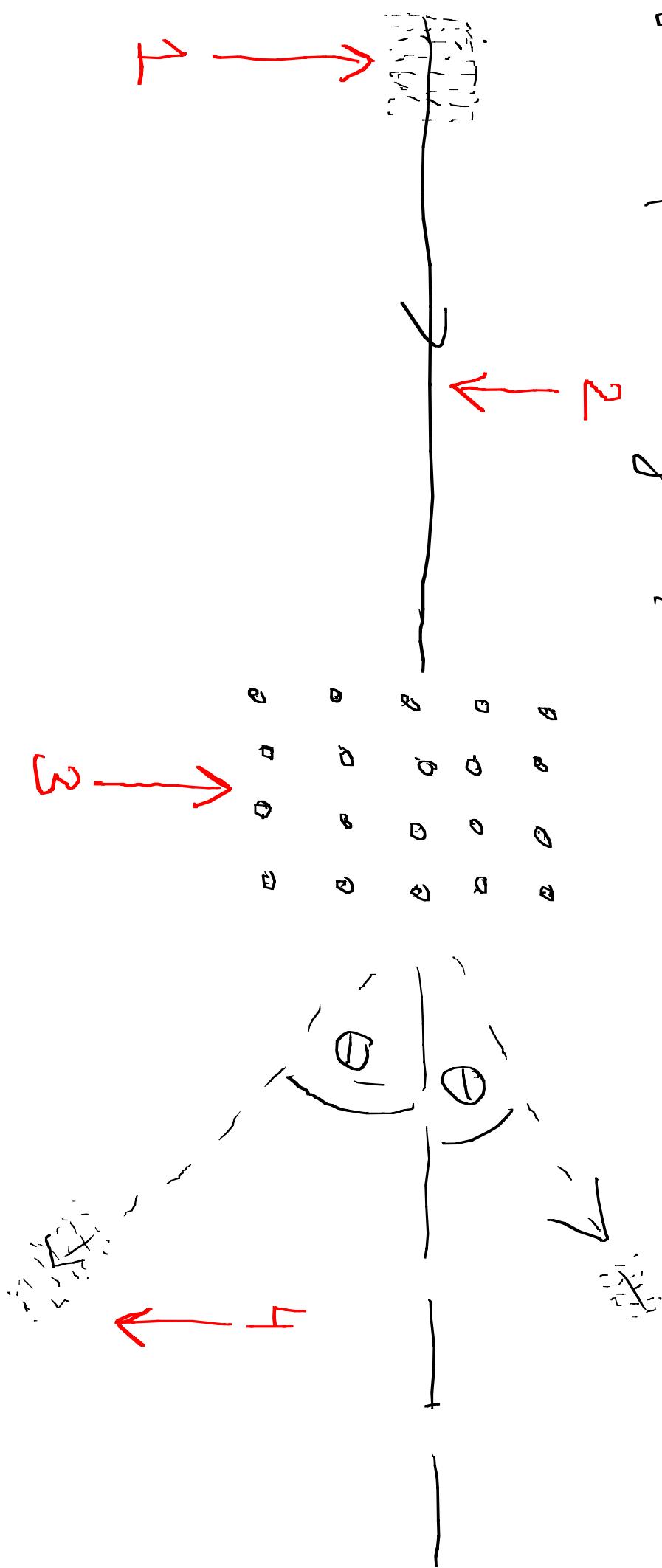
RUTHERFORD

§ 1. It is well known that the α and β particles suffer deflexions from their rectilinear paths by encounters with atoms of matter. This scattering is far more marked for the β than for the α particle on account of the much smaller momentum and energy of the former particle. There seems to be no doubt that such swiftly moving particles pass through the atoms in their path, and that the deflexions observed are due to the strong electric field traversed within the atomic system. It has generally been

Since the α and β particles traverse the atom, it should be possible from a close study of the nature of the deflexion to form some idea of the constitution of the atom to produce the effects observed. In fact, the scattering of high-speed charged particles by the atoms of matter is one of the most promising methods of attack of this problem. The develop-

2. JAK OPISYWAĆ ROZPRASTANIE?

Jakie parametry są istotne?



PRZEKRÓJ CZYNNY

na rozpraszanie do

stosunk ilości cząstek rozpraszających na j. czasu do

nateżenia wiązki podającej.

$$\sigma = \frac{\Delta N}{I} = \frac{\Delta N}{\int \frac{dn}{dt} dt}$$

- Może nas tylko interesować ΔN
dla konkretnego kota brylowego dla i-pedru p.

$$d\sigma = \frac{dN(\theta, \psi)}{\Delta t}$$

$$\rightarrow \sigma = \int d\sigma$$

"OBSZAR"
INTERESUJĄCY

3. JAK TO WYGLĄDA DLA $e^-p \rightarrow e^-p?$

punktowy

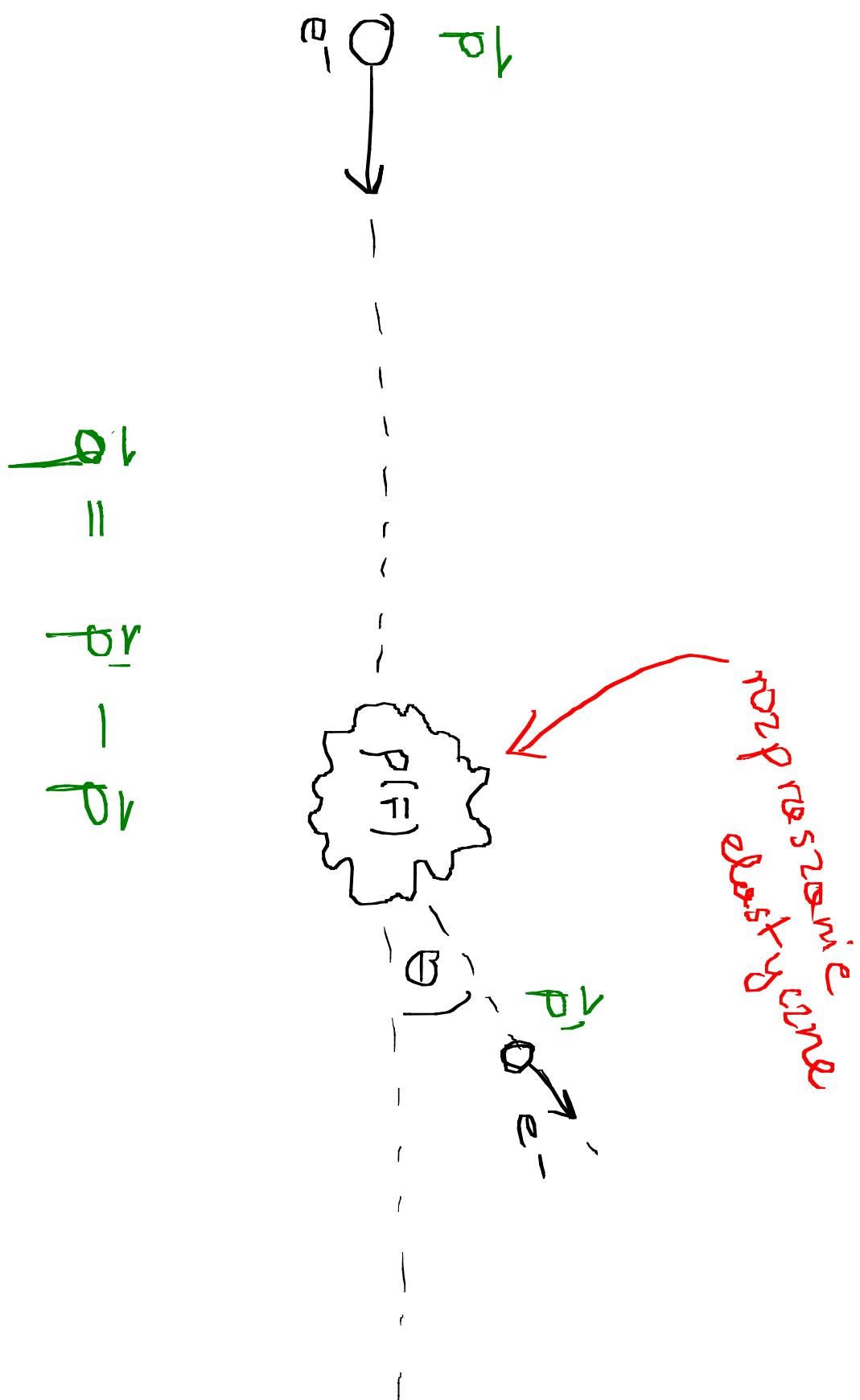
$$\text{Rutherford: } d\sigma = \frac{\left(\frac{e^2}{4\pi\epsilon_0 c}\right)^2}{E_k^2 \sin^4 \frac{\theta}{2}} d\Omega$$

$$\text{Mott: } d\sigma = \frac{\left(\frac{e^2}{4\pi\epsilon_0 c\hbar}\right)^2}{4|p|^2 \beta^2 \sin^4 \frac{\theta}{2}} d\Omega$$

$$\beta = \frac{\text{Vektorowa}}{c}, \quad E_k - \text{nied. energia kin. elektronu}$$

\vec{p} - pęd elektronu, θ - kat rozwarcia

ALE ZAKŁADALISMY, ŻE PROTON JEST PUNKTOWY!



$$\sigma = \sigma_{\text{Rutherford}} \cdot \int d^3r e^{i\vec{q} \cdot \vec{r}}$$

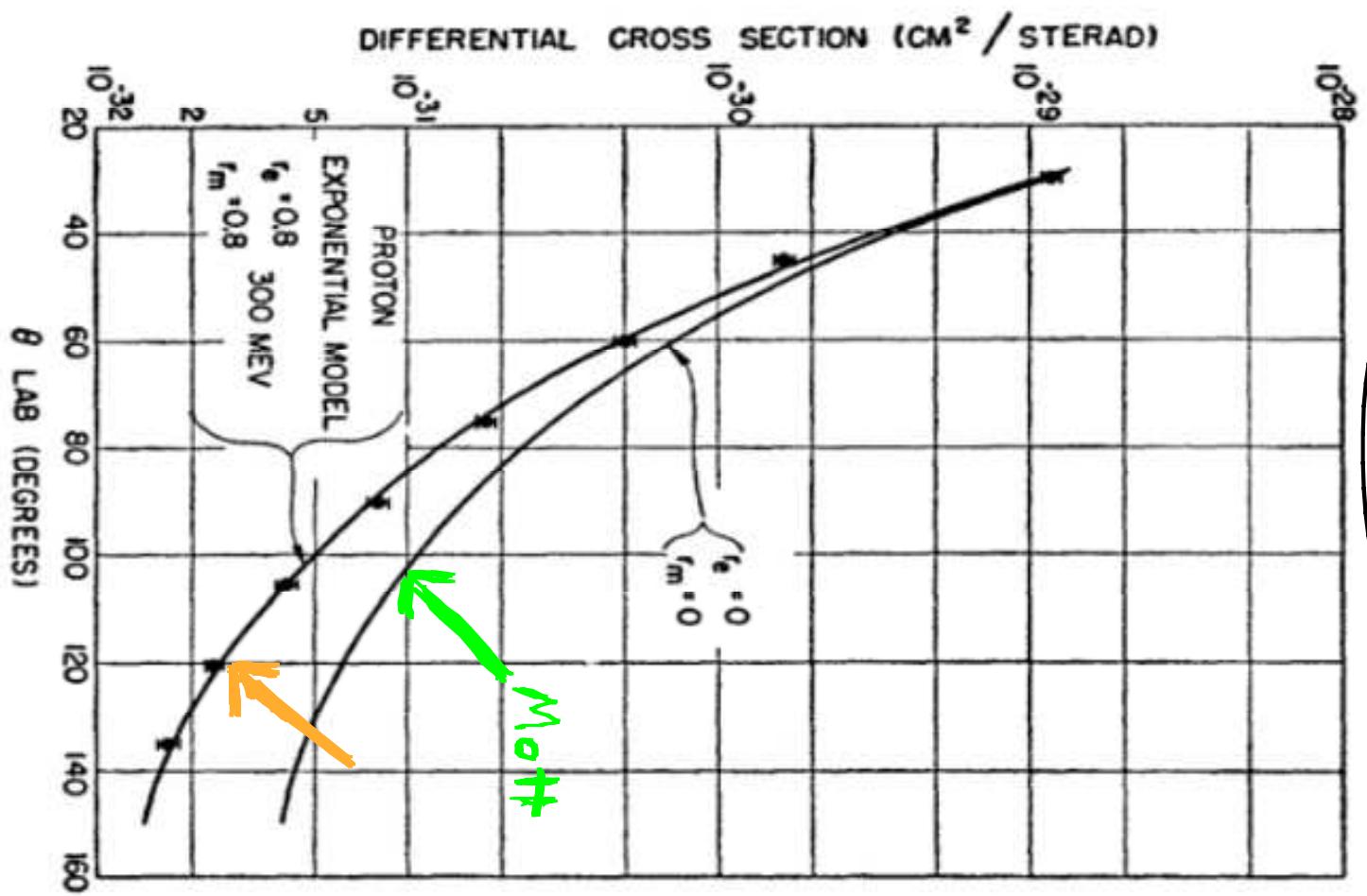
The diagram illustrates a scattering process. A wavy line labeled $\rho(\vec{F})$ enters from the left and interacts with a potential $V(r)$, represented by a dashed line. The outgoing wavefunction is labeled ρ' . Below the diagram, the text "ROZKŁAD TADUNKU W PROTONIE" is written.

$$|F(q^2)|^2 - \text{mierny dół.}$$

↓
CZYNNIK KSZTAŁTU (FORM FACTOR)

* - RACHUNEK W NIEREL. MK, W PRZYBŁIŻENIU BORNA, $V(F) = \text{POTEN-$
-CJAŁ ELEKT. OD ROZKŁADU TADUNKU $\rho(\vec{F})$).

HOFSTADTER



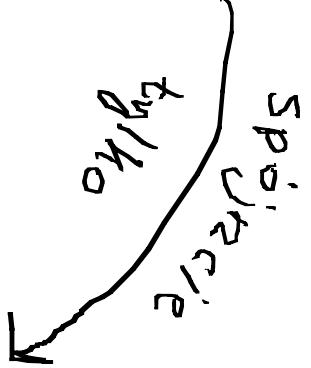
Model eksponensial:

$$F_D(q^2) = \frac{\lambda^3}{8\pi} e^{-\lambda r}$$

$$F_D(q^2) = \frac{1}{\left(1 + \frac{q^2}{\lambda^2}\right)^2}$$

4. Czy fizyka nie jest aby bardziej skomplikowana?

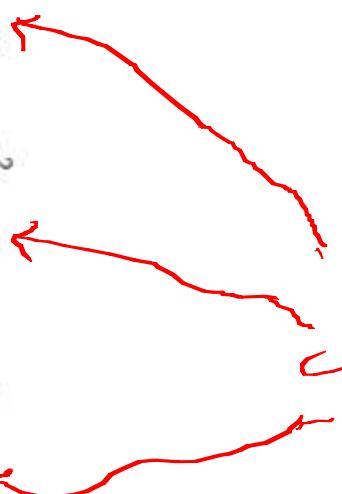
jest!



to ucić
jest?

Wzór Rosenblutha:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega} \right)_{Mott} \left\{ \frac{G_E^2 + \frac{q^2}{4m^2} G_M^2}{1 + \frac{q^2}{4m^2}} + \frac{q^2}{4m^2} G_M^2 \tan^2 \left(\frac{\theta}{2} \right) \right\}$$



PROTON MA ROZMIAR ZADUNKU !

MAGNETYZACJI - PROMIEN ZADUNKOWY
MAGNETYCZNY.

CZYLI MAMY Dwie FUNKCJE:

$$G_M(q^2)$$

$$G_E(q^2)$$



CZYNNIK

KSZTAŁTU

JAK OPISUJĄ STRUKTURĘ?

$$\rightarrow G_{E,M} \sim \left\{ d^3\vec{r} e^{i\vec{q}\cdot\vec{r}} \rho_{E,M}(\vec{r}) \right\}$$

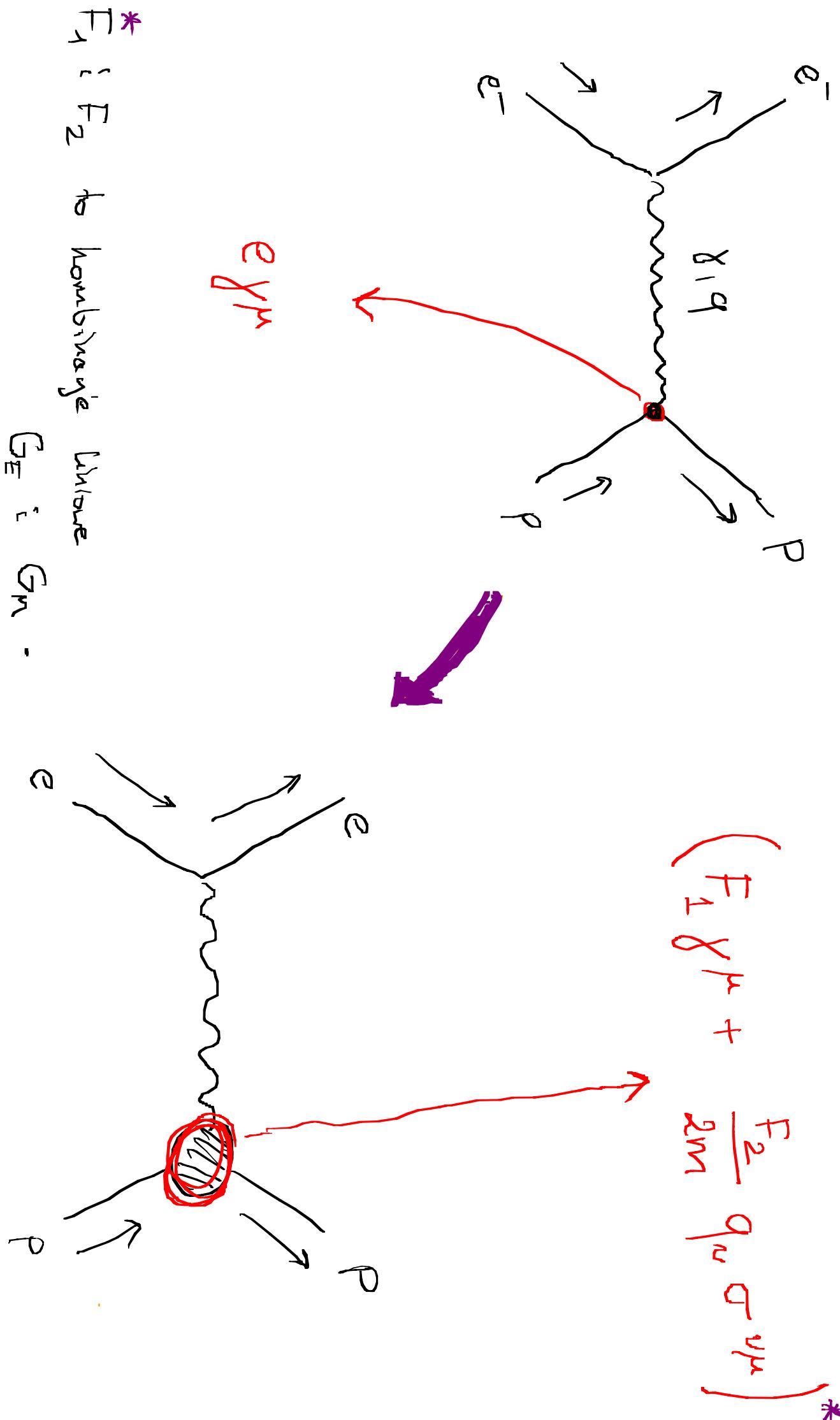
*

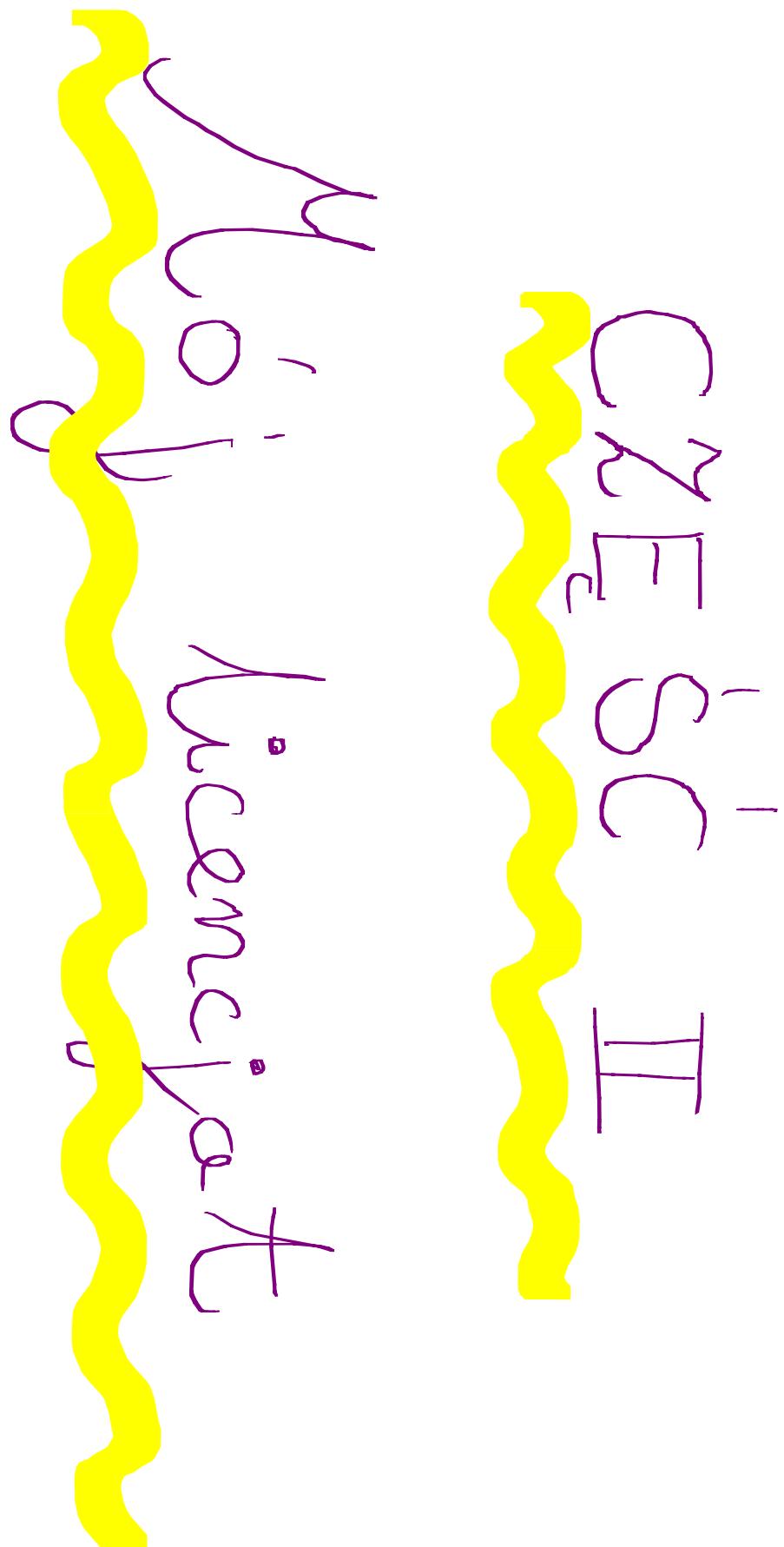
$$\rightarrow \langle r_{E,M}^2 \rangle = -6 \frac{d G_{E,M}(q^2)}{dq^2} \Big|_{q^2=0}$$

* - W UKŁADZIE SPŁOŻYKOWYM ROTONÓW

DLA ORIENTUJĄCY SIĘ W KWANTOWEJ TEORII POLA.

$$\left(F_1 \gamma^\mu + \frac{F_2}{2m} q_\nu \sigma^{\mu\nu} \right) *$$





5. JAK OPISYWAĆ ODD. KWARKÓW, GŁUONIÓW?

- gestosic Lagrangianu QCD:

$$\mathcal{L} = \sum_i \bar{q}_i (i\cancel{D} - m_i) q_i - \frac{1}{4} F_{\mu\nu}^a F_{\mu\nu}^a,$$

gdzie:

$$\cancel{D} = \left(\partial_\mu - ig_{QCD} A_\mu \right) \gamma^\mu, \quad A_\mu^a = A_\mu^a T^a$$

$$F_{\mu\nu}^a = \partial_\mu A_{\nu}^a - \partial_\nu A_{\mu}^a + g_{fab}^f A_\mu^a A_\nu^b$$

gdzie:

$$[T^a, T^b] = if_{abc} T_c$$

$$T_c = \frac{1}{2} \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

i t.d.

$$a, b, c \in \overline{1, 8}$$

6. A CZY NIE MA CZEŁÓŚĆ PROSTSZEJ?

$$H = H_0^f + H_0^{fb} + H_1 + H_2 + H_3,$$

$$H_0^f = \sum_{\lambda} \int [dp] |p\lambda\rangle \left[\frac{p^{\perp 2} + m_1^2 + g^2 \omega^2}{p^+} \right] \langle p\lambda|,$$

$$H_0^{fb} = \sum_{\lambda} \int [dp][dk] |p\lambda, k\rangle \left[\frac{p^{\perp 2} + m^2}{p^+} + \frac{k^{\perp 2} + \mu^2}{k^+} \right] \langle p\lambda, k|,$$

$$H_1 + H_2 = g \sum_{\lambda\sigma} \int [dp][dp'][dk] \Theta(\Lambda^2 - \kappa^2) 2(2\pi)^3 \delta^3(p + k - p')$$

$$\times \left\{ |p\lambda, k\rangle \bar{u}(p, \lambda) \left[1 + \frac{\delta m}{2p'^+} \gamma^+ \right] u(p', \sigma) \langle p'\sigma| + |p'\sigma\rangle \bar{u}(p', \sigma) \left[1 + \frac{\delta m}{2p'^+} \gamma^+ \right] u(p, \lambda) \langle p\lambda, k| \right\},$$

$$H_3 = g^2 \sum_{\lambda\sigma} \int [dp_1][dp_2][dk_1][dk_2] \Theta(\Lambda^2 - \kappa_1^2) \Theta(\Lambda^2 - \kappa_2^2) 2(2\pi)^3 \delta^3(p_1 + k_1 - p_2 - k_2)$$

$$\times |p_2\lambda, k_2\rangle \bar{u}(p_2, \lambda) \frac{\gamma^+}{2(p_1^+ + k_1^+)} u(p_1, \sigma) \langle p_1\sigma, k_1|,$$

prof. Cezary Perry

- teoria Yukawa (odcz. fermionu i skalarnego

nowa) ,

- dyrektywa operatorów obiektów do

działania podpreszowej :

$$|P, \lambda\rangle$$

$$|\rho, \lambda; k\rangle .$$

- teoria na frontie swietlonym,

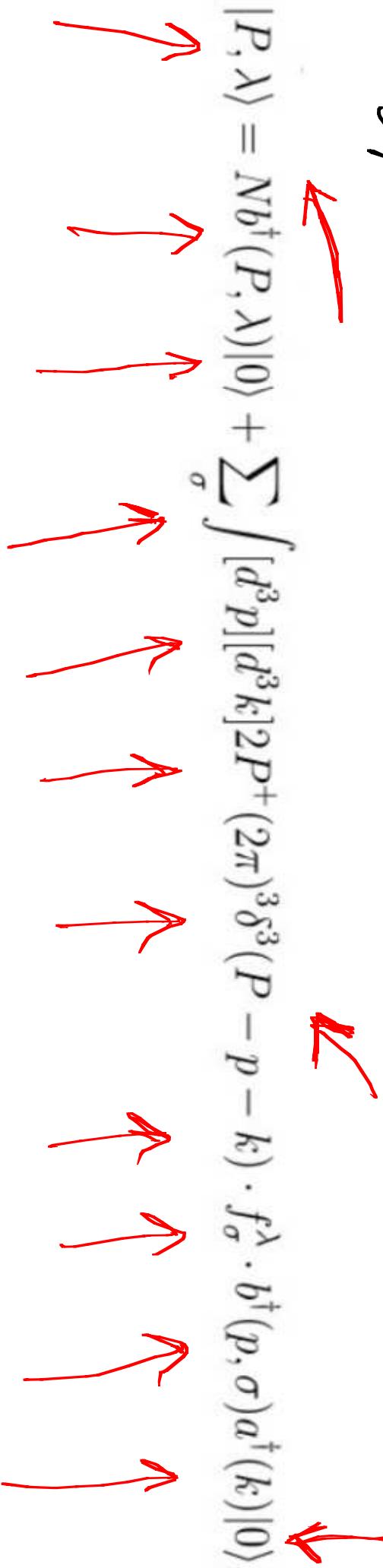
- regularyzacja: $\kappa + \Lambda < 1$, $\rho^+, k^+ > f$,
 $q^+ > k$,

7. MAM JUŻ TEORET - CO TERAZ?

- Stan zwierzący bosone i fermionu

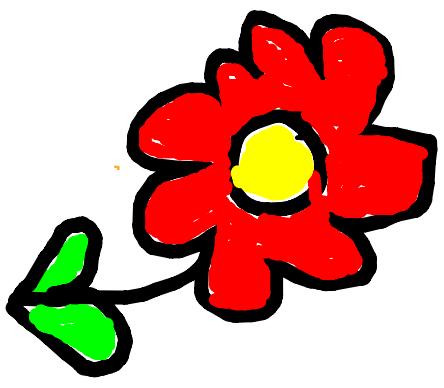
to stan wtedy powiązany hamiltonian,

• Wyjaśnia fakt:

$$|P, \lambda\rangle = Nb^\dagger(P, \lambda)|0\rangle + \sum_{\sigma} \int [d^3 p][d^3 k] 2P^+(2\pi)^3 \delta^3(P - p - k) \cdot f_{\sigma}^{\lambda} \cdot b^\dagger(p, \sigma) a^\dagger(k) |0\rangle,$$


8. A KIEDY BĘDZIE COŚ O UCENIACIE?

Już.



- Zapiszmy ten stan w prostszej formie i interpretujemy go:

$$|P, \lambda\rangle = Nb^\dagger(P, \lambda)|0\rangle + \sum_{\sigma} \int [d^3 p][d^3 k] 2P^+(2\pi)^3 \delta^3(P - p - k) \cdot f_{\sigma}^{\lambda} \cdot b^\dagger(p, \sigma) a^\dagger(k) |0\rangle,$$

(wóz tam) . $b^\dagger(p, \sigma) a^\dagger(k) |0\rangle,$

Analogia z mojego licencjatu.

$|P, \lambda\rangle$ - proton o pednie P i spinie λ

$b^+(p, \sigma) |0\rangle$ - try kwarki o pednie p

i spinie σ ,

$b^+(p, \sigma) a^+(k) |0\rangle$ - try kwarki i gluony

(ped p , spin σ)

(ped k)

czyli : fermion \equiv 3 kwarki

bozon \equiv gluony (ciasto gluonowe)

PRZEPISZMY TO RAZ JESZCZE, SYMBOLICZNIE:

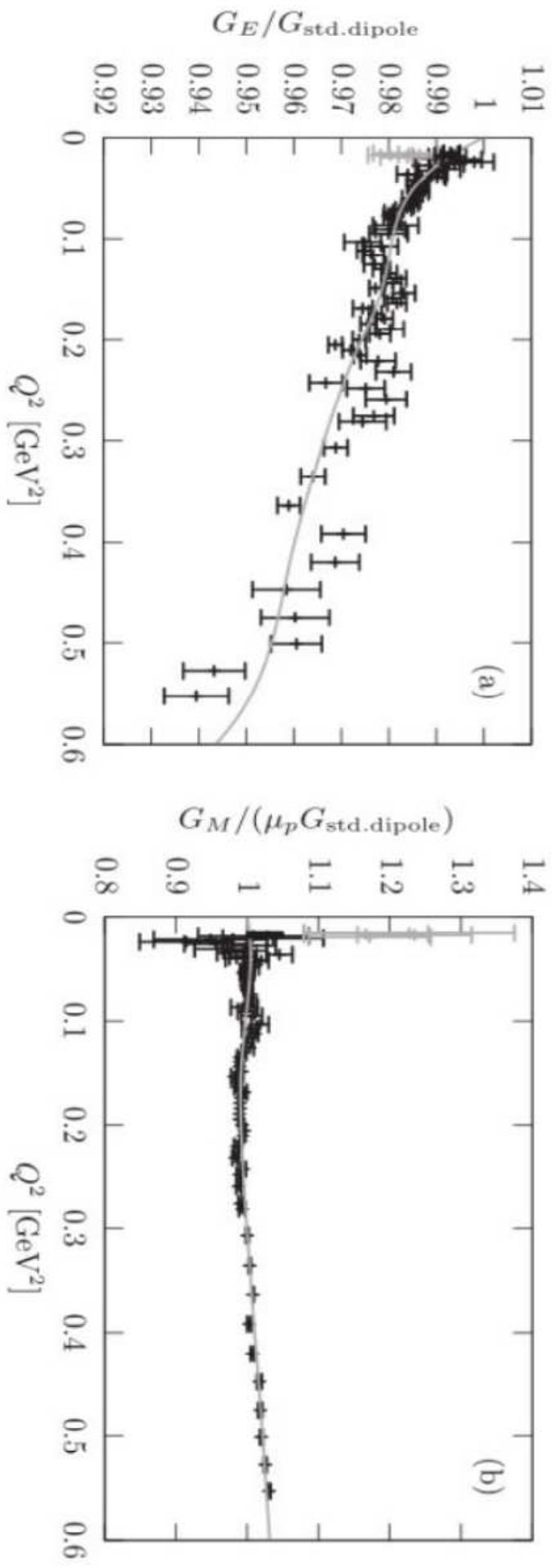
$$|p\text{rotón}\rangle = |3\text{ kوارك}\rangle + g |3\text{ kوارك i فلويون}\rangle$$

NP.:

$g \rightarrow 0$ model protónu bez gluonów,

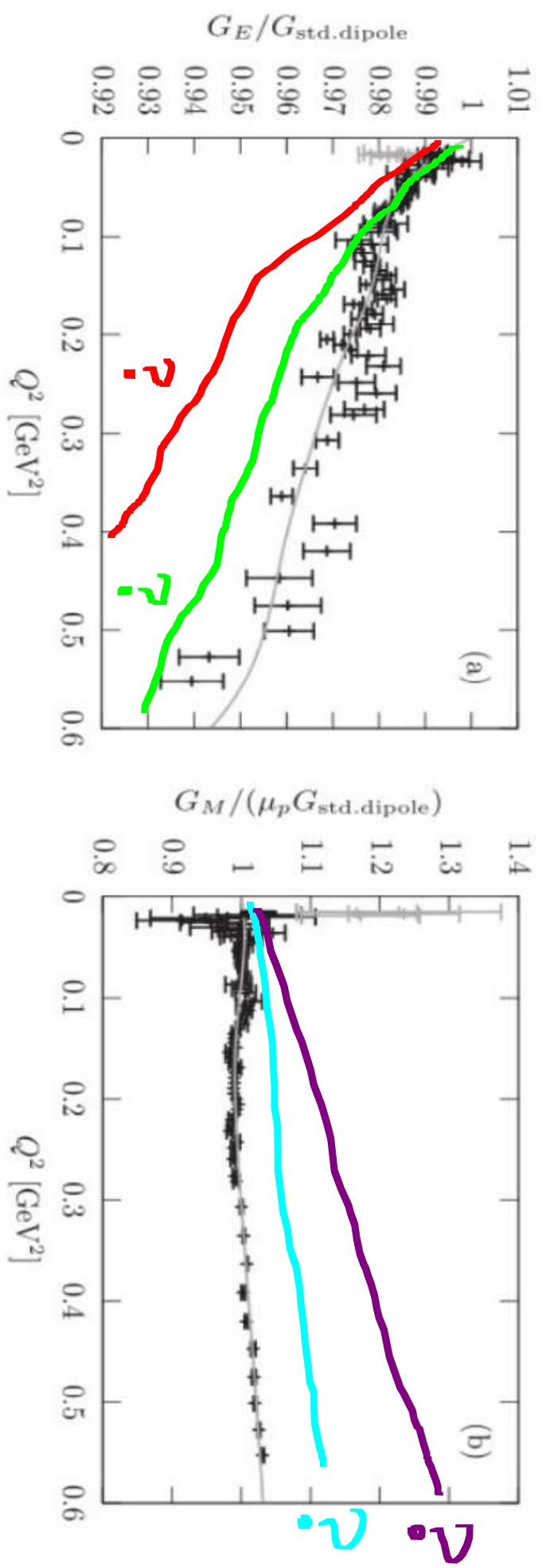
Co to g ? Ile wynosi?

3 KWARKI MAGA WŁASNE CZYNNIKI KSZTAŁTU



Rysunek: Bernauer *et al.*, rok 2013; czynniki kształtu protonu $G_E(Q^2)$, $G_M(Q^2)$.

3 KWARKI MASA WTAŚNIE
C24 NIKI KSZTATU



Rysunek: Bernauer *et al*, rok 2013; czynniki kształtu protonu $G_E(Q^2)$, $G_M(Q^2)$.

RACHUNKI POLEGAJĄ NA

PORÓWNANIU EL. MACIERZOWYCH

OPERATORA PRĄDU

$\langle \text{stan}' \mid j^+ \mid \text{stan} \rangle.$

(**BRAK TECHNICZNYCH SZCZEGÓŁÓW**)

Relativistic scattering and bound-state properties in a special Hamiltonian model

Martina Brisudová

Department of Physics, The Ohio State University, Columbus, Ohio 43210

Stanisław D. Glazek

Institute of Theoretical Physics, Warsaw University, 00-681 Warsaw, Poland

(Received 28 June 1993)



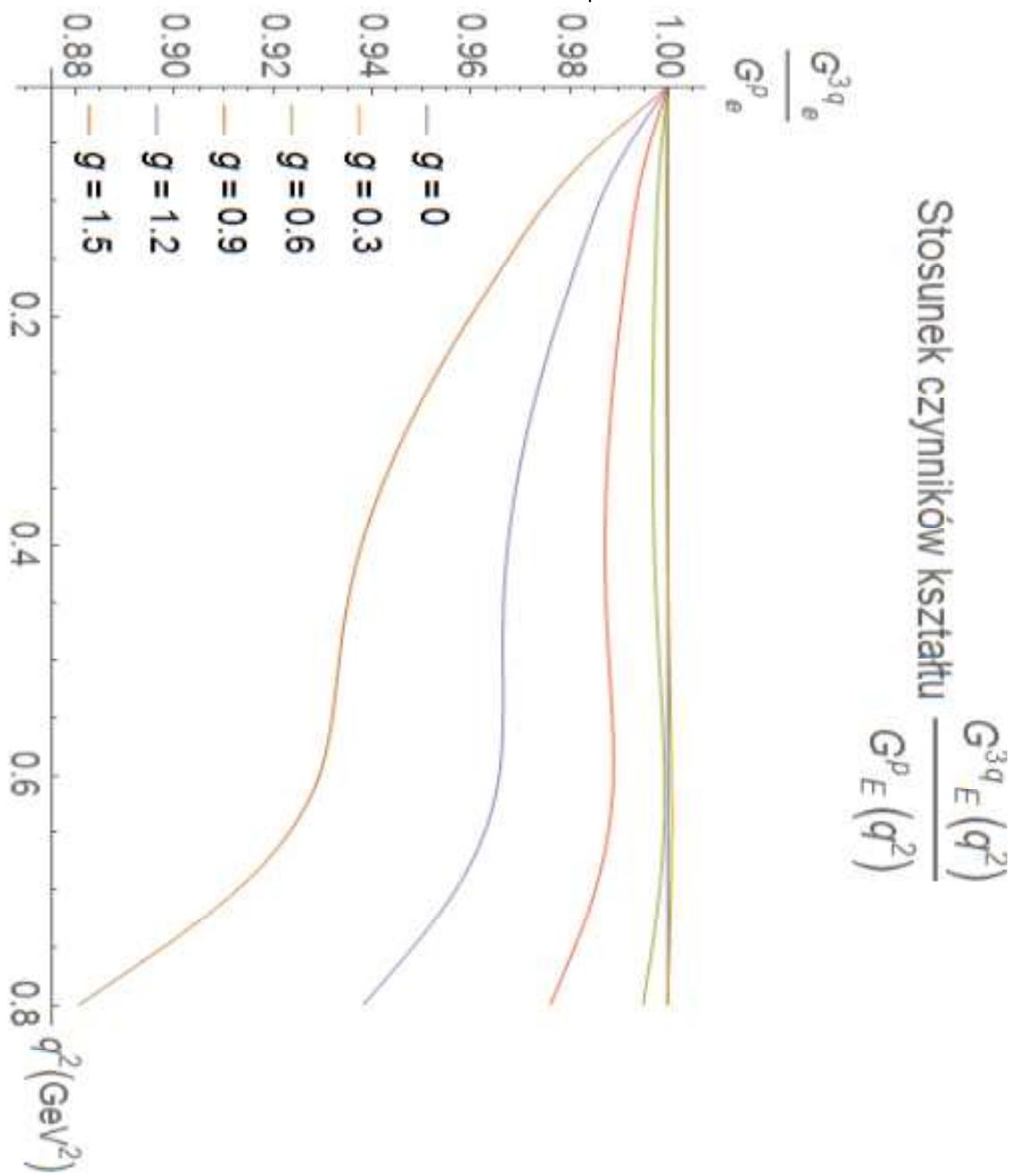
WYRĄŻENIA NA TE ELEMENTY

MACIERZOWE

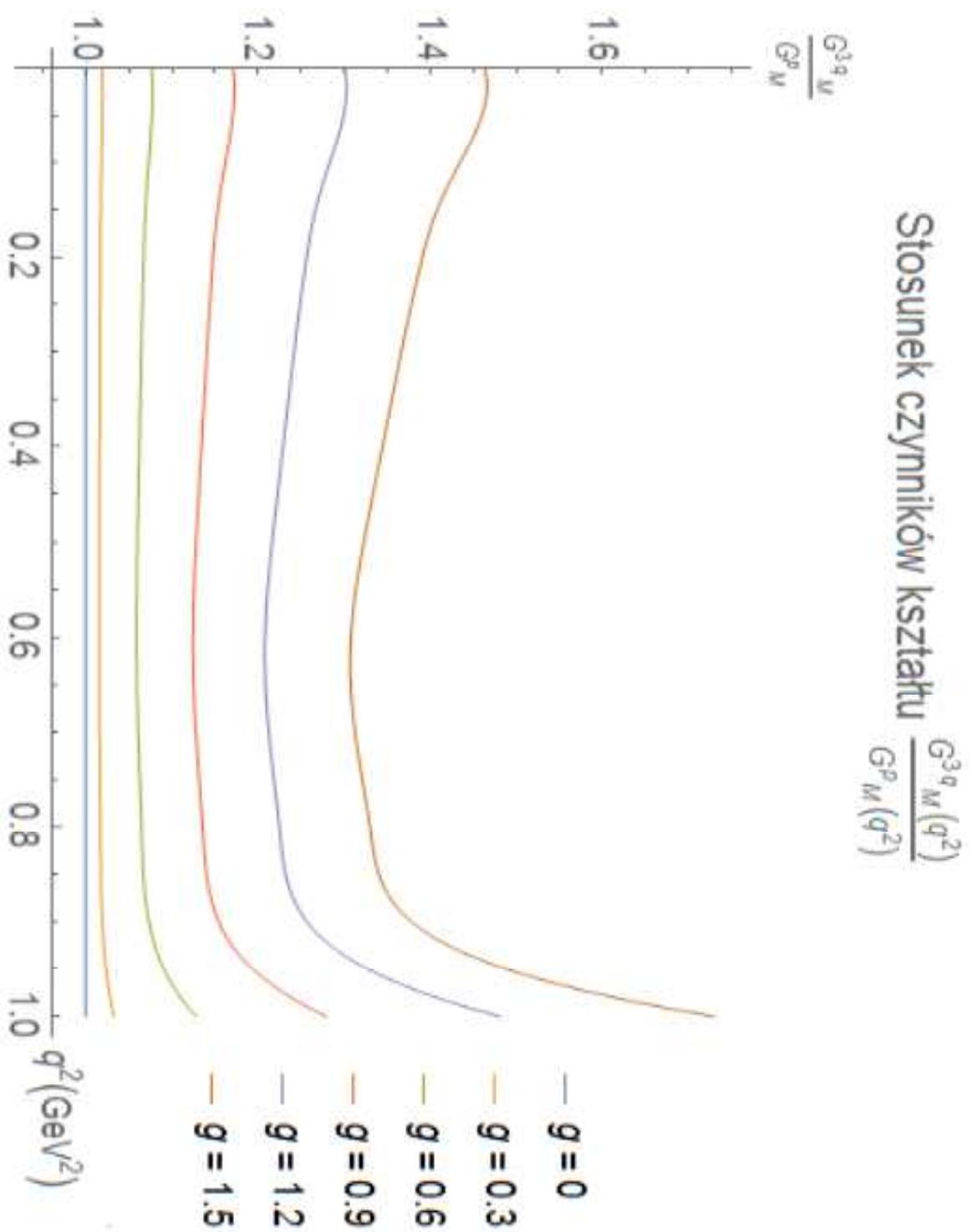


$$\gamma^+ \rightarrow F_1 \gamma^+ + \frac{F_2}{2m} i q_\nu \sigma^\nu + + \text{RACHUNKI}$$

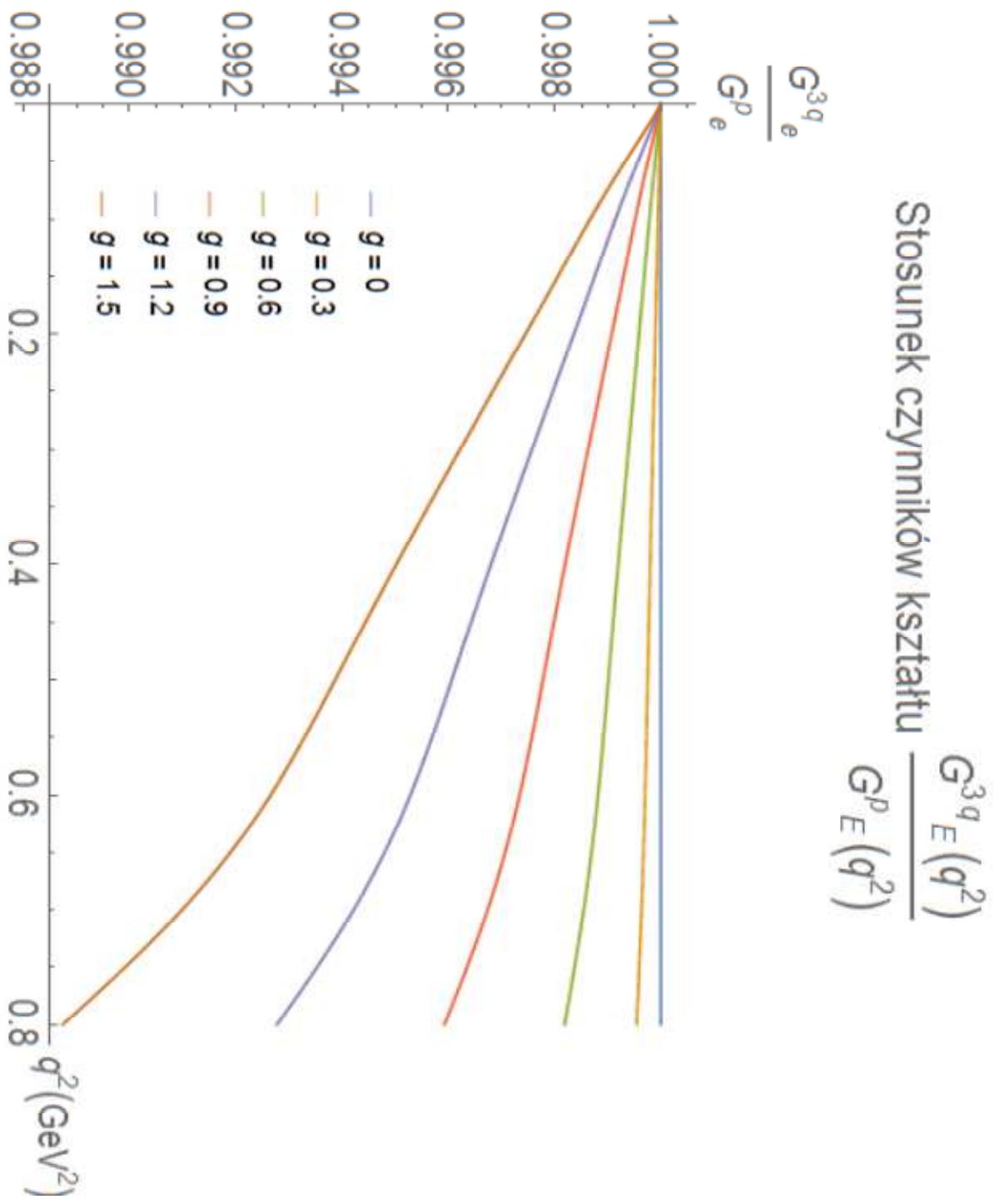
$\mu = 10^{-13} \text{ GeV}$ | $\Lambda = 90 \text{ GeV}$



$$\mu = 10^{-13} \text{ GeV} \quad \Lambda = 90 \text{ GeV}$$



$\mu = 1 \text{ GeV}$ $\Delta = 10 \text{ GeV}$



$\mu = \Lambda$ GeV , $\Lambda = 10$ GeV

Stosunek czynników kształtu $\frac{G^{3q}_M(q^2)}{G^p_M(q^2)}$

$$\frac{G^{3q}_M}{G^p_M}$$

1.015

= 1.010

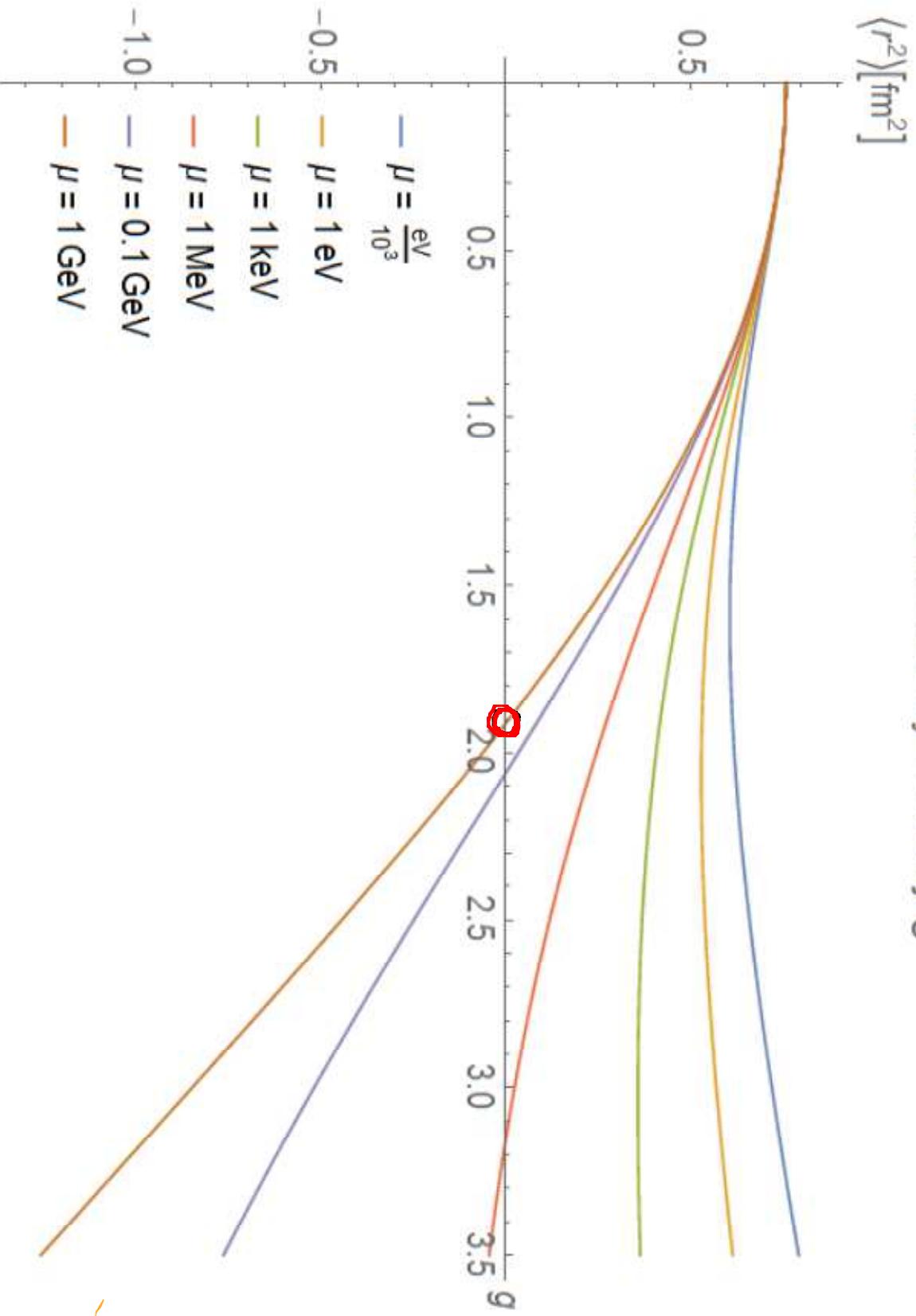
0.2
0.4
0.6
0.8
1.0

q^2 (GeV 2)

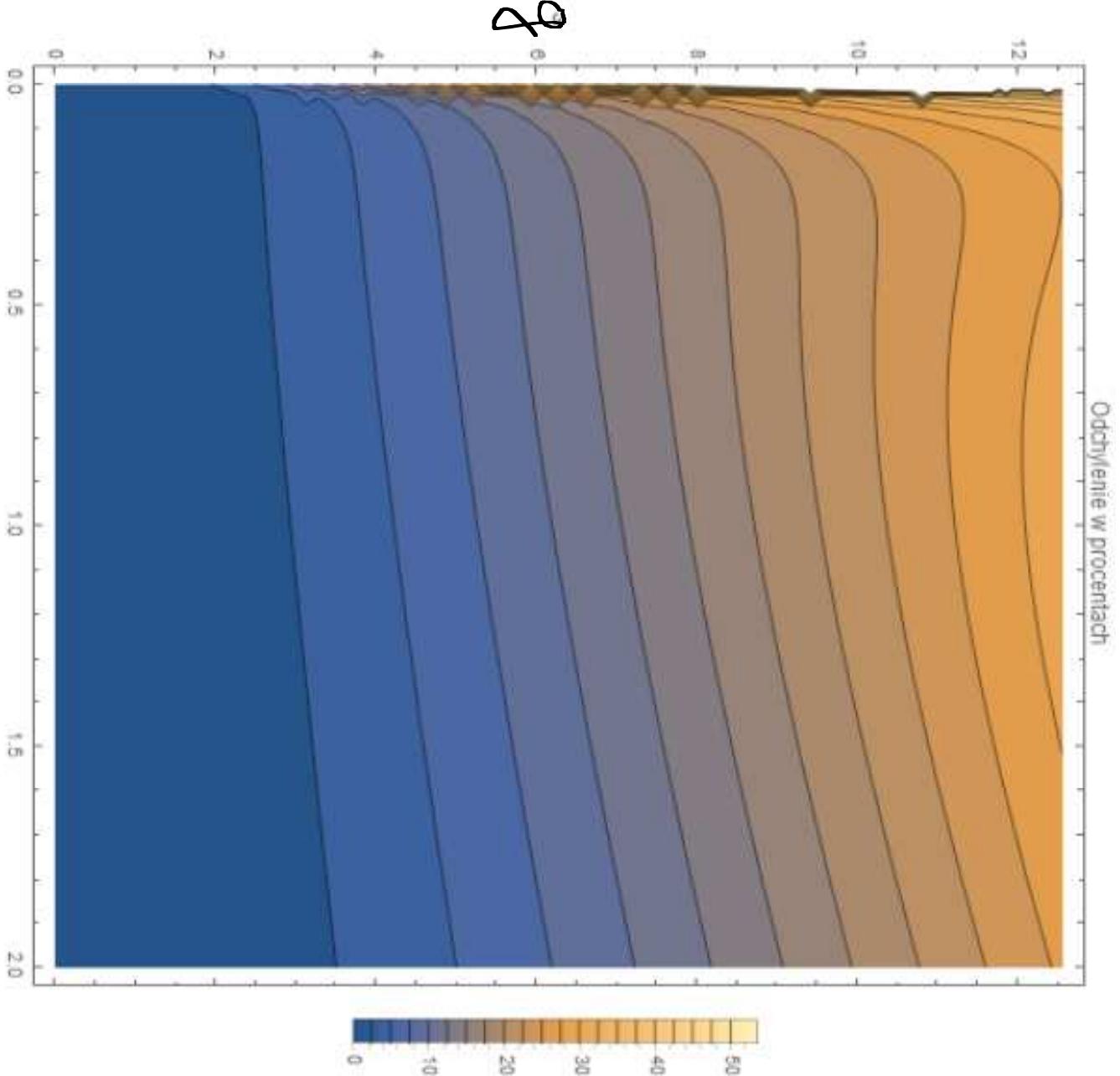
- $g = 0$
- $g = 0.3$
- $g = 0.6$
- $g = 0.9$
- $g = 1.2$
- $g = 1.5$

1.005

Promień ładunkowy w funkcji g
protonu

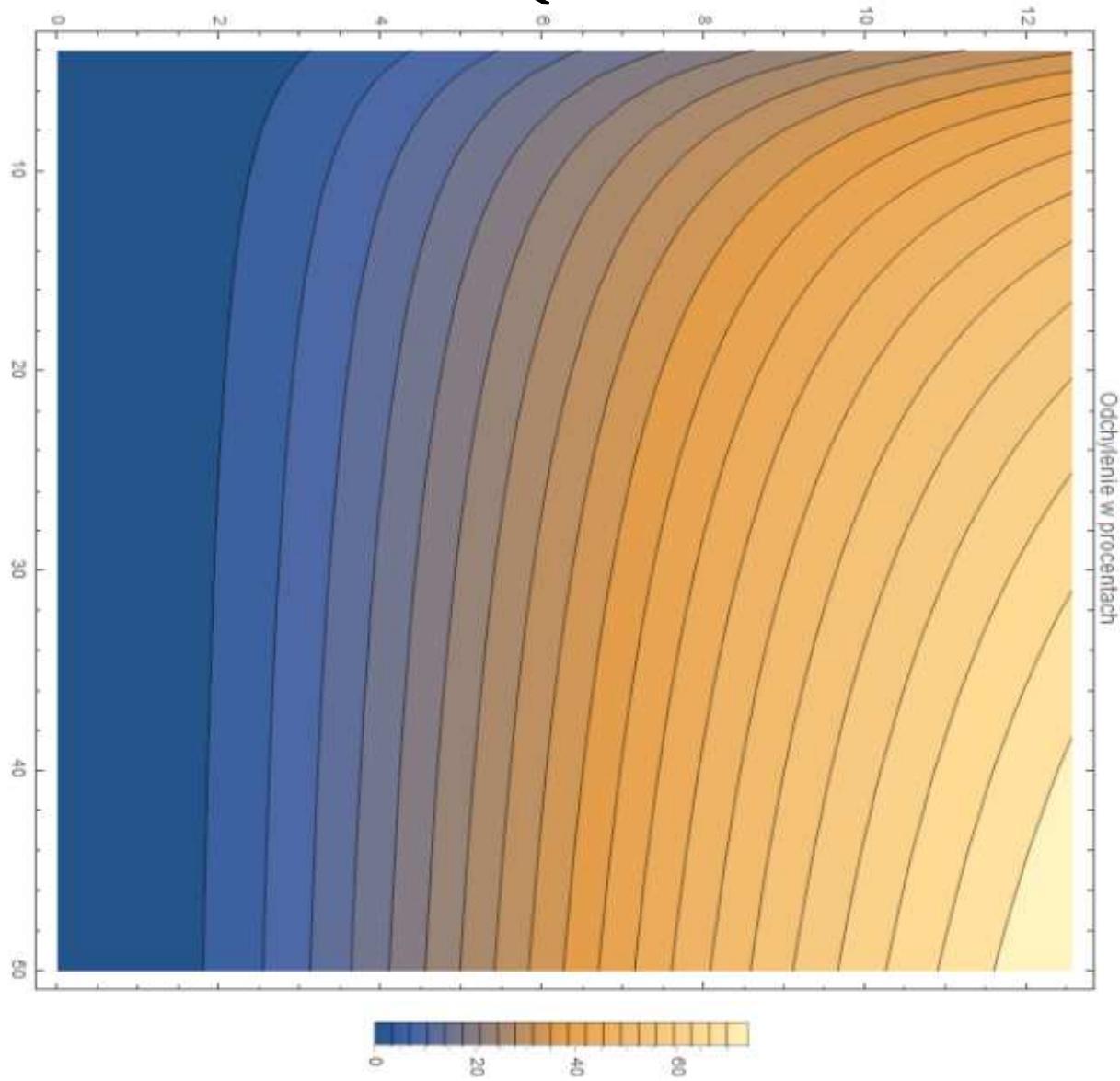


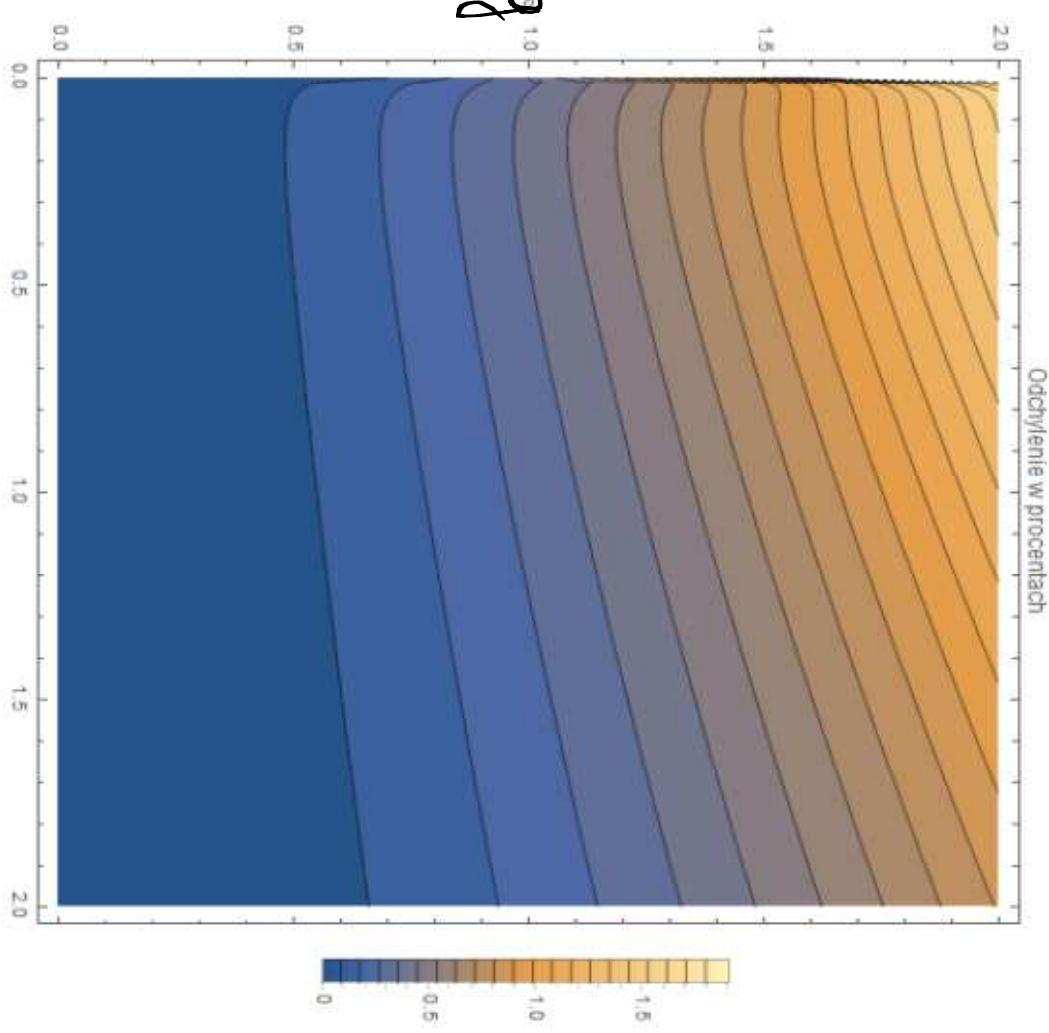
$\Lambda = 5 \text{ GeV}$



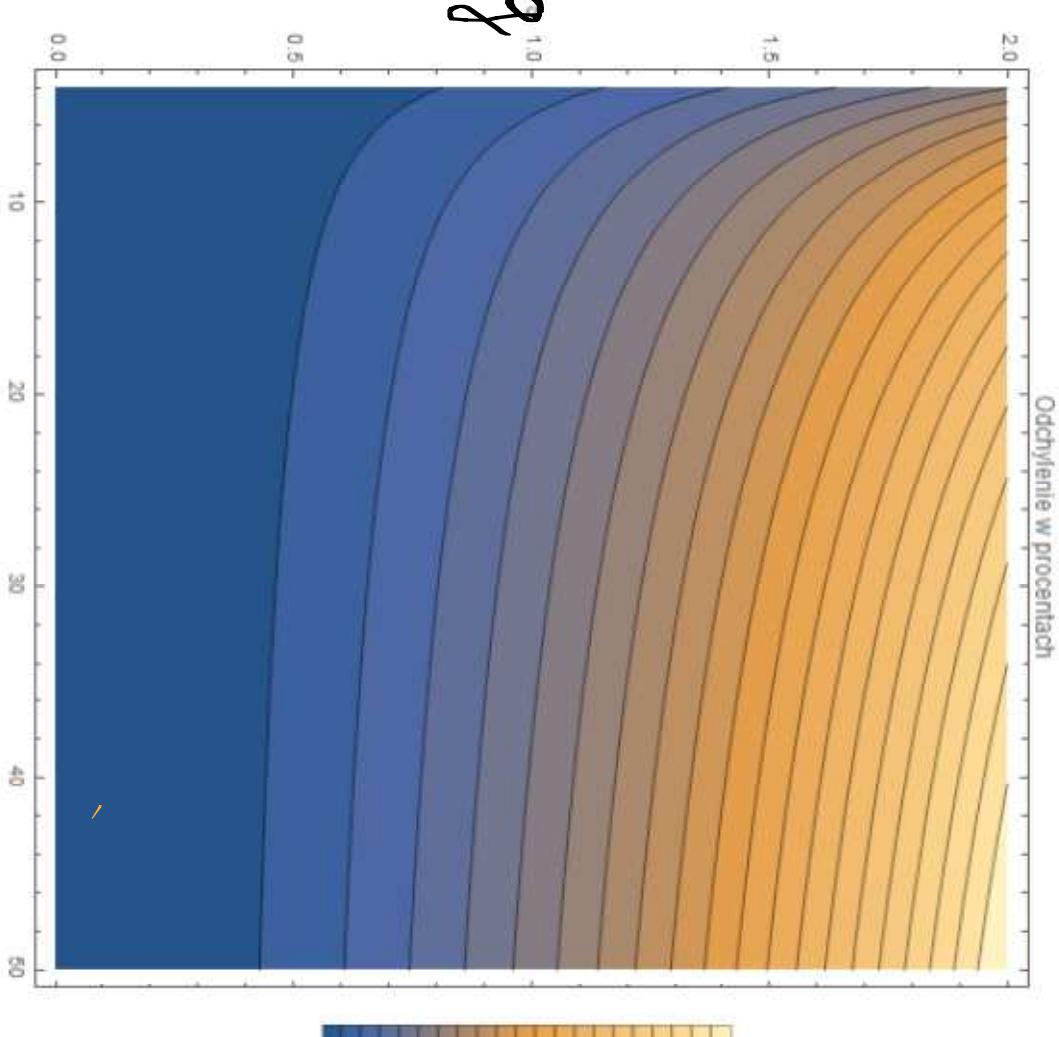
$\mu = 0.5 \text{ GeV}$

g





$\Delta = 5$ GeV



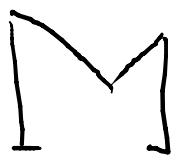
$\Delta = 0.5$ GeV

ДЕКУЗИ

СОФІАМІЛІН
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13 - Polski mlecz patentowy "Rodzaj wywaru",

"Rodzaj wywaru",



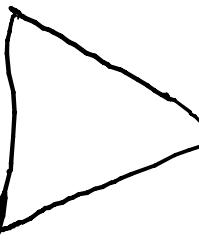
SIGMA



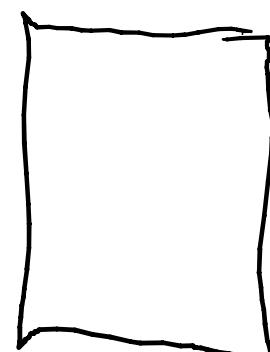
DZIKUN[®]



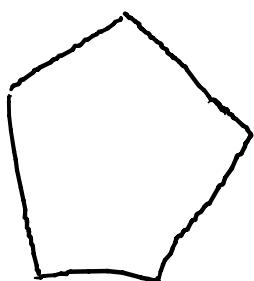
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